The Study on Water Resources Management in the Hashemite Kingdom of Jordan

FINAL REPORT VOLUME V
SUPPORTING REPORT
FOR
PART-A “WATER RESOURCES MANAGEMENT MASTER PLAN”

Chapter 4 Water Quality Conservation

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ANNEX TO 4.1.2 GROUNDWATER QUALITY

1. Existing Data of 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 study team reviewed all these water quality data but chose the wells and springs with records after 1995 for analysis.

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). There are only 20 records of coliform or fecal coliform for 14 wells in 1999. Among these water quality parameters, EC and NO_3 are thought to be the most important factors related to water contamination. By calculating the average values of the two parameters for the wells/springs with records after 1995, the distribution maps of EC and NO_3 were plotted for wells under the categories of aquifers (A1/A2/A4, Alluvium, B2/A7, B4/B5, Basalt, Kurnub and Ram), and for springs without stressing the aquifers. These maps are shown in Fig. 1.1-1 to 1.1-14.

(1) Characteristics of Well Water Quality in Different Aquifers

Generally speaking, the concentration of main cations and anions in the well water relates to water salinity (EC), but the concentration of nitrate (NO_3) is often an indicator of water pollution because its source may relate to many human activities. Therefore, in the following discussions attention will be paid mainly to EC and NO_3.

<u>A1/A2/A4 Aquifers</u>: Most of the wells belonging to this category are distributed in Amman-Zarqa basin and a few of them in Jordan Valley basin. Water salinity is low (EC < 1000 MicroS/cm) at the Jordan Valley side but becomes higher toward high land direction. Several wells with EC higher than 2000 MicroS/cm are found in the middle of the Amman-Zarqa basin (Fig.1.1-1). Regarding NO_3, several peaks higher than 50 mg/L are found in the west part of the Amman-Zarqa basin (Fig. 1.1-2).

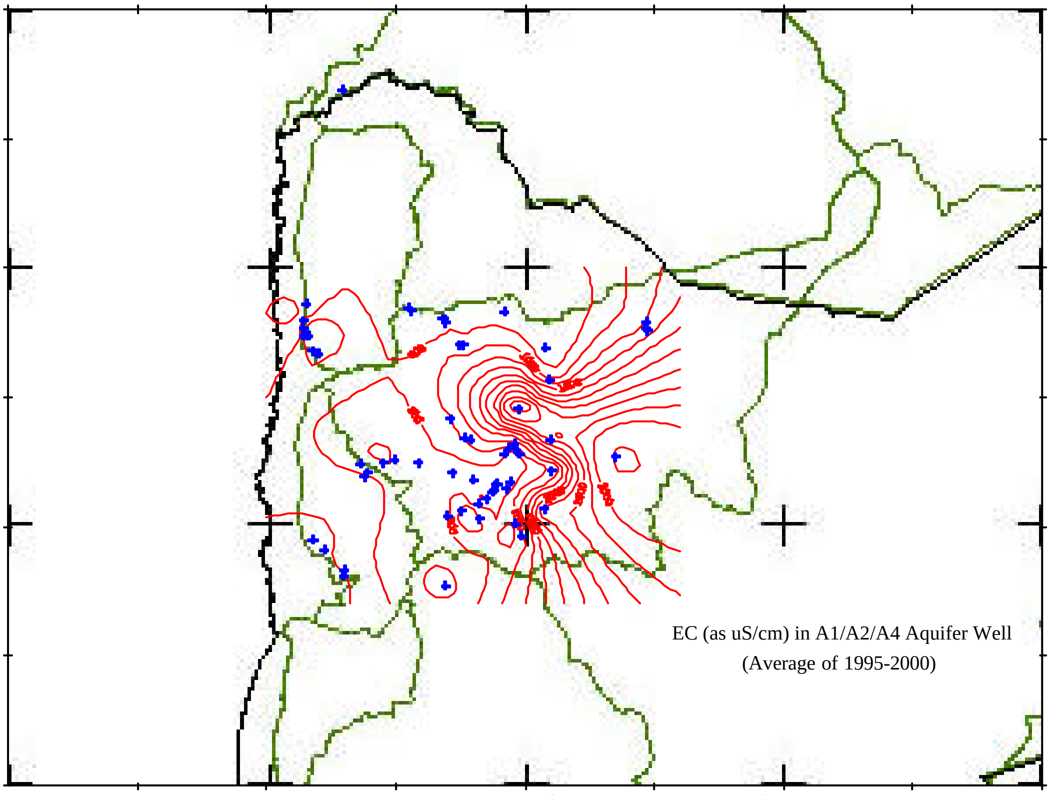


Fig. 1.1-1 EC in A1/A2/A4 Aquifer Wells (Ave. of 1995-2000)

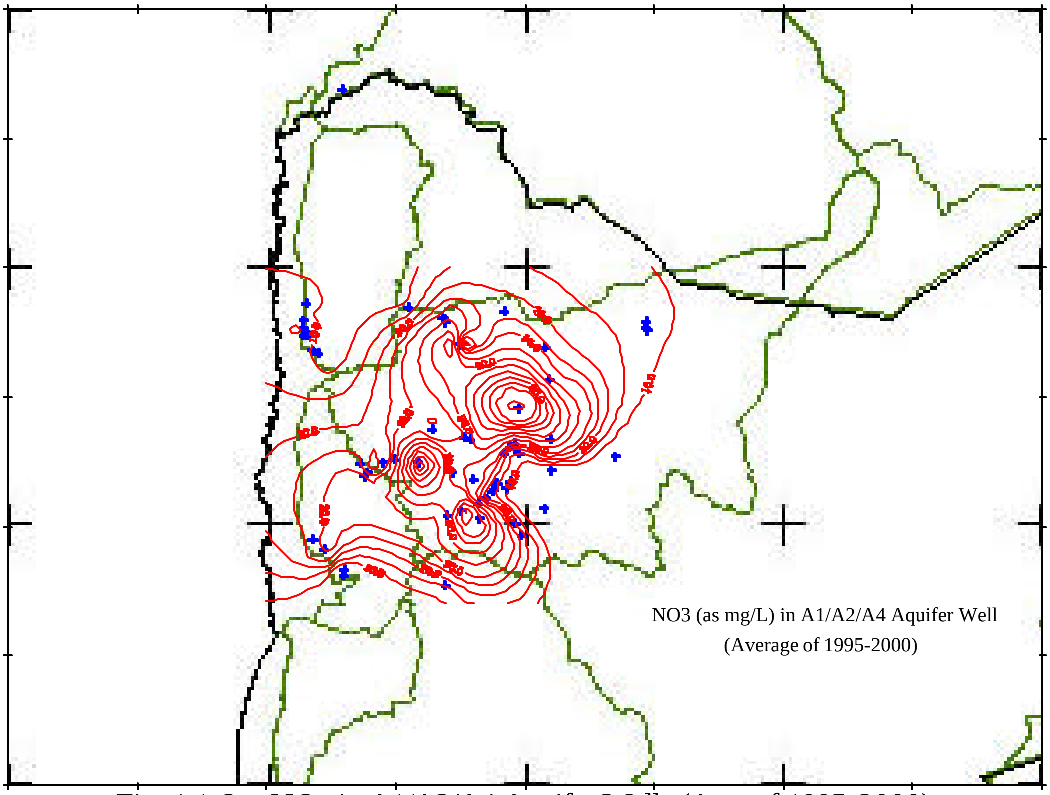


Fig. 1.1-2 NO_3 in A1/A2/A4 Aquifer Wells (Ave. of 1995-2000)

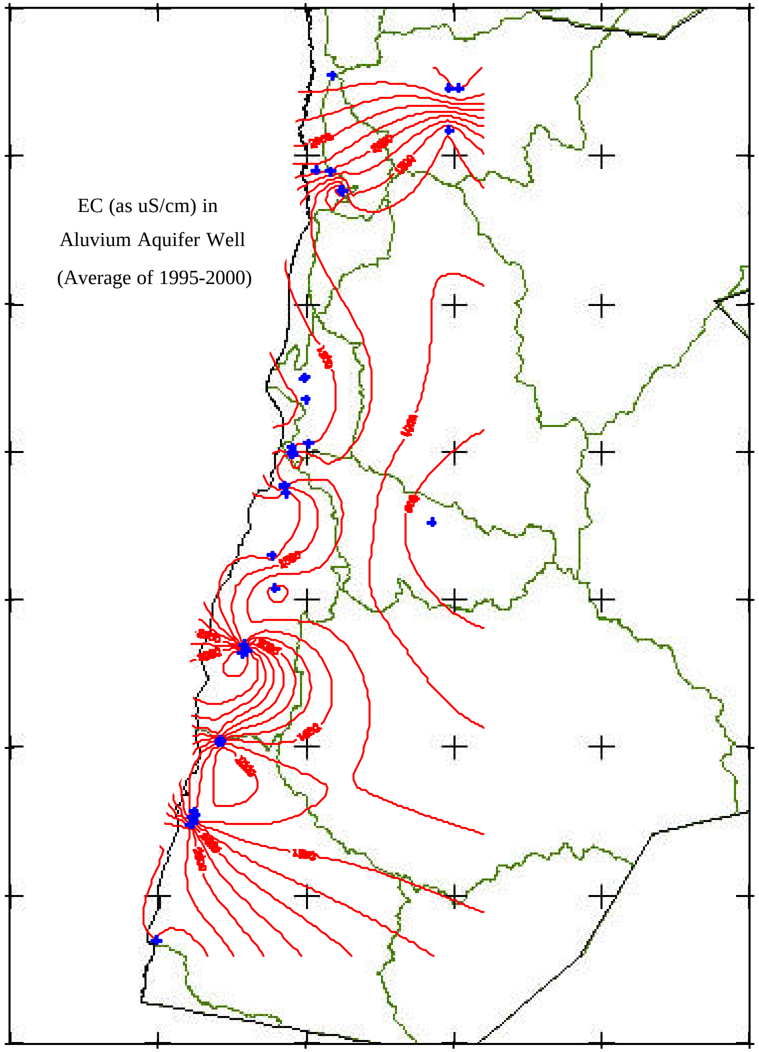


Fig. 1.1-3 EC in Alluvium Aquifer Wells (Ave. of 1995-2000)

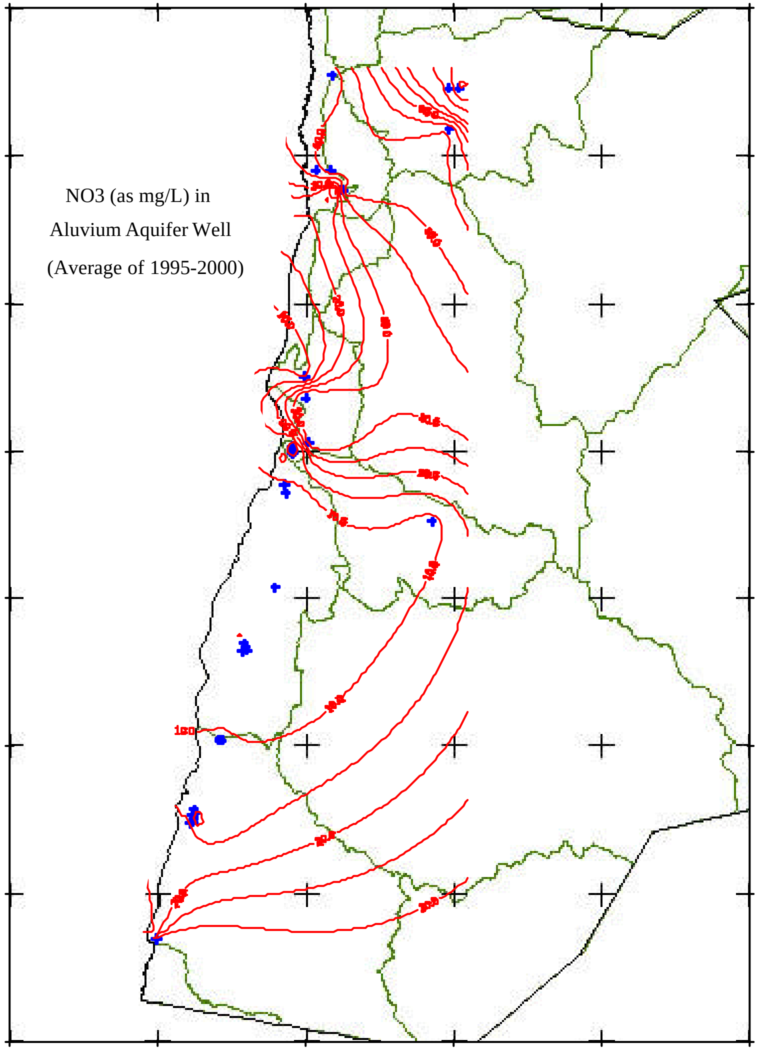


Fig. 1.1-4 NO_3 in Alluvium Aquifer Wells (Ave. of 1995-2000)

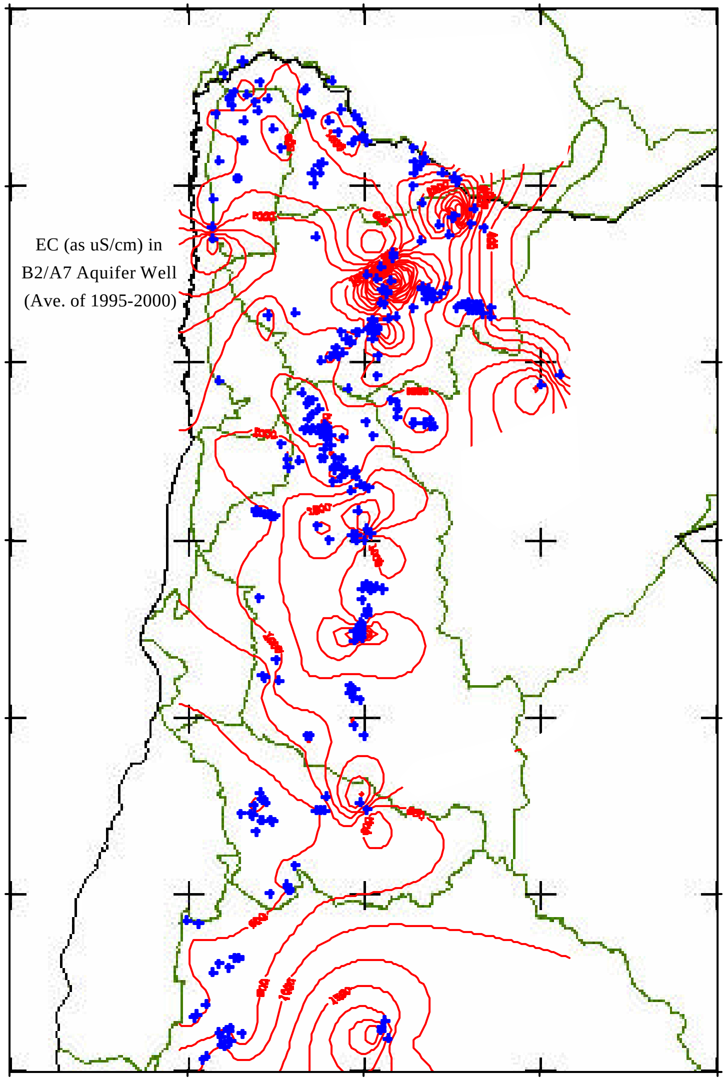


Fig. 1.1-5 EC in B2/A7 Aquifer Wells (Ave. of 1995-2000)

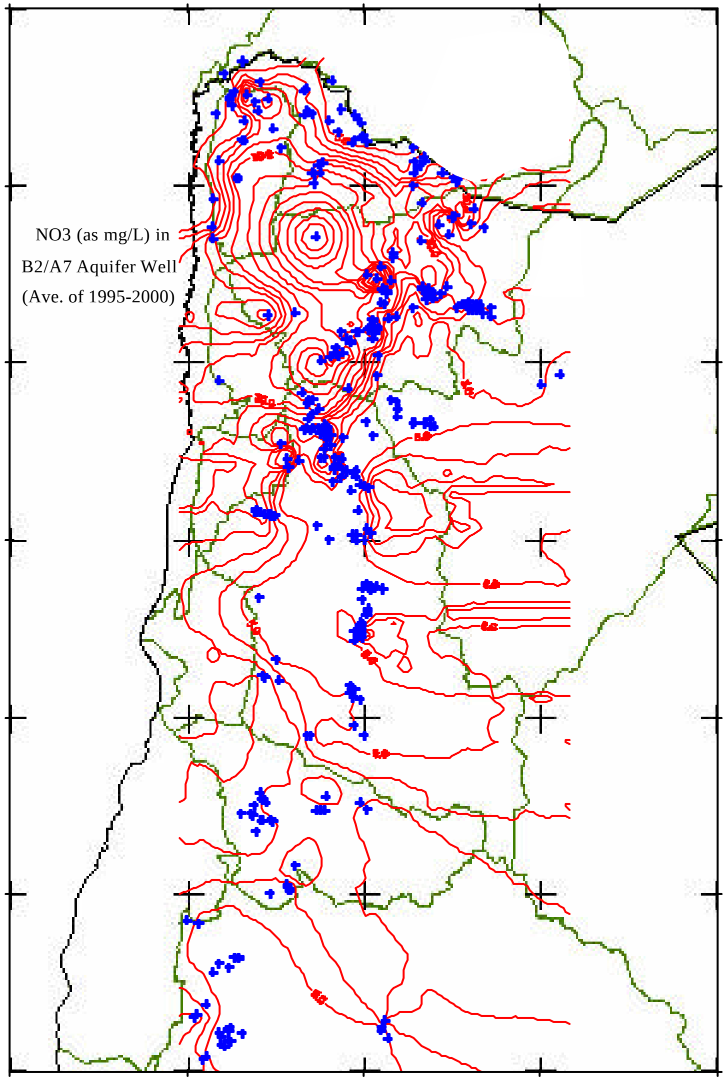


Fig. 1.1-6 NO_3 in B2/A7 Aquifer Wells (Ave. of 1995-2000)

