HAZARD MAPPING OF THE PHILIPPINES USING LIDAR (PHIL-LIDAR I)

LiDAR Surveys and Flood Mapping of Kabasalan River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
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LIST OF ACRONYMS AND ABBREVIATIONS

AAC	Asian Aerospace Corporation
Ab	abutment
ADZU	Ateneo de Zamboanga University
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
ATQ	Antique
AWLS	Automated Water Level Sensor
BA	Bridge Approach
BM	benchmark
CAD	Computer-Aided Design
CN	Curve Number
CSRS	Chief Science Research Specialist
DAC	Data Acquisition Component
DEM	Digital Elevation Model
DENR	Department of Environment and Natural Resources
DOST	Department of Science and Technology
DPPC	Data Pre-Processing Component
DREAM	Disaster Risk and Exposure Assessment for Mitigation [Program]
DRRM	Disaster Risk Reduction and Management
DSM	Digital Surface Model
DTM	Digital Terrain Model
DVBC	Data Validation and Bathymetry Component
FMC	Flood Modeling Component
FOV	Field of View
GiA	Grants-in-Aid
GCP	Ground Control Point
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HEC-HMS	Hydrologic Engineering Center - Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center - River Analysis System
HC	High Chord
IDW	Inverse Distance Weighted [interpolation method]
IMU	Inertial Measurement Unit
kts	knots
LAS	LiDAR Data Exchange File format
LC	Low Chord
LGU	local government unit
LiDAR	Light Detection and Ranging
LMS	LiDAR Mapping Suite
m AGL	meters Above Ground Level
MMS	Mobile Mapping Suite
MSL	mean sea level
NAMRIA	National Mapping and Resource Information Authority
NSTC	Northern Subtropical Convergence
PAF	Philippine Air Force
PAGASA	Philippine Atmospheric Geophysical and Astronomical Services Administration
PDOP	Positional Dilution of Precision
PPK	Post-Processed Kinematic [technique]
PRF	Pulse Repetition Frequency
PTM	Philippine Transverse Mercator
QC	Quality Check
QT	Quick Terrain [Modeler]
RA	Research Associate
RIDF	Rainfall-Intensity-Duration-Frequency
RMSE	Root Mean Square Error
SAR	Synthetic Aperture Radar
SCS	Soil Conservation Service
SRTM	Shuttle Radar Topography Mission
SRS	Science Research Specialist
SSG	Special Service Group
TBC	Thermal Barrier Coatings
UP-TCAGP	University of the Philippines – Training Center for Applied Geodesy and Photogrammetry
UTM	Universal Transverse Mercator
WGS	World Geodetic System

CHAPTER 1: OVERVIEW OF THE PROGRAM AND KABASALAN RIVER

Enrico C. Paringit, Dr. Eng., Mr. Mario Rodriguez, and Mr. Emir Epino

1.1 Background of the Phil-LiDAR 1 Program

The University of the Philippines Training Center for Applied Geodesy and Photogrammetry (UP TCAGP) launched a research program entitled “Nationwide Hazard Mapping using LiDAR” or Phil-LiDAR 1 in 2014, supported by the Department of Science and Technology (DOST) Grant-in-Aid (GiA) Program. The program was primarily aimed at acquiring a national elevation and resource dataset at sufficient resolution to produce information necessary to support the different phases of disaster management. Particularly, it targeted 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.

The program was also aimed at producing an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through DOST. The methods applied in this report are thoroughly described in a separate publication titled *Flood Mapping of Rivers in the Philippines Using Airborne LiDAR: Methods* (Paringit et al., 2017) available separately.

The implementing partner university for the Phil-LiDAR 1 Program is the Ateneo de Zamboanga University (ADZU). ADZU is in charge of processing LiDAR data and conducting data validation reconnaissance, cross section, bathymetric survey, validation, river flow measurements, flood height and extent data gathering, flood modeling, and flood map generation for the 18 river basins in the Zamboanga Peninsula. The university is located in Zamboanga City in the province of Zamboanga Sibugay.

1.2 Overview of the Kabasalan River Basin

Kabasalan River, located in the Northeastern part of Zamboanga Sibugay, traverses through the municipalities of Kabasalan, Naga, and Bayog. The river basin has a total land area of 141.68 sq.km and travels at 7.49 km/s, from the source to its mouth. The river is also considered as the political boundary of the municipalities of Kabasalan and Naga, both in Zamboanga Sibugay. The basin has a catchment area of 227 sq.km.

Its main stem, Kabasalan River, is part of the 18 river systems in the Zamboanga peninsula. It has an estimated length of 34.56 km which traverses the Barangays of Mamagon, Bangkaw-Bangkaw, Cainglet, and Bolo Batallion. It is bounded by barangays of Riverside and Santa Cruz in the North; Calapan in the East; Mahuboin the West; and Moro Gulf in the South. A total of 41,421 people are residing within the area based on the 2010 census of the National Statistics Office.

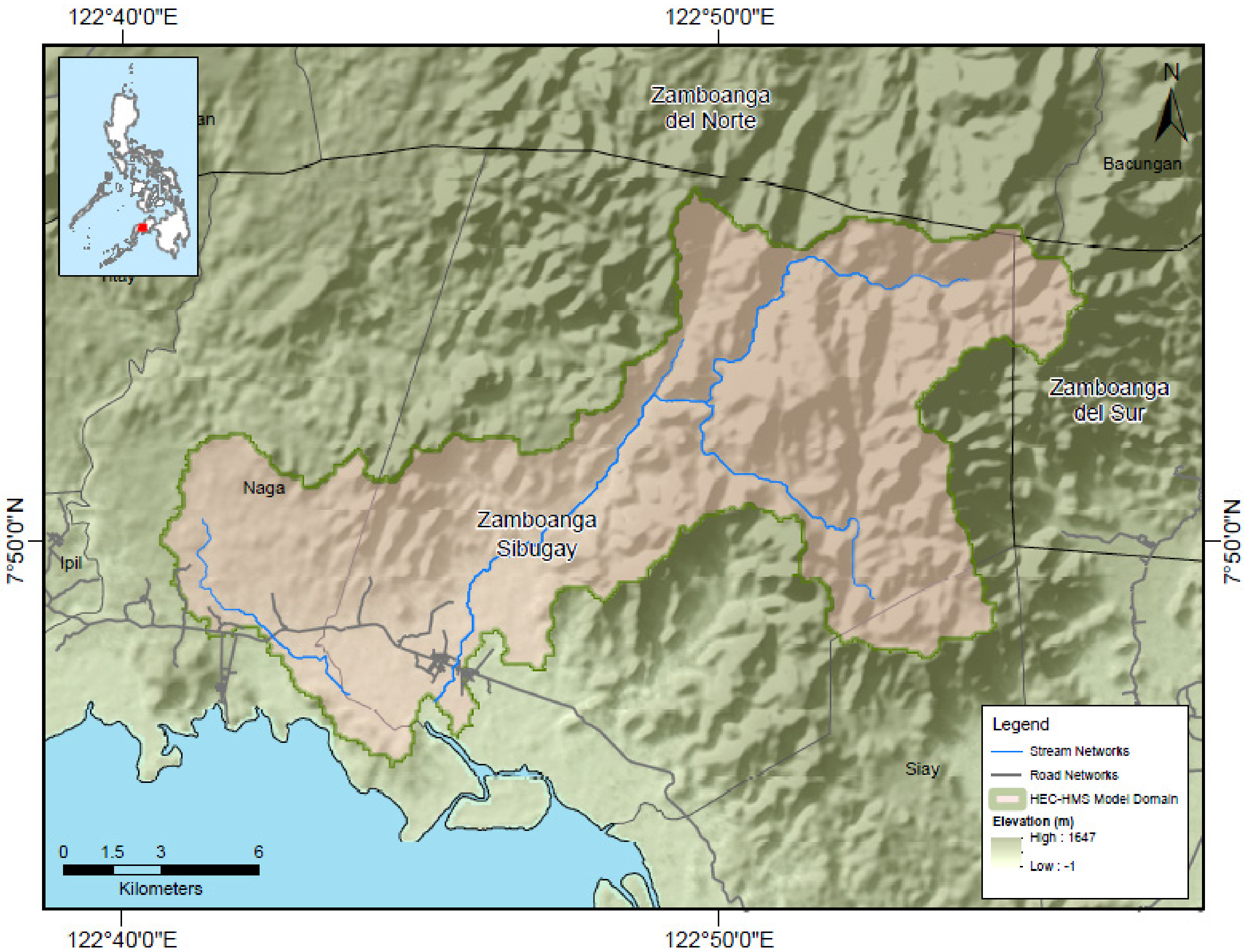


Figure 1. Map of the Kabasalan River Basin (in brown)

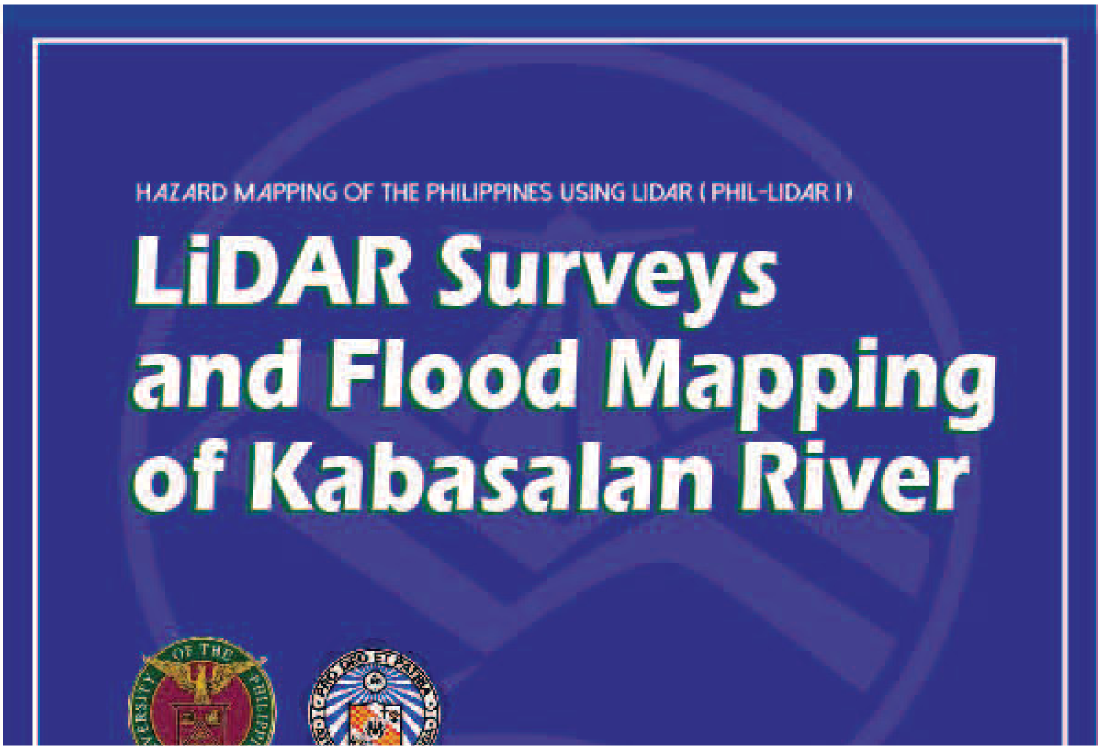


Figure 2. Kabasalan River

The original settlers of the area were the Subanen. According to narratives, “kabasalan” came from the word “babasal” which means red squash. In the earlier part of the 20th century, American explorers surveyed the area to look for a potential land area for the establishment of abaca and rubber plantation. When an American asked a native of the name of the place, he coincidentally pointed out to a red squash to which the native answered “babasal,” thinking that the American was asking for the plant’s name. As the plantation was established, the company recruited workers from Visayas and Luzon. The Cebuanos then called the place “Kabasalan,” adding up the prefix “ka-” which means “a place of”; thus, the name of the place became “Kabasalan,” which original means “a place of red squash.”

The Mines and Geosciences Bureau released in early 2017 the geo-hazard maps of the Municipality of Kabasalan which was based on the agency’s 2006 data. It was indicated in the geo-hazard maps that areas located near Kabasalan River has a high probability of flooding, which could reach up to 1 meter in height.

The Local Disaster Risk Reduction and Management Office (LDRRMO) of the municipality confirmed that the areas near the river are really prone to flooding. This was further confirmed when the LDRRM Office activated their rescue team last January 2017 to rescue residences of 3 barangays affected by the flooding caused by continuous raining in the area.

Figure 3. Rescue activity by the LDRRM of Kabasalan in January 2017

There were also two flooding events that occurred in 1972 and 1997. These events resulted from the overflowing of Kabasalan River due to heavy rains and huge tide that lasted for 3 to 4 days. Flooding affected 80 houses out of the 360 households residing in Barangays Calubihan and Poblacion according to the records of Kabasalan LGU. These events damaged the fish ponds and cages along the coastal barangays of. Sta. Cruz and Cainglet.

Figure 4. Rubber Plantation in Kabasalan

Fish ponds are prominent in the municipality, especially in the areas near the river. Mud crabs, lobsters, and other aquatic resources are being harvested in the area. Kabasalan is one of the popular suppliers of these products in the region.

The municipality is known for several rubber and abaca plantations. In early 20th century, American explorers surveyed the area to build up the plantations. In fact, one of the barangays in the municipality is named after the rubber company "Goodyear."

Sources:
LDRRM Office of Kabalasan
Mines and Geoscience Bureau- IX
Province of Zamboanga Sibugay

CHAPTER 2: LIDAR ACQUISITION IN KABASALAN FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Gracia Acuña, Engr. Gerome Hipolito, Engr. Grace B. Sinadjan, Ms. Sandra C. Poblete

The methods applied in this Chapter were based on the DREAM methods manual (Sarmiento et al., 2014) and further enhanced and updated in Paringit et al. (2017).

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Kabasalan Floodplain in Zamboanga Sibugay. These missions were planned for 12 lines that run for at most four and a half (4.5) hours including take-off, landing, and turning time. The flight planning parameters for the LiDAR system is found in Table 1. Figure 5 shows the flight plan for Kabasalan Floodplain survey.

Table 1. Flight planning parameters for Pegasus LiDAR system

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK70A	800,1100,1200	30	50	200	30	130	5
BLK72A	800,1100,1200	30	50	200	30	130	5
BLK73A	800,1200	30	50	200	30	130	5
BLK73B	800,1100,1200	30	50	200	30	130	5

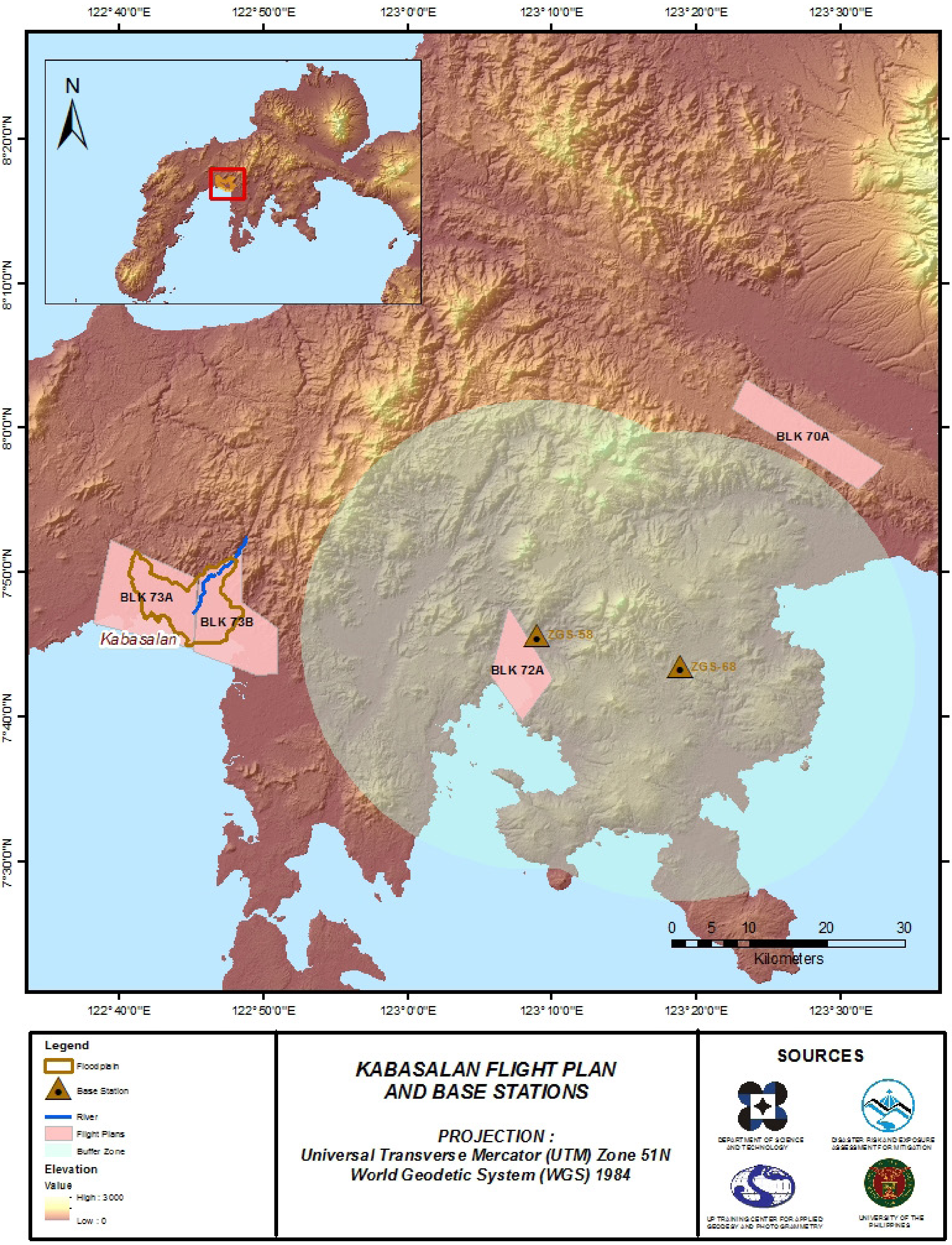
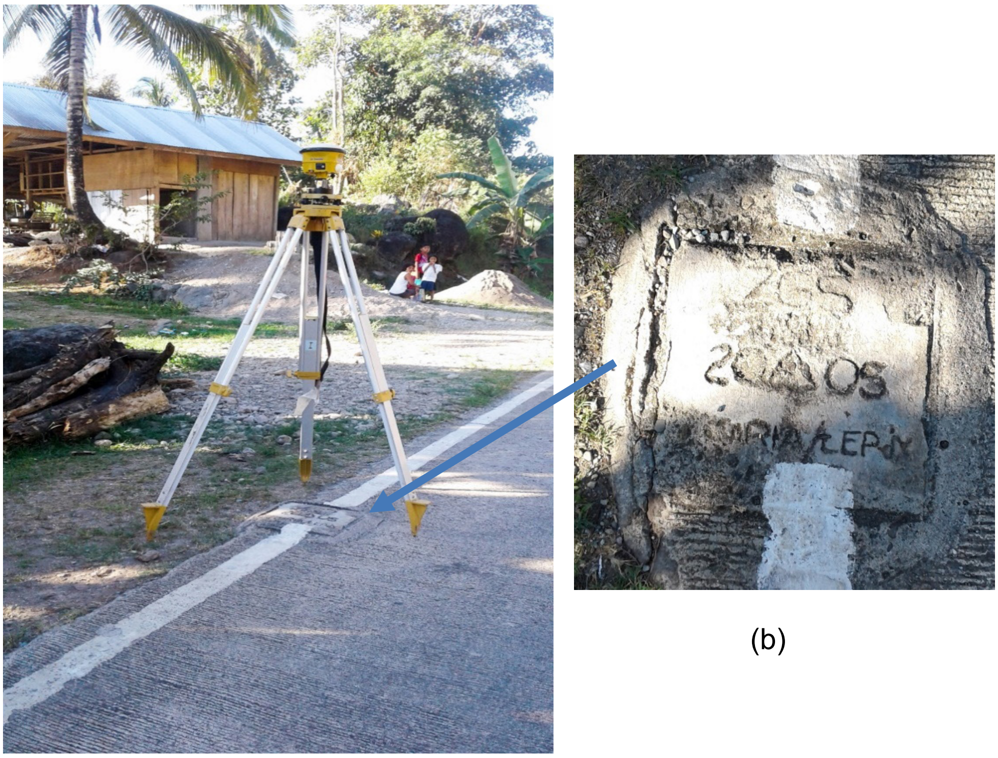


Figure 5. Flight plan and base stations used for Kabasalan Floodplain

2.2 Ground Base Station

The project team was able to recover two (2) NAMRIA ground control points: ZGS-58 and ZGS-68 which are of second (2^{nd})-order accuracy. The certifications for the NAMRIA reference points are found in ANNEX 2. These points were used as base stations during flight operations for the entire duration of the survey (February 24–26, 2016). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 985 and TOPCON GR5. Flight plans and location of base stations used during the aerial LiDAR acquisition in Kabasalan Floodplain are shown in Figure 5. ANNEX 4 lists the team members for the project.

Figure 6 and Figure 7 show the recovered NAMRIA reference points within the area. In addition, Table 2 and Table 3 show the details about the following NAMRIA control stations, while Table 4 shows the list of all ground control points occupied during the acquisition together with the corresponding dates of utilization. The data transfer sheets are found in ANNEX 6.



(b)

(a)

Figure 6. GPS set-up over ZGS-58 at Brgy. Sicade, Municipality of Kumalarang, Zamboanga del Sur (a) and NAMRIA reference point ZGS-58 (b) as recovered by the field team

Table 2. Details of the recovered NAMRIA horizontal control point ZGS-58 used as base station for the LiDAR acquisition

Station Name	ZGS-58	
Order of Accuracy	2^{nd}	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	7° 45’ 44.20587” North 123° 8’ 50.40994” East 31.65 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting Northing	516,245.79 meters 857,966.20 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7° 45’ 40.67639”North 123° 8’ 55.89231”East 96.974 meters

Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	516,245.79 meters 857,966.20 meters

(a)

(b)

Figure 7. GPS set-up over ZGS-68 at CENRO, Brgy. Poblacion, Municipality of Guipos, Zamboanga del Sur (a) and NAMRIA reference point ZGS-68 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point ZGS-68 used as base station for the LiDAR acquisition

Station Name	ZGS-68	
Order of Accuracy	2^{nd}	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	7° 43' 33.12722" North 123° 18' 488.96041" East 205.941 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting Northing	534,593.845 meters 854,250.138 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7° 43' 29.62251" North 123° 18' 54.44472" East 271.748 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	534,581.74 meters 853,951.14 meters

Table 4. Ground control points used during LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
February 24, 2016	23132P	1BLK73A055A	ZGS-58 & ZGS-68
February 26, 2016	23140P	1BLK73BS057A	ZGS-58 & ZGS-68

2.3 Flight Missions

Two (2) missions were conducted to complete the LiDAR data acquisition in Kabasalan Floodplain, for a total of eight hours and forty six minutes (846) of flying time for RP-C9122. All missions were acquired using the Pegasus LiDAR system. Table 5 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 6 presents the actual parameters used during the LiDAR data acquisition.

Table 5. Flight missions for LiDAR data acquisition in Kabasalan Floodplain

Date Surveyed	Flight Number	Flight Plan Area (km^2)	Surveyed Area (km^2)	Area Surveyed within the Floodplain (km^2)	Area Surveyed outside the Floodplain (km^2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
February 24, 2016	23132P	228	221.62	87.33	134.29	NA	4	11
February 26, 2016	23140P	369.6	288.69	13.62	275.07	NA	4	35
TOTAL		597.6	510.31	100.95	409.36	NA	8	46

Table 6. Actual parameters used during LiDAR data acquisition

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
23132P	800,1200	30	50	200	30	130	5
23140P	800,1100,1200	30	50	200	30	130	5

2.4 Survey Coverage

The LiDAR data acquisition covered the Kabasalan Floodplain (See ANNEX 7). Kabasalan Floodplain is located along the province of Zamboanga Sibugay with majority of the floodplain situated within the municipalities of Naga and Kabasalan. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 7. The actual coverage of the LiDAR acquisition for Kabasalan Floodplain is presented in Figure 8.

Table 7. List of municipalities and cities surveyed during Kabasalan Floodplain LiDAR survey

Province	Municipality/ City	Area of Municipality/City (km^2)	Total Area Surveyed (km^2)	Percentage of Area Surveyed
Zamboanga Sibugay	Naga	164.18	86.64	52.77%
	Kabasalan	317.28	95.02	29.95%
	Siay	186.47	32.23	17.29%
	Ipil	130.9	21.04	16.07%
	Titay	176.5	8.68	4.92%
Total		975.33	243.61	24.98%

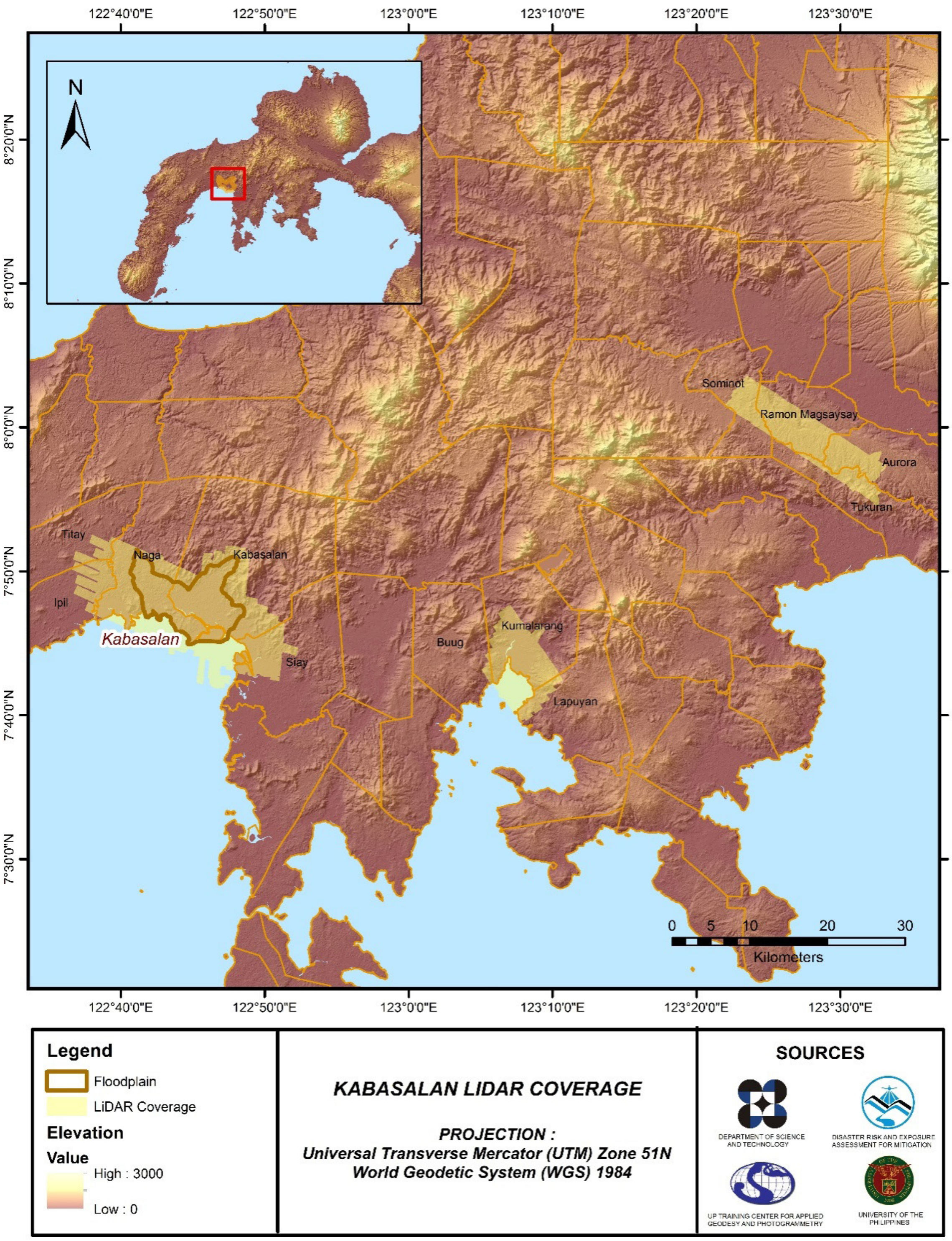


Figure 8. Actual LiDAR survey coverage for Kabasalan Floodplain

CHAPTER 3: LIDAR DATA PROCESSING FOR KABASALAN FLOODPLAIN

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The methods applied in this Chapter were based on the DREAM methods manual (Ang, et al., 2014) and further enhanced and updated in Paringit, et al. (2017).

3.1 Overview of the LIDAR Data Pre-Processing

The data transmitted by the Data Acquisition Component are checked for completeness based on the list of raw files required to proceed with the pre-processing of the LiDAR data. Upon acceptance of the LiDAR field data, georeferencing of the flight trajectory is done in order to obtain the exact location of the LiDAR sensor when the laser was shot. Point cloud georectification is performed to incorporate correct position and orientation for each point acquired. The georectified LiDAR point clouds are subject for quality checking to ensure that the required accuracies of the program, which are the minimum point density, vertical and horizontal accuracies, are met. The point clouds are then classified into various classes before generating Digital Elevation Models such as Digital Terrain Model and Digital Surface Model.

Using the elevation of points gathered in the field, the LiDAR-derived digital models are calibrated. Portions of the river that are barely penetrated by the LiDAR system are replaced by the actual river geometry measured from the field by the Data Validation and Bathymetry Component. LiDAR acquired temporally are then mosaicked to completely cover the target river systems in the Philippines. Orthorectification of images acquired simultaneously with the LiDAR data is done through the help of the georectified point clouds and the metadata containing the time the image was captured.

These processes are summarized in the flowchart shown in Figure 9.

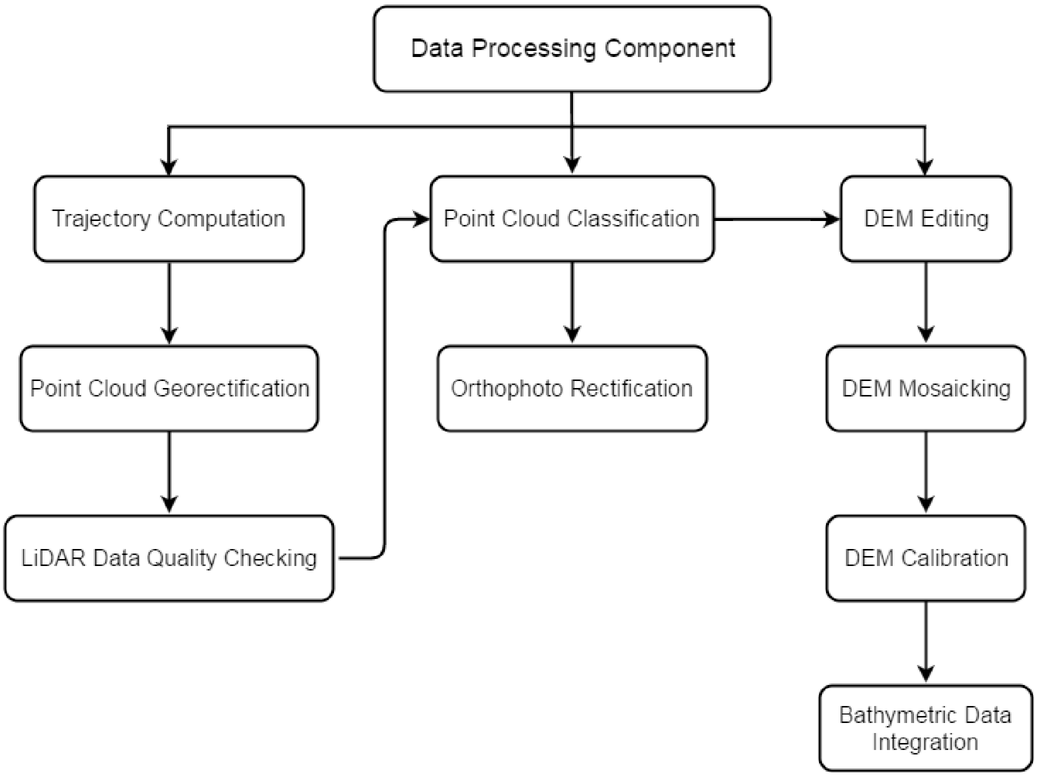


Figure 9. Schematic diagram for data pre-processing component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Kabasalan Floodplain can be found in ANNEX 5. Missions flown during the first survey conducted on February 2016 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system over Municipality of Naga and Kabasalan, Zamboanga Sibugay. The Data Acquisition Component (DAC) transferred a total of 50.90 Gigabytes of Range data, 571 Megabytes of POS data, and115.6 Megabytes of GPS base station data to the data server on March 07, 20156. There are no transferred raw image data for this floodplain. The Data Pre-Processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Kabasalan was fully transferred on March 10, 2016 as indicated on the Data Transfer Sheets for Kabasalan Floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 23132P, one of the Kabasalan flights, which is the North, East, and Down position RMSE values, are shown in Figure 10. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on February 21, 2016 00:00AM. The y-axis is the RMSE value for that particular position.

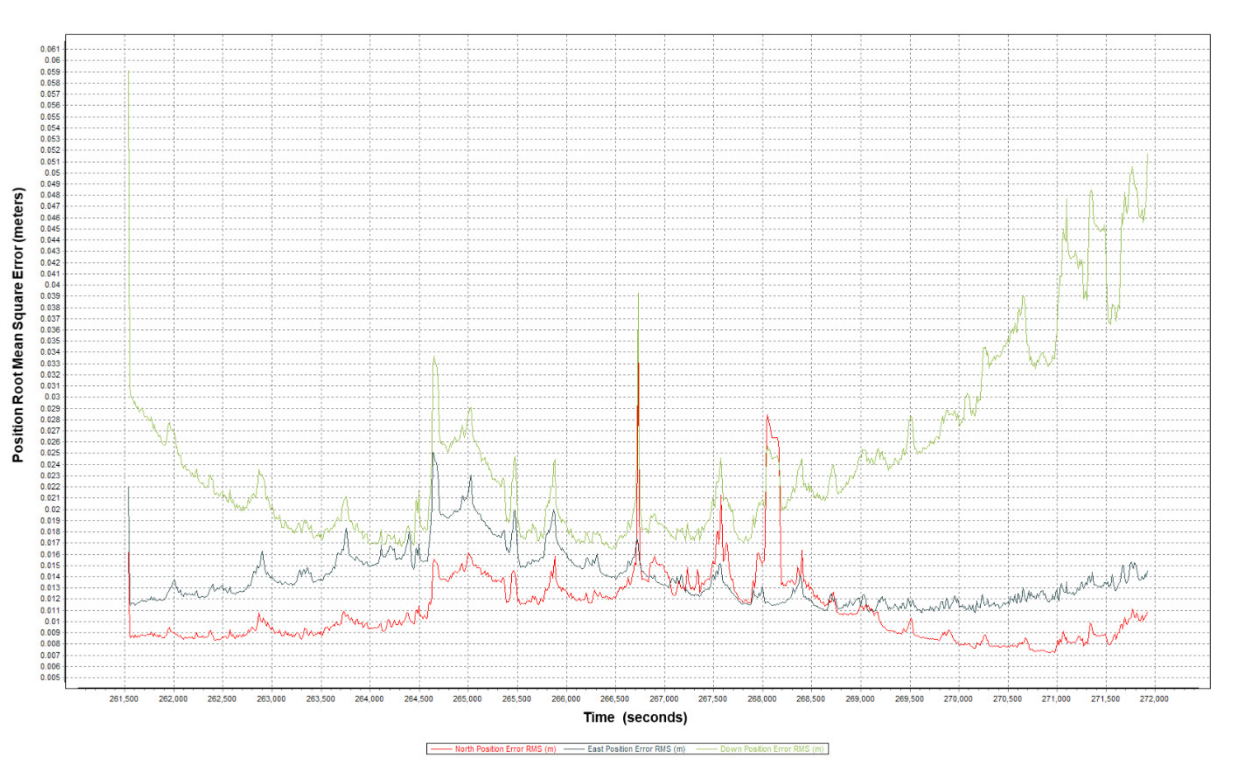


Figure 10. Smoothed Performance Metrics of Kabasalan flight 23132P

The time of flight was from 261,500 seconds to 272,000 seconds, which corresponds to morning of February 24, 2016. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimize the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 10 shows that the North position RMSE peaks at 3.30 centimeters, the East position RMSE peaks at 2.50 centimeters, and the Down position RMSE peaks at 3.92 centimeters, which are within the prescribed accuracies described in the methodology.

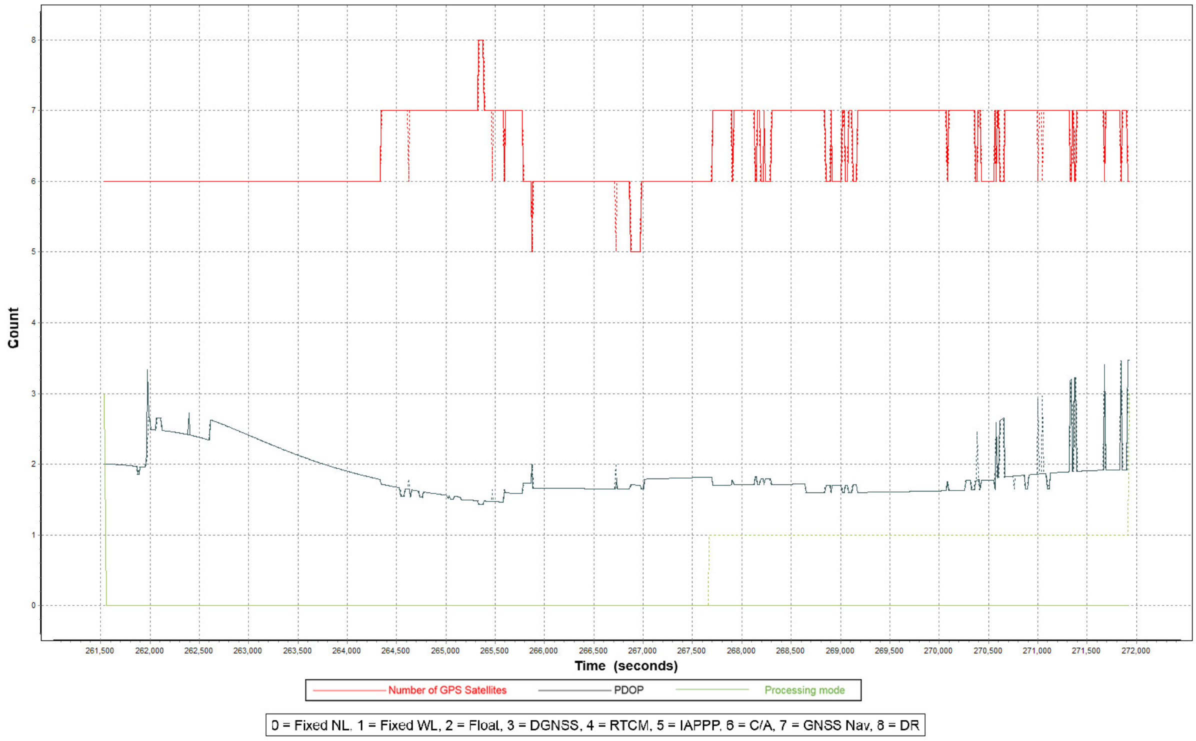


Figure 11. Solution status parameters of Kabasalan flight 23132P

The Solution Status parameters of flight 23132P, one of the Kabasala nflights, which are the number of GPS satellites, Positional Dilution of Precision, and the GPS processing mode used, are shown in Figure 11. The graphs indicate that the number of satellites during the acquisition did not go down below 5. Majority of the time, the number of satellites tracked was between 6 and 8. The PDOP value also did not go above the value of 3, which still indicates optimal GPS geometry. The processing mode stayed at the value of 0 for almost the entire survey time with some parts up to 1 attributed to the turn performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Kabasalan flights is shown in Figure 12.

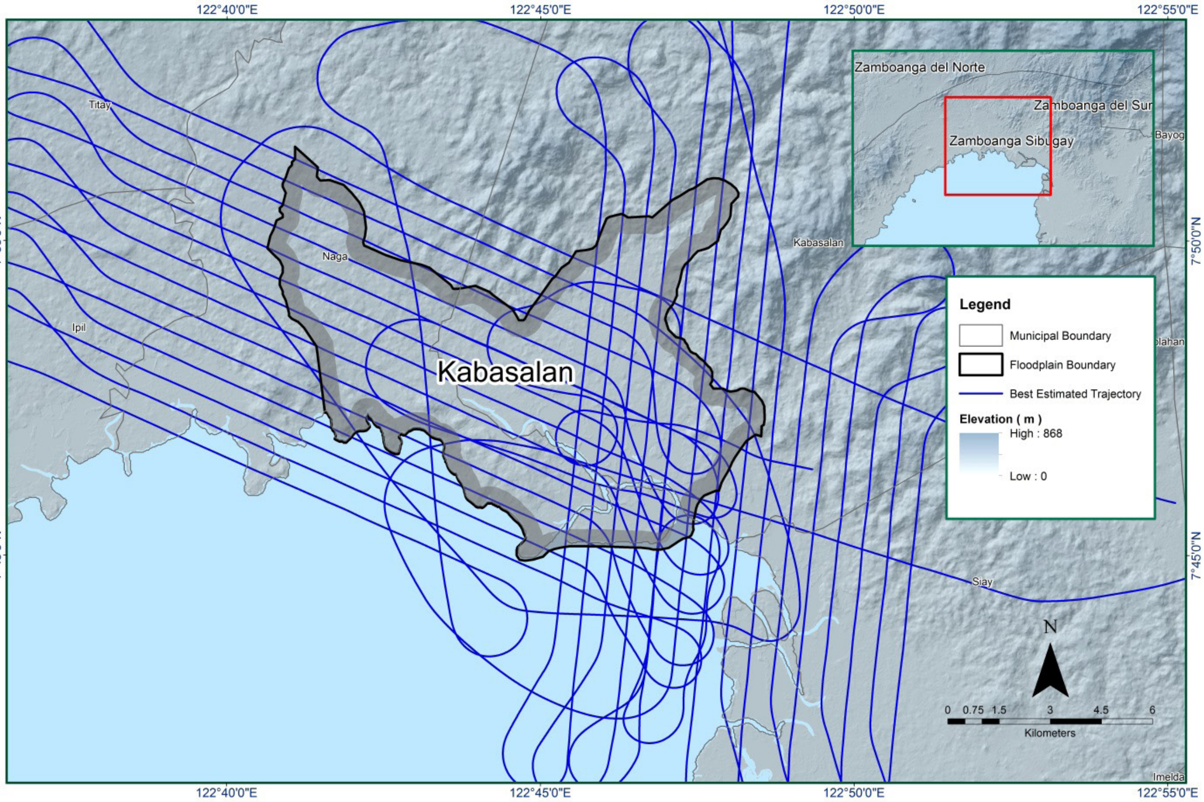


Figure 12. Best estimated trajectory of the LiDAR missions conducted over the Kabasalan Floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contain 33 flight lines, with each flight line containing two channels, since the Pegasus system contains two channels. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Kabasalan Floodplain is given in Table 8.

Table 8. Self-calibration results values for Kabasalan flights

Parameter	Acceptable Value	Computed Value
Boresight Correction stdev	(<0.001degrees)	0.000238
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.000943
GPS Position Z-correction stdev	(<0.01meters)	0.0086

The optimum accuracy was obtained for all Kabasalan flights based on the computed standard deviations of the corrections of the orientation parameters. Standard deviation values for individual blocks are available in ANNEX 8.

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Kabasalan Floodplain is shown in Figure 13. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

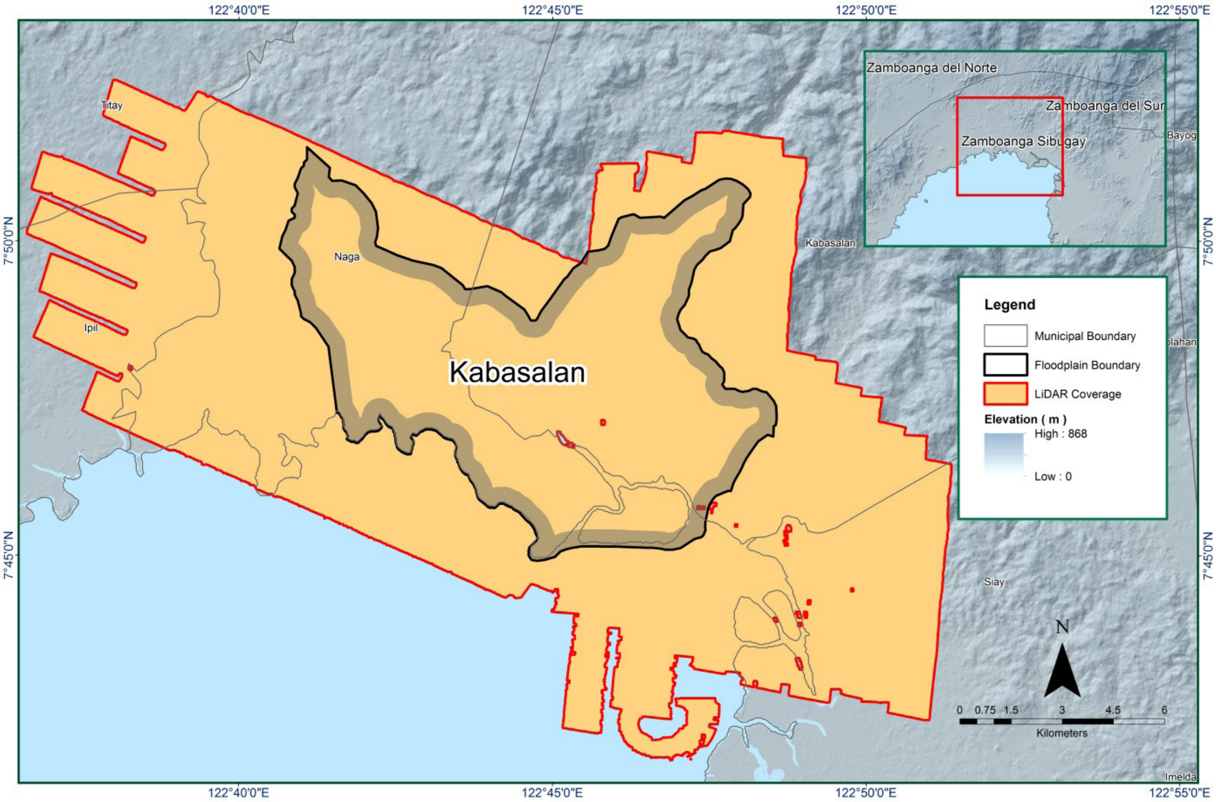


Figure 13. Boundary of the processed LiDAR data over Kabasalan Floodplain

The total area covered by the Kabasalan missions is 329.56 sq km that is comprised of two (2) flight acquisitions grouped and merged into three (3) blocks as shown in Table 9.

Table 9. List of LiDAR blocks for Kabasalan Floodplain

LiDAR Blocks	Flight Numbers	Area (sq. km)
Pagadian_Blk73A	23132P	182.03
Pagadian_Blk73A_supplement	23132P	61.77
Pagadian_Blk73B	23140P	85.76
TOTAL		**329.56**

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 14. Since the Pegasus system employs two channels, an average value of 2 (blue) is expected for areas where there is limited overlap, and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines.

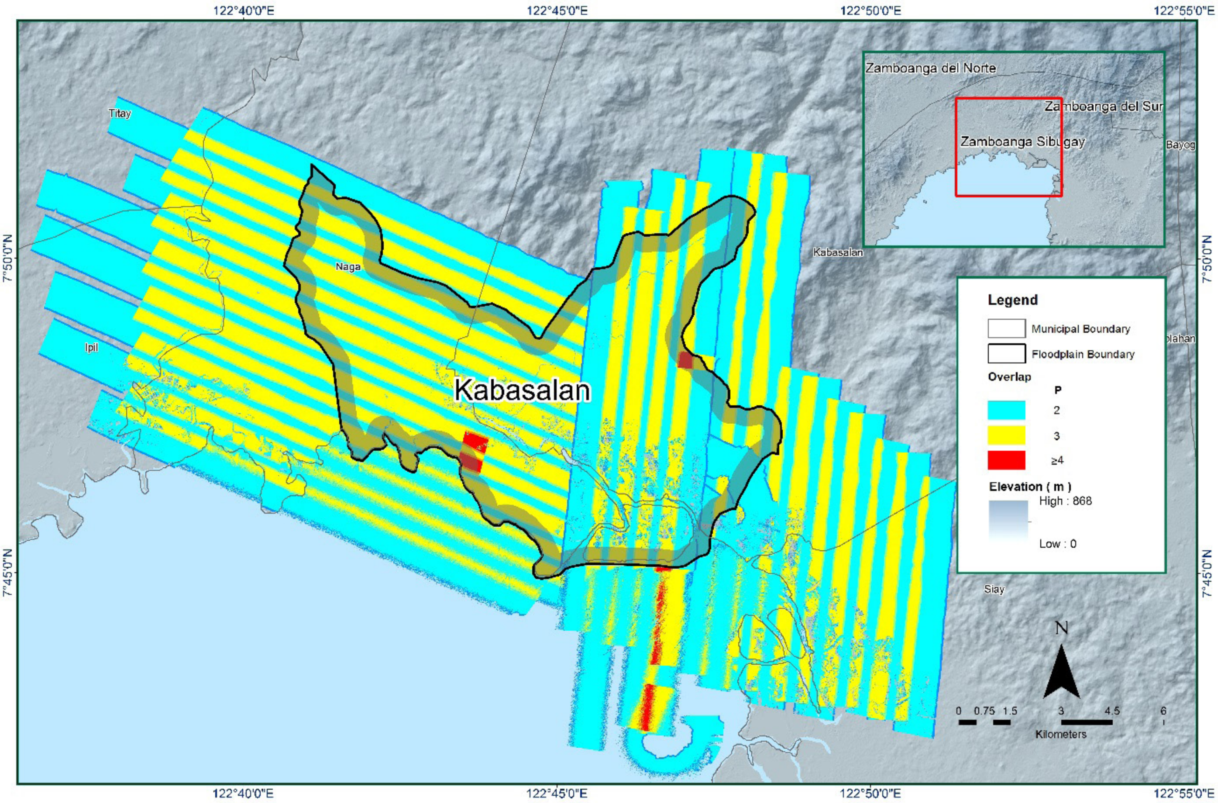


Figure 14. Image of data overlap for Kabasalan Floodplain

The overlap statistics per block for the Kabasalan Floodplain can be found in ANNEX 8. It should be noted that one pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 39.42% and 45.26%, respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 15. It was determined that all LiDAR data for Kabasalan Floodplain satisfy the point density requirement, and the average density for the entire survey area is 2.86 points per square meter.

