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Stormwater Management from the Safco III City to the Darou Salam II City

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Abstract A total absence of a rainwater planning tool is noted from Cité Safco III to Cité Darou Salam II via Cité Kanghé II. This study area is located in Sangalkam in the commune of Tivaoune Peulh, department of Rufisque in the Dakar region. This article aims to identify all the sources of recurring flooding phenomena in the area. Thus a pre-reconnaissance study was carried out to understand the nature of the soil and the topography of the land. The topographic data obtained after the measurements are processed to determine the lowest points of the terrain, followed by geotechnical studies to determine the soil properties. Then, hydrological and hydraulic studies from which the watersheds and structural dimensions are studied. Finally, the operation of the network is evaluated taking into account aspects of environmental and social aspects. A flood management plan has been proposed, including the installation of drainage systems and a retention basin. The covering is therefore designed so that the water flows by gravity towards the pool. The latter has a penetration surface of 1.93 ha, a covered volume of 32,329 m3 and a filling duration of 2.33 h.

Keywords: *Rainwater management, drainage, sizing, design, Kanghé, Darou Salam, Safco*

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1. Introduction

In Senegal, the issue of sanitation occupies a priority place. This issue of flooding is dealt with in various codes (water code, hygiene code, environment code, town planning code, construction code). On June 17, 2009, Law No. 2009-24 establishing the Sanitation Code was adopted by the National Assembly. In its article L8, it is stipulated that every municipality must have a master plan for the sanitation of rainwater and wastewater (sanitation code). Thus, the state of Senegal mobilized Two Hundred and Eight (208) billion CFA francs from 2012 to 2017 in the urban sanitation sub-sector for the implementation of important projects. This is the case with the ten-year flood control program which has enabled the construction or rehabilitation of several rainwater drainage works in Dakar and other regions.

However, there is a total absence of planning tools and rainwater drainage networks throughout the study area from Safco III to Darou Salam II via Kanghé II. In this area, flooding causes significant material damage in addition to serious environmental problems. These have a considerable negative impact on health, the economy and the well-being of populations. This situation affects almost the entire population and exposes them to constraints that threaten their survival.

Consequently, all these parameters require a much deeper diagnosis, hence the importance of this study. The main objective of this article is to make a technical study on the problems of stormwater flooding in this area and to plan a stormwater drainage master plan.

2. Materials and Methods

2.1. Data Acquisition

The commune of Tivaoune Peulh is located between latitudes 14°48'27''N and 14°48'31''N and longitudes 17°16'44''W and 17°16'53''W. It is at an altitude of 11m. Figure 1 illustrates the geographical location of the commune of Tivaoune Peulh.

The study area brings together the districts of Safco III, Kanghé II and Darou Salam II respectively. Figure 2 shows the geographical location of the study area in the commune of Tivaouane Peuhl.

Rainfall is the quantitative assessment of precipitation, its nature (rain, snow, sleet, fog) and distribution [1].

Based on data collected at ANACIM, the annual precipitation observed from 1992 to 2012 is shown in Figure 3.

Tivaouane Peulh
Administration
Country Senegal
Region Dakar
Department Rufisque

Geography Contact details
14° 48′ 35″ north, 17° 16′ 44″ west
Location Geolocation on the map: Senegal

