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Integration Of Runoff Harvesting To Enhance Vegetable Cultivation For Nyakivogera Marshland In Ruhango District

Ladislas Nizeyimana[1], Jean De La Paix Utazirubanda[1], Jean De Dieu Kamali[1], Clotilde Uwera[1], Liliane Uwamahoro[2]

[1]Department of Agriculture Engineering, Irrigation and Drainage Technology, Integrated Polytechnic Regional College (IPRC) Musanze, Rwanda

[2]Holland Green Tech, Kigali, Rwanda

Abstract – During the rain period, high discharge of water in marshland caused by uncontrolled runoff from the catchment causes floods lead to the reduction of agricultural command area which decreases the crop production and leads to unemployment for farmers, malnutrition and hunger. At other hand, in dry period, the marshland does not produce optimally due to lack of water to supplement the natural moisture. The harvesting of the water will permit the cultivation in all three agricultural seasons.

In this project, the rainfall data from METEO- RWANDA were used for getting the rainfall intensity in the catchment. The experiment such as geotechnical test was done for hydraulic structures stability; the topographic survey was done for getting the catchment area and slope of channel which will be needed in the hydraulic design. The use of combined data helped to get the durable solution of the flooding in the marshland and provided effective irrigation in the marshland. Rainfall considered in design were calculated by considering rainfall data of the past 40 years and dependability of 50%. By using a tabulated data representation method, the required dependable annually average rainfall value was found at 20th year which is 1228.5mm.

The area of the catchment: Delineation of catchment was done using the Arc GIS, the outlet was taken at the end of channel with the coordinates (Longitude: 29.795 o, Latitude: -2.216 o) and the catchment area was found to be 38.68 hectares. According to the characteristic of watershed where the soil is sand, the slope is 15.3%, and vegetable cover, the runoff coefficient was 0.58 and runoff volume calculated by using rational equation 275,606.604m3 (inflows per year).

By considering that the water requirement of pepper selected as suitable crop in the marshland for 10hactares, by considering water evaporation and that the agriculture will be done in all three seasons of the year by using the Peak sequent method, the minimum capacity requirement of the reservoir was calculated to be 17300 cum. For the safety of slope issues the allowable height is 11.4m. After the design, the reservoir has height of 7m, bottom width of 30m and bottom length of 60m.

Keywords – Runoff, Rainfall, Crop Water Requirement, Reservoir, Marshland.

I. INTRODUCTION

The Agriculture sector is the main economic activity in Rwanda where 64% of the working population are employed in Agriculture [[8.]].

Agriculture accounts for a more significant part of the foreign exchange earnings from the exports of products, including; coffee, tea, hides and skins, pyrethrum, and horticulture. 75% of Rwanda's agricultural production comes from smallholder farmers[[9.]].

Erosion is one of the biggest concerns of agricultural land. It has many impacts on agricultural production and food security in general [[8.]].

During the rainy season, high discharge of water in marshland caused by uncontrolled runoff from the catchment of surrounding zone of Kigali – Huye National Road specifically on the culvert located in Gitwa village of Munini cell causes erosion and floods lead to the reduction of agricultural command area which decreases the crop production and leads to unemployment for farmers, malnutrition and hunger.

At other hand, in dry season, the marshland does not produce optimally due to lack of water to supplement the natural moisture. Water scarcity is a major problem for smallholder farmers in sub-Saharan Africa, where agriculture is predominantly rained [[1.]]. Lack of basic infrastructure is one of reasons for the failure of irrigation schemes [[5.]].

As this situation is likely to stay the same in Nyakivogera marshland solutions are required that help farmers to cope with the limited availability of water for crop production. This research project aims to design Runoff harvesting system to enhance vegetable cultivation for Nyakivogera marshland. The harvesting of the water can solve erosion and flooding issues and can permit the cultivation in all three agricultural seasons. The hypotheses of this research are:

- The designed water reservoir is capable to regulate flooding in the marshland.
- The water to be harvested satisfies irrigation requirements in dry period.
- Surface irrigation is the most suitable irrigation system in the marshland.

