Valley Water

DRAFT

Water Supply Master Plan 2050

Executive Summary

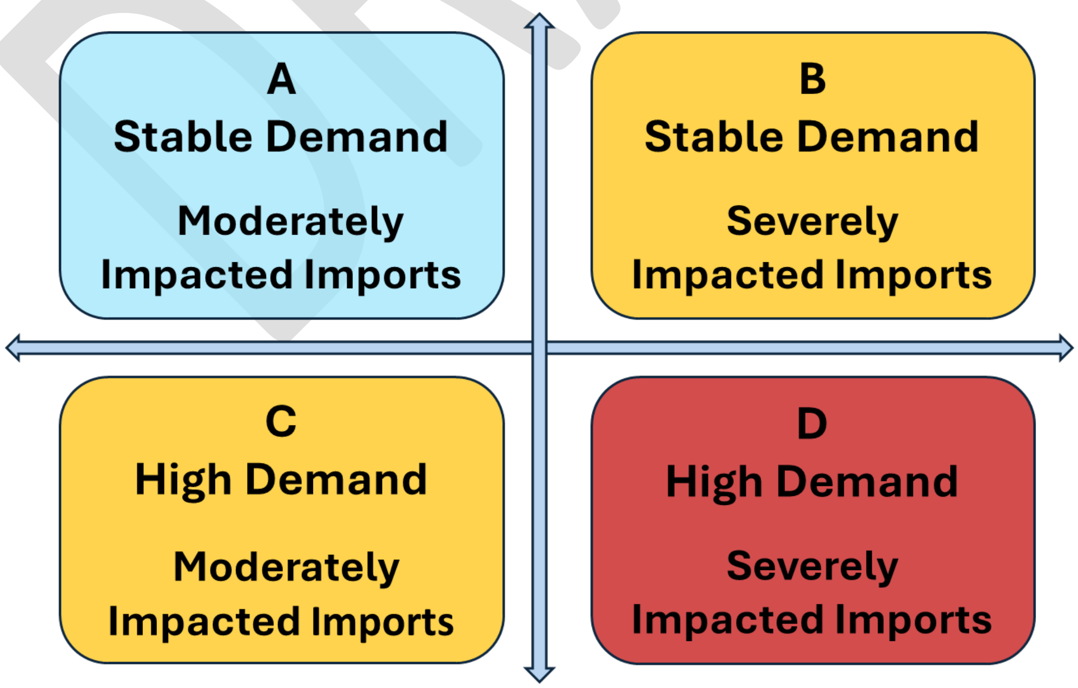
The Santa Clara Valley Water District (Valley Water) is responsible for providing water supply, groundwater management, flood protection, and environmental stewardship in Santa Clara County. Valley Water's service area encompasses the entirety of Santa Clara County, with 15 cities and nearly 2 million people. Valley Water's water supply includes surface water from local reservoirs, groundwater, imported water, and recycled water. In addition, Valley Water has invested in water conservation, which has helped keep the county's water demand relatively flat despite continuous growth.

The Water Supply Master Plan (WSMP) is Valley Water's guiding document for long-term water supply investments to ensure water supply reliability for Santa Clara County. The plan assesses future water supply outlook and demand projections and identifies strategies to meet the county's current and future needs to achieve Valley Water's Level of Service (LOS) goal. Valley Water's Board of Directors (Board) Policy E-2 established that its LOS goal is to "Meet 100 percent of annual water demand during non-drought years and at least 80 percent of demand in drought years." The WSMP 2050 updates the previous plan by assessing and adapting to changing conditions. The cornerstone of the WSMP 2050 is an adaptive management strategy to support investment decisions in the face of uncertainties associated with future conditions and project development.

Planning Approach

The WSMP 2050 analyzes four alternative futures based on the combination of demand projections and forecasted imported water supplies (Figure ES-1). This approach is intended to account for uncertainty in forecasted future demand and supply and provide an adaptive framework for decision-making.

Figure ES-1 Four Future Conditions for Planning



The stable demand assumes a flat demand at 2030 levels through 2050 at 330,000 acre feet per year (AFY). The high demand is projected to be 350,000 AFY, assuming significant, unmitigated impacts from growth and severe climate change. Both demands assume Valley Water achieves its long-term conservation goals. The imported water baseline supply scenarios were selected from the Department of Water Resources (DWR) modeling. The moderately impacted imports scenario represents State Water Project (SWP) and Central Valley Project (CVP) deliveries with small impact from climate change, while the severely impacted imports scenario represents significantly impacted deliveries, particularly during droughts.

Needs for Investment

Valley Water's current system and sources of water supply can meet demands during wet and normal years, but **extended droughts remain the biggest water supply challenge.** Under all four potential 2050 futures, Valley Water will experience water shortages if relying only on existing supplies and infrastructure during multi-year droughts. The shortages may start as early as 2030. In 2050, the average shortage over a six-year drought could be as much as 70,000 AFY, depending on the projected demand and imported water supply conditions. These shortages are large and already take into account meeting drought water use reduction calls and achieving long-term conservation goals. Valley Water needs to invest in new projects to address those shortages to ensure long-term water supply reliability for Santa Clara County. Without additional investments, the predicted shortages mean Valley Water will have a reduced service level, and therefore less water available to the community. A reduced level of service could have an immediate and real impact on residents and businesses, billions of dollars in economic losses, and could adversely and chronically affect economic development in the county.

Water Supply Strategy

Valley Water considers and evaluates a broad range of projects in the WSMP 2050 to address future water supply needs, including alternative supply projects, local and imported surface supply projects, storage projects, and recharge projects. The projects were evaluated using a number of criteria, including supply benefit, cost, reliability, likelihood of success, environmental impacts, jurisdiction and partnership, and public acceptance. Valley Water also developed water conservation and reuse goals as part of efforts to address future shortages. The established water conservation goal for 2050 is 126,000 AFY, and the goal for reuse is to develop 24,000 AFY of potable reuse by 2035, with a long-term vision to maximize water reuse in the county up to 32,000 AFY by 2050.

The water supply strategies were developed through portfolio analysis and evaluation. Depending on different considerations and factors, there are many combinations and strategies to achieve long-term water supply reliability. The portfolios that meet future water supply needs generally include a mix of supply and storage projects. To help outline investment options and present tradeoffs, potential investment strategies were developed based on three themes - **lower cost**, **local control**, and **diversified**. One representative portfolio for each strategy was selected and summarized in Table ES-1, along with the total lifecycle cost in 2025 dollars and expected supply or storage benefits. Actual benefits of each project and strategy vary by demand, hydrological condition, and how they operate in the system. And additional supply benefits can be achieved in portfolios when some projects complement each other and make the whole system much more efficient, highlighting the need for diversified projects to better utilize project potentials.

Table ES-1. Selected Portfolio for Each Water Supply Strategy

STRATEGY	PROJECTS	COST (BILLION)	ADDED BENEFITS
LOWER COST	San José Direct Potable Reuse Delta Conveyance Project B.F. Sisk Dam Raise Groundwater Banking (250,000 AF) South County Recharge	**$4.6**	38,000 AFY supply 314,000 AF storage Additional system flexibility
LOCAL CONTROL	San José Direct Potable Reuse Palo Alto Potable Reuse Pacheco without Partners Groundwater Banking (150,000 AF) South County Recharge	**$6.7**	32,000 AFY of supply 290,000 AF storage Additional system flexibility
DIVERSIFIED	San José Direct Potable Reuse Delta Conveyance Project B.F. Sisk Dam Raise Pacheco with Partners Groundwater Banking (350,000 AF) South County Recharge	**$5.9**	38,000 AFY supply 505,000 AF storage Additional system flexibility

Each strategy represents a pathway to future water supply reliability, but with tradeoffs:

- **Lower Cost** – Focuses on affordability and minimizing costs, with a mix of supply and storage projects. However, it has high risks, as all major projects require partnership and institutional agreements to be successful.

- **Local Control** – Focuses on the projects in the County that Valley Water exercises more control. However, it has the highest cost, as it includes the three most expensive projects being considered (two potable reuse projects and Pacheco).

- **Diversified** – Focuses on diversifying the existing system with a diverse set of projects. However, it has a relatively high cost and more institutional complexity since it includes more projects. This strategy can also meet the high demand for the worst-case future condition.

The three strategies are able to address the shortage for all futures except the worst case condition, and serve as the basis for developing strategies for that condition and an adaptive management framework.

Adaptive Management

Since there are different strategies to achieve future water supply reliability and given uncertainty in project development and future supply and demand conditions, an adaptive management approach was developed to provide the Valley Water Board with flexibility and the ability to make incremental investment decisions. The adaptive framework includes a roadmap and annual reporting. The roadmap outlines near- and mid-term actions and defines indicators and conditions to guide project decisions. The annual reporting tracks project progress and provides up-to-date information to help inform decision-making.

The roadmap includes recommended actions at different timelines, especially immediate actions as the starting point of the adaptive management framework:

- **Now –** focus on the **Lower Cost** strategy, which includes San Jose Potable Reuse, B.F. Sisk Dam Raise, Delta Conveyance Project, Groundwater Banking, and South County Recharge; Continue planning for Pacheco and Sites; Continue the Desalination feasibility study; Continue implementing conservation programs.

- **Near-term (2-3 years) –** Assess success/progress on project planning and implementation; Make project funding, participation, or go/no-go decisions based on indicators, new information, and actual conditions; Continue planning for other projects.

- **Mid-term (5 years) –** Assess progress on project implementation; Update demand projections and water supply outlook; Update WSMP

Annual reporting through the Monitoring and Assessment Program (MAP) will be a critical component of the adaptive management framework. A standard MAP report will be devised to include key elements of the WSMP, including progress on projects, conditions of indicators, and whether any adjustments are recommended. The timing of the MAP will be aligned with the annual Capital Improvement Program (CIP) Five-Year Plan and water rate-setting cycle to support related decision-making.

Plan Development

The WSMP 2050 was developed over two years with progress reports and opportunities for input and feedback to the Board and Committees throughout the process. In addition, the plan development included stakeholder feedback and review by an expert panel.

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Section 1 – Introduction

1.1 Overview

For nearly a century, Valley Water has met its mission to provide Silicon Valley with safe, clean water for a healthy life, environment, and economy. As one of the largest wholesale agencies in California, Valley Water is currently responsible for providing wholesale water supply, groundwater management, flood protection, and environmental stewardship in Santa Clara County.

Since its creation in 1929, Valley Water, together with its retail agencies and partners, has invested in water infrastructure and diverse sources of supply to fulfill its mission. Through careful planning and continued investments, Valley Water has developed and maintained a complex and interconnected water system that has reliably served Santa Clara County for many decades. Today, Valley Water has $7.5 billion in water utility assets and diverse supply sources, including local surface water, imported water, groundwater, and recycled water. Valley Water's water system has provided foundational support to Silicon Valley's vibrant, nearly $400 billion economy and the quality of life of about 2 million residents. In addition, Valley Water has made significant investments in water conservation since the early 1990s. Valley Water's conservation efforts, along with water use efficiency technology and regulations, have helped to keep the county's water demand relatively flat despite continuous growth.

Valley Water's Board Policy E-2 established that its LOS goal is to "Meet 100 percent of annual water demand during non-drought years and at least 80 percent of demand in drought years." Valley Water must continue to maintain reliable and adequate water supplies to meet its LOS goal. While Valley Water has successfully managed its water supply to meet the county's need, challenges to its future water supply reliability remain and are mounting. The dynamic shifts of California's hydrologic cycles will bring recurring droughts, one of Valley Water's greatest water supply challenges. Climate change impacts weather patterns and casts uncertainty on future water supply timing and availability. Moreover, water demand, the biggest driver of investment need, is changing and shaped by a range of social and economic factors and changing conditions. These challenges create the need for water supply investment and water policies to better prepare for the future. Valley Water remains in an era of investment to maintain existing water supply infrastructure while prudently developing new infrastructure in response to existing and emerging challenges.

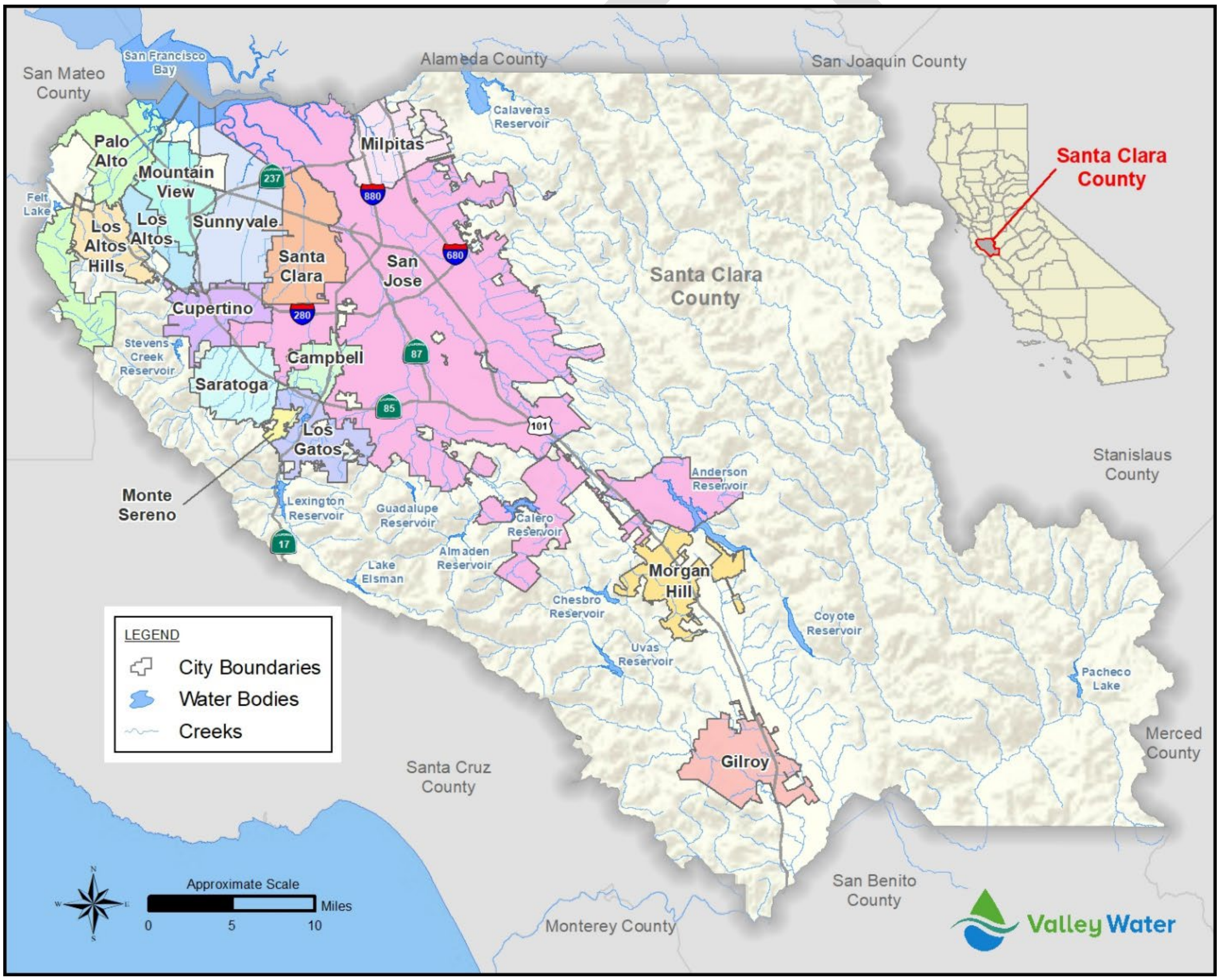
Achieving Valley Water's future water supply reliability requires thorough and careful planning. Valley Water's long-range WSMP is the tool that serves as the guiding document to determine the right level of investment by 2050 in order to maintain a viable system for the county's current and future needs.

1.2 Valley Water Background

Valley Water is a special district that provides water resources management for Santa Clara County. Formed in 1929 in response to groundwater overdraft and land subsidence, Valley Water became the wholesale agency to provide services for the entire county by the 1980s. Since then, Valley Water has been authorized to provide wholesale water supply, groundwater management, flood protection, and environmental stewardship in Santa Clara County.

Valley Water's service area includes the entirety of Santa Clara County, which is located at the southern end of San Francisco Bay (Figure 1-1). The county encompasses approximately 1,300 square miles and includes 15 cities from Palo Alto in the north to Gilroy in the south, with a population of nearly 2 million.

Figure 1-1. Santa Clara County



Valley Water Mission

Provide Silicon Valley safe, clean water for a healthy life, environment, and economy

To fulfill its mission, Valley Water has invested in water infrastructure and diverse sources of supply. In response to groundwater overdraft and land subsidence in northern Santa Clara County, in the 1930s Valley Water constructed six reservoirs to store winter rains for groundwater recharge and summer irrigation use. In the 1950s, four additional reservoirs were built, nearly tripling local storage to about 166,000 AF. Still, local supplies were not enough to meet the county's growing population and subsidence continued. In 1965, Valley Water began importing water from the SWP for groundwater recharge and use at drinking water treatment plants. Valley Water also began receiving water from the Federal CVP in 1987. By the end of the 20th century, groundwater levels recovered, and land subsidence was halted. Starting in the 1950s, Valley Water has worked to develop recycled and purified water in the county, and in 2014 began operating the Silicon Valley Advanced Water Purification Center (SVAWPC), a collaborative effort with the San Jose-Santa Clara Regional Wastewater Facility. The SVAWPC currently produces up to 8 million gallons of purified water per day to enhance non-potable supplies distributed by South Bay Water Recycling.

Today, Valley Water manages a complex and interconnected water supply system to store, treat, and distribute water. Valley Water wholesales drinking water to 13 water retailers, who then deliver water to their customers. Valley Water is also the Groundwater Sustainability Agency (GSA) for the Santa Clara and Llagas subbasins and sustainably manages local groundwater basins to support beneficial use by water retailers, private well users, and the environment.

1.3 Water Supply Planning

Valley Water has engaged in long-range planning to guide its water supply investments to ensure water supply reliability since the 1990s. The first long-range plan, the Integrated Water Resources Plan, was completed in 1996. In the following decades, the plan went through three updates. The most recent plan, WSMP 2040, was adopted by the Valley Water in 2019. With each update, the plan has evolved in response to the challenges of the times, but its fundamental goal remains the same - to ensure Valley Water has a reliable water system to serve Santa Clara County now and in the future, regardless of the challenges that emerge along the way.

1.3.1 Water Supply Master Plan 2040

The WSMP 2040 is Valley Water's existing long-range plan through 2040. The WSMP 2040 assesses future county-wide demands and needs and recommends a three-pronged strategy and a portfolio of projects to be invested to meet those needs:

1) Secure existing supplies and infrastructure. This includes securing local water rights, pipeline maintenance, dam retrofits, treatment plant improvements and other projects to maintain the existing system, as well as actions to secure imported water supplies.
2) Expand water conservation and reuse. This involves expanding the use of drought-resilient supplies and conservation because they are going to be most reliable in the future under a changed climate. These generally are local supplies, not dependent on rain, and are reliable during droughts.
3) Optimize the use of existing system to increase operational flexibility. In some years, supplies exceed demands. Additional facilities would increase Valley Water's flexibility to use or store these excess supplies, improving its ability to respond to outages or challenges like droughts or water quality problems.

These three elements together provide a framework for a sustainable and reliable future water supply and strike a balance between protecting existing assets, investing for the future, and making the most of the existing water supply system. In addition, the WSMP 2040 established an annual MAP to provide new information and project updates to support related decision-making.

1.3.2 Changed Conditions Since the WSMP 2040

Valley Water continues to face a number of ongoing and emerging challenges to its future water supply reliability. Since the adoption of the WSMP 2040, conditions have changed on multiple fronts, including another severe drought, shifts in demand patterns, and affordability issues. Valley Water must re-envision its future water supply strategy to continually adapt to changing conditions.

Severe Drought
Drought cycles have played an important role in spurring the re-examination of water management plans and policies to better prepare for the future. Since the adoption of the WSMP 2040 in 2019, California experienced another drought in 2020-2022. During this drought, Valley Water received record-low imported water allocations, which stress-tested the existing system. This most recent drought once again brought the need for a reliable water supply strategy sharply into focus and highlighted the need for additional investment and resilience. As droughts could continue to become more intense with climate change in the future, Valley Water needs to reinforce its diverse water supply portfolio to ensure reliability during severe droughts.

Imported Water Allocations
Imported water from the SWP and CVP is an important component of Valley Water's water supply portfolio, accounting for about 40% of its total supply. During the 2020-2022 drought, Valley Water received record low imported water allocation – 5% of SWP allocation and 0% of CVP agricultural allocation in 2021 and 2022, and 0% of the CVP M&I allocation in 2022. This is among the lowest allocations and poses unprecedented challenges to Valley Water's water supply planning and management. With climate change impacts and potential environmental regulations in the Sacramento-San Joaquin Delta (Delta), as well as state requirements to reduce the reliance on the Delta, future water supply availability from imported water is uncertain and generally expected to decrease. Imported water will continue to be an important source of supply to Santa Clara County, but its challenges need to be carefully considered in long-range planning efforts.

Demand Trend
Over the past 20 years, overall water use in the county has decreased despite a 25% increase in population. Water conservation efforts, advances in water efficient technology, and droughts contribute to the decline in water use. This demand trend, however, was not fully reflected in the WSMP 2040. The latest demographic and economic growth projections foresee a much denser growth pattern than in the past. The denser growth means lower water use per housing unit and signifies slower increases in water demand, which has major implications for long-range planning and investment in future water supplies.

Affordability
Water infrastructure projects are often large, expensive, and complex. While cost is always a major concern and hurdle to big water infrastructure projects, water affordability has become front and center of water supply planning, as project costs have skyrocketed due to high inflation and supply chain issues over the past few years. The high and fast-increasing cost of water infrastructure projects places a greater burden on water supply planning to identify wise investment strategies.

Direct Potable Reuse Regulation
The impacts of drought and climate change highlight the need for a locally controlled, drought-resilient water supply in Santa Clara County. Valley Water has been evaluating water reuse, in particular potable reuse, as a reliable and locally controlled source to mitigate drought risks and diversify the region's water supply portfolio. In October 2024, the State enacted the Direct Potable Reuse (DPR) regulations, which allow agencies to

pursue a new, more flexible approach to potable reuse.

1.4 WSMP 2050 Development

The WSMP 2050 continues Valley Water's approach to long-range planning by assessing and adapting to changing conditions facing Santa Clara County. The plan looks out further to 2050, to address both existing and emerging challenges and identify strategies to maintain the reliable water supply system that the county has enjoyed for many decades. The cornerstone of the WSMP 2050 is an adaptive management strategy to support investment decisions in the face of uncertainties associated with future conditions and project development.

The WSMP 2050 establishes planning goals to guide what Valley Water intends to achieve. Valley Water's mission is to provide a safe and reliable water supply now and in the future. To that end and consistent with Board Ends Policies, the planning goals of the WSMP 2050 are to:

- Ensure reliability and sustainability of the existing water supply system
- Diversify water supplies to meet the Level of Service goal
- Minimize the risk of shortage and disruption
- Maintain affordable water rates through cost-effective water supply investments and management

The WSMP 2050 was developed through collaboration with internal and external stakeholders, input and direction from the Valley Water Board and committees, and guidance from an independent expert panel.

1.5 Report Organization

The WSMP 2050 is organized as follows:

- Section 1 – Introduction: Provides an overview of Valley Water and need and purpose for the Water Supply Master Plan.

- Section 2 – Water Supply System: Details Valley Water's current water system, including sources of supply, major infrastructure, and conservation and demand management.

- Section 3 – Water Supply Challenges: Describes Valley Water's current and future water supply challenges.

- Section 4 – Water Supply Needs Assessment: Provides water supply needs assessment under multiple potential future baseline conditions.

- Section 5 – Project Options: Presents information on major projects being considered and evaluated in the plan.

- Section 6 – Water Supply Strategies: Describes portfolio analysis and potential water supply strategies for achieving water supply reliability.
- Section 7 – Adaptive Management Framework: Details a framework for making incremental management decisions in the face of uncertainty.
- Section 8 – Coordination and Outreach: Describes Board and committee engagement, public outreach, and independent expert support.

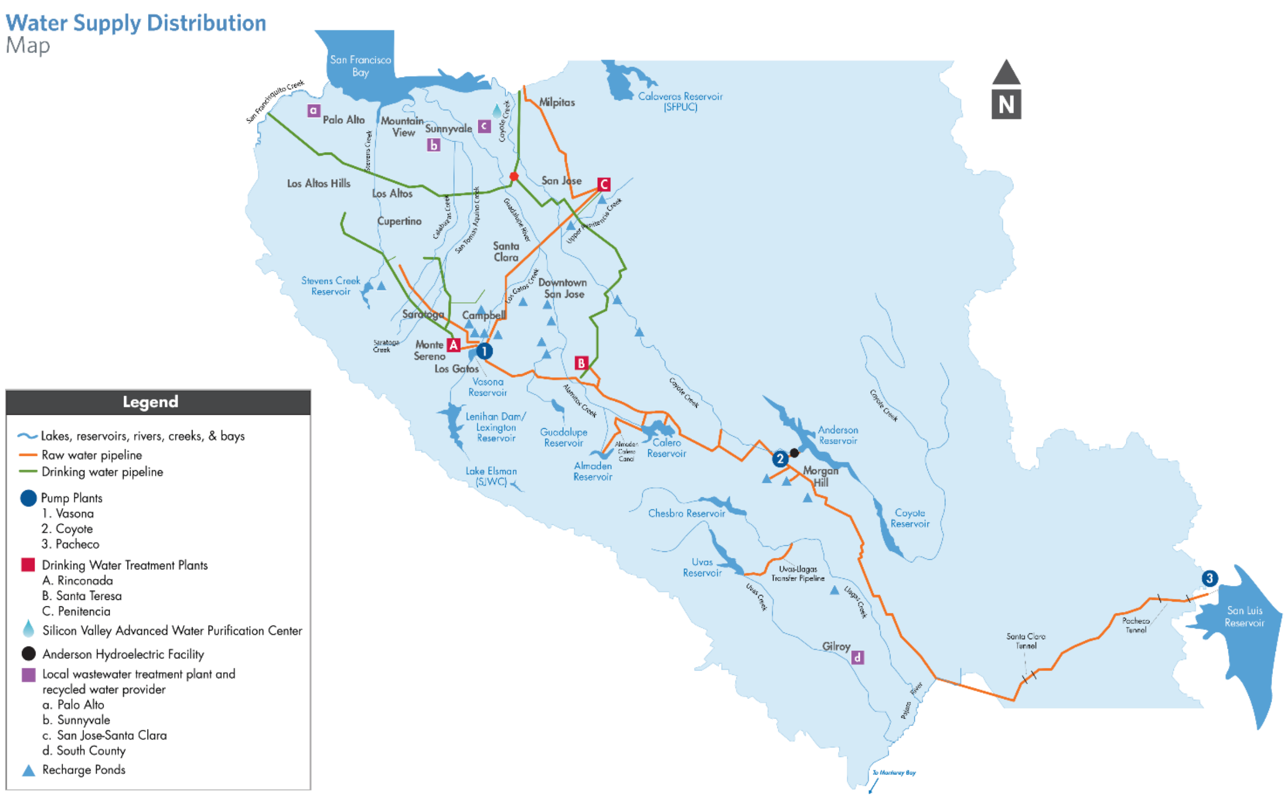
Section 2 – Water Supply System

Valley Water is the primary water resources management agency for Santa Clara County. Valley Water's water supply includes surface water from local reservoirs, groundwater, imported water, and recycled water. Together, these supplies are used to meet the county's demand for water.

2.1 Water Supply System Overview

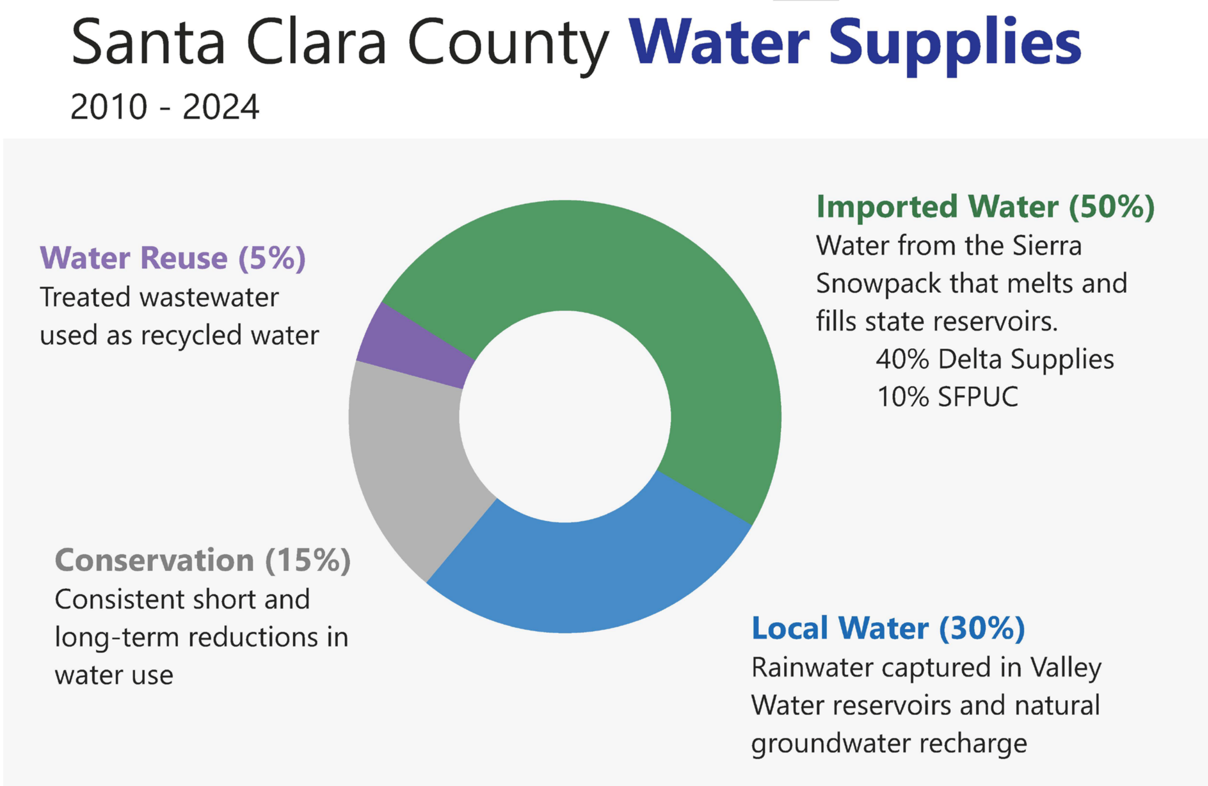
Valley Water manages an integrated water resources system to provide safe and clean water, flood protection, and stewardship of streams for Santa Clara County. Currently, Valley Water manages 10 dams and surface water reservoirs, three water treatment plants, an advanced recycled water purification center, a state-of-the-art water quality laboratory, 134 miles of raw and treated water pipelines, about 100 groundwater recharge ponds covering 285 acres, and more than 333 miles of jurisdictional streams, including 98 miles suitable for instream recharge (Figure 2-1).

Figure 2-1. Water Supply System



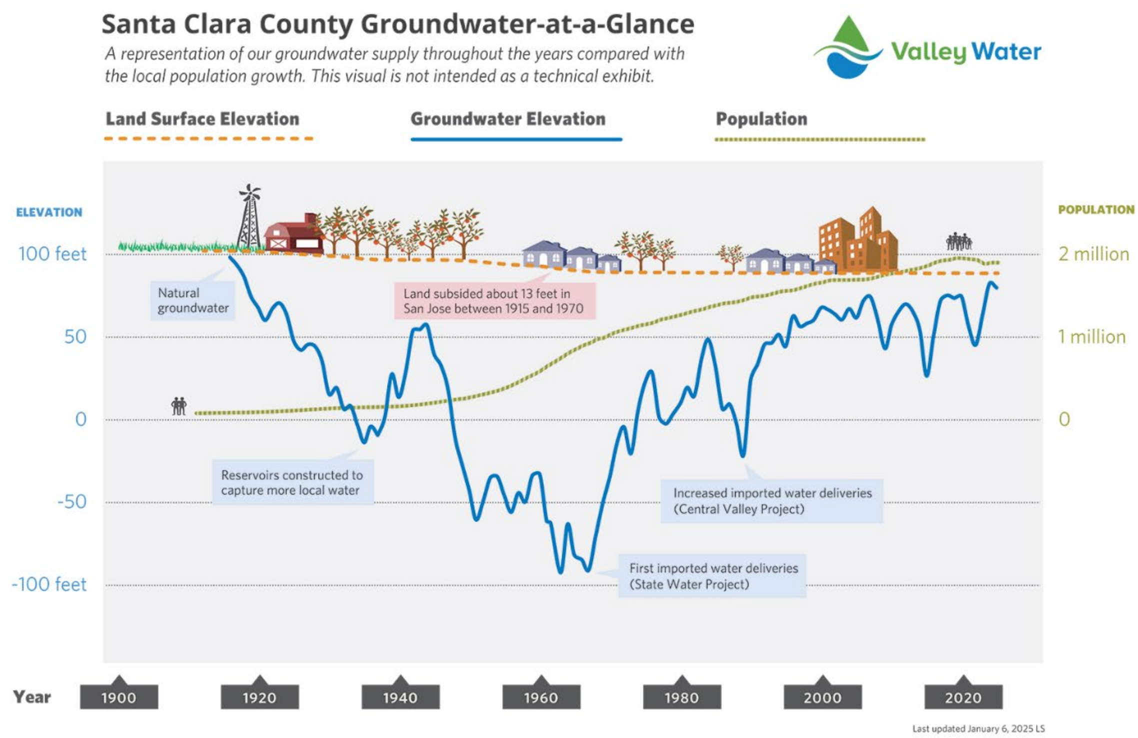
Water supplies for the county include local surface water and groundwater, imported water, and recycled water (Figure 2-2). Water conservation is also an important part of the water supply mix, helping reduce water demands and improve reliability during droughts. Local water supplies make up about half of the county's water supply. Local sources include natural groundwater recharge and surface water supplies, including surface water rights held by Valley Water, San Jose Water Company, and Stanford University. A small but growing portion of local water supply is recycled water used for non-potable purposes. Valley Water's imported water from the SWP, CVP, and supplies delivered by the San Francisco Public Utilities Commission (SFPUC) make up about another half of the county's supply.

Figure 2-2 Percentage of Water Supply from Different Sources



Valley Water has been a leader in conjunctive use in California for decades, utilizing imported and local surface water to supplement groundwater and maintain reliability in dry years. Conjunctive use helps protect local subbasins from overdraft, land subsidence, and saltwater intrusion and provides critical groundwater storage reserves for use during droughts or outages. After being formed to address declining groundwater levels and land subsidence, Valley Water constructed reservoirs to capture local water. However, local supplies became insufficient to meet the needs of the county's growing population around the middle of the last century. In response, Valley Water began importing water from the Delta via the SWP in 1965 and from the CVP in 1987. These investments, along with investments in water recycling and conservation, have resulted in sustainable groundwater subbasins and reliable water supplies for the County. Figure 2-3 shows how Valley Water's conjunctive water management strategy has dramatically contributed to a sustainable water supply.

Figure 2-3. Historic Groundwater Conditions



2.2 Local Surface Water

Valley Water currently has 20 appropriative water rights licenses and one filed water right permit with the State Water Resources Control Board totaling over 227,300 AFY. In addition, two of Valley Water's retailers, San Jose Water Company and Stanford University, have their own surface water rights that contribute to local surface water availability for their customers. Local runoff is captured in Valley Water's 10 reservoirs, with a total storage capacity of approximately 166,000 acre-feet, though several are operating at restricted capacity due to seismic stability concerns (Table 2-1). Most of the reservoirs are sized for annual operations, storing water in winter for use in summer and fall. The exception is the Anderson-Coyote reservoir system, which provides valuable carryover of supplies from year to year and emergency supplies. Anderson Reservoir, the largest Valley Water reservoir, sends water to drinking water treatment plants but is currently drained down to deadpool due to seismic concerns, and Valley Water is working on rebuilding the dam, to be completed by the end of 2033. Supplies captured in Calero Reservoir can also be sent to drinking water treatment plants as this reservoir serves as a backup to Valley Water's imported water sources. Also, supplies captured in all local reservoirs are released downstream to provide instream groundwater recharge and maintain aquatic habitats and, on many of the streams, to be diverted to off-stream percolation ponds.

Table 2-1. Existing Reservoir Capacities and Restrictions

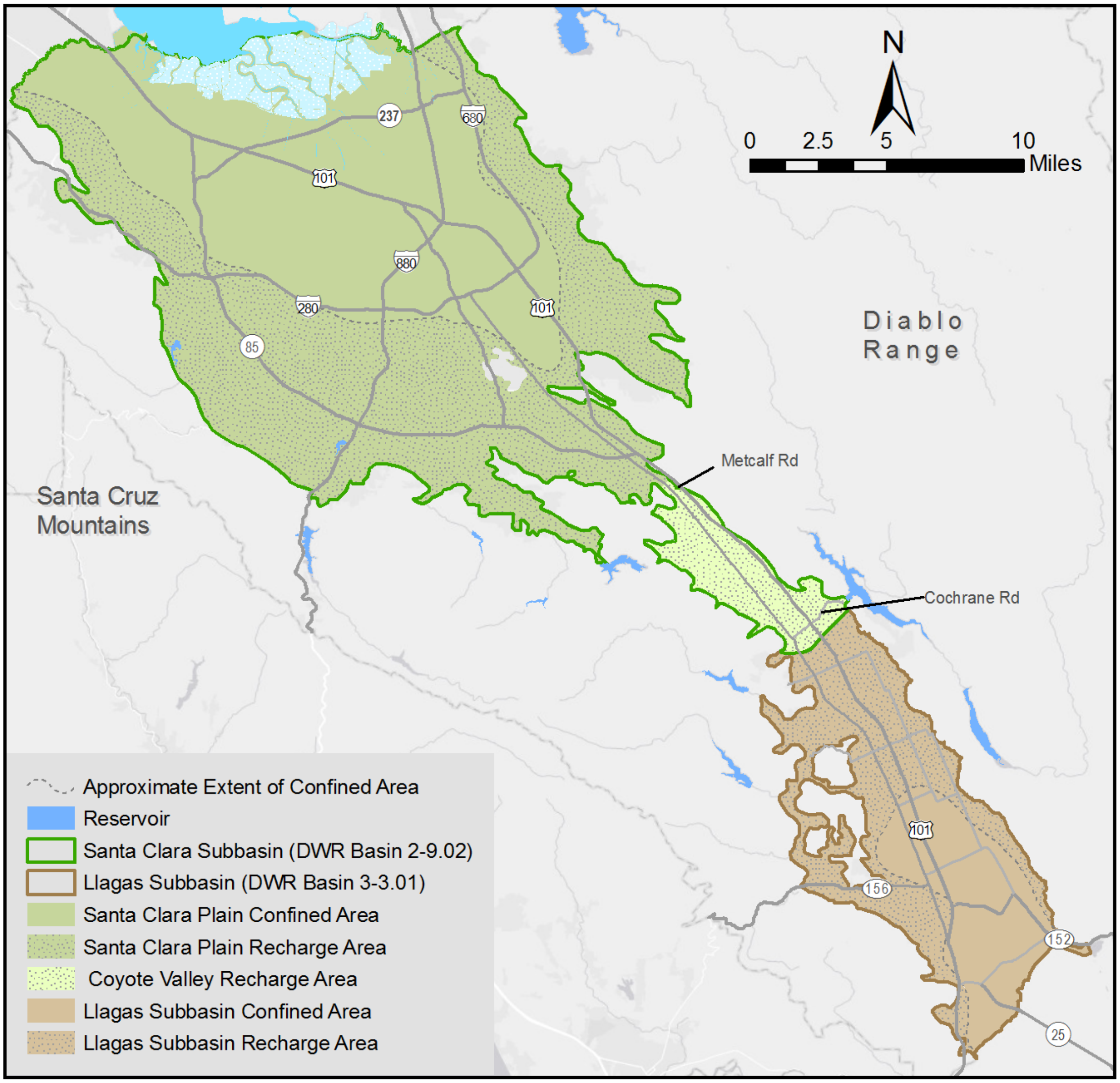
Reservoir	Capacity (AF)	Restricted Capacity (AF)	Restricted Capacity (%)
Almaden	1,555	1,443	93%
Anderson	89,278	3,159	3% (deadpool)
Calero	9,738	4,414	45%
Coyote	22,541	11,843	53%
Guadalupe	3,320	2,134	64%
Stevens Creek	3,056	No restriction	–
Lexington	18,534	No restriction	–
Chesbro	7,967	No restriction	–
Uvas	9, 688	No restriction	–
Vasona	463	No restriction	–
TOTAL	**166,140**	**62,701**	–

2.3 Groundwater

Valley Water manages the Santa Clara and Llagas subbasins for the benefit of well users and the environment. Since the 1930s, Valley Water's water supply strategy has been to maximize conjunctive use of surface water and groundwater supplies to enhance water supply reliability and avoid land subsidence. Local groundwater resources make up the foundation of the county's water supply, but they need to be augmented by Valley Water's comprehensive water management activities to reliably meet the needs of county residents, businesses, agriculture, and the environment. These activities include managed recharge of imported and local surface supplies and in-lieu groundwater recharge through the provision of treated surface water and raw water, acquisition of supplemental water supplies, and water conservation and recycling. As a water wholesaler agency, Valley Water does not directly deliver groundwater to customers but does have some limited emergency groundwater pumping capacity.

Santa Clara County includes portions of two groundwater basins as defined by Department of Water Resources (DWR): the Santa Clara Valley Basin (Basin 2-009) and the Gilroy-Hollister Valley Basin (Basin 3-003). The two groundwater subbasins within Santa Clara County managed by Valley Water are the Santa Clara Subbasin (Subbasin 2-009.02) and the Llagas Subbasin (Subbasin 3-003.01), which cover a combined surface area of approximately 385 square miles. Due to different land use and management characteristics, Valley Water further delineates the Santa Clara Subbasin into two groundwater management areas: the Santa Clara Plain and Coyote Valley, and the Llagas Subbasin is a separate groundwater management area (Figure 2-4). The estimated operational storage capacity of the groundwater subbasins is up to 548,000 AF. Valley Water's managed recharge capacity is up to approximately 144,000 AFY.

Figure 2-4. Santa Clara County Groundwater



Groundwater is pumped from the subbasins by retail water suppliers and private well owners to support municipal, industrial, agricultural, and domestic uses. Although most of the groundwater pumped is a result of Valley Water managed recharge programs, the subbasins are also recharged by the infiltration of rainfall and natural seepage through local creeks and streams. Valley Water includes natural groundwater recharge as a source of supply for long-term water supply planning purposes because it contributes to the available groundwater supply.

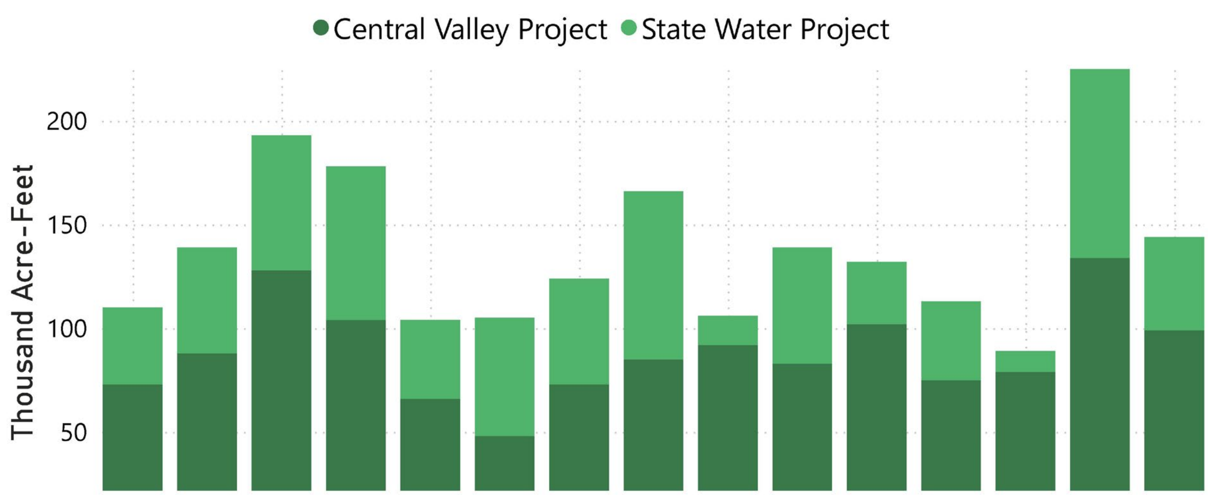
Valley Water continues to be a leader in groundwater management and local subbasins are sustainably managed in accordance with the District Act and Sustainable Groundwater Management Act (SGMA). Valley Water's approved Alternative to a Groundwater

Sustainability Plan and more detailed information on groundwater management is available at https://www.valleywater.org/your-water/groundwater.

2.4 Imported Water

Much of Valley Water's current water supply comes from hundreds of miles away from natural runoff and releases from reservoirs in the Sacramento Valley. This imported water is pumped out of the Sacramento-San Joaquin Delta and brought into the county through the complex infrastructure of the SWP and CVP. Valley Water holds contracts of 100,000 AFY from the SWP and 152,500 AFY from the CVP. The actual amount of water delivered is typically less than these contractual amounts and depends on hydrology, conveyance limitations, and environmental regulations. Valley Water may also augment its imported supplies by taking deliveries of available temporary flood flows from the Delta watershed when conditions allow the CVP or SWP to make these excess flows available. In addition, supplemental imported water is acquired through transfers and exchanges as needed and available. Figure 2-5 shows imported water delivery from the Delta from 2010 to 2024.

Figure 2-5 Imported Water Delivery from 2010 to 2024



The imported supplies are sent to Valley Water's three drinking water treatment plants, used for managed groundwater recharge, or stored in local, State, and Federal reservoirs for use in subsequent years. Valley Water also stores some of its imported water in the Semitropic Groundwater Bank in the San Joaquin Valley for withdrawal during dry periods or as otherwise needed.

2.5 SFPUC Supply

Eight retailers in the county have contracts with SFPUC to receive water from the SFPUC Regional Water System. The eight retailers, considered wholesale customers of SFPUC, are the cities of Palo Alto, Mountain View, Sunnyvale, Santa Clara, San José, and Milpitas; Purissima Hills Water District; and Stanford University. In addition, NASA-Ames is considered a retail customer of SFPUC. An intertie facility between Valley Water and SFPUC provides a backup supply to the residents of Alameda and Santa Clara Counties in an emergency or when planned maintenance activities require supplemental water supply from one agency to the other.

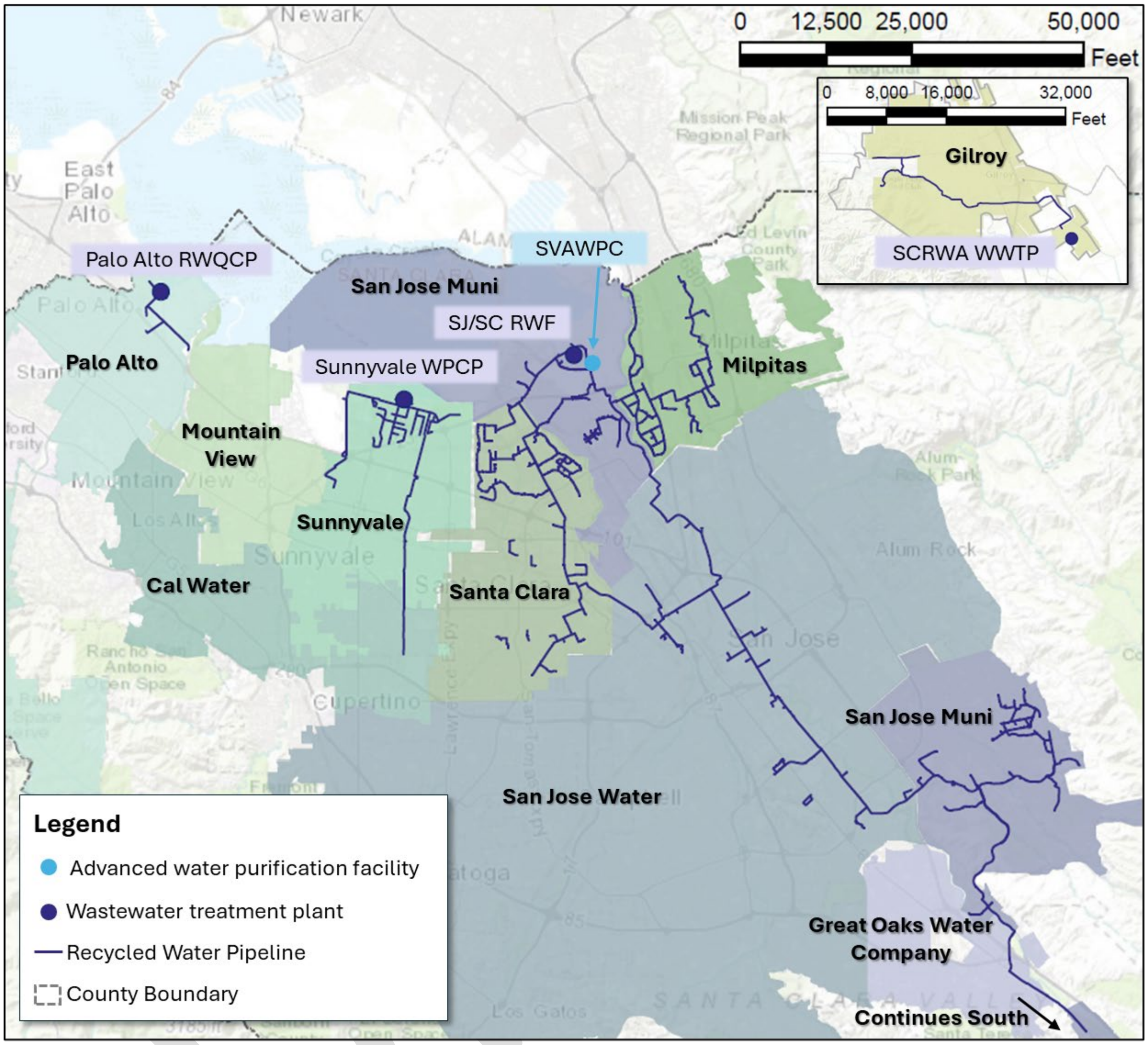
On average, SFPUC supply delivered in Santa Clara County is around 50,000 AFY. Valley Water does not control or administer SFPUC supplies in the county, however, those supplies meet some of the countywide demand and therefore are included in Valley Water's water supply analysis. If SFPUC supplies available to its wholesale customers are cut back significantly, the retailers with SFPUC contracts may request increased treated water from Valley Water and/or increase groundwater pumping, which will have implications for Valley Water's water supply strategy.

2.6 Recycled and Purified Water

A growing source of water supply for Santa Clara County is recycled and purified water. Recycled water is wastewater that is cleaned through multiple levels of treatment. Recycled water is used for non-potable purposes such as irrigation and industrial purposes. Purified water is highly treated water of wastewater origin that is cleaned to provide supply for potable (drinking) water purposes. Both recycled and purified water can help augment drinking water and groundwater supplies through in-lieu recharge; provide a reliable, drought-resilient, locally controlled water supply; and reduce reliance on imported water. Valley Water Board Ends Policy E-2.4 calls for "increase regional self-reliance through water conservation and reuse" and "Promote, protect and expand potable and non-potable water reuse."

Over the past decades, Valley Water has advanced water reuse in the county by leading water reuse planning efforts, providing funding for system expansion, developing wholesale recycled water programs, and constructing new infrastructure. About 11% of wastewater generated in the county is recycled, with recycled water on average at 17,000 AFY, or about 5% of the county's water supply, and distributed for non-potable uses such as landscape irrigation, industrial cooling, and dual plumbed facilities. This recycled water is produced at the four wastewater treatment plants in the county - Palo Alto Regional Water Quality Control Plant, City of Sunnyvale Water Pollution Control Plant, San José-Santa Clara Regional Wastewater Facility, and South County Regional Wastewater Authority (SCRWA). Figure 2-6 shows the existing non-potable system in the county.

Figure 2-6 Existing Non-Potable Recycled Water System in the County



In 2014, Valley Water completed the construction of the SVAWPC. The SVAWPC can produce up to 8 million gallons of purified water per day, which is currently blended with tertiary treated water to improve the quality for non-potable use by a wide variety of customers. Since March 2014, the SVAWPC has demonstrated the effectiveness of advanced treatment technologies to produce purified water suitable for potable use and set the stage for Valley Water to begin a potable reuse program.

Valley Water completed a Countywide Water Reuse Master Plan (CoRe Plan) in 2021 to identify feasible opportunities to expand water reuse, improve water supply reliability, and increase regional self-reliance. The CoRe Plan outlines Valley Water's opportunities and strategies toward achieving up to 24,000 AFY for potable water reuse. The CoRe Plan is available at https://fta.valleywater.org/fl/XNyG7Fja6T#folder-link/

As part of the WSMP 2050 development, Valley Water Board adopted a potable reuse goal of 24,000 AFY by 2035 and a long-term vision to maximize water reuse in the county up to 32,000 AFY by 2050. The 24,000 AFY potable reuse is consistent with what was identified in the CoRe plan and can be achieved with a project in collaboration with the cities of San José and Santa Clara. The long-term vision includes additional potable and non-potable reuse, desalination, stormwater capture, and other alternative water sources. The inclusion of a 2035 goal with the long-term vision promotes a phased approach that accounts for uncertainty with future demand and wastewater availability while balancing affordability and risk of overinvestment. More information on the development of the potable reuse goal can be found in Appendix A.

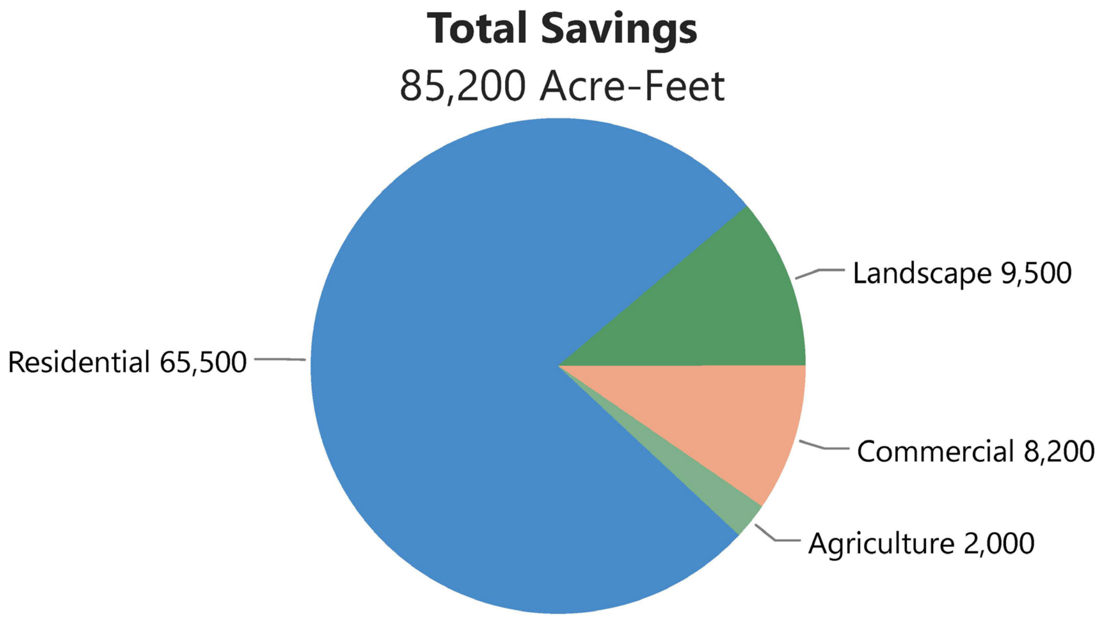
2.7 Water Conservation and Demand Management

Water conservation and demand management have long been an important Valley Water policy and effort to maximize water use efficiency and reduce water use in the county. Valley Water's first conservation programs were offered in 1992, and since then, policies and programs have continued to evolve to maximize program effectiveness. Valley Water's Board Ends Policy E-2.4 calls for "increase regional self-reliance through water conservation and reuse." Under this policy, Valley Water is to "maximize utilization of all demand management tools" and "incentivize water use efficiency and water conservation" as ways to promote water conservation. Following the most recent drought, Valley Water adopted a resolution to call for Water Conservation as a Way of Life in Santa Clara County.

Valley Water has been and continues to be a leader in water conservation. Since the 1990s, Valley Water has implemented many innovative, effective, and comprehensive water conservation programs in the county to achieve water use efficiency. To date, Valley Water has achieved an estimated 406,000 AF of cumulative water savings from a 1992 baseline. These savings are enough to supply the whole county for a year. Because of those investments in water-efficient plumbing and irrigation equipment, low-water landscapes, and new technology, as well as passive savings from regulatory requirements and policies, water use in the county over the past 20 years has remained relatively flat despite a 25% increase in population over the same period.

Santa Clara County is now one of the most water-efficient counties in the State, with annual savings of around 85,000 AFY as of Fiscal Year (FY) 2024 and a 10-year (2014-2023) average per capita water use of 69 gallons per day. Most of the savings are from the residential sector, predominantly indoor and driven by passive water savings (Figure 2-7). Program-specific water savings (or active savings) are trending increasingly toward outdoor savings. In FY 2024, outdoor conservation programs yielded over 50% of active savings for the first time. Without the savings, the county-wide demand would be much higher. Valley Water's continuous promotions and investments in conservation have helped significantly reduce the need for investments in other, more costly water supply options.

Figure 2-7 Fiscal Year 2024 Water Savings by Sector



Valley Water's long-term conservation goals are to achieve 99,000 AFY in water savings by 2030 and 110,000 AFY by 2040 (including 1,000 AFY stormwater capture). A water conservation goal of 126,000 AFY by 2050 is also established through this plan and discussed in Section 2.7.4. Meeting these goals is critical for achieving water supply reliability for the county. Currently, Valley Water has more than 20 active water conservation programs in place to reduce water consumption in homes, businesses, schools, government facilities, and agriculture. These programs are designed to achieve sustainable, long-term water savings and are implemented regardless of water supply conditions. In addition, plumbing codes, building codes, and market-driven forces also contribute to passive savings. Both active and passive water savings from Valley Water's programs are counted towards meeting the goals and saving estimates.

To identify strategies to achieve both Valley Water's aggressive long-term conservation goals and the State's "Making Conservation a California Way of Life" regulatory framework's objectives, Valley Water completed its Water Conservation Strategic Plan (Strategic Plan) in 2021. The Strategic Plan details specific recommendations and strategies for increasing participation rates in water conservation programs, addressing geographic or demographic disparity in participation trends, and considering the creation of new programs and conservation policies. Importantly, the Strategic Plan determined that the type and variety of programs Valley Water offers are sufficient to meet the long-term savings goals through 2040 if resources are invested to increase participation rates. Specific recommendations include maintaining drought-level participation rates during non-drought years and increasing participation in the commercial, industrial, and institutional sectors. Additional information about the Strategic Plan and available water conservation programs can be found at www.watersavings.org.

2.7.1 Active Conservation

Active conservation is water saved directly from water conservation programs implemented, administered, and/or funded by Valley Water. Valley Water has a wide range of programs to promote active conservation across sectors in the county.

Indoor Water Conservation

Indoor conservation continues to play an important role in the region's overall goal of achieving water-use efficiency. Over the past decade, Valley Water has developed a number of conservation programs that incentivize water savings in residents and businesses within Santa Clara County.

In 2019, Valley Water launched an Advanced Metering Infrastructure (AMI) meter cost-sharing program. AMI is an integrated system of meters and information systems that provides near real-time access to customer water use data, which can help identify leaks or abnormal use quickly so problems can be addressed in a timely manner. Through this cost-sharing program, Valley Water provides funding to water retailers in Valley Water's service area to convert utility customer meters to AMI. To encourage the installation of these meters, Valley Water will cost share up to $70 per installed AMI meter and will fund (when combined with water use reports) 50% of the cost of the software linked to AMI. Since its launch, Valley Water directly funded or indirectly supported AMI deployment for six retailers that will install up to 93,000 AMI meters, which once fully deployed represent approximately 20% of customer utility meters in the county. Valley Water is working with other retailers to continue sharing costs for AMI meter installation. In addition, Valley Water has offered rebates for the installation of submeters since 2008. The Submeter Rebate Program provides $150 per submeter installed at multi-family housing complexes, such as mobile home parks, condominium complexes, well owners, and Accessory Dwelling Units. Since 2008, Valley Water has funded the installation of 7,588 submeters.

Valley Water also has other new and ongoing programs to promote indoor water savings. Among the items popular with residents and business is the Online Shopping Cart Program, an online tool to streamline order requests for residential and CII customers to access free water conservation devices and educational materials. The Fixture Replacement Program is also popular, Valley Water has retrofitted nearly 9,000 fixtures, distributed or directly installed more than 438,000 low-flow showerheads and aerators, and over 330,000 low-flow or high-efficiency toilets and urinals throughout the county. In addition, Valley Water's Water Efficient Technology Rebate Program provides rebates for process, technology, and equipment retrofits that save water at CII properties. Since its launch in 1997, Valley Water has funded 114 projects, saving approximately 1,592 AFY. The WET Rebate continues to be one of Valley Water's most cost-effective programs in meeting the region's long-term savings goals.

Outdoor Water Conservation

As confirmed by Valley Water's 2021 Strategic Plan, outdoor water conservation programs have the greatest potential to save significant volumes of water in short-term drought responses and in achieving long-term savings goals. Valley Water provides financial incentives, including rebates and direct installation services, to every type of property with qualifying landscapes from residential to CII customers in order to reduce outdoor water use.

Valley Water began to focus on water-efficient landscapes by launching a Landscape Rebate Program in 2006. The program provides incentives for lawn conversion to water-wise landscapes, irrigation equipment upgrades, and rainwater capture. Currently, eligible participants receive $2 per square foot of irrigated turf grass or pool converted to low-water landscapes. This program's maximum rebate for customers is $3,000 and $100,000 for residential and CII sites, respectively. Through cost-sharing agreements, higher rebate rates and maximum rebate amounts are available in specific service areas throughout the county. Additional incentive details are available at www.watersavings.org. To date, over $14.3 million was rebated for approximately 17.5 million square feet of conversion. Valley Water also offers Direct Installation Services for those who qualify by funding a vendor to perform the work, and partners with local organizations to fund their lawn conservation.

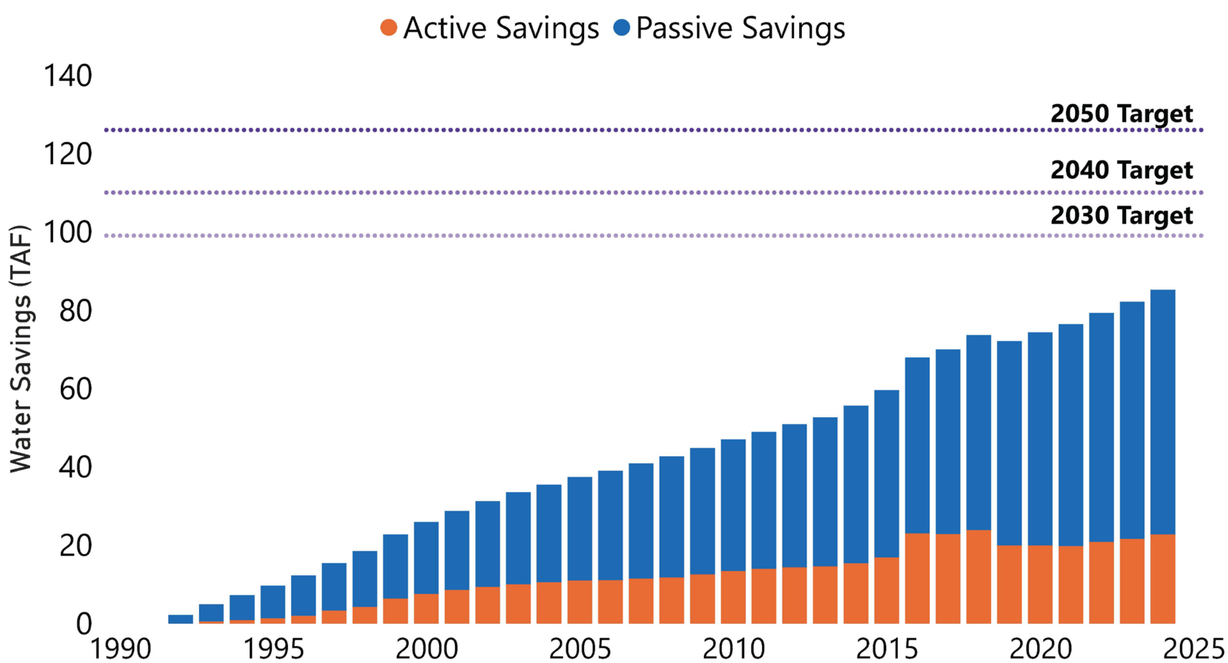
Additional outdoor conservation programs include a Graywater Rebate Program offering $200 per system. Eligible systems are for laundry-to-landscape graywater wherein water is diverted from a clothes washer to irrigate trees and plants. In addition, Valley Water provides landscape surveys and site-specific landscape water budgets to nearly 4,800 qualifying multifamily and CII sites, as well as free consultations or technical assistance to residential and CII customers.

Agricultural Water Conservation
The agricultural sector represents one of the lowest categories of water consumption in Valley Water's service area, representing about 8% of total water use in the county. Valley Water's 2022 Baseline Study of Agricultural Water Use in Santa Clara County found that the local agricultural sector was highly water efficient, but there is potential for achieving further water efficiency. Valley Water is progressively broadening its efforts to establish benchmarks for sustainable water conservation. Through the agricultural mobile irrigation laboratory program, Valley Water provides free irrigation system evaluations and irrigation efficiency services for growers to help improve irrigation efficiency in seasonal row crops, tree crops, greenhouse crops, nurseries, and vineyards. These services provide growers with information on how to achieve an irrigation efficiency of 80% or greater.

2.7.2 Passive Conservation

Passive conservation is water saved as a result of water efficiency requirements for plumbing fixtures in building codes, appliance water use standards, other regulations, and market forces. California urban water agencies, including Valley Water, spearheaded many of these code requirements and market transformations through the early adoption of technologies and support for key legislation. Since 1992, water use efficiency and energy codes have set efficiency standards for several types of water-using fixtures, including toilets, showerheads, faucet aerators, and clothes washers, among others. Since 2010, the proportion of passive savings from toilets increased due to the enactment of AB 715, which established the 1.28 gallons per flush toilet standard and mandated High Efficiency Toilets (HETs) in new construction, among other requirements. Over time, the State has implemented additional efficiency standards, which further contribute to passive savings. Passive savings are realized over time regardless of Valley Water's conservation programs, and account for 73% of Valley Water's total savings as of FY 2024. Figure 2-8 shows the growth of annual active and passive savings since the water conservation program's inception.

Figure 2-8 Annual Active and Passive Savings Since the 1990s



An additional source of potential passive savings is the Model Water Efficiency New Development Ordinance (MWENDO), developed in 2015 by a joint task force of several agencies and organizations led by Valley Water. The ordinance is intended to be adopted by jurisdictions in Santa Clara County to ensure water use efficiency in new development. The ordinance is designed to be customizable depending on cities' needs and includes a variety of water efficiency measures for new developments. Valley Water continues to promote the adoption of MWENDO, which would ensure that new developments meet strong water efficiency standards and result in passive savings.

2.7.3 Education and Outreach

Outreach and education increase public awareness of drought and water shortage and encourage the adoption of water-saving devices and practices. Valley Water maintains annual partnerships to promote water conservation programs countywide. Valley Water conducts outreach activities which include multi-media marketing campaigns directed at the diverse county population, website development and maintenance, social media, publications, public meetings, community events, interagency partnerships, corporate environmental fairs, water conservation workshops and seminars, and a speaker's bureau. Outreach efforts focus on supporting customers and key stakeholders to minimize adverse impacts resulting from drought conditions, and advance community knowledge, awareness, and understanding of the conservation and water supply services provided by Valley Water. In the recent drought, Valley Water in cooperation with retailer agencies conducted multi-lingual, multi-cultural water conservation advertising and outreach campaigns to urge residents and businesses to make permanent changes in their everyday uses of water. Starting in 2016, Valley Water has annually held the Landscape Summit, a forum for landscape professionals to learn about water issues in the county and California as a whole and how water relates to the landscaping industry.

Valley Water's outreach also involves partnerships, cost-sharing agreements, and grant programs. Collaboration with local water retailers, municipalities, and non-profit organizations presents mutually advantageous opportunities for Valley Water and its partners to meet shared objectives. In 2022, Valley Water entered a partnership with the Bay Area Water Supply and Conservation Agency to develop support services for water retailers in complying with the State of California's "Making Conservation a California Way of Life" legislation. Valley Water also maintains cost-sharing agreements with local water retailers and municipalities through its various programs. In addition, Valley Water provides up to $1,000,000 in grant funding to identify new, innovative conservation technologies and has awarded 14 grants, including several AMI pilots and other water-conserving technologies.

Valley Water's Education Outreach program provides grade-level classroom presentations, puppet shows, and tours of Valley Water facilities to schools, visitor groups, and residents within Santa Clara County. The objective is to educate pre-school through college students and residents about water conservation and other water-related topics. In addition to those activities, Valley Water provides free educational materials to educators as well as hands-on water education training.

2.7.4 Conservation Goal for 2050

Valley Water set its long-term conservation targets of 99,000 AFY by 2030 and 110,000 AFY by 2040 through the WSMP 2040. As part of the WSMP 2050 development, an additional conservation goal was established to promote and guide conservation efforts as the planning horizon is extended. Based on the 2021 Strategic Plan and analysis of Valley Water's existing programs and future potential, Valley Water developed a water conservation goal of 126,000 AFY by 2050, which is considered ambitious but achievable and balances benefits with affordability concerns. Achieving this conservation goal requires a 192% increase in participation levels of Valley Water's major conservation programs. This water conservation goal recognizes that Santa Clara County is already very water efficient and complements the State's "Making Water Conservation a Way of Life" regulation. It allows Valley Water to stay at the forefront of conservation with sufficient feasible program expansion options supported by community interest and reduce the need to invest in additional new supplies and/or storage. More information on the approach and assumptions used to develop the 2050 goal is provided in Appendix B.

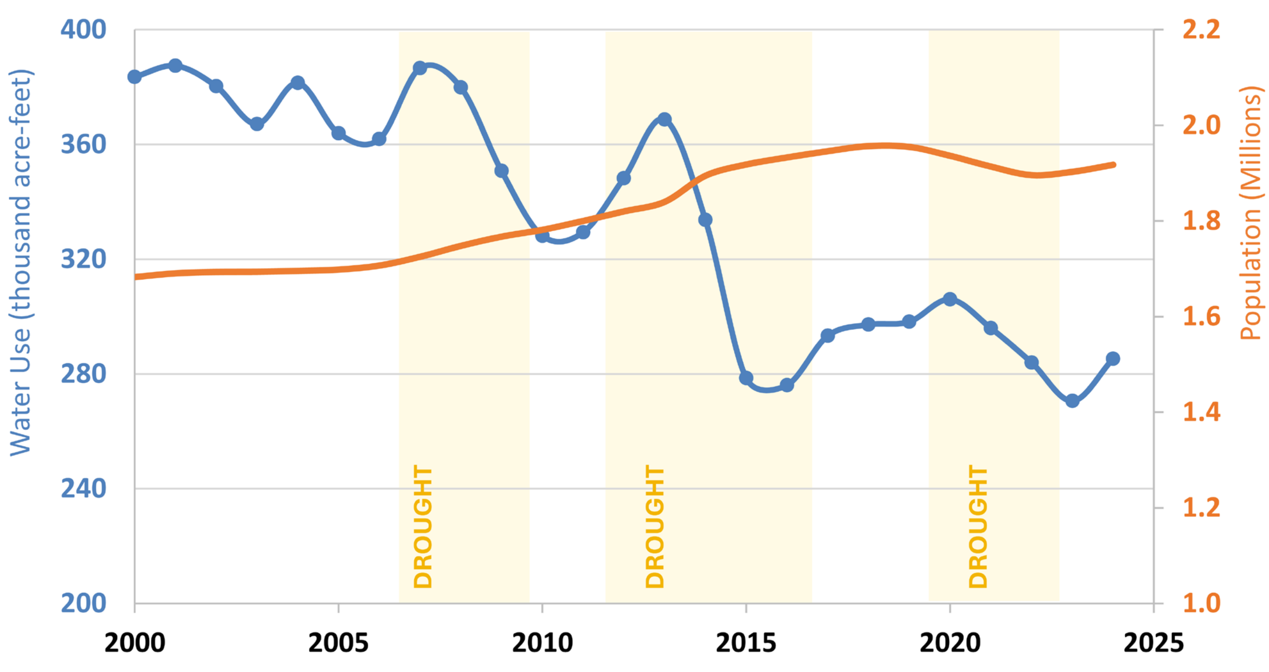
Section 3 – Water Supply Challenges

Valley Water's future water supply faces challenges from changing demands, climate change, aging infrastructure, and new regulations. Understanding these factors and how they impact water supply reliability over time is a key first step in developing the WSMP. This chapter describes and quantifies Santa Clara County's current water use, water demand projections through the year 2050, and other ongoing and emerging challenges. Demand estimates were generated by using Valley Water's Demand Model which was developed based on local planning assumptions and growth projections. Valley Water coordinated with the water retailers and local planning agencies on demand projections to the extent practicable.

3.1 Historical and Current Water Use

Water use in Santa Clara County includes domestic, municipal, industrial, and agricultural use. The countywide average annual water use from 2010 to 2024 is approximately 306,000 AFY. Actual water use changes from year to year and is influenced by a number of factors such as population growth, hydrology, water conservation, drought, and economic conditions (Figure 3-1). The countywide water use represents the total use of Valley Water supply, SFPUC supply, local water rights held by San Jose Water Company and Stanford University, and recycled water. Due in large part to Valley Water's investments in water conservation, overall water use in the county has decreased for the past 20 years despite a 25% increase in population over the same period.

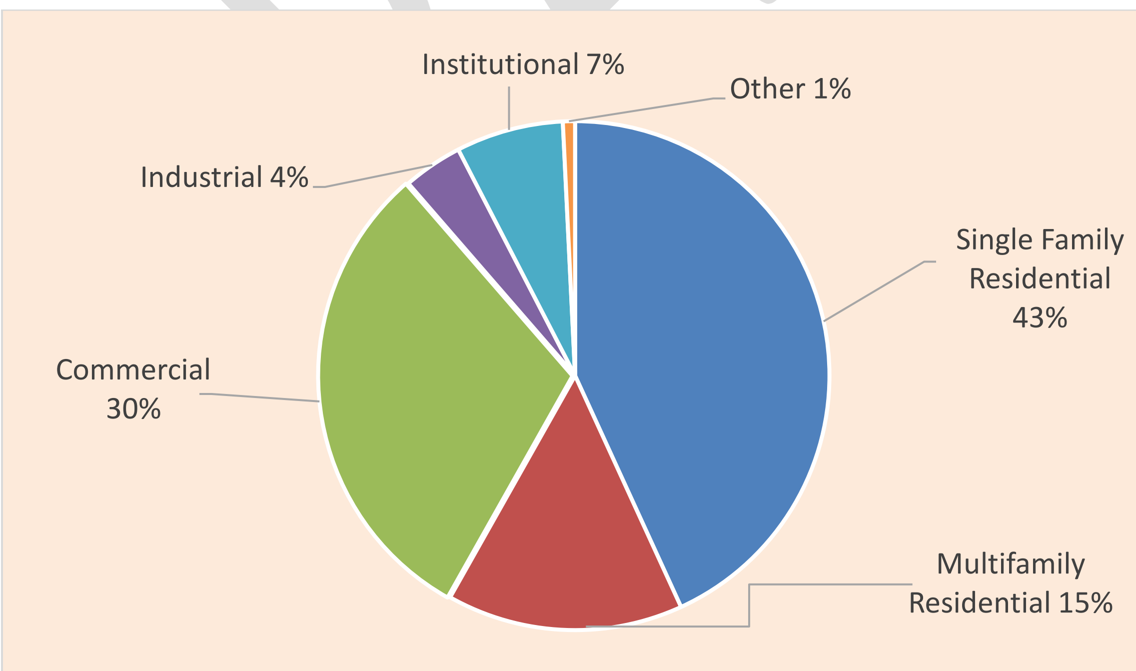
Figure 3-1. Historic Water Use and Population



There have been various significant decreases in water use during the extended droughts of 1987-1992, 2007-2010, 2012-2016, and 2020-2022. While water use often rebounds after droughts, it does not always return to pre-drought levels because some conservation measures, such as lawn conversion, result in permanent reductions. The 2020-2022 drought occurred while water use was rebounding close to the average water use from the previous drought. This drought suppressed further rebound. The two multi-year droughts in the past 10 years may have resulted in some permanent behavior changes that lowered water use in the county. Currently, countywide water use is still low but has shown signs of rebound since 2023. Historically, water use rebounds have occurred in Santa Clara County and California as a whole, following droughts and other disruptions. Drought rebound occurs because there are continued water needs such as agriculture water use, irrigation for functional turf (e.g., game fields and play areas), and the community returns to other pre-drought activities such as maintaining vegetable and community gardens.

Water use data from retailer billing information in 2018 were used to determine the approximate distribution of water use by sector (Figure 3-2). The chart represents data from only the retailers that track water use in these sectors. Since not all retailers track their use in all of these sectors, the chart does not represent the full countywide use. Nevertheless, it is still considered a relatively good picture of average water use distribution. Overall, more than half of water use is for residential, and CII sector (Commercial, Industrial, and Institutional) represents 41% of use. Since agriculture is supported nearly entirely by independent groundwater pumping, that use (which is significant in South County) is not reflected in the figure.

Figure 3-2. Retailer Water Use by Sector (2018)



3.2 Forecasted Future Demands

Future water demand is a key driver of water supply investment. Reasonable forecast of future demand is essential to determine the level of investment necessary to achieve water supply reliability. Valley Water manages a diverse portfolio of water supplies to provide water to Santa Clara County's thirteen water supply retailers and many independent well owners. The majority of water users in the county are direct customers of the water supply retailers, which develop their own water demand forecasts to support their long-range planning. However, as a wholesaler and groundwater sustainability agency, Valley Water is responsible for county-wide water resource planning. This requires a consistent approach and planning assumptions across the service area to ensure robust demand projections to guide future investments. To that end, Valley Water employs an econometric model to forecast future demands through 2050. The econometric model produces a forecast that includes past conservation, but future conservation is calculated outside of the model and deducted from a "planning baseline."

3.2.1 Demand Model

Valley Water's demand model is an econometric-based model built with the data and support of Santa Clara County water retailers and cities. Econometric models are statistical models that can capture and explain the impacts of long-term socioeconomic trends on water demands and are generally favored by academics and practitioners for long-term water demand analysis. Such models use demand relationships based on actual observed behavior to consider the effect of anticipated changes in demand factors on long-term demand.

Valley Water's demand model is not population-based and uses housing and industry characteristics instead because they are more closely correlated to water use patterns of different sectors. Valley Water's demand model estimates the rate at which households, business, and institutions use water. The demand model consists of four distinct sub-models that reflect the major water use sectors within the County. Sectors were developed based on available water use data from Valley Water and its retailers' billing data, including:

- Single family
- Multifamily
- Commercial, Industrial, and Institutional (CII)
- Non-retailer groundwater pumpers

The first three sectors reflect retailer water consumption, which represents the majority (around 87%) of countywide demands. The last sector includes all non-retailer groundwater pumping in the Municipal and Industrial (M&I) and domestic categories. For agricultural water users that have their own wells, water use was based on historical pumping data and not on the demand model.

Each model is essentially an equation estimated using multiple regression that defines the relationship between rates of water use and forecasting variables. The forecasting variables used include housing information, median income, economic information, water rates, and weather (Table 3-1).

Table 3-1. Forecasting Variables Used in the Demand Model

Forecasting Variable	Source
Water rates	Valley Water and retailers
Drought severity	Valley Water
Median income	US Census
Economic indices	Federal Reserve, Economic Cycle Research Institute
Housing density	Derived from US Census and CDOF
Persons per household	Derived from US Census and CDOF
Housing Units	Association of Bay Area Governments
Sectoral employment	Association of Bay Area Governments
Temperature and precipitation	PRISM (Parameter-elevation Relationships on Independent Slopes Model)

To capture geographic diversity throughout the county, unique statistical relationships were developed for each retailer. The models are designed to establish baseline demand projections without considering additional future water conservation. Future conservation targets are separately developed and deducted from the baseline projections.

Historic data were collected to support model development from Valley Water and its water retailers, the US Census, the Federal Reserve, and the California Department of Finance (CDOF) (Table 3-1). Monthly sectoral water use data from local water retailers for 2000-2019 were used as observed data for model fitting to drive the statistical relationships. Once those relationships are established, they can be used to estimate future water demands by adjusting the forecasting variables to reflect future conditions. More information on the development of the regression models can be found in Appendix C.

The overall model approach allows for demand forecast scenario analysis based on varying assumptions of future conditions. Several forecast scenarios may be explored, including climate change-adjusted weather, alternate assumptions around the timing and magnitude of drought recovery, alternate assumptions around urban development, and/or different assumptions around future economic conditions and growth.

3.2.2 Forecast Development

For the WSMP, the developed model was used to forecast future demands using the projected forecasting variables. Forecasts are primarily based on development and growth forecasts, climate change impacts, and drought rebound. More detailed documentation of future demand analysis, including data collection/processing and assumptions for all forecast variables, is provided in Section 5 of Appendix C.

Development and growth forecasts

The future growth is estimated based on housing development and CII growth. Forecasts for these sectors are from the Association of Bay Area Governments (ABAG) Plan Bay Area

2040 that was published in 2017 (ABAG 2017). The Plan Bay Area 2040 projections estimate single family housing units, multifamily housing units, jobs by employment sector, and total population at five-year intervals from 2015 through 2040 (Table 3-2). The projections were extrapolated out to 2045 using the rate of change from 2035 to 2040.

In 2021, ABAG released the Plan Bay Area 2050 as an update to the Plan Bay Area 2040. The new plan forecasts a nearly 75% increase in housing by 2050 to maximize housing growth rather than to forecast likely growth as done with the previous plans. Since then, ABAG has refined these projections and released Plan Bay Area 2050+ blueprint in 2024. However, the refined projections are not currently produced at a census tract /traffic analysis zone level and are only available at a regional level. So, they would not be directly suitable for use in the model without significant assumptions around the geographical distribution. Because of this, the timing of this release and the fact that Plan Bay Area 2050+ projections closely align with Plan Bay Area 2040 projections (within 3% for households), using the Plan Bay Area 2040 data for growth projection remains a reasonable approach.

Table 3-2. Santa Clara County Demographics from Plan Bay Area 2040 Projections

	2020	2025	2030	2035	2040	2045[1]
Population	1,986,340	2,098,695	2,217,750	2,387,165	2,538,320	2,699,046
Single-Family	409,395	409,280	411,725	418,715	422,960	427,248
Multi-Family	297,170	326,965	356,025	411,305	458,695	511,545
Households	679,425	718,565	757,690	815,980	860,810	908,103
Persons per Household	2.87	2.87	2.88	2.88	2.90	2.92
Total Jobs	1,120,420	1,159,110	1,198,370	1,231,000	1,289,870	1,351,555

[1]2045 values are calculated by increasing the 2040 values by the same rate of increase as 2035 to 2040 values.

Future housing units for areas served by retailers were derived from the rate of change in the ABAG projections and historical data. For the CII sector, job-based demand drivers were calculated as the total number of non-agricultural jobs from the ABAG jobs categories. In general, the ABAG projections portray a denser growth future for the region compared to the past (Table 3-2). The growth in housing is projected to be dominated by multi-family, with a 40% increase from 2025 to 2040. In contrast, the single-family sector grows at a much slower rate of 3.3% in the same period. Due to the new development trends and lack of vacant lots, housing density is projected to increase in the single-family sector. As housing density increases, average lot size and irrigable outdoor area tend to decrease. These development trends lead to lower water use per housing unit and are reflected in the demand projections.

Climate Change

Temperature and precipitation are the forecasting variables representing climate change in the demand model. Climate change impacts on temperature and precipitation (warmer temperature and less precipitation) could increase demands, and this increase would be primarily from greater outdoor irrigation needs across all water use sectors and greater cooling needs in the CII sector. Future temperature and precipitation are forecasted based on local climate analysis (Santa Clara University and Valley Water 2018) and from the PRISM Climate Group, which uses data from downscaled global circulation models (GCMs). The same climate models were also used in the analysis performed to estimate future supply needs. More discussion of climate change impacts is provided in Section 3.3.1.

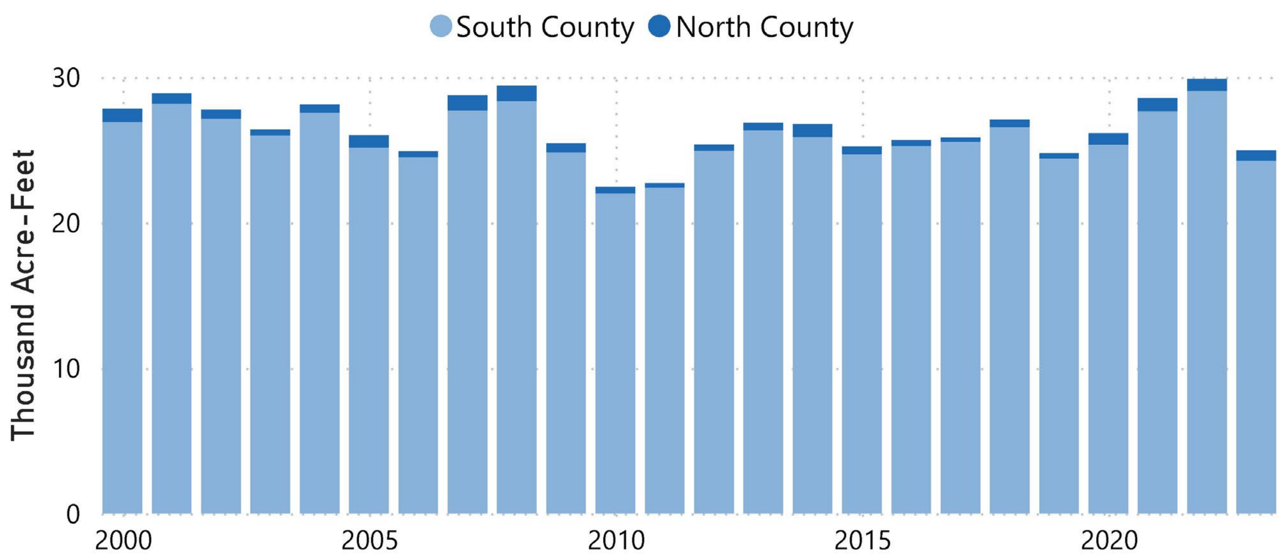
Drought Rebound

A key modeling assumption in forecasting water demand is defining a drought rebound. Historically, after a drought, water use returns to pre-drought levels within a few years of the drought's end and relaxation of water use restrictions; this is the 'drought rebound'. The county's water use began to rebound in 2017-2019 after the 2012-2016 drought (Figure 3-1), but California soon experienced another drought during 2020 –2022. The two multi-year droughts in the past 10 years seem to have resulted in some permanent behavior changes that depressed water use and prevented a full drought rebound in the county. However, historically, demand rebounds have occurred (Figure 3-1), so Valley Water is conservatively assuming there will be a muted drought rebound from the most recent drought, meaning water use will not rebound all the way back to previous levels. This assumption will be reevaluated as more water use data becomes available in the next few years and Valley Water updates its WSMP for the next planning cycle.

Agricultural Groundwater Pumping

Agricultural groundwater use was based on historical pumping data, not the demand model. Agricultural groundwater pumping in Santa Clara County has been generally consistent over the last twenty years at approximately 25,000 AFY (Figure 3-3). Historically, significant reductions in harvested acres and agricultural water use occurred before the 2000s, driven by urban development (particularly in North County) and higher productivity. Current local land use plans and agricultural reports indicate that the amount of harvested acreage will likely remain stable, with only minor declines due to increased urban development in the future. Given this stability, it is assumed that the average water use of 25,000 AFY from the last 25 years would be an appropriate and conservative representation of future agricultural water use and held constant into the planning horizon.

Figure 3-3. Historic Agricultural Groundwater Pumping



3.2.3 Forecasted Future Demands

While Valley Water uses the best available information to forecast future demand, it recognizes that uncertainty is an inherent part of any projections, and there is uncertainty in growth forecasts and ability to forecast climate change impacts on demands. To address this uncertainty, Valley Water developed two demand forecasts to reflect different levels of growth and climate change impacts and serve as the basis for adaptive management:

- **Stable demand** – This represents the lower demand forecast that assumes water use flattening starting in 2030, in part owing to the success of making water conservation a way of life and mitigating the impacts of growth on water use.
- **Higher demand** – This forecast assumes that the Plan Bay Area 2040 growth trends continue to 2050 and climate change impacts on demands are not fully mitigated by conservation and other measures.

Because of the lack of the ABAG growth data in the model beyond 2045, the higher demand was estimated through 2045 in the model. The 2050 demand was extrapolated from 2045 following the increasing trend (Figure 3-4).

The demand forecasts from the model are baseline demand projections without considering additional future water conservation, commonly referred to as unmitigated demand. Valley Water is committed to achieving its long-term conservation goals and has been using mitigated demands for past planning efforts. Valley Water's long-term conservation goals are to achieve 99,000 AFY of water savings by 2030, 110,000 AFY by 2040, and 126,000 AFY by 2050. These goals are deducted from the demand forecasts to get the mitigated demands that are used in the WSMP 2050 analyses (Table 3-3). Table 3-3 includes both unmitigated and mitigated demand for the higher-demand forecast, and for the stable demand, only mitigated demand is shown since it assumes the growth will be fully mitigated by conservation.

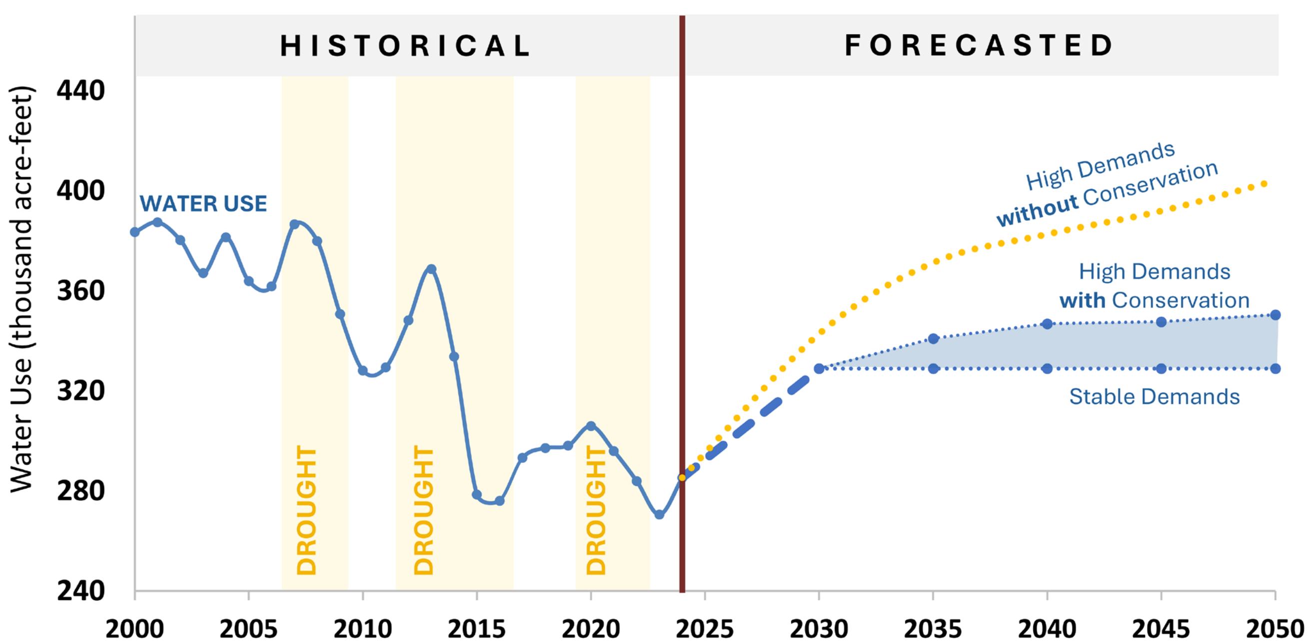
The demands in Table 3-3 are for normal years. During droughts, Valley Water also calls for short-term water use reductions to increase short-term savings of up to 20%. To reflect this drought response action,10% reduction was applied to the stable demand and 15% to high demand, resulting in a demand of 297,000 AFY for the drought years for both demand conditions. This reduced demand was incorporated in the modeling analysis.

Table 3-3. Forecasted Santa Clara County water demands through 2050

Demand Forecast	2030	2035	2040	2045	2050
Stable Demand (TAF)	330	330	330	330	330
High Demand without Conservation (TAF)	340	370	380	390	405
High Demand with Conservation (TAF)	330	340	345	350	350
Note: Numbers rounded to the nearest 5 TAF					

Both stable and high demands are well within the realm of historical water use, reflecting the demand trends while staying conservative for long-range planning to reduce risks and uncertainty (Figure 3-4). It is also clear that without conservation, county-wide demand would be much higher. Conservation remains a cost-effective solution to reduce water demand and, consequently, the need for investment in costly supply or storage projects.

Figure 3-4. Historical and Forecasted Water Demands



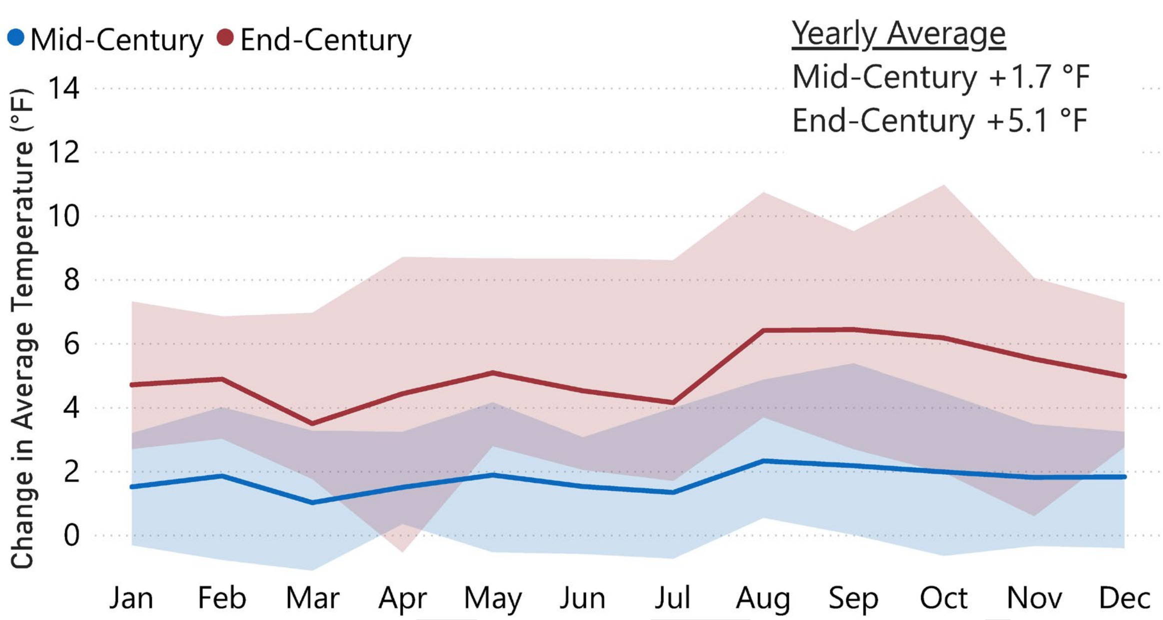
3.3 Other Water Supply Challenges and Uncertainties

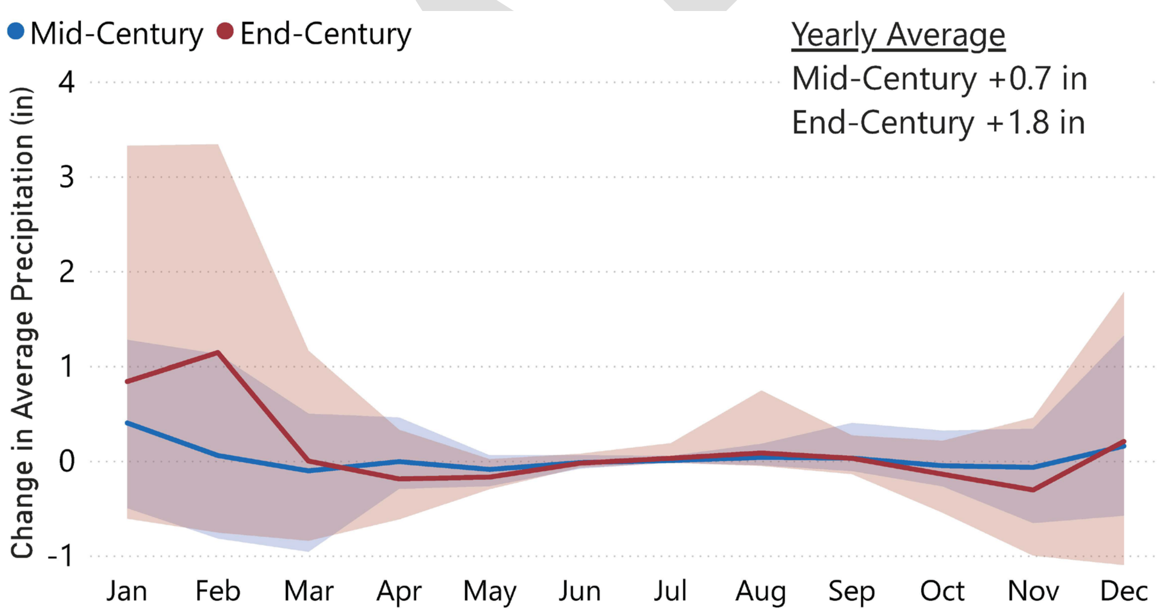
3.3.1 Climate Change

Climate change impacts not only demand as described above, but also supplies. Climate change impacts such as warming temperatures, shrinking snowpack, increasing weather extremes, wildfire, and prolonged droughts pose significant challenges in water resources management, leading to impacts to Valley Water's operational flexibility and water supply availability and quality. Already, climate change impacts are being observed across California and in the San Francisco Bay Area, and climate modeling projections indicate that these impacts will continue or become more extreme. Locally, Santa Clara County is expected to see increasing temperatures, which could result in more extreme heat and drought events and increased demands. Precipitation will continue to exhibit high year-to-year variability, abruptly swinging from periods of severe and extended drought to record-setting wet seasons, putting mounting pressure on management of Valley Water's available water supply. Extreme weather events are projected to increase in intensity, and droughts could be extended over historic conditions. More severe storms could result in increased flood risk and changes in surface runoff patterns that could challenge local water supply operations.

In supporting its long-range planning, Valley Water conducted a climate change study to evaluate the impacts of climate change on local reservoir inflows and evaporation, precipitation, temperature, as well as future demands. The climate change analysis used downscaled data from 10 global climate models recommended by the DWR Climate Change Technical Advisory Group (DWR, 2015) to determine the range of potential impacts. According to the analysis, the county's annual average temperature is projected to increase by mid-century, as well as the number of extreme heat days. Wet periods are expected to become more severe, as future precipitation is likely to come as large storm events. Figure 3-5 shows changes in average monthly temperature and precipitation due to climate change in the county. The bands represent the range of projected changes from the current condition based on downscaled climate models, while the lines represent the average across models at mid-century (blue) and end of century (red).

Figure 3-5. Change in Average Monthly Temperature and Precipitation due to Climate Change





Statewide and local changes in precipitation and temperature could impact Valley Water's local and imported water supplies, the effectiveness of potential water supply investments, and water demand patterns. Climate change drives the need to strengthen the existing system while developing new water infrastructure designed for this century's climate. For the WSMP 2050, climate change impacts were incorporated into future demand and supply projections, and Valley Water's water supply strategy of managing demands, providing drought-resilient supplies, and increasing system flexibility helps adapt to future climate change.

3.3.2 Aging Infrastructure

Valley Water builds and manages an integrated and diverse water supply system to provide safe, clean water to Santa Clara County. Maintaining existing water supplies and infrastructure is critical to water supply reliability. Much of Valley Water's infrastructure was built many decades ago and is aging. Valley Water needs to continue to replace the aging water supply infrastructure, retrofit its dams as necessary, and improve its water treatment plants for future reliability, all of which require significant investment. Valley Water has a robust Asset Management Program and CIP to ensure timely replacement and maintenance of existing infrastructure so it can continue functioning in providing water supply services.

3.3.3 Regulation

Valley Water supplies have previously been affected by changes in regulatory requirements, and additional requirements are anticipated in the future. Locally, the greatest impact of regulations has been on instream recharge operations, which have been modified over the past 25 years to comply with new regulatory requirements aimed at balancing water supply operations with fishery and other environmental needs. Additional future changes are anticipated as Valley Water implements the Fish and Aquatic Habitat Collaborative Effort (FAHCE) operations, which will restrict the use of Valley Water's creeks for conveyance and recharge, therefore reducing the flexibility of Valley Water to manage groundwater basins.

Valley Water's imported water supplies have also been affected by regulations related to environmental protection and remain vulnerable to impacts from future regulations aimed at protecting fisheries and water quality in the Delta. In addition, the Bay Delta Plan is anticipated to cause a shortfall in dry years to SFPUC's Regional Water System, which supplies some of Valley Water's retailers. The water supply needs assessment incorporated estimates for potential impacts of the Healthy Rivers and Landscapes Program - a comprehensive, multi-year solution to help meet requirements to protect beneficial uses in the Sacramento and San Joaquin watersheds, but the exact impacts of the Bay Delta Plan on the SFPUC supplies to Valley Water's retailers are not sufficiently understood yet and subject to change. If SFPUC supplies were to be reduced significantly due to this regulatory requirement, it could have ramifications for Valley Water's future water supply outlook and investment strategy.

3.3.4 Other Risks and Uncertainties

Other risks and uncertainties to water supply include fisheries protection measures, unexpected hazards and extreme events resulting in local and/or imported water outages, more stringent water quality standards, water quality contamination, SFPUC changes in contracts with local water retailers, seismic restrictions on local reservoirs, and demand growth different from projected. In addition, securing funding to invest in the projects and programs needed for reliable supplies will continue to be a big challenge.

Section 4 – Water Supply Needs Assessment

A key objective of the WSMP 2050 is evaluating and assessing Valley Water's baseline system capability in meeting current and projected county-wide demands over the planning horizon. The evaluations and assessments are to determine the level of reliability that can be achieved with the baseline system and identify whether new infrastructure may be required to alleviate system constraints and supply shortages. This chapter describes the planning approach, baseline assumptions, and water supply analysis to evaluate the reliability of Valley Water's existing system and future water supply needs.

4.1 Planning Approach

Long-range planning such as the WSMP relies on assumptions and projections of how the future may unfold over time. Key drivers of change such as climate, hydrological cycles, demographics, and economy are uncertain and may cast uncertainty into future water supply outlook, demand projection, and infrastructure needs. While long-range plans use the best available information to forecast future conditions, with evidence of an increasingly varied climate mounting and many uncertainties out of Valley Water's control looming on the horizon, the precise trajectory of how future supply and demand conditions may play out over the long term cannot be represented by a single view of the future. Therefore, rather than one single forecast as was done with past plans, Valley Water employs a scenario planning approach to present a range of plausible futures to address these uncertainties and provide the basis for adaptive management.

4.1.1 Scenario Planning

Scenario planning has been used for decades to help prepare for an uncertain future. The approach involves analyzing a range of possible futures that bracket likely future water supply and demand conditions and identifying projects and programs that can meet water supply needs under each potential future condition. As conditions change and new challenges and opportunities arise, decisions can be made according to the future condition that is considered most likely to occur. Scenario planning provides organizational flexibility by planning for multiple possible futures (scenarios) and promotes informed decision-making. This approach improves the understanding of a broader range of potential outcomes. In turn, those outcomes allow a greater understanding of potential challenges to water supply reliability and the impacts of possible policy direction, helping to inform actions. The key to this approach is identifying and assessing risks and uncertainties that could have a major impact on the future and, hence, on the success of any planning effort.

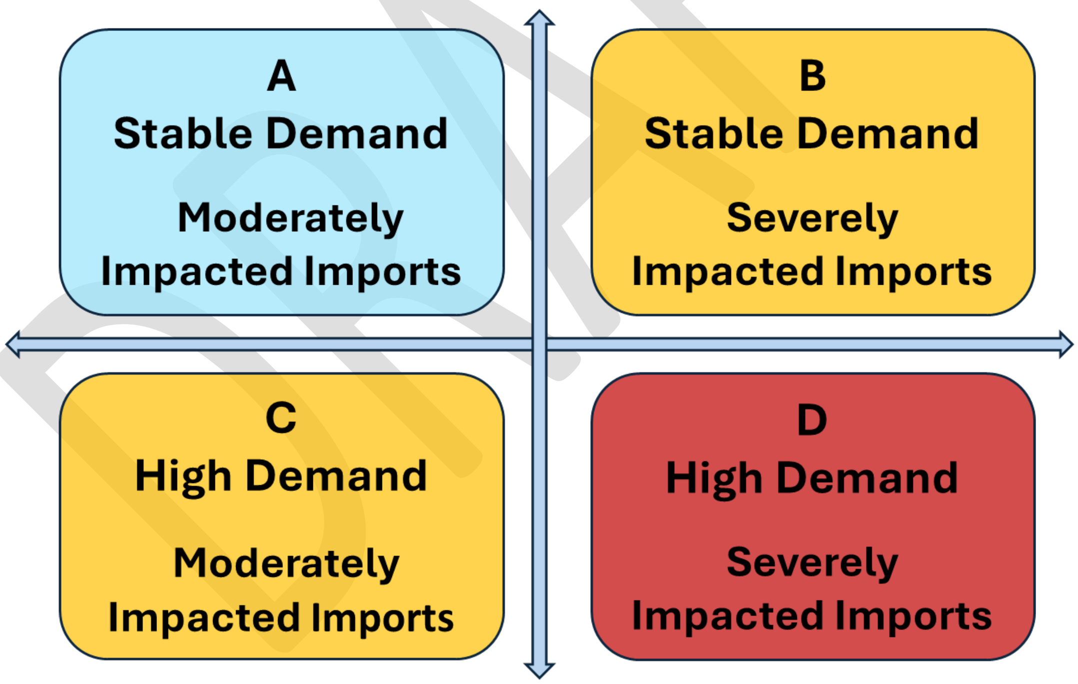
Scenario planning does not mean planning for the worst-case (or any particular) scenario but provides a sound foundation for adaptive management. This will allow for flexibility and the opportunity to refine decisions over time, so Valley Water can continue to provide adequate and reliable supplies to meet present and future needs. Scenario planning will assist Valley Water in identifying portfolios that work in a range of futures that could be expanded if needed, as imported water, climate impacts, and demand changes develop.

4.1.2 Future Condition Determination

The scenario planning approach began with defining plausible future conditions that represent the drivers that are most impactful to water reliability for the region but remain uncertain. Based on input received from internal staff and independent external experts, Valley Water developed four plausible futures based on projected **water demands** and **imported water supply**, because they encompass primary change drivers, including climate change, economic trends, and demographic changes, and reflect key risks and uncertainties associated with those drivers.

Imported water accounts for about half of Valley Water's annual supply and is subject to reductions during droughts. Imported water availability is the primary driver for reliability and therefore the most appropriate proxy for overall supply. Figure 4-1 shows the four futures developed to characterize distinct conditions of imported supply stability and countywide water demand.

Figure 4-1 Four Future Conditions



These four future conditions set the stage for identifying potential water supply gaps and investment strategies for addressing them. Each future is defined by a plausible high or low water demand coupled with a potential moderately or severely impacted imported water supply. The description of the four futures is provided below.

- **A – Stable Demand and Moderately Impacted Imports**
  This future is characterized by stable water demands and relatively stable imported supplies. Stable demand represents the low demand resulting from slow economic and demographic growth and continued water use efficiency. The imported supply availability remains relatively stable due to small impacts of climate change and regulatory constraints. This represents the best-case condition of the four futures.

- **B – Stable Demand and Severely Impacted Imports**
  This future is characterized by stable water demands and reduced imported supplies. Demand is suppressed by low economic and demographic growth and successful conservation efforts. The imported supply is significantly impacted by climate change compared to current conditions.

- **C – High Demand and Moderately Impacted Imports**
  This future is characterized by high demands and stable imported supplies. Demand is driven by high economic and demographic growth and severe local climate change impacts. Imported supplies remain relatively stable due to less due to lesser regulatory and climate change impacts outside the county.

- **D – High Demand and Severely Impacted Imports**
  This future is characterized by high demands and reduced imported supplies. Demands are driven by high economic and demographic growth and severe climate change impacts. Imported supplies are reduced due to significant climate change impacts. This represents the worst-case condition of the four futures.

With these four futures, Valley Water could confront uncertainty with different strategies that increase preparedness, improve resiliency, and manage vulnerabilities across a range of plausible outcomes. Scenario planning also allows Valley Water to weigh the tradeoffs among those strategies under a broad range of contingencies. By exploring a variety of future conditions, scenario planning is intended to account for uncertainty in forecasted future demand and supply and provide an adaptive framework for decision-making.

4.1.3 Demand and Baseline Supply Forecast

With the four future conditions, two sets of demand and imported supply forecasts need to be made. The demand forecast is combined with the imported supply forecasts and other baseline supplies to assess the reliability of the existing system and identify any potential gaps.

Demand Forecast

Section 3.2. describes the forecasting of stable demand and high demand. The stable demand represents the low end and assumes demands stay relatively flat through 2050; the high demand assumes significant, unmitigated impacts from growth and severe climate change, which increases outdoor water use in particular.

Imported Supply Forecast
Forecasts for future imported water supplies were based on the Delta Conveyance Project (DCP) modeling studies produced by the Department of Water Resources (DWR) using their CalSim3. The modeling results are published in the DCP Draft Environmental Impact Report (EIR) (DWR, 2022). The DCP EIR modeling was the most up-to-date and furthest projected representation of the statewide system. It includes rigorous climate change assumptions developed by DWR and informed by various emissions scenarios in an ensemble of global climate models. The water supply impacts captured by this modeling work provided a reasonable range of current water supply challenges and anticipated challenges associated with future changes in hydrologic patterns in California. More importantly, the DCP DEIR models had scenarios that could incorporate all the imported water projects that Valley Water is considering in the WSMP.

The DCP EIR modeling assumes existing regulatory conditions in 2022 and SWP and CVP infrastructure and considers a range of climate change impacts. Of the range of climate impacts modeled for the DCP EIR, the 2040 Central Tendency scenario and the 2040 Median scenario were selected for the WSMP to represent two potential future imported water conditions:

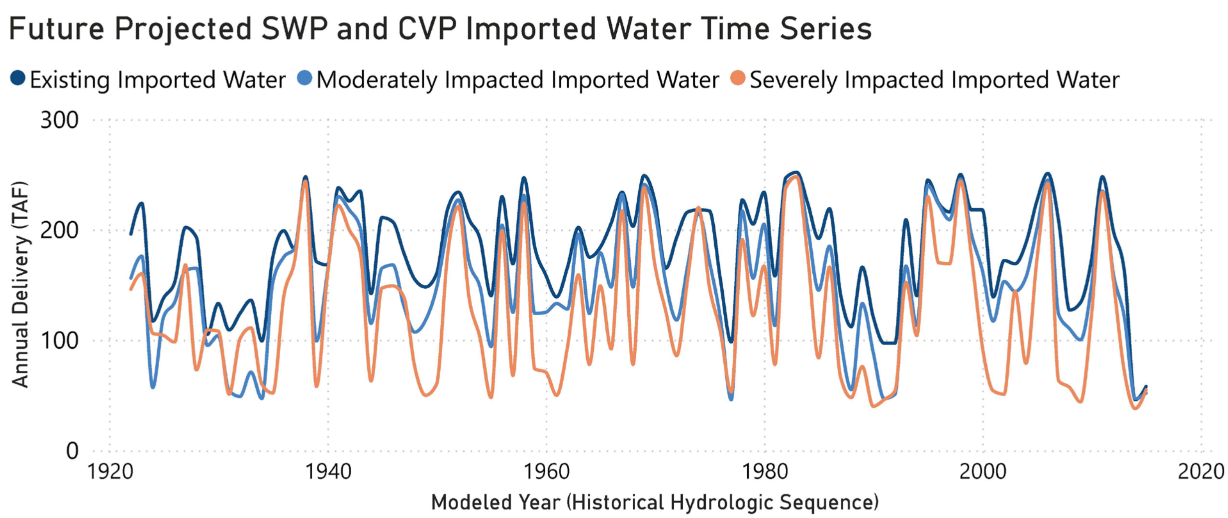
- **Moderately Impacted Imports** – Used the 2040 Central Tendency scenario. The 2040 Central Tendency scenario projects an increase in runoff, primarily due to higher precipitation levels and a shift in runoff timing caused by rising temperatures. The scenario also includes an assumption of 0.5 feet of sea level rise. Under this scenario, more precipitation falls as rain instead of snow, leading to earlier snowmelt and increased winter runoff. Evapotranspiration increases with rising temperatures, but the overall gain in precipitation offsets these losses, resulting in a net increase in runoff. Delta operations in response to future impacts from sea level rise, runoff timing, and environmental flow requirements lead to a small reduction in imported water available to the county despite the milder climate impacts.

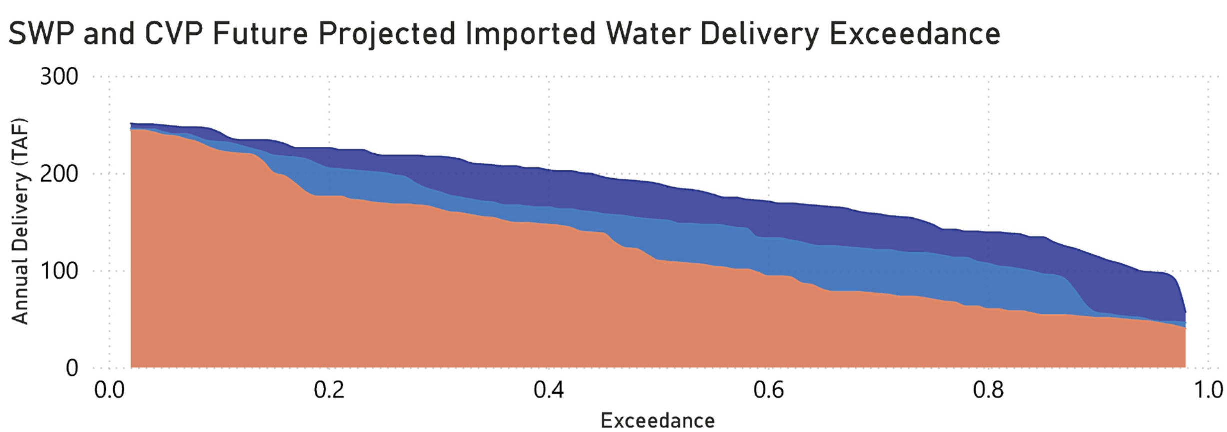
- **Severely Impacts Imports** – Used the 2040 Median climate change scenario. The scenario assumes the reliability of SWP and CVP deliveries would be significantly reduced due to climate change. The scenario assumes 1.8 feet of sea level rise. With warmer temperatures reducing snowpack and accelerating evapotranspiration, less water is available for surface runoff, which could lead to more frequent and prolonged drought conditions. Additionally, decreased spring runoff means reservoirs will receive less inflow at critical times when water is needed to meet demands.

Figure 4-2 shows the magnitude of projected changes in imported water supplies under future conditions compared to existing supplies. While the years shown are historical, the deliveries incorporate future assumptions about climate and regulatory changes. Existing supplies shown here for comparison are derived from the DCP EIR 2020 existing conditions model run. The exceedance probability axis indicates how often a given delivery volume is equaled or exceeded. For example, at 0.5 exceedance, the delivery volume shown is the amount to be exceeded in only 50% of years; deliveries will fall below that level the other half of the time. This midpoint highlights the relative reliability of each scenario, with the Severely Reduced Imported Water scenario showing significantly lower median deliveries than the other two. Overall, the changes are significant with the severely impacted imports scenario, which has ramifications for future water supply gaps and the need for new investments.

The DCP EIR modeling forecasts future SWP and CVP deliveries through 2040, however, the planning endpoint for this plan is 2050. Due to a lack of data to extrapolate the modeled deliveries beyond 2040, it was therefore assumed the imported water deliveries would stay the same from 2040 to 2050, to be conservative.

Figure 4-2 Existing and Forecasted Future Imported Water Deliveries





4.2 Baseline Assumption

The water supply needs assessment was based on a number of baseline assumptions that represent the existing water supply system and many anticipated improvements. The analysis assumes that existing infrastructure is maintained consistent with Valley Water's

Asset Management Plan. All anticipated improvements are currently either in the CIP and/or factored into the operational budget and therefore assumed to be completed according to their planned timelines.

4.2.1 Seismic Retrofit of Local Dams

Valley Water's 10 dams were built many decades ago in the 1930s and 1950s. Since that time, knowledge of seismic stability design and construction has improved substantially. While those dams have been well maintained over time and continue providing water supply and other benefits, several reservoirs have had operating restrictions imposed by the Department of Safety of Dams (Anderson, Almaden, Calero, Coyote, and Guadalupe reservoirs) due to seismic concerns. Valley Water plans to retrofit the five dams to remove operating restrictions and minimize the risk of dam failure in the event of a major earthquake in the region.

Anderson is Valley Water's largest reservoir. At full capacity, Anderson Reservoir holds up to 89,278 AF of water and serves as a critical facility for running the groundwater recharge program, storing imported water supplies, and holding 20,000 AF of emergency water supply. Valley Water initiated the Anderson Dam Seismic Retrofit Project in 2011. While work on the project was underway, in 2020 Valley Water was ordered by the Federal Energy Regulatory Commission to drain the reservoir to deadpool for seismic improvements. Valley Water has since worked on elements of rebuilding this reservoir and plans to complete construction by the end of 2033. The seismic stability evaluation of Almaden, Calero, and Guadalupe dams has also been completed. The retrofits of these three dams are in Valley Water's CIP and are expected to be completed by 2035. In addition, Coyote Dam was evaluated for seismic stability and has been recently included in the CIP for fiscal year 2025-2026 to start the planning phase for a seismic retrofit project.

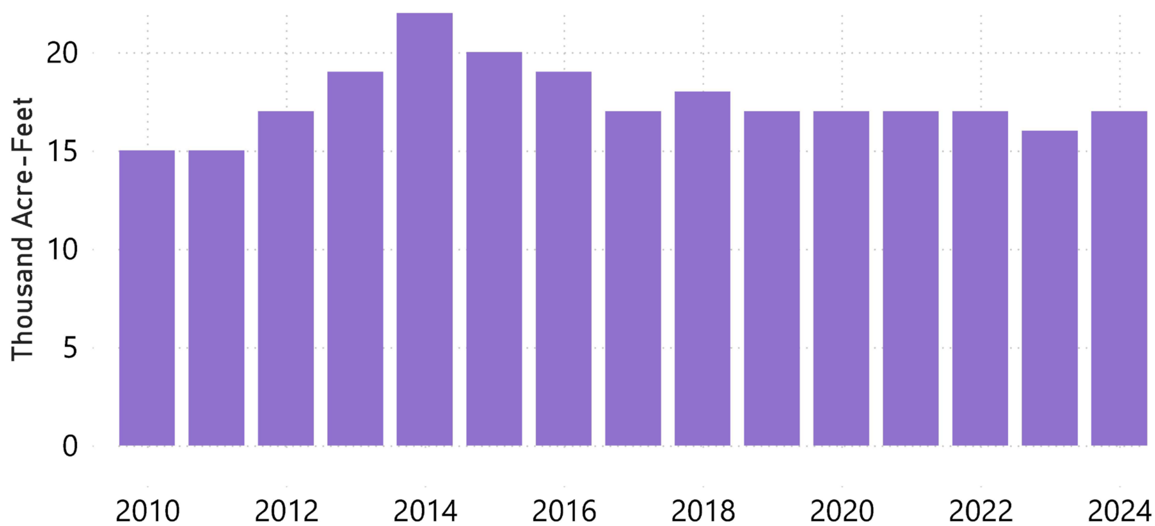
4.2.2 Recycled Water

Recycled water in Santa Clara County is primarily managed by cities and accounts for about 5% of the county's water supply, with an average of 17,000 AFY. Recycled water is distributed for non-potable uses such as landscape irrigation, industrial cooling, and dual plumbed facilities, which help offset the need for using potable water to meet those needs. Recycled water is produced at the four wastewater treatment plants in the county - Palo Alto Regional Water Quality Control Plant, City of Sunnyvale Water Pollution Control Plant, San José -Santa Clara Regional Wastewater Facility, and South County Regional Wastewater Authority.

Recycled water use in the county has diminished slightly since 2015 and remained relatively constant over the last five years (Figure 4-3). While it is anticipated that water recycling programs in the county may be expanded, these expansions are highly dependent upon funding and new development. At this time, landscape irrigation is the highest use, however, new ordinances are also requiring data centers and other large users to connect to the recycled water system.

For Valley Water, developing potable reuse was found to be more cost effective than non-potable reuse. One consideration for investment in non-potable and potable reuse is the declining trend in wastewater availability due to water conservation. Non-potable reuse requires a new pipe network to reach customers. The existing network already serves most of the large users. For the water supply needs assessment, non-potable recycled water use is assumed to increase to 23,000 AFY by 2030 with 5,000 AFY of planned increase in San José and remain stable through 2050. The non-potable reuse growth assumption is warranted during this time but should be reviewed through the annual MAP or the next WSMP update to ensure it accurately reflects the development trend of this source. In addition, if and when any major recycled water projects are developed in the future, they could be incorporated into the WSMP portfolios and analysis.

Figure 4-3 Non-Potable Recycled Water Use from 2010 to 2024



4.2.3 Water Conservation

Water conservation is integrated into the baseline conditions through demand forecasts. As described in Section 3.2, Valley Water's long-term conservation goals for 2030, 2040, and 2050 were incorporated into forecasted demands. By doing so, Valley Water assumes that those goals will be achieved through ongoing and future conservation efforts. While Valley Water is on track to meet the 2030 conservation goals, meeting the goals relies on the local community to implement conservation programs. As the county already achieves high water use efficiency, some demand hardening could limit the opportunities for high water savings.

4.2.4 Environmental Flow Requirements

Valley Water's local supply is impacted by the implementation of FAHCE. FAHCE was established to resolve a 1996 complaint with the State Water Resources Control Board over Valley Water's use of its appropriative water rights in the Stevens Creek, Coyote Creek, and Guadalupe River watersheds (Three Creeks). In 2003, Valley Water initialed a Settlement Agreement with relevant entities to balance the use of Three Creeks waters for meeting the county's water supply needs, while improving habitat conditions. In 2023, Valley Water's Board adopted the FAHCE Final EIR for two of the watersheds (Stevens Creek and Guadalupe River) and started the full implementation of FAHCE Plus flow measures, which modify reservoir releases to continue to support instream flow needs for fish in these two watersheds. The implementation of FAHCE in the Coyote Creek watershed will start after completion of the Anderson Dam Seismic Retrofit Project. The FAHCE reservoir operations are treated as baseline conditions in the water supply needs assessment.

4.3 Water Supply Needs Assessment

With no new investment, water supply needs under the baseline condition were assessed for each of the four future conditions through modeling analysis. Valley Water's Water Evaluation and Planning (WEAP) model was used for analysis.

4.3.1 WEAP

WEAP is a deterministic, linear water resources management model that takes inputs of water demand, supply information, and operational constraints and distributes water based on these inputs and specified system priorities. Valley Water uses the WEAP model as a tool to support its long-term water supply planning because it simulates Valley Water's managed current and future water resources. The WEAP model simulates Valley Water's water supply system, which is comprised of facilities to recharge the county's groundwater subbasins, the operation of reservoirs and creeks, water treatment and distribution facilities, and raw water conveyance facilities. The model also accounts for non-Valley Water sources and distribution, such as supplies from the SFPUC, non-potable recycled water, and local water developed by other agencies, such as San Jose Water Company.

WEAP operates on a monthly time-step that simulates the water supply and demand over 94 years, using the historic hydrologic sequence of 1922 through 2015. The historical data was modified to incorporate future climate change. Using modified historical data to represent future hydrological conditions is standard practice in water resources modeling. The DWR's CalSim modeling uses the same approach. The WEAP model tracks water resources throughout the county and the delivery of water to meet demands according to availability and priority. Demands in the system include retailer demands, agricultural demands, independent groundwater pumping, raw water deliveries, environmental flow requirements, and groundwater recharge. Output from the model includes monthly and annual reporting of a wide range of data such as groundwater storage levels, local reservoir operations, flows at key locations, and any shortages. Detailed documentation of the model setup, input data, key assumptions, and outputs used for this plan is provided in Appendix D.

4.3.2 Analysis Considerations

The baseline analysis assesses how baseline supplies can meet future demands, and unmet demand is then estimated as shortage. In the 94 years of the historical record used in the modeling analysis, the 1987-1992 drought represents the longest that the county has experienced. While the model tracks the system performance for all years that include other drought periods, the water supply needs assessment was focused on the 1987-1992 drought because any project options that can mitigate this extended dry period will also likely be able to mitigate other shorter droughts. During 2020-2022, California experienced another drought, which is currently outside the modeling period due to a lack of input data for SFPUC supply and imported water. While severe, this drought is similar to the 2012-2016 drought, which is modeled.

The baseline assumptions include Valley Water meeting its water conservation goal through 2050 through ongoing and long-term actions. In addition to that, during the droughts, Valley Water also calls for short-term water use reductions to increase short-term savings through behavior change, as other sources of supply become increasingly expensive and difficult to secure. Therefore, the analysis incorporates up to 10 or 15% water use reduction during droughts for the stable and high demands, respectively.

Valley Water's current contract for participation in the Semitropic Water Storage District groundwater banking will expire in 2035. Given the challenges that Semitropic has faced related to water quality and Sustainable Groundwater Management Act (SGMA) requirements and their potential impact on future groundwater banking at Semitropic, the modeling analysis treated Semitropic as a project option after 2035, with varying levels of storage capacity.

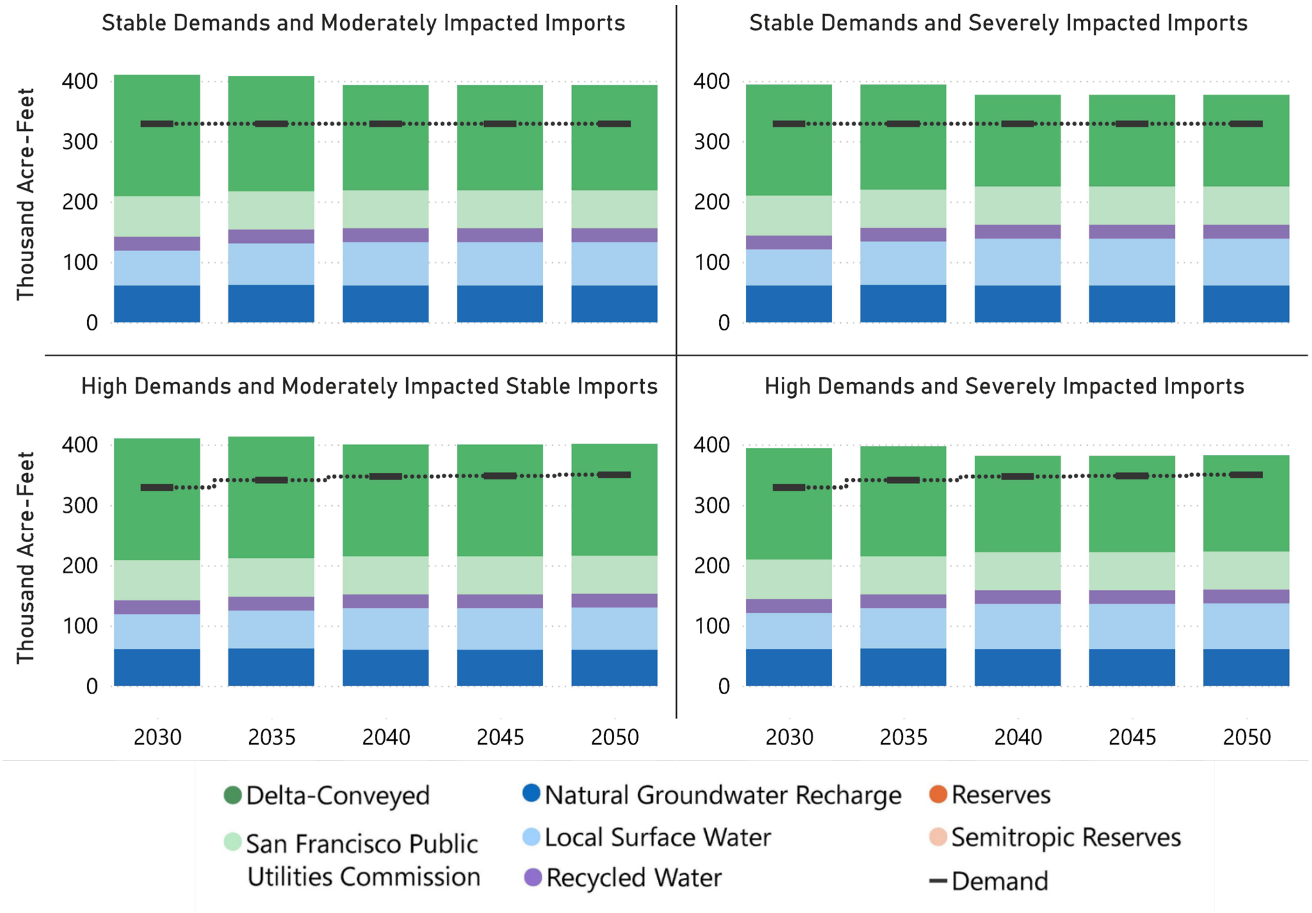
In addition, the analysis also assumes that local groundwater storage can be drawn down to the severe stage of the Water Shortage Contingency Plan. This does not represent a sustainable long-term groundwater condition, but these supplies represent water that may be needed to get through a prolonged drought.

4.3.3 Analysis Results

The water supply needs assessment used the WEAP model to estimate the frequency and magnitude of shortages for each future at five-year intervals from 2030 to 2050. Results were analyzed in five-year increments and for the year 2050, providing a comprehensive picture of the system's performance over time and at the end of the planning horizon.

With conjunctive management and continued investment, Valley Water's existing system has proven flexible and reliable in meeting future demands in most years. This will continue to be the case into the future. Under average and wet conditions, projected water supplies exceed projected demand through 2050 for all four futures (Figure 4-4), resulting in no shortages during average conditions. However, this outcome will be dependent on Valley Water achieving its long-term conservation goals and baseline assumptions, such as the dam seismic retrofits.

Figure 4-4 Demand and Supply Under Average Conditions



While the system performs well under average and wet conditions, extended droughts, however, remain the most significant challenge to long-term water supply reliability. As discussed in Section 4.3.2, the historical drought from 1987-1992 was the focus of the water supply needs assessment. This six-year event is used as a proxy for the kind of extended drought that may occur in the future, especially under climate change. The section below summarizes the analysis results for this six-year drought for each future.

To clearly communicate drought impacts, two types of plots were used to present analysis results for each future:

- **Average Annual Shortage by Planning Period (2030–2050):** This plot shows the average annual shortage (in thousand acre-feet per year) over the six-year drought, calculated at five-year planning increments from 2030 through 2050. It provides a high-level view of how the system's performance under drought conditions is expected to evolve over time, highlighting when supply gaps may emerge under each future.

- **Year-by-Year Shortage During the Drought in Planning Year 2050:** This plot focuses on the individual shortage in each year of the six-year drought, using conditions as projected in 2050. It illustrates the typical drought pattern, where shortages often do not appear in the early years but increase in the later years as stored reserves are depleted. This helps identify when the system is most vulnerable during extended droughts.

In these plots, the stacked bars represent the supply sources, and the black line represents demand. **Reserves** in the plots represent water stored in previous years and accessed during droughts, and **Semitropic Reserves** are only available if Valley Water continues participation in the Semitropic program after the 2035 contract expiration. For purposes of the graphs below, Semitropic Reserves continue to be included to illustrate the importance of groundwater banking in reducing shortages. Together, these plots provide both a long-term view and a detailed look at how the system is expected to perform during multi-year droughts.

Future A - Stable Demand and Moderately Impacted Imports
Under this future, future demand can be met with existing sources of supply through 2050 (Figure 4-5). However, if the Semitropic contract is not renewed by 2035, shortages are projected to begin as early as 2040.

During the six-year drought in 2050, a small shortage could occur in the last year of the drought with Semitropic in place, but without this groundwater bank, the shortage could begin earlier – in the third year of the drought – and grow significantly more severe (Figure 4-6). This underscores the importance of maintaining at least the existing level of Valley Water's storage programs to store enough water during wet years for use during droughts.

Figure 4-5 Demand and Supply from 2030 to 2050 in Five-year Increments

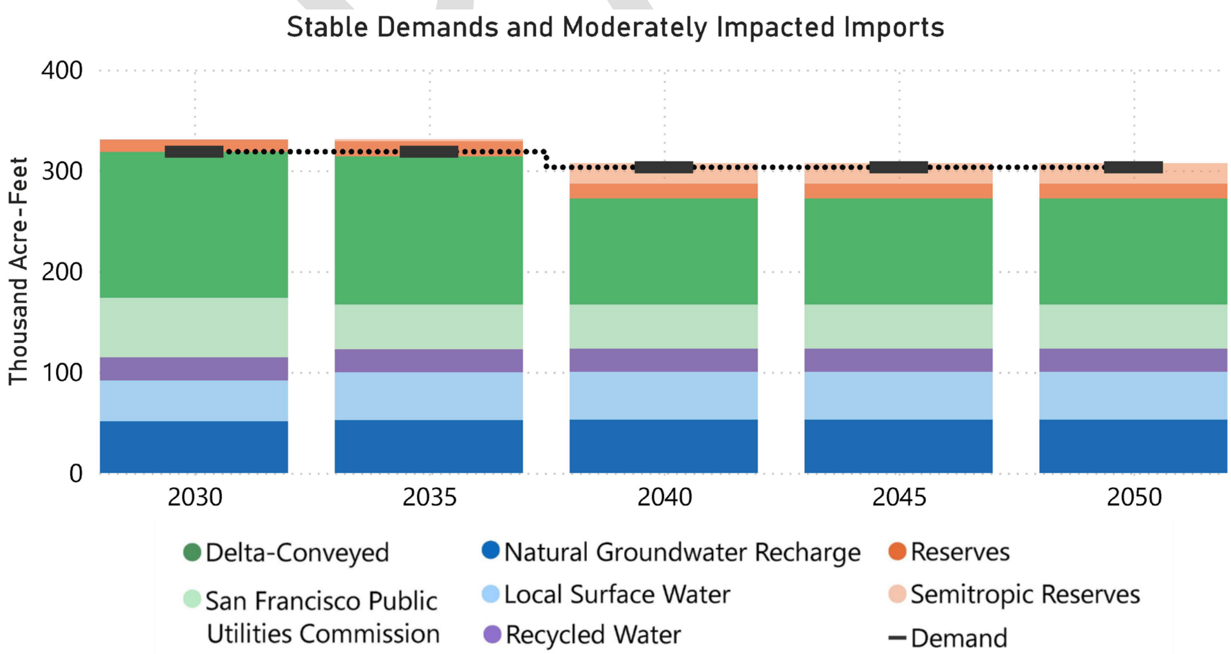
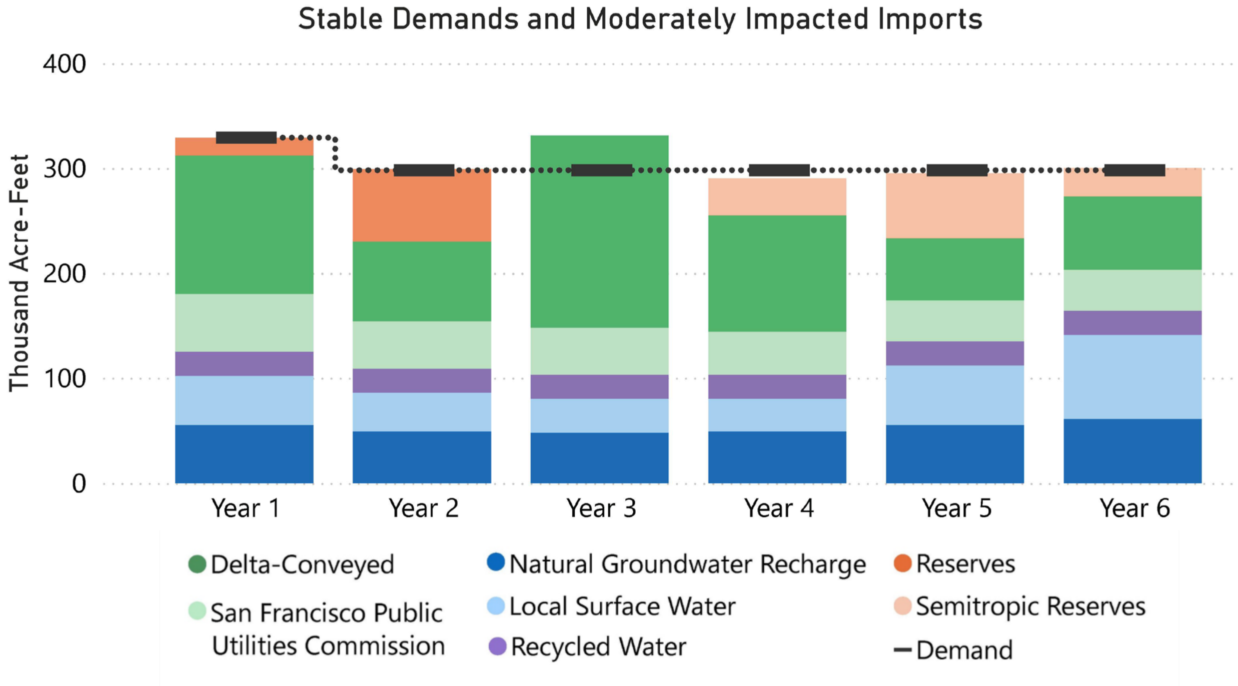


Figure 4-6 Demand and Supply During the Six-Year Drought in 2050



Future B - Stable Demand and Severely Impacted Imports
In this future, while demands remain stable, reduced imported water supplies lead to a shortage beginning in 2040, even when Semitropic is included (Figure 4-7). The shortage could reach up to 50,000 AF. The inclusion of Semitropic does lead to some reduction in the water shortages, but this is limited due to the depletion of imported supplies that would be used to replenish stored water leading into the drought.

During the six-year drought in 2050, shortages start in the third year and worsen in the fourth and fifth years. The system starts to recover the last year of the drought when more local and imported water becomes available (Figure 4-8). With reduced supplies, reserves in storage are depleted by the third year of the drought, both from being used to offset reduced supplies and from a lack of replenishment over time. Although some water remains in the Semitropic groundwater bank, its effectiveness is limited because, over the model simulation period leading up to the drought, the overall supply-demand balance results in lower starting storage levels at the beginning of the drought. This means less water is available in Semitropic at the onset of drought, reducing its ability to mitigate shortages during dry years. In addition, the annual put/take limit as well as operation constraints restricted Valley Water's ability to utilize water from that groundwater bank.

Figure 4-7 Demand and Supply from 2030 to 2050 in Five-year Increments

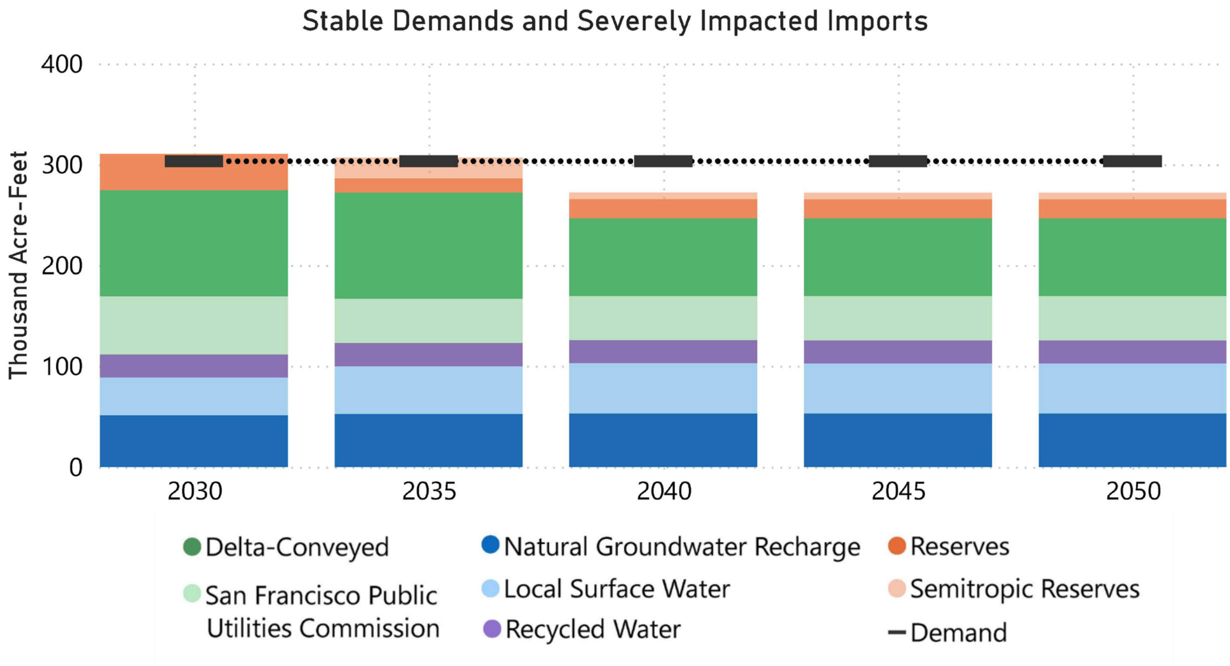
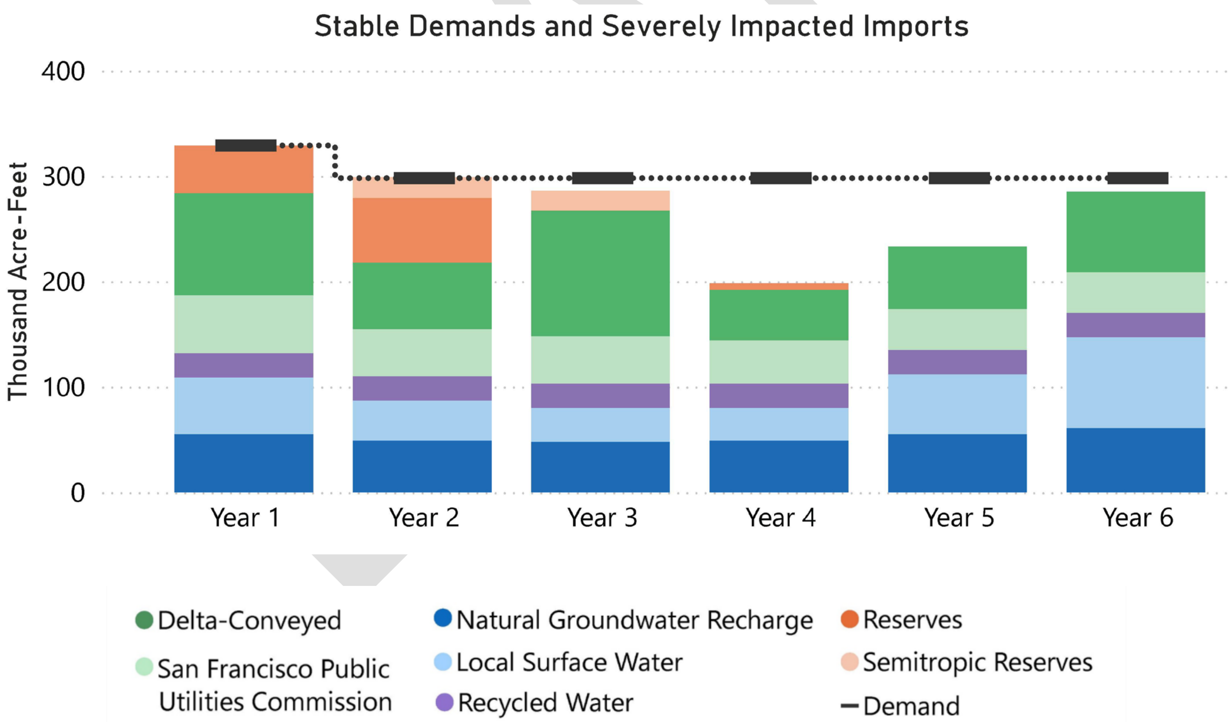


Figure 4-8 Demand and Supply During the Six-Year Drought in 2050



Future C - High Demand and Moderately Impacted Imports
In this future scenario, with high demand and stable imports, shortages would begin in 2040 (Figure 4-9). Although overall supply levels are relatively healthy, particularly in normal and

wet years, they are lower during drought conditions and are not high enough to fully offset the increase in demand.

During the six-year drought in 2050, shortage is predicted to start in year 4 and continue to build in years 5 and 6 after reserves are diminished (Figure 4-10). The high demand consumes the available supply more quickly, resulting in local storage and Semitropic Bank not having sufficient water storage during the drought to cover all 6 years of the higher demand.

Figure 4-9 Demand and Supply from 2030 to 2050 in Five-year Increments

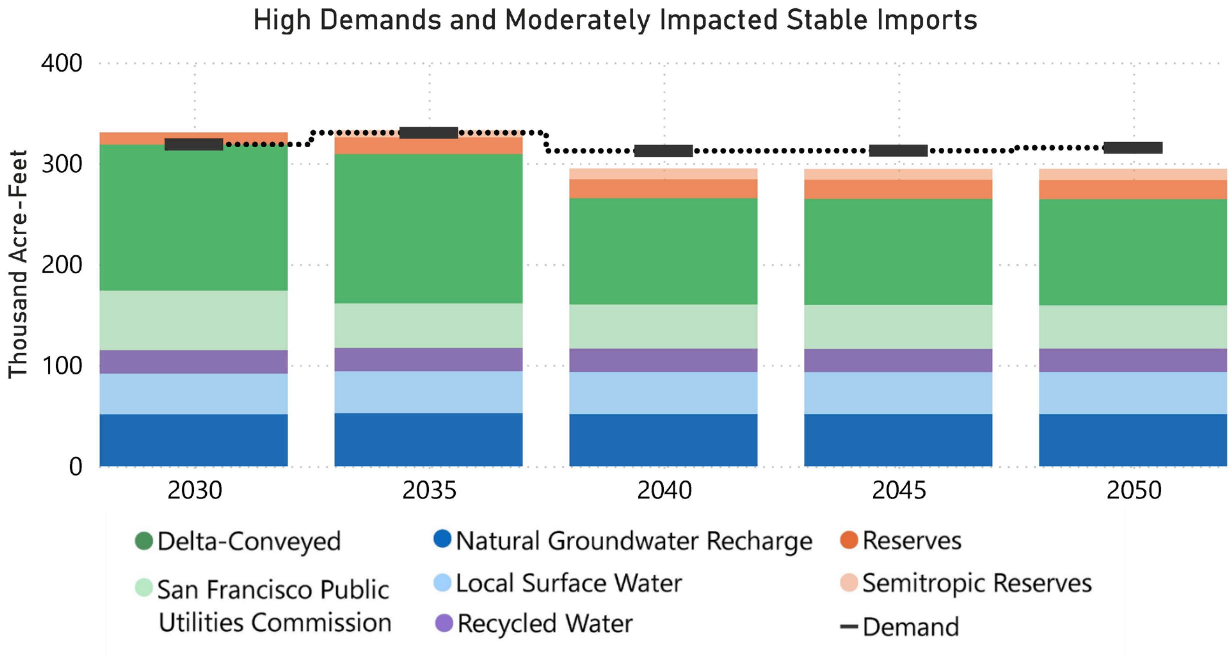
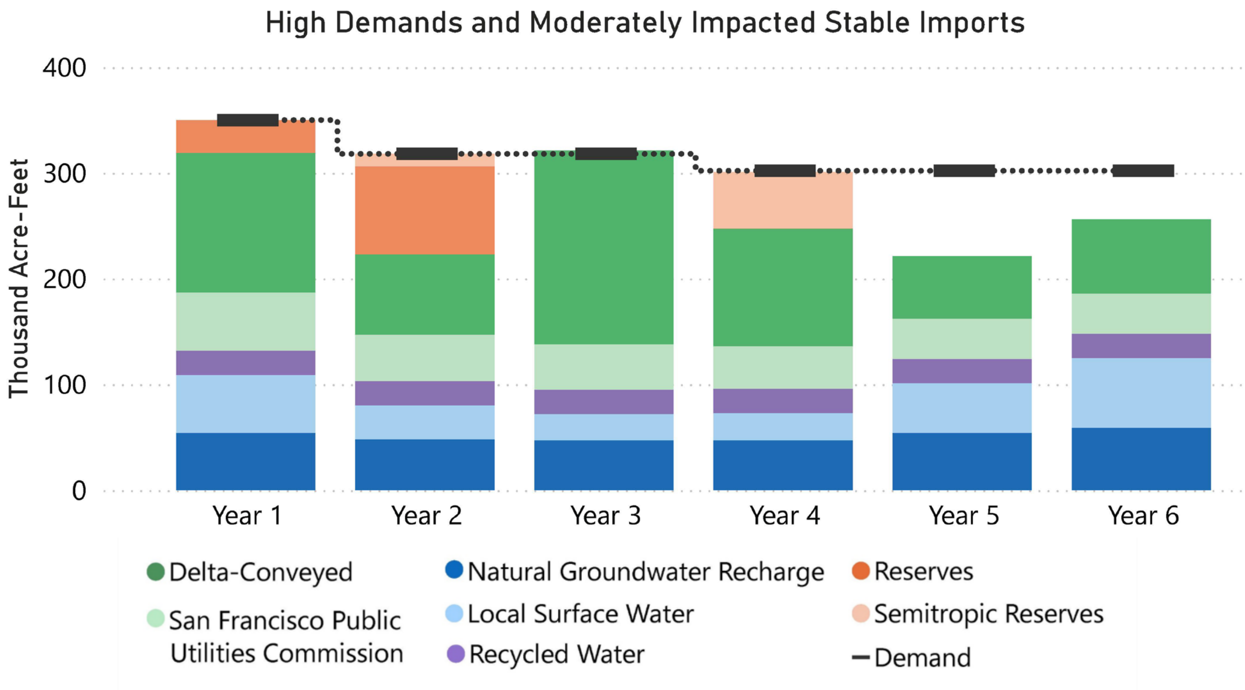


Figure 4-10 Demand and Supply During the Six-Year Drought in 2050



Future D - High Demand and Severely Impacted Imports
This is the worst-case scenario evaluated, with high demand coupled with reduced imports. Under this future, the shortages start in 2040 and are large. The maximum shortage is up to an average annual shortage of 120,000 AF over the drought by 2050.

During the six-year drought in 2050, the shortage starts in year 2 and becomes worst in year 4 (Figure 4-11) after reserves are diminished. The high demand and reduced imports result in local storage and Semitropic Bank not sufficiently recharged over time.

