Incentivizing Groundwater Recharge in the Pajaro Valley Through Recharge Net Metering (ReNeM)

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ABSTRACT Decades of groundwater overuse in the Pajaro Valley have contributed to an estimated groundwater overdraft of 12,100 acre-feet per year (AFY) in the basin. In response, the Pajaro Valley Water Management Agency adopted a pilot groundwater recharge program, called Recharge Net Metering (ReNeM). ReNeM encourages development of infiltration projects on private or public land by offering a rebate on groundwater pumping fees based on the net increase in infiltration. The rebate uses the following equation: $\text{Rebate} = W_{50}x\ (\text{Inf}_{\text{tot}} - \text{Inf}_{\text{inc}})$, where Inf_{inc} is the incidental infiltration that would have occurred without the project, Inf_{tot} is total measured infiltration, and W_{50} represents the proportion (50%) of the pumping fee assessed to the landowner based on location. The goal of Pajaro Valley's ReNeM pilot program is to infiltrate 1,000 AFY to the aquifer by creating and operating infiltration projects at multiple sites. This effort will help reduce groundwater overdraft and associated undesirable consequences (seawater intrusion, disconnection with surface water, and degradation to water quality). This case study analyzes the local conditions and institutions that make the ReNeM pilot program feasible, including previously established groundwater pumping fees, metered wells, and the existence of third-party certifiers able to verify the results of project sites. The ReNeM pilot has enabled increased recharge by creating new incentives that have drawn PV Water, landowners, and tenant farmers to develop recharge projects. The ReNeM pilot is the first and thus far only application of this approach, but the methods used by ReNeM may have potential applicability elsewhere. This potential will hinge on whether the pilot can prove the effectiveness of the rebate scheme and demonstrate measurable benefits in the Pajaro Valley. KEYWORDS water resources, managed aquifer recharge, environmental incentives, groundwater, institutions, governance

INTRODUCTION

In the Pajaro Valley, California, water managers, landowners, tenant farmers, and others are participating in an incentive program for managed aquifer recharge (MAR) called Recharge Net Metering (ReNeM). The mechanism behind ReNeM combines a rebate scheme, volumetric measurement of the performance of infiltration basins, and multiparty support for projects. The program uses these elements to encourage distributed recharge by individual landowners and tenant farmers. One unusual feature of ReNeM is its ability to create an incentive for recharge in which the benefits of infiltrated water can accrue to the health and sustainability of the aquifer, as opposed to being dedicated to any particular near- or long-term use. Although implementing MAR through ReNeM is still in a pilot phase in the Pajaro Valley, we argue that ReNeM's features distinguish it from other recharge programs and that programs based on ReNeM may have potential to contribute to groundwater sustainability in other basins.

This case study describes this novel scheme to encourage distributed MAR. The pilot program provides an example of performance-based rebates that refund groundwater pumping fees for landowners who develop MAR projects on their land. This article describes how ReNeM is used to incentivize distributed recharge projects that provide hydrologic

