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Estimation of Groundwater Recharge from Rainfall

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Abstract : *There bas been some attempt to predict rainfall recharge by statistical method using only point rainfall data and water table fluctuation disregarding the fact that water table fluctuation may be result of recharge from other sources. In the present paper an attempt has been made to check the validity of statistical approach. Using the Green and Ampt infiltration equation and soil moisture characteristics of a known soil, the recharge due to several rainfall events has been determined and the consequent water table fluctuation has been determined using the Hantush's solutiyn for water rise due to recharge from a rectangular spreading basin. Using the synthetic data of water table rise and rainfall values, a linear relation between rainfall and water table fluctuation has been established from which recharge due to rainfall has been estimated,. The recharge values computed by the two methods have been compared.*

1.0 Introduction

The major sources of recharge to aquifers in many areas are direct precipitation and stream runoff. Recharge from rainfall in an area is unevenly distributed in time and space and only a fraction of the annual precipitation percolates down to the watet table depending upon the topography, vegetal cover, soil moisture content, depth to water table, intensity and duration of rainfall, and other meteorological factors. Groundwater recharge due to rainfall through a vertical soil column can be assessed by solving the Fokker-Planck equation, that describes the process of one dimensional water transfer in unsaturated soil overlying the ground water table, satisfying the appropriate boundary and initial conditions. Simplified approach based on Green and Ampt infiltration equation can also be used to predict the recharge due to rainfall through a homogeneous vertical soil column. Morel-Seytoux (1985) has determined the recharge to an aquifer from a single rainfall event making use of the Green and Ampt infiltration equation. The initial recharge rate when the wetting front reaches water table and variation of recharge rate with time have been determined by him.

The structure of a groundwater system is given by the water balance equation which in its complete form is given by (Houston, 1983) : $\triangle S_{gw}=RF-ET+\triangle S_{uz}+R_{gw}-D_{gw}+R_{sw}-D_{sw}-Q$, where $\triangle S$ is the change in stored water voiume; RF is the total of all forms of precipitation; ET is evapotranspiration; R is recharge; D is discharge; Q is the abstraction; and the subscrips uz, gw, and sw rafer to the unsaturated zone, ground water, and surface water, respectively. Given the resonable assumption that the physical characteristics of the system are constant in time, $\triangle S_{gw}$ can be represented and replaced by $\triangle h$ (change in ground-water head). In its simplest torms, the water balance equation can be reduced to univariate models of the form $\triangle h=f$ (RF) or $\triangle h=f$ (Q). More likely are multivariate models of the form $\triangle h=f$ (RF,Q). In any particular system it is unlikely that the change in water level is instantaneous following rainfall and abstraction.

The effects of recharge and discharge are more likely to be attenuated; thus $\triangle h_t = a_o RF_t + a_l RF_{t-l} + \ldots + a_p RF_{t-p} - b_o Q_t - b_1 Q_{t-l} - \ldots - b_q Q_{t-q}$, where a and b represent transfer functions and the subscript t refers to the time origin. Application of time-series techniques to groundwater problems is a logical extension of the water balance approach (Houston, 1983). A system model essentially consists of input which is acted upon by a transfer function in order to produce output. The input data may be represented by recharge due to rainfall and discharge through pumping and the output by water table data. The transfer function of a system model is estimated by a statistical technique which produces a minimum error. In this the systems model differs basically from analytical or numerical models which are based upon physical laws established a priori. A system approach can not be considered a substitute for analytical or numerical methods. However, it can be used successfully where there are insufficient data to enable to attempt other methods. A recursive least square method has been developed by Vishwanathan (1983) to predict the daily water level in a bore hole making use of the rainfall on the same day and daily rainfall during the previous eight days. The model also predicts the rain fall recharge.

In the present paper, recharge due to several rainfall events has been estimated using the approach of Morel-Seytoux. An attempt has been made to check the validity of statistical approach. Using the Green and Ampt infiltration equation and soil moisture chracteristics of a known soil, the recharge due to several rainfall events has been predicted and the consequent water table fluctuation has been determined using the Hantush's solution for water table rise due to recharge from a rectangular spreading basin. Using the synthetic data of water table rise and rainfall values, a linear relation between rainfall and water table fluctuation has been established from which recharge due to rainfall has been computed and compared with that which is computed by Morel-Seytoux's approach.