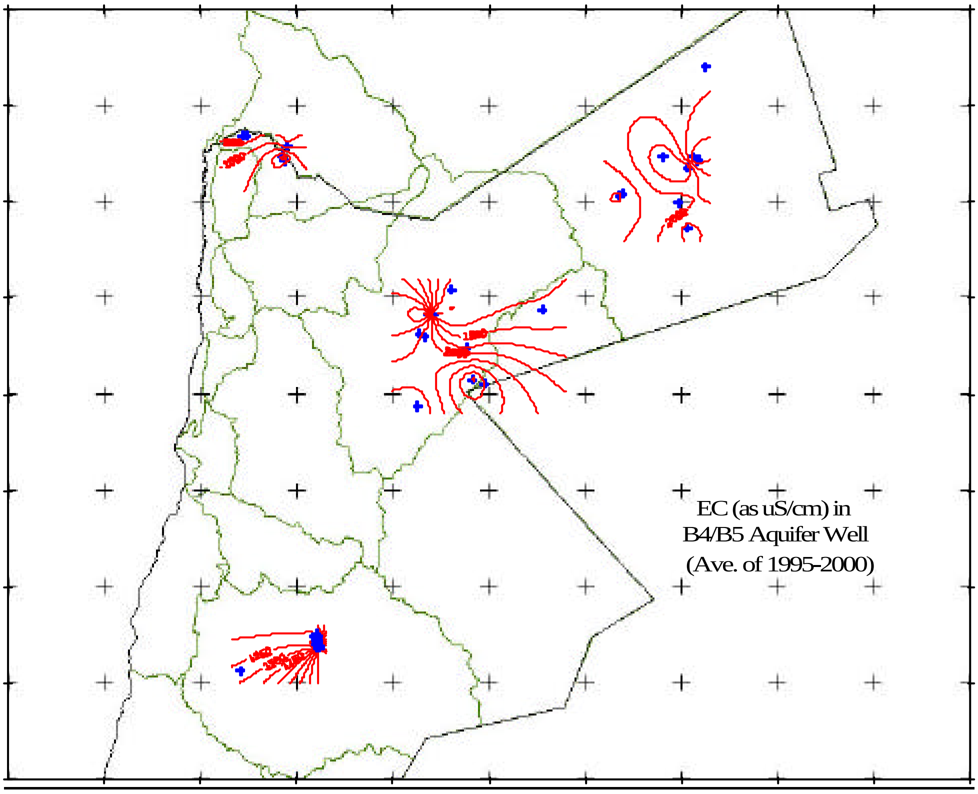


Fig. 1.1-7 EC in B4/B5 Aquifer Wells (Ave. of 1995-2000)

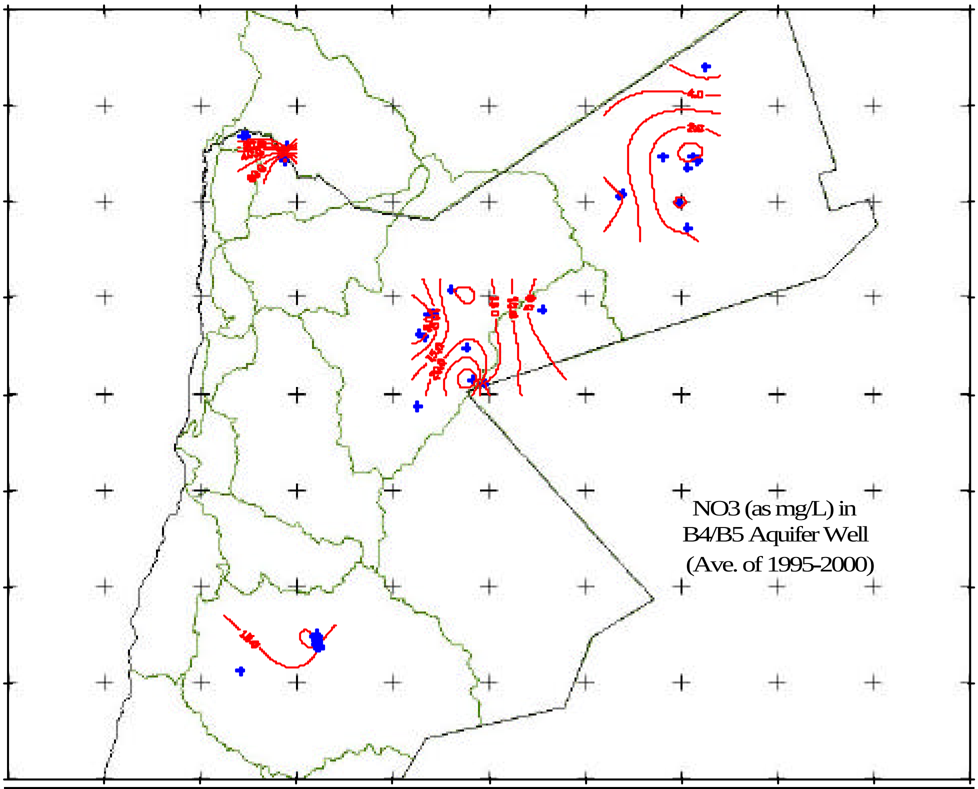


Fig. 1.1-8 NO_3 in B4/B5 Aquifer Wells (Ave. of 1995-2000)

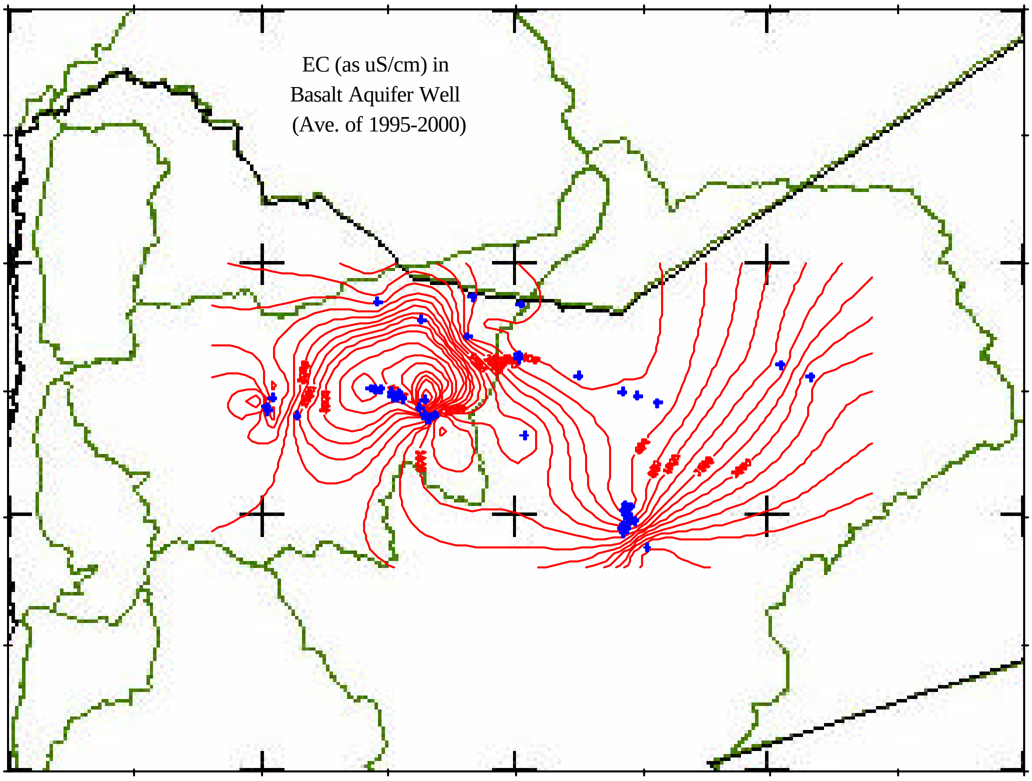


Fig. 1.1-9 EC in Basalt Aquifer Wells (Ave. of 1995-2000)

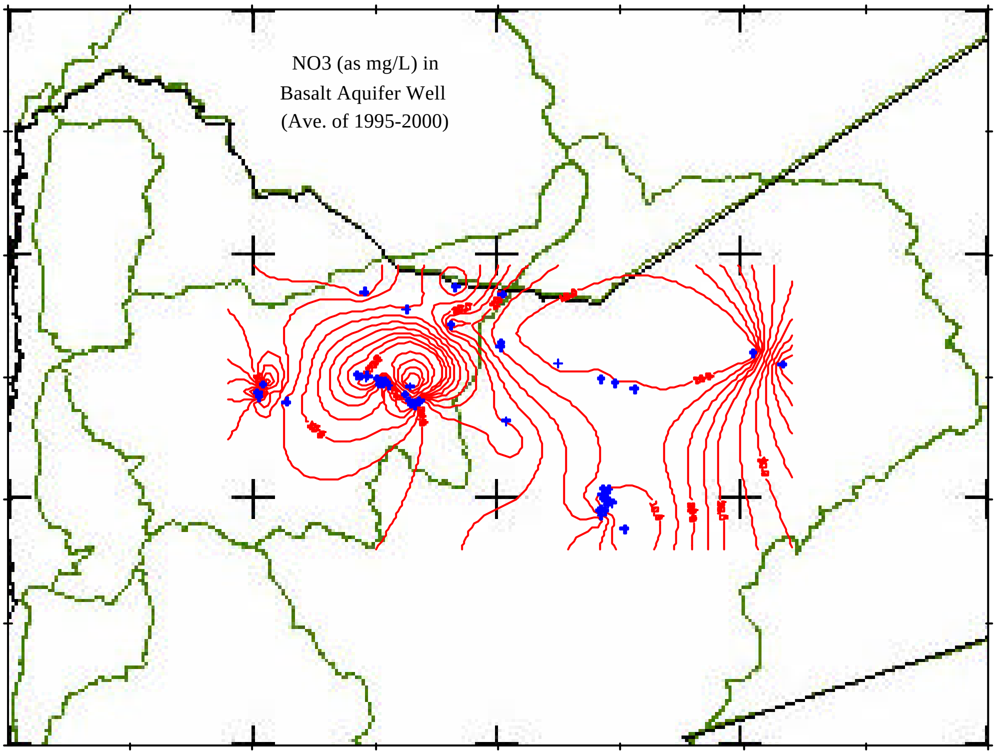


Fig. 1.1-10 NO_3 in Basalt Aquifer Wells (Ave. of 1995-2000)

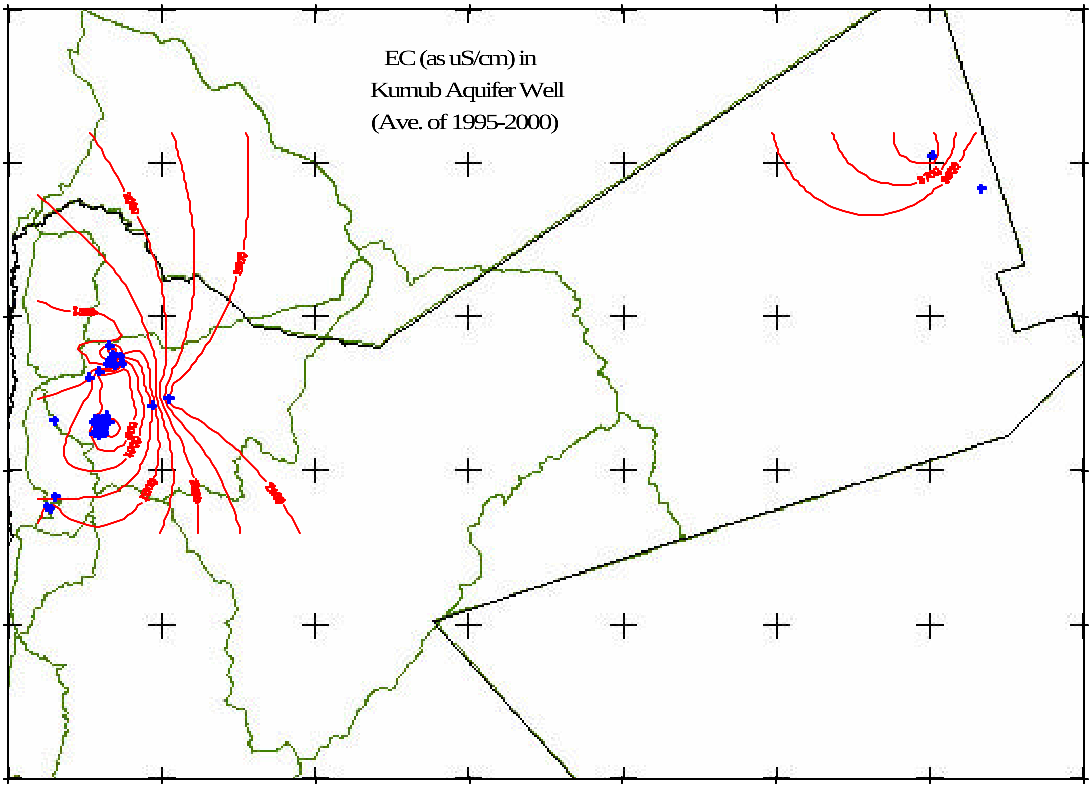


Fig. 1.1-11 EC in Kurnub Aquifer Wells (Ave. of 1995-2000)

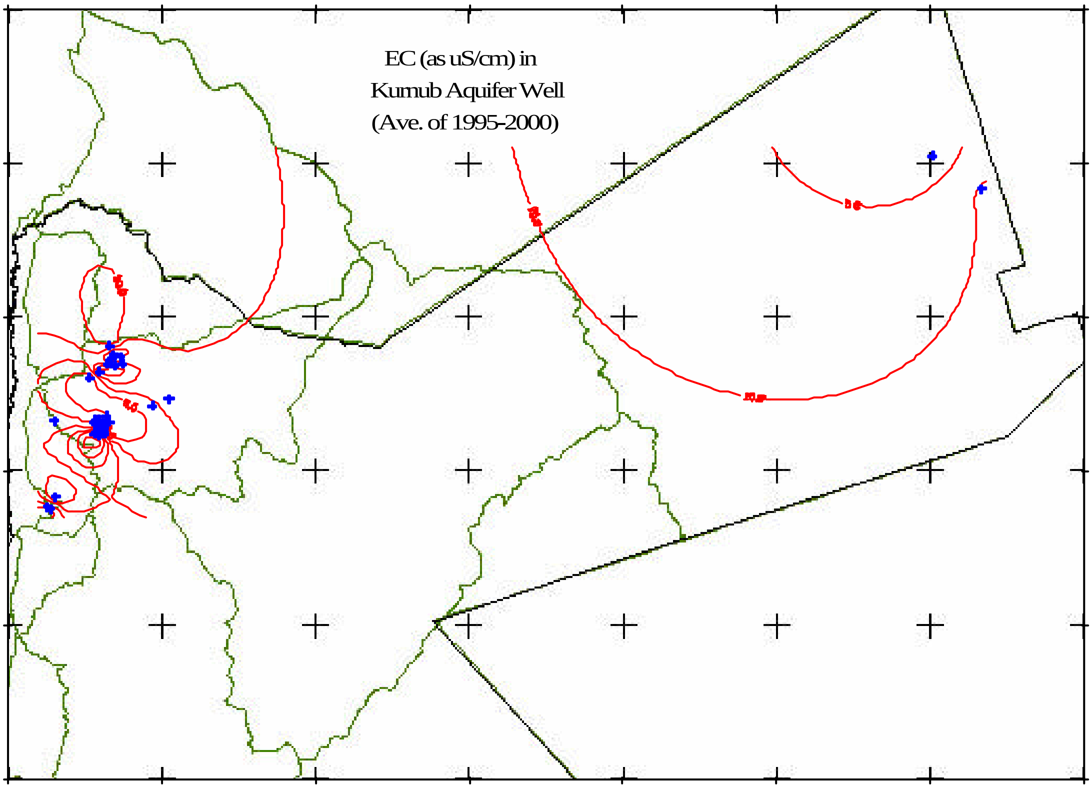


Fig. 1.1-12 EC in Kurnub Aquifer Wells (Ave. of 1995-2000)

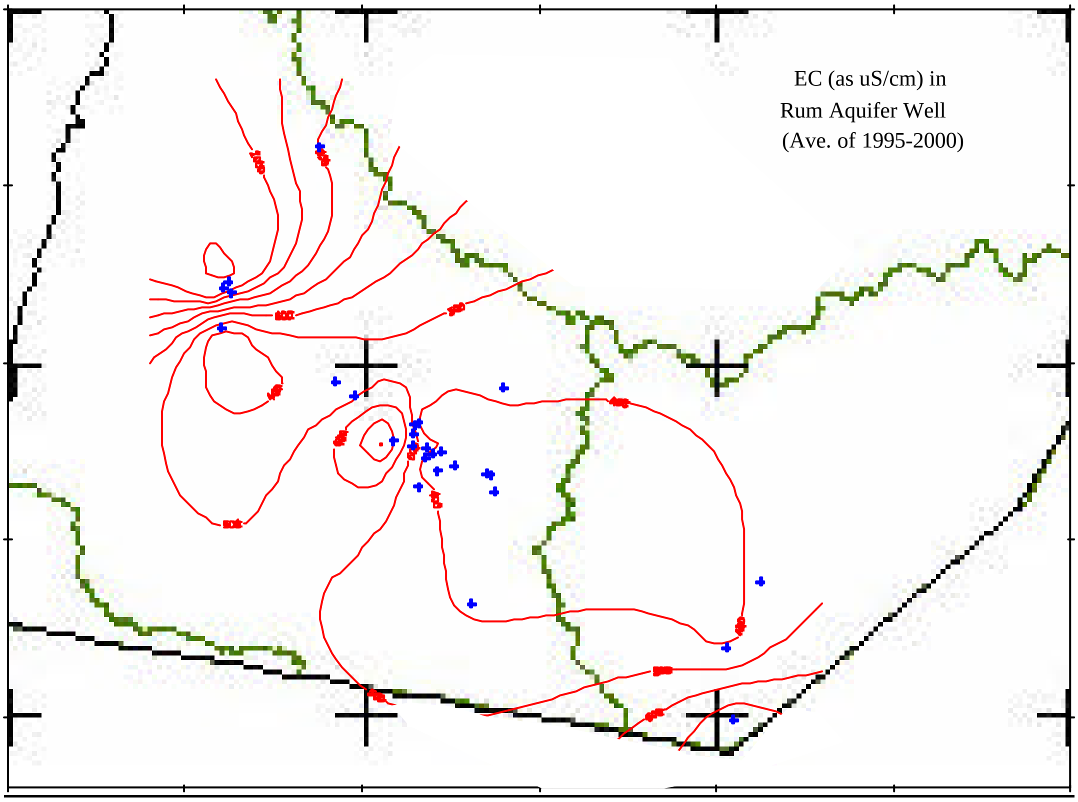


Fig. 1.1-13 EC in Ram Aquifer Wells (Ave. of 1995-2000)