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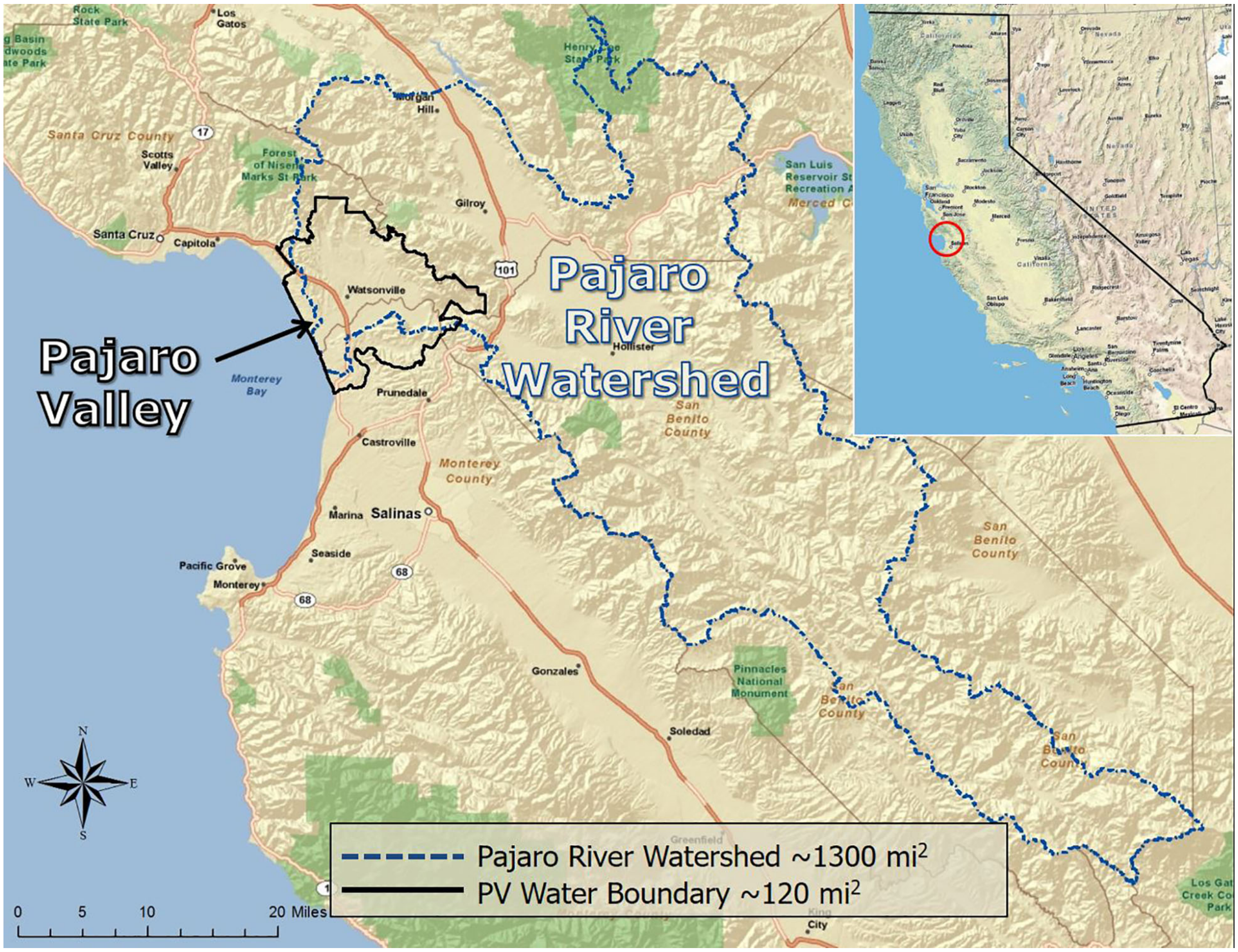

FIGURE 1. The Pajaro Valley is located on California's Central Coast, adjacent to Monterey Bay, and the PV Water service area is nested within the larger Pajaro River watershed. Map courtesy of PV Water.

benefits to the groundwater basin. These benefits include the goal of contributing to hydrologic balance and stabilizing groundwater levels in the basin and to providing ecological benefits by maintaining baseflows in rivers and streams. The article also considers how the methods in the ReNeM pilot could be expanded to greater scale within the Pajaro Valley or possibly adapted for use elsewhere.

CASE EXAMINATION

Methods

This case study forms part of the journal's special collection entitled "Institutional Dimensions of Groundwater Recharge." The collection examines empirical examples of MAR from across the United States to provide insights on the institutional structures and motivations of MAR implementation. An in-depth description of the special collection and its objectives, along with a discussion of the wider context of groundwater management concerns that MAR aims to address, is included in Miller et al. [1]. Each of the case studies in the collection examines a different physical and institutional design for MAR. Case studies were developed through an analysis of documents and expert interviews. Documents reviewed include reports from governmental agencies implementing the MAR projects, permits and reports from regulatory agencies, state laws and regulations, academic literature and technical reports, and news articles. Interviews were conducted with key individuals involved in the development of each project including government officials, regulators, and project implementers.

Local Background

The Pajaro Valley is located on California's Central Coast (figure 1). It is one of the most productive agricultural areas in California and is known particularly for its large output of high-value berry crops. Precipitation is highly seasonal, with the vast majority of rainfall occurring during November to May, and averages 21.9 in. per year. Surface water resources are scarce, and the valley lacks access to both the federal Central Valley Project and the State Water Project, which serve as water sources for areas further inland. Due to the lack of rainfall and surface water, the valley is heavily dependent on groundwater, which accounts for about 94% of current water use.

