# Pricing of Water and Effluent in a Sustainable Salt Regime

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**Abstract**. Water withdrawal and irrigation in arid zones increase salts concentration in aquifers. The utilization of effluent further augments the concentration by adding salts from households and industry. A sustainable salt regime can be maintained if salts are removed from at least some of the water sources. The paper analyzes theoretically the pricing of water and effluent in a sustainable regime for the Coastal aquifer in Israel.

## 1. Introduction

A substantial proportion of the water used in the urban sector finds its way to the sewerage and is treated and recycled as effluent. Urban users add salts to the water and these salts are carried in the effluent. Consequently irrigation with recycled water adds salts to the soil and the water beneath its surface; the accumulated salts are detrimental to soil structure and plants. A sustainable salt regime is a set of policies maintaining salt concentration at a constant level and preventing its accumulation.

Recycled water is however not the only source of salts, water from most sources, including desalinated seawater, carries some salts and therefore the analysis of a sustainable salt regime cannot be limited to the effect of effluent; a comprehensive approach is called for. This paper presents, as an example, an economic analysis of a sustainable salt regime in the Coastal region and the Coastal aquifer in Israel. The stylized elements of the hydrology of water and salts in the region are presented, alternative policies are compared, and associated prices are derived. The paper opens with a short background description of the water economy of the country.

## 2. Background

Israel has three major water reservoirs: Lake Kinneret (the Sea of Galilee) in the north, the Coastal aquifer along the shore of the Mediterranean Sea, and the Mountain aquifer further east, partly under the hills of the West Bank.[1] The Coastal region, the focus our analysis, receives water from all three reservoirs—Kinneret, Mountain, and the Coastal aquifer itself. It is expected that in the future it will also receive desalinated seawater. The water is supplied to the region's urban centers and agriculture.

The water in the reservoirs is replenished yearly by precipitation. Several sources add salts to the reservoirs; among them, salty springs, underground brines, ocean spray, and in the Coastal area salts are added with recycled effluent and imported with water brought in from

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* The paper is based on a study reported in Goldfarb and Kislev (2002).

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1 For a survey of the water economy of Israel, see Kislev (2006).

other regions. As indicated, salts are harmful to soils and crops and also, when their concentration is large, to households and industry. Hence the need to halt their accumulation.

Salts also leave the reservoirs—in water outflows. In the past, before the development of intensive agriculture, the concentration of salts in the Coastal aquifer was stable: outflows from the aquifer were equal to the replenishments, water left the reservoir either in springs and rivers or under the ground through the seawater-freshwater interface; in this way salts entering the aquifer were flushed away and minerals did not accumulate. Irrigation distorts this equilibrium: most irrigated water evaporates, either directly or through the plants, and consequently the natural outflow from the aquifer is reduced. But unlike water, salts do not evaporate; they remain on the surface of the land or in the subsoil and are carried downward into the groundwater with rainwater and irrigation return flow. Therefore, wherever irrigation is practiced, minerals accumulate in the aquifer. In the coastal aquifer, as indicated above, the accumulation is augmented with salts imported with water from non-coastal sources and salts added to the effluent.

## 3. Forecasts and Assumptions

The forecast for the area west of the water divide of Israel is that by the year 2020 total water supply will be[2] 2,206 MCM/Y and of those 1,135 MCM/Y from natural sources (fresh and saline), 621 MCM/Y effluent, and 450 MCM/Y desalinated sea water. Salts added are expected to reach 272,000 tons per year from natural sources and effluent and 9,000 tons from desalinated water (the concentration of salts in the desalinated water is 20 ppm of chlorides[3]). The forecast for the Coastal aquifer is that 126,000 tons chlorides will be added in 2020. The analysis is based on a set of simplifying assumptions; they are described below.

For simplicity, the Coastal aquifer is taken here as if it were a single cell reservoir into which all the salts deposited on the surface of the land are drained with rainwater and irrigation return flow. We are conducting the analysis for constant quantities of water and salts; in other words, the analysis is conducted for a steady state.