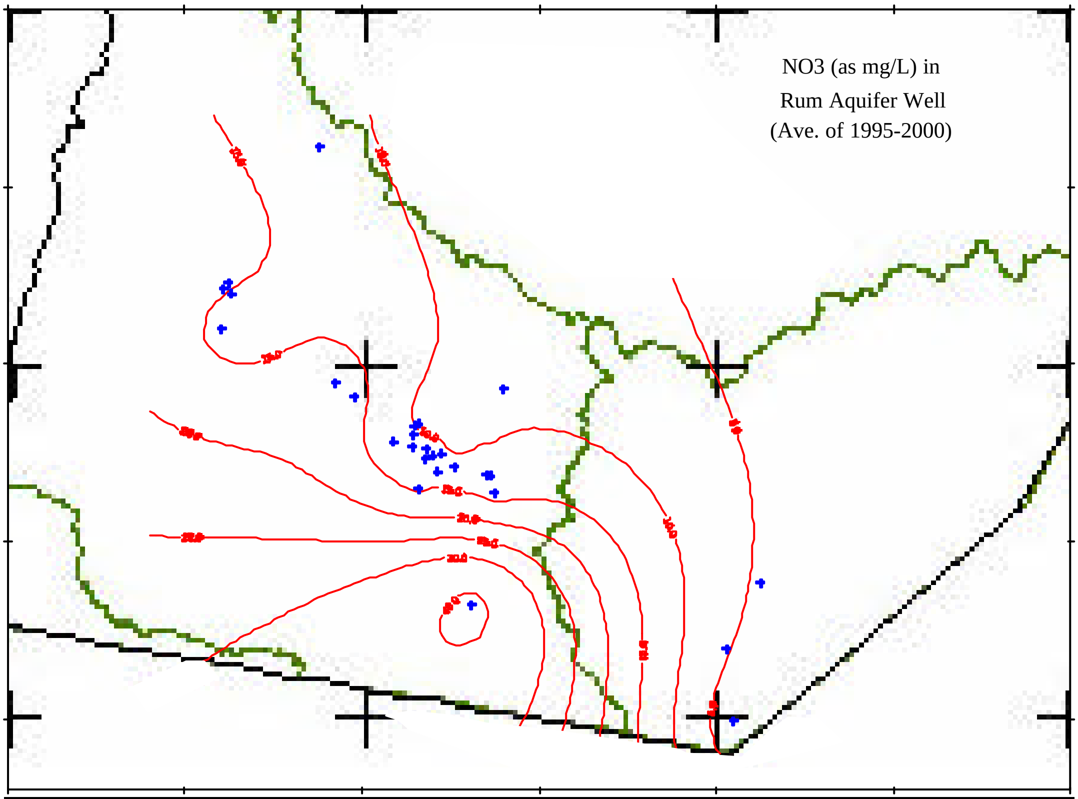


Fig. 1.1-14 NO_3 in Ram Aquifer Wells (Ave. of 1995-2000)

Alluvium Aquifers: Almost all the wells belonging to the Alluvium Aquifer are in the area near the border to the West Bank side, covering Amman-Zarqa basin, Jordan Valley basin, Dead Sea basin, and Wadi Araba basin. Most of these wells are slightly brackish with EC from 1500 to 2500 MicroS/cm (Fig. 1.1-3). NO_3 concentration is lower than 50 mg/L for most of the wells except those in the middle of the Amman-Zarqa basin (Fig. 1.1-4).

B2/A7 Aquifers: The B2/A7 aquifer wells are mainly distributed in Amman-Zarqa, Mujib, Yarmouk, North Jordan Valley and Hasa basins. Some wells in the middle of Amman-Zarqa basin show high salinities (EC higher than 2000-3000 MicroS/cm) and a few with EC = 1500-2000 in north part of Amman-Zarqa basin and middle of Mujib basin (Fig. 1.1-5). The average NO_3 concentrations for most of the wells are low but peaks higher than 50 mg/L appear in the middle of Amman-Zarqa basin (Fig. 1.1-6).

B4/B5 Aquifers: The number of wells with water quality records is not big for this aquifer. They scatter in Yarmouk, Azraq, Hamad and Jafer basins with EC ranging from 1000 to 2500 MicroS/cm except for the wells near the north border where EC is lower (Fig. 2.2.5-7). There are only two wells at Ramtha showing NO_3 concentration higher than 50 mg/L (Fig. 1.1-8).

Basalt Aquifer: Wells belonging to this aquifer are mainly in the east part of Amman-Zarqa basin and north part of Azraq basin. There are a group of wells in the area near Mabruka and Dulayl villages where water salinity is very high (EC > 3000 MicroS/cm). The peak of NO_3 (higher than 80 mg/L) appears in the same area coincidentally (Fig. 1.1-9 and Fig. 1.1-10).

Kurnub Aquifer: Most of the wells of this aquifer are in the west part of Amman-Zarqa basin. The salinity is generally low for these wells (EC < 1500 MicroS/cm) but shows a tendency of increase eastward especially if the two wells in Hamand basin near the east border are taken into account (Fig. 1.1-11). NO_3 concentration is low for all these wells (Fig. 1.1-12).

Rum Aquifer: Located in South Wadi Aqaba basin (Fig. 1.1-13 and Fig. 1.1-14), most of the wells in this aquifer show both low salinity (EC < 800 MicroS/cm) and NO_3 concentration (< 20 mg/L).

(2) Characteristics of Spring Water Quality

The springs with water quality monitoring records are mainly distributed in a belt area from north to south near the west boundary of the Kingdom. As can be seen from Fig. 2.2.5-15 where springs with different EC values are shown by different symbols, the high salinity springs are mainly found in South Jordan Valley basin and Dead Sea basin. With several exceptions, the general trend is salinity getting higher toward the Jordan Valley and Dead Sea side. Fig. 1.1-16 shows the distribution of NO_3 in the spring water with different symbols for different concentration ranges. There are several peaks of NO_3 higher than 100 mg/L in Amman-Zarqa and Dead Sea basins.

2. Investigation of Groundwater Quality

(1) Tendency of Deterioration of Groundwater Quality

Increase in Groundwater Salinity: By reviewing the historical data of groundwater quality, it is noticeable that the salinity of many wells and springs has increased substantially in the past years. The most serious condition is found with the wells in Amman-Zarqa basin. Table 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 MicroS/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 similar tendency. Some wells in Azraq, Dead Sea and Mujib basins have similar problem in the past years.

Increase in Nitrate Concentration of Groundwater: Fig. 1.2-1 and Fig. 1.2.-2 are the examples of some wells and springs which show apparent tendency of increase in NO_3 concentration. The four wells on the graph are in Amman-Zarqa basin but different aquifers (AL1197: A4 Aquifer, near Hashimiyya; AL2335: aquifer unknown, near Hashimiyya; AL1608: A2/A1 Aquifer, near Jerash; AL1075: B2/A7 Aquifer, near Dulayl). Of the four springs, one is in Dead Sea basin (CA0598: A7 Aquifer, near Karak), the other three in the west part of Amman-Zarqa basin (AL0800 and AL0954: Kurnub Aquifer; AL0868: A4 Aquifer).

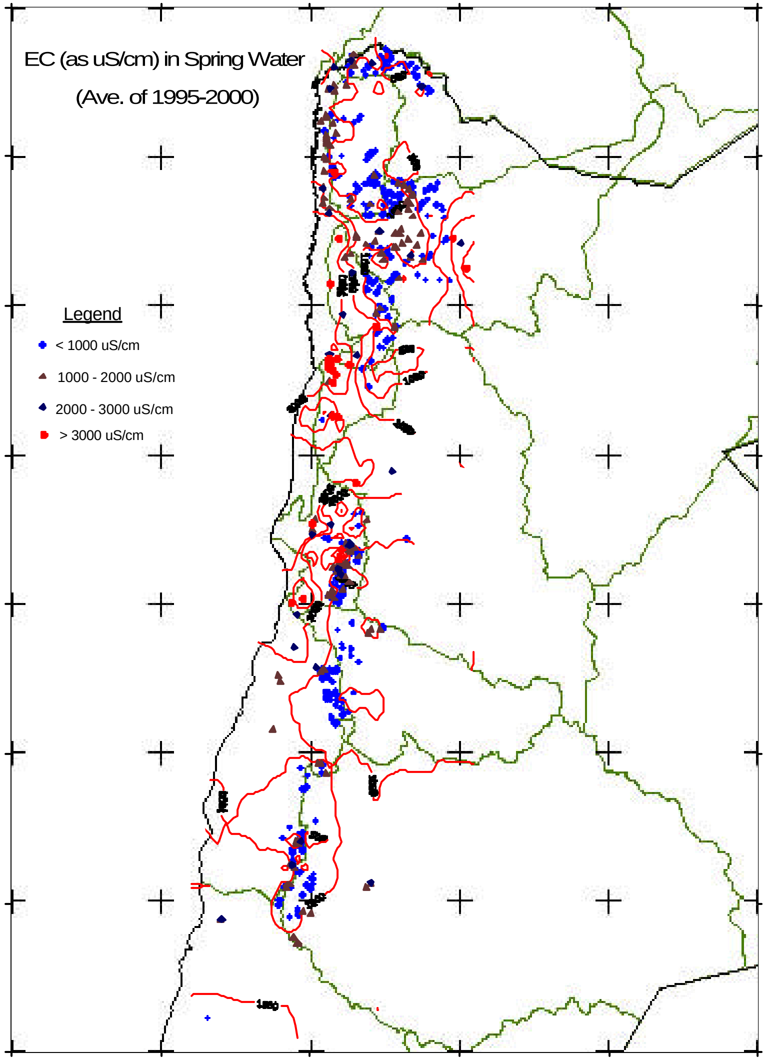


Fig. 1.1-15 EC in Spring Water (Ave. of 1995-2000)

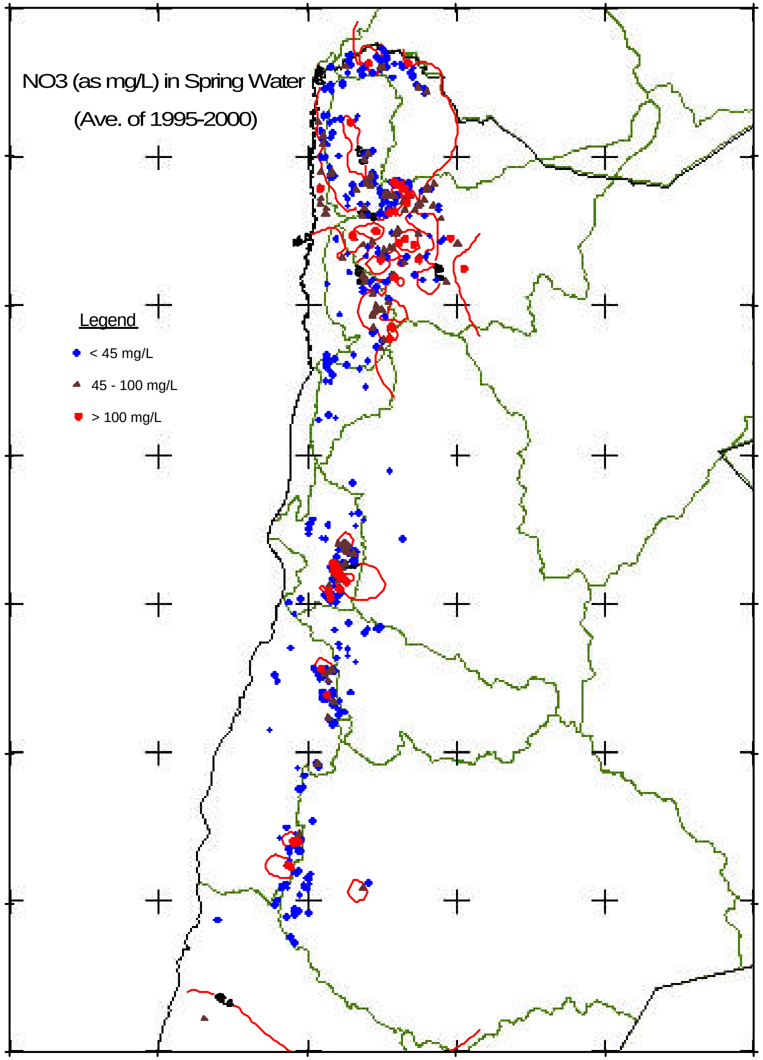


Fig. 1.1-16 NO_3 in Spring Water (Ave. of 1995-2000)

For comparison, salinity (EC) data are also shown on the graphs. It is seen that although at some location such as AL1197, water salinity did not change so much but NO_3 kept an apparent increase, in most cases the increase in NO_3 was accompanied by an increase in water salinity. Generally speaking, fluctuation in NO_3 happened more frequently than EC (the cases of AL2335, AL1608 and AL1075), but at some location such as AL1075, NO_3 varied in a very similar pattern as EC.

Table 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**

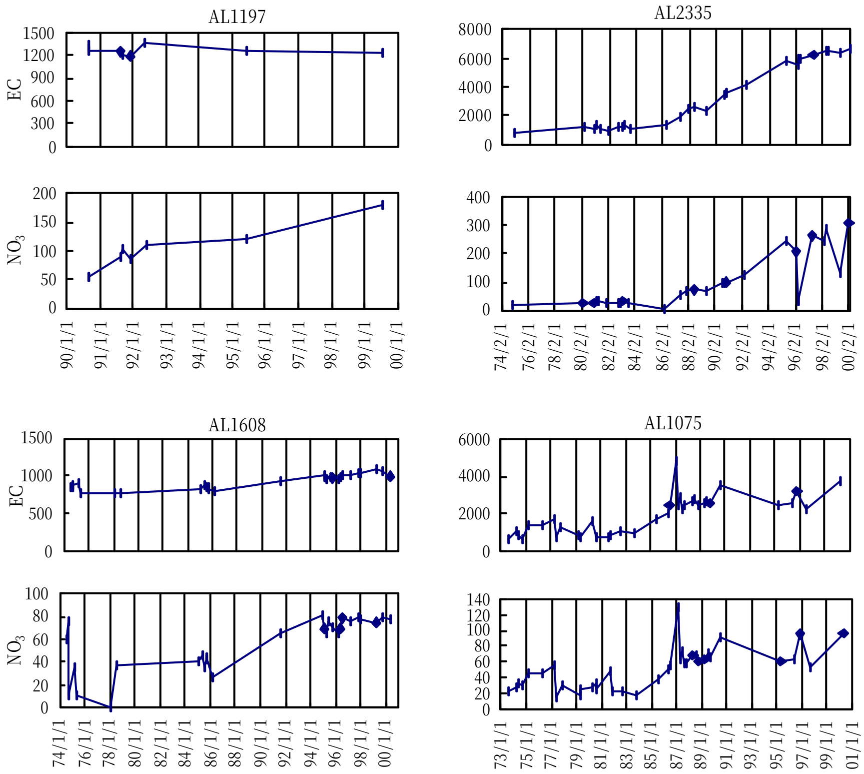


Fig. 1.2-1 Tendency of NO_3 Increase in Well Water

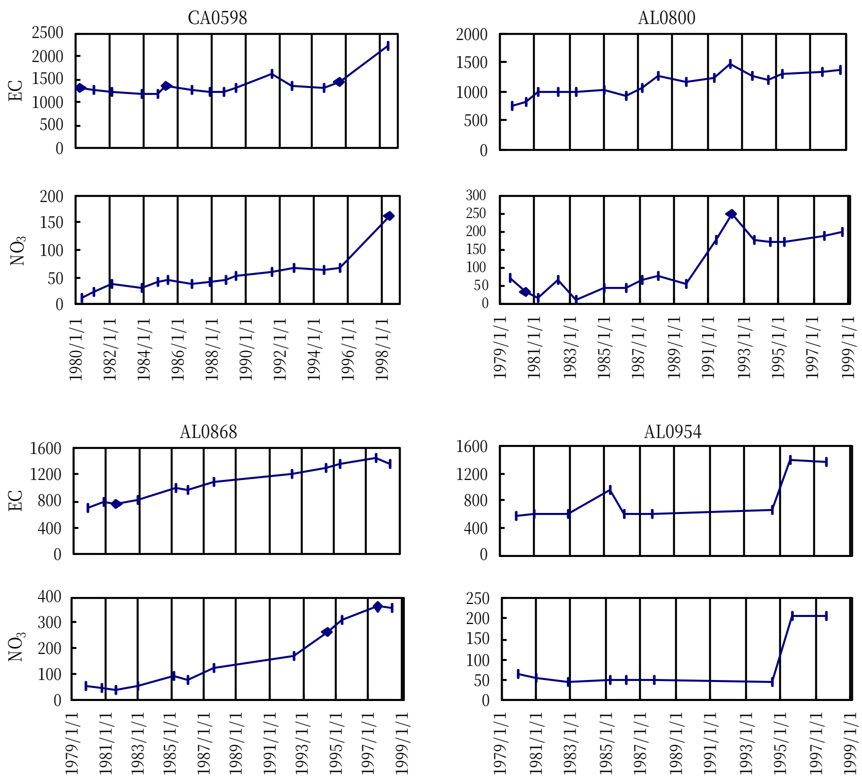


Fig. 1.2-2 Tendency of NO_3 Increase in Spring Water

(2) Investigation of Wells with High NO_3 Concentration

Although NO_3 is one of the anionic elements of the dissolved solids in water, it becomes an indicator of organic pollution when the concentration turns to be abnormally high. From the maps of distribution of NO_3 in wells at different aquifers shown in Fig. 1.1-16, we noticed that high NO_3 happened mainly in Amman-Zarqa basin and Yarmouk basin near the north border. According to the calculated average NO_3 concentrations of the wells with water quality monitoring records after 1995, there are totally 81 wells with NO_3 > 50 mg/L (the standard value of WHO Drinking Water Quality Guideline, 1993 and Jordanian Drinking Water Quality Standars, JS 286/1997), of which 61 are in Amman-Zarqa basin and 5 in Yarmouk basin; 33 wells with NO_3 > 70 mg/L (the maximum limit value in Jordanian Drinking Water Quality Standards), of which 29 are in Amman-Zarqa basin and 3 in Yarmouk basin; 15 wells with NO_3 > 100 mg/L, of which 13 are in Amman-Zarqa basin and the other 2 in Yarmouk basin. The value of 100 mg/L is arbitrarily chosen as a reference level of severe nitrate pollution because it is double of the WHO drinking water standard value and near the limit of FAO guideline of water quality for irrigation (NO_3-N > 30 mg/L, equivalent to 132.9 mg/L as NO_3 is considered to have severe impacts on irrigation use). The locations of these wells are shown in Fig. 1.2-3 with names of the nearby towns and villages for reference.

