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NK Thakur
M.Tech. Student, Department of Soil and Water Engineering, SV College of Agricultural Engineering and Technology and Research Station Faculty of Agricultural Engineering Indira Gandhi Krishi Vishwavidyalaya Raipur, Chhattisgarh, India

D Khalkho
Assistant Professor, Department of Soil and Water Engineering, SV College of Agricultural Engineering and Technology and Research Station Faculty of Agricultural Engineering Indira Gandhi Krishi Vishwavidyalaya Raipur, Chhattisgarh, India

P Katre
Assistant Professor, Department of Soil and Water Engineering, SV College of Agricultural Engineering and Technology and Research Station Faculty of Agricultural Engineering Indira Gandhi Krishi Vishwavidyalaya Raipur, Chhattisgarh, India

PK Jamrey
Subject Matter Specialist, Krishi Vigyan Kendra, IGKV, Gariyaband, Chhattisgarh, India

RK Mishra
Rural Agriculture Extension Officer, Department of Agriculture Development and FWBT, Government of Chhattisgarh, India

Corresponding Author:
PK Jamrey
Subject Matter Specialist, Krishi Vigyan Kendra, IGKV, Gariyaband, Chhattisgarh, India

Design of drainage network of the IGKV farm, Raipur, Chhattisgarh

NK Thakur, D Khalkho, P Katre, PK Jamrey and RK Mishra

Abstract
Study area has been divided into 34 blocks and drainage planning was done. CN- method was used to arrive at runoff volume which was converted into drainage coefficients. Drains were designed to carry these drainage volumes safely and quickly from the blocks to the outlets. To meet out the shortage of water during critical dry spells experienced during crop growth period, 4 Lift Irrigation Schemes (LIS) were proposed in the study to utilize the available flows in the rivulet during *Kharif* period and also during the initial phase of *Rabi* crop. Besides this surface water utilization was proposed to be increased by repair and maintenance of the existing diversion canal of Bharri Dam. Peak carrying capacity of the diversion canal was worked out to be 85 lps and the irrigation command of it is 32.5 ha. It was found that there are 42 no. of bore wells in which 32 is working and 10 bore wells is not working. The average discharge and water level fluctuation for 5 year period was found to be 5.8 lps and 12.35 m respectively. The potential of water resources was estimated. The available surface water and ground water during study period was found 0.71 MCM and 0.50MCM.

Keywords: drainage, *Rabi* crop.

Introduction
Water is the most precious gift of nature. Drainage is the artificial application of removal excess water from land. Some land requires drainage before it is possible to use it for any agricultural production; other land profits from either practice to increase production. Some land of course does not need either. Although either practice may be or both often are used for nonagricultural purposes to improve the environment, this article is limited to their application to agriculture. Water productivity can be improved by choosing well-adapted crop types, reducing unproductive water losses and maintaining healthy, growing crops through optimized water, nutrient, agronomic management, irrigation and drainage plan.
In general, improving agricultural water productivity, thus freeing up water for ecosystem functions, can be achieved by creating synergies across scales and between various agricultural sectors and the environment, and by enabling multiple uses of water and equitable access to water resources for different groups in society. Investigating and explaining the irrigation and drainage management indicators and their ability to define the status of a system to the system users is important. This applies to the Irrigation and drainage network systems in India. Without a proper understanding of the concept and relevance of such indicators, strengthening the network infrastructure with more and more interventions will not succeed in getting the desired benefit from such networks. This paper presents definition, measurement and practical application of water productivity. It is also widely accepted fact that there is no substitute for irrigated agriculture in terms of its production volume and drainage has a role to play here. The slogan of engineering science "No irrigation without drainage" can be extended: no sustainable agriculture without drainage.

Materials and methods
Study Area: Raipur district in located under the agro-climatic zone “Chhattisgarh plains” in the state of Chhattisgarh. The study area (IGKV farm Raipur) is situated 7 km away from Raipur district on Mahasamund road. The IGKV Raipur situated in 81° 41′ 20″ to 81 °43′ 15″ E longitude 21° 13′ 35″ to 21° 14′ 15″ N Latitude at elevation is 285-295 meter (MSL) and area of IGKV is 200 ha and Climate is Sub-tropical, annual rainfall recorded (yearly) 1064.7mm. The exact location of study site is depicted in Fig.