Decades of groundwater overdraft have contributed to groundwater depletion, lowering of water levels, seawater intrusion, and a decline in groundwater quality. Irrigators in the basin presently apply 50,000 to 60,000 acre-feet per year (AFY) of groundwater to crops, and the basin faces an estimated annual overdraft of 12,100 AFY, equivalent to about 20% of total annual pumping [2]. Meanwhile, climate change predictions suggest rainfall patterns in California will become more erratic, with rain events shifting to shorter duration and higher intensity. Climate change–induced sea-level rise is likely to further threaten the aquifer and exacerbate seawater intrusion in the valley [2].

In the face of these hydrologic conditions, the Pajaro Valley Water Management Agency (PV Water) is charged with addressing long-term groundwater overdraft in the basin. MAR has been an important part of PV Water's approach to doing so.

Laws and Regulations Governing Groundwater Use in the Pajaro Valley

Groundwater use in the Pajaro Valley is governed by state legislation which created PV Water and broader California groundwater laws. Groundwater use is also subject to regulations set by PV Water in order to meet its management obligations and remain economically viable.

PV WATER REGULATIONS. In 1984, the California Legislature created PV Water as a special act district to oversee water resources in the valley and to address long-term groundwater overdraft. PV Water follows a Basin Management Plan (BMP), which dictates water management and projects for the basin, with the goal of aiding PV Water in preventing further overdraft [2].[1] PV Water operates several water projects within the basin pursuant to the BMP. These include conservation programs, a MAR and recovery project, a water recycling facility that treats wastewater from the nearby city of Watsonville, and a coastal pipeline network that is used to deliver a blend of recovered MAR water, recycled water, and additional groundwater from farther inland in the basin to more coastal areas ("delivered water").

Since 1994, PV Water has charged all groundwater pumpers within the district a pumping fee [5]. The fees are currently US$246–338/AF, depending on the location of where the water is pumped [6]. Agricultural groundwater users who decide to forgo pumping or supplement their groundwater pumping with delivered water pay US$392/AF for supplemental irrigation water. These fees are significantly higher than other areas in California and the United States, where such fees exist at all. Delivered waters users are often near the coast in zones affected by seawater intrusion and choose to have this water delivered instead of only utilizing native groundwater [7]. Delivered water allows farmers to continue to grow crops in areas where the groundwater is contaminated or threatened by seawater intrusion.

To calculate pumping fees, PV Water requires metering of all wells that pump more than 10 AFY [8]. Pumping fees are calculated based on the amount of water pumped multiplied by the applicable pumping fee rate. The pumping fees make up 60–70% of the agency's revenues [9]. The fees are used to fund PV Water's operations, including agency administration, basin management, and facility operations [9]. Although these pumping fees are high, the farmers paying those fees often grow high-value crops. To illustrate, the total pumping fees paid in 2017 amounted to just over US$9 million, while the area produced around US$900 million in agricultural products [7, 9].

THE SUSTAINABLE GROUNDWATER MANAGEMENT ACT (SGMA). In 2014, California passed the SGMA. Under SGMA, the state categorized groundwater basins as low, medium, or high priority for more intensive management.[2] Newly formed local groundwater sustainability agencies (GSAs) in basins designated as high or medium priority are required to develop groundwater sustainability plans (GSPs). These GSPs must be designed to achieve groundwater sustainability by avoiding six "undesirable results," including significant and unreasonable lowering of groundwater levels, reduction of groundwater storage,

1. The BMP also serves as the basin-wide management plan under California's Groundwater Management Act (AB 3030) and was submitted as an alternative to the required Groundwater Sustainability Plan (GSP) under the Sustainable Groundwater Management Act (SGMA) [3, 4].

2. Priorities were determined based on eight main factors: the overlying population and its projected growth, the number of public supply wells and total wells, the amount of irrigated acreage, the degree of reliance on groundwater, the condition of groundwater resources, and other relevant information. Cal. Water Code 10933(b).

seawater intrusion, degraded water quality, land subsidence, and depletions of interconnected surface water that impact beneficial uses of surface water. High- and medium-priority basins that fail to adopt an adequate GSP or successfully implement their GSP may face intervention by the State Water Resources Control Board.

