LiDAR Surveys and Flood Mapping of Gahub River

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LIST OF ACRONYMS AND ABBREVIATIONS

AAC	Asian Aerospace Corporation
Ab	abutment
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
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]
ISU	Isabela State University

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
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 GAHUB RIVER

1.1 Background of the Phil-LiDAR 1 Program

(UP-TCAGP) launched a research program entitled "Nationwide Hazard Mapping using LiDAR" or Phil-LiDAR 1Phil-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.

Also, tThe 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).

The implementing partner university for the Phil-LiDAR 1Phil-LiDAR 1 Program is the Central Mindanao University (CMU). CMU 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 thirteen (13) river basins in the Central Mindanao Region. The university is located in the Municipality of Maramag in the province of Bukidnon.

1.2 Overview of the Gahub River Basin

Gahub River is located in Gingoog City, Misamis Oriental. Its basin has a total area of 3,313 hectares. It specifically lies within the grid coordinates of 125.1000° east longitude and 8.8167° north latitude. Gahub River Basin falls within forty (40) barangays including some part of Mount Balatucan Range Nature Park. It is bounded on the east by the Municipality of Magsaysay, on the west by the Municipality of Medina, and on the south by the Municipality of Claveria. It is one of the rivers with headwater emanating from Mt. Balatucan, particularly from Barangay Tinulungan, and drains to Gingoog Bay. Among the earliest settlers in the basin were the Manobo tribe who occupied and utilized the area for planting, fishing, and hunting. They were later joined by migrants from neighboring places.

The river has been accordingly a good provider of potable water to the people of Gingoog since the 19th century, which, up to this day, is being utilized for residential, commercial, and industrial purposes. This richness may be attributed to the relatively conserved dense vegetation in the upstream of the basin comprising secondary natural and plantation forests alongside coconut plantations. Moreover, a mixture of orchard of durian, marang, and pomelo, among others, also inhabits the basin.

Despite its rich natural resources, Gahub River is noted to have caused flooding particularly back in 2009 when a 1-meter flood affected over 2,000 individuals. According to focus group discussions and key informant interviews conducted with the locals, among the oldest remembered flood incidents which struck the area were floodings in as early as 1979. More recent incidents occurred in 2008, in 2009 during Ondoy, in 2013, in 2014 during Typhoon Agaton, and in 2015. Flood control dike was built to mitigate further potential damages.

Flood hazard maps were generated for this river using Light Detection and Ranging (LiDAR) technology under the Phil-LiDAR Program. The maps derived through flood modeling involved the development of Hydrologic Engineering Center's Hydrologic Model System (HEC-HMS) and River Analysis System (HEC-RAS) for precipitation-runoff and flood depth simulations, respectively.

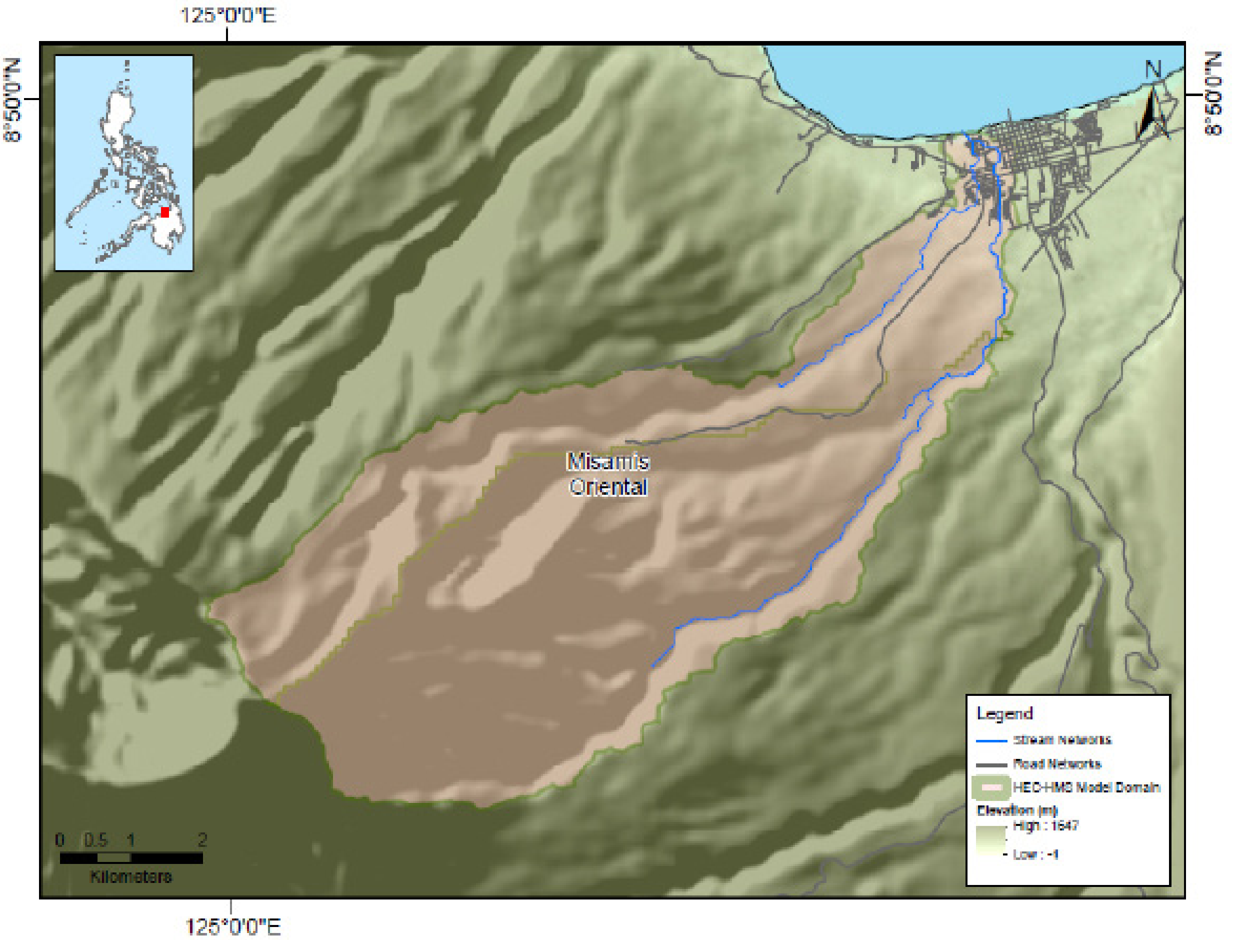

Figure 1. Map of the Gahub River Basin (in brown)

The basin model generated using Synthetic Aperture Radar (SAR) 10m Digital Elevation Model (DEM) and digitized river centerline consists of 21 subbasins, 21 reaches, and 23 junctions. The model was calibrated using the actual data during a rainfall event on October 26, 2016. Model performance was evaluated using statistical efficiency tests which revealed a very good rating. Hypothetical discharge scenarios were simulated using the calibrated model and Rainfall Intensity Duration Frequency (RIDF) data of Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) taken at a 21-year historical data of Butuan rain gauge. Subsequent flood movement was simulated using LiDAR Digital Terrain Model (DTM) generating flood extent and depth information. Flood hazard maps generated project the flood scenarios for the 5-, 25-, and 100-year return periods.

CHAPTER 2: LIDAR DATA ACQUISITION OF GAHUB FLOODPLAIN

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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 Gahub Floodplain in Misamis Oriental. These missions were planned for 12 lines and ran 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 2 shows the flight plan for Gahub Floodplain.

Table 1. Flight planning parameters for the Pegasus LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of view (ø)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK RXA	900	30	50	200	30	130	5
BLK RXB	900	30	50	200	30	130	5
BLK RXS	900	30	50	200	30	130	5
BLK 64A	900	30	50	200	30	130	5

[1] The explanation of the parameters used are in the volume "LiDAR Surveys and Flood Mapping in the Philippines: Methods."

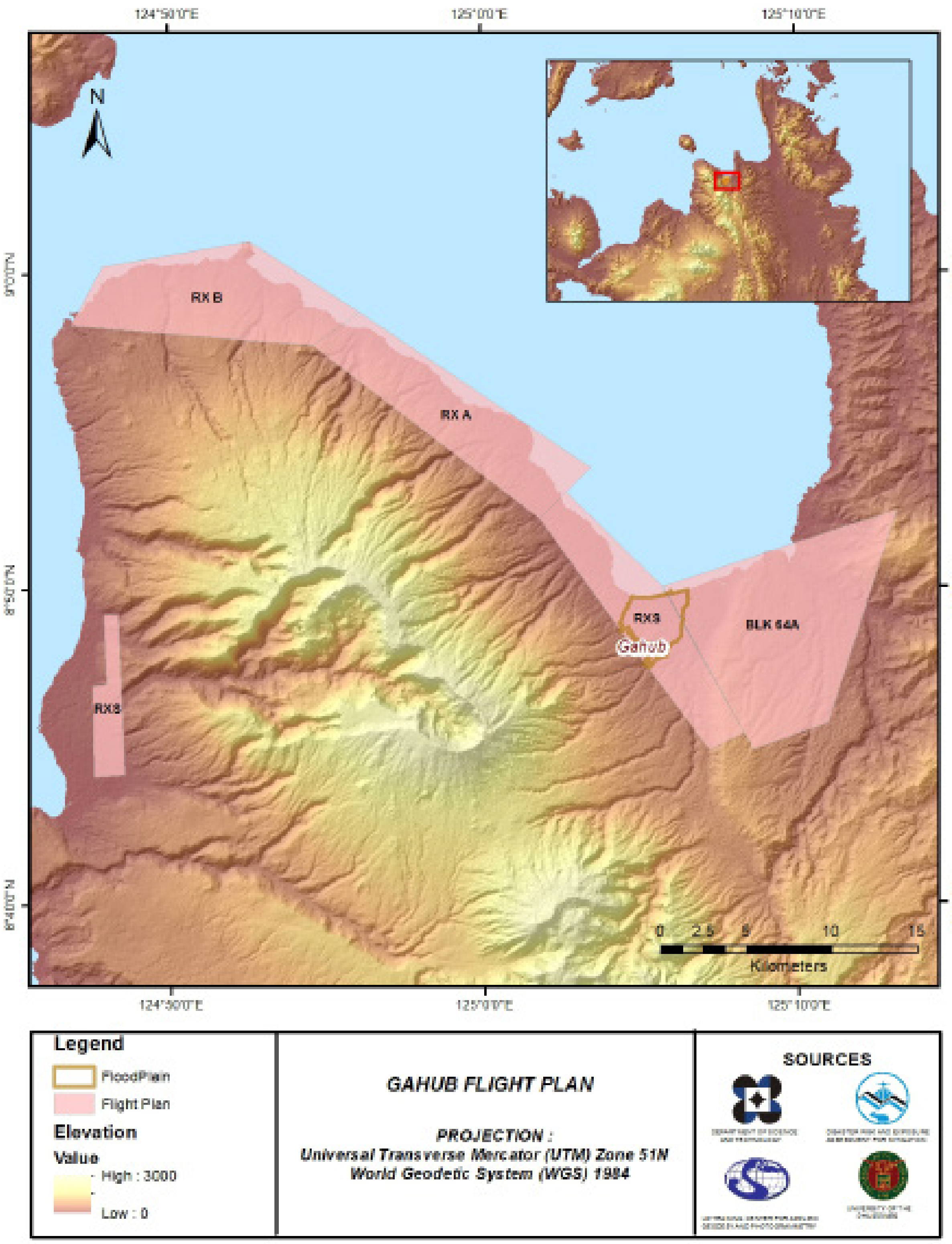


Figure 2. Flight Plans used for the Gahub Floodplain

2.2 Ground Base Stations

The project team was able to recover three (3) NAMRIA ground control points: MSE-31, MSE-32, and MSE-36 which are of second (2nd) -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 (May 28–-29, 2014). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 882 and SPS 852. Flight plans and location of base stations used during the aerial LiDAR acquisition in Gahub Floodplain are shown in Figure 3.

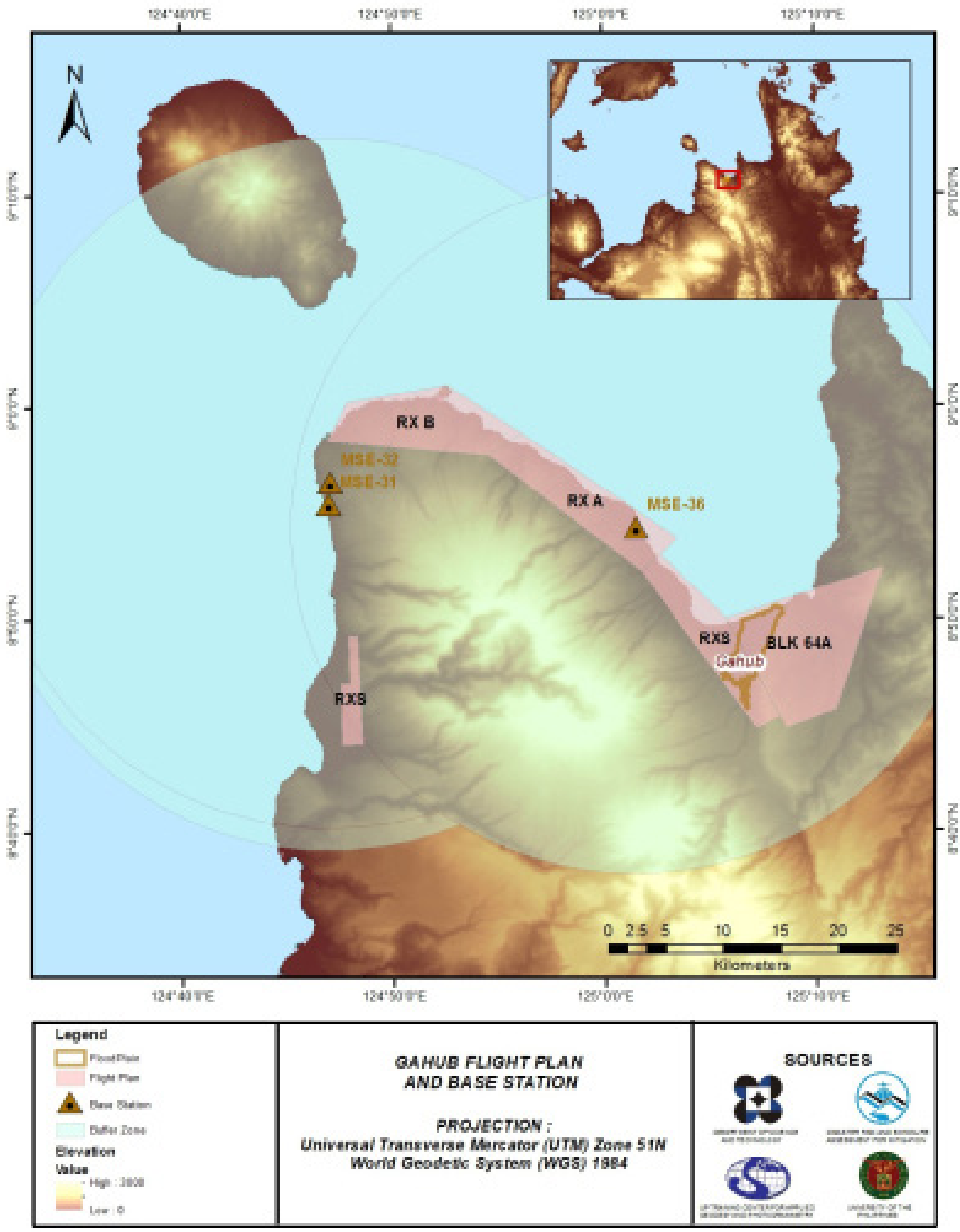


Figure 3. Flight Plans and base stations used for the Gahub Floodplain

Figure 4 to Figure 6 show the recovered NAMRIA reference points within the area. In addition, Table 2 to Table 4 show present the details about the following NAMRIA control stations, while Table 5 shows the list of all ground control points occupied during the acquisition together with the corresponding dates of utilization.


(a)

(b)

Figure 4. GPS set-up over MSE-31 inside the school grounds of Binuangan National High School of Sitio Naratulan, Binuangan, Misamis Oriental (a) and NAMRIA reference point MSE-31 (b) as recovered by the field team

Table 2. Details of the recovered NAMRIA horizontal reference point MSE-31 used as base station for the LiDAR acquisition.

Station Name	**MSE-31**	
Order of Accuracy	**2nd**	
Relative Error (Horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	18°19'2.39264" North 121°22'58.62210" East 17.98200 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting Northing	476032.898 meters 986806.828 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8°55'24.88251" North 124°47'0.81947" East 126.4900 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	696109.62 meters 986876.83 meters

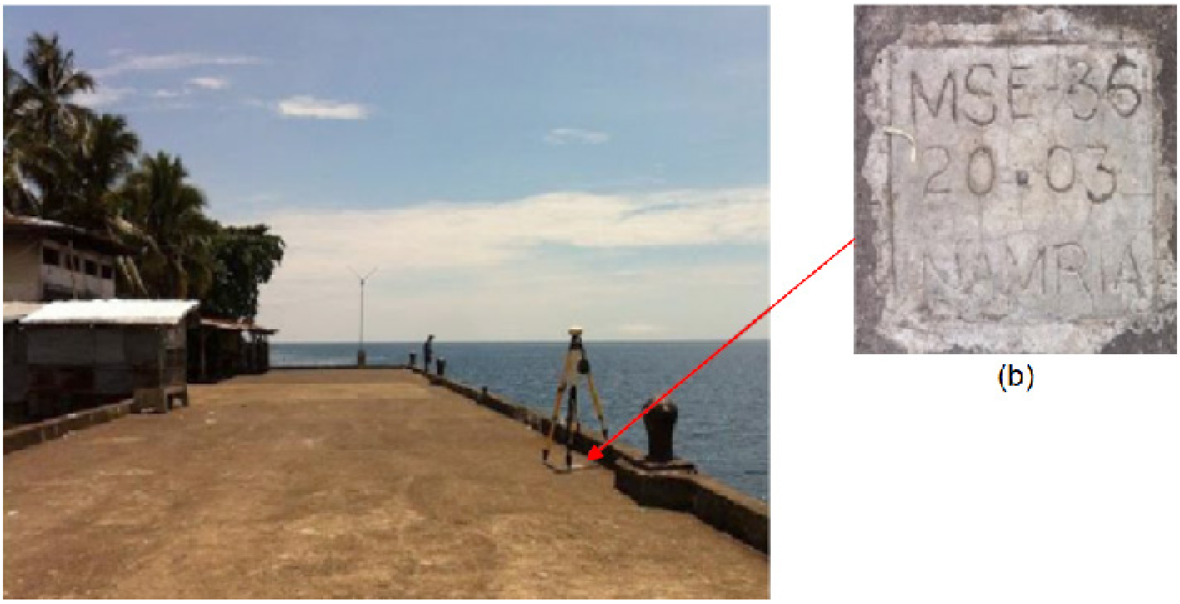
(b)

(a)

Figure 5. GPS set-up over MSE-32 inside Alicomohan Elementary school, just in front of the school's flag pole, situated at Barangay Alicomohan, Sugbongcogon, Misamis Oriental (a) and NAMRIA reference point MSE-32 (b) as recovered by the field team

Table 3. Details of the recovered NAMRIA horizontal control point MSE-32 used as base station for the LiDAR acquisition

Station Name	**MSE-32**	
Order of Accuracy	**2nd**	
Relative Error (Horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8°56'30.44605" North 124°46'58.97104" East 132.12900 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting Northing	476141.401 meters 988707.53 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8°56'26.75387" North 124°47'4.33290" East 199.10100 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	696045.73 meters 988828.70 meters



(b)

(a)

Figure 6. GPS set-up over MSE-36 within Medina municipal port(a) and NAMRIA reference point MSE-32 (b) as recovered by the field team

Table 4. Details of the recovered NAMRIA horizontal control point MSE-36 used as base station for the LiDAR acquisition

Station Name	MSE-36	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8°54'20.12398" North 125°1'28.36102" East 0.97100 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting Northing	502699.481 meters 984697.224 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8°54'16.46220" North 125°1'33.72408" East 68.61700 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	722630.22 meters 984961.57 meters

Table 5. Ground control points used during the LiDAR data acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
May 28,2014	1521P	1RXC148A	MSE-31, MSE-32,MSE-36
May 29,2014	1525P	1RXE149A	MSE-31, MSE-32,MSE-36

2.3 Flight Missions

Two (2) missions were conducted to complete the LiDAR data acquisition in Gahub Floodplain, for a total of eight hours and forty minutes (8+40) of flying time for RP-C9022. All missions were acquired using the Pegasus LiDAR system. Table 56 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 67 presents the actual parameters used during the LiDAR data acquisition.

Table 6. Flight missions for the LiDAR data acquisition of the Pamplona Floodplain.

Date Surveyed	Flight Number	Flight Plan Area (km2)	Surveyed Area (km2)	Area Surveyed within the Floodplain (km2)	Area Surveyed Outside the Floodplain (km2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
May 28,2014	1521P	139.2	132.45	0	132.45	NA	4	11
May 29,2014	1525P	153.85	132.81	10.34	122.47	NA	4	29
TOTAL		293.05	286.3	10.34	254.92	NA	8	40

Table 7. Actual parameters used during the LiDAR data acquisition

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (khz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
1521P	850	30	50	200	30	130	5
1525P	900	30	50	200	30	130	5

2.4 Survey Coverage

Gahub Floodplain is located in the province of Misamis Oriental with majority of the floodplain situated within the City of Gingoog. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 87. The actual coverage of the LiDAR acquisition for Gahub Floodplain is presented in Figure 7.

Table 8. List of municipalities and cities surveyed during Gahub Floodplain LiDAR survey

Province	Municipality/ City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Misamis Oriental	Kinoguitan	36.19	17.58	48.58%
	Talisayan	65.14	29.17	44.77%
	Medina	118,64	33.22	28%
	Balingoan	62.65	16.35	26.1%
	Gingoog	538	111.98	20.81%
	Balingasag	125.59	11.55	9.2%
	Binuangan	15.32	1.27	8.28%
	Lagonglong	46.63	2.94	6.31%
	Magsaysay	118.05	1.74	1.48%
TOTAL		**1007.57**	**225.8**	**22%**

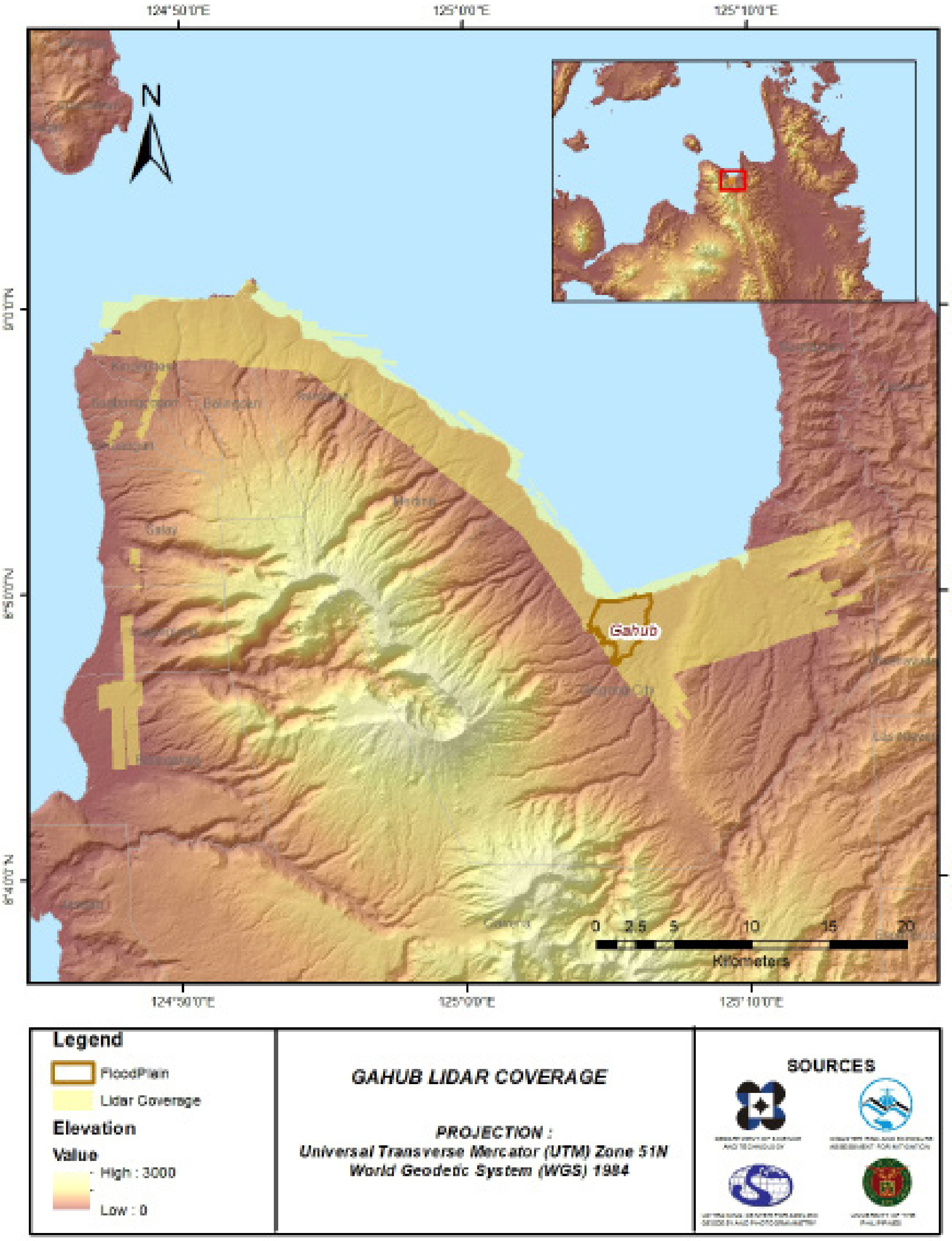


Figure 7. Actual LiDAR survey coverage for Gahub Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING FOR GAHUB 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 were 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 was done in order to obtain the exact location of the LiDAR sensor when the laser was shot. Point cloud georectification is was performed to incorporate correct position and orientation for each point acquired. The georectified LiDAR point clouds are were subject for quality checking to ensure that the required accuracies of the program, which are were the minimum point density, vertical and horizontal accuracies, are were met. The point clouds are were 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 were calibrated. Portions of the river that are were barely penetrated by the LiDAR system are were replaced by the actual river geometry measured from the field by the Data Validation and Bathymetry Component. LiDAR data acquired temporally are were then mosaicked to completely cover the target river systems in the Philippines. Orthorectification of images acquired simultaneously with the LiDAR data is was 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 8.

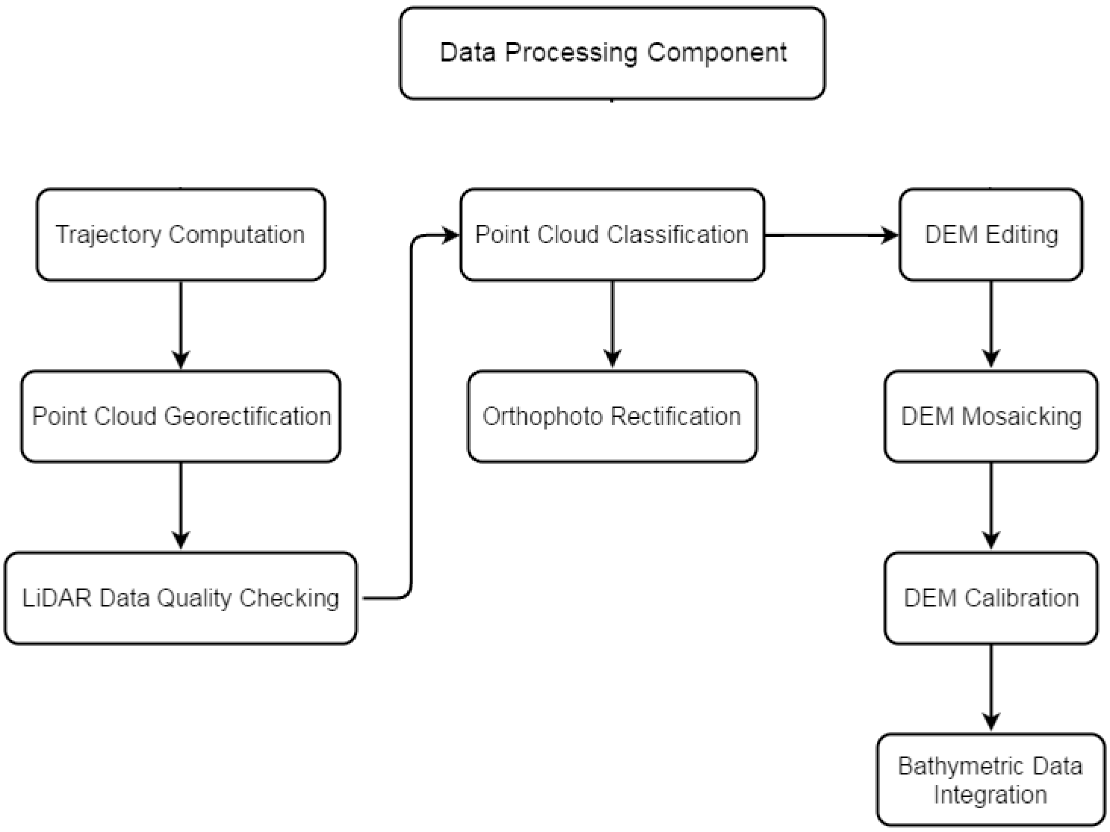

Figure 8. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Gahub Floodplain can be found in ANNEX A-5. Data Transfer Sheets. Missions flown during the first survey conducted on May 2014 and second survey on June 2014 were flown using the the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system over Gingoog City, Misamis Oriental.

The Data Acquisition Component (DAC) transferred a total of 54.50 Gigabytes of Range data, 517 Megabytes of POS data, and 15.37 Megabytes of GPS base station data to the data server on June 10, 2014 for the first survey and June 23, 2014 for the second survey. The Data Pre-Processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Gahub was fully transferred on June 23, 2014, as indicated on the data transfer sheets for Gahub Floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 1521P, one of the Gahub flights, which is the North, East, and Down position RMSE values, are shown in Figure 9. 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 May 28, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

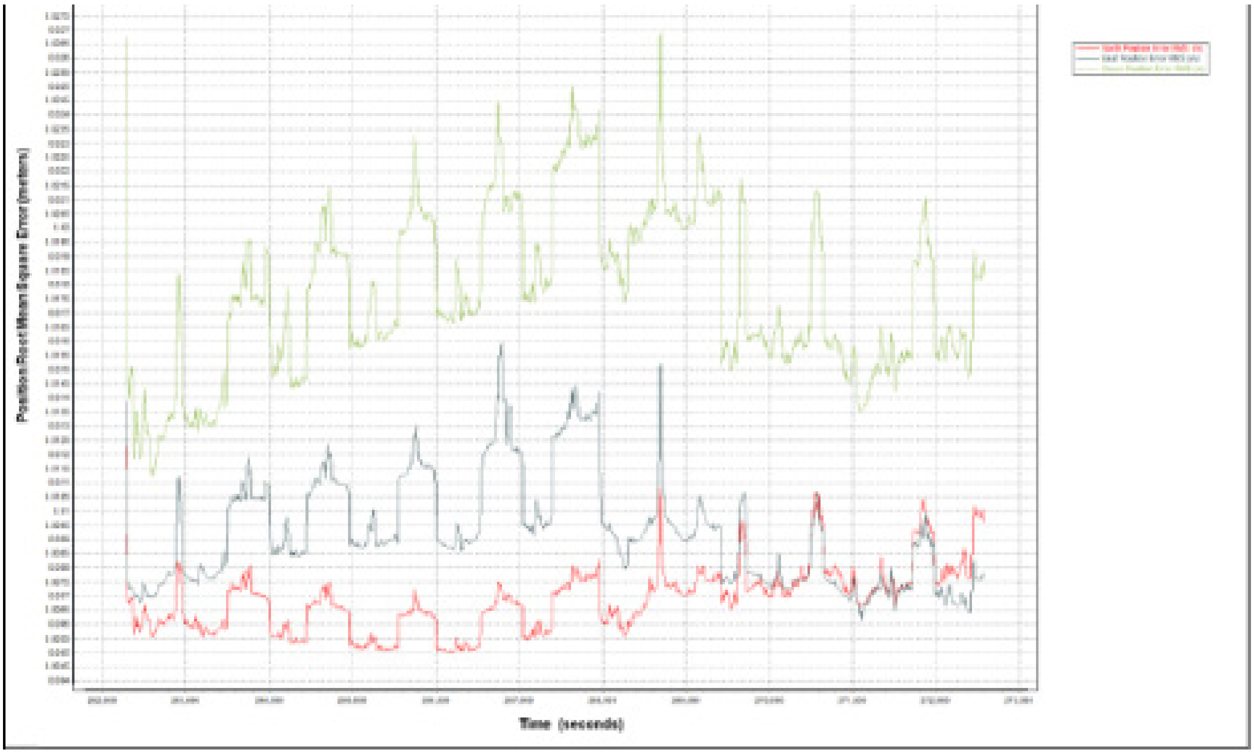

Figure 9. Smoothed Performance Metrics of Gahub Flight 1521P

The time of flight was from 262300 seconds to 272600 seconds, which corresponds to morning of May 28, 2014. 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 time the POS system starts computing for the position and orientation of the aircraft.

Redundant measurements from the POS system quickly minimized 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 9 B-2 shows that the North position RMSE peaks at 1.11 centimeters, the East position RMSE peaks at 1.60 centimeters, and the Down position RMSE peaks at 2.70 centimeters, which are within the prescribed accuracies described in the methodology.

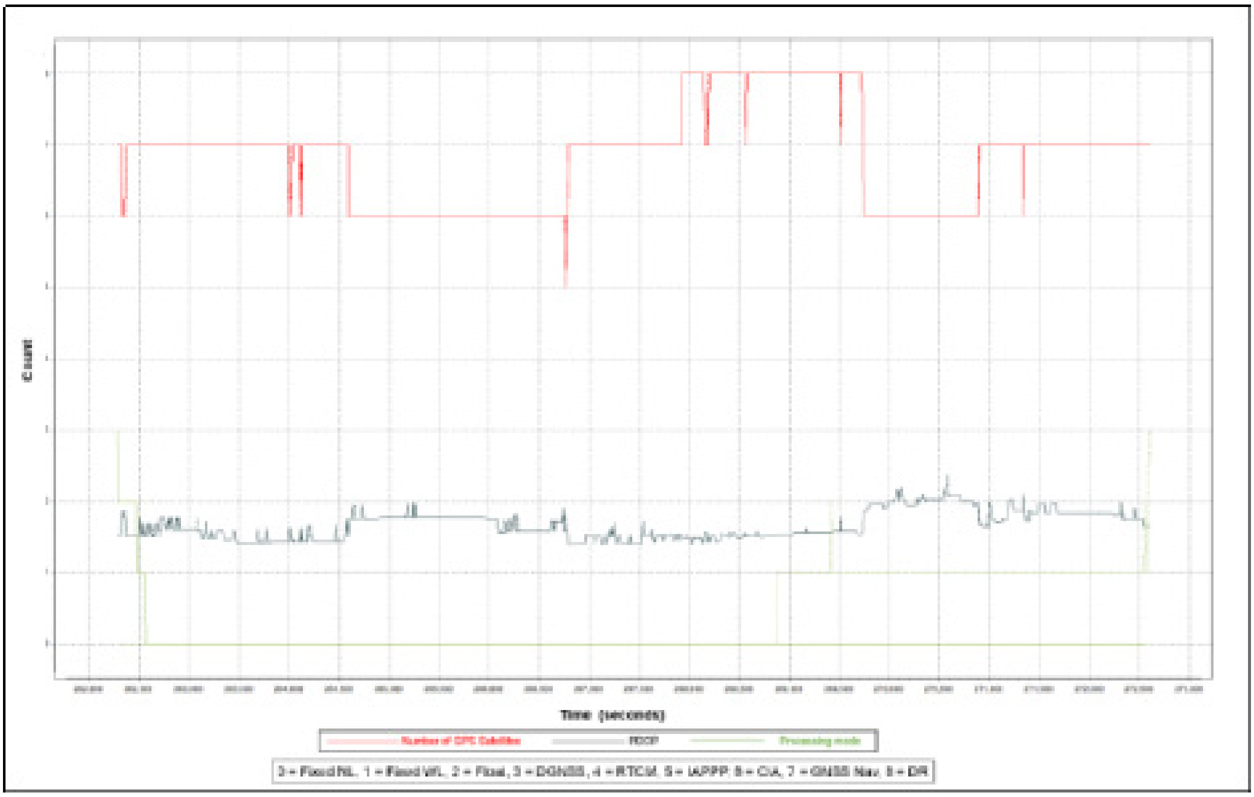

Figure 10. Figure 10.Solution Status Parameters of Gahub Flight 1521P

The Solution Status parameters of flight 1521P, one of the Gahub flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 10. The graphs indicate the number of satellites during the acquisition. 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 indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 1 attributed to the turns 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 Gahub flights is shown in Figure 11.

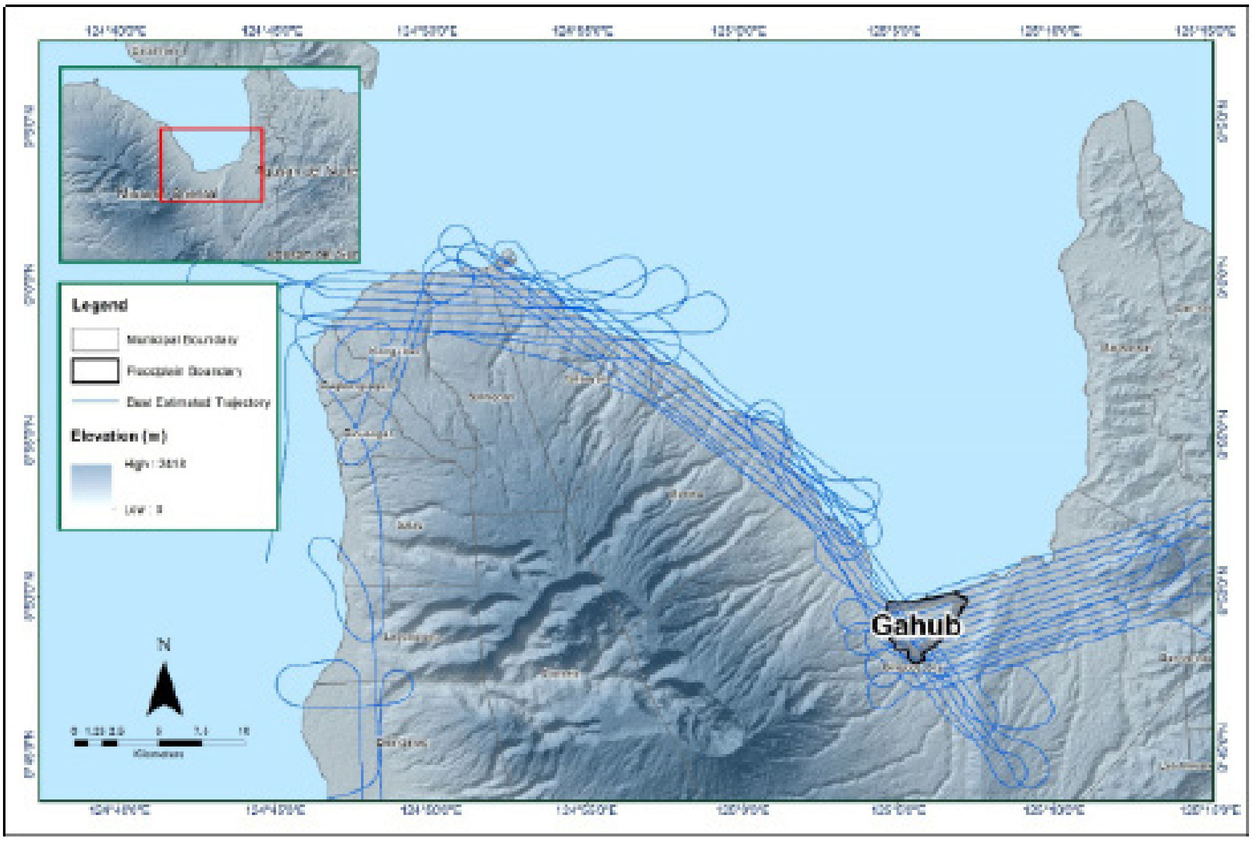

Figure 11. Best estimated trajectory for of LiDAR missions conducted over the Gahub Floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 42 flight lines, with each flight line containing one channel, 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 Gahub Floodplain are given in Table 9.

