Cost – Benefit Analysis of On-Farm Managed Aquifer Recharge in Alfalfa Fields and Almond Orchards

A report for U.S. Bureau of Reclamation by Dr. Samuel Sandoval Solis and Dr. Helen Dahlke

University of California, Davis.

Introduction

Since 1865 (DWR 1957), California has practiced underground water storage (referred in this document as Managed Aquifer Recharge (MAR) and extraction) through artificial recharge, but in many parts of the state, these efforts have been insufficient to meet its growing water demands, particularly for irrigated agriculture. During dry periods, vast agricultural areas depend upon groundwater for irrigation. In these regions, groundwater banking through underground storage should be an essential part of water management practice (Sandoval-Solis et al. 2010).

MAR is an application of conjunctive use of at least two water sources, typically surface water and groundwater. Conjunctive use of surface and ground waters is defined (Sahuillo and Lluria 2002) as the "*management of surface and groundwater resources in a coordinated operation to ensure that the total benefits of such a system exceed the sum of the benefits produced by managing of the two water sources separately.*" Benefits also include the prevention of aquifer overdraft and the improvement of water supply reliability. Conjunctive water management presents advantages and disadvantages that require consideration before implementation (Coe 1990). There are two main objectives for recharging aquifers:

1. Replenishment of groundwater is used to avoid environmental consequences such as saline intrusion in coastal areas, land subsidence and groundwater storage depletion in some areas in the Central Valley; and
2. Storage of water for future recovery; in wet years, excess surface water is diverted to spreading areas where it percolates into the underlying aquifer; meanwhile in dry years, that stored water is recovered through wells to be delivered to the end user.

As a type of conjunctive use, MAR implies either active or passive methods for recharging water into aquifers. The active method diverts water from the alternative water source (e.g., surface water) and spreads it into recharging areas (agricultural fields, ponds, floodplains, groundwater recharge zones, or injecting wells to recharge the aquifer). The passive method also referred to as in-lieu, uses surface water when available, during which time users may not extract water from the aquifer. This method considers groundwater replenishment by natural recharge and excess water from irrigation.

Some of the approaches aforementioned to recharge aquifers require purchasing of land and reengineering of said lands to accommodate the site for active aquifer recharge. An alternative to these strategies is the use of agricultural lands with good infiltration rates and crops tolerant to prolonged flooding. Identifiable risks involved in this practice are potential negative economic impacts on farm production and groundwater quality issues.

These report describes the construction of a on-fam MAR cost-benefit calculator work presents a conceptual framework to analyze the potential economic effects of groundwater banking on agricultural land (Ag-GB). The proposed framework looks at the tradeoffs between the potential benefits and costs derived from this practice at the irrigation district level.

Objective

The main objective of this study is to perform a Net Benefit Analysis for a range of on-farm MAR operations, where the associated cost and benefits were estimated for each operation proposed. We performed to perform a sensitivity analysis on what can be the size of the operation that can make more economically appealing OF-MAR for irrigation districts.

Methods

This study performed a net benefit analysis by calculating the cost and benefits for OF-MAR

Costs of On-farm MAR

Cost of agriculture operation

The cost of the agriculture operation that considers agricultural production and on-farm MAR is expressed in Equation [1].

$$Cost^{Crop} = \frac{Acreage*(EC^{Crop}+PC^{Crop}+SW^{Cost}+GW^{Cost}+Recharge^{Cost}+Turnout^{Cost})}{Recharge^{Volume}} \quad \text{... [1]}$$

Where $Cost^{Crop}$ is the total cost for the production of a given crop ($), *Acreage* is the spatial extent (in acres) of the production operation that in this case may vary from 10 acres to 1,000 acres, EC^{Crop} is the establishment cost for a given crop ($/acre), PC^{Crop} is the production cost for a given crop ($/acre), SW^{Cost} is the cost associated with surface water fees for crop production ($/acre), GW^{Cost} is the cost associated with groundwater fees and pumping for crop production ($/acre), $Recharge^{Cost}$ is the cost associated of the water used for recharging, and $Turnout^{Cost}$ is the cost associated with turnout operation, berming the perimeter of the field and any additional cost ($/acre).

The surface water cost (SW^{Cost}) for agriculture production is calculated using Equation 2

$$SW^{Cost} = AppliedWater^{Crop} * SW^{Percent\ Supply} * Water\ Fee^{SW} \text{...[2]}$$

Where $AppliedWater^{Crop}$ is the irrigated water in (acre-feet / acre) need to produce a crop, $SW^{Percent\ Supply}$ is the percentage of the applied water that is typically supplied from surface water sources, and $Water\ Fee^{SW}$ is the fee that a given water agency or provider charges (in $/acre-foot) to supply the surface water.

The groundwater cost (SW^{Cost}) for agriculture production is calculated using Equation 3

$$GW^{Cost} = AppliedWater^{Crop} * GW^{Percent\ Supply} * \left(Water\ Fee^{GW} + Aquifer^{Depth} * Pumping^{Cost}\right) \text{...[3]}$$

Where $GW^{Percent\ Supply}$ is the percentage of the applied water that is typically supplied from groundwater sources, and $Water\ Fee^{GW}$ is the fee that a given water agency or provider charges (in $/acre-foot) to supply the surface water, $Aquifer^{Depth}$ is an estimate of the average aquifer depth of the groundwater table, and $Pumping^{Cost}$ is the cost associated to lift one acre-feet of water by one foot in ($/acre-foot per 1-foot of lift).

The cost of the water to be recharged ($Recharge^{Cost}$) is calculated using Equation 4

$$Recharge^{Cost} = Recharge^{Depth} * Water\ Fee^{MAR} \ ...[4]$$

Where $Recharge^{Depth}$ is the intended water depth (in feet) of the volume of water to be recharged, and $Water\ Fee^{MAR}$ is the fee that a given water agency or provider charges (in $/acre-foot) to supply the surface water for aquifer recharge, if any.

Cost for an On-Farm MAR

The cost for On-Farm MAR are the last two terms of the total cost of the agriculture operation, because the cost associated establishment, production and water cost for agricultural production have to be spent with or without an On-farm MAR operation. The cost associated with the On-Fam MAR operation ($Cost^{OF-MAR}$) are calculated using Equation 5.

$$Cost^{OF-MAR} = Acreage * (Recharge^{Cost} + Turnout^{Cost}) \ ...[5]$$

Furthermore, it is possible to estimate the cost of each acre-feet recharged ($Unit\ Cost^{OF-MAR}$) using Equation 6

$$Unit\ Cost^{OF-MAR} = \frac{Acreage*(Recharge^{Cost}+Turnout^{Cost})}{Recharge^{Volume}} \ ... [6]$$

The volume of water recharged ($Recharge^{Volume}$) is calculated using Equation 7

$$Recharge^{Volume} = Acreage * Recharge^{Depth} ...[7]$$

Substituting Eq. 4 and 7 into Eq. 6 the unit cost of On-farm MAR can be rewritten as Equation 8

$$Unit\ Cost^{OF-MAR} = \frac{Recharge^{Depth}*Water\ Fee^{MAR}+Turnout^{Cost}}{Recharge^{Depth}} \ ... [8]$$

Eq. 8 shows that the cost of On-farm MAR not depends on the water to be recharged expressed as the depth of water to be recharged ($Recharge^{Depth}$), the fees associated with the water to be recharge ($Water\ Fee^{MAR}$) and the labor cost to operate the operation ($Turnout^{Cost}$)

Benefits of On-farm MAR

The benefits for On-Farm MAR ($Benefits^{\ OF-MAR}$) are calculated using Equation 9.

$$Benefits^{\ OF-MAR} = Cost\ GW^{No\ OF-MAR} - \ Cost\ GW^{OF-MAR} + GW\ Sold^{ID} \ ... [9]$$

Where $Cost\ GW^{No\ OF-MAR}$ (in $) is the current (business as usual) groundwater pumping cost were no On-farm MAR is implemented, $Cost\ GW^{OF-MAR}$ (in $) is the groundwater pumping cost if On-farm MAR is implemented, and $GW\ Sold^{ID}$ (in $) is the recovery cost for selling water, if any.

Benefits due to pumping cost

The groundwater pumping cost <u>without</u> On-farm MAR ($Cost\ GW^{No\ OF-MAR}$) is calculated using Equation 10.

$$Cost\ GW^{No\ OF-MAR} = Acreage^{ID} * CropUseGW^{Avg} * \left(Aquifer^{Depth} * Pumping^{Cost} + Water\ Fee^{GW}\right) \ldots [10]$$

Where $Acreage^{ID}$ is the acreage (in acres) of a given irrigation district implementing On-farm MAR, $CropUseGW^{Avg}$ is the average use of groundwater (acre-foot per acre) by the water users associated with an irrigation district.