2.0 Review

Unsaturated flow in the vadose zone has been analysed on the basis of Darcy's law with added complication that the hydraulic conductivity, k, is dependent on water content, θ, which also controls the pressure head. The hydraulic conductivity and soil moisture relationship and the capillary pressure and moisture content relationship are needed to analyse any unsaturated flow.

The representative capillary pressure drive H_f that appears in Green and Ampt infiltration equation is conveniently found from the available soil moisture capillary pressure relationship in the following manner as suggested by Bouwer :

$$H_f = \int_0^{h_{ci}} k_{rw}(\theta)\, dh_c \qquad (1)$$

where $k_{rw}(\theta) = k(\theta) / \tilde{k}$, h_c = capillary pressure head, h_{ci} = capillary pressure head corresponding to the initial soil moisture θ_i, prevailing at the onset of infiltration, and $\tilde{k}$ = hydraulic conductivity at natural saturation moisture content, $\tilde{\theta}$

2.1 Infiltration Prior to Ponding :

Up to time of ponding, infiltration rate is equal of the intensity of rainfall. At the time of ponding the relationship between cumulative rainfall and rainfall rate is given by (Morel-Seytoux, 1982) :

$$w_p = (\tilde{\theta} - \theta_i) H_f / (R^* - 1) \qquad \ldots\ldots (2)$$

and the expression for ponding time, t_p, for constant rainfall rate has been derived as :

$$t_p = \frac{(\tilde{\theta} - \theta_i)\, H_f}{R\,(R^* - 1)} \qquad \ldots\ldots (3)$$

where $\overset{*}{R} = R / \tilde{k}$. For variable rainfall pattern the expression for ponding time is (Morel-Seytoux, 1982) :

$$t_p = t_{j-1} + \frac{1}{R(J)} \left[\frac{(\tilde{\theta}-\theta_i)H_f}{R^*(J)-1} - \sum_{\gamma=1}^{J-1} R(\gamma)(t_\gamma - t_{\gamma-1}) \right] \quad \ldots\ldots (4)$$

where R (J) is the rainfall at J^{th} time and $R^*(J) = R(J) / \tilde{k}$. The position of the wetting front, Z_f, at ponding time is $Z_f = w_p / (\tilde{\theta} - \theta_i)$ (5)

2.2 Soil Moisture Movement During Rainfall After Ponding :

The cumulative infiltration, w, after ponding at any time t is given by (Morel-Seytoux, 1982) :

$$w - w_p = \tilde{k}(t - t_p) + (\tilde{\theta}-\theta_i)(H+H_f) \log_e \left[\frac{(H+H_f)(\tilde{\theta}-\theta_i) + w}{(H+H_f)(\tilde{\theta}-\theta_i) + w_p} \right] \quad \ldots\ldots (6)$$

If at any time the rainfall is less than the infiltration capacity, the infiltration rate is equal to the rainfall intensity in case the depth of water on the surface is equal to zero. The position of wetting front Z_f at time t is given by the relation $(Z_f = w / (\tilde{\theta} - \theta_i))$ ......(7)

2.3 Soil Moisture Movement After Cessation of Rainfall :

For the analysis of soil moisture movement during the post rainfall period the time parameter has been counted from the instant the rain stops. The actual profile at t = 0, has been replaced by a simpler rectangular profile with a uniform value of water content equal to the limiting value θ_l. The value θ_l is the water content necessary to transmit flux after capillary forces have become negligible as compared to those of gravity. At the end of rainfall the position of the wetting front has been given as :

$$Z^0_f = \frac{w}{\theta_l - \theta_i} = \frac{w}{(\tilde{\theta} - \theta_r)(\theta_l^* - \theta_i^*)} \quad \ldots\ldots (8)$$

where w = total infiltration at the end of rain, θ_r is the field capacity, and θ^* = is normalised water content defined as :

$$\theta^* = (\theta - \theta_r) / (\tilde{\theta} - \theta_r) \quad \ldots\ldots (9)$$