Table 9. Self-calibration Results values for Gahub flights.

Parameter	Acceptable Value	Computed Value
Boresight Correction stdev	<0.001degrees	0.000202
IMU Attitude Correction Roll and Pitch Correction stdev	<0.001degrees	0.000536
GPS Position Z-correction stdev	<0.01meters	0.0027

The optimum accuracy is obtained for all Gahub 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 Gahub Floodplain is shown in Figure 12. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

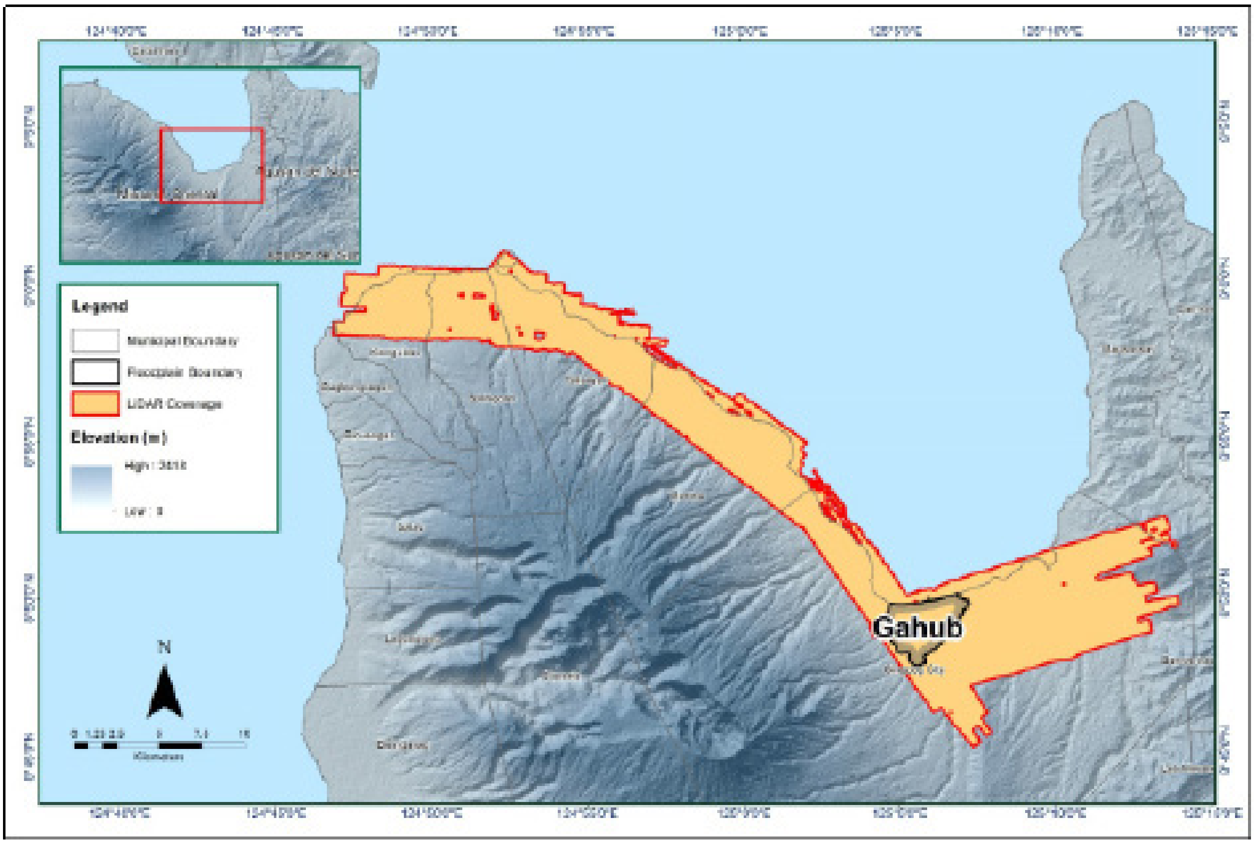

Figure 12. Boundary of the processed LiDAR data over Gahub Floodplain

The total area covered by the Gahub missions is 263.10 sq.kmsq km that is comprised of two (2) flight acquisitions grouped and merged into three (3) blocks as shown in Table 10.

Table 10. List of LiDAR blocks for Pamplona Floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
NorthernMindanao_Blk64A	1525P	128.02
NorthernMindanao_RX_BlkA	1521P	70.70
NorthernMindanao_RX_BlkB	1521P	64.38
TOTAL		263.10 sq.km

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location, is shown in Figure 13. Since the Since the Pegasus system both employs two channels, we would expect an average value of 2 (blue) for areas would be expected where there is limited overlap, and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines.

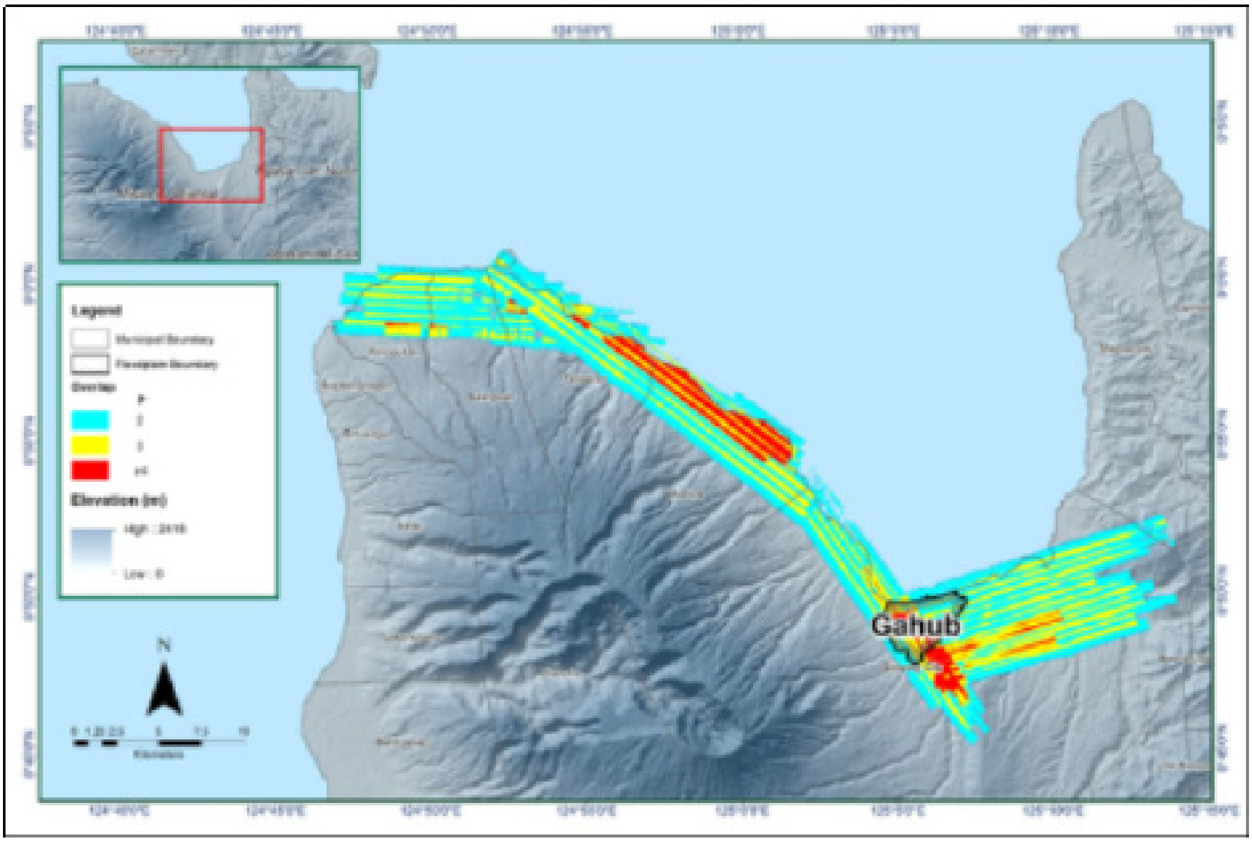

Figure 13. Image of data overlap for Gahub Floodplain.

The overlap statistics per block for the Gahub Floodplain can be found in ANNEX 8. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 38.03% and 50.40%, 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 14. It was determined that all LiDAR data for Gahub Floodplain satisfy the point density requirement, and the average density for the entire survey area is 7.95 points per square meter.

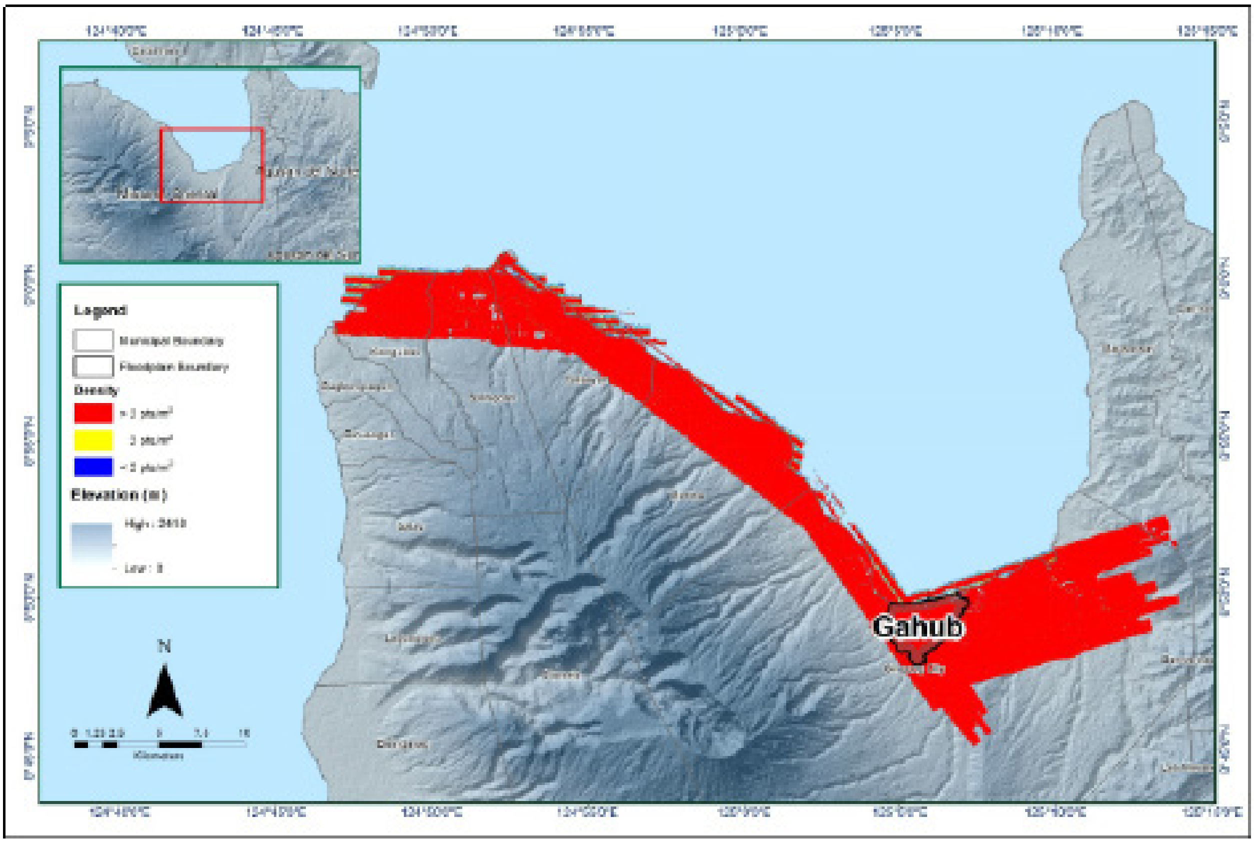

Figure 14. Pulse density map of merged LiDAR data for Gahub Floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 15. 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 0.20 m 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 0.20 m 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.

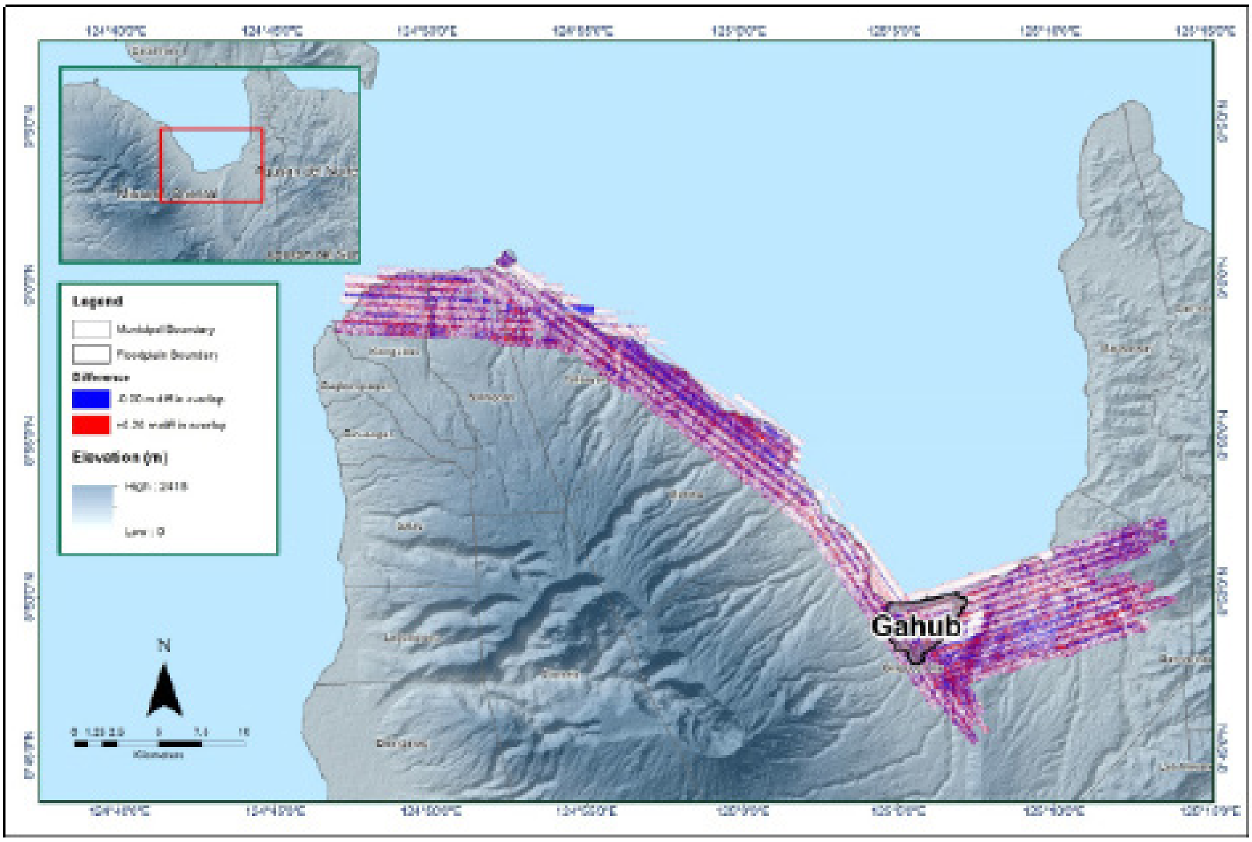

Figure 15. Elevation difference map between flight lines for Gahub Floodplain.

A screen capture of the processed LAS data from a Gahub flight 1521P loaded in QT Modeler is shown in Figure 16. 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.

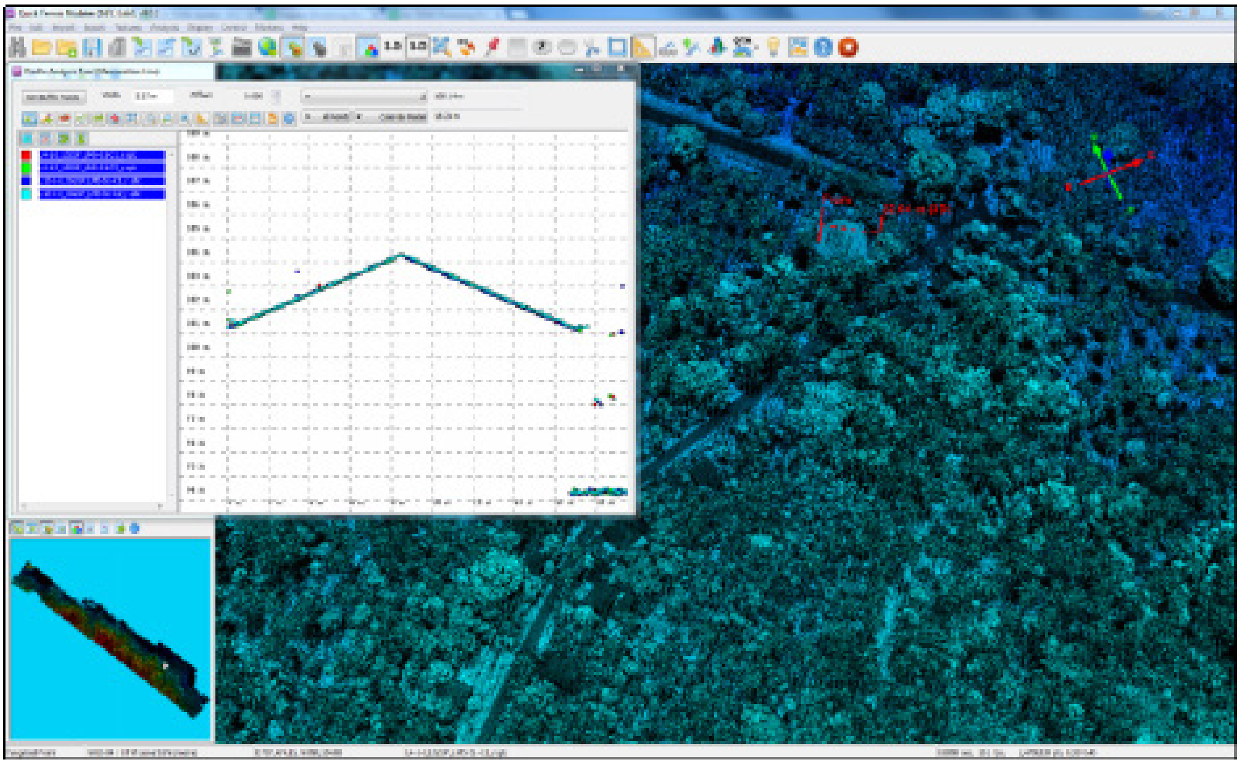

Figure 16. Quality checking for a Gahub flight 1521P using the Profile Tool of QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 11. Gahub classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	291,443,348
Low Vegetation	316,187,618
Medium Vegetation	570,163,046
High Vegetation	687,424,665
Building	35,885,091

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Gahub Floodplain is shown in Figure 17. A total of 382 1 km by 1 km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 11. The point cloud has a maximum and minimum height of 794.05 meters and 34.79 meters, respectively.

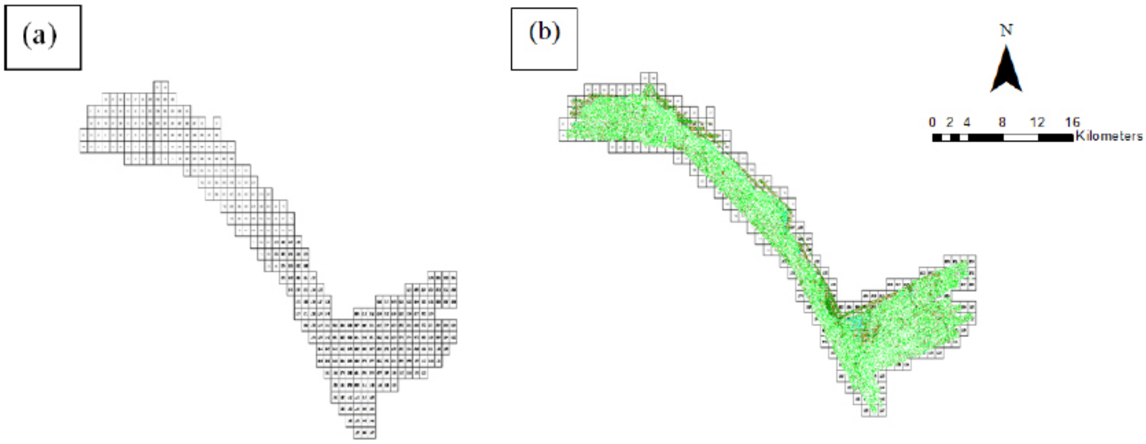

Figure 17. Tiles for Gahub Floodplain (a) and classification results (b) in TerraScan

An isometric view of an area before and after running the classification routines is shown in Figure 18. 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.

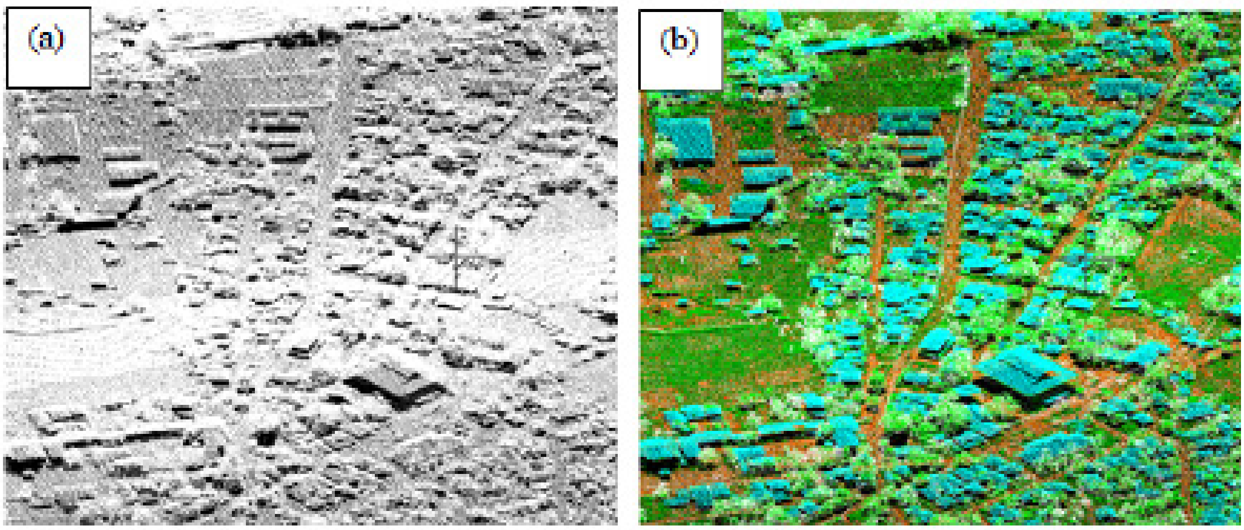

Figure 18. Point cloud before (a) and after (b) classification

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 19. It shows that DTMs are the representation of the bare earth while on the DSMs, all features such as buildings and vegetation are present.

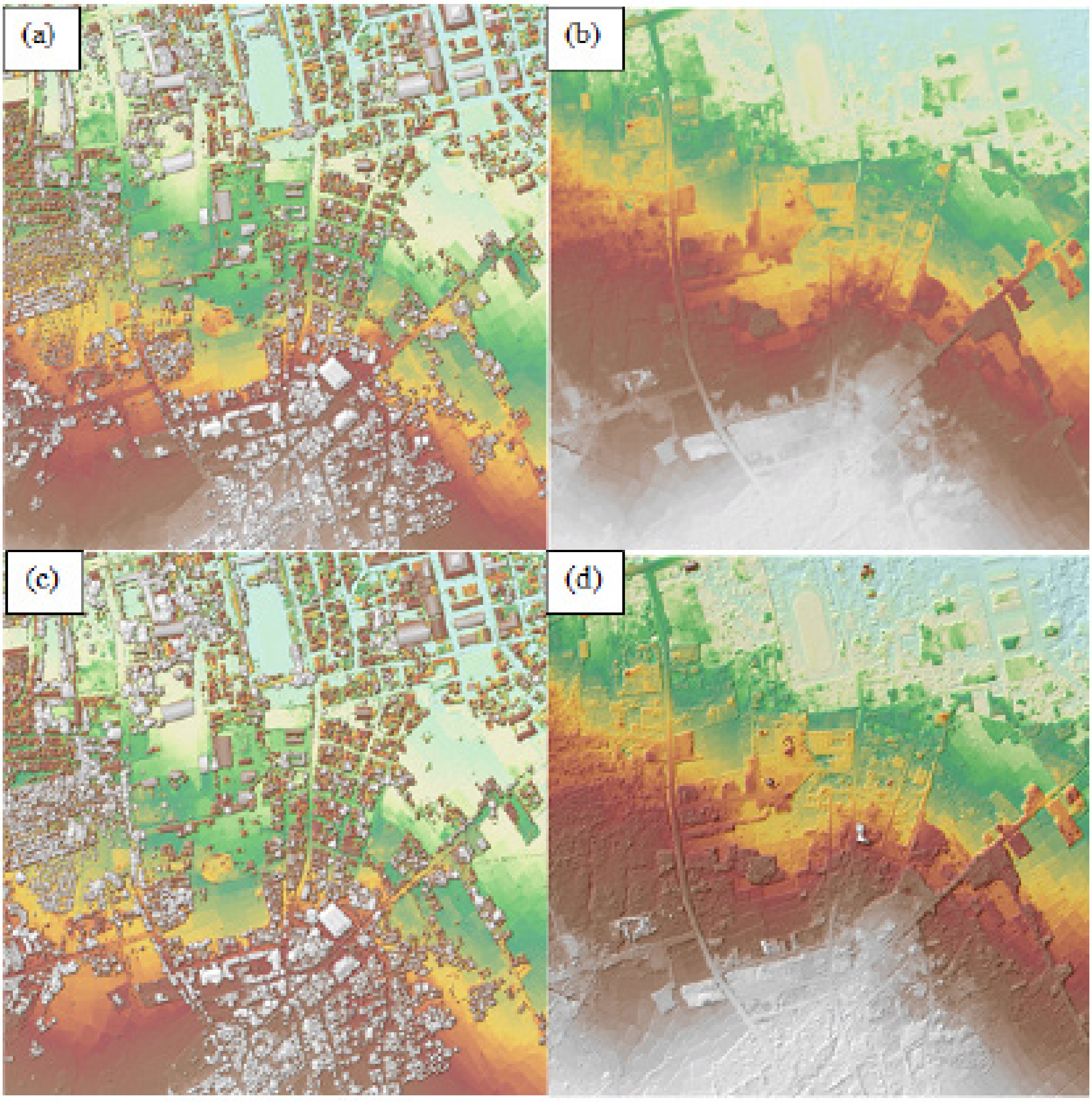

Figure 19. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Gahub Floodplain

3.7 LiDAR Image Processing and Orthophotograph Rectification

There are no available orthophotographs for Gahub Floodplain.

3.8 DEM Editing and Hydro-Correction

Three (3) mission blocks were processed for Gahub Floodplain. These blocks are were composed of Northern Mindanao blocks with a total area of 263.10 square kilometers. Table 12 shows the name and corresponding area of each block in square kilometers.

Table 12. LiDAR blocks with its corresponding areas.

LiDAR Blocks	Area (sq.km)
NorthernMindanao_Blk64A	128.02
NorthernMindanao_RX_BlkA	70.70
NorthernMindanao_RX_BlkB	64.38
TOTAL	263.10 sq.kmsq km

Portions of DTM before and after manual editing are shown in Figure 20. The bridge (Figure 20a) is also considered to be an impedance to the flow of water along the river and has to be removed (Figure 20b) in order to hydrologically correct the river. This was done through interpolation process wherein in which a specific polygon determines the upstream and downstream elevation values to generate an interpolated portion of a river and eventually remove the bridge footprint. On the other hand, object retrieval was done in misclassified ridges (Figure 20c and 20e) which have had been removed during classification process and have had to be retrieved to complete the surface and retain the correct terrain (Figure 20d and 20f). Object retrieval uses the secondary DTM (t_layer) to fill in these areas.

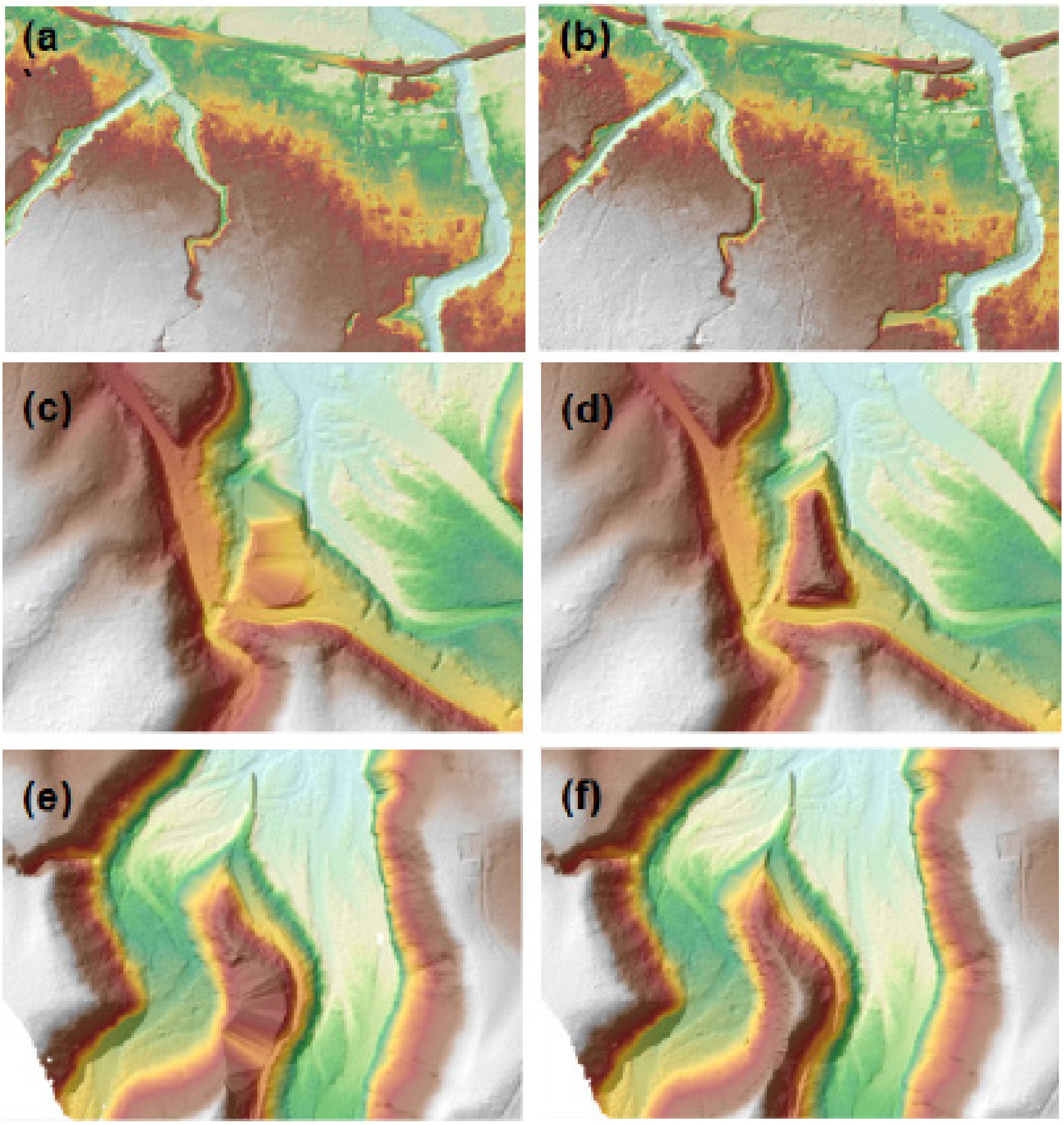

Figure 20. Portions in the DTM of Gahub Floodplain— – bridges before (a) and after (b) interpolation and misclassified ridges before (c, e) and after (d, f) data retrieval

3.9 Mosaicking of Blocks

The Gahub Floodplain lies within the mosaicked DEM of NorthernMindanao_Blk64A and NorthernMindanao_RX_BlkA blocks. The calibration was done in NorthernMindanao_Blk64A and was used as the reference block at the start of mosaicking because the validation points lies within the block. Table 13 shows the area of each LiDAR block and the shift values applied to calibrate the Gahub DEM during mosaicking

Table 13. Shift Values of each LiDAR Block of Gahub Floodplain

Mission Blocks	Shift Values (meters)		
	x	y	z
NorthernMindanao_Blk64A	0	0	-0.12
NorthernMindanao_RX_BlkA	0	0	-0.13
NorthernMindanao_RX_BlkB	0	0	-0.19

Mosaicked LiDAR DTM for Gahub Floodplain is shown in Figure 21. It can be seen that the entire Gahub Floodplain is 100% covered by LiDAR data.

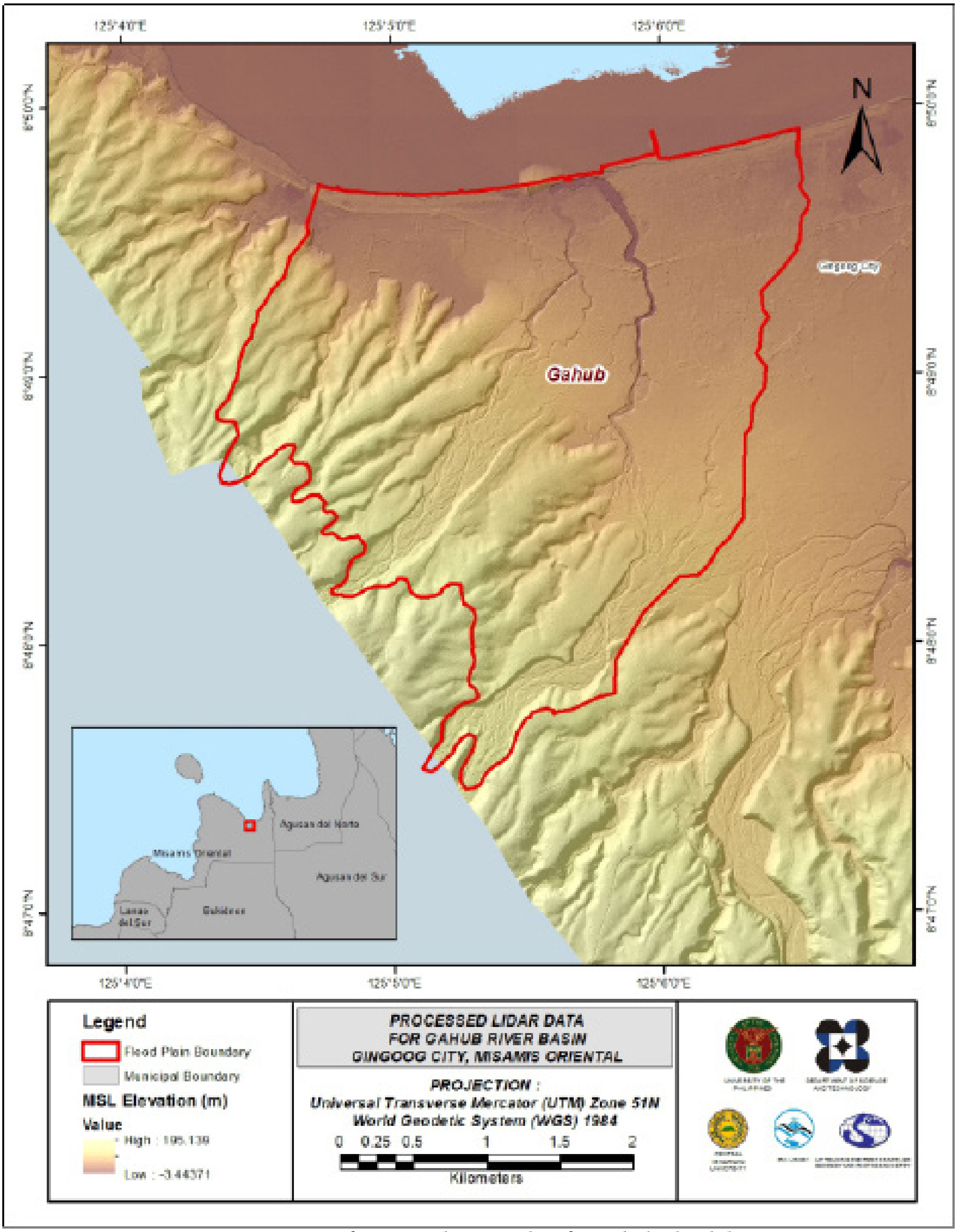

Figure 21. Map of processed LiDAR data for Gahub Floodplain

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model (DEM)

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Gahub to collect points with which the LiDAR dataset is was validated is shown in Figure 22. A total of 7,941 survey points were used for calibration and validation of Gahub LiDAR data. Eighty percent Random selection of 80% of the survey points, which were randomly selected and resulting to in 6,353 points, were used for calibration.

