ANALYSIS OF RAINFALL DATA AND SOIL PERMEABILITY

A CASE STUDY OF PANCHGANGA RIVER BASIN

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ABSTRACT

In India there are seven major rivers, out of those seven rivers Krishna is one of the major river and Panchganga is the sub-stream of Krishna River. The Panchganga River flows in Kolhapur district which is having 2627.31 km^2 of catchment area. In this area there are eight rain gauge stations. Too much of river water gets percolated in those catchment area so there is a need of study and analysis of rainfall and the infiltration rate in the catchment area. With the help of catchment area calculation, rainfall data, and rate of infiltration we can find out the maximum rainfall, runoff and also the rate of infiltration in the catchment area. From the Panchganga River Basin, it is observed that the Dajipur station have a maximum average rainfall (7647.6mm) while the Wadange station have minimum average rainfall (422.8 mm). There are mainly five types of soils. In this study area the black cotton soil is more in Kasari and Tulshi river catchment area so the infiltration rate is less (9.61 E-06 mm/sec) and runoff is more (56.24 inch) in that area.

Keywords: Rainfall, Catchment area, Rate of infiltration, GIS, ArcGIS 10.2.2

I. INTRODUCTION

Rain is a major component of the water cycle and is responsible for depositing most of the fresh water on the Earth. It provides suitable conditions for many types of ecosystems, as well as water for hydroelectric power plants and crop irrigation. The rainfall is measured by Rain gauge station. The Rain gauge station can be manually or automated. The rainfall intensity is measured in mm.

Soil permeability is the property of the soil to transmit water in the ground. If rate of infiltration is less that is the runoff is more and more quantity of rain water gets added in river. So the river water level increases. If infiltration rate is more that is more water transmit in to ground and runoff is also less. Some time the infiltration rate of soil is more but rainfall intensity is also more at that time the soil gets saturated and rate of runoff increases.

The Panchganga River flows through the borders of Kolhapur. It starts from Prayag Sangam (16^{o}44$^'$04$^{''}$ N, 74^{o}10$^'$44$^{''}$ E) (Village: Chikhli, Taluka: Karveer, Dist: Kolhapur). The Panchganga River flow Prayag Sangam at elevation of 530M and elevation at Narsobawadi is 520M. The Panchganga is formed by four streams, the Kasari, the Kumbhi, the Tulsi and the Bhogawati. Local tradition believes in an underground stream Saraswati which together with the other four streams make the Panchganga. But on Google earth image it shows the Panchganga river starts at Kode Bk (16°38'13'' N, 73°52'37'' E) (Elevation is 590M). The total length of Panchganga River is 133Km. The river flows in a deep bed that is well below 40 feet from the surrounding plain. Further downstream it develops an incised meander-core which includes the Narsobawadi (16°41'22'' N, 74°36'05'' E).

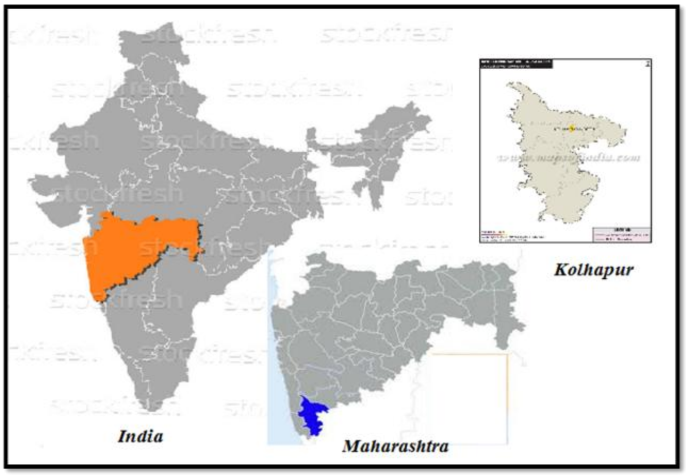

Fig no.1 Study Area Map

II. METHODOLOGY

For this Research work Base map of Panchganga river Basin was generated by using Arc-GIS Software. Rainfall data from year 1966 to 2014 was collected for required study area. The calculation of runoff was done from collected rainfall data. The soil samples were collected from study area and Permeability test was conducted afterwards the results were correlated to runoff and infiltration rate.