The groundwater pumping cost <u>with</u> On-farm MAR ($Cost\ GW^{OF-MAR}$) is calculated using Equation 11.

$$Cost\ GW^{OF-MAR} = Acreage^{ID} * CropUseGW^{Avg} * (Aquifer^{Depth} - Aquifer^{Depth\ OF-MAR})Pumping^{Cost} + Water\ Fee^{GW} \ldots [11]$$

Equation 11 is similar to Equation 10, with the difference that in this equation is introduced the variable of $Aquifer^{Depth\ OF-MAR}$ that estimate the water depth if on-farm MAR is implemented, which is calculated using Equation 12.

$$Aquifer^{Depth\ OF-MAR} = \frac{\frac{\left(Recharge^{Depth} * Acreage\right) * (1 - Percent\ GW\ Recovered) * (1 - Recharge\ lost)}{Aquifer\ Storage\ Coefficient}}{Acreage^{ID}} \ldots [12]$$

Where $Percent\ GW\ Recovered$ is percentage of the water recharged that a given irrigation district decide to recover, $Recharge\ lost$ is the percentage of water recharged that moves out of the irrigation district into a different area and cannot be recovered by the irrigation district implementing on-farm MAR, $Aquifer\ Storage\ Coefficient$ (also known as Storativity) is the volume of water released from storage per unit decline in hydraulic head in the aquifer.

Benefits due to groundwater recovery and selling

The benefits related to groundwater recovery and selling ($GW\ Sold^{ID}$) by a given irrigation district that operates and manage on-farm MAR is calculated using Equation 13.

$$GW\ Sold^{ID} = Recharge^{Depth} * Acreage * Percent\ GW\ Recovered * SellingPrice \ldots [13]$$

Where $SellingPrice$ is the economic value of the water sold (\$/acre-foot).

Net Benefits of On-farm MAR

The net benefits of implementing an on-farm MAR ($Net\ Benefits^{OF-MAR}$) are calculated by subtracting the benefits ($Benefits^{OF-MAR}$) minus the cost ($Cost^{OF-MAR}$) of management and operation using Equation 14.

$$Net\ Benefits^{OF-MAR} = Benefits^{OF-MAR} - Cost^{OF-MAR} \ldots [14]$$

Finally, the net benefits are divided by

$$Unit\ Net\ Benefits^{OF-MAR} = \frac{Net\ Benefits^{OF-MAR}}{Acreage^{ID}}$$

Interface

An interface was built to estimate the cost, benefits and net benefits of OF-MAR. The interface follows the logic and equations explained in the previous section. Figure 1 shows the layout of the interface that has two main sections, Inputs and Results

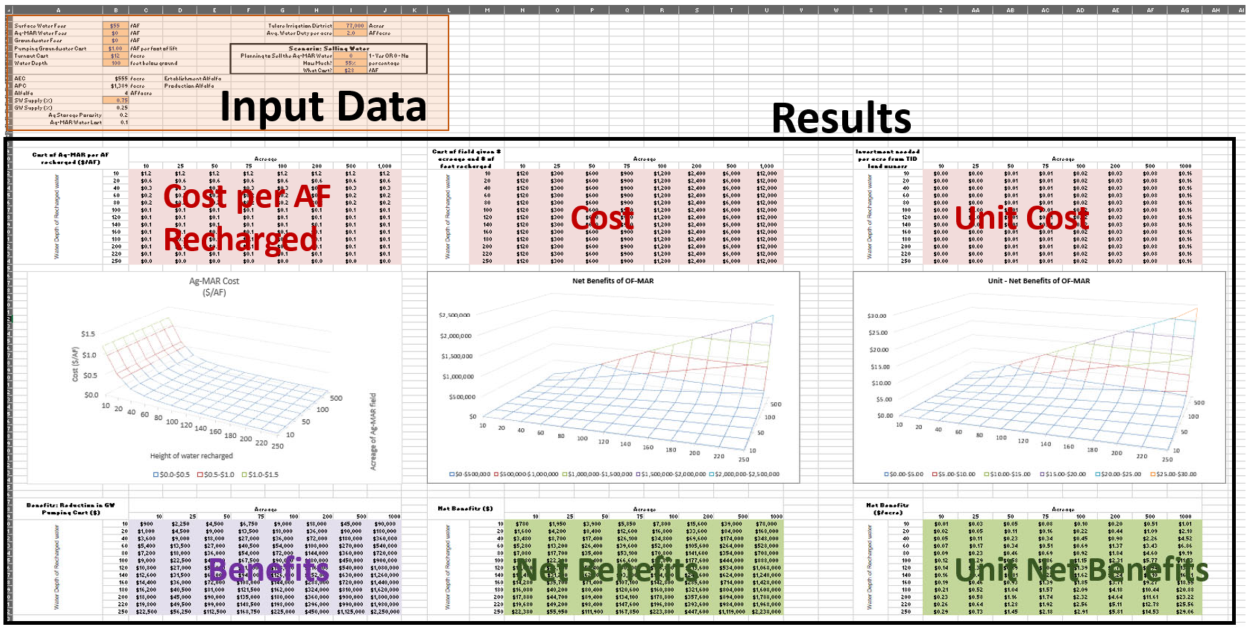

Figure 1 – On Farm Managed Aquifer Recharge (OF-MAR) Net-Benefits Interface

In turn, the input Data section is divided into 4 sections (see Figure 2): (a) basic cost data, (b) aquifer data, (c) irrigation district data and (d) Scenarios for selling the water recharged

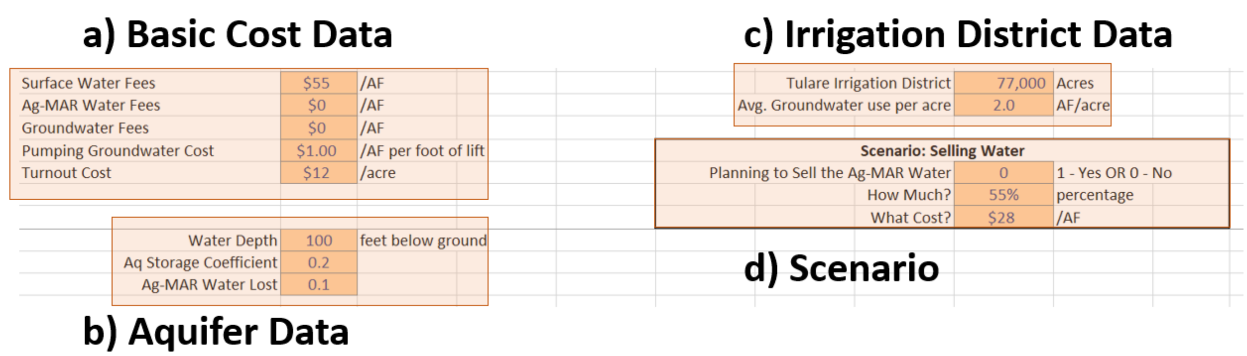

Figure 2 – input data interface

For Basic Cost, the user can input the water fees for agriculture production use of surface and groundwater, as well as if the surface water recharged had any cost. The pumping cost is the cost of to lift 1 acre-foot by one foot of lift, and finally the average water depth of the region. The aquifer data requires the water table depth, aquifer storage coefficient and the estimated fraction of water that is lost of the water recharged. In the irrigation district section, the user provides the information of the irrigation district that will implement the OF-MAR, it includes the acreage of the irrigation district, and the average use of groundwater per acre. In the scenario section, the user can turn on a scenario where the user explores the hypothetical case were the irrigation district sell the recharged water for a given recovery cost fee.

Results

Baseline

This section will provide the results for the baseline condition and perform a sensitivity analysis of the different variables that may affect the benefits, cost and net benefits of implementing OF-MAR. The baseline condition assumes the following variable:

1) The data of Tulare Irrigation District was used, whenever was possible, as the default variable for this estimation, including:
    a. Cost of surface water, $Water\ Fee^{SW}$ = \$55/acre-foot,
    b. Tulare Irrigation District Area, $Acreage^{ID}$ = 77,000 acres,
    c. Average groundwater use per acre, $ropUseGW^{Avg}$ = 2 acre-feet/acre
2) There is no associated fee for the surface water that is recharged $Water\ Fee^{MAR}$ = \$0/acre-foot nor groundwater fee $Water\ Fee^{GW}$ = \$0/acre-foot
3) The pumping cost proposed is $Pumping^{Cost}$ = \$0.25/acre-foot per foot of lift, this is a cost that has been adjusted for estimating the cost of an electric pump that in 2013 was \$0.20/acre-foot per foot of lift with a discount rate of 3% per year.
4) The turnout and berming cost proposed as follows $Turnout^{Cost}$ is = \$10/acre
5) For the baseline scenario, these are the aquifer properties values proposed for the baseline scenario $Aquifer^{Depth}$ = 100 feet, Aquifer storage coefficient = $Aquifer\ Storage\ Coefficient$ = 0.20 and percentage of OF-MAR lost $Recharge\ lost$ = 0.1

Table 1 and Figure 3 show the cost for implementing OF-MAR for the baseline conditions considering a series of combinations of the acreage where OF-MAR will be implemented, and the total amount of water that in the life time of the recharge facility will be recharged. As can be seen in Figure 3 and Table 1, the cost for implementing OF-MAR depends on the size (acreage) of the OF-MAR facility, even if the water depth recharged, the cost doe not increase as long as the water recharge is not subject to a water fee.

