Analysis of Aggregate Costs and Benefits of Hydraulic Control, Basin Re-Operation and Desalter Elements of Non-Binding Term Sheet

Prof. David Sunding
UC Berkeley

November 29, 2006

Summary

The report measures the economic costs and benefits of achieving hydraulic control through re-operation of the Chino Basin. Various scenarios are considered in the analysis, with scenarios chosen to reflect uncertainty regarding future values of water, the time path of annual overdrafts selected to dewater the basin, and the use of the resulting induced inflow from the Santa Ana River. As shown in Table 1, depending on the scenario chosen, the net benefits of achieving hydraulic control through basin re-operation range between $283.1 million and $438.8 million in 2006 dollars.

1. Introduction

Hydraulic control refers to the elimination or reduction to negligible quantities of discharge from the Chino North Management Zone to the Santa Ana River. Basin re-operation is defined as the increase in controlled overdraft as defined in the Judgment from 200,000 acre-feet over the period 1978 through 2017, to 600,000 acre-feet through 2030 with the 400,000 acre-feet allocated specifically to meet the replenishment obligation of the desalters.

2. Framework

The model of groundwater value used in this report is standard in the academic literature.[1] The net benefits in each period resulting from access to a groundwater resource are the gains from pumping (i.e., the demand for water) minus the costs of extraction in the current period and a "user cost" term that reflects the change in future consumption possibilities resulting from current choices. The stream of annual net benefits is then discounted back to current dollars using a discount factor predicated on the rate of interest.

---

[1] Brozovic, N., D. Sunding and D. Zilberman, "Optimal Management of Groundwater Over Space and Time." *Frontiers in Water Resource Economics*. D. Berga and R. Goetz, eds. New York: Springer-Verlag, 2005; Gisser, M., and Sanchez, D.A. "Competition versus Optimal Control in Groundwater Pumping." *Water Resources Research* (1980): 638-642; Brown, G., Jr., and Deacon, R. "Economic Optimization of a Single-Cell Aquifer." *Water Resources Research* (1975): 557-564.

The interest rate used in the analysis is 5.5%. This rate corresponds to the current risk-free long-term rate of interest, a relevant rate for public agencies with good credit. The discount factor for a payment occurring in some future period t is then $(1.055)^{-t} \approx e^{-0.055t}$.

Let y_t denote groundwater produced during period t, and x_t equal the stock of groundwater at beginning of period t. The value of the groundwater resource is then

$$Value = \sum_{t=0}^{\infty}(1+r)^{-t}\left[B(y_t)-C(x_t,y_t)\right],$$

where $B(y_t)$ denotes the benefits from groundwater production in period t, and $C(x_t, y_t)$ is the cost of extraction and recharge. In an economic optimization model, the problem is to find the time path of production and stock that maximizes the present value of access to the aquifer, subject to physical constraints such as the equation of motion $x_{t+1} = x_t + g(x_t,y_t) - y_t$ (where $g(x_t,y_t)$ denotes natural and artificial recharge) and regulatory constraints such as water quality objectives and requirements to operate the basin in a steady-state condition.

Viewed this way, basin re-operation and its alternatives can be modeled as different evolutions of production, stock and recharge. The net benefit of a particular basin re-operation strategy versus a baseline that maintains the current stock of groundwater is the difference of present value resulting from a particular choice of these policy variables.

The study period extends indefinitely into the future, but the period between the present and 2030 is modeled in more detail. This feature results from the fact that the Peace Agreement lasts until 2030, and more detailed environmental and water use modeling is available to this date. As described below, terminal values are assigned to key parameters from 2031 on, and at this point the groundwater system in the Chino Basin is assumed to enter into a steady state, with no expected change in production, groundwater elevation or recharge amounts.

Table 2 displays the assumptions made about groundwater production from the Chino Basin. All figures in the table are common to all scenarios considered, and thus these assumptions are not the basis for differences in value between scenarios. The table shows groundwater production increasing steadily throughout the study period. Desalter production is also increasing throughout the study period. Operating yield is set at 145,000 acre-feet through 2017, at which point it declines to 140,000 acre-feet annually. Finally, new stormwater recharge is assumed to be 12,000 acre-feet annually.

