Degradation of groundwater quality in the Güzelyurt basin, Northern Cyprus

Hüseyin Gökçekuş
Department of Civil Engineering, Near East University, Northern Cyprus

Vedat Doyuran
Department of Geological Engineering, Middle East Technical University, Ankara, Turkey

In Northern Cyprus the Güzelyurt groundwater basin constitutes the only aquifer which is presently exploited for irrigation and municipal water supply. In the Güzelyurt basin the groundwater occurs under unconfined conditions within the fanglomerates (Pliocene) and the surficial clastic deposits (Holocene). The Tertiary and pre-Tertiary rocks constitute the impervious and semi-pervious basement and the boundaries of the aquifer.

In arid and semi-arid regions, due to the thirst of vegetation and greater demand for human consumption, more water is withdrawn from the aquifer. Where natural recharge is limited, such excessive withdrawals produce considerable reduction in the aquifer storage, which results in progressive decline of the groundwater levels. In coastal aquifers, such as the Güzelyurt basin, excessive withdrawals do not only cause shortage of water supply but also degradation of water quality.

In the Güzelyurt groundwater basin degradation of groundwater quality occurs as a result of sea water intrusion and bedrock contamination. Excessive withdrawals from the aquifer have caused the groundwater levels to decline well below the mean sea level, which resulted in sea water intrusion extending for a distance of 2 km to 4 km inland from the coast. The lithological units exposed in the northern part of the watershed contain evaporites. These soluble rocks are the main causes of bedrock contamination.

Evaluation of hydrochemical data helped to distinguish the sources and areal distribution of the contaminants throughout the aquifer. The modified double-mass curve approach was particularly effective in delineating historical trends of the sea water intrusion.

Introduction

The Güzelyurt groundwater basin is located within a semi-arid coastal plain of Northern Cyprus. Since 1957 increasing rates of pumpage have caused progressive decline in the groundwater levels, locally reaching to 35-50 m below mean sea level (Gökçekuş and Doyuran, 1993). Limited natural recharge and excessive withdrawals from approximately 650 active municipal and irrigation wells have not only produced considerable reduction in the aquifer storage but also degradation of groundwater quality due to salt water intrusion and bedrock contamination.

In this paper the causes of groundwater degradation are described. A total of eighty water samples were collected from municipal water supply, irrigation and observation wells. Selection of sampling points was based on the degree and nature of contamination of the groundwater. Water sampling stations are concentrated along the coastal zone to determine the extent of the sea water intrusion. For bedrock contamination wells located at the northern part of the groundwater basin, where evaporites are exposed, are considered. The groundwater samples were analyzed for major ions, specific conductance, pH, and total dissolved solids. The results of hydrochemical data are presented in the form of tables, contour maps and water quality diagrams.

Hydrogeology

In the Güzelyurt basin the groundwater occurs under unconfined conditions within the surficial deposits (alluviums, talus, beach deposits, slopewash deposits, and river terrace deposits) and semi-consolidated and poorly cemented fanglomerates. The consolidated rocks of Pre-Tertiary (mostly pillow lavas) and Tertiary (limestone, conglomerate, marl, sandstone, chalk and evaporites) (Gökçekuş and Olgun, 1993) constitute the semi-pervious to impervious basement and the boundary of the aquifer (Fig. 1).

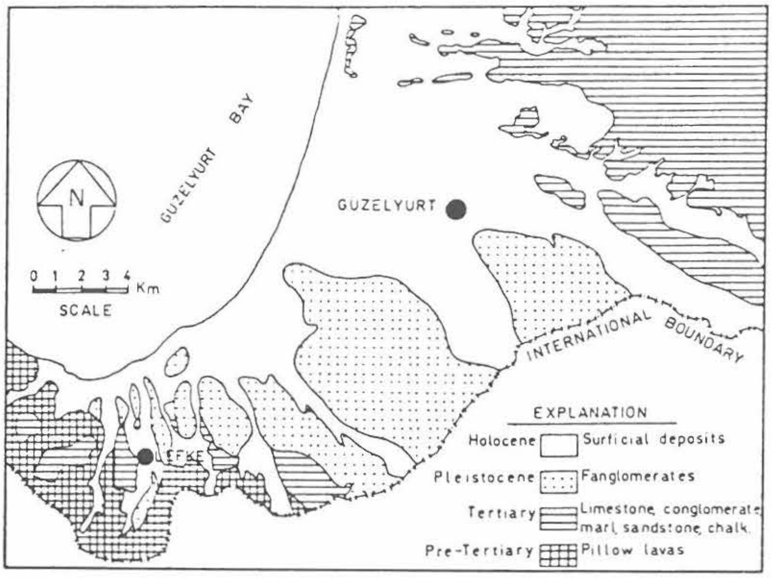

Fig. 1. Simplified geological map of the Güzelyurt groundwater basin

The transmissivities of the surficial deposits range between 250 m^2/day and 1500 m^2/day, whereas the fanglomerates have transmissivities in the range of 10 m^2/day and 250 m^2/day. The thickness of the surficial deposits ranges between 10 m and 120 m. The maximum thickness of the fanglomerates is estimated as 80 m. Only a few wells tap fanglomerates, however, they serve as avenues for subsurface recharge to the alluvial aquifer.

Hydrochemistry

CONTAMINATION DUE TO SEA-WATER INTRUSION: Table 1 depicts the chemical quality of the groundwater collected from selected wells of the Güzelyurt groundwater basin (Gökçekuş and Doyuran, 1995). Based on the salinity classification proposed by Robinove and others (1958) wells with sequence number 1 thru 51 and also including 54-56 show no salinity problem (for the location of wells refer to Fig. 2). Wells with sequence number 52 and 53, as well as 57 thru 71 yield slightly saline water. Those with sequence number 72 thru 77 yield moderately saline water and the rest are highly saline.

