# Scenario development for 2050 for the Israeli / Palestinian water sector

*Scenario analysis suggests that by 2050 the population of Israel, the West Bank and Gaza will grow from its current ten million to between 14 and 28 million. The scenarios developed are compared to available water resources and assessed for their viability. With all scenarios, except very high population growth in the context of inadequate co-operation between Israel and Palestine, the water resource needs of the entire population can be met. The analysis suggests that water need not be an obstacle to peace or economic development in the region.*

**Keywords:** Water resources, water sector, long-term planning, scenario analysis, Israel, Palestine, West Bank, Gaza

## Introduction

Israel, the West Bank and Gaza Strip are located between the Jordan River and the Mediterranean Sea. The West Bank and Gaza Strip (hereafter collectively referred to as Palestine), and Israel are very densely settled by global standards, having a higher population density than most European countries, and in the case of Palestine, average population density significantly exceeds that of all European Union states except Malta (Central Intelligence Agency, 2006). Because approximately half the land is arid and thus sparsely inhabited, effective population densities in much of Israel and Palestine are much higher than the average figures suggest.

Already Israel and Palestine have very low water resources availability compared to the global average (Food and Agriculture Organization, 2004). In the case of Palestine, this water scarcity directly impacts upon daily life and economic activity for much of the population. With rapid population growth in the region and water resources already inadequate, the long-term hydrological future of region appears problematic. Furthermore, the backdrop of the Israeli-Palestinian conflict hinders cooperation as well as economic and social development, and the implementation of technical solutions to the region's water crisis.

This paper assesses what are the long-term implications, in relation to water resources management, of Israel and Palestine's expected population growth by developing a range of feasible scenarios of the population of Israel and Palestine for the year 2050. They are then examined in relation to the available water resources to ascertain whether, assuming careful management, available water resources will be sufficient, and what types of management structures need to be considered.

The growth rates of the population and the degree of water scarcity that Israel and Palestine face are not unique, with serious problems of water scarcity projected to occur in an increasing number of countries in the coming decades. The Israeli-Palestinian conflict, however, adds a very high degree of uncertainty to long term planning in the region and suggests that that forecasting by the simple extrapolation of present trends may be inadequate. In addition, it is questionable whether the status quo is such that future projections should be based on it. Equally, the hydrological problems facing Israel and Palestine and the question of whether they are potentially manageable in the long term is of relevance elsewhere in the Middle East and elsewhere. However, given the extreme difficulties of the situation in Israel and Palestine, if the hydrological problems of this region are manageable, it would suggest that optimism elsewhere may also be warranted.

## Population estimates of Israel, the West Bank and Gaza in 2050.

The area of land between the Jordan River and the Mediterranean is 26,990 sq km in area and has a population of approximately ten million people (Central Intelligence Agency, 2006). Of this area, 20,770 sq km is in Israel, and 6,220 sq km is in Palestine. The current population of Israel is 6.4 million, that of Palestine is 3.9 million (Central Intelligence Agency, 2006); the population growth rate for Israel is 1.2 percent per year and in Palestine it is 3.3 percent. Thus it is expected that the population of both countries will increase significantly in the coming decades.

According to the United Nations Population Division medium variant estimates, in the year 2025, the population of Israel will be 8.6 million, growing to 10 million by 2050 (United Nations

Population Division, 2003). In Palestine, the population is expected to reach 6.9 million in 2025 and 11.1 million by 2050. Therefore, using the best (medium) estimates of the U.N., the population of the land between the Jordan River and the Mediterranean will be approximately 21.1 million people in the year 2050, assuming normal immigration and emigration from the land, and a decline in the fertility rates of the different population groups similar to that experienced elsewhere in the world. Under the high variant projection of the United Nations Population Division, population in Israel in 2050 is expected to reach 11.9 million, and Palestine 13 million (United Nations Population Division, 2003). Under the low variant projection, population is estimated to reach 8.3 million in Israel and 9.4 million in Palestine.

One factor that may have a significant effect on how the populations of Israel or Palestine grow over the coming decades is the movement of Palestinian refugees. In 2003 in the West Bank and Gaza Strip there were more than 1.5 million Palestinian refugees registered with the United Nations Relief and Works Agency for Palestinian Refugees in the Near East (United Nations Relief and Works Agency for Palestine Refugees in the Near East, 2004). According to this agency in 2003 there were a further 2.5 million Palestinian refugees in the Middle East who were not living in Israel or Palestine. Approximately 800,000 of these refugees live in Syria or Lebanon and remain without citizenship, unlike the 1.7 million Palestinians living in Jordan who have received citizenship. Like the Palestinian population living in Palestine the population growth rate of these communities is high, with the total population of refugees doubling over the last twenty years (United Nations Relief and Works Agency for Palestine Refugees in the Near East, 2004). It is possible that as part of a peace settlement between Israel and its neighbours some of these Palestinian refugees living abroad may return either to Palestine or to Israel.

Immigration to Israel from Jewish communities elsewhere has significantly increased Israel's population since its establishment in 1948. Since 1948 Israel has maintained a policy of unrestricted Jewish immigration. As a result of this policy (and other factors), between 1948 and 2003, approximately 2.9 million people immigrated to Israel, 1.0 million of whom arrived during the most recent wave of immigration between 1990 and 2000 (Israeli Central Bureau of Statistics, 2003). Since 2000, immigration has significantly slowed. While the vast majority of the global Jewish population will almost certainly remain in the Diaspora in the foreseeable future, some significant further immigration to Israel is probable. Accurately quantifying this in advance is impossible, but allowance for immigration based on past trends is already incorporated into the United Nations Population Division estimates.

