Precipitation Study in Flood Zones: San Mateo Atenco, State of Mexico, Mexico Case Study

M. García-Martínez*, O. Cruz-Castro, L. J. Osornio-Berthet, and J. Meléndez-Estrada

Postgraduate Studies and Research Section, Zacatenco Campus, National Polytechnic Institute, Mexico City, Mexico
Email: maggiegarciamartinez5@gmail.com (M.G.M.); ocruz@ipn.mx (O.C.C.); osornioberthet@hotmail.com (L.J.O.B.); jmelendeze@ipn.mx (J.M.E.)
*Corresponding author

Manuscript receive July 11, 2023; revised August 25, 2023; accepted September 25, 2023; published January 17, 2024

***Abstract*—This work is focused on analyzing the causes of flooding in the sub-basin belonging to the municipality of San Mateo Atenco: Almoloya-Otzolotepec, because the municipal territory is constantly threatened by hydrometeorological phenomena, such as hailstorms, frost and torrential rains. The maximum precipitation was analyzed in neighboring climatological stations and the precipitation at different return periods (2 to 1000) was determined through the Gumbel distribution, and its impact according to the Thiessen polygon method. With the information of the 24-hour intensities, the Intensity Duration Frequency (IDF) curves and the hietogram of the study area were plotted using the alternating block method. The above procedure was applied to the precipitation data from the 9 stations that affect the basin. The approach proposed in this work considers all the precipitation variables for the best approximation of the phenomena that may occur in the basin; it is an innovative model because it considers the weighted averages of precipitation for each area of influence and its surroundings; this information is useful for the implementation of flood protection projects, adequate design of drainage and sewage systems, and a rational use of the resource to guarantee better living conditions for the inhabitants. According to the results obtained, there is a slow hydrological response and the areas with the greatest runoff potential ($83<CN<100$) are located towards the central part of the basin where there is a significant concentration of bare soil.**

***Keywords*—Thiessen polygons, Gumbel, flood zones, precipitation**

I. Introduction

Water is one of the most valuable natural resources of any country due to the social and economic benefits derived from its conscious exploitation; however, along with the advantages there are also extreme situations, such as floods and droughts [1].

In the case of Mexico, the Natural Disasters Fund serves as a financial instrument through which the National Civil Protection System integrates a process that respects the responsibilities and needs of the different levels of government, whose purpose is to support the states of the Mexican Republic [2].

According to the international glossary of hydrology: flood is defined as “a rise of water above the normal level of the river channel”. In this case, “normal level” should be understood as a rise in surface water that does not cause damage, i.e., flooding is a higher-than-normal rise in a river channel, which may cause losses. According to the International Red Cross, during the period 1919–2004 they have assisted in more flood events than any other type. Globally, floods are increasing faster than any other disaster, largely because the rapid development of communities modifies local ecosystems, increasing the risk of flooding to which many populations are exposed [3].

On the other hand, flooding is defined as: “a rapid and usually brief rise in the water level in a river or stream to a maximum from which the water level falls at a slower rate” [4].

The purpose of this study is to analyze the causes of flooding in the sub-basin because 95.24% of the municipality’s surface area is flood-prone due to its location in the lowest area of the high plateau, and at least 30% of the territory (riparian zone) is in real vulnerability, which represents a risk for human settlements and their inhabitants. the effects can be reflected in human losses, damage to infrastructure, services, economic activities and damage to health. This study is based on a hydrological study to determine the level of vulnerability of the population based on the proposed methodology model, considering the influence of the maximum precipitation of each season by its weighted area; in addition to providing a basis for future studies and land management plans, which would prevent further catastrophes in the area and in turn would allow us to propose protection and care works for the citizens.

II. Methodology

The following methodology is used for the development of the methodology project: Fig. 1.