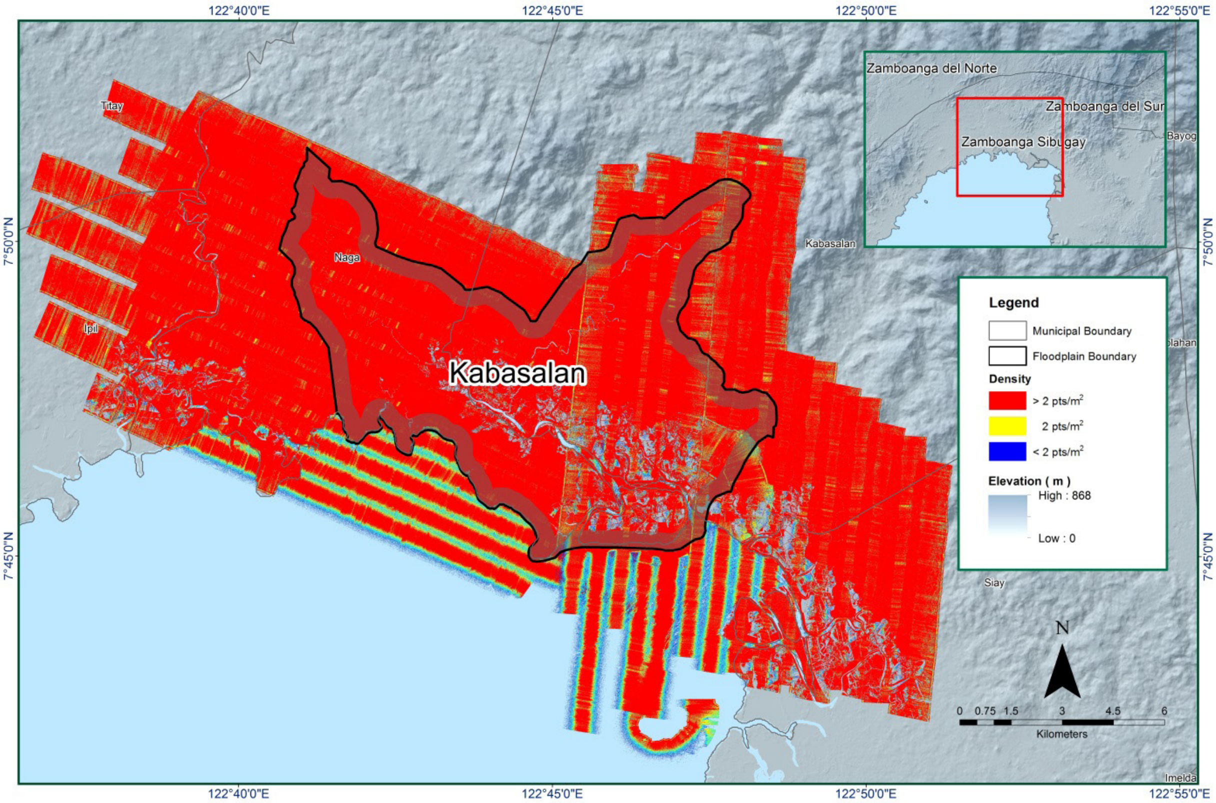


Figure 15. Pulse density map of merged LiDAR data for Kabasalan Floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 16. The default color range is from blue to red, where bright blue areas correspond to portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.20m relative to elevations of its adjacent flight line. Bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20m relative to elevations of its adjacent flight line. Areas with bright red or bright blue need to be investigated further using Quick Terrain Modeler software.

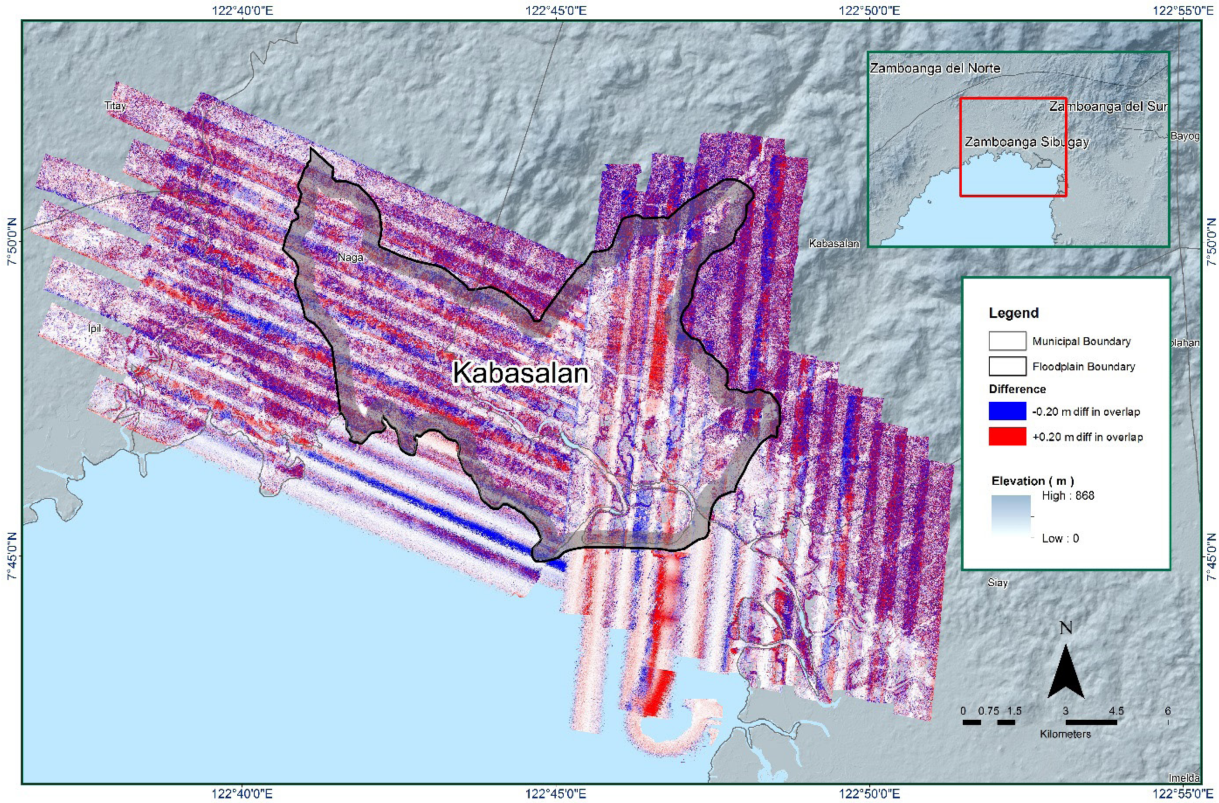


Figure 16. Elevation difference between flight lines for Kabasalan Floodplain

A screen capture of the processed LAS data from a Kabasalan flight 23132P loaded in QT Modeler is shown in Figure 17. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

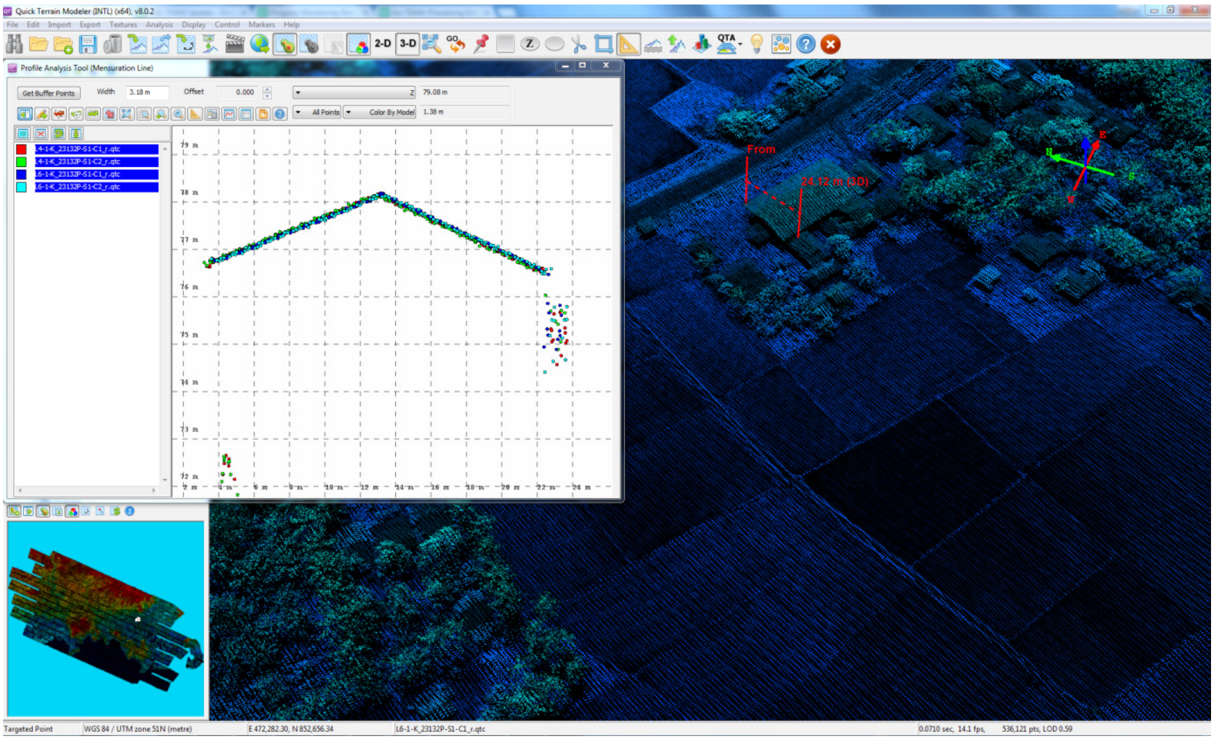


Figure 17. Quality checking for a Kabasalan flight 23132P using the Profile Tool of QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 10. Kabasalan classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	268,837,354
Low Vegetation	223,800,946
Medium Vegetation	334,948,854
High Vegetation	815,329,915
Building	9,556,051

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Kabasalan Floodplain is shown in Figure 18. A total of 449 1-km by 1-km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 10. The point cloud has a maximum and minimum height of 512.68 meters and 56.73 meters, respectively.

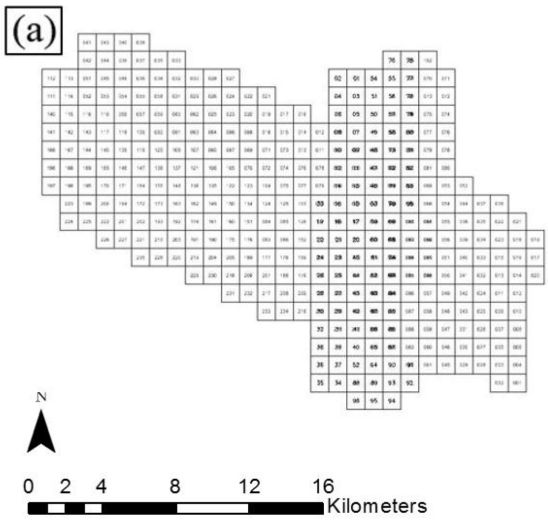


Figure 18. Tiles for Kabasalan Floodplain (a) and classification results (b) in TerraScan

An isometric view of an area before and after running the classification routines is shown in Figure 19. The ground points are in orange, the vegetation is in different shades of green, and the buildings are in cyan. It can be seen that residential structures adjacent or even below canopy are classified correctly due to the density of the LiDAR data.

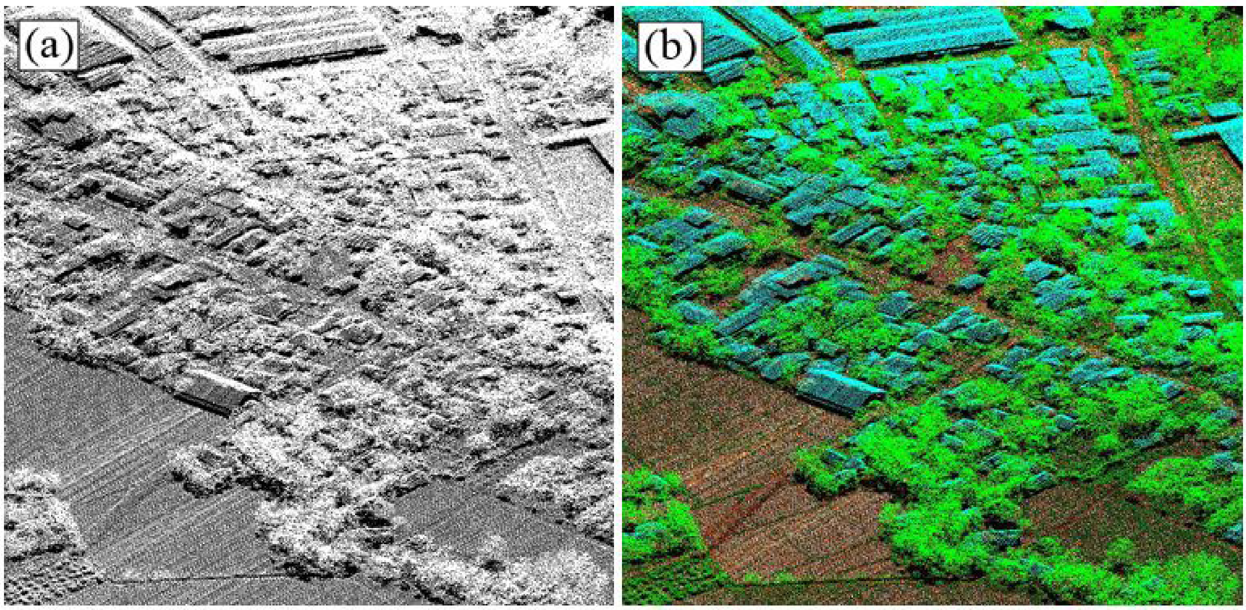


Figure 19. Point cloud before (a) and after (b) classification

The production of last return (V_ASCII) and the secondary (T_ ASCII) DTM, first (S_ ASCII) and last (D_ ASCII) return DSM of the area in top view display are shown in Figure 20. It shows that DTMs are the representation of the bare earth while on the DSMs, all features are present such as buildings and vegetation.

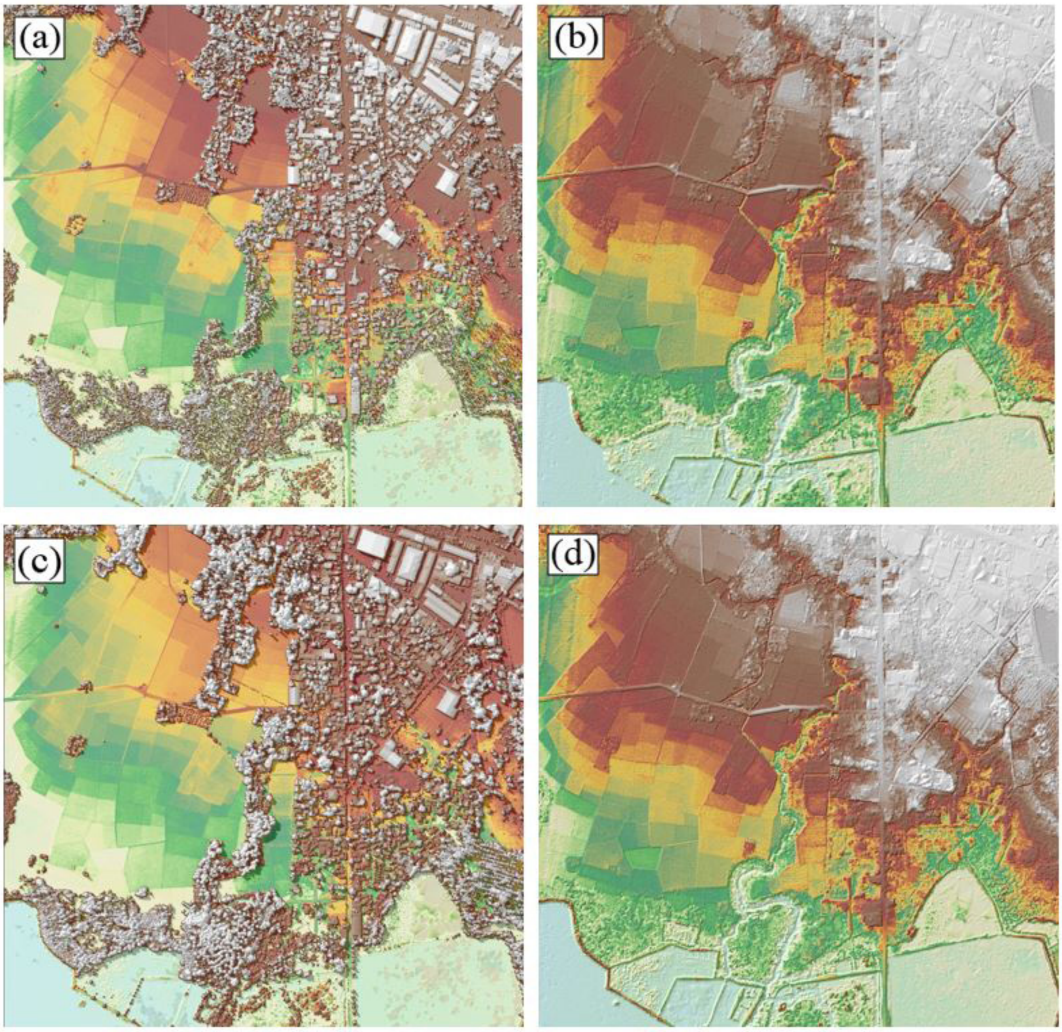


Figure 20. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Kabasalan Floodplain

3.7 LiDAR Image Processing and Orthophotograph Rectification

There are no available orthophotographs for the Kabasalan Floodplain.

3.8 DEM Editing and Hydro-Correction

Three (3) mission blocks were processed for Kabasalan Floodplain. These blocks are composed of Pagadian block with a total area of 329.56 sq.km. Table 11 shows the name and corresponding area of each block in square kilometers.

Table 11. LiDAR blocks with its corresponding area

LiDAR Blocks	Area (sq.km)
Pagadian_Blk73A	182.03
Pagadian_Blk7A_supplement	61.77
Pagadian_Blk73B	85.77
TOTAL	**329.56sq.km**

Portions of DTM before and after manual editing are shown in Figure 21. The rice field or fishpond embankment (Figure 21a) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 21b) to allow the correct flow of water. The bridge (Figure 21c) is also considered to be an impedance to the flow of water along the river and has to be removed (Figure 21d) in order to hydrologically correct the river.

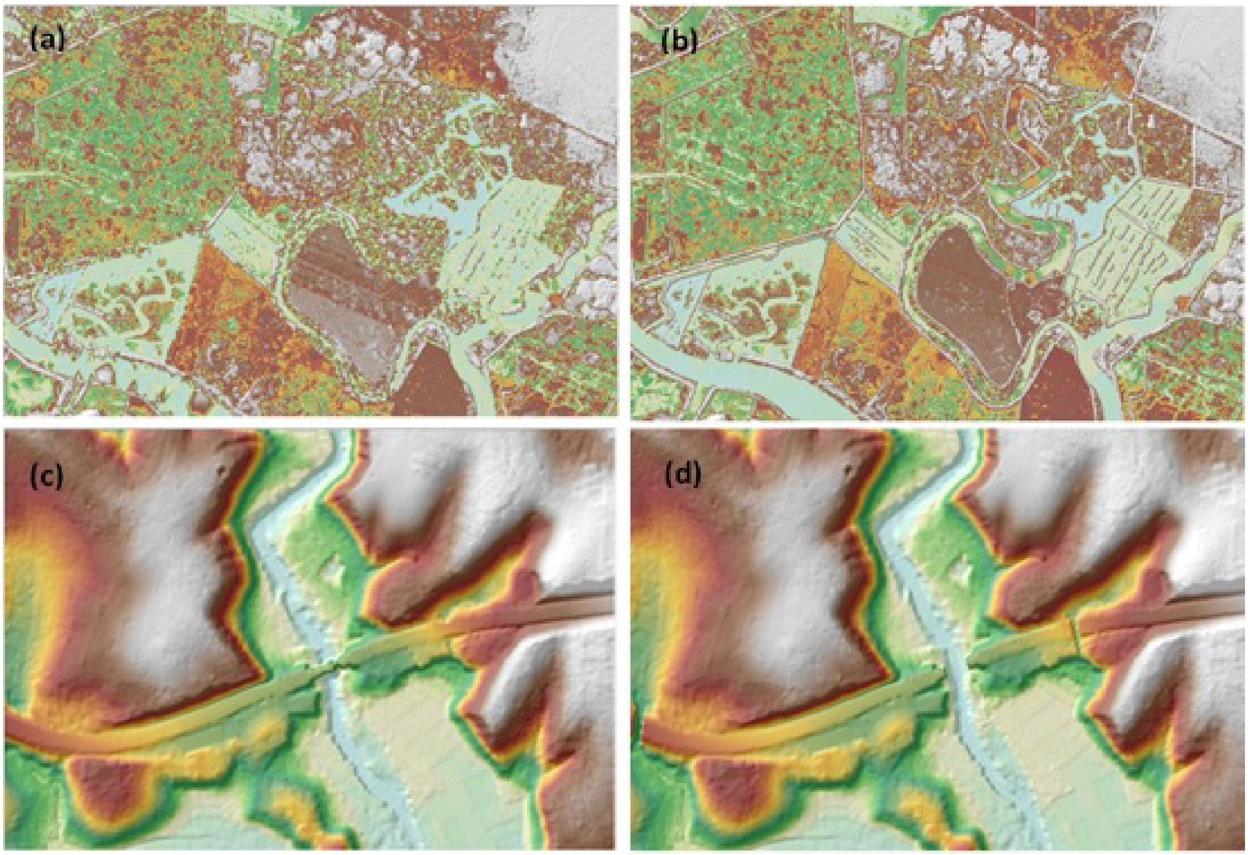


Figure 21. Portions in the DTM of Kabasalan Floodplain—a paddy field before (a) and after (b) data retrieval; a bridge before (c) and after (d) manual editing

3.9 Mosaicking of Blocks

Zamboanga_Blk75A was used as the reference block at the start of mosaicking. After which, Pagadian_Blk73A, Pagadian_Blk73A_supplement and Pagadian_Blk73B were mosaicked to the reference block.

Mosaicked LiDAR DTM for Kabasalan Floodplain is shown in Figure 22. It can be seen that the entire Kabasalan Floodplain is 100% covered by LiDAR data.

Table 12. Shift values of each LiDAR Block of Kabasalan Floodplain

Mission Blocks	Shift Values (meters)		
	x	Y	z
Pagadian_Blk73A	0.44	1.00	0.00
Pagadian_Blk73A_supplement	-2.00	1.00	0.00
Pagadian_Blk73B	-3.00	1.00	0.20

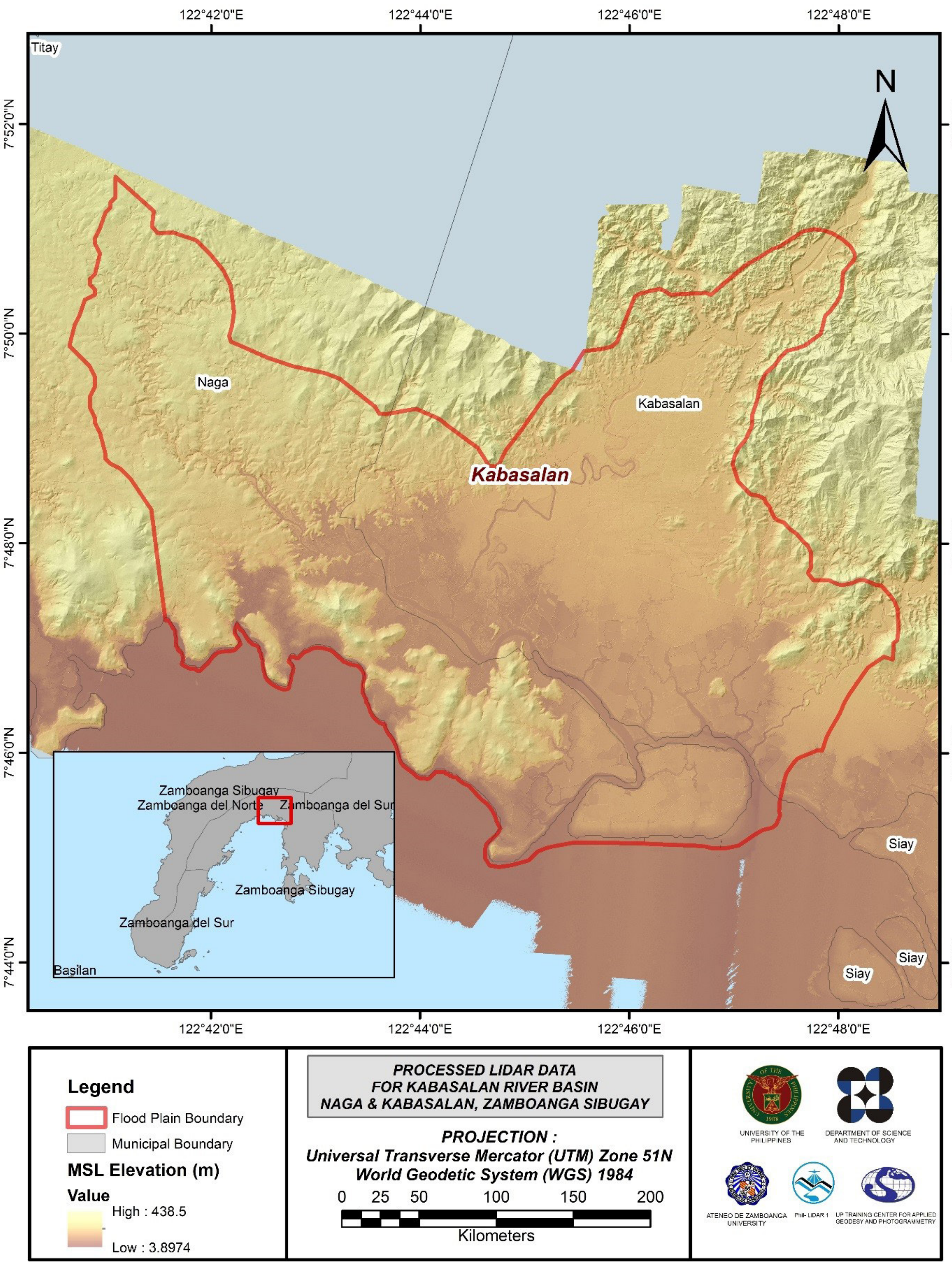


Figure 22. Map of Processed LiDAR data for Kabasalan Floodplain

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Kabasalan to collect points with which the LiDAR dataset is validated is shown in Figure 23.

Simultaneous mosaicking was done for the Zamboanga_Pagadian LiDAR blocks and the only available data that time was for Sanito. The Kabasalan Floodplain is included in the set of blocks previously mosaicked; therefore, the Sanito calibration data and methodology was used.

A total of 3,526 survey points from Sanito data were used for calibration and validation of all the blocks of Zamboanga_Pagadian LiDAR data. Random selection of 80% of the survey points, resulting in 2,820 points, was used for calibration. A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure 24. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration elevation values is 9.10 meters with a standard deviation of 0.05 meters. Calibration for Zamboanga_Pagadian LiDAR data was done by adding the height difference value, 9.10 meters, to Zamboanga mosaicked LiDAR data. Table 13 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

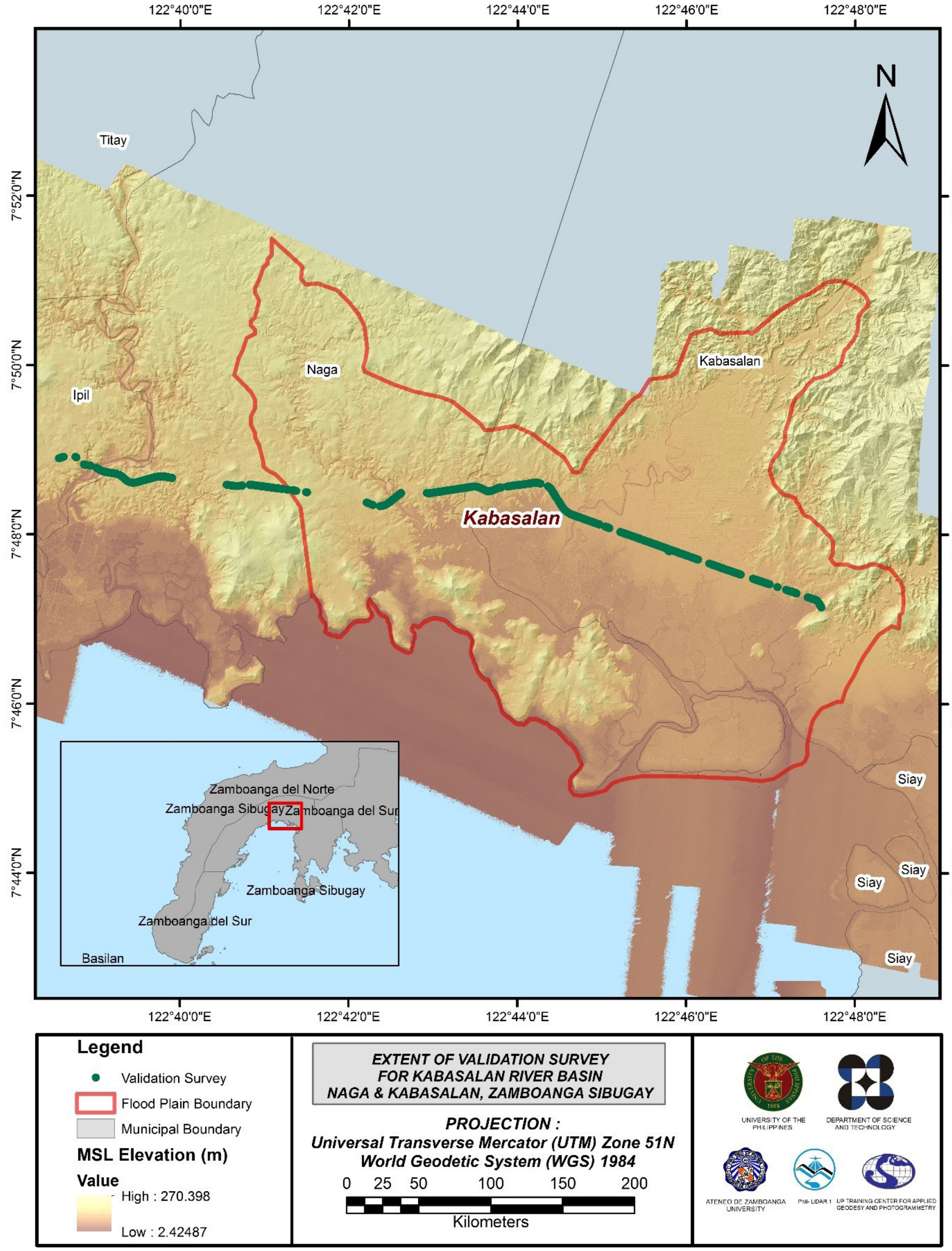


Figure 23. Map of Kabasalan Floodplain with validation survey points in green

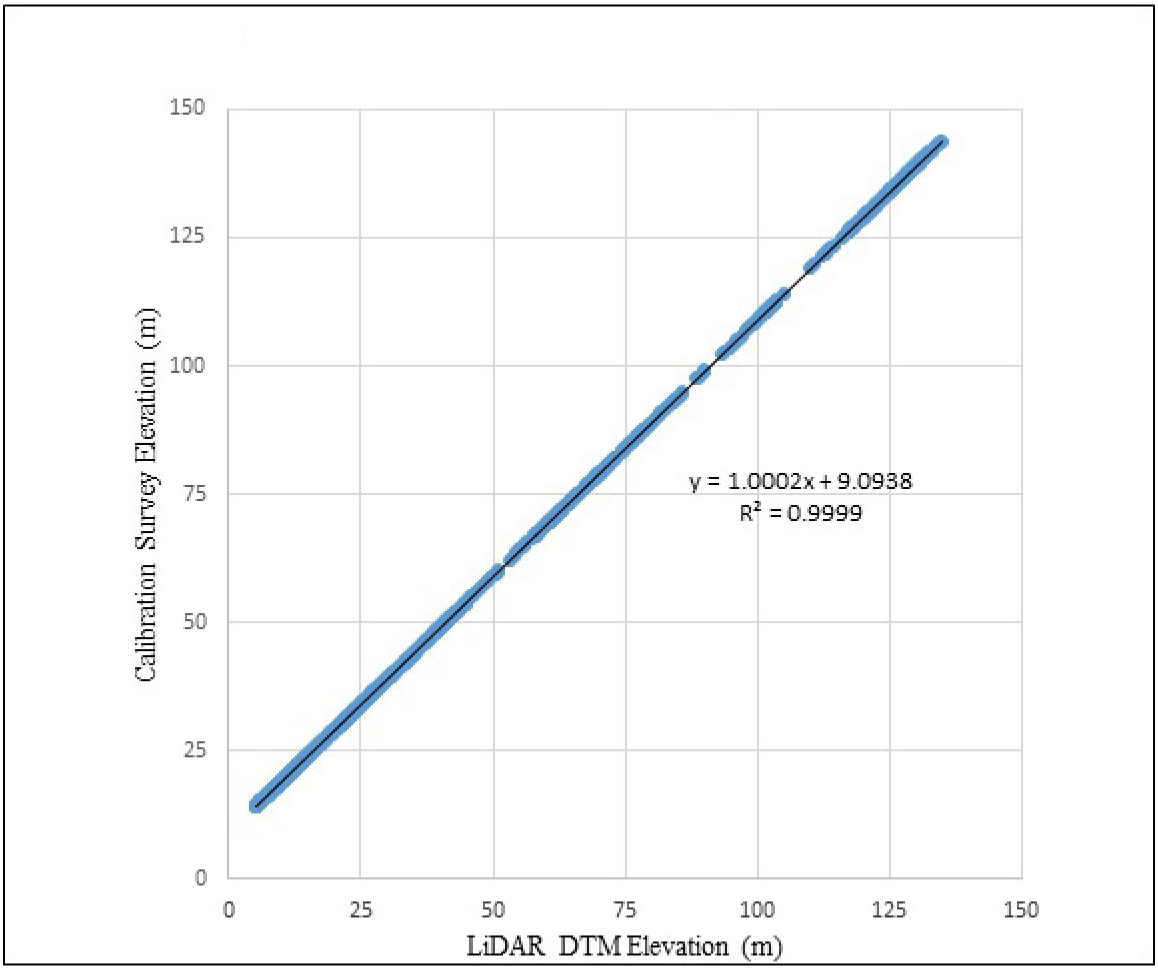


Figure 24. Correlation plot between calibration survey points and LiDAR data

Table 13. Calibration statistical measures

Calibration Statistical Measures	Value (meters)
Height Difference	9.10
Standard Deviation	0.05
Average	9.10
Minimum	8.99
Maximum	9.20

The Kabasalan Floodplain has a total of 1,293 survey points and only 20% of the total survey points, resulting in 259 points, were randomly selected and used for the validation of calibrated Kabasalan DTM. A good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM, is shown in Figure 25. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.20 meters with a standard deviation of 0.16 meters, as shown in Table 14.

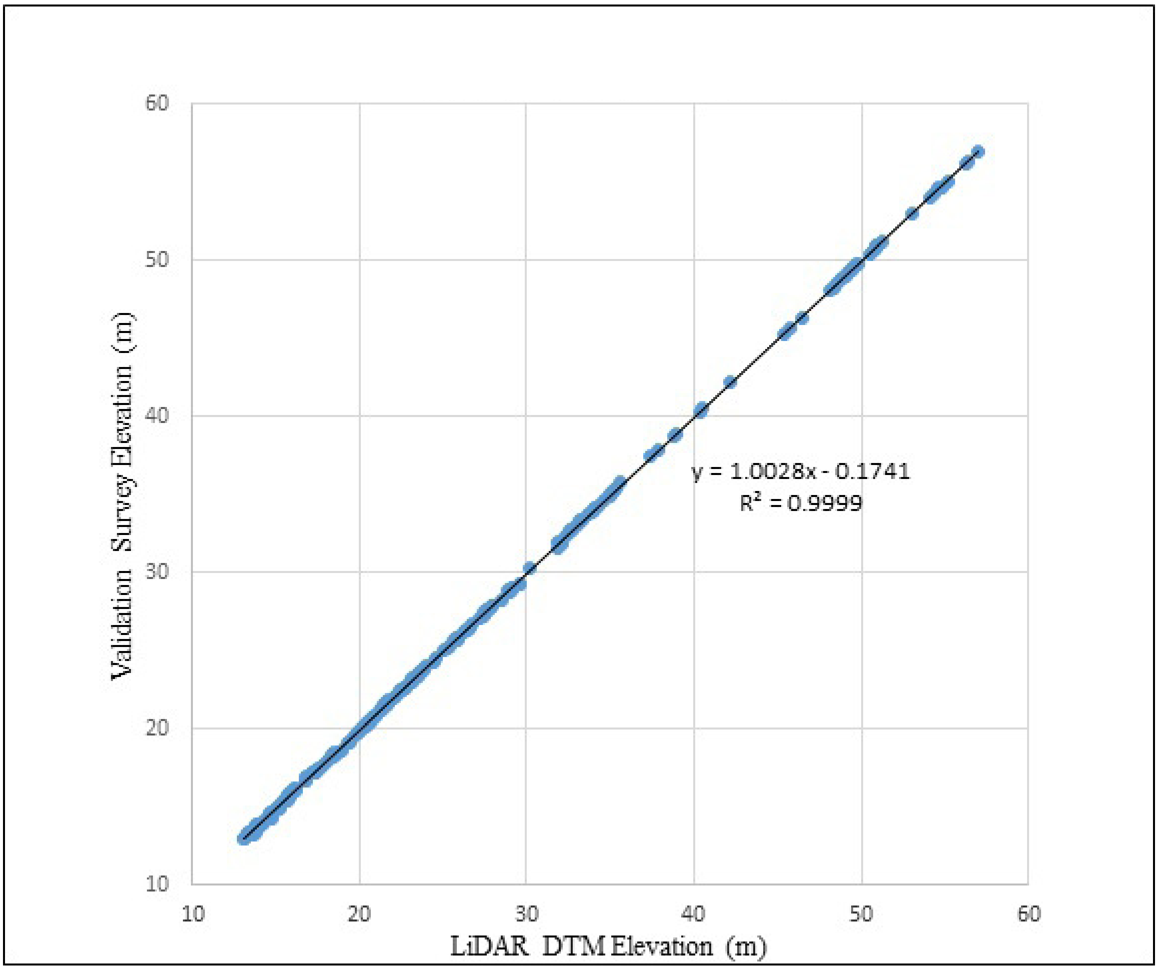


Figure 25. Correlation plot between validation survey points and LiDAR data

Table 14. Validation statistical measures

Validation Statistical Measures	Value (meters)
RMSE	0.20
Standard Deviation	0.16
Average	-0.13
Minimum	-0.45
Maximum	0.19

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and zigzag data were available for Kabasalan with 4,911 bathymetric survey points. The resulting raster surface produced was done by Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.27 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Kabasalan integrated with the processed LiDAR DEM is shown in Figure 26.

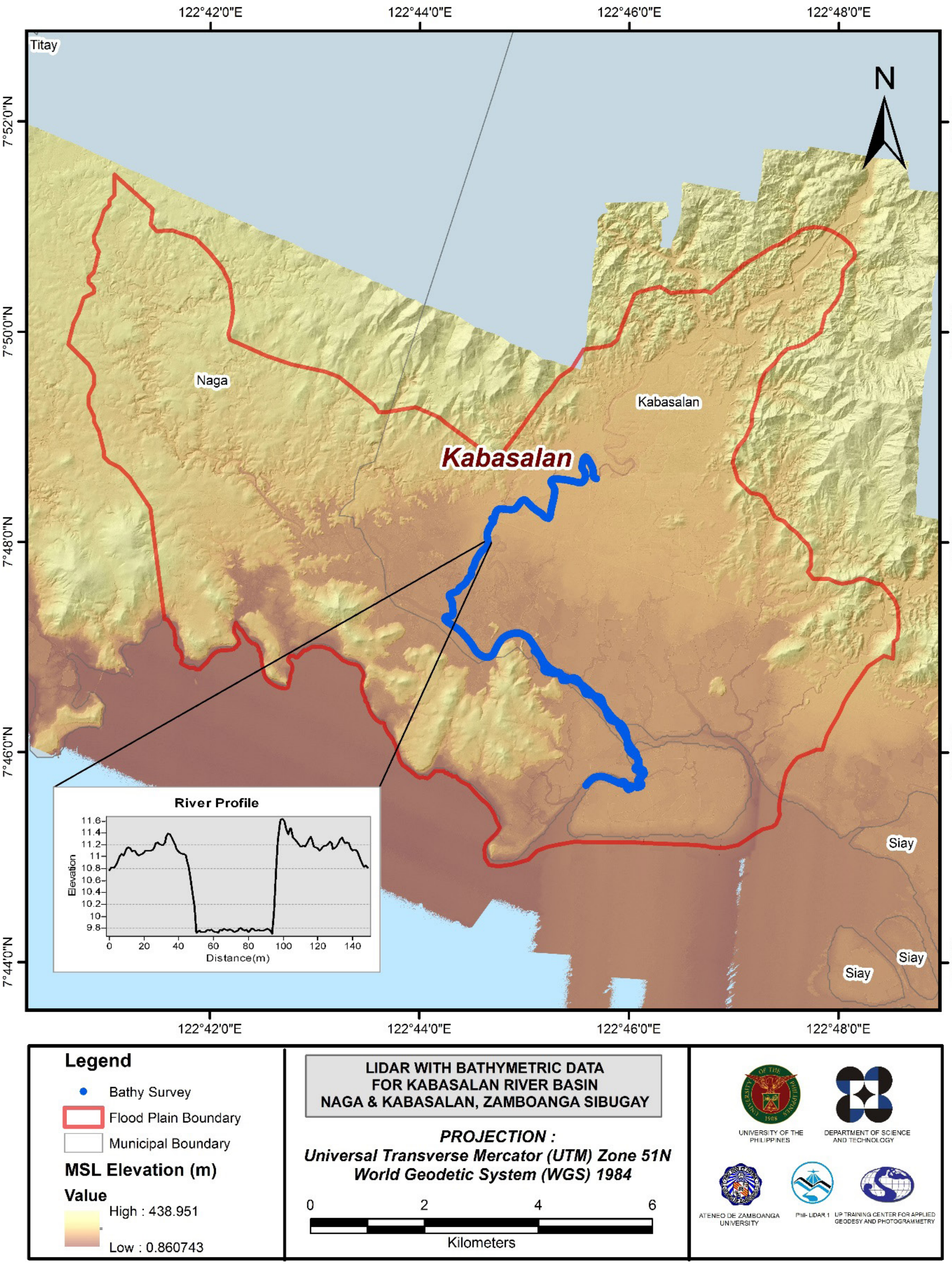


Figure 26. Map of Kabasalan Floodplain with bathymetric survey points shown in blue

3.12 Feature Extraction

The features salient in flood hazard exposure analysis include buildings, road networks, bridges, and water bodies within the floodplain area with 200 m buffer zone. Mosaicked LiDAR DEM with 1 m resolution was used to delineate footprints of building features, which consist of residential buildings, government offices, medical facilities, religious institutions, and commercial establishments, among others. Road networks comprise main thoroughfares such as highways and municipal and barangay roads essential for routing of disaster response efforts. These features are represented by a network of road centerlines.

3.12.1 Quality Checking of Digitized Features' Boundary

Kabasalan Floodplain, including its 200 m buffer, has a total area of 103.23 sq.km. For this area, a total of 5.0 sq.km, corresponding to a total of 976 building features, is considered for QC. Figure 27 shows the QC blocks for Kabasalan Floodplain.

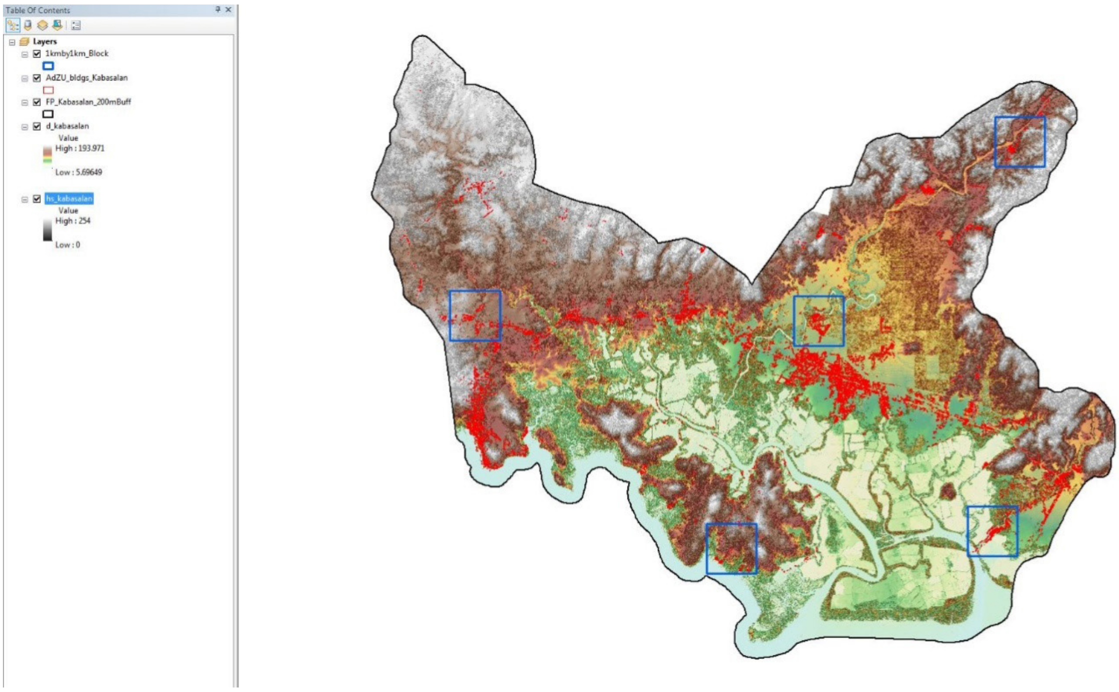


Figure 27. Blocks (in blue) of Kabasalan building features that were subjected to QC

Quality checking of Kabasalan building features resulted in the ratings shown in Table 15.

Table 15. Quality Checking ratings for Kabasalan building features

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Kabasalan	99.49	99.49	90.88	PASSED

3.12.2 Height Extraction

Height extraction was done for 9,996 building features in Kabasalan Floodplain. Of these building features, 401 were filtered out after height extraction, resulting in 9,595 buildings with height attributes. The lowest building height is at 2.0m, while the highest building is at 8.02m.

3.12.3 Feature Attribution

One of the Research Associate of ADZU Phil-LiDAR 1 was able to develop GEONYT, an offline web-based application for feature attribution extracted from a LiDAR-based Digital Surface Model and which attribution is conducted by combining automatic data consolidation, geotagging, and offline navigation. The app is conveniently integrated in a smart phone/ tablet. The data collected are automatically stored in database and can be viewed as CSV (or excel) and KML (can viewed via Google Earth). The GEONYT App was the main tool used in all feature attribution activity of the team.

The team, through the endorsement of the local government units of the municipality/city, hired a number of enumerators who conducted the house-to-house survey of the features using the GEONYT application. The team provided the enumerators smart tablets where the GEONYT is integrated. The number of days by which the survey was conducted was dependent on the number of features of the floodplain of the river basin; likewise, a number of enumerators are also dependent on the availability of the tablet and the number of features of the floodplain.

Table 16 summarizes the number of building features per type. On the other hand, Table 17 shows the total length of each road type, while Table 18 shows the number of water features extracted per type.

Table 16. Building features extracted for Kabasalan Floodplain

Facility Type	No. of Features
Residential	8639
School	276
Market	98
Agricultural/Agro-Industrial Facilities	36
Medical Institutions	17
Barangay Hall	27
Military Institution	3
Sports Center/Gymnasium/Covered Court	22
Telecommunication Facilities	2
Transport Terminal	7
Warehouse	33
Power Plant/Substation	2
NGO/CSO Offices	4
Police Station	3
Water Supply/Sewerage	4
Religious Institutions	96
Bank	1
Factory	1
Gas Station	6
Fire Station	1
Other Government Offices	34
Other Commercial Establishments	80
N/A	204
Total	**9595**

Table 17. Total length of extracted roads for Kabasalan Floodplain

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Kabasalan	28.79	34.94	0.00	22.53	0.00	**86.26**

Table 18. Number of extracted water bodies for Kabasalan Floodplain

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Kabasalan	83	0	1	0	456	**540**

A total of 6 bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

All extracted ground features were completely given the required attributes. All these output features comprise the flood hazard exposure database for the floodplain. This step completes the feature extraction phase of the project.

Figure 28 shows the Digital Surface Model (DSM) of Kabasalan Floodplain overlaid with its ground features.