The major factors, therefore, that will most likely determine how much Israel and Palestine's population grows over the next two generations are the speed with which the fertility rates fall, the movement of Palestinian refugees in the region, and the extent of Jewish immigration to Israel. On the basis of these factors, a number of population scenarios for 2050 are outlined below.

**Scenarios for 2050**

Table 1 outlines the various permutations possible for the scenarios for 2050 based upon different growth rates, migration patterns, and political structures.

The purpose of developing the scenarios is to identify the upper and lower bounds of the future population in Israel / Palestine in 2050, together with the most probable population. Therefore, in order to keep the number of scenarios that are developed manageable, all scenarios, except the upper and lower bounds and the medium scenarios, will be first assessed and then either dropped from further consideration or further explored where appropriate.

In terms of possible future political structures for Israel and Palestine, two scenarios are most probable, either that two fully sovereign states are created (namely, Israel and Palestine), or that a single bi-national state is created. The creation of two fully sovereign states is similar to the model adopted in the former Czechoslovakia, where the *Velvet Revolution* split the country into the Czech and Slovak Republics. A bi-national state is the model adopted by Belgium whereby only one sovereign state exists, but there are two distinct national communities with a high degree of autonomy in terms of how they run their affairs.

The option of a bi-national state to the west of the Jordan River seems unlikely in most situations as a bi-national option is not supported at present by the Israeli government nor any of the major Israeli political parties, nor by the Palestinian Authority, nor the international community. This suggests that a single bi-national state would only be probable if a Palestinian majority was to occur in both the Palestinian state and in the Israeli state, thus effectively creating two Palestinians states which may then choose to seek closer co-operation than is possible as two independent states and thus unite to form a single bi-national state.

A Palestinian majority occurring in Israel by 2050 is only likely if there is significant Palestinian immigration to Israel. Therefore, all bi-national state scenarios, except those involving Palestinian immigration to Israel can be dropped (scenarios A6, B6, C6, A9, B9, C9, A12, B12, and C12). The scenarios of large scale movement of Palestinian refugees to Israel (scenarios A1, B1 and C1), all likely to lead to a Palestinian majority in Israel are therefore effectively subsumed by scenarios A3, B3 and C3 since a bi-national state is the most likely outcome of a Palestinian majority in Israel. Scenarios A1, B1 and C1 can therefore be dropped.

The United Nations Population Division projections for 2050 assume normal migration patterns, based upon past migration trends and the policy stances of national governments. The projections, therefore, already take into account expected Israeli / Jewish immigration to Israel, so scenarios that specifically factor in such immigration (scenarios A4, A5, A6, B4, B5, B6, C4, C5, and C6) can be dropped since they are effectively doubling up the effect of Jewish immigration.

This paper is trying to establish upper and lower bounds for possible population scenarios for 2050, together with the medium (most probable) scenario for 2050. Therefore, an upper limit of possible population growth would be a scenario based upon the high population projections of the United Nations Population Division, together with significant Palestinian immigration. On this basis, scenarios based upon Palestinian immigration occurring in conjunction with either medium or low population projections can be dropped (A1, A2, A3, B1, B2, and B3). Similarly, scenarios based upon Israeli / Palestinian emigration occurring in conjunction with medium or high population growth can be dropped (scenarios A7, A8, C7 and C8), and the high and low population projections together with no change in immigration / emigration can be dropped (B10, B11, C10, and C11.)

This leaves scenarios A10, A11, (medium population scenarios), B7 and B8 (lower boundary population scenarios), and C2 and C3 (upper boundary population scenarios). These scenarios are therefore explored in more detail below.

## Medium population growth (A10 and A11)

These scenarios for 2050 are based upon population growth occurring in line with United Nations Population Division projections, with fertility rates falling as expected. They are also based upon the assumption that there are no unexpected population movements into or out of region, and that the boundary between Israel and Palestine is not altered. (In other words, the border between the West Bank and Gaza Strip (Palestine) and Israel more or less follows the “Green Line”, although minor border adjustments would likely occur as part of a peace settlement.) As such, they can be considered the most probable population scenarios based upon currently available information. On this basis, the population in Israel would reach 10 million, and in Palestine 11.1 million.

Scenarios A10 and A11 will hereafter be referred to as Scenario A since they have the same basis.

**Low population growth and significant net emigration from Israel and Palestine (B7 and B8)**

These scenarios represent the lower boundary of possible population growth in Israel and Palestine. They assume that the population growth in the region matches the low variant of the United Nations Population Division projections. They also assume that net migration from Israel and Palestine over the 2004 –2050 period results in a twenty percent reduction of the total final population, and that there is no significant movement of refugees. Assuming that the boundary between Israel and Palestine is not altered and no major population movement occurs between the two territories, then the population in Israel reach would reach 6.6 million and in Palestine 7.5 million.

Scenarios B7 and B8 will hereafter be referred to as Scenario B since they have the same basis.