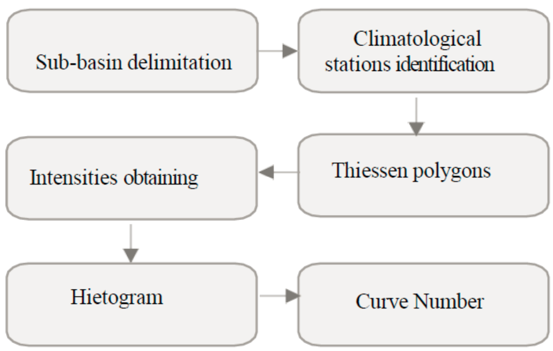

Fig. 1. Methodology.

A. *Description of Study Area*

The Municipality of San Mateo Atenco is located in the central zone of Mexico, it belongs to the Metropolitan Zone of the Toluca Valley, with the following extreme geographic coordinates: North Latitude 19°15’46.81’’ and West Longitude 99°31’56.75’’. The municipality has an area of 1,875.5 hectares, bordered to the north by the municipality of Toluca, to the south by the municipality of Metepec, to the west by the municipality of Lerma and by a disputed area (between the municipalities of Lerma, Ocoyoacac and San Mateo Atenco, with an approximate area of 650 hectares), and to the west by the municipality of Metepec. The municipality belongs to the micro-watershed of the Almoloya-Otzolotepec sub-watershed. For the purposes of this study, the sub-basin will be analyzed in its entirety, since it has been observed that there are several flood-prone municipalities in this area, so a study of the number of curves for the entire area would yield more consistent results for the development of future actions. The sub-basin has an approximate surface area of 816,644 km^2 corresponding to the R. Lerma-Toluca Basin. It has a more humid temperate sub-humid climate C(w2) (w) with winter precipitation of less than 5%. In this portion, the average temperature ranges between 12 ℃ and 18 ℃. The geographic coordinates of the geometric center are: latitude 19.316072 and an elevation of 2577 m [5] (Fig. 2).

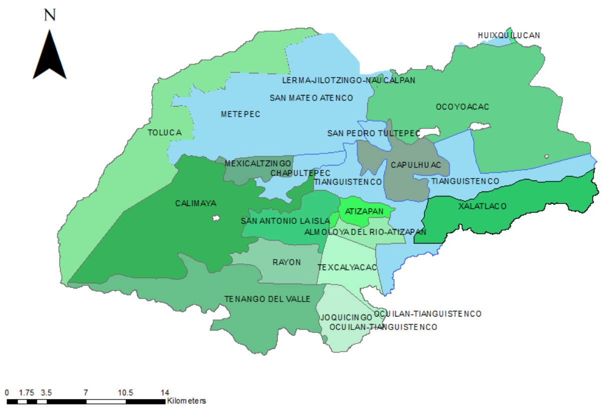

Fig. 2. Almoloya-Otzolotepec sub-basin.

B. Climatological Stations

The studies carried out for extreme hydrological events included the selection of a sequence of observation of maximum precipitation in the 9 climatological stations closest to the sub-basin. For the purposes of this work, a return time of 1000 years was considered because this period is considered useful for the study of flood zones, which was determined using the function of extreme values I or also known as Gumbel, mainly because it has been shown theoretically that it adjusts to the maximum values, in addition to being the statistical distribution most commonly used at present for the calculation of precipitation for a selected return period. Values were taken for the corresponding period of 1986–2016, the most current available values obtained from the National Climatological Database [6], which must comply with the condition of homogenization, i.e., the same period for all stations.

C. Thiessen Polygons

The Thiessen Tool proportionally distributes a coverage of points to generate polygons of defined areas of influence from each point. This methodology is used to study the spatial and temporal distribution of hydrological variables (temperature, precipitation, infiltration) and in engineering applications. Examples are given by authors such as [7–9]. They are created by joining points, tracing the perpendicular bisectors of the joining segments.

D. Concentrated 24-Hour Rainfall

For the purposes of this project, once the maximum 24-hour precipitation was obtained, with the different return times for each of the 9 climatological stations, these values were multiplied by their corresponding areas, obtained according to Thiessen's method, to finally obtain an average of the weighted precipitation, represented by Eq. (1), which will be called the 24-hour precipitation concentrate:

$$\bar{P} = \frac{1}{A_T}\sum_{i=1}^{n} A_i \times X_i = \frac{A_1X_1 + A_2X_2 + A_3X_3 + \cdots + A_nX_n}{A_T} \tag{1}$$

where:

P = Mean precipitation of sub-basin
n = Stations number within a sub- basin
X_i = Station precipitation i
A_T = Total area of sub-basin
A_i= Partial influence area of Thiessen polygon corresponding to station i.