Runoff taken as a problem for agricultural activities is turned to a solution to enhance vegetables production.

II. Materials And Methods

2.1. Description and location of the study area

The study area is located in Rwanda, Ruhango district, Ruhango Sector, near Kigali – Huye National Road.

2.2. Data collection

In this project, the historical data (rainfall data) of 40 years from METEO- RWANDA were used for getting the rainfall intensity in the catchment. The experiment such as geotechnical test was done for hydraulic structures stability; The topographic survey was done for getting the slope of channel which was needed in the hydraulic design.

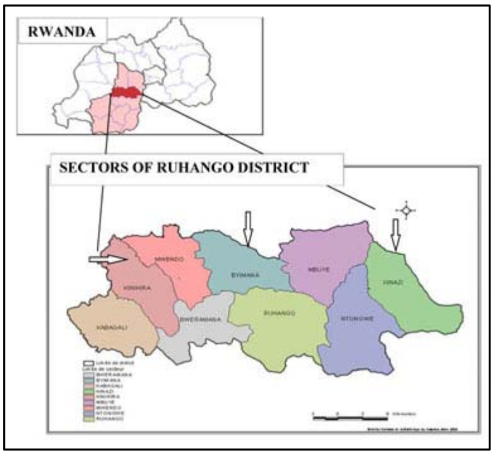

Figure 1: Map of Ruhango district (District development plan of Ruhango district)

The use of combination of existing data (rainfall data), topographic data from in situ and laboratory tests helped to get the durable solution of the flooding in the marshland.

Rainfall data in the catchment, especially the daily precipitations were collected as historical data; the topographic data (coordinates) was collected by using The total station instrument. The geotechnical (soil data) ware collected from experiment.

2.3. Geotechnical test

The geotechnical tests were done in Soil laboratory of Muhabura Integrated Polytechnic College; the samples were taken at the site in Ruhango District.

The geotechnical results were used for checking the slope stability of reservoir.

Figure 2 Soil sampling in Ruhango

2.4. Topography

The topography was done by using the Total station and GPS for taking the coordinates, the obtained results was used for getting the slope of the site by using AutoCAD 3D.

Figure 3: Topographic coordinates collection

2.5. Reservoir storage capacity design

Peak sequent method

When the sequent peak procedure is used to size a reservoir, two cycles of inflows and drafts are analysed. The use of two cycles results in the identification of the minimum reservoir capacity which, when simulated with the design inflows and drafts, will not only meet demands, but will also result in a final storage which equals or exceeds the initial storage[[12.]].

Sizing a reservoir using Sequent Peak Algorithm

This method is based on determining the deficit at each time step. It is simple but flexible in being able to consider a different demand at each period as well as estimates of losses.

The basic equation. is $\mathbf{K_t = K_{t-1} + D_t - Q_t}$ if $K_t > 0$; otherwise $K_t = 0$.

$\mathbf{D_t}$ is the demand at t. and $\mathbf{Q_t}$ is the inflow at t.

If a limited historic record is available, it is common practice to repeat the record in order to explore a critical period that may result.

III. Result And Discussion

3.1. Rainfall at Byimana weather station

The rainfall data from METEO- RWANDA and taken at Byimana weather station which is located near the Nyakivogera marshland, were collected and used for getting the rainfall intensity in the catchment.

