Chapter 4 Water Quality Conservation

Chapter 5 Water Allocation

CHAPTER 4
WATER QUALITY CONSERVATION

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4.1 Quality of Source Waters

4.1.1 Surface Water Quality

In Jordan, surface water quality monitoring is conducted regularly by Jordan Valley Authority (JVA), Water Authority of Jordan (WAJ) and the Royal Scientific Society (RSS). There are existing water quality records for the major surface water sources such as King Abdullah Canal (KAC), dams and reservoirs, and wadis.

4.1.1.1 King Abudullah Canal

The KAC receives water mainly from the following sources: Yarmouk River water through the tunnel, Tiberias Lake water through the inlet at Dajania, groundwater from Mukheiba Well field, and occasionally from Wadi Arab Reservoir. According to the long term monitoring data from JVA Lab, the average salinity of water from the Yarmouk is EC = 906 μS/cm (or TDS = 580 mg/L if a coefficient of 0.64 is used for converting EC to TDS), and that from the Tiberias is EC = 1081 μS/cm (TDS = 691 mg/L). Along the canal up to the location before the inflow from Zarqa River, EC keeps a value of 901 – 952 μS/cm, but becomes higher after mixing with water from Zarqa River (EC = 1673 – 1967 μS/cm as average and 3440 μS/cm as the maximum). RSS has 3 sites along the KAC for long term monitoring (see Fig. 4.1.1-1, C0: the tunnel from Yarmouk; C1: near Deir Alla Intake; C2: downstream the inflow from Zarqa River). The average values of the main water quality parameters at C0 and C1 are as following: TDS < 600 mg/L, BOD < 3 mg/L, TN < 4 mg/L, NO_3-N < 3 mg/L as N and TP < 0.5 mg/L.

Generally speaking, the quality is acceptable as source water for domestic water supply from its average values. However, the maximum values of certain items related to the nutrient substances in water are noticeably high. For example, according to the RSS data, the maximum TP detected at C0 and C1 reached a very high level after 1997 as can be seen from Table 4.1.1-1. Although the occurrence of algae bloom depends on many parameters, it is generally considered that TP > 1.0 mg/L represents a nutrient level sufficiently high to cause algae growth.

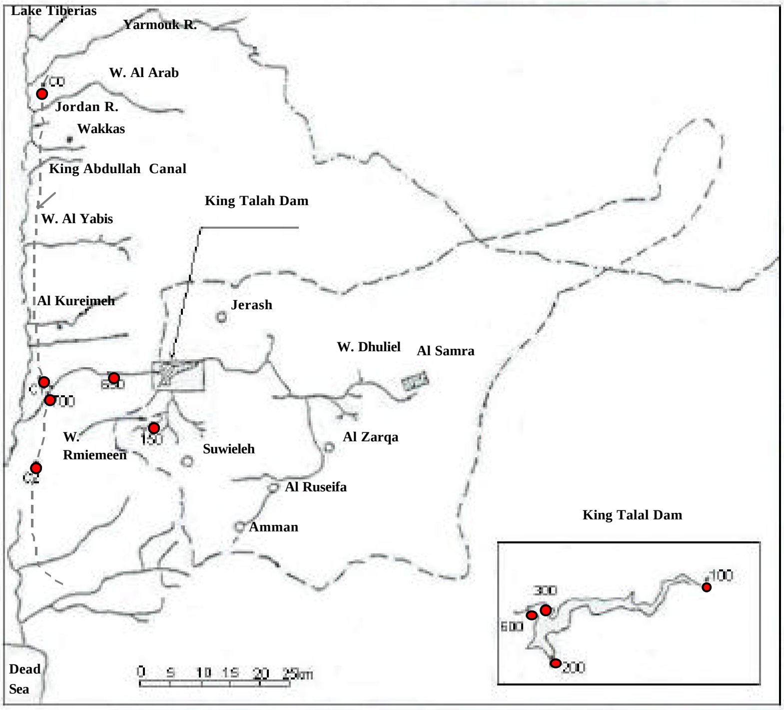


Fig. 4.1.1-1 Location Map of RSS Monitoring Sites for KTR and KAC

Table 4.1.1-1 Maximum TP Detected at Upstream Part of KAC

Year	Maximum TP (mg/L)	
	C0	C1
1997	1.32	1.29
1998	2.9	2.1
1999	1.4	3.3

Source: RSS Annual Report of Water Quality Monitoring for KTR and KAC

In the summer of 1998, unpleasant smell occurred with drinking water in the Greater Amman area. This gave rise to public concern about drinking water quality and investigations were conducted on the problem. It was identified that algae bloom in KAC and insufficient water purification in Zai Water Treatment Plant were the main reasons. In addition to certain actions taken in the water purification process, such as chemical oxidation and powdery activated carbon adsorption, the importance of monitoring and protection of the source water quality was stressed. As a measure in this regard, JVA strengthened the water quality monitoring program for KAC by starting monthly sampling from the 3 main sources to the canal (Yarmouk River, Mukhaiba Wells and Yarmouk water from Dajania) and along the canal at 3 locations (Waqqas Town, Abu Habeel and Deir Alla Intake) from August, 1998 under the assistance of RSS. Water quality items related to organic and nutrient substances have been analyzed since then. WAJ Laboratory also started a monthly water quality monitoring program from January, 1999 at about the same locations regarding 8 items (EC, pH, NO_3, PO_4, Chl-a, TOC, Odor and NH_4).

Fig. 4.1.1-2 and Fig. 4.1.1-3 show the monthly variation of organic and nutrient substances in the source water to the KAC and at several locations along the canal, based on the recent data from RSS and WAJ Lab. In addition to nitrogen (NO_3, T.kj-N) and phosphorous (TP, PO_4), both of the laboratories analyzed the total organic carbon (TOC), and WAJ Lab analyzed chlorophyll-a (Chl-a) as a direct indicator of algae growth.

Because the monitoring started after the occurrence of algae bloom in 1998 and has not yet covered a long period, no extreme condition is shown in these graphs. However, the data have revealed to certain extent the characteristics of water quality from each of the source waters and in the canal.

<u>Yarmouk Water</u>: The background level of NO_3 is between 10-25 mg/L which is higher

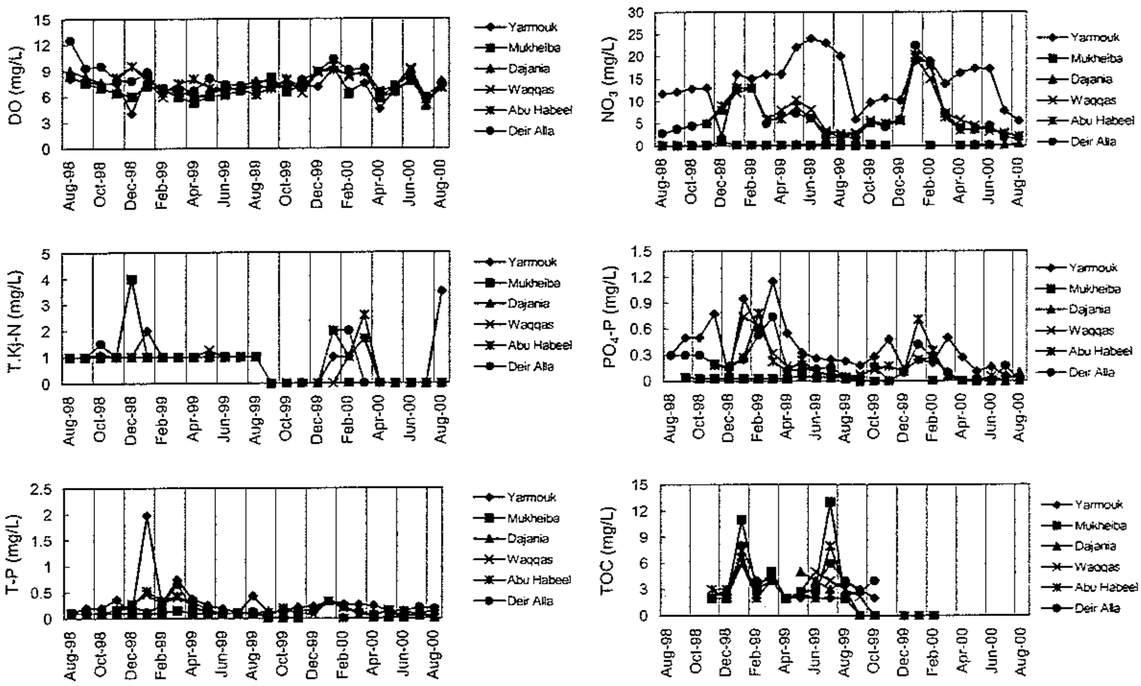


Fig. 4.1.1-2 Variation of Water Quality in KAC from Aug-98 to Aug-00
(Source: RSS Monitoring Data)

than the other sources. PO_4 and occasionally TP are also higher than the other sources and with peaks in the rainy season. This implies the influence of runoff from the upstream agricultural area on the river water quality. However, as can be seen from the Chl-a value, the potential of photosynthesis of the river water is relatively low.

<u>Mukheiba Water</u>: The well water is of very good quality – low contents of NO_3 and PO_4. The one high measurement of T.Kj-N and two peaks of TOC in Fig. 4.1.1-3 may be from some unknown reasons because the value of the same item in the other months is very low and discrepancy seems to be great (e.g. TOC in January and July of 1999) between Fig. 4.1.1-2 and Fig. 4.1.1-3.

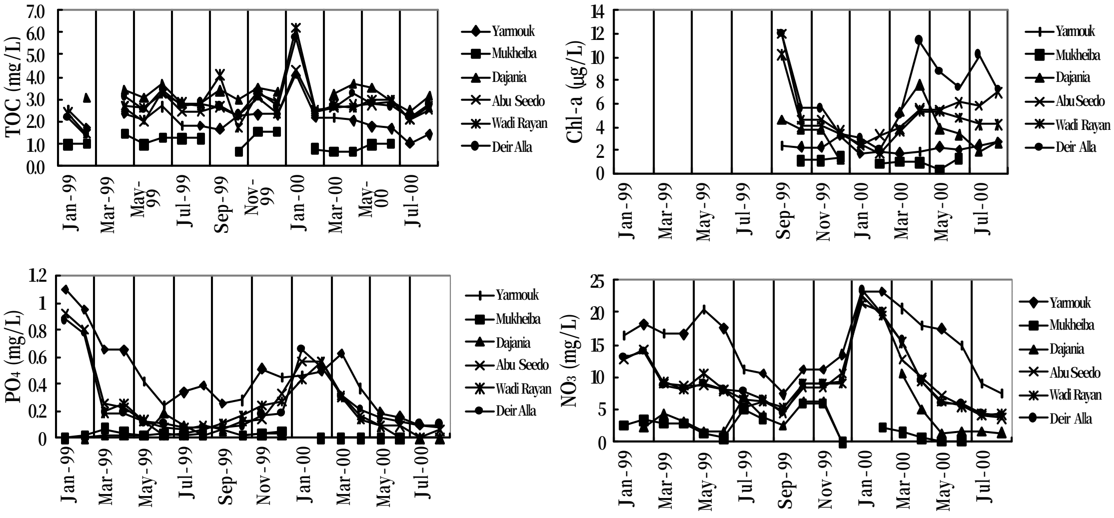


Fig. 4.1.1-3 Variation of Water Quality in KAC from Jan-99 to Aug-00
(Source: WAJ Lab Monitoring Data)

Dajania Water: This is the water imported to Jordan from Tiberias Lake. Little information had been available about the quality of water from this source until RSS and WAJ Lab started the monthly monitoring programs in August 1998 and January 1999, respectively. The background TOC is about 3.0 mg/L – relatively higher than the other sources. The values of the other water quality items, such as pH, NO_3, T. Kj-N, PO_4-P and T-P, are within the normal range of surface water.

Water in KAC: No apparent difference is noticed with water quality at different locations along the KAC. However, there seems to be a tendency that the potential of photosynthesis in the canal is higher than the source water as is shown by the Chl-a measurement results. At Deir Alla Intake, Chl-a was measured as 7-12 μg/L from April to August this year. Although it is still too early to draw any conclusion with the limitation of available data, eutrophication is the most important problem with KAC water, and more sophisticated investigation is required. Regarding other water quality parameters such as heavy metals and toxic substances, RSS and WAJ Lab have regular analysis records along the canal, at Zai intake and for the treated water from the Zai Water Treatment Plant. All the values are lower than the allowable levels of the Jordanian Drinking Water Quality Standard (JS 286) with most of them below the detection limits.

4.1.1.2 Zarqa River and King Talal Reservoir

The upper stream of the Zarqa River receives the effluent from the As Samra WWTP and flows to the KTR where water is stored and then sent to the Jordan Valley through the lower stream of the Zarqa River. This forms the main surface water flow system in the Amman-Zarqa Basin. The characteristics of water quality in this system are shown in Table 4.1.1-2 (average of available data after 1995).

Table 4.1.1-2 Water Quality of Zarqa River System

Location	Water Quality (as mg/L)						
	TDS	TSS	BOD_5	COD	TP	TN	B
As Samra inflow	1228	501	697	1634	15.5	103	-
As Samra outflow	1196	111	124	455	20.0	107	0.87
KTR inflow [a]	1318	84	51.6	141.4	9.0	59.4	0.57
KTR outflow [b]	1143	20.4	10.2	38.2	4.8	26.8	0.46
Diversion Weir [c]	1206	49.6	13.2	34.2	4.5	26.1	0.48

a, b, c- sites 100, 600 and 650 in Fig. 4.1.1-1
Source: RSS Annual Reports of Water Quality Monitoring for KTR (1995-1999)

As Samra inflow and outflow: As is shown in Table 4.1.1-2, the stabilization ponds in As Samra WWTP achieve removals for TSS, BOD_5, COD by 77.8%, 82.3%, 72.2%, respectively, but no removal for TP and TN at all, including TDS which is not the objective of treatment by biological processes. The design capacity of stabilization ponds was 68,000 m^3/d but the actual inflow to the plant was 166,855 m^3/d in 1999. The WWTP is over-loaded by a factor of 2.45. Therefore, the stabilization pond system cannot perform its function well. (Generally the stabilization ponds system under normal condition is capable of achieving a BOD/COD removal higher than 90%, TP/TN removal about 30 – 40%.)

Self-purification in the upper stream of Zarqa River: Apparent decreases in BOD_5, COD, TP and TN are seen as water flows from As Samra outlet to KTR inlet through the upper stream of Zarqa River. The decrease in the values of these water quality parameters is thought to be the result from two factors: the dilution with flows from other sources and the self-purification in the stream. According to the records of water flow at different locations of the Zarqa River-KTR system (Table 4.1.1-3), the average dilution factor in the period of 1995-1999 is evaluated as 1.463, which is the ratio of the flow at site 100 over the flow from As Samra effluent. To simplify the evaluation, water use before site 100 is not taken into account. After considering the influence of dilution, the net removals by self-purification in the upper stream of Zarqa River regarding BOD_5, COD, TP and TN are calculated as 39.12, 54.53, 34.16 and 18.79%, respectively. This shows that the river itself performs self-purification well for organic matters and nutrient substances. The study by HARZA (1996) has estimated that the flow time from As Samra outlet to KTR is about 18 hours. If the decay of BOD_5 is supposed to follow the first order reaction, then the decay rate k can be estimated as about 0.6617 d^{-1} which is comparatively a high level and shows the remarkable effect of self-purification partially from the favorable aeration condition in the river course and partially from the good biodegradability of the organic matters in the As Samra effluent. The decay rate of TP and that of TN are also very high.

Table 4.1.1-3 Flow Records at Different Locations of the Zarqa River-KTR System (1995-1999)

Year	As Samra Effluent (MCM)	KTR Inflow (MCM)				Dilution Factor	
		Site 100	Site 200	Rainfall in the Dam area	Total	R. Zarqa Upstream	KTR
1995	43.863	71.532	8.423	0.268	80.223	1.631	1.121
1996	46.597	72.691	8.588	0.512	81.791	1.560	1.125
1997	47.832	90.587	10.721	0.798	102.106	1.894	1.127
1998	54.506	64.802	7.662	0.516	72.98	1.189	1.126
1999	52.932	59.795	7.05	0.298	67.143	1.130	1.123
Total	245.73	359.407	42.444	2.392	404.243	1.463	1.125

* Dilution factor for R. Zarqa upstream is the ratio of the flow at site 100 over the flow of As Samra effluent, and that for KTR it is the ratio of the total flow over the flow at site 100

King Talal Reservoir: Fig. 4.1.1-4 shows the main parameters of water quality at different locations in the KTR (Site 100: inflow from Zarqa R., Site 200: inflow from W. Rmiemeen, Site 300: in middle of the reservoir, Site 600: outlet of the reservoir) and downstream of the Zarqa R. at the diversion weir (Site 650). Significant decreases in BOD_5, TP, TN are noticed from these graphs, as well as PO_4-P and the composition of different forms of nitrogen, i.e., NH_4-N and NO_3-N. Because the concentrations of BOD_5, TP and TN of inflow at site 200 (including effluent from Baqa WWTP) are apparently lower than those from the Zarqa R, this inflow contributes to dilution of pollutants in the KTR. After considering the dilution factor in the reservoir, the average removals of BOD_5, TP and TN are calculated as 78.41, 43.51 and 52.15%, respectively. Bacteriological parameters are also very important regarding the suitability of water for irrigation, because they relate to health risks associated with wastewater reuse (D.W. Westcot, FAO Water Report-10, 1997). Control of TFCC (total fecal coliform count) is supposed to be of first priority. It is noticeable that although the TFCC at the inlet of KTR (Site 100) is as high as 7500, it drops to less than 200 in the KTR (Site 300) and at the outlet (Site 600). According to the Jordanian Standard for Treated Domestic Wastewater (JS 893/1995), the treated wastewater should meet the following requirements: BOD_5 < 50 mg/L; PO_4-P < 15 mg/L; TN < 50 mg/L; NO_3-N < 25 mg/L; NH_4-N < 15 mg/L (not for fisheries); B < 1.0 mg/L and TFCC < 1000 (MPN/100mL). Although the effluent from As Samra does not meet the standard for the time being due to over loading, after the self-purification in the upper stream of Zarqa R., and then the biological degradation in the KTR, the quality of the outflow water from the reservoir becomes acceptable for downstream irrigation. However, from the present level of TP and TN, the KTR water quality is considered eutrophic. HARZA conducted water quality modeling for KTR (1996) and assessed the water quality for future flows after rehabilitation of As Samra WWTP. They concluded that with a flow of 320,000 m^3/d from As Samra, the water quality at KTR outlet would still be suitable for downstream irrigation, but nutrient substances would still be at eutrophic level.

Lower stream of Zarqa River: No apparent removal of pollutants is seen downstream the KTR to the diversion weir but slight increase in TDS, BOD_5, TSS and NO_3 is noticed, as well as TFCC. This is because most of the biodegradable pollutants have already been removed in the reservoir, and meanwhile additional pollutants may enter the stream from agricultural and pastoral activities. There are also inflows from springs, which contribute to the slight increase of water salinity. However, the variation of water quality in the lower stream of Zarqa River is minor, and the water supplied to Jordan Valley is acceptable for most of the irrigation purposes according to Jordanian Standard.

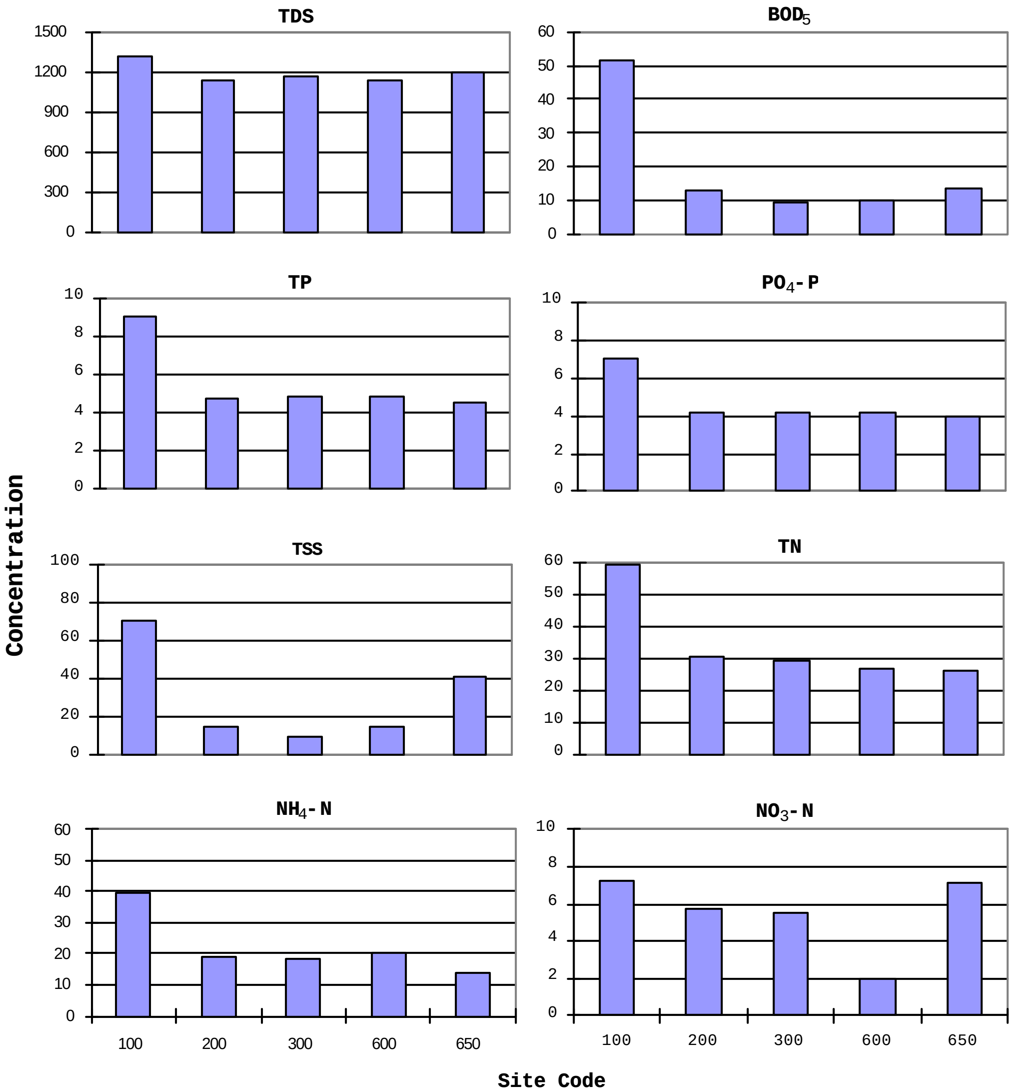


Fig. 4.4.1-4 Water Quality at Different Location of KTR
(See Fig. 4.1.1-1 for the location of each site)

The dilution factor of the treated wastewater at the downstream of the Zarqa River will change according to the expansion of As-Samra treatment plant and construction of the the Wadi Zarqa treatment plant in future as shown in next table.

Table 4.1.1-4 Dilution Factor of the Treated Wastewater at the Downstream of the Zarqa River

Year	Treated Wastewater Effluent (MCM/a)			Zarqa River Flow (MCM/a)		Dilution Ratio	
	As-Samra TP	W. Zarqa TP	Total[a]	Base Flow[b]	Flood Flow[c]	Dry Season[d]	Rainy Season[e]
1998	52.9	0	52.9	43.0	25.3	1.81	2.77
2010	61.2	40.3	101.5	43.0	25.3	1.42	1.92
2020	83.2	54.7	137.9	43.0	25.3	1.31	1.68

d=(a/2+b/2)/(a/2), e=(a/2+b/2+c)/(a/2)

4.1.1.3 Other Surface Waters

(1) Reservoirs

The following discussion is based on the JVA water quality monitoring data of 1995-2000 regarding EC, the main cationic and anionic ions. There are no records for heavy metals and other toxic substances.

Al Wehdah Dam Site: This is a dam ready for construction. The water sampling location is at the bridge. The average water salinity in the past five years is 845 µS/cm as EC (or 541 mg/L as TDS) and NO_3 is 27.1 mg/L. The water quality is generally acceptable for domestic use. However, NO_3 higher than 50 mg/L is occasionally detected. This may be affected by agricultural activity in the basin area.

Wadi Arab Dam: The average EC is 1011 µS/cm (TDS: 647 mg/L) and NO_3 is very low (4.9 mg/L). The water quality is generally acceptable for domestic use.

Ziqlab Dam: Average EC = 656 µS/cm (TDS = 420 mg/L), NO_3 = 12.2 mg/L. The water quality is good as source water for domestic use.

Wadi Kufrinja Weir: Average EC = 808 µS/cm (TDS = 517 mg/L), NO_3 = 39.6 mg/L. The water quality is generally acceptable for domestic use. However, NO_3 higher than 50 mg/L is occasionally detected.

Karameh Dam: High salinity is detected from the outflow of this dam with average EC as 3783 µS/cm and maximum EC as 6930 µS/cm. The source of salinity is identified to be from some saline springs within the reservoir, soil and irrigation return flow. Under the present condition, the water is not suitable for irrigation use. Water should be spilled out when the salinity reaches to 4,000micro siemens/cm.

(2) Jordan River

According to JVA monitoring data at 9 stations along the Jordan River, the water shows very high salinity (average EC = 4480 – 6663 µS/cm). At some location such as Price Mohammad Bridge, boron concentration is occasionally over 10 mg/L. The water is not suitable for any direct use at present.

(3) Wadis

There are water quality data for most of the wadis in the South Ghor area. According to water salinity, these wadis can be categorized into two groups: (a) slightly brackish water group from W. Zarqa Ma'in down to W. Mujib with EC value between 1500 – 3000 µS/cm, and (b) fresh water group from W. Ibn Hammad down to W. Khuneizira with EC value about 1000 µS/cm or lower. No abnormality is noticed with other water quality items.

(4) On Springs for drinking purpose

As can be seen from Fig. 1.1-15 and Fig. 1.1-16 in the Supporting Report Annex to 4.1.2, as the distribution of salinity and nitrate in spring water in the whole Kingdom, water in most of the springs is fresh (EC < 1000 µS/cm) except those in Jordan Rift Valley area where high salinity is shown. Nitrate concentration in some of the springs is high (NO_3 > 100 mg/L) and irrigation return flow is thought to be the main reason because these springs are in the densely agricultural area. Regarding the other water quality items such as heavy metals, there is no record of higher concentration than the Jordanian drinking water quality standard value.

According to WAJ data, all the springs currently used for public water supply are of good water quality – fresh and with low nitrate concentration. However, considerations should be taken for the protection of spring water from contamination, especially for those used for drinking purpose. The principles for groundwater quality conservation are suitable for springs, and in addition to this, because spring water may be directly polluted when it flows out of the ground surface, the principles for surface water quality conservation are also applicable to spring water under this condition.

4.1.2 Groundwater Quality

Regarding groundwater quality, historical data are stored in the Water Information System (WIS) of MOWI. There are totally 1148 wells and 742 springs with water quality records. The records for some of the wells and springs started as earlier as 1960, but most of them started in 1970s. As time passed, some of the sites were closed or the monitoring plans were changed. The number of wells with water quality records after 1995 becomes 653 and that of springs becomes 646. The water quality items in the WIS data base include water salinity (as EC), pH, main cations (Na, K, Ca, Mg) and anions (Cl, CO_3, HCO_3, NO_3, SO_4). Generally speaking, the concentration of main cations and anions in the groundwater relates to water salinity, but the concentration of nitrate (NO_3) is often an indicator of water pollution because its source may relate to many human activities. Therefore, EC and NO_3 are thought to be the most important factors related to water contamination.

4.1.2.1 Tendency of Deterioration of Groundwater Quality

By reviewing the historical data of groundwater quality in different areas and aquifers, it is noticed that Amman-Zarqa basin has the most serious problem with groundwater quality. The salinity of many wells and springs has increased substantially in the past years to a level far above the standard value for domestic or agricultural use. Table 4.1.2-1 compares the average EC values of the B2/A7 aquifer wells in the period of 1985-1989 with the period of 1995-1999. Among the 53 wells of this category with water quality monitoring records in these two periods, 40 wells show a great increase in EC within the past 15 years. The average increase is 324.4 μS/cm or 23.1% from the EC level in the 1985-1989 period. In Amman-Zarqa basin, wells belonging to other aquifers show more or less the similar tendency. Some wells in Azraq, Dead Sea and Mujib basins have the similar problem as well in the past years.

Salinity increase is often accompanied by an increase in nitrate concentration. Fig. 4.1.2-1 and Fig. 4.1.2-2 are the examples of some wells and springs which show apparent tendency of increase in NO_3 concentration. As can be seen from these figures, although fluctuation in NO_3 happens more frequently than EC, in many cases such as AL1608, AL1075, CA0598 and AL0868, NO_3 varies in a very similar pattern as EC. Fig. 4.1.2-3 and Fig. 4.1.2-4 show the distributions of EC and NO_3 respectively in the B2/A7 groundwater aquifer. Apparently, peaks of high EC and NO_3 are mainly concentrated in Amman-Zarqa basin.

