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Design of drains for available surface water and assessment of groundwater for a Chak of IGKV Farm, Raipur

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Abstract
With the advancement of drilling technology along with assured availability of electricity ground water extraction for irrigation started increasing. The current study carried out at research farm of Raipur campus of Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh facing the same problem. Study is performed with the aim to increase the utilisation of available surface water in the study area carried by diversion canal from one diversion structure (called *Bharri dam*) constructed on the rivulet in the study area (called *Chhokranala*). Actual carrying capacity of the diversion canal and other 6 drains in the study area was worked out on the basis of their existing dimensions and grades. Required discharge required to be carried out by the diversion canal and other six drains were also worked out on the basis of drainage coefficient. Based on the comparison of required discharge capacity with actual discharge capacity revised dimensions were proposed to drain out the study command quickly during the heavy rainfall. Total annual ground water recharge from the study area was assessed as 4,01,880 m^3, which is sum of ground water recharges through infiltration, return flow due to surface irrigation by diversion canal, return flow due to bore well irrigation and recharge from tank/ponds (67,500 m^3, 1,41,800 m^3, 1,86,400 m^3 and 6,180 m^3 respectively).

Keywords: Surface water, groundwater, drain design, drainage coefficient and chak

1. Introduction
Ground Water is the backbone of India's agriculture and drinking water security in urban and rural areas. Nearly 90% of rural domestic water use is based on groundwater while 70% of water used in agriculture is pumped from aquifers. Increasing evidence points to the fact that 50% of urban water usage is groundwater. Without water management the ground water level is decreasing day by day, the lack of rains, surface water is decreasing also. It means the volume of water on earth and its level is down day by day. Groundwater is also vital for the industrial sector in a large portion and if left unregulated may lead to critical inter-sectoral conflicts. Hence progress in both agriculture and industry is affected on how India is able to manage her groundwater resources.

A critical groundwater crisis prevails currently in India due to unnecessary over-extraction and groundwater pollution covering nearly 60 percent of all districts in India and posing a risk to drinking water security of the population. In addition to over-extraction and biological and chemical pollution, surplus groundwater and water logging is also a serious problem in many regions, impacting livelihood security of large sections of society. For increasing agriculture production appropriate water management practices are required by optimum use of precipitation or surface water to reduce the over exploitation of ground water and to stop the depletion of ground water table, we have to maximize the use of surface water during rainfall and convey the water through the canal or open channel. Keeping all these points in the mind, the present study was conducted at IGKV farm.

2. Material and Methods

2.1 Study Area

The study was carried out in IGKV Farm situated in Raipur district in 81° 41′ 31″ to 81°42′ 45″ E longitude and 21° 13′ 58 ″ to 21° 14′ 16″ N Latitude at elevation of 290-293 meter (MSL). Area of IGKV Farm is 100 ha which comes under Sub-tropical region of Chhattisgarh shown in Figure 1. It has annual rainfall 1202 mm. Study is performed for existing cropping pattern and on one main diversion canal and other 6 drains which is source of surface water available for irrigation cum drainage. Some places face problem of water logging which may require proper drainage system.