Table 1: Monthly rainfall at Byimana weather station

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly
1959	84.6	84.2	145.9	149.2	188.4	6.3	0	30.4	53.3	171.4	233.9	132.9	1280.5
1960	112.2	97.6	137.3	273.7	39	1.6	3.5	25.2	52.5	110.2	71.7	45.2	969.7
1961	69.3	121.2	150.4	96.5	99.2	2.1	7	0.8	120.7	144.6	222.2	199.3	1233.3
1962	168.5	13.4	130.4	123.1	199.3	15.5	18.4	93.1	104.4	272.4	124.2	131.1	1393.8
1963	167.4	99.9	80.2	205.6	402.4	47.5	0	43.8	148.5	33.7	110.8	205.9	1545.7
1964	93.3	162.5	106.5	272	68.7	9.9	66	22.1	44.5	134.8	144.6	70.4	1195.3
1965	89.7	69	102.4	282.9	141	8	0	42.5	103.7	111.5	146.4	78.1	1175.2
1966	30.7	164.5	163	179.8	61.9	22.7	0	100.8	72.2	65.2	136.4	43.7	1040.9
1967	40	63	111.3	169.3	293.6	49.4	24	7.8	130	30.9	143.4	193.9	1256.6
1968	128.2	171.5	213.8	187.8	91.6	67.8	8.8	0.2	36.7	55.4	170.6	96.1	1228.5
1969	88.9	85.7	123.1	121.7	135.4	1.4	0.3	0	65.5	65.3	106.9	44.2	838.4
1970	265.2	152.7	170.9	232	56.3	19.7	17.3	56.2	56.8	103	169.2	64.4	1363.7
1971	103.7	132.3	80.8	193.3	197.6	0	16.8	126.6	51.6	42.9	115.2	121.2	1182
1973	85.5	104.2	84	258.9	232.7	4.7	0	36.4	204.8	105.3	189.5	73.1	1379.1
1974	76.5	32.6	276.5	173.3	202.4	105.9	87.9	7.8	84.7	34.5	121.7	55.4	1259.2
1975	136	82.6	73.9	231.8	142.7	3.4	52.4	14.6	135.2	151.1	92	160.5	1276.2
1976	65.1	99.6	113.9	118.5	143.6	31.5	0	82.6	90	94.6	74.3	82.5	996.2
1977	116.3	87.2	105.4	237.4	93.6	7.2	5.5	66.3	119.3	121.7	161.6	109.2	1230.7
1978	85.1	125.2	243.1	173	127.8	22	0	39.5	37.1	55.4	106.1	106.9	1121.2
1979	210.1	150.3	36.3	185.6	234.7	52.3	0	21.5	5.5	28.8	140.9	129.9	1195.9
1980	81.9	96.9	86.2	204.5	160.1	3.8	0	8.9	154.2	110.4	182.9	122.5	1212.3
1981	62.2	69.7	150.7	186.9	174.2	0.2	0	148.8	107.5	79.7	62.9	83.4	1126.2
1983	12	200.7	131	68.7	3.3	32.1	18.6	36.7	45.4	124.7	177.4	151.4	1002
1985	83	126.7	163.7	263.9	65.8	30.6	0	0.7	181.8	113.5	157.9	143.3	1330.9
1986	169.6	155.4	128	368.9	183.7	51.2	0	25.1	43.1	145.5	78.4	112.1	1461
1988	99.3	172.3	216.6	218.4	4.6	113.1	0.3	105.4	60.2	97.4	112.9	56.1	1256.6
1989	142.3	160.5	201.7	220.4	96.7	37.7	21.1	61.5	8.4	75.2	59.1	104	1188.6
1990	65.9	119.9	191.2	55.2	258.7	4.4	0	34.4	88.9	90.8	136.5	110.3	1156.2

1991	140.1	140	125.1	120.3	152.9	53	14.5	31.2	37.9	99.6	64.9	135.5	1115
1992	107.8	86.5	178.5	161.1	119	89.4	1.9	1.7	83.2	169.3	103.3	149.9	1251.6
1998	210.8	274.9	150.4	198.9	135.6	55.1	11.5	25	41.9	94.9	117.8	66.9	1316.8
2011	157.5	86.4	69.8	76.2	57.2	193.7	13	31	75.2	114.1	240.4	120.5	1235
2012	11.7	74.8	70.2	281.3	168.9	16.6	6.5	54.4	63	123.1	138.5	108.1	1117.1
2013	87.8	27	260.8	170.8	125.4	0.4	0.2	59.5	164.9	65.3	78	204.7	1244.8
2014	42.7	95	115.7	33.3	53.5	53.5	10.3	60.7	153.7	88.2	109.3	281.1	1097
2015	79.8	117	52.6	209.8	160.7	61.2	1.4	16.4	65.7	121.3	93.3	73.4	1052.6
2016	92	58	190.1	152.7	54.2	0.8	3.1	16.5	221.7	101.3	136.7	62.5	1089.6
2017	34.2	78.2	112.5	144.7	111.5	0	28.6	9.5	45.2	86.6	139.5	77.3	867.8
2018	171.4	94.6	248.6	302.1	236.9	0	15.4	64	51.5	68	55.2	153.2	1460.9
2019	95.1	21.8	96.2	111.7	128.9	65.3	8.9	2.8	78.8	204.4	147.1	464.1	1425.1

According to the rainfall data, the designed value was calculated by using the dependability of 50%.