III. INVESTIGATION OF PANCHGANGA RIVER

3.1. Digital elevation model (DEM)

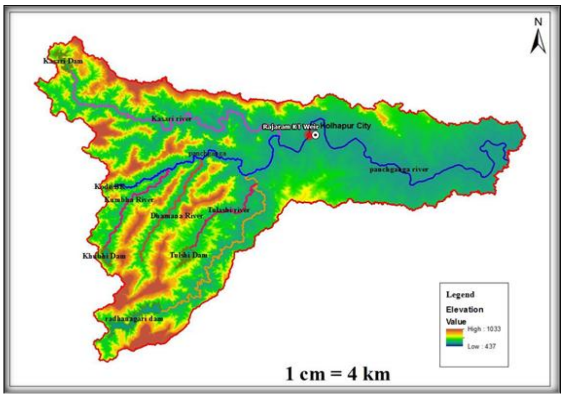

Fig no.2 Digital Elevation Models (DEM) of Study area

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Digital Elevation Models (DEM) are spatial data formats which depict the ground elevation of an area. DEMs have been used for the last two decades in various mapping and multi-disciplinary applications. DEMs depict the elevation of the earth's surface and it is therefore a continuous phenomenon. There are various sources of DEMs and the choice of what type of DEM to use depends on the particular application and the expected accuracy.

3.2. Flow Direction

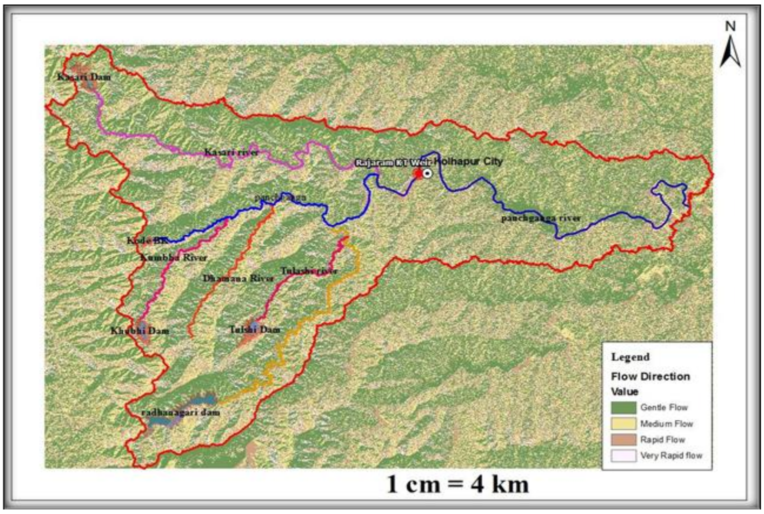

Fig no.3 Flow Direction of Study area

The eight direction pour point model is often used to determine in which direction water will flow. In a given grid cell, water can flow from one or more of its eight adjacent cells. Slope is the ultimate factor which decides how water flows in this model.

3.3. Flow accumulation

The Flow Accumulation tool calculates accumulated flow as the accumulated weight of all cells flowing into each down slope cell in the output raster. If no weight raster is provided, a weight of 1 is applied to each cell, and the value of cells in the output raster is the number of cells that flow into each cell. Cells with a high flow accumulation are areas of concentrated flow and may be used to identify stream channels. This is discussed in Identifying stream networks. Cells with a flow accumulation of 0 are local topographic highs and may be used to identify ridges.