Table 4.1.2-1 Comparison of Groundwater Salinity for B2/A7 Aquifer Wells in Amman-Zarqa Basin

Well ID	Average EC		Increase	Well ID	Average EC		Increase
	1985-1989	1995-1999			1985-1989	1995-1999	
AL1060	1863.8	1646.8	-217.0	AL1326	1648.3	1579.5	-68.8
AL1073	1010.0	933.3	-76.7	AL1331	1314.0	1311.0	-3.0
AL1075	2686.7	2850.0	163.3	AL1332	1095.0	1328.0	233.0
AL1076	2868.7	2504.9	-363.8	AL1340	1236.7	1164.0	-72.7
AL1079	1140.0	1117.8	-22.3	AL1352	1555.4	1365.5	-189.9
AL1081	1144.7	1637.4	492.6	AL1360	841.4	914.0	72.6
AL1082	1734.3	2329.4	595.1	AL1436	790.0	4865.0	4075.0
AL1087	1714.6	1363.5	-351.1	AL1479	756.7	1113.0	356.3
AL1093	3180.0	799.0	-2381.0	AL1547	1576.4	2290.0	713.6
AL1095	631.7	891.3	259.6	AL1551	1190.0	1237.7	47.7
AL1097	361.8	1031.0	669.2	AL1552	2260.0	2870.0	610.0
AL1119	840.0	939.8	99.8	AL1553	1590.0	2920.0	1330.0
AL1168	1142.5	2626.7	1484.2	AL1597	900.0	1182.0	282.0
AL1169	1482.5	2405.0	922.5	AL1627	642.8	664.9	22.1
AL1170	1620.0	3023.3	1403.3	AL1694	1845.0	1755.2	-89.8
AL1176	2508.0	3346.7	838.7	AL1710	907.0	1010.6	103.6
AL1177	2880.0	3190.0	310.0	AL1711	1143.8	1198.6	54.8
AL1180	1852.2	3425.0	1572.8	AL1806	1410.0	1236.0	-174.0
AL1230	1968.6	2545.4	576.8	AL1820	819.5	822.0	2.5
AL1275	681.8	1053.3	371.5	AL1830	908.4	1028.8	120.4
AL1276	1055.6	1542.2	486.6	AL1831	947.3	1113.8	166.4
AL1277	1087.5	1845.5	758.0	AL1843	887.9	1064.5	176.6
AL1301	1023.3	1300.4	277.1	AL1877	656.0	1220.5	564.5
AL1303	1096.9	1423.2	326.3	AL1899	3934.2	2608.4	-1325.7
AL1306	507.5	550.0	42.5	AL2114	849.6	1038.0	188.4
AL1319	1458.9	1693.9	235.0	AL2363	877.8	939.5	61.7
AL1322	2445.3	3910.0	1464.7				
Aquifer Average	**1985-1989**		**1995-1999**		**Increase**		**%**
	1407.0		**1731.4**		**324.4**		**+23.1**

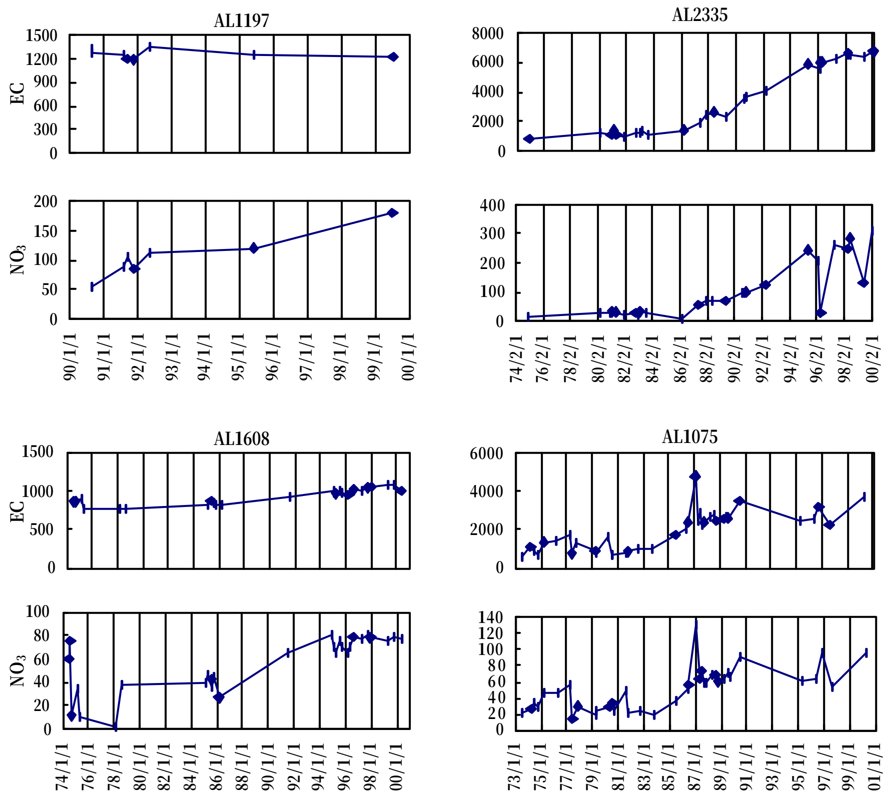


Fig. 4.1.2-1 Tendency of NO_3 Increase in Well Water

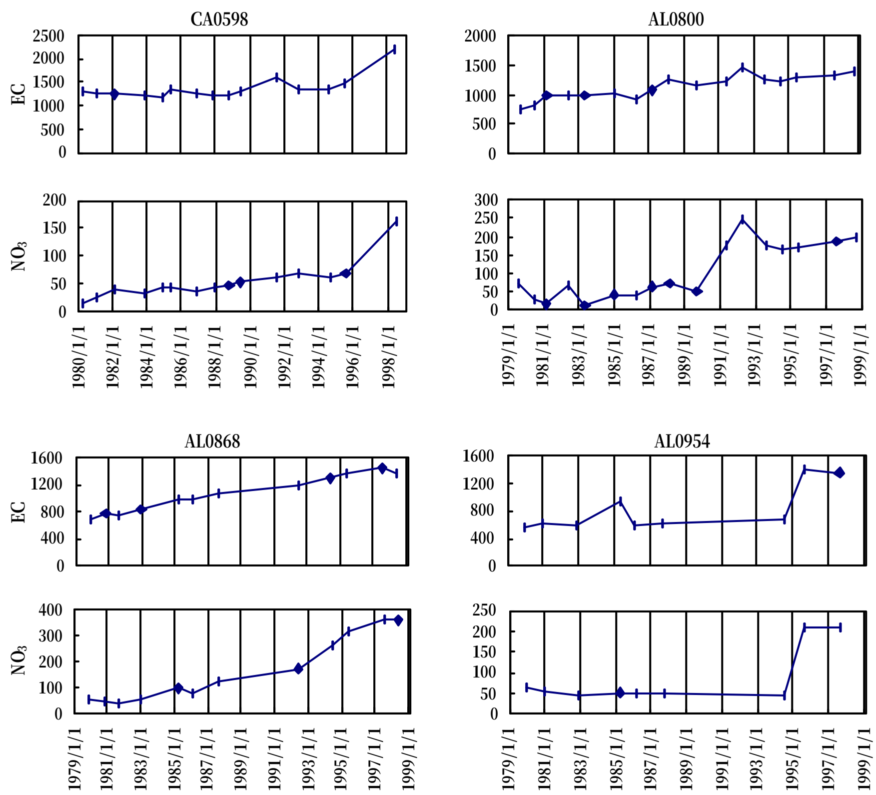


Fig. 4.1.2-2 Tendency of NO_3 Increase in Spring Water

4.1.2.2 Mechanism of Salinity Increase and Nitrate Concentration Increase

(1) Salinity Increase

Although the salinity increase is found nationwide, severe salinity increase area is found especially in Amman-Zarqa Basin. The nitrate concentration is also prominently high in the Basin. In addition, the salinity increase is always accompanied with the increase of the nitrate concentration as shown in Fig.4.1.2-1, Fig.4.1.2-2 the graphs showing groundwater quality change in Annex Report, despite the fact that nitrate concentration increase is not necessarily accompanied with salinity increase.

It is said that the salinity increase has been caused by over abstraction of the groundwater which induced the drawing of high salinity groundwater inflow from high saline water mass in the aquifers or from ground surface to the wells. However, for example, in the south Amman area the groundwater depletion centers do not necessarily coincide with the center of high salinity area (refer to Chapter 4.2). The mechanism of the salinity increase has not been clearly identified yet.

Many sources can be regarded as contaminant of salinity and nitrate such as sewage water. But, the sewage water never becomes a pollutant of salinity increase of groundwater because its salinity is too low ranging 1,000mg/lit to 1,500mg/lit in TDS. The regional salinity increase nationwide can not be explained by sewage infiltration.

The most noticeable phenomena suggesting the mechanism of salinity increase is that the salinity increase simultaneously takes place with the increase of nitrate concentration in almost all cases as mentioned before. The fluctuation patterns of these are completely synchronized even in the short time range as shown in Fig.4.1.2-1 and Fig.4.1.2-1 (also see Annex Report 4.1). This phenomena indicates that their contaminant is coming from same origin. That is, the contaminant not only has high salinity but also high nitrate concentration. Such contaminant might be restricted to irrigation return water.

From 1995 to 1998, a study was conducted on the origin of nitrates and salinization of groundwater in Amman-Zarqa Basin under the financial support of IAEA (International Atomic Energy Agency). From the contents of certain environmental isotopes such as $\delta^{18}O$, δD and $\delta^{15}N$, and their relationship with chemical items, it could be concluded that irrigation return water from the cultivated area through the saline soil and evaporation would have been the main source of salinization of the renewable groundwater.

Therefore, it is inferred that infiltration of irrigation return water including leaching water may be main cause of salinity increase in the renewable groundwater, in spite of the fact that some exceptions may be anticipated such as the case in the Azraq Basin where over abstraction has caused creeping of hyper saline water to the well field.

Assumed schematic mechanism of salinity increase in renewable groundwater is shown in Fig. 4.1.2-3.

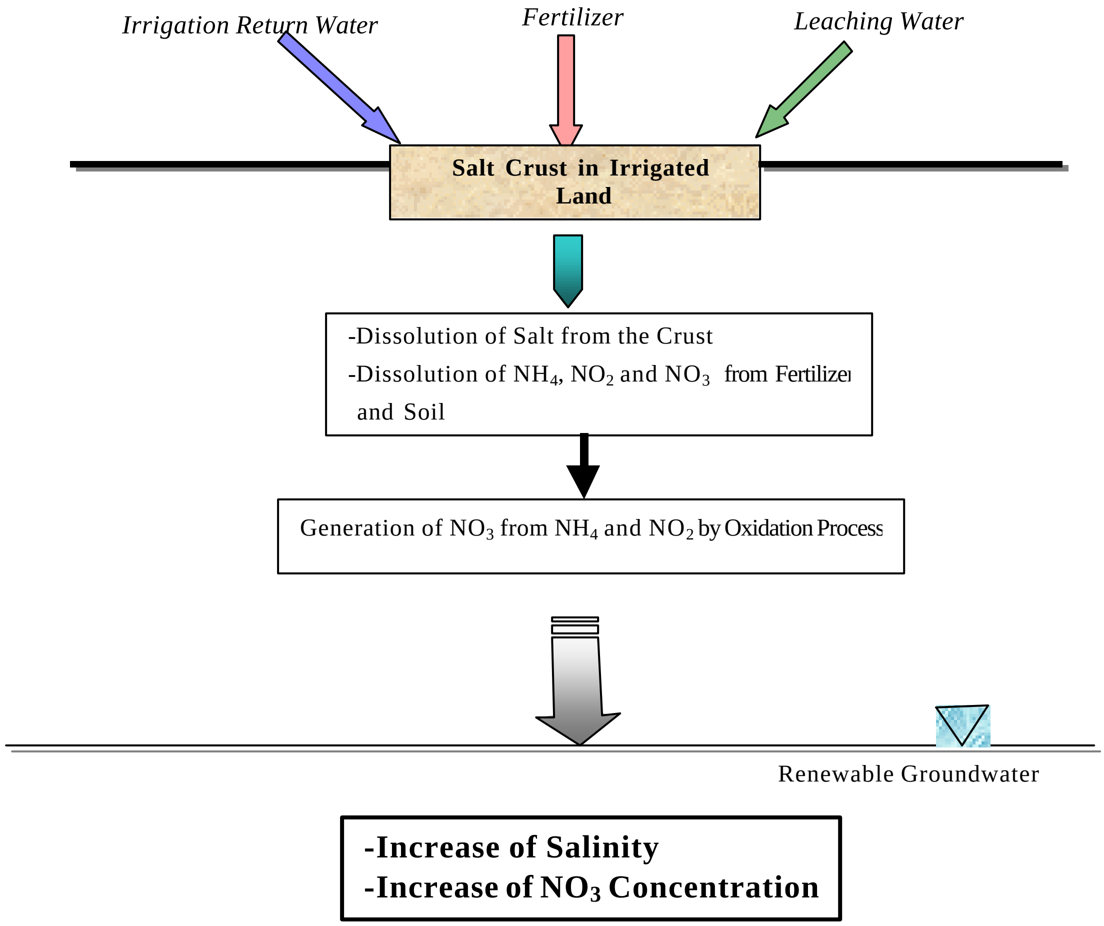


Fig.4.1.2-3 Mechanism of Simultaneous Increase of Salinity and Nitrate in Groundwater

(2) Increase of Nitrate Concentration

Regarding the source of nitrate in the groundwater, the irrigation return water is the main contaminant as described above. Since it was also reported in IAEA study mentioned before that the $\delta^{15}N$ values for most of the selected wells in the Dulayl-Hallabat area east of As Samra WWTP are between 5 to 8 and some higher than 9, it can be suggested that fertilizers and cultivated soil would be the main sources of nitrate.

However, based on the Hashimiyya- Sukhneh area downstream of As Samra WWTP in As Samra WWTP and the Zarqa River itself, it can be concluded that increase of the nitrate concentration is mainly from the wastewater system, at least for the wells in this area. However, it is expected that the condition will change after the rehabilitation of As Samra wastewater treatment system with a change of the treatment method.

Accordingly, it is inferred that the causes of nitrate concentration increase in renewable groundwater have led to the various factors as listed below:

- Infiltration of irrigation return water
- Infiltration of sewage water from treatment plants and Zarqa River

- Infiltration of sewage water from the household
- Infiltration of manure from animals
- Others

It is considered that the infiltration of sewage is only a single source for the nitrate increase in the restricted small area and it can not affect the nationwide area.

Therefore, it is inferred that infiltration of the irrigation return water is the main cause of the regional increase of nitrate concentration same as case in salinity increase.

4.1.2.3 General Evaluation of Groundwater Quality for Water Uses

(1) Water Quality for Domestic Supply

According to the 1998 data, for public water supply in the whole Kingdom groundwater takes about 84% of the total amount. The water is pumped from 348 wells (182.81 MCM) and 30 springs (19.47 MCM), of which 163 wells and 26 springs have water quality monitoring records. Based on the calculated average values of water quality data from 1995 to 2000, of these groundwater sources, 73% show a TDS value higher than 500 mg/L (the allowable salinity level in the Jordanian Standard), the number of sources with TDS higher than 1000 mg/L takes 9.0% and that higher than 1500 mg/L (the maximum limit in the Jordanian Standard) is 3.7%. As for nitrate, the number of sources with NO_3 concentration higher than 50 mg/L (the allowable level in the Jordanian Standard) takes 12.2% and that higher than 70 mg/L (the maximum limit in the Jordanian Standard) takes 5.3%. The highest TDS is 2321.9 for Well AL1022 in Mafraq (39.3 m^3/h) and the highest NO_3 concentration is 194.8 mg/L for Well AD1296 in Irbid (12.7 m^3/h). However, ion-exchange is applied at Well AD1296 for nitrate removal.

(2) Water Quality for Irrigation

About 60% of groundwater resources are used for irrigation in Jordan. According to FAO Guidelines of Water Quality for Irrigation (FAO, 1989), EC=700μS/cm is specified as the most favorable level below which no effect would be suspected to any kind of crop; EC=700-3000 μS/cm is the range where slight to moderate affects on some crops are anticipated; and EC=3000 μS/cm is the limit of severe effects on crops. Because the tolerance of different crops to salinity is different, 700 μS/cm is not usually a practical standard level adopted worldwide, and the medium value of the 700-3000 μS/cm range, i.e. approximately 2000 μS/cm is often considered to be an acceptable level for most crops. Taking 2000 μS/cm and 3000 μS/cm as two reference levels, among the wells and springs with water quality monitoring records 12.0% are unacceptable for irrigation and 5.7% are beyond the limit of severe effects.

Regarding nitrate, the severe effect level is 30 mg/L as N or 133 mg/L as NO_3 according to the FAO standard. There are 7 wells and 19 springs with NO_3 concentration beyond this limit among 640 wells and 383 springs with water quality monitoring records from 1995 to 2000.

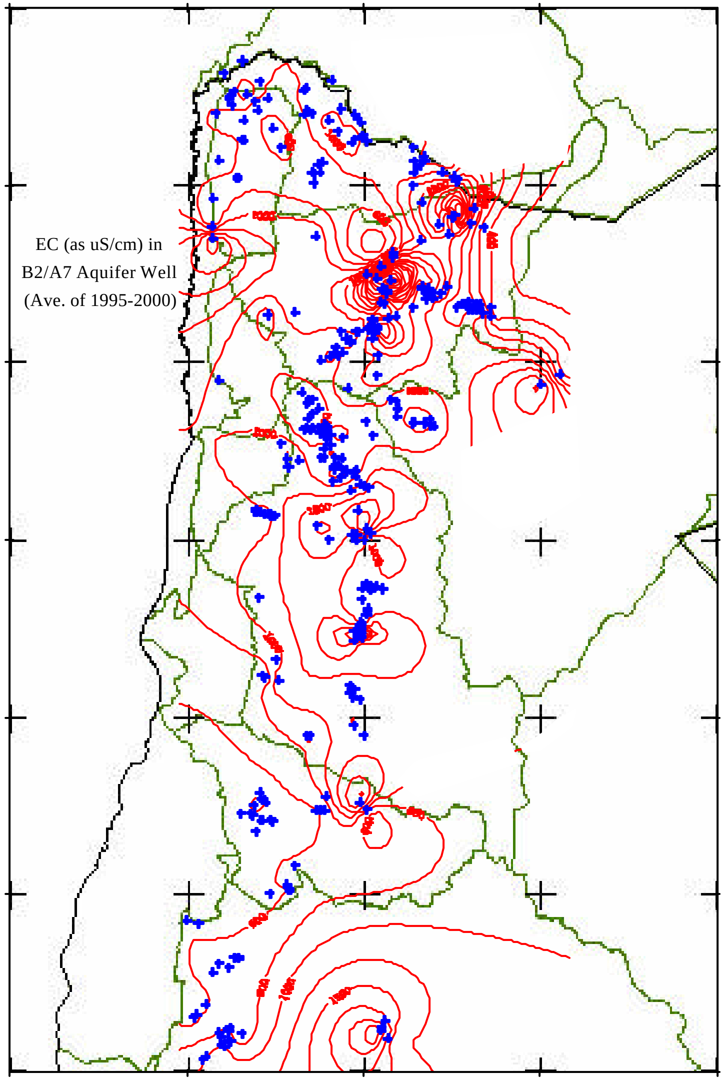


Fig. 4.1.2-4 EC in B2/A7 Groundwater
(Ave. of 1995-2000)

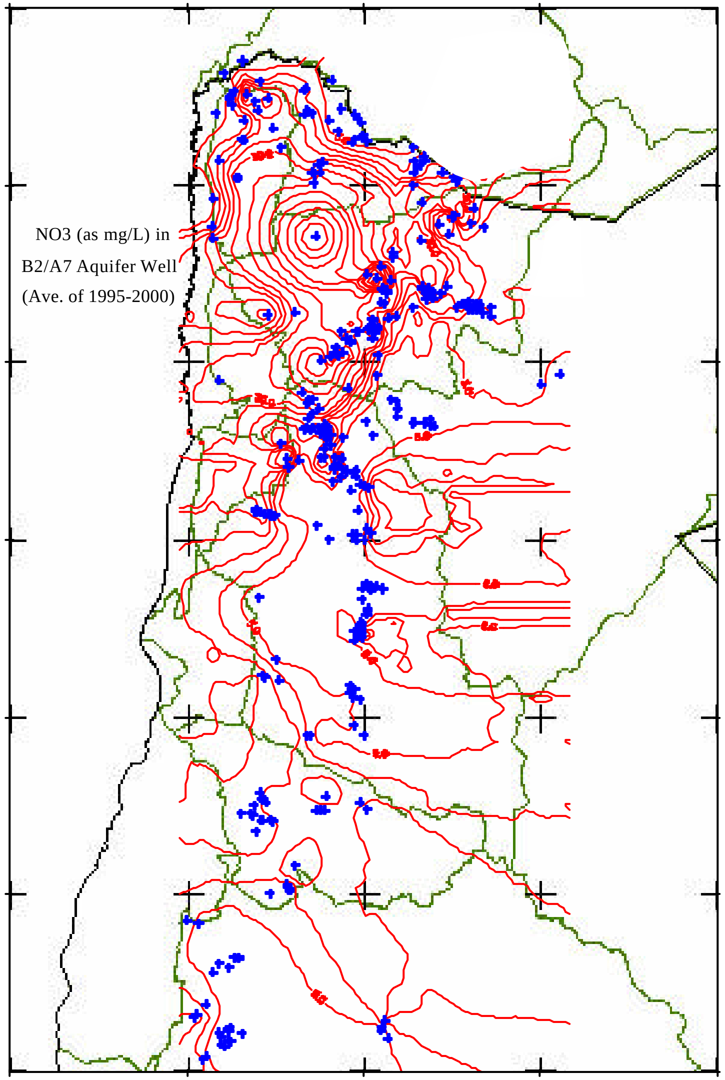


Fig. 4.1.2-5 NO_3 in B2/A7 Groundwater
(Ave. of 1995-2000)

4.2 Groundwater Quality Simulation Analysis

4.2.1 Location of the Simulation Area

South Amman area was selected as a groundwater quality simulation area of this Study for the following reasons.

- Amman-Zarqa Basin is the most important groundwater basin judging from the groundwater developing scale and the situation of the water quality deterioration. However, a real study by USAID including the groundwater quality simulation, Jordan Water Resource Policy Support, now is being carried out in this Basin from January 2000. Therefore, the result of the USAID study will be used effectively in JICA Study.

- Azrak Basin is also one of important basins in Jordan in the point of one of important domestic water sources of Amman with large scale discharge. However, it is not necessary to do a simulation in addition to several groundwater quality simulations, which have already been executed in Azrak Basin.

- A remarkable water quality deterioration area does not exist in other areas. At the same time, the water quality begins to deteriorate slightly in South Amman area in recent years though serious groundwater quality deterioration has not occurred yet. It is necessary to investigate the groundwater contamination measures in South Amman area now because groundwater will not be able to be used safely in the future.

Fig.4.2.1-1 shows location of the groundwater quality simulation area of this study. The area reaches from the southern outskirts of Amman in the north (N 145 Palestine Grid) to the area of Wadi Wala in the south (N110 Palestine Grid) and from E 225 Palestine Grid, east of Madaba, to E 260 Palestine Grid in the east.

This Area belongs to Amman Governorate in the administration and almost entire area belongs to the Wadi Wala catchment in the northern part of Mujib Basin with similar geographical features. The Qastal wellfield and the Qeen Alia International Airport are located in the central part of the area.

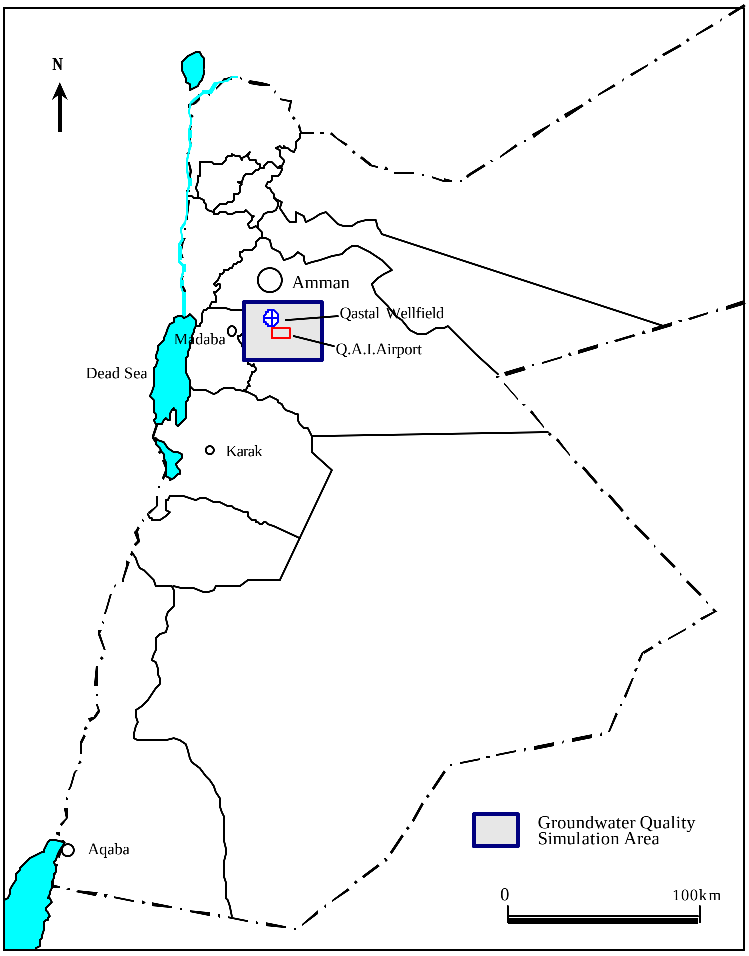


Fig.4.2.1-1 Location of the Groundwater Quality Simulation Area

4.2.2 Hydrogeological Situation

(1) Hydrogeological Units

Fig.4.2.2-1 shows distribution of hydrogeological units in this area.

The Upper Tournian to Campanian B2/A7 unit covers the entire central and western part of the area. The B2/A7 unit comprises limestone and chert with intercalations of dolomitic limestone, marl, chalk, and in its uppermost part the phosphate deposits. In the east, where the B2/A7 units is overlain by B3 formations. The B2/A7 is the only important aquifer in the area as shown in Fig.4.2.2-1.

The overlying Maastrichtian to Palaeocene Muwaqqar Formations (B3) consist of marl, partly chalky, with some intercalations of chalk and limestone. The B3 is aquitard.

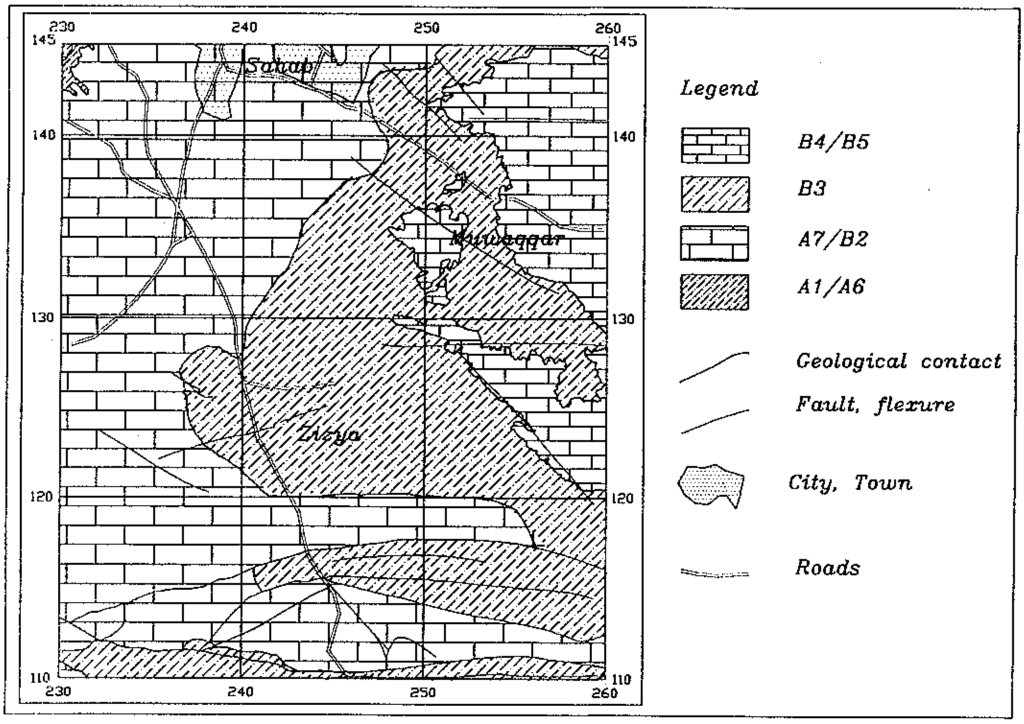


Fig.4.2.2-1 Distribution of Hydrogeological Units

Source: Special Report No.4, Mapping of Groundwater Vulnerability and Hazards to Groundwater in south of Amman (BGR-WAJ, 1999)

2) Existing Wells

Table 4.2.2-1 shows the number of existing wells of each aquifer in this area.

Two hundred (200) wells of 208 total wells are discharging from the B2/A7 aquifer. In addition, all of 7 wells of deeper aquifer are exploration wells. Therefore, only the B2/A7 is a developing aquifer in the area. The water of the B2/A7 aquifer is used for irrigation and the domestic water supply for the communities.