A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure 23. 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 0.64 meters with a standard deviation of 0.10 meters. Calibration of Gahub LiDAR data was done by subtracting the height difference value, 0.64 meters, to Gahub mosaicked LiDAR data. Table 14 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

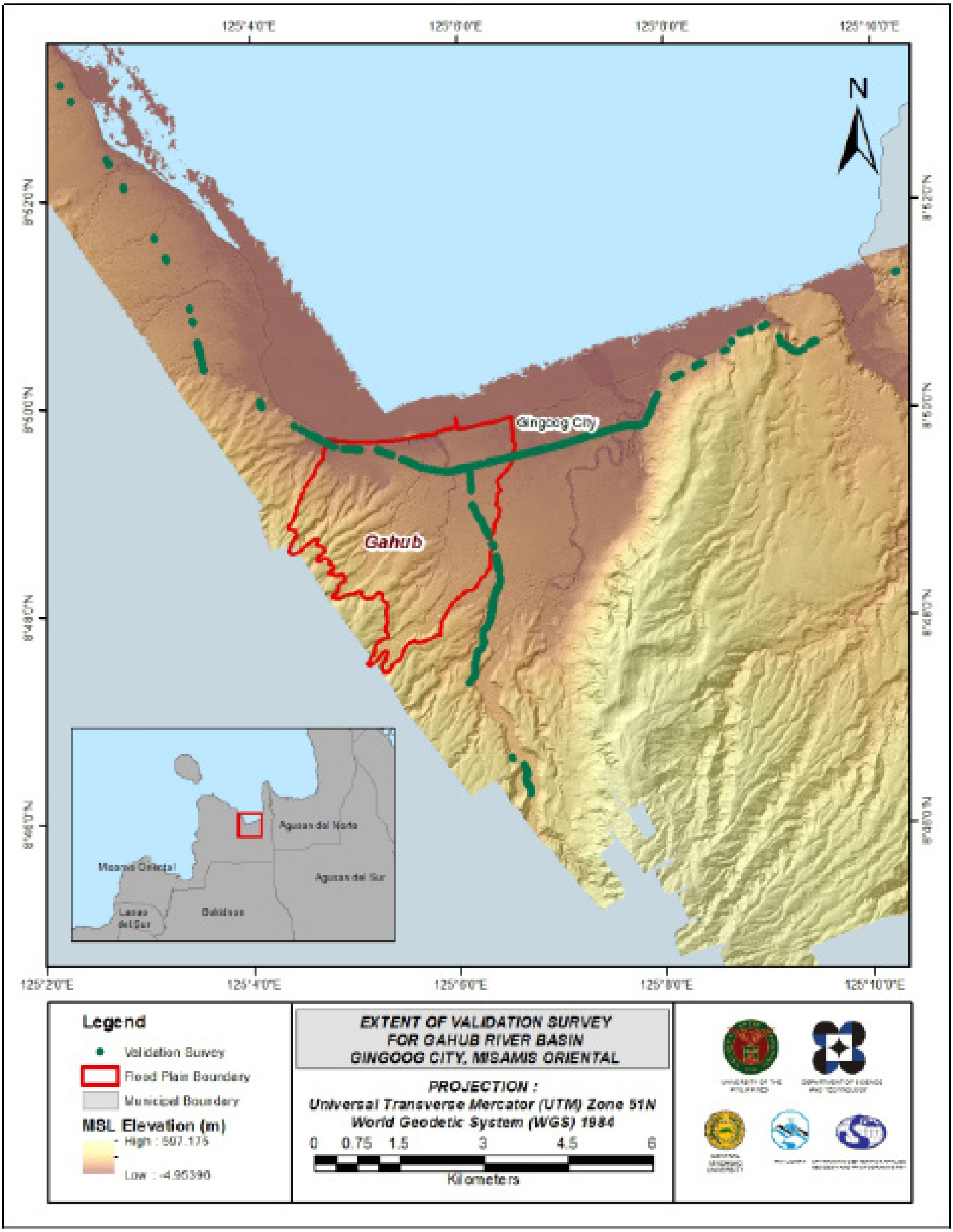

Figure 22. Map of Gahub Floodplain with validation survey points in green

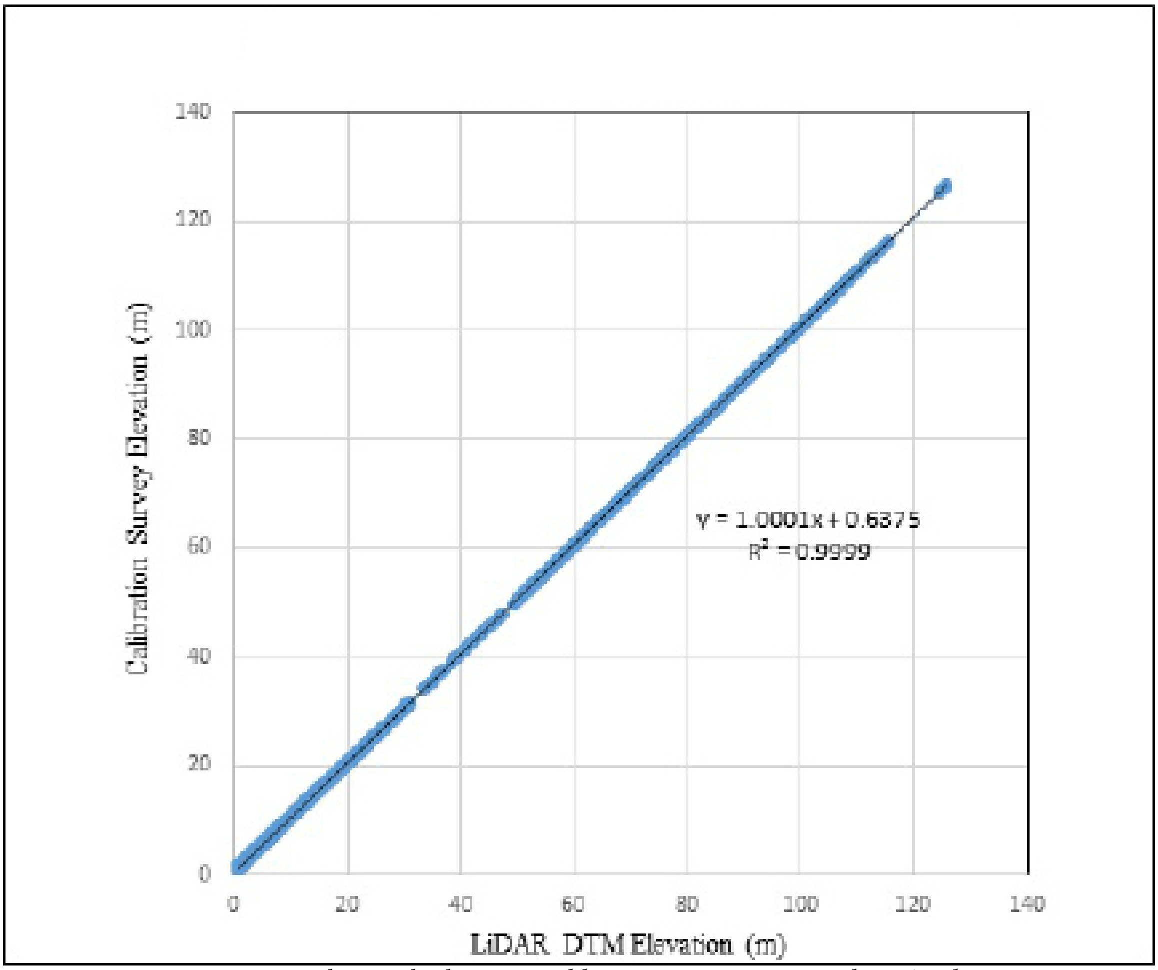

Figure 23. Correlation plot between calibration survey points and LiDAR data

Table 14. Calibration Statistical Measures

Calibration Statistical Measures	Value (meters)
Height Difference	0.64
Standard Deviation	0.10
Average	-0.64
Minimum	-0.42
Maximum	-0.85

The remaining 20% of the total survey points, resulting to in 1,588 points, were used for the validation of calibrated Gahub 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 24. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.10 meters with a standard deviation of 0.10 meters, as shown in Table 15.

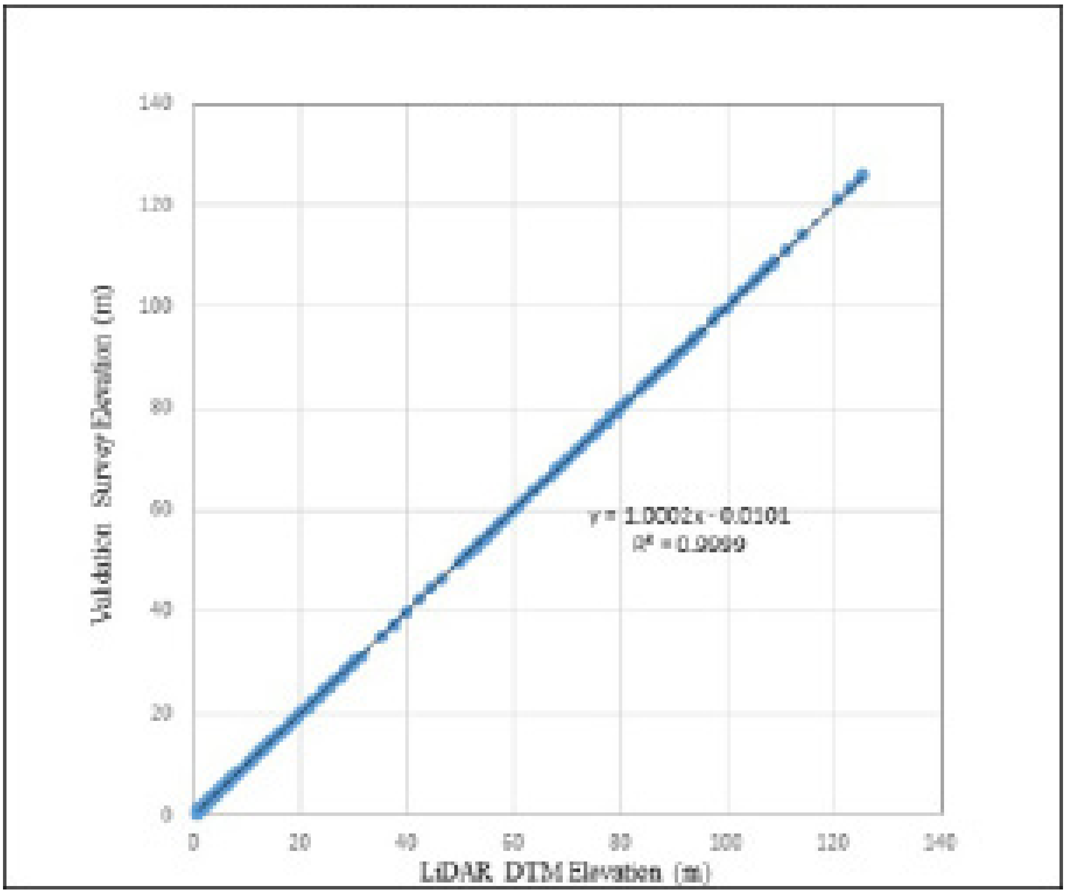

Figure 24. Correlation plot between validation survey points and LiDAR data

Table 15. Validation Statistical Measures

Validation Statistical Measures	Value (meters)
RMSE	0.10
Standard Deviation	0.10
Average	0.03
Minimum	-0.23
Maximum	0.37

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and zigzag were available for Gahub with 2,217 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 0.21 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Gahub integrated with the processed LiDAR DEM is shown in Figure 25.

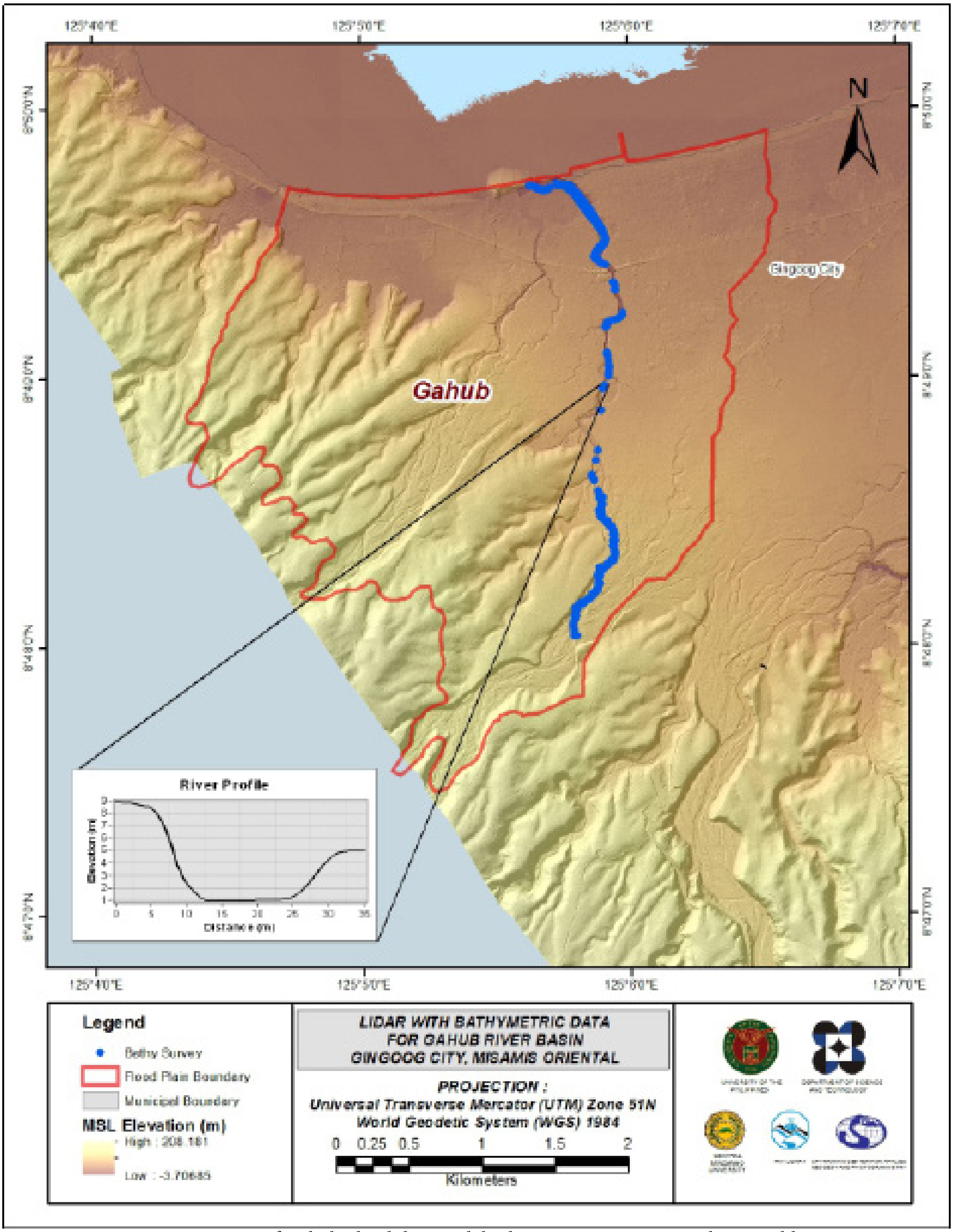

Figure 26. Map of Gahub Floodplain with bathymetric survey points shown in blue

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 of 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

Gahub Floodplain, including its 200 m buffer, has a total area of 15.62 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 2,603 building features, are considered for QC. Figure 26 shows the QC blocks for Gahub Floodplain.

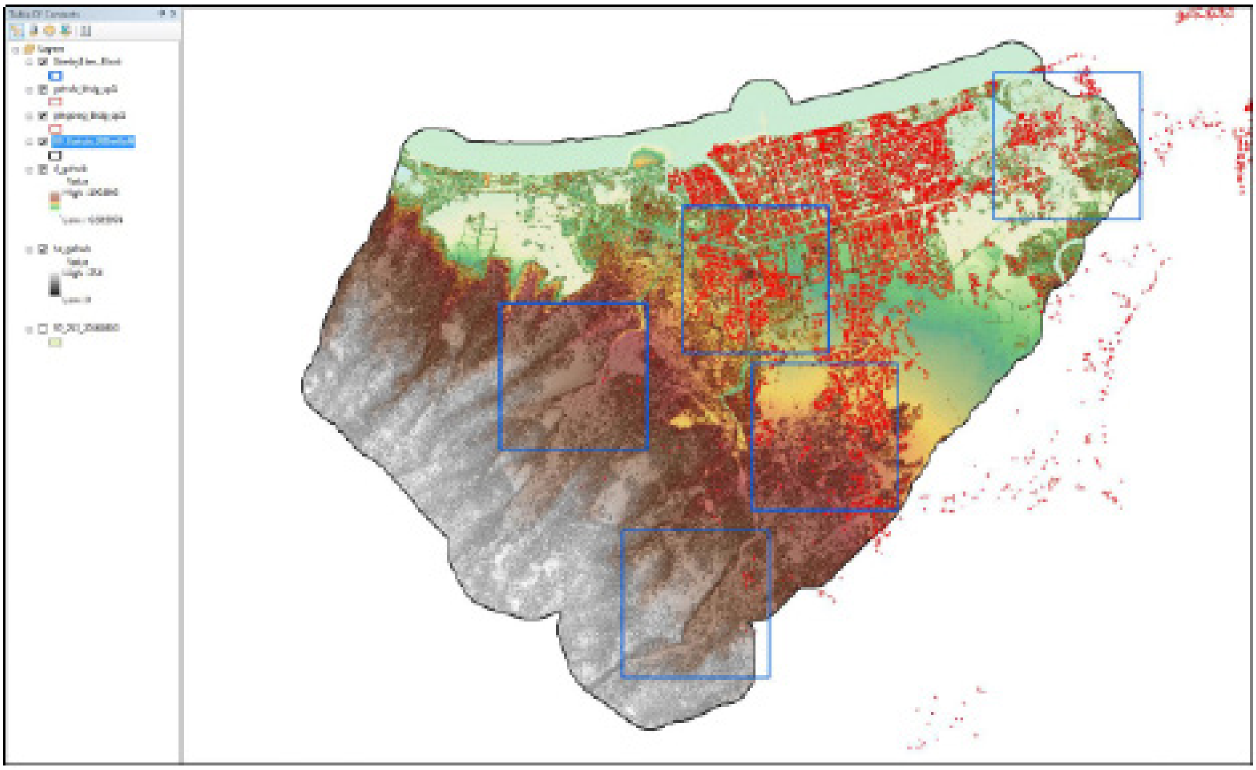

Figure 26. QC Bblocks for (in blue) of Gahub building features subjected to QC

Quality checking of Gahub building features resulted in the ratings shown in Table 16.

Table 16. Quality checking ratings for Gahub building features

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Gahub	99.96	100.00	98.92	PASSED

3.12.2 Height Extraction

Height extraction was done for 5,773 building features in Gahub Floodplain. Of these building features, 26 were filtered out after height extraction, resulting to in 5,747 buildings with height attributes. Filtered features were the features with less than 2 meters high. The lowest building height is at 2.00 m, while the highest building is at 8.52 m.

3.12.3 Feature Attribution

Field data collection for the attribution process was done through Geotagging (point to a specific feature and shoot method) using a handheld GPS with a built-in camera. The x, y, z, and the viewing direction of the GPS in 0-359 degrees during the photo capture were the essential information in the process. Using Arcmap's tool "Geotagged Photos to Points,", the symbology of the imported point shapefile was set as "Airfield" and the viewing angle was set as "Direction.". The "Path" is automatically created in the points' attribute table wherein the photo's directory is linked every after the "Identify" button is clicked to a specific point.

Table 17 summarizes the number of building features per type. On the other hand, Table 18 shows the total length of each road type, while Table 19 shows the number of water features extracted per type.

Table 17. Building features extracted for Gahub Floodplain

Facility Type	No. of Features
Residential	5,272
School	103
Market	0
Agricultural/Agro-Industrial Facilities	0
Medical Institutions	5
Barangay Hall	5
Military Institution	0
Sports Center/Gymnasium/Covered Court	5
Telecommunication Facilities	4
Transport Terminal	0
Warehouse	9
Power Plant/Substation	1
NGO/CSO Offices	0
Police Station	0
Water Supply/Sewerage	0
Religious Institutions	19
Bank	4
Factory	0
Gas Station	4
Fire Station	0
Other Government Offices	36
Other Commercial Establishments	281
Total	**5,747**

Table 18. Total length of extracted roads for Gahub Floodplain

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Gahub	58.50	3.86	0.00	62.36	4.85	69.32

Table 19. Number of extracted water bodies for Gahub Floodplain

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Gahub	2	0	0	0	0	2

A total of 2 bridges along the highway and 1 bridge downstream that are part of the river networks 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 completes the feature extraction phase of the project.

Figure 27 shows the Digital Surface Model (DSM) of Gahub Floodplain overlaid with its ground features.

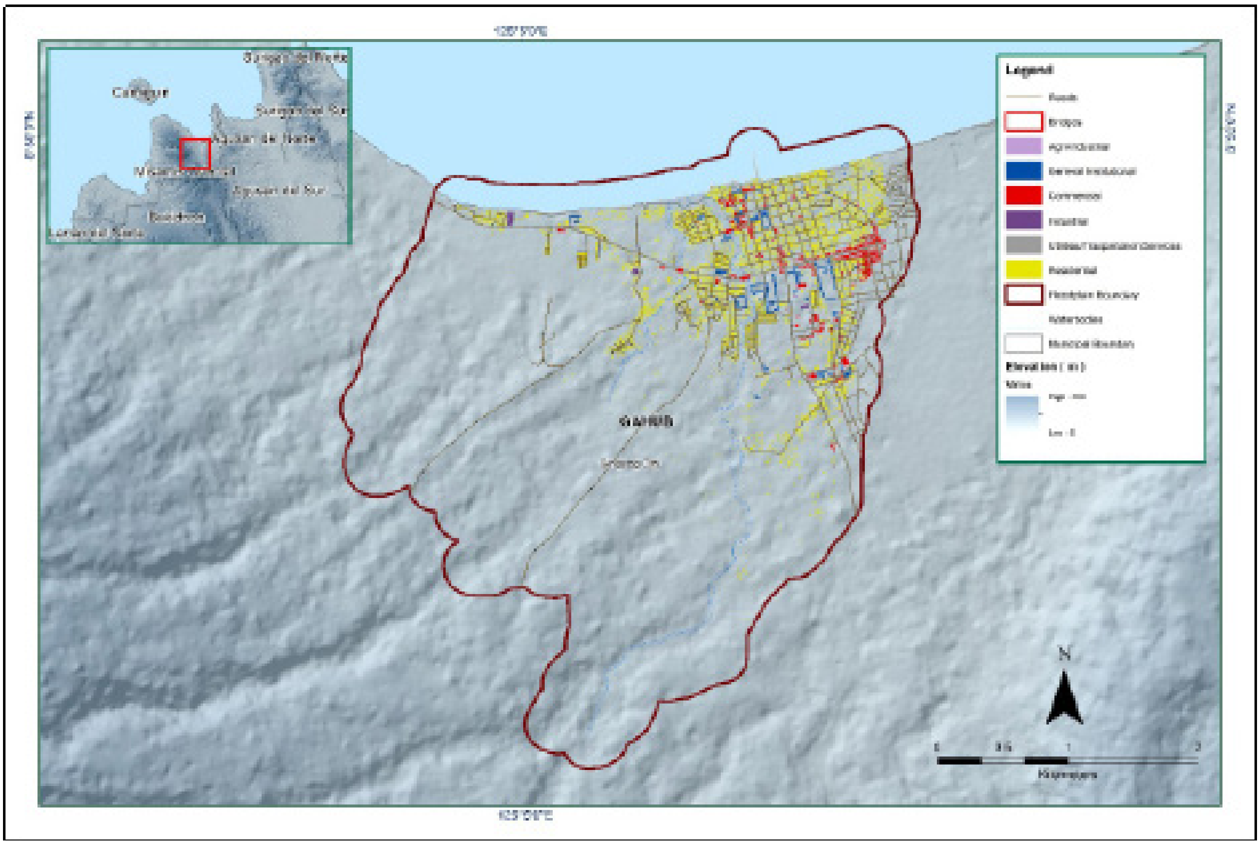

Figure 27. Extracted features for Gahub Floodplain

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

Engr. Louie P. Balicanta, Engr. Joemarie S. Caballero, Ms. Patrizcia Mae. P. dela Cruz, Engr. 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 of PHIL-LIDAR1 together with personnel of Central Mindanao University conducted a field survey in Gahub River on September 28 to October 12, 2015 with the following scope of work: reconnaissance; static survey; cross-section survey; LiDAR validation of about 65 km; and bathymetric survey covering an estimated 3.19 km length over Brgy. Murallon to Brgy.16., Gingoog City.using Trimble® GNSS PPK survey technique with OHMEX™ Echo Sounder (see Figure 28).

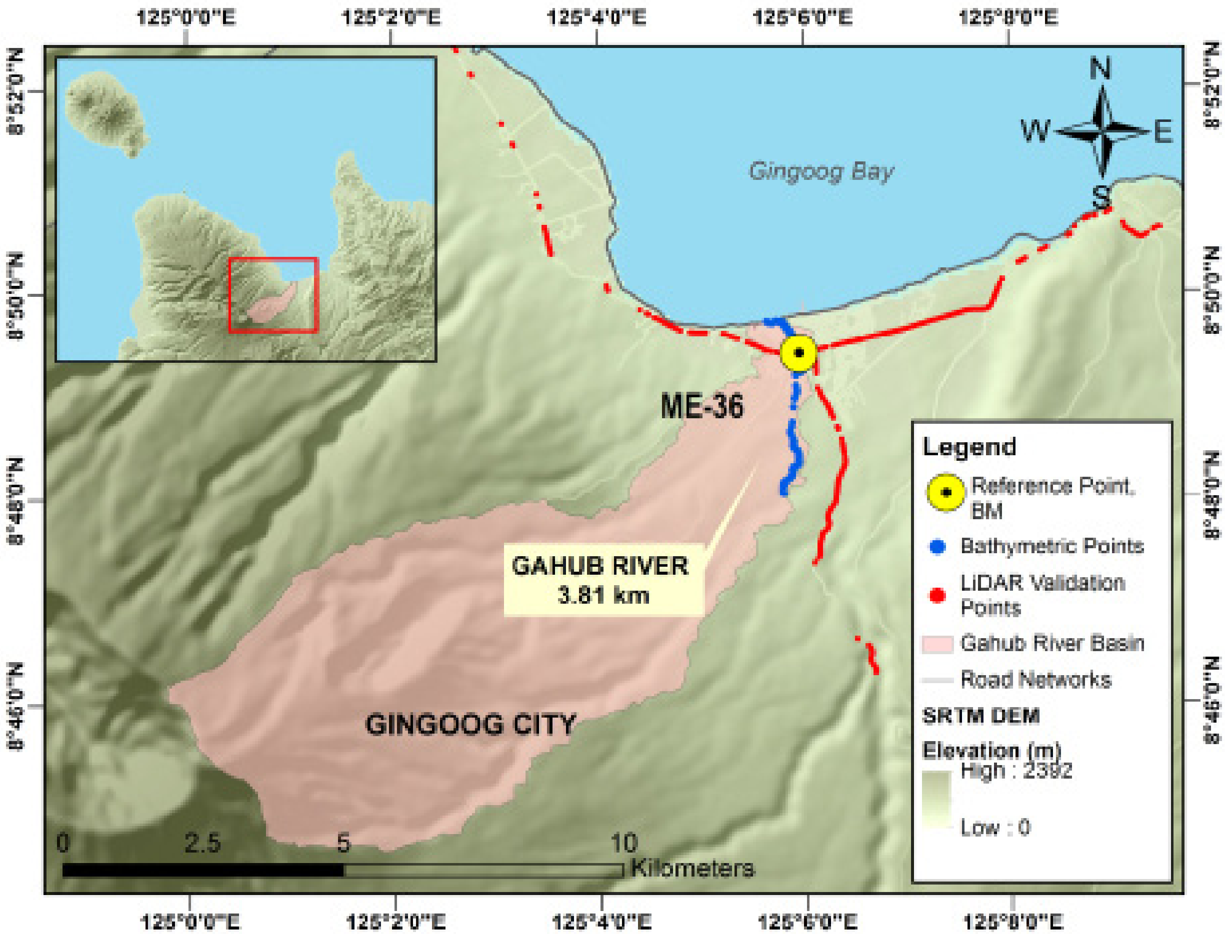

Figure 28. General survey area for Gahub River BasinExtent of the bathymetric survey (in blue) in Gahub River and the LiDAR data validation survey (in red)

4.2 Control Survey

The GNSS network used for Gahub River Basin is composed of a single loop established on September 9 – October 5, 2015 occupying the following reference points: MSE-35, a second-order GCP in Brgy. Pahindong, Municipality of Medina; and ME-36, a first-order BM in Brgy. Barangay 1 Poblacion, Gingoog City; Misamis Oriental.

A NAMRIA- established control points,: MSE-44 in Brgy. Kibungsod, Municipality of Magsaysay, was also used as marker during the survey.

The summary of reference and control points and its their location is summarized in Table 20 while the GNSS network established is illustrated in Figure 29.

Table 20. List of reference and control points occupied in Gahub River Survey
(Source: NAMRIA and UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (Meter)	Elevation in MSL (Meter)	Date Established
MSE-35	2nd Order, GCP	08°57'19.75841"N	124°57'19.75841"E	68.009	-	2003
ME-36	1st Order, BM	-	-	75.333	9.474	2007
MSE- 44	Used as marker	-	-	-	-	2003

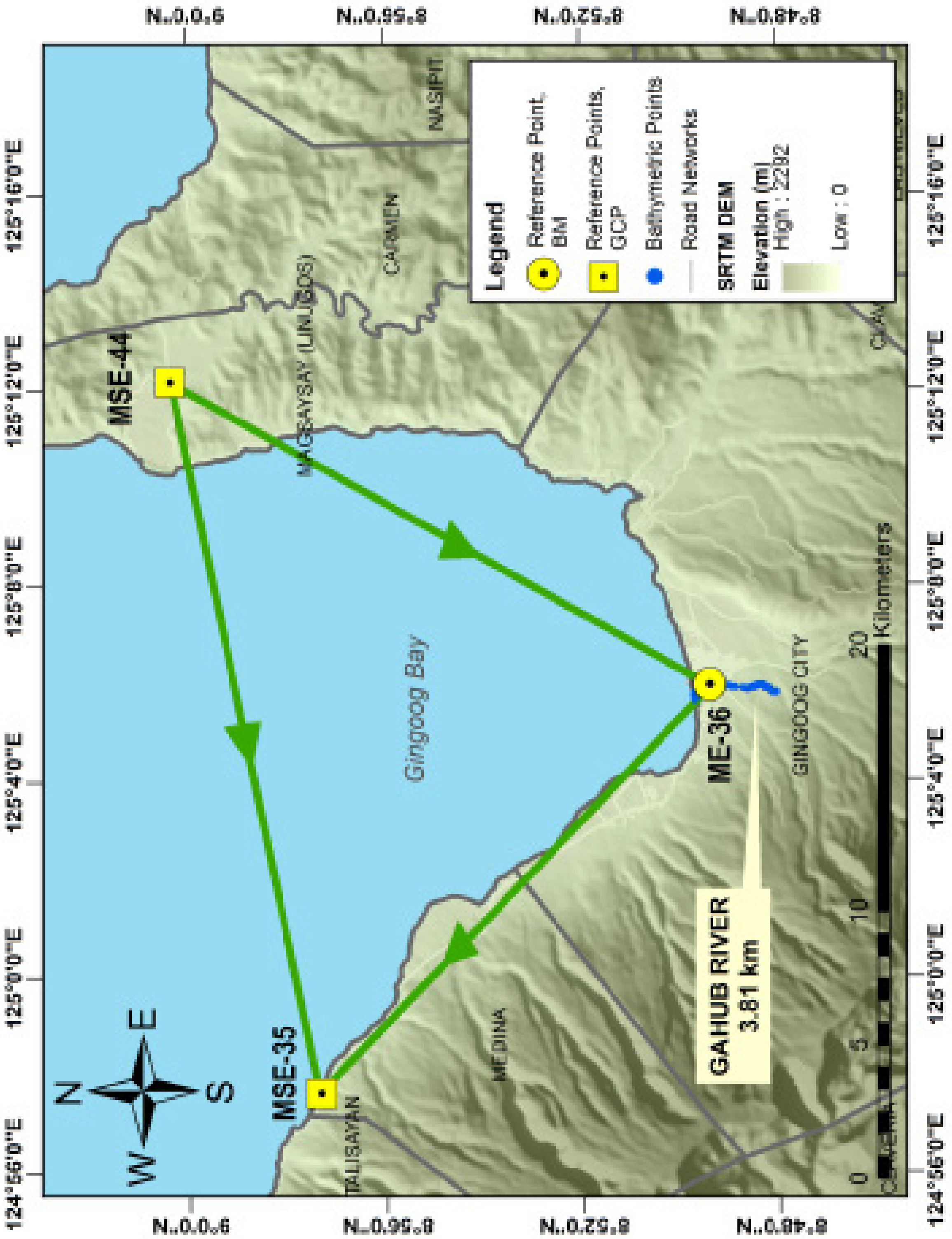

Figure 29. GNSS network covering Gahub River Basin field survey

The GNSS set-ups on recovered reference and control points in Gahub River are shown in Figure 30 to Figure 32.

Figure 30. Trimble® SPS 882 GPS set-up at MSE-35, Brgy. Talisayan, Misamis Oriental

Figure 31.Trimble® SPS 852 Base set-up at ME-36, Gingoog Bridge located at Gingoog City

Figure 32. Trimble® SPS 852 Base set-up at MSE-44, Kibungsod Bridge, located in Brgy. Kibungsod, Municipality of Magsaysay

4.3 Baseline Processing

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 case where one or more baselines did not meet all of these criteria, masking is was performed. Masking is done by removing 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 in Gahub River Basin survey is summarized in Table 21 generated by TBC software.

Table 21. Baseline processing report for Gahub River Basin static survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
ME-36 --- MSE-35	09-29-2015	Fixed	0.007	0.033	313°47'45"	21122.989	-7.312
ME-36 --- MSE-44	09-29-2015	Fixed	0.006	0.027	29°30'54"	23174.977	0.966
MSE-44 --- MSE-35	09-29-2015	Fixed	0.008	0.046	78°13'25"	27235.149	8.297

As shown in Table 21, a total of three (3) baselines were processed with coordinates of MSE-35 and elevation value of ME-36 held fixed. All of them passed the required accuracy.

4.4 Network Adjustment

After the baseline processing procedure, network adjustment is as performed using TBC. Looking at the Adjusted Grid Coordinates (Table 23) Table C-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 form:

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

Where:

xe is the Easting Error,
ye is the Northing Error, and
ze is the Elevation Error

for each control point. See the Network Adjustment Report shown in Table 22 to Table 24 for complete details.

Table 22. Control point constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
ME-36	Grid				Fixed
MSE-35	Local	Fixed	Fixed		
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 23. All fixed control points have no values for grid and elevation errors.

Table 23. Adjusted grid coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
ME-36	730883.858	0.009	975969.756	0.006	6.512	?	e
MSE-35	715551.148	?	990505.339	?	-0.349	0.056	LL
MSE-44	742189.569	0.009	996207.709	0.006	9.268	0.048	

With the mentioned equation,

$\sqrt{((x_e)^2 + (y_e)^2)}$ <20cm for horizontal and

$z_e < 10\ cm$ for the vertical,

the computation for the accuracy are as follows:

MSE-35

horizontal accuracy	=	Fixed
vertical accuracy	=	5.6 < 10 cm

ME-36

horizontal accuracy	=	$\sqrt{((0.9)^2 + (0.6)^2}$
	=	$\sqrt{(0.81 + 0.36)}$
	=	1.08 < 20 cm
vertical accuracy	=	Fixed

MSE-44

horizontal accuracy	=	$\sqrt{((0.9)^2 + (0.6)^2}$
	=	$\sqrt{(0.81 + 0.36)}$
	=	1.08 < 20 cm
vertical accuracy	=	4.8 < 10 cm

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

Table 24. Adjusted geodetic coordinates for control points used in the Gahub River Floodplain validation.

Point ID	Latitude	Longitude	Ellipsoid	Height	Constraint
ME-36	N8°49'24.00979"	E125°05'56.85831"	74.935	?	e
MSE-35	N8°57'19.75841"	E124°57'37.74118"	67.619	0.056	LL
MSE-44	N9°00'20.39882"	E125°12'10.65876"	75.908	0.048	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 24. Based on the result of the computation, the equation accuracy condition is satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table 25.

Table 25.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)
ME-36	1st Order, BM	8°49'24.00979"	125°05'56.85831"	74.935	975969.756	730883.858	6.512
MSE-35	2nd Order, GCP	8°57'19.75841"	124°57'37.74118"	67.619	990505.339	715551.148	-0.349
MSE-44	Used as Marker	9°00'20.39882"	125°12'10.65876"	75.908	996207.709	742189.569	9.268

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

Cross-section survey was conducted on October 08, 2015 at the upstream portion of Gahub River in Brgy. Murallon, Gingoog City using a digital level implementing open traverse method. The GPS Rover cannot initialize due to the dense canopy cover in the area. The area was identified as the flow data and depth gauge deployment site of the PHIL-LIDAR 1Phil-LiDAR 1 partner HEI, the Central Mindanao University.

The cross-sectional line of Gahub River deployment area is about 250 m with eighteen (18) cross-sectional points obtained using were obtained at a 10 meter-interval from the left to the right banks of the river facing downstream and at a 2-meter interval for the river bed. The location map is shown in Figure 33 while the resulting cross-sectional CAD diagram is shown in Figure 34.

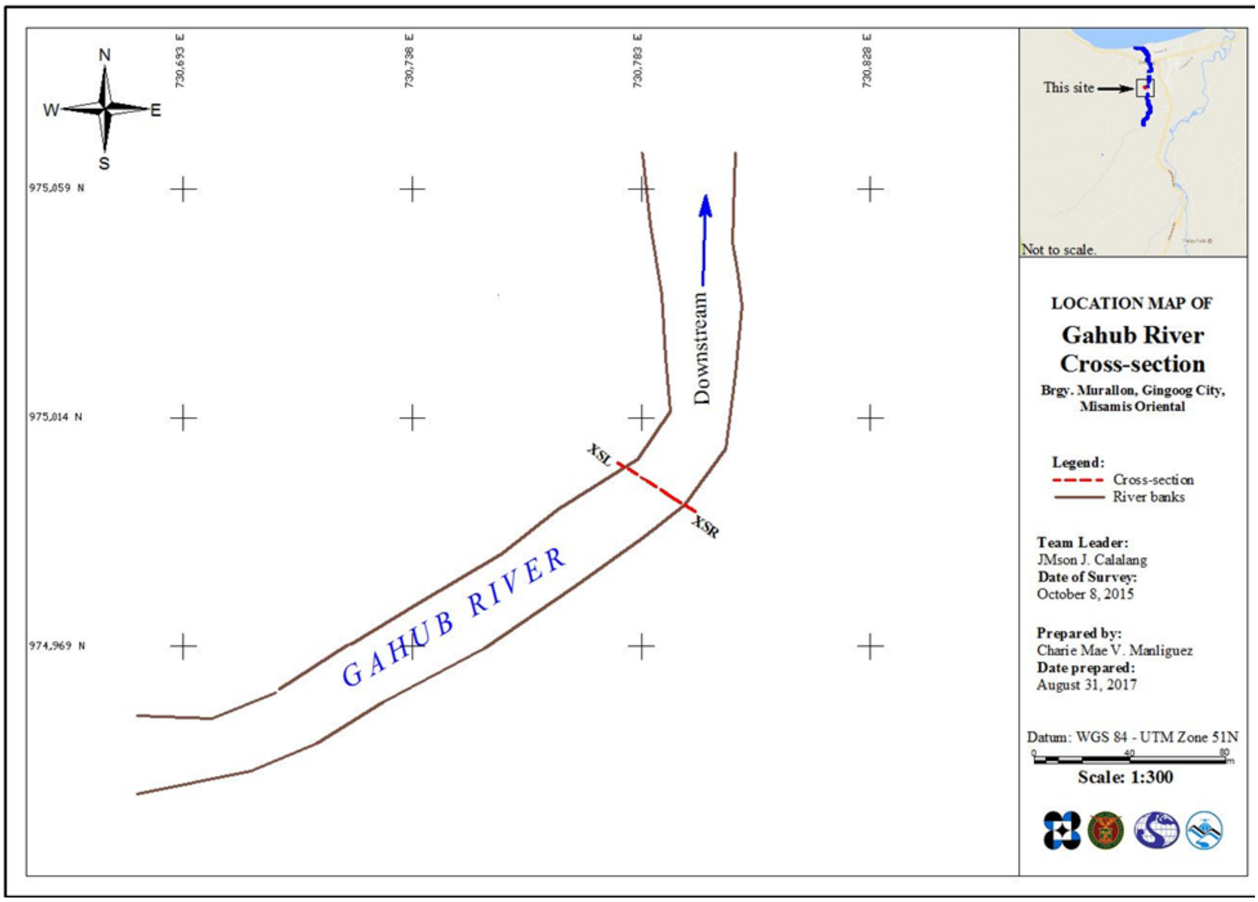

Figure 33. Location map of Gahub River cross-section

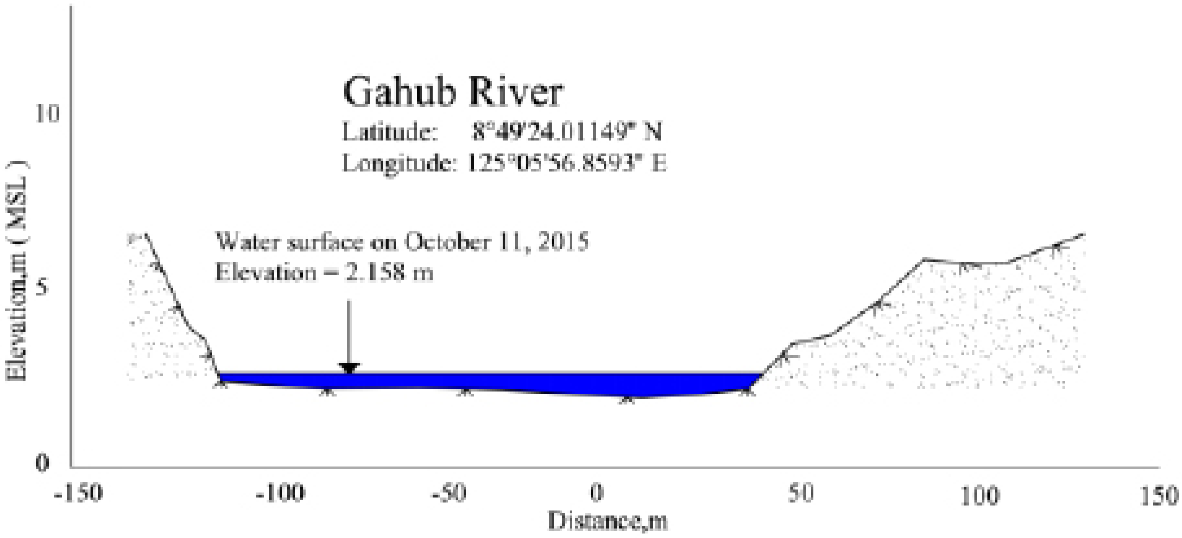

Figure 34. Cross-sectional diagram of Gahub River deployment site

4.6 Validation Points Acquisition Survey

LiDAR validation points acquisition survey was conducted on October 1, 2, and 7 2015 using a survey-grade GNSS rover receiver Trimble® SPS 985 mounted on a pole attached at the back of a vehicle as seen in Figure 35. It was secured with a nylon rope and cable ties to ensure that it was horizontally and vertically balanced. The antenna height was measured and recorded to be 2.428 m from the ground up to the bottom of antenna mount of the receiver.