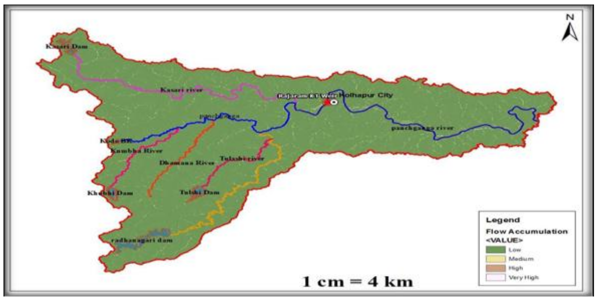

Fig no.4 Flow accumulation of Study area

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3.4. Catchment Area

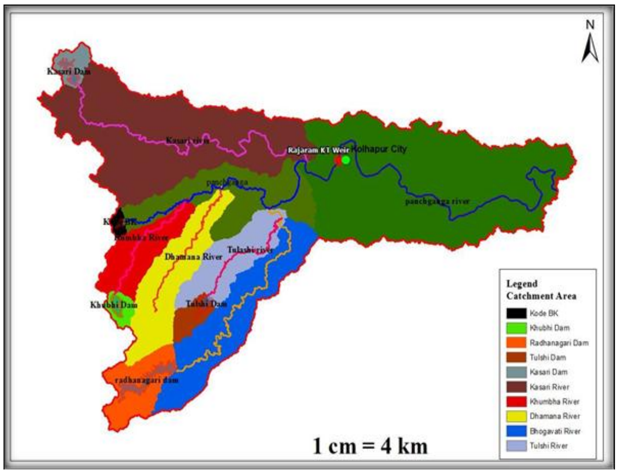

Fig no.5. River Catchment Area

A catchment is defined as the land area that contributes runoff to a given Hydro Edge. In the ArcGIS Hydro Data Model, catchments are intimately associated with the Hydro Edge about which they are formed, and as such are referred to as Edge Catchments. Any raindrop falling on an Edge Catchments and Watersheds Catchment has a unique path to a Hydro Edge and thus to being routed down through the Hydro Network. Edge Catchments are polygon features in the data model.

3.5. Rainfall data, Rain Gauge Station Details and Runoff

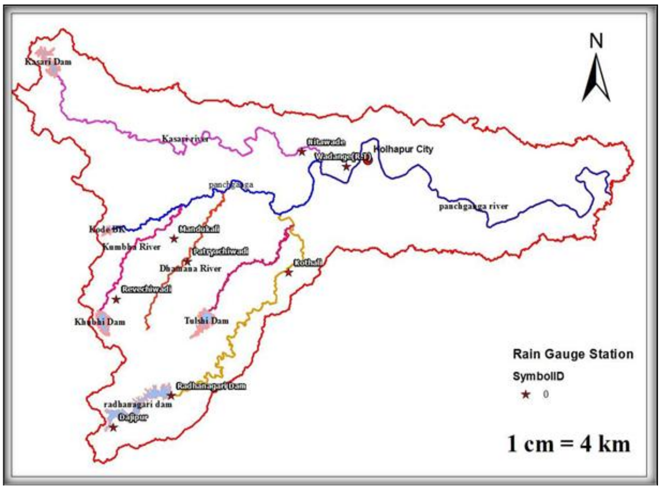

Fig no.6. Location map of Rain gauge Station

3.6. Runoff Calculation

For calculation of runoff Inglis Formula is used. The Inglis Formula is used for western Maharashtra.