Figure 4-11 Demand and Supply from 2030 to 2050 in Five-year Increments

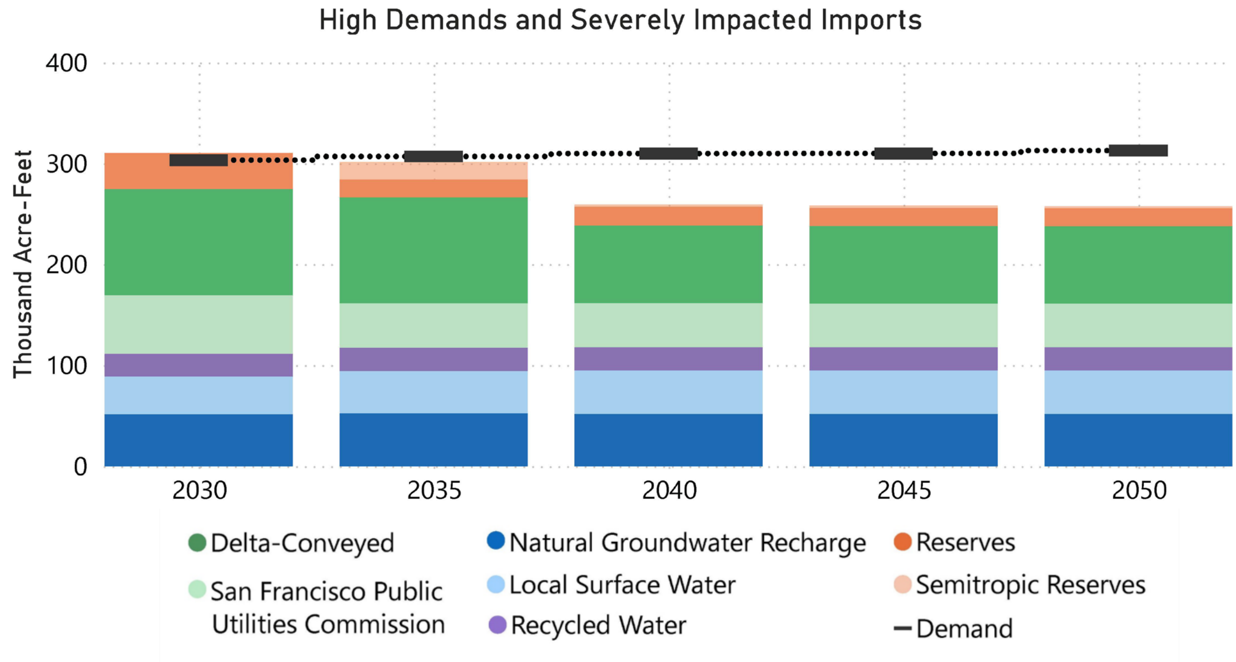
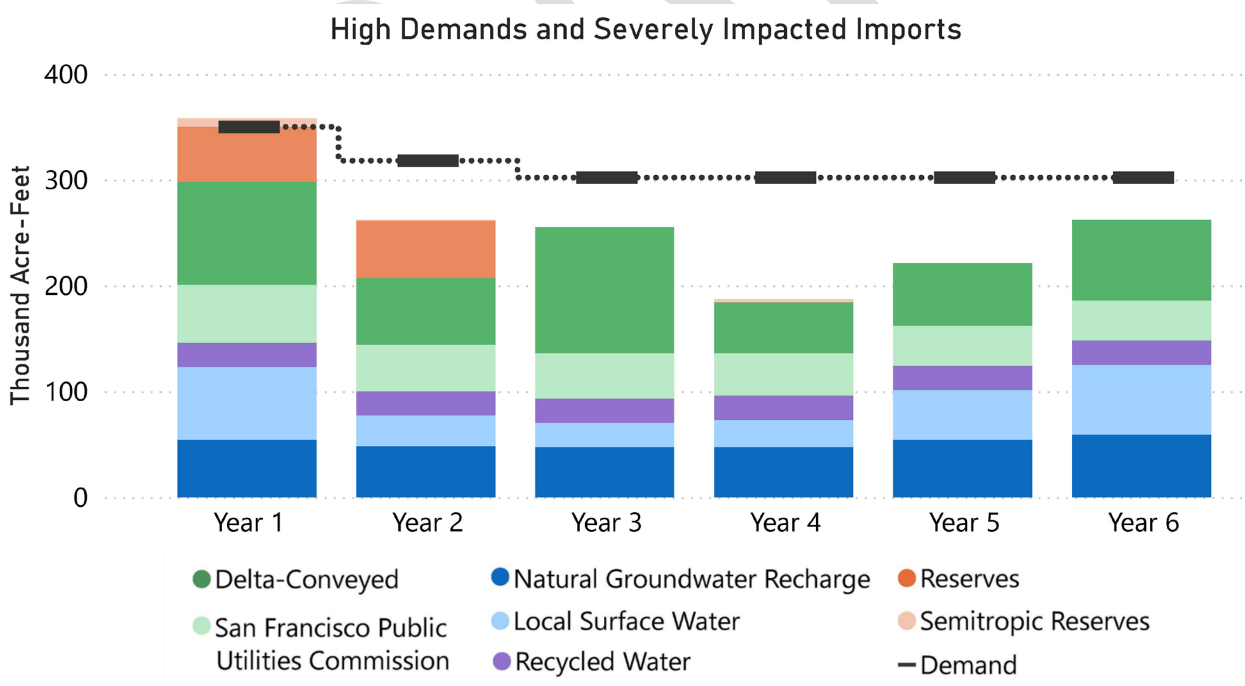


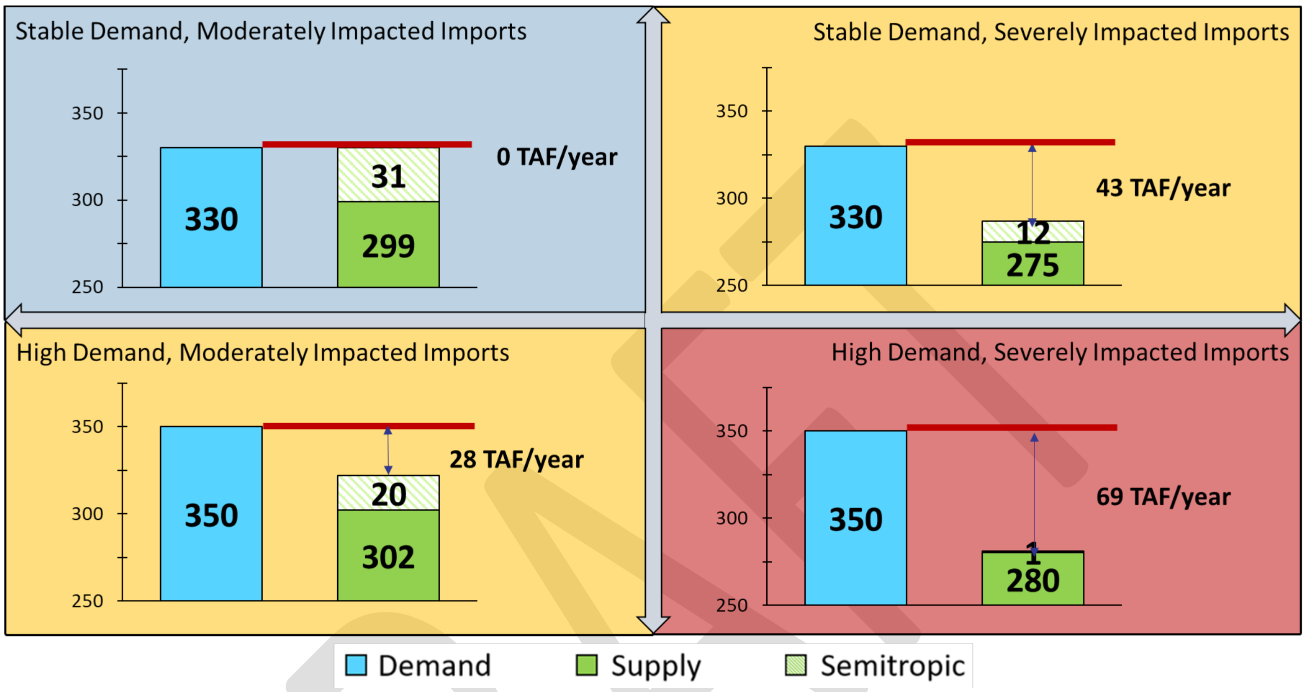
Figure 4-12 Demand and Supply During the Six-Year Drought in 2050



For each future condition, the average shortage during the six-year dry period was also estimated to provide the magnitude of shortages by the endpoint of the planning period. In 2050, the average shortage over a six-year drought could be as much as 70,000 AFY, depending on the projected demand and imported water supply conditions (Figure 4-13).

The shortages increase as demand increases and imported supplies decrease. The shortages also become larger and start earlier if the Semitropic contract is not renewed by 2035. The projected shortages represent future water supply needs in the county that Valley Water aims to meet to achieve its LOS goal.

Figure 4-13 Average Shortage During the Six-year Drought



4.3.4 Summary of Findings

The baseline water supply needs assessment identifies future water supply gaps to Valley Water's long-term water supply reliability. Findings from the assessment are summarized below.

- **System reliable under normal conditions.** Valley Water's current system and sources of supply can meet demands during wet and normal years.

- **Multiple-year droughts remain the biggest water supply challenge.** Valley Water will experience water shortages in all future conditions beginning in 2035. The shortages are highly sensitive to changes in water demands and imported supplies. They will start earlier and become bigger if the Semitropic Contract is not extended.

- **Demand growth increases risk.** Increased demands present a major risk to water supply reliability. While demands are not expected to increase significantly with efficient use, total demands can still increase as the population and economy grow over time.

- **Reduced imports contribute to water shortages even with stable demand.** Imported supplies remain a critical component of Valley Water's water supply portfolio. Future imported supplies face significant threats of uncertainty, including climate change and Delta regulations. Preserving Valley Water's existing imported supplies is crucial to minimize future water shortages.

- **Conservation is critical.** The analysis assumes Valley Water achieves both long-term conservation goals and short-term drought reduction calls. If these goals are not aggressively pursued and achieved, future shortages will be more severe, and the system will become more dependent on additional supplies to meet demands.

- **Action is needed in most futures.** The shortages are large in all futures except the future with stable demand and stable imports. Valley Water needs to invest in new projects and programs to address those shortages to ensure long-term water supply reliability for Santa Clara County.

4.4 Needs for Investment

The water supply needs assessment indicates that without new investment, Valley Water will experience large water shortages in the future during multi-year droughts, which could lead to a reduced service level. While a reduced service level would reduce or forego the needed level of investment, it could have an immediate and real impact on residents and businesses. These impacts could adversely and chronically affect potentially quality of life and economic development in the county, including rationing of water use during certain times of day, disruption of business operations (data centers, restaurants, tourism, recreation, etc.), and no irrigation for parks and trees. Agricultural production could be impacted by reduced water supply. If the shortage condition becomes chronic, it could lead to permanent land subsidence in northern Santa Clara County, which happened historically and took many decades of aggressive investment and management to halt. The reduced service level would also negatively impact Valley Water's operations and finances and put Valley Water outside the normal range of other water agencies' levels of service.

The cost of shortage would also be staggering. According to previous studies and preliminary cost-benefit analysis, the cost of shortage for the residential sector was estimated to be between $1.7 billion and $2.9 billion. For the agricultural sector, it will range from $230 million to $290 million. The cost of water shortage for businesses could range from $1.4 billion for 10% water rationing and $16.7 billion for 30% rationing. All costs are expressed in 2025 dollars. In addition, if the shortage condition becomes chronic, groundwater overdraft could lead to land subsidence and widespread and costly infrastructure damage over time which ranges in the billions. More information about the impacts of water shortage can be found in Appendix E.

As discussed above, the shortage calculations already incorporate both long-term conservation goals being met and short-term drought reductions. In addition, the shortages are also driven by impacts on imported supplies (not just demands). Therefore, investing in new projects is needed to help ensure that Valley Water can still supply Silicon Valley's vibrant community and economy with sufficient water supply.

Section 5 – Project Options

The water supply needs assessment indicates that with the baseline system, Valley Water will face shortages during a multi-year drought in the future. Valley Water needs to invest to secure its future. The future reliability of the system will be strongly dependent on demand trends, conservation savings, and imported water supply. Valley Water has been evaluating a suite of projects for continued planning and/or investment to meet future needs and goals. This chapter describes the project options considered in the WSMP 2050 to address potential supply shortages identified in the water supply needs assessment. The chapter includes a description of each project, followed by project evaluation and cost analysis, to provide a full picture of each project's benefits and risks/challenges to support decision-making.

5.1 Characterization of Projects

Valley Water considers and evaluates a broad range of projects in the WSMP 2050. Based on their primary benefits, the projects are characterized as alternative supply projects, surface supply projects, storage projects, and recharge projects. However, it should be noted that the projects' benefits are often more complex than indicated by this broad characterization.

Alternative supply

In the WSMP 2050, the alternative supply projects primarily include purified water and desalination projects. Purified water projects generate potable water through advanced treatment of wastewater. Purified water can be used for indirect potable reuse (IPR) through surface water or groundwater augmentation, or direct potable reuse (DPR) added directly to the distribution system. A desalination project would generate drinking water by purifying Bay water. Because these projects are less dependent on hydrological conditions, the alternative supply projects are dependable during drought and can provide water year-round. They can also further diversify Valley Water's existing sources of supply by adding a new local supply.

Surface supply

Surface supply projects provide surface water to Valley Water's system to increase its reliability and resilience. Currently, Valley Water's surface water supplies are generated from local reservoirs and imported from the Delta. Adding new and different supply sources can help fill the water supply gap identified under future dry-year conditions. Surface water supply projects would need to integrate with and rely on existing storage and conveyance infrastructure to bring their supplies to the Valley Water service area.

Storage

Storage projects include surface water and groundwater storage projects that allow for capturing excess water supply in wet years to be used during drought years. Surface water storage includes expanding existing reservoirs or building new reservoirs, while groundwater storage relies on aquifers that can be managed to store surface water through managed recharge. Storage has long been a critical component of Valley Water's water supply system. Valley Water's basic water supply strategy to compensate for supply variability is to store excess wet year supplies in storage (groundwater basin, local reservoirs, out-of-county storage) and draw on these reserve supplies during dry years to help meet demands. With the growing uncertainties of weather patterns and droughts due to climate change, the timing and magnitude of water availability could become extreme with prolonged droughts and big storms. Building sufficient storage to store excess water during big storms for use in dry years is essential for managing California's climate and hydrological cycles and securing water supply reliability. Both surface water and groundwater storage are critical to be prepared for a future with climate change, because surface water storage can accommodate large flows quickly. In addition, some storage projects can provide a certain amount of water storage or water supply for emergency response purposes that are outside of normal facility operations or average water supply. These emergency water supplies would be critically important during disasters, such as a Delta outage, and droughts.

Recharge

Recharge projects are projects to increase managed groundwater recharge and water supply reliability, primarily in South County. South County residents, businesses, and agriculture rely almost entirely on groundwater for water supply (Figure 5-1). With "weather whiplash" (frequent shifts between extremely wet and dry years) becoming more common and the high local reliance on groundwater, there is a need for additional recharge capacity in South County.

Figure 5-1 South County Water Use 2010-2019

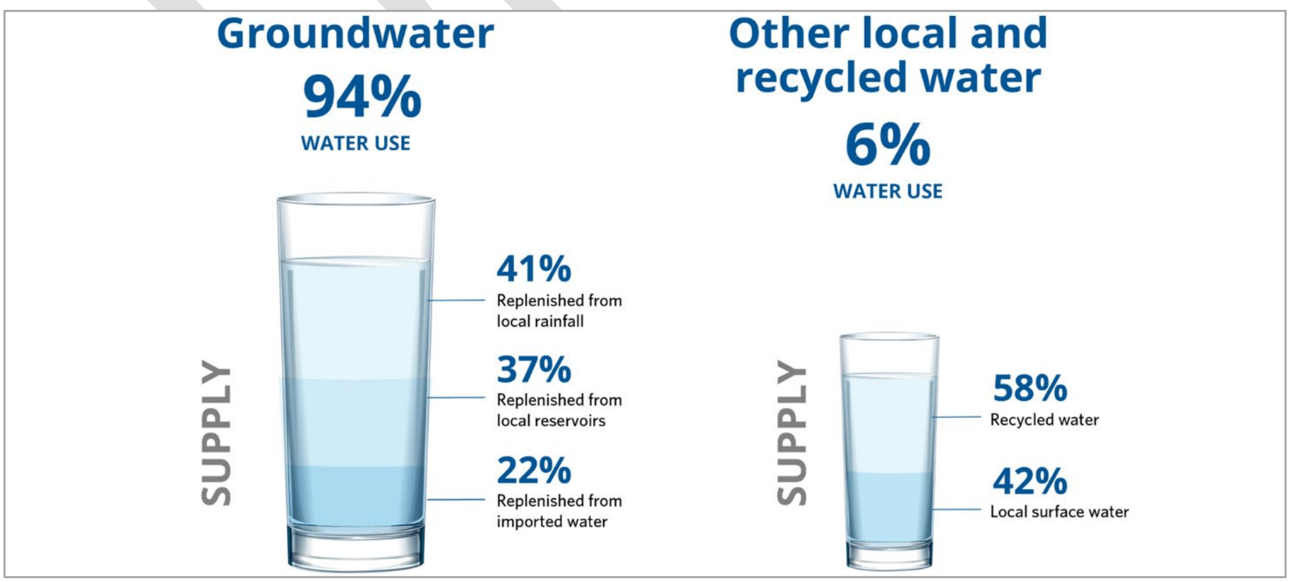
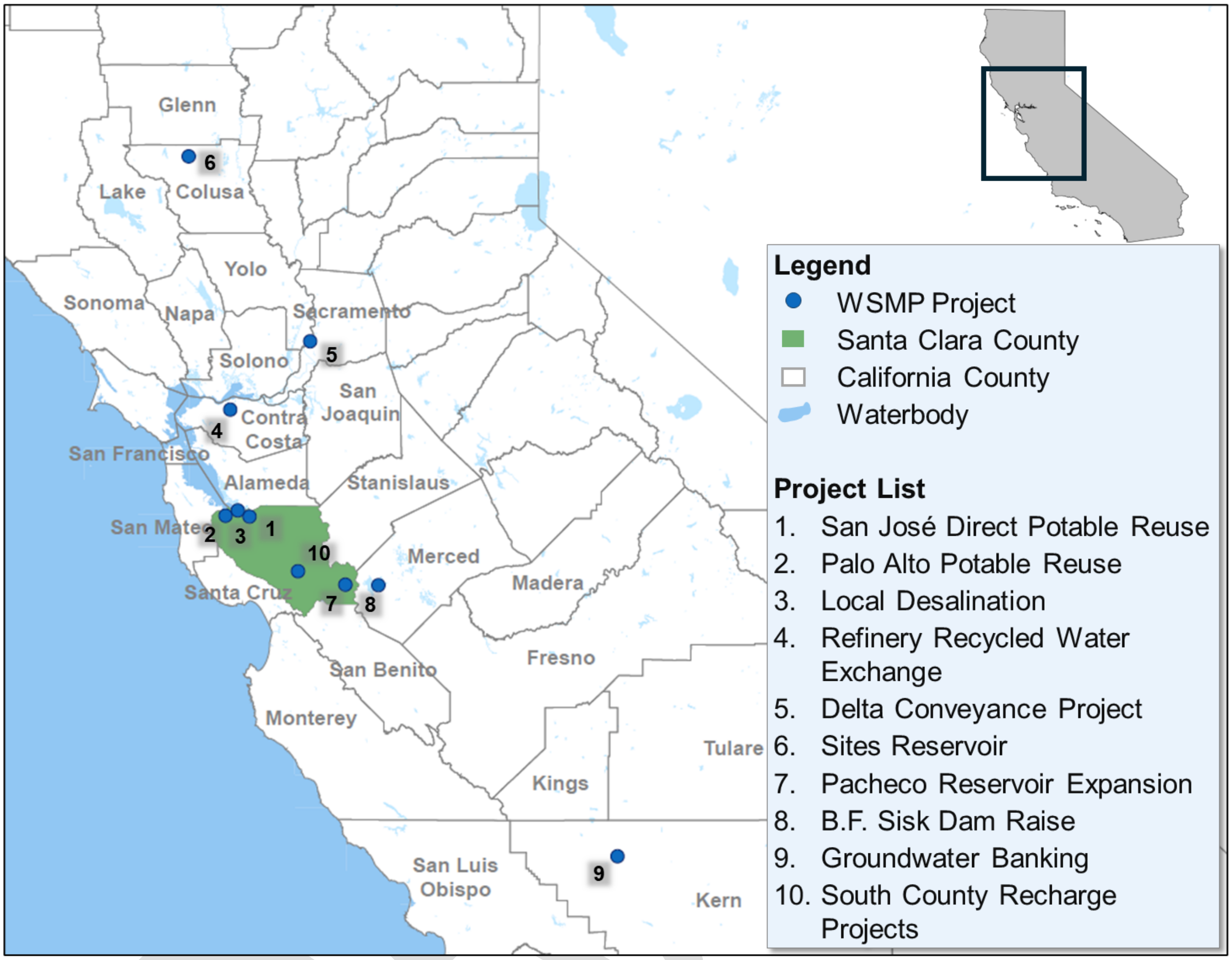


Table 5-1 shows the WSMP project options for each type of project. Figure 5-2 shows project locations. A detailed description of each project is provided in the next section.

Table 5-1 Projects Under Consideration

Project Type	Project
Alternative Supply	Palo Alto Potable Reuse
	San José Potable Reuse
	Refinery Recycled Water Exchange
	Local Seawater Desalination
Surface Supply	Delta Conveyance Project
	Sites Reservoir
Storage	B.F. Sisk Dam Raise
	Pacheco Reservoir Expansion
	Groundwater Banking
Recharge	Butterfield Channel Managed Aquifer Recharge
	Coyote Valley Recharge Pond(s)
	Madrone Channel Expansion
	San Pedro Ponds Improvement Project

Figure 5-2 Location of WSMP Project Options

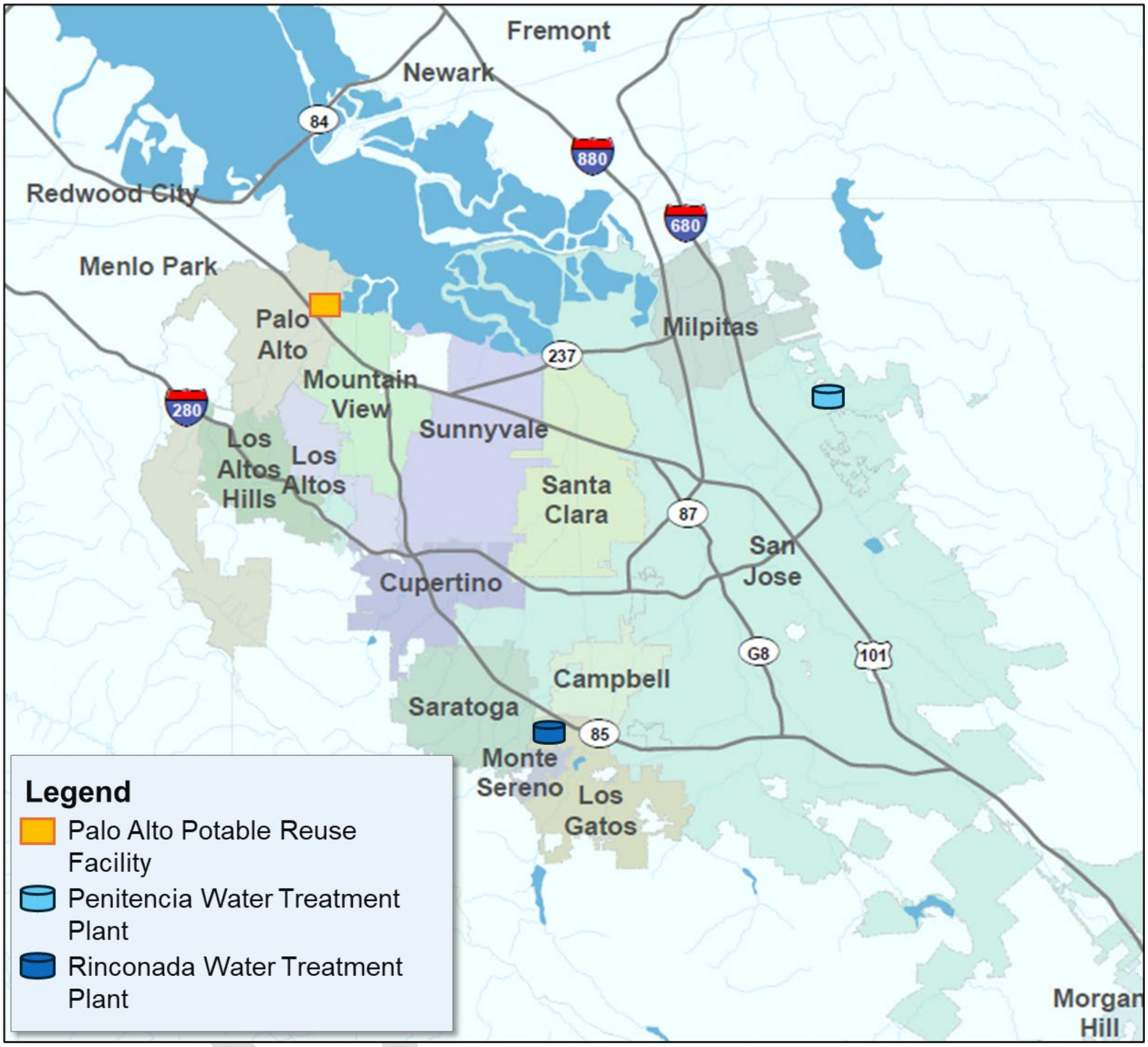


5.2 Overview of Projects

5.2.1 Palo Alto Potable Reuse

The Palo Alto Potable Reuse Project involves constructing an Advanced Water Purification Facility in Palo Alto capable of producing up to 8,400 AF of purified water per year for potable reuse. This is one of the potential projects identified in the Countywide Water Reuse Master Plan. The planned location for this project is at the former Los Altos Treatment Plant site in the City of Palo Alto (Figure 5-3), and effluent from the Palo Alto Regional Water Quality Control Plant (RWQCP) will be used as the supply source. In December 2019, Valley Water executed an agreement with the cities of Palo Alto and Mountain View that defined cost-sharing and supply commitments related to future water reuse. Key provisions of this agreement include a minimum commitment of approximately 11,000 AFY of wastewater effluent to Valley Water for purified water production and a water supply option for the cities of Palo Alto and Mountain View to request additional supply if needed.

Figure 5-3 Palo Alto Potable Reuse Project Location



This project was originally intended for indirect potable reuse, with purified water delivered to groundwater recharge ponds in the Los Gatos Recharge System. However, the new DPR regulations will allow for more flexible operations. The project will need extensive permitting to meet the new regulations, but once in operation, purified water can be used to augment both raw and treated water at Valley Water's water treatment plants (WTP). New pipelines will be needed to deliver water to the WTPs or Valley Water's recharge systems. The project will also require a reverse osmosis concentrate (ROC) management solution to meet required water quality standards for discharge.

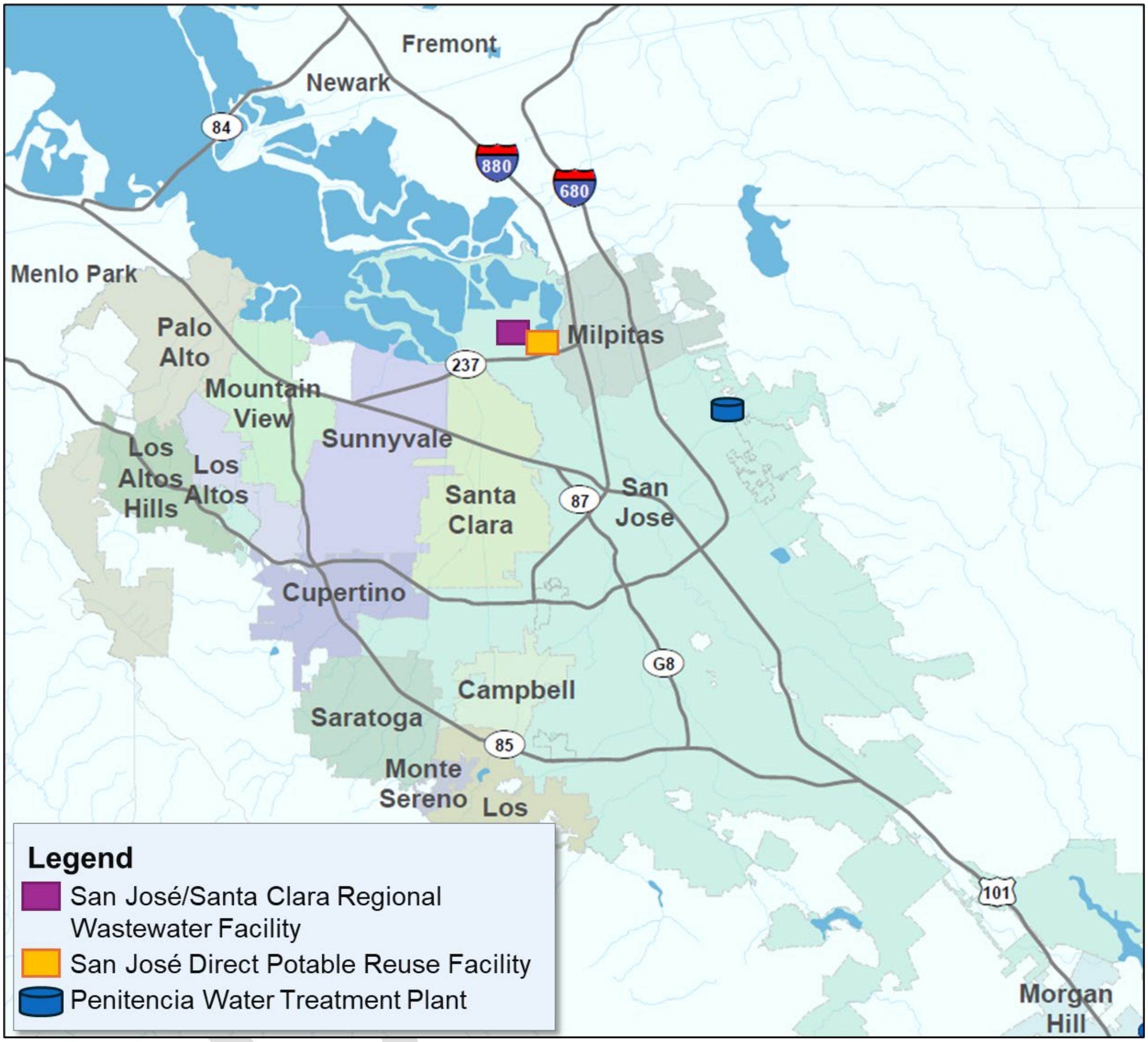
Public perception of potable reuse remains mixed. Valley Water continues to use the SVAWPC as a demonstration facility to engage and educate the public on the safety and benefits of potable reuse.

Due to rate impacts and affordability concerns, in 2024, the Valley Water Board placed the Palo Alto Potable Reuse Project on the CIP unfunded list in favor of pursuing the San Jose Potable Reuse Project, which has more wastewater available. The project currently remains at the early stage of planning.

5.2.2 San José Potable Reuse

The San José Direct Potable Reuse Project is a major project that Valley Water is pursuing for direct potable reuse. With this project, Valley Water plans to construct an advanced water purification facility adjacent to the existing SVAWPC in North San José through a partnership with the cities of San José and Santa Clara (Figure 5-4). The project would use effluent from the San José-Santa Clara Regional Wastewater Facility to produce up to 24,000 AFY of purified water for direct potable reuse. Valley Water does not have authority over the county's wastewater, so agreements with the local wastewater agencies are required to secure a supply source for this project. The project is currently planned to be online by 2035 and is considered the key to meeting the WSMP potable reuse goal of 24,000 AFY by 2035.

Figure 5-4 San José Direct Potable Reuse Project Location



The project is planned in two phases: Valley Water will first design and construct a DPR Demonstration Facility and Learning Center to develop validation studies needed to permit a full-scale DPR facility and to allow for more effective public outreach about the DPR process. This project is currently in the CIP. The full-scale facility project will design, construct, and permit a full-scale facility that meets the stringent regulatory requirements for DPR, along with the necessary infrastructure for delivery of product water to the distribution system.

The new DPR regulations approved in 2024 allow for purified water to be added directly to drinking water systems or to be used to supplement raw water supply for a drinking water treatment plant. For the San José DPR project, multiple points of potential connections are being considered, which allow for more flexible operations.

The project will also require a reverse osmosis concentrate (ROC) management solution to ensure protection of the sensitive South Bay. Valley Water is exploring various solutions, including nature based approaches.

5.2.3 Refinery Recycled Water Exchange

The Refinery Recycled Water Exchange would create a new imported water supply for Valley Water through the development of recycled water with project partners. For this project, Valley Water and Central Contra Costa Sanitary District (Central San) would partner to build a tertiary recycled water facility at Central San's existing wastewater treatment facility in Contra Costa County (Figure 5-5). Central San would provide the recycled water produced from the facility to two oil refineries in Contra Costa County in lieu of receiving Contra Costa Water District's (CCWD) CVP water. In exchange, CCWD would provide CVP supply to Valley Water. The new facility would be operated by Central San, and no operational changes would be required of Valley Water aside from coordinating imported water deliveries. The project is expected to provide 8,500-10,000 AFY of additional CVP water to Valley Water that may help Valley Water meet its level of service goal. If the project moves forward, the anticipated online date for this project would be 2030.

Figure 5-5 Location of Central San Facilities and Two Refineries

The project, however, faces significant uncertainty in both refinery demands and the delivery of CVP supplies. The project could produce and deliver recycled water year-round, but the refineries' demands may not require it. The refineries could also become idle in the future and reduce their demands. Since Valley Water would be receiving CVP water that is subject to water allocation by the U.S. Bureau of Reclamation (USBR), the water supply benefit will still rely on imported supplies and have the associated risk of reduced future allocations. In addition, the imported water exchange associated with the project has regulatory and operational uncertainties that could impact the reliability of Valley Water receiving the project water. A feasibility study and cost allocation analysis have been completed for this project, but continued coordination with USBR and CCWD is needed to evaluate the reliability of the exchange during droughts when there are less CVP supplies available. This project may also have competing interests. CCWD is currently evaluating the project in their long-term Future Water Supply Study, and East Bay Municipal Utility District (EBMUD) is also evaluating the project. In addition, transfer of the CVP supplies to Valley Water was envisioned via the Transfer Bethany Pipeline, which is no longer being planned.

5.2.4 Local Seawater Desalination

The Local Seawater Desalination Project would construct a desalination facility in northern Santa Clara County and treat seawater from the South San Francisco Bay. Desalinated water from this facility could provide water supplies directly to the treated water system for distribution to customers or augment raw water supplies, increasing Valley Water's operational flexibility. This project would be owned and managed by Valley Water but may require coordination with other local agencies, depending on the selected site. The desalination plant would also have a consistently available supply source, which would help mitigate risks of multi-year droughts and improve Valley Water's overall water supply reliability.

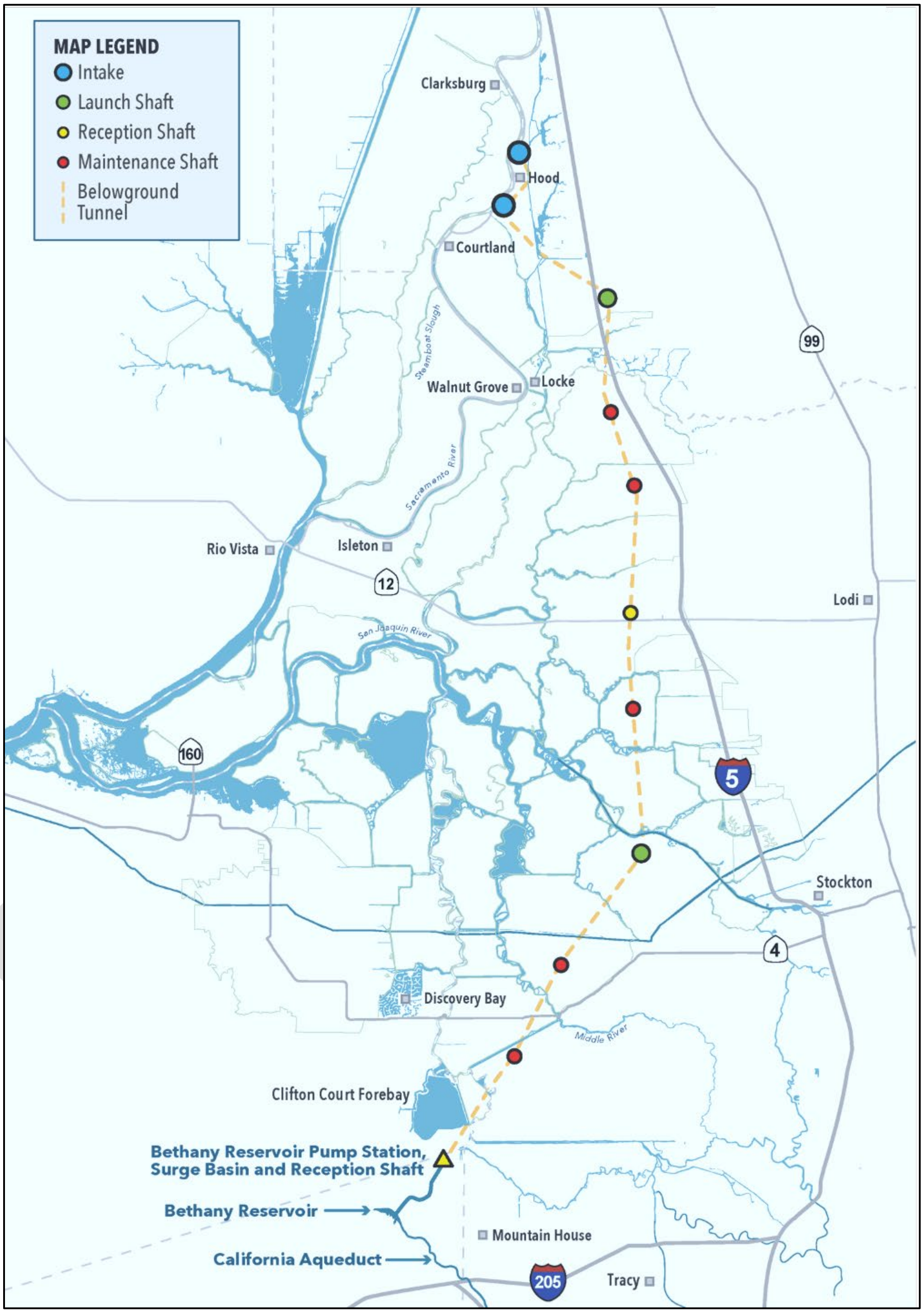
Valley Water is working on a feasibility study for this project, which is expected to be completed in 2025. For the WSMP analysis, this project is considered a backup project to the San Jose Potable Reuse project and assumed to have 24,000 AFY capacity with an online date of 2035, the same as the San José Potable Reuse project.

The treatment process for desalination is more energy intensive than the purification of wastewater. There are environmental concerns for this project related to the sensitive South Bay ecosystem, including the intake of water, brine effluent management, and the protection of habitats.

5.2.5 Delta Conveyance Project

The Delta Conveyance Project (DCP) is a DWR-led effort designed to help the SWP adapt to climate change and protect the SWP from water supply losses due to climate change, sea level rise, earthquakes, and flooding. The DCP involves constructing new facilities to divert water from the Sacramento River at two new intakes in the North Delta into a single tunnel that would convey water to existing facilities south of the Delta (Figure 5-6). Each intake would include a fish screen to protect at-risk species and would be capable of diverting 3,000 cubic feet per second (cfs), for a total maximum diversion rate of 6,000 cfs. It would be operated to capture excess flows from large storm events that cannot be currently diverted by existing SWP infrastructure. Another potential benefit of the DCP is that it could convey water transfers during times when conveyance across the Delta is not typically available, which would allow Valley Water to purchase water when water is less expensive to support better drought recovery and preparedness. DCP also aims to provide greater flexibility in how water is diverted, which has the potential to improve protection for at-risk species that live and migrate through the Delta. In addition to water supply and infrastructure resiliency benefits, the project would enhance and/or complement the benefits of other projects that are being considered under the WSMP 2050.

Figure 5-6 Delta Conveyance Project Preferred Alternative



Source: Department of Water Resources

The DCP would be owned and operated by DWR. However, the planning and design is governed by a Joint Exercise Powers Agreement, which established the Delta Conveyance Design and Construction Authority; Valley Water holds a position on that Board of Directors. There are currently 18 SWP contractors participating in the project. Valley Water's current participation level is 3.23%, which could provide approximately 14,000 AFY of water supply benefits on average. The project has significant implementation complexity, but no operational changes are needed for Valley Water to benefit from this project. Conveyance through DCP will be coordinated with DWR as part of Valley Water's routine SWP delivery scheduling.

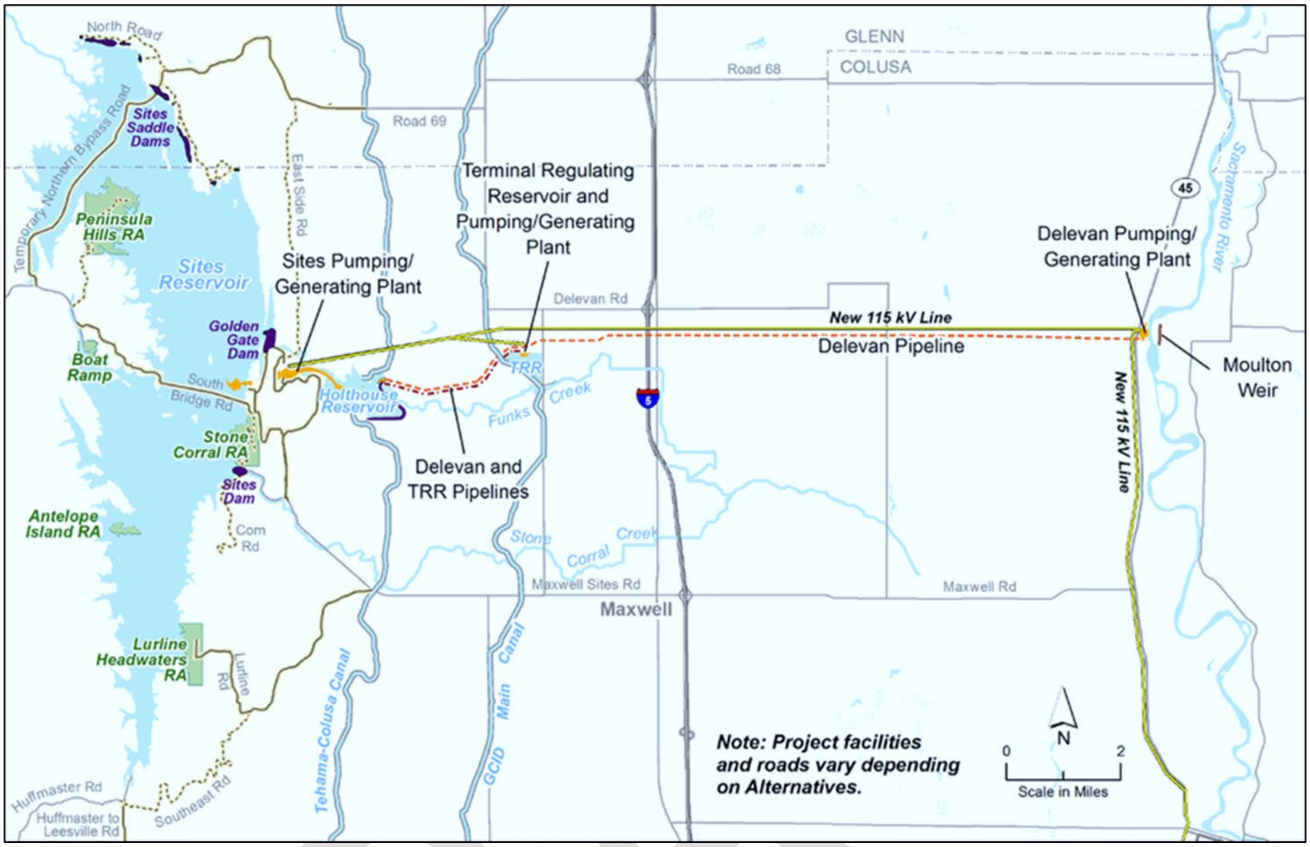
In December 2023, DWR released the Final Environmental Impact Report (FEIR). In parallel to the State process, the U.S. Army Corps of Engineers (USACE), in compliance with the National Environmental Policy Act (NEPA), plans to issue a final Environmental Impact Statement in mid-2025. DWR obtained an Incidental Take Permit for the project in February 2025, which documents how the project will comply with the California Endangered Species Act (CESA). The project also received permits, or Biological Opinions from U.S. Fish and Wildlife Service and National Marine Fisheries Service, for the Long-Term Operations of the DCP in late 2024, documenting compliance with the Federal Endangered Species Act (ESA) for operating the DCP. Several permits are still required and expected in 2025-2026, including construction focused Biological Opinions, amendments to the SWP's water rights via a Change in Point of Diversion Petition (CPOD) with the State Water Resources Control Board (SWB), and verification of consistency with the Delta Plan.

There are some long-term operational uncertainties related to potential regulatory changes, including updates to the SWB's Water Quality Control Plan. The project also faces public opposition due to rising costs and environmental concerns, but has political support from the State and many local water agencies. The project is anticipated to be online by 2045.

5.2.6 Sites Reservoir

Sites Reservoir is a proposed 1.41 million AF off-stream water supply reservoir located north of the Delta near the town of Maxwell in Colusa County (Figure 5-7). The reservoir is designed to divert and capture excess flows on the Sacramento River during storms that can be later released to provide water supply during dry years. In addition to providing water supply benefits, the Sites Reservoir will provide public benefits, including environmental water supply, recreation facilities, and regional flood benefits. Sites Reservoir is one of the storage projects in the California Water Commission's Water Storage Investment Program (WSIP).

Figure 5-7 Sites Reservoir



Source: Sites Project Authority

The project would rely on existing diversion facilities to divert water from the Sacramento River, but require a new diversion and discharge pipeline to connect the reservoir to existing canals. This project would provide dry year yield and storage benefits, and it would be operated in coordination with the SWP and CVP. The project also offers statewide operational flexibility to stabilize SWP/CVP deliveries under a changing climate and regulatory requirements. The project is managed by a Joint Powers Authority comprised of local agencies. Currently, the project is fully subscribed with 22 local agencies, the California Department of Fish and Wildlife, and USBR participating in the project. Design and permitting are currently underway, and the project is projected to be online by 2033.

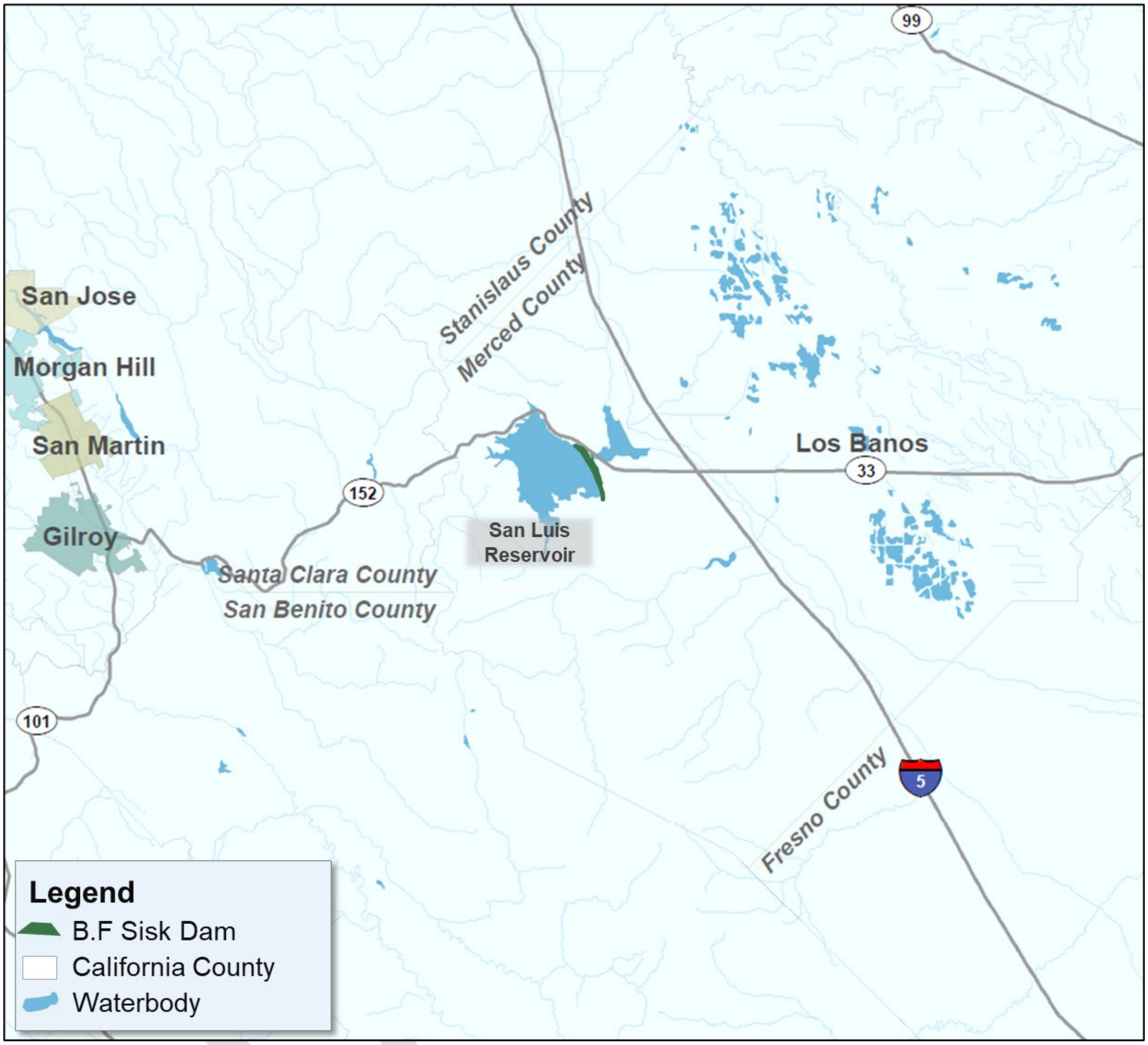
Valley Water is currently assuming a 2.7% participation level for the WSMP analysis, which could provide a dry-year yield of 9,200 AFY of water and 37,000 AF of storage. Participating in the project would give Valley Water priority for transfers involving Sites water and lease/purchase of additional storage which could provide additional dry year supply as needed. As the project would be integrated with the existing state and federal systems, no operational changes are needed from Valley Water aside from coordinating takes with other partners.

While the project has strong political support and has received funding from the State and Federal governments, it faces public opposition from environmental groups concerned with inundating a new area and through-delta conveyance. However, the project would provide environmental benefits for endangered fisheries on Sacramento River. There is also some uncertainty regarding costs.

5.2.7 B.F. Sisk Dam Raise

B.F. Sisk Dam forms San Luis Reservoir and is located southwest of Santa Clara County. San Luis Reservoir is a key component of the CVP and SWP systems (Figure 5-8). USBR is developing the B.F. Sisk Dam Raise and Reservoir Expansion Project (Sisk) in partnership with 6 local water agencies, including Valley Water, who are participating in the project through the San Luis & Delta-Mendota Water Authority (SLDMWA). The Sisk project will raise the existing B.F. Sisk Dam by 10 feet and increase the storage capacity of San Luis Reservoir by 130,000 AF. The project is being planned in conjunction with the B.F. Sisk Safety of Dams Modification Project, which is being undertaken by USBR and the DWR to address seismic risks of the existing dam.

Figure 5-8 B.F. Sisk Dam



USBR will continue to own and operate the expanded San Luis Reservoir, while participants will be provided storage capacity in proportion to their investments that can be used to store any water type available to them. Of the 130,000 AF of additional water storage capacity, USBR anticipates reserving 39,000 AF (30%) to use at its discretion while project participants expect to reserve the remaining 91,000 AF (70%) for their benefits.

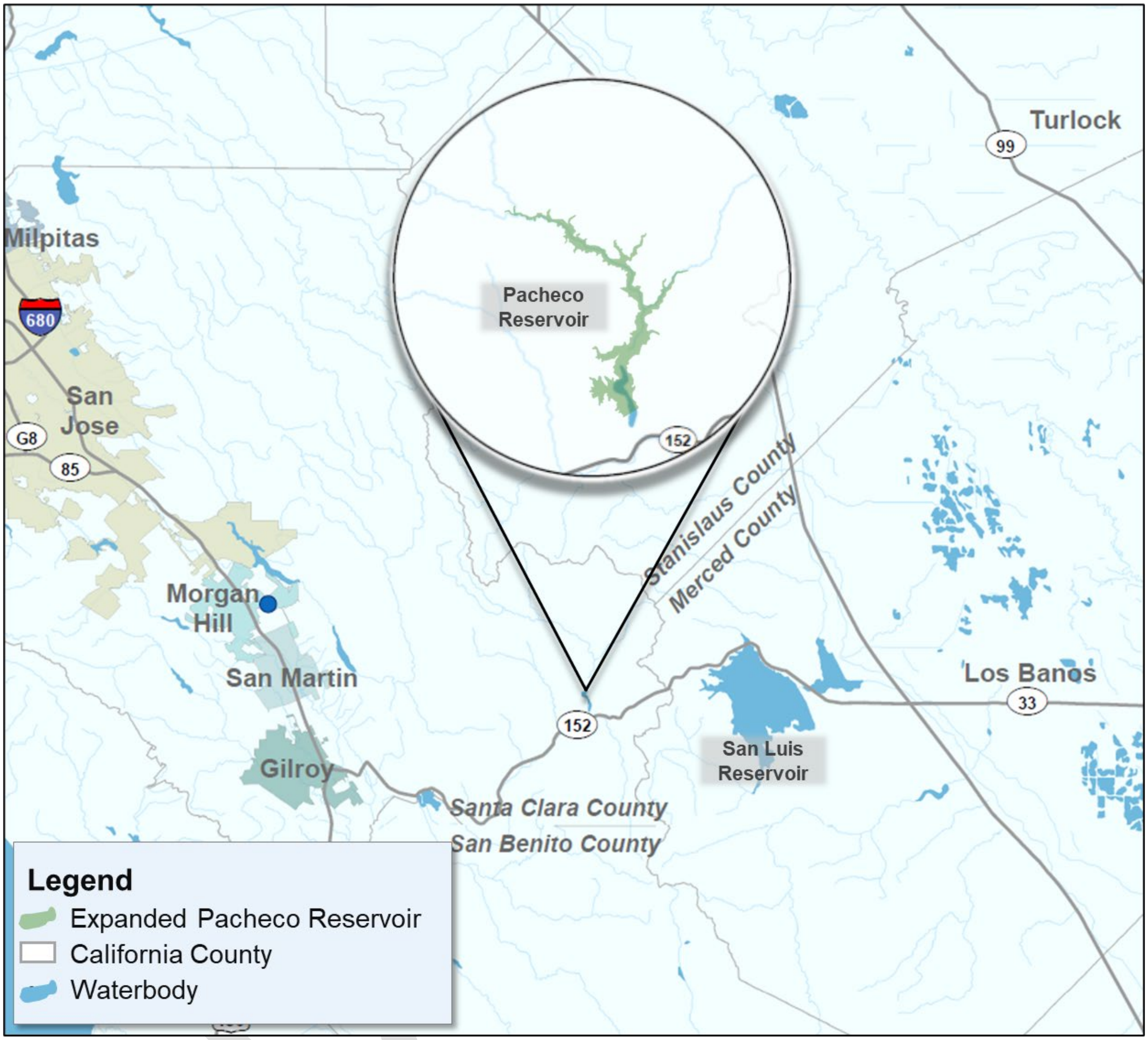
Valley Water has a current storage level of 63,560 AF for imported supplies, the largest share among the participants. If successful, the additional storage would help diversify Valley Water's storage portfolio and expand our ability to capture and store CVP and SWP surplus supplies when available. As it is an existing facility, the project would be operationally integrated with the CVP and SWP and would not require operational changes from Valley Water. Additionally, Valley Water is directly connected with San Luis Reservoir through Pacheco Pumping Plant and puts and takes would be coordinated through routine delivery scheduling. Overall, the project would enhance Valley Water's operational flexibility and could be used to either capture and use wet year water more frequently or store it for use during dry years.

The project faces very little public opposition, but the expansion would require modifying a portion of State Route 152, which will complicate the construction effort. In 2024, USBR and project participants concluded negotiations on the cost-sharing and space management for the expansion. Environmental permitting efforts are underway. The project has a projected operational date of 2035.

5.2.8 Pacheco Reservoir Expansion

The Pacheco Reservoir Expansion Project plans to construct a new earthfill dam to enlarge the existing reservoir, located on the lower end of North Fork Pacheco Creek in southeast Santa Clara County, from 5,500 to 140,000 AF (Figure 5-9). An expanded Pacheco Reservoir would increase water supply reliability to help meet municipal and industrial water demands in Santa Clara County during drought periods and emergencies, enhance operational flexibility, provide environmental flows for federally listed threatened Central California Coast Steelhead in Pacheco Creek, and address shortages due to regulatory and environmental restrictions. The expanded reservoir would be locally controlled and operated by Valley Water. The Pacheco Reservoir Expansion Project is also one of the WISP projects that has received state funding.

Figure 5-9 Pacheco Reservoir Expansion



New conveyance infrastructure, including a pipeline, tunnel, and pump station, would be required to connect the expanded reservoir to the existing Pacheco Conduit. The primary water sources to fill the expanded reservoir would be natural inflows from the North and East Forks of Pacheco Creek and imported water supplies from San Luis Reservoir. The expanded reservoir could also help with reducing spills of Valley Water's contract water in San Luis Reservoir and storing surplus supplies or excess flows from the Delta when they are available. With its connection to San Luis Reservoir, the Pacheco Reservoir Expansion Project could also reduce the impacts of San Luis Reservoir low-point events by moving the imported water to Pacheco Reservoir before algae growth in San Luis Reservoir degrades the water quality going to Valley Water and the treatment plants.

The project has completed 30% of the design and is advancing toward 60% design, with final design completion in late 2028. Extensive permitting and mitigation efforts are required, which will take time and increase the overall project cost. Permitting is currently in progress and is anticipated to be completed in 2028. Valley Water is working on the Recirculated Draft EIR (DEIR) to be released in 2026 for public review and comments. Valley Water is also actively exploring partnerships to reduce the costs to Valley Water. The project construction is expected to start in 2029 and be completed by 2036.

As with many surface water storage projects, the Pacheco project faces opposition from environmental groups due to environmental concerns and high project cost, but the project has public support from various trade unions, adjacent property owners, and other members of the public.

5.2.9 Groundwater Banking

Groundwater banking has historically been among the most cost-effective storage options. Valley Water currently holds a contract for 350,000 AF of storage in Semitropic Groundwater Bank (Semitropic) in Kern County, which will expire in 2035. A new agreement will need to be negotiated should Valley Water and Semitropic agree to extend the program. Valley Water is also exploring additional new groundwater banking projects to diversify its storage portfolio and increase recharge and recovery capacities. Discussions on these potential options are ongoing, but, to date, no agreement for specific programs or options has been finalized.

While groundwater banking remains one of the most viable storage options, the development and operation of new and existing banking programs carries significant regulatory, technical, and political challenges, including:

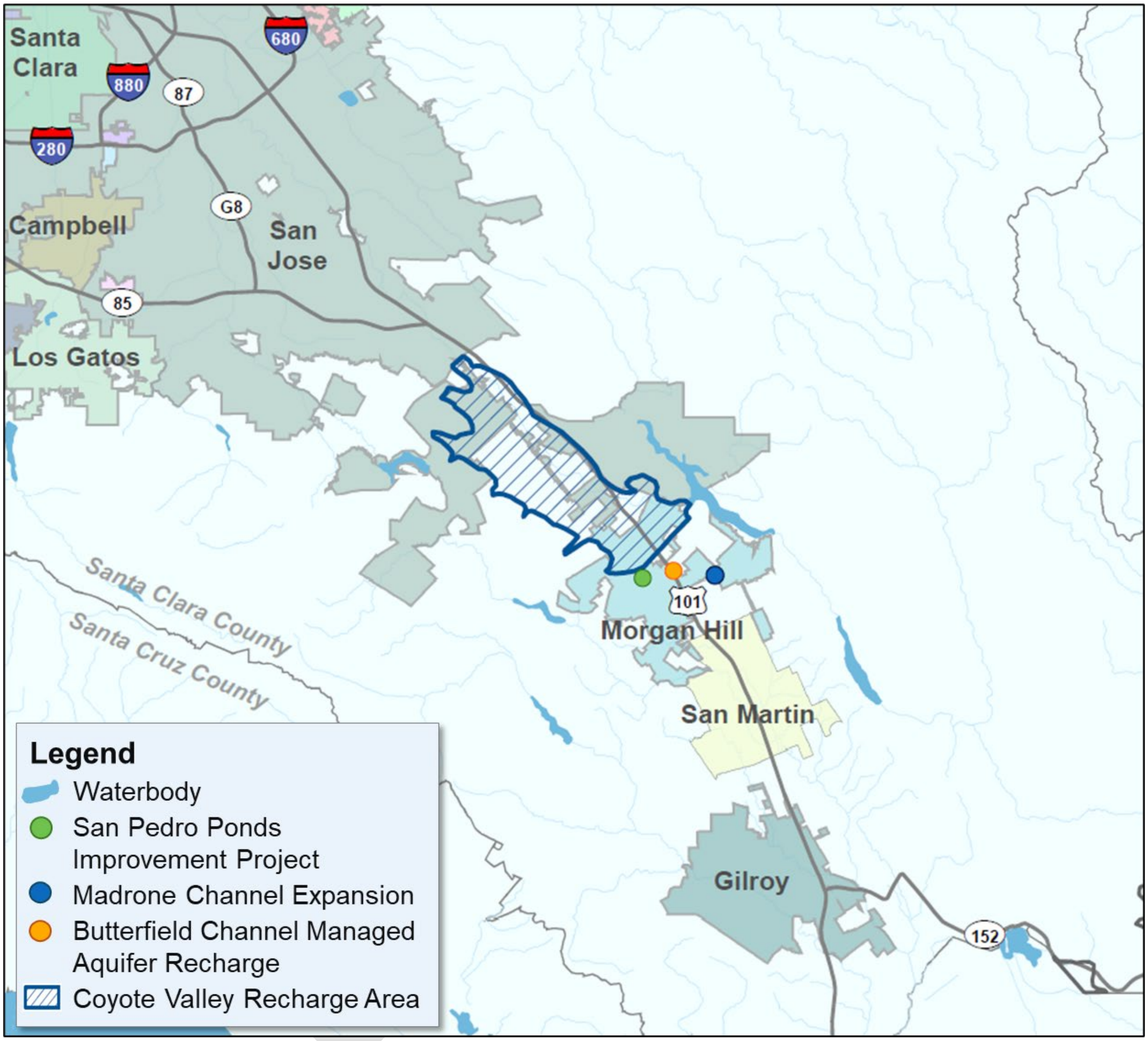
- Implementation of SGMA and its impact on banking operations, such as potential reductions on recovery in dry years
- Existing and future water quality requirements
- Develop of new groundwater storage facility requires buy-in and close coordination with local agencies and landowners
- Competition with other SWP and CVP contractor for storage and conveyance capacities
- Requires approval from DWR and USBR for storing and conveying SWP and/or CVP supplies

5.2.10 South County Recharge

Several recharge projects are being evaluated to increase managed recharge capacity and improve water supply reliability in South County (Figure 5-10). The projects are all in the preliminary planning phase and focus on maximizing the use of existing infrastructure. The WSMP analysis includes the Butterfield Channel Managed Aquifer Recharge, Coyote Valley Recharge Pond(s), Madrone Channel Expansion, and San Pedro Ponds Improvement Project.

Not all four managed recharge projects are needed to ensure reliable groundwater supplies. More substantial evaluation has been conducted for the San Pedro Ponds, with a recent study that identified eight alternatives that could fully or partially restore the 4,700-AFY operating capacity of the San Pedro Ponds. The evaluation will continue to determine which of the four managed recharge projects will best support water supply needs.

Figure 5-10 South County Recharge Projects



Butterfield Channel Managed Aquifer Recharge

Butterfield Channel in Morgan Hill is currently used by the city for stormwater management. This project proposes connecting it to Valley Water's raw water conveyance system so that imported water can be recharged along the channel during the summer months when it is not used for stormwater conveyance. The project would increase the recharge capacity for the Llagas Subbasin while maximizing the use of existing infrastructure in the county. A new turnout from the raw water pipeline will be needed to deliver water to the channel when supplies are available. High groundwater levels in the area may limit the recharge capacity, and further studies are needed. The project will also require close coordination with the City of Morgan Hill to determine when the channel is used for stormwater.

Coyote Valley Recharge Pond(s)

The Coyote Valley Recharge Pond(s) Project is a proposed recharge pond or a system of ponds to increase the managed aquifer recharge for the Coyote Valley, a groundwater management area that constitutes the southern end of the Santa Clara Subbasin, which is currently only recharged through Coyote Creek. The project would construct new recharge facilities off-stream of Coyote Creek and near the Cross Valley Pipeline, which could be used to supply imported water to the facilities. A new turnout and diversion pipeline from the Cross Valley Pipeline to the new facility will be required. Potential parcels of interest have been identified based on suitable geology and proximity to surface water supply, but property acquisition may be the most significant challenge. Valley Water will need to work with landowners in the area to determine if land is available to purchase for the recharge pond and to confirm site suitability. This project would help create operational flexibility for managed recharge operations in Coyote Valley and make operations less reliant on Coyote Creek flows and operational constraints (e.g., FAHCE). The Coyote Valley Recharge Pond could be operational by 2030 and operated under a range of hydrologic conditions. Even with limited surface water supplies in dry years, the facility would allow for continued recharge when imported water temperatures do not meet instream requirements.

Madrone Channel Expansion

Madrone Channel is an existing recharge facility in Morgan Hill comprised of ten recharge ponds, supplied by both imported and local water. Expanding the channel by adding one or two ponds downstream of the existing channel will increase the recharge capacity for the Llagas Subbasin. The new ponds may be especially useful emerging from drought conditions, when groundwater levels are low and more water supplies are available, to restore groundwater levels. There may be periods where relatively high groundwater conditions prevent the use of these new ponds, but Valley Water would not need the additional recharge capacity at that time. The project would require coordination with the City of Morgan Hill which uses the channel for stormwater discharge.

San Pedro Ponds Improvement Project

The San Pedro Recharge Ponds are located in unincorporated Santa Clara County near Morgan Hill and help to recharge the Llagas Subbasin. Currently, Valley Water is unable to operate the ponds at full capacity due to shallow groundwater conditions that interfere with the existing septic systems of properties adjacent to the ponds. Valley Water does not own these properties and would need to work with the landowners, the City of Morgan Hill, the County, and the Local Agency Formation Commission (LAFCO) to determine the most appropriate solution. Both physical and institutional changes are under consideration to maximize the use of the San Pedro Ponds. Depending on the solution, Valley Water anticipates the ponds can be brought back to full capacity by 2030.

5.3 Project Evaluation

Project evaluation is an important step in the WSMP 2050 development to develop a comprehensive understanding of each project's benefits and risks, which serves as the basis to develop and evaluate portfolios among different options and with different considerations. Since project options vary by nature/type and many are still at the early planning stage and will evolve, it is very challenging to quantify each project's full benefits and risks/challenges accurately and reliably. Therefore, project evaluation was done largely qualitatively to provide a comprehensive understanding of each project on its own merits as well as in comparison with others.

5.3.1 Evaluation Criteria and Process

A list of 14 criteria was developed to evaluate and compare projects. Table 5-2 shows the criteria and their descriptions. The criteria are generally consistent with the funding filters used by Valley Water's Capital Improvement Program. Among the evaluation criteria, the water supply benefit and cost are the most important criteria and can be quantified, and the rest are qualitative criteria. A subset of the criteria was also used for portfolio evaluation, which is discussed in Section 6.2.

Table 5-2 Project Evaluation Criteria

Evaluation Criteria	Description
Water Supply Benefit	Quantifiable water supply benefits of the project
Cost/Rate Impact	Construction, planning/design, O&M, and other costs
Timing	The year the project will be in service
Technical Feasibility	Technical ability to implement the project
Operation	How the project operates, specifically how it connects to the existing system and moves water around
Reliability	Reliability of the project in providing its primary benefits during periods of dry year need
Readiness/Likelihood of Success	The readiness of project implementation and chance of success
Flexibility	Operation/implementation across a wide range of conditions and whether it can enhance overall system flexibility
Jurisdiction/Partnership	Primary jurisdiction and partners of the project
Permitting/Legal Issues	Permits required and any legal Issues/concerns
Environmental Impacts/Justice	Anticipated positive or negative impacts on the natural environment and environmental justice
Public Acceptance	Public opinion and political support for the project

Inter-dependence	Whether the project will need other projects to be functioning or can magnify other projects
Risk/Challenges	Any significant risks/challenges that could potentially derail the project

A group of internal experts and project teams evaluated the projects. The evaluation started with a detailed analysis of the water supply benefit and cost of each project, followed by a qualitative assessment of each project's reliability in providing planned benefits, likelihood of success, environmental impacts, jurisdiction and partnership, public acceptance, and so on.

The environmental impacts of major projects are based on their published Environmental Impact Reports, which detail their impacts on natural and/or cultural resources and other aspects of the environment. In addition, Valley Water solicited input from the WSMP expert panel on project benefits and risks/challenges.

5.3.2 Evaluation Summary

The project evaluation confirms that while all projects are beneficial to Valley Water's long-term water supply reliability, no single project can meet all future needs and each project has risks and challenges. Some projects provide needed supply during droughts but are costly; others are lower in cost but are high risk or do not contribute significantly to drought reliability; and yet others require agreements with partners and therefore their success remains out of Valley Water's direct control. Furthermore, many projects are in the planning phase and are still evolving, adding further uncertainty to their costs, benefits, and risks. Therefore, portfolios of projects that complement each other could provide a balanced, diverse, and sustainable water supply to address future needs and challenges.

Table 5-3 provides a summary of each project's key benefits as well as associated risks and challenges based on the evaluation criteria. The water supply benefits represent average annual supply, and the actual benefits of each project vary by how they are paired with other projects, demand, and hydrological conditions. Cost analysis is discussed in Section 5.4.

Table 5-3 Summary of Project Evaluation Findings

Project	Benefits	Risks/Challenges
Palo Alto Potable Reuse	8,400 AFY of local, drought-resilient supply	• Requires agreements with Palo Alto • Public acceptance remains mixed • High capital and operational costs • Requires long-term ROC management solutions
San José Direct Potable Reuse	Up to 24,000 AFY of local, drought-resilient supply Increases system operational flexibility	• Requires agreements with City of San José • Public acceptance remains mixed • High capital and operational costs

		• Requires ROC management solutions
Local Seawater Desalination	Up to 24,000 AFY local, drought-resilient supply Increases system operational flexibility	• Environmental challenges, including brine management, power needs, and permitting in the sensitive Bay environment • High capital and operational cost • Multiple regulatory permitting steps
Refinery Recycled Water Exchange	On average 8,500 - 10,000 AFY of imported water supply Increases regional drought resiliency	• Uncertainty in refinery demands and delivery of CVP supply • Project also being considered by CCWD and EBMUD
Delta Conveyance Project	On average 14,000 AFY of imported water supply Help secure existing Delta-conveyed supplies Improve access to transfer supplies	• Implementation complexity • Long-term operational uncertainty • Active public opposition due to environmental concerns • Long-term financing uncertainty.
Sites Reservoir	Potential 9,200 AFY of imported water supply in dry years and 37,000 AF of storage Offers access for transfers and lease/purchase of additional storage Provides statewide water supply and environmental benefits to SWP and CVP	• Public opposition from environmental groups • Requires through-delta conveyance • Project is currently fully subscribed
Pacheco Reservoir Expansion	Locally controlled storage of 140, 000 AF Emergency storage with no annual carryover storage limit Downstream environment benefits Increases operational flexibility	• Public opposition • High cost • Environmental impact on cultural resources • Difficulty in securing partners, • Increased long-term environmental commitments
B.F. Sisk Dam Raise	More than 60,000 AF of storage for imported supplies Increases operational flexibility	• Storage of CVP supplies is not secure • Requires moving a portion of Route 152
Out-of-County Groundwater Banking	More cost-effective than other options	• No identified projects yet • Significant institutional, technical, and political hurdles

	Extend or diversity existing banking program, potentially increasing current put/take capacities	• Puts/takes may not be guaranteed
South County Recharge	Increase recharge capacity Maximize use of existing infrastructure Increase operational flexibility in South County	• May require landowner support • In preliminary planning phase

5.4 Cost Analyses

Cost is one of the most important factors when developing a recommended investment strategy because of its impact on water rates and affordability. Cost analysis for water infrastructure projects typically includes multiple metrics to provide a complete picture of their financial implications. The WSMP 2050 cost analysis was performed at the project and portfolio levels, including:

- Total lifecycle cost of each project
- Unit cost estimates of each project
- Total lifecycle cost of each feasible portfolio
- Rate impact of selected portfolios

Together, these four metrics help present a full picture of project and portfolio costs and provide a suite of parameters to evaluate and compare different projects and portfolios. The cost metrics are calculated using similar approaches to other agencies and are based on inputs from the external WSMP expert panel. This section summarizes how capital, annual, and unit costs were estimated for major projects. The cost for portfolios and rate impact analysis is provided in Section 6.

5.4.1 Cost Analysis Methodology

For each project, the cost analysis includes total lifecycle cost and unit cost estimates. The lifecycle cost includes capital and annual operations and maintenance (O&M) costs over a project's useful service life with financing. Since the WSMP projects are all at various stages of planning, their cost estimates vary in accuracy and reflect current project status. Therefore, the cost estimates are generally considered preliminary. For the projects led by other agencies such as DCP and Sisk, their capital and annual O&M costs were estimated based on Valley Water's participation level and share of the total project costs. For the projects led by Valley Water such as Pacheco and San Jose DPR, the costs were estimated through the design process or from cost estimates developed for the Palo Alto purified water project. The useful service life is the time before a project incurs any significant repair/replacement costs. The useful service life is assumed to be 30 years for purified water and desalination projects and 50 years for storage and other projects. The selected service life is consistent with peer agency practice (30 to 50 years), Valley Water's Asset Management Plan, and general observation of how large water infrastructure is maintained over time. The selected service life also considers the confidence regarding the long-term average interest rate beyond 30 years.

The unit cost is defined as the cost divided by the yield. While the unit cost is an important metric and typically used for comparison among projects, calculating unit cost for individual projects remains the most challenging cost metric because of the complexity and challenges associated with estimating water supply benefits of the projects, as they vary by how they are paired with other projects, demand, and hydrological conditions. This is particularly true for storage projects, as most, if not all, of the WSMP storage projects are not intended for annual operation. Rather, they are used mostly during droughts. Their water supply benefits also depend on the amount of storage that is already in the system. As a result, their supply benefits mostly occur in dry years but not in other years, which drives up their unit costs. Given these challenges, the unit cost was calculated separately for supply and storage projects using different approaches because they function very differently.

Supply Projects

The unit cost of supply projects was calculated using the levelized unit cost of water approach. The levelized unit cost of water is the cost that, if assigned to every unit of water produced or saved by the project of the analysis period, will equal the total lifecycle cost of the project, when discounted back to the base year. This approach will result in the full recovery of project costs. The levelized unit cost was further annualized to get the annualized unit cost. More information about the cost analysis assumption and data are provided in Appendix F.

Storage Projects

For storage projects, a "storage capacity cost" or cost per acre-foot of Valley Water storage capacity is calculated. This is a simple calculation to enable side-by-side comparison amongst storage projects. However, this is not a 'true' unit cost as commonly defined and, therefore, should not be used to compare with the unit costs of the supply projects.

5.4.2 Project Cost Summary

The total lifecycle cost and unit costs are provided in Table 5-4 for supply projects and Table 5-5 for storage projects. All costs are represented in 2025 dollars. These cost estimates are preliminary because they are mostly based on planning level data and should be updated regularly as the projects are better defined. In addition, the four recharge projects in South County are all in the preliminary planning phase, and their cost data is not available yet. Nevertheless, their costs will be lower by orders of magnitude than those of major supply and storage projects and will be estimated when the projects are better defined.

Table 5-4 Cost for Major Supply Projects (2025$)

Project	Average Annual Supply (AF)	Capital Cost (Million)	Annual O&M (Million)	Present Value (PV) Lifecycle Cost (Million)	Lifecycle Cost PV/Yield PV ($/AF)	Annualized Unit Cost ($/AF)
Palo Alto Potable Reuse	8,000	$800	$13.2	$1,740	$11,620	$10,300

San José Direct Potable Reuse	24,000	$2,190	$31.1	$2,980	$7,120	$5,880
Local Seawater Desalination	24,000	$2,190	$31.1	$2,980	$7,120	$5,880
Refinery Recycled Water Exchange	8,000	$260	$9.5	$470	$2,900	$2,760
Delta Conveyance Project	14,000	$670	$1.8	$780	$2,800	$1,950
Sites Reservoir	5,000	$150	$0.7	$140	$1,280	$1,090

Table 5-5 Cost for Major Storage Projects (2025$)

Project	Storage (AF)	Capital Cost (Million)	Annual O&M (Million)	PV Lifecycle Cost (Million)	Lifecycle Cost PV/Storage Capacity ($/AF)
B.F. Sisk Dam Raise	60,000	$450	$1.9	$540	$8,960
Pacheco Reservoir Expansion	140,000	$2,208	$2.6	$1,820	$12,970
Groundwater Banking	350,000	$290	$2.9	$380	$1,100

Section 6 – Water Supply Strategies

The WSMP evaluates a variety of project options, including alternative supply projects, local and imported surface supply projects, storage projects, and local recharge projects, to address future water supply needs. With the high number of potential projects, there are many combinations and strategies to achieve long-term water supply reliability, depending on different considerations and factors. Portfolio analyses were used to identify the combinations of projects needed to achieve water supply reliability under future supply and demand conditions. This section discusses portfolio development and evaluation as well as three water supply strategies to address future water shortages.

6.1 Portfolio Development

The WSMP evaluated 13 projects that represent a variety of project types and provide a range of benefits. The project evaluation in Section 5 confirms that while all projects are beneficial to Valley Water's long-term water supply reliability, no single project can meet all its future needs, and each project has risks and challenges. Therefore, portfolio analyses are used to identify the combinations of projects that may be needed to achieve water supply reliability under each future condition.

The portfolios were developed through an iterative process. The first set of portfolios was developed based on project evaluation, internal expert input, and past modeling efforts. Then, based on initial modeling analysis, a range of supply and storage combinations that worked for each future condition was identified and used to design more portfolios that would likely address projected shortages. In total, more than 100 portfolios were developed and evaluated to cover a full range of potential options and possibilities.

6.2 Portfolio Evaluation and Comparison

Evaluating and comparing different portfolios is a critical final step in identifying viable project combinations for recommendations. The portfolio evaluation was done both quantitatively and qualitatively, to provide a comprehensive understanding and comparison of tradeoffs.

6.2.1 Portfolio Evaluation Approach

Meeting water supply needs is the most important criterion in evaluating and comparing projects and portfolios, but other factors also need to be considered when making recommendations. To fully capture a wide range of benefits of the projects and address Valley Water's other needs, a tiered evaluation approach was used to compare and select portfolios using a subset of criteria that was discussed in Section 5.3.1. The selected criteria were ranked into two tiers:

- First tier - meeting water supply needs and costs

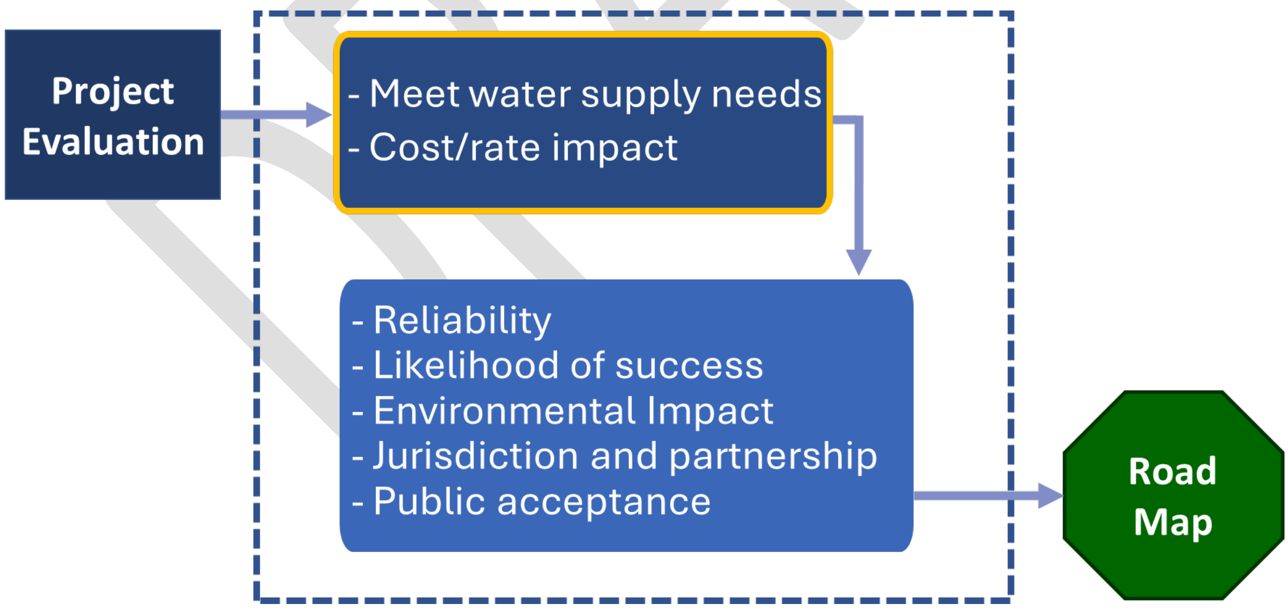
- Second tier - each project's reliability in providing planned benefits, likelihood of success, environmental impacts, jurisdiction and partnership, and public acceptance

The evaluation started with a detailed analysis of the water supply benefit and cost of each portfolio, followed by a qualitative assessment of each project's reliability in providing planned benefits, likelihood of success, environmental impacts, jurisdiction and partnership, and public acceptance. The process is described below and illustrated in Figure 6-1.

- Evaluate each portfolio's ability to meet water supply needs through modeling analysis. Any portfolios that cannot meet water supply needs were eliminated from further consideration.
- Develop cost estimates for each feasible portfolio
- Use the second-tier criteria to help differentiate the feasible portfolios with similar performance to narrow down choices and identify priorities. This step can also help to identify backup projects for each major project to lay the foundation for adaptive management.

At the end of this evaluation process, feasible portfolios were identified that represent different pathways and project combinations to achieve future water supply reliability. The identified portfolios provide a pool of options for recommendations.

Figure 6-1 Portfolio Evaluation and Comparison Process



6.2.2 Modeling Analysis of Portfolios

As the first step in portfolio analysis, more than 100 portfolios were evaluated through modeling analysis to determine how they may be able to meet water supply needs across the four possible futures. A modeling baseline, as described in Section 4, was used to evaluate various portfolios. The modeling analysis of portfolios was done in a stepwise fashion – first starting with testing individual projects, then gradually adding projects to build up portfolios. Each portfolio was added and integrated into the baseline model, and the model was re-run to obtain new results. The effectiveness of a given portfolio was primarily determined by its ability to eliminate water shortage during a six-year drought in 2050, as identified under the baseline condition. The WEAP model provided a consistent method of assessing the effectiveness of various portfolios.

Figure 6-2 and Figure 6-3 illustrate the process of portfolio development and how projects contribute to water shortage reduction during a multi-year drought. The individual projects were first added to the baseline, one at time, to understand their water supply benefit. Figure 6-2 shows average annual benefits during droughts, but actual benefits vary by hydrologic conditions. Once each project is modeled, they were used as building blocks to develop portfolios, by adding projects one by one until the shortage is eliminated (Figure 6-3). It is important to note that the benefits of the portfolio are greater than the simple sum up of each individual project benefit because some projects complement each other and make the whole system much more efficient, highlighting the need for diversified projects to better utilize project potentials.

Figure 6-2 Water Supply Benefits of Individual Project

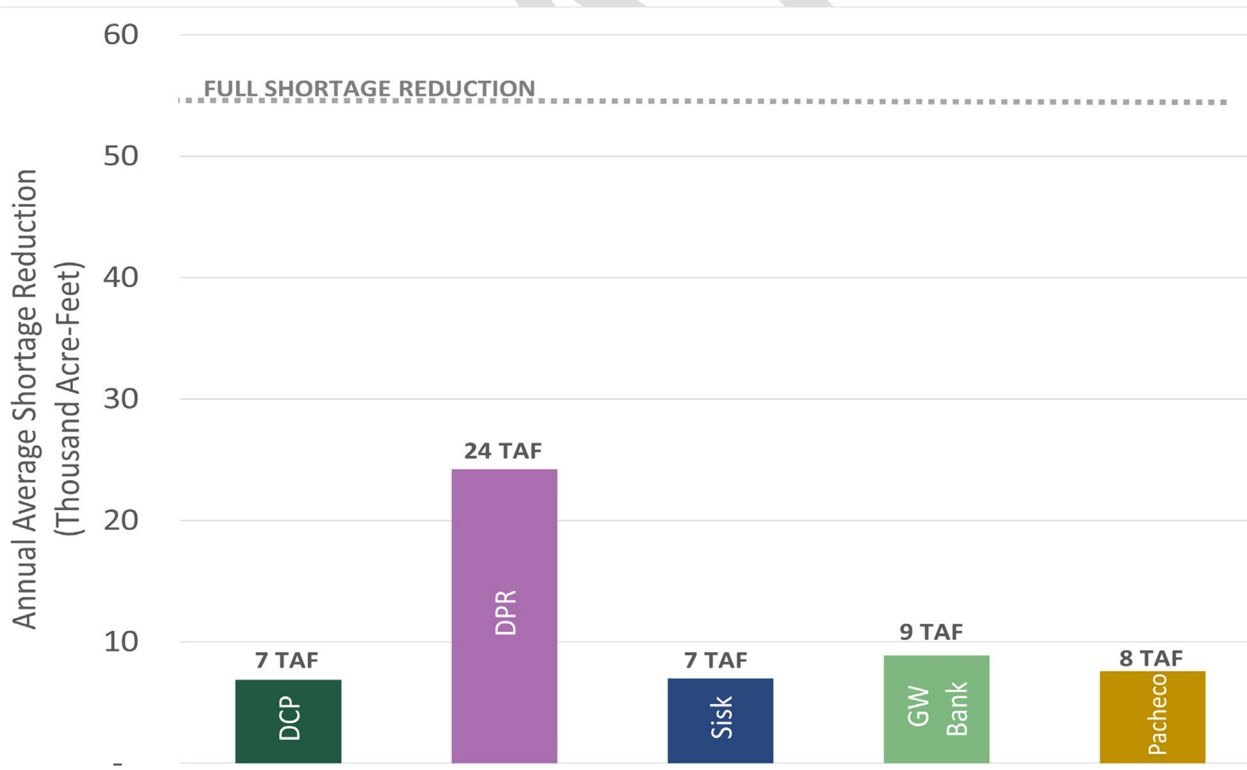
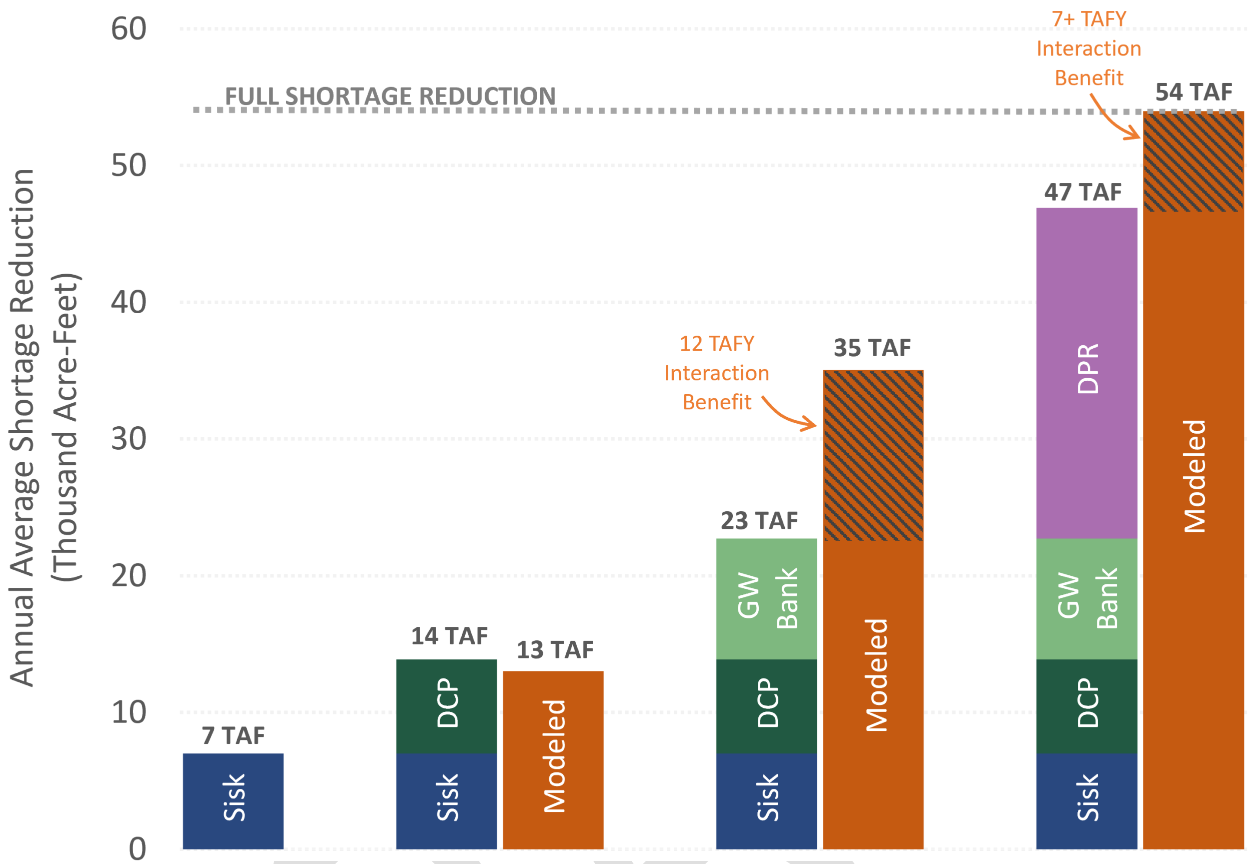


Figure 6-3 Development of Water Supply Portfolios



The modeling analysis shows that the performance of those portfolios varies depending on the water supply and demand conditions. Some will not address shortage under any future, others will only work for one or two futures, and only a few will work for all four futures. The numbers of feasible portfolios vary by futures. In general, as the situation moves from optimistic (stable demand and moderately impacted imports) to most challenging (high demand and severely impacted imports), the number of portfolios that can meet water supply needs becomes greatly reduced. The portfolios generally perform similarly for both the stable demand and severely impacted imports future and the high demand and moderately impacted imports future. The portfolios that met future water supply needs were then further evaluated using cost and the second-tier criteria to narrow the choices and formulate recommendations that best meet Valley Water's goals and needs.

The modeling analysis also provides some findings and insights that help further evaluate portfolios and develop recommendations:

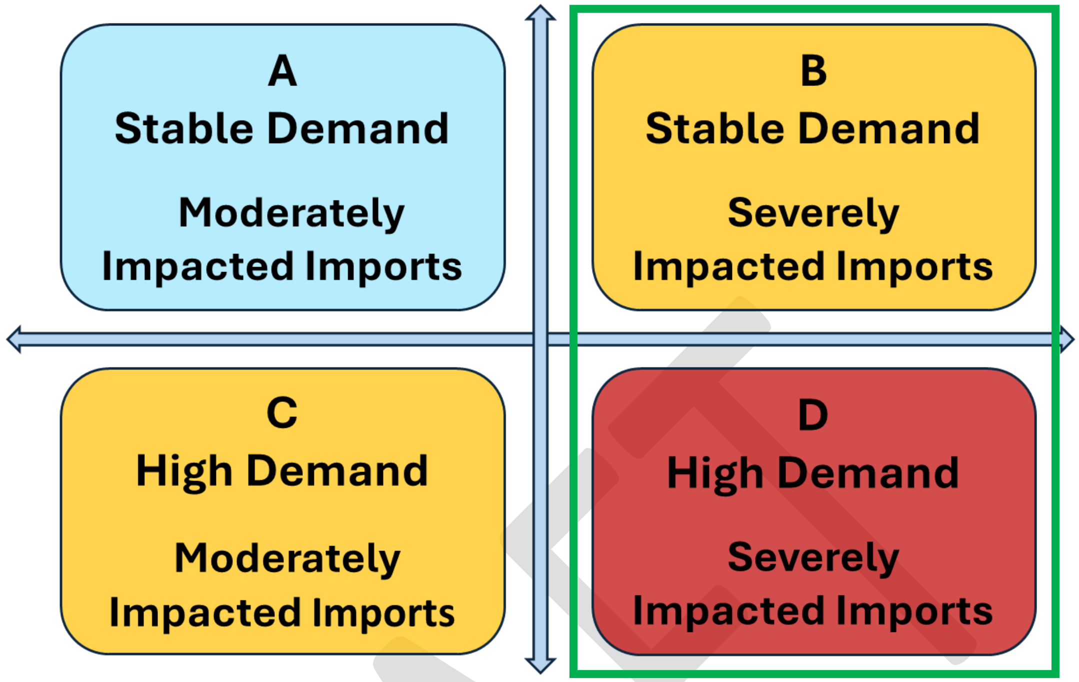
- Diversified water supplies increase water supply reliability by reducing reliance on any one source. In general, when one or more supply sources are challenged, the other sources are depended on more to satisfy the demands.
- Drought-resilient supply, such as direct potable reuse, coupled with storage is effective in eliminating shortage for all futures.

- Maintaining out-of-county groundwater storage is critical in securing water supply reliability, including the consideration of re-negotiating Semitropic contract when it expires.
- **Storage is vital to water supply reliability under current and future conditions.** Supplies and storage function in tandem – surface water supplies are needed to fill and refill storage before and after dry periods, while adequate storage capacity is needed to capture and store water when supplies become available. In addition to storage capacities, the put and take capabilities of groundwater banks are also critically important, especially during droughts, as they determine how effectively water can be stored when it is in excess and accessed when it is most needed.
- Diversifying and expanding existing storage programs, including improving take/put capacity, is needed to help reduce risk and mitigate drought impacts. With "weather whiplash" (frequent shifts between extremely wet and dry years) becoming more common due to climate change, ample storage capacity is needed to make the most use of surface supplies when they become available to capture excess water to be used during droughts.
- Supply projects generally work better when paired with storage projects by allowing for some excess supplies to be captured and stored, and these types of diversified portfolios could help improve the resilience of the water supply system.
- Under each future, multiple options can meet water supply needs, other factors such as cost and reliability, need to be considered to compare portfolios and develop recommendations.

6.2.3 Selection of Future Conditions

The WSMP 2050 analyzes four future supply and demand conditions (Figure 6-4) based on different combinations of imported water supplies (moderately impacted or severely impacted) and demand (stable or high). Based on the modeling analysis of portfolios, it is clear that the portfolios evaluated for the futures with severely impacted imported supply (B and D) also work for the two with moderately impacted imports (A and C). Also, future imported water supply will likely be reduced due to climate change and regulations. Given these circumstances and to be conservative, two futures with severely impacted imported supply (B and D, highlighted in the box) were selected to further evaluate portfolios and develop investment strategies.

Figure 6-4 Four Future Conditions for Planning



Since the two targeted futures have the same supply but different demands, further portfolio evaluation was focused on the stable demands and severely impacted imports future (B). The portfolios evaluated for this condition then serve as the foundation for developing portfolios for the worst-case condition (high demand and severely impacted imports (condition D). Section 6.3.3 discusses how to build upon portfolios for the stable demand and moderately impacted imports future to develop portfolios for the worst-case condition.

6.2.4 Portfolio Evaluation and Themes

Modeling analysis identified more than 40 portfolios that meet water supply needs for the future with stable demand and severely impacted imports. Following the modeling analysis, the total lifecycle cost of each portfolio was developed as the second step for comparing portfolios and identifying cost-effective strategies. The portfolio cost was the sum of the present values of each project in a portfolio, which was estimated and discussed in Section 5.4. As affordability becomes increasingly a concern due to rising project costs, portfolio cost is one of the most important criteria when comparing and prioritizing portfolios.

The high number of identified portfolios represents different ways to achieve water supply reliability from water supply perspectives, but other factors need to be considered to provide a balanced review of each of them and narrow down the options. To help outline investment options and present tradeoffs among the portfolios, three strategies - **Lower Cost, Local Control, and Diversified** - were developed to assist in further evaluation of the identified portfolios, focusing on different factors and considerations. The strategies are intended to reflect preferences for what criteria and priorities should be considered most important when developing an investment strategy.

- **Lower Cost** – Focuses on affordability and lower costs, to identify cost-effective options and minimize impacts on water rates.
- **Local Control** – Focuses on projects within Santa Clara County, over which Valley Water has more control. Having more local control increases the projects' likelihood of success.
- **Diversified** – Focuses on diversifying the existing system with a mix of local and imported supplies as well as storage projects, to increase the resilience and flexibility of the water supply system.

With these three strategies, the identified portfolios were compared using the second-tier criteria to assess the projects within each portfolio, including each project's reliability in providing planned benefits, likelihood of success, environmental impacts, jurisdiction and partnership, and public acceptance. At the end of this evaluation, the number of preferred portfolios was reduced to 10, with three each for Lower Cost and Local Control strategies, and four for the Diversified strategy. The portfolios removed include the ones that are too expensive, contain too many high-risk projects, or have too much overlap/similarity with other portfolios. The remaining 10 portfolios are considered viable options and were used to develop recommendations.

6.3 Water Supply Strategies

The three themes represent different approaches to water supply reliability. Under each theme, multiple portfolios can meet future water supply needs. This section discusses the selection of final portfolios, the rate impact of those portfolios, and the development of water supply strategies for the worst-case condition.

6.3.1 Three Representative Portfolios

Based on the project evaluation and discussions with both internal and external experts, one representative portfolio for each strategy was selected and summarized in Table 6-1, along with the total lifecycle cost and expected supply or storage benefits. Additional portfolios that would address projected shortages are provided in Appendix G. These three portfolios represent three potential investment strategies.

Table 6-1 Selected Portfolio for Each Water Supply Strategy

STRATEGY	PROJECTS	COST (BILLION)	ADDED BENEFITS
LOWER COST	San José Direct Potable Reuse Delta Conveyance Project B.F. Sisk Dam Raise Groundwater Banking (250,000 AF) South County Recharge	**$4.6**	38,000 AFY supply 314,000 AF storage Additional system flexibility

LOCAL CONTROL	San José Direct Potable Reuse Palo Alto Potable Reuse Pacheco without Partners Groundwater Banking (150,000 AF) South County Recharge	**$6.7**	32,000 AFY of supply 290,000 AF storage Additional system flexibility
DIVERSIFIED	San José Direct Potable Reuse Delta Conveyance Project B.F. Sisk Dam Raise Pacheco with Partners Groundwater Banking (350,000 AF) South County Recharge	**$5.9**	38,000 AFY supply 505,000 AF storage Additional system flexibility

Each strategy represents a pathway to future water supply reliability, but with tradeoffs:

- **Lower Cost** – Focuses on affordability and minimizing costs, with a mix of supply and storage projects. The strategy provides drought-resilient supply through potable reuse, diversifies existing storage, and secures existing imported supply through DCP. However, it has high risks, as all four major projects require partnership and institutional agreements to be successful.

- **Local Control** – Focuses on the projects in the county where Valley Water exercises more control. The strategy provides drought-resilient supply through potable reuse, diversifies existing storage, provides emergency storage, and reduces reliance on imported supply. However, it has the highest cost, as it includes the three most expensive projects being considered (two potable reuse projects and Pacheco).

- **Diversified** – Focuses on diversifying the existing system with a varied set of projects. The diversified strategy provides a similar variety of benefits as the other two strategies but builds in more resiliency and redundancy to help reduce the county's exposure to risk and uncertainty, including the risk of any one investment not performing up to expectations. However, it has a relatively high cost and more institutional complexity since it includes an additional project. This strategy can also meet the high demand for the worst-case future condition evaluated.

All three strategies include Direct Potable Reuse in San José, emphasizing the importance of having drought-resilient local supplies in the long-term strategy. This project is also needed in nearly all other portfolios in Appendix G. It should also be noted that all strategies require Valley Water to either maintain the existing level of storage or further diversify and develop additional storage.

The three strategies serve as the basis for developing portfolios for the worst-case condition and adaptive management framework.

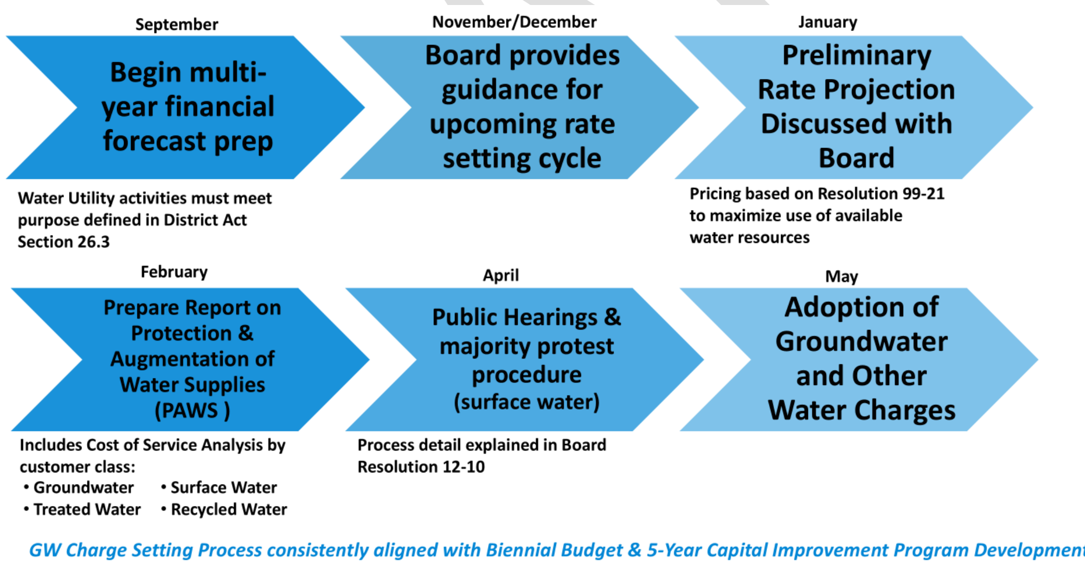
6.3.2 Water Rate Impact Analysis

The impacts of future investment(s) on water rates, also referred to as groundwater production charges, can provide further insights to help inform investment decisions and long-term financial planning.

As the county's primary water wholesaler, Valley Water makes sure there is enough safe, clean water for homes and businesses. To finance this monumental task, Valley Water collects revenue primarily from property taxes, well owners, agricultural water customers, and water retailers, such as San Jose Water Company. Most Santa Clara County residents do not pay a bill directly to Valley Water, instead they pay their local water retailer. The cost local residents pay the retailers, however, is affected by the cost to Valley Water of supplying that water. The Water Utility Enterprise’s major costs include operations, debt service, capital improvements to the treatment and delivery system, and water purchases from outside the county.

The rate impact analysis for the WSMP uses the same approach as Valley Water’s long-term financial forecasting and annual rate-setting analyses for the Water Utility Enterprise. The annual groundwater charge, or rate, setting process is outlined in Figure 6-5 below.

Figure 6-5 Annual Groundwater Charge-Setting Cycle



Valley Water has four groundwater benefit zones ensuring ratepayers are grouped in a way that reflects the most recent and relevant data regarding the services and benefits received by well users. Revenues and costs are tracked separately for each zone. The North County groundwater benefit zone is referred to as Zone W-2 and encompasses the Santa Clara Subbasin in North Santa Clara County (Figure 6-6). In the South County, the three groundwater benefit zones are as follows: Zone W-5, which encompasses the Llagas Subbasin; Zone W-7, which encompasses the Coyote Valley; Zone W-8, which encompasses areas in the foothills southeast of Uvas and Chesbro reservoirs (Figure 6-7).

Figure 6-6 North County Zone W-2 Groundwater Benefit Zone

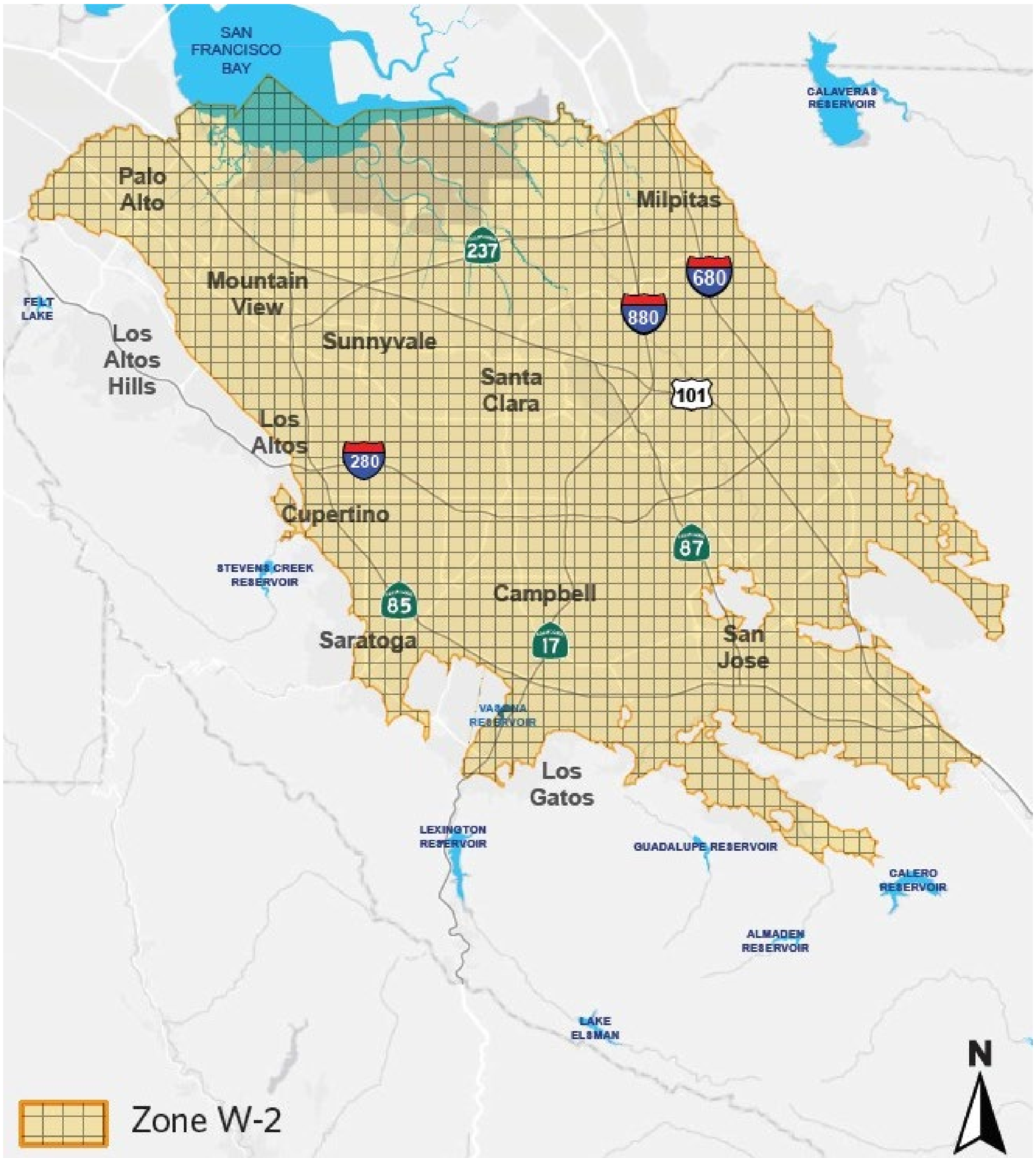
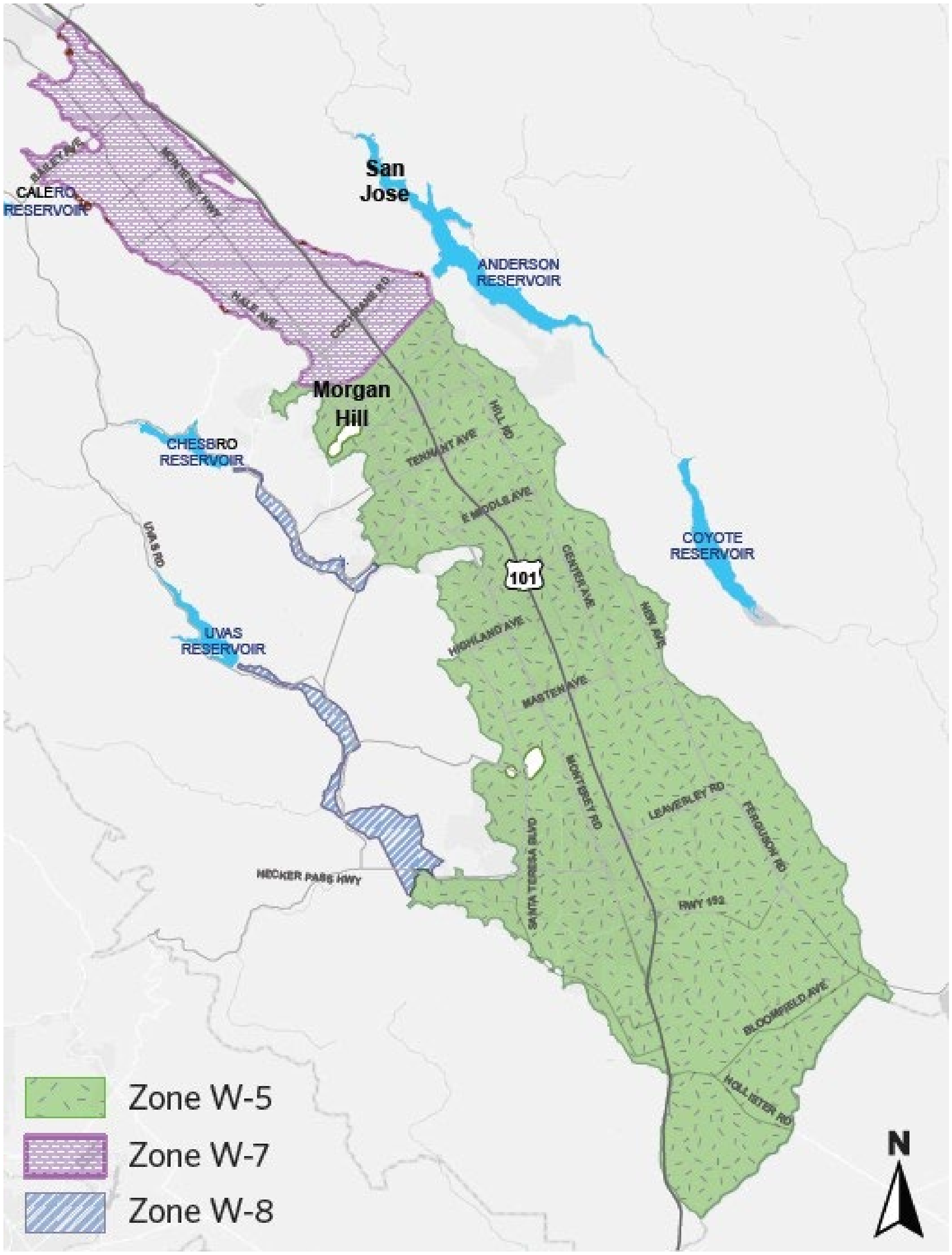


Figure 6-7 South County Groundwater Benefit Zones (W-5, W-7 & W-8)



As part of each portfolio evaluation, rate impacts for each portfolio were calculated. Staff-recommended rates for fiscal year 2025-2026 (FY 2025-26) include a baseline investment scenario that is most closely aligned with the Diversified portfolio, excluding expanded groundwater banking. The impacts of each investment scenario to North County Zone W-2 rates and average monthly impact are summarized in Table 6-2 below. The table shows the translation of portfolio costs to North County Zone W-2 Municipal and Industrial (M&I) rate ($/acre-foot) and an average monthly impact to a household using 15 hundred cubic feet of water per month.

Table 6-2 Portfolio Rate Impacts in North County Zone W-2

Portfolio	FY 26 to FY 30	FY 31 to FY 35	FY 36 to FY 40	FY 41 to FY 45	FY 46 to FY 50
FY 2025-26 Adopted Rates & PAWS Report	$2,986 / AF or $102.82 / month	$4,756 / AF or $163.80 / month	$6,807 / AF or $234.43 / month	$8,074 / AF or $278.08 / month	$8,878 / AF or $305.77 / month
Lower Cost	$2,986 / AF or $102.82 / month	$4,463 / AF or $153.71 / month	$6,225 / AF or $214.40 / month	$7,180 / AF or $247.29 / month	$7,895 / AF or $271.91 / month
Local Control	$3,207 / AF or $110.45 / month	$5,547 / AF or $191.05 / month	$7,339 / AF or $252.77 / month	$8,539 / AF or $294.09 / month	$9,719 / AF or $334.73 / month
Diversified	$2,986 / AF or $102.82 / month	$4,756 / AF or $163.80 / month	$6,814 / AF or $234.68 / month	$8,277 / AF or $285.08 / month	$9,422 / AF or $324.48 / month

Figures 6-8 through 6-11 are groundwater production charge projections specific to each of the four zones, through 2050, shown in 5-year averages.

Figure 6-8 Portfolio Rate Impacts in North County Zone W-2

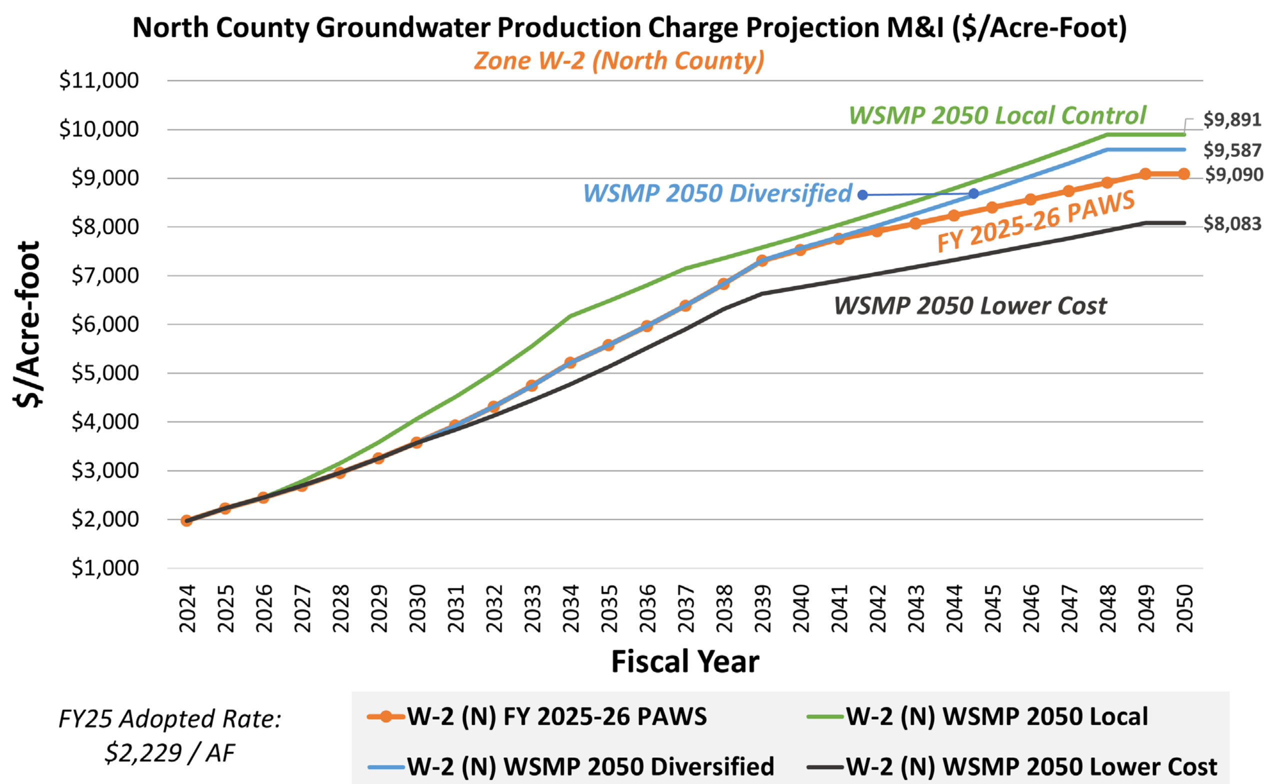


Figure 6-9 Portfolio Rate Impacts in South County Zone W-5

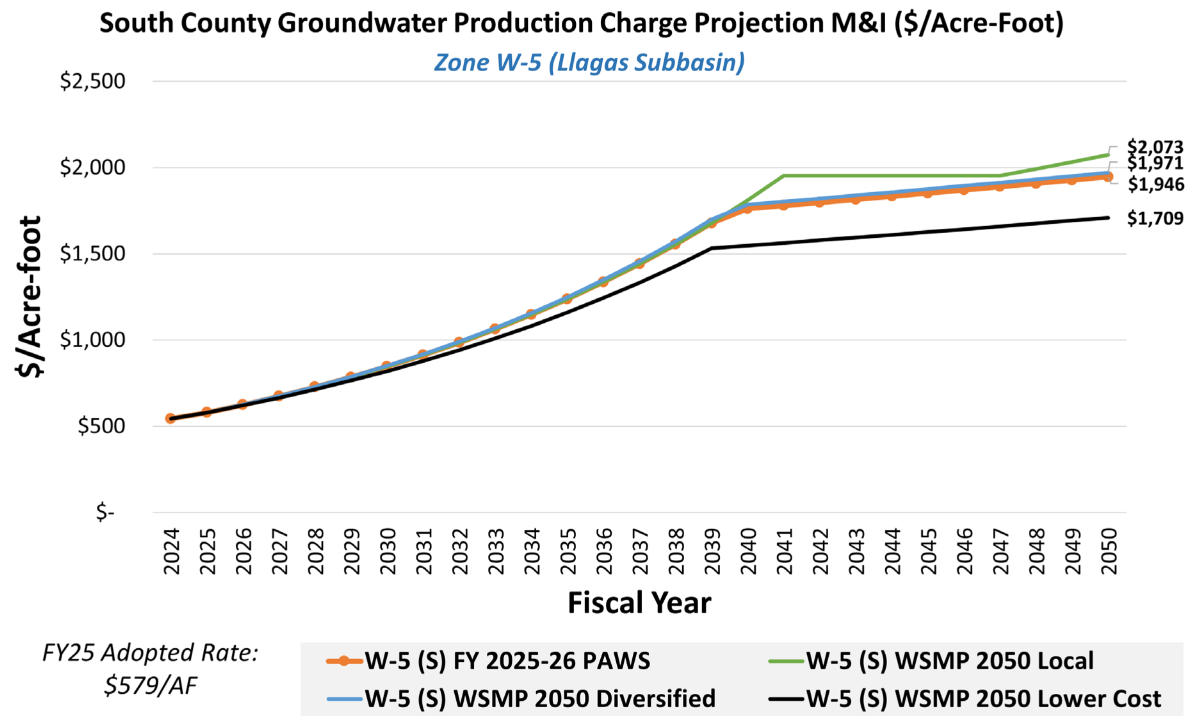


Figure 6-10 Portfolio Rate Impacts in South County Zone W-7

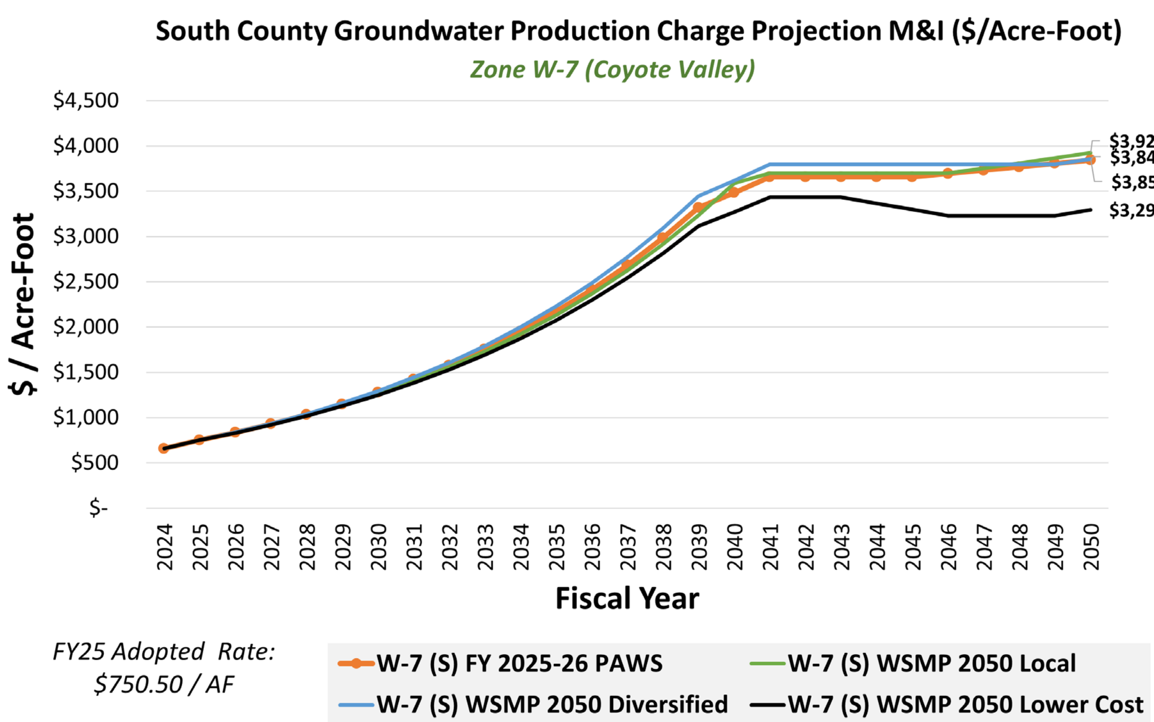
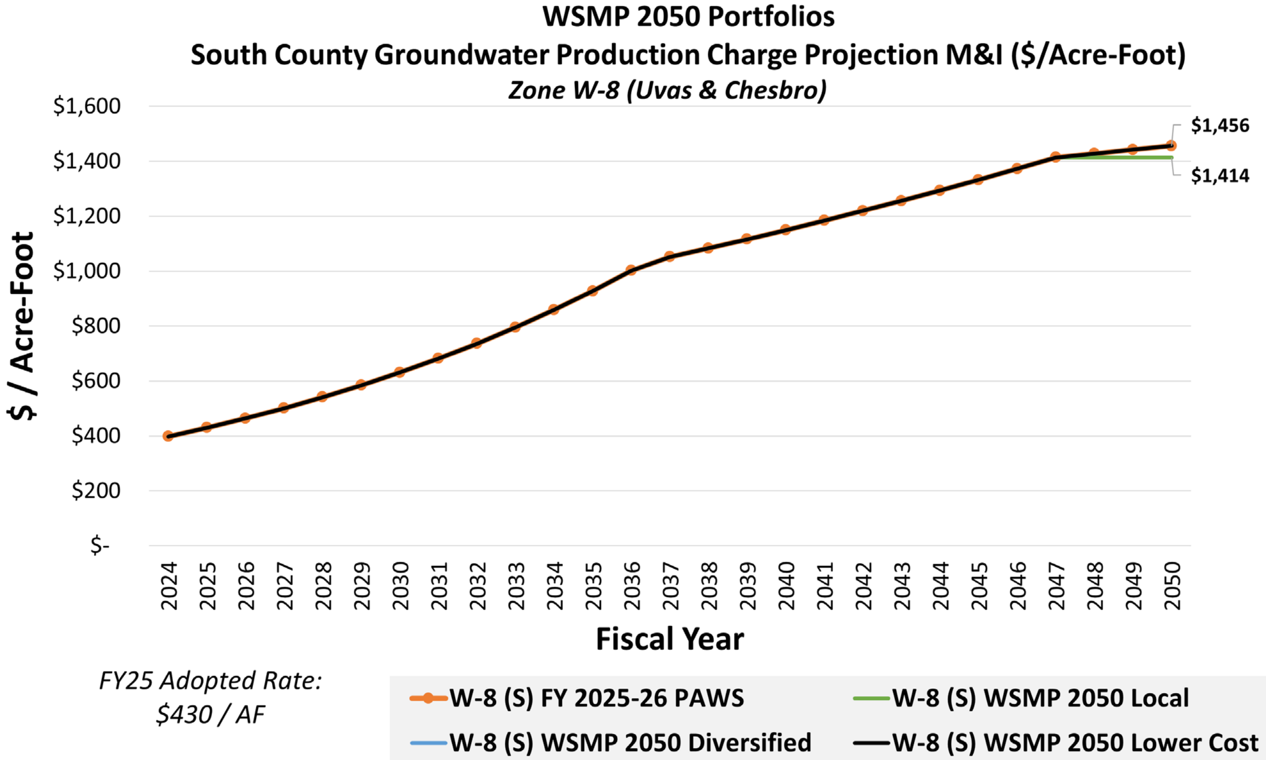


Figure 6-11 Portfolio Rate Impacts in South County Zone W-8



Valley Water adopts rates annually; staff-recommended rates for the next fiscal year are outlined in the Annual Protection and Augmentation of Water Supplies (PAWS) report, which is available online at www.valleywater.org.

6.3.3 Water Supply Strategies for High Demand

Water supply strategies were developed for the worst-case future condition of high demand and reduced imports. Since this condition has the same supply but higher demand than the focused condition B, the strategies were developed by adding projects to the three representative portfolios identified in Section 6.3.1 to meet the higher demand. This was done by adding projects to the portfolios and using the modeling analysis to determine if the new portfolios met water supply needs.

The analysis suggests that under the worst-case condition evaluated, more projects will be needed for the **Lower Cost** and **Local Control** strategies but not **Diversified,** which builds in enough resiliency and redundancy to meet higher demand (Table 6-3). For the Lower Cost strategy, groundwater banking capacity needs to increase to 350,000 AF, and Sites Reservoir needs to be included. Similarly, the Local Control strategy would also need to increase groundwater banking capacity and add local desalination, which significantly increases the portfolio cost.

Table 6-3 Portfolios for Worst-Case Condition Evaluated

Strategy	Projects	Portfolio Cost (Billion)
Lower Cost	San José Direct Potable Reuse, DCP, Sisk, Groundwater Banking (**350,000 AF**), South County Recharge, **Sites**	**$4.8**
Local Control	San José Direct Potable Reuse, Palo Alto Potable Reuse, Pacheco without Partners, Groundwater Banking (**250,000 AF**), South County Recharge, **Local Desalination**	**$9.9**
Diversified	San José Direct Potable Reuse, DCP, Pacheco with Partners, Sisk, Groundwater Banking (350,000 AF), South County Recharge	**$5.9**

While it is of interest to complete the analysis for the worst-case condition, given the current trend of the county-wide demand, this condition may be too conservative to be used as the basis for investment decisions. Therefore, this analysis serves as part of the adaptive management framework to provide a full picture of potential future conditions and how Valley Water can be prepared for any of those conditions.

6.4 Summary of Water Supply Strategy Development

The water supply strategies were developed through portfolio analysis and evaluation. Some insights and findings from the analysis are summarized below.

- With the high number of potential projects, there are many combinations and strategies to achieve long-term water supply reliability, depending on different considerations and factors.

- The portfolios that meet future water supply needs generally include a mix of supply and storage projects.

- Three themes were developed to outline investment options and present tradeoffs. Under each theme, multiple portfolios can meet future water supply needs.

- Each strategy has its merits but also risks and challenges. The goal of the recommended approach is to balance reliability and affordability.

- The worst-case condition requires more investment but is too conservative to be used as the basis for investment decisions.

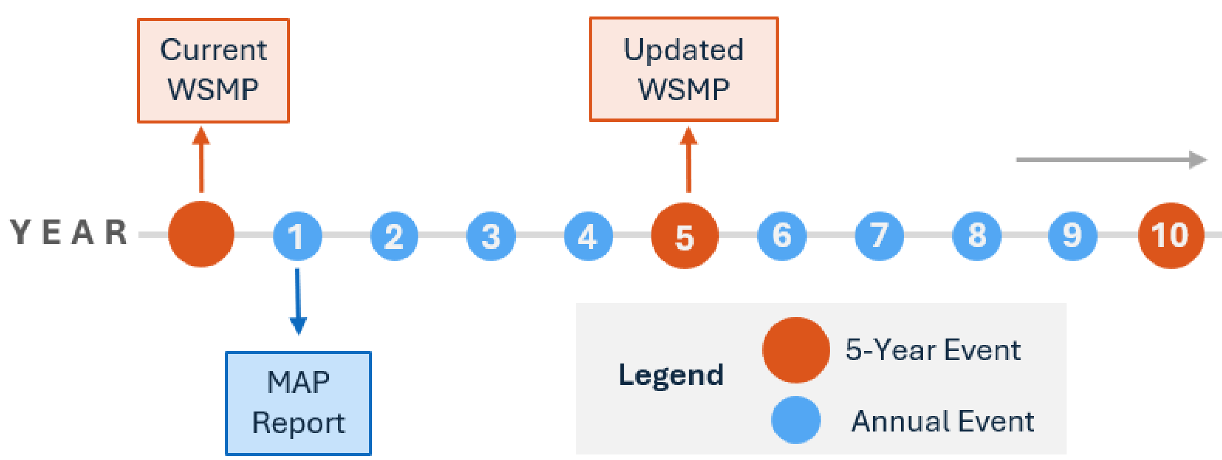
Section 7 – Adaptive Management

The three water supply strategies described in Section 6 represent different ways to achieve future water supply reliability, but each has tradeoffs, risks, and challenges. Because many WSMP projects are large and complex and still in the planning phase, they require a long lead time to fully develop and implement, during which many factors could dictate whether they will ultimately be successful. Uncertainty with forecasted future supply and demand conditions further challenges decision-making. Planning under such deep uncertainty requires an adaptive management approach to provide the Board with flexibility and the ability to make incremental investment decisions and refine them over time, based on evolving information and actual conditions. Incremental decisions based on actual conditions will help reduce the risk of over- or under-investing.

7.1 Adaptive Management Framework

The adaptive framework is intended to define a consistent, stepwise process of making project and program investment decisions. The framework includes a roadmap and annual reporting. The roadmap outlines near- and mid-term actions and defines indicators and conditions to guide project decisions. The annual reporting tracks project progress and provides up-to-date information to help inform decision-making. Figure 7-1 illustrates the framework and how the process works.

Figure 7-1 Adaptive Management Framework



7.2 Adaptive Management Roadmap

The adaptive management roadmap is a blueprint that outlines Valley Water's near- and mid-term actions and recommendations before the next WSMP update. The roadmap was proposed to include specific recommended actions at different timelines, especially immediate actions, as the starting point of the adaptive management framework (Table 7-1).

Table 7-1 Adaptive Management Roadmap

Timeline	Recommended Actions
Now	• Focus on implementing the **Lower Cost** strategy - San José Potable Reuse - B.F. Sisk Dam Raise - Delta Conveyance Project - Groundwater Banking - South County Recharge • Continue planning for Pacheco and Sites • Continue the Desalination feasibility study • Continue implementing conservation programs
Near-term (2-3 years)	• Annual MAP to assess success/progress on project planning and implementation • Make project funding, participation, or go/no-go decisions based on indicators, new information, and actual conditions • Continue planning for other projects.
Mid-term (5 years or more)	• Assess progress on project implementation • Update demand projections and water supply outlook • Update the WSMP

The recommendation of focusing on the **Lower Cost** strategy while continuing to plan for other projects is intended to balance affordability and reliability in the face of increasing rate pressures. Given that large water supply projects and partnerships can have uncertain outcomes, continued planning for additional projects is prudent and, therefore, recommended.

7.3 Annual Monitoring and Assessment Program

The recommended actions are impacted by numerous factors that will indicate the acceleration or change of course for certain actions. Since the magnitude, nature, and timing of these indicators will result in different responses and actions, it is important to continually review and understand the status of different projects and changed conditions. Doing so allows appropriate assessment of the next steps in developing the projects and helps Valley Water make informed decisions about how to proceed with each project as more information becomes available.

With the adaptive framework, a critical component is annual reporting through the Monitoring and Assessment Program (MAP). The MAP serves as both the monitoring report to track the progress of the WSMP implementation and a venue to make adjustments when needed. For this reporting, a standard report will be devised to include key elements of the WSMP, including:

- Progress on project planning and implementation
- Conditions on triggers and indicators
- Any adjustments should be made

A standard report will help the Board know what to expect every year; include the WSMP in the decision-making process for individual projects by reporting project status and progress within the WSMP framework; and provide continuity and consistency over time.

The following list of triggers and indicators will be tracked in the annual MAP. The triggers are related to projects and could potentially prompt go or no-go decisions. The indicators track hydrologic, socio-economic, and institutional trends to provide an up-to-date reality check. Together, they will help Valley Water decide whether to stay the course or pivot to different pathways.

Potential triggers for project decisions

- Negotiations and institutional agreements with other agencies (i.e., Sisk Dam Raise Project or direct potable reuse facility with the Cities of San José and Santa Clara)
- Upcoming project decisions
- Groundwater bank negotiations
- Projects completed, rendered infeasible, or abandoned
- New regulatory and permitting issues

Indicators to track trends

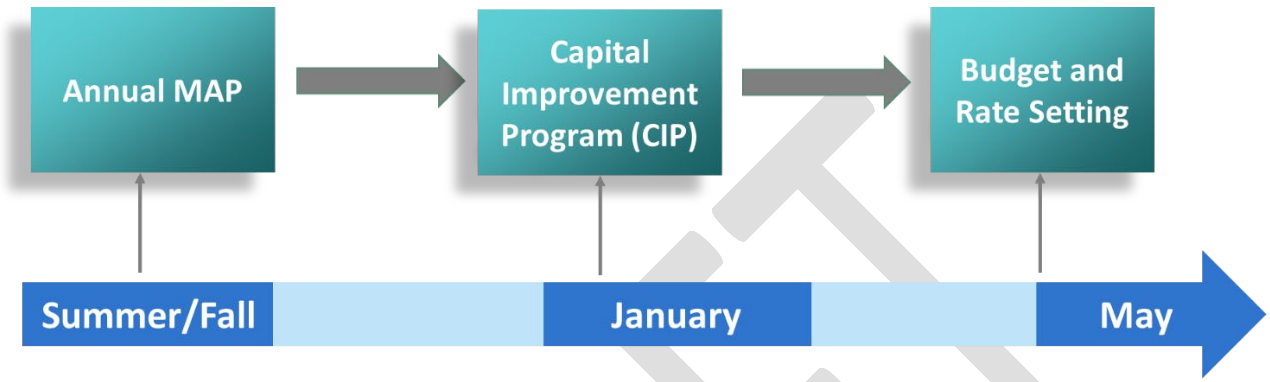
- Annual water use
- Annual supply
- Conservation measures (water savings, program participation)
- Imported water allocations
- Growth trend/demand
- Regional agreements and decisions by other agencies
- Regulations (state water board water use efficiency standards, Delta plan, etc.)

The actual triggers and indicators reported every year are not confined to the above list. The additional ones can be added as needed. The list could also vary from time to time, depending on the topics and focus of the reporting cycle.

7.4 Connection to Capital Improvement Program & Rate-Setting Process

Valley Water updates its five-year CIP on an annual basis. In concert with the CIP update, Valley Water conducts an annual rate-setting process to determine the water rates for its retailer and groundwater users. Both efforts consider ongoing and planned planning and implementation of various projects. To promote increased consistency among CIP, rate-setting process, and WSMP, the timing of the MAP will be aligned with the annual CIP five-year plan and water rate-setting cycle to support related decision-making (Figure 7-2). This allows the WSMP to be closely linked to the annual CIP and rate-setting processes, fulfilling its role as the guiding document for long-term investment strategy. Valley Water could better align those efforts to ensure Valley Water meets its short-term and long-term goals prioritized within the overall context of Valley Water's mission areas.

Figure 7-2 Link WSMP to CIP and Rate-Setting Process



7.5 Future Plan Updates

It is impossible to forecast with certainty what supply conditions and demand levels will be in 30 years. Likewise, it is impossible to forecast economic conditions or hydrologic trends. The roadmap and recommendations are based on projections of possible future conditions, but they must be adapted as conditions change. While the annual MAP will help ensure the WSMP is a living document and continues to provide a framework for efficient and effective investment in water supply reliability in the face of deep uncertainty, it is recommended the WSMP to be updated about every five years, to revisit the data, assumption, and analysis of future conditions and adjust the roadmap and investment strategies as needed according to new information and reality.

Section 8 – Stakeholder Outreach

The WSMP development involves comprehensive technical analysis, policy discussion, internal and external coordination and collaboration, and benchmarking with other water agencies. Throughout the plan development, Valley Water engaged with its Board, internal and external stakeholders, and the general public to seek input and shape the final product.

8.1 Internal Coordination

Valley Water created an internal workgroup to support the WSMP 2050 development. The workgroup is made up of staff from various Valley Water business areas, including engineering, finance, CIP, public affairs/communications, and environmental stewardship. From 2023 to 2025, the work groups met at least monthly to discuss technical issues, provide feedback on planning approaches and modeling analyses, and ensure consistency and alignment on key technical topics and with Board policy direction.

8.2 Board and Committee Update

Valley Water's Board of Directors provided oversight throughout the WSMP 2050 development, and broad policy discussions and reviews are held at the board and committee meetings. Staff presented five updates to the board between September 2023 and June 2025. Similar updates were also presented to several Board committees from 2023 to 2025 to seek input and feedback from those committees. Board and Committee meetings are summarized in Table 8-1.

Table 8-1 Summary of Board and Committee Meetings

Public Meeting	Date	Topic
Board of Directors Meeting		
	September 19, 2023	WSMP 2050 framework
	January 9, 2024	Needs assessment, portfolio analysis
	June 25, 2024	Project evaluation, water supply strategies, adaptive management framework
	July 9, 2024	Continued from June 2024 meeting
	December 10, 2024	Impacts of water shortages, adaptive management road map
	June 10, 2025	Draft plan
Committee Meetings		

Joint Water Resources Committee	January 3, 2024	WSMP 2050 framework
	April 2, 2025	Project evaluation, water supply strategies, adaptive management road map
Agricultural Water Advisory Committee	January 8, 2024	WSMP 2050 framework
	July 1, 2024	Project evaluation, water supply strategies, adaptive management framework
	April 7, 2025	Impacts of water shortages, adaptive management road map
Santa Clara Valley Water Commission	January 24, 2024	WSMP 2050 development overview
	October 23, 2024	Project evaluation, water supply strategies, adaptive management framework
	January 22, 2025	Adaptive management road map
Environmental and Water Resources Committee	October 16, 2023	WSMP 2050 framework
	April 15, 2024	Needs assessment, portfolio analysis
	October 21, 2024	Project evaluation, water supply strategies, adaptive management framework
	April 21, 2025	Impacts of water shortages, adaptive management road map

8.3 Stakeholder and Public Outreach

Stakeholder engagement is an important component of the WSMP update process and was carried out throughout the plan development. Valley Water presented the WSMP progress and milestones during four retailer meetings at various stages of the plan development to seek their input. The updates were also presented to an environmental stakeholder group and Water Commission between 2023 and 2025, as summarized in Table 8-2. In addition, Valley Water met individual stakeholder groups upon request and responded to questions and information requests from the public and stakeholder groups.

Table 8-2 Summary of Stakeholder Meetings

Stakeholder Meetings	Date	Topic
Water Retailer Meeting	March 30, 2023	Kickoff
	July 24, 2023	WSMP framework, demands
	October 18, 2023	WSMP 2050 development overview
	January 17, 2024	Needs assessment, portfolio analysis
	October 21, 2024	Impacts of water shortages, adaptive management road map
	May 19, 2025	Draft WSMP
Environmental Stakeholder Group	December 13, 2023	WSMP 2050 framework
Sierra Club	August 08, 2024	Storage and water supply strategy

In addition to formal meetings, Valley Water created the WSMP webpage (https://www.valleywater.org/your-water/water-supply-planning/water-supply-master-plan) and used it as a central place to advertise committee and board meetings when the WSMP was on the agenda, post meeting materials, and provide a point of contact to support public engagement. Valley Water also used stakeholder email lists, blogs, social media, communication newsletters, and other channels as ongoing opportunities to provide updates and engage the public and stakeholders.

8.4 Expert Engagement

The development of the WSMP 2050 involved comprehensive review and evaluation of Valley Water's future water supply needs and various projects and portfolios for providing a reliable supply of water for Santa Clara County. The primary analysis of the WSMP 2050 was performed by Valley Water staff, but an independent review from outside experts was done to ensure the data, assumptions, and analysis of the plan are sound and justifiable. To that end, Valley Water convened a panel of four experts to review staff's analyses and advise the WSMP development:

- David Sunding - Professor at University of California, Berkeley
- Newsha Ajami - Chief Development Officer for Research, Lawrence Berkeley National Lab
- Michael Anderson - State Climatologist, Department of Water Resources
- Yung-Hsin Sun - Senior Principal Consultant, Sunzi Consulting LLC

Valley Water staff has engaged the WSMP experts to seek their advice on key issues of the WSMP 2050 development throughout the process. The expert review focused on planning framework and approach, demand projection, cost analysis, project evaluation, and climate change analysis. The input and suggestions from the experts helped ensure appropriate approaches were used for the WSMP analysis.

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Appendix A – Potable Reuse Goal

File No.: 24-0740 **Agenda Date:** 8/28/2024
Item No.: 4.3.

COMMITTEE AGENDA MEMORANDUM
Recycled Water Committee

Government Code § 84308 Applies: Yes ☐ No ☒
(If "YES" Complete Attachment A - Gov. Code § 84308)

SUBJECT:
Discuss the Recycled Water Goal for the Water Supply Master Plan (WSMP); and Recommend to the Valley Water Board a Potable Reuse Goal of 24,000 Acre Feet per Year (AFY) by 2035, and a Long-Term Vision to Maximize Water Reuse in the County up to 32,000 AFY, (Including Additional Potable and Non-Potable Reuse, Desalination, Stormwater Capture, and Other Alternative Water Supply Sources) for Inclusion in the WSMP 2050.

RECOMMENDATION:
Recommend to the Valley Water Board a potable reuse goal of 24,000 AFY by 2035 and a long-term vision to maximize water reuse in the county up to 32,000 AFY, (including additional potable and non-potable reuse, desalination, stormwater capture, and other alternative water supply sources) for inclusion in the WSMP 2050.

SUMMARY:
Valley Water's Water Supply Master Plan (WSMP) is a guiding document for long-term water supply investments to ensure water supply reliability for the county. The WSMP is regularly updated to evaluate anticipated water demands and water supply and infrastructure projects. As one of the WSMP project options, water reuse is a locally controlled and drought resilient supply that will help ensure our county's water supply in the face of climate change. Valley Water's Board of Directors (Board) have set a goal to promote, protect, and expand potable and non-potable reuse within the county. At the July 31, 2024 Recycled Water Committee (Committee) meeting, the Committee asked staff to include a higher aspirational goal as part of the WSMP 2050, in addition to the 24,000 AFY potable reuse goal by 2035. Maintaining 24,000 AFY as the goal for portfolio modeling will provide the Board with flexibility to consider storage and supply projects in addition to potable reuse.

The following options for a higher aspirational goal were evaluated. The goal could be met with any combination of potable reuse and desalination, however, the options were developed based on actual potential projects and potential wastewater availability.

Option 1 45,000 AFY is based on potential available wastewater for potable reuse in Palo Alto, San

José and Sunnyvale. This analysis was previously presented to the Committee on December 6, 2023 and is summarized in the following table. This would be a high-cost option and would require amending the existing water transfer agreement with Palo Alto to allow for additional time for implementation and negotiating agreements with Sunnyvale in addition to San José.

Partner Agency	**Potential Future Wastewater Availability (AFY)**	**Potential Purified Water Production (AFY)**
Palo Alto	10,000	8,000
Sunnyvale	5,600	4,800
San José / Santa Clara	est. 40,000	24,000 - 32,000
SCRWA	Fully Utilized in the Summer	--
Countywide Total:	55,600	36,800 - 44,800

Option 2 48,000 AFY is based on a 24,000 AFY potable reuse project and a 24,000 AFY desalination project. Desalination feasibility is currently being studied as a back up to potable reuse. The cost of this option is estimated to be about $5.4 billion. Desalination could have higher greenhouse gas emissions and will face challenges with brine disposal. Some environmental stakeholders have expressed concern about desalination. The feasibility study approved by the Board on July 9, 2024 will provide additional information as to whether such a project would be feasible.

Option 3 32,000 AFY based on a Palo Alto and San José potable reuse project. The cost of this option would be $4.9 billion. The Palo Alto purified water project is currently being modeled as a Direct Potable Reuse project in the WSMP portfolio analysis.

Several of these options are already included in WSMP portfolios that were presented to the Board in July. The Local Control theme included one portfolio which included Option 2 and another portfolio that included Option 3. Option 1 has not been modeled specifically, but since it is close to the Option 2 amount it can be extrapolated that it would model in a similar manner. Based on WSMP modeling, if these portfolios were able to be implemented, no additional storage or supply projects would be needed except a smaller amount of groundwater banking. These Local Control portfolio costs range from $4.6 billion to $5.9 billion. In addition to being high-cost options, the portfolios with maximized potable reuse are more risky as they do not diversify storage and supply which is inconsistent with Valley Water's long-term planning goals.

At this time, with our current water supply system, a 24,000 AFY project is facing utilization issues, meaning that there is not sufficient demand, conveyance or storage during normal and wet years to utilize all of the water that would be produced, which is the majority of the time. A larger facility does not necessarily result in reduced per acre foot costs, if the water cannot be utilized in the system and risks overinvestment and stranded assets if the facility must be idled. Ultimately, the investment decision on potable reuse should be driven by the county's needs for water and considered along with other projects being evaluated in the WSMP to meet the Board's goal of affordable water rates. Therefore, a phased approach, with a realistic starting goal and flexibility to increase later as deemed needed towards an aspirational goal, is recommended given the risk and uncertainty associated with future demand, wastewater availability, and social/economic conditions.

Valley Water has supported non-potable reuse by our wastewater partners. Currently our wastewater partners recycle eleven percent of wastewater countywide.

Facility	2023 Wastewater Treated (AF)[1]	2023 Recycled Water Produced (AF)[2]	Recycled Water: Wastewater
Palo Alto	23,000	1,800	8%
Sunnyvale	15,000	0[3]	0%
San José/ Santa Clara	112,000	12,500	11%
South County	8,000	2,500	31%
Total:	158,000	16,800	11%

1. eSMR data, accessed 7/10/2024. Sum of daily average influent values.
2. SCVWD Water Tracker. Voluntary survey data provided by respective agency staff.
3. Sunnyvale's recycled water system is currently impacted by ongoing capital improvements at the water pollution control plant.

Our wastewater partners have plans to increase non-potable recycling per their Urban Water Management Plans (UWMP).

Facility	2023 Nonpotable Recycled Water Produced (AF) [1]	2045 Nonpotable Recycled Water Projections[2] (AF)
Palo Alto	1,800	800
Sunnyvale	0[2]	1,700
San José/ Santa Clara	12,500	21,700
South County	2,500	4,100

1. SCVWD Water Tracker. Voluntary survey data provided by respective agency staff.
2. 2020 Urban Water Management Plan. Valley Water. June 2021 (attachment 4)
3. Sunnyvale's recycled water system is currently impacted by ongoing capital improvements at the water pollution control plant.

Non-potable recycling, in some cases, might be a cost-effective way to use the right quality water for the right use, including irrigation, cooling towers, and data centers. Recognizing the increases in non-potable uses, staff recommendation is for Option 3 to be included as the aspirational goal with a review at the next WSMP update to determine if there is a water supply need for a larger project.

ENVIRONMENTAL JUSTICE AND EQUITY IMPACT:

There are no environmental justice and equity impacts associated with this agenda item. This action is unlikely to or will not result in adverse impacts and is not associated with an equity opportunity.

ATTACHMENTS:
Attachment 1: Alternative Water Supply Project Costs.
Attachment 2: Water Supply Master Plan 2050 Portfolios
Attachment 3: PowerPoint
Attachment 4: Link to 2020 Urban Water Management Plan

UNCLASSIFIED MANAGER:
Kirsten Struve, 408-630-3138

Appendix B – 2050 Conservation Goal

Santa Clara Valley Water District

File No.: 24-0448 **Agenda Date:** 5/17/2024
Item No.: 4.1.

COMMITTEE AGENDA MEMORANDUM
Water Supply and Demand Management Committee

Government Code § 84308 Applies: Yes ☐ No ☒
(If "YES" Complete Attachment A - Gov. Code § 84308)

SUBJECT:
Review Potential Water Conservation Targets for Inclusion in the 2050 Water Supply Master Plan; and Recommend to the Santa Clara Valley Water District Board the 126,000 Acre Feet per Year (AFY) (Option B) Water Conservation Goal by 2050 for Inclusion in the Water Supply Master Plan 2050.

RECOMMENDATION:
Recommend to Santa Clara Valley Water District Board the 126,000 Acre Feet per Year (Option B) water conservation goal by 2050 for inclusion in the Water Supply Master Plan 2050.

SUMMARY:
Santa Clara Valley Water District (Valley Water) is the primary water resources agency in Santa Clara County, California, and serves about 2 million residents, primarily through 13 water retailers. Valley Water has been providing water conservation programs to its retail agencies' customers since 1992 and offers over 20 programs to reach all customer sectors to achieve the Valley Water Board of Directors (Board) long-term 2030 and 2040 water conservation goals. The Water Supply and Demand Management Committee (formed by merging the Water Conservation and Demand Management Committee and Water Storage Exploratory Committee (Committee)) and the Board monitor progress on achieving conservation goals. Additionally, the Water Supply Master Plan (Master Plan) which includes the conservation goals is updated every five (5) years and has an annual Monitoring and Assessment Program (MAP) report that presents progress on meeting the conservation goal. Through the Master Plan and MAP updates, the Committee and Board can modify the goals as new technologies, regulations, and trends become available or enacted.

Valley Water is currently developing its Master Plan 2050 and seeks to identify new 2050 conservation goals for inclusion in the Master Plan. Staff are presenting three options to achieve additional savings beyond Valley Water's 2040 conservation goal of 110 thousand acre-feet a year (TAFY). Three (3) potential 2050 Conservation Goals (2050 Goals), the menu of conservation programs, and the cost-effectiveness of achieving the portfolios being considered were presented at the December 2023 and January 2024 Committee meetings. At the January 2024 meeting, the

Committee requested a report back with additional comprehensive rationale presented for Board analysis including further details of comparisons with other similar agencies, current water conservation performance indicators, and the implementation of option strategies. This memorandum includes these additional details.

Goal Development Approach

Valley Water developed three 2050 Goals by evaluating its current program, potential future programs, and peer agency programs. The evaluation of current and potential future program offerings included estimated water savings, estimated community interest, implementability, cost effectiveness, and support for retailers in achieving State regulations. Staff also reviewed peer agency programs to see if there are applicable programs that Valley Water has not yet evaluated. In general, staff found that the number and variety of Valley Water's programs are equal or exceed our peer agency programs, but plan on completing a more detailed benchmarking study of the conservation programs at peer agencies over the next year.

