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Groundwater Management in the Pajaro Valley

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Introduction

Balancing groundwater and surface water use can be complex in regions where neither is abundant. Groundwater is a finite resource, and therefore groundwater must be "recharged" after use or refilled. Therefore, in regions where both surface water and groundwater supplies are essential to maintaining a reliable water supply, water districts must manage the interactions between surface water and groundwater. "Conjunctive use" refers to coordinating the use of surface water and groundwater jointly to improve the overall reliability of water supply. For instance, when surface water supplies are plentiful, water districts (or individual water users) may use surface water in place of pumped groundwater, or divert surplus surface water to recharge groundwater reserves. Conversely, when surface water supplies are scarce, water users may be encouraged to pump groundwater instead.

In some regions water users have "overdrafted" groundwater or pumped out more than is naturally recharged over time. In California, a state with little groundwater regulation, individual water management agencies or districts, are left to manage their groundwater use independently. The California Groundwater Management Act (AB 3030), encourages local-level groundwater management, allowing districts to adopt groundwater management plans, although it stops short of requiring such plans (Nelson 2011). More recently, Senate Bill x7-6 requires that groundwater levels be monitored and reported statewide and also encourages local-level management; where authorities do not develop groundwater monitoring, the state may intervene.

Even with incomplete state regulation, many areas have adopted formal groundwater management plans and enforcement procedures because sustainable groundwater management can provide more reliable delivery of water to agricultural, municipal, industrial, and residential users. According to a recent statewide survey of 50 local groundwater management plans in California, principles of sustainable groundwater management include, pursuing a diverse "portfolio" of groundwater management options, relying on sound hydrologic data, involving stakeholders in planning and implementation of new projects, and focusing on feasible, cost-effective projects and programs (Nelson 2011). This case study describes an innovative water district's conjunctive use program that follows these principles and an agricultural industry-led group implementing local water conservation efforts, all with the aim of reducing groundwater overdraft in future years.

Background

California's Central Coast is a unique agricultural region where most farms rely primarily on groundwater. Seasonal surface water flows from natural rivers, streams, and creeks also provide a very small secondary source of freshwater to these regions. Few of California's coastal farm communities rely on water delivered through California's state and federal surface water - the State Water Project and Central Valley Project (SWP and CVP). Therefore, groundwater is an important and valuable resource to coastal agricultural regions.

Because coastal communities are bordered by the ocean, they face a unique challenge to the reliability of groundwater: seawater intrusion into coastal freshwater aquifers. Along the Central Coast, where many acres of valuable agricultural land lie at or below sea level, declining groundwater levels (due to overdraft) have enabled seawater to move inland into underground aquifers, contributing to saline groundwater, which can be unsuitable for irrigation. Therefore, coastal water suppliers are very interested in finding alternate freshwater sources not only to supplement supplies, but also for groundwater recharge. Higher groundwater levels slow the penetration of saltwater into the aquifer, and maintaining groundwater levels through groundwater recharge can sustain use of the aquifer into the future.

The Pajaro Valley

The Pajaro Valley near Watsonville is a small, primarily Hispanic and Latino farming community located in the lower reach of the Pajaro River basin in California's Central Coast region (see figure 1). The Valley is north of the Salinas Valley along the Monterey Bay, and spans the counties of Santa Cruz, Monterey and San Benito. Climate, soil, water, and a skilled farm labor force make the Pajaro Valley a fertile and productive agricultural region. The local economy is based on multi-million dollar agricultural industry that employs thousands of agricultural workers (PVWMA 2009a). Approximately 30% of Pajaro Valley land is dedicated to agricultural production (by acreage)(see Table 1) and roughly half of the Pajaro Valley is composed of undeveloped or uncultivated native grassland in the hills on the periphery of the valley (PVWMA 2002).

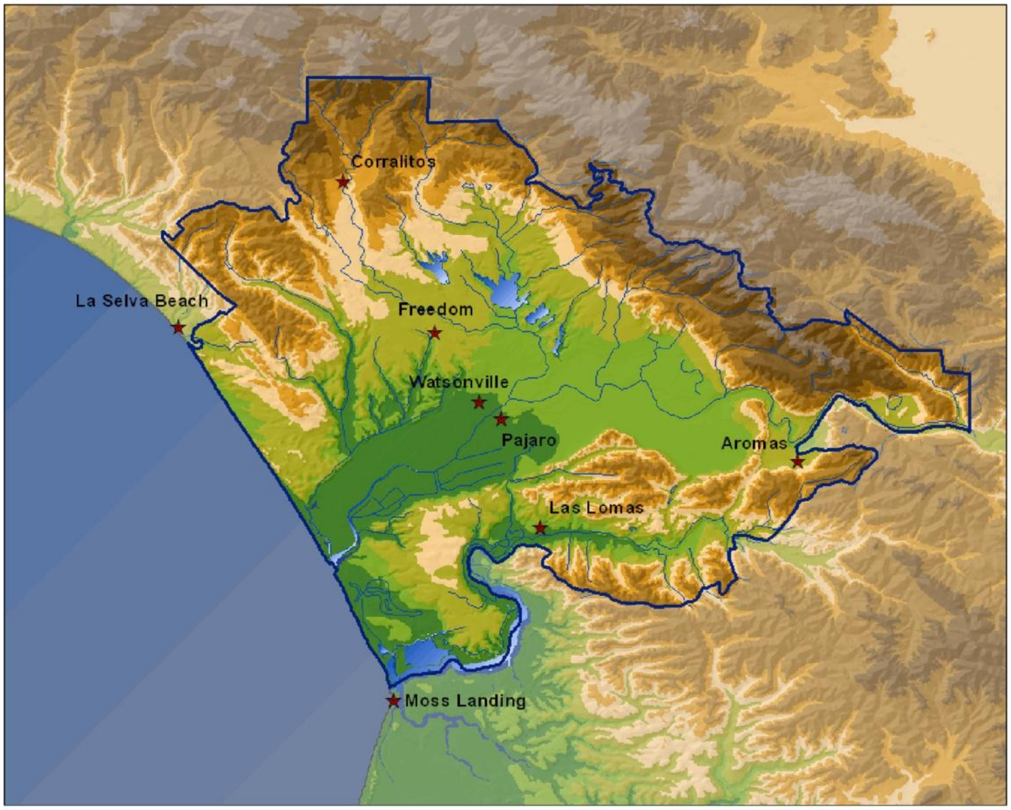


Figure 1. Topographic and water-features map of the Pajaro Valley Basin and surrounding area
Source: (PVWMA 2011a)

Table 1. Pajaro Valley Basin Land Use (by acreage)

Land Use Type	Acreage
Agricultural	30,200
Urban	12,860
Native (undeveloped and uncultivated)	48,996
TOTAL	92,056

Note: 1997 values; calculated by the PVWMA using DWR land use survey data for California counties, applied to PVWMA service area boundaries.
Source: (PVWMA 2002).