Table 2 and Figure 4 show the benefits for implementing OF-MAR for the baseline conditions considering a series of combinations of the acreage where OF-MAR will be implemented, and the total amount of water that in the life time of the recharge facility will be recharged. As can be seen in Figure 4 and Table 2, the benefits for implementing OF-MAR depends on both, the size (acreage) of the OF-MAR facility and the water depth recharged, because as more water is recharged then there are more benefits associated with less pumping cost due to a higher water table.

Table 3 and Figure 5 show the net benefits for implementing OF-MAR for the baseline conditions considering a series of combinations of the acreage where OF-MAR will be implemented and the total amount of water that in the life time of the recharge facility will be recharged. These results are obtained by subtracting the benefits minus the cost. **These results show that OF-MAR is economically**

feasible (Net benefits > 0) when there is no surface water fees for the water to be recharged, and low turnout cost.

Table 1.- Cost for the Baseline scenario OF-MAR considering combinations of the size of the OF-MAR facility (Acreage) and the water depth recharge during the life spam of the project

Cost of field given # acreage and # of feet recharged		Size of the on-farm facility (acres)							
		10	25	50	75	100	200	500	1,000
Hight of the Water Recharged during the lifespam of the facility	10	$100	$250	$500	$750	$1,000	$2,000	$5,000	$10,000
	20	$100	$250	$500	$750	$1,000	$2,000	$5,000	$10,000
	40	$100	$250	$500	$750	$1,000	$2,000	$5,000	$10,000
	60	$100	$250	$500	$750	$1,000	$2,000	$5,000	$10,000
	80	$100	$250	$500	$750	$1,000	$2,000	$5,000	$10,000
	100	$100	$250	$500	$750	$1,000	$2,000	$5,000	$10,000
	120	$100	$250	$500	$750	$1,000	$2,000	$5,000	$10,000
	140	$100	$250	$500	$750	$1,000	$2,000	$5,000	$10,000
	160	$100	$250	$500	$750	$1,000	$2,000	$5,000	$10,000
	180	$100	$250	$500	$750	$1,000	$2,000	$5,000	$10,000
	200	$100	$250	$500	$750	$1,000	$2,000	$5,000	$10,000
	220	$100	$250	$500	$750	$1,000	$2,000	$5,000	$10,000
	250	$100	$250	$500	$750	$1,000	$2,000	$5,000	$10,000

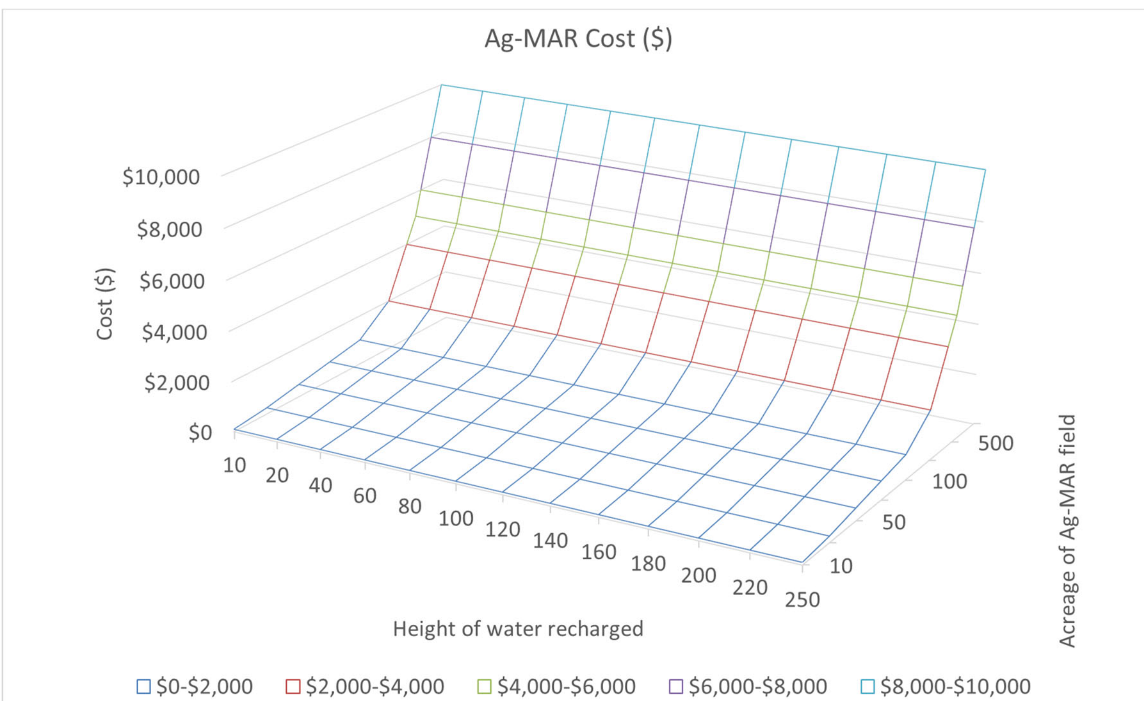

Figure 3 - Cost for the Baseline scenario OF-MAR considering combinations of the size of the OF-MAR facility (Acreage) and the water depth recharge during the life spam of the project

Table 2.- Benefits for the Baseline scenario OF-MAR considering combinations of the size of the OF-MAR facility (Acreage) and the water depth recharge during the life spam of the project

Benefits related to Reduction in GW Pumping Cost ($)		**Size of the on-farm facility (acres)**							
		10	**25**	**50**	**75**	**100**	**200**	**500**	**1000**
Hight of the Water Recharged during the lifespam of the facility	**10**	$228	$570	$1,140	$1,710	$2,280	$4,560	$11,401	$22,802
	20	$456	$1,140	$2,280	$3,420	$4,560	$9,121	$22,802	$45,604
	40	$912	$2,280	$4,560	$6,841	$9,121	$18,241	$45,604	$91,207
	60	$1,368	$3,420	$6,841	$10,261	$13,681	$27,362	$68,406	$136,811
	80	$1,824	$4,560	$9,121	$13,681	$18,241	$36,483	$91,207	$182,415
	100	$2,280	$5,700	$11,401	$17,101	$22,802	$45,604	$114,009	$228,019
	120	$2,736	$6,841	$13,681	$20,522	$27,362	$54,724	$136,811	$273,622
	140	$3,192	$7,981	$15,961	$23,942	$31,923	$63,845	$159,613	$319,226
	160	$3,648	$9,121	$18,241	$27,362	$36,483	$72,966	$182,415	$364,830
	180	$4,104	$10,261	$20,522	$30,783	$41,043	$82,087	$205,217	$410,434
	200	$4,560	$11,401	$22,802	$34,203	$45,604	$91,207	$228,019	$456,037
	220	$5,016	$12,541	$25,082	$37,623	$50,164	$100,328	$250,820	$501,641
	250	$5,700	$14,251	$28,502	$42,753	$57,005	$114,009	$285,023	$570,047