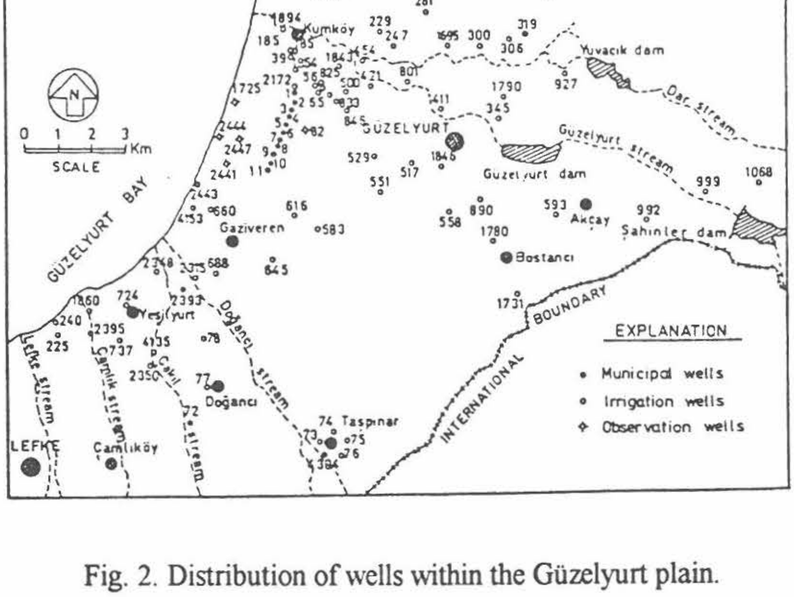

Fig. 2. Distribution of wells within the Güzelyurt plain.

Table 1. Chemical quality of groundwater samples collected from the Güzelyurt groundwater basin (Ir: Irrigation Well; O: Observation Well; M: Municipal Water Supply Well; SW: Sea Water).