Figure 1. Geographical location of the commune of Tivaoune Peulh

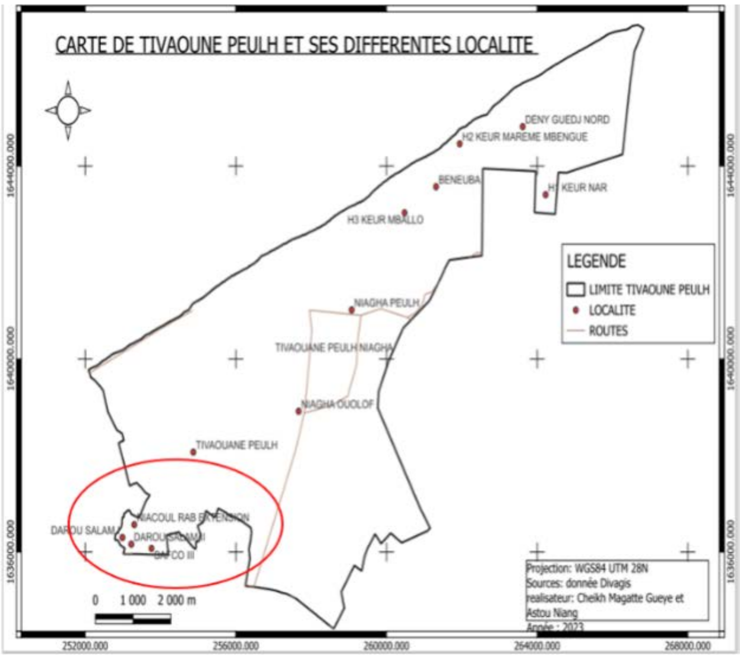

Figure 2. Location of the study area in the commune of Tivaouane PeuhlRainfall

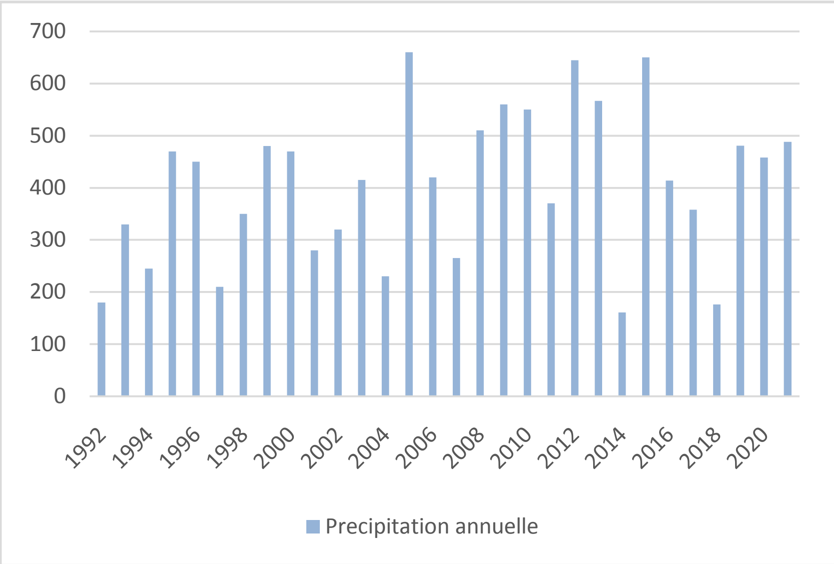

Figure 3. Annual rainfall recorded in Dakar (mm) from 1992 to 2012 (ANACIM, 2021)

Table 1. Monthly and Annual Rainfall in mm of Recorded Rainfall from 2012 to 2021 (ANACIM, 2021)

Année	Pluviometrie Mensuelle/Annuelle											
	Janvier	Février	Mars	Avril	Mai	Juin	Juillet	Août	Septembre	Octobre	Novembre	Décembre
2012	0	0	3,8	X	X	0,4	70,4	379,5	194,2	X	0,1	0
2013	0	0	0	0	0	0	29,4	300,1	192,8	30,6	4,6	9,4
2014	X	0	0	0	0	0	0,4	87	73,3	0,6	0	0
2015	X	X	0	0	0	0	34,2	349,7	183,9	82,2	0	0
2016	0	0	0	0	0	X	32,8	185,4	195	0,7	0,5	0
2017	0	0	0	0	0	1,1	92,8	150,5	97,3	15,8	0	0
2018	0	0	0	0	0	22,4	X	51	81,1	21,5	X	0
2019	0	0	0	0	0	0	38,4	168,1	209,1	64,9	0	0
2020	0	0	0	0	0	4,4	74	103	245	32	0	0
2021	0	0	0	0	0	14,7	1,4	310,2	144,1	17,9	0	0

Table 1 shows the monthly rainfall in Dakar from 2012 to 2021.