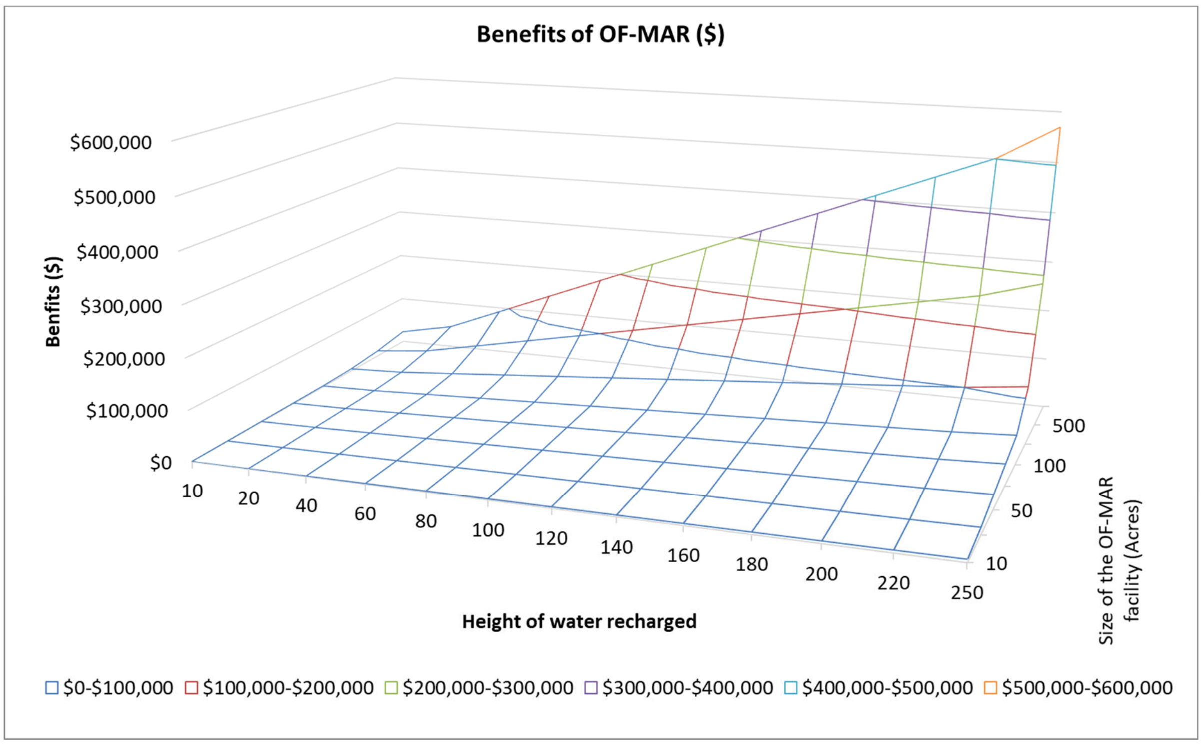

Figure 4 - Benefits for the Baseline scenario OF-MAR considering combinations of the size of the OF-MAR facility (Acreage) and the water depth recharge during the life spam of the project

Table 3.- Net Benefits for the Baseline scenario OF-MAR considering combinations of the size of the OF-MAR facility (Acreage) and the water depth recharge during the life spam of the project

Net Benefits ($)		Size of the on-farm facility (acres)							
		10	25	50	75	100	200	500	1000
Hight of the Water Recharged during the lifespam of the facility	10	$128	$320	$640	$960	$1,280	$2,560	$6,401	$12,802
	20	$356	$890	$1,780	$2,670	$3,560	$7,121	$17,802	$35,604
	40	$812	$2,030	$4,060	$6,091	$8,121	$16,241	$40,604	$81,207
	60	$1,268	$3,170	$6,341	$9,511	$12,681	$25,362	$63,406	$126,811
	80	$1,724	$4,310	$8,621	$12,931	$17,241	$34,483	$86,207	$172,415
	100	$2,180	$5,450	$10,901	$16,351	$21,802	$43,604	$109,009	$218,019
	120	$2,636	$6,591	$13,181	$19,772	$26,362	$52,724	$131,811	$263,622
	140	$3,092	$7,731	$15,461	$23,192	$30,923	$61,845	$154,613	$309,226
	160	$3,548	$8,871	$17,741	$26,612	$35,483	$70,966	$177,415	$354,830
	180	$4,004	$10,011	$20,022	$30,033	$40,043	$80,087	$200,217	$400,434
	200	$4,460	$11,151	$22,302	$33,453	$44,604	$89,207	$223,019	$446,037
	220	$4,916	$12,291	$24,582	$36,873	$49,164	$98,328	$245,820	$491,641
	250	$5,600	$14,001	$28,002	$42,003	$56,005	$112,009	$280,023	$560,047

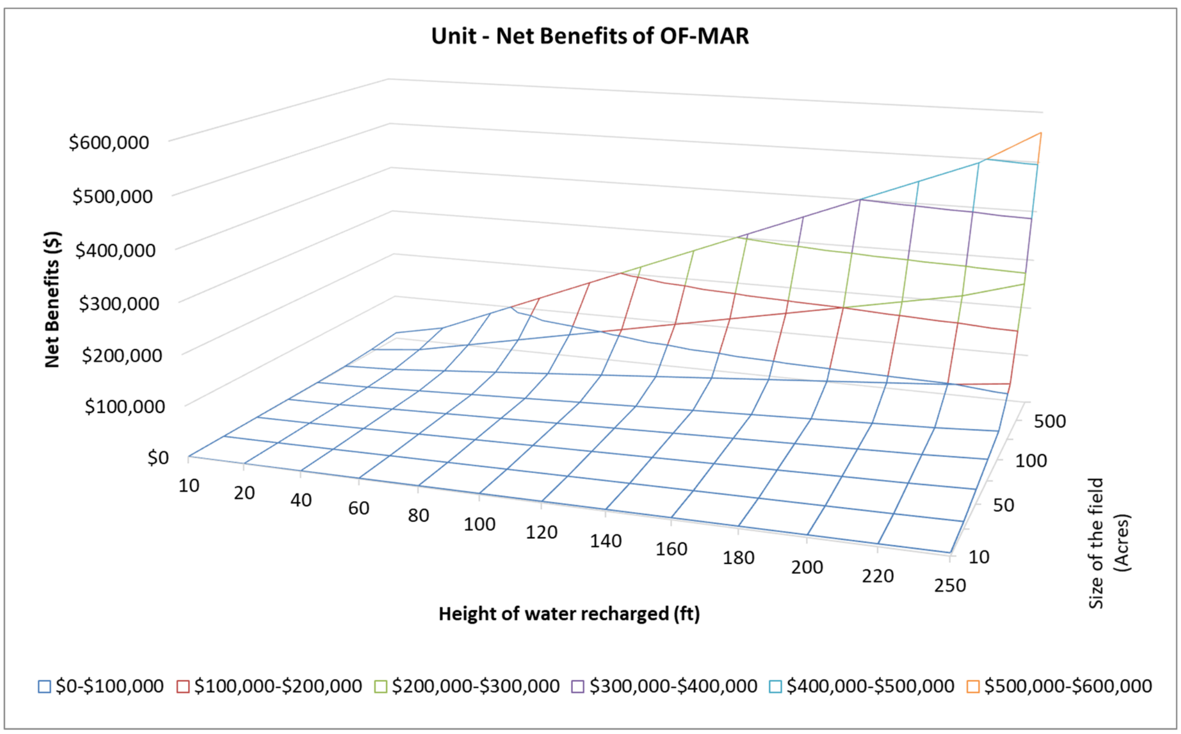

Figure 5 – Net - Benefits for the Baseline scenario OF-MAR considering combinations of the size of the OF-MAR facility (Acreage) and the water depth recharge during the life spam of the project

Sensitivity Analysis

Turnout Cost ($Turnout^{Cost}$)

This section performs a sensitivity analysis of the turnout cost on the economic feasibility of OF-MAR. Result in Figure 6 shows that for the baseline conditions all combinations are economically feasible, but **as the turnout cost increases** to $25/acre, $50/acre and $100/acre **results start becoming economically unfeasible** for recharging water height less than 10 feet, 20 feet and 40 feet respectively.

Net Benefits ($)	Size of the on-farm facility (acres)							
Hight of the Water Recharged during the lifespam of the facility	10	25	50	75	100	200	500	1000
10	$128	$320	$640	$960	$1,280	$2,560	$6,401	$12,802
20	$356	$890	$1,780	$2,670	$3,560	$7,121	$17,802	$35,604
40	$812	$2,030	$4,060	$6,091	$8,121	$16,241	$40,604	$81,207
60	$1,268	$3,170	$6,341	$9,511	$12,681	$25,362	$63,406	$126,811
80	$1,724	$4,310	$8,621	$12,931	$17,241	$34,483	$86,207	$172,415
100	$2,180	$5,450	$10,901	$16,351	$21,802	$43,604	$109,009	$218,019
120	$2,636	$6,591	$13,181	$19,772	$26,362	$52,724	$131,811	$263,622
140	$3,092	$7,731	$15,461	$23,192	$30,923	$61,845	$154,613	$309,226
160	$3,548	$8,871	$17,741	$26,612	$35,483	$70,966	$177,415	$354,830
180	$4,004	$10,011	$20,022	$30,033	$40,043	$80,087	$200,217	$400,434
200	$4,460	$11,151	$22,302	$33,453	$44,604	$89,207	$223,019	$446,037
220	$4,916	$12,291	$24,582	$36,873	$49,164	$98,328	$245,820	$491,641
250	$5,600	$14,001	$28,002	$42,003	$56,005	$112,009	$280,023	$560,047

