WATER VALUE, WATER MANAGEMENT, AND WATER CONFLICT: A SYSTEMATIC APPROACH*

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Abstract: This report on the work of an Israeli-Jordanian-Palestinian-American-Dutch project shows that water issues are best dealt with by thinking in terms of water values rather than water quantities. In this way, water conflicts can be reduced to disputes over money—in many cases, surprisingly little money. It is argued that actual free-water markets will not successfully allocate water resources, partly because water markets are unlikely to be competitive and partly because of externalities including both environmental concerns and the fact that countries place special values on the use of water in agriculture—values that exceed the returns to farmers. However, it is possible to build economic models of water use that incorporate such features and that can guide water management and infrastructure decisions. These models produce "shadow values" that can guide decisions in the same way free-market prices would if they could cope with the difficulties mentioned above. These shadow values can then be used to guide international (or other) cooperation in water. These methods are applied to Israel, Jordan, and Palestine, and the gains from cooperation are found to be much larger than the gains from reasonably large shifts in water ownership. By such means, water conflicts can be resolved.

Keywords: shadow prices, cost-benefit analysis, conflict resolution

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* The project, whose results are discussed here, is the work of a great many people—too many to acknowledge them all. Chief among those are the coauthors of Fisher et al. (2002, 2005), especially Annette Huber-Lee. A shorter form of this chapter appeared as Fisher (2002). The full discussion appears in Fisher et al. (2005). Parts of the chapter have been published elsewhere and are reprinted with permission from *Environment,* April 2006, 48, 3, Heldref Publications, 1319 18th St., NW, Washington, D.C. 20036-1802. www.heldref.org © 2006 (reprinted with permission of the Helen Dwight Reid Educational Foundation.) and from "Water Casus Belli or Source of Cooperation" in *Water in the Middle East.*

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1. THINKING ABOUT WATER: THE FISHELSON EXAMPLE

So important is water that there are repeated predictions of water as a *casus belli* all over the globe. Such forecasts of conflict, however, stem from a narrow way of thinking about water.

Water is usually considered in terms of quantities only. Two (or more) parties with claims to the same water sources are seen as playing a zero-sum game. The water that one party gets is simply not available to the other, so that one party's gain is seen as the other party's loss. Water appears to have no substitute save other water.

But there is another way of thinking about water problems, a way that can lead to dispute resolution and to optimal water management. That way involves thinking about the value of water and shows that water can be traded off for other things.

The late Gideon Fishelson, an outstanding economist of Tel Aviv University, once remarked that "Water is a scarce resource. Scarce resources have value, and, no matter how much one values water, one cannot value it at more than its cost of replacement."[1] He went on to point out that desalination of seawater puts an upper bound on the value of water to any country that has a seacoast. Consider, then, the following example:[2]

A major part of the conflicting water claims of Israel and Palestine[3] consists of rival claims to the water of the so-called Mountain Aquifer. (See Figure 1) That water comes from rainfall on the hills of the West Bank and then flows underground. Most of it (even before there was a state of Israel) has always been pumped in pre-1967 Israel, in or near the coastal plain where the well depths are considerably less than in the West Bank.

Currently, the cost of desalination on the Mediterranean Coast of Israel and Palestine is between 50 and 60 US cents per cubic meter (m^3). For purposes of this example, I shall use 60 ¢/m^3. Fishelson's principle means that the value of water on the Mediterranean Coast can never exceed 60 ¢/m^3 (unless there are large changes in energy prices). But the water of the Mountain Aquifer is not on the Mediterranean Coast. To extract it and convey it to the cities of the coast[4] would cost roughly 40 ¢/m^3. But that

[1] In this chapter, "valuing water" means valuing molecules of H_2O. Particular water sources can, of course, be valued for historical or religious reasons, but such value is not the value of the water as water.

[2] In this example, I have updated Fishelson's calculation to reflect current estimates.

[3] The use of names is a sensitive subject. I do not intend here to prejudge the ultimate outcome of the Israeli-Palestinian conflict. I use the term "Palestine" out of respect for my Palestinian colleagues, and because nearly all sides now predict the existence of a Palestinian state.

[4] This example assumes that this would be the efficient use of Mountain Aquifer water. Other cases are more complicated but do not lead to qualitatively different conclusions.

means that the value of Mountain Aquifer water *in situ* cannot exceed 20 ¢/m^3 (60¢/m^3–40 ¢/m^3).

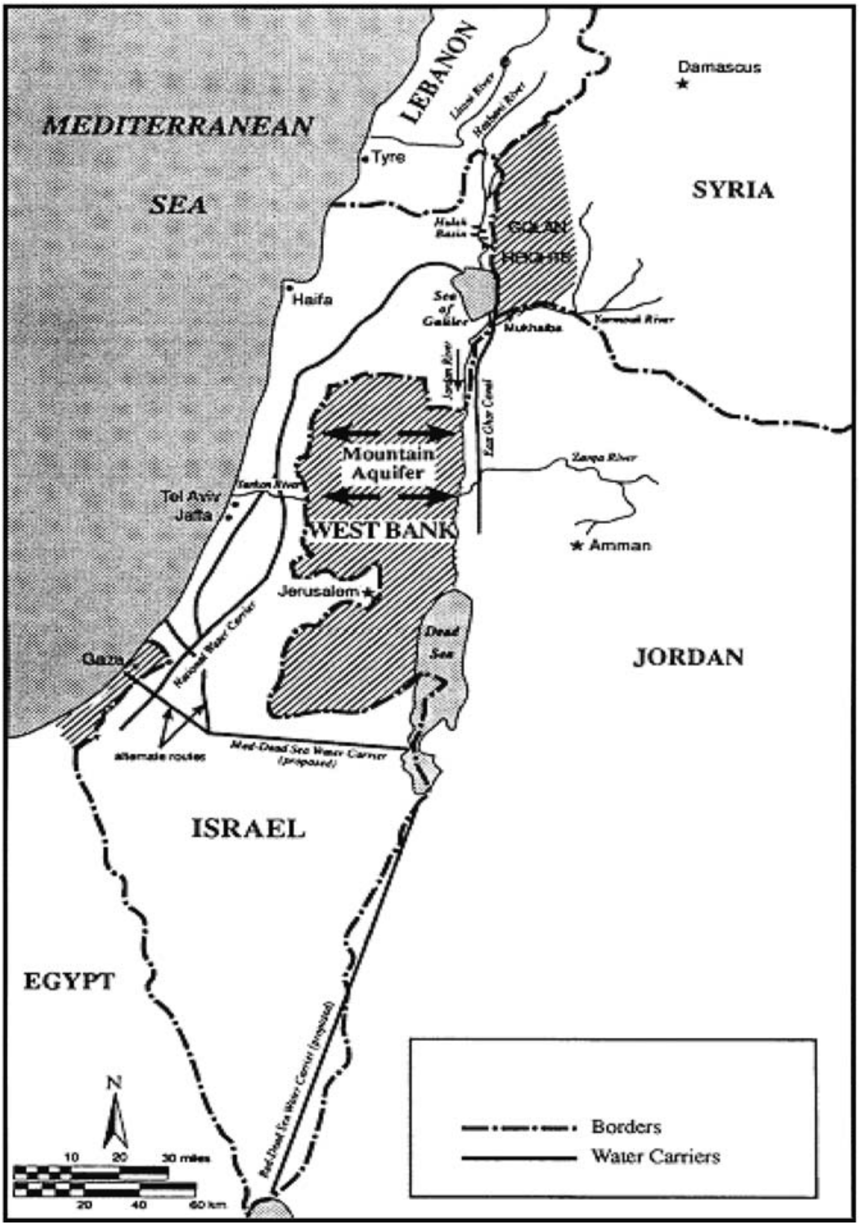

Figure 1: Simplified Map of the "Middle East" (Israel, Jordan, and Palestine), Its Major Water Resources, and Major Conveyance Infrastructure.[5]

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[5] Adapted from Wolf (1994), p. 27.