Agricultural land use is dominated by high value crops, including vegetables (14,000 acres), strawberries (7,000 acres), and tree fruits and nuts (4,000 acres) (PVWMA 2002). While the valley grows a host of fruits and vegetables, it is particularly well known for its berries: strawberries, raspberries, blueberries, and blackberries. California is the number one producer of strawberries and raspberries in the nation (in 2009, California produced 89% of the nation's strawberries) and Santa Cruz and Monterey Counties are among the top producing counties of strawberries and raspberries in the state (USDA-NASS 2010). Several large produce companies and familiar household product names are headquartered in the Pajaro Valley, including Driscoll's Berries and Martinelli's (apples and apple juices).

Nearly all of the Valley's water comes from groundwater pumping (PVWMA 2002). Prior to the introduction of the Agency's new recycled water supply, only 3% of the area's water supply came from surface sources (PVWMA 2002). In 2010, the second year of the Agency's delivery of recycled water (described in more detail in sections below), 4% of water supply came from surface sources (Lockwood and PVWMA 2011).

Table 2. Current and future (2040) water use and supply in PVWMA boundary of the Pajaro Valley Basin (estimated annual amounts in acre-feet)

Water Use (Demand)	Current Acre-Feet (AF)/Year	Future Acre-Feet (AF)/Year
Agricultural	59,300	64,400
Urban (Non-Agricultural)	12,200	16,100
Total Basin Demand	71,500	80,500
Water Supply		
Surface Water	2,100	2,100
Groundwater	69,000	78,000
- Sustainable Yield	(24,000)	(24,000)
- Basin Deficit	45,000	54,000
Total Basin Supply	71,100	80,100

Note: AF/year based on 2000 values; calculated by PVWMA. Agricultural water use is based on model simulations using crop demand by crop type; urban water use is based on monthly average urban water use during the 1994 – 97 hydrologic period. Urban includes municipal, industrial, and commercial water use. Supply calculations are rounded to two significant figures; supply does not exactly match demand due to rounding of significant figures, and because numbers are estimates based on a mix of metered data by the Agency, and model calculations based on historical data. Total basin supply is the sum of surface water and groundwater supplies based on metering data and models created by the PVWMA; basin "deficit" is the amount of water used annually above the "sustainable" groundwater yield amount. Sustainable yield is the current sustainable yield, and assumes continuation of current basin-wide pumping activities into the future. Groundwater deficit does not account for potential savings from conservation and efficiency measures.
Source: (PVWMA 2002).

Groundwater

In 1980, the California Department of Water Resources' (DWR) (see DWR 2011) named the Pajaro Valley as one of eleven basins in the state with critical conditions of groundwater overdraft (PVWMA 2006). Today, Pajaro Valley users pump nearly twice the sustainable yield of the Valley's groundwater basin annually, resulting in basin-wide groundwater overdraft (PVWMA 2009a). Historically, both coastal areas and inland areas of the valley maintained high groundwater levels (PVWMA 2002). However, overdraft from pumping lowers groundwater levels, which decreases the pressure differential between the fresh coastal aquifers and the saline sea water, allowing seawater to intrude (PVWMA 2002). Over time, inland groundwater levels have fallen below sea level, resulting in seawater being drawn into the coastal aquifer (see Figure 2) (PVWMA 2002). Seawater intrusion, which contributes to salt contamination of groundwater wells up the three miles inland, threatens the local agricultural economy because saline water is unusable for irrigation of many high value, salt-sensitive crops grown in the Pajaro Valley (PVWMA 2011c).