It is necessary to describe a scenario without basin re-operation in order to calculate the net benefits, if any, from this type of strategy. Table 3 displays the physical consequences of such an alternative. If the basin is not de-watered, then hydraulic control will not be achieved, and there will be water quality costs as a result. One such consequence is that relatively high-quality water must be used for recharge. In particular, the Basin would lose the ability to use relatively inexpensive recycled water for replenishment purposes

and would be forced to use water purchased from MWD instead.[2] Thus, Table 3 shows that the entire replenishment obligation for both normal and desalter production is met through the purchase of replenishment water from MWD.

In the event that hydraulic control is achieved, there are two types of benefits to the Chino Basin as a whole. The first benefit relates to water quality. As discussed above, if hydraulic control is achieved, then recycled water can be used for 30% of the total Basin replenishment obligation, up to an assumed capacity of 30,000 acre-feet annually.[3] The second benefit is that lowering the groundwater elevation in the Basin induces an inflow of water from the Santa Ana River. Specifically, forgiving a reduction in the stock of groundwater in the Basin results in an average of 9,900 acre-feet annually until the 400,000 acre-feet of depletion credits are exhausted, and then 12,500 acre-feet annually thereafter. This natural recharge is new yield in the Basin; as discussed below, it can be used either for reducing the desalter replenishment obligation or as an asset in its own right.

3. Scenarios

The valuation model is implemented under a variety of assumptions about how re-operation will occur, how the Santa Ana River inflows are treated, and the level of future water prices. This section describes the construction of alternative scenarios.

Implementation of Basin Re-Operation

The basic principle of basin re-operation is that it is a means of achieving hydraulic control by increasing cumulative overdraft by 400,000 acre-feet through 2030. Overdraft is to be achieved by forgiving the replenishment obligation of the desalters by some annual amount over a defined period of time. This general principle is silent about *how* the total quantity of forgiveness of desalter replenishment is to be allocated over time.

This analysis considers two possible implementation scenarios. The first scenario, termed the straightline alternative, envisions an annual overdraft of 20,346 acre-feet occurring until 2030, at which time the annual overdraft would fall to zero and the system is assumed to enter into a new steady-state from 2031 onward. The second scenario, called the most rapid depletion path alternative, sets the annual overdraft to eliminate the desalter replenishment obligation for as long as possible.

Tables 4 and 7 display annual overdraft amounts under these two alternatives for implementing basin re-operation. As described, the straightline alternative entails constant annual overdraft quantities, resetting to zero from 2031 onwards. The most rapid

---

[2] Alternatively, recycled water would have to be desalted prior to recharge. Costs are not available at this time for this option.
[3] Assumptions provided by Watermaster staff. If hydraulic control is achieved, it may be possible to increase this limit. In this case, the benefits resulting from basin re-operation would increase.

depletion path reaches a maximum annual overdraft of 30,289 acre-feet before dropping to zero in 2020.

Allocation of Induced Santa Ana River Inflow

A second dimension along which the scenarios vary is with regard to the allocation of Santa Ana River inflows induced by the reduction of the groundwater stock. A total of 12,500 acre-feet of new yield is assumed to result from the dewatering, and the scenarios differ in terms of the use of this new yield. One scenario allocates all Santa Ana River inflows from re-operation to reducing the desalter replenishment obligation. An alternative scenario treats these inflows as a resource to be used for any purpose; consequently, desalter replenishment obligations are higher under this assumption.

Tables 5 and 6 relate to the straightline depletion case and show replenishment obligations and sources under the two Santa Ana River inflow allocation alternatives. In Table 5, new yield is allocated to desalter replenishment, and the desalter replenishment obligation is negligible in the near term and reaches a maximum of 9,943 acre-feet during the study period. In Table 6, by contrast, total replenishment obligations are higher since the new yield can be used for any chosen purpose.

Tables 8 and 9 show replenishment obligations under the most rapid depletion path scenario. Results are similar as in the straightline depletion scenario, with the exception that desalter replenishment is forestalled until 2025 if new yield is allocated to this purpose.