Agro climate: Chhattisgarh state has been divided into three Agro-climate zones namely Chhattisgarh plains, Baster Plateau and Northern hill zone covering 51.0%, 28.0% and 21.0% of the geographical area, respectively as per NARP classification.

Chhattisgarh plain is the largest agro-climatic zone of the state covering 16 districts out of 27. The climate is sub-tropical characterized by extreme summer from March to May the study area comes under sub-tropical type of climate. Due to high rainfall and proximity to Eastern coast the climate remains *sub humid* for about five months. On the basis of rainfall and temperature the year may be divided into three distinct season's namely rainy season from June to October, winter season from November to February and summer season from March to June.

Land use and cropping pattern: The total area of IGKV farm Raipur where study was conducted was 200 ha. The gross cropped area in IGKV farm Raipur was 136 ha which 68% of the total geographical area. The net sown cropped area was 117 ha which 58.5% of the total geographical area. Area sown more than once area was 115 ha which 57.5% of the total geographical area. During *Kharif* season crops were grown in 95 ha and in *Rabi* season crops were grown in 89 ha only.

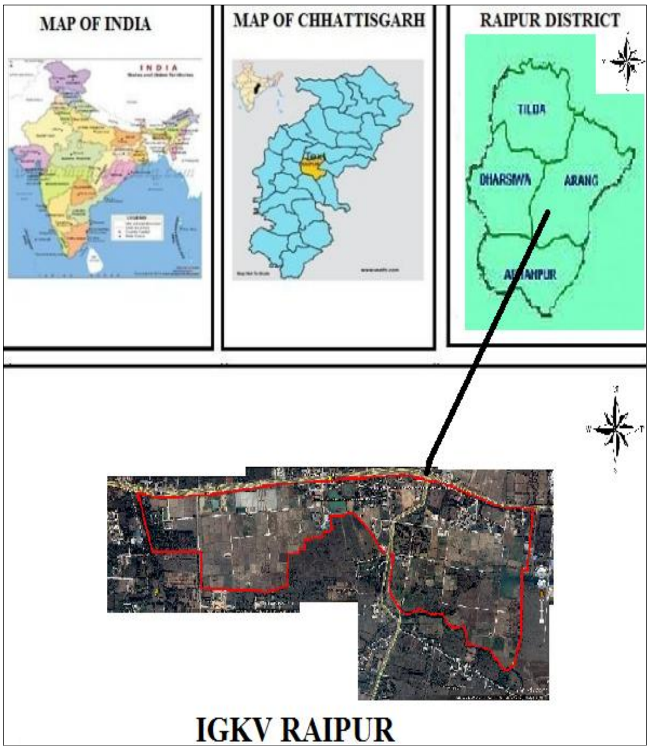


Fig 1: Location Map of the Study Area

Recharge from rainfall: For the purpose of recharge assessment using water level fluctuation method the monsoon season may be taken as May/June to October/November for all areas. Due to less demand for groundwater in view of adequate moisture in the soils, the resources available during this period are not fully utilized. Therefore it is 38 recommended that the groundwater recharge may be estimated on pre-monsoon (May/June) to post-monsoon (October/November). This is the dynamic groundwater which is available for us. Here groundwater recharge is estimated by using water level fluctuation method. Adequate data on groundwater level fluctuation were collected from Central Ground Water Board, (NCCR) Raipur. The change in storage was computed from the following equation:

$$S = A \times h \times Sy \quad \ldots 1$$

Where, S = change in storage m^3
A = area of the site (ha)
h = change in water level (m)
Sy= specific yield

The geological formation of the study area is limestone dolomite. The value of specific yield recommended by GEC (2006) for limestone formation is 3%.

Water Resources Development Plan: Water resource development plan has been prepared on the basis of integration of information on hydro geo-morphological characteristics, surface water availability, land use/cover, drainage, present status of ground water utilization and considering the present and long term needs of water in the study area. The present water availability in the micro watershed is presented in Table

Table1: Water availability

Water availability	in Mm^3
Rainfall volume	2.73
Runoff volume	0.71
Net ground water available	0.50

Calculation of discharge of canal (*Tar*): The amount of water passing a point on the stream channel during a given time is a function of velocity and cross-sectional area of the flowing water.

$$Q = A \times V \quad \ldots 2$$

Where, Q is stream discharge (m^3/sec), A is cross-sectional area (m^2) and V is flow velocity (m/sec).