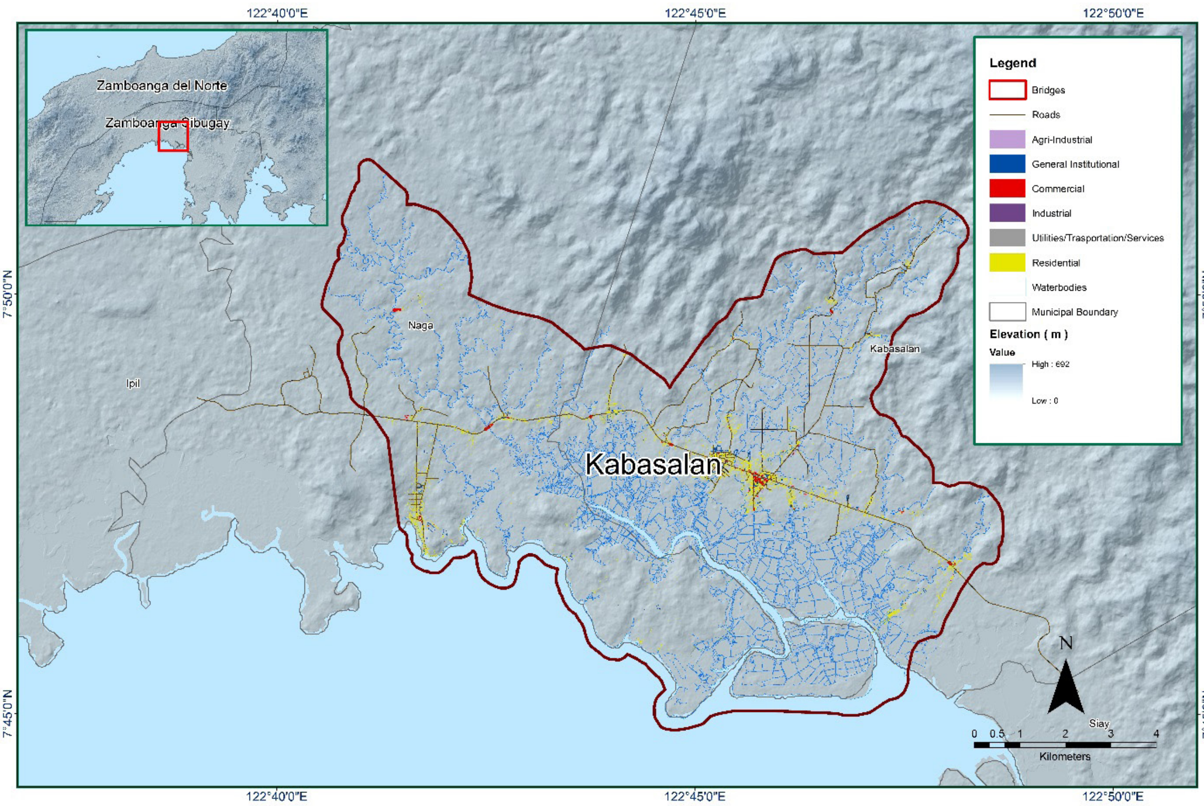


Figure 28. Extracted features for Kabasalan Floodplain

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS OF THE KABASALAN RIVER BASIN

Louie P. Balicanta, Joemarie S. Caballero, Patrizcia Mae. P. dela Cruz, Dexter T. Lozano, For. Dona Rina Patricia C. Tajora, Elaine Bennet Salvador, For. Rodel C. Alberto

The methods applied in this Chapter were based on the DREAM methods manual (Balicanta et al., 2014) and further enhanced and updated in Paringit et al. (2017).

4.1 Summary of Activities

The Data Validation and Bathymetry Component (DVBC) conducted field surveys in Kabasalan River on July 23, 2015 to August 7, 2015 with the following scope of work: reconnaissance survey to determine the viability of traversing the planned routes for bathymetric survey and recovery of control points to be occupied; courtesy call with Ateneo de Zamboanga University, Kabasalan LGUs, and PNP; control survey for the establishment of control point at Kabasalan Bridge approach; cross-section and bridge-as-built features determination and water level marking; validation points acquisition survey with an estimated distance of 18.2 km; and bathymetric survey of Kabasalan River starting from Brgy. Banker down to the barangays of Bolo Batalion, Caingle,t and Lumbayao with approximate length of 12.85 km (see Figure 29).

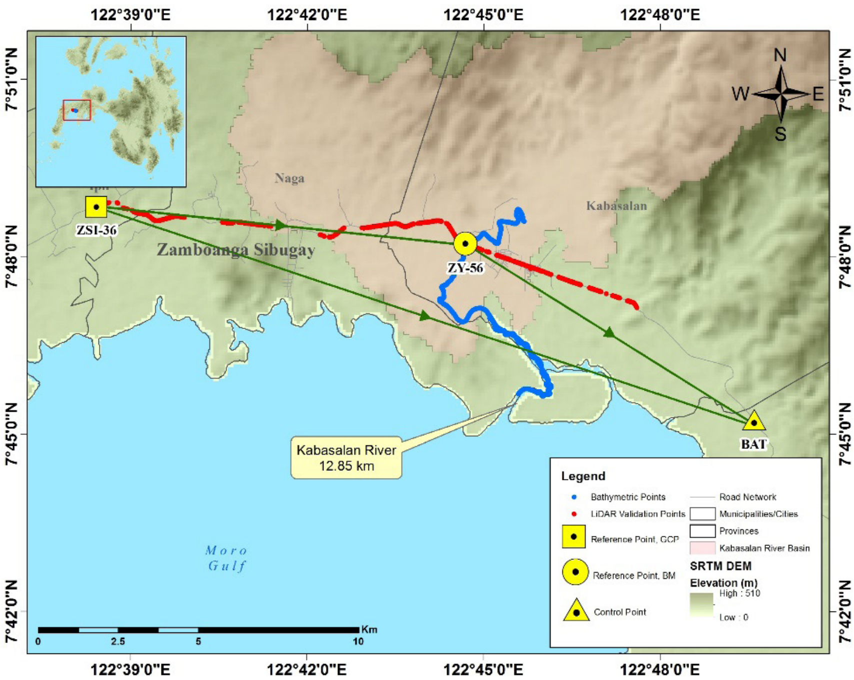


Figure 29. Extent of the bathymetric survey (in blue line) in Kabasalan River and the LiDAR data validation survey (in red)

4.2 Control Survey

Figure 30. GNSS network covering Kabasalan River.

The GNSS network used for Kabasalan River Survey was composed of a single loop established on July 25, 2015 occupying the following reference points: ZSI-36, a second-order GCP in Brgy. Bacalan, Municipality of Ipil; and ZY-56, a first-order BM located in the Pagadian-Zamboanga National Road, Brgy.Sininan, Municipality of Kabasalan.

A UP-established control point, BAT, established at the approach of Batu Bridge in Brgy. Batu, Siay, Zamboanga Sibugay was also occupied to use as marker during the survey.

The summary of reference and control points and its location is summarized in Table 19 while the GNSS network established is illustrated in Figure 30.

Table 19. Control points occupied during control survey in Kabasalan River, Zamboanga Sibugay (Source: NAMRIA, UP-TCAGP)

Control point Name	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoid Height, (m)	BM Ortho (m)	Date Established
ZSI-36	2nd Order, GCP	7°48’50.43692”	122°38’25.03291”	94.318	-	2006
ZY-56	1st Order, BM	-	-	74.265	6.187	2007
BAT	UP established	-	-	-	-	7-25-2015

The GNSS set-up on the recovered reference points, ZSI-36 and ZY-56, are shown in Figure 31 and Figure 32, respectively; while the established control point BAT is shown in Figure 33.

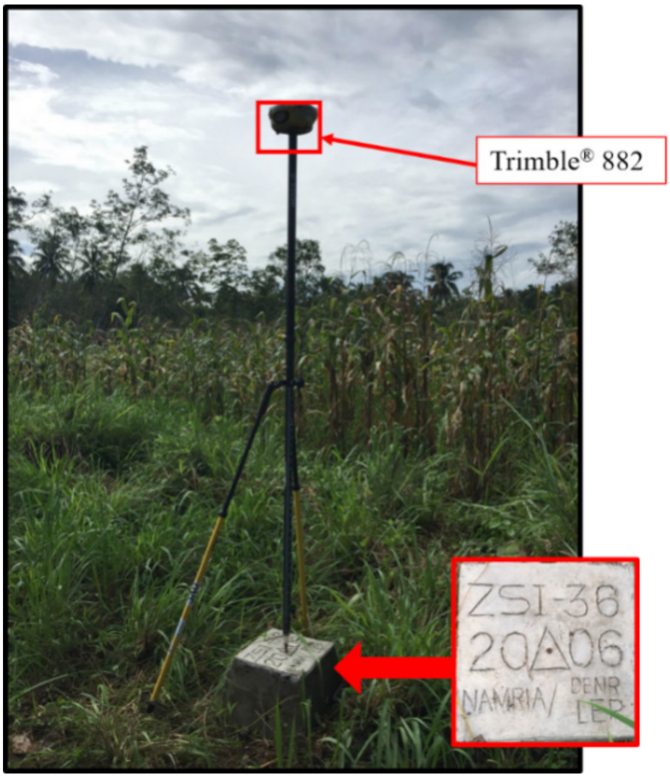


Figure 31. GNSS receiver, Trimble® SPS 882 set-up at reference point ZSI-36,in front of Iglesia Ni Cristo church along the National Highway, Brgy. Bacalan, Municipality of Ipil, Zamboaga Sibugay

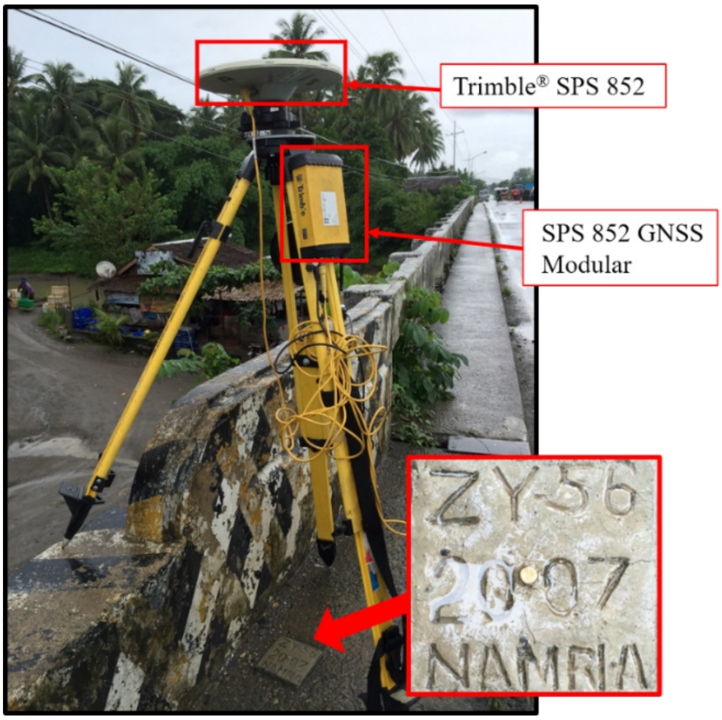


Figure 32. GNSS receiver, Trimble® SPS 852 set-up at benchmark ZY-56, along the Pagadian-Zamboanga National Road at the end of Kabasalan Bridge, Brgy. Sininan, Municipality of Kabasalan, Zamboanga Sibugay

Figure 33. GNSS receiver, Trimble® SPS 852 set-up at control point BAT, at Batu Bridge in Brgy. Batu, Municipality of Siay, Zamboanga Sibugay along the PAN-Philippine National Highway

4.3 Baseline Processing

The GNSS baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement, respectively. In cases where one or more baselines did not meet all of these criteria, masking is performed. Masking is done by removing/masking portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. Baseline processing result of control points used in Kabasalan River Basin survey is summarized in Table 20, generated by TBC software.

Table 20. Baseline processing report for Kabasalan River control survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
ZSI-36 --- BAT	7-25-2015	Fixed	0.005	0.018	107°51’19”	21599.394	-16.664
ZY-56 --- BAT	7-25-2015	Fixed	0.006	0.036	121°17’34”	10564.198	3.299
ZY-56 --- ZSI-36	7-25-2015	Fixed	0.007	0.025	95°38’06”	11586.285	-20.046
ZSI-36 --- BAT	7-25-2015	Fixed	0.005	0.027	107°51’19”	21599.364	-16.684
ZY-56 --- BAT	7-25-2015	Fixed	0.007	0.027	121°17’34”	10564.225	3.373

Three control points, ZSI-36, ZY-56, and BAT were occupied and observed simultaneously to form a GNSS loop. All 3 baselines acquired fixed solutions and passed the required ±20 cm and ±10 cm for horizontal and vertical precisions, respectively, as shown in Table 20.

4.4 Network Adjustment

After the baseline processing procedure, network adjustment is performed using TBC. Looking at the Adjusted Grid Coordinates (Table 22) of the TBC generated Network Adjustment Report, it is observed that the square root of the sum of the squares of x and y must be less than 20 cm and z less than 10 cm or in equation from:

$$\sqrt{((x_e)^2 + (y_e)^2)} < 20cm \text{ and } z_e < 10\ cm$$

Where:

x_e is the Easting Error,
y_e is the Northing Error, and
z_e is the Elevation Error

for each control point. See the Network Adjustment Report shown in Table 21 to Table 24 for complete details.

The three control points, ZSI-36, ZY-56, and BAT, were occupied and observed simultaneously to form a GNSS loop. Coordinates of ZSI-36 and elevation value of ZY-56 were held fixed during the processing of the control points as presented in Table 21. Through these reference points, the coordinates and elevation of the unknown control points were computed.

Table 21. Control Point Constraints

Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
ZSI-36	Local	Fixed	Fixed	
ZY-56	Grid			
Fixed = 0.000001(Meter)				

The list of adjusted grid coordinates, i.e., Northing, Easting, Elevation, and computed standard errors of the control points in the network, is indicated in Table 22. The fixed control ZSi-36 has no values for grid errors while ZY-56 has no value for elevation errors.

Table 22. Adjusted grid coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
BAT	480887.313	0.011	857115.876	0.008	9.534	0.078	
ZSI-36	460341.900	?	863753.414	?	26.102	0.080	LL
ZY-56	471866.790	0.013	862606.340	0.009	6.187	?	e

With the mentioned equation, for horizontal and for the vertical, the computation for the accuracy for the horizontal and vertical accuracy are as follows:

ZSI-36
horizontal accuracy = fixed
vertical accuracy = 8.0 cm < 10 cm

ZY-56
horizontal accuracy = $\sqrt{(1.3)^2 + (0.9)^2}$
= $\sqrt{1.69 + 0.81}$
= 1.58 < 20 cm
vertical accuracy = fixed

BAT
horizontal accuracy = $\sqrt{(1.1)^2 + (0.8)^2}$
= $\sqrt{1.21 + 0.64}$
= 1.36 cm < 20 cm
vertical accuracy = 7.8 cm < 10 cm

Following the given formula, the horizontal and vertical accuracy result of the three occupied control points are within the required accuracy of the program.

Table 23. Adjusted geodetic coordinates

Point ID	Latitude	Longitude	Ellipsoidal Height (Meter)	Height Error (Meter)	Constraint
AT	N7°45’14.71408”	E122°49’35.99365”	77.600	0.078	
ZSI-36	N7°48’50.43692”	E122°38’25.03291”	94.318	0.080	LL
ZY-56	N7°48’13.35741”	E122°44’41.37797”	74.265	?	e

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 23. Based on the result of the computation, the accuracy conditions are satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table 24.

Table 24. Reference and control points used and its location
(Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
ZSI-36	2nd order, GCP	7°48’50.43692”	122°38’25.03291”	94.318	863753.414	460341.900	26.102
ZY-56	1st order, BM	7°48’13.35741”	122°44’41.37797”	74.265	862606.340	471866.790	6.187
BAT	UP Established	7°45’14.71408”	122°49’35.99365”	77.600	857115.876	480887.313	9.534

4.5 Cross-section and Bridge As-Built and Water Level Marking

Cross-section and as-built survey was done on July 29 and August 2, 2015 in the downstream side of Kabasalan Bridge in Brgy. Sininan, Municipality of Kabasalanusing a GNSS receiver Trimble® SPS 882 in PPK survey technique as shown in Figure 34.

Figure 34. Cross-section and bridge as-built survey for Kabasalan Bridge, Brgy.Sininan, Municipality of Kabasalan. The construction of the new bridge is ongoing.

The cross-sectional line length of Kabasalan Bridge is about 217.88 meters with 94 cross-sectional points using ZY-56 as the GNSS base station. The summary of the location map, gathered cross-section in a diagram, and as-built data form of Kabasalan Bridge are displayed in Figure 35 to Figure 37, respectively.

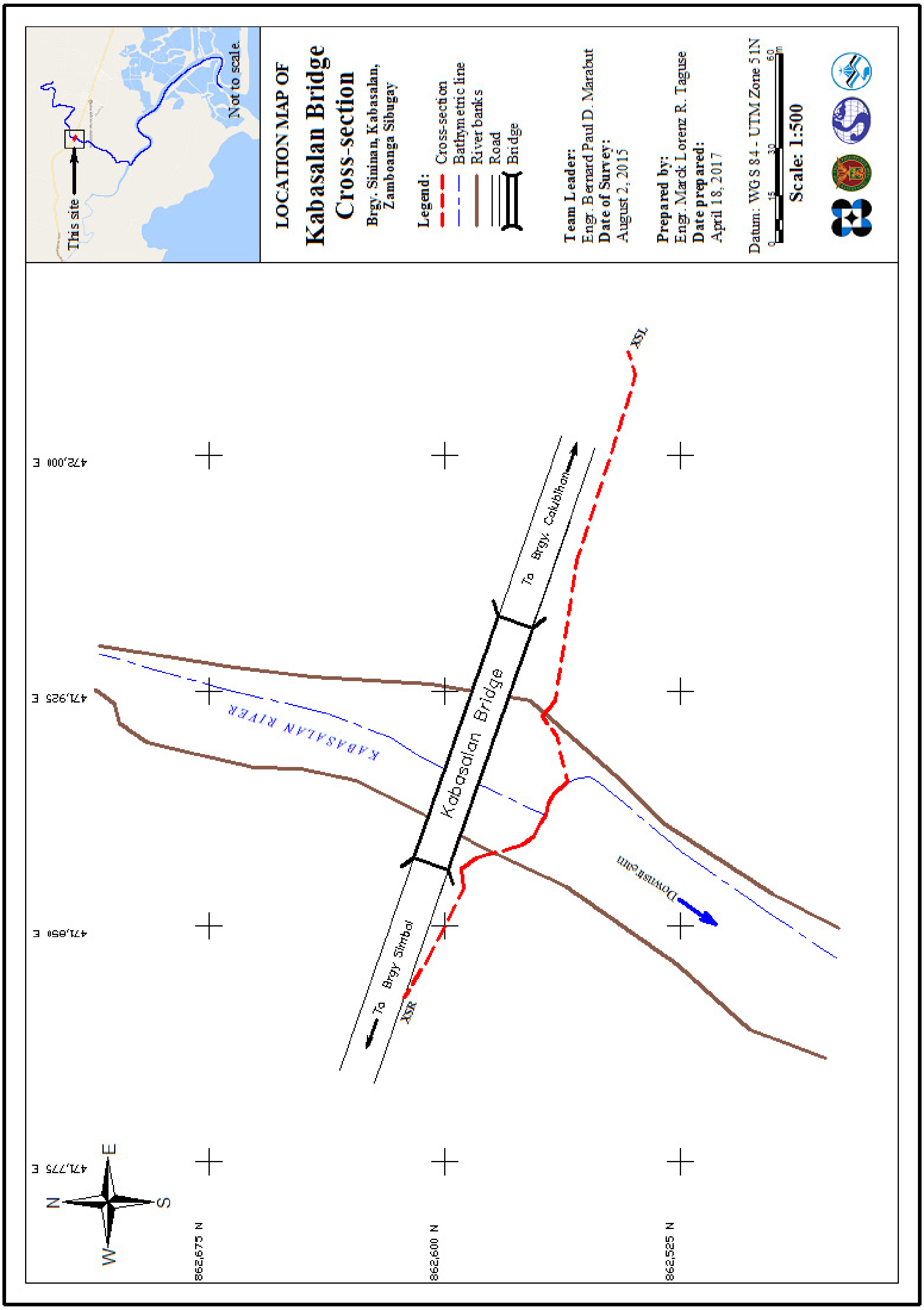


Figure 35. Kabasalan Bridge cross-sectional diagram

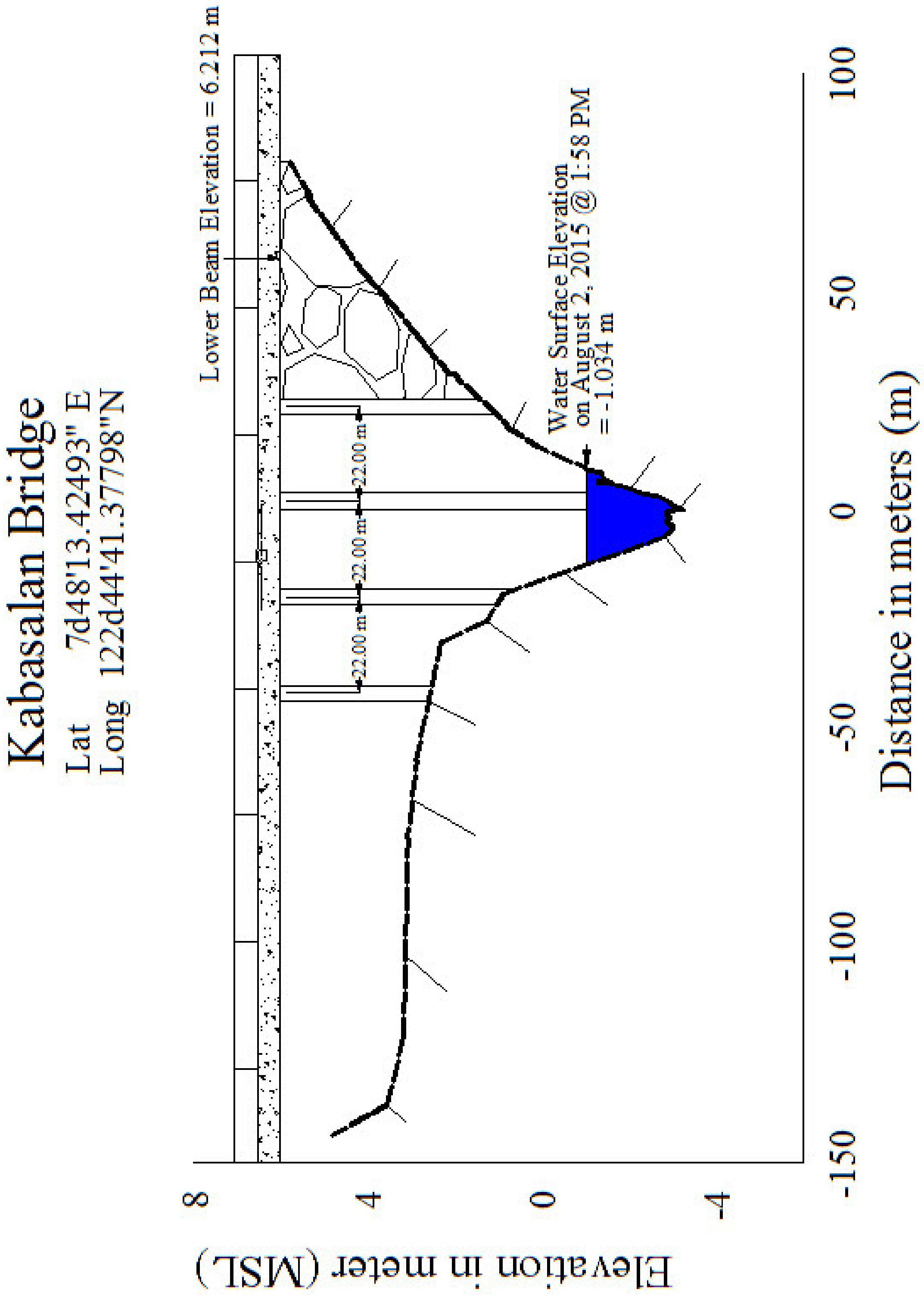


Figure 36. Kabasalan bridge cross-section location map

Bridge Data Form

Bridge Name: Kabasalan Bridge **Date:** August 2, 2015

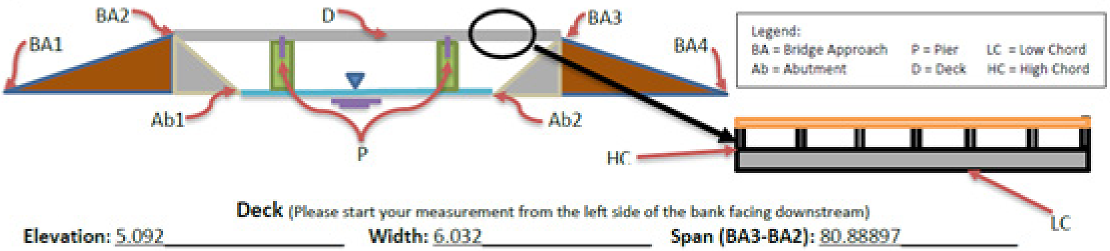
River Name: Kabasalan River **Time:** 3:30 P.M.

Location (Brgy, City, Region):

Survey Team: Team Bernard

Flow condition: low normal high **Weather Condition:** fair rainy

Latitude: 7d48'13.42493" **Longitude:** 122d44'41.37798"



Deck (Please start your measurement from the left side of the bank facing downstream)

Elevation: 5.092 **Width:** 6.032 **Span (BA3-BA2):** 80.88897

	Station	High Chord Elevation	Low Chord Elevation
1		8.336	7.246
2			
3			
4			
5			

Bridge Approach (Please start your measurement from the left side of the bank facing downstream)

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	5.65	BA3	129.259	6.473
BA2	48.37033	5.093	BA4	169.505	6.068

Abutment: Is the abutment sloping? Yes No; If yes, fill in the following information:

	Station (Distance from BA1)	Elevation
Ab1	72.8047	13.55
Ab2	124.788	2.919

Pier (Please start your measurement from the left side of the bank facing downstream)

Shape: Rectangular Cylinder **Number of Piers:** 3 **Height of column footing:** 0.43

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	60.151	6.504	
Pier 2	83.074	6.667	
Pier 3	106.044	6.627	
Pier 4			
Pier 5			
Pier 6			

NOTE: Use the center of the pier as reference to its station

Figure 37. Kabasalan bridge data form

Figure 38. Water level markings on the post of Kabasalan bridge

Water surface elevation in MSL of Kabasalan River was determined using Trimble® SPS 882 in PPK mode survey on August 2, 2015 at 1:58 P.M. This was translated onto marking the bridge's pier using a Digital Level. The marked pier shown in Figure 38 serves as reference for flow data gathering and depth gauge deployment by the accompanying SUC, ADZU, who is responsible for Kabasalan River.

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on August 2, 2015 using a survey-grade GNSS Rover receiver, Trimble®SPS 882, mounted on a range pole which was attached in front of the vehicle as shown in Figure 39. It was secured with a cable-tie to ensure that it was horizontally and vertically balanced. The antenna height was measured and recorded to be 2.293m from the ground up to the bottom of notch of the GNSS Rover receiver. The survey was conducted using PPK technique on a continuous topography mode using ZY-56 as the base station. The survey commenced from Brgy. Bacalan, Municipality of Ipil to Brgy. Buayan, Municipality of Kabasalan covering an approximate distance of 18.2 km with1,582 validation points. The gaps in the validation line as shown in Figure 40 were due to some difficulties in receiving satellite signals because of the presence of obstruction such as dense canopy cover of trees along the roads.

Figure 39. Trimble SPS882 set-up on a vehicle for validation points acquisition along the major roads near Kabasalan River

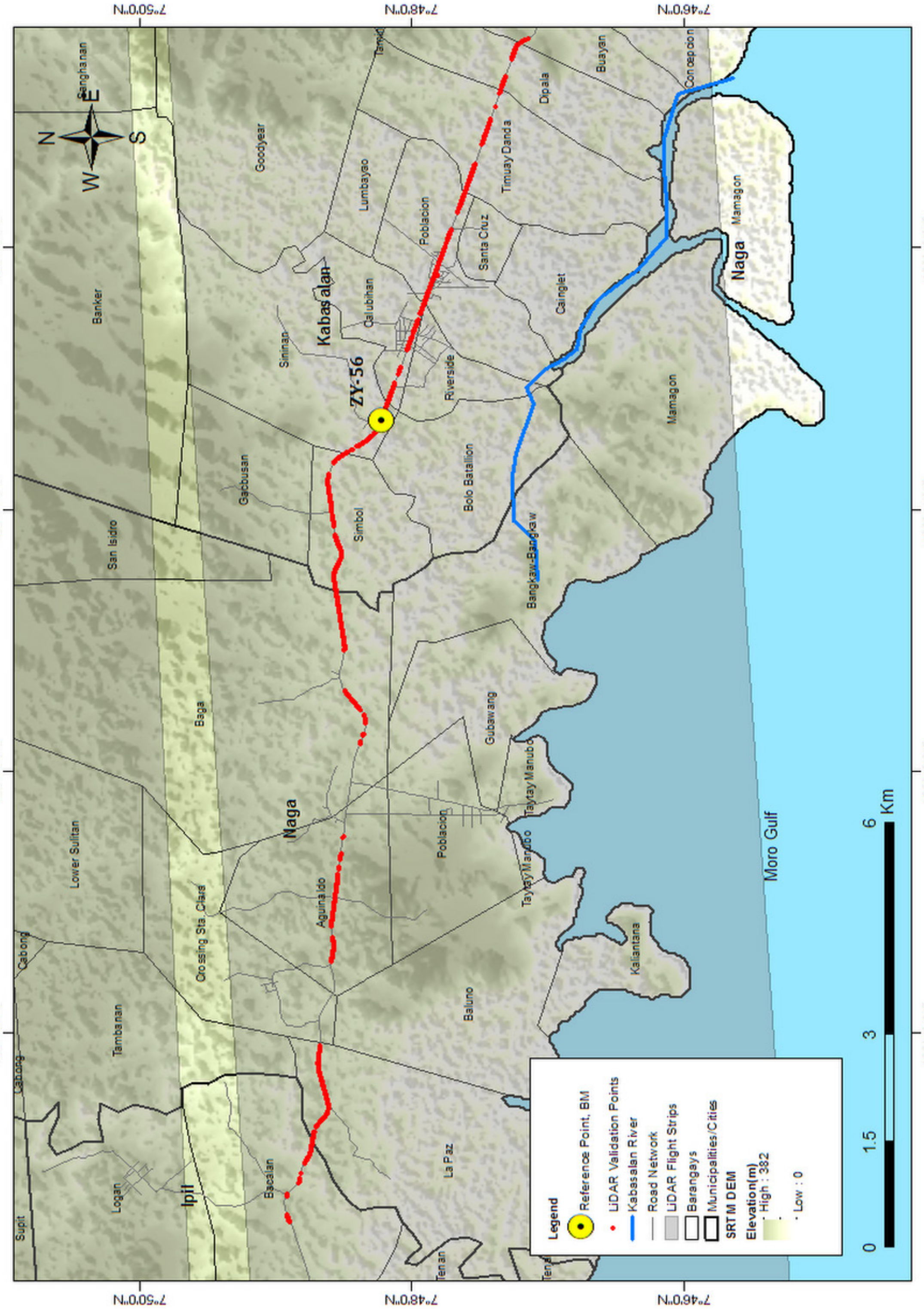


Figure 40. Validation points acquisition survey coverage for Kabasalan River Basin

4.7 Bathymetric Survey

Bathymetric survey of Kabasalan River was conducted on July 29, 2015 using Trimble® SPS 882 in GNSS PPK survey technique and an Ohmex™ single-beam echo sounder attached on a boat as shown in Figure 41. The entire survey coverage started in Brgy. Calubihan, Municipality of Kabasalan with coordinates 7°48'36.30333"122°45'41.34141" and ended at the mouth of the river in Brgy. Mamagon, Kabasalan, Zamboanga Sibugay with coordinates 7°45'41.48006"122°45'35.71393".

Figure 41. Bathymetric survey instrument set-up on a borrowed boat from Kabasalan local government accompanied by the Philippine Army personnel

The bathymetric line length is about 12.85 km, with a total of seven thousand fifty (7,050) bathymetric points using the reference point ZY-56, a first-order BM, was occupied as GNSS base station for the survey. The processed data were generated into map using a GIS software as shown in Figure 42.

Figure 42. Bathymetric survey of Kabasalan River

A CAD drawing was also produced to illustrate the Kabasalan riverbed profile. The surveyed portion of the river passed along the municipality of Kabasalan. The barangays covered are shown in Figure 43, namely Banker, Bolo Batallion, Cainglet, and Lumbayao. Additionally, an elevation drop of 5.1 meters was observed within the 12.85 km bathymetry line.

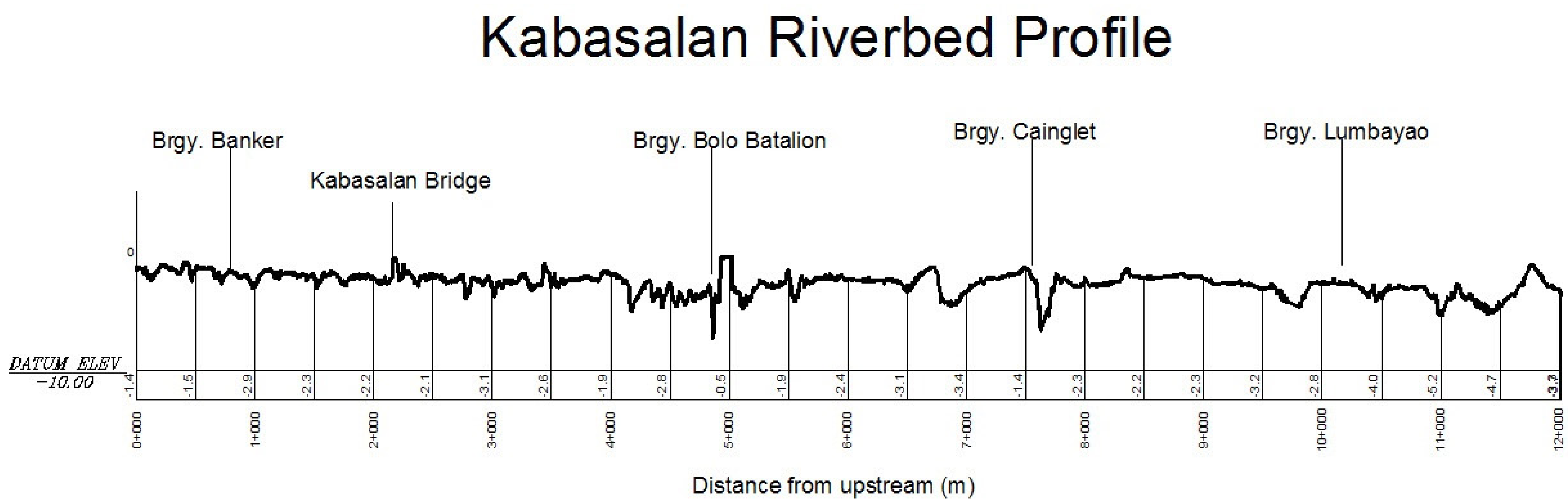


Figure 43. Riverbed profile of Kabasalan River

CHAPTER 5: FLOOD MODELLING AND MAPPING

Alfredo Mahar Lagmay, Christopher Uichanco, Sylvia Sueno, Marc Moises, Hale Ines, Miguel del Rosario, Kenneth Punay, Neil Tingin

The methods applied in this chapter were based on the DREAM methods manual (Lagmay et al., 2014) and further enhanced and updated in Paringit et al. (2017).

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

All components and data that affect the hydrologic cycle of the Kabasalan River Basin were monitored, collected, and analyzed. Rainfall, water level, and flow in a certain period of time, which may affect the hydrologic cycle of the Kabasalan River Basin were monitored, collected, and analyzed.

5.1.2 Precipitation

Precipitation data was taken from a manually read rain gauge set up at Brgy. Sanghanan, Kabasalan, Zamboanga Sibugay (7° 44’ 47.7” N, 122° 31’ 6.88” E) (Figure 44).The precipitation data collection started from November 5, 2016 at 12:00 midnigh tto November 5, 2016 at 6:00 PM with 10 minutes recording interval.

The total precipitation for this event in Brgy. Sanghanan was 58.4 mm. It has a peak rainfall of 5.8 mm on November 5, 2016 at 1:40 PM. The lag time between the peak rainfall and discharge is 1 hour and 30 minutes.

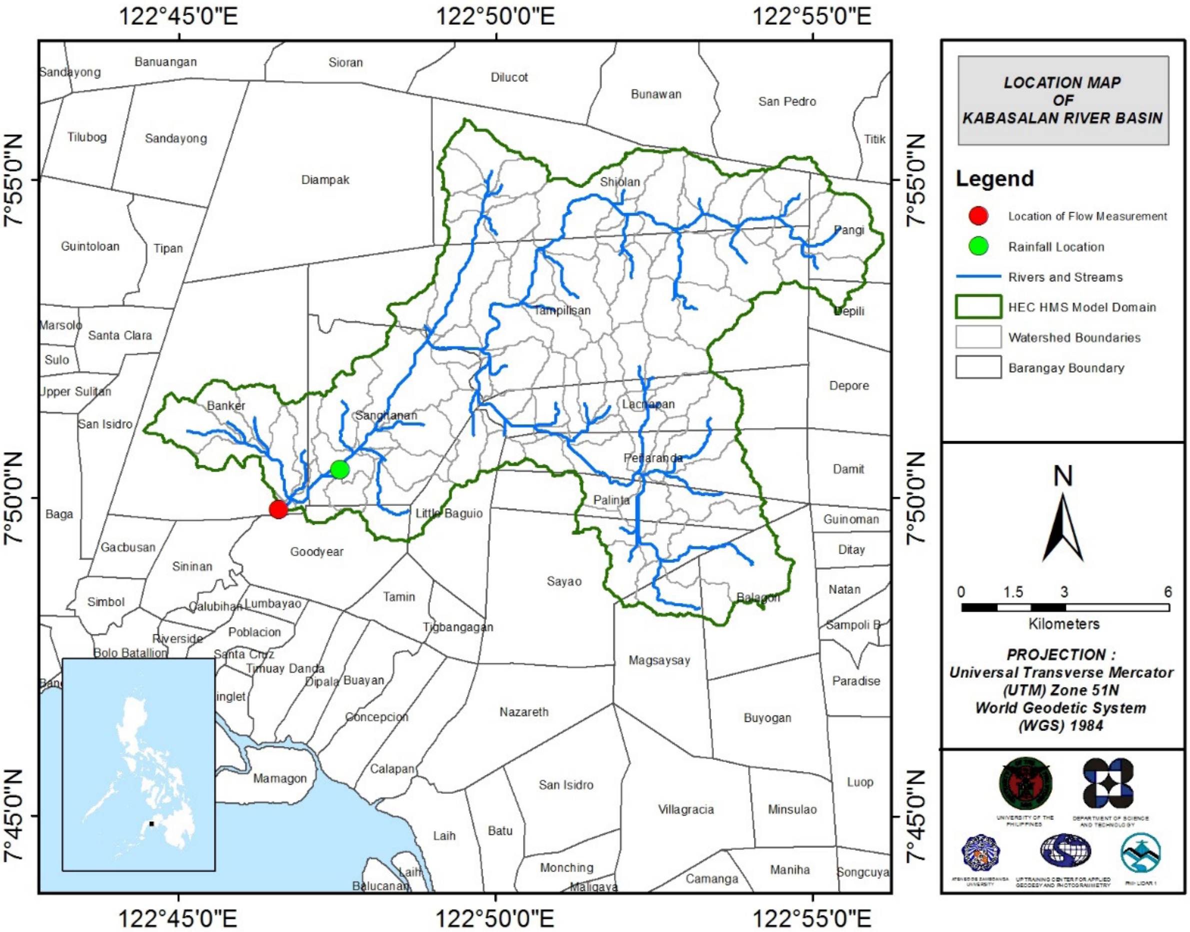


Figure 44. Location map of Kabasalan HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Tulay ng Pangulo, Brgy. Banker, Kabasalan, Zamboanga Sibugay (7° 49' 47.59" N, 122° 47' 32.56" E). It establishes the relationship between the observed water levels at Tulay ng Panguloand outflow of the watershed at this location.

For Tulay ng Pangulo, the rating curve is expressed as Q = 7E-114e3.3037h as shown in Figure 46.

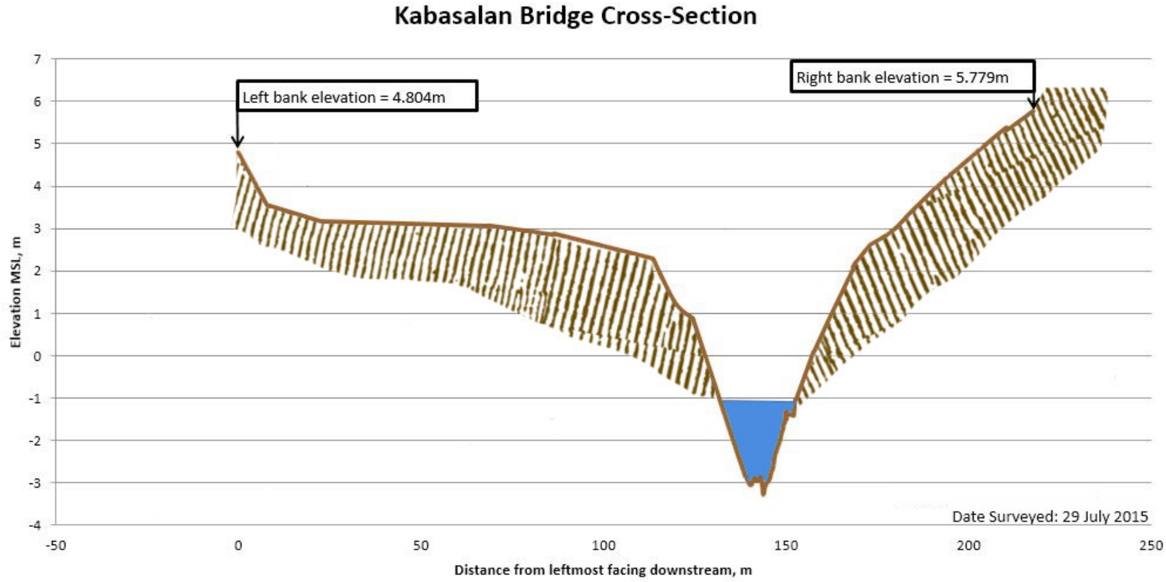


Figure 45. Cross-section plot of Tulay ng Pangulo

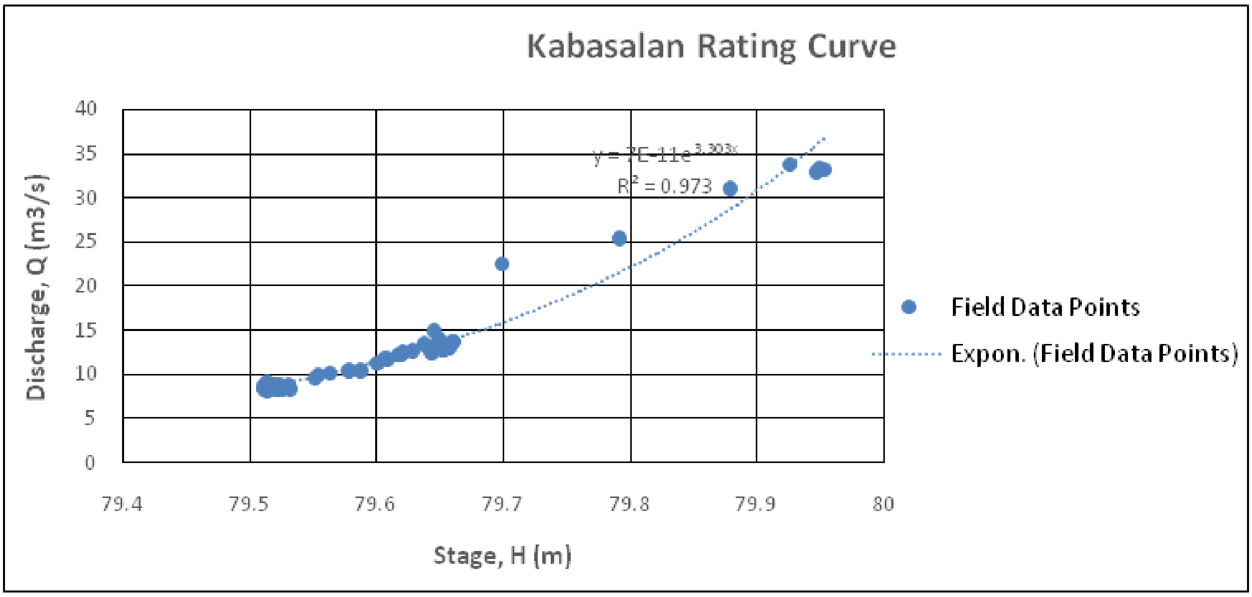


Figure 46. Rating curve at Tulay ng Pangulo, Brgy. Banker, Kabasalan, Zamboanga Sibugay

This rating curve equation was used to compute the river outflow at Tulay ng Pangulo for the calibration of the HEC-HMS model shown in Figure 46. Peak discharge is 140.8 cubic meters per second at 3:10 PM, November 5, 2016.

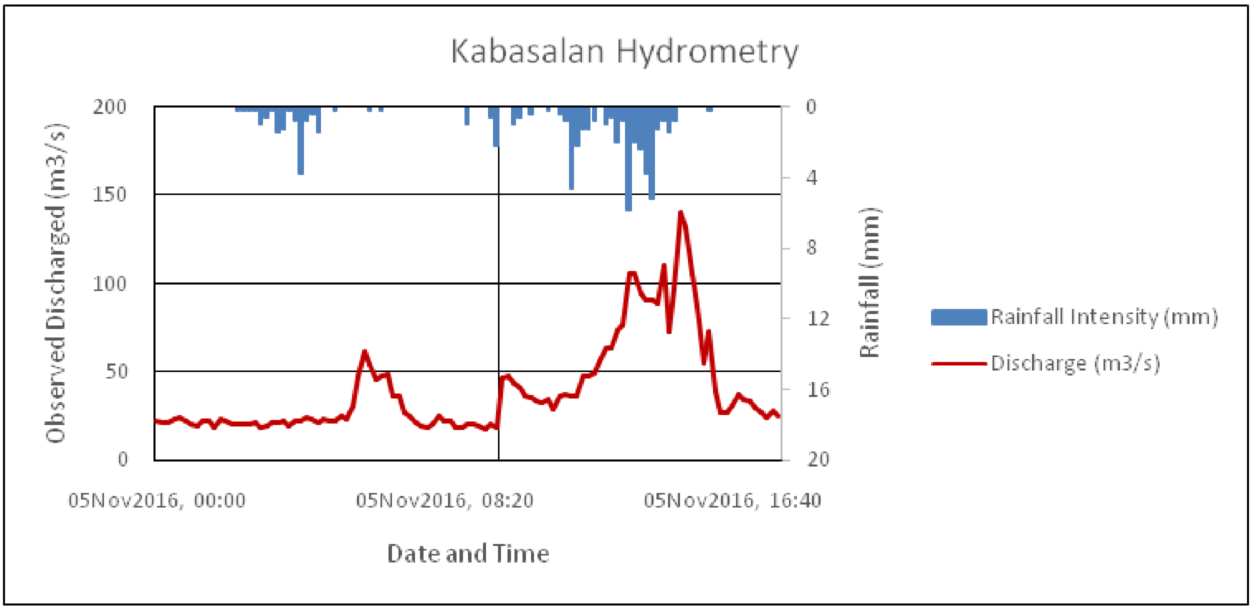


Figure 47. Rainfall and outflow data at Tulay ng Pangulo used for modeling

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Zamboanga City Rain Gauge. The RIDF rainfall amount for 24 hours was converted to a synthetic storm by interpolating and rearranging the value in such a way certain peak value will be attained at a certain time. This station chosen based on its proximity to the Kabasalan watershed. The extreme values for this watershed were computed based on a 59-year record.

Table 25. RIDF values for Zamboanga City Rain Gauge computed by PAGASA

COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION									
T (yrs)	**10 mins**	**20 mins**	**30 mins**	**1 hr**	**2 hrs**	**3 hrs**	**6 hrs**	**12 hrs**	**24 hrs**
2	15.5	23.3	28.4	36.9	45.6	50.7	60	66.1	77.3
5	21.4	31.6	38.3	50.4	61.2	38.2	82.5	91.5	107.8
10	25.3	37.1	44.8	59.4	71.6	79.8	97.5	108.3	127.9
15	27.5	40.2	48.5	64.4	77.4	86.4	105.9	117.8	139.3
20	29	42.3	51.1	68	81.5	91	111.8	124.4	147.3
25	30.2	44	53.1	70.7	84.7	94.5	116.3	129.5	153.4
50	33.9	49.1	59.2	79.1	94.4	105.4	130.4	145.3	172.3
100	37.5	54.2	65.3	87.4	104	116.2	144.3	161	191.1

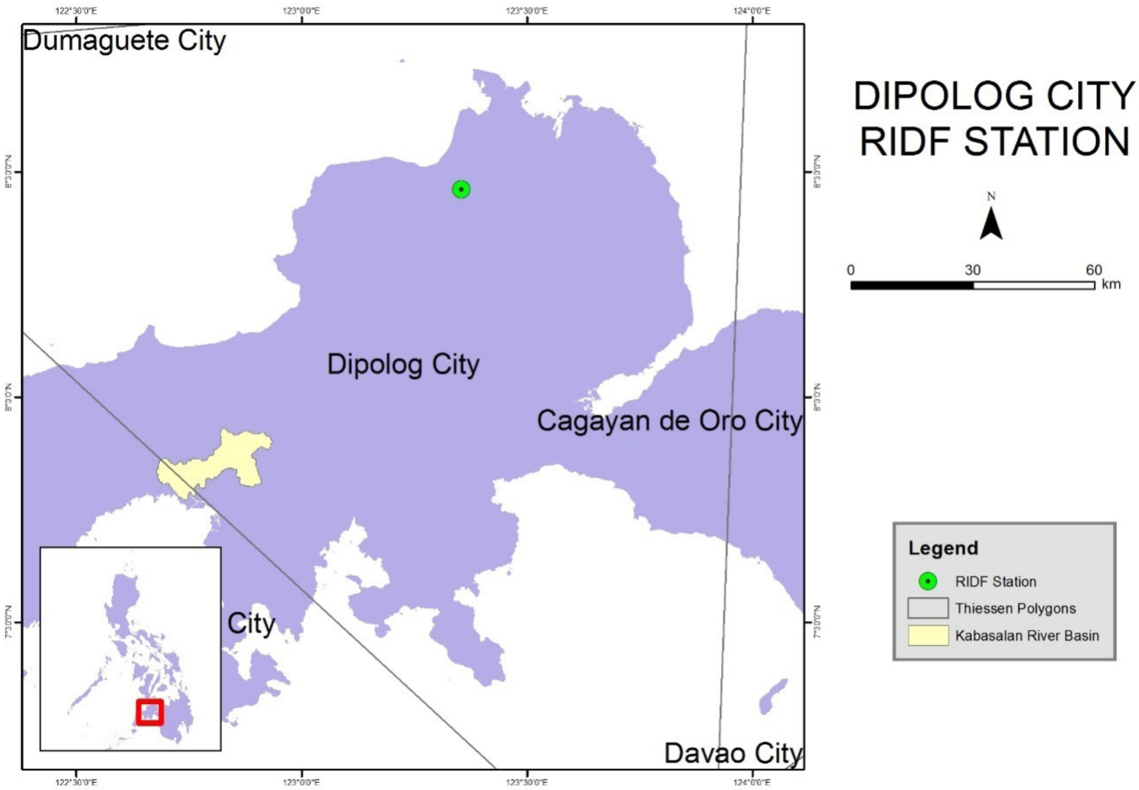


Figure 48. Dipolog City and Zamboanga City RIDF location relative to Kabasalan River Basin

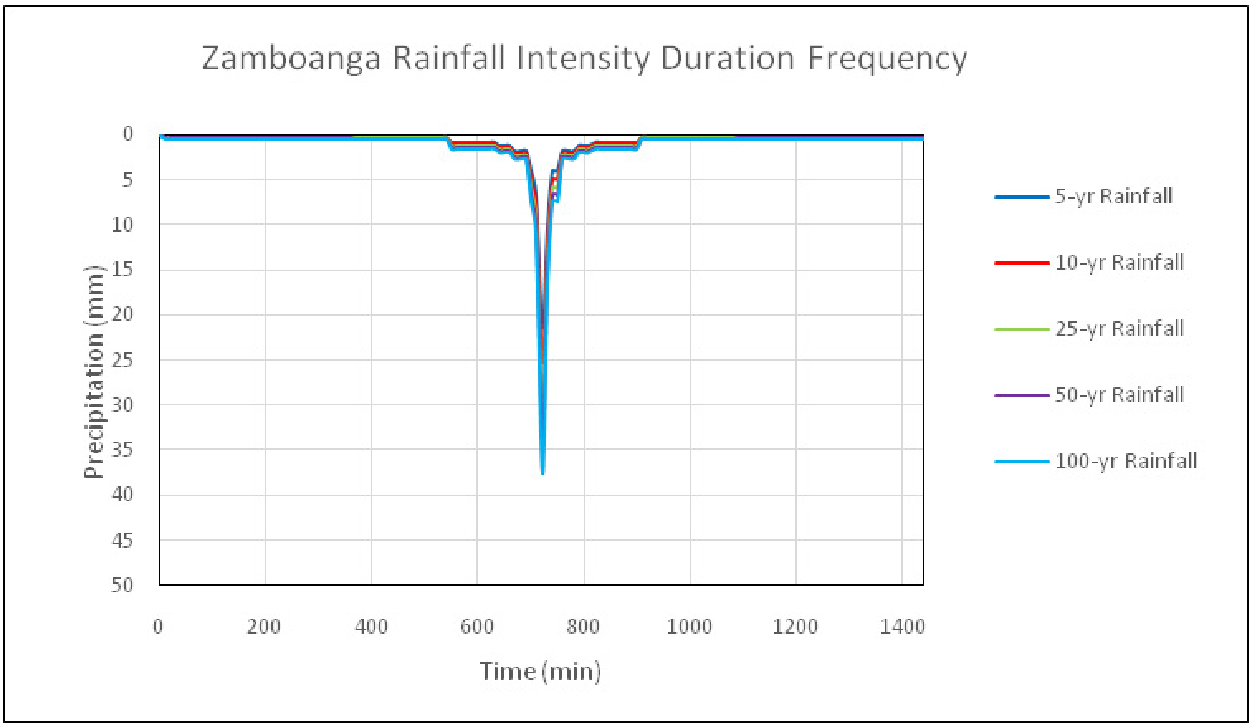


Figure 49. Synthetic storm generated for a 24-hr period rainfall for various return periods

5.3 HMS Model

The soil dataset was generated by the Bureau of Soils and Water Management (BSWM) under the Department of Agriculture (DAR). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Kabasalan River Basin are shown in Figures 50 and 51, respectively.