Future Water Prices

Given the important role of relative prices in the economic analysis, and given uncertainties regarding the evolution of water values in Southern California, the analysis considers two alternative scenarios regarding future water prices. These scenarios are taken from MWD and are commonly referred to as the high rate and low rate scenarios. MWD scenarios cover Tier 1 and Tier 2 water, as well as replenishment water. The high rate scenario has the Tier 2 rate growing at an annual rate of 3.11% for the next five years, and then by 4.50% from 2011 to 2030. The replenishment rate grows at 6.94% through 2011, and then at 4.50% to 2030. In the low rate scenario, the Tier 2 rate grows by 2.28% annually for the next five years, and then by 3.00% from 2011 to 2030. The replenishment rate is assumed to grow by 4.79% through 2011, and by 3.00% thereafter.

The current price of recycled water for replenishment is assumed to be $69 per acre-foot.[4] In the high rate scenario, this price was assumed to grow at the same rate of inflation as

---

[4] One public comment received after the July 26, 2006 presentation stated that the actual price paid for recycled water should be used in the analysis. While this price is not yet known, it is likely to exceed $69 per acre-foot. Note, however, that this study considers the aggregate costs and benefits of elements of the non-binding term sheet. Thus, changes in the price of recycled water have distributional as opposed to efficiency effects, that is, they change the relative level of benefits enjoyed by the parties in the Chino Basin rather than affecting the total level of benefits.

the Tier 2 and MWD replenishment prices: 4.50%. Similarly, the recycled water price grows by 3.00% annually in the low rate scenario.

4. Other Effects of Basin Re-Operation

An additional benefit of hydraulic control is a reduction in storage losses. Measuring the value of reduced storage losses is conditioned on several factors that are not fully known at present. Of course, the ex post performance of any groundwater storage program depends on the sequence of puts and takes, which depend in turn on the sequence of wet and dry years. Based on conversations with Watermaster staff, the groundwater storage program is assumed to be 400,000 acre-feet over the study period, but may range from 300,000 to 500,000 acre-feet.[5] Calculations provided by Wildermuth Environmental detail the relationship between average storage over the life of the MWD Dry Year Yield program and associated losses at 0.66 and 2 percent. Table 12 summarizes cumulative losses through 2028, together with present values calculated using the high and low rate scenarios for MWD replenishment rates as described above.

Assuming 2 percent loss and a 400,000 acre-foot storage program, the present value of reduced storage losses is $24.9 million in 2006 dollars in the high rate scenario and $20.4 million in the low rate scenario. These calculations are performed ex ante, and the actual magnitude of reduced storage losses will depend on factors including the size of the storage program, the percentage storage loss, the timing of puts and takes, and the actual replenishment rates charged by MWD. For the purpose of aggregating reduced storage loss benefits with other benefits and costs of basin re-operation, we will assume a 400,000 acre-foot storage program for both the high and low rate scenarios with storage losses equal to half of the amounts in Table 12 (recall that storage losses could range from 0 to 2 percent). The corresponding values of reduced storage losses are $12.4 million and $10.2 million for the high and low rate scenarios, respectively.

Achieving hydraulic control through basin re-operation will also result in higher pumping costs since forgiveness of the desalter replenishment operation is intended to lower the groundwater elevation in certain regions. The information needed to calculate the present value of increased pumping costs includes the quantity-weighted average change in lift in the Basin resulting from re-operation, the energy requirement per unit lift and energy costs per kilowatt-hour. Wildermuth Environmental provided the weighted average changes in groundwater elevation. The price of electricity is assumed to be $0.14/kwh, and the pumping efficiency is taken to be 75 percent. The California Energy Commission forecasts that commercial and agricultural electricity rates charged by investor-owner utilities operating in California will decline slightly in nominal terms until 2013, when

---

[5] The Peace Agreement provides that there is Target Storage of 500,000 acre-feet *in excess* of then existing storage, whereas this report only considers the Safe Harbor quantity of 500,000 acre-feet of storage in total. In some sense, there is a tradeoff between the decision to pursue max-benefit and the feasibility of obtaining the higher amount of storage. It should also be noted, however, that the basin is at the limit of shift capacity for export, and expansion of recharge to achieve greater storage is costly. Further, the PEIR only considered an additional 250,000 acre-feet of storage.

their forecast terminates.[6] This analysis assumes that nominal electricity prices are constant.

Combining this information, increased pump lift costs have a present value of $14.9 million in the straightline depletion scenario. In the rapid pulldown scenario, re-operation has a larger impact on the present value of energy costs since the groundwater elevation is reduced to the same level but at an earlier date. Increased energy costs have a present value of $19.4 million in this scenario. Both calculations include increased energy costs in the new basin steady state achieved after 2030.

