REGION 10

Tagoloan River Basin:

DREAM Flood Forecasting and Flood Hazard Mapping

TRAINING CENTER FOR APPLIED GEODESY AND PHOTOGRAMMETRY

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List of Abbreviations

ACDP	Acoustic Doppler Current Profiler
AOI	Area of Interest
ARG	Automated Rain Gauge
AWLS	Automated Water Level Sensor
DAC	Data Acquisition Component
DEM	Digital Elevation Model
DOST	Department of Science and Technology
DPC	Data Processing Component
DREAM	Disaster Risk Exposure and Assessment for Mitigation
DTM	Digital Terrain Model
DVC	Data Validation Component
FMC	Flood Modelling Component
GDS	Grid Developer System
HEC-HMS	Hydrologic Engineering Center – Hydrologic Modeling System
LiDAR	Light Detecting and Ranging
PAGASA	Philippine Atmospheric, Geophysical and Astronomical Services Administration
RIDF	Rainfall Intensity Duration Frequency
SCS	Soil Conservation Service
SRTM	Shuttle Radar Topography Mission
UP-TCAGP	UP Training Center for Applied Geodesy and Photogrammetry

Introduction

Introduction

1.1 About the DREAM Program

The UP Training Center for Applied Geodesy and Photogrammetry (UP TCAGP) conducts a research program entitled "Nationwide Disaster Risk and Exposure Assessment for Mitigation (DREAM) Program" funded by the Department of Science and Technology (DOST) Grants-in-Aid Program. The DREAM Program aims to produce detailed, up-to-date, national elevation dataset for 3D flood and hazard mapping to address disaster risk reduction and mitigation in the country.

The DREAM Program consists of four components that operationalize the various stages of implementation. The Data Acquisition Component (DAC) conducts aerial surveys to collect Light Detecting and Ranging (LiDAR) data and aerial images in major river basins and priority areas. The Data Validation Component (DVC) implements ground surveys to validate acquired LiDAR data, along with bathymetric measurements to gather river discharge data. The Data Processing Component (DPC) processes and compiles all data generated by the DAC and DVC. Finally, the Flood Modeling Component (FMC) utilizes compiled data for flood modeling and simulation.

Overall, the target output is a national elevation dataset suitable for 1:5000 scale mapping, with 50 centimeter horizontal and vertical accuracies. These accuracies are achieved through the use of state-of-the-art airborne Light Detection and Ranging (LiDAR) technology and appended with Synthetic-aperture radar (SAR) in some areas. It collects point cloud data at a rate of 100,000 to 500,000 points per second, and is capable of collecting elevation data at a rate of 300 to 400 square kilometers per day, per sensor

1.2 Objectives and Target Outputs

The program aims to achieve the following objectives:

a) To acquire a national elevation and resource dataset at sufficient resolution to produce information necessary to support the different phases of disaster management,
b) To operationalize the development of flood hazard models that would produce updated and detailed flood hazard maps for the major river systems in the country,
c) To develop the capacity to process, produce and analyze various proven and potential thematic map layers from the 3D data useful for government agencies,
d) To transfer product development technologies to government agencies with geospatial information requirements, and,

e) To generate the following outputs
1) flood hazard map
2) digital surface model
3) digital terrain model and
4) orthophotograph.

1.3 General Methodological Framework

The methodology to accomplish the program's expected outputs are subdivided into four (4) major components, as shown in Figure 1. Each component is described in detail in the following section.

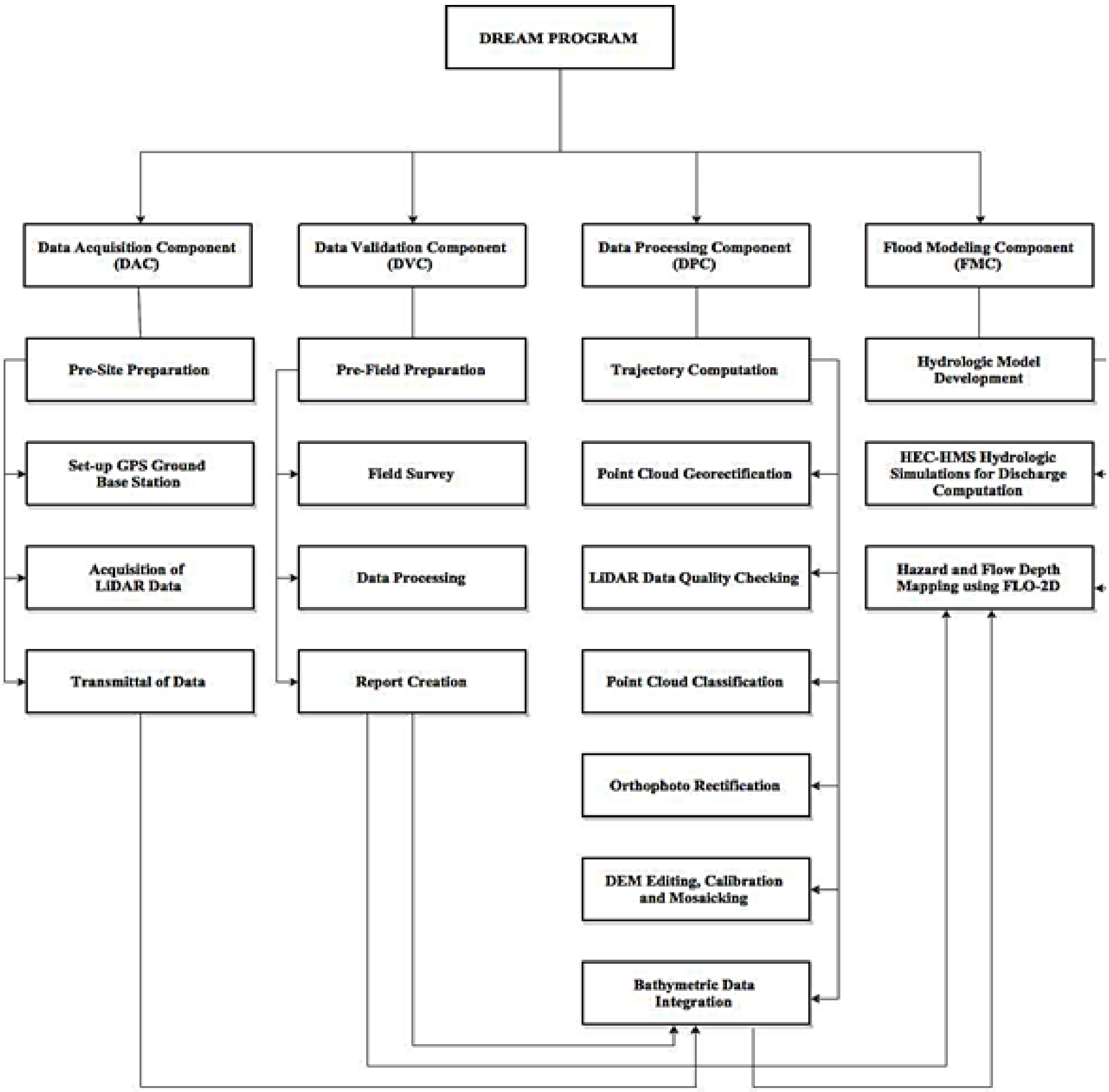


Figure 1. The general methodological framework of the program

1.4 Scope of Work of the Flood Modeling Component

The scope of work of the Flood Modeling Component is listed as the following:

a) To develop the watershed hydrologic model of the Tagoloan River Basin;
b) To compute the discharge values quantifying the amount of water entering the floodplain using HEC-HMS;
c) To create flood simulations using hydrologic models of the Tagoloan floodplain using FLO-2D GDS Pro; and
d) To prepare the static flood hazard and flow depth maps for the Tagoloan river basin.

1.5 Limitations

This research is limited to the usage of the available data, such as the following:

1. Digital Elevation Models (DEM) surveyed by the Data Acquisition Component (DAC) and processed by the Data Processing Component (DPC)
2. Outflow data surveyed by the Data Validation and Bathymetric Component (DVC)
3. Observed Rainfall from ASTI sensors

While the findings of this research could be further used in related-studies, the accuracy of such is dependent on the accuracy of the available data. Also, this research adapts the limitations of the software used: ArcGIS 10.2, HEC-GeoHMS 10.2 extension, WMS 9.1, HEC-HMS 3.5

1.6 Operational Framework

The flow for the operational framework of the Flood Modeling Component is shown in Figure 2.

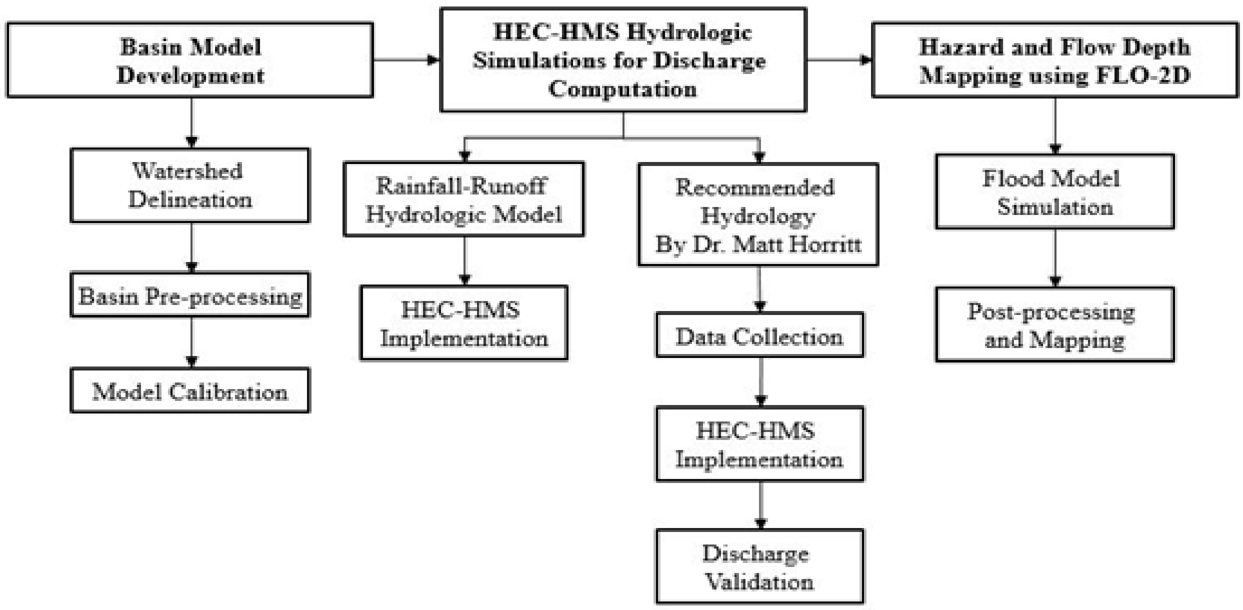


Figure 2. The operational framework and specific work flow of the Flood Modeling Component

The Tagoloan River Basin

The Tagoloan River Basin

The Tagoloan River Basin is located in Northern Mindanao. It is considered as the thirteenth largest river basin in the Philippines. It covers an estimated basin area of 1,704 square kilometers. The location of Tagoloan River Basin is as shown in Figure 3.

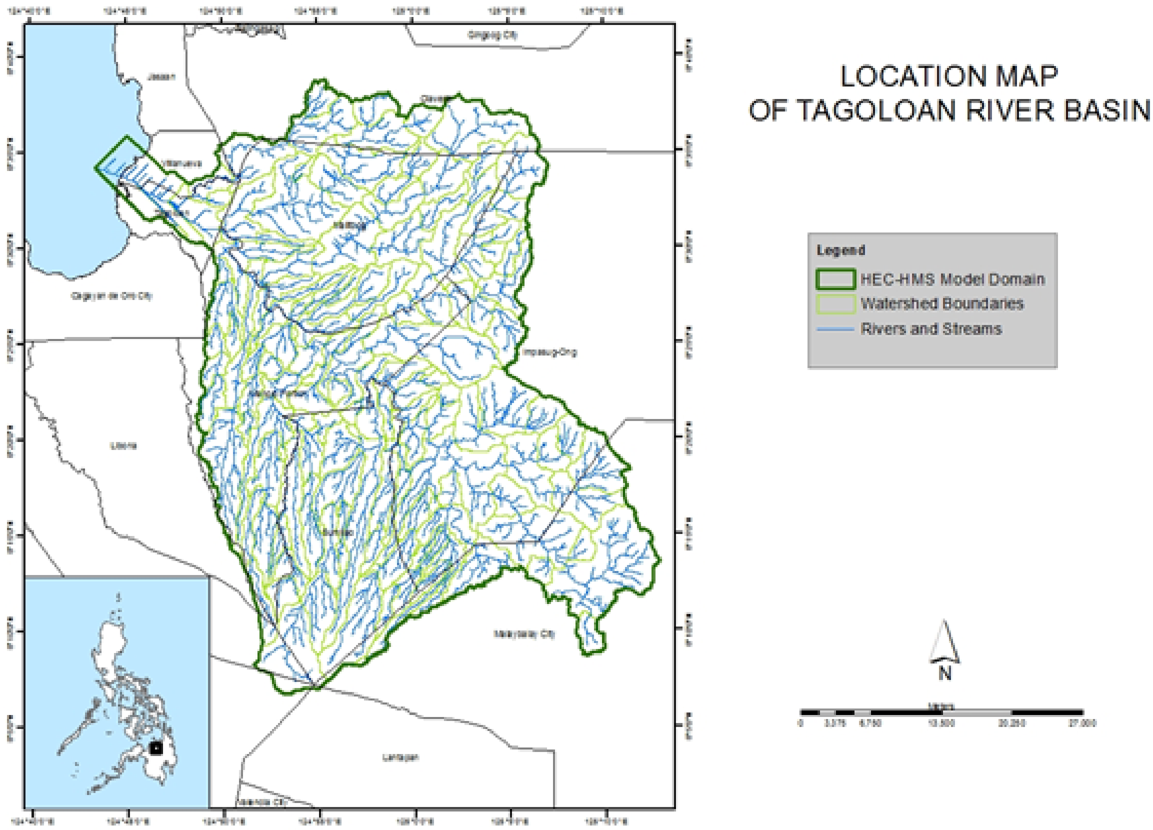


Figure 3. Tagoloan River Basin Location Map

The basin consists of the following rivers: Malitbog, Siloo, Titian, Mangima, Alulum, Amusig and Dila River. It traverses the Tagoloan River, flowing northwest, and drains into the Macajalar Bay. It encompasses the provinces of Bukidnon and Misamis Oriental.

The land and soil characteristics are important parameters used in assigning the roughness coefficient for different areas within the river basin. The roughness coefficient, also called Manning's coefficient, represents the variable flow of water in different land covers (i.e. rougher, restricted flow within vegetated areas, smoother flow within channels and fluvial environments).

The shape files of the soil and land cover were taken from the Bureau of Soils, which is under the Department of Environment and Natural Resources Management, and National Mapping and Resource Information Authority (NAMRIA). The soil and land cover of the Tagoloan River Basin are shown in Figures 4 and 5, respectively.

The Tagoloan River Basin

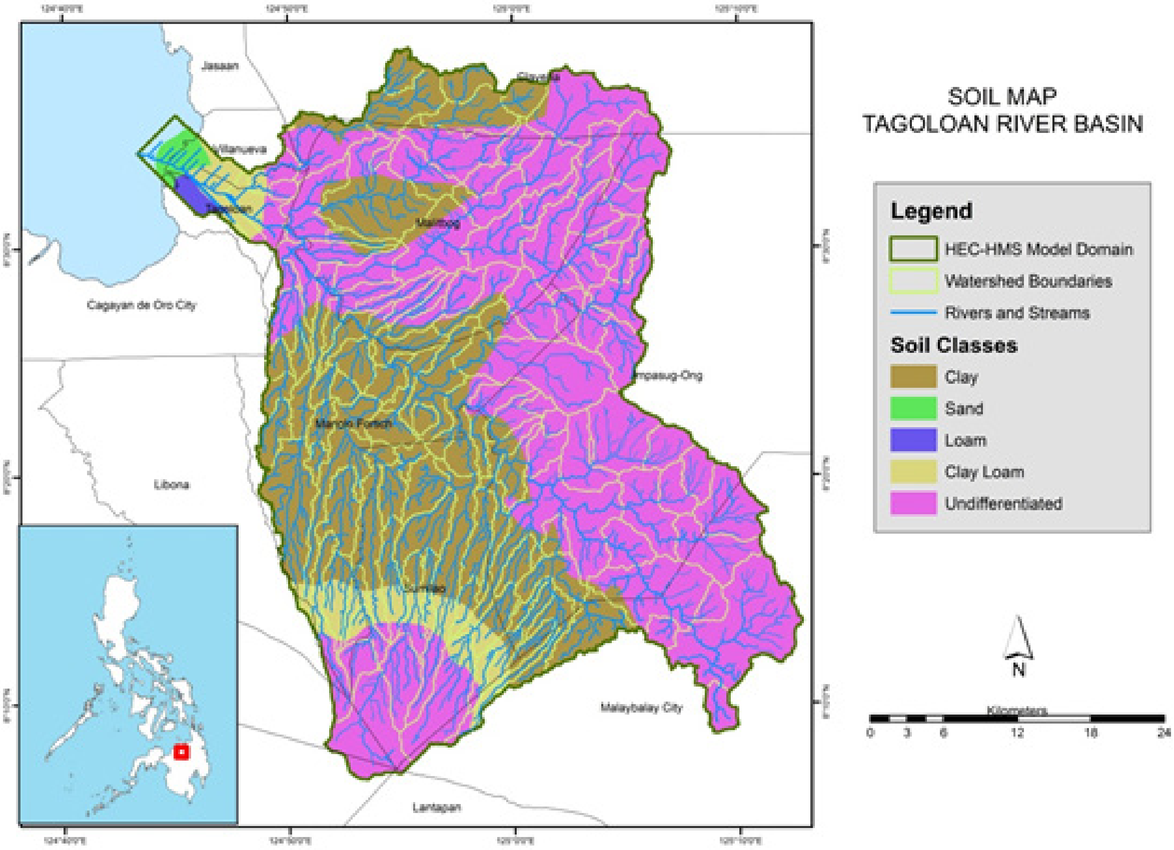


Figure 4. Tagoloan River Basin Soil Map

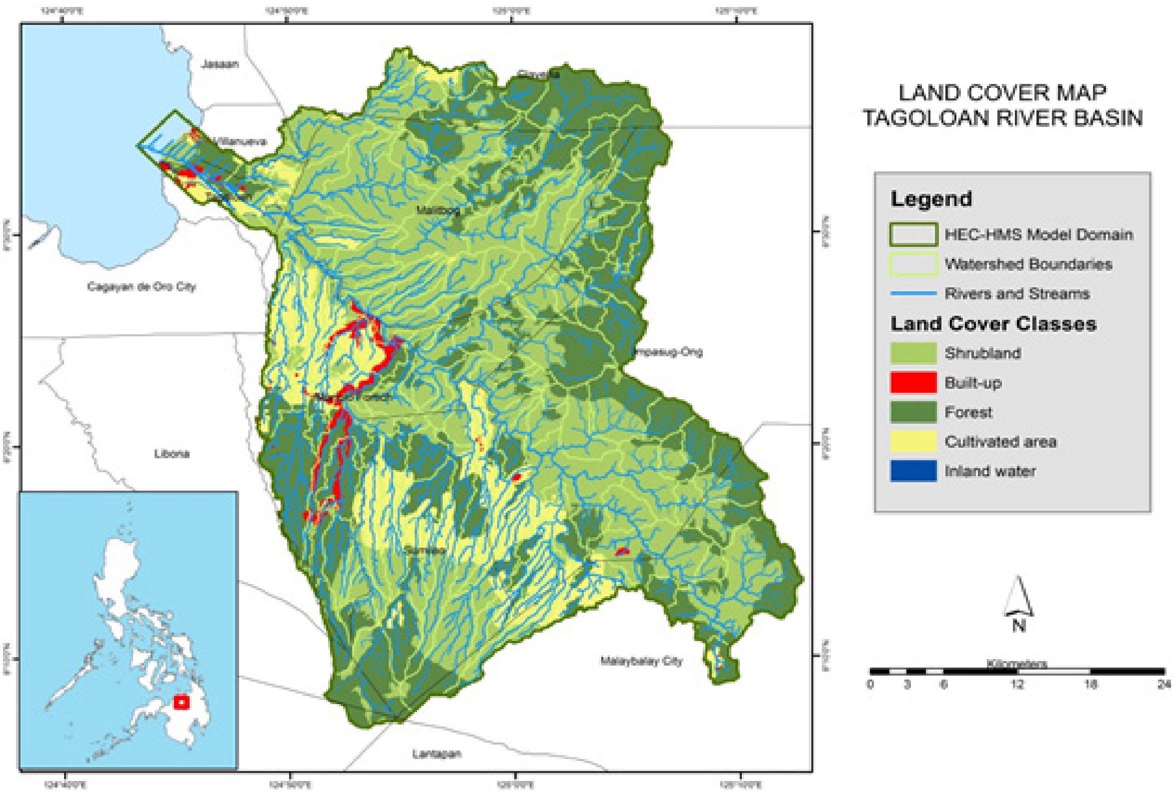


Figure 5. Tagoloan River Bain Land Cover Map

Methodology

3.1 Pre-processing and Data Used

Flood modeling involved several data and parameters to achieve realistic simulations and outputs. Figure 6 shows a summary of the data needed to for the research.

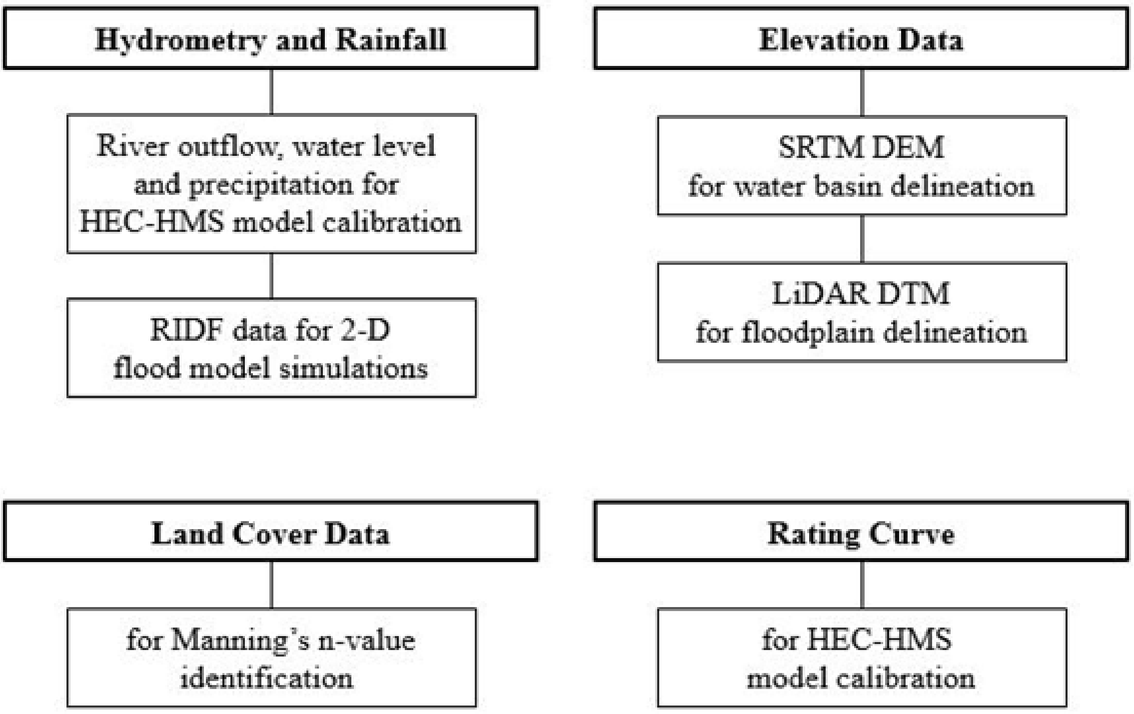


Figure 6. Summary of data needed for the purpose of flood modeling

3.1.1 Elevation Data

3.1.1.1 Hydro Corrected SRTM DEM

With the Shuttle Radar Topography Mission Digital Elevation Model (SRTM DEM) data as an input in determining the extent of the delineated water basin, the model was set-up. The Digital Elevation Model (DEM) is a set of elevation values for a range of points within a designated area. SRTM DEM has a 90 meter spatial mosaic of the entire country. Survey data of cross sections and profile points were integrated to the SRTM DEM for the hydro-correction.

3.1.1.2 LiDAR DEM

LiDAR was used to generate the Digital Elevation Model (DEM) of the different floodplains. DEMs used for flood modeling were already converted to digital terrain models (DTMs) which only show topography, and are thus cleared of land features such as trees and buildings. These terrain features would allow water to flow realistically in the models.

Figure 7 shows an image of the DEM generated through LiDAR.

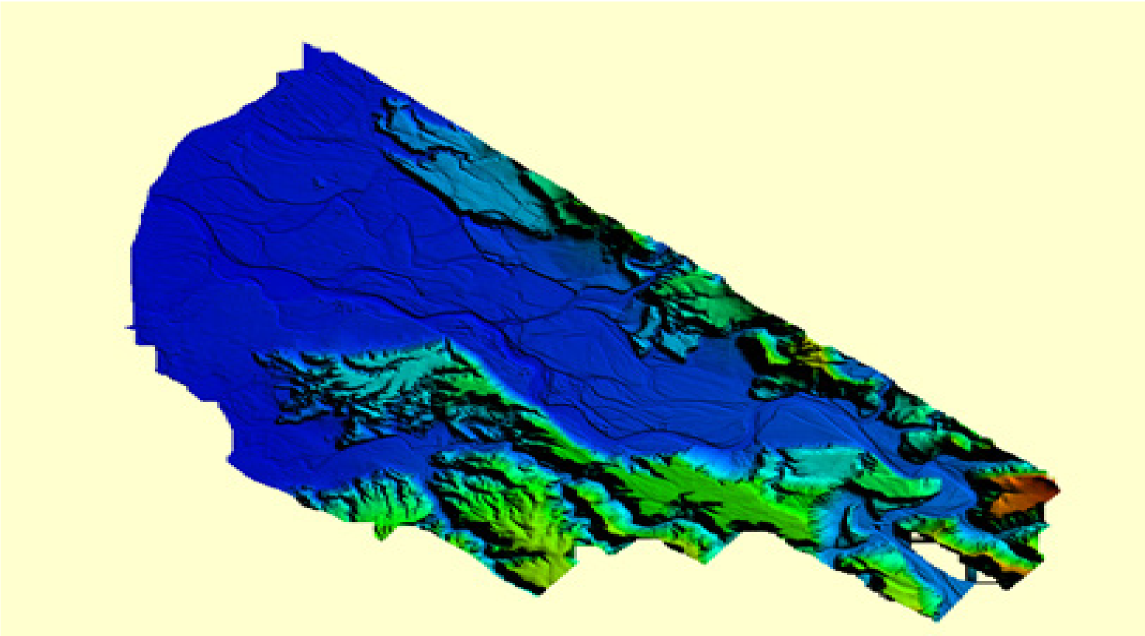


Figure 7. Digital Elevation Model (DEM) of the Tagoloan River Basin using Light Detection and Ranging (LiDAR) technology

Elevation points were created from LiDAR DTMs. Since DTMs were provided as 1-meter spatial resolution rasters (while flood models for Tagoloan were created using a 10-meter grid), the DTM raster had to be resampled to a raster grid with a 10-meter cell size using ArcGIS.

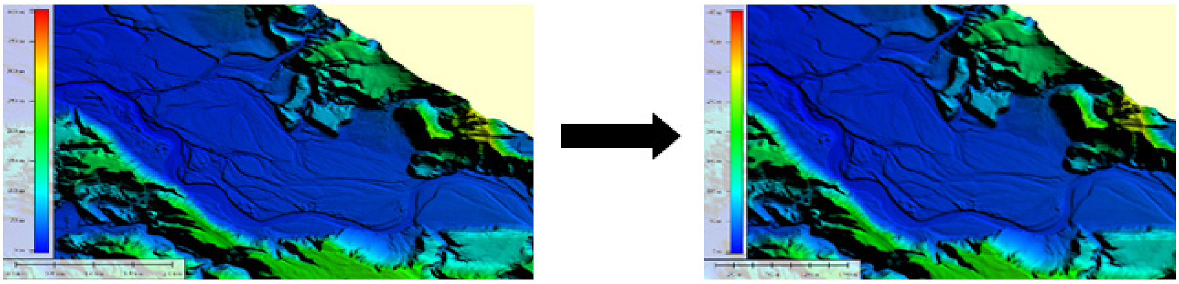


Figure 8. The 1-meter resolution LiDAR data resampled to a 10-meter raster grid in GIS software to ensure that values are properly adjusted

3.1.2 Land Cover and Soil Type

The land and soil characteristics are important parameters used in assigning the roughness coefficient for different areas within the river basin. The roughness coefficient, also called Manning's coefficient, represents the variable flow of water in different land covers (i.e. rougher, restricted flow within vegetated areas, smoother flow within channels and fluvial environments).

A general approach was done for the Tagoloan floodplain. Streams were identified against built-up areas and rice fields. Identification was done visually using stitched Quickbird images from Google Earth. Areas with different land covers are shown on Figure 9. Different Manning n-values are assigned to each grid element coinciding with these main classifications during the modeling phase.