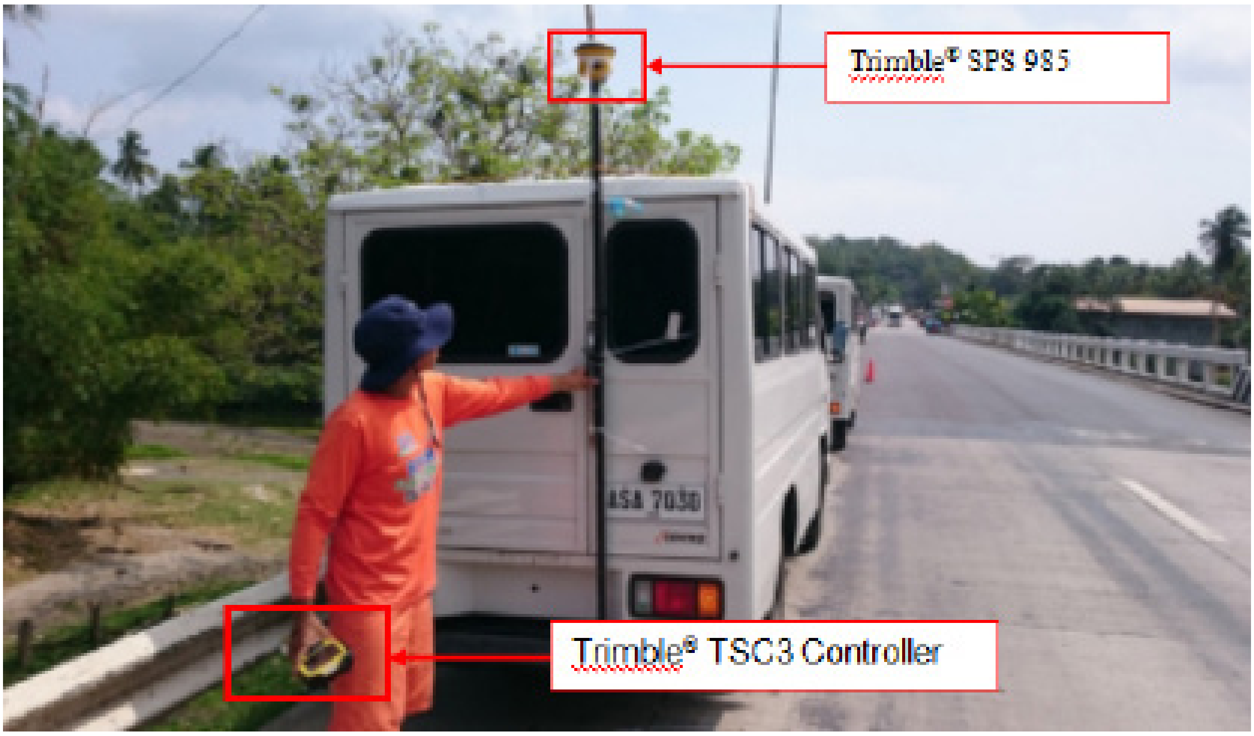

Figure 35. LiDAR Validation survey set up

The survey started from Brgy. San Luis, Gingoog City, going south through National high-way, traversing 27 barangays in Borongan City; seven barangays in the Municipality of Magsaysay; three (3) barangays in the Municipality of Carmen; and ten (10) barangays in the Municipality of Nasipit. It ended in Brgy. Cubicubi, Municipality. of Nasipit, Misamis Oriental. A total of 7,477 points were gathered with an approximate length of 65 km using ME-36 and MSE-44 as GNSS base stations for the entire extent validation points acquisition survey as illustrated in the map in Figure 36.

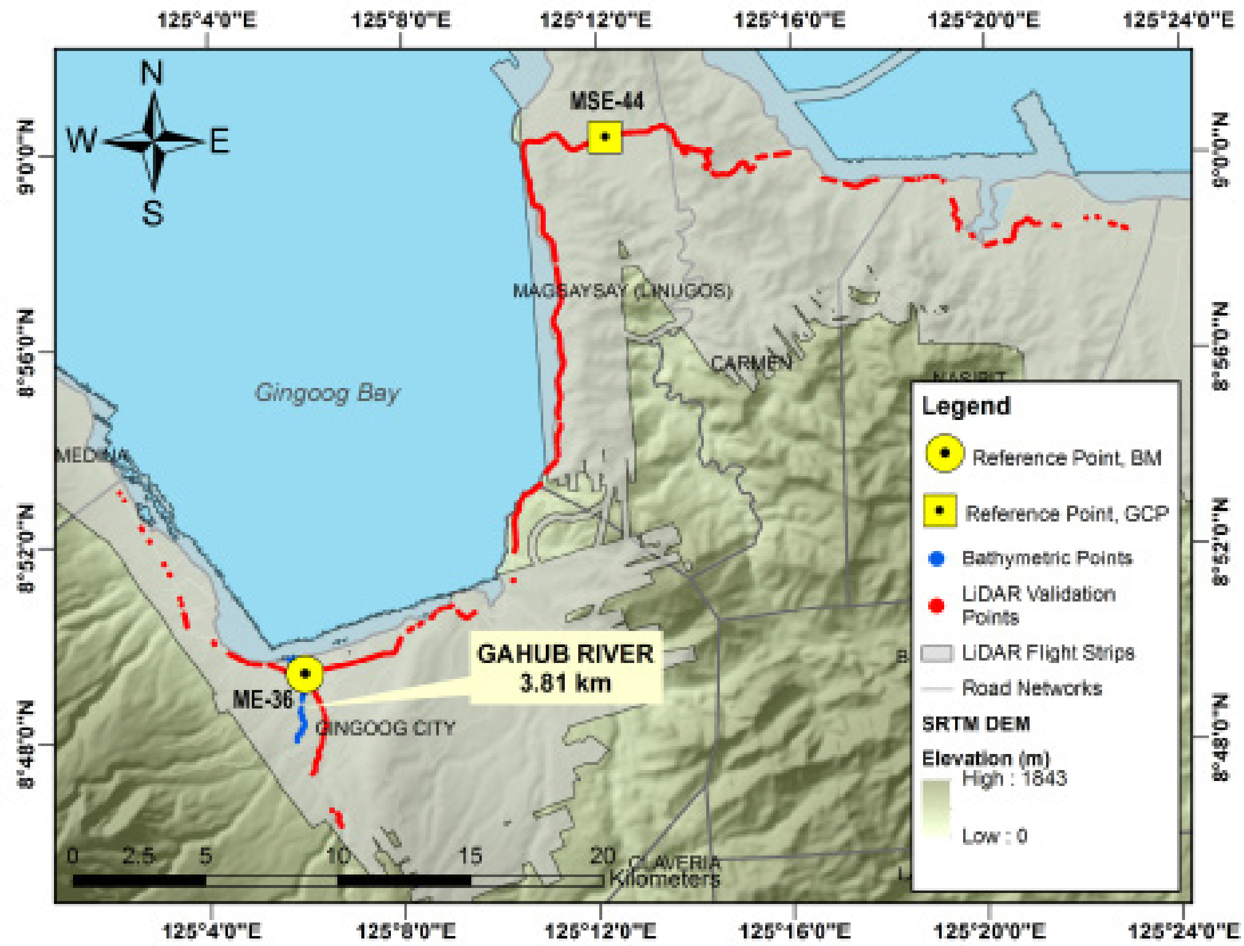

Figure 36. Validation points acquisition survey in Gahub River Basin

4.7 River Bathymetric Survey

Bathymetric survey was executed on October 6, 2015 using Trimble® SPS 882 in GNSS PPK survey technique and an Ohmex™ single- beam echo sounder mounted on a pole as shown in Figure 37. The survey started in Brgy. Poblacion-1 with coordinates 8°49’25.03551”N, 125°05’54.53804”E, down to the mouth of the river in Brgy. Poblacion-16 with coordinates 8°49’42.96917”N, 125°05’43.90978”E; both in Gingoog City.

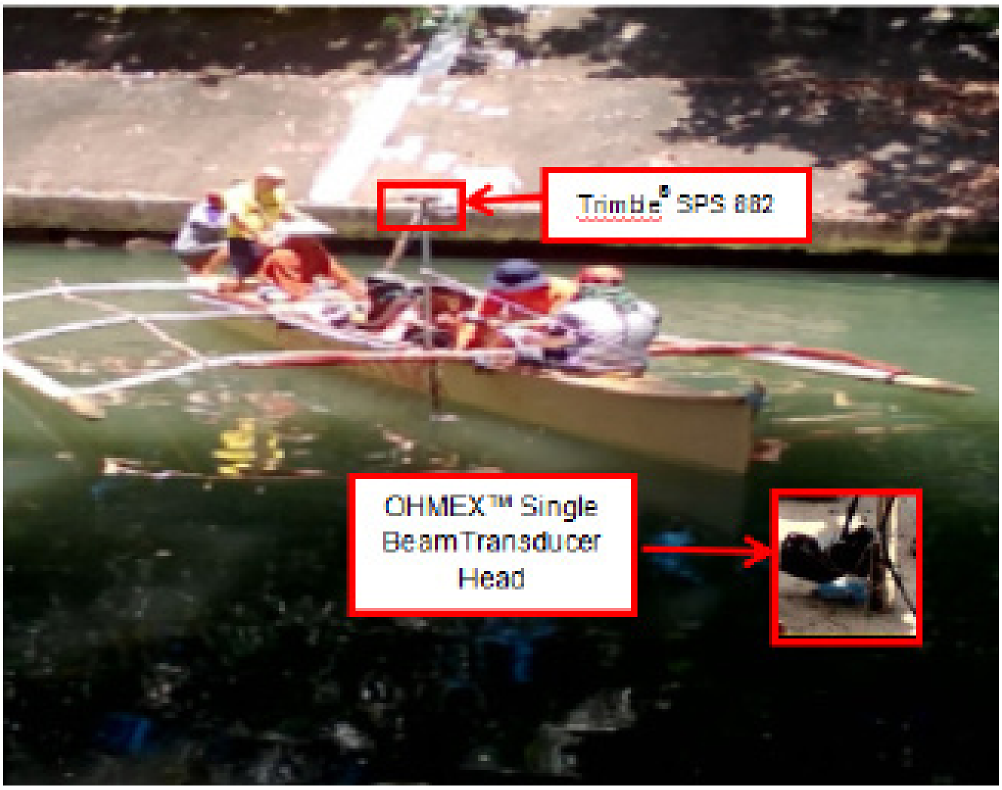

Figure 37. Bathymetric survey equipment set-up in a rented boat in Gahub River

Manual bathymetric survey in the shallow parts of the river was executed on October 2 and 4, 2015 using Trimble® SPS 882 in GNSS PPK survey technique as shown in Figure 38. The survey started from the upstream part of the river in Brgy. Murallon with coordinates 8°48’02.05933”N, 125°05’47.85614”E, traversed down by foot and ended at the starting point of the bathymetric survey using boat. The control point ME-36 was used as the GNSS base all throughout the bathymetric survey.

Figure 38. Set-up of manual bathymetricy survey for Gahub River using a Trimble® SPS 882 Rover

The bathymetric survey in Gahub River gathered a total of 2,217 bathymetric points covering an approximate length of 3.81 km traversing nine (9) barangays in Gingoog City, Misamis Oriental as shown in Figure 39. A CAD drawing was also produced to illustrate the riverbed of Gahub River. The highest and lowest elevation has a 55-m difference. The highest elevation observed was 52.536 m in MSL located at the upstream portion of the river in Brgy. Murallo while the lowest elevation observed was -3.843 m below MSL located at the downstream part of the river in Brgy. Poblacion-8 as illustrated in Figure 40.

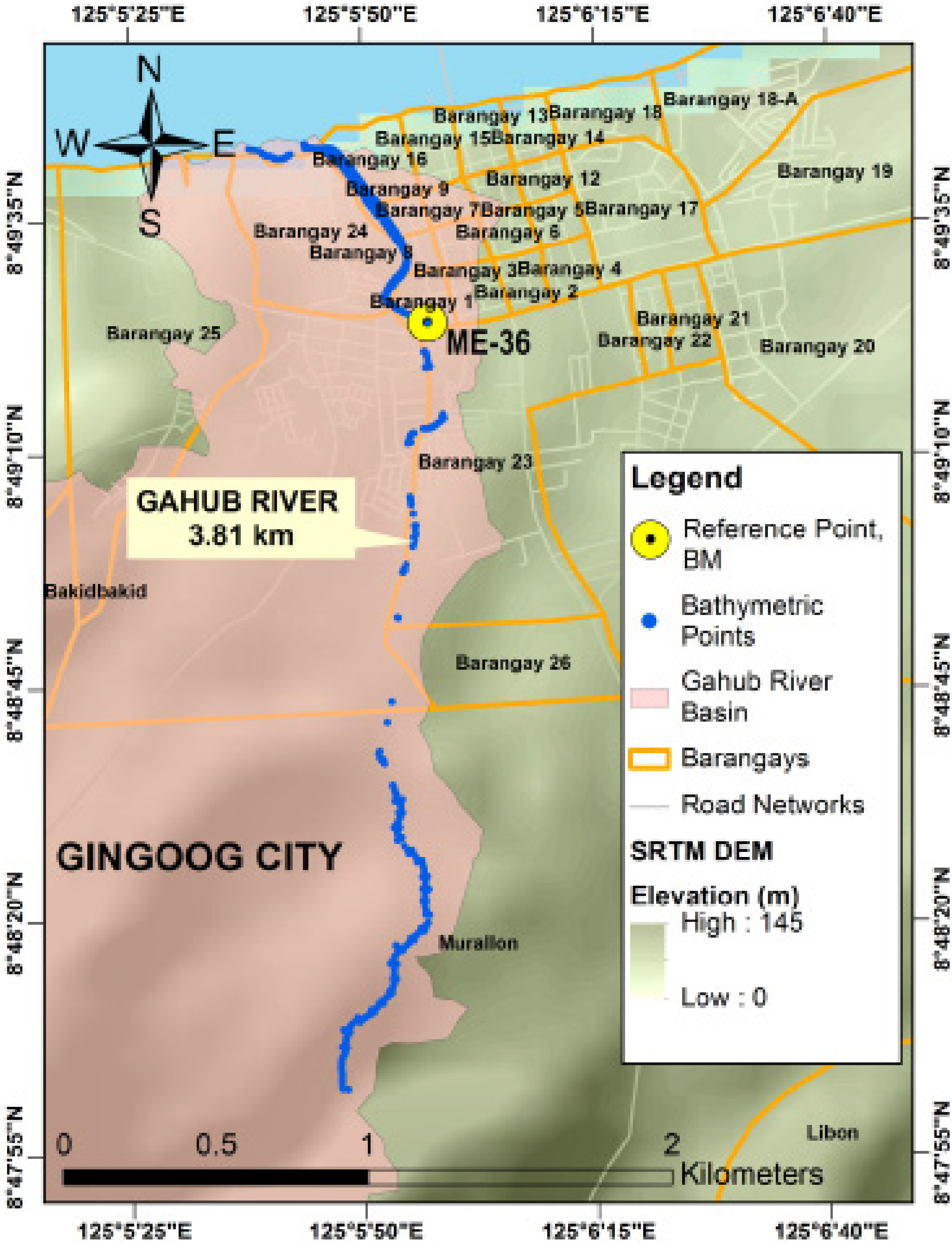

Figure 39. Actual extent of the Gahub bathymetry survey

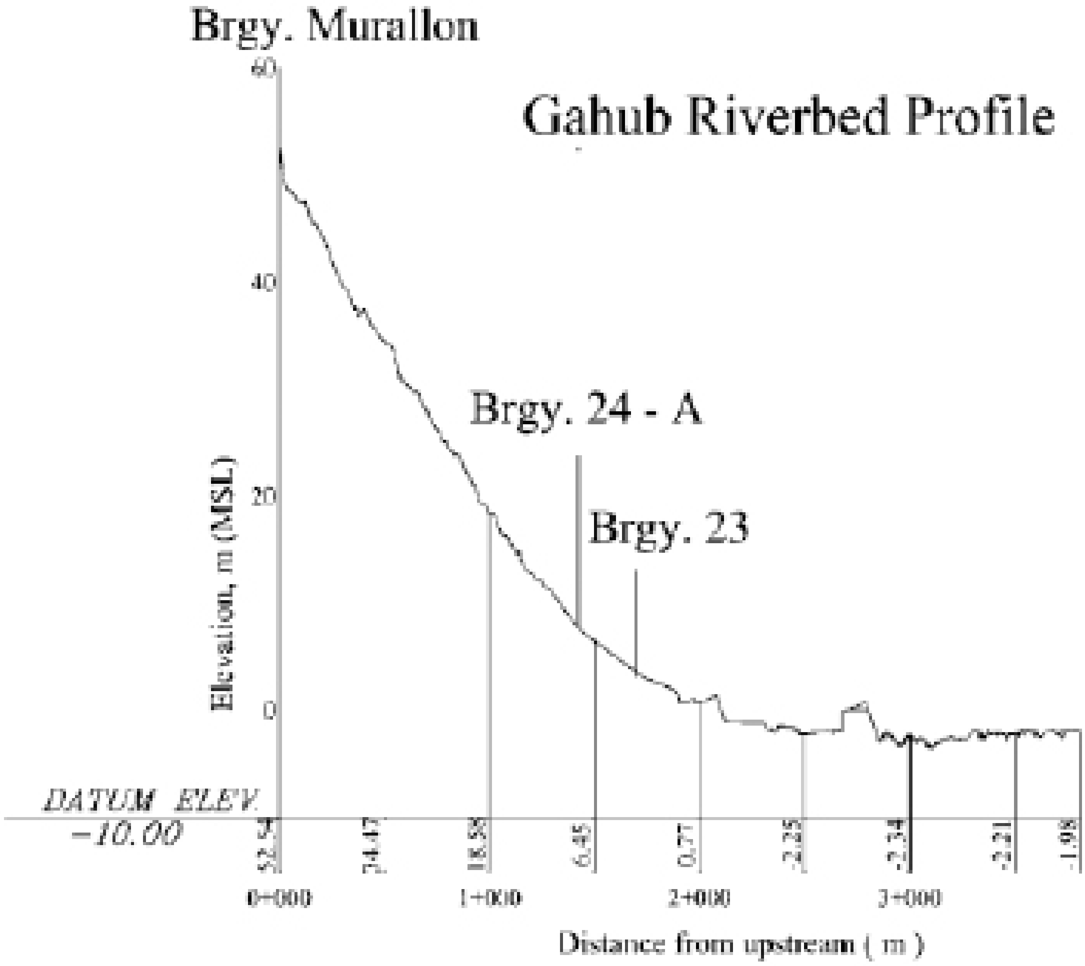

Figure 40. Gahub Riverbed profile

CHAPTER 5: FLOOD MODELING AND MAPPING

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

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 Gahub 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 Gahub River Basin were monitored, collected, and analyzed.

5.1.2 Precipitation

The fifteen (15)- minute interval precipitation data was taken from the manual rain gauge installed by CMU at Barangay Tinulungan, Gingoog City. The total precipitation for this event from Barangay Tinulungan rain gauge is 17.4 mm. Peak rainfall of 3.5 mm was recorded on 26 October 2016, at 1730. The location of the rain gauge is shown in Figure 41. The lag time between the peak rainfall and discharge is one (1) hour and fifty (50) minutes.

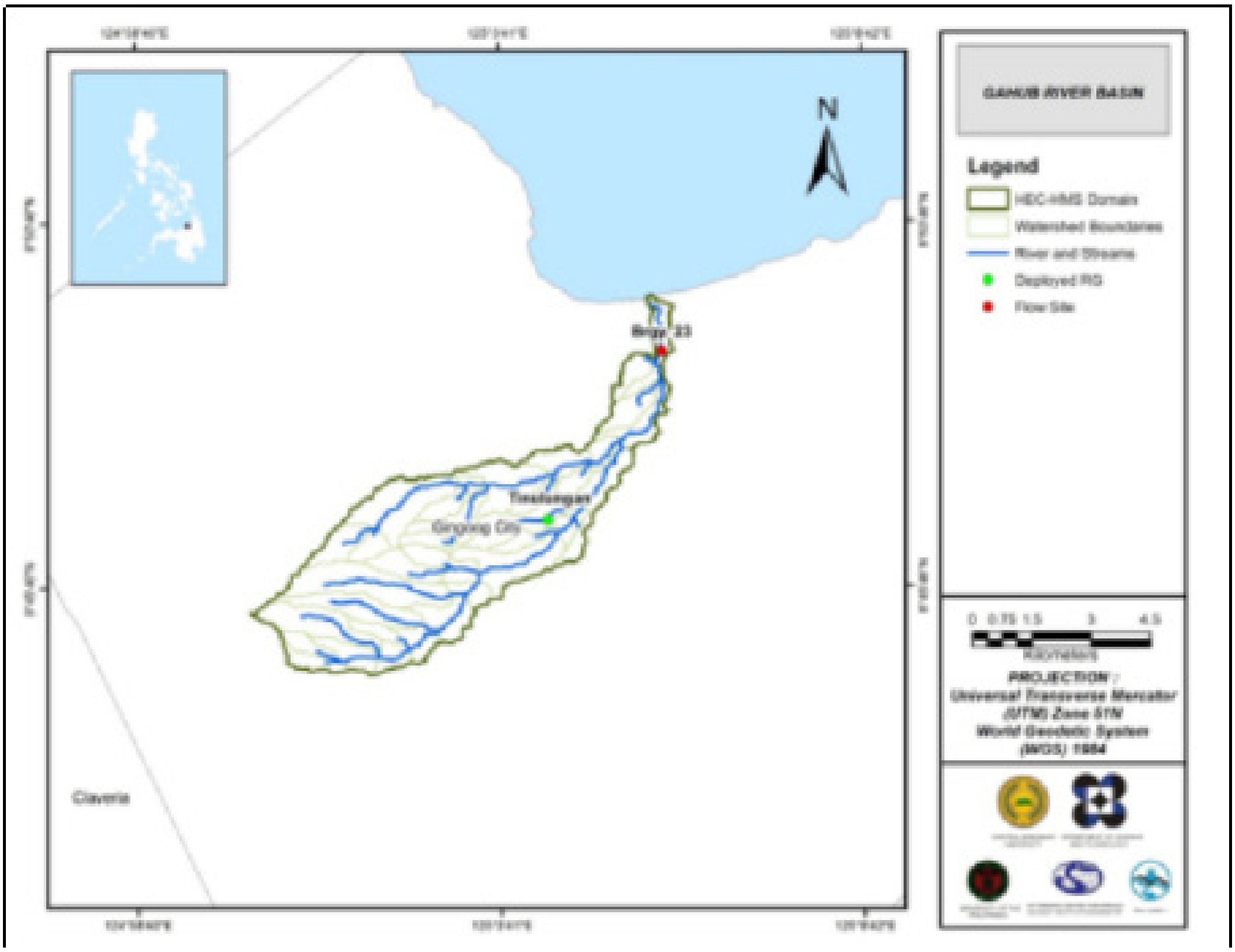

Figure 41. The Location map of Gahub HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

The river velocity and water level change used for the calculation of discharge were measured at the Barangay 23, Gingoog City. Peak discharge is 7.47 m3/s on October 26, 2016 at 1520. Figure 42 illustrates river discharge as influenced by the rate of the rainfall.

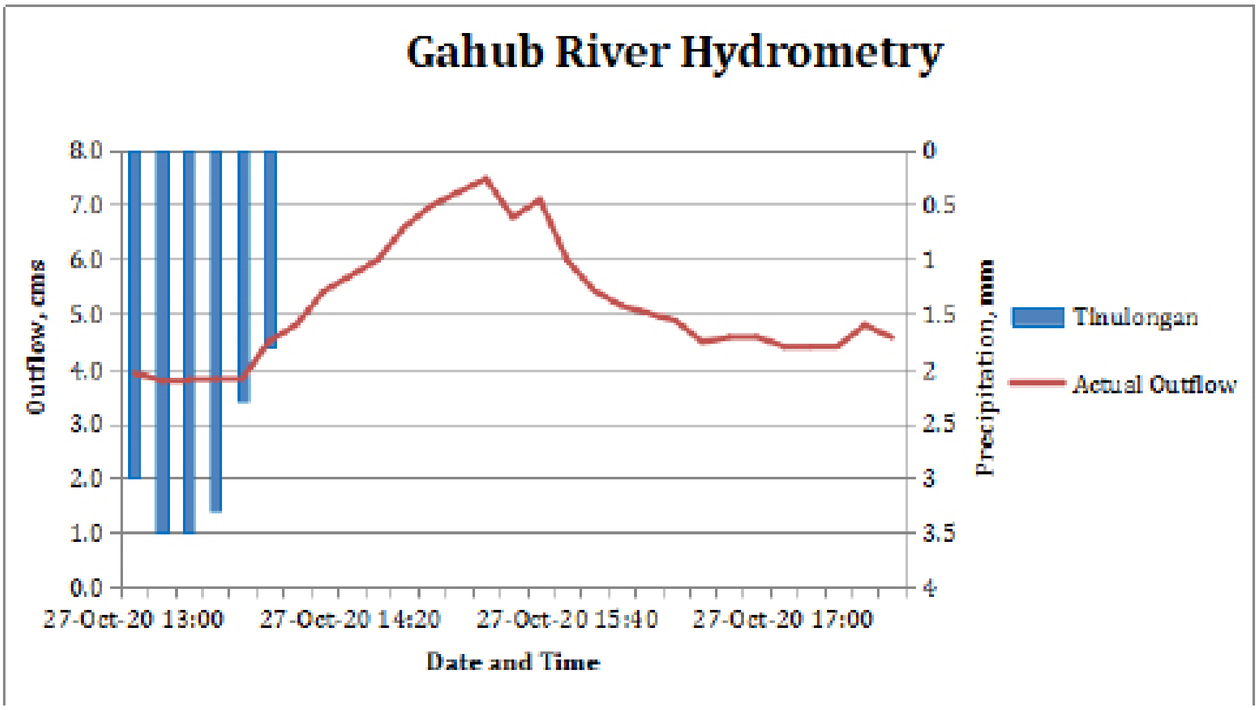

Figure 42. Rainfall and outflow data used for modeling

Using the gathered stage and discharge data, a rating curve was developed to illustrate the relationship between the observed stage of the river and discharge. Stage was determined by tying up the water surface elevation and water level change measured using a digital depth gauge. Meanwhile, discharge was calculated using the cross cross-section area, stage, and river velocity measured using a mechanical flow meter. The relationship is expressed in the form of the following equation:

$$Q=anh$$

where, Q : Discharge (m3/s),
h : Gauge height (reading from Linao Bridge depth gauge sensor), and
a and n : Constants.

For Gahub River, the rating curve is expressed as Q = 3E-37e29.503x as shown in Figure 43.

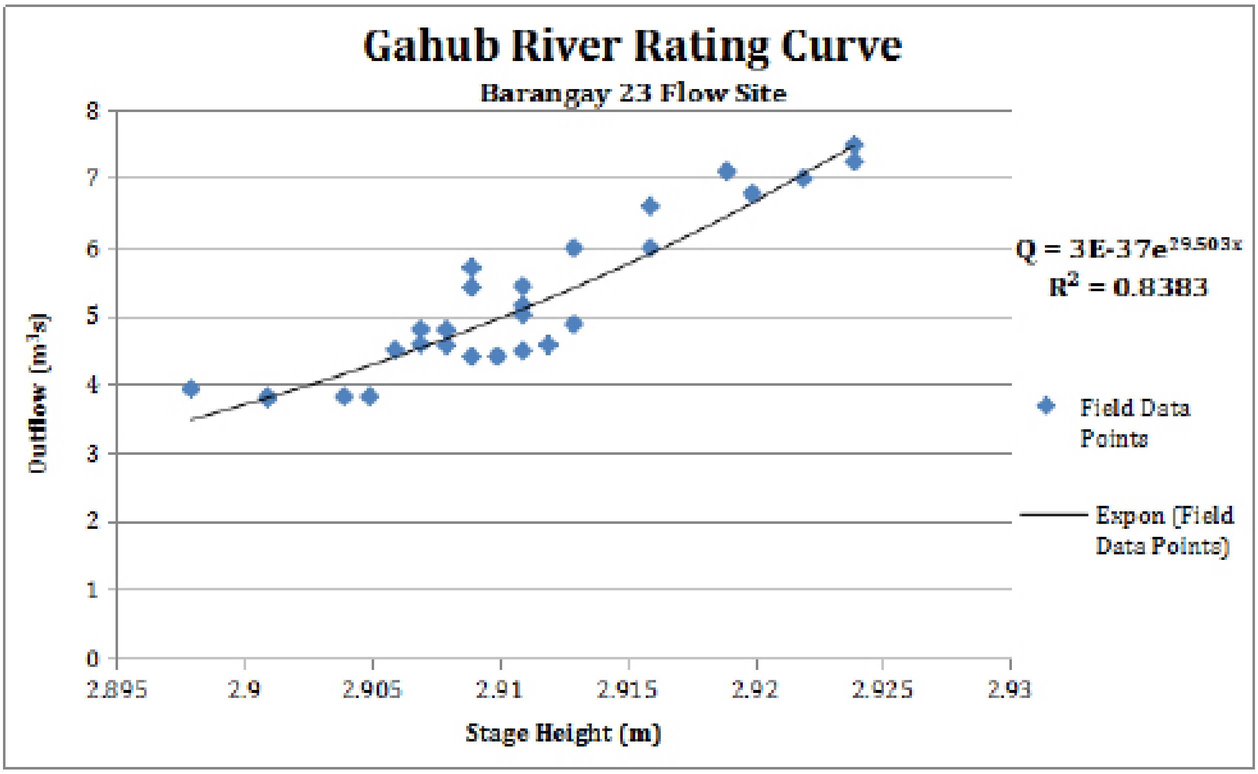

Figure 43. Rainfall and outflow data of Gahub River Basin, which was used for modeling.

5.2 RIDF Station

The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed for Rainfall Intensity Duration Frequency (RIDF) values for the Butuan Rain Gauge. The RIDF rainfall amount for 24 hours was converted to a synthetic storm by interpolating and re-arranging the values in such a way a certain peak value will would be attained at a certain time. This station is as chosen based on its proximity to the Gahub watershed. The extreme values for this watershed were computed based on a 21-year record.

Table 26. RIDF values for Butuan 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	18.2	28.2	32.4	40.8	55.5	63.7	81.7	100	126.4
5	23.9	36.6	41.7	52.9	71.2	81.3	104.6	142.6	175.2
10	27.6	42.1	47.9	60.8	81.5	93	119.7	170.8	207.5
15	29.7	45.3	51.4	65.3	87.4	99.6	128.3	186.7	225.7
20	31.1	47.4	53.8	68.5	91.5	104.2	134.2	197.9	238.5
25	32.3	49.1	55.7	70.9	94.6	107.7	138.8	206.5	248.3
50	35.8	54.3	61.5	78.4	104.3	118.7	153	232.9	278.6
100	39.2	59.5	67.3	85.8	114	129.5	167.1	259.1	308.6

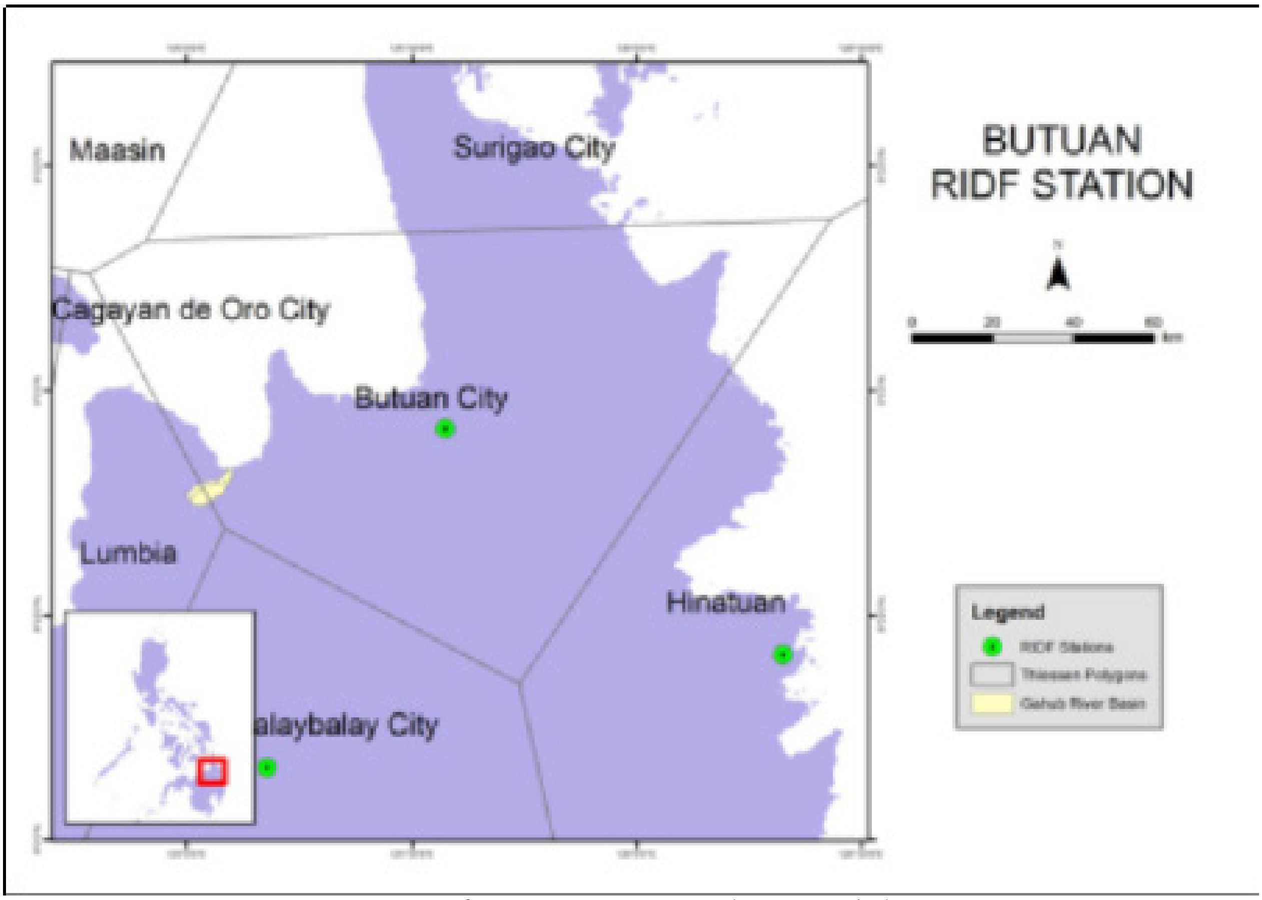

Figure 44. Location of Butuan RIDF Station relative to Gahub River Basin

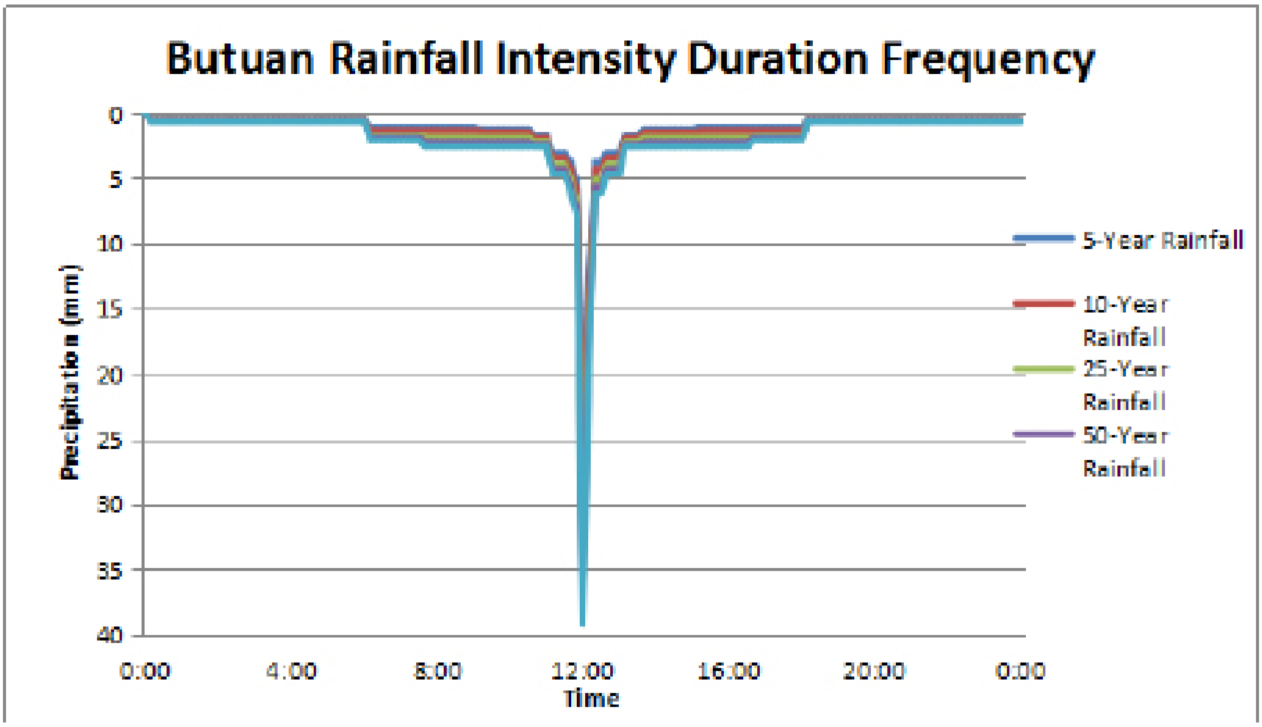

Figure 45. Synthetic storm generated for a 24-hour period rainfall for various return periods

5.3 HMS Model

The soil shapefile dataset was taken on 2004 from and generated by the Bureau of Soils and Water Management; this is under the Department of Environment and Natural Resources Managementagriculture. The land cover shape filedataset is was from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Gahub River Basin are shown in Figure 46 and Figure 47, respectively.

