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Evaluation of the Flood Area in the Presence of Climate Change: Ravine La Ronda Case, Ricardo Palma, Peru

Giovene Perez Campomanes[1,*], Maria Perez Campomanes[2], Carlos Carbajal Llosa[3]

[1]Civil Engineering, Faculty of Engineering, Continental University, Peru
[2]Industrial Engineering, Faculty of Engineering, Cesar Vallejo University, Peru
[3]National Institute of Agricultural Innovation, INIA, Peru

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Abstract In the district of Ricardo Palma, human settlements are located near streams, which are seriously affected during the heavy flooding season (rainy season), which increases due to the presence of the El Niño Southern Oscillation (ENSO) and the global effect of climate change. To get to know the flood zone 09 de Octubre - La Ronda, Ricardo Palma, software was applied to obtain the area of influence to study, and to know 10.5 software was applied to obtain the area of influence to study, and to know the rainfall record of the National Water Service. Meteorology and Hydrology of Perú (SENAMHI) for a continuous period of 27 years of maximum daily rainfall, with the HEC HMS 4.9 software the maximum design flows for different return periods were obtained, and the HEC RAS 6.2 software to obtain the flooding area. To find out the support of the authorities in the presence of the Niño Southern Oscillation (ENSO), and the global effect of climate change, a survey was carried out among the population, obtaining that 14.43% had the appropriate conditions to mitigate the impacts of the flooding due to intense rains, 22.93% received help in the presence of the El Niño phenomenon, and for 20.75%, there was a response from their authorities to the needs of the population in the presence of an emergency, and no changes that benefit the population were distinguished. The maximum design flows were calculated for a return period of 10 and 100 years, which vary between 31.7 m^3/s and 61.2 m^3/s, and that for a design flow of 61.2 m^3/s, the flooding area of 0.25 km^2 was obtained.

Keywords Precipitation, Climate Change, Flood Area, Rímac River, Quebrada La Ronda, Peru

1. Introduction

1.1. Flood Modeling

Flood modeling provides us with the information to select the most appropriate action to solve practical problems related to flooding [1]. Using simulated events, this experience can be replicated in other similar places with data availability [2]. The model results for flooding and depth were compared with verification data collected in the field [3]. The use of advanced technologies and integrated models allows us to have good risk management and reduce the effects of floods on society [4]. The risk of flooding is high, especially in its urbanized areas (alluvial plain) [5]. High-resolution coupled modeling generated information that represents local conditions and shows potential drainage failures in extreme scenarios [6].

The 2D FLO model, applied to a dried water ravine, seeks to match a known depth in the channel, generated by the passage of the recent debris flows, for a return period of 50 years [7]. Performing 2D hydraulic simulations (Using HEC-RAS). Including the gradient, the diffuse cognitive maps and the auto-organized maps allow us to do the simulated analysis [8]. The main novelty of the model is the fully coupled solution of the 2D sewer domains, and its application has demonstrated the robustness of the model [9]. The software has its dynamics and transferability of parameter values that are not always exact, while direct calibration of the model input parameters is essential to validate the calculated information [10]. It is necessary to understand the relation between flood frequency and its anthropogenic influences on LULC (land use/land cover) and climatic factors [11]).

1.2. Presence of Climate Change

The effects of climate change have been presented in recent years in the evaluation and management of flood risk, as well as in the creation of our resilience to climate change [12]. Physiographic regions can be used as large spatial units to plan future land use and design agricultural adaptation measures to climate change [13]. These anomalies generated by ENSO (El Niño-Southern Oscillation) are more important than long-term changes [14]. The calculations indicate that the 95% confidence interval in the precipitation data was wider than the predicted temperature data [15]. In the presence of climate change, the influence on temperature and precipitation is significant in the decrease in water availability in the upper part of the basin [16].