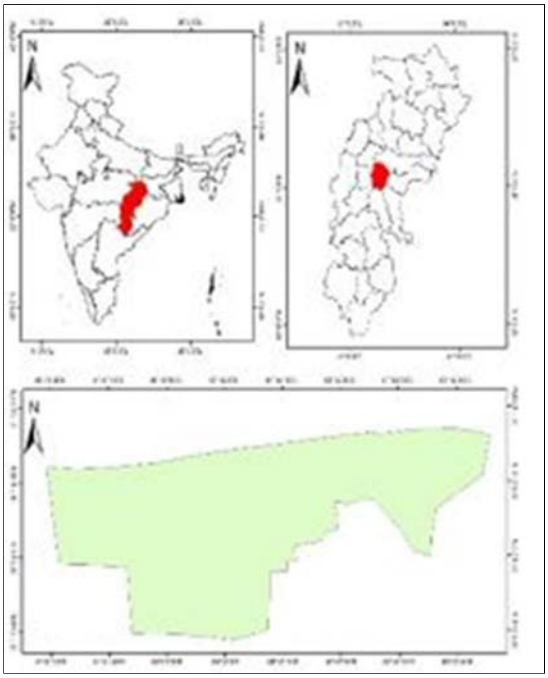

Fig 1: Location map of study area

2.2 Design of Parabolic Channel

Study area consists of one main diversion canal and respective 6 drains. To calculate their carrying capacity formula of natural grassed waterways. For design of grassed waterways, required various geometric characteristics such as cross-sectional area, it was taken in every 120 m along the length. Formula of grassed waterway Shown in the Table 1.

Table 1: Formula for grassed water way (Suresh, R., 2011) [11]

Area (A, m²)	Wetted perimeter (P, m)	Hydraulic Radius (R, m)	Top Width (T, m)
$\left(\frac{2}{3}\right) t.d$	$t + \left(\frac{8d^2}{3t}\right)$	$\frac{A}{P}$	$t\left(\frac{D}{d}\right)^{\frac{1}{2}}$

Where, t= Actual top width, m
d= Average depth, m and
D= Maximum depth, m

2.3 Manning's equation

The flow velocity is obtained by using the equation dividing the discharge with cross sectional area of channel after it's checked by manning's equation that shown below.

$$V = \frac{\left(S^{\frac{1}{2}}.R^{\frac{2}{3}}\right)}{n}$$

Where, V= Flow velocity (m/s)
S= Slope (m/m)
R= Hydraulic Radius (m) and
n = Roughness Coefficient

Table 2: Roughness coefficient for grassed waterway (Suresh, R., 2011) [11].

Description	N
Very long grass	0.02-0.06
Long grass	0.04-0.15
Medium grass	0.03-0.08
Very short grass	0.03-0.06

2.4 Drainage Coefficient

It is the design capacity of drainage system and is typically expressed as a depth of water removed in 24 hours (mm/day) for paddy and 12 hr for horticulture crop. It will be chosen that will economically remove excess water from the top part of the root zone within 24 to 48 hours. Calculated by following formula-

$$DC = Rainfall * Runoff$$

Total volume of water discharge(m^3) = DC * Area
Total volume of water discharge (m^3/sec) = Total volume of water discharge (m^3)/24*60*60

2.5 Ground water Assessment

In the IGKV farm, 21 bore wells are existing groundwater sources for irrigate to fields and domestic uses in the colony and office purposes out of which 12 are exclusively used for irrigation purpose shown in figure 2. For groundwater assessment we have required rainfall data from last 30 years and also electricity bill of last 12 months.

Fig 2: Location map of Bore wells

2.5.1 Rainfall infiltration factor method-

It is recommended to compare the rainfall recharge obtained from water level fluctuation approach with that estimated using rainfall infiltration factor method. Recharge from rainfall is estimated by using the following relationship –

$$R_{rf} = RFIF * A * \frac{R - a}{1000}$$

Where, Rrf = Rainfall recharge, ha-m
RFIF = Rainfall Infiltration
A = Area, ha

2.5.2 Recharge due to bore wells
Recharge due to applied ground water irrigation is estimated based on the following formula and value of return flow factor is shown in Table 3.

$$R_{GW1} = GD_1 * RFF$$

Where,
R_{GW1} = Recharge due to applied ground water irrigation, Mm^3
GD_1 = Gross Ground Water Draft For Irrigation, lit
RFF = Return flow factor

Table 3: Norms of Return flow from irrigation as recommended by GEC 1997 (Anonymous 2017) [1].