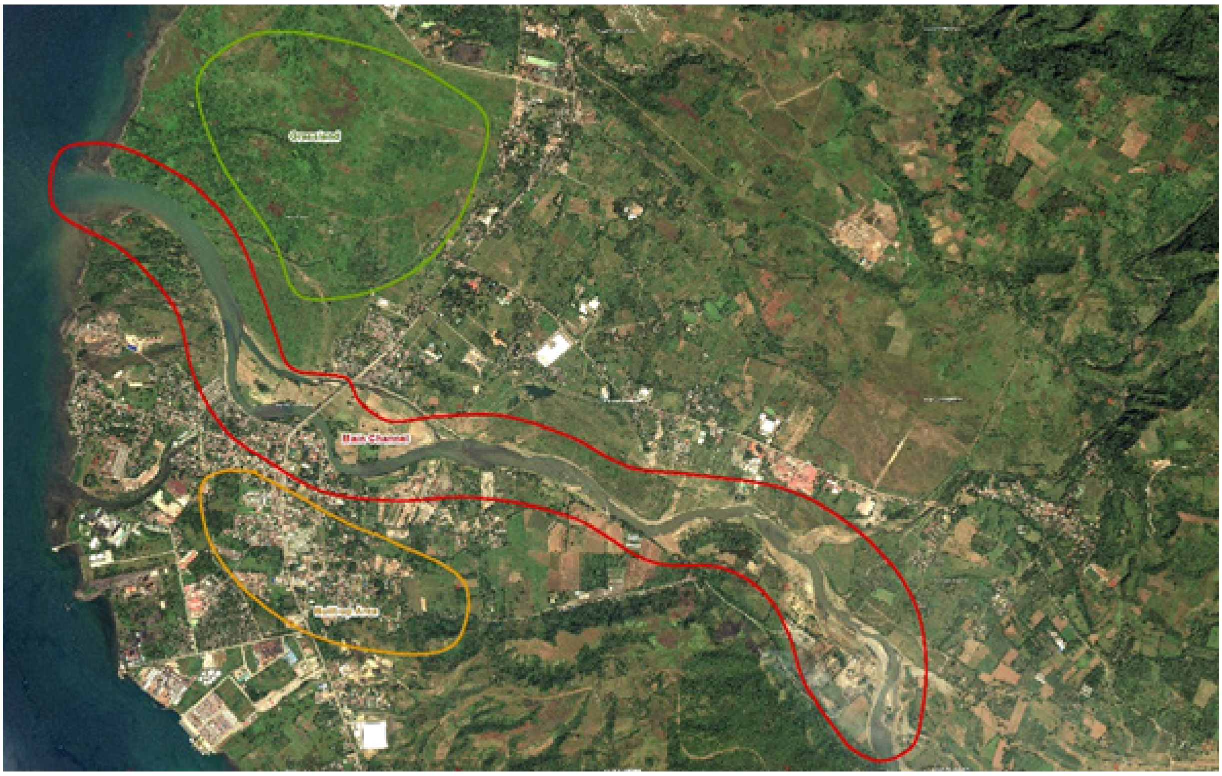


Figure 9. Stitched Quickbird images for the Tagoloan floodplain

3.1.3 Hydrometry and Rainfall Data

3.1.3.1 Hydrometry for different discharge points

3.1.3.1.1 Tagoloan Bridge, Bukidnon

The river outflow from the Data Validation Component was used to calibrate the HEC-HMS model. This was taken from Malitbog, Bukidnon (8°31'3.48"N, 124°49'55.54"E). This was recorded during November 9-12, 2013. Peak discharge is 331 cms.

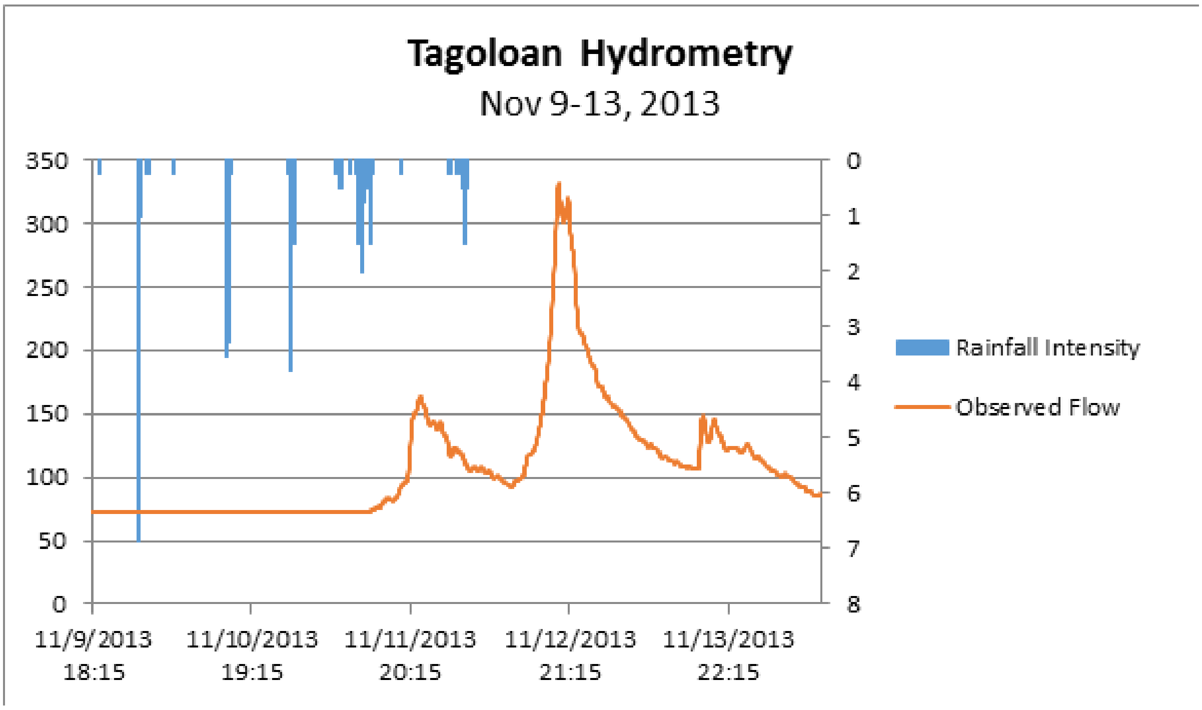


Figure 10. Tagoloan rainfall and outflow data used for modeling

3.1.3.1.2 Arch Bridge, Bukidnon

The river outflow was computed using the derived rating curve equation. This discharge was used to calibrate the HEC-HMS model. It was taken from Arch Bridge, Bukidnon (8°32'20."N, 124°52'55.99"E). The recorded peak discharge is 22.38cms at 09:00 PM, April 14, 2014.

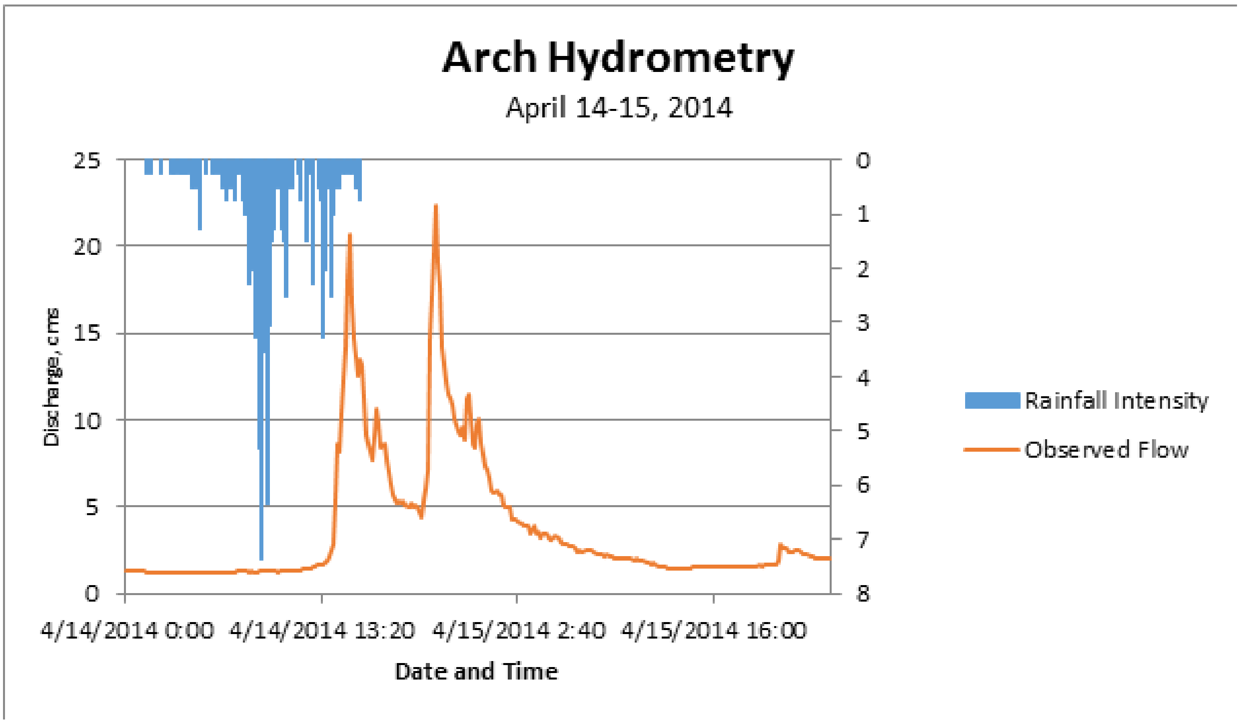


Figure 11. Arch rainfall and outflow data used for modeling

3.1.3.1.3 Mangima Bridge, Bukidnon

The river outflow was computed using the derived rating curve equation. This discharge was used to calibrate the HEC-HMS model. It was taken from Mangima Bridge, Bukidnon (8°22'37.34"N, 124°53'3.66"E). The recorded peak discharge is 135.55 cms at 15:45, January 20, 2014.

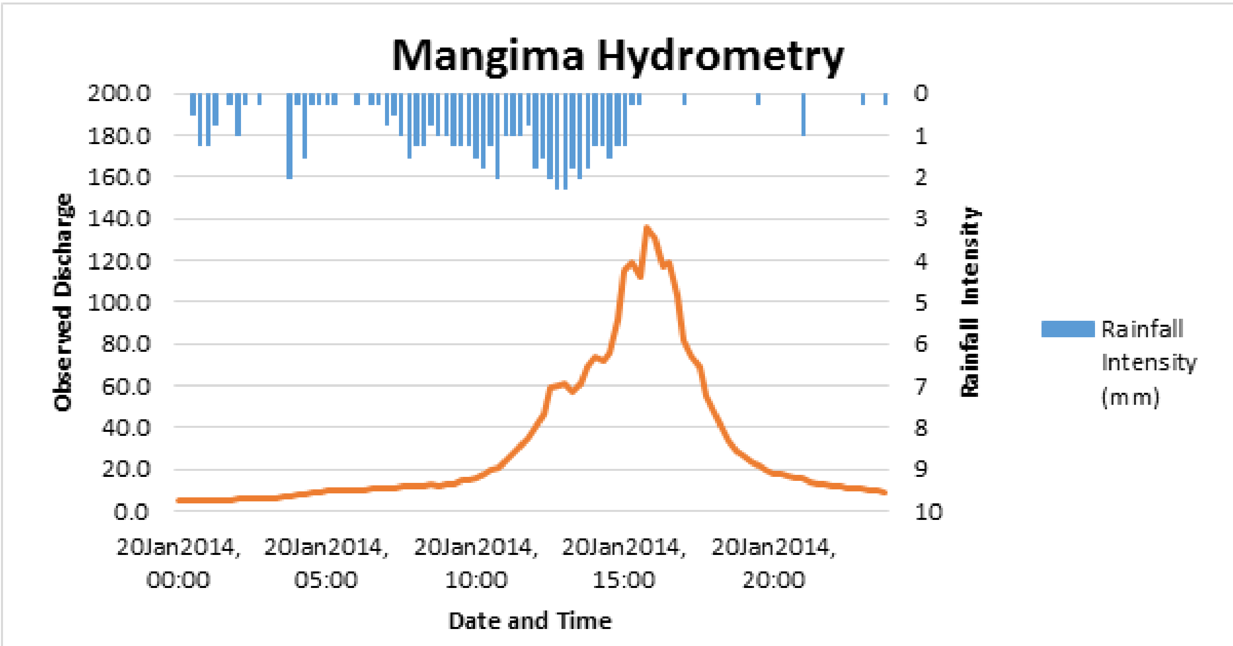


Figure 12. Mangima rainfall and outflow data used for modeling

3.1.3.2 Rainfall Intensity Duration Frequency

The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Tagoloan Rain Gauge. This station was chosen based on its proximity to the Tagoloan watershed. The extreme values for this watershed were computed based on a 26-year record.

Five return periods were used, namely, 5-, 10-, 25-, 50-, and 100-year RIDFs. All return periods are 24 hours long and peaks after 12 hours.

Figure 13. Thiessen Polygon of Rain Intensity Duration Frequency (RIDF) Stations for the whole Philippines

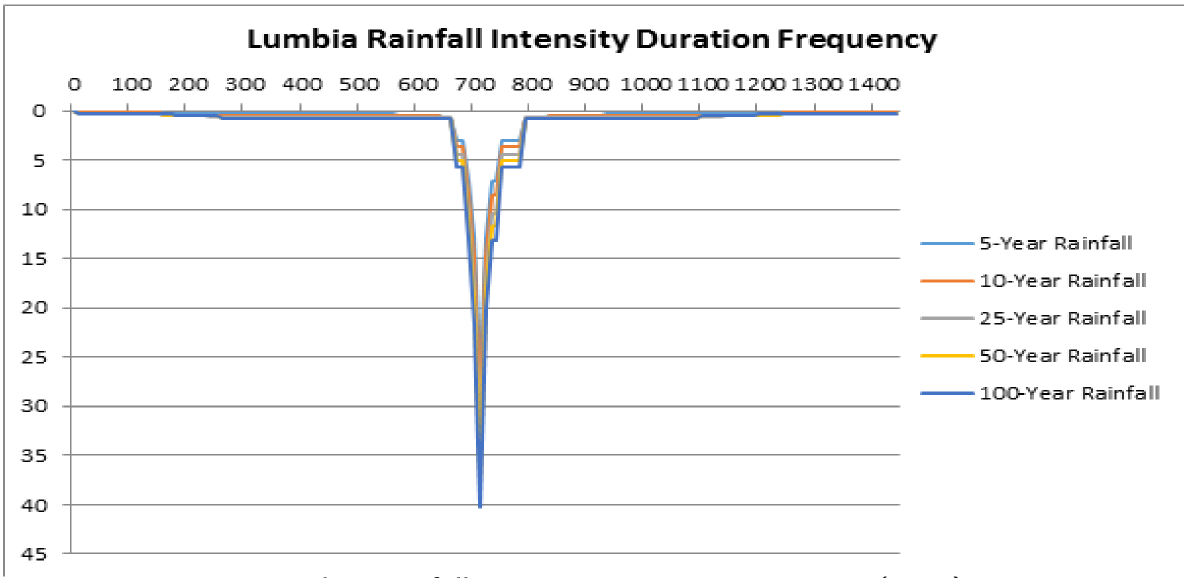


Figure 14. Lumbia Rainfall-Intensity Duration Frequency (RIDF) curves

The Tagoloan outflow was computed for the five return periods, namely, 5-, 10-, 25-, 50-, and 100-year RIDFs.

3.1.4 Rating Curves

Rating curves were provided by DVC. This curve gives the relationship between the observed water levels from the AWLS used and outflow watershed at the said locations.

Rating curves are expressed in the form of Equation 1 with the discharge (Q) as a function of the gauge height (h) readings from the AWLS and constants (a and n).

$$Q = a^{nh}$$

Equation 1. Rating Curve

3.1.4.1 Tagoloan Bridge Rating Curve

For Tagoloan Bridge, the rating curve is expressed as $Q = 0.0479e^{1.8583h}$ as shown in Figure 15.

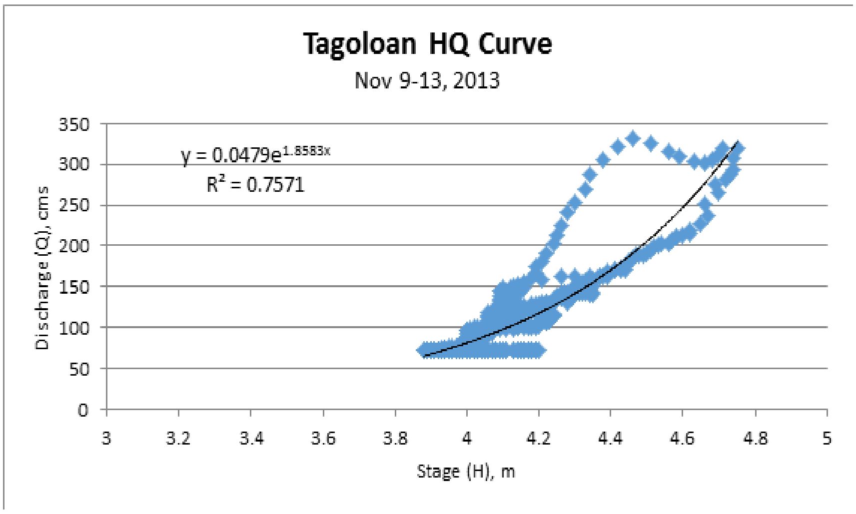


Figure 15. Water level vs. Discharge Curve for Tagoloan Bridge, Bukidnon

3.1.4.2 Arch Bridge Rating Curve

For Arch Bridge, the rating curve is expressed as $Q= 8E\text{-}143e^{2.6534h}$ as shown in Figure 16.

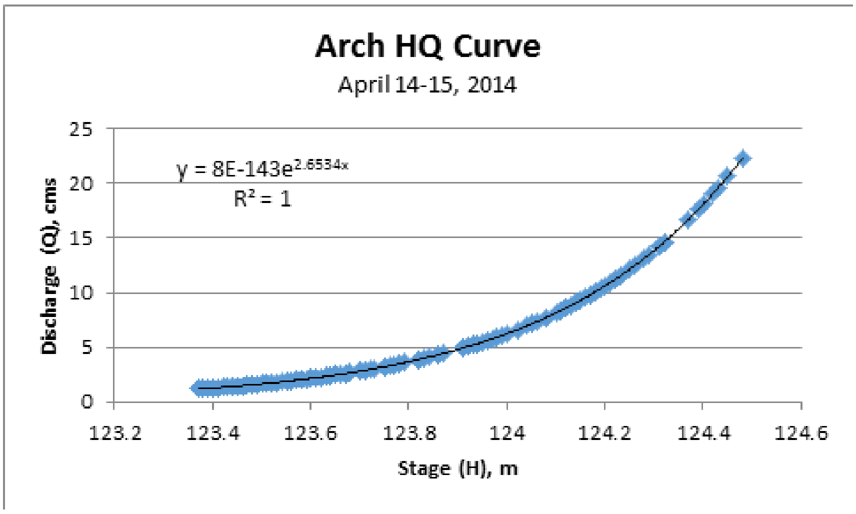


Figure 16. Water level vs. Discharge Curve for Arch Bridge, Bukidnon

3.1.4.3 Mangima Bridge Rating Curve

For Mangima Bridge, the rating curve is expressed as $Q = 0.0343e^{3.2099h}$ as shown in Figure 17.

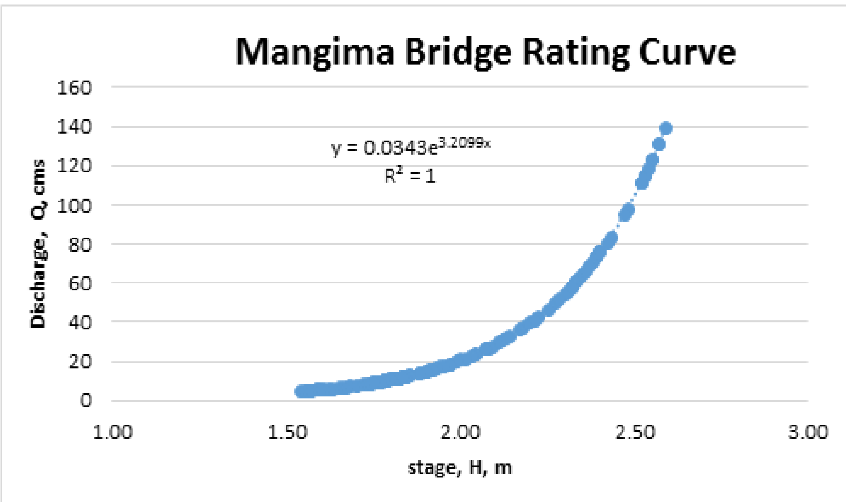


Figure 17. Water level vs. Discharge Curve for Mangima Bridge, Bukidnon

3.2 Rainfall-Runoff Hydrologic Model Development

3.2.1 Watershed Delineation and Basin Model Pre-processing

The hydrologic model of Tagoloan River Basin was developed using Watershed Modeling System (WMS) version 9.1. The software was developed by Aquaveo, a water resources engineering consulting firm in United States. WMS is a program capable of various watershed computations and hydrologic simulations. The hydrologic model development follows the scheme shown in the Figure 18.

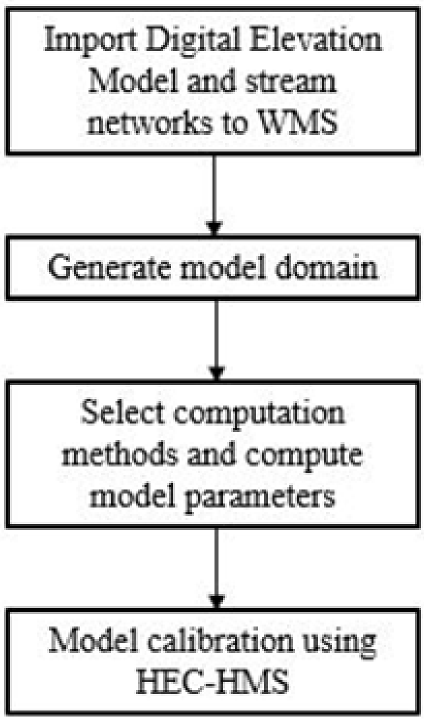


Figure 18. The Rainfall-Runoff Basin Model Development Scheme

Hydro-corrected SRTM DEM was used as the terrain for the basin model. The watershed delineation and its hydrologic elements, namely the subbasins, junctions and reaches, were generated using WMS after importing the elevation data and stream networks.

The parameters for the subbasins and reaches were computed after the model domain was created. There are several methods available for different calculation types for each subbasin and reach hydrologic elements. The methods used for this study is shown in Table 1. The necessary parameter values are determined by the selected methods. The initial abstraction, curve number, percentage impervious and manning's coefficient of roughness, n, for each subbasin were computed based on the soil type, land cover and land use data. The subbasin time of concentration and storage coefficient were computed based on the analysis of the topography of the basin.

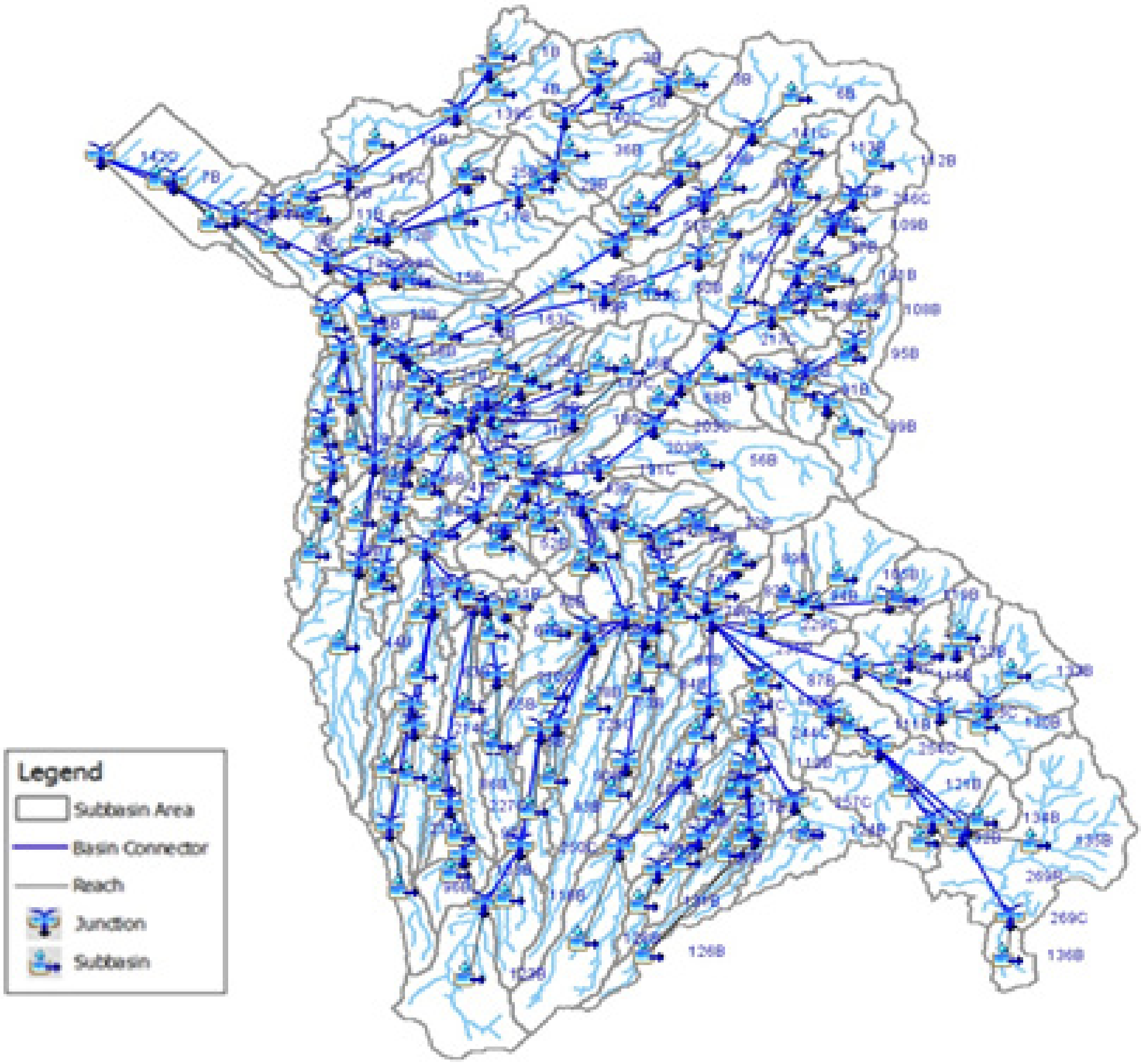


Figure 19. Tagoloan HEC-HMS Model domain generated by WMS

Table 1. Methods used for the different calculation types for the hydrologic elements

Hydrologic Element	Calculation Type	Method
Subbasin	Loss Rate	SCS Curve Number
	Transform	Clark's unit hydrograph
	Baseflow	Bounded recession
Reach	Routing	Muskingum-Cunge

3.2.2 Basin Model Calibration

The basin model made using WMS was exported to Hydrologic Modeling System (HEC-HMS) version 3.5, a software made by the Hydrologic Engineering Center of the US Army Corps of Engineers, to create the final rainfall-runoff model. The developers described HEC-HMS as a program designed to simulate the hydrologic processes of a dendritic watershed systems. In this study, the rainfall-runoff model was developed to calculate inflow from the watershed to the floodplain.

Precipitation data was taken from automatic rain gauges (ARGs) installed by the Department of Science and Technology – Advanced Science and Technology Institute (DOST-ASTI). There is only one (1) ARG located in the watershed. The location of the ARG is seen in Figure 20.

Total rain from Arch Bridge rain gauge is 67.81 mm. It peaked to 6.8 mm on 10, November 2013, 1:20am. The lag time between the peak rainfall and discharge is two days and six hours and ten minutes.

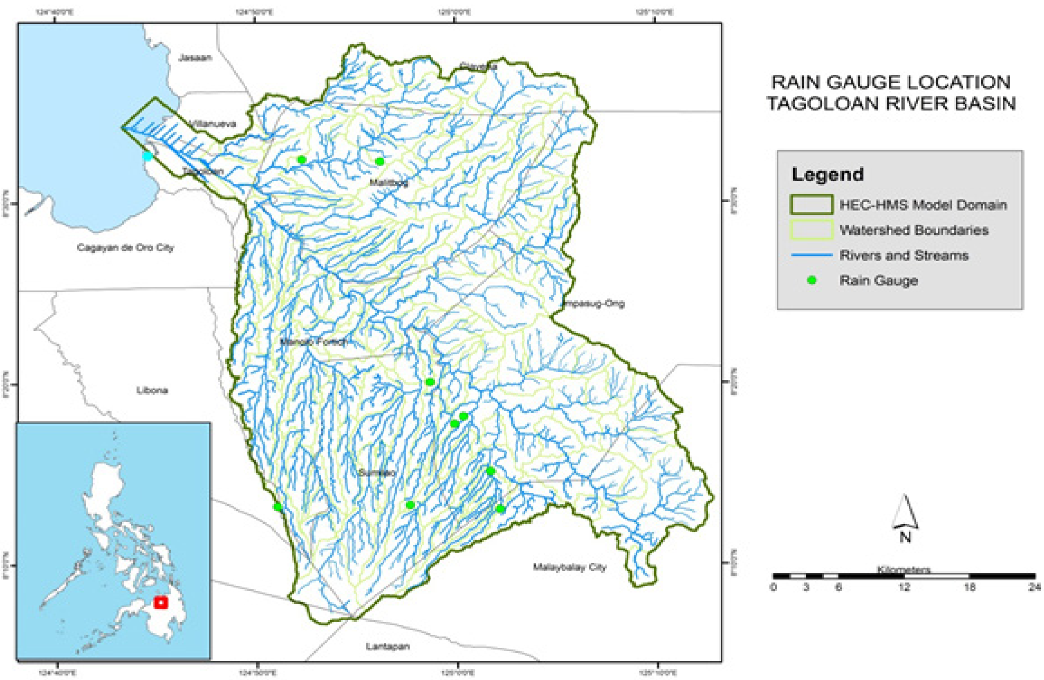


Figure 20. Location of rain gauge used for the calibration of Tagoloan HEC-HMS Model

The outflow hydrograph for the downstream-most discharge point with field data was also encoded to the model as a basis for the calibration. Using the said data, HEC-HMS could perform rainfall-runoff simulation and the resulting outflow hydrograph was compared with the observed hydrograph. The values of the parameters were adjusted and optimized in order for the calculated outflow hydrograph to appear like the observed hydrograph. Acceptable values of the subbasin and reach parameters from the manual and past literatures were considered in the calibration.