PV Water is the GSA for the Pajaro Valley, and the Pajaro Valley groundwater basin is designated as a critically overdrafted, high-priority groundwater basin. Pajaro Valley's BMP, along with additional informational and planning documents, was submitted as an alternative to the required GSP under SGMA and accepted by DWR in July 2019.[3]

The ReNeM Pilot Program

PV Water launched its ReNeM program at the start of the 2016–2017 water year. The 5-year pilot seeks to evaluate the potential of the ReNeM methodology to facilitate MAR while contributing modestly to PV Water's goal of addressing overdraft in the basin. Should assessment of costs and benefits, effort required for project siting and design, short- and long-term maintenance, and system performance prove favorable, the ReNeM program could be expanded beyond its pilot phase.

ReNeM uses an incentive-based system that encourages development of distributed groundwater recharge projects. It does so by providing rebates on pumping fees in exchange for infiltration of water into the aquifer. Eligible participants construct recharge sites on their properties. These "ReNeM projects" collect and infiltrate stormwater.

In the Pajaro Valley pilot program, ReNeM projects are developed at the request of and in collaboration with landowners and tenants who choose to participate. Two formal ReNeM projects are currently in operation, the performance of two additional ReNeM projects is being assessed, and additional sites for ReNeM projects are being evaluated for potential development.

RECHARGE. Water used for infiltration in ReNeM projects flows from hillslope drainage areas typically greater than 100 acres, routed via new or existing ditches or other structures toward targeted infiltration systems. These targeted infiltration systems are placed strategically where recharge can replenish underlying aquifers. High volumes of runoff are available due to (increasingly common) high-intensity rain events combined with the creation of impermeable surfaces in the basin as agricultural activities and urban areas expand [14]. The water collected represents a small percentage of runoff generated from the basin's hillslopes [15].

Infiltration versus Recharge

Infiltration is the amount of water that enters the soil from surface water sources.

Recharge is the amount of water actually reaching a defined aquifer. Recharge can be difficult to measure with precision. ReNeM tracks infiltration instead, which is consistent with the program's goal of incentivizing behavior, which benefits the basin as a whole.

ReNeM projects are sited, selected, and designed to infiltrate ≥100 AFY during a water year having median annual precipitation. Third-party certifiers from UC Santa Cruz and the Resource Conservation District of Santa Cruz County (RCD) provide objective assessment of the site suitability and design of infiltration systems. ReNeM projects in the Pajaro Valley are mostly in agricultural areas, although the availability of agricultural land is not essential for the program.

Considerations for site selection include drainage area, spatial and temporal precipitation patterns; land slope, cover and access; soil type and layering; underlying geology and hydrology, water quality of groundwater and stormwater; potential impacts on planned activities; and enthusiasm of landowners and tenants for dedicating a fraction of a property to stormwater collection and infiltration. The ability to measure potential infiltration also informs both initial site assessment and subsequent system design, in part because ReNeM links project operation to calculation of a pumping fee rebate.

ENVIRONMENTAL IMPLICATIONS. The environmental effects of hydromodification associated with distributed recharge projects that infiltrate stormwater come in two main forms: short-term changes in the runoff hydrograph associated with stormflows and long-term changes in baseflow. In principle, diversion of water to an infiltration basin will reduce the downstream hydrograph. ReNeM projects in the Pajaro Valley are unlikely to have negative impacts on the Pajaro River ecosystems because the infiltration systems operate only when surface waters in the

3. Aside from the BMP, other documents included in the alternative GSP submission included a Salt and Nutrient Management Plan and an environmental assessment for expansion of a water plant [10–13].

basin are experiencing high flows during major rain events [16]. In fact, the typical amount of water infiltrated, equivalent to <10 cubic feet/second, is small relative to streamflow. A change of this magnitude is undetectable during local storm events given the uncertainty of even the highest quality stream gauging [17, 18]. In addition, rivers and streams in agricultural and urban landscapes, which typically include large impervious surfaces, generally experience increased runoff during storm periods. Thus, the distributed MAR used in the Pajaro Valley ReNeM program tends to move hydrologic function in a predevelopment direction, slowing runoff, increasing infiltration, and extending the hydrograph. Even if this approach were "scaled up" by diverting from major rivers and flooding large landscapes [19], limited infiltration during flood hydrograph peaks is unlikely to negatively impact stream and river systems.