With several exceptions, these wells can be roughly divided into 3 groups according to their locations: (1) Dulayl-Hallabat area to the east of As Samra WWTP, (2) Hashimiyya-Sukhneh area downstream of As Samra WWTP and (3) Ramtha area. The study team took field trip to these areas and investigated the condition of these wells. The parameters for these wells are summarized in Table 1.2-2.

Wells in Dulayl-Hallabat Area: There are 5 wells with high NO_3 concentration in this area, all of them belonging to Basalt aquifer with depth about 100 m except for AL2595 (240 m). Dulayl-Hallabat area has long been an area with the problem of declination of groundwater table and deterioration of groundwater quality since early 1970s. In addition to high salinity, high concentration of NO_3 became a problem of public concerns. (Although not shown in Table 1.2-2, almost all wells with water quality monitoring records in this area show NO_3 concentration at least higher than 50 mg/L.) From 1995 to 1998, a study was conducted on the origin of nitrates and salinization of groundwater in this area under the financial support of IAEA (International Atomic Energy Agency). Both chemical and isotopic analyses were conducted for water from a number of wells in this area. 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 flows from the cultivated area through the saline soil and evaporation would have been the main source of salinization. Regarding the source of NO_3 in the groundwater, because 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 NO_3, but fermentation of ammonia from raw wastes or manures might also be the NO_3 source for some of the wells (Rimawi, 1991; Rimawi et al, 1993; Katbeh and Rimawi, 1999).

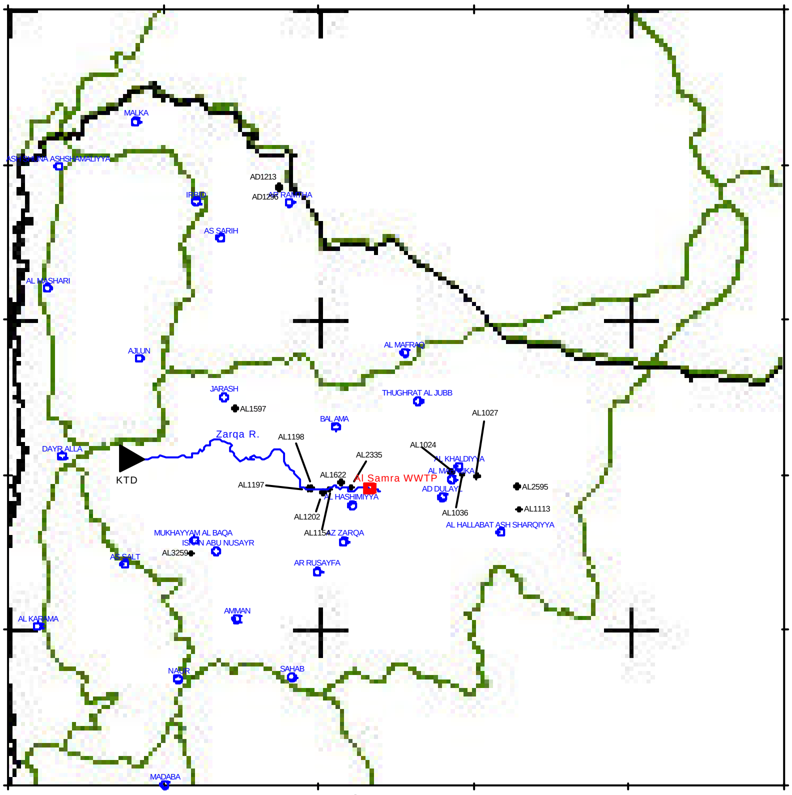


Fig. 1.2-3 Location of Wells with NO_3 > 100 mg/L

As a matter of fact, the Dulayl-Hallabat area and its surroundings are known as an area with intensive irrigated agriculture as well as stock farming activities. Many chicken farms and cattle fields can be seen among the agricultural lands. According to the information from the Ministry of Agriculture, the amount of fertilizers imported to and manufactured in Jordan keeps increasing. Among them the ammonium phosphate takes a large portion. This is undoubtedly a main source of NO_3 to the groundwater. In addition to this, manures from animals may become the source at some locations. During the field trip, the study team noticed that some of the wells are not well protected at all – scattered with garbage in the surrounding, small puddles nearby as drinking place for cattle. These are also point sources of pollution to the wells.

Because the direction of groundwater flow is westward in this area, it is unlikely that the stabilization ponds in As Samra WWTP at the downstream side may affect well water quality of this group.

<u>Wells in Hashimiyya-Sukhneh area</u>: The characteristics of the wells in Hashimiyya-Sukhneh area downstream of As Samra WWTP can be summarized as: (a) comparatively shallow (3 of them are only 9-39 m in depth) and (b) located in the vicinity of the stream of Zarqa River (10-50 m from the bank). Considering that this section of Zarqa River is carrying a constant flow of treated wastewater from As Samra to KTR and the concentration of total nitrogen is very high because of overloading at the WWTP (about 100 mg/L as N in the effluent, mostly NH_4-N), the wastewater is likely to be an intensive source of nitrate to this wells. In the IAEA study mentioned above, several samples were also taken from wells downstream of As Samra and the measured ^{15}N values ranged from 9.5 to 25.6. This provided an important evidence

that ammonia fermentation might be the main source of NO_3 in this area. On the other hand, according to long term observation result of water table upstream and downstream of As Samra, in contrast with a constant decrease of water level at the upstream side (Dulayl-Hallabat area), the water level at the downstream side (Hashimiyya-Sukhneh area) has shown an increase since 1986, i.e. after the construction of As Samra WWTP. Irrigation return flow may affect the groundwater quality in this area, but considering the high pollution intensity of penetration from the unprotected bottom of the stabilization ponds in As Samra WWTP and the Zarqa River itself, it can be concluded that groundwater pollution 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.

Wells at Ramtha Area:

The salinity of the two wells at Ramtha area is low in comparison with their high NO_3 concentration. In this case, irrigation return flow may not be the main reason of nitrate in the groundwater and therefore other pollution sources should be considered. Actually, the two wells are located at the bank of Wadi Ramtha which carries flood flow only in the rainy season. In Ramtha Town many people are still using small soil ponds for disposal of feces, and dumping garbage into the wadi area. This undoubtedly becomes the pollution source of the wells at the downstream side. At present time, water from the Mahasi 5 well is treated by ion exchange process to remove NO_3 before being supplied for domestic use.

Table 1.2-2 Parameters of Wells with NO_3 Concentration Higher than 100 mg/L

Ad Dulayl-Hallabat Area

Station ID	AL1024	AL1027	AL1036	AL1113	AL2595
Station Name	DP 18 Agr. (PP317)	DP 21 Nra (PP 327)	DP 29	Hamdan S. Blewy	Omar M. A. Qader Shaheen
Ownership	Gov.	Gov.	Gov.	Private	Private
Present Use	Irrigation	Irrigation	Irrigation	Irrigation	Irrigation
Aquifer[a]	Basalt	Basalt	Basalt	Basalt	Basalt
Depth (m)[a]	100	95	100	105	240
Yield (m^3/h)[a]	348	179	130	120	60
Pumping Test Date[a]	1965/10/1	1966/11/24	1972/3/6	1972/2/26	Unkown
Salinity at Test (TDS mg/L)	291	285	1320	288	412
Present Salinity (TDS mg/L)[b,c]	3094	3488	3405	1568	5834
Present NO_3 (mg/L)[c]	102.8	127.5	133.3	106.7	281.8

Hashimiyya-Sukhneh Area

Station ID	AL1154	AL1197	AL1198	AL1202	AL1622	AL2335
Station Name	Rashad Ayyoub	Nizar S. Sha'sha'a	Nizar S. Sha'sha'a	Taha Yasaa 4	Saleh K. Elsaleh 2	Jordan Pipes Manu. Co.
Ownership	Private	Private	Private	Private	Private	Ind.
Aquifer[a]	Alluvium	A4	Alluvium	-	A7	-
Present Use	Irrigation	Irrigation	Irrigation	Irrigation	Irrigation	Gardening
Depth (m)[a]	9	39	30	103	87	250
Yield (m^3/h)[a]	-	75	80	78	77	10
Pumping Test Date[a]	Unknown	1973/2/14	1975/2/1	Unknown	1978/6/7	1972/11/21
Salinity at Test (TDS mg/L)	499	691	812	-	396	-
Present Salinity (TDS mg/L)[b,c]	2289	2320	2173	2189	3443	3975
Present NO_3 (mg/L)[c]	180.9	150.8	129.4	102.5	234.6	194.4

Ramtha Area

Station ID	AD1213	AD1296
Station Name	Mahasi 1 (Ramtha Mun.)	Mahasi 5
Ownership	Gov.	Gov.
Aquifer[a]	B4	B4
Present Use	Domestic	Domestic
Depth (m)[a]	85	104
Yield (m^3/h)[a]	61	122
Pumping Test Date[a]	1971/5/5	1988/1/16
Salinity at Test (TDS mg/L)	640	1190
Present Salinity (TDS mg/L)[b,c]	993	1448
Present NO_3 (mg/L)[c]	119.9	201.1

Note:a- based on WIS data; b- calculated from EC value by multiplying 0.64 to yield TDS;
c- average values of 1995-1999

(3) Groundwater Quality in South Amman Area

To the south of the Greater Amman Municipality, the north part of Mujib basin is an intensive well field for domestic water supply (9.32MCM for water supply to Amman in 1998). Most of these wells belong to B2/A7 aquifer with comparatively good water quality as can be seen from the water quality distribution maps for this aquifer (Fig 1.1-5 and Fig 1.1-6). However, by reviewing the historical water quality monitoring data, it is found that some of the wells for domestic water supply show substantial increases in EC and NO_3 in the past years as can be seen from Fig.1.2-4. Comparing with groundwater aquifers in other water basins, few studies have been conducted for this area, and hence little is known about the characteristics of groundwater quality there. With the development in Greater Amman area, an increase in population and economic activities is envisaged in the South Amman area. Therefore, how to protect groundwater quality becomes an issue of concern in the water sector. Considering this condition and under the request of MOWI, groundwater simulation is conducted in this study regarding South Amman area. This will be explained in Annex to 4.2.5.

(4) General Evaluation of Groundwater Quality for Water Uses

In Jordan, the total abstraction of groundwater in 1998 was 484MCM, of which 182.81 MCM was used for domestic water supply. The other included water for irrigation, industrial and other uses, but irrigation water took more than 90%.

Water Quality for Domestic Supply: According to the WIS data, there were totally 348 wells used for public domestic water supply in 1998. Of these wells, 163 have water quality monitoring records. Based on the calculated average values of water quality data from 1995 to 2000, 133 of the 163 wells (81.6%) show a TDS value higher than 500 mg/L (the allowable salinity level in Jordanian Drinking Water Quality Standard, JS286/1997) where TDS is calculated from EC (as MicroS/cm) by a proportional factor of 0.64. The number of wells with TDS higher than double of the standard value, i.e. 1000 mg/L is 17 (10.4%), and that higher than 1500 mg/L (the maximum limit set in the Jordanian Standard) is 7 (4.3%). As for nitrate, the number of wells with NO_3 concentration higher than 50 mg/L (the allowable level in the Jordanian Standard) is 20 (12.3%), and that higher than 70 mg/L (the maximum limit set in the Jordanian Standard) is 10 (6.1%). Table 2.2.5-3 summarizes the information of those wells with high TDS and/or NO_3.

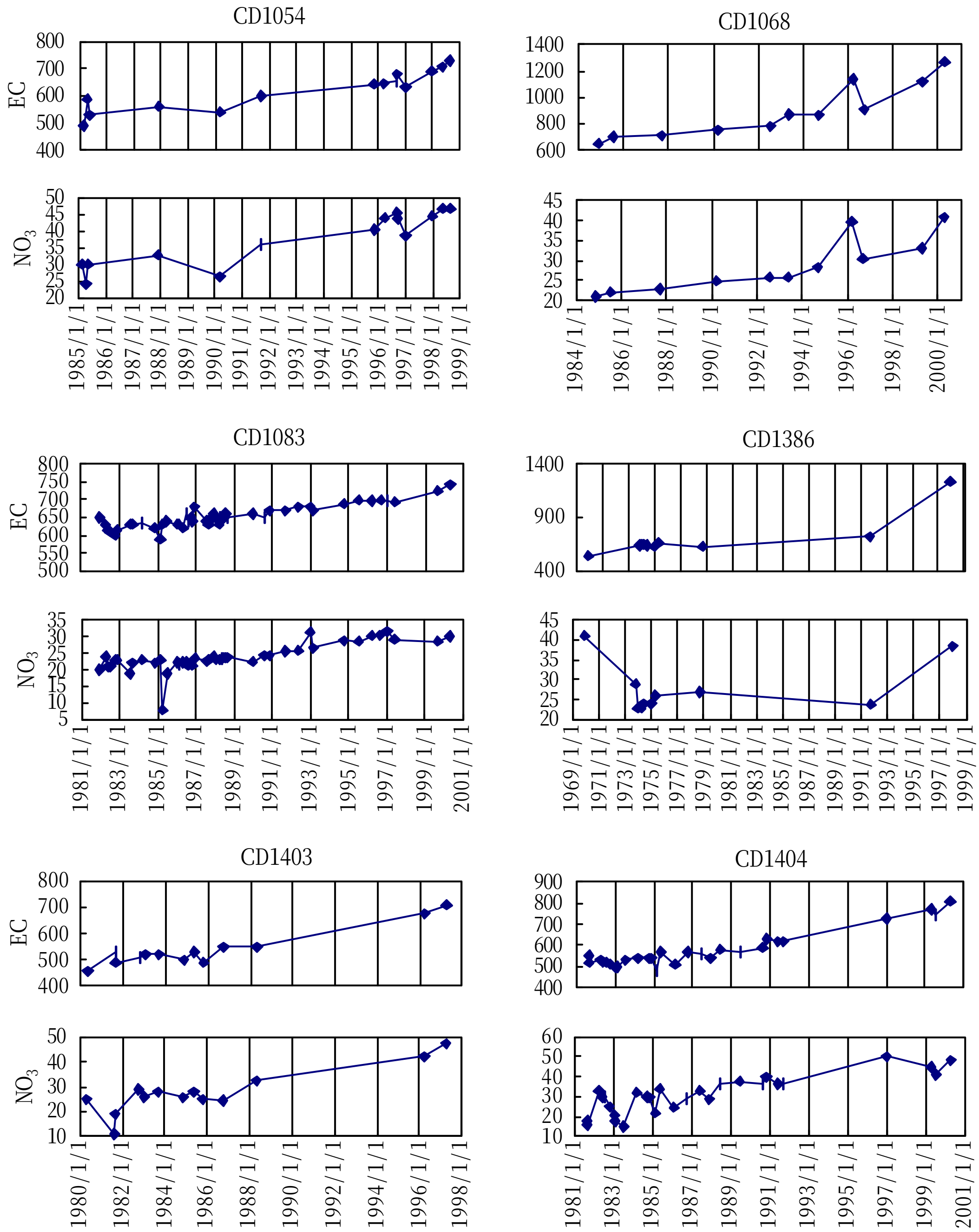


Fig. 1.2-4 Variation of Water Quality in South Amman Area
(Mujib Basin, B2/A7 Aquifer Wells)

Table 1.2-3 Public Wells for Domestic Water Supply but with High Concentrations of TDS and/or NO_3