High population growth and significant immigration of Palestinian refugees to Israel and Palestine (C2 and C3)

These scenarios represent the upper boundary of foreseeable population growth in Israel and Palestine. They assume that the population growth in the region matches the high variant of the United Nations Population Division projections. They also assume that the population growth rate for the 800,000 Palestinian refugees currently living in Syria and Lebanon matches that of the Palestinian population in Palestine, and this whole population migrates to Israel / Palestine, resulting in an addition 3 million people living in the land to the west of the Jordan River in 2050.

Given their lack of citizenship, the Palestinian refugees living in Lebanon and Syria are the most likely to migrate to Israel or Palestine if the opportunity arises. Not all of these people would necessarily relocate to Israel or Palestine if given the option but might settle elsewhere. However, such non-returnees may be balanced by those Palestinians living in other countries (such as Jordan) who would chose to return to their homeland if given the option.

Assuming that all the refugees from Syria and Lebanon settle in Palestine only, and there is no movement of refugees to Israel, then in 2050 the population of Israel reaches 11.9 million, and that of Palestine 16 million (scenario C2). Scenario C2 here after will be referred to as Scenario C.

Assuming that a bi-national state eventuates in the land to the west of the Jordan River, then the population of the area reaches 27.9 million in 2050 (scenario C3). Scenario C3 here after will be referred to as Scenario D.

The population projections resulting from these scenarios are shown in Table 2.

## The feasibility of the scenarios

Scenarios A to D all appear to be plausible given current growth rates and possible future political developments in the region. Scenario A is the "business as usual scenario", whereby fertility rates fall rapidly in-line with experiences elsewhere in the world and there are no sudden unexpected movements of population into or out of the region. Scenario B represents the lower boundary and Scenarios C and D represent an upper bound of possible populations in the year 2050 for Israel and Palestine. Assessing which particular scenario is the most likely to eventuate is not possible due to the extreme uncertainties facing the Middle East, particularly the region of Israel and Palestine itself. Within the remit of this paper, this is also not necessary.

Scenarios C and D, while representing an upper boundary of the possible populations of Israel and Palestine in the year 2050, are still plausible. If there is no settlement of the on-going conflict for some years, thus hindering economic development in Palestine, then fertility rates may indeed fall more slowly than expected. The present political positions of a number of key players in the region suggest that the large-scale movement of Palestinian refugees as part of a final peace settlement is probable. Hence, when (or perhaps if) a peace settlement in the region is achieved, this may well result in a significant boost to the population of Israel, Palestine, or perhaps both countries.

Scenario B represents a lower boundary of likely population growth in Israel and Palestine. Such a scenario could occur if the current conflict continues (or intensifies) for many years to come and forces many people to seek lives elsewhere due to the increasing economic and security difficulties that result.

All of the above scenarios, with the exception of scenario B in the case of Israel, envisage extremely high population densities, much higher than those of the present. Particularly in the case of Palestine with scenario C, where the population density for the country as a whole would reach more than 2,500 people per square kilometre, the question must be asked about whether this is physically achievable. However, there is evidence to suggest that this is physically achievable, even if not desirable.

The population density of the Tel Aviv district contains 1.2 million people in an area of 171 sq, km., thus giving a population density around 7,000 people per sq. km (Israeli Central Bureau of Statistics, 2003). The current population density of the Gaza Strip as a whole averages more than 3,500 people per square kilometre. Further more, the Palestinian built up area covers just 53.7 sq km (Palestinian Academic Society for the Study of International Affairs, 2003). With 94.7 percent of the population in the Gaza Strip living in urban areas or camps (Palestinian Academic Society for the Study of International Affairs, 2003), the population density in built up areas is around 22,000 people per sq. km.

While it is hardly desirable to emulate the overcrowded and poor living conditions that exist in much of Gaza, it is clear that extremely high densities already exist in specific parts of the region. However, such population densities also require a conceptual reassessment in that the area should not be seen as a predominantly rural hinterland supplying a few urban centres, but, instead, as an urban conglomerate whose existence depend on infrastructure links with a much wider hinterland than hitherto conceptualised. In this case, Gaza, for instance, may benefit from an analysis as a poorly equipped mega-city. Either way, the essentially urban nature of many areas also affects the viability of the political solutions as well.

## Available Water Resources

Both surface water and groundwater are available in the land between the Jordan River and the Mediterranean. In terms of fresh water supply, the major groundwater sources are the Mountain

Aquifer, which can be divided into three sub-basins (Western Mountain Aquifer, North-Eastern Mountain Aquifer, and Eastern Mountain Aquifer), as well as the Coastal Aquifer (U.S. Geological Survey, 1998). Both the Western Mountain Aquifer and the North-Eastern Mountain Aquifer are shared water resources, being located in both the West Bank and Israel, while the Eastern Mountain Aquifer is located entirely within the West Bank. The Coastal Aquifer underlies the Coastal Plain of Israel and the Gaza Strip. The only major surface water resource in the region is the Jordan River system, shared by Israel, the West Bank, Lebanon, Syria and Jordan. (See Figure 1 for a map of the study area and its water resources.)

Estimates of the available renewable water resources of Israel and Palestine vary. According to data published by the Israeli Ministry of National Infrastructures, the total average annual potential volume of renewable water available is 1,800 MCM (Ministry of National Infrastructure, 2002). This figure is broken down according to source in Table 3. According to data published by the Palestinian Water Authority, the total volume of available renewable water resources is 2634 MCM (Palestinian Water Authority, 2004). This figure is broken down according to source in Table 4.