A steady state is a characterization of a sustainable system and its implication here is that at any time, year in and year out, the same quantities of water and salts are added to the aquifer and identical quantities leave the reservoir. There is no accumulation, negative or positive, of water or salts. Because of the stochastic nature of the precipitation and other factors, even if a steady state prevails, it will be a stochastic steady state: the quantities entering the aquifer and the quantities leaving it will not be identical every year; the equality will be maintained only for the average. But, at this stage, we are disregarding the between years variations, and conduct the computations as if the years were identical.

## 4. An Illustration

This section of the paper opens the conceptual discussion of the study with agriculture as the single water-using sector. The empirical calculations for the Coastal aquifer, presented below, were prepared for the actual water economy of the region.

[2] Water units are: CM cubic meter, MCM million CM, and MCM/Y MCM per year.

[3] The most prevalent salt in the water is table salt (sodium chloride). The harmful element is sodium, but it is more convenient to test for chlorides. The unit of measurement is ppm, parts per million. It is useful to remember that one ppm is one ton per MCM.

In the illustration (Figure 1) precipitation is added to the groundwater (replenishment), part of the water is withdrawn for irrigation and the rest is outflow to the sea. Irrigated water evaporates from the surface of the land and through plants and part of it reaches the groundwater as irrigation return flow. In parallel to the water flows, salts are recorded in the diagram: concentration in ppm chlorides in parentheses and a quantity in tons. Theses magnitudes will be explained below.

### 4.1. THE ALGEBRAIC MODEL, WATER AND SALTS

Quantities in the illustrative model are flows per year. The variables are

| | Water in MCM | Salts, chlorides in tons per year |
|---|---|---|
| Replenishment | $R$ | |
| Autonomous salts | | $\Delta$ |
| Irrigation (fresh water) | $H$ | $M_H$ |
| Irrigation return flow | $Z$ | $M_Z$ |
| Outflow to sea | $Y$ | $M_Y$ |
| Evapotranspiration[4] | $E$ | |

As indicated above, salts are added to aquifers from ocean spray, underground brines, and seawater intrusion. These sources are termed here *autonomous* since the amount of salt added to the aquifer in this way is not a function of the quantity of water used (in the Coastal aquifer, in reality, there is also entry of salts from non-coastal sources in quantities proportional to the water used). Hence we treat the replenishment as if it did not carry any salt and write the autonomous amounts separately.

The balancing equations for a reservoir in the steady state are

Water balance

$$R + Z = H + Y \tag{1}$$

Salt balance

$$\Delta + M_Z = M_H + M_Y \tag{2}$$

Irrigation return flow

$$Z = 0.17H \tag{3}$$

Irrigation water balance

$$H = E + Z \tag{4}$$

Eqs. (1) and (2) describe the entry of water and salts into the reservoir and exit away from it. The water supply is augmented with the irrigation return flow. Salts come from autonomous sources. Eq. (3) defines that the return flow is 17% of the quantity of water in irrigation (an assessment received from hydrologists). The last, Eq. (4), completes the picture, it separates irrigation water to the part evaporated and the part returning to the reservoir.

[4] The sum of evaporation and plant transpiration.

