Restructuring of Water Usage in the Tigris-Euphrates Basin: The Impact of Modern Water Management Policies

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ABSTRACT
This paper examines the ramifications of late twentieth century water management schemes–especially those initiated by the Republic of Turkey–for the riparians of the Tigris and Euphrates rivers. The Turks' geographical position, and their ability to construct large water storage systems, has essentially given them command of the headwaters of the Euphrates and, to a lesser degree, the Tigris. The recent changes in water management of the Tigris-Euphrates basin have had, and will continue to have, profound consequences for the agricultural sectors of the economies of the riparian nations. By unilaterally decreasing the water available for irrigation in Syria and Iraq, Turkey has presented these nations with an aqueous conundrum that remains to be solved.

INTRODUCTION

The Tigris-Euphrates basin reveals evidence of water management projects dating back over six millennia. Throughout this period empires have waxed and waned. However, their power base has consistently been constructed on the wealth generated by irrigated agriculture (Beaumont, Blake, and Wagstaff 1988). The historical location of this activity has always been in the lower part of the basin in what is now the country of Iraq. The scales of development have varied from small diversion works to major engineering feats such as the Nahrawan canal built during the sixth century CE. Since the twelfth and thirteenth centuries, however, widespread land abandonment has occurred, associated with a breakdown of the strong central government necessary for sustained widespread irrigation. It was only in the late nineteenth century and early twentieth century that major irrigation development began to appear once more in the lower part of the Tigris-Euphrates basin.

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During this whole period, water management had been confined to the manipulation of the snow-melt flood waves of the two rivers in the lower part of the basin in the period from April to June. In low flood conditions there would be insufficient water available to irrigate all the crops which were planted and crop failures would occur in those highest areas of the flood plain at some distance from the river. In contrast, high flood conditions could not be easily controlled by the prevailing irrigation systems and so crop failure through excess amounts of standing water occurred. Besides these vagaries of the annual flood there were also problems associated with the high salinity of the soils. Given these difficulties, the drainage of saline irrigation waters from the fields was always a prime concern. The system of water management which grew up was one which attempted to minimize the risks to crop growth. Another characteristic feature of this era was that only a small proportion of the total water in the river was being utilized for human activity. The vast majority of the water flowed unused into the Persian Gulf.

HYDROLOGY OF THE TIGRIS-EUPHRATES BASIN

Understanding the hydrology of the basin is crucial to understanding the effects water management projects have on the rivers. The topography is such that all the highland regions are located in the north and eastern parts of the basin in Turkey, Iraq, and Iran. These mountains reach heights of almost 3,500 m to the south of Erzincan and of around 4,500 m in the upper part of the Euphrates catchment near Lake Van. In the Tigris basin heights of up to 4,200 m are recorded in southeast Turkey in the catchment of the Greater Zab. It is in these highlands that almost all of the flows of the two rivers are generated as annual precipitation totals commonly exceeding 1,000 mm. Precipitation in the basin is largely confined to the winter months from October through to April. This means that a large proportion of the total falls as snow on the uplands and consequently the water is locked in the solid state on the mountain slopes until temperatures begin to rise in spring and early summer.

Both the Tigris and the Euphrates are characterized by river regimes which exhibit strong snow-melt peaks….there still remains controversy over the actual annual flows of the two rivers, with different authors quoting different totals. However, these values tend to reflect differing observation periods, rather than fundamental disagreements as to how much water is present within the two river systems.

Both the Tigris and the Euphrates are characterized by river regimes which exhibit strong snow-melt peaks. On the Tigris the month of peak discharge is April, while on the Euphrates it is a month later in May. Measured in Iraq, the months of March, April and May account for 53% of the mean annual flow of the Tigris. The period of maximum flow on the Euphrates in Iraq is shorter and later than that of the Tigris and is usually confined to the months of April and May. Discharge during these two months accounts for approximately 42% of the annual total.

There still remains controversy over the actual annual flows of the two rivers, with different authors quoting different totals. However, these values tend to reflect differing observation periods, rather than fundamental disagreements as to how much water is present within the two river systems. The total flow of the Euphrates at Hit in northern Iraq is given as 31,820 MCM by Beaumont (1985). However, Kolars (1994) quotes a figure of 32,720 MCM. On the Tigris the overall discharge from the catchment is much greater and attains a value of around 52,665 MCM (Beaumont 1978). Kolars in 1994, however, quotes a value of 49,200 MCM.

The main difference between the Euphrates and Tigris in terms of how their discharge is generated is that the Tigris receives water from a series of major tributaries in the mid-portion of its course.

The mainstream of the Tigris has a flow of 23,210 MCM annually at Mosul in northern Iraq (Kolars quotes 20,500 MCM), while the tributaries contribute a further 29,455 MCM each year (Kolars quotes 28,700 MCM). The largest tributary is the Greater Zab, which produces almost half the flow of all the tributaries.

In contrast, on the Euphrates, all of the major tributaries are in the extreme upper part of the basin. This has important ramifications for the control of the two rivers. With the Euphrates it means that a single dam in the upper part of the catchment is capable of controlling a very large proportion of the flow of the river. The Ataturk Dam in Turkey achieves this level of control. On the Tigris, however, the fact that it receives water from the Greater Zab, the Lesser Zab, the Adhaim and the Diyala means that overall water management is more complex and requires the construction of a series of major dam projects on the individual tributaries to provide a comparable control of the flow.