Seq. No:	Well No:	Remarks	Cl	SO4	HCO3	CO3	Na	K	Ca	Mg	pH	TDS	SC	%Na	SAR
			Ions as meq/lt									mg/lt	uS/cm		
1	992	Ir	1.40	0.60	2.32	0.40	1.74	0.01	1.76	1.21	8.10	320	520	37.08	1.43
2	74	Ir	1.60	0.98	3.68	0.00	1.70	0.02	2.20	2.34	7.00	440	660	27.48	1.13
3	75	Ir	1.80	2.04	3.36	0.48	2.35	0.03	2.72	2.58	8.30	520	720	30.99	1.44
4	411	Ir	1.80	1.99	4.00	0.00	4.70	0.04	1.84	1.21	7.90	560	860	60.85	3.81
5	1790	Ir	2.00	1.49	2.92	0.56	4.78	0.02	1.20	0.97	8.30	480	670	68.87	4.59
6	345	Ir	2.10	1.36	3.20	0.48	4.70	0.03	1.52	0.89	8.30	500	830	66.25	4.28
7	72	M	2.20	1.14	6.96	0.16	3.83	0.04	2.80	3.79	8.30	750	950	37.00	2.11
8	4	M	2.40	1.59	2.48	0.96	4.17	0.05	1.28	1.93	8.50	490	720	56.80	3.29
9	56	Ir	2.60	1.42	4.16	0.00	4.78	0.03	1.44	1.93	7.50	580	780	58.80	3.68
10	2172	Ir	2.80	0.54	4.24	0.00	4.17	0.04	1.44	1.93	7.90	530	760	55.54	3.21
11	2395	M	2.80	6.34	5.36	1.76	3.26	0.05	3.20	9.75	8.30	1040	1730	20.36	1.28
12	737	Ir	3.00	3.21	6.72	0.96	2.52	0.11	2.96	8.30	8.50	920	1220	18.93	1.06
13	240	Ir	3.00	4.65	6.08	0.00	3.39	0.05	3.84	6.45	7.70	940	1170	25.05	1.49
14	4135	Ir	3.00	1.64	4.72	0.32	3.22	0.03	2.32	4.11	8.30	650	910	33.57	1.80
15	2	M	3.00	0.32	4.08	0.32	3.91	0.03	1.60	2.18	8.30	530	1010	51.04	2.84
16	225	Ir	3.20	3.30	5.60	0.80	3.83	0.06	2.40	6.61	8.30	860	1320	30.16	1.80
17	834	Ir	3.20	0.91	3.92	0.00	4.70	0.03	1.20	2.10	7.90	560	830	58.90	3.66
18	593	Ir	3.40	0.72	4.40	0.48	6.87	0.04	0.96	1.13	8.20	630	830	76.78	6.72
19	1854	Ir	3.40	2.40	3.44	0.00	3.65	0.04	0.96	4.59	7.50	610	910	39.94	2.19
20	801	Ir	3.40	3.02	4.56	0.00	6.00	0.09	2.00	0.89	8.10	780	990	73.68	6.66
21	999	Ir	3.50	2.15	3.60	0.00	3.04	0.03	3.68	2.50	8.00	620	870	33.19	1.73
22	558	Ir	3.50	0.49	2.96	0.00	4.26	0.04	1.36	1.29	8.10	470	720	61.87	3.70
23	1846	Ir	3.60	1.68	3.04	0.16	4.96	0.06	1.28	2.18	8.30	570	810	59.20	3.77
24	1856	Ir	3.60	1.83	3.52	0.00	2.74	0.03	3.20	2.98	7.50	590	960	30.95	1.56
25	78	Ir	3.60	0.64	5.52	0.00	5.48	0.07	1.23	2.98	8.10	680	1030	56.86	3.78
26	583	Ir	4.00	0.08	3.60	0.00	4.43	0.04	1.44	1.77	8.10	520	940	58.20	3.50
27	65	Ir	4.00	0.96	3.68	0.48	4.52	0.03	2.64	1.93	8.30	610	1110	49.89	2.99
28	1068	Ir	4.00	2.16	4.32	0.00	4.26	0.04	3.68	2.50	8.00	710	970	41.03	2.42
29	2350	Ir	4.20	1.29	4.48	0.32	3.65	0.04	1.60	5.00	8.50	670	1010	35.86	2.01
30	77	Ir	4.60	1.62	5.20	0.48	6.70	0.06	1.84	3.30	8.50	810	1160	56.81	4.18
31	4153	Ir	4.60	2.85	0.64	0.00	1.98	0.25	3.20	2.66	6.80	490	1020	27.56	1.16
32	832	Ir	4.80	0.96	5.28	0.00	5.87	0.03	2.96	2.18	6.90	760	1530	53.44	3.66
33	645	Ir	5.20	0.98	3.04	0.48	6.52	0.05	1.84	1.29	8.30	640	1020	67.73	5.21
34	39	Ir	5.20	3.11	4.56	0.00	4.96	0.04	3.68	4.19	8.10	850	1210	38.85	2.50
35	1731	Ir	5.40	1.29	3.76	0.00	8.70	0.06	0.76	0.93	8.00	710	1010	83.83	9.46
36	833	Ir	5.40	0.74	3.68	0.48	5.04	0.04	2.80	2.42	8.30	670	1090	49.32	3.12
37	9	M	5.40	0.98	3.36	0.80	6.09	0.03	2.08	2.34	8.30	680	1320	58.06	4.10
38	616	Ir	560	0.55	2.96	0.64	6.17	0.04	1.36	2.18	8.50	620	1010	63.69	4.64
39	517	Ir	5.80	0.78	3.20	0.00	7.39	0.07	1.76	0.56	8.00	650	910	76.28	6.86
40	890	Ir	6.00	0.45	3.92	0.48	8.48	0.04	1.00	1.33	8.20	780	1010	78.53	7.86
41	1780	Ir	6.00	0.80	3.76	0.48	8.70	0.05	1.16	1.13	8.20	730	1090	79.26	8.13
42	825	Ir	6.20	1.06	3.76	0.00	4.17	0.03	3.60	3.22	7.70	710	1170	38.11	2.26
43	824	Ir	6.20	1.32	3.76	0.00	4.17	0.04	3.44	3.63	7.50	720	1140	37.32	2.22
44	76	Ir	6.40	2.73	3.84	0.64	6.96	0.06	2.48	4.11	8.30	870	1320	51.58	3.83
45	724	Ir	6.60	2.01	7.60	0.00	3.70	0.05	4.48	7.98	7.50	650	1730	23.13	1.48
46	551	Ir	7.00	0.48	2.40	0.48	6.30	0.05	1.76	1.77	8.30	610	1120	64.27	4.74
47	73	Ir	7.00	2.22	3.92	0.64	5.87	0.03	3.04	4.84	8.20	870	1470	42.82	2.96
48	846	Ir	7.20	0.57	2.80	0.48	4.52	0.03	3.60	2.90	8.10	680	1260	41.18	2.51
49	4304	M	8.00	2.06	4.48	0.32	8.70	0.05	2.40	3.71	8.30	960	1450	58.88	4.98
50	660	Ir	8.00	2.77	3.60	0.00	6.52	0.06	3.84	3.95	8.00	910	1400	45.79	3.30
51	82	O	8.20	0.31	5.60	0.00	5.22	0.06	4.56	4.27	7.50	910	1690	37.42	2.48
52	529	Ir	8.20	3.72	3.84	0.00	9.91	0.06	1.76	4.03	7.50	1020	1500	63.26	5.82
53	823	Ir	8.60	4.07	3.68	0.00	4.35	0.02	4.48	7.50	7.60	1010	1240	26.73	1.78
54	11	M	10.20	0.40	3.68	0.64	8.69	0.04	2.56	3.63	8.20	920	1600	58.51	4.94
55	454	Ir	10.80	0.81	3.12	0.00	4.25	0.04	6.32	4.11	7.10	890	1690	29.19	1.87
56	229	Ir	12.20	0.75	3.04	0.00	7.83	0.05	4.56	3.55	7.10	970	1480	49.28	3.89
57	927	Ir	13.20	8.14	5.20	0.00	10.43	0.07	10.00	6.04	7.80	1690	2330	39.56	3.68
58	247	Ir	14.00	3.25	4.32	0.00	6.30	0.04	9.20	6.04	7.30	1320	2160	29.38	2.28
59	281	Ir	14.80	3.83	4.16	0.00	8.25	0.09	9.00	5.44	7.30	1400	2380	36.64	3.07
60	1763	Ir	15.60	4.26	5.60	0.32	21.30	0.26	1.36	2.86	8.20	1670	2480	83.63	14.66
61	319	Ir	16.00	7.51	4.80	0.00	15.00	0.26	6.00	7.05	7.60	1780	2530	53.90	5.87
62	1655	Ir	16.80	0.86	3.04	0.64	5.44	0.05	10.00	5.85	8.10	1240	2390	25.73	1.93
63	300	Ir	18.40	6.13	3.52	0.00	16.74	0.26	4.80	6.25	7.30	1730	2790	60.61	7.12
64	1894	Ir	18.80	1.48	2.40	0.00	6.78	0.04	7.80	8.06	7.50	1300	2330	30.07	2.41
65	500	Ir	20.40	1.50	2.80	0.00	4.78	0.05	11.00	8.87	8.00	1410	2380	19.55	1.52
66	1823	Ir	21.60	2.74	4.80	0.00	13.91	0.18	8.80	6.75	7.30	1770	2110	47.54	4.99
67	330	Ir	22.00	7.05	4.00	0.00	12.61	0.56	9.20	10.68	7.70	1990	2950	39.85	4.00
68	306	Ir	26.00	3.71	5.28	0.00	22.61	0.15	8.40	3.83	7.30	2160	3620	65.05	9.14
69	1848	Ir	33.60	8.22	4.64	0.00	15.00	0.16	17.40	13.90	6.90	2740	5060	32.63	3.79
70	7	M	41.60	3.84	3.04	0.00	16.09	0.06	15.00	17.33	7.60	2730	4240	33.31	4.00
71	471	Ir	48.80	4.72	2.72	0.00	10.43	0.08	27.40	18.33	7.50	2940	5060	18.59	2.18
72	1860	Ir	48.80	2.10	3.04	0.96	20.43	0.08	9.00	25.39	8.30	3010	5160	37.36	4.93
73	2348	Ir	50.00	1.79	2.88	0.00	10.87	0.05	23.60	20.15	8.00	3000	5590	19.97	2.32
74	1843	Ir	67.00	3.88	2.90	0.00	13.04	0.07	38.00	22.57	8.00	4070	6320	17.79	2.37
75	688	Ir	73.00	5.67	2.40	0.00	14.78	0.07	36.00	30.00	7.70	4440	7100	18.37	2.57
76	2315	Ir	79.00	4.54	3.20	0.00	19.57	0.08	42.00	25.19	7.70	4820	7610	22.63	3.38
77	2441	O	110.00	2.90	0.72	0.00	56.52	0.85	22.00	34.25	7.50	6280	9660	50.49	10.66
78	2447	O	200.00	4.32	2.00	0.00	69.57	0.19	60.00	76.56	7.20	11170	16270	33.81	8.42
79	2444	O	400.00	55.61	0.88	0.00	313.04	2.95	72.00	68.50	7.00	26510	28480	69.22	37.35
80	1725	O	400.00	34.54	5.84	0.00	339.13	0.69	24.00	76.56	7.50	25450	30510	77.17	47.83
81	SEA W	SW	640.00	73.09	2.08	1.28	547.83	11.67	28.00	128.95	8.40	41580	43000	78.09	61.84

