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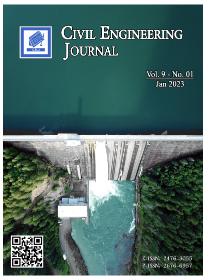

Extreme Event-based Rainfall-runoff Simulation Utilizing GIS Techniques in Irawan Watershed, Palawan, Philippines

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Abstract

River flow assessments and ecologically sustainable water management plans are now possible due to the advancement of sophisticated computer models. The US Army Corps of Engineers developed the HEC-HMS model, which can be used for various hydrological simulations. Rainfall-runoff modeling aids in estimating peak flows, which is critical for water resource management planning. On December 18, 2017, a heavy rainfall event in the ungauged Irawan basin in Puerto Princesa City, Palawan, Philippines, was simulated to determine the peak flow and amount of water. The current research aims to construct a rainfall-runoff simulation model. A specific hyetograph is used to make the hydrographs for the basin. This study utilizes ArcGIS and QGIS, which perform the geospatial analysis and provide the HEC-HMS model's hydrologic modeling inputs. The hydrological parameters were determined using soil type, land use, and land cover maps. Incorporating SCS loss, Clark unit hydrograph, and Muskingum flow routing, HEC-HMS was employed in the rainfall-runoff simulation. Rainfall data corresponding to the recorded streamflow was used to calibrate and validate the parameters. Several performance metrics, including Nash-Sutcliffe efficiency (NSE) and Percentage Bias (PBIAS), were utilized to evaluate the overall effectiveness of the system. An effective decision-making and warning system can be implemented using the developed model.

Keywords: Runoff; Rainfall, Hydrograph; Watershed; HEC-HMS; IWRM.

1. Introduction

The Philippines, with enormous water resources, have consistently resulted in severe water shortages in several places because water resources are distributed improperly, both geographically and temporally. Some major water-related issues that need to be addressed are droughts, urban floods, water scarcity, water pollution, and inaccessibility to potable water. All of these issues are compounded by the negative impacts on the ecosystem associated with climate change. Among the uncertainties resulting from environmental change is the possibility of a global redistribution of water resources [1]. As water demand continues to rise worldwide, Puerto Princesa City, Palawan, Philippines, is facing an immediate and near-future threat. Assessing and handling flash flooding is an excellent way to establish freshwater supplies while mitigating risks to residents and facilities. Flash floods in numerous parts of the world are an immense natural risk that has tremendous detrimental consequences, both socially and economically [2]. Valenzuela et al. [3] conducted research that evaluated national data on the coastal catastrophe risk in Puerto Princesa City through a topographical assessment, questionnaire surveys, and group interviews reflecting the current context. Still, community

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members do not clearly understand the risks, particularly coast-related dangers. In addition, the analysis finds that a recent tragedy has occurred, but it has not been correctly archived and passed on to the next generation. In the last quarter of 2020 and the first quarter of 2021, the city gets flooded owing to torrential rainfall, citing drainage as a contributing issue to flooding [4]. Residents in Barangays San Jose and San Pedro witnessed the unexpected rise of water that had been stagnant due to the absence of natural waterways.

One crucial aspect seen as a catalyst for achieving Integrated Water Resources Management (IWRM) objectives is integrated flood and drought management activities [5]. Water resource management may promote sustainable growth in economic and environmental contexts by assessing flood and flood risk [6]. Many traditional flood studies have been carried out over recent years using typical methods based on GIS, remote sensing, and hydrological models [7-9]. Historical Flash Flood Control Scenarios (FFMSs) primarily relied on engineered structures, including dams, bridges, decks, reservoirs, and other facilities. However, flash floods that are greater than the capacity of the engineering infrastructure may be brought on by climate change. Combining hydrological and hydraulic models is necessary to generate quality flood thematic maps for FFMS to assess places prone to flooding. Mathematical models are the best-known methods and are frequently applied for estimating flood risks [10, 11].

The hydrological cycle is comprised of two critical components: precipitation and runoff. Runoff occurs when excess rainwater accumulates on the land's surface. Watershed runoff is collected at drainage sites and gradually drains to an outlet after infiltration and evaporation. In a watershed, the interplay of climate, physiography, and geology influences the amount of runoff that occurs [12]. Climate change impacts the amount of precipitation and its severity and frequency [13, 14]. Precipitation impacts affect the volume of river discharge and maximum flows [14]. Knowing the quantity of runoff may assist solve numerous watershed management issues. The primary cause of floods is excessive runoff volume into channels [15]. Flood risk management requires estimating flood size, frequency, and severity [6], and urbanization alters them by raising the peak [16]. The agricultural use of surface runoff is another example. Surface runoff delivers nutrients in rural regions, and determining runoff may improve agricultural management. Thus, understanding rainfall-runoff processes is critical for watershed management and sustainable system design [17]. However, understanding the rainfall-runoff process is complex, and forecasting the quantity of runoff created is difficult owing to its nonlinear and multidimensional dynamics [18].

Rainfall-runoff simulation is now a critical method for ensuring sustainability and watershed management, as well as guarding against flood and drought hazards [19]. Flood modeling and mapping are vital for enhancing immediate and long-term assistance in impacted areas following this occurrence. New technologies, such as geoinformatics and its subfields, such as geographic information systems (GIS) and remote sensing (RS), are critical components of this continuous endeavour. Over the past decades, the study of these phenomena has been steady and has seen progress [20]. Several free software programs have been developed and spread during the last two decades, as well as vast global digital data repositories and countless research projects. The development of spatial analysis methods focused on GIS has been the fundamental explanation for improvements in flood simulation in recent decades. Weng [21] devised a methodology for connecting urban expansion studies to scattered hydrological models in this setting using an integrated RS and GIS approach. Under a comparable condition, Fortin et al. [22] proposed HYDROTEL, water flow simulation in a dispersed watershed suited with RS and GIS. The Soil and Water Assessment Tool (SWAT) was a model established in the 1990s that piqued the interest of researchers [23]. Many experiments subsequently took place in the intervening years, using SWAT for several objectives [24, 25].