The ReNeM program aims to contribute to achieving hydrologic balance and stabilizing groundwater levels in the basin, as well as maintaining critical baseflows in rivers and streams. To the extent that ReNeM contributes to raising groundwater levels, baseflows should improve, benefitting stream and riparian habitat and assisting with export of salts and nutrients from aquifers.

In practical terms, each ReNeM project that is part of the Pajaro Valley pilot program must satisfy relevant national, state, regional, and local regulations. Every ReNeM project in the program must individually satisfy requirements of the California Environmental Quality Act (CEQA). Projects operated through the ReNeM program to date have been implemented following a Negative Declaration under CEQA, indicating that there is no substantial evidence for negative environmental impact.

ACCOUNTING. Landowners or tenants who participate in the ReNeM program receive a rebate on pumping fees based on the amount of water successfully infiltrated by the project on their property. Third-party certifiers monitor the rate and quantity of infiltration using conventional and experimental techniques like mass balance or using heat as a tracer [14]. These measurements verify the amount of water successfully infiltrated in a given year.[4]

4. Infiltration is used instead of actual recharge in part because it is easier to measure and track than actual recharge to the aquifer itself and in part because it reflects the nature of the incentive in the ReNeM program [20].

PV Water uses these numbers to calculate the rebate. The rebate currently uses the following equation:

$$\text{Rebate} = W_{50}x\ (\text{Inf}_{\text{tot}} - \text{Inf}_{\text{inc}})$$

Here, Inf_{inc} is the incidental infiltration that would have occurred without the project, Inf_{tot} is total measured infiltration, and W_{XX} is the proportion (in this case 50%) of the pumping fee assessed to the landowner based on location. The pilot program uses the 50% factor in its rebate calculations to account for uncertainties, storage of soil water, recognition that not all infiltrated water is recoverable, and to ensure financial viability of the program for PV Water [16, 21]. For example, one project operating under the ReNeM program in Water year 2018–2019 generated 107 acre-feet of net infiltration benefit (Inf_{tot}–Inf_{inc}). Based on the rebate formula, this benefit would generate a rebate of US$12,360 outside the delivered water area and US$16,530 inside the delivered water area.

In concept, W_{XX} could be adjusted to refine program performance. For example, reducing W_{XX} could be justified if an expanded ReNeM program were oversubscribed (responding to demand by decreasing the magnitude of the incentive) or if a basin had more poorly characterized groundwater dynamics (accounting for greater uncertainty in the fate of infiltrated water by building in a greater safety factor). Conversely, a higher W_{XX} could be justified, for example, if there were not enough ReNeM participants or for installations that instituted more precise monitoring and tracking measures.

RECOVERY AND ACCOUNTING. Water that recharges into an aquifer can contribute to mitigating historical overdraft by raising water levels, reducing seawater intrusion, and diluting salts and nutrients. Consistent with the mission of PV Water, the recharged water is considered to contribute broadly as a nonextractive beneficial use [22]. Some of this water may be recovered and applied for irrigation, and some may improve the overall health of the basin by reducing overdraft or improving water quality.

In principle, recharged water is available for extraction, subject to the pumping fees administered by PV Water. In practice, once infiltrated, specific quanta of water cannot be tracked or controlled within an aquifer [23]. The difficulty measuring recharge and subsequent flows of groundwater points to a widely applicable tension in recharge schemes that arises from an interest in tracing and quantifying the benefits of MAR. Part of the significance of the Pajaro Valley program, and the ReNeM methodology, lies in its ability to sidestep a "molecular-level accounting" approach [24] where a recharger would obtain the right to later withdrawal of recharged water, whether or not it remains in the aquifer. ReNeM does not conduct such a full accounting, yet the method suits PV Water's needs: Any water that positively affects the water balance in the groundwater basin is consistent with PV Water's basin-wide jurisdiction and its mandate to address long-term groundwater overdraft. Under ReNeM, the financial incentive focuses on encouraging increased infiltration, which generates measurable benefits; infiltrated water is not considered "owned" by the party who infiltrated it but rather is accessible to the basin as a whole. ReNeM's structure thus contrasts with MAR schemes, including others described in this special collection, in which parties who participate in groundwater recharge are granted access to the recharged water for later use, while other basin water users and the environment are largely excluded from the benefits.