If saturation of soil surface has occurred at or before the end of rain, $\theta_l = \tilde{\theta}$ or $\theta_l^* = 1$, and

$$Z^0 = w / \{ (\tilde{\theta} - \theta_r)(1 - \theta_i^*) \} \quad \ldots\ldots (10)$$

If Z_f is depth to the wetting front and θ the water content of the soil behind the front at any later time, then

$$Z_f = \frac{w}{\theta - \theta_i} = \frac{w}{(\tilde{\theta} - \theta_r)\left[\frac{\theta - \theta_r}{\tilde{\theta} - \theta_r} - \frac{\theta_i - \theta_r}{\tilde{\theta} - \theta_r} \right]} = \frac{w}{(\tilde{\theta} - \theta_r)(\theta^* - \theta_i^*)} \quad \ldots\ldots (11)$$

when the wetting front reaches water table, $Z_f = D$, where D is the depth to water table. Hence,

$$D = \frac{w}{(\tilde{\theta} - \theta_r)(\theta^* - \theta_i^*)} \quad \ldots (12)$$

Eq. (12) gives θ^* at the time wetting front reaches the watertable.

2.4 Recharge After Wetting front Reaches Water Table :

Darcy's law for flow in unsaturated soil if capillary effects are neglected reduces to the form

$$q = \tilde{k}\, k_{rw}(\theta) \quad \ldots\ldots (13)$$

Expressing $k_{rw}(\theta)$ equal to $(\theta^*)^n$, eq. (13) becomes

$$q = \tilde{k}(\theta^*)^n \quad \ldots\ldots (14)$$

Eq. (14) gives the recharge rate when the wetting front reaches the water table.

Once the wetting front reaches the water table the recharge starts. The recharge rate is given by (Morel-Seytoux et al, 1984) :

$$R = \frac{q}{\left[1 + \frac{(n-1)\,\tilde{k}t}{\tilde{D}\,(\theta-\theta_i)} \left(\frac{q}{\tilde{k}}\right)^{\frac{n-1}{n}}\right]^{\frac{n}{n-1}}} \qquad \ldots (15)$$

where D is the water table position, q is recharge rate when recharge starts, and the time, t, is measured from the beginning of recharge.

3.0 Statement of the Problem

Recharge to an aquifer takes place through an unsaturated transition zone. The infiltration rate up to time of ponding is equal to the intensity of rainfall. The rate of infiltration decays with time after ponding and excess water contributes to overland flow. The water supply is discontinued i.e. the rainfall stops, and the infiltrated water continues to move downwards. No recharge takes place until the wetting front reaches the water table. It is aimed to predict the recharge due to several rainfall events. Using these recharge values, it is required to predict the water table rise. it is aimed to predict the recharge due to the several rainfall events by a statistical approach.

4.0 Theory

4.1 Time Taken by Wetting Front to Reach Water Table After Cessation of Rainfall :

If q is the drainage rate from the soil column between ground surface and the wetting front, then according to Morel-Seytoux et. al (1984).

$$\frac{d\theta}{dt} = -q / Z_f$$

$$\text{or} \quad \frac{d\theta^*}{dt} = -q / \{Z_f\,(\tilde{\theta-\theta_r})\} \qquad \ldots (16)$$

Eliminating Z_f from eq. (16) with the help of eq. (11) Morel-Seytoux et al have derived the following relation :

$$\frac{d\theta^*}{dt} = -\frac{q}{w}\,(\theta^*-\theta_i^*) \qquad \ldots (17)$$

or

$$\frac{d\theta^*}{dt} = -\frac{\tilde{k}}{w}\,(\theta^*)^n\,(\theta^*-\theta_i^*) \qquad \ldots (18)$$

For the first rainfall, $\theta_i=\theta_r$ and $\theta_i^*=0$; hence, eq. (18) reduces to

$$\frac{d\theta^*}{dt} = -\frac{\tilde{k}}{w}\,(\theta^*)^{n+1} \qquad \ldots (19)$$

Integrating eqs. (18) and 19) from time t=0 when rain stops to time when wetting front reaches the water table, and taking

