Groundwater Management in Saudi Arabia

Draft Synthesis Report

Food and Agriculture Organization of the United Nations

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1 Background

• Figure 1 Saudi Arabia

The Kingdom of Saudi Arabia has a land area of about 2.15 million km^2 and is the largest country in the Arabian Peninsula. It is bordered in the north by Jordan, Iraq, and Kuwait, in the east by the Persian Gulf, in the southeast and south by Qatar, the United Arab Emirates, Oman, and Yemen, and in the west by the Red Sea.

Geographically the country is dominated by arid desert. A mountain range runs along the western side of the country and separates the desert from the Red Sea coastal region, some 65 km wide, where much of the population live. In the east the coast line overlooks the Persian Gulf which is much wider than in the west and includes a region of oases.

The climate is dominantly arid with a semi-arid climate along the Red Sea coast. There are no perennial rivers in the Kingdom. Some surface water resources are available in the south east where annual rainfall is about 300mm between October and March. But elsewhere rainfall is low and erratic – about 100-150 mm/yr which is sufficient to sustain forage growth. But some regions may have no rainfall at all for several years. In the south eastern sand desert – known as the Empty Quarter – ten years may pass without rain.

The total population in 2005 was 24.6 million – of which 76 percent were Saudi nationals. Some 80 percent live in the towns and cities. Between 2000 and 2005 the annual population growth rate was 2.7 percent. In 2006, 97 percent of the urban population had access to improved water sources and the whole urban population had access to improved sanitation.

The national economy is dominated by oil but Saudi Arabia has always attached high importance to agriculture and food security even though environmental conditions are not ideal. At present agriculture contributes 3 percent of GDP mainly from an irrigated area of 1.73 million ha where cereals, fodder, dates, and some vegetables are grown. Fossil groundwater is the main source of water for irrigation. Some 600,000 people are estimated to be economically active in agriculture.

2 Water resources and water use

Renewable surface water and groundwater resources together with an assessment of water withdrawal are summarized from the FAO AQUASTAT database in Table 1.

Surface water runoff occurs mainly in the west of the country with some in the far south along the western coast. It is estimated at 2,200 MCM/yr, most of which infiltrates to recharge shallow aquifers. So although the renewable groundwater is 2,200 MCM/yr there is an overlap with surface water of 2,000 MCM which means the total renewable resource available is only 2,400 MCM/yr.

• Table 1 Annual water resources and water use in Saudi Arabia (from FAO AQUASTAT 2000)

Resource	**Renewable**
Surface water (MCM)	2,200
Groundwater (MCM)	2,200
Overlap (between sw and gw)	-2,000
Total (MCM)	2,400
Dam capacity (MCM)	99
Total/capita (CM)	97
Withdrawals	
By sector	
Agriculture (MCM)	20,800
Domestic (MCM)	2,130
Industry (MCM)	710
Total withdrawals (MCM)	23,640
Water withdrawal/capita (CM)	960
By source	
Surface water (MCM)	1,100
Groundwater (MCM)	21,400

Saudi Arabia is the largest producer of desalinated water in the world. In 2004 the volume of water supplied by the country's 30 government-operated desalination plants reached 1,100 MCM. By 2009, new plants will add an additional 580 MCM/yr. Desalinated water is used only for domestic and industrial purposes and is one of the possible substitutes for groundwater.

During the last two decades, there has been comprehensive development in all sectors together with increases in population and living standards. The annual national water demand has increased from 2,352 MCM in 1980 to more than 20,000 MCM in 2004 (Table 2). Irrigated agriculture consumes 88 percent of the water with domestic demand taking 9 percent and industry 3 percent. The boom in desert agriculture in the 1980s resulted in a rapid rise in water use to a point were agricultural consumption is about 10 times greater than the renewable water resources. The deficit is being met from fossil groundwater reserves but falling groundwater levels are now causing serious concerns.

• Table 2 Water use in Saudi Arabia (MCM/yr)

	Domestic &industry	**% of total**	**Agriculture**	**% of total**	**Total**
1980	502	21.3	1,850	78.7	2,352
1990	1,650	6.06	25,589	93.94	27,239
1997	2,063	11.17	16,406	88.83	18,469
1999	2,200	10.61	18,540	89.39	20,740
2004	2,740	13.52	17,530	86.48	20,270
2009	3,170	17.36	15,090	82.64	18,260