Table 4.2.2-1 Discharging Aquifer in the Simulation Area

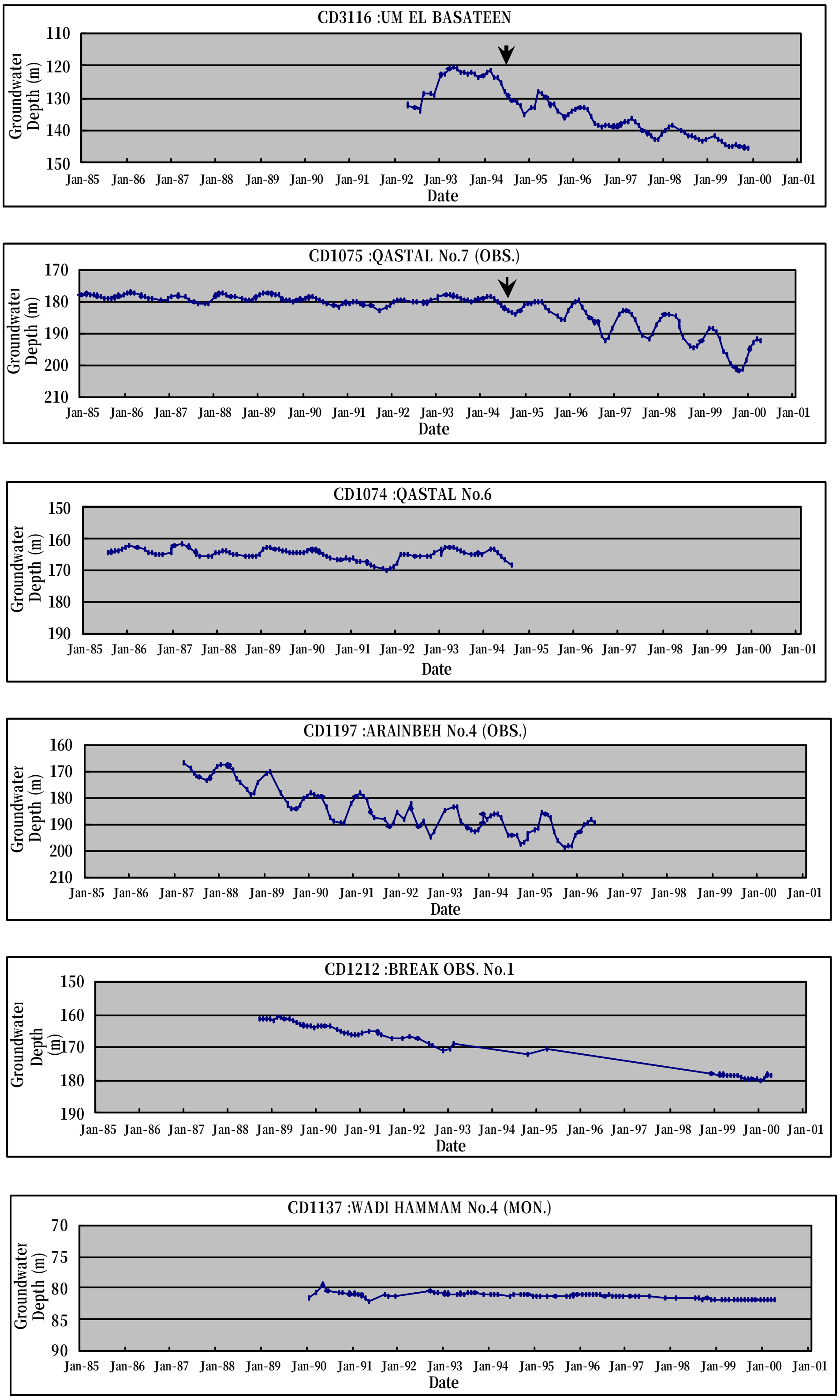
Aquifer	Number of Wells
B4	1
B2/A7	**200**
A4	6
Kurnub	1
Total	208

Source: WIS aquifer test data

3) Groundwater Level

i. Groundwater Level Fluctuation

In this area, there are several wells where the water level is observed for a long term as shown in Fig.4.2.2-. Only six wells of CD1074, CD1075, CD3116, CD1197, CD1137, and CD1212 have a relatively long-term observation data as shown in Fig.4.2.2-2.



Source: WIS, Water Level Data

Fig.4.2.2-2 Groundwater Level Fluctuations in South Amman

The following are understood for these figures.

- The seasonal fluctuations show that B2/A7 aquifer is unconfined in this area.
- At the monitoring wells located in the northern and central part of the area, the groundwater level started dropping since 1995.
- At the monitoring wells located in the southern part, the groundwater level started dropping before 1887.

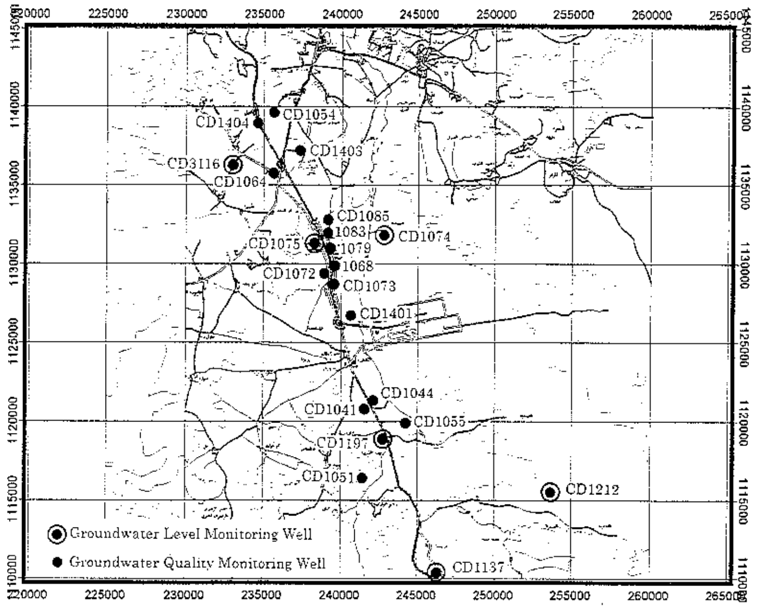


Fig.4.2.2-3 Location of the Groundwater Quality-Monitoring and Level-Monitoring Wells.

ii. Piezometric Potential

Piezometric contour line of B2/A7 aquifer is shown in Fig4.2.2-4. This map is prepared based on statistic water levels in the Aquifer Test Data from WIS. Fig4.2.2-4(1) and (2) correspond to groundwater heads distribution as above sea level and its change in 1985 and 2000.

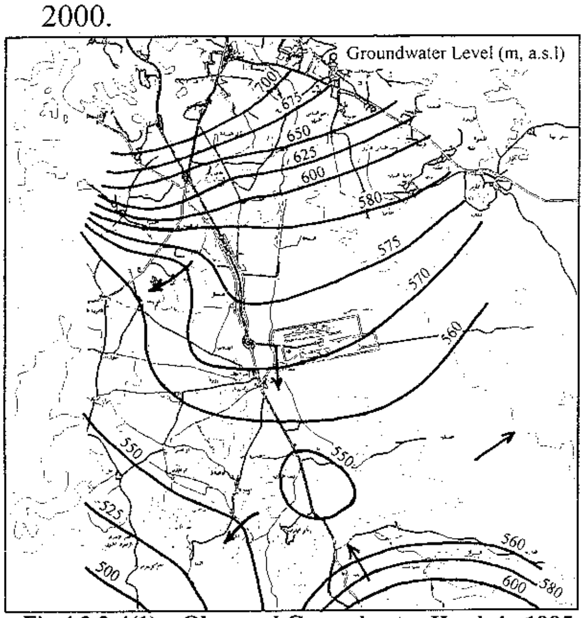


Fig.4.2.2-4(1) Observed Groundwater Heads in 1985

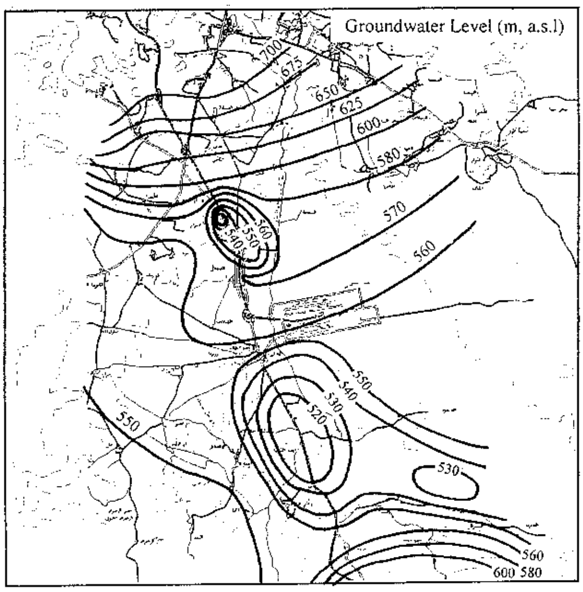


Fig.4.2.2-4(2) Observed Groundwater Heads in 2000

The followings are understood for these figures.

- In 1985, there was a small depression area of the groundwater level at Arainbeh in the southern part of the area.
- In 2000, two large-scale of depression areas, Qastal area in the central part of the area and Arainbeh area in the southern part, were found.

4.2.3 Groundwater Quality in South Amman

1) Long Term Fluctuations

There are many wells where the groundwater quality had been monitored in a long term of 10 years or more in this area. Most of these wells are located along the Desert Highway as showing in Fig.4.2.2-3.

Fig.4.2.3-1(1) shows groundwater quality fluctuations in the northern part of the area and Fig.4.2.3-1(2) is made for the central part and Fig.4.2.3-1(3) for the southern part. These figures are drawn using the WIS Water Quality Data. The following are understood for these figures.

- Fluctuations of EC and NO_3 show very similar trend.
- The NO_3 concentration is approaching the groundwater quality standard of 50 mg/L (the allowable level in the Jordanian Standard) in the northern part of the area although serious water quality deterioration has not yet occurred in this area.
- In the central part and the northern part of the area, the groundwater quality began to increase in about 1985 and it had been stable before 1985.
- In the southern part, there is no deterioration tendency of the groundwater quality.

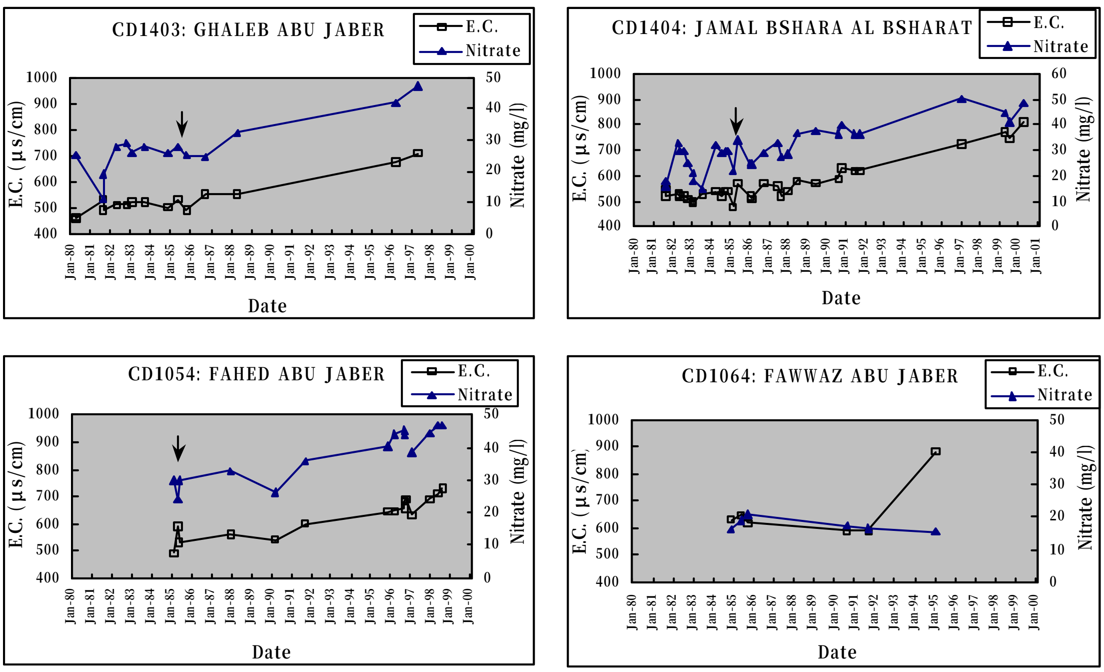
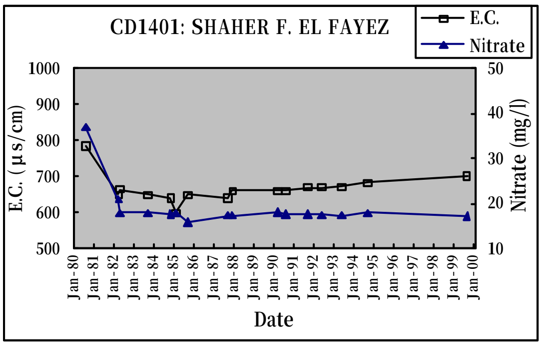
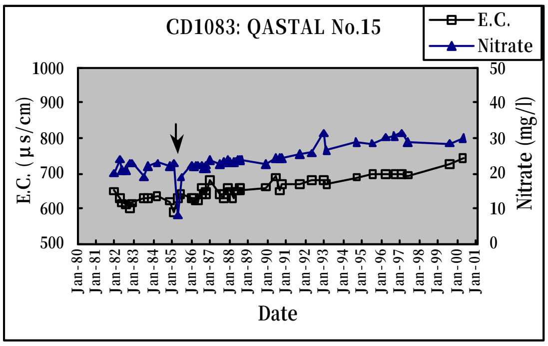
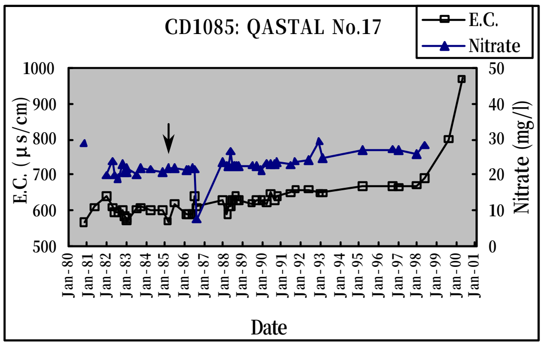
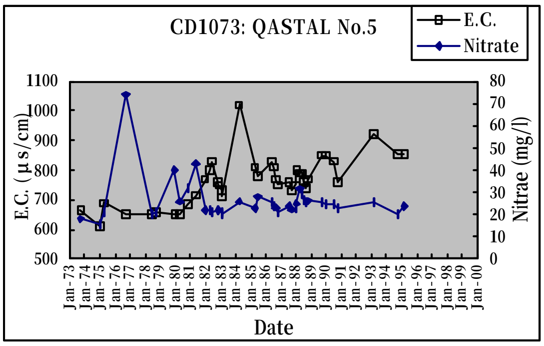


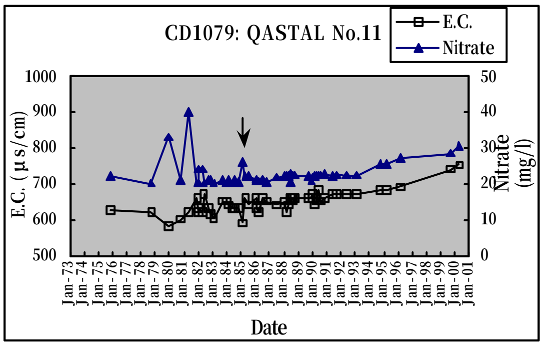
Fig.4.2.3-1(1) Groundwater Quality Fluctuations in the Northern Part of the Simulation Area

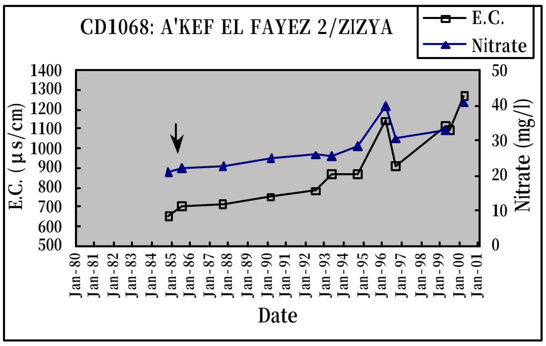












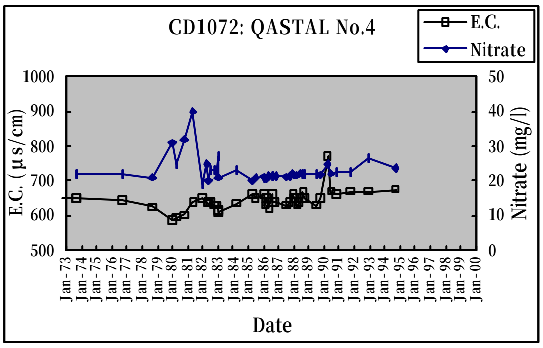


Fig.4.2.3-1(2) Groundwater Quality Fluctuations in the Central Part of the Simulation Area

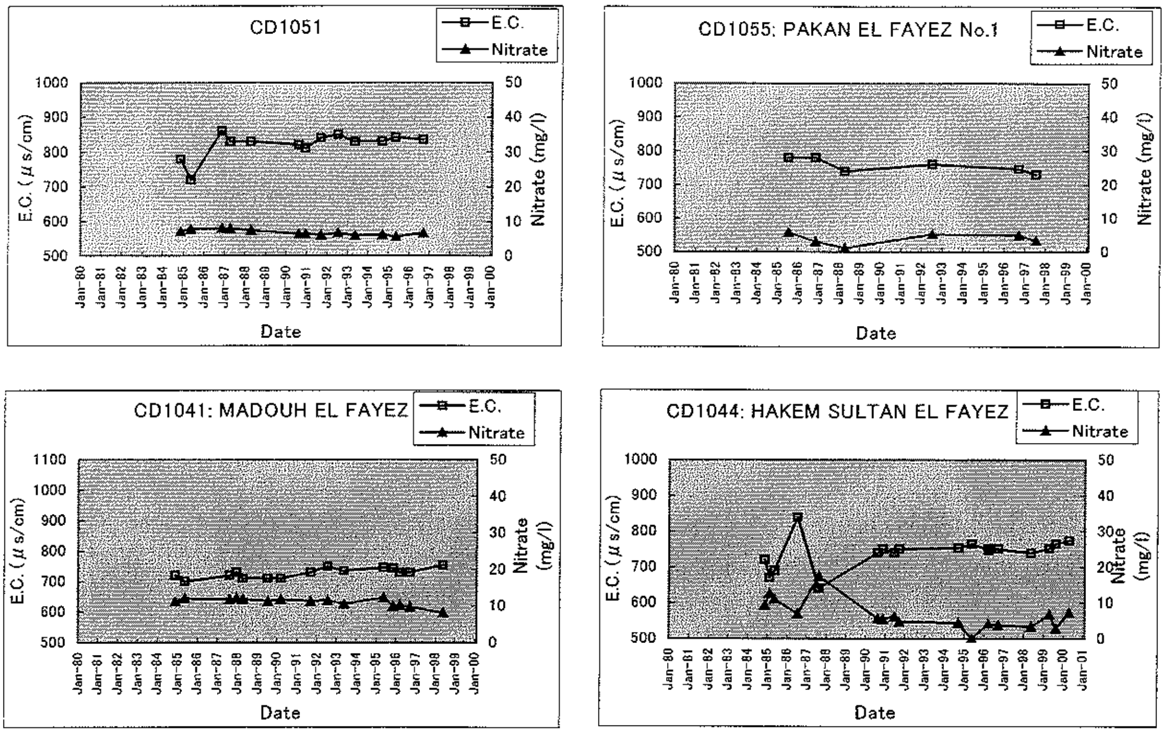


Fig.4.2.3-1(3) Groundwater Quality Fluctuations in the Southern Part of the Simulation Area

2) Spatial Distribution

i. Salinity

Groundwater salinity distribution maps were drawn using the Water Quality Data (Laboratory Data) and the Aquifer Test Data from WIS. Fig4.2.3-2(1) and (2) show salinity distribution (as E.C.) and its change in 1985 and 2000.

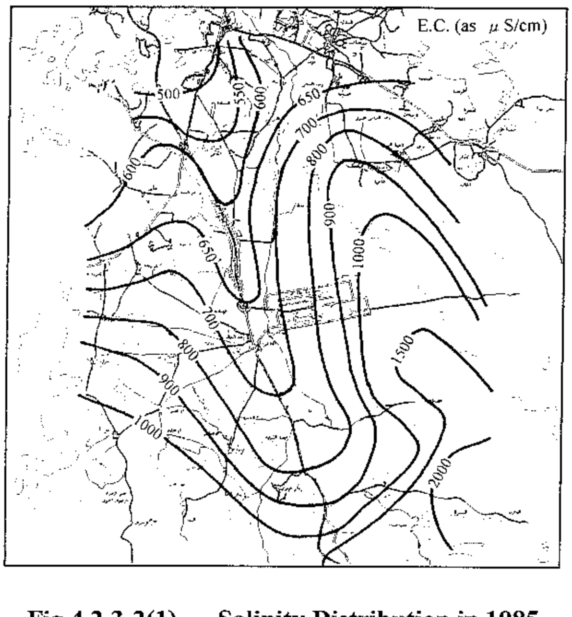


Fig.4.2.3-2(1) Salinity Distribution in 1985

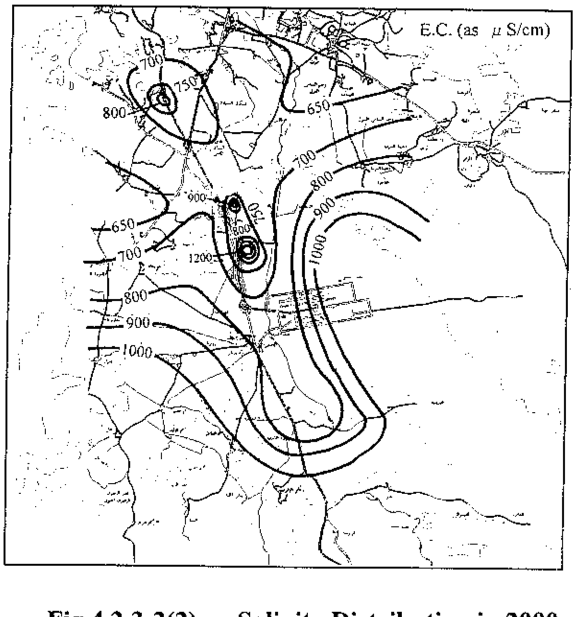


Fig.4.2.3-2(2) Salinity Distribution in 2000

The following are understood for these figures.

- The groundwater salinity is originally higher from north to south.
- Two salinity increase areas, Yadoudah in the northern part and Qastal of central part, are found.

ii. Nitrate Concentration

Distribution maps of the nitrate concentration were drawn using the Water Quality Data (Laboratory Data) from WIS. Fig.4.2.3-3(1) and (2) show nitrate concentration distribution and its change in 1985 and 2000.

The following are understood for these figures.

- The nitrate concentration at Yadudah in the northern part, Qastal in the central part and Arainbeh in southern part of the area is slightly higher than surrounding areas in 1985.
- Two nitrate concentration increase areas, Yadoudah in the northern part and Qastal of central part, are found. These areas correspond to the salinity increase areas.

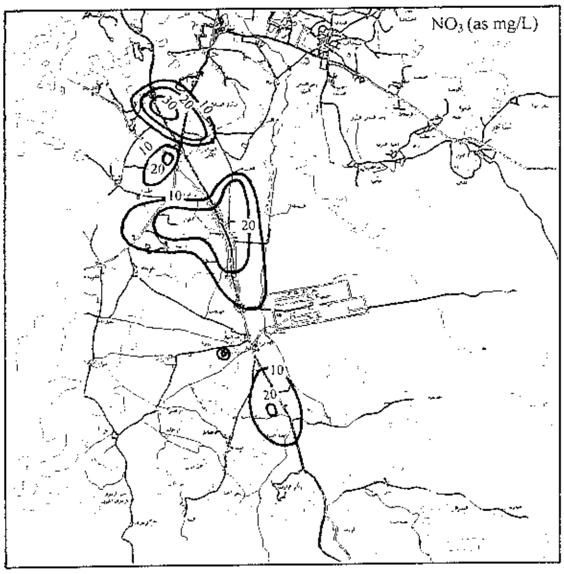


Fig.4.2.3-3(1) NO_3 Distribution in 1985.

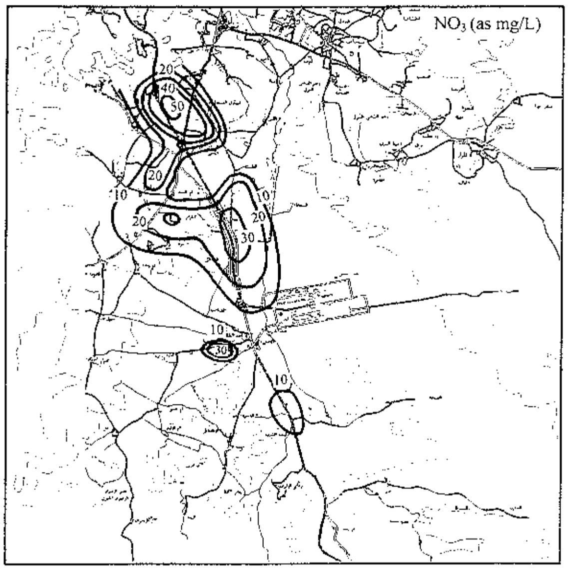


Fig.4.2.3-3(2) NO_3 Distribution in 2000.

4.2.4 Mechanism of Groundwater Flow and Groundwater Quality Deterioration

The main findings for the mechanism of groundwater flow and groundwater quality deterioration in South Amman are as follows, as a result of the above-mentioned analysis of existing data and the field survey in this area.

- The seasonal fluctuations of groundwater level show that B2/A7 aquifer is unconfined in this area.
- The water quality has not changed at all in the southern part of the area where the water level has been clearly dropping for many years. Therefore, the excessive

abstraction is not directly a cause of the groundwater quality deterioration in south Amman area.

- The salinity increasing areas and the nitrate increase area almost correspond with each other.
- The vegetable cultivation with a large amount of water and the fertilizer consumption is being done around the wells where the water quality is deteriorating.
- The origin of salinization and nitrification of groundwater can be due to irrigation return flows.

4.2.5 Groundwater Quality Simulation (Groundwater Flow and Mass Transport Model)

(1) Simulation Program

FEFLOW is employed for the groundwater quality simulation analysis. FEFLOW is the most advanced 3D finite element modeling program for groundwater flow, heat and contaminant transport . FEFLOW can import and link dada from external sources via GIS.

(2) Basic Conditions for the Simulation

1) Aquifer for the Simulation

The B2/A7 is the only developing aquifer in this area. Therefore, only the B2/A7 aquifer is the object aquifer for the simulation.

2) Stratigraphic Model

A stratigraphic model of the simulation area was constructed using available information about the thickness and extent of the geological formations, and structures. The bottom of B2/A7 was taken as bottom boundary. The bottom of the B3 is taken as the top of the B2/A7. The surface topographical elevation was taken as the top boundary for the model. GIS (Geographical Information System) ARC VIEW was used to interpret structural contour maps.

3) Boundary Conditions and Finite Element Mesh

Fig 4.2.5.-1 shows the model area shaped by boundary conditions. The model area except southwestern part is limited with no flow boundaries. In the northern part of the model area, the limit of saturation can be used as no flow boundary. In the southwestern part, the 540m groundwater level contour is used as a constant head boundary.

Finite element mesh is generated as shown in Fig.4.2.4-1.

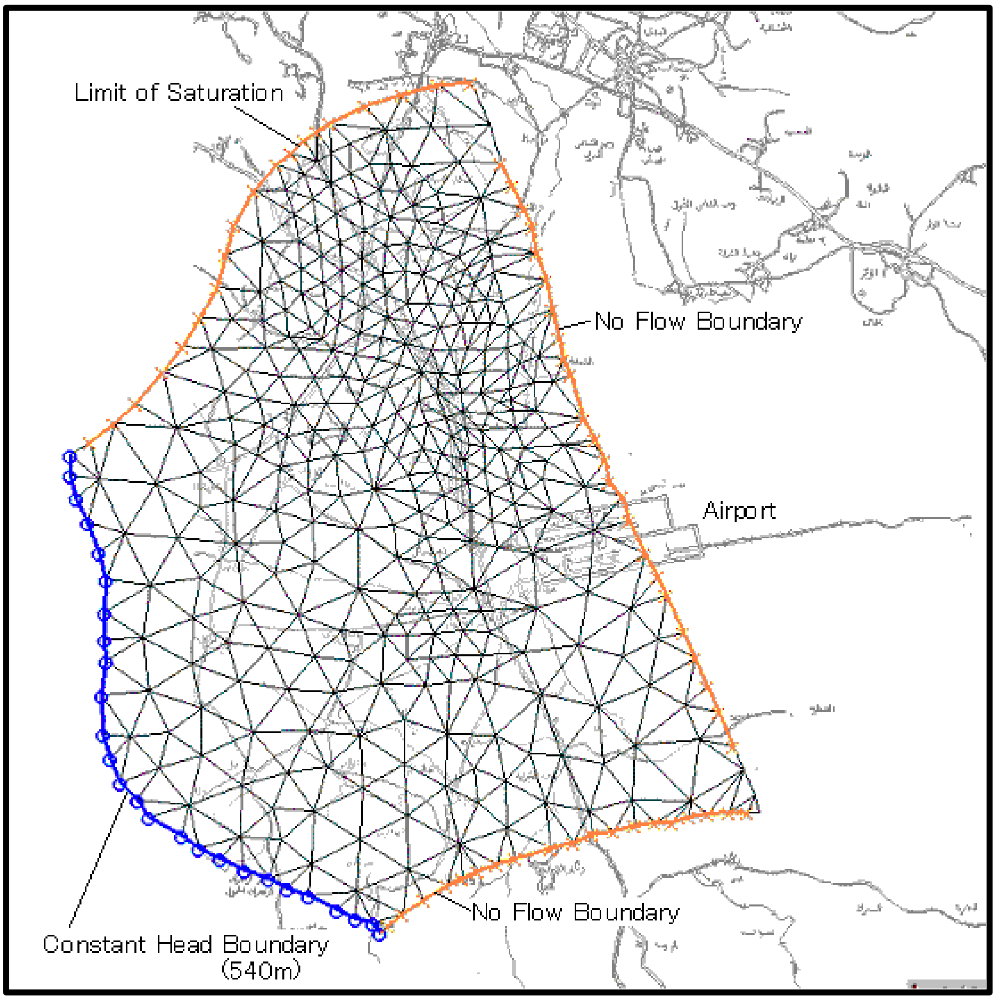


Fig.4.2.5-1 Model Area Showing Boundary Conditions and Finite Element Mesh

(3) Simulation Trial

The groundwater flow and mass transport simulation were conducted through trial and error by changing distribution of aquifer constants, sorption coefficient, molecular diffusion, longitudinal dispersion, transverse dispersion, concentration of mass infiltration and etc. until the present groundwater level contour and groundwater quality contour were reproduced with satisfactory accuracy.

(4) Results of the Reproduction Simulation of the Present Groundwater Level and Groundwater Quality (Calibration Simulation Results)

The initial groundwater level contour line in the year 1985 is shown in Fig.4.2.5-2. The simulated groundwater level contour line in the year 2000 is shown in the Fig.4.2.5-3. Three dimensional view of the simulated groundwater level is shown in the Fig.4.2.5-4.

As in these figures, it is judged that the reproduction of the present condition (calibration) was successfully done through several trial runs by changing various factors.