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One of the problems in the Tigris-Euphrates system has been the variability of flow from year to year. Long-term records on the upper Euphrates before the construction of major dams (1937-1964) have revealed that minimum discharge can fall to 16,871 MCM/y (1961), while a maximum value of 43,457 MCM/y was recorded (1963). An even wetter year was recorded in 1969 when the flow just north of the Turkish border registered an annual discharge of 53,548 MCM. Such large variations in discharge have always made it difficult to plan irrigation schedules efficiently in the lower part of the basin when no water storage capacity has been available. On the Tigris River a similar pattern of flow variation can be observed. The observation period is 1946 to 1985 for the Cizre gauging station, Turkey. The average annual flow here is 16,800 MCM. In 1961 the flow fell to a minimum value of only 7,891 MCM, while in 1969 it peaked at 34,340 MCM.

On the Euphrates, approximately 88% of the total flow of the main stream of the river is generated in Turkey, and a further 12% is added in Syria from the Sajur, the Balikh, and the Khabur. A substantial amount of precipitation which feeds these rivers falls over Turkey and enters them directly as runoff or as groundwater discharge. It is very difficult to estimate just how much of the flow of these rivers is contributed from Turkish precipitation. However, it does seem likely that precipitation falling over Turkey accounts for at least 95% of the total flow of the Euphrates. Along the Tigris River, Turkey provides approximately 32% of the river's discharge in terms of the mainstream. A large, although unknown, amount of the flow of the Greater Zab River also originates in Turkey. This discharge, together with that of the mainstream, probably raises the Turkish contribution to around 44% of the total flow of the Tigris.

Of the combined flow of the two rivers, approximately 63.2% is generated on Turkish territory. With so much of the water of the two rivers coming from precipitation falling over Turkey, it is not surprising that the Turkish government feels that it has a strong claim to make use of what it considers to be its own waters.

DEVELOPMENTS IN THE TWENTIETH CENTURY

The most important change in the twentieth century has been in the location of water management activity and the type of water controls introduced. In the Tigris-Euphrates basin it is only in the post-World War II period that the emphasis switches from downstream diversion schemes to upstream water storage projects. This represents a fundamental change in river management activity within the basin, brought about largely by the growing human ability to manipulate the environment through fossil fuel subsidies and technological change. This restructuring in the patterns of water usage has had a profound effect on all aspects of development within the basin. This is especially the case as the population distribution within the basin up to the 1960s reflected the traditional patterns of water management and agricultural production.

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Besides technological change there has also been an important political change. Prior to the twentieth century the whole of the Tigris-Euphrates basin was under the control of a unified, although sometime weak, government. This situation lasted through World War I with the collapse of the Ottoman Empire. After the War different political units controlled the upper, middle and lower parts of the basin. As a result the chance for unified development of the waters of the basin using twentieth century technology became increasingly remote.

After World War II, water management focused on the construction of water storage facilities in the highland parts of the basin in Turkey on the Euphrates and in both Turkey and Iraq on the Tigris River. This form of water management usually had two objectives: generation of hydro-electricity and provision of large quantities of water for irrigation purposes. As this development activity and planning took place in the 1960s and early 1970s, it soon became evident that there was not going to be enough water available in the two rivers to satisfy the planned needs of the three major countries located in the basin (Beaumont 1978). Negotiations to reach a settlement to the dispute over water volumes available to each of the riparian states have been attempted on a number of occasions, but have never been able to produce an agreement. Consequently, the three nations (Turkey, Iraq and Syria) all went ahead with their own development schemes with little consideration of the impact their projects would have on the other states in the basin.

Without doubt Turkey is in the strongest position with regard to its potential control of a large part of the water resources of the Tigris-Euphrates basin. It can develop its water management schemes, and the two downstream countries of Syria and Iraq will have to suffer the consequences of lower flow conditions. Initially Turkey constructed the Keban Dam in the 1960s on the upper Euphrates. However, it built this dam largely for the generation of hydro-electricity, and therefore, the volumes of water flowing down the river remained constant. What did change, however, was the pattern of discharge along the Euphrates. With the volume of water in the reservoir behind the Keban Dam, which amounted to 30,700 MCM of gross storage and 17,000 MCM of active storage, it was now possible for the Turkish government to exercise a large measure of control over the flow of the river. It did this to achieve a more uniform flow pattern, attempting to limit minimum flows to 400 m^3/s and maximum flows to 1000 m^3/s. As a result, major floods or extremely low flow conditions were effectively eliminated from the Euphrates River. With the opening of the Keban dam a new chapter in the water management of the Euphrates River began. Greater control of flow was now possible, but as yet there was little need to use the water within Turkey for any productive purposes. The first stage of the restructuring of water usage had begun.