3.3 HEC-HMS Hydrologic Simulations for Discharge Computations using PAGASA RIDF Curves

3.3.1 Discharge Computation using Rainfall-Runoff Hydrologic Model

The calibrated Rainfall-Runoff Hydrologic Model for the Tagoloan River Basin using WMS and HEC-HMS was used to simulate the flow for the five return periods, namely, 5-, 10-, 25-, 50- and 100-year RIDFs. Time-series data of the precipitation data using the Lumbia RIDF curves were encoded to HEC-HMS for the aforementioned return periods, wherein each return period corresponds to a scenario. This process was performed for Tagoloan Bridge. The output for each simulation was an outflow hydrograph from that result, the total inflow to the floodplain and time difference between the peak outflow and peak precipitation could be determined.

3.3.2 Discharge Computation using Dr. Horritt's Recommended Hydrological Method

The required data to be accumulated for the implementation of Dr. Horrit's method is shown on Figure 21.

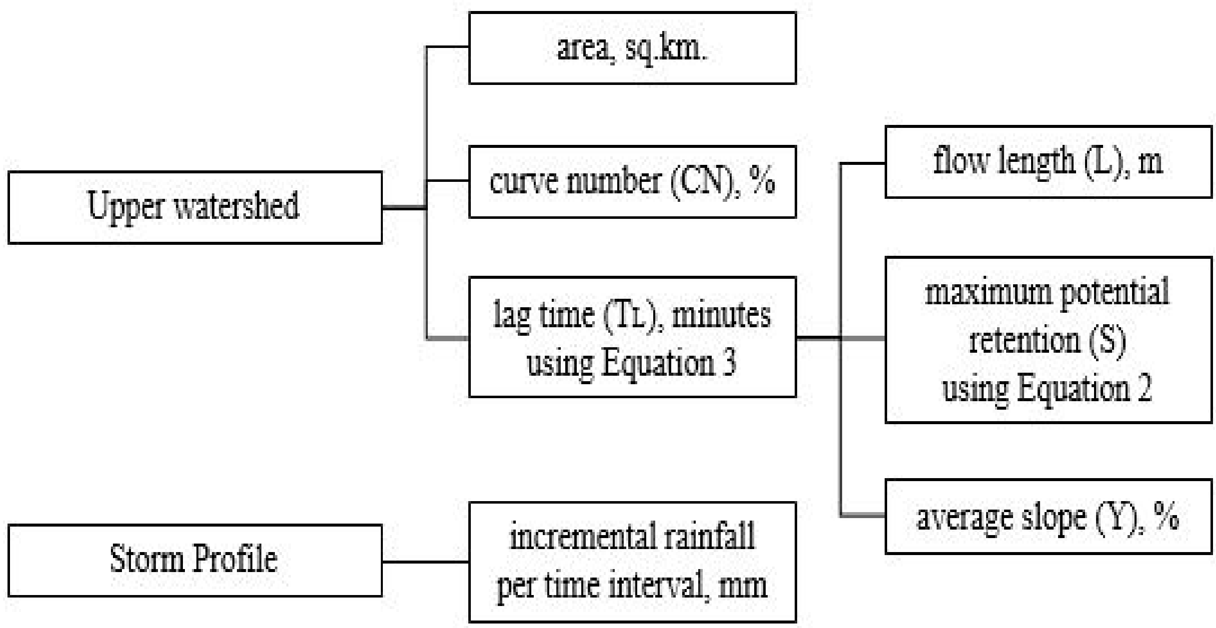


Figure 21. Different data needed as input for HEC-HMS discharge simulation using Dr. Horritt's recommended hydrology method

Flows from streams were computed using the hydrology method developed by the flood modeling component with Dr. Matt Horritt, a British hydrologist that specializes in flood research. The methodology was based on an approach developed by CH2M Hill and Horritt Consulting for Taiwan which has been successfully validated in a region with meteorology and hydrology similar to the Philippines.

3.3.2.1 Determination of Catchment Properties

RADARSAT DTM data for the different areas of the Philippines were compiled with the aid of ArcMap. RADARSAT satellites provide advance geospatial information and these were processed in the forms of shapefiles and layers that are readable and can be analyzed by ArcMap. These shapefiles are digital vectors that store geometric locations.

The watershed flow length is defined as the longest drainage path within the catchment, measured from the top of the watershed to the point of the outlet. With the tools provided by the ArcMap program and the data from RADARSAT DTM, the longest stream was selected and its geometric property, flow length, was then calculated in the program.

The area of the watershed is determined with the longest stream as the guide. The compiled RADARSAT data has a shapefile with defined small catchments based on mean elevation. These parameters were used in determining which catchments, along with the area, belong in the upper watershed.

Figure 22. Delineation of upper watershed for Tagoloan floodplain discharge computation

The value of the curve number was obtained using the RADARSAT data that contains information of the Philippine national curve number map. An ArcMap tool was used to determine the average curve number of the area bounded by the upper watershed shapefile. The same method was implemented in determining the average slope using RADARSAT with slope data for the whole country.

After determining the curve number (CN), the maximum potential retention (S) was determined by Equation 2.

$$S = \frac{1000}{CN} - 10$$

Equation 2. Determination of maximum potential retention using the average curve number of the catchment

The watershed length (L), average slope (Y) and maximum potential retention (S) are used to estimate the lag time of the upper watershed as illustrated in Equation 3.

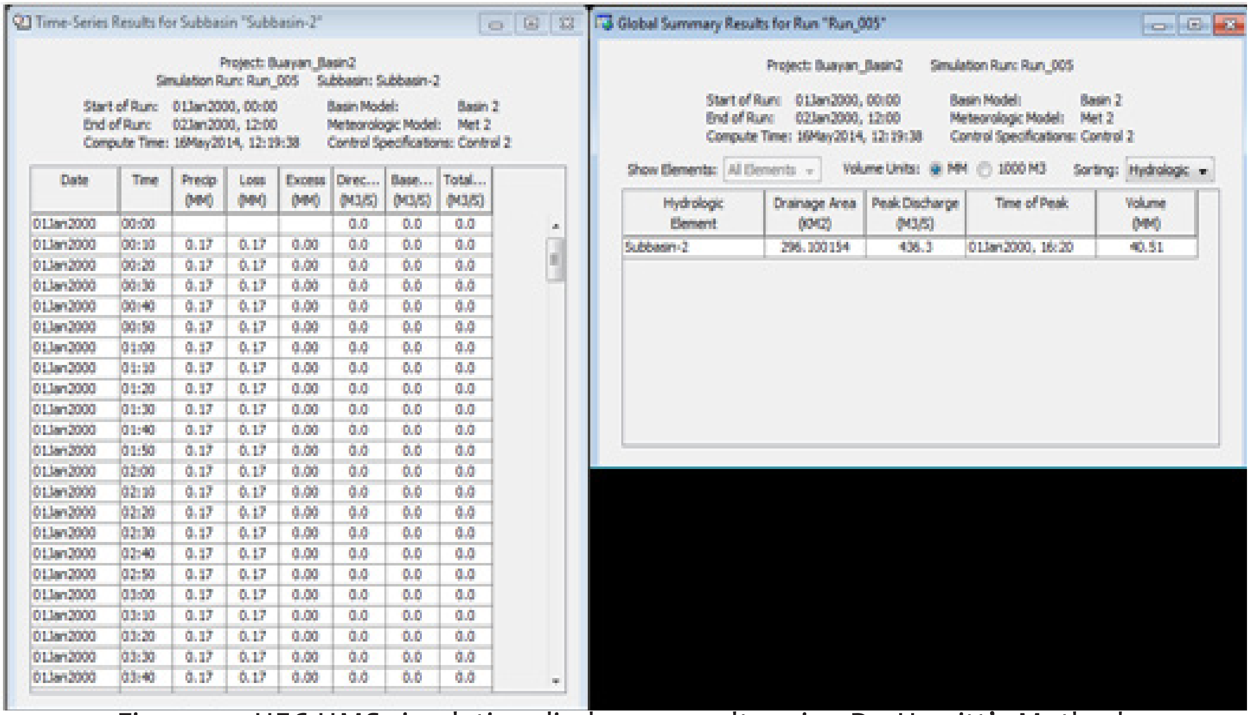
$$T_L = \frac{L^{0.8}(S+1)^{0.7}}{560Y^{0.5}}$$

Equation 3. Lag Time Equation Calibrated for Philippine Setting

Finally, the final parameter that will be derived is the storm profile. The synoptic station which covers the majority of the upper watershed was identified. Using the RIDF data, the incremental values of rainfall in millimeter per 0.1 hour was used as the storm profile.

3.3.2.2 HEC-HMS Implementation

With all the parameters available, HEC-HMS was then utilized. Obtained values from the previous section were used as input and a brief simulation would result in the tabulation of discharge results per time interval. The maximum discharge and time-to-peak for the whole simulation as well as the river discharge hydrograph were used for the flood simulation process. The time series results (discharge per time interval) were stored as HYD files for input in FLO-2D GDS Pro.



Date	Time	Precip (MM)	Loss (MM)	Excess (MM)	Direc... (M3/S)	Base... (M3/S)	Total... (M3/S)
01Jan2000	00:00				0.0	0.0	0.0
01Jan2000	00:10	0.17	0.17	0.00	0.0	0.0	0.0
01Jan2000	00:20	0.17	0.17	0.00	0.0	0.0	0.0
01Jan2000	00:30	0.17	0.17	0.00	0.0	0.0	0.0
01Jan2000	00:40	0.17	0.17	0.00	0.0	0.0	0.0
01Jan2000	00:50	0.17	0.17	0.00	0.0	0.0	0.0
01Jan2000	01:00	0.17	0.17	0.00	0.0	0.0	0.0
01Jan2000	01:10	0.17	0.17	0.00	0.0	0.0	0.0
01Jan2000	01:20	0.17	0.17	0.00	0.0	0.0	0.0
01Jan2000	01:30	0.17	0.17	0.00	0.0	0.0	0.0
01Jan2000	01:40	0.17	0.17	0.00	0.0	0.0	0.0
01Jan2000	01:50	0.17	0.17	0.00	0.0	0.0	0.0
01Jan2000	02:00	0.17	0.17	0.00	0.0	0.0	0.0
01Jan2000	02:10	0.17	0.17	0.00	0.0	0.0	0.0
01Jan2000	02:20	0.17	0.17	0.00	0.0	0.0	0.0
01Jan2000	02:30	0.17	0.17	0.00	0.0	0.0	0.0
01Jan2000	02:40	0.17	0.17	0.00	0.0	0.0	0.0
01Jan2000	02:50	0.17	0.17	0.00	0.0	0.0	0.0
01Jan2000	03:00	0.17	0.17	0.00	0.0	0.0	0.0
01Jan2000	03:10	0.17	0.17	0.00	0.0	0.0	0.0
01Jan2000	03:20	0.17	0.17	0.00	0.0	0.0	0.0
01Jan2000	03:30	0.17	0.17	0.00	0.0	0.0	0.0
01Jan2000	03:40	0.17	0.17	0.00	0.0	0.0	0.0

Hydrologic Element	Drainage Area (KM2)	Peak Discharge (M3/S)	Time of Peak	Volume (MM)
Subbasin-2	296.100154	436.3	01Jan2000, 16:20	40.51

Figure 23. HEC-HMS simulation discharge results using Dr. Horritt's Method

3.3.2.3 Discharge validation against other estimates

As a general rule, the river discharge of a 2-year rain return, Q_{MED}, should approximately be equal to the bankful discharge, $Q_{bankful}$, of the river. This assumes that the river is in equilibrium, with its deposition being balanced by erosion. Since the simulations of the river discharge are done for 5-, 25-, and 100-year rainfall return scenarios, a simple ratio for the 2-year and 5-year return was computed with samples from actual discharge data of different rivers. It was found out to have a constant of 0.88. This constant, however, should still be continuously checked and calibrated when necessary.

$$Q_{MED} = 0.88 Q_{5yr}$$

Equation 4. Ratio of river discharge of a 5-year rain return to a 2-year rain return scenario from measured discharge data

For the discharge calculation to pass the validation using the bankful method, Equation 5 must be satisfied.

$$50\%\, Q_{bankful} \leq Q_{MED} \leq 150\%\, Q_{bankful}$$

Equation 5. Discharge validation equation using bankful method

The bankful discharge was estimated using channel width (w), channel depth (h), bed slope (S) and Manning's constant (n). Derived from the Manning's Equation, the equation for the bankful discharge is by Equation 6.

$$Q_{bankful} = \frac{(wh)^{\frac{5}{3}} S^{\frac{1}{2}}}{n(w + 2h)^{\frac{2}{3}}}$$

Equation 6. Bankful discharge equation using measurable channel parameters

3.4 Hazard and Flow Depth Mapping using FLO-2D

3.4.1 Floodplain Delineation

The boundaries of subbasins within the floodplain were delineated based on elevation values given by the DEM. Each subbasin is marked by ridges dividing catchment areas. These catchments were delineated using a set of ArcMap tools compiled by Al Duncan, a UK Geomatics Specialist, into a single processing model. The tool allows ArcMap to compute for the flow direction and acceleration based on the elevations provided by the DEM.

Running the tool creates features representing large, medium-sized, and small streams, as well as large, medium-sized, and small catchments. For the purpose of this particular model, the large, medium-sized, and small streams were set to have an area threshold of 100,000sqm, 50,000sqm, and 10,000sqm respectively. These thresholds define the values where the algorithm refers to in delineating a trough in the DEM as a stream feature, i.e. a large stream feature should drain a catchment area totalling 100,000 sqm to be considered as such. These values differ from the standard values used (10,000sqm, 1,000 sqm and 100sqm) to limit the detail of the project, as well as the file sizes, allowing the software to process the data faster.

The tool also shows the direction in which the water is going to flow across the catchment area. This information was used as the basis for delineating the floodplain. The entire area of the floodplain was subdivided into several zones in such a way that it can be processed properly. This was done by grouping the catchments together, taking special account of the inflows and outflows of water across the entire area. To be able to simulate actual conditions, all the catchments comprising a particular computational domain were set to have outflows that merged towards a single point. The area of each subdivision was limited to 250,000 grids or less to allow for an optimal simulation in FLO-2D GDS Pro. Larger models tend to run longer, while smaller models may not be as accurate as a large one.

3.4.2 Flood Model Generation

The software used to run the simulation is FLO-2D GDS Pro. It is a GIS integrated software tool that creates an integrated river and floodplain model by simulating the flow of the water over a system of square grid elements.

After loading the shapefile of the subcatchment onto FLO-2D, 10 meter by 10 meter grids that encompassed the entire area of interest were created.

The boundary for the area was set by defining the boundary grid elements. This can either be done by defining each element individually, or by drawing a line that traces the boundaries of the subcatchment. The grid elements inside of the defined boundary were considered as the computational area in which the simulation will be run.

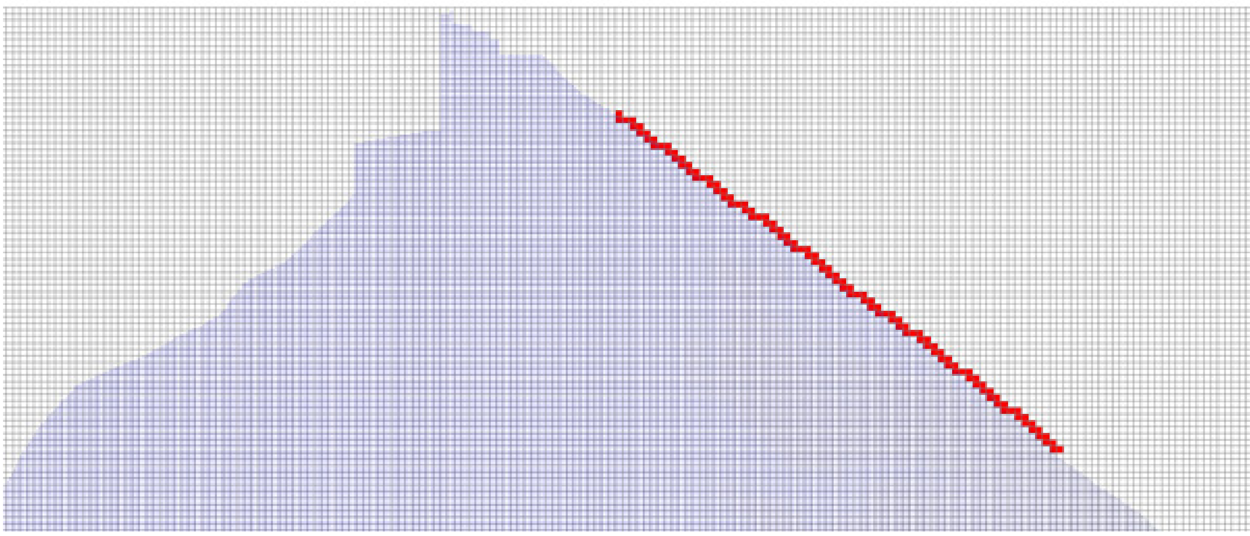


Figure 24. Screenshot showing how boundary grid elements are defined by line

Elevation data was imported in the form of the DEM gathered through LiDAR. These elevation points in PTS format were extrapolated into the model, providing an elevation value for each grid element.

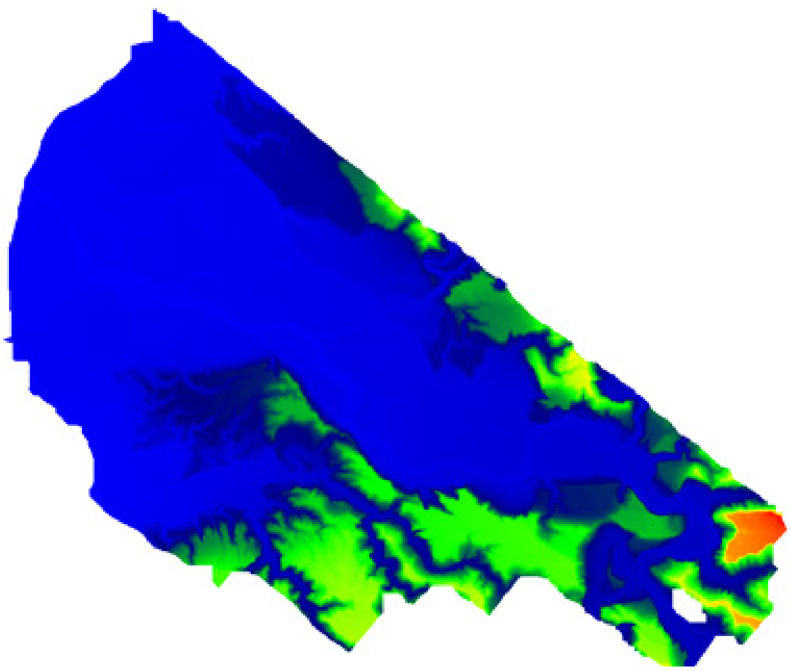


Figure 25. Screenshots of PTS files when loaded into the FLO-2D program

The floodplain is predominantly composed of rice fields, which have a Manning coefficient of 0.15. All the inner grid elements were selected and the Manning coefficient of 0.15 was assigned. To differentiate the streams from the rest of the floodplain, a shapefile containing all the streams and rivers in the area were imported into the software. The shapefile was generated using Al Duncan's catchment tool for ArcMap. The streams were then traced onto their corresponding grid elements.

These grid elements were all selected and assigned a Manning coefficient of 0.03. The DEM and aerial imagery were also used as bases for tracing the streams and rivers.

Figure 26. Areal image of Tagoloan floodplain

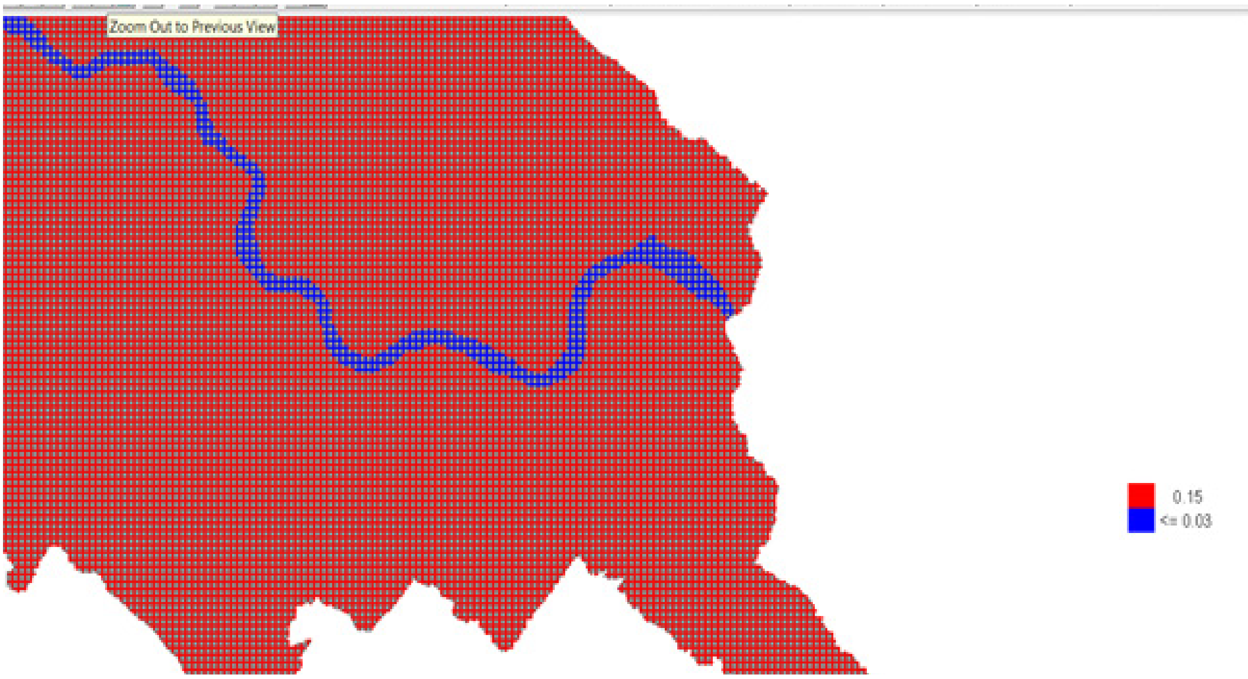


Figure 27. Screenshot of Manning's n-value rendering

After assigning Manning coefficients for each grid, the infiltration parameters were identified. Green-Ampt infiltration method by W. Heber Green and G.S Ampt were used for all the models. The initial saturations applied to the model were 0.99, 0.8, and 0.7 for 100-year, 25-year, and 5-year rain return periods respectively. These initial saturations were used in the computation of the infiltration value.

The Green-Ampt infiltration method by W. Heber Green and G.S Ampt method is based on a simple physical model in which the equation parameter can be related to physical properties of the soil. Physically, Green and Ampt assumed that the soil was saturated behind the wetting front and that one could define some "effective" matric potential at the wetting front (Kirkham, 2005). Basically, the system is assumed to consist of a uniformly wetted near-saturated transmission zone above a sharply defined wetting front of constant pressure head (Diamond & Shanley, 2003).

The next step was to allocate inflow nodes based on the locations of the outlets of the streams from the upper watershed. The inflow values came from the computed discharges that were input as hyd files.

Outflow nodes were allocated for the model. These outflow nodes show the locations where the water received by the watershed is discharged. The water that will remain in the watershed will result to flooding on low lying areas.

For the models to be able to simulate actual conditions, the inflow and outflow of each computational domain should be indicated properly. In situations wherein water flows from one subcatchment to the other, the corresponding models are processed one after the other. The outflow generated by the source subcatchment was used as inflow for the subcatchment area that it flows into.

The standard simulation time used to run each model is the time-to-peak (TP) plus an additional 12 hours. This gives enough time for the water to flow into and out of the model area, illustrating the complete process from entry to exit as shown in the hydrograph. The additional 12 hours allows enough time for the water to drain fully into the next subcatchment. After all the parameters were set, the model was run through FLO-2D GDS Pro.

3.4.3 Flow Depth and Hazard Map Simulation

After running the flood map simulation in FLO-2D GDS Pro, FLO-2D Mapper Pro was used to read the resulting hazard and flow depth maps. The standard input values for reading the simulation results are shown on Figure 28.

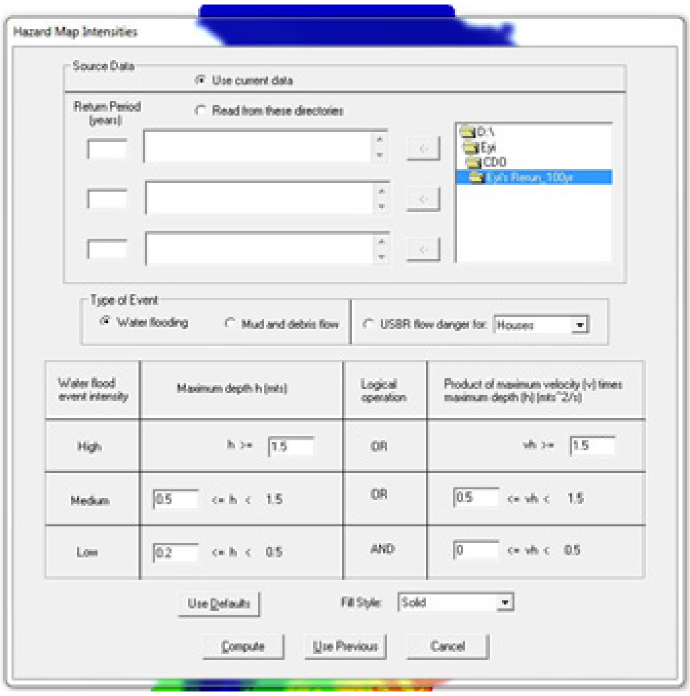


Figure 28. Flo-2D Mapper Pro General Procedure

In order to produce the hazard maps, set input for low maximum depth as 0.2 m, and vh, product of maximum velocity and maximum depth (m^2/s), as greater than or equal to zero. The program will then compute for the flood inundation and will generate shapefiles for the hazard and flow depth scenario.

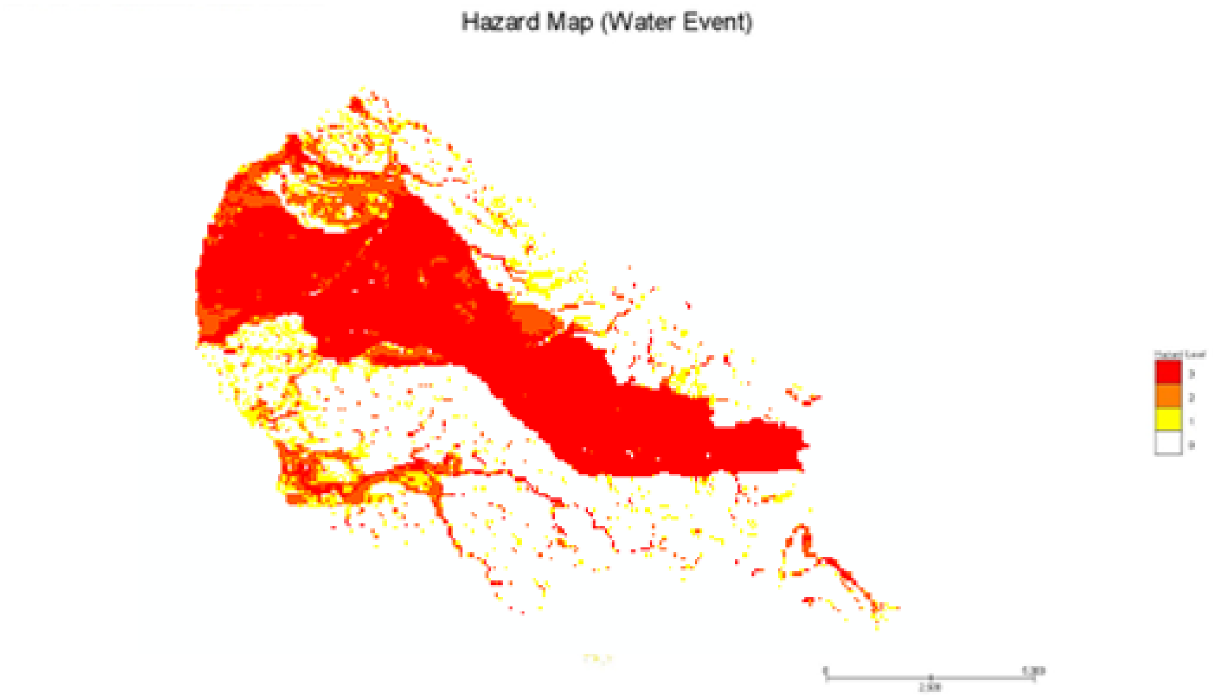


Figure 29. Tagoloan Floodplain Generated Hazard Maps using FLO-2D Mapper

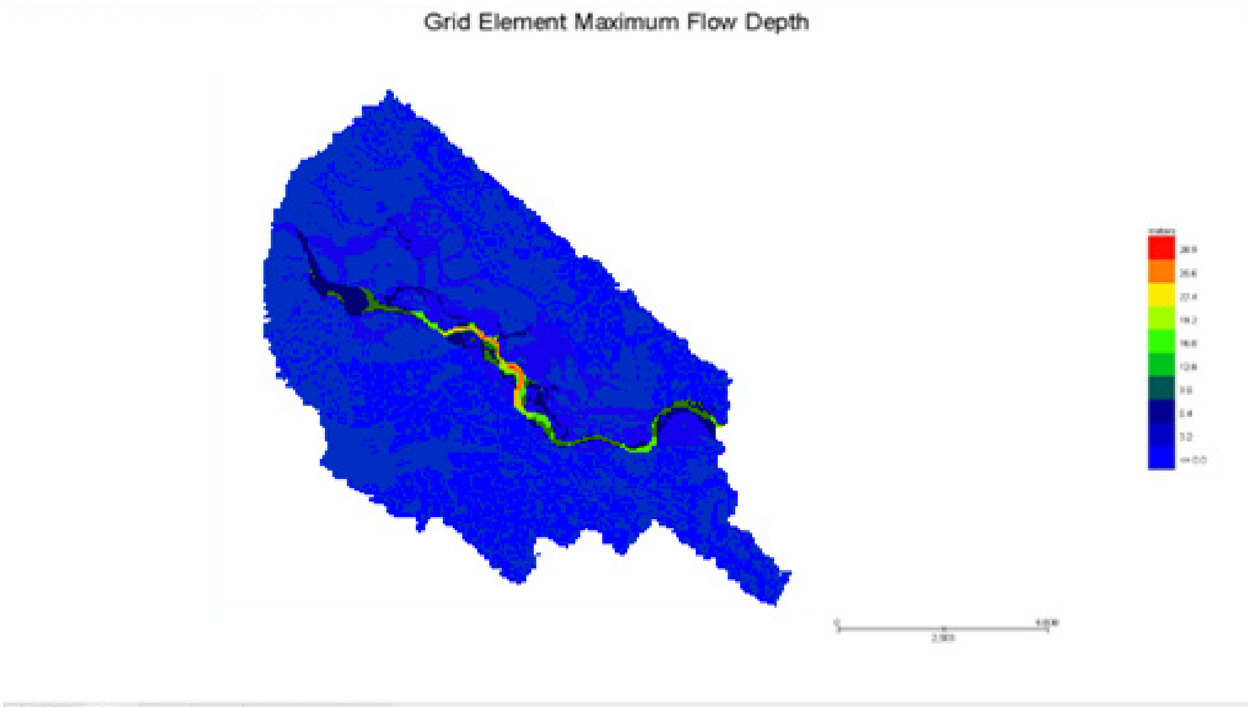
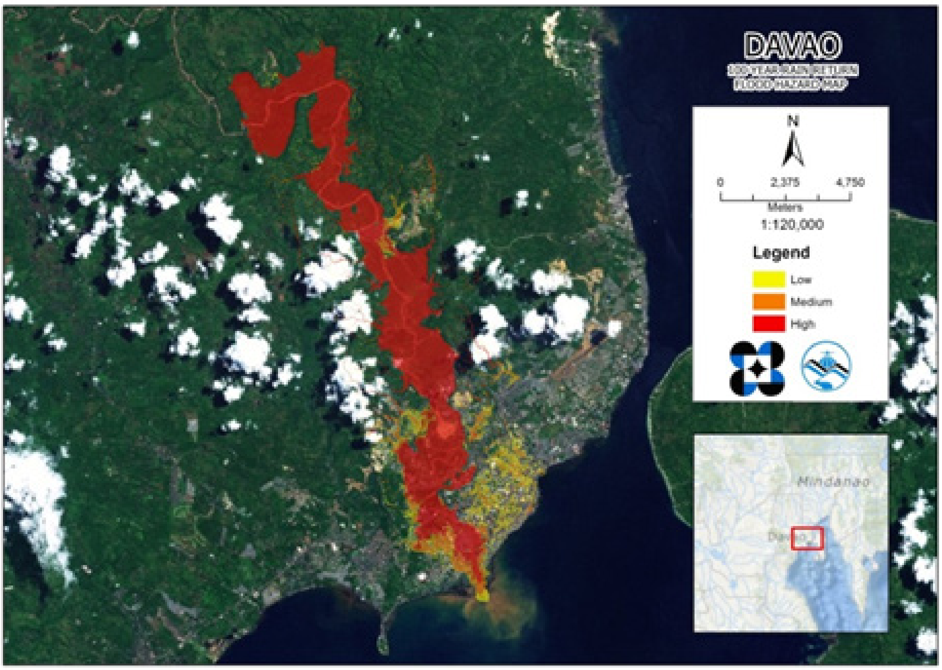


Figure 30. Tagoloan floodplain generated flow depth map using FLO-2D Mapper

3.4.4 Hazard Map and Flow Depth Map Creation

The final procedure in creating the maps is to prepare them with the aid of ArcMap. The generated shapefiles from FLO-2D Mapper Pro were opened in ArcMap. The basic layout of a hazard map is shown in Figure 31. The same map elements are also found in a flow depth map.