Source: Country Report

3 Groundwater supply and demand

3.1 Fossil aquifers

The main source of groundwater comes from six major consolidated sedimentary old-age aquifers located in the eastern and central parts of the country known as the Arabian Shelf. This is fossil groundwater, formed some 20,000 years ago, and is confined in sand and limestone formations about 300m thick at depths between 150–1,500 m. The natural recharge of these aquifers is negligible. According to the Water Atlas of Saudi Arabia there are 253,000 MCM of proven reserves with estimates up to 700,000 MCM of possible reserves. However, estimates of water stored and what is economically available to use are open to question and some sources suggest the exploitable fossil water could be as much as 2,000 MCM down to a depth of 300m. Table 3 shows the Ministry of Water and Environment's (MOWE) data and storage estimates for the six major aquifers. Ongoing resource assessments are expected to provide more reliable estimates of storage and what can be abstracted. One of the country's most valuable groundwater reserves is the Saq sanstone aquifer which extends across 300,000km^2 from Jordan in the north to the east and south of Saudi Arabia.

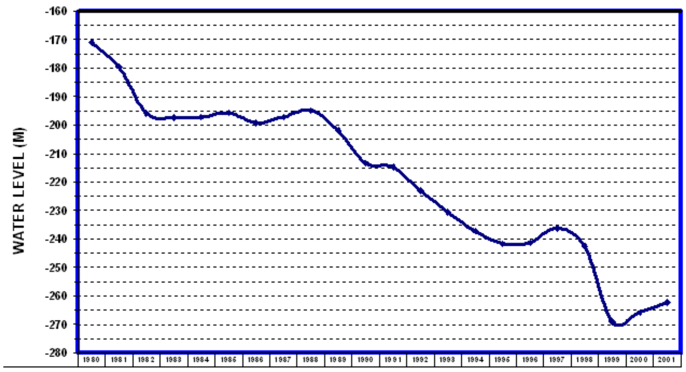
• Table 3 Major fossil water aquifers in Saudi Arabia

Aquifer	**Storage (MCM)**	**Available (MCM)**	**Area (km^2)**	**Thickness (m)**	**Fall in water table (1981-02)**	**Comments**
Saq sandstone	258,400	103,360	300,000	400-1200	16-76	Largest aquifer. High potential for development
Wajid sandstone	237,500	95,000	170,000	200-900	-	Only limited geological understanding
Tabuk (Tawil)	109,800	43920	~142,000	500-950	34	Upper unit of three sandstones separated by aquitards/aquicludes
Jawf limestones & sandstones	74,000	38,480	~85,000	~ 400	-	The indicated surface area includes the Sakakah aquifer
Minjur sandstones	171,300	111,340	~48,000	400	80-85	The indicated surface area includes the Dhruma aquifer
Wasia/Biyadh/Sakah sandstones	66,600	33,300		600	-	Largest system in the Kingdom after the Saq
Umm er Raduma limestone	6,000	3,000		300-700	52-97	Lack of understanding of many physical parameters
Total	**923,600**	**428,400**				

Source: Country Report

3.2 Falling groundwater levels

Table 3 also provides an indication of the fall in groundwater levels in fossil aquifers due to the significant levels of withdrawals, mainly for agriculture. A typical example is the Al Hassa Oasis in the eastern province which draws on fossil water. Until the late 1970s some 35 natural springs supplied the oasis and farmers used traditional irrigation practices to grow crops. To support the rapid expansion of commercial agriculture, tube



• Figure 2 Fall in groundwater level in Riaydh area

wells were drilled in the oasis and by the mid 1980s the natural springs had dried up. The wells, which were originally artesian, now have water levels some 40-60m below ground level – an average fall of 4m/yr.

