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Water Supply and Demand Modeling for the Jeddah-Makkah-Taif Area, Saudi Arabia: A. Present and Future Water Balance

OMAR S. ABU-RIZAIZA[1],
MOHAMED NASR ALLAM[2] and MOHAMED J. ABDURRAZZAK[3]
[1]*Department of Civil Engineering, King Abdulaziz University, Jeddah, Saudi Arabia*
[2]*Department of Irrigation and Hydraulics, Faculty of Engineering, Cairo University, Cairo, Egypt, and*
[3]*Department of Hydrology and Water Resources Management, Faculty of Meteorology, Environment and Arid Land Agriculture, King Abdulaziz University, Jeddah, Saudi Arabia*

ABSTRACT. The paper discusses the present and future (1985-2010) water demands and the water resources of the Jeddah-Makkah-Taif (JMT) area in the Western Region of Saudi Arabia. Also given are data on water distribution, sewerage systems and capacities of treatment plants. Both the available and the projected amounts of wastewater for reuse are estimated. With these data, water demands are matched against available water resources to show the present water status in a tabular display format of a water balance model. In addition, this paper addresses the impending water crisis if water demand and supply are not brought into balance.

Introduction

The National Development Plans for the Kingdom of Saudi Arabia entail the provision for water of adequate quality to meet public health standards and quantity to provide for the total requirements of the population at large, industry, and agriculture. To achieve these goals, the Fourth Development Plan states the following objectives for water resources: (a) provide sufficient quantities of high quality water to meet the needs of urban and rural populations, (b) secure water supplies to meet industrial development and agricultural expansion, (c) conserve and develop the current water resources efficiently, and (d) seek new water supplies.

Previous surveys (Abu-Rizaiza *et al.*, 1988) have shown the JMT area to be the most water deficient area of the Western Region; Jeddah, Makkah, and Taif are three of the seven large cities in the Kingdom. The JMT area is particularly important because of the Holy Mosque in Makkah, the largest airport and seaport of the Kingdom in Jeddah; and the resort city of Taif. In summer, government offices and thousands of people from Saudi Arabia and the surrounding Arabian Gulf countries move to Taif. The total population of the JMT, area which was 1,139,704 in 1974 (Ministry of Finance, 1975), has increased to an estimated 2,011,000 in 1986 (Abu-Rizaiza *et al.*, 1988). Water demand has increased from 57.0 Mm^3/y to 230.0 Mm^3/y (Ministry of Finance, 1988) during the same period, which is a 4 fold increase in ten years. At the same time, increase on the supply side through seawater desalination and renovated water has been from 7.0 Mm^3/y to around 110.0 Mm^3/y (S.W.C.C., 1987, and Water and Sewage Department, 1987). Development of these additional water supplies, however, has been less than the increase in demand.

The objectives of this paper are to present current and future (1985-2010) water resources data for: (a) water demands for municipal and industrial uses for the cities of Jeddah, Makkah, and Taif, and villages in the JMT area, irrigation use in the major wadis (watersheds) of the area; (b) water resources potential of the area's surface, ground, desalinated, and renovated waters; (c) comparison of the water demands and the water resources potential under present and future conditions using input/output approach; and (d) address the impending water crisis if supply and demand are not brought into balance.

The input-output model is originally an economic system which is divided into a variety of producing and consuming sectors. When listed respectively as rows and columns of a matrix, create the framework of a model. The matrix represents the system, the intersection of the rows and columns indicate the flow of goods and services between two sectors of economy. Similarly, water transfers between the producing and consuming sectors of a water system can be represented as a quantity in the matrix (Hendricks and De Haan, 1975). The fundamental principle of the input-output model is that it has to be mass balanced, in this case water balanced. The total amount of water received (entries) has to equal the total delivered (exits) (Bengoechea, 1979).

Water Demands

Water demands are classified into three categories: municipal; industrial; and irrigation in the major wadis of Fatimah, Khulays, Naaman, Turabah, Liyyah, and Wajj.