Station ID	Station Name	Governorate	Production (m^3/h)	TDS (mg/L)	NO_3 (mg/L)	Remarks
AB1377	Sleikhat 6	Irbid	52.2	**1427.7**	27.9	
AD1276	Mukheiba	Irbid	5.6	**1079.3**	1.5	
AD1296	Mahasi 5	Irbid	12.7	**1401.9**	**194.8**	Treated by ion Exchange
AL1022	DP 16 NRA	Mafraq	39.3	**2321.9**	**81.0**	
AL1023	DP 17	Mafraq	149.4	**2251.2**	**89.1**	
AL1230	Hashimiya 3	Zarqa	172.7	**1630.3**	42.6	
AL1254	Hashimiya 5	Zarqa	110.1	**1691.0**	43.8	
AL1319	Awajan 21	Zarqa	145.3	**1083.7**	58.9	
AL1558	KM 90	Mafraq	110	**1740.8**	38.9	
AL1608	Faleh M. El Gharaybeh 1	Jerash	19.4	644.8	**74.0**	
AL1830	AWSA 21	Amman	294.9	658.4	**90.9**	
AL1831	AWSA 22	Amman	92.6	712.8	**87.7**	
AL1837	AWSA 27	Amman	72.9	741.4	**92.9**	
AL1843	AWSA 33	Amman	162.7	681.3	**80.9**	
AL1846	Jabal El Naser 2	Amman	106.5	674.6	**81.1**	
AL1898	Zerqa 2	Zarqa	171.7	**1813.1**	60.7	
AL2690	Ain Ghazal Stn 2	Amman	84.7	765.9	**71.3**	
AL2715	Hashimiya 2	Zarqa	70.4	**1720.3**	43.0	
AN1005	Rawdah 6	Balqa	50.7	**1044.1**	24.6	
CA1012	Mazra'a 2	Karak	37.3	**1079.5**	7.1	
CA3007	Mazra'a 3	Karak	34.1	**1001.2**	34.2	
CD1105	Qatraneh 8	Karak	30.1	**1133.4**	12.0	
CD1108	Qatraneh 12	Karak	37.6	**1194.2**	10.6	
CD3221	Qatraneh 19	Karak	46.3	**1496.8**	9.2	

As has been discussed in the former sections, high concentration of NO_3 in groundwater mainly happens in Amman-Zarqa basin. This has also affected the wells for domestic water supply. It is noticeable that 2 wells in Mafraq (DP 16 and 17) are very saline and with high nitrate concentration but still being used for water supply. Generally speaking, TDS mainly affects the palatability of water, because water with TDS lower than 500 mg/L tastes good but becomes unpleasantly salty as TDS reaches about 1000 mg/L. As for nitrate, its toxicity to humans has been identified as its reduction to nitrite which may cause the oxidation of normal haemoglobin to methaemoglobin. The later is unable to transport oxygen to the tissues and thus causes a syndrome called 'methaemoglobinaemia'. Infants under 3 months of age are more at the risk than older children and adults. The safety level of nitrate in drinking water has been confirmed to be 10 mg/L as N, or approximately 50 mg/L as NO_3.
High salinity and high NO_3 concentration in these wells for domestic water supply is a problem to be fully considered.

<u>Water Quality for Irrigation</u>: According to FAO Guidelines of Water Quality for Irrigation (FAO, 1989), the following factors may cause irrigation problems: (a) salinity evaluated by EC or TDS, which affects crop water availability, (b) infiltration evaluated

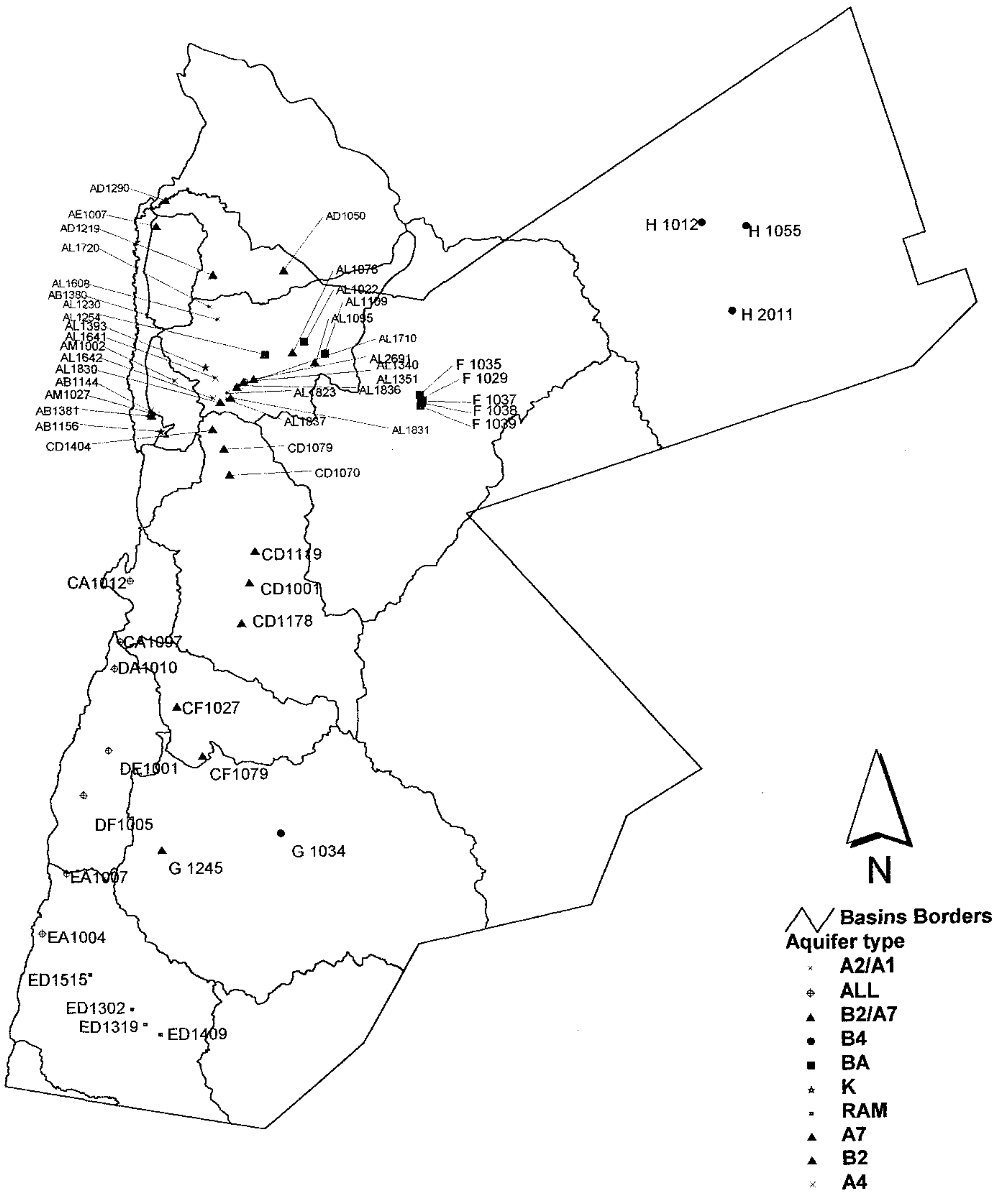
by EC and SAR (sodium adsorption ratio) together, which affects infiltration rate of water into the soil, (c) specific ion toxicity from sodium, chloride, boron or other trace elements, which affects sensitive crops and (d) miscellaneous effects from nitrate, bicarbonate or pH, which affect susceptible crops. Regarding well water in Jordan, because data for some of the related items such as SAR, boron are unavailable, discussions here are mainly concerning salinity and other related ions.

Of the 640 wells with water quality monitoring records, 37 wells (5.8%) show EC values higher than 3000 MicroS/cm - a level specified in FAO standard as the limit of severe affects on crops; 457 wells (71.4%) are within the range of 700-3000 MicroS/cm – slight to moderate affects on crops; the remaining 146 wells (22.8%) have EC value lower than 700 MicroS/cm – below this level none impacts would be suspected to any kind of crop. Because the tolerance of different crops to salinity is different, 700 MicroS/cm is not usually a practical standard level adopted worldwide, and the medium value of the 700-3000 MicroS/cm range, i.e. approximately 2000 MicroS/cm is often considered to be an acceptable level for most crops. Taking this as a reference level, the existing data have shown that 81 of the 640 wells (12.7%) have higher salinity and may not be suitable for irrigation use. High salinity is often accompanied with high concentrations of sodium and chloride in water. By analyzing data for the component ions, it is calculated that both Na and Cl concentrations exceed 5.0 meq/L. At this concentration level, Na and Cl may be toxic to some sensitive crops such as avocado, berries etc.

Regarding nitrate, the severe effect level is set as 30 mg/L as N (133 mg/L as NO_3) in the FAO standard. Although the number is not so big, there are some wells with very high NO_3 concentration being used for irrigation.

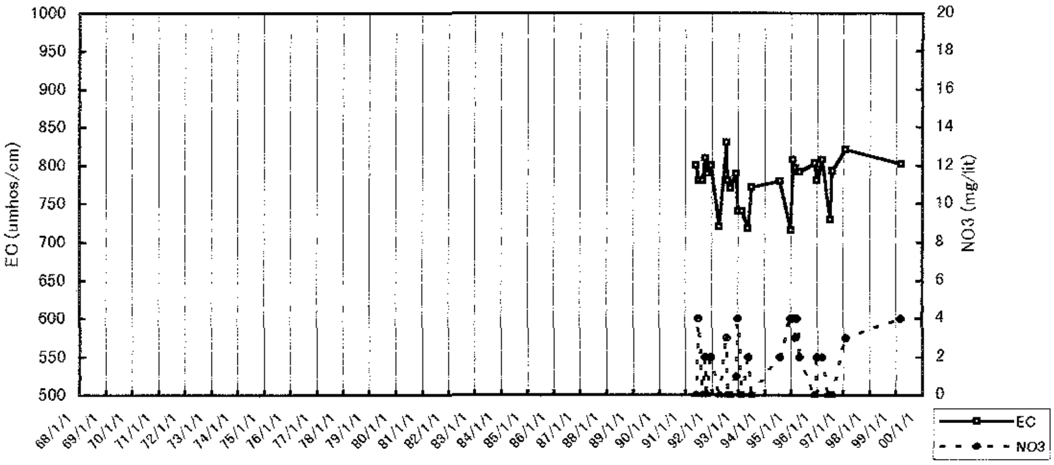
3. Groundwater Quality Monitoring Records (EC and Nitrate)

Location Map of Ground Water Quality Monitoring Wells

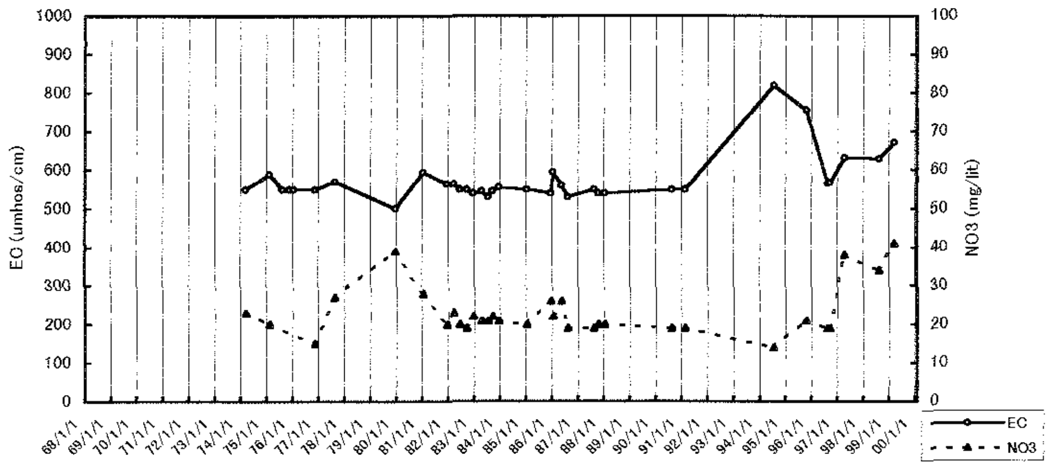


Groundwater Quality Monitoring Records in Yarmouk Basin

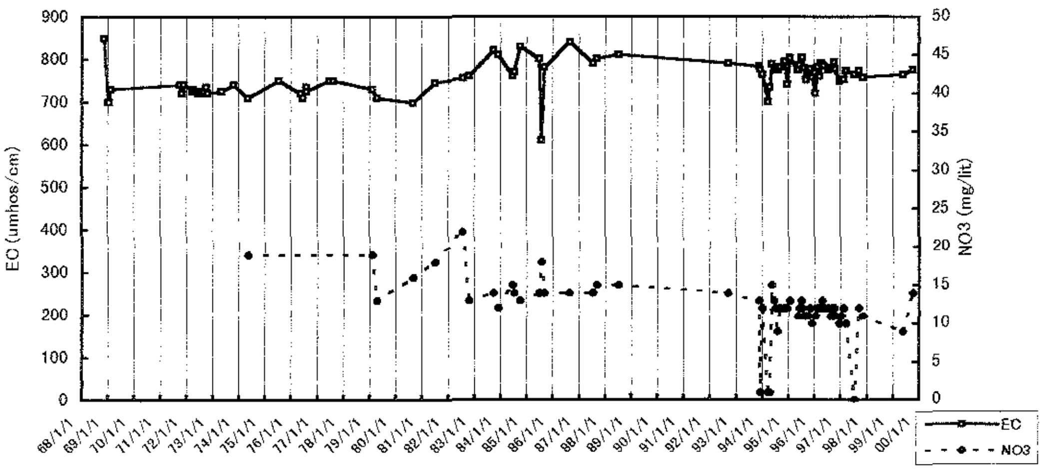
YARMOUK BASIN – AD1290 (B2/A7)



YARMOUK BASIN – AD1219 (B2/A7)

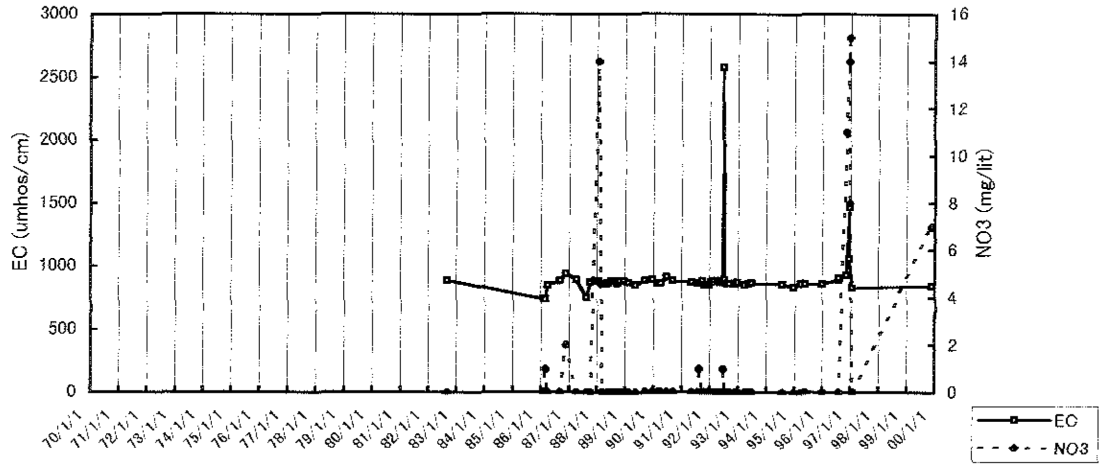


YARMOUK BASIN – AD1050 (B2/A7)

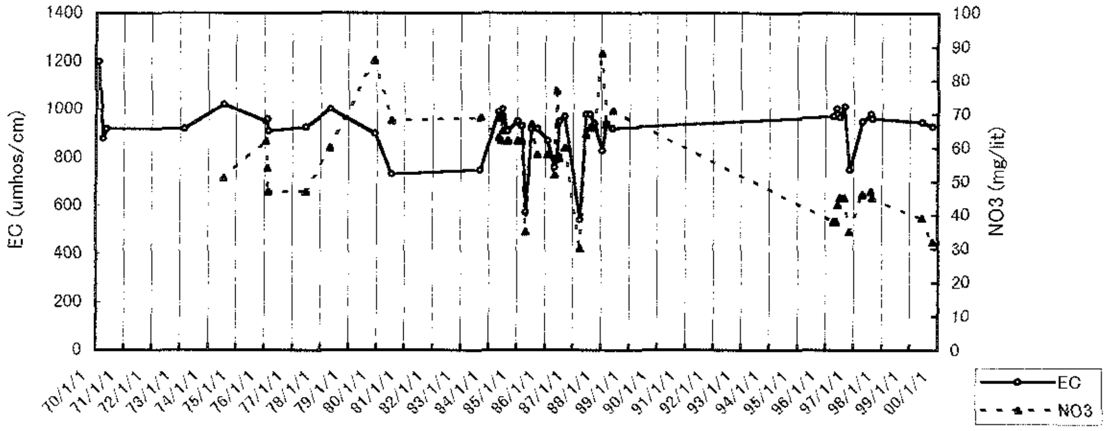


Groundwater Quality Monitoring Records in Rift Side Wadis Basin

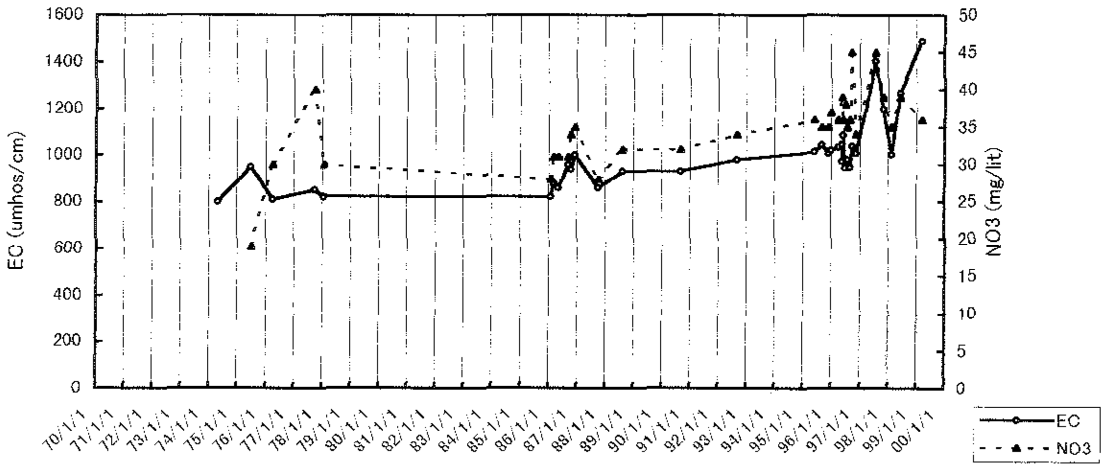
RIFT SIDE WADIS - AE1007 (B2/A7)