Valley Water offers a comprehensive set of over 20 programs that help all sectors (e.g., residential, agricultural, commercial, industrial, and institutional) reduce their water use and most are cost effective and/or provide important community education about water use and conservation. The current conservation program costs approximately $600/AF. However, certain programs could be expanded or added in the future if Valley Water increases investment in conservation.

The three 2050 Goals summarized in the next section offer different options for investing in water conservation through 2050. As the conservation goal increases, the cost increases, staffing needs increase, and implementability will likely become more difficult. Implementability may become more difficult because Santa Clara County is relatively efficient, so it may be necessary to engage new customers and install new water-saving technology. Our retail customer average residential gallons per capita per day (GPCD) in the county during non-drought conditions (using years 2018-2020) ranges between approximately 71-74. In comparison, average statewide residential GPCD during the same period was between 85-93. Therefore, Santa Clara County is approximately 20% more efficient than the State of California on average and is in the top 10 of most efficient counties. During drought, additional water use reduction calls may also become more challenging as our community becomes more efficient which could impact meeting Valley Water's Level of Service goal.

Valley Water also considered expected future water use regulations when designing the 2050 Goal options. Per Senate Bill 1157 (SB 1157), the State developed indoor residential water use limits of 42 GPCD starting in 2030. Valley Water estimates that indoor residential water use accounts for approximately 50% of all residential water use. Most of our retailers' customers already achieve the SB 1157 water use limits, although some retailers will need to work with their customers to reduce their water use to meet SB 1157. Each of the three 2050 Goals presented in the next section will help all of Santa Clara County to meet or continue meeting the SB 1157 water use limits.

Potential Conservation Savings Goals

The potential 2050 Goals would be fulfilled by leaning into Valley Water's existing program while still providing flexibility to enhance existing and add new programs. Three (3) potential 2050 Goals and unit costs have been identified and are described below:

1. *Option A Savings Goal* - 119 TAFY by 2050. This goal increases annual water savings by 10 TAFY above the 2040 goal. To achieve the increased savings, Valley Water would continue to offer the existing suite of programs but expand the reach of the programs to access more customers. This option acknowledges that current Valley Water programs are cost effective and provide water saving options to a wide range of users. This goal will cost the least, at approximately $1,230/acre-foot in 2023 dollars, while still providing additional conservation. However, this goal will not capitalize on proposed new cost-effective programs or incentives.

2. *Option B Savings Goal* - 126 TAFY by 2050. This goal increases annual water savings by 17 TAFY above the 2040 goal. To achieve the increased savings, Valley Water would need to significantly expand the reach of its current programs and add a leak assistance program. This would require additional conservation investment and increased staffing. To achieve this goal, Valley Water will need to increase annual average active water savings to 14 TAFY from 11 TAFY, which is equivalent to the water savings rate achieved during droughts when messaging and public awareness is at its greatest. Expanding the reach of existing programs and adding new programs will result in a total cost of $1,338/acre-foot in 2023 dollars. While this goal will require more investment than Option A, it does allow Valley Water to stay at the forefront of conservation by offering new innovative programs and technologies to Santa Clara County residents. With sufficient investment and retail agency outreach support, Valley Water could likely achieve Option B by 2050.

3. *Option C Savings Goal* - 133 TAFY by 2050. This goal increases annual water savings by 24 TAFY above the 2040 goal. To achieve the increased savings, Valley Water would need to do everything proposed in Option B while also reducing outdoor water use by an additional 25% compared to the 2020 estimated outdoor water use, expanding program offerings, and increasing staffing beyond that needed in Option B. While this option is technically feasible, its implementation would require significant expansion of our landscape rebate program and strong support from our retailers to encourage customer participation. Local ordinances that outlaw watering front yard lawns could help support this savings goal option, but Valley Water understands the significant difficulty and uncertainty involved in working with cities to implement such ordinances. Valley Water estimates that the effort involved to achieve Option C would cost $1,690/acre-foot.

Figure 1 summarizes the: (1) passive savings achieved as of 2020 within the Valley Water service area, (2) the active savings from past implementation as of 2020, (3) projected additional passive savings estimated to occur in the future, and (4) the additional active savings to be achieved from program implementation that would be required to achieve the potential 2050 Goals.

Figure 1. Potential 2050 Conservation Savings Goals - Active and Passive Savings

Staff Recommendation

Staff recommends the Committee recommend Option B as the 2050 Water Conservation Goal for Board adoption. Option B provides Valley Water an ambitious but implementable goal that will ensure Santa Clara County is a leader in conservation, ensure we use our water supplies wisely, and balances affordability concerns.

While Option A is the lowest cost alternative, based on the committee feedback so far, staff recommends choosing a more aggressive goal. By going with Option A, Valley Water may have to invest in additional expensive supply and storage projects in lieu of the additional savings that could be achieved with Option B. While Option B would require increasing participation by approximately 200%, which in turn will require additional staffing and funding resources, staff are confident that Valley Water can achieve Option B.

Option C would require significant investment to expand staff resources and program offerings. Even with the expanded funding, achieving Option C would still be very difficult and require significant support from our partner agencies. While technically feasible, there is uncertainty as to whether it could be achieved by 2050. If Valley Water chooses Option C, it may risk under-investing in other new supplies and storage if meeting the goal gets delayed and will also affect revenues.

To summarize, selecting Option B:

1) Is feasible

2) Balances costs with benefits
3) Reduces need to invest in additional new supplies and/or storage
4) Makes “Conservation a Way of Life” in Santa Clara County
5) Allows Valley Water to stay at the forefront of conservation

The long-term water conservation goals (i.e., 2030, 2040, and 2050) are monitored annually by the Committee and the Board as part of the long-term water conservation progress update and the Master Plan Monitoring and Assessment Program (MAP) update. Additionally, the Master Plan, including conservation goals, is updated every five (5) years. Through MAP and the Master Plan updates, the Committee and Board can modify the goals as new technologies, regulations, and trends become available or enacted. Therefore, staff think that Option B is an aggressive, achievable and productive goal, and that Valley Water has processes in place that can allow the Board to increase the goal if new technologies or regulations become available.

ENVIRONMENTAL JUSTICE AND EQUITY IMPACT:
Environmental justice and equity impact on EJ population are expected/likely to result from the implementation of the water conservation program to achieve 2050 Goals. The recommendation of Option B was selected to balance cost and benefit; the benefits and the impact/mitigation strategies on disadvantaged communities are discussed in greater detail below.

Water conservation offers a range of environmental justice benefits by promoting equitable access to clean water, reducing pollution, protecting ecosystems, mitigating climate change, saving costs for vulnerable communities, enhancing drought resilience, and empowering residents with knowledge and skills for sustainable water use. Valley Water provides such water conservation information in multiple languages and via various outreach techniques to reach all members of our community. Valley Water acknowledges that during drought, disadvantaged communities may be disproportionately impacted. To address these impacts, Valley Water promotes access to equitable and affordable water supplies (Water Supply Goal 2.6). Valley Water offers specific programs, such as the Lawn Busters program to provide water-efficient landscapes to low-income, elderly, disabled, or veteran homeowners and schools within disadvantaged communities.

ATTACHMENTS:
Attachment 1: PowerPoint
Attachment 2: 2050 Master Plan Potential Savings Goal Memo.
Attachment 3: 2050 Mstr. Pln. Conserv. Measure Dtls. & Portfolios
Attachment 4: Link to 2021 Water Conservation Strategic Plan

UNCLASSIFIED MANAGER:
Kirsten Struve, 408-630-3138

Final - 6 November 2023

MEMORANDUM

To: Ashley Shannon (Valley Water)
Metra Richert (Valley Water)

From: Andree Lee (EKI)
Anona Dutton (EKI)

Subject: 2050 Master Plan Potential Savings Targets
Valley Water
(EKI C00054.00)

Valley Water is currently developing its 2050 Master Plan (Master Plan) and seeks to identify Conservation Portfolio(s) for potential inclusion in the Master Plan. The Conservation Portfolio(s) will provide options to maintain or achieve additional savings beyond Valley Water's currently planned water conservation activities (i.e., the activities and anticipated savings through 2040 as identified in Valley Water's 2021 Water Conservation Strategic Plan [2021 Strategic Plan]).

This memorandum provides a summary of: (1) the potential 2050 Conservation Savings Targets (2050 Targets) for the Master Plan, and (2) the preliminary Conservation Measures List. Following Valley Water's review and confirmation of each potential 2050 Target and selection of up to ten Conservation Measures[1], EKI will identify up to three Conservation Portfolios (e.g., one for each of the 2050 Targets), each with a different combination of four to six measures.[2] EKI will evaluate the cost-effectiveness of achieving each 2050 Target through implementation of the associated measures. Valley Water may select one or more 2050 Targets and accompanying portfolios for inclusion in the Master Plan.

1. EXISTING 2040 CONSERVATION SAVINGS TARGET

EKI recently completed Valley Water's 2021 Strategic Plan that included, among other things, water use profiles for each Valley Water retail agency, a detailed analysis of the water conservation programs offered within Valley Water's service area, and recommendations to Valley Water on how to increase its long-term conservation savings from about 80 thousand acre-feet per year (TAFY) in 2022 to about 99 TAFY by 2030 and 109 TAFY by 2040 relative to a baseline of 1992. **Figure 1** shows the projected water savings to reach the 2040 Targets from achieved passive savings, active savings from past implementation, projected additional passive savings, and remaining savings needed from additional active programs.[3] Passive savings come from plumbing codes, appliance water use standards, and other regulations that improve water use efficiency over time. These passive savings would be realized over time regardless of Valley Water or retail agency conservation programs. Active savings come from water conservation

[1] Up to 10 conservation measures will be selected from the preliminary 15 Conservation Measures considered in the detailed analysis.
[2] It is important to note that measures not selected for inclusion in a portfolio may still be offered by Valley Water in the future.
[3] Valley Water, 2021. Adapted from Figure 4-6.

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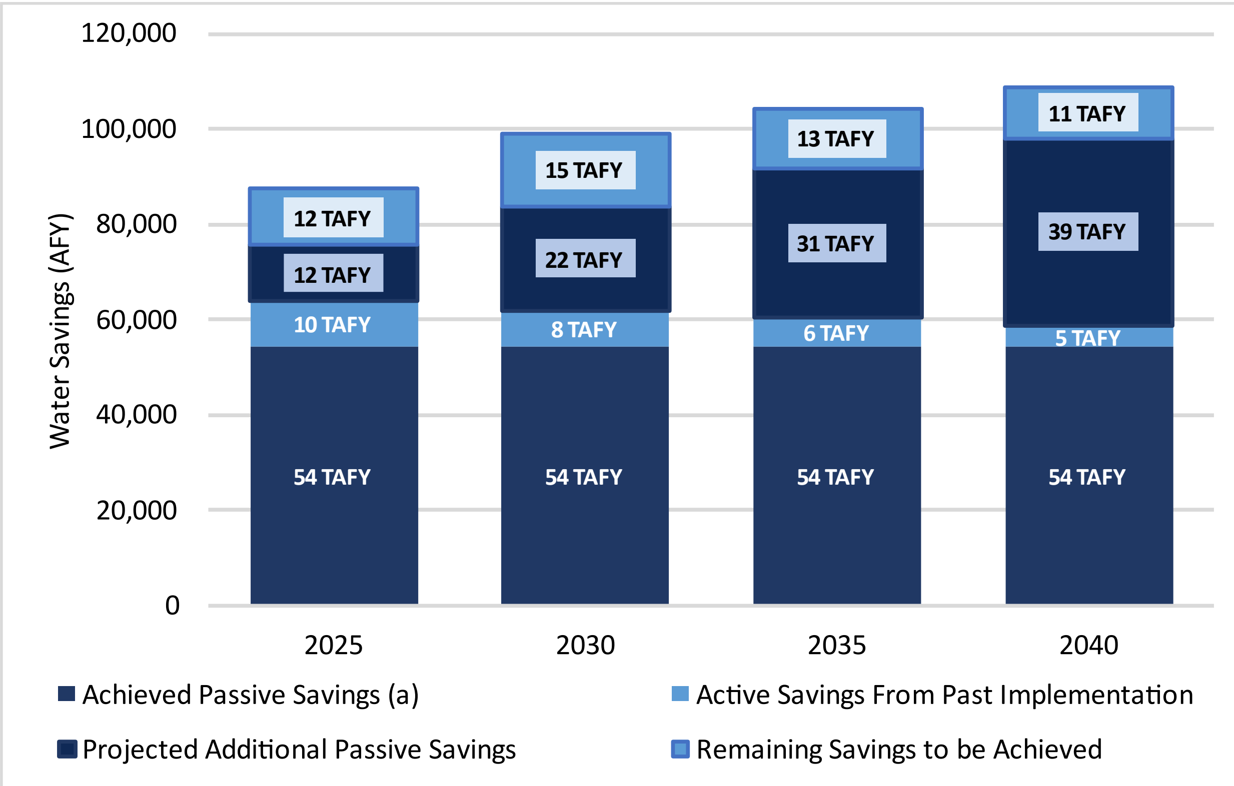
programs run by Valley Water or its retail agencies, such as plumbing fixture rebates, turf replacement rebates, and home water use reports and surveys.

Figure 1. Projected Water Savings to Reach 2040 Targets



Note:
(a) Achieved Passive Savings are estimated from 1992 onward, with 1992 as the first year that passive savings are accrued. Appendix D of Valley Water's 2021 Strategic Plan provides greater detail on the calculations and assumptions used to project water savings.

2. POTENTIAL CONSERVATION SAVINGS TARGETS

EKI has identified three potential 2050 Targets, described below, for consideration.

1. *Option A Savings Target*: This target assumes future conservation savings through 2050 at rates that are consistent with the water savings projected to be achieved from implementation of Valley Water's existing mix of conservation programs by 2040 (from the 2021 Strategic Plan), while accounting for a reduced future active conservation savings potential due to demand hardening. This target assumes existing conservation programs at recent average rates of implementation (i.e., median implementation rate for 2018 to 2020).
2. *Option B Savings Target*: This target assumes future conservation savings through 2050 at the rates projected to be achieved through implementation of the Broad Program Mix portfolio by 2040 (from the 2021 Strategic Plan), while accounting for a reduced future active conservation savings potential due to demand hardening. This target assumes that implementation rates are

scaled to achieve the 2030 and 2040 conservation targets in the 2021 Strategic Plan, then savings rates are sustained through the new 2050 target.

3. *Option C Savings Target*: This target assumes future conservation savings to achieve a goal of an additional 25% reduction in outdoor water use within Valley Water's service area by 2050 compared to estimated outdoor water use in 2020, which includes water savings achieved through implementation of Valley Water's existing programs. This target does not build upon the Option A or Option B targets.

The potential 2050 Targets for only active savings are provided in **Figure 2** below, and for both passive and active savings are provided in **Figure 3**. The methodology and assumptions are summarized in **Table** 1 and further described below.

Figure 2. Potential 2050 Conservation Savings Targets – Active Savings

Figure 3. Potential 2050 Conservation Savings Targets – Active and Passive Savings

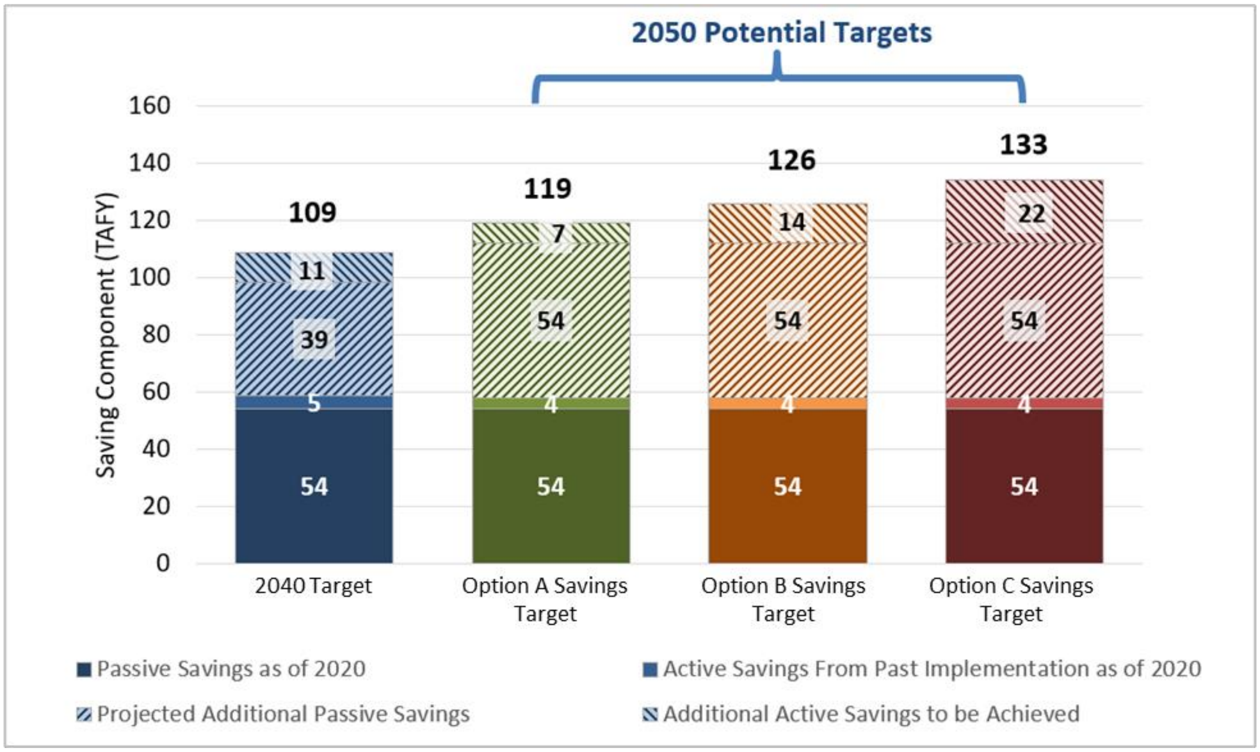


Table 1. Methodology and Assumptions for Calculating Savings Targets

	Option A Savings Target	Option B Savings Target	Option C Savings Target
Approach	Beyond the projected passive savings in 2050, maintaining a consistent active savings rate of 7 TAFY, which is consistent with the trend of active savings from 2020 through 2040 without the MWENDO[4] Scenario shown in the 2021 Strategic Plan (**Figure 1**).	Beyond the projected passive savings in 2050, maintaining a consistent active savings rate of 14 TAFY from program implementation, which is consistent with the active savings from the "Broad Program Mix" without MWENDO Scenario shown in the 2021 Strategic Plan.	Beyond the projected passive savings in 2050, targeting further outdoor water demand reduction in addition to the 2050 active savings from past programs targeting outdoor water use. This target does not specifically consider the MWENDO Scenario shown in the 2021 Strategic Plan.
Passive Savings as of 2020	54 TAFY as documented in the 2021 Strategic Plan.		
Active Savings From Past Implementation as of 2020	4 TAFY of active savings (residual savings[5]) is estimated to be available in 2050 from the past program implementation as of 2020 per the M.Cubed Model output.		
Future Additional Passive Savings	54 TAFY obtained by subtracting the 2020 estimated passive savings from the 2050 estimated passive saving per the M.Cubed Model dated 1 May 2021.		
Additional Savings to be Achieved	The identified additional savings to be achieved reduces from 15 TAFY in 2030 to 11 TAFY in 2040, as shown in **Figure 1**. Thus, assuming a linearly decreasing trend as a result of demand hardening, the active savings to be achieved in 2050 would be 7 TAFY.	Extend the "Broad Program Mix" without MWENDO Scenario saving rates in 2040 (i.e., 18 TAFY) to 2050. The savings rate is further adjusted by 4 TAFY to account for active savings from implementation through 2040. Thus, 14 TAFY of additional savings are needed to achieve a similar savings rate.	Reduce the estimated outdoor water demand in Valley Water's 11 urban retailers by 25% from the estimated outdoor water demand in 2020, for an additional 21 TAFY of savings.
2050 Target[6]	**119 TAFY**	**126 TAFY**	**133 TAFY**

2.1 Option A Savings Target

The Option A Savings Target assumes that Valley Water will seek to maintain a consistent trend of active conservation savings from 2040 through 2050 as planned from 2020 through 2040. Consistent with the savings trends from 2020 through 2040 without the MWENDO Scenario projected in the 2021 Strategic Plan and M.Cubed Model output, the Option A Savings Targets anticipates that passive conservation will continue to increase in the Valley Water service area through 2050, totaling 54 TAFY of additional passive savings from 2020 to 2050 in addition to the 54 TAF of passive savings achieved as of 2020. This target also assumes that 4 TAFY of residual active savings from past implementation of active conservation programs will be maintained in 2050. In addition to the passive savings and residual active savings, the Option A Savings Target aims to achieve an additional active savings of 7 TAFY in 2050. This is consistent with the trend of declining active savings from 2020 through 2040 shown in the 2021 Strategic Plan for the "Business as Usual" scenario without the MWENDO Scenario as a result of demand hardening.

2.2 Option B Savings Target

The Option B Savings Target assumes that Valley Water will achieve a consistent savings rate of 14 TAFY from program implementation beyond the residual active savings. This level of savings is consistent with the active savings from the "Broad Program Mix" without MWENDO Scenario shown in the 2021 Strategic Plan. Consistent with the savings trends projected in the 2021 Strategic Plan and M.Cubed Model output, the Option B Savings Targets anticipates that passive conservation will continue to increase in the Valley Water service area through 2050, totaling 54 TAFY of additional passive savings from 2020 to 2050 in addition to the 54 TAF of passive savings achieved as of 2020. This target also assumes that 4 TAFY of residual active savings from past implementation of active conservation programs will be maintained in 2050. In addition to the passive savings and residual active savings, the Option B Savings Target aims to achieve an additional active savings of 14 TAFY in 2050. This is consistent with the "Broad Program Mix" without MWENDO Scenario in the 2021 Strategic Plan, reduced by 4 TAFY to account for the residential active savings.

2.3 Option C Savings Target

The Option C Savings Target assumes that Valley Water will aim to reduce outdoor water use within the service area by 25% by 2050, compared to the estimated outdoor water use in 2020. Consistent with the other savings targets, the Option C Savings Targets anticipates that passive conservation will continue to increase through 2050, totaling 54 TAFY of additional passive savings from 2020 to 2050 in addition to the 54 TAF of passive savings achieved as of 2020. This target also assumes that 4 TAFY of residual active savings from past implementation of active conservation programs will be maintained in 2050. In addition to the passive savings and residual active savings, the Option C Savings Target aims to achieve an additional active savings of 21 TAFY in 2050. It is anticipated that the savings would be achieved through aggressive implementation of conservation measures primarily targeting outdoor water use. Further details on the methodology for estimating outdoor water use in the Valley Water service area are provided below.

2.3.1 Estimated Outdoor Water Demand within Valley Water

To establish the Option C Savings Target, current outdoor water use was estimated within the Valley Water service area using monthly production data for the Valley Water retail agencies. The potable water

[4] The Model Water Efficient New Development Ordinance (MWENDO) represents a new conservation initiative being pursued by Valley Water. The model ordinance is intended to be adopted by all cities within Santa Clara County. MWENDO savings are assumed will occur gradually increase over time, from 100 AFY in 2025 to 4,200 AFY in 2040.

[5] Active savings refers to savings generated by water conservation programs currently funded by Valley Water, whereas residual savings are savings refers to savings generated by water conservation programs previously funded by Valley Water.

[6] Total may not sum due to rounding.

production for 13 Valley Water retail agencies[7] is shown in **Table 2**. Red shading is used to highlight years where the agency's annual demand was higher than average, while blue shading indicates years where the demand was lower than the average demand from 2015 to 2022.

2.3.2 Methodologies and Assumptions of the Outdoor Water Demand Estimate

Table 3 presents the estimated proportion of outdoor water demand for each Valley Water retail agency. Red shading is used to highlight years where the annual outdoor demand proportion was higher than average, while blue shading indicates years where the proportion was lower than the average. In order to calculate the outdoor water demand, it is assumed that the minimum water production month represents indoor water usage exclusively and remains consistent throughout the year.[8] The remaining water production is then assumed to be allocated for outdoor water use. The minimum production month may vary by supplier, as shown in **Table 4**.

2.3.3 Outdoor Water Demand Estimate Results

Table 5 presents the estimated outdoor water demand for each Valley Water retail agency. The 2020 water demand was selected as the base year for outdoor water use reduction because it reflects the recent developments within Valley Water and is not constrained by drought restrictions. Similarly, red shading is used to highlight years where the annual outdoor demand was higher than average, while blue shading indicates years where the demand was lower than the average.

[7] DWR defines an "urban water supplier" as "a supplier, either publicly or privately owned, providing water for municipal purposes either directly or indirectly to more than 3,000 customers or supplying more than 3,000 acre-feet of water annually." Retail agencies that meet this definition are required to report their monthly water demand to the State Water Resources Control Board (SWRCB). Purissima Hills Water District and Stanford University do not meet this definition and thus do not report their monthly water demand to SWRCB. However, these suppliers do report their water demand to the Bay Area Supply and Conservation Agency (BAWSCA).

[8] It is important to note that some outdoor irrigation still occurs during the minimum water production month. However, for the purposes of this analysis, outdoor irrigation during the minimum water production month is assumed to be negligible.

Table 2. Total Potable Water Production (AFY)

Agencies (a)	2015	2016	2017	2018	2019	2020	2021	2022	Avg.
City of Gilroy	6,870	6,983	7,813	7,854	7,691	8,219	7,822	7,411	**7,583**
City of Milpitas	8,665	8,589	8,742	7,808	9,319	9,366	9,006	8,628	**8,765**
City of Morgan Hill	(b)	6,280	7,079	7,272	7,235	7,809	7,182	6,884	**7,106**
City of Mountain View	8,871	8,741	9,202	9,526	9,474	10,033	9,412	8,992	**9,281**
City of Palo Alto	9,539	9,901	10,921	10,918	10,775	11,222	10,922	11,282	**10,685**
City of Santa Clara	17,621	17,160	18,681	18,481	17,789	18,301	17,317	16,913	**17,783**
City of Sunnyvale	15,387	16,507	18,639	18,573	18,771	19,811	18,840	18,243	**18,096**
CWS - Los Altos	10,189	10,265	11,656	12,438	11,863	13,024	11,440	10,761	**11,454**
Great Oaks Water Company	8,943	8,911	9,996	10,277	10,393	(b)	10,379	9,389	**9,755**
Purissima Hills Water District	(b)	(b)	(b)	(b)	(b)	2,060	(b)	(b)	**2,060**
San José Municipal Water	16,072	15,740	16,563	17,069	16,860	17,545	16,636	15,989	**16,559**
San Jose Water Company	105,713	103,676	111,543	115,123	113,928	121,454	113,455	105,291	**111,273**
Stanford University	(b)	(b)	(b)	(b)	(b)	2,712	(b)	(b)	**2,712**

Abbreviations:

AFY = Acre-feet per year
CWS = California Water Service

Notes:

(a) Production data was obtained from the SWRCB for urban water suppliers as defined by DWR. Production data for suppliers that do not meet the definition of an urban water supplier was obtained from BAWSCA. This analysis only includes data starting in 2015 as this is the first year in which reliable data is available.
(b) Production data was not available.

Sources:

(1) SWRCB monthly reporting data dated 15 May 2023, accessed online via: https://www.waterboards.ca.gov/water_issues/programs/conservation_portal/conservation_reporting.html.
(2) BAWSCA monthly reporting data, provided on 28 June 2023.

Table 3. Estimated Outdoor Water Use Proportion

VW Agencies	2015	2016	2017	2018	2019	2020	2021	2022
City of Gilroy	29%	34%	40%	36%	40%	41%	34%	33%
City of Milpitas	17%	19%	22%	22%	21%	20%	24%	21%
City of Morgan Hill	(a)A	42%	48%	45%	43%	49%	40%	38%
City of Mountain View	27%	39%	37%	32%	35%	33%	29%	33%
City of Palo Alto	34%	37%	47%	40%	39%	36%	41%	40%
City of Santa Clara	22%	28%	33%	26%	27%	28%	25%	23%
City of Sunnyvale	25%	30%	34%	30%	31%	30%	28%	28%
CWS Los Altos	42%	46%	53%	45%	46%	50%	42%	45%
Great Oaks Water Company	28%	30%	35%	31%	34%	(a)	31%	27%
Purissima Hills Water District	(a)	(a)	(a)	(a)	(a)	67%	(a)	(a)
San José Municipal Water	26%	29%	35%	35%	35%	34%	30%	30%
San Jose Water Company	26%	27%	33%	30%	33%	34%	28%	26%
Stanford University	(a)	(a)	(a)	(a)	(a)	55%	(a)	(a)

<u>**Abbreviations:**</u>
AFY = Acre-feet per year
CWS = California Water Service

<u>**Note:**</u>
(a) Production data were not available.

Table 4. Minimum Water Production Month by Agency

Agencies	Month (a)						
	2015	2016	2017	2018	2019	2020	2021
City of Gilroy	Dec	Jan	Feb	Dec	Feb	Jan	Dec
City of Milpitas	Dec	Jan	Jan	Mar	Dec	Jan	Dec
City of Morgan Hill	Dec	Jan	Feb	Mar	Dec	Jan	Dec
City of Mountain View	Nov	Jan	Apr	Jan	Dec	Jan	Jan
City of Palo Alto	Nov	Jan	Jan	Dec	Feb	Jan	Jan
City of Santa Clara	Nov	Jan	Jan	Dec	Jan	Jan	Jan
City of Sunnyvale	Oct	Jan	Feb	Jan	Dec	Jan	Dec
CWS Los Altos	Dec	Jan	Feb	Dec	Feb	Jan	Dec
Great Oaks Water Company	Dec	Jan	Feb	Jan	Feb	Jan	Dec
Purissima Hills Water District	(b)	(b)	(b)	(b)	(b)	Jan	(b)
San José Municipal Water	Dec	Dec	Feb	Dec	Feb	Jan	Dec
San Jose Water Company	Dec	Jan	Feb	Jan	Feb	Jan	Dec
Stanford University	(b)	(b)	(b)	(b)	(b)	Apr	(b)

<u>**Note:**</u>
(a) Monthly water production was normalized by the number of days in a month.
(b) Production data were not available

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Table 5. Estimated Total Potable Water Production for Outdoor Use (AFY)

Agencies	2015	2016	2017	2018	2019	2020	2021	2022	Avg.
City of Gilroy	2,015	2,346	3,119	2,857	3,061	3,354	2,647	2,467	**2,733**
City of Milpitas	1,471	1,610	1,946	1,706	1,941	1,886	2,175	1,828	**1,820**
City of Morgan Hill	(a)	2,666	3,426	3,300	3,089	3,796	2,875	2,588	**3,106**
City of Mountain View	2,386	3,381	3,399	3,050	3,269	3,292	2,689	2,928	**3,049**
City of Palo Alto	3,287	3,648	5,093	4,363	4,161	4,072	4,516	4,507	**4,206**
City of Santa Clara	3,881	4,790	6,117	4,750	4,719	5,174	4,316	3,933	**4,710**
City of Sunnyvale	3,907	4,995	6,346	5,480	5,862	5,969	5,240	5,182	**5,373**
CWS Los Altos	4,296	4,691	6,174	5,544	5,505	6,558	4,802	4,869	**5,305**
Great Oaks Water Company	2,470	2,638	3,488	3,193	3,527	3,527 (b)	3,183	2,582	**3,076**
Purissima Hills Water District	(a)	(a)	(a)	(a)	(a)	1,382	(a)	(a)	**1,382**
San Jose Municipal Water	4,220	4,581	5,841	5,904	5,899	5,914	4,929	4,860	**5,268**
San Jose Water Company	27,158	28,457	36,802	34,707	37,542	41,825	31,645	27,503	**33,205**
Stanford University	(a)	(a)	(a)	(a)	(a)	1,500	(a)	(a)	**1,500**
Total	**55,092**	**63,804**	**81,751**	**74,854**	**78,575**	**86,750**	**69,018**	**63,247**	**71,636**

Abbreviations:
AFY = Acre-feet per year
CWS = California Water Service

Notes:
(a) Production data were not available.
(b) The estimated outdoor water demand of Great Oaks Water Company in 2020 is assumed to be similar to what it was in 2019.

As shown in **Table 5**, the total estimated outdoor water demand in the Valley Water service area in 2020 was approximately 85.4 TAFY. Assuming a 25% reduction after adjusting for the residual active savings from program implementation through 2040 for the irrigation sector[9], the outdoor water reduction target would be 21 TAFY, as shown in **Table 6**.

[9] The residual active savings in 2050 from program implementation through 2040 is estimated to be 0.433 TAFY per the "Business-As-Usual" without MWENDO Scenario.

Table 6. Outdoor Water Demand Reduction Target (TAFY)

	(a)	Values (b)	Unit
2020 Estimated Outdoor Demand	[A]	85.4	TAFY
2050 Active savings from past irrigation program implementation	[B]	0.4	TAFY
25% Reduction	[C]	21	TAFY

Notes:
(a) Values shown above are obtained by: [C] = ([A]-[B])*25%.
(b) Total may not sum due to rounding.

3. PRELIMINARY LIST OF CONSERVATION MEASURES

As shown in **Attachment A**, a comprehensive list of potential Conservation measures were evaluated using the following criteria:

- Measures that were previously identified in the 2021 Strategic Plan as having high water savings potential (e.g., savings potential above the median of 90 AF of water savings in 2030).
- Measures that target key end uses (irrigation, cooling tower, pool, etc.), in particular end uses that will not be impacted by passive conservation savings.
- Measures provide alternative supplies (e.g., rainwater, graywater, etc.).
- Measures that break down known customer barriers to participation (e.g., direct install turf, Water Efficient Technologies [WET] program, and leak repair assistance) or benefit a potentially underserved segment of Valley Water's customer base, such as renters and/or low-income residential customers.
- Measures that leverage and/or maintain the benefits of Valley Water's investment in Advanced Metering Infrastructure (AMI).
- Previously considered and new measures of interest to Valley Water and/or that have been successfully implemented by other agencies.

As shown in **Table 6**, EKI then developed a preliminary list of 15 Conservation Measures for potential inclusion in the Master Plan Conservation Portfolio(s) that met the following criteria:

1. Existing measures with estimated water savings above the median water savings in 2030 that meets at least one of the additional criteria described above; or
2. Potential new measures, for which estimated water savings have not yet been calculated, that meet at least two of the additional criteria described above.

Table 7. Preliminary List of Conservation Measures

Measure	Sector	Current Program	Previously Evaluated	Estimated Savings in 2030 (AF) (a)
Large Landscape Water Budgets	IRR	Yes	Yes	5,197
Rain Sensors	IRR	Yes	Yes	110
Large Land. Irrigation Controller	IRR	Yes	Yes	255
Flow Sensor with Automatic Shutoffs/Dedicated Irrigation Meter	IRR	Yes	Yes	219
Agriculture Mobile Lab	OTH	Yes	Yes	2,000
WET	CII	Yes	Yes	154
AMI Leak Alert & Home Water Report	SFR	Yes	Yes	811
Large Landscape Program	IRR	Yes	Yes	104
Residential Irrigation Controller, SFR	IRR	Yes	Yes	358
Turf Replacement Rebate	IRR	Yes	Yes	396
Whole House Graywater/Reuse	SFR	No	No	TBD
Leak Assistance Program	SFR	No	No	TBD
Direct Install Turf Replacement, SRF/MFR	IRR	No	No	TBD
Pool Covers	IRR	No	No	TBD
Submetering (Multi-family and ADU)	MFR	No	No	18,615

Abbreviations:

ADU = additional dwelling unit
AF = acre-feet
AMI = Advanced Metering Infrastructure
CCF = hundred cubic feet
CII = Commercial, Industrial, and Institutional
IRR = irrigation
MFR = Multi-Family Residential
OTH = other
SFR = Single-Family Residential
WET = Water Efficient Technologies

Notes:

(a) The estimated savings in 2030 are provided for informational purposes, based on Table 6-8 of the 2021 Strategic Plan and studies conducted by Valley Water to evaluate savings generated for submetering. These values will be re-evaluated, or developed where not currently available, in the subsequent modeling effort.

4. NEXT STEPS

Following Valley Water's approval of the 2050 Targets and selection of ten Conservation Measures for further analysis, EKI will identify up to three Conservation Portfolios (e.g., one for each of the 2050 Targets) each with a different combination of four to six programs. Modeling will be completed, in coordination with M.Cubed, to assess the magnitude of implementation of the selected measures that would be required to achieve the level of savings required for each target, as well as the overall cost per acre-foot saved for each portfolio.

ATTACHMENTS

Tables

Figures

References

Valley Water, 2021. Water Conservation Strategic Plan, Valley Water, dated July 2021.

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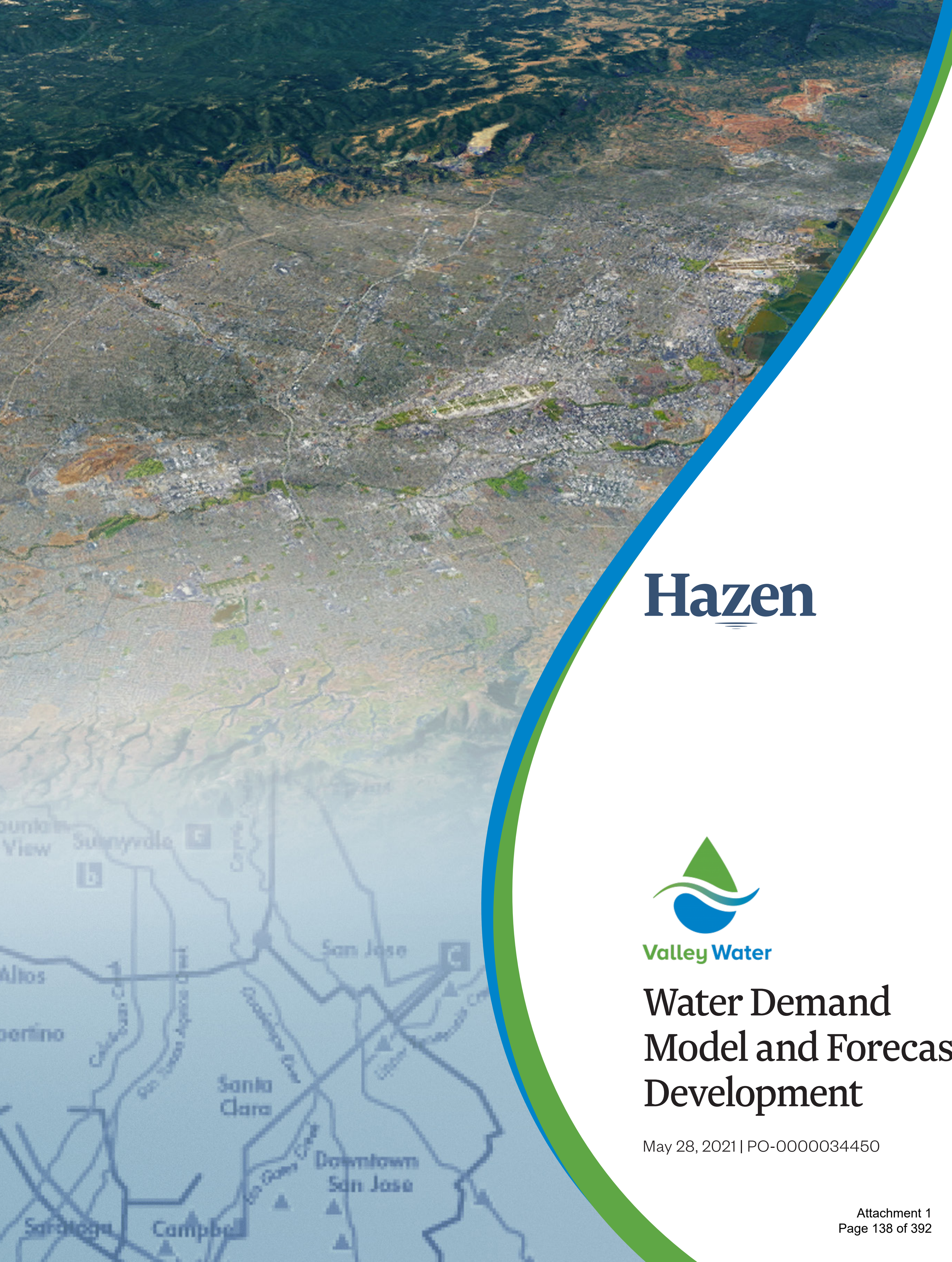
Appendix C – Demand Model Development



Hazen

Valley Water

Water Demand Model and Forecast Development

May 28, 2021 | PO-0000034450

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List of Acronyms

Abbreviation	Definition
ACS	American Community Survey
ABAG	Association of Bay Area Governments
AF	Acre-Foot
Ag	Agricultural
ANN	Artificial Neural Networks
AR	Auto-Regressive
ARIMA	Auto-Regressive, Integrated, and Moving Average
BAWSCA	Bay Area Water Supply and Conservation Agency
BEBR	Bureau of Economic and Business Research
CADOF	California Department of Finance
CCF	Hundred Cubic Feet
CCWD	Contra Costa Water District
CI	Commercial and Industrial
CII	Commercial, Industrial, and Institutional
Delta	Sacramento-San Joaquin Delta
DSS	Demand Side Management Least Cost Planning Decision Support System
ECRI	Economic Cycles Research Institute
GCM	General Circulation Model
GIS	Geographical Information System
GPED	Gallons per Employee per Day
GPUD	Gallons per Unit per Day
I	Integration
LEHD	Longitudinal Employer-Household Dynamics
LODES	LEHD Origin-Destination Employment Statistics

Abbreviation	Definition
MA	Moving Average
MFR	Multi-Family Residential
MG	Million Gallons
MGD	Million Gallons per Day
M&I	Municipal and Industrial
MSA	Metropolitan Statistical Area
MWD	Metropolitan Water District
NAICS	North American Industry Classification System
NR	Nonresidential
PAWS	Protection and Augmentation of Water Supplies
PPH	Persons per Household
PRISM	Parameter-elevation Regressions on Independent Slopes Model
SANDAG	San Diego Association of Governments
SCAG	Southern California Association of Governments
SCWA	Sonoma County Water Agency
SDCWA	San Diego County Water Authority
SFPUC	San Francisco Public Utilities Commission
SFR	Single Family Residential
Stanford	Stanford University
TAF	Thousand Acre-Feet
TBW	Tampa Bay Water
UWMP	Urban Water Management Plan
WEAP	Water Evaluation and Planning
WDPA	Water Demand Planning Area
WSPD	Water Supply Production Database
WUE	Water Utility Enterprise
Zone 7	Zone 7 Water Agency

Executive Summary

Water demand forecasts are a foundational element in water supply and infrastructure planning activities. In support of several ongoing planning initiatives, Santa Clara Valley Water District (Valley Water) has developed a new water demand model that will be used to forecast water demand in a consistent manner for the entire county. This report provides an overview of the model development process and reviews Valley Water's updated demand forecast through 2045.

Prior to selecting a modeling approach, Valley Water conducted a benchmark analysis of regional demand projection models. The analysis defined a typology for demand forecasting and reviewed several demand forecasting approaches applied by peer agencies to Valley Water. Based on the benchmark analysis and a detailed review of available historical data, Valley Water selected a statistical / econometric approach for the new demand model.

The new demand model was organized based on water provider type (i.e., retail agency or non-retail groundwater pumper) and further segmented by geography, sector/billing classification, and time. The demand model permits Valley Water to produce demand forecasts for each water use sector and geography described in Table ES-1. Based on input from retail agencies, retail agency recycled water consumption was included within the representation of the multifamily and Commercial, Industrial, and Institutional (CII) sectors.

Table ES-1: Summary of Demand Model Organization

Water Provider Type	Geography	Temporal Resolution	Water Use Sectors Represented
Retail agency	13 retail agency service areas	Monthly	• Single family • Multifamily • CII • Other water use
Non-retail groundwater pumper	2 groundwater basins	Annual	• Municipal and industrial (M&I) • Agricultural

The demand model was developed by regressing historical water consumption against several explanatory variables known to influence water demand (e.g., weather, water rates, economic conditions, housing density). The demand model showed strong performance in explaining historical patterns of consumption over the last 20 years (including two major droughts and the Great Recession) and was determined to be suitable for forecasting. Prior to forecasting, the demand model was calibrated to correct for any systematic biases in the average of model predictions for fiscal years 2009 to 2018.

A baseline future demand scenario was developed to reflect a reasonable reference for expected future conditions. A brief summary of the major assumptions defining the baseline future demand scenario are presented in Table ES-2. In addition to sectoral forecasts for retail agencies and non-retail groundwater pumpers, future nonrevenue water was also projected based on 2018 observations of differences between production and consumption. Future conservation was not explicitly included in the baseline demand scenario as it is forecasted using a separate water conservation tracking model (Valley Water, 2019). However, final demand forecasts include conservation as a line-item deduction.

Table ES-2: Summary of Conditions Represented in Baseline Future Water Demand Scenario

Model Assumption	Description
Growth / development trends	Projected growth (2020-2045) derived from Association of Bay Area Governments (ABAG) projections of single family housing units, multifamily housing units, non-agricultural jobs, and population
Future weather conditions	30-year historical normal weather
Water rates	Nominal price grows in time based on the 2020 Protection and Augmentation of Water Supplies (PAWS) report rates from 2020-2030, then increases each year by 5% after that
Future economy	Assume future conditions follow 30-year trend in economic growth
Median income	Assume constant income at 2018 value (real dollars)
Housing density	Derived based on ABAG-informed growth in housing units and existing land use
Persons per household	Derived based on ABAG projections of persons per household
Drought rebound	Assumes a 5-year (2020-2025) rebound to 50% of drought-influenced demand reductions

Table ES-3 presents forecasted water demand for Santa Clara County given the baseline scenario assumptions identified in Table ES-2. The water demand forecast is presented before and after future conservation savings are deducted. Before accounting for estimated conservation, total county-wide demand is expected to increase 75 thousand acre-feet (TAF) (25%) between 2020 and 2045. After accounting for future conservation, total county-wide demand is forecasted to increase 39 TAF (13%) between 2020 and 2045.

Table ES-3: Summary of County-Wide Baseline Water Demand Forecast (TAF)

Provider Type	Sector	2020	2025	2030	2035	2040	2045
Retail agency	Single family	101	115	114	114	115	114
	Multifamily	37	44	47	53	57	62
	CII	99	117	118	123	128	132
	Other	8	8	8	8	8	8
	Nonrevenue	14	16	17	17	18	18
	Raw water	2	2	2	2	2	2
Retail Agency Total		260	302	305	317	327	336
Non-retail pumpers	M&I	14	14	14	14	14	14
	Agricultural	25	25	25	25	25	25
Non-Retail Pumper Total		38	38	38	38	38	38
Total (no Conservation) [a]		**299**	**340**	**344**	**355**	**366**	**374**
Conservation [b]		0	12	25	30	36	36
Total (with Conservation)		**299**	**328**	**319**	**325**	**330**	**338**

[a] Refers to total forecasted demand from baseline model scenario, excluding conservation.
[b] Consistent with total county-wide projections of future conservation, provided by Valley Water from a separate model.

1. Introduction

Valley Water has developed a new model to forecast total water demand in Santa Clara County. Demand projections from the model will be used to support several planning initiatives and documents including:

- The 2021 Urban Water Management Plan (UWMP);
- Monitoring of and updates to the Water Supply Master Plan;
- Inputs to Valley Water's water supply planning model; and
- Evaluating conservation programs, capital projects, and other water supply investments.

Valley Water manages a diverse portfolio of water supplies to provide water to Santa Clara County's 13 retail agencies and non-retail groundwater pumpers. The majority of Santa Clara County customers obtain their water directly from a retail agency. As a result, each retailer develops their own water demand forecasts. These forecasts are useful and have been used to inform Valley Water's prior UWMPs. However, Valley Water is responsible for county-wide water resource planning activities (e.g., groundwater management, treated water production, potable reuse development, surface water infrastructure management and development, and active conservation program implementation) that are better served by a consistent modeling approach and assumptions across the service area.

Valley Water has historically developed its own water demand forecast for the county using the IWR-MAIN model, which has provided a consistent platform and basis for disaggregating forecasts into geographic areas and sectors. The IWR-MAIN model has not been supported in nearly two decades, further motivating Valley Water's interest in evaluating a new demand model approach and platform.

This report documents Valley Water's efforts in developing a new water demand model, including:

- A benchmark analysis of demand projection approaches applied by Valley Water's peers;
- Review of historical data collected to support model development; and
- Overview of the modeling approach and historical performance.

The report concludes with an application of the new water demand model under assumed future conditions and includes a summary of Valley Water's baseline water demand forecast to 2045, excluding water conservation.

2. Benchmark Analysis of Regional Demand Projection Models

This section supports the evaluation of a new demand model through a benchmarking analysis of the modeling approaches used by Valley Water's peer agencies. This section is organized by first reviewing a conceptual typology of demand forecasting elements, which is useful in characterizing and comparing the forecasting approaches among water supply utilities. The typology is supported with a detailed discussion of several quantitative methods often used to forecast demand. Given this background and framework, this section reviews the forecasting approaches employed by several regional water supply providers and wholesale agencies. These agencies include:

- San Francisco Public Utilities Commission (SFPUC)
- Bay Area Water Supply and Conservation Agency (BAWSCA)
- San Diego County Water Authority (SDCWA)
- Metropolitan Water District of Southern California (MWD)
- Tampa Bay Water (TBW) (FL)
- Contra Costa Water District (CCWD)
- Sonoma County Water Agency (SCWA)
- Zone 7 Water Agency (Zone 7)

This section concludes with a summary of the benchmarking analysis which includes a characterization of Valley Water's prior forecast approach and the implications of the analysis on selection of a new forecast modeling approach.

2.1 Typology for Demand Forecasting

This Section reviews a conceptual typology of demand forecasting elements, which is useful in characterizing and comparing the forecasting approaches between water supply utilities. The discussion on the working typology of long-term forecasting approaches presented in this Section was previously developed by Kiefer, Dzielgielewski, and Jones and will be featured in forthcoming published research for the Water Research Foundation (*Long Term Water Demand Forecasting for Water Resources and Infrastructure Planning, WRF Project 4667,* N.D., forthcoming). The typology is summarized below and prior to describing the approaches used by Valley Water peer water providers.[1]

In general, most of the differences in how water demand forecasts are prepared relate to specific details about underlying assumptions. However, stepping back from these details, there appears to exist four main elements that can add structure for classifying the features of a long-term water demand forecast. The working typology suggests that a long-term forecast is generally describable as the intersection of four main elements identified in the following Figure 2-1.

[1] The original intent of the typology was to add a structure around which the topic of water demand forecasting can be described and characterized and is based on the review of several reports and studies documenting long-term water demand forecasting efforts of almost 100 water utilities and related water management agencies. The review provides a representative assessment of the prevailing design features of current forecast practices.

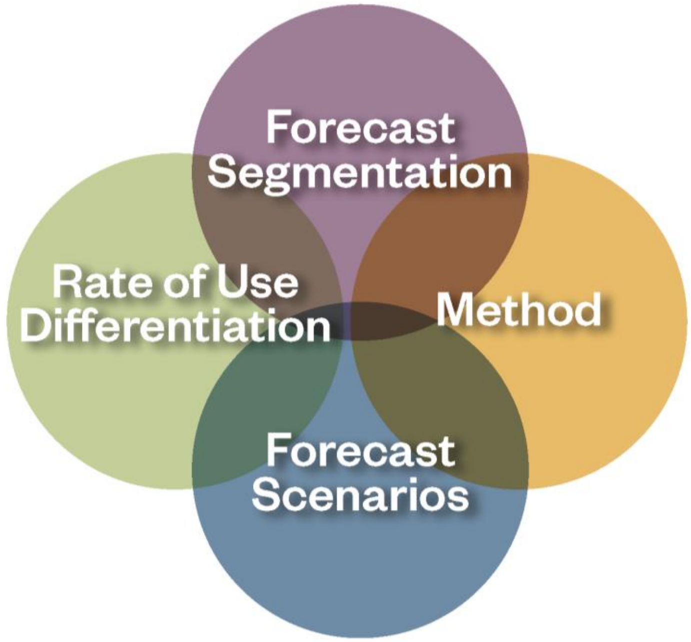

Figure 2-1: Long-term Water Demand Forecasting Typology as an Intersection of Four Main Descriptive Elements (adapted from Kiefer et al, N.D. forthcoming)

2.1.1 Forecast Segmentation

Forecast segmentation refers to whether and how a water demand forecast is broken down into component pieces. As shown in Figure 2-2, forecasts can be derived for the following dimensions:

- Groups of customers, such as billing classes or sectors defined by other criteria;
- End uses of water, which define specific water using purposes;[2]
- Geographical areas, which make up a current or future water service area; and
- Times of the year, such as seasons or months.

For example, a forecast may provide monthly predictions of water use for six water user types, broken into indoor and outdoor components, for 10 water delivery zones. On the other hand, a forecast without segmentation might simply reflect a prediction of total production demands for a given utility.

[2] Example end uses include irrigation, toilet flushing, showering, rinsing, etc. End uses are sometimes, but not always, tied to specific water fixtures.

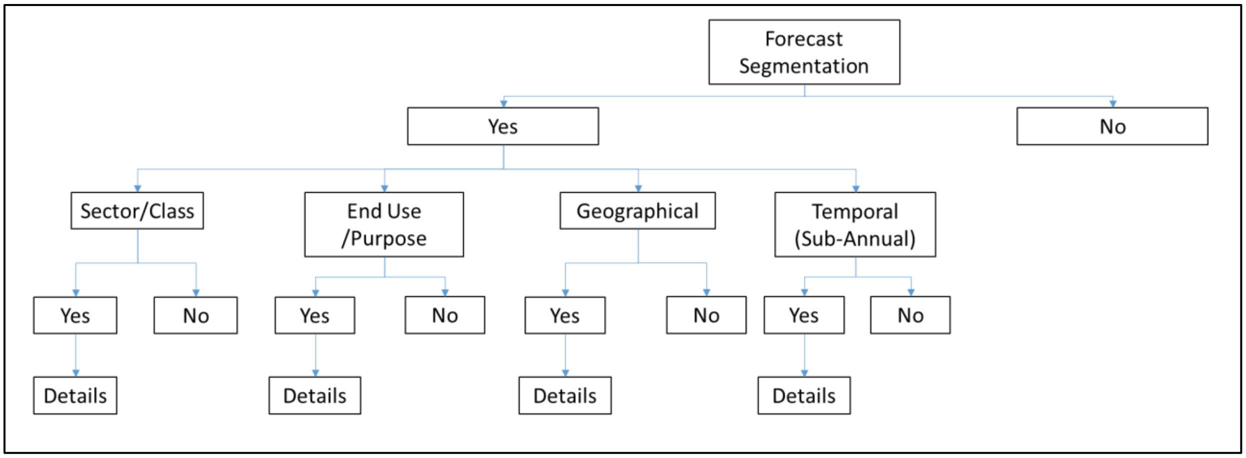

Figure 2-2: Typology Element Defining Forecast Segmentation (adapted from Kiefer et al, N.D. forthcoming)

The review of forecasting literature suggests that, in practice, forecast segmentation can involve many combinations among these forecast dimensions, as well as a wide variety in how each is defined. For example, one utility may forecast water use for single family and multifamily water billing sectors, while another may forecast for a combined residential sector defined by land use zoning criteria. A utility may choose to forecast for residential end uses of water, but not at the end use level for commercial and industrial classes. Some utilities may forecast total production demands by month by pressure zone, and others may forecast by Census tract for multiple sectors for low, mid, and high water using seasons.

2.1.2 Rate of Use Differentiation

Rate of use differentiation refers to splitting a forecast into a subcomponent that reflects water using intensity defined in Figure 2-3 below.

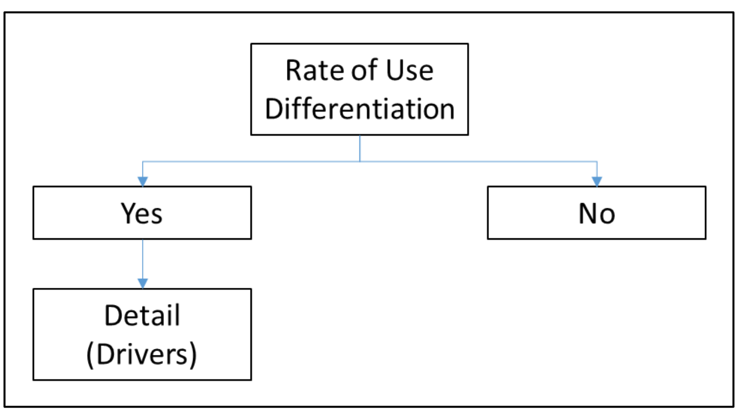

Figure 2-3: Differentiating Forecasted Rates of Water Use is Another Element of the Typology (adapted from Kiefer et al, N.D. forthcoming)

This implies that the forecast employs the use of one or more forecast "drivers". A driver is a count (N) of a variable that defines either scale or frequency, where for any given forecast dimension a prediction of water use (Q) is defined as:

$$Q \equiv N * \frac{Q}{N} \equiv N * q \quad (1)$$

Where simple conversion suggests the rate of use is q. Table 2-1 on the following page identifies several examples of driver variables and corresponding rate of use metrics that can be differentiated.

Table 2-1: Examples of Drivers and Rates of Use (adapted from Kiefer et al, N.D. forthcoming)

Driver Unit (*N*)	Corresponding Rate of Use (*q*)
Population	Per capita use
Households	Per household
Acres	Per acre
Employees	Per employee
Square feet	Per square foot
Accounts	Per account
Meters	Per meter
Toilet flushes	Per flush
Wash loads	Per load

With the addition of this typology element, one can begin to envision how typology elements intersect to describe a forecast. For example, a utility may not segment its water demand forecast, but may derive the forecast as the product of projected population and per capita use. A utility may use households as the driver for a residential sector and employees as the driver of a commercial class. It is also possible that a utility differentiates the rate of use only for a subset of classes. These are the types of details that are often encountered when reviewing forecast documentation.

2.1.3 Method

The "method" element of the working typology refers to how a forecast is calculated, i.e., the underlying arithmetic, and how information and assumptions about the future are connected to create a forecast. Forecast methods may consist of components from three different model types described in Table 2-2 on the following page.

Table 2-2: Description of Forecast Methods/Models (adapted from Kiefer et al, N.D. forthcoming)

Model Type	Description
Statistical	Consists of functional relationships estimated from observed historical data, which may define explanatory variables (i.e., covariates), or, alternatively, predict the future from past time series alone
Associative	Models connect (or associate) information to calculate forecasts without reference to statistical relationships estimated from historical data; they are functional or perform functions, but not statistical
Judgmental	Models that reflect forecast assumptions that are not immediately based on explicit statistical or associative calculations

The method element can also intersect other typology elements. Based on the review of utility forecasts, forecasts can be highly nuanced, employing multiple methods at the same time (which gives rise to the "combination" pathway in Figure 2-4). For example, a utility may predict water use per account in the single family sector as a statistical function of price and income (sector segmentation, rate of use differentiation, statistical method, with covariates), meanwhile assuming the number of single family accounts (drivers) and nonresidential sector demands change at a rate tied to population projections (associative). The same utility may assume that future demands for certain large users will stay constant (judgmental). Another utility may forecast total production demands by multiplying population (driver) projections by per capita usage (rates of use) that decline at a rate tied to estimates of future toilet flush volumes (associative) or assume future per capita usage rates reflect policy targets associated with conservation (judgmental) or engineering guidelines (judgmental).

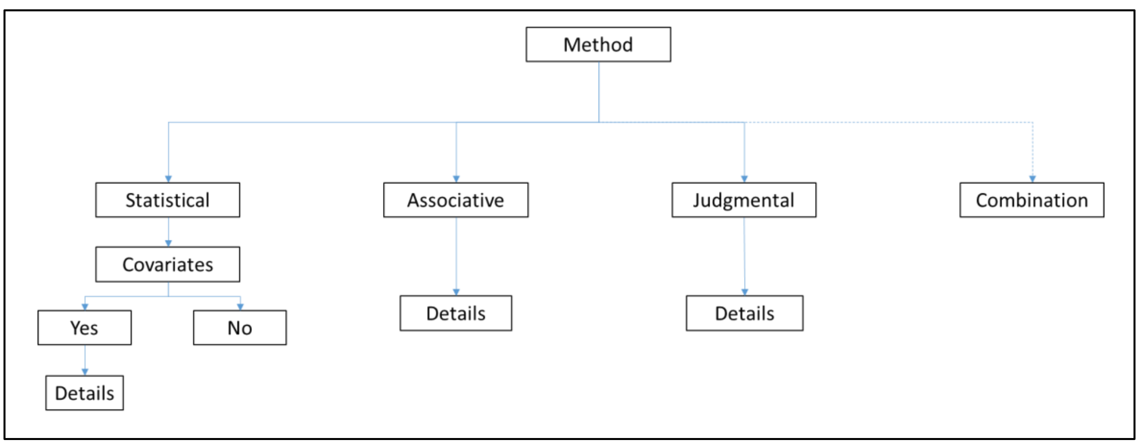

Figure 2-4: The Method Element Defines the Basis of Forecast Calculations (adapted from Kiefer et al, N.D. forthcoming)

2.1.4 Forecast Scenarios

The final element of the working typology defines whether and how alternative forecasts scenarios are calculated, as opposed to a single forecast scenario, which is assumed as given (Figure 2-5). Some examples of forecast scenarios include high and low growth scenarios, with and without conservation, hot/dry versus cool/wet weather conditions, and historical climate versus climate change. Scenarios can be introduced by varying any of the values of variables and assumptions comprising the method element of the typology and there are both qualitative and quantitative methods for creating and portraying the scenarios. Probabilistic simulation is one quantitative technique for generating many scenarios, encompassing hundreds or thousands of potential outcomes.

Although the calculations of alternative scenarios are highly dependent on features related to model method, they also can intersect with other typology elements. For example, rates of use may be treated as uncertain (i.e., allowed to vary), but driver counts may be portrayed as a single set of values, and vice versa. Some scenarios may assume development of additional geographic areas within the service area or different future land uses, different conservation scenarios may be applied to different sectors, and so on. The actual choice of forecast scenarios is often driven by planning objectives, reporting requirements, and the relative emphasis on addressing future uncertainties, which also reflect nuance and affect the details of any forecast.

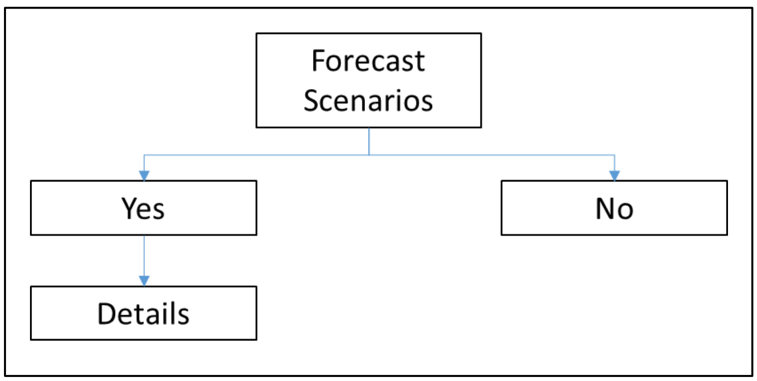

Figure 2-5: The Use of Alternative Forecast Scenarios is a Descriptive Element of the Typology (adapted from Kiefer et al, N.D. forthcoming)

2.2 Spectrum of Associative and Statistical Modeling Methods

The range of associative and statistical water use modeling methods is well developed. Billings and Jones (2008), Donkor et al. (2014), Rinaudo (2015), and others have summarized differences in forecasting models, which differ mechanically in form and function, as well as in data requirements and skills/training needed for application. Based on the review of Kiefer et al, (N.D. forthcoming), the sections below summarize several alternative model constructs, highlighting some of their best features and disadvantages. These generally reflect the menu of options available to Valley Water in terms of the method component of the forecasting typology, notwithstanding the ability to integrate multiple methods and many possible details about how they intersect with other typology elements, such as forecast segmentation and forecast scenarios.

2.2.1 Trend Extrapolation and Univariate Time Series Models

Trend extrapolation simply fits a trend line through an historical time series of observed water use values and uses this line to extrapolate future values. The underlying assumption of trend extrapolation is that water use can be explained by the passage of time and forecasts of future demand rely only on the value of a time counter or index that generates the trend.

Univariate time series models can be significantly more refined and statistically complex than simple trend extrapolation. As a class of models, they stem from the work of Box and Jenkins (1976). The time series literature is highly developed and specialized. In general, time series models can generally be described by the three component parts; Auto-Regressive, Integrated, and Moving Average (ARIMA). A purely auto-regressive (AR) model predicts water use using a statistical weighting of its past values. If considered necessary, adding a moving average (MA) component weighs past prediction errors of the AR component to improve predictions. Trend extrapolation and univariate time series techniques forecast water demand as a function of its past values, so there are relatively low data requirements. Although these approaches are seldom used in a long-term forecasting context they are technically adaptable to any forecast horizon. Since these types of models do not directly define cause and effect relationships, additional qualitative judgments may be needed to explain predicted movements in time.

2.2.2 Fixed Unit Use Coefficient Models

Unit use coefficient models are closely related to the "rate of use differentiation" component of the working typology, in that, by design, they differentiate unit rates of use from the count of units that are assumed to drive water use. Typically, unit usage rates, such as water use per capita, water use per household, or water use per employee, are derived and then multiplied by projections of corresponding units to derive forecasts of water use.

The most basic application of fixed unit use methods utilizes a single rate of use metric and a single forecast driver, such as multiplying an assumed per capita usage rate by projections of population. Disaggregated applications may use unit usage rates by customer class and/or geographic areas and/or seasonal time periods. A generic representation a fixed unit use coefficient model consisting of geographic (*g*), sectoral (*s*) and monthly (*m*) dimensions can be written as:

$$Q_t = \sum_{g}^{G} \sum_{s}^{S} \sum_{m}^{M} N_{g,s,m,t} * q_{g,s,m} \qquad \textbf{(2)}$$

Where the sums of the products of unit use coefficients (q) and driver units (N) calculate a forecast of total water use (Q) for future period t. In this formulation, the unit use coefficients do not vary in future time periods (and, hence, do not take the index t).

Fixed unit use coefficient models are technically straightforward and do not require advanced statistics. These types of models characterize expected values, but do not attempt to explain variability in the data used to calculate averages nor address variability through time. However, disaggregation of unit usage rates and relevant driver units into sectors, geographic areas, and time periods offers a mechanism to exploit underlying differences in water use patterns along these segments, which may improve the quality of forecast information. Given that historical data are used as a basis to derive the unit use coefficients, selection of unit usage rates to use in a forecast can require qualitative judgments or additional statistical analyses to "normalize" for the effects of weather and other circumstances. Future changes in the unit usage rates (for example, due to assumed changes in use caused by water efficiency improvements) may be integrated easily into the framework by permitting the coefficients to vary with time (t):

$$Q_t = \sum_{g}^{G} \sum_{s}^{S} \sum_{m}^{M} N_{g,s,m,t} * q_{g,s,m,t} \tag{3}$$

2.2.3 Regression and Econometric Models

Regression analysis and econometrics[3] are techniques for relating the values of two or more variables statistically. Regression models are equations estimated from observed data that predict how the value of a dependent variable (Y) changes in response to a change in the value of one or more independent variables (X). Thus, regression models reflect a functional relationship that usually implies a causal connection between the dependent variable and a set of independent variables. Ignoring the dimensions over which it is estimated (e.g., over time, geographic areas, or both), the classic linear regression model with one independent variable can be written as:

$$Y = \alpha + \beta X + \varepsilon \tag{4}$$

Where α denotes an "intercept" term that estimates the value of Y when X equals 0 and β is a regression parameter (or slope coefficient) that describes both the direction and degree that Y changes when X changes. The model error (or residual) term ε measures the difference between the predicted value of Y, given the value of X, and observed value of Y.

If values of Y and X are transformed into natural logarithms prior to estimation, then this implies a multiplicative formulation, where the value of the exponent β can be interpreted directly as an elasticity, which measures the percent change in Y stemming from a 1 percent change in X:[4]

$$Y = e^{\alpha} X^{\beta} e^{\varepsilon} \tag{5}$$

Multiple regression differs from this example using a single, independent variable only in that more variables are used to explain changes in the dependent variable.

The literature on regression analysis is expansive and the span of technical details and sophistication varies widely. In general, estimating regression models for the purposes of water demand forecasting requires academic training. A major benefit of using regression-based models is the ability to estimate cause-effect relationships from observed data that can be used to forecast future "what if" scenarios. However, aside from additional analytical requirements, one must also collect ample historical data upon which to estimate model parameters. For example, estimating the influence of weather, socioeconomic factors, and other explanatory variables on water use will require time-series and/or spatial observations of these factors paired with corresponding values of water use. Furthermore, in order to employ resulting models for forecasting, assumptions regarding future values of independent variables will be needed and finding sources for or deriving projections can require additional resources. However, regression models

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[3] Generally speaking, econometric models are regression models that incorporate variables that have interest to economists (such as price and income, among others).

[4] Note that the term e in Equation 5 represents the base of the natural logarithm.

permit forecasters and planners to estimate the sensitivity of forecasts to changes in assumptions about any of the factors that are specified.

2.2.4 End Use Accounting Models

End use models attempt either to build up estimates of demand from estimates of water use devoted to specific purposes or allocate estimates of water use into different purposes based on external sources of information.[5] Because of the intent that whole add up to the individual parts, these types of models are often called end use accounting models. Some end use models attempt to differentiate technology from behavior, which make them especially relevant for evaluating the effects of changes in water efficiency. Figure 2-6 shows one such end use framework[6], which first specifies different discrete levels of "mechanical efficiency" for a given end use and the percentage of the total stock of a given end use that corresponds to each efficiency level.

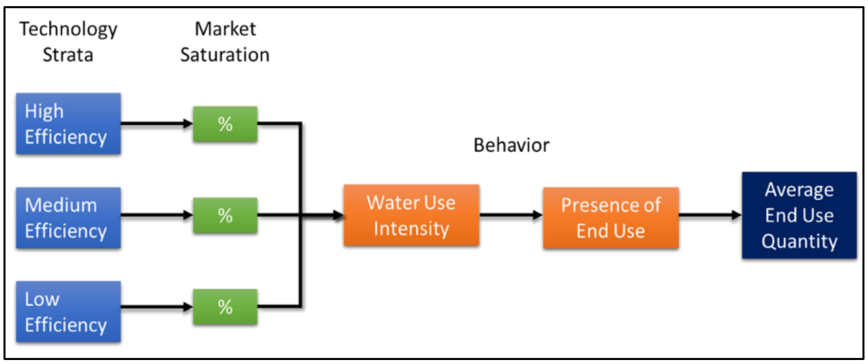

Figure 2-6: Example Elements of Water End Use Framework (adapted from Kiefer et al, N.D. forthcoming)

The novelty of the end use approach stems from the ability to compartmentalize how changes in consumption can occur. One difficulty with end use models is that they do not easily capture time series and geographical variability in water use that stem from factors other than water efficiency (such as weather and economic activity). Another difficulty is the wide range of process use and fixtures employed in the nonresidential sectors (such as cooling, rinsing, and specialized water processes), where less has been formalized in terms of mechanical efficiency levels and variability in water using behaviors. These difficulties often lead to the need to specify "catch-all" end use categories (such as "outdoor-other" or "non-residential other") in order to balance the accounting with observed data.

2.2.5 Hybrid and Other Model Types

There are other types of forecasting models that can be found in the literature, which distinguish themselves in certain ways from the types discussed above. For example, there are econometric methods

[5] The Residential End Uses of Water Study Update (DeOreo et al. 2016) and its predecessor study (Mayer et al. 1999) are often as used external sources that provide assumptions for allocating residential use into end use components.

[6] The general framework shown in Figure 2-6 was originally employed within the IWR-MAIN Water Demand Management Suite Conservation Manager.

that exploit the power of ARIMA techniques, and time series methods that can be extended to use information on independent variables. There are also machine learning techniques, such as application of artificial neural networks (ANN), which mine data in search of patterns that can be "learned". For the most part, such computational intelligence models have been used in the context of short-term forecasting.

There is a wide range of what can be called "hybrid models" used for long-term water demand forecasting, which reflects the nuance and creativity found in creating forecasts. For example, it is common to see various blends of coefficient, end use, and regression models used together, and with different degrees of modeling sophistication and complexity in application. It is fairly common practice to complement econometric forecast models with independent end use-based models to adjust econometric forecasts for the effects of passive water savings. Some hybrid techniques integrate input from independent or external sources to formulate custom forecasting equations. For example, simple per capita use projections can be adjusted using climatic, socioeconomic, conservation, and other parameters found in the literature or from inferences made from regression analysis of data collected for a different purpose. These types of examples are reflective of *modified forecast factor models,* which can be written in generalized form as:

$$Y_F = Y_B * \prod_j^J \left(\frac{X_{j,F}}{X_{j,B}}\right)^{\beta_j} \tag{6}$$

Where like equation (5), Y is the dependent variable that is being forecasted based on the values of j independent variables X and estimated elasticities (β) that define the response of Y to the specified set of independent variables. The index B represents a base or starting value and the index F denotes a different value for a forecast period. In this formulation, the forecasted value of Y is a multiplicative product (or scaling) of its base value, which is determined by the ratio change in the values of independent variables from their respective base values and their corresponding elasticities. Modified forecast factor models can be considered hybrid models to the extent that they use externally derived sources for statistical response parameters or use limited or partial local data to make statistical inferences about different and broader populations.

The principal advantage of hybrid models is that they can overcome data constraints by making appropriate use of available knowledge. However, use of external information, such as assumed elasticities, requires some judgments on applicability and credible sources, and mixing of different parameters from different sources with different embedded assumptions can complicate the formulation of scenarios and assessments of statistical confidence.

2.3 Forecasting Approaches Employed by Selected Bay Area Providers

This section presents a review of water demand forecasting approaches used by selected water providers in the Bay Area. The approaches used by each agency are evaluated with respect to the four primary elements of the typology discussed above, including some additional detail on models used and sources of projection data. The assessments are based on available information from recent Urban Water Management Plans, related water supply planning documents that describe forecasting processes, and in some cases direct experience of the study team in implementing these processes. It is important to caution that these summaries represent interpretations of the written documentation and there can be some uncertainty in these interpretations. This review was completed in 2019 and summarizes information on demand modeling prior to 2019. Most water agencies recently updated their modeling for the 2020 UWMPs which will be submitted to California Department of Water Resources (DWR) in 2021.

2.3.1 San Francisco Public Utilities Commission

SFPUC is a retailer and wholesaler that provides water partly or entirely within San Francisco, San Mateo, Santa Clara, Alameda, San Joaquin and Tuolumne Counties. The retail service area is home to a population of about 850,000, whereas the broader wholesale service area is estimated to have a population of about 1.8 million. SFPUC currently sources its water from the Hetch Hetchy system, as well as from local watersheds in the East Bay and on the Peninsula.

Table 2-3 summarizes elements of SFPUC forecast. The forecast is segmented into three primary sectors (not counting line items for estimated losses). The forecast differentiates between single and multifamily residential households and combines nonresidential users into a commercial and industrial (CI) sector. The forecasting method is primarily econometric prior to utilizing an end use model to estimate conservation scenarios. The conservation model is a customized version of the Alliance for Water Efficiency Water Conservation Tracking Tool. SFPUC forecasts employ auxiliary judgments about growth in the multifamily sector and future demands from suburban and wholesale customer groups/geographic areas.

The specification of variables within the econometric models differs by sector. The dataset used to estimate the econometric models included data from water providers outside of SFPUC to increase sample size and variability within the modeling data. Weather and income variables are used to normalize the starting point of the forecast to account for cooler and wetter conditions, as well lower incomes than in the recent past. Projections of forecast drivers are taken from San Francisco Planning Department estimates and median income projections reflect ABAG estimates. Price projections are derived from SFPUC's Division of Finance and adjusted for an assumed two percent annual rate of inflation. The effects of price are assumed to capture passive water efficiency. The initial passive savings estimates are added back into the retail forecast prior to applying the conservation model in order not to double count and to provide an explicit accounting of the estimated amount of water conserved by both passive and active measures.

Table 2-3: SFPUC Forecast Summary

Agency and Categorization and Population Served	Retail (0.85 M served) and Wholesale (~1.8 M served)
Sources for Model Input	• San Francisco Planning Dept. (drivers) • ABAG (median income growth) • SPUC Division of Finance
Documents Used in Forecast Review	SFPUC 2015 UWMP (SFPUC 2016)

Typology	Approach	Details
Forecast Segmentation	Segmented by sectors, geography, time	Sectors/Land Uses • Single-family Residential (SFR) • Multifamily Residential (MFR) • Commercial & Industrial (CI) • Retail Water Losses • Wholesale Water Losses Geographic • In City service • Suburban retail • 26 Wholesale customers Temporal • Annual
Rate of Use Differentiation	Differentiated	Drivers • Accounts/Households units (SFR) • Employees (CI)
Method	Statistical (Econometric) + Associative (End Use) + Judgmental	Modeled Variables (estimated elasticities) • Price (SFR: -0.24, MFR: -0.17, CI: -0.15) • Median Income (SFR: 1.02) • Summer Avg. Max Temperature (SFR: 0.11, CI: 0.48) • Annual Precipitation (SFR: -0.09, CI: -0.04) Other Assumptions • MFR escalation based on projected MFR household growth • Suburban retail demand held constant • Wholesale demand held constant at contractual obligations
Forecast Scenarios	Explicit Scenarios	• With passive conservation • With passive and active conservation

2.3.2 Bay Area Water Supply and Conservation Agency

BAWSCA represents the water supply planning interests of 24 municipalities/districts and two private utility companies (26 total member agencies) in Alameda, San Mateo and Santa Clara Counties. BAWSCA does not own or operate any water related infrastructure but can acquire water for its agencies and plays an important role in communicating their interests to larger organizations such as SFPUC and Valley Water. BAWSCA member agencies receive most of their supply from SFPUC, with the remainder derived from other local and regional sources including local, non-SFPUC owned surface water (e.g., Bear Gulch Reservoir); local groundwater on the Peninsula; groundwater in Santa Clara County managed by Valley Water; and treated surface water in Santa Clara County delivered from Valley Water.

Since BAWSCA is a representative agency there is not a requirement to submit a UWMP with forecasts of demands. However, BAWSCA does regularly coordinate with their member agencies to develop demand forecasts as well as provide in-depth detail on their current usage and conservation measures.

BAWSCA integrates econometric and end use-base models for preparation of annual demand forecasts for 3 user sectors across their 26 member agencies (Table 2-4). Water production per capita is forecasted using an econometric model for the first few years of the forecast horizon, which is then transitioned into an end-use framework for later years of the forecast. The forecasts are generated and contained within the Demand Side Management Least Cost Planning Decision Support System (DSS Model).[7] Past estimates of water savings from the DSS Model were added back to historical production data prior to development of the econometric model and short-term econometric forecasts. The DSS Model was then calibrated to weather-normalized econometric model forecasts.

The DSS Model initially allocates water use per capita (residential sectors) and water use per employee (nonresidential sector) into end use components based on estimates of indoor/outdoor splits and literature-based estimates of the distribution of indoor and outdoor use across specific end uses. The effects of passive and active water efficiency measures are then estimated at an end use level. Thus, population and employment projections drive the forecasts across retail areas, whereas the effects of efficiency influence the projections of use per capita and per employee.

[7] The DSS Model is proprietary and sold with “subscription” fees to Maddaus Water Management.

Table 2-4: BAWSCA Forecast Summary

Agency and Categorization and Population Served	Representative Agency (~1.8 M served)
Sources for Model Input	• Plan Bay Area - ABAG Projections 2013 • Member agency 2010 UWMPs • California Department of Finance • United States Census Bureau • Member agency specific planning documents
Documents Used in Forecast Review	Regional Water Demand and Conservation Projections (BAWSCA 2014)

Typology	Approach	Details
Forecast Segmentation	Segmented by sectors, geography, time	Sectors/Land Uses • Single-family Residential • Multifamily Residential • Nonresidential Geographic • 26 member agencies Temporal • Annual
Rate of Use Differentiation	Differentiated	Drivers • Population • Employees
Method	First 7 forecast years: Statistical (Econometric; production per capita) Remaining Forecast Years: Associative (End Use) + Judgmental	Modeled Variables (estimated elasticities) • Price (-0.168) • Unemployment Rate (-0.051) • Seasonality • Avg. Max Temperature Deviation (w/Seasonal Interactions) • Annual Precipitation Deviation (w/Seasonal Interactions) • Agency unique intercept (fixed effects) • Agency unique trend terms End Use Model • Residential and Nonresidential end uses allocated according to WaterRF research
Forecast Scenarios	Explicit Scenarios	• Before passive savings • With passive conservation • With passive and active conservation

2.4 Forecasting Approaches Employed by Peer Wholesale Agencies

This section presents a review of water demand forecasting approaches used by peer wholesale water providers, three of these wholesalers also reside in the Bay Area. As in the prior section, the four primary elements of the water demand forecasting typology are used as a basis for summarizing available documentation on forecasting methodologies employed, and that there can be some uncertainty in the interpretation of the available documentation. This review was completed in 2019 and summarizes information on demand modeling prior to 2019.

2.4.1 San Diego County Water Authority

SDCWA provides wholesale water deliveries to 24 member retail water agencies in San Diego County at the southern tip of California and serves approximately 3.3 million people over an area of about 950,000 acres. The SDCWA service areas covers about 1,500 square miles and is comprised of a mixture of dense urban areas and rural, predominantly agricultural, areas. The characteristics of individual member agencies vary considerably in terms of size, climate, and water customer base. About 80 percent of the region's water supply is imported from the Colorado River and Northern California. SDCWA is a member agency of (MWD, which is the SDCWA's largest supplier. The remaining water comes from local supply sources including groundwater, local surface water, recycled water, and conservation. SDCWA also has a 30-year Water Purchase Agreement with Poseidon Water for the purchase of up to 56,000 acre-feet of desalinated seawater per year, which is equivalent to almost 8 percent of the region's projected water demand in 2020.

Table 2-5 summarizes the features of SDCWA's forecast. The SDCWA forecast model is called CWA-MAIN,[8] due to its consistency with the spatially and sectorally disaggregated forecasting framework embodied in the original IWR-MAIN forecasting software tool.[9] SDCWA's production forecast is segmented into 4 retail sectors (including metered agriculture [Ag]). Line items for losses and unclassified use are added to the retail forecasts to generate forecasts of production demands. Forecasts are generated using a corresponding set of 4 econometric models estimated using historical data from member retail agencies. Sectoral models are estimated using a two-step procedure. First, sectoral model includes a socioeconomic component that is common to all retail agencies, with controls for historical watering restrictions and the effects of cyclical economic effects. Next, estimated responses to weather and seasonality are estimated uniquely for each member agency because of the influence of micro-climates within the region. The two-step process effectively creates a unique model for each retail agency and sector. Finally, the modeled demands are calibrated over a multiyear period by month to derive normalized starting values for the forecast.

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[8] The acronym MAIN, in both CWA-MAIN and IWR-MAIN refers to Municipal and Industrial Needs.

[9] Note that the SDCWA forecast is not contained or generated within IWR-MAIN but rather within various relational databases and spreadsheets.

The San Diego Association of Governments (SANDAG) is the primary source of both historical and projected values of model variables (e.g., median income, housing density, persons per household, and employment mix) and forecast drivers (i.e., households, employment, and irrigated acres). SANDAG socioeconomic forecasts are the "official" source of baseline projections. SDCWA's sectoral forecasts are generated by month, but usually aggregated up to annual values for reporting purposes. The baseline forecast scenario does not include estimates of impacts from future passive or active water conservation efforts, nor reductions in use from water supply shortage restrictions. Estimates of future conservation are estimated using the Alliance for Water Efficiency Water Conservation Tracking Tool and are treated as one of several supply sources that are used to evaluate how forecasted demands will be met. Climate change scenarios are selected from a range of downscaled climate projections and implemented using the climatic components of the sectoral models.

Table 2-5: SDCWA Forecast Summary

Agency and Categorization and Population Served	Wholesale (~3.3 M served)
Sources for Model Input	• SANDAG • SDCWA assessments of crop types and requirements
Documents Used in Forecast Review	• Water Demand Model and Forecast Update 2015 (Hazen 2015) • 2015 UWMP (SDCWA 2016)

Typology	Approach	Details
Forecast Segmentation	Segmented by sectors, geography, time	Sectors/Land Uses • Single-family Residential • Multifamily Residential • Nonresidential • Agricultural • Unclassified • Losses Geographic • 24 member agencies (including Pendleton Military Reservation) Temporal • Annual • Monthly
Rate of Use Differentiation	Differentiated	Drivers • Households • Employees • Irrigated acres
Method	Statistical (Econometric) + Judgmental + Associative (End Use)	Modeled Variables (estimated elasticities) • Price (SFR: -0.23, MFR: -0.14, NR: -0.17 to -0.34, AG: -0.61) • Median Household Income (SFR: 0.54, MFR: 0.07) • Persons per Household (SFR: 0.44, MFR: 0.56) • Housing Density (SFR: -0.31, MFR: -0.30) • USD Economic Index • Watering Restrictions • Employment Mix • Employment Density • Normal Avg. Max Temperature • Avg. Max Temperature Deviation • Normal Precipitation • Precipitation Deviation • Crop type distribution • Crop evapotranspiration requirements
Method (continued)		Notes • Pendleton demands provided externally to model • Price elasticities for the single-family, multifamily, and nonresidential sectors are reduced by 20 percent in early years of the forecast horizon
Forecast Scenarios	Explicit Scenarios	• Climate Change • Single hot/dry year • Consecutive hot/dry years • w/Conservation

2.4.2 Metropolitan Water District of Southern California

The majority of Southern California's population is served by MWD. The district is a wholesaler that supplies its 26 member agencies over a service area of 5,200 square miles in Los Angeles, Orange, Riverside, San Diego and Ventura counties. Although the MWD service area only covers 14 percent of the area of these counties, it supplies 85 percent of the population. About half of the of MWD's supplies come from local surface water, groundwater basins and the L.A. Aqueduct. The other half of the district's supply comes from the Bay-Delta system through the State Water Project and the Colorado River. Metropolitan has several projects within each of its member agencies exploring local supply sources including desalination, groundwater recovery, and water recycling.

MWD's demand forecast takes a broad perspective, estimating "total demand" on MWD to include M&I), Seawater Barrier, Groundwater Replenishment, and Retail Agriculture demands (Table 2-6). Retail M&I demand forecasts are generated from a set of three econometric models estimated for the single-family residential, multifamily residential, and composite CII sectors, respectively. M&I forecasts are further segmented by County and member agency and both the econometric modeling and projections use an annual time step. The specification of model variables differs across econometric models, including the definition of the variable capturing the influence of price. The models are estimated from historical data collected from MWD member agencies and their respective retailers.

Prior to model estimation, estimates of past water conservation savings generated from MWD's Conservation Savings Model were added to the observed historical consumption data. The Conservation Savings Model is an end use model designed to estimate the effects of code-based and active efficiency measures over time. Projections of per household demand for the residential sectors and per employee demand for the CII sector are multiplied by projections of households and employees, respectively, to obtain baseline "pre-conservation" forecasts in volumetric terms. The Southern California Association of Governments (SCAG) and SANDAG are the primary source of projection data for model inputs and forecast drivers. The "pre-conservation" forecasts deduct estimated savings from the Conservation model to produce "post-conservation" forecasts, which reflect the remainder of Retail demands that are expected to be met through other supply sources. The models are calibrated to reproduce 2013 "post-conservation" demands by MWD member agency and sector.

Table 2-6: MWD Forecast Summary

Agency and Categorization and Population Served	Wholesale (~19 M served)
Sources for Model Input	• SANDAG • SCAG
Documents Used in Forecast Review	• 2015 Integrated Water Resources Plan (IRP) Technical Appendices (MWD 2015) • 2015 UWMP (MWD 2016)

Typology	Approach	Details
Forecast Segmentation	Segmented by sectors, geography, time	Sectors/Land Uses • Retail M&I (SFR, MFR, CII, Unmetered) • Retail Agriculture* • Seawater Barrier* • Groundwater Replenishment* Geographic • 26 member agencies • 6 Counties Temporal • Annual ** Prepared by member agencies and groundwater management districts*
Rate of Use Differentiation	Differentiated	Drivers • Households • Employees
Method	Statistical (Econometric) + Judgmental + Associative (End Use)	Modeled Variables (estimated elasticities) • Average Price (SFR: 0 to -0.50) • Median Tier Price (MFR: -0.11, NR: -0.43) • Median Household Income (SFR: 0.29, MFR: 0.17) • Persons per Household (SFR: 0.10, MFR: 0.14) • Median Lot Size (SFR: 0.69, MFR: 0.16) • Share of Employment in Manufacturing • Avg. Max Temperature (SFR, CII only) • Annual Precipitation (SFR only) • Annual Cooling Degree Days (CII only) Notes • Reported SFR price elasticity implied range from interaction with lot size variable • Estimated price elasticities reduced by 33 percent in early part of forecast horizon
Forecast Scenarios	Explicit Scenarios	• Single dry year • Multiple dry years • With conservation

2.4.3 Tampa Bay Water

TBW is a wholesale water provider to more than 2.5 million people in the Tampa Bay (FL) region. Residential demands account for nearly 75 percent of billed water consumption, with the remainder associated with the needs of commercial businesses and industry. Tampa Bay Water's water demand is comprised of demands from six member governments, or members, across a three-county area. These member demands are satisfied through bulk deliveries of water from Tampa Bay Water at 15 points of potable water connection. Members then use these bulk deliveries to satisfy retail demand for individually billed water accounts. In addition, some members resell water on a wholesale basis to other local utilities. Members provide water to customers located within seven geographical planning units known as Water Demand Planning Areas (WDPAs). The region's water is blended from three different sources: groundwater, surface water and desalinated seawater. TBW's water supply facilities include a 120 million gallons per day (mgd) surface water treatment plant, a 25 mgd Tampa Bay Seawater Desalination Plant, a 15.5 billion gallon reservoir, and 120 mgd of permitted capacity from groundwater.

TBW's forecast is based on a set of three econometric models, which project monthly unit usage rates for the single-family, multifamily, and nonresidential sectors, respectively (Table 2-7). The sectoral water use models were estimated from data at a Census Tract scale and were subsequently calibrated to and applied at the WDPA level. Parcel-level data on water use were aggregated up to tract level for modeling and provided key information on specific attributes, such as housing density, year built, and business type. Model calibrations were designed to reproduce recent 3-year average demands by sector and WDPA. Forecast drivers include housing units for the residential sectors and building square footage for the nonresidential sector. For the forecast, future nonresidential square footage is assumed to follow employment projections, which were available for the region.

Average efficiency of toilet fixtures was taken as an indicator of general trends in baseline and future water efficiency. Water efficiency factors were based on changes in average flush volume estimates derived from a fixture stock model. The efficiency index was used as an explanatory variable in the econometric models alongside other variables, allowing direct estimation and projections of passive efficiency using the index as a proxy. The use of the efficiency index variable permits direct development of baseline and passive efficiency forecast scenarios using the econometric model. In addition, future values of model inputs are generated using Monte Carlo simulation and assumptions about input distributions, which produce a probabilistic forecast interval for sector and total production demands.

In general, projections of model inputs required derivation from several sources, since there is no metropolitan planning organization to rely upon. The main sources for assumptions include the University of Florida and Moody's Economy.com, which provides county-level projections for several socioeconomic and demographic metrics for purchase or via paid subscription.

Table 2-7: TBW Forecast Summary

Agency and Categorization and Population Served	Wholesale (~2.5 M served)
Sources for Model Input	• University of Florida Bureau of Economic and Business Research (BEBR) • Moody's
Documents Used in Forecast Review	• Personal communication • Long-Term Demand Forecast Model Redevelopment and Base-Period 2014-2016 Forecasts (Hazen and Sawyer, forthcoming)

Typology	Approach	Details
Forecast Segmentation	Segmented by sectors, geography, time	<u>Sectors/Land Uses</u> • SFR • MFR • NR • Member Wholesale • Unbilled <u>Geographic</u> • 7 WDPAs <u>Temporal</u> • Annual • Monthly
Rate of Use Differentiation	Differentiated	<u>Drivers</u> • Households • Square footage / employees
Method	Statistical (Econometric) + Judgmental	<u>Modeled Variables (estimated elasticities)</u> • Price (SFR: -0.33, MFR: -0.18, NR: -0.31) • Median Household Income (SFR: 0.28, MFR: 0.07, NR: 0.31) • Persons per Household (SFR: 0.36) • Housing Density (SFR: -0.13, MFR: -0.11) • Fraction Accounts with Reclaimed Water (SFR and NR only) • Passive Efficiency Index • Share of NR Sq. Footage among 10 Industry Classes • Seasonality • Avg. Max Temperature Departure from Normal • Monthly Precipitation Departure from Normal
Forecast Scenarios	Explicit Scenarios	• Baseline • With passive savings • Probabilistic

2.4.4 Contra Costa Water District

CCWD is both a water retailer and wholesaler, providing water to approximately 500,000 people in central and eastern Contra Costa County California. Retail customers for treated water reside in the communities of Clayton, Clyde, Concord, Pacheco, Port Costa and parts of Martinez, Pleasant Hill and Walnut Creek. CCWD provides treated water on a wholesale basis to the City of Antioch, the Golden

State Water Company in Bay Point, and a portion of the City of Brentwood, and untreated water to the cities of Antioch, Martinez, and Pittsburg, and Diablo Water District. The District obtains its water supply exclusively from the Sacramento-San Joaquin Delta (Delta), distributing water through the Contra Costa Canal. CCWD has four untreated water storage reservoirs and operates three water treatment plants. The distribution system for treated water also relies on treated water storage reservoirs, pump stations, and pipelines.

The description of CCWD's forecasting approach (Table 2-8) was based on review of CCWD's recent UWMP, as well as documentation obtained from a chapter of CCWD's Future Water Supply Study (marked as Draft Final). The model used to project municipal demands within the treated water service area and municipalities is reported to include the effects of "influence factors". These factors include unemployment rate, per capita income, and weather. Population projections are utilized, which implies that the influence factors are used to estimate per capita use. The effects of weather are estimated on monthly data, though all forecasts are provided on an annual basis. Future use in unincorporated areas are assumed to change proportionally with future population. Industrial use projections are based primarily on assumptions utilizing available information and are held constant over the forecast period, except for an allowance for future industrial expansion. Untreated irrigation demands, evaporative losses, and conveyance losses are held constant at calculated levels. The forecasts do not include the effects of water savings from passive and active programs, which are considered as sources of supply.

Table 2-8: CCWD Forecast Summary

Agency and Categorization and Population Served	Total system (500,000; ~200,000 retail)
Sources for Model Input	• Planning documents of member municipalities • California Department of Transportation • ABAG
Documents Used in Forecast Review	• 2015 UWMP (CCWD 2016) • Future Water Supply Study – Final Draft (Chapter 4)

Typology	Approach	Details
Forecast Segmentation	Segmented by sectors, geography, time	Sectors/Land Uses • Municipal • Industrial • Untreated water irrigation demands Geographic • Treated Water Service Area • 6 municipalities • Unincorporated areas Temporal • Annual
Rate of Use Differentiation	Differentiated (implied for municipal users in the treated water service area, municipalities, and unincorporated areas)	Drivers • Population
Method	Statistical (Econometric) + Judgmental	Modeled Variables • Unemployment rate • Per capita income • Precipitation • Avg. Max. Daily Temperature
Forecast Scenarios	Explicit Scenarios	• Normal weather • Dry weather (reported)

2.4.5 Sonoma County Water Agency

SCWA is a wholesale water provider that serves a large area of Sonoma County and the eastern portion of Marin County. The Agency is responsible for supplying 14 municipalities and in 2015 served an estimated a population of 614,196 people. SCWA supply is almost entirely surface water from the Russian River treated for potable use. SCWA can use groundwater from the Santa Rosa Plain to augment surface water when necessary. The agency has obligations to adjust flowrates in the Russian River to help rehabilitation efforts of threatened salmon species. Projected demand for 2040 exceeds the agency's maximum allocations, and, as a result, SCWA is seeking larger allocations and more storage space in Lakes Mendocino and Sonoma, which are operated in coordination with the U.S. Army Corps of Engineers.

Table 2-9 on the following page provides a summary of SCWA's water demand forecast features. SCWA employs a judgmental water demand forecasting method in that the agency compiles demand forecasts of the agencies to which it provides wholesale water. These demands are segmented as "sales to other agencies," and are net demands on SCWA, counting the effects of any water conservation and recycled water projects, as well as system losses. There is some indication that the 14 agencies served by SCWA use consistent forecasting and conservation assessment methodologies, such as the DSS Model.

SCWA's forecast contains eight other categories, although current forecasts are non-zero only for Agricultural Irrigation (which is constant over the forecast horizon), "Retail demand for use by agencies that are primarily wholesalers", and Losses. For the "Retail demand for use by agencies that are primarily wholesalers" category, SCWA forecasts water use based on estimated rates of population growth. Losses reflect SCWA's estimates of transmission losses and are top of any losses estimated by SCWA's retailers.

Table 2-9: SCWA Forecast Summary

Agency and Categorization and Population Served	Wholesale (~0.6 M served)
Sources for Model Input	• Forecasts embed assumptions used by Agency customers, including conservation • Association of Bay Area Governments (ABAG)
Documents Used in Forecast Review	• 2015 UWMP (SCWA 2016)

Typology	Approach	Details
Forecast Segmentation	Segmented by category, geography, time	Forecast Categories • Sales to other agencies • Transfers to other agencies • Exchanges to other agencies • Groundwater recharge • Saline water intrusion barrier • Agricultural irrigation • Wetlands or wildlife habitat • Retail demand for use by agencies that are primarily wholesalers with a small volume of retail sales • Losses Geographic • 8 Water Contractors • 5 Other Transmission System Customers • 1 Municipal Water District • Collection of Other small users Temporal • Annual
Rate of Use Differentiation	Not differentiated	N/A
Method	Judgmental + Associative	• Sales to other agencies compiled as sum of demand forecasts provided by Contractor and District UWMPs • Retail demand for use by agencies that are primarily wholesalers based on population growth
Forecast Scenarios	None	N/A

2.4.6 Zone 7 Water Agency

Zone 7 is a wholesaler that serves a population of about 240,000 people served by four water retailers including the cities of Pleasanton and Livermore, California Water Service Company-Livermore, and Dublin San Ramon Services District. Zone 7 also provides untreated water for agricultural irrigation of

3,500 acres. Zone 7 derives the majority of its water from the State Water Project (around 80 percent) and operates four wellfields primarily for backup supply during droughts. During wet years, Zone 7 uses a portion of its State Water Project water, along with local surface runoff water to recharge the region's groundwater basin. Zone 7 also has groundwater-banking rights in Kern County, which can be drawn upon during drought.

As indicated in Table 2-10, Forecasts for Zone 7's water retailers are based on each retailer's own forecasting methodologies. Zone 7 aggregates the forecasts of its retailers into a "Sales to other agencies" category and does not report the forecasts of retailers individually. Zone 7 derives forecasts for a small set of 6 retail customers, which is held constant over the forecast horizon. Water for groundwater recharge, groundwater banking, and surface storage are counted in the categorization of demands. Zone 7's forecasts contain separate line items for losses associated with storage and transmission.

Table 2-10: Zone 7 Forecast Summary

Agency and Categorization and Population Served	Wholesale (~0.24 M served)
Sources for Model Input	• Forecasts embed assumptions used by Agency customers, including conservation
Documents Used in Forecast Review	• 2015 UWMP (Zone 7 2016)

Typology	Approach	Details
Forecast Segmentation	Segmented by category, geography, time	Forecast Categories • Sales to other agencies • Agricultural irrigation • Retail demand for use by agencies that are primarily wholesalers with a small volume of retail sales (Direct Retail) • Groundwater recharge • Other-Groundwater Banking • Other-Surface Water Storage • Losses-Storage • Losses-Transmission • Potable water • Raw water Geographic • Service area wide Temporal • Annual
Rate of Use Differentiation	Not differentiated	N/A
Method	Judgmental	• Forecast compiled as sum of demand forecasts provided by Contractor and District UWMPs
Forecast Scenarios	None	N/A

2.5 Summary of Benchmarking Analysis

The review of water demand forecasting methodologies employed by selected Bay Area water providers and other wholesale water agencies shows a diversity of practices and as indicated in the typology of forecasting approaches, a significant amount of nuance in application. Statistical (econometric) models tend to be developed in cases where ample historical data permits and when there is interest in explaining variability. Several estimated elasticities for economic and demographic variables are available from those agencies reviewed, as well as from the literature, but their values vary due to several factors.

End use models tend to be employed when water conservation alternatives are being evaluated for implementation and to account for the effects of passive measures so they can be deducted off of future "baseline" demands. The Alliance for Water Efficiency Water Conservation Tracking tool and the DSS Model were referenced frequently in the reviewed documentation. These models tend to focus on allocating per unit (e.g., per capita) rates of water use into end use components using the findings of available end use research, but do not technically represent "bottom up" approaches that attempt to model individual end uses separately to arrive at a total rate of consumption.

Econometric and end use models are often used together to generate "with conservation" forecast scenarios. The types of forecast scenarios that are generated tend to be limited to those associated with climate and water conservation, though some models can generate several other scenarios based on socioeconomic model parameters. For the California agencies reviewed, the scenarios that are implemented tend to be tied to UWMP requirements.

Differentiation of unit rates of water usage from volumetric totals is common, and with population, housing, and employment often used as forecast drivers. These drivers represent unit counts that are generally more likely to be forecasted by regional and metropolitan planning agencies, such as ABAG. Typically, forecasts are segmented into annual time steps for reporting purposes, and in some cases the annual values reflect sums of monthly forecast values. Geographical disaggregation of demand forecasts is common, generally revolving around jurisdictions or planning areas served by the water agency.

There seems to be a distinct divergence in forecasting approaches used by water wholesalers. There are those who model and forecast the demands of water retailers and those who take the forecasts of water retailers directly as input into the preparation of their forecasts. The former seems more applicable to cases where institutional arrangements are clear cut (such as when a single regional wholesaler serves a defined geographic region) and/or when routine data collection mechanisms with retailers have been in place for some time. The latter case could be viewed as an efficient use of available information, particularly for periodic reporting requirements (such as UWMPs in California).

With a few exceptions (e.g., BAWSCA and SCWA), most water supply utilities did not explicitly identify a modeling platform or tool for developing their demand forecasts. Based on Hazen and Sawyer's experience on the subject, most utilities that employ associative and statistical modeling methods fit their forecast equations in statistical modeling packages, such as R, MATLAB, or SAS.[10] However, these statistical modeling packages are usually not the application used to calculate the forecasts themselves. When conducting forecast exercises (e.g., conducting scenario analysis), utilities often house their

[10] Excel can potentially be used in simple cases.

forecast equations in a spreadsheet, geographical information system (GIS) application, relational database, or dashboard application in order to streamline alteration of model parameters and conditions.

2.5.1 Characterization of Valley Water's Prior Forecast Approach

Valley Water's 2015 UWMP describes the features of Valley Water's water demand forecast methodology. Valley Water's forecast is segmented by its 13 water retailers and is reported in five-year increments. Additional line items include forecasts for agricultural groundwater pumping, independent groundwater pumping, raw water, and losses, which, except for losses, are assumed constant over the forecast horizon. The forecast is reported in terms of annual totals but can be post-processed into months. Forecasts prepared by Valley Water's retailers are compiled and aggregated to calculate the forecast, which generally classifies the forecast as judgmental within the demand forecasting typology. There are no explicit additional forecast scenarios reported in Valley Water's 2015 UWMP, and the forecasts generated by the retailers embed (to the extent they were evaluated) any estimated effects from water conservation and recycled water. The 2015 UWMP does, however, provide a discussion on some of the forecasting uncertainties that may ultimately influence the accuracy of the forecast, such as rate of rebound from past drought management actions, the potential for future water use mandates, economic development patterns, and climate change. Though the 2015 UWMP did not review any explicit scenarios, Valley Water actively conducts internal scenario analysis as part of their planning activities, which includes the most recent "trending scenario" used to inform the most recent Water Supply Master Plan.

Though the forecasts reported in Valley Water's 2015 UWMP are generally based directly on the forecasts prepared by water retailers, Valley Water prepared its own county-wide forecast segmented by service area, independent pumpers, and agriculture for water supply planning purposes using the IWR-MAIN Water Demand Management Suite's Forecast Manager module. Fundamental inputs for IWR-MAIN include selection of a base year, designation of geographic areas (i.e., service areas), and definition of sectors. For this effort, a base year (2013) was selected, 12 retailers were defined as study areas[11], and 7 sectors were classified (single-family, multifamily, commercial, industrial, institutional, irrigation, and other). Historical estimates and projections for housing and jobs were consolidated from ABAG and US Census data at the Census tract level and then aggregated geographically by retailer. Using ABAG rates of change in housing and jobs, growth factors were calculated and applied by retailer and water use sector to generate retail forecasts county-wide and by retailer. Although considerable judgment was involved in defining the forecast factors, this secondary approach employed by Valley Water can be classified as an associative model, in that future changes in consumption are associated with projected rates of change in housing and employment. Implicitly, this technique equates to an application of a fixed coefficient model, which was generalized earlier in Equation (2).

2.5.2 Benchmarking Implications for Valley Water

Overall, the implication of the benchmarking analysis is that there is considerable "freedom of choice" for Valley Water in terms of adopting a forecasting methodology or forecasting model, consistent with the

[11] Stanford was not explicitly modeled in the prior forecast.

nuances of the working demand forecasting typology. However, several internal factors / requirements indicate that a model framework with the following characteristics will meet Valley Water's demand forecasting needs:

- Statistical / econometric analytical approach;
- Rate of use differentiation; and
- Segmentation by water use provider and time of year.

A statistical / econometric approach is recommended based on the availability of historical data and Valley Water's desire to explain variability in demand and conduct scenario analyses. There is substantial historical data available to support robust fitting of statistical models; a detailed review of the historical data is presented in Section 3. Communication with Valley Water staff indicates a desire to better understand the historical variability in county-level water demand as well as the explanatory factors influencing variability. In addition to understanding historical variability, Valley Water desires the ability to develop scenario-based demand forecasts using varying key parameters, such as projections of housing units and density. Statistical models are ideal for these applications, as they allow for the empirical quantification of the magnitude and direction of external factors (e.g., socioeconomic and climactic) on water demand. Understanding these relationships with historical data provides a basis for future scenario analysis using differing projections of the external factors/drivers. An end use accounting approach is not recommended given Valley Water's investment in a stand-alone conservation forecast model.

The recommendation for rate of use differentiation is directly related to Valley Water's desire to understand historical variability and to conduct future scenario analyses. Understanding how the rate of water use varies over time is useful in understanding overall trends in water demand, as it disconnects the influence of driver unit growth – which characterizes the future number of people, housing units, and employment that may be served in the future – from the intensity at which water might be used by end users. Differentiating rates of water use allows for a more complete analysis of the influence of external factors on different segments of water demand.

Finally, Valley Water's long-term planning process involves integrated modeling of future water supply and demand. Valley Water conducts these exercises in its Water Evaluation and Planning (WEAP) model, which uses forecasted water demand as a model input. The WEAP model runs on a monthly time step and has different model "nodes" for water specific supply providers (e.g., retail agencies and non-retail groundwater pumpers). Given this structure, a water demand model segmented by water use provider and time of year was recommended.

3. Historical Data Collection and Review

This section documents the data collection and data processing activities performed to support development of the water demand model. Data sources documented in this section are limited to historical datasets; review of datasets describing projected future conditions/assumptions are documented in Section 4.

3.1 Purpose and Scope of Historical Data Collection

The benchmarking analysis discussed in Section 2 reviewed a typology of commonly used demand forecasting methods. Together with a review of Valley Water data availability and forecasts performed by other peer agencies, it was recommended that the following methodological elements would meet Valley Water's needs:

- Model segmentation by type of provider (i.e., retail agency, non-retailer groundwater pumper), geography, sector/billing classification, and time of year.
- Differentiation of rate of use (i.e., characterizing consumption to reflect water use intensity) based on dividing billed consumption by a count of driver units (e.g., housing units).
- A statistically based modeling approach (e.g., regression/econometric, modified forecast factor).[12]

Development / parameterization of segmented statistical models requires a robust historical dataset consisting of water consumption, driver units, and explanatory variables used to explain variability in water use. Table 3-1 provides a summary of the datasets obtained for these categories as well as the raw data sources collected to support them. The following sections provide a detailed description for each dataset summarized in Table 3-1.

[12] A detailed summary of the model segmentation, rate of use differentiation, and statistical approach is provided in Section 4.

Table 3-1: Summary of Historical Data Collected for Model Development

Data Category	Dataset	Data Source(s)
Water use	Historical billed consumption and accounts	• Retailer billing records • Groundwater production from Valley Water's Water Supply Production Database (WSPD)
Driver units	Single family and multifamily housing units	California Department of Finance
	Sectoral employment	US Census
	Campus population[a]	BAWSCA Annual Survey
Explanatory variables	Observed weather	Parameter-elevation Regressions on Independent Slopes Model (PRISM)
	Water rates	• Valley Water provided compilation of retailer residential sector water rates • Groundwater rates by charge zone
	Drought restrictions	Valley Water records of timing of restrictions (i.e., beginning and end dates) and severity (i.e., the requested amount of cutback in percentage terms)
	Economic index	Economic Cycles Research Institute (ECRI) U.S. Monthly Coincident Index
	Median income	US Census
	Housing density	• California Department of Finance
	Persons Per Household	• Valley Water GIS data
	Relative sectoral economic activity	• US Census • ABAG

[a] Campus population is a driver unit for Stanford University (Stanford) only. See Section 3.3.3.

3.2 Data Collected from Retail Agencies

Each of Valley Water's 13 water supply retail agencies provided historical records of billed consumption and number of accounts to support development of the demand model. This section provides an overview of the data provided and discusses how retailer data was standardized prior to use in model development.

3.2.1 Description of Retailer Data

Valley Water's retailer agencies were asked to provide monthly historical billed consumption and accounts, by billing classification, from year 2000 to 2018 (or as many years that were reasonably obtainable). Billed consumption is representative of total water use from all supply sources (i.e., treated water purchased from Valley Water, groundwater, local surface water, and deliveries from SFPUC). Figure 3-1 provides a summary of the historical data provided by each retail agency as well as an identification of the implemented billing cycle (i.e., monthly, or bimonthly). The time period requested for water use data covers a representative period of modern water use while obtaining a statistically robust dataset size.

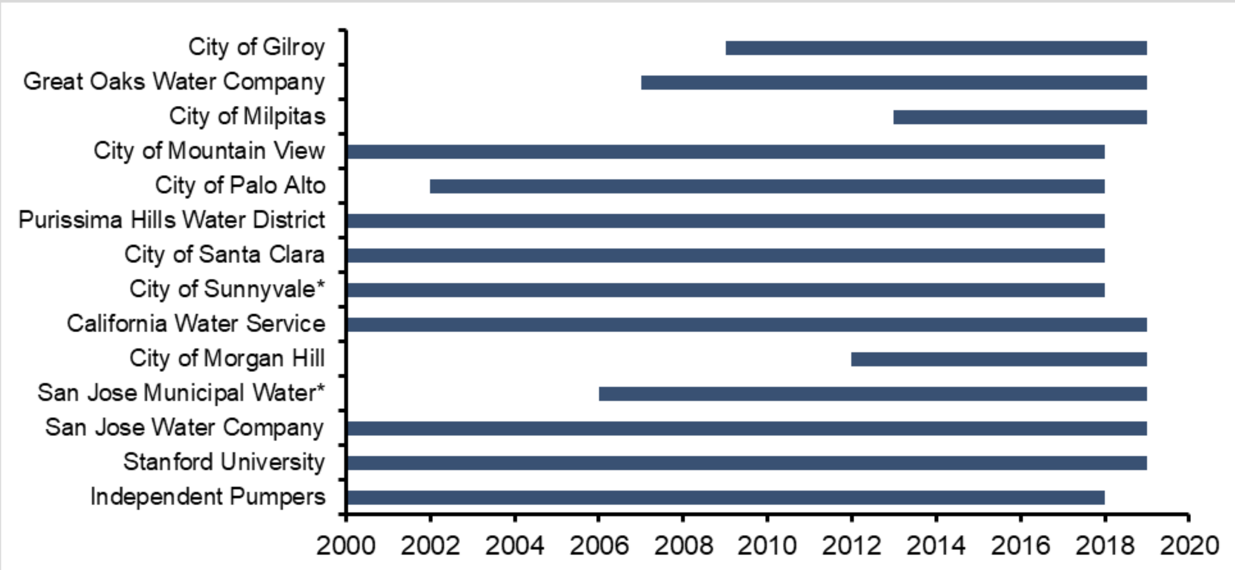


Figure 3-1: Summary of Time Range of Available Billing Data Provided by Retail Agencies (Agencies with Bi-Monthly Data Marked with Asterisk)

Consumption data was not consistently available back to 2000 for all retailers. The majority of retail agencies (8 of 13) provided historical consumption and account data as far back as at least 2002 and all agencies were able to provide data up to at least 2018. Five agencies provided a smaller record of data, spanning 6-12 years rather than the requested 18 years. In order to maximize the number of observations for estimation, all available water use records were retained in the modeling dataset. Thus, the dataset represents an "unbalanced panel" (i.e., not all retail agencies have the same number of observations for the same time periods).

Retail agencies provided billing and account data organized by their internal billing classifications. Billing classifications were relatively consistent between retailer agencies for defining residential water use (i.e., most retail agencies characterized separate classifications for single family and multifamily sectors). Billing classifications were less consistent in describing non-residential uses. Most agencies defined a commercial billing classification, however distinction and definition of industrial, institutional, and irrigation (i.e., landscape) classes were inconsistent across retail agencies. It is not uncommon for water utilities to differ in how specific non-residential accounts/end uses are classified and billed. For example, certain retail agencies include industrial or institutional uses within their commercial billing classification. Similarly, landscape use is not necessarily limited to a single end use and not all retailers reported landscape use (e.g., water billed within a landscape category could represent use at commercial, industrial, institutional, and residential properties). A summary of billing classifications provided by each retail agency is provided in Appendix A.

3.2.2 Standardization of Retailer Data

As identified in Section 3.2.1, data provided by retail agencies had unique characteristics, particularly associated with billing classifications and billing cycles. The proposed statistical modeling strategy involved pooling historical observations across all retail agencies, which requires standardization of retail agency billing classification and consumption.[13] Billing classifications for each retail agency were initially assigned a standardized water use sector which are further summarized in Table 3-2 below.

Table 3-2: Summary of Standardized Water Use Sectors

Standardized Water Use Sector	Description
Single Family	Water use associated with single family residential homes
Multifamily	Water use associated with multifamily residential properties
Commercial	Water use associated with commercial developments (e.g., offices, hotels, restaurants)
Industrial	Water use associated with industrial applications (e.g., manufacturing, mining, warehousing)
Institutional	Water use associated with institutional activity (e.g., educational services, public administration, hospitals/health care)
Landscape / Recycled	Water use associated with outdoor non-residential (typically non-agricultural) irrigation
Other	Other water use, often categorized as “other” by retail agencies, but also inclusive of classifications not well represented by the standardized water use sectors above (e.g., construction, fire line, miscellaneous)

For each retail agency, water consumption was converted to million gallons (MG) and totaled by standardized water use sector. Analysis of these data (including initial testing of econometric model development[14]) suggested inconsistent classification of commercial, industrial, and institutional activity among retail agencies (e.g., inclusion of industrial or institutional water uses within a commercial billing classification). Additional data, such as identification of specific accounts and associated water uses, was not available to further pre-process and standardize the retail agency non-residential consumption.

Uncertainty and inconsistency in retail agency definitions associated with commercial, industrial, and institutional water use can affect the fit and performance of statistical demand models. To address this, the commercial, industrial, and institutional sectors were combined into an aggregate “CII” sector for modeling. Discussions with retail agencies’ staff provided additional information supporting the allocation of landscape and recycled water use into other modeled sectors. For Valley Water’s modeling, recycled water is considered a supply to meet demands rather than as a demand. Valley Water relies on retailer UWMP forecasts of the proportion of total demands that would be met through recycled water and uses those numbers to quantify the non-potable recycled water demand within Santa Clara County. A summary of the final model sectors used for model development is provided in Table 3-3 on the following page. A detailed summary of the translation between retail agency billing classifications, standardized water use sectors, and model sectors is presented in Appendix A. Figure 3-2 provides a historical record of total annual billed consumption for all 13 retail agencies for years in which all data was available (i.e., 2013-2018).

[13] Ibid.
[14] Ibid.

Table 3-3: Summary of Final Sectors Used for Demand Model Development

Standardized Water Use Sector	Model Sector	Description
Single Family	Single Family	Water use associated with single family residential homes
Multifamily	Multifamily	Water use associated with multifamily residential properties
Commercial	CII	Water use associated with all CII activity
Industrial		
Institutional		
Landscape / Recycled	Included in CII and/or multifamily sectors based on input from retail agencies	Water use associated with outdoor non-residential (typically non-agricultural) irrigation
Other	Other	Other water use, often categorized as "other" by retail agencies, but also inclusive of classifications not well represented by the standardized water use sectors above (e.g., construction, fire line, miscellaneous)

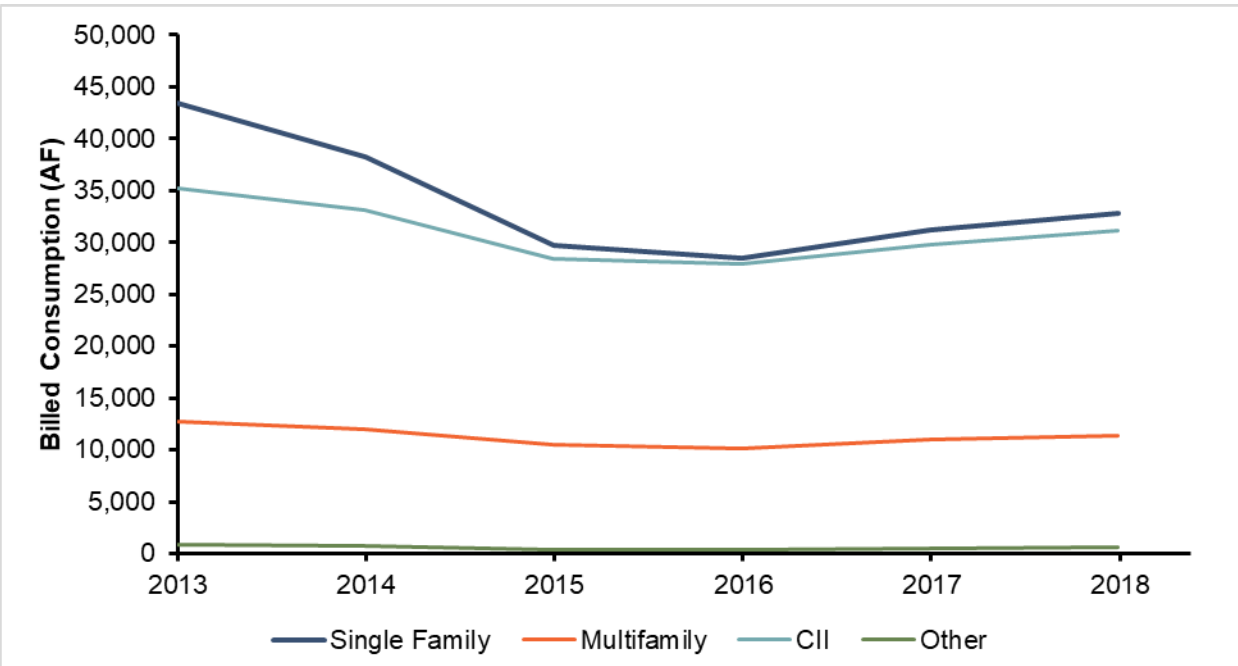


Figure 3-2: Total Annual Consumption by Model Sector

3.3 Development of Retail Agency Driver Units

Driver units reflect the size or scale of a water use sector and allow for differentiation of rate of use from total consumption. In order to be useful for model development and forecasting, driver units must have a consistent historical record coincident with consumption and have a corresponding future dataset representing projected driver unit counts. Driver units were selected for each model sector to meet criteria for model development and efficient forecasting. The selected driver units for each model sector are shown in Table 3-4. The following sections detail the data sources and data processing used to develop estimates of drivers for each retail agency and model sector.

Table 3-4: Driver Units by Model Sector

Model Sector	Driver Unit
Single Family	Housing Units
Multifamily	Housing Units
CII	Jobs, Population (for Stanford only)
Other	N/A[a]
[a] Other water use was projected as a percentage of total single family, multifamily, and CII consumption. See Section 4.	

3.3.1 Residential Housing Units

Housing units for the residential sectors (single family and multifamily) were developed based on data from the California Department of Finance (CADOF) and retail agency provided number of accounts. Driver units for single family residential water use were assumed to be equal to the number of single family accounts reported by retail agencies as the number of single family accounts is generally a good indicator of the number of single family housing units. Multifamily accounts are an inappropriate measure of housing units, as many multifamily dwellings are collectively billed based on a single meter. To account for this, multifamily housing units were calculated by subtracting the estimated total number of single family housing units (equal to single family accounts) from the total number of housing units reported by CADOF. Note that only total residential accounts were available for San Jose Water Company rather than single family and multifamily accounts; as such, single family housing units for San Jose Water Company were estimated directly from single family housing units reported by CADOF.

Distinct housing unit data were required for each retail agency to support model development. CADOF data were available by city boundaries, which required geoprocessing to retailer service area boundaries. Geoprocessing was performed using GIS overlays of city and census tract boundaries (County of Santa Clara Open Data Portal) , retail agency service area boundaries (California Department of Water Resources Water Management Planning Tool) , and parcel-level land use data from the Santa Clara County Assessor. Figure 3-3 illustrates an example of how city boundaries were aggregated to retailer service area boundaries. In Figure 3-3, the two large bold boundaries represent two retailer boundaries and the six numbered boundaries with dashed borders represent city boundaries. The number of residential parcels were first spatially aggregated within city boundaries. The percent of parcels in each city that fell within each retailer service area boundary was then calculated, resulting in a city-retailer ratio. For example, in Figure 3-3, 50% of city 5 falls within the Retailer A boundary, and 50% falls within the Retailer B boundary. The CADOF housing units associated with each city were multiplied by the city-retailer ratio and values were summed by retailer boundary, as demonstrated in Table 3-5.

Figure 3-3: Example of Overlapping City Boundaries within Retailer Service Area Boundaries

Table 3-5: Example of City-Retailer Ratio Calculations

City	DOF Housing Units	City-Retailer Ratio		DOF Value x City-Retailer Ratio	
		Retailer A	Retailer B	Retailer A	Retailer B
1	100	1	0	100	0
2	200	0	1	0	200
3	100	0	1	0	100
4	300	1	0	300	0
5	500	0.5	0.5	250	250
6	300	0	1	0	300
Total	**1500**	**-**	**-**	**650**	**850**

The processed housing units for the latest concurrent year (2017) are presented by retailer in Table 3-6. Note that Purissima Hills Water District has no parcels classified as multifamily residential land use and was therefore excluded from the multifamily residential model. Time series plots of processed residential housing units are presented in Appendix B.

Table 3-6: 2017 Estimated Residential Driver Units by Retailer (Average Housing Units)

Retail Agency	Single Family Housing Units	Multifamily Housing Units
California Water Service	16,943	6,569
City of Gilroy	13,210	1,115
City of Milpitas	12,397	9,106
City of Morgan Hill	10,002	2,851
City of Mountain View	12,495	20,683
City of Palo Alto	15,167	13,688
City of Santa Clara	17,181	29,263
City of Sunnyvale	23,794	30,681
Great Oaks Water Company	19,834	10,681
Purissima Hills Water District	2,070	-
San Jose Municipal Water	25,452	12,832
San Jose Water Company	206,175	114,104
County-Wide Retail Agency Total	**374,719**	**251,573**

3.3.2 CII Jobs

CII jobs were estimated from data obtained from the U.S. Census Bureau Longitudinal Employer-Household Dynamics (LEHD) Origin-Destination Employment Statistics (LODES) dataset (U.S. Census Bureau, 2020). The LODES dataset provides a historical estimate of the number of jobs by industry, provided by census tract for 2002 to 2017. Similar to the residential sectors, census tract-level CII jobs needed to be geo-processed to align with retail agency service area boundaries. Tract-retail agency scaling ratios were calculated based on non-residential parcels using the same general approach described in Section 3.3.1.

The LODES data categorizes jobs by North American Industry Classification System (NAICS) sector, which is the standard used by federal statistical agencies. Historical driver units used for model fitting were equivalent to the sum of all non-agricultural jobs reported in the LODES dataset. All NAICS sectors excluding "Agriculture, Forestry, Fishing and Hunting" were aggregated to estimate total CII jobs. The processed CII jobs for the latest concurrent year (2017) by retail agency is shown in Table 3-7. Time series plots of processed CII jobs are presented in Appendix C.

Table 3-7: 2017 Estimated CII Driver Units by Retailer (Average Non-Agricultural Jobs)

Retail Agency	Total Jobs
California Water Service	57,736
City of Gilroy	13,156
City of Milpitas	43,708
City of Morgan Hill	15,482
City of Mountain View	85,356
City of Palo Alto	115,603
City of Santa Clara	110,535
City of Sunnyvale	68,720
Great Oaks Water Company	21,294
Purissima Hills Water District	2,618
San Jose Municipal Water	84,085
San Jose Water Company	417,012
County-Wide Retail Agency Total	**1,066,863**

Although driver units are the total number of all non-agricultural jobs, distinct economic sectors were maintained to use as explanatory variables in the model. These explanatory variables are described in Section 3.6.8.

3.3.3 Stanford University Population

Stanford has several characteristics that dictate different driver unit classification and processing from the other retail agencies. As an educational institution, all water use associated with Stanford was classified with the CII sector for the purposes of Valley Water's demand model development. Despite being classified as CII, number of jobs is not an entirely appropriate driver unit since employees make up only a portion of the water users at the university; as of 2015, Stanford serves approximately 23,000 students in addition to 14,000 faculty and staff. To account for all water users the total population (students and staff) of the Stanford campus is used as the driver unit.

Total population reported by the 2018-2019 BAWSCA annual survey (BAWSCA 2020) was used as driver units for Stanford. Figure 3-4 shows the historical total population for Stanford from this data source.

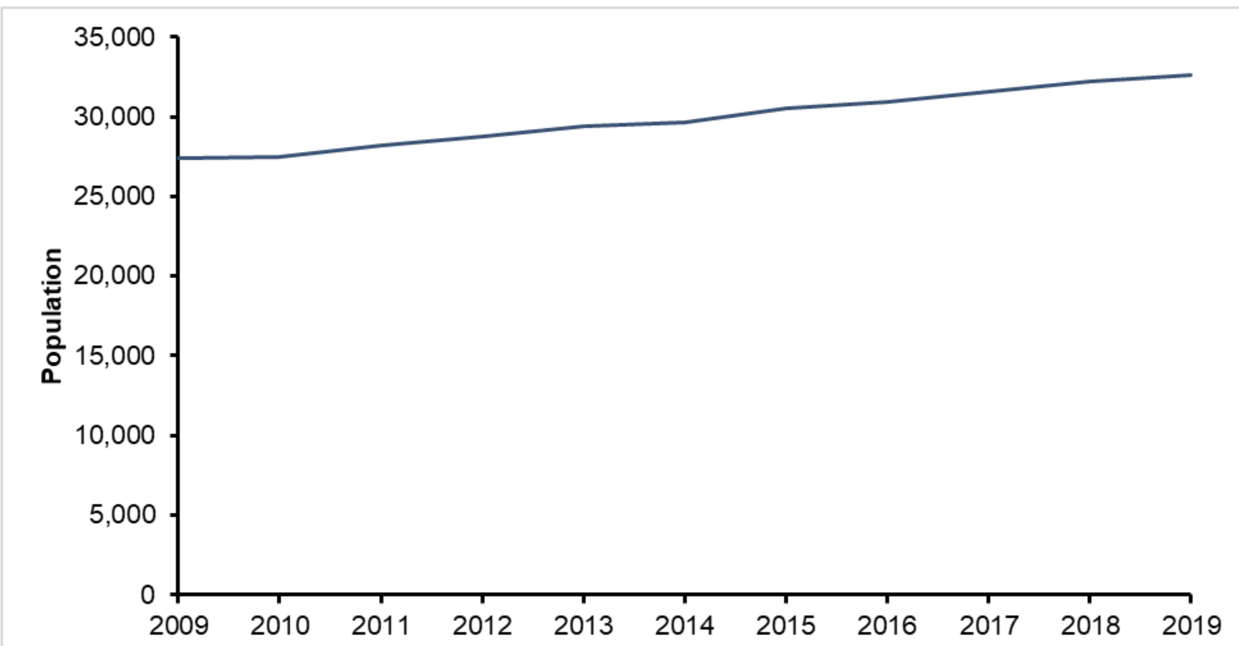


Figure 3-4: Stanford Total Population (Staff and Students)

3.4 Calculation of Retail Agency Rate of Use

Consistent with the recommended modeling approach recommended in Section 2.5, historical rates of water use (gallons per driver unit per day) were calculated for each of the retail agencies and model sectors identified in Table 3-3 using the consumption data reviewed in Section 3.2 and the driver unit data reviewed in Section 3.3. Calculated historical rates of use were also smoothed in order to standardize for consumption billed on monthly and bimonthly cycles. The smoothing approach for rate of use calculations is summarized below (Mays 2002):

1. Calculate the average number of monthly billed accounts for each year, retail agency, and model sector. For retail agencies billed on a bimonthly basis, the average number of monthly billed accounts is multiplied by 2.
2. For each year, retail agency, and model sector calculate the ratio of driver units (i.e., housing units and number of jobs) by the average monthly billed accounts calculated in (1) above.
3. Multiply the annual units per account ratio calculated in (2) above by the observed number of billed accounts. This provides an estimate of the number of monthly driver units billed (U_t).
4. Calculate the smoothed rate of use for bimonthly retail agencies (7) and monthly retail agencies (8), where q is the smoothed rate of use, Q_t is the billed consumption in the current month, U_t is the billed number of driver units in the current month. The variables $t+1$ and $t+2$ denote the next two subsequent months.

$$q = \left(0.25 * \frac{Q_t}{U_t} + 0.25 * \frac{Q_{t+2}}{U_{t+2}}\right) * \left(\frac{0.5U_t + 0.5U_{t+2}}{0.5U_t + U_{t+1} + 0.5U_{t+2}}\right) + 0.5 * \left(\frac{Q_{t+1}}{U_{t+1}}\right) * \left(\frac{U_{t+1}}{0.5U_t + U_{t+1} + 0.5U_{t+2}}\right) \quad \textbf{(7)}$$

$$q = \left(\frac{Q_t}{U_t}\right) * \left(\frac{U_t}{0.5U_t + 0.5U_{t+1}}\right) + \left(\frac{Q_{t+1}}{U_{t+1}}\right) * \left(\frac{U_{t+1}}{0.5U_t + 0.5U_{t+1}}\right) \quad \textbf{(8)}$$

Figure 3-5 and Figure 3-6 below show the historical smoothed rate of use for the single family, multifamily, and CII sectors averaged across all retail agencies (i.e., county-wide average).

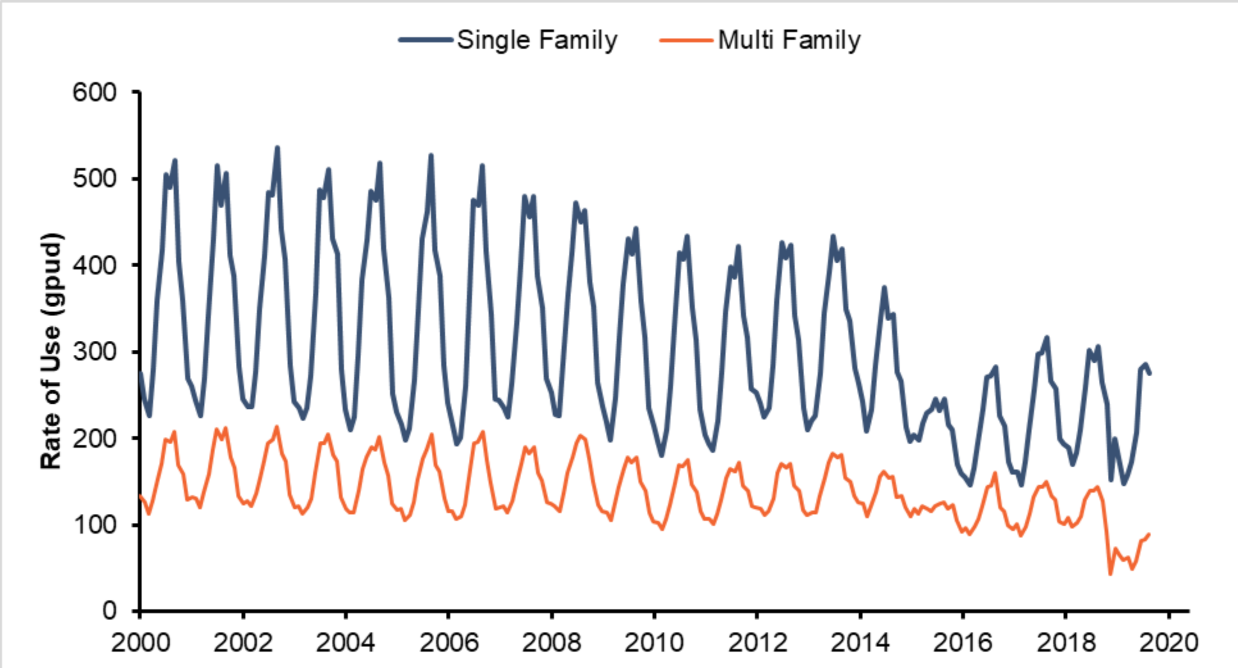


Figure 3-5: County-Wide Smoothed Rate of **Use for Single Family and Multifamily Sectors**

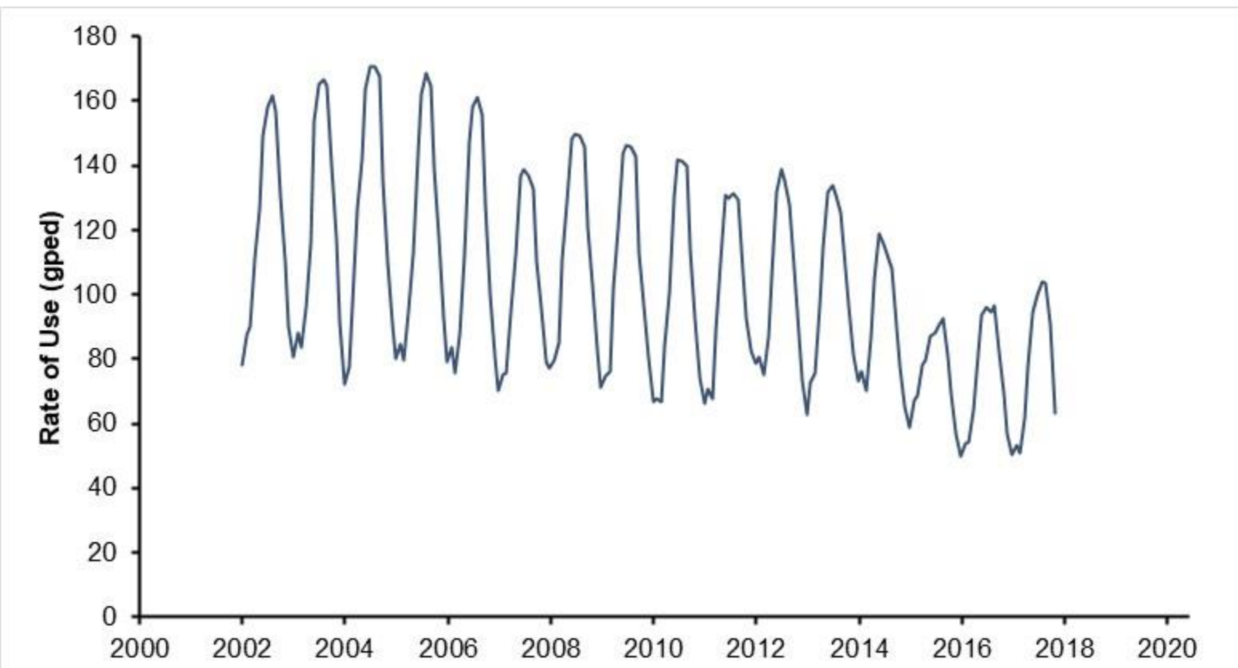


Figure 3-6: County-Wide Smoothed Rate of Use for the CII Sector

3.5 Data from Non-Retail Groundwater Pumpers

Non-retail groundwater pumpers include private well owners that are outside of the retailers' service areas. Available data for non-retail groundwater pumpers were provided by individual wells and included estimated or measured water use, water use type, groundwater charge zone, data frequency, and well status. The total water use and total number of wells were aggregated annually by water use type and groundwater charge zone.

3.5.1 Description of Available Consumption Data

Non-retail groundwater pumping data were available from 2000 to 2018. Historical groundwater use was summarized by groundwater charge zone and water use type.

Each well is located in a specific charge zone which corresponds to the groundwater basin or geographic area where the well is located. The groundwater basins include Santa Clara Plain (referred to as charge zone "W2") as well as the Llagas and Coyote Valley sub-basins (referred to as charge zone "W5"). Water use was aggregated by charge zone. Figure 3-7 shows the groundwater charge zones.

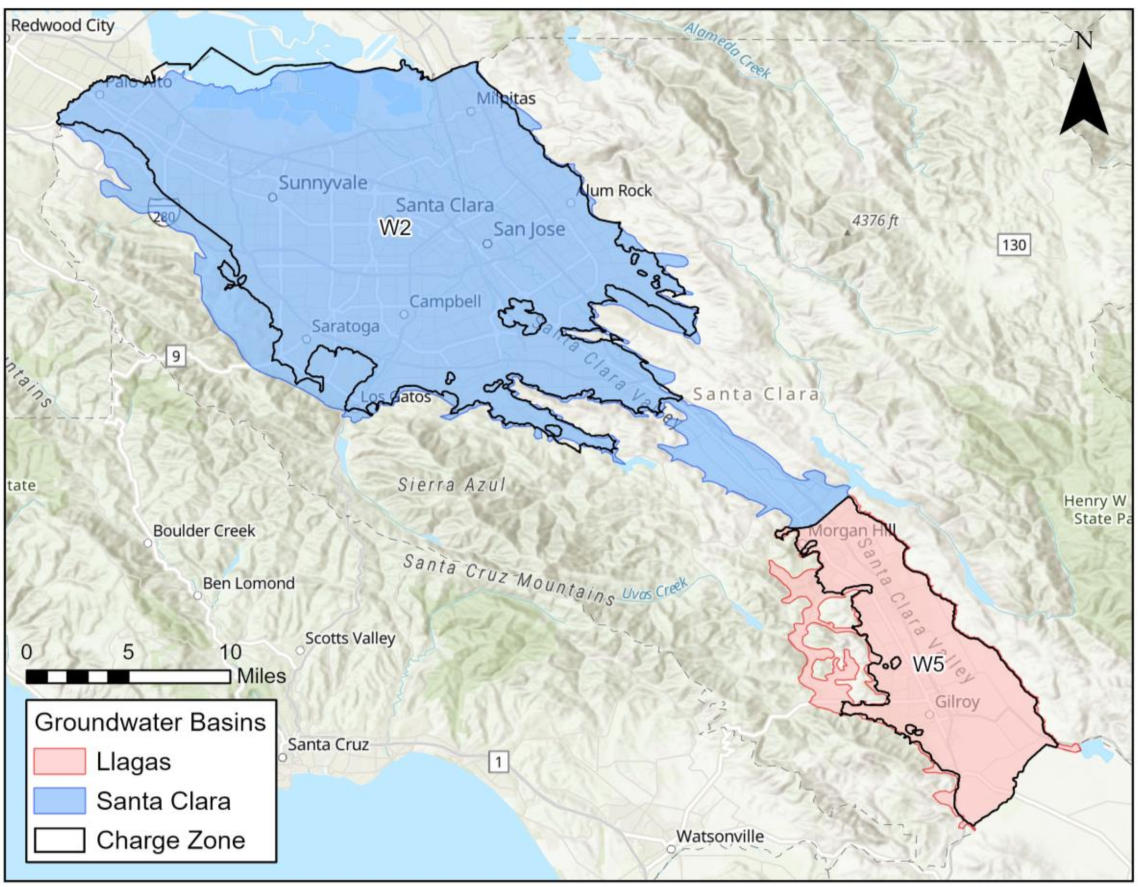


Figure 3-7: Map of Groundwater Basins and Charge Zones

Water use type was originally classified as either agricultural, municipal, or domestic. Municipal and domestic water use were combined into a single M&I category, resulting in two water use types: agricultural and M&I.

Billing data were reported at a monthly, semi-annual, or annual resolution. M&I use was reported monthly or semi-annually. Agricultural water use was typically reported annually or semi-annually. The semi-annual data were typically reported twice a year in January and July. For agricultural water use, the semi-annual and annual data were typically estimated values using a “table of averages” approach that approximates water use based on the crop type being irrigated. As a result, a monthly resolution for model fitting was not possible; water use was aggregated to an annual average water use in mgd.

Historical annual average water use by groundwater charge zone and water use type is shown in Figure 3-8. Agricultural use in the W5 charge zone represents the majority of overall groundwater use and has remained relatively constant since 2000 with some interannual variability. In the W2 charge zone, M&I use comprises the majority of groundwater use and has been steadily decreasing since 2000, while agricultural use in the W2 charge zone has been less than 0.5 mgd for the last 20 years. Annual M&I use in the W5 charge zone has remained approximately in the range of 5 to 9 mgd.

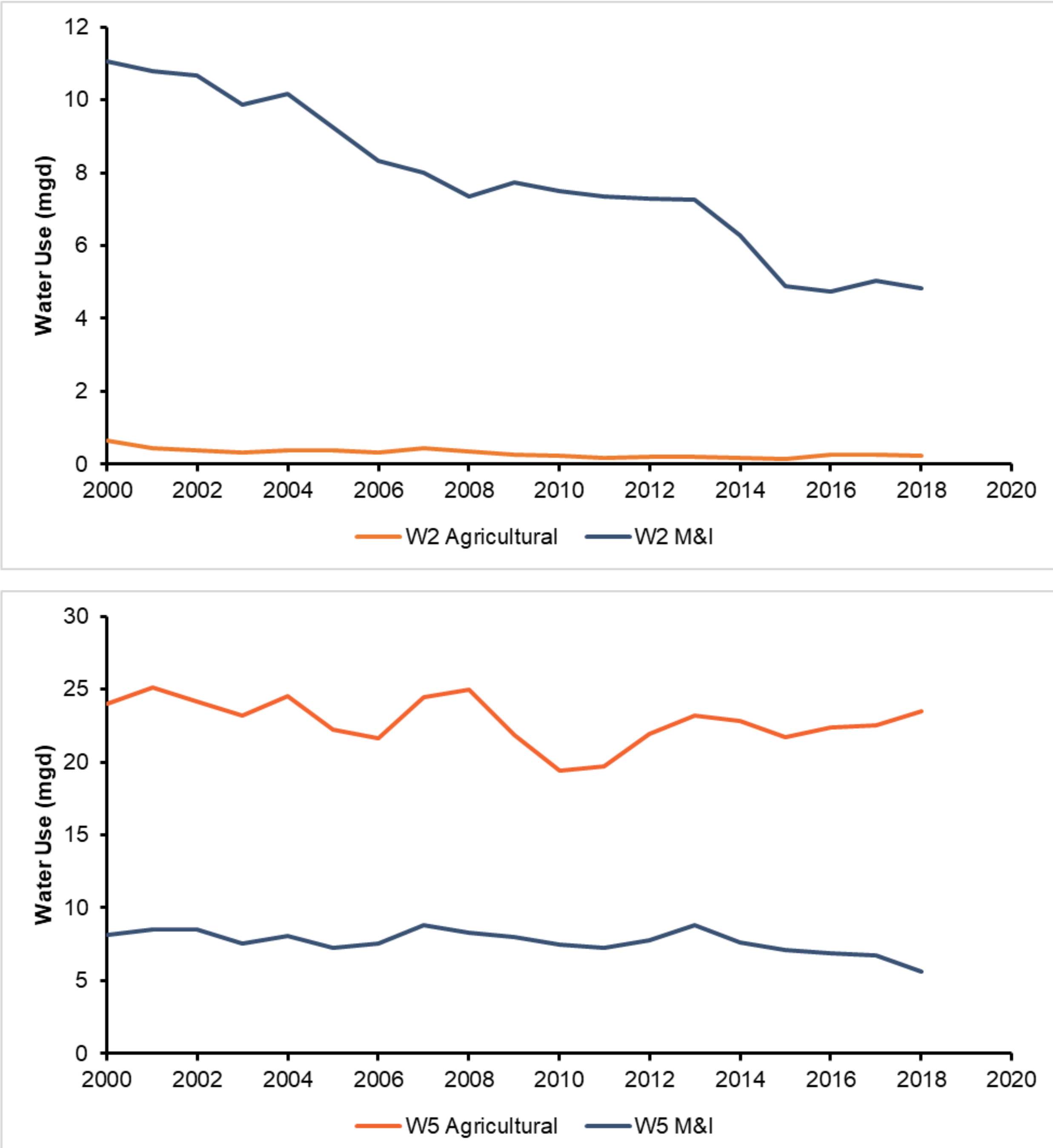


Figure 3-8: Historical Annual Average Groundwater Use (mgd) by Water Use Type for Groundwater Charge Zone W2 (top) and W5 (bottom). Note difference in y-axis scale.

3.5.2 Driver Units

Groundwater use was not well characterized on a per-unit basis by traditional driver units such as jobs, housing units, or population.[15] Population and number of wells were explored as potential driver units, to calculate average annual water use per person or per well, respectively. Figure 3-9 shows population for the two groundwater charge zones and Figure 3-10 shows the number of wells by groundwater charge zones and water use type. Population has been steadily increasing in both areas. The number of wells has remained relatively constant since 2000, with considerably more wells classified as M&I use than agricultural use. Note that the number of wells for M&I water use was incomplete in 2018 and is not shown.

Figure 3-8 above showed that water use has been decreasing or remaining constant over the last 20 years. The trends in groundwater use and population are opposite. Since both number of wells and groundwater use have remained relatively constant since 2000, there is little to no variability in groundwater use per well, which is not well-represented by a typical econometric demand model built to explain variability. Further, there is no existing data source that projects number of wells into the future that could be used for generating a forecast. As a result, groundwater pumping data used in model fitting was summarized on a volumetric basis (i.e., in mgd) rather than a per-unit use basis (i.e., in gallons per driver unit per day). No driver units were used in model fitting for groundwater use.

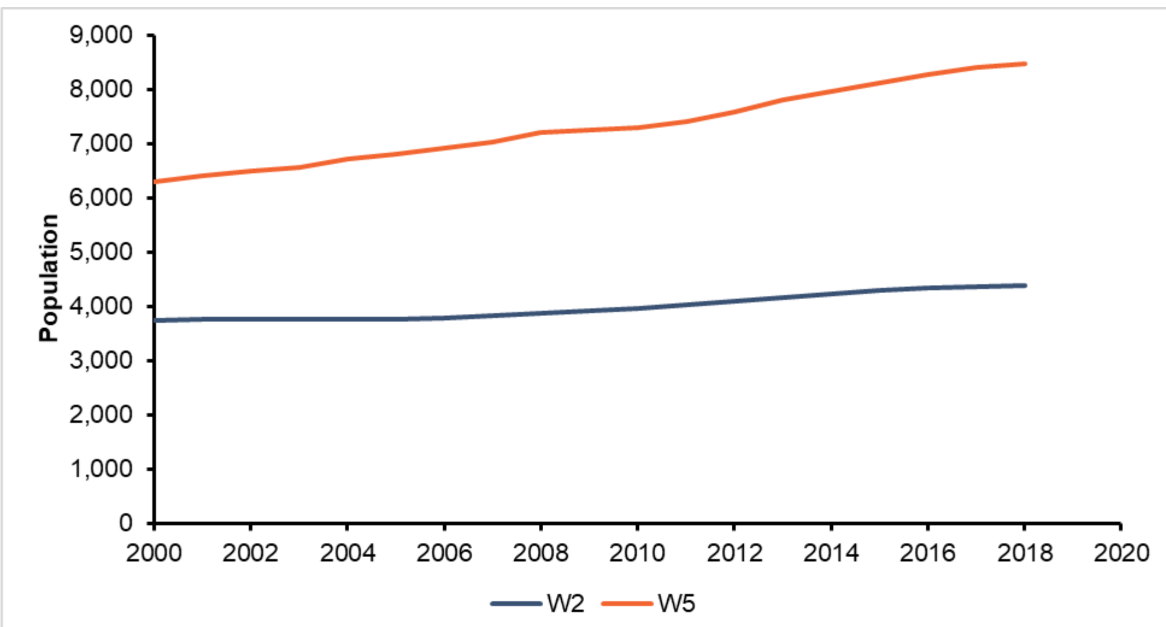
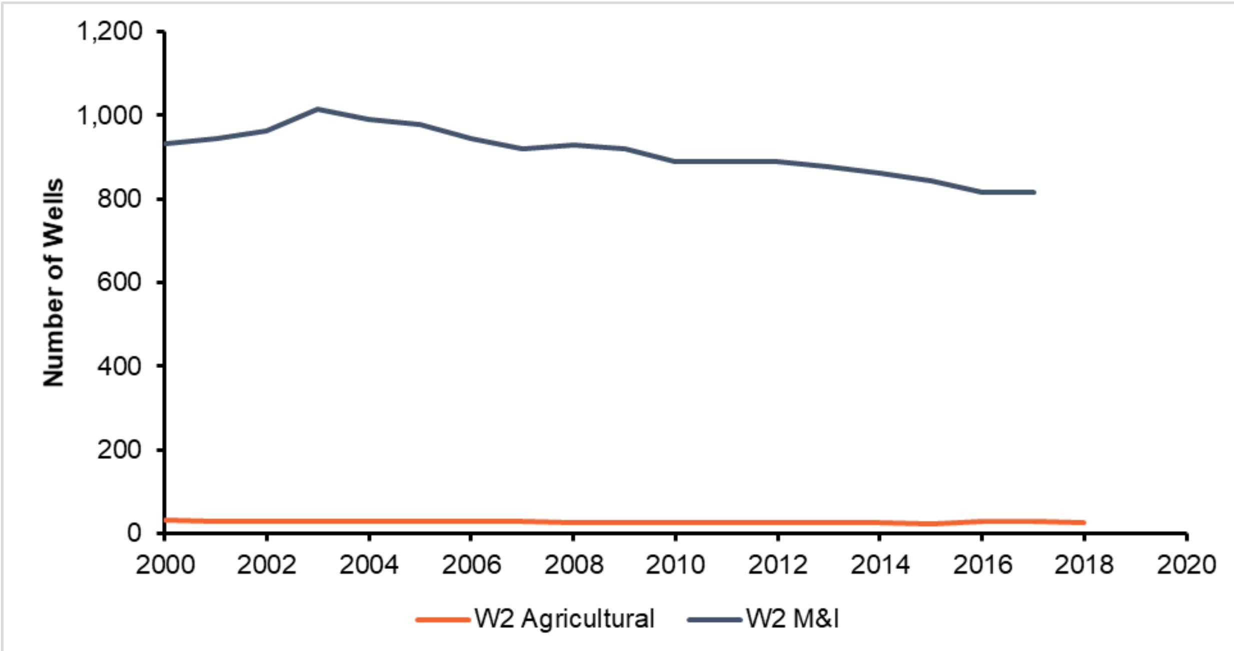


Figure 3-9: Total Population by Groundwater Charge Zone

[15] End uses of water for non-retailer groundwater pumpers is highly uncertain within the M&I sector. For example, it is difficult to determine from billing records whether a particular well within the M&I sector is primarily a residential service or meeting a CII application. Uncertainty in end uses make it difficult to accurately decide on and assign appropriate driver units, such as housing units or number of jobs.