$\theta^*=\theta^*_1=1$ at time t=0, yields for n=4 :

$$t = \frac{w}{\tilde{k}}\left[\frac{1}{(\theta_i^*)^4}\log_e\frac{\theta^*(1-e_i^*)}{\theta^*-\theta_i} + \frac{1}{(\theta_i^*)^3}\left(1-\frac{1}{\theta^*}\right) + \frac{1}{2(\theta_i^*)^2}\left(1-\frac{1}{(\theta^*)^2}\right) + \frac{1}{3\theta_i^*}\left(1-\frac{1}{(\theta^*)^3}\right)\right] \qquad \ldots (20)$$

and

$$t = \frac{w}{4\tilde{k}}\left[\left(\frac{1}{\theta^*}\right)^4 - 1\right] \qquad \ldots (21)$$

respectively. From eqs. (21) and (20) the time a wetting front takes to reach the water table after cessations of each rainfall can be calculated for the first and for subsequent rainfall events after knowing θ^* from eq (12). For sandy soil, n is equal to 4.

Using eqs. (14), and (15) recharge to the water table has been calculated for five days after each rainfall. At the end of five days after each rainfall, the rate of recharge becomes quite small. The amount of water left in soil, and the soil moisture content are calculated at the end of five days and this value of soil moisture content has been used as θ_i for next rainfall.

4.2 Hantush's Solution For Rise In Water Table Height :

The water table height at the centre of a large square area of dimensions 2_a, is given by the expression (Hantush, 1967) :

$$h^2 = h_0^2 + 2w\bar{h}t/\phi \int_0^1 [\text{erf}\{a/(2(Tt/\tau\phi)^{1/2})\}]^2 d\tau \quad \dots (22)$$

where w = constant rate of percolation, $\bar{h}$ = weighted mean depth of saturation during the period of flow, h = height of water table above the base of aquifer, h_0 = the initial depth of saturation of the aquifer, T = transmissivity of aquifer, t = time since the incidence of recharge, and ϕ = specific yield.

Let the rise in water table height due to continuous recharge at unit rate be defined as K(t). From eq. (22) an expression for K(t) can be obtained as :

$$K(t) = t/\phi \int_0^1 [\text{erf}\{a/(2(Tt\tau/\phi)^{1/2})\})^2 d\tau \quad \dots (23)$$

Let the time span be discretised by uniform time steps. Let the rise in water table height at the end of n^{th} time step due to unit recharge per unit area taking place during the first unit time period be designated as δ (n). δ (n) is given by the relation :

$$\delta(n) = K(n) - K(n-1) \quad \dots (24)$$

$$\delta(1) = K(1) \quad \dots (25)$$

The water table rise, s(m), at the end of m th day due to variable recharge is given by

$$s(m) = \sum_{\gamma=1}^{m} \delta(m-\gamma+1)\, R(\gamma) \quad \dots (26)$$

4.3 A Statistical Method :

Vishwanthan (1983) has developed a linear model which estimates the daily water level in a bore hole given the rainfall on the same day and the daily rainfall during eight previous days. The relation is :

$$s_t = \lambda_t s_{t-1} + a_{0t}\, R_t + a_{1t}\, R_{t-1} + a_{2t}\, R_{t-2} + \dots + a_{8t}\, R_{t-8} + b_t \quad \dots (27)$$

$$s_t^* = s_t + e_t \quad \dots (28)$$

where s_t = estimated water level rise in the bore hole above certain datum level, and s_t^* = measured water level in the bore hole, R_t = rainfall. e_t = error between estimated and actual water table level; $\lambda_t, a_{0t}, a_{1t} \dots a_{8t}, b_t$ are model parameters. Using the above analysis and assuming the parameters to be independent of time, one can write

$$s(8) = \lambda s(7) + a_1R(8) + a_2R(7) + a_3R(6) + \dots + a_8R(1)$$

$$s(9) = \lambda s(8) + a_1R(9) + a_2R(8) + a_3R(7) + \dots + a_8R(2)$$

$$s(i) = \lambda s(n-1) + a_1R(i) + a_2R(i-1) + a_3R(i-2) + \dots + a_8R(i-7)$$

The model parameters λ, $a_1, a_2 \dots a_8$ can be found in the following way.