ELEMENTS
1. River Basin Name
2. Hazard/Flow Depth Shapefile
3. Provincial Inset
4. Philippine Inset
5. Hi-Res image of the area
6. North Arrow
7. Scale text and Bar

Figure 31. Basic Layout and Elements of the Hazard Maps

Results and Discussion

4.1 Efficiency of HEC-HMS Rainfall-Runoff Models calibrated based on field survey and gauges data

4.1.1 Tagoloan Bridge, Bukidnon HMS Model Calibration Result

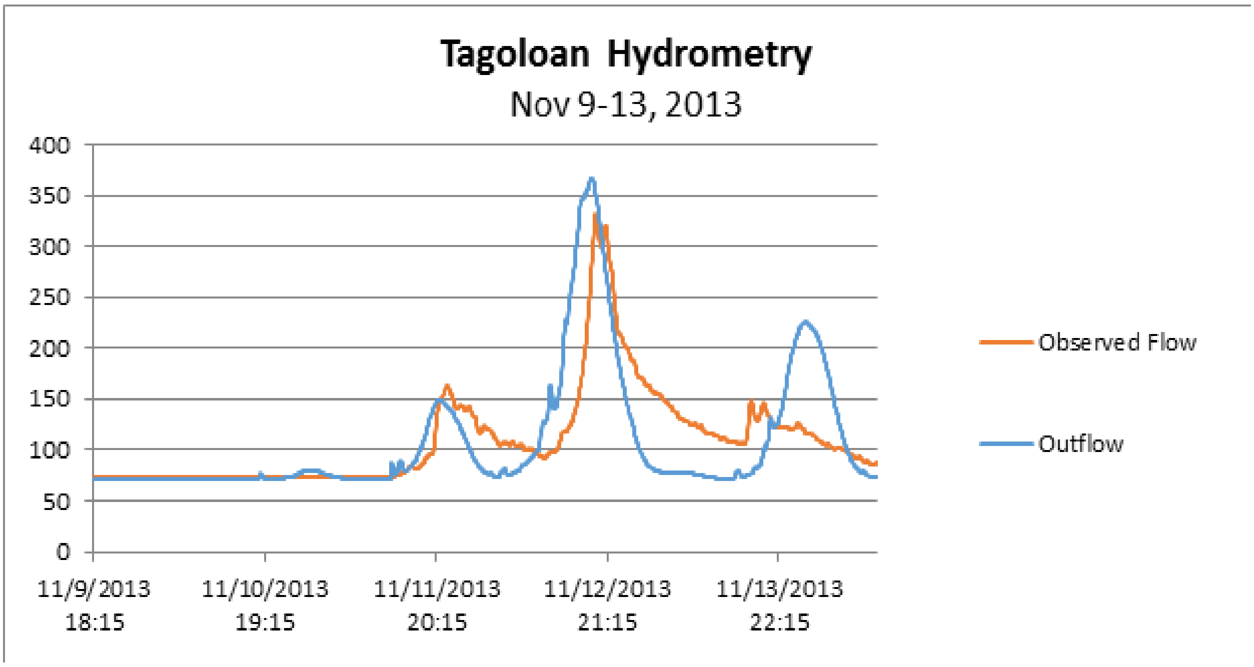


Figure 32. Tagoloan Bridge Outflow Hydrograph produced by the HEC-HMS model compared with observed outflow.

After calibrating the Tagoloan HEC-HMS river basin model, its accuracy was measured against the observed values. The comparison between the two discharge data are shown in Figure 32.

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 44.9 m3/s.

The Nash-Sutcliffe (E) method was also used to assess the predictive power of the model. Here the optimal value is 1. The model attained an efficiency coefficient of 0.26.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is 1.09

The Observation Standard Deviation Ratio, RSR, is an error index. A perfect model attains a value of 0 when the error in the units of the valuable a quantified. The model has an RSR value of 0.86

4.1.2 Arch Bridge, Bukidnon HMS Model Calibration Result

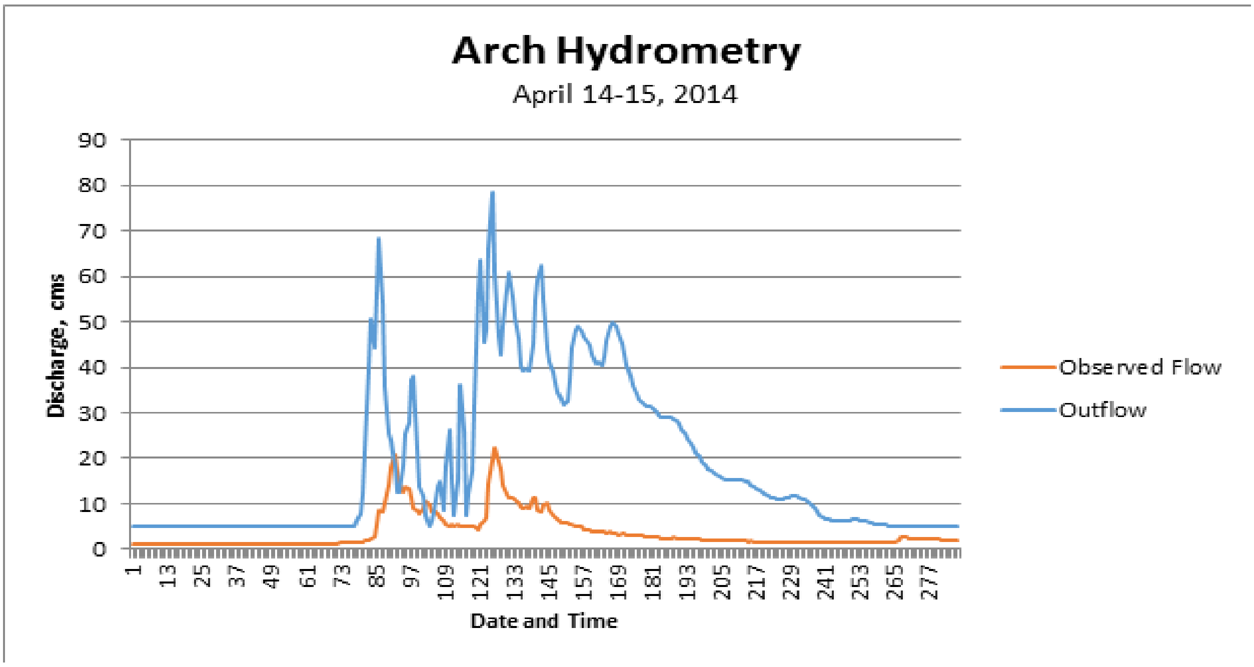


Figure 33. Arch Bridge Outflow Hydrograph produced by the HEC-HMS model compared with observed outflow

After calibrating the Arch HEC-HMS river basin model, its accuracy was measured against the observed values. The comparison between the two discharge data are shown in Figure 33.

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 23.1 m3/s.

The Nash-Sutcliffe (E) method was also used to assess the predictive power of the model. Here the optimal value is 1. The model attained an efficiency coefficient of -28.34.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is -80.18

The Observation Standard Deviation Ratio, RSR, is an error index. A perfect model attains a value of 0 when the error in the units of the valuable a quantified. The model has an RSR value of 5.42

4.1.3 Mangima Bridge, Bukidnon HMS Model Calibration Result

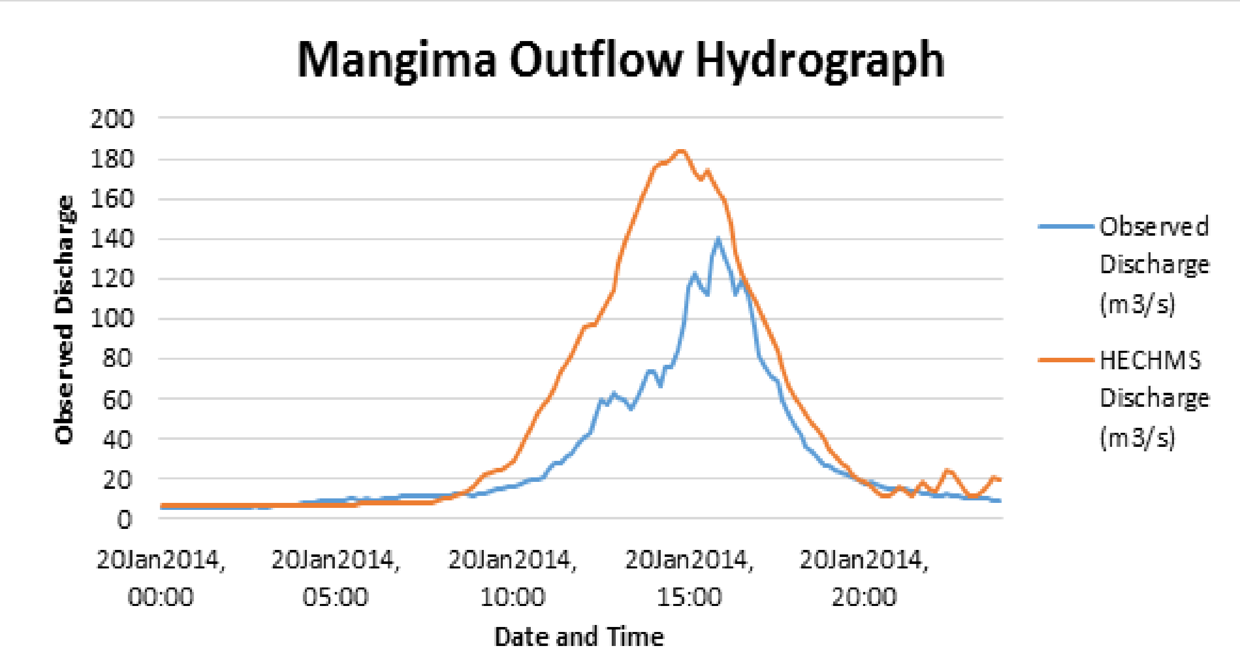


Figure 34. Mangima Bridge Outflow Hydrograph produced by the HEC-HMS model compared with observed outflow.

After calibrating the Mangima HEC-HMS river basin model, its accuracy was measured against the observed values. The comparison between the two discharge data are shown in Figure 34.

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 33.4 m3/s.

The Nash-Sutcliffe (E) method was also used to assess the predictive power of the model. Here the optimal value is 1. The model attained an efficiency coefficient of 0.04.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is -36.29.

The Observation Standard Deviation Ratio, RSR, is an error index. A perfect model attains a value of 0. The model has an RSR value of 0.98.

The calibrated models of the other discharge points are used in flood forecasting. DREAM Program offers the LGUs and other disaster mitigation agencies a water level forecast tool, which can be found on the DREAM website.

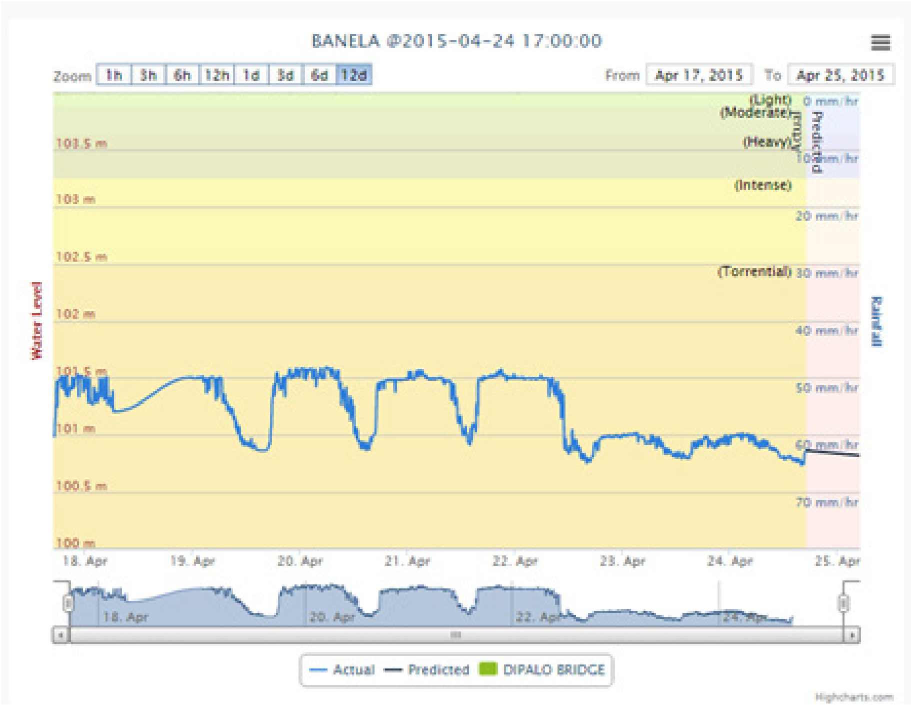


Figure 35. Sample DREAM Water Level Forecast

Given the predicted and real-time actual water level on specific AWLS, possible river flooding can be monitored and information can be disseminated to LGUs. This will help in the early evacuation of the probable affected communities. The calibrated models can also be used for flood inundation mapping.

4.2 Calculated Outflow hydrographs and Discharge Values for different Rainfall Return Periods

4.2.1 Hydrograph using the Rainfall-Runoff Model

4.2.1.1 Tagoloan Bridge, Bukidnon

The outflow of Tagoloan using the Lumbia Rainfall Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on PAGASA data are shown in Figures 36-40. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

In the 5-year return period graph, the peak outflow is 5267.4 cms. This occurs after 2 hours and 40 minutes after the peak precipitation of 27.1 mm, as shown on Figure 36.

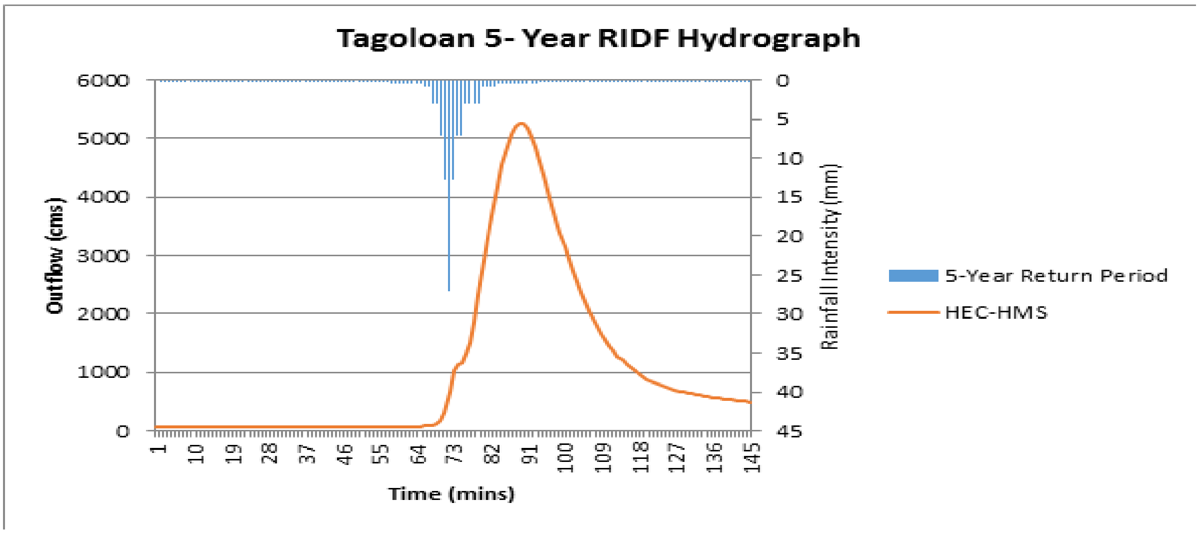


Figure 36. Tagoloan Outflow hydrograph generated using the Lumbia 5-Year RIDF in HEC-HMS

In the 10-year return period graph, the peak outflow is 7205.5 cms. This occurs after 2 hours and 30 minutes after the peak precipitation of 30.2 mm, as shown on Figure 37.

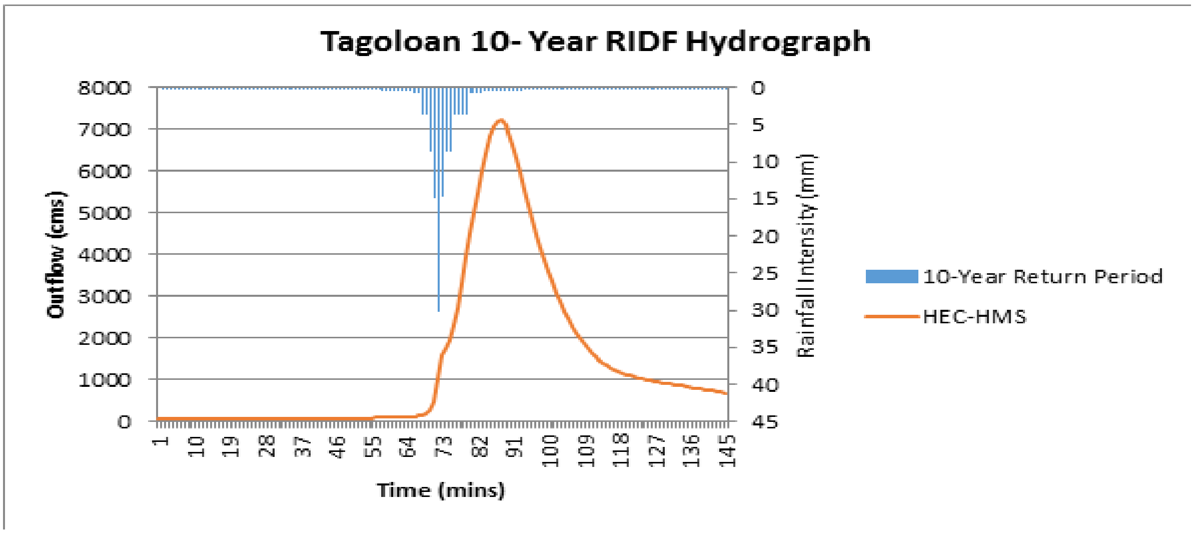


Figure 37. Tagoloan Outflow hydrograph generated using the Lumbia 10-Year RIDF in HEC-HMS

In the 25-year return period graph, the peak outflow is 9958.5 cms. This occurs after 2 hours and 10 minutes after the peak precipitation 34.2 mm, as shown on Figure 38.

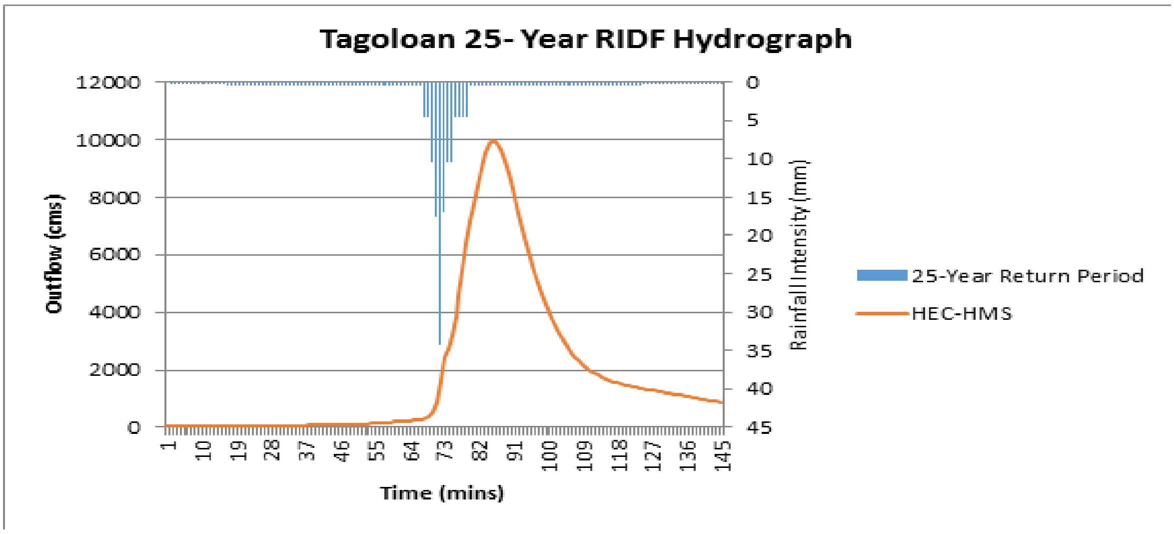


Figure 38. Tagoloan Outflow hydrograph generated using the Lumbia 25-Year RIDF in HEC-HMS

In the 50-year return period graph, the peak outflow is 12207.8 cms. This occurs after 2 hours after the peak precipitation of 37.2 mm, as shown on Figure 39.

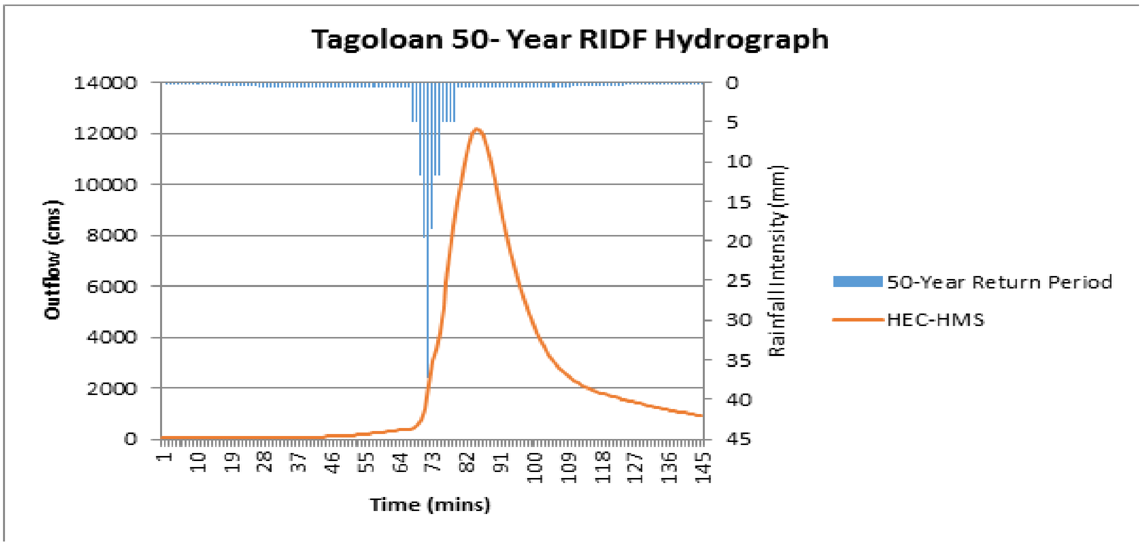


Figure 39. Tagoloan Outflow hydrograph generated using the Lumbia 50-Year RIDF in HEC-HMS

In the 100-year return period graph, the peak outflow is 14420.2 cms. This occurs after 2 hours after the peak precipitation of 40.2 mm, as shown on Figure 40.

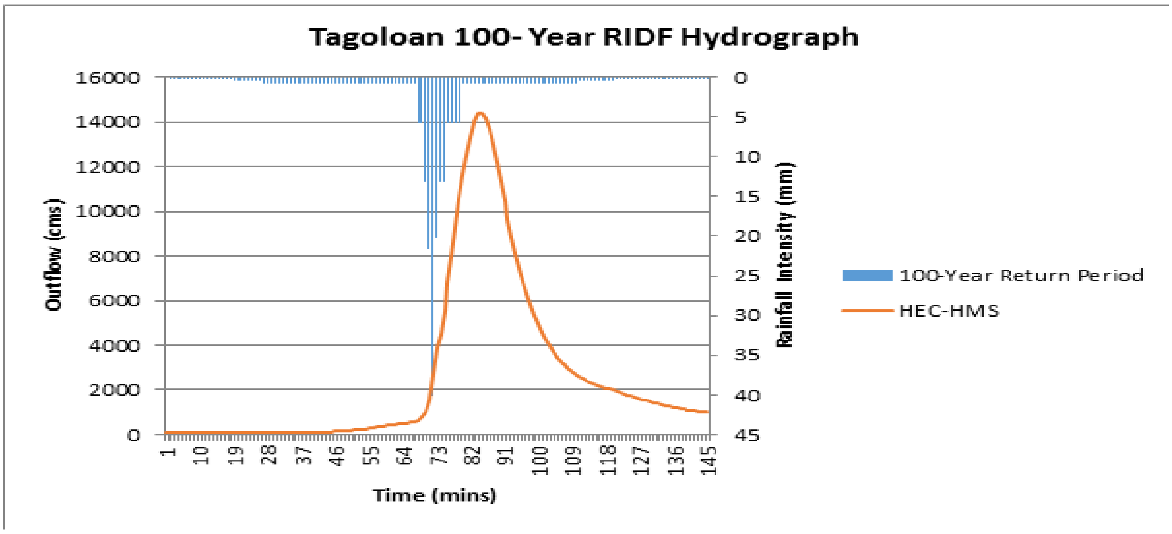


Figure 40. Tagoloan Outflow hydrograph generated using the Lumbia 100-Year RIDF in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of Tagoloan discharge using the Lumbia Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 2.

Table 2. Summary of Tagoloan discharge using the Lumbia Station Rainfall Intensity Duration Frequency (RIDF)

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (cms)	Time to Peak
5-Year	185.3	27.1	5267.4	2 hours and 40 minutes
10-Year	225	30.2	7205.5	2 hours and 30 minutes
25-Year	275.2	34.2	9958.5	2 hours and 10 minutes
50-Year	312.4	37.2	12207.8	2 hours
100-Year	349.3	40.2	14420.2	2 hours

4.2.1.2 Arch Bridge, Bukidnon

The outflow of Arch using the Lumbia Rainfall Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on PAGASA data are shown in Figures 41-45. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

In the 5-year return period graph, the peak outflow is 548.4cms. This occurs after 10 minutes after the peak precipitation of 27.1 mm, as shown on Figure 41.