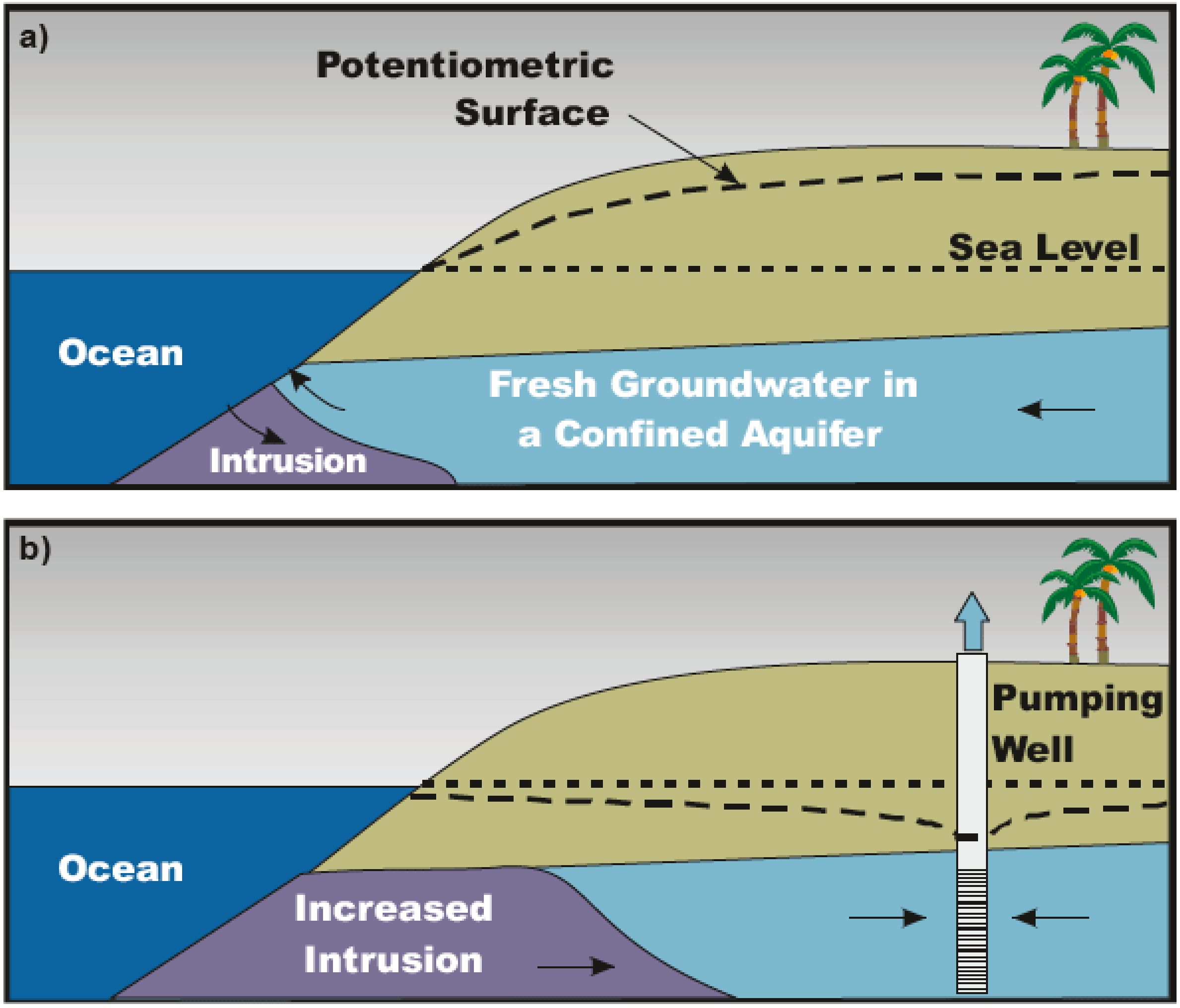


Figure 2. Historical and current groundwater levels impacted by seawater inundation along the coast
Note: This image depicts the process of seawater intrusion into a coastal aquifer. The first image (a) shows slight seawater intrusion into a groundwater aquifer. The second image (b) show how drilling a pumping well to extract groundwater can cause increased seawater intrusion.

Source: (WRD 2007)

In the Pajaro Valley, the landward movement of seawater into the aquifer averages 200 feet per year (Wallace and Lockwood 2010). Nearly half the valley's groundwater basin is below sea-level year-round, and nearly two-thirds of the basin is below sea level in the fall after the summer irrigation season (see Figure 3); groundwater elevations near the coast remain below sea level throughout the year despite fluctuations in rainfall (Wallace and Lockwood 2010). Seawater intrusion has moved further inland over the past 25 years, and even more inland seawater intrusion is expected, especially during drought events as groundwater recharge declines due to reduced precipitation and stream runoff (Wallace and Lockwood 2010, PVWMA 2002).

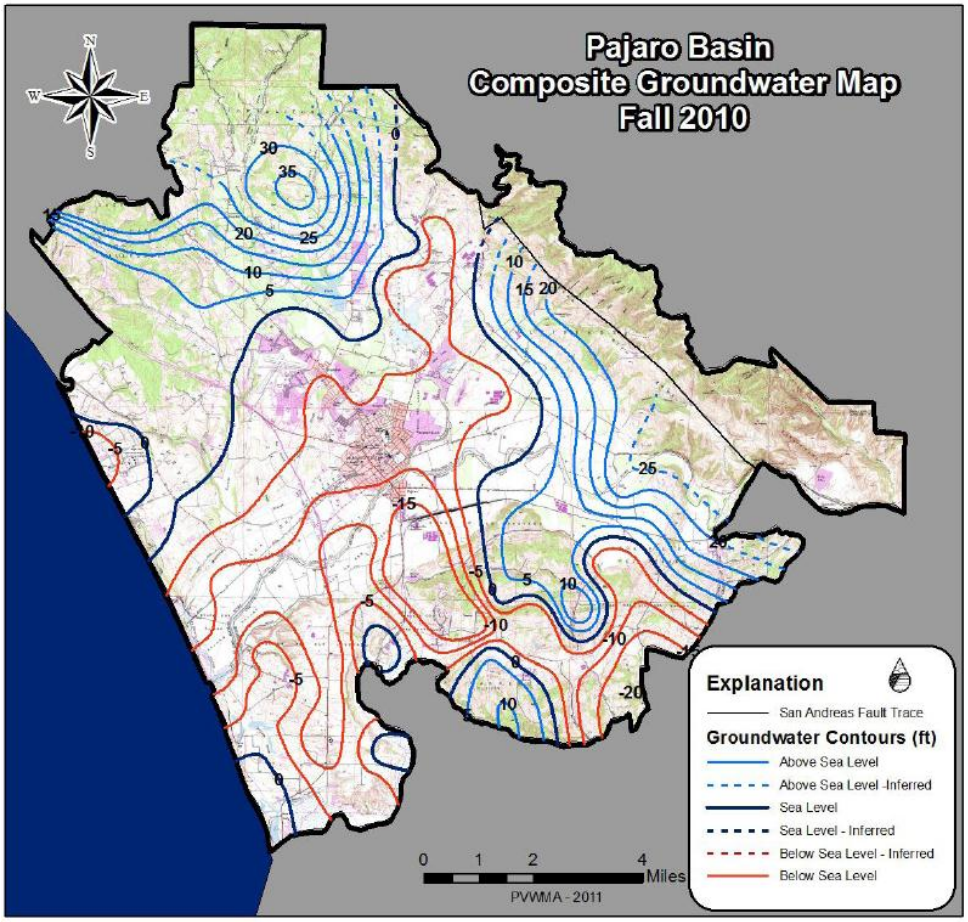


Figure 3. Fall 2010 groundwater level contours in the Pajaro Valley Basin
Note: Colored lines indicate feet above (blue) or below (red) sea level.
Source: (PVWMA 2011c)

Pajaro Valley Water Management Agency

Until the 1940s, the Pajaro Valley's groundwater levels were so high that water would well up to the surface near the coast year round (PVWMA 2011c). Little more than a decade later, the DWR identified seawater intrusion along the Monterey Bay in 1953 and the groundwater problem was confirmed yet again by the US Bureau of Reclamation (USBR) in 1964 (PVWMA 2011c). At this time, state and federal planners envisioned the new Central Valley Project (CVP) as the water supply solution to the Central Coast's groundwater depletion and seawater intrusion problems (Lockwood 2011a). However, despite the USBR's commitment of a 19,900 AF/year of CVP water to the Pajaro Valley in 1975 (an entitlement still held by the PVWMA, but currently leased to other Central Valley water districts) a pipeline connecting the Pajaro Valley and the CVP was never built (PVWMA 2011c). Originally, this was due to the high cost of construction and local opposition (Lockwood 2011a, Bannister 2011b). More recently there have been concerns about CVP reliability due to climate fluctuations and environmental legislation. With no alternative source of water and increased withdrawals, the groundwater aquifer has been gradually depleted over the years. It wasn't until the late 1980s, following formation of the PVWMA that Pajaro Valley basin-wide water supply planning began, and efforts were aimed at cost-effective conservation and conjunctive use programs aimed at resolving the saltwater intrusion problem (PVWMA 2011c).

Today, the need to abate groundwater overdraft and prevent further seawater intrusion into the coastal aquifer drives the PVWMA's conjunctive use and groundwater management program. Beginning in the early 1990s, the PVWMA started establishing a water supply system that today combines surface, groundwater, and recycled water to sustain valley farms and work to recharge declining groundwater aquifers. The Agency still has much to do, and in its ongoing basin management planning efforts, is working alongside university researchers, as well as with local stakeholder groups to develop the most cost-effective and efficient programs and projects (Table 3).