Writing the above equations in matrix notation

$$\begin{bmatrix} s(7) & R(8) & R(7) & R(3) & R(2) & R(1) \\ s(8) & R(9) & R(8) & R(4) & R(3) & R(2) \\ s(9) & R(10) & R(11) & R(11) & R(14) & R(15) \\ s(i-1) & R(i) & R(i-1) & R(i-5) & R(i-6) & R(i-7) \\ s(n-1) & R(n) & R(n-1) & R(n-5) & R(n-6) & R(n-7) \end{bmatrix} \cdot \begin{bmatrix} \lambda \\ a_1 \\ a_2 \\ . \\ a_8 \end{bmatrix} = \begin{bmatrix} s(8) \\ s(9) \\ s(10 \\ s(i) \\ s(n) \end{bmatrix}$$

$$[A]\ [B] = [C] \quad (29)$$

where [A] is the left-hand matrix, [B] is the left-hand column matrix and [C] is the righthand column matrix, Multiplying eq. (29) by [A'];

$$[A']\ [A]\ [B] = [A']\ [C] \quad \dots (30)$$

or

$$\{[A'][A]\}^{-1}\{[A'][A]\}[B] = \{[A'][A]\}^{-1}[A'][c] \quad \ldots(31)$$

Hence,

$$[B] = \{[A'][A]\}^{-1}[A'][C] \quad \ldots(32)$$

The transfer function coefficients are given by Eq. (32).

5.0 DATA USED IN THE STUDY

The soil moisture characteristics required for estimation of infiltration rate have been obtained from the experimental results of Sonu (1973). The variation of capillary pressure, (h_c), with the volumetric soil moisture content (θ), and relation of capillary pressure with relative permeability, $k_{rw}(\theta)$, for a silty loam soil are shown in Figs. 1 (a) and 1 (b) respectively.