$R = 0.85P - 12$

Where, R = Run –off in inches, P = Annual

Rainfall in inches

Ex.1. Dajipur Station

R = (0.85 x 190) – 12

R = 149.58 inches

Table no 1. Annually Rainfall data

Sr.	YEAR	REVYAC	MANDU	DAJIPUR	KOTHAL	PATRYACHI	RADHANAG	WADA	NITWADE
1	1966	1372.5		4825.0	1259.4	2208.6	4350.0	2186.0	
2	1967	4935.8		5015.4	1024.7	2922.6	4927.9	1201.0	
3	1968	3607.5		3836.4	852.0	2160.7	3852.0	425.0	
4	1969	5355.4		5486.4	1548.0	2916.3	4758.5	961.2	
5	1970	6066.5		6663.6	1343.4	2899.8	5207.6	956.6	
6	1971	5387.0		7145.0	926.4	2552.6	4627.2	684.0	
7	1972	3592.6		3939.2	647.2	1740.6	3179.9	422.8	
8	1973	5713.4		6312.0	1051.4	3181.2	5087.0	771.0	
9	1974	5152.3		5613.4	1144.6	2326.0	4019.8	721.8	
10	1975	6673.0		6168.2	1661.8	2944.6	5419.9	787.9	
11	1976	5016.8		5146.8	1319.8	2858.4	4658.0	881.2	
12	1977	5945.6		6074.0	1339.0	3243.4	4571.6	976.6	
13	1978	7175.8		7022.8	1267.4	3493.8	5441.5	1108.9	
14	1979	5340.2		5145.8	1346.6	3425.9	4630.8	856.0	
15	1980	6187.6		6977.6	1406.0	4210.6	5691.7	1202.8	
16	1981	5684.8	3393.09	5840.8	1257.0	2869.4	4806.0	1257.0	
17	1982	5732.7	3817.7	6018.4	1221.1	2769.2	4802.1	916.4	
18	1983	6502.2	4495.1	7598.4	1464.2	2964.0	5098.2	1000.0	
19	1984	5329.6	3888.8	5658.6	1080.4	2349.8	4364.0	700.8	
20	1985	5165.0	3535.0	6134.0	1051.0	1983.2	4229.6	713.6	
21	1986	3881.0	3672.0	622.2	892.0	2430.0	3644.0	523.2	
22	1987	4128.9	3087.6	4863.2	779.2	1735.0	3069.0	726.5	
23	1988	5013.6	4013.8	5236.3	804.6	2545.0	3919.1	1036.6	
24	1989	5038.6	3735.4	5299.8	825.8	2374.5	4011.2	669.1	
25	1990	6113.1	4933.5	6048.0	737.6	2934.5	5011.4	905.6	
26	1991	5219.7	4876.6	5864.3	1254.8	3073.7	4075.9	1352.3	
27	1992	4792.0	4131.8	5174.6	1002.7	2379.2	3470.6	817.6	
28	1993	6246.6	4872.0	6321.6	1423.8	2925.8	4125.3	1271.6	
29	1994	6688.0	6327.1	6593.4	1771.8	3978.6	4984.1	1466.6	
30	1995	4158.5	3354.3	5211.2	950.4	1978.6	3374.1	951.9	
31	1996	4639.2	3338.1	5035.1	866.7	2409.8	2977.8	972.1	1139.0
32	1997	5768.6	5119.4	6487.7	1464.2	3627.9	4574.6	1309.1	1335.9
33	1998	5351.3	4041.8	6559.2	1116.8	2636.4	3428.8	994.8	1135.9
34	1999	5597.3	4561.3	6590.2	1837.1	3135.8	3870.1	1084.0	1174.5
35	2000	4377.2	3195.5	4707.5	918.2	2276.0	3047.1	798.8	983.2

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36	2001	4414.7	3330.9	5325.2	766.5	2145.6	3255.6	676.0	954.5
37	2002	4786.6	3613.4	5432.2	943.4	2464.8	3713.7	736.8	857.1
38	2003	4398.6	3153.0	4669.7	820.8	1975.0	3607.2	563.4	703.7
39	2004	4931.0	4247.9	5631.0	1219.4	2827.7	4441.7	1023.8	1159.4
40	2005	6755.0	6535.8	6933.6	1226.5	4481.7	6282.0	1913.0	2037.9
41	2006	6883.4	6768.4	7221.7	1679.0	4460.9	6964.6	1468.0	1933.7
42	2007	5208.6	5432.4	6982.5	946.1	3708.0	5747.7	1031.4	1413.6
43	2008	5709.8	4379.8	5958.3	1587.4	3375.4	4816.4	1286.2	1201.9
44	2009	4475.1	3749.6	5594.4	1414.2	2742.5	4503.5	1007.1	1155.9
45	2010	4818.6	3714.4	6661.3	1380.1	2325.0	3584.7	1079.9	1139.4
46	2011	6512.1	5006.2	7647.6	1283.6	3234.5	5402.7	1053.3	1259.3
47	2012	2460.4	3843.0	6417.0	1088.0	2460.4	4284.9	788.0	943.3
48	2013	6345.8	4856.6	6893.6	1029.8	3282.2	5405.0	1044.0	1096.5
49	2014	4845.6	4734.6	5434.2	1019.8	3074.4	4639.0	1000.7	1063.0
50	2015	2998.3	2790.5	3517.0	567.6	1842.2	2713.6	736.1	737.0
51	2016	5701.3	4348.8	6421.2	1063.6	2801.6	4323.0	1171.3	1401.3
Average Annual		5169.9	4269.2	5867.1	1154.8	2816.9	4439.9	984.1	1182.2

