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Design Of Drainage System For Street 2A Between Streets 9 And 11

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Abstract

The following report is focused with the purpose of developing an adequate description of the hydrological and hydraulic characteristics that surround the urban area of the municipality of Arauquita and specifically the sections of the roads of race 2a between 9th and 11th streets in the Araguaney urbanization that will be improved through the construction of rigid concrete pavements. The drainage areas are estimated according to the defined storm drainage network; the design method and flow calculation for said system are also defined. The calculation parameters and the IDF curve are defined. The design of the drainage system is based on Colombian regulations such as RAS-2000, Resolution 330 of 2017 and the land use plan. The design flow is performed by the rational method; the IDF curves of the municipality of Arauca, the return period according to the area, the inflow time, outflow time and travel time are taken according to the equations shown in the results; the runoff coefficient is taken according to the type of soil by means of table 2 and the design flow is obtained section by section with its length and own area.

Keywords: *design; hydrologic; drainage; road; flow rate.*

1. Introduction

Hydrology is the principal science that studies the inland waters (Silva Busso, A. (2020) above and below the earth's surface and in the atmosphere (Lozano-Rivas, W. A. 2018). The constant circulation of water from the land and the sea through the biosphere and the atmosphere by evaporation (Lareu, R., Latorre, V., & Padilla, N. A. 2020), evapotranspiration (loss of water from soils by evaporation and transpiration in plants) (Serio, L., Antelo, M., & Zalazar, S. M. F. 2019), precipitation (Medina, J. A. S., González, P. H., & Sinoga, J. D. R. 2019) and currents, constitutes the hydrological cycle (DEMO, A. P. M.).

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The regulations define the curves of intensity (Curo Salazar, R. C. 2021), duration and frequency as the climatological basis for the estimation of design flows (Montaño-Cañola, S. A., & Espinoza-Correa, J. E. (2022). These curves synthesize the characteristics of the maximum extreme precipitation (Herrera-Ramos, D. F., & Rojas-Arias, L. D. (2022) events of a given area and define the average rainfall intensity for different durations of precipitation events with specific return periods (Rubiano Sánchez, F. (2021).

To determine extreme rainfall data, which is required for hydraulic infrastructure design (Nieves, M., & Adrián, O. (2022), storm drainage, surplus control, land use planning and hydrological risk planning (Perahia, R., & Lasanta, T. I. (2021). For a hydrological design it will depend on how significant the construction being designed is. For minor infrastructure, recurrences between 2-100 years are used, in which extreme precipitation values are taken (Catalini, C. G., Guillén, N. F., García, C. M., Bazzano, F., & Baraguet, M. M. (2021).

2. Method

The purpose of this study is to

- Estimation of drainage areas according to the defined corridor of the storm sewer network.
- Definition of the design method and calculation of the design flow for a storm sewer system.
- Definition of the intensity, duration and frequency curves - IDF.
- Definition of other calculation parameters for the estimation of the design flow, return period, rainfall intensity, runoff coefficient and time of concentration.

The preparation of the hydrological and hydraulic study of the designs is based on the standards and specifications described below:

- RAS 2000 - Title D: domestic wastewater and rainwater collection and disposal systems.
- Resolution 330 of 2017
- City Land Use Plan.

The development of the hydrological study applicable to the design project of the rainwater system for the construction of a rigid pavement located in race. 2A between 9th and 11th street of Barrio Araguaney, municipal head, municipality of Arauquita - department of Arauca country Colombia is presented.

2.1. Design flow rate

For the estimation of the design flow, the rational method will be used, which is recommended by Resolution 330 of 2017 and the RAS-2000 in its Chapter D.4.3.2.