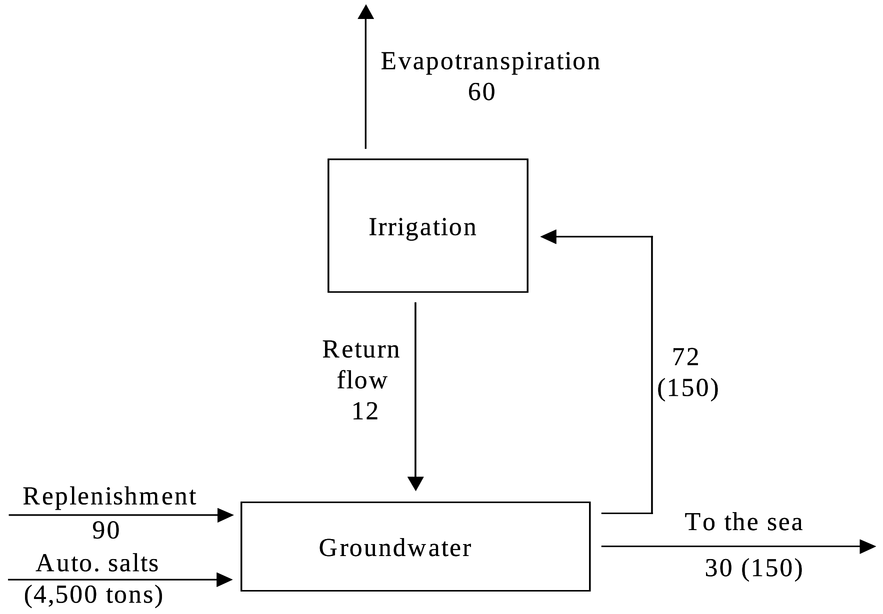


Figure 1. Conceptual illustration, water flows

Note: numbers are quantities of water; in parentheses: salt concentration or a quantity (tons).

For the sake of the illustration, let us assume (water in MCM/Y; salts, chlorides, in tons per year): replenishment *R*=90, autonomous salts $\Delta$ =4,500. Groundwater outflow to the Mediterranean Sea *Y*=30. As indicated, in the steady state, entering quantities are identical to quantities leaving the aquifer. By equation (1), the balance for water is

$$90 + 0.17H = H + 30$$

Hence irrigation *H*=72, return flow *Z*=12, evapotranspiration *E*=60 (Figure 1).

To calculate the concentration of salts in the flows of water in the model, recall that in the steady state all salts added to the aquifer leave it (here to the sea). Accordingly, define the concentration of salts in the outflow to the sea as *P* and write the equality $\Delta = M_Y$

$$4500 = 30P \qquad (5)$$

The solution to the equation is *P*=150; that is, the concentration of salts in the outflow to the sea is 150 ppm chlorides. Also, since groundwater is the source the outflow, the concentration of chlorides in the groundwater will be 150 ppm as well, and this will also be the concentration of salts in the irrigation water.

To sharpen the intuitive grasp of the concept of the steady state notice that the endogenous variable in the model is the concentration of salts in the groundwater and consider a slight modification of the basic data: assume that exit of water to the sea is not 30 MCM/Y but 25 MCM/Y. The solution of Eq. (5) will now be 180 ppm chlorides (not 150). With a smaller quantity flowing to the sea, the concentration of salts in the aquifer is larger; the larger concentration ensures that, even with a smaller outflow, all the salts added from whatever sources are flushed to the sea (180*25=4,500).

## 5. The Coastal Aquifer

Only salts from autonomous sources entered the aquifer in the above illustration, and they all left the reservoir with water drained to the sea. In the real modern world of the Coastal region, with intensive agriculture and large urban centers, salts enter with imported water from Lake Kinneret, the Mountain aquifer, and effluent. In addition, the sea is not the only outlet for water leaving the aquifer; some fresh water and substantial quantities of effluent are exported to other regions. Taking all these factors into account and repeating the above calculations, one finds that a steady state could be maintained in the aquifer's water with salt concentration of 500 ppm. This concentration is however too high for households and agriculture; the sustainability of the aquifer cannot rely solely on natural processes and salts must also be removed actively.

We examined 12 alternatives for salt concentration and removal including 3 quality goals for the water economy (50 ppm chlorides in the supplied water, 100 ppm, and 150 ppm) and 4 salt removal options (three alternatives of desalination of water from different source and, one, removal of the recycled wastewater to the sea). Space does not permit a complete report of the economic examination of the alternatives. We shall only indicate that the least cost alternative was found to be desalination of water from the Coastal aquifer. But even the least cost alternative is expensive: based on currently available information, salt removal will increase the cost of water supply to the Coastal region by 50%.

