THE ESTIMATION OF GROUNDWATER RECHARGE FROM WATER LEVEL AND PRECIPITATION DATA

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SUMMARY: The amount of precipitation that reaches the zone of saturation depends upon several factors. Because of these factors, determining the recharge to aquifers is a difficult problem in all water resources studies. A study for determining quantitative groundwater recharge is illustrated by the analysis of water level fluctuations in Kütahya-Çavdarhisar plain in Turkiye. The recharge of the groundwater in the study area is from precipitation.

Key Words: Groundwater Recharge, Precipitation, Water Level.

INTRODUCTION

Precipitation occurs in several forms, including rain, snow, and hail, but only rain is considered in this discussion. The first rain wets vegetation and other surfaces and then begins to infiltrate into the ground. The first infiltration replaces soil moisture, and, thereafter, the excess percolates slowly across the intermediate zone to the zone of saturation. Water in the zone of saturation moves downward and laterally to sites of groundwater discharge such as springs on hillsides or seeps in the bottoms of streams and lakes or beneath the ocean (3).

The amount of moisture which a land area loses by evapotranspiration depends primarily on the incidence of precipitation, secondly on the climatic factors of temperature, humidity etc. and thirdly on the type, manner of cultivation and extent of vegetation. The amount may be increased, for example, by large trees whose roots penetrate deeply into the soil, bringing up and transpiring water which otherwise would be beyond the influence of surface evaporation (11).

In the dry period, when evapotranspiration rates exceed available moisture from precipitation, recharge to the water table is negligible and groundwater levels decline (Figures 1-2).

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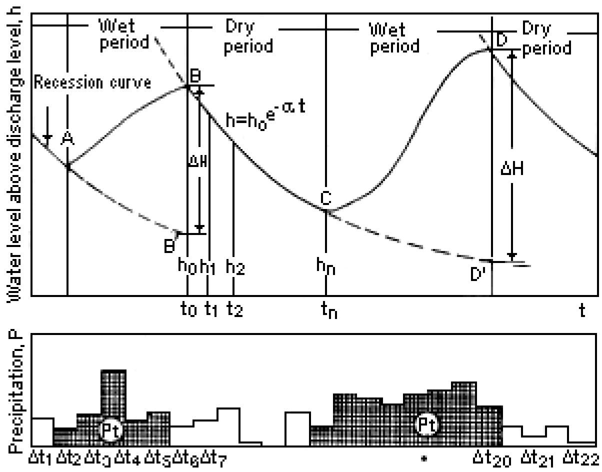

Figure 1: Fluctuations in water levels caused by recharge from precipitation.

Records of water level fluctuations in wells are worth the cost and trouble of collecting only if they are used as a basis for hydrologic interpretations. Although water level records have been vital to the reaching of conclusions regarding the occurrence and development of groundwater in specific areas, many such records still await interpretation. Similarly, a wealth of climatologic and other hydrologic data is in need of analysis (8).

In the general case it is possible to calculate the total level oscillation amplitude due to infiltration if the overall recession regime, i.e. the behavior of the aquifer without external recharge, is known (1,6). Degallier (1) found that

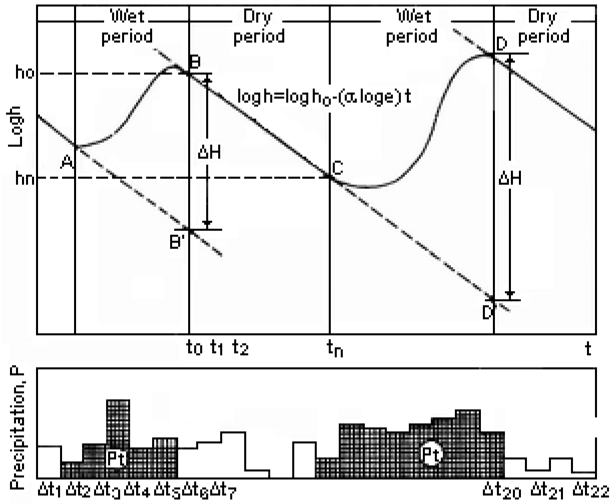

Figure 2: Fluctuations in water levels caused by recharge precipitation.

the component forming a grounwater hydrograph, including those from a groundwater system, frequently each had a recession that could be approximated by simple exponential relationships of the from (Figure 1):

$$h = h_0 \ e^{-at} \quad (1)$$

where h_0 and h are the water level above discharge level at the beginning of the measurement period and after a certain time (t) respectively and a is known as coefficient of recession or discharge coefficient.