With this method, the peak rainwater flow will be calculated based on the average intensity of the precipitation event with a duration equal to the time of concentration of the drainage area and a runoff coefficient. The equation of the rational method is:

$Q = C \times I \times A$

Where:
Q= Surface flow (L/s)
C = Runoff coefficient (dimensionless)
I = Average rainfall intensity (L/s.Ha)
A = Drainage area (Ha)

Or also:

$$Q = 2{,}78 \times C \times I \times A$$

Dónde:
Q = Surface flow (L/s)

C = Runoff coefficient (dimensionless)
I = Average rainfall intensity (mm/hr)
A = Drainage area (Ha)
2,78 = Conversion factor

According to Resolution 330 of 2017, the rational method is suitable for small drainage areas up to 700 ha.

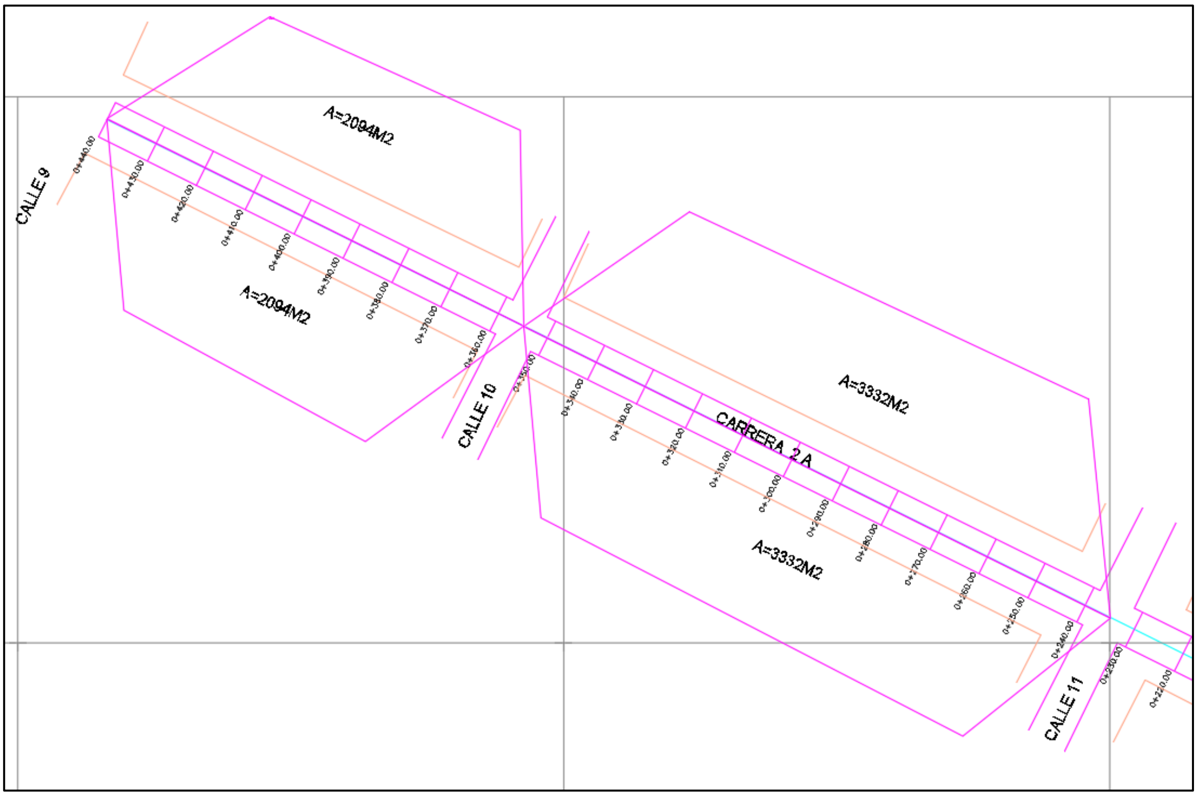
3. Results and discussion

3.1. Drainage area

It is defined that the drainage areas for a rainwater system (Niño Cotrina, J. M., & Garcia Chozo, M. X. 2021) must include the tributary area of the section under consideration and will be determined by direct measurement on plans and their delimitation must be consistent with the natural drainage networks.