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To utilize more of the water in the Tigris and Euphrates, Turkey has embarked upon an ambitious series of schemes which are now usually referred to as the South-East Anatolia Project (Bagis 1989; Bilen 1994a and b; Altinbilek 1997). This project consists of 13 individual, but related, schemes on the Tigris and Euphrates rivers. Seven of these schemes are located on the Euphrates River. When fully implemented in the early years of the twenty-first century, they will permit the irrigation of 1,083,000 ha and will utilise up to 9,000 MCM of water each year. On the Tigris River, the six planned schemes will irrigate 558,000 ha and use 3,700 MCM each year. These figures for water use come from official Turkish sources presented in the main planning documents for the scheme. However, field evidence suggests that water usage will be around 10,000 m^3/ha. This indicates that actual water use figures could be in excess of 10,000 MCM/y on the Euphrates and over 5,580 MCM on the Tigris. The second stage of water restructuring in the Euphrates basin can be said to have begun with the first delivery of irrigation waters through the Urfa Tunnels in 1995.

Of particular interest with the South-eastern Anatolia Project is the high level of commitment the government of Turkey has shown toward it. The financial provision for such projects from international organizations such as the World Bank is always dependent upon an agreement as to water use by all the states within the river basin. From an early stage in the planning process, Turkey realized that it would not be able to gain the agreement of Syria and Iraq for the use of the water volumes it proposed. Consequently, it was forced to finance the project entirely from funds generated within Turkey. This was a substantial drain on the finances of the nation, but indicates just how important the project was to the economic development of the nation.

On the Euphrates in Turkey, the key structure is the Ataturk Dam, which is located approximately 80 km upstream from the Syrian border. Its two main purposes are to produce hydro-electricity and to provide water for the irrigation projects being developed along the Syrian border. The reservoir has a gross storage capacity of 48,700 MCM and an active storage capacity of 19,300 MCM. As a result of the construction of the Ataturk Dam, Turkey has now stated that in the future (since 1990) it would only guarantee a flow downstream from the dam of 500 m^3/sec. This represents about 50% of the natural flow of the Euphrates River at the Turkish border. Both Syria and Iraq have disputed this figure and have stated that the minimum flow should average at least 700 m^3/sec. Turkey has so far rejected this claim.

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The pattern of water release from the Ataturk Dam is further complicated by the fact that there are eight turbines in the dam which are capable of generating electricity. When running at full power, each of these turbines has a water throughput of 225 m^3/sec. This means that if all eight were running at the same time at full capacity, the water discharge from the dam would be 1800 m^3/sec. It would seem likely that maximum electricity generation from the Ataturk Dam will take place during the winter months, but actual amounts are difficult to predict. As far as water discharge is concerned, what seems likely to happen is that during winter the release of water from the dam may be well in excess of the 500 m^3/sec guaranteed by the Turkish government. In effect, this might mean a major change in the discharge pattern of the river, with maximum flow conditions in future occurring during the winter months instead of in April and May. Downstream states are, therefore, likely to receive more water than they perhaps expected, but it will arrive at a time of year when it is not very convenient in terms of their likely water needs.

In the future, Turkey may well face a choice between irrigation and hydro-electricity generation. Irrigation has such a large demand for water that the use of the generators in the Ataturk Dam will have to be severely limited in terms of their operating times if the maximum irrigation program is to be attained. At the current time this might not be a problem for the Turkish government. However, as demands for electric power increase in the next century it is possible that Turkey might be willing to sacrifice some of its newly irrigated land so that more power can be produced. In the final analysis, everything will depend on whether the highest monetary value can be obtained from a cubic meter of water used for irrigation or for power production.

When all the reservoirs on the Tigris-Euphrates system have been completed in the early years of the next century, the Turkish government will have substantial control over the flows of the two rivers. On the Euphrates, the active, or usable, storage of all the reservoirs which have been built or planned is 42,000 MCM. This compares with an annual flow of the Euphrates at the Syrian border of 30,377 MCM. Effectively, therefore, the storage capacity of the system is 1.38 times the annual discharge of the river, which means that the flow of the river can be easily regulated except during long drought periods, or a run of very wet years. On the Tigris, Turkey's degree of control over the flow of the river is less marked. The planned active storage of the reservoirs on the upper Tigris is expected to be 15,246 MCM. This compares with an average annual flow of 16,718 MCM for the river at the Cizre gauging station, which indicates that total water storage is less than the discharge of an average year.

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What is quite clear from this analysis is that Turkey really does have a stranglehold on the waters of the Euphrates River. At least 88% of the river's flow is generated within the country, and it has the ability to store a water volume equivalent to 1.38 times the average annual flow of the river at the Syrian border. However, Turkey has claimed that it will maintain a flow of 500 m^3/sec of water across the border into Syria (15,768 MCM). Given the high storage capacity which Turkey now possesses along the river it seems likely that it would be able to achieve this objective without cutting back on its own irrigation needs. The expected irrigation demand in Turkey is thought likely to be at least 10,000 MCM each year, while the downstream flow requirement is 15,768 MCM. This gives a total annual demand of 25,768 MCM. To cause serious problems, the flow of the river would have to fall below 20,000 MCM/y for a number of years. The available long-term records reveal that the flow of the River Euphrates has only fallen below 20,000 MCM on three occasions in the 40 year period prior to 1980.