To put this in perspective, observe that 100 million cubic meters (MCM) per year of Mountain Aquifer water is a very large amount in the dispute. If the Palestinians were to receive this, they would have nearly double the amount of water they now have. But the Fishelson calculation shows that 100 MCM/year of Mountain Aquifer water is not worth more than $20 million/year. *This is a trivial sum between nations. Certainly, it is not worth continued conflict.*

And it must not be thought that the desalination-cost driven numbers are more than an upper bound. We find below that desalination will not be cost-effective on the Mediterranean Coast for a number of years except in times of very substantial drought. In more normal times, the water of the Mountain Aquifer is worth much less than 20¢/m^3.

2. THE WATER ECONOMICS PROJECT

Fishelson's remarks were a principal impetus to the creation of the Water Economics Project (WEP).[6] That project is a joint effort of Israeli, Jordanian, Palestinian, Dutch, and American experts. It is facilitated by the government of The Netherlands with the knowledge and assent, but not necessarily the full agreement, of the regional governments.

The WEP has produced a tool for the rational analysis of water systems and water problems. Its goals are as follows:

1. To create models for the analysis of domestic water systems. These models can be used by planners to evaluate different water policies, to perform cost-benefit analyses of proposed infrastructure—taking systemwide effects and opportunity costs into account—and generally for the optimal management of water systems.
2. To facilitate international negotiations in water. This has several aspects:

- The use of the Project's models leads to rational analysis of water problems. In particular, it separates the problems of water ownership and water usage. In so doing, it enables the user to value water ownership in money terms (after imposing his or her own social values and policies). This enables water negotiations to be conducted with water seen as something that can, in principle,

[6] Formerly the Middle East Water Project (MEWP).

be traded. Further, since the Project shows that water values are not, in fact, very high (partly because of the availability of sea-water desalination), the water problem can be made manageable. (The Project has had some success in promoting this point of view among professionals, but it is certainly far from being universally understood or accepted.)

- By using the Project's tools to investigate the water economy of the user's own country, the user can evaluate the effect of different water ownership settlements. (By making assumptions about the data, policies, and forecasts of other parties, the user can gain information about effects on the other parties as well.) This should assist in preparing negotiating positions if the ultimate agreement is to be of the standard water-ownership-division type with no further cooperation.
- Perhaps most important of all, the Project shows clearly that cooperation in water tends to be for the benefit of all parties. Such cooperation in the form of an agreement to trade water at model prices can lead to large gains to all participants (sellers as well as buyers) and is a superior solution to the standard water-quantity-division agreement. Our results show that there are large benefits to both Israel and Palestine from such an arrangement. The gains are far larger than the value of changes in the ownership of more or less of the disputed water is likely to be.
- Beyond the economic gains of such an arrangement are the gains from a flexible, cooperative water agreement in which allocations change for everyone's benefit as situations change. Such an agreement can turn water from a source of stress into a source of cooperation.

In sum, the Project hopes to promote "outside-the-box" thinking about water problems and thus to remove them as an obstacle to peace negotiations. We will show how this is possible by explaining the ideas underlying the project in greater detail and then presenting some results obtained.[7]

[7] The most extensive discussion of the WEP's methods and results is Fisher et al. (2005). See also Fisher et al. (2002). Differences in numerical results between previously published work and the present chapter are due to data revisions.

3. WATER VALUES, NOT WATER QUANTITIES

Returning to Fishelson's example, the result of the calculation of the value of the water of the Mountain Aquifer may seem surprising. But the really important insight here is that one should think about water by analyzing water values and not just water quantities. This should not come as a surprise. After all, economics is the study of how scarce resources are or should be allocated to various uses. Water is a scarce resource, and its importance to human life does not make its allocation too important to be rationally studied.

In the case of most scarce resources, free markets can be used to secure efficient allocations. This does not always work, however; the important results about the efficiency of free markets require the following conditions:

1. The markets involved must be competitive consisting only of very many, very small buyers and sellers.
2. All social benefits and costs associated with the resource must coincide with private benefits and costs, respectively, so that they will be taken into account in the profit and loss calculus of market participants.

Neither of these conditions is generally satisfied when it comes to water, partly because water markets will not generally be competitive with many small sellers and buyers, and partly because water in certain uses—for example, agricultural or environmental uses—is often considered to have social value in addition to the private value placed on it by its users. The common use of subsidies for agricultural water, for example, implies that the subsidizing government believes that water used by agriculture is more valuable than the farmers themselves consider it to be.

This does not mean, however, that economic analysis has no role to play in water management or the design of water agreements. One can build a model of the water economy of a country or region that explicitly optimizes the benefits to be obtained from water, taking into account the issues mentioned above.[8] Its solution, in effect, provides an answer in which the optimal nature of markets is restored and serves as a tool to guide policy makers.

Such a tool does not itself make water policy. Rather it enables the user to express his or her priorities and then shows how to implement them optimally. While such a model can be used to examine the costs and benefits of different policies, it is not a substitute for, but an aid to the policy maker.

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[8] The pioneering version of such a model (although one that does not explicitly perform maximization of net benefits) is that of Eckstein et al. (1994).

It would be a mistake to suppose that such a tool only takes economic considerations (narrowly conceived) into account. The tool leaves room for the user to express social values and policies through the provision of low (or high) prices for water in certain uses, the reservation of water for certain purposes, and the assessment of penalties for environmental damage. These are, in fact, the ways that social values are usually expressed in the real world.

I first briefly describe the theory behind such tools applied to decisions within a single country. I then consider the implications for water negotiations and the structure of water agreements. I give examples drawn from the analysis of water in the Middle East.

4. THE "WAS" TOOL

The tool is called WAS, or the "Water Allocation System." At present, it is a single year, annual model, although the conditions of the year can be varied and different situations evaluated. (Since this chapter was written, a multi-year version has been developed.)

The country or region to be studied is divided into districts. Within each district, demand curves for water are defined for household, Industrial, and agricultural use of water. Extraction from each water source is limited to the annual renewable amount. Allowance is made for treatment and reuse of wastewater and for interdistrict conveyance. This procedure is followed using actual data for a recent year and projections for future years.