The research review revealed that the Earth's temperature has been increasing regularly. By 0.8 C (1.4 F) since 1880, negatively affecting the Earth's overall climate, causing abrupt extreme events (droughts, floods, hurricanes, tornadoes, and acid rain) [17]. These changes generate periods of increase and decrease in flood risk [18].

1.3. Flooding in Urban Streams

The current state of the dried water ravines studied is generally similar: the presence of human settlements on the edges of the slopes, invasions with homes built in an anti-technical manner, wastewater discharges, garbage deposits and debris in all areas with access to them [19]. It is necessary to assess risks comprehensively, which makes it more important to have a greater amount of data, which must be available and used by all parties involved [20]. Obtaining depth and flood risk maps for specific return periods [21]. These are useful for policy formulation and prioritization of prone areas based not only on the degree of flood coverage, but also on the possible types of infrastructure affected [22]. This research will be key to meaningful and proactive action against floods, mitigation and adaptation [23].

In the communities of the states of Carolina (United States), in recent years, there has been a notable increase in flooding that is related to factors (precipitation, change in land use in a rapidly growing part of the country, sea level rise in coastal environments) [24]. If we evaluate the influence of evapotranspiration, in more prolonged or intermittent rain events, this can be an important tool for urban planners to make decisions in the future, and to understand and evaluate systems comprehensively [25]. This information shows us the difficulty in analyzing the frequency of floods [26]. The change is from wastelands to urbanized areas in the lower Kelani River basin. It has a direct effect on temporary flood zones [27].

Currently, climate change is present in all types of extreme events. If we consider the variation in temperatures, as a variable of climate change, we are confirming its effect mainly in the modeling and simulations of floods. Currently, the important variables in its design are rainfall, temperatures and soil quality generating changes in urban areas. The present investigation seeks to calculate the flooded areas in the quebrada 09 de Octubre - La Ronda, in the presence of the El Niño 2024 phenomenon, and climate change. It began with a survey applied to 506 people, the area of influence of the rainfall station, which in our case was Chosica. The intensities and maximum design flows were calculated for the different return periods. Information will be presented below.

2. Materials and Methods

2.1. Study Area

La Quebrada 09 de Octubre – La Ronda is in the district of Ricardo Palma - Chosica, province of Lima, Peru, on the banks of the Rímac River, approximately 36 kilometers east of Lima. Currently, approximately 400 families live in the ravine, in the area near the huaicos (Figure 1).

2.2. Development of a Survey

A survey was carried out, validated by experts, to the residents of the Human Settlement October 9 – La Ronda (Figure 2), with the purpose of knowing the support of the authorities of the Ricardo Palma district in the face of the presence of El Niño Southern Oscillation (ENSO), and the global effect of climate change. The survey was applied on September 13, 2023, to 200 inhabitants of the area and its surroundings. 3 of the 18 questions were used, which are most related to the present investigation, allowing us to know the current state of the population.