On the Euphrates, the key to the downstream states of Syria and Iraq making the best use of the waters of the river lies in their storage of as much of the water made available to them from Turkey during the winter period as possible. Both states already have storage facilities available, but their combined capacity is low. In Syria the Tabqa Dam, built by the Russians in the late 1960s and early 1970s, has a storage capacity of 11,900 MCM. In Iraq, the Haditha Dam, another project constructed by the Russians, has a storage capacity of 6,400 MCM. Taken together, these two facilities are capable of holding only about 58% of the original annual flow of the river at Hit, Iraq. Given Turkey's need for hydro electricity, the water releases from the Ataturk Dam in winter may well exceed the 500 m^3/sec guaranteed by the Turkish government. The strategy of the two downstream countries must be to ensure that their reservoirs are full at the end of the winter period so that the water can be utilized for irrigation as soon as the agricultural season begins. Iraq will find itself in a very difficult position. With only 6,400 MCM of storage it is possible that a proportion of the winter flow of the river will flow into the Shatt al-Arab and effectively be wasted. The only other possibility might be early season watering of the fields to build up soil moisture concentrations.

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Syria is in the unusual position of being a downstream country with regard to Turkey and an upstream one in comparison with Iraq. Like Turkey, Syria had not made much use of the waters of the river prior to the 1960s. With the construction of the Tabqa Dam in the 1970s, there had been ambitious plans for major irrigation projects along the Euphrates, particularly in the lower reaches of the Rivers Balikh and Khabour (Manners and Sagafi-Nejad 1985). However, owing largely to a lack of funding, these projects did not commence large-scale development until the late 1980s. In the mid-1980s it is claimed that no more than 208,000 ha were being irrigated (Kolar and Mitchell 1991). Over the last few years, however, the pace of development of irrigation networks has been considerable. Associated with this trend has been a marked increase in water use. There is still uncertainty as to just how much irrigated land will be developed adjacent to the Euphrates River, but estimates suggest that it will be at least 475,000 ha by the early years of the twenty-first century. The expected water demand will be on the order of 4,750 MCM each year. However, certain government sources have suggested that the total irrigated area along the River Euphrates may eventually rise to close to one million ha. This does appear to be rather optimistic, but if achieved it would raise the water need to around 10,000 MCM/y. The greatest potential for this extra irrigation development would seem to be located in the lower part of the Khabour basin.

The actual amounts of land which are cultivated in Syria are crucial as far as Iraq is concerned. If the lower figure proves to be the correct one, then Iraq should receive slightly more than 10,000 MCM of water each year. If the Syrian irrigated area grows to around 1 million ha, then the volume of water Iraq will receive will fall to about 5,000 MCM. It should be remembered that these figures probably represent minimum values and that Turkey is likely to release larger quantities of water than it has guaranteed as a result of power generation during the winter months. It is worth noting that during the 1960s Iraq was claimed to be using at least 16,368 MCM of water each year for irrigation in the region between Hit and Hindiyah (Ubell 1971).

Syria also has a border on the Tigris River in the extreme northeast of the country with Turkey on the opposite bank. Over the last few years Syria has approached Turkey about the possibility of extracting water from the Tigris and releasing it into the upper part of the Khabour basin. From an engineering point of view this would be a fairly straight forward project. Iraq, however, is not keen to lose water from the Tigris which it considers to belong to itself, even though in the long term it might well benefit from greater flows along the Euphrates.

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Since the early 1980s and the beginnings of the war with Iran, it has been extremely difficult to obtain accurate statistics on agricultural activity within Iraq. Although Iraq has known for almost 20 years that it would face smaller water amounts once the Southeastern Anatolia and the Syrian irrigation schemes were completed, there is little evidence to suggest that Iraq has planned any formal adjustments to its own irrigated areas. Indeed, it is only in the 1990s with the opening of new Syrian projects and the completion of the Ataturk Dam that Iraq has had to face up to the issue of smaller water amounts. Its response seems to have been to leave it to the local districts to cope as best they can with the smaller water volumes. This seems to imply that the more difficult areas to irrigate in any region will be abandoned first, thereby causing the total irrigated crop area to contract.

The position in the Tigris watershed is at the moment less critical than in the Euphrates. In the first place, Turkey controls a much smaller part of the total flow, namely 16,800 MCM out of a total of 52,665 MCM each year. This represents only 31.9% of the average flow. Turkey also theoretically could control the upper part of the Greater Zab, but topographic conditions make this highly unlikely. Of the total volume of water in the Tigris, Turkey, at the moment, has plans to utilize up to 5,500 MCM for irrigation schemes, although many of these projects will not be complete until the early years of the twenty-first century. As yet, Turkey has not made any statement as to a particular value of flow level which it will guarantee on the Tigris. Equally, in terms of the total active water storage capacity which it controls, Turkey will have only 15,246 MCM located within its borders. This represents only 29.4% of the mean annual flow for the basin as a whole.

From the above, it can be seen that Iraq has much greater control of the waters of the Tigris than it has of the Euphrates. Once Turkey's needs have been met, this will leave about 47,165 MCM for Iraq. This is an enormous quantity of water and should, theoretically, permit the irrigation of up to 3,628,000 ha with a water rate of 13,000 CM/ha or up to 4,716,500 ha with an irrigation rate of 10,000 m^3/ha.