Like any other exponential formula, on a semilogarithmic paper when water level above discharge level is plotted to the log scale and time to the arithmetic scale, the recession curves plot as nearly as straight lines (Figure 2). In the log system with base 10, the formula is a follows

$$\log h = \log h_0 - 0.4343at \quad (2)$$

The shape of the recession curves depend on the water yielding properties of the equifer material, the transmissivity and the geometry (4).

The recovery of the water level, dH, under natural hydrological conditions is a mirror image of the recession curve. The recovery of the water level varies from year to year, depending on the amount of total precipitation (P_t) in wet period (Figures 1 and 2).

Groundwater levels are influenced by seasonal cycles in such factors as recharge from precipitation, evapotranspiration, and discharge from wells and show a seasonal pattern of fluctuations (10). The degree of correlation between fluctuations of groundwater level and fluctutation of total precipitation (P_t) in wet period furnishes a clue as to the freeness of the connection between recharge and total precipitation (P_t) in wet period.

This study considers the direct estimation of recharge using recovery of the groundwater level (dH) and total precipitation (P_t) during wet period (Figure 3).

The line regression equation is

$$\Delta H = a + bP_t \quad (3)$$

where ΔH is recovery of groundwater level, and P_t is total precipitation during the wet period, a and b are the regression coefficients.

Precipitation intercpet, P_e is intersection of the total precipitation recovery straight line with zero-total precipitation axis (Figure 3) and it represents the amount of surface runoff and evapotranspiration for the same period. Recovery or recharge from precipitation is a function of the amount of total precipitation (P_t).

If the intercept is P_e, the recharge (P_s) is estimated as

$$P_s = P_{tc} - P_e \quad (4)$$

where P_{tc} is the result of the computation of the total precipitation by means of equation (3) during the wet period in a year.

Table 1: Monthly and annual precipitation, in millimeters, at Çavdarhisar.

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June	July	Aug.	Sept.	Annual
1975	24.6	34.8	54.1	49.0	34.4	75.6	31.7	58.5	92.5	30.2	10.8	1.2	497.4
1976	23.3	91.1	73.2	41.8	28.2	25.0	77.0	43.8	24.7	20.5	3.9	11.0	463.5
1977	71.6	22.7	114.6	23.8	24.4	29.8	86.0	2.0	32.2	15.9	39.2	38.0	500.2
1978	71.4	56.1	82.3	112.0	111.3	60.3	56.9	31.1	4.5	0.0	9.0	80.5	675.4
1979	65.4	38.2	47.9	162.6	31.8	14.4	16.3	99.8	43.1	16.2	3.2	7.6	546.5
1980	63.4	85.8	75.6	136.3	9.2	100.0	40.0	3.8	5.2	14.0	6.2	43.0	582.5
1981	20.0	58.2	119.6	135.1	49.1	35.8	41.0	68.1	31.9	1.5	3.5	11.5	575.3
1982	40.7	62.7	174.5	34.3	26.4	20.5	90.0	29.5	11.9	17.2	34.6	0.5	542.8
1983	30.5	10.0	42.7	81.0	42.6	11.7	45.4	31.8	39.1	109.4	1.8	0.0	446.0
1984	23.4	154.7	50.5	75.3	102.3	86.6	90.4	35.8	3.1	46.1	9.2	0.0	677.4

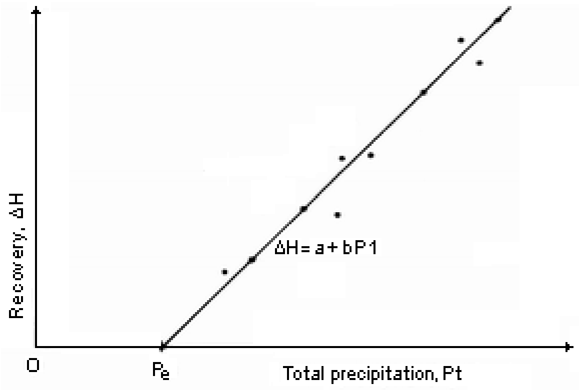

Figure 3: Total preciptiation in wet period-recovery of the groundwater level relationship in aquifers.