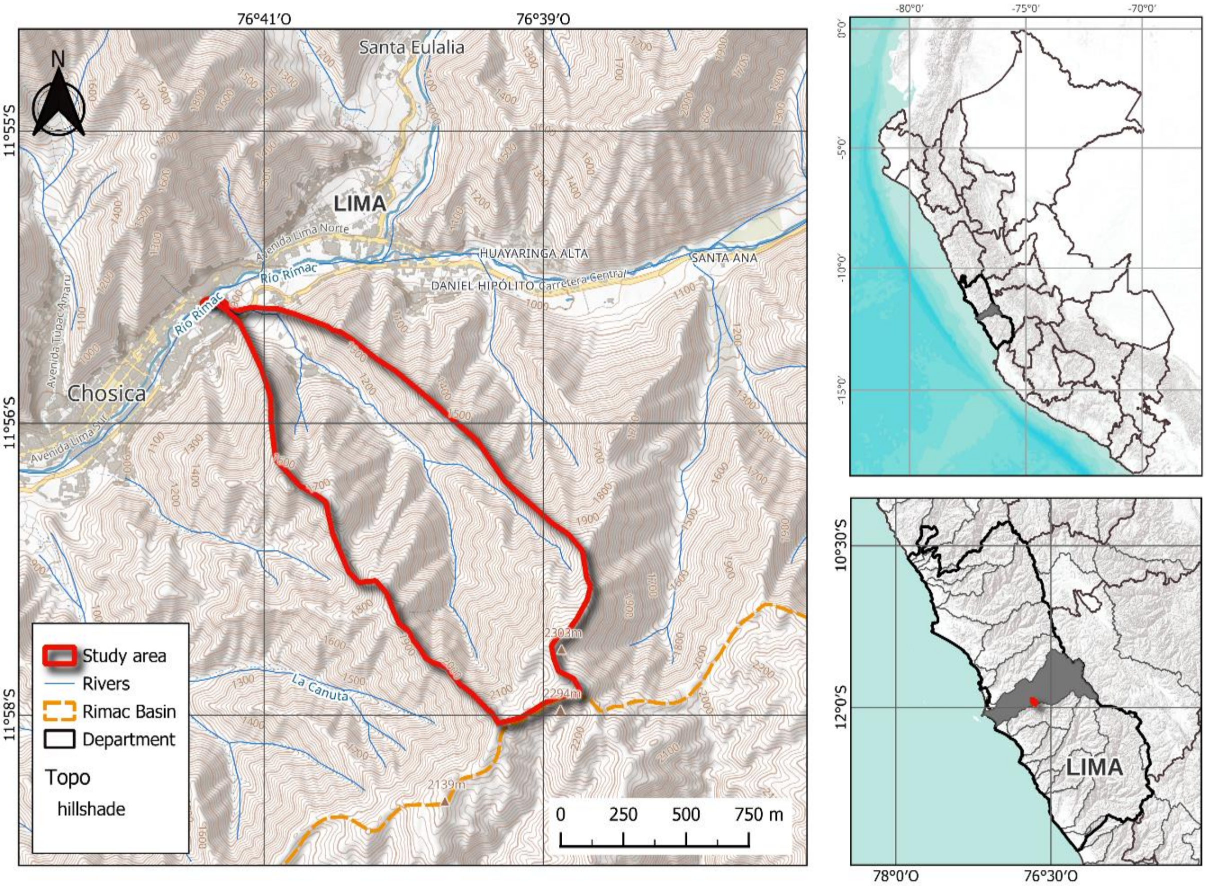

Figure 1. Location of the population and the study area on October 9 – La Ronda

Figure 2. Location of the affected population and the study area on October 9 – La Ronda

2.3. Determination of the Study Area

The area of the main channel of the dried water ravine until its mouth in the R ímac River was identified, using the ArcGIS software version 10.5 to obtain the geomorphological parameters of the study area. First, the DEEM (Representation) was obtained. Raster of a continuous surface, which refers to the surface of the earth, of the geographical maps of Peru, obtains a filter to obtain the delimitation of the water dried ravine, of the study area: (Figure 3). Likewise, an area of influence of 8 km^2 was calculated and a perimeter of 14.73 km was determined.

The area of influence was also calculated, as shown in Figure 2, and figure 4.