5. Results

Table 1 summarizes the results of the economic analysis. The figures in the table are the net benefits resulting from access to the Chino Basin aquifer under the alternative management and price scenarios described in the previous section. In all cases, basin re-operation results in aggregate net benefits. However, there are significant differences in net benefits depending on the realization of future water prices and the use of Santa Ana River inflows induced by reducing the stock of groundwater. The rapidity with which basin re-operation is implemented matters less.

When Santa Ana River inflow is allocated to desalter replenishment and overdraft occurs in constant annual amounts to 2030, basin re-operation results in gains of between $283.1 and $391.4 million in present value terms, depending on the growth of water prices and how the replenishment credit is used over time. These gains result from the ability to use recycled water for a fraction of recharge if hydraulic control is achieved, the value of new yield, and the value of the forgiven desalter replenishment.[7]

Since new yield is reliable, in any case more reliable than a supply of replenishment water, allocating it to desalter replenishment would seem to be inefficient. The Tier 2 rate is well above the price of replenishment water, which is a weighted average of the MWD replenishment rate and the price of recycled water. When Santa Ana River inflows are decoupled from replenishment obligations, the gains from straightline basin re-operation are between $341.9 and $438.8 million.

There is a small increase in the net benefits of basin re-operation when the most rapid overdraft strategy is implemented. Several factors explain this result. First, in the most rapid depletion scenario, the 30,000 acre-foot constraint on annual recycling recharge binds more frequently. Accordingly, less recycled water is recharged over the study

---

[6] http://www.energy.ca.gov/electricity/rates_iou_vs_muni_nominal/medium_commercial.html; http://www.energy.ca.gov/electricity/rates_iou_vs_muni_nominal/agricultural.html

[7] Another potential source of loss is the option value of the water taken from the groundwater stock. That is, water used to avoid desalter replenishment is water that is not available in the event of a major disruption in surface water supplies to the region. Given the difficulty of describing and quantifying these future states of nature, option values have not been calculated. However, conversations with Watermaster staff indicate that dewatering will not result in any meaningful loss of operational flexibility since the percentage depletion of the aquifer envisioned through re-operation is relatively small.

period under this scenario. Second, while the most rapid depletion strategy delays replenishment, it also hastens the date at which a large replenishment obligation occurs once the desalter replenishment forgiveness of 400,000 acre-feet is exhausted.[8] Given the relatively low real discount rate used in this study (i.e., the nominal discount rate minus the rate of growth of water prices), it is not surprising that dynamic factors such as this do not have a large effect on net benefits.

---

[8] This study has not considered the capital and operating costs of expanding recharge capacity. Allocating Santa Ana River inflows to desalter replenishment delays the date at which capacity is exceeded, as does the most rapid depletion strategy.

Table 1: Net Benefits of Hydraulic Control, Basin Re-Operation and Desalter Production

(Figures in millions of 2006 dollars)

Gain Over Baseline: SAR Inflow Allocated to Desalter Replenishment

	High Rate	*Low Rate*
Straightline	388.6	283.1
Most Rapid	391.4	288.4

Gain Over Baseline: SAR Inflow Unallocated

	High Rate	*Low Rate*
Straightline	436.2	341.9
Most Rapid	438.8	347.7

Source: Calculated.

Table 2: Production, Operating Yield and Stormwater Recharge

Year	Total Production	Chino Desalter Production	Operating Yield	New Stormwater Recharge
2006	223,505	30,019	145,000	12,000
2007	230,566	31,923	145,000	12,000
2008	237,634	33,827	145,000	12,000
2009	244,702	35,731	145,000	12,000
2010	251,874	37,748	145,000	12,000
2011	251,768	38,980	145,000	12,000
2012	251,661	40,212	145,000	12,000
2013	251,551	41,445	145,000	12,000
2014	251,557	42,789	145,000	12,000
2015	250,216	42,789	145,000	12,000
2016	250,427	42,789	145,000	12,000
2017	250,640	42,789	145,000	12,000
2018	250,851	42,789	140,000	12,000
2019	251,060	42,789	140,000	12,000
2020	251,270	42,789	140,000	12,000
2021	254,049	42,789	140,000	12,000
2022	256,827	42,789	140,000	12,000
2023	259,605	42,789	140,000	12,000
2024	262,384	42,789	140,000	12,000
2025	265,163	42,789	140,000	12,000
2026	266,133	42,789	140,000	12,000
2027	267,104	42,789	140,000	12,000
2028	268,074	42,789	140,000	12,000
2029	269,044	42,789	140,000	12,000
2030	270,014	42,789	140,000	12,000

Source: Wildermuth Environmental.