Table no 2. Annually Runoff data

Sr.	YEAR	REVYACH	MANDUK	DAJIPUR	KOTHALI	PATRYACHI	RADHANAGA	WADANGE	NITWADE
1	1966	862.71		3799.57	766.50	1573.94	3395.51	1554.71	
2	1967	3893.82		3961.53	566.86	2181.30	3887.10	716.83	
3	1968	2763.91		2958.62	419.95	1533.19	2971.89	56.72	
4	1969	4250.75		4362.18	1012.00	2175.94	3743.00	512.84	
5	1970	4855.64		5363.56	837.96	2161.90	4125.02	508.93	
6	1971	4277.63		5773.07	483.24	1866.56	3631.31	277.04	
7	1972	2751.23		3046.06	245.74	1175.83	2400.17	54.85	
8	1973	4555.28		5064.48	589.57	2401.28	4022.44	351.05	
9	1974	4077.98		4470.22	668.85	1673.80	3114.63	309.20	
10	1975	5371.56		4942.15	1108.80	2200.01	4305.62	365.42	
11	1976	3962.72		4073.30	817.88	2126.69	3657.51	444.79	
12	1977	4752.80		4862.02	834.21	2454.19	3584.01	525.94	
13	1978	5799.27		5669.12	773.31	2667.19	4323.99	638.48	
14	1979	4237.82		4072.45	840.68	2609.43	3634.37	423.35	
15	1980	4958.66		5630.67	891.21	3276.93	4536.82	718.36	
16	1981	4530.95	2581.52	4663.65	764.46	2136.04	3783.40	764.46	
17	1982	4571.70	2942.71	4814.73	733.92	2050.81	3780.09	474.73	
18	1983	5226.27	3518.94	6158.75	940.72	2216.51	4031.95	545.85	
19	1984	4228.80	3003.19	4508.67	614.24	1694.05	3407.42	291.33	
20	1985	4088.79	2702.23	4913.06	589.23	1382.20	3293.09	302.22	
21	1986	2996.56	2818.77	224.47	453.98	1762.27	2794.95	140.26	
22	1987	3207.43	2321.65	3832.06	358.02	1171.07	2305.83	313.19	
23	1988	3960.00	3109.52	4149.44	379.63	1860.09	3028.97	576.98	
24	1989	3981.26	2872.70	4203.45	397.66	1715.06	3107.31	264.37	
25	1990	4895.28	3891.86	4839.91	322.64	2191.42	3958.13	465.55	
26	1991	4135.32	3843.46	4683.64	762.59	2309.83	3162.35	845.53	
27	1992	3771.50	3209.90	4096.95	548.14	1719.06	2647.45	390.69	
28	1993	5008.85	3839.55	4683.64	906.35	2184.02	3204.37	776.88	
29	1994	5384.32	5077.32	4096.95	1202.37	3079.58	3934.90	942.76	
30	1995	3232.61	2548.52	5072.64	503.65	1378.29	2565.36	504.93	605.63
31	1996	3641.52	2534.74	5303.85	432.45	1745.09	2228.25	522.11	664.09