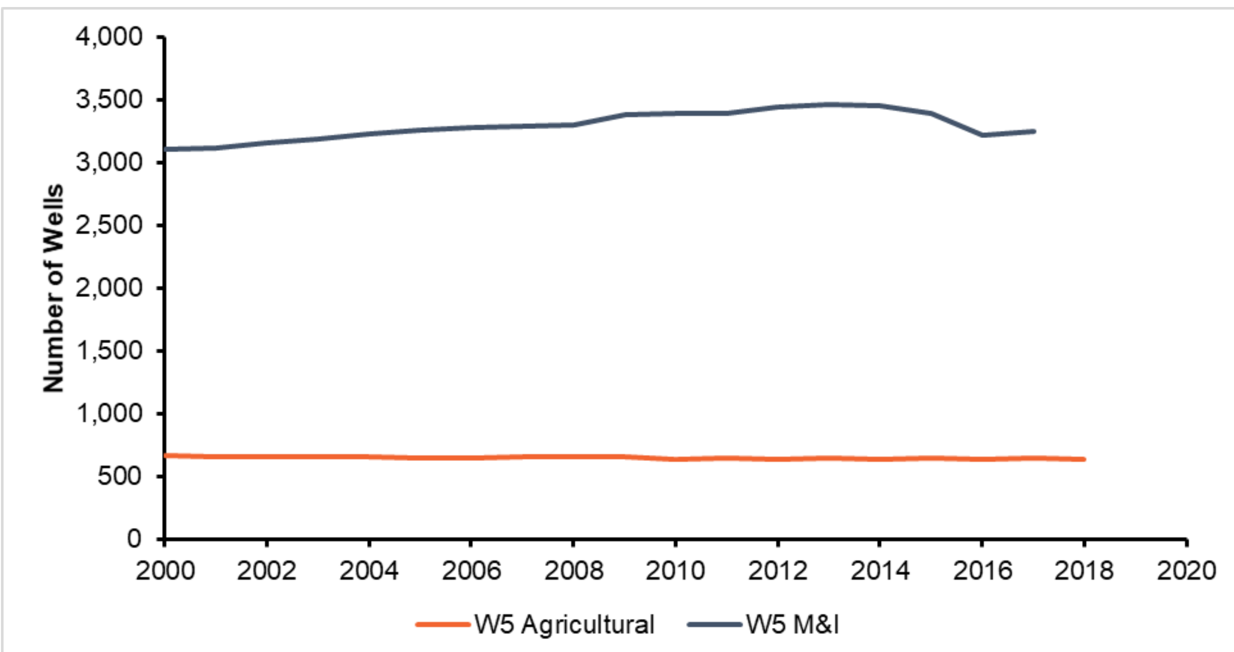


Figure 3-10: Total Number of Wells by Water Use Type for Charge Zone W2 (top) and W5 (bottom). Note the difference in y-axis scale.

3.6 Collection and Processing of Explanatory Variables

Several explanatory variables were collected in the development of Valley Water's demand model. To be considered for use, potential predictors needed to pass the following conceptual criteria:

- Logical connection to explaining changes in water consumption;
- Historical record consistent with the time series of observed water consumption; and
- Availability of future projections consistent with the desired forecast horizon (i.e., 2020-2045) or a reasonable means for assuming projected values.

Table 3-8 provides a general overview of the collected explanatory variables and their relevance to explaining changes in water consumption. The following sections provide documentation of the raw data sources and the necessary data processing implemented for each of these variables.

Table 3-8: Summary of Collected Explanatory Variables

Explanatory Variable	Relevance to Water Consumption
Temperature	Higher than normal temperatures are associated with higher demands.
Precipitation	Higher than normal rainfall is associated with lower demands.
Price	Economic theory suggests negative correlation with demand.
Drought restrictions	The presence of drought restrictions tends to decrease the amount of water consumed by customers.
Economic index	Water demand is positively correlated with economic fluctuations of the business cycle. The index is modeled in form of departures from long-term trend.
Median income	Economic theory suggests positive correlation of income with demand; generally geographical areas with higher median incomes tend to use more water.
Housing density	Housing density is negatively correlated with demand; on average, residences with more units per acre (or smaller parcel sizes) tend to use less water for outdoor uses.
Persons per household	Positively correlated with demand; generally, residences with more people tend to use larger amounts of water.
Mix of Industries / economic activity	The representation of industries / economic activity with a geographical area is related to the amount of water used within the CII sector.

3.6.1 Historical Weather Data

It is advantageous to have specific weather data for each geographical segmentation (i.e., retail service area boundaries) represented within a demand model, especially in geographic areas that may have micro-climates due to gradients in elevation and proximity to large water bodies. Most weather or climate datasets are provided at individual stations and can be interpolated between stations to obtain data geographically specific estimates for a target location. The PRISM dataset (PRISM Climate Group 2004) provides gridded weather data at a 4-kilometer resolution and was easily processed to retail agency boundaries. For each retailer, the PRISM grid cell that contained the centroid of the agency's service area boundary was identified. Weather variables collected from the PRISM dataset included maximum temperature (degrees Fahrenheit) and total precipitation (inches per month).

Weather data were normalized to average conditions, in order to make observed weather independent of normal cyclical seasonal cycles. Weather data were normalized by calculating departures from historical normal values. Historical normal values were calculated for each retailer as the average values by month based on all values from 1981 to 2010. Departures were then calculated as the monthly value minus the historical normal for both the raw scale and natural log-transforms, following Equation (9):

$$Departure = X_{i,t} - \bar{X}_i \qquad \textbf{(9)}$$

Where $X_{i,t}$ is an observed monthly value in month *i* and X_i is the historical normal value in month *i*. A positive departure indicates above-normal conditions, and a negative value indicates below-normal conditions. Table 3-9 on the following page summarizes the maximum temperature and total precipitation historical normal values by retailer.

Table 3-9: Historical 30-Year Normal Values (based on 1981 to 2010) for Weather Variables by Retailer

Retail Agency	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Maximum Temperature (°F)													
California Water Service	58.7	62.1	65.6	69.5	74.0	78.6	80.6	80.8	80.3	75.3	65.5	58.7	70.8
City of Gilroy	60.2	63.5	67.7	72.7	78.5	83.9	88.1	87.9	85.4	78.4	67.5	59.9	74.5
City of Milpitas	58.4	61.9	65.6	69.3	73.7	78.3	80.7	80.8	80.0	74.5	65.2	58.4	70.6
City of Morgan Hill	59.9	63.2	67.3	71.5	77.7	84.1	88.5	87.6	85.0	77.2	66.8	59.3	74.0
City of Mountain View	58.2	61.5	64.7	68.6	72.5	76.6	77.8	78.1	78.0	73.6	65.0	58.4	69.4
City of Palo Alto	59.2	62.5	66.2	70.6	75.6	80.6	83.0	83.1	82.0	76.4	65.9	59.0	72.0
City of Santa Clara	58.3	61.9	65.5	69.3	73.7	78.3	80.7	80.6	79.9	74.6	65.1	58.3	70.5
City of Sunnyvale	58.6	61.9	65.4	69.3	73.7	78.2	80.2	80.3	79.9	74.9	65.3	58.6	70.6
Great Oaks Water Company	59.1	62.5	66.4	70.2	75.7	81.0	84.6	84.3	82.3	75.6	65.9	58.7	72.2
Purissima Hills Water District	59.9	62.9	66.7	71.9	77.4	82.7	85.4	85.5	84.0	77.9	66.6	59.6	73.4
San Jose Municipal Water	58.5	62.1	66.0	69.9	74.7	79.4	82.1	82.0	81.0	75.0	65.3	58.4	71.3
San Jose Water Company	58.4	62.1	66.1	70.1	75.1	80.0	82.9	82.7	81.5	75.4	65.3	58.3	71.5
Stanford University	58.8	62.3	65.9	70.0	75.0	79.9	82.0	82.2	81.0	75.7	65.5	58.7	71.4
Total Precipitation (in)													
California Water Service	3.48	3.52	2.74	1.12	0.44	0.11	0.01	0.03	0.15	0.83	1.92	3.01	17.35
City of Gilroy	4.49	4.25	3.28	1.30	0.49	0.11	0.00	0.03	0.23	1.08	2.39	3.77	21.43
City of Milpitas	2.98	2.95	2.38	1.08	0.51	0.09	0.01	0.02	0.16	0.83	1.57	2.45	15.03
City of Morgan Hill	4.46	4.40	3.13	1.17	0.54	0.09	0.00	0.03	0.18	0.90	2.03	3.47	20.41
City of Mountain View	3.08	3.06	2.44	1.05	0.41	0.10	0.00	0.02	0.14	0.77	1.75	2.69	15.52
City of Palo Alto	4.15	4.31	3.25	1.33	0.50	0.13	0.01	0.03	0.16	1.00	2.21	3.56	20.64
City of Santa Clara	2.91	2.96	2.34	1.05	0.44	0.09	0.01	0.02	0.13	0.74	1.52	2.38	14.58
City of Sunnyvale	3.12	3.13	2.43	1.07	0.44	0.10	0.01	0.02	0.14	0.77	1.70	2.62	15.55
Great Oaks Water Company	3.30	3.18	2.63	1.07	0.58	0.09	0.00	0.03	0.14	0.86	1.64	2.54	16.06
Purissima Hills Water District	5.01	5.18	3.90	1.58	0.60	0.13	0.01	0.03	0.17	1.13	2.73	4.39	24.88
San Jose Municipal Water	2.91	2.86	2.38	1.12	0.51	0.09	0.00	0.02	0.15	0.77	1.56	2.37	14.74
San Jose Water Company	3.26	3.31	2.63	1.08	0.43	0.09	0.00	0.02	0.14	0.76	1.62	2.70	16.05
Stanford University	3.95	3.93	3.10	1.27	0.49	0.11	0.01	0.03	0.15	0.94	2.24	3.68	19.89

3.6.2 Water Rates / Price

A time series of historical water rates for each retail agency were represented by water rates for the single family residential billing class, which was provided by Valley Water. Volumetric charges are used as the instrument for price. When consistently available over the period of record, the volumetric charge for the second tier was the price instrument used for retailers with tiered rates. Changes in single family residential water rates tended to reflect timing of changes in other sectors and were therefore used as a convenient proxy for all model sectors to estimate the response in water use to changes in price.

Stanford does not use billing rates. Instead, price for Stanford was modeled using the Water Utility Enterprise (WUE) rates by fiscal year, provided by Valley Water. The M&I groundwater/surface water for the W2 charge zone (North County) was used for Stanford.

Water use rates for non-retail groundwater pumpers were also calculated from WUE rates. For the non-retail groundwater pumpers M&I water use, M&I groundwater/surface water rates for the W2 and W5 charge zones were used. For the non-retail agricultural groundwater pumping, the agricultural groundwater/surface water rate was used for the W2 charge zone, and the net agricultural rate was used for the W5 charge zone.

All water rates were adjusted for inflation by normalizing prices to 2015 dollar values. A time series of historical inflation by year was used to calculate an adjustment factor to achieve this normalization. Table 3-10 below shows the average historical normalized price in 2015 dollar values per hundred cubic feet (2015 $/ccf) or per acre-foot (2015$/AF) by retailer, as well as the normalized value in 2018. Historical values ranged widely over the available period of historical data (2000 to 2018). Appendix D provides graphical summaries of historical water rates for each retail agency and non-retail groundwater pumping category identified in Table 3-10.

Table 3-10: Normalized Water Use Rate (2015$/ccf or 2015$/AF) by Retailer

Retailer Agency / Water Provider	Average Normalized Water Use Rate, 2000-2018 (2015$/ccf)	2018 Normalized Water Use Rate (2015$/ccf)
California Water Service	$3.23	$5.04
City of Gilroy	$1.96	$3.90
City of Milpitas	$2.32	$0.98
City of Morgan Hill	$1.84	$2.26
City of Mountain View	$4.24	$6.21
City of Palo Alto	$6.86	$8.54
City of Santa Clara	$3.15	$5.41
City of Sunnyvale	$3.44	$4.85
Great Oaks Water Company	$2.54	$3.17
Purissima Hills Water District	$4.16	$6.13
San Jose Municipal Water	$2.76	$3.62
San Jose Water Company	$3.09	$3.42
Rates Calculated from Valley Water Wholesale Water Rates (2015$/AF)		
Stanford University	$645.23	$1,113.79
Non-Retail Groundwater Pumpers, Ag W2	$29.64	$23.56
Non-Retail Groundwater Pumpers, Ag W5	$18.55	$23.56
Non-Retail Groundwater Pumpers, M&I W2	$645.23	$1,113.79
Non-Retail Groundwater Pumpers, M&I W5	$286.49	$392.39

3.6.3 Drought Restrictions

Drought effects were represented by the presence of drought restrictions (a binary value 0 or 1) multiplied by severity of the requested cutback from Valley Water. For example, if 10% cutbacks were in place, the drought effect variable was equal to 0.1. Two indices were developed and evaluated during model development; one index represented cutbacks during the drought of 2006 to 2008, and the second index represented cutbacks from the 2013 to 2016 drought. The time series of the historical drought effect variables are shown in Figure 3-11.

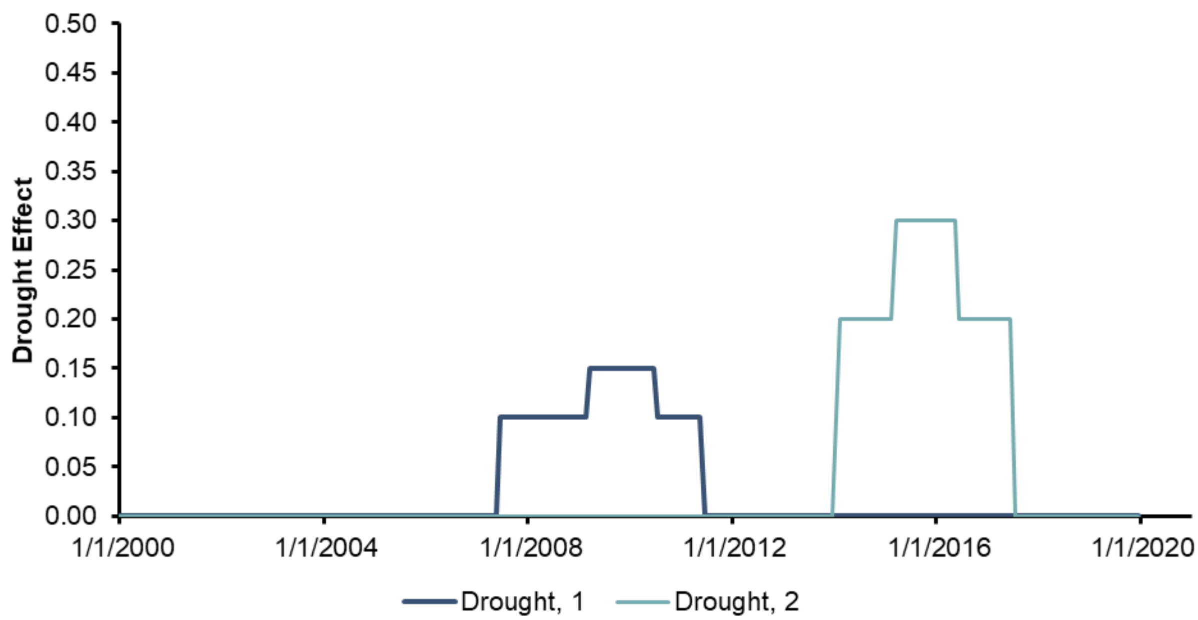


Figure 3-11: Drought Effect

3.6.4 Economic Indices

Several economic indices were collected and explored as potential model predictors. A summary of these indices is presented in Table 3-11 below.

Table 3-11: Summary of Economic Indices Collected for Model Fitting

Dataset	Source
U.S. Monthly Coincident Index[(a)]	ECRI (ECRI 2021)
Monthly Economic Conditions Index for San Jose-Sunnyvale-Santa Clara, CA (metropolitan statistical area [MSA]) Seasonally Adjusted Annual Rate	Federal Reserve Bank of St. Louis Economic Research Division (FRED Economic Data)
Monthly Unemployment Rate in San Jose-Sunnyvale-Santa Clara, CA (MSA)	Federal Reserve Bank of St. Louis Economic Research Division (FRED Economic Data)
[(a)] Proprietary index for entire country. Includes a mix of metrics intended to coincide with the state of the economy in any given time period.	

Figure 3-12 through Figure 3-14 illustrate the economic indices defined in Table 3-11 above. Though these indices are constructed and defined differently, major macroeconomic events, including the early

2000’s dot-com bubble and the Great Recession, are clearly visable in each index. Note that peaks in the unemployment rate often lag the timing of recessions with slower recoveries to pre-recession levels.

The ECRI U.S. Monthly Coincident Index (ECRI index, Figure 3-14) shows a steady upward trend throughout the collected record, which is consistent with general long-term growth in the economy. The trend in the time series of the ECRI index was removed during model development, in order to better identify short term fluctuations in economic activity. The additional economic index was derived from the ECRI index by detrending the natural log of the index (i.e., regressing 30 years of monthly log-transformed index values against a linear time counter) (see Figure 3-15). The detrended series clearly shows the timing and magnitude of the dot-com bubble and the Great Recession, while highlighting periods of postive and negative economic growth relative to long-term trend. All economic indices illustrated in Figure 3-12 to Figure 3-15 were tested as predictor variables in model development. The detrended version of the ECRI index was eventually selected as it resulted in the most consistent coefficient estimates from the group.[16]

[16] Refer to Section 4.1.4.

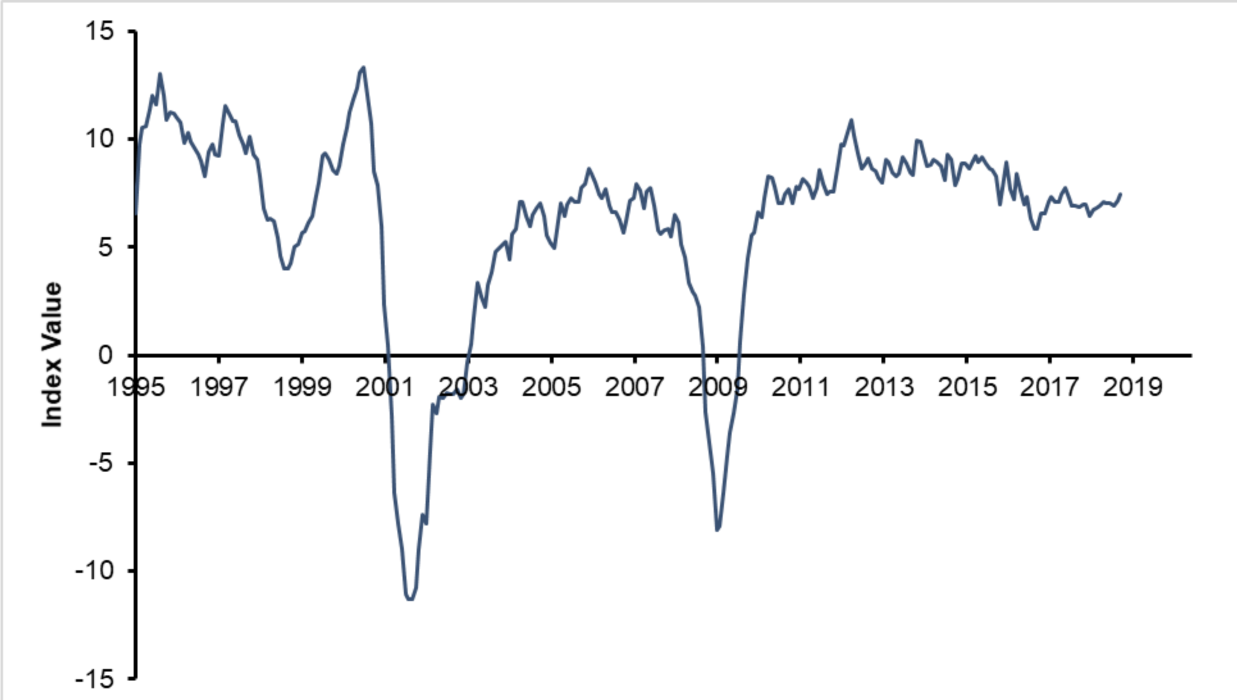


Figure 3-12: Monthly Economic Conditions Index for San Jose-Sunnyvale-Santa Clara, CA

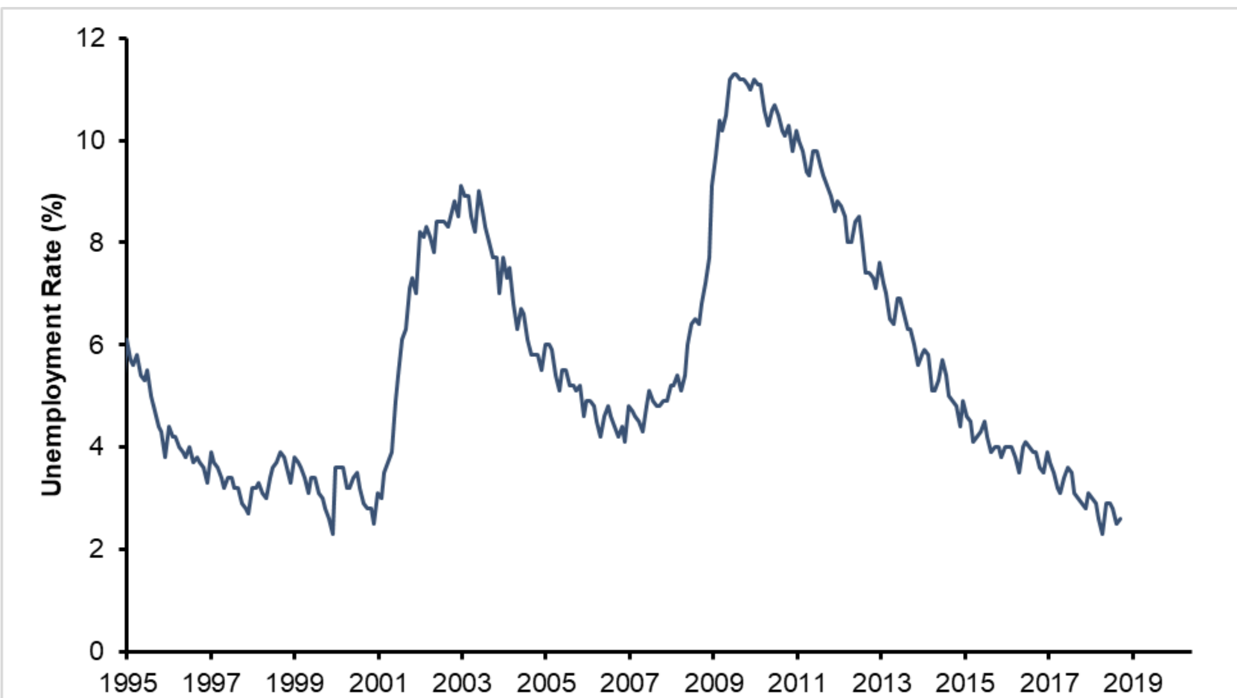


Figure 3-13: Monthly Unemployment Rate in San Jose-Sunnyvale-Santa Clara, CA

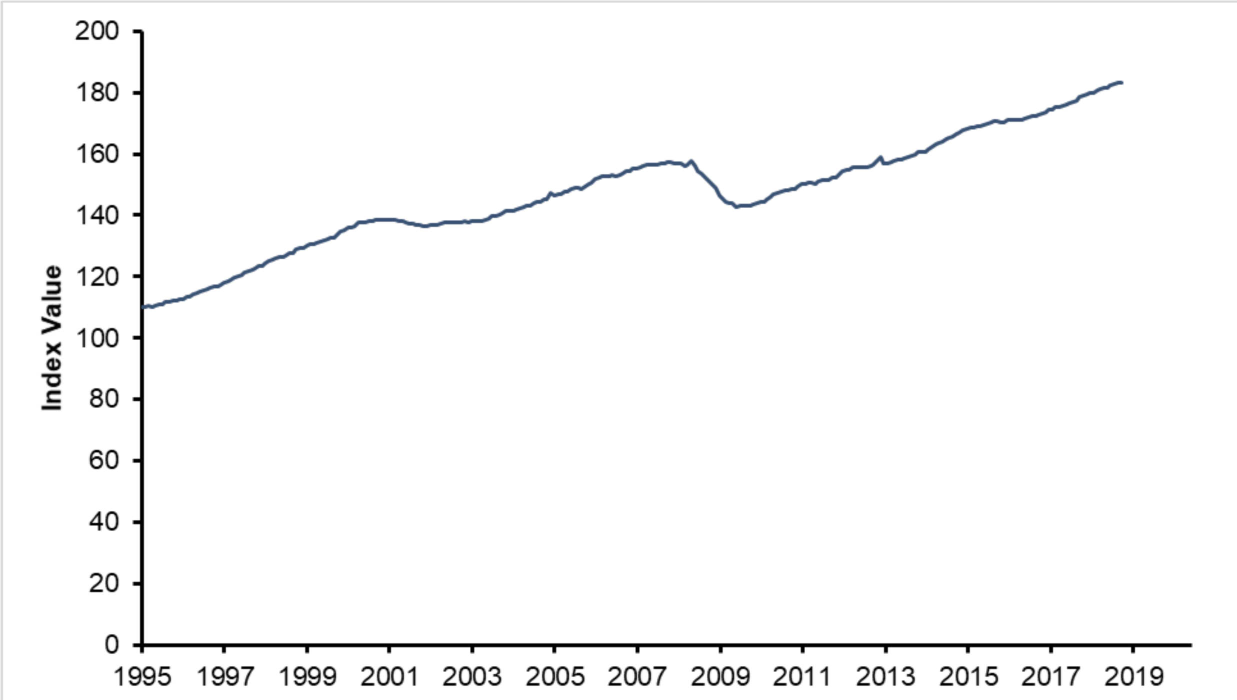


Figure 3-14: ECRI U.S. Monthly Coincident Index

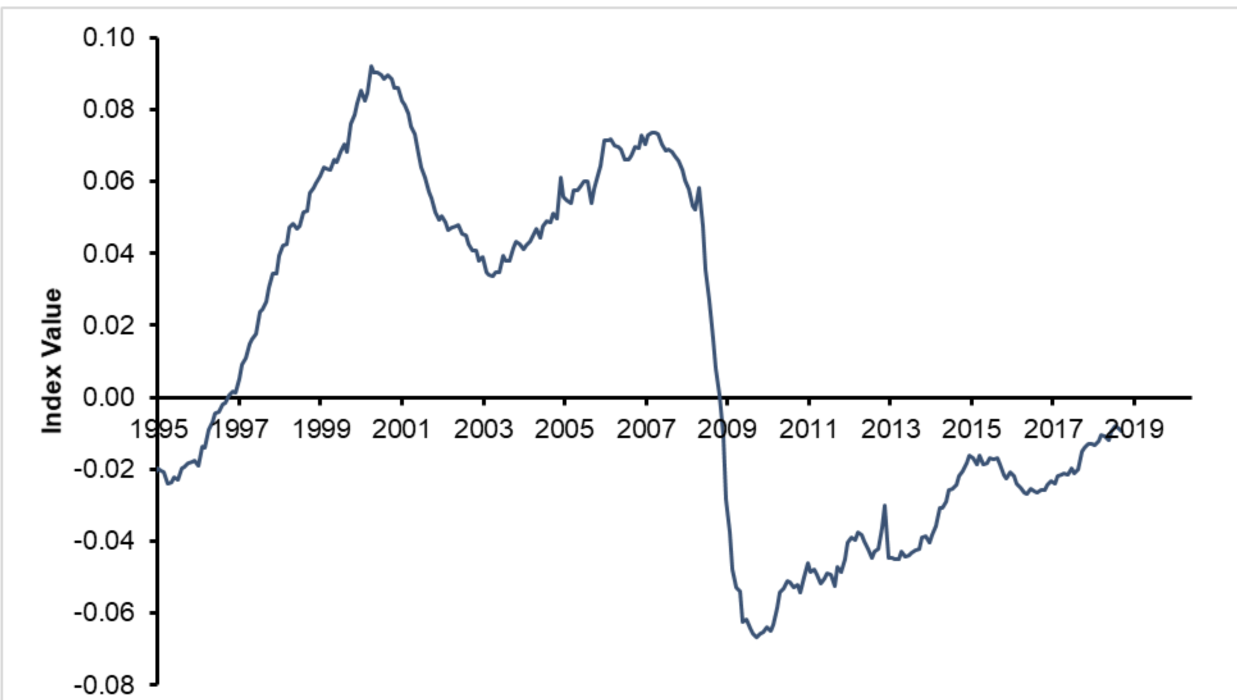


Figure 3-15: Detrended and Logged ECRI U.S. Monthly Coincident Index

3.6.5 Median Income

Median household income was estimated from the US Census American Community Survey (ACS) data as the median value of all census tracts within each retailer's service area boundary. Median income was identified as a potential explanatory variable for the residential sectors. Values were calculated as the average value across Census ACS survey data available from 2013 to 2017. Median income was adjusted for inflation by normalizing to 2015 dollar values and held constant over time for each retailer. Table 3-12 shows the normalized median income value by retailer. Note that median income for Stanford is not identified in Table 3-12 as its entire demand is considered CII.

Table 3-12: Normalized Median Income by Retailer (2015$)

Retail Agency	Average Median Household Income ACS (2013-2017; 2015$)
California Water Service	$156,235
City of Gilroy	$91,643
City of Milpitas	$108,352
City of Morgan Hill	$109,752
City of Mountain View	$138,060
City of Palo Alto	$144,307
City of Santa Clara	$107,272
City of Sunnyvale	$125,285
Great Oaks Water Company	$108,184
Purissima Hills Water District	$206,782
San Jose Municipal Water	$116,052
San Jose Water Company	$106,368

3.6.6 Housing Density

Housing density was derived from housing units derived for each retailer (see Section 3.3.1) divided by the total parcel area of multi-family and single family housing. Total parcel areas were provided by Valley Water based on processed GIS records. Table 3-13 shows the categories used in Valley Water's GIS data and their single family or multi-family characterization.

Table 3-13: Classification of Residential Land Use Categories

Classification	Valley Water Land Use Category
Single Family	Single family
	Single family 5-10 units
	Single family 11-20 units
	Single family <51-100 units
	Single family 51-100 units
	Single family duplicate
Multifamily	Condo/townhouse
	Condo/townhouse 11-20 units
	Condo/townhouse 21-50 units
	Condo/townhouse duplicate null
	Condo/townhouse null
	Five or more family
	Five or more family 5- 10 units
	Five or more family 11- 20 units
	Five or more family 21- 50 units
	Five or more family 51-100 units
	Five or more family > 100 units
	Five or more family apartments/offices
	Five or more family govt restricted/subsidized/other
	Five or more family govt restricted/subsidized/section 221d3
	Five or more family govt restricted/subsidized/section 236
	Five or more family lifecare includes skilled nursing
	Five or more family mobile home park
	Five or more family retirement complex/meals/recreation/no care
	Five or more family seniors only/no services
	Office uses office condo
	Two family
	Three/four family

Table 3-14 shows the average housing density (in units per acre) for each retailer for both single family and multifamily housing. Housing units varied over time, whereas geographic area was held constant. As a result, housing density varied slightly with changes in housing units. Single family housing density was typically within +/-5% of the average value, and multi-family housing density was typically within +/-10% of the average value. Note that housing density for Stanford is not identified in Table 3-14 as its entire demand is considered CII.

Table 3-14: Housing Density by Retailer

Retail Agency	Single Family Density (Housing Units/Acre)	Multifamily Density (Housing Units/Acre)
California Water Service	3.1	13.83
City of Gilroy	3.48	5.69
City of Milpitas	8.34	21.34
City of Morgan Hill	1.98	8.22
City of Mountain View	11.23	20.18
City of Palo Alto	4.91	33.09
City of Santa Clara	8.58	27.47
City of Sunnyvale	9.06	18.48
Great Oaks Water Company	6.34	20.62
Private well owner	1.47	
Purissima Hills Water District	0.75	19.58
San Jose Municipal Water	4.97	18.62
San Jose Water Company	5.34	13.83

3.6.7 Persons per Household

Persons per household is a derived parameter calculated as ACS total population by housing type divided by the number of households. Values were first calculated on a census tract level then aggregated to retail service area boundaries. Persons per household was calculated separately for single family and multifamily residences. Table 3-15 shows the average persons per household by retailer. Values varied slightly over time but were typically within +/-5% of the average value. Note that Persons per household for Stanford is not identified in Table 3-15 as its entire demand is considered CII.

Table 3-15: Persons per Household (PPH) by Retailer

Retail Agency	Persons per Household (Single family)	Persons per Household (Multifamily)
California Water Service	2.87	2.41
City of Gilroy	3.44	3.37
City of Milpitas	3.53	2.66
City of Morgan Hill	3.08	2.91
City of Mountain View	2.66	2.11
City of Palo Alto	2.83	1.93
City of Santa Clara	2.99	2.34
City of Sunnyvale	2.93	2.38
Great Oaks Water Company	3.38	2.91
NASA Ames	3.57	3.69
Private well owner	3.11	2.47
Purissima Hills Water District	2.77	2.78
San Jose Municipal Water	3.77	2.55
San Jose Water Company	3.24	2.53

3.6.8 Mix of Industries / Economic Activity

For the CII model sector, additional explanatory variables were developed to reflect the mix of CII activity within each retail service area. These parameters were derived from historical LODES employment data (see Section 3.3.2). LODES employment data by NAICS sector were aggregated to six employment sectors defined by ABAG, as shown in Table 3-16. The ABAG sectors were used to maintain consistency with available employment projections.

Table 3-16: NAICS Sector Jobs by Model Sector

NAICS Sector	ABAG Sector
Agriculture, Forestry, Fishing and Hunting	Agriculture and Natural Resources
Administration & Support, Waste Management and Remediation	Financial and Professional Service
Finance and Insurance	
Management of Companies and Enterprises	
Professional, Scientific, and Technical Services	
Real Estate and Rental and Leasing	
Accommodation and Food Services	Health, Educational and Recreational Service
Arts, Entertainment, and Recreation	
Educational Services	
Health Care and Social Assistance	
Construction	Information, Government and Construction
Information	
Public Administration	
Manufacturing	Manufacturing, Wholesale and Transportation
Mining, Quarrying, and Oil and Gas Extraction	
Transportation and Warehousing	
Utilities	
Wholesale Trade	
Other Services (excluding Public Administration)	Retail
Retail Trade	

The five non-agricultural ABAG sectors were considered for the mix of industries/economic activity explanatory variables – Financial and Professional Service; Health, Educational and Recreational Service; Information, Government and Construction; Manufacturing, Wholesale and Transportation; and Retail The ratio of jobs within an ABAG employment sector to the total number of non-agricultural jobs was calculated for each retailer. These values varied by year.

Table 3-17 shows the average ratio of jobs within each ABAG sector by retailer, which were used as the mix of industries/economic activity explanatory variables. Historical values from 2002 to 2018 were typically within +/-10% of the average value.

Table 3-17: Average Mix of Industries/Economic Activity by Retailer and ABAG Sector

Retail Agency	Financial and Professional Service	Health, Educational and Recreational Service	Information, Government and Construction	Manufacturing, Wholesale and Transportation	Retail
California Water Service	20%	31%	5%	30%	14%
City of Gilroy	11%	40%	11%	13%	25%
City of Milpitas	22%	22%	11%	31%	14%
City of Morgan Hill	18%	28%	10%	32%	13%
City of Mountain View	32%	17%	25%	15%	10%
City of Palo Alto	28%	41%	11%	12%	9%
City of Santa Clara	28%	18%	9%	37%	8%
City of Sunnyvale	32%	16%	8%	35%	9%
Great Oaks Water Company	16%	42%	3%	28%	10%
Purissima Hills Water District	21%	57%	6%	7%	9%
San Jose Municipal Water	21%	13%	10%	48%	8%
San Jose Water Company	24%	31%	13%	16%	16%

3.6.9 Number of Groundwater Wells

For groundwater use, the number of wells was aggregated by billing sector and groundwater basin. The number of wells was considered as an explanatory variable for the groundwater use models only. Figure 3-10 in Section 3.5.2 shows the total number of wells.

3.7 Historical Data Collection Summary

Data collection efforts resulted in a robust historical dataset consisting of consumption, driver units, and explanatory variables. Several raw data sources required pre-processing in order to be suitable for model development, which included development of rate of use time series, geo-processing of census tract-level socioeconomic data to retail agency service area boundaries, and data normalization/standardization. The overall dataset represents a wide range of explanatory variables that are known to influence water demand and are concurrent with historical observations of retail agency and non-retail groundwater pumper consumption. A detailed review of the demand model development using this dataset is provided in the following Section 4.

4. Modeling Approach and Development

This section documents the modeling approach selected to develop Valley Water's updated demand model. Major characteristics of the modeling approach include a statistical/econometric analytical framework, differentiation of rates of water use from drivers of growth, and model segmentation based on geography (e.g., retail agency), time of year, and water use sector. This section includes a summary of the statistical model fits and performance compared to historical observations of water consumption. Discussions of model fits and performance are organized based on water use sector segmentation and includes the following sectors:

- Single family;
- Multifamily;
- CII; and
- Non-retailer groundwater pumpers.

4.1 Modeling Approach

Valley Water's new demand model is organized following the characteristics identified in Section 3.1. This section provides a general overview of this approach to establish context for detailed discussions on model development in Sections 4.2 – 4.5.

4.1.1 Model Segmentation

The demand model was segmented based on type of provider, i.e., retail agency or non-retail groundwater pumper. Within each provider type, the model was further segmented by geography, sector/billing classification, and time of year. For retail provided water, model geographies were based on each retail agency's service area within Santa Clara County. Billing classifications often differed among retail agencies necessitating standardization of billing classifications into common sectors (e.g., single family, multifamily, CII). Appendix A provides a detailed summary of the billing classifications for each retail agency, and the standardized sectors used for modeling; Valley Water directly solicited the retail agencies for input in standardizing billing classifications, particularly for classes that have the potential to span across multiple water use sectors (e.g., landscape irrigation and recycled water). Non-retail groundwater pumpers were organized geographically by groundwater basin charge zone, including W2 (representing the Santa Clara Plain sub-basin management area) and W5 (representing the Llagas sub-basin and Coyote Valley sub-basin management area). Water use classifications for non-retail groundwater pumpers are consistent across each charge zone and include agricultural, municipal, and domestic water use types. These water use classifications were ultimately organized into two model sectors, M&I and Ag.

The retail agency demands were modeled using a monthly timestep, and non-retail groundwater pumper demands were modeled using an annual timestep. Non-retail groundwater pumper annual demands were then post-processed to monthly demands using a monthly distribution. Figure 4-1 further details the hierarchical structure of model segmentation.

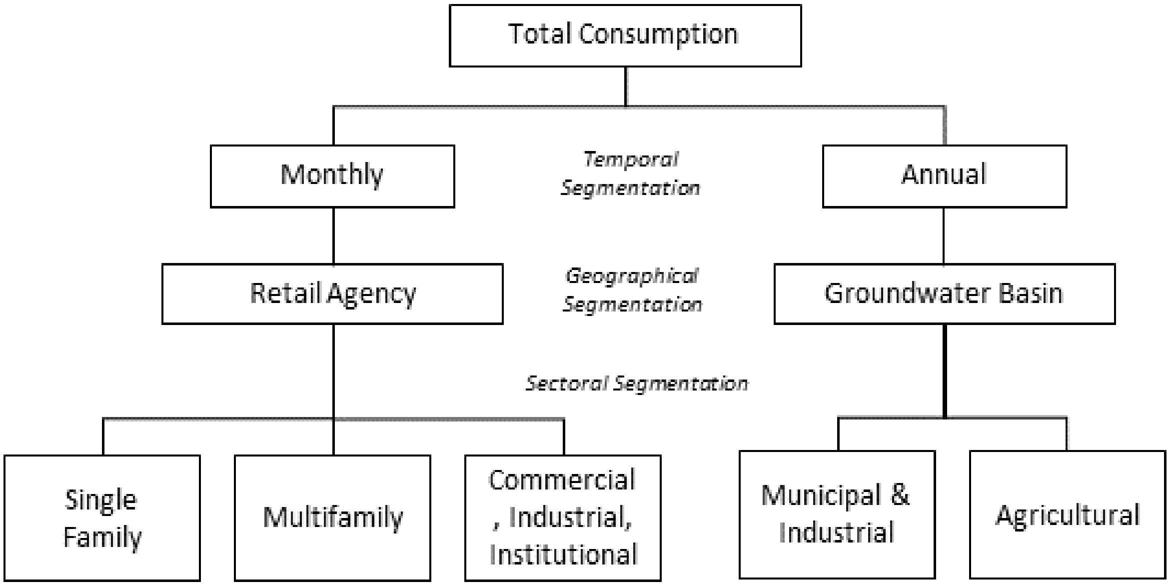


Figure 4-1: Hierarchy of Model Segmentation

4.1.2 Rate of Use Differentiation

Rate of use differentiation (i.e., characterizing consumption to reflect water using intensity) was applied in developing the retailer models. Rates of use were calculated given Equation (10) below, where for any given model sector Q reflects volumetric consumption, N is the count of driver units, and q is the rate of water use per driver unit.

$$Q \equiv N * \frac{Q}{N} \equiv N * q \qquad \textbf{(10)}$$

Rate of use differentiation requires a reliable and consistent historical driver unit dataset for model development and a corresponding future dataset representing projected driver unit counts. Consistent and reliable driver unit datasets for the retailer models were developed using data from CADOF (historical data) and ABAG (future projected data).[17] Corresponding driver units were not available for the non-retailer groundwater pumpers, so models were developed on a volumetric basis. Table 4-1 documents the driver units and corresponding rate of use for each retail model sector.

Table 4-1: Driver Units and Rate of Use for Each Retail Model Sector

Model Sector	Driver Unit (*N*)	Corresponding Rate of Use (*q*)
Single Family Multifamily	Housing units	Consumption per housing unit
CII	Employees	Consumption per employee
CII (Stanford)	Population	Consumption per capita

[17] Refer to Section 3.3.

4.1.3 Method / Statistical Approach

Valley Water collected historical consumption data from its retail agencies,[17] which generally spanned the period 2000-2018.[18] This dataset was sufficient from temporal, geographical, and sectoral perspectives (following sectoral standardization) to explore fitting customized statistical/econometric models. Development of historical econometric models provide a strong analytical benefit in forecasting demand, as they allow for the estimation of cause-effect relationships between weather, price, socioeconomic, and other factors that lead to variability in water demand. Quantifying these causal relationships allows for analysis of "what-if" scenarios that are uncertain, but important to consider for planning (e.g., climate change, development patterns, drought recovery).

Development of statistical/econometric models is an iterative process. Figure 4-2 (below) and Table 4-2 (following page) outline the process used to fit the econometric models.

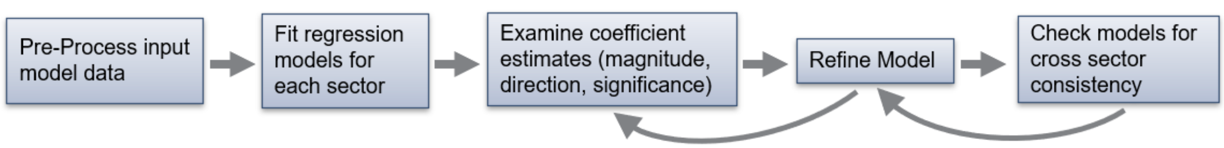


Figure 4-2: Process for Developing Statistical / Econometric Models

[18] Retail agencies submitted historical billing records of varying lengths. Sufficient retailers submitted records from 2000-2018 to establish model fits over the time period.

Table 4-2: Description of Model Fitting Procedures

Model Fitting Procedure	Description
Pre-process model input data[a]	Conduct necessary pre-processing calculations prior to model fitting, e.g.: • Geographical processing of driver units. • Calculate per-unit use. • Calculate natural logarithms of per-unit use and appropriate predictors. • Calculate departures from normal conditions for appropriate predictors (i.e., economic trend and weather). • Calculate any index, “dummy”, or interacted parameters (e.g., seasonal cycle, geography, drought severity). • Smoothing monthly and bimonthly data to adjust for irregular billing cycles.
Fit regression models for each sector	Use statistical estimation software (e.g., R, SAS, EViews) to fit linear regression equations to per unit use with the initially selected predictor variables.
Examine coefficient estimates and measure of fit	Check measures of fit (e.g., R^2) and coefficient estimates for reasonable magnitude, direction/sign, and significance.
Refine model to improve measures of fit and coefficient estimates	If the model fit is poor or if coefficient estimates are illogical or insignificant, several actions can be taken, including but not limited to: • Identifying and removing outlier data points that have significant leverage on coefficient estimates. • Remove predictors with insignificant or illogical coefficient estimates from the regression equation. • Testing alternate specifications of predictor variables.
Check models for cross-sector consistency	Model fits and predictors are compared across sectors to judge estimates relative to prior expectations; e.g., testing if the relative effects of price and socioeconomic variables vary by sector in a logical way based on past experience.
[a] Model data pre-processing is detailed in Section 3.	

4.1.4 Summary of Model Predictors

Several model predictors were used to develop Valley Water’s demand model. To be considered for use, potential predictors needed to pass the following conceptual criteria:

- Logical connection to explaining changes in water consumption;
- Historical record consistent with the time series of observed water consumption; and
- Availability of future projections consistent with the desired forecast horizon (i.e., 2020-2045) or a reasonable basis for assuming or generating projected values.

Initial selection of model predictors is discussed in detail in Section 3.6. However, during the model fitting process, derivatives of initial variables were also developed and included in subsequent model equations. One example is time lags on weather variables; supplementary variables were created from the temperature and precipitation time series at one to three-month lags. These lagged weather variables aimed to capture a delayed or persistent response in water use. A second example is an extended drought effect variable. The initial drought variables were directly calculated from historical water use restrictions. A supplemental drought variable was created that extended the last historical occurrence of mandatory water restrictions (2017) through the end of the historical dataset (2019); this “extended drought effect” variable was considered to represent inertia in behavioral changes in water use after the water use restrictions were no longer in place (i.e., delayed drought rebound). Table 4-3 details the predictors used to develop the demand models and identifies the expected sign and magnitude of the coefficient estimates resulting from the linear regression.

Table 4-3: Description of Demand Model Predictors

Predictor Variable	Log Transformed?	Expectations about Coefficient Estimates	Description
Departure from normal temperature[a]	Yes	Positive sign	Represents difference from long-term temperature. Higher than normal temperatures are associated with higher demands.
Departure from normal precipitation[a]	Yes	Negative sign	Represents difference from long-term precipitation. Higher than normal rainfall is associated with lower demands.
Seasonal index	No	Larger absolute magnitudes for agencies with greater seasonal peaking	Reflects the cyclical pattern in water use where demands a generally higher in the summer and lower in the winter. Represented in the model as a sine / cosine pair of variables.[b]
Price	Yes	Negative sign with absolute value between 0 and 1	Economic theory suggests negative correlation with demand.
Economic index	Yes	Positive sign	Several economic indices were explored as potential predictors[c] with the detrended ECRI selected as the index that produced the most reasonable coefficient estimates across model sectors. Water demand is positively correlated with economic fluctuations of the business cycle. The index is modeled in form of departures from long-term trend.
Housing density	Yes	Negative sign (commonly with absolute value between 0 and 1)	Housing density is negatively correlated with demand; on average, residences with more units per acre (or smaller parcel sizes) tend to use less water on outdoor uses.
Median income	Yes	Positive sign (commonly with absolute value between 0 and 1)	Economic theory suggests positive correlation of income with demand; generally geographical areas with higher median incomes tend to use more water.
Persons per household	Yes	Positive sign (commonly with absolute value between 0 and 1)	Positively correlated with demand; generally, residences with more people tend to use larger amounts of water.
Mix of Industries / economic activity[d]	Yes	N/A	The representation of industries / economic activity with a geographical area is related to the amount of water used within the CII sector. Fitted parameters for these variables are generally unique by utility, thus there is no generally accepted range of coefficient estimates.
Drought Severity	No	Negative sign	Reflects the effect of drought restrictions from the most recent drought (2014-2017, with extended restrictions though 2019) on water demand.[e] Defined as the presence of drought restrictions (represented as a binary) multiplied by the requested cutback (e.g. 0-30%).

[a] Lagged values of temperature and precipitation were also evaluated and included as model predictors as the influence of weather on water demand can persist several months.

[b] Most sectors have a single sine/cosine pair representing the seasonal cycle, except for Stanford. Stanford has two sine/cosine pairs to capture seasonal effects associated with the academic calendar. See Section 4.4.3 for additional discussion.

[c] Other economic indices explored as potential predictors are documented in Section 3.6.4.

[d] Detail on the derivation of specific predictors representing mix of industries / economic activity is documented in Section 3.6.8.

[e] A unique prediction variable was also evaluated for the 2008-2011 drought but was dropped during the model development process as the coefficient estimate was not statistically significant. The 2008-2011 drought overlapped with the severe economic downturn of the Great Recession which likely mutes its statistical significance.

4.2 Single Family Regression Development

This section reviews the development of the statistical regression for the single family residential sector.

4.2.1 Model Predictors and Fitted Coefficients

The fit for the final single family regression is presented in Table 4-4. Coefficient estimates are within the expected range for all explanatory variables.

Table 4-4: Single-Family Regression Predictors and Coefficients

Variable	Coefficient	Standard Error	t-Statistic	Probability
Intercept	3.821	0.324	11.776	<0.05
Seasonal index 1[a]	-0.283 (avg) -0.045 to -0.185	0.013 (avg) 0.008 to 0.026	-24.086 (avg) -7.379 to -24.086	<0.05
Seasonal index 2[a]	-0.262 (avg) -0.616 to -0.064	0.013 (avg) 0.008 to 0.026	-23.026 (avg) -44.960 to -3.786	<0.05
Departure from normal temperature	1.008	0.135	7.464	<0.05
Departure from normal temperature, 1-month lag	0.824	0.137	5.997	<0.05
Departure from normal temperature, 2-month lag	0.354	0.137	2.583	<0.05
Departure from normal temperature, 3-month lag	0.306	0.127	2.413	<0.05
Departure from normal precipitation	-0.008	0.003	-3.01	<0.05
Departure from normal precipitation, 1-month lag	-0.009	0.003	-3.649	<0.05
Departure from normal precipitation, 2-month lag	-0.004	0.003	-1.582	0.114
Price	-0.085	0.009	-9.942	<0.05
Economic index	0.945	0.101	9.316	<0.05
Housing density	-0.406	0.007	-60.745	<0.05
Median income	0.195	0.025	7.778	<0.05
Persons per household	0.473	0.04	11.907	<0.05
Drought severity, extended	-1.506	0.048	-31.109	<0.05
[a] Seasonal indices are unique to each retail agency.				

Variables with an increasing effect on water use (i.e., a positive coefficient) included temperature, economic index, median income, and persons per household. Variables with a decreasing effect on water use (i.e., a negative coefficient) included precipitation, price, housing density, and the extended drought effect.

4.2.2 Historical Model Performance

Figure 4-3 shows the observed and predicted per-unit use for the single family sector in gallons per unit per day (gpud) calculated as a unit-weighted average across all retail agencies. Performance of the single family regression is summarized in Table 4-5 which shows performance metrics for unit-weighted average county-wide demand. Visual inspection of the time series plot and review of the model fit parameters showed good performance at the county-wide level, including strong agreement with the observed seasonal cycle and ability to reproduce declining consumption during the Great Recession, recovery between the Great Recession and the recent drought, and the sharp decline and muted recovery following the most recent drought.

Historical performance of the single family regression was also strong at the retail agency-level. Model fit statistics calculated at the retail agency-level generally mirrored county-wide performance. Model fit statistics and time series plots for each retailer are presented in Appendix E.

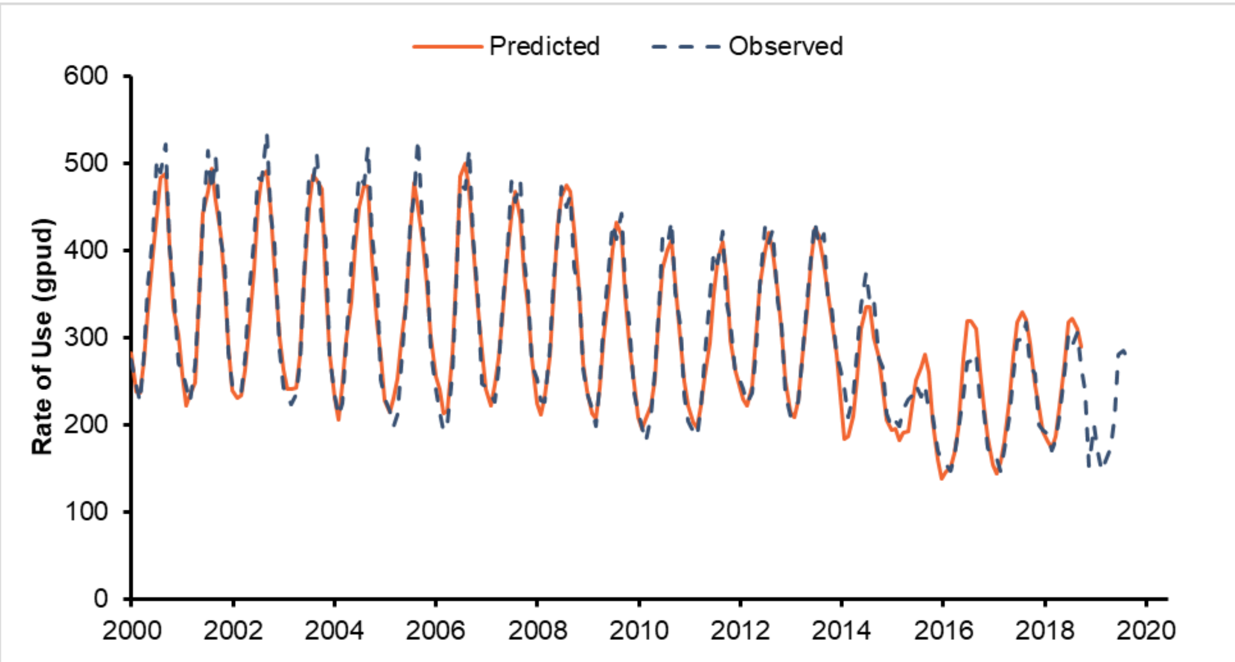


Figure 4-3: County-Wide Single-Family Observed and Predicted Per Unit Rate of Use

Table 4-5: County-Wide Single-Family Regression Performance Metrics

Regression Statistic[(a)]	Value
R-squared	0.95
Average Observed Value (gpud)	305.71
Mean Absolute Percentage Error	5.82%
Mean Bias	-1.13%
[(a)] Statistics calculated using county-wide unit-weighted average observations and predicted values from the regression fits.	

4.3 Multifamily Regression Development

This section reviews the development of the statistical regression model for the multifamily residential sector.

4.3.1 Model Predictors and Fitted Coefficients

The fit for the final multifamily regression is presented in Table 4-6. Though most predictors are the same as the single family sector, several predictors (e.g., median income and 2-month lagged departure from precipitation) were dropped and certain predictors (e.g., the intercept term and drought severity) were allowed to vary by retail agency. These modifications to the model design resulted in stronger measures of fit and more reasonable coefficient estimates. Final coefficient estimates presented in Table 4-6 are within the expected range for all explanatory variables.

Table 4-6: Multifamily Regression Predictors and Coefficients

Variable	Coefficient	Standard Error	t-Statistic	Probability
Intercept	5.209	0.074	70.141	<0.05
Agency-specific intercepts[a]	-0.223 (avg) -0.719 to 0.280	0.013 (avg) 0.007 to 0.023	-31.555 (avg) -104.09 to 15.203	<0.05
Seasonal index 1[b]	-0.161 (avg) -0.372 to -0.056	0.012 (avg) 0.006 to 0.031	-16.311 (avg) -35.651 to -3.872	<0.05
Seasonal index 2[b]	-0.138 (avg) -0.255 to -0.056	0.012 (avg) 0.006 to	-13.943 (avg) -29.588 to -13.943	<0.05
Departure from normal temperature	0.488	0.098	4.974	<0.05
Departure from normal temperature, 1-month lag	0.514	0.100	5.155	<0.05
Departure from normal temperature, 2-month lag	0.397	0.094	4.226	<0.05
Departure from normal temperature, 3-month lag	0.194	0.092	2.101	<0.05
Departure from normal precipitation	-0.002	0.002	-1.127	0.260
Departure from normal precipitation, 1-month lag	-0.006	0.002	-2.954	<0.05
Price	-0.055	0.013	-4.347	<0.05
Economic index	1.568	0.091	17.226	<0.05
Housing density	-0.205	0.011	-18.105	<0.05
Persons per household	0.900	0.057	15.788	<0.05
Drought severity, extended[c]	-0.718	0.044	-16.294	<0.05

[a] Several agencies including San Jose Water Company, San Jose Municipal Water, Great Oaks Water Company, City of Gilroy, California Water Service, and the City of Sunnyvale were fitted with agency-specific intercept terms in order to optimize historical model performance.

[b] Seasonal indices are unique to each retail agency.

[c] Recorded drought severity coefficient estimate is for all agencies except San Jose Water Company, which was fitted an agency-specific drought severity coefficient.

Variables with an increasing effect on water use (i.e., a positive coefficient) included temperature, economic index, and persons per household. Variables with a decreasing effect on water use (i.e., a negative coefficient) included precipitation, price, housing density, and the extended drought effect.

4.3.2 Historical Model Performance

Figure 4-4 shows the observed and predicted per-unit use for the multifamily sector in gpud calculated as a unit-weighted average across all retail agencies.[19] Performance of the multifamily regression is summarized in Table 4-7 which shows performance metrics for unit-weighted average county-wide demand. Visual inspection of the time series plot and review of the model fit parameters showed good model performance at the county-wide level, including strong agreement with the observed seasonal cycle and ability to reproduce declining consumption during the Great Recession, recovery between the Great Recession and the recent drought, and the sharp decline and muted recovery following the most recent drought.

Historical performance of the multifamily regression was also strong at the retail agency-level. Model fit statistics calculated at the retail agency-level generally mirrored county-wide performance. Model fit statistics and time series plots for each retailer are presented in Appendix F.

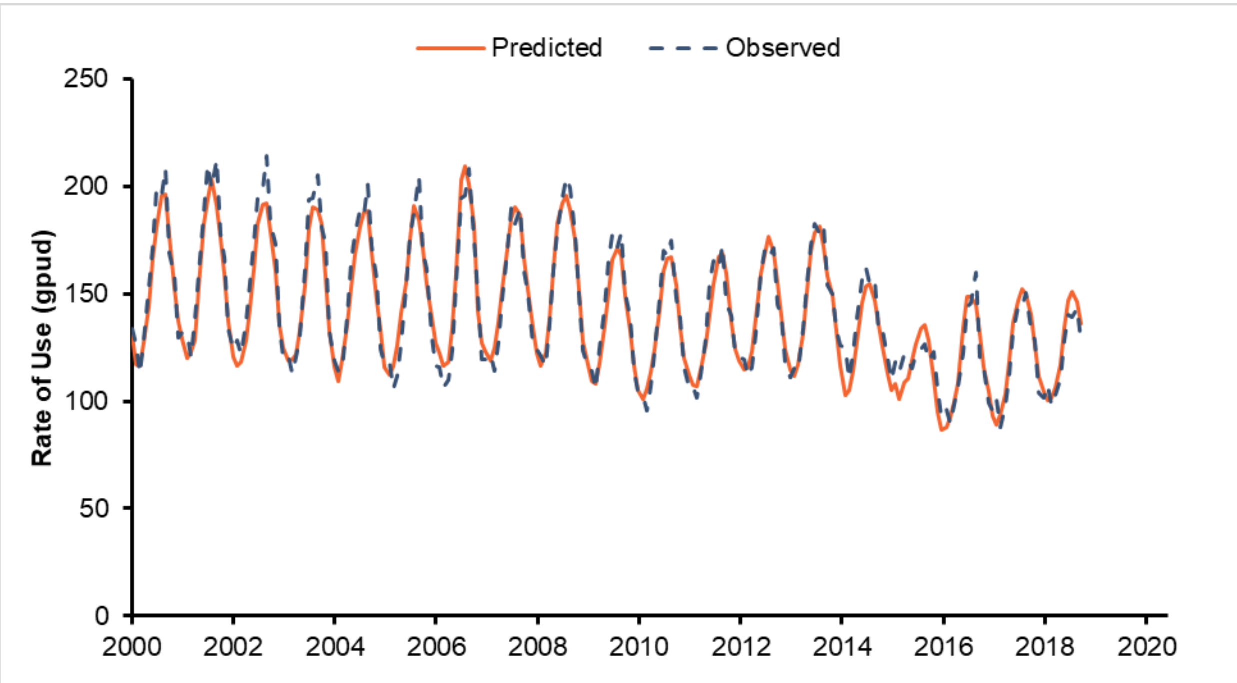


Figure 4-4: County-Wide Multifamily Observed and Predicted Per Unit Rate of Use

[19] Figure 4-4 excludes an outlier monthly observed datapoint for a single retail agency.

Table 4-7: County-Wide Multifamily Regression Performance Metrics

Regression Statistic[a]	Value
R-squared	0.94
Average Observed Value (gpud)	142.26
Mean Absolute Percentage Error	4.53%
Mean Bias	-0.87%
[a] Statistics calculated using county-wide unit-weighted average observations and predicted values from the regression fits.	

4.4 CII Regression Development

This section reviews the development of the statistical regression for the CII sector. Distinct regressions representing the commercial, industrial, and institutional water use sectors[20] were initially considered. However, different billing classification schemes among retail agencies introduced definitional uncertainty in sectoral water use and driver units. For example, certain agencies lacked a distinct industrial billing classification while others combined commercial and institutional categories. Additional verification of water use at the account-level was not possible given the data constraints for this project.[21] In response to these constraints and uncertainties, total use within the commercial, industrial, and institutional sectors was consolidated into a single composite CII regression. The benefit of combining these sectors is a more parsimonious representation with respect to number of sectors, while providing a means to use the mix of industries to explain CII water use variability across retail agencies.

4.4.1 Model Predictors and Fitted Coefficients

Model predictors for the final CII regression equation along with their statistics are in Table 4-8. Note that understanding/quantifying the types of economic activity occurring within the County are important to understanding changes in CII consumption over time. Since individual regressions for the commercial, industrial, and institutional sectors were not developed, predictor variables representing the relative proportion of employment among different industry groupings was used in the CII regression. Proportional employment based on industry grouping is meant to reflect the relative mix of industries/economic activity within each retail agencies' service area. Most CII model predictors are similar to those used for the single family and multifamily sectors, however certain variables (e.g., 3-month lagged departure from normal temperature) were excluded during the regression refinement process. Final coefficient estimates presented in Table 4-8 are within the expected range for all explanatory variables.

[20] Refer to Appendix A for a summary of standardized sectors by retail agency.
[21] The finest spatial resolution of all consumption data was at the retail agency-level.

Table 4-8: CII Regression Predictors and Coefficients

Variable	Coefficient	Standard Error	t-Statistic	Probability
Intercept	-0.186	0.268	-0.695	0.49
Seasonal index 1[a]	-0.29 (avg) -0.41 to -0.17	0.02 (avg) 0.01 to 0.03	-20.79 (avg) -33.3 to -9.2	<0.05
Seasonal index 2[a]	-0.34 (avg) -0.53 to -0.10	0.02 (avg) 0.01 to 0.03	-23.34 (avg) -39.2 to -3.5	<0.05
Departure from normal temperature	1.037	0.158	6.580	<0.05
Departure from normal temperature, 1-month lag	0.912	0.161	5.657	<0.05
Departure from normal temperature, 2-month lag	0.370	0.158	2.340	<0.05
Departure from normal precipitation	-0.003	0.003	-0.997	0.32
Departure from normal precipitation, 1-month lag	-0.007	0.003	-2.312	<0.05
Departure from normal precipitation, 2-month lag	-0.002	0.003	-0.692	0.49
Price	-0.062	0.025	-2.453	<0.05
Economic index	0.963	0.140	6.881	<0.05
Proportion of total Employment (Retail)	0.142	0.032	4.430	<0.05
Proportion of total Employment (Professional Services)	0.499	0.031	16.065	<0.05
Proportion of total Employment (Information, Government, and Construction)	0.093	0.026	3.508	<0.05
Proportion of total Employment (Industrial)	0.351	0.026	13.249	<0.05
Proportion of total Employment (Health Education, and Recreational Services)	0.466	0.059	7.923	<0.05
Drought severity, extended	-1.424	0.070	-20.232	<0.05
[a] Coefficients vary by retailer.				

Variables with an increasing effect on water use (i.e., a positive coefficient) included temperature, economic index, and the mix of industries/economic activity ratios. Variables with a decreasing effect on water use (i.e., a negative coefficient) included precipitation, price, and the extended drought effect.

4.4.2 Historical Model Performance

Figure 4-5 shows the observed and predicted per-unit use for the CII sector in gallons per employee per day (gped) calculated as a unit-weighted average for across all retail agencies. Performance of the CII model is summarized in Table 4-9 which shows regression performance metrics for county wide demand. Visual inspection and performance metrics showed good model performance including the same seasonal cycle and quantities. The CII regression was also able to reproduce declining consumption during the Great Recession, recovery between the Great Recession and the recent drought, and the sharp decline and muted recovery following the most recent drought.

Historical performance of the CII regression was also strong at the retail agency-level. Model fit statistics calculated at the retail agency-level generally mirrored county-wide performance. Model fit statistics and time series plots for each retailer are presented in Appendix G.

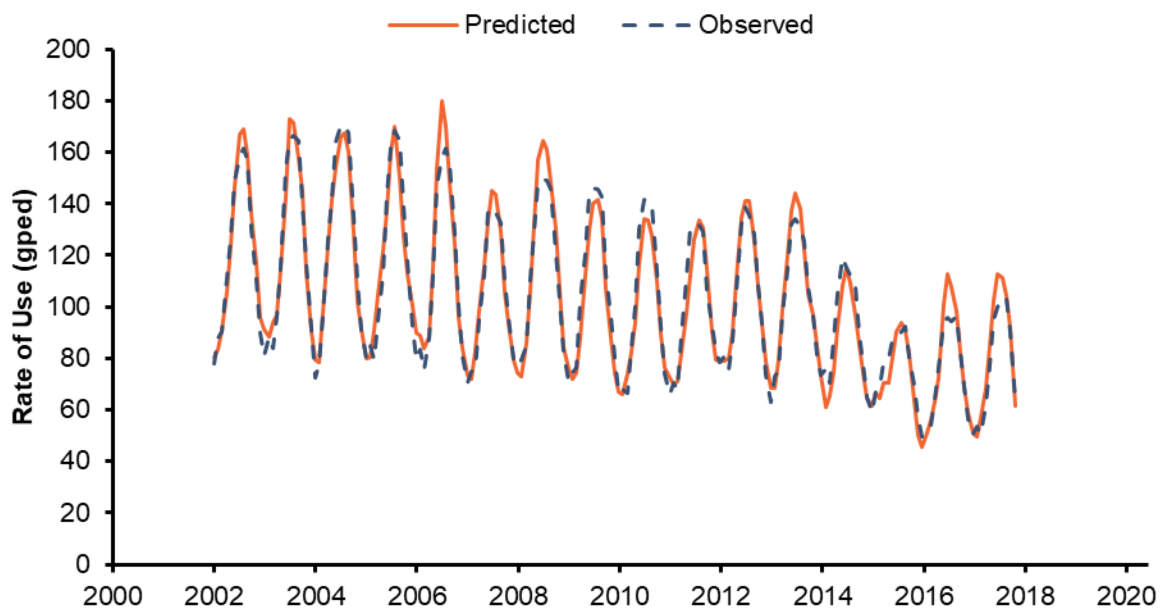


Figure 4-5: CII Observed and Predicted Rate of Use

Table 4-9: County-Wide CII Regression Performance Metrics

Regression Statistic[(a)]	Value
R-squared	0.96
Average Observed Value (gped)	103.89
Mean Absolute Percentage Error	5.08%
Mean Bias	-0.06%
[(a)] Statistics calculated using county-wide unit-weighted average observations and predicted values from the regression fits.	

4.4.3 Stanford University Regression Development

As an academic institution, Stanford is considered part of the CII sector. However, an independent regression for Stanford was developed given its unique characteristics among retailers. Unlike other retail agencies, Stanford does not have accounts in the traditional sense as individual users are not billed. Additionally, employee water use as the sole driver unit (consistent with the CII sector for other retailers) is not appropriate for Stanford as students account for a significant portion of water use. This distinction informed the decision to use population (understood to be total faculty, staff, and students) as the driver unit for Stanford. Since the driver unit for the Stanford CII model was population, rather than jobs like the rest of the retailers' CII use, rate of use must be modeled separately. It is expected that the significant variables and/or magnitudes of coefficients would be different for Stanford than the other retailers' CII sectors due to the difference in driver units. A discussion of Stanford's regression predictors and fitted coefficients is presented in Appendix H. A summary of the Stanford's historical model performance is included in Appendix G.

4.5 Non-Retail Groundwater Pumper Regression Development

Historical water use for non-retail groundwater pumpers includes groundwater use by private well owners that are outside of retailers' service areas. Historical groundwater use was reported by groundwater basin and billing classification. The groundwater basins include Santa Clara Plain (referred to as charge zone "W2") as well as Coyote Valley sub-basin management area and the Llagas sub-basin and (referred to as charge zone "W5"). Water use was classified as either agricultural or M&I. M&I can include residential domestic water use.

Historical regression fits for non-retail groundwater pumpers were performed on annual water use. Agricultural water use was typically reported annually or semi-annually. M&I use was reported monthly or semi-annually. As a result, a monthly resolution for model fitting was not possible.

Further, historical model fits for non-retail groundwater pumpers were performed on a volumetric basis. Typical driver units for groundwater use, such as number of wells, did not support the "rate of use times driver" approach that was used for single family, multifamily, and CII model development.

Fitted models were only finalized for the M&I sector for the two groundwater basins. Agricultural use was often reported semi-annually (in January and July) and was estimated by a "table of averages" approach based on crop type, resulting in a lack of variability that could be modeled by predictor variables. Initial exploration of statistical/econometric model development showed that agricultural water use has been generally constant over the last twenty years and was not well-characterized by typical predictor variables.

4.5.1 Model Predictors and Fitted Coefficients

Model predictors for the non-retail groundwater pumpers M&I regression models along with their statistics are in Table 4-10. The two groundwater zones were modeled separately; a combined regression provided no improvement in the statistical significance of coefficients.

Table 4-10: Predictors for Non-Retail Groundwater Pumpers M&I Regression.

Basin	Variable	Coefficient	Std. Error	t-Statistic	Prob.
W2	Intercept	-0.59	4.08	-0.14	0.89
	Drought	-0.70	0.20	-3.54	<0.05
	Price	-0.81	0.06	-13.31	<0.05
	Temperature[a]	1.83	0.93	1.98	0.07
W5	Intercept	1.43	0.47	3.04	<0.05
	Number of Wells	0.19	0.04	5.56	<0.05
	Drought	-0.31	0.15	-2.09	0.06
	Price	-0.12	0.05	-2.41	<0.05
	Precipitation[a]	-0.09	0.02	-3.62	<0.05

[a] Temperature and precipitation for non-retail groundwater pumper models were in absolute terms, not departures from normal.

Variables with an increasing effect on water use (i.e., positive coefficient) included maximum temperature (used in the W2 model only) and number of wells (used in the W5 model only). Variables with a decreasing effect on water use (i.e., negative coefficient) included the extended drought effect, price, and precipitation (used in the W5 model only). Economic indices, density, and median income were not found to be statistically significant for the groundwater M&I regressions. Note that temperature was found to be statistically significant for the W2 charge zone but not for the W5 charge zone regression, while precipitation was found to be statistically significant for W5 but not W2.

4.5.2 Historical Model Performance

Performance of the groundwater M&I regressions is summarized in Table 4-11. Figure 4-6 and Figure 4-7 show the observed and predicted demand for the M&I sector for groundwater charge zone W2 and W5, respectively. The M&I W5 regression had a lower correlation coefficient than all other model fits described in Sections 4.2 – 4.4, likely due to the relatively constant annual average water use over the available period.

Table 4-11: Regression Performance Metrics for Groundwater M&I Models

Regression Performance Metric	M&I, W2	M&I, W5
R-squared	0.96	0.81
Average Observed Value (mgd)	7.81	7.68
Mean Absolute Percent Error	4.32%	3.54%
Mean Bias	-0.22%	-0.09%

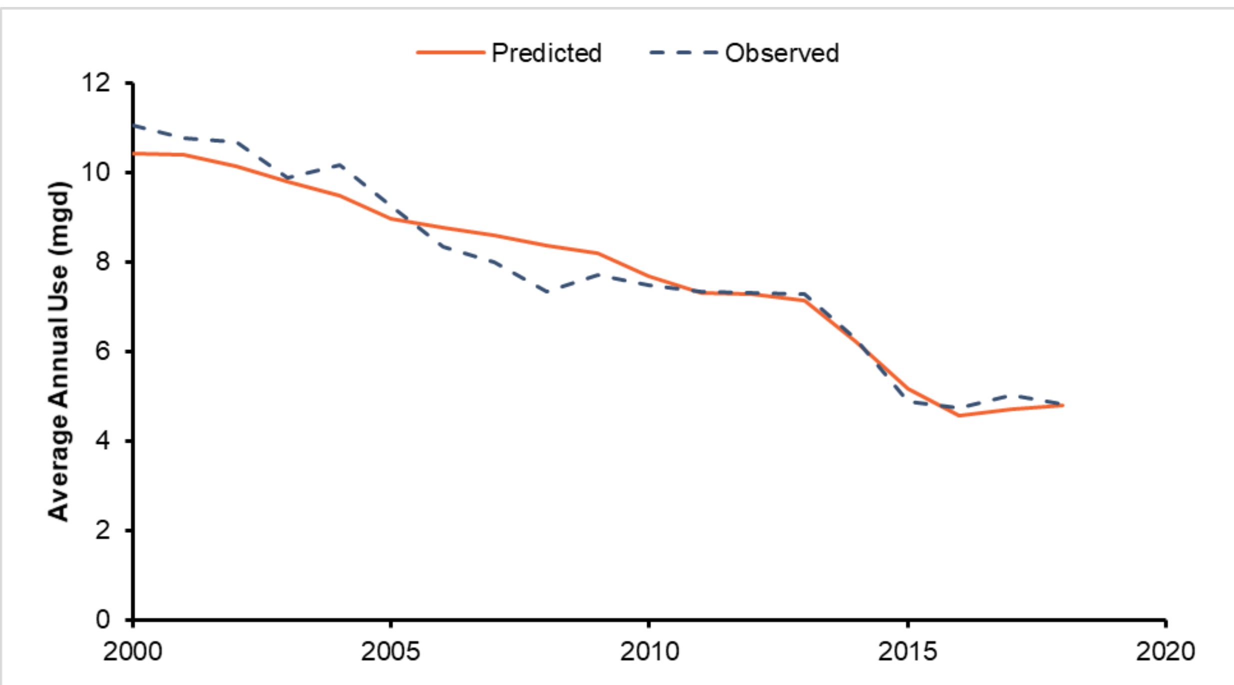


Figure 4-6: Observed and Predicted M&I Demand for Groundwater Basin W2

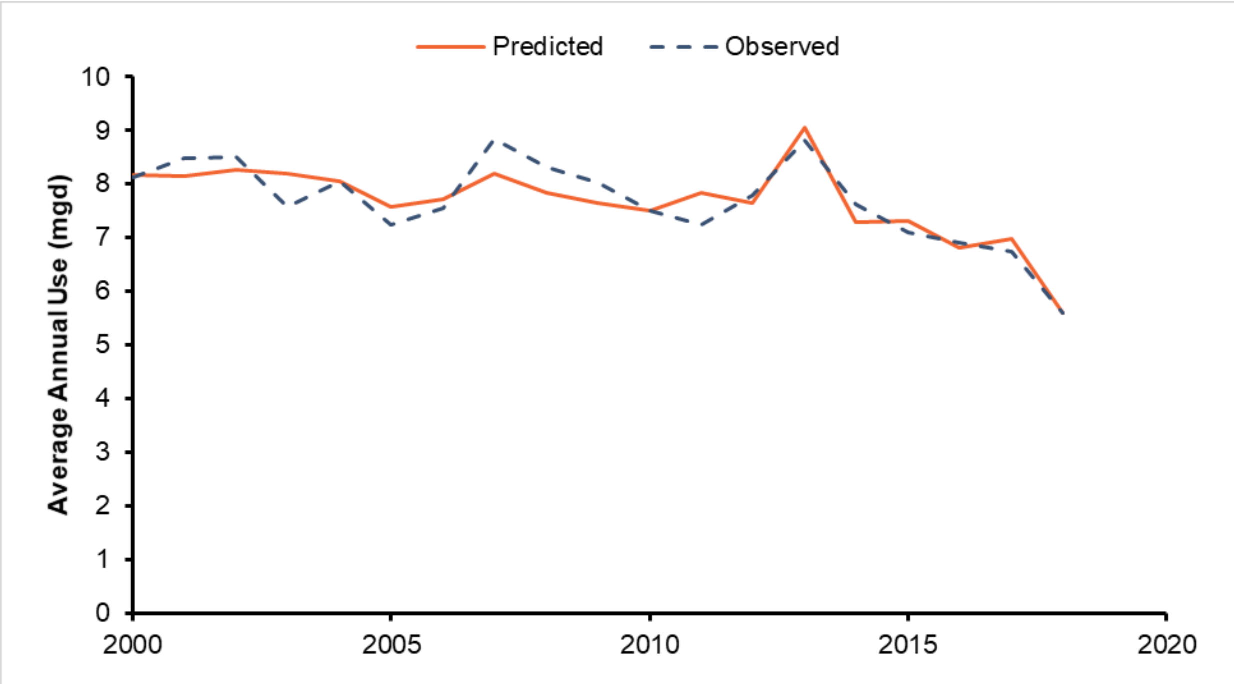


Figure 4-7: Observed and Predicted M&I Demand for Groundwater Basin W5

Figure 4-8 on the following page shows historical agricultural water use for the W2 and W5 charge zones. Agricultural water use in the W2 charge zone is less than 1 mgd and has been slightly declining over the last twenty years. Agricultural water use in the W5 charge zone has been generally constant over the last twenty years at approximately 23 mgd. Initial exploration of statistical/econometric model development showed that agricultural water use was not well-characterized by typical predictor variables. Agricultural water use in both charge zones would be well-represented by an average water use from a historical reference period that is then held constant into the future.

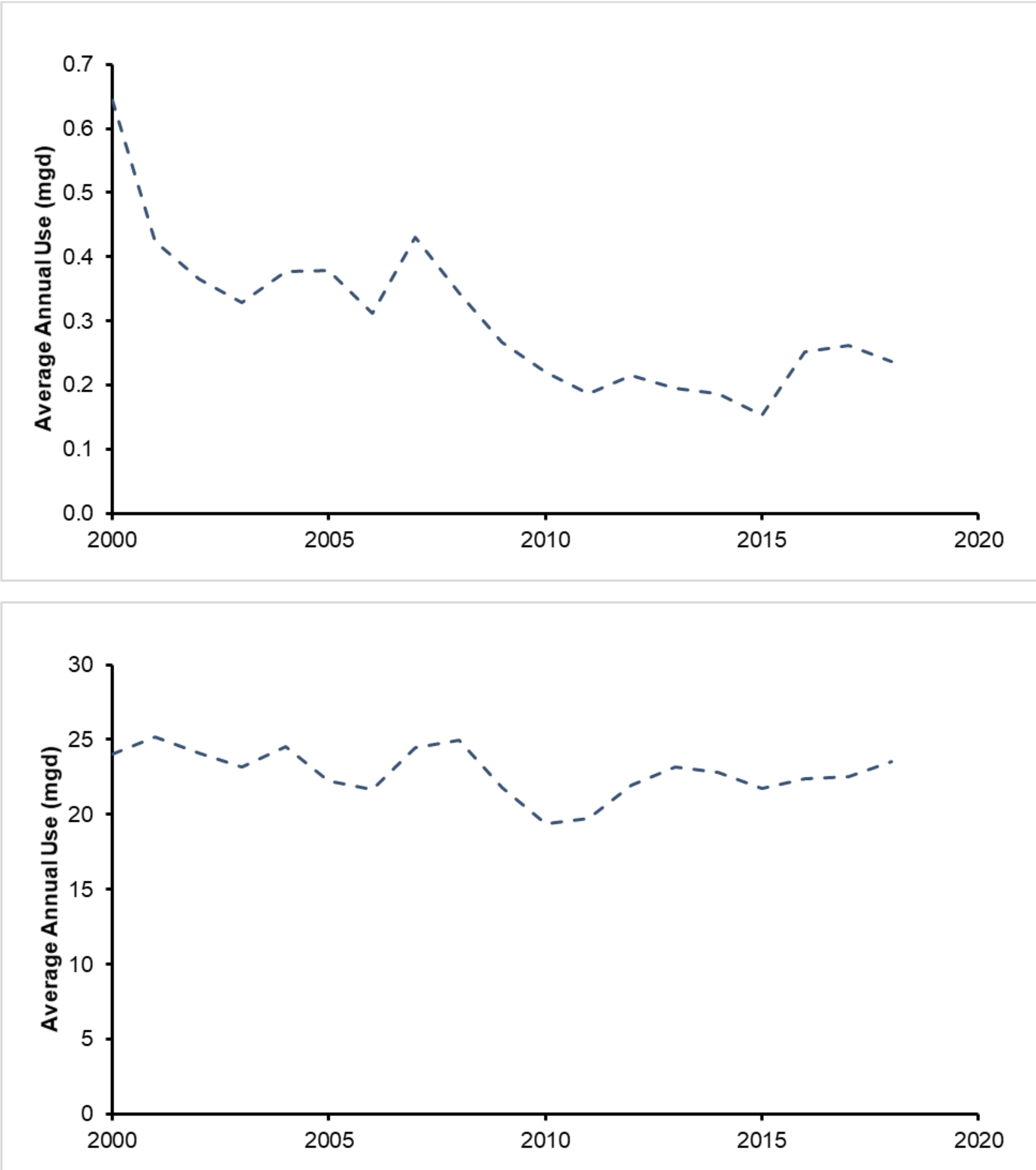


Figure 4-8: Observed Agricultural Demand for Groundwater Basin W2 (top) and W5 (bottom)

4.6 Model Development Summary

In summary, the statistical/econometric regressions presented in this Section show strong performance in explaining historical patterns of consumption over the last 20 years, including two major droughts and the Great Recession. All regressions had R-squared values of 0.81 or greater. The retailer-specific regressions, which represent the majority of water use in the County, had R-squared values of 0.94 or greater. None of the regressions demonstrated a large consistent bias. Based on this analysis, the estimated regression equations reflect a suitable basis for forecasting.

The overall model approach allows for demand forecast scenario analysis based on varying assumptions of future conditions. Several forecast scenarios may be explored, including climate change-adjusted weather, alternate assumptions around the timing and magnitude of drought recovery, alternate assumptions around urban development, and/or different assumptions around future economic conditions. For any of these future scenarios, the model coefficients presented in this section should be maintained as they reflect the best fitted estimates of causal relationships between external socioeconomic conditions and historical water demand given the available modeling data. Model scenarios can also be developed to address uncertainties in future predictor variables, such as housing/job growth and density. Future inputs in these scenarios could be conducted as a sensitivity analysis or be driven by alternate growth projections.

On a regular basis, overall model performance should be evaluated. Annually, forecasted consumption and input assumptions (e.g., driver unit counts, economic conditions, water rates, etc.) can be compared with observed conditions as data becomes available to monitor predictive performance. Less frequently (around every 5 years) model predictors should be revaluated using the process outlined in Figure 4-2. Major events, such as another drought or a severe economic recession may necessitate reexamination and/or refitting model coefficients and may cause changes in longer term expectations over the forecast period. As more data becomes available on the impacts of COVID-19 on county demographics and water use (e.g., potential shifts in CII to residential demand), reexamination of the underlying sectoral rates of water use as well as model coefficients should be conducted.

5. Future Demand Analysis

The purpose of this section is to document the future demand analysis, including data collection, data processing, and forecast assumptions. Demand projections presented in this Section do not consider additional water conservation and are called "baseline" projections. Projections of future conservation savings are generated separately by Valley Water and then deducted from the baseline projections. The models establish baseline demand projections from 2020 to 2045 at a monthly timestep. Data sources documented in this section are limited to projected future datasets. Review of historical datasets are documented in Section 3, and review of the modeling approach is documented in Section 4.

5.1 Baseline Scenario Assumptions

This section reviews the future conditions and assumptions that define Valley Water's baseline demand projection scenario. Future conditions and assumptions were defined for each element of the water demand model, including sectoral driver units and explanatory variables. Growth in driver units was tied to ABAG projections for relevant metrics through 2040, as published in 2017. Future conditions for all other explanatory variables were selected to represent expected changes or to remain constant. A summary of the baseline demand scenario assumptions for driver units and explanatory variables are summarized in Table 5-1 on the following page. Development of future datasets used to define the inputs are further detailed in Section 5.2.

5.1.1 Evaluation of ABAG Projections

ABAG projections are an important data source for Valley Water's demand forecast as they are used to derive four model inputs. In recognition of this importance, ABAG projections of Santa Clara County households and population for 2015, 2019, and 2020 were compared against the U.S. Census ACS estimates and CADOF estimates in Table 5-2. The ABAG projected households was 2.4% higher than ACS estimates in 2015 and 4.6% higher than ACS estimates in 2019. ABAG projected population was closer to ACS estimates, falling within 0.4% in 2015 and 3.0% higher in 2019. ABAG projected households and population were within 1.6% of CADOF estimates in both years. The difference in 2020 between ABAG projected households and population and CADOF households and population were slightly larger than in 2019 but still within 2.1%. At the county-wide level, prior ABAG projections are reasonably close to accepted historical estimates and are suitable for inclusion as a data source for Valley Water's demand forecast. To account for differences at the retail agency-level, ABAG driver unit projections were adjusted to align with CADOF estimates (refer to Section 5.2.1).

Table 5-1: Summary of Baseline Scenario Data Sources and Assumptions

Input	Source	Assumptions
Driver Units	ABAG	• Initialized with historical 2018 value and grown using the rate of change in ABAG projected single family housing units, multifamily housing units, non-agricultural jobs, and population [(a)]
Monthly Maximum temperature and Total Precipitation	PRISM	• 30-year historical normal weather [(b)]
Water Rates	Retailers	• Nominal price grows in time based on the 2020 PAWS report rates from 2020-2030, then increase each year by 5% after that [(c)] • Prices are adjusted for inflation assuming 3% each year
Detrended Economic Factor	ECRI Coincident Index	• Assume long-term trend economy based on the detrended ECRI coincident index
Median Income	US Census	• Assume constant income at 2018 value (real dollars)
Housing Density	ABAG	• North County retailers assume housing density derived from ABAG projected housing units divided by constant (2018) residential acres • South County retailers assume constant density at 2018 value
Persons Per Household	ABAG	• Initialized with historical 2018 value and grown using rate of change in ABAG total PPH projections
Relative Sectoral Employment	ABAG	• Calculated based on ABAG projections of non-agricultural jobs
Drought Rebound	N/A [(d)]	• Assumes a 50% rebound by 2025 in water use following the last drought period
Seasonality	-	• Sine/cosine functions to capture monthly pattern

[(a)] Stanford University is the only retail agency utilizing population as a driver unit.

[(b)] Climate change scenarios use General Circulation Model (GCM) projections of temperature and precipitation were also developed, but not applied to the baseline scenario. Climate change projections are further discussed in Section 5.2.2.

[(c)] A constant water rate scenario was also considered, which assumed 2018 deflated price value.

[(d)] Representation of drought rebound is further discussed in Section 5.2.9.

Table 5-2: Comparison of Santa Clara County ABAG Projections with ACS and CADOF Historical Estimates

Source	Households			Population		
	2015	2019	2020	2015	2019	2020
ABAG 2017	648,900	673,320 [(a)]	679,425	1,909,680	1,971,008 [(a)]	1,986,340
U.S. Census	633,786	643,637	N/A	1,918,044	1,927,852	N/A
CADOF	652,007	671,439	674,588	1,912,180	1,954,833	1,945,166
Percent Difference between ABAG and U.S. Census	2.4%	4.6%	N/A	-0.4%	3.0%	N/A
Percent Difference between ABAG and CADOF	-0.5%	0.3%	0.7%	-0.1%	1.6%	2.1%

[(a)] ABAG 2019 values are interpolated between available projected values in 2015 and 2020 in order to compare to U.S. Census data.

5.1.2 Model Calibration

Raw output of the forecasts were multiplied by calibration factors to account for biases in the historical model fits. Calibration factors were derived from the ratio of average observed to average predicted total water demand over a defined set of years. The selected calibration period was fiscal years 2009 to 2018 because it covers a wide range of conditions that were known to affect water use. Calibration factors were independent to each retail agency and sector and are summarized in Table 5-3 below.

Table 5-3: Calibration Factors by Sector and Retailer

Retail Agency	Single Family Residential	Multifamily Residential	CII	Agricultural Water Use	M&I Water Use
California Water Service	1.134	0.995	0.972	-	-
City of Gilroy	0.996	1.005	0.998	-	-
City of Milpitas	1.005	1.024	1.003	-	-
City of Morgan Hill	0.911	0.963	1.004	-	-
City of Mountain View	0.932	0.984	0.988	-	-
City of Palo Alto	0.995	0.995	1.089	-	-
City of Santa Clara	1.012	1.050	1.002	-	-
City of Sunnyvale	0.997	0.971	0.999	-	-
Great Oaks Water Company	1.006	1.014	0.999	-	-
Purissima Hills Water District	1.001	-	0.956	-	-
San Jose Municipal Water	0.982	1.047	1.003	-	-
San Jose Water Company	1.004	1.011	1.009	-	-
Stanford University	-	-	1.003	-	-
Independent Pumpers, W2	-	-	-	1.000	1.000
Independent Pumpers. W5	-	-	-	1.000	0.998

5.2 Development of Forecast Inputs

This section reviews the data sources and methodology applied to develop future values of variables contained in the demand model.

5.2.1 Retailer Driver Units

Driver units reflect the size or scale of a water use sector and allow for differentiation of rate of use from total consumption. The selected driver units for each model sector are shown in

Table 5-4 on the following page. All driver units were derived from the ABAG 2017 Plan Bay Area Projections 2040 (ABAG 2017) , which estimate single family residential housing units, multifamily residential housing units, jobs by sector, and total population at five-year intervals from 2015 through 2040. Driver units of jobs for the CII model sector were calculated as the total number of non-agricultural jobs from the ABAG jobs categories, which included: Health, Education and Recreational Service; Financial and Professional Services; Informational, Government and Construction; Manufacturing, Wholesale and Transportation; and Retail.

Table 5-4: Driver Units by Model Sector

Model Sector	Driver Unit
Single Family	Housing Units
Multifamily	Housing Units
CII	Jobs, Population (for Stanford only)
Other	N/A[a]

[a] Other water use was projected as a percentage of total single family, multifamily, and CII consumption. See Section 5.3.5.

ABAG projections were available at census tract level geographies, which required geoprocessing to retailer service area boundaries. Geoprocessing was performed using GIS overlays of census tract boundaries and retail agency service area boundaries to aggregate ABAG projections by retail agency; this geoprocessing is described further in Section 3.3.1.

ABAG projections at the retailer level did not always align in magnitude with the historical driver units. To ensure consistency from historical to future datasets, the future time series for driver units were developed by calculating the rate of change in the ABAG projections and modifying the last historical value of the driver units by the corresponding ABAG rate of change. Further, the future driver units needed to be extended to 2045, the end year of the demand projections. The rate of change in ABAG projections from 2035 to 2040 was repeated for the period from 2040 to 2045 in order to extrapolate the projected driver unit values to 2045. An illustration of the difference between ABAG projections, historical driver units, and projected driver units is shown in Figure 5-1. The resulting county-wide projected driver units are shown in Figure 5-2 (housing units) and Figure 5-3 (total non-agricultural jobs) on the following page. Time series plots of processed future driver units by retailer are included in the appendices associated with sectoral demand forecasts described in Section 5.3.

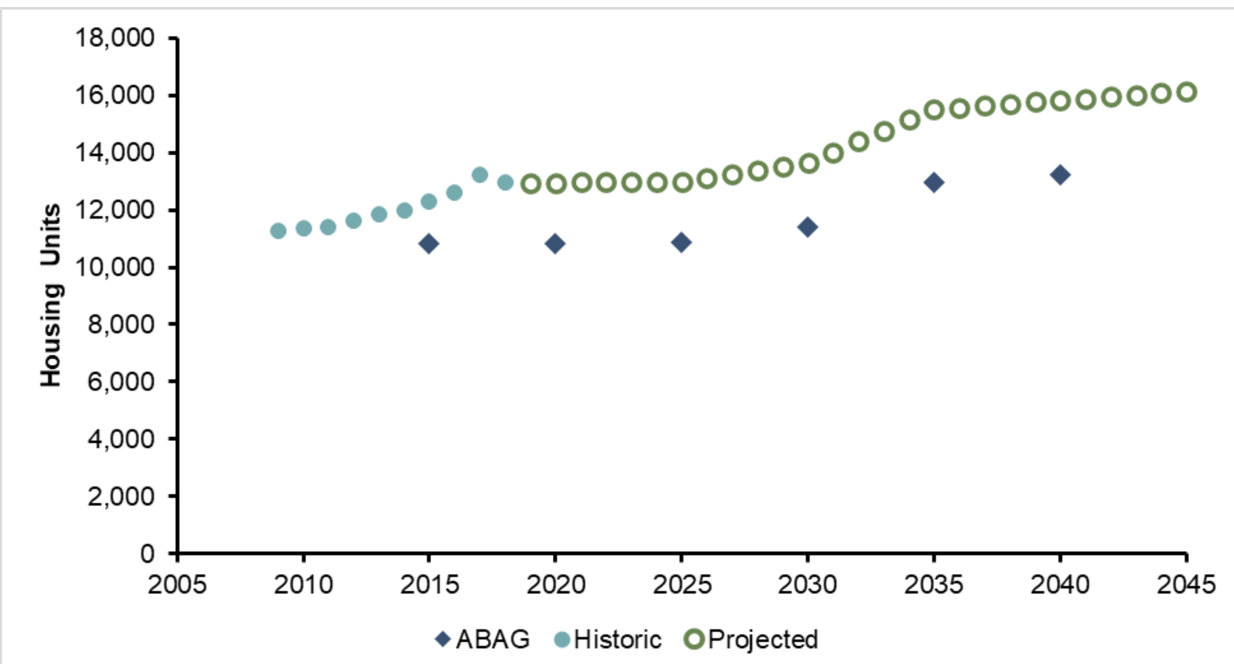


Figure 5-1: Example of ABAG Projections and Driver Units

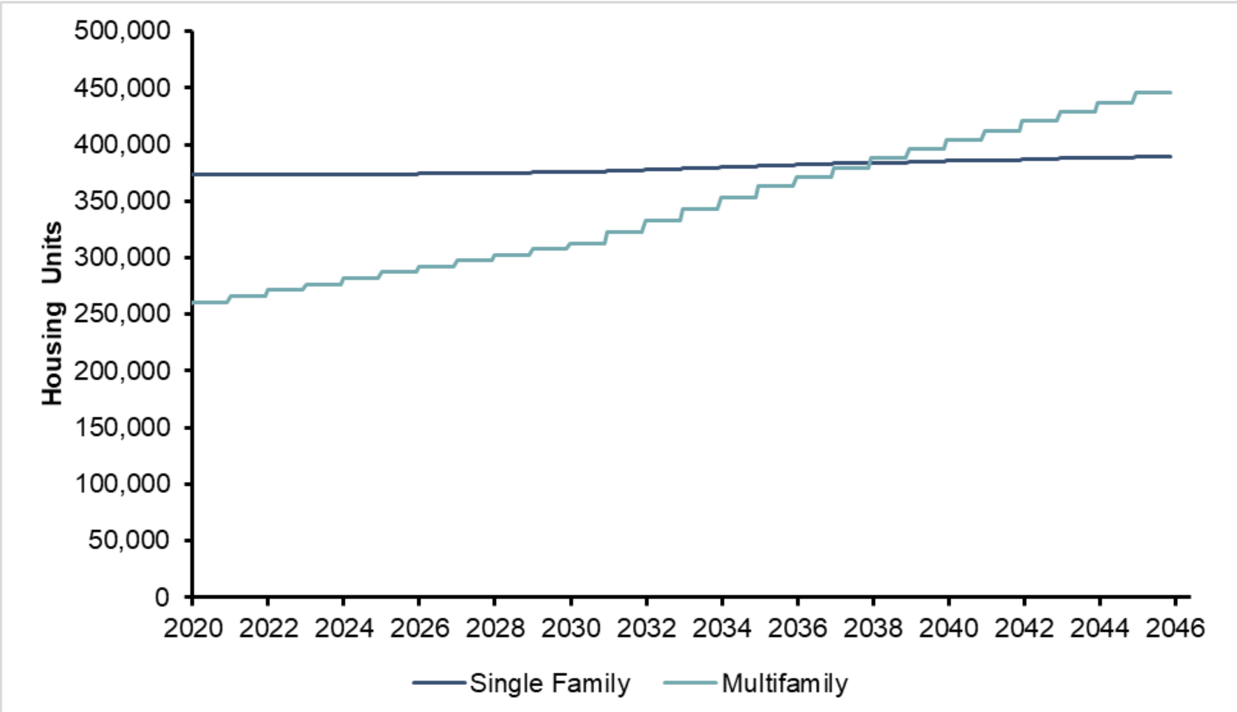


Figure 5-2: County Wide ABAG-Derived Housing Unit Projections

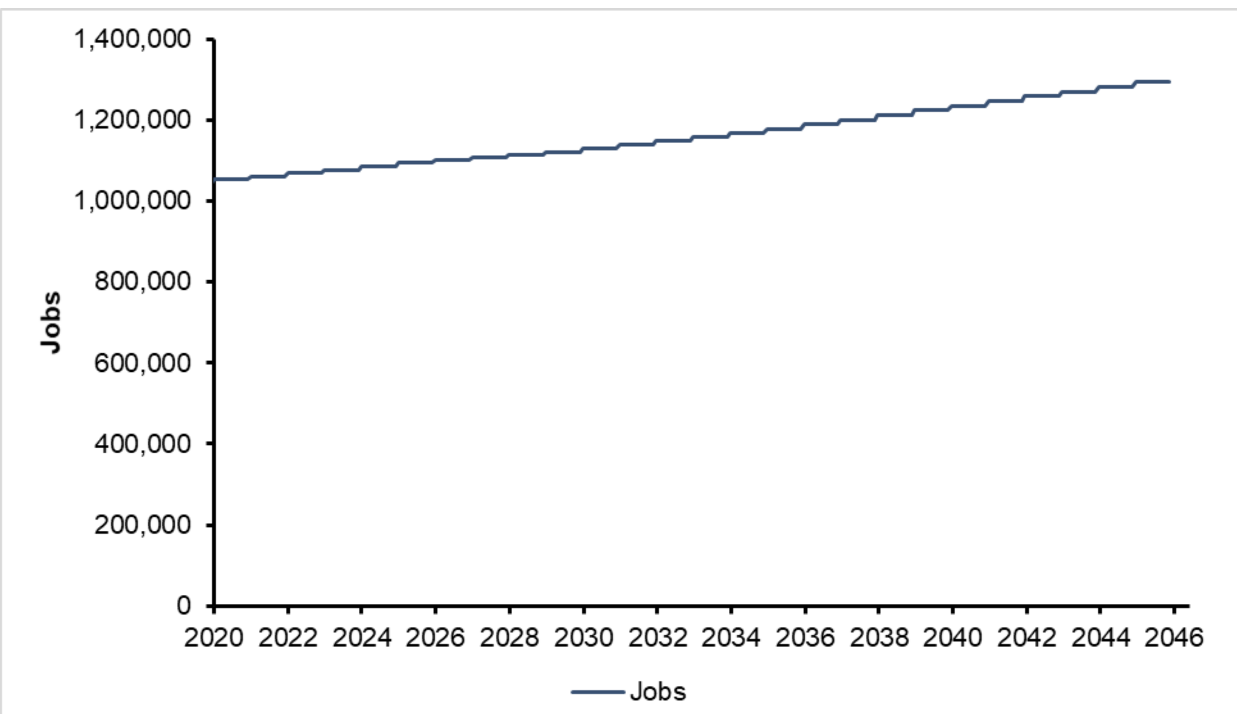


Figure 5-3: County Wide ABAG-Derived Total Non-Agricultural Job Projections

5.2.2 Weather and Climate

For the water demand model baseline scenario, future precipitation and temperature values were assumed to be equal to historical normal values. Historical normal values were calculated as the average values by month based on all values from 1981 to 2010. As defined in Section 3.6.1, the demand model uses departures from historical normal precipitation and temperature for the retailer forecasts and unadjusted historical normal precipitation and temperature for non-retail pumper forecasts. Given this, future weather inputs in the retailer forecasts are reflected by projected departure values of 0 for the precipitation and temperature variables.

Additional demand scenarios can be developed that consider the potential effects of climate change on precipitation and temperature using data from 16 downscaled global circulation models (GCMs) recommended by Professor Ed Maurer of Santa Clara University (Santa Clara University and Valley Water 2018). These GCMs include the 10 GCMs recommended for California by the California Department of Water Resources Climate Change Technical Advisory Group (California DWR CCTAG, 2015). Historical precipitation and temperature time series were developed using a different dataset: PRISM (refer to Section 3.6.1). To correct for this difference in source data and to generate future values, the PRISM historical normal values were multiplied by the ratio of GCM projected values to GCM historical values calculated over the same time period as the PRISM historical normal (1981 to 2010). This adjustment is shown in the Equation (11) below.

$$PRISM_{future} = PRISM_{historical\ normal} * \frac{GCM_{future}}{GCM_{historical\ normal}} \tag{11}$$

Table 5-5 presents the average forecasted percentage change in precipitation and temperature between the PRISM historical normal and projected 2040 values. This percent change was applied to the historical normal values for each retailer.

Table 5-5: Average Percent Change in Precipitation and Temperature between Historical Normal and Projected 2040 Values

GCM	Precipitation	Temperature
access1-0	-14%	4.4%
canesm2	36%	5.4%
ccsm4	0.3%	3.2%
cesm1-bgc	42%	3.2%
cmcc-cms	12%	3.9%
cnrm-cm5	57%	2.8%
csiro-mk3-6-0	32%	4.3%
gfdl-cm3	16%	5.2%
gfdl-esm2g	28%	3.5%
hadgem2-cc	29%	4.6%
hadgem2-es	-6.6%	6.0%
inmcm4	4.1%	2.6%
miroc5	-11%	4.1%
mpi-esm-lr	91%	3.8%
mri-cgcm3	32%	2.0%
noresm1-m	32%	3.9%

5.2.3 Water Prices

Projections of future water rates were included as an explanatory variable in the water demand model. Two future paths for water prices were considered: a constant rate scenario that assumes constant inflation-adjusted water prices from 2018 and a variable price scenario based on Valley Water's proposed water charges from the 2020-21 PAWS 2020 Report (Valley Water 2020). The variable prices were derived by modifying the last historical water rate value (from 2018) by the rate of change in price per year from the PAWS 2020 Report values available from 2020 to 2030 and a 5% increase each subsequent year from 2035-2045. These nominal prices were adjusted for inflation assuming 3% each year. The inflation-adjusted water rates in dollars per hundred cubic feet (2015$/ccf) for each retailer are shown in Table 5-6 on the following page.

For Stanford, the projected water rates were similarly derived from the rate of change in the PAWS 2020 report. Historical water rates were based on the WUE rate (see Section 3.6.2 for more detail) in dollars per acre-foot ($/AF). Projected water rates used the last historical WUE rate value and were updated over time following the inflation-adjusted rate of change from the PAWS 2020 report. Stanford projected water rates are also shown in Table 5-6.

Water rates for non-retail pumpers were held constant at 2018 historical values.

Table 5-6: Water Rates (2015$/ccf) by Retailer

Year	California Water Service	City of Gilroy	City of Milpitas	City of Morgan Hill	City of Mountain View	City of Palo Alto	City of Santa Clara	City of Sunny-vale	Great Oaks Water Company	Purissima Hills Water District	San Jose Muni-cipal Water	San Jose Water Company	Stanford [(a)]
2019	$5.04	$3.90	$0.98	$2.26	$6.21	$8.54	$5.41	$4.85	$3.17	$6.13	$3.62	$3.42	$2.56
2020	$5.22	$4.05	$1.01	$2.35	$6.44	$8.85	$5.60	$5.02	$3.28	$6.35	$3.75	$3.55	$2.65
2021	$5.51	$4.31	$1.07	$2.50	$6.80	$9.34	$5.92	$5.30	$3.47	$6.71	$3.96	$3.74	$2.80
2022	$5.82	$4.58	$1.13	$2.66	$7.18	$9.86	$6.25	$5.60	$3.66	$7.08	$4.18	$3.95	$2.95
2023	$6.15	$4.87	$1.19	$2.83	$7.58	$10.42	$6.60	$5.91	$3.87	$7.48	$4.41	$4.18	$3.12
2024	$6.49	$5.18	$1.26	$3.01	$8.00	$11.00	$6.97	$6.24	$4.08	$7.90	$4.66	$4.41	$3.29
2025	$6.85	$5.51	$1.33	$3.20	$8.45	$11.61	$7.36	$6.59	$4.31	$8.34	$4.92	$4.66	$3.48
2026	$7.24	$5.86	$1.40	$3.40	$8.93	$12.27	$7.77	$6.96	$4.55	$8.81	$5.20	$4.92	$3.67
2027	$7.65	$6.24	$1.48	$3.62	$9.43	$12.95	$8.21	$7.35	$4.81	$9.30	$5.49	$5.19	$3.88
2028	$8.07	$6.63	$1.56	$3.85	$9.95	$13.68	$8.66	$7.76	$5.08	$9.82	$5.79	$5.48	$4.10
2029	$8.53	$7.05	$1.65	$4.09	$10.51	$14.44	$9.15	$8.20	$5.36	$10.37	$6.12	$5.79	$4.33
2030	$9.00	$7.50	$1.74	$4.35	$11.10	$15.25	$9.66	$8.66	$5.66	$10.95	$6.46	$6.11	$4.57
2031	$9.18	$7.65	$1.78	$4.44	$11.32	$15.56	$9.85	$8.83	$5.77	$11.17	$6.59	$6.24	$4.66
2032	$9.37	$7.81	$1.82	$4.53	$11.55	$15.87	$10.05	$9.01	$5.89	$11.40	$6.72	$6.36	$4.75
2033	$9.55	$7.96	$1.85	$4.62	$11.78	$16.18	$10.25	$9.19	$6.01	$11.62	$6.86	$6.49	$4.85
2034	$9.75	$8.12	$1.89	$4.71	$12.01	$16.51	$10.46	$9.37	$6.13	$11.86	$6.99	$6.62	$4.94
2035	$9.94	$8.28	$1.93	$4.81	$12.25	$16.84	$10.67	$9.56	$6.25	$12.09	$7.13	$6.75	$5.04
2036	$10.14	$8.45	$1.96	$4.90	$12.50	$17.18	$10.88	$9.75	$6.38	$12.34	$7.28	$6.89	$5.14
2037	$10.34	$8.62	$2.00	$5.00	$12.75	$17.52	$11.10	$9.95	$6.50	$12.58	$7.42	$7.02	$5.25
2038	$10.55	$8.79	$2.04	$5.10	$13.00	$17.87	$11.32	$10.15	$6.63	$12.83	$7.57	$7.16	$5.35
2039	$10.76	$8.97	$2.09	$5.20	$13.26	$18.23	$11.55	$10.35	$6.77	$13.09	$7.72	$7.31	$5.46
2040	$10.97	$9.15	$2.13	$5.31	$13.53	$18.59	$11.78	$10.56	$6.90	$13.35	$7.88	$7.45	$5.57
2041	$11.19	$9.33	$2.17	$5.41	$13.80	$18.96	$12.01	$10.77	$7.04	$13.62	$8.04	$7.60	$5.68
2042	$11.42	$9.52	$2.21	$5.52	$14.08	$19.34	$12.25	$10.98	$7.18	$13.89	$8.20	$7.75	$5.79
2043	$11.65	$9.71	$2.26	$5.63	$14.36	$19.73	$12.50	$11.20	$7.32	$14.17	$8.36	$7.91	$5.91
2044	$11.88	$9.90	$2.30	$5.74	$14.64	$20.12	$12.75	$11.43	$7.47	$14.45	$8.53	$8.07	$6.03
2045	$12.12	$10.10	$2.35	$5.86	$14.94	$20.53	$13.00	$11.65	$7.62	$14.74	$8.70	$8.23	$6.15

[(a)] Stanford water rates are presented in this table in dollars per ccf but were included in the demand model in dollars per acre-ft ($/AF).

5.2.4 Detrended Economic Factor

For the baseline water demand forecast, the future economy was assumed to be at long term trend. The ECRI coincident index is a measure of the macro-economy that captures cycles in economic activity based on tracking indicators of production, employment, income, and sales. Historically, the ECRI index is characterized by long-term positive growth with shorter-term fluctuations of higher or lower than average growth related to business cycles. The detrended ECRI index provides focus on potentially meaningful periods of more acute economic fluctuations to capture the effects of the business cycle on unit rates of water consumption. The assumption of long term trend economy for the baseline forecast scenario assumed the ECRI index followed the long-term historical trend, represented by a projected value of 0 for the detrended ECRI coincident index.

5.2.5 Median Income

Median income was included as an explanatory variable in the water demand model. Median income by retailer was held constant at the historical 2018 level denominated in inflation-adjusted 2015 dollar values, as shown in Table 5-7.

Table 5-7: Median Household Income

Retail Agency	Median Income
California Water Service	$156,235
City of Gilroy	$91,643
City of Milpitas	$108,352
City of Morgan Hill	$109,752
City of Mountain View	$138,060
City of Palo Alto	$144,307
City of Santa Clara	$107,272
City of Sunnyvale	$125,285
Great Oaks Water Company	$108,184
Purissima Hills Water District	$206,783
San Jose Municipal Water	$116,052
San Jose Water Company	$106,368

5.2.6 Housing Density

Housing density was included as an explanatory variable in the single family and multifamily residential model sectors. Separate variables were created for single family housing density and multifamily housing density. Two scenario options for density were considered based on discussions with Valley Water staff: a constant density condition and a variable density condition. The constant density condition assumed a “build out” scenario where development of additional housing units would occur in new land area at prevailing historical densities, while the variable density condition assumed a “build up” scenario where housing units could vary within a constant land area thereby affecting average density. Retail agencies in the South County (Gilroy and Morgan Hill) were assumed to have constant housing density and all other retail agencies were assumed to have variable housing density. Constant density was held at the last historical value. Variable density was derived from the projected number of single family or multifamily housing units (see Section 5.2.1) divided by the land area classified as residential land use within the retail service area boundary.

Table 5-8 shows the housing density values for each retailer in 2045 (representing the variable density option) compared to the last historical value (representing the constant density option). Time series graphs of variable density for each retailer are in Appendix I.

Table 5-8: Single Family and Multifamily Residential Housing Density (Units/Acre)

Retail Agency	2019		2045	
	Single Family Housing Density	Multifamily Housing Density	Single Family Housing Density	Multifamily Housing Density
California Water Service	3.14	16.08	3.17	18.90
City of Gilroy	5.92	5.26	5.92	5.26
City of Milpitas	6.74	22.92	7.25	38.10
City of Morgan Hill	2.78	8.87	2.78	8.87
City of Mountain View	10.89	21.16	11.51	33.39
City of Palo Alto	4.74	35.61	4.75	41.23
City of Santa Clara	6.83	31.42	6.88	40.86
City of Sunnyvale	8.47	20.02	8.62	41.13
Great Oaks Water Company	7.22	22.43	8.13	27.98
Purissima Hills Water District	0.74	--	0.75	--
San Jose Municipal Water	5.45	23.21	5.62	73.55
San Jose Water Company	5.54	21.35	5.66	37.18

5.2.7 Persons Per Household

Persons per household was used as an explanatory variable in the single family and multifamily residential model sectors. Separate variables were created for single family persons per household and multifamily persons per household. The ABAG 2017 projections provide future estimates of total persons per household. Future conditions for persons per household were derived by modifying the last historical single family and multifamily persons per household values by the rate of change in the ABAG overall persons per household projections. 2045 projected persons per household by retailer are shown in Table 5-9. Time series values of persons per household for each retailer are in Appendix J.

Table 5-9: Projected Persons Per Household in 2045

Retail Agency	Single Family Persons per Household	Multifamily Persons per Household
California Water Service	3.00	2.52
City of Gilroy	3.90	3.82
City of Milpitas	3.77	2.84
City of Morgan Hill	3.38	3.19
City of Mountain View	2.89	2.29
City of Palo Alto	2.95	2.01
City of Santa Clara	3.09	2.42
City of Sunnyvale	3.03	2.46
Great Oaks Water Company	3.54	3.05
Purissima Hills Water District	2.98	2.99
San Jose Municipal Water	3.49	2.36
San Jose Water Company	3.38	2.64

5.2.8 Relative Sectoral Employment

Ratios of sectoral employment were included as an explanatory variable in the CII model sector. These ratios of sectoral employment represent the estimated mix of CII activity within each retail service area. The projected number of jobs by sector were obtained from the ABAG 2017 projections, as described in Section 5.2.1. The projected ratios of sectoral employment were then calculated as the number of jobs in each sector divided by the total non-agricultural jobs. A summary of projected ratios of sectoral employment for 2045 is shown in Table 5-10. Time series values of sectoral employment ratios for each retailer are in Appendix K.

Table 5-10: Projected Ratio of Sectoral Employment by ABAG Sector and Retailer in 2045

Retail Agency	Health, Educational, and Recreational Service	Financial and Professional Services	Informational, Government and Construction	Manufacturing, Wholesale and Transportation	Retail
California Water Service	39%	16%	3%	35%	8%
City of Gilroy	41%	5%	10%	15%	29%
City of Milpitas	27%	26%	13%	23%	12%
City of Morgan Hill	32%	11%	12%	30%	15%
City of Mountain View	28%	25%	34%	5%	8%
City of Palo Alto	38%	28%	19%	8%	7%
City of Santa Clara	28%	39%	9%	18%	6%
City of Sunnyvale	29%	35%	11%	17%	8%
Great Oaks Water Company	51%	11%	6%	22%	12%
Purissima Hills Water District	55%	11%	8%	10%	16%
San Jose Municipal Water	24%	26%	17%	27%	5%
San Jose Water Company	41%	20%	12%	13%	13%
Stanford	42%	38%	10%	8%	2%

5.2.9 Drought Rebound

Drought rebound was included as an explanatory variable in the water demand model. In econometric analysis detailed in Section 4, the drought variables represented the fraction of demand cutbacks. Figure 5-4 shows post-drought non-agricultural water production for Valley Water and five peer Bay Area water supply agencies.[22] Water use for Valley Water and its Bay Area peers slightly rebounded from the 2013-2016 drought in 2017, but then stayed relatively flat in 2018 and 2019.

[22] Data for Alameda County Water District, Contra Costa Water District. East Bay Municipal Water District, Marin Municipal Water District, and San Francisco Public Utilities Commission was retrieved from the CA State Water Resources Control Board's Water Urban Water Supplier Monthly Report Database (2020).

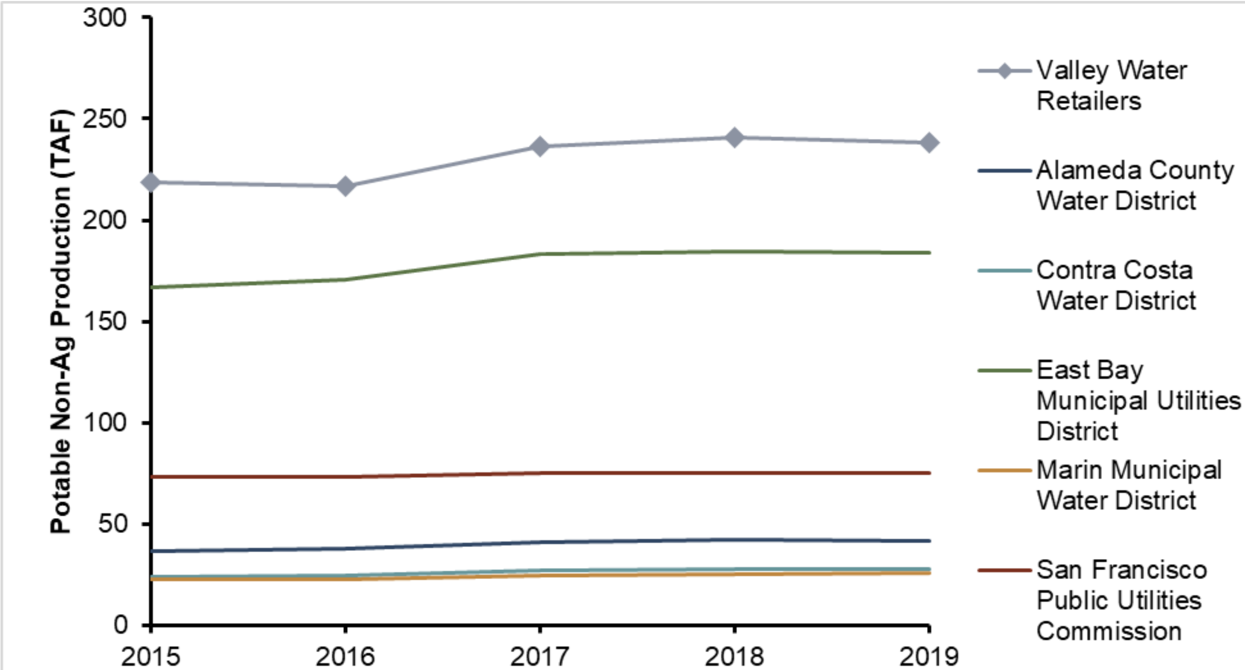


Figure 5-4: Valley Water and other Bay Area Water Agency Post-Drought Production

It is expected that there are some behavioral changes adopted during the last drought that will dissipate in the future, but there are also possible permanent changes that could preclude a full drought rebound, such as reduced water use due to increased rates or removal or replacement of landscape materials. To approximate this drought rebound and potential persistence of consumer behavior, the projected drought effect variable was represented by a surrogate demand cutback decreasing from 20% to 10% over the first five years of the demand forecast and remaining at 10% through 2045. A time series of the implied persistence of demand reductions associated with the drought effect variable is shown in Figure 5-5 on the following page.

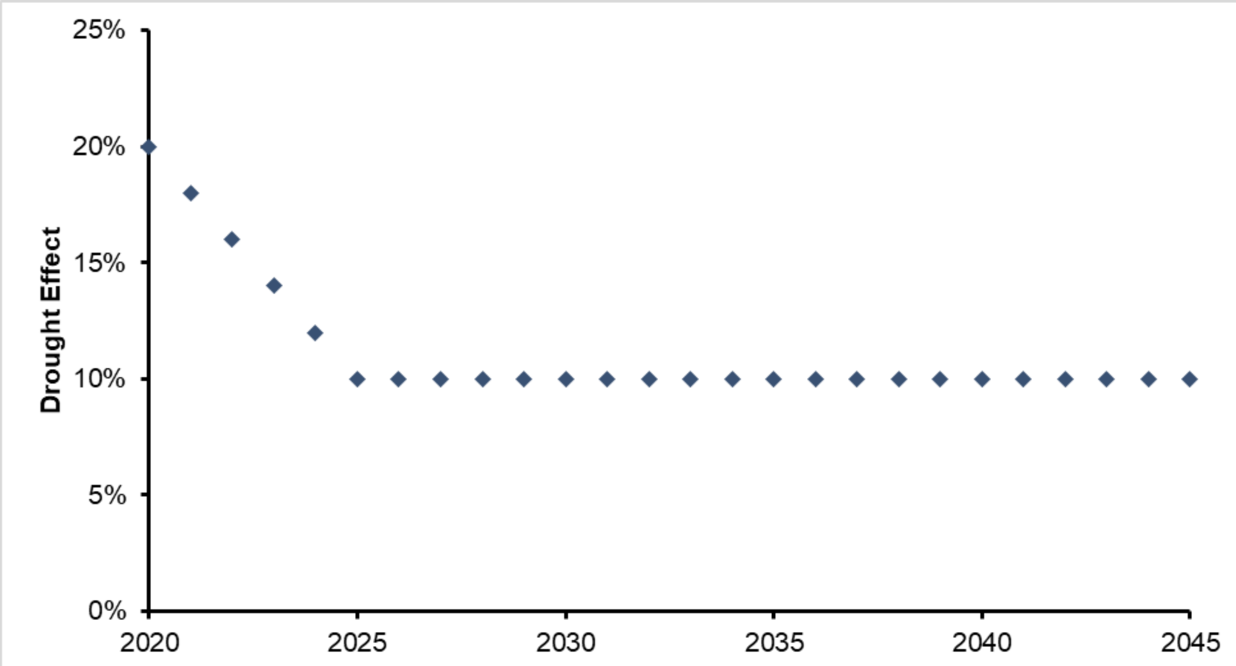


Figure 5-5: Projected Persistence of Demand Reductions from Drought Variable

For the non-retail pumper demand forecast, the drought effect variable was held at zero to indicate no prolonged drought effect (i.e., assumes that non-retail pumper demand has already rebounded).

5.2.10 Seasonality

Seasonal indices were included as explanatory variables in the water demand model. These seasonal indices are represented in the model as a sine/cosine pair of variables to capture the cyclical monthly pattern in water use where demands are generally higher in the summer and lower in the winter. Most sectors had a single sine/cosine pair representing the seasonal cycle, except for Stanford. Stanford had two sine/cosine pairs to more effectively capture seasonal effects associated with the academic calendar.

5.3 Baseline Sectoral Forecasts

This section provides a summary of the baseline demand forecasts by each model sector. Note that the model output summarized in the following sections reflects the baseline scenario and does not include projected water conservation.

5.3.1 Single Family

Figure 5-6 shows the county-wide monthly single family residential projected water demand. Annual values are projected to increase from 2020 to 2025, then remain relatively constant through 2045. The projected driver units of single family housing units remained relatively constant over time, but the projected single family residential rate of use increased from 2020 to 2025. The increase in rate of use from 2020 to 2025 was caused by the decreasing drought effect variable (i.e., drought rebound) in that timeframe. The forecasted values remaining relatively constant from 2025 to 2045 are caused by relatively constant projected driver units and increasing water price and density. Time series plots of monthly projected single family residential water demand by retailer are provided in Appendix L.

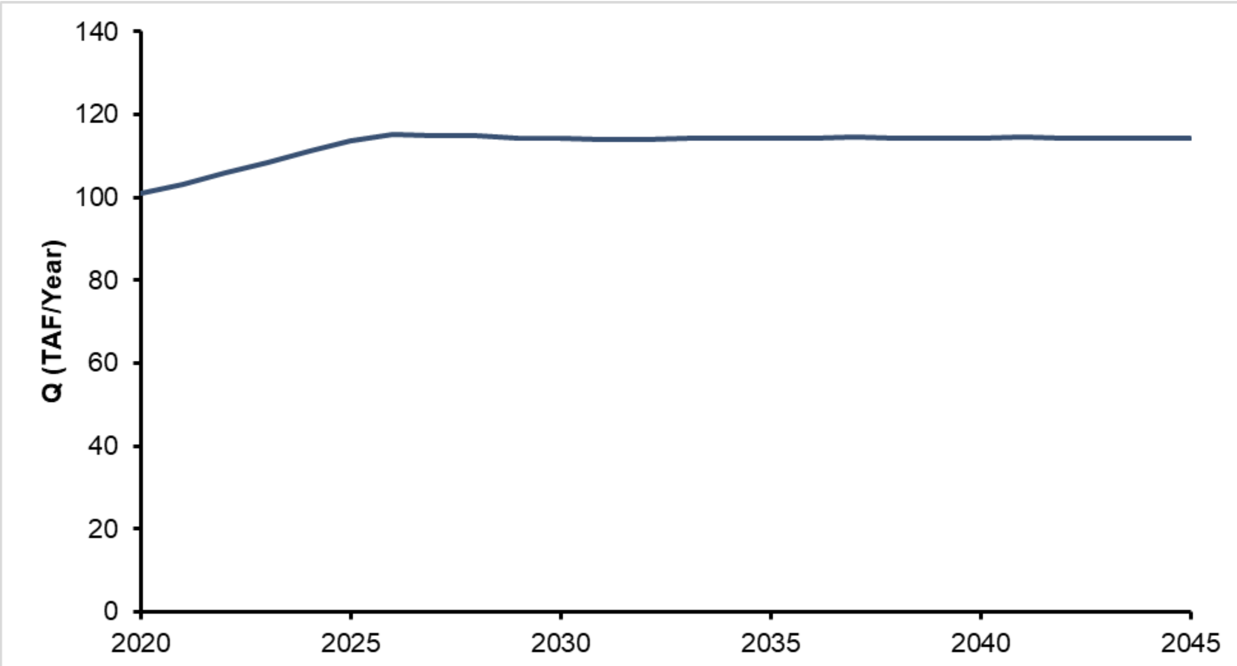


Figure 5-6: Annual Single Family Projected Demand

5.3.2 Multifamily

Figure 5-7 shows the county-wide monthly multifamily residential projected water demand. Annual values are projected to steadily increase from 2020 through 2045. This increase is largely driven by an increase in multifamily housing units over time. Time series plots of monthly projected multifamily residential water demand by retailer are provided in Appendix M.

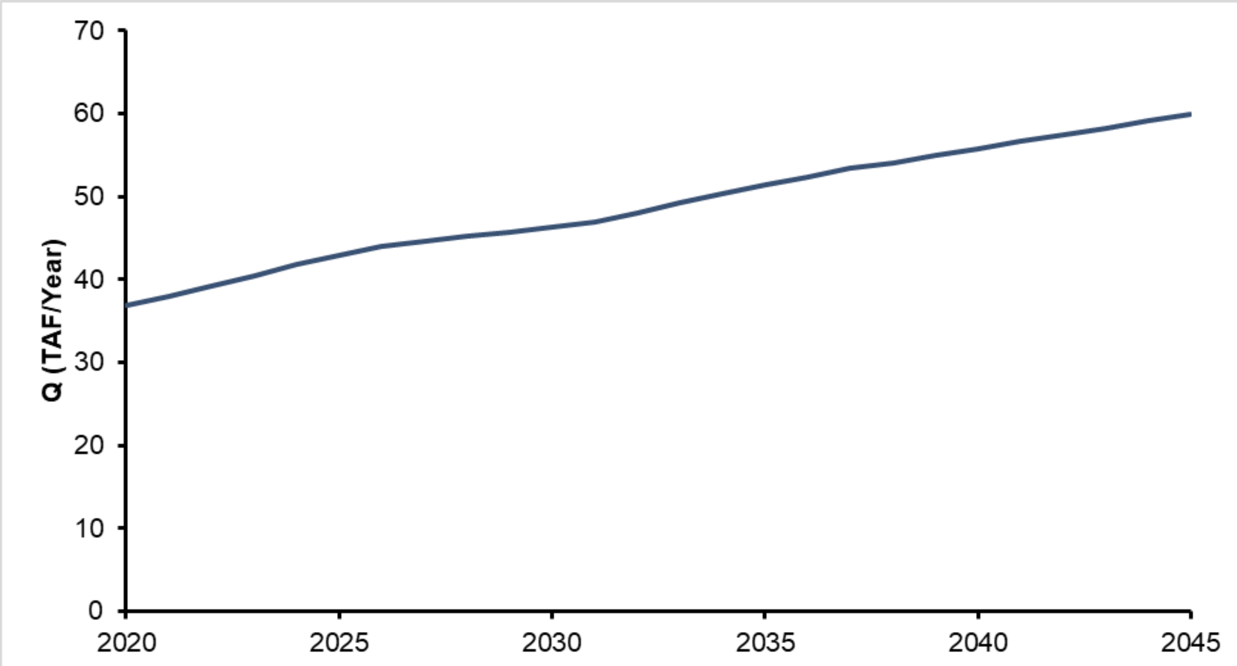


Figure 5-7: Annual Multifamily Projected Demand

5.3.3 CII

Figure 5-8 shows the county-wide monthly CII projected water demand. Time series plots of monthly projected CII water demand by retailer are provided in Appendix N. Demands are projected to steadily increase from 2020 through 2045. This increase is largely driven by an increase in the driver units of total non-agricultural jobs. A steeper increase in CII demand occurs from 2020 to 2025, which is caused by the drought rebound over the same time frame.

Projected demand from 2025 to 2030 has a slightly flatter rate of increase than other periods. The variable water rate from 2020 to 2030 followed the 2020 PAWS report rate changes, which were typically larger increases per year than the 5% assumed increase in price from 2030 to 2045. The effect on projected CII demand from 2025 to 2030 suggests that drought rebound had a larger impact on projected rate of use than price.

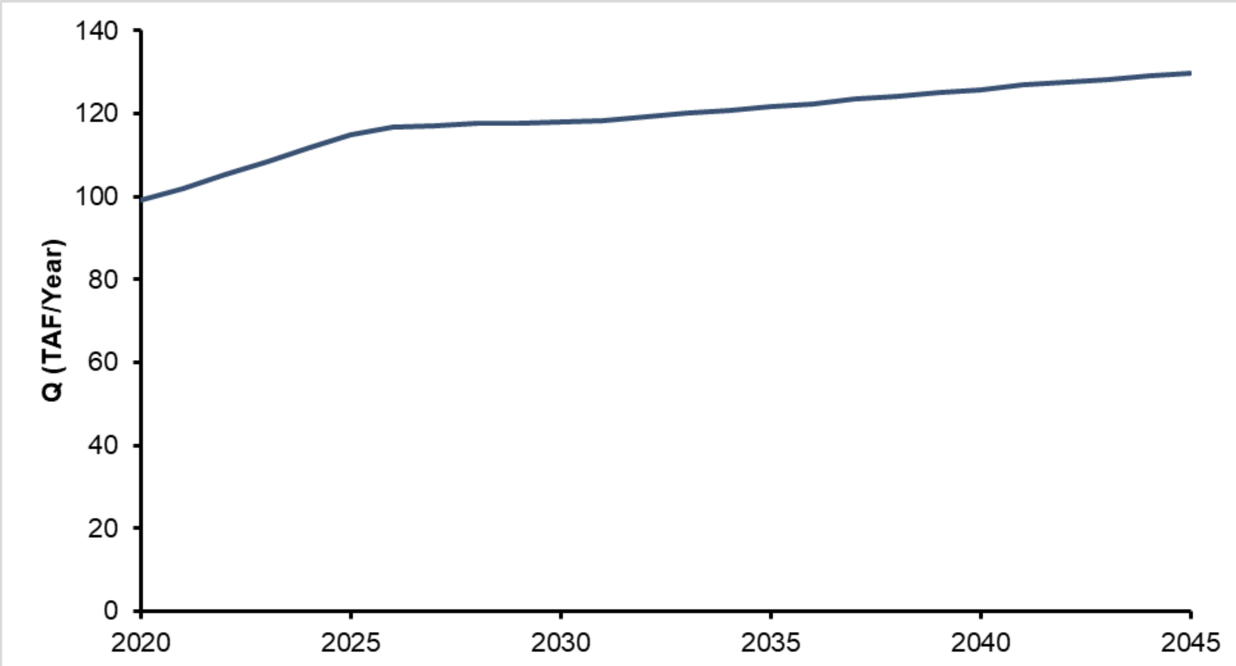


Figure 5-8: Annual CII Projected Demand

5.3.4 Non-Retail Pumpers

Figure 5-9 shows the annual non-retail pumpers projected groundwater demand for M&I groundwater use. Agricultural groundwater use was held constant at a rate of 24.7 TAF per year, based on the average historical value from 2009 to 2018 (refer to Section 4.5). For the non-retail pumpers M&I water use, the baseline scenario assumed no drought effect and constant price. These conditions resulted in a constant annual projected demand. Time series plots of projected groundwater demand by sector and charge zone are provided in Appendix O.

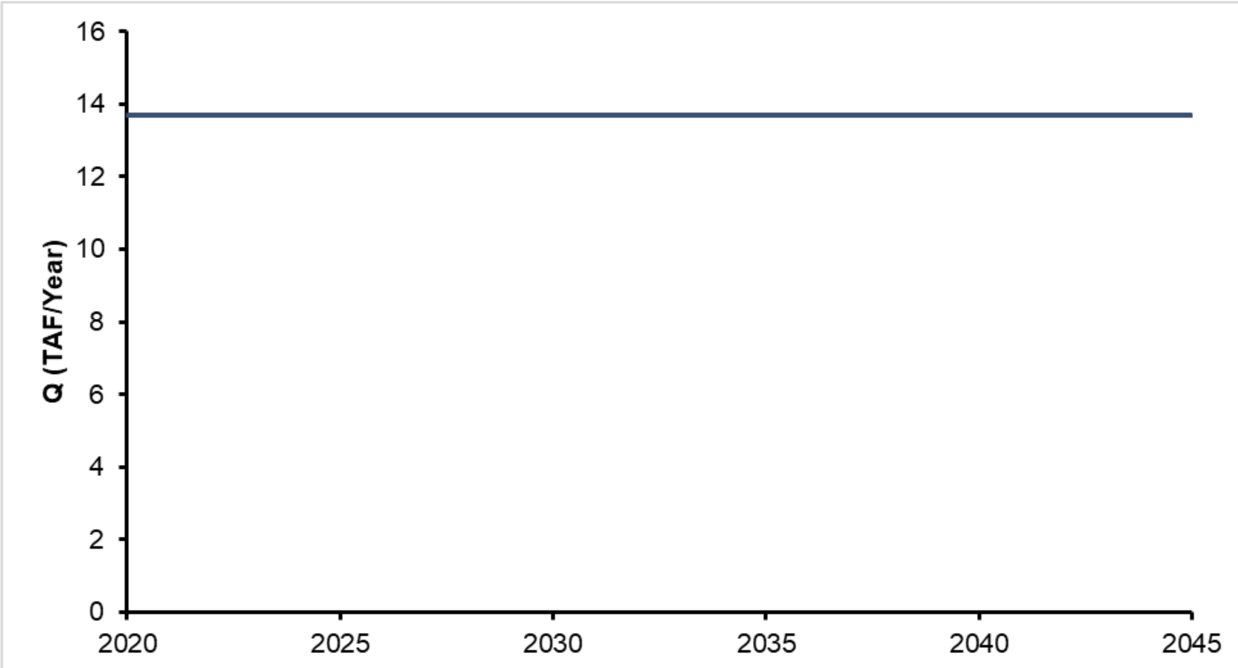


Figure 5-9: Annual Non-Retail Pumpers Projected M&I Demand

Since non-retail pumpers groundwater demand was projected on an annual basis, a set of monthly factors was used to provide a monthly estimate of demand. The monthly factors are shown in Table 5-11. Monthly non-retail pumper M&I projected demands developed with these factors are presented in Figure 5-10 on the following page.

Table 5-11: Monthly Factors for Non-Retail Pumpers Demand

Month	Percent of Annual Demand
January	3.1%
February	3.8%
March	6.7%
April	9.3%
May	11.7%
June	13.1%
July	14.0%
August	12.6%
September	10.5%
October	7.7%
November	4.5%
December	3.0%

The demand model estimates projected demand for the W2 and W5 charge zones. Starting in 2020, Valley Water split W5 into three charge zone: W5, W7, and W8. The projected demand for the W5 charge zone was split into two zones which overlay the Llagas sub-basin (W5 and W8), and the Coyote Valley (W7). W5/W8 represented a constant 75% of the original W5 charge zone (Llagas sub-basin) and W7 represented a constant 25% of the original W5 charge zone (Coyote Valley).

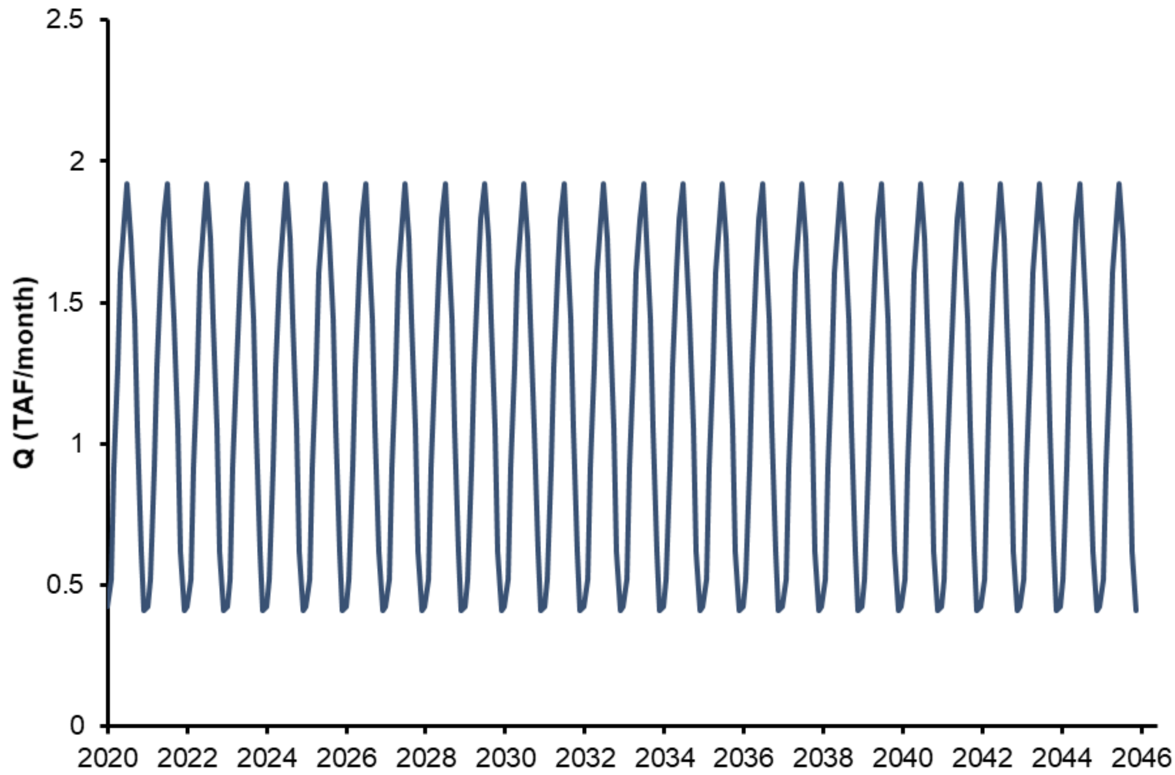


Figure 5-10: Monthly Non-Retail Pumpers Projected M&I Demand

5.3.5 "Other" Consumption

Some – predominantly low volume – water use categories do not fit neatly into single family, multifamily or CII sectors such as "fireline", "Other Water Utilities", and "Other". To account for these "other" water uses, a relative ratio for other uses to total use was used to generate forecast values. The ratio was assumed to be constant into the future based on the historical average from 2009 to 2018. Table 5-12 shows the ratios of "other" water uses to total use for each retailer. Figure 5-11 shows the projected annual "other" water use. Note that applying the constant ratio to an increasing total demand results in increasing volume of "other" water use over time. Time series plots of monthly projected "other" consumption by retailer are provided in Appendix P.

Table 5-12: Percent Other Water Consumption by Agency

Agency	Other Retail Factor
California Water Service	0.24%
City of Gilroy	14.71% [(a)]
City of Milpitas	0.10%
City of Morgan Hill	0%
City of Mountain View	0.14%
City of Palo Alto	0.03%
City of Santa Clara	0%
City of Sunnyvale	0.05%
Great Oaks Water Company	0.58%
Purissima Hills Water District	0.65%
San Jose Municipal Water	0.23%
San Jose Water Company	0.70%
Stanford University	0%

[(a)] Landscape water use was included in the "other" water use category at the instruction of City of Gilroy. Refer to Appendix A.

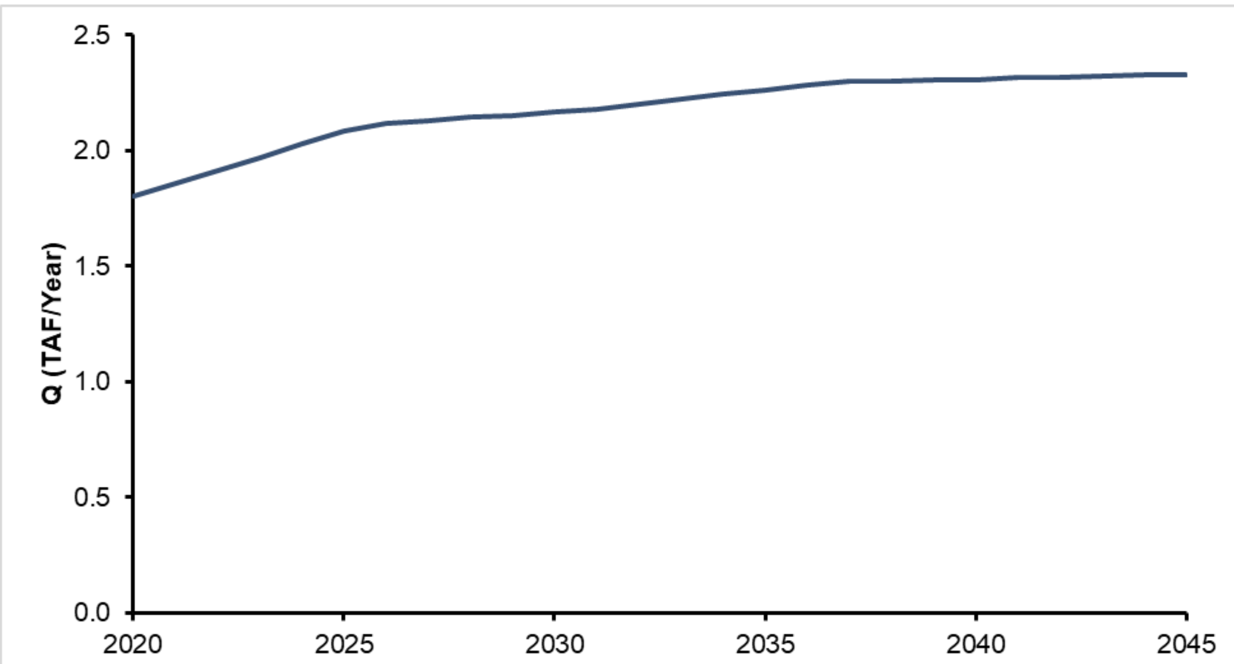


Figure 5-11: Annual "Other" Projected Demand

San Jose Municipal Water and Gilroy did not include recycled water in the consumption data; thus it was explicitly excluded from retail forecast development. The long-term averages of recycled water production were assumed to be constant into the future and were added back to the total demand forecast along with the retail sector demands to correct for the recycled water being excluded from the model forecast. Forecasted annual recycled water uses for San Jose Municipal Water and Gilroy are shown in Table 5-13.

Table 5-13: Recycled Water Quantities

Agency	Recycled Water (TAF/year)
City of Gilroy	2.01
San Jose Municipal Water	3.83

5.3.6 Nonrevenue Water

Nonrevenue water represents the difference between the amount of water produced and the amount of water sold through the retailers' systems so that altogether the forecasts represent total production demand. Estimates of nonrevenue water were determined based on the ratio difference between production and consumption for each retailer in 2018. The ratio was calculated from 2018 values because it was the most recent year with complete data. The annual nonrevenue water demand is shown in Figure 5-12. Note that applying the constant ratio to an increasing total demand results in increasing volume of nonrevenue water over time. A table of 2018 nonrevenue percentages and time series plots of projected nonrevenue water demand by retailer are provided in Appendix Q.

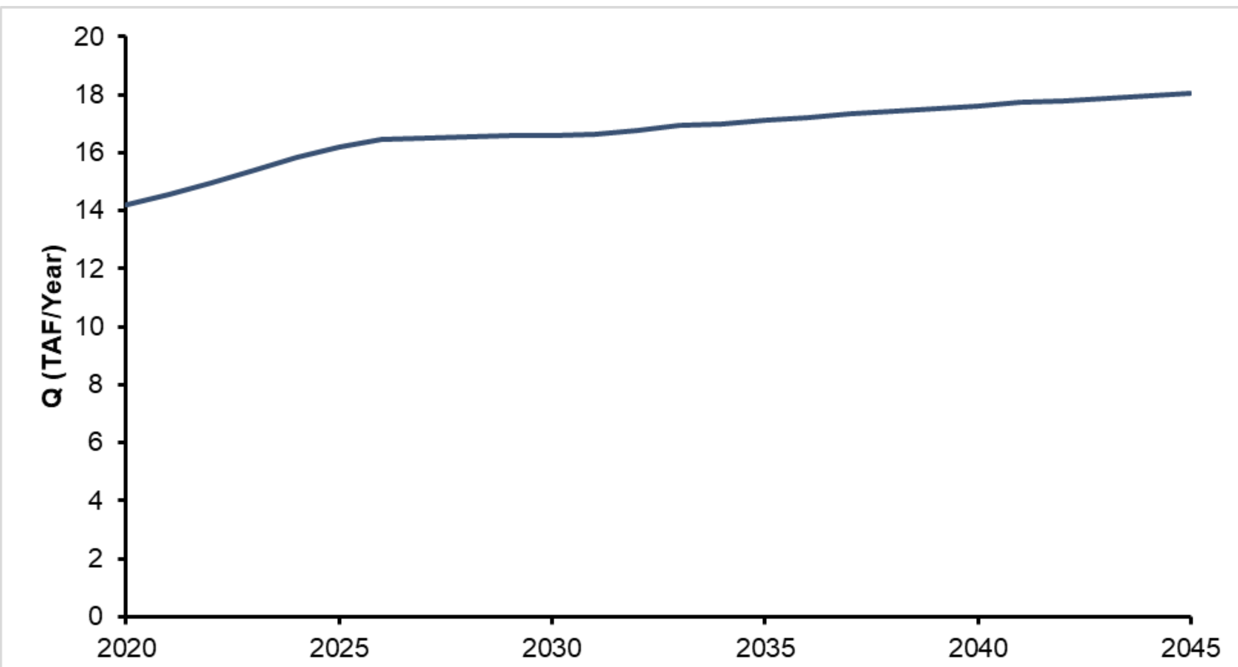


Figure 5-12: Annual Projected Nonrevenue Water

5.3.7 Raw Water

Raw water represents a small amount of untreated imported and local surface water used primarily for landscape and agricultural irrigation. Due to planned changes in Valley Water's Untreated Water Program rules and some customers switching to recycled water, the future raw water demands were estimated by assuming the average of historical use for customers that are anticipated to remain in the program and holding that demand at a constant rate into the future, as described in Valley Water's 2015 UWMP (Valley Water, 2016). The assumed raw water demand was 1.7 TAF/year.

5.3.8 County-Wide Totals

The total county-wide projected production demand is shown in Figure 5-13 and includes the sum of projections for the single family, multifamily, and CII sectors; total non-retail pumper demand (M&I plus Ag); other retailer consumption, and nonrevenue water. Future conservation is not included.

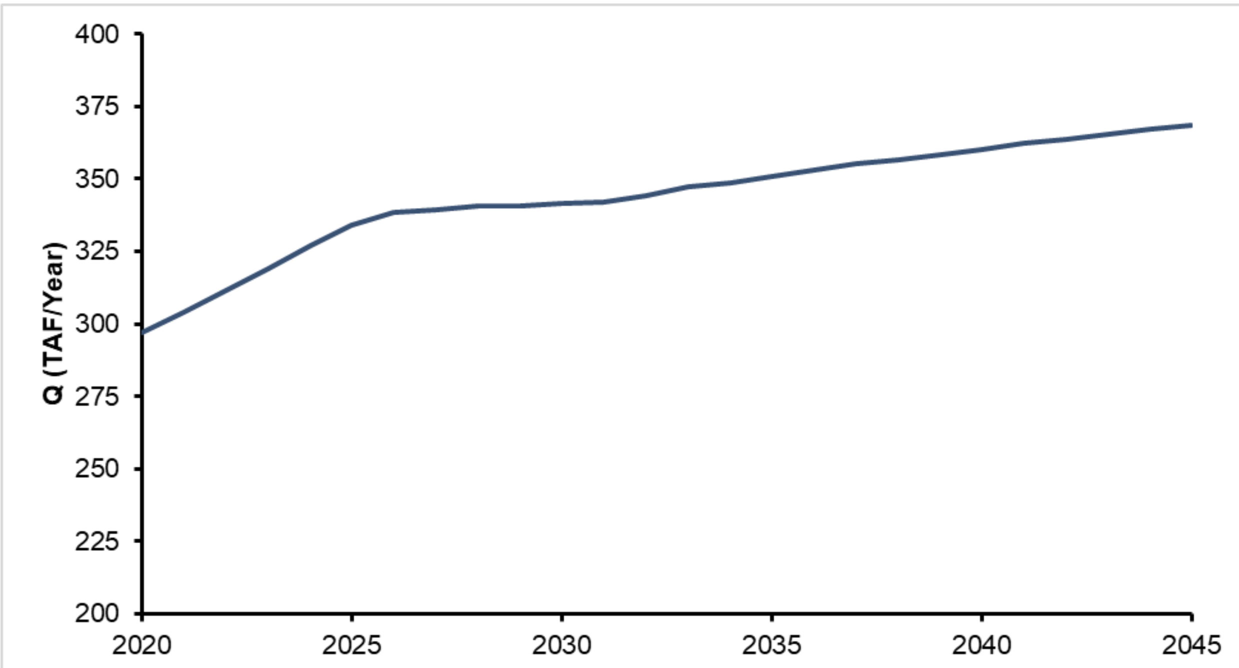


Figure 5-13: Annual Total Projected Demand

Projected total production demands given the baseline scenario are expected to increase over the next 35 years to approximately 374 TAF in 2045. The rate of change in the forecast is not constant over time. The most recognizable period of growth (300 TAF to 340 TAF) occurs in 2020-2025 during the assumed drought rebound. Following this period, projected demand remains relatively flat until approximately 2030, where it begins to steadily increase to 2045. This pattern is mostly attributable to driver unit growth dampened by the effect of increasing water rates and increasing housing density.

5.4 Forecast Impact Factor Analysis

The derivation of "impact factors" is helpful for evaluating the relative effect of each explanatory variable on forecasted water use. Impact factors are calculated by comparing the ratio change in forecasted volumetric water use with the ratio change in each forecasted explanatory variable to identify the explanatory variables that had the largest impact. For this analysis ratio changes are the forecasted water use and forecasted driver units, where the ratio change is calculated as the end value (2045) divided by the start value (2020). The multiplicative nature of the demand model makes calculation of the impact factors straightforward, where ratio changes between end (2045) to start (2020) values are simply raised to the power of the calibrated model coefficient.[23] Equation (12) shows how impact factors were calculated for each explanatory variable and driver units. The impact factor tables for each retail model sector and retail agency are presented in Appendix S.

$$Impact\ Factor_X = \left(\frac{X_{end}}{X_{start}}\right)^{Coefficient_X} \tag{12}$$

Aside from projected growth in housing units in the single family residential sector, the largest impact on increasing forecasted water use was generally in order of magnitude the drought rebound assumption, followed by single family residential PPH. The impact of price and single family residential density dampened that increase. Since climate variables in the baseline forecast scenario were assumed to be equal to historical normal values (i.e., no change), indicating no impact on forecasted water use.