Source of irrigation	Type of crop	Water table below ground level		
		<10m	10-25	>25
Ground water	Paddy	25	15	5
Surface water	Non-paddy	30	20	10
Ground water	Paddy	45	35	20
Surface water	Non-paddy	50	40	25

2.5.3 Gross ground water draft
Study area consist various bore wells used for irrigation; among them 5 pumps are used for computation of ground water draft. To calculate it we have required electricity bill of 12 months, discharge of pumps and catchment area of pump and cropping pattern. The norm used for computing ground water draft is the unit draft. Pumping is being done in various seasons and number of such days during each season. The Unit Draft during a particular season can be computed using the following equation-

Unit Draft= Discharge in (m^3/hr.) * No. of Pumping hrs in a day * No. of days

2.5.4 Recharge due to canal
Recharge due to canals is to be estimated based on the following formula and recommended value of seepage factor shown in Table 4.

$$R_c = WA * SF * Days$$

Where, R_c = Recharge from Canals, Mm^3
WA=Wetted Area, (Wetted Perimeter X Length of Canal Reach), Mm^3

SF= Seepage Factor

Table 4: Norms for recharge due to seepage from canals (GEC 1997) (Anonymous 2017) [1].

Formation	Canal Seepage factor ham/day/million square meters of wetted area		
	Recommendation	Minimum	Maximum
Unlined canals in normal soils with some clay content along with sand	17.5	15	20
Unlined canals in sandy soil with some silt content	27.5	25	30
Lined canals in normal soils with some clay content along with sand	3.5	3	4
Lined canals in sandy soil with some silt content	5.5	5	6
All canals in hard rock area	3.5	3	4

2.5.5 Recharge due to Tanks/Ponds
Recharge due to Tanks &Ponds is to be estimated based on the following formula:

$$R_{TP} = AWSA * N * RF$$

Where, R_{TP}= Recharge due to Tanks & Ponds, Mm^3
AWSA = Average Water Spread Area, ha
N = Number of days Water is available in the Tank/Pond
RF = Recharge Factor

2.5.6 Total ground water recharge
It is the sum of all ground water recharge through different source

$$\text{Total GW recharge} = R_{rf} + R_{GW1} + R_C + R_{TP}$$

3. Results and Discussion
3.1 Design of drains for available Surface water
3.1.1 Determination of Drainage coefficient
Drainage coefficient is used to calculate the required discharge carrying capacity of main canal and other six drains of the study area. In this present study, 10 years of rainfall data was analysed, from which average rainfall of 10 years was worked out as 1251 mm and one-day peak rainfall was worked out as 278.6 mm. The runoff produces for paddy land, horticulture crop and urban area are considered to be 74%, 58%, 98% respectively (Kim *et al.*, 2014) [7]. The required discharge rate of main canal and the rest of six drains is shown in the Table 5, catchment area of drains shown in figure 3.

Fig 3: Location map of drains

Table 5: Required discharge rate of drains

Drains	Rainfall (m)	Runoff (%)	DC(m)	Total volume of water discharge(m^3)	Required discharge rate (m^3/sec)
Main canal(i)	0.2786	74	0.206	19871.735	0.229
Main canal(ii)	0.2786	74	0.206	44561.317	0.515
Main canal(iii)	0.2786	74	0.206	90450.744	1.046
1	0.2786	74	0.206	24689.582	0.285
2	0.2786	74	0.206	29658.959	0.343
3	0.2786	74	0.206	16230.467	0.188
4(i)	0.2786	58	0.161	9615.617	1.969
4(ii)	0.2786	98	0.273	75465.758	1.746
4(iii)	0.2786	98	0.273	54374.891	1.258
5	0.2786	58	0.161	9454.998	0.218
6	0.2786	98	0.273	8747.817	0.101

3.1.2 Actual Carrying capacity of drains
The Study area consists of main diversion canal and 6 drains, the cross-section of these drains was measured at every 120m along the length of the drains. To calculate the carrying capacity of drains (parabolic shaped), the natural grassed water way formula has been used. The actual carrying capacity of existing drains is shown in Table 6.