Areal distribution of saline water throughout the aquifer may be seen from the isochloride contour map (Fig. 3). Here the chloride concentrations expressed in mg/l provide invaluable clues about the extent of salt water intrusion into the aquifer. High chloride concentrations are observed along the coastal strip of approximately 2 km wide. Around Kumköy, due to overdrafts from irrigation well field the isochloride contours extend considerably inland from the shore line. Similar anomaly may be observed between Yeşilyurt and Gaziveren. Here, the shape of the isochloride contours suggest upconing phenomenon resulting from overpumping of the irrigation wells.

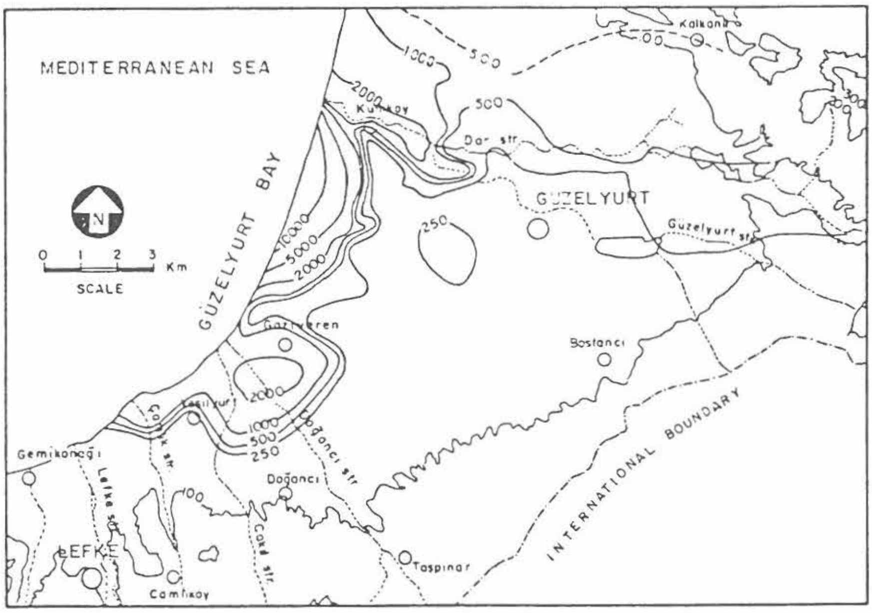

Fig. 3. Isochloride contour map.

An attempt is made to group the wells according the their degree of contamination. The major ion given in Table 1 are entered to the trilinear diagram (Fig. 4). From the figure four distinct groups may be distinguished. The wells represented by solid triangles form Group A, which are located close to the shore line. They are characterized by high suphate and chloride (80%-100%) concentrations. Group B wells (squares) are mostly located between Kumköy and Yuvacık dam. In these wells moderately high sulphate and chloride (50%-80%) concentrations are noted. Group C wells (circle and triangle) are mostly located around Yeşilyurt. In these wells chloride concentrations range between 15% and 45%, and they are characterized by bicarbonate and carbonate type water. Group D wells (circles) are mostly located at the central and western part of the groundwater basin. They are characterized by variable chloride concentrations and high bicarbonate and carbonate ions.

A number of researchers (Chapelle, 1983; Mercado, 1985; and Şen and Al-Dakheel, 1986) attempted one-to-one correlation between anions and cations to establish the hydrochemical pattern of the groundwater. Relationships between chloride and selected ions are given in Fig. 5. Here Na^+/Cl^- molar ration of 0.95, as suggested by Richter and Kreitner (1987), is also indicated. This ratio increases in fresh water and decreases in saline water. From Fig. 5 it is clearly seen that almost all wells of Groups A and B lie below molar ratio of 0.95.

The double-mass curve is used to check the consistency of hydrological data by comparing data for a single station with that of a pattern composed of the data from several other stations in the area (Searcy and Hardison, 1960). This technique is adopted to the study area to explain the historical trends of the sea water intrusion.