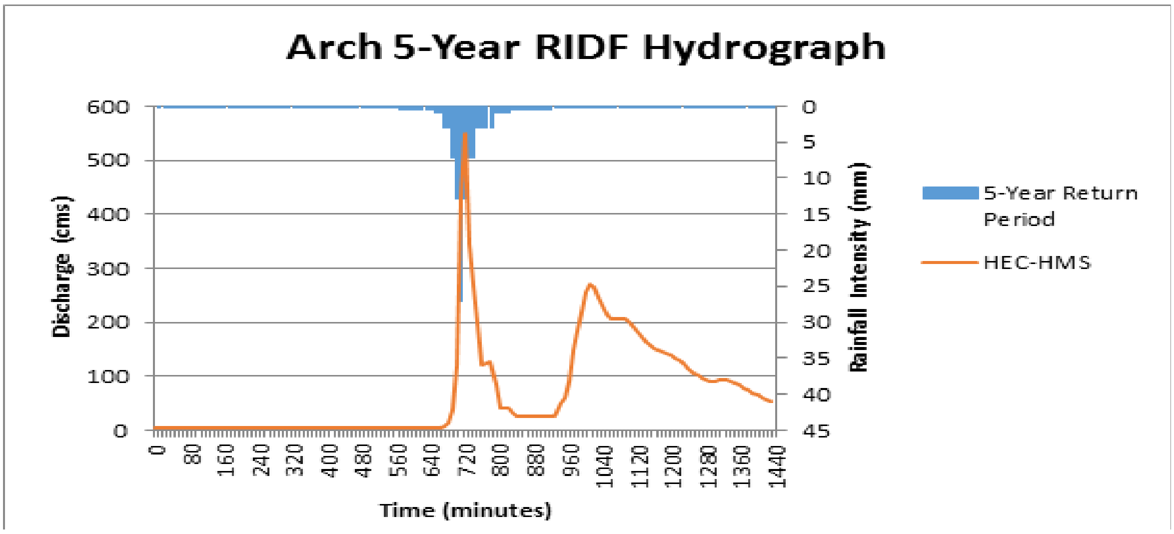


Figure 41. Arch Outflow hydrograph generated using the Lumbia 5-Year RIDF in HEC-HMS

In the 10-year return period graph, the peak outflow is 734.9cms. This occurs after 10 minutes after the peak precipitation of 30.2 mm, as shown on Figure 42.

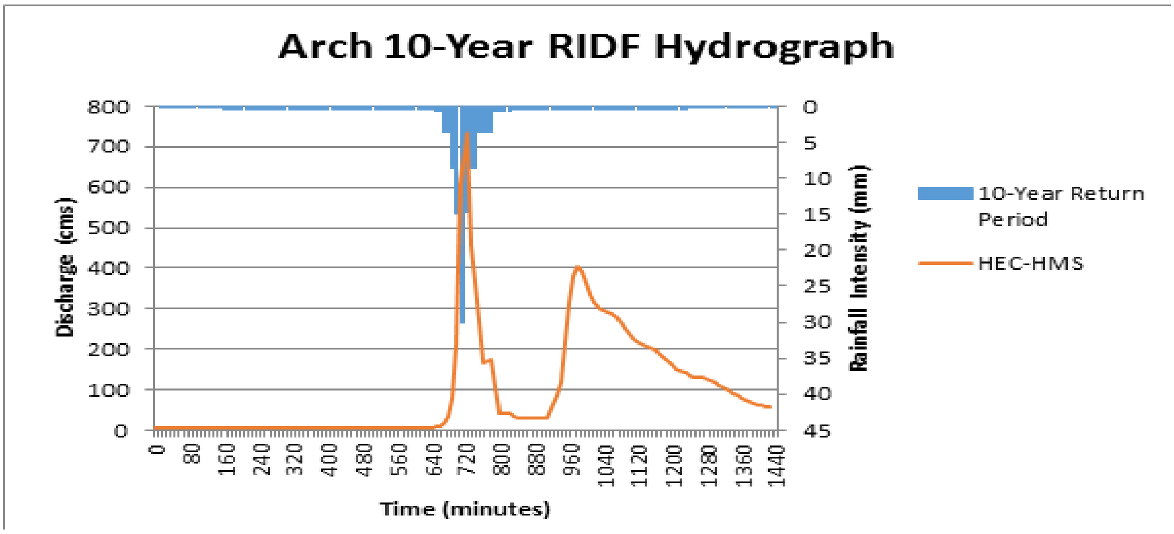


Figure 42. Arch Outflow hydrograph generated using the Lumbia 10-Year RIDF in HEC-HMS

In the 25-year return period graph, the peak outflow is 976.5cms. This occurs after 10 minutes after the peak precipitation of 34.2 mm, as shown on Figure 43.

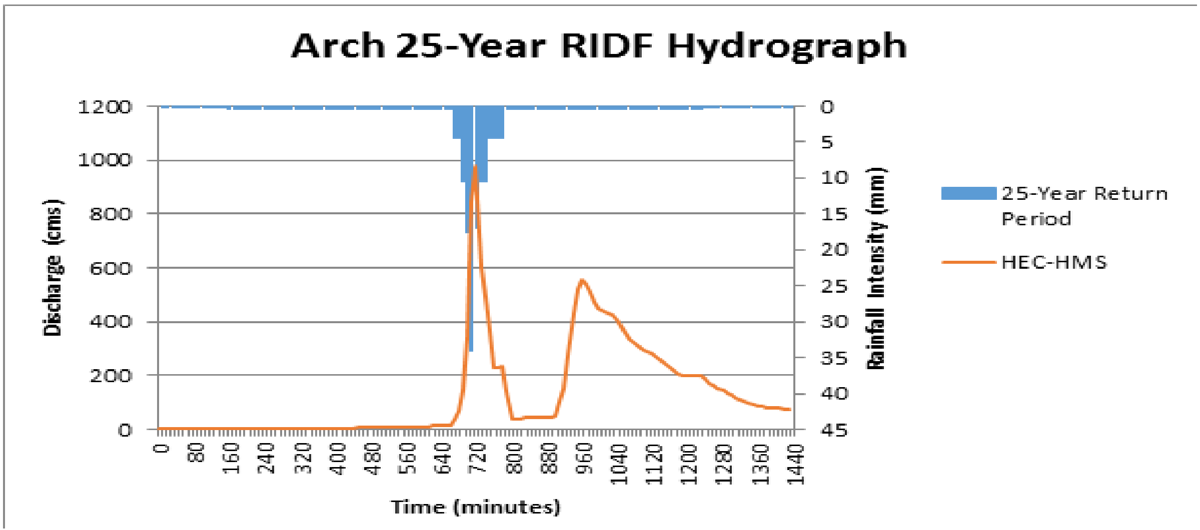


Figure 43. Arch Outflow hydrograph generated using the Lumbia 25-Year RIDF in HEC-HMS

In the 50-year return period graph, the peak outflow is 1157.2cms. This occurs after 10 minutes after the peak precipitation of 37.2 mm, as shown on Figure 44.

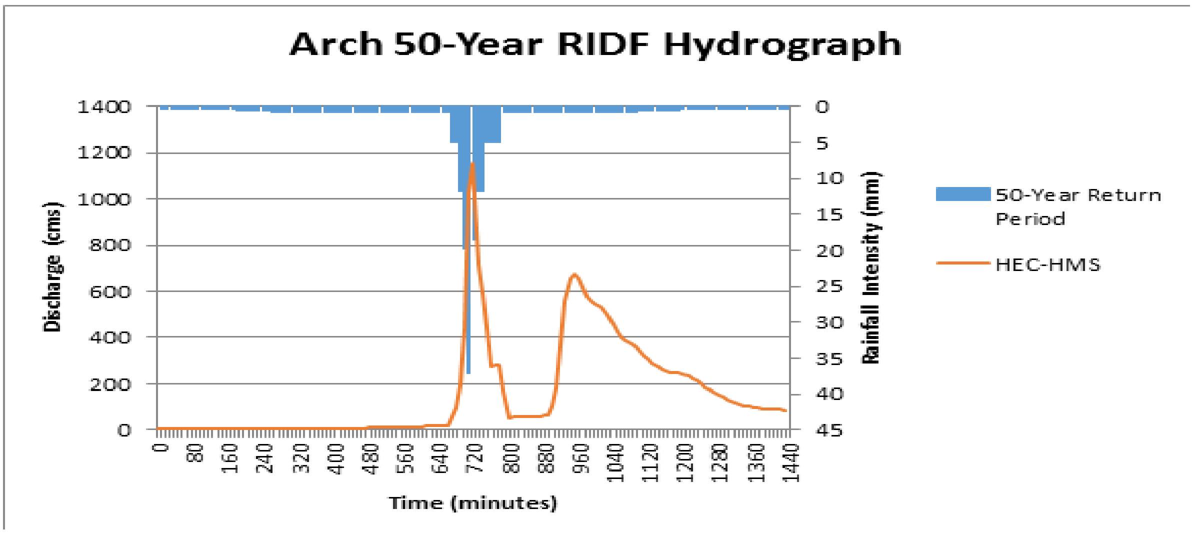


Figure 44. Arch Outflow hydrograph generated using the Lumbia 50-Year RIDF in HEC-HMS

In the 100-year return period graph, the peak outflow is 1342.4cms. This occurs after 10 minutes after the peak precipitation of 40.2 mm, as shown on Figure 45.

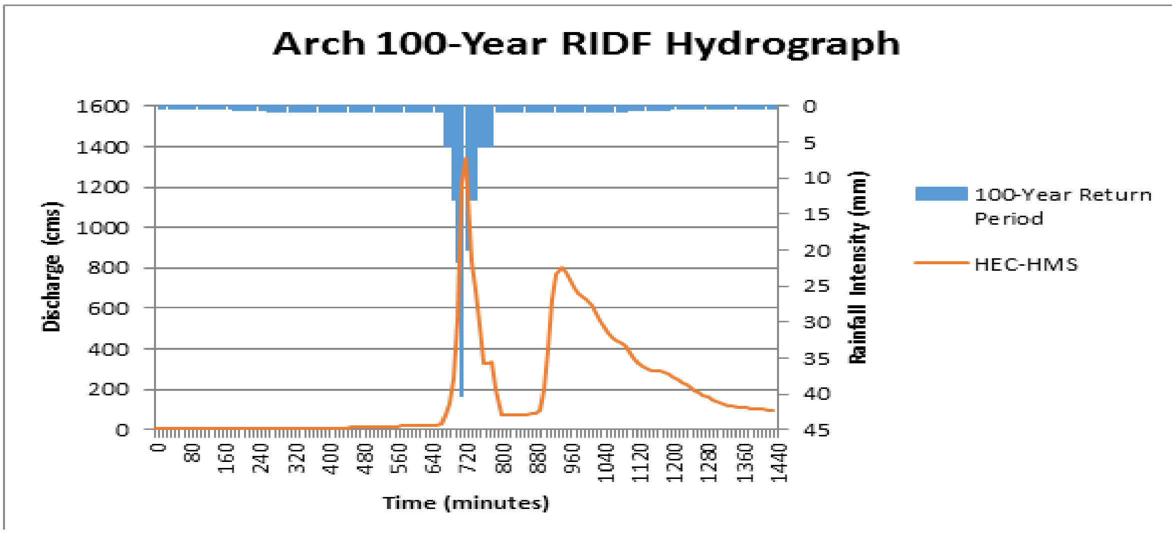


Figure 45. Arch Outflow hydrograph generated using the Lumbia 100-Year RIDF in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of Arch, Bridge discharge using the Lumbia Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 3.

Table 3. Summary of Arch Bridge discharge using the Lumbia Station Rainfall Intensity Duration Frequency (RIDF)

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (cms)	Time to Peak
5-Year	129.20	27.1	548.4	10 minutes
10-Year	155.99	30.2	734.9	10 minutes
25-Year	189.79	34.2	976.5	10 minutes
50-Year	214.80	37.2	1157.2	10 minutes
100-Year	239.7	40.2	1342.4	10 minutes

4.2.1.3 Mangima Bridge, Bukidnon

The outflow of Mangima using the Lumbia Rainfall Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on PAGASA data are shown in Figures 46-50. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

In the 5-year return period graph, the peak outflow is 1358.8 cms. This occurs after 50 minutes after the peak precipitation of 27.1 mm, as shown on Figure 46.

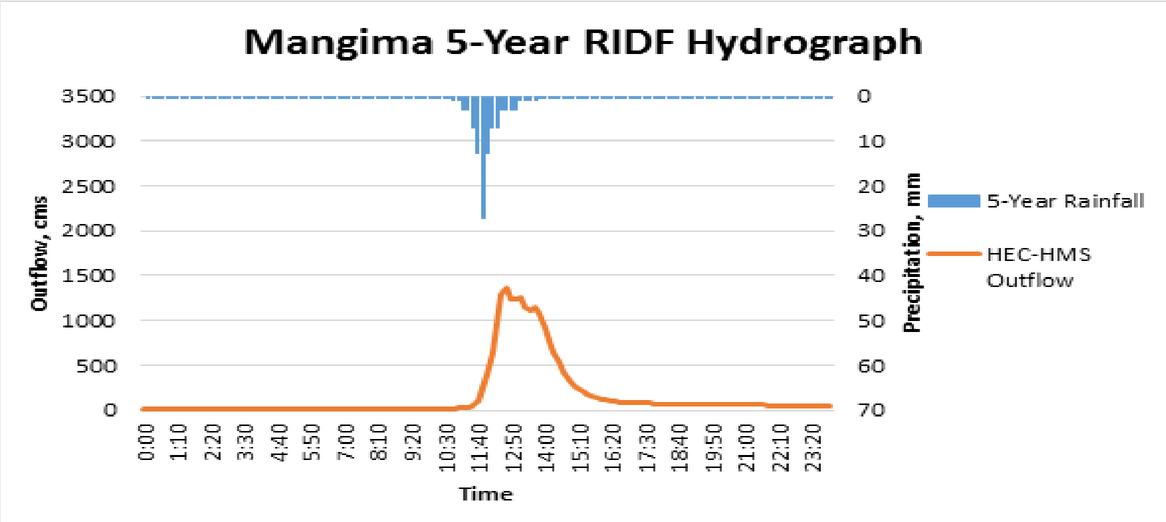


Figure 46. Mangima Outflow hydrograph generated using the Lumbia 5-Year RIDF in HEC-HMS

In the 10-year return period graph, the peak outflow is 1728.4 cms. This occurs after 50 minutes after the peak precipitation of 30.2 mm, as shown on Figure 47.

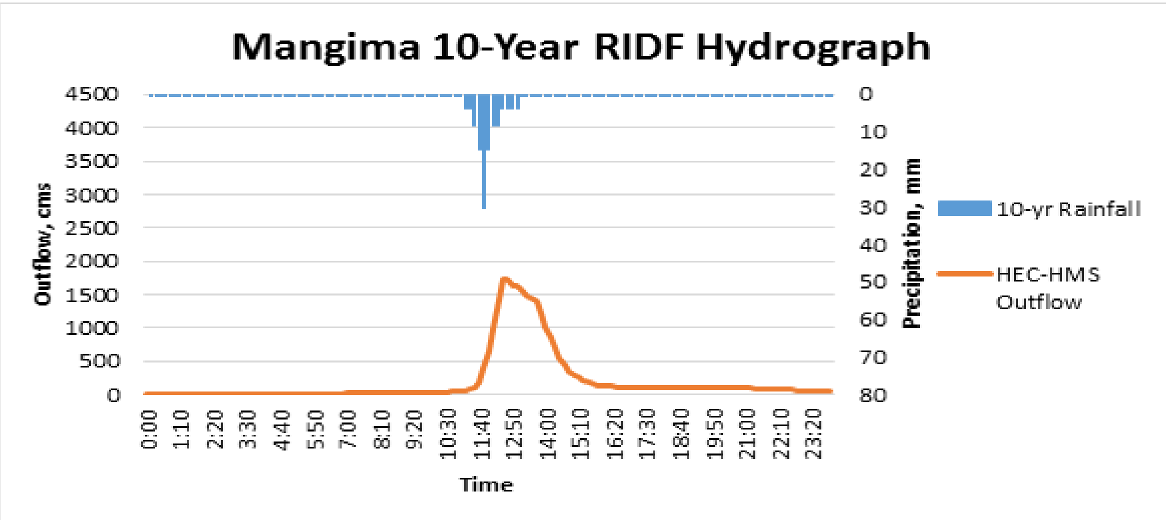


Figure 47. Mangima Outflow hydrograph generated using the Lumbia 10-Year RIDF in HEC-HMS

In the 25-year return period graph, the peak outflow is 2265.2 cms. This occurs after 40 minutes after the peak precipitation of 34.2 mm, as shown on Figure 48.

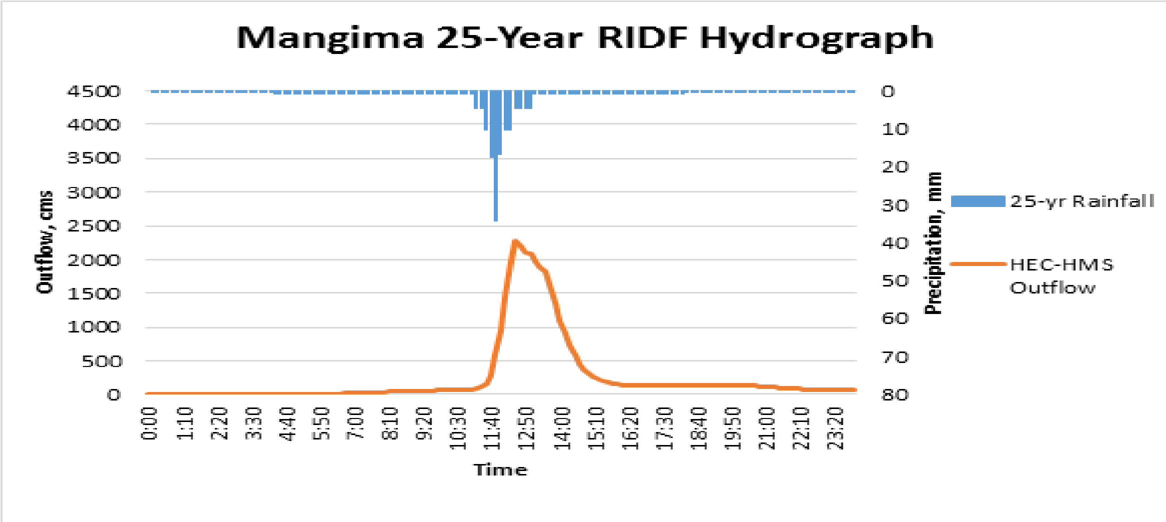


Figure 48. Mangima Outflow hydrograph generated using the Lumbia 25-Year RIDF in HEC-HMS

In the 50-year return period graph, the peak outflow is 2669.1 cms. This occurs after 40 minutes after the peak precipitation of 37.2 mm, as shown on Figure 49.

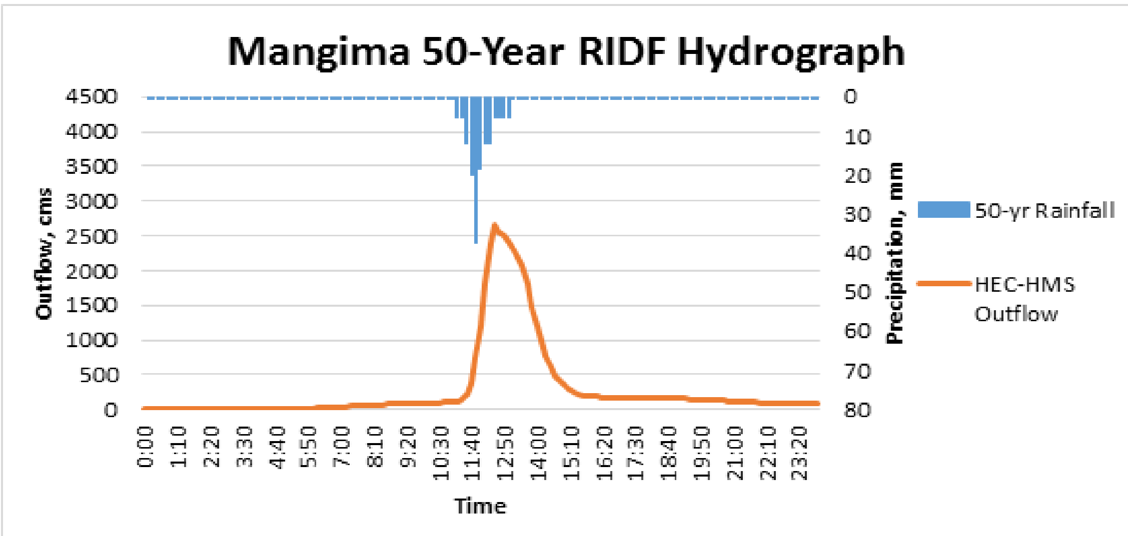


Figure 49. Mangima Outflow hydrograph generated using the Lumbia 50-Year RIDF in HEC-HMS

In the 100-year return period graph, the peak outflow is 3064.2 cms. This occurs after 40 minutes after the peak precipitation of 40.2 mm, as shown on Figure 50.

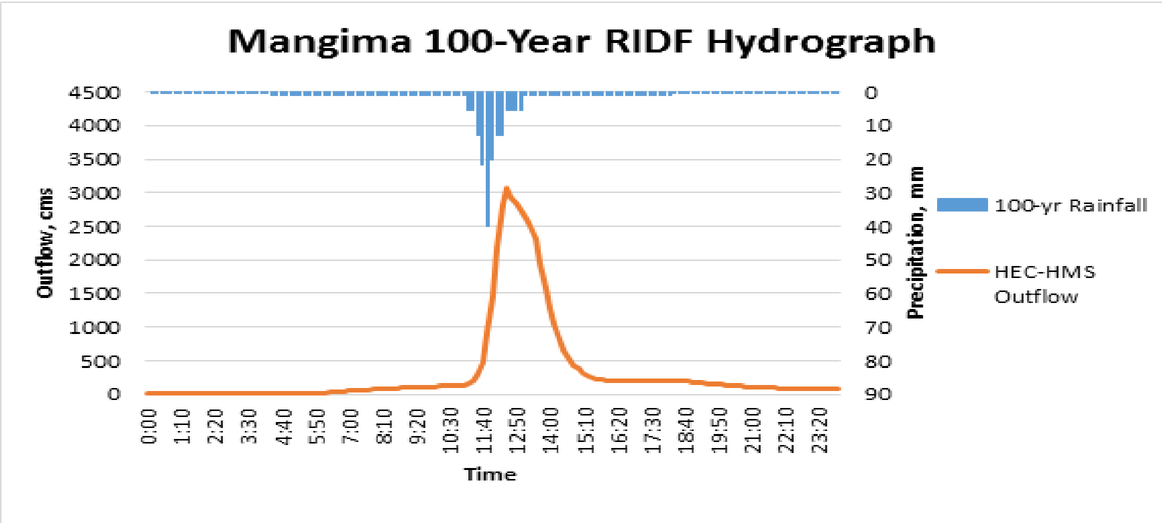


Figure 50. Mangima Outflow hydrograph generated using the Lumbia 100-Year RIDF in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of Mangima discharge using the Lumbia Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 4.

Table 4. Summary of Mangima Bridge discharge using the Lumbia Station Rainfall Intensity Duration Frequency (RIDF)

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (cms)	Time to Peak
5-Year	129.2	27.1	1358.8	50 minutes
10-Year	156	30.2	1728.4	50 minutes
25-Year	189.8	34.2	2265.2	40 minutes
50-Year	214.8	37.2	2669.1	40 minutes
100-Year	239.7	40.2	3064.2	40 minutes

4.2.2 Discharge Data using Dr. Horritt's Recommended Hydrological Method

The river discharge values using Dr. Horritt's recommended hydrological method are shown in Figure 51.

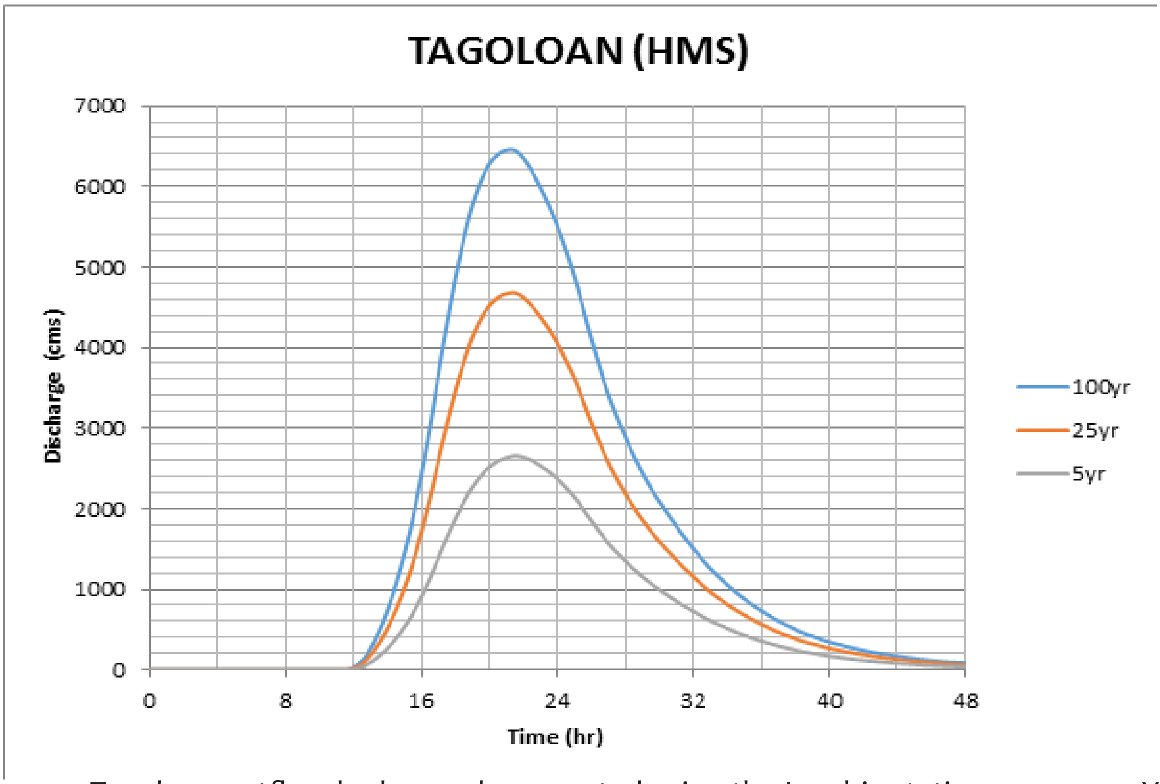


Figure 51. Tagoloan outflow hydrograph generated using the Lumbia station 5-, 25-, 100-Year RIDF in HEC-HMS

The peak discharge values are summarized in Table 5.

Table 5. Summary of Tagoloan river discharge using the recommended hydrological method by Dr. Horritt

RIDF Period	Peak discharge (cms)	Time-to-peak
5-Year	2,655.4	21 hours, 30 minutes
25-Year	4,682.9	21 hours, 20 minutes
100-Year	6,458.7.3	21 hours, 10 minutes

The comparison of discharge values obtained from HEC-HMS, Q5yr, and from the bankful discharge method, Qbankful, are shown in Table 6. Using values from the DTM of Tagoloan, the bankful discharge for the river was computed.

Table 6. Validation of river discharge estimate using the bankful method

Floodplain	Qbankful, cms	Q5yr, cms	Validation
Tagoloan (1)	2,129.34	2,336.75	Pass

The value from the HEC-HMS discharge estimate was able to satisfy the condition for validating the computed discharge using the bankful method. The computed value was used for the discharge point that did not have actual discharge data. The calibrated discharge data were also used for areas in the floodplain that were modeled. It is recommended, therefore, to use the actual value of the river discharge for higher-accuracy modeling.

4.3 Flood Hazard and Flow Depth Maps

The following images are the hazard and flow depth maps for the 5-, 25-, and 100-year rain return scenarios of the Tagoloan river basin.