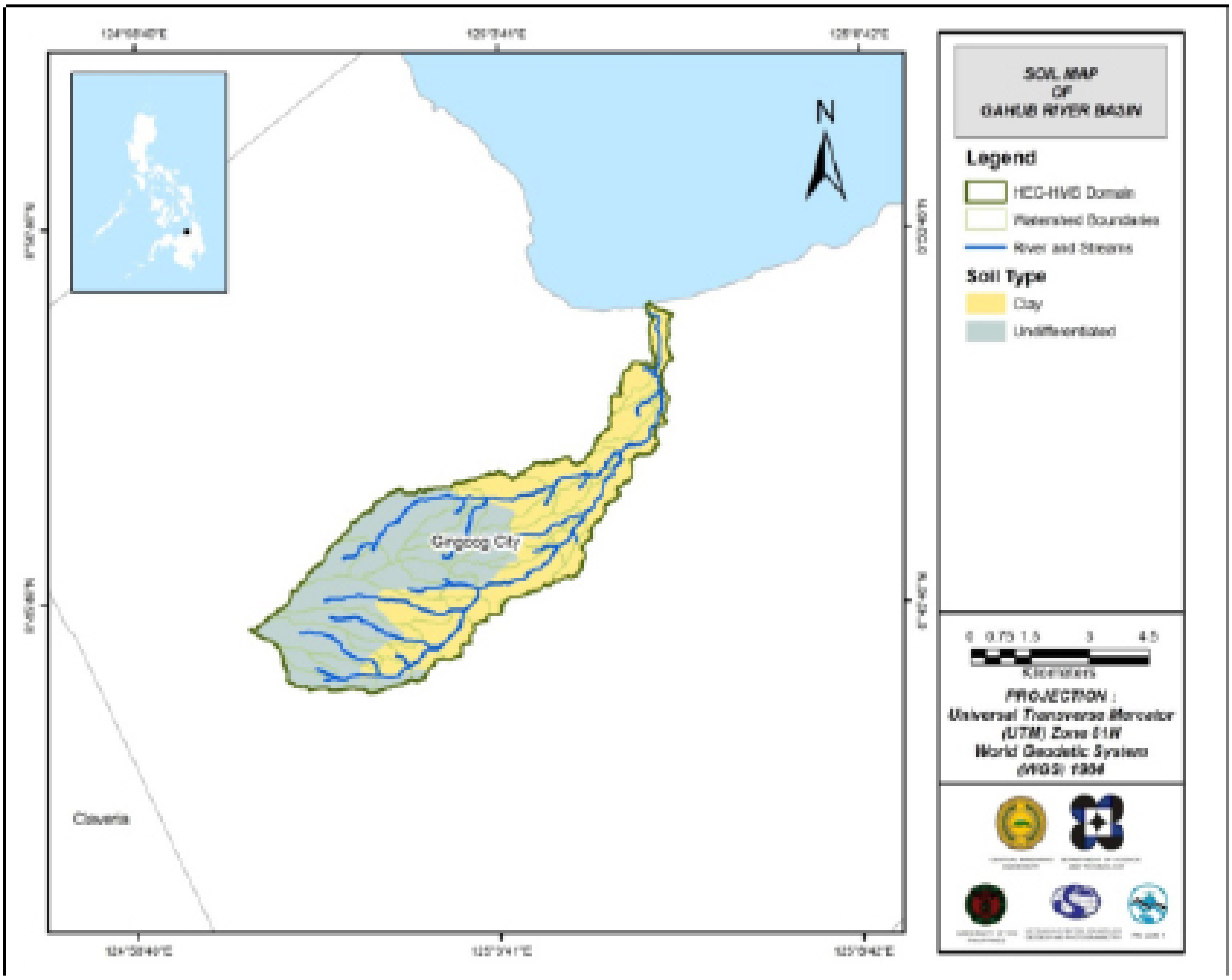

Figure 46. Soil map of the Gahub River Basin

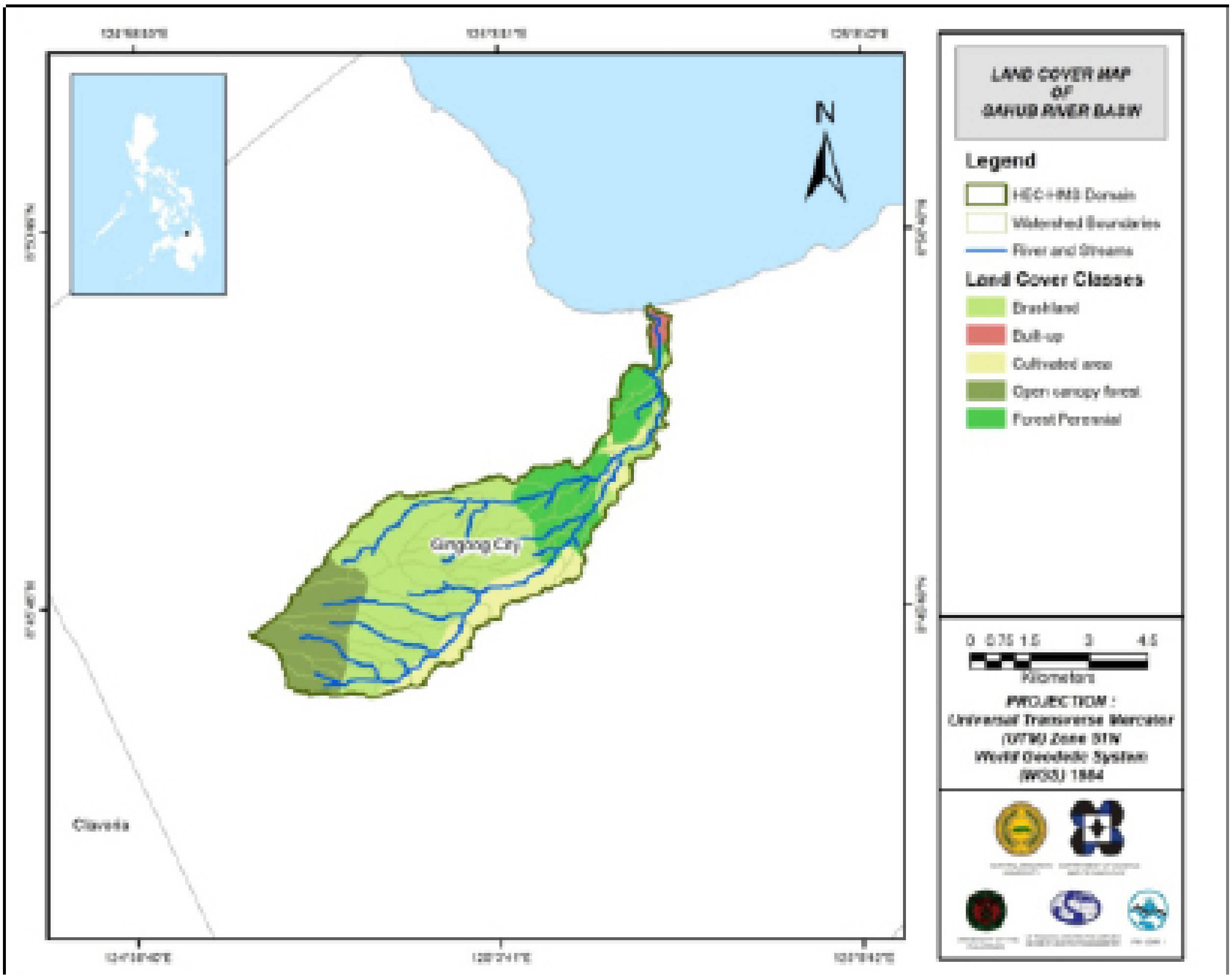

Figure 47. Land cover map of the Gahub River Basin

For Gahub, two (2) soil classes were identified. These are clay and undifferentiated soil. Moreover, five (5) land cover classes were identified. These include brushland, built-up, cultivated area, open canopy forest, and forest perennial.

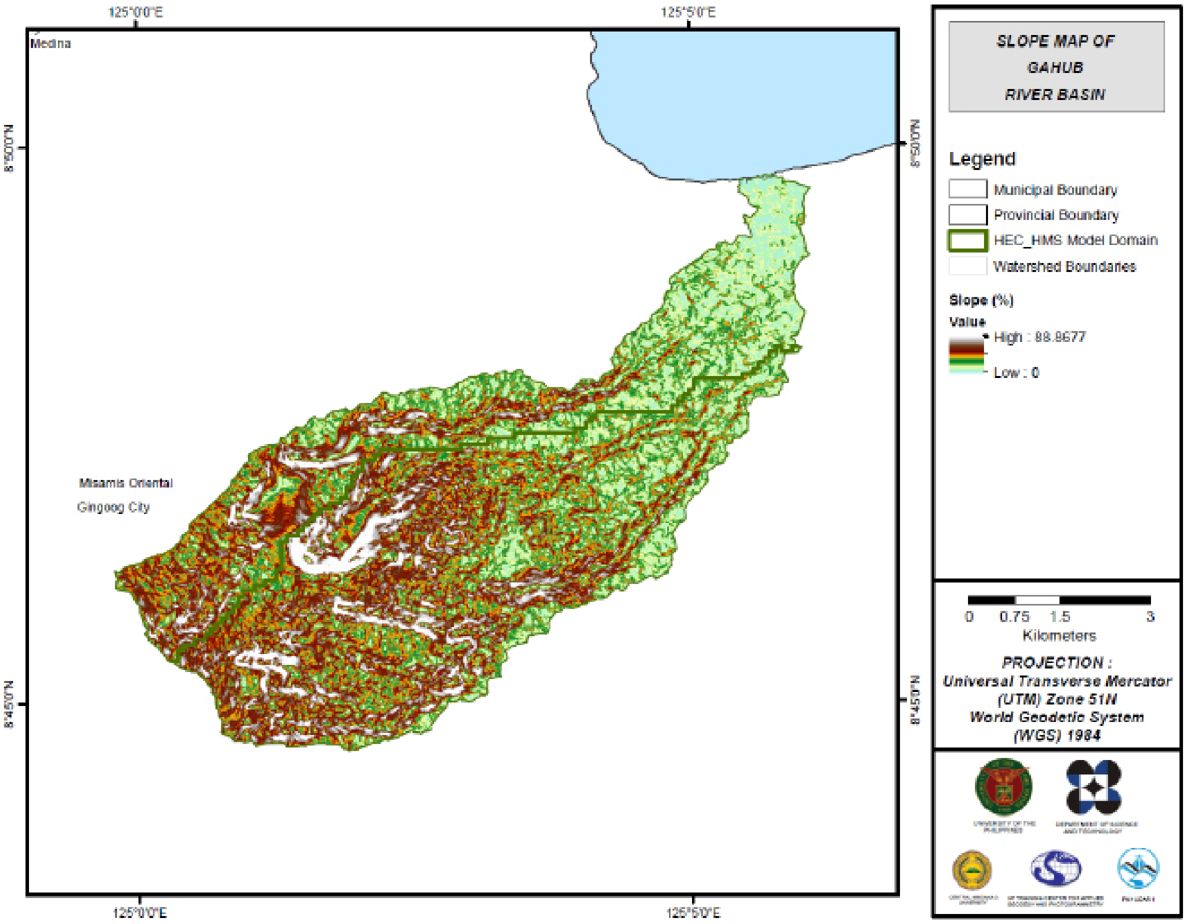

Figure 48. Slope map of Gahub River Basin

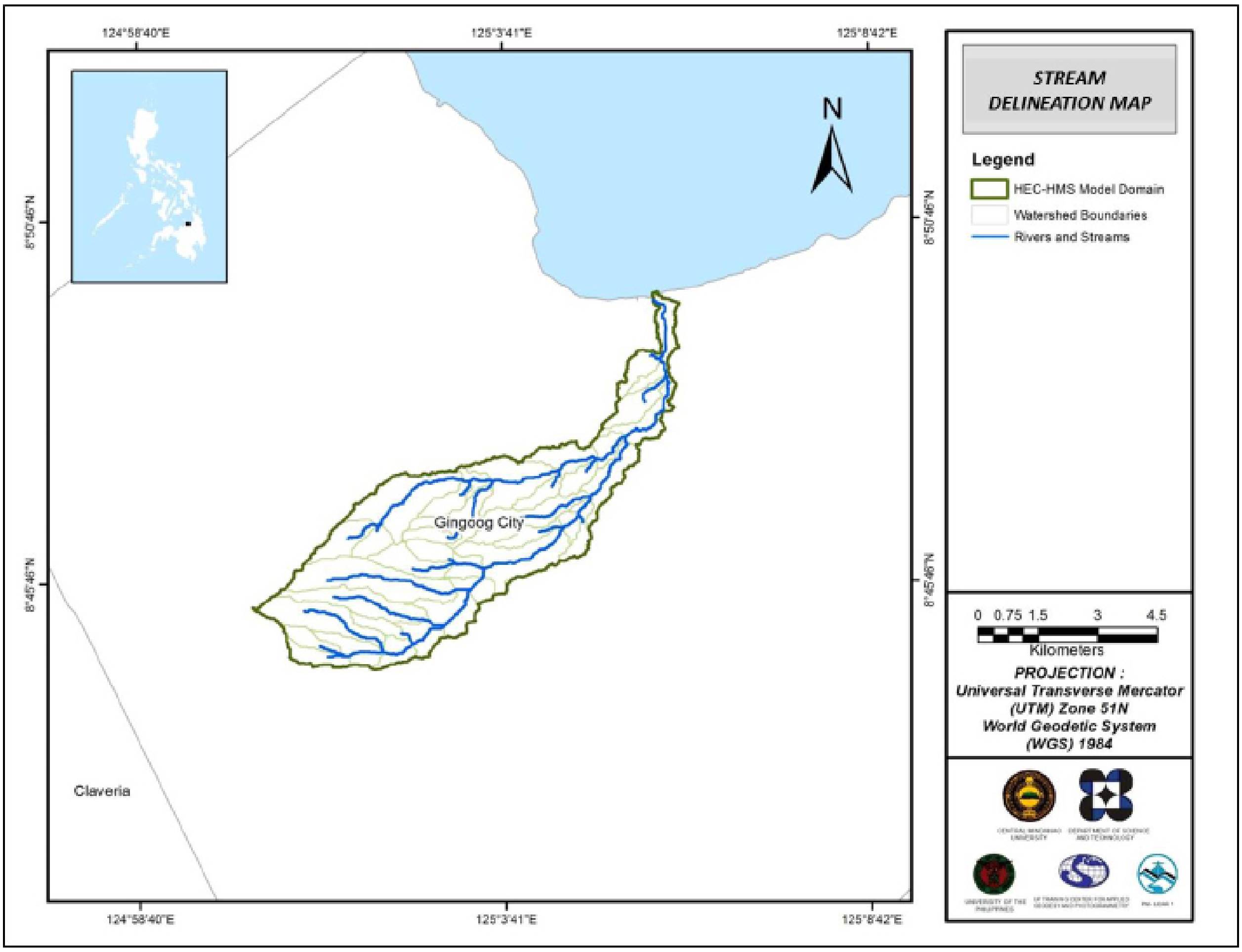

Figure 49. Stream delineation map of Gahub River Basin

The hydrologic model of Gahub River Basin was created using the Hydrologic Engineering Center – Hydrologic Modeling System (HEC- HMS) simulation software specifically designed to simulate the precipitation-runoff processes of watershed systems. Basin was delineated using Synthetic Aperture Radar (SAR) 10 m Digital Elevation Model (DEM) and digitized river centerline extracted from Google Earth through ArcGIS10.1 extension tool GeoHMS10.1.

The Gahub basin model consists of 21 sub basins, 21 reaches, and 23 junctions. The main outlet was assigned at the estuary (Figure 50). The delineated subbasins range from 0.0026 to 4.34 km2 in area, and with an average area of 1.57 km2. The basins were identified based on soil and land cover characteristics of the area. Precipitation from the 26 October 2016 was taken from a deployed CMU manual rain gauge. Finally, it was calibrated using discharge data gathered at Barangay 23 flow site using mechanical flow meter and a depth gauge for water level measurement.

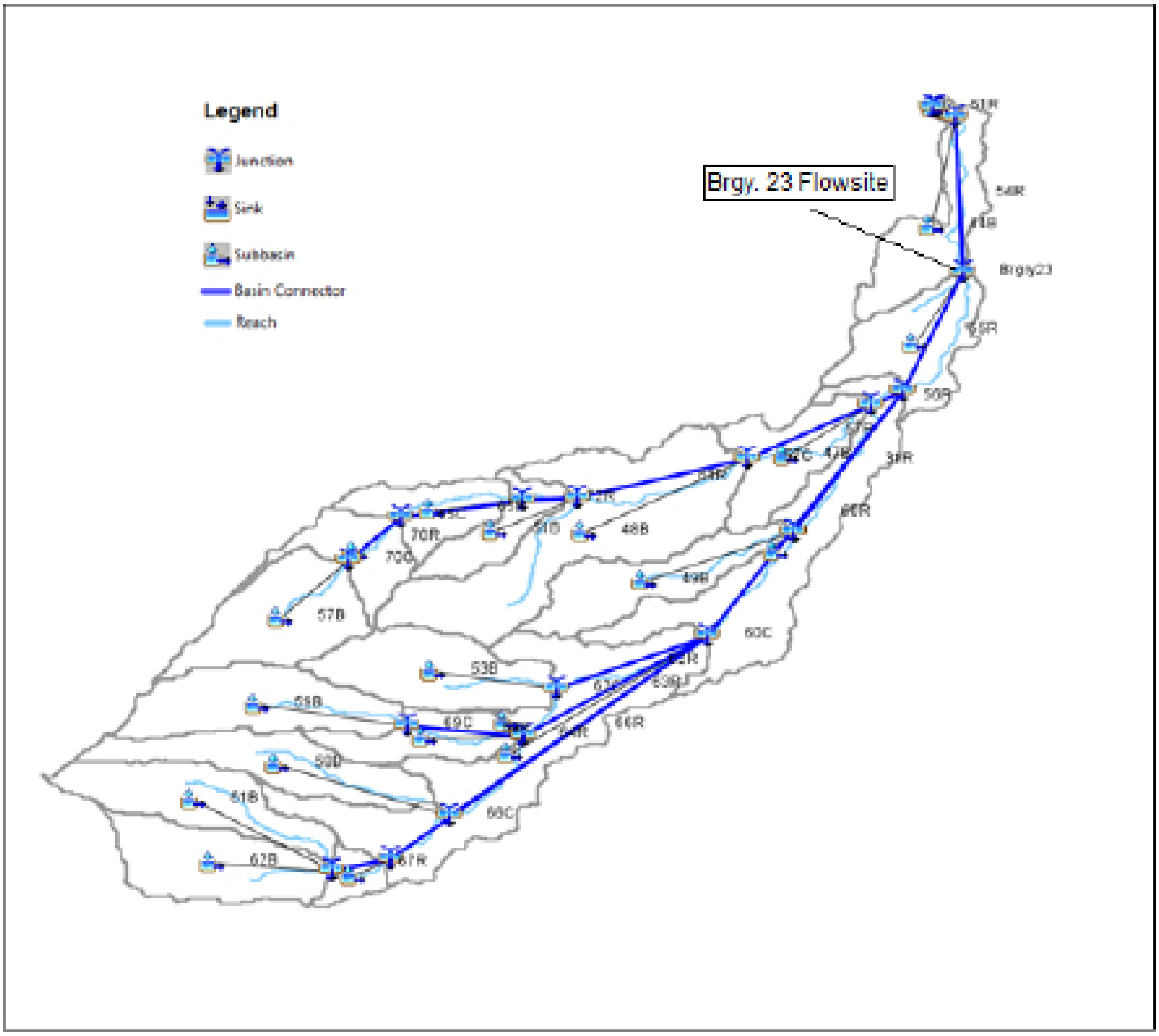

Figure 50. HEC-HMS generated Gahub River Basin Model

5.4 Cross-section Data

Riverbed cross-sections of the watershed were necessary in the HEC-RAS model setup. 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.

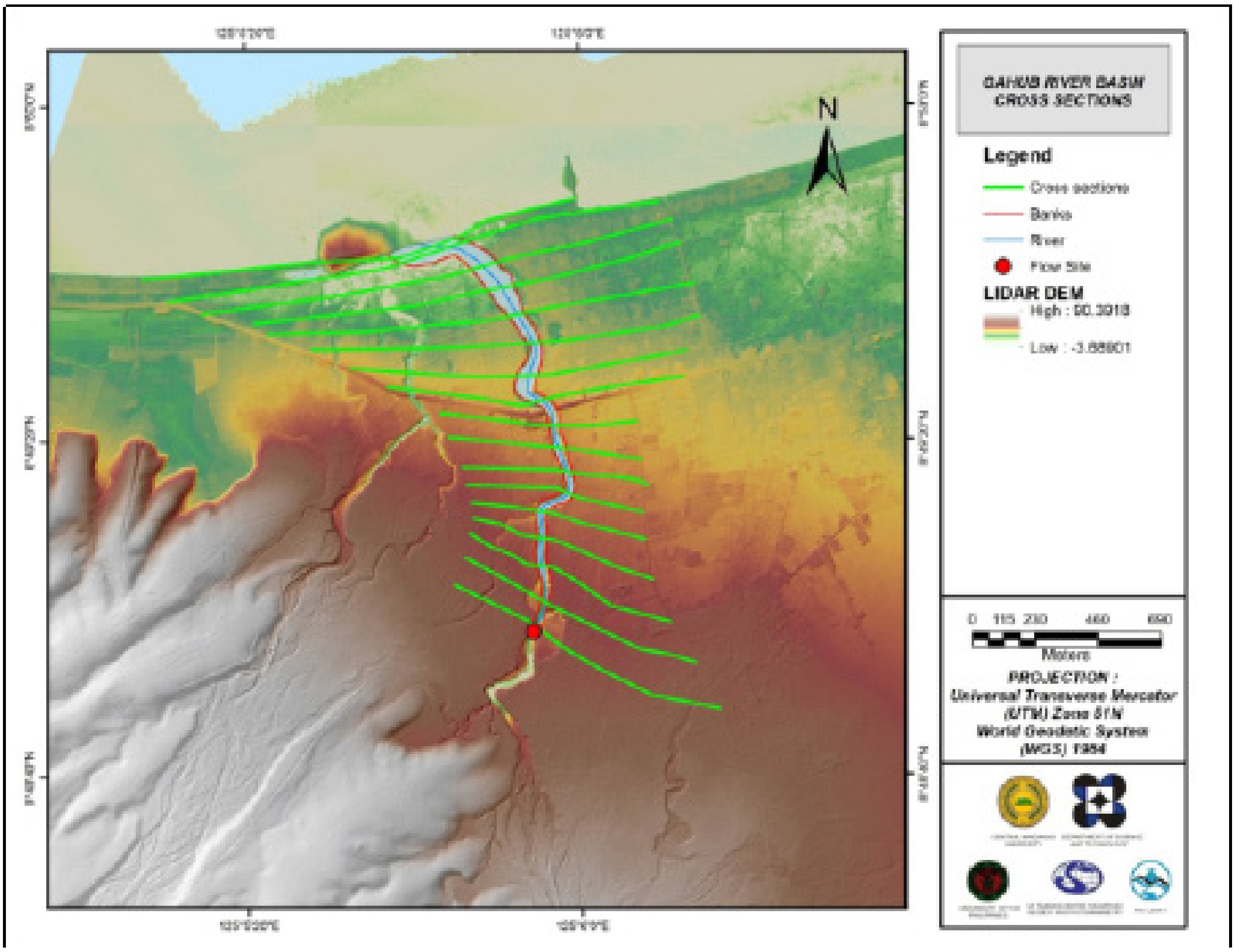

Figure 51. Gahub River Cross-section generated using HEC GeoRAS tool

5.5 Flo 2D Model

The automated modeling 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 was divided into square grid elements, 10 meter by 10 meter in size. Each element was assigned a unique grid element number which served as its identifier, then attributed with the parameters required for modeling such as x-and y-coordinate of centroid, names of adjacent grid elements, Manning coefficient of roughness, infiltration, and elevation value. The elements were 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 South of the model to the North, following the main channel. As such, boundary elements in those particular regions of the model were assigned as inflow and outflow elements, respectively.

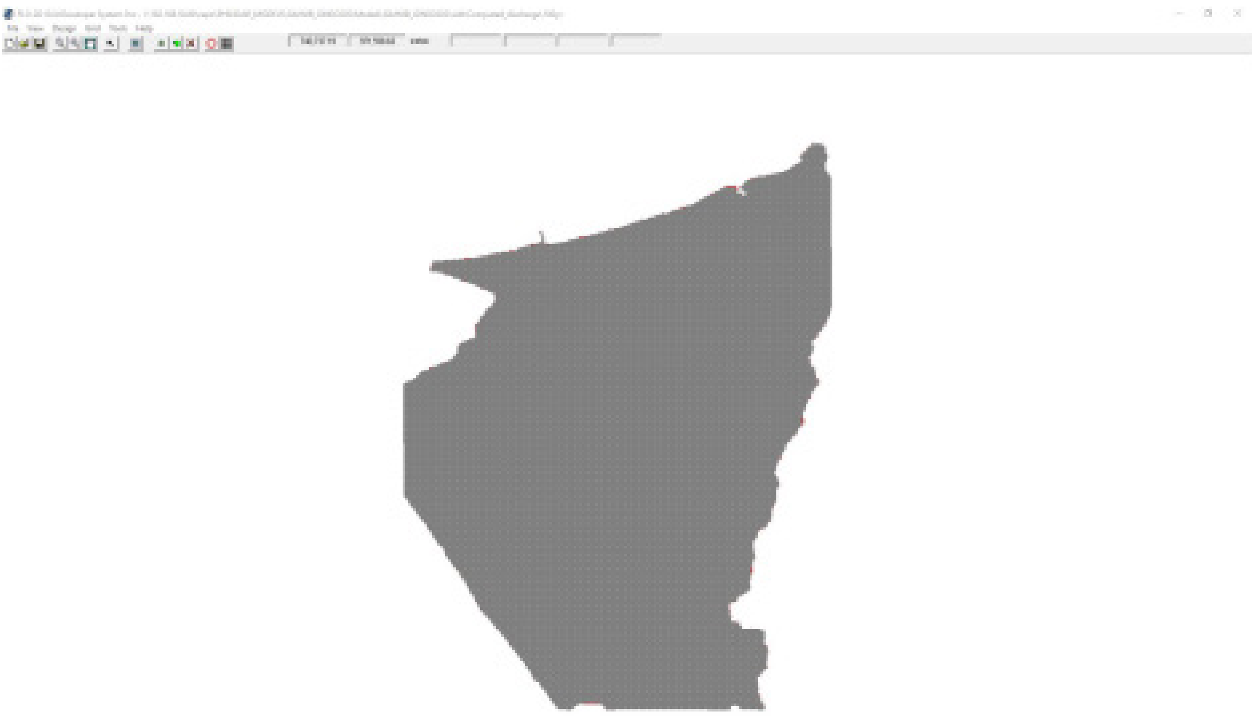

Figure 52. Screenshot of subcatchment with the computational area to be modeled in FLO-2DFLO-2D GDS Pro

The simulation was then run through FLO-2D GDS Pro. This particular model had a computer run time of 24.35986 hours. After the simulation, FLO-2D Mapper Pro was 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 created the following food hazard map. Most of the default values given by FLO-2D Mapper Pro were 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 m2/s.

The creation of a flood hazard map from the model also automatically created a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in FLO-2D Mapper was not a good representation of the range of flood inundation values, so a different legend was used for the layout. In this particular model, the inundated parts covered a maximum land area of 32,230,100.00 m2.

There is a total of 34,436,373.72 m3 of water entering the model. Of this amount, 9,612,326.70 m3 is due to rainfall while 24,824,047.02 m3 is inflow from other areas outside the model. 4,052,283.00 m3 of this water is lost to infiltration and interception, while 2,471,692.96 m3 is stored by the floodplain. The rest, amounting up to 27,912,403.53 m3,is outflow.

5.6 Results of HMS Calibration

After calibrating the Gahub HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 53 shows the comparison between the two discharge data.

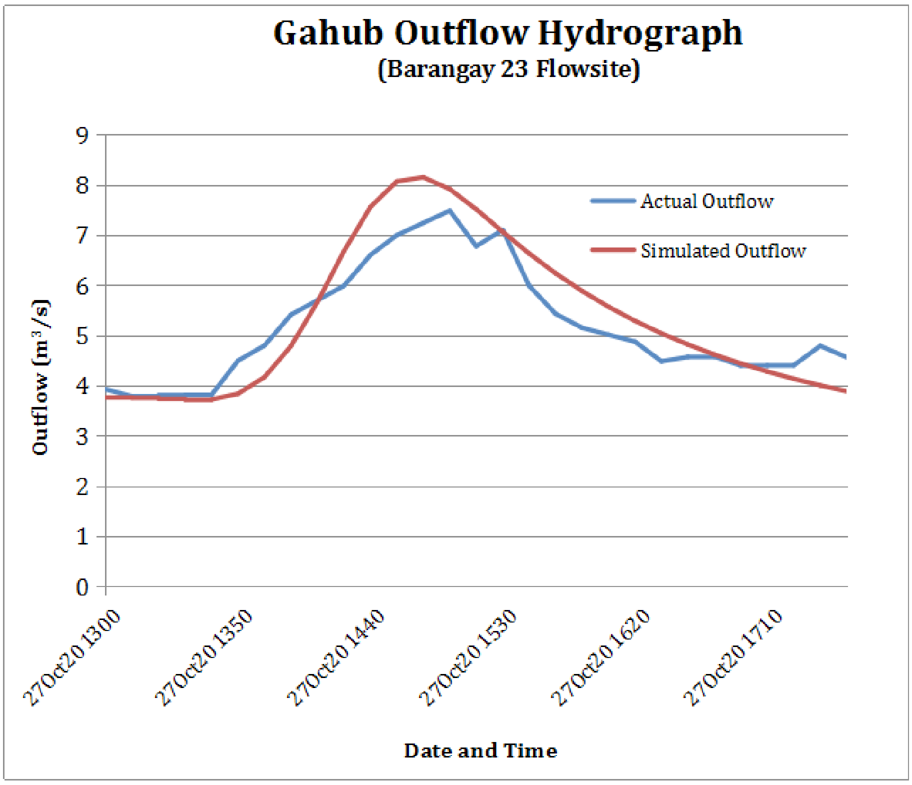

Figure 53. Outflow hydrograph of Gahub produced by the HEC-HMS model compared with observed outflow

Table 27 shows adjusted ranges of values of the parameters used in calibrating the model.

Table 27. Range of calibrated values for the Gahub River Basin

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	3.42 – 6.51
			Curve Number	70 – 95
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.14 – 1.17
			Storage Coefficient (hr)	0.25 – 2.10
	Baseflow	Recession	Recession Constant	0.33
			Ratio to Peak	0.016
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.0004

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 3.42 mm to 6.51 mm signifies that there is a minimal amount of infiltration or rainfall interception by vegetation.

The 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. The range of 70 to 95 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For Gahub, the basin mostly consists of brushlands and the soil consists of clay and undifferentiated soil.

The 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 0.14 hours to 2.10 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, while ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.33 indicates that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.016 indicates a steeper receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.0004 corresponds to a low value but is within the range of possible values for Manning's n.

Table 28. Summary the efficiency test of the Gahub HMS Model

Accuracy measure	Value
RMSE	0.55
r2	0.84
NSE	0.75
PBIAS	8.73
RSR	0.49

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 0.55 (m3/s).

The Pearson correlation coefficient (r2) assesses the strength of the linear relationship between the observations and the model. This A 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 0.84.

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 0.75.

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 8.73.

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 0.49.

5.7 Calculated outflow hydrographs and discharge values for different rainfall return periods

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph (Figure 54) shows the Gahub River outflow using the Butuan 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 the Philippine Atmospheric Geophysical and Astronomical Services Administration (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.

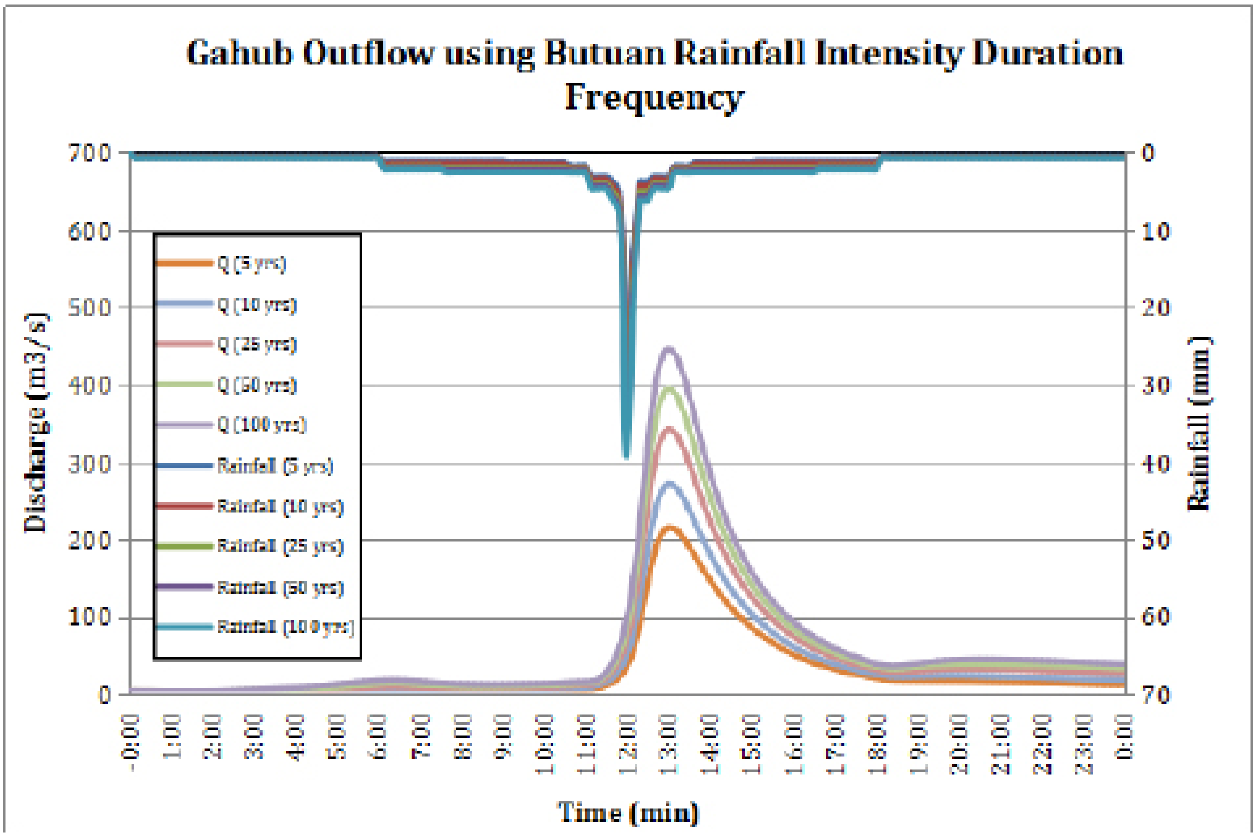

Figure 54. Outflow hydrograph at Gahub Station generated using Butuan RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow, and time to peak of the Gahub discharge using the Butuan Rainfall Intensity-Duration-Frequency curves (RIDF curves) in five different return periods is shown in Table 29.

Table 29. Peak values of the Gahub HEC-HMS Model outflow using the Butuan RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	175.2	23.9	215.26	60 minutes
10-Year	207.5	27.6	271.0	60 minutes
25-Year	248.3	32.3	341.7	60 minutes
50-Year	278.6	35.8	394.29	60 minutes
100-Year	308.6	39.2	446.17	60 minutes

5.7.2 Discharge data using Dr. Horritt's recommended hydrologic method

The river discharge values for the nine rivers entering the floodplain are shown in Figure 55 to Figure 60 and the peak values are summarized in Table 30 to Table 35.

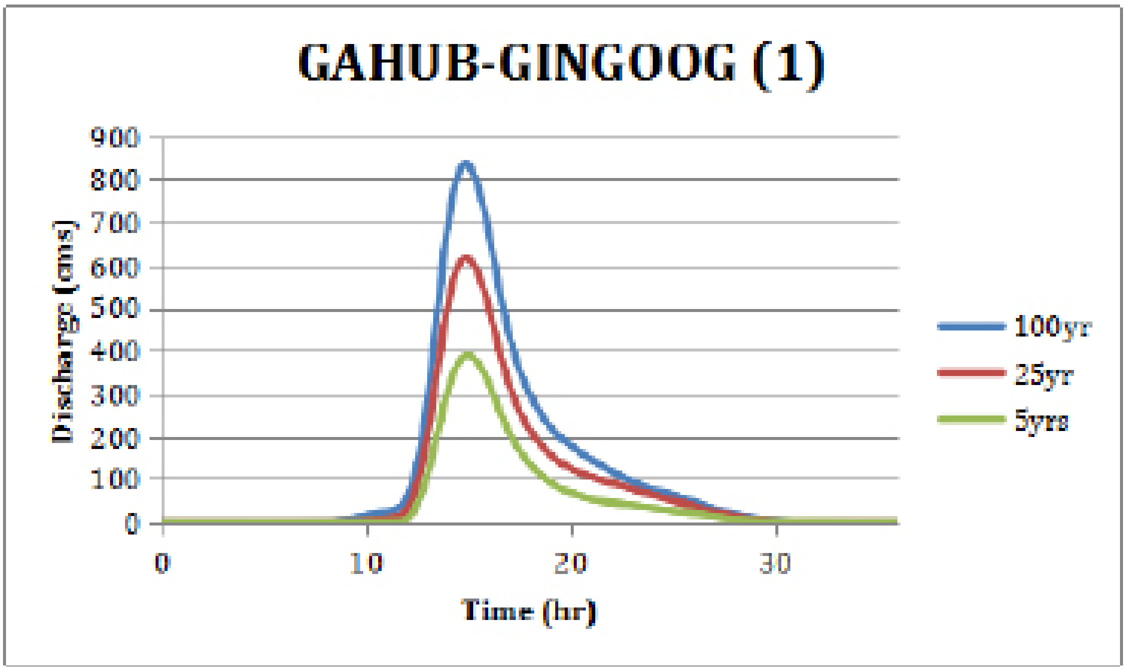

Figure 55. Gahub-Gingoog River (1) generated discharge using 5-, 25-, and 100-year Lumbia rainfall intensity-duration-frequency (RIDF) in HEC-HMS

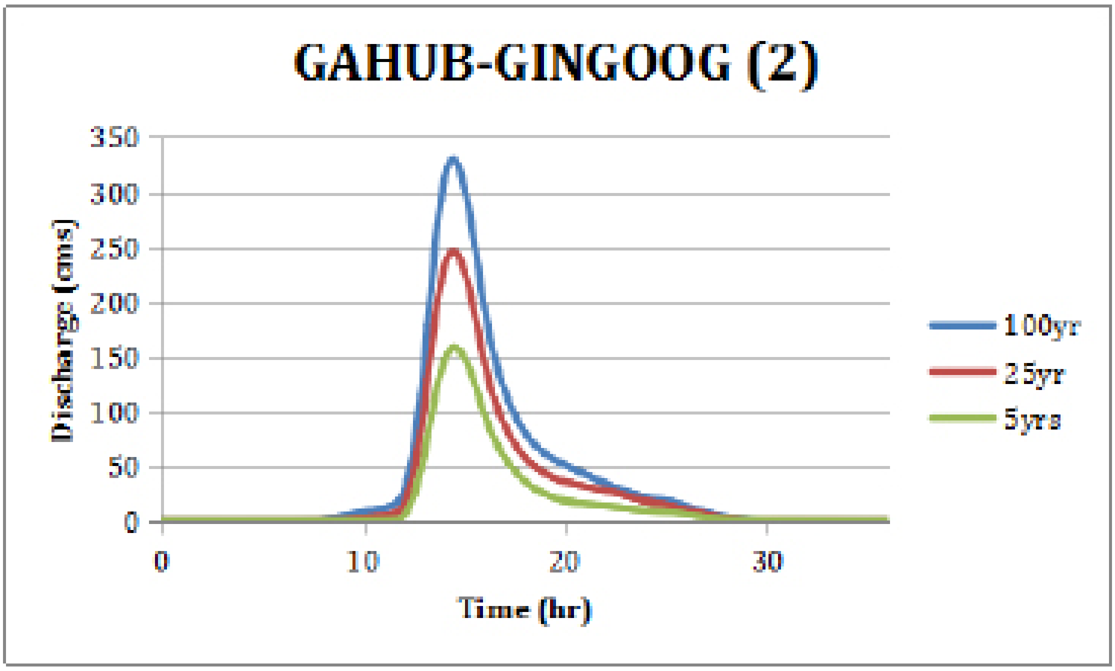

Figure 56. Gahub-Gingoog River (2) generated discharge using 5-, 25-, and 100-year Lumbia rainfall intensity-duration-frequency (RIDF) in HEC-HMS

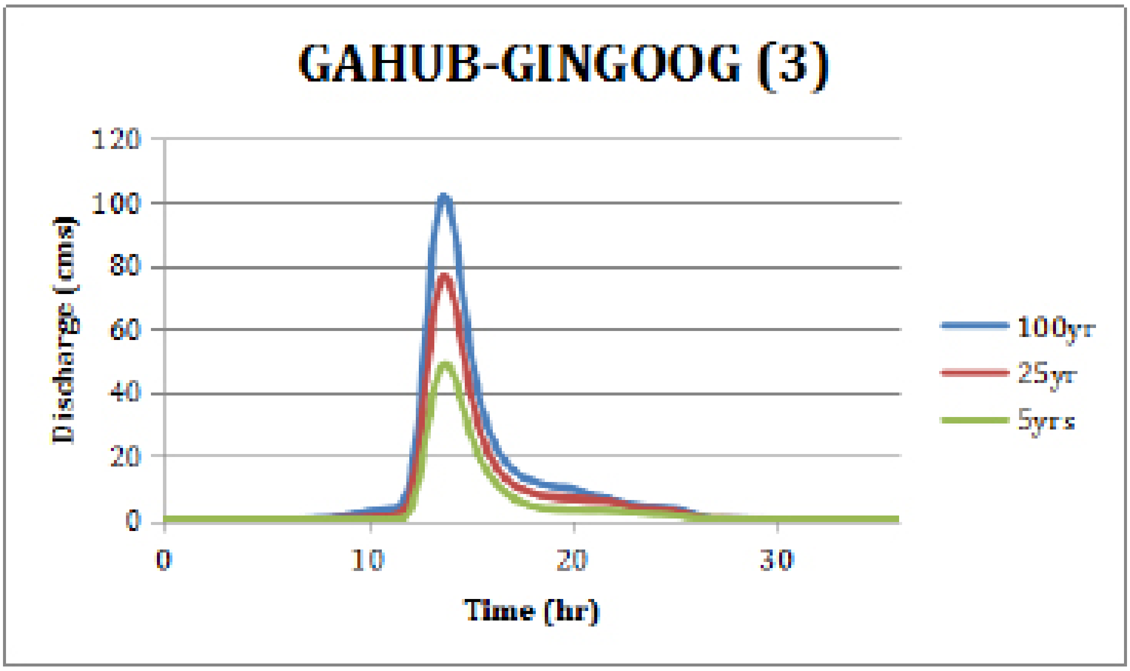

Figure 57. Gahub-Gingoog Rriver (3) generated discharge using 5-, 25-, and 100-year Lumbia rainfall intensity-duration-frequency (RIDF) in HEC-HMS