The HEC-HMS is among the models that have been studied in a variety of different applications. This model was applied to simulate the phenomenon of a short downpour in Catalonia, Spain, yielding outstanding results and sensitivity control [26]. Using the HEC-HMS and MIKE11 models together, Ranaee et al. [27] were able to simulate floods in two river systems and validate their findings using on-site measurements. G. Gül, et al. [28] coupled the hydrological model (HEC-HMS) with the hydraulic model (HEC-RAS) to manage the operation of flood control systems. Popescu et al. [29] created a model that integrated the HEC-HMS and HEC-RAS models to evaluate Romania's flood risk reduction management system. Another vital part of the HEC-HMS model is the study of Mendes and Maia [30], who attempted the parameter estimation on a portion of Portugal's largest basin. A separate application of the HEC-HMS and HEC-RAS models was attempted by Zahrani et al. [31] to alleviate flood danger in metropolitan areas adjacent to the dry basin's outlet in Saudi Arabia. In previous research studies, the notable use of HEC-HMS was apparent.

Azam et al. [32] created a flood warning system for the Mushim stream catchment in Korea using HEC-HMS for runoff estimation, which is critical in the flood alert process. The HEC-HMS model was used to determine the importance of each physical variable across all watersheds in Egypt's western Suez Gulf by applying a pseudo-storm in the same way to all catchments [33]. To develop a comprehensive coordination technique that connects rainfall-runoff modeling, Youssef et al. [12] assessed the dangerous level of flash floods in arid places with limited or no hydrologic data using GIS methodologies and geomorphic characteristics. Guduru et al. employed the HEC-HMS model to simulate streamflow, forecast flood frequency, and compare the results to statistical probability distribution functions to identify the most effective probability distribution functions to match observed streamflow data for the Meki River watershed [34].

Although many hydrologic models are available, choosing the "best" one for analyzing floods at sub-catchment level is still challenging since flood occurrences are chaotic and there are a variety of local factors in the vulnerable areas that are unclear [35-37]. Additionally, precise elaboration of the relevant hydrological parameters of the regions requires good capture of the accompanying rainfall processes that frequently cause floods [38]. Unfortunately, most places in the Philippines' precipitation and associated runoff mechanisms are still not sufficiently observed, making it more difficult to develop highly accurate rainfall-runoff modeling tools that may be utilized for flood early warning and preparation. Looking in to the above knowledge gap, the current work took advantage of an extreme rainfall event that occurred on December 18, 2017, to develop a rainfall-runoff model for the Irawan basin, Puerto Princesa City; the process of selecting meteorological models, as well as the factors that impact this process, are examined. A defined hyetograph and frequency storm method is combined with a frequency storm technique to study the severe event in the meteorological model, which results in the generation of peaks in the basin's flow rate and volume. The results of both methods are compared to the values obtained from simulations and observations. According to Nash–Sutcliffe efficiency, the best method spans from 1 to negative infinity. A difference of 1 means the simulated and observed hydrographs are very similar. This research aims to investigate the hydrological characteristics of Irawan Watershed; the primary purpose of this study is to simulate basin-wide streamflow at its highest point. In response to achieving Integrated Water Resources Management (IWRM) objective to integrate flood and drought management activities, this study will be based on incorporating GIS modules and the Hydrological Modeling System (HEC-HMS) models. The main focus of GIS models is the processing and analysis of DEM morphometric properties. The basin delineation will be done utilizing GIS tools and HEC-HMS input data. The HEC-HMS works with hydrologic equations that determine rainfall and runoff interactions, creating hydrographs. The developed hydrological model can be used for various purposes, including flood forecasting and investigating climate change's influence on runoff and watershed management.

2. Study Area

Irawan Watershed, one of the substantial watersheds in Puerto Princesa City, is situated within 9° 47’ to 9° 53’ in the north latitude and 118° 37’ to 118° 43’ in the east longitude, around 14 km from the city proper and 580 km from Manila (Figure 1). It covers an area of 3,679 hectares and is located in Puerto Princesa City, within the political boundaries of barangay Irawan and a small portion of barangay Bacungan. The area has seven sub-watersheds, each with its own specified stream channel. The Puerto Princesa City Water District (PPCWD) presently manages the watershed's maintenance.

