Studies on groundwater recharge through surface drains

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Abstract

A mathematical model is developed for the estimation of groundwater recharge through surface drains for both free flow as well as detained flow conditions. The Dupuit-Forchheimmer equation is solved using the Crank-Nicolson central finite difference scheme, to obtain the mound height matrix. The Gaussian elimination method was used to solve the matrix, to obtain the mound height at different radial distances across the drain. Various hydrogeological parameters like hydraulic conductivity, specific yield, etc. are determined by field investigations. Surface runoff available due to a particular rainfall event is correlated with recharge rate available in the drain. The model gives volume of water recharged for various rainfall events under different antecedent moisture conditions for both free flow and detained flow conditions. The value of recharge rate computed by using the model for a particular depth of flow in the drain is matched with the observed values. The model is more sensitive to change in the value of specific yield than hydraulic conductivity.

Keywords: finite difference model, groundwater recharge, surface drain, water table

List of symbols

a	=	area of cross-section of flow at any z (m)
A_x	=	1 for zone (1) and 0 for zone (2)
b	=	average bed width of drain (m)
drl	=	total drain length (km) = 12 km
D	=	L/2
e	=	specific yield of the aquifer
h	=	height of the water table above the base of the aquifer after the incidence of recharge. h is termed as h_1 in Zone 1 and h_2 in Zone 2
h_o	=	depth of water table above impermeable layer
i	=	0,1,2……. n for $i\Delta x \le L$
IR_z	=	infiltration rate along the drain bed (m/s)
j	=	0,1, 2……n for $j\Delta t \le 24$ hr
K	=	hydraulic conductivity of the aquifer
L	=	radius of influence along radial distance from drain, at which recharge volume is assumed to meet initial water table
n_d	=	Manning's roughness coefficient which depends upon surface roughness of drain
	=	0.03
p(z,t)	=	time varying recharge rate(m^3/s), defined as recharge volume rate per unit area receiving it
$q_{z,t}$	=	net discharge in drain at any longitudinal distance z and at any time instant t (m^3/s)
	=	$q_p - SL_z$
	=	$q_p - IR_z*(b + 2\sqrt{2}y(z,t))*z$
q_p	=	peak flow rate for longitudinal distance z (m^3/s)
$q_{o(m)}$	=	discharge (m^3/s) as overflow from m^{th} pool into $(m+1)^{th}$ pool
q(z,t)	=	area under the mound curve at any longitudinal distance z and time t
Q(t)	=	volume recharged along the drain at any time t (m^3)
r	=	$\Delta t/(\Delta x)^2$
R	=	hydraulic radius at any z (m)
s	=	height of groundwater mound above the initial water table after the incidence of recharge. s is termed as s_1 in Zone 1 and s_2 in Zone 2
s_o	=	slope of drain (m/m)
	=	0.000314
SL_z	=	seepage losses upto distance z in drain(m^3/s)
	=	0 at z = 0.
	=	IR_z*wp_z*z
t	=	time since incidence of recharge
T	=	top width of drain (m)
wp_z	=	wetted perimeter at distance z
	=	$IR_z(b + 2\sqrt{2}y)z$
x	=	radial distance across the centre of drain (m)
y(z,t)	=	depth of flow in drain at any time t (m)
y_o	=	initial depth of flow
$y_{m,j}$	=	depth of flow at m^{th} pool and at time node j (m)
z	=	longitudinal distance along drain (m)
Δx	=	radial distance step
Δz	=	longitudinal distance step
Δt	=	time step i.e. time difference between two nodes along t- axis
α	=	h_o/e

Introduction

The over-exploitation of groundwater resources is posing a serious problem of declining water tables, which have been declining at an average rate of 0.23 m/a during the past 15 years almost all over the Punjab State, India (Gupta et al., 1995). This situation of a declining water table can be handled by one of the methods of artificial groundwater recharge. It has been assessed that 0.5 m ha-m surplus runoff is available for recharge in Punjab State. The 7 000 km length of surface drains available make the drains an attractive tool for recharging this surplus runoff, which usually goes waste during monsoons. Therefore a mathematical model simulating the hydraulics of groundwater

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