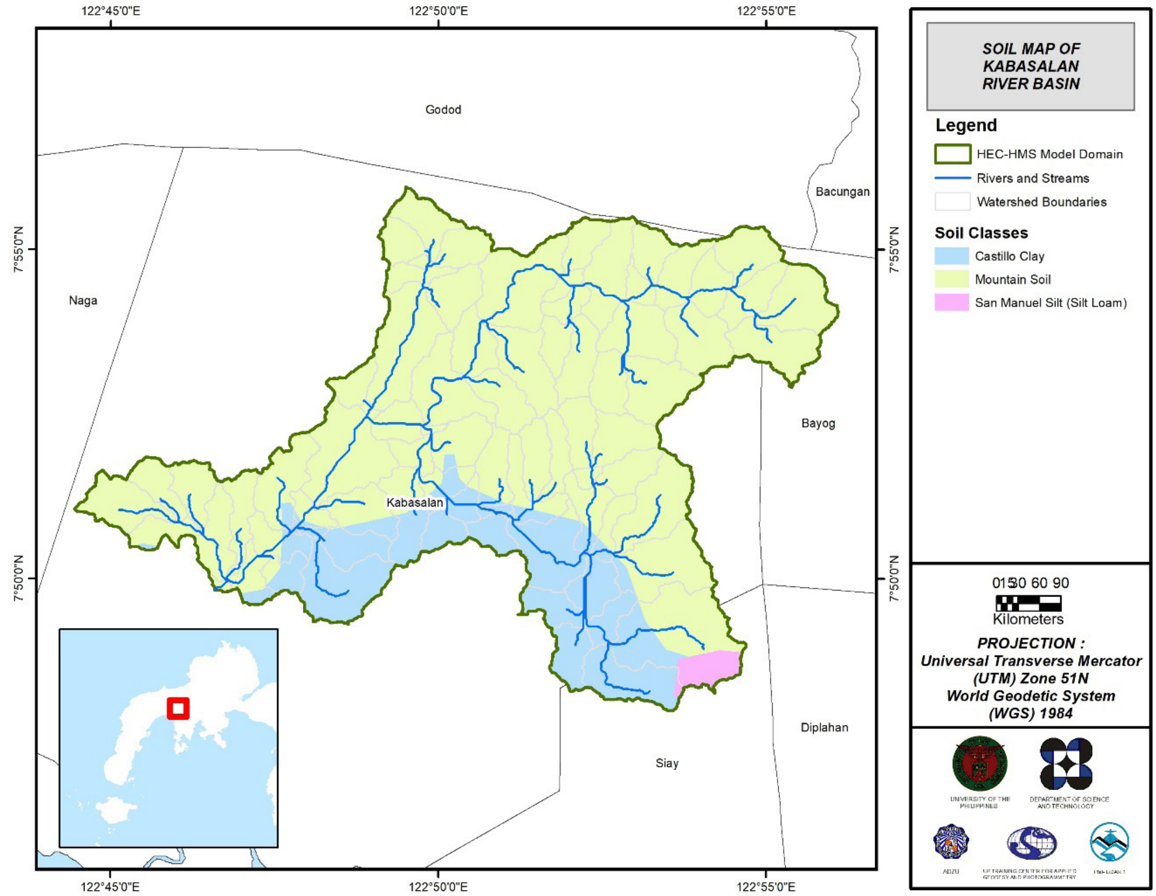


Figure 50. Soil map of Kabasalan River Basin

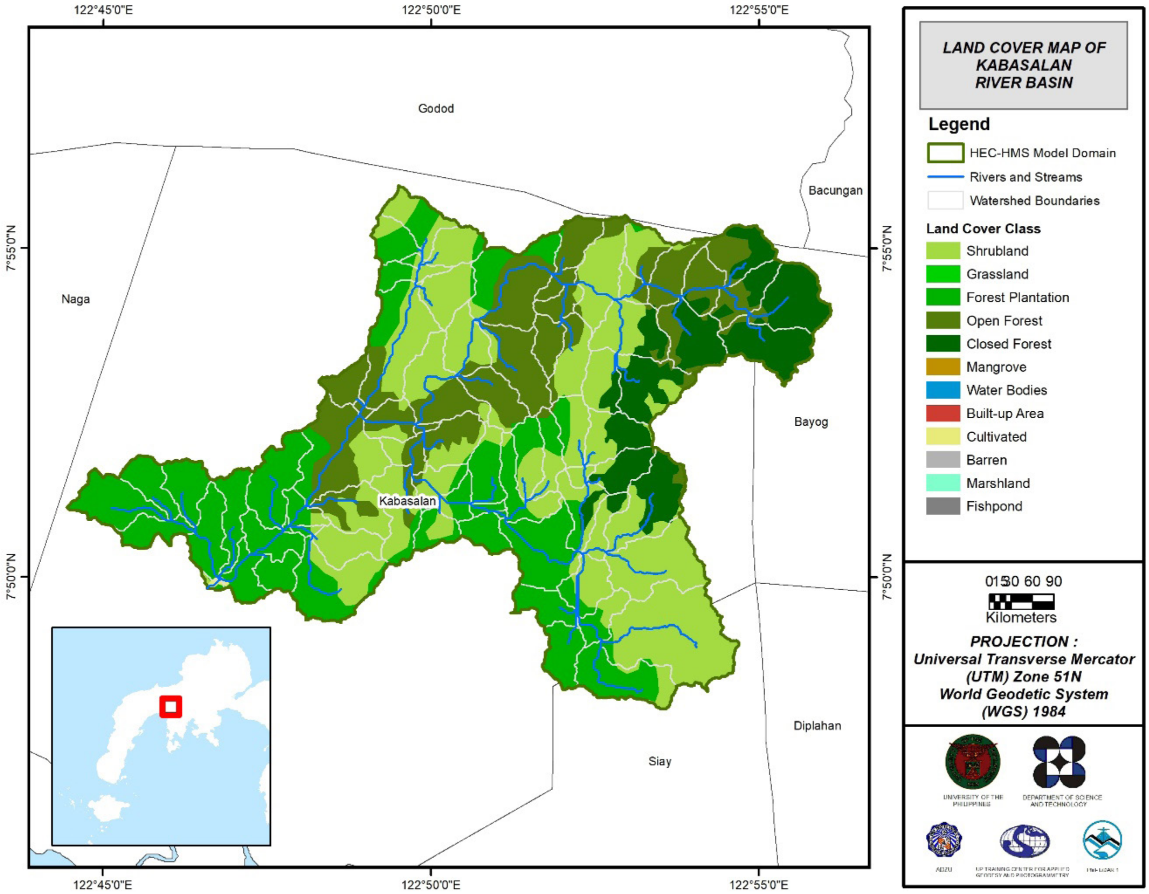


Figure 51. Land cover map of Kabasalan River Basin (Source: NAMRIA)

For Kabasalan, the soil classes identified were clay, silt, and mountain soil. The land cover types identified were shrubland, open canopy forest, closed canopy forest, grassland, and cultivated areas.

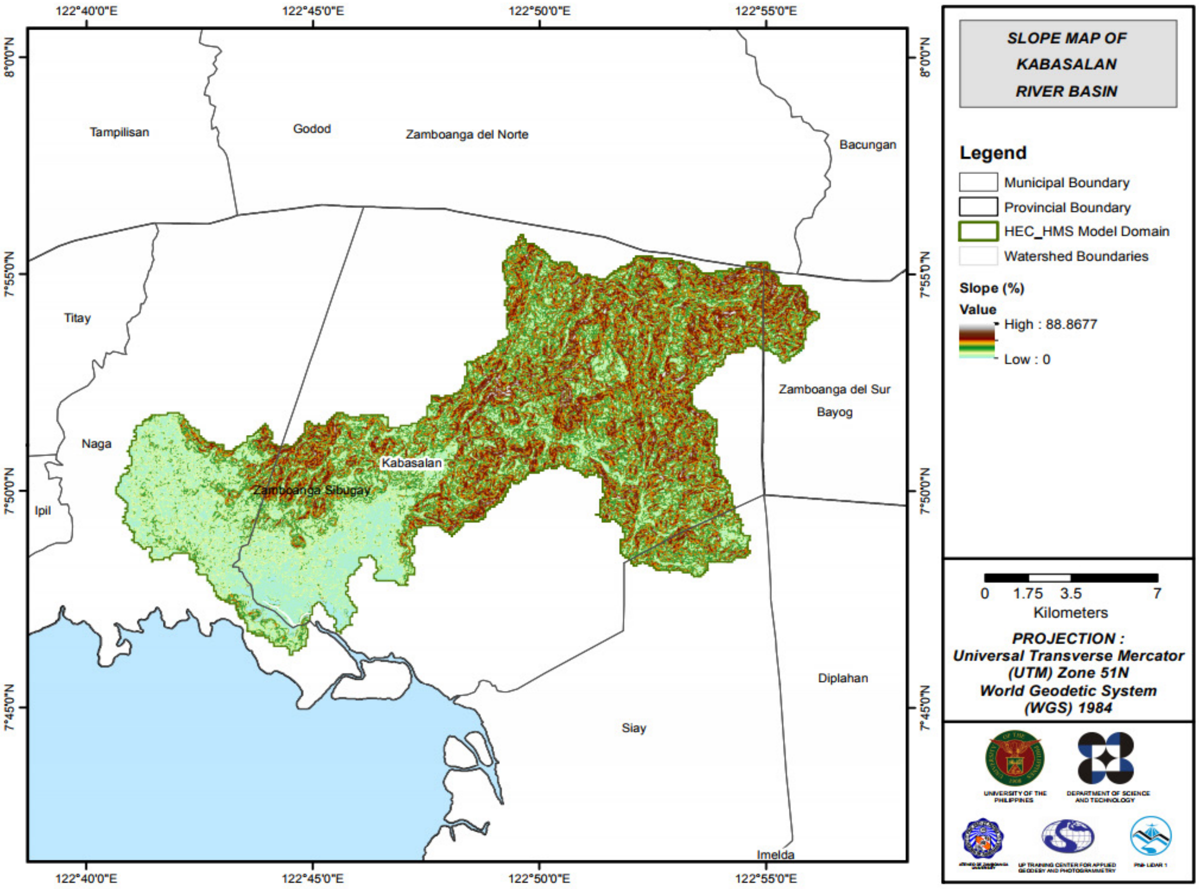


Figure 52. Slope map of Kabasalan River Basin

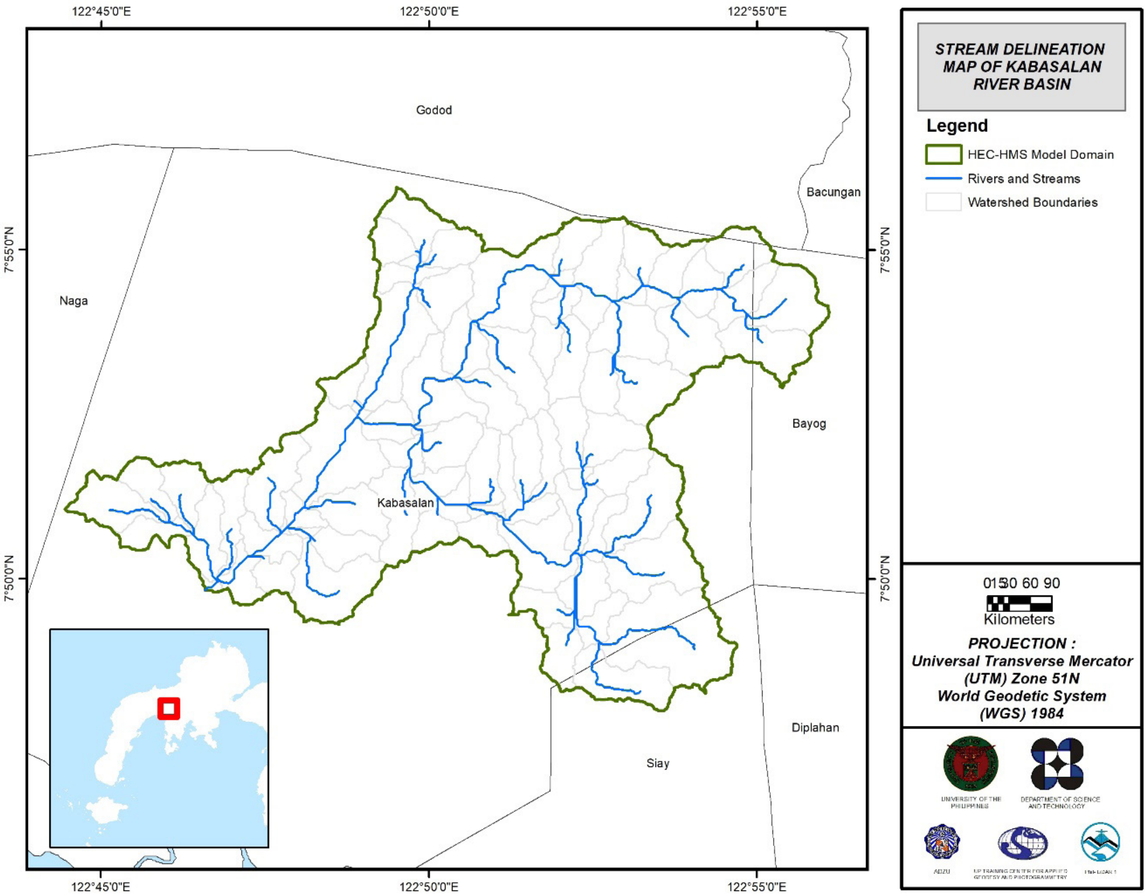


Figure 53. Stream delineation map of Kabasalan River Basin

Using the SAR-based DEM, the Kabasalan basin was delineated and further subdivided into subbasins. The model consists of 83 subbasins, 41 reaches, and 41 junctions as shown in Figure 54 (see ANNEX 10). The main outlet is at Tulay ng Pangulo.

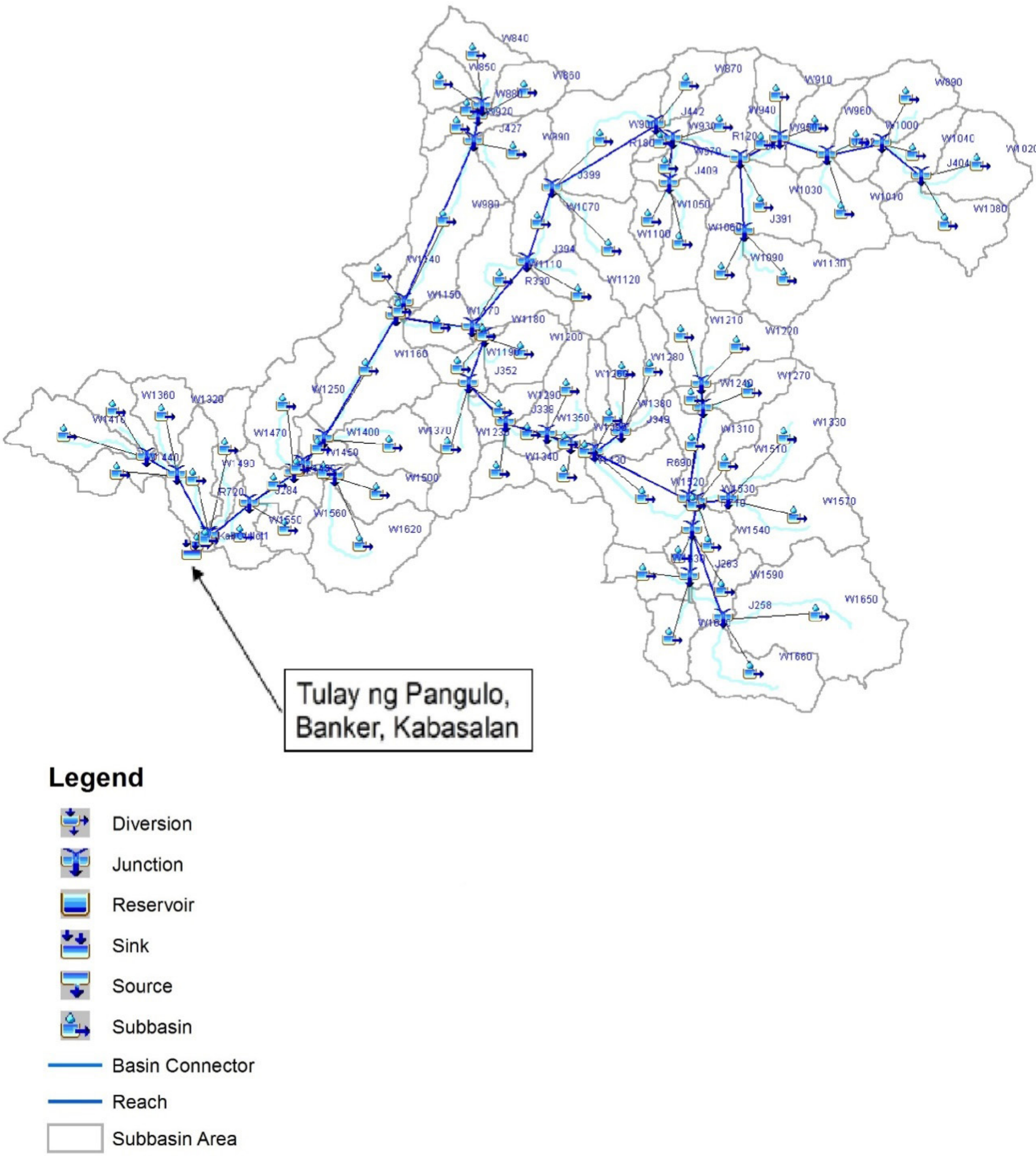


Figure 54. The Kabasalan river basin model generated using HEC-HMS

5.4 Cross-section Data

Riverbed cross-sections of the watershed are necessary in the HEC-RAS model set-up. The cross-section data for the HEC-RAS model was derived from the LiDAR DEM data. It was defined using the Arc GeoRAS tool and was post-processed in ArcGIS.

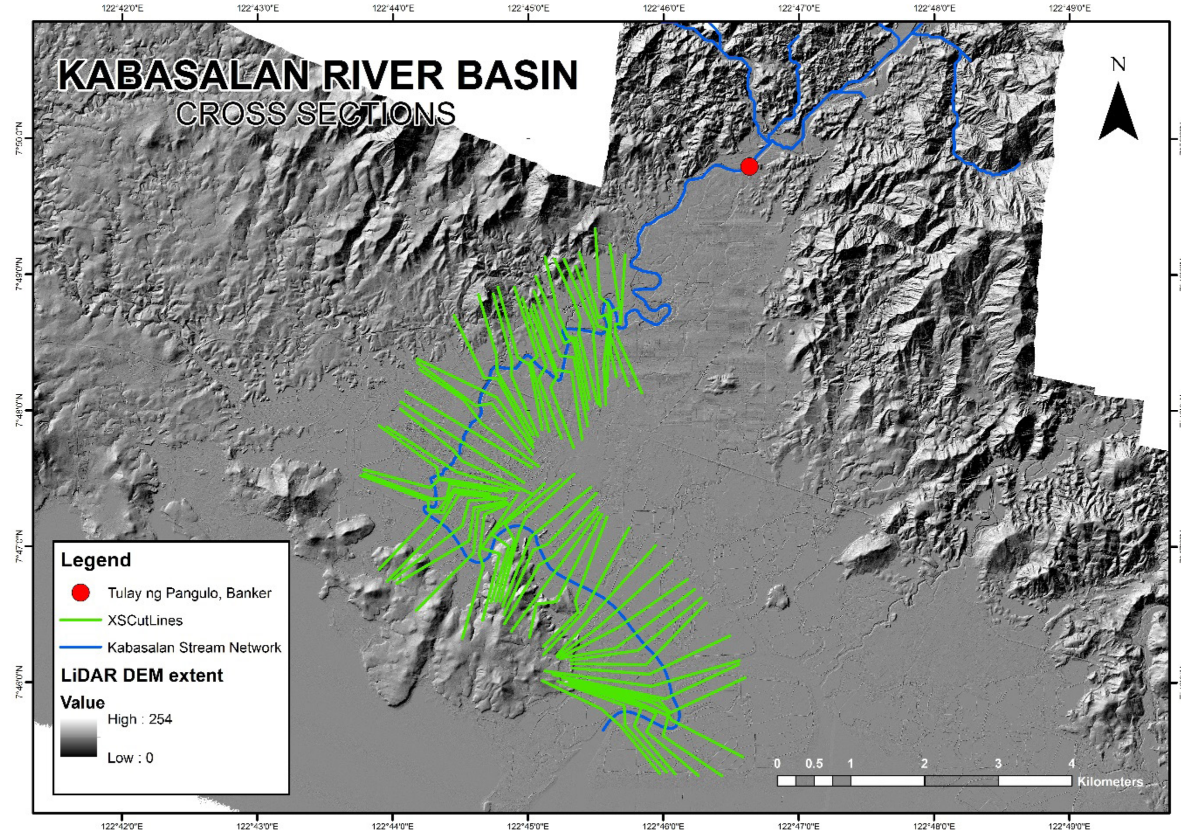


Figure 55. River cross-section of Kabasalan River generated through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

The automated modelling process allows for the creation of a model with boundaries that are almost exactly coincidental with that of the catchment area. As such, they have approximately the same land area and location. The entire area is divided into square grid elements, 10 meter by 10 meter in size. Each element is assigned a unique grid element number which serves as its identifier, then attributed with the parameters required for modelling such as x-and y-coordinate of centroid, names of adjacent grid elements, Manning coefficient of roughness, infiltration, and elevation value. The elements are arranged spatially to form the model, allowing the software to simulate the flow of water across the grid elements and in eight directions (north, south, east, west, northeast, northwest, southeast, southwest).

Based on the elevation and flow direction, it is seen that the water will generally flow from the northeast and the northwest of the model to the south, following the main channel. As such, boundary elements in those particular regions of the model are assigned as inflow and outflow elements, respectively.

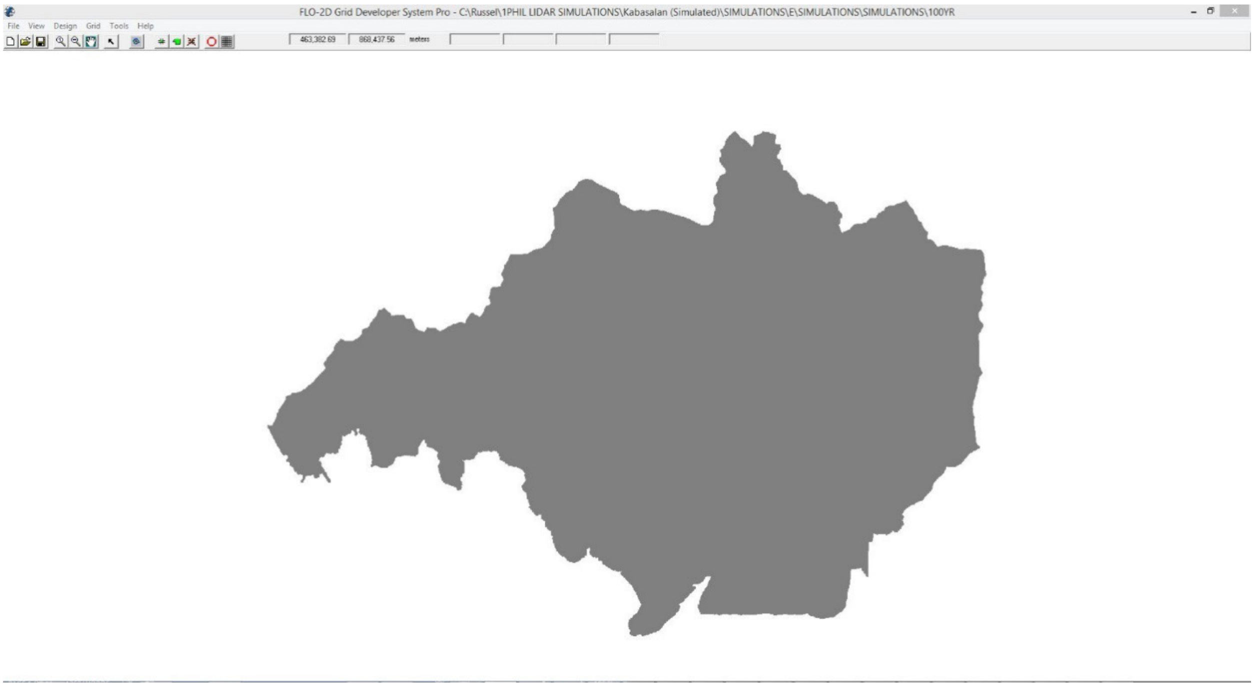


Figure 56. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 89.44629 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (maximum depth) is set at 0.2 m while the minimum vh (product of maximum velocity (v) times maximum depth (h)) is set at 0 m^2/s. The generated hazard maps for Kabasalan are in Figure 62, Figure 64 and Figure 6.

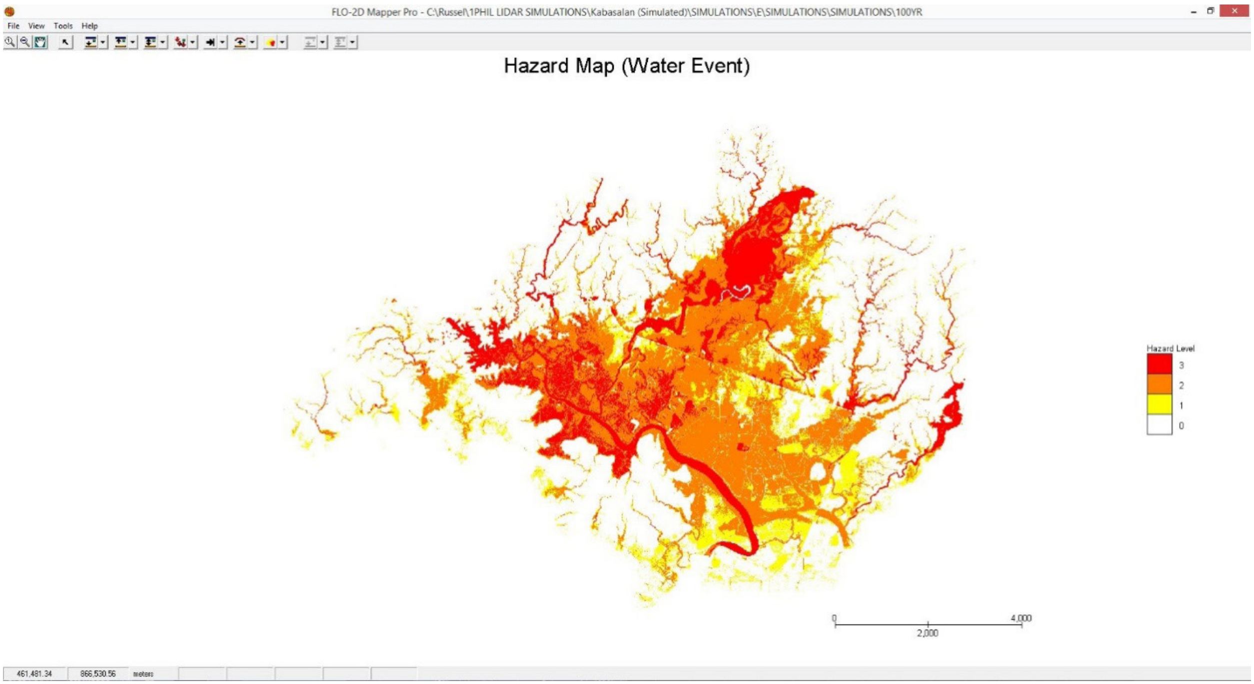


Figure 57. Generated 100-year rain return hazard map from FLO-2D Mapper

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 84 648 288.00 m^2.The generated flood depth maps for Kabasalan are in Figures 63, 65, and 67.

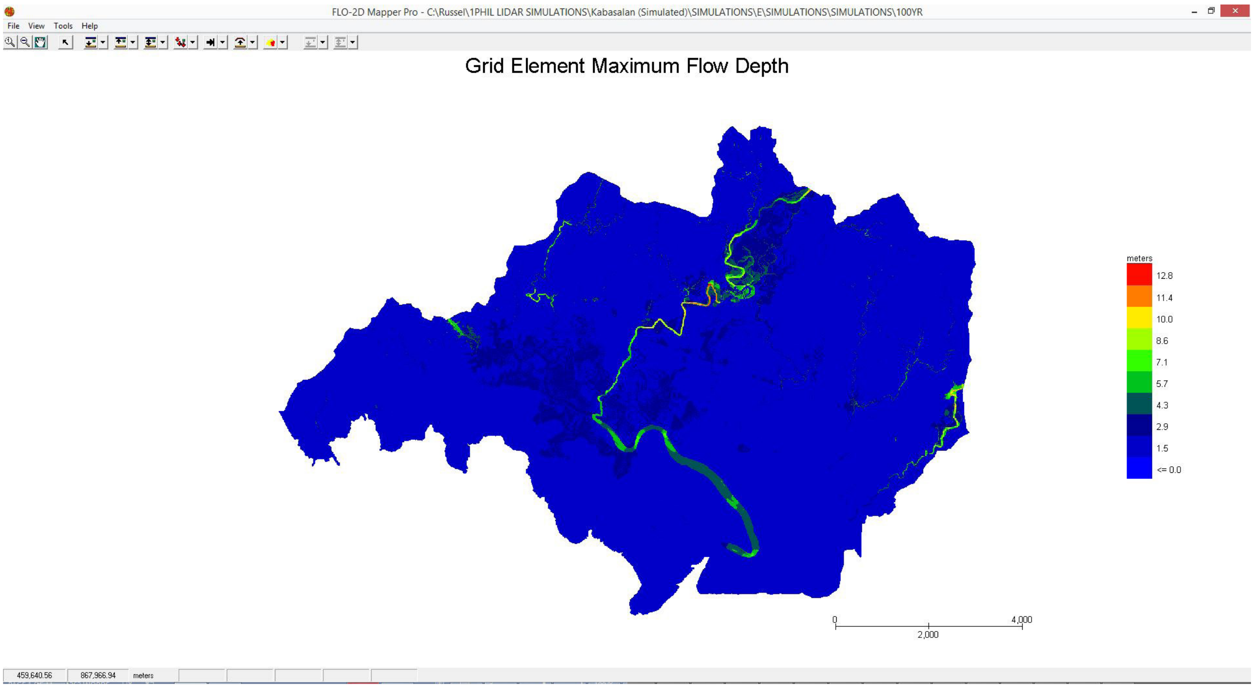


Figure 58. Generated 100-year rain return flow depth map from FLO-2D Mapper

There is a total of 44 637 125.46 m^3 of water entering the model. Of this amount, 17 642 227.88 m^3 is due to rainfall while 26 994 897.57 m^3 is inflow from other areas outside the model. 10 602 902.00 m^3 of this water is lost to infiltration and interception, while 23 804 571.08 m^3 is stored by the flood plain. The rest, amounting up to 10 229 602.94 m^3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Kabasalan HEC-HMS river basin model (see ANNEX 9), its accuracy was measured against the observed values. Figure 59 shows the comparison between the two discharge data.

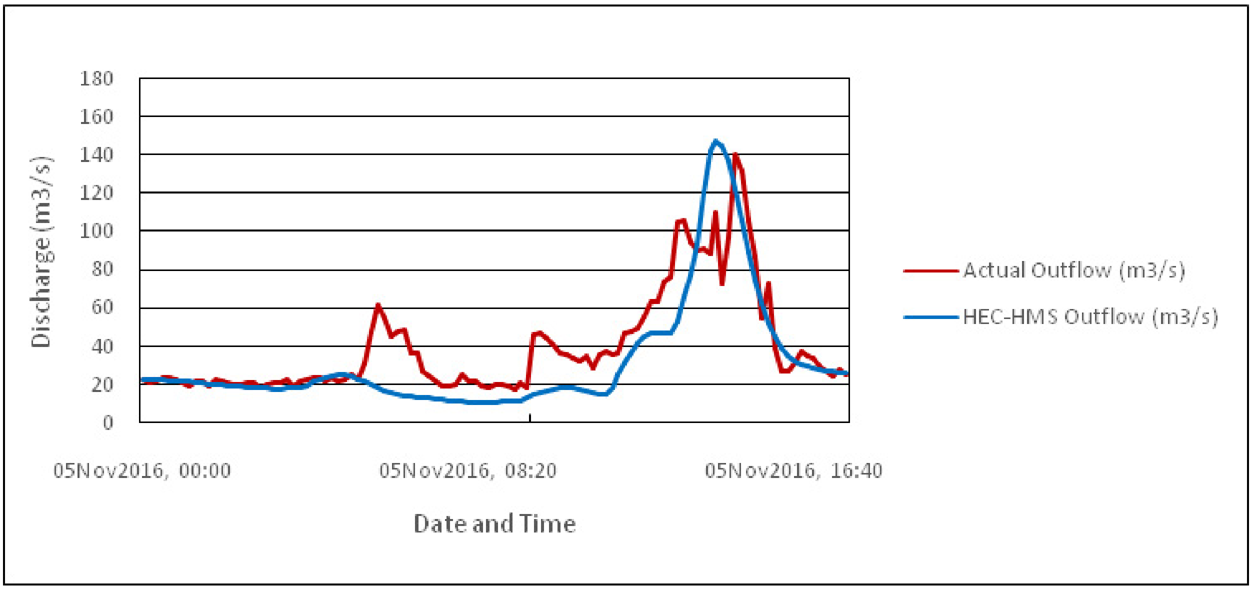


Figure 59. Outflow hydrograph of Kabasalan produced by the HEC-HMS model compared with observed outflow

Enumerated in Table 26 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 26. Range of calibrated values for Kabasalan

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.0010 – 0.0083
			Curve Number	32 – 54
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.017 – 0.308
			Storage Coefficient (hr)	0.017 – 0.567
	Baseflow	Recession	Recession Constant	0.09 – 0.14
			Ratio to Peak	0.15
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.005 – 0.012

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 0.0010 mm to 0.0083 mm means that there is a minimal amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. For Kabasalan, the basin mostly consists of tree plantations and cultivated areas and the soil consists of clay and mountain soil.

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.017 hours to 0.567 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.09 to 0.14 indicates that the basin is likely to quickly go back to its original discharge. Ratio to peak of 0.15 indicates a steep receding limb of the outflow hydrograph.

Table 27. Summary of the Efficiency Test of Kabasalan HMS Model

Accuracy Measure	Value
RMSE	194.4134
r^2	0.9732
NSE	0.557867
PBIAS	18.87612
RSR	0.664931

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 194.4134 (m^3/s).

The Pearson correlation coefficient (r^2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.9732.

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 0.557867.

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 18.87612.

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 0.664931.

5.7 Calculated outflow hydrographys and discharge values for different Rainfall Return Periods

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph (Figure 60) shows the Kabasalan outflow using the Zamboanga City 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 PAG-ASA data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

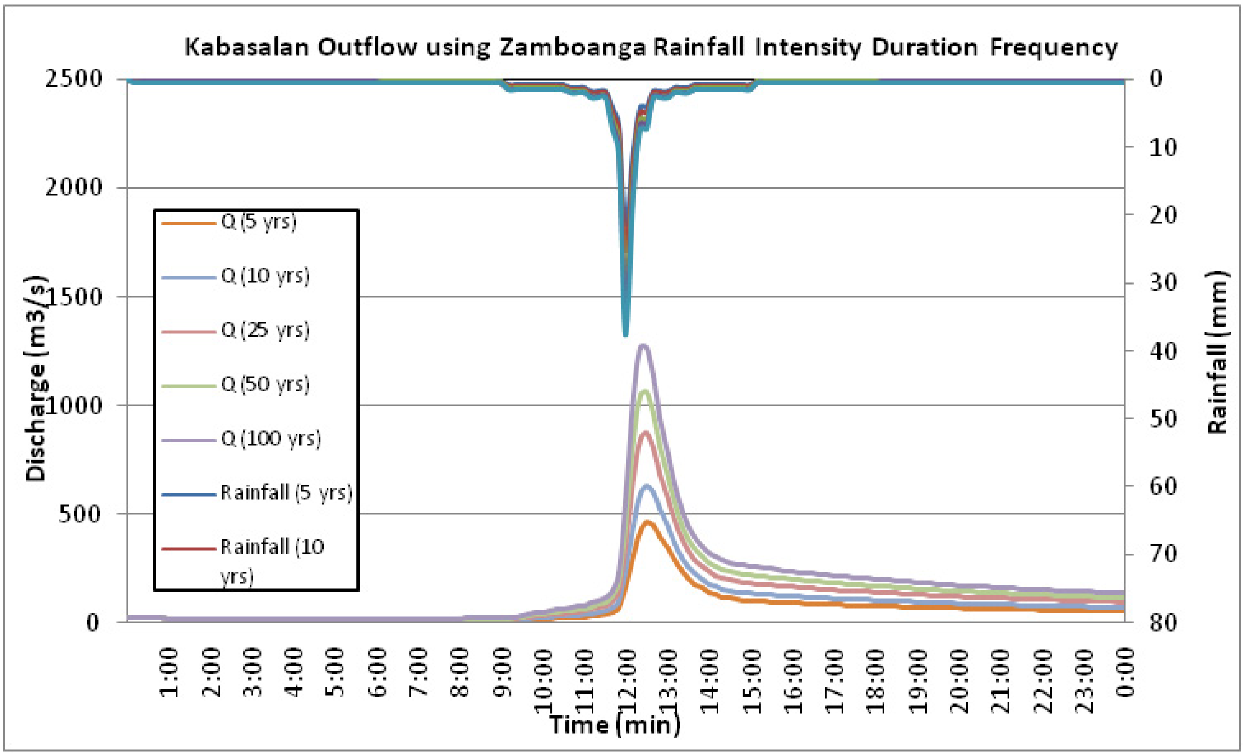


Figure 60. Outflow hydrograph at Tulay ng Pangulo Station generated using Zamboanga City RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Kabasalan discharge using the Zamboanga City RIDF in five different return periods is shown in Table 61.

Table 28. Peak values of the Kabasalan HEC-HMS Model outflow using the Zamboanga City RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m^3/s)	Time to Peak
5-Year	107.8	21.4	461.55	12 hours 30 minutes
10-Year	127.9	25.3	632.14	12 hours 30 minutes
25-Year	153.4	30.2	874.97	12 hours 30 minutes
50-Year	172.3	33.9	1065.46	12 hours 30 minutes
100-Year	191.1	37.5	1268.06	12 hours 20 minutes

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model are used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. The sample generated map of Kabasalan River using the calibrated HMS base flow is shown in Figure 61.

Figure 61. Sample output of Kabasalan RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figure 62 to Figure 68 show the 5-, 25-, and 100-year rain return scenarios of the Kabasalan Floodplain. The floodplain covers two municipalities namely Kabasalan and Naga. Table 29 shows the percentage of area affected by flooding per municipality.

Table 29. Municipalities affected in Kabasalan Floodplain

Municipality	Total Area	Area Flooded	% Flooded
Kabasalan	320.54	40.59	13%
Naga	151.72	22.88	15%