Environmental issues are handled in several ways. Water extraction is restricted to annual renewable amounts; an effluent charge can be imposed; the use of treated wastewater can be restricted; and water can be set aside for environmental (or other) purposes. Other environmental restrictions can also be introduced.

The WAS tool permits experimentation with different assumptions as to future infrastructure. For example, the user can install treatment plants, expand or install conveyance systems, and create seawater desalination plants.

Finally, the user specifies policies toward water. Such policies can include: specifying particular price structures for particular users; reserving water for certain uses; imposing ecological or environmental restrictions, and so forth.

Figure 2 shows an example of the main menu that the user sees when using WAS.

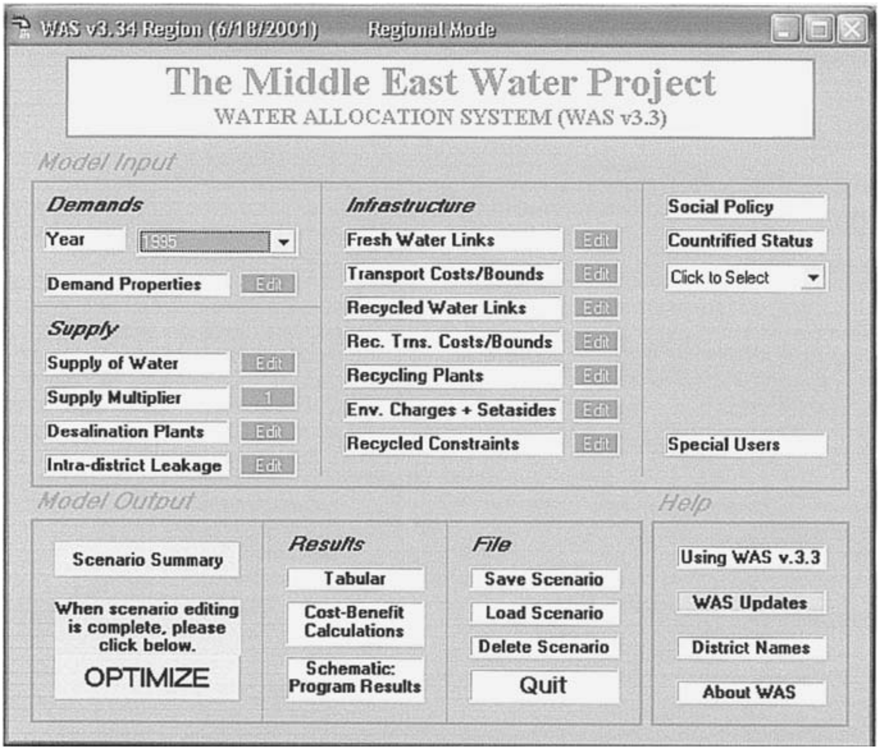

Figure 2: Water Allocation System: WAS Main Menu.

Given the choices made by the user, the model allocates the available water so as to maximize total net benefits from water. These are defined as the total amount that consumers are willing to pay for the amount of water provided, less the cost of providing it.[9]

Along with the optimal allocation of water, WAS generates a *shadow value* for water in each district. The shadow value of water in a district shows the amount by which net benefits would increase if there were an additional cubic meter of water available there. It is the true value of additional water in that district. Similarly, the shadow value of water at the source is the *scarcity rent* of the water in that source—the true measure of what water is worth at the margin.

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[9] The total amount that consumers are willing to pay for an amount of water, Q*, is measured by the area up to Q* under their aggregate demand curve for water. Note that "willingness to pay" includes ability to pay. The provision of water to consumers that are very poor is taken to be a matter for government policy embodied in the pricing decisions made by the user of WAS.

One should not be confused by such use of marginal valuation. The fact that water is necessary for human life is taken into account in WAS by assigning large benefits to the first relatively small quantities of water allocated. But the fact that the benefits derived from the first units are greater than the marginal value does not distinguish water from any other economic good. It merely reflects the fact that demand curves slope down and that water would be (even) more valuable if it were scarcer.

It is the scarcity of water and not merely its importance for existence that gives water its value. Where water is not scarce, it is not valuable.

WAS provides a powerful tool for the analysis of the costs and benefits of various infrastructure projects. For example, if one runs the model without assuming the existence of seawater desalination facilities, then the shadow values in coastal districts provide a cost target that seawater desalination must meet to be economically viable. Alternatively, by running the model with and without a proposed conveyance line, one can find the increase in annual benefits that the line in question would bring. Taking the present discounted value of such increases gives the net benefits that should be compared with the capital cost of plant construction. Note that such calculations take into account the system-wide effects that result from the projected infrastructure.

5. INFRASTRUCTURE ANALYSIS: SOME RESULTS

The first WAS-generated results concern Israel, Palestine, and Jordan, and are presented for each party separately, assuming each of them only has access to the water it had at the end of 2003. Results involving cooperation are given later.

5.1. Desalination: Israel

Figure 3 shows the shadow values obtained for 2010, both in a situation of normal availability of natural resources, "normal hydrology" (the upper numbers), and in a severe drought, when that availability is reduced by 30 percent (the lower numbers). Israel's price policy ("Fixed Price Policies") of 1995 are assumed to remain in effect. These policies heavily subsidize water for agriculture while charging higher prices to household and industrial users. Note that Israel's practice of reducing the quantity of subsidized agricultural water in times of drought has not been modeled, so the results are *more* favorable to the need for desalination than would be the case in practice.[10]

The important result with which to start can be seen in the upper shadow values for the coastal districts: Acco, Hadera, Raanan, Rehovot, and Lachish. The highest shadow value is at Acco and is only $.319/m^3— well below the cost of desalination. This means that desalination plants would not be needed in years of normal hydrology.

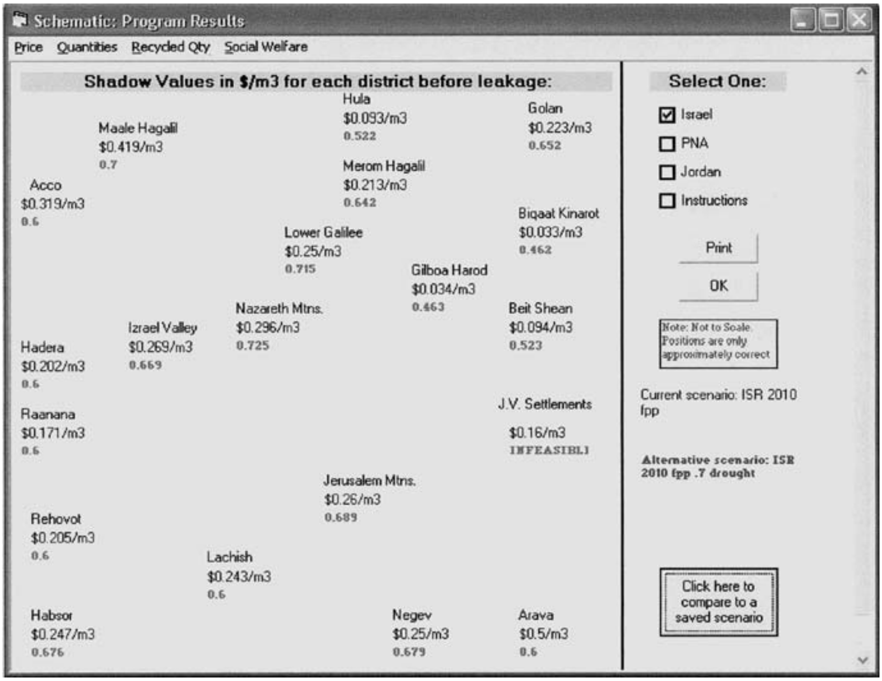

Figure 3: 2010 Shadow Values with Desalination: Normal Hydrology vs. 30 Percent Reduction in Naturally Occurring Fresh Water Sources; Fixed-Price Policies in Effect.