Agency staff and managers, along with two community-initiated agricultural stakeholder groups (primarily composed of local landowners and growers), are currently working to improve the Agency's groundwater management and conjunctive use program through an ongoing basin-wide "Basin Management Plan" (BMP) process. The BMP not only guides the Agency's water management activities, but also doubles as a basin-wide groundwater management plan, meeting the requirements of the state Groundwater Management Act (AB 3030) (PVWMA 2006). Projects under consideration as part of the BMP include those proposed by the community through a public input process completed in July 2011. All projects will be reviewed by a technical team to assess their viability (structurally and economically). Below, we discuss several of PVWMA's key conjunctive use and groundwater management projects, both operational and under consideration.

Table 3. Existing and potential future projects contributing to the PVWMA's conjunctive use program

Project/Program	Project Type	Description	Yield (AF/year)
Recycled Water Facility (RWF)	**Recycled Water**	(Operational) The RWF reclaims urban wastewater for use in agricultural irrigation. Urban wastewater from the city of Watsonville is treated and disinfected, mixed with groundwater, and delivered to farms. Production is limited by storage capacity, especially during winter months when there is low demand. PVWMA could increase storage of recycled water by using existing growers' ponds, building reservoirs, or storing water underground (see "Infiltration of Recycled Water" below). With increased capacity, annual yield of the RWF could be increased to 6,000 AF/year, a 2,000 AF/year increase from current production.	1,600-4,000
Harkins Slough Recharge	**Groundwater**	(Operational) The project pumps winter runoff from a slough (or river channel) to a recharge pond where it percolates into the groundwater aquifer. The stored water is either pumped out in the summer for irrigation, or is kept underground to recharge the aquifer. Research teams from UC Santa Cruz and Stanford (Departments of Hydrogeology and Geophysics, respectively) have been studying the recharge pond to better understand infiltration and aid the PVWMA in maintaining steady rates of recharge and recovery of stored water. Recharge is limited by the gradual sealing of the recharge pond floor by sediments, and variability in rates of recharge and movement of water in the underground aquifer.	<200 (800 stored)
Murphy Crossing Recharge Basins	**Groundwater**	(Under Consideration) Project would divert and infiltrate winter flows from the Pajaro River into the groundwater aquifer through inland dry streambeds. In the summer, stored water could be pumped and delivered to farms. The Agency previously submitted a water rights application (1995) and certified an EIR for the project (1999), but permitting was delayed due to concerns about sediments at the proposed infiltration sites and water quality. Since this time, the project has been modified, and will require new permitting.	980
College Lake	**Surface Water**	(Under Consideration) This project transports water from an existing seasonal lake to the RWF for treatment, storage, and delivery. This water would be mixed with recycled water and groundwater, thereby increasing total supplies available to farmers. Water would be distributed through the existing coastal distribution system. The Agency has already submitted a water rights application (1995) and completed a CEQA evaluation (1999), but the permitting process was delayed due to concerns over steelhead trout passage at the lake. Since this time, the project has been modified, and will require new permitting.	1,800-2,300
Infiltration of Recycled Water	**Groundwater; Recycled Water.**	(Under Consideration) The PVWMA could percolate or inject recycled water underground via pond/reservoir, "spreading" along the coast, or injection well. Water would be infiltrated during low-demand winter months and withdrawn during high-demand summer months. Water could also be stored to recharge the aquifer. Water would be distributed through the existing coastal distribution system. Injection or percolation of reclaimed water is limited under existing Regional Water Quality Control Board criteria and Department of Public Health regulation. Proper criteria would need to be met, and regulation potentially changed for this project to be implemented.	2,000
Agricultural Conservation and Efficiency	**Demand Management**	(Under Consideration) Local grower/landowner groups, in coordination with the PVWMA, would encourage on-farm conservation and efficiency and promote the use of efficient irrigation technologies.	2,500
Land Fallowing	**Demand Management**	(Under Consideration) Project would fallow marginal land and up to 8,000 acres of coastal agricultural land (valued at $1,600 per acre), where groundwater is contaminated (salty). Conservation easements or environmental restoration projects may be considered on fallowed land parcels.	200

Note: This table summarizes existing and *some* of the potential future projects being considered under the PVWMA's current Basin Management Plan (BMP) process. The projects listed are those that would contribute directly to the Agency's conjunctive use efforts. The table does not include all existing or potential projects and programs. A complete list of programs and projects considered by the Agency as part of its current planning process can be found on the PVWMA website at: http://www.pvwma.dst.ca.us/committees/ad_hoc_bmp_committee.shtml.
Source: (PVWMA 2011d and 2011e, Koenig 2011, Bannister 2011a, Lockwood 2011b).

Groundwater Recharge

In the Pajaro Valley, “natural” or incidental recharge results from percolation into the basin from natural waterways, fed by rainfall or snowmelt, and from excess water applied for crop irrigation (Wallace and Lockwood 2010). Yet, natural recharge is not enough to maintain groundwater levels, and therefore groundwater must be recharged through “artificial” means as well. Artificial recharge captures and retains water in surface impoundments (dams, dikes, and infiltration areas) to allow water to percolate into the underlying basin. An additional form of recharge is “in-lieu,” which refers to the groundwater that remains in basin when groundwater users switch to surface water instead of pumping from aquifers. The PVWMA’s conjunctive use program employs all of these artificial recharge strategies.

Groundwater recharge not only replenishes underground aquifers, but can also provide storage of water for later use. For example, surplus winter flows from a river may be stored underground, and withdrawn in the summer for irrigation when surface water supplies are scarce. This also allows flexibility to respond to seasonal and inter-annual variability, as water can be stored in wet periods for use in dry ones. This will be increasingly important as climate change is projected to increase the frequency and intensity of extreme weather events, including floods and droughts.

The Harkins Slough Recharge project, completed in 2001, is the first groundwater recharge project constructed by the Agency. The project turns winter storm water flows from a river channel (Harkins Slough) into irrigation water usable in the summertime by storing water underground. Water banked in the winter and then recovered in the summer during the irrigation season is delivered to growers in coastal areas of the basin where there is seawater intrusion (PVWMA 2011d). Using existing flood control pumps on Harkins Slough, the Agency pumps water during winter high-flow periods, filters and then transports the water one mile to a 14-acre percolation basin (a shallow hilltop lake) where the water percolates down into the basin’s Aromas Sands aquifer (PVWMA 2011d). Irrigation drained from nearby fields is also pumped to the pond for recharge (Lockwood 2011b).