The fact that Iraq has so much water available in the Tigris basin may go some way to explaining why its criticism of Turkey's stance on the Euphrates River has been so restrained. It is true that complaints have been made about the release of only 500 m^3/sec by Turkey on the Euphrates, but they have not been pursued with the vigor that might have been expected if Iraq's vital interests were indeed being threatened.

With all the water to which it has access on the Tigris, it is conceivable that Iraq might well decide to divert part of this water over to the irrigated areas along the Euphrates. This could be achieved via the Tharthar Depression, but experiments have shown that this is likely to increase the salinity of the water considerably and so is unlikely to be a practical proposition. Another suggestion is a tunnel/canal following for the most part the 500 m contour between the Tigris and the Euphrates. This would be a large scale project, as the canal would be over 200 km in length. However, if built, it would be able to deliver water to the Euphrates downstream from the Haditha Dam. The flow of water into the canal could easily be controlled from the Mosul Dam on the Tigris. Such a scheme would permit the continued cultivation of much of the land on the Euphrates in Iraq which will soon be going out of cultivation as the result of the reduced water supply along the river following the expansion of the Turkish irrigated area. This obviously has considerable attraction to the Iraqi government, since it would mean that the social disruption in the villages along the river would be minimized.

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FUTURE WATER DEMANDS

The demand for water can be thought of in two principal ways: first, a demand which can be satisfied because water is available, and second, a demand which cannot be met owing to water scarcity. Until the 1960s the water demands of all three countries in the basin could be satisfied with water to spare. Since then, as water demands in the upper part of the basin have increased, the situation has changed and will continue to do so for the next two decades until all the planned irrigation projects are fully commissioned.

Several scholars have addressed the problem of demand for water over the years and all have reached the same conclusion, namely, that there is not sufficient water in the Euphrates River to meet the needs of the three countries with interests in the watershed (Beaumont 1978; Kliot 1994; Kolars 1994; Altinbilek 1997). On the Tigris, the situation is less serious, but even here the most optimistic scenarios only register a flow into the Shatt al-Arab of about 9,500 to 10,500 MCM when all the irrigation schemes are in operation (Kolars 1994; Altinbilek 1997).

On the Euphrates, both Kolars and Kliot suggest a maximum water demand in Turkey of around 21,500 MCM each year when all the irrigation projects are commissioned (Table 1).

This seems a very high figure when it is remembered that the planned irrigation area on the Euphrates only amounts to 1,083,000 ha. With the water volume quoted this would seem to imply a water usage rate of 19,853 cubic m per hectare or a much larger area under irrigation. A more realistic calculation would seem to be a figure of about 10,000 m^3/ha, giving a total water demand figure of 10,830 MCM. Even if an irrigation tariff of 12,000 m^3/ha was used, a maximum demand of only 12,996 MCM is reached. On top of this there are, of course, evaporation losses from the major dams along the Euphrates which amount to 1083 MCM. This gives a total of between 11,913 and 14,079 MCM, which is reasonably close to the figure quoted by Altinbilek (Table 2).

For Syria, Kolars quotes a water demand of 11,995 MCM and Kliot, 13,400 MCM, while Altinbilek gives a total of only 5,500 MCM. Here the situation is much more difficult to assess, because everything depends on the size of the irrigated area which is eventually developed by Syria. It would seem that the total figure will be between 475,000 and 1,000,000 ha when all projects are completed. However, at the moment, it is difficult to be any more precise than this as the Syrian government has been extremely slow to begin the schemes which were planned more than 20 years ago. Annual water demands for these irrigated regions would be 4,750 MCM (for the lower value of 10,000 m^3/ha) to 12,000 MCM (for the higher value of 12,000 m^3/ha). On top of this evaporation from the reservoirs along the Euphrates is 630 MCM each year (Table 2).

The question of water demand in Iraq becomes something of a theoretical concept. If Turkey and Syria extract the maximum expected volumes of water from the Euphrates, the discharge into Iraq will be reduced to around 5,000 MCM each year. Evidence suggests that even in the 1960s Iraq was extracting 16,368 MCM between Hit and Hindiyah to irrigate around 1,230,000 ha (Ubell 1971). It is also known that considerable irrigation was taking place downstream

Table 1 Potential water demand on the Euphrates after the year 2020 in MCM/y.

Country	Kolars	Kliot	Altinbilek
Turkey	21,600	21,500	14,500
Syria	11,995	13,400	5,500
Iraq	17,000	16,000	15,500
Total demand	50,595	50,900	35,500
Available water	32,720	31,000	31,680
Balance	-17,875	-19,900	-3,820

(Kolars 1994; Kliot 1994; Altinbeck 1997)

Table 2 Revised water demand estimates for the Euphrates basin for the period after the year 2020 in MCM/y (author's estimates). (Note: for Syria and Turkey the minimum irrigated area values are calculated using a minimum water tariff of 10,000 m^3/ha and the maximum area values with a tariff of 12,000 m^3/ha. For Iraq the water tariffs used are 13,300 m^3/ha and 15,000 m^3/ha respectively.)