This methodology is innovative since, unlike the traditional method, it implicitly contemplates the influence of the maximum precipitation of each station by its weighted area, being a contribution that can be used for future probabilistic studies of precipitation and intensity.

E. Intensities Concentrations

From the 24-hour rainfall analysis, the method proposed by Aparicio [10] was used to calculate the intensities by distributing the rainfall in times less than 1 hour and from 1 to 24 hours to obtain the IDF curves.

F. Hietogram Elaboration by the Alternating Block Method

For hietogram elaboration, the IDF curve to be worked on is selected, i.e., the IDF curve must be available according to the required return time. The design time or time of concentration of the basin is divided into similar time intervals and the total amount of precipitation that occurs in each time interval is calculated by the product of the intensity by the duration of each interval, thus being able to find the value of the intensity of precipitation according to the time interval obtained in the first step. With the precipitation values obtained, each consecutive value is subtracted according to the result. Finally, the hietogram is plotted, taking into account that the maximum value will be the central bar of the graph. For the construction of the hietogram it is assumed that the average intensity of a set of blocks has to be equal to the intensity across the IDF curve for any given time interval.

G. Assignment of Land Uses

A hydrologic soil group (HSG) is a set of soils that have similar runoff generation behavior and are classified into one of the following categories [11]. Soil hydrologic groups are directly related to the minimum saturated infiltration rate of that soil, distinguishing four groups from higher to lower infiltration capacity, named A, B, C and D. According to the fraction of sand (diameter 0.05–2 mm), silt (diameter 0.002 to 0.05 mm) and clay (diameter less than 0.002 mm), soils can be classified into different textures, the hydrologic group being determined by various abacuses such as the textural triangle of classification from the United States Department of Agriculture [12].

- Group A: are predominantly sandy soils, where water is freely transmitted through the profile and therefore have a low runoff potential when completely wet.
- Group B: are soils with moderately fine to moderately coarse textures that have a moderately low runoff potential when completely wet.
- Group C: Soils with a layer that limits vertical water movement and moderately fine to fine textures. Runoff potential is moderately high when wet.
- Group D: Soils with high runoff potential and very low infiltration rates. The textures are clayey, the water table is high or they are shallow soils, settled on impermeable material.

The group of land uses in the sub-basin was assigned based on the development of a thematic map generated with the support of Geographic Information Systems (GIS), which for this study was carried out using ArcMap. The soil characteristics allowed defining the corresponding GHS using texture as the main assignment criterion, the chosen GHS corresponds to the highest percentage within the area, or by averaging the closest areas.

H. Curve Number Determination

Curve number (CN) is a method for calculating the effective precipitation produced by a storm in a given area. From the determination of land uses, the curve number map is generated by combining the land cover map and the hydrologic soil group map using the ArcCN tool for ArcGIS [13], which incorporates the Natural Resources Conservation Service tables [11]. Curve numbers for different combinations of hydrologic soils and land cover groups can be found in the NRCS tables [14]. Bauwe *et al*. [15, 16] conducted hydrological assessments in watersheds using the curve number methodology, together with other models, obtaining good results by applying the curve number method.

III. RESULTS AND DISCUSSION

Using the Thiessen polygon method, data from 9 climatological stations near or within the study sub-basin were analyzed (Fig. 3). Table 1 shows the area of influence of each of the existing stations and given the qualitative data interpolation method, an average precipitation of 82.06 mm was obtained for the sub-basin.