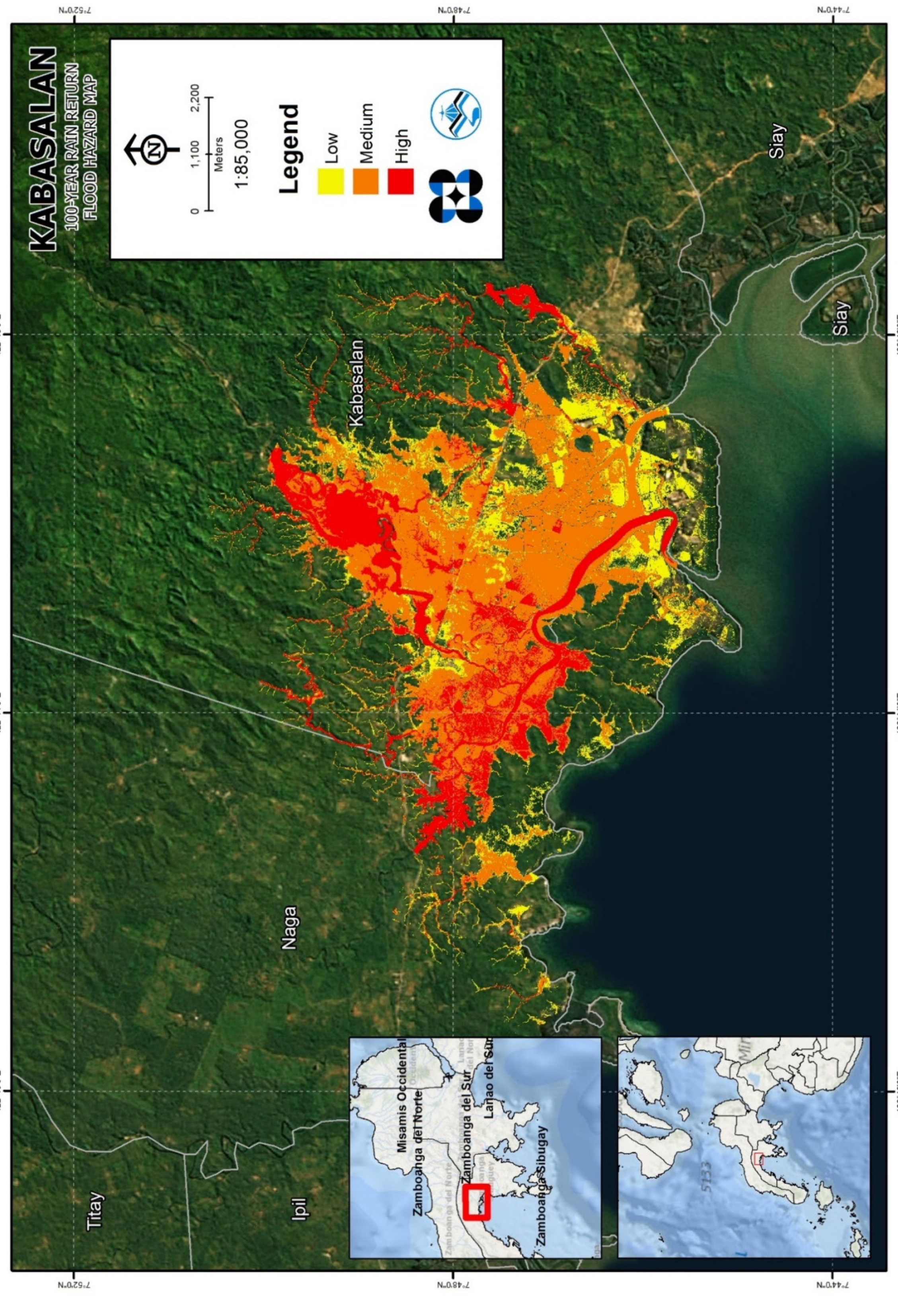


Figure 62. 100-year Flood Hazard Map for Kabasalan Floodplain

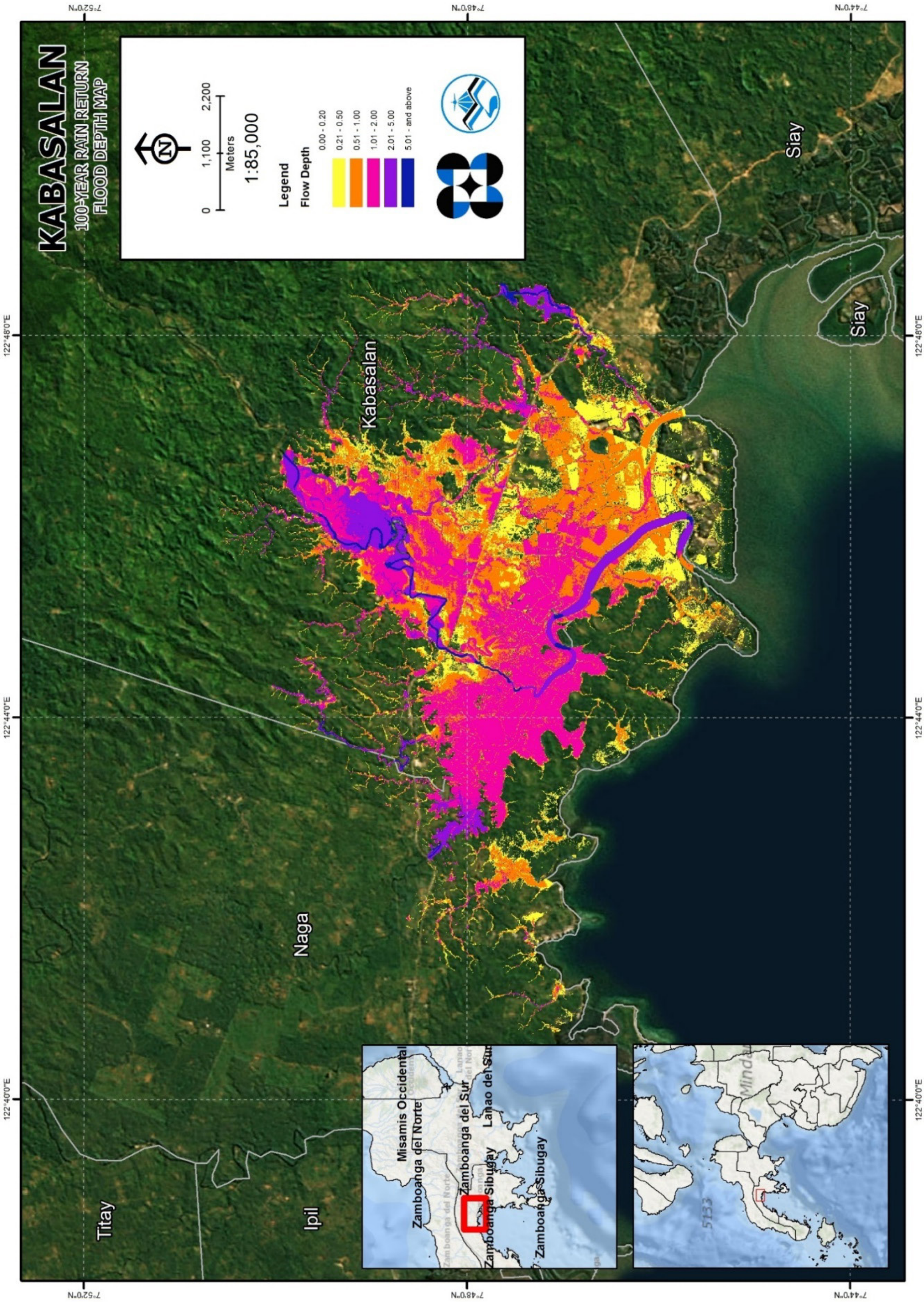


Figure 63. 100-year Flow Depth Map for Kabasalan Floodplain

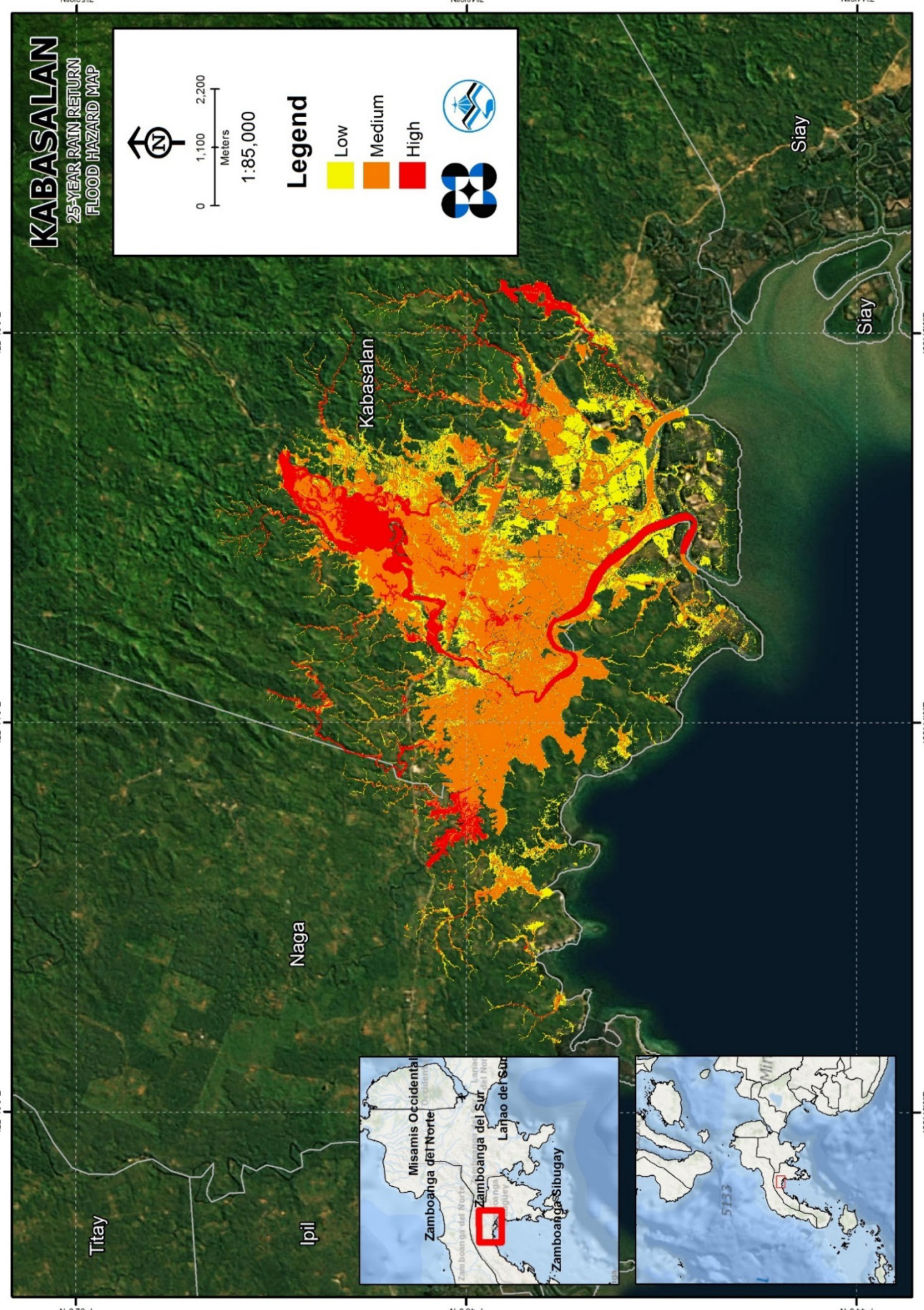


Figure 64. 25-year Flood Hazard Map for Kabasalan Floodplain

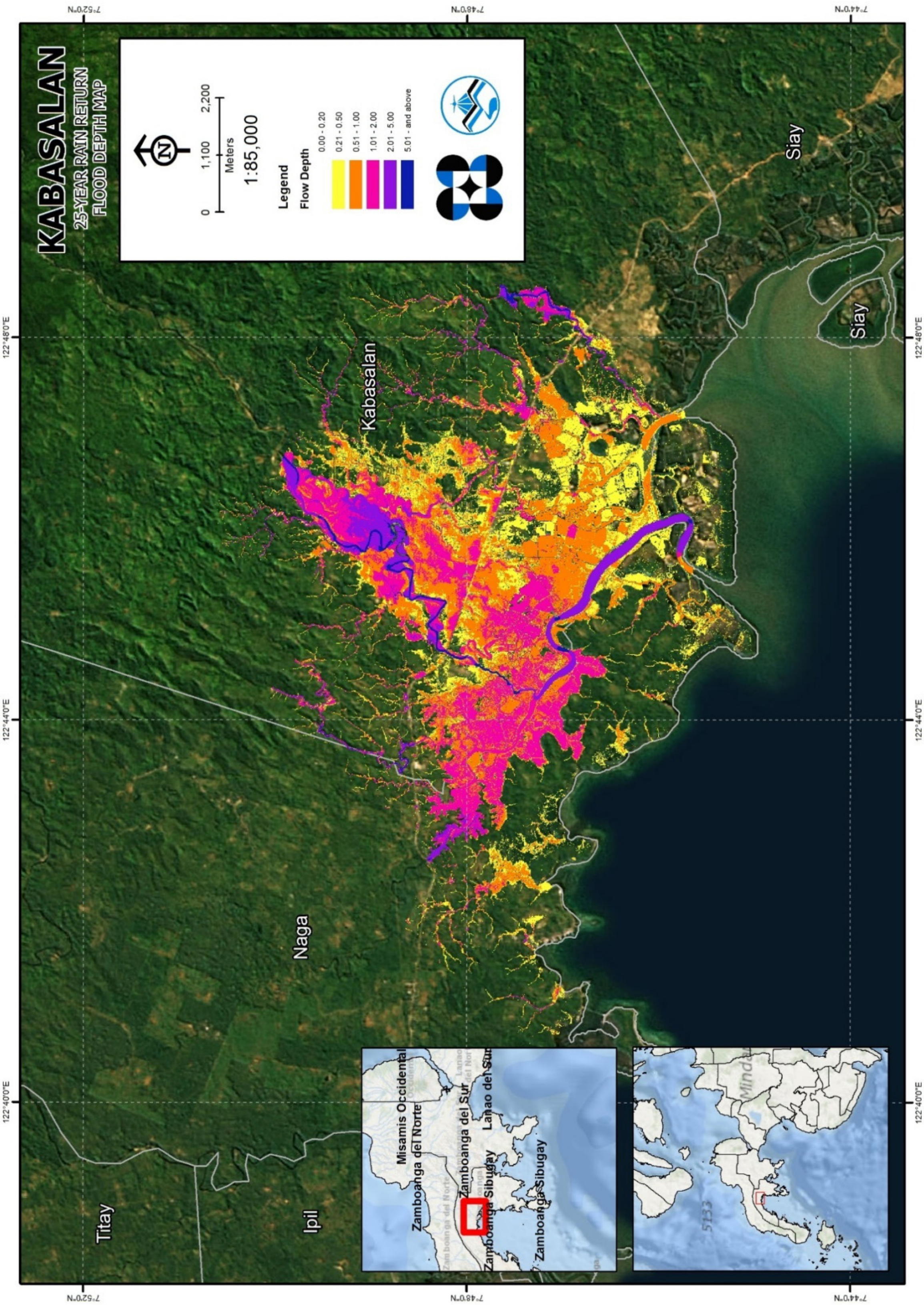


Figure 65. 25-year Flow Depth Map for Kabasalan Floodplain

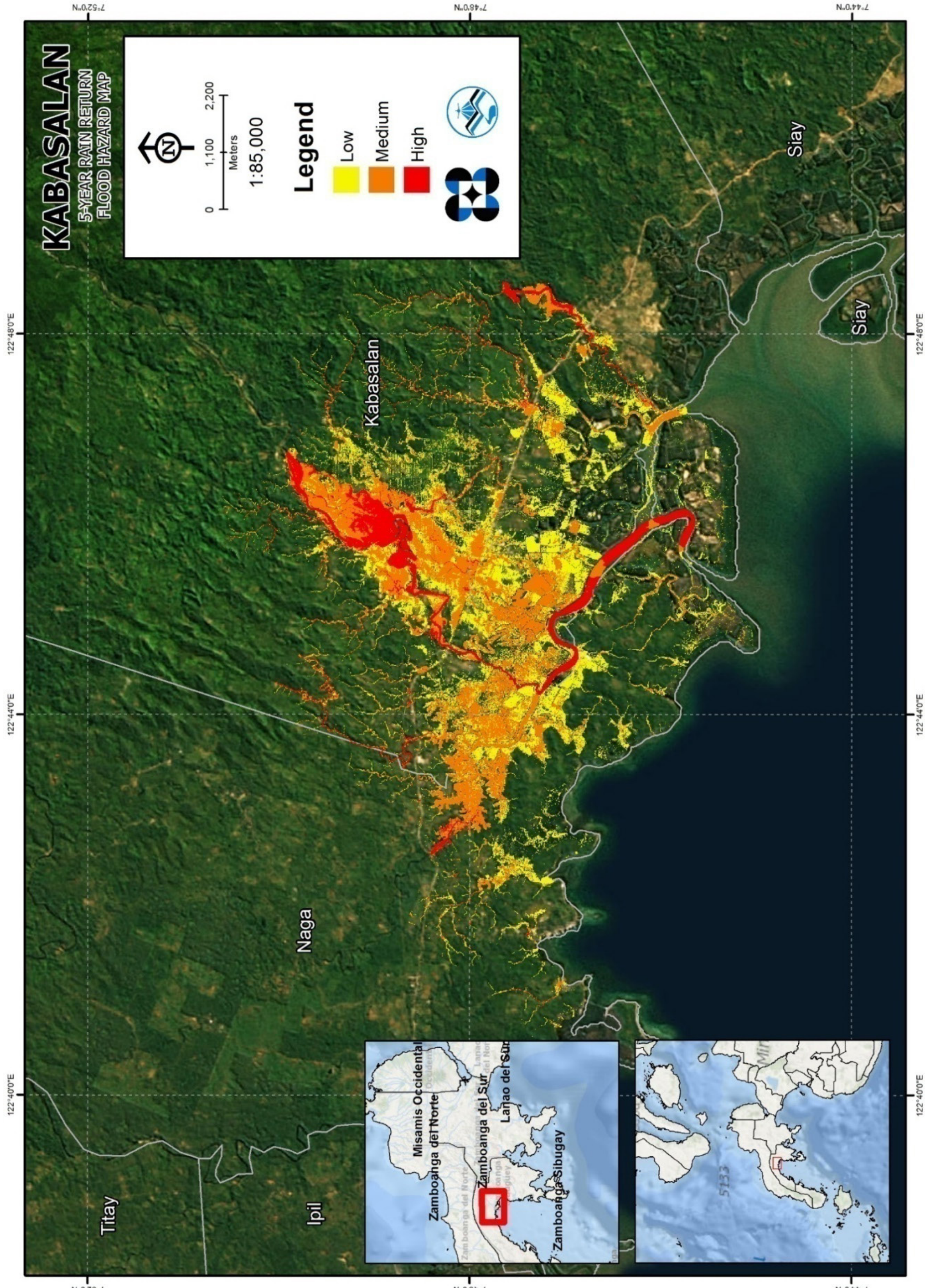


Figure 66. 5-year Flood Hazard Map for Kabasalan Floodplain

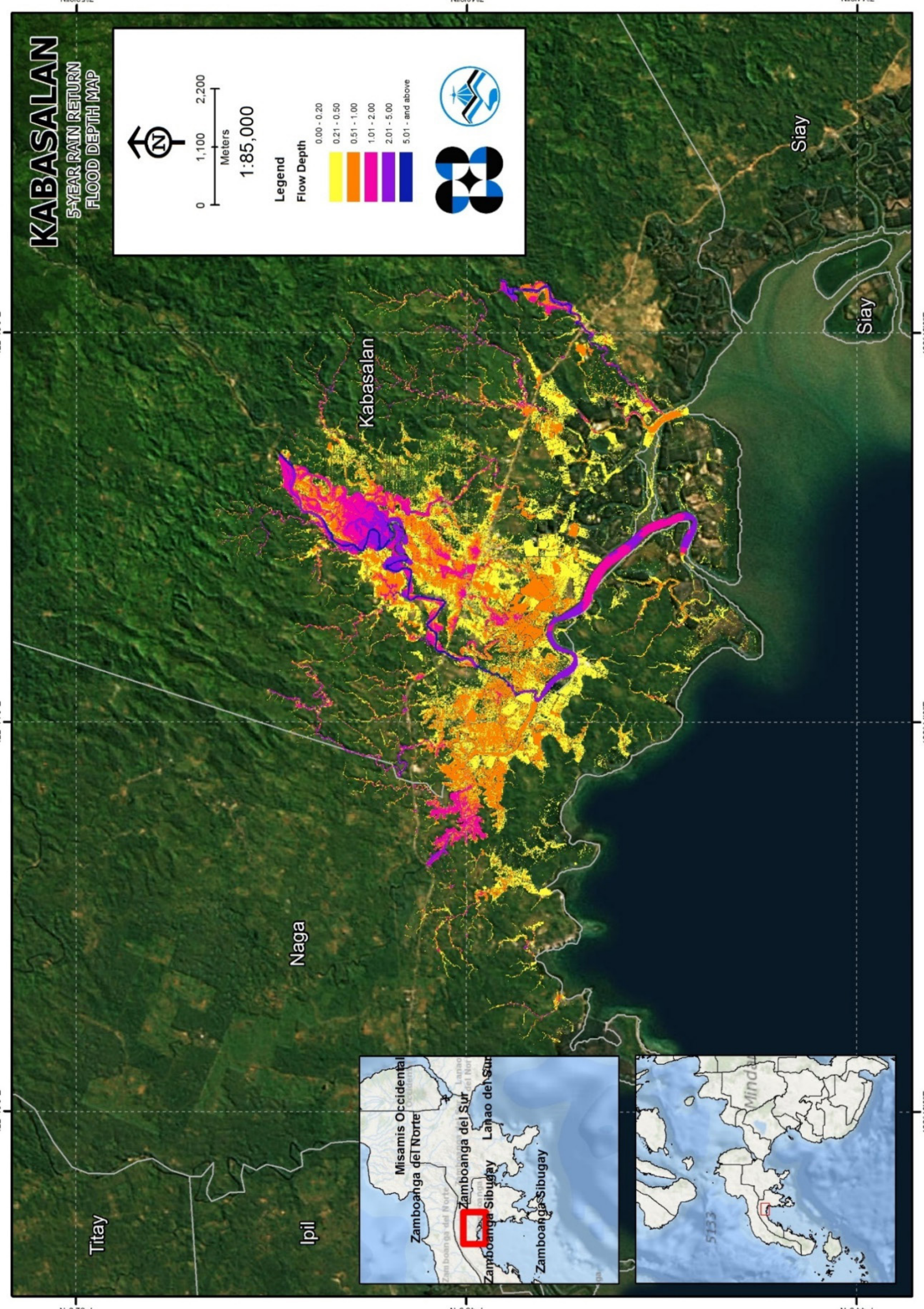


Figure 67. 5-year Flood Depth Map for Kabasalan Floodplain

5.10 Inventory of Areas Exposed to Flooding of Affected Areas

Affected barangays in Kabasalan river basin, grouped by municipality, are listed below. For the said basin, four municipalities consisting of 35 barangays are expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 57.96011% of the municipality of Kabasalan with an area of 320.5441 sq. km. will experience flood levels of less than 0.20 meters; 3.37726% of the area will experience flood levels of 0.21 to 0.50 meters; while 2.58531%, 1.20833%, 0.93113%, and 0.32944% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay .

Table 30. Affected areas in Kabasalan, Zamboanga Sibugay during a 5-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Kabasalan (in sq. km.)										
	Banker	Bolo Batallion	Buayan	Cainglet	Calapan	Calubihan	Concepcion	Dipala	Gacbusan	Goodyear	Lacnapan
0.03-0.20	17.16	1.14	3.46	1.18	0.5	0.31	1.7	2.65	3.02	8.91	9.8
0.21-0.50	0.39	1.04	0.33	0.75	0.012	0.42	0.17	0.5	0.11	0.72	0.25
0.51-1.00	0.28	1.24	0.2	0.17	0.0048	0.72	0.12	0.17	0.079	0.73	0.13
1.01-2.00	0.32	0.029	0.14	0.046	0.0027	0.25	0.069	0.06	0.067	0.84	0.076
2.01-5.00	0.22	0.22	0.092	0.026	0	0.11	0.11	0.022	0.047	0.27	0.099
> 5.00	0.029	0.026	0.011	0	0	0.028	0.042	0	0	0.02	0.042

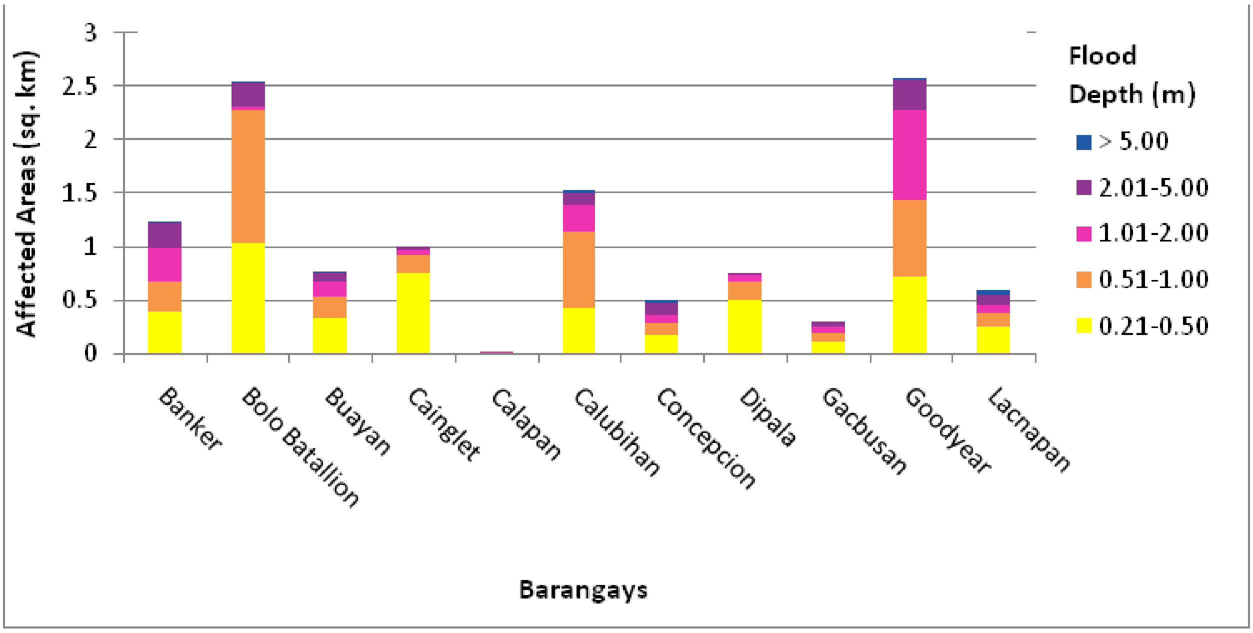


Figure 68. Affected areas in Kabasalan, Zamboanga Sibugay during a 5-year rainfall return period

Table 31. Affected areas in Kabasalan, Zamboanga Sibugay during a 5-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Kabasalan (in sq. km.)										
	Little Baguio	Lumbayao	Nazareth	Palinta	Penaranda	Poblacion	Riverside	Sanghanan	Santa Cruz	Sayao	Shiolan
0.03-0.20	9.42	0.74	0.071	8.32	9.34	1.61	0.33	17.04	0.47	14.25	21.86
0.21-0.50	0.24	0.32	0.000021	0.18	0.18	0.93	0.34	0.35	0.14	0.33	0.47
0.51-1.00	0.11	0.17	0	0.11	0.11	0.88	0.48	0.27	0.058	0.25	0.21
1.01-2.00	0.057	0.066	0	0.065	0.11	0.1	0.12	0.29	0.0004	0.2	0.13
2.01-5.00	0.053	0.014	0	0.1	0.14	0.044	0.012	0.36	0	0.096	0.18
> 5.00	0.0026	0	0	0.024	0.045	0.0002	0	0.34	0	0.0025	0.13

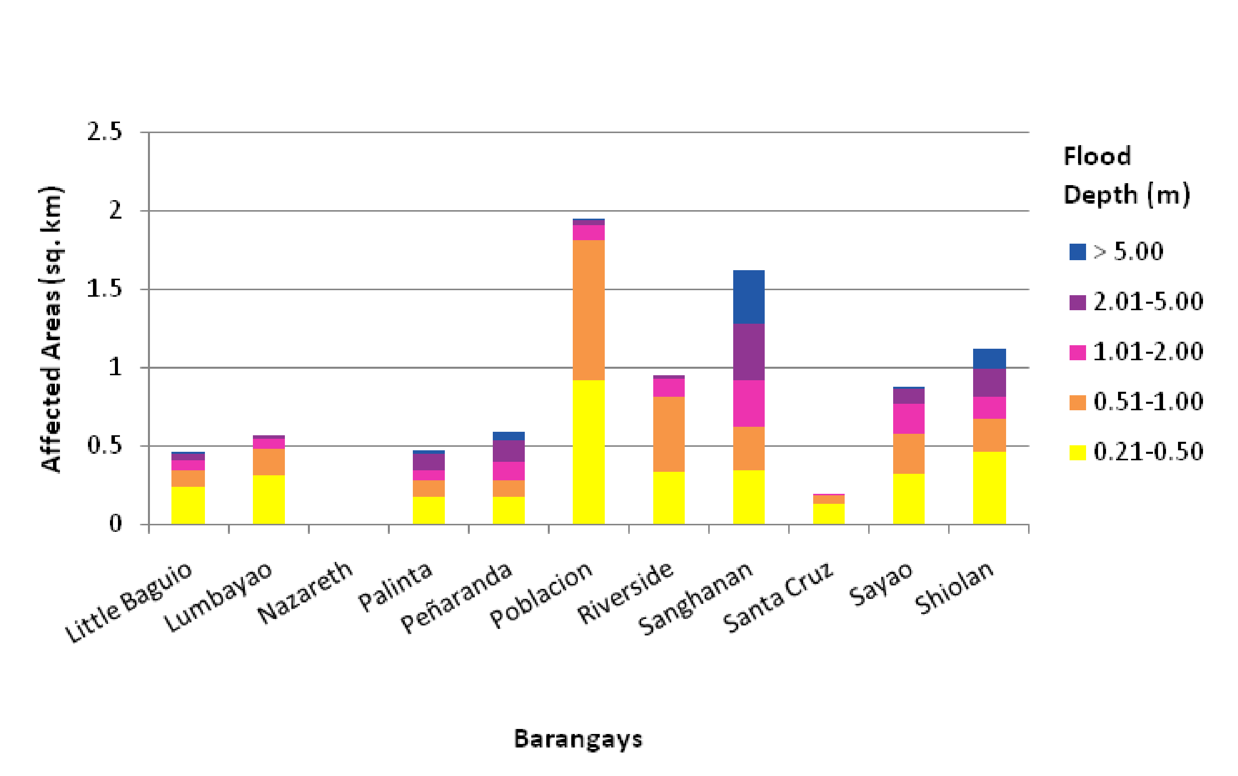


Figure 69. Affected areas in Kabasalan, Zamboanga Sibugay during a 5-year rainfall return period

Table 32. Affected areas in Kabasalan, Zamboanga Sibugay during a 5-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Kabasalan (in sq. km.)					
	Simbol	Sininan	Tamin	Tampil-isan	Tigban-gagan	Timuay Danda
0.03-0.20	1.57	3.58	3.42	37.74	2.17	4.05
0.21-0.50	0.43	0.65	0.079	0.72	0.1	0.7
0.51-1.00	0.51	0.59	0.047	0.34	0.14	0.18
1.01-2.00	0.052	0.35	0.042	0.23	0.12	0.032
2.01-5.00	0.034	0.33	0.014	0.26	0.11	0.015
> 5.00	0.0036	0.17	0.0001	0.14	0.002	0

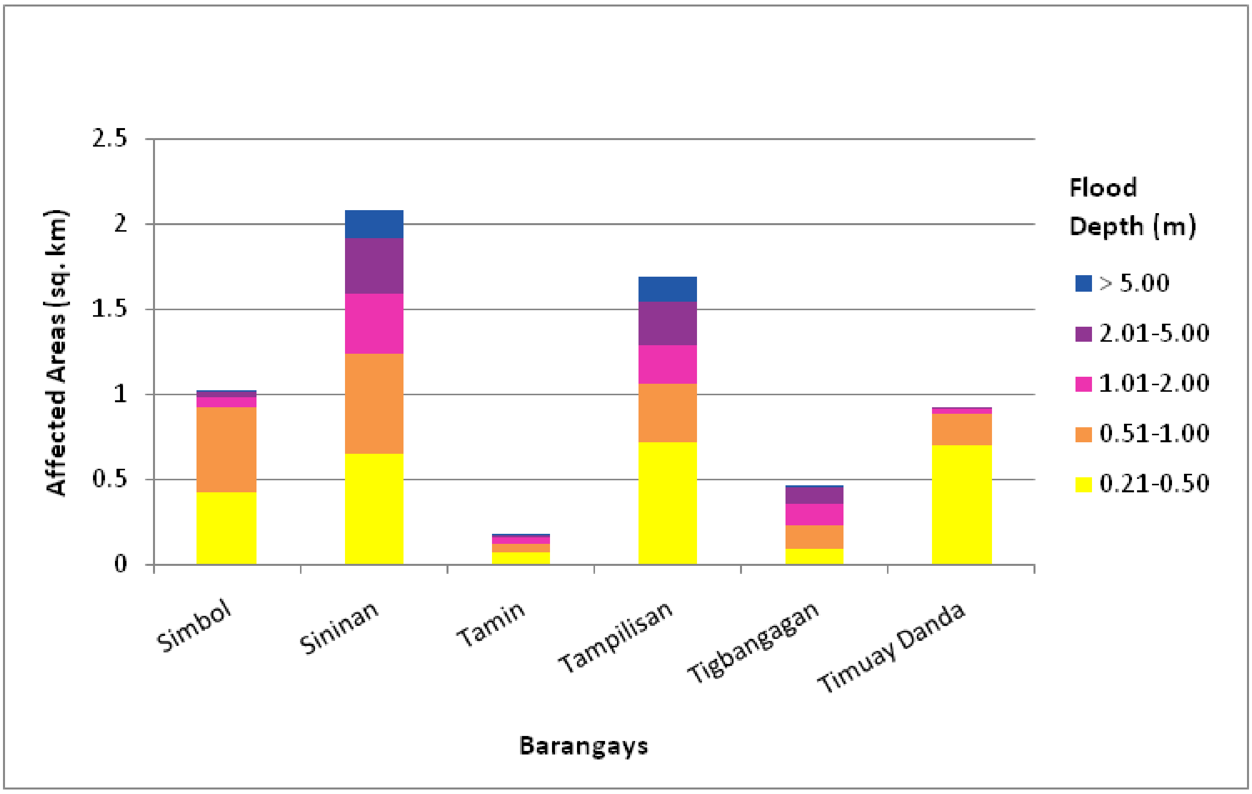


Figure 70. Affected areas in Kabasalan, Zamboanga Sibugay during a 5-year rainfall return period

For the 5-year return period, 39.15077% of the municipality of Naga with an area of 151.7202 sq. km will experience flood levels of less than 0.20 meters; 2.57392% of the area will experience flood levels of 0.21 to 0.50 meters; while 1.57233%, 0.67827%, 0.25887%, and 0.02693% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 33. Affected areas in Naga, Zamboanga Sibugay during a 5-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Naga (in sq. km.)							
	Agui-naldo	Baga	Baluno	Bang-kaw-Bangkaw	Cabong	Crossing Sta. Clara	Gu-bawang	Lower Sulitan
0.03-0.20	1.75	14.95	0.97	3.18	0	1.45	2.92	6.16
0.21-0.50	0.083	0.59	0.035	0.9	0	0.05	0.41	0.3
0.51-1.00	0.044	0.52	0.015	0.77	0	0.025	0.14	0.21
1.01-2.00	0.015	0.39	0.0061	0.2	0	0.026	0.077	0.13
2.01-5.00	0.0053	0.17	0.0022	0.00043	0	0.052	0.0016	0.082
> 5.00	0	0.016	0	0	0	0.025	0	0

Table 34. Affected areas in Naga, Zamboanga Sibugay during a 5-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Naga (in sq. km.)						
	Mamagon	Pobla-cion	San Isidro	Sulo	Tamba-nan	Taytay Manubo	Upper Sulitan
0.03-0.20	10.67	2.92	3.58	0.054	1.08	0.82	0.61
0.21-0.50	0.77	0.14	0.1	0.0022	0.067	0.037	0.026
0.51-1.00	0.17	0.083	0.068	0.0003	0.049	0.009	0.02
1.01-2.00	0.044	0.024	0.03	0	0.0016	0.0016	0.0029
2.01-5.00	0.045	0.0045	0.0024	0	0	0	0
> 5.00	0.000058	0	0	0	0	0	0

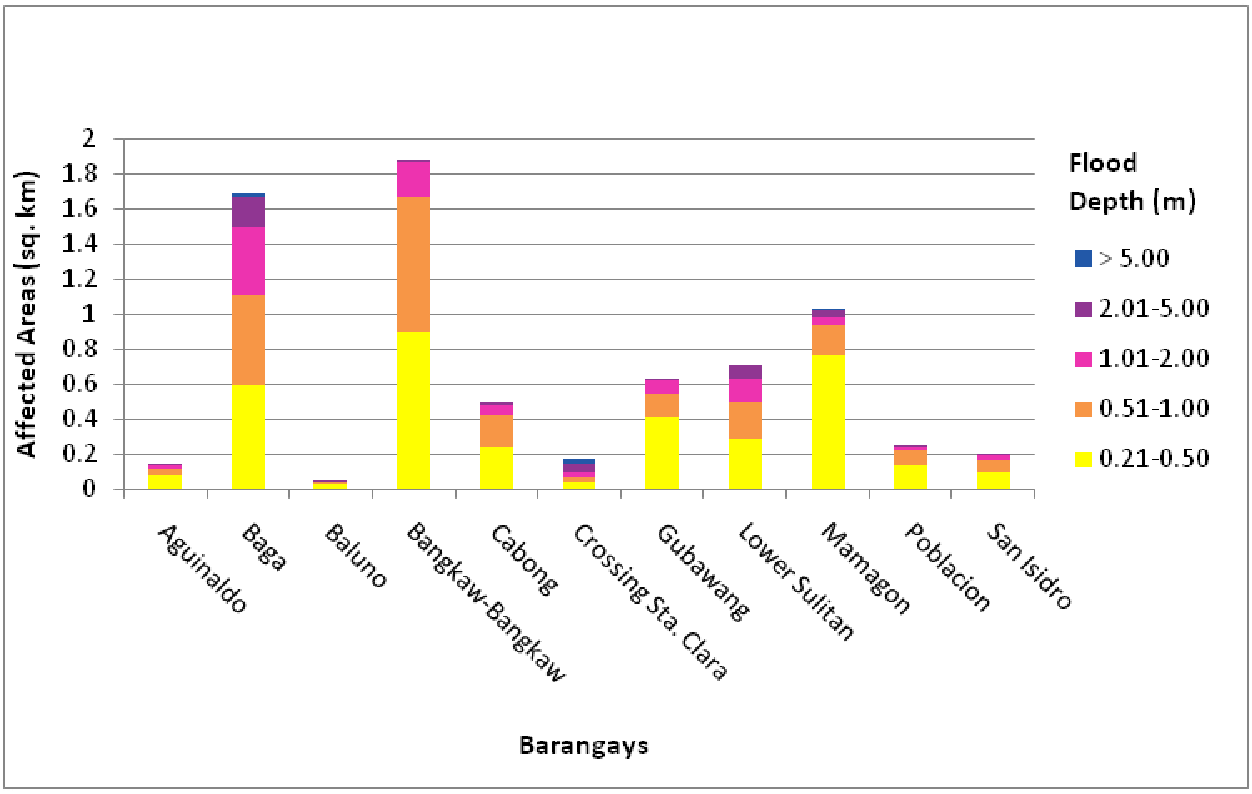


Figure 71. Affected areas in Naga, Zamboanga Sibugay during a 5-year rainfall return period

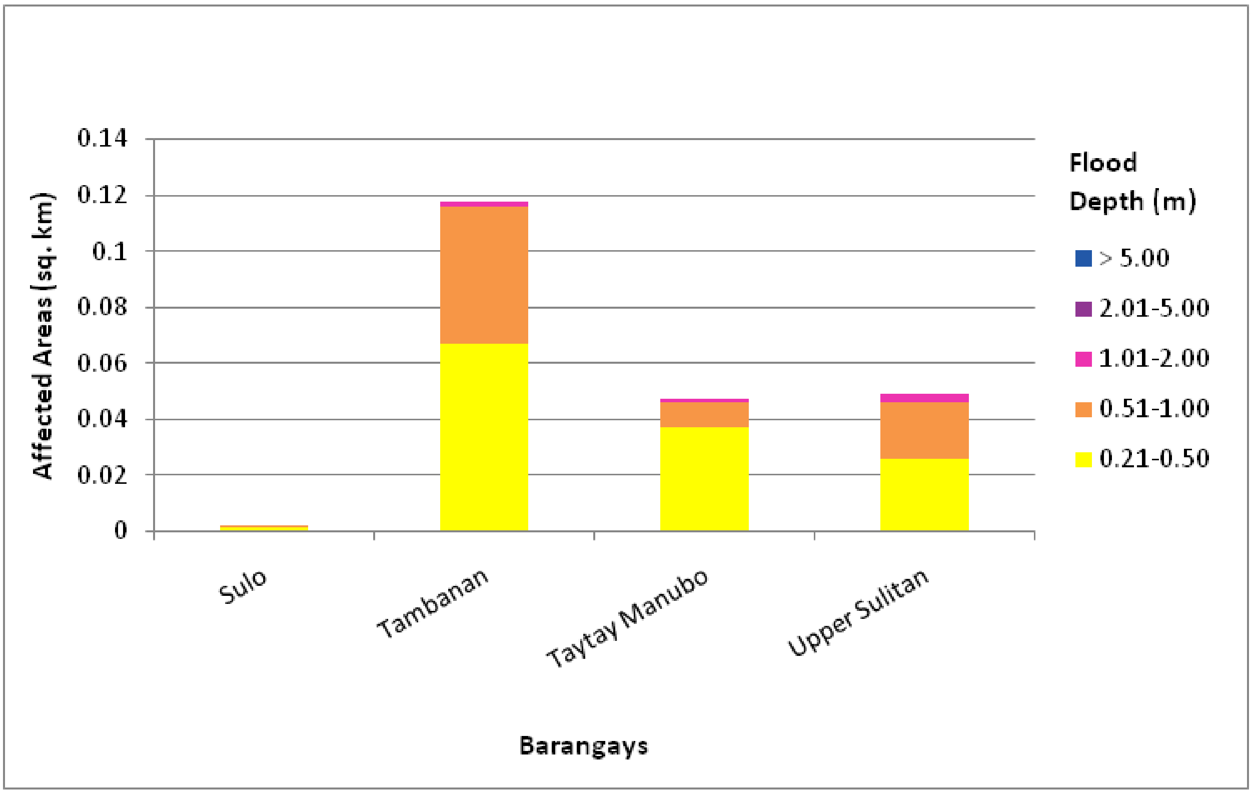


Figure 72. Affected areas in Naga, Zamboanga Sibugay during a 5-year rainfall return period

For the 25-year return period, 3.09611% of the municipality of Kabasalan with an area of 320.54 sq. km will experience flood levels of less than 0.20 meters; 2.38056% of the area will experience flood levels of 0.21 to 0.50 meters; while 3.20336%, 2.24606%, 0.96272%, and 0.32252% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 35. Affected areas in Kabasalan, Zamboanga Sibugay during a 25-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Kabasalan (in sq. km.)										
	Banker	Bolo Batal-lion	Buay-an	Cainglet	Cala-pan	Calubi-han	Con-cep-cion	Dipala	Gac-busan	Good-year	Lacna-pan
0.03-0.20	1.08	0.2	0.62	0.082	0	0.059	0.39	0.54	0.35	1.54	0
0.21-0.50	0.21	0.4	0.39	0.37	0	0.18	0.18	0.83	0.12	0.8	0
0.51-1.00	0.19	1.14	0.23	1.46	0	0.75	0.079	0.53	0.097	0.74	0
1.01-2.00	0.27	1.52	0.16	0.09	0	0.65	0.13	0.13	0.089	1.09	0
2.01-5.00	0.36	0.19	0.15	0.071	0	0.13	0.12	0.041	0.073	0.62	0.099
> 5.00	0.083	0.058	0.026	0	0	0.055	0.06	0	0.0058	0.037	0.042

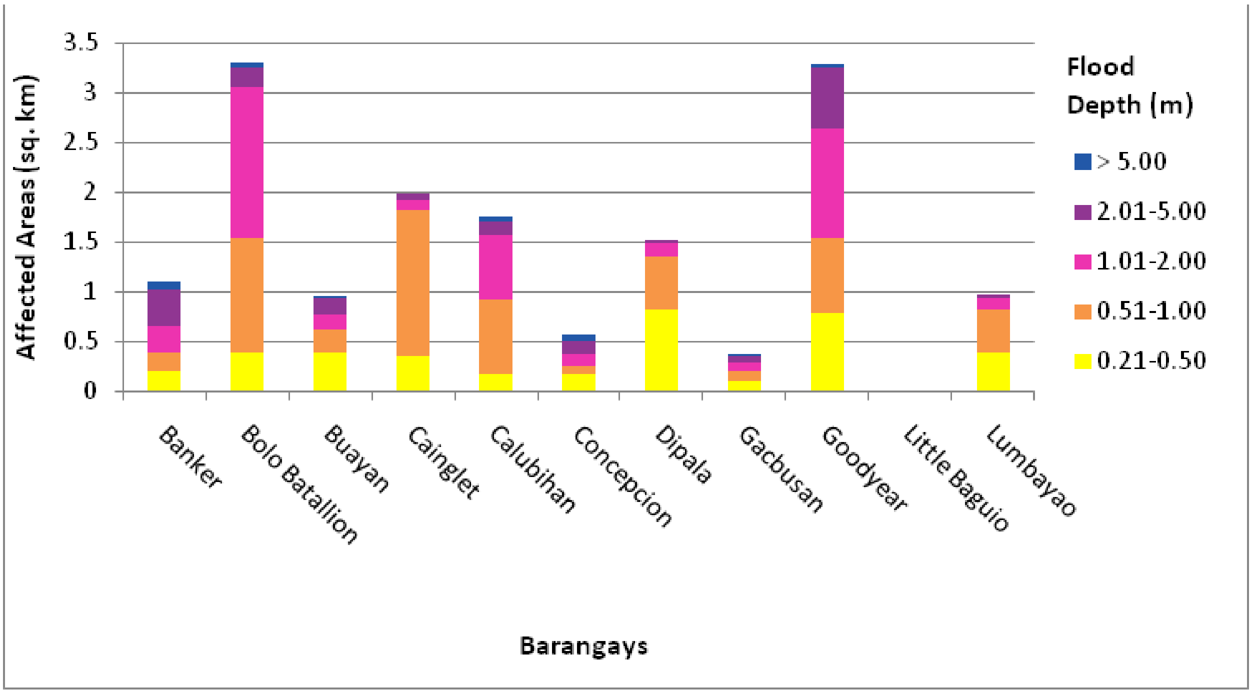


Figure 73. Affected areas in Kabasalan, Zamboanga Sibugay during a 25-year rainfall return period

Table 36. Affected areas in Kabasalan, Zamboanga Sibugay during a 25-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Kabasalan (in sq. km.)										
	Little Baguio	Lum-bayao	Naza-reth	Palinta	Pe-naran-da	Pobla-cion	River-side	Sang-hanan	Santa Cruz	Sayao	Shio-lan
0.03-0.20	0.18	0.12	0	0	0	0.38	0.032	1.37	0.16	0	0
0.21-0.50	0.015	0.4	0	0	0	0.8	0.17	0.22	0.23	0	0
0.51-1.00	0.007	0.44	0	0	0	1.22	0.5	0.15	0.15	0	0
1.01-2.00	0.0013	0.12	0	0	0	0.74	0.54	0.18	0.04	0	0
2.01-5.00	0.053	0.03	0	0.1	0.14	0.056	0.022	0.49	0	0.096	0.18
> 5.00	0.0026	0	0	0.024	0.045	0.0067	0	0.45	0	0.0025	0.13

Table 37. Affected areas in Kabasalan, Zamboanga Sibugay during a 25-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Kabasalan (in sq. km.)					
	Simbol	Sininan	Tamin	Tampil-isan	Tigbanga-gan	Timuay Danda
0.03-0.20	0.2	0.55	0.52	0	0.0013	0.95
0.21-0.50	0.2	0.41	0.081	0	0	1.26
0.51-1.00	0.54	0.77	0.053	0	0	0.99
1.01-2.00	0.47	0.66	0.044	0	0.000009	0.13
2.01-5.00	0.048	0.49	0.022	0.26	0.11	0.021
> 5.00	0.02	0.2	0.0004	0.14	0.002	0

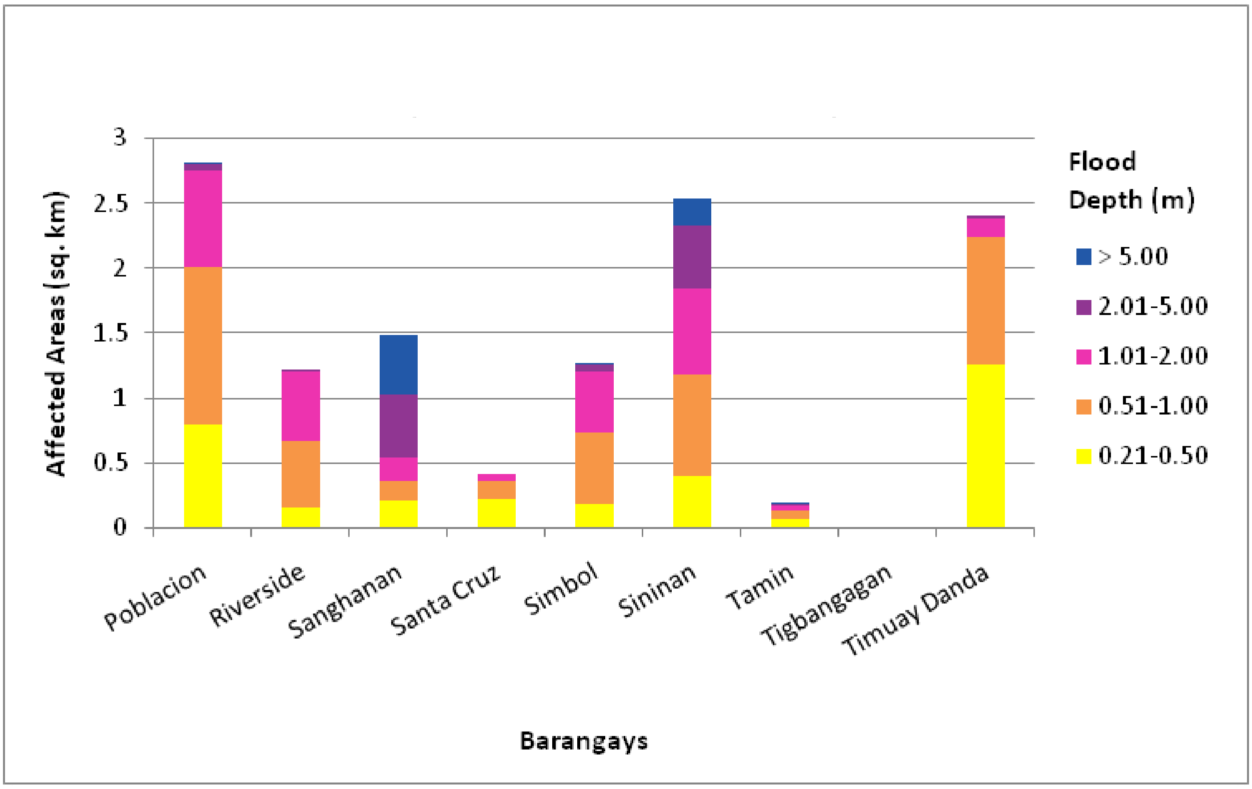


Figure 74. Affected areas in Kabasalan, Zamboanga Sibugay during a 25-year rainfall return period

For the 25-year return period, 7.13710% of the municipality of Naga with an area of 151.72 sq.km will experience flood levels of less than 0.20 meters; 2.26951% of the area will experience flood levels of 0.21 to 0.50 meters; while 1.68095%, 1.70085%, 0.47381%, and 0.11924% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 38. Affected areas in Naga, Zamboanga Sibugay during a 25-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Naga (in sq. km.)							
	Aguinal-do	Baga	Baluno	Bang-kaw-Bang-kaw	Cabong	Cross-ing Sta. Clara	Gu-bawang	Lower Sulitan
0.03-0.20	0.32	2.24	0.18	0.58	0	0.22	0.66	0.88
0.21-0.50	0.089	0.57	0.049	0.26	0	0.059	0.41	0.3
0.51-1.00	0.055	0.55	0.02	0.52	0	0.033	0.33	0.23
1.01-2.00	0.033	0.55	0.0077	1.36	0	0.025	0.11	0.17
2.01-5.00	0.0043	0.32	0.0035	0.045	0	0.051	0.03	0.15
> 5.00	0.006	0.087	0	0	0	0.069	0	0.015

Table 39. Affected areas in Naga, Zamboanga Sibugay during a 25-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Naga (in sq. km.)						
	Mama-gon	Pobla-cion	San Isidro	Sulo	Tamba-nan	Taytay Manubo	Upper Sulitan
0.03-0.20	4.24	0.64	0.34	0	0.052	0.19	0
0.21-0.50	1.31	0.12	0.066	0	0.033	0.054	0
0.51-1.00	0.53	0.13	0.053	0	0.022	0.013	0
1.01-2.00	0.2	0.047	0.023	0	0.0059	0.0028	0.0029
2.01-5.00	0.07	0.0083	0.0042	0	0	0	0
> 5.00	0.0034	0	0.00066	0	0	0	0

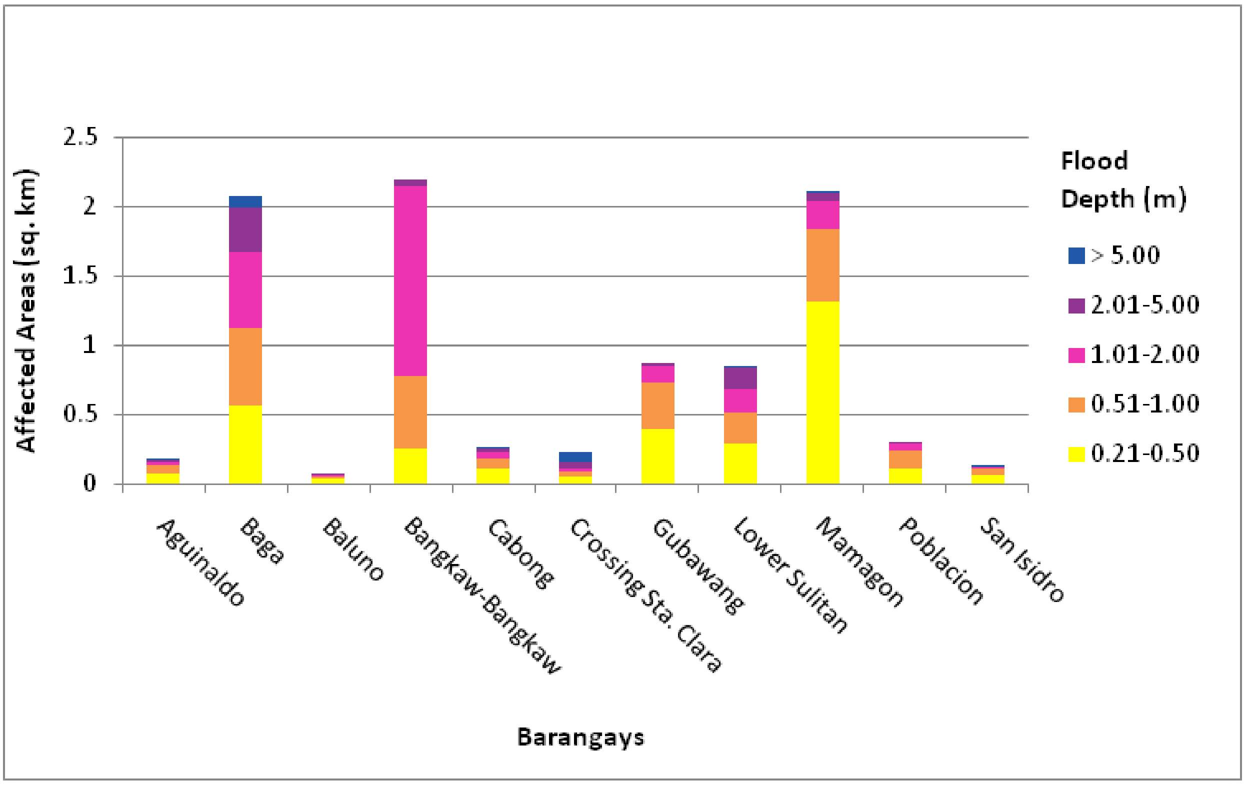


Figure 75. Affected areas in Naga, Zamboanga Sibugay during a 25-year rainfall return period