INSTITUTIONAL ARRANGEMENTS. Collaboration between PV Water, local landowners, and the third-party certifiers is a critical part of the Pajaro Valley ReNeM program. PV Water calculates and issues the rebate to landowners or tenants as applicable. PV Water also controls the overall management, oversight, and administration of its ReNeM program. PV Water is governed by the PV Water Board of Directors, with four directors elected by voters living within the agency boundaries. The remaining selection of the three remaining directors reflects the agricultural character of the area: They are appointed by Monterey County, Santa Cruz County, and the City of Watsonville but are required to derive at least 51% of their net income from agriculture [7]. The Board of Directors possesses sole authority to terminate the program at any time during the pilot stage [21].

Landowners or tenants provide the land for the recharge sites. Sites could be of any size, but the pilot program has considered installations ranging from 1 to 5 acres, a small fraction of landowners' total acreage. The effectiveness of a given site for recharge will depend on a combination of soil type, underlying geology, drainage area, groundwater levels, topography, and existing infrastructure, and thus, the program is designed to allow landowners to evaluate the suitability of sites on their property, with assistance from the third-party certifiers. Once stormwater collection and infiltration systems are installed, these stakeholders are responsible for maintenance and upkeep. This is the primary basis for PV Water supplying a rebate: to offset loss of land use and operation and maintenance costs associated with hosting a project.

The third-party certifiers, UC Santa Cruz and the RCD, play an important role by securing grant funding for the project sites, designing the infiltration sites, and verifying the amount and quality of water infiltrated at each site. If the program is expanded beyond its pilot phase, these institutional arrangements will likely shift.

PROJECT FUNDING. The Pajaro ReNeM pilot is developing the concepts underlying ReNeM, but doing so depends on funding from state and federal agencies, foundations, and academic sources [16, 21] obtained by the RCD and UC Santa Cruz in their capacity as third-party certifiers [16]. These grants and contracts cover most of the pilot program's activities, including site evaluation and permitting, project design and installation, validation to certify the performance of the infiltration sites, and assessments of impacts on water quality [16].

The funding model in the ReNeM pilot will need refinement to be locally sustainable or applied in other areas. A full realization of the ReNeM approach and methodology would ideally be more, or entirely, financially self-sufficient, at least in the Pajaro Valley where marginal water costs are significantly higher than most other locations in the United States.

PROGRAM REVENUE AND COSTS. For PV Water, the pilot requires minimal capital costs and human resource demands because of a combination of the structure of the ReNeM methodology and access to grant funding. This has given the agency a chance to assess performance and better understand potential costs and obligations going forward. Over time, the pilot ReNeM program will allow researchers to develop better cost estimates for a potentially expanded program of this kind and to refine the funding and financing models (see below Discussion).

DISCUSSION. Once the Pajaro Valley pilot program is fully implemented, its goal is to add 1,000 AFY to the Pajaro Valley aquifer system. This amount of water is equivalent to about 8% of the total estimated overdraft in the basin. Although its ReNeM program is not officially a part of PV Water's current BMP, the addition of water to the basin through the ReNeM program offers PV Water a margin for error in achieving its basin sustainability goals. It diversifies PV Water's project portfolio by allowing the agency to expand its water supply options and develop new recharge projects without purchasing or leasing land or managing construction and operation of individual sites. ReNeM also serves as a hedge against climate change. Recharged water benefits water users and residents across the Pajaro Valley by improving the health of the aquifer. Increased recharge using stormwater contributes to avoiding undesirable hydrologic consequences, reducing seawater intrusion, helping to sustain baseflow to streams, and reducing local flood risk from runoff during storms. The local economy also benefits as increases to the water supply allow agricultural users to irrigate crops and support other farm-related activities.

The pilot program remains in a formative phase, but its potential impact is significant. From a hydrologic perspective, significant amounts of stormwater exist, as does land suitable for recharge. Regional modeling suggests that the 1,000 AFY goal of the ReNeM program could be met by recharging $\sim 4\%$ of hillslope runoff from the Pajaro Valley during years having median hydrologic conditions and $<2\%$ of hillslope runoff during wet years [15]. GIS-based studies of suitability for MAR in the Pajaro Valley, based on consideration of soils and subsurface conditions, suggest that there are thousands of acres suitable for MAR projects distributed throughout the basin [25, 26].