During 2021, precipitation is observed from June to October and is more frequent in August with a precipitation of 310 mm. All this data collected makes it possible to make an analysis of the rainfall trend of this area from 1992 to 2021. During its 29 years (1992-2021), the lowest rainfall was observed in 2014 with a total of 161 mm and the highest in 2005 with a total of 660 mm. In addition, there is a variation in rainfall from year to year, and to analyse this mobility, we used the method of "deviations from the interannual average" given by Formula 1.

$$E_M = P_I - P_M \quad (1)$$

The method of deviations from the interannual mean makes it possible to assess for each day of the period studied the degree of positive or negative abnormality in any given year in relation to the average of the series thus illustrated in Figure 4.

Figure 4 shows that 17 of the 29 mean deviations are positive and the remaining 12 are negative. Relative humidity is the amount of water vapour in the air relative to the maximum capacity it can hold. It is expressed as a percentage (%) and depends on temperature and pressure [2]. Figure 5 shows the relative humidity values in (%) for the year 2021. The average relative humidity in Dakar ranges from 66% in December to 83% in September. Its annual average is 76%.

In the study area, the implementation of a stormwater drainage system becomes urgent as populations face flooding problems every winter, as shown in Figure 6.

Drainage refers to all the means that aim to evacuate rainwater to the natural environment (rivers, lakes, etc.), basins or treatment plants [3].

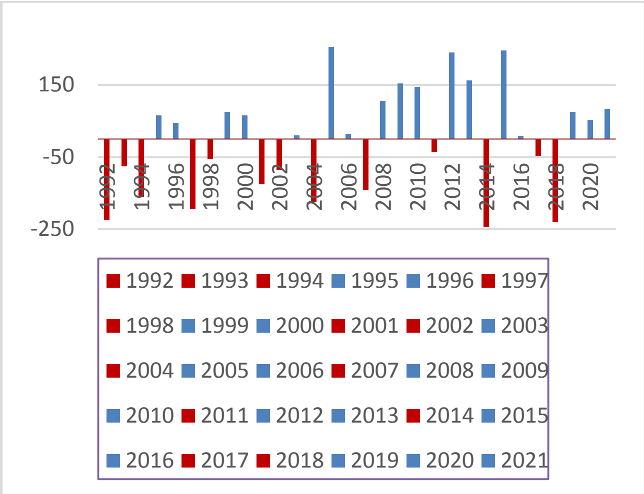

Figure 4. Degree of positive or negative abnormality in annual rainfall from 1992 to 2021