Velocity measurement
Material required:-

- Tape measure
- Stop-watch
- Rod, yard or meter stick to measure depth
- At least three highly visible buoyant objects such as a drifting branches or logs, pine cone, coffee stir sticks, half filled bottles, or oranges (objects buoyant enough not to be effected by the wind)

Float method
This method measures surface velocity. Mean velocity was obtained using a correction factor. The basic idea is to measure the time that it takes the object to float a specified distance downstream.

$$V_{surface} = \text{travel distance/ travel time} = L/t$$

The surface velocities are typically higher than mean or average velocities.

$$V_{mean} = k\, V_{surface}$$

Where, k is a coefficient that generally ranges from 0.8 for rough beds to 0.9 for smooth beds (0.85 is a commonly used value)

Step 1 Choose a suitable straight reach with minimum turbulence (ideally at least 3 channel widths long).
Step 2 Mark the start and end point of reach.
Step 3 If possible, travel time should exceed 20 seconds.

Step 4 Drop the object into the upstream of marker.
Step 5 Start the watch when the object crosses the upstream marker and stop the watch when it crosses the downstream marker.
Step 6 Repeat the measurement at least 3 times and use the average in further calculations.
Step 7 Measure stream's width and depth across at least one cross section where it is safe to wade. If possible, measure depth across the stream's width at the start and stop markers and average the two but if measuring one cross section choose the downstream side. Use a marked rod, a yard or meter stick to measure the depth at regular intervals across the stream. Ten depth measurements is the minimum required but more is better, especially in larger streams. Or another method, walk heals to toe, and measure stream depth every left big toe, along the downstream cross section.

Surface runoff estimation: Surface runoff of the watershed was estimated by using the SCS curve number method, also known as the Hydrologic Soil Cover Complex Method, developed by the Soil Conservation Service (SCS) of the U.S. Department of Agriculture for use in rural areas.
As per the developed runoff curve number by USDA, SCS the surface runoff was estimated by the equation:

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)}$$

where, Q is the daily runoff (mm), P is the daily rainfall (mm), S is a retention parameter (mm), I_a is initial abstraction (mm) during the period between the beginning of rainfall 1and runoff in equivalent depth over the catchment, (taken as 0.3S for most of the watersheds in India) and S is the potential maximum retention (mm). The value of S (mm) was calculated by using the following formula:

$$S = 2540/(25.4 + \text{CN})$$

CN is the curve number for average antecedent moisture condition (AMC) II which varies from 1 to 100.

Antecedent moisture conditions: Antecedent moisture condition denotes the sum of proceeding 5 day's rainfall, to current day rainfall, for which the runoff is going to be estimated by curve number method. Antecedent moisture condition is considered as AMC-I, when the sum of previous 5 days rainfall is less than 36 mm, it is considered as AMC-II, when it is between 36 to 53 mm rainfall, and it is under AMC-III when the sum of previous 5 days rainfall was greater than 53 mm during the growing season (monsoon period). The available readymade tables gives curve number values for AMC-II, which was converted to the respective antecedent moisture condition AMC-I or AMC-II, prevailed in the watershed on the day in question.

Runoff curve numbers: The runoff curve numbers for monsoon seasons were worked out for hydrologic soil group – B. The present land use/cover was identified as paddy sown area, plantations, and settlements and vegetated land. For antecedent moisture condition II and I_a=0.3S, the weighted curve number for watershed was obtained as 89.1 for hydrologic soil group B which was then converted to AMC-I and AMC-III and found as 77.5 and 96.1 respectively.

Calculation of curve number: Following steps were taken for calculation of curve numbers.
Step I: The size of study area, type of soil and land use in study area was determined and percentage area under various soil hydrologic groups was evaluated.
Step II: The appropriate hydrologic cover complex numbers by interpolation were obtained from standard tables.
Step III: Weighted curve numbers were found out giving due weightage to the area under different land uses.
Step IV: Potential maximum retentions and depth of runoff were worked out
Step V: Depth of runoff was converted in to volume of runoff by following relation

Volume of runoff (m^3) = Runoff (mm) x Drainage area (ha) x 10.