Results and Discussion

Flood Hazard Maps and Flow Depth Maps

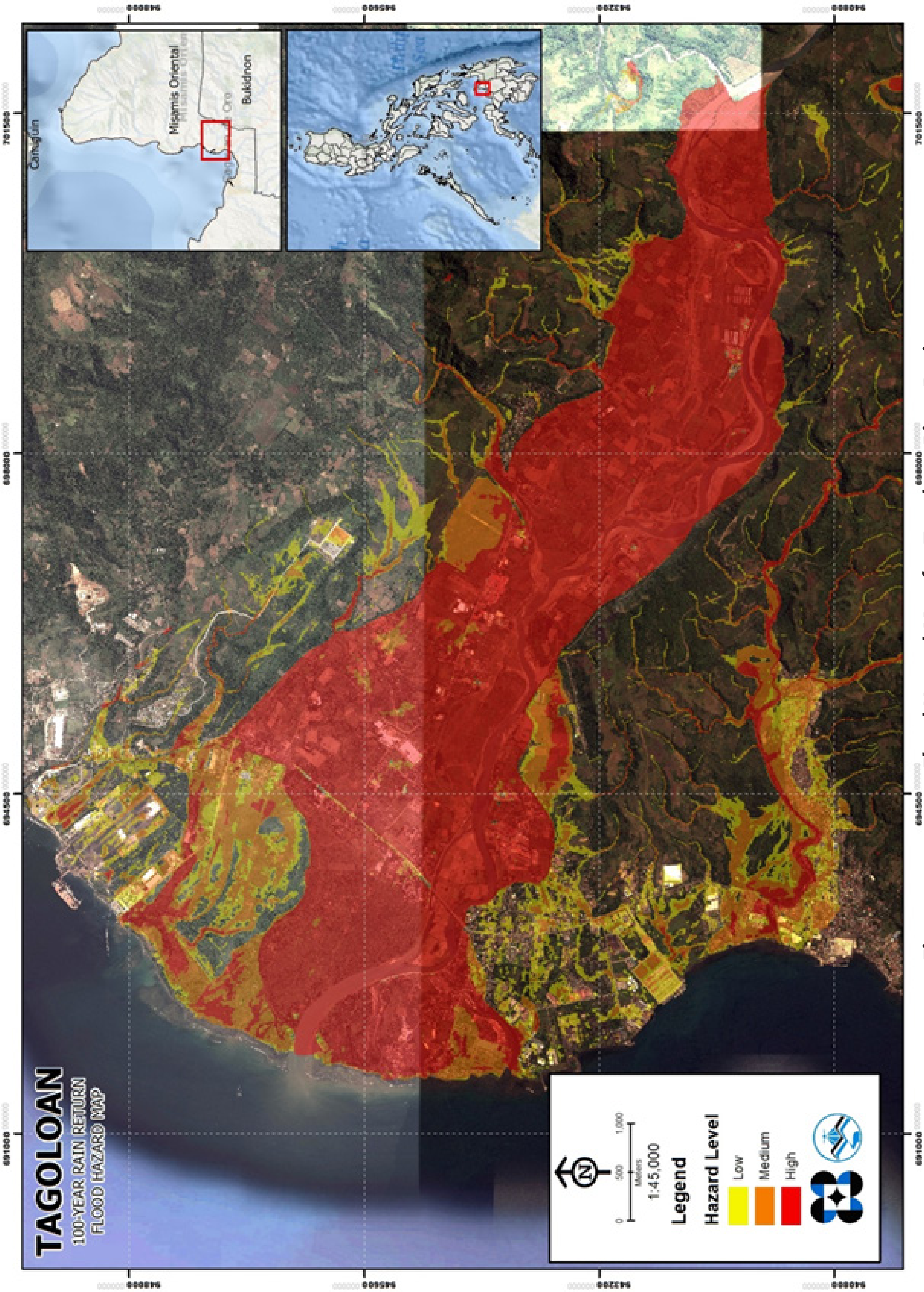


Figure 52. 100-year Flood Hazard Map for Tagoloan River Basin

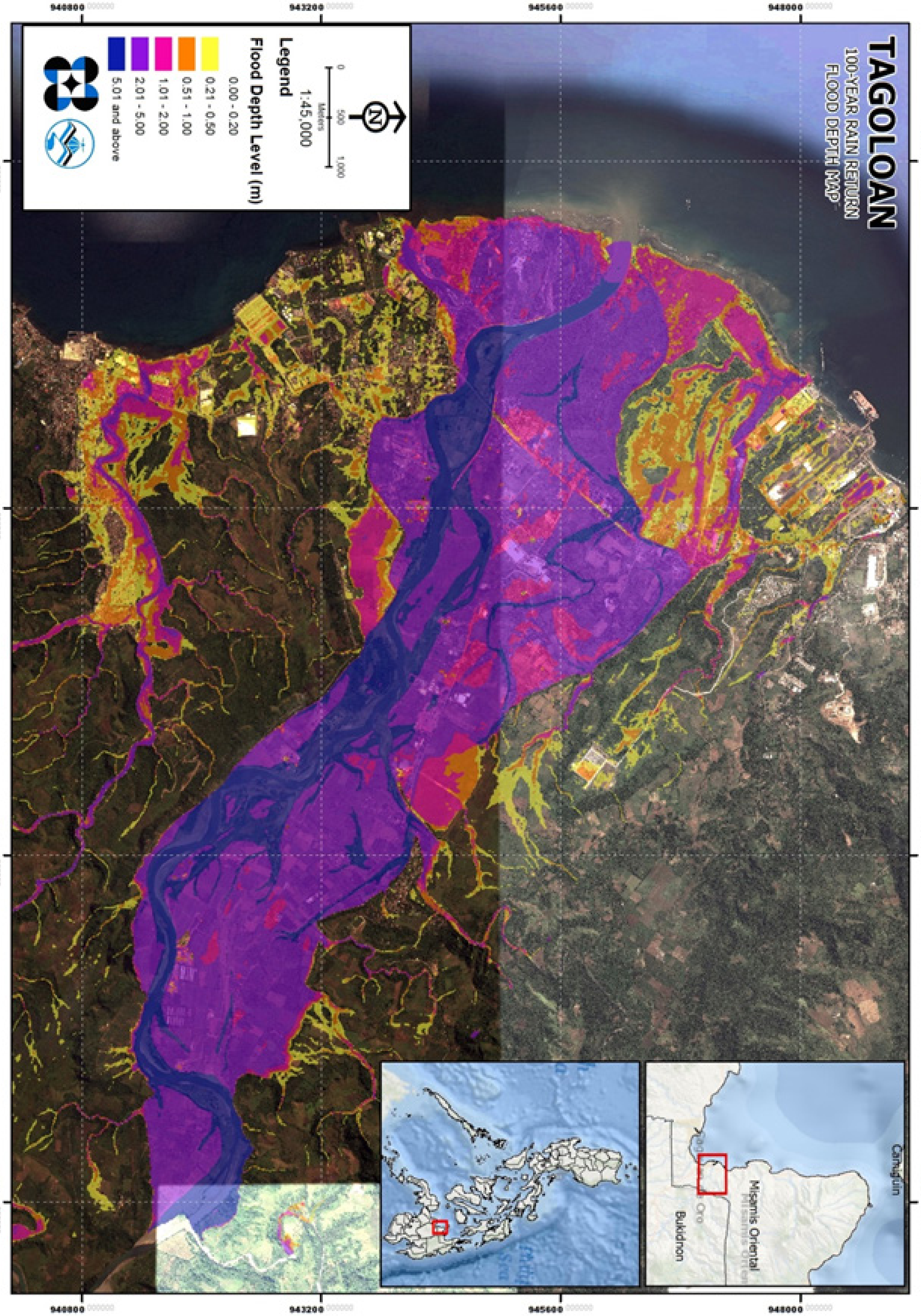


Figure 53. 100-year Flow Depth Map for Tagoloan River Basin

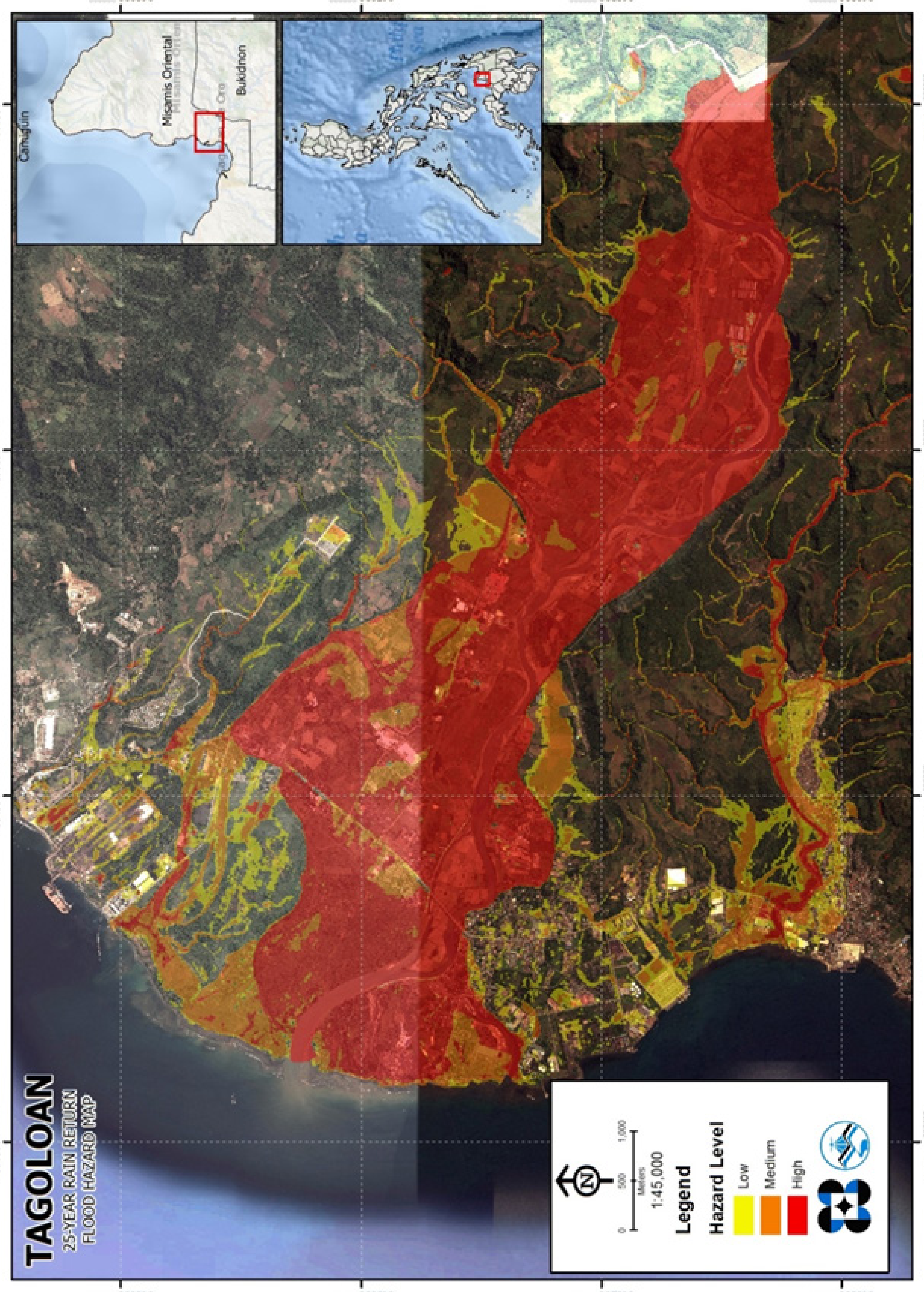


Figure 54. 25-year Flood Hazard Map for Tagoloan River Basin

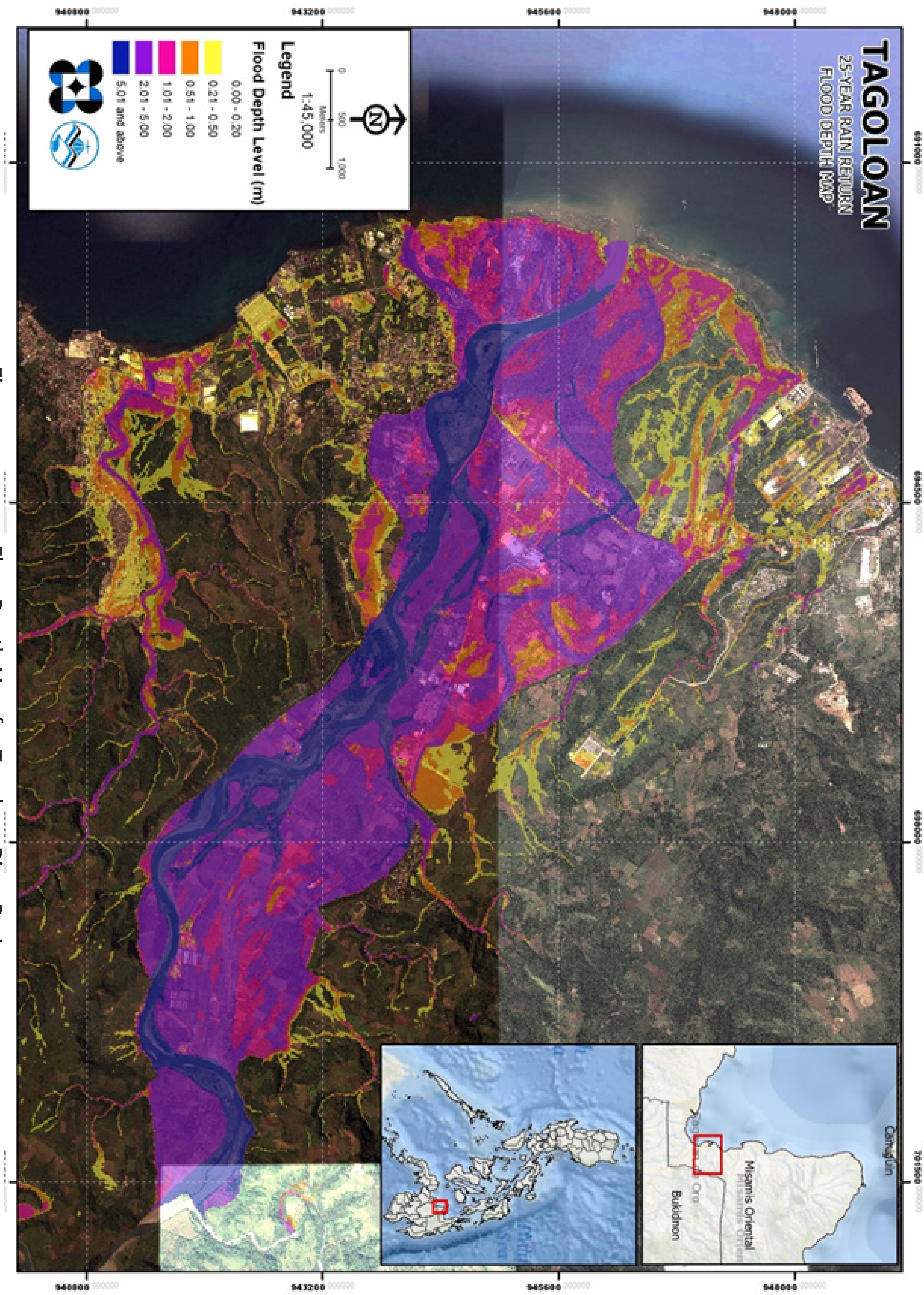


Figure 55. 25-year Flow Depth Map for Tagoloan River Basin

Results and Discussion

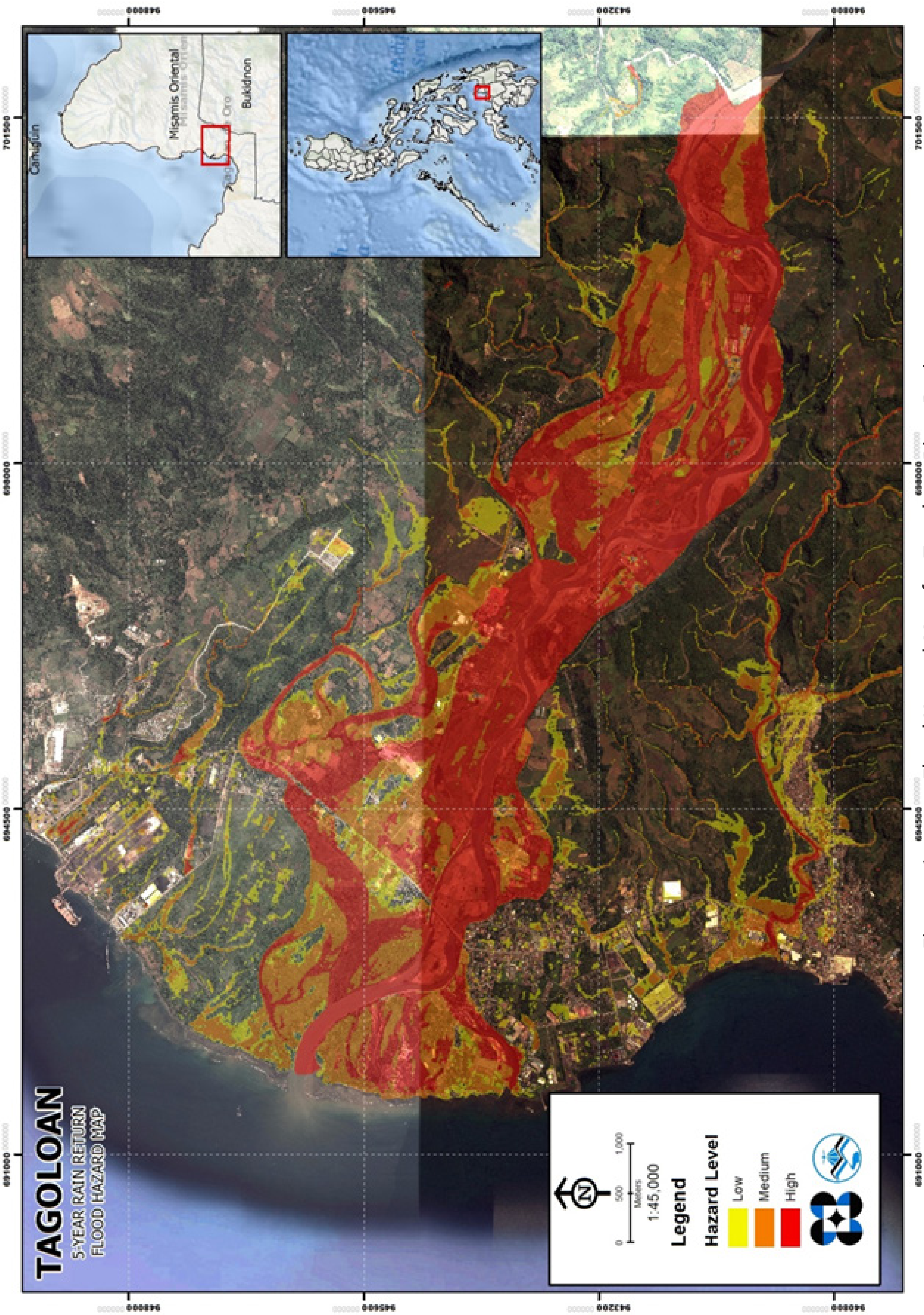


Figure 56. 5-year Flood Hazard Map for Tagoloan River Basin

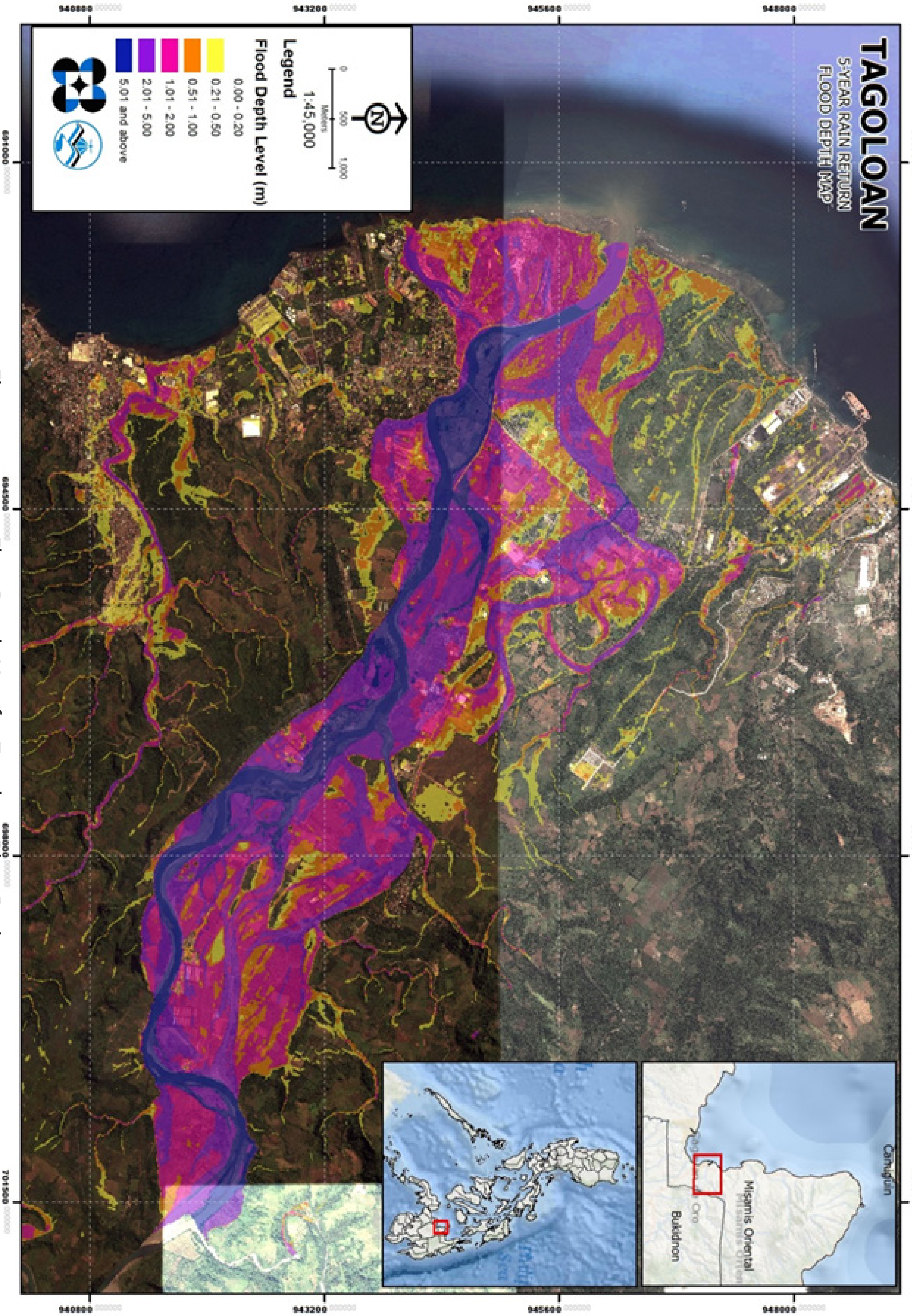


Figure 57. 5-year Flow Depth Map for Tagoloan River Basin

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Appendix

Appendix A. Tagoloan Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
100B	14.7725	72.1	0	0.046888	0.07502	Discharge	0.25444	1	Ration to Peak	0
101B	7.252	77.8	0	0.021666	0.034666	Discharge	0.18641	1	Ration to Peak	0
102B	17.117	69	0	0.06197	0.0991532	Discharge	0.30592	1	Ration to Peak	0
103B	11.3805	77	0	0.0525	0.084	Discharge	0.3471	1	Ration to Peak	0
104B	11.4	77	0	0.02	0.022666	Discharge	0.0318522	1	Ration to Peak	0
105B	11.1	77.47	0	0.0675	0.108	Discharge	1.1718	1	Ration to Peak	0
106B	15.675	70.83	0	0.060642	0.097028	Discharge	0.24995	1	Ration to Peak	0
107B	7.6	77	0	0.031666	0.050666	Discharge	0.33291	1	Ration to Peak	0
108B	6.873	78.74	0	0.075	0.12	Discharge	0.30609	1	Ration to Peak	0
109B	10.725	78.04	0	0.024166	0.038666	Discharge	0.32399	1	Ration to Peak	0
10B	11.3805	78.83	0	0.074166	0.118666	Discharge	0.35952	1	Ration to Peak	0

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
110B	7.625	64.33	0	0.041666	0.066666	Discharge	0.60182	1	Ration to Peak	0
111B	11.3805	77	0	0.0725	0.116	Discharge	0.51543	1	Ration to Peak	0
112B	17.5935	77	0	0.0525	0.084	Discharge	0.97247	1	Ration to Peak	0
113B	11.3805	77	0	0.068334	0.109334	Discharge	0.29521	1	Ration to Peak	0
114B	6.7665	68.41	0	0.0525	0.084	Discharge	0.51449	1	Ration to Peak	0
115B	13.98	77	0	0.04218	0.067486	Discharge	0.95305	1	Ration to Peak	0
116B	18.344	78.77	0	0.066666	0.106666	Discharge	0.71112	1	Ration to Peak	0
117B	10.509	64.5	0	0.0675	0.108	Discharge	0.15026	1	Ration to Peak	0
118B	20.273	67.5	0	0.0325	0.052	Discharge	0.19647	1	Ration to Peak	0
119B	7.4665	78.38	0	0.115	0.184	Discharge	0.44526	1	Ration to Peak	0
11B	10.5465	81.25	0	0.0575245	0.0920392	Discharge	0.13734	1	Ration to Peak	0

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
120B	13.9555	65.27	0	0.025	0.04	Discharge	0.503	1	Ration to Peak	0
121B	11.4115	75.75	0	0.081762	0.13082	Discharge	1.6632	1	Ration to Peak	0
122B	9.2215	77	0	0.096666	0.154666	Discharge	0.3926	1	Ration to Peak	0
123B	12.4575	78.32	0	0.058334	0.093334	Discharge	1.5135	1	Ration to Peak	0
124B	11.0865	64.54	0	0.095834	0.153334	Discharge	0.86379	1	Ration to Peak	0
125B	10.9665	69	0	0.054245	0.086792	Discharge	0.23776	1	Ration to Peak	0
126B	9.976	73.15	0	0.12375	0.198	Discharge	0.38287	1	Ration to Peak	0
127B	7.3675	75.36	0	0.028334	0.045334	Discharge	0.31581	1	Ration to Peak	0
128B	11.3805	77.46	0	0.052778		Discharge	1.3453	1	Ration to Peak	0
129B	7.3955	77.65	0	0.047734	0.076374	Discharge	0.40924	1	Ration to Peak	0
12B	7.349	71.8	0	0.031666	0.050666	Discharge	0.87896	1	Ration to Peak	0

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
130B	7.587	77.34	0	0.0275	0.044	Discharge	0.90902	1	Ration to Peak	0
131B	7.2815	77	0	0.046666	0.074666	Discharge	0.22112	1	Ration to Peak	0
132B	7.0305	77.53	0	0.0225	0.036	Discharge	0.23191	1	Ration to Peak	0
133B	8.9875	77.64	0	0.13625	0.218	Discharge	0.99234	1	Ration to Peak	0
134B	17.289	77	0	0.0525	0.084	Discharge	0.245	1	Ration to Peak	0
135B	9.746	77.72	0	0.065556	0.104888	Discharge	2.7731	1	Ration to Peak	0
136B	10.8785	80.6	0	0.051666	0.082666	Discharge	0.32988	1	Ration to Peak	0
13B	9.259	73.95	0	0.035	0.056	Discharge	0.87013	1	Ration to Peak	0
14B	11.3805	72.16	0	0.065	0.104	Discharge	1.0173	1	Ration to Peak	0
15B	14.0065	59.5	0	0.057778	0.0924444	Discharge	0.19148	1	Ration to Peak	0
16B	7.6125	79.63	0	0.06867	0.109874	Discharge	0.13869	1	Ration to Peak	0

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
17B	18.538	60.37	0	0.042222	0.0675556	Discharge	1.883	1	Ration to Peak	0
18B	11.3805	70.11	0	0.048184	0.077094	Discharge	0.4108	1	Ration to Peak	0
19B	19.5315	80.45	0	0.0695375	0.11126	Discharge	0.5241	1	Ration to Peak	0
1B	16.7595	58.41	0	0.035556	0.056888	Discharge	0.33348	1	Ration to Peak	0
20B	9.5945	77	0	0.144	0.2304	Discharge	0.49589	1	Ration to Peak	0
21B	10.35	73.12	0	0.03	0.048	Discharge	0.48718	1	Ration to Peak	0
22B	17.549	77	0	0.0375	0.06	Discharge	0.27808	1	Ration to Peak	0
23B	11.6695	66.27	0	0.034166	0.054666	Discharge	0.32133	1	Ration to Peak	0
24B	17.1745	67.27	0	0.0825	0.132	Discharge	0.19062	1	Ration to Peak	0
25B	10.39	77	0	0.041666	0.066666	Discharge	0.10635	1	Ration to Peak	0
26B	16.688	66.11	0	0.051666	0.082666	Discharge	0.21675	1	Ration to Peak	0

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
27B	7.587	69.45	0	0.088334	0.141334	Discharge	0.17279	1	Ration to Peak	0
28B	11.729	72.63	0	0.061666	0.098666	Discharge	1.2345	1	Ration to Peak	0
29B	8.1535	70.88	0	0.049166	0.078666	Discharge	0.62023	1	Ration to Peak	0
2B	9.8435	59.14	0	0.058334	0.093334	Discharge	0.39739	1	Ration to Peak	0
30B	7.587	68.52	0	0.06	0.096	Discharge	0.36509	1	Ration to Peak	0
31B	10.7	59.66	0	0.050834	0.081334	Discharge	0.44351	1	Ration to Peak	0
32B	19.957	70.97	0	0.0675	0.108	Discharge	0.43206	1	Ration to Peak	0
33B	13.3785	60.35	0	0.05	0.08	Discharge	0.24291	1	Ration to Peak	0
34B	14.9625	77	0	0.048334	0.077334	Discharge	0.22881	1	Ration to Peak	0
35B	19.0755	68.41	0	0.060834	0.097334	Discharge	0.28458	1	Ration to Peak	0
36B	18.82	75.7	0	0.025	0.04	Discharge	1.044	1	Ration to Peak	0

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
37B	16.137	72.07	0	0.084166	0.134666	Discharge	0.38242	1	Ration to Peak	0
38B	11.5725	77	0	0.041666	0.066666	Discharge	0.15885	1	Ration to Peak	0
39B	7.587	70.36	0	0.043334	0.069334	Discharge	0.18824	1	Ration to Peak	0
3B	17.246	56	0	0.068334	0.109334	Discharge	0.35094	1	Ration to Peak	0
40B	12.0355	65.5	0	0.141666	0.22666	Discharge	0.40368	1	Ration to Peak	0
41B	11.8925	62.93	0	0.0725	0.116	Discharge	0.1934	1	Ration to Peak	0
42B	7.587	57.11	0	0.0525	0.084	Discharge	0.20145	1	Ration to Peak	0
43B	8.5935	57.44	0	0.054166	0.086666	Discharge	0.9728	1	Ration to Peak	0
44B	19.957	61.15	0	0.0525	0.084	Discharge	1.4958	1	Ration to Peak	0
45B	19.6915	68.7	0	0.065834	0.105334	Discharge	0.51453	1	Ration to Peak	0
46B	16.9335	77	0	0.060834	0.097334	Discharge	0.39064	1	Ration to Peak	0

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
47B	8.7125	59.56	0	0.058334	0.093334	Discharge	0.12536	1	Ration to Peak	0
48B	12.0575	67.85	0	0.0375	0.06	Discharge	0.35519	1	Ration to Peak	0
49B	15.9345	68.11	0	0.0275	0.044	Discharge	0.29034	1	Ration to Peak	0
4B	7.9115	59.29	0	0.033334	0.053334	Discharge	0.90632	1	Ration to Peak	0
50B	17.0395	77	0	0.059166	0.094666	Discharge	0.79367	1	Ration to Peak	0
51B	7.587	74.72	0	0.106666	0.170666	Discharge	0.60023	1	Ration to Peak	0
52B	19.271	56	0	0.139166	0.22266	Discharge	0.37596	1	Ration to Peak	0
53B	9.2805	56.33	0	0.071666	0.114666	Discharge	0.17398	1	Ration to Peak	0
54B	13.713	77	0	0.041666	0.066666	Discharge	0.30069	1	Ration to Peak	0
55B	7.587	60	0	0.054166	0.086666	Discharge	0.14952	1	Ration to Peak	0
56B	11.3105	74.46	0	0.064166	0.102666	Discharge	2.1671	1	Ration to Peak	0