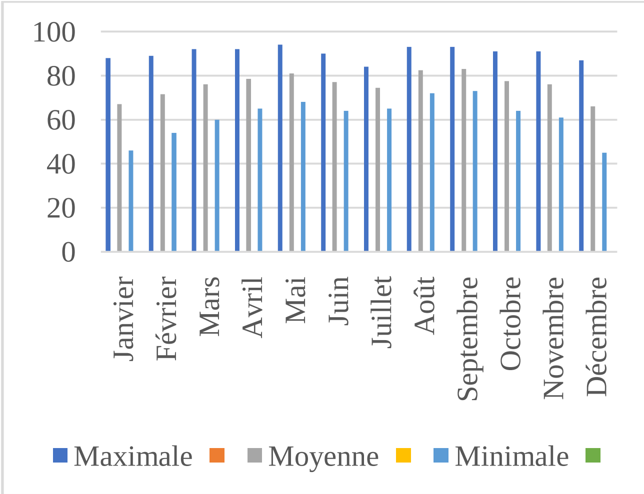

Figure 5. Histogram of relative humidity in (%) for the year 2021

Figure 6. Basin of the Kanghe II city during the wintering period

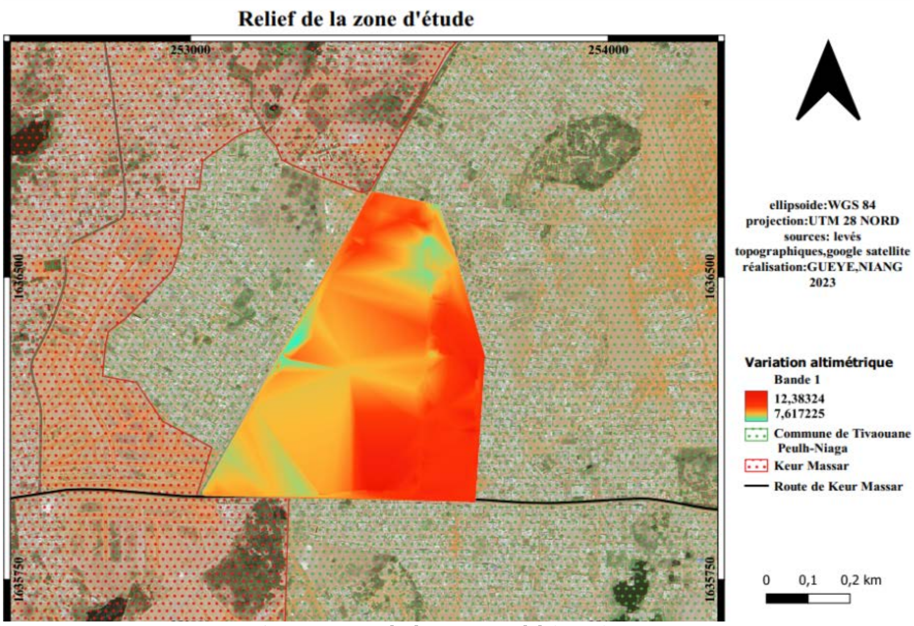

Figure 7. Digital Elevation Model (DTM)

2.2. Data processing and Analysis

This study is based on the topography, geotechnical and hydraulic components in order to have a technical overview of the area. The aim is to understand the situation of the land and the hydrological network [4]. Figure 7 illustrates the Digital Elevation Model (DTM) using QGIS software.

The contour lines in Figure 8 show that the terrain is more or less flat and then the elevation changes from 7 to 12 m, so the flooding is not caused mainly by the terrain.

Figure 8 shows the contour lines of the study area.

The following geotechnical tests were conducted to characterize the soil:

- Sand equivalence;
- Particle size;
- Specific weight;
- Bulk density.

The hydrological study highlights the determination of watershed flows and their characteristics [5,6,7].