(a) Baseline. Turnout Cost $10/acre

Net Benefits ($)	Size of the on-farm facility (acres)							
Hight of the Water Recharged during the lifespam of the facility	10	25	50	75	100	200	500	1000
10	-$22	-$55	-$110	-$165	-$220	-$440	-$1,099	-$2,198
20	$206	$515	$1,030	$1,545	$2,060	$4,121	$10,302	$20,604
40	$662	$1,655	$3,310	$4,966	$6,621	$13,241	$33,104	$66,207
60	$1,118	$2,795	$5,591	$8,386	$11,181	$22,362	$55,906	$111,811
80	$1,574	$3,935	$7,871	$11,806	$15,741	$31,483	$78,707	$157,415
100	$2,030	$5,075	$10,151	$15,226	$20,302	$40,604	$101,509	$203,019
120	$2,486	$6,216	$12,431	$18,647	$24,862	$49,724	$124,311	$248,622
140	$2,942	$7,356	$14,711	$22,067	$29,423	$58,845	$147,113	$294,226
160	$3,398	$8,496	$16,991	$25,487	$33,983	$67,966	$169,915	$339,830
180	$3,854	$9,636	$19,272	$28,908	$38,543	$77,087	$192,717	$385,434
200	$4,310	$10,776	$21,552	$32,328	$43,104	$86,207	$215,519	$431,037
220	$4,766	$11,916	$23,832	$35,748	$47,664	$95,328	$238,320	$476,641
250	$5,450	$13,626	$27,252	$40,878	$54,505	$109,009	$272,523	$545,047

(b) Turnout Cost $25/acre

Net Benefits ($)	Size of the on-farm facility (acres)							
Hight of the Water Recharged during the lifespam of the facility	10	25	50	75	100	200	500	1000
10	-$272	-$680	-$1,360	-$2,040	-$2,720	-$5,440	-$13,599	-$27,198
20	-$44	-$110	-$220	-$330	-$440	-$879	-$2,198	-$4,396
40	$412	$1,030	$2,060	$3,091	$4,121	$8,241	$20,604	$41,207
60	$868	$2,170	$4,341	$6,511	$8,681	$17,362	$43,406	$86,811
80	$1,324	$3,310	$6,621	$9,931	$13,241	$26,483	$66,207	$132,415
100	$1,780	$4,450	$8,901	$13,351	$17,802	$35,604	$89,009	$178,019
120	$2,236	$5,591	$11,181	$16,772	$22,362	$44,724	$111,811	$223,622
140	$2,692	$6,731	$13,461	$20,192	$26,923	$53,845	$134,613	$269,226
160	$3,148	$7,871	$15,741	$23,612	$31,483	$62,966	$157,415	$314,830
180	$3,604	$9,011	$18,022	$27,033	$36,043	$72,087	$180,217	$360,434
200	$4,060	$10,151	$20,302	$30,453	$40,604	$81,207	$203,019	$406,037
220	$4,516	$11,291	$22,582	$33,873	$45,164	$90,328	$225,820	$451,641
250	$5,200	$13,001	$26,002	$39,003	$52,005	$104,009	$260,023	$520,047

(c) Baseline. Turnout Cost $50/acre

Net Benefits ($)	Size of the on-farm facility (acres)							
Hight of the Water Recharged during the lifespam of the facility	10	25	50	75	100	200	500	1000
10	-$772	-$1,930	-$3,860	-$5,790	-$7,720	-$15,440	-$38,599	-$77,198
20	-$544	-$1,360	-$2,720	-$4,080	-$5,440	-$10,879	-$27,198	-$54,396
40	-$88	-$220	-$440	-$659	-$879	-$1,759	-$4,396	-$8,793
60	$368	$920	$1,841	$2,761	$3,681	$7,362	$18,406	$36,811
80	$824	$2,060	$4,121	$6,181	$8,241	$16,483	$41,207	$82,415
100	$1,280	$3,200	$6,401	$9,601	$12,802	$25,604	$64,009	$128,019
120	$1,736	$4,341	$8,681	$13,022	$17,362	$34,724	$86,811	$173,622
140	$2,192	$5,481	$10,961	$16,442	$21,923	$43,845	$109,613	$219,226
160	$2,648	$6,621	$13,241	$19,862	$26,483	$52,966	$132,415	$264,830
180	$3,104	$7,761	$15,522	$23,283	$31,043	$62,087	$155,217	$310,434
200	$3,560	$8,901	$17,802	$26,703	$35,604	$71,207	$178,019	$356,037
220	$4,016	$10,041	$20,082	$30,123	$40,164	$80,328	$200,820	$401,641
250	$4,700	$11,751	$23,502	$35,253	$47,005	$94,009	$235,023	$470,047

(d) Turnout Cost $100/acre

Figure 6 – Sensitivity Analysis of the economic feasibility when the turn out cost changes from the Baseline scenario ($10/acre) to (b) $25/acre , (c) $50/acre and (d) $100/acre

Water fees of the surface water to be recharged ($Water\ Fee^{MAR}$)

This section performs a sensitivity analysis on the variable $Water\ Fee^{MAR}$ which is the fee that a given water agency or provider charges (in $/acre-foot) to supply the surface water for aquifer recharge, if any. Result in Figure 7 shows that this variable is very sensitive, when the cost increase from $0/acre-foot to $2/acre-foot results start becoming economically unfeasible for recharging water height less than 20 feet, then all results become economically unfeasible when these water fees are of $5/acre-foot and $10/acre-foot. Thus, **a slight increase in any water agency that would like to charge a certain fees (even as small as $2/AF), it will become the OF_MAR practice unfeasible.**

Net Benefits ($)	Size of the on-farm facility (acres)							
Hight of the Water Recharged during the lifespam of the facility	10	25	50	75	100	200	500	1000
10	$128	$320	$640	$960	$1,280	$2,560	$6,401	$12,802
20	$356	$890	$1,780	$2,670	$3,560	$7,121	$17,802	$35,604
40	$812	$2,030	$4,060	$6,091	$8,121	$16,241	$40,604	$81,207
60	$1,268	$3,170	$6,341	$9,511	$12,681	$25,362	$63,406	$126,811
80	$1,724	$4,310	$8,621	$12,931	$17,241	$34,483	$86,207	$172,415
100	$2,180	$5,450	$10,901	$16,351	$21,802	$43,604	$109,009	$218,019
120	$2,636	$6,591	$13,181	$19,772	$26,362	$52,724	$131,811	$263,622
140	$3,092	$7,731	$15,461	$23,192	$30,923	$61,845	$154,613	$309,226
160	$3,548	$8,871	$17,741	$26,612	$35,483	$70,966	$177,415	$354,830
180	$4,004	$10,011	$20,022	$30,033	$40,043	$80,087	$200,217	$400,434
200	$4,460	$11,151	$22,302	$33,453	$44,604	$89,207	$223,019	$446,037
220	$4,916	$12,291	$24,582	$36,873	$49,164	$98,328	$245,820	$491,641
250	$5,600	$14,001	$28,002	$42,003	$56,005	$112,009	$280,023	$560,047

(a) Baseline. Water Fee OF-MAR $0/acre-feet

Net Benefits ($)	Size of the on-farm facility (acres)							
Hight of the Water Recharged during the lifespam of the facility	10	25	50	75	100	200	500	1000
10	-$72	-$180	-$360	-$540	-$720	-$1,440	-$3,599	-$7,198
20	-$44	-$110	-$220	-$330	-$440	-$879	-$2,198	-$4,396
40	$12	$30	$60	$91	$121	$241	$604	$1,207
60	$68	$170	$341	$511	$681	$1,362	$3,406	$6,811
80	$124	$310	$621	$931	$1,241	$2,483	$6,207	$12,415
100	$180	$450	$901	$1,351	$1,802	$3,604	$9,009	$18,019
120	$236	$591	$1,181	$1,772	$2,362	$4,724	$11,811	$23,622
140	$292	$731	$1,461	$2,192	$2,923	$5,845	$14,613	$29,226
160	$348	$871	$1,741	$2,612	$3,483	$6,966	$17,415	$34,830
180	$404	$1,011	$2,022	$3,033	$4,043	$8,087	$20,217	$40,434
200	$460	$1,151	$2,302	$3,453	$4,604	$9,207	$23,019	$46,037
220	$516	$1,291	$2,582	$3,873	$5,164	$10,328	$25,820	$51,641
250	$600	$1,501	$3,002	$4,503	$6,005	$12,009	$30,023	$60,047