The values given in Tables 3 and 4 are significantly different. However, the figures given by the Palestinian Water Authority for the Mountain Aquifer match those agreed upon and specified in the *Israeli-Palestinian Interim Agreement on the West Bank and Gaza Strip* (the Oslo 2 Agreement) signed in 1995, suggesting that the figures for this aquifer are likely to be reasonably accurate or at least politically acceptable to both sides.

## Resolving the discrepancies in data

There is no agreed publicly accessible database relating to water resources and their use in Israel and Palestine (Rouyer, 2000). While Israel has developed its own detailed database, Palestinian water experts question the accuracy of officially released data since access to the raw data is generally not permitted (Rouyer, 2000). Furthermore, as argued by Alatout (2000), water data is always subject to bias. Even the most objective Israeli or Palestinian scientist or analyst will tend to produce figures that favour the position of their nation; scientific knowledge is itself socially constructed and is thus influenced by the cultural, institutional and historical conditions of its production (Alatout, 2000).

Since water resources are generally being fully used (or in some cases overused) in the region (U.S. Geological Survey, 1998), data on water production and consumption can give some indication of resource availability although the reliability of this data is also open to question. During the ten years to 2001, total water production in Israel (excluding wastewater reuse) averaged 1785 MCM per year (Israeli Central Bureau of Statistics, various years). Palestinian water use is approximately 271 MCM per year (Palestinian Water Authority, 2004). However, the aquifer in Gaza is being overdrawn at a rate of approximately 87 MCM per year, and the Eastern Mountain aquifer is thought to be under exploited by 78 MCM, thus suggesting that the sustainable yield of the water resources currently available for Palestinian use is 262 MCM per year (Palestinian Water Authority, 2004).

These usage figures therefore suggest that the total annual renewable water resource of the land to the west of the

Jordan River is approximately 2047 MCM. The above usage data (if accurate) suggests that of this 2047 MCM, 1785 MCM is currently exploited by Israel and 262 could potentially be exploited sustainably by the Palestinian population of the West Bank and Gaza.

Given that the Jordan River, which makes up 30 to 40 percent of this total, is a water resource shared by other riparian states with whom there is no water sharing agreement (namely Syria and Lebanon) the long term supply of 2047 MCM to Israel and Palestine is not guaranteed. Furthermore, with the aquifer under Gaza being depleted unsustainably, a further 50 MCM of supply is likely to be lost. However, given that 2000 MCM is the approximate quantity of sustainable annual water supply currently available (excluding the overexploited and thus degrading Gaza Coastal Aquifer), this figure will be used here in the discussion. It will be assumed that the approximate quantities of water available from the different sources are 300 MCM from the Coastal Aquifer, 172 MCM from the Eastern Mountain Aquifer, 145 MCM from the North-Eastern Mountain Aquifer, 362 MCM from the Western Mountain Aquifer, 700 MCM from the Jordan River system, and 321 MCM from other sources found entirely within Israel's borders, such as surface runoff and a number of small aquifer such as the Western Galilee Aquifer. The Mountain Aquifer is the highest quality water source in the region.

At present there is no final agreement between Israel and Palestine on water issues, with water being discussed without resolution during the final negotiations between the two sides as part of the Peace Process of the 1990s. However, given the importance of a secure water supply for human health and national development, it is imperative that some sort of water sharing agreement that is grounded in international law be reached in the near future, though this will probably have to await some sort of peace settlement.

## Cross boundary water resources management

It is reasonably clear under international law that Israel and Palestine are expected to co-operate in their use of their shared water resources, for both groundwater and surface water, although how precisely the two nations should manage their shared resources is not specified.

The Jordan River borders the West Bank before it flows into the Dead Sea and thus as a riparian to this river, Palestine has riparian rights to a portion of its flow under international water law just as Israel has riparian rights because of a portion of the river basin lies within its territory. The Eastern Mountain Aquifer lies wholly within the West Bank and so is not a shared water resource. With the North-Eastern Mountain Aquifer and the Western Mountain Aquifer, however, while the majority of the recharge zones lie within the West Bank, much of the natural discharge area lies within Israeli territory. This allowed Israel to exploit part of the aquifer's potential even prior to its occupation of the West Bank (Trottier, 1999). Thus both of these aquifers are shared water resources. The Coastal Aquifer is also a shared water resource since there is some east-west flow through the aquifer towards the Mediterranean (U.S. Geological Survey, 1998).

The population projections raise the fundamental question of whether there is sufficient water available to meet likely demand in Israel and Palestine. On the basis of food self sufficiency (in the context of sub-Saharan Africa) Falkenmark (1986) proposed a water scarcity index, whereby a country with less than 1000 cubic metres of water per capita is suffering water scarcity where water shortages would threaten economic development and human health and well-being. This benchmark figure has since been widely accepted as an indication of when a country faces water scarcity since approximately 1000 cubic metres of water per capita per year is required for food production, either in the form of irrigation water or naturally occurring soil water (Allan, 1997).

Allan (1997) argues that the Middle East was the first major region of the world to run out of water, with most of the countries of the region gradually developing water deficits over the last few decades; Israel, for example, ran out of water in the 1950s. As countries have developed water deficits the shortfall in available water compared to the quantity required to maintain food self sufficiency has been met by food imports, primarily, the import of low value grains from Europe and North America (Allan, 1997). Allan (1997) terms this trade in grains as "virtual water" since water is effectively embedded in such water intensive commodities, with such food imports being available in non-affluent countries. Given widespread participation in global food markets, questions of food self-sufficiency can only realistically be assessed at the global level (Allan, 2001); hence assessing the adequacy of a nation's water supply on the basis of food self sufficiency is of doubtful validity.