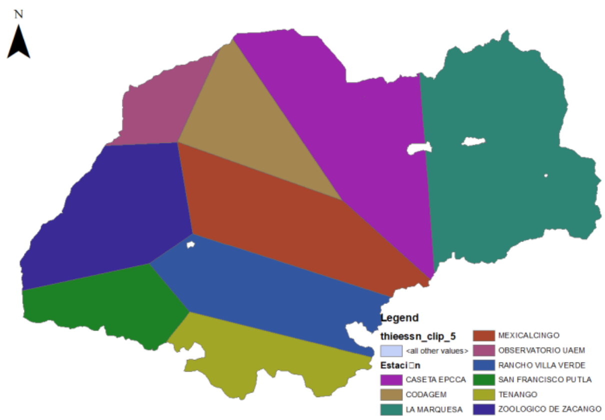

Fig. 3. Thiessen polygons for the sub-basin.

As can be seen in Table 1, the Mexicalcingo station has the greatest percentage of influence on the study basin.

Table 1. Climatological stations areas of influence

Climatological station	Key	Station influence area	
		km^2	%
Mexicalcingo	15056	106.17	13.08
La Marquesa	15045	179.14	22.06
EPCCA Booth	15315	137.35	16.92
CODAGEM	15266	63.54	7.83
Zacango Zoo	15395	97.36	11.99
Rancho Villa Verde	15373	89.68	11.05
San Francisco Putla	15240	52.34	6.45
Tenango	15122	54.67	6.73
UAEM Observatory	15367	31.68	3.90

Using Gumbel distribution, the information was processed considering 20 years and with this, 9 tables (one per station) of frequency factor were elaborated, indicating the probability of occurrence of a maximum precipitation for return times from 2 to 100 years. Table 2 shows the process carried out at Mexicalcingo Station, repeating the process for the other stations.

Table 2. Maximum flows for different return periods by Gumbel distribution in Mexicalcingo Station

T (years)	YT	Exceedance Probability P = F(x)	Non-exceedance probability 1-F(x)	Z	z correction
2	0.367	0.5	0.5	164.877	186.311
5	1.500	0.2	0.8	216.731	244.906
10	2.250	0.1	0.9	251.063	283.701
25	3.199	0.04	0.96	294.441	332.718
50	3.902	0.02	0.98	326.621	369.082
100	4.600	0.01	0.99	358.564	405.178

From Gumbel distribution, the Dick Peschke method was used to obtain the maximum rainfall from 1 to 24 hours for the same return times. Table 3 shows at the top the maximum rainfall in mm at 24 hours for their respective return times (2 to 100 years) which were previously calculated with the Gumbel Distribution. It is important to mention that this process was repeated for each of the remaining 8 stations.

Table 3. Mexicalcingo station precipitation with return periods

Time (minute)	Precipitation in 24 hours (mm)					
	186.31	244.91	283.70	332.72	369.08	405.18
	Return period (years) by Gumbel					
	2	5	10	25	50	100
	Precipitation (mm)					
60	84.18	110.65	128.18	150.32	166.75	183.06
120	100.10	131.58	152.43	178.76	198.30	217.70
180	110.78	145.62	168.69	197.84	219.46	240.92
240	119.04	156.48	181.27	212.59	235.82	258.89
300	125.87	165.46	191.67	224.78	249.35	273.74
360	131.74	173.17	200.61	235.27	260.98	286.50
480	141.57	186.09	215.57	252.81	280.44	307.87
720	156.67	205.94	238.56	279.78	310.36	340.71
1080	173.38	227.91	264.01	309.63	343.47	377.06
1440	186.31	244.91	283.70	332.72	369.08	405.18

Table 4 shows the weighted average resulting from the data of 9 stations, multiplied by the area of influence obtained by the Thiessen polygons of each station.

Table 4. Maximum daily Precipitation by rain duration and frequency distributed by Thiessen polygons

Precipitation (mm) / Time (minutes)	Return period (years)					
	2	5	10	25	50	100
60	119.65	158.31	183.90	216.24	240.24	264.05
120	142.28	188.26	218.70	257.16	285.69	314.01
180	157.46	208.34	242.03	284.59	316.17	347.51
240	169.20	223.88	260.08	305.81	339.74	373.42
300	178.91	236.72	275.00	323.36	359.24	394.85
360	187.26	247.76	287.82	338.44	375.99	413.26
480	201.22	266.24	309.28	363.68	404.03	444.08
720	222.69	294.64	342.28	402.47	447.13	491.45
1080	246.44	326.07	378.80	445.41	494.83	543.88
1440	264.82	350.39	407.04	478.62	531.73	584.44

Based on the information obtained in Table 4 and to develop the IDF curves, the proposal of Aparicio [17] was used to elaborate Table 5, which takes into account the weighted average of all the stations. The intensity values are given by the discretized precipitation divided by the duration of precipitation expressed in hours for the same time intervals.