When water is recovered from the underneath the basin (pumped out of the ground by wells surrounding the recharge pond), it is pumped into the PVWMA’s Coastal Distribution System (a pipeline system constructed to supply water to 7,000 acres of coastal farmland most impacted by seawater intrusion) where it is blended with two additional local well water supplies and recycled water, and delivered to 2,000 acres in Santa Cruz and Monterey Counties (PVWMA 2011d). The PVWMA holds a permit to pump 2,000 AF of water from Harkins Slough, but average annual diversions for recharge have thus far been around 1,000 AF per year due to a lack of flow through the slough and the capacity of the recharge pond; a total of 7,000 AF have already been percolated into the basin, and over 1,000 AF have been recovered and delivered since the beginning of the project. In 2010, the Agency diverted and stored 900 AF of water, of which 160 AF was recovered and delivered to farms; the rest was left to recharge the aquifer (Wallace and Lockwood 2010).

The Agency is currently working with scientists from U.C. Santa Cruz and Stanford in order to better understand groundwater recharge in the basin and improve the percolation and recovery speed of the recharge basin. The Harkins Slough project is one of the more studied groundwater recharge ponds in California, and findings stemming from research of the pond are already contributing new technical knowledge to the field of sustainable groundwater management (Lockwood 2011b). These findings include new methods for modeling conjunctive use programs and the movement of water in groundwater aquifers (Hanson et al. 2010), as well as water quality insights such as the finding that groundwater recharge may significantly reduce the concentration of contaminants (nitrate from fertilizers) found in irrigation runoff (Schmidt et al. 2009). In the years to come, work will continue on the Harkins Slough project in order to boost its groundwater recharge and water supply storage capacities.

Recycled Water and Conjunctive Use

Growers in California are increasingly looking to recycled water as a way to meet their irrigation demands in the face of growing water scarcity and water quality concerns. Water recycling (also known as water reuse or water reclamation) is the reuse of water that has been discharged as wastewater, and it typically involves high levels of treatment in order to make it safe for reuse. Over the past decade, recycled water has been used primarily as a supplement to dwindling local water supplies. Recycled water in California is most commonly used for agricultural irrigation, but it also goes to other uses such as groundwater recharge (CAWSI n.d.). In the case of the Pajaro Valley, recycled water is used to supplement groundwater supplies and support the Agency's groundwater recharge and seawater intrusion prevention by providing "in-lieu" recharge (groundwater not pumped and replaced by other water supplies). In the future, recycled water may be used directly to recharge the aquifer (see "Recycled Water as Groundwater" below).

The Agency partnered with the City of Watsonville to build a Recycled Water Facility (RWF) which provides treated urban wastewater to landowners and growers in the basin for irrigation (PVWMA 2011d). Wastewater is conveyed from homes and business in Watsonville (the Pajaro Valley's urban center) to the RWF, where it is filtered and disinfected (through primary, secondary, and tertiary treatment) (PVWMA 2011d). The recycled water is mixed with groundwater and distributed to farms through the Agency's Coastal Distribution System.

In 2010, the RWF's full first year of operation, recycled water comprised 60% (1,600 AF out of a total of 2,700 AF) of the water delivered to coastal areas in the basin (PVWMA 2011d). The Agency estimates that 2011 deliveries will grow to around 4,000 AF (PVWMA 2009a). The RWF supplies could be further expanded if more storage is made available in the winter when water demand is lower, as the facility has up to 6,000 AF/year of production capacity (PVWMA 2011d). The Agency could create storage in two ways – expanding onsite storage, or conveying the treated water to infiltration areas where it could be stored underground and pumped during the irrigation season (or used to boost groundwater levels). Underground storage options for recycled water, however, are subject to strict environmental regulation in order to protect against groundwater contamination.

Recycled Water as Groundwater

Recycled water is typically used only for non-potable or indirect potable uses. Indirect potable reuse refers to situations where recycled water is blended with potable water supplies, such as in groundwater basins, storage reservoirs, or streams. Recycled water can be percolated into the aquifer in the same way that surface water is in the Harkins Slough project – by "spreading" water across large surface features like ponds, channels, or individual catch basins (or parcels of land), to percolate through the ground and into an aquifer. Another recharge method is by injection directly into an underground aquifer through recharge wells. The Pajaro Valley's shallow aquifer allows both possibilities to be considered by the PVWMA.

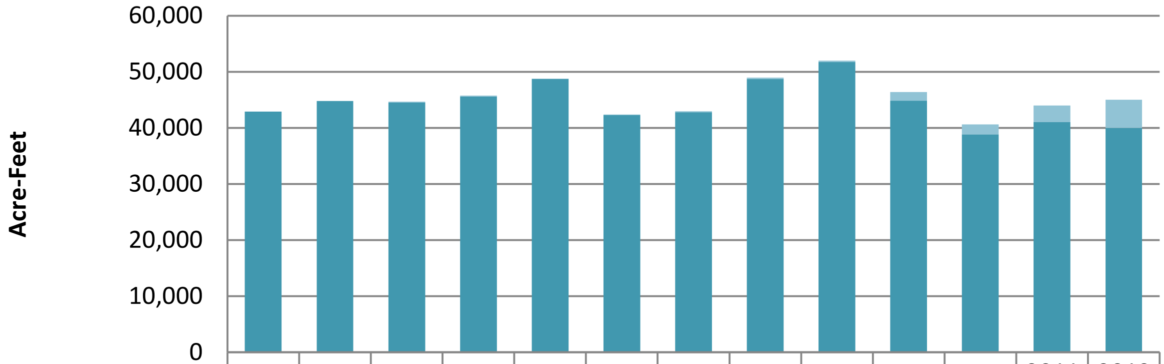
There exist substantial regulatory barriers to the use of recycled water for groundwater recharge and storage, due concerns about injection of poor quality water into aquifers used as potable sources of water – in California and nationwide (Asano et al. 2004, NRC 1994). In the Pajaro Valley, regulatory agencies have reason for concern as groundwater is used for drinking water as well as irrigation water. However, a properly operated water reuse project can produce higher quality water than that provided by many traditional water supplies and successful projects have been safely implemented with the appropriate planning and precautions (Asano et al. 2004). Mary Bannister, General Manager of the PVWMA states that storage and use of recycled water represents the valley's "biggest hope." (Bannister 2011b). Storage of surplus recycled wastewater produced in the wintertime (when the water is not used immediately by farms) is a potentially large source of additional irrigation water for the valley and could help address overdraft (Bannister 2011b).

Recycled water quality standards, and the production, conveyance, and use or recycled water is regulated by the California Department of Public Health (DPH) and the California State Water Resources Control Board through its nine Regional Water Quality Control Boards. In the case of Pajaro Valley, the Regional Water Quality Control Board is willing to permit percolation of recycled water in the Pajaro Valley so long as it meets the Recycled Water Regulations established by the DPH and contained within Title 22 of the California Code of Regulations (Mary Banniser 2011b, Feeney 2011). Title 22 assigns each application of recycled water a required level of treatment, including agricultural and groundwater recharge applications (Sheikh and EBMUD 2009). Under existing rules, the injection of recycled water through a well or spreading for recharge purposes is restricted. For example, recycled water for well injection must be brought to potable quality before being injected into an aquifer, which in this case requires costly reverse osmosis treatment (Feeney 2011). To date, there are only four facilities of this type statewide (Feeney 2011).