RIFT SIDE WADIS - AM1002 (A1/6)

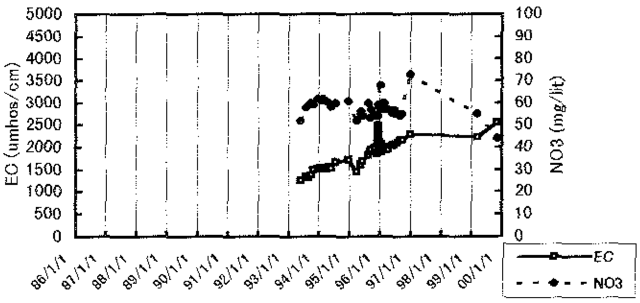


RIFT SIDE WADIS - AM1027 (A1/6)

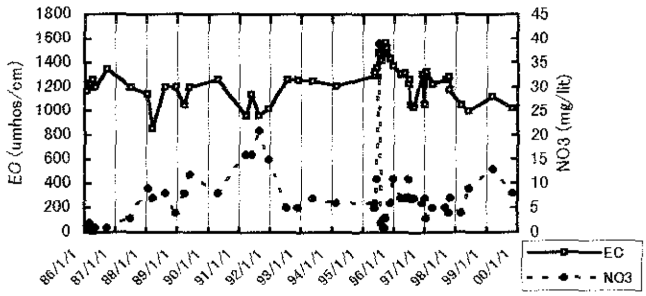


Groundwater Quality Monitoring Records in Jordan Valley Basin

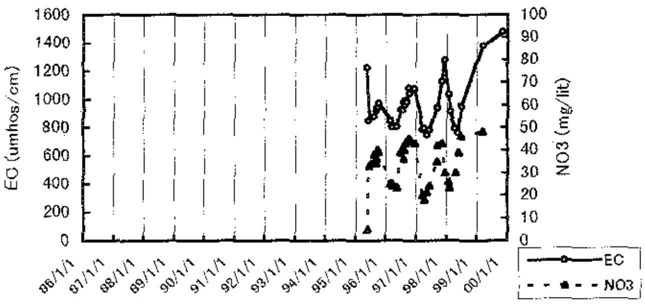
JORDAN VALLEY BASIN - AB1381 (All)



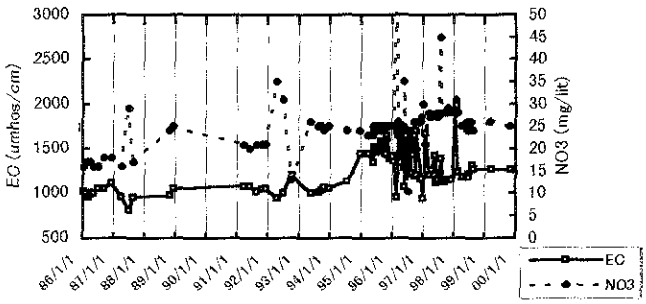
JORDAN VALLEY BASIN - AB1380 (A1/6)



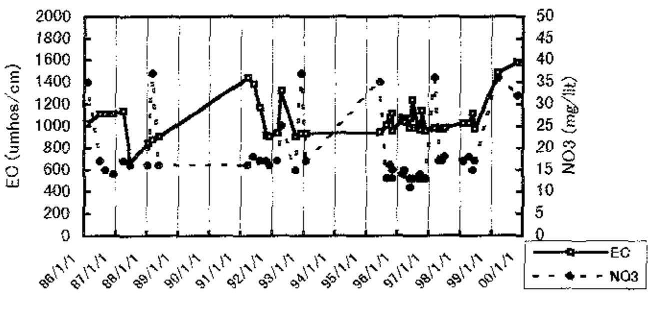
JORDAN VALLEY BASIN - AB1347 (B2/A7)



JORDAN VALLEY BASIN - AB1156 (Kurnob)

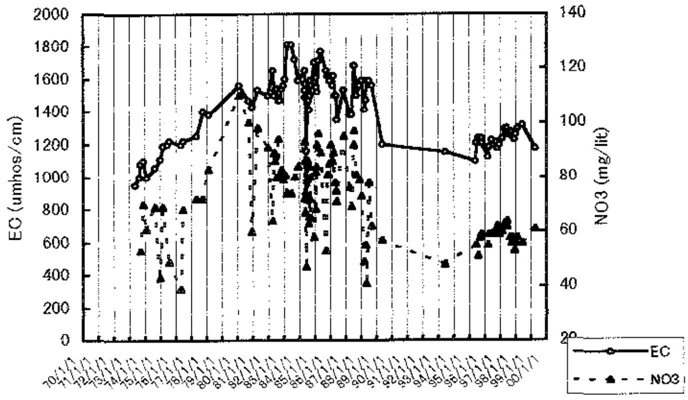


JORDAN VALLEY BASIN - AB1144 (A1/6)

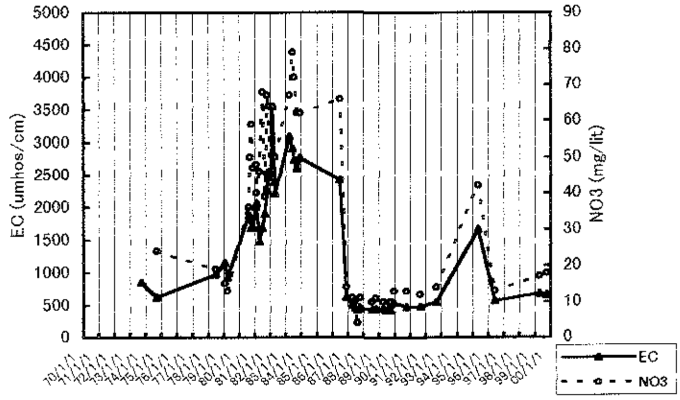


Groundwater Quality Monitoring Records in Amman – Zarqa Basin (1)

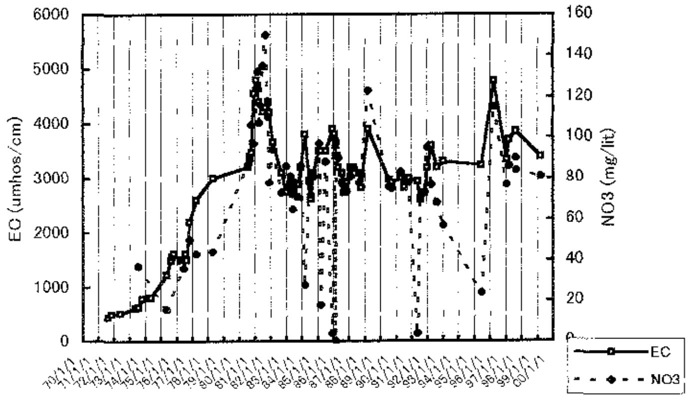
AMMAN-ZARQA – AL1351 (All)



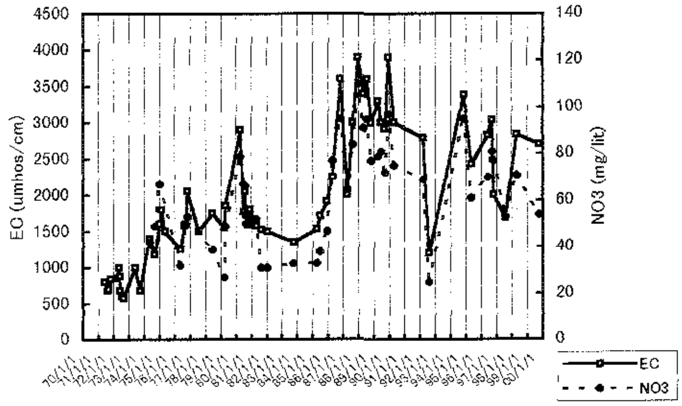
AMMAN-ZARQA – AL1095 (B2/A7)



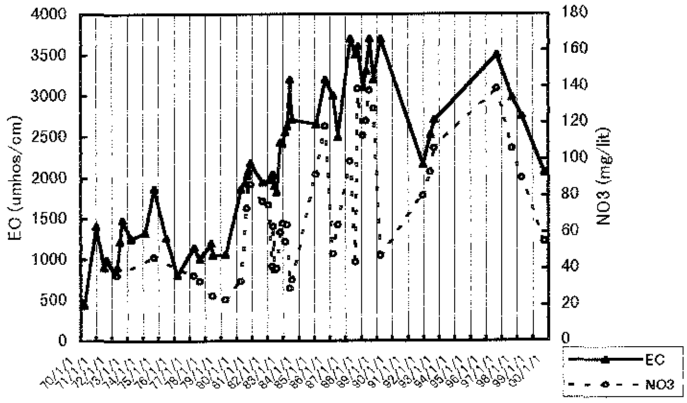
AMMAN-ZARQA – AL1022 (Basalt)



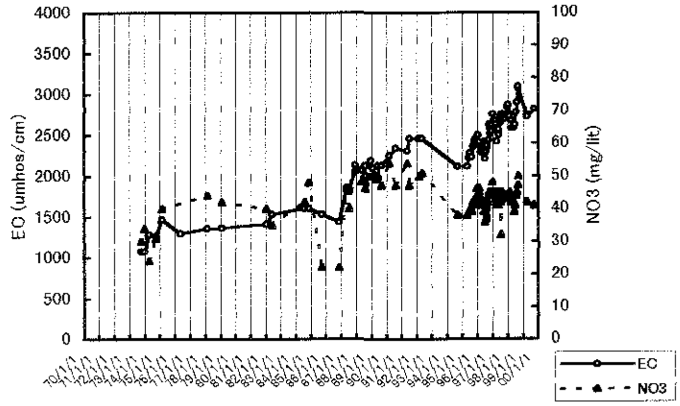
AMMAN-ZARQA – AL1076 (B2/A7)



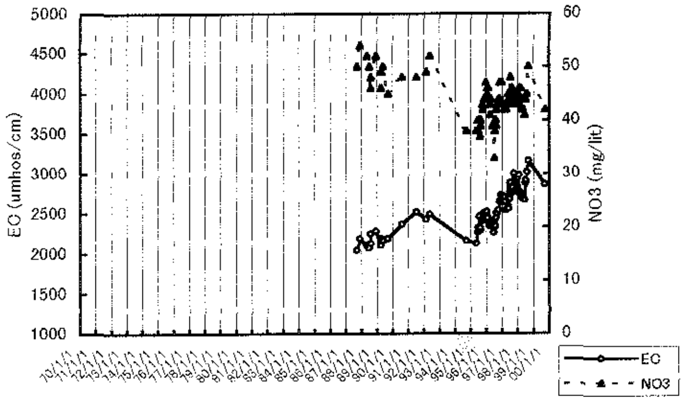
AMMAN-ZARQA – AL1109 (Basalt)



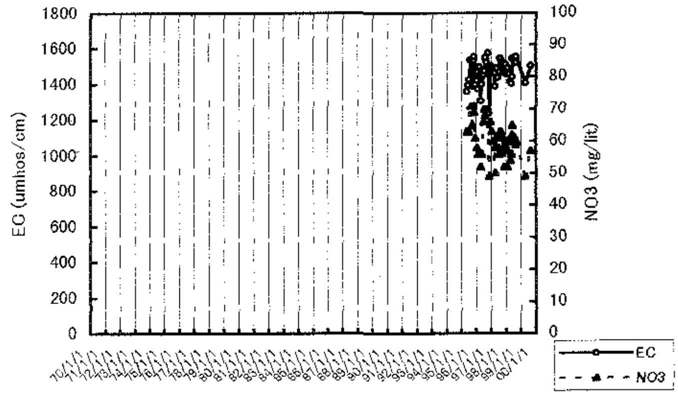
AMMAN-ZARQA – AL1230 (B2/A7)



AMMAN-ZARQA – AL1254 (Basalt)

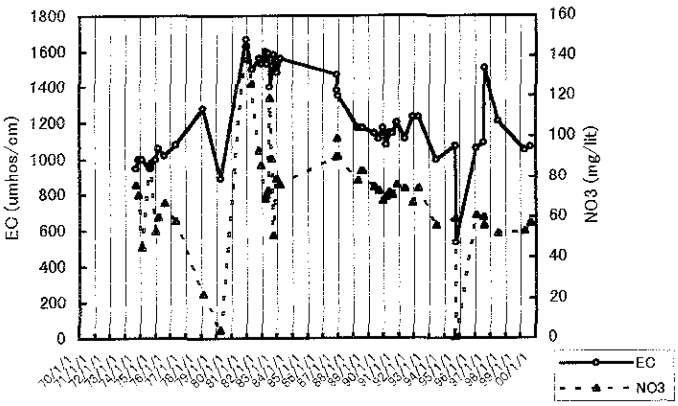


AMMAN-ZARQA – AL2691(B2/A7)

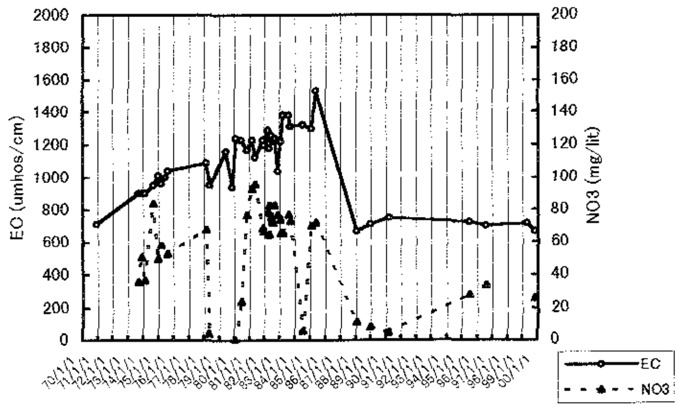


Groundwater Quality Monitoring Records in Amman - Zarqa Basin (2)

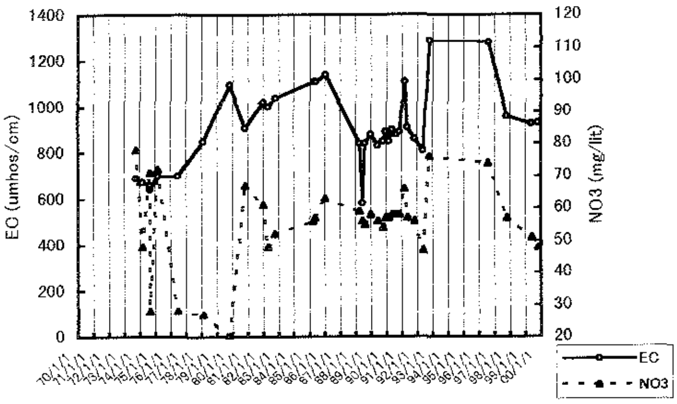
AMMAN-ZARQA - AL1340 (B2/A7)



AMMAN-ZARQA - AL1720 (A1/6)



AMMAN-ZARQA - AL1710 (B2/A7)



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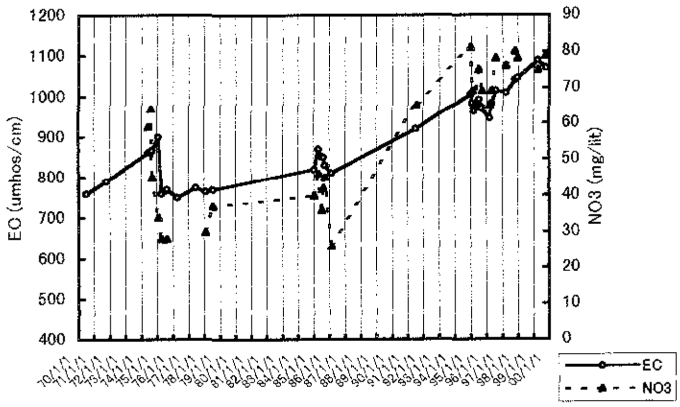

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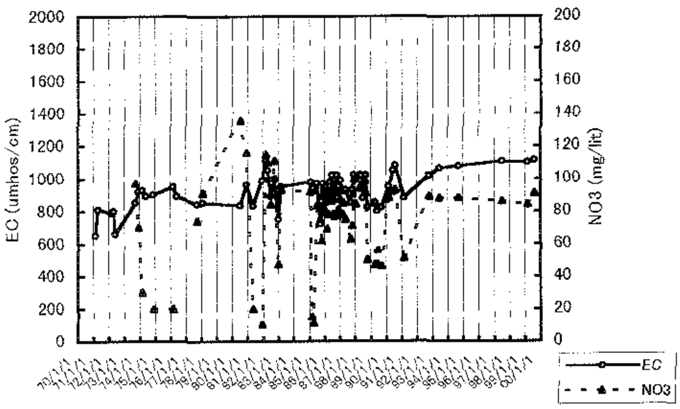