Table 5. Precipitation intensity by duration of rain and its frequency distributed by Thiessen polygons

Intensity (mm/hr) / Time (min)	Return period (years)					
	2	5	10	25	50	100
60	119.65	158.31	183.90	216.24	240.24	264.05
120	71.14	94.13	109.35	128.58	142.84	157.01
180	52.49	69.45	80.68	94.86	105.39	115.84
240	42.30	55.97	65.02	76.45	84.94	93.36
300	35.78	47.34	55.00	64.67	71.85	78.97
360	31.21	41.29	47.97	56.41	62.66	68.88
480	25.15	33.28	38.66	45.46	50.50	55.51
720	18.56	24.55	28.52	33.54	37.26	40.95
1080	13.69	18.12	21.04	24.75	27.49	30.22
1440	11.03	14.60	16.96	19.94	22.16	24.35

IDF curves for different return periods are shown below (Fig. 4), it can be seen that they behave as decreasing functions, that is, intensity decreases at as duration of the rain event increases.

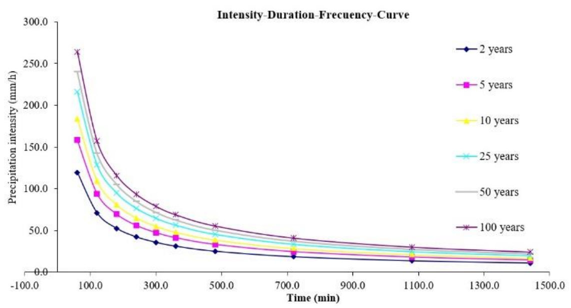

Fig. 4. Sub-basin IDF curves.

Regarding the results obtained, it can be observed that with a return period T of 2 years and 60 minutes duration, the rainfall intensity is 119.65 mm/h. That is, on average, a rainfall event with an intensity of 119.65 mm/h greater and with a duration of 60 minutes occurs once every 2 years.

It is important to consider that in future projects in the study area there are flooding problems, for example the municipality of San Mateo Atenco, which is constantly affected by flooding in that area.

Finally, Table 6 can be constructed from the intensity data, considering the following for the columns: 1) The duration is expressed in minutes; 2) the intensity, which is already a function of the values of k, m and n and the return period can vary depending on the needs of the project to be carried out, in this case 200 years were considered; 3) accumulated runoff resulting from the product of the intensity and duration (hours); 4) incremental runoff resulting from the difference in precipitation of each interval; and 6) the hietogram using the alternating block method.

Table 6. Alternating block method

Duration (min)	Intensity (mm/hr)	Accumulated water depth (mm)	Increased water depth (mm)	Hietogram
60	283.15	283.15	283.15	6.63
120	168.36	336.72	53.57	7.09
180	124.21	372.65	35.92	7.63
240	100.11	400.44	27.78	8.27
300	84.68	423.41	22.97	9.06
360	73.86	443.16	19.74	10.05
480	59.52	476.20	15.63	13.09
720	43.91	527.00	11.34	53.57
1080	32.40	583.23	8.27	12.14
1440	26.11	626.72	6.63	6.85

According information obtained in Table 5, hietogram is constructed, as can be seen in Fig. 5, the maximum precipitation occurs in the interval 720-780 min.