Table 1 shows the actual municipal and industrial water usages in the major three cities of Jeddah, Makkah, and Taif and rural villages in the year 1985, which is selected as the base year in this study. Projected demands for the years 2000 and 2010 (Abu-Rizaiza *et al.*, 1988) are also given in Table 1. In addition to the listed industrial use of Jeddah, 38.0 Mm^3/y of seawater are used for cooling water. The irrigation usages in the major wadis of the JMT area in 1985 are given in Table 2 (Abu-Rizaiza *et al.*, 1988). Since 1970, the area under cultivation has not increased, and the Ministry of Agriculture and Water (MAW, 1985) has assumed that irrigational water demands will remain the same for the next 25 years.

TABLE 1. Municipal, rural, and industrial 1985 water usage and projected 2000 and 2010 demands of the Jeddah, Makkah and Taif Area in million cubic meters (Mm^3).

Year	Jeddah			Makkah			Taif			Villages	Total
	Munici-pal	Indus-trial	Total	Munici-pal	Indus-trial	Total	Munici-pal	Indus-trial	Total		
1985	94.8	8.6	103.4	45.7	2.1	47.8	11.4	0.5	11.9	8.4	171.5
2000	162.1	16.2	178.3	102.9	4.7	107.6	19.8	0.9	20.7	14.3	320.9
2010	246.6	22.4	269.0	145.1	6.6	151.7	26.6	1.2	27.8	21.8	470.3

Conservative estimates of water demands were prepared by taking into consideration installation of water savings devices in the municipal and industrial sectors and introducing the advanced irrigation technologies of sprinkling and drip systems. The conservative water demands are about 85% of the normal demands (Abu-Rizaiza *et al.*, 1988).

Water Supplies

The Western Region of the Kingdom consists of many basins draining toward the Red sea and a few directed inland. These watersheds, called wadis, are narrow valleys with steep slopes which at times convey flash floods. Geologically, this region, called the Arabian Shield, is composed of Precambrian plutonic, volcanic, and metamorphic rock formations. The major wadis of JMT area oriented to the Red Sea are: Fatimah, Khulays, and Naaman while the wadis draining inland are Liyyah, Wajj, and Turabah. Figure 1 shows the location of these wadis. Although surface water in wadis is available only in small quantities, varying from year to year, recharge from runoff is the major source of groundwater.

Recharge of groundwater depends completely on the hydrological cycle and renewal occurs seasonally. Along the escarpment, ground cover is largely impervious crystalline rocks on steep gradients. These features cause flash floods upstream in the wadis. Crystalline rocks of the Arabian Shield allow rapid infiltration of precipitation through fractures and fissures, thus, floods gradually disappear in the lower reaches of the valleys. Upstream groundwater quality in the valleys is always good with total dissolved solids (TDS) ranging from 200 to 1000 mg/l (Abu-Rizaiza *et al.*, 1988).

The water supply in the JMT area may be classified into three different categories: groundwater, desalinated water, and renovated water.