ESTIMATION OF GROUNDWATER RECHARGE

Kütahya-Çavdarhisar plain is situated in the west part of the Middle Anatolia Region, within the boundaries of Kütahy province, between the 39° 02' - 39° 23' latitudes and 29° 24' - 29° 27' longitudes. The plane area is 160 km^2, and the drainage area 855 km^2. The climate is moderate and rather humid.

The Paleozoic schists form the base. The Mezozoic marbles are discordant with Paleozoic schist and they placed on them. The Cenozoic formations are placed on Paleozoic and Mesozoic formations with a discordance.

The groundwater bearing formation of the plain is limestone level of the Neogene. The recharge of the groundwater in the study area is supplied by precipitation. The discharge of the plain takes places from the Esatlar spring. The Esatlar spring discharging from karstified limestone at about 14 km North of Çavdarhisar town is an important water resource. This spring discharges at about 970 m elevation and its discharge is 1, 790 m^3/s in September 1974.

Precipitation was recorded at Çavdarhisar in this plain during the analysis period (Table 1). The average annual precipitation during the period of record at Çavdarhisar was 550,7 millimeters.

Groundwater levels are measured monthly in Susuzkaya (7538-A) observation well in Kütahya-Çavdahisar Plain (Table 2-Figure 4). The water level data above discharge level during the period April 1974 to April 1985 are given in Table 3.

Groundwater levels fluctuate naturally in response to a sequence of climatic events and to constraints imposed by hydrogeologic and topographic characteristics.

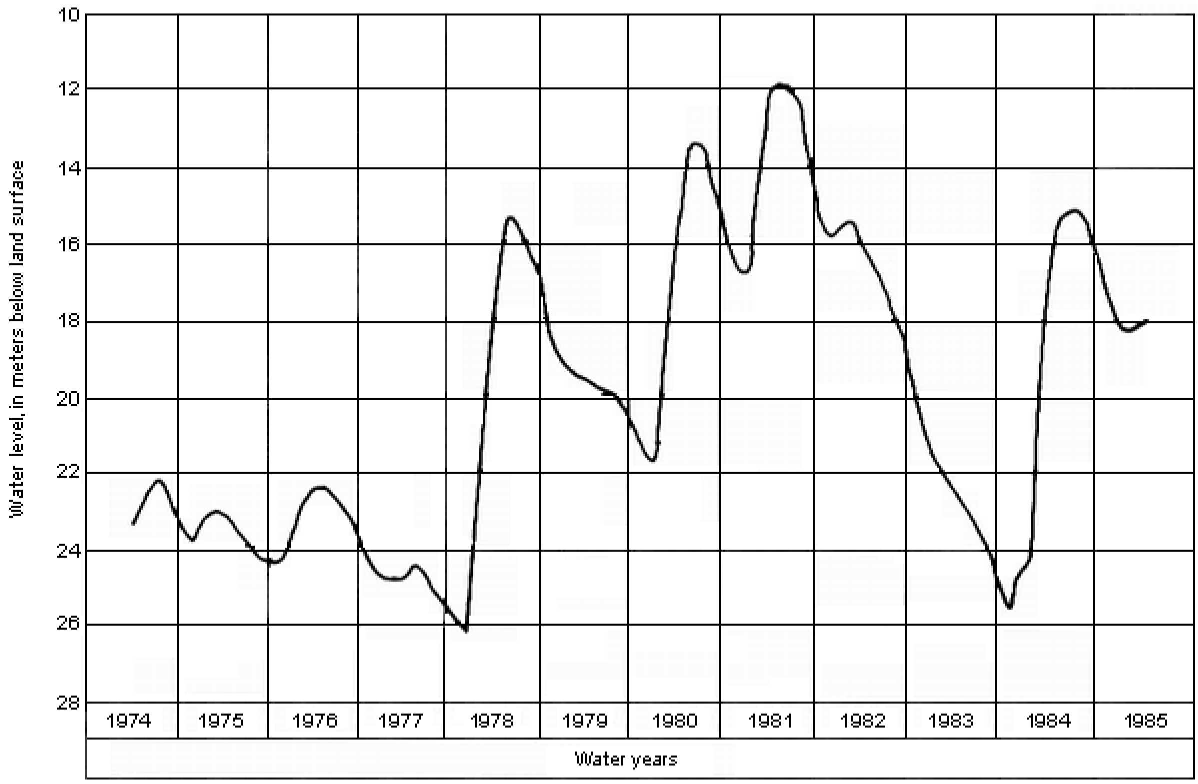

Figure 4: Fluctuations in water levels in Susuzkaya (7535-A) observation well caused by recharge from precipitation.