Multifamily residential impact factors were similar to those for single family residential. Drought and multifamily residential PPH had impact factors that caused forecasted water use to increase, while price and multifamily residential density had impact factors that caused forecasted water use to decrease. The impact factor for drought was smaller in magnitude for multifamily residential water use than single family residential water use due to relatively lower estimated effects from drought restrictions. For CII, the change in forecasted water use (excluding Stanford) was driven by drought, price, and the sectoral employment ratios. Drought had a similar impact factor for CII as for single family residential water use. Price had a similar impact factor for CII as for both single family and multifamily residential water use, due to the relatively small differences in estimated price elasticities.

The impact of sectoral employment ratios varied by retail agency. For most retail agencies, the effect of a projected increase in the proportion of Health, Educational and Recreational Service jobs had an increasing impact on the forecasted water use, while the projected change in the proportion of Industrial jobs and Professional Services jobs had a decreasing impact on the forecasted water use. The impact factor associated with Information, Government, and Construction jobs and Retail jobs were generally small, indicating a smaller effect on forecasted water use than other sectoral employment categories given the baseline scenario values. The net impact factor of all five sectoral employment ratios was calculated as the product of all five sectoral employment impact factors. Looking at the net effect, changes in sectoral employment ratios had an increasing effect for half of the retail agencies and a decreasing effect for the other half of the retail agencies. The retail agencies where CII forecasted water use was most affected by changes in sectoral employment were California Water Service (net increasing effect) and City of Gilroy (net decreasing effect).

Stanford CII water use was modeled separately from the other retail agencies. For Stanford, the change in forecasted water use was driven by drought and price. The effect of price was large enough to overcome the effect of drought rebound assumptions and increasing driver units, resulting in decreasing forecasted water use for Stanford.

[23] This exponential transformation was required because the demand model used variables in natural log-space. Driver units implicitly have an exponent of 1.

6. Future Considerations and Forecast Summary

The baseline forecast scenario may be considered to be somewhat conservative given the assumptions about drought rebound (i.e., relatively lower risk of under-predicting demand). The drought rebound assumptions are reasonable given prior drought rebounds for Valley Water and other California water suppliers. Still, it is prudent to monitor trends over the next few years and adjust the rebound assumptions accordingly.

The impacts of climate change should be monitored and considered in future scenarios. All climate models analyzed in the development of this Section identified increases in average temperature by 2040 (see Table 5-5). Changes in precipitation were more varied, as the ensemble of climate models identified both increases and decreases in average precipitation. The exact impact of these changes on demand is uncertain, as water demand is expected to increase with temperature but decrease with increased precipitation.

In addition to monitoring the drought rebound and considering climate change, recent conditions stemming from the COVID-19 pandemic should be monitored for impacts on water demand. In particular, the baseline assumptions around trend economy and certain demographic variables, such as persons per household, may need to be adjusted as more information becomes available. Demand shares between the residential and CII sectors may also require adjustment depending on the length of regional stay-at-home orders and long-term trends in remote work.[24] Lastly, anecdotal trends in regional employment, such as major tech companies leaving the Bay Area or switching to a more permanent work-from-home model should be monitored for potential adjustments to the number of projected jobs within the county and/or the geographical distribution of employment across the retailers.

6.1 Forecast Summary

The baseline scenario results represent a projection of future water demand for Valley Water without additional conservation. The scenario assumptions outlined in Section 5.1 reflect a reasonable "best guess" for future conditions of parameters that are known to influence water demand derived from multiple available sources. The forecast uses ABAG data to depict local/regional trends in demographics and development in the demand model. Consistent with regional trends, demands in the single family sector are forecasted to remain relatively flat over the next 35 years as there is not expected to be substantial growth in single family housing units. Growth in residential demand is largely forecasted to occur within the multifamily sector, which is consistent with expectations about higher growth in multifamily housing. Demands in the CII sector are also expected to increase, which is consistent with ABAG forecasts of total jobs in the county. Increasing water rates and housing density are expected to have some modulating effect on demand (as housing density and water rates increase, water demand decreases), however, under the baseline scenario projected changes in the values of these variables do not generally counteract the effect of growth in overall driver units.

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[24] Systematic shifts in demand shares between residential and CII sectors may require refitting of the econometric models defined in Section 4.

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Appendix A: Standardization of Retailer Billing Classifications to Model Sectors

Table A-1: Model Segmentation by Retailer and Billing Classification

Retail Agency	Billing Classification	Standardized Sector	Model Sector
California Water Service	SFR	Single Family	Single Family
	MFR	Multifamily	Multifamily
	COM	Commercial	CII
	GOV	Institutional	
	IND	Industrial	
	IRRI	Landscape	
	OTH	Other	Other
City of Gilroy	SFR	Single Family	Single Family
	MFR	Multifamily	Multifamily
	Commercial/Institutional	Commercial	CII
	Industrial	Industrial	
	Landscape	Landscape	Other
	Other	Other	
City of Milpitas	Single Family	Single Family	Single Family
	Multifamily	Multifamily	Multifamily
	Commercial	Commercial	CII
	Industrial	Industrial	
	Institutional	Institutional	
	Irrigation(a)	Landscape	Multifamily / CII
	Other RW(b)	Recycled	Multifamily / CII
	Other	Other	Other
City of Morgan Hill	Outside City Residential	SFR	Single Family
	Residential	SFR	
	Multiple	MFR	Multifamily
	Commercial	Commercial	CII
	Fire Sprinklers	Commercial	
	Hydrant Meters	Commercial	
	Landscape Irrigation	Commercial	
	Public City Accounts	Institutional	
	Public City Landscape	Institutional	
City of Mountain View	Single Family	SFR	Single Family
	Multifamily	MFR	Multifamily
	Landscape Irrigation(c)	Landscape	Multifamily/CII
	Commercial	Commercial	CII
	Recycled Commercial	Commercial	
	Industrial	Industrial	
	Blended Irrigation	Recycled	
	Recycled Irrigation	Recycled	

Retail Agency	Billing Classification	Standardized Sector	Model Sector
	Other	Other	Other
	Other Recycled (Construction)	Other	
City of Palo Alto	Single Family	SFR	Single Family
	Multifamily	MFR	Multifamily
	Commercial	Commercial	CII
	Industrial	Industrial	
	Public Facility	Institutional	
	City Facility	Institutional	
	Recycled Water	Institutional	
	Irrigation(d)	Landscape	Single Family/Multifamily/ CII
	Other	Other	Other
City of Santa Clara	Single Family	SFR	Single Family
	Multifamily	MFR	Multifamily
	Commercial	Commercial	CII
	Industrial	Industrial	
	Institutional	Institutional	
	Municipal	Institutional	
	Recycled Water(e)	Landscape	Multiple Family/CII
City of Sunnyvale	Single Family	SFR	Single Family
	Multifamily	MFR	Multifamily
	Other (Mobile Home Parks)	MFR	
	Commercial	Commercial	CII
	Irrigation	Commercial	
	Recycled	Commercial	
	Institutional	Institutional	
	Fireline	Other	Other
Great Oaks Water Company	SFR	SFR	Single Family
	MFR	MFR	Multifamily
	Business	Commercial	CII
	Private Landscaping	Commercial	
	Industrial	Industrial	
	Public Authorities	Institutional	
	Schools	Institutional	
	Agriculture	Agriculture	Other
Purissima Hills Water District	Single Family	SFR	Single Family
	Institutional	Institutional	CII
	Irrigation	Institutional	
	Other	Other	Other
San Jose Municipal Water	Single family	SFR	Single Family
	Multi-Family	MFR	Multifamily
	Commercial	Commercial	CII
	Industrial	Industrial	
	Government	Institutional	
	Public	Institutional	

Retail Agency	Billing Classification	Standardized Sector	Model Sector
	Irrigation[f]	Landscape	Multifamily / CII
	Temporary	Other	Other
San Jose Water Company	Residential[g]	Residential	Single Family / Multifamily
	Commercial (Residential and Business) [h]	Residential/Commercial	Single Family / Multifamily / CII
	Business	Commercial	CII
	Industrial	Industrial	
	Irrigation	Institutional	
	Public Authorities	Institutional	
	Recycled Water	Landscape	
	Miscellaneous	Other	Other
	Other Water Utilities	Other	
Stanford University	Academic	Institutional	CII
	Athletics		
	CEF/Cogen		
	Construction		
	Faculty/Staff Housing		
	Flushing		
	Lake System		
	Medical School		
	Other Support Facilities		
	Student Housing/Dining		

[a] The City of Milpitas identified that their Irrigation billing classification is approximately allocated 25-30% to residential, 0.5-1% government irrigation, 20-25% city irrigation, and 40-50% commercial/industrial irrigation. Given this information Hazen allocated historical Irrigation use to the Multifamily sector (28%) and the CII sector (72%).

[b] The City of Milpitas identified that their Other RW billing classification is approximately 1-3% residential irrigation, 1-3% government irrigation, 15-20% city irrigation, and 80-90% commercial/industrial irrigation. Given this information Hazen allocated historical Other RW to the Multifamily sector (2%) and the CII sector (98%).

[c] The City of Mountain View identified that their landscape irrigation billing classification was made up of about 50% commercial, 20% multifamily residential, and 30% parks/city use. Based on this information Hazen allocated landscape irrigation use to the CII sector (80%) and the multifamily sector (20%).

[d] The City of Palo Alto identified that their Irrigation billing classification was made up of 55% commercial, 18% City facilities, 18% multifamily residential, 6% industrial, 2% at public facilities (non-city) and 1% at residential single family. Given this information Hazen allocated historical Irrigation use to the single family sector (1%), multifamily sector (18%), and the CII sector (81%).

[e] The City of Santa Clara identified that their recycled water billing classification was allocated across the commercial, industrial, municipal, institutional, and multifamily billing classes, but did not identify relative proportions. Given this information, Hazen allocated recycled water use to the multifamily and CII sectors proportional to historical water use.

[f] San Jose Municipal Water identified that their irrigation billing classification was allocated across the commercial, industrial, institutional, and multifamily billing classifications, but did not identify relative proportions. Given this information, Hazen allocated recycled water use to the multifamily and CII sectors proportional to historical water use.

[g] San Jose Water Company (SJWC) has a single residential billing classification. Based on SJWC's 2015 UWMP, the 85% of the historical consumption in the residential billing classification was allocated to the single family sector and 15% was allocated to the multifamily sector.

[h] SJWC had a combined residential and CII billing classification between 2000-2010. Based on an analysis of post-2010 consumption data and discussions with SJWC staff, 61.4% of the Commercial (Residential and Business) classification was allocated to the residential classification and 38.6% was allocated to business. Residential consumption in the period was allocated 85% to the single family sector and 15% to the multifamily sector based on the 2015 UWMP.

Appendix B: Summary of Retail Agency Residential Driver Units

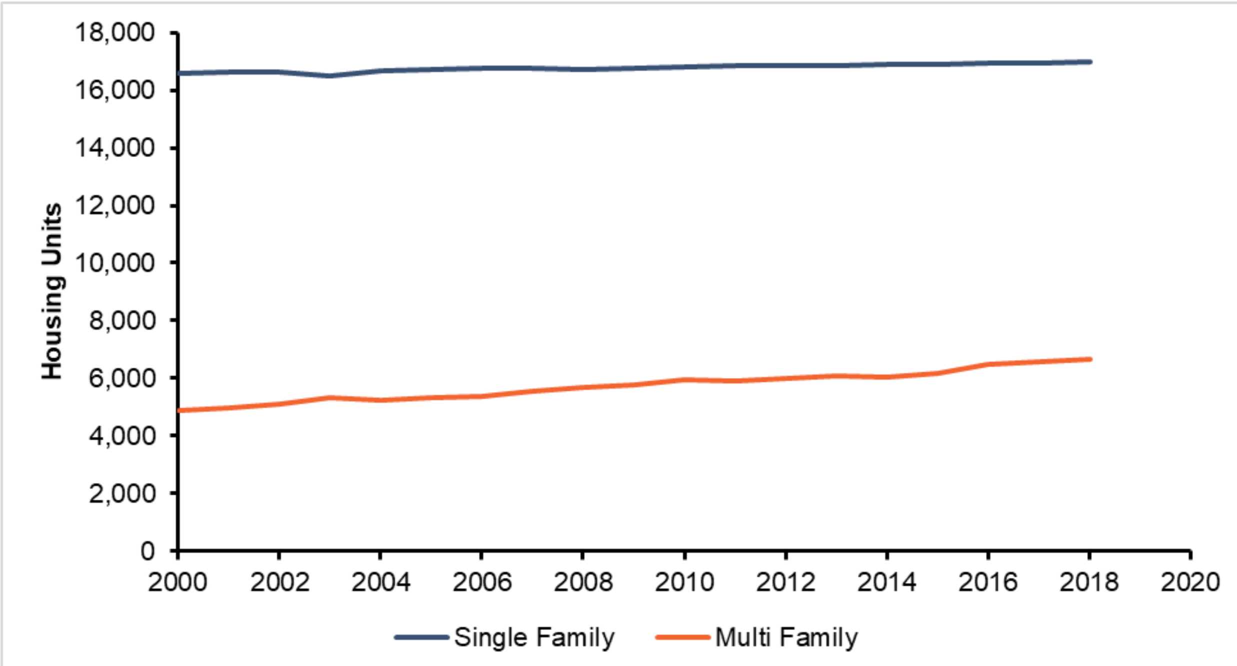

Figure B-1: California Water Service Single Family and Multifamily Housing Units

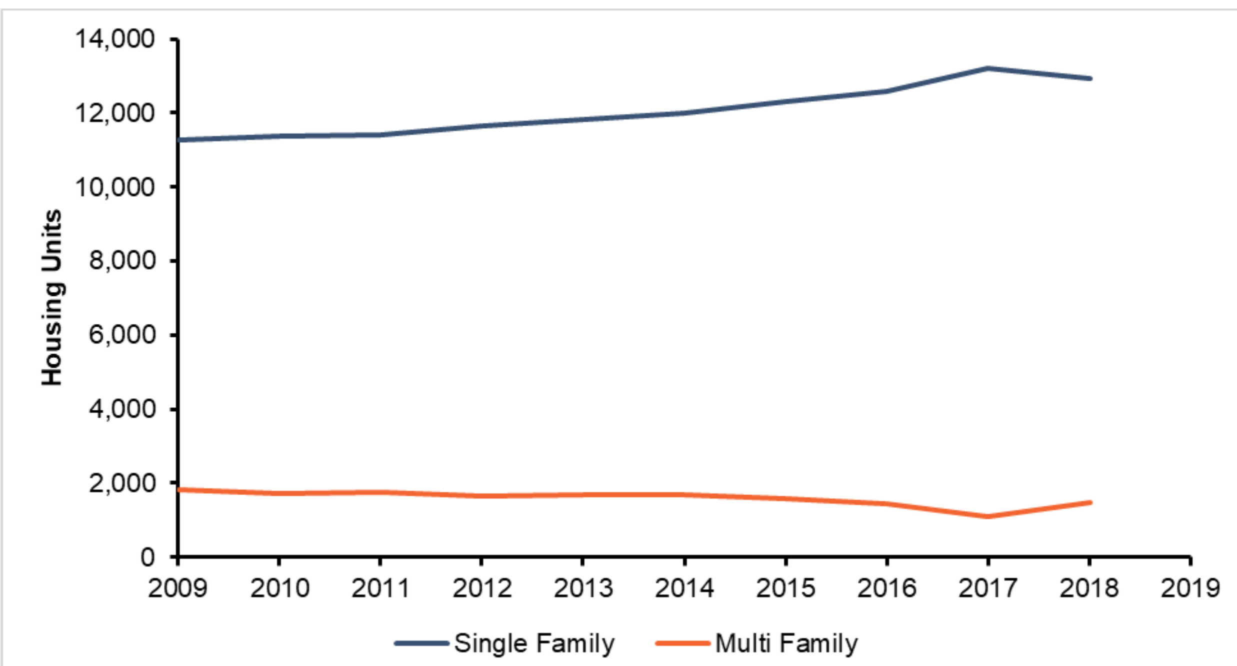

Figure B-2: City of Gilroy Single Family and Multifamily Housing Units

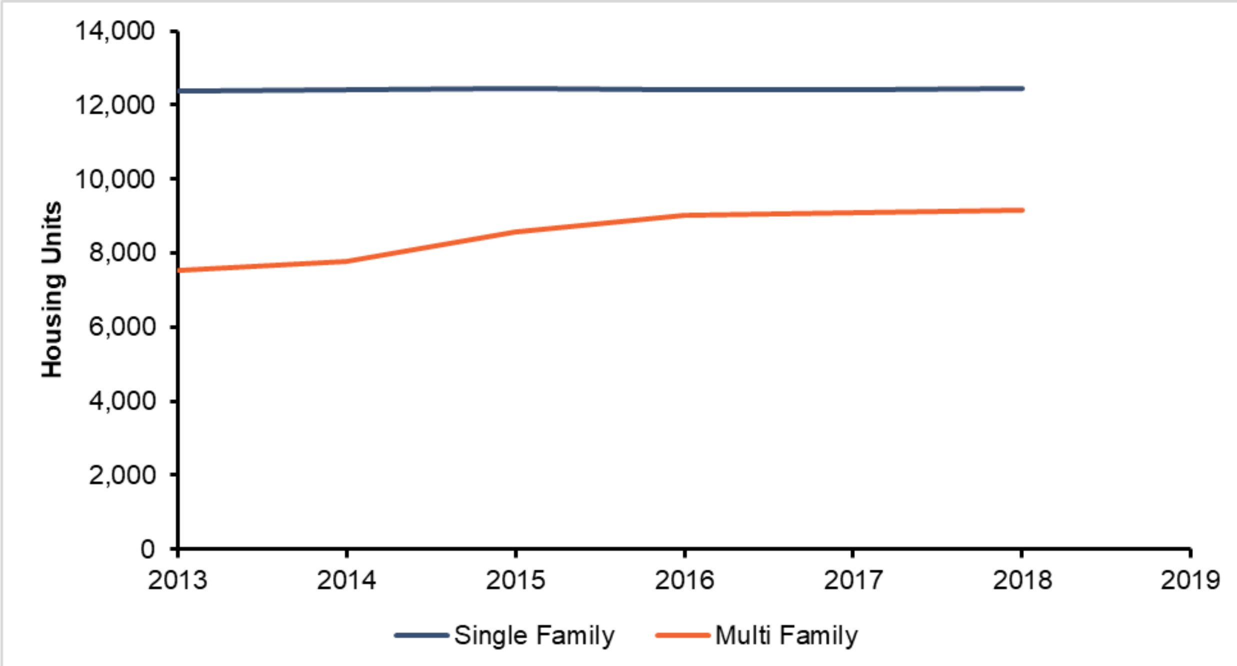

Figure B-3: City of Milpitas Single Family and Multifamily Housing Units

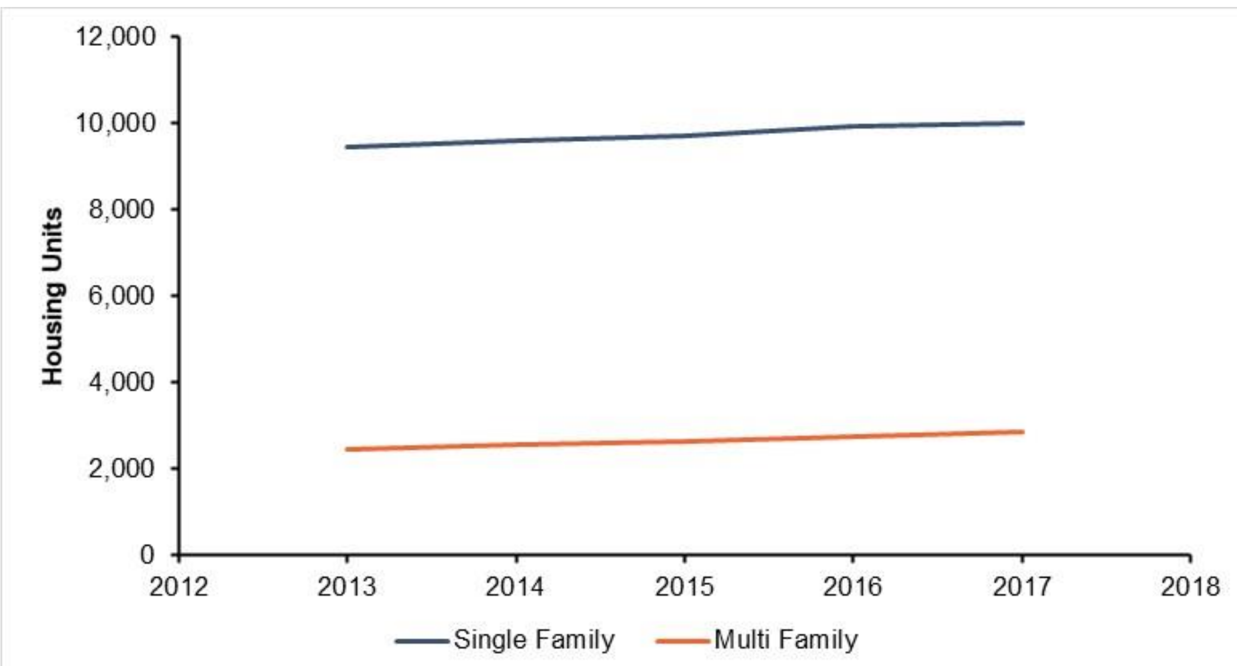

Figure B-4: City of Morgan Hill Single Family and Multifamily Housing Units

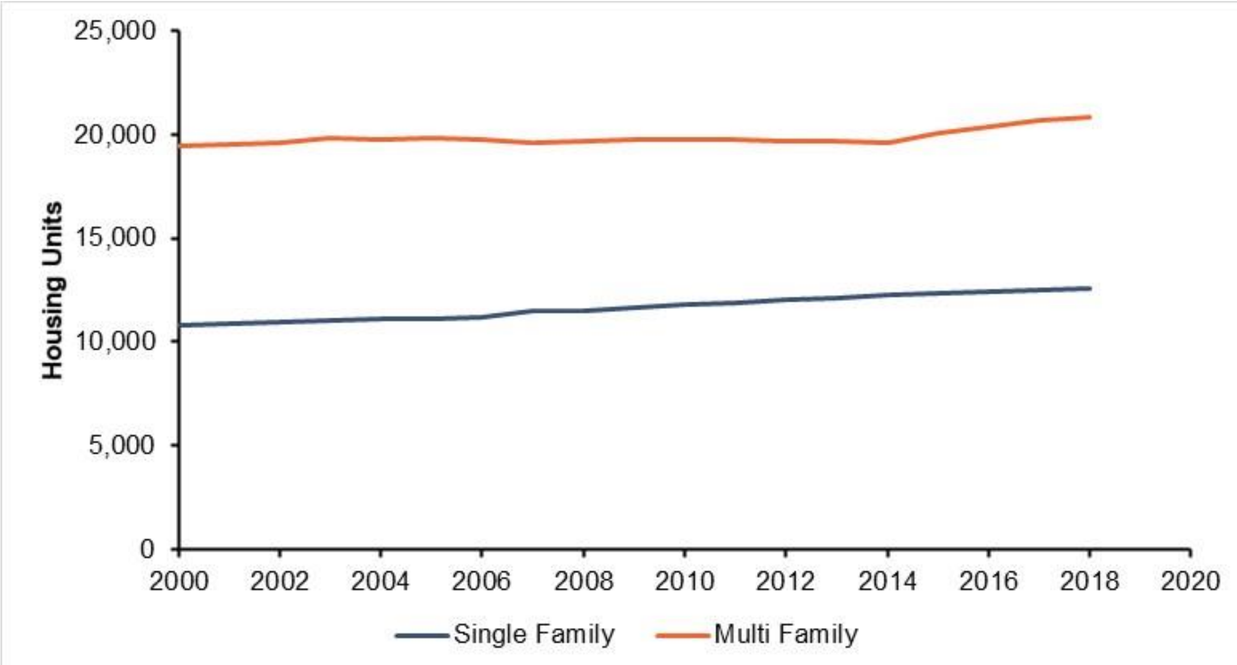

Figure B-5: City of Mountain View Single Family and Multifamily Housing Units

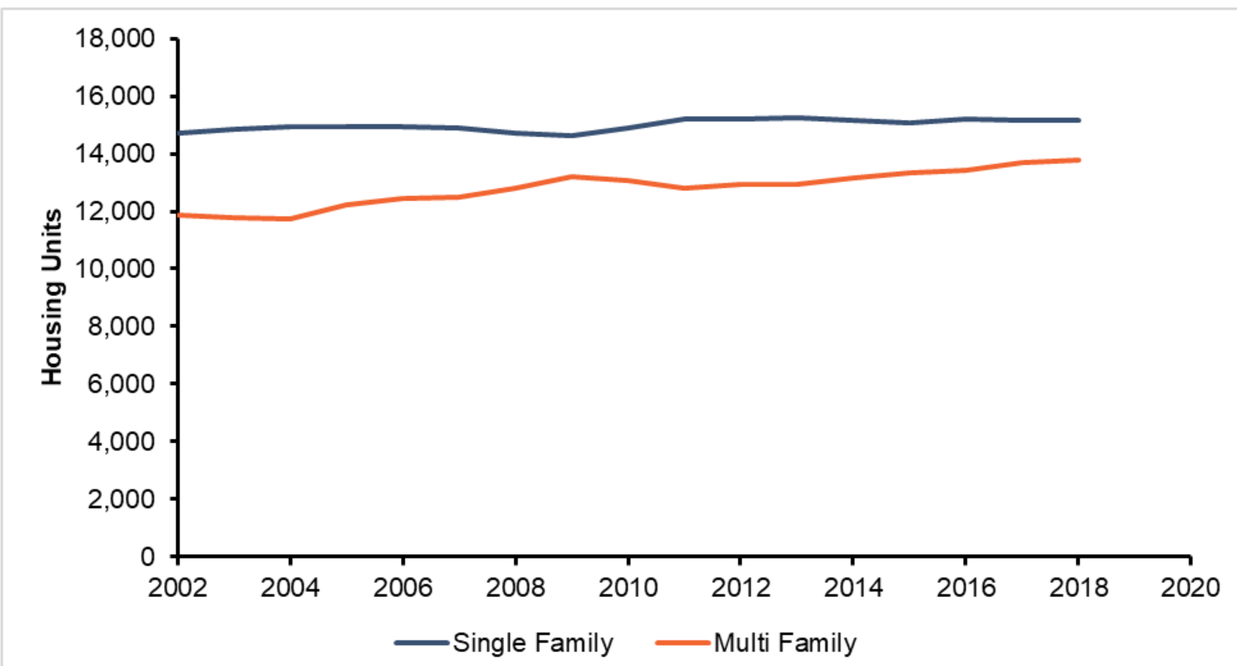

Figure B-6: City of Palo Alto Single Family and Multifamily Housing Units

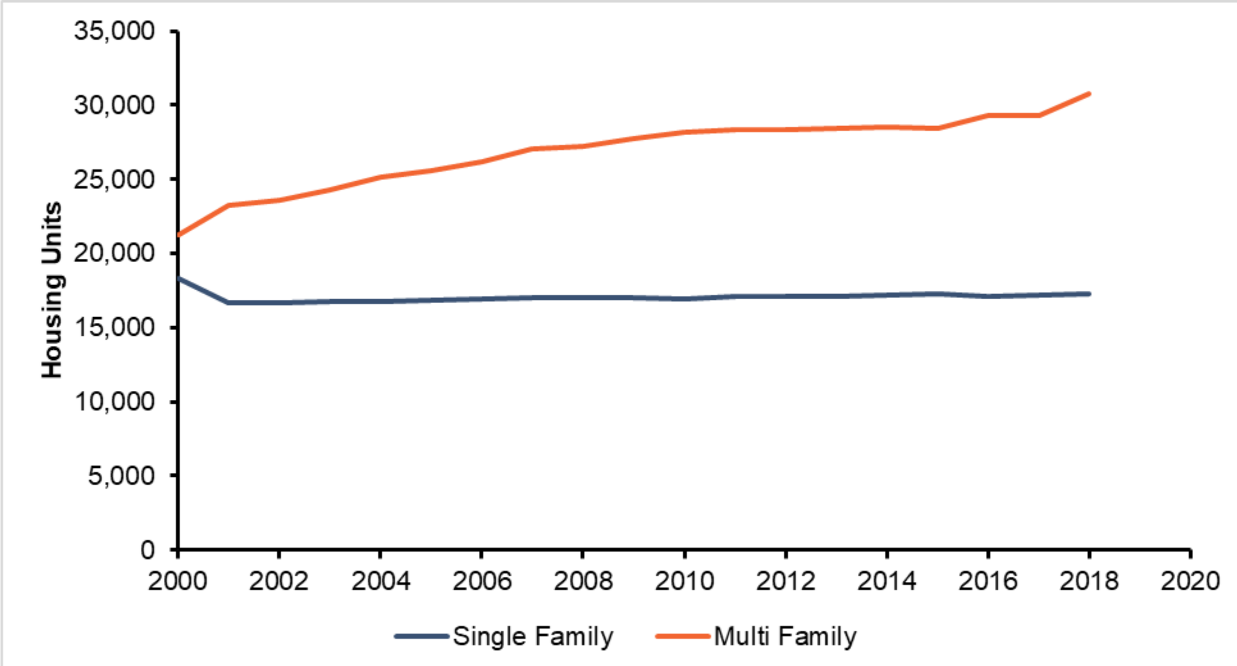

Figure B-7: City of Santa Clara Single Family and Multifamily Housing Units

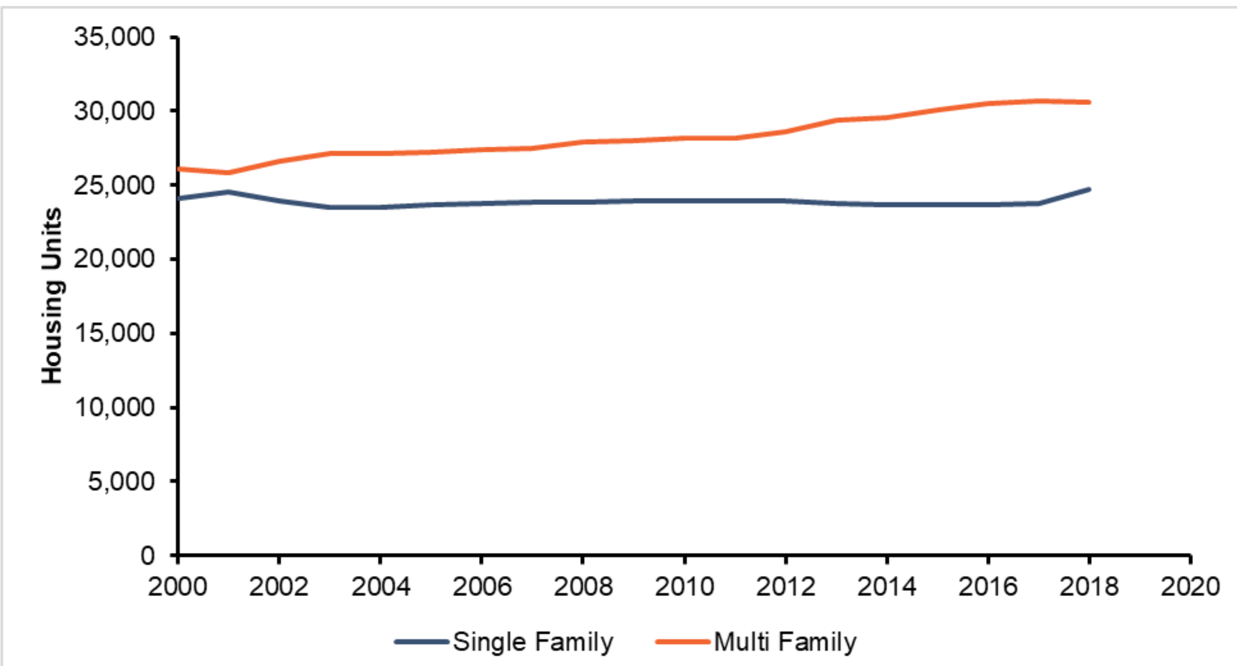

Figure B-8: City of Sunnyvale Single Family and Multifamily Housing Units

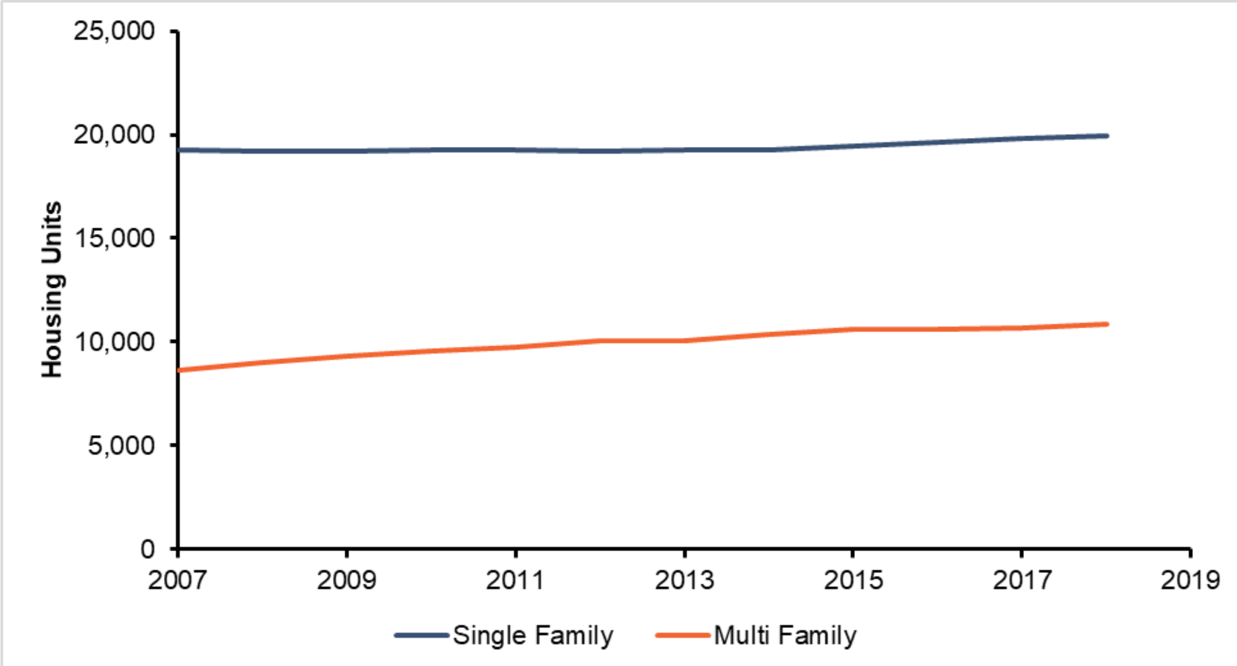

Figure B-9: Great Oaks Water Company Single Family and Multifamily Housing Units

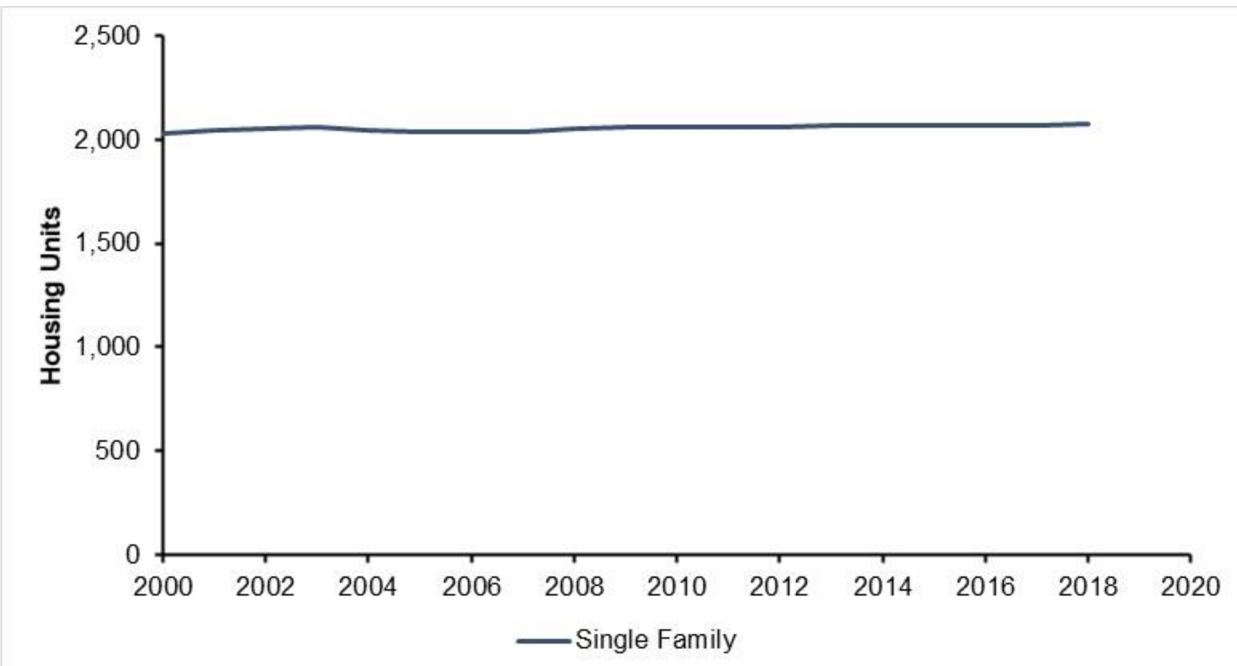

Figure B-10: Purissima Hills Water District Single Family and Multifamily Housing Units

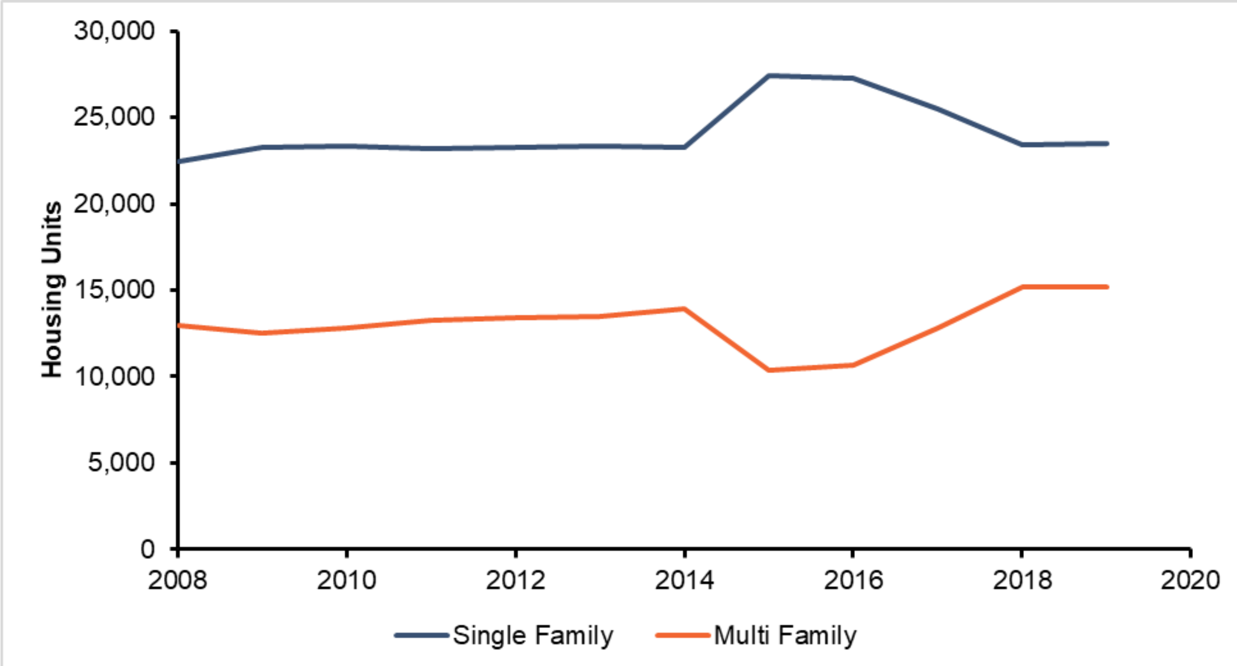

Figure B-11: San Jose Municipal Water Single Family and Multifamily Housing Units[25]

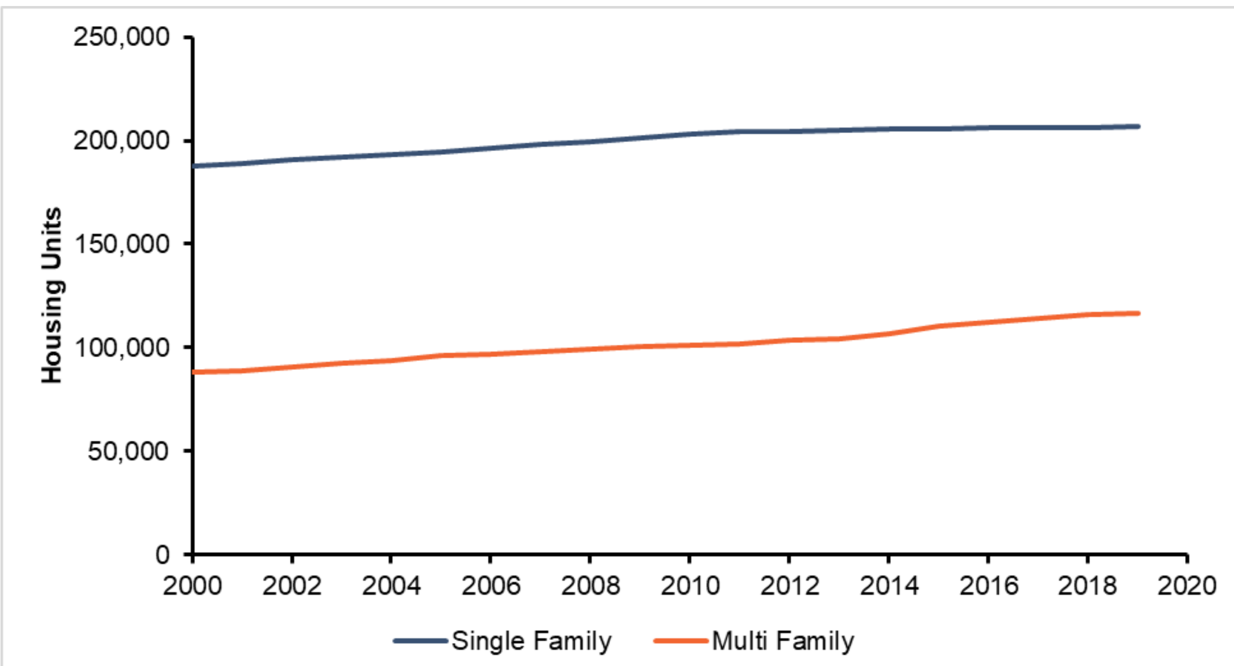

Figure B-12: San Jose Water Company Single Family and Multifamily Housing Units

[25] A temporary shift in single family accounts without associated information on the number of multifamily units per account lead to a corresponding temporary change in multifamily housing units.

Appendix C: Summary of Retail Agency CII Jobs

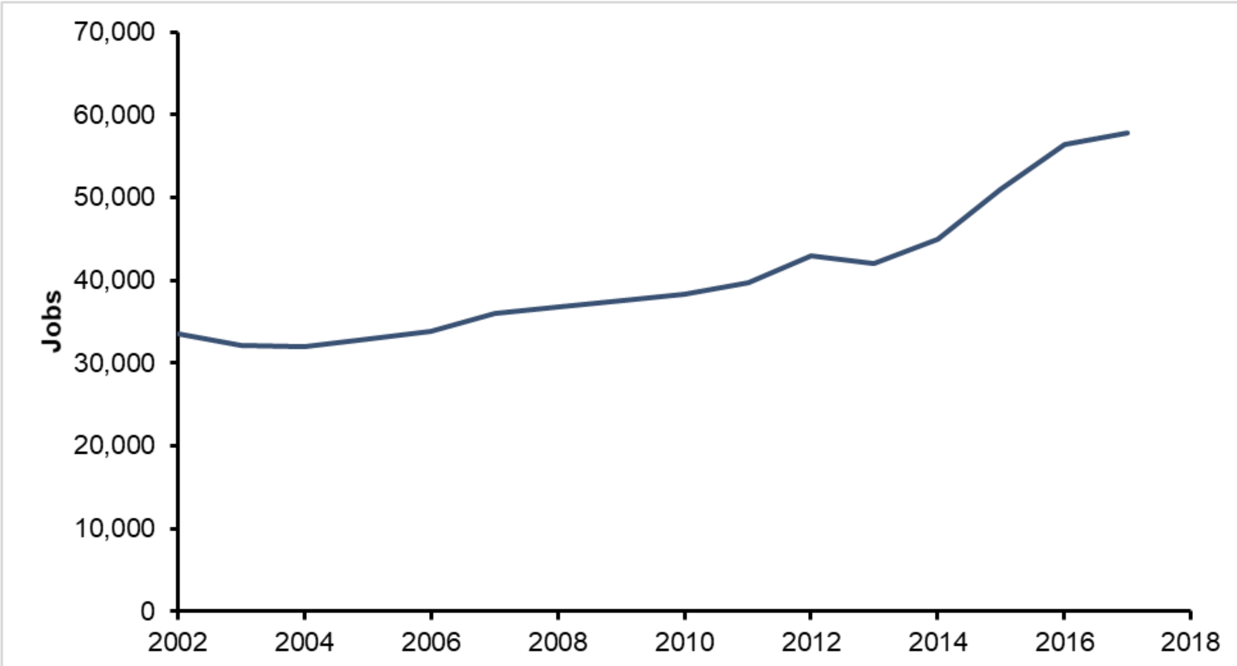

Figure C-1: California Water Service Jobs

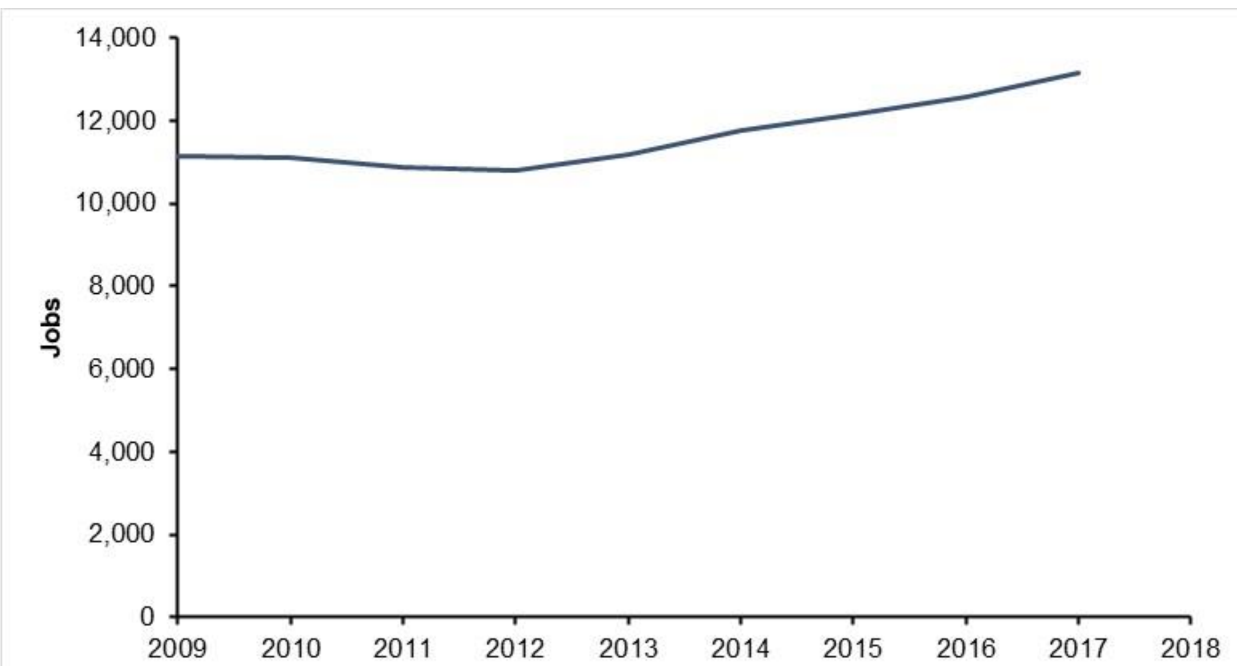

Figure C-2: City of Gilroy Jobs

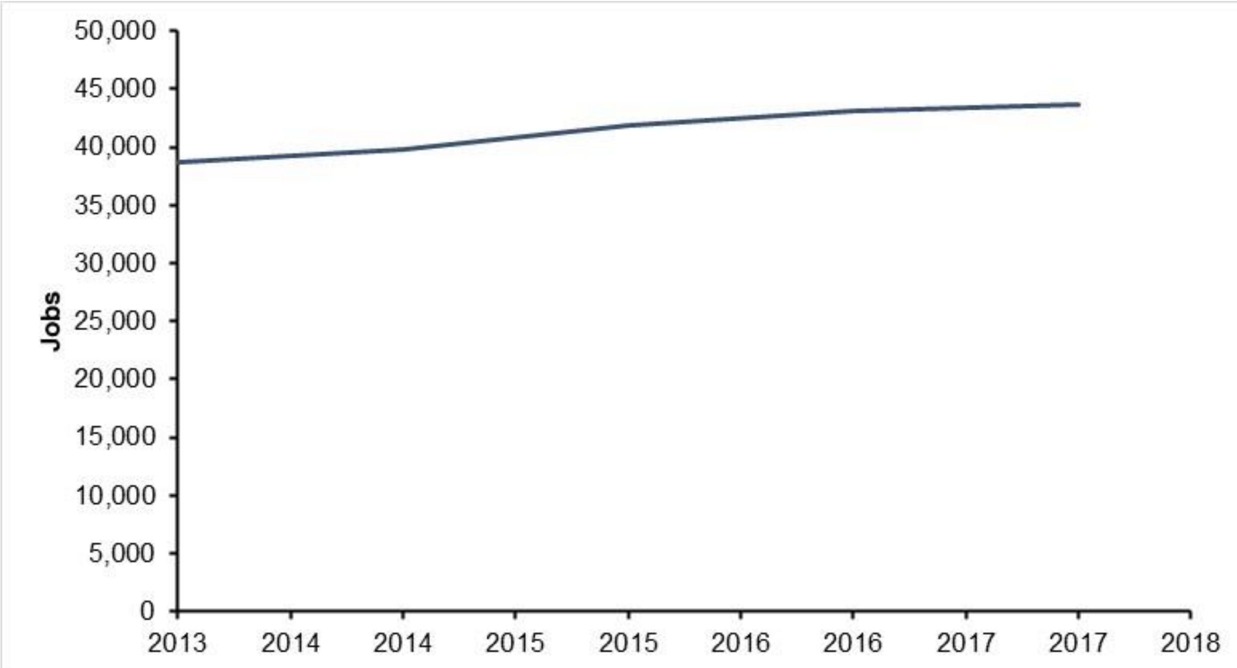

Figure C-3: City of Milpitas Jobs

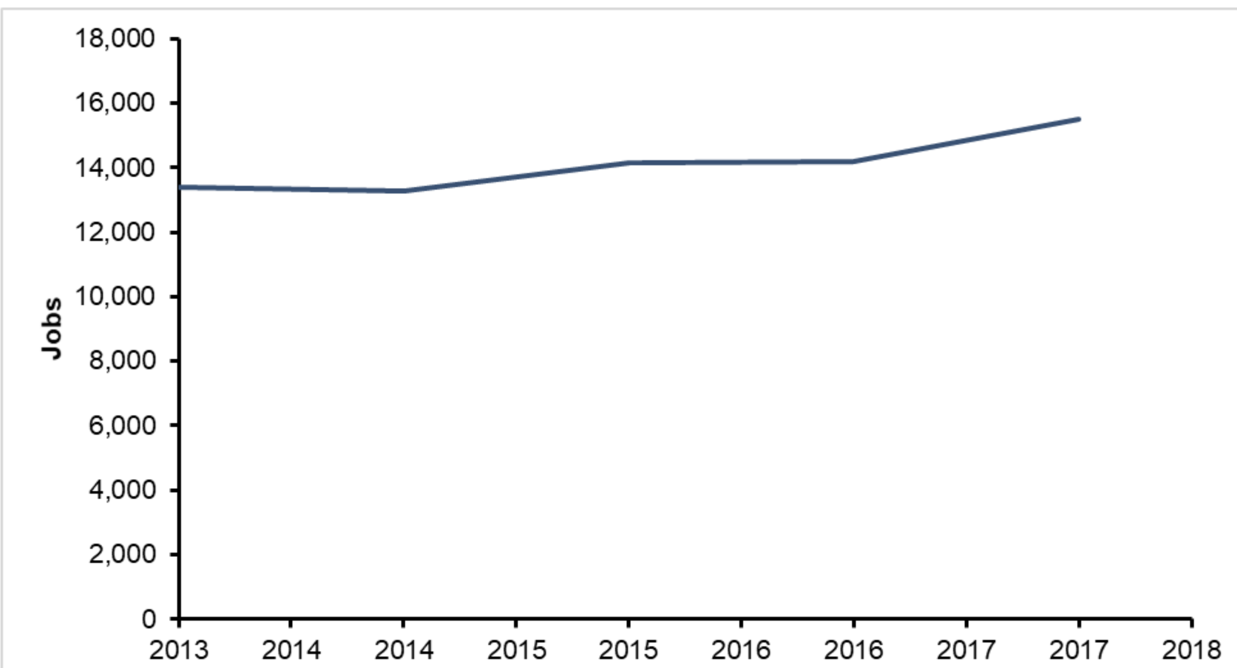

Figure C-4: City of Morgan Hill Jobs

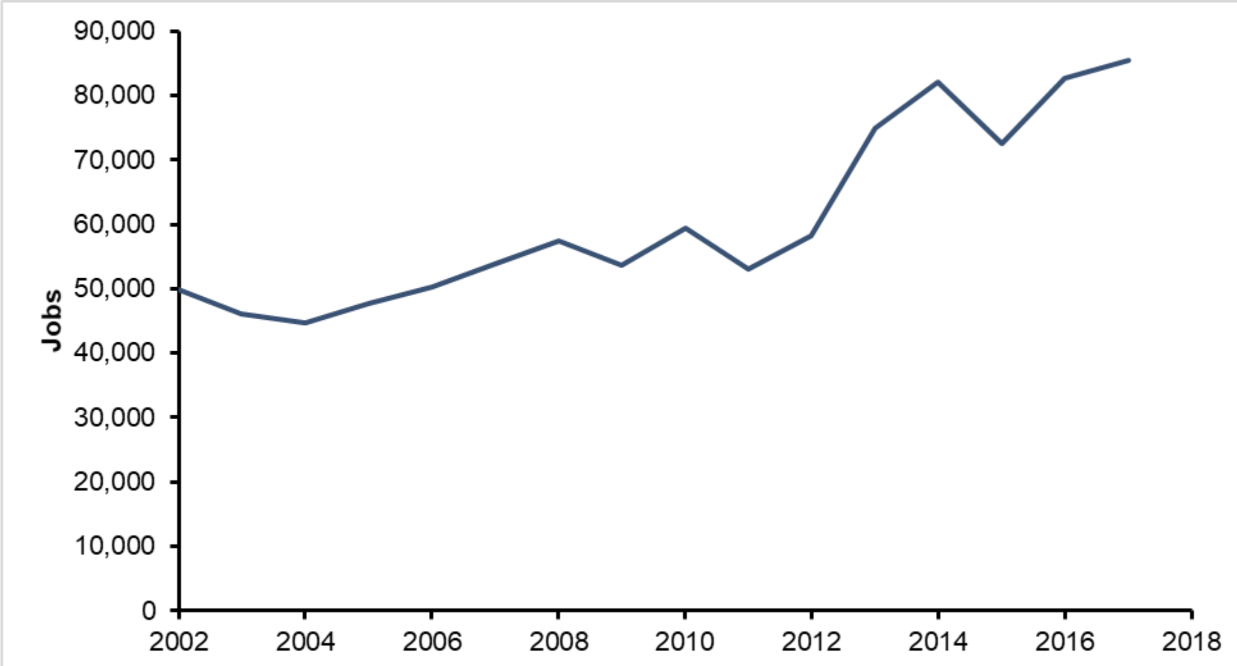

Figure C-5: City of Mountain View Jobs

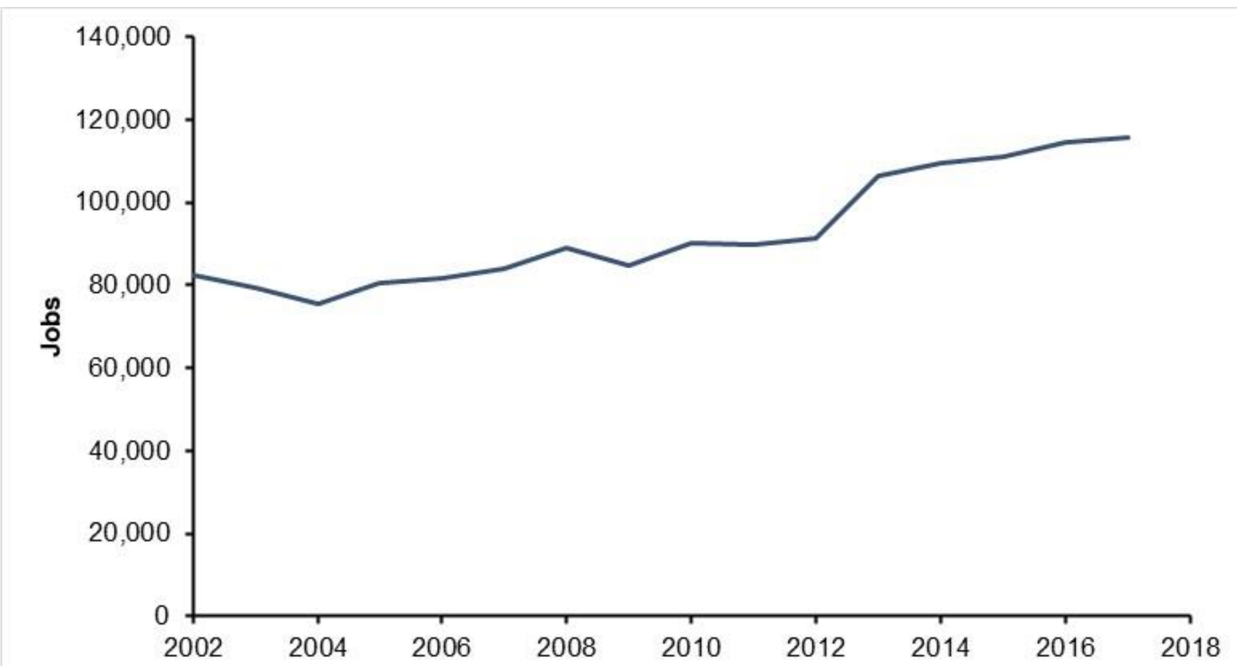

Figure C-6: City of Palo Alto Jobs

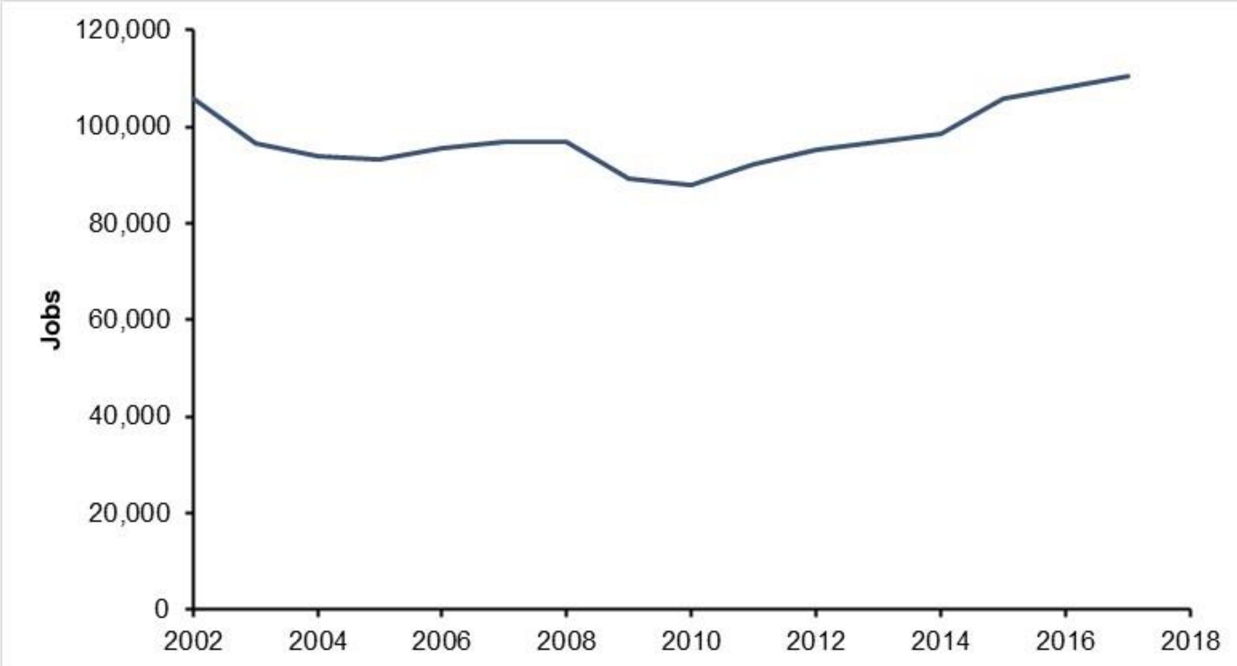

Figure C-7: City of Santa Clara Jobs

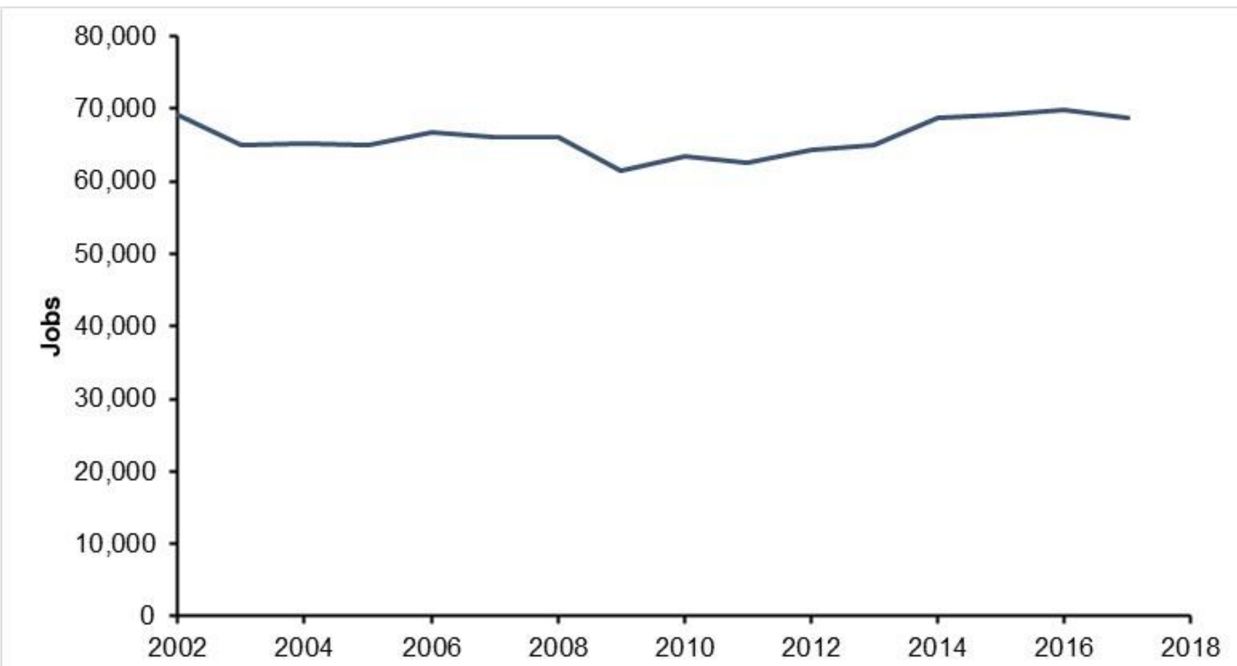

Figure C-8: City of Sunnyvale Jobs

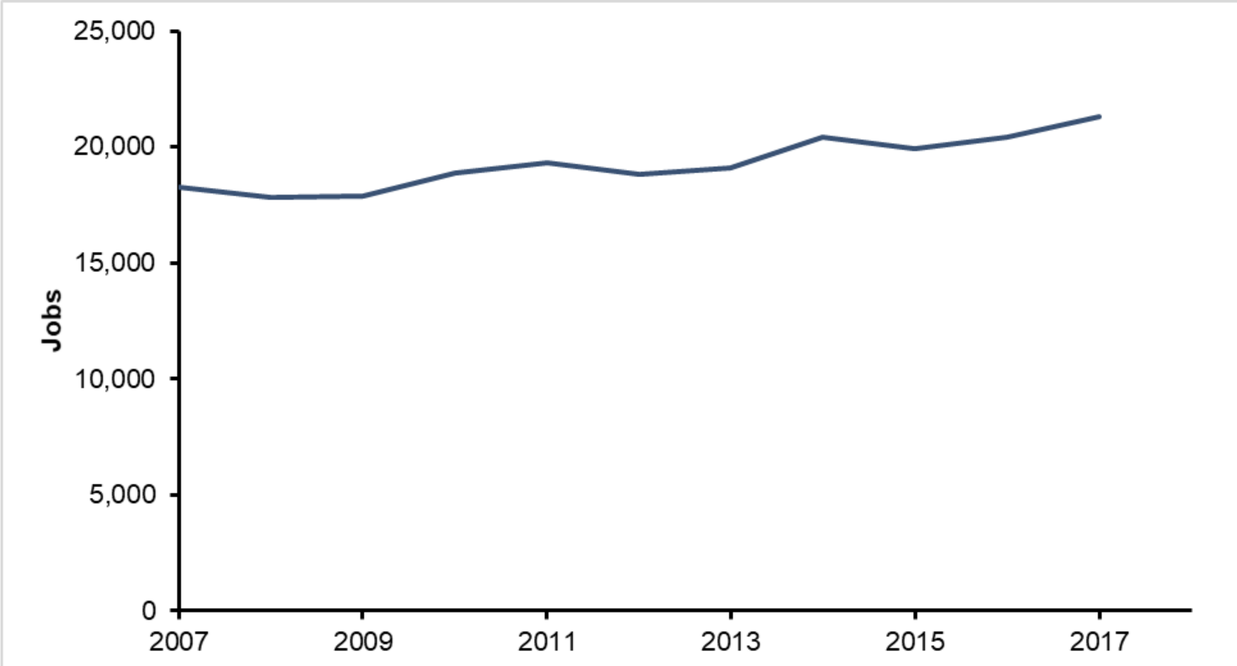

Figure C-9: Great Oaks Water Company Jobs

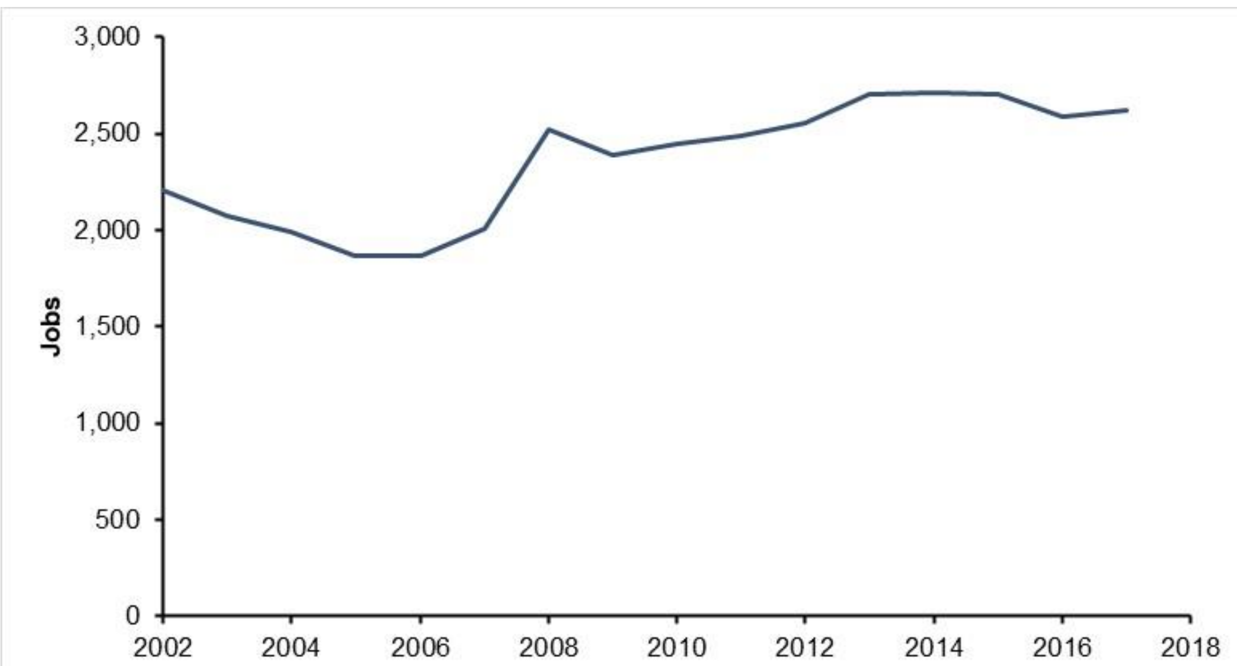

Figure C-10: Purissima Hills Water District Jobs

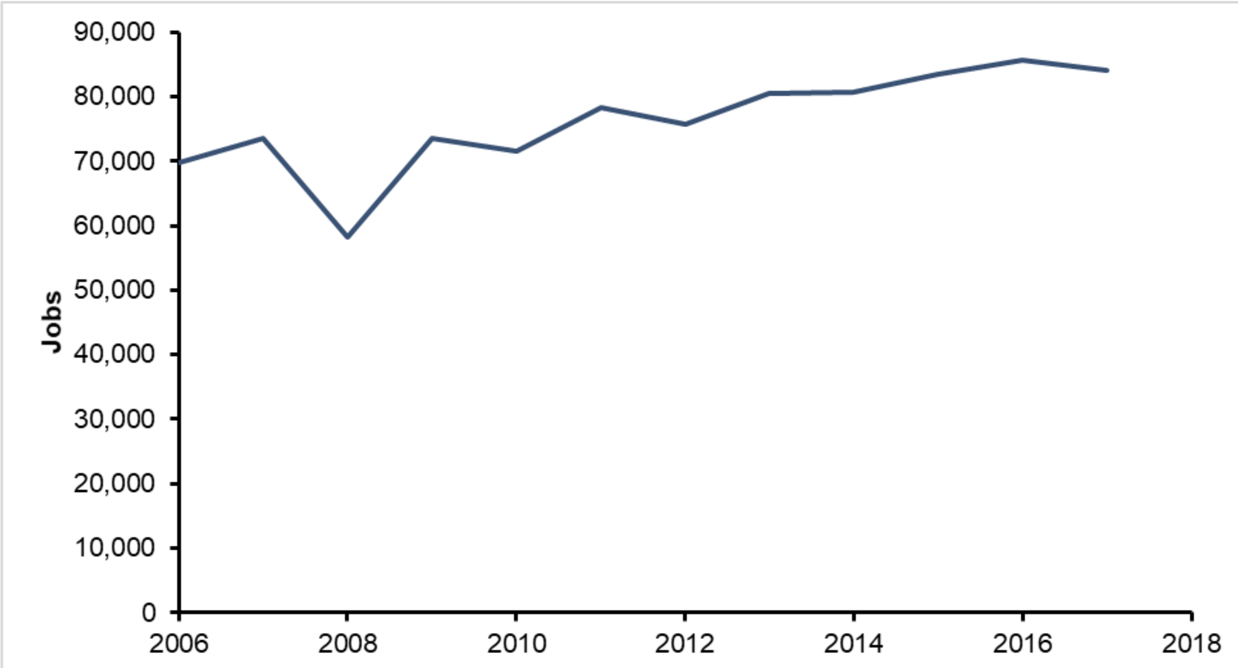

Figure C-11: San Jose Municipal Water Jobs

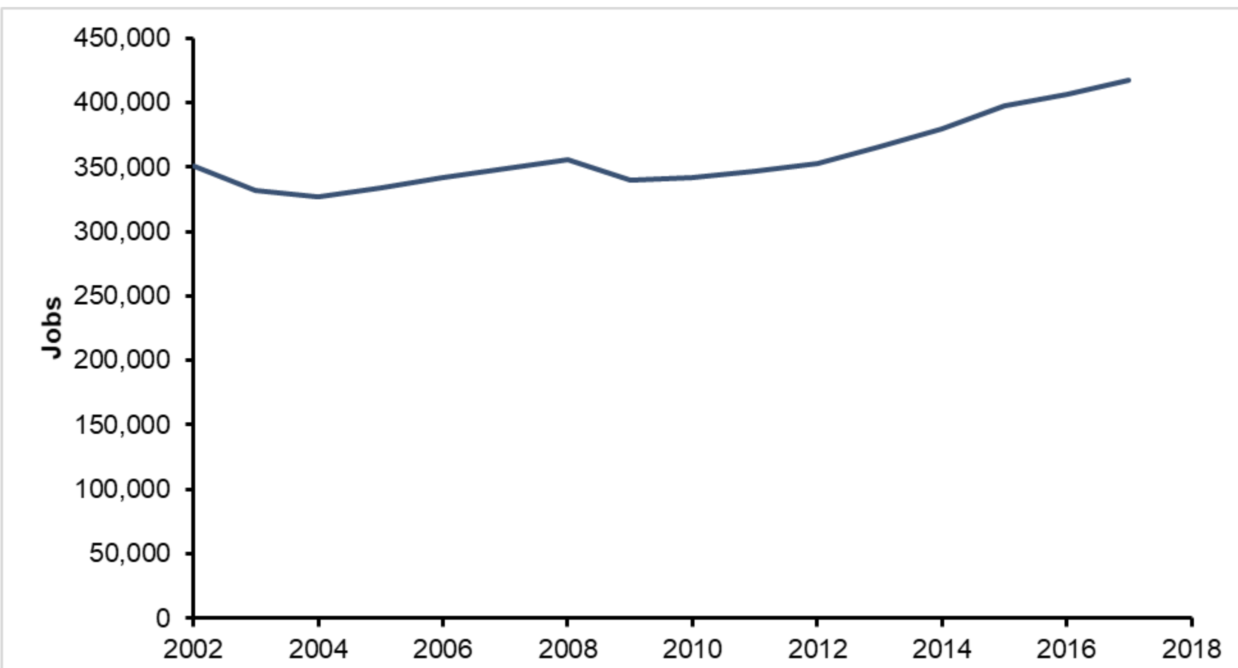

Figure C-12: San Jose Water Company Jobs

Appendix D: Summary of Historical Water Rates

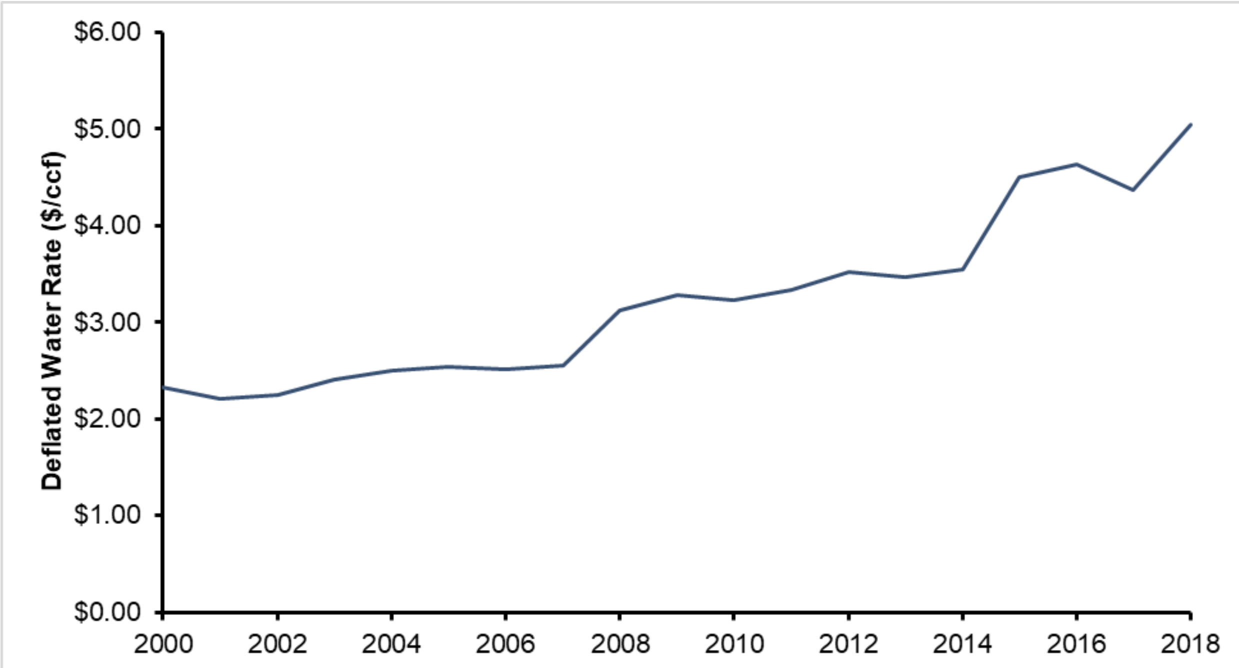

Figure D-1: California Water Service Historical Water Rates

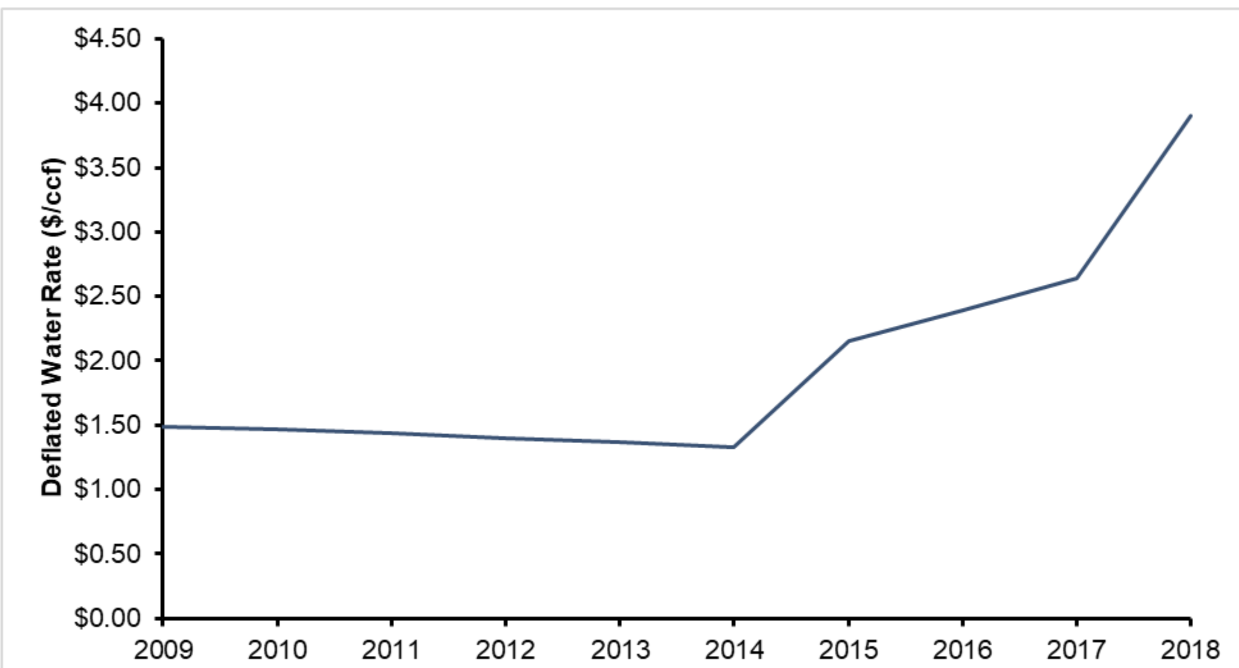

Figure D-2: City of Gilroy Historical Water Rates

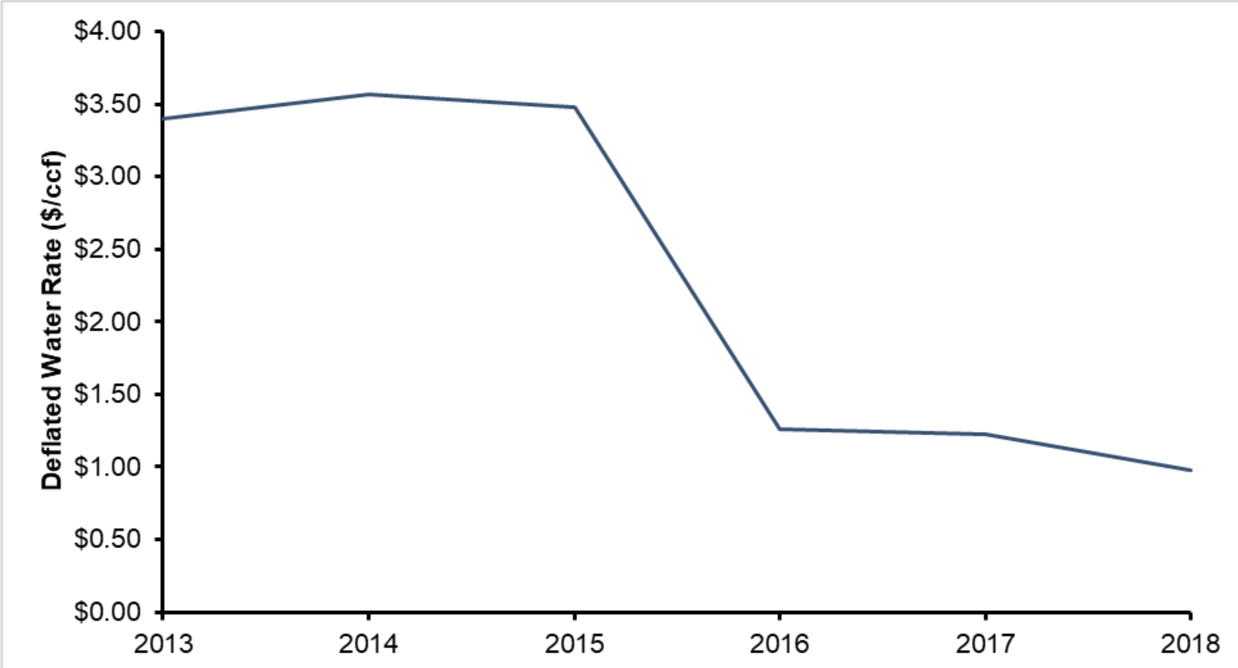

Figure D-3: City of Milpitas Historical Water Rates

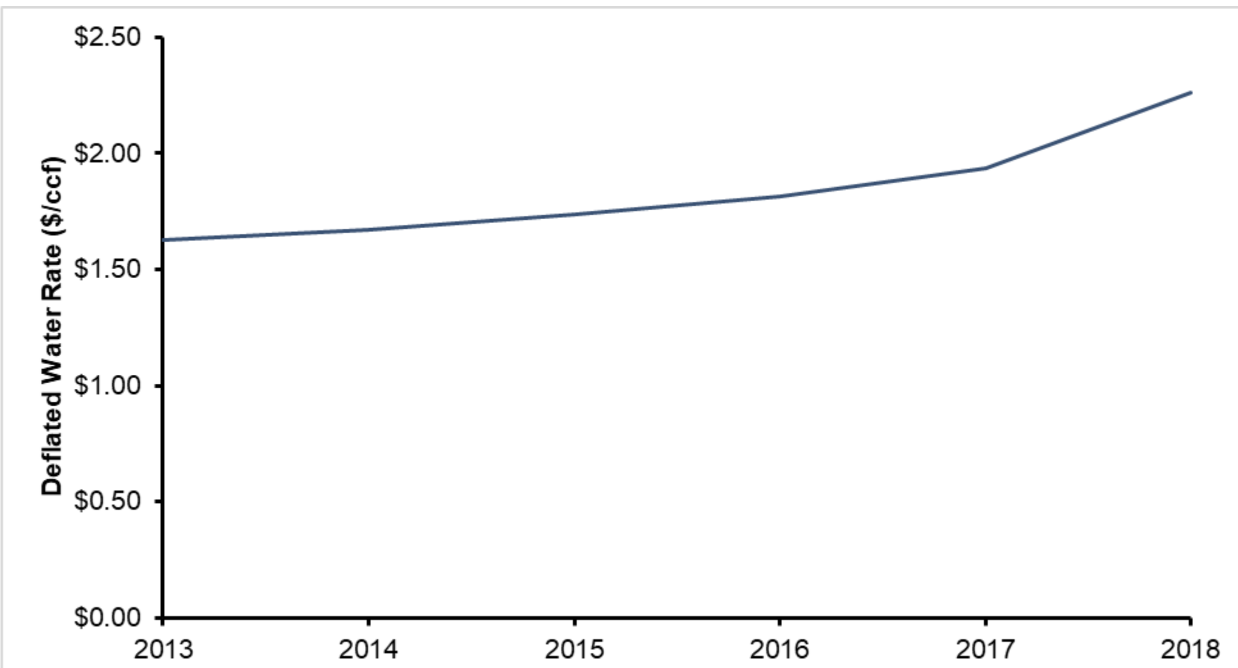

Figure D-4: City of Morgan Hill Historical Water Rates

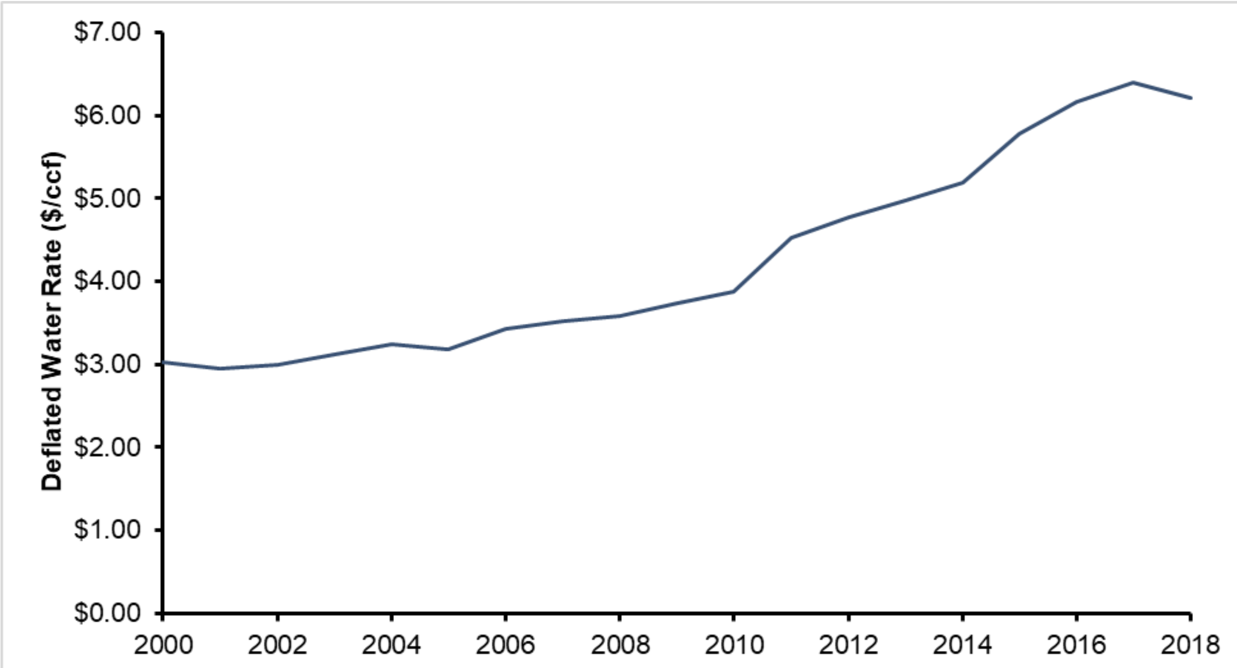

Figure D-5: City of Mountain View Historical Water Rates

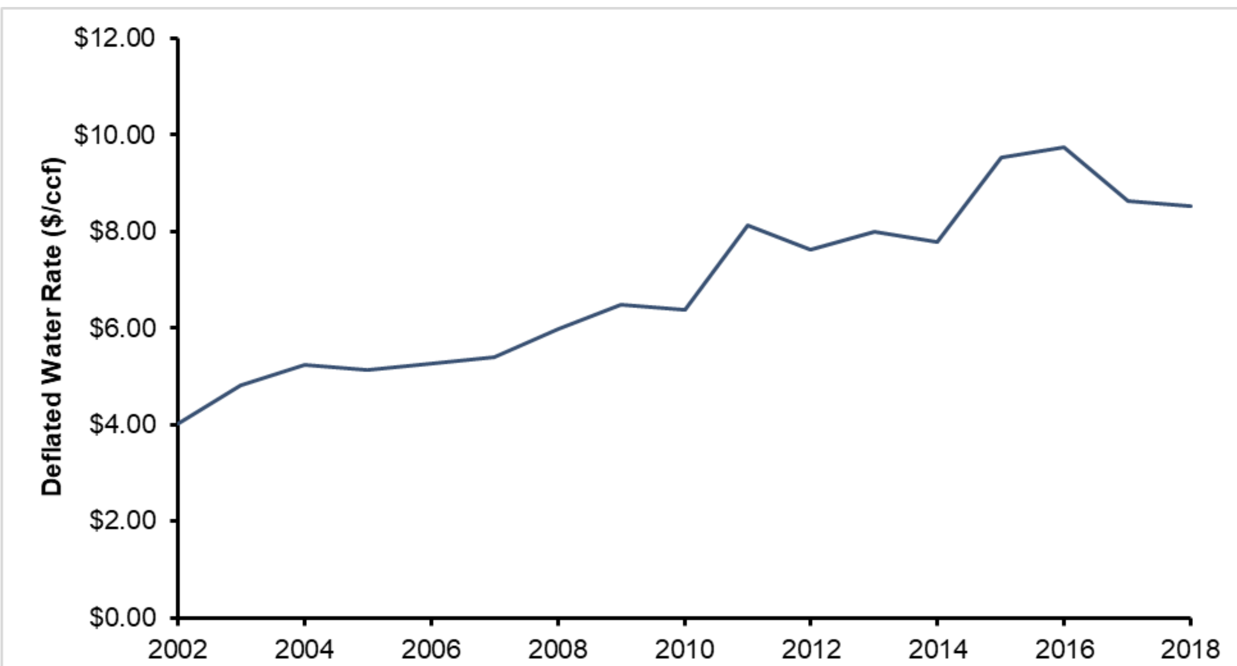

Figure D-6: City of Palo Alto Historical Water Rates

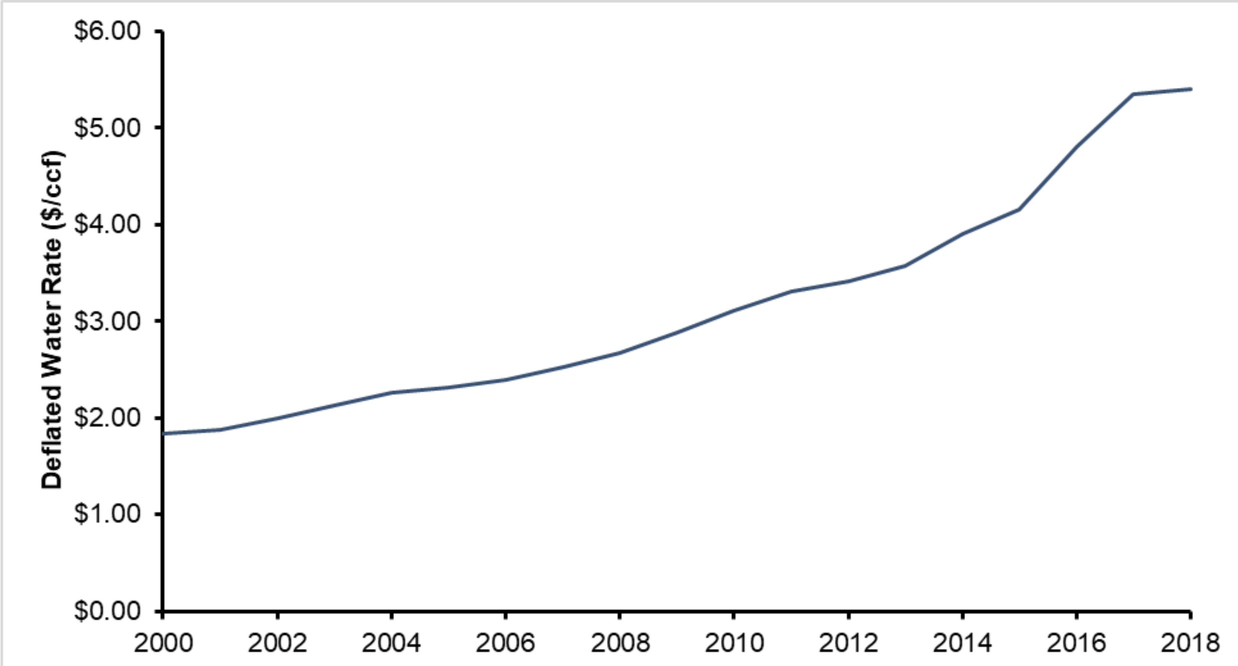

Figure D-7: City of Santa Clara Historical Water Rates

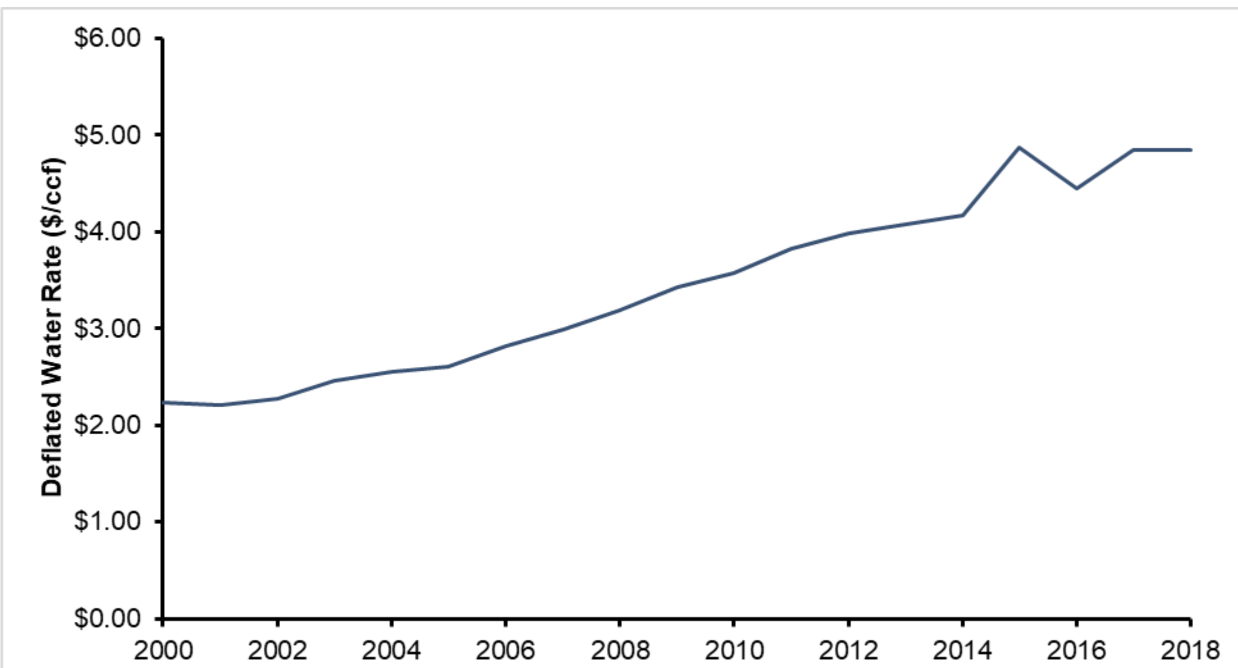

Figure D-8: City of Sunnyvale Historical Water Rates

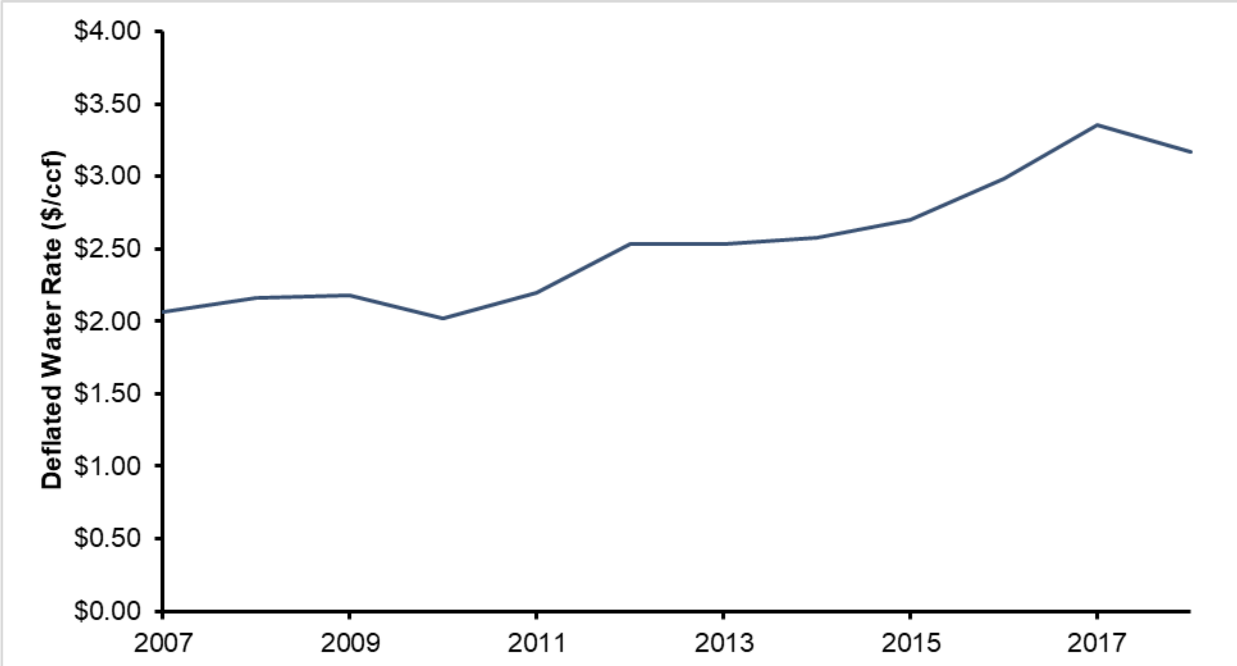

Figure D-9: Great Oaks Water Company Historical Water Rates

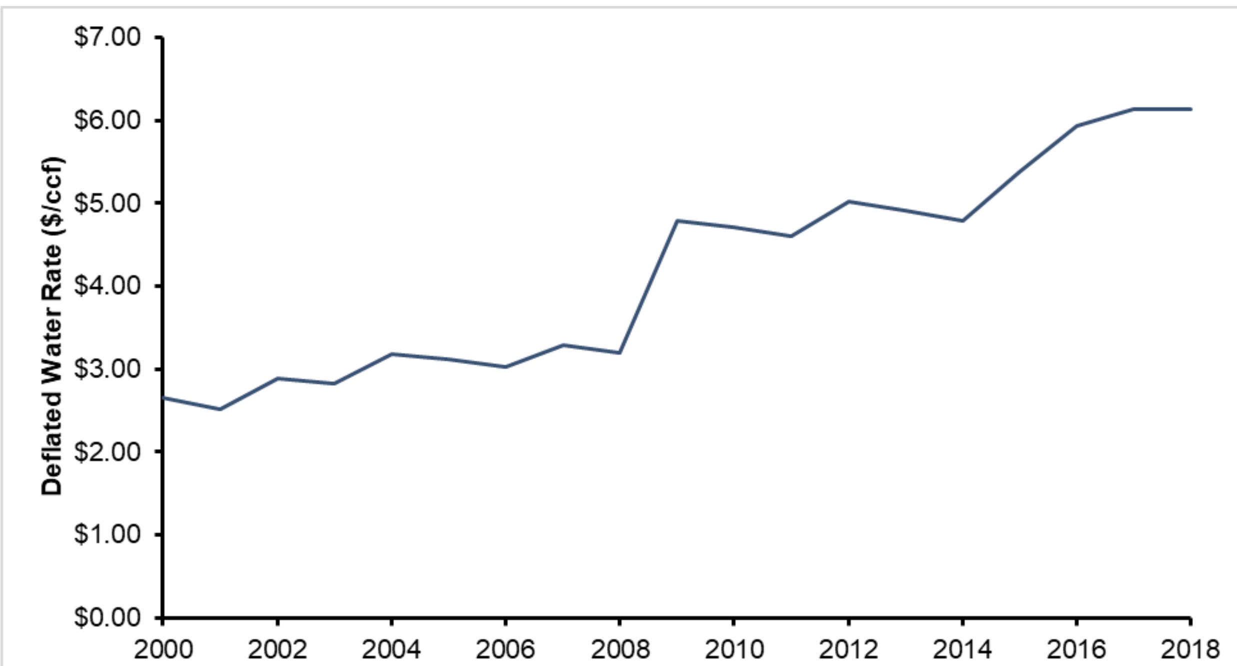

Figure D-10: Purissima Hills Water District Historical Water Rates

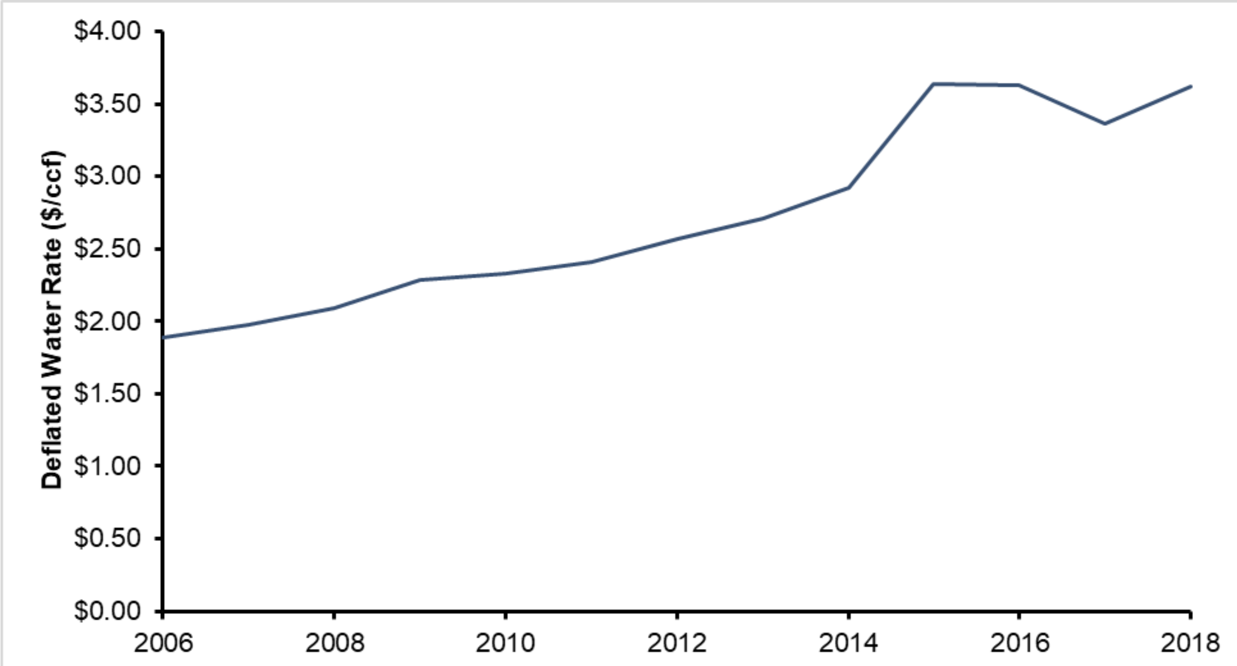

Figure D-11: San Jose Municipal Water Historical Water Rates

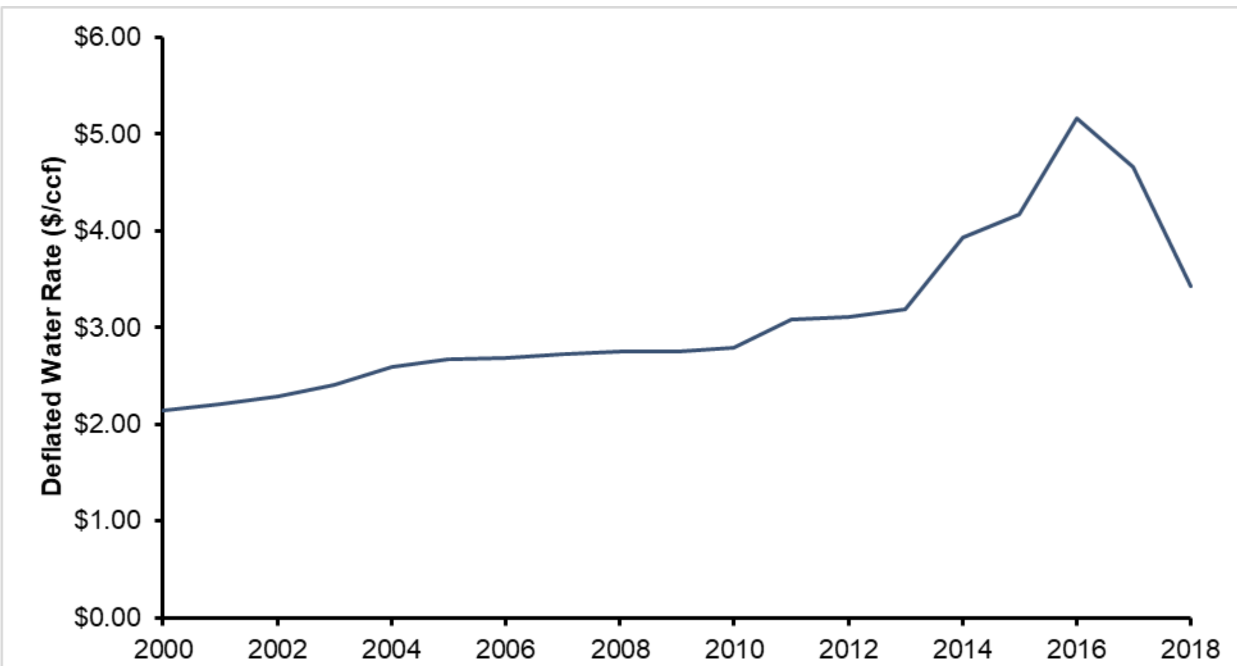

Figure D-12: San Jose Water Company Historical Water Rates

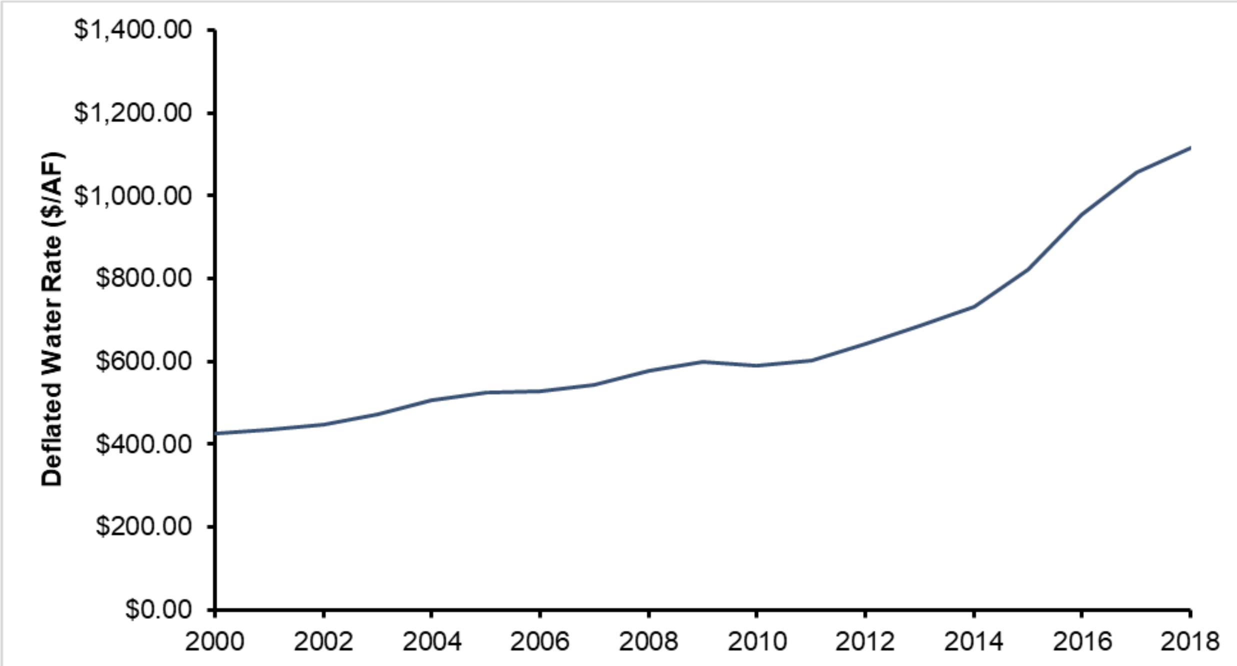

Figure D-13: Stanford University Historical Water Rates

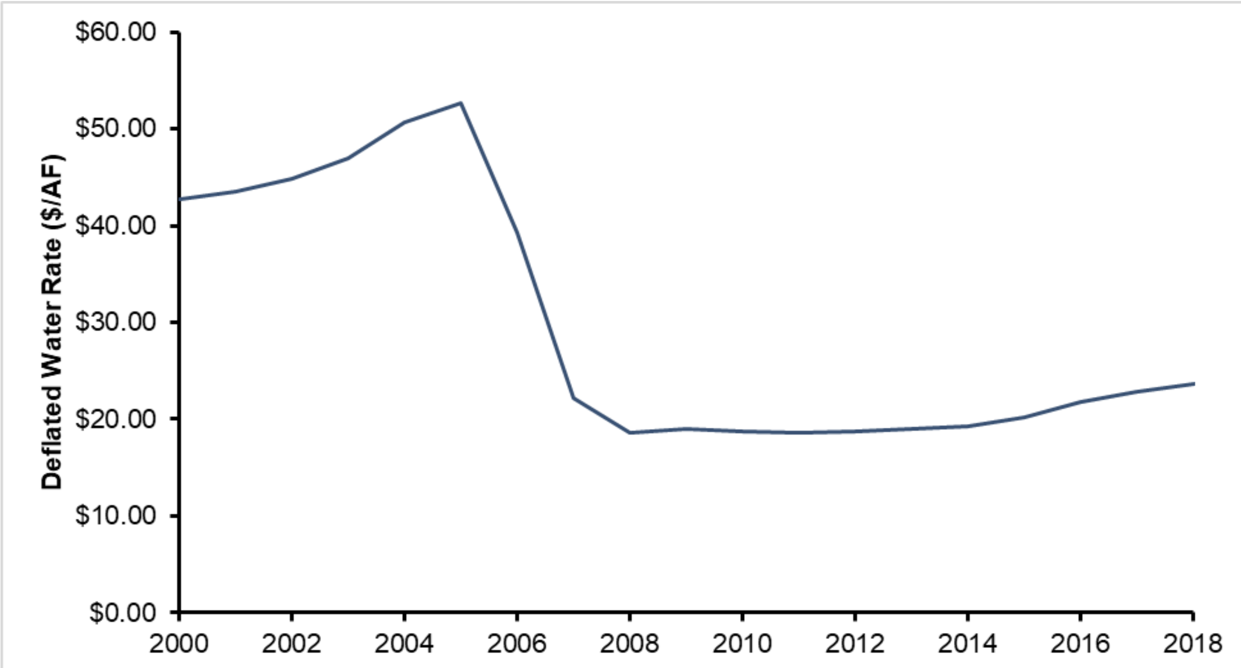

Figure D-14: Non-Retail Groundwater Pumpers, Ag W2 Historical Water Rates

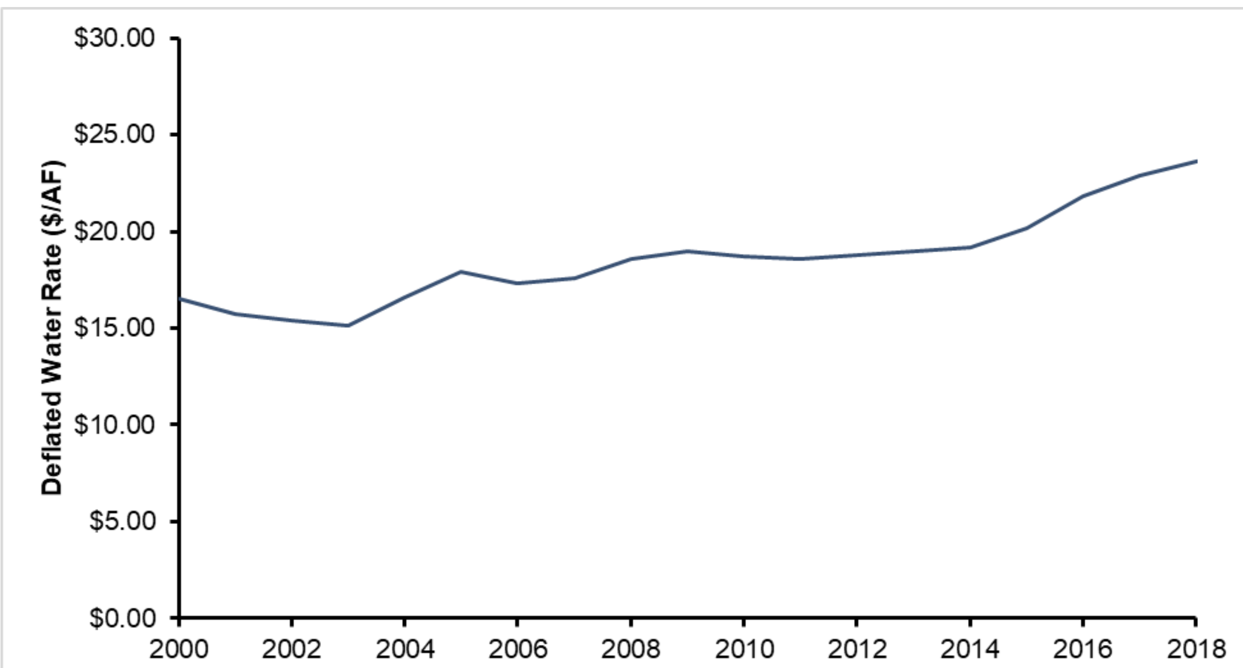

Figure D-15: Non-Retail Groundwater Pumpers, Ag W5 Historical Water Rates

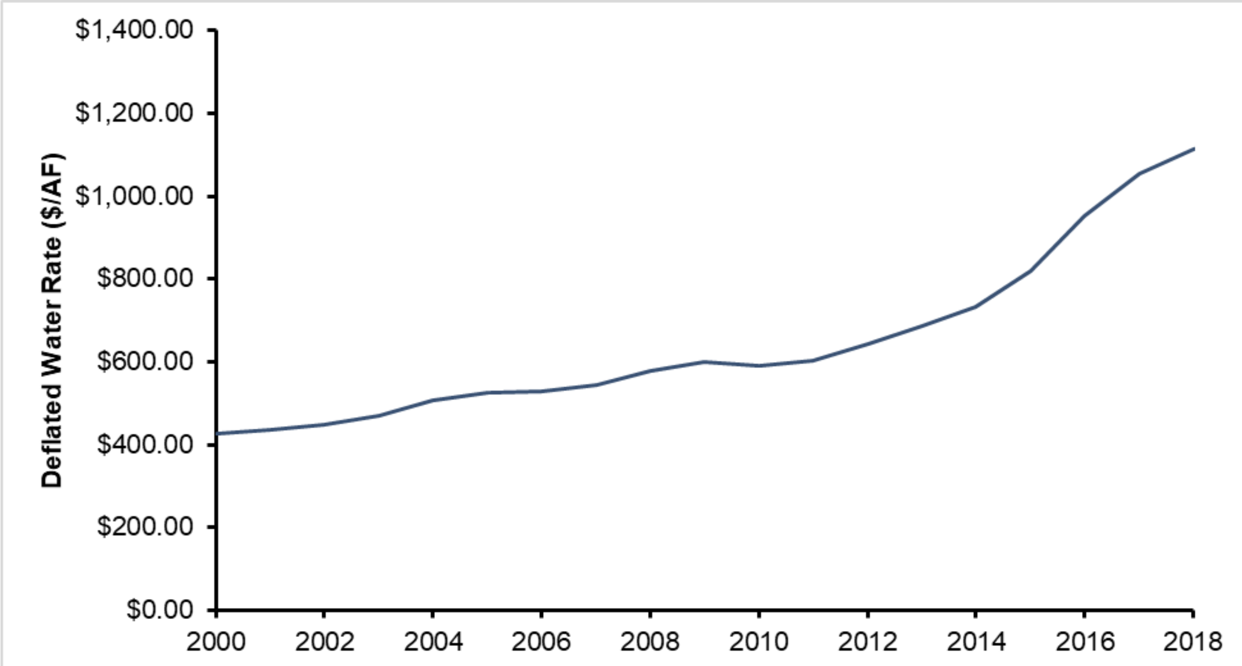

Figure D-16: Non-Retail Groundwater Pumpers, M&I W2 Historical Water Rates

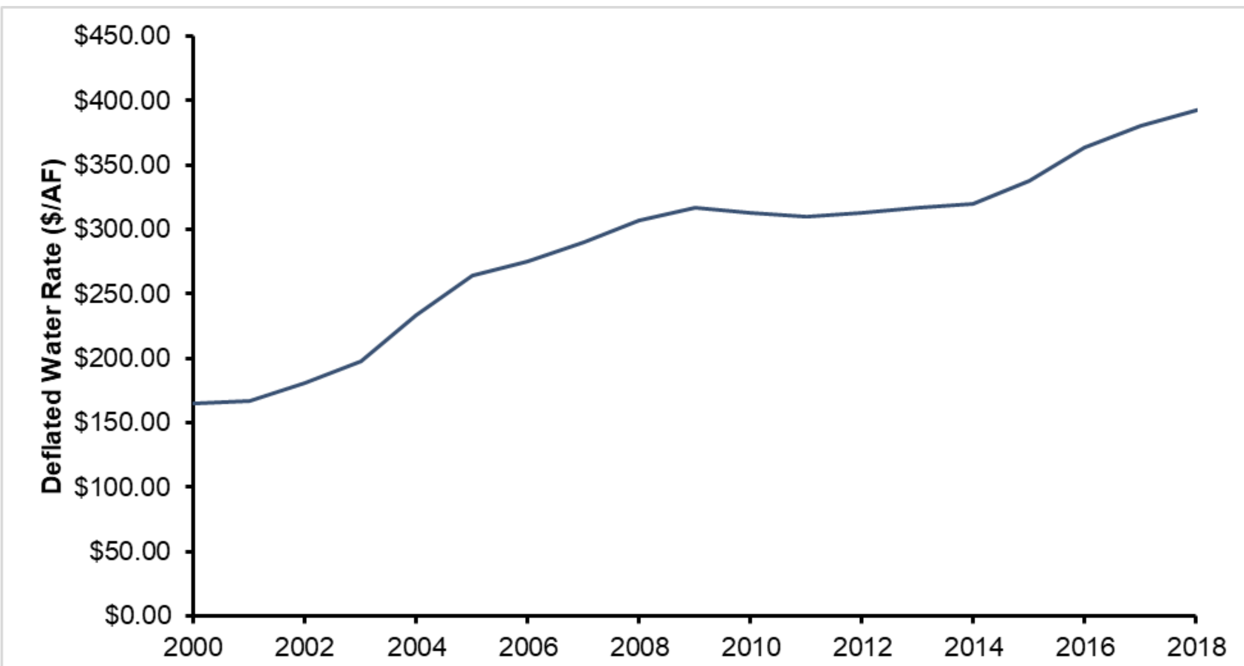

Figure D-17: Non-Retail Groundwater Pumpers, M&I W5 Historical Water Rates

Appendix E: Retail-Level Single Family Model Performance

Table E-1: Summary of Single-Family Model Fit Statistics by Retailer

Retail Agency	R-squared	Average Observed Value (gpud)	Mean Absolute Percentage Error	Mean Bias
California Water Service	0.97	449.67	13.20%	-11.96%
City of Gilroy	0.97	306.66	7.39%	-0.08%
City of Milpitas	0.85	199.37	8.12%	-0.09%
City of Morgan Hill	0.96	338.73	12.81%	10.90%
City of Mountain View	0.98	234.39	7.09%	5.46%
City of Palo Alto	0.98	317.59	6.62%	1.31%
City of Santa Clara	0.97	294.92	6.66%	-2.93%
City of Sunnyvale	0.95	273.63	7.86%	-1.86%
Great Oaks Water Company	0.94	286.73	8.84%	-0.86%
Purissima Hills Water District	0.97	677.67	15.13%	4.78%
San Jose Municipal Water	0.95	319.96	8.31%	1.75%
San Jose Water Company	0.96	283.84	8.03%	-0.62%
Stanford University	--	--	--	--

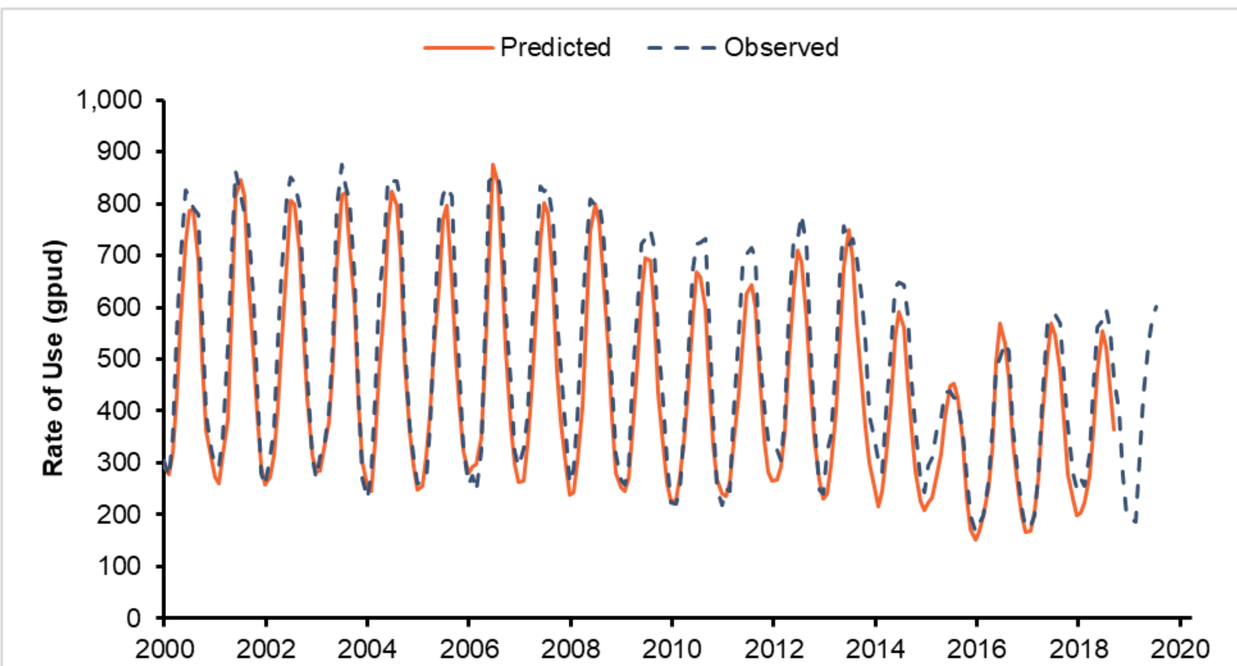

Figure E-1: California Water Service Single Family Observed and Predicted Per Unit Rate of Use

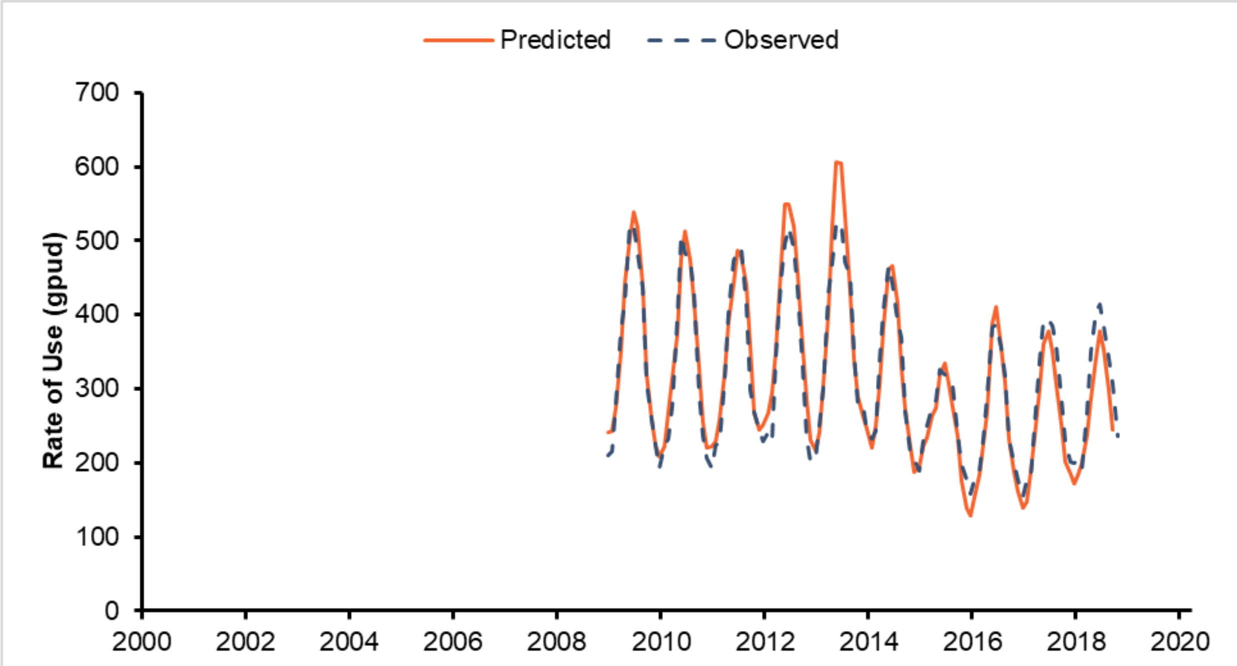

Figure E-2: City of Gilroy Single Family Observed and Predicted Per Unit Rate of Use

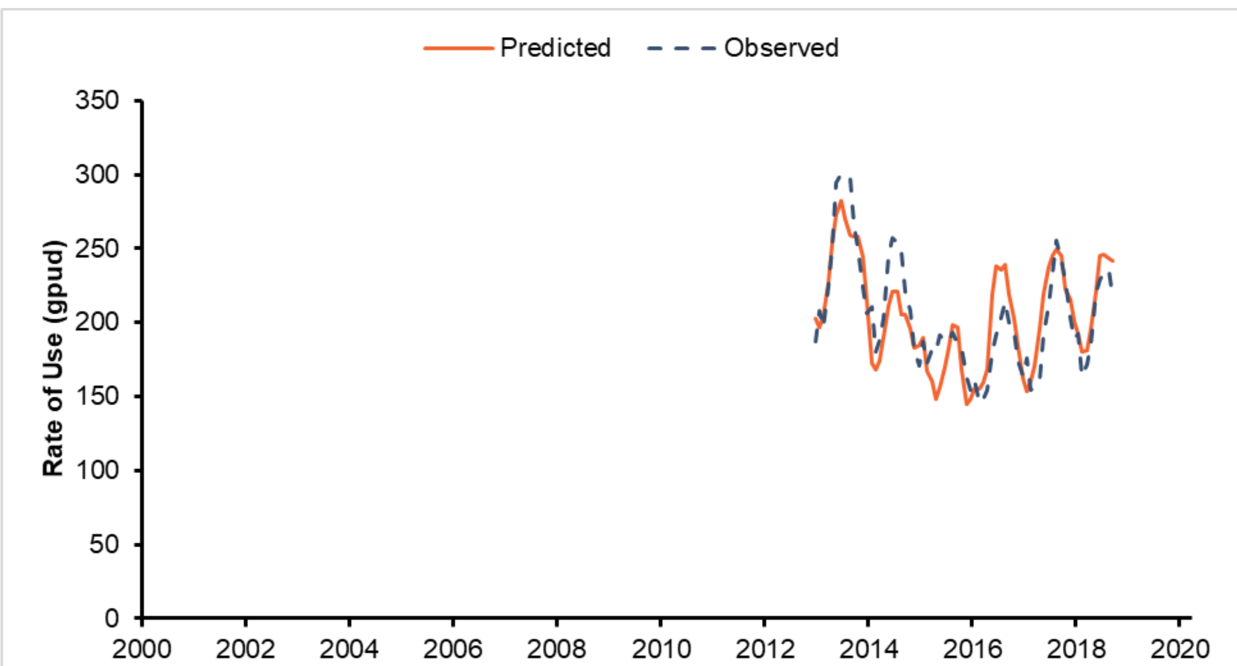

Figure E-3: City of Milpitas Single Family Observed and Predicted Per Unit Rate of Use

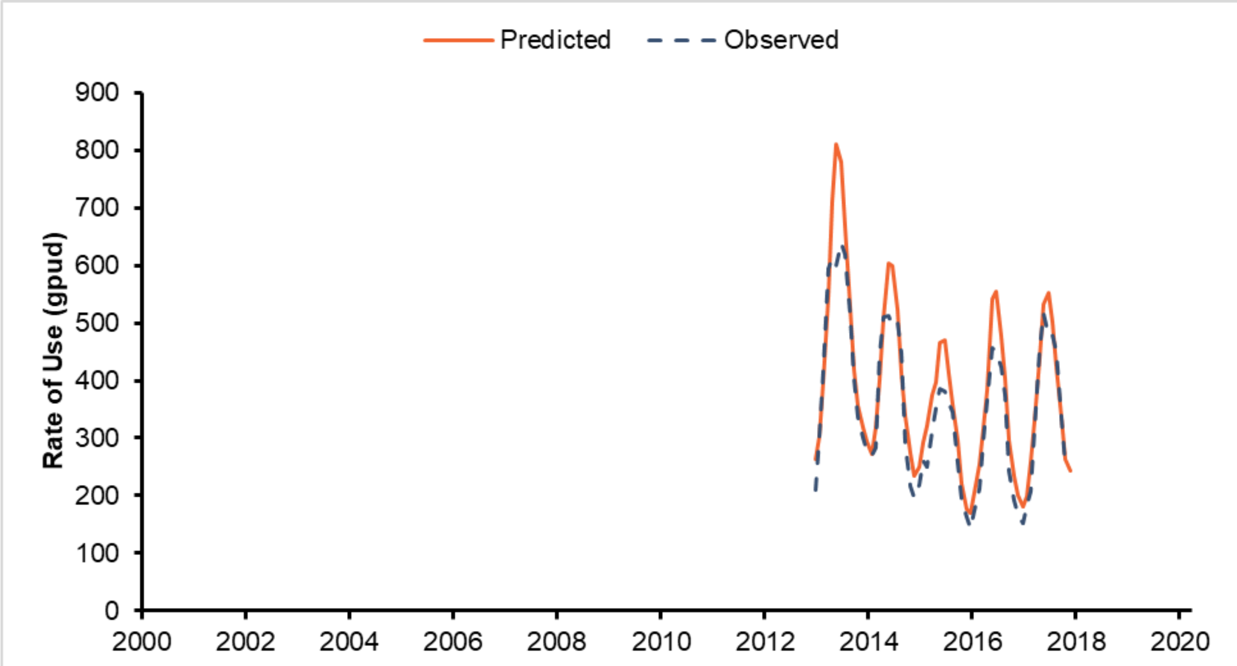

Figure E-4: City of Morgan Hill Single Family Observed and Predicted Per Unit Rate of Use

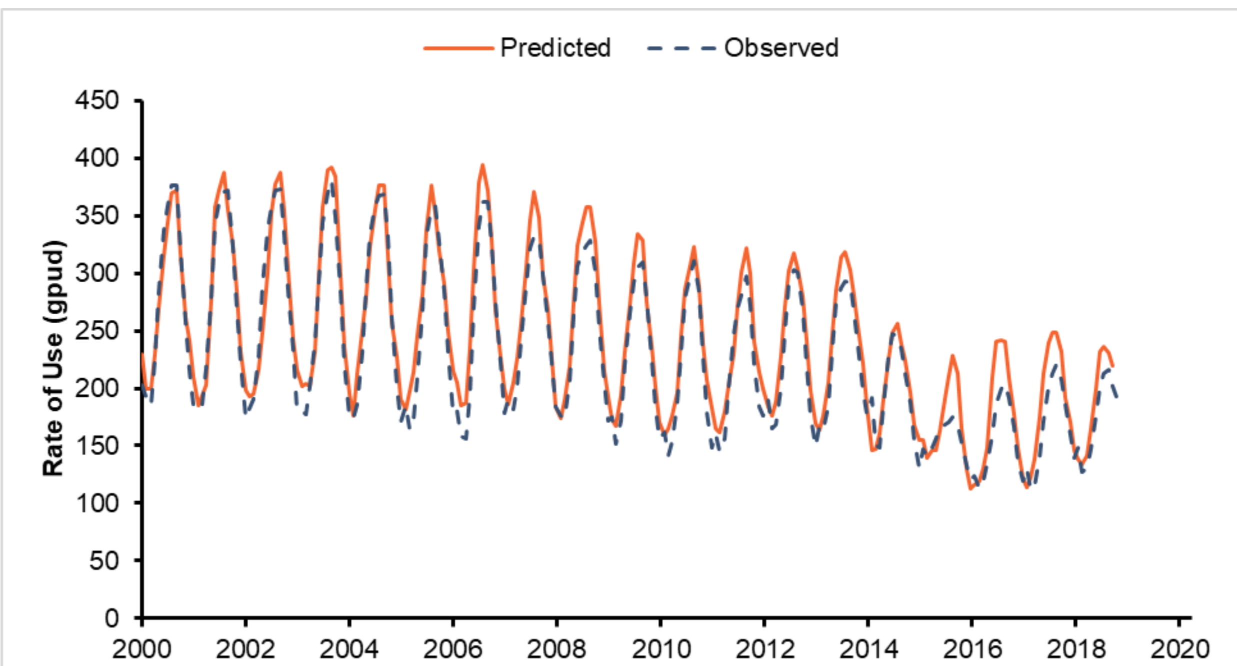

Figure E-5: City of Mountain View Single Family Observed and Predicted Per Unit Rate of Use

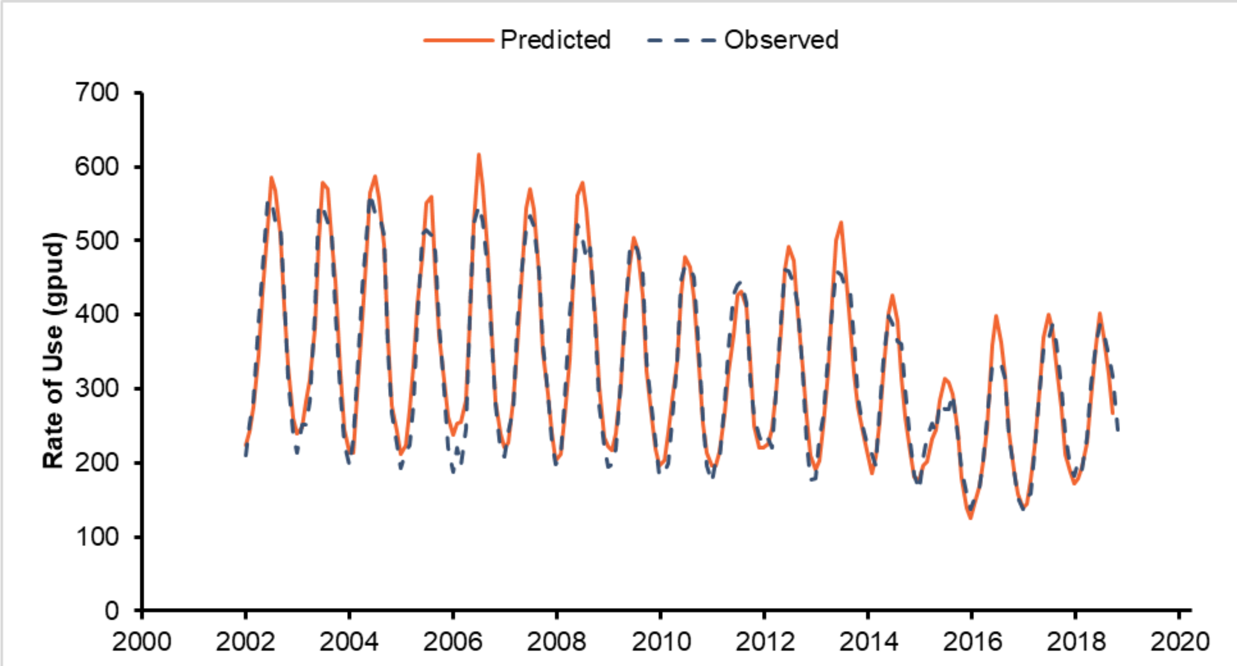

Figure E-6: City of Palo Alto Single Family Observed and Predicted Per Unit Rate of Use

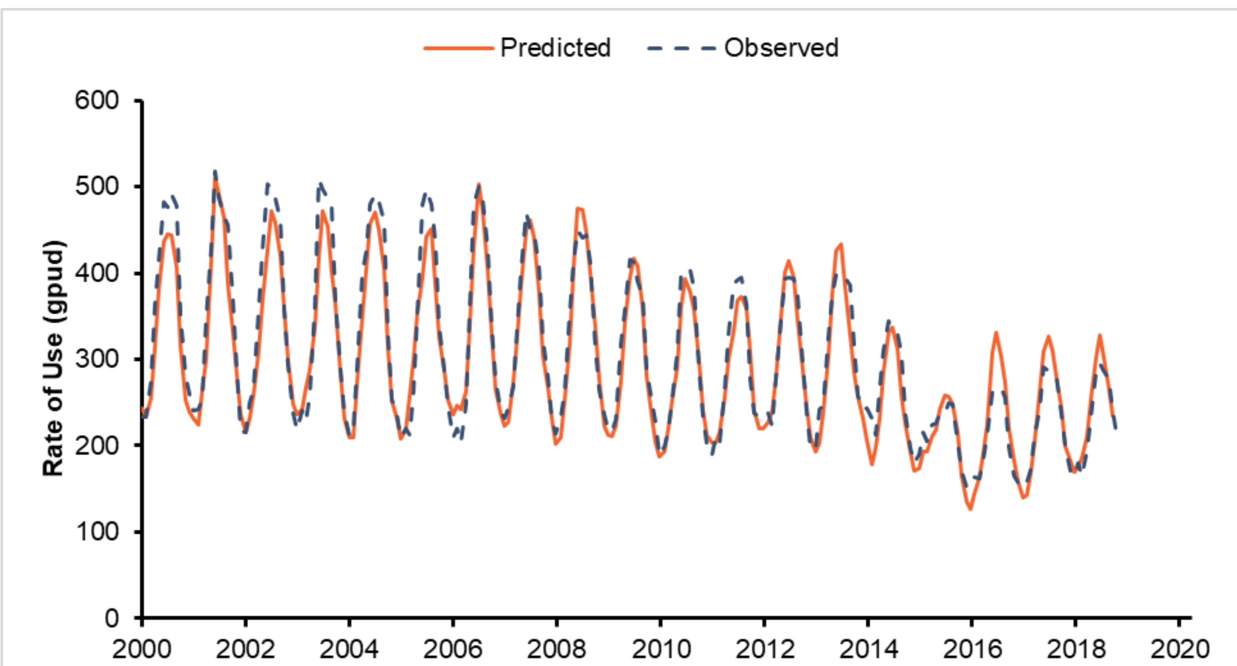

Figure E-7: City of Santa Clara Single Family Observed and Predicted Per Unit Rate of Use

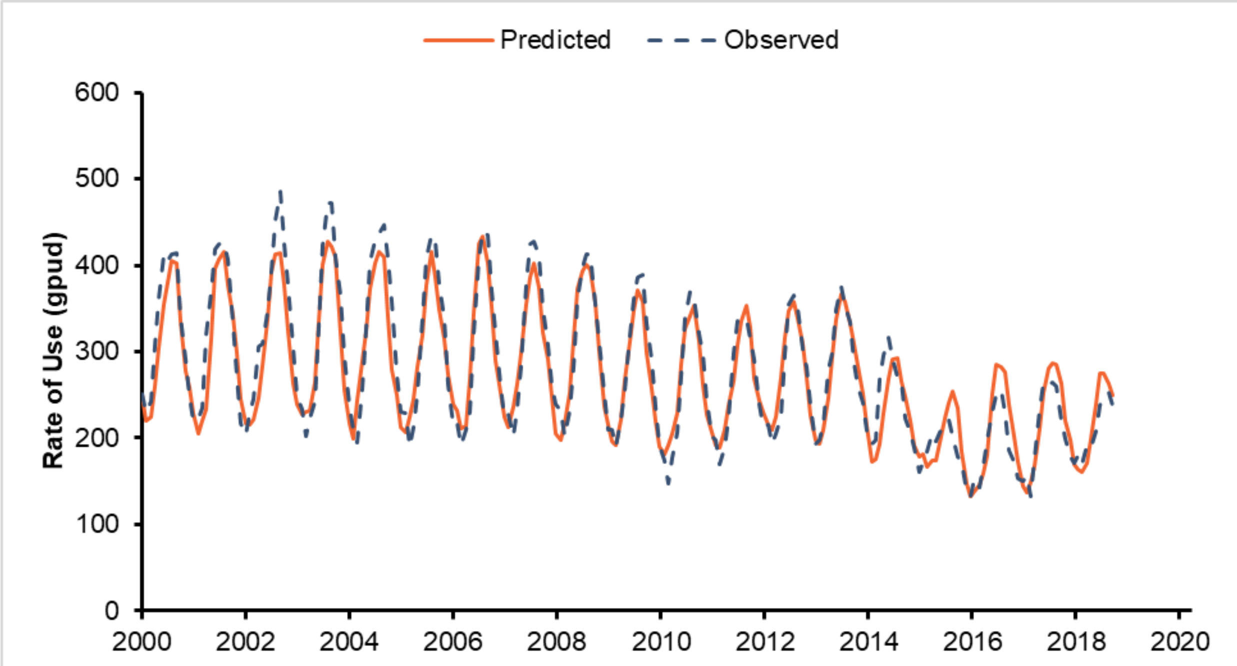

Figure E-8: City of Sunnyvale Single Family Observed and Predicted Per Unit Rate of Use

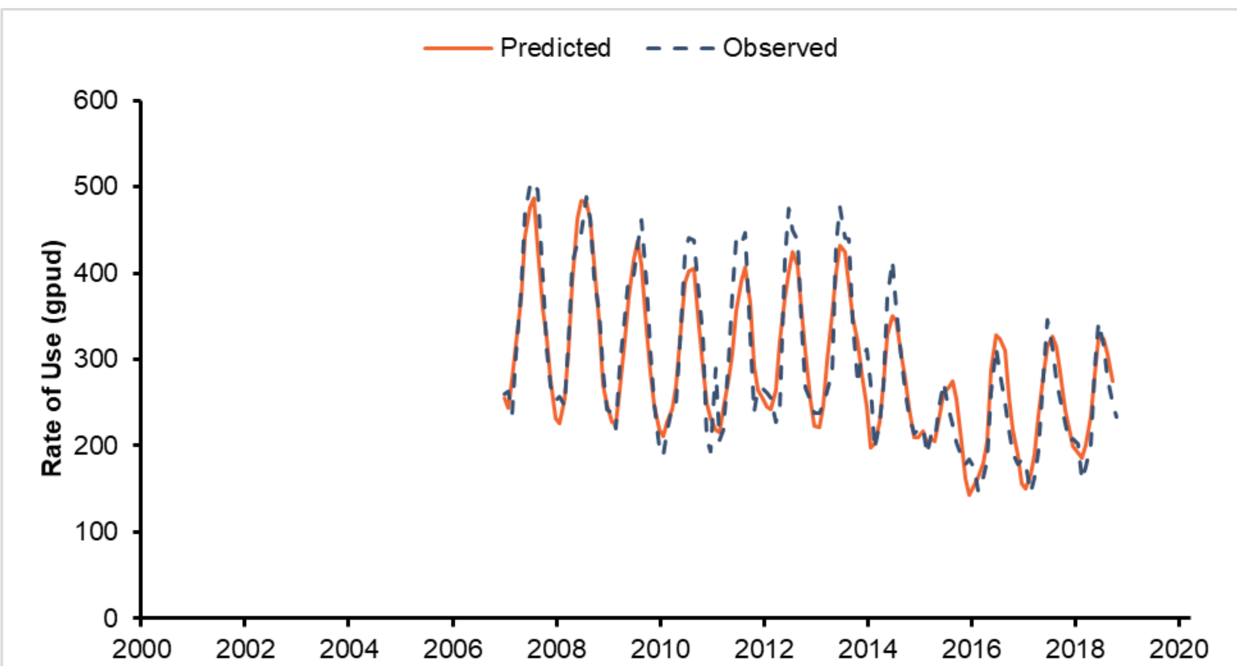

Figure E-9: Great Oaks Water Company Single Family Observed and Predicted Per Unit Rate of Use

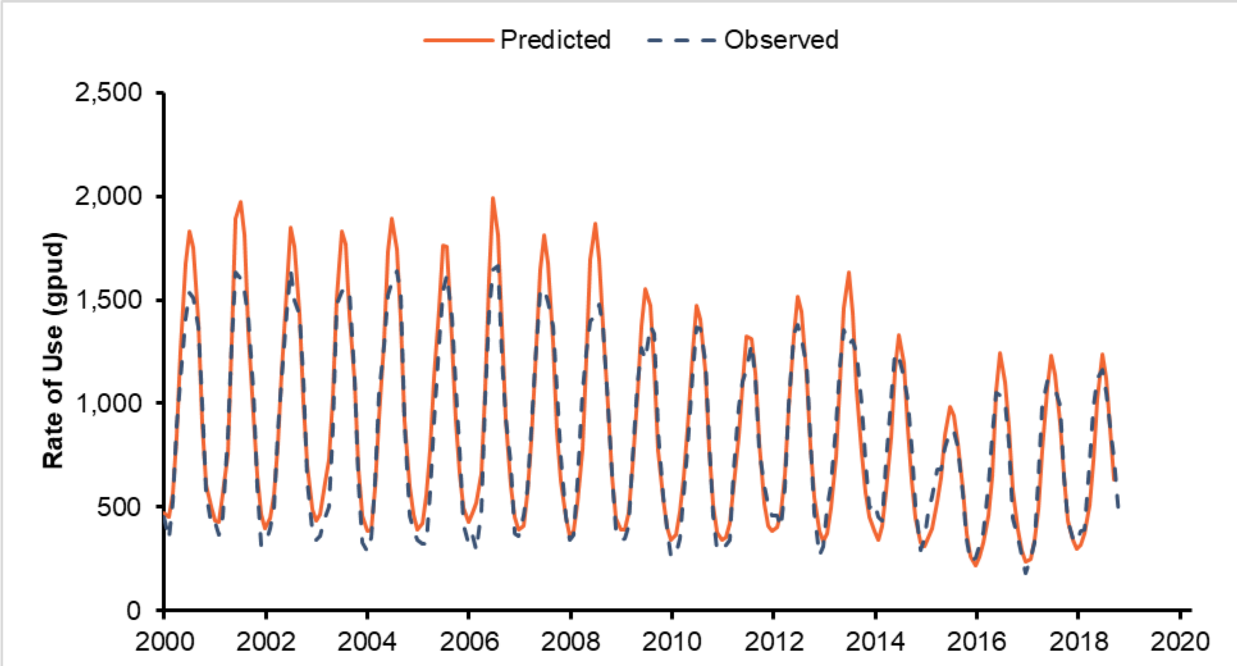

Figure E-10: Purissima Hills Water District Single Family Observed and Predicted Per Unit Rate of Use

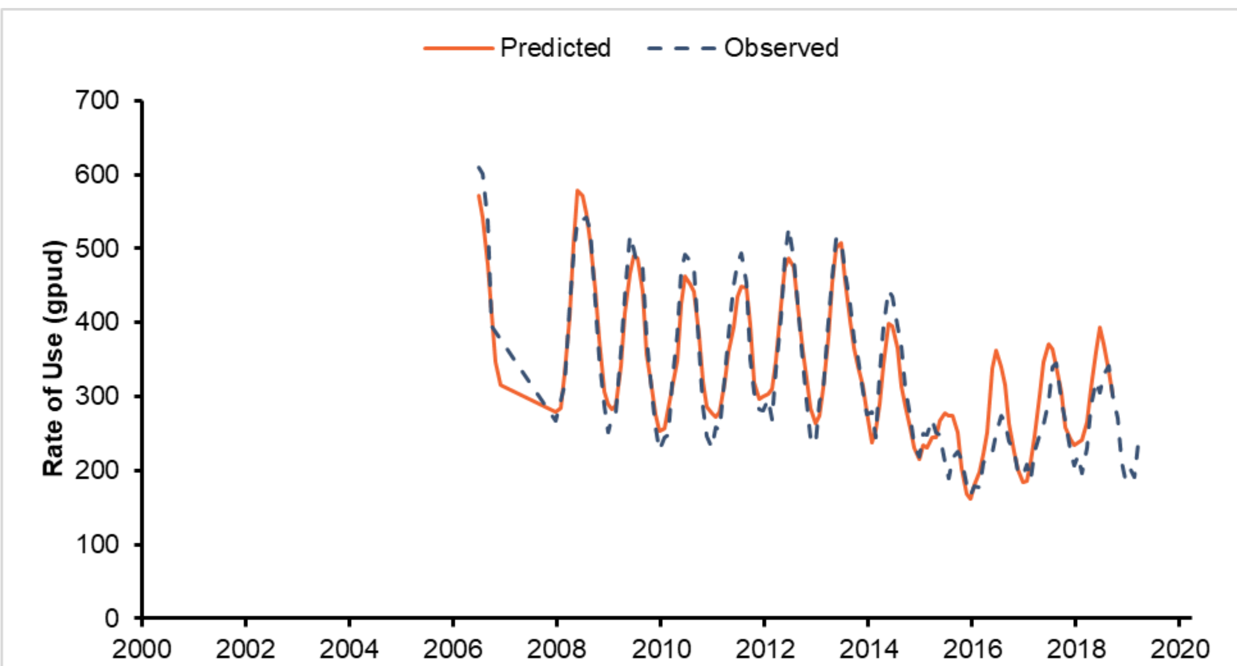

Figure E-11: San Jose Municipal Water Single Family Observed and Predicted Per Unit Rate of Use