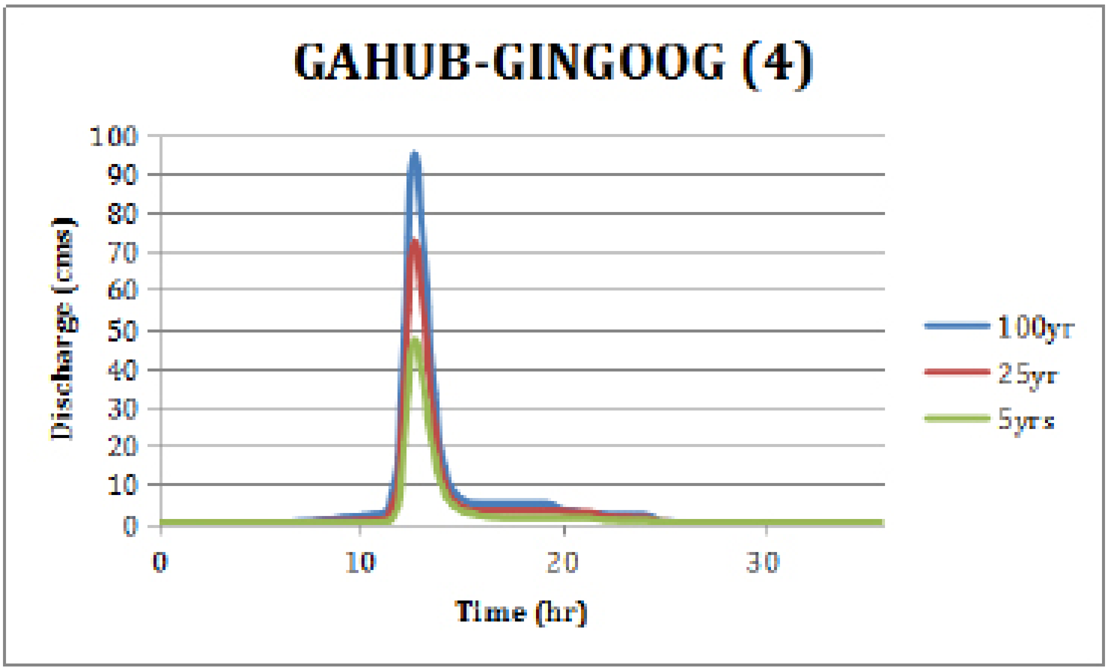

Figure 58. Gahub-Gingoog River (4) generated discharge using 5-, 25-, and 100-year Lumbia rainfall intensity-duration-frequency (RIDF) in HEC-HMS

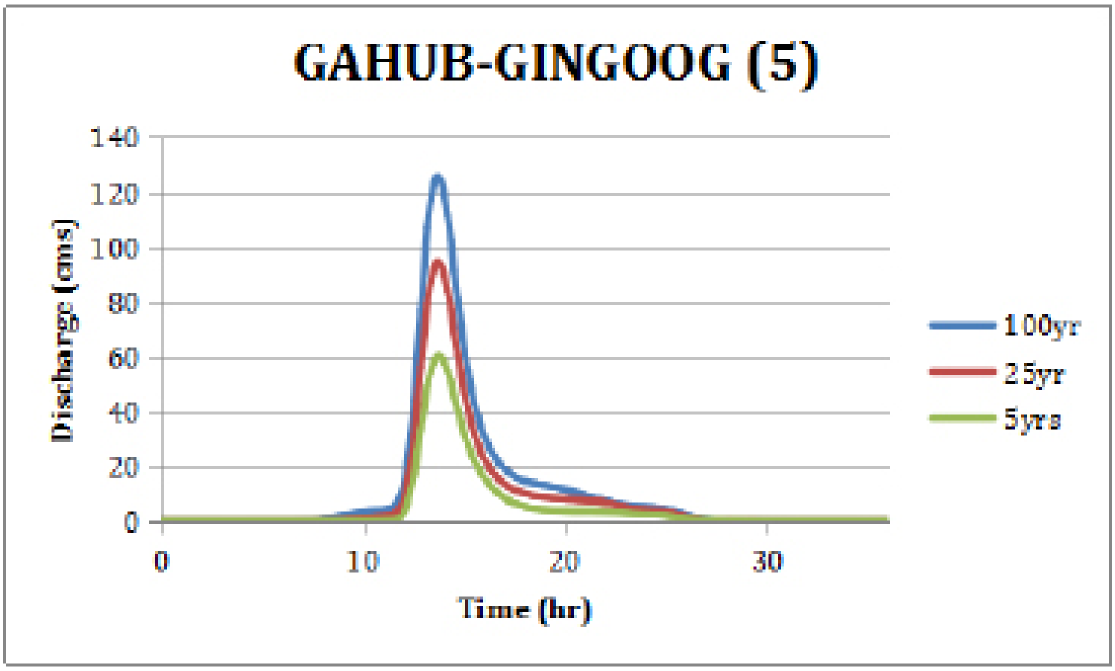

Figure 59. Gahub-Gingoog River (5) generated discharge using 5-, 25-, and 100-year Lumbia rainfall intensity-duration-frequency (RIDF) in HEC-HMS

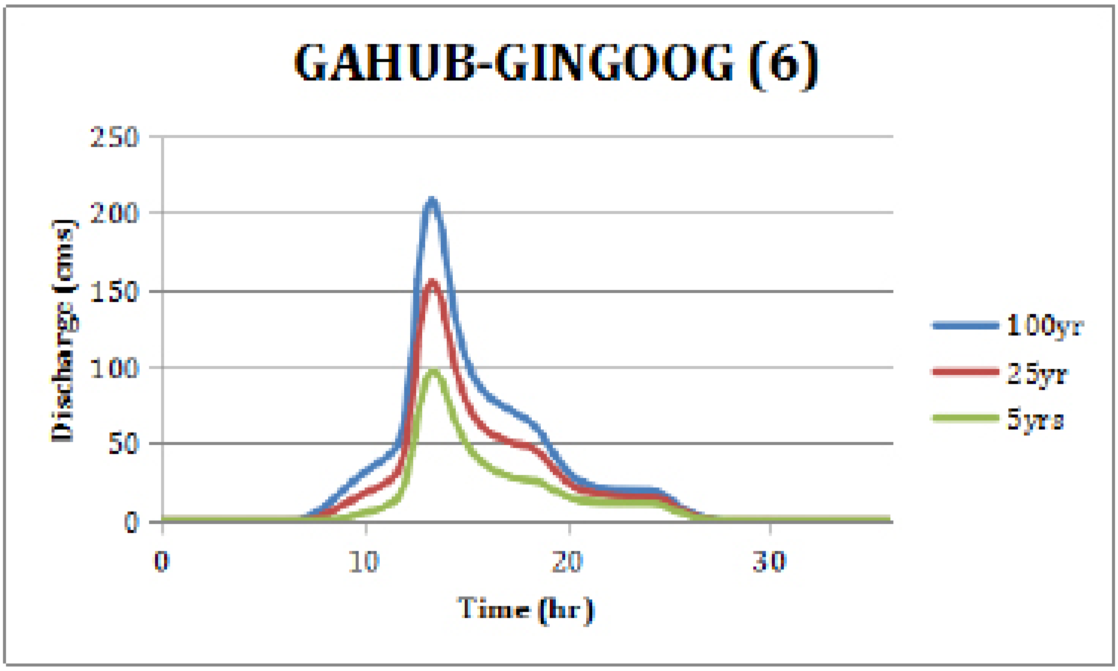

Figure 60. Gahub-Gingoog River (6) generated discharge using 5-, 25-, and 100-year Lumbia rainfall intensity-duration-frequency (RIDF) in HEC-HMS

Table 30. Summary of Gahub-Gingoog River (1) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	835.8	14 hours, 50 minutes
25-Year	617.3	14 hours, 50 minutes
5-Year	389.0	15 hours

Table 31. Summary of Gahub-Gingoog River (2) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	328.2	14 hours, 30 minutes
25-Year	245.3	14 hours, 30 minutes
5-Year	157.5	14 hours, 30 minutes

Table 32. Summary of Gahub-Gingoog River (3) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	101.9	13 hours, 40 minutes
25-Year	76.4	13 hours, 40 minutes
5-Year	49.0	13 hours, 50 minutes

Table 33. Summary of Gahub-Gingoog River (4) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	95.1	12 hours, 40 minutes
25-Year	72.4	12 hours, 40 minutes
5-Year	47.3	12 hours, 40 minutes

Table 34. Summary of Gahub-Gingoog River (5) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	125.5	13 hours, 40 minutes
25-Year	94.1	13 hours, 40 minutes
5-Year	59.9	13 hours, 40 minutes

Table 35. Summary of Gahub-Gingoog River (6) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	208.5	13 hours, 20 minutes
25-Year	155.1	13 hours, 20 minutes
5-Year	96.6	13 hours, 20 minutes

Table 36. Validation of river discharge estimates

Discharge Point	QMED(SCS), cms	QBANKFUL, cms	QMED(SPEC), cms	VALIDATION	
				Bankful Discharge	Specific Discharge
Gahub-Gingoog (1)	342.320	639.157	262.649	PASS	PASS
Gahub-Gingoog (2)	138.600	231.653	124.700	PASS	PASS
Gahub-Gingoog (3)	43.120	48.914	40.568	PASS	PASS
Gahub-Gingoog (4)	41.624	71.544	23.419	PASS	FAIL
Gahub-Gingoog (5)	52.712	54.423	47.567	PASS	PASS
Gahub-Gingoog (6)	85.008	73.490	102.266	PASS	PASS

Five out of six of the results from the HEC-HMS river discharge estimates were able to satisfy the conditions for validation using the bankful and specific discharge methods. One did not pass the conditions for validation using the specific discharge methods and will would need further recalculation. The passing values are were based on theory but are were supported using other discharge computation methods so they were good to use flood modeling. These values will would need further investigation for the purpose of validation. It is therefore recommended to obtain actual values of the river discharges for higher-accuracy modeling.

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 will be 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. For this publication, only a sample output map river was is to be shown. The sample generated map of Gahub River using the calibrated HMS base flow is shown in Figure 61.

Figure 61. Sample output of Gahub RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10 m resolution. Figure 62 to Figure 66 show the 5-, 25-, and 100-year rain return scenarios of the Gahub - Gingoog Floodplain. The floodplain, with an area of 32.23 sq. kmsq km., covers the city of Gingoog. Table 37 shows the percentage of area affected by flooding per municipality.

Table 37. Municipalities affected in Gahub Floodplain

Municipality	Total Area	Area Flooded	% Flooded
Gingoog	578.36	32.19	5.57%

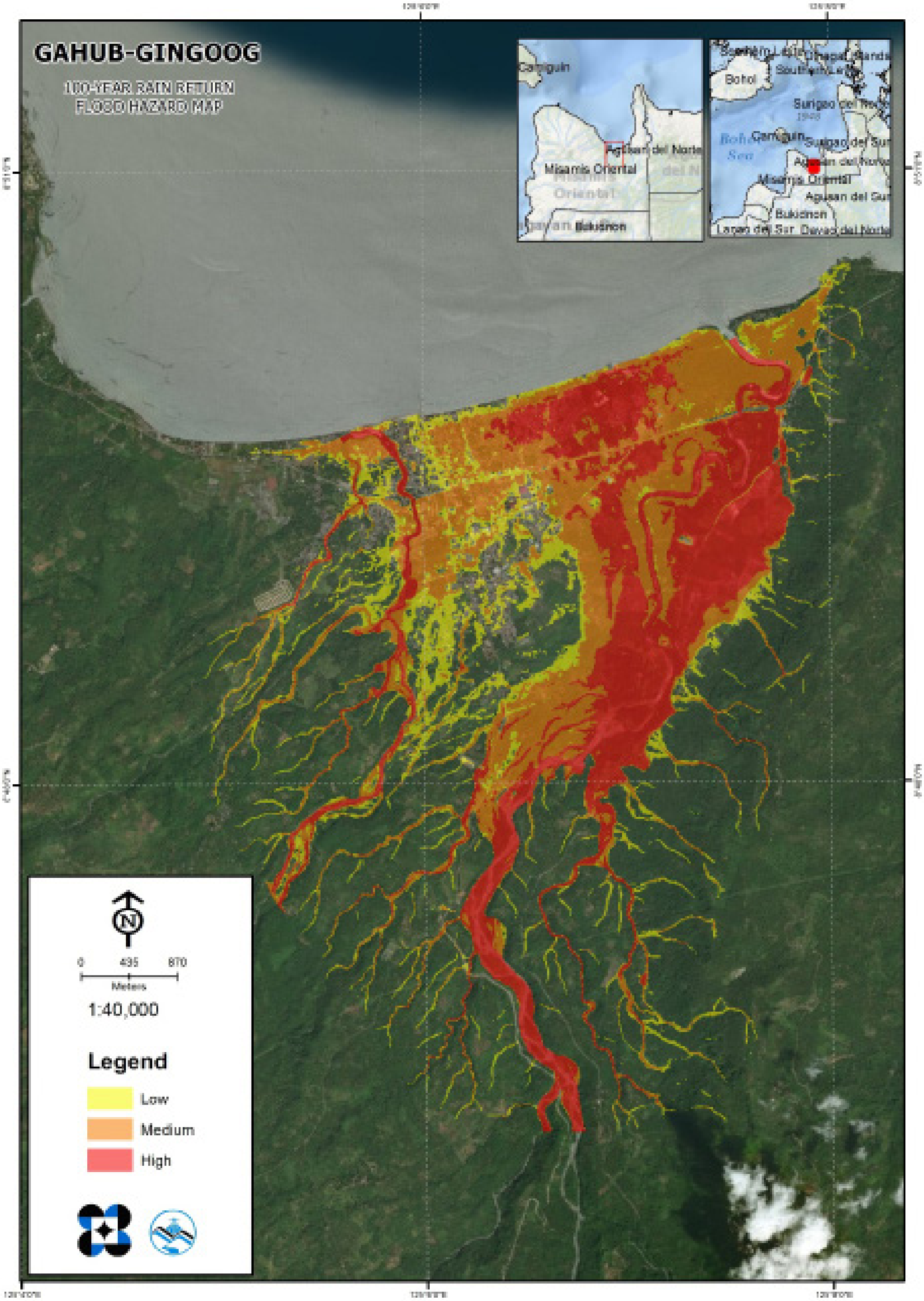

Figure 62. 100-year flood hazard map for Gahub-Gingoog Floodplain

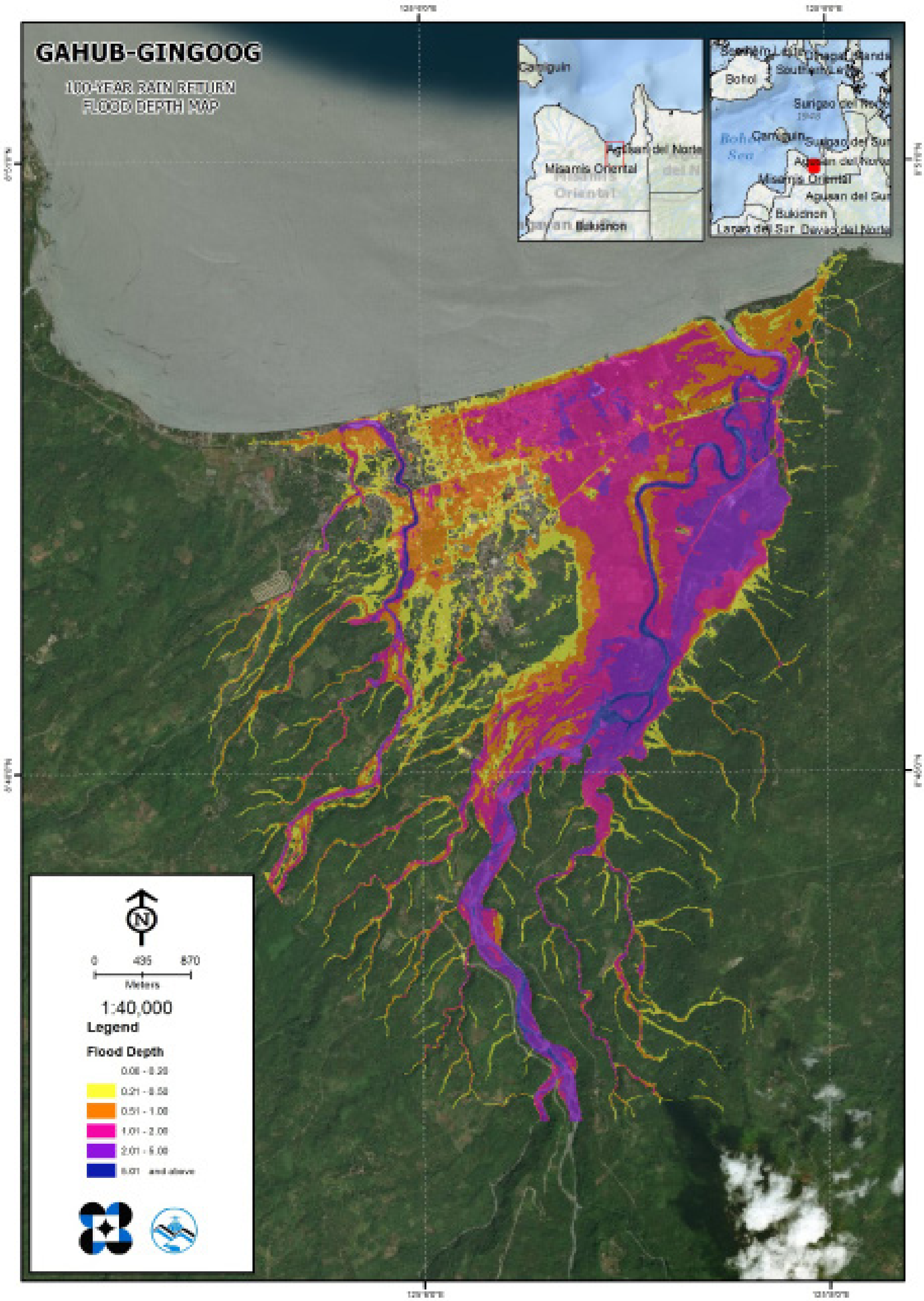

Figure 63. 100-year flow depth map for Gahub-Gingoog Floodplain

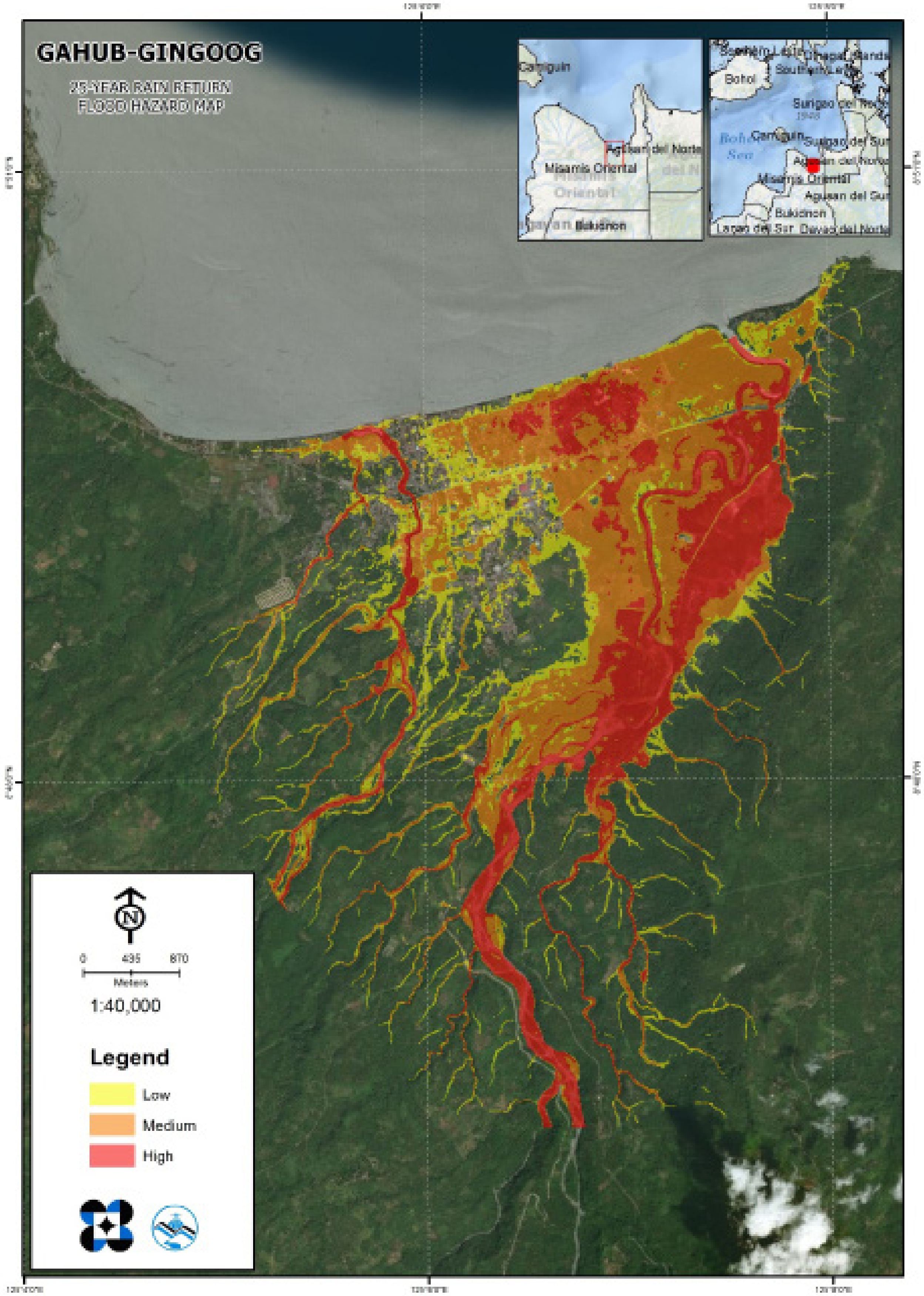

Figure 64. 25-year flood hazard map for Gahub-Gingoog Floodplain

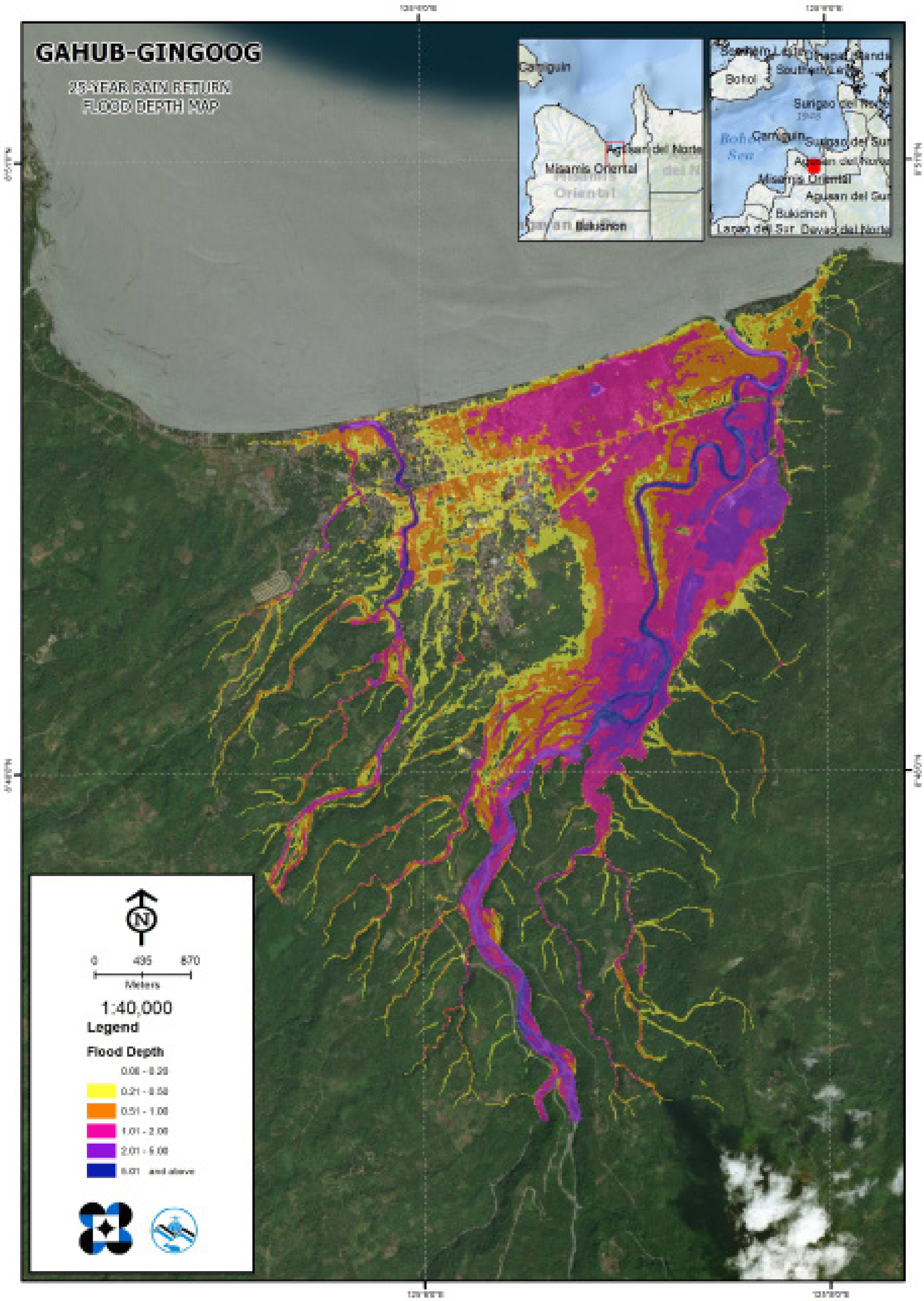

Figure 65. 25-year flow depth map for Gahub-Gingoog Floodplain

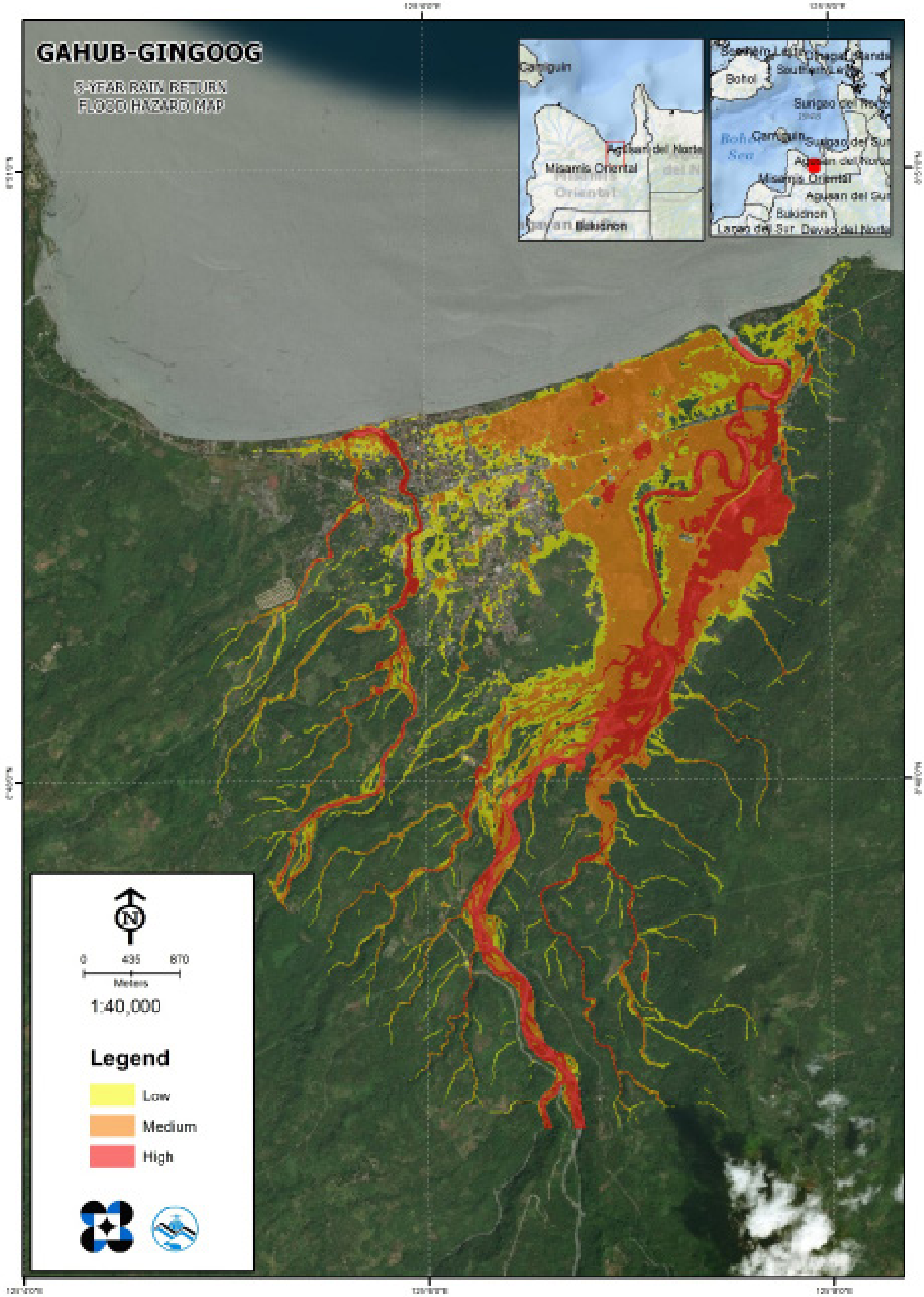

Figure 66. 5-year flood hazard map for Gahub-Gingoog Floodplain

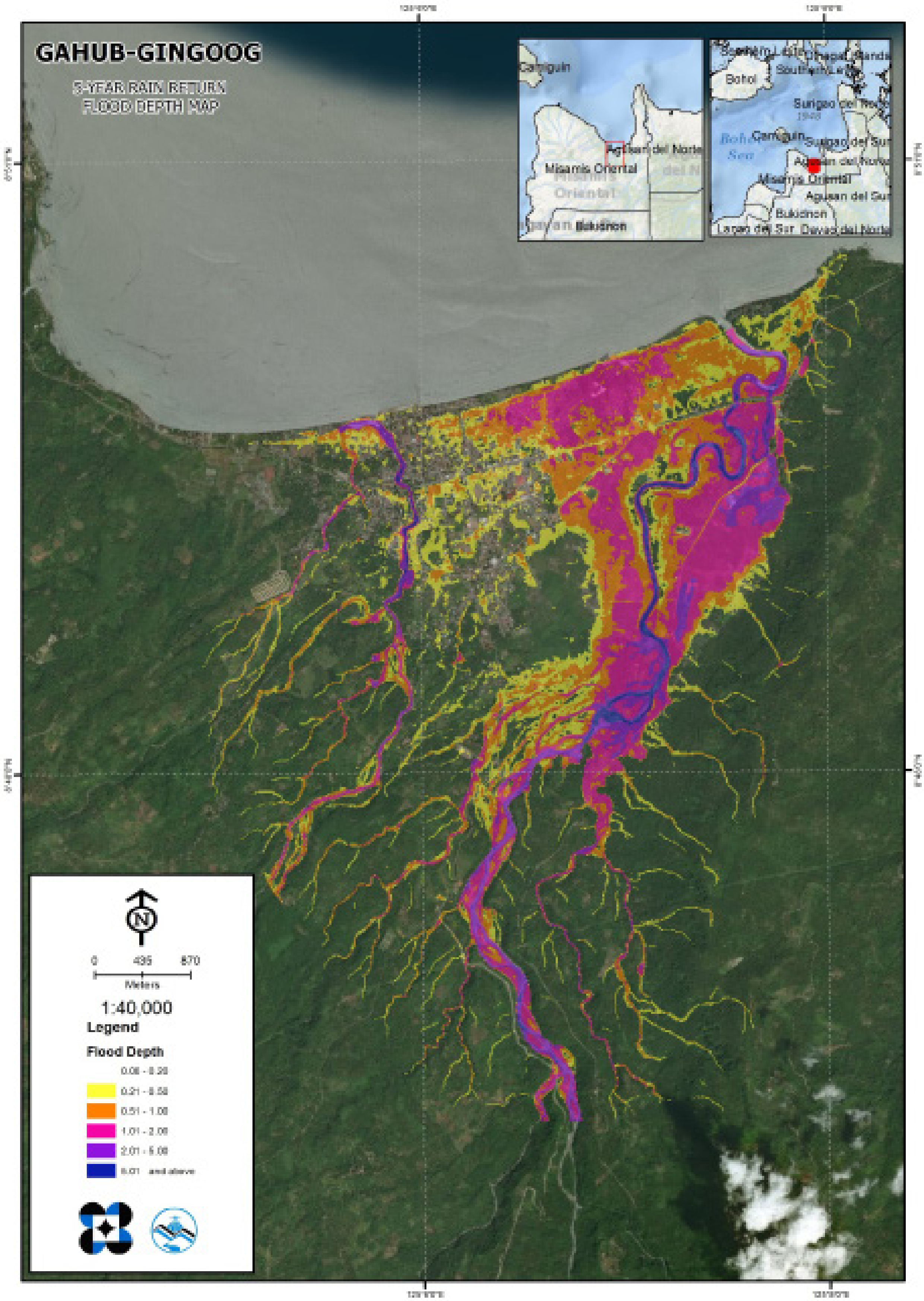

Figure 67. 5-year flood depth map for Gahub-Gingoog Floodplain

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Gahub-Gingoog River Basin are listed below. For the said basin, one municipality consisting of 43 barangays are is expected to experience flooding when subjected to 5-, 25-, and 100-yr rainfall return period.

For the 5-year return period, 4.05% of Gingoog City with an area of 538.032214 sq. km. will experience flood levels of less than 0.20 meters;. 0.57% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.53%, 0.59%, 0.19%, and 0.04% 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 Table 38 to Table 41 are the affected areas in square kilometers by flood depth per barangay.

Table 38. Affected areas Gingoog City, Misamis Oriental during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Gingoog City (in sq. km)										
	Bagubad	Bakidbakid	Barangay 1	Barangay 10	Barangay 11	Barangay 12	Barangay 13	Barangay 14	Barangay 15	Barangay 16	Barangay 17
0.03-0.20	0.0037	0.43	0.026	0.018	0.0092	0.0027	0.013	0.022	0.035	0.038	0.067
0.21-0.50	0.0001	0.037	0.00063	0.0023	0.013	0.013	0.011	0.012	0.0056	0.0045	0.054
0.51-1.00	0	0.018	0.00063	0	0	0.006	0.0092	0.0045	0	0.0022	0.045
1.01-2.00	0	0.0017	0.0012	0	0	0	0	0	0	0.0023	0.001
2.01-5.00	0	0	0.0054	0	0	0	0	0	0	0.017	0
> 5.00	0	0	0.0011	0	0	0	0	0	0	0	0

Table 39. Affected areas Gingoog City, Misamis Oriental during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Gingoog City (in sq. km)										
	Barangay 18	Barangay 18-A	Barangay 19	Barangay 2	Barangay 20	Barangay 21	Barangay 22	Barangay 22-A	Barangay 23	Barangay 24	Barangay 24-A
0.03-0.20	0.034	0.062	0.13	0.03	0.26	0.03	0.013	0.85	0.26	0.12	0.92
0.21-0.50	0.016	0.072	0.23	0.0023	0.21	0.014	0.022	0.19	0.22	0.047	0.12
0.51-1.00	0.018	0.21	0.45	0.0013	0.52	0.00054	0.0017	0.071	0.039	0.034	0.049
1.01-2.00	0.0046	0.3	0.35	0	0.52	0	0	0.051	0.008	0.0087	0.033
2.01-5.00	0	0.0007	0.049	0	0.085	0	0	0.0012	0.022	0.008	0.028
> 5.00	0	0	0.0077	0	0.056	0	0	0.0017	0.0085	0.0017	0.0032

Table 40. Affected areas Gingoog City, Misamis Oriental during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Gingoog City (in sq. km)										
	Barangay 25	Barangay 26	Barangay 3	Barangay 4	Barangay 5	Barangay 6	Barangay 7	Barangay 8	Barangay 9	Binakalan	Daan-Lungsod
0.03-0.20	0.23	0.17	0.023	0.02	0.016	0.021	0.019	0.01	0.014	1.94	0.61
0.21-0.50	0.038	0.019	0.0034	0.01	0.009	0.0037	0.0042	0.0011	0.00093	0.086	0.17
0.51-1.00	0.019	0.0014	0.00035	0.00051	0	0	1.1E-06	0.0013	0.00062	0.067	0.058
1.01-2.00	0.0065	0.00011	0	0	0	0	0	0.00034	0.0012	0.11	0.0093
2.01-5.00	0.0028	0.00013	0	0	0	0	0	0.0016	0.0053	0.094	0.019
> 5.00	0	0	0	0	0	0	0	0.00048	0	0.0083	0.0005

Table 41. Affected areas Gingoog City, Misamis Oriental during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Gingoog City (in sq. km)										
	Lawit	Libon	Mimbalagon	Murallon	Punong	Samay	San Juan	San Miguel	Santiago	Tinulongan	Daan-Lungsod
0.03-0.20	1.33	5.4	0.079	5.03	0.022	0.086	0.039	0.89	2.37	0.096	0.61
0.21-0.50	0.044	0.31	0.0022	0.76	0.0002	0.011	0.0034	0.039	0.22	0.024	0.17
0.51-1.00	0.018	0.19	0.00026	0.6	0	0.016	0	0.036	0.33	0.023	0.058
1.01-2.00	0.011	0.29	0	0.58	0	0.04	0	0.0073	0.8	0.013	0.0093
2.01-5.00	0.0052	0.081	0	0.3	0	0.035	0	0	0.25	0.0007	0.019
> 5.00	0	0.00093	0	0.082	0	0.0007	0	0	0.036	0	0.0005

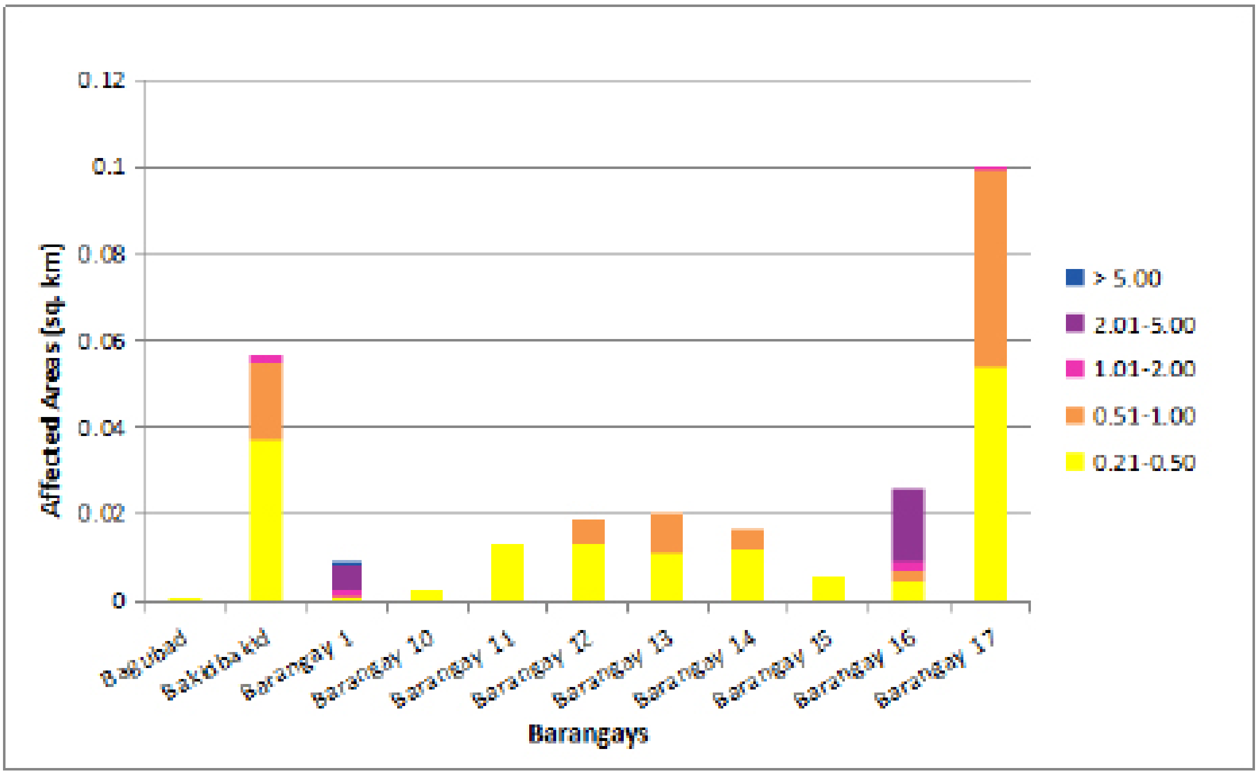

Figure 68. Affected areas in Gingoog City, Misamis Oriental during a 5-year rainfall return period