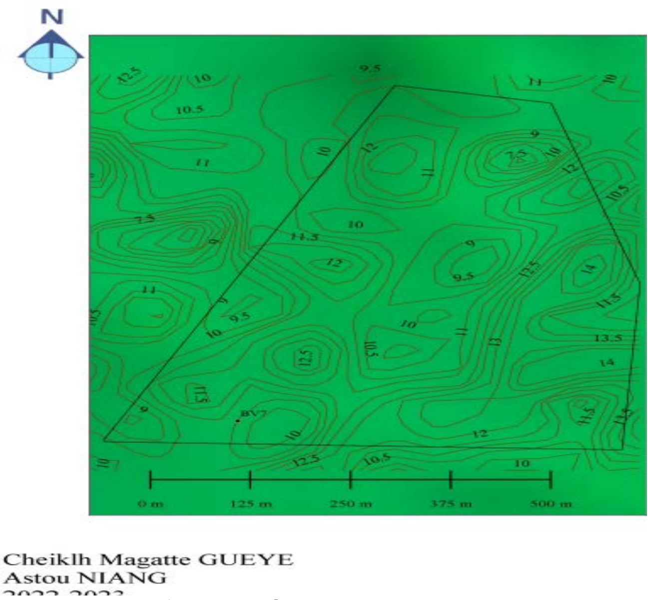

Figure 8. Study Area Contour Lines

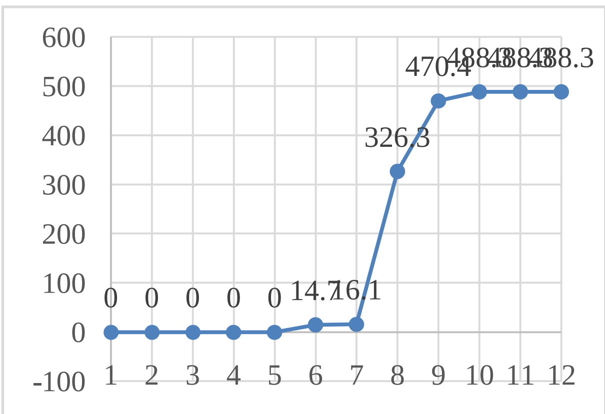

Figure 9. Cumulative rainfall curve during the year 2021

3. Results and Discussions

Table 2 shows the results of the permeability coefficient calculation.

The average of the measurements of K= 〚1,371.10〛^(-6) m/s which is between 2*10-7 m/s and 2*10-3 m/s, so the soil is permeable.

Figure 9 shows the cumulative rainfall curve during the year 2021.

Table 2. Calculation of the permeability coefficient

t (s)	D (m)	h (cm)	h (m)	k (m/s)	K moyenne
0		30	0,3		
60		26,1	0,261	7,25E-05	
120		25	0,25	1,5E-05	
180		22,8	0,228	2,4E-05	
240		21	0,21	1,71E-05	
300		19,5	0,195	1,29E-05	
360		18	0,18	1,19E-05	
420		16,4	0,164	1,21E-05	
480		14,1	0,141	1,75E-05	
540		14	0,14	7,41E-07	
600	0,125	12,9	0,129	7,75E-06	1,3717E-05
660		10,5	0,105	1,79E-05	
720		9,6	0,096	7,18E-06	
780		9,9	0,099	-2,29E-06	
840		8	0,08	1,48E-05	
900		7,8	0,078	1,65E-06	
960		6,8	0,068	8,41E-06	
1020		5,9	0,059	8,22E-06	
1080		5	0,05	9,07E-06	
1140		4,5	0,045	5,49E-06	
1200		3,5	0,035	1,25E-05	

In Senegal, a ten-year return period (T=10 years) is generally chosen (TOUNKARA, 2021). Choosing the return period consists of finding the intensity of rain that gives the maximum flow to the outfall. The sizing intensity is given by several formulas, the most widely used in Senegal is that of Montana, defined as follows :

$$I = a * t^{-b}$$

I : average maximum intensity of return period T observed over a period t ;

a and b: the adjustment parameters obtained from the IDF curves.

This is the curve reflecting the evolution of rainfall intensity as a function of duration on a bi-logarithmic scale.

Figure 10 shows the IDF Dakar curve with return period T = 10.

The IDF curve will allow us to find the coefficients a and b of Montana's formula by the method of least squares.

Table 3 illustrates the subwatersheds of the study area and their characteristics.