Measurement and Pricing

One critical element of sustainable groundwater management is measurement and monitoring of extraction. While the California legislature acknowledges that groundwater pumping data is required for proper management (Cal. Water Code § 10750(b)), there is no legal requirement that individual, private well owners in California monitor and report their groundwater extraction (Nelson 2011). Nevertheless, water districts can independently, through their individual groundwater management programs, measure district-owned well water pumping, and may also require owners of private wells within the district's boundary to meter and report their water use. Thus, districts can gain important information about the scarcity of groundwater, the potential for recharge, local impacts of groundwater depletion (such as land subsidence), and ecological information such as data concerning linked surface-groundwater systems (Nelson 2011). This information ultimately contributes to a district's ability to manage water supplies.

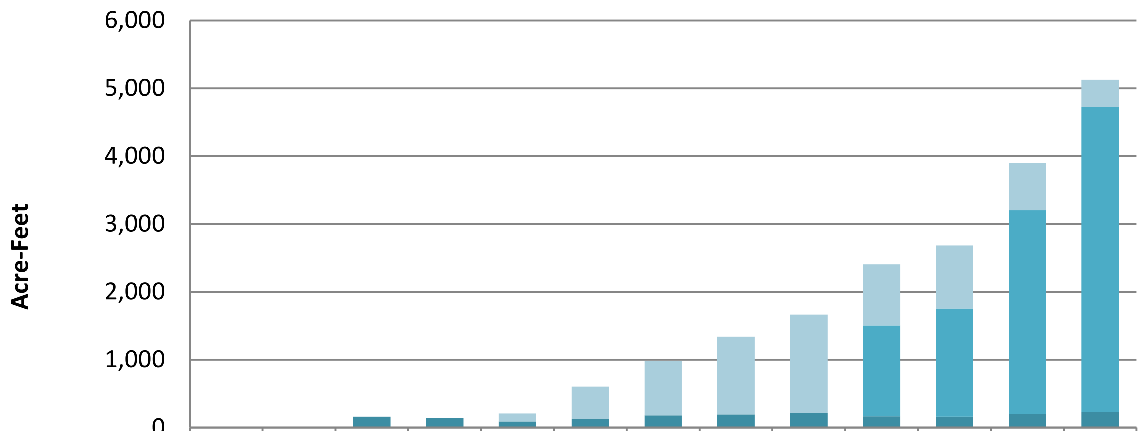
The PVWMA accounts for both groundwater, surface water, and recycled water supplies comprehensively despite the fact that water is supplied to farms in mixed form (such as combined recycled and groundwater supplied through the Coastal Distribution System). Measurement of agricultural water use is different from urban water measurement where water supplies are delivered from a centralized system and metered at the individual household or business level. Agricultural water is not necessarily delivered via a single centralized system and metered at each individual farm – instead, surface water supplies are often measured in bulk flows into an area, or at weirs or gates along an irrigation canal that serves multiple farms. And, water supplies from groundwater wells – belonging to the district or to private landowners – may or may not be metered, or reported to a local water district. In the case of the PVWMA, nearly all water uses within the Agency's boundaries are metered (only 1% of average annual groundwater is from un-metered wells), and all water use is reported to the Agency so that the Agency has a thorough understanding of its total water use and demand. This provides them with extremely important information that can be used in a variety of ways, for example, helping understand to what degree new projects and programs are offsetting groundwater use (see Figure 4a and 4b).



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011 *	2012 *
Delivered Water	0	0	158	138	87	124	177	191	212	1,505	1,754	3,000	5,000
Groundwater	42,89	44,75	44,49	45,61	48,71	42,26	42,77	48,75	51,77	44,86	38,87	41,00	40,00

Figure 4a. Pajaro Valley Agricultural Water Use, 2000-2010, and 2011-2012 (estimated)
Notes: *Indicates estimates (2011 and 2012) based on projections to 2012 for delivered water made by the PVWMA (PVWMA 2009) and calculations using the most recent 5-year (2006-2010) average groundwater use data as provided in (Lockwood 2011x [source below]). Estimated 2011 AF are rounded median values between 2010 values and 2012 projection. 2011 and 2012 estimates are rough, best-case scenario projections.

Delivered water includes only recycled water and recharged water from the Harkins Slough Recharge Project (not new groundwater that is pumped from blend wells and mixed into delivered supplies). Groundwater includes water pumped by metered and un-metered private wells, and blend wells which include Agency-owned wells and Watsonville city wells. Harkins Slough recharge water is water that has been percolated into the groundwater basin through a recharge pond, and then extracted via dedicated wells. Of total annual groundwater pumped in the Agency's boundaries (based on a 2006-2010 average), 97% is from metered wells, 1% is from un-metered wells, and 2% is from blend wells.



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011*	2012*
Blend Wells	0	0	0	0	120	479	804	1,146	1,453	900	926	700	400
Recycled Water	0	0	0	0	0	0	0	0	0	1,343	1,597	3,000	4,500
Harkins Slough	0	0	158	138	87	124	177	191	212	162	157	200	225

Figure 4b: Delivered Water, 2000-2010, and 2011-2012 (estimated)
Notes: *Indicates estimates (2011 and 2012) based on projections to 2012 for delivered water made by the PVWMA (PVWMA 2009); estimated 2011 AF are rounded median values between 2010 values and 2012 projection. 2011 and 2012 estimates should be taken as rough, best-case scenario projections.

Delivered water includes full delivered water supplies: recycled water, recharged water from the Harkins Slough Recharge Project (not new groundwater), and blend wells (new groundwater) from district-owned and Watsonville city wells. Blend wells are wells that pump groundwater for mixing with recycled and recharged water that is delivered through the PVWMA Coastal Distribution system (therefore, blend well water is pumped inland instead of on the coast to reduce coastal pumping where there are seawater intrusion risks). Recycled water is treated wastewater from the city of Watsonville. Harkins Slough recharge water is water that has been percolated into the groundwater basin through a recharge pond, and then extracted via dedicated wells.
Source (Figure 4a-b): (Lockwood and PVWMA 2011, PVWMA 2009b)

In 2009 and 2010, years during which the recycled water supply system became operational, the Agency produced and delivered 1,343 AF, and 1,597 AF of recycled water in 2009 and 2010 respectively, increasing its annual delivered water by more than 60% compared to 2008 before recycled water deliveries began (Lockwood and PVWMA 2011). While Harkins Slough recharge water still constitutes a minimal source of supply, delivering on average 156 AF/year, combined with new recycled water sources, those supplies have begun to augment supply and recharge the aquifer (most recharged Harkins Slough water has not been withdrawn, but remains underground). The amount of water supplied (and recharged) through the Harkins Slough Recharge Project and Recycled Water Facility is projected to increase in coming years (PVWMA 2009b).