Table 6: Actual Carrying capacity of existing drains

Drains	Top width (m)	Depth (m)	Area (m^2)	Perimeter (m)	Hydraulic radius (m)	Velocity (m/sec)	Actual carrying capacity (m^3/sec)
Main canal(i)	1.72	0.459	0.526	2.686	0.196	0.344	0.181
Main canal(ii)	2.75	0.418	0.766	4.031	0.190	0.321	0.246
Main canal(iii)	2.98	0.466	0.925	4.705	0.196	0.440	0.407
1	1.73	0.331	0.381	2.235	0.170	0.551	0.210
2	1.95	0.387	0.503	2.730	0.184	0.301	0.151
3	1.184	0.216	0.170	1.331	0.128	0.295	0.050
5	2.164	0.338	0.487	2.823	0.172	0.684	0.334
6	1.184	0.216	0.170	1.331	0.128	0.560	0.095
4(i)	3	0.35	0.7	3.98	0.175	0.635	0.444
4(ii)	1.8	0.48	0.576	2.90	0.198	0.626	0.360
4(iii)	2	0.47	0.626	3.17	0.197	0.508	0.318

3.1.3 Design of drains
To design the main canal and the 6 respective drains, the actual carrying capacity and required carrying capacity of drain calculated above are compared. After comparison it is clear that the required carrying capacity of most of the drains was found to be more than the actual carrying capacity except drain 5. In order to get the sufficient carrying capacity, the new dimensions have been proposed, which are shown in the Table 7.

Table 7: Proposed dimension of drains

Drains	Existing Dimensions (m)		Actual Carrying capacity (m^3/sec)	Required carrying capacity (m^3/sec)	Proposed dimensions (m)	
	Top width	Depth			Top width	Depth
Main canal(i)	1.72	0.459	0.181	0.229	1.9	0.52
Main canal(ii)	2.75	0.418	0.246	0.515	3.22	0.72
Main canal(iii)	2.98	0.466	0.407	1.046	5	0.72
1	1.73	0.331	0.210	0.285	Sufficient	0.42
2	1.95	0.387	0.151	0.343	2.3	0.70
3	1.184	0.216	0.050	0.187	1.8	0.42
4(i)	3	0.35	0.444	1.969	5.13	0.85
4(ii)	1.8	0.48	0.360	1.746	5	0.85
4(iii)	2	0.47	0.318	1.258	4.45	0.85
5	2.164	0.338	0.333	0.218	Sufficient	Sufficient
6	1.184	0.216	0.095	0.101	Sufficient	0.23

3.2 Assessment of Groundwater
3.2.1 Total annual Ground water recharge
Annul recharge through different sources in IGKV farm was estimated by following the norms suggested by Ground Water Estimation Committee (GEC-1997) and modification suggested by GEC in 2015.Ground water recharge calculated through infiltration method for the study area was 67500m^3, ground water recharge due to canal was141800m^3, recharge due to bore wells irrigation calculated based on ground water draft was 186400$m^3$and recharge due to tank/ponds irrigation was 6180m^3. Total annual ground water recharge (GWR) for study area was found to be 401880m^3. Parameters used in formula are showing in Table 8.

Table 8: Parameters used in GWR calculation

Ground water Recharge due to	Parameter	Values
Infiltration method	RFIF (infiltration factor-LT01)	6%
	Area	100, ha
	Normal annual rainfall	1251.43, mm
	Threshold of annual rainfall	125.143, mm
Canal	Wetted area	6589.8, m²
	Seepage factor	17.5, ha-m/days-Mm³
	No. of Days	123
Bore wells irrigation	Return flow factor	Paddy -35% Non-paddy-15%
Tank / Ponds	Average wetted spread area	2.4 ha
	No. of days available water in tanks/pond	184
	Recharge factor	1.4 mm/day

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