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
57B	19.957	67.81	0	0.0325	0.052	Discharge	0.96376	1	Ration to Peak	0
58B	14.1575	61.45	0	0.095	0.152	Discharge	0.69836	1	Ration to Peak	0
59B	14.133	76.25	0	0.02	0.025334	Discharge	0.34423	1	Ration to Peak	0
5B	11.621	59.85	0	0.041666	0.066666	Discharge	0.79547	1	Ration to Peak	0
60B	8.127	77	0	0.13	0.208	Discharge	0.37576	1	Ration to Peak	0
61B	18.828	56.86	0	0.024166	0.038666	Discharge	0.17786	1	Ration to Peak	0
62B	14.86	73.24	0	0.0575	0.092	Discharge	0.63302	1	Ration to Peak	0
63B	7.5015	64.94	0	0.04	0.064	Discharge	0.694681	1	Ration to Peak	0
64B	11.047	77	0	0.0275	0.044	Discharge	0.64018	1	Ration to Peak	0
65B	7.6385	69.19	0	0.059166	0.094666	Discharge	0.92005	1	Ration to Peak	0
66B	9.3565	56	0	0.046666	0.074666	Discharge	0.13096	1	Ration to Peak	0

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
67B	14.625	64.21	0	0.035	0.056	Discharge	0.38291	1	Ration to Peak	0
68B	10.948	64.25	0	0.020834	0.033334	Discharge	0.3621	1	Ration to Peak	0
69B	14.468	68.61	0	0.1475	0.236	Discharge	0.37809	1	Ration to Peak	0
6B	9.8095	75.76	0	0.038334	0.061334	Discharge	1.5578	1	Ration to Peak	0
70B	16.466	57.43	0	0.104166	0.166666	Discharge	0.19569	1	Ration to Peak	0
71B	12.4935	63.09	0	0.053334	0.085334	Discharge	0.3042	1	Ration to Peak	0
72B	7.587	77.2	0	0.08	0.128	Discharge	0.13922	1	Ration to Peak	0
73B	7.587	69.69	0	0.099166	0.158666	Discharge	1.5492	1	Ration to Peak	0
74B	14.047	76.88	0	0.075834	0.121334	Discharge	0.70973	1	Ration to Peak	0
75B	10.5265	73.08	0	0.071666	0.114666	Discharge	0.58984	1	Ration to Peak	0
76B	8.4985	63.46	0	0.108334	0.173334	Discharge	0.43541	1	Ration to Peak	0

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
77B	7.4125	69.88	0	0.084166	0.134666	Discharge	0.34149	1	Ration to Peak	0
78B	7.235	63.71	0	0.030834	0.049334	Discharge	0.73361	1	Ration to Peak	0
79B	9.252	72.14	0	0.090834	0.145334	Discharge	0.54998	1	Ration to Peak	0
7B	6.9485	78.33	0	0.028334	0.045334	Discharge	1.7071	1	Ration to Peak	0
80B	7.587	60.67	0	0.0675	0.108	Discharge	0.56008	1	Ration to Peak	0
81B	8.4665	67.03	0	0.1325	0.212	Discharge	0.40205	1	Ration to Peak	0
82B	7.587	77	0	0.035834	0.057334	Discharge	0.9984	1	Ration to Peak	0
83B	6.8705	77	0	0.0183333	0.029334	Discharge	0.361	1	Ration to Peak	0
84B	7.587	64.39	0	0.0775	0.124	Discharge	0.56212	1	Ration to Peak	0
85B	7.3025	77.37	0	0.031666	0.050666	Discharge	0.36713	1	Ration to Peak	0
86B	6.752	70.7	0	0.051666	0.082666	Discharge	0.277586	1	Ration to Peak	0

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
87B	8.4665	74.93	0	0.073334	0.117334	Discharge	2.3198	1	Ration to Peak	0
88B	7.587	77.41	0	0.05	0.08	Discharge	0.50369	1	Ration to Peak	0
89B	6.8705	77.83	0	0.081666	0.130666	Discharge	0.15905	1	Ration to Peak	0
8B	7.4845	68.83	0	0.0625	0.1	Discharge	0.055935	1	Ration to Peak	0
90B	7.587	73.3	0	0.04	0.064	Discharge	0.25068	1	Ration to Peak	0
91B	7.3025	78.52	0	0.02	0.032	Discharge	0.34497	1	Ration to Peak	0
92B	6.752	77	0	0.0575	0.092	Discharge	0.31831	1	Ration to Peak	0
93B	8.4665	75	0	0.073334	0.117334	Discharge	0.50782	1	Ration to Peak	0
94B	7.587	77	0	0.05	0.08	Discharge	0.70437	1	Ration to Peak	0
95B	6.8705	78.71	0	0.081666	0.130666	Discharge	0.68601	1	Ration to Peak	0
96B	7.4845	77.24	0	0.0625	0.1	Discharge	0.47708	1	Ration to Peak	0

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
97B	7.587	77	0	0.04	0.064	Discharge	0.43177	1	Ration to Peak	0
98B	7.3025	77.67	0	0.02	0.032	Discharge	0.16621	1	Ration to Peak	0
99B	6.752	79	0	0.0575	0.092	Discharge	0.61593	1	Ration to Peak	0
9B	38.67	77.34	0	0.091666	0.146666	Discharge	0.62599	1	Ration to Peak	0

Appendix B. Tagoloan Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
136R	Automatic Fixed Interval	11463.09	0.00833	0.0024	Trapezoid	30	45
137R	Automatic Fixed Interval	11239.84	0.00775	0.0024	Trapezoid	30	45
138R	Automatic Fixed Interval	23423.49	0.0086	0.0024	Trapezoid	30	45
139R	Automatic Fixed Interval	36410.71	0.00386	0.0024	Trapezoid	30	45
140R	Automatic Fixed Interval	11559.52	0.00456	0.0024	Trapezoid	30	45
141R	Automatic Fixed Interval	17633.16	0.00456	0.003528	Trapezoid	30	45
143R	Automatic Fixed Interval	14484.66	0.00456	0.0036178	Trapezoid	30	45
144R	Automatic Fixed Interval	27444.63	0.00386	0.0024	Trapezoid	30	45
145R	Automatic Fixed Interval	8378.022	0.00077	0.0024	Trapezoid	30	45
146R	Automatic Fixed Interval	7484.563	0.00077	0.003528	Trapezoid	30	45
147R	Automatic Fixed Interval	19986.26	0.00077	0.0024	Trapezoid	30	45
148R	Automatic Fixed Interval	7246.298	0.00094	0.0024	Trapezoid	30	45
149R	Automatic Fixed Interval	18989.78	0.00094	0.003528	Trapezoid	30	45
150R	Automatic Fixed Interval	13493.97	0.0044	0.0024	Trapezoid	30	45
151R	Automatic Fixed Interval	9328.487	0.00001	0.003528	Trapezoid	30	45
152R	Automatic Fixed Interval	16149.59	0.00004	0.0024	Trapezoid	30	45
153R	Automatic Fixed Interval	14260.41	0.00004	0.0024	Trapezoid	30	45
154R	Automatic Fixed Interval	9478.294	0.00287	0.0024	Trapezoid	30	45
155R	Automatic Fixed Interval	6911.976	0.00287	0.0024	Trapezoid	30	45
156R	Automatic Fixed Interval	8288.708	0.00626	0.0024	Trapezoid	30	45
157R	Automatic Fixed Interval	8783.158	0.00626	0.0024	Trapezoid	30	45
158R	Automatic Fixed Interval	9034.367	0.00022	0.0024	Trapezoid	30	45
159R	Automatic Fixed Interval	10943.4	0.00766	0.0024	Trapezoid	30	45
160R	Automatic Fixed Interval	24482.18	0.0045	0.0024	Trapezoid	30	45
161R	Automatic Fixed Interval	15711.84	0.00537	0.003528	Trapezoid	30	45
162R	Automatic Fixed Interval	9801.298	0.00048	0.0024	Trapezoid	30	45
163R	Automatic Fixed Interval	20887.28	0.00175	0.0024	Trapezoid	30	45
164R	Automatic Fixed Interval	32027.42	0.00238	0.0024	Trapezoid	30	45
165R	Automatic Fixed Interval	28908.64	0.0045	0.0024	Trapezoid	30	45
166R	Automatic Fixed Interval	3145.729	0.00099	0.0024	Trapezoid	30	45
167R	Automatic Fixed Interval	3230.214	0.00396	0.0024	Trapezoid	30	45
168R	Automatic Fixed Interval	10082.16	0.00318	0.0024	Trapezoid	30	45
169R	Automatic Fixed Interval	7281.956	0.01413	0.0024	Trapezoid	30	45
170R	Automatic Fixed Interval	4620.543	0.00382	0.0024	Trapezoid	30	45
171R	Automatic Fixed Interval	9705.03	0.00289	0.0024	Trapezoid	30	45

Appendix

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Man-ning's n	Shape	Width	Side Slope
172R	Automatic Fixed Interval	9693.574	0.00079	0.0024	Trapezoid	30	45
173R	Automatic Fixed Interval	7818.079	0.01672	0.0024	Trapezoid	30	45
174R	Automatic Fixed Interval	12294.25	0.00835	0.0024	Trapezoid	30	45
175R	Automatic Fixed Interval	9502.297	0.00234	0.0024	Trapezoid	30	45
176R	Automatic Fixed Interval	13974.21	0.00847	0.0024	Trapezoid	30	45
177R	Automatic Fixed Interval	7096.355	0.00065	0.0024	Trapezoid	30	45
178R	Automatic Fixed Interval	4615.915	0.00164	0.0024	Trapezoid	30	45
179R	Automatic Fixed Interval	21118.27	0.00252	0.0024	Trapezoid	30	45
180R	Automatic Fixed Interval	21991.32	0.00491	0.0024	Trapezoid	30	45
181R	Automatic Fixed Interval	18222.57	0.00725	0.0024	Trapezoid	30	45
182R	Automatic Fixed Interval	6579.994	0.0102	0.0024	Trapezoid	30	45
183R	Automatic Fixed Interval	14120.14	0.0031	0.0024	Trapezoid	30	45
184R	Automatic Fixed Interval	11316.39	0.00275	0.0024	Trapezoid	30	45
185R	Automatic Fixed Interval	26515	0.00311	0.0024	Trapezoid	30	45
186R	Automatic Fixed Interval	30430.23	0.00263	0.0024	Trapezoid	30	45
187R	Automatic Fixed Interval	8638.46	0.00329	0.0036	Trapezoid	30	45
188R	Automatic Fixed Interval	11518.57	0.00369	0.0036	Trapezoid	30	45
189R	Automatic Fixed Interval	6602.202	0.006	0.0036	Trapezoid	30	45
190R	Automatic Fixed Interval	13034.31	0.00352	0.0036	Trapezoid	30	45
191R	Automatic Fixed Interval	17097.55	0.00196	0.0036	Trapezoid	30	45
192R	Automatic Fixed Interval	14204.74	0.0035	0.0036	Trapezoid	30	45
193R	Automatic Fixed Interval	19148.15	0.00126	0.0036	Trapezoid	30	45
194R	Automatic Fixed Interval	12523.34	0.01757	0.0036	Trapezoid	30	45
195R	Automatic Fixed Interval	23896.2	0.00925	0.0036	Trapezoid	30	45
196R	Automatic Fixed Interval	10706.23	0.00421	0.0036	Trapezoid	30	45
197R	Automatic Fixed Interval	9894.361	0.00199	0.0036	Trapezoid	30	45
198R	Automatic Fixed Interval	12504.34	0.00412	0.0036	Trapezoid	30	45
199R	Automatic Fixed Interval	23190	0.0054	0.0036	Trapezoid	30	45
200R	Automatic Fixed Interval	5168.01	0.00221	0.0036	Trapezoid	30	45
201R	Automatic Fixed Interval	13756.15	0.00593	0.0036	Trapezoid	30	45
202R	Automatic Fixed Interval	6487.091	0.00271	0.0036	Trapezoid	30	45
203R	Automatic Fixed Interval	17884.15	0.00239	0.0036	Trapezoid	30	45
204R	Automatic Fixed Interval	8865.402	0.0012	0.0036	Trapezoid	30	45
205R	Automatic Fixed Interval	5395.761	0.01091	0.0036	Trapezoid	30	45
206R	Automatic Fixed Interval	7607.172	0.00125	0.0036	Trapezoid	30	45
207R	Automatic Fixed Interval	8693.716	0.02682	0.0036	Trapezoid	30	45
208R	Automatic Fixed Interval	27314.23	0.00324	0.0036	Trapezoid	30	45

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Man-ning's n	Shape	Width	Side Slope
209R	Automatic Fixed Interval	13263.77	0.00531	0.0036	Trapezoid	30	45
210R	Automatic Fixed Interval	15125.07	0.00547	0.0036	Trapezoid	30	45
211R	Automatic Fixed Interval	8365.7	0.0009	0.0036	Trapezoid	30	45
212R	Automatic Fixed Interval	22282.29	0.00476	0.0036	Trapezoid	30	45
213R	Automatic Fixed Interval	9633.147	0.00337	0.0036	Trapezoid	30	45
214R	Automatic Fixed Interval	25846.54	0.00516	0.0036	Trapezoid	30	45
215R	Automatic Fixed Interval	11181.5	0.00394	0.0036	Trapezoid	30	45
216R	Automatic Fixed Interval	13362.31	0.00479	0.0036	Trapezoid	30	45
217R	Automatic Fixed Interval	12609.68	0.00327	0.0036	Trapezoid	30	45
218R	Automatic Fixed Interval	8330.037	0.0019	0.0036	Trapezoid	30	45
219R	Automatic Fixed Interval	4495.161	0.00633	0.0036	Trapezoid	30	45
220R	Automatic Fixed Interval	14968.65	0.01041	0.0036	Trapezoid	30	45
221R	Automatic Fixed Interval	31565.82	0.00402	0.0036	Trapezoid	30	45
222R	Automatic Fixed Interval	4554.421	0.00167	0.0036	Trapezoid	30	45
223R	Automatic Fixed Interval	11835.41	0.00361	0.0036	Trapezoid	30	45
224R	Automatic Fixed Interval	10168.32	0.01959	0.0036	Trapezoid	30	45
225R	Automatic Fixed Interval	19347.17	0.00614	0.0036	Trapezoid	30	45
226R	Automatic Fixed Interval	12866.81	0.00366	0.0036	Trapezoid	30	45
227R	Automatic Fixed Interval	12590.71	0.00478	0.0036	Trapezoid	30	45
228R	Automatic Fixed Interval	21604.67	0.00364	0.0036	Trapezoid	30	45
229R	Automatic Fixed Interval	12511.57	0.00247	0.0036	Trapezoid	30	45
230R	Automatic Fixed Interval	3624.38	0.00372	0.0036	Trapezoid	30	45
231R	Automatic Fixed Interval	27420.8	0.00508	0.0036	Trapezoid	30	45
232R	Automatic Fixed Interval	10530.22	0.00399	0.0036	Trapezoid	30	45
233R	Automatic Fixed Interval	10533.78	0.00539	0.0036	Trapezoid	30	45
234R	Automatic Fixed Interval	8346.761	0.01095	0.0036	Trapezoid	30	45
235R	Automatic Fixed Interval	20002.37	0.00212	0.0036	Trapezoid	30	45
236R	Automatic Fixed Interval	14535.76	0.00886	0.0036	Trapezoid	30	45
237R	Automatic Fixed Interval	22246.31	0.004	0.0036	Trapezoid	30	45
238R	Automatic Fixed Interval	11700.06	0.00665	0.0036	Trapezoid	30	45
239R	Automatic Fixed Interval	11440.61	0.00462	0.0036	Trapezoid	30	45
240R	Automatic Fixed Interval	26619.27	0.0048	0.0036	Trapezoid	30	45
241R	Automatic Fixed Interval	32334.99	0.00503	0.0036	Trapezoid	30	45
242R	Automatic Fixed Interval	13174.53	0.00279	0.0036	Trapezoid	30	45
243R	Automatic Fixed Interval	14583	0.00504	0.0036	Trapezoid	30	45
244R	Automatic Fixed Interval	11875.47	0.00372	0.0036	Trapezoid	30	45
245R	Automatic Fixed Interval	35504.97	0.00128	0.0036	Trapezoid	30	45

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
246R	Automatic Fixed Interval	6293.406	0.00659	0.0036	Trapezoid	30	45
247R	Automatic Fixed Interval	10485.81	0.00844	0.0036	Trapezoid	30	45
248R	Automatic Fixed Interval	14856.88	0.0055	0.0036	Trapezoid	30	45
249R	Automatic Fixed Interval	38720.65	0.00192	0.0036	Trapezoid	30	45
250R	Automatic Fixed Interval	24634.89	0.00477	0.0036	Trapezoid	30	45
251R	Automatic Fixed Interval	7560.155	0.00963	0.0036	Trapezoid	30	45
252R	Automatic Fixed Interval	15761.68	0.01321	0.0036	Trapezoid	30	45
253R	Automatic Fixed Interval	4461.835	0.00488	0.0036	Trapezoid	30	45
254R	Automatic Fixed Interval	12505.5	0.00146	0.0036	Trapezoid	30	45
255R	Automatic Fixed Interval	11972.31	0.00461	0.0036	Trapezoid	30	45
256R	Automatic Fixed Interval	13441.16	0.00847	0.0036	Trapezoid	30	45
257R	Automatic Fixed Interval	22539.35	0.00443	0.0036	Trapezoid	30	45
258R	Automatic Fixed Interval	10000.73	0.00213	0.0036	Trapezoid	30	45
259R	Automatic Fixed Interval	11274.45	0.0022	0.0036	Trapezoid	30	45
260R	Automatic Fixed Interval	16890.52	0.00448	0.0036	Trapezoid	30	45
261R	Automatic Fixed Interval	19916.74	0.00577	0.0036	Trapezoid	30	45
262R	Automatic Fixed Interval	9956.864	0.01637	0.75	Trapezoid	30	45
263R	Automatic Fixed Interval	23713.86	0.00389	0.75	Trapezoid	30	45
264R	Automatic Fixed Interval	10041.97	0.00511	0.75	Trapezoid	30	45
265R	Automatic Fixed Interval	19691.32	0.00135	0.75	Trapezoid	30	45
266R	Automatic Fixed Interval	9360.895	0.00297	0.75	Trapezoid	30	45
267R	Automatic Fixed Interval	26725.42	0.00286	0.75	Trapezoid	30	45
268R	Automatic Fixed Interval	27255.78	0.00128	0.75	Trapezoid	30	45
269R	Automatic Fixed Interval	23543.14	0.00102	0.75	Trapezoid	30	45

Appendix C. Arch Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
17B	18.538	60.37	0	0.084444	0.067556	Discharge	1.883	1	Ration to Peak	0
25B	10.39	77	0	0.083332	0.066666	Discharge	0.10635	1	Ration to Peak	0
29B	8.1535	70.88	0	0.098332	0.078666	Discharge	0.62023	1	Ration to Peak	0
2B	9.8435	59.14	0	0.116668	0.093334	Discharge	0.39739	1	Ration to Peak	0
36B	18.82	75.7	0	0.05	0.04	Discharge	1.044	1	Ration to Peak	0
3B	17.246	56	0	0.136668	0.109334	Discharge	0.35094	1	Ration to Peak	0
5B	11.621	59.85	0	0.083332	0.066666	Discharge	0.79547	1	Ration to Peak	0

Appendix D. Arch Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
137R	Automatic Fixed Interval	11239.84	0.00775	0.024	Trapezoid	30	45
138R	Automatic Fixed Interval	23423.49	0.0086	0.024	Trapezoid	30	45
140R	Automatic Fixed Interval	11559.52	0.00456	0.024	Trapezoid	30	45
160R	Automatic Fixed Interval	24482.18	0.0045	0.024	Trapezoid	30	45
164R	Automatic Fixed Interval	32027.42	0.00238	0.024	Trapezoid	30	45
171R	Automatic Fixed Interval	9705.03	0.00289	0.024	Trapezoid	30	45

Appendix E. Mangima Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
100B	14.7725	86.52	0	0.093776	0.07502	Discharge	0.25444	1	Ration to Peak	0
101B	7.252	93.36	0	0.043332	0.034666	Discharge	0.18641	1	Ration to Peak	0
102B	17.117	82.8	0	0.12394	0.099153	Discharge	0.30592	1	Ration to Peak	0
103B	11.3805	92.4	0	0.105	0.084	Discharge	0.3471	1	Ration to Peak	0
104B	11.4	92.4	0	0.04	0.022666	Discharge	0.031852	1	Ration to Peak	0
105B	11.1	92.964	0	0.135	0.108	Discharge	1.1718	1	Ration to Peak	0
106B	15.675	84.996	0	0.121284	0.097028	Discharge	0.24995	1	Ration to Peak	0
107B	7.6	92.4	0	0.063332	0.050666	Discharge	0.33291	1	Ration to Peak	0
108B	6.873	94.488	0	0.15	0.12	Discharge	0.30609	1	Ration to Peak	0
109B	10.725	93.648	0	0.048332	0.038666	Discharge	0.32399	1	Ration to Peak	0
10B	11.3805	94.596	0	0.148332	0.118666	Discharge	0.35952	1	Ration to Peak	0

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
110B	7.625	77.196	0	0.083332	0.066666	Discharge	0.60182	1	Ration to Peak	0
111B	11.3805	92.4	0	0.145	0.116	Discharge	0.51543	1	Ration to Peak	0
112B	17.5935	92.4	0	0.105	0.084	Discharge	0.97247	1	Ration to Peak	0
113B	11.3805	92.4	0	0.136668	0.109334	Discharge	0.29521	1	Ration to Peak	0
114B	6.7665	82.092	0	0.105	0.084	Discharge	0.51449	1	Ration to Peak	0
115B	13.98	92.4	0	0.08436	0.067486	Discharge	0.95305	1	Ration to Peak	0
116B	18.344	94.524	0	0.133332	0.106666	Discharge	0.71112	1	Ration to Peak	0
117B	10.509	77.4	0	0.135	0.108	Discharge	0.15026	1	Ration to Peak	0
118B	20.273	81	0	0.065	0.052	Discharge	0.19647	1	Ration to Peak	0
119B	7.4665	94.056	0	0.23	0.184	Discharge	0.44526	1	Ration to Peak	0
11B	10.5465	97.5	0	0.115049	0.092039	Discharge	0.13734	1	Ration to Peak	0

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
120B	13.9555	78.324	0	0.05	0.04	Discharge	0.503	1	Ration to Peak	0
121B	11.4115	90.9	0	0.163524	0.13082	Discharge	1.6632	1	Ration to Peak	0
122B	9.2215	92.4	0	0.193332	0.154666	Discharge	0.3926	1	Ration to Peak	0
123B	12.4575	93.984	0	0.116668	0.093334	Discharge	1.5135	1	Ration to Peak	0
124B	11.0865	77.448	0	0.191668	0.153334	Discharge	0.86379	1	Ration to Peak	0
125B	10.9665	82.8	0	0.10849	0.086792	Discharge	0.23776	1	Ration to Peak	0
126B	9.976	87.78	0	0.2475	0.198	Discharge	0.38287	1	Ration to Peak	0
127B	7.3675	90.432	0	0.056668	0.045334	Discharge	0.31581	1	Ration to Peak	0
128B	11.3805	92.952	0	0.105556	0.084444	Discharge	1.3453	1	Ration to Peak	0
129B	7.3955	93.18	0	0.095468	0.076374	Discharge	0.40924	1	Ration to Peak	0
12B	7.349	86.16	0	0.063332	0.050666	Discharge	0.87896	1	Ration to Peak	0

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
130B	7.587	92.808	0	0.055	0.044	Discharge	0.90902	1	Ration to Peak	0
131B	7.2815	92.4	0	0.093332	0.074666	Discharge	0.22112	1	Ration to Peak	0
132B	7.0305	93.036	0	0.045	0.036	Discharge	0.23191	1	Ration to Peak	0
133B	8.9875	93.168	0	0.2725	0.218	Discharge	0.99234	1	Ration to Peak	0
134B	17.289	92.4	0	0.105	0.084	Discharge	0.245	1	Ration to Peak	0
135B	9.746	93.264	0	0.131112	0.104888	Discharge	2.7731	1	Ration to Peak	0
136B	10.8785	96.72	0	0.103332	0.082666	Discharge	0.32988	1	Ration to Peak	0
13B	9.259	88.74	0	0.07	0.056	Discharge	0.87013	1	Ration to Peak	0
14B	11.3805	86.592	0	0.13	0.104	Discharge	1.0173	1	Ration to Peak	0
15B	14.0065	71.4	0	0.115556	0.092444	Discharge	0.19148	1	Ration to Peak	0
16B	7.6125	95.556	0	0.13734	0.109874	Discharge	0.13869	1	Ration to Peak	0

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
17B	18.538	72.444	0	0.084444	0.067556	Discharge	1.883	1	Ration to Peak	0
18B	11.3805	84.132	0	0.096368	0.077094	Discharge	0.4108	1	Ration to Peak	0
19B	19.5315	96.54	0	0.139075	0.11126	Discharge	0.5241	1	Ration to Peak	0
1B	16.7595	70.092	0	0.071112	0.056888	Discharge	0.33348	1	Ration to Peak	0
20B	9.5945	92.4	0	0.288	0.2304	Discharge	0.49589	1	Ration to Peak	0
21B	10.35	87.744	0	0.06	0.048	Discharge	0.48718	1	Ration to Peak	0
22B	17.549	92.4	0	0.075	0.06	Discharge	0.27808	1	Ration to Peak	0
23B	11.6695	79.524	0	0.068332	0.054666	Discharge	0.32133	1	Ration to Peak	0
24B	17.1745	80.724	0	0.165	0.132	Discharge	0.19062	1	Ration to Peak	0
25B	10.39	92.4	0	0.083332	0.066666	Discharge	0.10635	1	Ration to Peak	0
26B	16.688	79.332	0	0.103332	0.082666	Discharge	0.21675	1	Ration to Peak	0

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
27B	7.587	83.34	0	0.176668	0.141334	Discharge	0.17279	1	Ration to Peak	0
28B	11.729	87.156	0	0.123332	0.098666	Discharge	1.2345	1	Ration to Peak	0
29B	8.1535	85.056	0	0.098332	0.078666	Discharge	0.62023	1	Ration to Peak	0
2B	9.8435	70.968	0	0.116668	0.093334	Discharge	0.39739	1	Ration to Peak	0
30B	7.587	82.224	0	0.12	0.096	Discharge	0.36509	1	Ration to Peak	0
31B	10.7	71.592	0	0.101668	0.081334	Discharge	0.44351	1	Ration to Peak	0
32B	19.957	85.164	0	0.135	0.108	Discharge	0.43206	1	Ration to Peak	0
33B	13.3785	72.42	0	0.1	0.08	Discharge	0.24291	1	Ration to Peak	0
34B	14.9625	92.4	0	0.096668	0.077334	Discharge	0.22881	1	Ration to Peak	0
35B	19.0755	82.092	0	0.121668	0.097334	Discharge	0.28458	1	Ration to Peak	0
36B	18.82	90.84	0	0.05	0.04	Discharge	1.044	1	Ration to Peak	0

Appendix

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
37B	16.137	86.484	0	0.168332	0.134666	Discharge	0.38242	1	Ration to Peak	0
38B	11.5725	92.4	0	0.083332	0.066666	Discharge	0.15885	1	Ration to Peak	0
39B	7.587	84.432	0	0.086668	0.069334	Discharge	0.18824	1	Ration to Peak	0
3B	17.246	67.2	0	0.136668	0.109334	Discharge	0.35094	1	Ration to Peak	0
40B	12.0355	78.6	0	0.283332	0.22666	Discharge	0.40368	1	Ration to Peak	0
41B	11.8925	75.516	0	0.145	0.116	Discharge	0.1934	1	Ration to Peak	0
42B	7.587	68.532	0	0.105	0.084	Discharge	0.20145	1	Ration to Peak	0
43B	8.5935	68.928	0	0.108332	0.086666	Discharge	0.9728	1	Ration to Peak	0
44B	19.957	73.38	0	0.105	0.084	Discharge	1.4958	1	Ration to Peak	0
45B	19.6915	82.44	0	0.131668	0.105334	Discharge	0.51453	1	Ration to Peak	0
46B	16.9335	92.4	0	0.121668	0.097334	Discharge	0.39064	1	Ration to Peak	0

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
47B	8.7125	71.472	0	0.116668	0.093334	Discharge	0.12536	1	Ration to Peak	0
48B	12.0575	81.42	0	0.075	0.06	Discharge	0.35519	1	Ration to Peak	0
49B	15.9345	81.732	0	0.055	0.044	Discharge	0.29034	1	Ration to Peak	0
4B	7.9115	71.148	0	0.066668	0.053334	Discharge	0.90632	1	Ration to Peak	0
50B	17.0395	92.4	0	0.118332	0.094666	Discharge	0.79367	1	Ration to Peak	0
51B	7.587	89.664	0	0.213332	0.170666	Discharge	0.60023	1	Ration to Peak	0
52B	19.271	67.2	0	0.278332	0.22266	Discharge	0.37596	1	Ration to Peak	0
53B	9.2805	67.596	0	0.143332	0.114666	Discharge	0.17398	1	Ration to Peak	0
54B	13.713	92.4	0	0.083332	0.066666	Discharge	0.30069	1	Ration to Peak	0
55B	7.587	72	0	0.108332	0.086666	Discharge	0.14952	1	Ration to Peak	0
56B	11.3105	89.352	0	0.128332	0.102666	Discharge	2.1671	1	Ration to Peak	0