(b) Water Fee OF-MAR $2/acre-feet

Net Benefits ($)	Size of the on-farm facility (acres)							
Hight of the Water Recharged during the lifespam of the facility	10	25	50	75	100	200	500	1000
10	-$372	-$930	-$1,860	-$2,790	-$3,720	-$7,440	-$18,599	-$37,198
20	-$644	-$1,610	-$3,220	-$4,830	-$6,440	-$12,879	-$32,198	-$64,396
40	-$1,188	-$2,970	-$5,940	-$8,909	-$11,879	-$23,759	-$59,396	-$118,793
60	-$1,732	-$4,330	-$8,659	-$12,989	-$17,319	-$34,638	-$86,594	-$173,189
80	-$2,276	-$5,690	-$11,379	-$17,069	-$22,759	-$45,517	-$113,793	-$227,585
100	-$2,820	-$7,050	-$14,099	-$21,149	-$28,198	-$56,396	-$140,991	-$281,981
120	-$3,364	-$8,409	-$16,819	-$25,228	-$33,638	-$67,276	-$168,189	-$336,378
140	-$3,908	-$9,769	-$19,539	-$29,308	-$39,077	-$78,155	-$195,387	-$390,774
160	-$4,452	-$11,129	-$22,259	-$33,388	-$44,517	-$89,034	-$222,585	-$445,170
180	-$4,996	-$12,489	-$24,978	-$37,467	-$49,957	-$99,913	-$249,783	-$499,566
200	-$5,540	-$13,849	-$27,698	-$41,547	-$55,396	-$110,793	-$276,981	-$553,963
220	-$6,084	-$15,209	-$30,418	-$45,627	-$60,836	-$121,672	-$304,180	-$608,359
250	-$6,900	-$17,249	-$34,498	-$51,747	-$68,995	-$137,991	-$344,977	-$689,953

(c) Water Fee OF-MAR $5/acre-feet

Net Benefits ($)	Size of the on-farm facility (acres)							
Hight of the Water Recharged during the lifespam of the facility	10	25	50	75	100	200	500	1000
10	-$872	-$2,180	-$4,360	-$6,540	-$8,720	-$17,440	-$43,599	-$87,198
20	-$1,644	-$4,110	-$8,220	-$12,330	-$16,440	-$32,879	-$82,198	-$164,396
40	-$3,188	-$7,970	-$15,940	-$23,909	-$31,879	-$63,759	-$159,396	-$318,793
60	-$4,732	-$11,830	-$23,659	-$35,489	-$47,319	-$94,638	-$236,594	-$473,189
80	-$6,276	-$15,690	-$31,379	-$47,069	-$62,759	-$125,517	-$313,793	-$627,585
100	-$7,820	-$19,550	-$39,099	-$58,649	-$78,198	-$156,396	-$390,991	-$781,981
120	-$9,364	-$23,409	-$46,819	-$70,228	-$93,638	-$187,276	-$468,189	-$936,378
140	-$10,908	-$27,269	-$54,539	-$81,808	-$109,077	-$218,155	-$545,387	-$1,090,774
160	-$12,452	-$31,129	-$62,259	-$93,388	-$124,517	-$249,034	-$622,585	-$1,245,170
180	-$13,996	-$34,989	-$69,978	-$104,967	-$139,957	-$279,913	-$699,783	-$1,399,566
200	-$15,540	-$38,849	-$77,698	-$116,547	-$155,396	-$310,793	-$776,981	-$1,553,963
220	-$17,084	-$42,709	-$85,418	-$128,127	-$170,836	-$341,672	-$854,180	-$1,708,359
250	-$19,400	-$48,499	-$96,998	-$145,497	-$193,995	-$387,991	-$969,977	-$1,939,953

(d) Water Fee OF-MAR $10/acre-feet

Figure 7 – Sensitivity Analysis of the economic feasibility when the water fees of the surface water recharged changes from the Baseline scenario ($0/ acre-foot) to (b) $2/ acre-foot, (c) $5/ acre-foot and (d) $10/acre-foot

Pumping cost ($Pumping^{Cost}$)

This section performs a sensitivity analysis on the variable $Pumping^{Cost}$ which is the cost associated to lift one acre-feet of water by one foot in ($/acre-foot per 1-foot of lift). Result in Figure 8 shows that this variable has a positive effect in OF-MAR, **the greater the cost for water pumping, the more net benefits can be achieved.**

Net Benefits ($)	Size of the on-farm facility (acres)							
Hight of the Water Recharged during the lifespam of the facility	10	25	50	75	100	200	500	1000
10	$128	$320	$640	$960	$1,280	$2,560	$6,401	$12,802
20	$356	$890	$1,780	$2,670	$3,560	$7,121	$17,802	$35,604
40	$812	$2,030	$4,060	$6,091	$8,121	$16,241	$40,604	$81,207
60	$1,268	$3,170	$6,341	$9,511	$12,681	$25,362	$63,406	$126,811
80	$1,724	$4,310	$8,621	$12,931	$17,241	$34,483	$86,207	$172,415
100	$2,180	$5,450	$10,901	$16,351	$21,802	$43,604	$109,009	$218,019
120	$2,636	$6,591	$13,181	$19,772	$26,362	$52,724	$131,811	$263,622
140	$3,092	$7,731	$15,461	$23,192	$30,923	$61,845	$154,613	$309,226
160	$3,548	$8,871	$17,741	$26,612	$35,483	$70,966	$177,415	$354,830
180	$4,004	$10,011	$20,022	$30,033	$40,043	$80,087	$200,217	$400,434
200	$4,460	$11,151	$22,302	$33,453	$44,604	$89,207	$223,019	$446,037
220	$4,916	$12,291	$24,582	$36,873	$49,164	$98,328	$245,820	$491,641
250	$5,600	$14,001	$28,002	$42,003	$56,005	$112,009	$280,023	$560,047

(a) Baseline. Pumping cost $0.25/acre-foot per foot of lift

Net Benefits ($)	Size of the on-farm facility (acres)							
Hight of the Water Recharged during the lifespam of the facility	10	25	50	75	100	200	500	1000
10	$350	$875	$1,750	$2,625	$3,500	$7,000	$17,500	$35,000
20	$800	$2,000	$4,000	$6,000	$8,000	$16,000	$40,000	$80,000
40	$1,700	$4,250	$8,500	$12,750	$17,000	$34,000	$85,000	$170,000
60	$2,600	$6,500	$13,000	$19,500	$26,000	$52,000	$130,000	$260,000
80	$3,500	$8,750	$17,500	$26,250	$35,000	$70,000	$175,000	$350,000
100	$4,400	$11,000	$22,000	$33,000	$44,000	$88,000	$220,000	$440,000
120	$5,300	$13,250	$26,500	$39,750	$53,000	$106,000	$265,000	$530,000
140	$6,200	$15,500	$31,000	$46,500	$62,000	$124,000	$310,000	$620,000
160	$7,100	$17,750	$35,500	$53,250	$71,000	$142,000	$355,000	$710,000
180	$8,000	$20,000	$40,000	$60,000	$80,000	$160,000	$400,000	$800,000
200	$8,900	$22,250	$44,500	$66,750	$89,000	$178,000	$445,000	$890,000
220	$9,800	$24,500	$49,000	$73,500	$98,000	$196,000	$490,000	$980,000
250	$11,150	$27,875	$55,750	$83,625	$111,500	$223,000	$557,500	$1,115,000

(b) Pumping cost $0.50/acre-foot per foot of lift

Net Benefits ($)	Size of the on-farm facility (acres)							
Hight of the Water Recharged during the lifespam of the facility	10	25	50	75	100	200	500	1000
10	$575	$1,438	$2,875	$4,313	$5,750	$11,500	$28,750	$57,500
20	$1,250	$3,125	$6,250	$9,375	$12,500	$25,000	$62,500	$125,000
40	$2,600	$6,500	$13,000	$19,500	$26,000	$52,000	$130,000	$260,000
60	$3,950	$9,875	$19,750	$29,625	$39,500	$79,000	$197,500	$395,000
80	$5,300	$13,250	$26,500	$39,750	$53,000	$106,000	$265,000	$530,000
100	$6,650	$16,625	$33,250	$49,875	$66,500	$133,000	$332,500	$665,000
120	$8,000	$20,000	$40,000	$60,000	$80,000	$160,000	$400,000	$800,000
140	$9,350	$23,375	$46,750	$70,125	$93,500	$187,000	$467,500	$935,000
160	$10,700	$26,750	$53,500	$80,250	$107,000	$214,000	$535,000	$1,070,000
180	$12,050	$30,125	$60,250	$90,375	$120,500	$241,000	$602,500	$1,205,000
200	$13,400	$33,500	$67,000	$100,500	$134,000	$268,000	$670,000	$1,340,000
220	$14,750	$36,875	$73,750	$110,625	$147,500	$295,000	$737,500	$1,475,000
250	$16,775	$41,938	$83,875	$125,813	$167,750	$335,500	$838,750	$1,677,500