On the other hand, such plants would be desirable in severe drought years. In the lower numbers in Figure 3, desalination plants operate in all the coastal districts at an assumed cost of $.60/m^3. The required sizes of such plants (obtained by running WAS without restricting plant capacity and observing the resulting plant output) are given in Table 1.

[10] The infeasibility listed for the Jordan Valley Settlements in the drought case reflects the fact that the full amount of subsidized water demanded by agriculture cannot be delivered there at the fixed prices cannot be delivered.

Results for 2020 are similar, although, as one should expect, it does not take so severe a drought to make desalination efficient, and the required plant sizes in each district are larger.

Of course, much of the costs of desalination consist of capital costs—included here in the price (or target price) per m^3. Such costs are largely incurred when the plant is constructed. After that, the plants would be used in normal years unless the operating costs were above the upper shadow values in Figure 3 (highest $\$.319/m^3$). Israel therefore needs to consider whether the insurance for drought years provided by building desalination plants is worth the excess capital costs.[11] (Note that the system of Fixed Price Policies contributes substantially to the need for desalination; without such policies, the plants required for severe drought would be far smaller than shown in Table 1, and some would not be required at all.)

Table 1: Desalination (or Import) Requirements in Mediterranean Coastal Districts in 2010 with 30 Percent Reduction in Natural Fresh Water Sources and Fixed-Price Policies in Effect.

District	**Water requirements (MCM/Year)**
Acco	80
Hadera	64
Raanana	17
Rehovot	51
Lachish	29
TOTAL	241

5.2. Desalination: Palestine

A similar analysis for Palestine produces quite a surprising result. Palestine can desalinate seawater only on the seacoast of the Gaza Strip (See Figure 1). Consider Figure 4 on the following page. Here results for 2010 are presented on the assumption that Palestine builds recycling plants and conveyance lines.

[11] Note that a multi-year version of WAS (discussed below) could be of substantial aid in such a calculation.

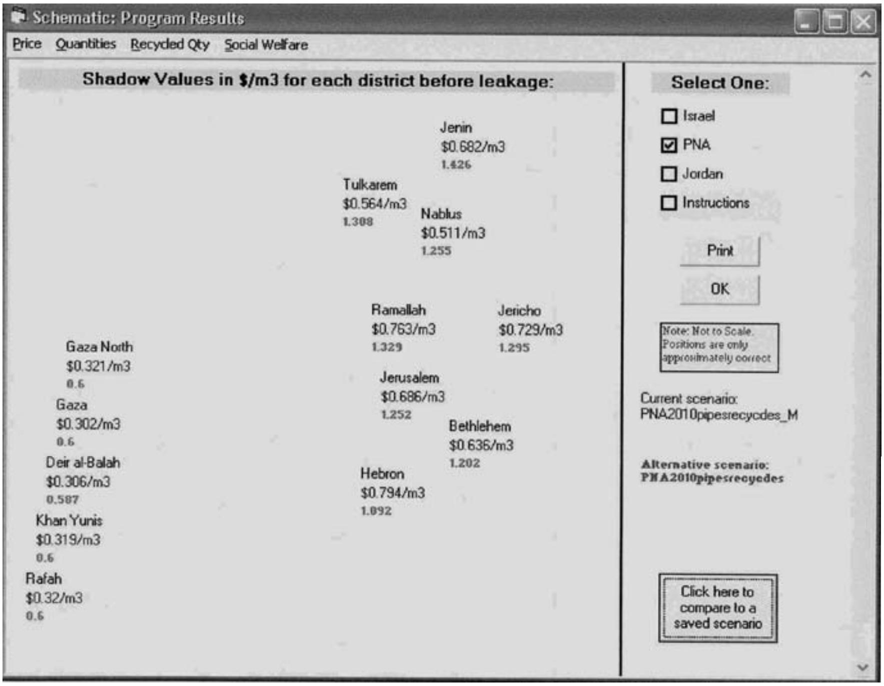

Figure 4: Comparison of Full Infrastructure Scenario in PNA in 2010 with and without Double the Quantity from the Mountain Aquifer.

The lower shadow values are for the case in which Palestine has only its current natural water resources. We see that desalination at $.60/m^3 is efficient in two of the Gazan districts. But the reason for this is not the obvious one of population growth in Gaza. Rather, it is because with its limited water resources on the Southern West Bank, it would actually pay Palestine to desalinate water in Gaza and *pump it uphill* to Hebron! This occurs because, without such pumping, and with Palestine allocated so little water on the West Bank, the difference between the shadow value in Hebron (the value of an additional cubic meter of water there) and that in Gaza exceeds the cost of conveyance. If the Palestinian West Bank water were doubled, and the lower shadow values obtained, desalination would cease to be efficient at prices higher than $.356/m^3. Of course, this result is for a year of normal hydrology and for a middle estimate of Gazan population growth, but the main point remains the same. Without more water or cooperation in water with Israel (see below), Palestine should build one or more desalination plants at Gaza by 2010; but with more water on the West Bank or with cooperation with Israel, that necessity will disappear. Even in 2020, the need for Gazan desalination plants will remain a close question in years of normal hydrology, our results suggesting that such plants would be barely cost-efficient at costs above $.55/m^3$. An important implication of these results will appear when we consider cooperation below.

5.3. Jordan and the Interdependence of Infrastructure Decisions

For Jordan (where seawater desalination is currently possible only at Aqaba on the Red Sea), we report results on other issues.