Following the recommendations of the standard and in the construction of a base that allows us to quickly identify the natural drainage over the area of influence of the design project and thus define the drainage areas, and with the obtaining of topographic information, contour lines, the drainage areas are defined for each section of the rainwater system as shown in the following figure:

Figure 1. Drainage areas for each section of the pluvial system



3.2. Intensity - duration - frequency curves

In the verification of the existence of IDF curves for the locality or zone of influence, the IDF curves of the municipality of Arauca were taken, which are described as follows

Figure 2. IDF curve

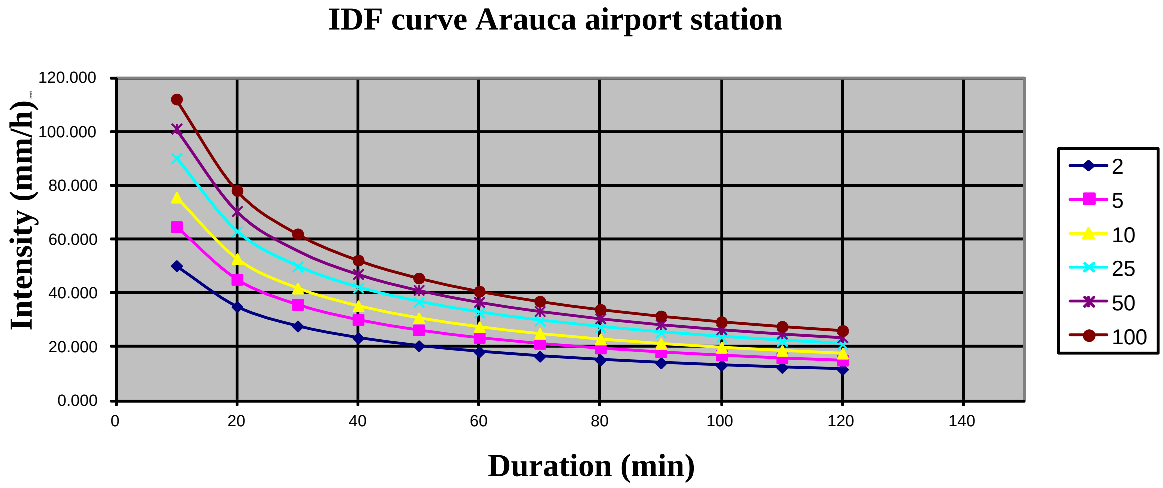


Table 1. Intensities for mm/h durations.

TR	Intensities for the durations of (mm/h)										
	10min	20min	30min	40min	50min	60min	70min	80min	90min	100min	110min	120min
2	50,168	34,986	27,750	23,381	20,403	18,217	16,536	15,192	14,088	13,161	12,375	11,691
5	64,672	45,101	35,773	30,138	26,303	23,486	21,317	19,584	18,161	16,967	15,952	15,073
10	75,643	52,752	41,842	35,254	30,764	27,471	24,933	22,906	21,242	19,848	18,657	17,628
25	90,147	62,866	49,865	42,013	36,663	32,738	29,714	27,288	25,315	23,653	22,236	21,011
50	101,119	70,518	55,934	47,126	41,125	36,723	33,328	30,618	28,396	26,532	24,942	23,566
100	112,095	78,169	62,003	52,238	45,587	40,707	36,946	33,942	31,477	29,408	27,646	26,125

Finally, with the IDF curves reported above, the equation of these I-D-F's is established as follows:

Where:
Tr= Return period (years)
d = Rainfall duration (min)
K, m, n = Constants

Result

$$I = \frac{186{,}16713 * Tr^{0{,}20302}}{d^{0{,}59341}}$$

Source: author.

The spreadsheet with which the above I-D-F's equation was obtained by the consultant.

3.3. Design return period

The design return period should be determined in accordance with the importance of the areas and with the damage (González Mártinez, L. A., & Guarnizo Buitrago, T. F. (2021), damage or inconvenience that periodic flooding may cause to inhabitants, vehicular traffic, commerce, industry, etc. The selection of the return period is then associated with the protection characteristics and importance of the study area (Acosta Morales, J. F. (2022).