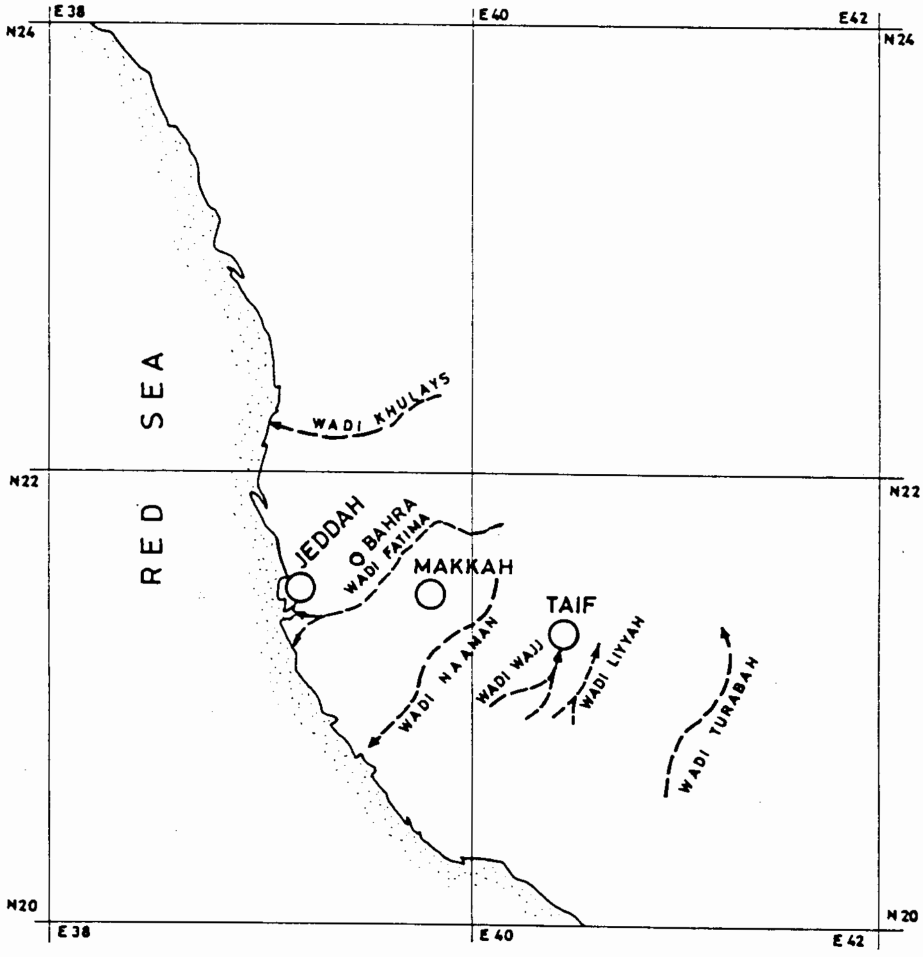

FIG. 1. Location of major wadis in the JMT area, Saudi Arabia.

Groundwater

Tables 2 and 3 list groundwater withdrawals in 1985 and the expected values and the standard deviations of the groundwater potential for the six wadis in the JMT area (Abu-Rizaiza *et al.*, 1988). The coefficient of variation (standard deviation/expected value) for all wadis, except the smallest wadis of Wajj and Liyyah, is greater than 1.0. For reliable groundwater utilization, the withdrawals should be less than the expected potential and, for efficient utilization, the water uses should be flexible enough to survive under drought conditions. Municipal water use cannot tolerate significant variation in supply, whereas agricultural activities are more flexible. Changes in the cropping pattern or size of cultivated areas may be undertaken to accommodate the quantity of groundwater in storage. In other words, a time lag exists between the response of agricultural usage and a decreasing supply of groundwater due to drought. System flexibility, nevertheless, depends on the design condition.

TABLE 2. Groundwater withdrawals and usage from the major wadis of the JMT area in 1985 (Mm^3).

Wadi	Groundwater withdrawals		Total
	Irrigation use	Municipal use	
Fatimah	28.0	27.0	55.0
Khulays	28.4	6.9	35.3
Naaman	1.0	22.0	23.0
Turabah	9.5	4.4	13.9
Wajj & Liyyah	1.0	2.8	3.8
Total	67.9	63.1	131.0

TABLE 3. Expected values and standard deviations of the groundwater recharge in the major wadis of the JMT area (Mm^3/y).

Wadi	Expected value	Standard deviation	Coefficient of variation
Fatimah	66.5	84.4	1.2
Khulays	45.6	48.0	1.1
Naaman	24.6	26.8	1.1
Turabah	24.7	27.4	1.1
Liyyah	3.0	2.0	0.7
Wajj	4.9	4.5	0.9
Total	169.3		

Allam and Abu-Rizaiza (1988) showed that plans based on amounts higher than the expected values of the input factors are inferior to plans based on amounts less than or equal to the expected values, regardless of the probability distributions of the input factors. In this situation, because of the high values of the standard deviations of the groundwater potential, the design amounts should be lower than the expected values for robust performance. Identification of optimum robust performance requires economic data on benefits and costs of the irrigational water. It also requires identification of the redundant components and the operating rules of agricultural activities. Without these data, the design amounts of groundwater potential are considered to be equal to the amounts that achieve the 70% reliability level. The groundwater withdrawals that achieve 70% reliability level in each wadi are shown in Table 4. For higher reliability levels of 90% or more, the corresponding groundwater potential is relatively small. These higher reliability levels should be considered only if groundwater is considered as a municipal water source (Abu-Rizaiza *et al.*, 1994).

TABLE 4. Groundwater withdrawals that achieve 70% reliability level (Mm^3/y).