Without action, Jordan faces an increasing water crisis in Amman and nearby districts. Indeed, our results show that if nothing were done, the shadow value of water in Amman would reach roughly $27/m^3$ by 2020 (and that too in years of normal hydrology). This is not a tenable situation, and the value of $27/m^3$ is not presented as a value that people will pay for water but as an indication of the coming water-scarcity crisis. To alleviate this, Jordan has various options:

1. Jordan has plans to increase the capacity of the conveyance line that takes the Jordan River to Amman from 45 MCM/year to 90 MCM/year no later than 2005. This would reduce the shadow value in Amman in 2020 from $27.23 to $10.56 /m^3$. The gain in net benefits in 2010 is approximately $2 million/ year, which, by 2020, reaches almost $500 million/year. (Our evaluation of the other options assumes this conveyance line to be in place.)
2. Jordan could attempt to reduce the large leakage in pipes in Amman and other districts. We find that, by 2020, this would result in an increase in Jordanian water benefits of about $250 million/year, probably making it worth the capital costs involved—not counting the disruption to the population. Nevertheless, this does not satisfactorily alleviate the crisis and only reduces the shadow value in Amman to about $6.43/m^3$, which is still unacceptably high.
3. Jordan is considering the construction of a conveyance line from the Disi fossil aquifer to Amman. This will help considerably. If the conveyance line will carry about 100 MCM per year by 2020, then the benefits from its construction will reach more than $300 million per year by that date. The resulting shadow value in Amman would be about $1.44/m^3$, which is still high, but not catastrophically so. Adding leakage reduction to this would take the value down to about $1.13, but, of course, such reduction might not be worth the

capital costs involved, with the added benefits as of 2020 falling from \$250 million per year in the absence of the Disi-Amman pipeline to about \$93 million per year in its presence. It should also be noted that, given the expansion of the conveyance line from the Jordan River, the Disi-Amman pipeline would not be used in 2010.

4. There are grand plans for the oft-discussed Israeli-Jordanian construction of a canal to take water from the Red Sea to the Dead Sea, the so-called "Peace Canal." While the canal, if constructed, will largely be built for other reasons, there would be water benefits associated with it. In particular, it is planned to use the downfall of water in the canal to generate electricity, and then to use that electricity to desalinate some of the seawater involved and pump it to Amman. It is estimated that it would cost about 22¢/m^3 to pump such water uphill to Amman. Assuming that the shadow value of water in Amman is at least \$1.13/m^3, as a result of the combination of leakage reduction and the transfer of water from the Disi aquifer, this would be efficient if such desalination would cost less than about \$.91/m^3. This seems guaranteed *if the main capital costs of canal construction and electricity generation are allocated to other uses* and the capital costs of desalination include only the construction of the desalination plant and the laying of the pipeline from the plant to Amman. The energy costs involved in operating costs would surely be lower with hydroelectric generation than with fuel-fired plants.

But note the following. The effects of the Red Sea–Dead Sea project would undoubtedly reduce the shadow value of water in Amman to a figure well below \$1.13/m^3 in 2020. If the shadow value in Amman were at such a level, it would no longer make sense to transport water to Amman from the Disi Aquifer. In such a case, that water could efficiently be used in the Aqaba district, quite possibly forestalling the necessity of a desalination plant there.

This does not mean that it would be a mistake to build the Disi-Amman pipeline. Far from it. First, the Red Sea–Dead Sea Canal may never be built. Second, if it is built, it will be a long time before it is complete. During that period, and after 2010, the Disi-Amman pipeline may very well be highly necessary to avert the Amman water crisis.[12]

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[12] If the only problem in Jordanian water management were the coming crisis in Amman, then this could be readily solved by a further expansion of the conveyance system bringing water from the Jordan River to the capital. (It is interesting to note that expansion of the conveyance system, *not* additional water *ownership*, is what would be directly involved.)

Note how the benefits of an infrastructure project depend on what other projects have been undertaken. Note further how WAS can be used to investigate such interdependencies.

6. WATER OWNERSHIP AND THE VALUE OF WATER

The view of water as an economic, if special, commodity has important implications for the design of a lasting water arrangement that is to form part of a peaceful agreement among neighbors. WAS can be used to explore resolution of water disputes.

There are two basic questions involved in thinking about water agreements: the question of water ownership and the question of water usage. One must be careful to distinguish between these questions.

All water users are effectively buyers irrespective of whether they own the water themselves or purchase water from another. An entity that owns its water resources and uses them itself incurs an opportunity cost equal to the amount of money it could otherwise have earned through selling the water. An owner will thus use a given amount of owned water if and only if the use of it is valued at least as much as the money to be gained through its sale. The decision of such an owner does not differ from that of an entity that does not own its water and must consider buying needed quantities of water: the nonowner will decide to buy if and only if it values the water at least as much as the money involved in its purchase. *Ownership only determines who receives the money (or the equivalent compensation) that the water represents*.

Water ownership is thus a property right entitling the owner to the economic value of the water. Hence, a dispute over water ownership can be translated into a dispute over the right to monetary compensation for the water involved.

The property rights issue of water ownership and the essential issue of water usage are analytically independent. For example, resolving the question of where water should be efficiently pumped does not depend on who owns the water. While both ownership and usage issues must be properly addressed in an agreement, they can and should be analyzed separately.[13]

However, this would divert the river water from its current principal use in which it is mixed with wastewater and used in agriculture in the Jordan Valley. Jordan could not then continue to subsidize Jordan Valley agriculture. The effects of such an action are not readily captured without an analysis of the social consequences.

[13] This is an application of the well-known Coase Theorem of economics. See Coase 1960.

The fact that water ownership is a matter of money can be explained in a different way. It is common for countries to regard water as essential to their security because water is essential for agriculture and countries wish to be self-sufficient in their food supply. This may or may not be a sensible goal, but the possibility of desalination implies the following:

Every country with a seacoast can have as much water as it wants if it chooses to spend the money to do so. Hence, so far as water is concerned, every country with a seacoast can be self-sufficient in its food supply if it is willing to incur the costs of acquiring the necessary water. Disputes over water among such countries are merely disputes over costs, not over life and death.

The monetization of water disputes may be of some assistance in resolving them. Consider bilateral negotiations between two countries, A and B. Each of the two countries can use its WAS tool to investigate the consequences to it (and, if data permit, to the other) of each proposed water allocation. This should help in deciding on what terms to settle, with a possibility to trade water for other, non-water concessions. Indeed, if, at a particular proposed allocation, A would value additional water more highly than B, then both countries could benefit by having A get more water and B get other things that it values more. (Note that this does not mean that the richer country gets more water. That only happens if it is to the poorer country's benefit to agree.)[14]

Of course, the positions of the parties will be expressed in terms of ownership rights and international law, often using different principles to justify their respective claims. The use of the methods described here in no way limits such positions. Indeed, the point is not that the model can be used to help decide how allocations of property rights should be made. Rather the point is that water can be traded for non-water concessions, with the trade-offs measured by WAS.

Moreover, such trade-offs will frequently not be large. For example, water on the Golan Heights (see Figure 1) is often said to be a major problem in negotiations between Israel and Syria, because the Banias River that rises on the mountains of the Golan is one of the three principal sources of the Jordan River. By running the Israeli WAS model with different amounts of water, we have already evaluated this question.

In 2010, the loss of an amount of water roughly equivalent to the entire flow of the Banias springs (125 million cubic meters annually) would be

[14] If trading off ownership rights considered sovereign is unacceptable, the parties can agree to trade short-term permits to use each others' water. See below.

worth no more than $5 million/year to Israel in a year of normal water supply and less than $40 million/year in the event of a reduction of thirty percent in naturally occurring water sources. At worst, water can be replaced through desalination, so that the water in question (which has its own costs) can never be worth more than about $75 million/year. These results take into account Israeli fixed-price policies towards agriculture.