For the selection or prediction of a fair return period, Resolution 330 of 2017 and the RAS-2000 in its Table D.4.2. establishes the return periods or degree of protection that are a function of the drainage area, which the consultant makes the decision to comply with for the design project the one indicated with the column denominated as "acceptable".

Table 2. Return period or degree of protection

Drainage area characteristics	Minimum (years)	Acceptable (years)	Recommended (years)
Initial sections in residential areas with tributary areas smaller than 2 ha.	2	2	3
Initial sections in commercial or industrial zones, with tributary areas of less than 2 ha.	2	3	5
Sewer sections with tributary areas between 2 and 10 ha.	2	3	5
Sewerage sections with tributary areas larger than 10 ha	5	5	10
Open channels in flat areas and draining areas larger than 1000 ha *.	10	25	25
Canales abiertos en zonas montañosas (alta velocidad) o a media ladera, que drenan áreas mayores a 1000 ha	25	25	50

Note: *Part lined at 10 years, plus free edge at 100 years.

For the design project under study, a return period or degree of protection of 2 years is used for the accumulated drainage areas of the storm drainage sections, whether ditches, canals or pipes, of less than 2 hectares, and a return period or degree of protection of 3 years for the accumulated tributary areas of the storm drainage sections, whether ditches, canals or pipes, of between 2 and 10 hectares.

3.4. Rainfall Intensity

The rainfall intensity (Curo Salazar, R. C. (2021) for the design project under study is calculated by estimating the peak rainfall flow corresponding to the average rainfall intensity given by the IDF curve, for the design return period defined based on the established and with a duration equivalent to the runoff concentration time whose estimation is defined below.

3.5. Results of precipitation intensities

The precipitation intensity (Rolón Heredia, J. A. (2021). Analysis of precipitation time series for its use in the planning of microwave systems in Colombia.calculated for each of the sections of the project under study, was taken through a hydrological study carried out in the project, estimated with the I-D-f's equation.

3.5. Time of concentration

The time of concentration corresponds to the sum of the entry time and travel time in the rainwater collector (Rodríguez Cuero, S. A., & Yánez Encalada, J. E. (2022).

The inflow time corresponds to the time required for the runoff to reach the collector sump and the travel time is associated with the travel or transit time of the water within the collector.

$$Tc = Te + Tt$$

Where:

Te = Entry time

Tt = Transition time

For this design, the consultant takes 10 minutes as the minimum concentration time in initial wells, complying with the recommendation of the standard. In the same way, the recommendation of this same numeral is followed, where if two or more collectors converge to the same connection structure, the concentration time at that point should be considered as the greater of the concentration times of the respective collectors.

3.6. Inlet time

The standard recommends several formulas for estimating inflow time (Castillo García, C. L., Abreu Franco, D. E., & Álvarez González, M. 2021). The consultancy selects the U.S. FAA equation which is frequently used for surface runoff in urban areas. Its formula is as follows:

$$Te = \frac{0.707 \times (11 - C) \times L^{1/2}}{S^{1/3}}$$

Where:

Te = Inlet time

C = Runoff Coefficient

L = Length of tributary area

S = Average slope of tributary area

3.7. Travel time

The standard recommends the following formula for its calculation:

$$Tt = Lc / (60 \times V)$$

Where:

Lc = Collector length

V = Flow velocity in the collector

3.7. Concentration time results

The times of concentration calculated for each of the sections of the project under study were taken from the hydrological study carried out on the project according to the procedure and in relation to this report by the environmental consulting and hydraulics company.

Time of concentration

Tc=0.3(L/So 0.25)0.75.

Where:

L= Length from the farthest point of the watershed to the sinkhole in kms.

So= Difference in elevation over L, in %.

Tc= Time of concentration in hours.

Tc= 0.3 (0.70/ 0.14 0.25)0.75 = 0.33 hours = 20min.