Table 2: Depth to water, in meters, in Susuzkaya (7538-A) observation well.

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1974	-	-	-	-	-	-	23.55	22.84	22.63	22.27	22.53	23.00
1975	23.63	24.03	23.48	23.25	23.20	23.17	23.42	23.56	23.75	24.05	24.22	24.43
1976	24.50	24.47	24.19	23.72	23.10	22.70	22.41	22.42	22.54	22.81	23.29	23.66
1977	24.18	24.47	24.66	24.84	24.82	24.75	24.85	24.62	24.65	24.93	25.28	25.63
1978	25.65	26.06	26.08	-	20.74	18.54	16.84	15.77	15.39	15.57	15.92	16.59
1979	17.07	17.87	18.61	19.23	19.33	19.48	19.53	19.63	19.71	19.83	19.93	20.43
1980	21.03	21.51	21.93	-	18.35	17.00	15.40	13.65	13.49	13.65	14.12	14.85
1981	15.59	16.44	16.97	16.39	14.93	12.93	12.07	11.85	12.01	12.37	12.72	13.73
1982	14.74	15.59	15.60	15.67	15.60	15.73	16.00	16.28	16.55	17.13	17.95	18.72
1983	19.35	20.00	20.66	21.55	21.94	22.30	22.43	22.77	23.06	23.42	24.00	24.59
1984	25.08	25.65	24.95	24.75	22.03	20.19	19.33	16.41	15.40	15.27	15.47	16.03
1985	16.65	16.79	-	18.34	18.20	18.18	18.16	-	-	-	-	-