Actually, a sustainable salt regime is not the only policy alternative for the Coastal aquifer. It has been suggested in Israel that, because of its precarious position under urban centers and intensive agricultural areas, and because of the high cost of a sustainable salt regime, the aquifer would better be abandoned and its water replaced by desalinated seawater. By our calculations, this recommendation is erroneous; if followed it will double the cost of water supply in the Coastal region (compared to an increase of 50% for a sustainable regime).

## 6. Prices and Extraction Levies

We set prices equal to marginal costs. The economic rational behind marginal cost prices is that they deliver the relevant information, they are presenting the individual users of water, in any of the sectors, with the cost of the resource to society at large. With this policy, individuals can act freely, following their own private interests but, when doing so, directed to take into account the correct effects of their actions on others.[5] Among the marginal cost items we include the scarcity value of water; its corresponding price is the extraction levy. Scarcity values arise when sources of water are utilized up to capacity—up to the safe yield. The scarcity value is a marginal cost since, when all available water is utilized, an additional unit supplied to one individual (say a farmer) is taken away from another. The loss where the supply was reduced is the cost. Unlike conventional prices paid to the providers of water, the extraction levy is collected by the government; the government functions here as the representative of society, of the public at large, since society is the owner of he resource.

The marginal costs are determined theoretically in a mathematical programming model presented in the Appendix. The model is both broader, in some aspects, and narrower (in others) than the framework of the discussion in the article. It incorporates agricultural production, a feature that is not included explicitly in the paper, but, for simplicity, import of mountain water and exit of water and effluent from the region are disregarded in the formulation of the Appendix. The objective function of the programming model is the value

[5] This is not the place for an elaboration of the issues of marginal cost prices; one difficulty will be illustrated below and in the Appendix in the discussion of cost recovery.

of agricultural output *minus* the cost of the water economy. The sources of freshwater are the Coastal aquifer, Lake Kinneret, and seawater desalination; effluent is used in agriculture. There are two consuming sectors in the model—urban and agriculture. The urban sector receives a predetermined quantity of water. A given ratio of the water used in this sector is collected as sewage and, after treatment, provided as effluent. Irrigation deposits salts on the surface of the land and identical quantities are added to the water in the aquifer. Additional salts come from autonomous sources (ocean spray and underground brines). Freshwater desalination is used to remove the salts. By assumption, prices are set equal to marginal cost. The Appendix considers two cases that differ by the demand for water.

In the low demand case, the Coastal region is supplied with freshwater from the local aquifer and from Lake Kinneret; seawater is not desalinated. Salts are removed by desalination of natural water. The price of freshwater is determined by the marginal product of water in agriculture and it is set, in equilibrium (at maximum net income), to equal the cost of moving water from Lake Kinneret *plus* the cost per CM of removing from the water of the Coastal aquifer the salts imported with the lake's water. The price farmers pay for the effluent is a fraction of the price of fresh water, the fraction representing the comparative productivity of the recycled wastewater.

In this low demand case, only the coastal water is scarce and has, in the model, a scarcity value. This value, and hence the extraction levy of coastal water, is equal to the price of freshwater *minus* the cost of its withdrawal from the aquifer. No scarcity value is attributed to the water of Lake Kinneret. The urban sector is seen in the program as if selling the effluent to agriculture; hence the net price urban dwellers pay for water equals the opportunity cost, the marginal productivity of water in agriculture, *plus* the cost of treating the sewage *minus* the price farmers pay for the effluent (recall that only part of the water ends as effluent).