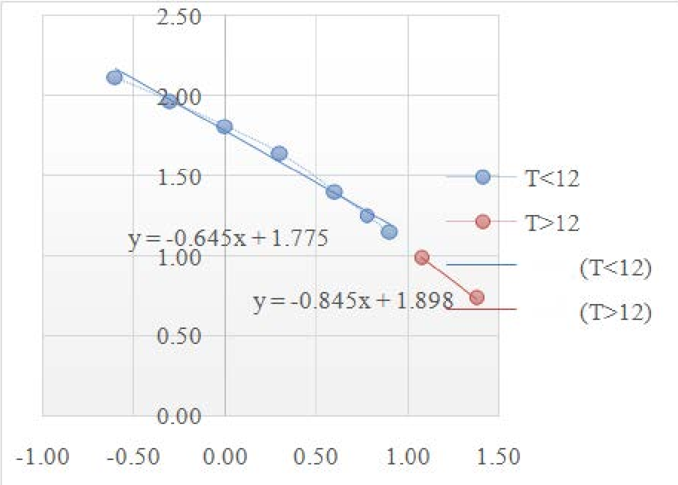

Figure 10. IDF Dakar curve with return period T = 10 years

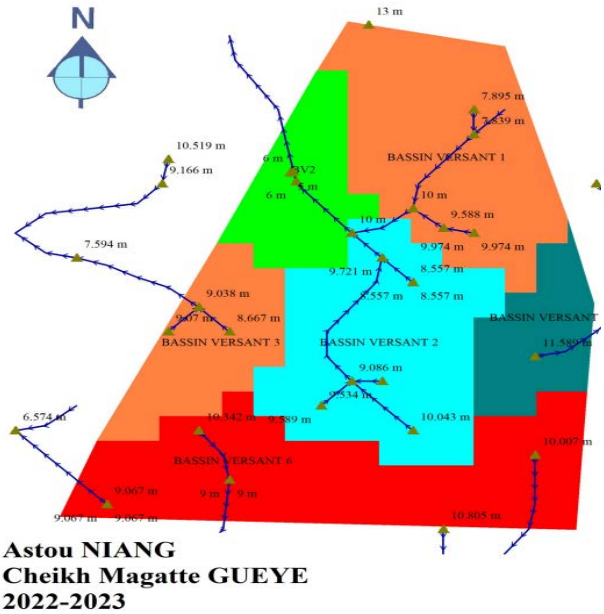

Figure 11. Assembling watersheds

Table 3. The sub-watersheds of the study area and their characteristics

Les Sous	surface	surface	périmètre	Leq m	Z(max)	Z(min)	pente BV
bassin versant	km²	ha	km	km	m	m	m/m
SBV1	0,0196	1,96	0,70057	0,28	13	5	0,029
SBV2	0,00905	0,905	0,46585	0,18	8	4	0,022
SBV3	0,01659	1,659	0,62114	0,24	5	4	0,004
SBV4	0,0196	1,96	0,93171	0,42	8	4	0,010
SBV5	0,0588	5,88	1,24	0,50	8	4	0,008
SBV6	0,00754	0,754	0,46585	0,19	8	4	0,021
SBV7	0,01659	1,659	0,69938	0,29	8	4	0,014
SBV8	0,0196	1,96	0,61995	0,22	5	4	0,005
SBV9	0,01659	1,659	0,77642	0,34	8	4	0,012
SBV10	0,03358	3,358	0,84398	0,32	9	5	0,013
SBV11	0,02715	2,715	0,93052	0,40	8	4	0,010
SBV12	0,03619	3,619	1,008	0,42	5	4	0,002
SBV13	0,0377	3,77	0,93052	0,36	6	4	0,006
SBV14	0,01206	1,206	0,54409	0,22	9	5	0,018
SBV15	0,0754	7,54	1,477	0,62	6	4	0,003
SBV16	0,01206	1,206	0,46585	0,16	6	4	0,013
SBV17	0,01659	1,659	0,5429	0,18	9	4	0,028
SBV18	0,04675	4,675	1,009	0,38	9	5	0,010

Figure 11 illustrates the assembly of watersheds

Table 4 illustrates the characteristics of the assembled watersheds

Table 4. Characteristics of Assembled Basins

bassin versant	Seq	Leq	Tceq	Tceq	Ceq	I
	Ha	km	mn	h		mm/h
BV1	8,90	1,32	32,58	0,54	0,85	91,33
BV2	7,99	0,76	31,36	0,52	0,85	93,80
BV3	5,88	0,50	16,42	0,27	0,85	147,75
BV4	3,36	0,32	9,90	0,17	0,85	210,73
BV5	5,73	0,36	8,87	0,15	0,85	227,70
BV6	16,29	0,62	15,89	0,26	0,85	151,16

Table 5 shows the choice of the appropriate calculation method for each watershed.