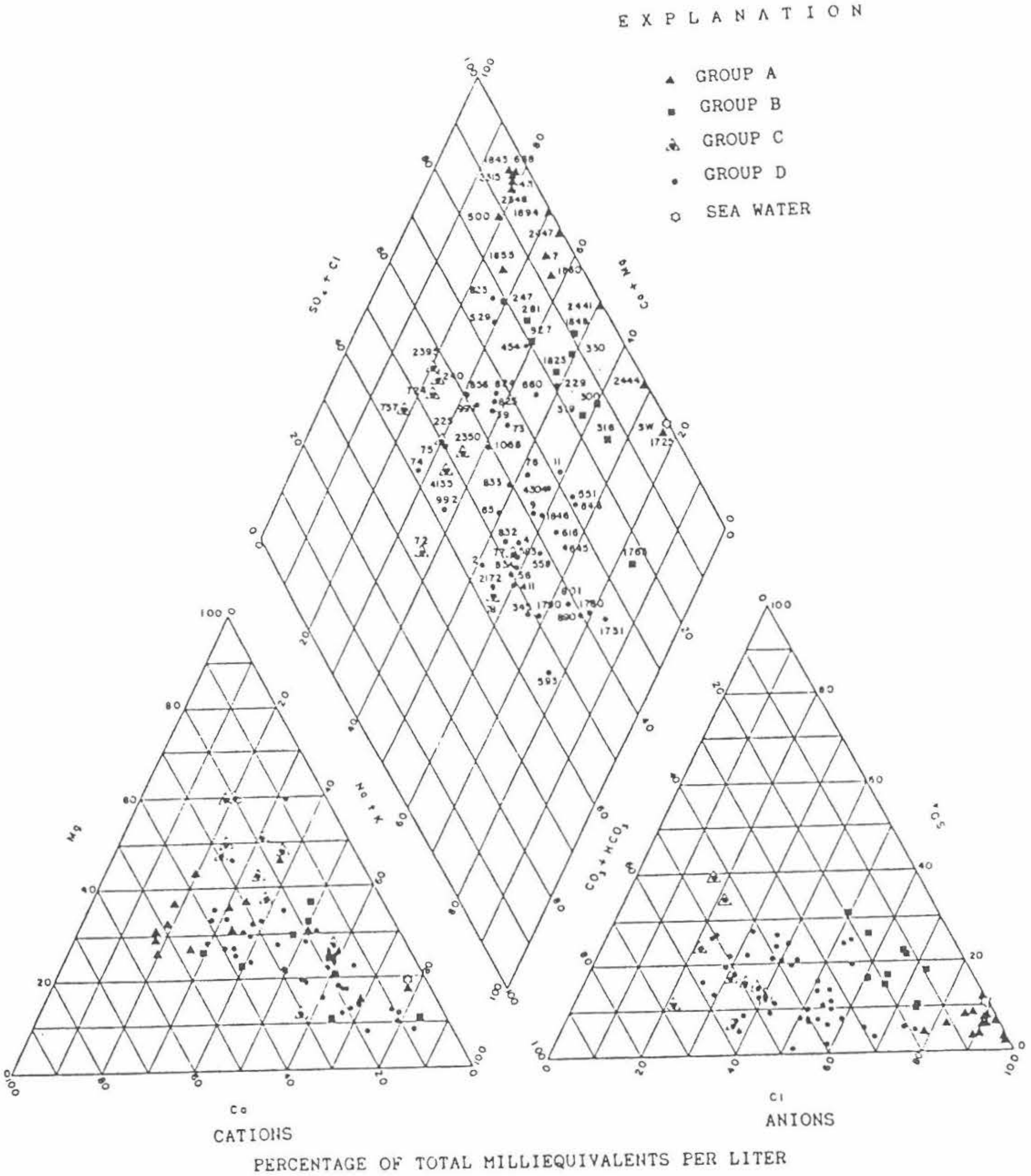

Fig. 4. Trilinear diagram for the group of wells.

The wells affected from sea water contamination (2444, 688, 2447, and 1725) were selected as single stations and twenty wells with constant chloride concentrations, which are located in the central part of the basin, were taken as pattern. Average annual and cumulative chloride values were calculated for the period 1977 thru 1987. For the double-mass curve the cumulative chloride values of each selected well are plotted against cumulative chloride values of the pattern (Fig. 6). The slope of the line represents constant of proportionality between the quantities. The breaks in the slope of the double-mass curve mean that a change in the constant of proportionality between the two variables has occurred. The chloride concentration of the contaminated wells show significant variations with time. Fig. 6 suggests that depending upon the distance from the shore line each well reflects historical fingerprints of the salt water intrusion.

BEDROCK CONTAMINATION: The chemical composition of the groundwater is controlled by the lithology of the catchment area and of the aquifer . In the Güzelyurt groundwater basin major source of recharge is through infiltration of precipitation. During this process some of the soluble minerals are leached from the bedrock and introduced to the groundwater reservoir.