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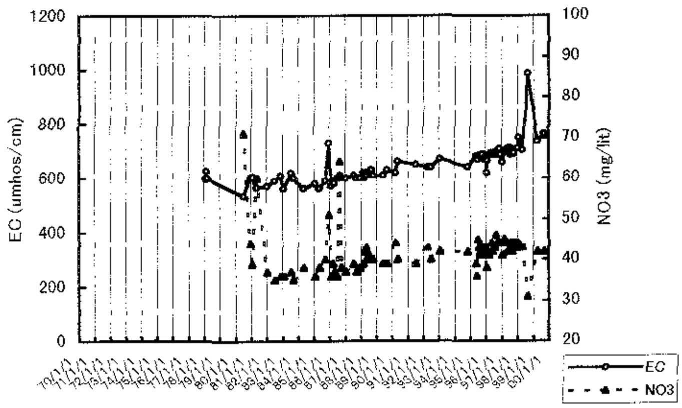
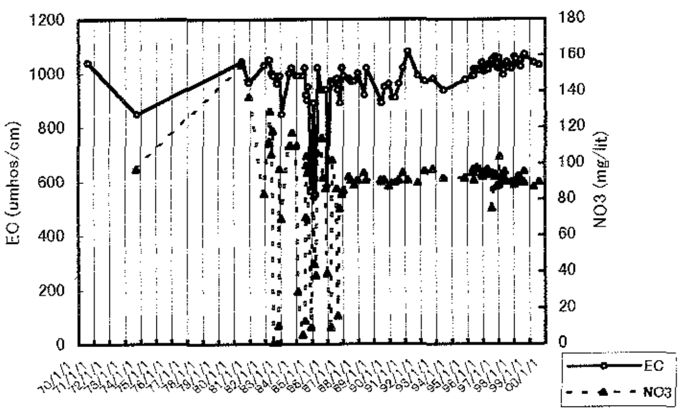
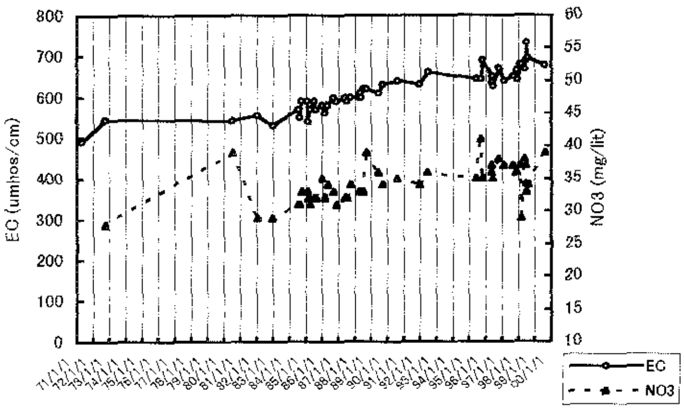


AMMAN-ZARQA - AL1830 (B2/A7)

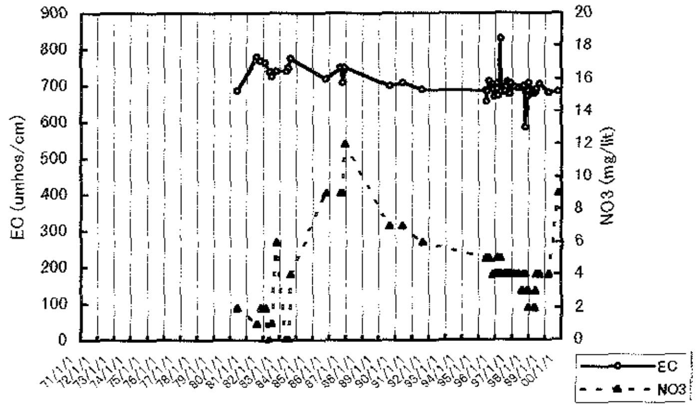


Groundwater Quality Monitoring Records in Amman – Zarqa Basin (3)

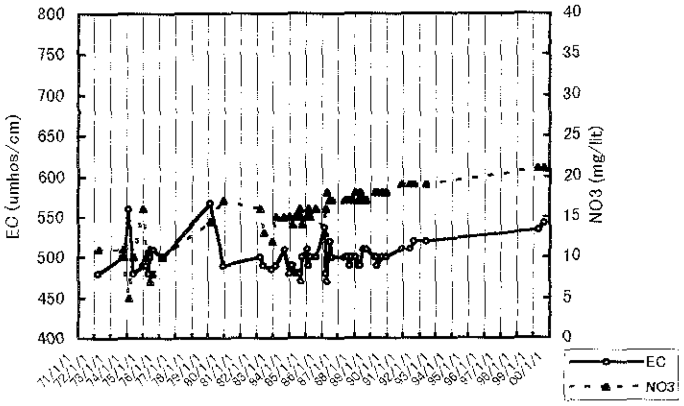
AMMAN-ZARQA - AL1642 (A1/6)



AMMAN-ZARQA - AL1393 (Kurnob)



AMMAN-ZARQA - AL1823 (A1/6)



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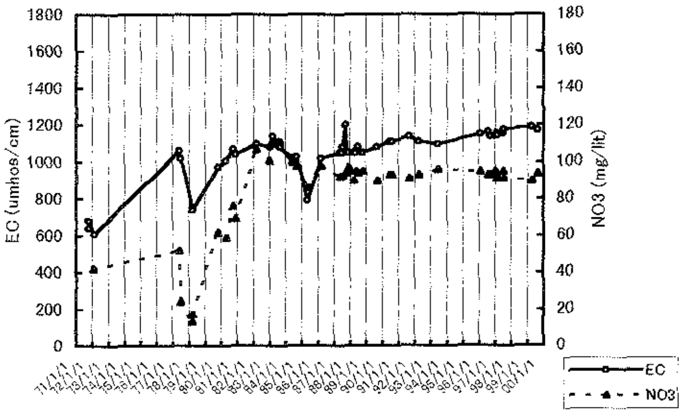
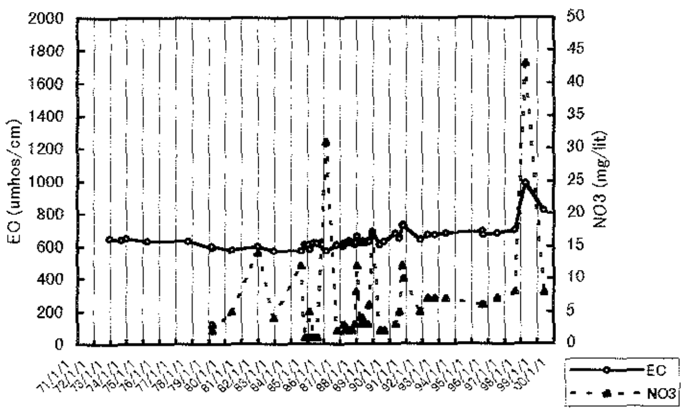
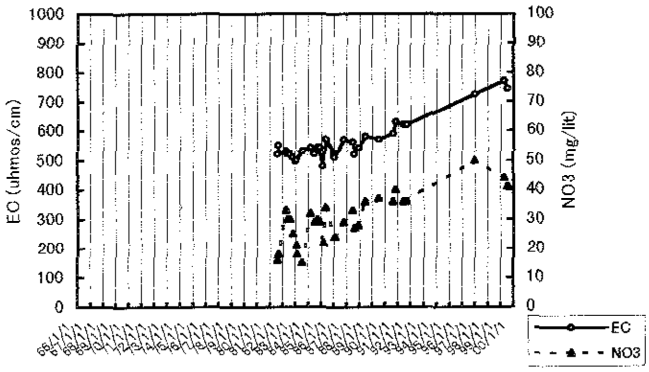


AMMAN-ZARQA - AL1836 (A1/6)

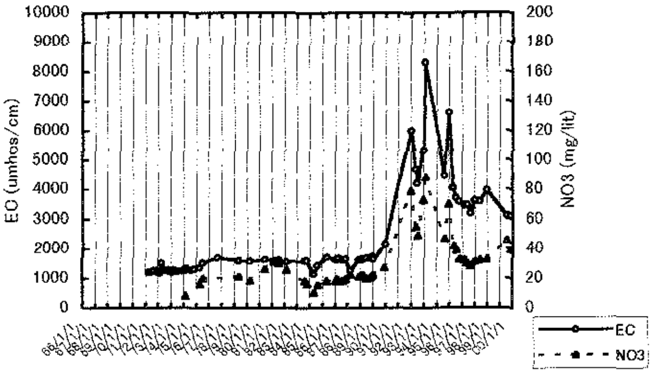


Groundwater Quality Monitoring Records in Dead Sea Basin (1)

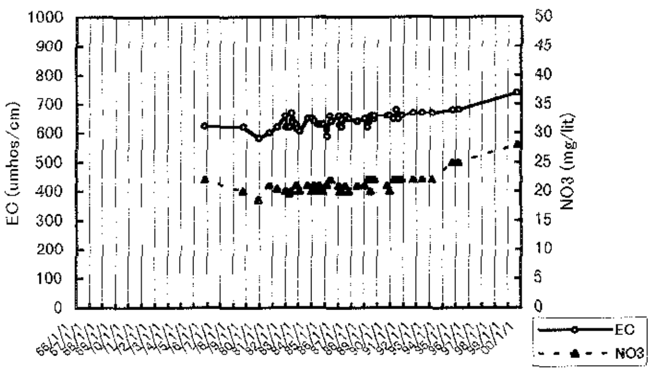
DEAD SEA BASIN - CD1404 (B2/A7)



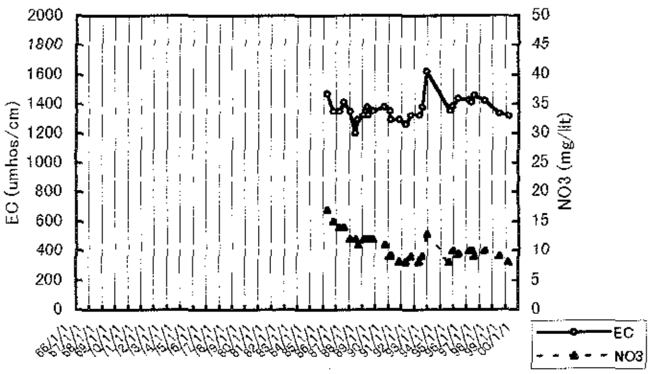
DEAD SEA BASIN - CD1001 (B2/A7)



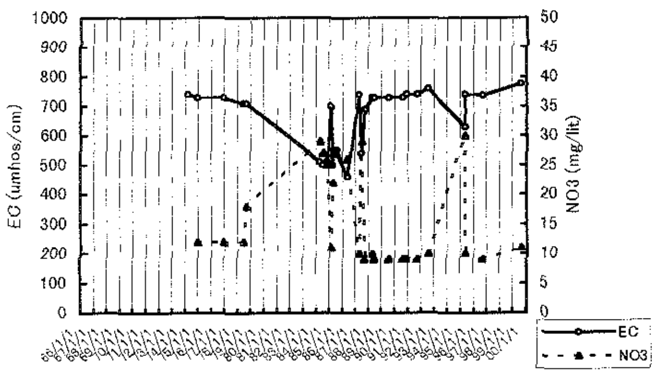
DEAD SEA BASIN - CD1079 (B2/A7)



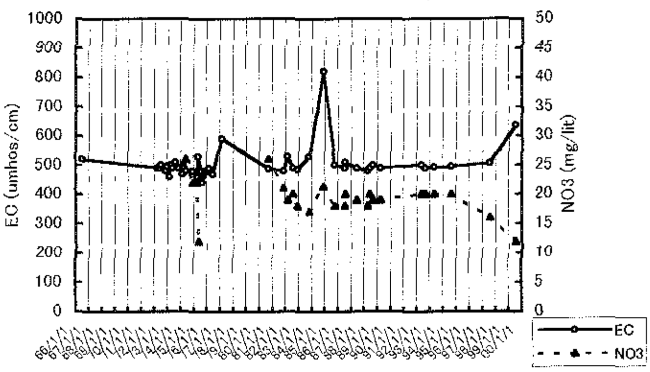
DEAD SEA BASIN - CD1178 (B2/A7)



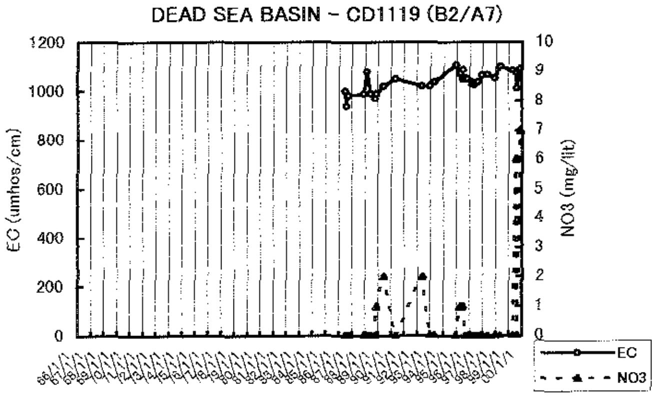
DEAD SEA BASIN - CD1070 (B2/A7)



DEAD SEA BASIN - CF1027 (B2/A7)



DEAD SEA BASIN - CD1119 (B2/A7)



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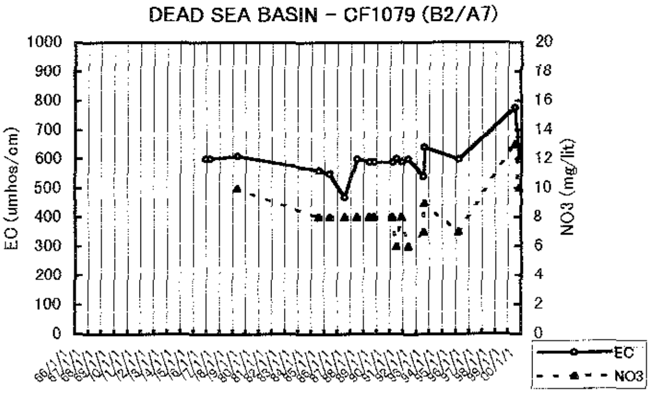
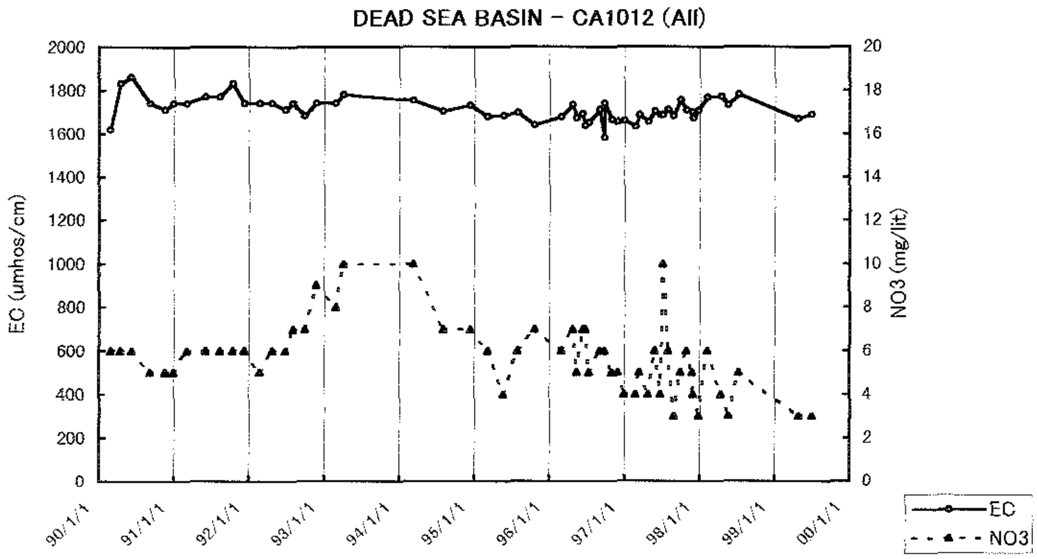
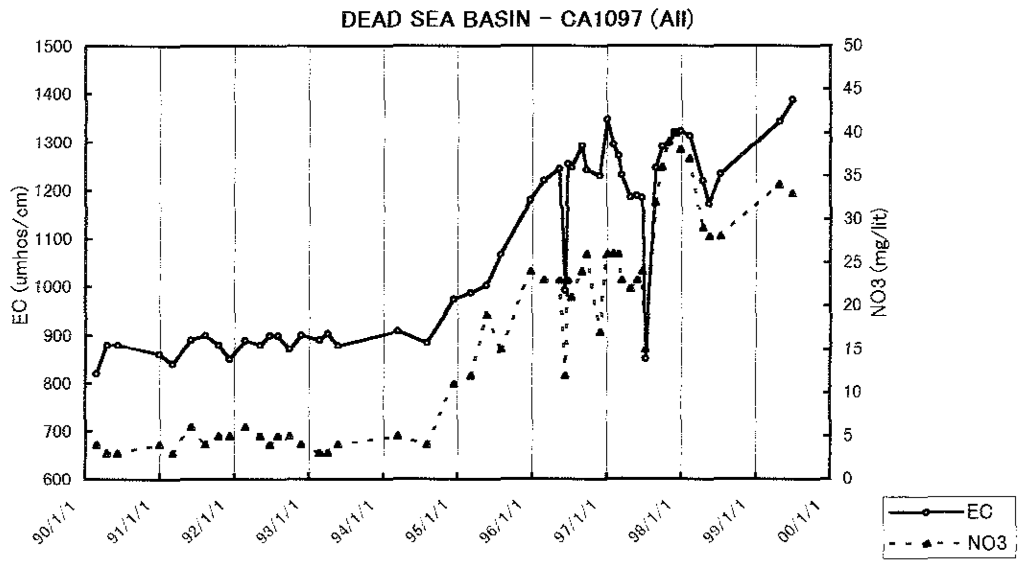