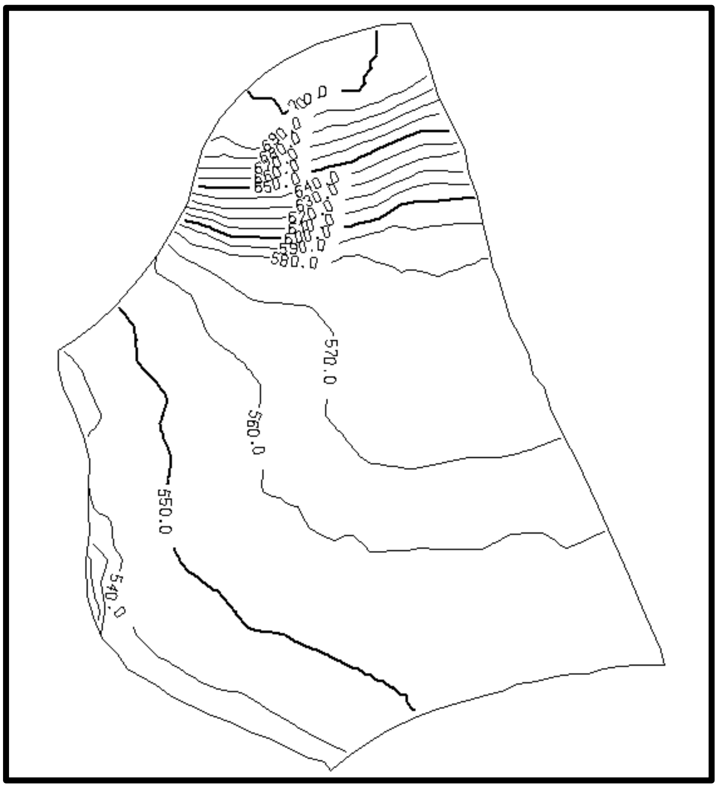


Fig.4.2.5-2 Initial Groundwater Contour Lines in the year 1985

Fig.4.2.5-3 Simulated Groundwater Contour Lines in the year 2000

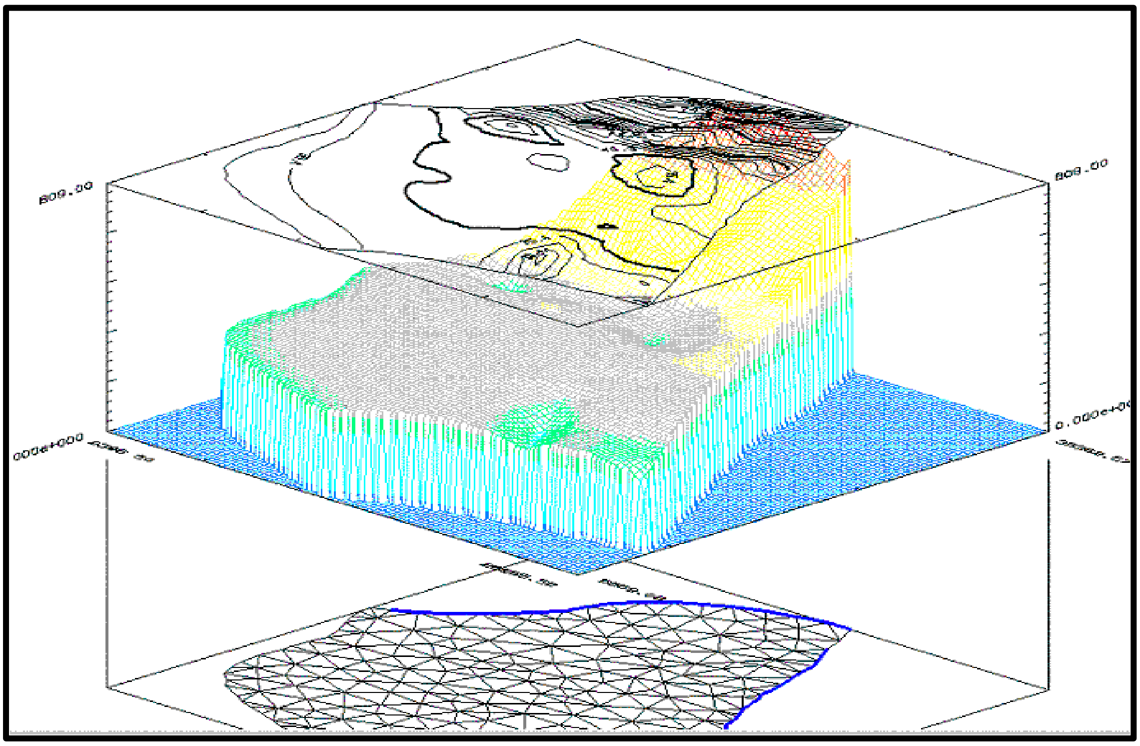


Fig.4.2.5-4 Three dimensional view of the simulated groundwater level in the year 2000

The final calculated groundwater flow balance for time frame of 15 years from 1985 is shown in Table 4.2.5-1. The groundwater recharge amount is estimated at 12.92 MCM/year and the groundwater abstraction is 21.48 MCM/year. The excessive pumping is being done and its amount is about two times compared with the safe yield.

Table 4.2.5-1 Calculated groundwater flow balance for the time stage 15 years from 1985

Fluxes through outer boundaries	Groundwater abstraction through wells	Recharge	Water Budget
-1.96 MCM/year	-21.97 MCM/year	12.92 MCM/year	-11.01 MCM/year

The initial groundwater salinity contour in the year 1985 is shown in the Fig.4.2.5-5 and contour in the year 200 is shown in Fig.4.2.5-6. The initial nitrate (NO3) concentration contour in the year 1985 and the nitrate concentration in the year 2000 are shown in Fig.4.2.5-7 and Fig.4.2.5-8 respectively. The salinity increasing areas and the nitrate increasing areas are corresponding with irrigation areas. Over pumping will support the increase of salinity and nitrate concentration in the irrigation area.

It is inferred that the salinity and nitrate concentration will change during the infiltration in the irrigated areas through trial run of the calibration simulation.

	Original Concentration	Concentration after Infiltration
Salinity	500 – 900mg/lit	3,000 – 9,000mg/lit
Nitrate	20 – 30 mg/lit	150 – 450mg/lit

Above simulation results are almost coincident with previous study (O. Rimawi and E. Salameh, 1999).

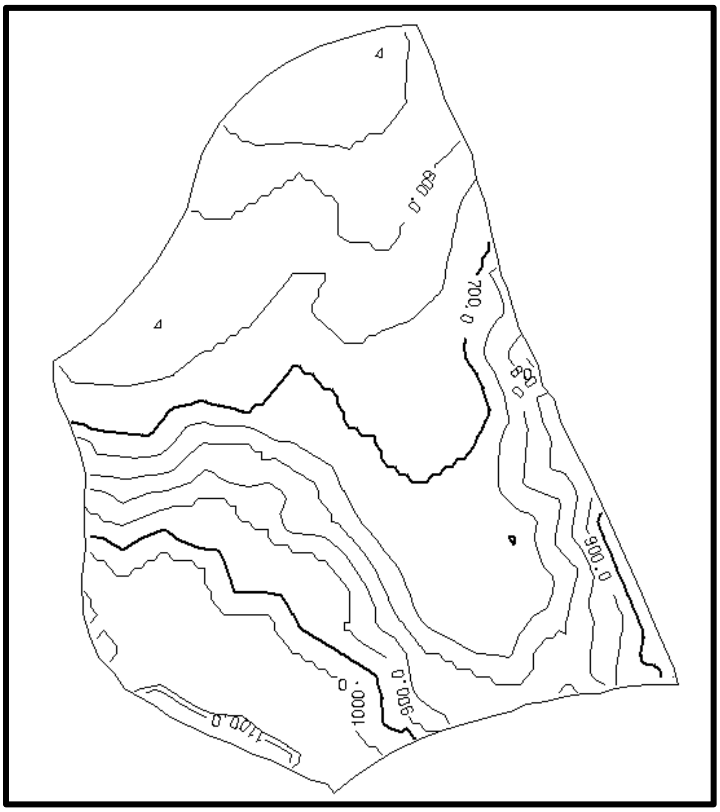


Fig.4.2.5.5 Initial groundwater salinity contour in the year 1985

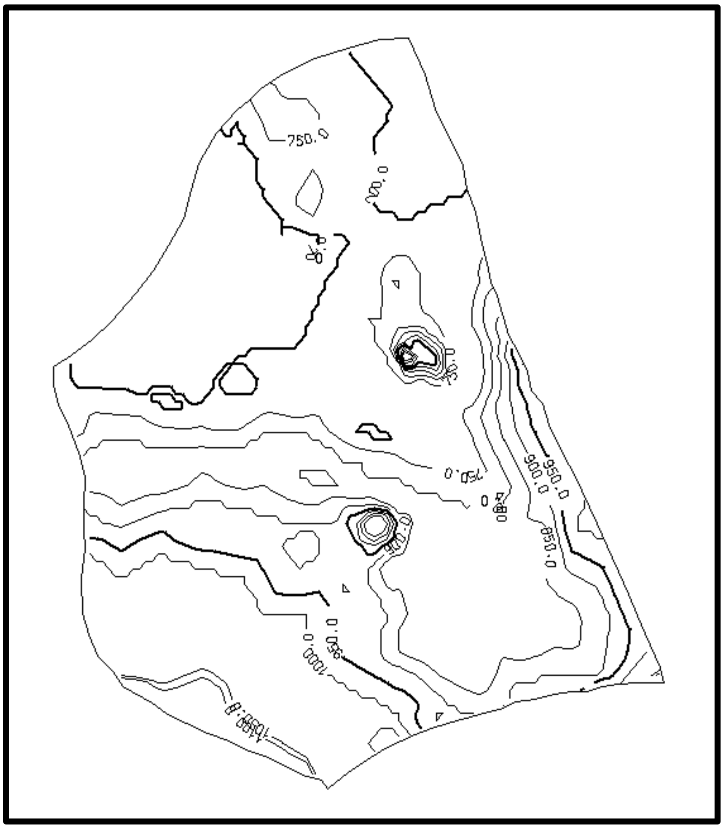


Fig.4.2.5-6 Groundwater salinity contour in the year 2000

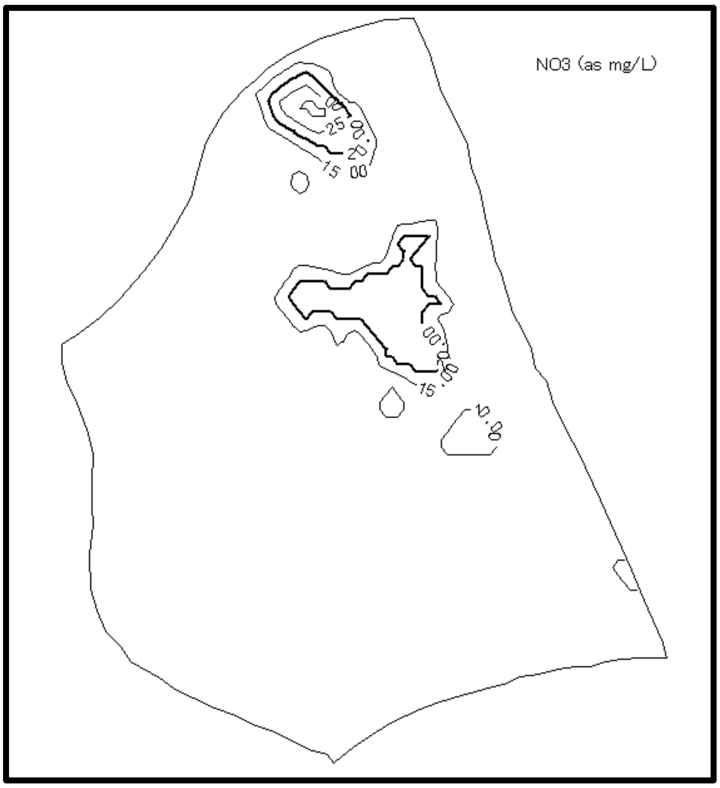


Fig.4.2.5-7 Initial nitrate (NO_3) concentration contour in the year 1985

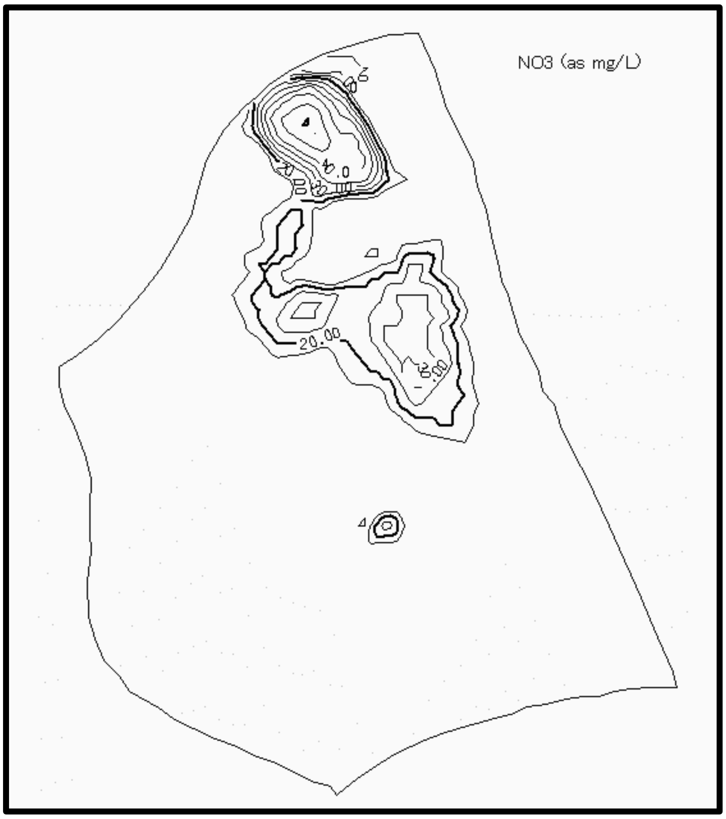


Fig.4.2.5-8 Nitrate concentration contour in the year 2000

(5) Future Prediction

1) Setting of Scenarios for Future Prediction

The most important issue is the protection of the groundwater resources from the over abstraction. Therefore, the first step of the future prediction is done to assume how much the abstraction should be reduced for the sustainable development of the renewable groundwater.

In the second step of the future prediction, the groundwater quality deterioration, increase of the salinity and nitrate concentration is predicted by changing irrigation water use. The optimum abstraction amount of groundwater simulated in the first step is given for the second step predictive simulation.

Flow of the future prediction is schematically shown below:

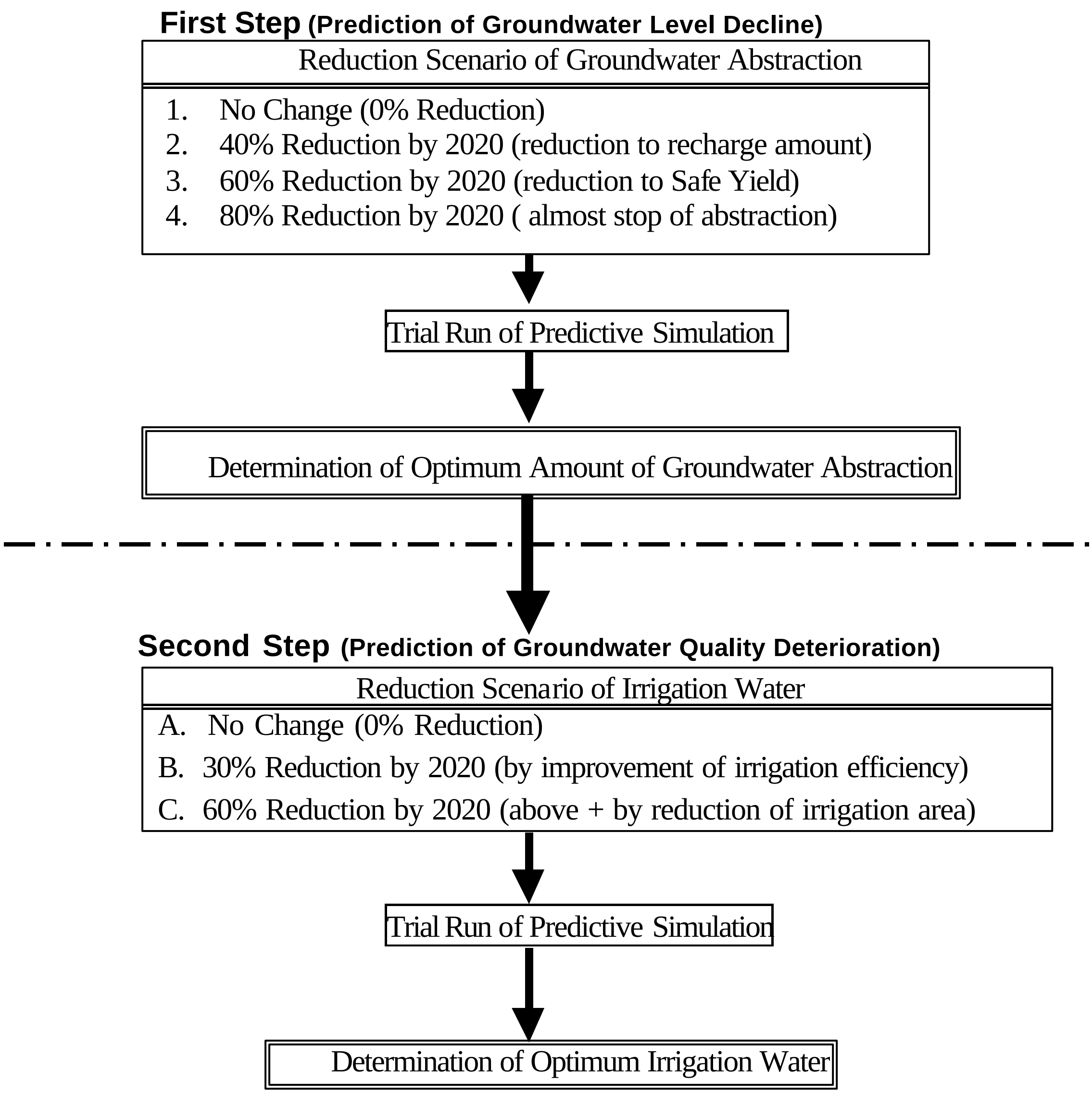


Fig. 4.2.5-9 Flow of Predictive Simulation of Future conditions

Reduction scenarios for both of groundwater abstraction and irrigation water were set up based on following concepts:

- Case of increase of groundwater abstraction and irrigation water use were not considered because it is obvious the groundwater resources must be spoiled in such cases in future
- Irrigation will be continued in the Upland areas in future
- Both of groundwater abstraction and irrigation water will be gradually decreased and reach to final target at 2020
- The prediction will be also done until 2040 after 20 years after the achievement of the target reductions in both of groundwater abstraction and irrigation water use
- The groundwater abstraction and irrigation water use will be constant after 2020

2) Results of the Future Prediction of Groundwater Level Decline (First Step)

Predicted future conditions of groundwater level decline is shown in Fig.15 and 16 of Supporting Report Vol. V.

a. Case 1 (No reduction, Present abstraction continued without any change)

Present abstraction amount of around 25 MCM/a will not be changed in future in this case

As shown in Fig.15 and 16 of Supporting Report Vol. V, groundwater level decline will be still continuing after 40 years and maximum decline from the present level will reach to 40m at 2020 and to 60m at 2040. As the present maximum decline from the natural level before groundwater development is estimated at around 30m as shown in Fig. 4.2.2-4, the maximum decline at 2040 will reach to 90m from the natural level. In this case, simulation results show that the maximum depth to the groundwater level will deepen up to around 300m at 2040. Therefore, it is quite clear that the groundwater will be exhausted in near future in this case.

It is concluded that the groundwater resource will be definitely spoiled if the present manners of groundwater abstraction will be continued without any reduction measures.

b. Case 2 (40% reduction, Reduction to recharge amount)

The present abstraction of about 25 MCM/a will be reduced to 15 MCM/a by 2020 in this case.

As shown in Fig.15 and 16 of Supporting Report Vol. V, groundwater level decline rate will get smaller but still being continued after 40 years. The maximum decline from the present level will reach to 20m at 2020 and to 30m at 2040. The maximum decline from the natural level will reach to 60m at 2040. The maximum depth to the groundwater level will deepen up to around 270m at 2040. Therefore, it is inferred that the groundwater level decline will not completely stop in Case 2 that the abstraction amount is almost same with the recharge amount.

It is concluded that the groundwater resource may not be conserved properly even if the groundwater abstraction amount will be restricted to recharge amount.

c. Case 3 (60% reduction, Reduction to safe yield)

The present abstraction of about 25 MCM/a will be reduced to 10 MCM/a by 2020 in this case.

As shown in Fig.15 and 16 of Supporting Report Vol. V, groundwater level decline will get smaller but and almost stable after 2020. The maximum decline from the present level will reach to 10m at 2020 and recover to the present level at 2040. The maximum decline from the natural level will be around 30m at 2040. The maximum depth to the groundwater level will be around 200m at 2040 which is almost same with the present maximum depth. The influence area of the depression cones will be also reduced but still remained.

According to the predictive simulation results mentioned above, it is anticipated that the groundwater resource might be conserved despite that depression cones will still remain in Case 3.

d. Case 4 (80% reduction, Almost stop of abstraction)

The present abstraction of about 25 MCM/a will be reduced to 5 MCM/a by 2020 in this case.

As shown in Fig.15 and 16 of Supporting Report Vol. V, groundwater level will gradually increase in future. The groundwater level decline from the present level will be almost nil at 2020 and recover to natural level 2040. The maximum depth to the groundwater level will recover to around 170m at 2040. The wide influence area of the depression cones will almost disappear.

This simulation results show that the groundwater abstraction amount should be reduced by more than 80% for the recovery to the natural level.

The results of the future prediction of groundwater level decline are summarized in next table.

Table 4.2.5-2 Results of the Future Prediction of Groundwater Level Decline

Case	Reduction of Abstraction		Reduction Period	Groundwater Level at 2040	
	Reduc. Ratio (%)	Reduc. Amount (MCM/a)		Max. Decline from the Present Level (m)	Max. Depth to Groundwater Table (m)
1	0	0	2000-2020	-60	-300
2	40	10	2000-2020	-30	-270
3	60	15	2000-2020	0 (no change)	-200 (present max. depth)
4	80	20	2000-2020	+30 (recover to natural level)	-170 (natural max. depth)

It is assumed that Case 3 is optimum and realistic reduction amount because the decline of groundwater level may be almost stopped in this case.

Therefore, the groundwater abstraction rate of Case 3 will be applied for second step of simulation which is groundwater quality prediction.

3) Future Prediction of Groundwater Quality Deterioration (Second Step)

Predicted future conditions of groundwater quality, salinity and nitrate concentration, in 2020 and 2040 are shown in Fig.17 to Fig.20 of Supporting Report Vol. V respectively.

a. Case A (No change of irrigation water use)

The present irrigation water of about 18 MCM/a will not be neither reduced nor increased in future in this case.

As shown in Fig.17 and Fig.18 of Supporting Report Vol. V, salinity will continuously increase and the maximum salinity (electric conductivity) of the groundwater will reach to around 1,500 μs/cm in electric conductivity (around 1,100mg/lit in TDS) at 2020 and to 1,900 μs/cm (around 1,300mg/lit in TDS) at 2040.

Nitrate concentration will also continuously increase and the highest concentration will be around 90mg/lit at 2020 and exceed 100mg/lit at 2040.

It is concluded that the groundwater quality will be continuously deteriorated if the present manners of water use for irrigation will be continued even without any changes.

b. Case B (30% reduction by irrigation efficiency improvement and other measures)

The present irrigation water of about 18 MCM/a will be reduced to 13 MCM/a by 2020 in this case.

Increase of salinity and nitrate concentration will be slow-downed and get almost stable after 2020 despite that they will still slightly increase as shown in Fig.17 to Fig.20 of Supporting Report Vol. V. The maximum salinity of the groundwater will reach to 1,300 μs/cm (around 900mg/lit in TDS) at 2020 and to 1,400 μs/cm (around 1,000mg/lit in TDS) at 2040. Nitrate concentration will also slowly increase and the highest concentration will reach to 80mg/lit at 2020 and be almost stable after that.

It is inferred that the groundwater quality deterioration may almost stop or be highly slow-downed if the irrigation water use will be reduced by 30% of present use despite that the present groundwater quality may not be improved.

c. Case C (60% reduction, Reduction by improvement of irrigation efficiency and other measures + Reduction of irrigation area)

The present irrigation water of about 18 MCM/a will be reduced to 7 MCM/a by 2020 in this case.

Salinity and nitrate concentration will keep present level until 2020 and slightly get lower after 2020. The maximum value of salinity will be around 1,200 μs/cm (around 850mg/lit in TDS) at 2020 and 1,100 μs/cm (around 800mg/lit in TDS) at 2040 as shown in Fig.17 and Fig.18 of Supporting Report Vol. V. The maximum nitrate concentration will be around 60mg/lit at 2020 and 50mg/lit at 2040.

It is anticipated that the groundwater quality might be recovered after 2020 if the irrigation water will be reduced to more than half of present use.

The results of the predictive simulation on groundwater quality deterioration are summarized in next table.

Table 4.2.5-3 Results of the Future Prediction of Groundwater Quality Deterioration

Case	Reduction of Irr. Water Use		Reduction Period	Groundwater Quality at 2040			
	Reduc. Ratio (%)	Reduc. Amount (MCM/a)		Max. Increase from the Present Concent. (mg/lit)		Max. Concentration (mg/lit)	
				Salinity	Nitrate	Salinity	Nitrate
A	0	0	2000-2020	+300	+50	1,300	100
B	30	5	2000-2020	0	+30	1,000	80
C	60	11	2000-2020	-200	0	800	50

Groundwater abstraction amount : 10MCM/a (Case 3)

It is assumed that Case B is optimum reduction of irrigation water because the salinity may not increase further and present salinity level might be almost kept in future. In addition, 30% reduction of irrigation water is anticipated to be technically viable by the improvement of irrigation efficiency and other measures according to the on-going WRPS being conducted in Amman/Zarqa Basin by USAID.

The maximum nitrate concentration has presently reached to 50mg/lit which is the upper limit of the WHO standard in the northern part of the simulated area as shown in Fig.4.2.3-3. Since the high nitrate concentration is limited in small areas, the wells for municipal use should be shifted from these areas to the other areas in which low nitrate concentration is low.

(6) Consideration on Simulation Results

1) Necessary Measures for Groundwater Resource Conservation in the South Amman Area

As described in section (5), the groundwater abstraction should be reduced by 60% for the sustainable groundwater development. It means that present abstraction amount of 25 MCM/a should be reduced to less than 10 MCM/a by 2020 which is regarded as safe yield in the South Amman area.

For the groundwater quality conservation, not for improvement, the irrigation water should be reduced by 30% in order to prevent the further deterioration because the present salinity and nitrate concentration levels are still almost less than the standard of potable water. It means that present irrigation water amount of 18 MCM/a should be reduced less than 13 MCM/a by 2020 in order to conserve the groundwater quality.

Consequently, following two measures are recommended for the conservation of the groundwater resource in the South Amman area based on the groundwater simulation results:

I. 60% reduction of present groundwater abstraction for the prevention of the groundwater level depletion

II. 30% reduction of present irrigation water for the conservation of the groundwater quality

Since the irrigation water totally depends on groundwater, target of the measure II will be totally achieved by implementing measure I. From the standing point that the sustainable irrigation should be continued in the Upland area, new water source such as treated wastewater should be used for the irrigation in order to supplement the groundwater reduction as follows:

Table 4.2.5-4 Necessary Reduction of Groundwater Abstraction in the South Amman

	Present Abstraction (MCM/a)	Optimum Abstraction Amount for Stopping Further G.W. Level Decline (Measure I, MCM/a)	Optimum Amount of Irrigation Water for Stopping Further G.W. Quality Deterioration (Measure II, MCM/a)	New Water Source Amount Needed for Sustainable Irrigation (B-A, MCM/a)
Municipal	7	3	-	-
Irrigation	18	7[A]	13[B]	6
Total	25	10	-	-

Note : Abstraction for the Municipal use is also subject to reduction

If the new water source will not be available, the irrigation activities in the South Amman area must be somewhat restricted. According to the on-going USAID project in Amman/Zarqa Basin (WRPS), more than 50% reduction of irrigation water might be possible by "Irrigation Advisary Service (7%)", "Wells buy out (24%)" and "Enforcement of abstraction limit (24%). Same measures can be applied to the South Amman area for the reduction of the irrigation water.

2) Deterioration Mechanism of the Groundwater Quality

In principle, groundwater quality must be improved more or less if the contaminant will be reduced. However, it is assumed that the groundwater quality can not be recovered even the contaminant (irrigation water) will be reduced by 30% in this case study.

It is inferred through the groundwater simulation that the groundwater quality deterioration, especially for increase of salinity and nitrate concentration, is not only dependant on the infiltrated irrigation return flow but also groundwater abstraction. In practice, the irrigation return flow is the main contaminant in this case, but the depression areas induced by groundwater abstraction play indirect role of groundwater quality deterioration.

The depression cone is formed covering the irrigation areas if the groundwater is abstracted in the irrigated areas. Infiltrated irrigation return flow will be caught in the depression cone and it can not outflow or disperse out side of the cone. The infiltrated irrigation water flows toward the center of the cone and it is abstracted by the wells. Abstracted groundwater including the irrigation return flow is again scattered in the irrigation area and infiltrate to the underground. In addition, salinity and nitrate concentration are increasing in this circulation. The schematic drawing of such ***vicious circulation*** is shown in Fig. 4.2.5-10.