Country	Irrigation Water Use	Evaporation	Total
Turkey	10,830-13,000	1,100	12,000 -14,000
Syria	4,750-12,500	630	5,400 -12,600
Iraq	24,400-27,500	600	25,000 - 28,100
		Total demand	42,300 - 54,800
		Available water	31,800
		Balance	-10,500 to 23,000

from Hindiyah at this time, though exact amounts are unknown. Altinbilek (1997) states that in 1970 only 400,000 ha were being irrigated along the Euphrates and 800,000 ha along the Tigris. However, these figures would seem to be incorrect. McLachlan (1985) states that the irrigated area in Iraq in 1970 was 3,680,000 ha. The vast majority of this would be located in the Tigris-Euphrates basin. Kliot quotes figures from the late 1980s and early 1990s which estimate the actual irrigated area along the Euphrates River in Iraq as 1.0 to 1.29 million ha. It is, however, acknowledged that at this time the irrigated area had been reduced as a result of the Iran-Iraq war of the 1980s. The total area on the Euphrates which can be irrigated is thought to be 1,833,000 ha (Kliot 1994). If this is a realistic figure it means that total water demand at some time in the future could rise to 24,379 MCM/y with an irrigation rate of 13,300 cubic metre/hectare. For a rate of 15,000 cubic m per hectare the total demand would rise to 27,495 MCM (Table 2). Table 2 clearly shows that the potential water deficit on the Euphrates River after the year 2020 might be as high as from 10,500 to 23,000 MCM each year. Since there will be enough water in the river to satisfy the full needs of both Turkey and Syria, it will be Iraq which will be least able to satisfy its potential needs.

On the Tigris the overall situation is similar. There is general agreement that water demand for Turkey will be between 6,700 and 8,000 MCM each year (Table 3). The calculations of the present author suggest that the likely water demand for the planned irrigation of 558,000 ha will be between 5,580 and 6,696 MCM/y (Table 4). Evaporation from a total of nine proposed reservoirs, with a total surface area of 693 km^2 is likely to add a further 624 MCM to the demand. This is based on an evaporation rate in these upland valleys of 900 mm/y.

Syria's use of water from the Tigris remains something of an enigma. It would be possible to divert water from the Tigris and pump it into the upper Khabur. However, without the active support of Turkey it would only be possible to obtain significant quantities of water during the high flow period. What is certain, though, is that Syria's demand for water to be used within the catchment of the River Tigris itself will be small as it does not have access to suitable land.

Potential water demand in Iraq is high with estimates from 29,200 to 40,000 MCM/y (Table 3). As with the Euphrates, it is exceedingly difficult to obtain accurate statistics as to the area of irrigated land. Kliot quotes a figure of 2 million ha being irrigated in the Tigris basin in the late 1980s and a total irrigable area of between 2.8 and 4 million ha (Kliot 1994). If these figures are correct, potential water demand could rise to values of between 37,240 and 60,000 MCM/y based on water tariff figures of 13,300 to 15,000 m^3/ha (Table 4). Prediction of maximum evaporation losses for all the reservoirs in Iraq is difficult to calculate owing to the lack of data, but will be at least 1,000 MCM/y. Taking these figures for the Tigris as a whole suggests a surplus of around 8,000 MCM/y for the lowest figures, but a deficit of over 15,500 MCM/y if the higher values are utilized (Table 4).

If the newly calculated water demand data for the Euphrates and Tigris Rivers are summed, they provide an estimate of the overall balance for the basin in the period after 2020 (Tables 2 and 4). The minimum data estimates point to a possible water deficit of 2,233 MCM /y. However, the maximum values reveal a huge potential deficit of 38,641 MCM. This, it will be noted, is greater than the average flow of the Euphrates River.

WATER QUALITY AND ENVIRONMENTAL / RESOURCE ISSUES

In all the water management projects which have been planned to date for the Tigris-Euphrates basin, the emphasis has been on water volumes, with relatively little consideration being given to water quality. In general, the natural water quality of the Tigris-Euphrates basin is high, especially during the spring/early summer snow-melt period. Within the next decade or so it is possible that water quality along the mainstreams of the Tigris and the Euphrates might change significantly for the worse. The main problem is that, with most of the diverted water being used for irrigation, there is a potentially serious problem with regard to the quality of the irrigation return waters. In general about 20% of the water which is applied in irrigation drains off the fields and makes its way into adjacent water courses or percolates downwards to the water table. From here this water will eventually drain back into stream and river systems.

This water will carry with it a wide range of dissolved chemicals. Some of these will be naturally occurring, including various salts

Table 3 Water demand and water availability on the Tigris in the period after 2020. MCM/annum. (Kolars 1994; Kliot 1994; Altinbilek 1997).

Country	Kolars	Kliot	Altinbilek
Turkey	6,700	7,200	8,000
Syria	0	500	0
Iraq	29,200	40,000	31,900
Total demand	38,700	47,700	39,900
Available water	49,200	48,000-52,600	49,570
Balance	10,500	300-4,900	9,670

which are present in dryland soils. However, these waters will also pick up a wide range of chemicals, including pesticides, herbicides and petroleum products which are associated with modern agricultural practices. The net result is that the quality of any receiving waters can be severely affected by these irrigation return waters. What is difficult, however, is to be able to predict just how severe an effect will be generated, as this depends so much on local environmental conditions and the actual agricultural practices which are being utilised. On the Euphrates it is possible to identify two rivers which will carry most of the return waters from the Turkish irrigation projects. These are the Rivers Balikh and Khabur. On these rivers, estimates suggest that flows are likely to increase significantly as a result of the addition of irrigation return waters. This will be of especial significance on the Balikh River, which has a low annual discharge. Estimates here suggest that when all the Turkish and Syrian irrigation projects are in operation, the flow of the river might increase up to 3.5 times its normal flow as a result of the impact of irrigation return waters (Beaumont 1996). Just what the impact of these waters will be on the quality of the mainstream of the Euphrates is unknown, but it might well be considerable during the low summer flow period.