The procedure adopted to compute the dependable rainfall value for a given dependability percentage **p.** The available rainfall data of the past **N** years was first of all arranged in the descending order (from bigger to small value) of magnitude. The order number **m** (which shows the dependable rainfall), given by the equation: $\mathbf{m} = N.\frac{P}{100}$ order number **m** is then computed, and rainfall value corresponding to this order number in the tabulated data represent the required dependable rainfall value is at m=40*50%=20, the designed value was taken at **m**=20.

Table 2: Design rainfall

S.N	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly
Dependability value at 50%, where m=20	92	99.6	130.4	186.9	135.6	22	5.5	31.2	75.2	101.3	136.4	110.3	1228.5

The area of the catchment

The delineation of catchment was done using the Arc GIS, the outlet was taken at the end of channel with the coordinates (Longitude:**29.795** ^{o}, Latitude**: -2.216** ^{o}).

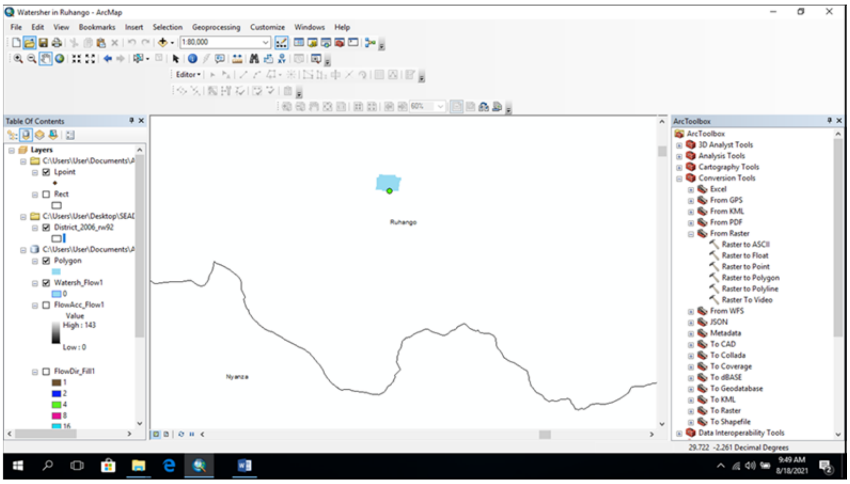

Figure 4: Catchment delineation in Ruhango District

After the delineation, the catchment area is **38.68** hectares.

3.2. Estimation of losses

The evaporation losses are calculated using a simple formula for estimating evaporation rates in various climates, using temperature data alone. This is a simplified Penman formula for the evaporation rate from a lake as

where $T_m = T + 0.006h$, h is the elevation (metres), T is the mean temperature, A is the latitude (degrees) and T is the mean dew-point

$$E_0 = \frac{700\ T_m/(100-A)+15(T-T_d)}{(80-T)}(\text{ mm day}^{-1})$$

$$(T-T_d) = 0.0023h + 0.37\ T + 0.53\ R + 0.35\ R_{ann} - 10.9^\circ\ \text{C}$$

where R is the mean daily range of temperature and R_{ann} is the difference between the mean

temperatures of the hottest and coldest months. Thus, the evaporation rate can be estimated simply from values for the elevation, latitude and daily maximum and minimum temperatures. From the above formula, the monthly evaporations are presented in the table of evaporations.

3.3. Crop water requirement

The irrigation water requirement was analysed using CROPWAT model of FAO referring to sweet pepper, one among the crops grown in the area. Calculations based on one-hectare land.