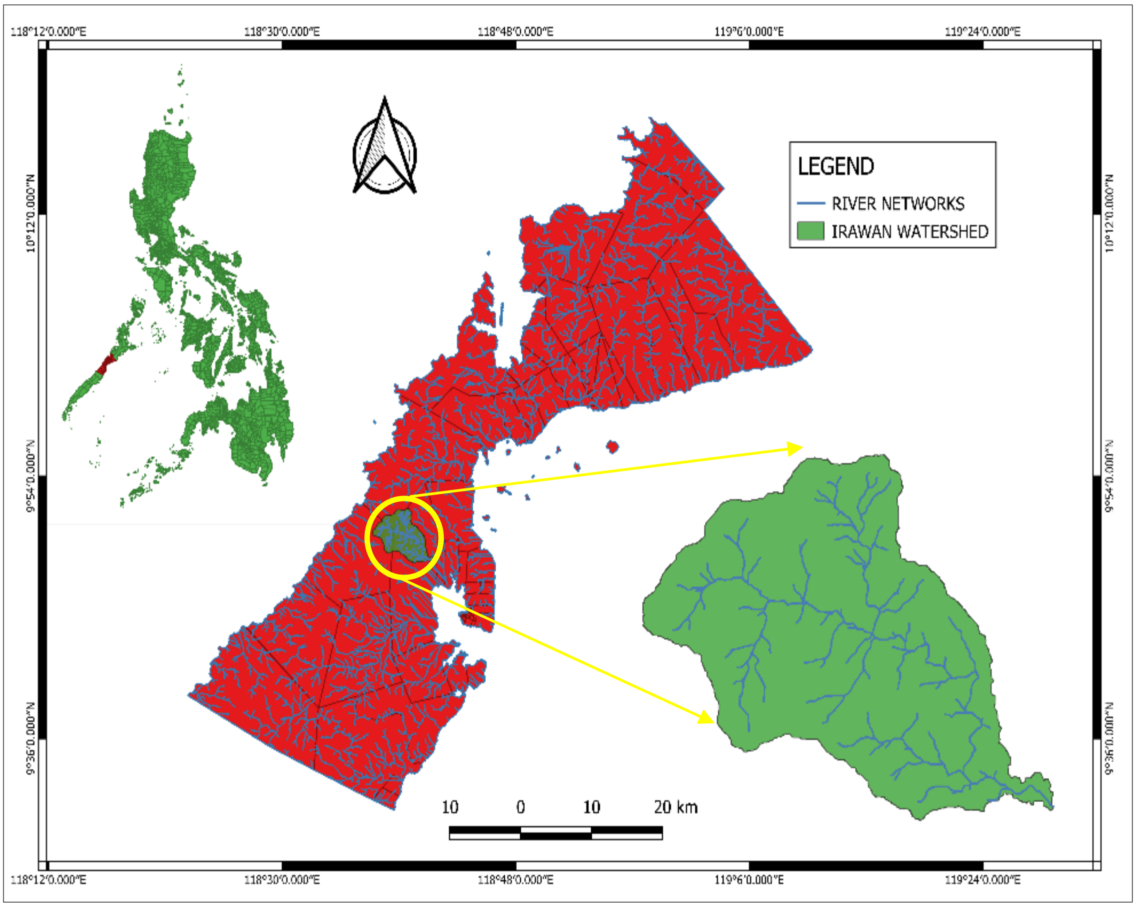

Figure 1. The location map of Irawan Watershed

The watershed has a Type III climate marked by mild seasons, from December to April, the weather is usually dry, whereas the remainder of the year is rainy. Based on the past 5–years (2007–2011) record from the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA), Puerto Princesa City station has rainfall ranging from 1,489.6 to 2,338.3 mm, averaging approximately 1,769.14 mm. The temperature, on the other hand, was averaged at 28.32 °C.

Puerto Princesa City's watershed area totals 115,610 hectares, six small river basins and five main river basins are included in this list. Listed in Table 1 are the eleven watersheds and their respective catchment areas. It is important to note that Babuyan, Montible, Langogan, Inagawan, and Bacungan river are the five river basins with the largest catchment area (25, 20, 14, 12, and 10 percent, respectively). Only a small portion of the city's water supply comes from the Irawan watershed, which covers about 3% of the total catchment area.

Table 1. Significant rivers and catchment regions in the watersheds of Puerto Princesa City [39]

Major Rivers	Catchment Area (hectares)	% of Total
Babuyan River	28,786	24.89
Montible River	23,156	20.02
Langogan River	16,292	14.09
Inagawan River	14,592	12.62
Bacungan River	11,343	9.81
Sabang River	1,674	1.44
Cabayugan River	3,814	3.29
Irawan River	3,679	3.18
Tanabag River	5,622	4.86
Concepcion River	4,225	3.65
Bahile River	2,427	2.09
Total	115,610	100.00

3. Materials and Methods

The current research will take an integrated approach (Figure 2). The combination of QGIS, data and practices pertaining to the HEC-HMS will be utilized to achieve the objectives. Accordingly, the following are the divisions that will be used to organize the work of this research:

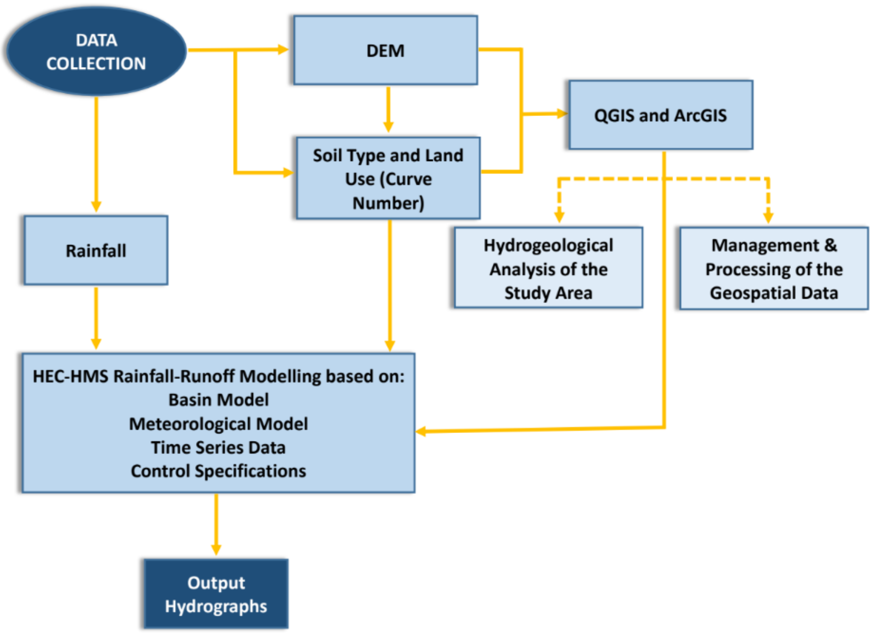

Figure 2. Schematic representation of an integrated rainfall-runoff model

3.1. Irawan Watershed Rainfall Distribution Analysis

A systematic water modeling was conducted to estimate the surface runoff. Data were acquired from the Puerto Princesa Synoptic Station of the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA), such as daily rainfall and period of rain. A specified hyetograph was utilized for the simulation.

3.2. Curve Number (CN) Determination

Empirical curve numbers derived from soil and land cover data were used to characterize the runoff parameters of each catchment. Land use/land cover map was downloaded from Geoportal Philippines, acquired on February 4, 2021, while soil map was obtained from Puerto Princesa City Engineering Office. Data preparation and digitalization of maps were done using ArcGIS 10.8.

Hydrologic Soil Group (HSG) defined the soil parameter determined by soil texture as presented in Table 2. The curve number for soil cover for a typical pre-existing moisture level was determined based on the classification [40], as shown in Table 3.

Table 2. Hydrologic Soil Group Description [41]

Soil Group	Description
A	sand, loamy sand, or sandy loam
B	silt loam or loam
C	Sandy clay loam
D	Clay loam, silty clay loam, sandy clay, silty clay, or clay

Table 3. Curve Numbers for Land Cover and Soil Groups [40]

Land Use/Land Cover	Hydrological Soil Group			
	A	B	C	D
Annual Crop	67	78	85	88
Brush/Shrubs	30	48	65	73
Built-up	89	92	94	93
Grassland	30	58	71	78
Open Forest	36	60	79	79
Closed Forest	30	55	70	77
Open Barren	63	77	85	88
Perennial Crop	45	66	85	88

The composite curve number was computed for each catchment using the HEC-GeoHMS Project Extension on ArcGIS 10.8 by combining a feature class and a lookup table to generate a curve number grid, as illustrated in Figure 3. Rounding off the closest whole number yielded the composite curve number.

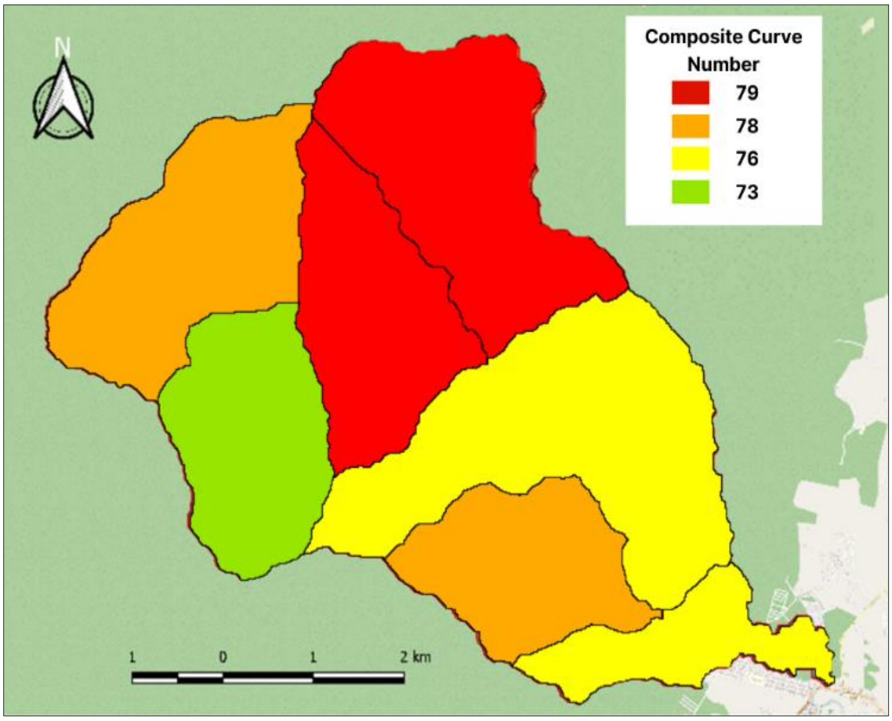

Figure 3. The composite curve number map

3.3. Rainfall-Runoff Modeling with HEC-HMS

In this study, modeling watersheds will integrate GIS and hydrological models. Some GIS approaches available are automating basin delineation, geometric parameter computations, cross-section extractions from topography data, flood plain definition and plotting, storm drain analysis, and runoff analysis. This study utilized the HEC-HMS version 4.5, which The Army Corps of Engineers created in the United States. The program is typically used to simulate rainfall-runoff dynamics in dendritic watershed systems. The excess rainfall was calculated using Soil Conservation Service-CN (SCS-CN) technique. During the development of the rainfall-runoff model, the phases will be separated into three sections: basin modeling, meteorological modeling, model simulations and outputs.