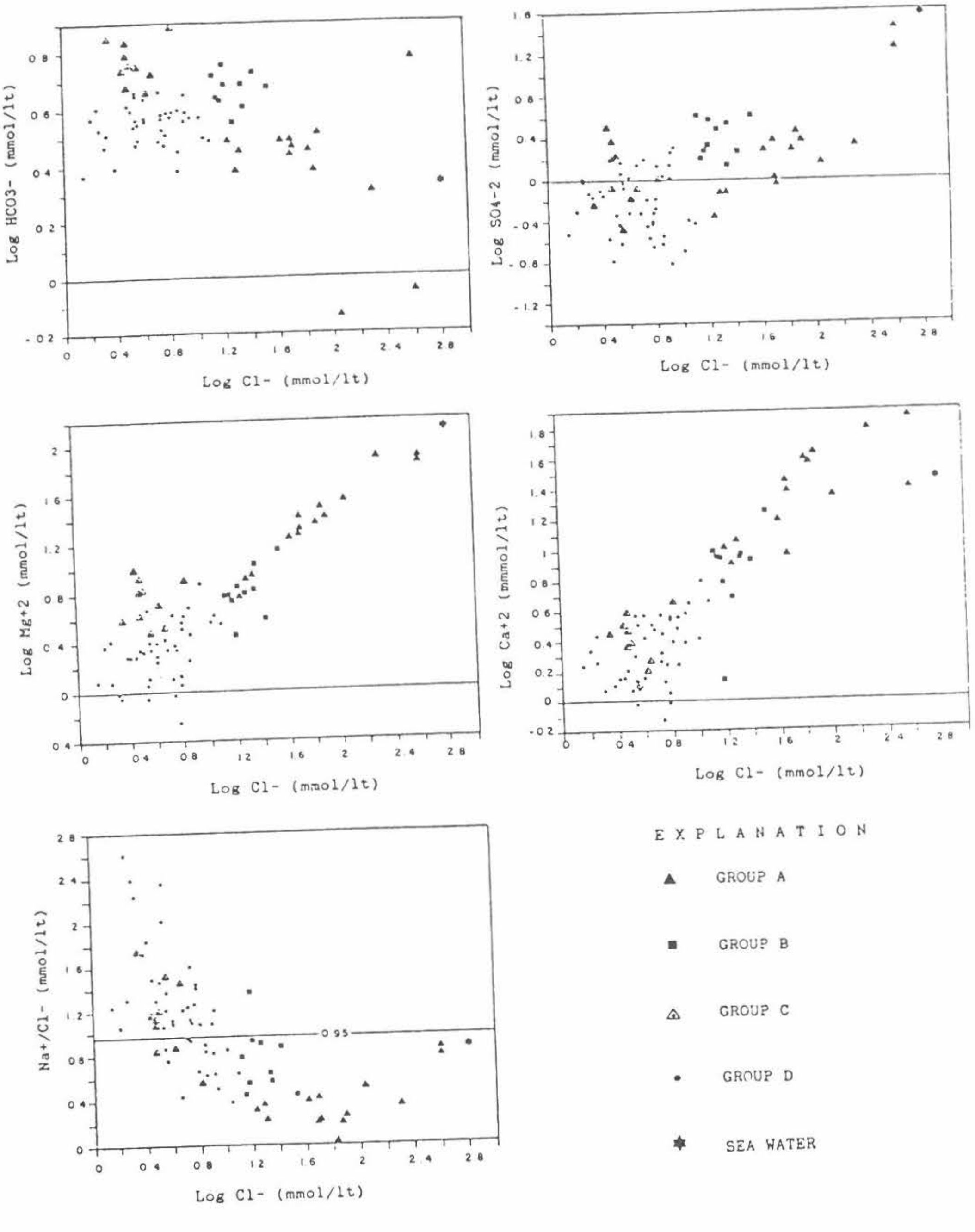

Fig. 5. Relationship between Cl^- and selected ions

Different types of soluble rocks are exposed in the groundwater basin and its watershed. Carbonate and evaporite containing Tertiary rocks crop out at the northern and eastern part of the basin. The fanglomerates (Pliocene) contain carbonate cement and caliche deposits. In order to assess the influence of bedrock contamination the saturation index of certain minerals are evaluated using the computer program WATEQB (Arıkan, 1988). The saturation index (SI) is widely used by a number of researchers, such as Langmuir (1971), Chapelle (1983) and Lee (1985). Langmuir (1971) stated that the sample is saturated if SI falls within the range of -0.1 and 0.1. Lee (1985) classified the SI values as follows: For $SI>0.1$, the specific mineral is oversaturated and precipitation is possible; for $SI=\pm0.1$, the specific mineral is saturated and precipitation or dissolution is possible; for $SI<0.1$, the specific mineral is undersaturated and dissolution is possible.

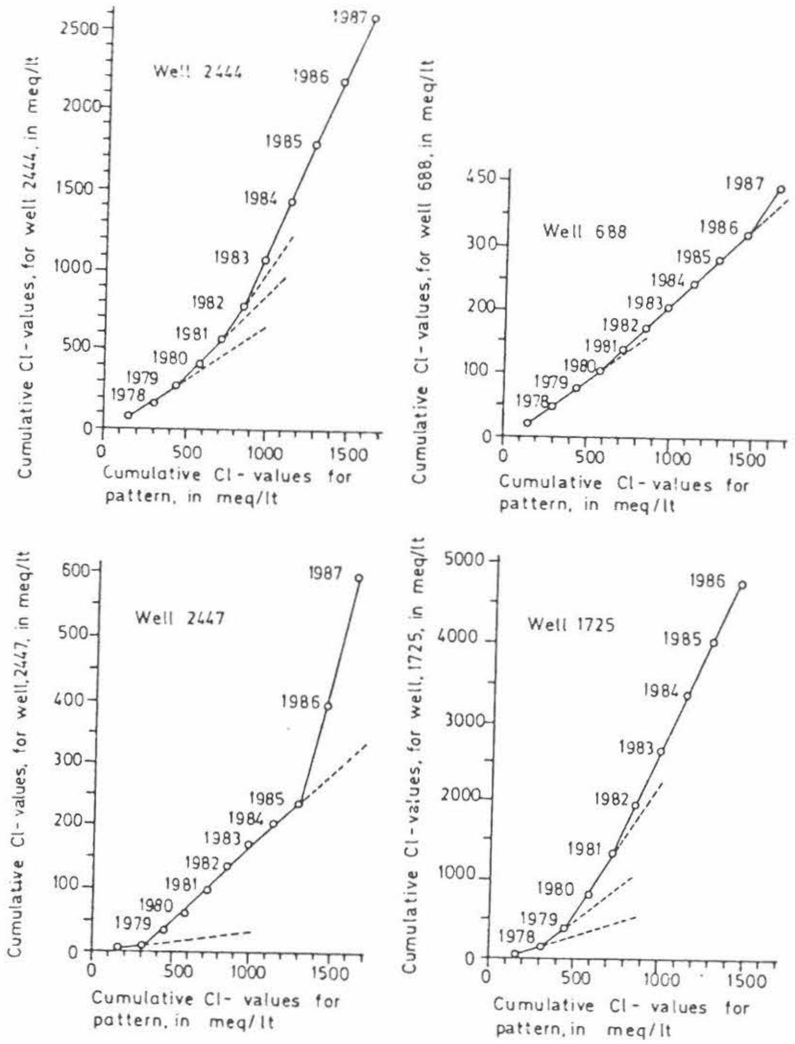

Fig. 6. Double-mass curve of selected wells

Table 2 summarizes the distribution of SI values for gypsum, halite, and calcite for each group of wells defined in the previous section. In all groups gypsum saturation index shows no positive value. This suggests that there is no gypsum saturation. However, in the wells located at the northern part of the groundwater basin as well as along the shoreline relatively high SI values are noted (Fig. 7). These may imply bedrock contamination in the north and sea water contamination along the coastal strip.

$SO_4^{=}/Cl^-$ ratios given in Table 2 are used to compare $SO_4^{=}$ enrichment of the groups A and B. In group B wells more than four-fold increase in the ratio is noted. This may be attributed to bedrock contamination at that part of the aquifer. In group C and D wells an increase in the $SO_4^{=}/Cl^-$ ratio is attributed to low Cl^- content of the groundwater.

All groups show calcite oversaturation. The increasing calcite saturation index in the northeast and in the east (Fig. 8) directly correlate with the distribution of the carbonate sequences of the groundwater basin.

Conclusions

Grouping of wells on the basis of their degree of their contamination is accomplished through salinity data and trilinear diagrams. The wells of group A and B yield groundwater of high and moderately high sulphate and chloride concentrations, respectively. Isochloride contour map suggests that the sea water front has advanced 2 km to 4 km inland from the sea. The wells of group C and D are less affected from the sea water intrusions and they yield carbonate-bicarbonate type water.