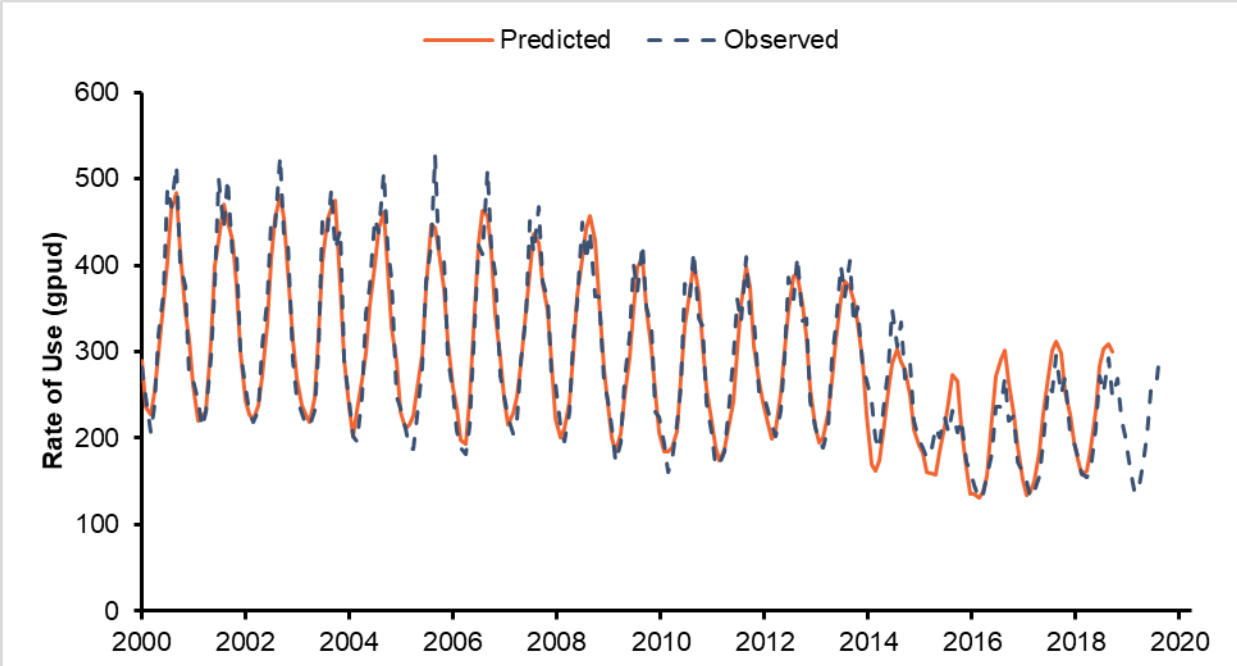

Figure E-12: San Jose Water Company Single Family Observed and Predicted Per Unit Rate of Use

Appendix F: Retail-Level Multifamily Model Performance

Table F-1: Summary of Multifamily Model Fit Statistics by Retailer

Retail Agency	R-squared	Average Observed Value (gpud)	Mean Absolute Percentage Error	Mean Bias
California Water Service	0.95	109.58	5.60%	-0.39%
City of Gilroy	0.73	433.88	7.96%	-0.54%
City of Milpitas	0.83	203.06	7.83%	-1.87%
City of Morgan Hill	0.87	250.30	6.36%	3.81%
City of Mountain View	0.96	170.18	4.98%	1.58%
City of Palo Alto	0.94	138.00	5.78%	-0.04%
City of Santa Clara	0.94	184.99	5.41%	-2.82%
City of Sunnyvale	0.90	178.45	6.67%	-0.65%
Great Oaks Water Company	0.83	161.38	7.14%	-0.09%
Purissima Hills Water District	--	--	--	--
San Jose Municipal Water	0.62	259.92	17.93%	-3.35%
San Jose Water Company	0.96	102.51	8.21%	-0.79%
Stanford University	--	--	--	--

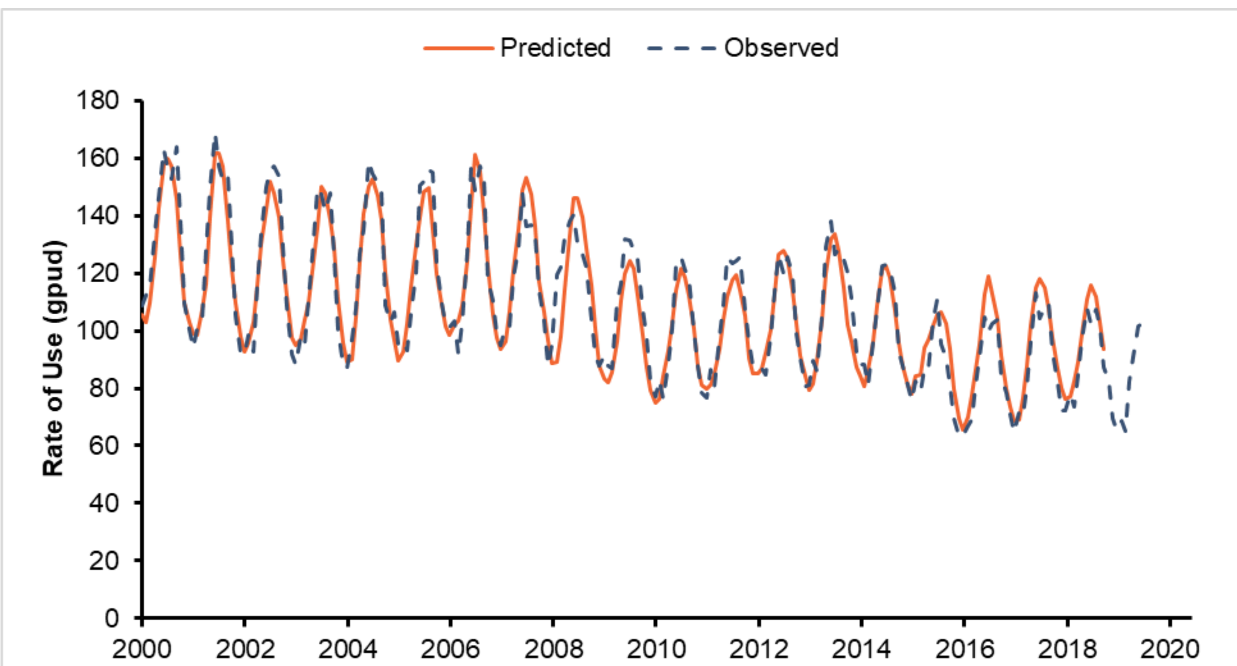

Figure F-1: California Water Service Multifamily Observed and Predicted Per Unit Rate of Use

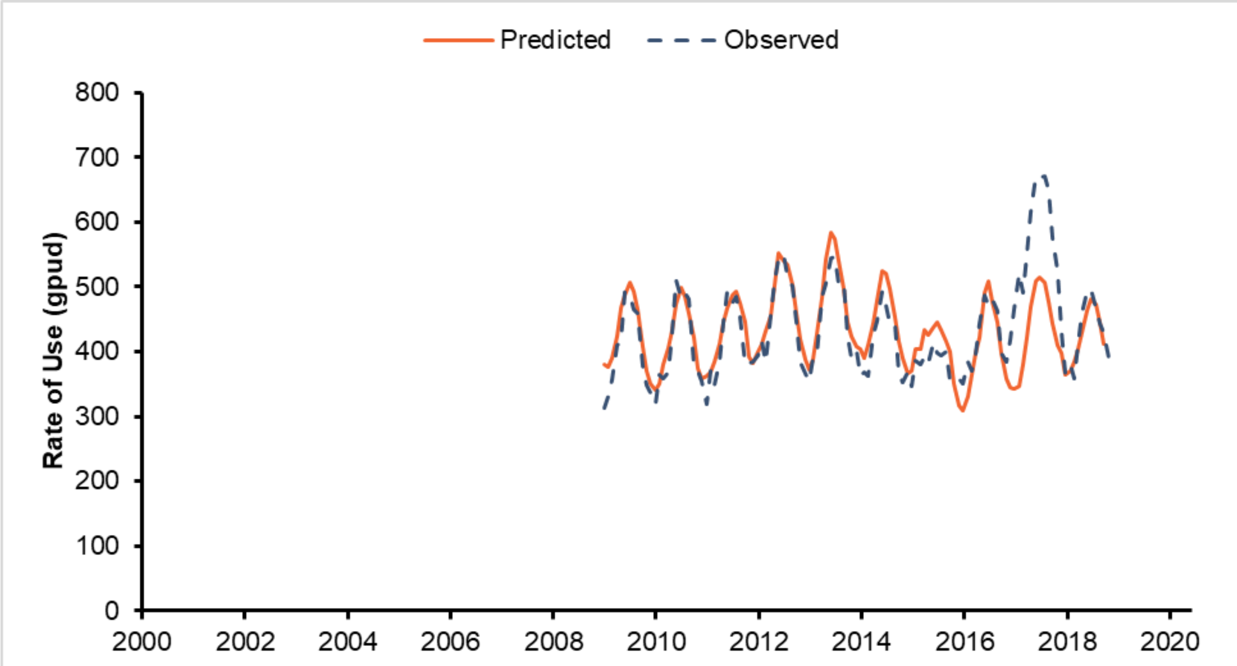

Figure F-2: City of Gilroy Multifamily Observed and Predicted Per Unit Rate of Use

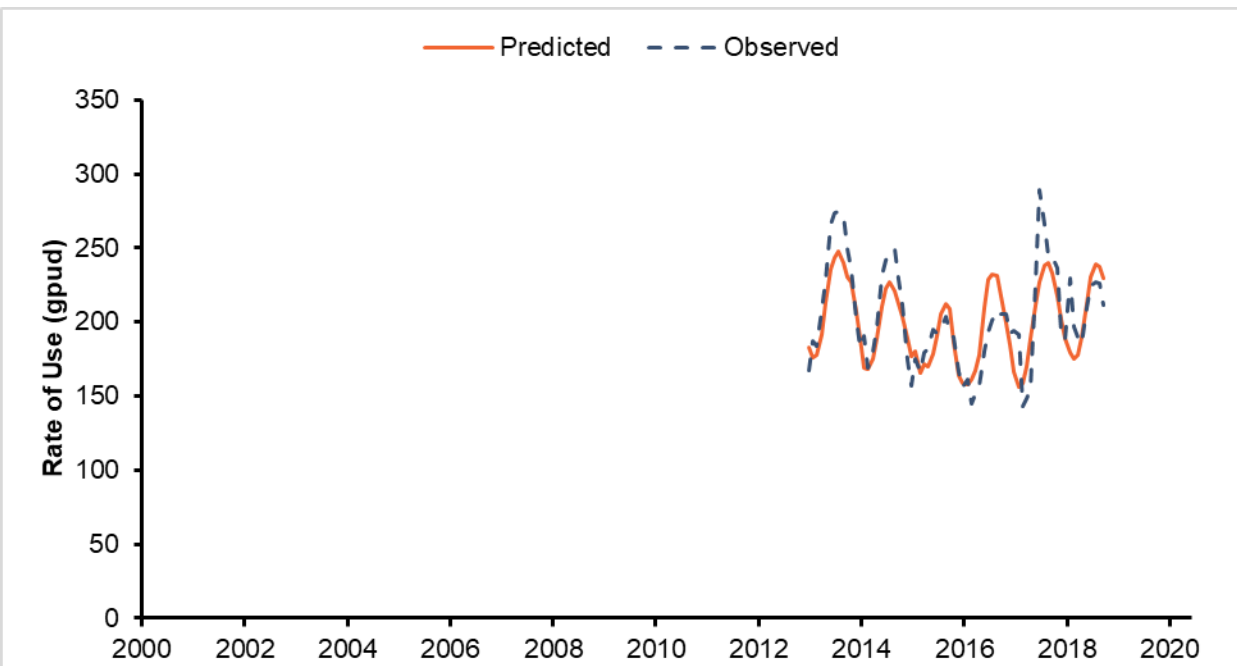

Figure F-3: City of Milpitas Multifamily Observed and Predicted Per Unit Rate of Use

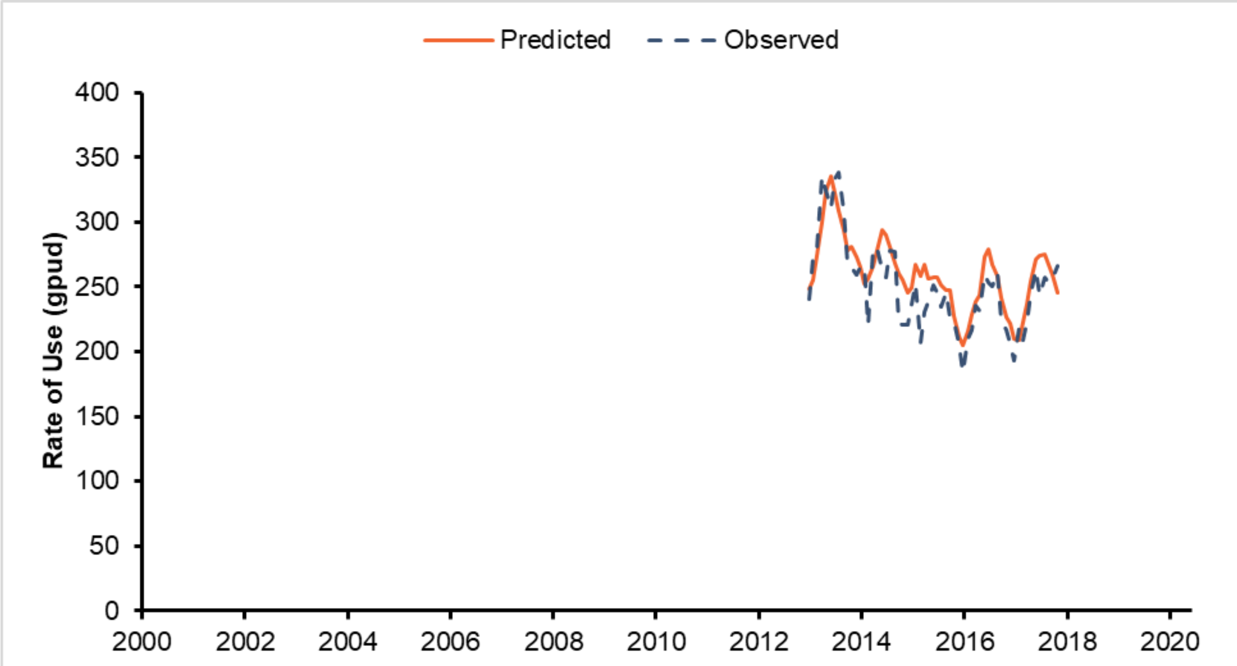

Figure F-4: City of Morgan Hill Multifamily Observed and Predicted Per Unit Rate of Use

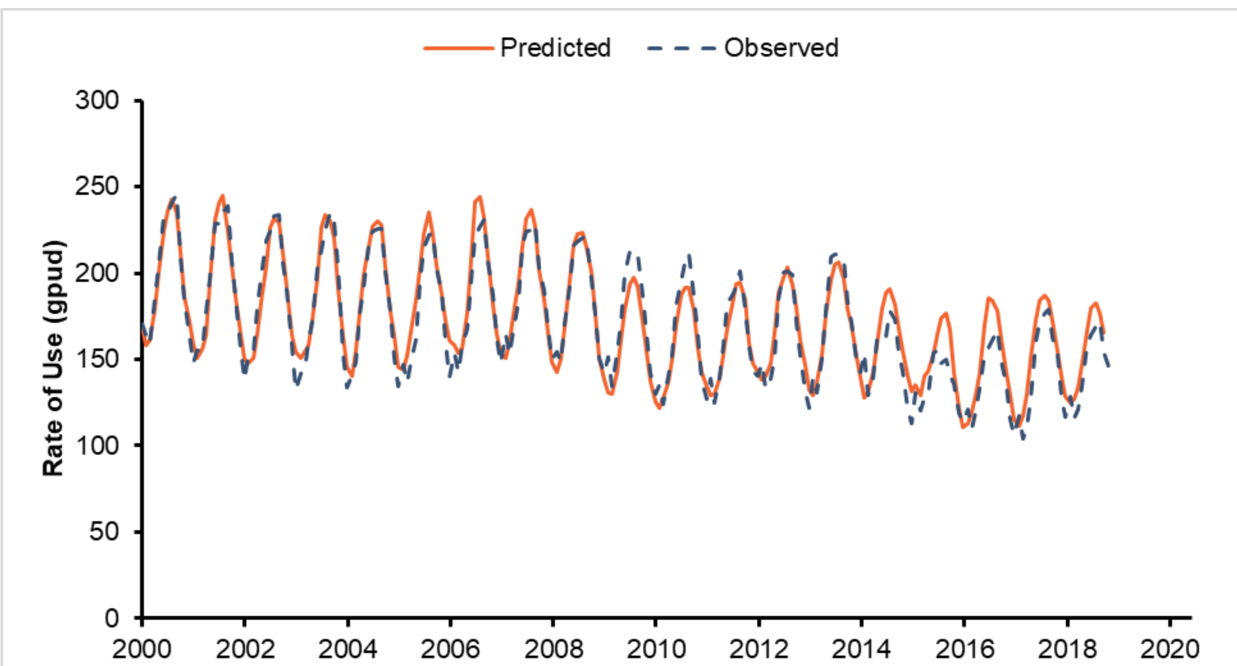

Figure F-5: City of Mountain View Multifamily Observed and Predicted Per Unit Rate of Use

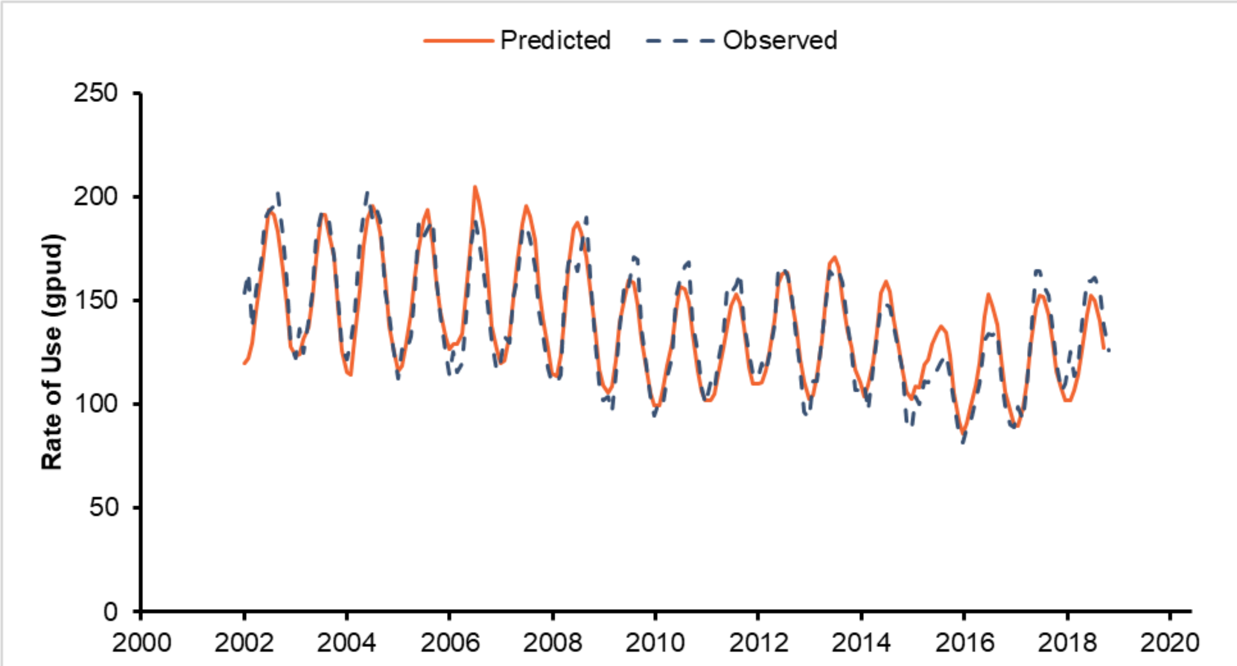

Figure F-6: City of Palo Alto Multifamily Observed and Predicted Per Unit Rate of Use

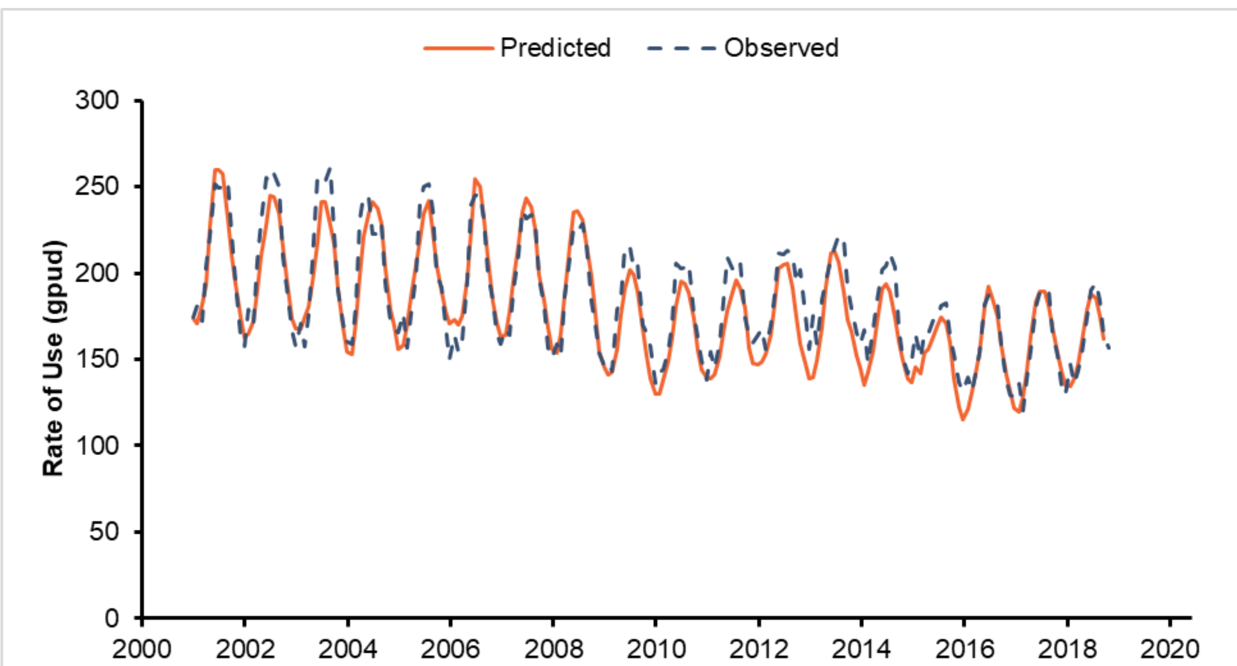

Figure F-7: City of Santa Clara Multifamily Observed and Predicted Per Unit Rate of Use

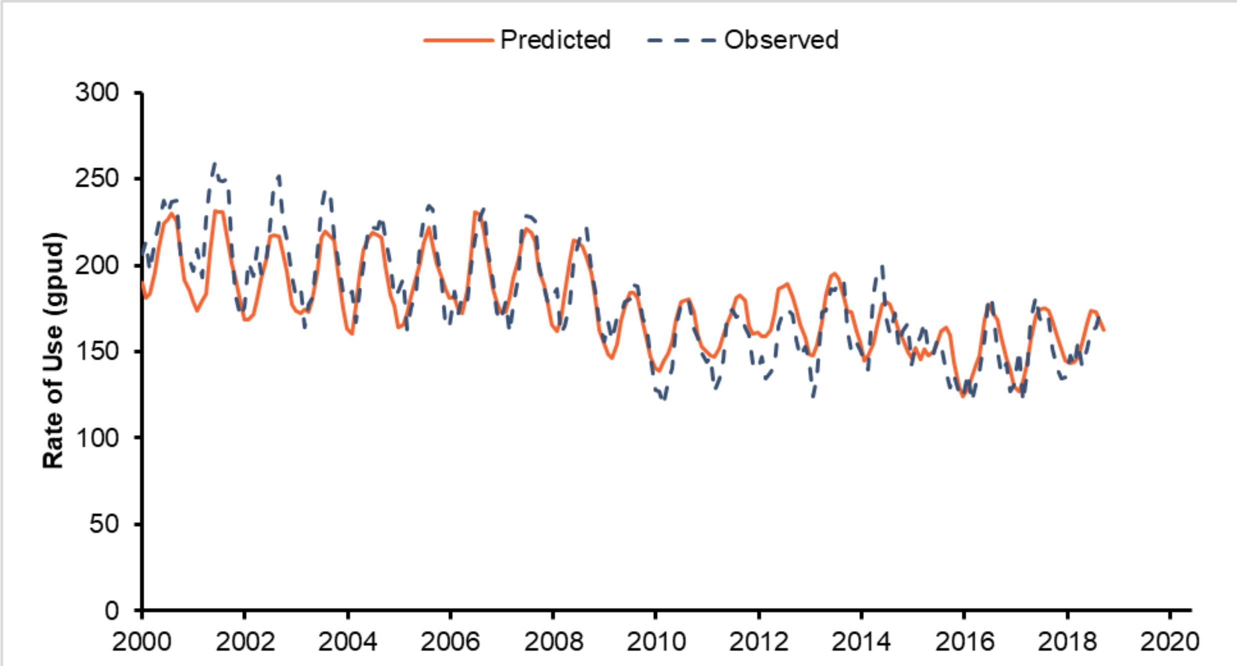

Figure F-8: City of Sunnyvale Multifamily Observed and Predicted Per Unit Rate of Use

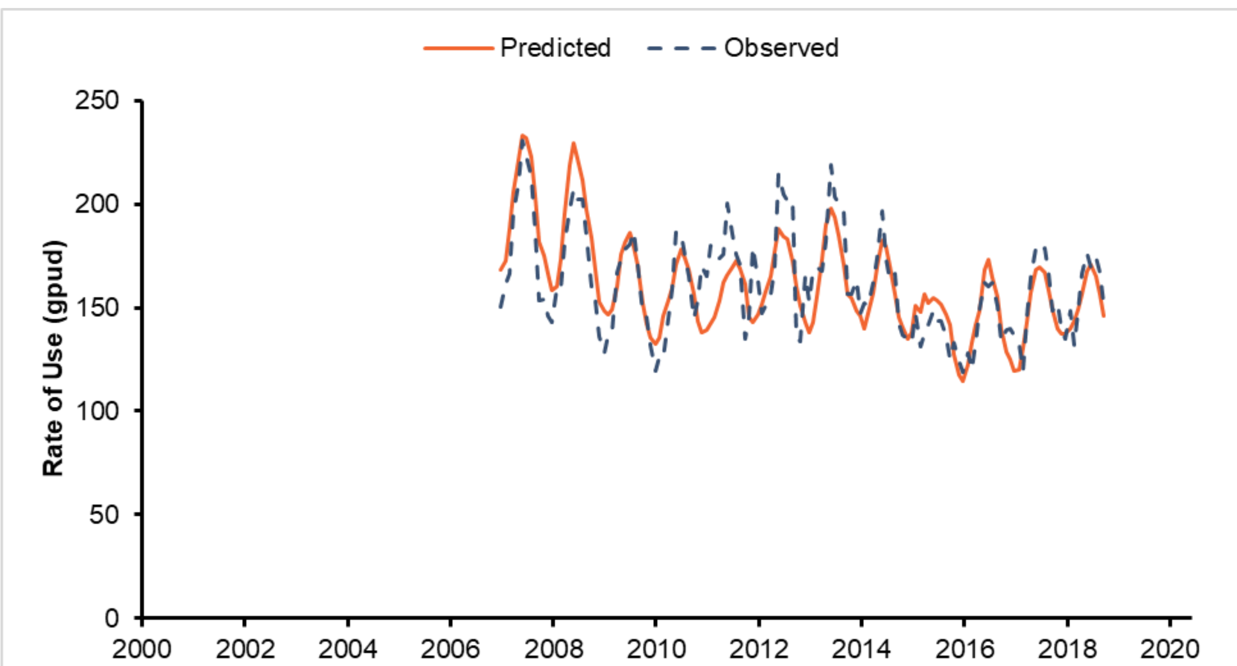

Figure F-9: Great Oaks Water Company Multifamily Observed and Predicted Per Unit Rate of Use

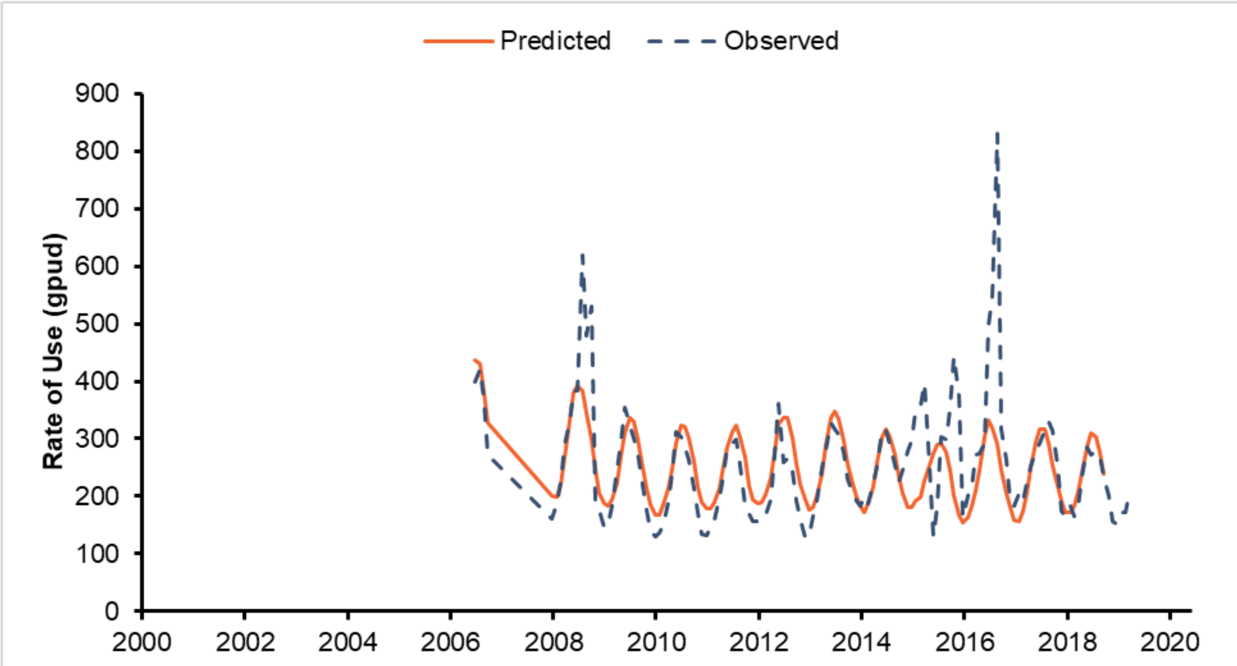

Figure F-10: San Jose Municipal Water Multifamily Observed and Predicted Per Unit Rate of Use

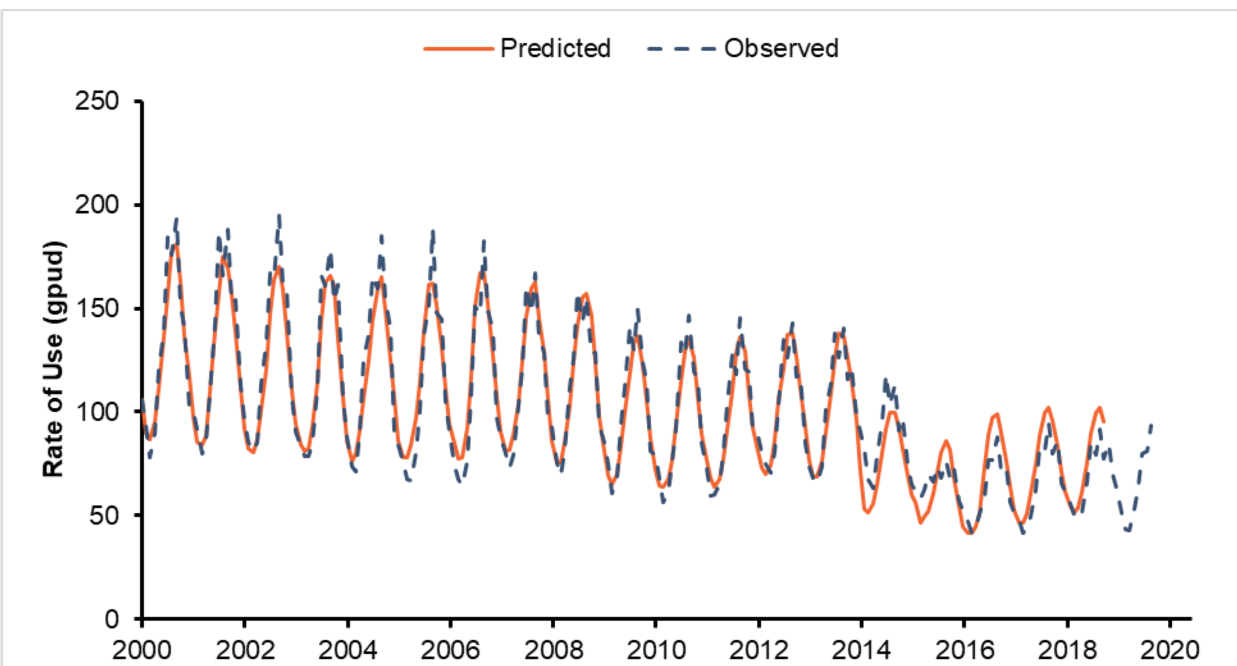

Figure F-11: San Jose Water Company Multifamily Observed and Predicted Per Unit Rate of Use

Appendix G: Retail-Level CII Model Performance

Table G-1: Summary of CII Model Fit Statistics by Retailer

Retail Agency	R-squared	Average Observed Value (gpud)	Mean Absolute Percentage Error	Mean Bias
California Water Service	0.97	68.07	6.97%	-1.08%
City of Gilroy	0.87	109.39	10.34%	-0.02%
City of Milpitas	0.85	96.81	11.38%	-0.70%
City of Morgan Hill	0.96	124.09	8.70%	0.32%
City of Mountain View	0.97	70.96	8.70%	-0.92%
City of Palo Alto	0.92	44.98	12.36%	1.65%
City of Santa Clara	0.95	112.88	6.50%	0.06%
City of Sunnyvale	0.95	106.69	8.12%	-0.68%
Great Oaks Water Company	0.96	108.41	8.96%	-0.23%
Purissima Hills Water District	0.94	49.72	16.45%	-4.01%
San Jose Municipal Water	0.90	72.93	9.52%	-1.67%
San Jose Water Company	0.97	129.97	5.40%	-0.05%
Stanford University	0.94	95.53	10.93%	0.51%

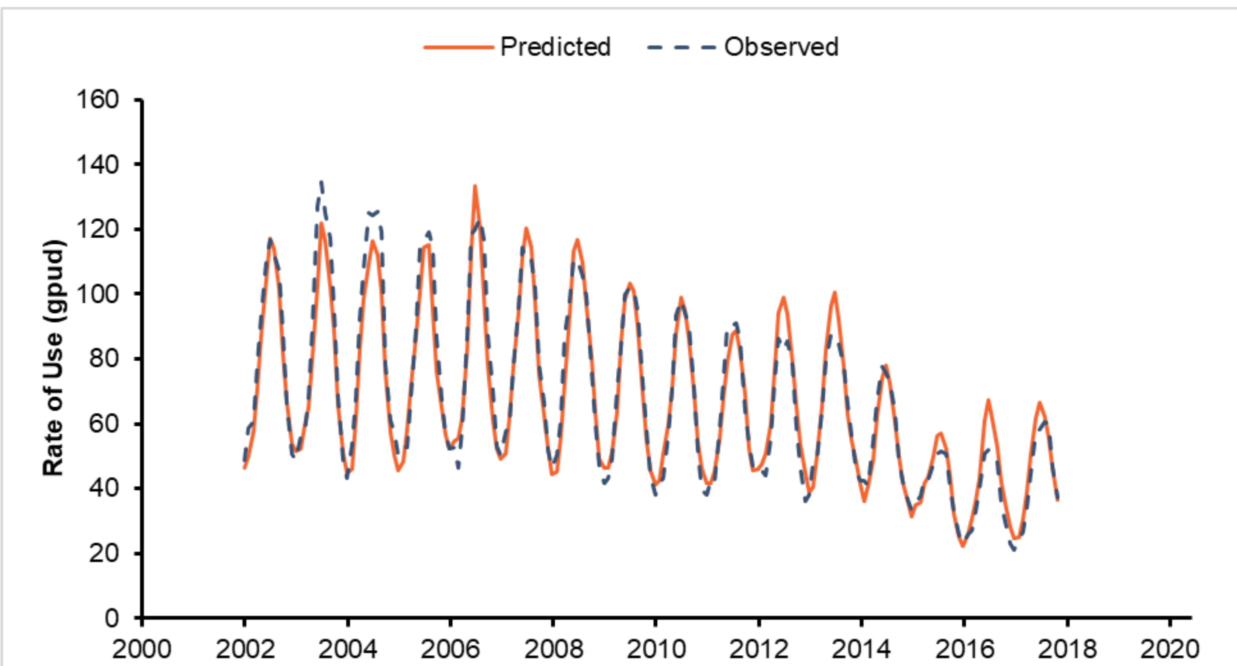

Figure G-1: California Water Service CII Observed and Predicted Per Unit Rate of Use

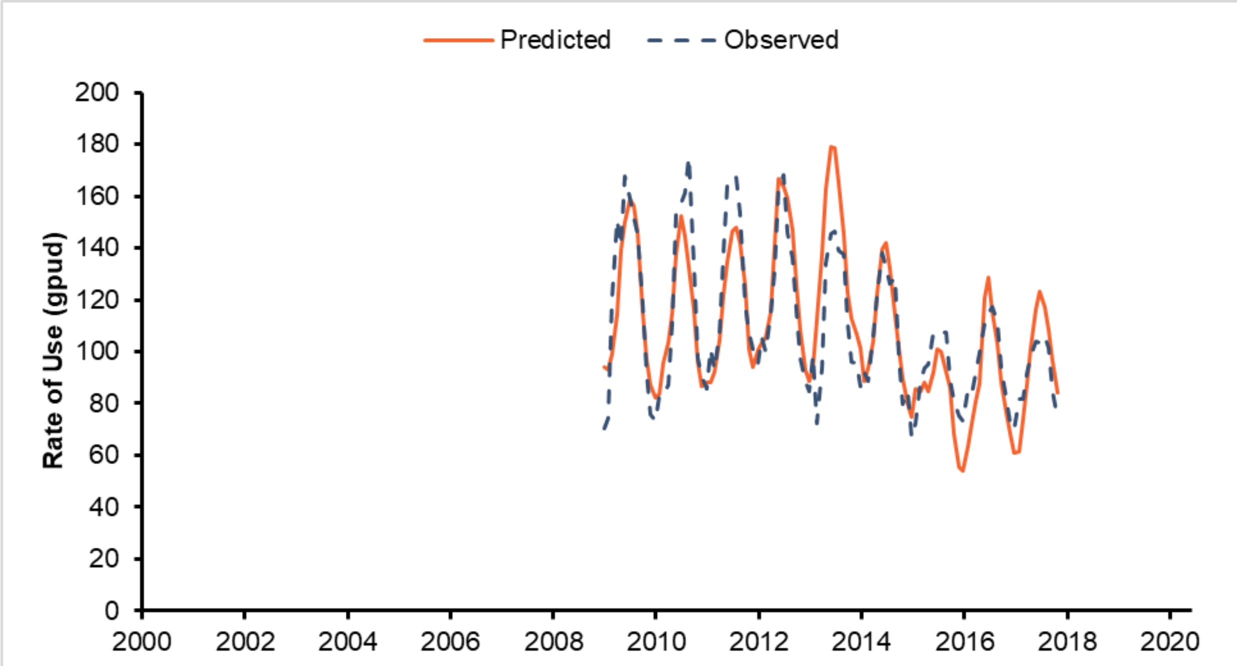

Figure G-2: City of Gilroy CII Observed and Predicted Per Unit Rate of Use

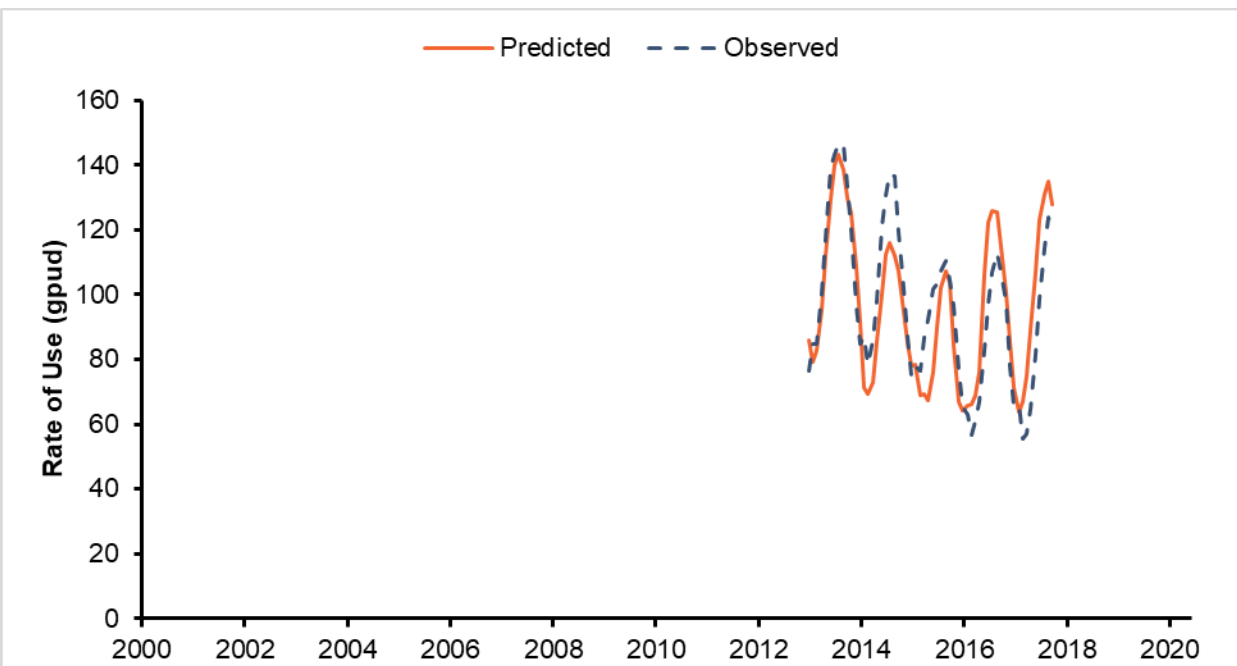

Figure G-3: City of Milpitas CII Observed and Predicted Per Unit Rate of Use

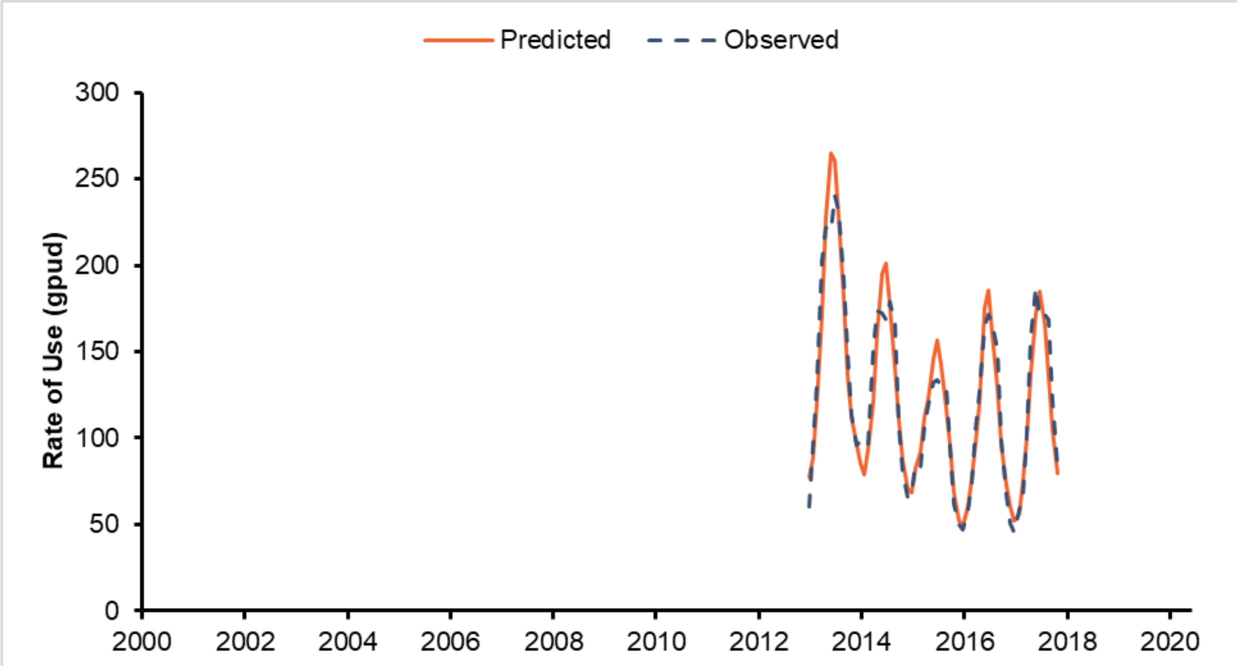

Figure G-4: City of Morgan Hill CII Observed and Predicted Per Unit Rate of Use

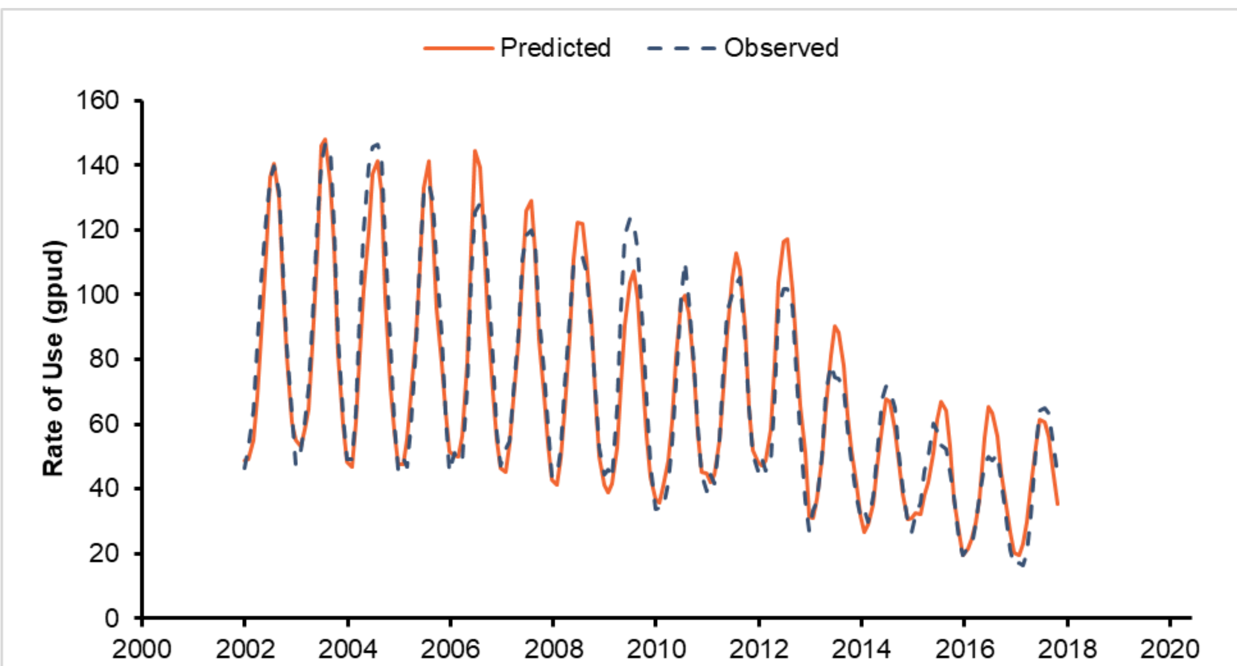

Figure G-5: City of Mountain View CII Observed and Predicted Per Unit Rate of Use

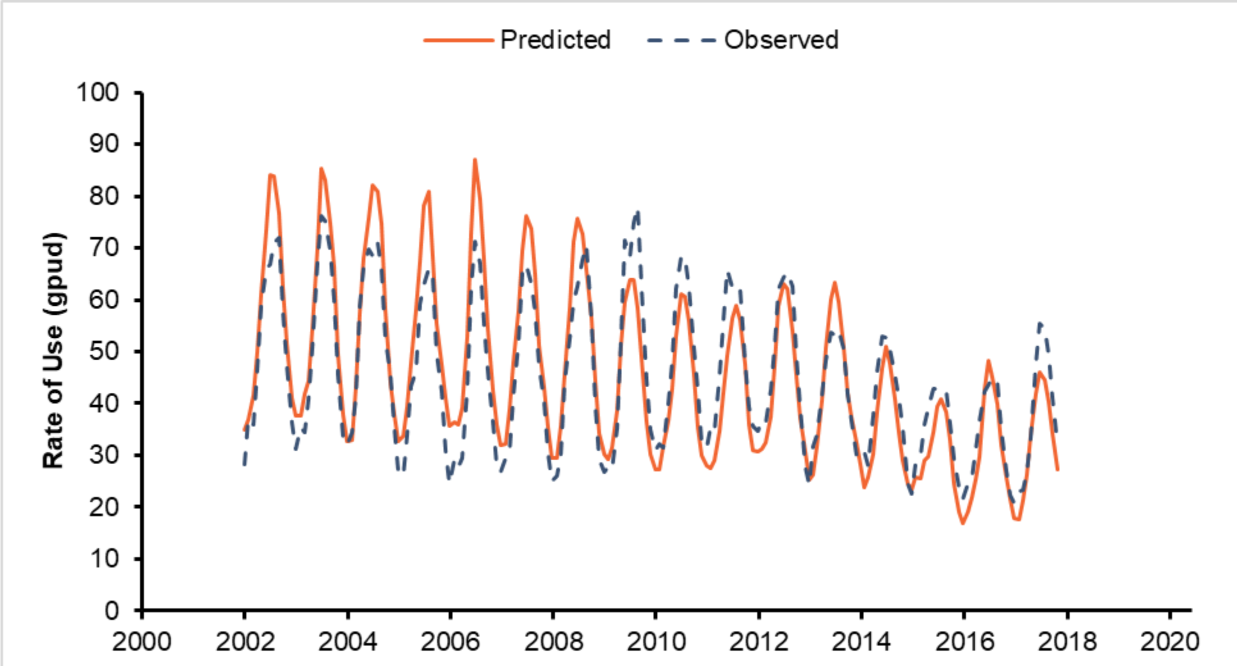

Figure G-6: City of Palo Alto CII Observed and Predicted Per Unit Rate of Use

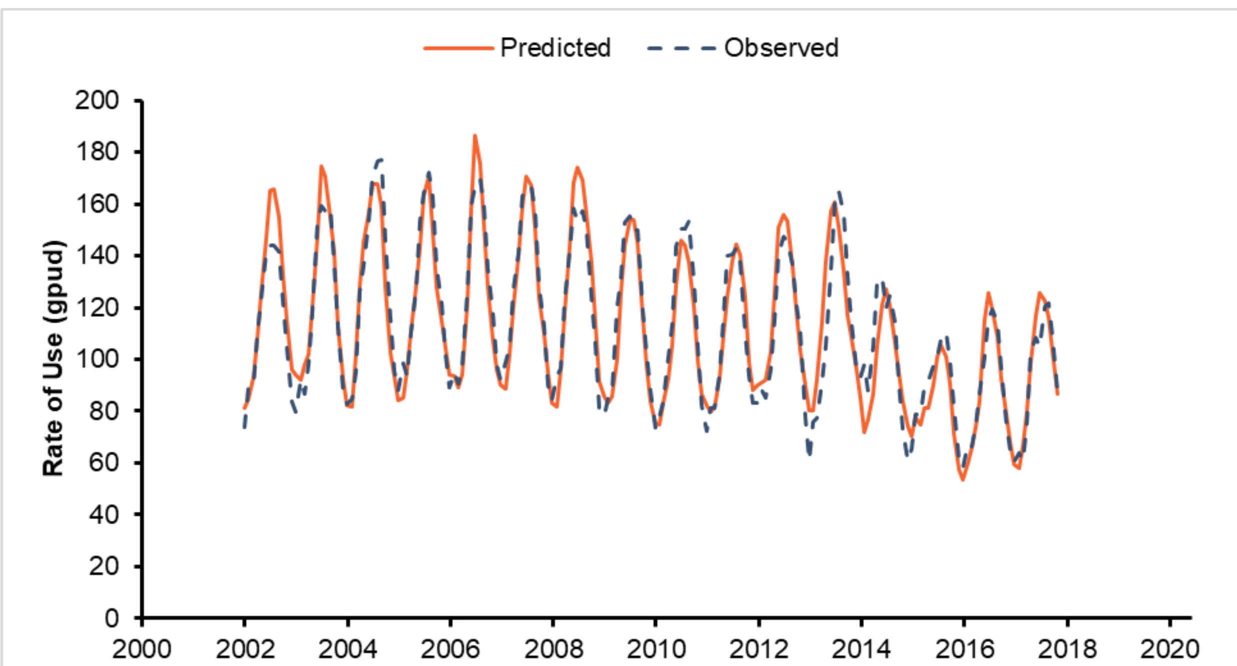

Figure G-7: City of Santa Clara CII Observed and Predicted Per Unit Rate of Use

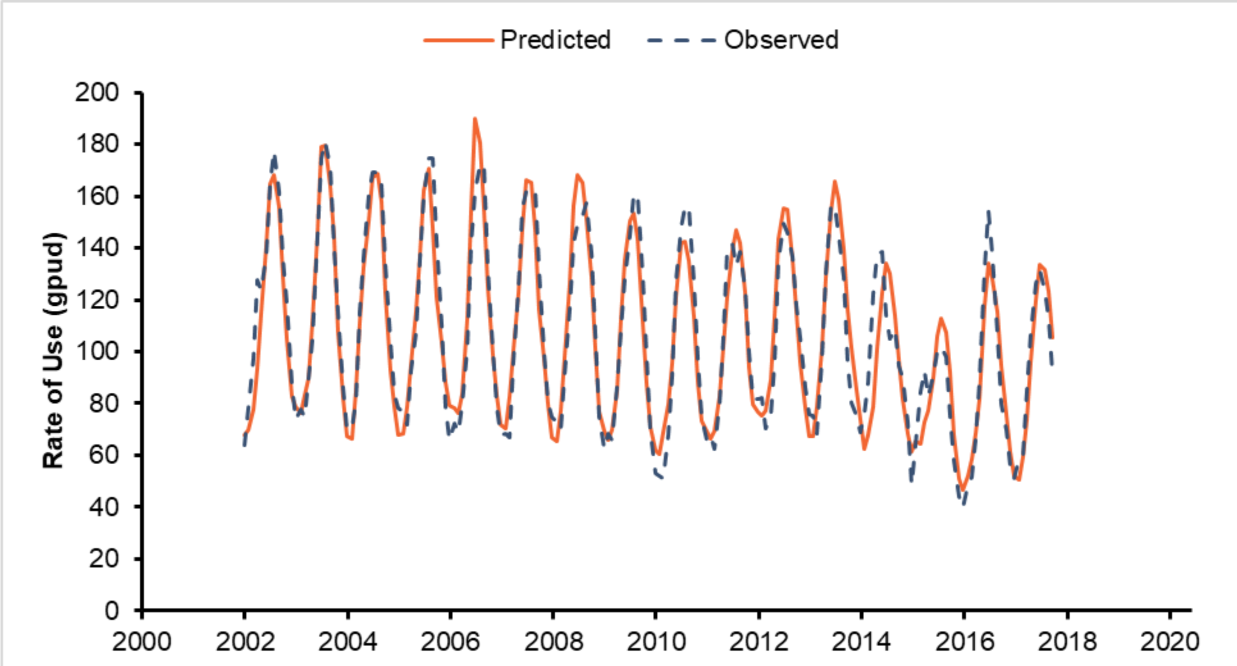

Figure G-8: City of Sunnyvale CII Observed and Predicted Per Unit Rate of Use

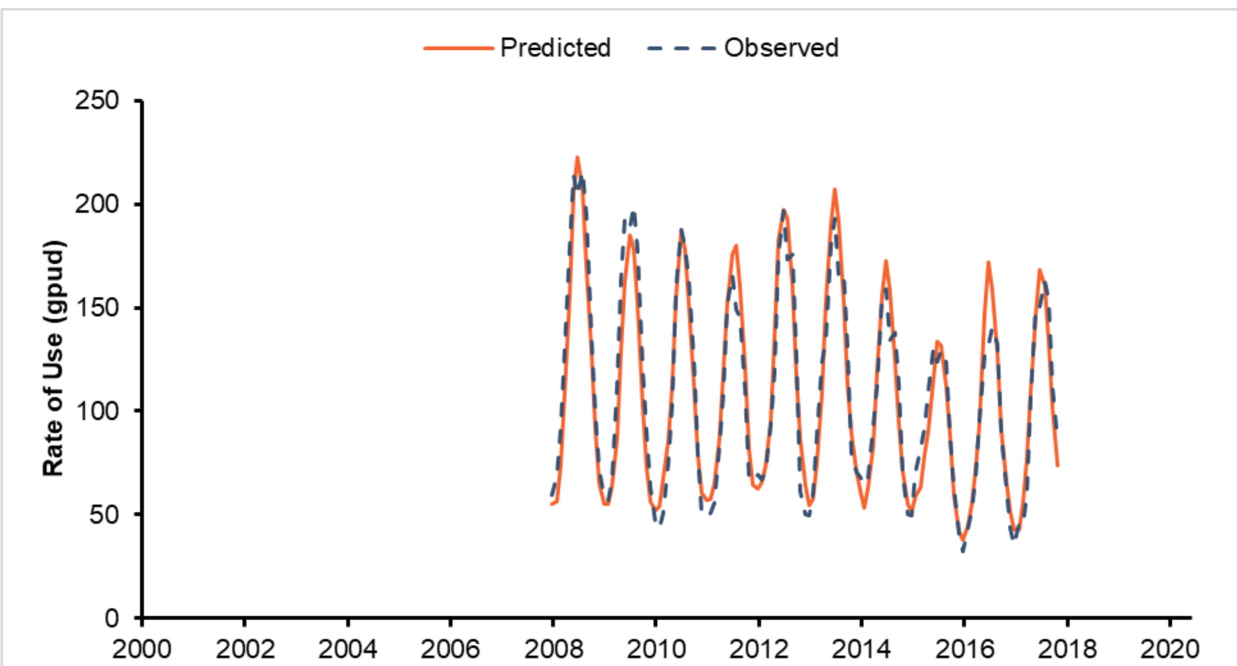

Figure G-9: Great Oaks Water Company CII Observed and Predicted Per Unit Rate of Use

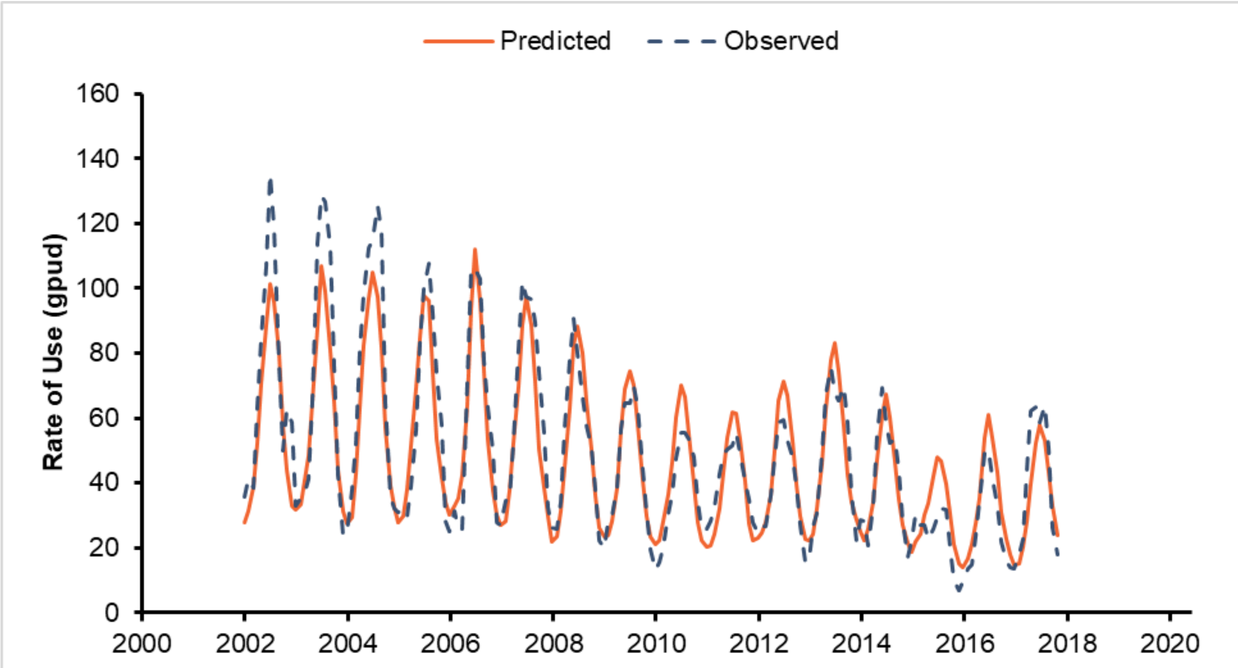

Figure G-10: Purissima Hills Water District CII Observed and Predicted Per Unit Rate of Use

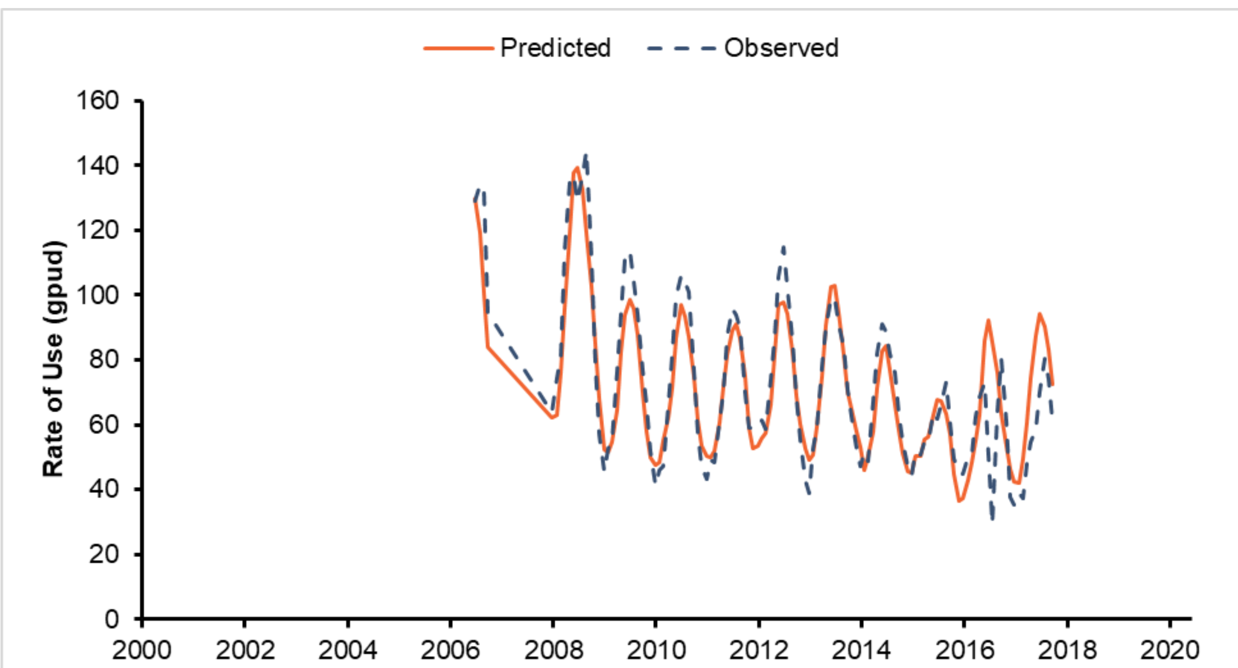

Figure G-11: San Jose Municipal Water CII Observed and Predicted Per Unit Rate of Use

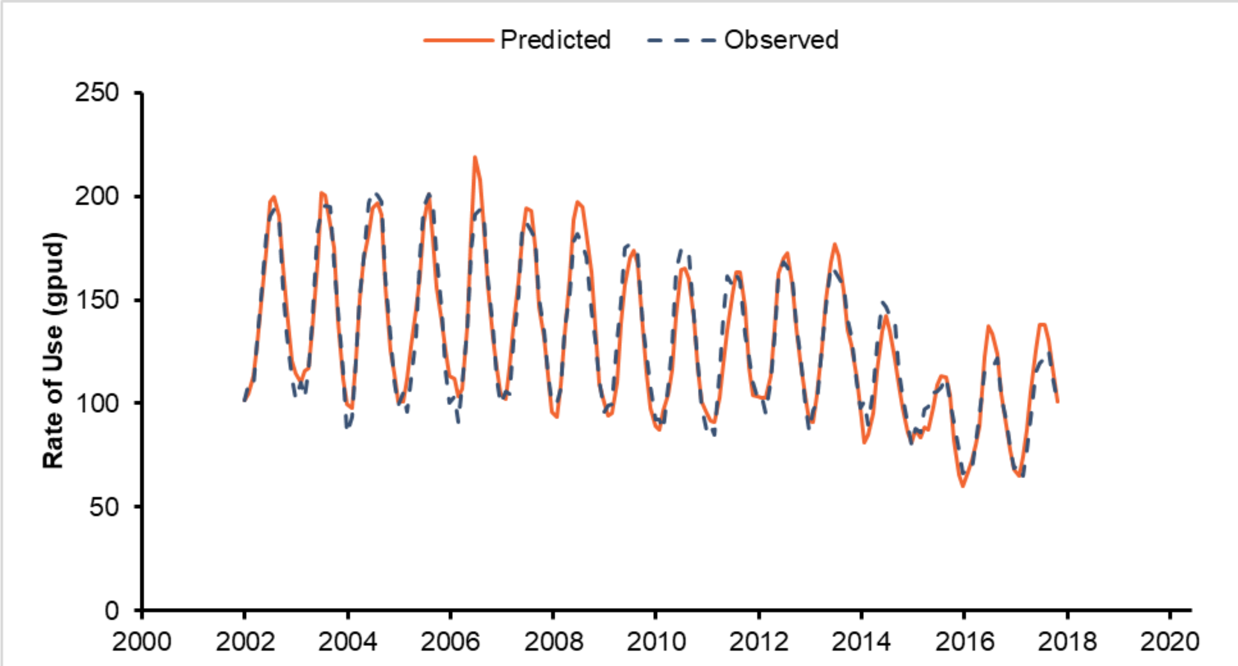

Figure G-12: San Jose Water Company CII Observed and Predicted Per Unit Rate of Use

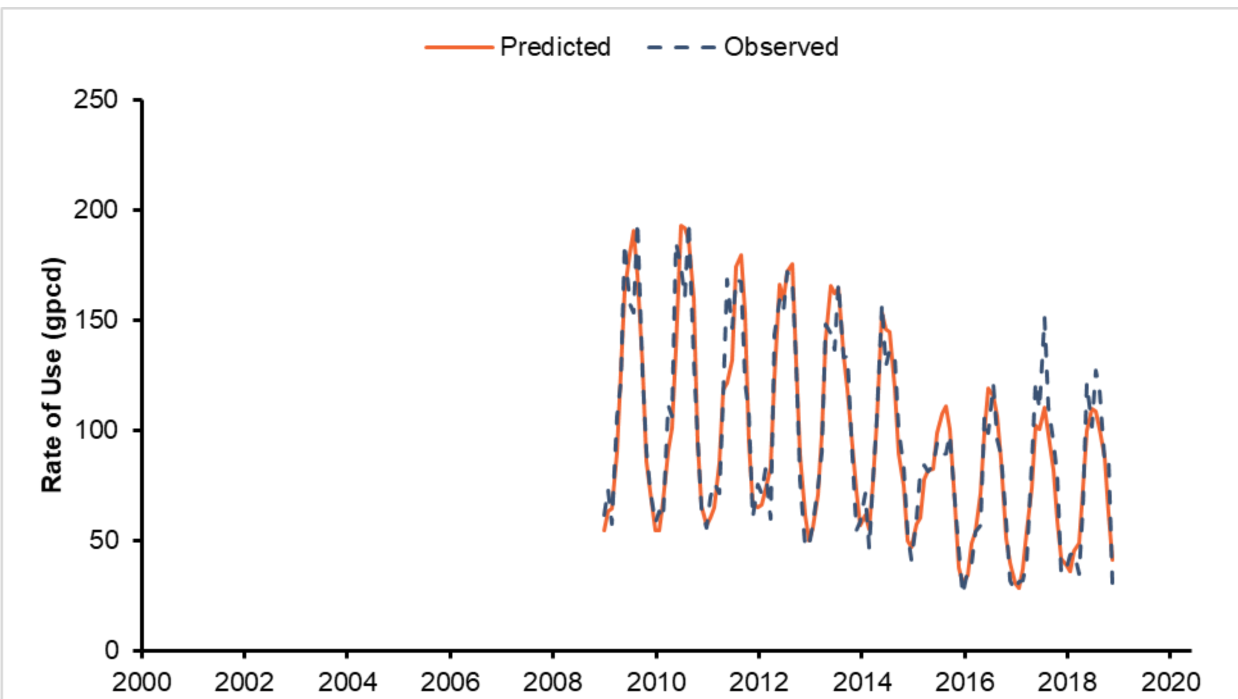

Figure G-13: Stanford University CII Observed and Predicted Per Unit Rate of Use

Appendix H: Stanford Model Predictors and Fitted Coefficients

Final regression predictors for the Stanford regression equation along with their statistics are in Table H-1 below. Coefficient values align with expectations for each variable. Variables with an increasing effect on water use (i.e., a positive coefficient) included temperature only. Variables with a decreasing effect on water use (i.e., a negative coefficient) included the seasonal pattern terms, precipitation, price, and the extended drought effect. Economic indices, density, and median income were not found to be statistically significant in the Stanford CII model.

Table H-1: Stanford CII Model Predictors and Coefficients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Intercept	9.15	0.67	13.71	<0.05
Seasonal index 1	-0.47	0.02	-21.54	<0.05
Seasonal index 2	-0.40	0.02	-18.85	<0.05
Seasonal index 3	-0.05	0.02	-2.59	<0.05
Seasonal index 4	-0.04	0.02	-1.76	0.08
Departure from normal temperature, 1-month lag	1.71	0.50	3.40	<0.05
Departure from normal precipitation	-0.02	0.01	-2.77	<0.05
Departure from normal precipitation, 1-month lag	-0.04	0.01	-4.21	<0.05
Departure from normal precipitation, 2-month lag	-0.01	0.01	-1.32	0.19
Price	-0.70	0.10	-6.75	<0.05
Drought severity, extended	-0.86	0.21	-4.06	<0.05