In the high demand case, seawater desalination is activated and the marginal productivity of water in agriculture is equal to the cost of desalination *plus* the cost of the removal of the (small amount) of salts left in the desalinated water. Desalinated water is supplied when the other water sources cannot satisfy the demand. Hence, in this case, the withdrawal constraint in Lake Kinneret is binding and the scarcity value of its water is positive; it is equal to the marginal productivity of water at the coast *minus* the cost of moving the water from the lake, and *minus* the cost of removing the salts carried in the Kinneret water. It is interesting to examine the difference in the cost of the lake's water in the two demand cases. In the low demand case, the users of water at the coast pay for the removal of the imported salts; the higher salt concentration in the water from Lake Kinneret, the higher the price of water. In the high demand case, on the other hand, water users pay the same price whatever the salt concentration in the lake's water. The fisc, the taxpayers, pays for the removal of the salts: the higher the concentration, the lower the extraction levy. The government sells low quality (salty) water and is paid accordingly.

The setting of prices, here equal to marginal costs, raises the question of cost recovery. It is shown in the Appendix that the revenue collected in the water economy covers total cost, including the cost of the scarcity rent of the constrained water sources, except for the cost of removing the autonomous salts. This last cost item will have to be covered by the public at large; it will be a cost item in the government budget. On the other hand, the extraction levy, is an income item in the budget. The utilization of the Coastal aquifer is economically justified if the revenue from the levy at least covers the cost of the removal of the autonomous salts.

**APPENDIX: PRICES IN THE WATER ECONOMY**

*Functions and Variables*

| | |
|---|---|
| F( ) | A well-behaved production function in agriculture (NIS[6] per year) |
| f( ) | Value of water's marginal product in agriculture (NIS per CM) |
| b | Constraint or requirement of provision (CM per year) |
| M | Freshwater (CM per year) |
| R | Effluent (CM per year) |
| $\mu$ | Salt concentration in water (ppm, gram chlorine per CM) |
| $\delta$ | Addition of salt (gram per CM, per year) |
| $\Delta$ | Autonomous addition of salts (grams per year) |
| $\lambda, \phi$ | Lagrange multipliers (shadow prices) |
| $\gamma$ | Value of effluent in agriculture relative to freshwater |
| r | Ratio of effluent in urban water |
| C | Cost (NIS per CM) |
| P | Price (NIS per CM) |
| E | Extraction levy (NIS per CM). |

*Indexes*

| | |
|---|---|
| A | Agriculture |
| U | Urban |
| K | Kinneret |
| H | Coastal region or aquifer |
| DH | Desalination of coastal water |
| DK | Desalination of Kinneret water |
| T | Desalination of seawater |
| R | Effluent. |

*The Structure of Cost*

Average cost is assumed to be constant per source, scale effects are disregarded and the cost rises; the lowest cost is for withdrawal of coastal water, next is Kinneret's water at the coast, and the most expensive is desalinated seawater.

$$C_H < C_K < C_T$$

*Equality Constraints*

Freshwater: provision to agriculture and the urban sector is equal to supply for the coastal aquifer, Kinneret, and seawater desalination

$$M_A + M_U = M_H + M_K + M_T$$

Effluent: the supply to agriculture is equal to the quantity collected and treated in the urban sector

$$R_A = rM_U$$

Salt: the quantity added to the coastal region is eliminated by desalination of coastal or Kinneret water (recall that the concentration of chlorides in the desalinated water is 20 ppm)

[6] New Israeli Sheqel.

$$\Delta + \mu_K M_K + \delta_R R_A + 20 M_T = \left(\mu_H - 20\right) M_{DH} + \left(\mu_K - 20\right) M_{DK}$$

Urban water constraint

$$M_U = b_U$$

## *Inequalities*

| | |
|---|---|
| Coastal Aquifer, extraction | $M_H \le b_H$ |
| Kinneret, extraction | $M_K \le b_K$ |
| Coast, desalination | $M_{DH} \le M_H$ |
| Kinneret, desalination | $M_{DK} \le M_K$ |

*Nonnegativity*

All the quantity variables are nonnegative.