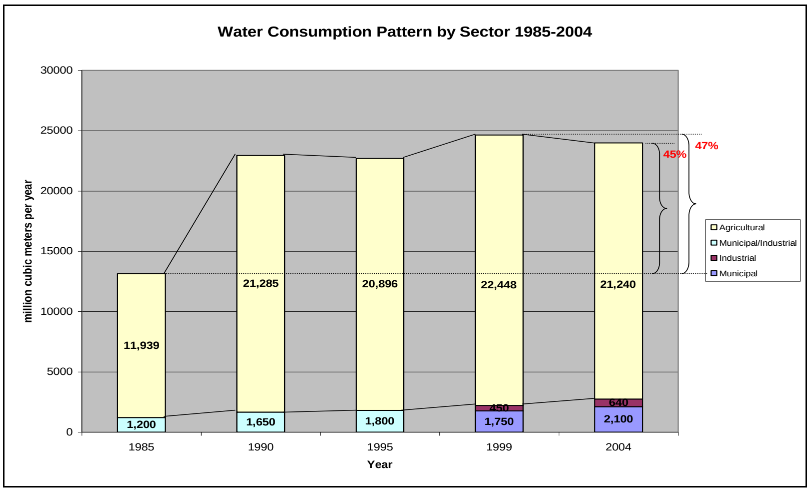
3.3 Renewable groundwater

Saudi Arabia also has about 2,200 MCM annually renewable groundwater which is stored in more than twenty layered principal and secondary aquifers of different geological ages. These are recharged by rainfall and runoff water flow in the wadis in the areas of higher rainfall in the west and south west along the coastal region. Efforts have been made to enhance recharge by constructing dams to slow surface flows and encourage infiltration. The dams also have the benefit of storing water for irrigation and this has played a fundamental role in settling Bedouins in their normal environment by enabling them to take up more stable farming activities. However, this water is very vulnerable to droughts which can last several years in places.

Renewable groundwater resources are also being over-exploited particularly those in the west of the country. Abstraction has far exceeded the safe yield of these smaller aquifers and the groundwater table is falling in important wadis such as Wadi Fatimah and Wadi Numan in the Makka area. The authorities are now turning to desalination for municipal water needs as a more dependable, but more expensive, source of supply.

4 Drivers for change

Over the past two decades, water consumption patterns in the Kingdom have changed dramatically (Figure 3) with most of the additional water coming from non-renewable groundwater resources. This is now well recognised as unsustainable and was the result of a policy aimed at achieving 'food security' rather than 'water security'.



• Figure 3 Water use by sector from 1985-2004 (source: Country Report)

4.1 Water supply and sanitation

Household water use has grown steadily – 4-5 percent annually – in line with population growth. Industrial water use increased by more than 8 percent from 2000-2004. Households and industry together use about 9 percent of water in the Kingdom.

Domestic and industrial water use is largely un-metered but estimated capita water use across the country now ranges from 200-240 l/day. However, water use is much higher among urban populations which are concentrated in three administrative regions – Riyadh,

Mekkah, and the Eastern Region. Some reports suggest capita water use as high as 800 l/day. This may be inaccurate but generally water use in urban areas appears high compared to international standards of 150-200 l/day. With the population expected to reach 27 million by 2010 and increasing at 2.5 percent, domestic water demand is also expected to grow.

4.2 Agriculture

In 1975 water consumption in agriculture was less than 2,000 MCM/yr but this has now increased substantially. By 1985 it had reached over 11,000 MCM/yr and this almost doubled to over 21,000 MCM/yr by 1990. Data in Table 4 shows the growth in irrigated area and the contribution from renewable and non-renewable sources. Although there are some discrepancies in the data when compared to Figure 3 they demonstrate the trend in consumption. This rapid increase in consumption was the result of the incentives provided by the government to increase agricultural production. Consumption peaked in 1999 and has since fallen slightly following the introduction of measures to curb demand. But the overall effect of this has been limited.

• Table 4 Evolution of water consumption for irrigation

Year	Irrigated area (ha)	Non-renewable Groundwater (MCM)	Renewable Water (MCM)	Total water consumption (MCM)
1980	437,177	3,199	4 273	7,472
1985	946,395	8,503	3104	11,607
1990	1,379,154	11,230	5 283	16,513
1994	1,595,546	14,224	5 941	20,165
1995	1,302,363	12,539	6 549	19,099
1999	Not available	Not available	Not available	18,303
2004	Not available	Not available	Not available	18,000

Source: Country Report

Even though climate conditions are not well suited to major crop production, Saudi Arabia has always attached high importance to the agricultural sector and it has been given priority in the various development plans. The agricultural sector is dominated by large farming companies ranging from a few hundred hectares up to several thousand hectares, mostly located in areas with good quality groundwater aquifers. With few exceptions they are all equipped with modern irrigation systems (MIS) and run as commercial enterprises but this does not necessarily mean they irrigate efficiently. Many farms were established with no prior investigation of water availability, no data are available on water use, and many are thought to be profligate with little consideration for water saving. In some cases a lack of planning and management of water supplies has led to aquifer depletion and farms being abandoned as uneconomic.

The agricultural sector is expected to achieve the goals of economic development which include food security, diversifying the production base, and minimizing the reliance on oil petroleum as the main source of national income. The government provided support and encouragement for the private sector to invest in agriculture including subsidies, interest-free loans, free distribution of uncultivated land, and unrestricted access to groundwater. In addition the government provided the infrastructure – roads, dams, irrigation and drainage systems, and extension services. All this led to the achievement of self-sufficiency in some important food crops such as wheat, dates, table eggs, fresh milk, and some vegetable products.