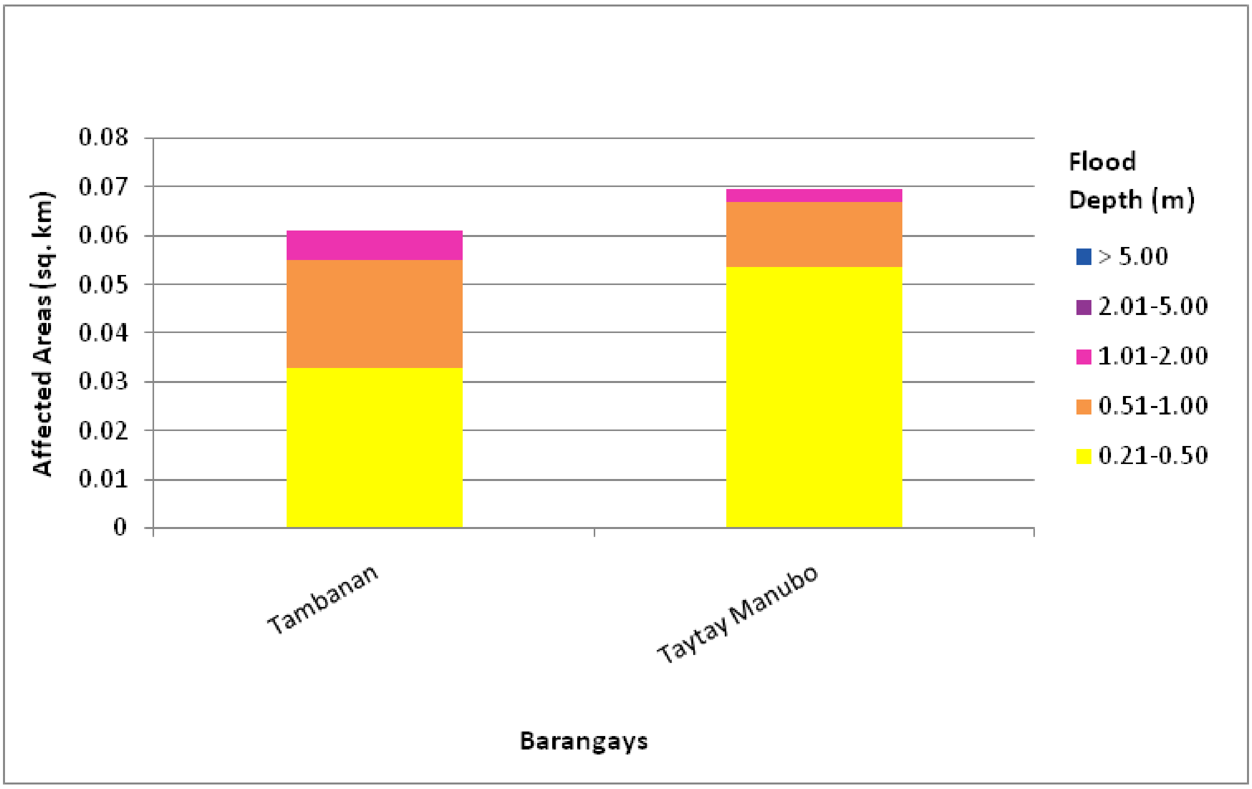


Figure 76. Affected areas in Naga, Zamboanga Sibugay during a 25-year rainfall return period

For the 100-year return period, 2.97245% of the municipality of Kabasalan with an area of 320.54 sq. km will experience flood levels of less than 0.20 meters; 1.68983% of the area will experience flood levels of 0.21 to 0.50 meters while 3.01735%, 3.48163%, 1.05987%, and 0.44293% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 40. Affected areas in Kabasalan, Zamboanga Sibugay during a 100-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Kabasalan (in sq. km.)										
	Bank-er	Bolo Batal-lion	Buay-an	Cainglet	Cala-pan	Calu-bihan	Con-cep-cion	Dipala	Gac-busan	Good-year	Lacna-pan
0.03-0.20	1.36	0.073	0.68	0.024	0	0.023	0.4	0.37	0.42	1.78	0
0.21-0.50	0.22	0.18	0.4	0.091	0	0.11	0.19	0.65	0.12	0.68	0
0.51-1.00	0.19	0.57	0.27	0.91	0	0.57	0.093	0.89	0.1	0.84	0
1.01-2.00	0.26	2.51	0.16	1.03	0	0.93	0.074	0.23	0.1	1.15	0
2.01-5.00	0.43	0.18	0.2	0.071	0	0.14	0.19	0.062	0.085	0.86	0.099
> 5.00	0.12	0.071	0.044	0	0	0.061	0.076	0	0.017	0.041	0.042

Table 41. Affected areas in Kabasalan, Zamboanga Sibugay during a 100-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Kabasalan (in sq. km.)										
	Little Baguio	Lum-bayao	Naza-reth	Palinta	Pe-naran-da	Pobla-cion	River-side	Sang-hanan	Santa Cruz	Sayao	Shio-lan
0.03-0.20	0.2007	0.050	0	0	0	0.217	0.0097	1.82	0.087	0	0
0.21-0.50	0.014	0.2003	0	0	0	0.61	0.076	0.23	0.253	0	0
0.51-1.00	0.0095	0.608	0	0	0	1.26	0.403	0.14	0.181	0	0
1.01-2.00	0.0022	0.237	0	0	0	1.21	0.75	0.16	0.105	0	0
2.01-5.00	0.053	0.042	0	0.10	0	0.067	0.034	0.35	0	0.096	0.18
> 5.00	0.0026	0	0	0.024	0	0.013	0	0.74	0	0.0025	0.13

Table 42. Affected areas in Kabasalan, Zamboanga Sibugay during a 100-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Kabasalan (in sq. km.)					
	Simbol	Sininan	Tamin	Tampilisan	Tigbanga-gan	Timuay Danda
0.03-0.20	0.18	0.57	0.62	0	0.0013	0.66
0.21-0.50	0.11	0.36	0.086	0	0	0.84
0.51-1.00	0.26	0.66	0.060	0	0.00006	1.65
1.01-2.00	0.90	0.90	0.051	0	0	0.402
2.01-5.00	0.057	0.56	0.029	0.26	0.000009	0.036
> 5.00	0.023	0.21	0.0006	0.14	0.002	0

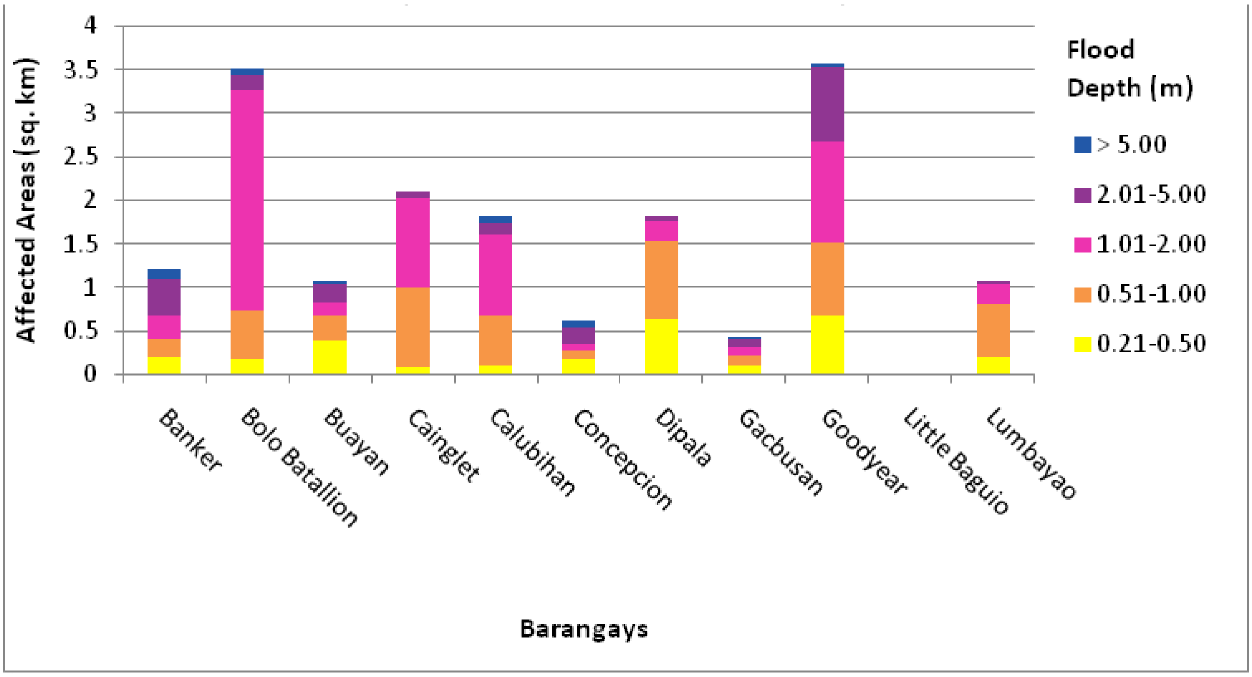


Figure 77. Affected areas in Kabasalan, Zamboanga Sibugay during a 100-year rainfall return period

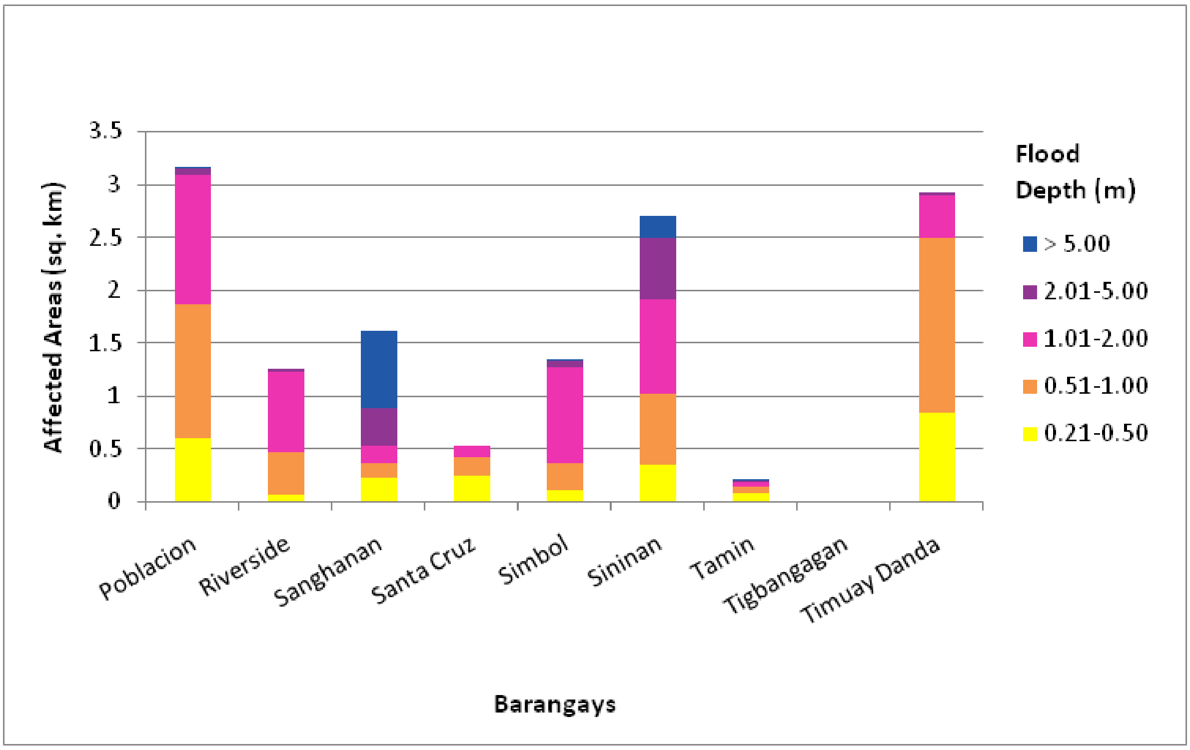


Figure 78. Affected areas in Kabasalan, Zamboanga Sibugay during a 100-year rainfall return period

For the 100-year return period, 7.40371% of the municipality of Naga with an area of 151.72 sq.km will experience flood levels of less than 0.20 meters; 2.68250% of the area will experience flood levels of 0.21 to 0.50 meters; while 1.94076%, 2.16934%, 0.67126%, and 0.21505% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 43. Affected areas in Naga, Zamboanga Sibugay during a 25-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Naga (in sq. km.)							
	Aguinal-do	Baga	Baluno	Bang-kaw-Bang-kaw	Cabong	Cross-ing Sta. Clara	Gu-bawang	Lower Sulitan
0.03-0.20	0.39	2.63	0.21	0.65	0	0.26	0.68	0.99
0.21-0.50	0.09	0.59	0.059	0.24	0	0.062	0.4	0.31
0.51-1.00	0.066	0.56	0.022	0.23	0	0.043	0.4	0.24
1.01-2.00	0.039	0.59	0.0099	1.7	0	0.028	0.14	0.21
2.01-5.00	0.0064	0.45	0.0046	0.14	0	0.047	0.08	0.16
> 5.00	0.0087	0.14	0	0	0	0.095	0	0.066

Table 44. Affected areas in Naga, Zamboanga Sibugay during a 25-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Naga (in sq. km.)						
	Mama-gon	Pobla-cion	San Isidro	Sulo	Tamba-nan	Taytay Manubo	Upper Sulitan
0.03-0.20	3.68	0.78	0.37	0	0.054	0.22	0
0.21-0.50	1.91	0.13	0.064	0	0.032	0.062	0
0.51-1.00	1.06	0.13	0.064	0	0.027	0.016	0
1.01-2.00	0.41	0.075	0.026	0	0.013	0.004	0.0029
2.01-5.00	0.068	0.012	0.0068	0	0	0	0
> 5.00	0.0073	0	0.0021	0	0	0	0

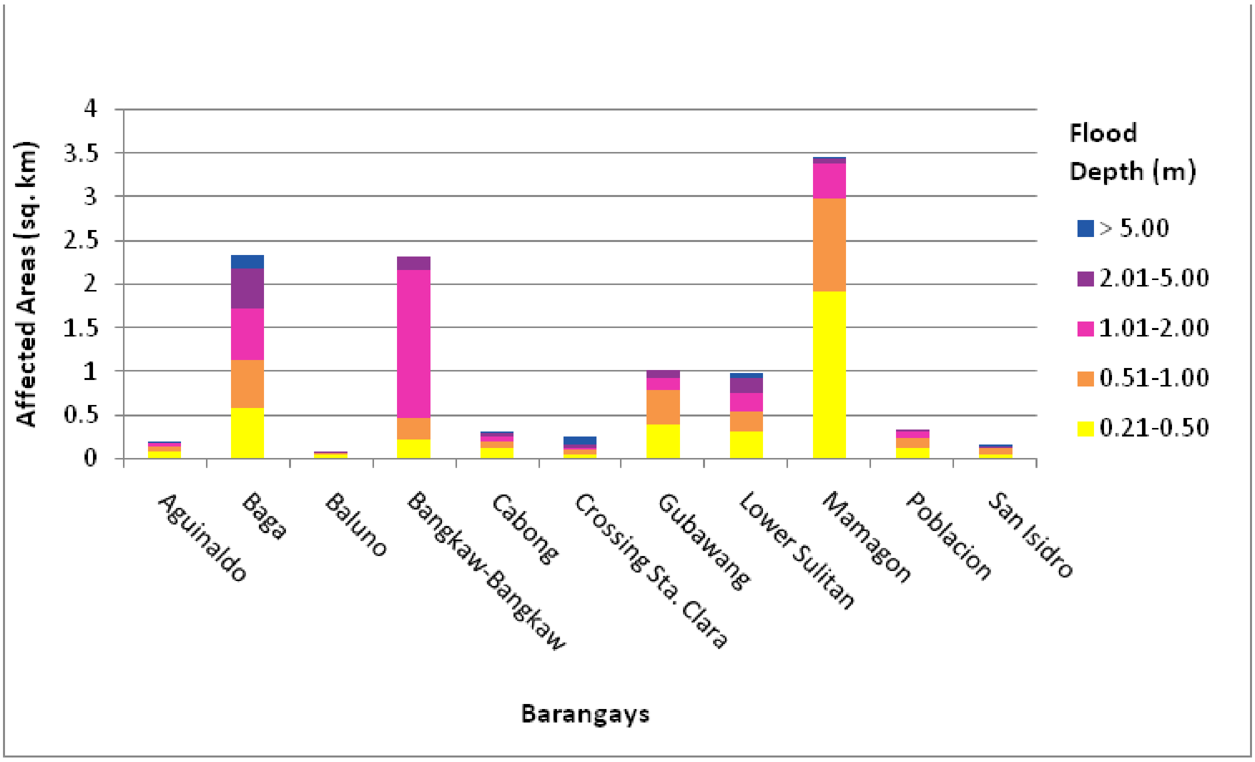


Figure 79. Affected areas in Naga, Zamboanga Sibugay during a 100-year rainfall return period

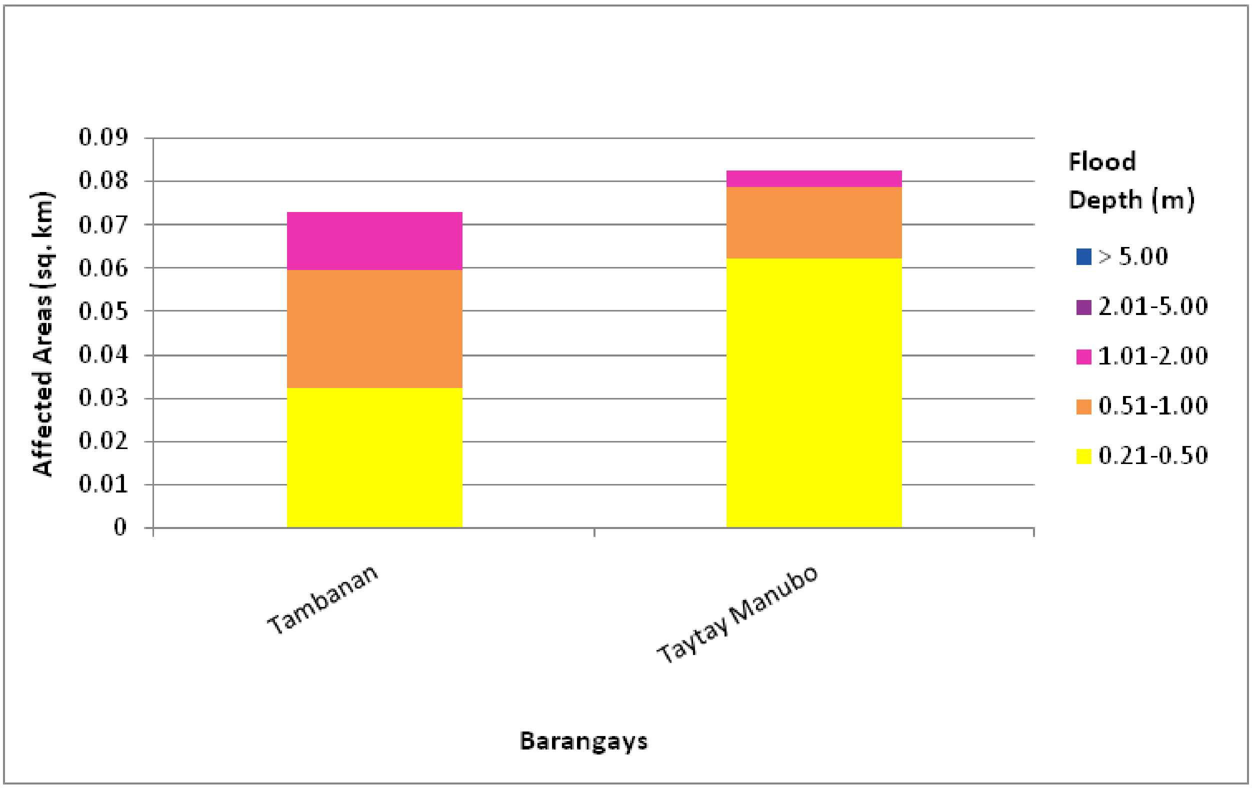


Figure 80. Affected areas in Naga, Zamboanga Sibugay during a 100-year rainfall return period

Of the 43 identified educational institutions in Kabasalan Floodplain, 9 schools were assessed to be exposed to the low-level flooding during a 5-year scenario while 8 and 1 schools were assessed to be exposed to medium- and high-level flooding, respectively, in the same scenario. In the 25-year scenario, 12 schools were assessed to be exposed to low-level flooding while 9 and 4 schools were assessed to be exposed to medium- and high-level flooding, respectively, in the same scenario. For the 100-year scenario, 8 schools were assessed to be exposed to the low-level flooding while 14 and 5 schools were assessed to be exposed to medium- and high-level flooding, respectively, in the same scenario.

Seventeen (17) medical institutions were identified in Kabasalan Floodplain. All were assessed to be exposed to medium-level flooding in the three different scenarios.

5.11 Flood Validation

In order to check and validate the extent of flooding in different river systems, there is a need to perform validation survey work. Field personnel gather secondary data regarding flood occurrence in the area within the major river system in the Philippines.

From the Flood Depth Maps produced by Phil-LiDAR 1 Program, multiple points representing the different flood depths for different scenarios are identified for validation.

The validation personnel then went to the specified points identified in a river basin and gathered data regarding the actual flood level in each location. Data gathering was done through a local DRRM office to obtain maps or situation reports about the past flooding events or interview some residents with knowledge of or have had experienced flooding in a particular area.

The actual data from the field were compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed.

The flood validation consists of 218 points randomly selected all over the Kabasalan Floodplain. It has an RMSE value of 0.78. The validation points are listed in Annex 11.

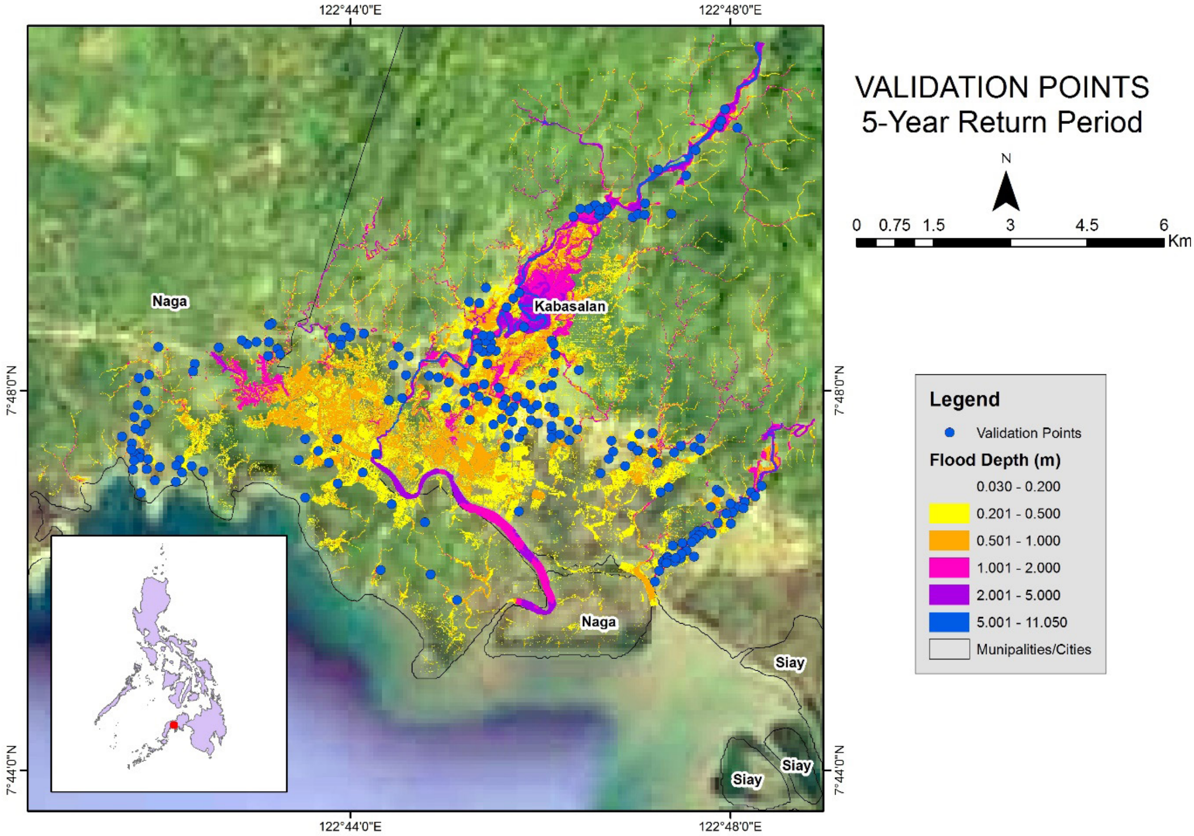


Figure 81. Validation points for 5-year Flood Depth Map of Kabasalan Floodplain

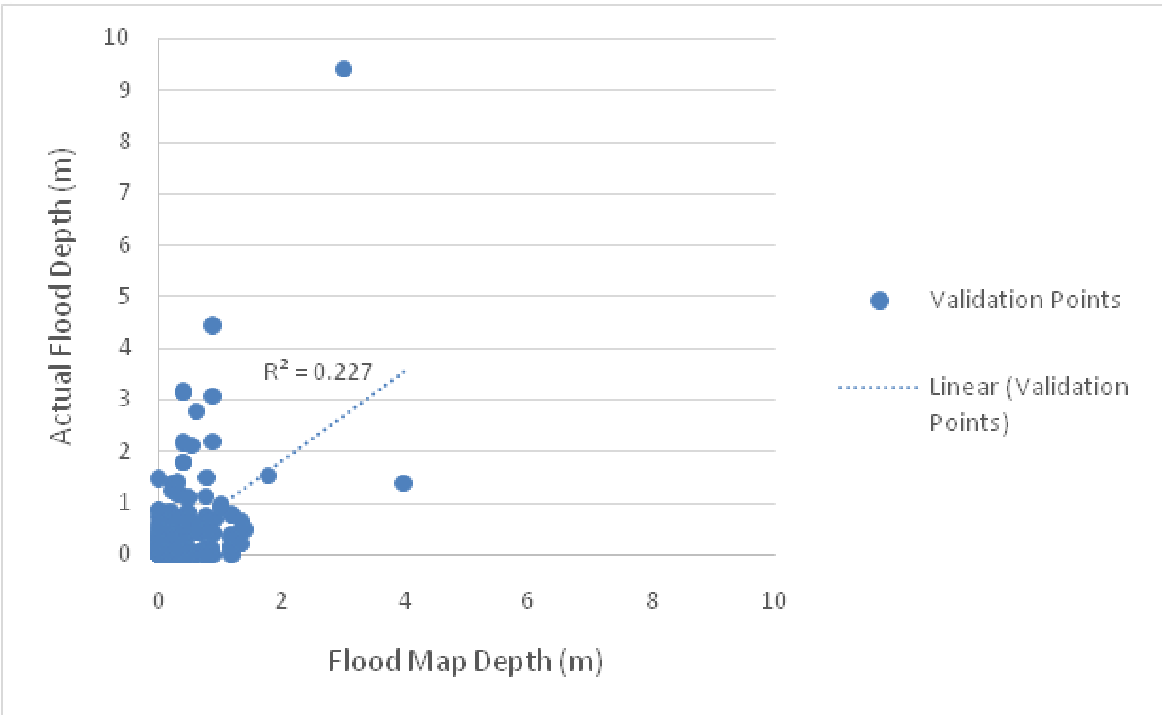


Figure 82. Flood map depth vs actual flood depth

Table 45. Actual flood depth vs simulated flood depth in Kabasalan

Actual Flood Depth (m)	Modeled Flood Depth (m)						
	0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
0-0.20	92	18	7	2	0	0	119
0.21-0.50	20	10	7	8	3	0	48
0.51-1.00	15	6	8	2	5	0	36
1.01-2.00	4	5	3	1	0	0	13
2.01-5.00	0	0	0	1	0	1	2
> 5.00	0	0	0	0	0	0	0
Total	131	39	25	14	8	1	218

The overall accuracy generated by the flood model is estimated at 50.92%, with 111 points correctly matching the actual flood depths. In addition, there were 52 points estimated one level above and below the correct flood depths while there were 40 points and 9 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 53 points were overestimated while a total of 54 points were underestimated in the modelled flood depths of Kabasalan.

Table 46. Summary of accuracy assessment in Kabasalan River Basin Survey

	No. of Points	%
Correct	111	**50.92**
Overestimated	53	**24.31**
Underestimated	54	**24.77**
Total	218	**100.00**

REFERENCES

Ang M.O., Paringit E.C., et al. 2014. DREAM Data Processing Component Manual. Quezon City, Philippines: UP Training Center for Applied Geodesy and Photogrammetry.

Balicanta L.P., Paringit E.C., et al. 2014. DREAM Data Validation Component Manual. Quezon City, Philippines: UP Training Center for Applied Geodesy and Photogrammetry.

Brunner, G. H. 2010a. HEC-RAS River Analysis System Hydraulic Reference Manual. Davis, CA: U.S. Army Corps of Engineers, Institute for Water Resources, Hydrologic Engineering Center.

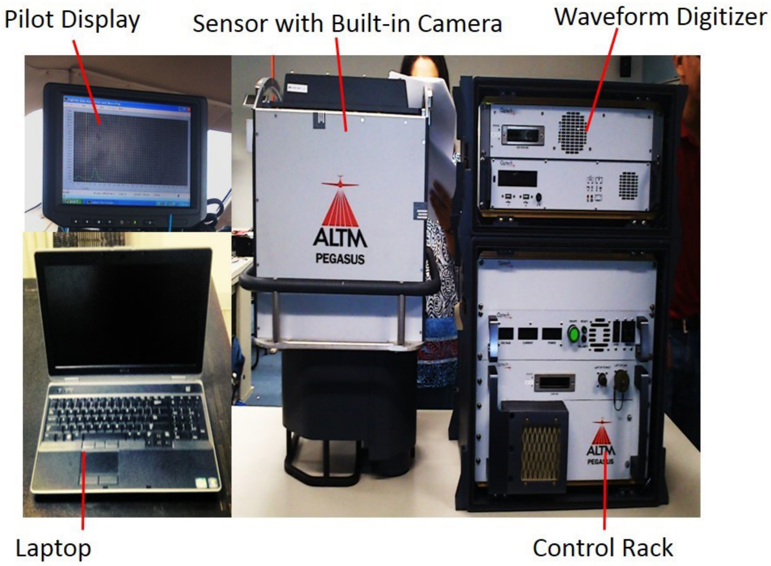
Lagmay A.F., Paringit E.C., et al. 2014. DREAM Flood Modeling Component Manual. Quezon City, Philippines: UP Training Center for Applied Geodesy and Photogrammetry.

Paringit E.C, Balicanta L.P., Ang, M.O., Sarmiento, C. 2017. Flood Mapping of Rivers in the Philippines Using Airborne Lidar: Methods. Quezon City, Philippines: UP Training Center for Applied Geodesy and Photogrammetry.

Sarmiento C., Paringit E.C., et al. 2014. DREAM Data Acquisition Component Manual. Quezon City, Philippines: UP Training Center for Applied Geodesy and Photogrammetry.

UP TCAGP 2016, Acceptance and Evaluation of Synthetic Aperture Radar Digital Surface Model (SAR DSM) and Ground Control Points (GCP). Quezon City, Philippines: UP Training Center for Applied Geodesy and Photogrammetry.

Annex 1. OPTECH Technical Specification of the Pegasus Sensor



Parameter	Specification
Operational envelope (1,2,3,4)	150-4000 m AGL, nominal
Laser wavelength	1064 nm
Horizontal accuracy (2)	1/5,500 x altitude, (m AGL)
Elevation accuracy (2)	<5-35 cm, 1 σ
Effective laser repetition rate	Programmable, 33-167 kHz
Position and orientation system	POS AV™ AP50 (OEM); 220-channel dual frequency GPS/GNSS/Galileo/L-Band receiver
Scan width (WOV)	Programmable, 0-50˚
Scan frequency (5)	Programmable, 0-70 Hz (effective)
Sensor scan product	1000 maximum
Beam divergence	Dual divergence: 0.25 mrad (1/e) and 0.8 mrad (1/e), nominal
Roll compensation	Programmable, ±5˚ (FOV dependent)
Range capture	Up to 4 range measurements, including 1st, 2nd, 3rd, and last returns
Intensity capture	Up to 4 intensity returns for each pulse, including last (12 bit)
Video Camera	Internal video camera (NTSC or PAL)
Image capture	Compatible with full Optech camera line (optional)
Full waveform capture	12-bit Optech IWD-2 Intelligent Waveform Digitizer (optional)
Data storage	Removable solid state disk SSD (SATA II)
Power requirements	28 V; 900 W;35 A(peak)
Dimensions and weight	Sensor: 260 mm (w) x 190 mm (l) x 570 mm (h); 23 kg Control rack: 650 mm (w) x 590 mm (l) x 530 mm (h); 53 kg
Operating temperature	-10˚C to +35˚C (with insulating jacket)
Relative humidity	0-95% no-condensing

Annex 2. NAMRIA Certificates of Reference Points Used

1. ZGS-58

Republic of the Philippines
Department of Environment and Natural Resources
NATIONAL MAPPING AND RESOURCE INFORMATION AUTHORITY

February 24, 2016

CERTIFICATION

To whom it may concern:

This is to certify that according to the records on file in this office, the requested survey information is as follows -

Province: **ZAMBOANGA DEL SUR**

Station Name: **ZGS-58**

Order: **2nd**

Island: **MINDANAO**	Barangay: **SICADE**		
Municipality: **KUMALARANG**	MSL Elevation:		

PRS92 Coordinates

Latitude: **7° 45' 44.20587"**	Longitude: **123° 8' 50.40994"**	Ellipsoidal Hgt: **31.65000 m.**

WGS84 Coordinates

Latitude: **7° 45' 40.67639"**	Longitude: **123° 8' 55.89231"**	Ellipsoidal Hgt: **96.97400 m.**

PTM / PRS92 Coordinates

Northing: **858266.608 m.**	Easting: **516251.478 m.**	Zone: **4**

UTM / PRS92 Coordinates

Northing: **857,966.20**	Easting: **516,245.79**	Zone: **51**

Location Description

ZGS-58
Is located about 200 m. NNE of the intersection of the national highway and the road going to Poblacion, Kumalarang. It is about 190 m. NE of the PNP Checkpoint and Collection post, 190 m. NNE of a waiting shed and 400 m. NNE of ZGS-59. Mark is the head of a 3 in. copper nail embedded and centered on a 30 cm. x 30 cm. cement putty, with inscriptions "ZGS-58 2005 NAMRIA/LEP-IX".

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8089868 I**
T.N.: **2016-0411**

RUEL DM. BELEN, MNSA
Director, Mapping And Geodesy Branch

9 9 0 2 2 4 2 0 1 6 1 4 0 3 2 1

NAMRIA OFFICES:
Main : Lawton Avenue, Fort Bonifacio, 1634 Taguig City, Philippines Tel. No.: (632) 810-4831 to 41
Branch : 421 Barraca St. San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3494 to 98
www.namria.gov.ph

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

CIF/4701/12/09/814

2. ZGS-68

Republic of the Philippines
Department of Environment and Natural Resources
NATIONAL MAPPING AND RESOURCE INFORMATION AUTHORITY

February 10, 2016

CERTIFICATION

To whom it may concern:

This is to certify that according to the records on file in this office, the requested survey information is as follows -

Province: **ZAMBOANGA DEL SUR**

Station Name: **ZGS-68**

Order: **2nd**

Island: **MINDANAO**	Barangay: **POBLACION**		
Municipality: **GUIPOS**	MSL Elevation:		

PRS92 Coordinates

Latitude:	**7° 43' 33.12722"**	Longitude:	**123° 18' 48.96041"**	Ellipsoidal Hgt:	**205.94100 m.**

WGS84 Coordinates

Latitude:	**7° 43' 29.62251"**	Longitude:	**123° 18' 54.44472"**	Ellipsoidal Hgt:	**271.74800 m.**

PTM / PRS92 Coordinates

Northing:	**854250.138 m.**	Easting:	**534593.845 m.**	Zone:	**4**

UTM / PRS92 Coordinates

Northing:	**853,951.14**	Easting:	**534,581.74**	Zone:	**51**

Location Description

ZGS-68
Is located on the lot of the CENRO of Guipos. It is on the E end of the S sidewalk along the entrance way of CENRO from the national road, 15 m. E of the said office and 2.5 m. from the centerline of the driveway. Mark is the head of a 3 in. copper nail embedded and centered on a 30 cm. x 30 cm. cement putty, with inscriptions "ZGS-68 2005 NAMRIA/LEP-IX".

Requesting Party:	**UP DREAM**
Purpose:	**Reference**
OR Number:	**8089774 I**
T.N.:	**2016-0335**

RUEL DM. BELEN, MNSA
Director, Mapping And Geodesy Branch

NAMRIA OFFICES:
Main : Lawton Avenue, Fort Bonifacio, 1634 Taguig City, Philippines Tel. No.: (632) 810-4831 to 41
Branch : 421 Barraca St. San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3494 to 98
www.namria.gov.ph

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Annex 3. Baseline Processing Reports

For the Kabasalan River Basin, there are no baseline processing reports for NAMRIA ground control points.

Annex 4. The Survey Team

<table>
<tr><th>Data Acquisition Component Sub-Team</th><th>Designation</th><th>Name</th><th>Agency/ Affiliation</th></tr>
<tr><td>PHIL-LIDAR 1</td><td>Program Leader</td><td>ENRICO C. PARINGIT, D.ENG</td><td>UP-TCAGP</td></tr>
<tr><td>Data Acquisition Component Leader</td><td>Data Component Project Leader – I</td><td>ENGR. LOUIE P. BALICANTA</td><td>UP-TCAGP</td></tr>
<tr><td>Survey Supervisor</td><td>Chief Science Research Specialist (CSRS)</td><td>ENGR. CHRISTOPHER CRUZ</td><td>UP-TCAGP</td></tr>
<tr><td rowspan="2">LiDAR Operation</td><td rowspan="2">Supervising Science Research Specialist (Supervising SRS)</td><td>LOVELY GRACIA ACUÑA</td><td>UP-TCAGP</td></tr>
<tr><td>LOVELYN ASUNCION</td><td>UP-TCAGP</td></tr>
<tr><td colspan="4">FIELD TEAM</td></tr>
<tr><td rowspan="3">LiDAR Operation</td><td>Senior Science Research Specialist (SSRS)</td><td>PAULINE JOANNE ARCEO</td><td>UP-TCAGP</td></tr>
<tr><td rowspan="2">Research Associate (RA)</td><td>ENGR. KENNETH QUISADO</td><td>UP-TCAGP</td></tr>
<tr><td>ENGR. GRACE SINADJAN</td><td>UP-TCAGP</td></tr>
<tr><td>Ground Survey, Data Download and Transfer</td><td>RA</td><td>JASMIN DOMINGO</td><td>UP-TCAGP</td></tr>
<tr><td rowspan="3">LiDAR Operation</td><td>Airborne Security</td><td>SSG. LEE JAY PUNZALAN</td><td>PHILIPPINE AIR FORCE (PAF)</td></tr>
<tr><td rowspan="2">Pilot</td><td>CAPT. CESAR ALFONSO III</td><td>ASIAN AEROSPACE CORPORATION (AAC)</td></tr>
<tr><td>CAPT. JERICHO JECIEL</td><td>AAC</td></tr>
</table>

Annex 5. Data Transfer Sheet for Kabasalan Floodplain Flights

DATA TRANSFER SHEET
PAGADIAN 3/7/16

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
02/20/2016	23116P	1BLK76NO051A	Pegasus	2.29 GB	NA	11.9 MB	294 MB	NA	NA	24.4 GB	0 B	63.8 MB	2KB	2KB	148/252/232	NA	Z:\DAC\RAW DATA
02/21/2016	23120P	1BLK69D052A	Pegasus	2.6 GB	NA	12 MB	298 MB	22.5 GB	NA	25.9 GB	0 B	59.6 MB	2KB	1KB	580/100/91/8 2	NA	Z:\DAC\RAW DATA
02/22/2016	23124P	1BLK69AB053A	Pegasus	1.89 GB	NA	11.4 MB	270 MB	NA	NA	21.1 GB	0 B	3.12 MB	1KB	NA	125/108/98/8 7/78/76	NA	Z:\DAC\RAW DATA
02/23/2016	23128P	1BLK70B054A	Pegasus	2.22 GB	NA	12.8 MB	273 MB	311 MB	NA	23.3	0 B	44.4 MB	1KB	NA	92/90/80/73	NA	Z:\DAC\RAW DATA
02/24/2016	23132P	1BLK73A055A	Pegasus	10.3 MB	NA	12.5 MB	266 MB	NA	NA	24.4 GB	0 B	49.7 MB	2KB	1KB	84/84/72/76/5 7	NA	Z:\DAC\RAW DATA
02/26/2016	23140P	1BLK73BS057A	Pegasus	2.47 GB	NA	13.5 MB	305 MB	NA	NA	26.5 GB	0 B	65.9 MB	2KB	1KB	85/83	NA	Z:\DAC\RAW DATA

Received from

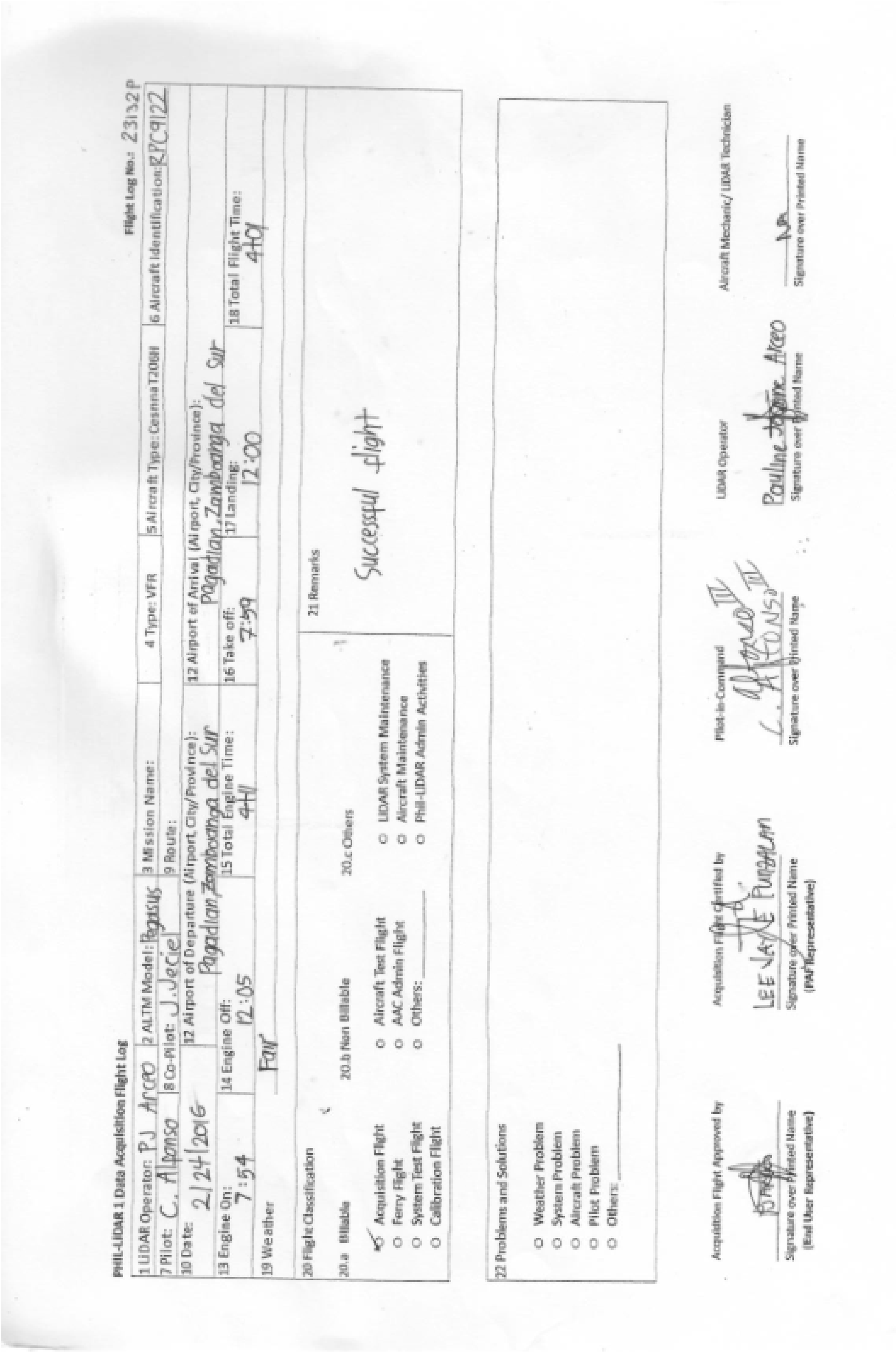
Name R. PUNTO
Position RA
Signature

Received by

Name AC Bongat
Position SSRS
Signature 3/10/16

Annex 6. Flight Logs

Flight Log for 1BLK73A055A Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 23132P

1 LiDAR Operator: P.J. Arceo	2 ALTM Model: Pegasus	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RPC9122
7 Pilot: C. Alfonso	8 Co-Pilot: J. Jeciel	9 Route:			
10 Date: 2/24/2016	12 Airport of Departure (Airport, City/Province): Pagadian Zamboanga del Sur		12 Airport of Arrival (Airport, City/Province): Pagadian, Zamboanga del Sur		
13 Engine On: 7:54	14 Engine Off: 12:05	15 Total Engine Time: 4+11	16 Take off: 7:59	17 Landing: 12:00	18 Total Flight Time: 4+01
19 Weather: Fair					

20 Flight Classification

20.a Billable
- ✓ Acquisition Flight
- o Ferry Flight
- o System Test Flight
- o Calibration Flight

20.b Non Billable
- o Aircraft Test Flight
- o AAC Admin Flight
- o Others: ____

20.c Others
- o LiDAR System Maintenance
- o Aircraft Maintenance
- o Phil-LiDAR Admin Activities

21 Remarks

Successful flight

22 Problems and Solutions
- o Weather Problem
- o System Problem
- o Aircraft Problem
- o Pilot Problem
- o Others: ____

Acquisition Flight Approved by: [signature] Signature over Printed Name (End User Representative)

Acquisition Flight Certified by: LEE JAYLE PUNGALAN, Signature over Printed Name (PAF Representative)

Pilot-in-Command: C. ALFONSO III, Signature over Printed Name

LiDAR Operator: Pauline Joanne Arceo, Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician: NA, Signature over Printed Name

Flight Log for 1BLK73BS057A Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2318OP

1 LiDAR Operator: K Quisado	2 ALTM Model: Pegasus	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RPC9122
7 Pilot: C. Alfonso	8 Co-Pilot: J. Jeciel	9 Route:			
10 Date: 2/26/2016	12 Airport of Departure (Airport, City/Province): Pagadian, Zamboanga del Sur		12 Airport of Arrival (Airport, City/Province): Pagadian, Zamboanga del Sur		
13 Engine On: 9:15	14 Engine Off: 13:50	15 Total Engine Time: 4+35	16 Take off: 9:20	17 Landing: 13:45	18 Total Flight Time: 4+25
19 Weather: Fair to Partly Cloudy					

20 Flight Classification

20.a Billable
- ✓ Acquisition Flight
- ○ Ferry Flight
- ○ System Test Flight
- ○ Calibration Flight

20.b Non Billable
- ○ Aircraft Test Flight
- ○ AAC Admin Flight
- ○ Others: ____________

20.c Others
- ○ LiDAR System Maintenance
- ○ Aircraft Maintenance
- ○ Phil-LIDAR Admin Activities

21 Remarks

Successful flight

22 Problems and Solutions
- ○ Weather Problem
- ○ System Problem
- ○ Aircraft Problem
- ○ Pilot Problem
- ○ Others: ____________

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LIDAR Operator	Aircraft Mechanic/ LIDAR Technician
[signature]	LEE J. PURAGAN [signature]	C. Alfonso III [signature]	Kenneth Quisado [signature]	NA
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

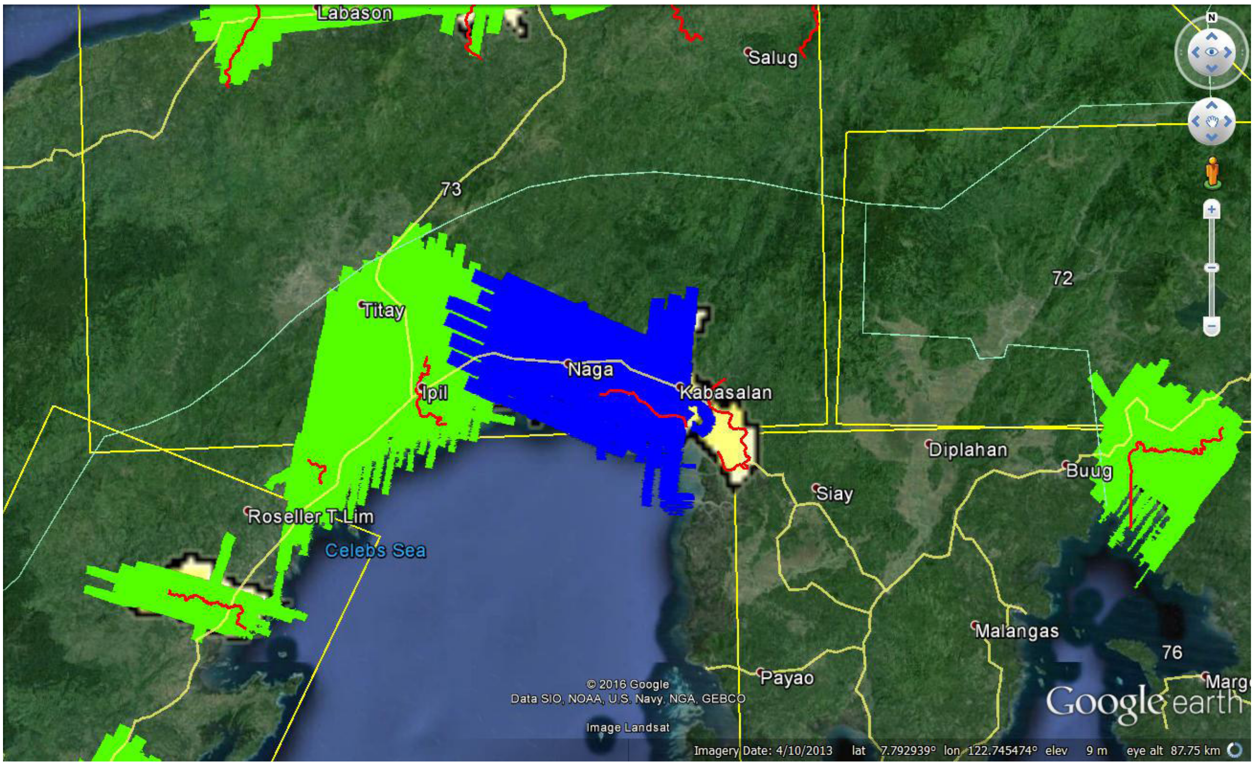
Annex 7. Flight Status Report

PAGADIAN and DIPOLOG REFLIGHTS (February 24 to February 26, 2016)					
FLIGHT NO	**AREA**	**MISSION**	**OPERATOR**	**DATE FLOWN**	**REMARKS**
23132P	BLK 73A, 73B	1BLK73A055A	PJ Arceo	February 24, 2016	Restarted the system several times due to sensor temperature increase. Encountered lost Channel A error. No LAS output. Surveyed floodplains over Zamboanga Sibugay.
23140P	BLK 73B, 72A, 70A	1BLK73BS057A	K. Quisado	February 26, 2016	Encountered lost Channel A. completed BLK 73B and voids over BLK72A and 70A.