Metered wells in the valley pumped less groundwater in 2010 than in any year over the past decade: 37,642 AF compared to an average of 44,007 AF. In 2010, metered groundwater pumping declined by 14% from 2009 (a drought year, during which groundwater pumping was high), and by 9% from 2006 (a wet year, when groundwater pumping was lower) (Lockwood and PVWMA 2011). These achievements in groundwater use reduction, aquifer recharge, and new supply augmentation are still small compared to the total water demands and groundwater use abatement needs of the Agency, but they demonstrate the PVWMA's dedication to pro-actively working towards sustainable groundwater management in the years to come.

The PVWMA charges volumetrically for water. Like water measurement, the way in which a water district charges for water supplies is also different than in cities. In some cases, water districts bill agricultural water users in the form of a flat fee for the number of acres irrigated, but increasingly districts charge volumetrically for the amount of water each individual uses. The Water Conservation Act of 2009 (Senate Bill X7-7) requires that all large irrigation districts adopt volumetric water pricing. The PVWMA has four different volumetric service rate classes (see table 4).

Table 4. Service Rate Classes and Costs for Pajaro Valley Water Management Agency Customers

Service Rate Class	Cost (per Acre-Foot)
Metered Wells – Outside Delivered Water Zone	$162
Metered Wells – Inside Delivered Water Zone	$195
Unmetered Wells	$156 (or $92 annually)
Delivered Water	$306

Note: These rates became effective in the final quarter of 2010.
Source: (Wallace and Lockwood 2010, Lockwood 2011b)

In 2010, the Agency developed and passed a new rate structure in order to provide the funds necessary to develop their groundwater and recycled water projects (Wallace and Lockwood 2010). According to Proposition 218 requirements for rate increases, the new rate structure required district-wide approval by residential, commercial, and agricultural water users, who approved the fee increase to support the Agency's work on the new basin management plan projects (Wallace and Lockwood 2010). Rate increases primarily impacted the cost of water that users received through the Agency-operated distribution system (an increase of $44/AF for delivered water), and the cost of pumped groundwater (an increase of $35/AF for metered wells inside the delivery zone), thereby encouraging water users who might otherwise pump groundwater to switch to delivered surface water, a large portion of which is now from recycled water (Wallace and Lockwood 2010, Lockwood 2011). Water users pumping groundwater from wells located outside the delivery zone incurred only a $2/AF increase in the cost of their water (Wallace and Lockwood 2010, Lockwood 2011b).

Compared to other neighboring agricultural water districts, PVWMA's rates are similar or slightly higher; one example of a district with similar charges (but that delivers CVP water) is the nearby San Benito County Water District (SBCWD 2011). Once the PVWMA has evaluated and approved a new set of projects and programs following the current basin-wide water management planning process (the BMP process is scheduled to finish in 2013), the Agency will attempt to finance new projects and programs through available grant funding, and will also propose a new rate structure (to become effective in 2015) as needed to continue to fund ongoing and new conjunctive use activities (Lockwood 2011b, PVWMA 2011c).

The Community Water Dialogue

In addition to the long-term, water supply focus of the PVWMA, local agricultural growers have formed the "community water dialogue" to find more near-term solutions to reducing agricultural water demand in the valley. The dialogue has several water conservation efforts including increased irrigation efficiency with soil tensiometers, education for Irrigation efficiency, rotational fallowing, and a pilot program on performance-based conservation incentives.

Education for Irrigation Efficiency

The dialogue is coordinating trainings in irrigation scheduling, including using evapo-transpiration data and understanding measurements of distribution uniformity, which are critical for optimizing irrigation efficiency. Driscoll's, the Resource Conservation District of Santa Cruz County (RCDSCC), and PVWMA can all play a role. Dialogue members estimate annual costs of $12,000 – $18,000, based on $3,000 estimated per training, with 3 to 6 trainings per year.

Increased Irrigation Efficiency with Soil Tensiometers and Real-Time Communication

Soil tensiometers can provide real-time data on in-situ soil characteristics and irrigation effectiveness. This effort involves installation of soil tensiometers and a network of communication towers to provide data that would allow growers to manage irrigation needs with increased accuracy and reduce water use (Figure 5). Dialogue participants estimate a water demand reduction of 1,000-2,000 acre-feet per year (AFY), assuming that 50,000 AFY of water is used for agriculture and that 20% of agriculture demand will use this new system.

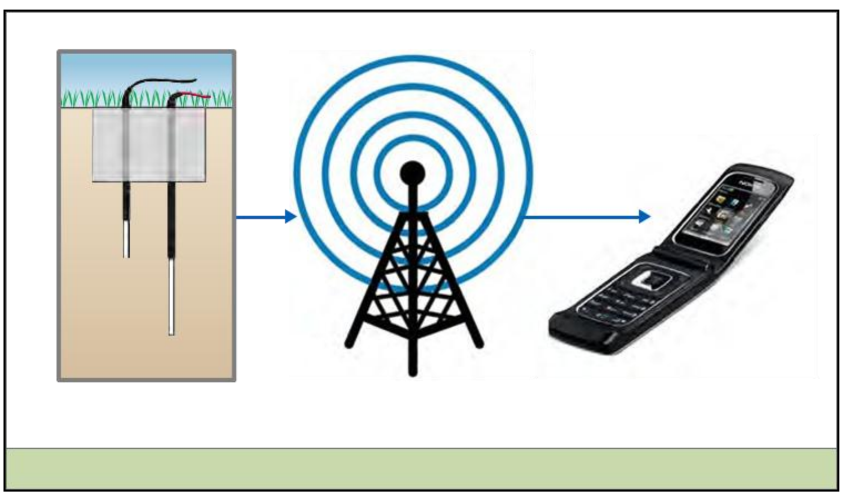


Figure 5. Soil moisture probes relay information to communications towers, which then alert growers with real-time information by text message or e-mail

The costs for setting up a communications system are around $50,000, assuming 5 base stations 15 repeater towers at $7,100 and $3,000 each. Growers would rent soil moisture probes at $150/ month and then be able to use the communications towers for free to receive real-time soil moisture information. This fall, the group is locating tower locations and willing landowners with the goal of having growers using the data by the spring of 2012.

Rotational Fallowing

Rotational fallowing can reduce water use by putting fallowing into the land rental cycle (Figure 6). Dialogue members estimate that allowing fields to fallow more often could save 750 – 1,250 AFY, assuming 2.5 AF/Ac are used on an average ranch and if there is an annual rotation of 300 - 500 fallowed acres. Costs are high, from $600,000-$1,350,000 as this solution involves renting land at $2,000 - $2,700 per acre.