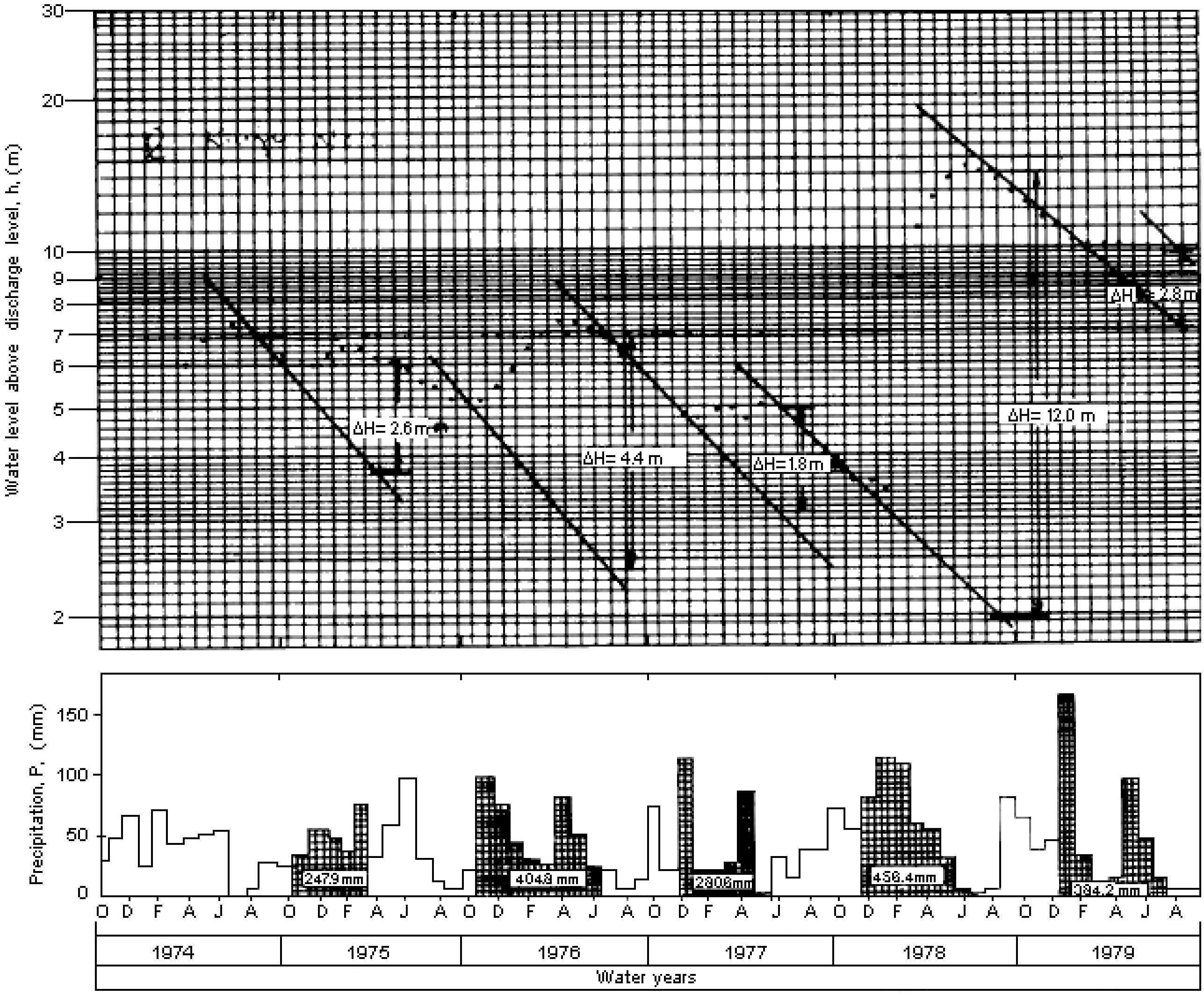

Figure 5: Fluctuations in water levels caused by recharge from precipitation.

Table 3: Water level above discharge level (h), in meters, in Susuzkaya (7538 - A) observation well.

Altitude of the observation well : 999.63 m Altitude of discharge level : 970.00 m												
Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June	July	Aug.	Sept.
1974	-	-	-	-	-	-	6.08	6.79	7.00	7.36	7.10	6.63
1975	6.00	5.60	6.15	6.38	6.43	6.46	6.21	6.07	5.88	5.58	5.41	5.20
1976	5.13	5.16	5.44	5.91	6.53	6.93	7.22	7.21	7.09	6.82	6.34	5.97
1977	5.45	5.16	4.97	4.79	4.81	4.88	4.78	5.01	4.98	4.70	4.35	4.00
1978	3.98	3.57	3.55	-	8.89	11.09	12.79	13.86	14.24	14.06	13.71	13.04
1979	12.56	11.76	11.02	10.40	10.30	10.15	10.10	10.00	9.92	9.80	9.70	9.20
1980	8.60	8.12	7.70	-	11.28	12.63	14.23	15.98	15.98	15.98	15.51	14.78
1981	14.04	13.18	12.66	13.24	14.70	16.70	17.56	17.98	17.62	17.26	16.91	15.90
1982	14.89	14.04	13.73	13.96	14.03	13.90	13.63	13.35	13.08	12.50	11.68	10.91
1983	10.28	9.63	8.97	8.08	7.69	7.30	7.20	6.86	6.57	6.21	5.63	5.04
1984	4.55	3.98	4.68	4.90	7.60	9.44	10.30	13.22	14.23	14.36	14.16	13.60
1985	12.99	12.84	-	11.29	11.43	11.45	11.47	-	-	-	-	-