Table 3: Crop water requirement results per season and month

Month	CRW (mm)
Jan	67.8
Feb	11.6
Mar	14.4
Apr	1
May	22.8
Jun	61.6
Jul	101.9
Aug	126.3
Sep	87.8
Oct	20.1
Nov	18.7
Dec	51.9

Month	$T-T_d$	Evaporation daily (mm day^{-1})	Evaporation Monthly (mm month^{-1})
Jan	6.3	1.7	53.9
Feb	6.2	1.8	49.3
Mar	6.0	1.8	55.1
Apr	5.3	1.9	55.5
May	5.1	1.9	57.9
Jun	5.9	1.7	51.0
Jul	6.3	1.6	51.0
Aug	6.7	1.7	51.6
Sep	6.6	1.7	51.5
Oct	6.4	1.7	54.1
Nov	5.7	1.8	53.6
Dec	6.0	1.7	54.1
TOTAL in mm year^{-1}			638.6

The irrigation requirement is high in the dry period mostly in July and August and very low in April as a rainy month. This is due to the fact that the analysis of rain data recommends to use dependable rain setting in areas with much water as the case of Ruhango.

The following table shows the estimated crop water requirement per hectare per month.

3.4. Geotechnical test

The geotechnical test (direct shear test) was performed in order to ensure the stability of reservoir slope, and the soil identification was done for knowing the type of soil.

Table 4:Shear test results

SN	SHEAR TEST SAMPLES	C: Unit cohesion(Kpa)	ϕ:Shearing Angle (angle degrees)
1	Sample 1	18.92	41.53
2	Sample 2	24.832	41.3
3	Sample 3	20.39	41.75
4	Sample 4	31.5	43.95
5	Sample 5	19.24	39.48
6	Sample 6	15.66	39.64
7	Sample 7	19.791	42.87
8	Sample 8	35.39	46.52
Average		**23.2**	**42.13**

Sieve analysis test

According to the sieve analysis which is in annex, the soil is classified as Sand soil.

Unit Weight of Different Types of Sand

The followings are the typical value of different types of sand [[11.]]. A cut is to be made in a sand soil having

γ= 15.4kN/m^3, c' = 23.2 kN/m^2, Ø' = 42.13°. The side of the cut slope must be made at an angle of 45° with the horizontal.

For general slope stability analysis of permanent cuts, fills, and landslide repairs, a minimum safety factor of **1.25** should be used. Larger safety factors should be used if there is significant uncertainty in the analysis input parameters [[10.]]. Let use **3** as safety factor.

Determination of the depth of the cut slope

$$\mathrm{Fc} = \frac{C'}{C'd} \; or \; \mathrm{C'd} = \frac{C'}{Fc'} = \frac{C'}{Fs} = \frac{23.2}{3} = 7.73\mathrm{kN}/m^3$$

Similarly,

$$\mathrm{F}\emptyset' = \frac{\tan \emptyset'}{\tan \emptyset' d} or \tan \emptyset' d = \frac{\tan \emptyset'}{\mathrm{F}\,\emptyset'} = \frac{\tan \emptyset'}{\mathrm{Fs}} = \frac{\tan 42.13^0}{3}$$

$$\emptyset' d = tan^{-1}\left[\frac{\tan 42.13^0}{3}\right] = 16.77^{\circ}$$

Substituting the preceding values of $\boldsymbol{C'd}$ and $\boldsymbol{\emptyset' d}$ in this below equation

$\mathbf{H} = \frac{4C'd}{\gamma}\left[\frac{Sin\ \beta . Cos\ \emptyset' d}{1-\text{Cos}(\beta-\emptyset' d)}\right] = \frac{4*7.73}{15.4}\left[\frac{Sin\ 45 . Cos\ 16.77}{1-\text{Cos}(45-16.77)}\right]$ = 11.4m, for the safety of slope issues the allowable height is **11.4m**.

3.5. Topographic data

The coordinates taken are included the Easting, Northing and elevations. These data were using for producing the topographic map.