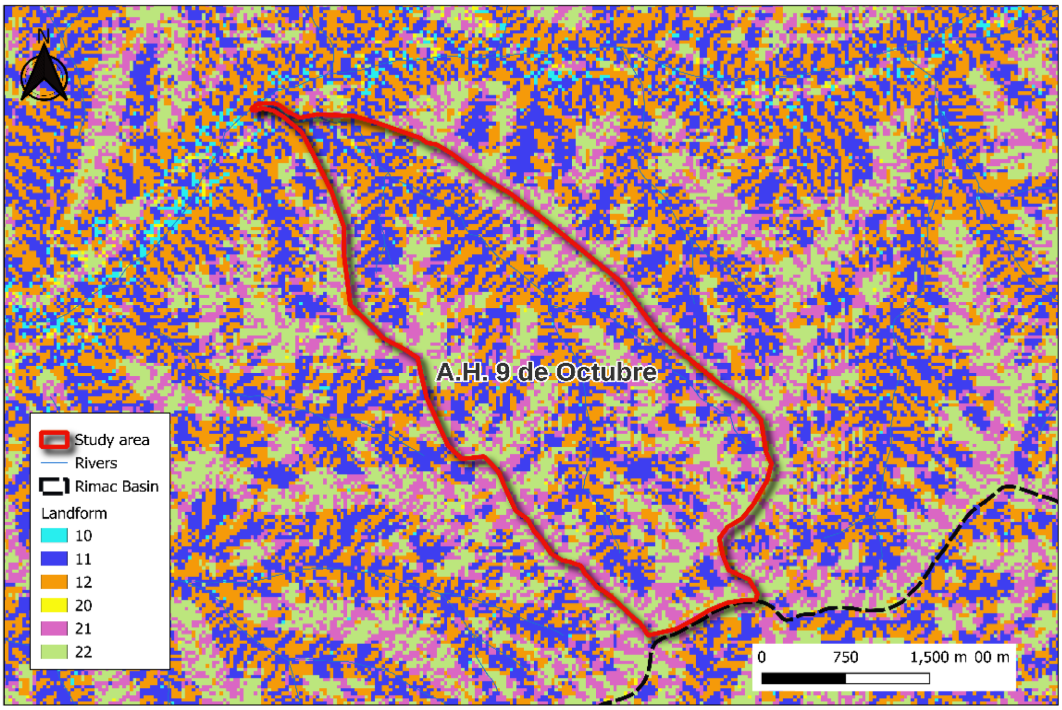

Figure 3. Identifying the study area using ArcGIS software version 10.5

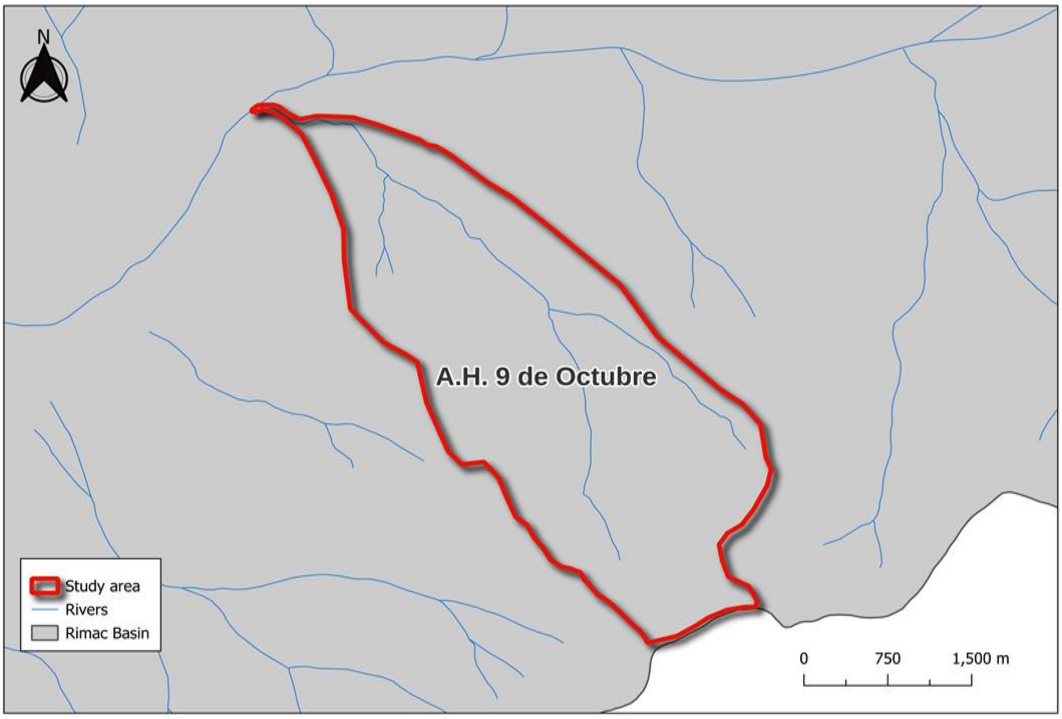

Figure 4. The basin area is shown, using Arcgis version 10.5 software

2.4. Calculation of the Maximum Design Flow

The input data are the records of maximum daily precipitation for the last 27 years, from the SENAMHI station located in Chosica. Subsequently, the Hydronogmon software was used to calculate the maximum intensities for different return periods: 10, 20, 30, 50, 75 and 100. Then, using ARCGIS version 10.5 and the Hec-Hms software version 4.9, the flow rates were determined. Design maximums, for the corresponding return periods. With this information, and using the software? HEC-RAS simulation was carried out in the channels of the Human Settlement of October 9 – La Ronda-Ricardo Palma.

2.5. Calculation of the Flood Area

Knowing the area of influence of the study area, Human Settlement October 9 – La Ronda, and the input data of the design flows for different return periods, the Hec–Ras software 6.2 was used, to determine the flood area in the study area. With this process, it is possible to visualize the contour lines, cross sections and the slope of the basin. It was possible to know that the affected area and its influence on the population settled are very close to the dried water ravine, which is the flood zone. To evaluate the behavior of the data obtained, field visits were made with topography and maximum flows as input data for different return periods. The information was entered into the HEC Ras software, and as output data, different sections were obtained to obtain a map of flood zones. A digital elevation model (DEM) of the study area was taken as a reference, and the available tools were used. QGIS software focuses on the study of landforms, and the depth of the valley in general. Vertical differences in relief were identified and calculated as the difference between elevation and an interpolated ridge level.