Shuval (1992) suggests a figure of 125 cubic metres per capita per year as a minimum water requirement which incorporates domestic needs as well as modest industrial and gardening needs. While the WHO / UNICEF (2000) adopted the much lower figure of 7.3 cubic metres per capita per year (20 litres per capita per day) this figure serves as an absolute global minimum for water supply and only makes allowance for very basic domestic needs. Domestic water consumption in all developed countries is far higher than this figure, and this figure makes no allowance for the water requirements for maintaining a non-agricultural economy (Feitelson & Chenoweth, 2002). The figure of 125 cubic metres per capita per year provides an indication of the water requirements for maintaining a modern industrial / service based economy. It also provides an indication of the water required for household-based food production during a transition to a modern industrial-service economy.

The readily available natural fresh water resources of a country no longer limit fresh water supply. Water imports from elsewhere (such as Turkey) are possible but desalination is also of growing importance as costs have fallen. For example, the cost of water agreed upon recently for a new desalination plant in southern Israel was $US0.527 per cubic metre of water, with the plant to produce 100 million cubic metres of fresh water per year from Mediterranean water (Lokiec & Kronenberg, 2003). Desalination requires ready access to a source of saline water and so is a potential option for the Gaza Strip and Israel but not the West Bank.

While the cost of desalinating seawater is slowly falling, the current cost of producing desalinated seawater is similar to the cost of water provided to Israeli consumers, which are uniform across the country (Kislev, 2002). Residential users in Israel pay between $US0.61 and $US1.27 per cubic metre, depending upon the quantity consumed (Kislev, 2002). While these prices are higher than the price of desalinated water, the current desalination price of $US0.57 does not include distribution costs. Desalination, therefore, even without significant further cost reductions is clearly able to meet urban, and to a lesser extent, industrial water requirements for Israel and Palestine if domestic and industrial demands for water exceed the natural renewable fresh water resources. However, due to the high energy requirements of desalination compared to the cost of accessing surface water or groundwater from the aquifers, it is unlikely that desalination will ever be able to be used to support agriculture within the foreseeable future.

**Water Management options for Israel and Palestine**

There are a number of possibilities for managing the shared water resources of Israel and Palestine and achieving an equitable allocation of water resources between the two nations. It would be possible to jointly manage the water resources of Israel and Palestine. With 2000 MCM per year of water available from renewable natural sources, desalination and / or the recycling of wastewater could make up any shortfall. Haddad et al (1999) argue that due to the high level of hydrological interdependence between Israel and Palestine, and the susceptibility of the aquifers to degradation, integrated management as a single system is required. Haddad et al (1999) explore various mechanisms for joint management of the shared aquifers of Israel and Palestine.

Integrated management would require extensive co-operation between Israel and Palestine, including the establishment of a joint water authority to manage and distribute the available resources. Because of this and the associated loss of sovereignty it would entail, it is uncertain whether such a solution could be achieved. Furthermore, with more rapid population growth occurring in Palestine than in Israel, the Israeli government may prefer to seek a permanent water resources division at the time of a peace settlement rather than see its own allocation slowly eroded overtime as its percentage of the population of the region slowly decreases. From the Palestinian perspective, Palestinian negotiators to a peace settlement may also prefer a fixed allocation of the resource rather than depending upon the future success of joint management processes.

Dividing the water resources would provide both nations with the much greater autonomy in terms of how they develop, though with Lake Tiberias and the majority of the storage capacity of the Mountain Aquifer located in Israeli territory, little inter-annual storage would be available to Palestine. Also, the Northern West Bank is relatively water rich, and the southern West Bank and Gaza is relatively water poor, but there is no north-south water conveyance network within Palestine similar to what presently exists within Israel. Furthermore, sustainably managing an aquifer at maximum sustainable yield is difficult to achieve with a single management authority but is even more difficult with a jointly managed resource. Therefore, if separate management was chosen, there would still be a need for a joint monitoring body and some level of co-operation.

Assuming that a division of the water resources was chosen with the creation of two separate water networks in mind, then Palestine could be expected to claim full sovereign control over the Eastern Mountain Aquifer (172 MCM) and thus seek to exclude this from negotiations. Israel could be expected make a similar claim with respect to sources of water resources located entirely within Israel (321 MCM). It might also make a similar claim to the Coastal Aquifer since the east-west flow of this aquifer from Israel into Gaza is limited and most of the aquifer’s recharge and discharge area is located to the north, wholly within Israeli territory. Furthermore, with the on-going over-exploitation of the Gazan portion of the Coastal Aquifer likely to permanently degrade the aquifer, its shared status with Israel may become a mute point since the aquifer under Gaza will effectively cease to exist.

One readily conceivable division would be to give Palestine first right of use to the Mountain Aquifer but no use of the Jordan River system or water from the Israeli portion of the Coastal Aquifer. Such a division of water resources would provide Palestine with access to 679 MCM of water, and Israel 1,321 MCM. This split would effectively give priority to the upper riparian of each water resource, with any un-used allocation becoming available for use by the other party. However, because much of the inter-annual storage area of the Mountain Aquifer underlies Israeli territory, Palestine would not be able to fully exploit the resource without Israeli assistance. An alternative division of the water resources may be to divide the Mountain Aquifer and the available water from the Jordan River system equally between the Israel and Palestine. This would provide Palestine with 690 MCM of water, and Israel 1310 MCM.