Table 3: Replenishment Obligations and Sources – No Basin Re-Operation

Year	Normal Production Replenishment Obligation	Chino Desalter Replenishment Obligation	MWD Replenishment	Recycling Replenishment
2006	36,487	30,019	66,505	0
2007	41,643	31,923	73,566	0
2008	46,806	33,827	80,634	0
2009	51,970	35,731	87,702	0
2010	57,126	37,748	94,874	0
2011	55,788	38,980	94,768	0
2012	54,448	40,212	94,661	0
2013	53,107	41,445	94,551	0
2014	51,768	42,789	94,557	0
2015	50,427	42,789	93,216	0
2016	50,638	42,789	93,427	0
2017	50,851	42,789	93,640	0
2018	56,062	42,789	98,851	0
2019	56,271	42,789	99,060	0
2020	56,482	42,789	99,270	0
2021	59,260	42,789	102,049	0
2022	62,038	42,789	104,827	0
2023	64,816	42,789	107,605	0
2024	67,595	42,789	110,384	0
2025	70,374	42,789	113,163	0
2026	71,344	42,789	114,133	0
2027	72,315	42,789	115,104	0
2028	73,285	42,789	116,074	0
2029	74,255	42,789	117,044	0
2030	75,225	42,789	118,014	0

Source: Calculated.

Normal Production Replenishment Obligation = Total Production – Desalter Production – Operating Yield – New Stormwater Recharge

Desalter Replenishment Obligation = Desalter Production

Table 4: Overdraft and SAR Inflow – Straightline Depletion Scenario

Year	Annual Overdraft	Cumulative Overdraft	SAR Inflow
2006	16,000	16,000	9,900
2007	16,000	32,000	9,900
2008	16,000	48,000	9,900
2009	16,000	64,000	9,900
2010	16,000	80,000	9,900
2011	16,000	96,000	9,900
2012	16,000	112,000	9,900
2013	16,000	128,000	9,900
2014	16,000	144,000	9,900
2015	16,000	160,000	9,900
2016	16,000	176,000	9,900
2017	16,000	192,000	9,900
2018	16,000	208,000	9,900
2019	16,000	224,000	9,900
2020	16,000	240,000	9,900
2021	16,000	256,000	9,900
2022	16,000	272,000	9,900
2023	16,000	288,000	9,900
2024	16,000	304,000	9,900
2025	16,000	320,000	9,900
2026	16,000	336,000	9,900
2027	16,000	352,000	9,900
2028	16,000	368,000	9,900
2029	16,000	384,000	9,900
2030	16,000	400,000	9,900

Sources: Annual and Cumulative Overdraft: Assumed; SAR Inflow, Wildermuth Environmental.

Table 5: Replenishment Obligations and Sources – Straightline Depletion Scenario with SAR Inflow Allocated to Desalter Replenishment

Year	Normal Production Replenishment Obligation	Chino Desalter Replenishment Obligation	MWD Replenishment	Recycling Replenishment
2006	36,487	4,119	28,424	12,182
2007	41,643	6,023	33,366	14,300
2008	46,806	7,927	38,314	16,420
2009	51,970	9,831	43,261	18,541
2010	57,126	11,848	48,282	20,692
2011	55,788	13,080	48,208	20,660
2012	54,448	14,312	48,133	20,628
2013	53,107	15,545	48,056	20,595
2014	51,768	16,889	48,060	20,597
2015	50,427	16,889	47,121	20,195
2016	50,638	16,889	47,269	20,258
2017	50,851	16,889	47,418	20,322
2018	56,062	16,889	51,065	21,885
2019	56,271	16,889	51,212	21,948
2020	56,482	16,889	51,359	22,011
2021	59,260	16,889	53,304	22,845
2022	62,038	16,889	55,249	23,678
2023	64,816	16,889	57,194	24,512
2024	67,595	16,889	59,139	25,345
2025	70,374	16,889	61,084	26,179
2026	71,344	16,889	61,763	26,470
2027	72,315	16,889	62,443	26,761
2028	73,285	16,889	63,121	27,052
2029	74,255	16,889	63,801	27,343
2030	75,225	16,889	64,480	27,634

Source: Calculated.