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
57B	19.957	81.372	0	0.065	0.052	Discharge	0.96376	1	Ration to Peak	0
58B	14.1575	73.74	0	0.19	0.152	Discharge	0.69836	1	Ration to Peak	0
59B	14.133	91.5	0	0.04	0.025334	Discharge	0.34423	1	Ration to Peak	0
5B	11.621	71.82	0	0.083332	0.066666	Discharge	0.79547	1	Ration to Peak	0
60B	8.127	92.4	0	0.26	0.208	Discharge	0.37576	1	Ration to Peak	0
61B	18.828	68.232	0	0.048332	0.038666	Discharge	0.17786	1	Ration to Peak	0
62B	14.86	87.888	0	0.115	0.092	Discharge	0.63302	1	Ration to Peak	0
63B	7.5015	77.928	0	0.08	0.064	Discharge	0.694681	1	Ration to Peak	0
64B	11.047	92.4	0	0.055	0.044	Discharge	0.64018	1	Ration to Peak	0
65B	7.6385	83.028	0	0.118332	0.094666	Discharge	0.92005	1	Ration to Peak	0
66B	9.3565	67.2	0	0.093332	0.074666	Discharge	0.13096	1	Ration to Peak	0

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
67B	14.625	77.052	0	0.07	0.056	Discharge	0.38291	1	Ration to Peak	0
68B	10.948	77.1	0	0.041668	0.033334	Discharge	0.3621	1	Ration to Peak	0
69B	14.468	82.332	0	0.295	0.236	Discharge	0.37809	1	Ration to Peak	0
6B	9.8095	90.912	0	0.076668	0.061334	Discharge	1.5578	1	Ration to Peak	0
70B	16.466	68.916	0	0.208332	0.166666	Discharge	0.19569	1	Ration to Peak	0
71B	12.4935	75.708	0	0.106668	0.085334	Discharge	0.3042	1	Ration to Peak	0
72B	7.587	92.64	0	0.16	0.128	Discharge	0.13922	1	Ration to Peak	0
73B	7.587	83.628	0	0.198332	0.158666	Discharge	1.5492	1	Ration to Peak	0
74B	14.047	92.256	0	0.151668	0.121334	Discharge	0.70973	1	Ration to Peak	0
75B	10.5265	87.696	0	0.143332	0.114666	Discharge	0.58984	1	Ration to Peak	0
76B	8.4985	76.152	0	0.216668	0.173334	Discharge	0.43541	1	Ration to Peak	0

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
77B	7.4125	83.856	0	0.168332	0.134666	Discharge	0.34149	1	Ration to Peak	0
78B	7.235	76.452	0	0.061668	0.049334	Discharge	0.73361	1	Ration to Peak	0
79B	9.252	86.568	0	0.181668	0.145334	Discharge	0.54998	1	Ration to Peak	0
7B	6.9485	93.996	0	0.056668	0.045334	Discharge	1.7071	1	Ration to Peak	0
80B	7.587	72.804	0	0.135	0.108	Discharge	0.56008	1	Ration to Peak	0
81B	8.4665	80.436	0	0.265	0.212	Discharge	0.40205	1	Ration to Peak	0
82B	7.587	92.4	0	0.071668	0.057334	Discharge	0.9984	1	Ration to Peak	0
83B	6.8705	92.4	0	0.036667	0.029334	Discharge	0.361	1	Ration to Peak	0
84B	7.587	77.268	0	0.155	0.124	Discharge	0.56212	1	Ration to Peak	0
85B	7.3025	92.844	0	0.063332	0.050666	Discharge	0.36713	1	Ration to Peak	0
86B	6.752	84.84	0	0.103332	0.082666	Discharge	0.277586	1	Ration to Peak	0

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
87B	8.4665	89.916	0	0.146668	0.117334	Discharge	2.3198	1	Ration to Peak	0
88B	7.587	92.892	0	0.1	0.08	Discharge	0.50369	1	Ration to Peak	0
89B	6.8705	93.396	0	0.163332	0.130666	Discharge	0.15905	1	Ration to Peak	0
8B	7.4845	82.596	0	0.125	0.1	Discharge	0.055935	1	Ration to Peak	0
90B	7.587	87.96	0	0.08	0.064	Discharge	0.25068	1	Ration to Peak	0
91B	7.3025	94.224	0	0.04	0.032	Discharge	0.34497	1	Ration to Peak	0
92B	6.752	92.4	0	0.115	0.092	Discharge	0.31831	1	Ration to Peak	0
93B	8.4665	90	0	0.146668	0.117334	Discharge	0.50782	1	Ration to Peak	0
94B	7.587	92.4	0	0.1	0.08	Discharge	0.70437	1	Ration to Peak	0
95B	6.8705	94.452	0	0.163332	0.130666	Discharge	0.68601	1	Ration to Peak	0
96B	7.4845	92.688	0	0.125	0.1	Discharge	0.47708	1	Ration to Peak	0

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
97B	7.587	92.4	0	0.08	0.064	Discharge	0.43177	1	Ration to Peak	0
98B	7.3025	93.204	0	0.04	0.032	Discharge	0.16621	1	Ration to Peak	0
99B	6.752	94.8	0	0.115	0.092	Discharge	0.61593	1	Ration to Peak	0
9B	38.67	92.808	0	0.183332	0.146666	Discharge	0.62599	1	Ration to Peak	0

Appendix F. Mangima Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
136R	Automatic Fixed Interval	11463.09	0.00833	0.00312	Trapezoid	0.3	0.45
137R	Automatic Fixed Interval	11239.84	0.00775	0.00312	Trapezoid	0.3	0.45
138R	Automatic Fixed Interval	23423.49	0.0086	0.00312	Trapezoid	0.3	0.45
139R	Automatic Fixed Interval	36410.71	0.00386	0.00312	Trapezoid	0.3	0.45
140R	Automatic Fixed Interval	11559.52	0.00456	0.00312	Trapezoid	0.3	0.45
141R	Automatic Fixed Interval	17633.16	0.00456	0.004586	Trapezoid	0.3	0.45
143R	Automatic Fixed Interval	14484.66	0.00456	0.004703	Trapezoid	0.3	0.45
144R	Automatic Fixed Interval	27444.63	0.00386	0.00312	Trapezoid	0.3	0.45
145R	Automatic Fixed Interval	8378.022	0.00077	0.00312	Trapezoid	0.3	0.45
146R	Automatic Fixed Interval	7484.563	0.00077	0.004586	Trapezoid	0.3	0.45
147R	Automatic Fixed Interval	19986.26	0.00077	0.00312	Trapezoid	0.3	0.45
148R	Automatic Fixed Interval	7246.298	0.00094	0.00312	Trapezoid	0.3	0.45
149R	Automatic Fixed Interval	18989.78	0.00094	0.004586	Trapezoid	0.3	0.45
150R	Automatic Fixed Interval	13493.97	0.0044	0.00312	Trapezoid	0.3	0.45
151R	Automatic Fixed Interval	9328.487	0.00001	0.004586	Trapezoid	0.3	0.45
152R	Automatic Fixed Interval	16149.59	0.00004	0.00312	Trapezoid	0.3	0.45
153R	Automatic Fixed Interval	14260.41	0.00004	0.00312	Trapezoid	0.3	0.45
154R	Automatic Fixed Interval	9478.294	0.00287	0.00312	Trapezoid	0.3	0.45
155R	Automatic Fixed Interval	6911.976	0.00287	0.00312	Trapezoid	0.3	0.45
156R	Automatic Fixed Interval	8288.708	0.00626	0.00312	Trapezoid	0.3	0.45
157R	Automatic Fixed Interval	8783.158	0.00626	0.00312	Trapezoid	0.3	0.45
158R	Automatic Fixed Interval	9034.367	0.00022	0.00312	Trapezoid	0.3	0.45
159R	Automatic Fixed Interval	10943.4	0.00766	0.00312	Trapezoid	0.3	0.45
160R	Automatic Fixed Interval	24482.18	0.0045	0.00312	Trapezoid	0.3	0.45
161R	Automatic Fixed Interval	15711.84	0.00537	0.004586	Trapezoid	0.3	0.45
162R	Automatic Fixed Interval	9801.298	0.00048	0.00312	Trapezoid	0.3	0.45
163R	Automatic Fixed Interval	20887.28	0.00175	0.00312	Trapezoid	0.3	0.45
164R	Automatic Fixed Interval	32027.42	0.00238	0.00312	Trapezoid	0.3	0.45
165R	Automatic Fixed Interval	28908.64	0.0045	0.00312	Trapezoid	0.3	0.45
166R	Automatic Fixed Interval	3145.729	0.00099	0.00312	Trapezoid	0.3	0.45
167R	Automatic Fixed Interval	3230.214	0.00396	0.00312	Trapezoid	0.3	0.45
168R	Automatic Fixed Interval	10082.16	0.00318	0.00312	Trapezoid	0.3	0.45
169R	Automatic Fixed Interval	7281.956	0.01413	0.00312	Trapezoid	0.3	0.45
170R	Automatic Fixed Interval	4620.543	0.00382	0.00312	Trapezoid	0.3	0.45
171R	Automatic Fixed Interval	9705.03	0.00289	0.00312	Trapezoid	0.3	0.45

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
172R	Automatic Fixed Interval	9693.574	0.00079	0.00312	Trapezoid	0.3	0.45
173R	Automatic Fixed Interval	7818.079	0.01672	0.00312	Trapezoid	0.3	0.45
174R	Automatic Fixed Interval	12294.25	0.00835	0.00312	Trapezoid	0.3	0.45
175R	Automatic Fixed Interval	9502.297	0.00234	0.00312	Trapezoid	0.3	0.45
176R	Automatic Fixed Interval	13974.21	0.00847	0.00312	Trapezoid	0.3	0.45
177R	Automatic Fixed Interval	7096.355	0.00065	0.00312	Trapezoid	0.3	0.45
178R	Automatic Fixed Interval	4615.915	0.00164	0.00312	Trapezoid	0.3	0.45
179R	Automatic Fixed Interval	21118.27	0.00252	0.00312	Trapezoid	0.3	0.45
180R	Automatic Fixed Interval	21991.32	0.00491	0.00312	Trapezoid	0.3	0.45
181R	Automatic Fixed Interval	18222.57	0.00725	0.00312	Trapezoid	0.3	0.45
182R	Automatic Fixed Interval	6579.994	0.0102	0.00312	Trapezoid	0.3	0.45
183R	Automatic Fixed Interval	14120.14	0.0031	0.00312	Trapezoid	0.3	0.45
184R	Automatic Fixed Interval	11316.39	0.00275	0.00312	Trapezoid	0.3	0.45
185R	Automatic Fixed Interval	26515	0.00311	0.00312	Trapezoid	0.3	0.45
186R	Automatic Fixed Interval	30430.23	0.00263	0.00312	Trapezoid	0.3	0.45
187R	Automatic Fixed Interval	8638.46	0.00329	0.00468	Trapezoid	0.3	0.45
188R	Automatic Fixed Interval	11518.57	0.00369	0.00468	Trapezoid	0.3	0.45
189R	Automatic Fixed Interval	6602.202	0.006	0.00468	Trapezoid	0.3	0.45
190R	Automatic Fixed Interval	13034.31	0.00352	0.00468	Trapezoid	0.3	0.45
191R	Automatic Fixed Interval	17097.55	0.00196	0.00468	Trapezoid	0.3	0.45
192R	Automatic Fixed Interval	14204.74	0.0035	0.00468	Trapezoid	0.3	0.45
193R	Automatic Fixed Interval	19148.15	0.00126	0.00468	Trapezoid	0.3	0.45
194R	Automatic Fixed Interval	12523.34	0.01757	0.00468	Trapezoid	0.3	0.45
195R	Automatic Fixed Interval	23896.2	0.00925	0.00468	Trapezoid	0.3	0.45
196R	Automatic Fixed Interval	10706.23	0.00421	0.00468	Trapezoid	0.3	0.45
197R	Automatic Fixed Interval	9894.361	0.00199	0.00468	Trapezoid	0.3	0.45
198R	Automatic Fixed Interval	12504.34	0.00412	0.00468	Trapezoid	0.3	0.45
199R	Automatic Fixed Interval	23190	0.0054	0.00468	Trapezoid	0.3	0.45
200R	Automatic Fixed Interval	5168.01	0.00221	0.00468	Trapezoid	0.3	0.45
201R	Automatic Fixed Interval	13756.15	0.00593	0.00468	Trapezoid	0.3	0.45
202R	Automatic Fixed Interval	6487.091	0.00271	0.00468	Trapezoid	0.3	0.45
203R	Automatic Fixed Interval	17884.15	0.00239	0.00468	Trapezoid	0.3	0.45
204R	Automatic Fixed Interval	8865.402	0.0012	0.00468	Trapezoid	0.3	0.45
205R	Automatic Fixed Interval	5395.761	0.01091	0.00468	Trapezoid	0.3	0.45
206R	Automatic Fixed Interval	7607.172	0.00125	0.00468	Trapezoid	0.3	0.45
207R	Automatic Fixed Interval	8693.716	0.02682	0.00468	Trapezoid	0.3	0.45
208R	Automatic Fixed Interval	27314.23	0.00324	0.00468	Trapezoid	0.3	0.45

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
209R	Automatic Fixed Interval	13263.77	0.00531	0.0036	Trapezoid	30	45
210R	Automatic Fixed Interval	15125.07	0.00547	0.0036	Trapezoid	30	45
211R	Automatic Fixed Interval	8365.7	0.0009	0.0036	Trapezoid	30	45
212R	Automatic Fixed Interval	22282.29	0.00476	0.0036	Trapezoid	30	45
213R	Automatic Fixed Interval	9633.147	0.00337	0.0036	Trapezoid	30	45
214R	Automatic Fixed Interval	25846.54	0.00516	0.0036	Trapezoid	30	45
215R	Automatic Fixed Interval	11181.5	0.00394	0.0036	Trapezoid	30	45
216R	Automatic Fixed Interval	13362.31	0.00479	0.0036	Trapezoid	30	45
217R	Automatic Fixed Interval	12609.68	0.00327	0.0036	Trapezoid	30	45
218R	Automatic Fixed Interval	8330.037	0.0019	0.0036	Trapezoid	30	45
219R	Automatic Fixed Interval	4495.161	0.00633	0.0036	Trapezoid	30	45
220R	Automatic Fixed Interval	14968.65	0.01041	0.0036	Trapezoid	30	45
221R	Automatic Fixed Interval	31565.82	0.00402	0.0036	Trapezoid	30	45
222R	Automatic Fixed Interval	4554.421	0.00167	0.0036	Trapezoid	30	45
223R	Automatic Fixed Interval	11835.41	0.00361	0.0036	Trapezoid	30	45
224R	Automatic Fixed Interval	10168.32	0.01959	0.0036	Trapezoid	30	45
225R	Automatic Fixed Interval	19347.17	0.00614	0.0036	Trapezoid	30	45
226R	Automatic Fixed Interval	12866.81	0.00366	0.0036	Trapezoid	30	45
227R	Automatic Fixed Interval	12590.71	0.00478	0.0036	Trapezoid	30	45
228R	Automatic Fixed Interval	21604.67	0.00364	0.0036	Trapezoid	30	45
229R	Automatic Fixed Interval	12511.57	0.00247	0.0036	Trapezoid	30	45
230R	Automatic Fixed Interval	3624.38	0.00372	0.0036	Trapezoid	30	45
231R	Automatic Fixed Interval	27420.8	0.00508	0.0036	Trapezoid	30	45
232R	Automatic Fixed Interval	10530.22	0.00399	0.0036	Trapezoid	30	45
233R	Automatic Fixed Interval	10533.78	0.00539	0.0036	Trapezoid	30	45
234R	Automatic Fixed Interval	8346.761	0.01095	0.0036	Trapezoid	30	45
235R	Automatic Fixed Interval	20002.37	0.00212	0.0036	Trapezoid	30	45
236R	Automatic Fixed Interval	14535.76	0.00886	0.0036	Trapezoid	30	45
237R	Automatic Fixed Interval	22246.31	0.004	0.0036	Trapezoid	30	45
238R	Automatic Fixed Interval	11700.06	0.00665	0.0036	Trapezoid	30	45
239R	Automatic Fixed Interval	11440.61	0.00462	0.0036	Trapezoid	30	45
240R	Automatic Fixed Interval	26619.27	0.0048	0.0036	Trapezoid	30	45
241R	Automatic Fixed Interval	32334.99	0.00503	0.0036	Trapezoid	30	45
242R	Automatic Fixed Interval	13174.53	0.00279	0.0036	Trapezoid	30	45
243R	Automatic Fixed Interval	14583	0.00504	0.0036	Trapezoid	30	45
244R	Automatic Fixed Interval	11875.47	0.00372	0.0036	Trapezoid	30	45
245R	Automatic Fixed Interval	35504.97	0.00128	0.0036	Trapezoid	30	45

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
246R	Automatic Fixed Interval	6293.406	0.00659	0.00468	Trapezoid	0.3	0.45
247R	Automatic Fixed Interval	10485.81	0.00844	0.00468	Trapezoid	0.3	0.45
248R	Automatic Fixed Interval	14856.88	0.0055	0.00468	Trapezoid	0.3	0.45
249R	Automatic Fixed Interval	38720.65	0.00192	0.00468	Trapezoid	0.3	0.45
250R	Automatic Fixed Interval	24634.89	0.00477	0.00468	Trapezoid	0.3	0.45
251R	Automatic Fixed Interval	7560.155	0.00963	0.00468	Trapezoid	0.3	0.45
252R	Automatic Fixed Interval	15761.68	0.01321	0.00468	Trapezoid	0.3	0.45
253R	Automatic Fixed Interval	4461.835	0.00488	0.00468	Trapezoid	0.3	0.45
254R	Automatic Fixed Interval	12505.5	0.00146	0.00468	Trapezoid	0.3	0.45
255R	Automatic Fixed Interval	11972.31	0.00461	0.00468	Trapezoid	0.3	0.45
256R	Automatic Fixed Interval	13441.16	0.00847	0.00468	Trapezoid	0.3	0.45
257R	Automatic Fixed Interval	22539.35	0.00443	0.00468	Trapezoid	0.3	0.45
258R	Automatic Fixed Interval	10000.73	0.00213	0.00468	Trapezoid	0.3	0.45
259R	Automatic Fixed Interval	11274.45	0.0022	0.00468	Trapezoid	0.3	0.45
260R	Automatic Fixed Interval	16890.52	0.00448	0.00468	Trapezoid	0.3	0.45
261R	Automatic Fixed Interval	19916.74	0.00577	0.00468	Trapezoid	0.3	0.45
262R	Automatic Fixed Interval	9956.864	0.01637	0.975	Trapezoid	0.3	0.45
263R	Automatic Fixed Interval	23713.86	0.00389	0.975	Trapezoid	0.3	0.45
264R	Automatic Fixed Interval	10041.97	0.00511	0.975	Trapezoid	0.3	0.45
265R	Automatic Fixed Interval	19691.32	0.00135	0.975	Trapezoid	0.3	0.45
266R	Automatic Fixed Interval	9360.895	0.00297	0.975	Trapezoid	0.3	0.45
267R	Automatic Fixed Interval	26725.42	0.00286	0.975	Trapezoid	0.3	0.45
268R	Automatic Fixed Interval	27255.78	0.00128	0.975	Trapezoid	0.3	0.45
269R	Automatic Fixed Interval	23543.14	0.00102	0.975	Trapezoid	0.3	0.45

Appendix G. Tagoloan Discharge from HEC-HMS Simulation

DIRECT FLOW (cms)							
Time (hr)	100-yr	25-yr	5-year	Time (hr)	100-yr	25-yr	5-year
0	0	0	0	5.8333	0	0	0
0.1667	0	0	0	6	0	0	0
0.3333	0	0	0	6.1667	0	0	0
0.5	0	0	0	6.3333	0	0	0
0.6667	0	0	0	6.5	0	0	0
0.8333	0	0	0	6.6667	0	0	0
1	0	0	0	6.8333	0	0	0
1.1667	0	0	0	7	0	0	0
1.3333	0	0	0	7.1667	0	0	0
1.5	0	0	0	7.3333	0	0	0
1.6667	0	0	0	7.5	0	0	0
1.8333	0	0	0	7.6667	0	0	0
2	0	0	0	7.8333	0	0	0
2.1667	0	0	0	8	0	0	0
2.3333	0	0	0	8.1667	0	0	0
2.5	0	0	0	8.3333	0	0	0
2.6667	0	0	0	8.5	0	0	0
2.8333	0	0	0	8.6667	0	0	0
3	0	0	0	8.8333	0	0	0
3.1667	0	0	0	9	0	0	0
3.3333	0	0	0	9.1667	0	0	0
3.5	0	0	0	9.3333	0	0	0
3.6667	0	0	0	9.5	0	0	0
3.8333	0	0	0	9.6667	0	0	0
4	0	0	0	9.8333	0	0	0
4.1667	0	0	0	10	0	0	0
4.3333	0	0	0	10.167	0	0	0
4.5	0	0	0	10.333	0	0	0
4.6667	0	0	0	10.5	0	0	0
4.8333	0	0	0	10.667	0	0	0
5	0	0	0	10.833	0.1	0	0
5.1667	0	0	0	11	0.2	0.1	0
5.3333	0	0	0	11.167	0.7	0.5	0.2
5.5	0	0	0	11.333	1.7	1.1	0.4
5.6667	0	0	0	11.5	3.2	2	0.9

DIRECT FLOW (cms)							
Time (hr)	100-yr	25-yr	5-year	Time (hr)	100-yr	25-yr	5-year
11.667	6.2	4	1.8	18	4874.3	3469.9	1880.1
11.833	12.9	8.4	3.8	18.167	5046.9	3596.1	1952.6
12	28.5	19.1	9.1	18.333	5206.7	3713.4	2020.8
12.167	52.3	35.4	17.3	18.5	5360.8	3826.8	2087.1
12.333	79.5	54.2	26.8	18.667	5507.7	3935.4	2151.1
12.5	111.4	76.2	37.9	18.833	5646.6	4038.5	2212.5
12.667	148.6	101.9	50.9	19	5770	4130.6	2268
12.833	197	135.5	68.1	19.167	5877.9	4211.9	2318
13	257.5	177.6	89.7	19.333	5978.3	4287.9	2365.2
13.167	324.6	224.4	113.9	19.5	6070.9	4358.4	2409.5
13.333	397	275.1	140.2	19.667	6155.3	4423.2	2450.9
13.5	474.3	329.2	168.4	19.833	6226.2	4478.4	2487
13.667	557.7	387.7	199	20	6281.2	4522.3	2517.1
13.833	648.8	451.7	232.6	20.167	6326.6	4559.2	2543.4
14	745.3	519.8	268.5	20.333	6365.2	4591.3	2566.9
14.167	845.8	590.6	306	20.5	6397.7	4618.9	2588
14.333	951	664.9	345.4	20.667	6423.8	4641.8	2606.3
14.5	1062.4	743.5	387.2	20.833	6441.3	4658.5	2621.2
14.667	1183.8	829.4	433	21	6452.1	4670.2	2633.2
14.833	1313.5	921.3	482.1	21.167	6458.3	4678.6	2643.1
15	1447.7	1016.4	533.2	21.333	6458.7	4682.9	2650.8
15.167	1587.3	1115.4	586.3	21.5	6450.6	4681.2	2655.4
15.333	1733.5	1219.1	642	21.667	6427	4668.4	2653.7
15.5	1892.7	1332	702.8	21.833	6390.1	4646	2646.8
15.667	2064.2	1453.8	768.4	22	6347.2	4619.3	2637.4
15.833	2241.5	1579.9	836.5	22.167	6298.6	4588.2	2625.4
16	2425	1710.4	907.2	22.333	6245.8	4554	2611.4
16.167	2614.2	1845	980.1	22.5	6187.7	4515.8	2595
16.333	2812.3	1986.2	1056.8	22.667	6124.2	4473.6	2576.1
16.5	3020.2	2134.5	1137.5	22.833	6057.5	4428.9	2555.6
16.667	3233.6	2286.9	1220.6	23	5987.8	4381.8	2533.5
16.833	3450.4	2441.9	1305.4	23.167	5915	4332.5	2510
17	3668.1	2597.9	1391.1	23.333	5839	4280.7	2484.9
17.167	3881.9	2751.6	1476.1	23.5	5759.1	4225.9	2458
17.333	4089	2900.7	1559	23.667	5676.4	4169	2429.7
17.5	4291.3	3046.8	1640.7	23.833	5591.4	4110.4	2400.1
17.667	4490.9	3191.2	1721.9	24	5503.5	4049.6	2369.3
17.833	4686.6	3333.2	1802.1	24.167	5411.2	3985.5	2336.5

DIRECT FLOW (cms)							
Time (hr)	100-yr	25-yr	5-year	Time (hr)	100-yr	25-yr	5-year
24.333	5312.2	3916.6	2300.9	30.667	1881.1	1437.7	898.7
24.5	5207.9	3843.8	2263	30.833	1830.4	1399.6	875.4
24.667	5100.5	3768.6	2223.7	31	1780.4	1362	852.3
24.833	4989.9	3691.1	2182.9	31.167	1731.4	1325.1	829.6
25	4875.4	3610.7	2140.5	31.333	1684.3	1289.6	807.7
25.167	4754.1	3525.4	2095.2	31.5	1638.6	1255.1	786.4
25.333	4626.9	3435.8	2047.5	31.667	1593.7	1221.1	765.4
25.5	4497.2	3344.2	1998.5	31.833	1549.3	1187.6	744.8
25.667	4365.5	3251	1948.4	32	1505.3	1154.4	724.4
25.833	4234.4	3157.9	1898	32.167	1461.7	1121.6	704.2
26	4106.9	3067.2	1848.7	32.333	1418.6	1089.1	684.3
26.167	3983.6	2979.3	1800.5	32.5	1375.9	1056.9	664.6
26.333	3862.5	2892.7	1752.8	32.667	1333.8	1025.1	645.1
26.5	3743.3	2807.3	1705.5	32.833	1292.9	994.1	626.1
26.667	3626.9	2723.6	1658.8	33	1254.2	964.8	608
26.833	3517	2644.3	1614.2	33.167	1218.2	937.3	590.9
27	3415.6	2570.9	1572.6	33.333	1183.8	911	574.4
27.167	3319.6	2501.2	1532.8	33.5	1150.4	885.4	558.3
27.333	3226.8	2433.7	1493.9	33.667	1117.6	860.3	542.5
27.5	3136.8	2368.1	1455.9	33.833	1085.4	835.7	527.1
27.667	3049.5	2304.3	1418.9	34	1053.8	811.5	512
27.833	2966.1	2243.3	1383.2	34.167	1022.8	787.7	497.1
28	2885.7	2184.3	1348.6	34.333	992.2	764.3	482.5
28.167	2806.9	2126.4	1314.5	34.5	962.2	741.4	468.1
28.333	2729.9	2069.8	1281.1	34.667	933.2	719.1	454.2
28.5	2654.7	2014.4	1248.3	34.833	905.7	698	440.9
28.667	2582.7	1961.3	1216.7	35	879.4	677.8	428.1
28.833	2513.7	1910.2	1186.2	35.167	853.8	658	415.6
29	2446	1860.1	1156.3	35.333	828.8	638.7	403.4
29.167	2379.8	1811	1126.8	35.5	804.1	619.7	391.4
29.333	2315.4	1763.2	1098	35.667	779.8	601	379.6
29.5	2254.5	1717.8	1070.5	35.833	755.9	582.7	368.1
29.667	2197.4	1675.1	1044.5	36	732.3	564.6	356.7
29.833	2142.4	1633.9	1019.2	36.167	709.2	546.8	345.6
30	2088.8	1593.7	994.5	36.333	686.6	529.4	334.7
30.167	2036.1	1554.1	970.2	36.5	665	512.8	324.2
30.333	1983.9	1514.9	946.1	36.667	644.6	497	314.2
30.5	1932.3	1476.1	922.3	36.833	625	481.9	304.6

DIRECT FLOW (cms)							
Time (hr)	100-yr	25-yr	5-year	Time (hr)	100-yr	25-yr	5-year
37	606	467.1	295.2	43.333	187.1	144.2	91
37.167	587.3	452.7	286.1	43.5	181.3	139.7	88.2
37.333	569.1	438.6	277.2	43.667	175.8	135.5	85.5
37.5	551.2	424.9	268.5	43.833	170.5	131.4	83
37.667	533.7	411.4	260	44	165.4	127.4	80.5
37.833	516.5	398.2	251.7	44.167	160.4	123.6	78
38	499.7	385.3	243.6	44.333	155.5	119.8	75.6
38.167	483.6	372.9	235.8	44.5	150.6	116.1	73.3
38.333	468.7	361.4	228.5	44.667	145.9	112.4	71
38.5	454.7	350.6	221.6	44.833	141.3	108.9	68.8
38.667	441.2	340.1	215	45	136.7	105.4	66.6
38.833	428.2	330	208.5	45.167	132.4	102.1	64.5
39	415.5	320.2	202.3	45.333	128.3	98.9	62.5
39.167	403	310.6	196.2	45.5	124.5	96	60.7
39.333	390.8	301.2	190.3	45.667	120.9	93.2	58.9
39.5	378.9	292	184.5	45.833	117.4	90.4	57.1
39.667	367.2	283	178.8	46	113.9	87.8	55.4
39.833	355.8	274.3	173.3	46.167	110.6	85.2	53.8
40	345	265.9	168	46.333	107.3	82.6	52.2
40.167	334.8	258	163	46.5	104.1	80.2	50.6
40.333	325	250.4	158.2	46.667	100.9	77.7	49.1
40.5	315.5	243.1	153.5	46.833	97.9	75.4	47.6
40.667	306.2	235.9	148.9	47	95.1	73.2	46.2
40.833	297.1	228.9	144.5	47.167	92.5	71.2	44.9
41	288.2	222	140.2	47.333	90	69.3	43.7
41.167	279.4	215.3	135.9	47.5	87.7	67.5	42.5
41.333	270.8	208.7	131.8	47.667	85.4	65.7	41.3
41.5	262.4	202.2	127.7	47.833	83.3	64	40.2
41.667	254.2	195.9	123.8	48	81.1	62.3	39.1
41.833	246.6	190	120				
42	239.3	184.4	116.5				
42.167	232.3	179	113				
42.333	225.5	173.7	109.7				
42.5	218.7	168.5	106.4				
42.667	212.2	163.4	103.2				
42.833	205.7	158.5	100				
43	199.4	153.6	97				
43.167	193.2	148.8	94				

DREAM

Disaster RIsk and Exposure Assessment for Mitigation