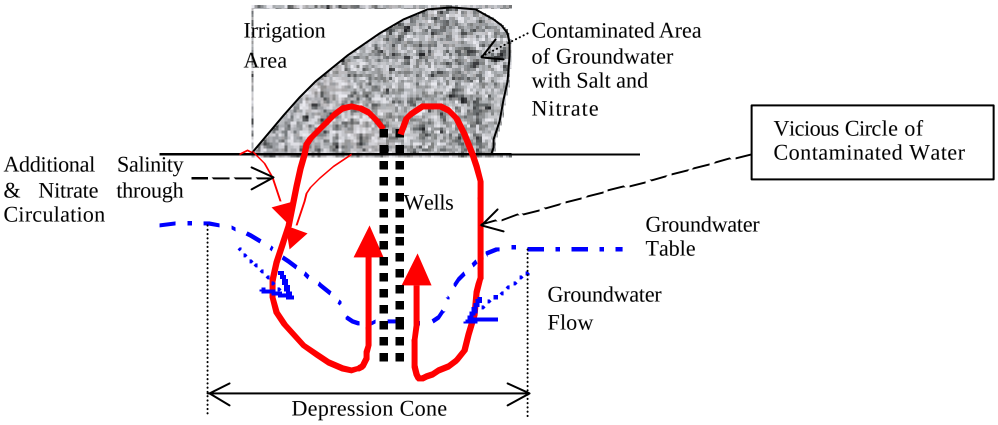


Fig. 4.2.5-10 Schematic Drawing of Vicious Circle of Groundwater Deterioration in the Irrigated Area

Fig. 4.2.3-2(2) and Fig. 4.2.3-3(3) also reinforce the contaminant circulation system shown above because the highly concentrated areas distribute spottily without any dispersion or elongation toward the downstream in these figures.

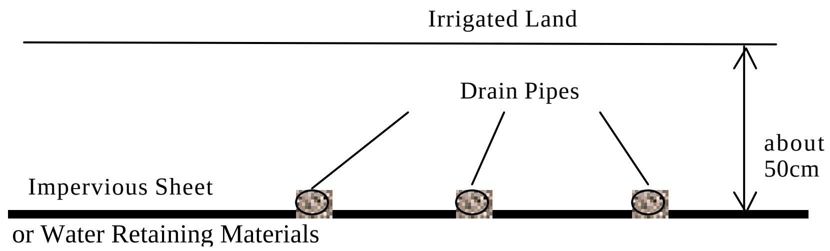
The most problematic phenomena caused by this mechanism is that the salt and nitrate will continuously accumulate in the stagnant groundwater until the irrigated soil will be completely leached. Generally speaking, groundwater contamination caused by such mechanism cannot be mitigated drastically even in the small scaled irrigation if the groundwater abstraction will be continued in the irrigated area. On the contrary, advantage can be found in such type of the contamination because the contamination will remain in the restricted area and not spread widely. Anyway, the groundwater quality in this circle will not be improved unless the irrigation water will be greatly reduced as mentioned in section (5).

For the recovery of the groundwater quality to the previous natural level without the reduction of irrigation, it is considered that only the drastic measures can solve this problem as described below:

i. Relocation of irrigation areas to the outside of depression cones formed by the well fields, the infiltrated contaminant will be dispersed and diluted by the natural groundwater flow and its concentration will decrease

ii. Abandonment of farms or shifting to other areas if the groundwater quality deteriorates, contaminated groundwater in the abandoned farm might be remedied after several tens years by the dispersion and diluted by the natural groundwater flow

iii. Prevention of the infiltration of irrigation return flow by installation of drainage system (not applicable for trees)



3) Negative Impacts to be Caused by Reuse of Treated Wastewater for Irrigation

As mentioned in section 1), deficit among reduction of groundwater for irrigation and reduction of irrigation water will be filled up by reuse of the treated wastewater. It is considered that groundwater contamination and salt accumulation might take place in this case because the salinity and nitrate concentration of treated wastewater is generally higher than fresh groundwater.

The salinity of irrigation water abstracted in South Amman Area ranges from 500mg/lit to 900mg/lit as mentioned in section (4). The salinity level of the treated wastewater is 700 to 1,200mg/lit as described chapter 3.1.3.1. Such a small difference between them will be negligible because the salinity will increase by five to ten times of original concentration after touching with the irrigated soil as mentioned in 4.2.4 (4). So, it is judged that the salinity level of groundwater used for irrigation is almost same with that of treated wastewater from the view point of the salt accumulation. Therefore, it is obvious that the salt accumulation in the soil and salinity increase of groundwater will not happen if the present irrigation manner including regular leaching will be continued in future.

The reuse of treated wastewater for irrigation will not cause serious groundwater contamination by nitrate too because the nitrate concentration of the treated wastewater must be lower than 50mg/lit according to JS 893/1995 (Department for Standard and Metrology). Nitrate concentration of 50mg/lit is the upper limit of potable water in WHO Standard.

Therefore, it can be concluded that the reuse of treated wastewater for irrigation purpose will cause neither salt accumulation in the soil nor groundwater contamination unless the present irrigation method will change.

4) Accuracy and Sensitivity of the Simulation

As the hydrogeological model for the simulation was constructed based on the existing study report and data base (WIS) without any new investigation, the accuracy of the simulation is greatly depending on these data.

The simulation results greatly changed according to the distribution of the transmissivity (T) both in groundwater seepage and contaminant transportation. "T" is most sensitive factor in the trial run of the simulation. Other coefficients such as storage coefficient, dispersion length, and etc. were not so sensitive compared with T.

The existing studies and data base are not prepared aiming the specific purposes for groundwater contamination analysis. The data is not necessarily sufficient for contaminant transport simulation. Especially for the three dimensional distribution of T and groundwater quality (vertical change of T and concentration), data were completely absence. Such values were hypothetically assumed in the simulation.

It should be noted that the simulation done in this Study should be regarded as mere reference for the formulation of groundwater conservation measures in South Amman area. The simulation results should be verified and revised based on the monitoring results after the implementation of the measures for groundwater resource conservation which are reduction of groundwater abstraction and reduction of irrigation water.

4.3 Proposed Plan for Water Quality Conservation

4.3.1 Surface Water Quality Conservation Plans

Surface water resources in Jordan consist of two parts: one is the surface water from the north border area including Yarmouk River water and water from other sources based on the 1994 Peach Treaty; another is surface water from dams and wadis inside Jordanian territory. For surface water utilization, the KAC is playing a very important role for transferring the water from the north border area southward for domestic water supply to Greater Amman as well as irrigation in the Jordan Valley area. As has been discussed in 4.1.1.1, because KAC receives water from different sources and travels a long way as an open waterway at present time, special attention should be paid to this canal for water quality protection. Surface waters are renewable water resources, and should therefore be utilized as much as possible. The availability of the water depends on its quantity and also its quality. Therefore, source water quality protection for all the reservoirs has to be taken into consideration. Correct decision on any plan or measure for solving water quality problems depends on accurate grasp of the characteristics of water quality. For these reasons establishment of a functional water quality monitoring system is indispensable. Under these considerations, the following plans can be proposed for surface water quality conservation.

4.3.1.1 KAC Water Quality Monitoring and Protection

(1) Strengthening KAC Water Quality Monitoring Program

After the occurrence of unpleasant smell from drinking water in the summer of 1998, RSS and WAJ Lab began monthly water quality monitoring for the source water to KAC and along the canal. This is a good start, but a well organized monitoring and information system has not been established yet. As a matter of fact, the RSS activity is under a contract with JVA for water management in Jordan Valley area, and WAJ Lab activity is responsible for the source water management of the domestic water supply to Greater Amman. As is mentioned in 4.1.1, at present the two labs are conducting water quality monitoring almost at the same locations and regarding the similar parameters. In order to strengthen water quality monitoring, the following measures shall have to be taken.

- Formulate an integrated water quality monitoring program under the umbrella of MOWI for the KAC and each of its water sources.

- Establish a common database for KAC water quality and incorporate it into the WIS system.

- Within the KAC water quality monitoring program, on the basis of regular sampling and analysis of ordinary chemical items, organics and nutrients related items as is being currently conducted, increase the frequency of analysis for TOC, TN, TP, DO, Chl-a etc. during the summer season. Although KAC is not an isolated water body, water often flows very slowly and algae growth within the canal may happen in the long and humid summer time. Therefore, Algae Growth Potential (AGP) test is recommendable to be conducted at least monthly in summer period.

- Start regular monitoring of water quality items related to fertilizers, pesticides and other micro-pollutants to assist the identification of pollution sources to the KAC.

(2) Protection of KAC Water

Because KAC is an open waterway, the water inevitably receives pollutants during its flowing from the north border through the Jordan Valley to the Deir Alla intake where water is pumped to Zai Water Treatment Plant. Two options are suggested to strengthen the protection of KAC water.

- Option 1: Establish protection belts at the two sides of the canal, each with a width of at least 20 m. Entries of human beings and animals to the protection zone should be strictly prohibited and any footbridge across the canal should be removed. Instead of footbridges, a limited number of larger bridges with sufficient protection measures should be constructed only at the location where a bridge is really needed.

- Option 2: Change the open waterway to a protected canal by covering the KAC from the north border up to Deir Alla intake with concrete or steel plate. The coverage will play two important roles in the protection of KAC water – one is to completely prevent any pollutants from entering the canal, another is to keep the water from photosynthetic processes so that algae growth can be effectively restrained.

4.3.1.2 Protection of Dams and Reservoirs

As is mentioned in 4.1.1.3, water in most of the dams in Jordan is suitable for domestic and irrigation use, but further protection of water quality is still necessary. Due to scarcity of rainfall in Jordan, water levels in many dams are very low during the long dry season. Intrusion of people and animals into the reservoir area often happens in the low water period, and direct pollution thus becomes possible.

(1) Protection of Dams for Domestic Water Supply

At present, only Wadi Arab Dam partially supplies water (about 23 MCM/yr) to the KAC for domestic use. In the future, Al Wehdah Dam will provide about 50 MCM/yr for water supply to Amman-Zarqa area after its completion possibly in 2004. It is noticed that at the Al Wehdah Dam site, NO_3 concentration is occasionally higher than 50 mg/L (refer to 4.1.1.3) from the influence of agricultural activity in the basin area. Therefore, special attention should be paid to the protection of such important water resources.

Regarding these dams for domestic water supply, the following measures have to be taken for water quality protection.

- Specify protection zones for the reservoir area. Any agricultural or stock farming activity shall be strictly prohibited and human intrusion shall also be controlled within the protection zone. With a shortage of water front area in Jordan, the reservoir area may be inevitably used for recreational activities, but these activities should be controlled so that the impact on water quality shall be reduced to the minimum.

- Erase point source of pollution to the reservoir. The reservoir and its inflow streams should be free from the entry of any industrial, domestic or stock farming wastes.

- Reduce non-point source of pollution to the reservoir. Agricultural chemicals such as fertilizers and pesticides contain harmful substances and are often the main source of nitrate in water. Restriction on their use in the basin area is very important to water quality protection.

- Strengthen dam management and water quality monitoring. Apt management of the dam and reservoir is the most important action of water quality protection. Water quality monitoring will cover, not only the general chemical items (such as salinity, pH, main cationic and anionic ions), but also the items related to toxic effect on human health such as heavy metals and organic chemicals which are specified in Jordanian drinking water quality standard but cannot be easily removed by conventional water treatment processes. In addition, water quality items related to algae growth should be stressed. It is recommendable that the water quality monitoring data shall be compiled into the WIS system (see 4.3.1.3 below).

(2) Protection of Dams for Irrigation

Most of the dams in Jordan are used for irrigation purpose. Generally speaking, there exists no water quality problem with most of the existing dams except for the salinity problem of Karameh Dam, which is affecting the dam's function at present. Measures have been taken to stop the saline flows into the dam but saline sources inside the dam need to be carefully solved in order to enable the dam to play its function as it is designed. Considering the scarcity of water in Jordan, all the dams are important water resources and maximum utilization of them for multi-purposes including domestic water supply in local area will become necessary in the future. Therefore, improvement and protection of the dam water quality to higher level will be required. In this regard, the principles mentioned in the former section are also applicable to the dams for irrigation.

4.3.1.3 Improvement of Surface Water Quality Monitoring and Information System

The WIS of MOWI is a well established database for water in Jordan. Unfortunately, there is not yet any information about surface water quality in the database at present. On the other hand, the activity of surface water quality monitoring is not yet well planned and organized. Improvement on these two aspects becomes necessary.

(1) Improvement of Surface Water Quality Monitoring System

Regarding surface water quality monitoring system, suggestions have already been given by the Water Quality Improvement and Conservation Project (WQICP) funded by USAID (Water Monitoring System Adequacy Report, 1995). In the WQICP report, 130 sites have been proposed for surface water quality monitoring, of which 47 are new sites and others are existing ones. The monitoring program has been proposed in 5 categories: municipal, urban/industrial, drinking water, irrigation and atypical sites. Each category contains several subcategories with parameters for monthly, quarterly, semi-annual and annual monitoring. These proposals have provided the baseline for formulating the future plan of surface water quality monitoring.

It is recommendable that MOWI shall specify all the surface water bodies in Jordan according to their present uses and future utilization plans. According to the characteristics of source water quality for different uses, and the scale of water supply, surface water can be largely specified into the following 3 groups.

- Group 1 – source water for centralized drinking water supply. KAC and its source waters shall be put into this category, because part of the water is supplied to the Greater Amman area.

- Group 2 – source water for local drinking water supply and non-restricted irrigation. Basically speaking, the quality of water required for non-restricted irrigation is not much different from that for the source water for drinking water supply regarding water salinity, nitrate etc.

- Group 3 – source water for restricted irrigation.

Regarding Group 1, water quality monitoring items shall include most of the parameters included in the Jordanian drinking water quality standard (JS 286) and some special biological parameters related to algae growth as is suggested in 4.3.1.1. For Group 2, the water quality monitoring items are basically the same as Group 1 but without the special biological consideration. As for Group 3, the existing water quality monitoring scheme is thought to be suitable.

(2) Improvement of Water Information System

Regarding surface water, the main problem with the WIS is lack of coordination among water quality monitoring, data manipulation and management of the database. At present, there are mainly 3 data sources for surface water quality: JVA Lab, WAJ Lab and RSS Lab under a contract with JVA. All these data are managed at each lab respectively and in different ways, and none of them have been compiled into the WIS database. This problem has to be solved under the coordination of MOWI. Suggestions in this regard are the following.

- Establish the database for surface water quality in the WIS. All the historic data from different sources shall be collected, rearranged and inputted into the database.

- In accordance with the integrated surface water quality monitoring program as is suggested in the former section, put the data into corresponding categories according to water uses. For example, regarding water bodies of Group 1 and Group 2, in addition to the common chemical items (such as salinity, pH, main cationic and anionic ions), toxic parameters, items related to nutrient level (such as TN, TP) and organic matters (BOD/COD, DO) should also be included.

- Increase the number of users of the database to cover the related agencies and departments within MOWI. This is important for a smooth establishment of the surface water quality database because all the historical data are currently managed by these agencies and departments, and acquisition of the firsthand data may need their cooperation.

4.3.2 Groundwater Quality Conservation Plans

4.3.2.1 Countermeasures for Salinity Problem

As is discussed in 4.1.2.2, infiltration of irrigation return flow is the main reason for the increase in groundwater salinity. This is a nationwide problem but most serious in Amman-Zarqa basin where extensive irrigation is being practiced in the upland area. To solve this problem, the following measures are suggested.

The groundwater deterioration simulation results in the South Amman area indicates that the groundwater deterioration may not further progress if the irrigation water will be reduced by 30%.

Though the hydrogeological conditions and deterioration mechanism may differ area to area, the simulation results may not be applicable for other areas.

However, as the simulated area is one of the severe deteriorated areas of groundwater quality in Jordan, reduction of around 30% of irrigation water might stop the deterioration in other areas.

The groundwater quality deterioration has prominently taken place in the Upland. From the standing point of sustainable development of groundwater (stopping the nation-wide groundwater level decline), groundwater abstraction should be reduced to around 60% of present abstraction (about 40% reduction) in whole Jordan (refer to Chapter 2.2.5). Since the irrigation in the Upland is mainly dependant on the groundwater, the 30% reduction of the irrigation water use will be achieved as a result of the implementation of the reduction measures of the groundwater abstraction in the Upland.

According to the on-going USAID project in Amman/Zarqa Basin (WRPS), more than 50% reduction of the groundwater abstraction for the irrigation purpose might be possible by "Irrigation Advisory Service (7%)", "Wells buy out (24%)" and "Enforcement of abstraction limit (24%)". Same measures can be principally applied to the other governorates or areas in Jordan for the reduction of the groundwater abstraction.

Therefore, the reduction of the groundwater abstraction for the irrigation should be employed as a main measure against the groundwater quality deterioration. The groundwater quality monitoring should be carefully done during the step-wise implementation of the measures mentioned above. The final target of the reduction of the irrigation water should be determined based on the actual groundwater quality monitoring results.

4.3.2.2 Countermeasures for Nitrate Problem

As a result of investigation of wells with high NO_3 concentration, it is understood that the nitrate problem can be put into two categories: one is the problem that happens simultaneously with the increase in salinity with irrigation return flow as the main reason; another is the problem that happens in some locations with no direct relation to irrigation return flow and independent of salinity. The former is a nationwide problem, and its solution can be incorporated into the countermeasures for salinity problem as is discussed in 4.3.2.1. The latter is a local problem which happens in certain places where intensive pollutant source (point source) can be easily identified. Because the number of such wells is small and the extent of influence is limited, the realistic way to solve the problem is to change the usage of the water according to its quality and even to close these wells if the water quality is not suitable for any purpose of use.

The groundwater deterioration simulation results in the South Amman area also indicates that the increase of the nitrate concentration in the groundwater may not greatly progress if the irrigation water will be reduced by 30%.

Therefore, the reduction of the groundwater abstraction for the irrigation purpose should be also employed as main measure for the nitrate problem same as for the salinity problem described in the former section.

4.3.2.3 Improvement of Water Quality Monitoring and Information System

Groundwater quality monitoring has been conducted routinely since 1970s and historical data are available in the WIS database. However, water sampling and analysis are not following a regular program. For example, the number of wells with water quality monitoring records in any of the recent 3 years (1997-1999) is 488, but the number of wells monitored in 1997, 1998 and 1999 are 312, 202 and 283, respectively, with only 78 wells having water quality records in each year. The frequency of sampling within each year is also irregular. Consequently, for many important groundwater sources, water quality records are not continuous. This thus affects the worth of the historical data. Therefore it is recommendable that a regular program should be formulated regarding sampling locations and frequency, so as to accumulate a complete set of groundwater quality records for assisting future studies.

Another problem with the existing program is that the monitoring items are limited to salinity (EC), pH, main cations and anions for all the wells regardless of water use. This is not enough to reflect entirely the characteristics of water quality at different aquifers and locations. Regarding wells and springs for domestic water supply, biological items, heavy metals and organic compounds should also be considered.

Regarding groundwater quality monitoring program, detailed suggestions have been given by the WQIC Project funded by USAID (Water Monitoring System Adequacy Report, 1995) with recommendation on water quality sampling sites and water quality analysis parameters. These should be considered in formulating the future plan for groundwater quality monitoring.

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CHAPTER 5
WATER ALLOCATION

CHAPTER 5 WATER ALLOCATION

5.1 Basic Concept for Water Allocation

The main aim of this project is to carry out a comprehensive assessment, with a certain degree of precision, of the available and potential water resources and project water demands in light of the distribution of population, industry, tourism, agriculture, water use and the ongoing and future development programs. The end product of this project as spelled out in the inception report is the formulation of the "Water Resources Management Plan" on the Governorate level. The plan is intended to provide an overall picture of the water resources and demand and to serve as a guideline in managing, via optimum water resources allocation and utilization, in the twelve Governorates forming the kingdom. They are the Governorates of: Amman, Zarqa, Mafraq, Irbid, Ajloun, Jerash, Balqa, Madaba, Karak, Maan, Tafielah and Aqaba.

The assessment of the available water resources forms a major component towards the preparation of the water resources management plan in Jordan and streamlines the allocation of these recourses so as to satisfy the projected water demands in the short, medium and long terms (2005, 2010, 2015 and 2020) respectively. Considerable efforts were made to obtain realistic estimates of the available water resources, making use of the already established Water Information System (WIS) and data base in the MWI. The outcome of the various investigations that have been carried out so far in Jordan were also consulted

The major components of the Country's water resources are surface and groundwater. The evaluation of these resources was made on basin levels as a first step. The availability, potentiality and water resources development prospects were then translated into Governorate scales (Administrative Areas). These areas do not represent hydrological balances. They indicate the water supply/demand administrative areas. Therefore, the analyses refer to the data of the present water consumption and the projected situation in each Governorate. Generally speaking, the average-year conditions have been considered rather than the dry and wet years, as there is no significant difference when compared with average year records. Non-conventional water resources (treated wastewater effluents, desalinated water from sea and/or brackish groundwater), and regional water resources are also considered as supplementary sources to the total available water resources in each Governorate, wherever they occur.

Projection of water demands were made applying appropriate demand scenarios (refer to Chapter 1.5) through the discussion with the MWI, WAJ and JVA competent officials. Other relevant institutions were also consulted in this respect. Preliminary Water allocations which were done in the study, primarily consider satisfying the water demands pertaining to municipal, industrial and tourist purposes as a priority. Irrigation water projections were considered for the the existing irrigated areas and aftermath residual availability of the water resources, adopted crop patterns and exploitability of water resources rather than the availability of land resources.

The projections on water demand paid particular attention to a realistic assessment of unit demand figures pertaining to domestic water use, water requirements for the major industries, the prospects of tourist developments and allowances for unaccounted flows and physical water losses in the water delivery systems. The water requirements of small industrial projects during the planning period were intended to be met using their own water supply facilities, which occurs in each governorate

The major irrigation centers in Jordan are primarily centered in the Jordan Valley and utilize the available surface water resources. Other irrigation schemes rely on groundwater resources exploitation and occur mainly in the upland areas. Irrigation water projections and allocation should be dictated by the adopted water use policies in this regard. The main controlling parameters are: the prevailing overdraft conditions in Jordan, particularly in the upland areas, the overall water shortages that have been experienced in most of the country during the last decade, and the spatial occurrence of the major water sources bodies within the kingdom. In addition, water quality deterioration in some areas within the country was another parameter considered.

The upland areas are totally dependent, for their water requirements, on the potential groundwater, spring flows, and developed surface water through rainfall/runoff harvesting struc tures and the resultant wastewater effluents after being treated. The Jordan Valley area relies primarily on surface water total flows in the Yermouk-Jordan Rivers and Jordan Rift Valley side wadis. This indicates the fact that Jordan valley will remain an area which depends on the water resources of neighboring areas. That is why a more effective management of these resources has to be achieved or addressed. In addition, the Jordan Valley region relies partially on the imported treated wastewater effluent from the upland areas (refer to Chapter 3.2).

In compliance with the water strategy of the government, sector policy and guidelines of the MWI confirmed by the JICA Study Team, there are some considerations which should be taken into account for water allocation in some parts of the country. These considerations, among other things, pertain to:

- Water allocations for domestic, industrial and tourist purposes are of priority.
- After the construction of Wehda Dam as envisaged in 2005, About 20-30MCM/a of water may be conveyed to the Irbid Governorate for municipal demand. As per the outcome of this study, it is ecpected that the provision of water supplies to Irbid Governorate to the Minicipal demand may reach up to 81MCM by the year 2020.
- Wastewater treated effluents reuse is of prime importance. About 5 MCM/a from the As-Samra Treatment Plant effluent should be allocated by the year 2005, for the Power Plant in the Zarqa governorate.
- About 39MCM/a should be allocated for the Lajoon Oil-Shale industry in the Karak Governorate by the year 2020, developing brackish groundwater desalination..
- Industrial water requirements in the Aqaba Governorate should be thoroughly considered, making use of possible seawater desalination and wastewater treated effluent in the area.
- About 20MCM/a as from 2005 may be allocated desalinated brackish groundwater from the Hisban-Kafrain and Zara Zarqa-Ma'in well field to the minicipal demandin the Greater Amman area as well as Dead Sea coasted area

development. Based on JICA present study, this amount would reach up to 49 MCM including 6 MCM for touristic demand by the year 2020.

- About 7.5 MCM/a should be allocated for new Industrial City in Ramtha area/Irbid Governorate, as from 2004.

5.2 Summation of Available Water Resources and Demand Perspective in Jordan

In accordance with the investigation carried out to evaluate the available water resources on a countrywide scale vis-à-vis the projected water demand based on Scenario-1, Scenario-2 and Scenario-3 for all sectors, it can be smmarized here under.

5.2.1 Available Water Resources

Among the available water resources, sustainable development volume for the surface water, groundwater and Peace Treaty Water (Peace Water) are determined according to the development and constraining plans Wastewater effluent increases depend on the municipal and tourist water consumptions. Desalination water can be developed more until the potential limit but the treatment cost is still high and considered a supplemental resource. Therefore in this study the available water resources in the planning period are considered as shown in the table below.

Table 5.2.1-1 Available Water Resources (MCM)

Resource	2005	2010	2015	2020
Surface Water	424	431	446	446
Peace Water	60	90	90	90
Renewable Groundwater	368	337	307	275
Fossil Fresh Griundwater (Disi)	65	92	104	130
Desalinated Brackish Water	43	53	72	85
Desalinated Sea Water (Aqaba)	5	5	17	17
Total[A]	942	1,008	1,036	1043
Wastewater Effluent (Sn. 1)[B]	112	177	220	246
Wastewater Effluent (Sn. 2)[C]	108	177	232	285
Wastewater Effluent (Sn. 3)[D]	103	162	209	246
Senario-1 Total (A + B)	1,054	1,185	1,250	1,289
Senario-2 Total (A + C)	1,050	1,185	1,268	1,328
Senario-3 Total (A + D)	1,045	1,170	1,243	1,289

In addition to these, there are some profound water resource development schemes such as, "Red Sea Dead Sea Canal Project", "Water Transportation from Turkey" and "Disi – Aqaba Hydropower RO Brackish Groundwater Desalination Scheme". Their implementations are not yet concluded and needs more investigation on technical and regional issues.

In view of the prevailing water resources situation in Jordan, the present renewable groundwater abstraction (about 420 MCM as estimated in 1998) has to be reduced to such an extent not to exeed the estimated safe yield of about 275 MCM/a by the year 2020. Out of this total groundwater abstraction , the irrigation water allocation should also be reduced from 266 MCM as estimated by the World Bank in 1998 (including Disi non-renewable groundwater) to about 103 MCM/a by the year 2020.

5.2.2 Demand Perspective and Selection of Scenario

In the study three scenarios of future water demand were examined in municipal, industrial and touristic water use as detailed in Chapter 1.5 and summary of all sectors are three tables below in which the basic policy of irrigation water demand keeping the current water use was taken into consideration as constant. These irrigation demands will be detailed by governorate basis using "Digital National Water Master Plan" module in the Pre-Feasibility Study.

A total quantity of water resources available from the sustainable development of surface water, groundwater and peace water were re-evaluated and determined as the available quantity in this Study. The increase of treated wastewater due to increase of municipal water demand was also predicted. Although the potential quantity of brackish water is high, the use of desalination requires a high processing cost and it will remain supplementary. The available quantities of these water resources were shown in Table 5.2.1-1. Next tables show the water demand in target years which was estimated based on the demand scenarios described in chapter 4. In addition, the relationship between future supply and demand by scenario is schematically shown in Fig.5.2.2-1.

Projected Water Demand Scenario-1 (MCM)

Water Demand	1998	2005	2010	2015	2020
Municipal	237	273	368	445	501
Industrial	39	76	94	114	130
Touristic	1	7	11	16	16
Irrigation	623	694	703	670	630
Total	**900**	**1,050**	**1,176**	**1,245**	**1,277**

Projected Water Demand Scenario- 2 (MCM)

Water Demand	1998	2005	2010	2015	2020
Municipal	237	273	368	493	587
Industrial	39	80	102	134	169
Touristic	1	11	17	19	21
Irrigation	623	981	1,002	992	963
Total	**900**	**1,345**	**1,489**	**1,638**	**1,740**

Projected Water Demand Scenario-3 (MCM)

Water Demand	1998	2005	2010	2015	2020
Municipal	237	260	341	443	510
Industrial	39	72	89	110	132
Touristic	1	10	16	17	17
Irrigation	623	694	703	670	630
Total	**900**	**1,036**	**1,149**	**1,240**	**1,289**

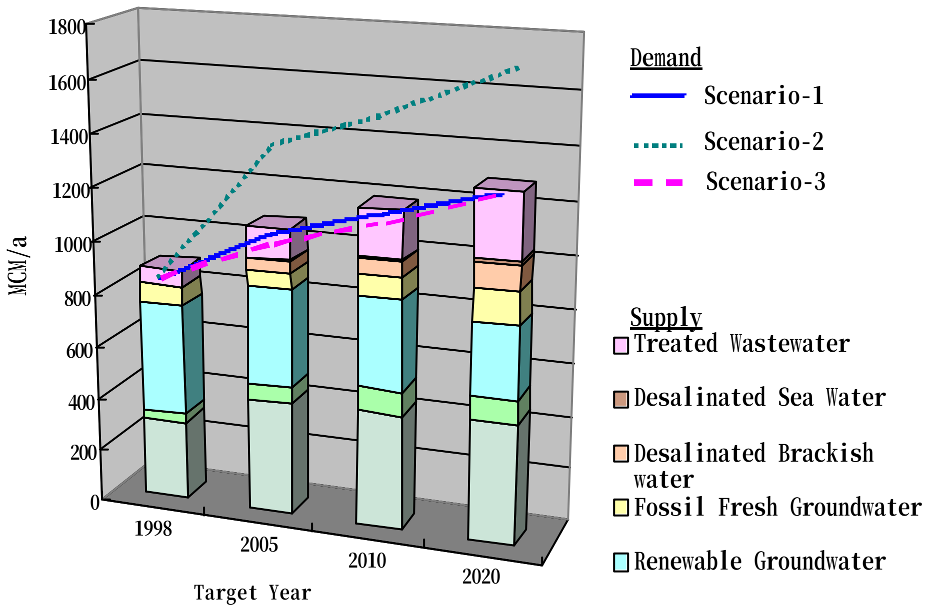

Fig. 5.2.2-1 Balance between Supply and Demand in Target Years by Scenario

Scenario 2 indicates the target water demand which will satisfy the target municipal water demand (150 l/c/d) and target irrigation demand which is estimated based on the future agricultural development schemes. Hence the water demand will extremely exceed the possible supply amount by 412MCM/a in the target year of 2020 as shown in Fig. 5.2.2-1, it is concluded that the Scenario 2 is impossible for its realization.

For Scenario 1 and Scenario 2, as the water demands of both of them will remain within possible water supply amount as shown in Table 5.2.2-1, it is assumed that these are realistic scenarios.