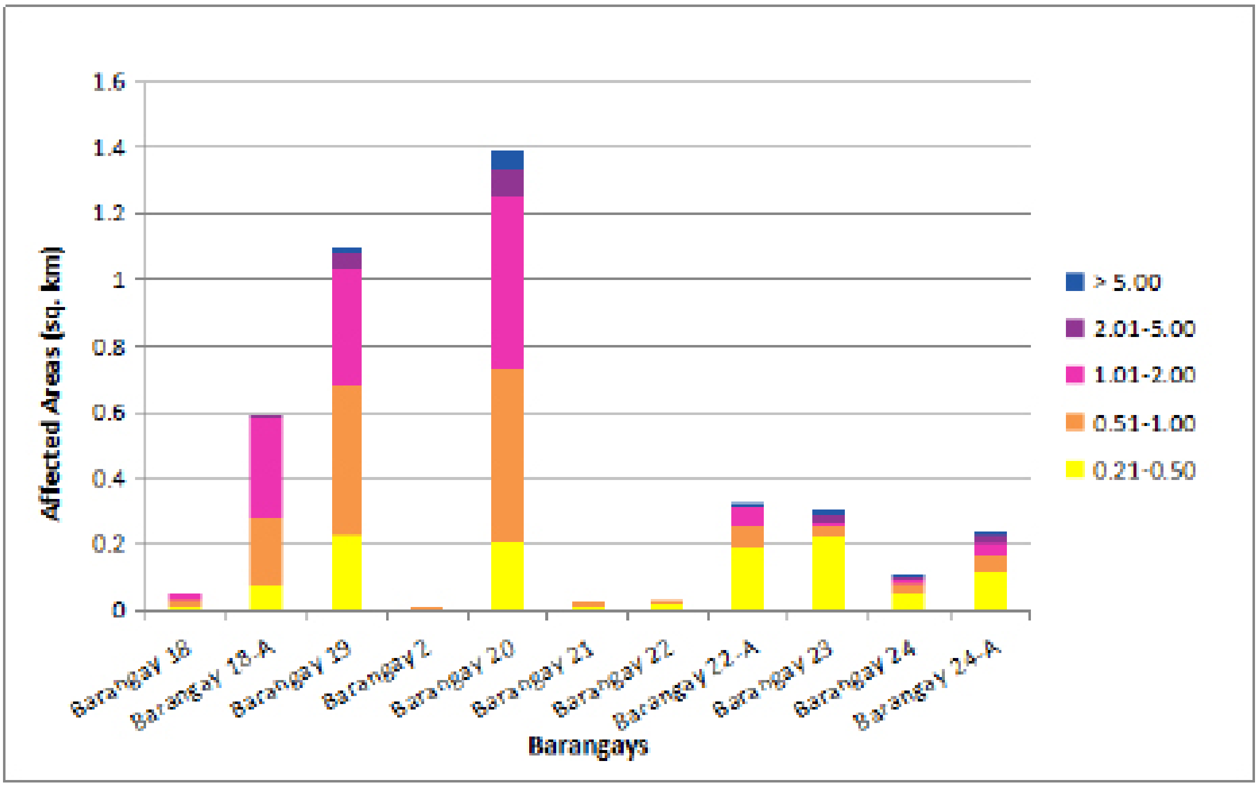

Figure 69. Affected areas in Gingoog City, Misamis Oriental during a 5-year rainfall return period

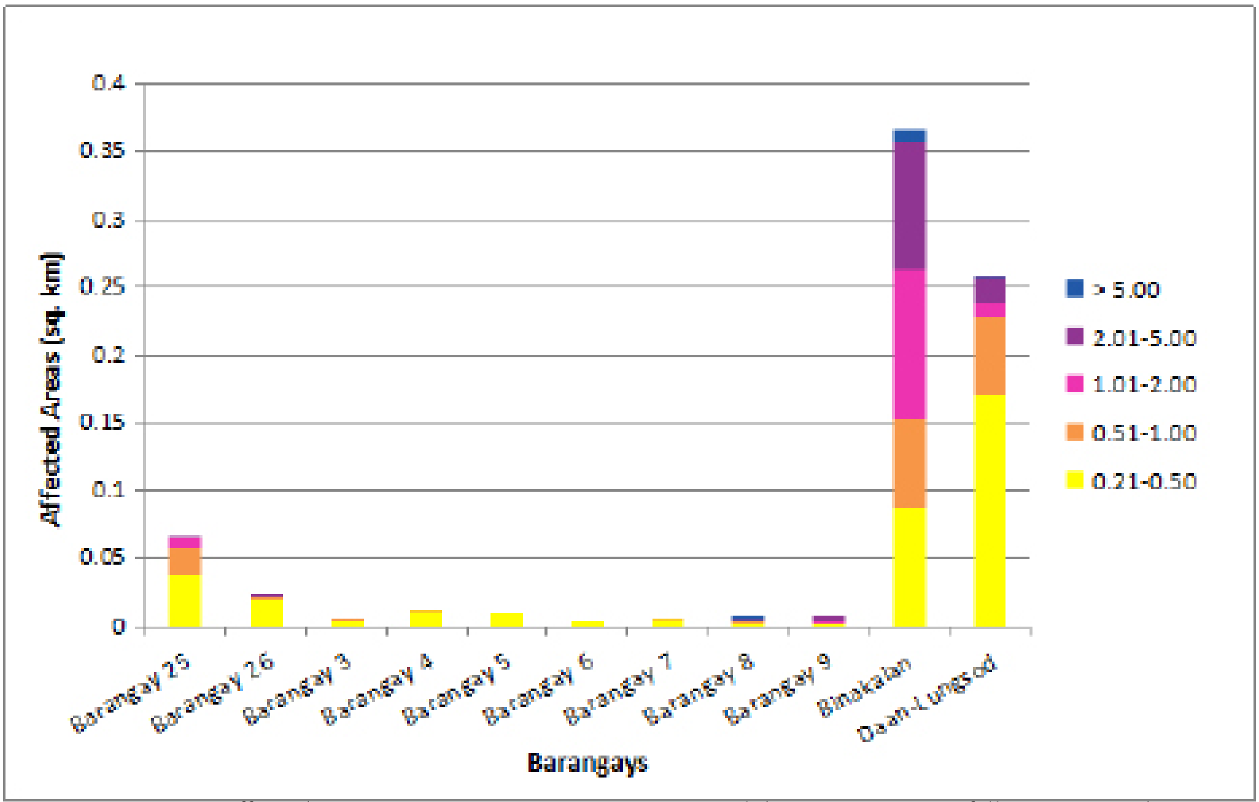

Figure 70. Affected areas in Gingoog City, Misamis Oriental during a 5-year rainfall return period

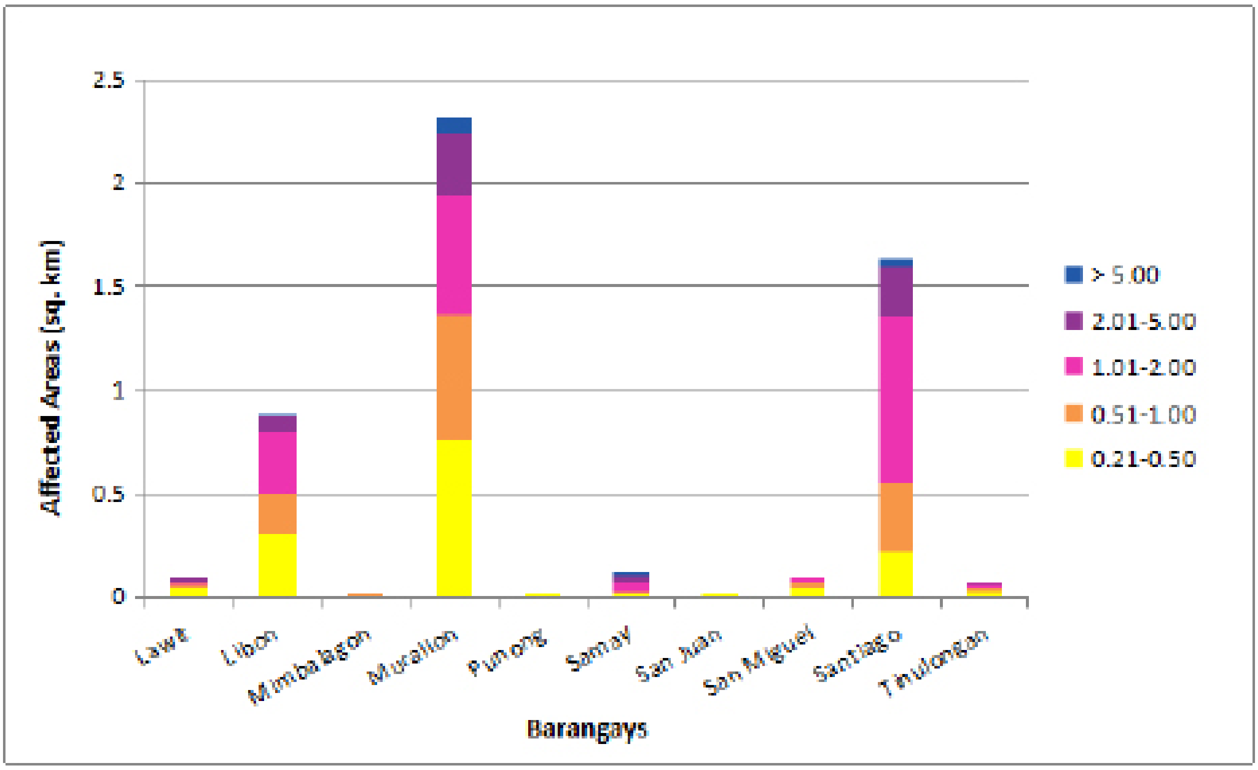

Figure 71. Affected areas in Gingoog City, Misamis Oriental during a 5-year rainfall return period

For the 25-year return period, 3.75% of Gingoog City with an area of 538.032214 sq. km. will experience flood levels of less than 0.20 meters.; 0.54% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.55%, 0.76%, 0.32%, and 0.05% 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 Table 42 to Table 45 are the affected areas in square kilometers by flood depth per barangay.

Table 42. Affected areas Gingoog City, Misamis Oriental during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Gingoog City (in sq. km)										
	Bagubad	Bakidbakid	Barangay 1	Barangay 10	Barangay 11	Barangay 12	Barangay 13	Barangay 14	Barangay 15	Barangay 16	Barangay 17
0.03-0.20	0.0037	0.42	0.025	0.015	0.00091	0.00066	0.01	0.011	0.029	0.037	0.015
0.21-0.50	0.0001	0.036	0.00055	0.0052	0.016	0.0055	0.0067	0.016	0.012	0.0047	0.046
0.51-1.00	0	0.025	0.00078	0	0.0048	0.016	0.016	0.01	0	0.0032	0.073
1.01-2.00	0	0.0032	0.001	0	0	0	0.0004	0	0	0.002	0.033
2.01-5.00	0	0	0.0046	0	0	0	0	0	0	0.017	0
> 5.00	0	0	0.0025	0	0	0	0	0	0	0	0

Table 43. Affected areas Gingoog City, Misamis Oriental during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Gingoog City (in sq. km)										
	Barangay 18	Barangay 18-A	Barangay 19	Barangay 2	Barangay 20	Barangay 21	Barangay 22	Barangay 22-A	Barangay 23	Barangay 24	Barangay 24-A
0.03-0.20	0.012	0.018	0.032	0.027	0.13	0.019	0.0011	0.71	0.097	0.099	0.8
0.21-0.50	0.018	0.056	0.081	0.0041	0.18	0.019	0.019	0.26	0.19	0.045	0.2
0.51-1.00	0.024	0.13	0.41	0.0021	0.33	0.006	0.016	0.093	0.22	0.053	0.075
1.01-2.00	0.018	0.43	0.62	0.00024	0.86	0	0	0.096	0.011	0.014	0.044
2.01-5.00	0	0.011	0.051	0	0.1	0	0	0.001	0.023	0.0083	0.033
> 5.00	0	0	0.017	0	0.065	0	0	0.0019	0.011	0.0026	0.006

Table 44. Affected areas Gingoog City, Misamis Oriental during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Gingoog City (in sq. km)										
	Barangay 25	Barangay 26	Barangay 3	Barangay 4	Barangay 5	Barangay 6	Barangay 7	Barangay 8	Barangay 9	Binakalan	Daan-Lungsod
0.03-0.20	0.21	0.15	0.011	0.005	0.0029	0.01	0.016	0.0096	0.013	1.92	0.54
0.21-0.50	0.037	0.038	0.014	0.022	0.019	0.014	0.0067	0.00088	0.0014	0.089	0.15
0.51-1.00	0.035	0.0032	0.0028	0.0039	0.0024	0.00031	1.1E-06	0.0018	0.00098	0.048	0.14
1.01-2.00	0.0074	0.00034	0	0	0	0	0	0.00054	0.0013	0.088	0.012
2.01-5.00	0.0045	0.00023	0	0	0	0	0	0.0012	0.0055	0.15	0.022
> 5.00	0	0	0	0	0	0	0	0.00084	0	0.021	0.0009

Table 45. Affected areas Gingoog City, Misamis Oriental during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Gingoog City (in sq. km)										
	Lawit	Libon	Mimbalagon	Murallon	Punong	Samay	San Juan	San Miguel	Santiago	Tinulongan	Barangay 17
0.03-0.20	1.32	5.29	0.078	4.68	0.022	0.078	0.038	0.88	2.29	0.081	0.015
0.21-0.50	0.047	0.34	0.0024	0.67	0.0002	0.0026	0.0044	0.039	0.16	0.027	0.046
0.51-1.00	0.022	0.16	0.00036	0.73	0	0.013	0.0002	0.038	0.21	0.027	0.073
1.01-2.00	0.012	0.32	0	0.71	0	0.035	0	0.015	0.73	0.019	0.033
2.01-5.00	0.0087	0.16	0	0.47	0	0.058	0	0.0003	0.57	0.0026	0
> 5.00	0	0.0029	0	0.1	0	0.0014	0	0	0.042	0	0

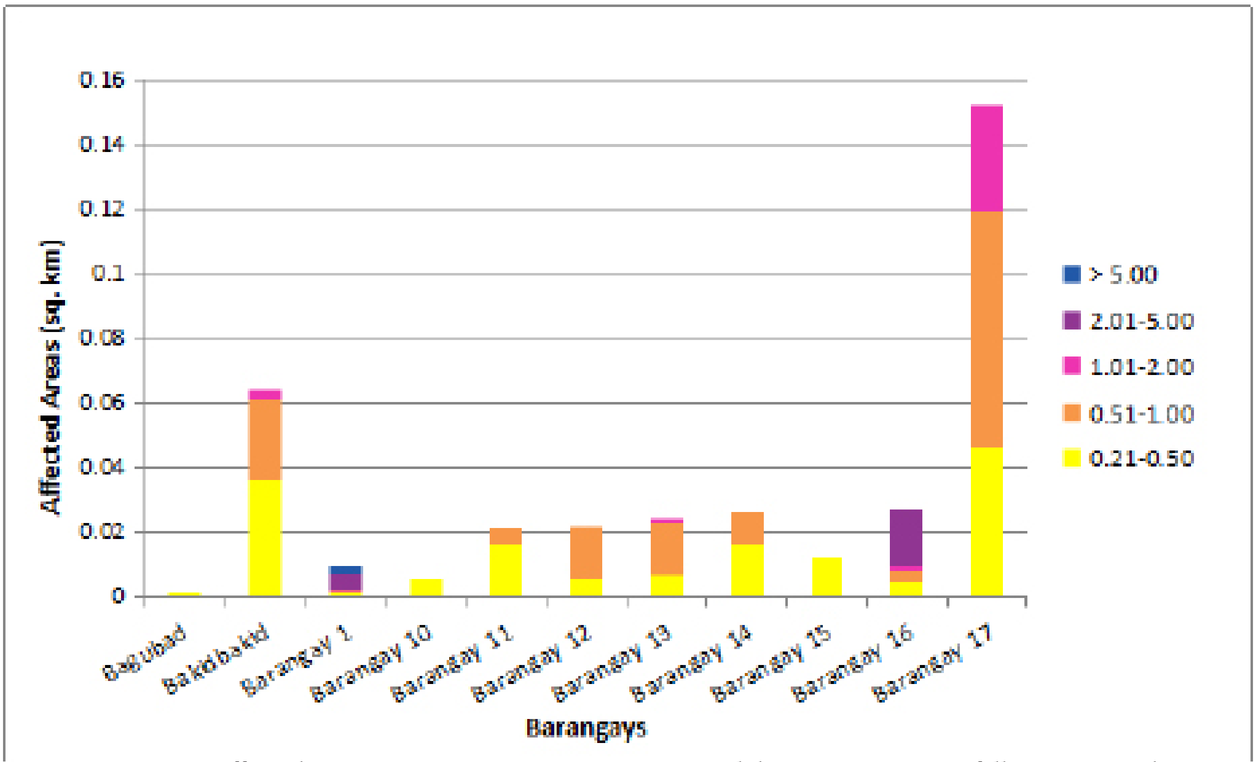

Figure 72. Affected areas in Gingoog City, Misamis Oriental during a 25-year rainfall return period

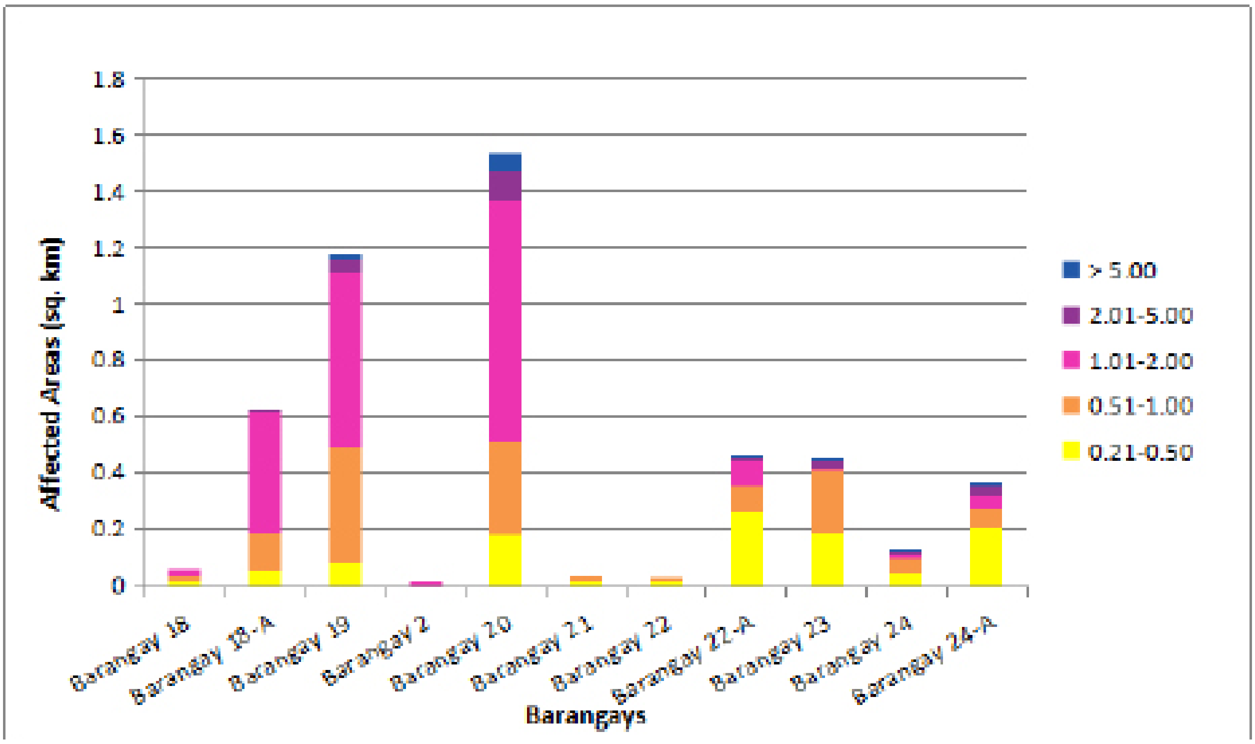

Figure 73. Affected areas in Gingoog City, Misamis Oriental during a 25-year rainfall return period

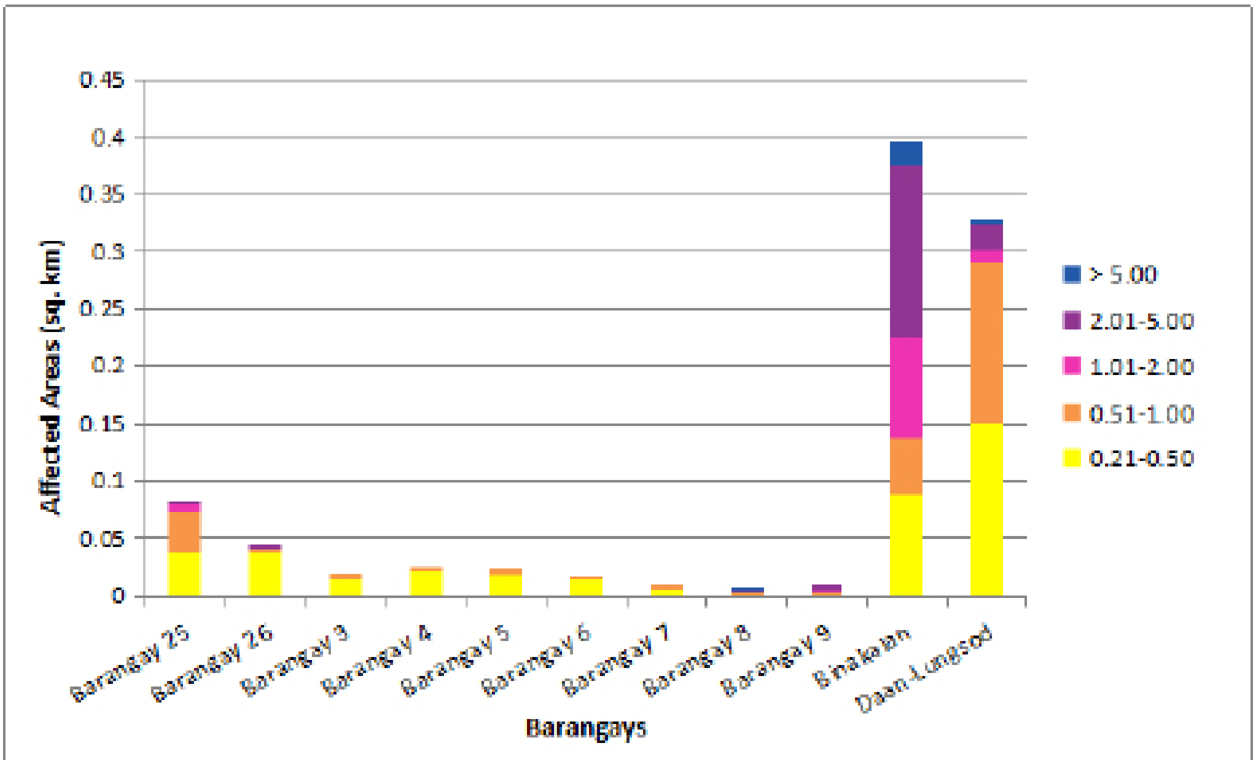

Figure 74. Affected areas in Gingoog City, Misamis Oriental during a 25-year rainfall return period

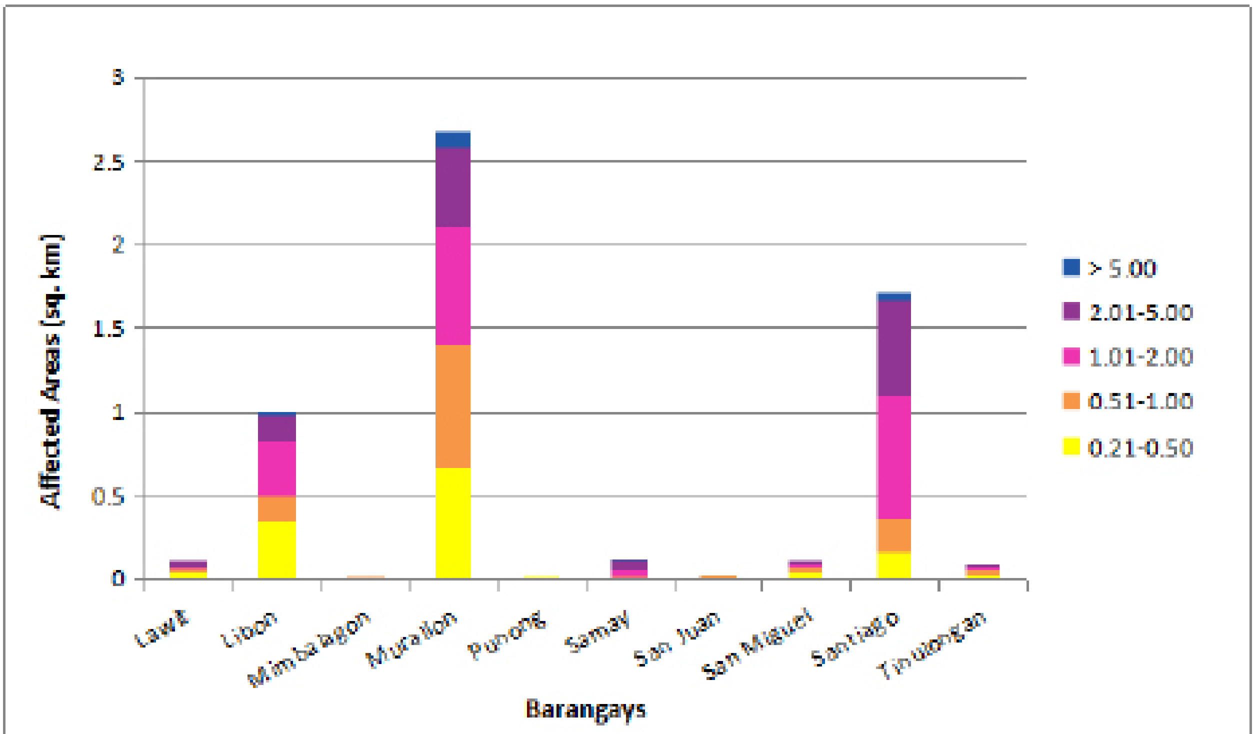

Figure 75. Affected areas in Gingoog City, Misamis Oriental during a 25-year rainfall return period

For the 25-year return period, 3.75% of Gingoog City with an area of 538.032214 sq. km. will experience flood levels of less than 0.20 meters.; 0.54% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.55%, 0.76%, 0.32%, and 0.05% 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 Table 42 to Table 45 are the affected areas in square kilometers by flood depth per barangay.

Table 46. Affected areas Gingoog City, Misamis Oriental during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Gingoog City (in sq. km)										
	Bagubad	Bakidbakid	Barangay 1	Barangay 10	Barangay 11	Barangay 12	Barangay 13	Barangay 14	Barangay 15	Barangay 16	Barangay 17
0.03-0.20	0.0037	0.42	0.024	0.012	0	0.00011	0.0056	0.0036	0.016	0.036	0.0035
0.21-0.50	0.0001	0.037	0.0013	0.0075	0.0082	0.0017	0.007	0.018	0.022	0.0046	0.034
0.51-1.00	0	0.029	0.0011	0.00086	0.014	0.019	0.018	0.016	0.0024	0.0038	0.059
1.01-2.00	0	0.0051	0.0012	0	0	0.0011	0.0028	0.0003	0	0.0023	0.07
2.01-5.00	0	0.0001	0.0039	0	0	0	0	0	0	0.017	0
> 5.00	0	0	0.0037	0	0	0	0	0	0	0	0

Table 47. Affected areas Gingoog City, Misamis Oriental during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Gingoog City (in sq. km)										
	Barangay 18	Barangay 18-A	Barangay 19	Barangay 2	Barangay 20	Barangay 21	Barangay 22	Barangay 22-A	Barangay 23	Barangay 24	Barangay 24-A
0.03-0.20	0.0015	0.0073	0.02	0.022	0.08	0.013	0	0.6	0.044	0.063	0.71
0.21-0.50	0.019	0.033	0.029	0.0088	0.1	0.018	0.0086	0.29	0.11	0.064	0.22
0.51-1.00	0.024	0.11	0.29	0.0019	0.26	0.014	0.028	0.15	0.33	0.064	0.12
1.01-2.00	0.027	0.46	0.71	0.0015	0.97	0	0.0001	0.12	0.04	0.018	0.056
2.01-5.00	0	0.031	0.14	0	0.17	0	0	0.0013	0.024	0.0084	0.038
> 5.00	0	0	0.022	0	0.07	0	0	0.002	0.012	0.0034	0.0082

Table 48. Affected areas Gingoog City, Misamis Oriental during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Gingoog City (in sq. km)										
	Barangay 25	Barangay 26	Barangay 3	Barangay 4	Barangay 5	Barangay 6	Barangay 7	Barangay 8	Barangay 9	Binakalan	Daan-Lungsod
0.03-0.20	0.19	0.089	0.0034	0.00082	0.00077	0.002	0.014	0.0089	0.012	1.89	0.5
0.21-0.50	0.04	0.091	0.015	0.014	0.0092	0.018	0.0094	0.0013	0.0017	0.096	0.11
0.51-1.00	0.044	0.0062	0.0086	0.016	0.015	0.0051	0.000019	0.0017	0.0013	0.047	0.21
1.01-2.00	0.0086	0.0015	0.00014	0.0001	0	0	0	0.0008	0.0013	0.059	0.02
2.01-5.00	0.0056	0.00024	0	0	0	0	0	0.0012	0.0056	0.18	0.024
> 5.00	0	4E-07	0	0	0	0	0	0.001	0.000091	0.033	0.0016

Table 49. Affected areas Gingoog City, Misamis Oriental during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Gingoog City (in sq. km)										
	Lawit	Libon	Mimbalagon	Murallon	Punong	Samay	San Juan	San Miguel	Santiago	Tinulongan	Daan-Lungsod
0.03-0.20	1.3	5.22	0.078	4.42	0.022	0.076	0.037	0.88	2.25	0.072	0.54
0.21-0.50	0.055	0.35	0.0025	0.69	0.0002	0.0014	0.0056	0.039	0.15	0.026	0.15
0.51-1.00	0.024	0.16	0.00063	0.64	0	0.0051	0.0002	0.037	0.13	0.029	0.14
1.01-2.00	0.013	0.26	0	0.83	0	0.029	0	0.021	0.62	0.024	0.012
2.01-5.00	0.01	0.27	0	0.66	0	0.074	0	0.00098	0.82	0.0049	0.022
> 5.00	0	0.0054	0	0.12	0	0.0028	0	0	0.045	0	0.0009

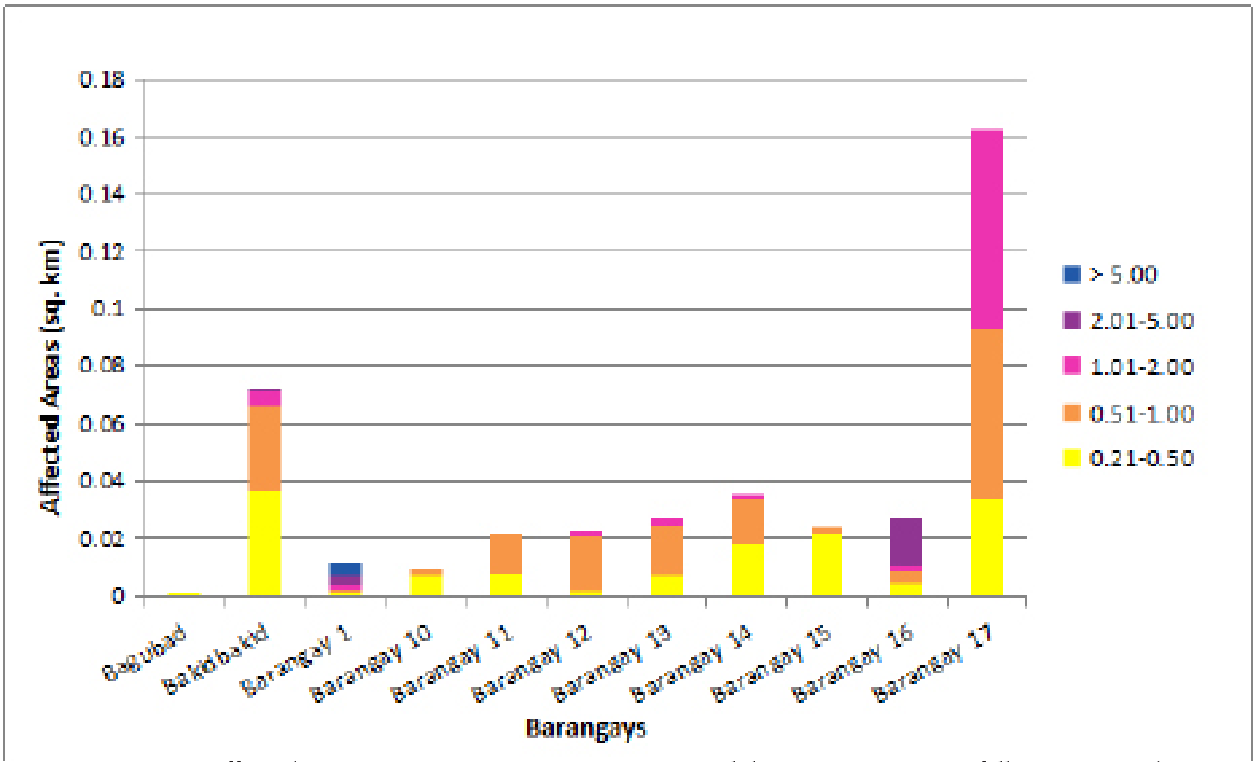

Figure 76. Affected areas in Gingoog City, Misamis Oriental during a 100-year rainfall return period

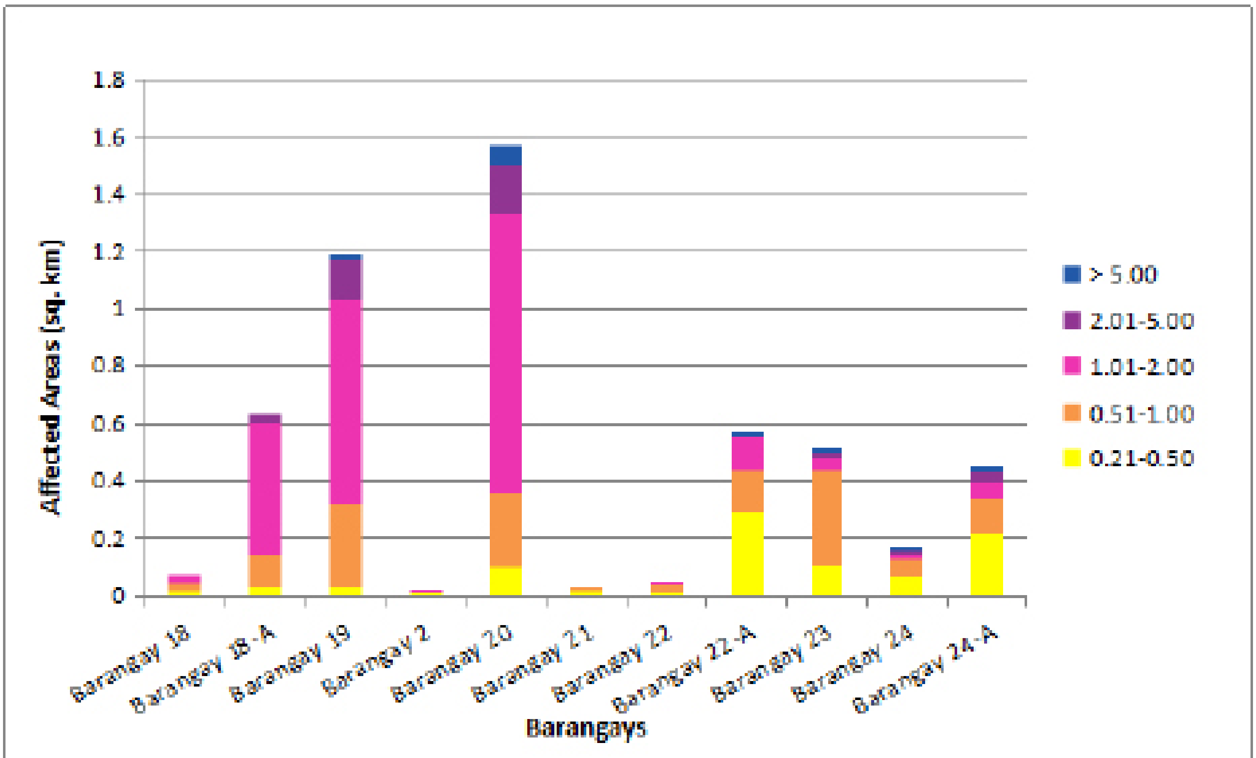

Figure 77. Affected areas in Gingoog City, Misamis Oriental during a 100-year rainfall return period

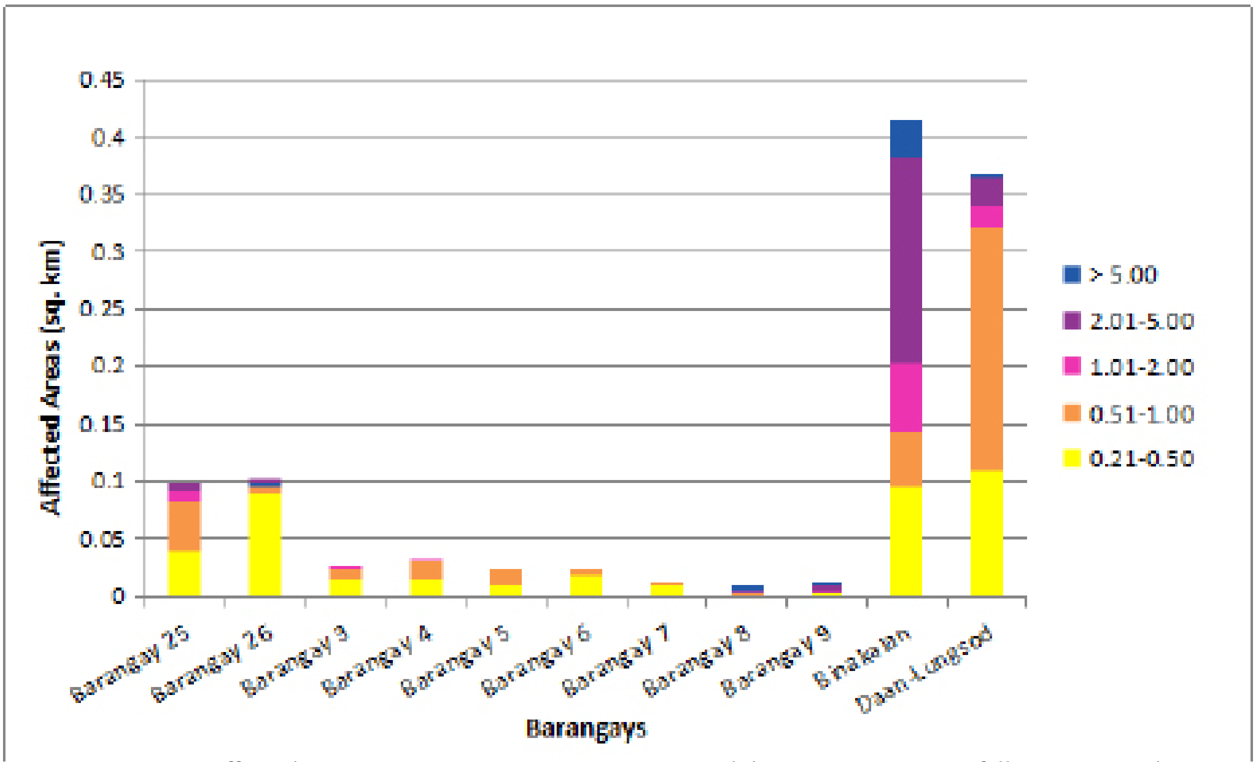

Figure 78. Affected areas in Gingoog City, Misamis Oriental during a 100-year rainfall return period

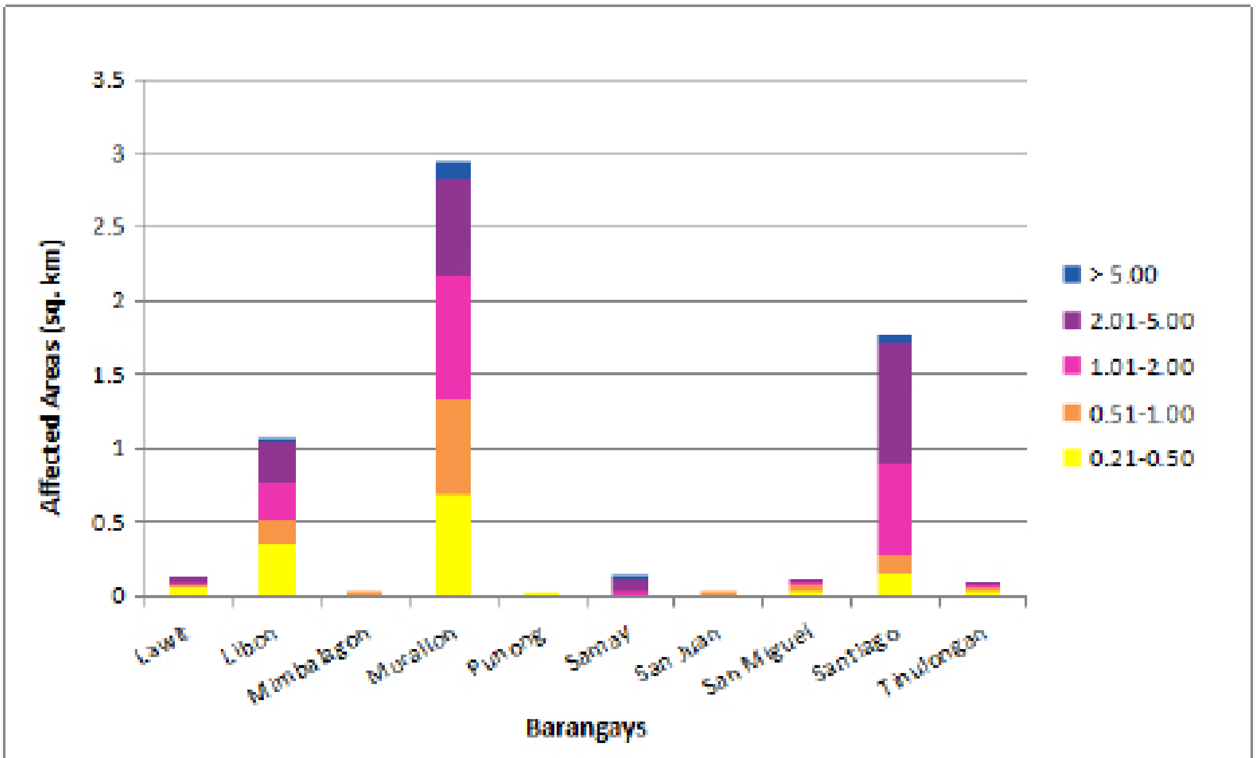

Figure 79. Affected areas in Gingoog City, Misamis Oriental during a 100-year rainfall return period

Among the barangays of Gingoog City in Misamis Oriental, Murallon is projected to have the highest percentage of area that will experience flood levels at 1.37%. Meanwhile, Libon posted the second highest percentage of area that may be affected by flood depths at 1.16%.