3.3.1. Basin Model (Methods and Parameters)

The basin model will depict the various elements and the interactions between them. In the initial step, it is necessary to identify the catchment's sub-basins. Advanced Land Observing Satellite (ALOS)-derived DEM with 12.5m resolution was downloaded from ASF data search vertex, type ALOS PALSAR 2006-2011, acquired on May 1, 2021. According to these findings, the Irawan basin was subdivided using hydrology-based DEM in QGIS into seven sub-basins, as seen in Figure 3. All sub-basins (numbers 1, 2, 3, 4, 5, and 6) send all of their runoff to sub-basin 7, which serves as the Irawan Basin's terminal outlet.

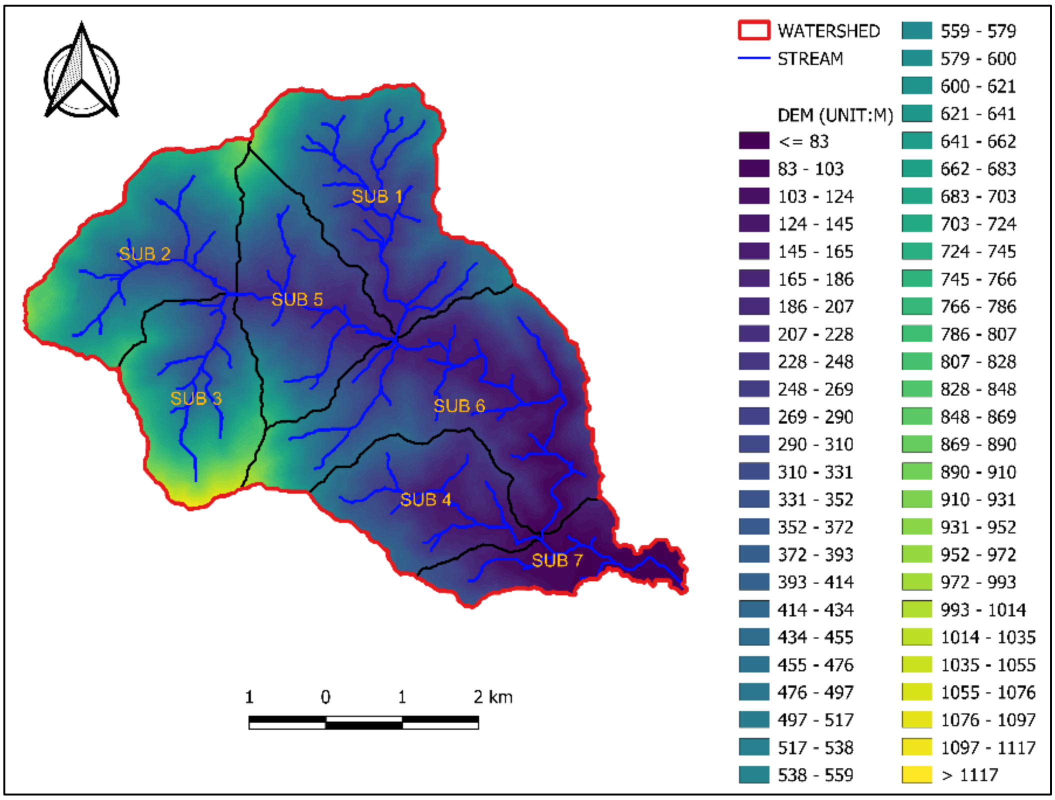

Figure 4. Sub-basin delineation of Irawan watershed

Calculating the Curve Number (CN) upriver of the watershed in the HEC-HMS was made possible by analyzing land use and soil maps from the research region. HEC-HMS was used to prepare the time-series statistics. Rainfall gauge information will be input using a selected hyetograph in time series data. Data from the Irawan basin's discharge was utilized to calibrate and validate the model. The model has additional limitations such as CN, initial abstraction, and impervious area for each sub-basin. The shapefiles generated from QGIS were integrated into the HEC-HMS hydrological model.

The Irawan basin was modeled using the SCS-CN approach, which allowed for estimating the volume runoff gathered from each subbasin. The runoff transform technique was chosen as the Clark unit hydrograph, and the Muskingum method was utilized to simulate streamflow routing. Detailed instructions for the HEC-HMS procedures may be found in the guidebook [42]. The CN value assigned to an area is determined by its land use and soil type. Land use and soil type are aggregated in ArcGIS to achieve this step.

The basin and reach features included the river length, river and basin slope, basin centroid, the longest flow path, and centroidal flow path. The reach joins two junctions, as does the outflow. The loss, runoff transform, and baseflow models were used to determine the discharge.

3.3.2. Meteorological Model

Rainfall quantity and intensity is the representation of the meteorological model. Numerous approaches are available in HEC-HMS for representing rain events across the whole basin. These approaches are gauge data, user hyetographs, and the SCS hypothetical storm. Hyetograph was used for this study. For the model parameters, a 24-hour hyetograph was used.

3.3.3. Simulations and Outputs from the Model

Calculations were made for each basin to determine the centroid and longest flow lengths and the mean slope. Table 4 illustrates a few of the numerous geomorphological parameters. Following the establishment of the basin and meteorological models and the specification of model standards, this step consisted of the model execution and outputs. Each event is simulated day-to-day (24 hours) with a 1-hour time. The model results from all runs were gathered for each junction, reach, and sub-basin. Computed and observed hydrographs were compared, and model parameters were optimized using Nash-Sutcliffe Efficiency (NSE) index.