LAS BOUNDARIES PER FLIGHT

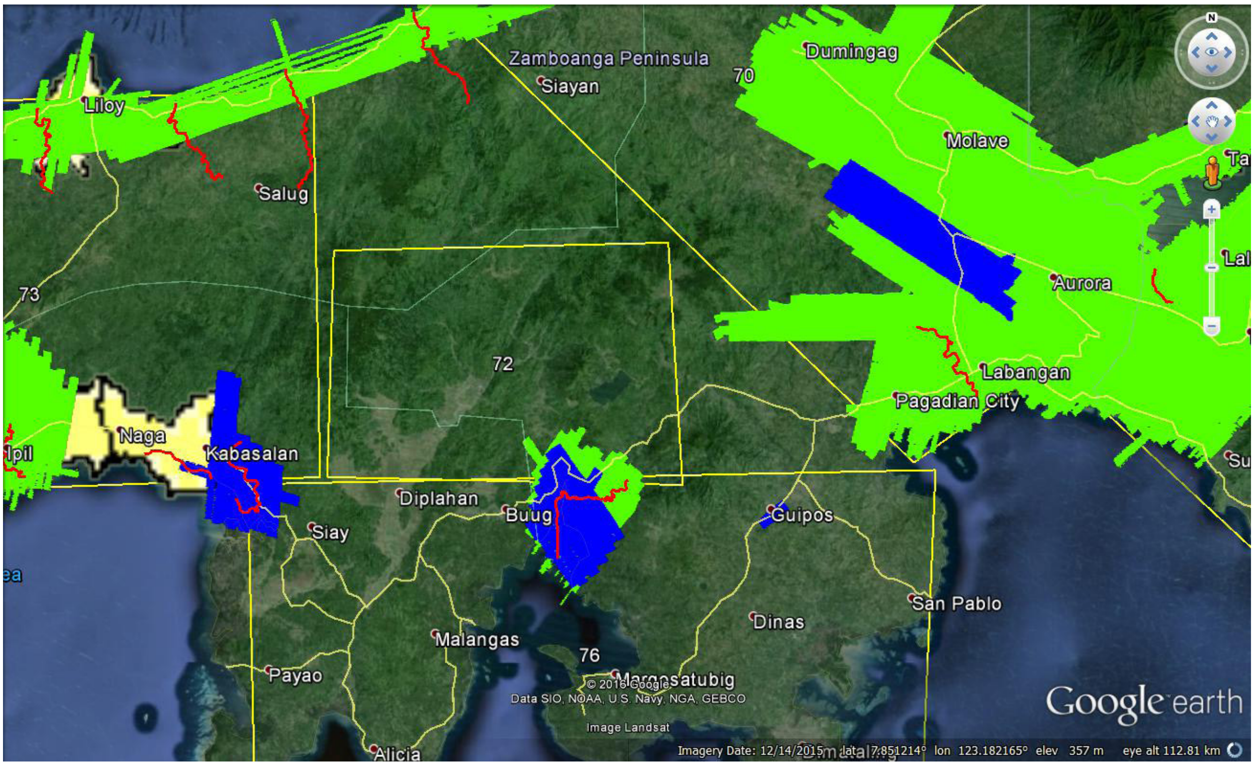
Flight No.: 23132P
Area: BLK 73A, 73B
Mission Name: 1BLK73A055A
Parameters: Altitude: 800/1200 m; Scan Frequency: 30 Hz;
Scan Angle: 25 deg; Overlap: 30%

LAS



Flight No.: 23140P
Area: BLK 73B, 72A, 70A
Mission Name: 1BLK73BS057A
Parameters: Altitude: 800/1100/1200 m; Scan Frequency: 30Hz;
Scan Angle: 25deg; Overlap: 30%

LAS



Annex 8. Mission Summary Report

Flight Area	Pagadian
Mission Name	73A
Inclusive Flights	23132P
Range data size	24.4
POS data size	266
Base data size	49.7
Image	n/a
Transfer date	March 10, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	3.3
RMSE for East Position (<4.0 cm)	2.6
RMSE for Down Position (<8.0 cm)	5.1
Boresight correction stdev (<0.001deg)	0.000238
IMU attitude correction stdev (<0.001deg)	0.002381
GPS position stdev (<0.01m)	0.0086
Minimum % overlap (>25)	45.26
Ave point cloud density per sq.m. (>2.0)	3.04
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	235
Maximum Height	356.21 m
Minimum Height	58.38 m
Classification (# of points)	
Ground	151,535,157
Low vegetation	140,778,106
Medium vegetation	205,446,183
High vegetation	523,304,913
Building	5,697,858
Orthophoto	No
Processed by	Engr. Kenneth Solidum, Engr. Mark Joshua Salvacion, Engr. Ma. AilynOlanda

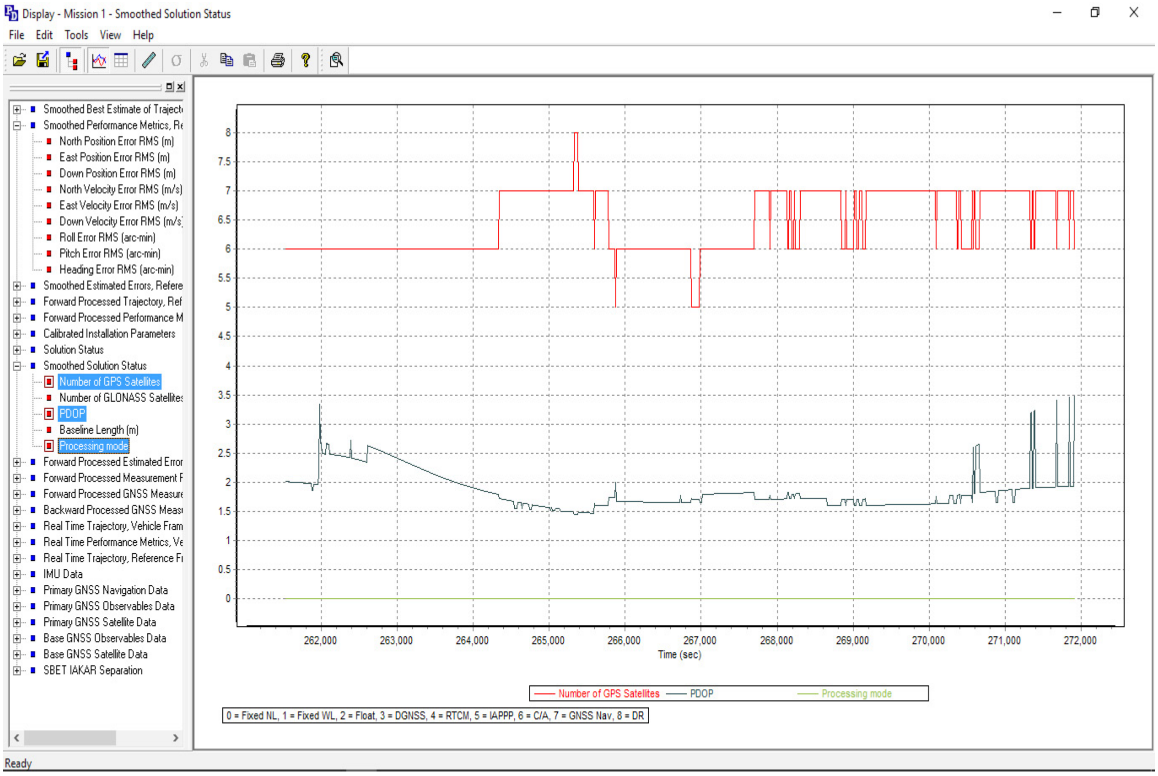


Figure 1.1.1. Solution Status

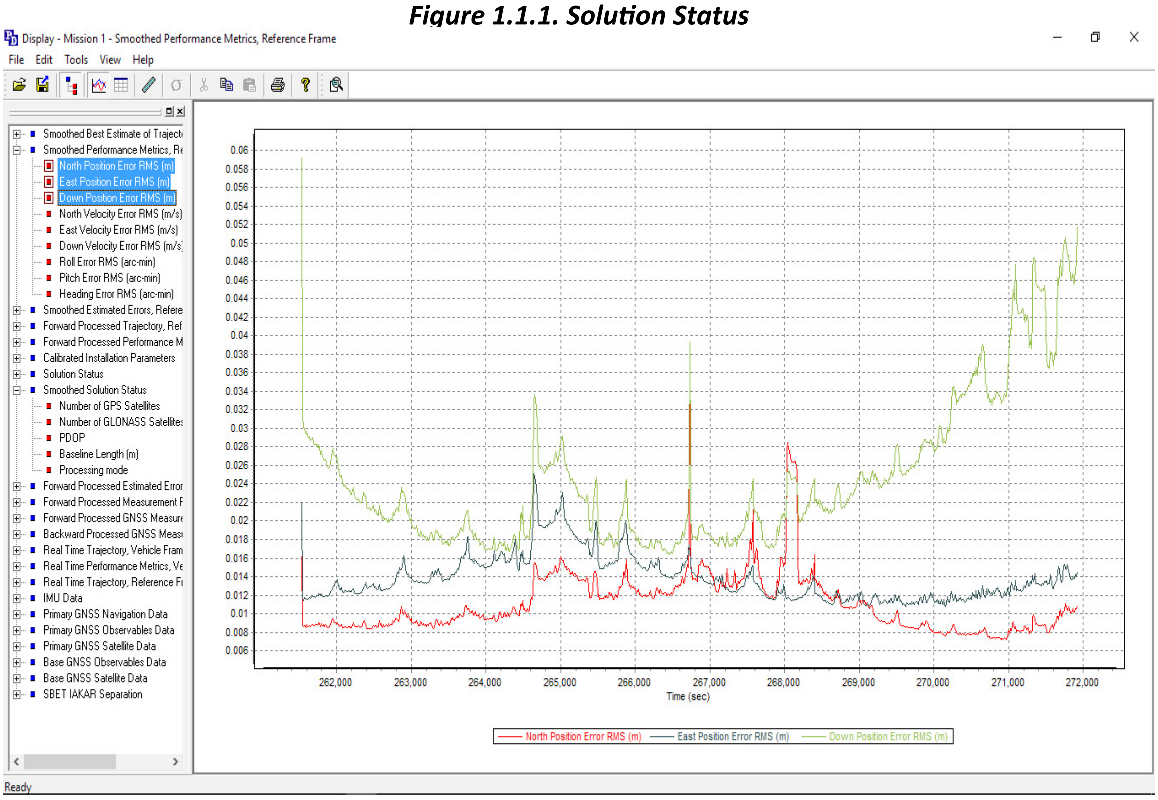


Figure 1.1.2. Smoothed Performance Metric Parameters

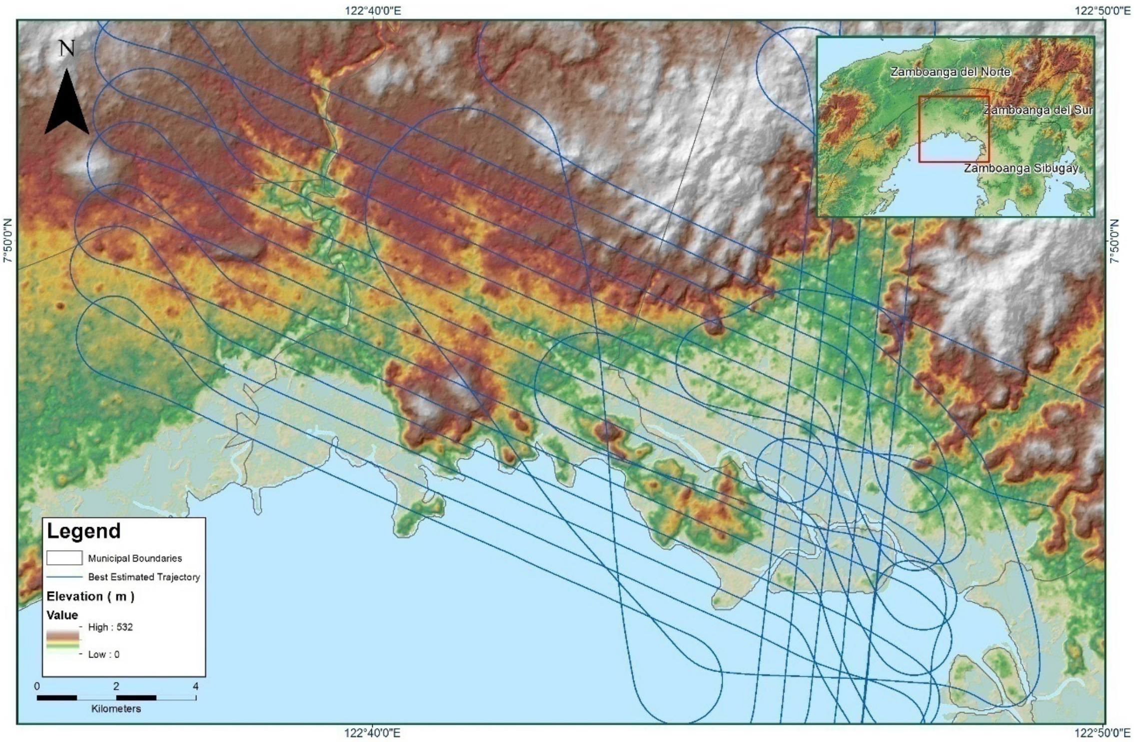


Figure 1.1.3. Best Estimated Trajectory

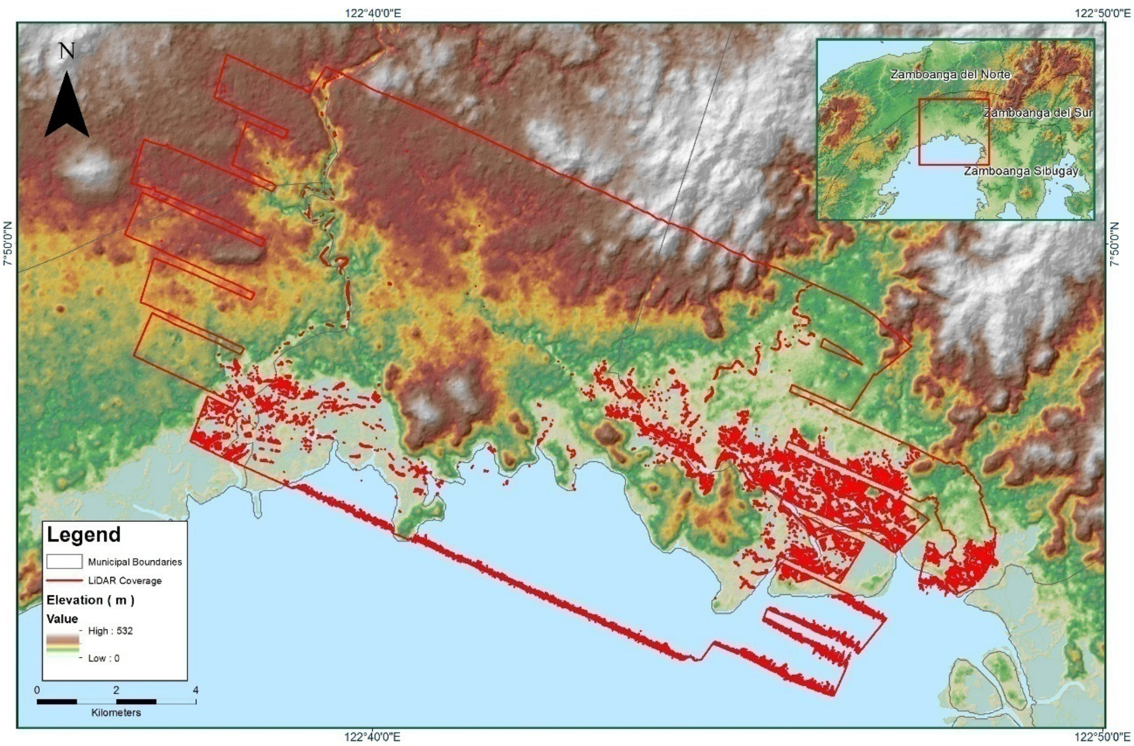


Figure 1.1.4. Coverage of LiDAR Data

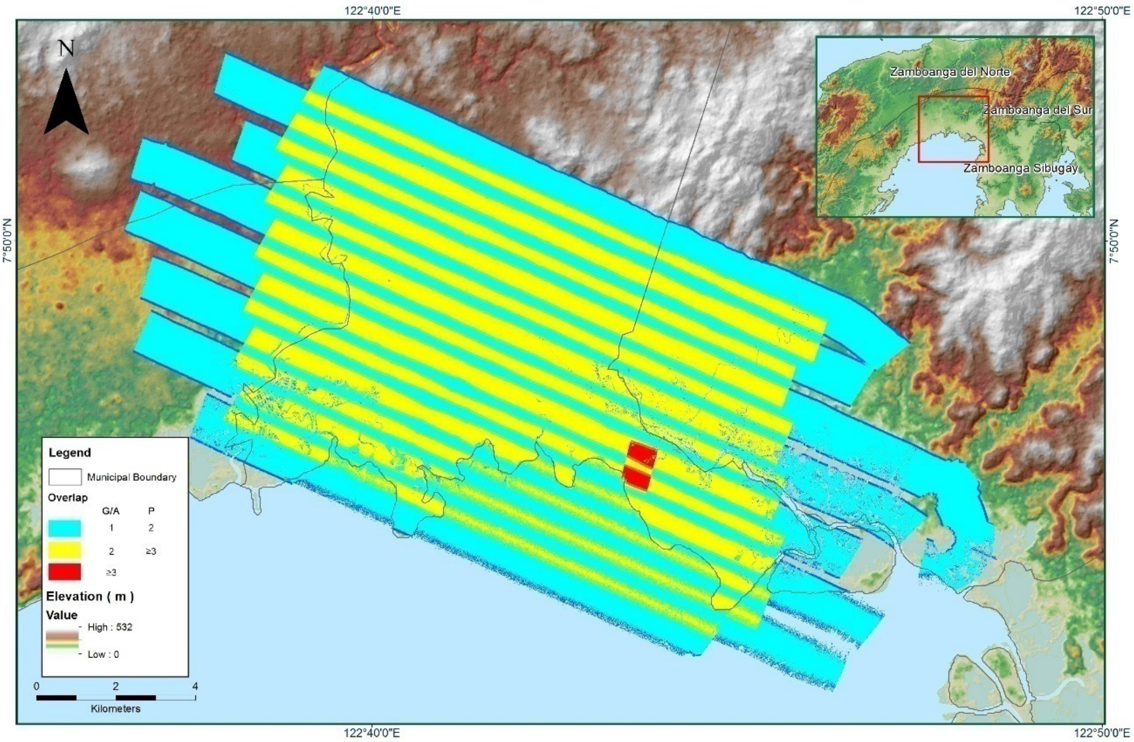


Figure 1.1.5. Image of data overlap

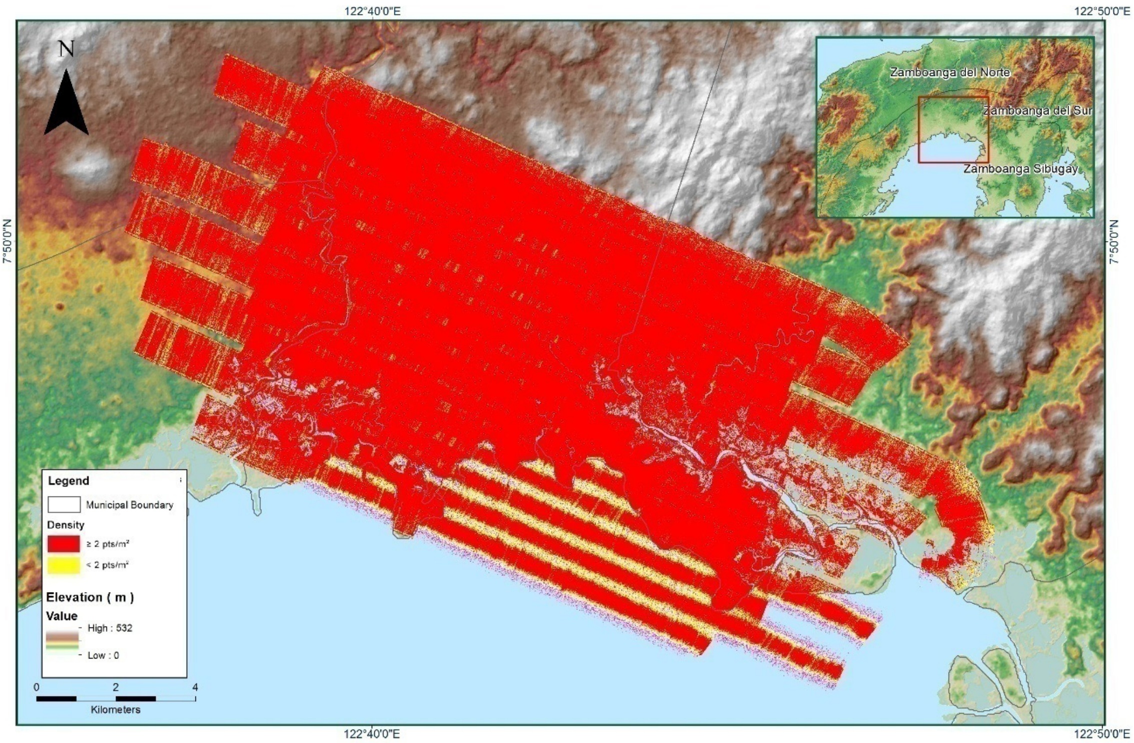


Figure 1.1.6. Density map of merged LiDAR data

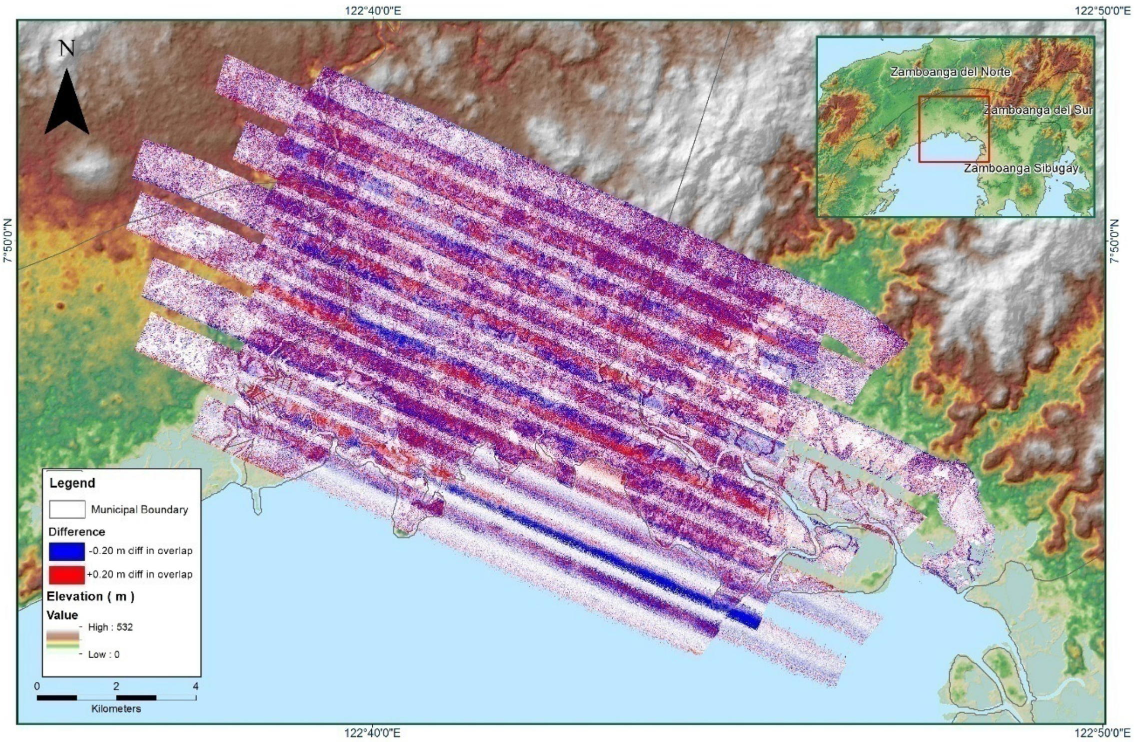


Figure 1.1.7. Elevation difference between flight lines

Flight Area	Pagadian
Mission Name	73A_Supplement
Inclusive Flights	23132P
Range data size	24.4
POS data size	266
Base data size	49.7
Image	n/a
Transfer date	March 10, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	3.3
RMSE for East Position (<4.0 cm)	2.6
RMSE for Down Position (<8.0 cm)	5.1
Boresight correction stdev (<0.001deg)	0.000406
IMU attitude correction stdev (<0.001deg)	0.005082
GPS position stdev (<0.01m)	0.0096
Minimum % overlap (>25)	40.13
Ave point cloud density per sq.m. (>2.0)	2.70
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	98
Maximum Height	287.13 m
Minimum Height	56.73 m
Classification (# of points)	
Ground	51,081,330
Low vegetation	43,565,906
Medium vegetation	50,678,603
High vegetation	38,220,733
Building	1,396,988
Orthophoto	No
Processed by	Engr. Kenneth Solidum, Engr. Justine Francisco, Engr. Elainne Lopez

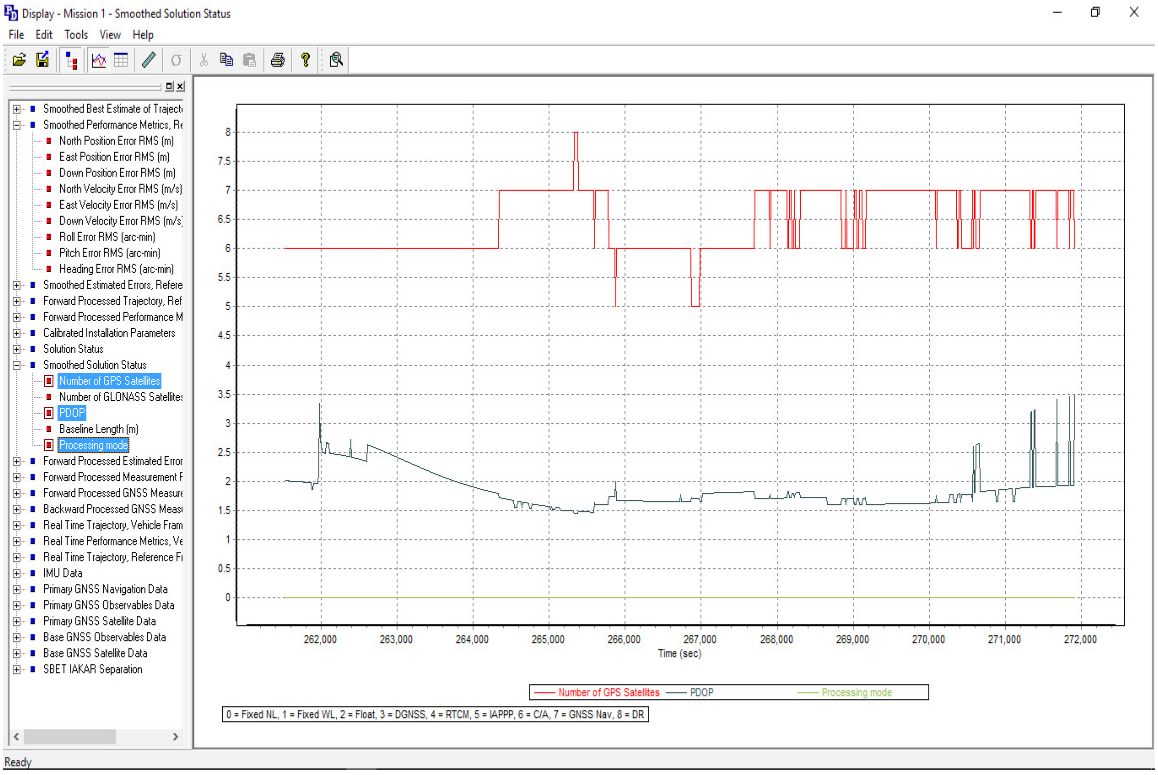


Figure 1.2.1. Solution Status

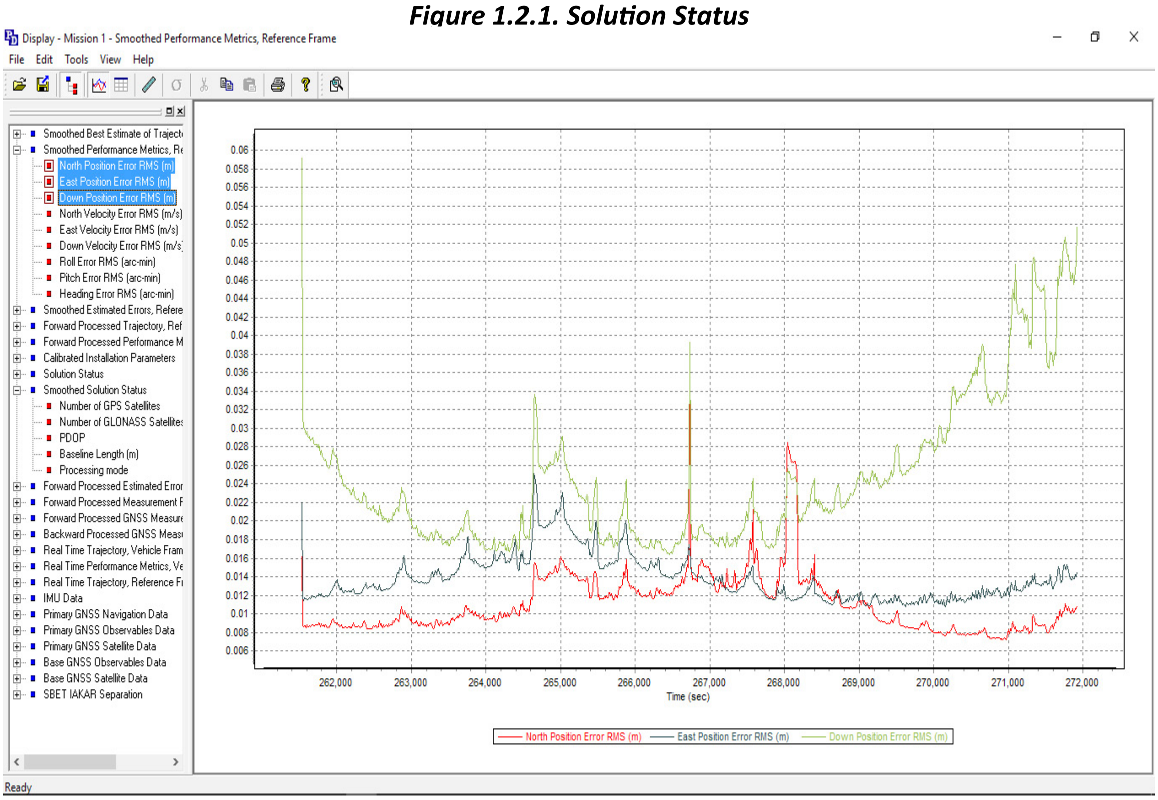


Figure 1.2.2. Smoothed Performance Metric Parameters

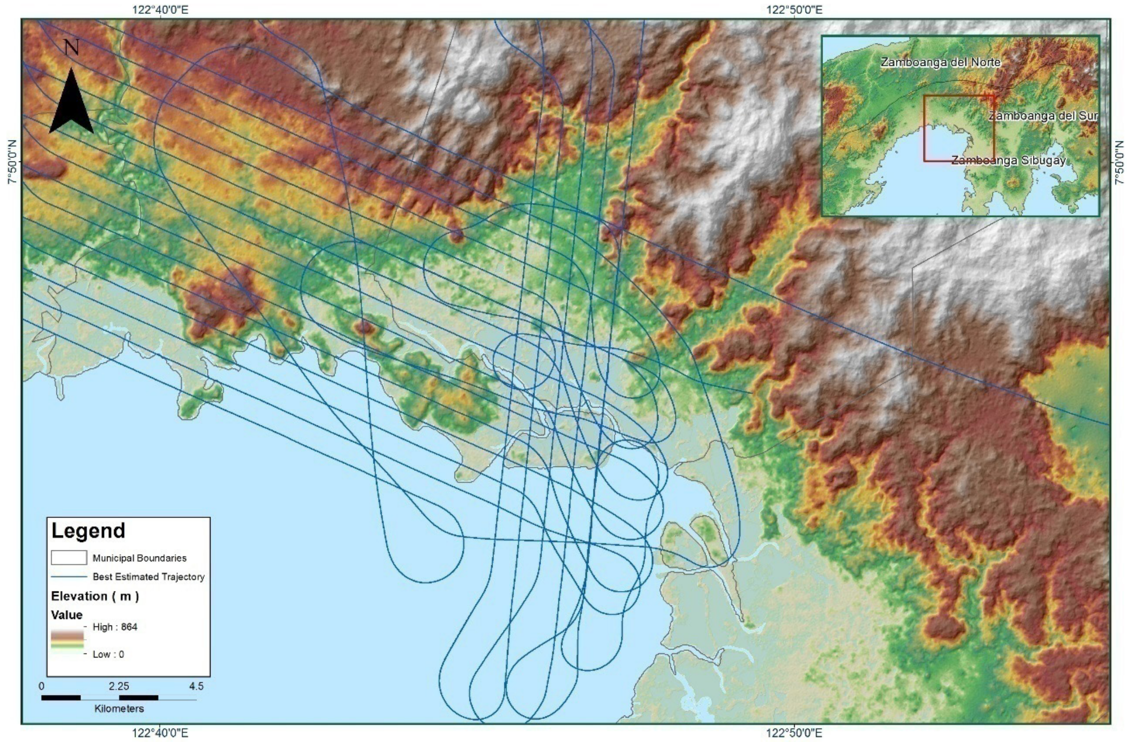


Figure 1.2.3. Best Estimated Trajectory

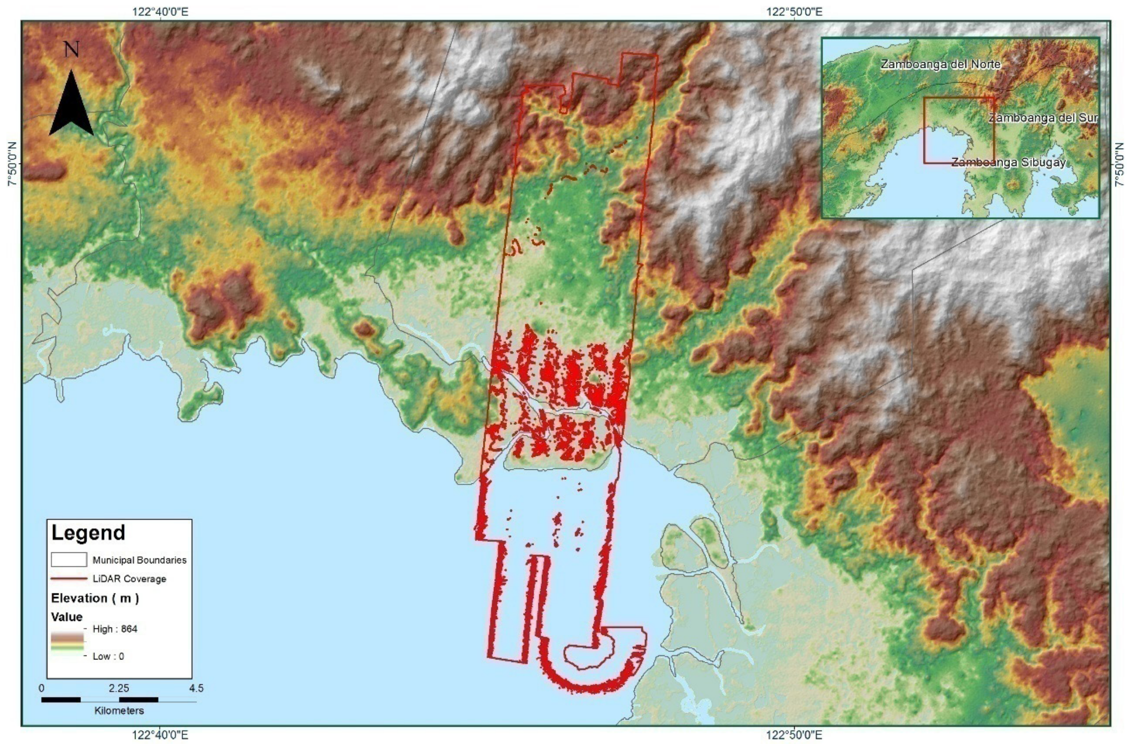


Figure 1.2.4. Coverage of LiDAR Data

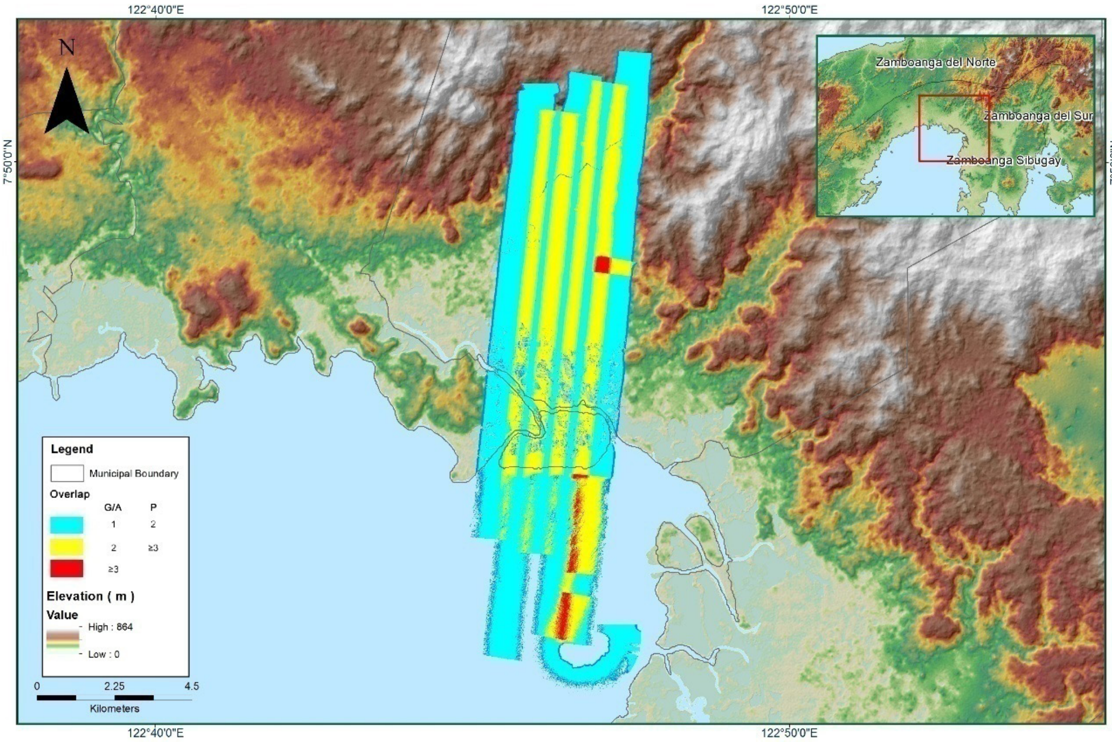


Figure 1.2.5. Image of data overlap

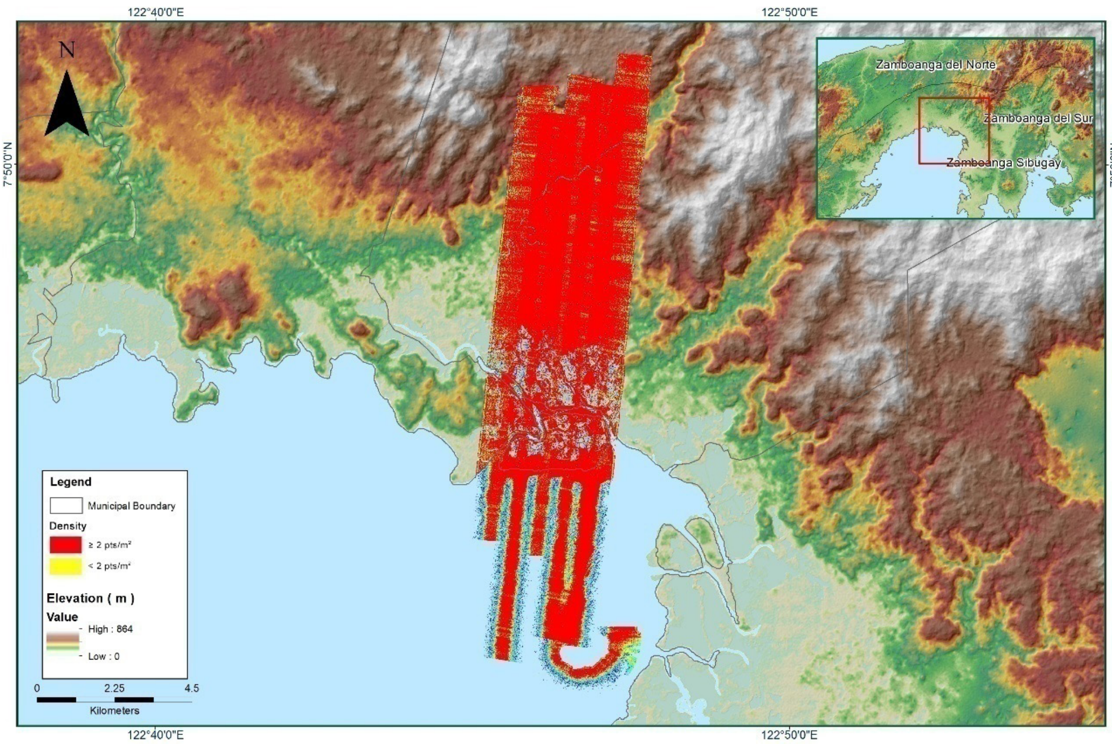


Figure 1.2.6. Density map of merged LiDAR data

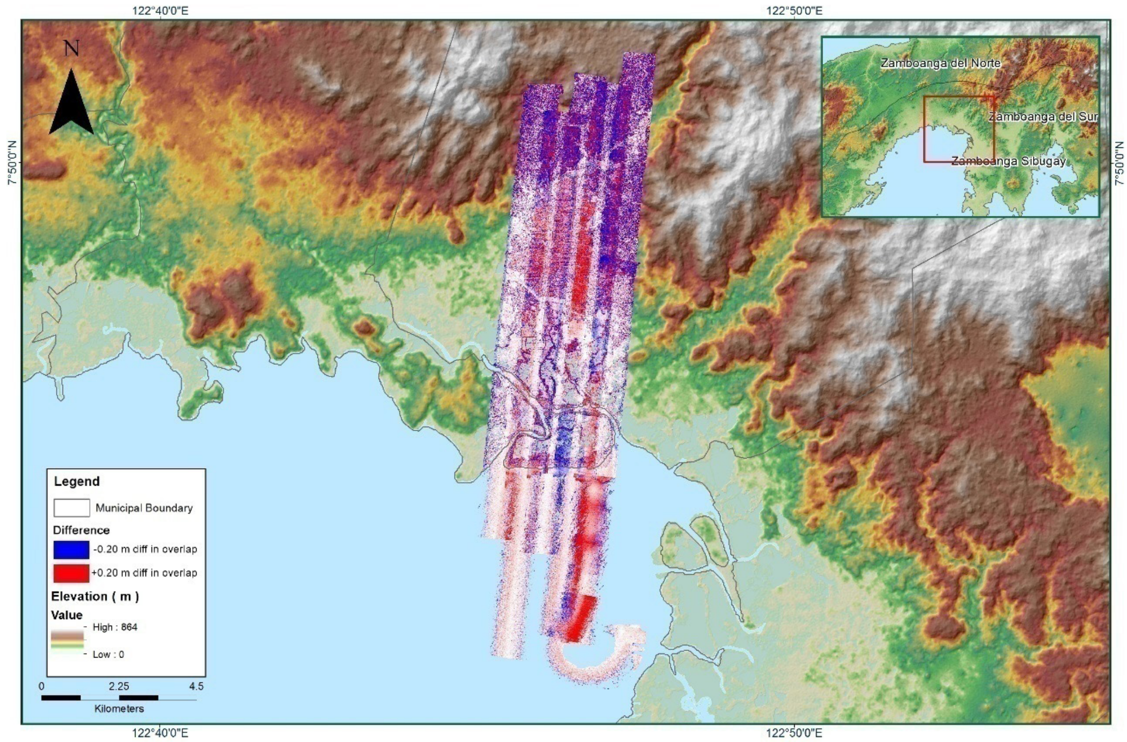


Figure 1.2.7. Elevation difference between flight lines

Flight Area	Pagadian
Mission Name	73B
Inclusive Flights	23140P
Range data size	26.5
POS data size	305
Base data size	65.9
Image	n/a
Transfer date	March 10, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	8.4
RMSE for East Position (<4.0 cm)	6.9
RMSE for Down Position (<8.0 cm)	1.6
Boresight correction stdev (<0.001deg)	0.000236
IMU attitude correction stdev (<0.001deg)	0.000494
GPS position stdev (<0.01m)	0.0013
Minimum % overlap (>25)	39.42
Ave point cloud density per sq.m. (>2.0)	2.83
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	116
Maximum Height	512.68 m
Minimum Height	66.73 m
Classification (# of points)	
Ground	66,220,867
Low vegetation	39,456,934
Medium vegetation	78,824,068
High vegetation	253,804,269
Building	2,461,205
Orthophoto	No