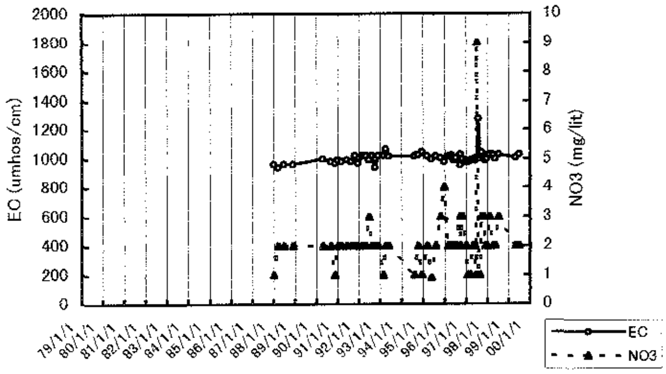
Groundwater Quality Monitoring Records in Dead Sea Basin (2)



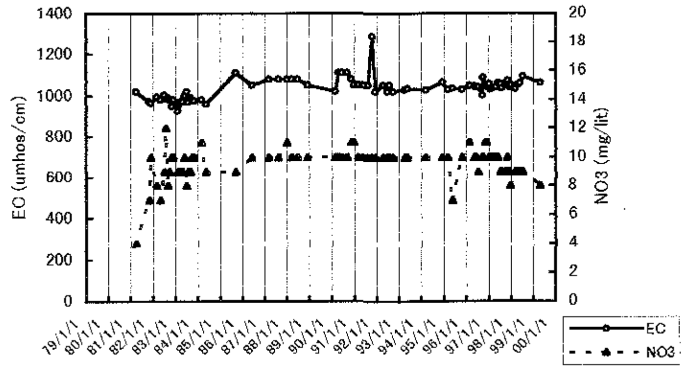


Groundwater Quality Monitoring Records in Wadi Araba Basin

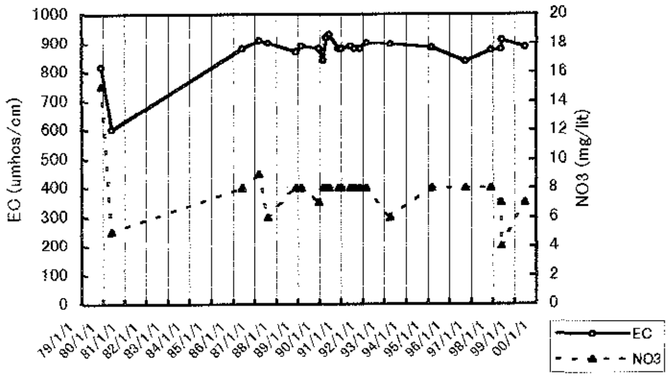
NORTH WADI ARABA BASIN - DA1010 (All)



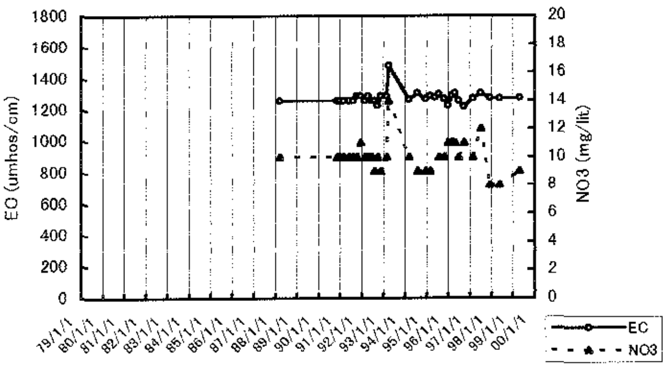
SOUTH WADI ARABA BASIN - EA1004 (All)



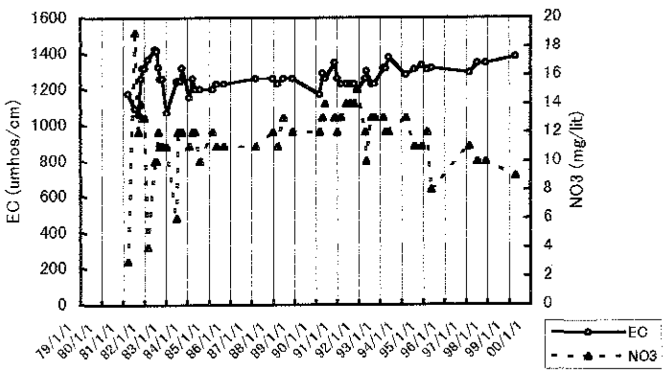
NORTH WADI ARABA BASIN - DE1001 (All)



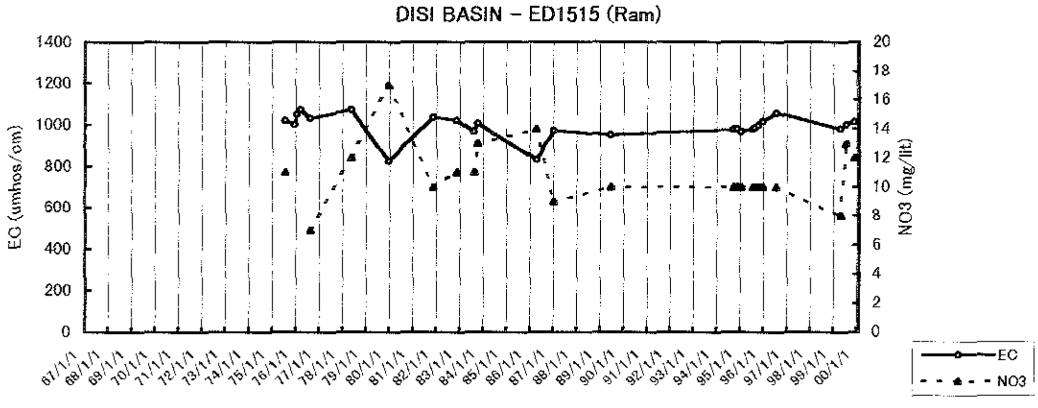
NORTH WADI ARABA BASIN - DF1005 (All)

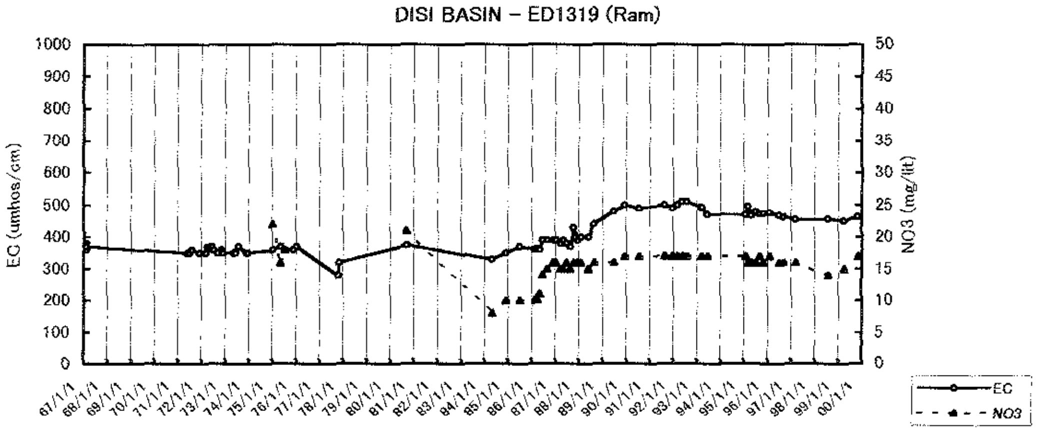


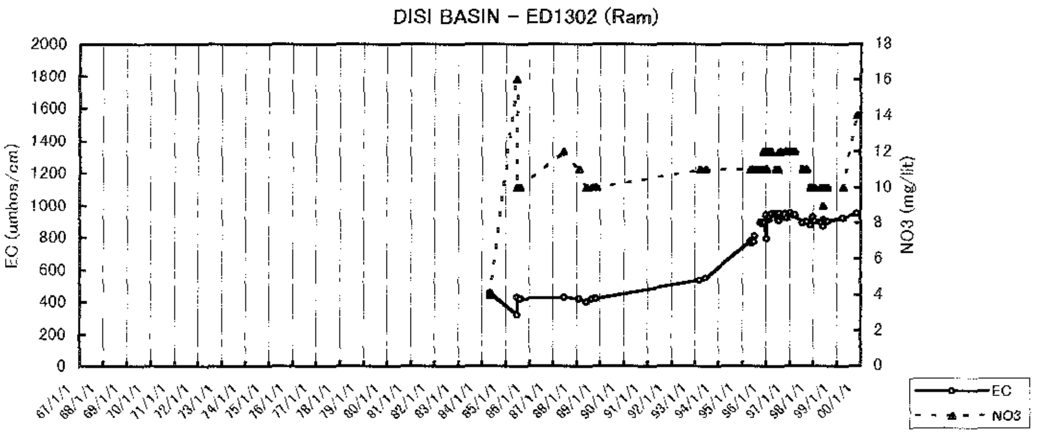
NORTH WADI ARABA BASIN - EA1007 (All)

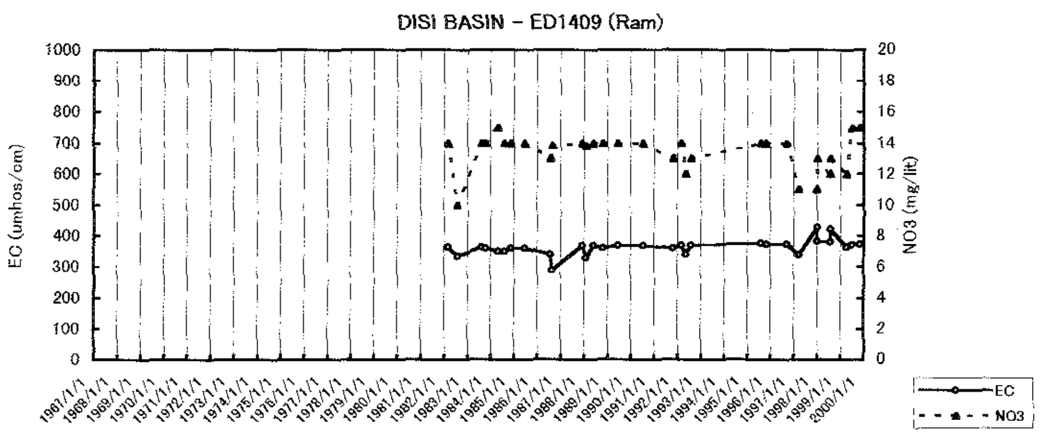


Groundwater Quality Monotoring Records in Disi Basin

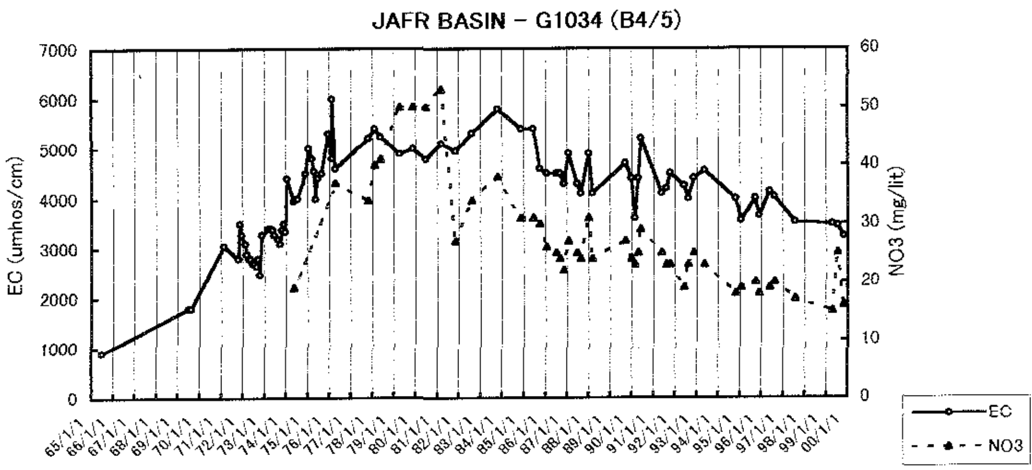


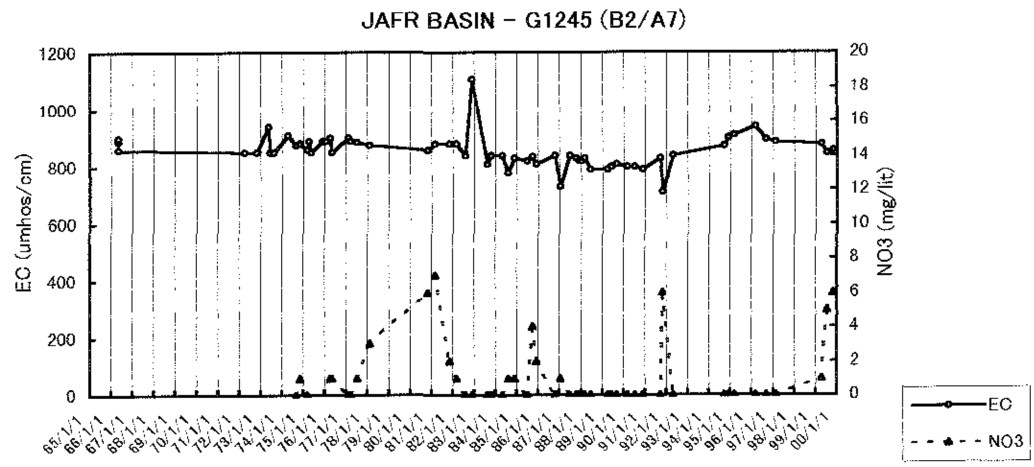




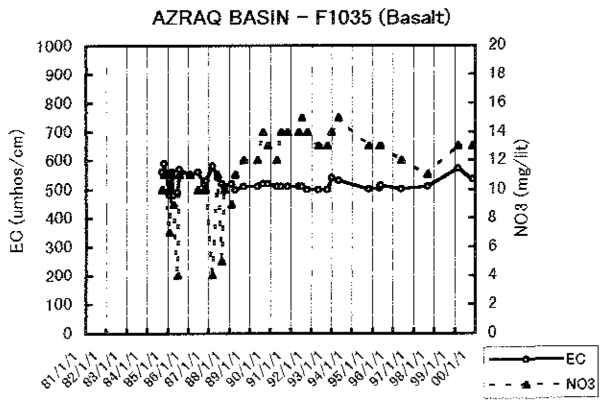


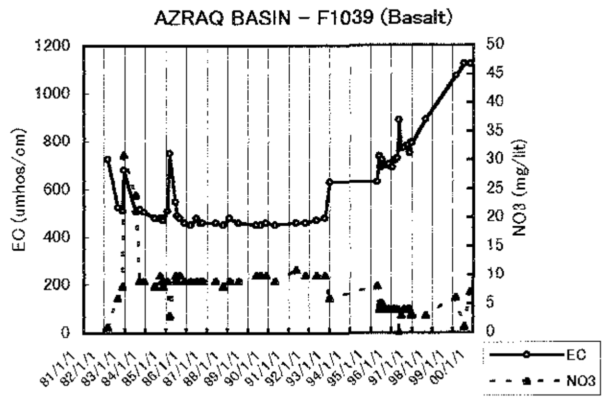
Groundwater Quality Monitoring Records in Jafr Basin

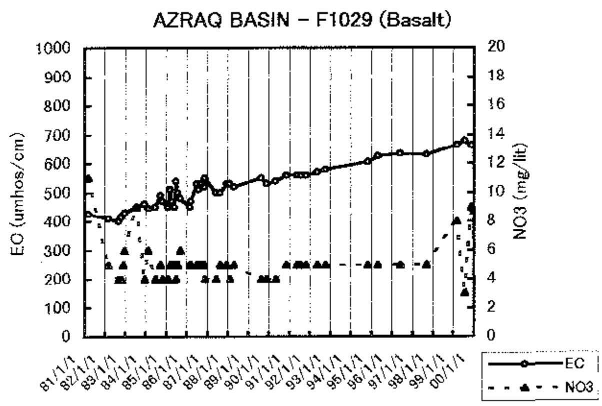


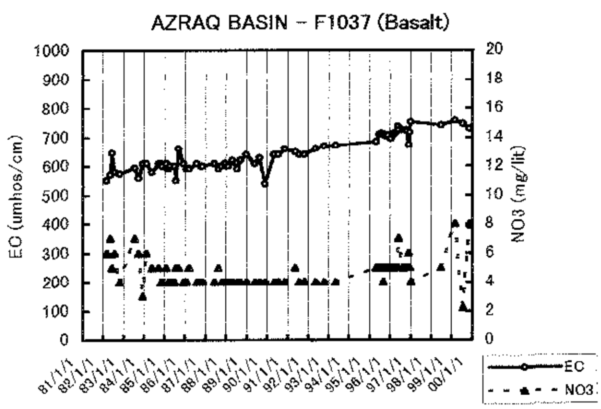


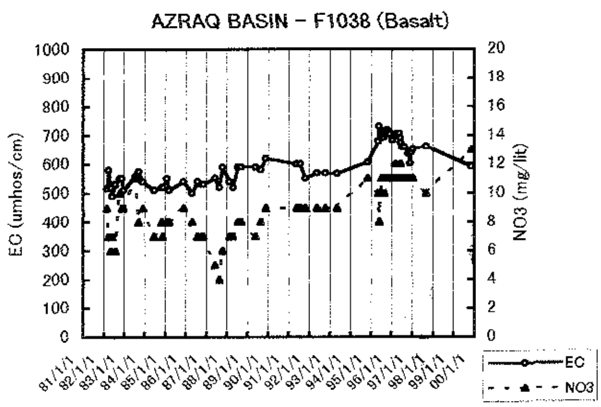
Groundwater Quality Monitoring Records in Azraq Basin











Groundwater Quality Monitoring Records in Hamad Basin