Table 4. Geomorphological parameters

Basin Name	Longest flow length (m)	Slope (%)
_W2	3034.56	12.78
_W3	3000.83	22.22
_W1	3634.56	7.098
_W5	2446.02	2.535
_W6	5649.14	1.398
_W4	3333.67	9.800
_W7	1024.64	22.83

3.4. HEC-HMS Parameter Calibration and Validation

Calibration of the model was performed using observed streamflow data at the basin's outlet. Numerous statistical indicators such as Nash-Sutcliffe efficiency (NSE) and Percentage Bias (PBIAS) of the model were used to assess its reliability. The eminence of the input limits the functioning of the adjusted hydrological simulation. Multiple variables were considered, including lag time, concentration time, curve number, and storage coefficient. The HEC-HMS model was attuned to produce a model capable of simulating the observed peaks, times, and volumes. In HEC-HMS, Muskingum parameters X and K, initial abstraction and lag time were taken into account. The HEC-HMS optimization technique was used to estimate these model parameters. In order to compare the simulated and observed stream flows, each parameter was modified and the simulation results were displayed and compared. Table 5 provides the model's statistical index for calibration and validation.

Table 5. Parameters considered for calibrating the model

Basin Name	Weighted Curve Number (CN)	Time of concentration (Tc)	Storage coefficient (Sc)
W2	78.026	4.818	8.95
W3	73.706	5.46367	10.15
W1	79.000	4.67733	8.67
W5	79.010	4.67567	8.69
W6	76.596	5.0275	9.32
W4	78.379	4.76683	8.85
W7	76.219	5.08333	9.43

4. Results and Discussion

Hydrologic soil groups are based on estimates of runoff potential and infiltration rate. Figure 5 depicts the geographical distribution of soil texture based on data from the Puerto Princesa City Engineering Office**.** Only two Hydrologic Soil Group Description (HSGD) was present in the study area. HSG C (Sandy clay loam) has a low infiltration rate which covers 33.62% of the total area with 981.32 km^2. While HSG D (Clay loam, silty clay loam, sandy clay, silty clay, or clay) has a significant potential for runoff and little infiltration, covering 66.38% with a total area of 1,813.53 km^2.

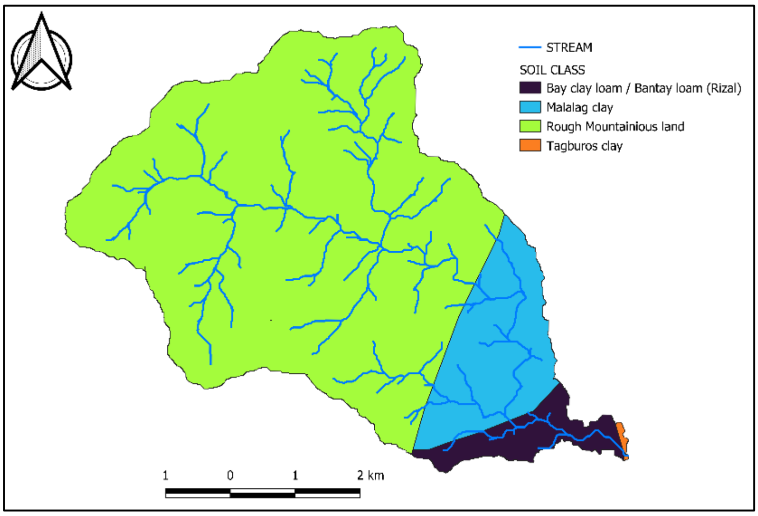

Figure 5. Soil classification map of Irawan watershed

Multiple physical factors were considered during this study. The significance of soil type and the land use/land cover on the watershed's response in terms of hydrological parameters is represented by the CN [43]. Further, runoff generation can be substantially influenced by the CN [44]. Another consideration in determining the curve number is the land use and land cover of the area. Figure 6 shows the land use/land cover map obtained from Geoportal Philippines. In order to acquire the curve numbers for each land use/land cover intersection, the land use/land cover classes were combined with the HSG. The study area comprises mainly Open Forest, covering 97.7931% of the total area. The percentage of area coverage of different land use/land cover as seen in Table 6. Runoff generation directly relates to the curve number value [44]. Consequently, the smaller value of CN denotes a low runoff coefficient, whereas the higher number denotes a high runoff coefficient [45].

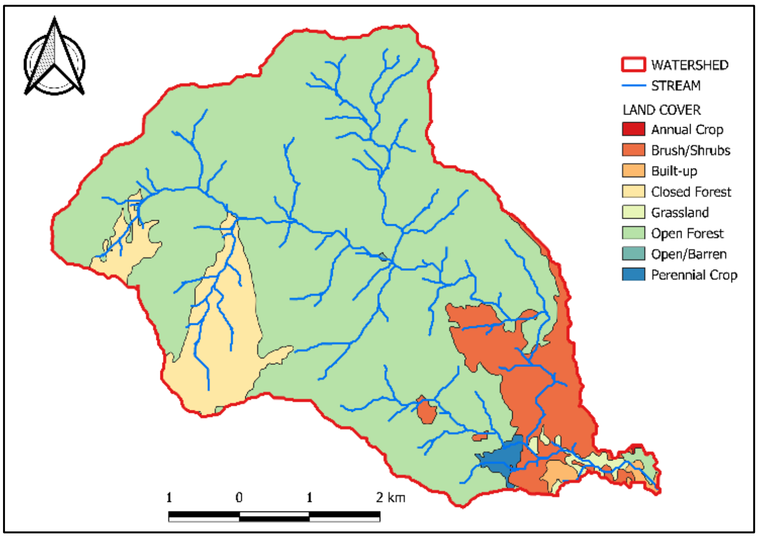

Figure 6. Year 2015 land use map of Irawan watershed

Table 6. Land Use/Land Cover

Land Use/Land Cover	Area (km^2)	Percentage of area coverage (%)
Annual Crop	0.34	0.0126
Brush/Shrubs	43.25	1.5832
Built-up	1.84	0.0675
Grassland	0.71	0.0258
Open Forest	2,671.54	97.7931
Closed Forest	13.69	0.5010
Open Barren	0.01	0.003
Perennial Crop	0.45	0.0165
Total	2,731.83	100.00