A crucial and novel contribution of ReNeM lies in the concept that, if effectively implemented and scaled, it could provide an incentive for distributed projects sited to take advantage of the varied hydrologic conditions around the basin, using MAR for the benefit of landowners and basin conditions alike. The rebate on groundwater pumping fees provides a significant monetary benefit to landowners who participate in the ReNeM program. Groundwater pumping fees in the Pajaro Valley are an outlier in California and significantly higher than most other regions of the United States.[5] The rebate serves to reduce the cost of water as a production input. ReNeM's rebate structure also provides a strong incentive for landowners and tenants to help operate and maintain infiltration systems on their land. The more water that landowners successfully infiltrate, the larger the rebate on their pumping fees. The better designed and maintained a recharge site is, the more likely it will infiltrate higher amounts of water.

Preliminary evidence also suggests the Pajaro Valley ReNeM program may be a catalyst for a broader interest in recharge. In the Pajaro Valley, many local landowners are interested in contributing to basin sustainability in material ways, and the ReNeM program may provide a new tool for such engagement. As of this writing, demand for participation exceeds capacity of the third-party certifiers to conduct thorough site investigations. One reason for this limit is the small size of the program, itself a consequence of how it is currently funded: University and agency staff are working on a time available basis with little or no programmatic funding. One goal of the ReNeM pilot program is to assess actual costs in terms of personnel time, supplies, equipment, and other components, so that ReNeM can be compared to other approaches designed to increase available supply or reduce demand.

The incentives to participate in the ReNeM program are distinct from other financial tools geared toward balancing water budgets. PV Water could arguably have pursued an alternative financial incentive by simply increasing its pumping fees. One may suppose that higher pumping fees could contribute to greater restraint in use of a groundwater resource in the Pajaro Valley or elsewhere. Even if necessary local support were forthcoming to enable such an increase, there are a range of reasons why this strategy would likely both have its own set of challenges and a distinct set of results. First, increasing water costs alone may not reduce demand as hoped. This is because higher water costs can incentivize a switch to more valuable crops, including perennial or more water intensive crops. Second, within the Pajaro Valley, costs and the perception of pressures on the water resource are both significant enough that farmers already utilize extensive technology for water use efficiency such as micro-drip irrigation on the high-value crops grown in the basin. Third, increasing fees alone does not provide an incentive to capture additional water for recharge, as the ReNeM program does. Finally, the program does not, in its current form, create any costs for non-participants.

A MAR program that uses ReNeM methodology could be revenue neutral or positive for an agency. Contrasting ReNeM to conservation programs illustrates its

5. But see Michael Kiparsky, Kathleen Miller, Anita Milman, William Blomquist, Annapurna Holtzapple. In revision for this Special Collection. Groundwater Recharge to Address Seawater Intrusion and Supply in an Urban Coastal Aquifer: Orange County Water District, Orange County, California. Case Studies in the Environment.

potential significance, were ReNeM to be taken to greater scale in the Pajaro Valley or its methods adopted elsewhere. Conservation programs are geared to reduce water use and thus reduce payments to a water agency when bills are linked to delivered water. In contrast, if an expanded ReNeM program were structured such that amortized costs are less than the revenue generated when infiltrated water is eventually pumped back out and assessed a pumping fee, then PV Water's budget will ultimately benefit. Such project development and operating costs will include site assessment, servicing bonds, and payment for performance. Costs are likely to vary considerably by basin and region, but when empirical estimates are available, they will enable more useful modeling of the viability of recharge programs of this and other types.

In the Pajaro Valley, a large-scale ReNeM program could be run adaptively over time. For example, the equation for rebates could be adjusted as described above to respond to local conditions or levels of participation.

Ultimately, a ReNeM program could in concept make itself obsolete by being so successful that a combination of rebates and reduction in water use impacted PV Water's ability to conduct its programs. However, in that case, those programs would likely no longer be necessary as it would indicate a return to a more balanced or even net positive groundwater balance. A more likely outcome of a successful ReNeM program would be that it contributed to overall sustainability as part of a portfolio of management activities.