Both of these divisions result in a similar gross water distribution and would double the amount of water available to Palestine compared to the present level. It would also divide the total water resources west of the Jordan River at a ratio roughly similar to the current population ratio, thus in this sense could be seen as equitable. However, it would do little to solve the water problems of the Gaza Strip without Israeli willingness to facilitate a water transfer through its territory from the West Bank, or without the use of desalination. The discussion below considers the population scenarios A to D in relation to the first of these resources divisions, although given that the volumes of water are similar, the result would be similar for either.

**The hydrological viability of Israel and Palestine under population scenarios A to D**

**Scenario A: Israel: 10 million; Palestine: 11.1 million, medium population growth.**

Under this scenario there would be sufficient water available in Israel to meet urban and industrial needs, although severe cuts to the amount of freshwater going to Israeli agriculture would be required as per capita water resources for Israel would fall to 132 cubic metres per capita. Some of this could be replaced by recycled wastewater from urban areas that would be available in increasing quantities.

In Palestine, the available freshwater would be insufficient for developing a modern industrial economy or a high standard of living. However, the water resources available to Palestine located in the West Bank would approximately cover Palestinian needs in the West Bank. Despite this, due to inter-annual climatic variation, the water situation in the West Bank would be somewhat precarious and might require the purchase of water from outside in drier years or the use of recycled wastewater for some industrial or domestic needs.

In Gaza, water requirements would need to be met by desalination or water imports from outside the region. Since the Gazan population is located close to the Mediterranean and thus little pumping would be required, supply costs of such water would not add significantly to the total cost of this water.

Under this scenario, large quantities of wastewater would be produced in the Gaza Strip but with the extremely high population density of the Gaza Strip, potential for agricultural uses of this water would be limited. This might permit a water trade with Israel, whereby wastewater from the Gaza Strip might be exchanged for the supply of freshwater. Such a trade could be used, for example, to alleviate any shortfall in freshwater supply for domestic and industrial use in the West Bank in years of below average rainfall, or reduce the quantity of water Gaza would be required to desalinate.

If a joint integrated water resources system was created for Israel and Palestine, then three-quarters of the region’s domestic and industrial needs could be met from natural water sources, with the remaining water (approximately 650 MCM) coming from desalination plants along the Mediterranean. Such an amount is certainly conceivable given that the Israeli government in 2002 published tenders for desalination plants totalling 305 MCM per year (Israeli Ministry of Foreign Affairs, 2002). From a resource management and environmental perspective, this integrated management solution for this scenario would be the optimum since the total amount of desalination in the region could be kept to a minimum and water could allocated purely on the basis of domestic need.

Scenario A represents the most likely situation if the current status quo is maintained in terms of expected population growth rates and migration. The above analysis is based upon the first water redistribution considered in the previous section. If, however, there is no change to the present water resources distribution between Israel and Palestine, then water resources by 2050 would be even more inadequate for the Palestinian population than at present. Only 23 cubic metre of water per capita would be available, a mere third of what is available today. Such a situation would produce a humanitarian disaster.

**Scenario B: Israel: 6.6 million; Palestine: 7.5 million, low population growth and net emigration from both areas**

Israel would suffer a reduction in its water resources per capita compared today, but its water resources would remain comfortably above 125 cubic metres per capita. Thus it would be capable of maintaining reserve for times of drought and for use in agriculture.

In Palestine, in the West Bank, water resources would also comfortably remain above 125 cubic metres per capita, thus also allowing some limited use of fresh water for agriculture. In Gaza, as with scenario A, desalination would be required. However, given the surplus (from urban and industrial needs at least) in the West Bank, there would be a real possibility of a water transfer from the West Bank via Israel. Similarly, the purchase of fresh water from Israel might also be a possibility. If good neighbourly relations were established an arrangement whereby Israel was to supply some of its freshwater to Gaza for domestic purposes in return for receiving treated wastewater for use in agriculture might work to the benefit of both sides. A single integrated system would facilitate such an arrangement and allow optimum management of the water resources.

**Scenario C: Israel: 11.9 million; Palestine: 16 million, high growth and Palestinian immigration**

Israel would require modest desalination capacity to supplement its available natural water resources in order to meet its urban and industrial water requirements. However, in Palestine the situation would be difficult. Only half of the water requirements of the West Bank population would be able to be met from Mountain Aquifer. Unless several hundred MCM of water could be purchased from outside sources, water resources per capita in the West Bank would be lower than at present and thus the population would probably suffer considerable hardship. If water was not imported then it is probable that the Mountain Aquifer would become degraded through overuse further reducing water resources, and a large scale emigration of people (environmental refugees) could result. In Gaza, as with scenarios A and B, large-scale desalination would be required.

The severe water problems Palestine would face under this scenario might be avoided if a single integrated water system was established for Israel and Palestine. Since this would be of much greater benefit to Palestine than Israel, reaching agreement on such a management system might be difficult. However, if agreement on an integrated system was not reached then water trading between Israel and Palestine would hopefully still occur.