In all the water management projects which have been planned to date for the Tigris-Euphrates basin, the emphasis has been on water volumes, with relatively little consideration being given to water quality.

Water management projects, wherever they are located, will also have an impact on the overall ecology of the river. The most important changes will be in terms of the regime of the river as well as on water volume. With all the storage facilities now located in the upper part of the basin of the two rivers, the snowmelt peaks, which were such characteristic features of the two rivers, have been greatly reduced. This is particularly the case on the Euphrates River. The effect of this will probably be greatest in the lower part of the basin in the wetlands of the Shatt el-Arab, where the whole ecology of the marshes has evolved in response to these snow-melt peaks. With the attenuation of these peaks, together with the much lower overall flows which the marshes will be receiving, the impact on the natural

Table 4 Revised water demand figures for the Tigris River for the period after the year 2020 in MCM/year (author's estimates). (Note: For Turkey the minimum irrigated area values are calculated using a minimum water tariff of 10,000 m^3/ha and the maximum area values with a tariff of 12,000 m^3/ha. For Iraq the water tariffs used are 13,300 m^3/ha and 15,000 m^3/ha respectively.)

Country	Irrigation Water Use	Evaporation	Total
Turkey	5,600-6,700	630	6,200-7,300
Syria	0	0	0
Iraq	37,200-60,000	1,000	38,200-61,000
Total demand	44,400-68,300		
Available water	52,700		
Balance	+8,200 to -15,700		

environment will be considerable. The future survival of the marshes must, therefore, be put in question merely as a result of the changes which have occurred, or are likely to occur, in the upper parts of the basin in Turkey, Syria and Iraq. However, there are other more local pressures which the marshes have to face as well. These concern the large drainage canals which the Iraqi government has decided to build through the marshlands of southern Iraq. When fully completed these channels will carry the water from the two rivers through the marsh regions much more rapidly and lead to further dewatering of these wetland regions.

Given the political standing of Saddam Hussein in the West it is not surprising that many Western commentators have placed all the blame on Iraq for the potential disruption of the ecology of the marshes of the Shatt al-Arab. This is, however, a rather extreme view of the situation as the future of the marshes has already been threatened by the major new irrigation works in the upper part of the basin. In reality, the Iraqi actions have merely exacerbated what was already a critical situation. It also has to be recognized that attitudes to the draining of wetlands have changed markedly in the relatively recent past. When the Israelis drained the Huleh Marshes in the 1950s, it was regarded at the time as a great feat of human ingenuity in converting a marshy "wasteland" into productive agricultural land. When the Iraqis undertook the same operation in the 1990s current convention wisdom accuses them of ecological devastation.

There is no doubt that the marshes of the Shatt el-Arab represent one of the world's great wetlands and that the drainage of this ecosystem will destroy a rare environment. However, the Iraqis will claim that valuable agricultural land can be produced from the marshes. While it is likely that high quality agricultural land can be created, the question has to be posed as to where the water to irri-

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gate this new land will come from. There is also concern that at least part of the Iraqi government's reason for draining the marshes is to exercise greater political control over the inhabitants of this highly inaccessible landscape rather than to produce more food for its people.

All three countries of the basin are suffering from the effects of continued population growth, which will greatly increase the pressure on available resources (see Winkler, this volume). Although it is true that the populations of the three countries do not all dwell within the basins of the Tigris-Euphrates, there can be no doubt that the impact of this growth will be felt there. The population growth rates experienced by all three countries during this century have been remarkable (Table 5). From the 1940s to the present day their populations have increased by between three to five-fold, and between 1995 and 2025, in the cases of Iraq and Syria, they look likely to more than double again. Even in Turkey a more than fifty percent growth rate is postulated.

While it is likely that high quality agricultural land can be created, the question has to be posed as to where the water to irrigate this new land will come from. There is also concern that at least part of the Iraqi government's reason for draining the marshes is to exercise greater political control over the inhabitants of this highly inaccessible landscape rather than to produce more food for its people.

Besides population increases, there are also increases in the standards of living of the populations. In turn this means that water usage in an urban/industrial context is likely to go up also. Although the increases are high in percentage terms, the actual water volumes remain low when compared with the predicted irrigation demands. Even so, obtaining sufficient water for some of the rapidly growing cities may begin to cause problems.