Note that it is *not* suggested that giving up so large an amount of water is an appropriate negotiating outcome, but water is not an issue that should hold up a peace agreement. These are trivial sums compared to the Israeli GDP (gross domestic product) of roughly $100 billion/year or to the cost of fighter planes.

Similarly, a few years ago, Lebanon announced plans to pump water from the Hasbani river—another source of the Jordan. Israel called this a *casus belli* and international efforts to resolve the dispute were undertaken. But whatever one thinks about Lebanon's right to take such an action, it should be understood that our results for the Banias apply equally well to the Hasbani. The effects on Israel would be fairly trivial.[15]

Water is not worth war.

7. COOPERATION: THE GAINS FROM TRADE IN WATER PERMITS

Monetization of water disputes, however, is neither the only nor, perhaps, the most powerful way in which the use of WAS can promote agreement. Indeed, WAS can assist in guiding water cooperation in such a way that all parties gain.

The simple allocation of water quantities, after which each party then uses what it "owns," is not an optimal design for a water agreement. Suppose that property rights issues have been resolved. Since the question of water ownership and the question of water usage are analytically independent, it will generally not be the case that it is optimal for each party simply to use its own water.

Instead, consider a system of trade in water permits—short term licenses to use each other's water. The purchase and sale of such permits would be in quantities and at prices (shadow values) given by an agreed-on version of the WAS model run jointly for the two (or more) countries

[15] Of course, the question naturally arises as to what the effects on Syria and Lebanon, respectively would be in these two situations. Without a WAS model for those two countries, I cannot answer that question. Both countries would surely profit from such a model, but, as of yet, they have not been willing to cooperate in building one.

together. (The fact that such trades would take place at WAS-produced prices would prevent monopolistic exploitation.). There would be mutual advantages from such a system, and the economic gains would be a natural source of funding for water-related infrastructure.

Both parties would gain from such a voluntary trade. The seller would receive money it values more than the water given up (else, it would not agree); the buyer would receive water it values more than the money paid (else, it would not pay it). While one party might gain more than the other, such a trade would not be a zero-sum game but a win-win opportunity.

The WEP has estimated the gains to Israel and Palestine from such cooperation, and finds them to exceed the value of changes in water ownership that reflect reasonable differences in negotiating positions.

To illustrate this, we begin by examining the gains to Israel and Palestine from such cooperation starting from varying assumptions about the ownership of the Mountain Aquifer (see Figure 1). To simplify matters, the case we examine is one in which Israel owns all of the water of the Jordan River. This is to be taken as merely an assumption made for the purposes of generating illustrative examples; it is *not* a political statement as to the desirable outcome of negotiations. We find such gains generally to exceed the value of changes in such ownership that reflect reasonable differences in negotiating positions.

Figures 5A and 5B illustrate such findings and more for years of normal hydrology. In those figures, we have arbitrarily varied the fraction of Mountain Aquifer water owned by each of the parties from 80 percent to 20 percent. (The present division of the water is about 76 percent to Israel and 24 percent to Palestine.[16] Results for that division can be approximated by interpolation, but are, of course, fairly close to those for 80 percent Israeli ownership.)

The two line graphs in Figure 5A show the gains from cooperation in 2010 for Israel and Palestine, respectively, as functions of ownership allocations.[17] Israeli price policies for water ("Fixed Price Policies") are assumed to be the same as in 1995, with large subsidies for agriculture and much higher prices for households and industry.

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[16] The "Mountain Aquifer" actually consists of several sub-aquifers. It is very difficult to secure accurate information on how the water in each of these is now divided. The 76 percent–24 percent split mentioned in the text is therefore an approximation applying to the total. In the runs reported below, where necessary, we have used that split to represent existing circumstances. Of course, the general conclusions are not affected by this, and the quantitative results cannot be far off.

[17] The results discussed in this section are all for years of normal hydrology. Results for drought years are not qualitatively different, although all numbers are larger.

Starting at the left, we find that Palestine benefits from cooperation by about $170 million per year when it owns only 20 percent of the aquifer.[18] In the same situation, Israel benefits by about $12 million per year. As Palestinian ownership increases (and Israeli ownership correspondingly decreases), the gains from cooperation fall at first and then rise. At the other extreme (80 percent Palestinian ownership), Palestine gains about $84 million per year from cooperation, and Israel gains about $36 million per year. In the middle of the figure, total joint gains are about $84–95 million per year.[19]

It is important to emphasize what these figures mean. As opposed to autarky, each party benefits as a buyer by acquiring cheaper water. Moreover, each party benefits as a seller *over and above* any amounts required to compensate its people for increased water expenses.

Why do the gains first decrease and then increase as Palestinian ownership increases? That is because, at the extremes, there are large gains to be made by transferring water from the large owner to the other party. Palestine has large benefits, seen at the left-hand side of the diagram, because it can obtain badly needed water; it has large gains at the right-hand side because, when it owns most of the Mountain Aquifer water, it can gain by selling relatively little-needed water to Israel (which gains as well). The same phenomenon holds in reverse for Israel—although there the effects are smaller, largely because Israel is assumed to own a great deal of water from the Jordan River.

One might suppose that the gains would be zero at some intermediate point, but that is not the case. The reason for this is as follows:

It is true that a detailed, noncooperative water agreement could temporarily reduce the gains from cooperation to zero. That would require that the agreement exactly match in its water-*ownership* allocations the optimizing water-*use* allocations of the optimizing cooperative solution. That is very unlikely to happen in practice (and, if it did, would only reach an optimal solution that would not last as populations and other factors changed). In our runs, it does not happen for two reasons.

1. We have not attempted to allocate ownership in the Mountain Aquifer in a way so detailed as to match geographic demands. Instead, we have allocated each common pool in the aquifer by the same percentage split.

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[18] Here and later, the gains with this division are so large as to dominate the scale of the Figure. This must be taken into account in examining the results.

[19] While the qualitative conclusions remain the same, the quantitative results are substantially different from those presented in Fisher, et al. (2002). This is due partly to

2. There are gains from cooperation in these runs that do not depend on the allocation of the Mountain Aquifer. For example, it is always efficient for treated wastewater to be exported from Gaza to the Negev for use in agriculture.