**Scenario D: Bi-national state: 27.9 million, high growth and Palestinian Immigration**

A bi-national state would almost certainly result in a single integrated water system. With a population of 27.9 million, significant desalination would be required to supplement natural water resources, with approximately 1,500 MCM being required to be produced each year. The need to pump significant quantities of water from low lying coastal areas to the hill country of the West Bank would add to water supply costs. The integrated network and bi-national nature of the state, however, would permit cross subsidisation by coastal areas, as currently occurs in Israel today. With real economic growth and falling desalination costs, water might be less expensive than today for most domestic consumers in real terms.

The large population would produce similarly large quantities of wastewater. With treatment, this would provide a significant resource for use in agriculture. Available land areas would likely be limited, however, due to the large population. Nonetheless, some areas of potential agricultural land would probably remain in the Negev Desert, and where such areas did not overlie any aquifer recharge areas, wastewater treatment costs would be minimal.

Table 5 presents data relating to scenarios A to D.

## Discussion and conclusion

It is imperative that a fairer distribution of the water resources of Israel and Palestine be achieved if an environmental and human disaster (in relation to water resources) is to be avoided. If this is achieved, then it appears that there are realistic management options that would allow the hydrological needs of the populations of Israel and Palestine to be met. Water need not be an obstacle to peace or economic development in the region.

By 2050 under all scenarios considered in this paper, except the low population growth of scenario B, the population of Israel and Palestine will increase significantly, probably to levels that are difficult to conceive based on present populations. The already high population density of the land, the lack of significant water resources relative to population, and the on-going conflict between Israel and the Palestinians, suggest that many real challenges lie ahead. However, with all scenarios, except the high population growth of scenario C occurring in the context of inadequate co-operation, it is conceivable that the domestic and industrial water resource needs of the population will be met if good management occurs. This finding is perhaps contrary to the common wisdom relating to water resources in Israel, Palestine or the wider Middle East, which sees water as a major impediment to a peaceful or prosperous future, and sees the world as heading towards a major hydrological crisis.

Only in the case of scenario B for Israel is any significant quantity of fresh water likely to remain for use in agriculture. In every scenario for Palestine recycled wastewater is likely to become the only agricultural water source, and there will be little space for agriculture anyway as urban areas come to dominate the Palestinian landscape. The continued decline of agriculture in Israel will be unlikely to present any insurmountable challenges as agriculture in Israel is already insignificant (less than 3 percent) in terms of its contribution to GDP or employment. In Palestine, however, achieving rapid economic development in the absence of a significant contribution from agriculture will present a major challenge for the Palestinian government and the international donor community.

For all the scenarios an integrated water resources system to manage the water resources of Israel and Palestine as a single unit is preferable from a water resources management perspective. This would also result in the lowest overall net economic and environmental cost since the use of desalination would be able to be minimised. However, where a much larger Palestinian population relative to the Israeli population occurs, it is difficult to imagine such a solution being acceptable politically in Israel since Israel might be worse off than with separate management.

Even without a fully integrated water resources system, there is significant potential for the trading of water resources between Israel and Palestine. In particular, the large urban population of Gaza will produce considerable quantities of wastewater whose potential use in the Gaza Strip will be limited (due to space limitations) but this water could be productively used for agriculture in the adjacent Negev Desert of Israel. At the same time, the West Bank will possibly have need of additional quantities of freshwater to meet its basic domestic and industrial requirements but unlike Israel, lacks access to the sea for desalination, so in some situations there may be a need for Israel to supply water produced in its Mediterranean desalination plants.

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**Tables and Figures:**

**Table 1:** Basis of scenarios for population in Israel and Palestine in 2050.

| | | Population growth | | |
|---|---|---|---|---|
| | | Medium | Low | High |
| Palestinian immigration | To Israel | A1 | B1 | C1 |
| | To Palestine | A2 | B2 | C2 |
| | To bi-national state | A3 | B3 | C3 |
| Jewish immigration | To Israel | A4 | B4 | C4 |
| | To Palestine | A5 | B5 | C5 |
| | To bi-national state | A6 | B6 | C6 |
| Israeli / Palestinian emigration | From Israel | A7 | B7 | C7 |
| | From Palestine | A8 | B8 | C8 |
| | From bi-national state | A9 | B9 | C9 |
| No change in immigration / emigration | From Israel | A10 | B10 | C10 |
| | From Palestine | A11 | B11 | C11 |
| | From bi-national state | A12 | B12 | C12 |

**Table 2:** Population projects, resulting population density and resulting water resources per capita (assuming no redistribution of resource or augmentation through desalination) for the different scenarios.

| Scenario | Geographic area | Population (millions) | Population density (persons /km2) |
|---|---|---|---|
| Current situation | Israel | 6.4 | 306 |
| | Palestine | 3.9 | 625 |
| A | Israel | 10 | 481 |
| | Palestine | 11.1 | 1785 |
| B | Israel | 6.6 | 318 |
| | Palestine | 7.5 | 1206 |
| C | Israel | 11.9 | 573 |
| | Palestine | 16 | 2572 |
| D | Bi-national state | 27.9 | 1034 |

**Table 3:** Available renewable water according to source in Israel / Palestine (Israeli data). (Source: Ministry of National Infrastructure, 2002).

| Resource | Renewable water (MCM/year) |
| --- | --- |
| Coastal Aquifer | 320 |
| Mountain Aquifer | 370 |
| Lake Tiberias / Jordan River | 700 |
| Other sources | 410 |
| Total | 1,800 |