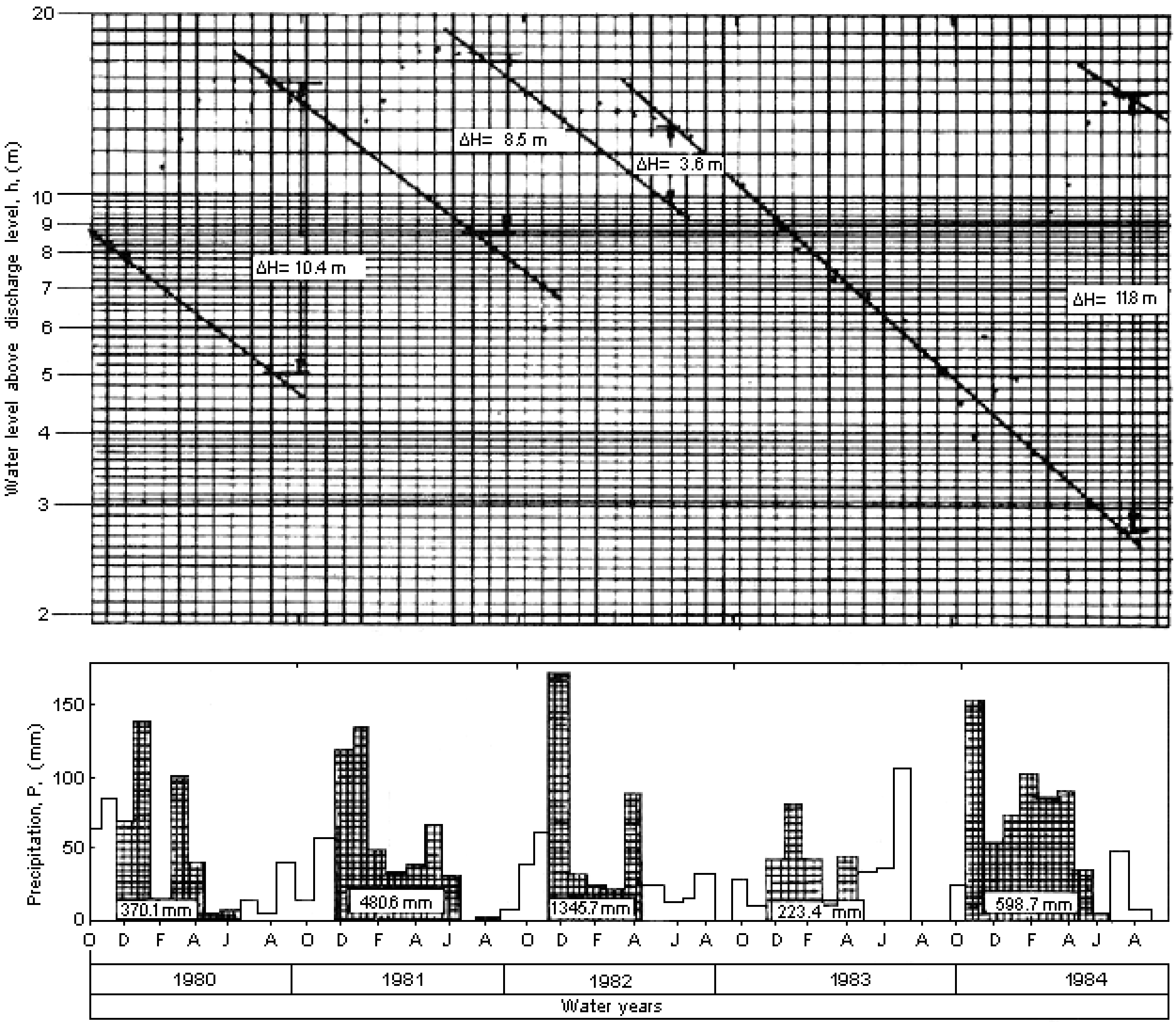

Figure 6: Fluctuations in water levels caused by recharge from precipitation.

Table 4: The results of linear regression analysis.

Type of relation	Number of observations	Correlation coefficient, r	Sdandard error of estimated	Computed F value	Table ($F_{0.05}$) F + value	Regression equation
Total precipitation-recovery relation	10	0.821	2.681	16.603	5.32	$\Delta H = -6.31 + 0.032P,$

Table 5: Summary of hydrologic characteristics in Kütahya-Çavdarhisar plain.