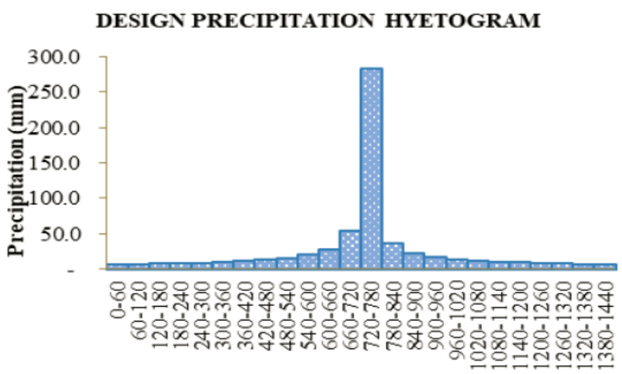

Fig. 5. Hyetogram of sub-basin.

A. *Sub-Basin Land Use*

Fig. 6 shows the land use of the sub-basin area; it is important to note that most of the territory is occupied by cropland and urban settlements, information to be considered for the determination of the rainfall-runoff coefficient. Over time, the area of forests and pastures (green and light green colors) has been reduced and replaced by croplands (orange color) and urban settlements (light gray color); the increase in these areas has increased the impermeability of the soil, along with the other factors mentioned, making it more susceptible to flooding.

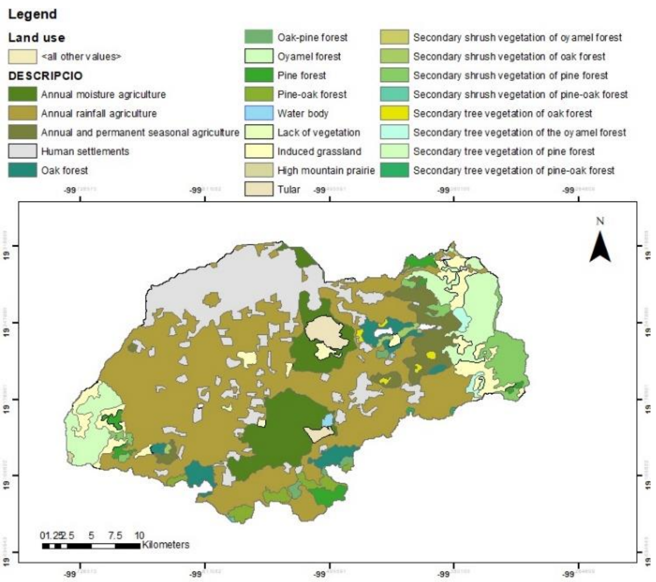

Fig. 6. Land use of sub-basin.

B. Land Cover

The land cover map shows that the predominant land cover is annual rainfed agriculture, which occupies approximately 38.92% of the total area [18, 19] (Fig. 7).

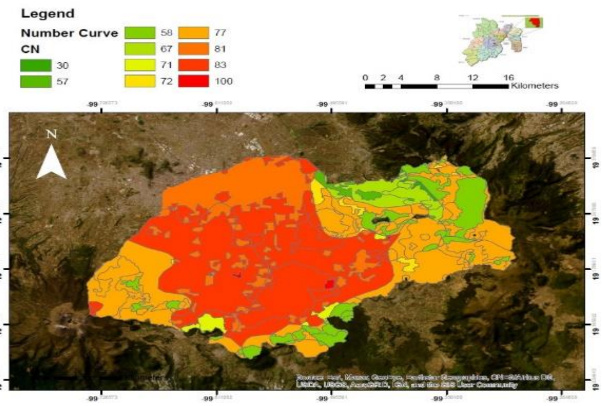

Fig. 7. Number curve of sub-basin.

Table 7 shows the different combinations of land cover and hydrological soil group that were found in the Almoloya-Otzolotepec sub-basin. To each combination corresponds a curve number representing its runoff potential. The lowest values are found in group A soils covered by forest or secondary vegetation, while the highest values are found in group C soils with annual moisture agriculture with almost 40% of the total cover. Water bodies are assigned a NC equal to 100 because all the rain that falls on them is directly converted into runoff. It is also observed that the higher the development and density of the vegetation, the lower the runoff and the higher the infiltration. The effect of plants on the hydrological response of the land is related to their capacity to improve the structure of the soil and therefore its permeability, to provide organic matter, to slow the flow of water over the land and to prevent the sealing of the surface due to the direct impact of rain [14].