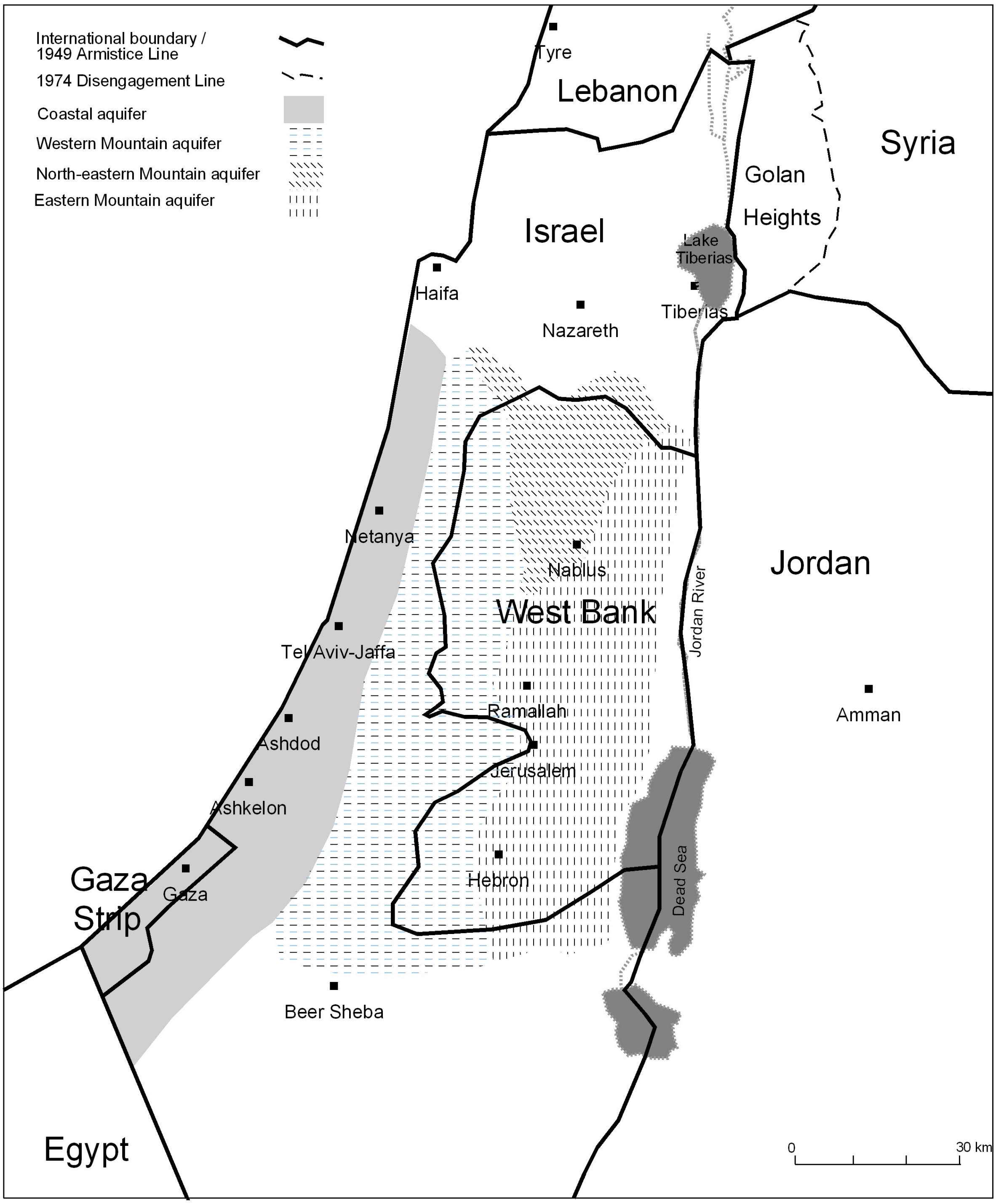
**Table 4:** Available renewable water by source in Israel / Palestine (Palestinian data). (Source: Palestinian Water Authority, 2004)

| Resource | | Renewable water (MCM / year) | |
|---|---|---|---|
| Groundwater total including: | | 1454 | |
| Mountain aquifer | Eastern Mountain Aquifer | 172 | 679 |
| | North-eastern Mountain Aquifer | 145 | |
| | Western Mountain Aquifer | 362 | |
| Coastal aquifer | Coastal Aquifer | 254 | 304 |
| | Gaza portion of aquifer | 50 | |
| Jordan River | | | 965 |
| Runoff | | | 215 |
| Total | | | 2634 |

**Table 5:** Summary of scenarios A to D

| Scenario | Geographic area | Population (millions) | Population density (persons /sq km) | Water Resources based upon hypothesised water resource division (cubic metres per capita) |
|---|---|---|---|---|
| Current situation | Israel | 6.1 | 306 | 281a |
| | Palestine | 3.5 | 625 | 67 a |
| A | Israel | 10 | 481 | 132 |
| | Palestine | 11.1 | 1785 | 61 |
| B | Israel | 6.6 | 318 | 200 |
| | Palestine | 7.5 | 1206 | 91 |
| C | Israel | 11.9 | 573 | 111 |
| | Palestine | 16 | 2572 | 42 |
| D | Bi-national state | 27.9 | 1034 | 72 |

Note: a: with current water resources division




## Notes

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Figure 1: A map of the study area, showing approximate locations of the shared aquifers and surface water resources.