In summary, the sites located in the lowest area have the lowest elevation values according to the DEM and will have a greater difference compared to the interpolated crest value. Therefore, they are more susceptible to flooding. Processing was concluded in December 2023.

3. Results

3.1. The Survey Carried out on the Population of the Study Area

Three questions were selected, as they are more related to the topic purpose of the research:

a) Do you have conditions to adopt appropriate mitigation measures against the impacts of intense rains?

From Table 1, as can be seen, the responses “acceptable” and “very acceptable” represent 14.43% of the total, and the responses “very little” and “little” represent 61.47%. That is to say, only 14.43% state that they have adequate conditions to mitigate the impacts of flooding due to intense rains.

b) Have they provided help against the presence of the El Niño Phenomenon to you and/or your community?

From Table 2, the responses ‘very little’ and ‘little’ represent 54.15%. Only 22.93% of the surveyed residents responded ‘acceptable’ and ‘very acceptable’, i.e. they received help in the presence of El Niño.

c) How do your local authorities respond to the needs of the population in the presence of an emergency?

From Table 3, only 20.75% of the total number of respondents consider that there is a response from their authorities to the needs of the population in the presence of an emergency.

Table 1. Do you consider that you are in a position to take appropriate measures to reduce or mitigate the impacts of flooding due to heavy rains?

Total	Very little	Little	Regular	Acceptable	Very acceptable
	1	2	3	4	5
(%)	42.89	18.58	24.11	8.30	6.13

Table 2. Have they provided assistance to you or your community to prepare for the presence of the El Niño phenomenon?