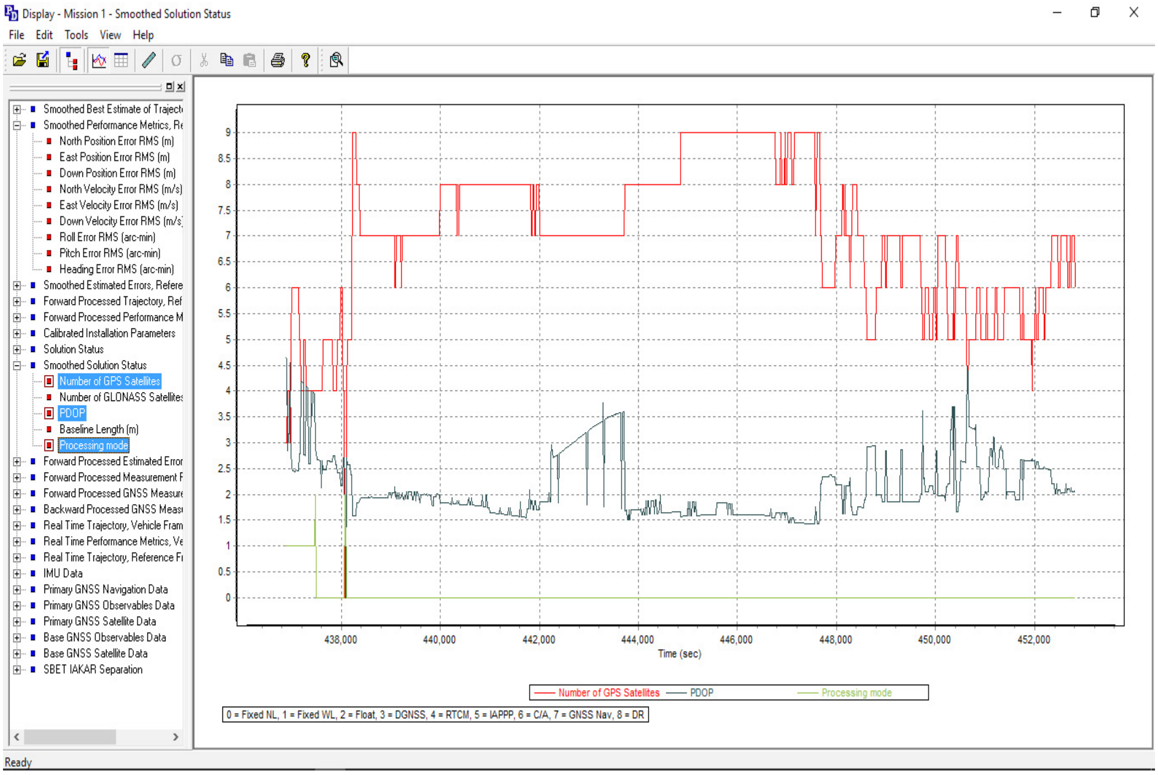


Figure 1.3.1. Solution Status

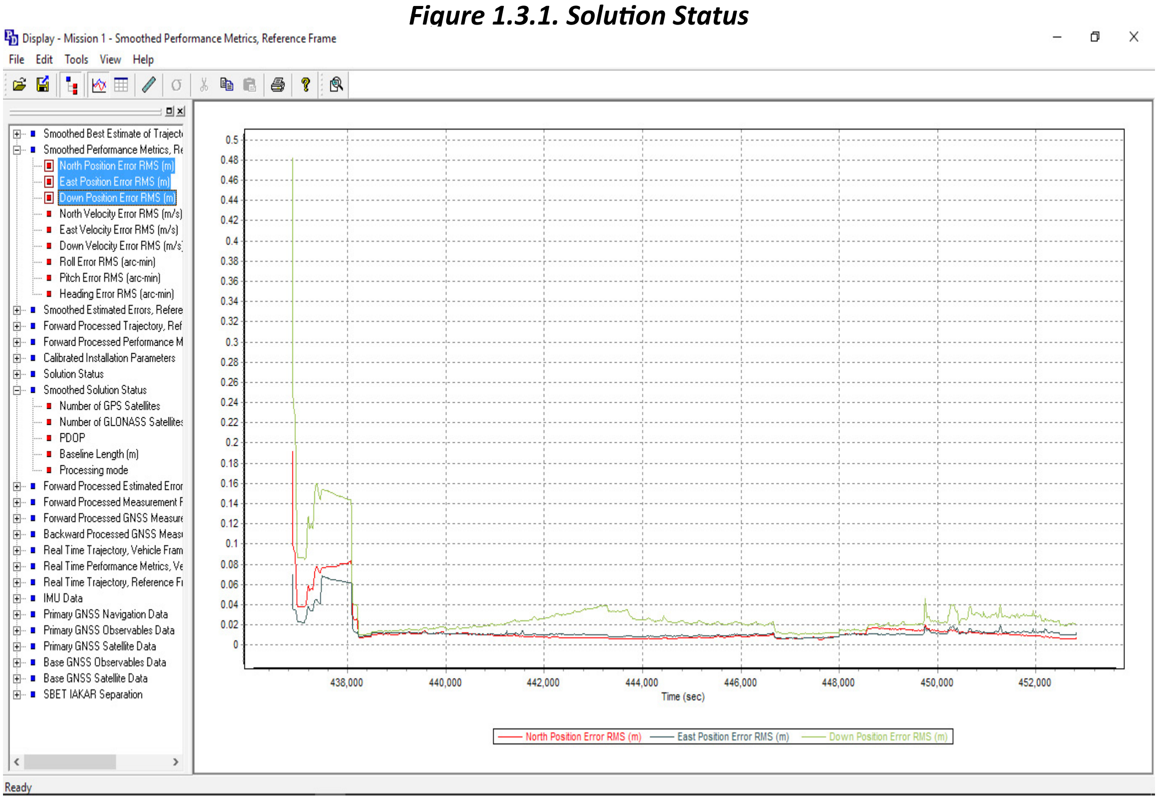


Figure 1.3.2. Smoothed Performance Metric Parameters

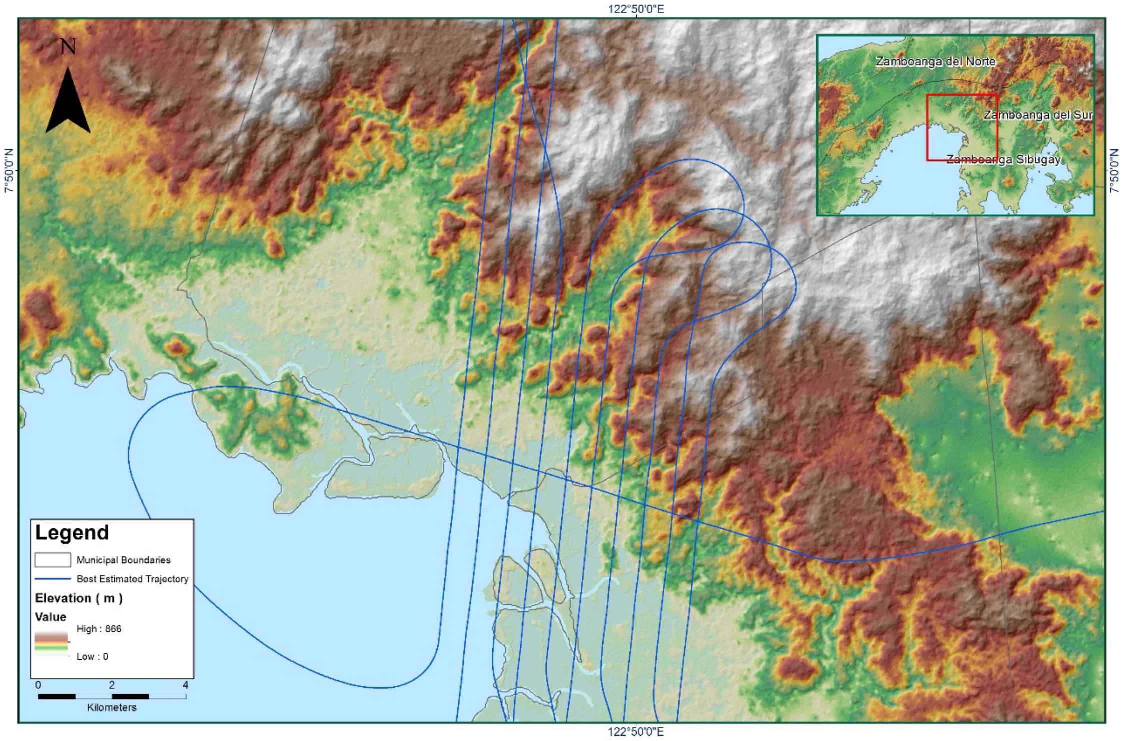


Figure 1.3.3. Best Estimated Trajectory

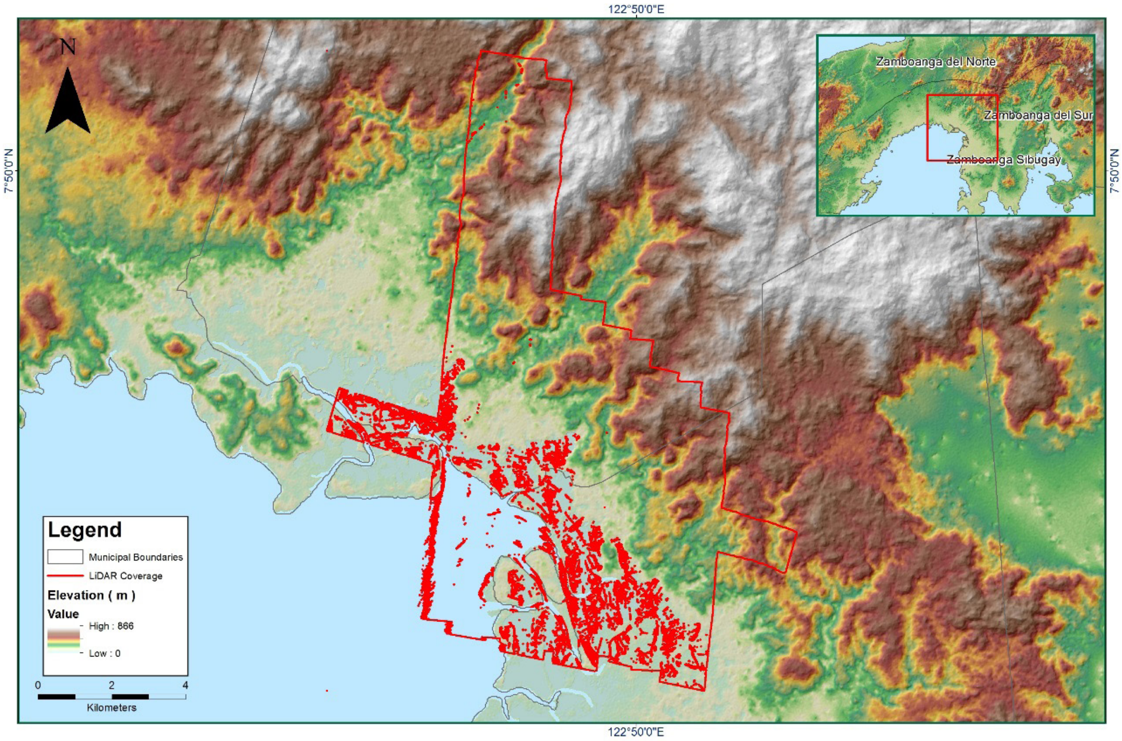


Figure 1.3.4. Coverage of LiDAR Data

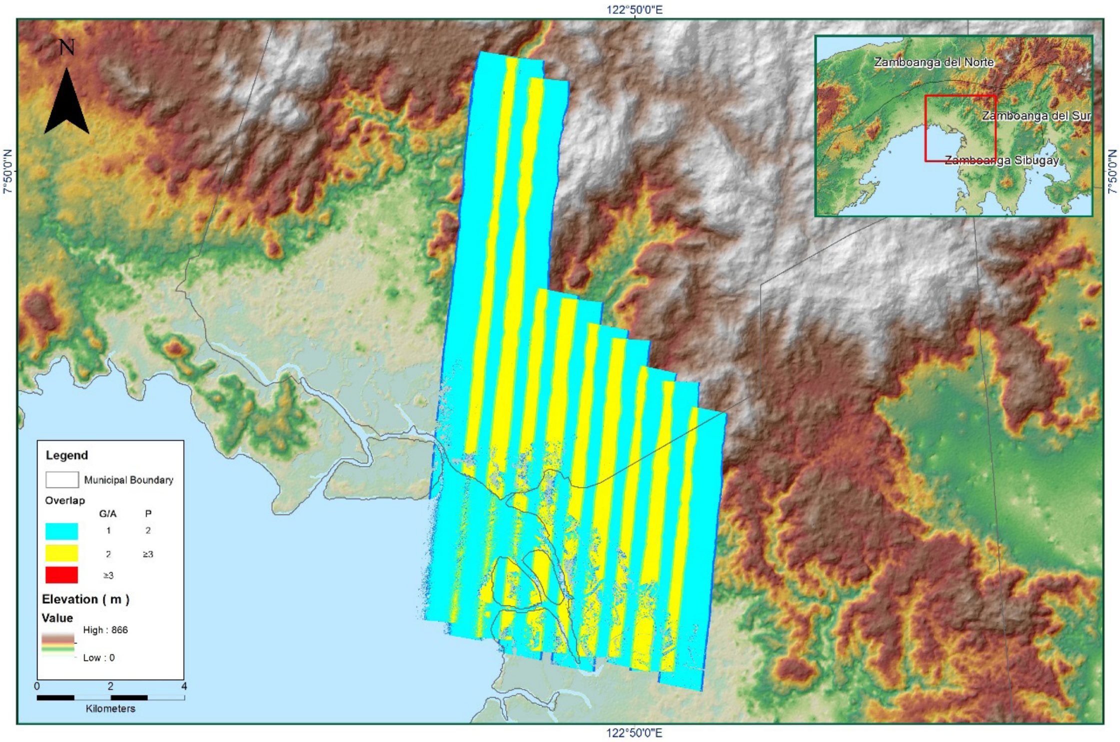


Figure 1.3.5. Image of data overlap

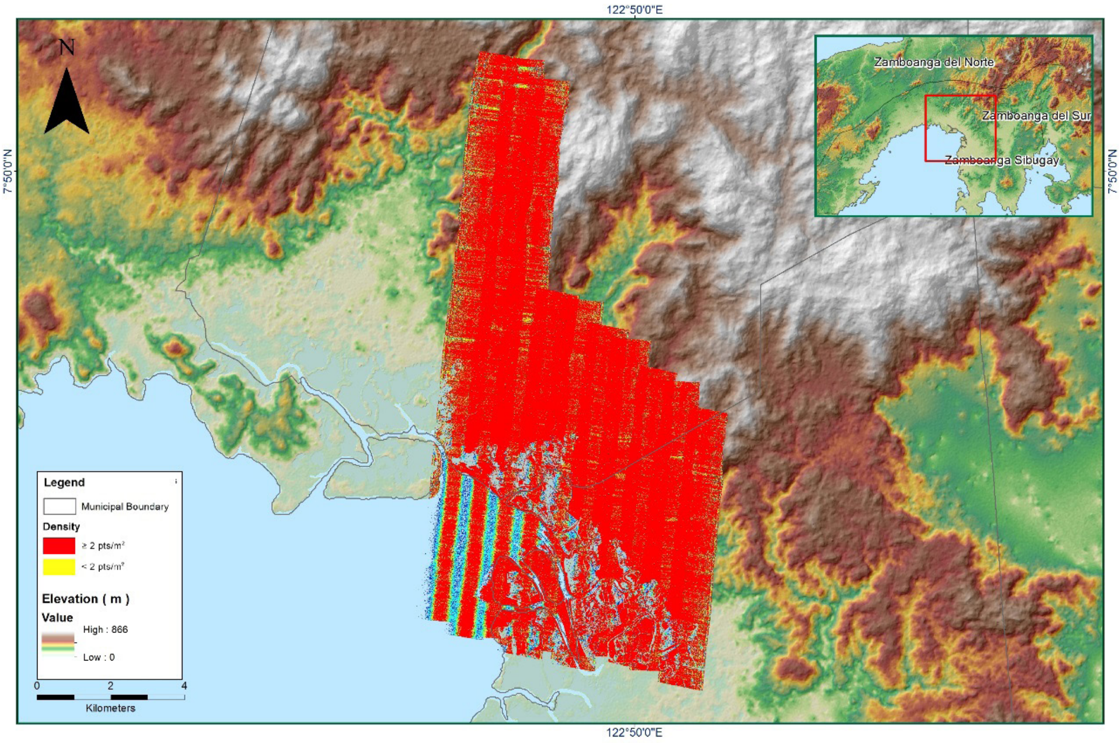


Figure 1.3.6. Density map of merged LiDAR data

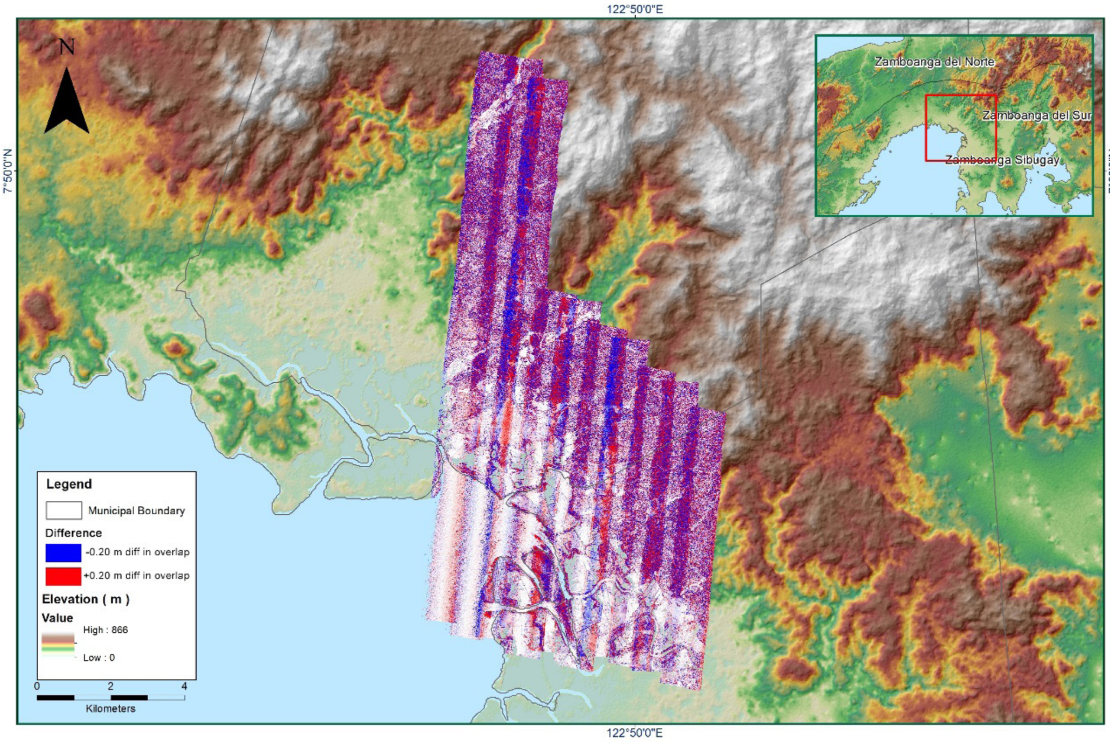


Figure 1.3.7. Elevation difference between flight lines

Annex 9. Kabasalan 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
W1660	0.0018628	52.527	0.0	0.13073	0.32002	Discharge	0.47254	0.0904325	Ratio to Peak	0.15074
W1650	0.0039966	54.082	0.0	0.30752	0.50217	Discharge	1.1559	0.0904483	Ratio to Peak	0.15074
W1640	0.0010457	49.137	0.0	0.085523	0.20936	Discharge	0.24391	0.0904447	Ratio to Peak	0.15075
W1630	0.0015608	35.966	0.0	0.064544	0.15801	Discharge	0.20937	0.090444	Ratio to Peak	0.15075
W1620	0.001351	50.371	0.0	0.10046	0.16068	Discharge	0.59214	0.0904441	Ratio to Peak	0.15075
W1610	0.0025405	36.397	0.0	0.082976	0.0902782	Discharge	0.0252867	0.0904439	Ratio to Peak	0.15075
W1600	0.0017447	38.61	0.0	0.017	0.017	Discharge	9.58433E-5	0.090444	Ratio to Peak	0.15075
W1590	0.0020806	45.952	0.0	0.1182	0.19385	Discharge	0.17683	0.0904439	Ratio to Peak	0.15075
W1580	0.0015608	35.967	0.0	0.14857	0.24366	Discharge	0.0669306	0.0904439	Ratio to Peak	0.15075
W1570	0.0049977	49.27	0.0	0.23275	0.56698	Discharge	0.60939	0.0901334	Ratio to Peak	0.15074
W1560	0.0013306	46.162	0.0	0.070623	0.07684	Discharge	0.16669	0.090444	Ratio to Peak	0.15075
W1550	0.0020476	45.136	0.0	0.093885	0.10215	Discharge	0.19370	0.0904439	Ratio to Peak	0.15075
W1540	0.0024381	48.259	0.0	0.10072	0.16519	Discharge	0.19916	0.135	Ratio to Peak	0.15075
W1530	0.0015608	52.871	0.0	0.017	0.025313	Discharge	0.0020606	0.0904439	Ratio to Peak	0.15075
W1520	0.0012047	35.06	0.0	0.10963	0.17981	Discharge	0.53495	0.135	Ratio to Peak	0.15075
W1510	0.0053793	37.34	0.0	0.10323	0.2527	Discharge	0.16103	0.135	Ratio to Peak	0.15075
W1500	0.0012213	47.423	0.0	0.065382	0.0711333	Discharge	0.24218	0.090444	Ratio to Peak	0.15075
W1490	0.002565	42.04	0.0	0.15967	0.25538	Discharge	0.30745	0.0904442	Ratio to Peak	0.15075
W1480	0.0018529	46.423	0.0	0.10656	0.11593	Discharge	0.22253	0.090444	Ratio to Peak	0.15075
W1470	0.0026301	42.042	0.0	0.20109	0.33263	Discharge	0.25178	0.0904443	Ratio to Peak	0.15075
W1460	0.0011017	52.158	0.0	0.035325	0.05765	Discharge	0.0316602	0.090444	Ratio to Peak	0.15075
W1450	0.0010197	35.967	0.0	0.03182	0.05193	Discharge	0.0117887	0.090444	Ratio to Peak	0.15075
W1440	0.0024501	43.682	0.0	0.12018	0.13076	Discharge	0.19105	0.09	Ratio to Peak	0.15075

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
W1430	0.0010823	53.408	0.0	0.057187	0.0937868	Discharge	0.16613	0.0904439	Ratio to Peak	0.15075
W1420	0.0015608	52.871	0.0	0.03976	0.064888	Discharge	0.0104469	0.0904439	Ratio to Peak	0.15075
W1410	0.0040029	38.353	0.0	0.13578	0.14773	Discharge	0.38567	0.09	Ratio to Peak	0.15075
W1400	0.0016165	43.999	0.0	0.077018	0.12318	Discharge	0.12313	0.0904441	Ratio to Peak	0.15075
W1390	0.0016011	53.385	0.0	0.055584	0.0888987	Discharge	0.0425225	0.0904439	Ratio to Peak	0.15075
W1380	0.004419	41.141	0.0	0.11583	0.18998	Discharge	0.26874	0.0904439	Ratio to Peak	0.15
W1370	0.0031002	40.442	0.0	0.13143	0.143	Discharge	0.34898	0.0904441	Ratio to Peak	0.15
W1360	0.0045075	36.757	0.0	0.1326	0.2146	Discharge	0.22074	0.09	Ratio to Peak	0.15
W1350	0.0027054	47.969	0.0	0.051802	0.0860701	Discharge	0.12953	0.0904439	Ratio to Peak	0.15
W1340	0.001431	50.77	0.0	0.05553	0.0888135	Discharge	0.16699	0.0904439	Ratio to Peak	0.15
W1330	0.0045945	51.318	0.0	0.2825	0.46104	Discharge	0.55572	0.0903556	Ratio to Peak	0.15
W1320	0.0039255	38.61	0.0	0.12746	0.19784	Discharge	0.25378	0.09	Ratio to Peak	0.15
W1310	0.0052677	37.663	0.0	0.12551	0.20584	Discharge	0.25341	0.0902513	Ratio to Peak	0.15
W1300	0.0058336	36.079	0.0	0.13165	0.21485	Discharge	0.20255	0.135	Ratio to Peak	0.15
W1290	0.0039303	38.594	0.0	0.09655	0.23635	Discharge	0.19351	0.090444	Ratio to Peak	0.15
W1280	0.0048645	38.88	0.0	0.10051	0.16471	Discharge	0.24732	0.0904439	Ratio to Peak	0.15
W1270	0.007077	50.552	0.0	0.101	0.16565	Discharge	0.23566	0.135	Ratio to Peak	0.15
W1260	0.0045686	39.823	0.0	0.11925	0.29193	Discharge	0.27162	0.090444	Ratio to Peak	0.15
W1250	0.0024989	42.766	0.0	0.0166667	0.41086	Discharge	0.43824	0.0904442	Ratio to Peak	0.15
W1240	0.008255	46.8	0.0	0.051007	0.083243	Discharge	0.0547744	0.0904439	Ratio to Peak	0.15
W1230	0.0031836	36.031	0.0	0.1418	0.34712	Discharge	0.39178	0.0904441	Ratio to Peak	0.15
W1220	0.0073953	49.479	0.0	0.12026	0.19722	Discharge	0.32128	0.0904437	Ratio to Peak	0.15
W1210	0.0052426	37.737	0.0	0.10581	0.25902	Discharge	0.24732	0.0904439	Ratio to Peak	0.15
W1200	0.0034036	38.22	0.0	0.097436	0.10601	Discharge	0.30863	0.090444	Ratio to Peak	0.15
W1190	0.0045926	51.327	0.0	0.11819	0.18902	Discharge	0.15059	0.0904441	Ratio to Peak	0.15

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
W1180	0.00508	38.22	0.0	0.039172	0.063929	Discharge	0.0237052	0.090444	Ratio to Peak	0.15
W1170	0.0053546	37.412	0.0	0.095853	0.15397	Discharge	0.21095	0.0904441	Ratio to Peak	0.15
W1160	0.003362	35.272	0.0	0.13015	0.47792	Discharge	0.75189	0.0904442	Ratio to Peak	0.15
W1150	0.0034036	38.22	0.0	0.031482	0.051379	Discharge	0.0236413	0.090444	Ratio to Peak	0.15
W1140	0.0034471	38.025	0.0	0.10088	0.10976	Discharge	0.16841	0.0904441	Ratio to Peak	0.15
W1130	0.0065594	52.396	0.0	0.1627	0.39829	Discharge	0.45474	0.0904438	Ratio to Peak	0.15
W1120	0.005632	37.106	0.0	0.11934	0.29216	Discharge	0.29616	0.0904441	Ratio to Peak	0.15
W1110	0.0070674	50.584	0.0	0.21677	0.54148	Discharge	0.52017	0.0904442	Ratio to Peak	0.15
W1100	0.0055875	36.752	0.0	0.27246	0.29687	Discharge	0.44220	0.0904441	Ratio to Peak	0.15
W1090	0.0081666	47.062	0.0	0.13511	0.22144	Discharge	0.25440	0.0904438	Ratio to Peak	0.15
W1080	0.0040601	35.482	0.0	0.16009	0.26239	Discharge	0.43698	0.0904437	Ratio to Peak	0.15
W1070	0.008255	46.8	0.0	0.25306	0.41301	Discharge	0.29913	0.0904441	Ratio to Peak	0.15
W1060	0.0058622	36.002	0.0	0.14852	0.24359	Discharge	0.30309	0.0904439	Ratio to Peak	0.15
W1050	0.00508	35.1	0.0	0.082383	0.20168	Discharge	0.17261	0.0904439	Ratio to Peak	0.15
W1040	0.0056037	36.706	0.0	0.088354	0.1449	Discharge	0.27295	0.0904438	Ratio to Peak	0.15
W1030	0.0077328	32.422	0.0	0.15311	0.25111	Discharge	0.42377	0.0904439	Ratio to Peak	0.15
W1020	0.0040998	35.261	0.0	0.13821	0.33834	Discharge	0.46046	0.0904437	Ratio to Peak	0.15
W1010	0.0057434	36.323	0.0	0.13515	0.33086	Discharge	0.42460	0.0904438	Ratio to Peak	0.15
W1000	0.0052224	37.796	0.0	0.081696	0.2	Discharge	0.23943	0.0904438	Ratio to Peak	0.15
W990	0.0081868	47.002	0.0	0.25485	0.41592	Discharge	0.28889	0.0904442	Ratio to Peak	0.15074
W980	0.005281	37.624	0.0	0.2191	0.36561	Discharge	0.72037	0.0904442	Ratio to Peak	0.15074
W970	0.00508	35.1	0.0	0.072228	0.11847	Discharge	0.13119	0.0904439	Ratio to Peak	0.15075
W960	0.0055595	36.829	0.0	0.093621	0.15354	Discharge	0.26796	0.0904438	Ratio to Peak	0.15075
W950	0.0079852	47.608	0.0	0.12218	0.20039	Discharge	0.10789	0.0904439	Ratio to Peak	0.15075
W940	0.0065915	52.278	0.0	0.27057	0.44158	Discharge	0.45679	0.0904439	Ratio to Peak	0.15074

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
W930	0.0050358	38.353	0.0	0.065694	0.16081	Discharge	0.0841344	0.090444	Ratio to Peak	0.15075
W920	0.0045418	41.082	0.0	0.071067	0.11366	Discharge	0.14201	0.0904441	Ratio to Peak	0.15075
W910	0.0069548	50.974	0.0	0.094986	0.23253	Discharge	0.21779	0.0904439	Ratio to Peak	0.15075
W900	0.0047919	35.915	0.0	0.30843	0.33724	Discharge	0.72069	0.0904441	Ratio to Peak	0.15074
W890	0.0054554	37.88	0.0	0.099787	0.16366	Discharge	0.32777	0.0904438	Ratio to Peak	0.15074
W880	0.0039255	42.042	0.0	0.037086	0.060525	Discharge	0.0268042	0.1035	Ratio to Peak	0.15075
W870	0.0045498	40.699	0.0	0.10178	0.24915	Discharge	0.20990	0.090444	Ratio to Peak	0.15075
W860	0.0076553	48.637	0.0	0.13536	0.33135	Discharge	0.22522	0.135	Ratio to Peak	0.15075
W850	0.0063156	35.364	0.0	0.096185	0.23546	Discharge	0.19391	0.135	Ratio to Peak	0.15075
W840	0.006193	35.14	0.0	0.10905	0.26696	Discharge	0.27389	0.0904441	Ratio to Peak	0.15064

Annex 10. Kabasalan Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R30	Automatic Fixed Interval	267.28	0.0199238	0.012	Trapezoid	20	0.01
R60	Automatic Fixed Interval	464.26	0.00059	0.012	Trapezoid	20	0.01
R80	Automatic Fixed Interval	597.99	0.0401345	0.008	Trapezoid	20	0.01
R100	Automatic Fixed Interval	1116.7	0.0276431	0.012	Trapezoid	20	0.01
R110	Automatic Fixed Interval	1315.7	0.0463368	0.0080398	Trapezoid	20	0.01
R120	Automatic Fixed Interval	1664.7	0.0186788	0.0080362	Trapezoid	20	0.01
R130	Automatic Fixed Interval	1064.7	0.0239603	0.012	Trapezoid	20	0.01
R150	Automatic Fixed Interval	1357.1	0.0462105	0.012	Trapezoid	20	0.01
R170	Automatic Fixed Interval	1118.4	0.0710821	0.0080181	Trapezoid	20	0.01
R180	Automatic Fixed Interval	3562.9	0.0227604	0.012	Trapezoid	20	0.01
R230	Automatic Fixed Interval	1826.1	0.0273304	0.0079415	Trapezoid	20	0.01
R260	Automatic Fixed Interval	1775.4	0.0095652	0.0080243	Trapezoid	20	0.01
R300	Automatic Fixed Interval	3998.9	0.0367418	0.0082803	Trapezoid	20	0.01
R310	Automatic Fixed Interval	356.27	0.0779984	0.008	Trapezoid	20	0.01
R320	Automatic Fixed Interval	1714.3	0.0608810	0.012	Trapezoid	20	0.01
R330	Automatic Fixed Interval	2725.2	0.0223105	0.012	Trapezoid	20	0.01
R340	Automatic Fixed Interval	405.56	0.0666391	0.0080349	Trapezoid	20	0.01
R360	Automatic Fixed Interval	1192.3	.0005867491483375926	0.012	Trapezoid	20	0.01
R390	Automatic Fixed Interval	539.71	0.0867470	0.008038	Trapezoid	20	0.01
R410	Automatic Fixed Interval	1329.5	0.0084942	0.0080343	Trapezoid	20	0.01
R440	Automatic Fixed Interval	959.41	0.0017788	0.012	Trapezoid	20	0.01
R460	Automatic Fixed Interval	3217.2	0.0088739	0.0080309	Trapezoid	20	0.01
R480	Automatic Fixed Interval	576.98	0.00059	0.012	Trapezoid	20	0.01

R520	Automatic Fixed Interval	556.27	0.0086962	0.0080321	Trapezoid	20	0.01
R530	Automatic Fixed Interval	891.84	0.0093209	0.012	Trapezoid	20	0.01
R560	Automatic Fixed Interval	765.69	0.0064446	0.0080328	Trapezoid	20	0.01
R580	Automatic Fixed Interval	240.42	0.00059	0.00784	Trapezoid	20	0.01
R590	Automatic Fixed Interval	784.97	0.0082540	0.00784	Trapezoid	20	0.01
R610	Automatic Fixed Interval	783.55	0.0437879	0.0072	Trapezoid	20	0.01
R630	Automatic Fixed Interval	2225.8	0.0376264	0.0080391	Trapezoid	20	0.01
R650	Automatic Fixed Interval	214.85	0.0296386	0.0080348	Trapezoid	20	0.01
R660	Automatic Fixed Interval	755.27	0.0430165	0.012	Trapezoid	20	0.01
R670	Automatic Fixed Interval	1181.0	0.00059	0.008	Trapezoid	20	0.01
R690	Automatic Fixed Interval	2937.5	0.0080160	0.0080243	Trapezoid	20	0.01
R710	Automatic Fixed Interval	685.27	0.0217009	0.012	Trapezoid	20	0.01
R720	Automatic Fixed Interval	1676.1	0.0113071	0.0053333	Trapezoid	20	0.01
R740	Automatic Fixed Interval	30	0.00059	0.008	Trapezoid	20	0.01
R750	Automatic Fixed Interval	1395.8	0.0089365	0.0080333	Trapezoid	20	0.01
R760	Automatic Fixed Interval	442.34	0.0067381	0.0080202	Trapezoid	20	0.01
R780	Automatic Fixed Interval	984.85	0.00059	0.0080094	Trapezoid	20	0.01
R800	Automatic Fixed Interval	2286.7	0.0086388	0.012	Trapezoid	20	0.01

Annex 11. Kabasalan Field Validation

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
1	7.79845	122.760545	0.85	0.15	Flooding	0.70	5 -Year
2	7.797127	122.761944	0.16	0.3	Flooding	-0.14	5 -Year
3	7.796343	122.761254	0.49	0.5	Flooding	-0.01	5 -Year
4	7.790034	122.760463	0.36	0.175	Flooding	0.19	5 -Year
5	7.790194	122.782717	0.18	0.15	Flooding	0.03	5 -Year
6	7.789428	122.783729	0	0		0.00	5 -Year
7	7.809139	122.730207	0	0.75	flooding	-0.75	5 -Year
8	7.808876	122.731779	0	0.75	flooding	-0.75	5 -Year
9	7.80796	122.731581	0	0.75	flooding	-0.75	5 -Year
10	7.809932	122.735651	0.71	0.75	flooding	-0.04	5 -Year
11	7.791142	122.779101	0.08	0.5	flooding	-0.42	5 -Year
12	7.789415	122.783714	0	0.75	flooding	-0.75	5 -Year
13	7.83874	122.787314	1.55	1.78	Flood	-0.23	5 -Year
14	7.79772	122.763879	0.68	0.25	Flooding	0.43	5 -Year
15	7.796682	122.764983	0.36	0.25	Flooding	0.11	5 -Year
16	7.795011	122.759856	0.4	0.4	Typhoon	0.00	5 -Year
17	7.810089	122.733405	0.94	1	Flooding	-0.06	5 -Year
18	7.8094	122.733211	0	0.75	Flooding	-0.75	5 -Year
19	7.809933	122.73565	0.71	0	None	0.71	5 -Year
20	7.792239	122.7701	0	0.1	Lawin	-0.10	5 -Year
21	7.792956	122.768632	0.11	0.1		0.01	5 -Year
22	7.794516	122.761754	0.09	0.15	Flooding	-0.06	5 -Year
23	7.811	122.732435	0	0.5	Karen	-0.50	5 -Year
24	7.789206	122.779443	0	0		0.00	5 -Year
25	7.786686	122.781543	0.44	0		0.44	5 -Year
26	7.797337	122.760018	1.4	0.25	Typhoon	1.15	5 -Year
27	7.793986	122.758411	0.05	0.1	Typhoon	-0.05	5 -Year
28	7.792208	122.761075	0.11	0.2	Typhoon	-0.09	5 -Year
29	7.793157	122.77311	0.12	0.25	Typhoon	-0.13	5 -Year
30	7.794494	122.771648	0.85	0.2	Typhoon	0.65	5 -Year
31	7.796868	122.769012	0.11	0.1	Typhoon	0.01	5 -Year
32	7.79607	122.769129	0.33	0.1	Typhoon	0.23	5 -Year
33	7.791641	122.768619	0	0.2	Typhoon	-0.20	5 -Year
34	7.79372	122.768604	0	0.2	Typhoon	-0.20	5 -Year
35	7.770501	122.791276	0	0.3	Flood	-0.30	5 -Year
36	7.782971	122.789197	0	0		0.00	5 -Year
37	7.772738	122.789893	0.07	0		0.07	5 -Year
38	7.77949	122.800957	0.2	0.3	Flood	-0.10	5 -Year
39	7.778589	122.800385	0.32	0.3	Flood	0.02	5 -Year
40	7.774912	122.796683	0.11	0.2	Flood	-0.09	5 -Year
41	7.775245	122.794307	0.28	0.2	Flood	0.08	5 -Year
42	7.769768	122.788069	0.7	0.5	Flood	0.20	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
43	7.770143	122.788319	1.8	0.4	Flood	1.40	5 -Year
44	7.770793	122.788938	0.22	0.3	Flood	-0.08	5 -Year
45	7.770559	122.78906	0	0.3	Flood	-0.30	5 -Year
46	7.770063	122.789433	0	0.3	Flood	-0.30	5 -Year
47	7.76989	122.790191	0.42	0.2	Flood	0.22	5 -Year
48	7.771836	122.792288	0	0.2	Flood	-0.20	5 -Year
49	7.779552	122.796544	0	0		0.00	5 -Year
50	7.780074	122.800023	0	0.4	Flood	-0.40	5 -Year
51	7.774632	122.793554	0	0.4	Flood	-0.40	5 -Year
52	7.775342	122.795268	0.14	0.2	Flod	-0.06	5 -Year
53	7.773238	122.791588	0.09	0.2	Flood	-0.11	5 -Year
54	7.782147	122.787728	0.21	0.3	Flood	-0.09	5 -Year
55	7.77671	122.797766	0.68	0.3	Fkood	0.38	5 -Year
56	7.778331	122.79926	0.22	0.1	Flood	0.12	5 -Year
57	7.776621	122.800058	0.61	0.3	Flood	0.31	5 -Year
58	7.770838	122.793603	0.19	0.3	Flood	-0.11	5 -Year
59	7.774544	122.79455	3.14	0.4	Flood	2.74	5 -Year
60	7.773965	122.793889	2.15	0.4	Flood	1.75	5 -Year
61	7.773321	122.79321	0.18	0.2	Flood	-0.02	5 -Year
62	7.771292	122.79137	0.28	0.2	Flood	0.08	5 -Year
63	7.770597	122.790382	1.18	0.3	Flood	0.88	5 -Year
64	7.76832	122.787511	0.57	0		0.57	5 -Year
65	7.769668	122.788727	1.8	0.4	Flood	1.40	5 -Year
66	7.783187	122.805506	0.04	0		0.04	5 -Year
67	7.782105	122.803582	3.13	0.4		2.73	5 -Year
68	7.781388	122.804326	0.21	0.4	Flood	-0.19	5 -Year
69	7.766419	122.786739	0	0.5	Flood	-0.50	5 -Year
70	7.790005	122.79368	0	0		0.00	5 -Year
71	7.789458	122.79464	0	0		0.00	5 -Year
72	7.790266	122.79125	0	0		0.00	5 -Year
73	7.806792	122.757529	0.44	0.9		-0.46	5 -Year
74	7.808325	122.757996	0.42	0.65		-0.23	5 -Year
75	7.804638	122.757366	0.57	0.8		-0.23	5 -Year
76	7.805206	122.754669	0.04	0		0.04	5 -Year
77	7.832166	122.778206	0.17	0.3		-0.13	5 -Year
78	7.832084	122.776911	0	0.35		-0.35	5 -Year
79	7.832355	122.77605	0.35	0.5		-0.15	5 -Year
80	7.808543	122.757099	0.39	0.35		0.04	5 -Year
81	7.808218	122.755612	0	0.6	Flood	-0.60	5 -Year
82	7.801064	122.756814	0.75	1.2		-0.45	5 -Year
83	7.800439	122.754943	1.1	0.5		0.60	5 -Year
84	7.830474	122.772445	0	0.1		-0.10	5 -Year
85	7.8325	122.776375	0.34	1.2		-0.86	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
86	7.809596	122.757843	9.42	3		6.42	5 -Year
87	7.809867	122.75388	0.31	0		0.31	5 -Year
88	7.830727	122.776869	1.45	0		1.45	5 -Year
89	7.831591	122.77817	1.39	4		-2.61	5 -Year
90	7.8316	122.777039	1.37	0.3		1.07	5 -Year
91	7.831765	122.775095	0	0.5	Ondoy	-0.50	5 -Year
92	7.806927	122.758821	0.7	0.93	Flood	-0.23	5 -Year
93	7.831804	122.773663	0.06	0.7	Flooding	-0.64	5 -Year
94	7.806742	122.756502	0	0.73	Flooding	-0.73	5 -Year
95	7.807321	122.755765	0.43	0.7	Flooding	-0.27	5 -Year
96	7.803017	122.753446	0.07	0		0.07	5 -Year
97	7.809605	122.756566	2.21	0.9		1.31	5 -Year
98	7.806037	122.743563	0	0.6		-0.60	5 -Year
99	7.798642	122.742401	0.15	0.5		-0.35	5 -Year
100	7.798275	122.740062	0.08	1.2		-1.12	5 -Year
101	7.802655	122.743107	0.22	0		0.22	5 -Year
102	7.804444	122.740823	0	0.2		-0.20	5 -Year
103	7.8076	122.741731	0.85	0.5		0.35	5 -Year
104	7.788894	122.737847	0.41	0.9		-0.49	5 -Year
105	7.832767	122.785031	0.15	0.8		-0.65	5 -Year
106	7.830905	122.789664	0	0		0.00	5 -Year
107	7.830317	122.782849	0	0.8		-0.80	5 -Year
108	7.830886	122.783782	0	0.9		-0.90	5 -Year
109	7.830823	122.784963	0	0.5		-0.50	5 -Year
110	7.846396	122.797942	2.78	0.6		2.18	5 -Year
111	7.84926	122.799055	3.07	0.9		2.17	5 -Year
112	7.847277	122.798352	4.42	0.9		3.52	5 -Year
113	7.842149	122.793879	0	0		0.00	5 -Year
114	7.837672	122.792207	0	0		0.00	5 -Year
115	7.846005	122.801222	0	0		0.00	5 -Year
116	7.816096	122.761901	0.87	0		0.87	5 -Year
117	7.814544	122.760695	0.66	0.8		-0.14	5 -Year
118	7.81707	122.762908	0.09	0.85		-0.76	5 -Year
119	7.817998	122.757097	0	0.8		-0.80	5 -Year
120	7.815506	122.75413	0	0.8		-0.80	5 -Year
121	7.803567	122.773416	0	0		0.00	5 -Year
122	7.791455	122.731008	0.15	0		0.15	5 -Year
123	7.815257	122.755948	0.06	0		0.06	5 -Year
124	7.789037	122.786294	0.87	0		0.87	5 -Year
125	7.792454	122.786325	0	0	Nome	0.00	5 -Year
126	7.792288	122.783976	0	0	None	0.00	5 -Year
127	7.787959	122.778655	0	0	None	0.00	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
128	7.785462	122.777188	0.09	0	Coastal area	0.09	5 -Year
129	7.802527	122.747103	0.15	1.2	Flood	-1.05	5 -Year
130	7.802212	122.748711	0	1.2	Flood	-1.20	5 -Year
131	7.801382	122.750614	0.19	1.2	Flood	-1.01	5 -Year
132	7.799791	122.753314	0.4	1.2	Flood	-0.80	5 -Year
133	7.797704	122.753447	0.34	1.3	Flood	-0.96	5 -Year
134	7.796941	122.750129	0.46	1.4	Flood	-0.94	5 -Year
135	7.798051	122.757286	0.65	1.35	Flood	-0.70	5 -Year
136	7.798905	122.755862	0.51	1.35	Flood	-0.84	5 -Year
137	7.794818	122.754279	0.23	1.35	Flood	-1.12	5 -Year
138	7.778753	122.762861	0.07	0	Typhoon	0.07	5 -Year
139	7.791701	122.762947	0.14	0.1	Typhoon	0.04	5 -Year
140	7.791196	122.771691	0	0		0.00	5 -Year
141	7.797393	122.766088	0.27	0.4	Flood any time	-0.13	5 -Year
142	7.79422	122.766214	0.08	0		0.08	5 -Year
143	7.794725	122.765002	0.28	0		0.28	5 -Year
144	7.79705	122.768234	0.29	0.1		0.19	5 -Year
145	7.79284	122.763638	0.33	0.2		0.13	5 -Year
146	7.780403	122.802557	0.2	0.14		0.06	5 -Year
147	7.779316	122.802283	0.25	0.1		0.15	5 -Year
148	7.791506	122.794721	0.08	0		0.08	5 -Year
149	7.811065	122.763773	2.12	0.56		1.56	5 -Year
150	7.791438	122.730978	0.15	0.38		-0.23	5 -Year
151	7.808732	122.7686	0.49	0.8		-0.31	5 -Year
152	7.808114	122.768942	1.51	0.8		0.71	5 -Year
153	7.800939	122.764893	0.68	0.3		0.38	5 -Year
154	7.807335	122.758028	0.6	0.54		0.06	5 -Year
155	7.798843	122.762515	1.25	0.2		1.05	5 -Year
156	7.806269	122.769236	1.2	0.34		0.86	5 -Year
157	7.800442	122.767273	0.23	0.2		0.03	5 -Year
158	7.800861	122.768639	0.28	0.2		0.08	5 -Year
159	7.803566	122.77341	0	0		0.00	5 -Year
160	7.803097	122.768934	0	0.05		-0.05	5 -Year
161	7.800441	122.75935	1.13	0.75		0.38	5 -Year
162	7.782523	122.7976	0	0.25		-0.25	5 -Year
163	7.782058	122.798162	0	0.04		-0.04	5 -Year
164	7.787255	122.787186	1.13	0.5	ondoy	0.63	5 -Year
165	7.78907	122.79013	0	0		0.00	5 -Year
166	7.807569	122.699658	0.67	0.5		0.17	5 -Year
167	7.808073	122.715192	0	0		0.00	5 -Year
168	7.807494	122.710199	0.13	0		0.13	5 -Year
169	7.808479	122.719031	0.07	0		0.07	5 -Year
170	7.808469	122.716845	0	0		0.00	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
171	7.807256	122.720486	0	0		0.00	5 -Year
172	7.806035	122.718889	0	0		0.00	5 -Year
173	7.806334	122.720993	0	0		0.00	5 -Year
174	7.808784	122.714263	0	0		0.00	5 -Year
175	7.811745	122.719574	0	0		0.00	5 -Year
176	7.811421	122.719073	0.06	0		0.06	5 -Year
177	7.763188	122.752057	0.36	0		0.36	5 -Year
178	7.767661	122.747432	0	0		0.00	5 -Year
179	7.791869	122.693263	0	0.1		-0.10	5 -Year
180	7.804629	122.705986	0.1	0.3		-0.20	5 -Year
181	7.803287	122.705711	0	0		0.00	5 -Year
182	7.776821	122.746403	0	0		0.00	5 -Year
183	7.768465	122.738649	0	0		0.00	5 -Year
184	7.786116	122.69518	0	0	During high tide	0.00	5 -Year
185	7.78199	122.696576	0.06	0		0.06	5 -Year
186	7.790701	122.695002	0	0		0.00	5 -Year
187	7.789068	122.696391	0	0		0.00	5 -Year
188	7.792764	122.696517	0.09	0		0.09	5 -Year
189	7.793272	122.695575	0.09	0		0.09	5 -Year
190	7.788819	122.6954	0.32	0		0.32	
191	7.788164	122.69638	0	0		0.00	
192	7.787689	122.69536	0	0		0.00	
193	7.794026	122.6974	0.06	0		0.06	
194	7.795288	122.69541	0.06	0		0.06	
195	7.79662	122.69785	0	0		0.00	
196	7.80268	122.698	0.29	0		0.29	
197	7.802144	122.69619	0	0		0.00	
198	7.799808	122.69733	0	0		0.00	
199	7.797381	122.69605	0	0		0.00	
200	7.789561	122.69491	0.92	1	During heavy rain	-0.08	
201	7.78777	122.70335	0	0		0.00	
202	7.786835	122.70277	0	0		0.00	
203	7.785581	122.70378	0.04	0		0.04	
204	7.785769	122.70751	0	0		0.00	
205	7.783936	122.70267	0	0		0.00	
206	7.784185	122.69905	0	0		0.00	
207	7.786683	122.70546	0	0		0.00	
208	7.786516	122.6999	0.1	0		0.10	
209	7.787899	122.69782	0.04	0		0.04	
210	7.786161	122.69761	0	0		0.00	
211	7.781192	122.72536	0.05	0		0.05	
212	7.783635	122.73108	0.52	0		0.52	

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
213	7.787291	122.72952	0	0		0.00	
214	7.78005	122.740556	0	0		0.00	
215	7.785551	122.735481	0.51	0.6	During high tide,heavy rain	-0.09	
216	7.78932	122.72766	0.49	0.6	During high tide,heavy rain	-0.11	
217	7.791466	122.725381	0	0		0.00	
218	7.787772	122.724236	0.11	0		0.11	
				RMSE	0.78		

Annex 12. Educational Institutions Affected in Kabasalan Floodplain

Municipality	Barangay	Name of Institution	Rainfall Scenario		
			5-year	25-year	100-year
Kabasalan	Simbol	SIMBOL ELEMENTARY SCHOOL	None	None	None
Kabasalan	Sininan	Brgy.Daycare	None	None	None
Kabasalan	Sininan	MADRASA	None	None	None
Kabasalan	Sininan	SININAN ELEM. SCHOOL	None	None	None
Kabasalan	Timuay Danda	Timuay Danda Elementary School	None	None	None
Kabasalan	Simbol	SIMBOL NATIONAL HIGH SCHOOL	None	None	Low
Kabasalan	Sininan	ARABIC SCHOOL	None	None	Low
Kabasalan	Poblacion	Goodyear Elementary School	None	Low	Low
Kabasalan	Poblacion	KAC agape school	None	Low	Low
Kabasalan	Santa Cruz	Stack Cruz elementary School	None	Low	Low
Kabasalan	Sininan	CANACAN ELEM. SCHOOL	None	Low	Low
Kabasalan	Concepcion	CONCEPTION ELEM. SCHOOL	Low	Low	Low
Kabasalan	Banker	Day Care	None	Low	Medium
Kabasalan	Calubihan	Daycare Center	None	Low	Medium
Kabasalan	Riverside	Day Care Center	None	Low	Medium
Kabasalan	Poblacion	Goodyear School	Low	Low	Medium
Kabasalan	Poblacion	Goodyear School Daycare	Low	Low	Medium
Kabasalan	Buayan	DIPALA ELEM. SCHOOL	Low	Medium	Medium
Kabasalan	Poblacion	Start Cruz elementary school	Low	Medium	Medium
Kabasalan	Santa Cruz	Start Cruz elementary school	Low	Medium	Medium
Kabasalan	Sininan	Primary school	Low	Medium	Medium
Kabasalan	Calubihan	KABASALAN SCIENCE AND TECHNOLOGY HIGH SCHOOL	Medium	Medium	Medium
Kabasalan	Calubihan	KNHS	Medium	Medium	Medium
Kabasalan	Santa Cruz	Lumbayao Elem School	Medium	Medium	Medium
Kabasalan	Calubihan	KABASALAN NATIONAL HIGH SCHOOL	Medium	Medium	High
Kabasalan	Calubihan	KABASALAN INSTITUTE OF TECHNOLOGY	Medium	High	High
Kabasalan	Calubihan	KABASANALAN CENTRAL ELEMENTARY SCHOOL	Medium	High	High
Kabasalan	Poblacion	Cainglet primary school	Medium	High	High
Kabasalan	Sanghanan	SALUPAN PRIMARY SCHOOL	High	High	High
Naga	Taytay Manubo	Day Care Center	None	None	None
Naga	Taytay Manubo	NAGA CENTRAL ELEMENTARY SCHOOL	None	None	None
Naga	Baga	BAGS NATIONAL HIGH SCHOOL	None	None	None
Naga	Baga	LOWER SULITAN ELEMENTART SCHOOL	None	None	None
Naga	Bangkaw-Bangkaw	BANGKAW-BANGKAW ELEMENTARY SCHOOL	None	None	None
Naga	Bangkaw-Bangkaw	Madrasa	None	None	None
Naga	Bangkaw-Bangkaw	Pre school	None	None	None

Naga	Mamagon	Madrasa	None	None	None
Naga	Mamagon	MES	None	None	None
Naga	Mamagon	MES Kindergarten	None	None	None
Naga	Poblacion	Aguinaldo elementary sch.	None	None	None
Naga	Taytay Manubo	NAGA NATIONAL HIGH SCHOOL	Low	Low	Low
Naga	Baga	BAGS ELEMENTARY SCHOOL	Low	Low	Medium
Naga	Poblacion	School	Medium	Medium	Medium

Annex 13. Medical Institutions Affected in Kabasalan Floodplain

Municipality	Barangay	Name of Institution	Rainfall Scenario		
			5-year	25-year	100-year
Kabasalan	Concepcion	Daycare center	Medium	Medium	Medium
Kabasalan	Poblacion	Path finder hostpital	Medium	Medium	Medium
Kabasalan	Poblacion	Wooton	Medium	Medium	Medium
Kabasalan	Poblacion	Goodyear health center	Medium	Medium	Medium
Kabasalan	Poblacion	LGU	Medium	Medium	Medium
Kabasalan	Poblacion	Goodyear hospital	Medium	Medium	Medium
Kabasalan	Poblacion	Kabasalan General Hospital	Medium	Medium	Medium
Kabasalan	Riverside	Health Station	Medium	Medium	Medium
Kabasalan	Riverside	Health Station	Medium	Medium	Medium
Naga	Taytay Manubo	Health center	Medium	Medium	Medium
Naga	Taytay Manubo	Brgy.health center	Medium	Medium	Medium
Naga	Bangkaw-Bangkaw	BANGKAW-BANGKAW Bns center	Medium	Medium	Medium