Wadi	Withdrawals
Fatimah	35.0
Khulays	20.0
Naaman	10.0
Turabah	16.0
Wajj	1.9
Liyyah	0.6
Total	83.5

Desalinated Water

The JMT area has two desalination plants: the Jeddah plant supplies the city of Jeddah, and the Shoaiba plant supplies Makkah and Taif. The Jeddah plant started operation in 1974 and the Shoaiba plant in 1988. The capacity of Jeddah plant in 1985 was 114.0 Mm^3/y. The planned capacities of the Jeddah and Shoaiba plants by year 2000 are of 206.0 and 110.0 Mm^3/y, respectively (Ministry of Planning, 1990).

Renovated Water

Water reuse, started only few years ago, applies a limited amount of wastewater for irrigation and industrial uses. Currently in Jeddah, the major reuse is landscape irrigation along roadways and in public parks. The remainder of treated wastewater is discharged to the Red Sea. In Taif, the majority of reclaimed water is used for landscape irrigation with the excess discharged to wadi Wajj. In Makkah, wastewater is disposed of in wadi Naaman a few kilometers away from the city. Water reuse depends greatly on the quantity and quality of treated wastewater. At the present time, the capacities of the wastewater treatment plants in the Jeddah, Makkah and Taif are much less than the raw wastewater flows.

In 1985, the total capacity of the six plants in Jeddah was 47.0 Mm^3/y while the amount of wastewater was about 80.0 Mm^3/y (about 80% of the water use) (Water and Sewage Department, 1987). Two treatment plants with a capacity of 178.0 Mm^3/y are in the planning stage to accommodate the wastewater of Jeddah for the next 10 years. In 1985, Makkah had only one wastewater treatment plant with a capacity of 11.0 Mm^3/y, which was much less than the wastewater flow of the city estimated to be 30.0 Mm^3/y. Expansion of the capacity of this treatment plant is planned for 29.0 Mm^3/y, and another treatment plant with a capacity of 41.0 Mm^3/y is being considered (Ministry of Planning, 1985).

At Taif city in 1987, construction of the first wastewater treatment plant was completed. The capacity of the plant is 22.0 Mm^3/y and will be expanded to 36.5 Mm^3/y by the year 2000. This capacity is expected to be adequate for the next 20 years or more.

The sewer systems in 1985 were serving less than 70% of the inhabited areas of the major cities. The remaining areas were served with septic tanks. By the year 2000, all of the three cities are planned to be completely sewered (Ministry of Planning, 1985).

After construction of the planned wastewater treatment plants, large amounts of treated wastewater will be available for reuse by industry and for agricultural and landscape irrigation.

Water Status in 1985

The water supply and demand situation of the JMT area is presented for the base year 1985 using Input-Output (I/O) tables. As shown in Table 5 for Jeddah, the total water entries are 159.0 Mm^3, which is the sum of 114.0 Mm^3 from the desalination plant, 3.35 Mm^3 of groundwater for Wadi Khulays, 3.65 Mm^3 of groundwater from Wadi Fatimah, and 38.0 Mm^3 of seawater from the Red Sea (MAW, 1986). In addition, an intermediate source 6.0 Mm^3 is treated wastewater recycled for landscape irrigation. The Ministry of Agriculture and Water (MAW) estimated water losses in the water distribution network to be 20% (MAW, 1986) which is equivalent to an exit of 24.0 Mm^3 to groundwater. The total fresh water use in the city was estimated to be 97.0 Mm^3, municipal use of 90.0 Mm^3 and industrial use 7.0 Mm^3. These water usages were slightly less than the actual usage of 103.4 Mm^3 (Table 1).

In 1985, the sewer system of Jeddah served only about 50% of the city with the remaining area served by septic tanks (Abu-Rizaiza *et al.*, 1988). Collected wastewater is treated and discharged into the Red Sea, while the wastewater in septic tanks seeps to groundwater. The exists for wastewater in Table 5 are seepage from septic tanks to groundwater (38.5 Mm^3), evaporation to the atmosphere (total of 25.4 Mm^3), and discharges to the Red Sea from municipal and industrial treatment plants (30.0 and 2.5 Mm^3). Recycling of the relatively large amount of wastewater should be considered in any future plans for the city. Seepage from the septic tanks (38.5 Mm^3) and leakage from the water distribution system (24.0 Mm^3) has resulted in a significant rise to the water table causing considerable damage to roads, buildings, and underground utilities. [In 1989, a subsurface drainage system was constructed to lower the water table with the drainage water is being discharged to the Red Sea (Water and Sewage Department, 1989)].