This leads us to the question of whether water in the twenty-first century can continue to be used for irrigation purposes in dryland regions (Beaumont 1994; 1997). The issues are water availability and maximum economic productivity. There is no doubt that if water is available at zero cost, as is the case with water in most rivers in the Middle East, then it will be used by local farmers for irrigation purposes. This is, indeed, the basis of traditional agriculture throughout the region and it is often the only way available for the peoples of the area to farm. In the future, however, with continued increases of pressure on available water resources, many governments will be forced to cut back the volumes of water allocated to irrigated agriculture in an attempt to ensure that the urban/industrial regions receive all the water they need for continued growth. It is important

Table 5 Populations in millions. (Population Reference Bureau, 1995)

Country	1940s	1960s	1972	1995	2025
Turkey	17.8	27.7	37.6	61.4	95.6
Syria	2.5	4.4	6.6	14.7	33.5
Iraq	4.1	6.7	10.4	20.6	52.6

to realize that this urban/industrial demand is relatively small when compared with irrigation needs and should be able to be easily met from available resources (Beaumont 1997).

CONCLUSION: THE QUEST FOR MAXIMUM WATER PRODUCTIVITY

It is possible to recognize in the Tigris-Euphrates basins evidence of water management strategies stretching over more than six millennia. However, the length of time of operation of the different systems varies enormously. The system which lasted the longest was one which can be described as manipulation of the flood waves of the two rivers. With this method, the water volumes provided by the rivers were accepted as fixed and the management strategy consisted of utilizing a relatively small proportion of the spring and early summer flood-melt waves for irrigation purposes in the lower part of the basin. In some years, the diversion works were overwhelmed by the sheer magnitude of the floods, while in other years there was insufficient water to irrigate all the land that it had been intended to cultivate. This strategy was utilized from about six thousand years ago when irrigation first began in the Tigris-Euphrates lowlands up to the opening of the Keban Dam in the 1960s.

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The second stage began in the 1960s with the creation of significant water storage capacity behind dams in the upland parts of the two catchments. For the first time, there was an attempt to store water from the time it was generated by nature to the time it was needed by human societies. At first the storage capacity was small, but with time, as more dams were completed, the total volume of water in storage has grown. By the time the South-eastern Anatolia project in Turkey is completed in the early years of the twenty-first century, total water storage capacity in Turkey alone will be in excess of the annual flow of the two rivers within its boundaries.

Through the forty year period, from 1960 to the end of the twentieth century, there has also been a change from excess water availability to a situation in which there may not be enough water to meet the planned requirements of the riparian countries. From the year 2000 onwards we can foresee a new phase in water management, characterized by growing water shortages. This pressure on the available water resources will be compounded by major declines in water quality along the mainstreams of the Tigris and Euphrates Rivers as more and more irrigation projects are opened in the upper parts of the basin. Just how severe this decline in water quality will be and its impact on other water users is impossible to estimate at the present time.

With continued population growth, increasing attention will be focused on the feasibility of using irrigation water to produce food crops. It is certainly possible that during the early decades of the twenty-first century there might well be a decrease in irrigated agriculture throughout the basin as increasing volumes of water are transferred to economically more productive uses in urban/industrial environments.

In effect, the twentieth century has seen a restructuring of water use in the basin of the Tigris-Euphrates. Although the main elements of the new management strategy are already in place, in terms of the major dams and reservoirs, the full impact of these changes will not be realized for at least another decade. Inevitably the restructuring of water usage will have economic and social impacts as well, which will be painful for the local inhabitants. In the lower part of the basin, rural areas will not be able to sustain the same high level of population that has been the case in the past. This might suggest that rural depopulation will increase, putting further pressures on the already crowded urban centers. By contrast, both rural and urban populations seem bound to increase in the upper part of the basin in Turkey, as economic opportunities grow hand in hand with the expansion of irrigated areas which have previously not been cultivated in any widespread manner.

In effect, the twentieth century has seen a restructuring of water use in the basin of the Tigris-Euphrates. Although the main elements of the new management strategy are already in place, in terms of the major dams and reservoirs, the full impact of these changes will not be realized for at least another decade.

The next stage in water management in the Tigris-Euphrates basin is likely to concern adjustments with a new emphasis on the value of water. The critical factor is likely to be the maximum economic productivity which can be achieved from the utilization of a cubic meter of water. Just how quickly this approach will permeate the basin will depend on the pressure put on the water resource base and how individual governments will react. In Turkey, considerable political and financial resources have already been committed to agricultural development. However, it will be interesting to see if there is a change in cropping patterns within the basin with less emphasis being placed on the lower value crops such as wheat and barley. Under the proposed irrigation schedules for the Southeastern Anatolia Project, wheat is planned to account for 25% of the irrigated area, and barley and other feed grains a further 15% (Altinbilek 1997). A relatively small cut-back in these figures would release large quantities of water which could be utilized for other purposes, including hydroelectric power.

A similar change will probably also occur in Iraq. In the short-term it seems inevitable that there will be land abandonment along the Euphrates as Turkey's use of the Euphrates increases. 1995 was the year when the first water for irrigation purposes was sent through the Urfa tunnels in Turkey from the lake behind the

Ataturk Dam, and over the next decade the volume of water utilized for such purposes seems set to increase rapidly. Iraq will, therefore, have to come to terms quickly with a changing situation in which available water amounts along the Euphrates will steadily decline. However, Iraq is fortunate in possessing large oil reserves, which means that it should be able to substitute money for water and so obtain the food it needs by the purchase of crops on the world market (see Allan, this volume).

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