Survey and Mapping of the Study Area
The survey of the study area was made first by moving around the area and marking out the physical features, which delineated its boundaries, based on some land demarcation points as given by old map and generated to contour map with the use of GIS arc map 10.

Topographic survey: After mapping the IGKV farm the next step taken was to conduct topographic survey in order to depict the relief or topography of the study area.
The topography of the area was attempted to be depicted by the contour map of the area. In order to start the grid survey, area was divided into a series of squares of equal size. The elevations of the ground at the corners of the squares were taken with the help of dumpy level. For this the benchmark was selected near the road, the well-identified and rigid point. With reference to this bench mark, all the points in the field as close as 60 m distance were covered up to know their elevations. Thus in contour survey the grid spacing was kept as 60 m. These elevations were then plotted on the map at all the corner points of each square. Contour interval or vertical interval selected for drawing the contour lines was 5 m.

Proposed of Drainage plan
Design of Drainage System: Time required for removal of excess water is 6-8 hours for vegetable crops, 24 hours for general crops, 72 hours for rice crop (Gupta *et al*., 1971) [1-2]. In study area Also to harvest water from the drainage area and storing water harvesting pond, a well-designed drainage system is required. To mitigate the water logging problem, a surface drainage system was designed. The Hydrologic Soil Cover Complex Method was used for estimation of runoff volume to be disposed through the surface drainage system. According to this method, the runoff was estimated by:

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)}$$

Where,
Q = runoff (mm), P = rainfall (mm), S = maximum potential retention (mm)
Analyzing the properties of IGKV Raipur such as the soil type, infiltration rate, hydrologic soil group etc. The design rainfall P was adopted as the 5-year 24-hour rain, which was maximum value of one day 235 mm on analysis of 15years rainfall data (2000-2014). Accordingly, Q of the above equation was found as value. This was converted in to discharge by the excess water removal time. Thus, the designs

discharge from area. In the study area is divided to 34 blocks for drainage then particular design of the drainage line because all drainage line included to diverged canal (Tar) Using this as the design drainage coefficient and adopting Manning's equation for the hydraulic design (with n = 0.016, side slope 1:1), In the channel flow determined as the velocity is fixed (1.2 m/s) because clay loam soil then other value is selected to the design. Dimension data is bed width, depth assuming and top width, cross sectional area, then finally discharge is calculated.
The following dimensions are

Top width = B+2D

Where,
B= bed width (m), D= depth (m)
Cross sectional area A = (T+B)/2 □ D

Where,
B= bed width (m), D= depth (m), T = Top width (m)
Wetted perimeter $P = B + 2D\sqrt{m^2 + 1}$
Velocity $V = \frac{R^{2/3} \times S^{1/2}}{n}$

Where,
R= hydraulic radius (m), S= slope, n = roughness coefficient

Q = A × V

Where,
A = Cross sectional area (m^2)

V = velocity (m/s)

Result and Discussions
The results of the investigations made in IGKV farm Raipur, Raipur along with discussion is presented in this chapter. It also deals with the comparison of the results obtained in this study with the results obtained elsewhere under similar or other conditions with the given set of restrictions. The results and discussion presented in this chapter are confined to the pre-assigned objectives of the study in context of the requirement and mandate of the IGKV farm Raipur. Results obtained after careful analysis are also included in this chapter.

Surface Water: There are few surface water bodies and groundwater bodies being pumped in the study area. Surface water bodies are present in the form of tanks, flowing water in the adjacent stream being stored behind one of the tank locally called *Bharri* dam (T-1) and diverted through diversion works (locally called "*Tar*") to the university fields. Potential water availability in the form of surface runoff that could be harnessed has been assessed in the study.

Water Resource Assessment: The existing availability of water resources of the study area were worked out on the basis of data collected from AICRP on GWU project of SWE, IGKV Raipur. The results obtained through a systematic analysis are discussed.

Surface water assessment: Surface water use and surface water availability from existing surface water structures including surface runoff, is essential to assess the surface water component in this region. With the suitable method and on the availability of data same has been worked out. Runoff from study area.
Volume of water available as runoff in the study area was worked out on the basis of depth of runoff calculated using SCS curve method as explained in chapter 3 the runoff was estimated as 353.3 mm for the study area. For the study area (353.5 mm) considering the land use land cover pattern of the study area.