Table 5. Choice of Flow Method

watershed	Seq	Choice of method
	Ha	
BV1	8,90	CAQUOT
BV2	7,99	CAQUOT
BV3	5,88	CAQUOT
BV4	3,36	RATIONNELLE
BV5	5,73	CAQUOT
BV6	16,29	CAQUOT

The sizing will therefore be done by the Caquot method.

$$\mathbf{Q = k * C^{u} * I^{v} * A^{w}}$$

The results of the flow calculation using the Caquot method are presented in Table 6.

Table 6. Result of the flow calculation using the Caquot method

watershed	Seq	C	P	K	U	v	w	Qcaquot
	Ha		m/m					m3/s
BV1	8,90	0,85	0,0030	3,96	1,25	0,36	0,74	2,0325
BV2	7,99	0,85	0,0040					2,0673
BV3	5,88	0,85	0,0080					2,1140
BV4	3,36	0,85	0,0127					1,6486
BV5	5,73	0,85	0,0055					1,8210
BV6	16,29	0,85	0,0065					4,1932

If the factor of M (elongation coefficient) is significantly different from 2, the peak flow rate Qp must be corrected by the following form correction factor m:

$$\mathrm{M} = \max\left(0{,}8 * \frac{L}{100 * \sqrt{A}}\right)$$

$$m = \left(\frac{M}{2}\right)^{\frac{0{,}84 * b}{1 + 0{,}287 * b}}$$

The results of the Caquot flow calculation after correction are presented in Table 7.

Retention ponds are areas designed to contain stormwater to prevent flooding. It is essential in stormwater drainage systems. It is a permanent body of water into which rainwater and runoff collected during the rainy season are discharged. Their size depends on their purpose (multi-purpose use) and the volume of retention required. Their size will determine the type of use and layout.

Table 7. Result of the flow calculation by the Caquot method after correction

Watersheds		L-hydraulique	L/100*(S)1/2	M	m	Q
BV1	0,8	283,16	8,45	8,45	1,93	3,93
BV2		364,68	10,31	10,31	2,12	4,38
BV3		139,34	3,38	3,38	1,27	2,69
BV4		333,19	6,11	6,11	1,67	2,75
BV5		141,78	3,39	3,39	1,27	2,32
BV6		217,21	8,77	8,77	1,97	8,24

The advantages and disadvantages of the retention pond are presented in Table 8.

Table 8. Advantages and disadvantages of the retention basin (Tounkara, 2021)

Benefits	Disadvantages
• Ability to recreate an ecosystem • Low investment if it is the development of an existing body of water • Possibility of reusing rainwater • Reduced maintenance of green spaces • Efficient decontamination of rainwater by settling particles.	• Significant land holdings most of the time. • Risk of odour nuisance (water stagnation, rotting of plants, etc.) due to lack of construction or lack of maintenance. • Ensure appropriate management to prevent eutrophication of the pond (removal of aerators), proliferation of mosquitoes, frogs

Table 9 illustrates the characteristics of the storage pond.

Table 9. Characteristics of the storage basin

Retention basin	Vmax	Sinf	P	Trempli	Trempli
	m3	ha	m	mn	h
BR	32329	1,93	16,7761	139,69	2,33

4. Conclusion

In this paper, a hydrological study was conducted using terrain from topographic surveys and rainfall data. This study makes it possible to understand the evolution of height measurements, horizontal curves but also the different solutions recommended for rainwater storage. However, the design has some limitations, especially given the rapid population growth and future occupation of the area.

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