32	1997	4602.24	4050.00	4128.09	940.72	2781.26	3586.57	808.78	831.58
33	1998	4247.26	3133.34	3978.29	645.20	1937.84	2611.90	541.42	661.45
34	1999	4456.52	3575.25	5213.94	1257.92	2362.66	2987.29	617.30	694.28
35	2000	3418.65	2413.44	5274.76	476.26	1631.27	2287.20	374.70	531.56
36	2001	3450.55	2528.62	5301.13	347.22	1520.35	2464.56	270.24	507.14
37	2002	3766.90	2768.92	3699.62	497.70	1791.87	2854.24	321.96	424.29
38	2003	3436.85	2377.29	4225.06	393.41	1375.23	2763.65	174.45	293.80
39	2004	3889.74	3308.66	4316.08	732.48	2100.57	3473.51	566.09	681.44
40	2005	5441.31	5254.85	3667.46	738.52	3507.54	5038.96	1322.49	1428.73
41	2006	5550.54	5452.71	4485.19	1123.43	3489.85	5619.61	943.95	1340.09
42	2007	4125.87	4316.25	5593.24	500.00	2849.40	4584.46	572.56	897.67
43	2008	4552.22	3420.86	5838.31	1045.52	2566.47	3792.25	789.30	717.59
44	2009	3501.93	2884.78	5634.84	898.18	2028.10	3526.08	551.89	678.46
45	2010	3794.12	2854.84	4763.60	869.18	1672.95	2744.51	613.81	664.43
46	2011	5234.69	3953.70	4454.05	787.09	2446.61	4290.99	591.19	766.42
47	2012	1788.13	2964.23	5361.61	620.70	1788.13	3340.13	365.51	497.61
48	2013	5093.23	3826.45	6200.60	571.20	2487.19	4292.94	583.27	627.93
49	2014	3817.09	3722.67	5153.80	562.69	2310.43	3641.35	546.44	599.44
50	2015	2245.69	2068.93	5559.21	178.03	1262.26	2003.51	321.36	322.13
51	2016	4544.99	3394.49	4317.78	599.95	2078.37	3372.54	691.56	887.21
Average		4101.79	3402.48	4616.89	677.49	2091.41	3447.91	532.33	729.67

3.7. Soil analysis

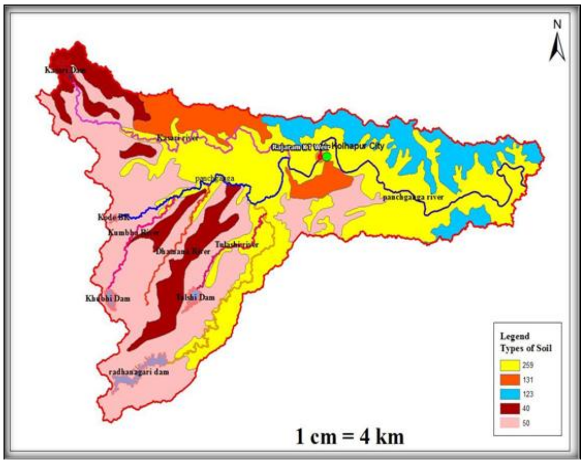

Fig no.7 Type of soil map

Table no.3 Type of Soil and Their Description

Sr No	Soil Sample	Color Code	Description
1	040		Shallow, well drained, loamy soils on moderately sloping spurs with severe erosion and strong stoniness; associated with slightly deep, loamy soils with severe erosion and strong stoniness.
2	050		Very shallow, well drained, loamy soils on moderately steeply sloping Sahyadri eastern slopes with very severe erosion and strong stoniness; associated with rock outcrops.
3	123		Very shallow, well drained, loamy soils on gently sloping undulating lands with

			moderate erosion; associated with shallow, well drained, fine soils with moderately erosion.
4	131		Shallow, well drained, clayey soils on gently sloping lands with very shallow, well drained, loamy soils with moderate erosion and moderate stoniness.
5	259		Deep, well drained, fine, calcareous soils on gently sloping valley with moderate erosion and slight salinity; associated with deep, moderately well drained, fine, calcareous soils with moderate erosion.