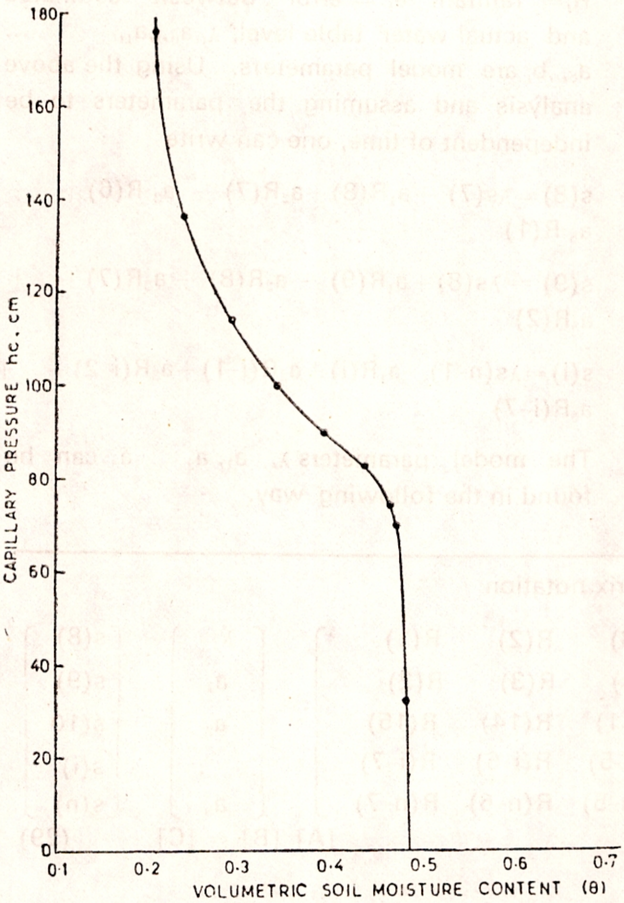

Fig. 1 (a)—Variation of h_c with θ for the silty loam soil

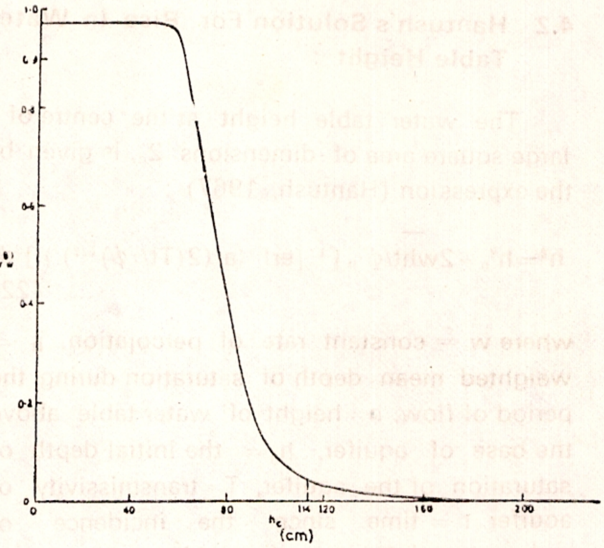

Fig. 1 (b)—Variation ef $K_{rw}(\theta)$ with h_c for silty loam soil

i. The initial soil moisture content θ_r and saturation moisture content $\tilde{\theta}$ are taken to be 0.2425 and 0.485 respectively.

ii. $\tilde{K}$ for the silt loam has been taken as 0.02088 m/hour.

iii. The value of H_f for $\theta_i = 0.2425$ is found to be 0.7711 m.

iv. The rainfall data and depth to water table have been assumed.

6.0 RESULTS AND DISCUSSION

Results have been obtained for three cases of different types of storms. The storms taken are arbitrary. In the first case, four different storms of variable rainfall rate have been taken.

In the second case, a single storm of variable rainfall rate has been repeated four times.

In the third case, a storm of constant rainfall rate has been repeated four times.

The quantity infiltrated, the percentage of rainfall recharged. and percentage of infiltrated quantity recharged for different successive rains have been presented in Table 1. From the table it is seen that for higher initial soil moisture content θ_i the quantity of infiltration is less. But the percentage of infiltrated quantity that joins the water table is higher for higher value of θ_i. At some times the recharge is more than 100% of the current rainfall is being recharged. The time taken by wetting front to reach the water table, which has been assumed to exist at a depth of 5 m, varies from about 10 hours to 24 days depending upon the rainfall intensity and initial soil moisture content, Thus the time lag between rainfall and water table rise would vary considerably depending on the initial soil moisture content.

Table 1 — Percentage of total rainfall and cumulative infiltration that goes as recharge and time to reach water table

Case	Storm No.	Initial soil Moisture Content (θ_i)	Total Rain (m)	Quantity Infiltrated (m)	% of rainfall recharged	% of infiltration recharged	Time to reach water table (hrs.)
I	1	.2425	.42	.3528	1.36	1.62	585.31
	2	.3119	.43	.3326	18.14	23.45	64.27
	3	.3628	.175	.1696	73.83	76.18	33.04
	4	.3015	.175	.1750	101.7	101.7	190.87
II	1	.2425	.42	.3528	1.36	1.62	585.31
	2	.3119	.42	.3253	17.79	22.96	66.44
	3	.3620	.42	.3030	57.21	79.31	20.54
	4	.3746	.42	.3015	74.52	103.81	14.79
III	1	.2425	.48	.4350	2.73	3.01	309.09
	2	.3269	.48	.4012	34.96	41.82	32.34
	3	.3736	.48	.3750	85.85	109.89	10.14
	4	.3661	.48	.3797	75.46	95.39	12.55