Well no : 7538 - A Meterological station: Çavdarhisar			Precipitation shoal, P_c: 197.2 mm	
Water Year	Annual precipition P_y, (mm)	Computed total precipitation $P_{t\,c}$, (mm)	Recovery, ΔH (m)	Recharge P_s, (mm)
1975	497.4	275.3	2.5	78.1
1976	463.5	334.7	4.4	137.5
1977	500.2	253.4	1.8	56.2
1978	675.4	572.2	12.0	375.0
1979	546.5	284.7	2.8	87.5
1980	582.5	522.2	10.4	325.0
1981	575.3	462.8	8.5	265.6
1982	542.8	309.7	3.6	112.5
1983	446.0	197.2	0.0	0.0
1984	677.4	559.7	11.6	362.5
Average	550.7	377.2		180.0

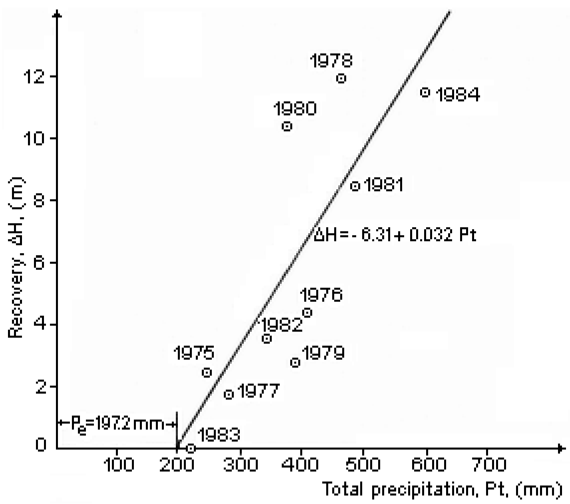

Figure 7: Total precipitation in wet period - Recovery of the ground water level relationship in Kütahya - Çavdarhisar plain.

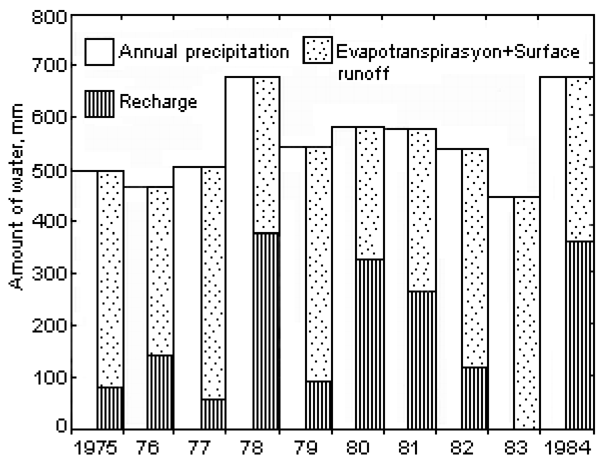

Figure 8: Groundwater recharge, 1975-1984, in Kütahya - Çavdarhisar plain.

Groundwater recharge is largest during late fall, winter, and spring months, when plants are dormant and evaporation rates are small. In the summer when evapotranspiration rates exceed available moisture from precipitation, recharge to the water table innegligible and groundwater levels decline (Figures 5 and 6).

The recovery of the water level (ΔH) and total precipitation (P_t) during the wet period in a year for water years 1975-1984 are given in Figures 5 and 6. The results linear regression analysis are given in Tabel 4.

The linear regression equation during selected period given below (Figure 7).

$$\Delta H = -6.31 + 0.032\, P_t \qquad (5)$$

The average precipitation intercept (P_e) of this aquifer is 197.2 mm (Figure 7). The computed values ($P_{t\,c}$) of total precipitation by means of equation (5) for water years 1975-1984 are given in Table 5.

The results of the computation of the recharge from precipitation (P_s) of this aquifer by means of equation (4) for the same period are given in Table 5 and in Figure 8.

Annual recharge in this area during the ten years ranges from 375.0 millimeters in 1978 to 0.0 millimeters in 1983. The average annual recharge during the period 1975 to 1984 is 180.0 millimeters (Table 5). This is about 33 percent of the average annual precipitation.

CONCLUSION

The aim of this study has been a synthesis of the results which can be obtained by analysis of water level fluctuations. The accuracy of the results which can be obtained by analysis of water level fluctuations. The accuracy of the results depends exclusively on the base of water level observation data.

The present work suggests Kütahya-Çavdarhisar plain. The groundwater bearing formation of the plain is limestone level of the Neogene. The recharge of the groundwater in this area is from precipitation. The groundwater discharge of the plain takes place from Esatlar spring. The Esatlar spring discharging from karstified limestone at about 14 km north of Çavdarhisar town is an important water resource. The average annual recharge during the period 1975 to 1984 is 180.00 mm. This is about 33 percent of the average annual precipitation.

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