Source: Soil Maps of India

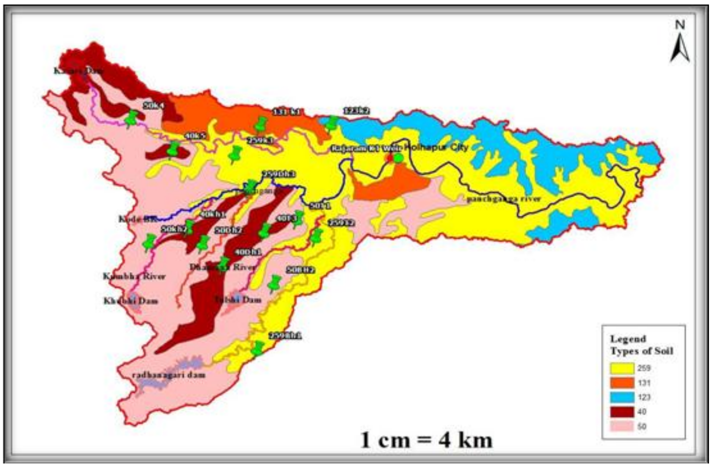

Fig no 8. Soil Sample location map

3.8. Water Content and Infiltration Soil test

Infiltration is the process by which water on the ground surface enters the soil. Infiltration rate in soil science is a measure of the rate at which soil is able to absorb rainfall or irrigation. It is measured in inches per hour or millimetres per hour. The rate decreases as the soil becomes saturated. The infiltration rate is the velocity or speed at which water enters into the soil. It is usually measured by the depth (in mm) of the water layer that can enter the soil in one hour. An infiltration rate of 15 mm/hour means that a water layer of 15 mm on the soil surface will take one hour to infiltrate. The infiltration rate can be finding out by using falling head method.

The rate of infiltration is determined by soil characteristics including ease of entry, storage capacity, and transmission rate through the soil. The soil texture and structure, vegetation types and cover, water content of the soil, soil temperature, and rainfall intensity all play a role in controlling infiltration rate and capacity.

3.8.1. Infiltration Calculation

1. Area of Stand pipe (a) cm^2 = 0.785
2. Cross section area of soil sample (A) cm^2 = 78.539
3. Length of sample (L) cm = 12.7

$$K = 2.303 \frac{a \times l}{A \times t} \log_{10} \frac{h1}{h2}$$

Example, 1) Sample no .50k4

$$K = 2.303 \frac{a \times l}{A \times t} \log_{10} \frac{h1}{h2}$$

h1= 87.5 cm, h2 = 11.8 cm

$$K = 2.303 \frac{0.785 \times 12.7}{78.53 \times 20} \log_{10} \frac{87.5}{11.8}$$

$K = 1.67 \times 10^{-5}$ mm/Sec

Table no 4 Results of Permability Test

Sr. No.	Sample No	Water Content in %	Permeability (k) (mm/sec)
1	131K1	18.4	1.56E-05
2	123K2	17.8	1.19E-05
3	259K3	21.4	9.61E-06
4	50K4	24.4	1.67E-05
5	40K5	18.4	8.84E-06
6	40kh1	21.8	1.22E-05
7	50Kh2	24.6	1.08E-05
8	40Dh1	19.2	1.53E-05
9	50Dh2	19.8	1.37E-05
10	259Dh3	16.8	1.13E-05
11	50T1	18.4	1.14E-05
12	259T2	19.2	7.68E-06
13	40T3	17.4	4.68E-06
14	259Bh1	18.2	1.29E-05
15	50Bh2	16.2	1.24E-05

IV. CONCLUSION

1. In the catchment area of Panchganga River, it is observed that, the Dajipur station have a maximum average rainfall (7647.6 mm) while the Wadange station have minimum average rainfall (422.8 mm).
2. In this catchment area there are mainly five types of soils. For this, fifteen samples were collected and test for the permeability test. From the permeability test it was observed that, the sample 50Kh2 was having a Maximum Infiltration Rate and the rate was 1.08E-05 mm/sec, and the soil is Very shallow, well drained,

and radish loamy type. Also the sample 259K3 was having a minimum Infiltration Rate and the rate was 9.61E-06 mm/sec, and the soil is Black cotton soil.

3. In this study area the black cotton soil is more in Kasari and Tulashi river catchment area so the infiltration rate is less and runoff is more in that area.

V. ACKNOWLEDGMENT

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