TABLE 5. Input-output annual water balance for Jeddah for year 1985 (Figures are in Mm^3).

Output origins	Input destinations	Intermediate source						Use sectors			Exits			
		Blending plant	Distribution sytems	Septic tanks	Municipal wastewater treatment plant (s)	Industr. waste-water treatment plant (s)	Advanced wastewater treatment plant	Municipal use	Recreational use	Industrial use	Ground water	Atmosphere	Red sea	Output totals
ENTRIES	Desalination Plant (s)	114.00												114.0 114.0
	Wadi Khulays	3.35												3.35
	Wadi Fatimah		3.65											3.65
	Red Sea									38.0				38.0
INTERMEDIATE SOURCES	Blending Plant		117.35											117.35
	Distribution Systems							90.0		7.0	24.0			121.0
	Septic Tanks										38.5			38.5
	Municipal Wastewater Treatment Plant (s)								6.0				30.0	36.0
	Industrial Wastewater Treatment Plants (s)												2.5	2.5
	Advanced Wastewater Treatment Plant (s)													
USE SECTORS	Municipal Use			36.0	36.0							18.0		90.0
	Recreational Use										0.6	5.4		6.0
	Industrial Use			2.5		2.5						2.0	38.0	45.0
	Input totals	117.35	121.0	38.5	36.0	2.5		90.0	6.0	45.0	63.1	25.4	70.5	615.35

According to the MAW (MAW, 1986), in 1985 Makkah received through two main pipelines 13.3 Mm^3 of groundwater from wadi Naaman and 13.5 Mm^3 of groundwater from Wadi Fatimah. Another pipeline from Wadi Naaman to the Holy Mosque transferred about 3.7 Mm^3 of groundwater. In addition, approximately 10.0 Mm^3 of groundwater was trucked to Makkah in tankers, about 5.0 Mm^3 from wadi Naaman and 5.0 Mm^3 from wadi Fatimah. This supply was used in the 42% of the city not connected to the water distribution system (Abu-Rizaiza *et al.*, 1988). Accordingly, the total water supply in 1985 was 40.5 Mm^3, which is less than the 47.8 Mm^3 given in Table 1. Assuming leakage losses from the distribution system of approximately 20%, the total water use shown in Table 6 is 36.7 Mm^3, 3.7 $Mm^3$for the Holy Mosque and 32.0 Mm^3 municipal and industrial uses.

In 1985, only 50% of Makkah area was served with a sewer system. The remaining area was served with septic tanks. The return flow is estimated as 80% of the water use (Abu-Rizaiza *et al.*, 1988). Only 1.0 Mm^3 out of the 28.6 Mm^3 of the wastewater was reused in irrigating landscape. The remainder either seeped from septic tanks to groundwater or was discharged after treatment into the wadi Naaman. Of the discharged wastewater only 30% was assumed to percolate to groundwater, while 70% was lost through evaporation.

Taif receive in 1985, through two main pipelines connected to the distribution system, 4.4 Mm^3 and 1.9 Mm^3 of groundwater from wadi Turabah and wadi Wajj, respectively (MAW, 1986). In addition, 0.9 Mm^3 of water wadi Wajj was trucked in by tankers (Water and Sewage Department, 1987). Assuming 20% for the leakage losses in the distribution system, the total water used in Taif as shown in Table 7, was 6.0 Mm^3. This amount is about 50% of the 1985 estimated water usage of the city (Table 1).

In 1985, the sewer system was serving only 30% of Taif. The remaining area was served with septic tanks. Since no treatment plant existed, the collected wastewater was discharged to wadi Wajj, a few kilometers downstream from the city. As shown in Table 7, 30% of this water (0.5 Mm^3) was assumed to recharge aquifer of wadi Wajj with the remainder lost in evaporation (Abdurrazzak *et al.*, 1989). Since Taif is sited on the main stream of wadi Wajj, seepage from the septic tanks fed the groundwater aquifer estimated 3.3 Mm^3.