(c) Pumping cost $0.75/acre-foot per foot of lift

Net Benefits ($)	Size of the on-farm facility (acres)							
Hight of the Water Recharged during the lifespam of the facility	10	25	50	75	100	200	500	1000
10	$800	$2,000	$4,000	$6,000	$8,000	$16,000	$40,000	$80,000
20	$1,700	$4,250	$8,500	$12,750	$17,000	$34,000	$85,000	$170,000
40	$3,500	$8,750	$17,500	$26,250	$35,000	$70,000	$175,000	$350,000
60	$5,300	$13,250	$26,500	$39,750	$53,000	$106,000	$265,000	$530,000
80	$7,100	$17,750	$35,500	$53,250	$71,000	$142,000	$355,000	$710,000
100	$8,900	$22,250	$44,500	$66,750	$89,000	$178,000	$445,000	$890,000
120	$10,700	$26,750	$53,500	$80,250	$107,000	$214,000	$535,000	$1,070,000
140	$12,500	$31,250	$62,500	$93,750	$125,000	$250,000	$625,000	$1,250,000
160	$14,300	$35,750	$71,500	$107,250	$143,000	$286,000	$715,000	$1,430,000
180	$16,100	$40,250	$80,500	$120,750	$161,000	$322,000	$805,000	$1,610,000
200	$17,900	$44,750	$89,500	$134,250	$179,000	$358,000	$895,000	$1,790,000
220	$19,700	$49,250	$98,500	$147,750	$197,000	$394,000	$985,000	$1,970,000
250	$22,400	$56,000	$112,000	$168,000	$224,000	$448,000	$1,120,000	$2,240,000

(d) Pumping cost $1.00/acre-foot per foot of lift

Figure 8 – Sensitivity Analysis of the economic feasibility when the turn out cost changes from the Baseline scenario ($10/acre) to (b) $25/acre , (c) $50/acre and (d) $100/acre

Selling the water recharge ($Percent\ GW\ Recovered$)

This section performs a sensitivity analysis on the variable $Percent\ GW\ Recovered$ which is the percentage of the water recharged that a given irrigation district decide to recover. Result in Figure 9 shows that this variable has a positive effect in OF-MAR, **the more water the OF-MAR management agency can charge for recovering the water recharged, the greater the net benefits that can be achieved.**

Net Benefits ($)		Size of the on-farm facility (acres)							
		10	25	50	75	100	200	500	1000
Hight of the Water Recharged during the lifespam of the facility	10	$128	$320	$640	$960	$1,280	$2,560	$6,401	$12,802
	20	$356	$890	$1,780	$2,670	$3,560	$7,121	$17,802	$35,604
	40	$812	$2,030	$4,060	$6,091	$8,121	$16,241	$40,604	$81,207
	60	$1,268	$3,170	$6,341	$9,511	$12,681	$25,362	$63,406	$126,811
	80	$1,724	$4,310	$8,621	$12,931	$17,241	$34,483	$86,207	$172,415
	100	$2,180	$5,450	$10,901	$16,351	$21,802	$43,604	$109,009	$218,019
	120	$2,636	$6,591	$13,181	$19,772	$26,362	$52,724	$131,811	$263,622
	140	$3,092	$7,731	$15,461	$23,192	$30,923	$61,845	$154,613	$309,226
	160	$3,548	$8,871	$17,741	$26,612	$35,483	$70,966	$177,415	$354,830
	180	$4,004	$10,011	$20,022	$30,033	$40,043	$80,087	$200,217	$400,434
	200	$4,460	$11,151	$22,302	$33,453	$44,604	$89,207	$223,019	$446,037
	220	$4,916	$12,291	$24,582	$36,873	$49,164	$98,328	$245,820	$491,641
	250	$5,600	$14,001	$28,002	$42,003	$56,005	$112,009	$280,023	$560,047

(a) Baseline. Percent of groundwater recovered: 0%, and water price: $0/acre-foot

Net Benefits ($)		Size of the on-farm facility (acres)							
		10	25	50	75	100	200	500	1000
Hight of the Water Recharged during the lifespam of the facility	10	$319	$797	$1,594	$2,391	$3,188	$6,375	$15,938	$31,875
	20	$738	$1,844	$3,688	$5,531	$7,375	$14,750	$36,875	$73,750
	40	$1,575	$3,938	$7,875	$11,813	$15,750	$31,500	$78,750	$157,500
	60	$2,413	$6,031	$12,063	$18,094	$24,125	$48,250	$120,625	$241,250
	80	$3,250	$8,125	$16,250	$24,375	$32,500	$65,000	$162,500	$325,000
	100	$4,088	$10,219	$20,438	$30,656	$40,875	$81,750	$204,375	$408,750
	120	$4,925	$12,313	$24,625	$36,938	$49,250	$98,500	$246,250	$492,500
	140	$5,763	$14,406	$28,813	$43,219	$57,625	$115,250	$288,125	$576,250
	160	$6,600	$16,500	$33,000	$49,500	$66,000	$132,000	$330,000	$660,000
	180	$7,438	$18,594	$37,188	$55,781	$74,375	$148,750	$371,875	$743,750
	200	$8,275	$20,688	$41,375	$62,063	$82,750	$165,500	$413,750	$827,500
	220	$9,113	$22,781	$45,563	$68,344	$91,125	$182,250	$455,625	$911,250
	250	$10,369	$25,922	$51,844	$77,766	$103,688	$207,375	$518,438	$1,036,875

(b) Percent of groundwater recovered: 25%, and water price: $10/acre-foot

Net Benefits ($)		Size of the on-farm facility (acres)							
		10	25	50	75	100	200	500	1000
Hight of the Water Recharged during the lifespam of the facility	10	$513	$1,281	$2,563	$3,844	$5,125	$10,250	$25,625	$51,250
	20	$1,125	$2,813	$5,625	$8,438	$11,250	$22,500	$56,250	$112,500
	40	$2,350	$5,875	$11,750	$17,625	$23,500	$47,000	$117,500	$235,000
	60	$3,575	$8,938	$17,875	$26,813	$35,750	$71,500	$178,750	$357,500
	80	$4,800	$12,000	$24,000	$36,000	$48,000	$96,000	$240,000	$480,000
	100	$6,025	$15,063	$30,125	$45,188	$60,250	$120,500	$301,250	$602,500
	120	$7,250	$18,125	$36,250	$54,375	$72,500	$145,000	$362,500	$725,000
	140	$8,475	$21,188	$42,375	$63,563	$84,750	$169,500	$423,750	$847,500
	160	$9,700	$24,250	$48,500	$72,750	$97,000	$194,000	$485,000	$970,000
	180	$10,925	$27,313	$54,625	$81,938	$109,250	$218,500	$546,250	$1,092,500
	200	$12,150	$30,375	$60,750	$91,125	$121,500	$243,000	$607,500	$1,215,000
	220	$13,375	$33,438	$66,875	$100,313	$133,750	$267,500	$668,750	$1,337,500
	250	$15,213	$38,031	$76,063	$114,094	$152,125	$304,250	$760,625	$1,521,250

(c) Percent of groundwater recovered: 50%, and water price: $10/acre-foot

Net Benefits ($)		Size of the on-farm facility (acres)							
		10	25	50	75	100	200	500	1000
Hight of the Water Recharged during the lifespam of the facility	10	$706	$1,766	$3,531	$5,297	$7,063	$14,125	$35,313	$70,625
	20	$1,513	$3,781	$7,563	$11,344	$15,125	$30,250	$75,625	$151,250
	40	$3,125	$7,813	$15,625	$23,438	$31,250	$62,500	$156,250	$312,500
	60	$4,738	$11,844	$23,688	$35,531	$47,375	$94,750	$236,875	$473,750
	80	$6,350	$15,875	$31,750	$47,625	$63,500	$127,000	$317,500	$635,000
	100	$7,963	$19,906	$39,813	$59,719	$79,625	$159,250	$398,125	$796,250
	120	$9,575	$23,938	$47,875	$71,813	$95,750	$191,500	$478,750	$957,500
	140	$11,188	$27,969	$55,938	$83,906	$111,875	$223,750	$559,375	$1,118,750
	160	$12,800	$32,000	$64,000	$96,000	$128,000	$256,000	$640,000	$1,280,000
	180	$14,413	$36,031	$72,063	$108,094	$144,125	$288,250	$720,625	$1,441,250
	200	$16,025	$40,063	$80,125	$120,188	$160,250	$320,500	$801,250	$1,602,500
	220	$17,638	$44,094	$88,188	$132,281	$176,375	$352,750	$881,875	$1,763,750
	250	$20,056	$50,141	$100,281	$150,422	$200,563	$401,125	$1,002,813	$2,005,625

(d) Percent of groundwater recovered: 75%, and water price: $10/acre-foot

Figure 9 – Sensitivity Analysis of the economic feasibility when the agency in charge of the OF-MAR decides to sell 0%, 25%, 50% and 75% at $10/acre-foot

Analysis of equal spatial distribution of Net benefits within the irrigation district jurisdiction

Let us assume that the all the net benefits (positives or negatives) are equally distributed in every unit of area (acre) of the irrigation district that is managing the OF-MAR. Result in Figure 10 shows the results some key results of the previous subsections. As can be seen, this benefits can be translated in the baseline scenario from $0/acre to $7.18/acre, which in terms of the overall operation of certain agricultural commodities, is a very small income gain. For the scenario where the turnout cost was increased up to $100/acre, you can see that the losses (negative net benefits) are small, few cents per acre, compared with the gains. For the scenario where the surface water fee of the recharged water is $5/acre-foot, you can see that the losses for a given acre vary from $0/acre to $9.06/acre, which is not that much. Finally, when half of the water recharged is recovered and the water price of the water is sold at a price of $10/acre-foot, the gains per acre vary from $0 to $19.76/acre.