Case I — Different storms of varying rainfall rate

Case II — Same storm of varying rainfall rate repeated

Case III — Same storm of constant rainfall rate repeated

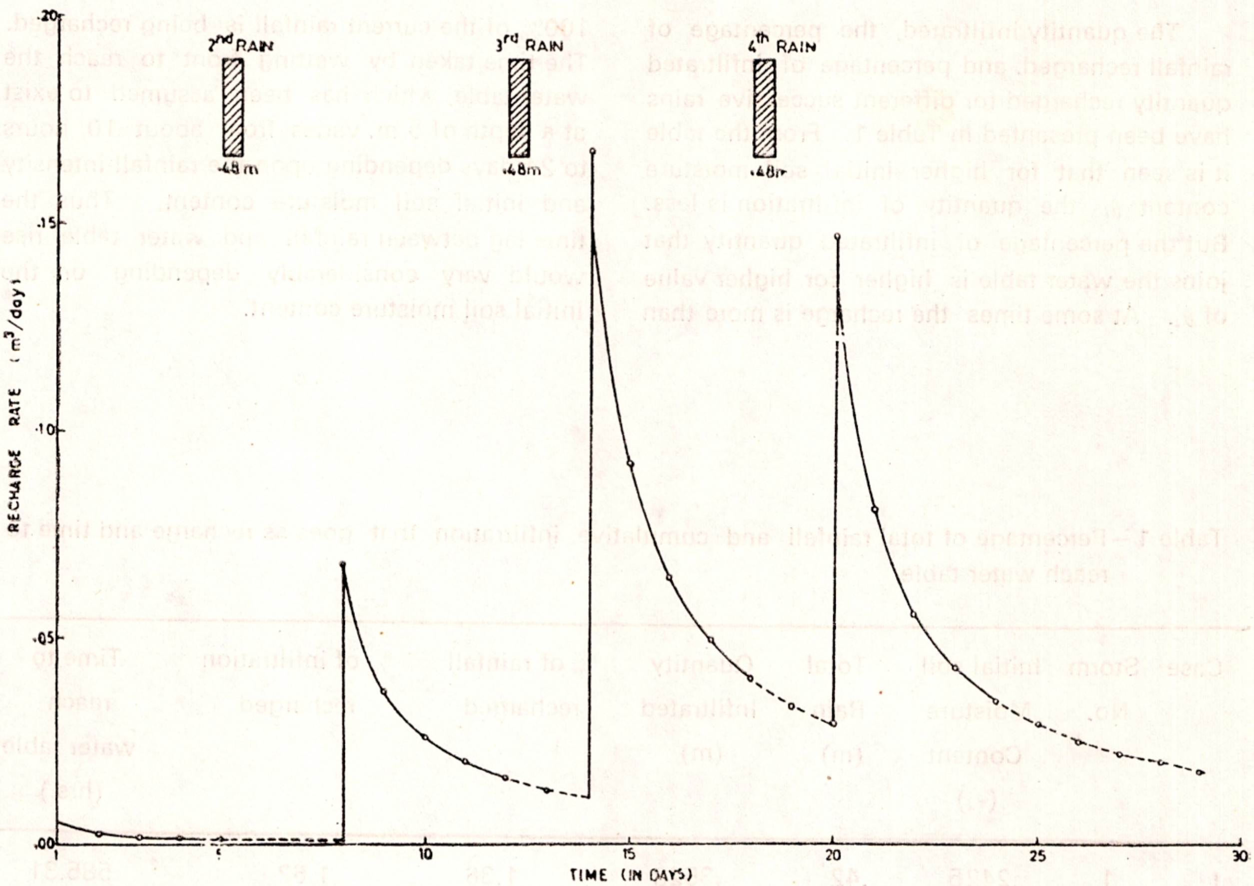

Fig. 2 : Variation of ground water recharge with time subsequent to occurrence of same storm of constant intensity.

Continuous variation of recharge with time during storm and inter storm periods is shown in Fig. 2.

The daily recharge values have been computed for the three cases of rainfall events and are resented in Teble 2. The water table rise at the centre of a square of 1000 m × 1000 m has been computed consequent to these recharge using Hantush's solution for aquifer parameters T = 1000 m²/day and $\phi = 0.2425$

The water table rise is also calculated using the statistical method. As there will be a time lag between the occurrence of rainfall and the consequent recharge, eq. (27) is modified to

$$s = \lambda s_{i-1} + a_1 R_{i-3} + a_2 R_{i-4} + \ldots\ldots + a_8 R_{i-10} \quad \ldots(33)$$

The increase in water table rise due to rainfall recharge on any day would be $h_i - \lambda h_{i-1}$. Therefore recharge rate would be $(h_i . \lambda h_{i-1}) \phi$. The contribution towards this recharge in the i^{th} day by previous rainfall would be determined by the parameters a_1, a_2 etc. The parameters of the statistical method are given in Table 3. Comparison of watet table rise evaluated using actual groundwater recharge and Hantush's solution with those evaluated by statistical method has been given in Table 4.