Runoff volumes available = 0.3535 m X 200 ha
= 70.7 ha-m

Capacity and command of diversion canal ("*Tar*"): Longitudinal sections of the bed and bunds of diversion canal are shown in Figure from the graph available grade were worked out to be 0.1 %. Bund height clearly shows that a space for maximum 60 cm pounding is available with a free board of 15 cm. Calculations for arriving at the carrying capacity of diversion canal.
Calculations showed that carrying capacity of the diversion canal is 45.62 lps. Available flows through diversion canal were worked out by multiplying the discharge carrying capacity of the diversion canal by the number of probable canal operation days (75 days).
Available flows in canal = 0.04562 m^3 x 75 days x 24 hr x 3600 sec
= 0.2956 Mm^3
= 29.56 ha-m

Surface water availability
Total Available surface water = Volume available in water bodies/ Check Dams + Runoff volume available + Available flows in canal
= 16.203 + 70.7 + 29.56
= 116.46 ha-m = 1.165 Mm^3

Net groundwater availability: The net groundwater availability has been computed after deducting the natural discharge from the replenishable groundwater resources as per GEC norm. The net available groundwater was found to be 0.50 Mm^3.

Longitudinal section
This type of leveling is known as longitudinal sectioning. In high way, railway, canal or sewage line projects of the ground along selected routes are required. In such cases, along the route, at regular interval readings are taken and RL of various points are found. Then the section of the route is drawn to get the profile.

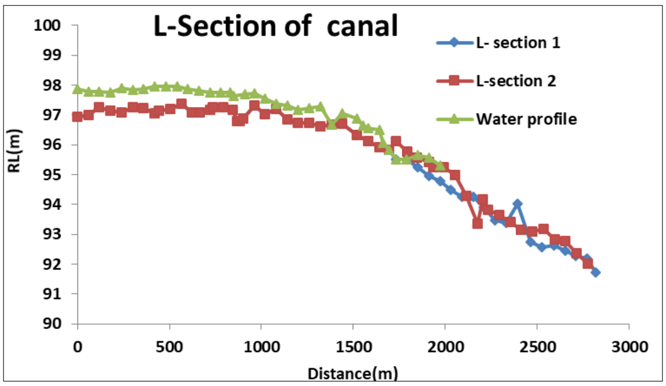
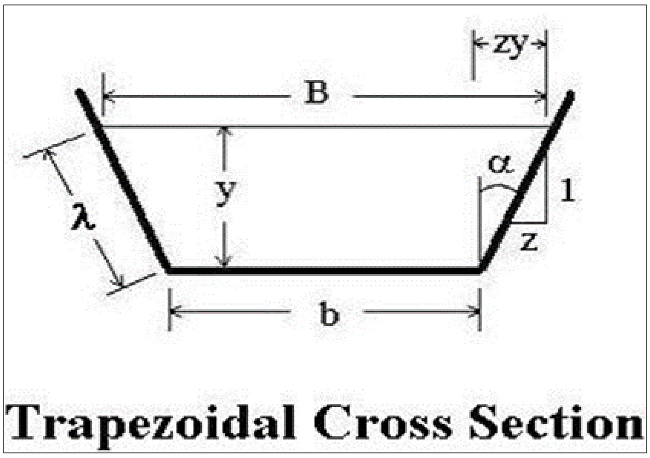


Fig 2: section of diversion canal

Proposed Drainage plan
On the basis of standard methodologies described in materials and methods and dimension of trapezoidal cross section used for drainage design.