CONCLUSION

The Pajaro Valley ReNeM program is the first and as of this writing only attempt to implement MAR using the methods described in this case study. We are aware of no other groundwater recharge project in the United States that offers groundwater pumpers a rebate on their pumping fees if they successfully operate an infiltration project on their land. ReNeM links infiltration and recharge to a rebate of pumping fees in a novel and likely unique way. The program is notable in that infiltrated water is not considered "owned" by the party who infiltrated it but rather is accessible to the basin as a whole. This contrasts with MAR schemes in which access to the recharged water supply is granted based on whether the party directly participated in the recharge activities which added water to the basin. By offering the potential for a rebate on pumping fees, the ReNeM approach provides an incentive for individual landowners to participate in the improvement of water resource conditions in a basin.

The unique elements of the ReNeM program, and its potential to provide a novel set of incentives, suggests the possibility that its methods could be adapted in other areas. New programs that use ReNeM methodology could provide incentives for a range of activities by landowners, tenants, municipalities, and other stakeholders that could benefit groundwater resources in a basin. However, as noted, the Pajaro Valley ReNeM program is still in pilot phase. Unanswered questions remain before adoption in other areas is possible. First, the expected benefits of the ReNeM pilot to the Pajaro Valley basin are long-term and may not be immediately apparent. Almost by definition, a pilot program is exploring a novel mechanism, with uncertain results. The simple structure of the ReNeM program is one of its benefits, but the lack of molecular-level accounting of infiltrated water means that tracing and specifically assigning the distinct impacts of this program will likely be impossible at a fine scale, even if the overall contribution to infiltration can be precisely measured. This limitation is not unique to ReNeM, as it is present in essentially all recharge enhancement projects. Most MAR programs will face similar issues with benefit tracking, but these are exacerbated based on the basin-as-beneficiary nature of ReNeM.

Second, further advances in the financing model will also be possible and beneficial. Implementation of MAR using a ReNeM approach requires a substantial investment in time, capital funding, design, and building new projects. In addition to capital and operating costs, there are opportunity costs for use of both land and time. Whether landowners and tenants will find the rebate sufficient to offset costs from taking some land out of production will depend on numerous factors that vary year by year and are difficult to predict—one key contribution of the pilot program lies in the chance to empirically determine whether and under what conditions landowners will respond to incentives to develop distributed recharge projects. Rather than depending on external grants for primary capital costs as the pilot program does, other ReNeM-inspired programs could be structured such that water supply agencies or landowners take on the costs of design, construction, operation, and maintenance of their respective infiltration sites, in anticipation of the returns from extraction fees or other operating fees. Similarly, the costs of a third-party certifier to validate the amount of water recharged may be incorporated into standard basic measurement and operation activities. The agency's costs, including managing the program, calculation of the rebate fee (or a simple payment system), issuing checks, and other administrative costs, could also be internalized in the fee and rebate structure [16].

Third, performance is uncertain. Although the ReNeM pilot incentivizes collection of excess runoff when it is available, there is no guarantee how much recharge will occur in a particular year. Similarly, the level of water quality that recharge projects must meet may also vary by location, and some regions may require pretreatment of water before it is recharged. Legal questions surrounding the ability to use stormwater runoff may also vary based on location. However, ReNeM has the benefit of inherent flexibility. Although ReNeM in the Pajaro Valley is focused on distributed recharge, ReNeM does not require a particular type of water source or recharge design and could in concept be adapted for other methods, such as centralized recharge projects that capture flood waters, aquifer storage and recovery of treated wastewater, or any other measurable and quantifiable method. In the Pajaro Valley, results from the 5-year pilot ReNeM program should help to resolve outstanding questions and refine the method.

Regardless of these challenges, the ReNeM methodology is a novel and conceptually distinct set of programmatic incentives for infiltration and recharge, and its success and potential broader adoption will be worth watching in future years. In the Pajaro Valley, much will depend on an assessment of performance at the end of the pilot period. Research is underway to evaluate the feasibility of ReNeM-like programs in other basins, and analysis of the distribution of costs and benefits of the program will also be forthcoming as the program matures. Although any application of ReNeM methods in other settings is unlikely to be identical in design to that applied in the Pajaro Valley, the pilot program provides a platform for testing tools and methods, assessing the sustainability of agency and stakeholder interest, and understanding how it might be possible to align diverse interests in support of regional resources.

AUTHOR CONTRIBUTIONS

KM, MK, and AF researched and wrote the paper.

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COMPETING INTERESTS

The authors have declared that no competing interests exist.

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