Demand curves of both of Scenario 1 and Scenario 3 are almost coincident each other as shown in Fig. 5.2.2-1. The main differences between them are that the population growth rate is high and water consumption rate per capita is low in Scenario 1 and the population growth rate is low and water consumption rate per capita is high in Scenario 2 as shown in Table 5.2.2-1.

Therefore, Scenario 1 will be employed for the projection of the water demand in the Water Resources Management Master Plan taking the possibility of the delay of the water resources development into consideration.

Table 5.2.2-1 Total Water Demand of Each Scenario in 2020

(Unit: MCM/a)

<table>
<tr><th>Scenario</th><th>MIT Demand</th><th>Irrigation Demand</th><th>Total</th><th>Judgment</th></tr>
<tr><td rowspan="2">Scenario1
(Base Scenario)</td><td>648</td><td>630</td><td rowspan="2">1,278</td><td rowspan="2">○:Water demand will remain within possible water supply. It is applicable for all cases because high population growth rate and low consumption rate are adopted in this scenario</td></tr>
<tr><td colspan="2">Population: 9,180,000</td></tr>
<tr><td rowspan="2">Scenario 2
(Target Scenario)</td><td>777</td><td>963</td><td rowspan="2">1,740</td><td rowspan="2">:Water demand will extremely exceed possible water supply. This scenario is impossible for its realization</td></tr>
<tr><td colspan="2">Population: 9,180,000</td></tr>
<tr><td rowspan="2">Scenario 3</td><td>659</td><td>630</td><td rowspan="2">1,289</td><td rowspan="2">△: Water demand will remain within possible water supply. But, it may not be realistic in case of the rapid population growth because low population growth rate and high consumption rate are adopted in this scenario</td></tr>
<tr><td colspan="2">Population: 7,990,000</td></tr>
</table>

○: Applicable, : Not applicable, △: Applicable but accompanied with some uncertainties

In general, the study considers that efficient management and optimization of allocation and utilization of the of the country's water resources, is of vital importance. Maximizing replenishable groundwater resources and conserving non-renewable resources have to be the main features of the national water use strategy. Many of the aquifers that provide groundwater in Jordan are fissured and offer limited storage capacity for natural groundwater recharge in the winter season, the low water demand period. Therefore, the possibility may exist for optimum usage of these sources in the winter season and conservation of the non-renewable resources for the summer season. This needs further investigation.

The proposed water allocation strategy as spelled out in the following text, has taken into consideration some risk management options in some governorates. These measures or options rely primarily on the availability of surface water resources in particular, and on the prevailing water resources situation on a countrywide scale, in general. The surface water resources availability depends mainly on the prevailing climatic changes, the man-made influence on the shared surface water by the riparian and the over-all impact of groundwater depletions in the aquifers feeding the base flows.

5.2.3 Measures for Drought Year

In this Water Resources Management Master Plan, annual average precipitation was adopted. However annual precipitations are fluctuating with a certain range and dry year when the available water resource is decreased shall be considered. Theses years from 1998 are actually categorized into dry years. At the same time not only the dry years but there are some other factors effecting available water resources such as delaying water resources development projects or rescheduling the implementation of the peace treaty water.

In this Master Plan, groundwater from Lajoun well field which has a yield capacity of 11 MCM/a is proposed as an emergency water source because it is fossil groundwater and possible to store without flowing.

But drought more than that is also expected and for this situation a case study was conducted in order to examine the scale of the effect to water allocation and the possible measures to be taken.

In this case study assumption that drought happens in the year of 2005 and it decreases the surface water in all the country 25% which is expected to happen probably in 20 years according to the hydrological analysis of the study.

Assumptions in the water resources management side are summarized in Table 5.2.3-1 and are postponing the groundwater reduction scheme one year and so on.

Table 5.2.3-1 Water Resources Management in Drought Year

Unit:MCM/a

	Alteration	Dry	Average	Dif.
Decrease of Surface Water Flow	75%	450.2	337.7	-112.6
Postponing Groundwater Reduction	1 year	369.9	379.9	10.0
Non-renewable Fossil Groundwater (Lajoun)	100%	0.0	11.0	11.0
Non-renewable Fossil Groundwater (Disi/Ma'an)	100%	61.9	61.9	0.0
Treated Wastewater Reduction	90%	112.3	101.1	-11.2
Peace Treaty	100%	60.0	60.0	0.0
Brackish Groundwater Desalination (Balqa/Karak)	100%	44.0	44.0	0.0
Seawater desalination (Aqaba)	100%	5.0	5.0	0.0
Surface Water Flow Down		1103.2	1000.5	-102.8

Water allocation and required water demand management based on the above drought conditions are sown in country level in the Table 5.2.3-2. It is necessary to reduce the municipal water 10% except in Aqaba where seawater desalination is deployed. Municipal water is decreased 26.1 MCM. On the other hand irrigation water by surface water is required to reduce 15%, and treated waste water is also decreased according to the decrease of the municipal water. Consequently total irrigation water allocated is decreased 67.8 MCM/a.

This kind of demand management is only implemented by rationing water supply but if it is achieved water supply and use are balanced.

Table 5.2.3-2 Demand Management

Unit:MCM/a

	Alteration	Average	Dry	Dif.
Total Municipality		272.7	246.5	-26.1
Municipal demand except Aqaba	90%	261.3	235.2	-26.1
Municipal demand for Aqaba	100%	11.4	11.4	0.0
Industrial Water	100%	76.1	76.1	0.0
Tourisric Water	100%	6.9	6.9	0.0
Irrigation Water	91%	717.3	649.5	-67.8
Surface Water	85%	391.1	333.9	-57.3
Groundwater	100%	189.1	189.1	0.0
Disi Fossil Water	100%	44.0	44.0	0.0
Treated Wastewater Reuse	89%	93.1	82.6	-10.6
Total		1073.0	979.0	-94.0

Water allocation in 12 Governorates and Water sources in each water demand sector are summarized in Table 5.2.3-3 and Table 5.2.3-4 respectively.

Table 5.2.3-3 Water Allocation in 12 Governorates by 2005 Drought and Average Conditions

Unit:MCM/a

Governorate	MIT		Irrigation		Total	
	Dry	Average	Dry	Average	Dry	Average
Amman	92.1	102.1	41.3	42.1	133.4	144.2
Zarqa	57.1	60.9	62.0	65.2	119.1	126.1
Mafraq	17.2	19.0	50.4	50.5	67.6	69.6
Irbid	44.5	48.4	136.1	150.8	180.5	199.2
Ajloun	4.7	5.2	6.7	6.8	11.4	12.0
Jerash	5.5	6.1	10.8	11.9	16.3	18.0
Balqa	21.9	24.0	204.6	230.9	226.6	254.9
Madaba	12.7	13.9	6.8	8.1	19.5	22.0
Karak	28.2	29.3	55.6	73.4	83.8	102.6
Ma'an	15.8	16.5	46.2	46.4	62.1	62.9
Tafielah	9.7	10.0	8.9	11.6	18.6	21.6
Aqaba	20.1	20.1	19.1	19.6	39.2	39.7
Total	329.5	355.6	648.5	717.3	979.0	1073.0

Table 5.2.3-4 Water sources in Each Demand Sector by 2005 Drought and Average

Drought in 2005

Sector	Total Supply	SW	PT	GW	DISI	BGD	SWD	WWTE
Municipal	252.7	45.2	0.0	150.3	16.2	36.0	5.0	0.0
Industrial	76.1	4.7	0.0	40.4	12.0	4.0	0.0	15.0
Touristic	7.2	2.4	0.0	0.1	0.7	4.0	0.0	0.0
Irrigation	648.5	273.9	60.0	188.1	44.0	0.0	0.0	82.6

Average in 2005

Sector	Total Supply	SW	PT	GW	DISI	BGD	SWD	WWTE
Municipal	273.3	86.4	0.0	140.7	5.2	36.0	5.0	0.0
Industrial	76.1	5.5	0.0	39.3	12.3	4.0	0.0	15.0
Touristic	7.2	2.4	0.0	0.1	0.7	4.0	0.0	0.0
Irrigation	717.3	331.1	60.0	189.0	44.0	0.0	0.0	93.1

SW: surface water, PT: Pease Treaty, GW: groundwater, DISI: Disi water, BGD: brackish groundwater desalination, SWD: Seawater desalination, WWTE: Treated waste water effluent

5.3 Water Allocation Strategy in 12 Governorates

The available gross quantity of water resources shown in Table 5.2.2-1 was divided into the individual quantities to be allocated to the 12 Governorates throughout the country. On the other hand, the water demand in each target year (2005, 2010, 2015 and 2020) was calculated by Governorate using the GTZ module.

The balance between supply and demand in each Governorate was taken by the inter-Governorate water transportation. These allocated water quantities are based on the planned or normal year's available water resource quantity, but it is foreseen that the actually available quantity may be lower than the planned quantity due to some factors such as the supply of peace treaty water and hydrological drought years. To avoid these problems in case of emergency, the additional plan of emergency water distribution was separately formulated taking into consideration the increase in groundwater abstraction and the acquisition of fossil groundwater (in Lajoun area).

By 2005, it will be needed to both convey the desalinated water produced by Wadi Zarqa Ma'in, Zara Spring Project from Jordan Valley to Amman Metropolitan area through the high lift pumping system and also to convey the surface water produced by the Wehda Dam construction project to Greater Irbid by high lift pumping system. By 2010, it will be needed to convey the fossil fresh groundwater from Disi-Mudawara area to Amman Metropolitan area. In addition, the municipal water will become short in several Governorates in the south region in 2020. Consequently, it will be needed to divide the fossil fresh groundwater for allocation to those Governorates.

In view of the previous introductory notes, the water allocation strategy on the Governorate level may be presented in the following text.

5.3.1 Amman Governorate:

1) Available water resources:

(a) Groundwater resources:

Renewable groundwater resources are encountered in the upper aquifer system that occurs partly in Amman–Zarqa, Azraq and Mujib basins. The estimated safe yield of renewable groundwater resources within the governorate is in the order of 34 MCM/a. About 62 MCM is being abstracted from the potential aquifers in the governorate (1998 estimates). Brackish groundwater within the lower aquifer system (the sandy Aquifers) can be encountered at depth but not yet totally assessed. Groundwater quality in the area is generally of good to fair quality (500 – 1000 ppm). Deterioration of groundwater quality is vulnerable along the Seil region where some of the industrial waste is being disposed and as a result of the overdraft conditions that have been experienced in the governorate. Hence, it may be deduced that groundwater exploitation from within the governorate has to be reduced from 64 MCM to 34 MCM by the year 2020, through the reduction of Irrigation water from 30 MCM in 2005 to about 17 MCM in the year 2020

Groundwater supplies to the governorate of Amman are mainly produced from the well fields in the areas of: Qastal, Swaqa, wadi Wala-heidan (Madaba governorate), Katraneh (Karak governorate) and Azraq (Zarqa Governorate) in addition to local well fields. The total external water sources to Amman governorate to meet the MIT demands is in the order of 61 MCM including about 39.6 MCM from Zai WTP(LEMA April 2000). The estimated internal water resources, primarily groundwater and local spring waters are about 31 MCM (WIS data base 1998 esimates) for the MIT demands as well.

(b) **Surface water Resources:**

Surface water sources in the governorate are limited to rainfall/runoff harvesting in wadis of Swaqa and Al- Botum and the Ras el Ain and Wadi-Sir springs flows. The total surface water resources potential in the governorate is estimated at about 7.4 MCM/a. Out of this total, about 3.4 MCM/a is and will be utilized for irrigation. The rest of the total (4.0 MCM/a) would be allocated for municipal purposes during the planning period.

In addition external surface water supplies to the governorate is being conveyed from Yermouk River water via KAC/Der Alla intake to Zai Treatment Plant. About 39.6 MCM of water supplies has been conveyed to Amman (LEMA, April 2000). The Der Alla – Zai water conveyer system is expected to provide 90 MCM/a when it operates in 2003.

(c) **Nonconventioal water supplies**.

There are three existing treated wastewater effluents from the treatment Plants of Abu Nseir and Wadi Essir. The total effluent volume would be about 8 MCM in 2005. Additional three Plants are planned to be constructed at Al-Jeeza, Na'ur and Queen Alia Airport. The total effluent would reach about 16 MCM/a by 2020. In addition, about 40 MCM would be made available by 2004 to Amman governorate after the execution of the proposed Mujib-Zara-Zarqa Main desalinated brackish groundwater Project.

2) Water Demand

As regards water demand for Amman governorate for Municipal, industrial and tourist demands is shown in the following table. The municipal water demand relied on the population growth rates and per capita dialy water consumption. Three scenarios were considered for the demand projections as consulted with MWI officials. The same methodology was applied for the industrial and tourist water demands computation. Per capita water consumption included water leakage percentage in the delivery systems, which ranged from 25% in 1998 down to 15% by the year2020. The per capita water consumption employed for projections ranged from 136 lcd in 1998 up to 176 lcd for scenarios 2 and 3 or up to 151 lcd for the Scenario-1.

As regards water projection for irrigation, it is intended to take into account the availability of the surface water resources in the Amman governorate and would not exceed 3.4 MCM except the development of water harvesting of about 3 MCM/a until the year of 2015.

Amman Governorate (AM) MIT Water Demand (MCM)

Year	Municipal			Industrial			Touristic			Total		
	Sn. 1	Sn. 2	Sn. 3	Sn. 1	Sn. 2	Sn. 3	Sn. 1	Sn. 2	Sn. 3	Sn. 1	Sn. 2	Sn. 3
1998	85.14	85.14	85.14	0.86	0.86	0.86	0.77	0.77	0.77	86.77	86.77	86.77
2005	99.94	99.94	95.42	1.14	1.23	1.05	1.02	1.28	1.06	102.1	102.45	97.53
2010	136.69	136.80	126.77	1.33	1.54	1.21	1.23	1.79	1.23	139.25	140.13	129.21
2015	167.98	186.19	167.43	1.48	1.93	1.39	1.39	2.67	1.46	170.85	190.79	169.22
2020	191.80	224.95	195.33	1.56	2.41	1.61	1.57	3.98	1.69	194.93	231.34	198.63

Amman Governorate Total Water Requirement (Sn. 1) (MCM)

Year	Municipal	Industrial	Touristic	Irrigation	Total Demand*	Export to other Govt.	Total Water Requirement
1998	85.14	0.86	0.77	37	**124**	**5**	**129**
2005	99.94	1.14	1.02	42	**144**	**0**	**144**
2010	136.69	1.33	1.23	42	**181**	**0**	**181**
2015	167.98	1.48	1.39	41	**211**	**0**	**211**
2020	191.80	1.56	1.57	39	**234**	**0**	**234**

* Total Demand does not include intergovernorate water transfer

3) Highlights of Water Allocation

Water requirements to satisfy the MIT demands for Amman governorate, are furnished at present from the internal water resources (About 31 MCM) and external ones (about 61 MCM) totaling to 92 MCM as estimated in 1998. Out of this Total about 5 MCM is conveyed to Balqa, Madaba and Karak Governorates leaving about 87 MCM for the governorate consumption.

In order to satisfy the projected water demand in the Amman governorate it is envisaged that the Mujib-Zara-Zarqa Ma'in Saline Water Desalinization Project, the groundwater potential of the Disi / Ram aquifer in the south and the Yermouk surface waters via Der Alla intake would be considered. Provision of these potential resources may be phased so as to meet the water demands during the planning period (up to 2020) as shown in the table below which reflect the normal conditions in the Governorate.

Amman Governorate Water Allocation (Normal Conditions) (MCM)

Year	Total Demand	Local Sources (MCM)						Possible Avail. Sources (MCM)					Export to other Govt.	Total Requirment (MCM)
		SW		GW		WWE		Disi	SW		Balqa Des. BGW	From other Govt.		
		UP	JRV	UP	JRV	UP	JRV		Zai	Weh				
1998	**130**	7		62		1		0	36		0	24	**4 BA, MA, KA**	**130**
2005	**144**	7		53		8		0	55		11	10 MF 8 MA 2	**0**	**144**
2010	**181**	7		47		12		27	58		31	0	**0**	**181**
2015	**212**	10		41		15		48	58		40	0	**0**	**212**
2020	**234**	10		34		16		75	59		40	0	**0**	**234**

Avail. : Available, SW : Surface Water, GW : Groundwater, WWE : Wastewater Effluent, Weh : Wehda Dam, PT : Peace Treaty Water, Des. : Desalination, UP : Upland, JRV : Jordan Rift Valley, Govt. : Governorate

In case of dry conditions that result in the reduction of the Yarmouk River stream flows may prevail in the country, emergancy conditions may be followed. These conditions may dictate the lowering of the surface water volume conveyed to Amman Governorate by about 20% (as could be revealed by the behavior of the climatic changes generally prevailing in Jordan). In addition the potential groundwater resources in Karak Governorate (Lajoun well field) and Mafraq Governourate (Corridor well field) may be considered as alternative sources to satisfy Amman Governorate water requirments. The table below describes the water allocatoun senario during the emergancy conditions in Greater Amman.

Amman Governorate Water Allocation (Emergency Conditions), (MCM)

Year	Total Water Demand	Local Sources (MCM)						Possible Avail. Sources (MCM)					Total Requirmnt. (MCM)
		SW		GW		WWE		Disi	SW		Balqa Des. BGW	From other Govt.	
		UP	JRV	UP	JRV	UP	JRV		Zai	Weh			
1998	**130**	7		62		1		0	36		0	24	**130**
2005	**144**	7		53		8		0	30		31	14 MF 5 MA 3 KA 6	**144**
2010	**181**	7		47		12		25	46		31	13 MF 5 KA 8	**181**
2015	**212**	10		41		15		48	46		40	12 MF 5 KA 7	**212**
2020	**234**	10		34		16		75	47		40	11 MF 5 KA 6	**234**

Avail. : Available, SW : Surface Water, GW : Groundwater, WWE : Wastewater Effluent, Weh : Wehda Dam, PT : Peace Treaty Water, Des. : Desalination, UP : Upland, JRV : Jordan Rift Valley, Govt. : Governorate

5.3.2 Zarqa Governorate

1) Available Water Resources

(a) Groundwater resources

Groundwater conditions in Zarqa Governorate are almost similar to those in Amman Governorate. The estimated groundwater safe yield is about 47 MCM/a. The abstraction as estimated in 1998 is about 90 MCM. General overdraft conditions are presently experienced in most of the aquifers in Amman-Zarqa basin in which both Amman and Zarqa governorates occur. Groundwater quality is generally good to fair (750-1,500 mg/lit in TDS). During the planning period, it is intended to reduce groundwater abstraction down to about 47 MCM/a, particularly for irrigation purposes from 40 MCM in 2005 to 22 MCM in 2020 from within the governorate.

Groundwater supplies to the governorate are mainly provided from the local well fields. Groundwater from Mafraq, Khalidiyah and Azraq well fields is conveyed to Zarqa and mostly (about 19 MCM as reported in 1998) was transferred to Amman Governorate via Khaw Pumping Station. Total internal resources are about 39 MCM and the external ones are about 15 MCM (WIS and WAJ, 1998).

(b) Surface Water Resources

Surface water resources are mainly from Zarqa River total flows (base, flood and spring flows) which are stored behind KTD and utilized totally in irrigation in Jordan Valley (Irbid and Balqa Governorates). In addition to the current surface and spring water development of about 16 MCM/a, water harvesting of about 2 MCM/a are estimated to be utilized in the upland ares of the governorate, mainly for local dry farming and livestock purposes (Table A2.1.5-1 in Supporting Report).

(c) Treated Wastewater Resources

As-Samra Treatment Plant effluent is the main source of water flowing along Wadi Dhuleil-Zarqa to KTR. The present flows are estimated at 46 MCM and it will increase by time up to 83 MCM by the year 2020. Additional planned treatment plants in Zarqa are on the agenda. Its estimated effluent volume would be 40 MCM in 2010 and is expected to reach about 54 MCM by 2020. The total treatment wastewater flow into Zarqa River and then to KTR (Balqa) available for reuse is expected to reach about 137 MCM by the year 2020. The breakdown of such reuses by the year 2020 are:102 MCM (irrigation in Jordan Valley IR/BA governorates), 20 MCM (for Industrial in AM/ZA) and 15 MCM for local reuse along wadi Zarqa.(refere to Balqa governorate WWT effluent in Section 5.3.7)

2) Water Demand

The table below shows the water demand for Zarqa Governorate for municipal, industrial and tourist demands based on Scenario (1). As regards irrigation water demand, it is based on the available water resources in the governorate.

Zarqa Governorate (ZA) MIT Water Demand (MCM)

Year	Municipal			Industrial			Touristic			Total		
	Sn. 1	Sn. 2	Sn. 3	Sn. 1	Sn. 2	Sn. 3	Sn. 1	Sn. 2	Sn. 3	Sn. 1	Sn. 2	Sn. 3
1998	32.35	32.35	32.35	6.14	6.14	6.14	0.01	0.01	0.01	38.50	38.50	38.50
2005	38.50	38.50	36.77	22.42	22.98	21.79	0.01	0.02	0.01	60.93	61.50	58.57
2010	53.19	53.19	49.28	23.64	24.70	22.84	0.02	0.02	0.02	76.85	77.91	72.14
2015	65.95	73.07	65.70	24.59	27.52	24.04	0.02	0.04	0.02	90.56	100.63	89.76
2020	76.02	89.02	77.36	25.13	30.67	25.43	0.02	0.06	0.02	101.17	119.75	102.81

Zarqa Governorate Total Water Requirement (Sn. 1), (MCM)

Year	Municipal	Industrial	Touristic	Irrigation	Total Demand	Export to other Govt.	Total Water Requirement
1998	32.35	6.14	0.01	65	**104**	**61**	**165**
2005	38.50	22.42	0.01	65	**126**	**43**	**169**
2010	53.19	23.64	0.02	60	**136**	**77**	**213**
2015	65.95	24.59	0.02	58	**149**	**93**	**242**
2020	76.02	25.13	0.02	54	**155**	**103**	**258**

The projection of industrial water demand took into account the sudden increase related to the Electric Power Station and its industrial water waste in the future.

3) Highlights of Water Allocation

Water requirements of Zarqa Governorate are mainly out of its local governorate resources. About 40 MCM are locally produced and about 15 MCM of water from external resources as estimated in 1998 (MWI feedbacks). The amount of water being transferred to Amman (via Khaw Station) and Jerash is in the order of 20 MCM leaving about 39 MCM for the governorate MIT uses (WIS data base 1998).

In order to satisfy the projected water demand within Zarqa Governorate, the major possible sources are from Disi/Ram aquifer in the south and from desalinated brackish groundwater from Balqa Governorate. The table below shows the proposed water allocation strategy taking into account the water needs in other governorates mainly (Amman).

Zarqa Governorate Water Allocation (MCM)

Year	Total Water Demand	Local Sources (MCM)						Possible Avail Sources (MCM)					Export* to other Govt.	Total Require-ment (MCM)
		SW		GW		WWE		Disi	SW		Balqa Des. BGW	From other Govt.		
		UP	JRV	UP	JRV	UP	JRV		ZAI	Weh				
1998	**104**	16		89		46		0			0	13 (MF)	**61** AM 20, BA 41(ww)	**165**
2005	**126**	16		76		67		0			0	10 (MF)	**43** BA/IR, 3 loss	**169**
2010	**136**	16		66		101		12			5	13 (MF)	**77** BA/IR, 6 loss	**213**
2015	**149**	18		57		123		14			5	17 (MF) 9 (IR)	**93** BA/IR, 7 loss	**242**
2020	**155**	18		47		138		16			5	20 (MF) 15 (IR)	**103** BA/IR, 8 loss	**258**

*Export out of wastewater efluent transferred to Jordan Valley (KTR) /Balqa Governorate.
Avail. : Available, SW : Surface Water, GW : Groundwater, WWE : Wastewater Effluent, Weh : Wehda Dam, PT : Peace Treaty Water, Des. : Desalination, UP : Upland, JRV : Jordan Rift Valley, Govt. : Governorate

5.3.3 Mafraq Governorate

1) Available water recourses

(a) **Groundwater Resources**:

The area encompasses the northern part of the Amman-Zarqa and Azraq basins and includes Hamad basin. Basalt and Rijam aquifers are the main producing ones in the governorate. The middle aquifer system includes fair to poor ground-water quality 1000-2500 ppm. The upper aquifer system includes good water quality (<1000 ppm) in general.

Localized fair groundwater quality (more than 1000 ppm) may be encountered in some areas in Mafraq due to excessive irrigation application in these areas .
In 1998, groundwater abstraction was estimated at 90 MCM while the safe yield is about 77 MCM within the governorate. It is planned to reduce groundwater abstraction in Mafraq down to safe yield in 2020, through the lowering of the irrigation water allocation from 48 in 2005 down to 26 MCM in 2020.

Groundwater supplies to the governorate are from local well fields. Practically the area is considered as self sufficient in view of water production. It also provides water supplies to Zarqa, Irbid and Jerash governorate (about 19 MCM/1998 estimate) (WIS and WAJ 1998).

(b) **Surface water resources and treated wastewater Effluents**:

Only rainfall/runoff harvesting storage structures occur in this governorate. Surface water resources are reported to range 7-10 MCM/a on wet years. The resources are primarily for livestock and dry farming purposes.

Treated wastewater effluent is very limited and would not exceed 1-2 MCM/a in 2020.

2) Water demand

As regards water demand projections, the same methodology was employed like in other governorates in Jordan. The table below shows the water demand as per scenario (1) explained earlier. Irrigation water demand within Mafraq is totally provided from the groundwater resources encountered in the upper aquifer system in the area.

It is worthwile mentioning here that water demand projections in Mafraq may not reflect the actual municipal supplies in the Governorate. The high estimates of per capita consumption may be attributed to the high rate of UFW due to the administrative and physical losses and the resultant impact on the groundwater abstractions from within the Governorate. Lowering per capita consumptions during the planning period is considered as of 2010 taking into account the efficient water legeslations to combat illeagal groundwater abstractions, rehabilitation of water supply networks and the matching of per capita consumptions on a country wide scale.

Mafraq Governorate (MF) MIT Water Demand (MCM)

Year	Municipal			Industrial			Tour.	Total		
	Sn. 1	Sn. 2	Sn. 3	Sn. 1	Sn. 2	Sn. 3		Sn. 1	Sn. 2	Sn. 3
1998	19.25	19.25	19.25	0.25	0.25	0.25	0.0	19.50	19.50	19.50
2005	18.74	18.74	17.89	0.30	0.32	0.27	0.0	19.04	19.06	18.16
2010	21.88	21.88	20.27	0.35	0.40	0.31	0.0	22.23	22.28	20.58
2015	22.49	24.82	22.32	0.38	0.50	0.36	0.0	22.87	25.32	22.68
2020	20.77	24.24	21.05	0.40	0.63	0.42	0.0	21.17	24.87	21.47

Mafraq Governorate Total Water Requirement (Sn. 1), (MCM)

Year	Municipal	Industrial	Touristic	Irrigation	Total Demand	Export to other Govt.	Total Water Requirement
1998	19.25	0.25	0	56.0	**76**	**18** ZA 13, R 3, JA 2	**94**
2005	18.74	0.30	0	51.0	**70**	**18** AM 5, ZA 11, JA 1, AJ viaIR 1	**88**
2010	21.88	0.35	0	45.0	**67**	**19** ZA 13, AJ viaIR 3, JA 3	**86**
2015	22.49	0.38	0	41.3	**64**	**26** ZA,16, AJ viaIR 5 JA 5	**90**
2020	20.77	0.40	0	36.4	**57**	**30** ZA 20, AJ viaIR 4, JA 6	**87**

Avail. : Available, SW : Surface Water, GW : Groundwater, WWE : Wastewater Effluent, Weh : Wehda Dam, PT : Peace Treaty Water, Des. : Desalination, UP : Upland, JRV : Jordan Rift Valley, Govt. : Governorate

3) Highlights of water Allocation

Water requirements in Mafraq are totally satisfied from the internal groundwater resources. As stated earlier**,** the governorate is considered as self-sufficient and a water source for other governorates. The table below describes the proposed water allocation senario taking into account the prevailing water resources potrentials throughout the planning period in the governorate.

Mafraq Governorate Water Allocation (MCM)

Year	Total Water Demand	Local Sources (MCM)						Possible Avail. Sources (MCM)					Export to other Govt.	Total Require-ment (MCM)
		SW		GW		WWE		Disi	SW		Des. BGW	From other Govt.		
		UP	JRV	UP	JRV	UP	JRV		Zai	Weh.				
1998	**76**	2		90		1							**18** ZA 13, IR 3, JA 2	**94**
2005	**70**	2		86		1							**18** AM 5, ZA 11, JA1 AJ viaIR 1	**88**
2010	**67**	2		83		1							**19** ZA13, AJ viaIR 3, JA 3	**86**
2015	**64**	9		80		1							**26** ZA 16, AJ viaIR 5 JA 5	**90**
2020	**57**	9		77		1							**30** ZA20, AJviaIR 4 JA 6	**87**

Avail. : Available, SW : Surface Water, GW : Groundwater, WWE : Wastewater Effluent, Weh : Wehda Dam, PT : Peace Treaty Water, Des. : Desalination, UP : Upland, JRV : Jordan Rift Valley, Govt. : Governorate

5.3.4 Irbid Governorate

1) Available Water Resources

(a) Groundwater Resources

Renewable groundwater resources are encountered in both the upper and middle aquifer system within the governorate. Good producing well fields from the B_2/A_7 aquifer exist in Mukheiba, Wadi El Arab and other localities in both the Uplands and Jordan Valley escarpment. The estimated safe yield of renewable groundwater in Irbid Governorate is in the order of 29 MCM/a. The total groundwater abstraction from the potential aquifers in the governorate is about 46 MCM (1998 estimates) (Ch. 2). As per the general policy regarding groundwater production, it has to be reduced to the above-mentioned safe yield (29 MCM/a), through the reduction of irrigation water allocation, from 17 MCM in 2005 down to about13MCM/a as from 2020. Groundwater quality in the area is generally good (less than 1,000 ppm).