Table 5: Topographic coordinates

SN	Easting	Northing	Elevation		SN	Easting	Northing	Elevation		SN	Easting	Northing	Elevation
1	477188	4754929	1708.713		31	477075.6	4754917	1703.298		61	477172.9	4754911	1705.192
ST1	477188	4754908	1706		32	477074.2	4754892	1698.375		62	477213.3	4754905	1705.872
2	477194.5	4754932	1709.771		33	477074.3	4754873	1696.445		63	477216.1	4754886	1703.874
3	477200.3	4754925	1708.828		34	477072	4754851	1695.925		64	477208.2	4754872	1701.757
4	477194.1	4754915	1706.389		35	477097.1	4754832	1694.75		65	477225.7	4754866	1701.97
5	477187.6	4754914	1705.942		36	477127.4	4754830	1694.322		66	477242.4	4754860	1701.645
6	477180.5	4754922	1707.147		37	477133.4	4754855	1694.851		67	477263.1	4754866	1704.473
7	477172	4754924	1707.56		38	477153.3	4754855	1694.968		68	477269.4	4754878	1706.565
8	477163.3	4754925	1707.2		39	477150.9	4754830	1694.057		69	477288.9	4754878	1708.707
9	477153.7	4754930	1706.32		40	477154.4	4754800	1693.11		70	477301	4754859	1706.421
10	477140.1	4754939	1706.993		41	477173.8	4754793	1693.153		71	477282.6	4754842	1700.6
11	477125.3	4754932	1704.835		42	477188.5	4754751	1694.899		72	477257.9	4754849	1700.56
12	477117.3	4754924	1703.739		43	477213.6	4754744	1695.907		73	477281.5	4754856	1703.347
13	477116.3	4754907	1700.832		44	477248.4	4754737	1693.882		74	477287.4	4754883	1709.158
14	477105	4754881	1696.736		45	477253.3	4754780	1691.442		75	477253.2	4754901	1709.256
15	477100.3	4754861	1695.559		46	477235.5	4754798	1692.241		76	477231.6	4754913	1709.099
16	477095.2	4754834	1694.826		47	477226.3	4754821	1694.348		77	477215.5	4754916	1708.685
17	477110.1	4754815	1694.141		48	477213.3	4754850	1698.549		78	477199.6	4754926	1708.724
18	477130.7	4754792	1693.322		49	477196.2	4754860	1698.603		79	477187.5	4754896	1703.236
19	477156.2	4754768	1693.567		50	477176.2	4754869	1697.174		80	477194.3	4754884	1702.083
20	477127.8	4754775	1694.249		51	477162.4	4754863	1695.643		81	477198	4754951	1713.116
21	477100.2	4754758	1696.123		52	477146.9	4754871	1696.372		82	477196.5	4754951	1713.271
22	477080.8	4754747	1697.447		53	477145.8	4754894	1698.162		83	477209.2	4754974	1717.898
23	477068.8	4754761	1696.861		54	477147.5	4754907	1700.379		84	477207.4	4754975	1717.99
24	477046	4754778	1698.518		55	477161.3	4754908	1702.863		85	477219	4755005	1724.636
25	477042.9	4754817	1698.244		56	477172.9	4754892	1701.899		86	477217.3	4755006	1724.59
26	477013.4	4754840	1698.19		57	477172.7	4754883	1699.698		87	477223.9	4755020	1729.102
27	477016.1	4754862	1697.82		58	477178.1	4754904	1703.688		88	477220.3	4755021	1729.205
28	477010.5	4754905	1702.301		59	477185.4	4754902	1705.118		89	477232.7	4755014	1728.892

29	477010.4	4754931	1707.884		60	477181.7	4754909	1705.61		90	477195.2	4755022	1729.068
30	477044.8	4754920	1704.807										

After analysing the topographic coordinates by AutoCAD civil 3D, the slope of the site is 15.3%, This shows that the water can flow by gravity system.

The surface irrigation can be adopted especially fallow irrigation.