*The programming problem*

Equation (A.1) is the Kuhn-Tucker Lagrangian of the programming problem. Following Simon and Blume (1994), we write specific multipliers for the constraints: $\lambda$ for equalities and $\phi$ for inequalities. In this formulation, the quantities are the primal variables, they are the activities of the program; the Lagrange multipliers are the dual variables.

$$\begin{aligned} L = & F(M_A + \gamma R_A) - C_H M_H - C_K M_K - C_T M_T \\ & - C_A R_A - C_D (M_{DH} + M_{DK}) \\ & - \lambda_M (M_A + M_U - M_K - M_H - M_T) \\ & - \lambda_R (R_A - r M_U) - \lambda_D [\Delta + \mu_K M_K + 20 M_T + \delta_R R_A \\ & - (\mu_H - 20) M_{DH} - (\mu_K - 20) M_{DK}] \\ & - \lambda_U (b_U - M_U) - \phi_H (M_H - b_H) - \phi_K (M_K - b_K) \end{aligned} \tag{A.1}$$

We skip the derivation of the first order conditions and demonstrate application in two cases; the first corresponds to relatively low demand for water in the Coastal region; the second case represents conditions of higher demand.

*Case I*

By construction, in the solution of this case, extraction from the coastal aquifer is up to the constraint and additional quantities of water are moved from Kinneret; part of the water extracted in the coast is desalinated (seawater is not desalinated); freshwater is supplied to the urban sector and to agriculture; effluent is supplied to agriculture.

Writing formally,

$$\begin{aligned} & M_A > 0 \\ & R_A = r M_U > 0 \\ & M_H = b_H > 0 \\ & 0 < M_K < b_K \\ & M_U = b_U > 0 \end{aligned} \tag{A.2}$$

The value of the primal variables that do not appear in Eq. (A.2) is zero.

Combining the first order derivatives and Eq. (A.2), the following multipliers were factored out

$$
\begin{aligned}
\lambda_D &= C_D/(\mu_H - 20) \\
\lambda_M &= f(M_A + \gamma R_A) = C_K + C_D \mu_K/(\mu_H - 20) \\
\phi_H &= f(M_A + \gamma R_A) - C_H \\
\lambda_R &= \gamma f(M_A + \gamma R_A) - C_A - C_D \delta_R/(\mu_H - 20) \\
\lambda_U &= \lambda_M - \lambda_R r \\
&= f(M_A + \gamma R_A)(1 - r\gamma) + r[C_A + C_D \delta_R/(\mu_H - 20)]
\end{aligned}
\tag{A.3}
$$

The first shadow price in Eq. (A.3) is of desalinated coastal water. It is the cost of desalination of one CM divided by the amount of salt removed; that is, $\lambda_D$ is the cost of salt removal per gram of chloride.

The multiplier in the second equation in the set (A.3), $\lambda_M$, is the Value of the Marginal Productivity of water in the Coastal region's agriculture and it is also equal to the marginal cost of water provision. The cost of moving water from Lake Kinneret to the Coastal region is higher than the cost of local extraction. Hence, if in the solution of Eq. (A.1) water is moved, the marginal cost of freshwater, $\lambda_M$, is the cost of the lake's water at the Coast and this magnitude is equal to the cost of moving the water from the lake *plus* the cost of removing the salts brought by its water.

The third equation defines the scarcity cost of Coastal water, $\phi_H$; it equals to the VMP of water *minus* cost of extraction; in other words, to the cost of water from Lake Kinneret *minus* extraction from the Coastal aquifer.

The value of the effluent in coastal agriculture is $\lambda_R$ and it is its VMP (water's multiplied by $\gamma$) *minus* the cost of sewage treatment and the removal of the salts added in the urban sector. The cost of water to the urban sector is the opportunity cost of freshwater in agriculture *minus* the value of the effluent the town transfers to the farm sector; that is, the program visualizes the urban sector as purchasing water, treating its sewage, and selling the effluent to farmers at a price equal to its VMP.

Given the multipliers of the set of equations (A.3), the prices and the extraction levy will be

$$
\begin{aligned}
P_A &= \lambda_M = f(M_A + \gamma R_A) = C_K + C_D \mu_K/(\mu_H - 20) \\
P_R &= \gamma P_A \\
P_U &= \lambda_U \\
E_H &= \phi_H
\end{aligned}
\tag{A.4}
$$

By the first line in (A.4) farmers (and urban users) pay for the transfer of water from Kinneret and also for the removal of the salts carried by the water from this source. The last attribute will be modified in the next case, but first we turn to the question of cost recovery.