Table 8 is the I/O annual water balance for the JMT area for the year 1985 showing the total water uses in the use sector of recreational, municipal, and industrial uses of the major cities including the Holy Mosque in Makkah, municipal water use of villages, and agricultural use in the five wadis. In this table, the distribution systems of the major cities are grouped under one intermediate source "distribution systems". Intermediate sources for the wastewater transferred are by trucks, municipal wastewater treatment plants, and septic tanks. Agricultural usages are based on surface flood irrigation. Ten percent of the irrigation water is assumed to percolate to the groundwater and 90% lost by evapotranspiration. The groundwater aquifer of Jeddah is not considered as an exit in this I/O presentation. The seepage water from septic tanks and the water leaked from the distribution system are tabulated as dis-

TABLE 6. Input-output annual water balance for Makkah for year 1985 (Figures are in Mm^3).

Output origins	Input destinations	Intermediate sources: Blending plant	Intermediate sources: Trucks	Intermediate sources: Distribution systems	Intermediate sources: Septic tanks	Intermediate sources: Municipal wastewater treatment plant (s)	Use sectors: Municipal use	Use sectors: Recreational use	Use sectors: Industrial use	Use sectors: Holy Mosque	Exits: Groundwater (Wadi Naaman)	Exits: Atmosphere	Output totals
ENTRIES	Desalination Plant(s)												
	Wadi Fatimah		5.0	13.5									18.5
	Wadi Naaman		5.0	13.3						3.7			22.0
INTERMEDIATE SOURCES	Blending Plant												
	Trucks						9.0		1.0				10.0
	Distribution Systems						21.0		1.0		4.8		26.8
	Septic Tanks										13.6		13.6
	Municipal Wastewater Treatment Plant(s)							1.0			4.2	9.8	15.0
USE SECTORS	Municipal Use				12.0	12.0						6.0	30.0
	Recreational Use										0.1	0.9	1.0
	Industrial Use				1.6						0.4		2.0
	Holy Mosque					3.0						0.7	3.7
	Input Totals		10.0	26.8	13.6	15.0	30.0	1.0	2.0	3.7	22.7	17.8	142.6

TABLE 7. Input-output annual water balance for Taif for year 1985 (Figures are in Mm^3).

Output origins \ Input destinations		Intermediate sources						Use sectors			Exits		
		Blend-ing plant	Trucks	Distri-bution systems	Septic tanks	Municipal wastewater treatment plant (s)	Advanced wastewater treatment plant	Munici-pal use	Recrea-tional use	Indus-trial use	Ground-water (Wadi Wajj)	Atmos-phere	Output totals
ENTRIES	Desalination Plant (s)												
	Wadi Turabah			4.4									4.4
	Wadi Wajj		0.9	1.9									2.8
INTERMEDIATE SOURCES	Blending Plant												
	Trucks							0.9					0.9
	Distribution Systems							4.8		0.3	1.2		6.3
	Septic Tanks										3.3		3.3
	Municipal Wastewater Treatment Plant (s)										0.5	1.0	1.5
	Advanced Wastewater Treatment Plant												
USE SECTORS	Municipal Use				3.06	1.5						1.14	5.7
	Recrational Use												
	Industrial Use				0.24							0.06	0.3
	Input totals		0.9	6.3	3.3	1.5		5.7		0.3	5.0	2.2	25.2

TABLE 8. Input-output annual water balance for the JMT area for year 1985 (Figures are in Mm^3).