But this was all built on the use of significant amounts of fossil groundwater – hence the rapid rise in water consumption to current levels of over 20,000 MCM/yr, although in

recent years it has started to fall as government introduced measures to curb agricultural demand. Corrective policies were introduced to reduce water consumption and wastage, subsidies were reduced, and there was a moratorium on granting new agricultural lands. However, the decline has not been enough and major agricultural activities continue to put pressure on water resources. Many old springs and shallow aquifers have dried up in the course of the past 20 years and some commercial farms have seen groundwater levels fall by more than 200m. This situation, compounded by the low value of the crops grown, has forced several commercial operations to abandon their farming activities completely even though the cost of energy for pumping is heavily subsidized.

Because agricultural development receives good support it transfers pressure onto other water users. Urban users now rely more on desalinated water even though most are close to or lie directly above sufficient groundwater reserves to meet their domestic needs at a much lower cost.

The root of the problem is still the economic signals given to farmers. Even in the arid regions where the opportunity cost of water is substantial, farmers will continue to produce water-intensive crops if the farm-level price or availability of water does not reflect its scarcity value. Since 2000 the government has been reducing subsidies and encouraging farmers to reduce water use by subsidizing fruit tree seedlings to promote fruit crops to replace cereal crops. But this will put pressure again on groundwater when trees mature. The government is also reducing the quantity of wheat it purchases in-country and banning farmers from exporting wheat and forage.

Clearly the current situation is not sustainable in the long term not just in terms of water availability but also in the considerable cost to the government budget, which is subsidizing the energy cost of pumping, and the lack of a legal, regulatory and institutional framework for efficiently managing water resources.

4.3 Environment

One of the consequences of profligate water use in and around the main cities is that shallow water tables have been rising for the past 20 years or so. Excessive water use for domestic and amenity irrigation and leakage from both water supply and sewerage systems, and the lack of surface water drainage have all added to this localized but important problem. The increase in water use has led to excessive amounts of wastewater which is now leading to problems of pollution which in turn is impacting public health and living standards.

Little is known about groundwater quality and groundwater pollution in the country. But there are concerns that in many aquifers, including the deep fossil groundwater, water does not meet standards set for potable use and in some cases salinity makes it even unacceptable for agriculture. In the Al Hassa region for example, salinization of land has reduced the irrigable area from 16,000 ha to around 8,000 ha. Excessive use of groundwater has led to saline intrusion in many coastal aquifers along the east coast.

Accelerating household demand for water led to an increase in sewage effluent which was usually disposed of in the sea or the nearest valley. But water scarcity is changing this approach to one of treatment and potential use in agriculture and industry. Some 5 million people now have established treatment works and others are being planned.

5 Groundwater management

5.1 Institutions governing groundwater

In 2001 a Ministry of Water was created to contain part of the Ministry of Municipal and Rural Affairs (MOMRA) and part of the former Ministry of Agriculture and Water (MOAW). This new ministry was responsible for supervising the water sector, developing water related policies, and setting up mechanisms and instruments aimed at managing the water resources and water services delivery in an efficient and sustainable way. In 2004 the Ministry of Water also became responsible for the electricity sector and was restructured as the Ministry of Water and Electricity (MOWE) in order to ensure optimum coordination between the development of water desalination and electricity production.

MOWE has two main water programmes – water resources development, which includes all activities related to geological and hydrological studies, wastewater reuse investigations, well drilling and dam construction, and the preparation of the national water plan; and drinking water supply. Although MOWE deal with the water resources aspects of irrigation, the Ministry of Agriculture (MOA), in 2005, created the General Administration of Irrigation Affairs (GAIA) to be responsible for organizing, planning, monitoring, developing, operating, and maintaining irrigation and drainage projects. The functions of the MOA do overlap with those of MOWE, since agriculture is by far the main water user in the country and the main cause of aquifer depletion. There is also some overlap between the two Ministries in the area of wastewater reuse.

This lack of clarity of ministerial objectives and responsibilities and the presence of many players in the area of water resource management can lead to less effective planning, implementation delays, and increased costs. The existence of multiple staff at various agencies with similar skills precludes attaining a critical threshold for hiring not just technical staff but also staff trained in areas hitherto neglected such as pollution control, legal, economic, social science, and management. However, the establishment of the MOWE is a step towards streamlining water resources management in the country.

5.2 The regulatory framework

Comprehensive regulations are now in force to protect and conserve water resources and they set out the responsibilities of the various institutions involved in water management. But despite the existence of regulations and decrees to control excessive groundwater use, the government has had limited success. Enforcement capacity is weak. Limited capacity and the widespread nature of groundwater abstraction make monitoring extremely difficult and costly.