Appendix I: Projected Residential Housing Density by Retailer

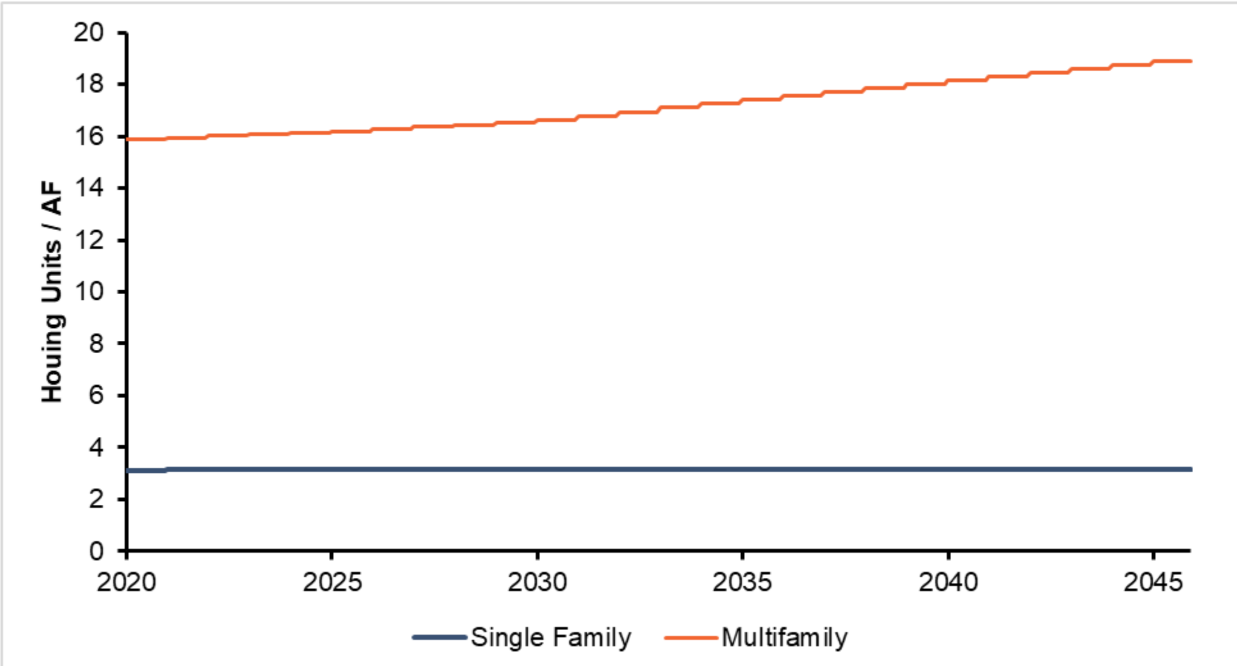

Table I-1: California Water Service Residential Housing Density

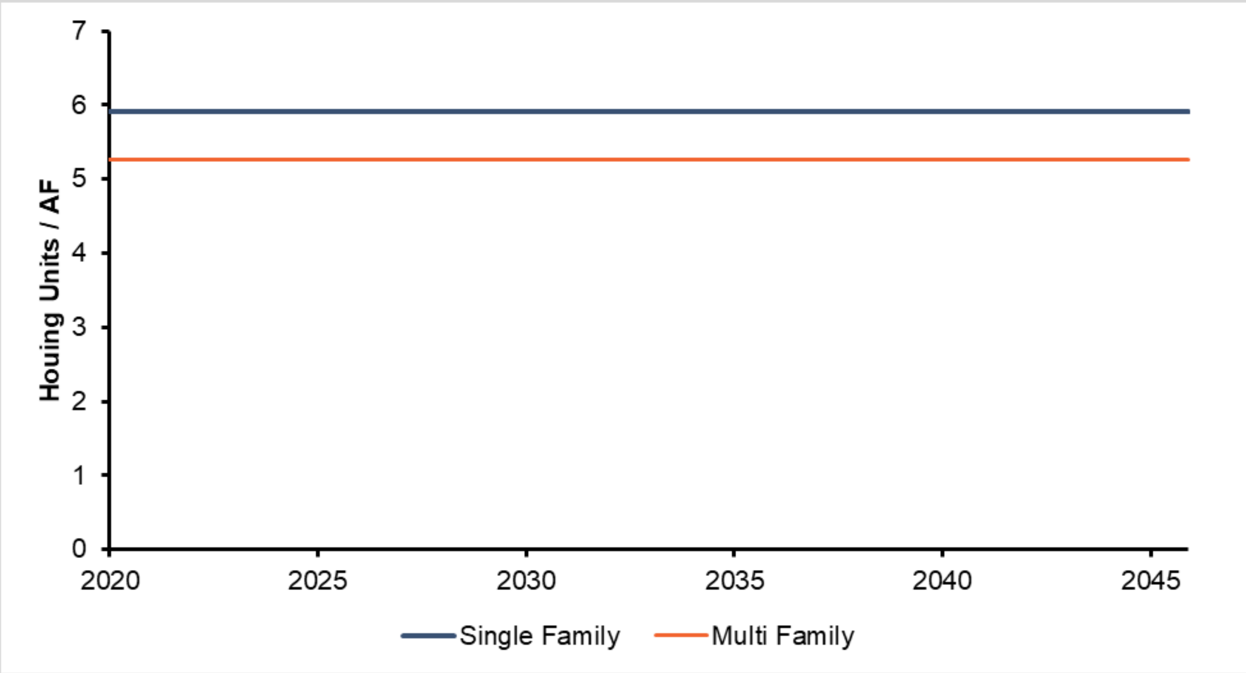

Figure I-2: City of Gilroy Residential Housing Density

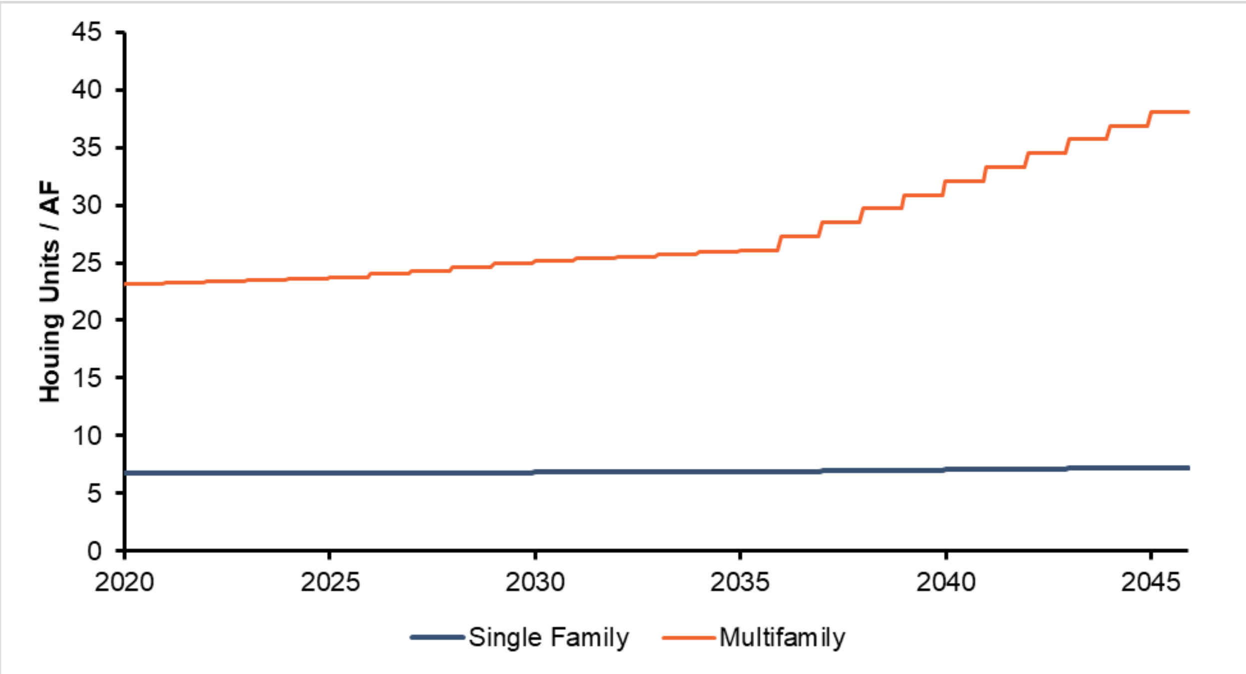

Figure I-3: City of Milpitas Residential Housing Density

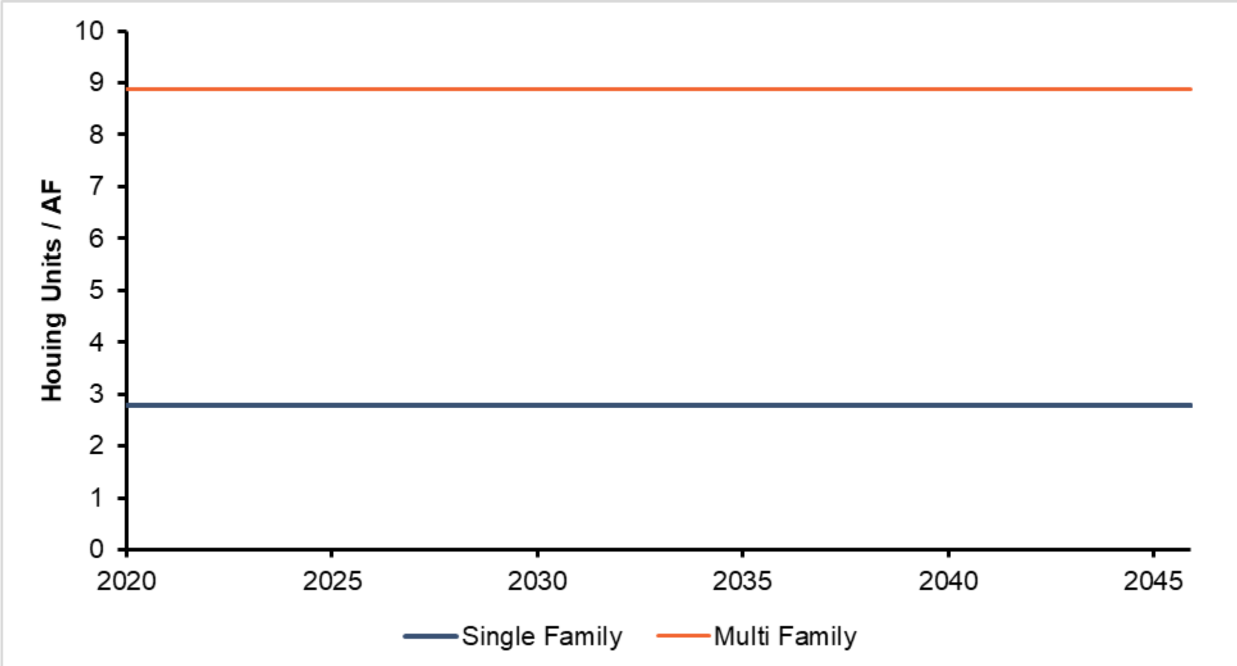

Figure I-4: City of Morgan Hill Residential Housing Density

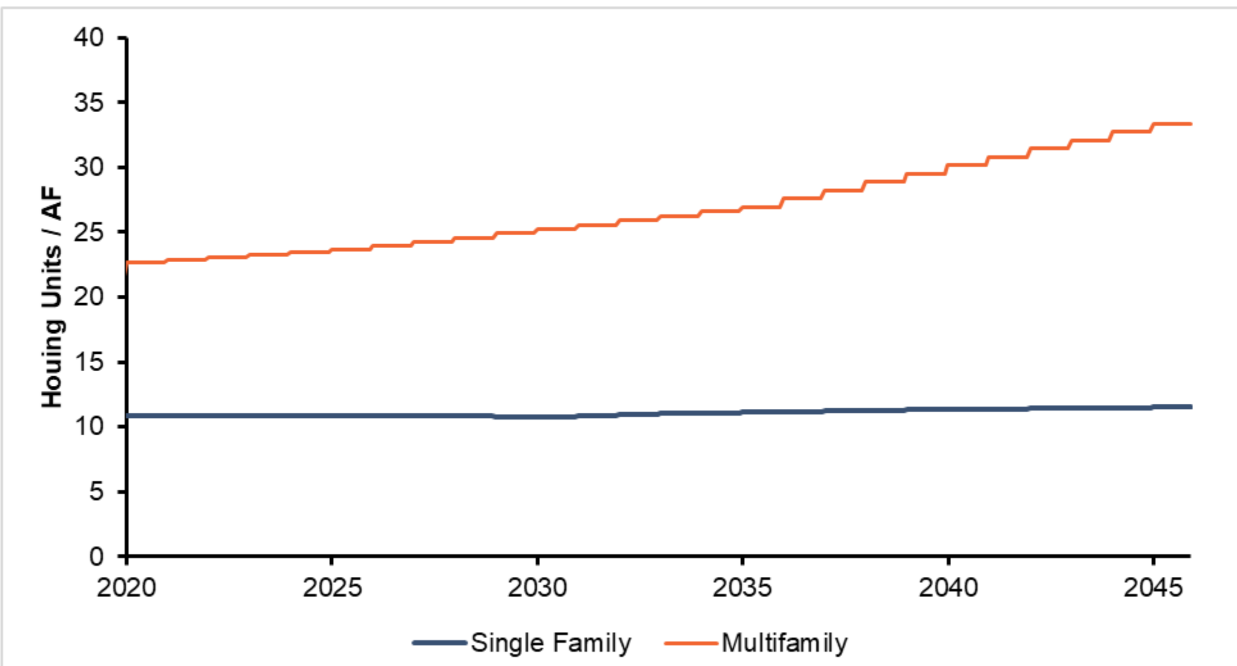

Figure I-5: City of Mountain View Residential Housing Density

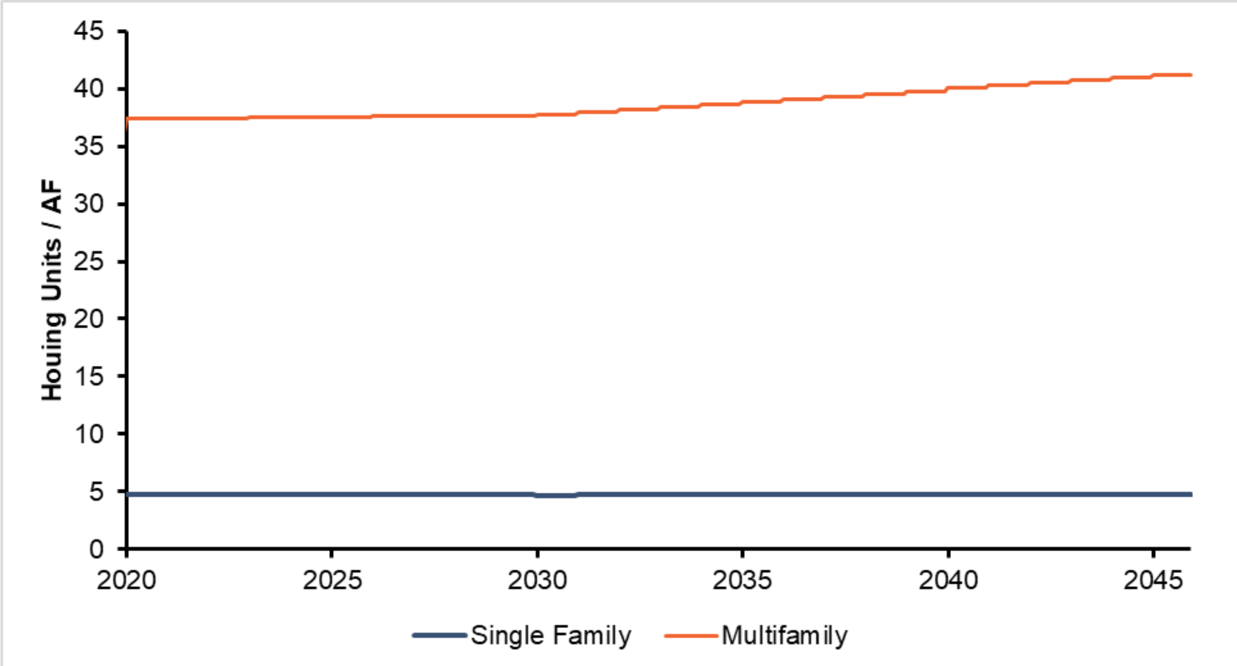

Figure I-6: City of Palo Alto Residential Housing Density

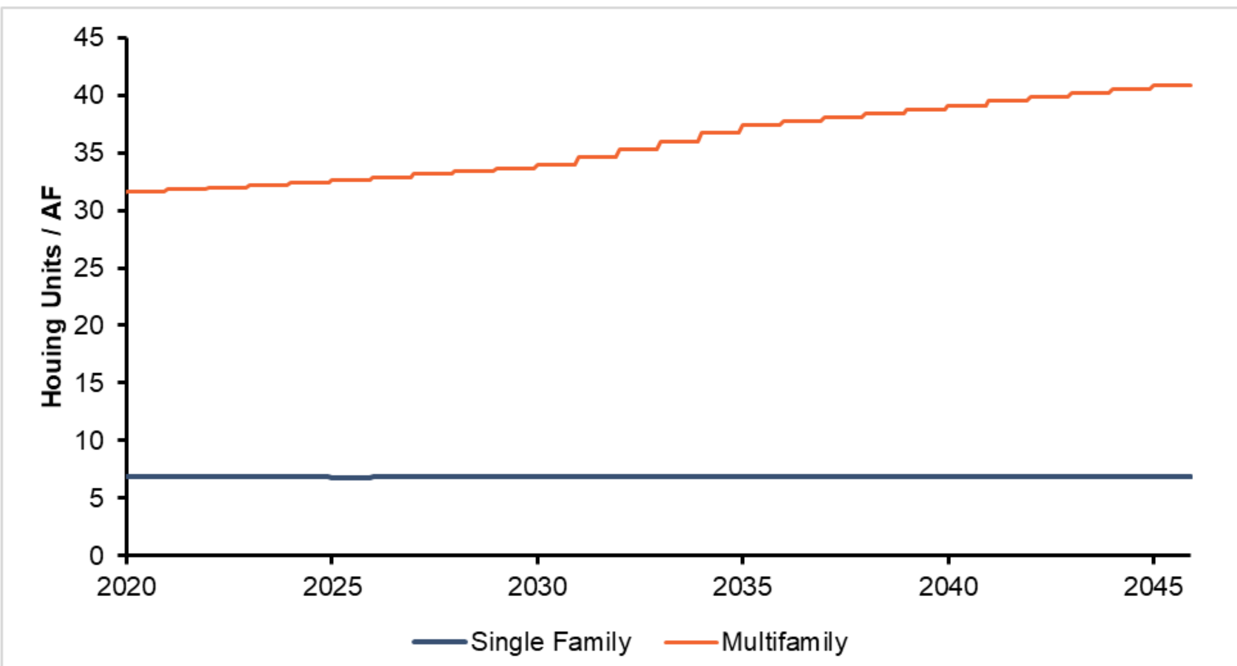

Figure I-7: City of Santa Clara Residential Housing Density

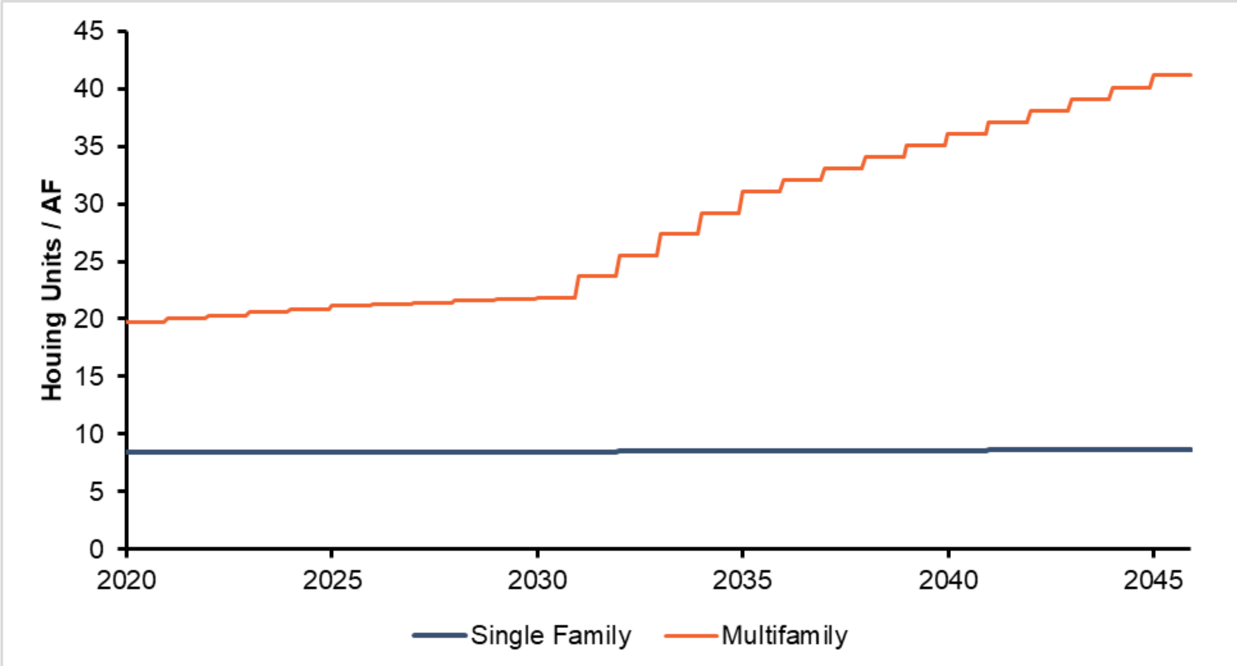

Figure I-8: City of Sunnyvale Residential Housing Density

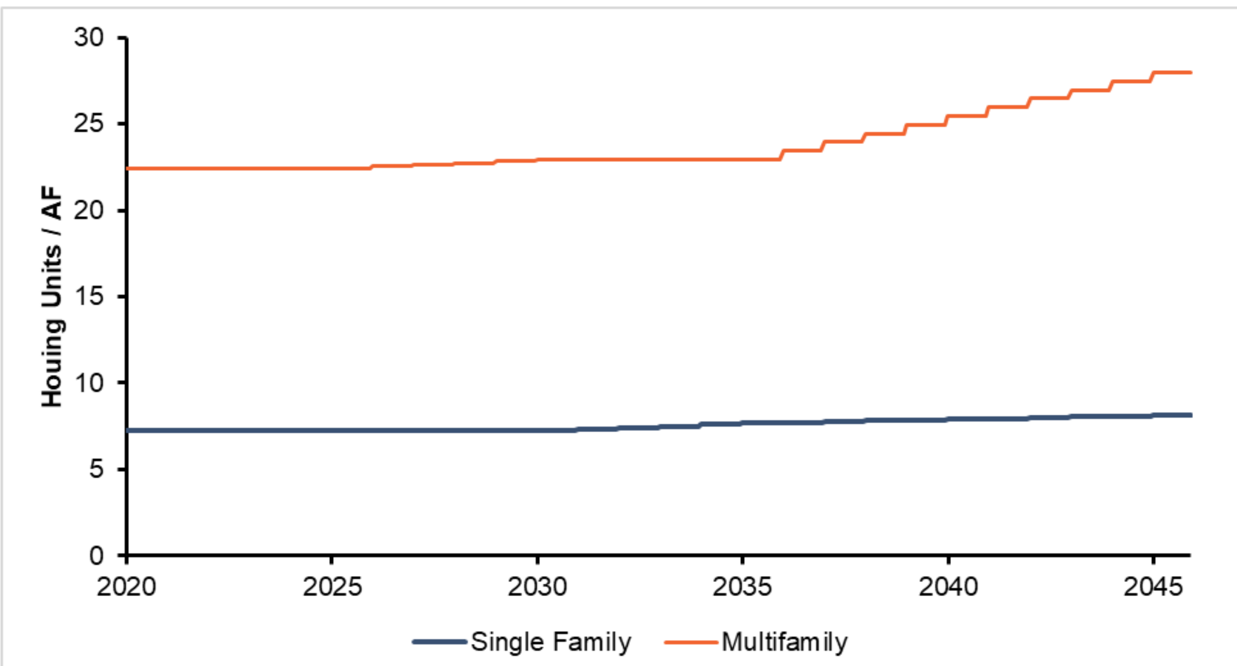

Figure I-9: Great Oaks Water Company Residential Housing Density

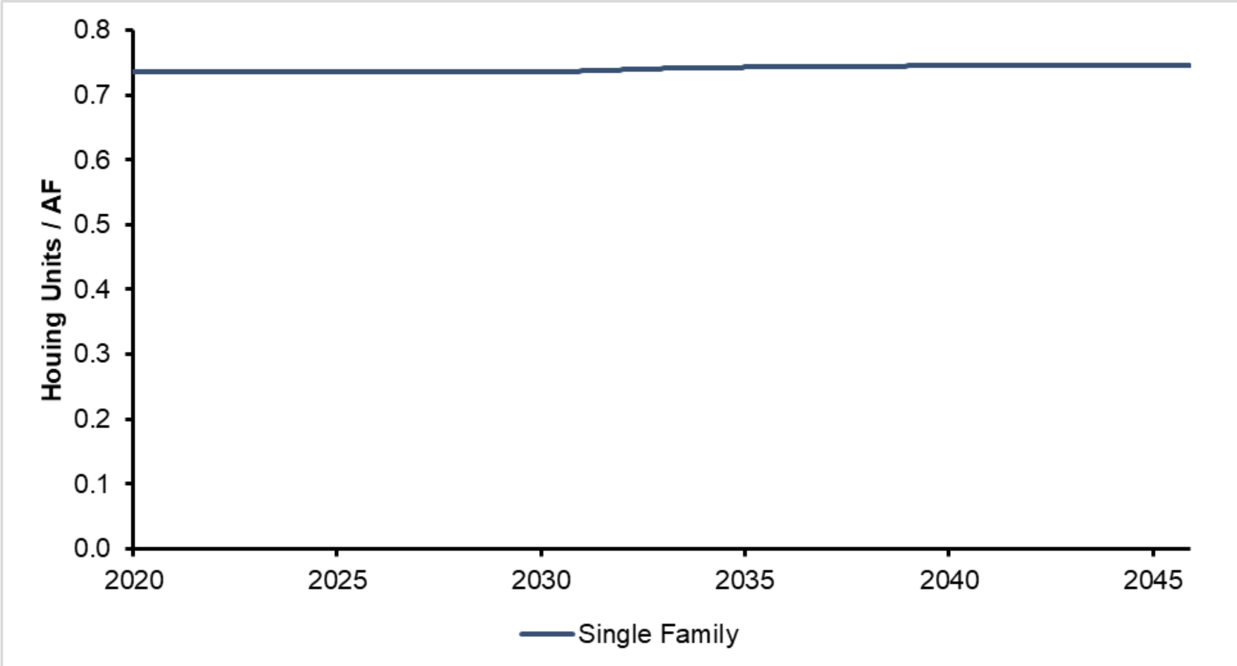

Figure I-10: Purissima Hills Water District Residential Housing Density

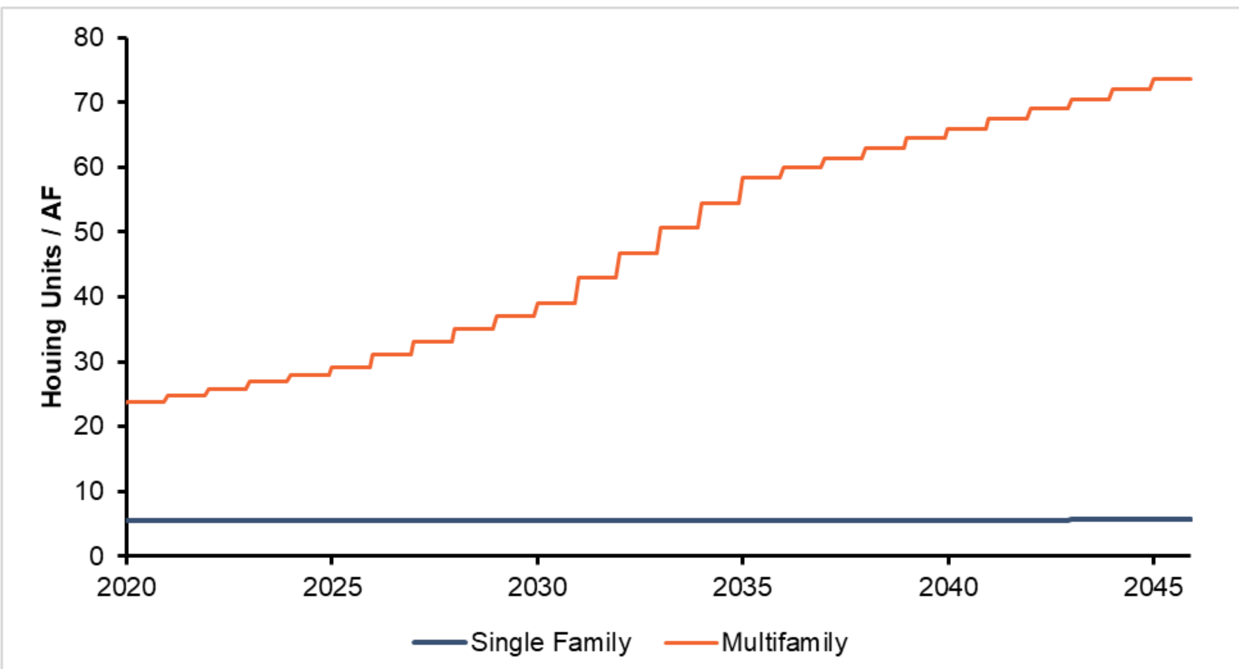

Figure I-11: San Jose Municipal Water Residential Housing Density

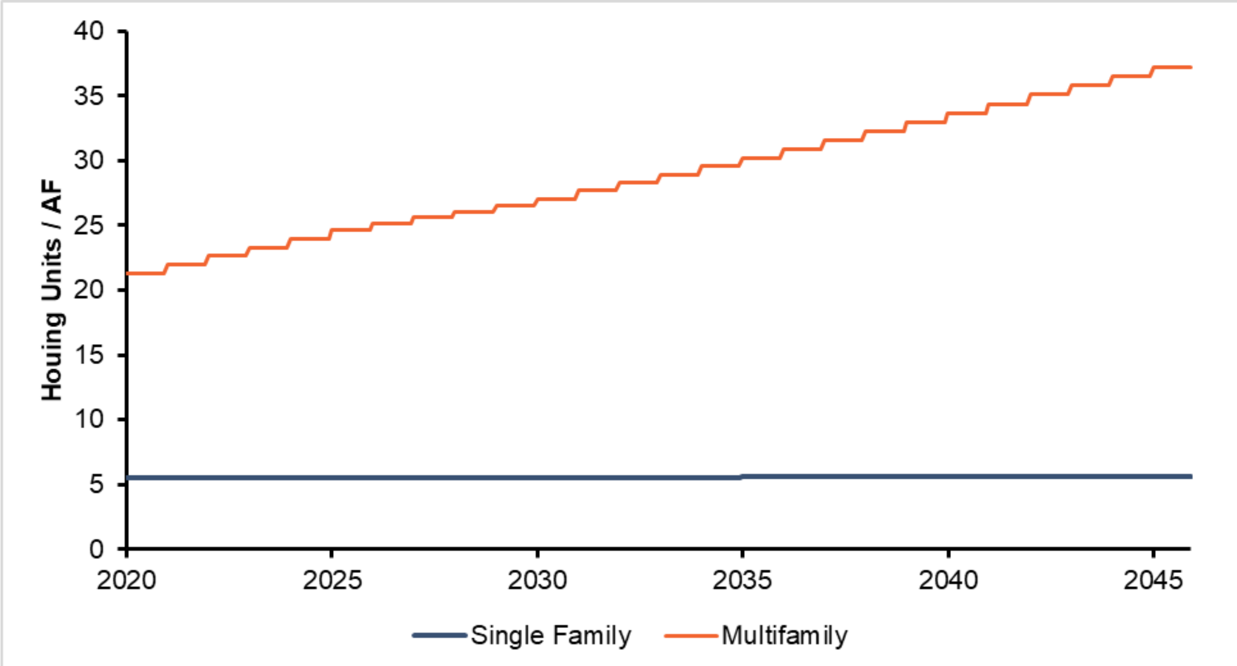

Figure I-12: San Jose Water Company Residential Housing Density

Appendix J: Projected Persons per Household by Retailer

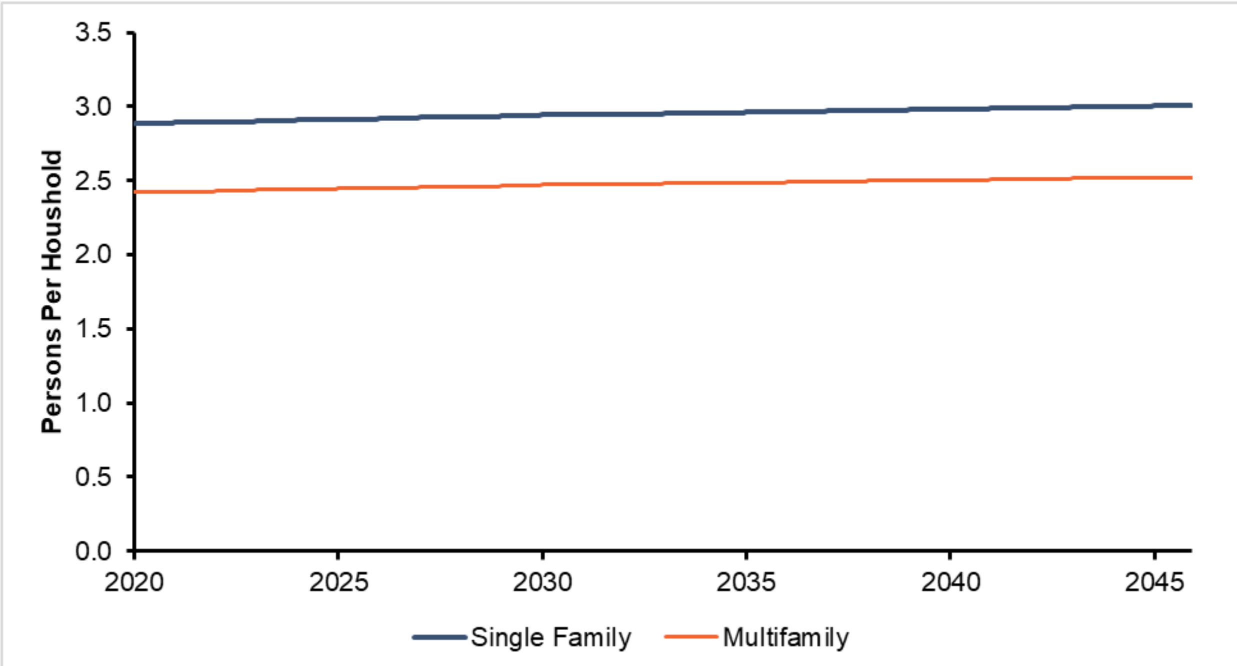

Table J-1: California Water Service Residential Persons Per Household

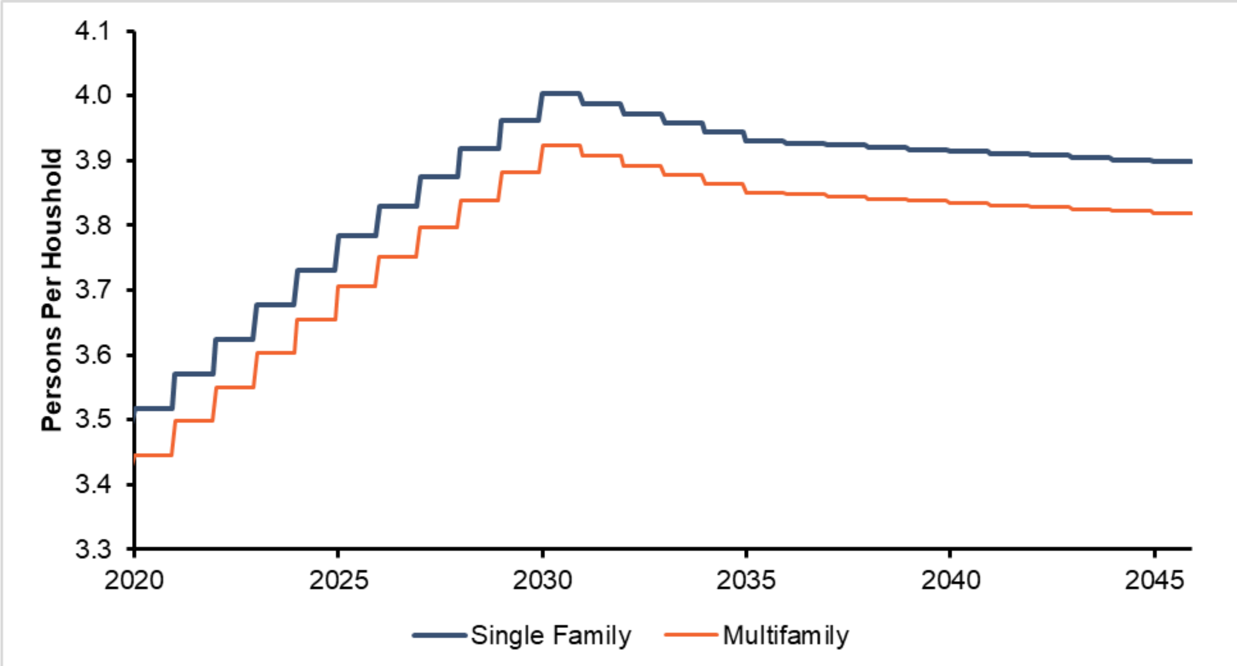

Figure J-2: City of Gilroy Residential Persons Per Household

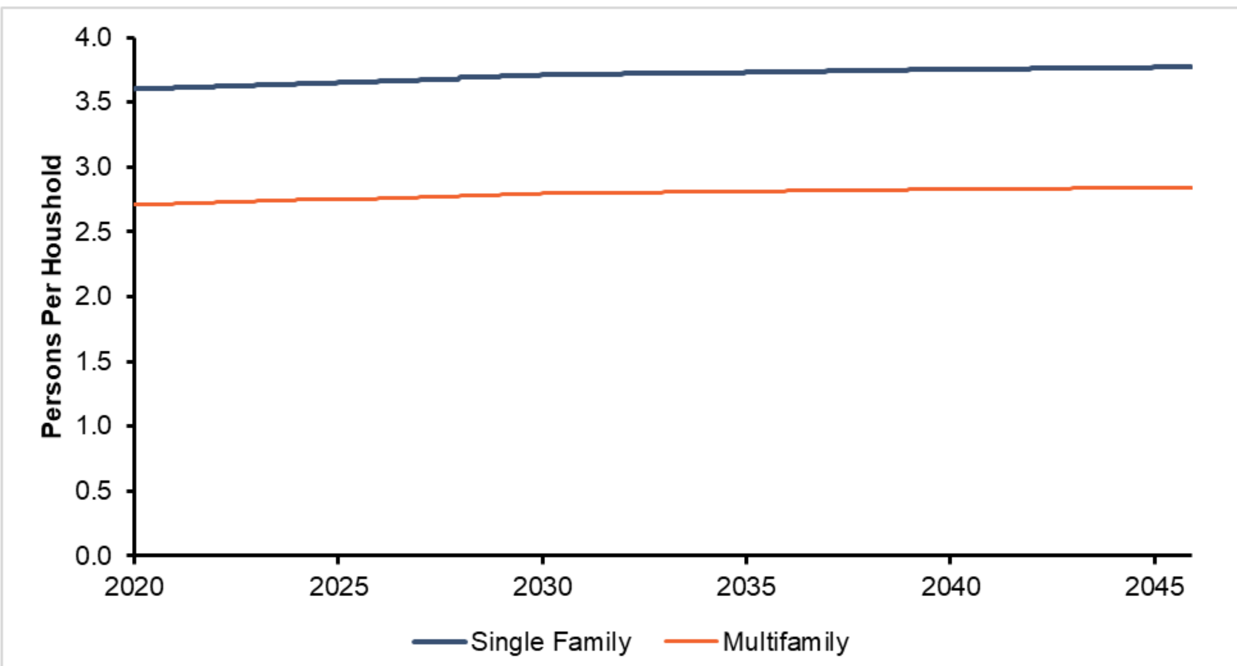

Figure J-3: City of Milpitas Residential Persons Per Household

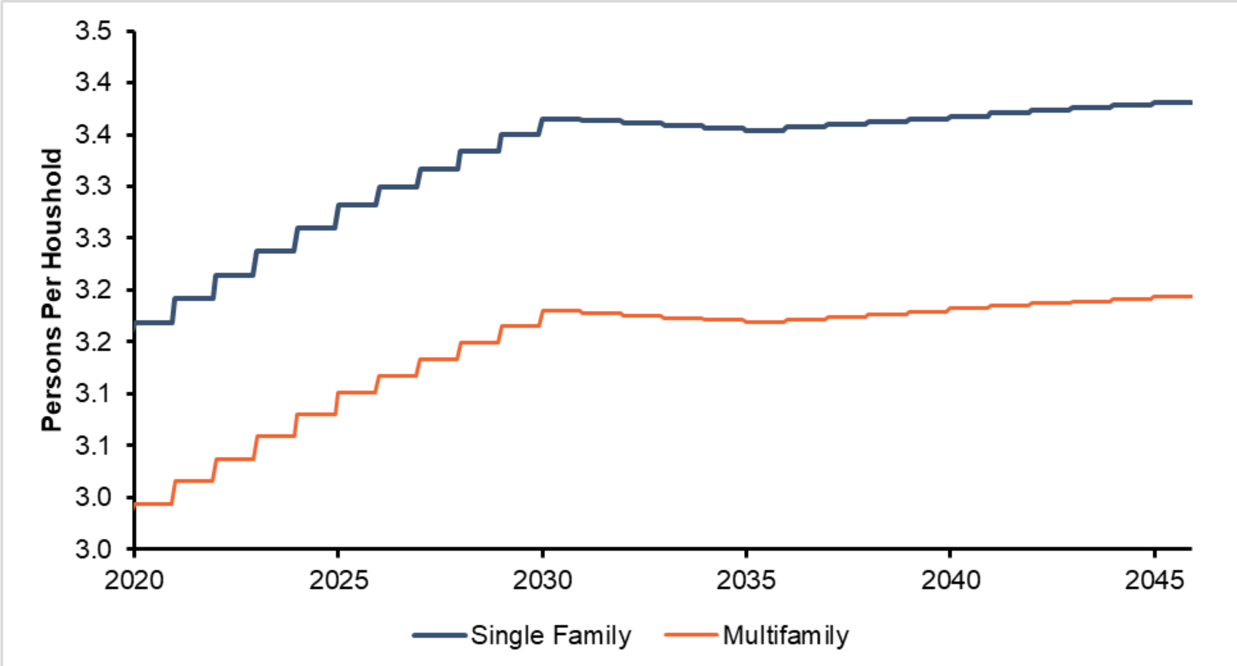

Figure J-4: City of Morgan Hill Residential Persons Per Household

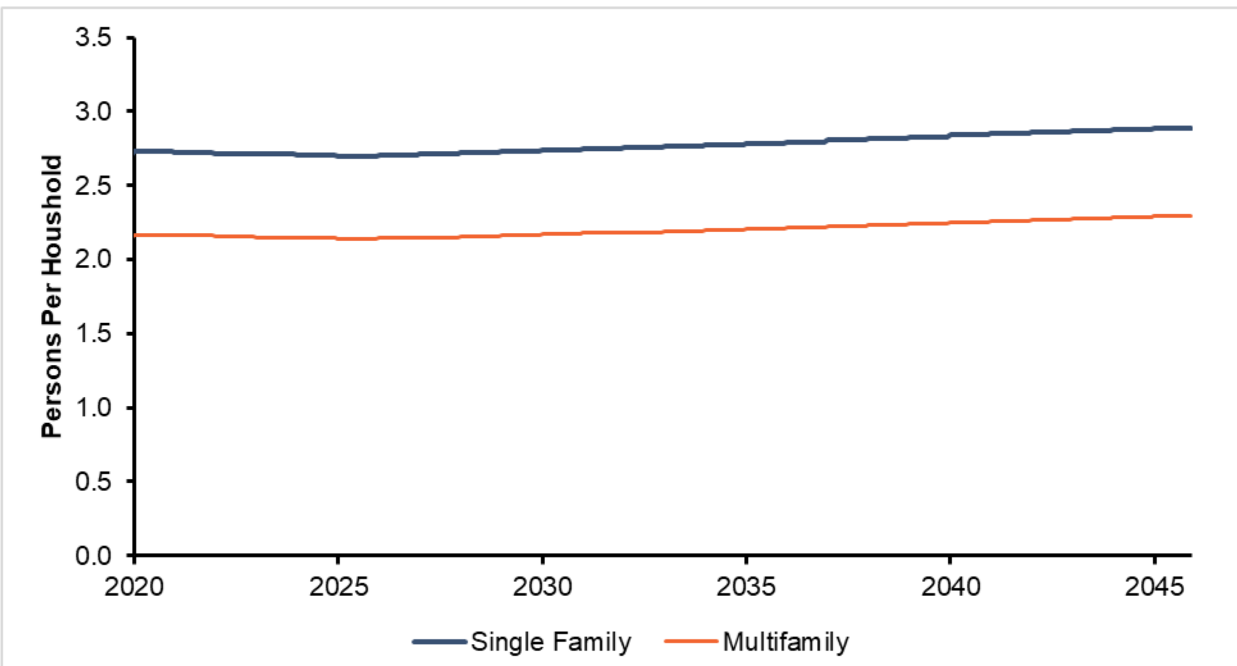

Figure J-5: City of Mountain View Residential Persons Per Household

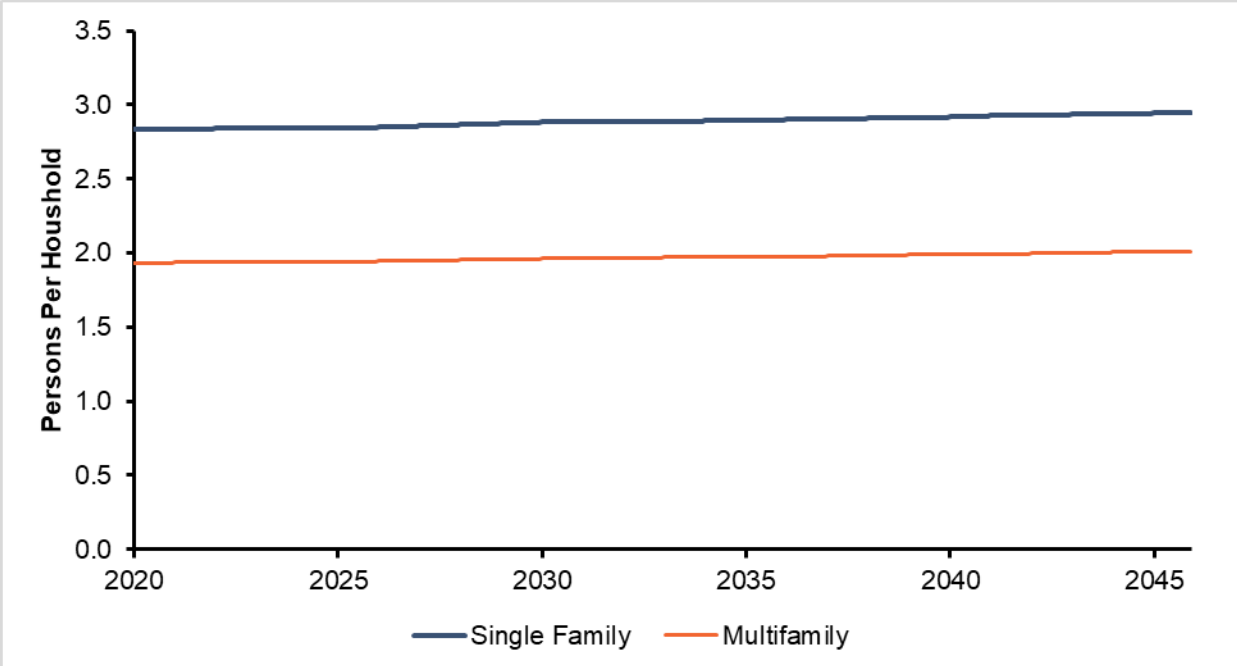

Figure J-6: City of Palo Alto Residential Persons Per Household

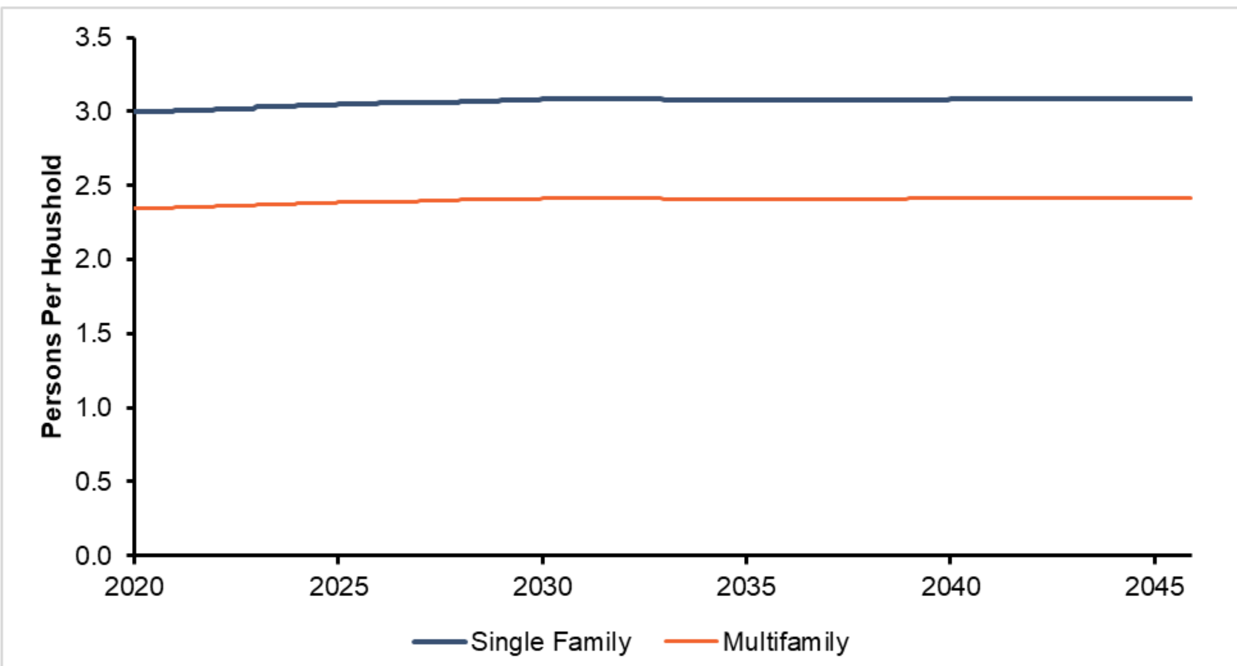

Figure J-7: City of Santa Clara Residential Persons Per Household

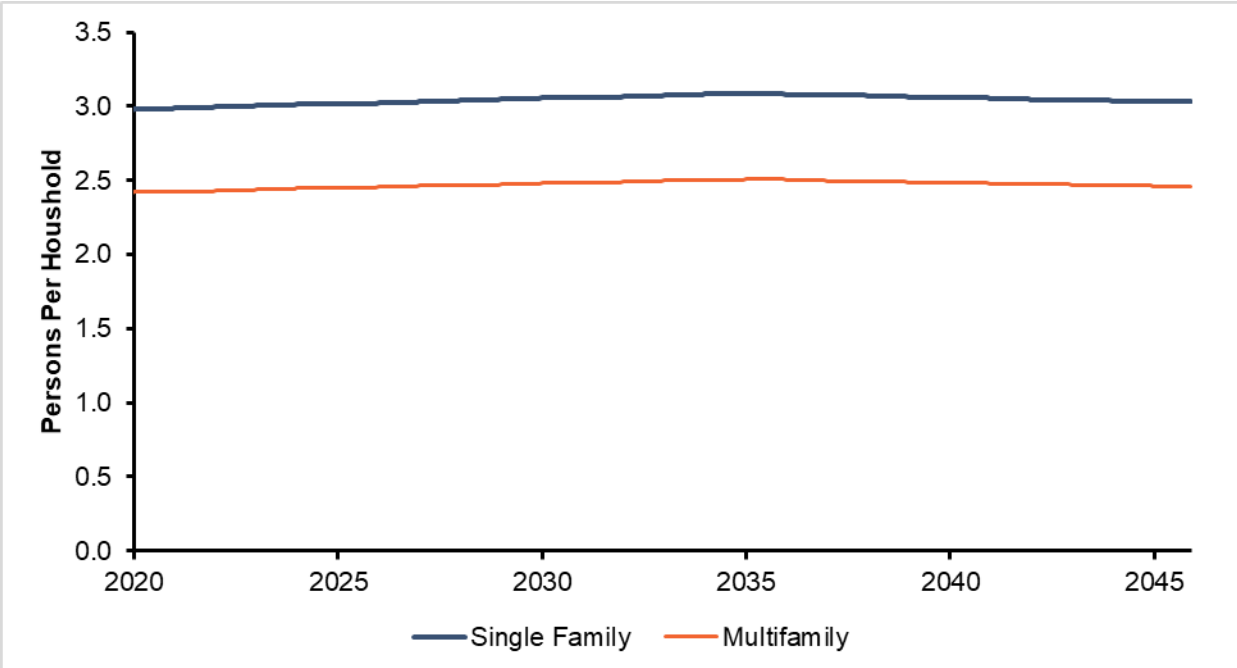

Figure J-8: City of Sunnyvale Residential Persons Per Household

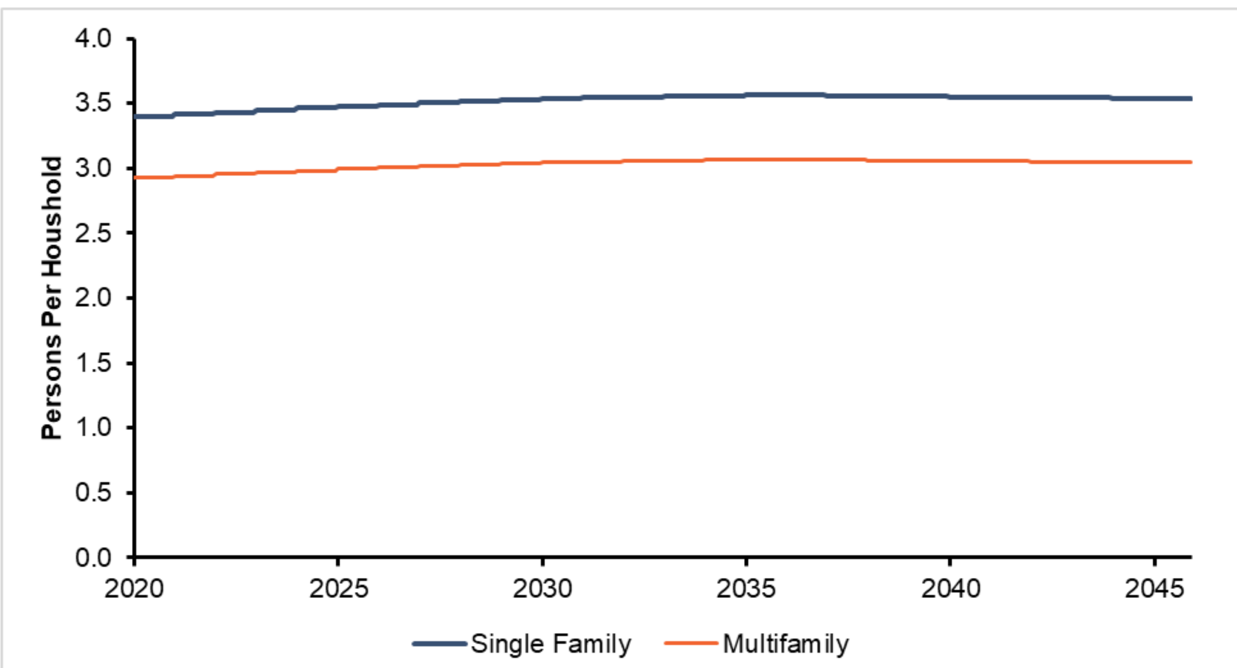

Figure J-9: Great Oaks Water Company Residential Persons Per Household

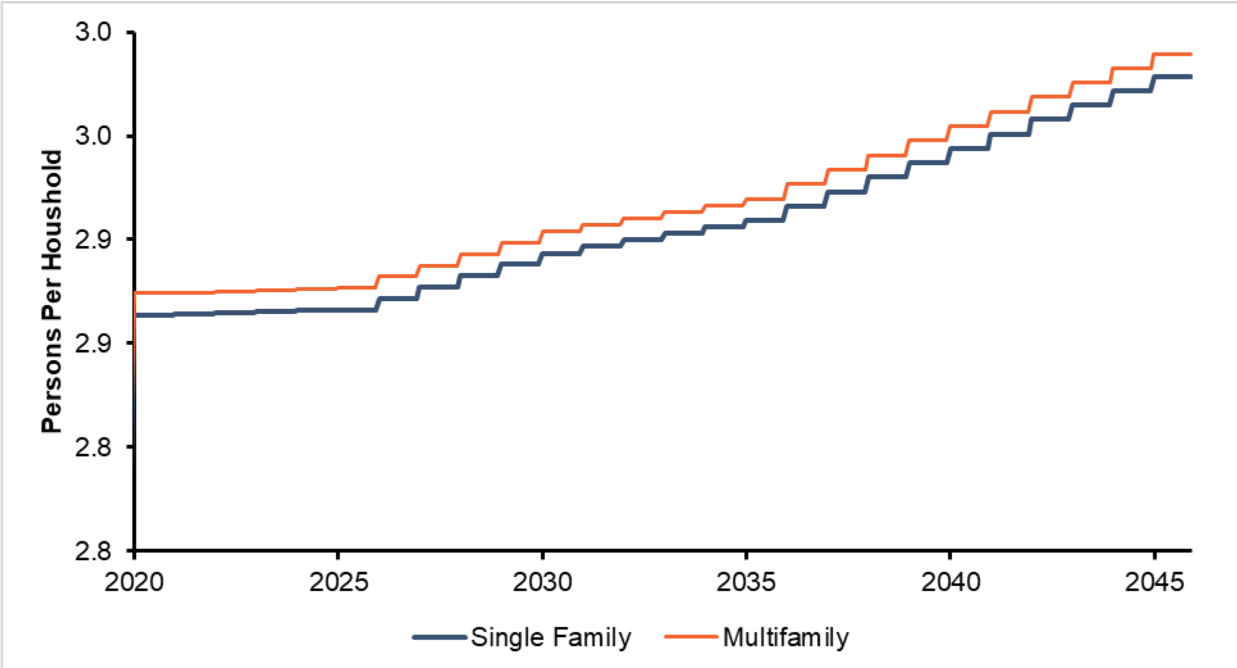

Figure J-10: Purissima Hills Water District Residential Persons Per Household

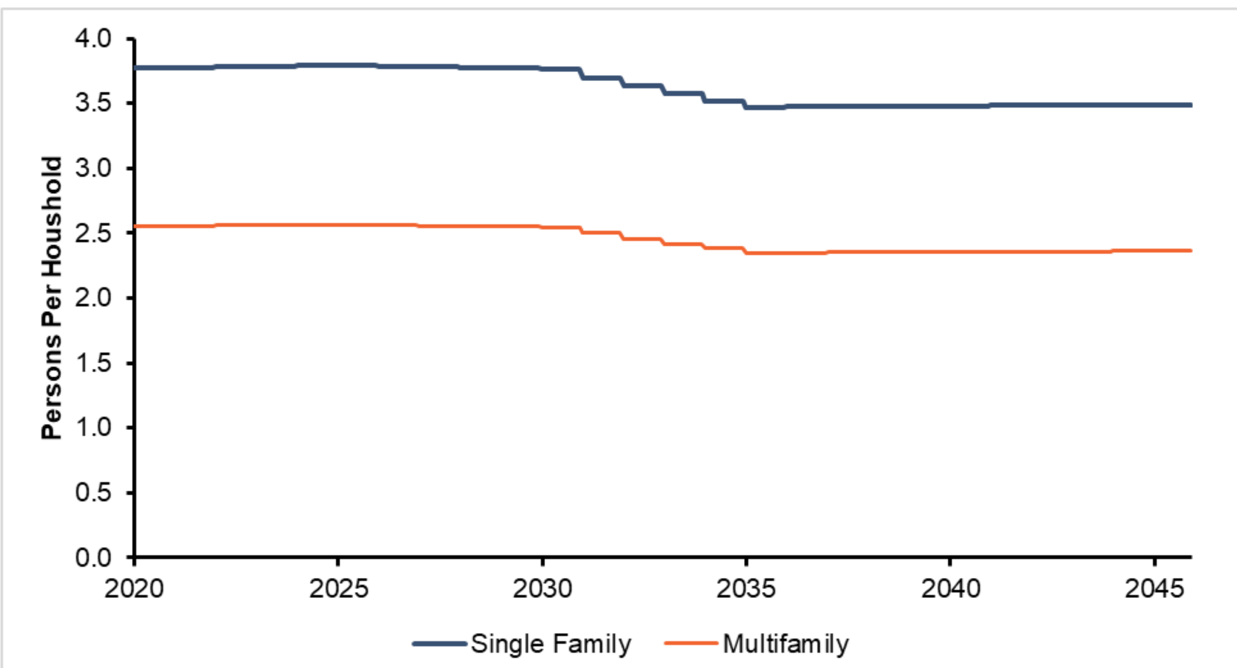

Figure J-11: San Jose Municipal Water Residential Persons Per Household

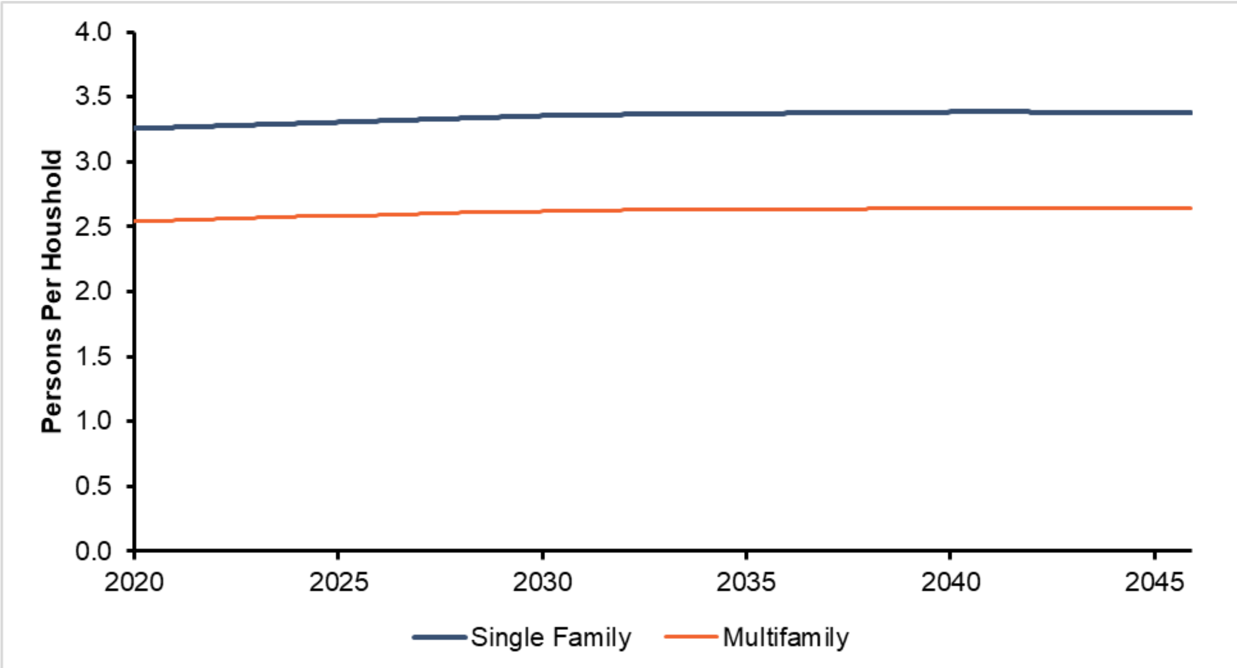

Figure J-12: San Jose Water Company Residential Persons Per Household

Appendix K: Projected Employment Ratios by Retailer

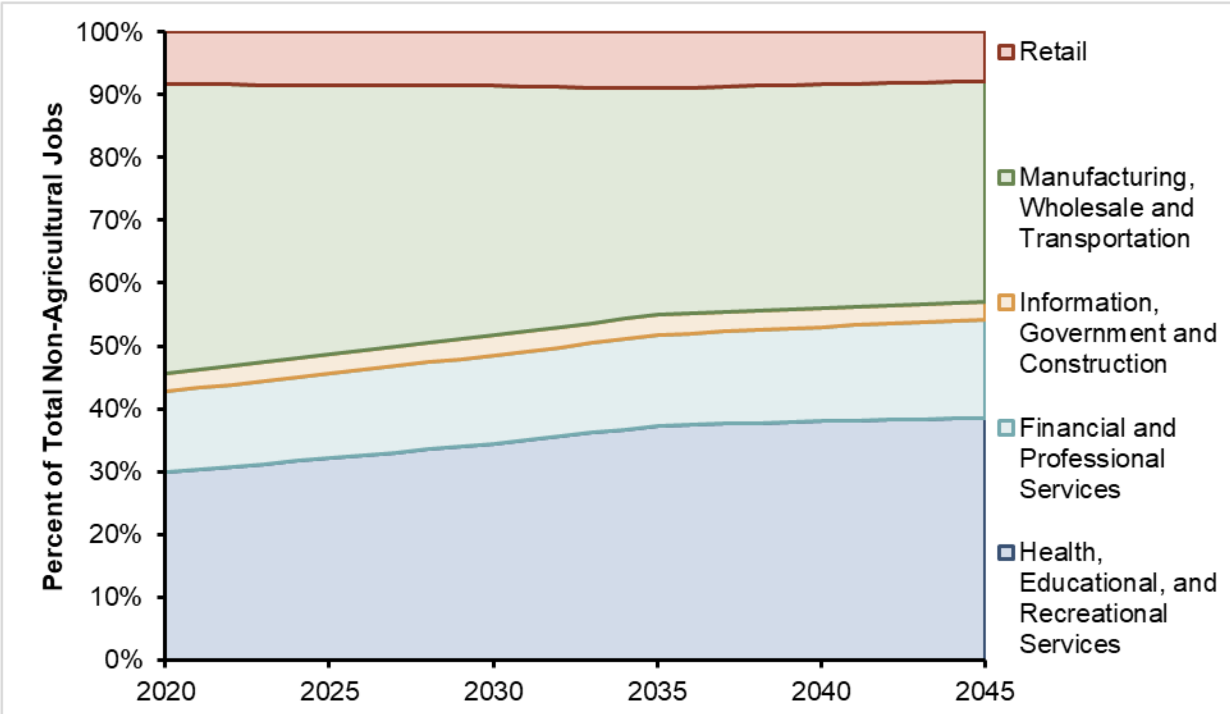

Figure K-1: California Water Service Projected Sectoral Employment Ratios

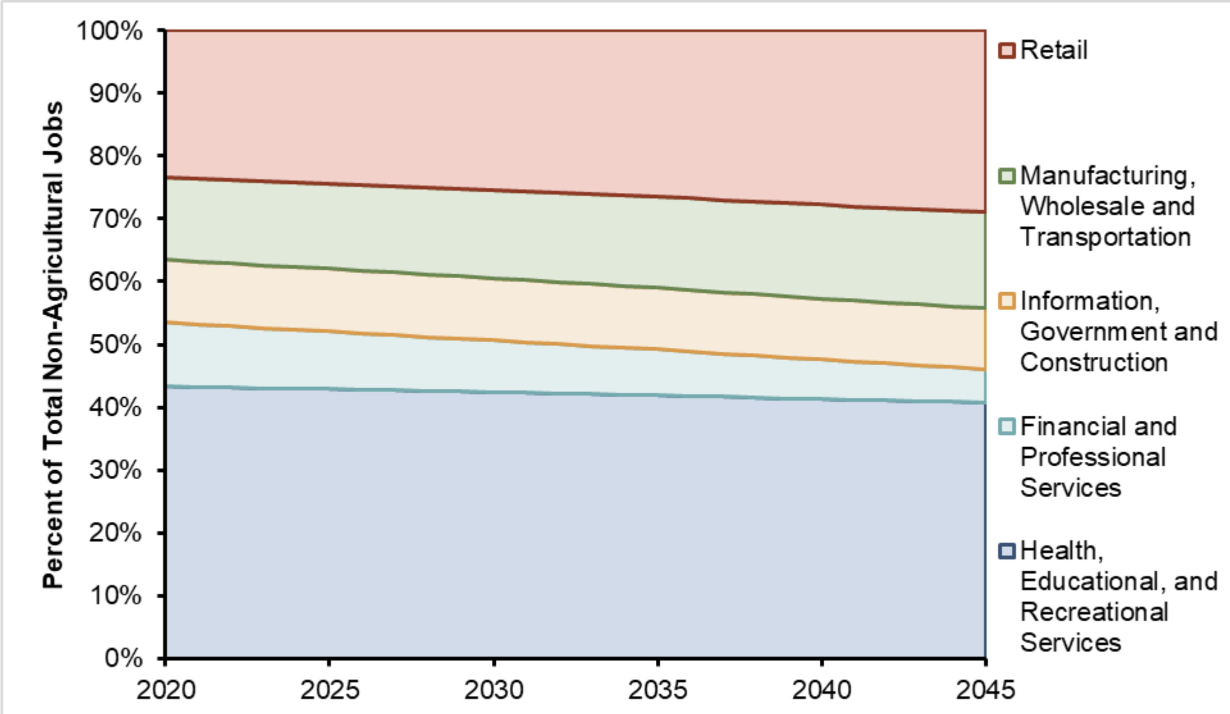

Figure K-2: City of Gilroy Projected Sectoral Employment Ratios

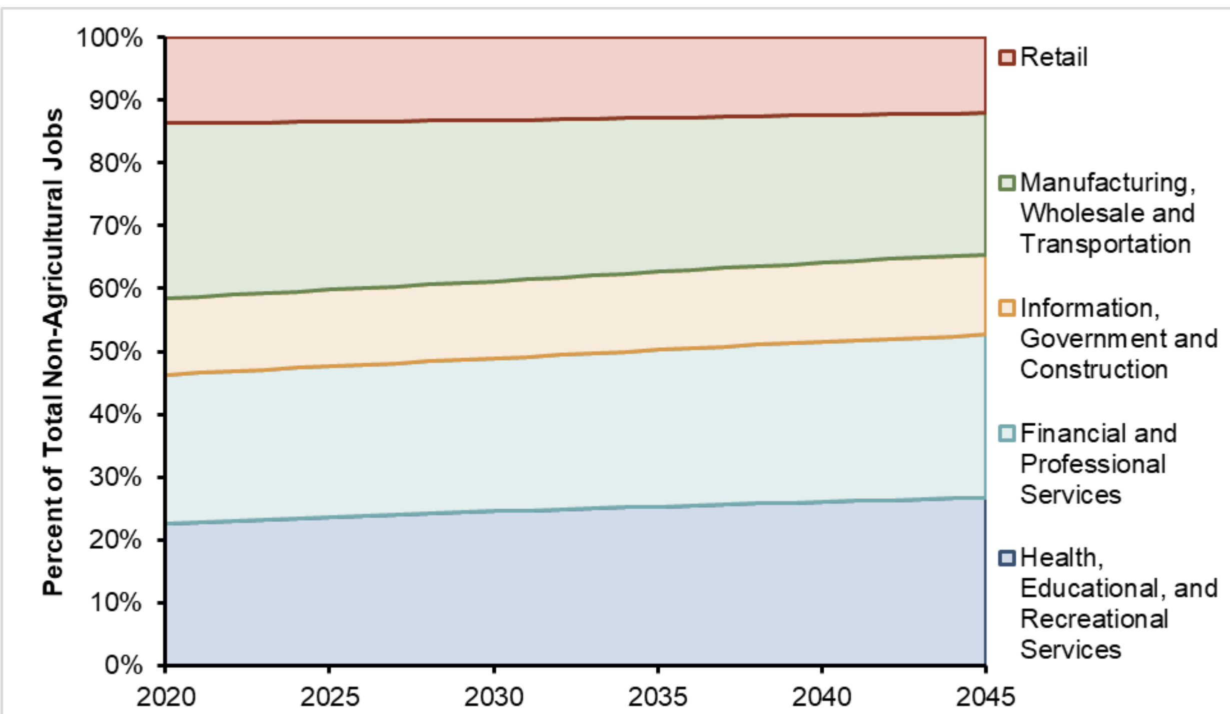

Figure K-3: City of Milpitas Projected Sectoral Employment Ratios

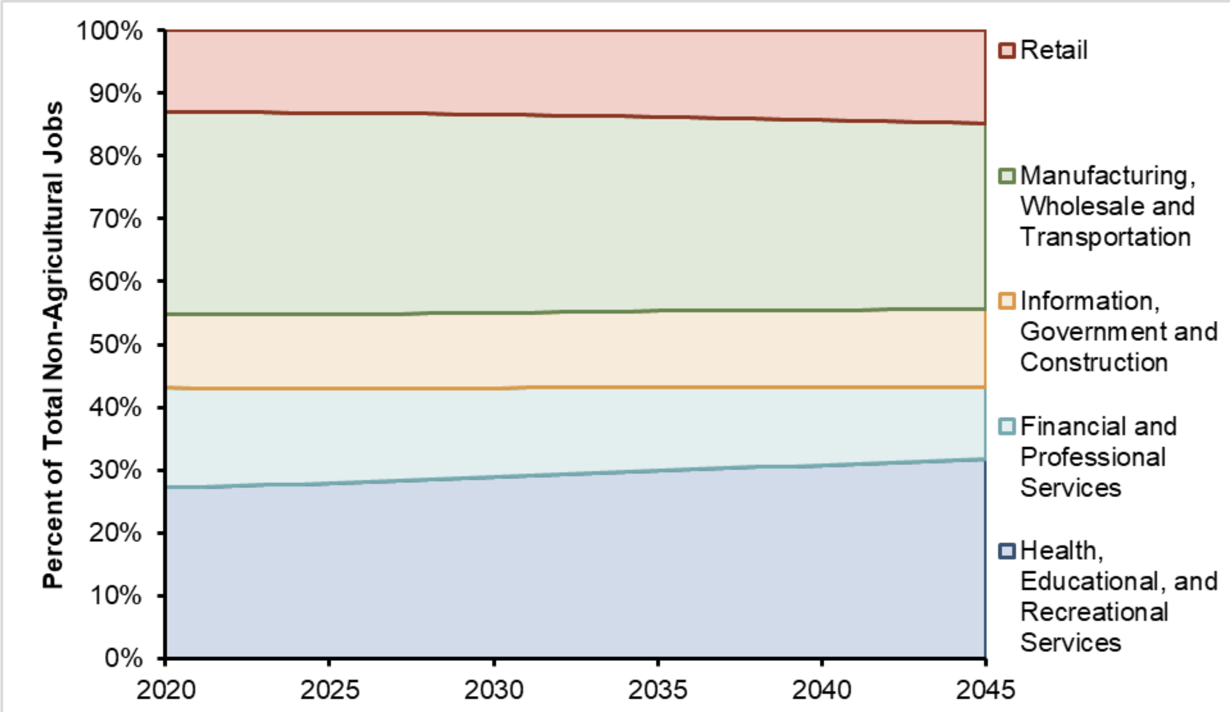

Figure K-4: City of Morgan Hill Projected Sectoral Employment Ratios

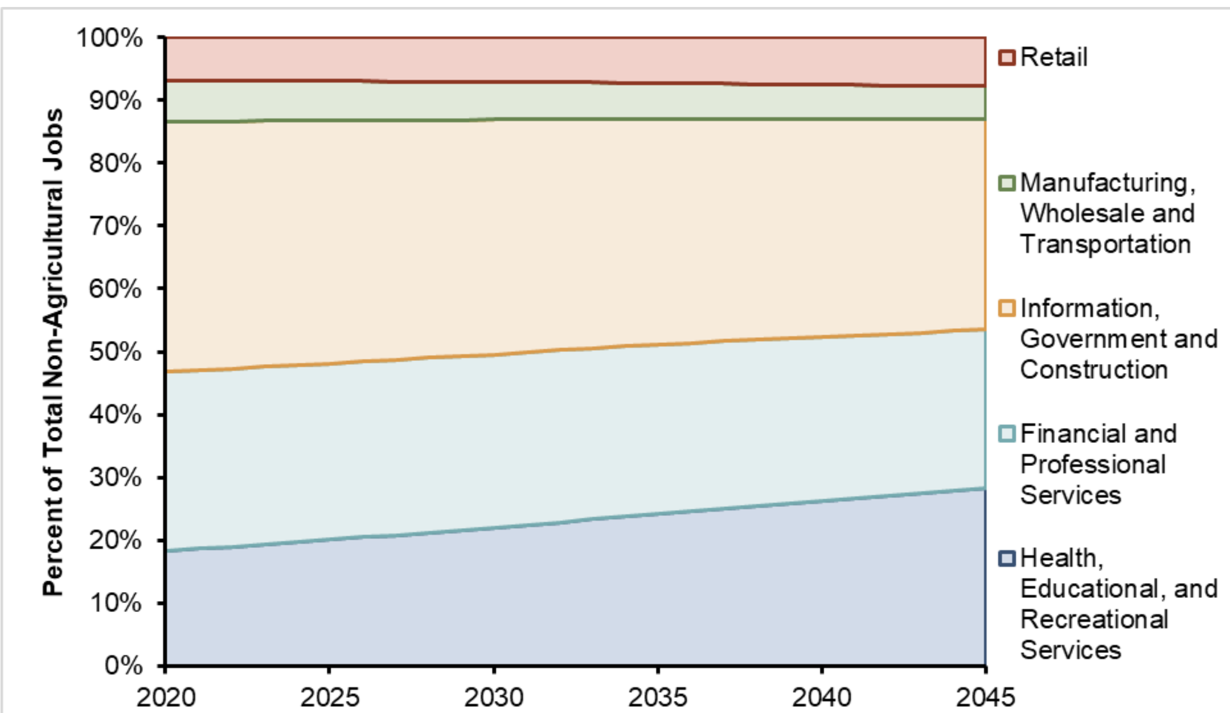

Figure K-5: City of Mountain View Projected Sectoral Employment Ratios

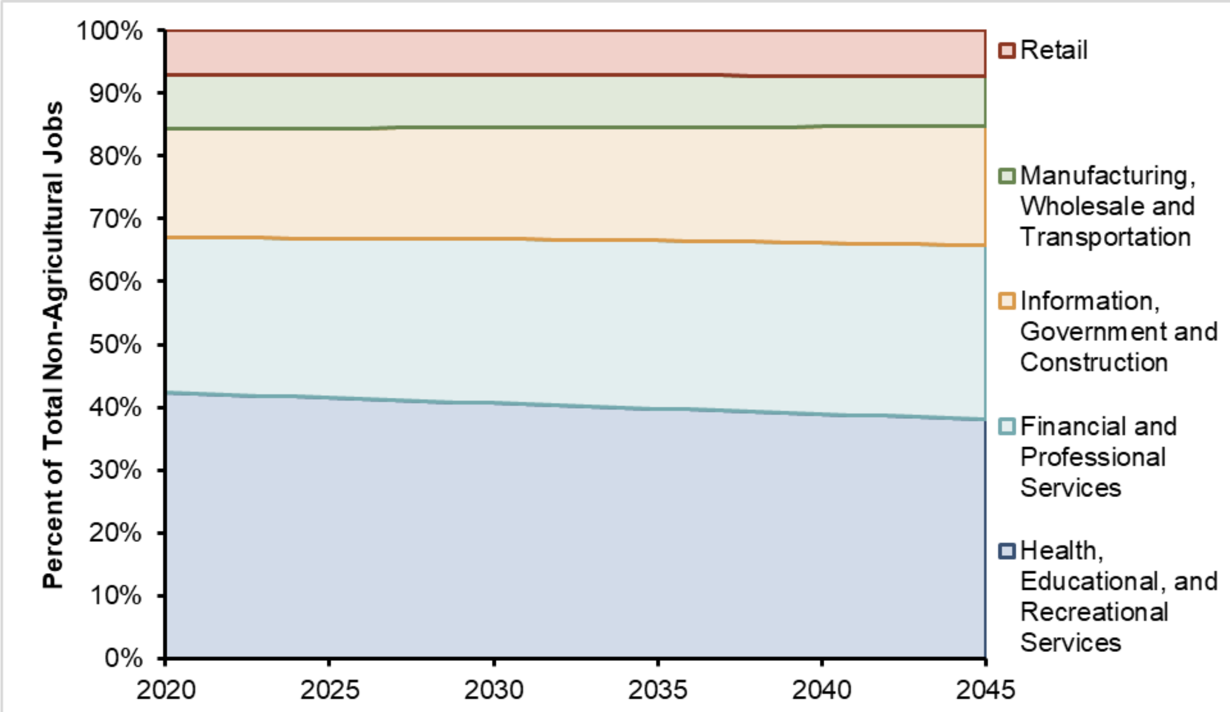

Figure K-6: City of Palo Alto Projected Sectoral Employment Ratios

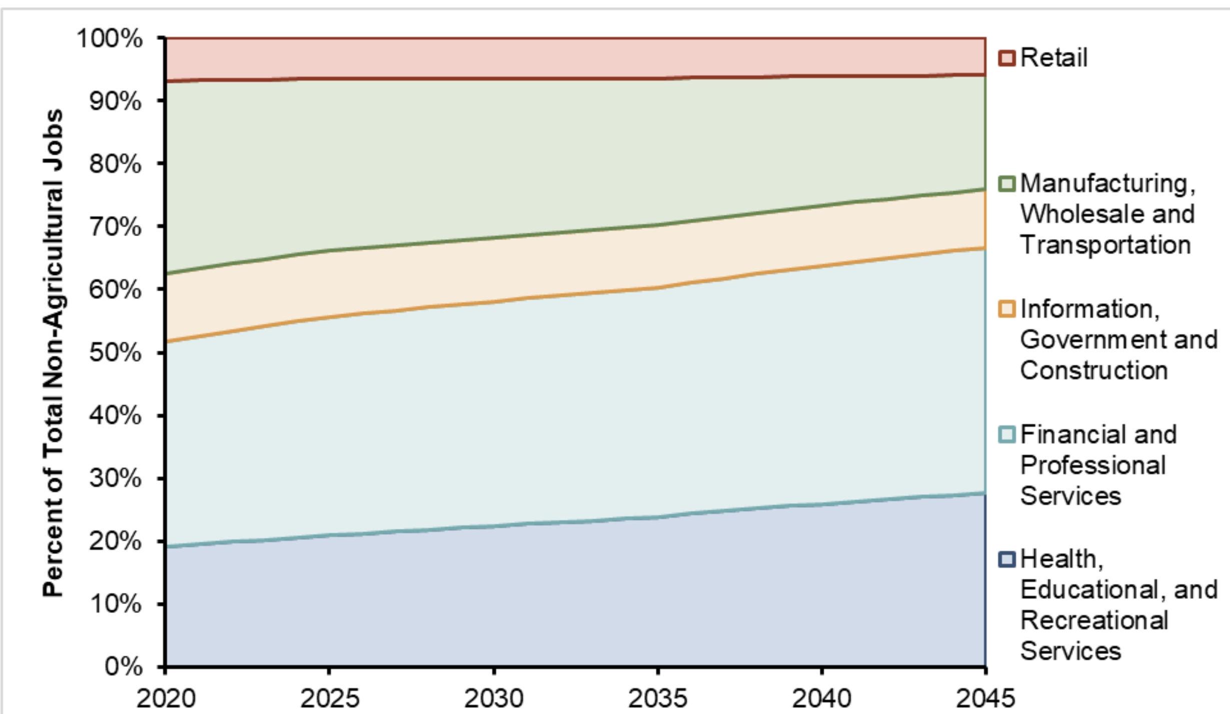

Figure K-7: City of Santa Clara Projected Sectoral Employment Ratios

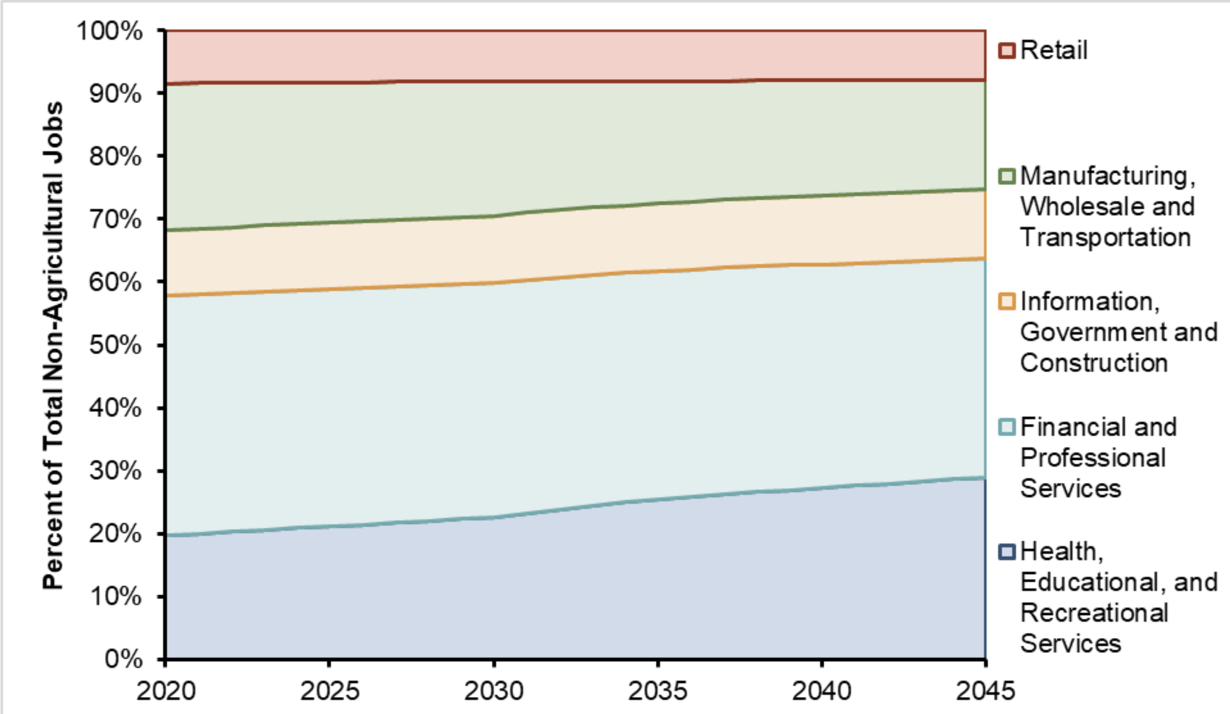

Figure K-8: City of Sunnyvale Projected Sectoral Employment Ratios

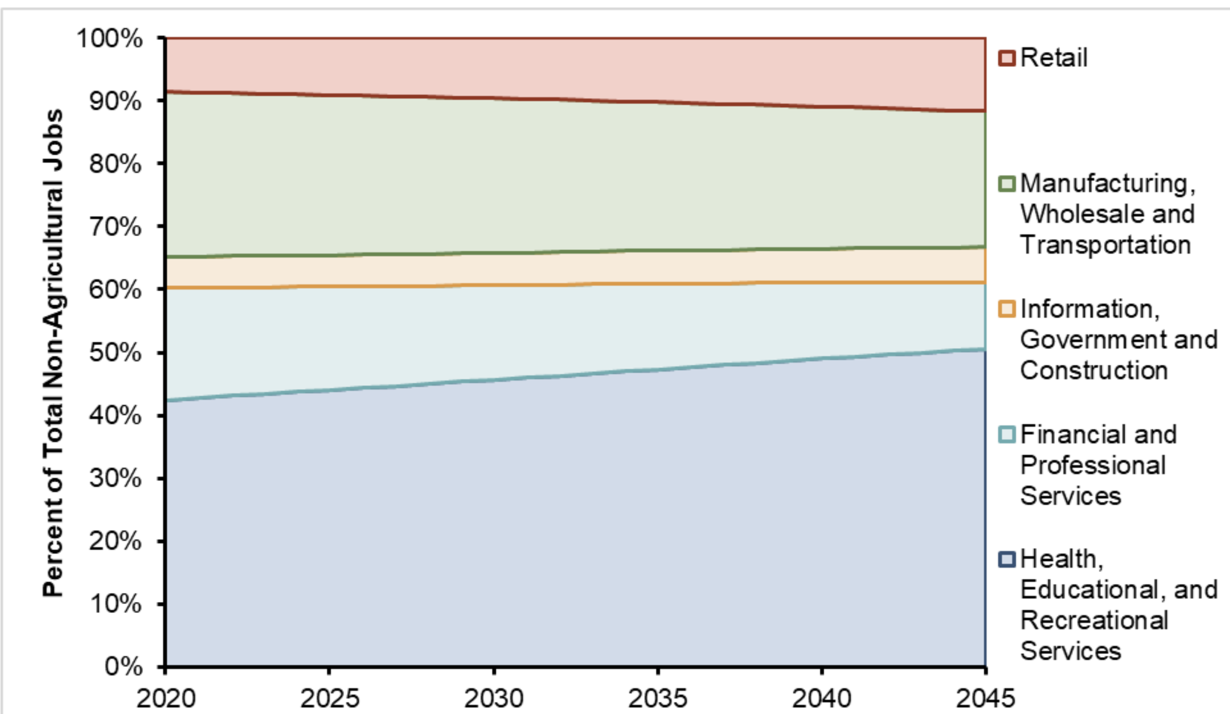

Figure K-9: Great Oaks Water Company Projected Sectoral Employment Ratios

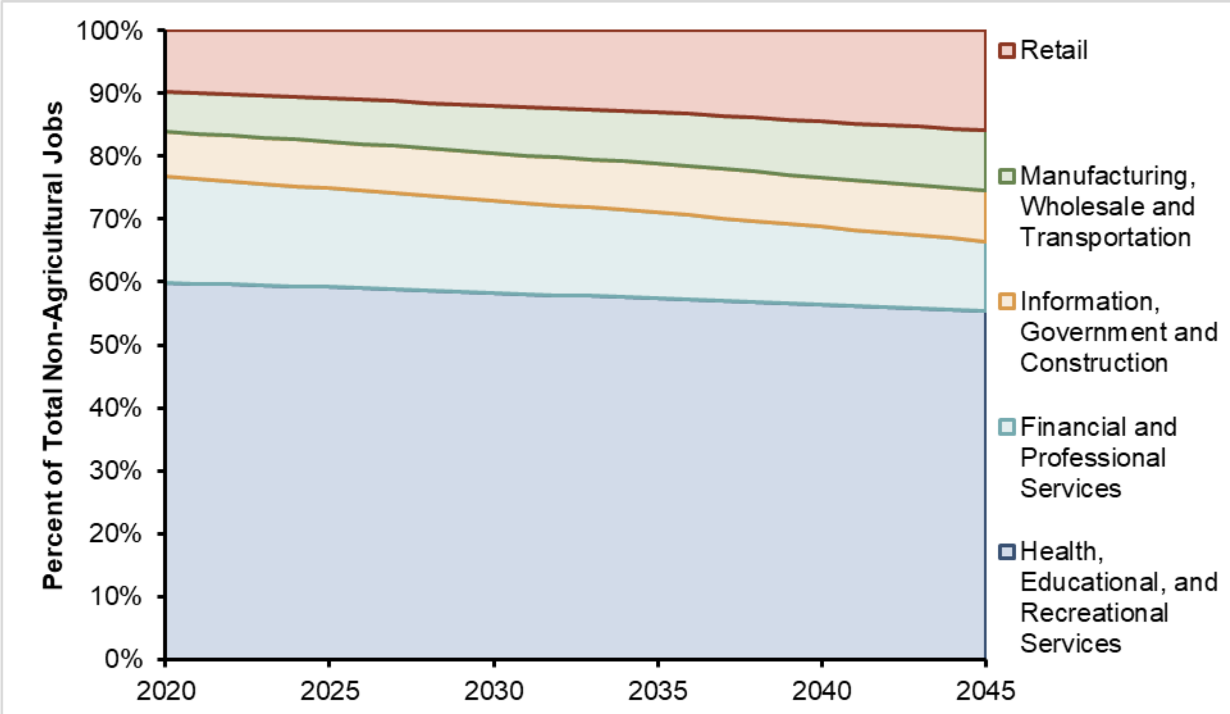

Figure K-10: Purissima Hills Water District Projected Sectoral Employment Ratios

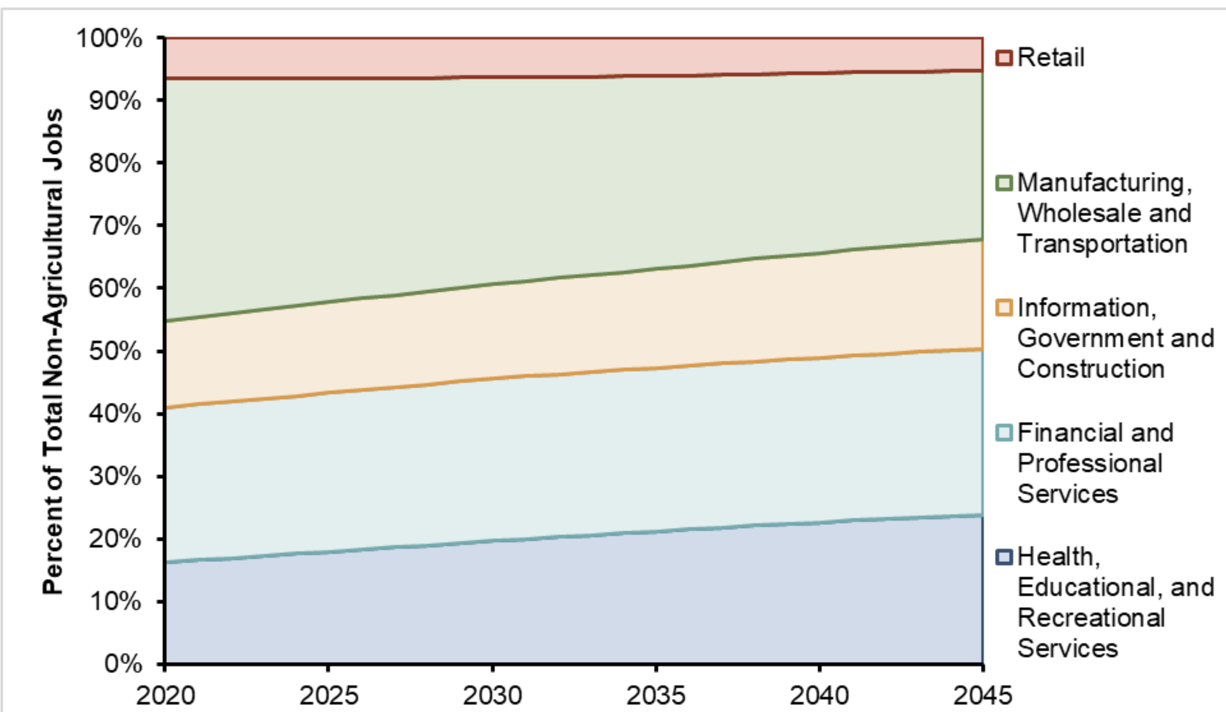

Figure K-11: San Jose Municipal Water Projected Sectoral Employment Ratios

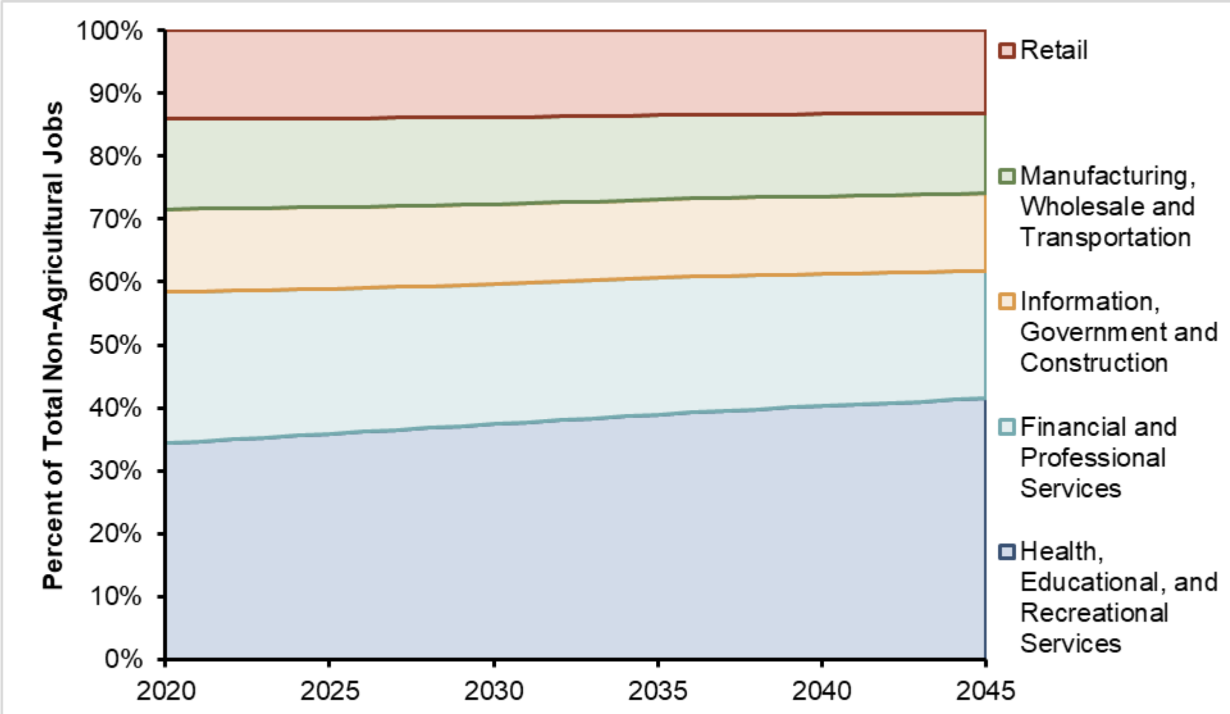

Figure K-12: San Jose Water Company Projected Sectoral Employment Ratios

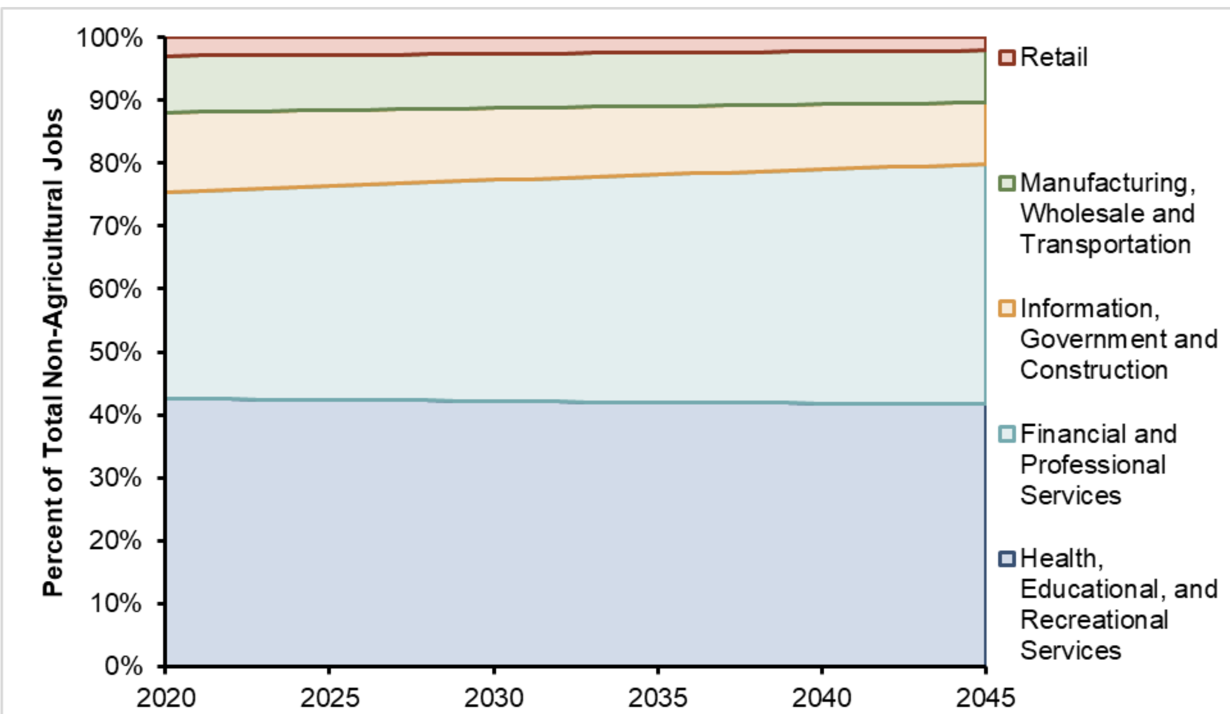

Figure K-13: Stanford Projected Sectoral Employment Ratios

Appendix L: Projected Single Family Residential Demand by Retailer

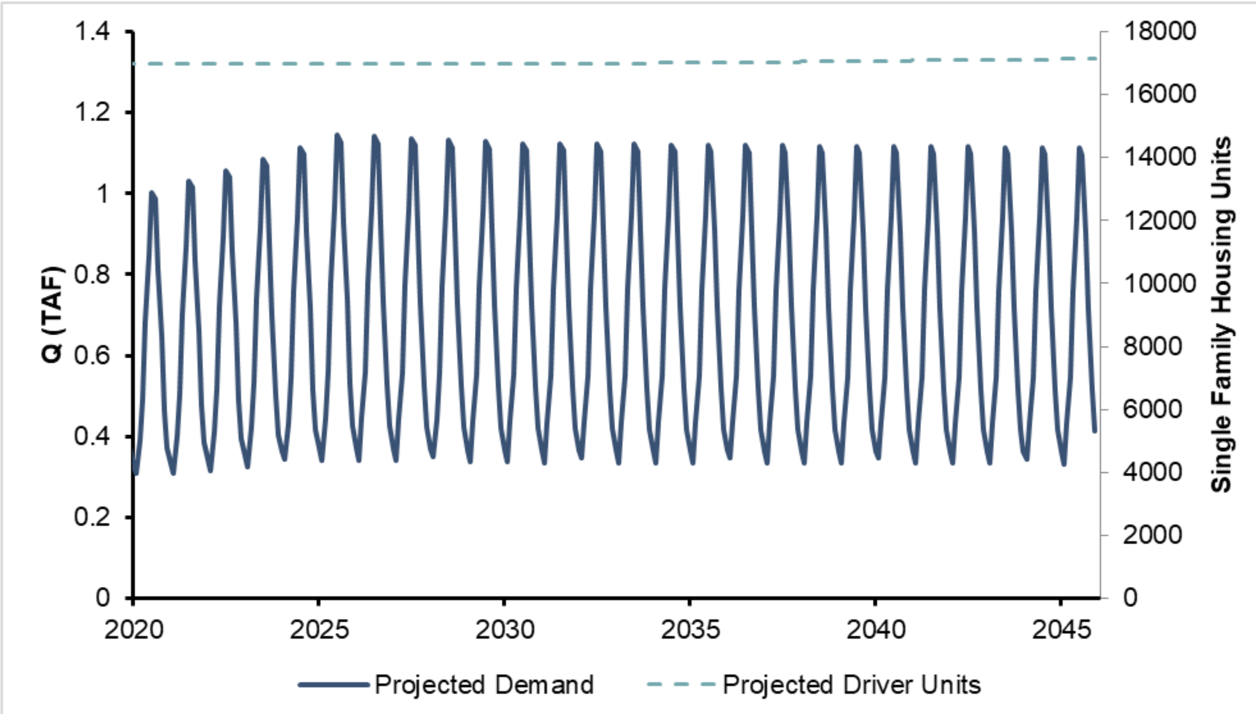

Figure L-1: California Water Service Single Family Residential Demand Projection

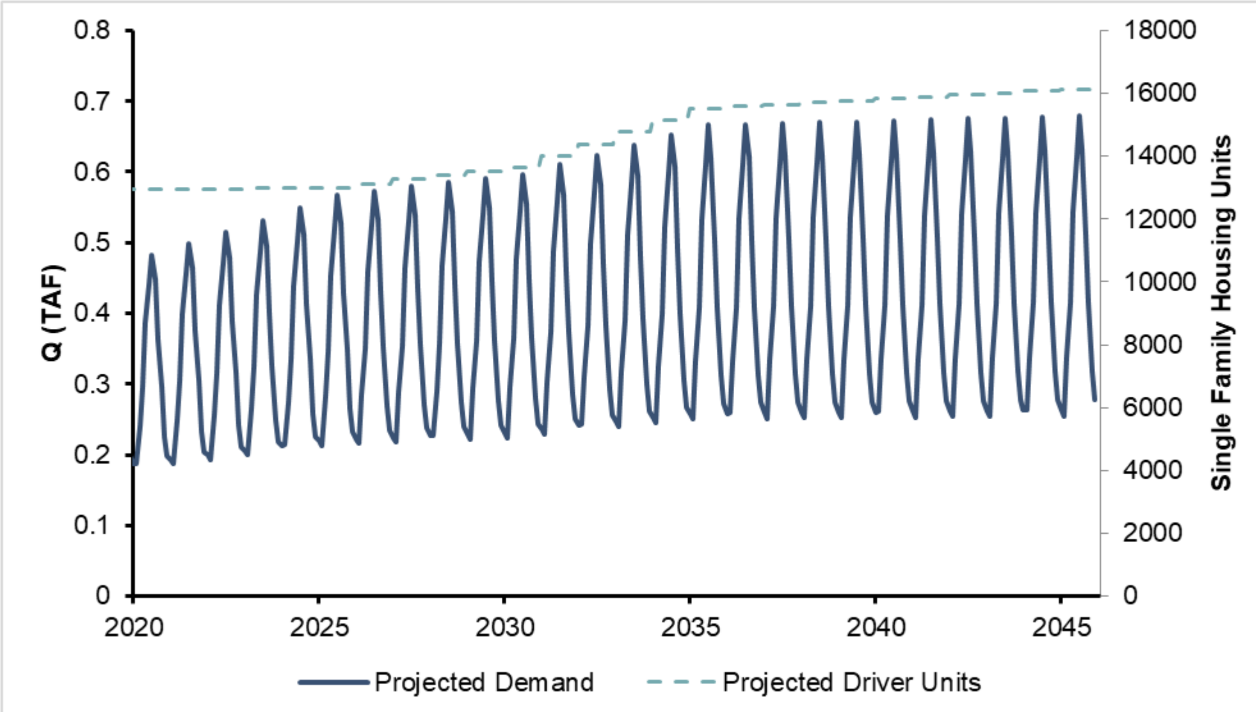

Figure L-2: City of Gilroy Single Family Residential Demand Projection

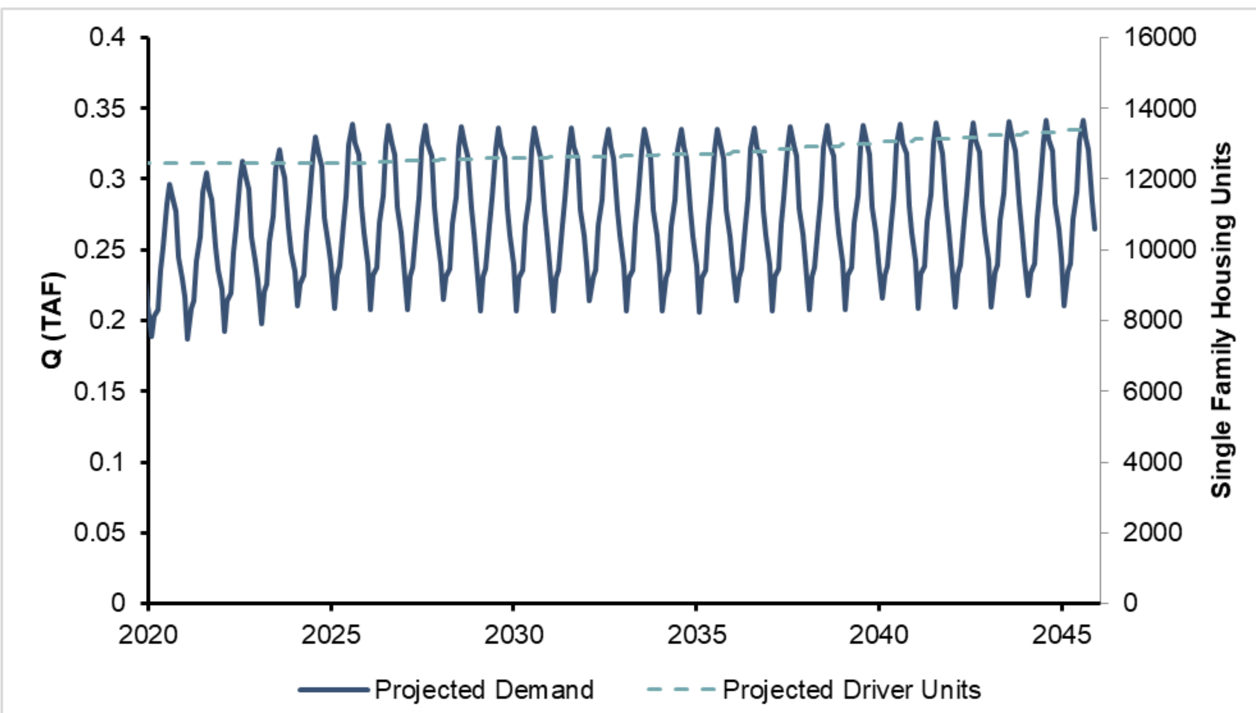

Figure L-3: City of Milpitas Single Family Residential Demand Projection.

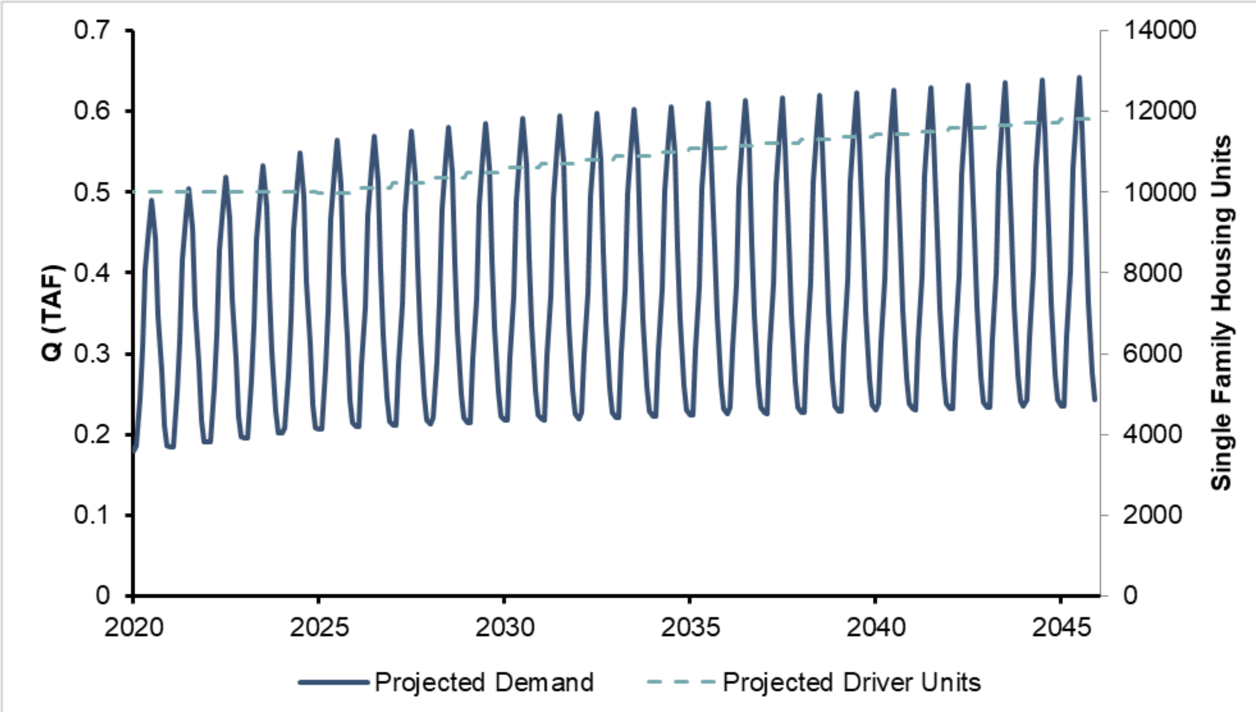

Figure L-4: City of Morgan Hill Single Family Residential Demand Projection

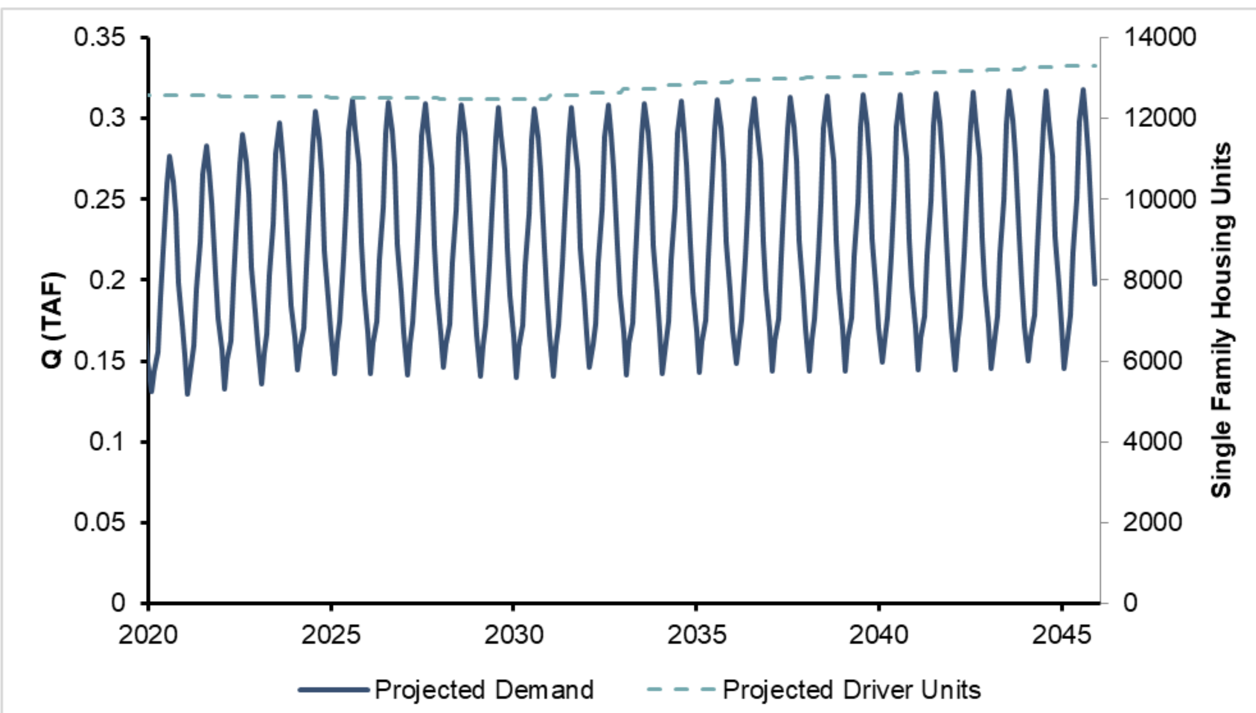

Figure L-5: City of Mountain View Single Family Residential Demand Projection

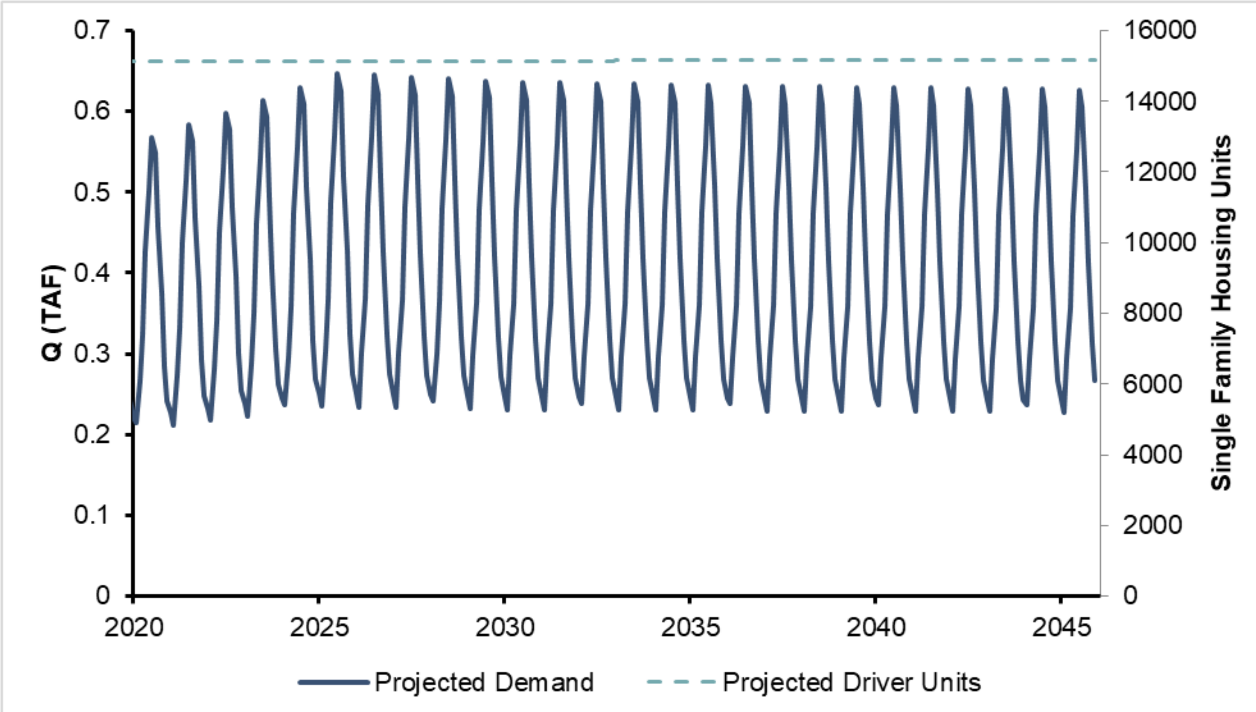

Figure L-6: City of Palo Alto Single Family Residential Demand Projection

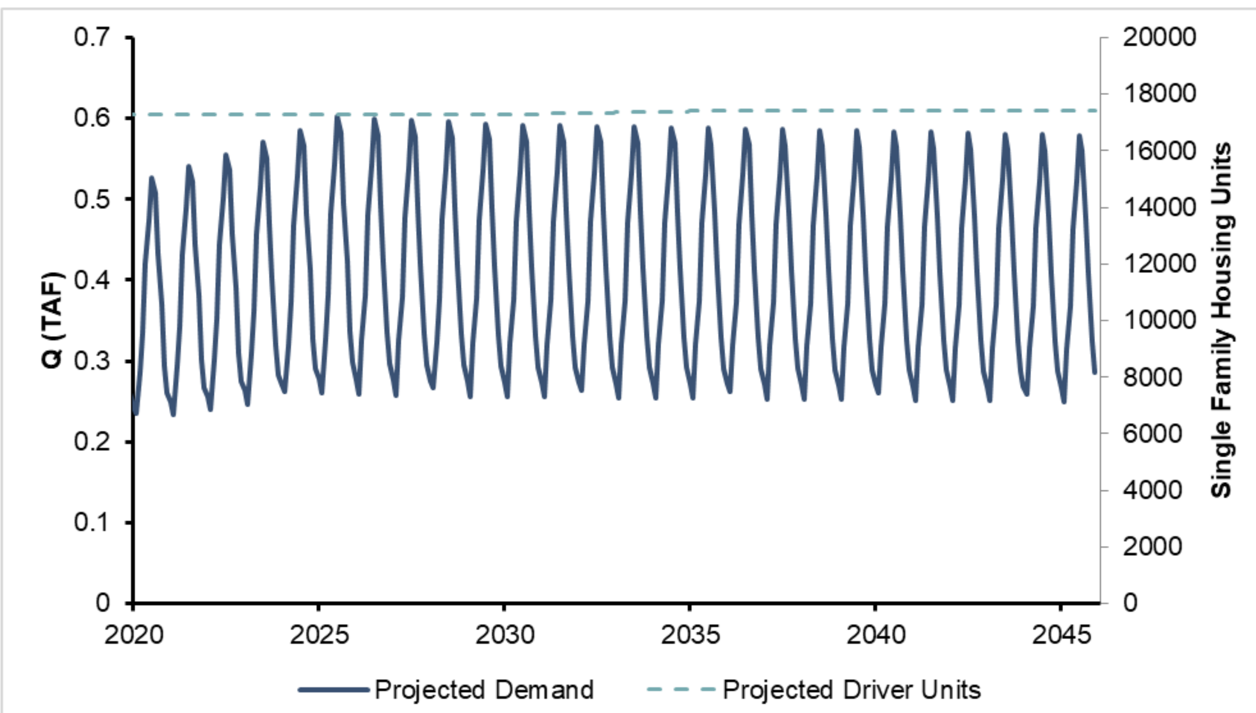

Figure L-7: City of Santa Clara Single Family Residential Demand Projection

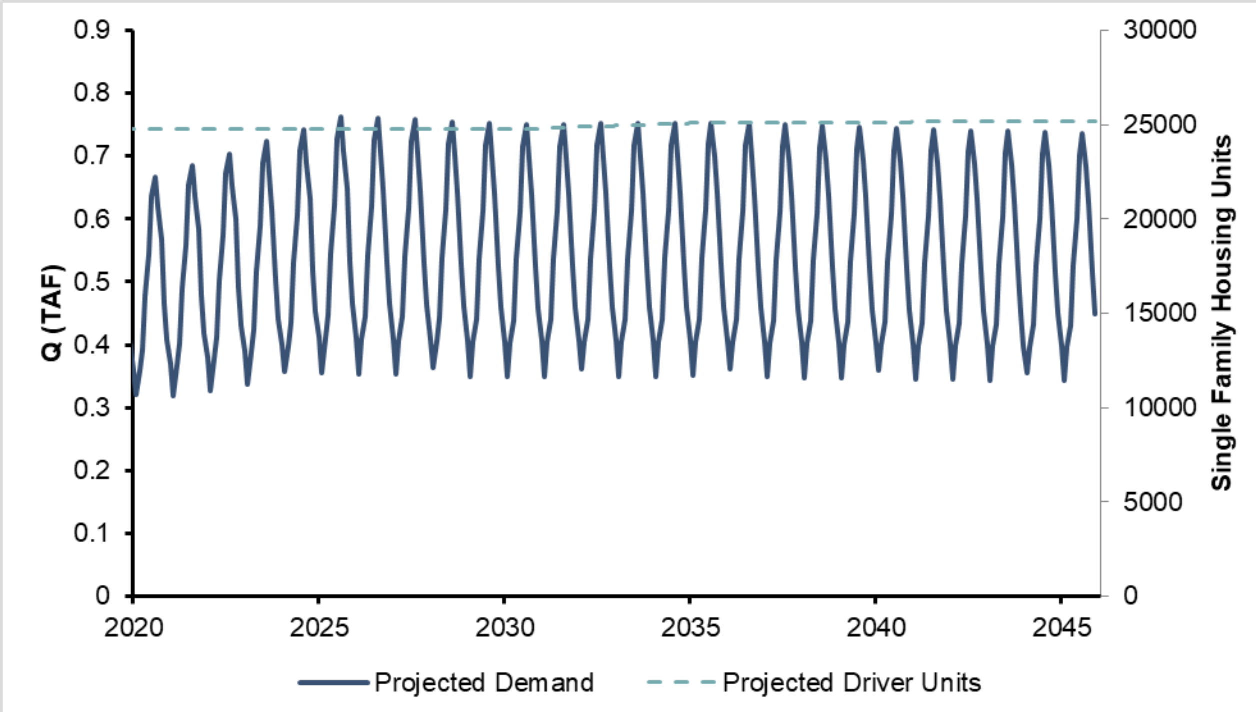

Figure L-8: City of Sunnyvale Single Family Residential Demand Projection

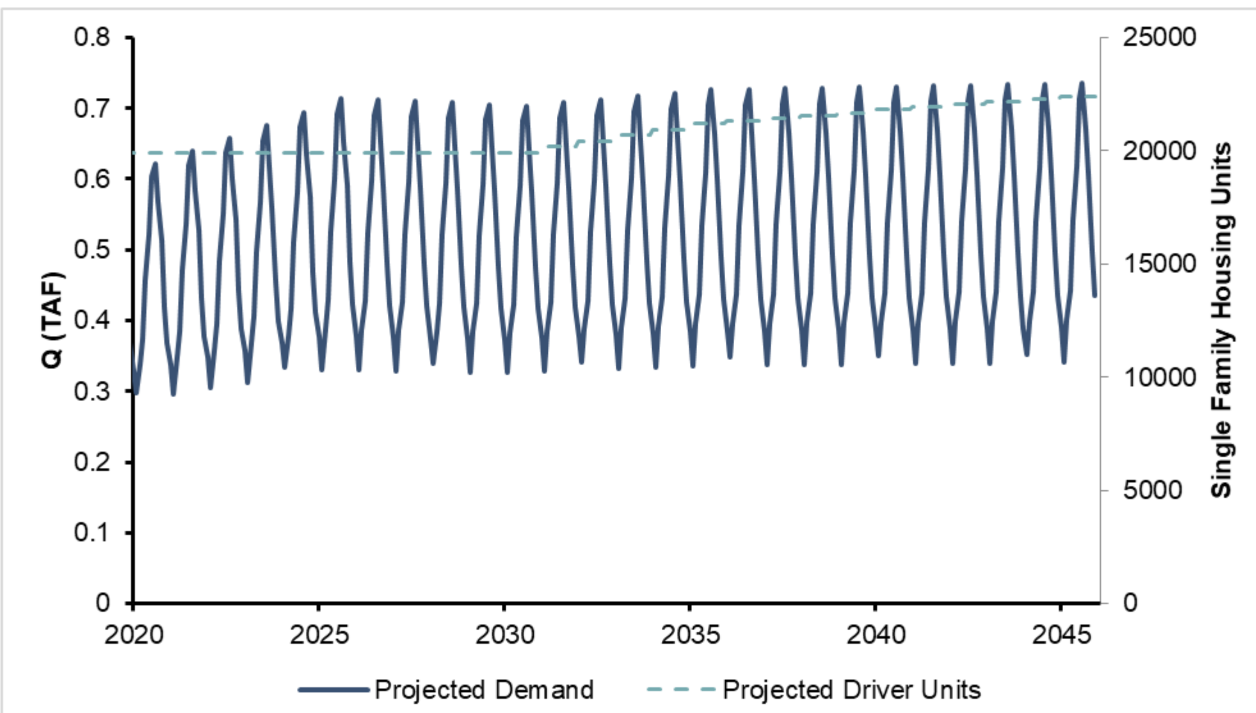

Figure L-9: Great Oaks Water Company Single Family Residential Demand Projection

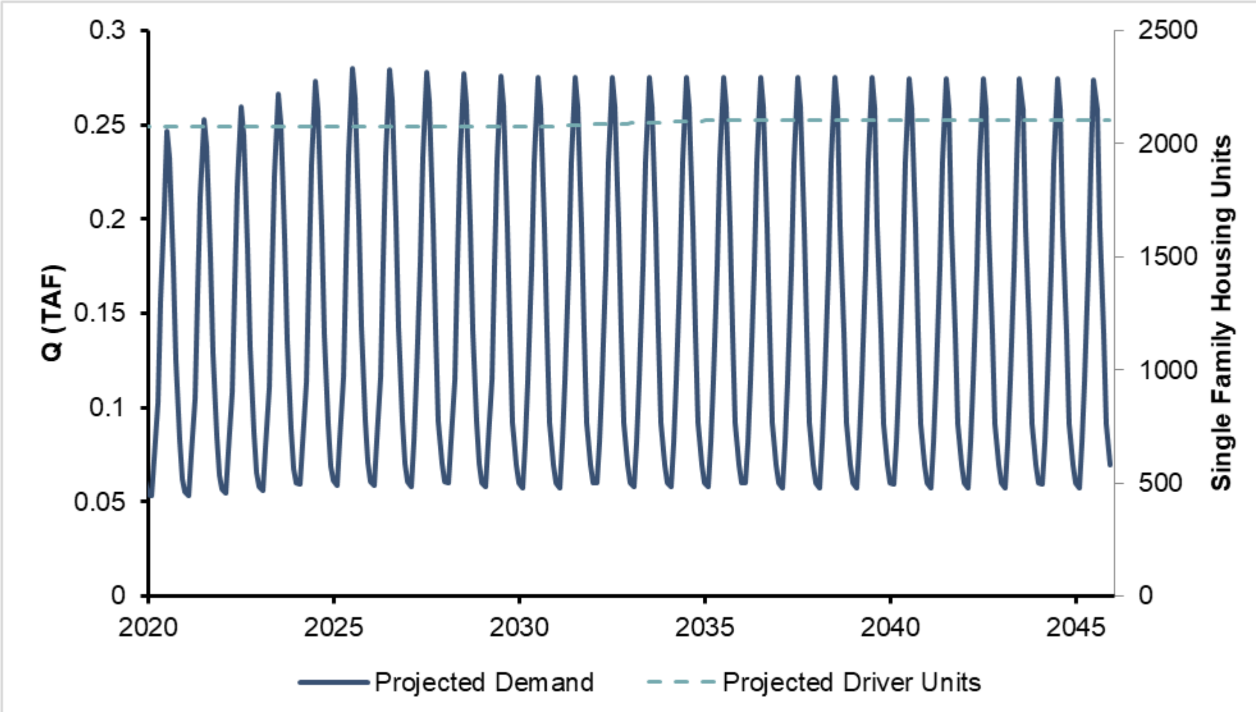

Figure L-10: Purissima Hills Water District Single Family Residential Demand Projection

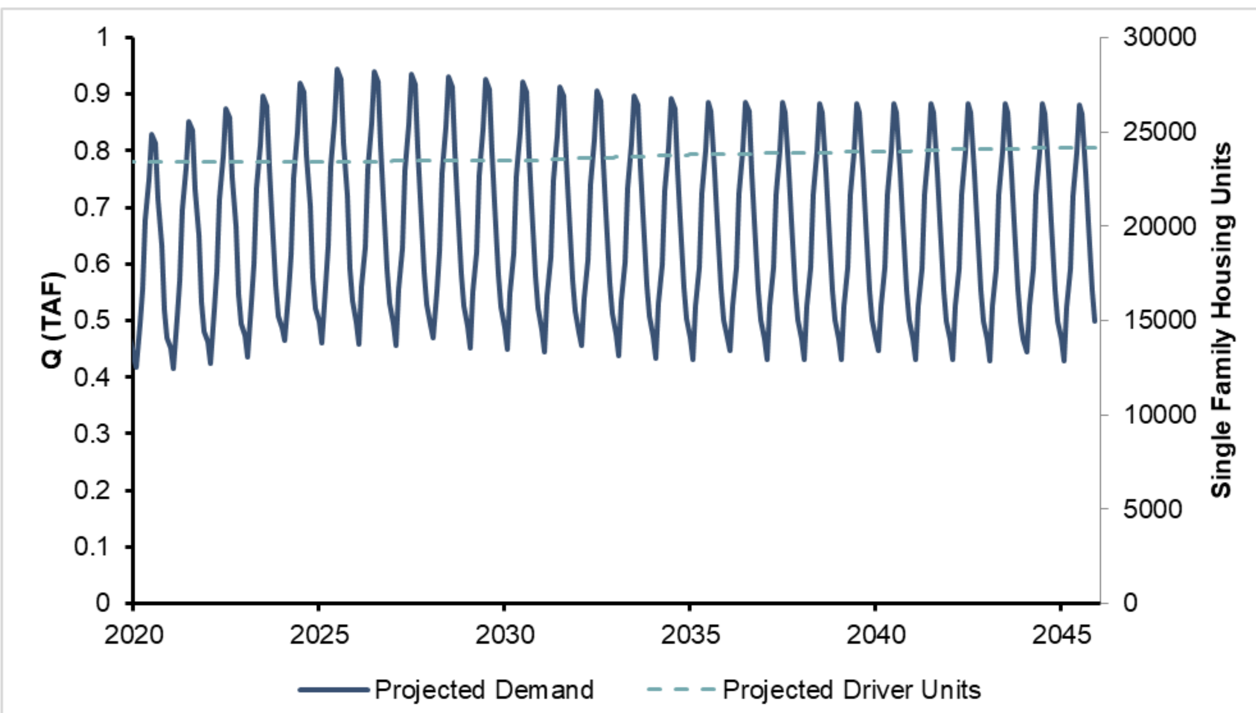

Figure L-11: San Jose Municipal Water Single Family Residential Demand Projection

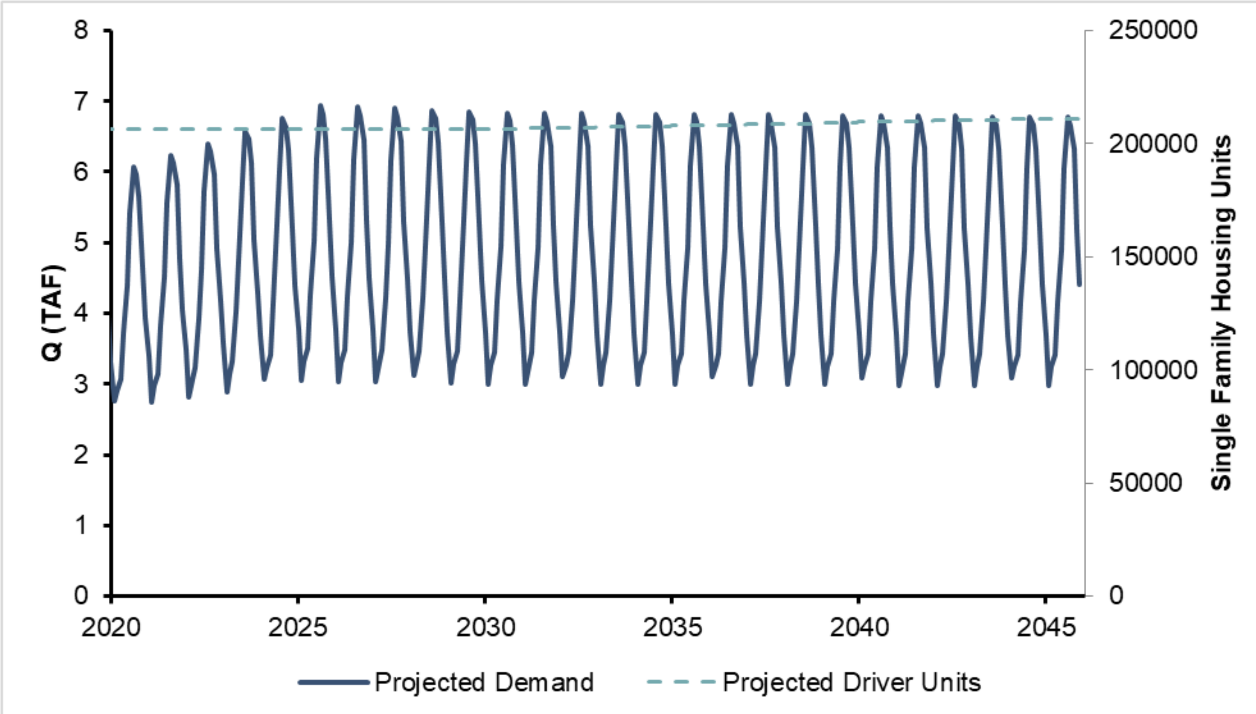

Figure L-12: San Jose Water Company Single Family Residential Demand Projection

Appendix M: Projected Multifamily Residential Demand by Retailer

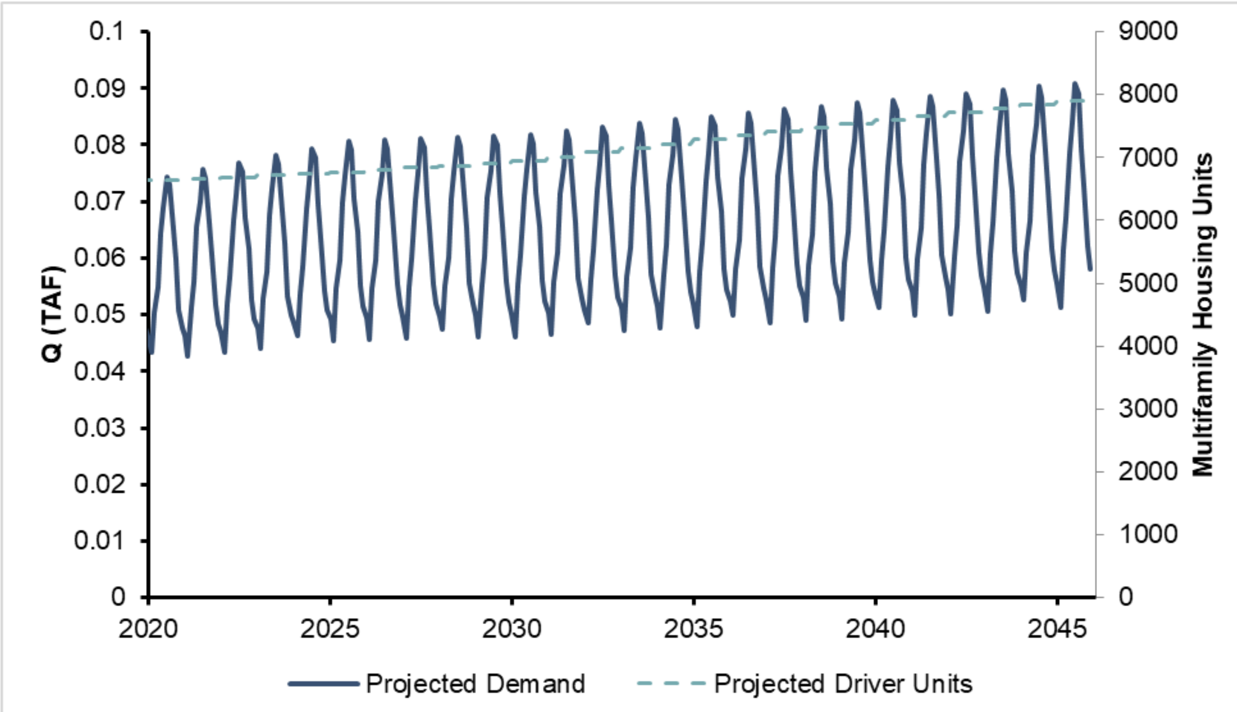

Figure M-1: California Water Service Multifamily Residential Demand Projection

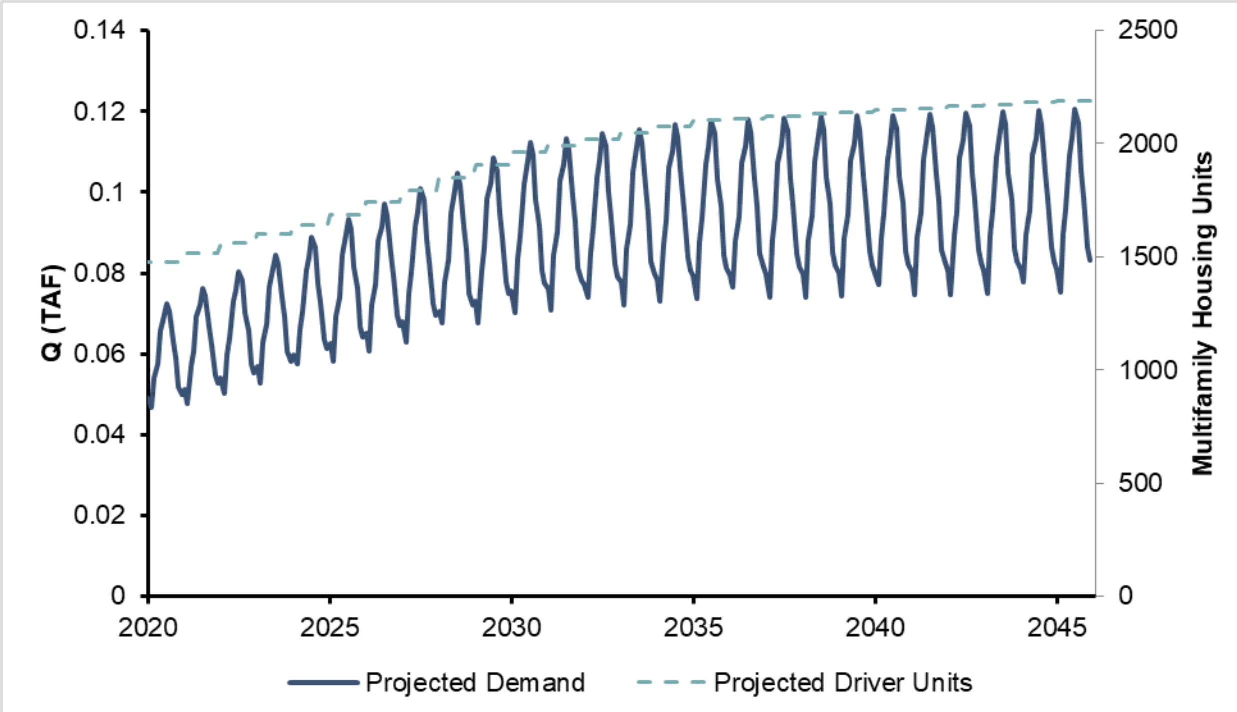

Figure M-2: City of Gilroy Multifamily Residential Demand Projection

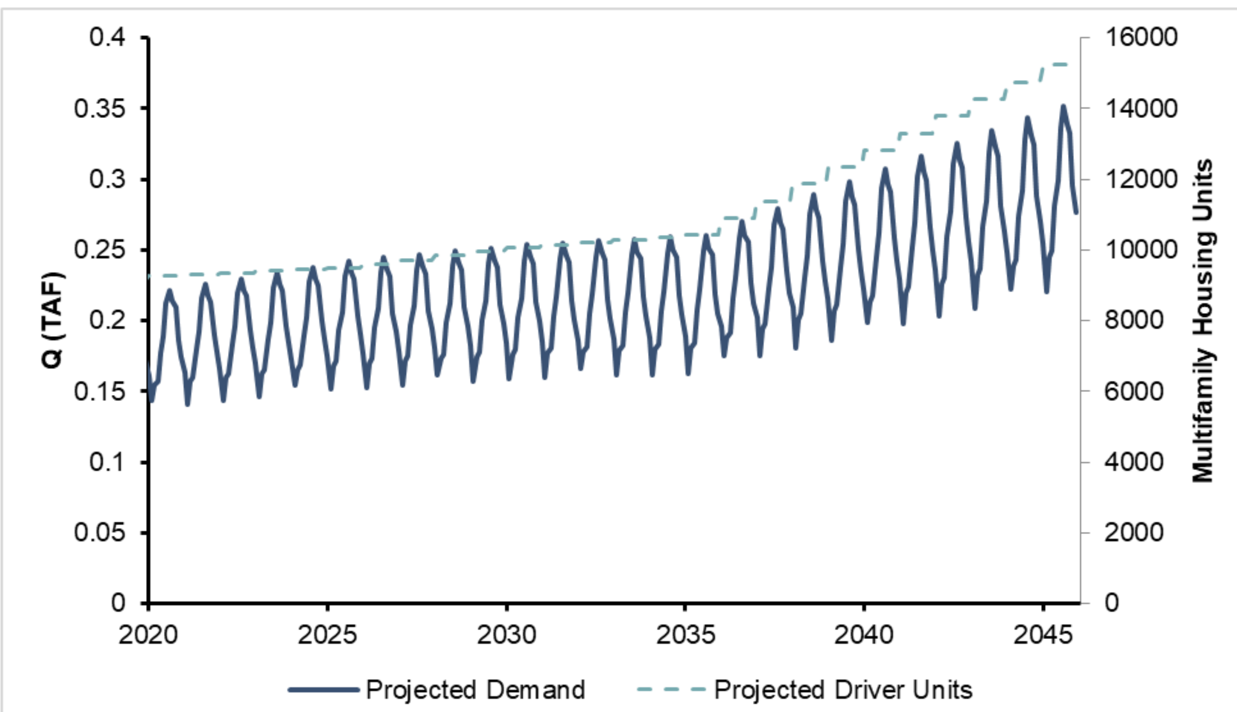

Figure M-3: City of Milpitas Multifamily Residential Demand Projection.

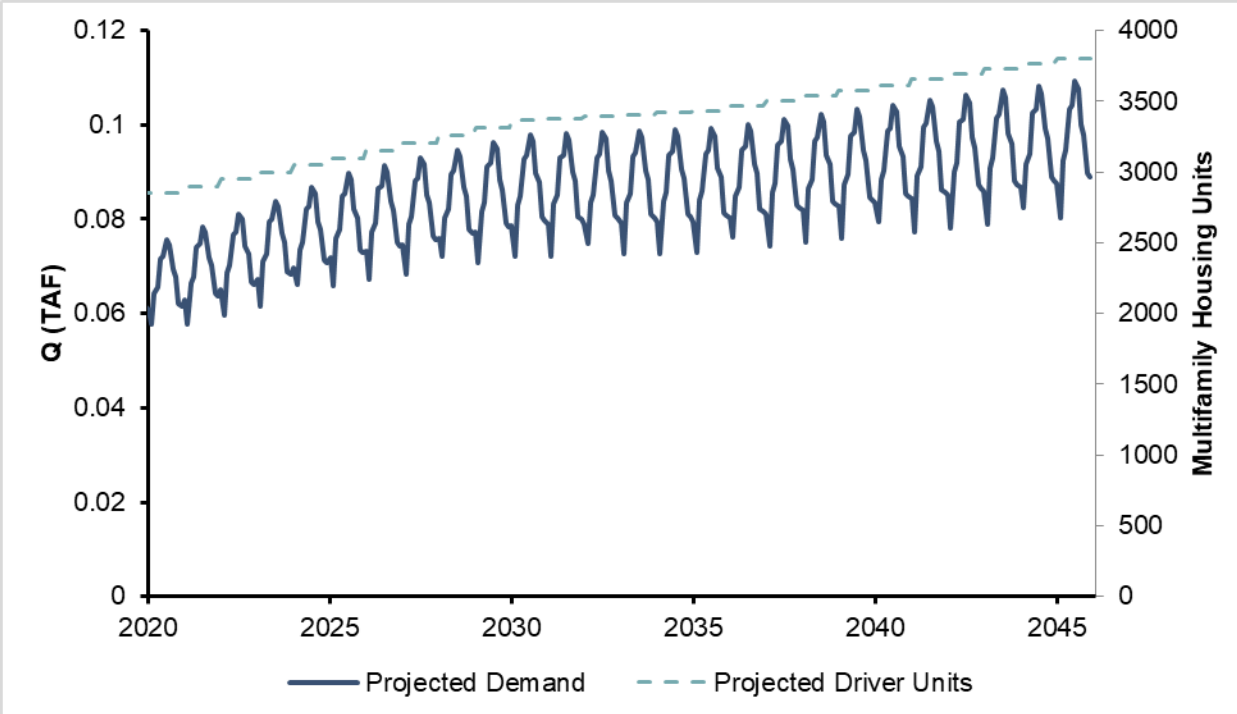

Figure M-4: City of Morgan Hill Multifamily Residential Demand Projection

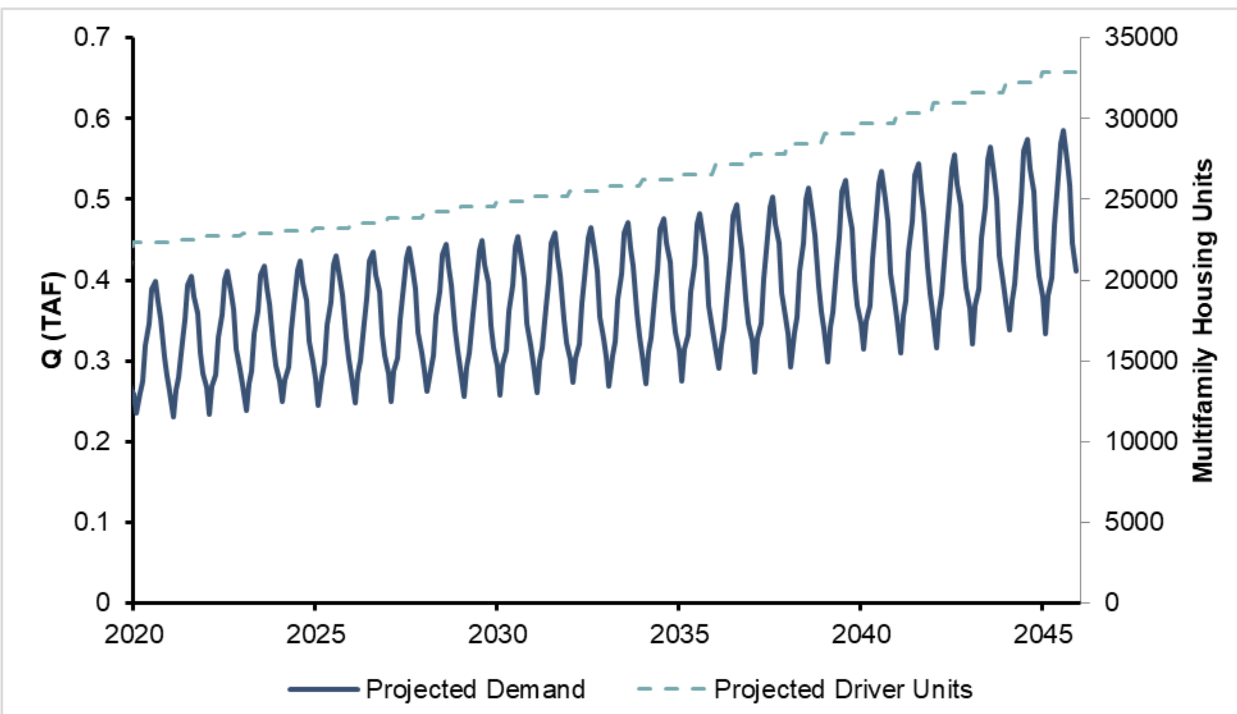

Figure M-5: City of Mountain View Multifamily Residential Demand Projection

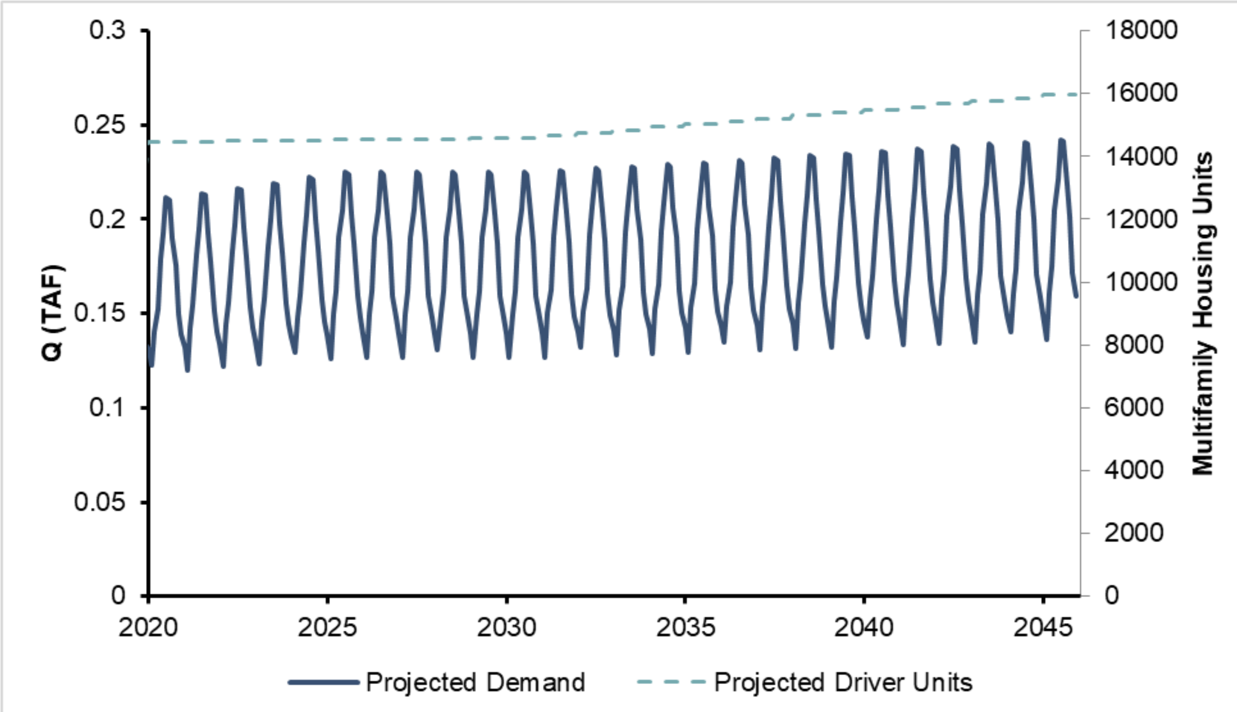

Figure M-6: City of Palo Alto Multifamily Residential Demand Projection

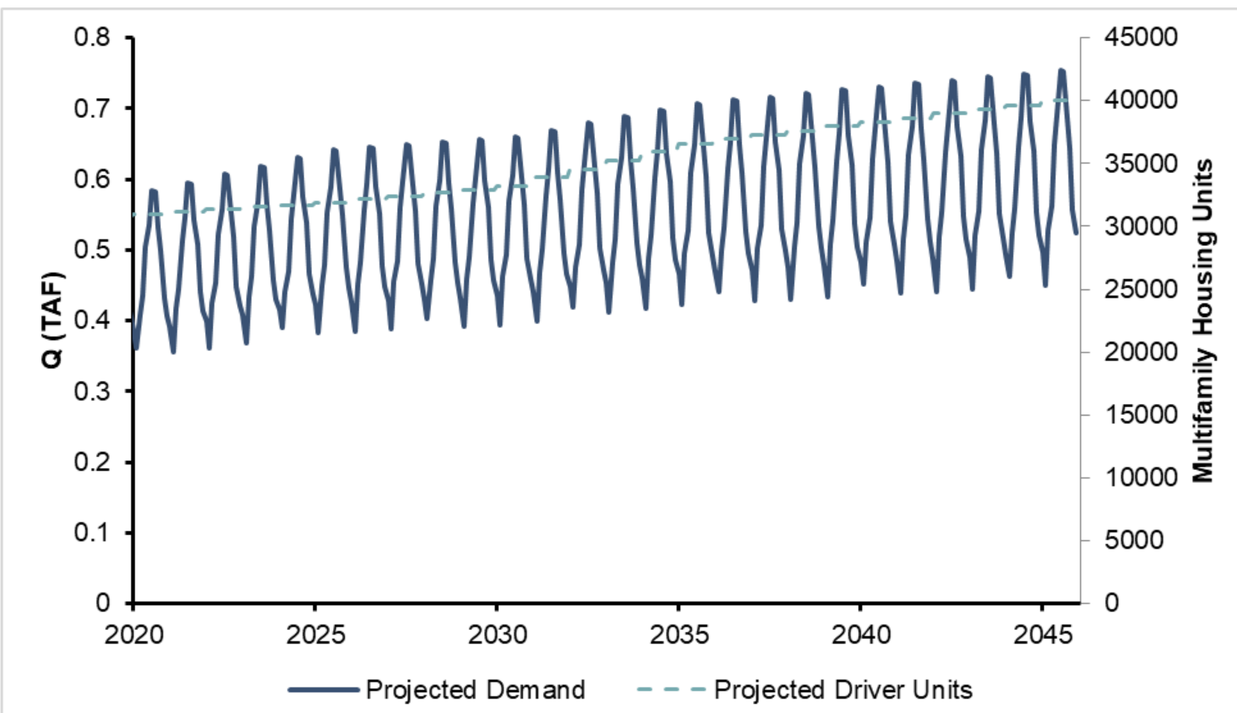

Figure M-7: City of Santa Clara Multifamily Residential Demand Projection

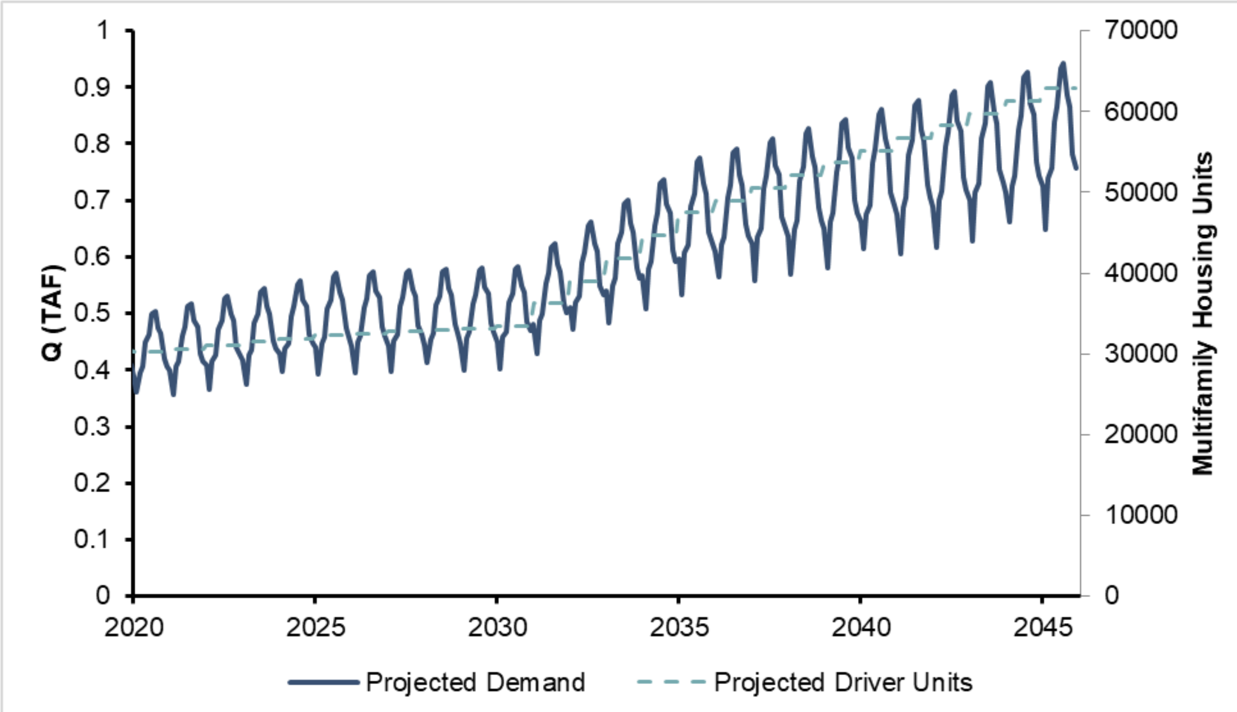

Figure M-8: City of Sunnyvale Multifamily Residential Demand Projection

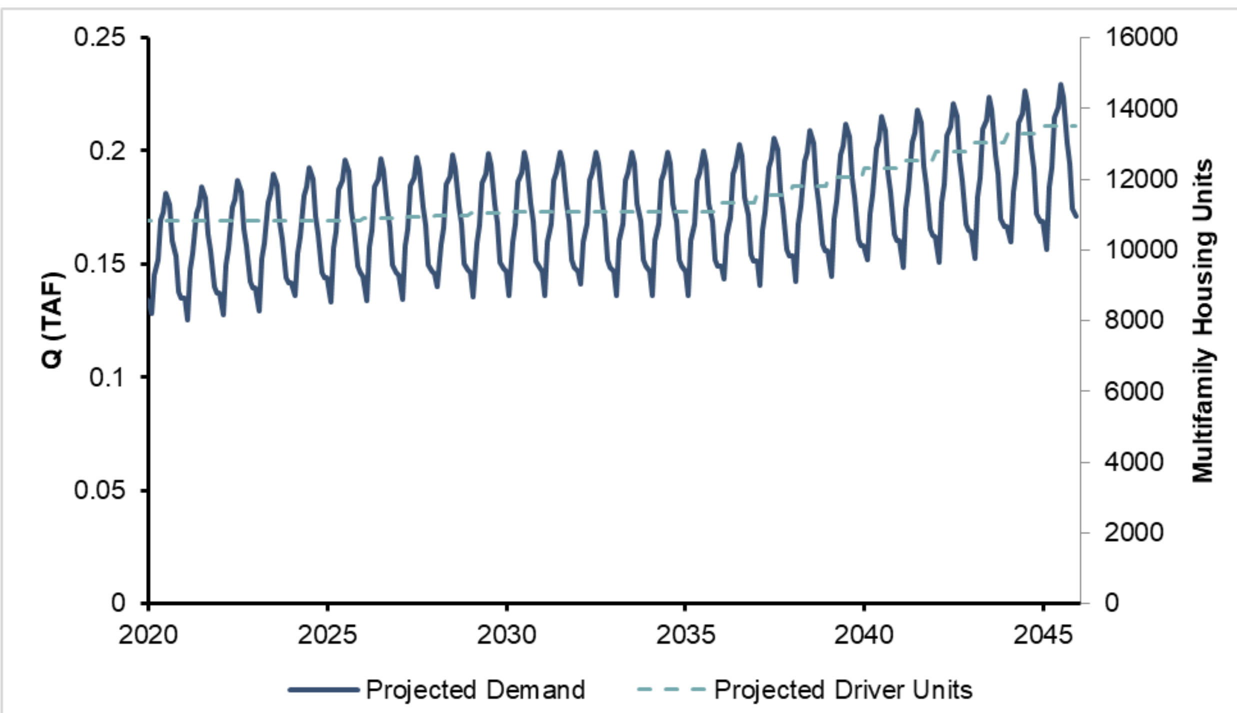

Figure M-9: Great Oaks Water Company Multifamily Residential Demand Projection

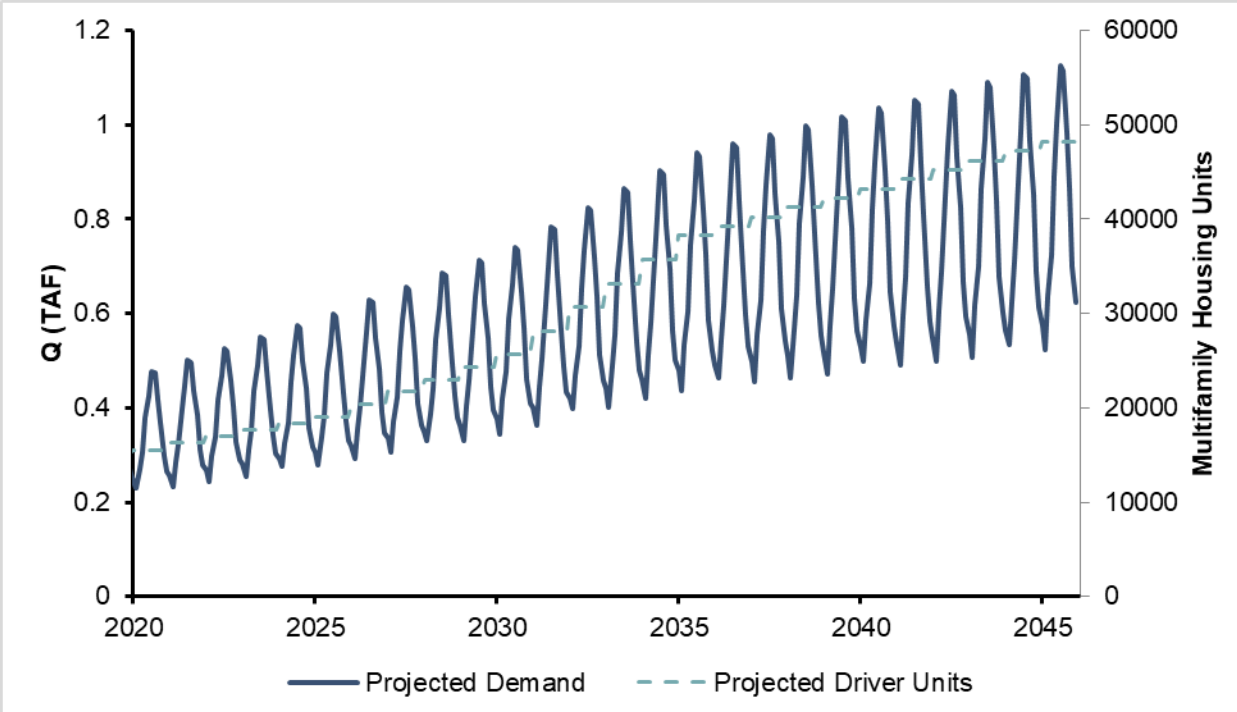

Figure M-10: San Jose Municipal Water Multifamily Residential Demand Projection

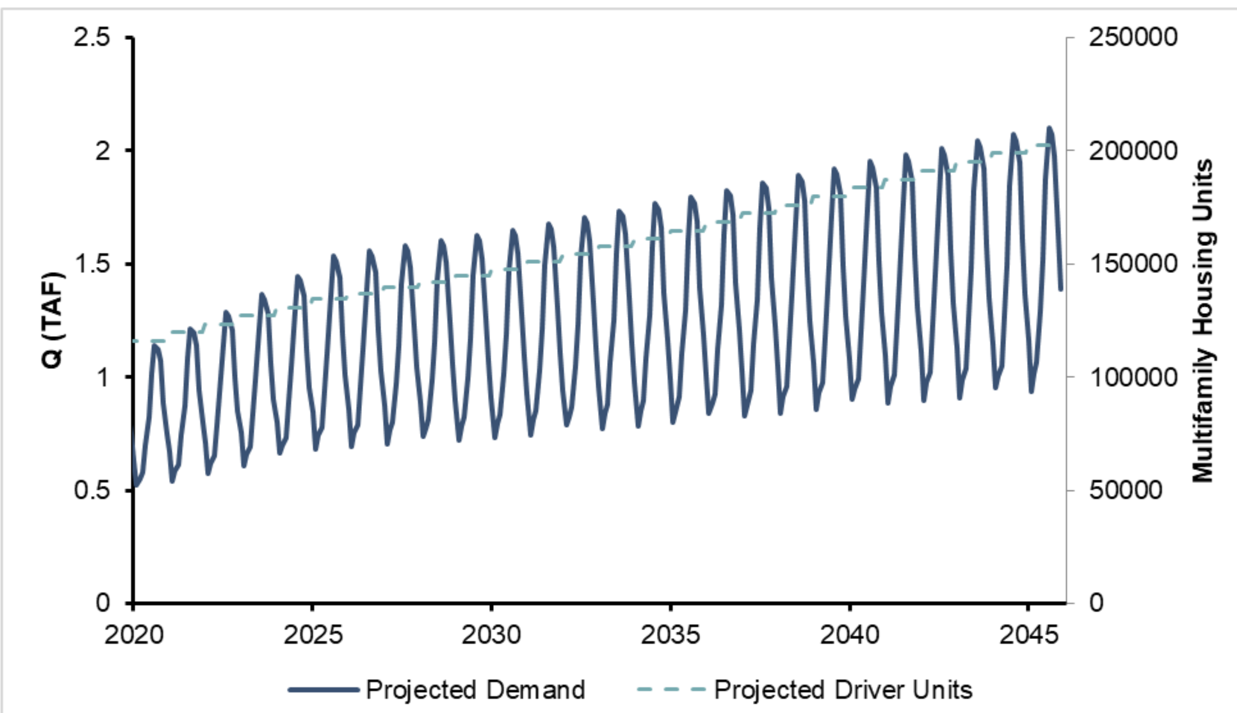

Figure M-11: San Jose Water Company Multifamily Residential Demand Projection

Appendix N: Projected CII Demand by Retailer

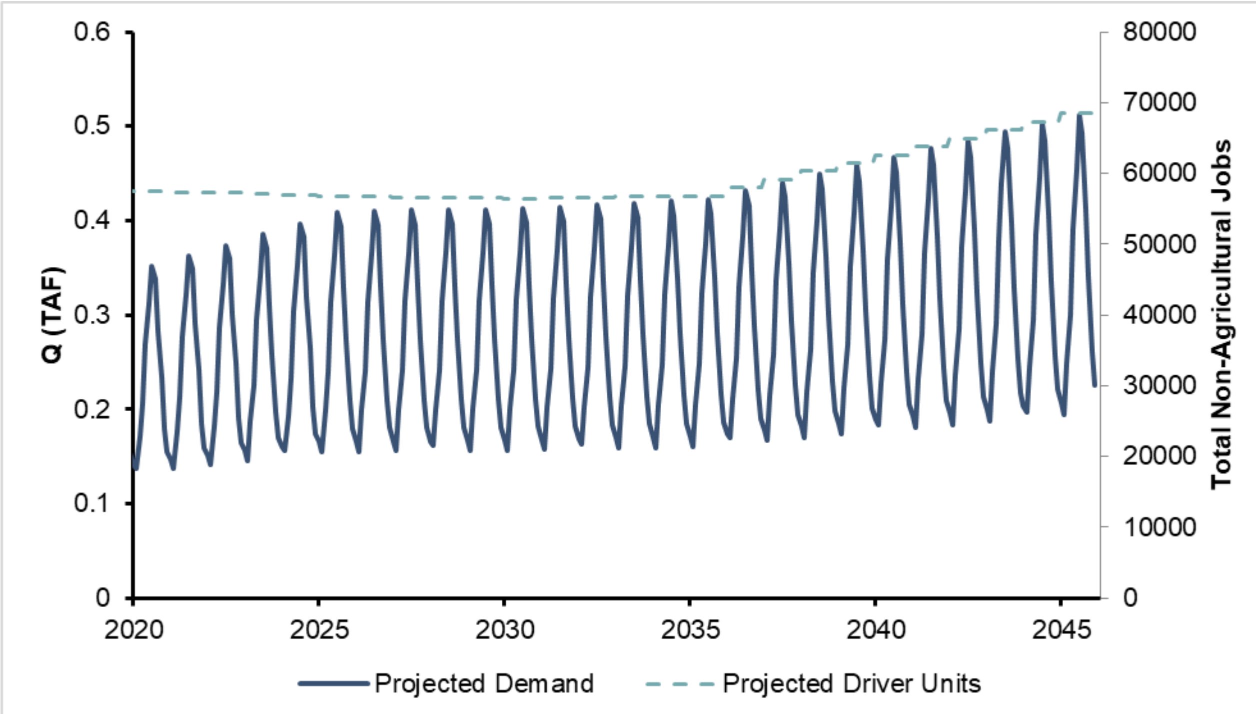

Figure N-1: California Water Service CII Demand Projection

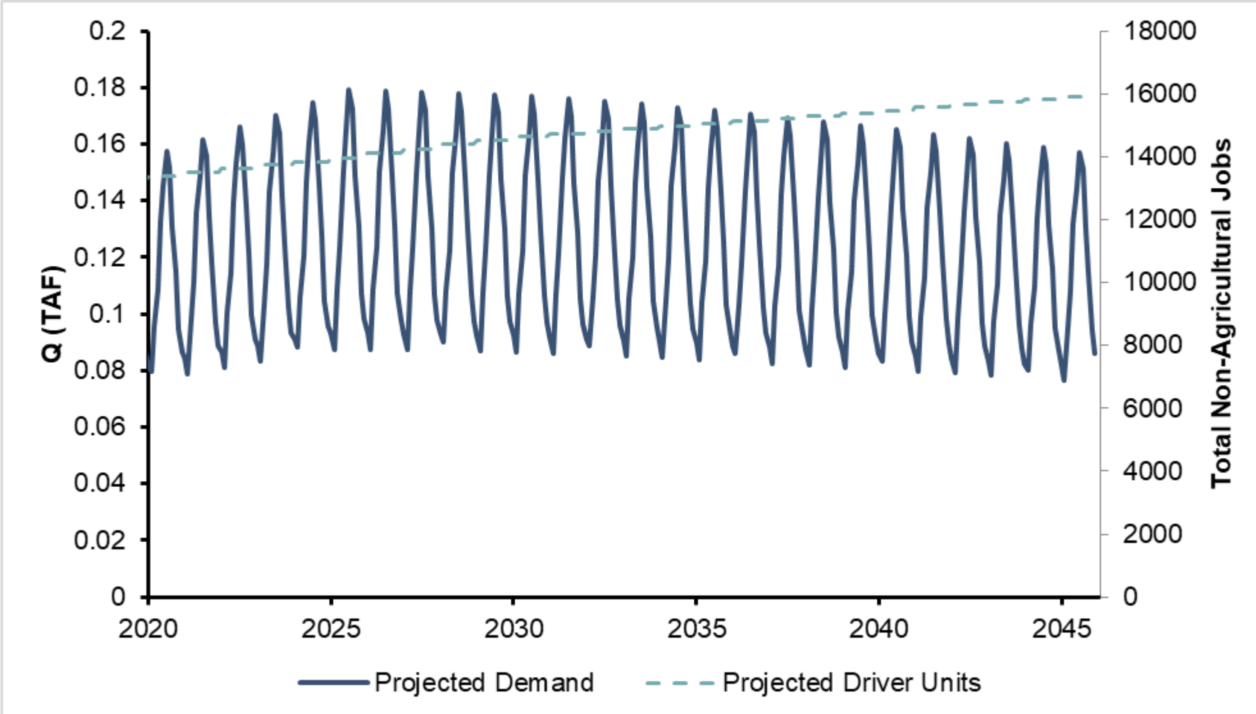

Figure N-2: City of Gilroy CII Demand Projection

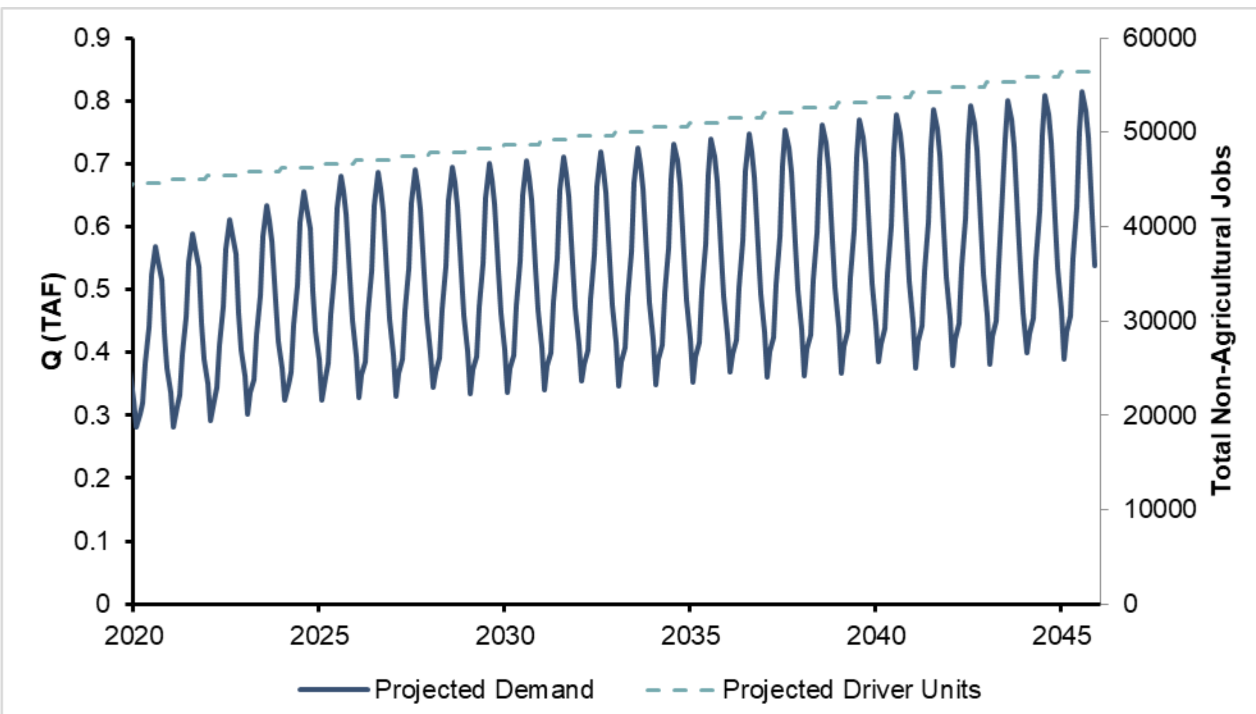

Figure N-3: City of Milpitas CII Demand Projection.

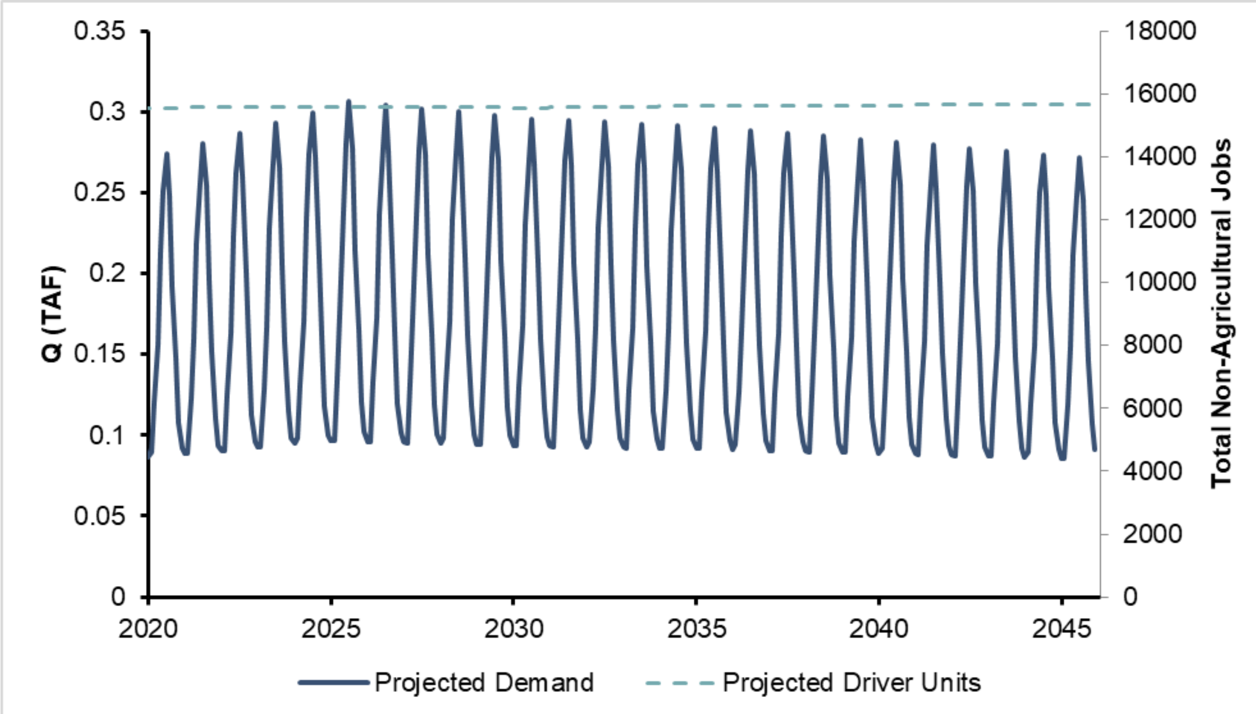

Figure N-4: City of Morgan Hill CII Demand Projection

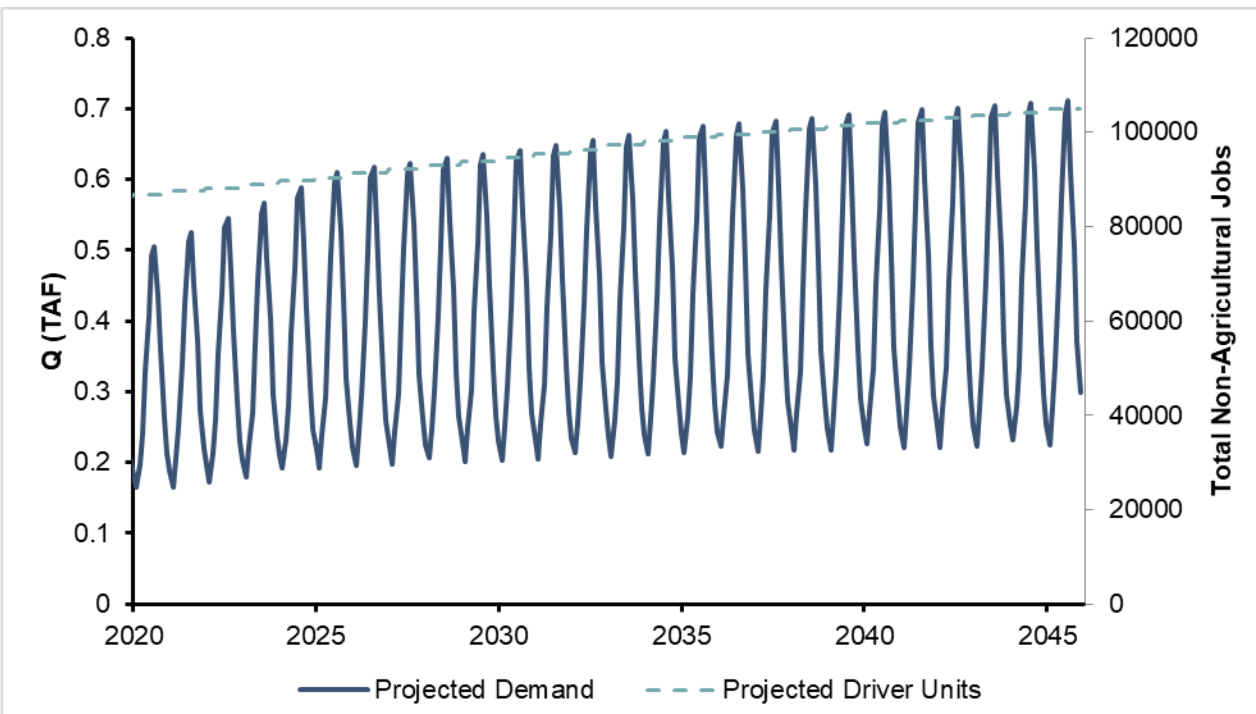

Figure N-5: City of Mountain View CII Demand Projection

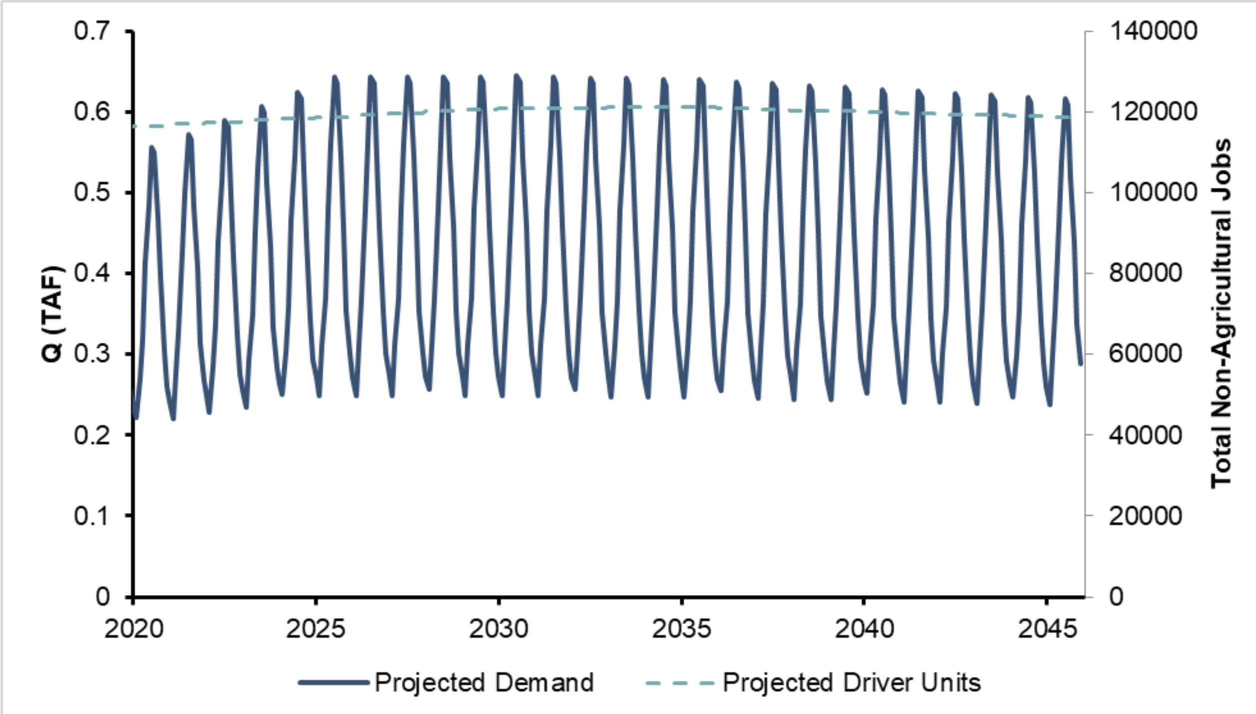

Figure N-6: City of Palo Alto CII Demand Projection

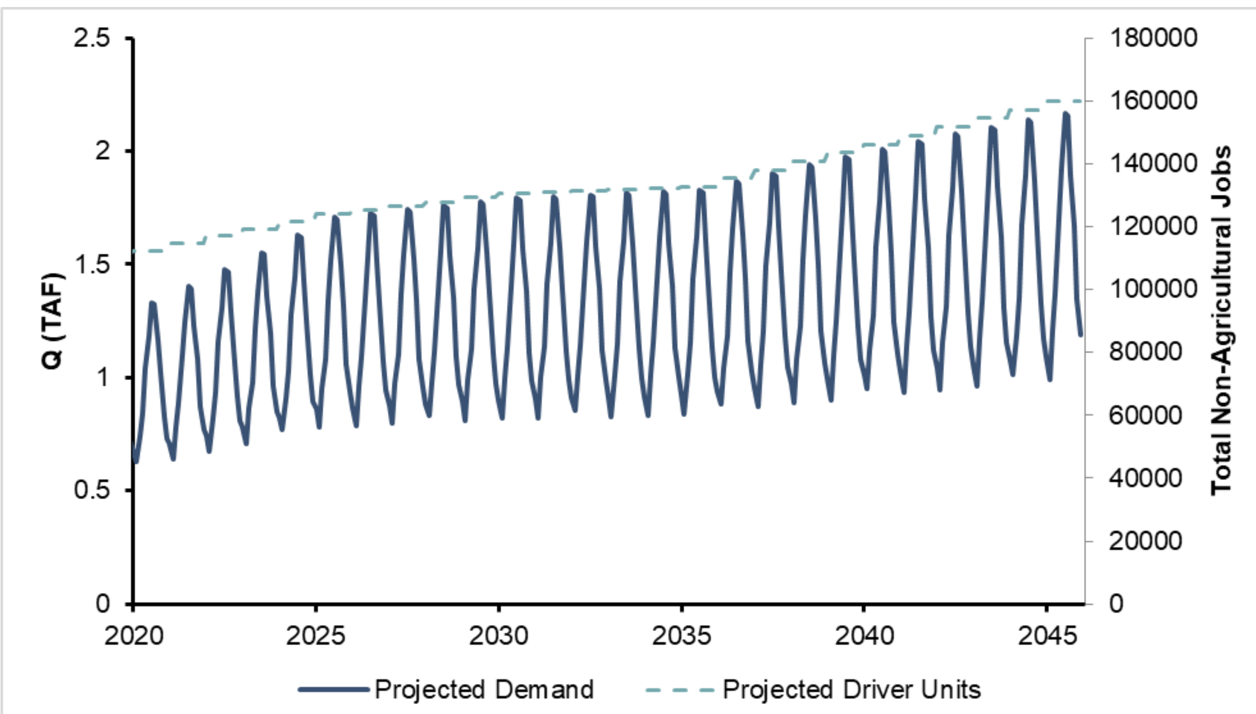

Figure N-7: City of Santa Clara CII Demand Projection

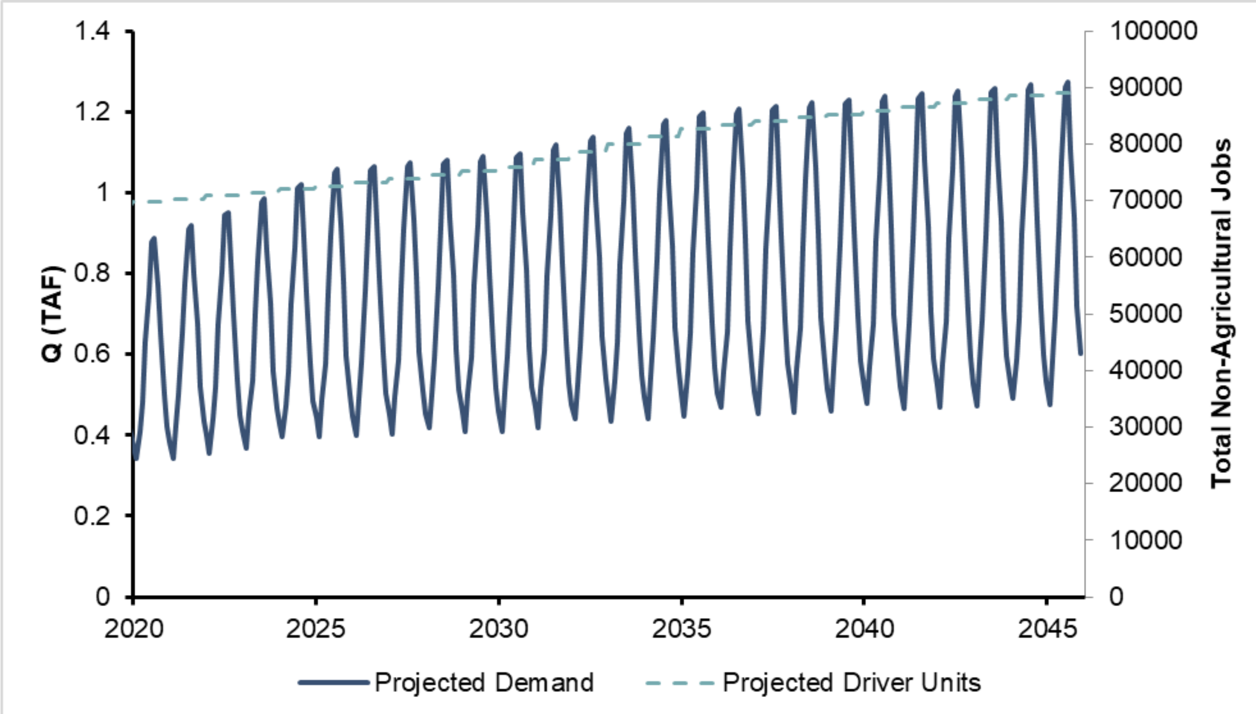

Figure N-8: City of Sunnyvale CII Demand Projection

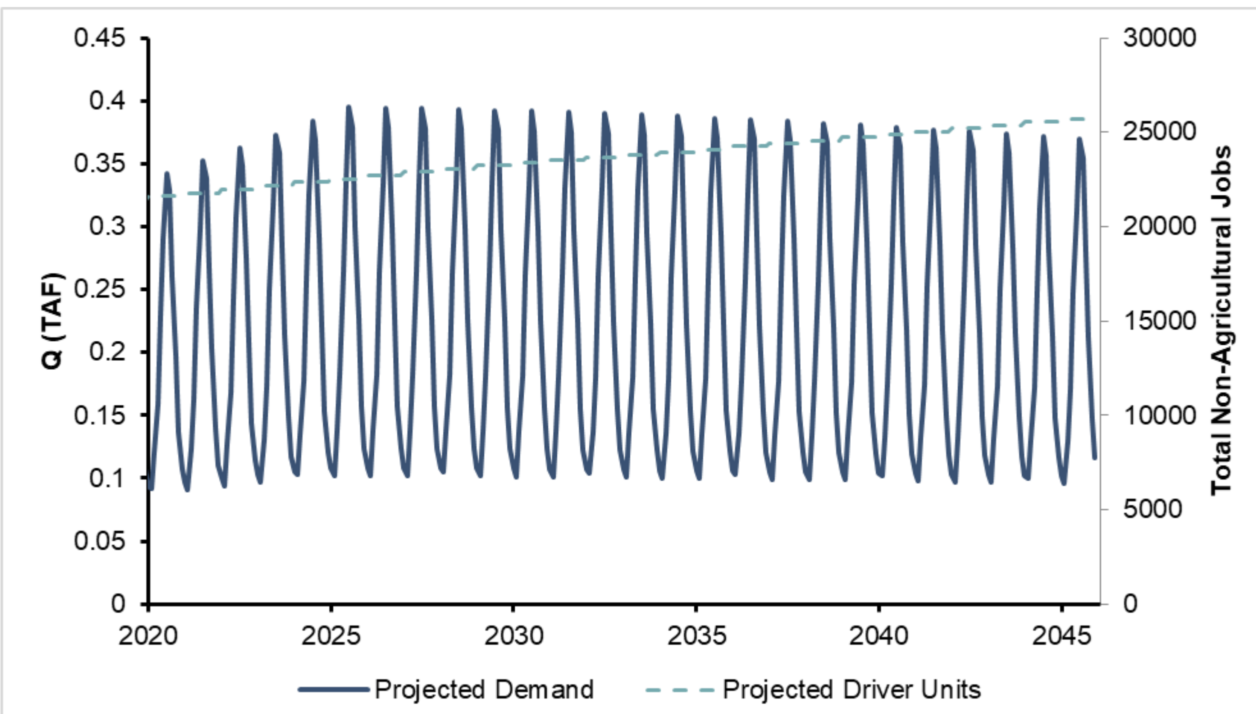

Figure N-9: Great Oaks Water Company CII Demand Projection

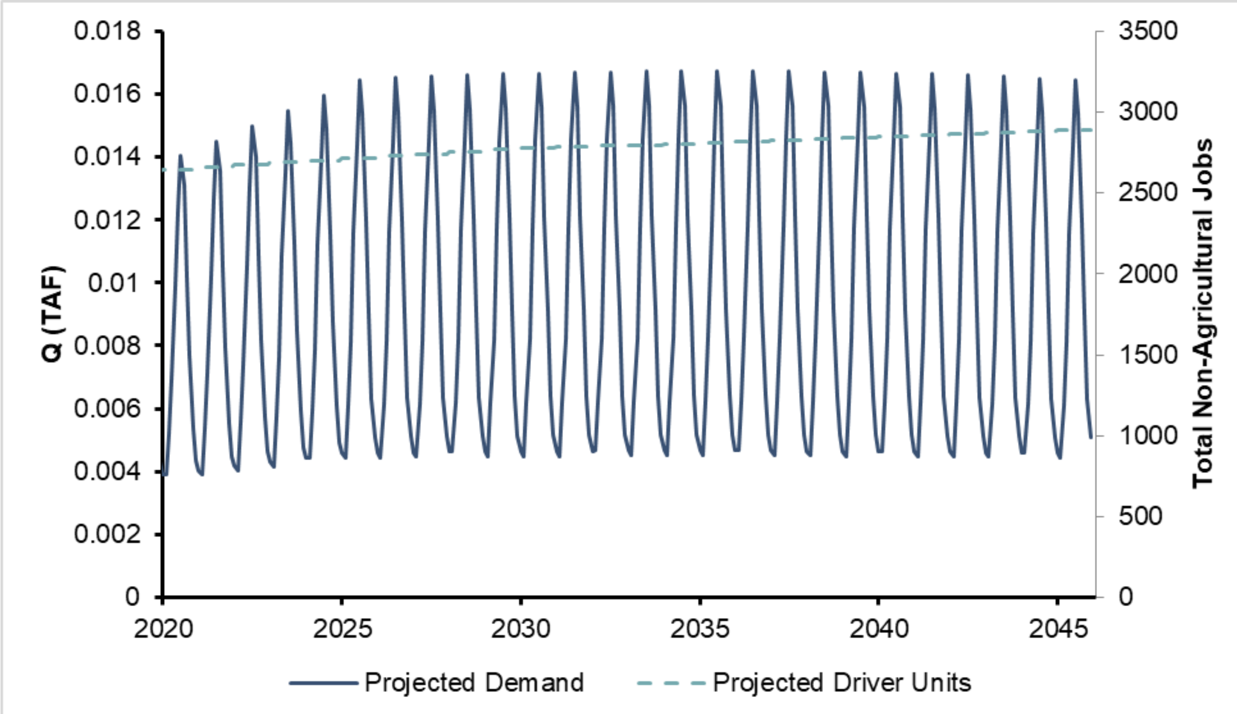

Figure N-10: Purissima Hills Water District CII Demand Projection

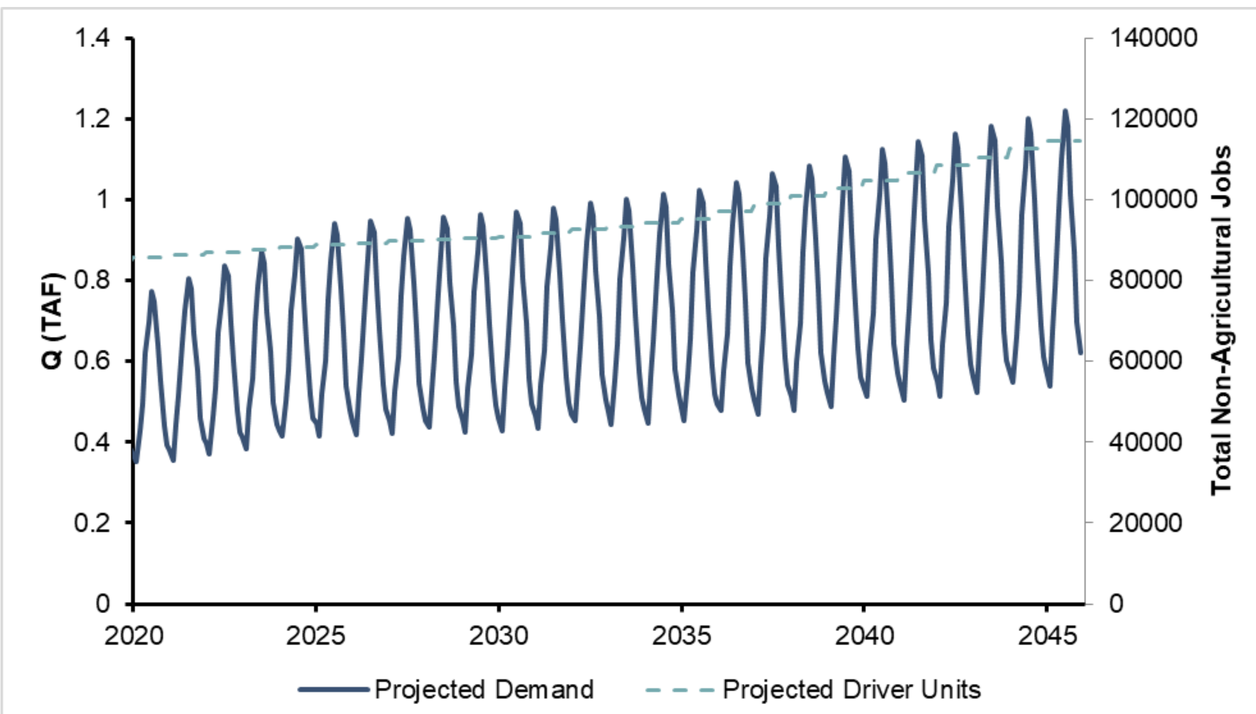

Figure N-11: San Jose Municipal Water CII Demand Projection

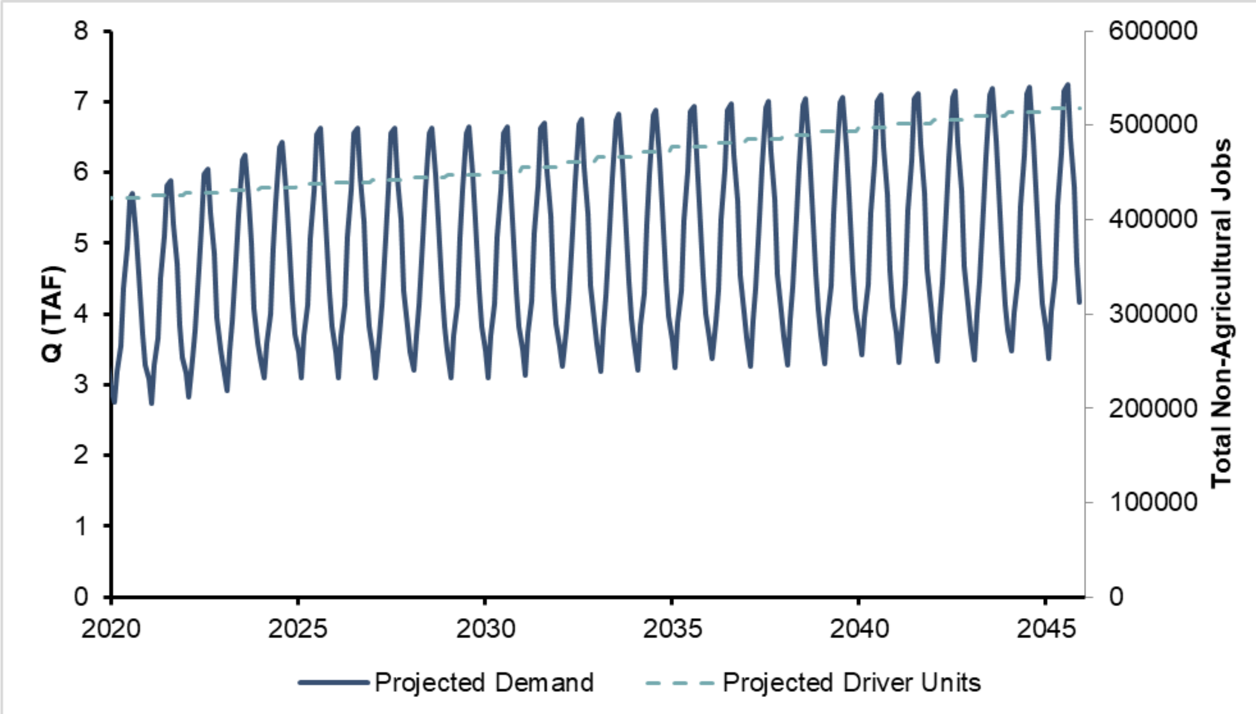

Figure N-12: San Jose Water Company CII Demand Projection

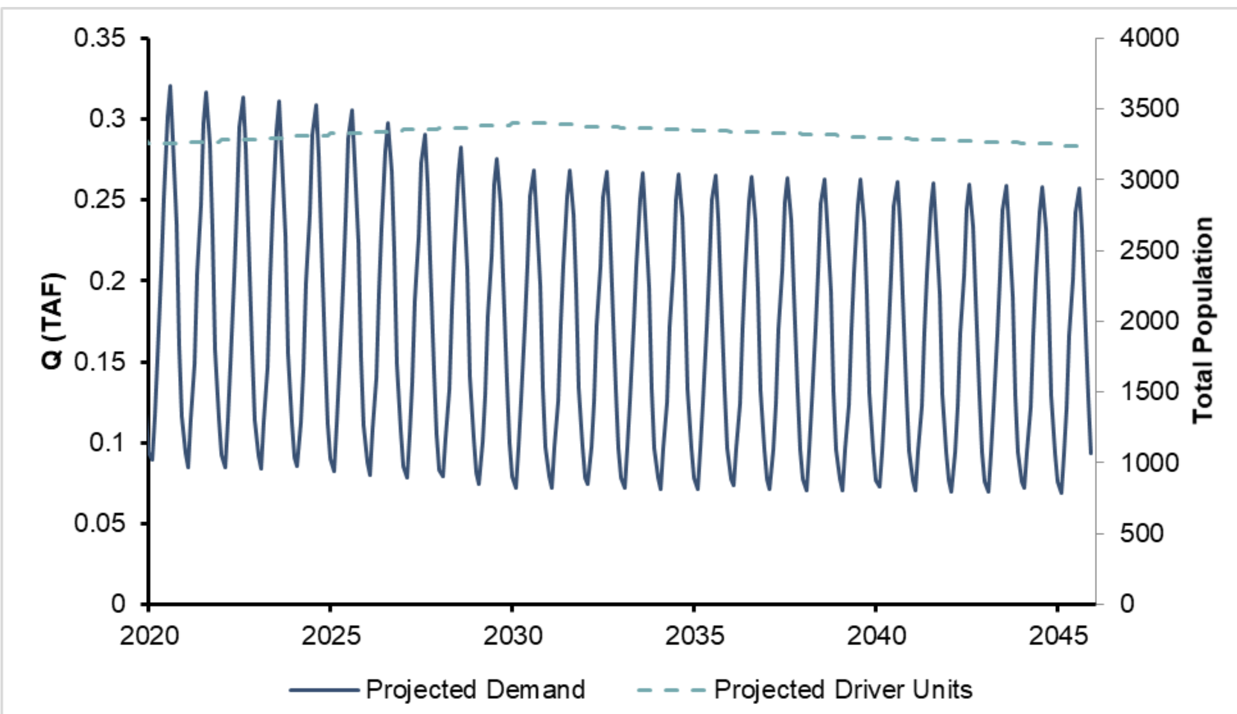

Figure N-13: Stanford University CII Demand Projection

Appendix O: Projected Non-Retail Groundwater Pumpers Demand

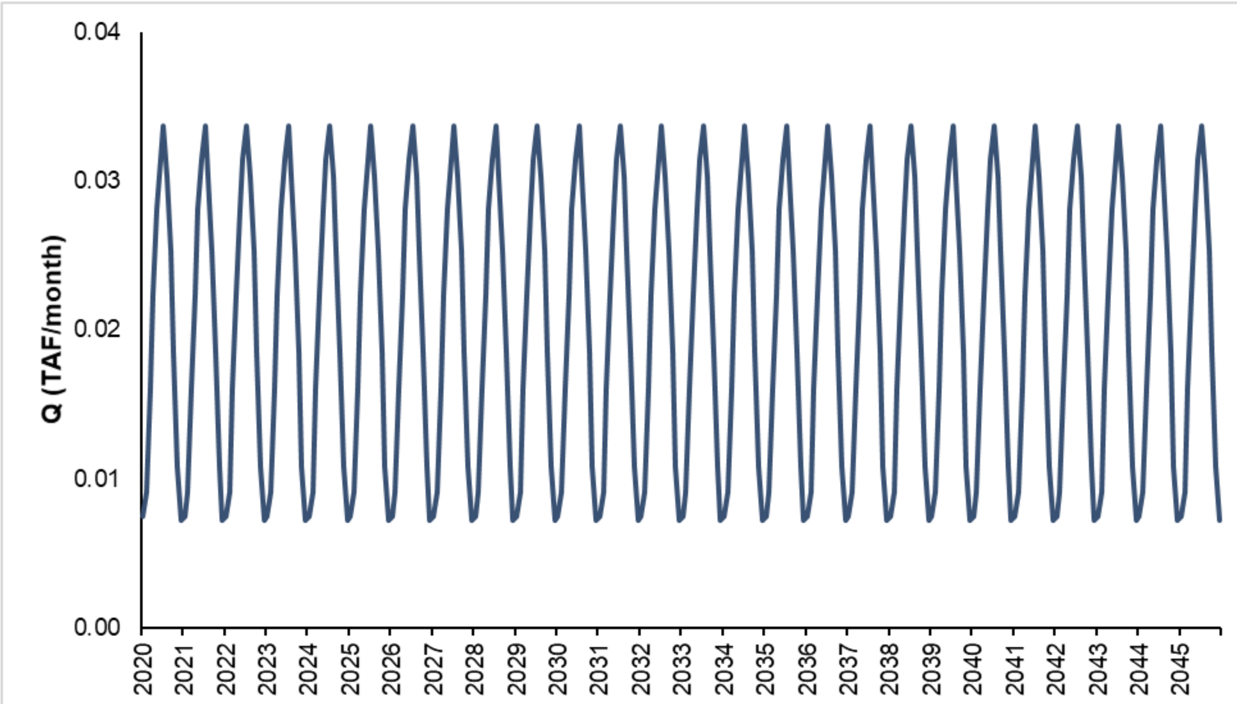

Figure O-1: Agricultural Non-Retail Pumpers Demand Projection in W2 Charge Zone

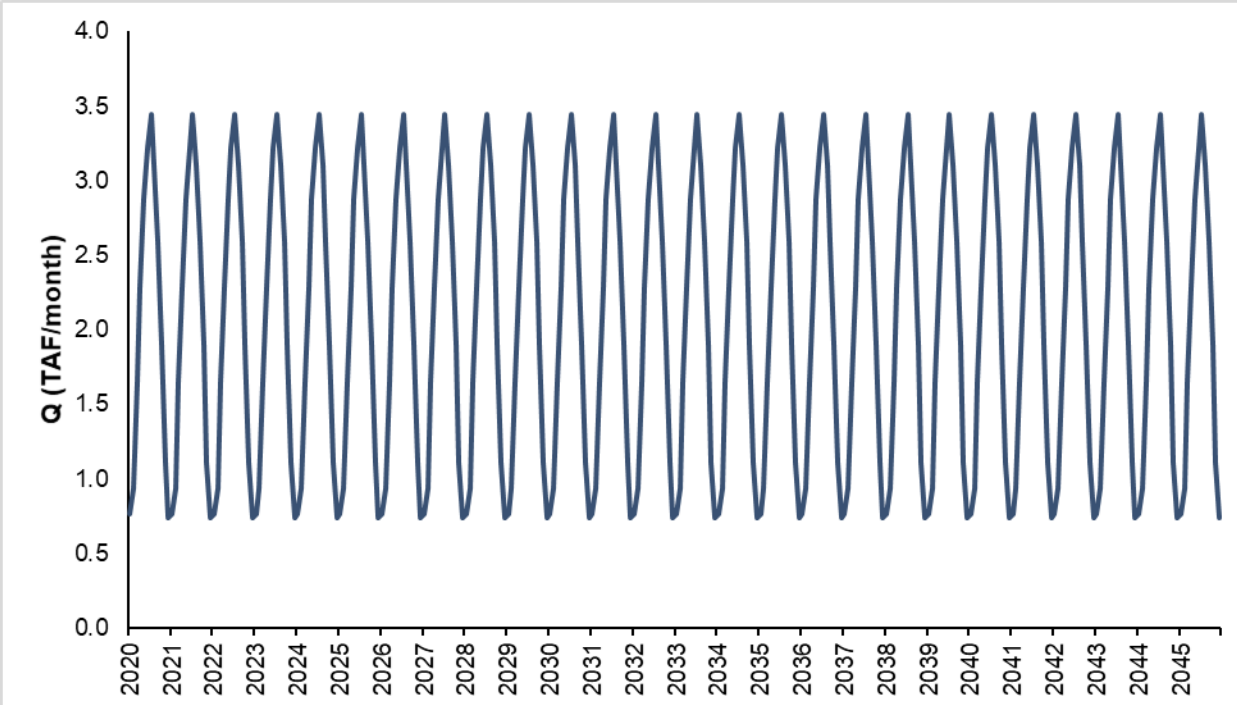

Figure O-2: Agricultural Non-Retail Pumpers Demand Projection in Modified W5 Charge Zone

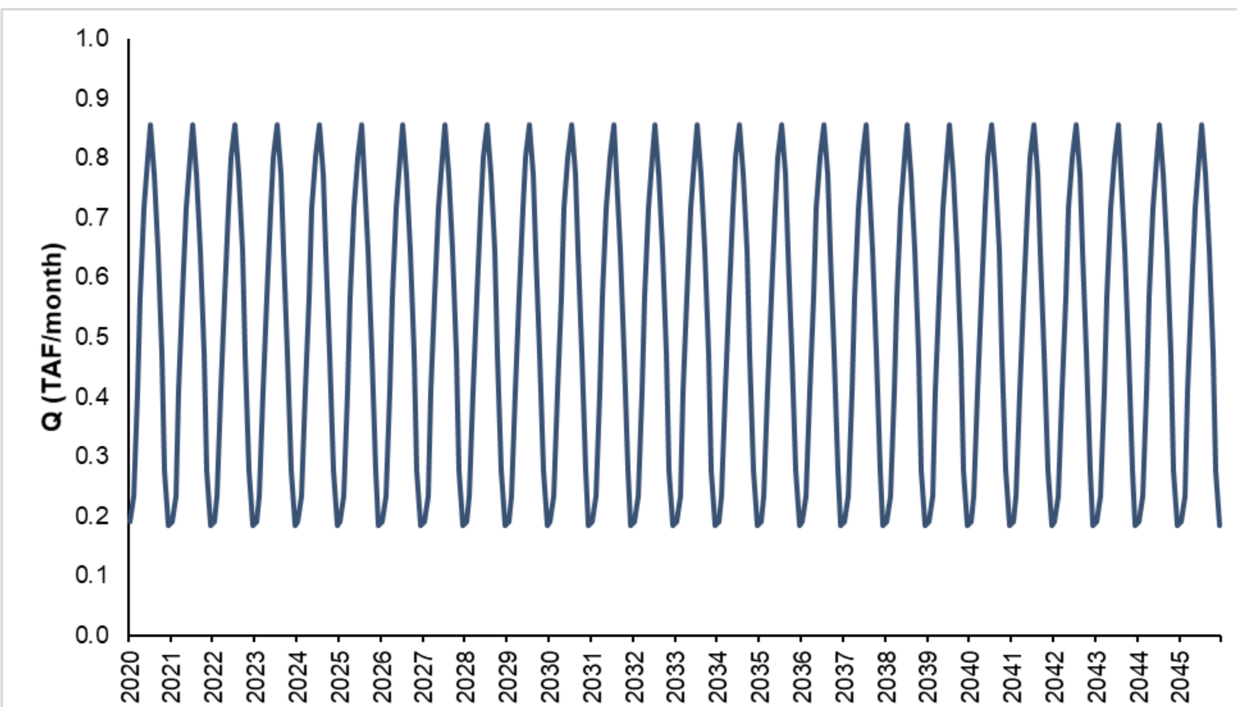

Figure O-3: Agricultural Non-Retail Pumpers Demand Projection in New W7 Charge Zone