*Cost Recovery*

The cost function being linear, payment for water and effluent of prices equal to marginal cost covers all cost <u>except</u> the cost of the removal of the autonomous quantity of salt, $\Delta_H$ ,

$$\begin{aligned} &P_A M_A + P_R R_A + P_U M_U \\ &= \left(M_A + M_U\right)\left[C_K + C_D \mu_K / \left(\mu_H - 20\right)\right] + R_A\left[C_A + C_D \delta_R / \left(\mu_H - 20\right)\right] \\ &= \left(C_H + E_H\right) M_H + C_K M_K + C_A R_A + C_D M_{DH} - C_D \Delta_H / \left(\mu_H - 20\right) \end{aligned} \tag{A.5}$$

The first line in Eq. (A.5) is the payment of water by users. The last line is cost by item: coastal water (included the extraction levy), Kinneret water, effluent, and salt removal. Two equalities were utilized in moving from the first to the last line in Eq. (A.5),

$$\begin{aligned} &M_A + M_U = M_H + M_K \\ &M_{HD} = \left(\Delta_H + \mu_K M_K + \delta_R R_A\right) / \left(\mu_K - 20\right) \end{aligned} \tag{A.6}$$

The first four components of the last line in Eq. (A.5) sum the cost of the water economy, including the extraction levy for costal water. The deduction of the fifth term in the line indicates that the payment for water and effluent does not cover total cost; in particular, it does not cover the cost of removing the autonomous salts.

*Case II*

This case corresponds to higher profitability in agriculture than in Case I and therefore the solution calls for larger quantities of water, the extraction constraint in the Kinneret is met, and seawater is desalinated. Formally, we add to the set (A.2)

$$\begin{aligned} &M_K = b_K > 0 \\ &M_T > 0 \end{aligned} \tag{A.7}$$

The shadow price of freshwater is now

$$\lambda_M = f\left(M_A + \gamma R_A\right) = C_T + 20 C_D / \left(\mu_H - 20\right) \tag{A.8}$$

The marginal cost of desalinated water is the cost of desalination *plus* the cost of removing the (small amounts of) salts desalinated water adds to the aquiver.

The other multipliers will be in this case

$$\begin{aligned} &\lambda_D = C_D / (\mu_H - 20) \\ &\phi_H = C_T + 20 C_D / \left(\mu_H - 20\right) - C_H \\ &\phi_K = C_T + 20 C_D / \left(\mu_H - 20\right) - C_K - C_D \mu_K / (\mu_H - 20) \\ &\lambda_R = \gamma\left[C_T + 20 C_D / \left(\mu_H - 20\right)\right] - C_A - C_D \delta_R / (\mu_H - 20) \\ &\lambda_U = \left[C_T + 20 C_D / \left(\mu_H - 20\right)\right](1 - r\gamma) + r[C_A + C_D \delta_R / (\mu_H - 20)] \end{aligned} \tag{A.9}$$

Again, the prices are

$$
\begin{aligned}
P_A &= \lambda_M \\
P_R &= \gamma P_A \\
P_U &= \lambda_U \\
E_H &= \phi_H \\
E_K &= \phi_K
\end{aligned}
\qquad \text{(A.10)}
$$

Here, in Case II, the scarcity value of Lake Kinneret water, $\phi_K$ , is positive; it was zero in Case I. Unlike in the previous case, now the cost of removing the salts carried from the lake is shouldered by the public at large (the government budget) and not just by the users in the coastal area. To see this, examine the components of $\phi_K$ : the higher the concentration of salts in the lake's water ( $\mu_K$ ) the lower the scarcity value. The government provides the coastal users with water of low quality (salty) and is paid accordingly.

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