5.3 Development of human resources

In addition to strengthening the institutional structures there is progress in developing human resources which are essential to provide the sector with enough skilled personnel for water sector management, and to execute the water policies effectively. A number of colleges and departments within universities have been established to satisfy the demand for water professionals and technicians across the water sector.

5.4 Economic instruments

There is no pricing for water for agricultural purposes. Once a borehole has been drilled, the owner has the right to produce water at his own cost with no tariffs being collected by the water authorities.

One of the major steps implemented by Ministry of Water and Electricity is privatization. This reform will include water pricing, efficiency improvement, water adequacy and equity enhancement.

Domestic tariffs were introduced in 1994 to enhance people's awareness of the value of water. The tariff varies between US$0.027-1.0/CM depending on the amount of water being used. But this is only a small fraction of the actual cost of water production and transportation and does little to provide incentives to conserve water. There are no charges for wastewater treatment and disposal.

5.5 Trans-boundary aquifer management

Saudi Arabia shares aquifers with other countries around it. It is estimated that a total of 394 MCM/yr flows from aquifers from Saudi Arabia to Jordan (180 MCM/yr), Bahrain (112 MCM/yr), Iraq (80 MCM/yr), Kuwait (20 MCM/yr), and Qatar (2 MCM/yr).

The Saq al-Disi aquifer is the most significant shared aquifer at the moment. It is a deep sandstone fossil aquifer 320 km long that lies mostly underneath Saudi Arabia and stretches across into Jordan. Both Jordan and Saudi Arabia started pumping from the aquifer in the 1980s and a treaty exists between the two countries for Jordan to take 20 MCM/yr. The impact of al-Disi on the economies of Jordan and Saudi Arabia is substantial and could well be a source of tension in the future. Jordan is already taking 180 MCM/yr, which is more than agreed, and has accused Saudi Arabia of misusing the aquifer because of the large withdrawals made to support cereal production. In order to sustain the existing level of use Saudi Arabia may be willing to use its trade advantages to influence Jordan at the bargaining table.

6 Future perspective

Water resource management in Saudi Arabia differs from most other countries in a number of ways. It relies heavily not just on groundwater but also on desalination, it has oil wealth and so provides water almost for free, and there is as yet no separation between the institutions charged with policy and regulation, and providing services. Also despite massive investments in the water sector substantial inequities still remain and there are serious weakness in institutional capacity and governance.

However, the water sector is seen as holding great potential for development and growth and it is expected that more than US$200 billion will be invested over the next 20 years on water and power projects, especially in water treatment plants, sewage plants, and desalination projects. The government is also taking steps to improve the water sector's regulatory framework and pave the way for privatization, especially in power and water desalination projects. As part of the privatization drive, the government is reassessing water tariffs and is developing a national water plan to encourage foreign investments in water projects. The Saline Water Conversion Corporation (SWCC) has signed contracts with legal, strategic, financial, and technical advisers to develop a comprehensive plan for the privatization of the state-owned water company with a deadline for completion as early as 2008. The creation of a National Water Company (NWC) would also separate service provision from policy and regulation under MOWE.

The most urgent need is to increase domestic water capacity in order to keep up with a growing population and the trend towards urbanization. With a population growing at an average annual rate of 2.5 percent, the government faces a major challenge in meeting the water needs of its burgeoning population over the next 20 years. This is expected to reach 9.6 MCM/day by 2030, some 3,500 MCM/yr. The intention is to expand the desalination capacity from its present level of 1,300 MCM/yr to 3,500 MCM/yr by 2020.

Most 5-year development plans include water sector strategies that address water conservation measures such as improving irrigation efficiency, decreasing demand in the agricultural sector, monitoring and protecting groundwater resources, and supply augmentation through desalination.

Agriculture, as the largest consumer of water still has poor water productivity. The MOA is developing a new agriculture strategy geared towards greater macro-economic development of the sector, while sustaining the base resources and increasing water productivity. But as water consumption is more than 10 times the renewable groundwater resource, it will take more than adjustment at the edges to resolve the imbalance between supply and demand. Demand is satisfied from fossil water at present but for how long? Desalination can play a role by taking domestic and industrial water users away from groundwater but inevitably there will be a need for radical reforms in the country's water strategy to bring the use of renewable and non-renewable water into line with a stable and sustainable future.

Managers will also need a comprehensive water quality and pollution control framework and hydrological and hydro-geological monitoring networks to provide a sound basis for management. This is already in hand in the country's 7th National Plan. Additionally human capacity will also be needed and not just infrastructure.

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