Output origins	Input destinations	Intermediate source: Blending plant	Intermediate source: Trucks	Intermediate source: Distribution systems	Intermediate source: Septic tanks	Intermediate source: Municipal waste-water treatment plants	Intermediate source: Industrial waste-water treatment plants	Use sectors: Municipal use	Use sectors: Recreational use	Use sectors: Industrial use	Use sectors: Agricultural use	Use sectors: Villages	Use sectors: Holy Mosque	Exits: Wadi Fatimah	Exits: Wadi Khulays	Exits: Wadi Naaman	Exits: Wadi Turabah	Exits: Wadi Wajj & Liyyah	Exits: Red sea	Exits: Atmosphere	Output totals
ENTRIES	Desalination Plants (s)	114.0																			114.0
	Wadi Fatimah		5.0	17.15							28.0	4.85									55.0
	Wadi Khulays	3.35									28.4	3.55									35.3
	Wadi Naaman		5.0	13.3							1.0		3.7								23.0
	Wadi Turabah			4.4							9.5										13.9
	Wadi Wajj & Liyyah		0.9	1.9							1.0										3.8
	Red Sea									38.0											38.0
INTERMEDIATE SOURCES	Blending Plant			117.35																	117.35
	Trucks							9.9		1.0											10.9
	Distribution Systems							116.1		8.0						4.8		1.2	24.0		154.1
	Septic Tanks													3.7	2.7	13.6		3.3	38.5		61.8
	Municipal Wastewater Treatment Plant (s)								7.0							4.2		0.5	30.0	10.8	52.5
	Industrial Wastewater Treatment Plants																		2.5		2.5
USE SECTORS	Municipal Use				51.3	49.5														25.2	126.0
	Recreational Use															0.1			0.6	6.3	7.0
	Industrial Use				4.1		2.5												38.0	2.4	47.0
	Agricultural Use													2.8	2.8	0.1	1.0	0.1		61.1	67.9
	Villages				6.4															2.0	8.4
	Holy Mosque					3.0														0.7	3.7
	Input totals	117.35	10.9	154.1	61.8	52.5	2.5	126.0	7.0	47.0	67.9	8.4	3.7	6.5	5.5	22.8	1.0	5.1	133.6	108.5	942.15

charges to the Red Sea. This is in an agreement with the current situation in the city where subsurface pipe networks is being constructed to collect groundwater recharge and discharge it to the Red Sea.

Imbalance between Water Demands and Water Supplies

The projected water demand in JMT area in the year 2000 and 2010 are 320.9 Mm^3, and 470.3 Mm^3, respectively, as given in Table 1. These increased water demands, while very substantial, are, nevertheless, quite likely. If the present water practices are not changed, an acute water shortage will occur. The solution to this problem cannot be found by only searching for additional water supplies, but requires bringing the needs for water in balance with available sources through efficient usage of the existing water supplies. To move toward this goal, water resources planning alternatives under current and future water conditions should be applied through the input-output water transactions approach. The part B of this paper applies this approach to the JMT area in Saudi Arabia.

Conclusion

This paper presents the present and future (1985-2010) water demands and supplies for the Jeddah-Makkah-Taif (JMT) area in the Western Region of Saudi Arabia. The extent of existing water distribution networks, wastewater collection systems and capacities of wastewater treatment plants are given. Based on this information, the available and the projected quantities of wastewater for reuse are estimated. With knowledge gained from evaluation of these data, water demands can be matched against available water resources to show a water balance model in a tabular display format. Water Input-Output scenarios can then be used to address an impending water crisis if water demand and supply are not brought into balance.

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نمذجة العرض والطلب على مياه منطقة جدة – مكة المكرمة – الطائف بالمملكة العربية السعودية
أ – التوازن المائي تحت الظروف الحالية والمستقبلية

عمر سراج أبو رزيزة و **محمد نصر الدين علام** و **محمد جميل عبد الرزاق**

عمر سراج أبو رزيزة: أستاذ إدارة وتخطيط موارد المياه المشارك ، قسم الهندسة المدنية ، كلية الهندسة ، جامعة الملك عبد العزيز

محمد نصر الدين علام: أستاذ هندسة الرى ، والهيدروليكا ، كلية الهندسة ، جامعة القاهرة

محمد جميل عبد الرزاق: أستاذ علوم وإدارة موارد المياه المشارك ، كلية الأرصاد ، جامعة الملك عبد العزيز

المستخلص : تناقش هذه الورقة كميات المياه المطلوبة والمتاحة في منطقة جدة ، مكة المكرمة ، الطائف والتي تقع في غرب المملكة العربية السعودية خلال الفترة (١٩٨٥ – ٢٠١٠م) . كما حددت الورقة أيضا سعات شبكات المياه وشبكات الصرف الصحي في هذه المدن ، ثم استخدمت هذه المعلومات لتقدير كميات المياه المبتذلة التي يمكن إعادة استعمالها خلال نفس الفترة . بعد ذلك تمت مقارنة بين الكميات المطلوبة والمتاحة في جدول لتبيان العجز المائي الذي ستقابله المنطقة إذا لم يتم موازنة مائية بين الطلب والمتاح .