There are further results to be read from Figure 5A. The heights of the various bars in the figure show the value to the parties, *without cooperation*, of a change in ownership of 10 percent of the Mountain Aquifer (about 65 MCM per year or nearly half of the amount of Mountain Aquifer water now taken by the Palestinians). These are shown as functions of ownership positions midway within each 20 percentage point

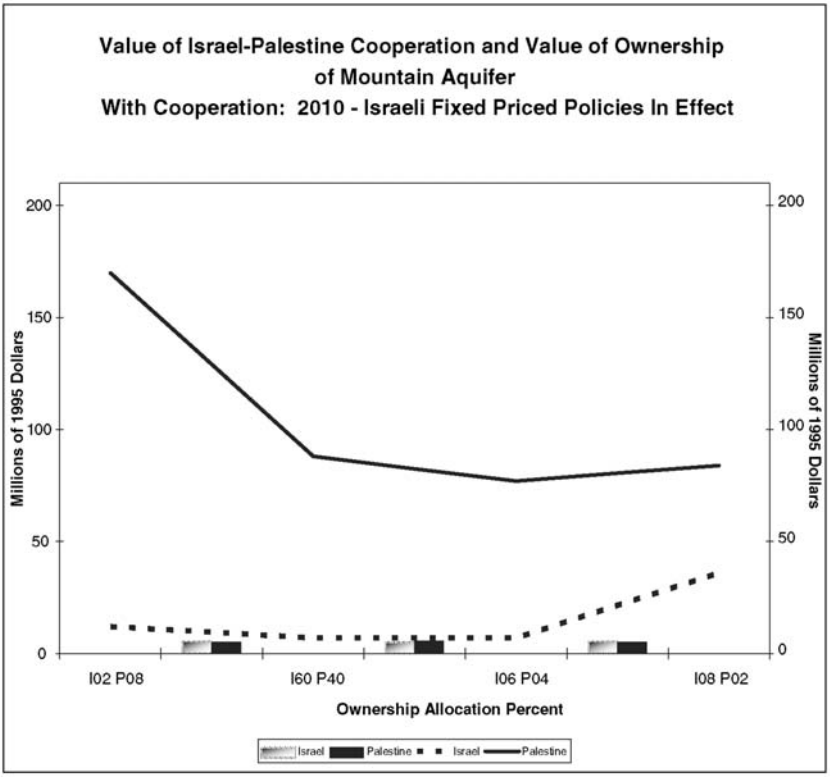

Figure 5A: Value of Israel-Palestine Cooperation and Value of Ownership of Mountain Aquifer: Without Cooperation

improved data, but mostly from a more realistic treatment of intra-district leakage in Palestine, which affects the value of water.

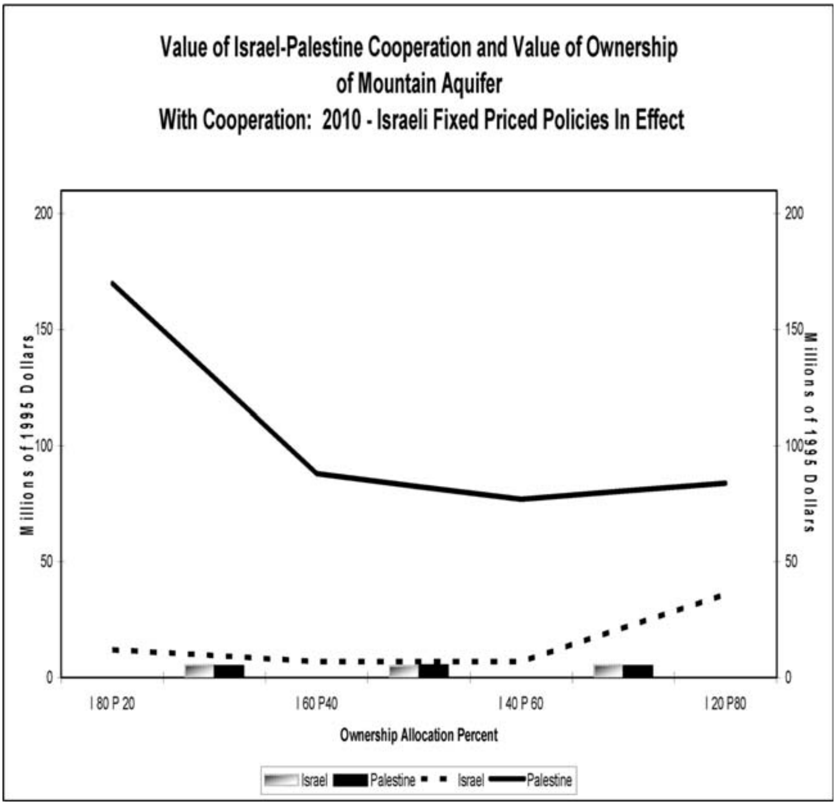

Figure 5B: Value of Israel-Palestine Cooperation and Value of Ownership of Mountain Aquifer: With Cooperation.

interval. For example, the left-hand-most set of bars shows the value to each of the parties of an ownership shift of 10 percent of the Mountain Aquifer starting at an allocation of 70 percent to Israel and 30 percent to Palestine; the next set of bars examines the value of a such a change starting at 50-50. Note that the value of cooperation is generally greater than, or at least comparable to, the value of such ownership changes. This is especially true for Palestine, but holds for Israel as well.

Further, now look at Figure 5B. This differs from Figure 5A only in the height of the ownership-value bars. In Figure 5B, the height of those bars represents the value of shifts of 10 percent aquifer ownership *in the presence of cooperation.* That value is about $8 million/year. The lesson is clear:

Ownership is surely a symbolically important issue, and symbols really matter. But cooperation in water reduces the practical importance of ownership allocations—already not very high—to an issue of very minor proportions.

The results for 2020 are qualitatively similar to those for 2010.

8. THE REAL BENEFITS FROM COOPERATION

The greatest benefits from cooperation may not be monetary, however. Beyond pure economics, the parties to a water agreement would have much to gain from an arrangement of trade in water permits. Water allocations that appear adequate at one time may not be so at other times. As populations and economies grow and change, fixed water quantities can become woefully inappropriate and, if not properly readjusted, can produce hardship. *A system of voluntary trade in water permits would be a mechanism for flexibly adjusting water allocations to the benefit of all parties and thereby for avoiding the potentially destabilizing effect of a fixed water quantity arrangement on a peace agreement.* It is not optimal for any party to bind itself to an arrangement whereby it can neither buy nor sell permits to use water.

Moreover, cooperation in water can assist in bringing about cooperation elsewhere. For example, as already indicated, the WAS model strongly suggests that, even in the presence of current Israeli plans, it would be efficient to have a water treatment plant in Gaza, with treated effluent sold to Israel for agricultural use in the Negev where there is no aquifer to pollute. (Indeed, since this suggestion arose in model results, there has been discussion of this possibility.) Both parties would gain from such an arrangement. *This means that Israel has an economic interest in assisting with the construction of a Gazan treatment plant.* This would be a serious act of cooperation and a confidence-building measure.

9. PROBLEMS AND CONCLUSIONS

Naturally, there are a number of issues that arise when considering such a cooperative arrangement. Chief among them is that of security. What if one of the partners to such a scheme were to withdraw? Of course, such withdrawal would be contrary to the interest of the withdrawing party, but, as we have sadly seen, people and governments do not always act in their own long-run self interest.

The main cost of such a withdrawal would occur if the non-withdrawing party had failed to build infrastructure that would be needed without cooperation but not with it. In the case of Israel and Palestine, it might appear that such risk would be chiefly Palestinian, since they, but *not* Israel, would need desalination plants in the absence of cooperation but not in its presence. Israel, by contrast, already has a highly developed system of water infrastructure and any decision to build desalination plants does not depend on a decision to cooperate or not cooperate with Palestine.