Table 2—Total recharge at the end of each day

Case	Storm No.	Recharge at the end of				
		1st day	2nd day	3rd day	4th day	5th day
I	1	.0023	.0013	.0009	.0007	.0006
	2	.0317	.0174	.0121	.0093	.0075
	3	.0525	.0289	.0200	.0153	.0124
	4	.0073	.0040	.0028	.0021	.0017
II	1	.0023	.0013	.0009	.0007	.0006
	2	.0304	.0167	.0116	.0089	.0072
	3	.0977	.0537	.0372	.0285	.0231
	4	.1273	.0699	.0485	.0372	.0302
III	1	.0053	.0029	.0020	.0016	.0013
	2	.0682	.0375	.0260	.0199	.0162
	3	.1676	.0920	.0639	.0490	.0397
	4	.1473	.0809	.0561	.0430	.0349

Table 3 – Parameters of the statistical method

Parameter	Case I	Case II	Case III
λ	.9933	.9867	.9663
a_1	.1622	.3390	.4244
a_2	.3178	.2312	,4309
a_3	.1872	.2601	.4123
a_4	.1326	.1988	.3425
a_5	.1004	.1558	.2912
c_6	.0775	.4762	.5904
a_7	.0663	.1652	.6947
a_8	,0232	.4150	.2701

Table 4—Comparison of water table rises evaluated using actual groundwater recharge and Hantush's solution and evaluated by statistical method

Time (hr.)	Case I Hantush solution	Case I Statistical method	Case II Hantush solution	Case II Statistical method	Case III Hantush solution	Case III Statistical method
1	.0231	.0209	.0231	.0207	.0534	.0469
2	.0248	.0230	.0248	.0228	.0572	.0516
3	.0260	.0246	.0260	.0244	.0601	.0553
4	.0270	.0956	.0270	.1714	.3404	.2618
5	.1571	.1635	.1516	.1260	.4936	.5357
6	.2283	.2366	.2197	.2615	.5990	.6749
7	.2772	.2838	.2666	.3022	.6778	.7432
8	.3139	.3186	.3016	.3300	.7383	.7948
9	.3420	.3451	.3285	.5024	.7849	.9969
10	.3637	.3682	.3493	.3952	1.4632	1.0920
11	.3802	.3713	.7465	.5231	1.8267	1.7473
12	.5895	.4061	.9607	.8823	2.0707	1.9720
13	.6999	.6412	1.1055	1.0473	2.2479	2.1989
14	.7726	.7280	1.2116	1.2026	2.2393	2.3367
15	.8244	.7907	1.2912	1.2810	2.4761	2.4390
16	.8618	.8365	1.3506	1.3410	3.0342	2.6762
17	.8884	.8696	1.8499	1.5374	3.3113	3.4693
18	.9067	.8941	2.1081	2.0420	3.4798	3.5363
19	.9183	.9330	2.2741	2.3579	3.5874	3.5606
20	.9246	.9677	2.3885	2.3557	3.6539	3.6311
21	.9270	.9512	2.4676	2.4421	3.6930	3.6707
22	.9263	.9440	2.5204	2.5017	3.7032	3.8492
23	.9239	.9377	2.5530	2.6916	3.6988	3.9120
24	.9200	.9313	2.5698	2.5900	3.6810	3.7040
25	.9240	.9254	2.5744	2.7140	3.6533	3.5572
26	.9147	.9219	2.5695	2.5401		
27	.9005	.9086				
28	.8840	.8945				
29	.8661	.8781				

7. CONCLUSION

It is possible to estimate groundwater recharge by statistical approach, that makes use of water table data monitored in an observation well and the rainfall in the area. Statistical approach does not require the details of the soil moisture characteristics and the soil moisture accounting for estimation of rainfall recharge. In the analytical approach presented in this report, the recharge is to be estimated by Green and Ampt equation and it is to be verified by comparing the consequent water table rise computed by Hantush method with the actual observation.

From the study it is found that the infiltration that occurs during the earlier rainfalls satisfies the soil moisture deficiencies and the rainfall contributions to groundwater recharge is less than 18% of the precipitation. The later rainfalls contribute more to the groundwater recharge, which is of the order of 57% of the precipitation. However these results are point recharge values predicted for a silty loam soil.

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