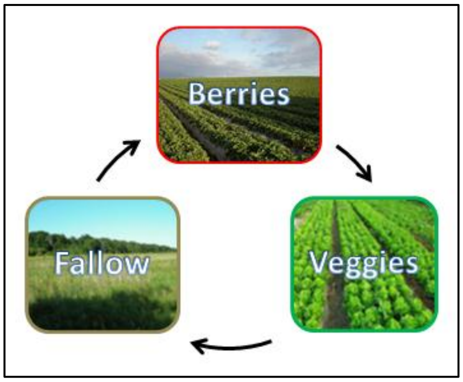


Figure 6. Suggested land use cycle in the Pajaro Valley

Performance-Based Conservation Incentive Pilot

Performance-Based Conservation Incentive Pilot is a new pilot program developed in partnership between the Resource Conservation District of Santa Cruz County and Driscoll's Strawberry Associates Inc, made possible by a grant from the USDA's Conservation Innovation Program. The pilot's goals are to:

- Improve conservation outcomes for water quality and quantity in the Pajaro Valley; while stimulating innovation through standardized metrics and conservation incentive structure;
- Create new economic opportunities for farmers, while allowing them flexibility of new approaches in meeting nutrient and aquifer impacts targets; and
- Create a replicable model to be used in other geographic settings, crops, and to be adapted by agricultural policy makers and the private sector.

The partnership achieves this by: developing appropriate performance-based indicators and metrics for setting nutrient reduction and water conservation targets; and developing a standardized incentive structure for nutrients and water conservation and means of verification for conservation incentive payments. Possible incentives include rebates, credits for water conserved and intentionally recharged, and water cost savings (particularly if the PVWMA adopts a tiered water pricing structure).

Conclusions: Applying the Principles of Sustainable Groundwater Management

Pursuing a Diverse Portfolio

To work towards sustainable groundwater management, the Pajaro Valley is in the process of implementing a variety of programs, including a combination of additional supplies developed through water recycling and reuse, new groundwater recharge and storage options, and more aggressive water conservation and efficiency.

Relying on Sound Data

A critical component of the PVWMA's conjunctive use program is data collection and analysis. Using a hydrologic model of the basin, the PVWMA measures current water use and estimates future water supply and demand in order to guide the agencies planning activities. Currently, the PVWMA estimates that every year, water users in the Pajaro Valley basin pump 45,000 AF more than the amount hydrologists have determined to be the basin's annual "sustainable yield" - the amount of water that can be withdrawn annually without depleting the aquifer (PVWMA 2002). By 2040, due to expected increases in both urban and agricultural water demands, the annual groundwater deficit will increase by an estimated additional 9,000 AF, meaning that in order to make groundwater use sustainable – now and in the future – the Agency will need to balance supply and demand (PVWMA 2002). Accurate information about water availability and water demand in the Agency's boundaries enables the PVWMA to make informed management and planning decisions.

Involving Stakeholders

Both the "Community Water Dialogue" and the PVWMA's basin management planning process has brought together local stakeholders – landowners, farmers, residents, Agency staff, and university research and consulting firms to improve the knowledge base and find shared solutions. The agricultural community is active in working to supplement technical information acquired by the Agency with knowledge from the field. Dave Cavanaugh, owner of a nursery in the Pajaro Valley foothills, PVWMA board member, and chair of the BMP committee, notes that the participation of farmers in the Agency's planning process has been important, especially when generating new ideas for how to efficiently manage the Agency's supplies: "Back in '02, conservation was identified as something that could cut water use by 5%...if farmers look at the question, there are things that might make sense to them that wouldn't to engineers and hydrologists. Through fallowing and other conservation efforts, we might be able to get the savings up to 20%" (Lockwood and Wallace. 2010).

Focusing on feasible, cost-effective projects and programs

The PVWMA's BMP process considers all feasible water supply options yet focuses on cost-effectiveness and local relevance. The PVWMA is on the forefront of experimenting with the use of recycled water in groundwater recharge and conjunctive use activities, and sometimes operates in uncharted territory with few established guidelines. Because of this, the Agency works with local university research teams to understand and improve their projects. Nevertheless, new methods of risk analysis and proactive policies are needed to guide groundwater recharge projects that use recycled water (Asano et al. 2004). Alongside individual water districts, state, regional, and local water management and public health agencies will need to work together to streamline the safe and effective integration of recycled water into conjunctive use systems at a larger scale.

Additionally, the PVWMA experience with the permitting of groundwater infiltration sites highlights the need for more research on the ecosystem impacts of infiltration, especially where groundwater recharge intersects with the operations of natural stream systems (such as in the PVWMA's Murphy Crossing and College Lake projects – see description in Table 3). Fisheries maintenance will continue to be an important part of water management, and therefore will require a better understanding of when groundwater extraction or infiltration projects do and do not pose a risk to the environment. Better scientific understanding of surface-groundwater interactions will help streamline the evaluation of groundwater recharge activities and help water districts make the most environmentally-friendly choices.

Lastly, new projects are costly, even the most cost-effective projects. Water districts struggle not only to fund projects, but also to comply with new state laws governing their ability to change rate structures (e.g., Proposition 218 passed in 1996 restricts local governments' ability to impose assessments and property-related fees, and requires elections to approve many local government revenue raising methods). Interpretation of Proposition 218 is largely left to individual water districts. Multiple interpretations have been challenged in court, including one earlier rate increase by the PVWMA for which the district was required to refund fees to customers for having not properly complied with the proposition (Lockwood and Wallace 2010, Bannister 2011b).

The Pajaro Valley approved a new rate structure in 2010 that the Agency proposed because it assessed that higher fees were required in order to fund its ongoing and new projects. In its own reading of Proposition 218 requirements, the Agency submitted notices of the rate increase to well owners and rate payers in the basin who then had the opportunity to protest the increase; if a majority of rate payers protested the increase, the Agency would not enact the rate change (Lockwood and Wallace 2010). Following a series of public meetings held by the PVWMA, issuance of a formal notice (to which users could protest) and an additional up-or-down vote by mail-in-ballot, as well as advocacy by the basin's largest water users supporting the water rate increase, the Agency achieved only a minority of protests, and majority support (through their ballot process) for the new rate structure (Lockwood and Wallace 2010).

In addition, local efforts have identified not only the more immediate benefits of water conservation and efficiency but also the costs associated with different options, from education to real-time soil moisture monitoring infrastructure, to land rental costs associated with rotational fallowing. In the future, it will be critical to compare all of these options and most aggressively pursue those that remain the most feasible and cost-effective.

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