Normal Production Replenishment Obligation = Total Production – Desalter Production – Operating Yield – New Stormwater Recharge

Desalter Replenishment Obligation = Desalter Production – Annual Overdraft – SAR Inflow

Recycling Replenishment = min[0.3*(Normal Production Replenishment Obligation + Desalter Replenishment Obligation), 30,000]

MWD Replenishment = Normal Production Replenishment Obligation + Desalter Replenishment Obligation - Recycling Replenishment

Table 6: Replenishment Obligations and Sources – Straightline Depletion Scenario with SAR Inflow Unllocated

Year	Total Replenishment Obligation	MWD Replenishment	Recycling Replenishment
2006	50,505	35,354	15,152
2007	57,566	40,296	17,270
2008	64,634	45,244	19,390
2009	71,702	50,191	21,511
2010	78,874	55,212	23,662
2011	78,768	55,138	23,630
2012	78,661	55,063	23,598
2013	78,551	54,986	23,565
2014	78,557	54,990	23,567
2015	77,216	54,051	23,165
2016	77,427	54,199	23,228
2017	77,640	54,348	23,292
2018	82,851	57,995	24,855
2019	83,060	58,142	24,918
2020	83,270	58,289	24,981
2021	86,049	60,234	25,815
2022	88,827	62,179	26,648
2023	91,605	64,124	27,482
2024	94,384	66,069	28,315
2025	97,163	68,014	29,149
2026	98,133	68,693	29,440
2027	99,104	69,373	29,731
2028	100,074	70,074	30,000
2029	101,044	71,044	30,000
2030	102,014	72,014	30,000

Source: Calculated.

Total Replenishment Obligation = Total Production – Operating Yield – Annual Overdraft – New Stormwater Recharge

Recycling Replenishment = min[0.3*Total Replenishment Obligation, 30,000]

MWD Replenishment = Total Replenishment Obligation - Recycling Replenishment

Table 7: Overdraft and SAR Inflow – Most Rapid Depletion Scenario

Year	Annual Overdraft	Cumulative Overdraft	SAR Inflow
2006	20,119	20,119	9,900
2007	22,023	42,141	9,900
2008	23,927	66,069	9,900
2009	25,831	91,900	9,900
2010	27,848	119,748	9,900
2011	29,080	148,828	9,900
2012	30,312	179,141	9,900
2013	31,545	210,685	9,900
2014	32,889	243,574	9,900
2015	32,889	276,463	9,900
2016	32,889	309,352	9,900
2017	32,889	342,241	9,900
2018	32,889	375,130	9,900
2019	24,870	400,000	9,900
2020	0	400,000	12,500
2021	0	400,000	12,500
2022	0	400,000	12,500
2023	0	400,000	12,500
2024	0	400,000	12,500
2025	0	400,000	12,500
2026	0	400,000	12,500
2027	0	400,000	12,500
2028	0	400,000	12,500
2029	0	400,000	12,500
2030	0	400,000	12,500

Sources: Annual and Cumulative Overdraft: Assumed; SAR Inflow: Wildermuth Environmental.

Table 8: Replenishment Obligations and Sources – Most Rapid Depletion Scenario with SAR Inflow Allocated to Desalter Replenishment

Year	Normal Production Replenishment Obligation	Chino Desalter Replenishment Obligation	MWD Replenishment	Recycling Replenishment
2006	36,487	0	25,541	10,946
2007	41,643	0	29,150	12,493
2008	46,806	0	32,764	14,042
2009	51,970	0	36,379	15,591
2010	57,126	0	39,988	17,138
2011	55,788	0	39,051	16,736
2012	54,448	0	38,114	16,335
2013	53,107	0	37,175	15,932
2014	51,768	0	36,238	15,530
2015	50,427	0	35,299	15,128
2016	50,638	0	35,447	15,191
2017	50,851	0	35,596	15,255
2018	56,062	0	39,243	16,819
2019	56,271	8,019	45,003	19,287
2020	56,482	30,289	60,739	26,031
2021	59,260	30,289	62,684	26,865
2022	62,038	30,289	64,629	27,698
2023	64,816	30,289	66,574	28,532
2024	67,595	30,289	68,519	29,365
2025	70,374	30,289	70,663	30,000
2026	71,344	30,289	71,633	30,000
2027	72,315	30,289	72,604	30,000
2028	73,285	30,289	73,574	30,000
2029	74,255	30,289	74,544	30,000
2030	75,225	30,289	75,514	30,000

Source: Calculated.