It can be seen that the hydrological response is slow, with floods occurring over a relatively long period of time (several hours or days), and mainly causing material damage. The areas with the highest runoff potential (83<CN<100) are located towards the central part of the basin where there is a significant concentration of bare land. The areas with the lowest potential (30<CN<57) are mainly located in the south, where forest cover is combined with soils of hydrological group C. The weighted average curve number for the sub-basin had a value of 77, which suggests that the general conditions of the territory tend to favor runoff over infiltration.

Table 7. Assignment of curve number for each soil-cover association

Coverage type	**GHS**	**Area (km^2)**	**%**	**NC**
Human settlements	A	7.38	0.91	57
Human settlements	B	9.99	1.24	72
Human settlements	C	119.94	14.84	81
Oyamel forest	B	74.29	9.19	58
Annual rainfall agriculture	A	26.85	3.32	67
Secondary shrush vegetation of pine forest	A	2.980	0.37	67
Pine-oak forest	C	10.67	1.32	71
Secondary shrush vegetation of oyamel forest	B	62.45	7.73	77
Annual moisture agriculture	C	314.59	38.92	83
Induced grassland	C	4.76	0.59	83
Oak forest	A	2.00	0.25	30
Water body	-	1.98	0.24	100
Induced grassland	B	37.21	4.60	77
Annual rainfall agriculture	B	133.19	16.48	77
	TOTAL	808.28	100	

Knowing the hydrography of the site makes it possible not only to know which areas are susceptible to risks, but also to avoid possible disasters resulting from the lack of an adequate drainage system and typical rainfall in the area. For example, in 2007 rainy season the affected areas were the neighborhoods of Guadalupe, Santiago, San Nicolás, San Juan, San Pedro, San Mateo and La Concepción; 1242 houses, 120 commercial premises and 10 public buildings were affected. It is for this reason that studies of this nature allow us to analyze the existing situation in order to propose works to improve the current conditions [20].

IV. Conclusions

Flooding in the sub-basin is not only the natural result of the area's location, but also of the poor management of solid waste in the streets, which has led to inadequate drainage. These results are due to the geographical area in which it is located, which shows that in this area of the Almoloya-Otzolotepec sub-basin there are flooding problems in a large part of the municipalities.

The methodology used for the approximation of maximum precipitation at different return periods resulted in values higher than those normally found in the country, with values close to 300 mm/h at its maximum intensity with times of 720 to 780 min, which is the critical situation, indicating that the region belongs to a sub-humid climate, information that is corroborated by the type of dominant vegetation; Considering the curve number for these soil conditions indicates that in general there is little filtration and given the morphological conditions, there tends to be flooding problems in the established urban areas. The hydrological data obtained are useful for the design of protection and channelization works as well as for hydrodynamic modeling.

It is important to mention that the accuracy of this methodology is based on the fact that the greater the amount of existing precipitation data, the better the accuracy will be. However, it allows us to extrapolate to any area where it is desired to know events of this nature and it is suggested to take as a basis for an optimal land use planning program, because Mexico as other countries are being affected by a disorderly urban growth, unfortunately this problem is aggravated in Mexico since it is located on a lake and it is nowadays where the consequences are felt more present.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

MGM and CCO proposed and coordinated the general approach of the article. OBLJ oversaw the development of the methodology by completing the Gumbel precipitation and distribution data, EMJ oversaw the overall methodology and contributed to the number curve and references. All authors read and approved the final manuscript.

ACKNOWLEDGMENT

Thanks are given to División de Operación y Promoción a la Investigación del Instituto Politécnico Nacional, Escuela Superior de Ingeniería y Arquitectura Unidad Zacatenco Sección de Estudios de Posgrado e Investigación UZ and Consejo Nacional de Humanidades, Ciencias y Tecnologías (CONAHCYT).

REFERENCES

[1] G. V. Zucarelli, "Identification of extreme water events in the Parana River basin," *Technology and Water Sciences*, vol. 4, no. 5, pp. 181–187, November-December 2013.