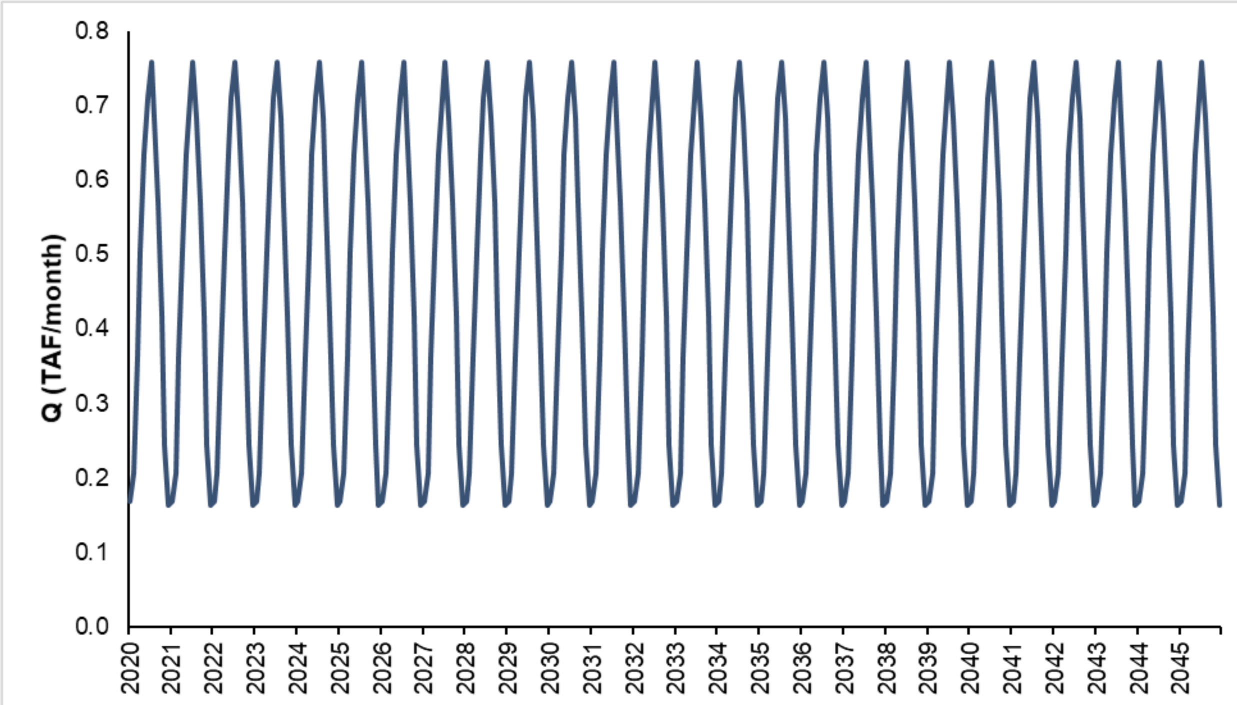

Figure O-4: M&I Non-Retail Pumpers Demand Projection in W2 Charge Zone

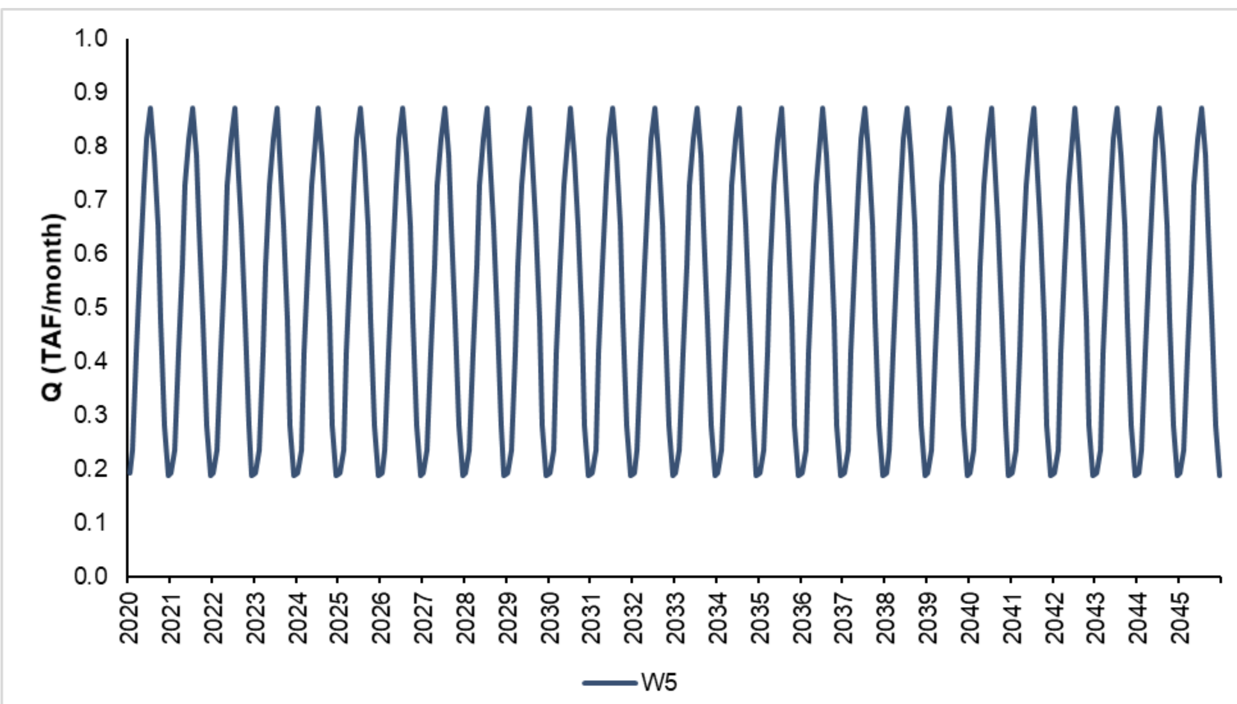

Figure O-5: M&I Non-Retail Pumpers Demand Projection in Modified W5 Charge Zone

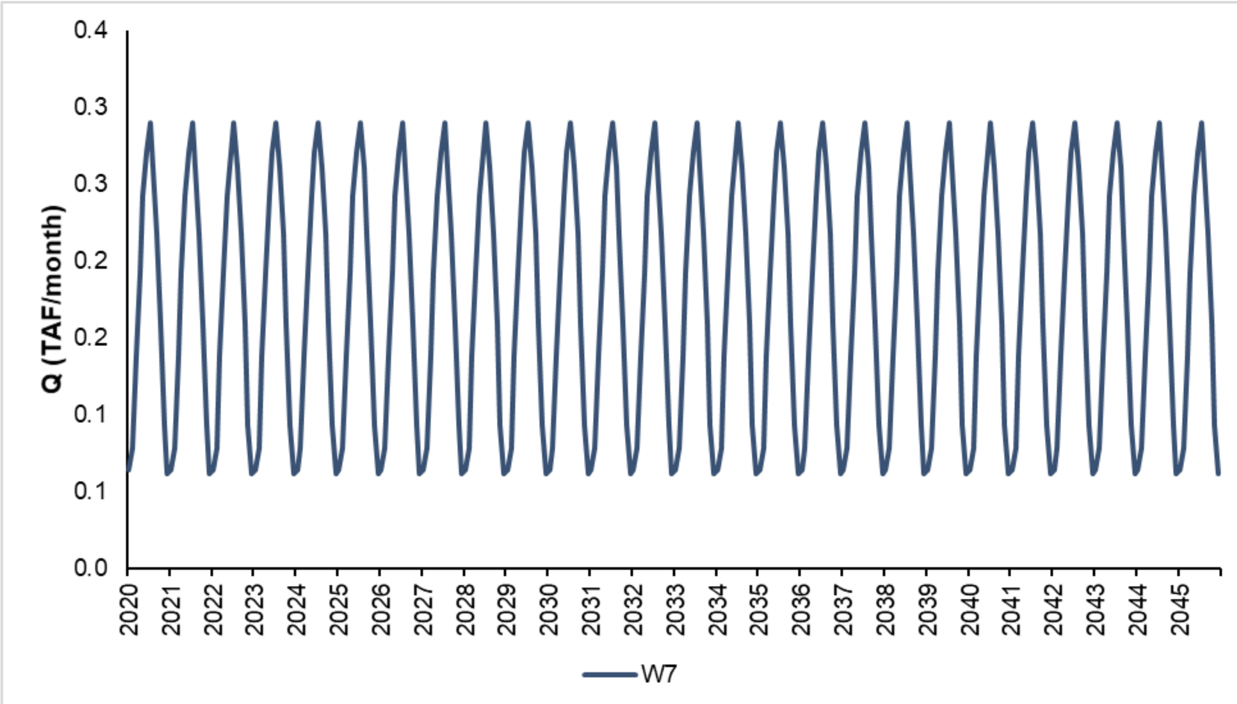

Figure O-6: M&I Non-Retail Pumpers Demand Projection in New W7 Charge Zone

Appendix P: Projected "Other" Consumption by Retailer

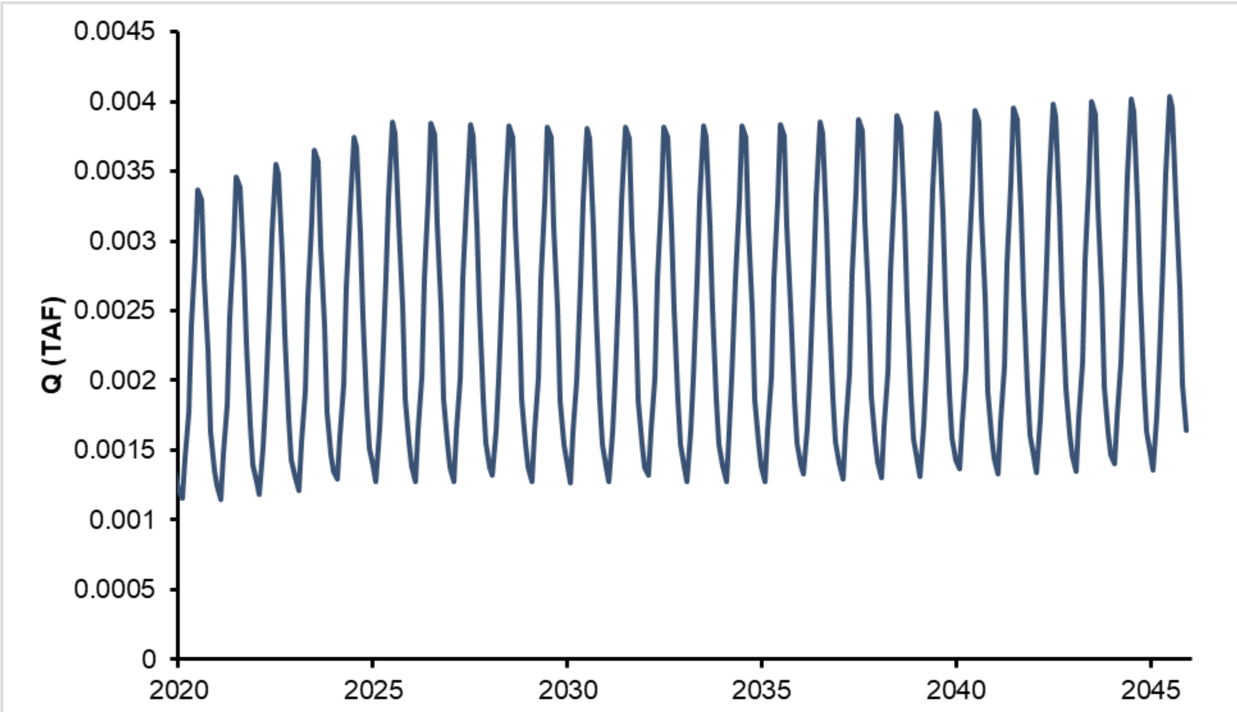

Figure P-1: California Water Service "Other" Demand Projection

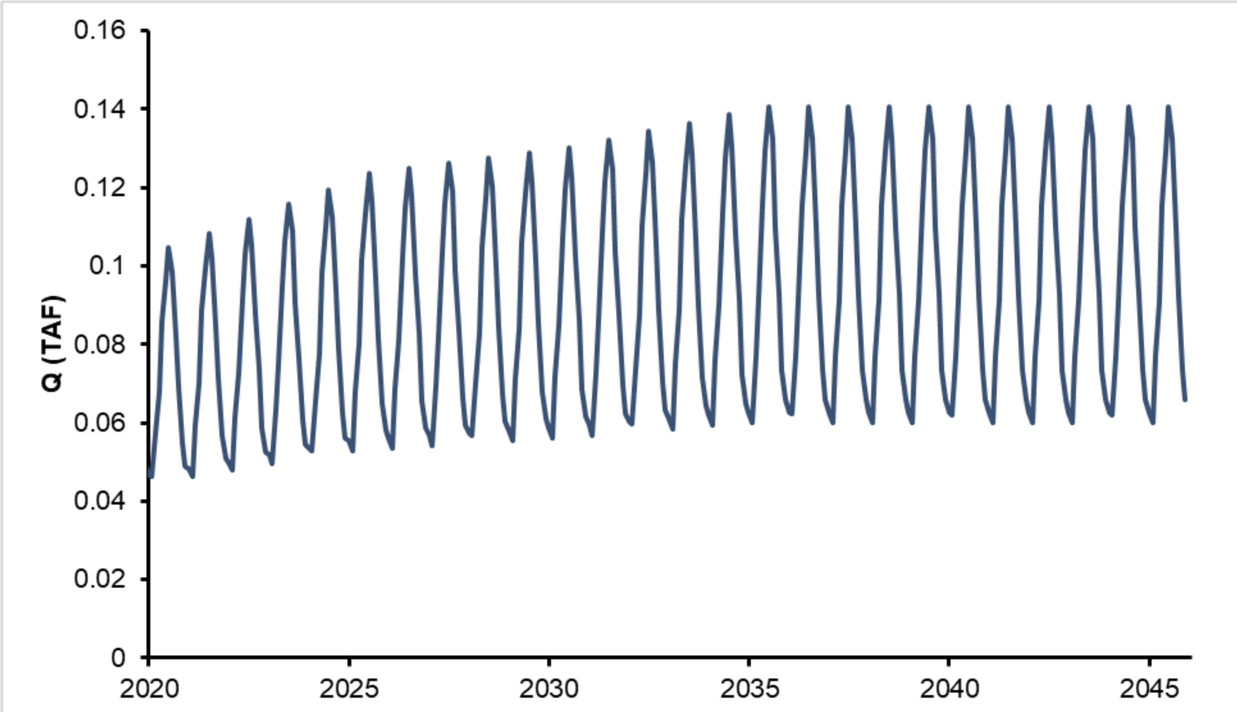

Figure P-2: City of Gilroy "Other" Demand Projection

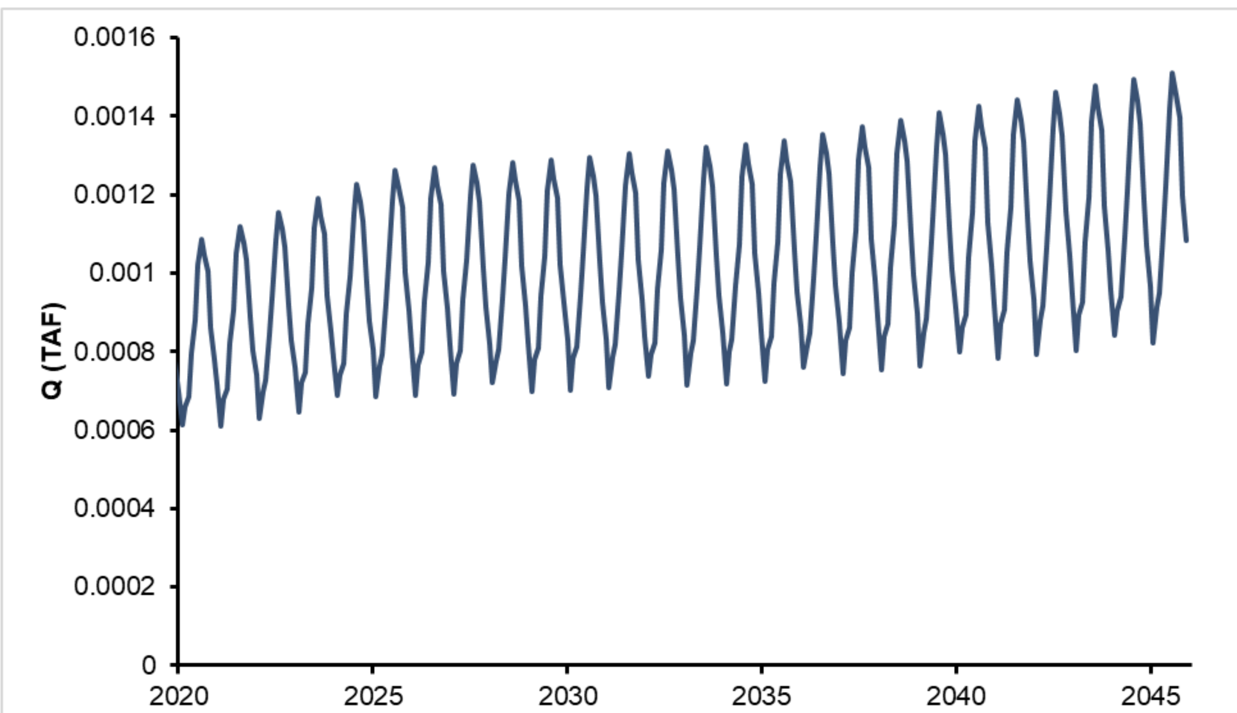

Figure P-3: City of Milpitas "Other" Demand Projection

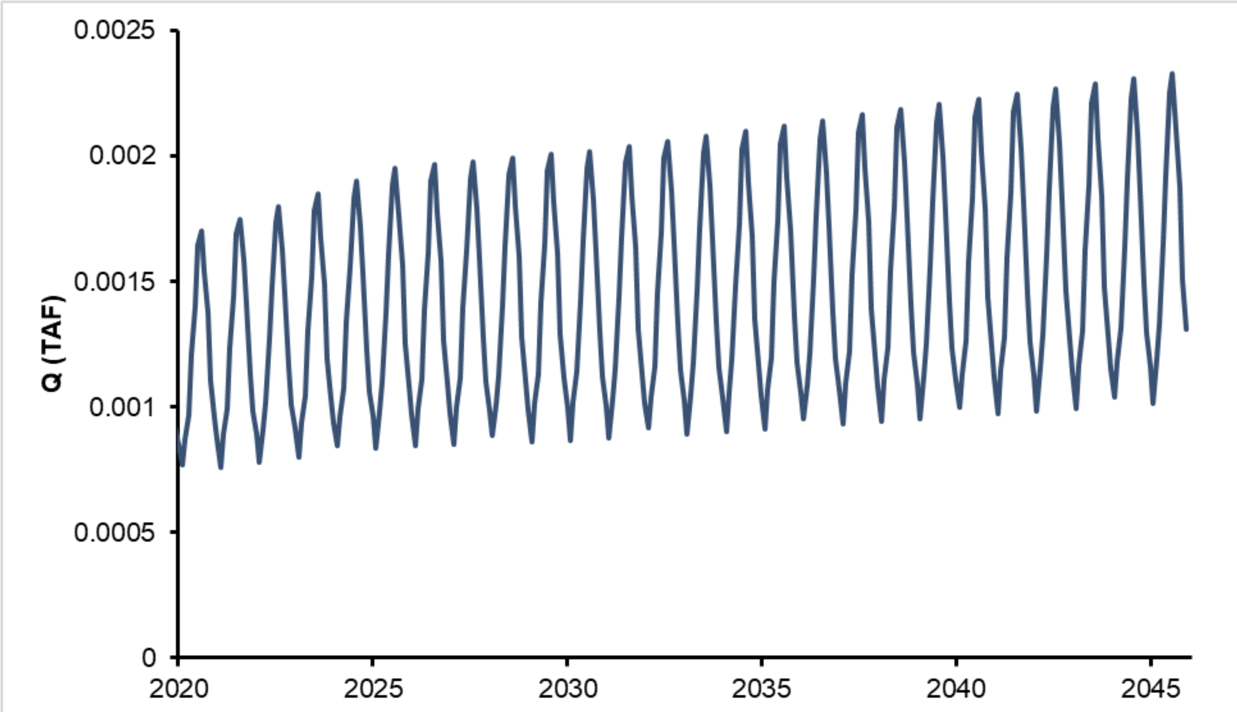

Figure P-4: City of Mountain View "Other" Demand Projection

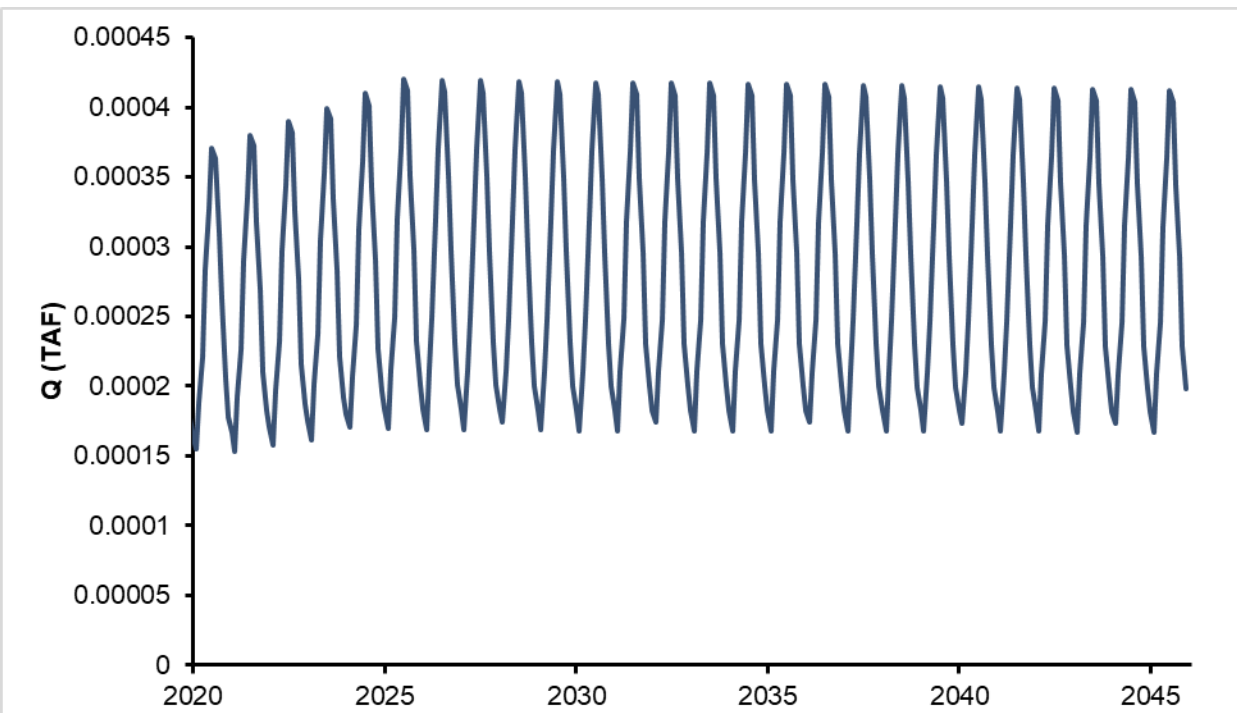

Figure P-5: City of Palo Alto "Other" Demand Projection

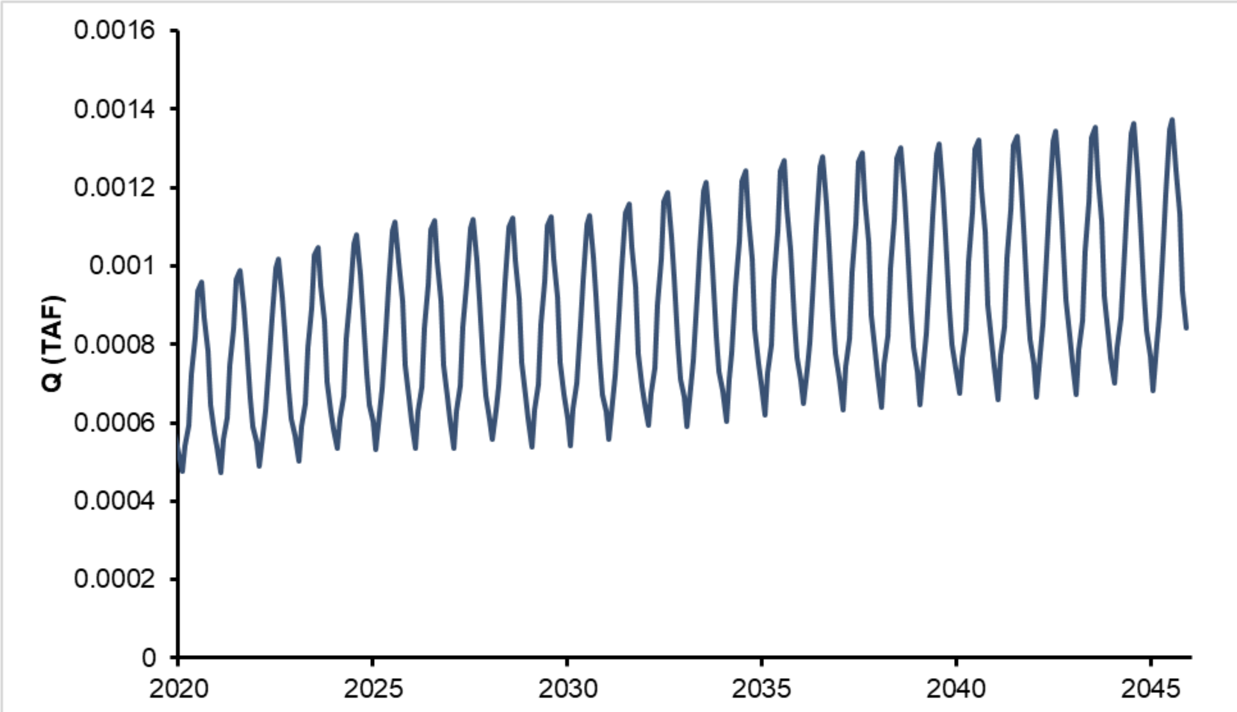

Figure P-6: City of Sunnyvale "Other" Demand Projection

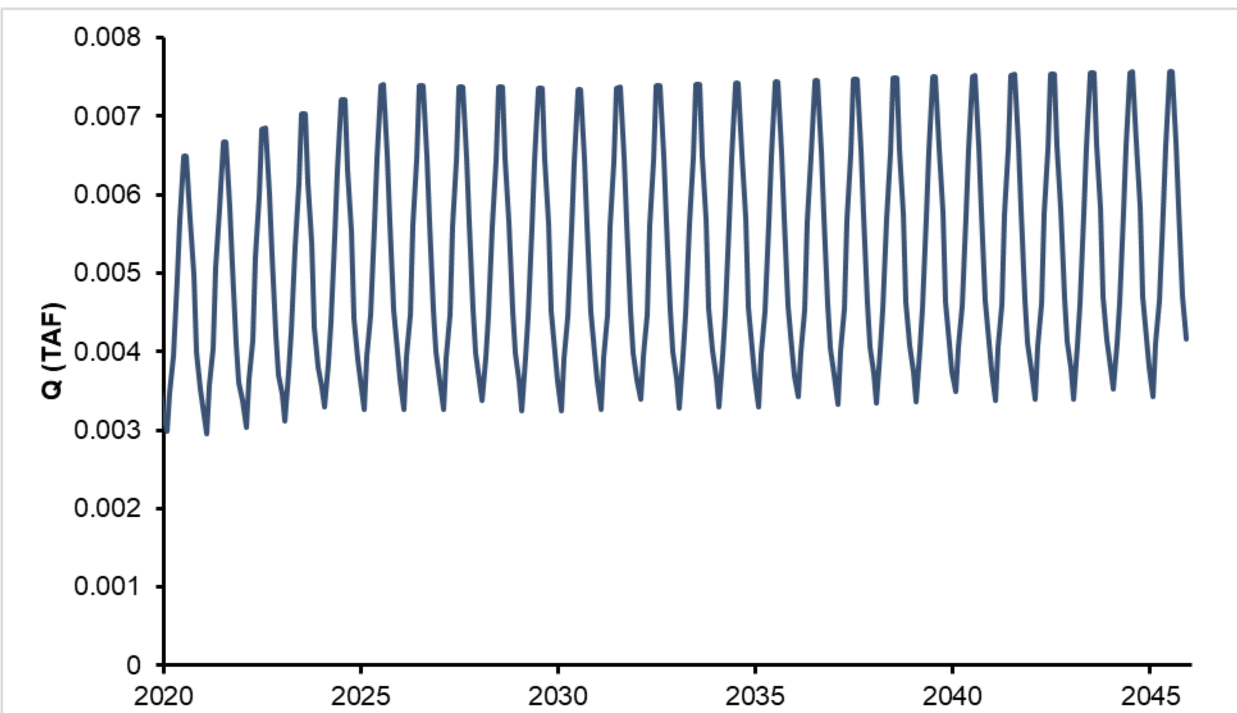

Figure P-7: Great Oaks Water Company "Other" Demand Projection

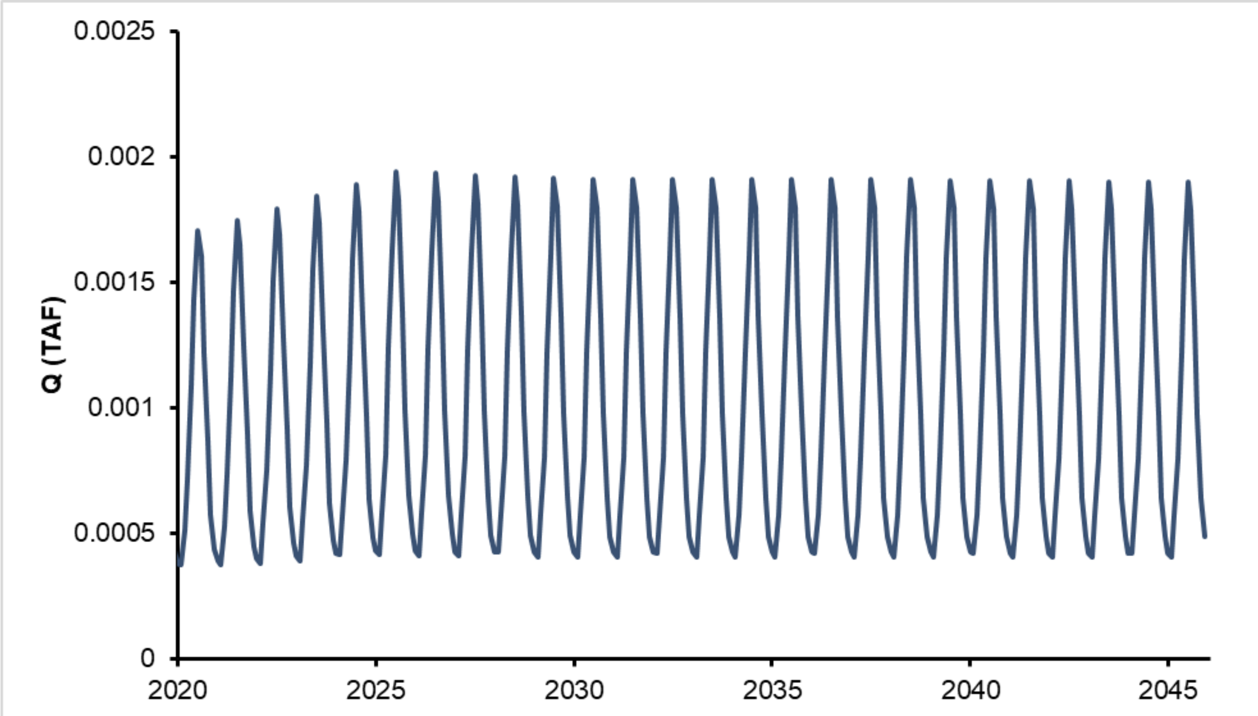

Figure P-8: Purissima Hills Water District "Other" Demand Projection

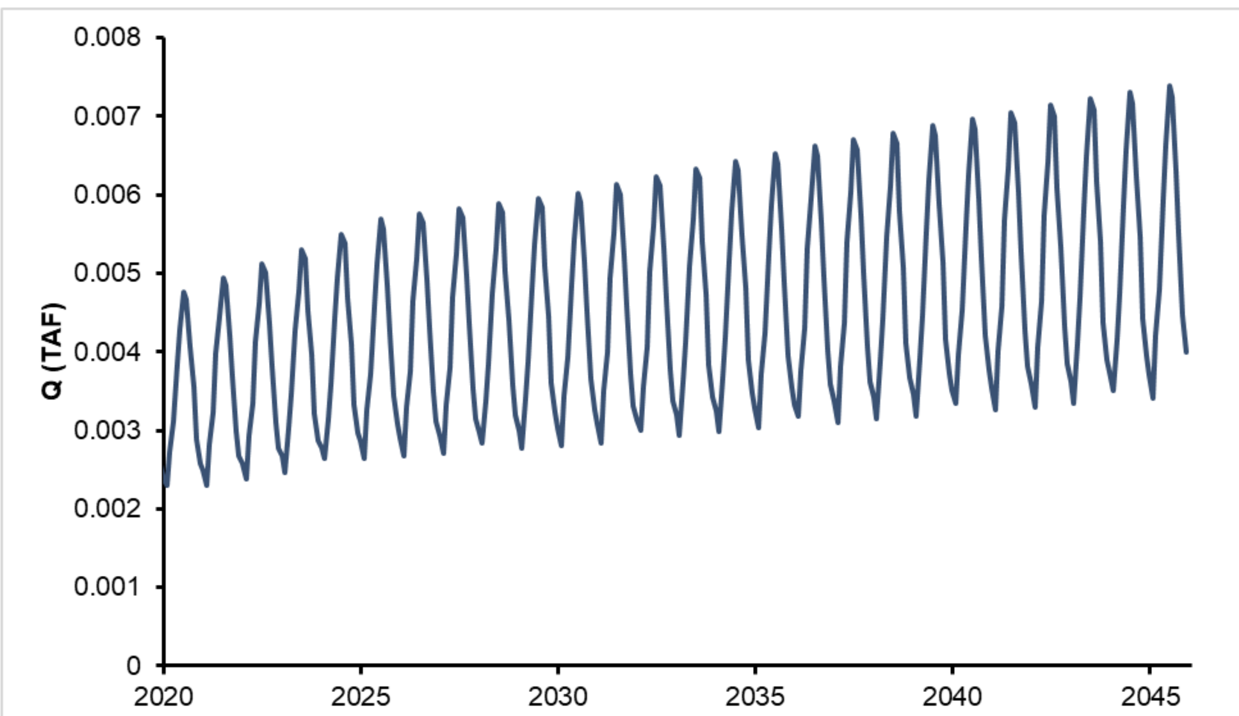

Figure P-9: San Jose Municipal Water "Other" Demand Projection

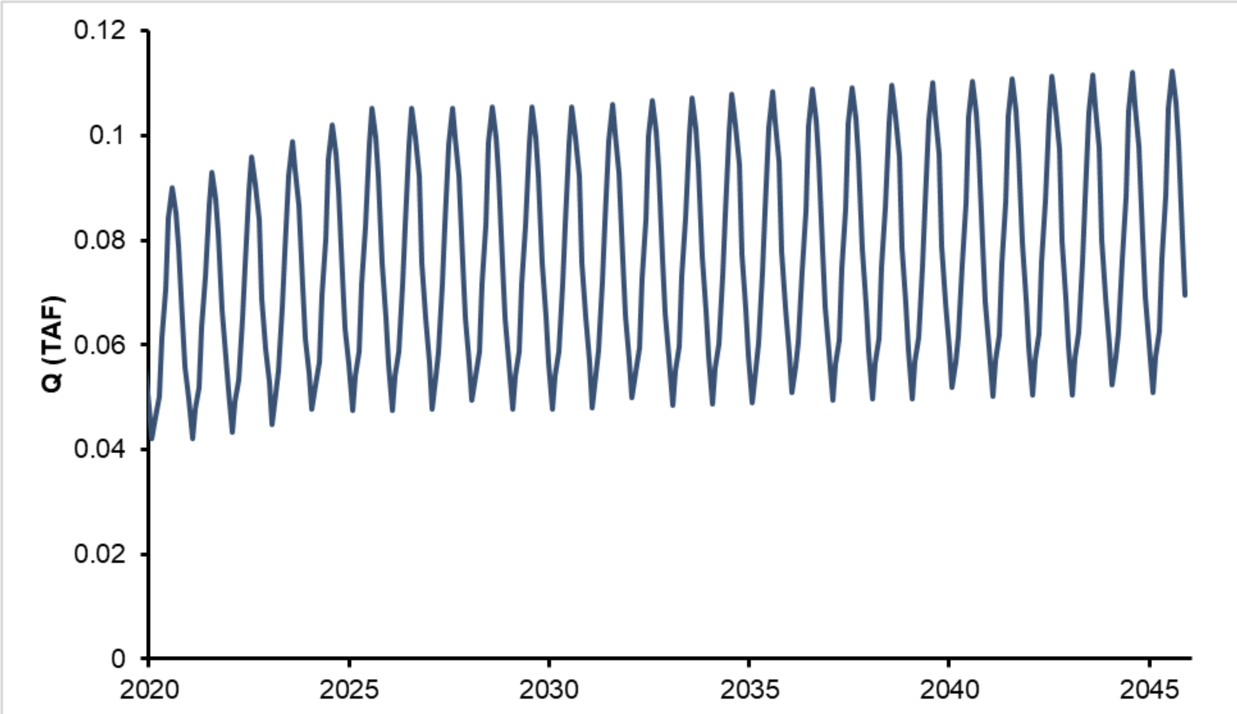

Figure P-10: San Jose Water Company "Other" Demand Projection

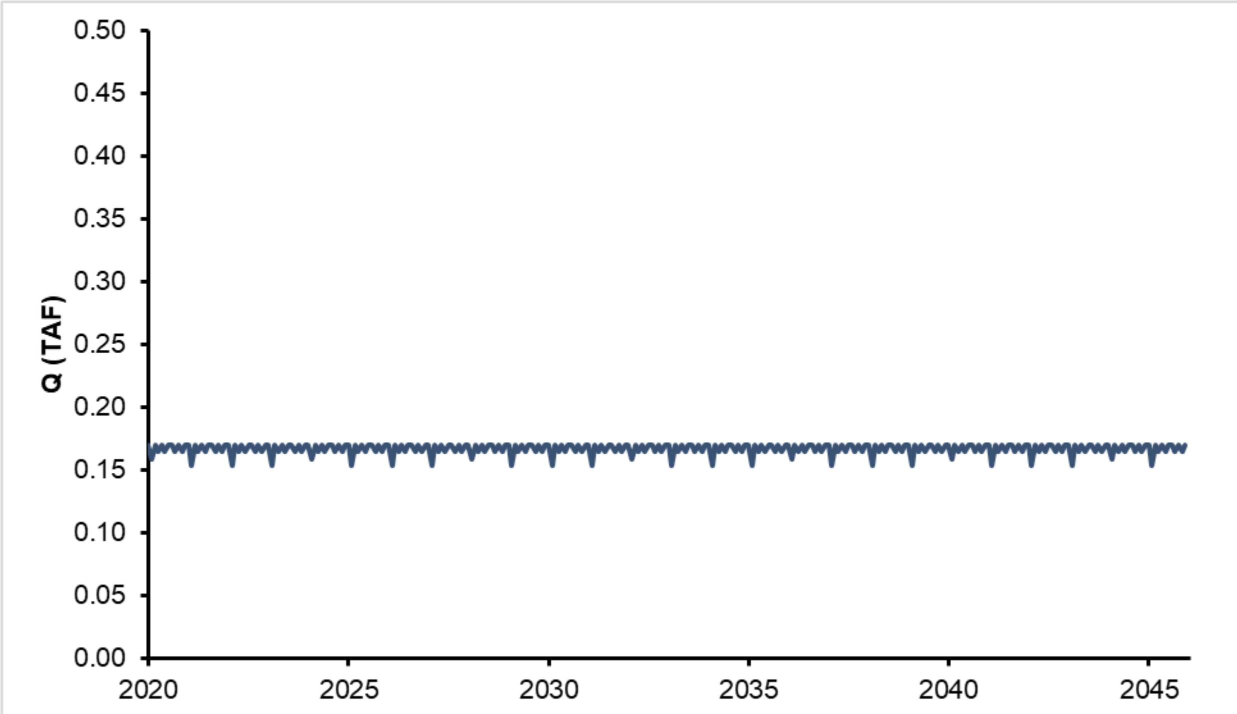

Figure P-11: City of Gilroy "Other" Recycled Water Demand Projection

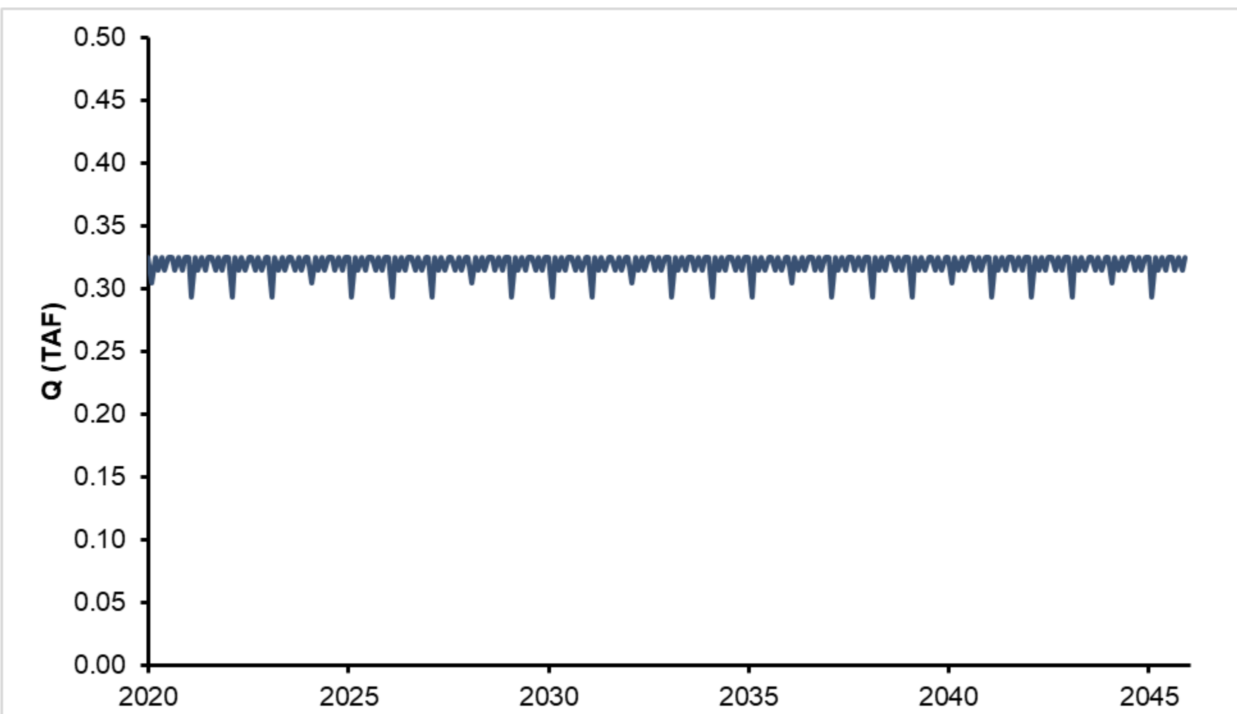

Figure P-12: San Jose Municipal Water "Other" Recycled Demand Projection

Appendix Q: Projected Nonrevenue Water by Retailer

Table Q-1: Percent Nonrevenue Water by Retailer

Agency	Percent Nonrevenue
California Water Service	6.19%
City of Gilroy	10.95%
City of Milpitas	6.06%
City of Morgan Hill	10.85%
City of Mountain View	4.16%
City of Palo Alto	4.52%
City of Santa Clara	6.82%
City of Sunnyvale	4.30%
Great Oaks Water Company	5.99%
Purissima Hills Water District	4.53%
San Jose Municipal Water	6.01%
San Jose Water Company	5.21%
Stanford University	12.14%

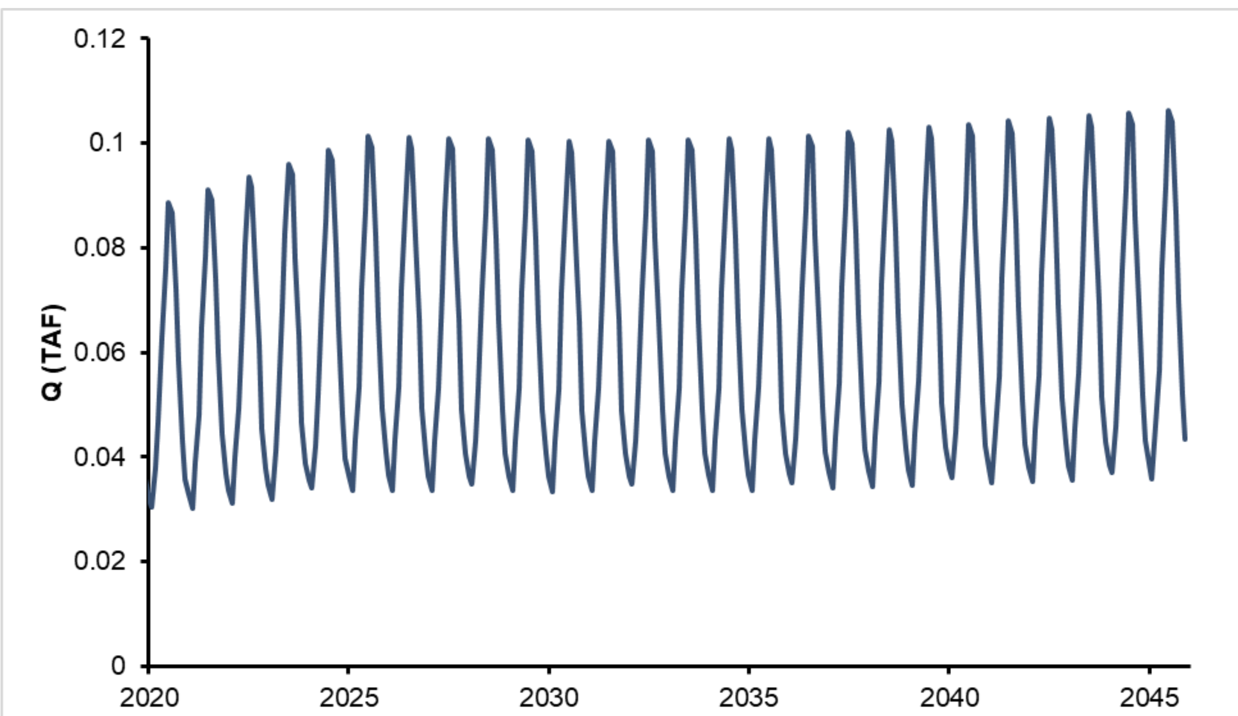

Figure Q-1: California Water Service Nonrevenue Water Projection

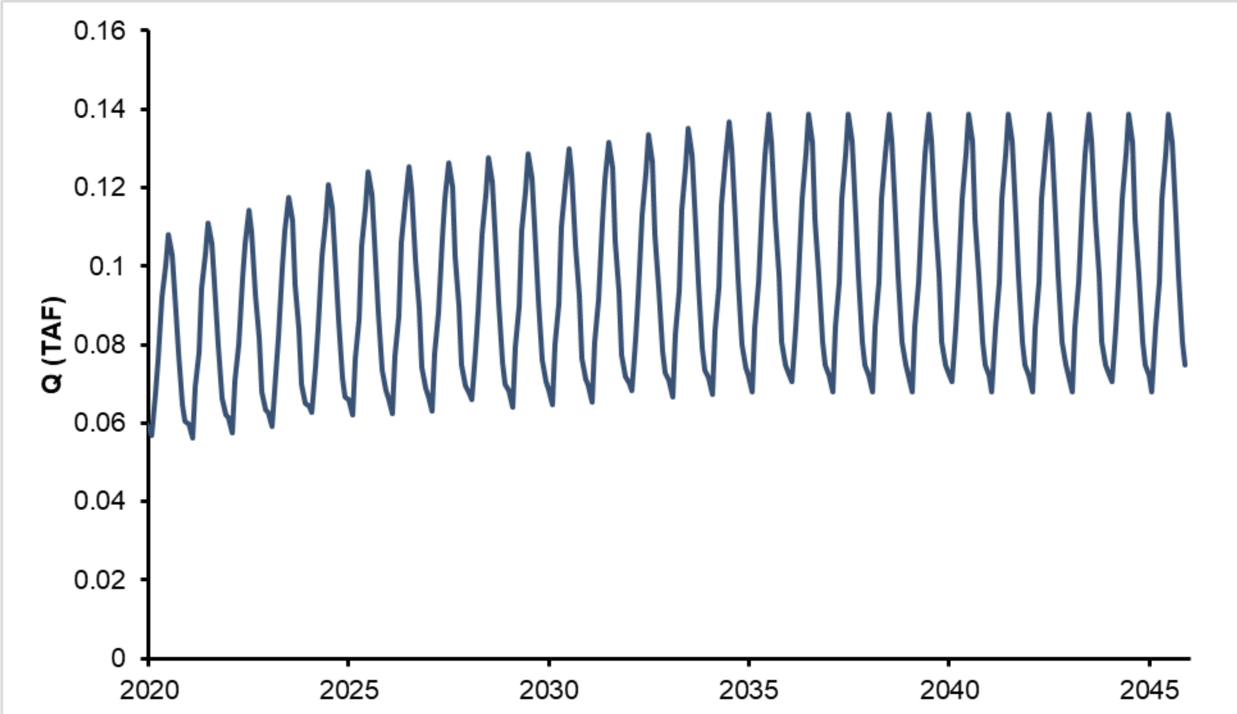

Figure Q-2: City of Gilroy Nonrevenue Water Projection

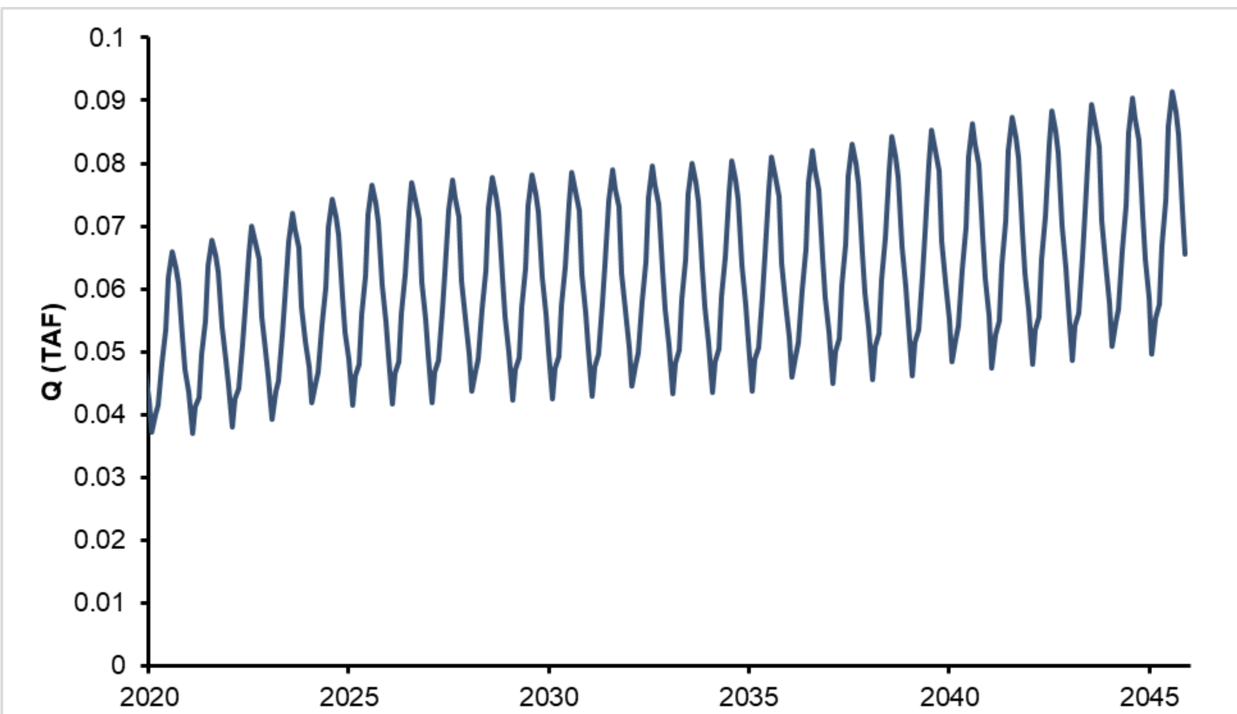

Figure Q-3: City of Milpitas Nonrevenue Water Projection

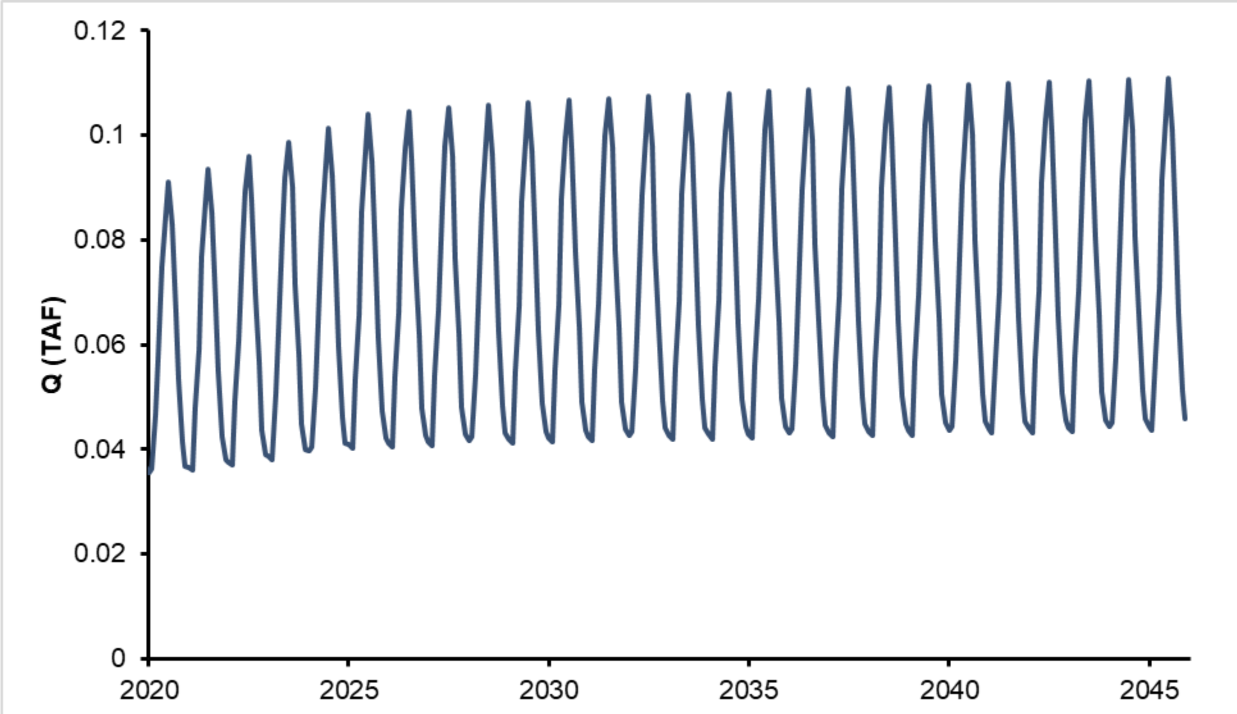

Figure Q-4: City of Morgan Hill Nonrevenue Water Projection

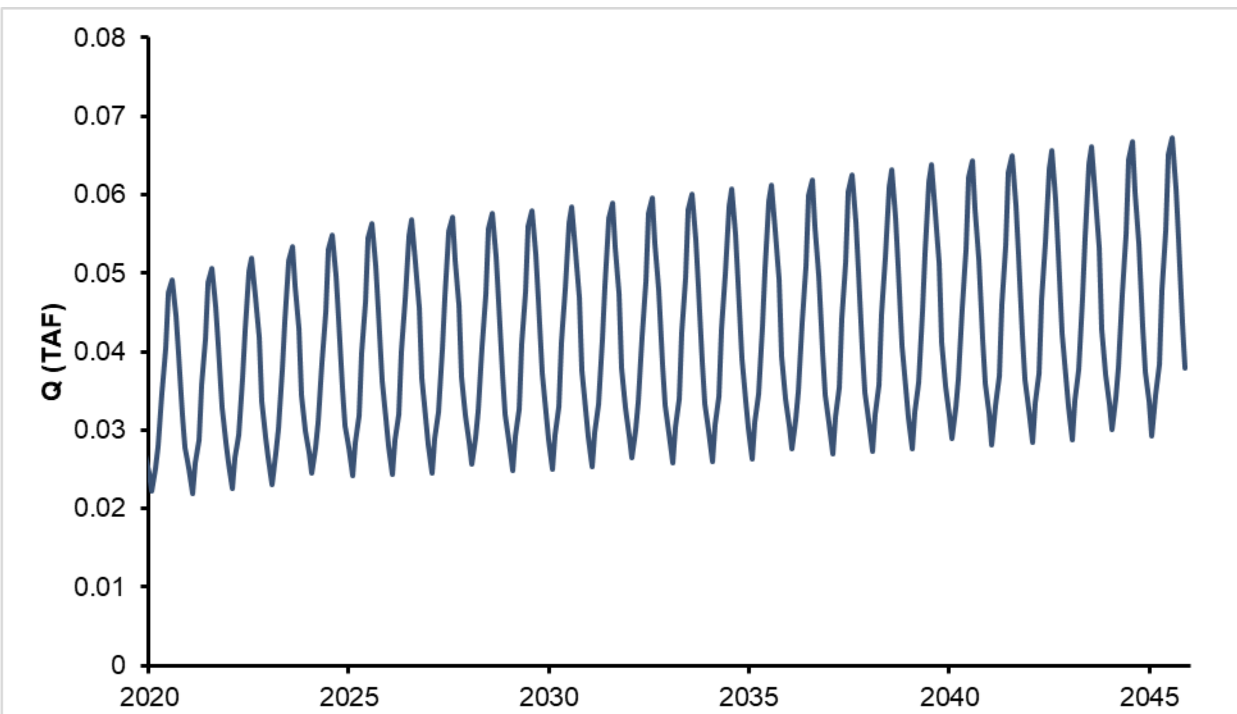

Figure Q-5: City of Mountain View Nonrevenue Water Projection

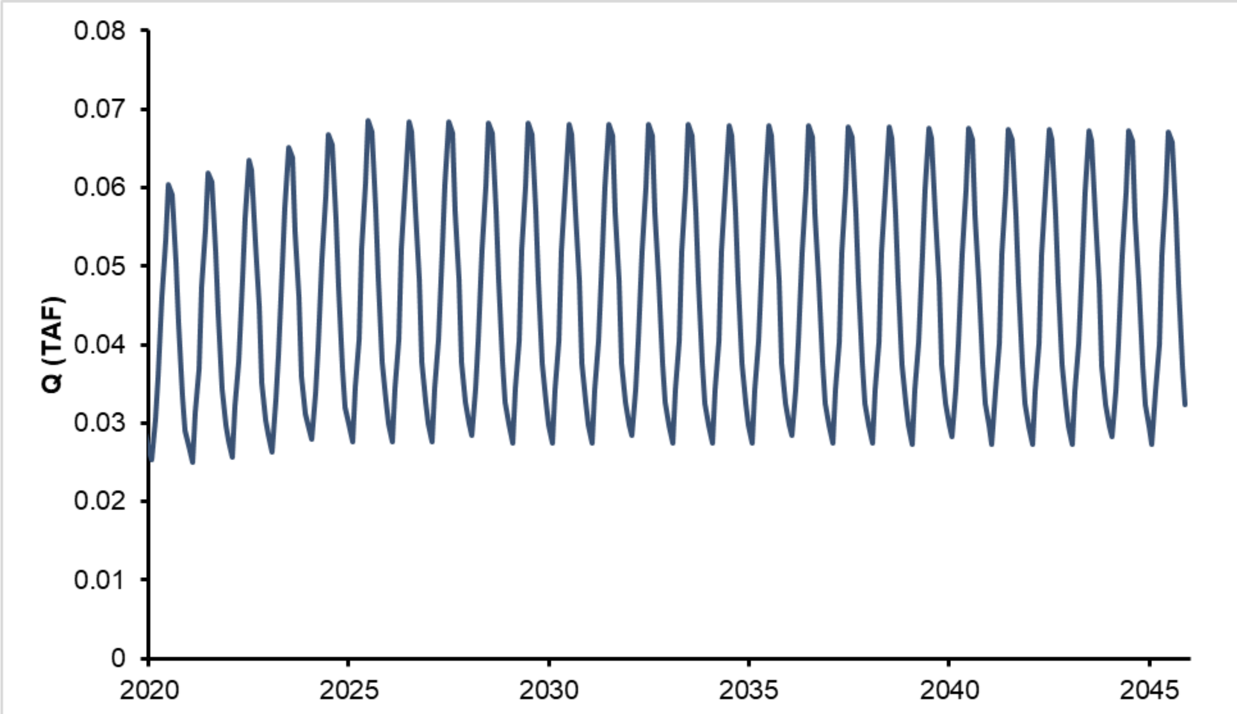

Figure Q-6: City of Palo Alto Nonrevenue Water Projection

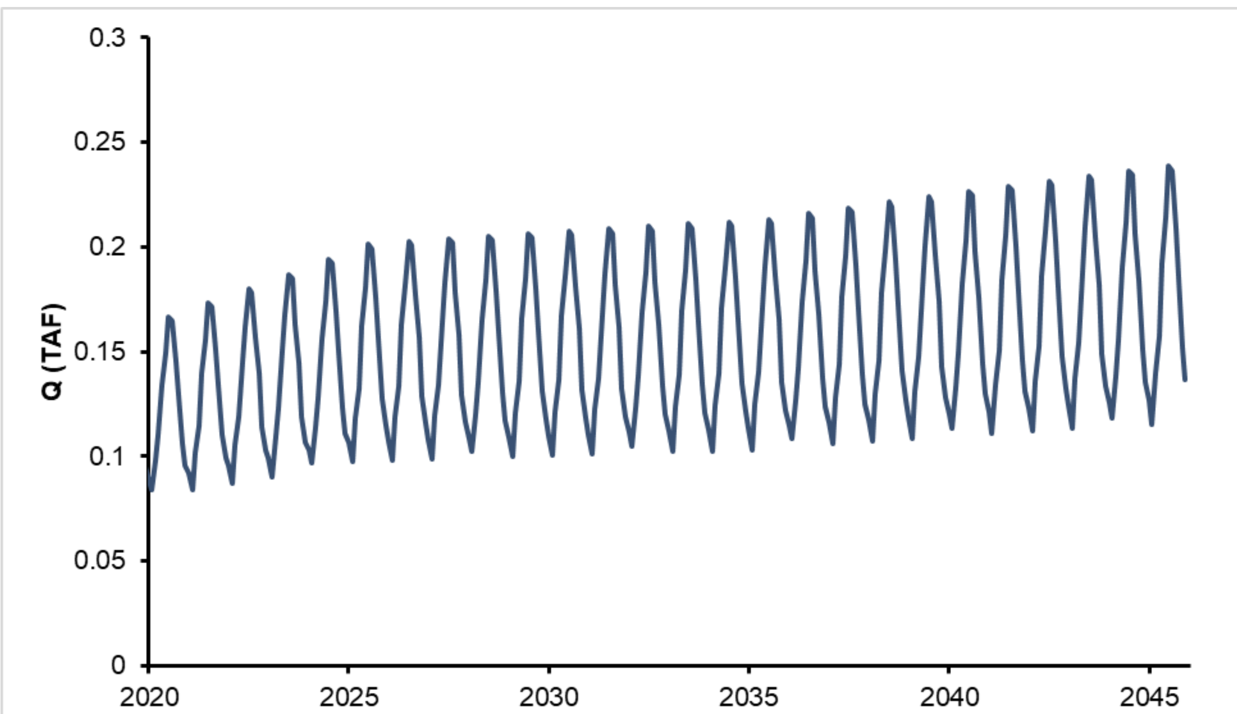

Figure Q-7: City of Santa Clara Nonrevenue Water Projection

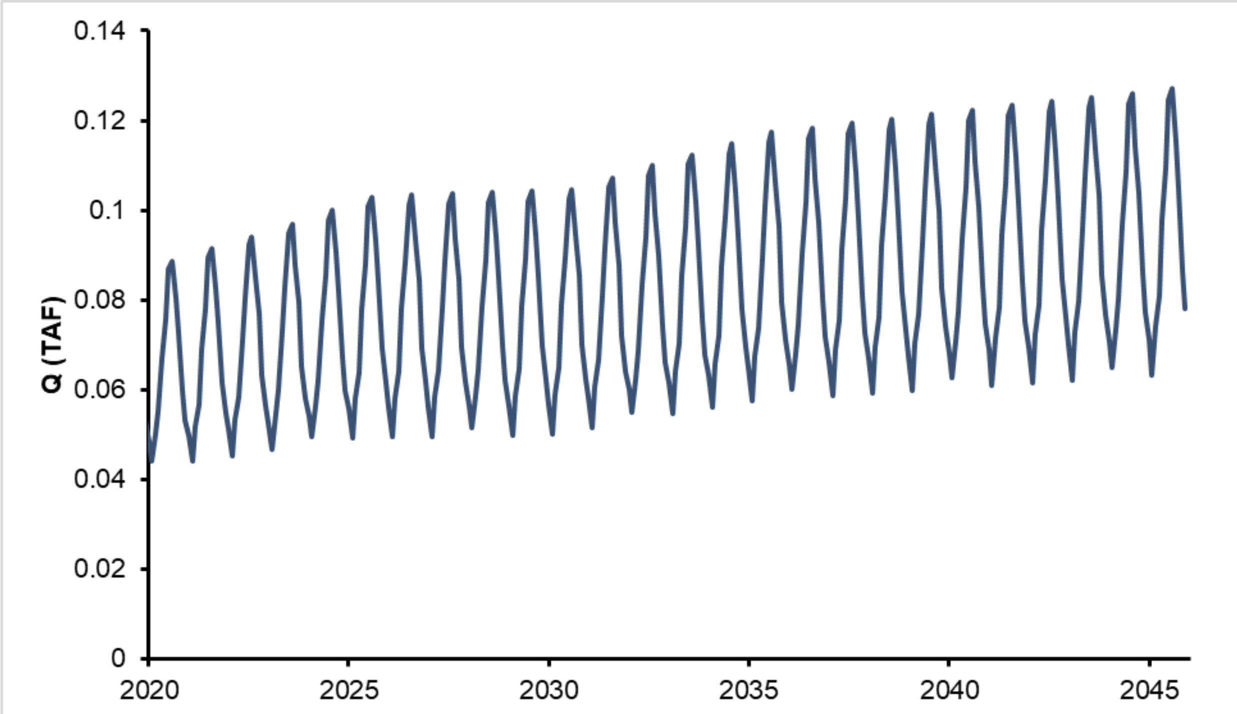

Figure Q-8: City of Sunnyvale Nonrevenue Water Projection

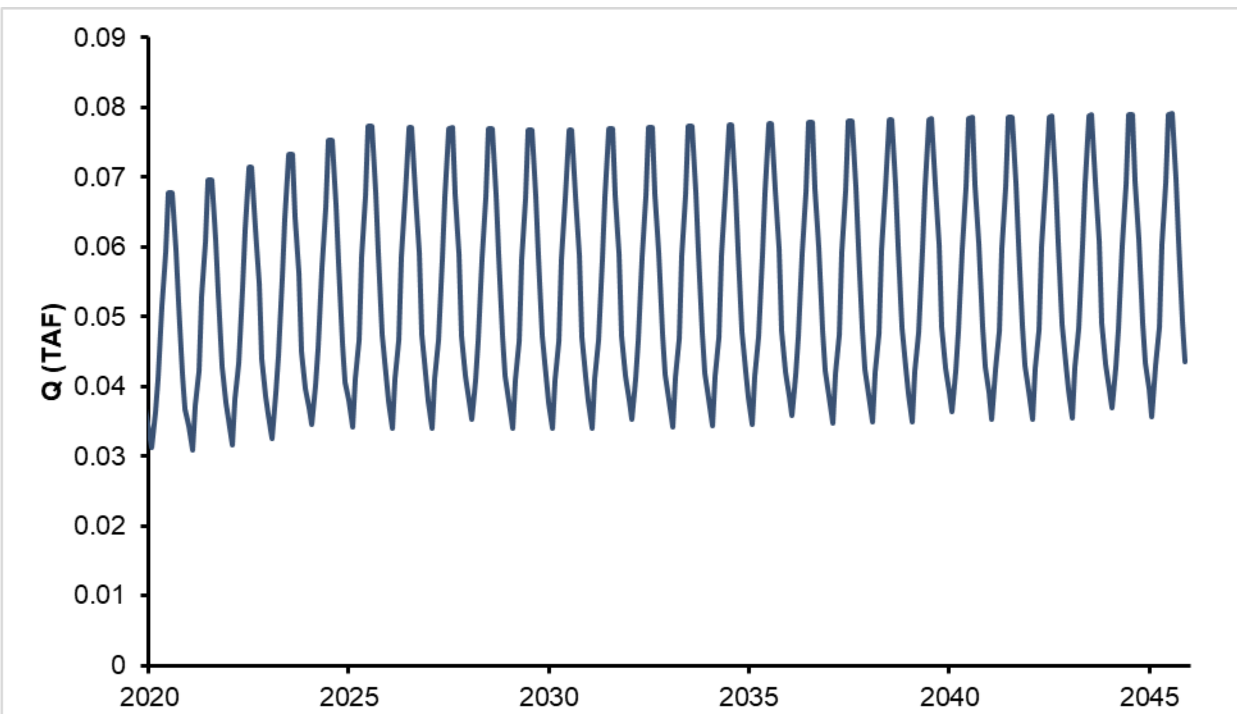

Figure Q-9: Great Oaks Water Company Nonrevenue Water Projection

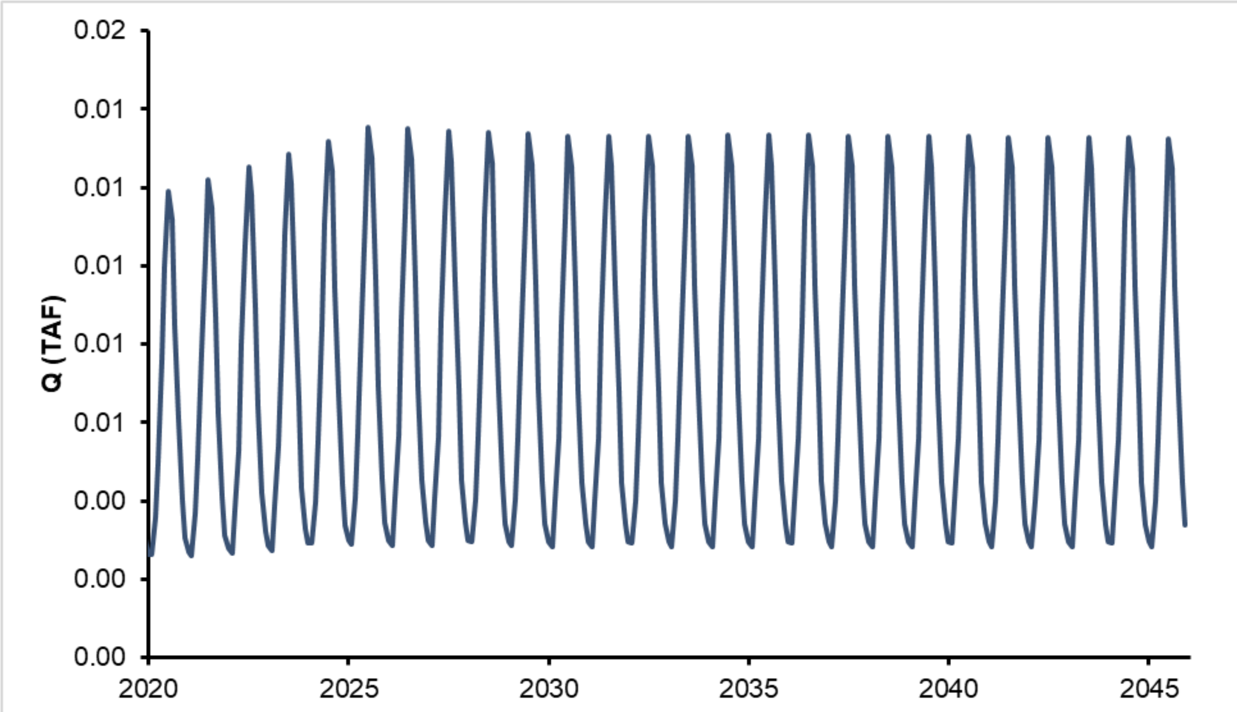

Figure Q-10: Purissima Hills Water District Nonrevenue Water Projection

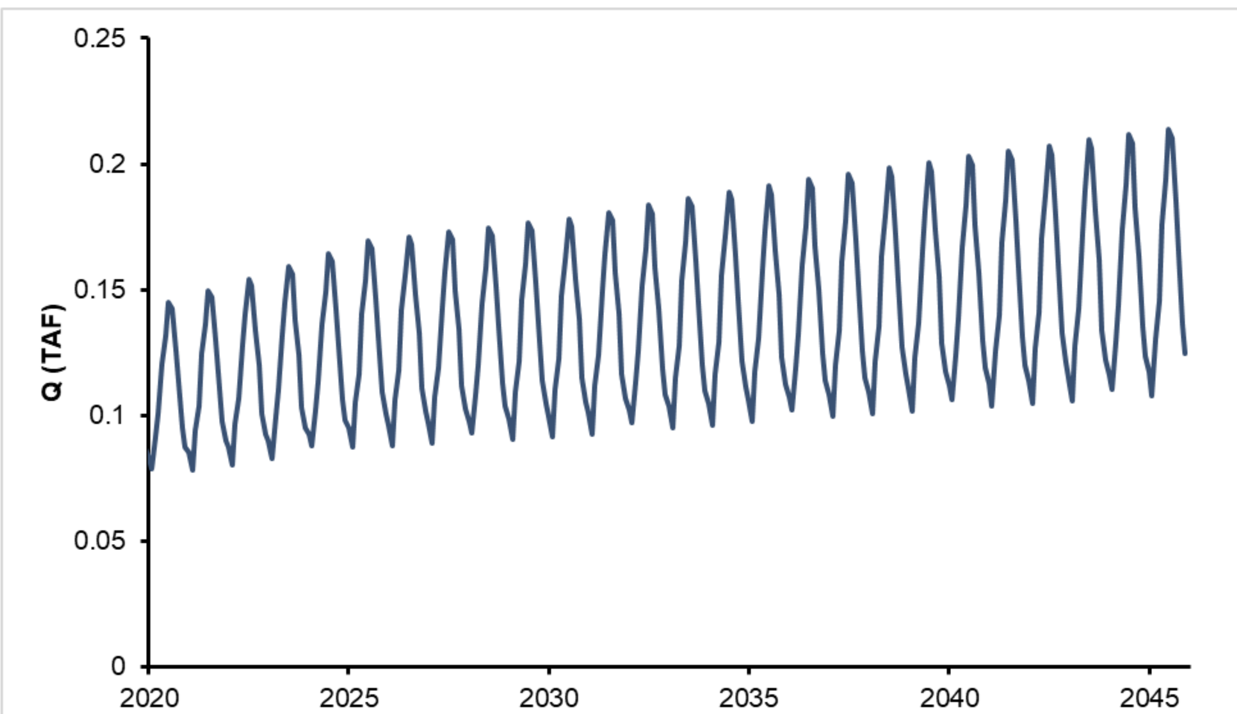

Figure Q-11: San Jose Municipal Water Nonrevenue Water Projection

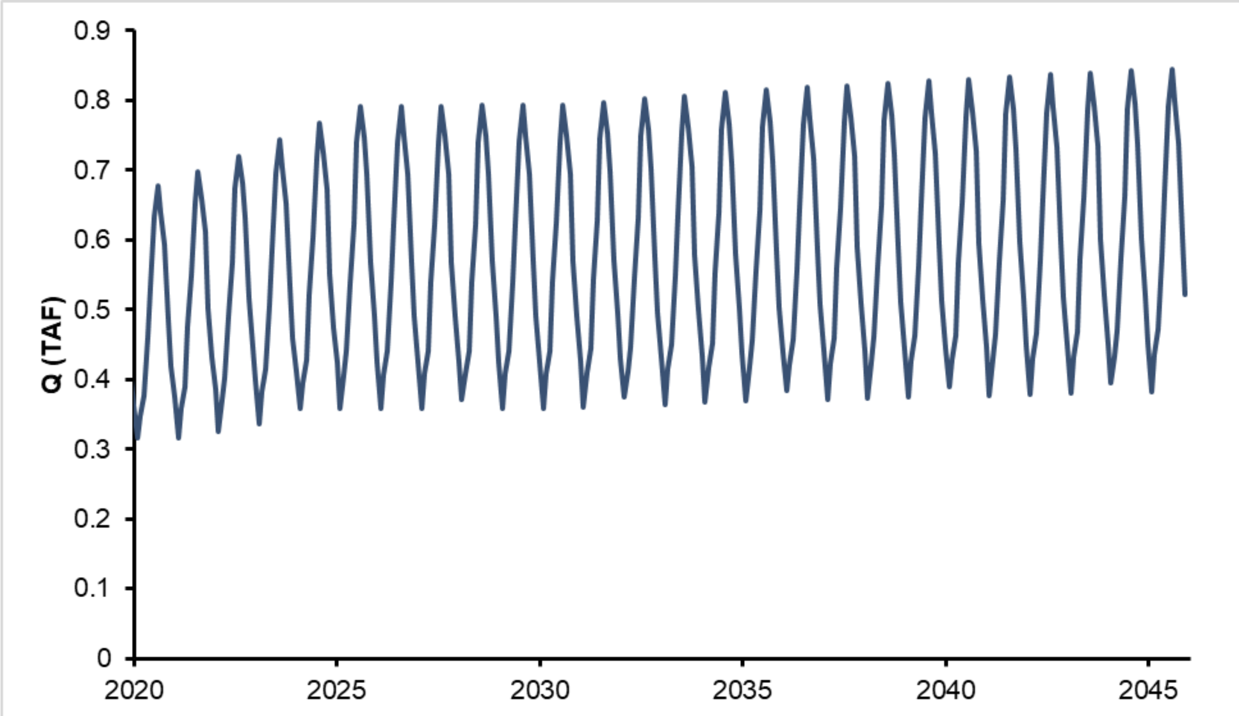

Figure Q-12: San Jose Water Company Nonrevenue Water Projection

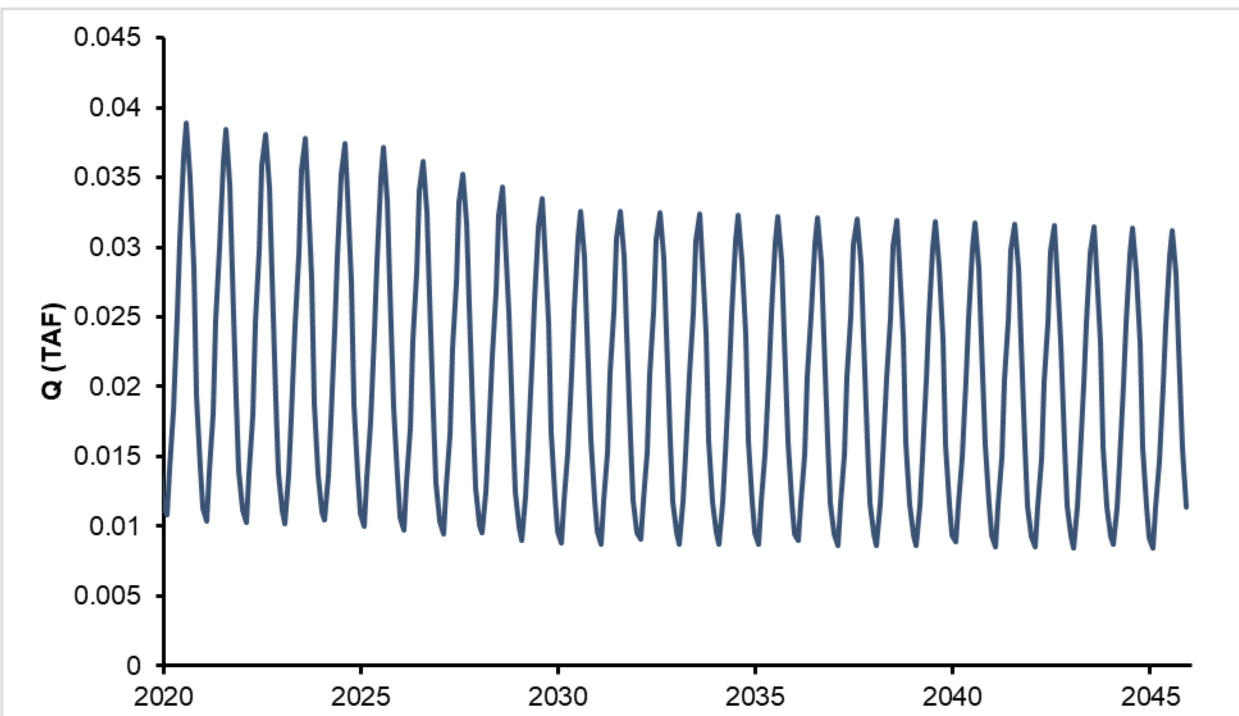

Figure Q-13: Stanford University Nonrevenue Water Projection

Appendix R: Projected Total Demand by Retailer

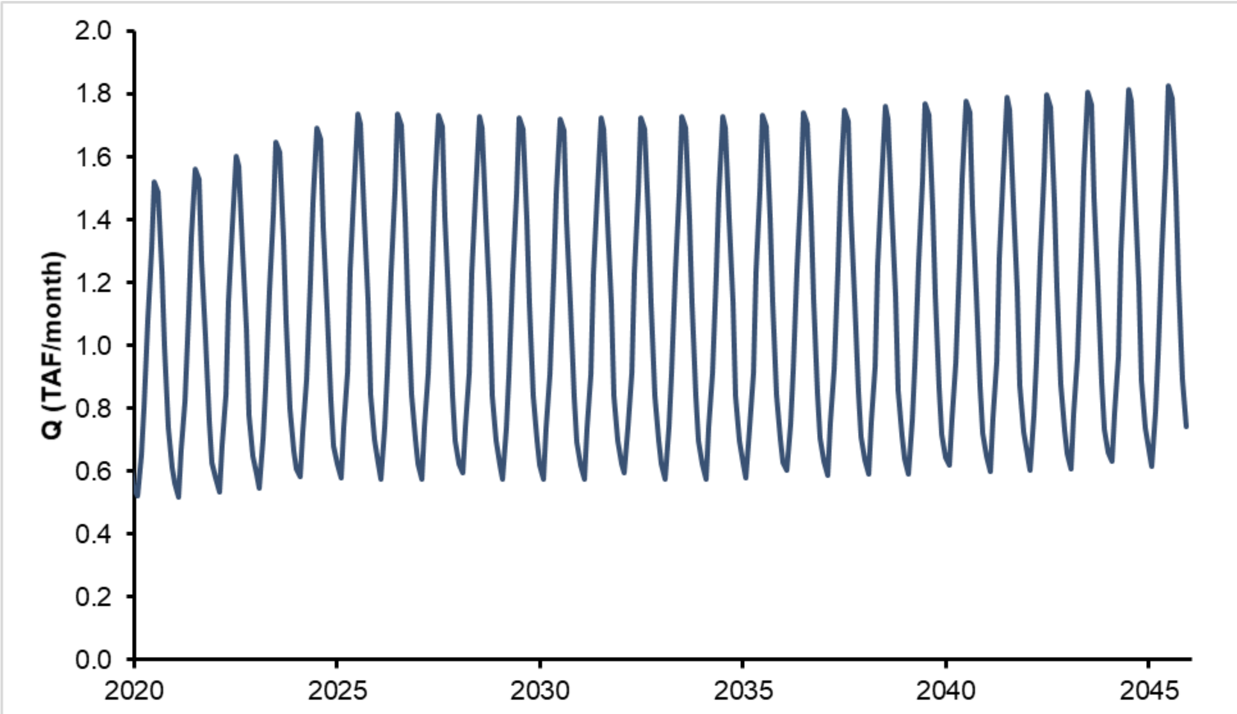

Figure R-1: California Water Service Total Demand Projection

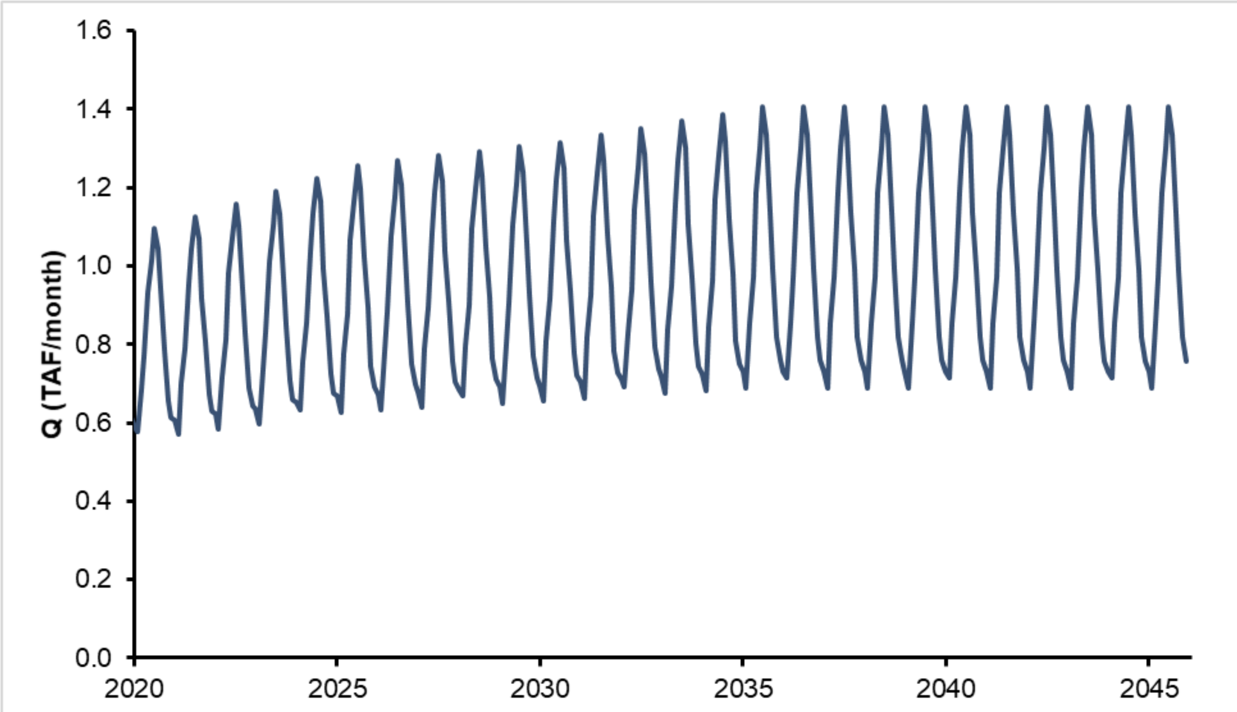

Figure R-2: City of Gilroy Total Demand Projection

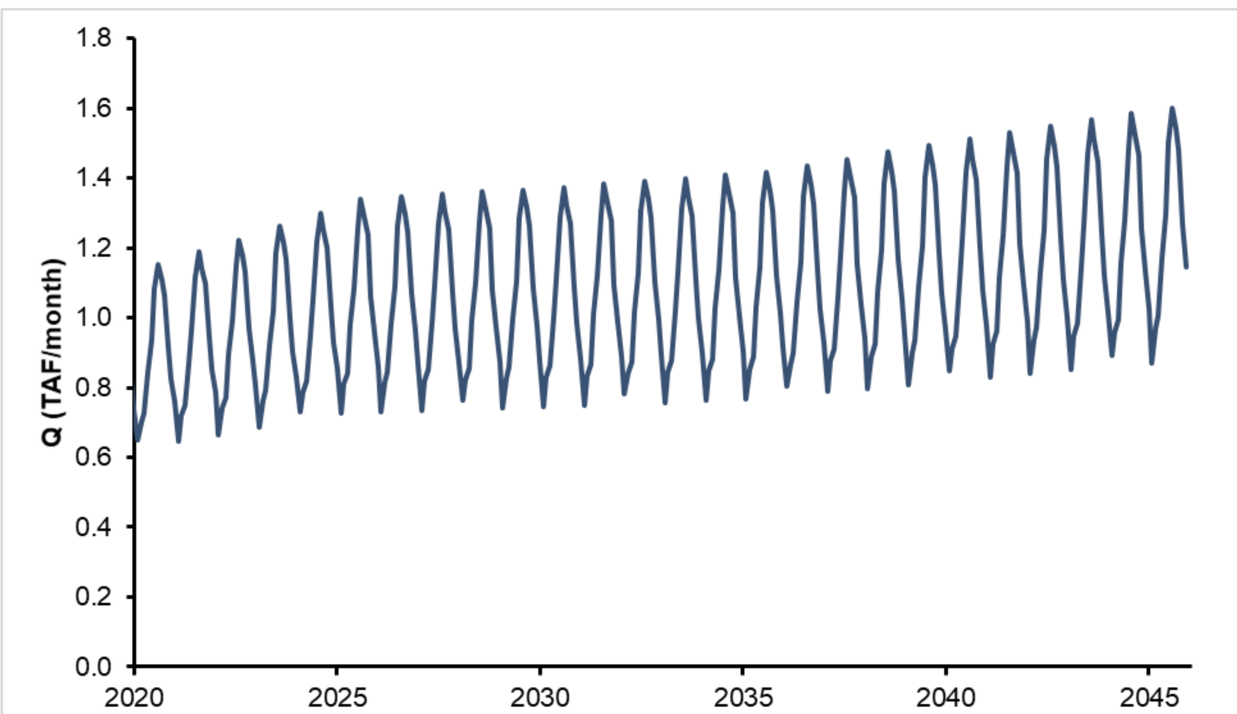

Figure R-3: City of Milpitas Total Demand Projection

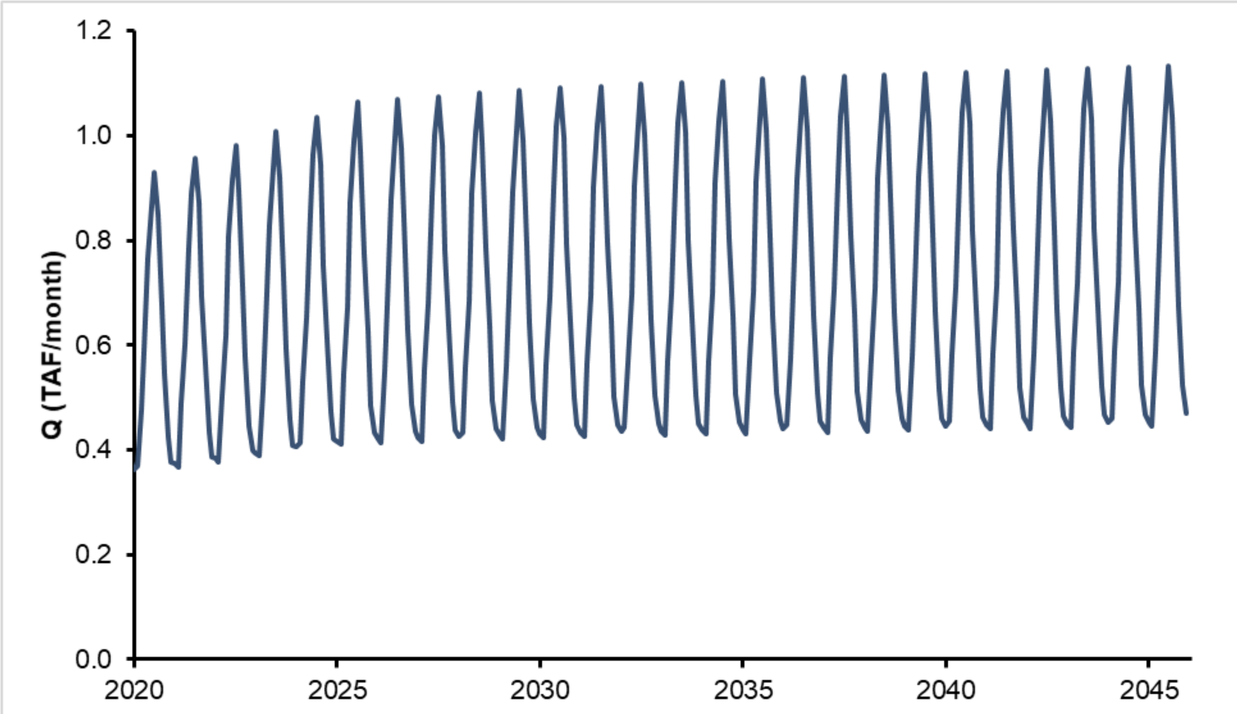

Figure R-4: City of Morgan Hill Total Demand Projection

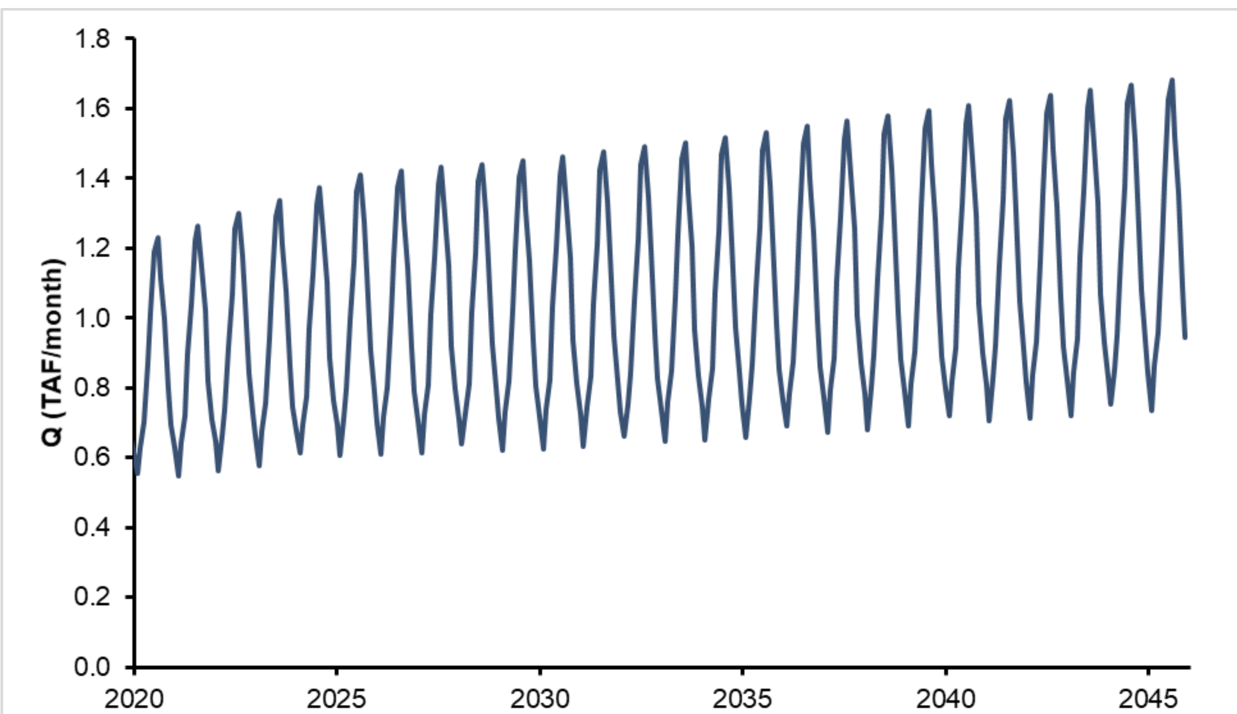

Figure R-5: City of Mountain View Total Demand Projection

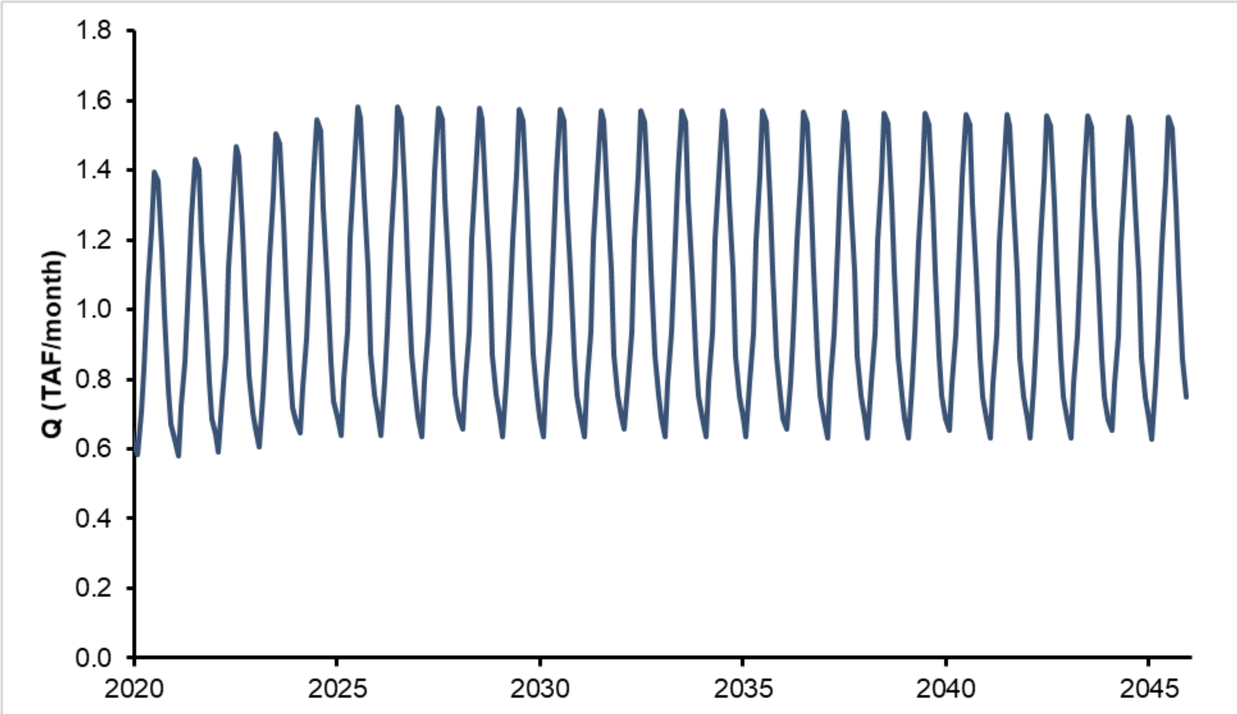

Figure R-6: City of Palo Alto Total Demand Projection

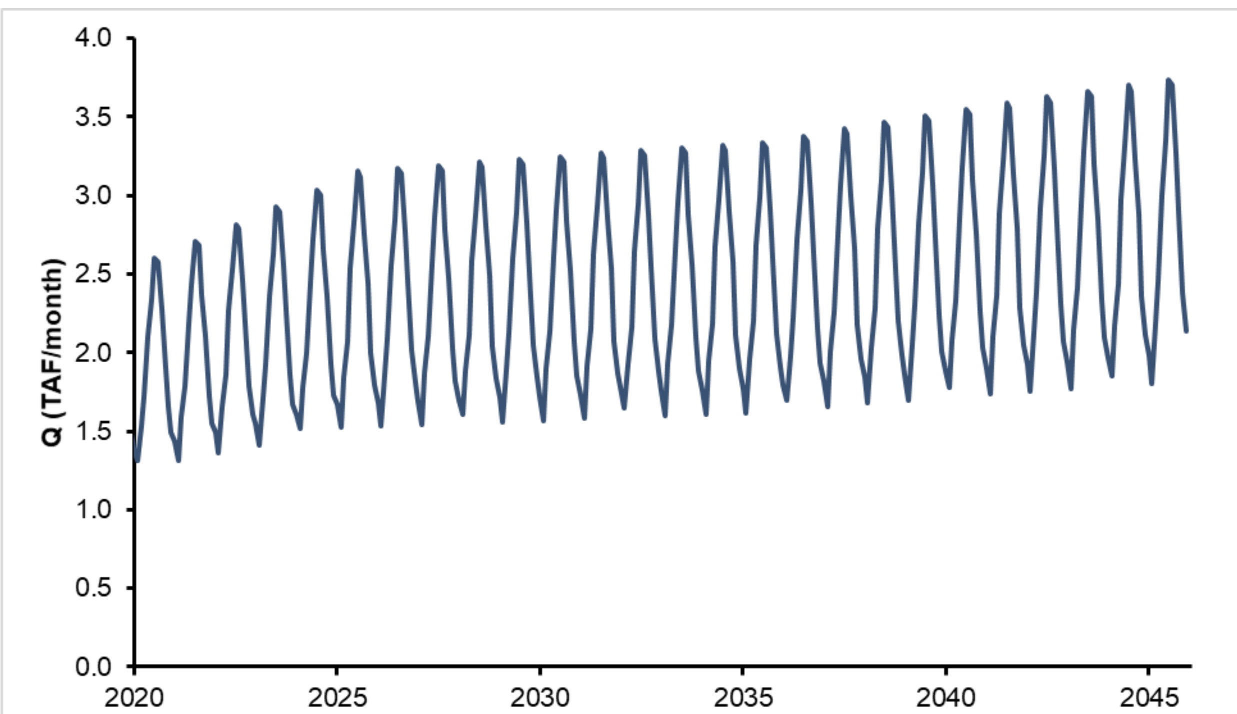

Figure R-7: City of Santa Clara Total Demand Projection

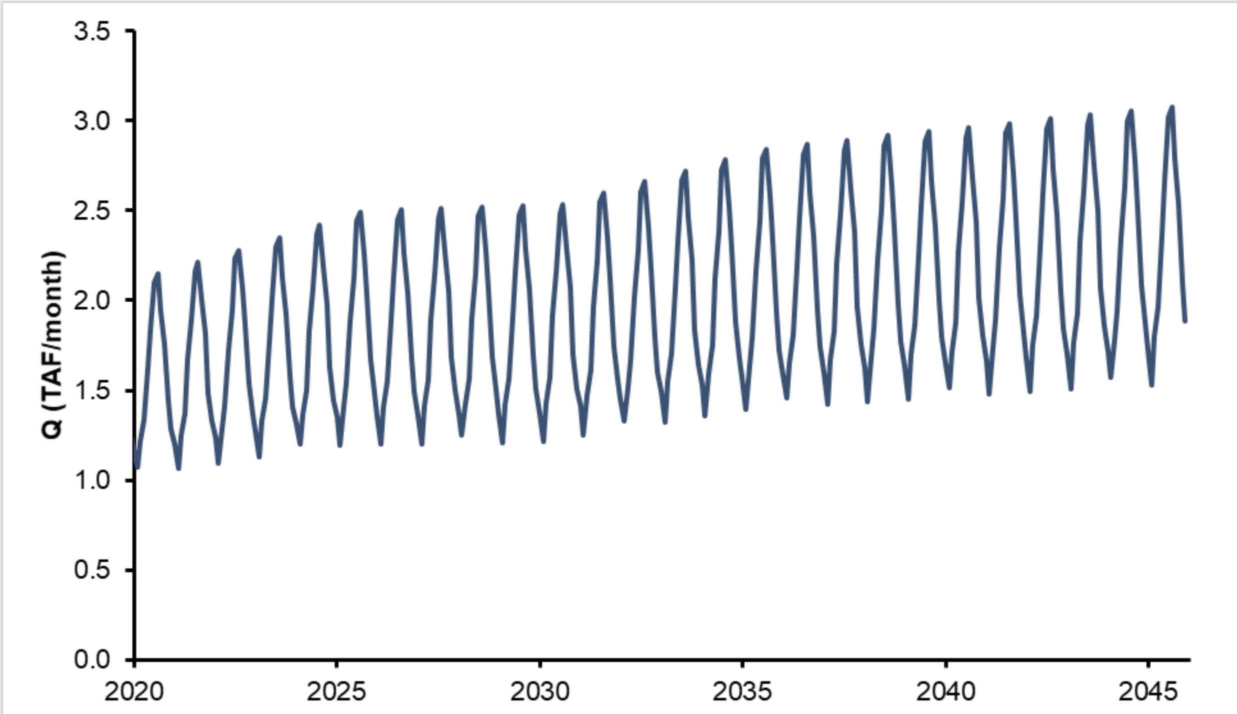

Figure R-8: City of Sunnyvale Total Demand Projection

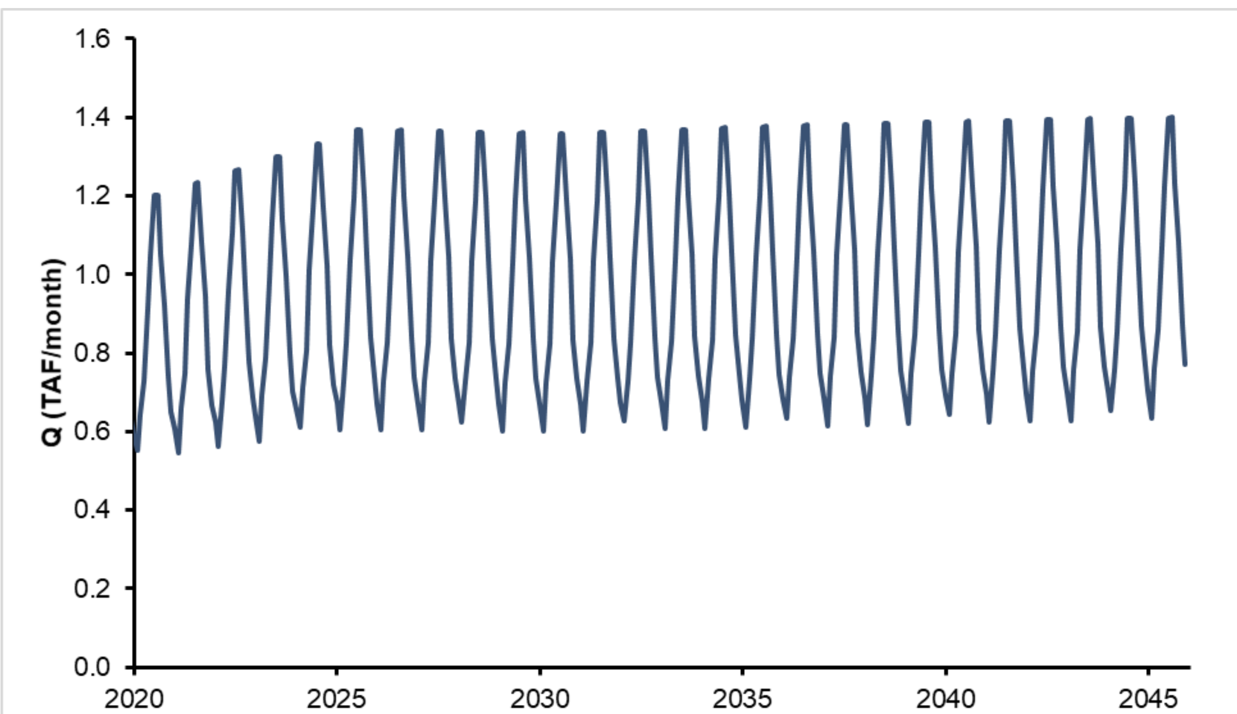

Figure R-9: Great Oaks Water Company Total Demand Projection

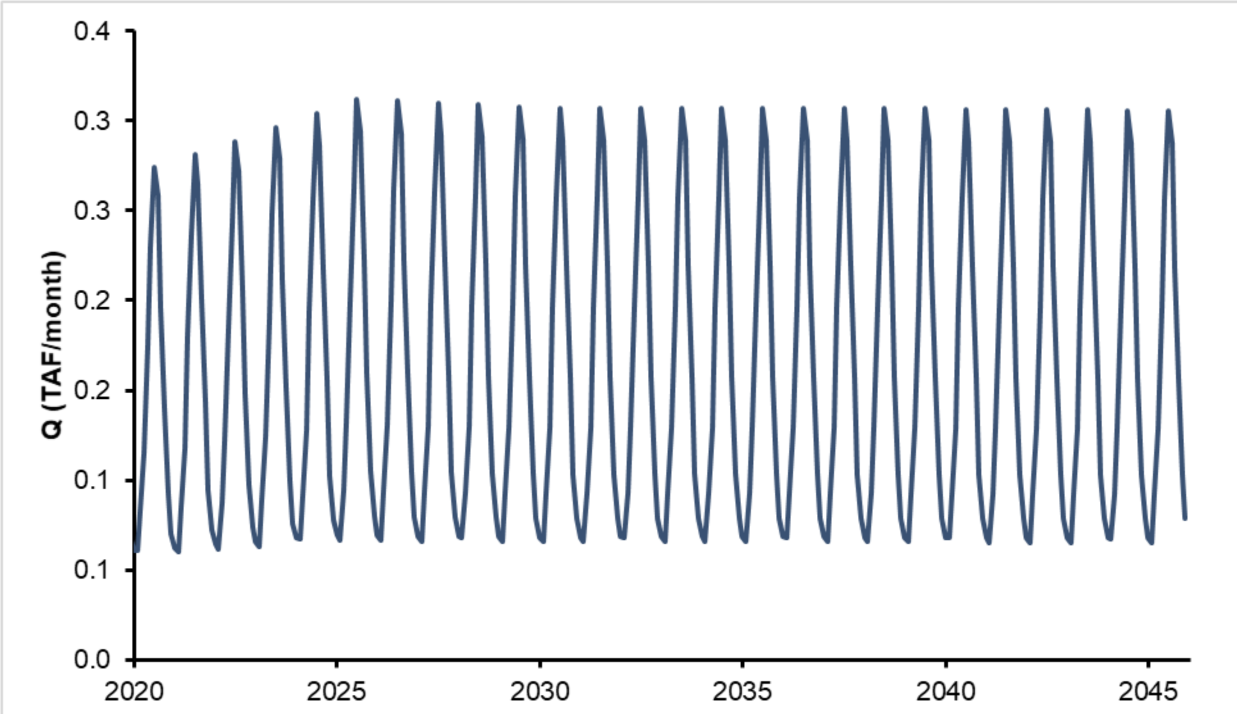

Figure R-10: Purissima Hills Water District Total Demand Projection

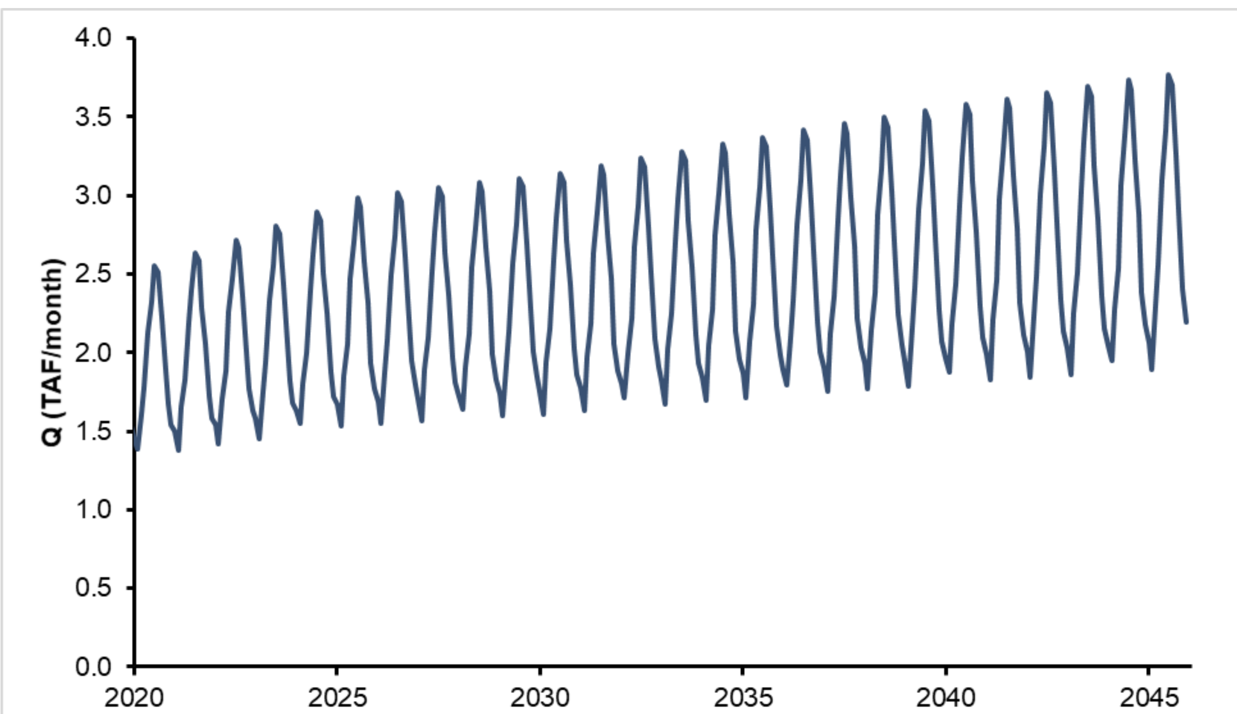

Figure R-11: San Jose Municipal Water Total Demand Projection

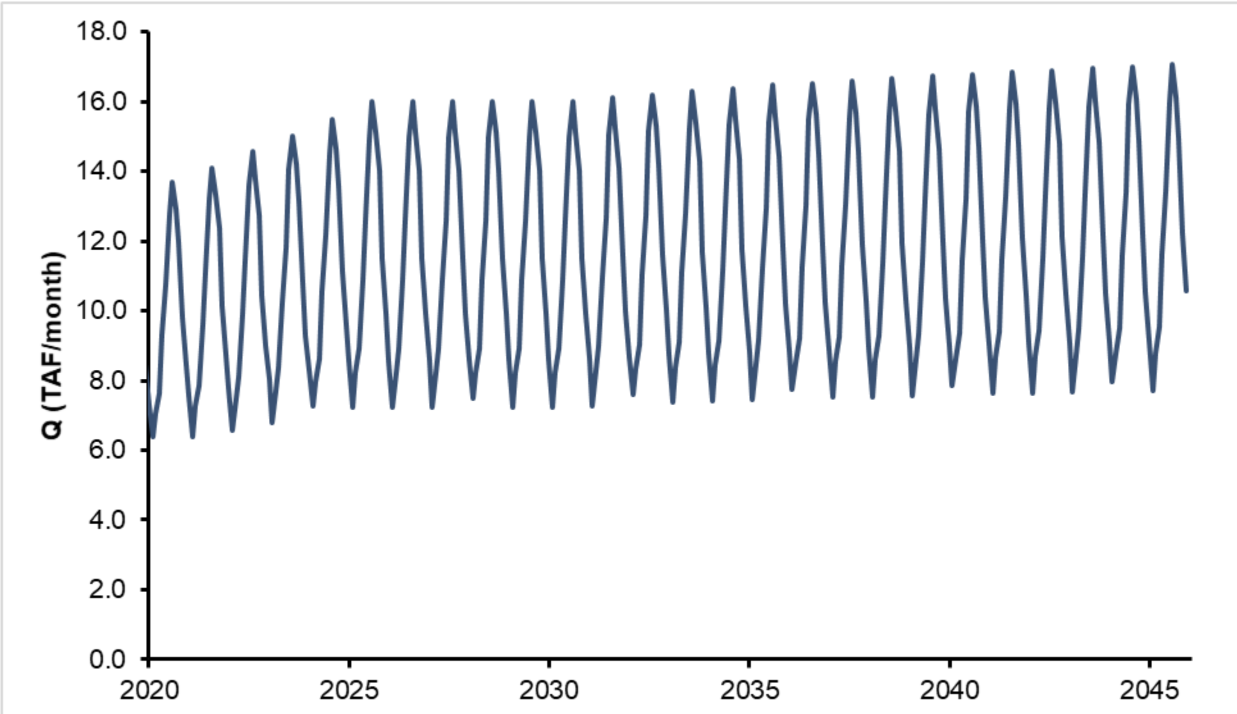

Figure R-12: San Jose Water Company Total Demand Projection

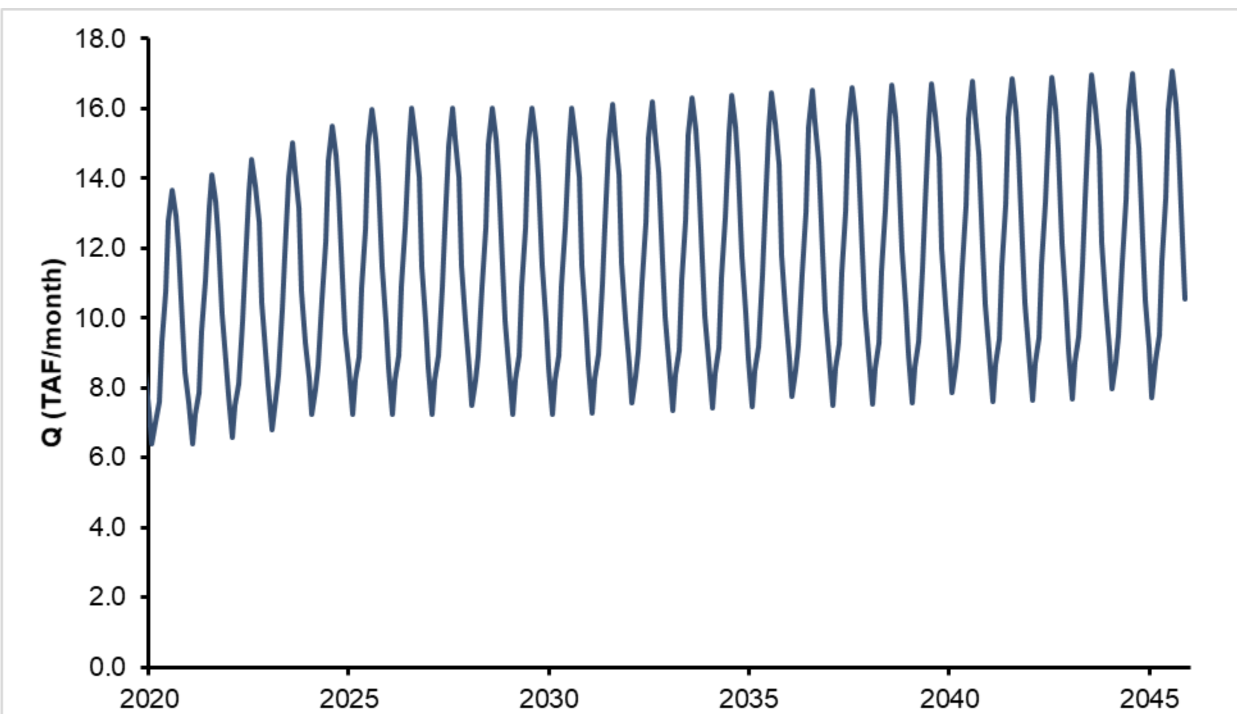

Figure R-13: Stanford University Total Demand Projection

Appendix S: Impact Factor Analysis Tables

Table S-1: Summary of Impact Factor for Single Family Residential Forecast

	Ratio Change[(a)]		(Ratio Change)^Coefficient[(a)]											
Retail Agency	**Volumetric Water Use**	**Driver Units**	**Drought**	**Median Income**	**Price**	**Single Family Density**	**Single Family Persons Per Household**	**Precipitation**	**Temperature**	**Precipitation, Lag 1**	**Temperature, Lag 1**	**Precipitation, Lag 2**	**Temperature, Lag 2**	**Temperature, Lag 3**
California Water Service	**1.11**	**1.01**	**1.16**	1.00	*0.93*	1.00	**1.02**	1.00	1.00	1.00	1.00	1.00	1.00	1.00
City of Gilroy	**1.41**	**1.25**	**1.16**	1.00	*0.93*	1.00	**1.05**	1.00	1.00	1.00	1.00	1.00	1.00	1.00
City of Milpitas	**1.16**	**1.08**	**1.16**	1.00	*0.93*	*0.97*	**1.02**	1.00	1.00	1.00	1.00	1.00	1.00	1.00
City of Morgan Hill	**1.31**	**1.18**	**1.16**	1.00	*0.93*	1.00	**1.03**	1.00	1.00	1.00	1.00	1.00	1.00	1.00
City of Mountain View	**1.15**	**1.06**	**1.16**	1.00	*0.93*	*0.98*	**1.03**	1.00	1.00	1.00	1.00	1.00	1.00	1.00
City of Palo Alto	**1.10**	**1.00**	**1.16**	1.00	*0.93*	1.00	**1.02**	1.00	1.00	1.00	1.00	1.00	1.00	1.00
City of Santa Clara	**1.10**	**1.01**	**1.16**	1.00	*0.93*	1.00	**1.01**	1.00	1.00	1.00	1.00	1.00	1.00	1.00
City of Sunnyvale	**1.10**	**1.02**	**1.16**	1.00	*0.93*	*0.99*	**1.01**	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Great Oaks Water Company	**1.18**	**1.13**	**1.16**	1.00	*0.93*	*0.95*	**1.02**	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Purissima Hills Water District	**1.11**	**1.01**	**1.16**	1.00	*0.93*	*0.99*	**1.02**	1.00	1.00	1.00	1.00	1.00	1.00	1.00
San Jose Municipal Water	**1.06**	**1.03**	**1.16**	1.00	*0.93*	*0.99*	*0.96*	1.00	1.00	1.00	1.00	1.00	1.00	1.00
San Jose Water Company	**1.12**	**1.02**	**1.16**	1.00	*0.93*	*0.99*	**1.02**	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Notes:
(a) Values greater than 1 are indicated by bold text; values less than 1 are indicated by italic text.

Table S-2: Summary of Impact Factor for Multifamily Residential Forecast

	Ratio Change[a]		(Ratio Change)^Coefficient[a]									
Retail Agency	**Volumetric Water Use**	**Driver Units**	**Drought**	**Price**	**Multifamily Density**	**Multifamily Persons Per Household**	**Precipitation**	**Temperature**	**Precipitation, Lag 1**	**Temperature, Lag 1**	**Temperature, Lag 2**	**Temperature, Lag 3**
California Water Service	**1.22**	**1.19**	**1.07**	*0.95*	*0.97*	**1.04**	1.00	1.00	1.00	1.00	1.00	1.00
City of Gilroy	**1.66**	**1.48**	**1.07**	*0.95*	1.00	**1.10**	1.00	1.00	1.00	1.00	1.00	1.00
City of Milpitas	**1.59**	**1.64**	**1.07**	*0.95*	*0.90*	**1.04**	1.00	1.00	1.00	1.00	1.00	1.00
City of Morgan Hill	**1.44**	**1.33**	**1.07**	*0.95*	1.00	**1.06**	1.00	1.00	1.00	1.00	1.00	1.00
City of Mountain View	**1.47**	**1.47**	**1.07**	*0.95*	*0.92*	**1.05**	1.00	1.00	1.00	1.00	1.00	1.00
City of Palo Alto	**1.15**	**1.10**	**1.07**	*0.95*	*0.98*	**1.03**	1.00	1.00	1.00	1.00	1.00	1.00
City of Santa Clara	**1.29**	**1.29**	**1.07**	*0.95*	*0.95*	**1.03**	1.00	1.00	1.00	1.00	1.00	1.00
City of Sunnyvale	**1.87**	**2.08**	**1.07**	*0.95*	*0.86*	**1.02**	1.00	1.00	1.00	1.00	1.00	1.00
Great Oaks Water Company	**1.27**	**1.25**	**1.07**	*0.95*	*0.96*	**1.04**	1.00	1.00	1.00	1.00	1.00	1.00
San Jose Municipal Water	**2.35**	**3.10**	**1.07**	*0.95*	*0.79*	*0.93*	1.00	1.00	1.00	1.00	1.00	1.00
San Jose Water Company	**1.84**	**1.74**	**1.20**	*0.95*	*0.89*	**1.03**	1.00	1.00	1.00	1.00	1.00	1.00

Notes:
(a) Values greater than 1 are indicated by bold text; values less than 1 are indicated by italic text.

Table S-3: Summary of Impact Factor for CII Forecast

Retail Agency	Ratio Change[(a)]		(Ratio Change)^Coefficient[(a)]														
	Volumetric Water Use	Driver Units	Drought	Price	Price (based on WUE Rate)	Precipitation	Temperature	Precipitation, Lag 1	Temperature, Lag 1	Precipitation, Lag 2	Temperature, Lag 2	Ratio of Health, Education and Recreational Services Jobs	Ratio of Industrial Jobs	Ratio of Information, Government, and Construction Jobs	Ratio of Professional Services Jobs	Ratio of Retal Jobs	Net Impact, Sectoral Employment Ratios
California Water Service	**1.46**	**1.19**	**1.15**	*0.95*	-	1.00	1.00	1.00	1.00	1.00	1.00	**1.13**	*0.91*	1.00	**1.10**	*0.99*	**1.12**
City of Gilroy	1.00	**1.19**	**1.15**	*0.95*	-	1.00	1.00	1.00	1.00	1.00	1.00	*0.97*	**1.06**	1.00	*0.73*	**1.03**	*0.77*
City of Milpitas	**1.44**	**1.27**	**1.15**	*0.95*	-	1.00	1.00	1.00	1.00	1.00	1.00	**1.08**	*0.93*	1.00	**1.05**	*0.98*	**1.04**
City of Morgan Hill	*0.99*	**1.01**	**1.15**	*0.95*	-	1.00	1.00	1.00	1.00	1.00	1.00	**1.08**	*0.97*	**1.01**	*0.84*	**1.02**	*0.90*
City of Mountain View	**1.41**	**1.21**	**1.15**	*0.95*	-	1.00	1.00	1.00	1.00	1.00	1.00	**1.23**	*0.92*	*0.98*	*0.94*	**1.02**	**1.06**
City of Palo Alto	**1.11**	**1.02**	**1.15**	*0.95*	-	1.00	1.00	1.00	1.00	1.00	1.00	*0.95*	*0.97*	**1.01**	**1.06**	**1.01**	*0.99*
City of Santa Clara	**1.63**	**1.42**	**1.15**	*0.95*	-	1.00	1.00	1.00	1.00	1.00	1.00	**1.19**	*0.83*	*0.99*	**1.09**	*0.98*	**1.05**
City of Sunnyvale	**1.44**	**1.28**	**1.15**	*0.95*	-	1.00	1.00	1.00	1.00	1.00	1.00	**1.20**	*0.90*	**1.01**	*0.96*	*0.99*	**1.03**
Great Oaks Water Company	**1.08**	**1.19**	**1.15**	*0.95*	-	1.00	1.00	1.00	1.00	1.00	1.00	**1.08**	*0.93*	**1.01**	*0.77*	**1.05**	*0.83*
Purissima Hills Water District	**1.17**	**1.09**	**1.15**	*0.95*	-	1.00	1.00	1.00	1.00	1.00	1.00	*0.96*	**1.15**	**1.01**	*0.81*	**1.07**	*0.98*
San Jose Municipal Water	**1.58**	**1.34**	**1.15**	*0.95*	-	1.00	1.00	1.00	1.00	1.00	1.00	**1.20**	*0.88*	**1.02**	**1.03**	*0.97*	**1.08**
San Jose Water Company	**1.27**	**1.22**	**1.15**	*0.95*	-	1.00	1.00	1.00	1.00	1.00	1.00	**1.09**	*0.96*	*0.99*	*0.92*	*0.99*	*0.95*
Stanford University	*0.80*	**1.33**	**1.09**	-	*0.56*	1.00	-	1.00	1.00	1.00	-	-	-	-	-	-	-

Notes:
[(a)] Values greater than 1 are indicated by bold text; values less than 1 are indicated by italic text.

Hazen

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Appendix D – Water Supply Modeling

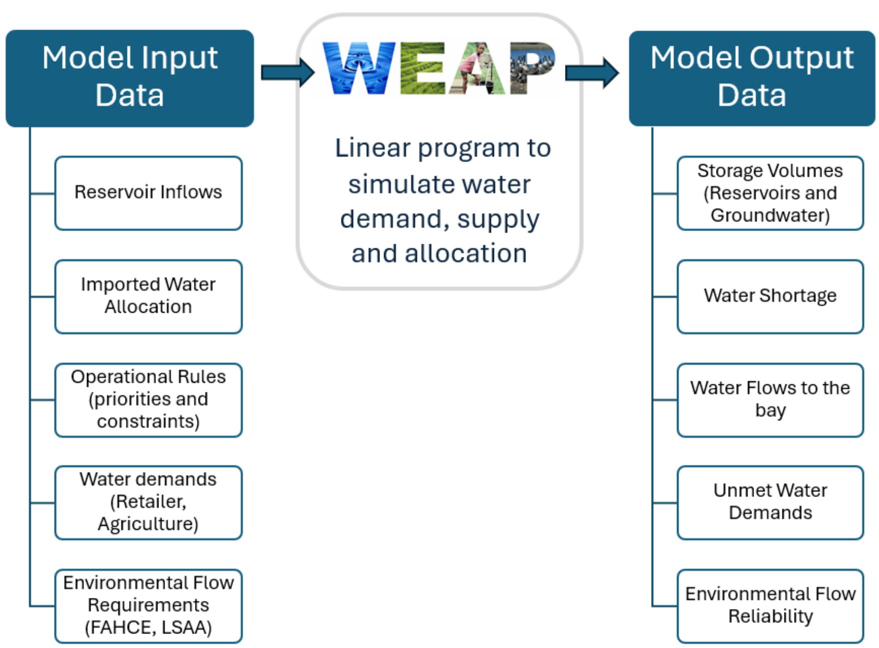
Appendix D: Water Supply Modeling

1 WEAP Model Background

The Water Evaluation and Planning (WEAP) system, developed by the Stockholm Environment Institute (SEI), is a decision-support tool used for water resources planning and management. This modeling platform supports the Water Supply Master Plan (WSMP) by simulating water demands and supplies, conducting scenario analysis, and assessing the impacts of project investments on Santa Clara County's water supplies and expected future needs. The WEAP model is a well-established and extensively vetted tool at Valley Water, having been used for multiple planning efforts, including environmental impact assessments and long-term water supply planning. Its integration into Valley Water's decision-making process ensures consistency in evaluating future supply reliability and operational strategies. The model is designed to reflect actual system operations and constraints as closely as possible, providing a realistic foundation for exploring tradeoffs, testing assumptions, and guiding decisions.

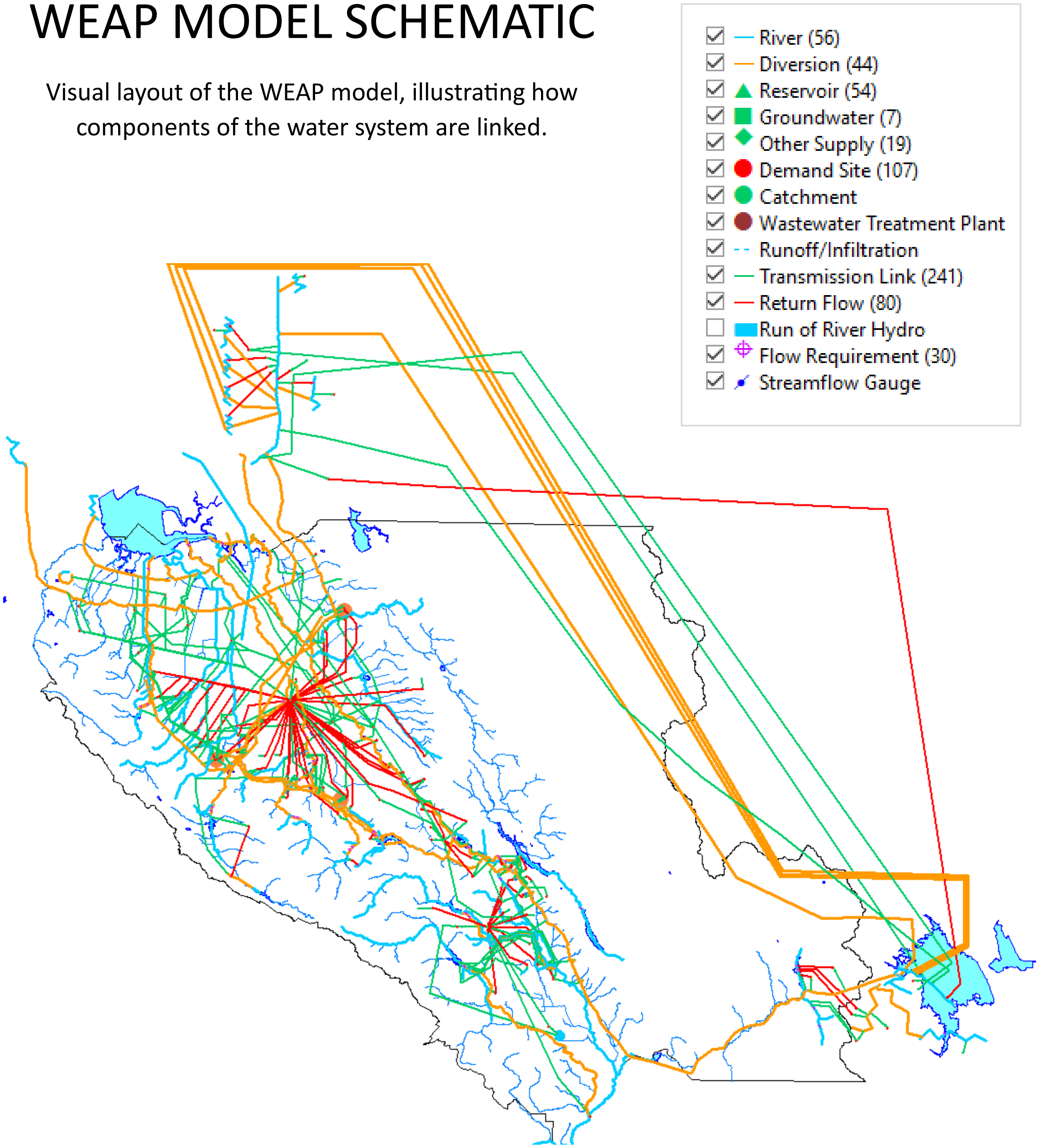
WEAP operates using a linear programming approach, which optimizes water allocation by distributing available water resources across competing demands based on priorities and constraints. This ensures that residential, agricultural, and environmental needs are met as efficiently as possible within a set of defined parameters. The model tracks water throughout Santa Clara County, including imported water, rainfall, recycled water, groundwater storage levels, reservoir levels, river flow, treatment plant production, groundwater recharge, and groundwater pumping.

The general modeling approach integrates water sources, distributes water throughout the system based on operational constraints and priorities and supplies it to meet demands such as retailer supply. The next sections in this appendix go into detail on these data inputs in the model, operational constraints defined within the model, and output generated for analysis.



WEAP MODEL SCHEMATIC

Visual layout of the WEAP model, illustrating how components of the water system are linked.



2 Model Data Inputs

Model Data	Description	Data Source
State Water Project (SWP) and Central Valley Project (CVP)	Forecasted using CalSim II for CVP/SWP deliveries under different climate scenarios (DCP 2020 Existing Conditions Base, DCP 2040 0.5 ft Central Tendency, and DCP 2040 1.8 ft Median).	CalSim II (DCP 2020/2040)
San Francisco Public Utility Commission (SFPUC)	SFPUC supplies modeled using Bay Area Water Supply and Conservation Agency (BAWSCA) supply model median scenario between the Existing Conditions/No Bay Plan scenario and SFPUC No VA Bay Plan scenario assumes the Bay Plan is enacted without a Voluntary Agreement (VA).	BAWSCA supply model
Local Reservoir Inflows	Reservoir inflows modeled from historical data (1922-2015), adjusted using Global Circulation Models (CESM1 & CCSM4). Downscaled using Localized Constructed Analogs (LOCA) method and input into the VIC hydrologic model to simulate climate-adjusted inflow scenarios.	Historical records (1922-2015) modified to incorporate CESM1 & CCSM4 GCM model data
Natural Groundwater Recharge	Natural groundwater recharge estimated based on rainfall that incorporates climate change impacts. For Santa Clara Subbasin, recharge estimates derived from MODFLOW simulations covering 1922-2015.	Rainfall data, MODFLOW simulations, historical groundwater recharge records
Retailer and Agricultural Water Demands	Retailer and agricultural demands projected using a demand model. Forecasts incorporate historical water usage, economic indicators (housing growth, median income), and climate projections (ABAG, CDOF, Prism data). Climate adjustments derived from GCM downscaled data.	Valley Water demand model
Evaporation Losses	Reservoir evaporation losses calculated using historical evaporation measurements. Future evaporation projections adjusted based on downscaled temperature changes from CESM1 & CCSM4 models, consistent with local climate change impact assumptions.	Evaporation data modified to incorporate CESM1 & CCSM4 GCM model data
Recycled Water	Recycled water supply is based on the historical average.	Historical Data

3 Model Operational Rules

WATER SYSTEM OPERATIONS
System Priorities
Water is allocated based on a structured priority system that ensures environmental flows, potable water supply, and groundwater recharge are met before lower-priority uses. The model follows a predefined sequence of allocations to optimize system performance and reliability.
In-stream Flow Requirements
Maintains minimum streamflow levels to support fish and aquatic habitats, in compliance with Fisheries and Aquatic Habitat Collaborative Effort (FAHCE) and Lake and Streambed Alteration Agreement (LSAA) agreements. Environmental flows are prioritized even during droughts to prevent ecosystem degradation.
Managed Groundwater Recharge
Groundwater recharge is actively managed through a network of recharge ponds and direct percolation facilities. Water is allocated to recharge operations based on groundwater basin levels, demand forecasts, and available imported supplies.
Water Treatment Plant Operations
Valley Water operates three main treatment plants - Rinconada, Penitencia, and Santa Teresa - each with defined treatment capacities. Operations are adjusted based on available imported water, system demands, and water quality considerations.
Surface Water Supply Operations
San Luis Reservoir low-point constraints influence CVP deliveries. When storage falls below critical levels, CVP allocations to Santa Teresa and Rinconada Water Treatment Plants are reduced, requiring alternative supply strategies.
Imported Water Carryover Operations
Carryover storage from SWP and CVP contracts is managed to prevent water loss from spills. Storage levels are monitored to determine the optimal use of carryover water before regulatory thresholds are reached.
Semitropic Water Bank Operations
Valley Water participates in the Semitropic Water Bank with a total storage capacity of 350 TAF. The current contract is set to expire in 2035. Water is stored through an exchange system rather than direct physical transfers, with withdrawals occurring when Santa Clara Plain groundwater storage falls below 278 TAF or treated water demands require additional supply. Annual withdrawal capacity is subject to State Water Project (SWP) allocations, and a reserve of 189 TAF is maintained for extended drought conditions. Annual put-and-take restrictions are 31.6 TAFY.

4 Modeling Approach

General WEAP Model Setup and Assumptions

The WEAP model simulates water system performance by utilizing historical hydrology records from 1922 to 2015 as its baseline. Future modeled year projections (2030–2050 at 5-year increments) incorporate temporal changes to:

- **Climate impacts**: Including temperature, precipitation, and evaporation changes.
- **Projected water demands**: Reflecting population growth, economic trends, climate projections, and conservation efforts.
- **Planned project investments**: Such as expanded reservoirs, local supply projects, stormwater capture, and new recharge facilities.

As a deterministic model, WEAP produces consistent results for the same inputs, enabling the evaluation of water supply needs and the identification of effective project portfolios to address future challenges.

Scenario Simulation

The WEAP model simulates multiple scenarios for each demand year, varying key factors such as demand levels, imported water availability, and climate conditions. These scenarios are designed to explore a range of possible futures and evaluate the performance of water supply portfolios under differing conditions. Scenarios are defined by three key dimensions:

- **Demand Scenarios**: High and low water demands, reflecting varying water use reduction potential and conservation levels.
- **Local and Imported Supplies**: High and low supply scenarios, capturing variability in reservoir inflows and imported water allocations.
- **Climate Conditions:** Two different climate models (CESM1 and CCSM4), representing regional variability in temperature, precipitation, and sea level rise impacts.

Scenarios are modeled in **5-year increments**, representing evolving conditions:

- **2030:** Two scenarios exploring moderate and severely impacted imported water availability, current climate conditions, and one demand projection.
- **2035–2050**: A "four-quadrant approach," combining high and low water demand with high and low imported water supply availability.

Climate Change

The modeling approach incorporates local climate change effects by adjusting climate-driven model inputs based on downscaled climate projections. Two Global Circulation Models (CESM1 and CCSM4) were selected for their ability to represent regional climate patterns in California, as identified by the Climate Change Technical Advisory Group (CCTAG). These models were downscaled using the Localized Constructed Analogs (LOCA) method, which provides high-resolution climate data specific to Santa Clara County. These climate-adjusted outputs were incorporated into WEAP to evaluate future conditions.

Key local climate change impacts included in the model:

- **Reservoir Inflows:** Based on downscaled precipitation data incorporated into a Variable Infiltration Capacity (VIC) hydrologic model.
- **Natural Groundwater Recharge:** Adjusted based on changes in downscaled precipitation.
- **Evaporation Losses:** Adjusted based on temperature changes.
- **Water Demand:** Downscaled data integrated into the demand model, accounting for precipitation and temperature impacts on water use. This is done outside WEAP modeling.

Modeled Water Use Reduction

To ensure fair comparisons across scenarios, the WEAP model incorporates standardized triggers for water use reductions. These triggers are based on imported water allocation thresholds, avoiding reliance on fluctuating modeled volume-based factors. This consistent approach ensures that portfolio evaluations focus on system performance under comparable conditions rather than variations in operational timing. Modeled water use reductions are capped in the model based on the demand scenario. The high demand scenario has a greater potential for conservation than the lower demand scenario where conservation is already a norm. The reductions are capped at 15% and 10% for the high and low demand scenarios, respectively.

Level of Service (LOS) Goal

Valley Water's LOS goal is defined as:

- **100% reliability** during normal years
- **80% reliability** during droughts

Groundwater storage levels serve as key indicators of system health in the model. If groundwater falls below critical thresholds, reductions beyond 20% would be required to maintain supply. Such conditions signal that the scenario does not meet the LOS goal.

Water Shortage Evaluation

The WEAP model evaluates water shortages by adding a hypothetical supplemental supply when groundwater falls below the LOS threshold levels. This is not an actual water source but a modeling tool used to identify and quantify unmet system needs, referred to as shortage.

This approach helps quantify:

- The gap between existing resources and required reliability.
- The volume of additional supply needed to meet the LOS goal.

A portfolio of projects is considered effective if it eliminates the need for supplemental water by maintaining groundwater levels above the critical threshold. This ensures supply reliability during droughts while meeting LOS objectives.

Model Outputs

The WEAP model provides key outputs that help evaluate water supply alternatives:

- **Storage Levels:** Including reservoirs, groundwater basins, and banks (e.g., Semitropic)
- **Water Shortages:** Quantifying unmet demands and the volume of water needed during droughts to meet the LOS goal
- **Project specific outputs:**
  - Reservoir projects: Volume of water stored and utilized during drought conditions
  - Supply project: Supplies delivered and utilization rate
  - Recharge-focused projects: Amount of water delivered to percolation ponds
- **Environmental Flows:** Percent of flow requirements met
- **Model Efficiency Outputs:** ensure that proposed portfolios address both supply reliability and operational efficiency under various scenarios
  - Unused carryover water in SWP and CVP systems
  - Creek Flows to San Francisco and Monterey Bays beyond what is requirement for environmental flows
  - Modeled groundwater overflow

5 Model Scenarios

GENERAL MODEL SETTINGS	
Historical Hydrology	1922 – 2015
Demand Year	2050
WEAP Model Version	WEAP 2023.0
Elements modeled	Complete water supply system
General Scenario Description	Planned operations thru 2050
Model Method	Deterministic

All Scenarios	
Semitropic Contract Allocation	35% until 2035, then 0% after
Reservoir Seismic Upgrades	Almaden, Anderson, Calero, and Guadalupe are completed in 2035
"No Regrets" Stormwater Package Included	South County Agricultural Land Stormwater Project, Rain Barrel Rebate Program, and Centralized Stormwater Capture in northern Santa Clara County beginning in 2035
Non-Potable Recycled Water	18,000 TAFY[1]
FAHCE Scenario	FAHCE+ Modified
San Francisco Public Utilities Commission (SFPUC)	BAWSCA supply model median scenario[2]
Rinconada Water Treatment Plant Capacity	90 MGD[3]
Penitencia Water Treatment Plant Capacity	40 MGD
Santa Teresa Water Treatment Plant Capacity	100 MGD

[1] Based on Average of previous 10 years

[2] SFPUC supplies are based on the BAWSCA supply model, using the median scenario between the "SFPUC No VA Bay Plan" scenario and the "Existing Conditions/No Bay Plan" scenario.

[3] Assumes Rinconada improvement project is completed.

Demand Year 2030		
	Stable Demand, Moderately Impacted Imports	Stable Demand, Severely Impacted Imports
Annual Demands	330 TAF	330 TAF
Maximum Water Use Reduction	15%	15%
Imported Water Climate Scenario	DCP 2020 Existing Conditions Base	DCP 2040 Central Tendency Climate with 0.5 ft Sea Level Rise
Climate Change GCM Model[4]	No Climate Change Impacts	No Climate Change Impacts

Demand Year 2035				
	Stable Demand, Moderately Impacted Imports	Stable Demand, Severely Impacted Imports	High Demand, Moderately Impacted Imports	High Demand, Severely Impacted Imports
Annual Demands	330 TAF	330 TAF	340 TAF	340 TAF
Maximum Water Use Reduction	10%	10%	15%	15%
Imported Water Climate Scenario	DCP 2020 Existing Conditions Base	DCP 2040 Central Tendency Climate with 0.5 ft Sea Level Rise	DCP 2020 Existing Conditions Base	DCP 2040 Central Tendency Climate with 0.5 ft Sea Level Rise
Climate Change GCM Model	CESM1	CESM1	CESM1	CESM1

Demand Year 2040				
	Stable Demand, Moderately Impacted Imports	Stable Demand, Severely Impacted Imports	High Demand, Moderately Impacted Imports	High Demand, Severely Impacted Imports
Annual Demands	330 TAF	330 TAF	345 TAF	345 TAF
Maximum Water Use Reduction	10%	10%	15%	15%

[4] Downscaled and perturbed datasets from CMIP5 GCM models for local reservoir inflows, reservoir evaporation, water demands, precipitation, and natural groundwater recharge.

Imported Water Climate Scenario	DCP 2040 Central Tendency Climate with 0.5 ft Sea Level Rise	DCP 2040 Median Climate with 1.8 ft Sea Level Rise	DCP 2040 Central Tendency Climate with 0.5 ft Sea Level Rise	DCP 2040 Median Climate with 1.8 ft Sea Level Rise
Climate Change GCM Model	CESM1	CESM1	CCSM4	CCSM4
Demand Year 2045				
	Stable Demand, Moderately Impacted Imports	Stable Demand, Severely Impacted Imports	High Demand, Moderately Impacted Imports	High Demand, Severely Impacted Imports
Annual Demands	330 TAF	330 TAF	355 TAF	355 TAF
Maximum Water Use Reduction	10%	10%	15%	15%
Imported Water Climate Scenario	DCP 2040 Central Tendency Climate with 0.5 ft Sea Level Rise	DCP 2040 Median Climate with 1.8 ft Sea Level Rise	DCP 2040 Central Tendency Climate with 0.5 ft Sea Level Rise	DCP 2040 Median Climate with 1.8 ft Sea Level Rise
Climate Change GCM Model	CESM1	CESM1	CCSM4	CCSM4
Demand Year 2050				
	Stable Demand, Moderately Impacted Imports	Stable Demand, Severely Impacted Imports	High Demand, Moderately Impacted Imports	High Demand, Severely Impacted Imports
Annual Demands	330 TAF	330 TAF	365 TAF	365 TAF
Maximum Water Use Reduction	10%	10%	15%	15%
Imported Water Climate Scenario	DCP 2040 Central Tendency Climate with 0.5 ft Sea Level Rise	DCP 2040 Median Climate with 1.8 ft Sea Level Rise	DCP 2040 Central Tendency Climate with 0.5 ft Sea Level Rise	DCP 2040 Median Climate with 1.8 ft Sea Level Rise
Climate Change GCM Model	CESM1	CESM1	CCSM4	CCSM4

Appendix E – Water Shortage Impacts

Santa Clara Valley Water District

Valley Water

File No.: 24-0896 **Agenda Date:** 12/10/2024
Item No.: 5.1.

BOARD AGENDA MEMORANDUM

Government Code § 84308 Applies: Yes ☐ No ☒
(If “YES” Complete Attachment A - Gov. Code § 84308)

SUBJECT:
Receive an Update on the Development of Santa Clara Valley Water District’s Water Supply Master Plan 2050; and Approve the August 28, 2024, Recycled Water Committee Recommendation to set Potable Reuse Goal of 24,000 Acre-Feet per Year by 2035 and a Long-Term Vision to Maximize Water Reuse in the County up to 32,000 Acre-Feet per Year.

RECOMMENDATION:

A. Receive an update on the development of Santa Clara Valley Water District’s Water Supply Master Plan 2050 and provide feedback;
B. Consider and approve the August 28, 2024, recommendation of the Recycled Water Committee to set a potable reuse goal of 24,000 acre-feet per year by 2035, as well as a long-term vision to maximize water reuse in the County up to 32,000 acre-feet per year in the Water Supply Master Plan 2050, including additional potable and non-potable reuse, desalination, stormwater capture, and other alternative water sources; and
C. Provide additional feedback and direction on refined adaptive management framework.

SUMMARY:

The Water Supply Master Plan (WSMP) is Santa Clara Valley Water District’s (Valley Water) guiding document for long-term water supply investments to ensure water supply reliability for Santa Clara County. Updated approximately every five years, this long-range plan assesses projected future county-wide demands and evaluates and recommends water supply and infrastructure projects to meet those demands to achieve Valley Water’s level of service goal through the planning horizon. Valley Water’s level of service goal, as established in Board Ends Policy 2, is to “Meet 100 percent of annual water demand during non-drought years and at least 80 percent of demand in drought years.”

Valley Water is working on developing the WSMP 2050. At the June 25, 2024, Board of Directors (Board) meeting, staff presented the third update on the development of the WSMP 2050, including project evaluation, cost analysis for projects and portfolios, representative portfolios that meet water supply needs under three themes, and a proposed adaptive management approach to support decision-making in the face of uncertainty. As a follow-up to the June meeting, the Board approved the 2050 conservation goal of 126,000 acre-feet per year (AFY) at the July 9, 2024, meeting and

requested that the potable reuse goal be further discussed by the Recycled Water Committee.

This memorandum summarizes the progress since July, including the refined potable reuse goal, a discussion of acceptable level of service, cost of shortage discussion, refined road map with recommendations, and incorporates input from the Board and stakeholders.

Potable Reuse Goal

Potable reuse is a locally controlled and drought-resilient supply that is effective in mitigating drought risks. The Recycled Water Committee discussed the potable reuse goal in July and August and recommends a goal of 24,000 AFY of potable reuse by 2035, which can be achieved with a project in collaboration with the Cities of San José and Santa Clara (Attachment 1). In an effort to explore additional potable reuse, the Committee also recommends including a long-term vision to maximize water reuse in the county up to 32,000 AFY. This long-term vision includes additional potable and non-potable reuse, desalination, stormwater capture, and other alternative water sources. Including a 2035 goal with a long-term vision promotes a phased approach that accounts for uncertainty with future demand and wastewater availability while balancing affordability and risk of overinvestment.

Discussion of Level of Service

At the July 9, 2024, Board meeting, Chair Hsueh provided written comments and requested a discussion of the acceptable Level of Service (LOS) in the WSMP update (Attachment 2). The comments asked for elaboration on the potential impacts of a reduced LOS on the local community and Valley Water's operations and cost, as well as the trade-offs of a reduced LOS vs investment to maintain the current service level.

Valley Water's current LOS was updated in the WSMP 2040 and subsequently established in Board Ends Policy 2. The LOS was developed with public and stakeholder input and intended to strike a balance between minimizing shortages and the costs associated with the previous higher LOS goal of meeting at least 90 percent of water demand in drought years. Similar to past practices, the WSMP 2050 uses the established LOS goal to identify future water shortages and the required long-term investments to address them. Based on the current LOS, the identified shortages (ranging from 2,000 to 72,000 AFY) mean that without investment, Valley Water will have a lower LOS under all future conditions, except for the best-case future (stable demand and moderately impacted imported water supplies). The shortages were calculated assuming that Valley Water can meet its long-term water conservation goals and achieve an additional 10 to 15 percent water use reduction during droughts for stable and high demand conditions, respectively.

While a reduced service level would reduce or forego the needed level of investment, it could have an immediate and real impact on residents and businesses and adversely and chronically affect economic development in the county. One of the reasons for that is Santa Clara County is already among the most water efficient counties. Currently, Santa Clara County has already achieved a high level of water use efficiency, with an average residential (indoor and outdoor) water use (over last ten years) of 69 gallons per capita per day, lower than the state average and standard. In addition, with State regulations Making Conservation a Way of Life and banning irrigation of non-functional turf (which are factored into the 2050 conservation goal) and as Valley Water works to meet long-term water conservation goals, outdoor use will continue to decline. It is possible that demand hardens, which leaves few areas to make additional reductions in the future to successfully meet drought calls for conservation.

Depending on the demand and water supply situation that develops in the future, a reduced LOS or insufficient water supply could potentially disrupt activity in homes, schools, government, and businesses and adversely affect public health and safety. Some impacts could include lower quality of life (i.e., rationing of water use during certain times of day), disruption of business operations (data centers, restaurants, tourism, recreation, etc.), and no irrigation for parks and trees. Some of these impacts happened during the last drought in the North Bay and communities in the Central Valley. In addition, agricultural production could be impacted by reduced water supply. If the shortage condition becomes chronic, it could lead to permanent land subsidence, which historically happened in the northern portion of the county and took several decades of aggressive investment and management to halt. Impacts of subsidence in today's highly urbanized Silicon Valley would be much more severe than when the county had substantially more agricultural lands. While Valley Water has the authority to control groundwater pumping, retailers and groundwater pumpers work to cut back during droughts based on voluntary/mandatory calls and incentives. With a lower LOS, it is likely that enforcement mechanisms would need to be developed.

The reduced service level would also negatively impact Valley Water's operations and finances. As discussed above, groundwater pumping restrictions would likely need to be implemented to avoid resumed subsidence. With a much tighter margin of error and counting on our community to conserve when it is already very efficient, Valley Water may also need to rely on purchasing emergency water supply. Financially, Valley Water will experience additional drought spending including cost of purchasing emergency supplies. During the 2020-2023 drought, Valley Water spent $79.5 million on drought management.

In addition, a reduced service level would put Valley Water outside the normal range of other water agencies' levels of service (Table 1), which are all at or above 80 percent except one. This will undermine Valley Water's credibility and could have ripple effects on retailers' operations and their long-range planning and compliance with state regulations, such as Urban Water Management Plans.

Given the above-mentioned impacts of water shortage and reduced LOS, it is critical that Valley Water continues to make necessary investments to maintain the current LOS and mitigate future droughts, to fulfill our mission of providing safe, clean water to Santa Clara County's residents, businesses, and agricultural community.

Table 1 Peer Agency Level of Service Goal

Agency	LOS during drought
Metropolitan Water District	100%
Alameda County Water District	At least 90%
Zone 7 Water Agency	At least 85%
East Bay Municipal Utility District	At least 85%
Contra Costa Water District	At least 85%
San Diego County Water Authority	At least 80%
San Francisco Public Utilities Commission	At least 80%
Valley Water	At least 80%
Marin Municipal Water District	At least 75%

Cost of Shortage Discussion
At the last Board update (June 2024), staff presented cost analyses at both project and portfolio levels, including water rate impacts. As part of the overall cost and benefit analysis, a cost of shortage analysis was performed to estimate the economic benefits of water supply investment to help inform investment decisions. The benefits were measured by avoided costs and estimated separately for residential, agricultural, and business sectors because they require different approaches.

The cost of shortage for the residential sector is estimated as the dollar amount that water users would be willing to pay to avoid water shortages. It is based on the economic theory of demand and relies on price elasticities and forecasted demands (among other variables). The calculation used the same approach[1] as developed for the WSMP 2040 but with updated data. For representative portfolios, the present value of the cost of shortage (in 2023 dollars) was estimated to be $1.6 billion for the stable demand and $2.8 billion for the high demand, and there is not much difference among portfolios as they can all achieve similar water supply reliability.

The economic impact of water shortages on agricultural communities was estimated based on the county's crop production. It was assumed that crop production would be reduced in proportion to the estimated water shortage. Using this simple assumption, the present value of the estimated impact on agriculture will range from $220 million to $280 million. In the past 10 years, the agricultural production in the county, however, has remained stable without much impact from droughts, because farmers were able to pump groundwater for irrigation due to Valley Water ensuring healthy groundwater levels. In a 2022 policy brief[2], the Public Policy Institute of California (PPIC) estimated that during the last drought, state-wide crop revenue losses and increased pumping costs were at $1.1 billion in 2021. Similar impacts could happen in the county during future droughts, if groundwater availability is not sufficient.

The cost of water shortage for businesses, however, is challenging to estimate because the impacts of water shortage vary by business type depending on how essential water is to them. As a result, the estimate usually requires significant time and effort and involves surveys and/or reviews of various economic activities. Even with a robust analysis, the estimate is generally considered high level. Given this, and time and resource constraints, the economic impact on businesses was drawn by reference from previous studies. In 2022, the Municipal Water District of Orange County did a study on the economic impacts of water shortages in Orange County[3], which estimated that a 15 percent water shortage for a year would cost $5.3 billion[4] direct reduction in business output and associated indirect impacts, while a 30 percent water shortage could result in $11.2 billion[4] of business impacts. Since Santa Clara County is similar to Orange County in Gross Domestic Product (GDP), it could be assumed that water shortage in our county would have a similar level of impact. In 2010, Valley Water did a similar study[5], which provided an estimate of approximately $1.2 billion[6] sales revenue decrease for 10 percent water rationing and $14.2 billion[6] for 30 percent rationing. All costs are escalated to 2023 dollars from originally reported numbers, based on the U.S. Bureau of Labor Statistics (BLS) Consumer Price Index for the San Francisco Area.

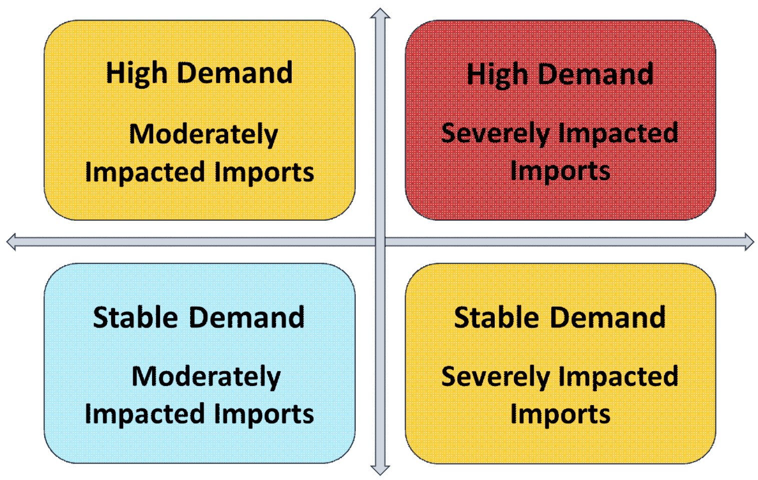
In addition, if the shortage condition becomes chronic, groundwater overdraft could lead to land subsidence and widespread and costly infrastructure damage over time. The groundwater basin in northern Santa Clara County managed by Valley Water is vulnerable to land subsidence, with historic overdraft causing up to 14 feet of permanent subsidence in the greater San José metropolitan area[7], the heart of Silicon Valley. This resulted in seawater intrusion, increased flood risk, and widespread damage to infrastructure. Historic damage to infrastructure and associated repair was estimated to be more than $756 million in 2013 dollars[7]. Currently, the San José-Santa Clara Regional Wastewater Facility is below sea level and receives and treats wastewater from more than 1.5 million people and serves a business sector with more than 17,000 main sewer connections. Sewer lines, storm drains, and associated pumping stations can be compromised by subsidence. Similarly, water supply pipelines, supply wells, and other health and safety infrastructure, including levees, roads, bridges, railroad alignments, hospitals, schools, and the power grid are all susceptible to damage if subsidence were to begin again.

While quantifying the potential economic impacts of water shortages is desirable, it is important to note that these types of analysis, by their nature, cannot completely and accurately capture the full spectrum of economic impacts, because of the complex nature of drought impacts on various aspects of society and the difficulty quantifying some benefits (i.e. quality of life, environmental benefits, etc.). At best, they present a snapshot of a high-level, order-of-magnitude estimation of quantifiable benefits with many underlying assumptions, including how water will be distributed and used in the future. Water supply is one of the most critical existential resources for a region's survival and prosperity; its value is far beyond what can be measured monetarily. Therefore, providing a safe and reliable water supply is not only economically beneficial but also helps secure the future of our county for generations to come.

Water Supply Strategy for Worst-Case Condition

The WSMP 2050 analyzes four future supply and demand conditions (Figure 1) based on different combinations of imported water supplies (moderately or severely impacted) and demand (stable or high). At the June Board update, representative portfolios for three themes (lower cost, local control, diversified) were presented for the future condition of stable demand and severely reduced imports. The portfolios evaluated for this condition generally perform similarly to another middle-of-road condition (high demand and moderately impacted imports). There is very little shortage for the best-case condition (stable demand and moderately impacted imports) that would require investment.

Figure 1 Four Future Conditions for Planning



To complete the full analysis for all four future conditions, further portfolio analysis was completed to identify projects that would be needed to address the worst-case future condition of high demand and severely reduced imports. Since this condition is similar to the middle-of-road condition (stable demand and severely reduced imports) but with higher demand, the portfolios were developed by growing from the three representative portfolios identified for that condition to meet the higher demand.

The analysis suggests that under the worst-case condition, more projects will be needed for the **Lower Cost** and **Local Control** themes but not **Diversified**, which builds in enough resiliency and redundancy to meet higher demand (Table 2). However, given the current trend of urban demand, the worst-case condition may be too conservative to be used as the basis for investment decisions. Therefore, this analysis serves as part of the adaptive management framework to provide a full picture of potential future conditions and how Valley Water can be prepared for any of the four conditions.

Table 2 Portfolios for Worst-case Condition

Strategies	Projects[1]	Portfolio Cost[2] (Billion)
Lower Cost	San José Direct Potable Reuse, DCP, Sisk, Groundwater Banking (**350,000 AF**), South County Recharge, **Sites**	**$4.3**
Local Control	San José Direct Potable Reuse, Palo Alto Potable Reuse, Pacheco without Partners, Groundwater Banking (**350,000 AF**), South County Recharge, **Local Desalination**	**$7.0**
Diversified	San José Direct Potable Reuse, DCP, Pacheco with Partners, Sisk, Groundwater Banking (350,000 AF), South County Recharge	**$5.3**

[1]Conservation is factored in the baseline condition.
[2]Portfolio cost includes the sum of the present value total cost for each project.

Adaptive Management Framework
At the June Board update, an adaptive management approach was proposed to provide the Board with flexibility and the ability to make incremental investment decisions in the face of deep uncertainty associated with future conditions and project development and implementations. The adaptive framework is intended to define a consistent, stepwise process of making project and program investment decisions. The framework includes a roadmap and annual reporting. The roadmap outlines near- and mid-term actions and defines indicators and conditions to guide project decisions. The annual reporting tracks project progress and provides up-to-date information to help inform decision-making.

The proposed roadmap was refined to include more specific recommended actions at different timelines, especially immediate actions as the starting point of the adaptive management framework:

- **Now -** focus on the **Lower Cost** strategy, which includes San José Potable Reuse, B.F. Sisk Dam Raise, Delta Conveyance Project, Groundwater Banking, and South County Recharge; Continue planning for Pacheco and Sites; Continue the Desalination feasibility study; Continue implementing conservation programs.
- **Near-term (2-3 years) -** Assess success/progress on project planning and implementation; Make project funding, participation, or go/no-go decisions based on indicators, new information, and actual conditions; Continue planning for other projects.
- **Mid-term (5 years) -** Assess progress on project implementation; Update demand projections and water supply outlook; Update WSMP

Staff recommends the lower cost strategy while continuing to plan for other projects as a way to balance affordability and reliability. Given that large water supply projects and partnerships can have uncertain outcomes, continued planning for additional projects is recommended.

Annual reporting through the Monitoring and Assessment Program (MAP) will be a critical component of the adaptive management framework. A standard MAP report will be devised to include key elements of the WSMP, including progress on projects, conditions of indicators, and whether any adjustments are recommended. The timing of the MAP will be aligned with the annual CIP Five-Year Plan and Water Rate-Setting Cycle to support related decision-making.

The list of indicators and metrics that will be tracked in the annual MAP include:

- Progress of negotiations and agreements with other agencies (i.e., Sisk Dam Raise Project or direct potable reuse facility with the Cities of San José and Santa Clara)
- Timing of upcoming project decisions
- Regulatory and permitting issues
- Annual water use
- Annual supply
- Success of Conservation measures (water savings, program participation)
- Growth trend/demand
- Regional collaborative agreements and decisions by other agencies
- Evolving water quality standards

In the next few years, major decisions will come up for several projects. Through this adaptive management framework, the Board will have multiple opportunities along each project's trajectory to make informed decisions on investments. It also allows the WSMP to be closely linked to the annual CIP and rate-setting processes, fulfilling its role as the guiding document for long-term investment strategy.

Outreach Efforts

Stakeholder engagement is an important component of the WSMP 2050 development process and is carried out throughout the plan development. In October 2024, staff presented updates at the Water Commission, Environmental Water Resources Committee, and retailer meetings. Staff also met with environmental stakeholders to discuss their questions and responses to written comments. In addition, Valley Water continues to use the WSMP webpage (<https://www.valleywater.org/your-water/water-supply-planning/water-supply-master-plan>), stakeholder email list, blogs, social media, and communication newsletter as ongoing opportunities to provide updates and engage the public and stakeholders.

Expert Panel

Valley Water convened an expert panel to support WSMP analyses and provide feedback on this Board update. Valley Water continues engaging the expert panel on various topics. The following experts serve on the panel:

- David Sunding, Professor at University of California, Berkeley
- Newsha Ajami, Chief Development Officer for Research, Lawrence Berkeley National Lab
- Michael Anderson, State Climatologist, Department of Water Resources
- Yung-Hsin Sun, Senior Principal Consultant, Sunzi Consulting LLC

Next Steps

Based on Board feedback and direction, staff will finalize the analysis and roadmap and start drafting the plan.

[1] Water Supply Master Plan 2040, Valley Water, 2019
[2] 'Policy Brief: Drought and Californias Agriculture <https://www.ppic.org/publication/policy-brief-drought-and-californias-agriculture/>, Public Policy Institute of California, 2022
[3] The Economic Impacts of Water Shortages in Orange County, Brattle, 2022.
[4] The study reported $5.1 billion for 15 percent water shortage and $10.8 billion for 30 percent shortage in 2022 dollar.
[5] Economic Analysis of Water Shortage in Santa Clara County, Berkeley Economic Consulting, 2010.
[6] The study reported $883 million for 10 percent shortage and $10.7 billion for 30 percent shortage in 2010 dollar.
[7] Land Subsidence from Groundwater Use in California, Borchers and Carpenter, 2014.

ENVIRONMENTAL JUSTICE AND EQUITY IMPACT:
The Water Supply Master Plan addresses water supply equity by ensuring a cost-effective, high-quality supply is available for all of Santa Clara County, including disadvantaged communities.

FINANCIAL IMPACT:
There is no financial impact associated with this item.

CEQA:
The recommended actions do not constitute a project under CEQA because they do not have the potential for resulting in direct or reasonably foreseeable indirect physical change in the environment.

ATTACHMENTS:
Attachment 1: Potable Reuse Goal
Attachment 2: 07092024 Handout 6.1-G, Hsueh
Attachment 3: PowerPoint

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Appendix F – Cost Analysis Method and Assumptions

Appendix F - Cost Analysis Method and Assumptions

Methodology

For supply projects, two unit costs were calculated, the levelized and annualized unit cost.

$$\textbf{Levelized Unit Cost (\$/AF)} = \frac{\text{Present Value of Total Costs (\$2025)}}{\text{Present Value of Project Yield over Lifetime (AF)}}$$

$$\textbf{Annualized Unit Cost } (\$/\mathbf{AF}) = \frac{\mathit{Amortized\ Present\ Value\ of\ Total\ Costs}\ (\$2025)}{\mathit{Average\ Annual\ Project\ Yield\ over\ Lifetime}\ (AF)}$$

For storage projects, the unit cost was calculated as the present value of the lifecycle cost of the project over the storage capacity of the project.

$$\textbf{Storage Project Unit Cost (\$/AF)} = \frac{\text{Present Value of Costs (\$2025)}}{\text{Storage Capacity (AF)}}$$

Assumptions

The total cost of the project includes the debt service based off the capital cost, annual costs once the project is online, and any prior year costs. The cost calculations assumed a 3% inflation rate, a 5.5% nominal discount rate, and a 2.43% real discount rate. Annual Costs include Operations & Maintenance and Removal & Replacement costs. Palo Alto Potable Reuse also includes the annual cost of water for the project.

Debt Service calculations for WSMP projects assume a 30-year repayment term, with different interest rates depending on the project, summarized in the table below.

Debt Service Interest Rates

Project	Debt Service Interest Rate
Palo Alto Potable Reuse	7.24% blended borrowing rate
Delta Conveyance Project	5.1% borrowing rate for WIFIA loans, and revenue bond borrowing rates that range from 5% to 7%
Sites Reservoir	5.31% borrowing rate
Pacheco Reservoir	4.7% borrowing rate for WIFIA planning and design loan, 5.7% for WIFIA construction loan, 6.55% for revenue bonds
Other Projects	5.5% borrowing rate

The following projects are further along and have prior year actual costs related to planning and design which were factored into the total project cost.

- Potable Reuse Palo Alto
- Delta Conveyance Project
- Pacheco Reservoir Expansion
- B.F Sisk Dam Raise

Appendix G – Additional Portfolios

Appendix G – Additional Portfolios that Meet Water Supply Needs

	Portfolios						
Project	**Lower Cost**		**Local Control**		**Diversified**		
Palo Alto Potable Reuse					X		
San José Direct Potable Reuse	X		X	X	X	X	X
Local Seawater Desalination				X			
Refinery Recycled Water Exchange	X	X				X	
Delta Conveyance Project		X					X
Sites Reservoir						X	X
Pacheco Reservoir Expansion		With Partners	No Partners			With Partners	
B.F. Sisk Dam Raise		X			X	X	X
Groundwater Banking (Thousand Acre-Feet)	350	350	350	150	250	150	250
South County Recharge Projects	X	X	X	X	X	X	X
Portfolio Cost ($Billion)	**3.8**	**3.3**	**5.2**	**6.1**	**5.5**	**5.5**	**4.7**

Valley Water

Clean Water • Healthy Environment • Flood Protection

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