Interestingly, this conclusion may not hold. We saw above that the WAS results show that it will not be cost-effective (at least in years of normal hydrology) for Palestine to build desalination facilities in the Gaza Strip (its only seacoast) simply to supply the growing Gazan population. Rather, with water ownership greatly restricted on the West Bank, it would pay (without cooperation) to build such facilities and expensively pump desalinated water uphill to Hebron. But this result (which holds only with Palestine owning less than 20 percent of the Mountain Aquifer) also implies that a withdrawal by Israel from a cooperative agreement could be met by Palestine temporarily pumping more than permitted by treaty on the West Bank while building a desalination plant at Gaza.[20] This reduces the importance of the security issue under discussion.

Hence, for both parties, cooperation appears to be a superior policy to autarky. In an atmosphere of trust, cooperation would be likely to benefit Palestine even more than Israel, at least in the short run. But, of course, such an atmosphere does not currently exist. Cooperation requires a partner, and, as of late 2004, that did not appear to be immediately likely. Each party is likely to suspect the good faith of the other, even though the proposed arrangement would benefit both.

Despite this, I continue to believe that cooperation is both valuable and possible. As already discussed, water is not worth conflict and can become an area for confidence-building measures. Further, if autarky is truly desired, then one should simply build desalination plants as needed. Autarky in naturally occurring water is a foolish policy except as a money-saving device—and the money it saves is not great. Every country with a seacoast can have as much water as it wants if it chooses to spend the money to do so. Hence, every country with a seacoast can be self-sufficient if it is

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[20] Of course, there would also have to be a conveyance line. A refusal by Israel to permit this would be a serious matter—and an act whose principal intent would be to harm Palestine. In such an event, Palestinian pumping of the Mountain Aquifer beyond agreed-upon amounts would have to continue, but there would be larger, non-water issues to worry about.

willing to incur the costs of acquiring the necessary water. As a result, disputes over water among such countries should be merely disputes over costs, not over life and death.

10. AFTERWORD: VIEWING TWO OTHER CASES FROM A "WAS" PERSPECTIVE

To show the versatility of the WAS tool, we end by briefly looking at two other chapters in this volume from this perspective

10.1. The Schoengold and Zilberman Chapter

In their review of various problems involved in a sensible water policy—especially of incentive problems—Schoengold and Zilberman (henceforth "S&Z"), not surprisingly, find that such problems abound. They state: "Many regions have a perception of water crisis, because existing water resources are not sufficient to meet growing needs. In most cases, the real problem *is water management crisis*. Incentives for efficient and sociably responsible management of water are lacking. Water projects that cannot be justified economically, and are damaging environmentally, are being built. Users are paying well below the value of the water they use, and are encouraged to consume water. Polluters of water bodies are not penalized. … To achieve sustainable water use, water policies and institutions have to be reformed."

They list numerous examples of mismanagement, including:

- ignored environmental costs of water projects
- waterborne diseases
- displacement of native populations
- downstream positive externalities produced by upstream canal maintenance
- future costs of potential water projects such as increased salinity and water logging of soils
- depletion of fossil aquifers such as the Oglala Aquifer in the Western United States.

S&Z then go on to consider water trading schemes and their failings. All of these problems need to be handled, and partial analysis will not do so satisfactorily, nor, given the externalities present will private water markets. WAS, on the other hand, will handle at least some of the problems and, in particular, will permit a system-wide view of the effects of different actions. As we have seen, WAS will also generate shadow values for water in different locations; these are the efficiency prices to be charged unless overridden for special social purposes. Further, WAS can be used to guide water trading schemes.

That is not to say that WAS can do everything. Consider environmental issues, for example. Such issues are of two general kinds: environmental concerns over the state of the water system itself (salinity, pollution, the effects of pumping rates on the aquifers, etc.) and the effects of water actions on water-related parts of the environment (species survival, green lands, etc.). The present version of WAS handles both of these in the same way. The user must specify restrictions on water use designed to preserve environmental values. Examples include setting aside water for environmental purposes, preventing more than a certain fraction of irrigation water from being treated wastewater, and restricting water extraction from a source to the annual renewable amount, thus preventing overpumping.

But note that WAS will not tell the user what it is worth to impose such restrictions. Instead, it will provide the costs (both total and marginal) of doing so. By varying the restrictions, the user can then try to decide how tight they should be by explicitly or implicitly estimating the value of their environmental effects.

There would be more help from an expanded WAS, one that is not a single-year but a multi-year model. Such a multi-year WAS would optimize the present value of net benefits over a number of years. In so doing, it could directly include hydrological models of water sources, especially aquifers, and internalize the effects of one year's actions on the state of the water system in later years. It would also assist analysis of the interdependence of infrastructure projects and the order in which they should be built.

Note, in particular, that such a model would readily handle the problem of the rate at which fossil aquifers should be depleted, and other issues of the first kind listed above. It would also allow systematic investigation of the effects on optimal policy of the stochastic nature of the climate.

Such a model has been on the drawing boards of the WEP for some time, and has been constructed since this chapter was presented. Even so, problems will still remain. Not even a multi-year WAS can directly handle environmental issues of the second kind—issues such as the benefits of affecting species survival or preserving green open space. Here the user can, as before, find out the system-wide costs of various actions that can be taken, but the benefits of such actions must be estimated externally.

But, as S&Z show, a system-wide analysis of water policy is crucial, and WAS provides a tool with which this can be done systematically.

10.2. The Güner Chapter

Güner's work, "Evolutionary Explanations of Syrian-Turkish Water Conflict," presents an evolutionary game in which Syria desires water concessions from Turkey, while Turkey seeks Syrian recognition of Turkish sovereignty over a certain territory, Hatay. Each population is divided into hawks and doves, and hawks never concede anything. Hawks and doves meet each other randomly. The "fitness" of one side's hawks increases when a hawk of that side obtains a concession from a dove of the other and a greater "fitness" of hawks than of doves in the same country leads to an expansion of the number of hawks therein. The model evolves into a permanent state of either instability or noncooperation.

This model is not, of course, highly realistic—nor is it intended to be—but its depressing conclusion points to an important issue.

There is an explicit recognition among the doves of the two modeled countries that water can be traded off for other things (here, territorial recognition). Notwithstanding this, such a trade does not take place, because of the existence of large segments of the two populations that will not concede and the disappointing nature of the interactions of the doves of one side with the hawks of the other. This results in the doves becoming discouraged, as it were, and the political power of the hawks growing.

This case illustrates two important points about the potential role that WAS, an economic model designed to optimize benefits for different groups, can play in attenuating water conflicts:

1. While the use of WAS should prevent war from being a *casus belli*, it will not succeed in bringing about a solution to international water conflicts unless the countries involved are interested in arriving at a peaceful arrangement. Otherwise, water can be used harshly as a negotiating lever or even as a weapon.
2. It is not enough for only some people in the disputing countries to understand the message that water cooperation and trading is a win-win situation. Even if water experts understand it, there will be no progress unless political leaders do so. Further, even if political leaders understand it, there may be no success without a full-scale program of public education on the subject. That is devoutly to be wished.