I = 80 mm/Hour (data extracted from the IDF curve for the municipality of Saravena).

Saravena). With a return period of 5 years and time of concentration of 20min.

3.8. Runoff coefficient

The runoff coefficient, C, is a function of the type of soil, the degree of permeability of the area (Loyo Taboada, A., & López Alvarado, R. M. 2021), the slope of the terrain and other factors that determine the fraction of precipitation that becomes runoff.

According to the standard for its determination, infiltration losses in the soil and other runoff retarding effects must be considered. Likewise, it must include considerations on urban development, land use plans and local legal provisions on land use.

For drainage areas that include subareas with different runoff coefficients, the C value representative of the area should be calculated as the weighted average with the respective areas.

$$= \frac{(\Sigma C.A)}{\Sigma A}$$

Where:

C = Runoff Coefficient (dimensionless).

A = Tributary area

Table 3. Surface area types

Type of surface	C
Covers	0,75-0,95
Asphalt pavements and concrete surfaces	0,70-0,95
Cobblestone roads	0,70-0,85
Commercial or industrial areas	0,60-0,95
Residential, with adjoining houses, predominantly hard zoning	0,75
Multi-family residential, with contiguous blocks and hard landscaping between them	0,60-0,75
Single-family residential, with contiguous houses and predominantly landscaped gardens	0,40-0,60
Residential, with houses surrounded by gardens or significantly separated multifamily houses	0,45
Residential, with predominantly green areas and park-like cemeteries	0,3
Slopes without vegetation	0,6
Hillsides with vegetation	0,3
Recreational parks	0,20-0,35

Source. Runoff or imperviousness coefficients

3.9. Selection of runoff coefficients

The runoff coefficients (Vargas Vargas, C. L. 2022) calculated in the development of this project were 0.7, according to the type of surfaces considered for each section and weighting calculations.

Determine runoff coefficient:

$$C= 0.14+0.65 * 0.75 +0.05*0.02 = 0.63$$

i= Impermeability coefficient= 0.75.(impervious areas).

3.10. Design flow rate

The methodology for calculating the design flow rate is presented in this study, with the clarity that from the selected method the flow rates for the system diagnosis were obtained. In which it is taken from the hydrological study of flow and section by section.

Table 4. Calculation of design flow

Section	Initial Tranche	Final Section	Length [m]	n Manning	C Racional	Own Area [Ha]	Accum. Area. [Ha]	{38} Q own [l/s]
C-1	T-1	T-2	85	0,015	0,7	0,209	0,209	42,41
C-2	T-3	T-4	85	0,015	0,7	0,209	0,209	42,41
C-3	T-5	T-6	120	0,015	0,7	0,333	0,543	146,927
C-4	T-7	T-8	120	0,015	0,7	0,333	0,543	146,927

5. Conclusions

The evaluation parameters used for the design of the rainwater system for the addresses: race 2A between street 9 and 11 of Barrio Araguaney municipal head, municipality of Arauquita - department of Arauca, are those given by Title D of the Technical Regulations of the Drinking Water and Basic Sanitation Sector RAS - 2000 and resolution 330 of 2017.

The consultant performs the designs on a detailed topography. On the defined corridor, the existing sewerage networks are raised with the taking of the manhole covers, special structures (channels, gutters, ditches, boxes, poles, trees), facings (roads and sidewalks) and in general all the structures and pipes that contribute as important information.

When carrying out the diagnosis and check of hydraulic works of evacuation of the area. No storm drainage network was found. After calculating the flow rate, the alternative solution is to manage the rainwater superficially through a longitudinal slope until it reaches the surrounding roads and is thus managed by them.

The roadways of the sections will not have ditches to collect surface runoff; this function will be fulfilled by the longitudinal and transversal slopes of the structure, complemented by lateral confinement sardinels. The waters for these sections will be captured by the drainage system that will work by surface runoff, taking advantage of the availability of favorable slopes (longitudinal and transversal), which will flow into a parallel rainwater channel along the entire length of the road.

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