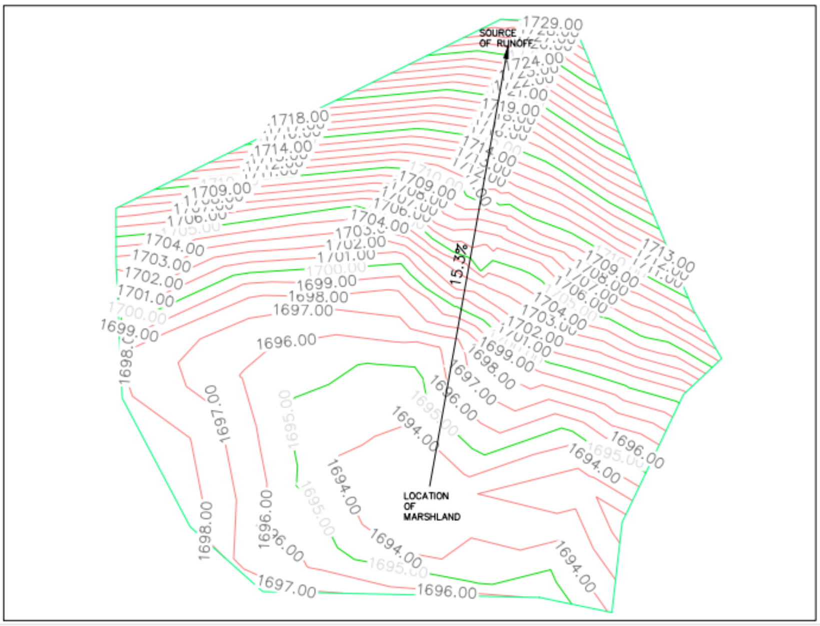

Figure 5: Topographic map

Runoff coefficient

According to the characteristic of watershed where the soil is sand, the slope is 15.3%, and vegetable cover, the runoff coefficient is $\mathbf{C}=C_r+C_i+C_v+C_s=0.28+0.08+0.12+0.1=0.58$.

The contribution of rainfall (runoff)to reservoir

The runoff volume is given by the rational Equation :
$\boldsymbol{Q = C\,I\,A}$ where:
$\boldsymbol{Q}$ = volume of water that can be collected by one pond throughout the month from drainage basin in m^3/month, $\boldsymbol{C}$ = 0.58 (runoff coefficient),$\boldsymbol{I}$ = mm/month (rainfall intensity) ,and $\boldsymbol{A}$ = ha (drainage area).The runoff volume is given by the rational Equation, *during the year, the harvested runoff is*

$$Q = C\,I\,A = 0.58 * 1228.5\text{mm} * 38.68\text{ha} = 0.58 * 1.2285\text{m} * 38.68 * 10000\text{m}^2 = \mathbf{275{,}606.604m^3}$$

The runoff (inflows) per year is 275606.604 m^3.

*Evaporation Volume(losses) per year= EA=638.6*50*50/1000=1596.5* m^3

The water requirement (demand) per year on 10 hectares is 87840 m^3, according to the inflows which are greater than the outflow (losses, demand), there is the availably of water in the catchment.

3.6. Reservoir design

Using the Peak sequent method, the reservoir storage capacity was calculated.

Table 6: Reservoir capacity calculation

Time in Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall in mm	92	99.6	130.4	186.9	135.6	22	5.5	31.2	75.2	101.3	136.4	110.3
Runoff in cum	18860	20418	26733	38315	27799	4510	1127.5	6396	15416	20767	27963	22612
Evaporation in mm	53.9	49.3	55.1	55.5	57.9	51	51	51.6	51.5	54.1	53.6	54.1
Evaporation in Cum	134.8	123.3	137.75	138.75	144.8	127.5	127.5	129	128.8	135.3	134	135.3
Inflow(Q) in Cum	18726	20295	26595	38176	27654	4383	1000	6267	15288	20632	27829	22477
Demand(mm/ha)	67.8	11.6	14.4	1	22.8	61.6	101.6	126.3	87.8	20.1	18.7	51.9
Demand(mm/10ha)	678	116	144	10	228	616	1016	1263	878	201	187	519
Demand in Cum	6780	1160	1440	100	2280	6160	10160	12630	8780	2010	1870	5190
Q in Cum	18726	20295	26595	38176	27654	4383	1000	6267	15288	20632	27829	22477
R in Cum	6780	1160	1440	100	2280	6160	10160	12630	8780	2010	1870	5190
Kt-1 in Cum	0	0	0	0	0	0	1777.4	10937	17300	10793	0	0
K in Cum	0	0	0	0	0	1777	10937	**17300**	10793	0	0	0