Total	Very little	Little	Regular	Acceptable	Very acceptable
	1	2	3	4	5
(%)	27.47	26.68	22.92	13.04	9.88

Table 3. How the authorities in your locality respond to the needs of the population in the event of an emergency

Total	Very little	Little	Regular	Acceptable	Very acceptable
	1	2	3	4	5
(%)	27.67	27.67	23.91	15.22	5.53

Table 4. Maximum intensities (mm) and maximum flows (m^3/s), for the different return periods

T(years)	Intensities Max (mm)	Q Max (m^3/s)
10	17.53	31.7
25	25.29	36
30	30.6	40.9
50	38	43.8
75	45	50.1
100	50	61.2

Figure 5. The humid zone according to the simulation for a flow rate of 61.2 m^3/s, for a return period of 100 years

3.2. Calculation of the Maximum Design Flow

From Table 4, the minimum maximum intensity value was 17.53 mm, and the maximum was 50 mm. The minimum flow rate was 31.7 m^3/s for T: 10, and the maximum was 61.2 m^3/s for T: 100.

3.3. The Flood Area Using Hec-Ras Software

According to the DEM, sites located in the lowest area with the lowest elevation values will have a greater difference compared to the interpolated crest value, and, therefore, are more susceptible to flooding than higher areas. These differences allow for a better visualization of the flood (Figure 5).

Table 5. The flood area obtained with the Hec-Ras software

Areas floodable		
Q_{max}	Area	
	m^2	km^2
62 m^3/s	225309.202	0.225

Where
Q_{max}: Maximum design flow

From Table 5, the obtained the floodable area of 0.225 km^2, but luckily for the population, it is located in the lower part of the study area that ends on a road near the Rímac River (Figure 6).