Historical fingerprints of sea water intrusion are well distinguished through double-mass curves. Depending on the distance to the shore line the selected wells show significant goundwater degradation in late 1970's and early to middle 1980's.

The saturation index of minerals such as gypsum, halite, and calcite provided valuable clues for bedrock contamination. Increasing calcite saturation in the northeast and east of the groundwater basin correlate well with the distribution of carbonate sequences of the Tertiary units.

Table 2. Gypsum, halite, and calcite saturation indices and $SO_4^{=}/Cl^{-}$ for group of wells.

Seq. No:	Well No:	SO4/Cl	SATURATION INDEX GYPSUM	HALITE	CALCITE
GROUP A					
62	1856	0.05	-1.78	-5.76	1.00
64	1894	0.08	-2.03	-5.60	-0.22
65	500	0.07	-1.54	-5.74	0.87
70	7	0.09	-1.18	-4.94	0.56
71	471	0.10	-0.91	-5.07	0.64
72	1860	0.04	-1.67	-4.77	0.96
73	2348	0.04	-1.38	-5.04	1.08
74	1843	0.06	-0.95	-4.86	1.21
75	688	0.08	-0.84	-4.77	0.82
76	2315	0.06	-0.87	-4.62	0.99
77	2441	0.03	-1.36	-4.03	-0.13
78	2447	0.02	-1.01	-3.72	0.32
79	2444	0.14	-0.01	-2.81	-0.27
80	1725	0.09	-0.65	-2.77	0.60
MIN		0.02	-2.03	-5.76	-0.27
MAX		0.14	-0.01	-2.77	1.21
AVG		0.067	-1.155	-4.607	0.601
STD		0.03	0.50	0.92	0.48
GROUP B					
57	927	0.62	-0.87	-5.59	0.86
58	247	0.23	-1.24	-5.77	0.32
59	281	0.26	-1.19	-5.64	0.33
60	1763	0.27	-1.91	-5.20	0.50
61	319	0.47	-1.12	-5.35	0.43
63	300	0.33	-1.27	-5.24	-0.08
66	1823	0.13	-1.38	-5.26	0.34
67	330	0.32	-1.02	-5.30	0.61
68	306	0.14	-1.28	-4.97	0.34
69	1848	0.24	-0.79	-5.06	0.11
MIN		0.13	-1.91	-5.77	-0.08
MAX		0.62	-0.79	-4.97	0.86
AVG		0.302	-1.207	-5.338	0.375
STD		0.14	0.29	0.24	0.24
GROUP C					
7	72	0.52	-2.03	-6.75	1.05
11	2395	2.26	-1.38	-6.74	0.90
12	737	1.07	-1.66	-6.81	1.17
13	240	1.55	-1.38	-6.69	0.50
14	4135	0.55	-1.94	-6.69	0.82
16	225	1.03	-1.70	-6.60	0.85
25	78	0.18	-2.58	-6.38	0.46
29	2350	0.31	-2.21	-6.49	0.82
30	77	0.35	-2.06	-6.20	0.95
45	724	0.30	-1.70	-6.31	0.47
MIN		0.18	-2.58	-6.81	0.46
MAX		2.26	-1.38	-6.20	1.17
AVG		0.812	-1.864	-6.565	0.798
STD		0.64	0.36	0.20	0.23

Seq. No:	Well No:	SO4/Cl	SATURATION INDEX GYPSUM	HALITE	CALCITE
GROUP D					
1	992	0.43	-2.34	-7.27	0.34
2	74	0.61	-2.09	-7.22	-0.53
3	75	1.13	-1.73	-7.04	0.75
4	411	1.11	-1.73	-6.25	0.57
5	1790	0.75	-2.16	-6.68	0.40
6	345	0.65	-2.11	-6.67	0.55
8	4	0.66	-2.13	-6.66	0.53
9	56	0.55	-2.14	-6.58	-0.17
10	2172	0.19	-2.53	-6.60	-0.83
15	2	0.11	-2.73	-6.60	0.67
17	834	0.28	-2.40	-6.49	0.13
18	593	0.21	-2.59	-6.31	0.41
19	1854	0.71	-2.14	-6.58	-0.46
20	801	0.89	-1.73	-6.25	0.55
21	999	0.61	-1.62	-6.65	0.62
22	558	0.14	-2.58	-6.49	0.31
23	1846	0.47	-2.13	-6.42	0.43
24	1856	0.51	-1.74	-6.68	0.09
26	583	0.02	-3.34	-6.42	0.40
27	65	0.24	-2.07	-6.42	0.81
28	1068	0.54	-1.63	-6.45	0.70
31	4153	0.62	-1.54	-6.71	-1.33
32	832	0.20	-2.05	-6.23	-0.37
33	645	0.19	-2.20	-6.15	0.59
34	39	0.60	-1.53	-6.28	0.79
35	1731	0.24	-2.46	-6.01	0.02
36	833	0.14	-2.18	-6.24	0.83
37	9	0.18	-2.18	-6.16	0.65
38	616	0.10	-2.58	-6.13	0.62
39	517	0.13	-2.30	-6.04	0.32
40	890	0.08	-2.80	-5.97	0.36
41	1780	0.13	-2.50	-5.97	0.41
42	825	0.17	-1.95	-6.27	0.35
43	824	0.21	-1.88	-6.27	0.13
44	76	0.43	-1.74	-6.04	0.74
46	551	0.07	-3.29	-6.03	0.48
47	73	0.32	-1.75	-6.08	-0.83
48	846	0.08	-2.20	-6.17	0.63
49	4304	0.26	-1.88	-5.85	0.79
50	660	0.35	-1.57	-5.98	0.61
51	82	0.04	-2.43	-6.06	0.41
52	529	0.45	-1.77	-5.79	-0.21
53	823	0.47	-1.40	-6.13	0.26
54	11	0.04	-2.54	-5.74	0.65
55	454	0.08	-1.90	-6.04	-0.10
56	229	0.06	-2.05	-5.72	-0.26
MIN		0.02	-3.34	-7.27	-1.33
MAX		1.13	-1.40	-5.72	0.83
AVG		0.357	-2.137	-6.321	0.278
STD		0.28	0.43	0.35	0.49
sw	1111	0.11	-0.42	-2.37	0.88