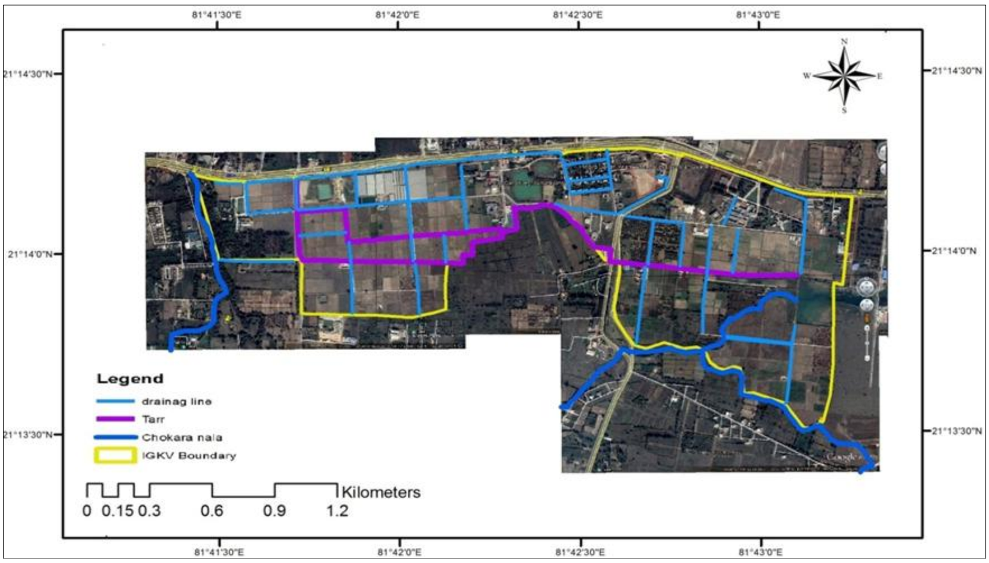


Fig 3: Proposed drainage design plan in study area

Table 2: Dimension of Drainage design

Block	Q (m^3/s) Estimated	B m	D M	T M	A m^2	S Side slope	V m/s	Q (m^3/s) Calculated
1	0.18	0.25	0.3	0.85	0.16	1.1	1.2	0.19
2	0.08	0.16	0.2	0.56	0.07	1.1	1.2	0.09
3	0.22	0.26	0.32	0.90	0.19	1.1	1.2	0.22
4	0.12	0.21	0.25	0.71	0.11	1.1	1.2	0.14
5	0.20	0.26	0.32	0.90	0.19	1.1	1.2	0.22
6	0.21	0.26	0.32	0.90	0.19	1.1	1.2	0.22
7	0.13	0.21	0.25	0.71	0.11	1.1	1.2	0.14
8	0.09	0.16	0.2	0.56	0.07	1.1	1.2	0.09
9	0.16	0.25	0.3	0.85	0.16	1.1	1.2	0.19
10	0.09	0.16	0.2	0.56	0.07	1.1	1.2	0.09
11	0.14	0.21	0.25	0.71	0.11	1.1	1.2	0.14
12	0.21	0.26	0.32	0.90	0.19	1.1	1.2	0.22
13	0.08	0.16	0.2	0.56	0.07	1.1	1.2	0.09
14	0.15	0.25	0.3	0.85	0.16	1.1	1.2	0.19
15	0.13	0.21	0.25	0.71	0.11	1.1	1.2	0.14
16	0.09	0.16	0.2	0.56	0.07	1.1	1.2	0.09
17	0.1	0.21	0.25	0.71	0.11	1.1	1.2	0.14
18	0.15	0.25	0.3	0.85	0.16	1.1	1.2	0.19
19	0.17	0.25	0.3	0.85	0.16	1.1	1.2	0.19
20	0.07	0.16	0.2	0.56	0.07	1.1	1.2	0.09
21	0.16	0.25	0.3	0.85	0.16	1.1	1.2	0.19
22	0.26	0.29	0.35	0.99	0.22	1.1	1.2	0.27
23	0.34	0.33	0.4	1.13	0.29	1.1	1.2	0.35
24	0.22	0.26	0.32	0.90	0.19	1.1	1.2	0.22
25	0.04	0.16	0.2	0.56	0.07	1.1	1.2	0.09

26	0.19	0.25	0.3	0.85	0.16	1.1	1.2	0.19
27	0.08	0.16	0.2	0.56	0.07	1.1	1.2	0.09
28	0.06	0.16	0.2	0.56	0.07	1.1	1.2	0.09
29	0.06	0.16	0.2	0.56	0.07	1.1	1.2	0.09
30	0.14	0.21	0.25	0.71	0.11	1.1	1.2	0.14
31	0.09	0.16	0.2	0.56	0.07	1.1	1.2	0.09
32	0.09	0.16	0.2	0.56	0.07	1.1	1.2	0.09
33	0.13	0.21	0.25	0.71	0.11	1.1	1.2	0.14
34	0.09	0.16	0.2	0.56	0.07	1.1	1.2	0.09

Conclusions

Drainage plan of the study area was prepared successfully with the help of created resource map to relive the area from the water excess by utilizing the proposed drainage canals.

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