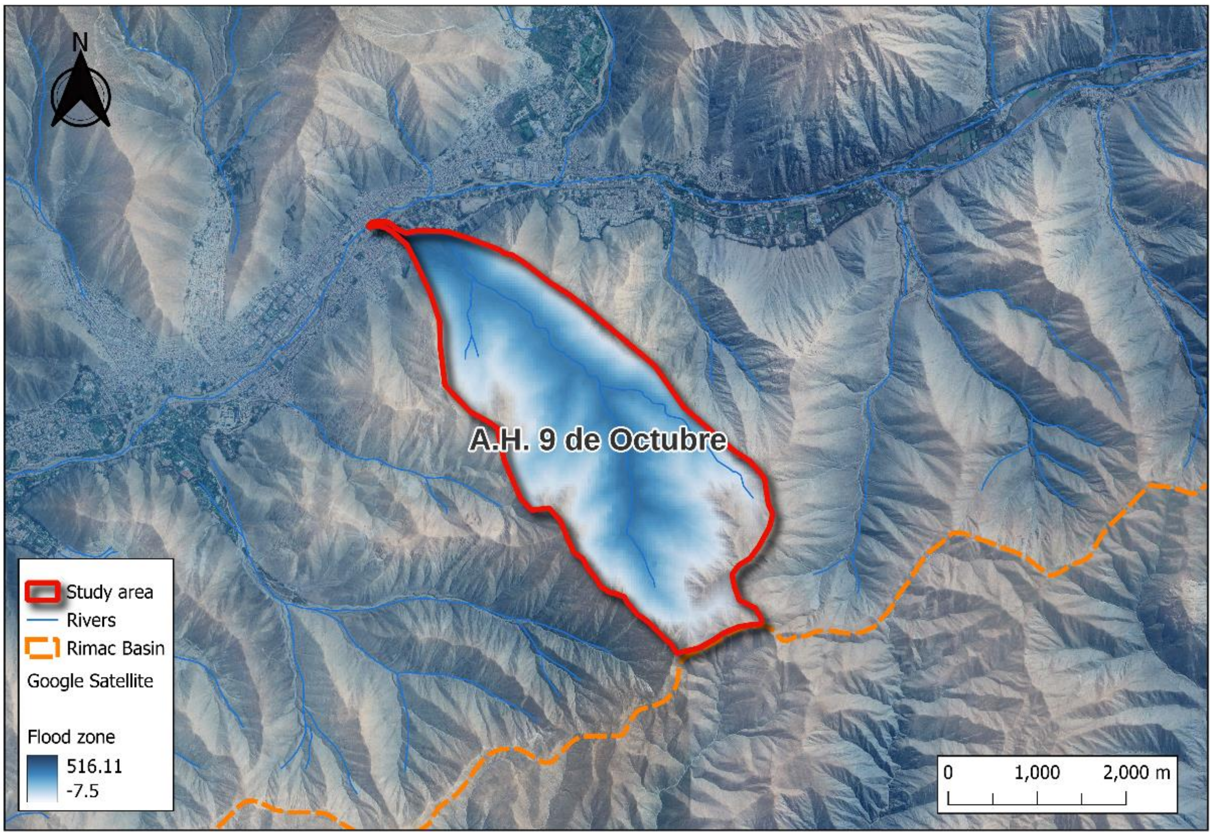

Figure 6. Simulation for a flow rate of 61.2 m^3/s for a return period of 100 years

Regarding the floodable area, it was observed that in the lower part of the study area, there is an entrance road to the study area, generating a lower degree of vulnerability. Finally, a comparison was made of the results obtained from presenting these design flows and the flooding areas obtained in the present design; it was possible to detect that they resemble those presented in 2012 (Figure 6).

4. Discussion

From the survey applied, it was observed that only 14.43% of the residents of A.H. 9 de octubre- La Ronda have the appropriate conditions to mitigate the impacts of the flood due to the intense rains, 22.93% have help from the authorities in the presence of the El Niño Phenomenon, and 20.75% feel that there is a response of its authorities to the needs of the population in the face of an emergency. That is to say, there is little planning by municipal and government authorities to respond to emergencies due to the local effects of the El Niño Phenomenon and climate changes related to global climate change; a population is observed unprotected in the event of an emergency. Likewise [28] shows us the extremely precarious occupation conditions in some sectors, mainly in marginal and peripheral areas. Even when residents have property titles, they do not have access to minimum basic services. There are no coordinated actions at the various levels of government; there is no comprehensive urban development project that involves interventions in relation to territorial and environmental planning and occupation; housing construction has not been prohibited in highly vulnerable areas such as ravines.

From the study carried out using the HEC HMS 4.9 software, the design flows of 31.7 m^3/s for T = 10 years, and 61.2 for T = 100 years were obtained, however, from the study carried out, hydrological modeling with the HEC-HMS 4.9 has obtained extreme flows of 9 -11-13.4 m^3/sec, for return periods of 50-100-200 years respectively.

With HEC-RAS 6.2, it was possible to obtain the flooding of 0.225 km^2 in the study area. The flooding areas in the Canasbamba (Yungay) hamlet of 3.43 - 3.80 - 4.13 have also been determined, Hectares (Ha), for different return periods [29]. The intensity and duration of rainfall are what determine the occurrence of floods, generating maximum rainfall, and increasing the risk of flooding [30]. These results allow us to recognize urban areas where the threat is present, affecting an approximate area of 6 km^2 [31]. Additional research is necessary to validate the satellite information and generate rainfall results, and their effects on flooding [32].

5. Conclusions

The maximum design flows obtained were 31.7 m^3/s for T = 10 years, and 61.2 for T = 100 years, and the flooding area is 0.25 km^2, for a design flow of 61.2 m^3/s.

Only 14.43% of the human settlement A. H. 9 de Octubre – La Ronda perceives that it has the appropriate conditions to mitigate the impacts of the flood due to the intense rains. 22.93% affirm that they have help from authorities in the presence of the El Niño phenomenon, and 20.75% feel that there is a response from its authorities to the needs of the population in the presence of an emergency, which leads us to conclude that there are no recent changes that benefit the population.

Coordinated work is necessary on the part of government authorities to responsibly face the increase in housing construction in ravine areas, which are highly sensitive areas to periodic flooding, and El Niño events, as is the case from the Ravine 09 de October-La Ronda. Finally, I must indicate that the results do not imply the impacts of future climate changes.

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