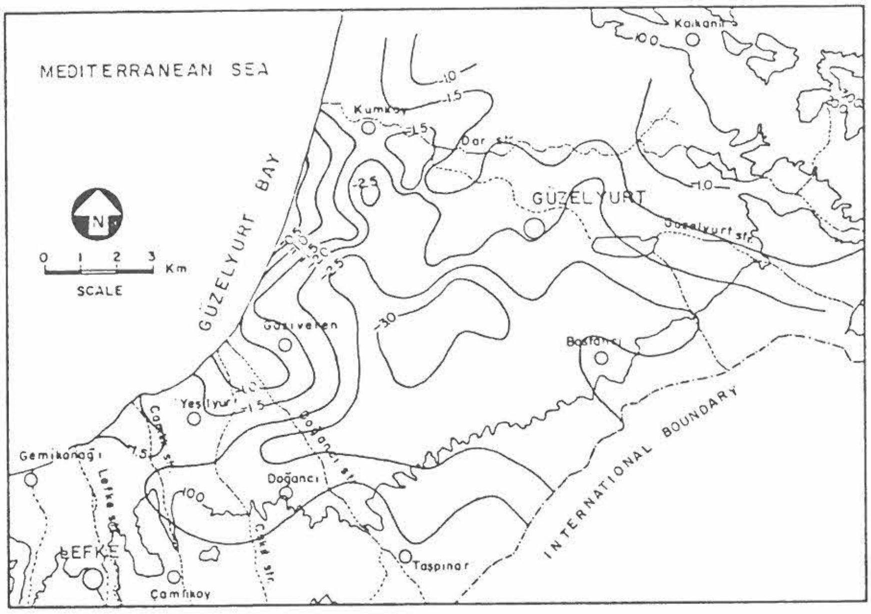

Fig. 7. Areal distribution of gypsum saturation index.

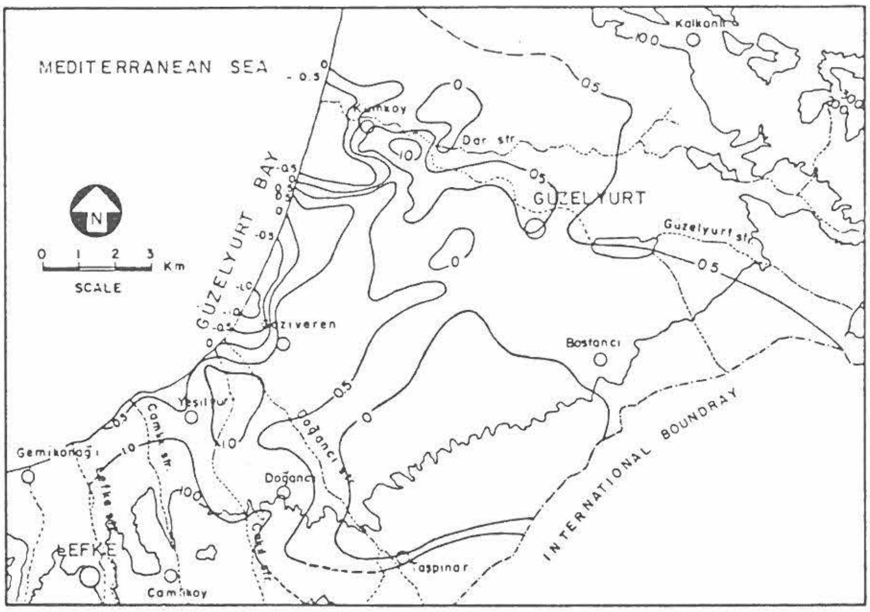

Fig. 8. Areal distribution of calcite saturation index.

REFERENCES

ARIKAN, A., 1988: Wateqb-basica revision of Wateqf for IBM personal computers-Groundwater, 26, 2, 222-227.

CHAPELLE, F.H., 1983: Groundwater geochemistry and calcite cementation of the Aguia aquifer in Southern Maryland-Water Resources Research, 19,1, 545-556.

GÖKÇEKUŞ, H. & OLGUN, E., 1993: Cenozoic stratigraphy of the Güzelyurt basin, Turkish Republic of Northern Cyprus-TAPG Bulletin, 5, 1, 57-68.

GÖKÇEKUŞ, H. & DOYURAN, V., 1993: Mining groundwater: A case study from Northern Cyprus-Advances in Civil Engineering, First Technical Congress, vol. II, Gazi Mağusa, Northern Cyprus, 819-829.

GÖKÇEKUŞ, H. & DOYURAN, V., 1995: Evaluation of hydrochemical data from Güzelyurt aquifer (Turkish Republic of Northern Cyprus) through cluster analysis-Turkish Journal of Earth Sciences,4, 1-10.

LANGMUIR, D., 1971: The geochemistry of some carbonate groundwater in central Pennsylvania-Geochim. Cosmochim. Acta, 35, 1023-1045.

LEE, R.W., 1985: Geochemistry of groundwater in Cretaceous sediments of the southern coastal plain of eastern Mississippi and western Alabama-Water Resources Research, 21, 10, 1545-1556.

MERCADO, A., 1985: The use of hydrochemical patterns in carbonate sand and sandstone aquifers identify intrusions and flushing of saline water-Groundwater, 23,5,635-645.

RICHTER, B.C. & KREITLER, C.W., 1987: Geochemistry of salt water beneath the rolling planes, North Central Texas-Groundwater, 24, 6, 735-742.

ROBINOVE, C.J., LANGFORD, R.H. & BROOKHART, J.W., 1958: Saline-water resources of North Dakota-U.S. Geol. Survey Water-Supply Paper 1428, 72pp.

SEARCY, J.K. & HARDISON, C.H., 1960: Double-mass curves; with a section on fitting curves to cyclic data-U.S. Geological Survey Water-Supply Paper, 1541-B, 31-36.

ŞEN, Z. & AL-DAKHEEL, A., 1986: Hydrochemical facies evaluation in Umm Er Radhuma limestone, eastern Saudi Arabia-Groundwater, 24, 5, 626-635.