(b) Surface Water Resources

Surface water resources are the major component of the total available water resources in Irbid Governorate. It is primarily from the Yarmouk River water and the side wadis issuing from Jordan Valley eastern escarpment that lies within the governorate. Its total volume is about 150 MCM (1998 estimates :14 in the uplands and 136 in JV area). It would reach about 332 MCM/a as of 2010, including the peace treaty water (242+90) and after construction of Wehda dam by 2005 (Ch. 2). Water quality is good to excellent in general. A good volume of the available surface water in Irbid Governorate is being transferred via KAC for irrigation purposes within Jordan Valley and for MIT purposes in both of Amman and Balqa Governorates via Deir Alla intake.

(c) Treated Wastewater Effluent

Four treatment plants exist in the governorate. Six other are planned to be operational by the year 2010. Total treated effluent from the existing plants is about 5 MCM at present and will rise up to about 41 MCM upon completion of the other plants on the agenda, between the years 2005 to 2015. Plans to reuse these effluents either in Jordan Valley or adjacent to the treatment plants themselves.

2) Water Demand

The projection of water demands in Irbid was made as per the developed Scenario (1) employed in other governorates for the municipal, industrial and tourist water needs. As regards water demand projection for agricultural use, the availability of surface, groundwater and reuse of treated wastewater effluents are taken into consideration. The table below shows the demand projections for all uses based on Scenario-1.

Irbid Governorate (IR) MIT Water Demand (MCM)

Year	Municipal			Industrial			Touristic			Total		
	Sn. 1	Sn. 2	Sn. 3	Sn. 1	Sn. 2	Sn. 3	Sn. 1	Sn. 2	Sn. 3	Sn. 1	Sn. 2	Sn. 3
1998	30.47	30.47	30.47	1.04	1.04	1.04	0.02	0.02	0.02	31.53	31.53	31.53
2005	39.52	39.52	37.74	8.89	8.99	8.77	0.02	0.03	0.02	48.43	48.54	46.53
2010	57.63	57.63	53.40	9.12	9.22	8.97	0.03	0.04	0.03	66.78	66.89	62.40
2015	75.01	83.09	74.72	9.29	9.84	9.19	0.03	0.06	0.03	84.33	92.99	83.94
2020	90.37	105.9	91.95	9.39	10.43	9.45	0.04	0.09	0.04	99.80	116.42	101.44

Irbid Governorate Total Water Requirement (Sn. 1), (MCM)

Year	Municipal	Industrial	Touristic	Irrigation	Total Demand	Export to other Govt.	Total Water Requirement
1998	30.47	1.04	0.02	113	**145**	**93 (AM,BA)**	**238**
2005	39.52	8.89	0.02	151	**200**	**159 (AM,BA)**	**359**
2010	57.63	9.12	0.03	167	**235**	**163 (AM,BA)**	**498**
2015	75.01	9.29	0.03	167	**252**	**152 (AM,ZA,BA)**	**404**
2020	90.37	9.39	0.04	167	**268**	**136 (AM,ZA,BA)**	**404**

3) Highlights of Water Allocation

Water supplies within Irbid Governorate are furnished from all sources of water. The major sources utilized for MIT are the groundwater being produced from several local well fields in the upland and Jordan Valley eastern escarpment, and Tabaqat Fahl spring water. The internal resources volume of water produced as estimated in 1998 is about 33 MCM.

About 3 MCM is being transferred from Mafraq wells. Part of the groundwater produced from within the governorate (about 2 MCM) is exported to Jerash and Ajloun governorates, leaving about 35 MCM for the MIT water demand in Irbid areas. In order to satisfy all sectors demand during the planning period, the table below indicates the water allocation strategy for Irbid Governorate in total. It can be seen that surface water from Yermouk River furnishes a major component to meet the irrigation and domestic demands in Irbid, Amman and Balqa governorate as well as Jordan Valley irrigation schemes.

Irbid Governorate Water Allocation (Normal Conditions), (MCM)

Year	Total Demand	Local Sources (MCM)						Possible Avail. Sources (MCM)						Export to other Govt.***	Total Required (MCM)
		SW		GW		WWE		Disi	SW*			Des. BGW	From other Govet.		
		UP	JRV	UP	JRV	UP	JRV		ZAI	PT	Weh.				
1998	**145**	14	136	8	37	5				35			2** (AJ)	**93** AM 32, BA 60	**238**
2005	**200**	14	229	12	28	14				60			2** (AJ)	**159** AM 55, BA 105	**359**
2010	**234**	14	229	15	21	26				90			2 (AJ)	**163** AM 58, BA 106	**397**
2015	**251**	14	229	18	15	35				90			2 (AJ)	**152** AM 58, ZA 9, BA84	**404**
2020	**268**	14	229	21	8	39				90			2 (AJ)	**136** AM 59, ZA 15, BA 59	**404**

* Including wehda water and side wadis
** Wadi Rajib and others water in Ajloun Govemorate used in JRV/Irbid governorate.
*** Based on the availability of Surface Water Resources.
Avail. : Available, SW : Surface Water, GW : Groundwater, WWE : Wastewater Effluent, Weh : Wehda Dam, PT : Peace Treaty Water, Des. : Desalination, UP : Upland, JRV : Jordan Rift Valley, Govt. : Governorate

In case of dry conditions that may prevail in the country and/or inavailability of other surface water resources, it is envisaged that the available surface water reesources in Irbid governorate may be lowered by 20% in an average. The table below shows the possible water allocation senario as an alternative during the emergancy conditions. Accordingly the expected export volumes of transferred water supplies to other governorates, namely Amman, Balqa and Zarqa may be reconsidered.

Irbid Governorate Water Allocation (Emergancy Conditions), (MCM)

Year	Total Dem-and	Local Sources (MCM)						Possible Avail. Sources (MCM)						Export to other Govt.***	Total Reqrd. (MCM)
		SW*		GW		WWE		Disi	SW			Des. BGW	From other Govt.		
		UP	JR	UP	JR	UP	JR		ZAI	PT	Weh				
2005	**200**	14	183	12	28	13				60			2** (AJ)	**125** AM 25 BA 100	**325**
2010	**234**	14	183	15	21	26				90			2 (AJ)	**130** AM 41 BA 89	**364**
2015	**251**	14	183	18	15	35				90			2 (AJ)	**119** AM 40 ZA 7 BA 72	**370**
2020	**268**	14	183	21	8	39				90			2 (AJ)	**106** AM 40 ZA 10 BA 56	**374**

* Including wehda water and side wadis

** Wadi Rajib and others' water in Ajloun governorate used in Irbid/ JRV governorate.

*** Based on the availability of Surfase Water Resources.

Avail. : Available, SW : Surface Water, GW : Groundwater, WWE : Wastewater Effluent, Weh : Wehda Dam, PT : Peace Treaty Water, Des. : Desalination, UP : Upland, JRV : Jordan Rift Valley, Govt. : Governorate

5.3.5 Ajloun Governorate

1) Available Water Resources.

Renewable groundwater resources occur in the upper and middle aquifer systems. The estimated safe yield is only about 2 MCM/a . Most of these aquifers are being drained naturally by wadi cuts and spring flows which contribute to the base flows of wadis: Kufringa, Rajib and others that issue from the Jordan Valley eastern escarpment within the governorate. The present groundwater abstraction is about 2 MCM. Groundwater quality is generally good (<1000 ppm).

Limited treated sewage effluent originates from wadi Kufringa treatment plant. At present the effluent volume is about 1 MCM and would reach about 3.1 MCM by the year 2020.

Surface water resources originate from a number of springs and base flows that occur in the area. About 11 MCM/a including wastewater effluent is being utilized in agriculture water use in the area. No development potentials of the presently available surface water are envisaged during the planning period in the governorate.

2) Water Demand and Allocation:

The estimated demand projections for MIT in the governorate as per scenario are as follows:

Ajloun Governorate (AJ) MIT Water Demand (MCM)

Year	Municipal			Industrial			Touristic			Total		
	Sn. 1	Sn. 2	Sn. 3	Sn. 1	Sn. 2	Sn. 3	Sn. 1	Sn. 2	Sn. 3	Sn. 1	Sn. 2	Sn. 3
1998	3.94	3.94	3.94	0.0	0.0	0.0	0.0	0.0	0.0	3.94	3.94	3.94
2005	5.22	5.22	4.99	0.0	0.0	0.0	0.0	0.0	0.0	5.22	5.22	4.99
2010	7.71	7.71	7.14	0.0	0.0	0.0	0.0	0.0	0.0	7.71	7.71	7.14
2015	10.15	11.24	10.11	0.0	0.0	0.0	0.0	0.01	0.0	10.15	11.25	10.11
2020	12.35	14.47	12.56	0.0	0.0	0.0	0.0	0.01	0.0	12.35	17.48	12.56

Ajloun Governorate Total Water Requirement (Sn. 1), (MCM)

Year	Municipal	Industrial	Touristic	Irrigation	Total Demand	Export to other Govt.	Total Water Requirement
1998	3.94	0.00	0.00	6	**10**	**2 (IR/JRV)**	**12**
2005	5.22	0.00	0.00	7	**12**	**2 (IR/JRV)**	**14**
2010	7.71	0.00	0.00	8	**16**	**2 (IR/JRV)**	**18**
2015	10.15	0.00	0.00	8	**18**	**2 (IR/JRV)**	**20**
2020	12.35	0.00	0.00	9	**21**	**2 (IR/JRV)**	**23**

As regards water allocation, local resources within the governorate are expected to meet the projected demands during the planning period. At present about 1-2 MCM of water is being conveyed from Mafraq governorate and would rise up to 7 MCM by the year 2020. About 2 MCM/a is envisaged to be diverted to be utilized for agriculture water use in Jordan Valley (Irbid Governorate) area.]

Ajloun Governorate (AJ) Water Allocation (MCM)

Year	Total Water Demand	Local Sources (MCM)						Possible Avail. Sources (MCM)					Export to other Govt.	Total Water Requirement
		SW		GW		WWE		Disi	SW		Des. BGW	From other Govt.		
		UP	JRV	UP	JRV	UP	JRV		Zai	Weh				
1998	**10**	9	2	1		1						1 MF(via IR)	**2** IR/JRV	**12**
2005	**12**	9	2	1		1						1 MF(via IR)	**2** IR/JRV	**14**
2010	**15**	9	2	1		2						3 MF(via IR)	**2** IR/JRV	**17**
2015	**18**	9	2	2		3						5 MF(via IR)	**2** IR/JRV	**20**
2020	**21**	9	2	2		3						7 MF(viaIR)	**2** IR/JRV	**23**

Avail. : Available, SW : Surface Water, GW : Groundwater, WWE : Wastewater Effluent, Weh : Wehda Dam, PT : Peace Treaty Water, Des. : Desalination, UP : Upland, JRV : Jordan Rift Valley, Govt. : Governorate

5.3.6 Jerash Governorate

1) Available Water Resources

As in Ajlun governorate, the aquifers which occur in Jerash are mainly the upper and middle aquifer systems. The wadis which are incised in the western terrain of the governorate, naturally drain them. Kurnub sandstone aquifer crops out in most of the area. Groundwater of good to fair quality do exist in the governorate

Groundwater safe yield in the area is estimated at 8 MCM/a. The water supplies in the governorate to meet the MIT demands, are mainly from internal sources: local springs and wells. About 1.54 MCM from internal sources and 2.3 MCM from Irbid, Mafraq and Zarqa governorates.

Base flows and spring waters are contributing to the Zarqa River total flow. In addition, the treated wastewater effluents from the existing wastewater treatment plants, produces about 1 MCM at present and will increase to about 5 MCM by the year 2020.

2) Water demand and Allocation

The projected water demands for the governorate for all purposes are estimated as follows:

Jerash Governorate (JA) Water Demand (MCM)

Year	Municipal			Industrial	Touristic		Total		
	Sn. 1	Sn. 2	Sn. 3	Sn. 1,2,3	Sn. 1,3	Sn. 2	Sn. 1	Sn. 2	Sn. 3
1998	4.55	4.54	4.45	0.0	0.0	0.0	4.55	4.55	4.55
2005	6.14	6.14	5.86	0.0	0.0	0.0	6.14	6.14	5.86
2010	9.16	9.16	8.49	0.0	0.0	0.0	9.16	9.16	8.49
2015	12.17	13.47	12.11	0.0	0.0	0.0	12.17	13.47	12.11
2020	14.90	17.47	15.17	0.0	0.0	0.01	14.90	17.48	15.17

Jerash Governorate Total Water Requirement (Sn. 1), (MCM)

Year	Municipal	Industrial	Touristic	Irrigation	Total Demand	Export to other Govt.	Total Water Requirement
1998	4.55	0.00	0.00	12	**16.55**	**8** BA	**25**
2005	6.14	0.00	0.00	12	**18.14**	**9** BA 8 KTR 1	**27**
2010	9.16	0.00	0.00	12	**21.16**	**11** BA 8 KTR 3	**32**
2015	12.17	0.00	0.00	11	**23.17**	**12** BA 8 KTR 4	**35**
2020	14.90	0.00	0.00	11	**25.90**	**13** BA 8 KTR 5	**39**

The table below shows the possible available sources to satisfy the above stated water demands in the governorate. The table indicates that the governorate is almost self sufficient from its internal sources.

Jerash Governorate (JA) Water Allocation (MCM)

Year	Total Demand	Local Sources (MCM)						Possible Avail. Sources (MCM)					Export to other Govt.	Total (MCM)
		SW		GW		WWE		Disi	SW		Des. BGW	From other Govt.		
		UP	JRV	UP	JRV	UP	JRV		Zai	Weh				
1998	**17**	12	8	4			0					0	**8** BA	**25**
2005	**18**	12	8	5			1					1 (MF)	**9** BA 8 KTR 1	**27**
2010	**21**	12	8	6			3					3 (MF)	**11** BA 8 KTR 3	**32**
2015	**23**	12	8	7			4					5 (MF)	**12** BA 8 KTR 4	**35**
2020	**26**	12	8	8			5					7 (MF)	**13** BA 8 KTR 5	**39**

Avail. : Available, SW : Surface Water, GW : Groundwater, WWE : Wastewater Effluent, Weh : Wehda Dam, PT : Peace Treaty Water, Des. : Desalination, UP : Upland, JRV : Jordan Rift Valley, Govt. : Governorate

5.3.7 Balqa Governorate

1) Available water resources

Available groundwater resources are encountered in the middle aquifer system including Kurnab sandstone. The groundwater safe yield within the governorate is about 19 MCM/a.. The1998 estimates for groundwater abstraction is about 47 MCM. Therefore serious overdraft conditions are prevailing in the area. Groundwater of good to fair quality is generally encountered in the area. In the Valley area of the governorate poor water quality (>2000 ppm) is generally encountered in Karameh-S.Shuneh area. Water supplies for the governorate are mainly provided from local sources (groundwater and some springs). External sources, mainly from Irbid governorate via Zai Treatment plant from KAC surface water. Total internal sources as estimated in 1998 are about 14 MCM while the external ones are about 5 MCM.

Surface water resources are made up of base flows in the wadis of shueib – Kufrain and the spring flows that drain the aquifers in the region. Two existing dams are presently storing the floods in these wadis. The estimated total capacity of these dams is 10 MCM. Karameh dam is storing the surplus Yarmouk floodwaters during the wet season. It has a storage capacity of 55 MCM. The dam water is meant to provide irrigation water in south Jordan Valley area of the governorate during summer time in conjunction with the potential groundwater from the private sector well fields.

The treatment wastewater effluent from the existing and planned treatment plants in the governorate is another local source utilized mainly in agriculture. The total effluent is about 5 MCM in the year 2000 and would be about 54.7 MCM from the planned Wadi Zarqa Treatment Plant, by the year 2020. In addition about 83 MCM/a would be transferred to Balqa governorate from As-samra treatment plant via KTR (Zarqa governorate) and 24.6 MCM from BA/JA to JRV by the year 2020. Out of this total WWT effluent about 15 and 20 MCM would be allocated for Local irrigation and industrial uses respectively in the uplands.The total residual volume would be allocated for irrigation purposes in Balqa governorate.

2) Water Demands and Allocation

As regards Balqa governorate water demands for Municipal, Industrial and Tourist (MIT) and based on Scenario-1 , it is shown in the table below.

Balqa Governorate (BA) MIT Water Demand (MCM)

Year	Municipal			Industrial			Touristic			Total		
	Sn. 1	Sn. 2	Sn. 3	Sn. 1	Sn. 2	Sn. 3	Sn. 1	Sn. 2	Sn. 3	Sn. 1	Sn. 2	Sn. 3
1998	19.05	19.05	19.05	0.45	0.45	0.45	0.01	0.01	0.01	19.51	19.51	19.51
2005	20.75	20.75	19.81	0.59	0.64	0.54	2.67	5.13	5.13	24.01	26.52	25.48
2010	26.84	26.84	24.87	0.69	0.80	0.63	4.70	7.29	7.29	32.23	34.93	32.79
2015	31.14	34.48	31.01	0.77	1.00	0.72	6.94	7.29	7.29	38.85	42.77	39.02
2020	33.52	39.29	34.11	0.81	1.26	0.84	6.94	7.29	7.29	41.27	47.84	42.24

Balqa Governorate Total Water Requirement (Sn. 1), (MCM)

Year	Municipal	Industrial	Touristic	Irrigation	Total Demand	Export to other Govt.	Total Water Requiremt.
1998	19.05	0.45	0.01	124	**144**	**41** Karameh dam 25 fresh / 16 ww	**185**
2005	20.75	0.59	2.67	213	**238**	**12** AM 11 MA 1	**250**
2010	26.84	0.69	4.70	234	**267**	**37** AM 31 ZA 5 MA 1	**304**
2015	31.14	0.77	6.94	220	**259**	**46** AM 40 ZA 5 MA 1	**305**
2020	33.52	0.81	6.94	197	**239**	**46** AM 40 ZA 5 MA 1	**285**

Groundwater abstraction in Balqa governorate is intended to be reduced to the safe yield rate. It is utilized for both MIT and irrigation purposes. Treated wastewater effluent would be totally utilized in agriculture blended by the surface water flows in KAC. In order to meet the irrigation demands in the Valley area of Balqa, the stored Yarmouk flood waters in Karameh dam may be made available as and when required. As regards the proposed tourist water demand projection, sudden increase was considered to cope with the Dead Sea coastal area development. The table below shows the water allocation strategy to meet the projected demands through out the planning horizon.

Balqa Governorate Water Allocation (MCM)

Year	Water Dem-and	Local Sources (MCM)						Possible Avail. Sources (MCM)					Export to other Govt.	Total Requird. (MCM)
		SW		GW		WWE		Disi	SW		Des. BGW	From other Govt.		
		UP	JRV	UP	JRV	UP	JRV		Zai	Weh				
1998	**144**	7	21	7	38		42 BA,ZA JA(26) +16 local		5		0	65 25 KAC & 40 KTR	**41** Karameh dam 25 KAC 16 WW	**185**
2005	**238**	7	21	7	31		51 BA,ZA JA(47) +4 local		7		20 0 local 20 KA/Mujib	126 IR 99 JA 7 (KAC & KTR)	**12** AM 11 MA 1	**250**
2010	**267**	7	21	7	25		90 BA,ZA JA (83) +7 local		20		40 15 local 25 KA/Mujib	93 IR 85 JA 8 (KAC & KTR)	**37** AM 31 ZA 5 MA 1	**304**
2015	**259**	7	21	6	19		110 BA,ZA JA(102) +8 local		25		49 24 local 25 KA/Mujib	67 IR 59 JA 8 (KAK / KTR)	**46** AM 40 ZA 5 MA 1	**305**
2020	**239**	7	21	6	13		122 BA,ZA JA (113) +9 local		28		49 24 local 25 KA/Mujib	38 IR 30 JA 8 (KAC/ KTR)	**46** AM 40 ZA 5 MA 1	**285**

Avail. : Available, SW : Surface Water, GW : Groundwater, WWE : Wastewater Effluent, Weh : Wehda Dam, PT : Peace Treaty Water, Des. : Desalination, UP : Upland, JRV : Jordan Rift Valley, Govt. : Governorate

5.3.8 Madaba Governorate

1) Available water resources

Renewable groundwater resources are encountered in the upper and middle aquifer systems. Nonrenewable groundwater flows from the lower aquifer system as underflows and baseflows in the lower reaches of the governorate towords Dead Sea area. Water supplies for the governorate are provided from local well fields and from the groundwater resources from Karak governorate (Swaqa-Qatraneh area). The local internal resources are in the order of 10.7 MCM (1998 estimates). The external ones are about 6 MCM. Out of both resources, about 5 MCM/a is being transferred to Amman governorate municipal demand leaving about 12 MCM for MIT demands in Madaba governorate.

Groundwater safe yield is estimated at 9 MCM. The groundwater abstraction is about 14 MCM that resulted in serious decline of wadi Wala base flow.

Surface water resources are mainly from Zerqa ma'en base flow and Zara springs flow. At present the total flows of these sources needs to be developed in the future and is expected to reach up to 14 MCM/a by the year 2010.

Treated wastewater effluent in the area is very limited and amounted to 1.2 MCM at present and it would rise up to about 4 MCM/a by the year 2020. It is totally being utilized for irrigation purpose in the vicinity of Madaba treatment plant.

2) Water demand and location

Based on Scenario-1 the total MIT demands are:

Madaba Governorate (MA) MIT Water Demand (MCM)

Year	Municipal			Industrial			Touristic			Total		
	Sn. 1	Sn. 2	Sn. 3	Sn. 1	Sn. 2	Sn. 3	Sn. 1	Sn. 2	Sn. 3	Sn. 1	Sn. 2	Sn. 3
1998	11.72	11.72	11.72	0.17	0.17	0.17	0.0	0.0	0.0	11.89	11.89	11.89
2005	11.29	11.29	10.78	0.23	0.24	0.21	2.35	3.29	3.28	13.87	14.82	14.27
2010	13.11	13.11	12.15	0.26	0.31	0.24	4.41	6.56	6.55	17.78	19.98	18.94
2015	13.34	14.74	13.26	0.29	0.38	0.28	6.55	6.57	6.55	20.18	21.69	20.09
2020	12.16	14.23	12.36	0.31	0.48	0.32	6.56	6.60	6.56	19.03	21.31	19.24

Madaba Governorate Total Water Requirement (Sn. 1), (MCM)

Year	Municipal	Industrial	Touristic	Irrigation	Total Demand	Export to other Govt.	Total Water Requirement
1998	11.72	0.17	0	8	**20**	**4** AM	**24**
2005	11.29	0.23	2.35	8	**22**	**2** AM 2	**24**
2010	13.11	0.26	4.41	9	**27**	**0**	**27**
2015	13.34	0.29	6.55	9	**29**	**0**	**29**
2020	12.16	0.31	6.56	10	**29**	**0**	**29**

Irrigation water demand is based on the available water resources in the governorate. The tourist water demand took into consideration the sudden increase related to Zerqa Ma'en hot springs Spa health care as well as other tourist developments along the Dead See Costal areas.

A water allocation strategy is proposed as spelled out in the table below:

Madaba Governorate Water Allocation (MCM)

Year	Water Dem.	Local Sources (MCM)						Possible Avail. Sources (MCM)						Total Requirement (MCM)
		SW		GW		WWE		Disi	SW		Des. BGW	From other Govt.	Export to other Govt.	
		UP	JRV	UP	JRV	UP	JRV		Zai	Weh				
1998	**20**	5	0	13	0	1		0			0	5 AM	**4** AM	**24**
2005	**22**	5	5	11	1	2		0			1 (BA)	0	**2** AM 2	**24**
2010	**27**	5	5	10	1	3		0			1 (BA)	0		**27**
2015	**29**	5	5	9	1	3		5			1 (BA)	0	**0**	**29**
2020	**29**	5	5	8	1	4		5			1 (BA)	0	**0**	**29**

Avail. : Available, SW : Surface Water, GW : Groundwater, WWE : Wastewater Effluent, Weh : Wehda Dam, PT : Peace Treaty Water, Des. : Desalination, UP : Upland, JRV : Jordan Rift Valley, Govt. : Governorate

5.3.9 Karak Governorate

1) Available water resources:

Renewable groundwater resources are tapped in the upper and middle aquifer systems Nonrenewable groundwater is encountered in the lower aquifer system (Disi/Ram). Good throughput towards the Dead Sea area and as base flows in wadis Hasa, Mujib and Zarqa-Ma'in are taking place. The governorate encompasses parts of Mujib and Hasa basins in south Jordan. Hence surface water potential is very promising in this governorate. The estimated available surface water at present is around 54 MCM/a (1998 estimates) in both the Up lands and south Ghor areas (Jordan Rift Valley). Future development prospects of these resources are about 82 MCM by the year 2020 after constructing of the planned dams in the area. These resources would be totally allocated for irrigation purposes except some springs (Sara, Yarout and Shihabieh) are used for municipal and tourist purposes.

Local water supplies (wells and springs water) that are used to satisfy the MIT demands are about 13 MCM/a (1998 estimates). The governorate is considered as self sufficient as regards, Municipal, Tourist as well as irrigation demands. In order to meet the Lajjun Oil-shale industrial demand, provision of water supplies to meet such demand would be either from Disi non-remewable grounewater and/or from desalinated local brackish grouneater as noted in the text and tables below.

2) Water demand and Allocation

The table below shows the projected MIT water demands based on Scenario-1. The industrial water demand projection took into account the water requirements for the projected oil shale industry in the area.

Karak Governorate (KA) MIT Water Demand (MCM)

Year	Municipal			Industrial			Touristic			Total		
	Sn. 1	Sn. 2	Sn. 3	Sn. 1	Sn. 2	Sn. 3	Sn. 1	Sn. 2	Sn. 3	Sn. 1	Sn. 2	Sn. 3
1998	9.35	9.35	9.35	11.72	11.72	11.72	0.01	0.01	0.01	21.08	21.08	21.08
2005	10.87	10.87	10.38	18.39	19.55	17.12	0.01	0.02	0.01	29.27	30.44	27.51
2010	14.77	14.77	13.68	30.64	33.14	29.00	0.01	0.02	0.01	45.42	47.93	42.69
2015	18.02	19.96	17.95	45.57	51.55	44.46	0.02	0.03	0.02	63.61	71.54	62.43
2020	20.45	23.96	20.80	59.67	70.99	60.29	0.02	0.05	0.02	80.14	95.0	81.11

Karak Governorate Total Water Requirement (Sn. 1), (MCM)

Year	Municipal	Industrial	Touristic	Irrigation	Total Demand	Export to other Govt.	Total Water Requirement
1998	9.35	11.72	0.01	55	76	0	76
2005	10.87	18.39	0.01	68	97	0	97
2010	14.77	30.64	0.01	73	118	0	118
2015	18.02	45.57	0.02	72	136	0	136
2020	20.45	59.67	0.02	72	153	0	153

Local surface and groundwater sources within the governorate can easily be allocated to satisfy the projected demands until the year 2015. Later in the year 2015, industrial water demand shall be manged to maximum of 50 MCM/a instead of 60 MCM/a. The additional industrial water requirements as from 2015 may be secured from South

Jordan (Aqaba Governorate) via the Disi Water Conveyor or prferably from the potential brackish groundwater from the middle aquifer system (A1/6-Kurnub) which is believed to occur in the area (BGR investigation).

Water resources allocation strategy during the planning period.is shown in the table below. There are very limitted imported water to, but other than the table below about 25 MCM/a, mainly Mujib water from the Governorate wiil be exported to Balqa/Jordan Valley for the brackish groundwater desalination at Sweima .

Karak Governorate Water Allocation (MCM)

Year	Total Water Demand	Local Sources (MCM)						Possible Avail. Sources (MCM)				Export to other Govt.	Total Water Requirement (MCM)
		SW		GW		WWE		Disi*	Des. BGW	Des. Sea Water	From other Govt		
		UP	JRV	UP	JRV	UP	JRV						
1998	**76**	18	36	18	9	0		0			0	**0**	**76**
2005	**97**	18	56	16	7	1		0			0	**0**	**97**
2010	**118**	18	64	16	5	1		2	13 local		0	**0**	**118**
2015	**136**	18	64	15	3	2		11	23 local		0	**0**	**136**
2020	**153**	18	64	15	1	2		17	36 local		0	**0**	**153**

* : Local desalinated brackish groundwater may be considered as an alternative for substitution of Disi Water
** : Out of exported water, 23 MCM/a would be conveyed to Muntazah PS/Amman Governorate after desalination.
Avail. : Available, SW : Surface Water, GW : Groundwater, WWE : Wastewater Effluent, Weh : Wehda Dam, PT : Peace Treaty Water, Des. : Desalination, UP : Upland, JRV : Jordan Rift Valley, Govt. : Governorate

5.3.10 Ma'an Governorate

1) Available Water Resources.

Local groundwater supplies occur from Disi/Ram aquifer in Mudawara area (non-renewable groundwater) The upper aquifer system is producing renewable groundwater for irrigation purposes in Jafer and Sirhan areas. The total potential volume of both groundwaters in the area ranged from 120-130 MCM/a including Disi, Jafer-Sirhan areas. As regards surface water potentials in Ma'an governorate, it is very limited and would not exceed 7 MCM/a by the year 2020 after constructing some flood water structures and water harvesting. About 1 MCM of treated wastewater effluent is being produced at present. It would reach about 3 MCM/a by the year 2020.

2) Water demand and Allocation.

The projected water demands for MIT and irrigation are shown in the following tables. Irrigation demand would be met from Disi-Mudawara non-renewable groundwater and from other renewable ones in Jafer and Shoubak areas.