Normal Production Replenishment Obligation = Total Production – Desalter Production – Operating Yield – New Stormwater Recharge

Desalter Replenishment Obligation = Desalter Production – Annual Overdraft – SAR Inflow

Recycling Replenishment = min[0.3*(Normal Production Replenishment Obligation + Desalter Replenishment Obligation), 30,000]

MWD Replenishment = Normal Production Replenishment Obligation + Desalter Replenishment Obligation - Recycling Replenishment

Table 9: Replenishment Obligations and Sources – Most Rapid Depletion Scenario with SAR Inflow Unllocated

Year	Total Replenishment Obligation	MWD Replenishment	Recycling Replenishment
2006	46,387	32,471	13,916
2007	51,543	36,080	15,463
2008	56,706	39,694	17,012
2009	61,870	43,309	18,561
2010	67,026	46,918	20,108
2011	65,688	45,981	19,706
2012	64,348	45,044	19,305
2013	63,007	44,105	18,902
2014	61,668	43,168	18,500
2015	60,327	42,229	18,098
2016	60,538	42,377	18,161
2017	60,751	42,526	18,225
2018	65,962	46,173	19,789
2019	74,190	51,933	22,257
2020	99,270	69,489	29,781
2021	102,049	72,049	30,000
2022	104,827	74,827	30,000
2023	107,605	77,605	30,000
2024	110,384	80,384	30,000
2025	113,163	83,163	30,000
2026	114,133	84,133	30,000
2027	115,104	85,104	30,000
2028	116,074	86,074	30,000
2029	117,044	87,044	30,000
2030	118,014	88,014	30,000

Source: Calculated.

Total Replenishment Obligation = Total Production – Operating Yield – Annual Overdraft – New Stormwater Recharge

Recycling Replenishment = min[0.3*Total Replenishment Obligation, 30,000]

MWD Replenishment = Total Replenishment Obligation - Recycling Replenishment

Table 10: Prices – High Price Scenario

Year	Tier 2 Price	Replenishment Price	Recycling Price
2006	427	238	69
2007	427	238	72
2008	459	275	75
2009	473	297	79
2010	486	314	82
2011	497	331	86
2012	519	346	90
2013	543	361	94
2014	567	378	98
2015	593	395	103
2016	619	412	107
2017	647	431	112
2018	676	450	117
2019	707	471	122
2020	739	492	128
2021	772	514	134
2022	807	537	140
2023	843	561	146
2024	881	587	152
2025	920	613	159
2026	962	641	166
2027	1,005	669	174
2028	1,050	700	182
2029	1,098	731	190
2030	1,147	764	198

Source: Metropolitan Water District of Southern California.

Table 11: Prices – Low Price Scenario

Year	Tier 2 Price	Replenishment Price	Recycling Price
2006	427	238	69
2007	427	238	71
2008	450	261	73
2009	457	268	75
2010	463	282	78
2011	477	300	80
2012	491	309	82
2013	506	318	85
2014	521	328	87
2015	537	338	90
2016	553	348	93
2017	570	358	96
2018	587	369	98
2019	604	380	101
2020	622	391	104
2021	641	403	107
2022	660	415	111
2023	680	428	114
2024	700	441	117
2025	722	454	121
2026	743	467	125
2027	765	481	128
2028	788	496	132
2029	812	511	136
2030	836	526	140

Source: Metropolitan Water District of Southern California.

Table 12: Expected Value of Reduced Storage Losses

Program Size	Losses	Present Value - High Rate	Present Value - Low Rate
300,000	80,175	18,647,350	15,290,827
400,000	106,900	24,863,133	20,387,769
500,000	133,626	31,079,149	25,484,903

Source: Wildermuth Environmental.