Net Benefits ($/acre)		Size of the on-farm facility (acres)							
		10	25	50	75	100	200	500	1000
Hight of the Water Recharged during the lifespam of the facility	10	$0.00	$0.00	$0.01	$0.01	$0.02	$0.03	$0.08	$0.16
	20	$0.00	$0.01	$0.02	$0.03	$0.05	$0.09	$0.23	$0.45
	40	$0.01	$0.03	$0.05	$0.08	$0.10	$0.21	$0.52	$1.04
	60	$0.02	$0.04	$0.08	$0.12	$0.16	$0.32	$0.81	$1.62
	80	$0.02	$0.06	$0.11	$0.17	$0.22	$0.44	$1.10	$2.21
	100	$0.03	$0.07	$0.14	$0.21	$0.28	$0.56	$1.40	$2.79
	120	$0.03	$0.08	$0.17	$0.25	$0.34	$0.68	$1.69	$3.38
	140	$0.04	$0.10	$0.20	$0.30	$0.40	$0.79	$1.98	$3.96
	160	$0.05	$0.11	$0.23	$0.34	$0.45	$0.91	$2.27	$4.55
	180	$0.05	$0.13	$0.26	$0.38	$0.51	$1.03	$2.56	$5.13
	200	$0.06	$0.14	$0.29	$0.43	$0.57	$1.14	$2.86	$5.71
	220	$0.06	$0.16	$0.31	$0.47	$0.63	$1.26	$3.15	$6.30
	250	$0.07	$0.18	$0.36	$0.54	$0.72	$1.44	$3.59	$7.18

(a) Baseline. Unit Benefit ($/acre)

Net Benefits ($/acre)		Size of the on-farm facility (acres)							
		10	25	50	75	100	200	500	1000
Hight of the Water Recharged during the lifespam of the facility	10	-$0.01	-$0.03	-$0.05	-$0.08	-$0.10	-$0.20	-$0.50	-$1.01
	20	-$0.01	-$0.02	-$0.04	-$0.05	-$0.07	-$0.14	-$0.36	-$0.71
	40	$0.00	$0.00	-$0.01	-$0.01	-$0.01	-$0.03	-$0.06	-$0.13
	60	$0.00	$0.01	$0.02	$0.03	$0.05	$0.09	$0.23	$0.45
	80	$0.01	$0.03	$0.05	$0.08	$0.10	$0.21	$0.52	$1.04
	100	$0.02	$0.04	$0.08	$0.12	$0.16	$0.32	$0.81	$1.62
	120	$0.02	$0.06	$0.11	$0.17	$0.22	$0.44	$1.10	$2.21
	140	$0.03	$0.07	$0.14	$0.21	$0.28	$0.56	$1.40	$2.79
	160	$0.03	$0.08	$0.17	$0.25	$0.34	$0.68	$1.69	$3.38
	180	$0.04	$0.10	$0.20	$0.30	$0.40	$0.79	$1.98	$3.96
	200	$0.05	$0.11	$0.23	$0.34	$0.45	$0.91	$2.27	$4.55
	220	$0.05	$0.13	$0.26	$0.38	$0.51	$1.03	$2.56	$5.13
	250	$0.06	$0.15	$0.30	$0.45	$0.60	$1.20	$3.00	$6.01

(b) Turnout Cost $100/acre

Net Benefits ($/acre)		Size of the on-farm facility (acres)							
		10	25	50	75	100	200	500	1000
Hight of the Water Recharged during the lifespam of the facility	10	$0.00	-$0.01	-$0.02	-$0.04	-$0.05	-$0.10	-$0.24	-$0.49
	20	-$0.01	-$0.02	-$0.04	-$0.06	-$0.08	-$0.17	-$0.42	-$0.84
	40	-$0.02	-$0.04	-$0.08	-$0.12	-$0.16	-$0.31	-$0.78	-$1.56
	60	-$0.02	-$0.06	-$0.11	-$0.17	-$0.23	-$0.45	-$1.14	-$2.27
	80	-$0.03	-$0.07	-$0.15	-$0.22	-$0.30	-$0.60	-$1.49	-$2.99
	100	-$0.04	-$0.09	-$0.19	-$0.28	-$0.37	-$0.74	-$1.85	-$3.70
	120	-$0.04	-$0.11	-$0.22	-$0.33	-$0.44	-$0.88	-$2.21	-$4.42
	140	-$0.05	-$0.13	-$0.26	-$0.38	-$0.51	-$1.03	-$2.56	-$5.13
	160	-$0.06	-$0.15	-$0.29	-$0.44	-$0.58	-$1.17	-$2.92	-$5.84
	180	-$0.07	-$0.16	-$0.33	-$0.49	-$0.66	-$1.31	-$3.28	-$6.56
	200	-$0.07	-$0.18	-$0.36	-$0.55	-$0.73	-$1.45	-$3.64	-$7.27
	220	-$0.08	-$0.20	-$0.40	-$0.60	-$0.80	-$1.60	-$3.99	-$7.99
	250	-$0.09	-$0.23	-$0.45	-$0.68	-$0.91	-$1.81	-$4.53	-$9.06

(c) Water Fee OF-MAR $5/acre-feet

Net Benefits ($/acre)		Size of the on-farm facility (acres)							
		10	25	50	75	100	200	500	1000
Hight of the Water Recharged during the lifespam of the facility	10	$0.01	$0.02	$0.03	$0.05	$0.07	$0.13	$0.33	$0.67
	20	$0.01	$0.04	$0.07	$0.11	$0.15	$0.29	$0.73	$1.46
	40	$0.03	$0.08	$0.15	$0.23	$0.31	$0.61	$1.53	$3.05
	60	$0.05	$0.12	$0.23	$0.35	$0.46	$0.93	$2.32	$4.64
	80	$0.06	$0.16	$0.31	$0.47	$0.62	$1.25	$3.12	$6.23
	100	$0.08	$0.20	$0.39	$0.59	$0.78	$1.56	$3.91	$7.82
	120	$0.09	$0.24	$0.47	$0.71	$0.94	$1.88	$4.71	$9.42
	140	$0.11	$0.28	$0.55	$0.83	$1.10	$2.20	$5.50	$11.01
	160	$0.13	$0.31	$0.63	$0.94	$1.26	$2.52	$6.30	$12.60
	180	$0.14	$0.35	$0.71	$1.06	$1.42	$2.84	$7.09	$14.19
	200	$0.16	$0.39	$0.79	$1.18	$1.58	$3.16	$7.89	$15.78
	220	$0.17	$0.43	$0.87	$1.30	$1.74	$3.47	$8.69	$17.37
	250	$0.20	$0.49	$0.99	$1.48	$1.98	$3.95	$9.88	$19.76

(d) Percent of groundwater recovered: 50%, and water price: $10/acre-foot

Figure 10 – Sensitivity Analysis of the economic feasibility when the agency in charge of the OF-MAR decides to sell 0%, 25%, 50% and 75% at $10/acre-foot

Conclusions

The present study describes the design of a net benefits analysis integrated by the estimation of benefits and cost for on-far managed aquifer recharge (OF-MAR). The sensitivity analysis for this study shows that:

- Ideal conditions considered in the baseline scenario provide a suit of results that are economically feasible, specifically when there are no surface water fees for the water to be recharged, and low turnout cost.

There are two conditions that can make the OF_MAR practice economically unfeasible:

- as the turnout cost increases results start becoming economically unfeasible
- a slight increase in any water agency that would like to charge a certain fees (even as small as $2/AF), it will become the OF_MAR practice economically unfeasible.

There are two conditions that can make the OF_MAR practice economically more profitable:

- the greater the cost for water pumping, the more net benefits can be achieved because OF_MAR reduces the cost of pumping due to the increase in the water table
- if possible, the more water the OF-MAR management agency can charge for recovering the water recharged, the greater the net benefits that can be achieved

Finally, the unit net benefit analysis show that benefits per unit of area (acre) when OF_MAR practice is implemented may vary from $0/acre to $7.18/acre in the baseline scenario, and for some of the more pessimistic scenarios (water fee for OF0MAR $5/acre-foot) result vary in a loss of $0/acre to $9.06/acre, while selling the water recharge can increase the profitability of OF-MAR from $0/acre to $19.76/acre.