Ma'an Governorate (MN) MIT Water Demand (MCM)

Year	Municipal			Industrial			Touristic			Total		
	Sn. 1	Sn. 2	Sn. 3	Sn. 1	Sn. 2	Sn. 3	Sn. 1	Sn. 2	Sn. 3	Sn. 1	Sn. 2	Sn. 3
1998	6.86	6.86	6.86	7.22	7.22	7.22	0.10	0.10	0.10	14.18	14.18	14.18
2005	7.08	7.08	6.76	9.32	10.03	8.54	0.13	0.16	0.13	16.53	17.27	15.43
2010	8.76	8.76	8.11	10.86	12.56	9.85	0.16	0.23	0.16	19.78	21.55	18.12
2015	9.65	10.68	9.61	12.05	15.73	11.36	0.18	0.34	0.18	21.88	26.75	21.15
2020	9.82	11.46	9.95	12.72	19.69	13.11	0.20	0.51	0.22	22.74	31.66	23.28

Ma'an Governorate Total Water Requirement (Sn. 1), (MCM)

Year	Municipal	Industrial	Touristic	Irrigation		Total Demand	Export to other Govt.	Total Water Requirement
				Disi	Others			
1998	6.86	7.22	0.10	41	12	**67**	**1**	**68**
2005	7.08	9.32	0.13	34	12	**63**	**3**	**66**
2010	8.76	10.86	0.16	15	12	**47**	**35**	**81**
2015	9.65	12.05	0.18	10	14	**46**	**45**	**90**
2020	9.82	12.72	0.20	0	13	**36**	**63**	**99**

The governorate is considered as a potential source for provision of water supplies to satisfy the MIT water demands in North Jordan as shown in the next table:

Ma'an Governorate Water Allocation (MCM)

Year	Total Dem-and	Local Sources (MCM)						Possible Avail. Sources(MCM)					Export to other Govt.	Total Water Require-ment.
		SW		GW		WWE		Disi	SW		Des. BGW	From other Govt.		
		UP	JRV	UP	JRV	UP	JRV		Zai	Weh				
1998	**67**	4		22		1		42					**1**	**68**
2005	**63**	4		19	1	1		41					**3**	**66**
2010	**47**	4		17	1	2		58					**35**	**81**
2015	**46**	7		15	1	2		65					**45**	**90**
2020	**46**	7		13	1	3		76					**63**	**99**

Avail. : Available, SW : Surface Water, GW : Groundwater, WWE : Wastewater Effluent, Weh : Wehda Dam, PT : Peace Treaty Water, Des. : Desalination, UP : Upland, JRV : Jordan Rift Valley, Govt. : Governorate

As per the envisaged water allocation strategy spelled out earlier, it is intended to gradually reduce private sector irrigation activities in Ma'an governorate where the non-renuable groundwater potential in Disi/Ram aquifer is being utilized. This strategy is aiming at diverting the utilization of Disi water to satisfy the MIT demands elsewhere in North Jordan particularly in the Greater Amman area..

In order to comply with this policy, the Government competent water authoroties may initiate certain measures to mobilize the private sector irrigation activities to other areas where slightly adequate water volumes have been allocated for irrigation purposes particularly in Jordan Rift Valley (North and South Ghors including wadi Araba areas).

5.3.11 Tafielah Governorate

1) Available water resources.

Renewable groundwater resources are encountered mainly in the middle and upper aquifer systems. Also nonrenewable groundwater resources are flowing as underflows towards the Dead Sea and north Wadi Araba areas. Groundwater quality of the renewable sources is generally good to fair. Good water quality is encountered in the lower reaches of the wadis incised within the Rift Valley eastern escarpment. The safe yield of the renewable sources is estimated at 12 MCM/a. The 1998 groundwater abstraction is only about 8 MCM, giving rise to potential sources for future development.

There is a good surface water potential in the governorate for present and future development via rainfall/runoff storage structures. The present total surface water uses is about 7 MCM and expected to be developed up to 10 MCM/a by the year 2005 upon completion of the ongoing and planned water storage projects.

As regards treated wastewater effluent it is very limited and it will not exceed 1-2 MCM/a in 2020 in the governorate. In general, the governorate is considered as self-sufficient by its local resources.

2) Water demand and Allocation

As per Scenario-1 the projected water demands for MIT as well as for irrigation demand is shown in the following table:

Tafielah Governorate (TA) MIT Water Demand (MCM)

Year	Municipal			Industrial			Touristic		Total		
	Sn. 1	Sn. 2	Sn. 3	Sn. 1	Sn. 2	Sn. 3	Sn. 1 , 3	Sn. 2	Sn. 1	Sn. 2	Sn. 3
1998	2.35	2.35	2.35	5.29	5.29	5.29	0.0	0.0	7.64	7.64	7.64
2005	3.24	3.24	3.09	6.75	7.27	6.18	0.0	0.0	9.99	10.51	9.27
2010	4.89	4.89	4.53	7.86	9.10	7.13	0.0	0.0	12.75	13.99	11.66
2015	6.55	7.25	6.52	8.73	11.39	8.23	0.0	0,0	15.28	18.64	14.75
2020	8.01	9.46	8.22	9.22	14.27	9.49	0.0	0.01	17.30	23.74	17.71

Tafielah Governorate Total Water Requirement (Sn. 1), (MCM)

Year	Municipal	Industrial	Touristic	Irrigation	Total Demand (MCM)	Export to other Govt.	Total Water Requirement (MCM)
1998	2.35	5.29	0.0	8	**16**	**0**	**16**
2005	3.24	6.75	0.0	11	**21**	**0**	**21**
2010	4.89	7.86	0.0	11	**24**	**0**	**24**
2015	6.55	8.73	0.0	11	**27**	**0**	**27**
2020	8.01	9.22	0.0	11	**29**	**0**	**29**

To meet these demands, the potential surface water resources and local groundwater resources are adequate enough to satisfy the above stated projected demands. No water resoueces are envisaged to be imported to or exported from the Governorate.

Tafielah Governorate Water Allocation (MCM)

Year	Total Demand	Local Sources (MCM)						Possible Avail. Sources(MCM)				Export to other Govt.	Total Requirement (MCM)
		SW		GW		WWE		Disi	Des. BGW	Des. Sea Water	From other Govt		
		UP	JRV	UP	JRV	UP	JRV						
1998	**16**	4	3	8							1 (MN)	**0**	**16**
2005	**21**	4	6	8		1		3			0	**0**	**21**
2010	**24**	4	6	8	1	1		4			0	**0**	**24**
2015	**27**	4	6	10	1	1		5			0	**0**	**27**
2020	**29**	4	6	11	1	1		6			0	**0**	**29**

Avail. : Available, SW : Surface Water, GW : Groundwater, WWE : Wastewater Effluent, Weh : Wehda Dam, PT : Peace Treaty Water, Des. : Desalination, UP : Upland, JRV : Jordan Rift Valley, Govt. : Governorate

5.2.12 Aqaba Governorate

1) Available water resources:

One of the major nonrenewable groundwater resources potential occurs in this governorate. The main aquifer system in the area is Disi/Ram aquifer. As per the simulation model of the Disi/Ram aquifer performance, it was deduced that the potential non-renewable groundwater can withstand annual withdrawals at a rate of 100-110 MCM/a.

Surface water resource in the governorate is very rare. It would not exceed 1 MCM/a by the year 2010. Limited irrigation activities are being practiced in south Wadi Araba area. The major agriculture activities are located in Disi-Sahl al-Sawan area in th governorate. Treated wastewater effluent presently produced in Aqaba governorate is about 2 MCM. It is expected to reach up to 7 MCM/a by the year 2020. A desalinated sea water plant is envisaged to be installed in Aqaba to meet the local MIT demands as from 2010. In this respect and based on the outcome of the present JICA study, it is essential to consider desalinated sea and/or brackish grounwater potentials in South Wadi Araba as a replacement to the utilisation of the Disi non-renewable grounwater resources to meet Aqaba water demand.

2) Water demand and allocation:

The table below shows the MIT water demands based on Scenario-1. The irrigation water demands are met by the groundwater potential encountered in the Disi/Ram aquifer in Qa' Disi area and from the well fields in south Wadi Araba area .

Aqaba Governorate (AQ) MIT Water Demand (MCM)

Year	Municipal			Industrial			Touristic			Total		
	Sn. 1	Sn. 2	Sn. 3	Sn. 1	Sn. 2	Sn. 3	Sn. 1	Sn. 2	Sn. 3	Sn. 1	Sn. 2	Sn. 3
1998	12.05	12.05	12.05	5.81	5.81	5.81	0.52	0.52	0.52	18.38	18.38	18.38
2005	11.37	11.37	10.86	8.05	8.82	7.38	0.69	0.86	0.71	20.11	21.05	18.95
2010	12.90	12.90	11.95	9.38	9.81	8.51	0.83	1.21	0.83	23.11	23.92	21.29
2015	12.67	14.09	12.67	10.41	14.10	9.82	0.94	1.80	0.98	24.02	29.99	23.47
2020	11.01	12.89	11.19	10.99	17.83	11.33	1.06	2.69	1.14	23.06	33.41	23.66

Aqaba Governorate Total Water Requirement (Sn. 1), (MCM)

Year	Municipal	Industrial	Touristic	Irrigation		Total Demand	Export to other Govt.	Total Water Requirement
				Disi	Others			
1998	12.05	5.81	0.52	10	6	**34**	**0**	**34**
2005	11.37	8.05	0.69	10	10	**40**	**0**	**40**
2010	12.90	9.38	0.83	5	11	**39**	**12**	**51**
2015	12.67	10.41	0.94	0	7	**32**	**38**	**70**
2020	11.01	10.99	1.06	0	9	**32**	**54**	**86**

Aqaba in general is considered as a source to provide MIT water demands for north Jordan as well as the local irrigation areas in the governorate. The exported waters from the governorate are proposed to be 12, 38 and 54 MCM in the years 2010,2015 and 2020 respectively as indicated in the table next:

Aqaba Governorate Water Allocation (MCM)

Year	Total Demand	Local Sources (MCM)						Possible Avail. Sources (MCM)				Export to other Govt.	Total Water Requirement (MCM)
		SW		GW		WWE		Disi	Des. BGW	Des. Sea water	From other Govt.		
		UP	JRV	UP	JRV	UP	JRV						
1998	**34**	1		6	0		2	26*		0		**0**	**34**
2005	**40**	1		5	2		4	24		5		**0**	**40**
2010	**39**	1		5	2		5	34		5		**12**	**51**
2015	**32**	1		6	2		6	38		17		**38**	**70**
2020	**32**	1		6	2		7	54		17		**54**	**86**

* : Indicates non-renewable groundwater production from Aqaba to meet local use and exports north Jordan.

Avail. : Available, SW : Surface Water, GW : Groundwater, WWE : Wastewate Effluent, Weh : Wehda Dam, PT : Peace Treaty Water, Des. : Desalination, UP : Upland, JRV : Jordan Rift Valley, Govt. : Governorate

5.4 Main Features of Water Allocation Strategy

Referring to the previous discussion, and bearing in mind the limited water resources in the country and their venerability to climatic conditions which makes it very difficult to arrive at reliable estimates, a flexible water allocation main features that responds to long term socio-economic changes is envisaged. The bases of the water allocation scheme to develop and manage surface and groundwater resources throughout Jordan as proposed in the previous text rest mainly on the following but not limited:

- Achieving a balance in the agricultural activities between JRV and the Uplands throughout the country.
- Implementing a strict agricultural pattern plan that saves water and satisfies local market demand to such an extent that agriculture water use maintains its maximum estimates as in 1998.
- Using of treated wastewater for agricultural purposes in areas surrounding treatment plants, in as much as possible and diverts the residual treated effluent to JRV.
- Total dependency on local Jordanian water resources to satisfy demand for domestic use, without resorting to import drinking water from outside the kingdom for political and security reasons in addition to the high cost entailed.
- Following up the adopted priority policy for water allocation, where domestic purposes comes first then industrial and tourist purposes.
- Providing all populated areas in Jordan with clean water and extending sewerage networks to serve those areas.
- Connecting all available water resources (for drinking and industrial purposes) throughout the kingdom. These step aims at using more than one resource to meet the demand at any one time and for the sake of flexibility of the proposed water allocation plan.
- Reducing groundwater abstraction in the Uplands to the extent not to exceed the estimated safe yield on gradual bases during the planning period.
- Exerting efforts by the competent authorities to initiate certain measures to mobilize the private sector irrigation activities to other areas of slightly adequate volumes of water supplies may be allocated for irrigation such as JRV (North and South Ghors including S. wadi Araba).
- Satisfying the local industrial demands, in as much as feasible by the provision of desalinated brackish groundwater potentials occurring in some areas such as Mujib and South Wadi Araba hydrolgeogical units.
- Connecting most of the groundwater resources in the Uplands via main water carrier to control the production and utilization of Jordan's groundwater resources for all purposes as far as possible.

5.5 Brief Note on the Major Water Resources Available in Jordan

From the previous discussion, it is obvious that the majority of available water resources at present and in the near future consist mainly of:

1) **Groundwater produced from the well fields of: -**

Mukhaibeh Wadi Arab, Sama Sdoud/Sumayya, Amman-Zarqa , Azraq , Mafraq/Al-Aqib, Duhleil/Hallabat , Qastal, Swaqa-Katraneh, Wallah, Sultaneh, Widi Al-abyad, Al-Hassa/Jurf El-Daraweesh, Ma'an/Qa' /Tahouneh/Shoubak, Disi-Mdawarah, Al-Qwairah, Wadi Al-Yutem, Jordan Valley and Southern Ghor

2) **The springs water of:**

Greater Amman Region, Jarash, Ajloun, Karak, Tafeilah and others.

3) **Surface water resources**

On the long term, potential or even assured water resources can be out of the surface water from Yarmouk River via Deir-Alla project and Wehda Dam. In addition to baseflow and floodflow waters stored behind the dams constructed or planned, such as on Wadis Walah , Mujib Hasa and others .

4) **Regional water resources**

They are the water resources that may be made available to Jordan via agreements or water treaties with neighboring countries.

Following are some observations on the major available water resources in Jordan:

i) **Deir Alla Water**

The assumption that Deir Alla waters will be available, all the year around may be very optimistic due to many reasons, the most important of which are:

a) Syria, one of the riparian countries is currently storing water as per the upper Yarmouk Project. In summer time, the upstream riparian utilizes an appreciable portion of the base flow in the river. These actions may have its impact on the floodwaters and the base flow of the Yarmouk River.

b) The fluctuation of the available surface water quantities seeping from Yarmouk River is generally based on the climatic conditions prevailing in the Yarmouk Basin in total. Also the flood of the Yarmouk river is short lived with a duration of not more than few minutes, which makes it very difficult to harness some of its waters, particularly till the year of constructing the proposed Wehda Dam

c) Whatever the quantities of rainfall and the resulting floods are, they can't be used as a measure of the availability of water resources for KAC unless the Wehda Dam Project is completed. The reason being that it has a fixed maximum capacity of 20 cubic meters per second (though the duration of a water influx of more than (20) cubic meters per second doesn't exceed 27 days annually)(Hirzalla 1987). Also, the surface flow of the Yarmouk River; with values ranging between 12 and 20 cubic meters per second; takes place during 38 days per year. As for the rest of the year (300 days), the surface flow values ranges between (5) to (12) cubic meters per second. The average canal intake of water does not exceed 4 cubic meters per second.

In addition to the points previously mentioned, the facts on the ground indicate that whenever there is a water shortage in Yarmouk River, Jordan is the country who suffers most, among the Riparian of the River Basin.

Based on the above discussion, water allocation scenarios for Amman and Irbid Governorates were proposed as described in Section 5.3.1 and 5.3.4 respectively.

ii) **Walah-Heidan and Mujib waters**

The utilization of surface water (flood and base flow) flowing towards the Dead Sea for thousands of years is regarded as a necessity of national, economic and social significance. A task long overdue to utilize this important water resource of about 35MCM/a, plus a potential to store flood water during rainy seasons in the proposed dams on upper Wallah and Mujib(Al-Rameil, Al Nakheelah and others) with an estimated total capacity of approximately 12 MCM/a.

In addition to the previously mentioned sources, another important water source is encountered in the water bearing formation (middle and lower aquifer systems) whose groundwater is flowing towards the Dead Sea eastern escarpment. Several wells were drilled in the area allowing for about 11 MCM to be utilized yearly to augment water supplies to Amman and Madaba governorates. Such a utilization had a remarkable effect on the base flow between the wells location and Al- Heidan spring area. The implementation of this project involves an integrated approach utilizing surface and groundwater potentials in Wala -Heidan –Mujib Hydrogeological unit. In addition, the potential brackish groundwater resources in the upper aquifer system may be developed as well. The implementation of this project would furnish adequate water supplies to meet the industrial water demands in Karak Governorate.

iii) **Groundwater Resources of Mukheiba and Wadi Al-Arab Well fields**

Previous studies have indicated that about (30-40) MCM of ground- water can be utilized annually from Wadi Al-Arab and Mukheiba well fields. This water source can be considered a sound and sure water source in quantity and quality wise on the long term and may level the unexpected fluctuating Yarmouk River surface water resources due to reasons described earlier.

The renewable groundwater resources out of Mukheiba well field are potential source for Greater Amman via Irbid region or through KAC/Jordan valley using Deir-Alla pumping station. Drilling productive water wells inside the Eastern Heights overlooking Jordan Valley can also harness (10-15) MCM annually (within the area extending from wadi Sbeirra to Wadi Al- Arab).

Studies on the groundwater resources within the Yarmouk Basin, which recharges Mukheiba wells, show that a portion of the natural recharging source to the water bearing layers comes from outside the Jordanian territories. The studies also indicate that the water source feeding Mukheiba wells is different from that of Wadi Al-Arab wells, even though both fields lie in the same Yarmouk basin. It follows from the above discussion that people in charge should give priority to utilize its water and pump it directly to Irbid and to Greater Amman region or via Jordan Valley in view of the great need for such a water source as predicted by the present study.

iv) **Water Conveyance Project**

In view of the water shortage-alarming situation, it is inevitable for the Government of Jordan to plan and manage the available and potential water resources via the execution of some water development and management projects. One of these projects is the construction of A "National Water Conveyance Scheme" The Scheme will rely on conjunctive use of groundwater (fresh and brackish) and River Yermouk surface water for Domestic purposes in the Uplands and Irrigation and industrial purposes in the Jordan Valley. Under this scheme it is expected to study the feasibility, design and construct three Main Water Carriers: the first one starts from Yermouk River in the North to Amman via Irbid governorate. The second water carrier would start from Mudawara in the South, northwards to Greater Amman via Tafeilah and Karak governorates. The third water carrier would start from Mujib Dam- Zarqa Main-Zara to Husban- Kufrain and northward to Muntazah pumping station /Amman governorate.

The main components of this Scheme are:

a) Disi- Amman Conveyer (the southern conveyor):

It was proved that the potential groundwater resources of the Rum- Disi aquifer (fossil groundwater) in Southern Jordan are appreciable in quantity and quality upon wise mining. A high standard of management is needed to maximize the benefits of staged development of management is needed to maximize the benefits of stages development of the resource and onward conveyance system to North Jordan via Greater Amman. The Conveyer is expected, in addition to Disi flow (100- 120 MCM/a) to encounter groundwater flows from the existing well fields on- route and equipped with turn- outs to feed all settlements in Southern Jordan. The conveyer would furnish an efficient tool to manage water supply services within the governorates of Amman, Karak, Maan and Tafila (refer to water allocation scenarios as presented in Section 5.3.1, 5.3.9, 5.3.10 and 5.3.11 respectively). Aqaba water supply may be secured from local groundwater resources, including desalinated seawater within the governorate aiming at reducing pumpage from Disi well field to Aqaba region in as much as possible (5-26). Madaba Governorate water supply is also expected to be from its local water resources. The Project main elements are: lying out of about 310 km. pipeline, drilling of a number of wells, construction of reservoirs and 3-4 pumping stations. Optimization of water allocations for irrigation water demand in Disi- Mudawara area and to meet M&I demands in greater Amman has to be addressed in the study. It is reported that this Conveyer is under investigation, its feasibility and fund raising stage.

Recent water studies of Disi-Mdawarah area confirm the presence of high quality ground water. Surveys also indicate that an estimated annual withdrawal of (110) MCM of water for various purposes can be developed from this area on a long-term basis. The aquifer performance simulation model indicated that the ground water level after (50) years would be at a depth of 325 meters. Therefore, the agriculture projects in the sandy basin of Disi should be curtailed. The groundwater in this basin should be utilized to balance the deficit arising from the growing MIT water demands expected to arise by the end of the planning period. The recommended quantity from this source is expected to be around 50 MCM/a at present, and should not exceed 130 MCM/a by the end of the planning period.

Conveying Disi water will regulate water supplies among the various governorates of south Jordan till the governorate of Amman. Such a pipeline will accommodate water from neighboring wells and provide water supply to populated centers situated along its path as mentioned earlier. This water supply method will provide great flexibility in utilizing the various available water resources in a way that reinforces the competent water authority's ability to deal with emerging situations.

b) River Yermouk- Amman (the Northern Conveyer)

The Project aim is to determine the least cost solution for a primary conveyance system to transport surplus water from North Jordan (Mukheiba well field and River Yarmouk) to Amman- Zarqa area complementing the Southern Conveyer. Alternative design flows and routings for conveying waters available in North Jordan to Greater Amman should be considered in implementing the project. It is expected that the existing 600mm ductile iron pipeline between Za'atari pumping station and Haufa reservoir at Irbid would be considered in the study.

The Project is expected to be implemented in two stages namely: preliminary designs and routings for a pipeline conveying about 20-30 MCM/a from Mukheiba well field to Amman, either across North Jordan or via Jordan Valley to Der Alla intake. The second stage of the Project involves the development of the Yermouk River water, initially through direct abstraction intake from the River and after the construction of the Wehda Dam. This part of the pipeline is expected to convey 60-90 MCM/a to Amman- Zarqa region. The Conveyer would facilitate water resources management for M&I water demands within Amman, Zarqa, Balqa, Ajlun, Jerash and Irbid Governorates As for the Southern Conveyer, optimization of water allocations for water requirements in Jordan Valley (irrigation) and to meet water demands in North Jordan has to be addressed.

c) Mujib-Zara-Zarqa Ma'in–Amman Saline Water Conveyer

The Conveyer layout will start from Mujib Dam soth-westwards to Zara-Zarqa Ma'in linking with Hisban-Kafrein brackish groundwater in the southern Jordan Valley to Muntazah pumping station /Amman governorate. The Conveyer will transport the Mujib surface water (25 MCM/a) and the desalinated brackish groundwater resources encountered in Kafrein, Hisban Sweima areas in addition to the saline spring flows along the Dead Sea shore (40 MCM/a). These resources are supposed to meet part of the MIT water demands in Amman governorate and the Dead Sea coastal area developments (refer to Section 5.3.1, 5.3.7 and 5.3.9). The Conveyer is expected to have a total length of around 87 km and a lifting head of about 1000 m. It is understood that the scheme is under investigation and expected to be operational by 2004 (refer to section 10.2.3).

d) Azraq and Siwaqa –Qatraneh well fields

Based on the growing MIT water demands in Amman, Zarqa and/or Irbid governorates , the competent authorities may think of increasing the production rate from the present well fields in Azraq and / or Siwaqa-Qatraneh for a certain period so as to meet such demands.

In case of Azraq, this is absolutely not recommended. The reason being that the surge of highly saline water from Al-Sabkha area located to the south and south east of the Azraq well field is inevitable. This influx will deteriorate the ground water reserves in Azraq area. Re-utilizing this ground water resource in a short period of time will be questionable. The duration of the period is difficult to judge based on the present available data and relevant investigations carried out in the area.

It may be advisable to pump water from far points through drilling more widely apart wells in the present reservoir, but the surge of highly saline water is still a high possibility even though it may take a longer time which can't be estimated at present. Based on the hydrogeological investigations carried out in the area, the rate of 15 MCM annually is considered as sound and safe.

Water studies for Al-Mujib basin indicated that the production of ground water from the upper section of the basin located in Qastal-Siwaqa-Qatraneh area exceeds the estimated annual groundwater recharge. The flow net analysis method followed in estimating the basin's potential is an approximate one that depends on several variables with high variation and tolerance. In addition, the "fractured chert limestone" water bearing layers in the basin lack vertical and horizontal homogeneity, thus rendering the ground water estimation process doubtful.

Hence, a decision to increase pumping from Siwaqa and Qatraneh present wells is not recommended due to the nature of the water bearing layers and because the design of the present wells doesn't allow for such a measure. The logic behind the later is that most of these wells don't penetrate the whole aquifer thickness because the drilling was stopped once sand appeared to avoid potential sand complications. Wells are drilled far apart from each other to avoid localized depletion and to prevent closing some previously drilled. ones.

In view of the present relevant information, it is recommended that overall pumping from Siwaqa and Qatraneh wells should not exceed (15) MCM/a, as is the case in Azraq area.

v) **Regional water resources**

What is meant here by "regional water resources" is the surface water resource to be made available as per the Peace Treaty (PT) signed in August 1994 between Jordan and Israel. The water allocation scenarios as proposed in the previous Chapter (5.3) has totally considered the amount of 90 MCM/a as committed in favor of Jordan. If any violation that may take place in the future, the water allocations for Amman, Irbid and Balqa may seriously be interrupted. As regards Yarmouk River water availability, it was presented earlier under (item 5.5-i). Water allocation scenarios reflecting risk management have been proposed so as to consider such conditions.

Water allocation by main project is shown in Table 5.5-1. It is noted that the allocation shown in the table is subject to change according to the modification of the plans in future.

Table 5.5-1 Water Allocation by Project

Govt.	Main Water Projects		2005					2010					2020				
			Local Use (MCM/a)		Export (MCM/a)			Local Use (MCM/a)		Export (MCM/a)			Local Use (MCM/a)		Export (MCM/a)		
			MIT	Irrigation	Govt.	MIT	Irrigation	MIT	Irrigation	Govt.	MIT	Irrigation	MIT	Irrigation	Govt.	MIT	Irrigation
Amman	Reuse of TWW	Five Treatment Plants (Abu Nizeir, Wadi Essir, Al Jeeza, Naur, North Q. Alia Airport)	0	6.3		0	0	0	12.0		0	0	0	16.2		0	0
Zarqa	Reuse of TWW	As Samra*	15.0	10.0	Balqa	0	42.5	15.0	10.0	Balqa	0	36.2	20.0	15.0	Balqa	0	48.2
	*Including Losses during Conveyance	Wadi Zarqa*	0	0		0	0	0	0	Balqa	0	40.3	0	0	Balqa	0	54.7
Mafraq	Reuse of TWW	Mafraq	0	0.7		0	0	0	1.0		0	0	0	1.4		0	0
Irbid	Reuse of TWW	Ten Treatment Plants (Irbid Central, Ramtha, Wadi Arab, Wadi Hassan, Al Masar Al Shamali, Dair Abi Said, Kufur Asad, North Jordan Valley, Torra, Wadi Shallala)	0	13.9		0	0	5	21.3		0	0	5	34.3		0	0
	Peace Water	Desalination Conveyor to Urban Jordan	0	60.0		0	0	0	60.0		0.0	0	0	60.0		0	0
		Storage on Jordan River and Side Wadis	0	0		0	0	0	30.0		0	0	0	30.0		0	0
	Surface Water	Al Wehda Dam	22.0	8.0	Balqa	19	44.0	40.0	8.0	Balqa	19	26	81.0	12.0		0	0
Ajloun	Reuse of TWW	Kufranja	0	1.3		0	0	0	2.2		0	0	0	3.1		0	0
Jerash	Reuse of TWW	Two Treatment Plamts (Jerash East and West)	0	0	Balqa	0	1.0	0	0	Balqa	0	3.0	0	0	Balqa	0	5.0
Balqa	Reuse of TWW	Six Treatment Plants (Baqa, Fuhis, Salt, Dair Alla, Shunah South, Dead Sea East Coast)	0	4.1		0	0	0	6.8		0	0	0	9.3		0	0
	Brackish Groundwater/ Spring Water Desalination	Hisban/Kafrein	0	0		0	0	0	0		0	0	0	0	Amman	9.0	0
		Sweima	8.0	0	Madaba	1.0	0	3.0	0	Madaba	1.0	0	3.0	0	Madaba	1.0	0
		(W. Zarqa Ma'in/Zara Spring)			Amman	11.0	0			Amman	36.0				Amman	36.0	0
Madaba	Reuse of TWW	Madaba	0	1.6		0	0	0	2.7		0	0	0	3.8		0	0
	Brackish Water	to W. Zarqa Ma'in /Zara Spring Project	0	0	to Balqa (Sweima)	(11)	0	0	0	to Balqa (Sweima)	(22)	0	0	0	to Balqa (Sweima)	(22)	0
	Surface Water	Wala Dam	5.2	0		0	0	5.2	0		0	0	5.2	0		0	0
Karak	Reuse of TWW	Two Treatment Plants (Karak, Mazar, Muta, Adnaniya)	0	0.6		0	0	0	1.5		0	0	0	2.3		0	0
	Brackish Groundwater	El Lajoun Desal. Project (for Oil Shale Project)	0	0		0	0	13.0	0		0	0	36.0	0		0	0
	Surface Water	Mujib Dam	12.0	0	to Balqa (Sweima)	(15.0)	0	12.0	0	to Balqa (Sweima)	(30)	0	12.0	0	to Balqa (Sweima)	(30)	0
		Tanur Dam	0	8.0		0	0	0	8.0		0	0	0	8.0		0	0
		Small Dams	0	0		0	0	0	7.0		0	0	0	7.0		0	0
	Fresh Fossil Groundwater	Lajoun Wells (for Emergency Use only)	0	0	Amman	(11)	0	0	0	Amman	(11)	0	0	0	Amman	(11)	0
Ma'an	Reuse of TWW	Two Treatment Plants (Ma'an, Wadi Mousa)	0	1.2		0	0	0	1.8		0	0	0	2.8		0	0
	Fresh Fossil Groundwater	Disi	4.2	34.0	Tafielah	2.8	0	8.6	15.0	Tafielah	4.0	0	12.9	0	Tafielah	6.0	0
										Amman, other areas	30.0	0			Amman, other areas	57.1	0
Tafielah	Reuse of TWW	Tafielah	0	0.5		0	0	0	0.8		0	0	0	1.1		0	0
	Surface Water	Feedan Dam	0	2.5		0	0	0	2.5		0	0	0	2.5		0	0
Aqaba	Reuse of TWW	Two Treatment Plants (Aqaba, Aqaba South Coast)	0	4.0		0	0	0	5.0		0	0	5.0	1.8		0	0
	Sea Water Desalination	Aqaba Sea Water Desalination	5.0	0		0	0	5.0	0		0	0	17.0	0		0	0
	Fresh Fossil Groundwater	Disi	14.0	10.0		0	0	16.8	5.0	Amman, other areas	11.8	0	0	0	Amman, other areas	54.1	0

Note: Water allocation by project is subject to change according to future modification of the plans

Govt. : Governorate