Time in Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall in mm	92	99.6	130.4	186.9	135.6	22	5.5	31.2	75.2	101.3	136.4	110.3
Runoff in cum	18860	20418	26733	38315.25	27799	4510.1	1128	6396.1	15416	20767	27963	22612
Evaporation in mm	53.9	49.3	55.1	55.5	57.9	51	51	51.6	51.5	54.1	53.6	54.1
Evaporation in Cum	134.75	123.25	137.75	138.75	144.75	127.5	127.5	129	128.75	135.25	134	135.25
Inflow(Q) in Cum	18726	20295	26595	38176.5	27654	4382.6	1000	6267.1	15288	20632	27829	22477
Demand(mm/ha)	67.8	11.6	14.4	1	22.8	61.6	101.6	126.3	87.8	20.1	18.7	51.9
Demand(mm/10ha)	678	116	144	10	228	616	1016	1263	878	201	187	519
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Kt-1 in Cum	0	0	0	0	0	0	1777	10937	17300	10793	0	0
K in Cum	0	0	0	0	0	1777.4	10937	17300	10793	0	0	0

The minimum capacity requirement is **17300** cum.

Dimension of reservoir

The proposed height is **7m**, the dimension, the design was done by AutoCAD 3D - Hydra flow. After the design, the reservoir has height of 7m, bottom width of 30 and bottom length 60m.

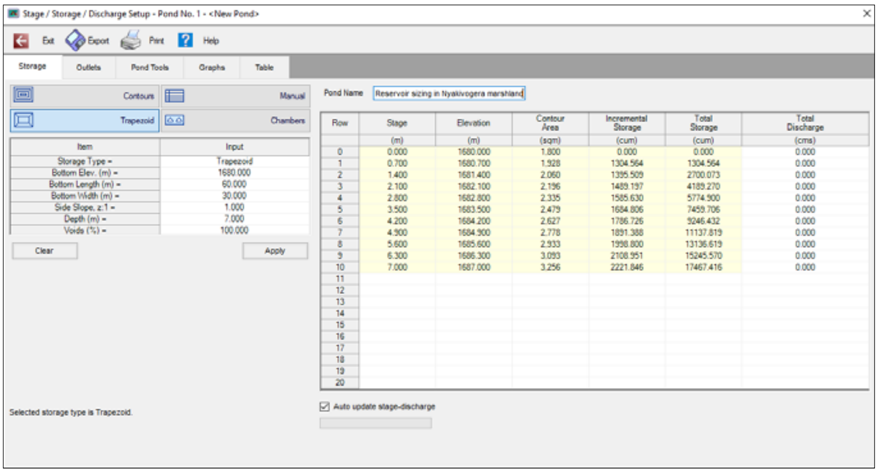

Figure 6: Sizing of reservoir

IV. Conclusion And Recommendation

4.1. Conclusion

The inflows are higher compared the outflows; the farmers can use the store water in irrigation during dry season. The area of the catchment was found to be 38.68 hectares.

According to the characteristic of watershed where the soil is sand, the slope is 15.3%, and vegetable cover, the runoff coefficient was 0.58 and runoff volume calculated by using rational equation is 275,606.604m^3 (inflows per year).

By considering that the water requirement of pepper selected as suitable crop in the marshland for 10 hectares, by considering water evaporation and that the agriculture will be done in all three seasons of the year by using the Peak sequent method, the minimum capacity requirement of the reservoir was calculated to be 17300 cum. The reservoir: For the safety of slope issues the allowable height is 11.4m. The designed reservoir is able to store required water in irrigation.

4.2. Recommendation

Private sector is recommended to construct the reservoir. Once it is constructed farmers should protect the upstream for erosion control at hillside. Regular maintenance of the infrastructures must be done for the issue of performance. Farmers are advised to use stored water only in all agricultural season.

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