The slope of the basin can also have a big impact on how much runoff occurs [46]. Thus, runoff travels to the basin's outlet point more rapidly, the steeper it is. The most influential watershed characteristics were curve number and lag time. Despite having a similar pattern to the observed one, the model persistently underestimated streamflow. Accordingly, a number of researchers gotten remarkably comparable findings [47-49]. With the help of an optimization tool, the HEC-HMS may be used to model the rainfall-runoff process of watershed systems and compare the simulated streamflow to the actual flow [49, 50]. The sub basins were clustered by slope, land use, and flow continuity. Figure 7 depicts the catchment's hydrologic elements.

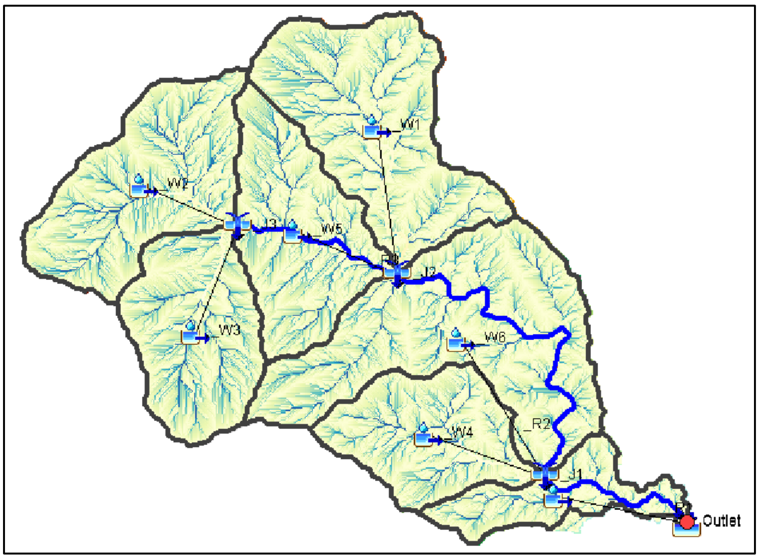

Figure 7. HEC-HMS model of the Irawan Watershed

Observed precipitation and discharge data are used to create the basin's meteorological model. The Irawan basin rainfall and streamflow data are used to calibrate and validate the model. The simulation uses a time step of 1h based on the data accessible. Time-series data from the precipitation and discharge gauge were generated using the collected observations. The meteorological model used a specified hyetograph for the model development.

At the airport, the high precipitation occurrence of 101.4 mm in the basin on 18 December 2017 was recorded. The 12-hour storm produced rainfall with a high intensity of 126.2 mm in the ungauged basin in a single day. The model is calibrated and verified for the given hyetograph approach. Table 7 shows the simulation of an extreme rainfall event using HEC-HMS with time intervals of 1 hour. This is because of how long it takes for water to move through the basin, how impermeable it is, and other components in the basin.

Table 7. Time series simulated and observed – 1 h duration

Date	Time	Observed Flow, m^3/s	Simulated Flow, m^3/s	Time	Observed Flow, m^3/s	Simulated Flow, m^3/s	Time	Observed Flow, m^3/s	Simulated Flow, m^3/s
18-Dec-2017	12:00 AM	43.5	38.7	8:00 AM	387.3	358.9	4:00 PM	312.8	297.9
18-Dec-2017	1:00 AM	54.7	48	9:00 AM	431.9	400.1	5:00 PM	292.2	275.6
18-Dec-2017	2:00 AM	57.2	59.6	10:00 AM	455.6	418.3	6:00 PM	271.9	253.9
18-Dec-2017	3:00 AM	100.5	80.4	11:00 AM	441.2	413.7	7:00 PM	250.7	233.7
18-Dec-2017	4:00 AM	135.7	117.4	12:00 PM	412.7	393.2	8:00 PM	234.6	215.9
18-Dec-2017	5:00 AM	196.5	171.1	1:00 PM	384.8	367.5	9:00 PM	220.5	201
18-Dec-2017	6:00 AM	255.7	235.5	2:00 PM	355.7	343.1	10:00 PM	198.6	187.9
18-Dec-2017	7:00 AM	347.2	301.2	3:00 PM	336.3	320.3	11:00 PM	185.6	175.6

4.1. Model Calibration

Calibration is a way to modify the model's parameters so that the model's output is similar to the data it is based on. Uncertainty surrounds the parameter values used in modeling research. Curve number, lag time, and imperviousness are all essential calibration parameters. The Muskingum parameters X and K are changed in this study to bring the measured and modeled values closer together. The trial K values are set between 0.1 and 1 within the permissible range, and the weighting factor X is set to between 0 and 3. Calibration seeks to find parameters whose modification affects the model's results. The result illustrates how imperviousness is affected by the slope, stream length, and travel time. The model's calibration shows the difference between simulated and actual hydrographs at the Irawan Basin outlet. Figure 8 shows the simulated and observed hydrographs.