[2] Fonden. Civil Protection. The Natural Disaster Fund of Mexico. (2012). [Online]. Available: http://www.proteccioncivil.gob.mx/work/models/ProteccionCivil/Almacen/fonden_resumen_ejecutivo.pdf.

[3] Mexican Institute of Water Technology (IMTA). (2014). Floods. National Center for Disaster Prevention. ISBN: 970-628-870-8. [Online]. Available: https://agua.org.mx/wp-content/uploads/2014/06/INUNDACIONES_CENAPRED.pdf

[4] WMO/Unesco Panel on Terminology, International Glossary of Hydrology, Geneva: Secretariat of the World Meteorological Organization, 1974.

[5] INEGI, National Institute of Statistics and Geography. Compendium of municipal geographic information. San Mateo Atenco Mexico (2010), Mexico, CA: Wadsworth, 1993, pp. 123–135.

[6] CLICOM. (2020). [Online]. Available: http://clicom-mex.cicese.mx/mapa.html.

[7] J. L. Aragón *et al.*, "Spatial distribution of hydrological variables. Implementation and evaluation of interpolation methods," *Engineering, Research and Technology Magazine*, April-June, pp. 1–15, Mexico: UNAM, 2018.

[8] R. Pizarro, C. Ramírez, and J. Flores, "Comparative analysis of five methods for the estimation of annual areal precipitations in extreme periods," *Forest (Valdivia)*, vol. 24, no. 3, pp. 31–38, 2003. https://dx.doi.org/10.4067/S0717-92002003000300003

[9] N. Sánchez, "Calculation of the mean precipitation over the Guajira peninsula using the Thiessen method," *New Granada Science and Engineering Magazine*, vol. 26, no. 1, Bogota Colombia, 2017.

[10] F. Aparicio, *Fundamentals of Surface Hydrology*, Balderas, Mexico: Limusa, p. 303, 1997.

[11] NRCS, "Hydrologic soil-cover complexes," *Part 630 Hydrology National Engineering Handbook, Natural Resources Conservation Service*, NJ: IEEE Press, 1993, ch. 3, pp. 121–123.

[12] U.S. Dept. of Agriculture (USDA), Soil survey manual. Chapter 3, USDA Handbook 18, USDA Natural Resource Conservation Service (NRCS), Soil Science Division Staff, Washington, DC. 2017.

[13] X. Zhan and M. Huang, "ArcCN-Runoff: an ArcGIS tool for generating curve number and runoff maps," *Environmental Modelling & Software*, vol. 19, pp. 875–879, 10, 2004. doi: http://dx.doi.org/10.1016/j.envsoft.2004.03.001

[14] NRCS, "Module 103 runoff concepts," *Hydrology Training Series, Soil Conservation Service*, USA: USDA, 1989.

[15] A. Bauwe, P. Kahl, and B. Lennartz, "Hydrologic evaluation of the curve number and Green and Ampt infiltration methods by applying Hooghoudt and Kirkham tile drain equations using SWAT," *Journal of Hydrology*, 2016.

[16] A. Petroselli, S. Grimaldi, and N. Romano, "Curve-Number/Green-Ampt mixed procedure for net rainfall estimation: A case study of the Mignone watershed," *Procedia Environmental Sciences*, vol. 19, pp. 113–121, 2013.

[17] A. Breña, "Principles and fundamentals of surface hydrology (1st ed.)," Metropolitan Autonomous University, 2013.

[18] European Environment Agency (EEA). (2018). Corine Land Cover (CLC) 2018. [Online]. Available: https://land.copernicus.eu/pan-european/corine-landcover/clc2018.

[19] K. Kontgis, "Global land use/land cover with Sentinel-2 and deep learning," *IGARSS 2023-2023 IEEE International Geoscience and Remote Sensing Symposium*, 2021.

[20] T. Aparicio, A. C. Vargas, M. Milagros, M. Gaytán, and J. Francisco, "Floods, civil protection and inhabitants of San Mateo Atenco, State of Mexico," *Geographical Research*, no. 72, pp. 68–81, 2010.