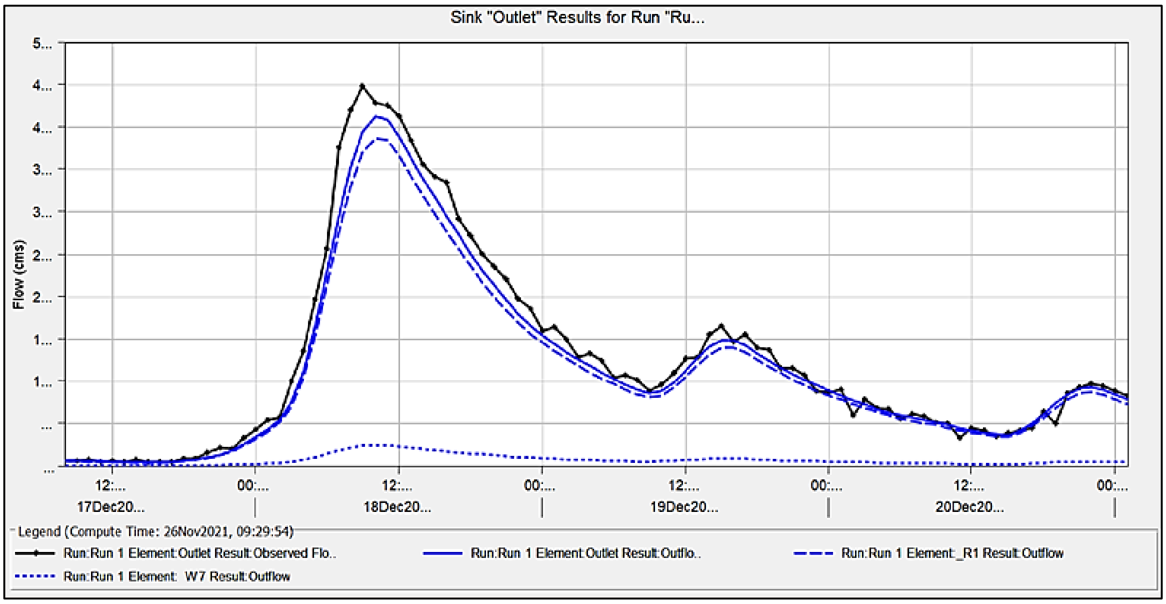

Figure 8. Calibrated HEC-HMS simulated hydrographs for Irawan watershed

The model was evaluated using two statistical variables. The Nash–Sutcliffe efficiency (NSE) and the Percent-Bias coefficient are used to assess the performance and reliability of the HEC-HMS model. NSE values of 0.5–1.0 indicate that the observed and projected hydrographs correlate well [51]. When computing the NSE value, it is found that the hydrograph created following the simulation closely matches the observed hydrograph, with a Nash–Sutcliffe coefficient of 0.988 using the stated hydrograph approach. Correspondingly, the same set of possible values (0.8–0.9) was achieved throughout the validation period. The second metric, percent-bias, PBIAS, quantifies the average likelihood of simulated peak flows exceeding or falling short of observed peak flows [52, 53]. PBIAS is optimum at 0.0, indicating that the model's simulation is correct. Positive values overstate the bias; negative values understate it. The bias in our model is underestimated throughout both validation and calibration.

5. Conclusions

A calibrated HEC-HMS model is used to roughly calculate the direct runoff volume and peak discharges using the meteorological technique to identify the influencing elements in the Irawan basin for an extreme single-event rainfall. The terrain processing approach uses a 12.5 m resolution digital elevation model to delineate basins and catchments.

The land use/land cover statistics are created to understand better the peak runoff associated with different land use classifications. Surface runoff in the basin is forecasted using hydrologic modeling, implemented in the basin. The SCS curve number loss technique is used to calculate the basin's hydrologic deficits because it requires fewer parameters.

The hyetograph was used to run the modeling simulation. In this study, just one outlier event was taken into account, but it was still imperative. It is interesting to note how well the predicted peak discharge and runoff volume match the observed measurements. The NSE of 0.988, RMSE of 0.10, and PBIAS of -0.0611 were found in the HEC-HMS results utilized for rainfall-runoff simulation in the Irawan Basin.

The runoff response of a watershed varies depending on the hydrological features of the site. The availability of data, the purpose of the model, and the required level of accuracy all play a role in determining which models are used to represent the catchment in hydrologic processes. Measuring catchment hydrological parameters in various hydrological processes requires a large amount of observed data collected over an extended period. Still, the results of this catchment modeling may serve as preliminary values for further calibration, analysis, and comparison.

Given the Philippines' vulnerability to typhoons and floods, proactive disaster risk reduction measures are needed. Robust hydrological modeling for flood forecasting, structural solutions for flood protection, and environmentally sound land management within the watershed are three approaches to achieving this. The following stages for this research include refining soil and land cover parameterization to develop land usage and capacity indicator maps of different ecosystem services, identifying trade-offs, and running the model under multiple land cover scenarios. The rainfall-runoff modeling capabilities of the land use and capability indicator model may then be compared with HEC models to measure how well the model represents the watershed's hydrological response.

6. Declarations

6.1. Author Contributions

Conceptualization, J.C.C. and E.B.T.; methodology, J.C.C., V.C.A.A, and E.B.T; resources, J.C.C. and V.C.A.A; data curation, J.C.C. and V.C.A.A; visualization, J.C.C.; writing – original draft preparation. J.C.C.; Supervision, E.B.T.; writing – reviewing and editing, E.B.T. All authors have read and agreed to the published version of the manuscript.

6.2. Data Availability Statement

The data presented in this study are available in the article.

6.3. Funding

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6.5. Conflicts of Interest

The authors declare no conflict of interest.

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