Moreover, the generated flood hazard maps for the Gahub-Gingoog Floodplain were used to assess the vulnerability of the educational and medical institutions in the floodplain. Using the flood depth units of PAG-ASA for hazard maps ("Low,", "Medium,", and "High"), the affected institutions were given their individual assessment for each flood hazard scenario (5-year, 25-year, and 10-year).

Table 50. Areas covered by each warning level with respect to the rainfall scenarios

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	3.10	2.96	2.84
Medium	4.96	5.17	5.02
High	2.38	3.97	5.23
TOTAL	**10.44**	**12.1**	**13.09**

Of the 25 identified educational institutionse in Gahub Floodplain, seven (7) schools were discovered to be exposed to low-level flooding during a 5-year scenario, while three (3) schools were found to be exposed to medium-level flooding in the same scenario.

In the 25-year scenario, 11 schools were found to be exposed to low-level flooding, while seven (7) schools were discovered to be exposed to medium-level flooding.

For the 100-year scenario, seven (7) schools were discovered to be exposed to low-level flooding, while 12 schools were exposed to medium-level flooding. See Appendix DANNEX 12 for a detailed enumeration of educational institutions affected in Gahub Floodplain.

Apart from this, five (5) medical institutions were identified in the GiingoogGahub Floodplain, one of which was assessed to be exposed to low-level flooding during the 5- and 25- year scenarios. For the 100-year scenario, two (2) institutions are assessed to be exposed to low-level flooding while one (1) is found to be exposed to medium-level flooding. See Appendix EANNEX 13 for a detailed enumeration of medical institutions affected in Gahub Floodplain.

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 gathered 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 1Phil-LiDAR 1 Program, multiple points representing the different flood depths for different scenarios are were identified for validation.

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

After which, the actual data from the field will bewere 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 366 points randomly selected all over the Gahub Floodplain. It has an RMSE value of 0.95.

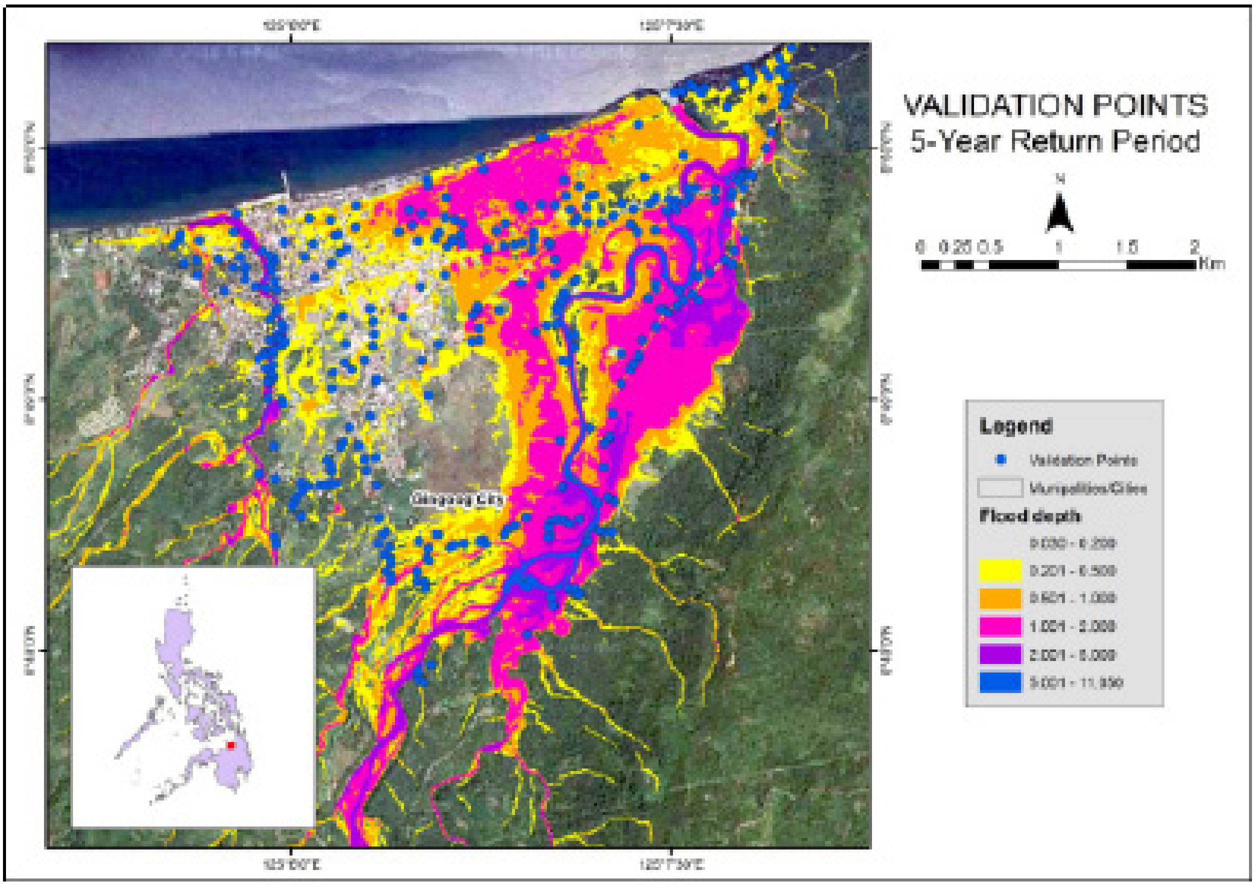

Figure 80. Gahub-Gingoog flood validation points

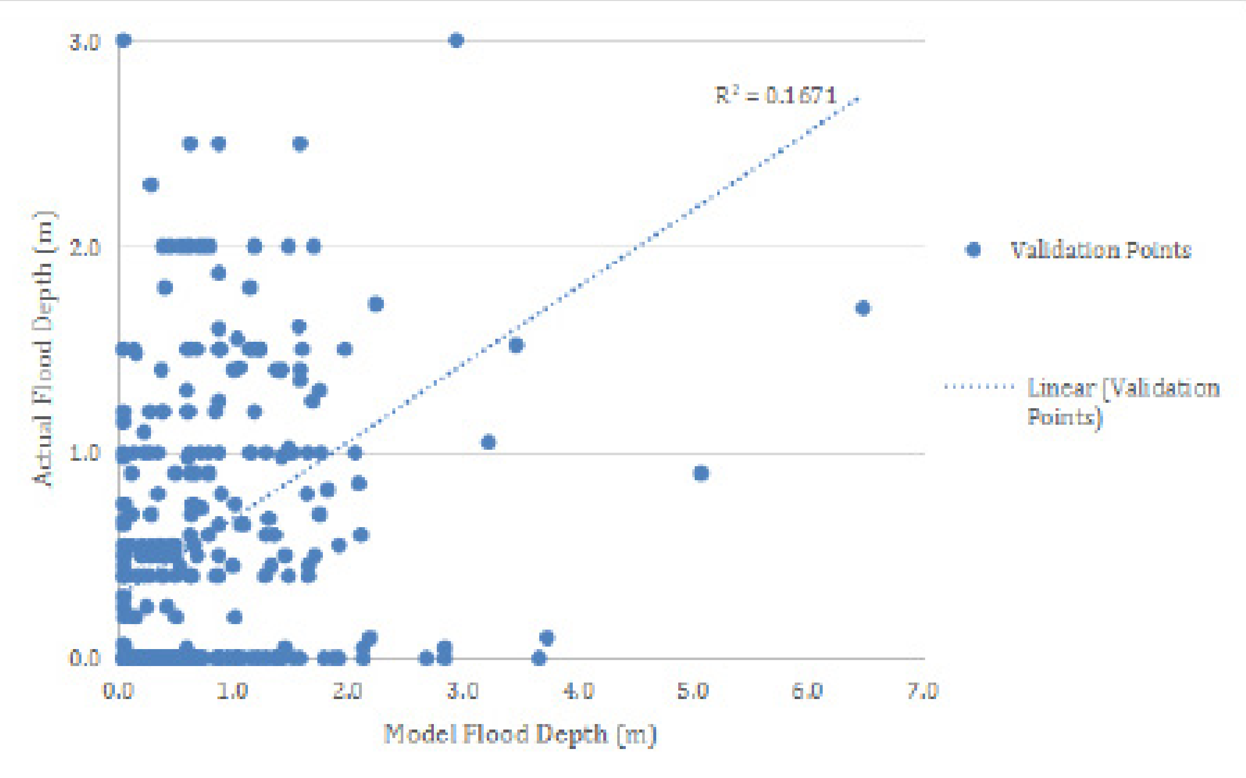

Figure 81. Flood map depth vs. actual flood depth

Table 51. Actual flood vs. simulated flood depth at differnentdifferent levels in the Gahub - Gingoog River Basin

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	62	37	37	27	9	0	172
0.21-0.50	18	15	9	7	0	0	49
0.51-1.00	14	13	21	19	3	1	71
1.01-2.00	6	8	19	26	3	1	63
2.01-5.00	2	1	3	1	1	3	11
> 5.00	0	0	0	0	0	0	0
Total	102	74	89	80	16	5	366

The overall accuracy generated by the flood model is was estimated at 34.15% with 125 points correctly matching the actual flood depths. In addition, there were 109 points estimated one level above and below the correct flood depths while there were 73 points and 46 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 4 points were overestimated while a total of 85 points were underestimated in the modeled flood depths of Gahub - Gingoog.

Table 45. The summary of the Accuracy Assessment in the Gahub River Basin Survey

	No. of Points	%
Correct	125	34.15
Overestimated	156	42.62
Underestimated	85	23.22
Total	366	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.

ANNEXES

Annex 1. OPTECH Technical Specification of the Pegasus Sensor

Table A-1.1 Technical specification of the Pegasus Sensor

Parameter	Specification
Operational envelope (1,2,3,4)	150-5000 m AGL, nominal
Laser wavelength	1064 nm
Horizontal accuracy (2)	1/5,500 x altitude, 1σ
Elevation accuracy (2)	< 5-20 cm, 1σ
Effective laser repetition rate	Programmable, 100-500 kHz
Position and orientation system	POS AV ™AP50 (OEM)
Scan width (FOV)	Programmable, 0-75 ˚
Scan frequency (5)	Programmable, 0-140 Hz (effective)
Sensor scan product	800 maximum
Beam divergence	0.25 mrad (1/e)
Roll compensation	Programmable, ±37˚ (FOV dependent)
Vertical target separation distance	<0.7 m
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)
Image capture	5 MP interline camera (standard); 60 MP full frame (optional)
Full waveform capture	12-bit Optech IWD-2 Intelligent Waveform Digitizer
Data storage	Removable solid state disk SSD (SATA II)
Power requirements	28 V, 800 W, 30 A
Dimensions and weight	Sensor: 630 x 540 x 450 mm; 65 kg;
	Control rack: 650 x 590 x 490 mm; 46 kg
Operating Temperature	-10°C to +35°C
Relative humidity	0-95% non-condensing

1 Target reflectivity ≥20%

2 Dependent on selected operational parameters using nominal FOV of up to 40° in standard atmospheric conditions with 24-km visibility

3 Angle of incidence ≤20°

4 Target size ≥ laser footprint

5 Dependent on system configuration

Annex 2. NAMRIA Certificates of Reference Points Used in the LiDAR Survey

1. MSE-31

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

June 06, 2014

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: **MISAMIS ORIENTAL**	
	Station Name: **MSE-31**	
Island: **MINDANAO**	Order: **2nd**	Barangay: **SITIO: NARATULAN**
Municipality: **BINUANGAN**		
	PRS92 Coordinates	
Latitude: **8° 55' 28.57032"**	Longitude: **124° 46' 55.45600"**	Ellipsoidal Hgt: **59.48400 m.**
	WGS84 Coordinates	
Latitude: **8° 55' 24.88251"**	Longitude: **124° 47' 0.81947"**	Ellipsoidal Hgt: **126.49000 m.**
	PTM Coordinates	
Northing: **986806.828 m.**	Easting: **476032.898 m.**	Zone: **5**
	UTM Coordinates	
Northing:	Easting:	Zone:

Location Description

MSE-31
From the town proper of Medina, travel W along provincial road for about 40km to the municipality of Binuangan. Just beside Km. Post 1389 is Binuangan National High School. Station is located just within the school, about 4m W on the 3rd post of the wall inline with the school gate, and about 9m W of Km post 1389. Approximately 300 m past the school is the municipal hall. Station mark is the head of a 4" copper nail, top-centered on a 30cm x 30cm x 60cm concrete block, protruding by about 7cm, with inscriptions, MSE-31, 2003 NAMRIA.

Requesting Party: **UP-TCAGP**
Pupose: **Reference**
OR Number: **8796290 A**
T.N.: **2014-1289**

For **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

Figure A-2.1 MSE-31

2. MSE-32

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

June 06, 2014

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: **MISAMIS ORIENTAL**	
	Station Name: **MSE-32**	
Island: **MINDANAO** Municipality: **SUGBONGCOGON**	Order: **2nd**	Barangay: **ALICOMOHAN**
	PRS92 Coordinates	
Latitude: **8° 56' 30.44605"**	Longitude: **124° 46' 58.97104"**	Ellipsoidal Hgt: **132.12900 m.**
	WGS84 Coordinates	
Latitude: **8° 56' 26.75387"**	Longitude: **124° 47' 4.33290"**	Ellipsoidal Hgt: **199.10100 m.**
	PTM Coordinates	
Northing: **988707.53 m.**	Easting: **476141.401 m.**	Zone: **5**
	UTM Coordinates	
Northing: **988,828.70**	Easting: **696,045.73**	Zone: **51**

Location Description

MSE-32
From the town proper of Medina, travel W along provincial road for about 40kms. to the municipality of Sugbongcogon. Approximately a km. S of the municipal hall, and just before the boundary of Binuangan and Sugbongcogon, is Alicomohan Elementary School in barangay Alicomohan. The station is located on the E edge of a concrete platform, and beside the western corner of a staircase. It is approximately halfway between the school gate and the flagpole, about 12m WNW of the flagpole, and about 12m ESE of the school gate. It is also about 50cm SW of the junction between the E edge of the concrete platform and the second set of concrete steps. Station mark is the head of a 2-1/2" copper nail, top-centered on a 15cm x 15cm cement putty with inscriptions, MSE-32, 2003 NAMRIA.

Requesting Party: **UP-TCAGP**
Pupose: **Reference**
OR Number: **8796290 A**
T.N.: **2014-1290**

For 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

Figure A-2.2 MSE-32

3. MSE-36

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

June 24, 2014

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: **MISAMIS ORIENTAL**	
	Station Name: **MSE-36**	
	Order: **2nd**	
Island: **MINDANAO**		Barangay: **SOUTH POBLACION**
Municipality: **MEDINA**		
	PRS92 Coordinates	
Latitude: **8° 54' 20.12398"**	Longitude: **125° 1' 28.36102"**	Ellipsoidal Hgt: **0.97100 m.**
	WGS84 Coordinates	
Latitude: **8° 54' 16.46220"**	Longitude: **125° 1' 33.72408"**	Ellipsoidal Hgt: **68.51700 m.**
	PTM Coordinates	
Northing: **984697.224 m.**	Easting: **502699.481 m.**	Zone: **5**
	UTM Coordinates	
Northing: **984,961.57**	Easting: **722,630.22**	Zone: **51**

Location Description

MSE-36
The station is located at Medina municipal port, Brgy. South Poblacion, Medina, Misamis Oriental. Medina municipal port is just in front of Tiro residence, and about 85m SSE of Medina lighthouse where station MSE-47 is located. Beside the port is a Beer na beer warehouse. The station is approximately 60cm W of the E edge of the pier and approximately 20m N from the S end of the pier. Station mark is the head of a 4" copper nail, top-centered on a 19cm x 18cm cement putty, with inscriptions, MSE-36, 2003 NAMRIA.

Requesting Party: **Engr. Cruz**
Pupose: **Reference**
OR Number: **8796376 A**
T.N.: **2014-1438**

For **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

Figure A-2.3 MSE-36

Annex 3. Baseline Processing Reports of Control Points used in the LIDAR Survey

There are no baseline processing reports available for the Gahub river basin.

Annex 4. The LiDAR Survey Team Composition

Table A-4.1 LiDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	UP-TCAGP
		LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	JASMINE ALVIAR	UP-TCAGP
	Research Associate (RA)	GRACE SINADJAN	UP-TCAGP
	RA	ENGR. IRO NIEL ROXAS	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	LANCE KERWIN CINCO	UP-TCAGP
LiDAR Operation	Airborne Security	SSG. LEE JAY PUNZALAN	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. JEFFREY JEREMY ALAJAR	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. CESAR ALFONSO III	AAC

Annex 5. Data Transfer Sheet For Gahub Floodplain

DATA TRANSFER SHEET
06/10/2014(Northern Mindanao) Ongoing

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	
5/22/2014	1497P	1BLK67B142A	PEGASUS	1.8	1342	8.61	201	31.8	221	19.1	NA	5.19	1KB	1KB	49	NA	Z:\Airborne_Raw\1497P
5/23/2014	1501P	1BLK67C143A	PEGASUS	3	1221	14.1	271	77.3	539	29.5	NA	7.61	1KB	1KB	59/56	NA	Z:\Airborne_Raw\1501P
5/24/2014	1505P	1BLK67BC144A	PEGASUS	2.25	759	10	212	46.7	340	21.8	NA	7.68	1KB	1KB	97	NA	Z:\Airborne_Raw\1505P
5/25/2014	1509P	1RDXE145A	PEGASUS	2.4	338	11.2	254	NA 31.6/22	~~31.6/22~~ NA	26.2	NA	4.96	1KB	1KB	50/43	NA	Z:\Airborne_Raw\1509P
5/27/2014	1517P	1RXE147A	PEGASUS	2.74	1497	12	235	NA	NA	27.7	NA	9.7	1KB	1KB	78/72	NA	Z:\Airborne_Raw\1517P
5/28/2014	1521P	1RXC148A	PEGASUS	2.39	490	12	252	NA	NA	28	NA	5.54	1KB	1KB	52	NA	Z:\Airborne_Raw\1521P

Received from

Name C. Joaquin
Position
Signature

Received by

Name JOIDA PRIETO
Position SSRS
Signature 6/10/2014

Figure A-5.1 Data Transfer Sheet for Gahub Floodplain - A

DATA TRANSFER SHEET
06/20/2014(Northern Mindanao)

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	
29-May-14	1525P	1RXB149A	PEGASUS	1.6	457	9.27	265	na	na	26.5	NA	9.83	1KB	1KB	40	NA	Z:\Airborne_Raw\1525P
31-May-14	1533P	1BLK67151A	PEGASUS	3.32	270	14.4	224	43.2	428	33.3	NA	8.87	1KB	1KB	47/38	NA	Z:\Airborne_Raw\1533P
2-Jun-14	1541P	1BLK71B153A	PEGASUS	4	242	0	285	19.7	139	39	674MB	12.6	1KB	1KB	47/45/40/34	NA	Z:\Airborne_Raw\1541P
3-Jun-14	1545P	1BLK71C154A	PEGASUS	4.13	2259	13	253	69.7	533	40.1	272MB	9.95	1KB	1KB	141	NA	Z:\Airborne_Raw\1545P
4-Jun-14	1549P	1BLK71D155A	PEGASUS	3.48	150	14.3	264	NA	NA	34.6	NA	11.2	1KB	1KB	54/50/45	NA	Z:\Airborne_Raw\1549P
7-Jun-14	1561P	1RXE158A	PEGASUS	NA	44	NA	187	NA	NA	22	NA	8.1	1KB	1KB	71	NA	Z:\Airborne_Raw\1561P
8-Jun-14	1565P	1BLK71B159A	PEGASUS	NA	16	5.35	168	22.1	163	13.3	NA	7.75	1KB	1KB	36	NA	Z:\Airborne_Raw\1565P

Received from

Name C. JOAQUIN
Position RA
Signature [signature]

Received by

Name JOIDA F. PRIETO
Position SSRS
Signature [signature] 6/23/2014

Figure A-5.2 Data Transfer Sheet for Gahub Floodplain - B

Annex 6. Flight Logs for Flight Missions

1. Flight Log for 1521P Mission

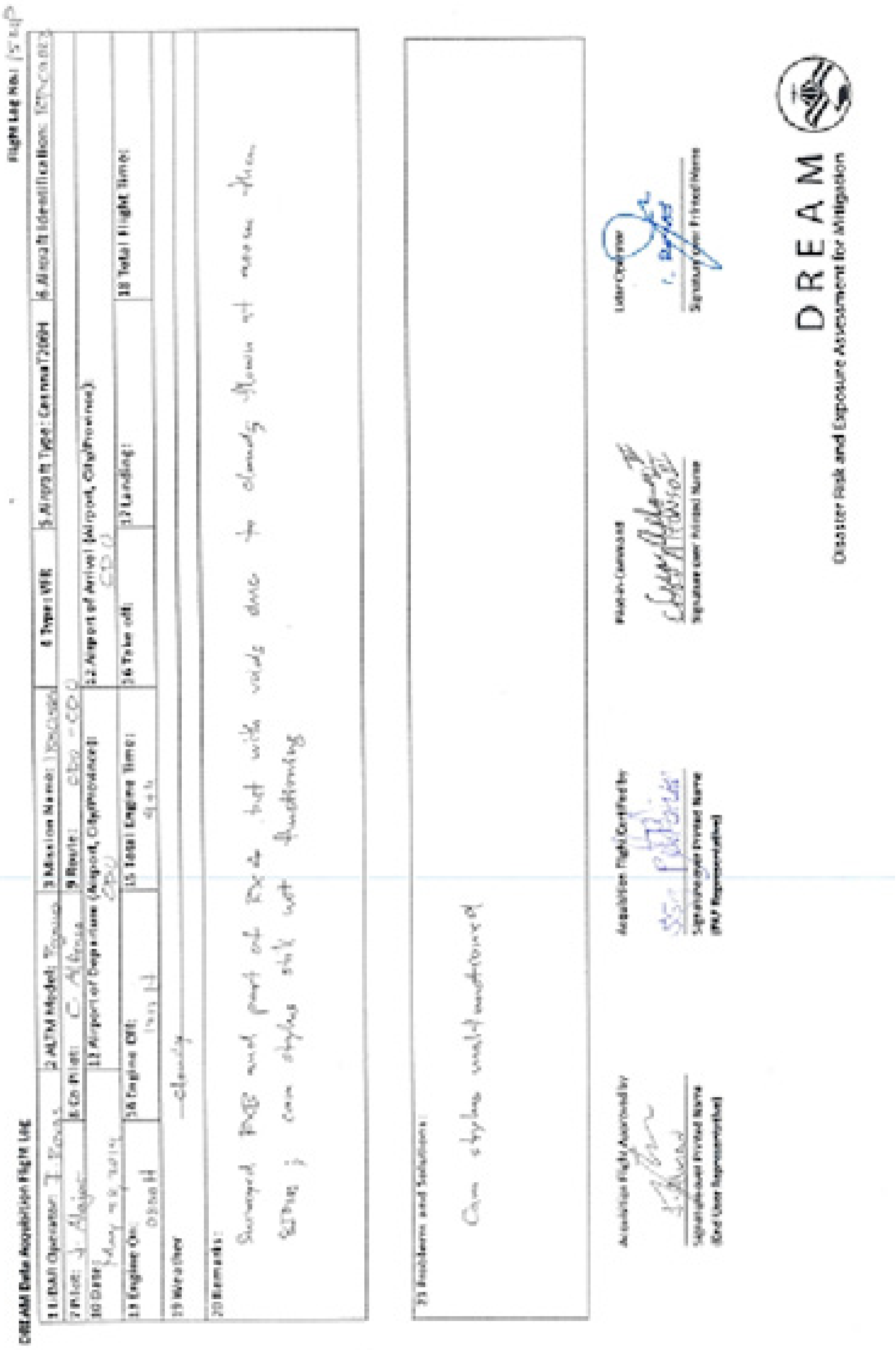

Figure A-6.1 Flight Log for 1521P Mission

2. Flight Log for 1525P Mission

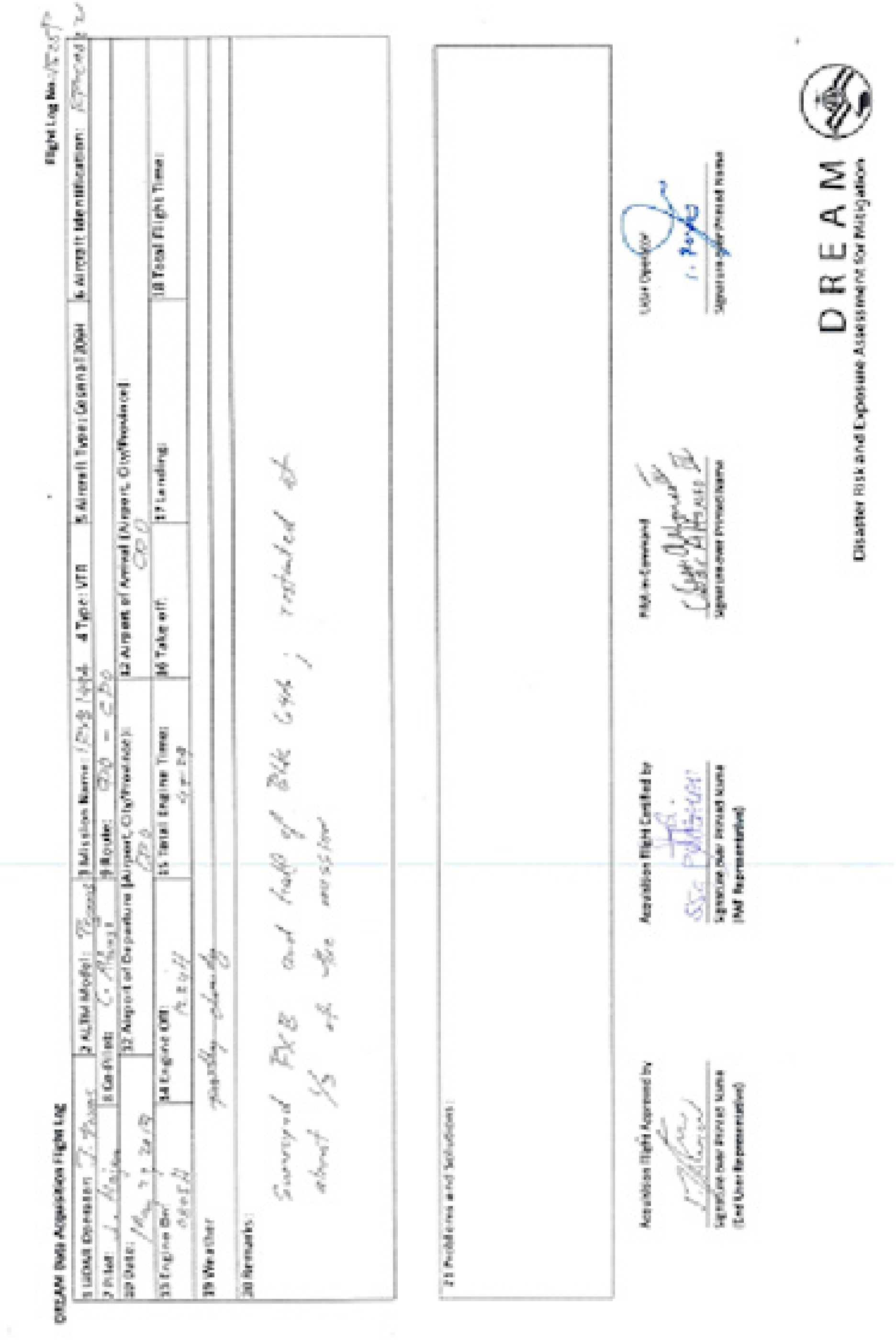

Figure A-6.2 Flight Log for 1525P Mission

Annex 7. Flight Status Reports

Table 7.1 Flight Status Reports

NORTHERN MINDANAO (May 28-29, 2014)					
FLIGHT NO	**AREA**	**MISSION**	**OPERATOR**	**DATE FLOWN**	**REMARKS**
1521P	RX A, B, RXSupple-ment (RXS)	1RXC148A	I. Roxas	May 28, 2014	Surveyed RX B and part of RX A but with voids due to clouds; flown at 900m then 850m; cam stylus still not functioning; to be renamed to 1RXB148A
1525P	BLK 64A, RXS	1RXE149A	I. Roxas	May 29, 2014	Surveyed RX B and half of BLK 64A; restarted at about 1/3 of the mission, no output LAS for lines after restart

LAS BOUNDARIES PER FLIGHT

Flight No. : 1521P

Area: RX A, RX B

Mission Name: 1RXC148A

Parameters: Altitude: 900m; Scan Frequency: 30Hz;

Scan Angle: 25deg; Overlap: 30%

LAS

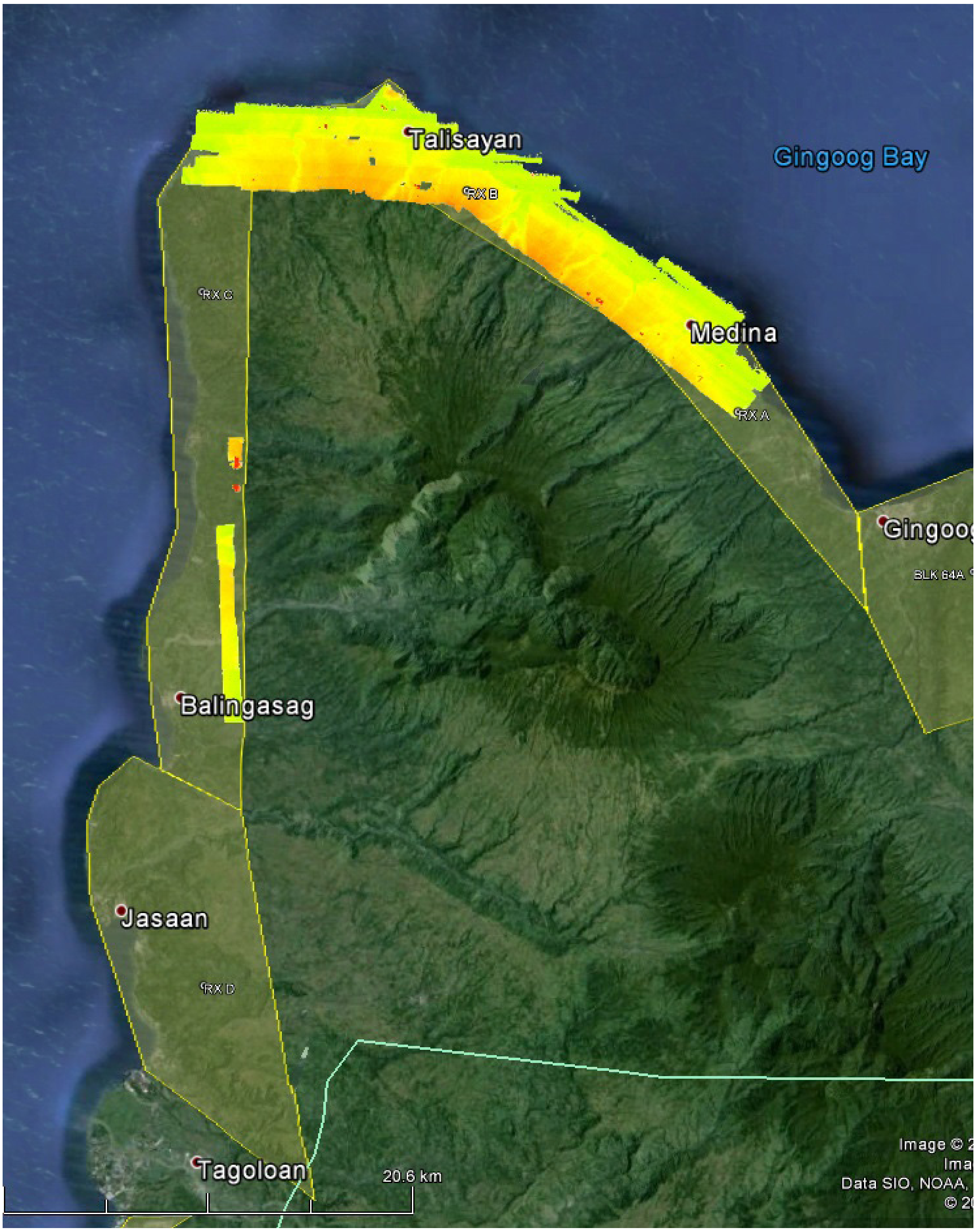

Figure A-7.1 Swath for Flight No. 1521P

Flight No. : 1525P

Area: RX A, BLK 64A

Mission Name: 1RXB149A

Parameters: Altitude: 900m; Scan Frequency: 30Hz;

Scan Angle: 25deg; Overlap: 30%

LAS

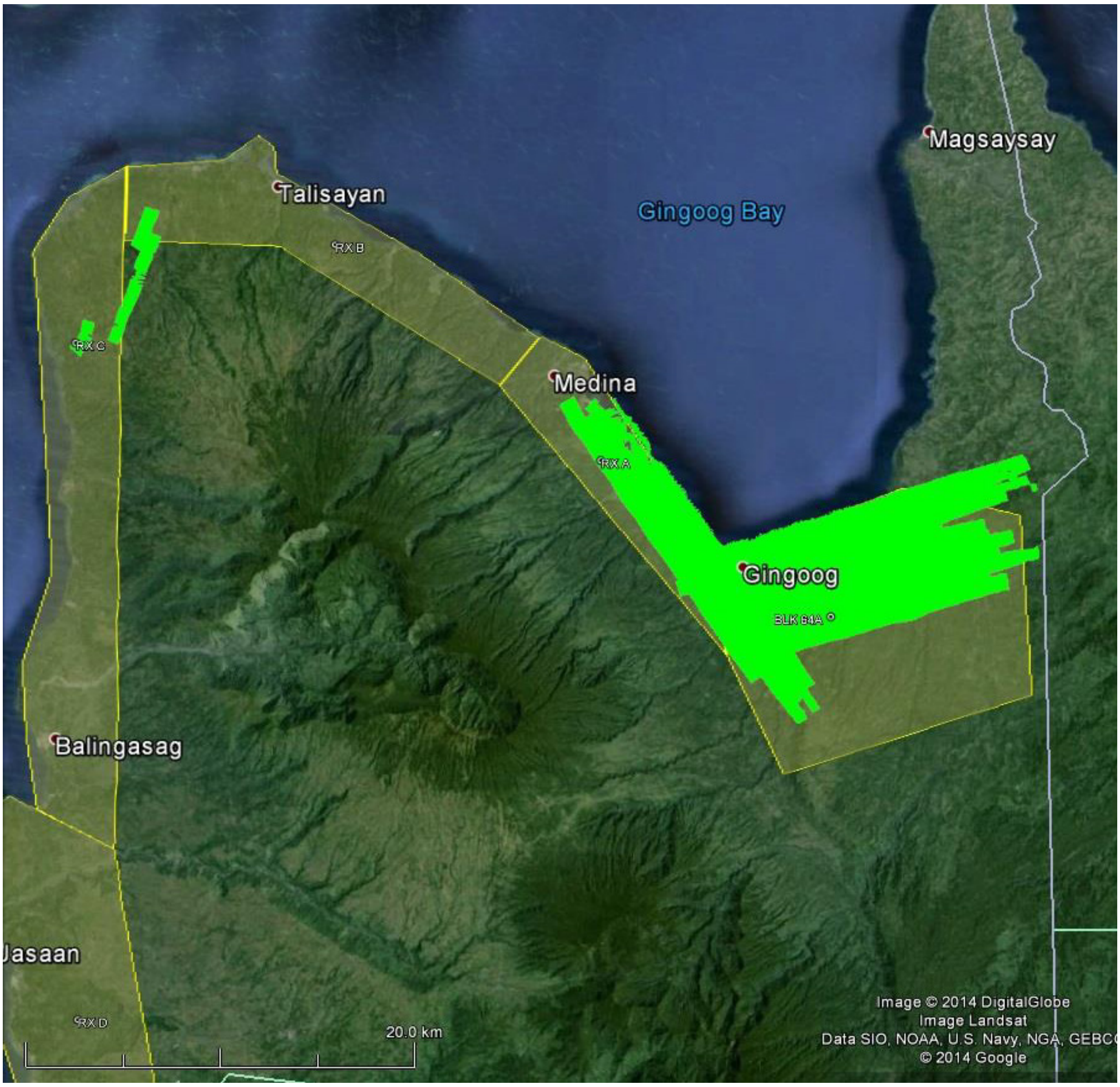

Figure A-7.2 Swath for Flight No. 1525P

Annex 8. Mission Summary Reports

Table A-8.1 Mission Summary Report for Mission Blk64A

Flight Area	Northern Mindanao
Mission Name	Blk64A
Inclusive Flights	1525P
Range data size	26.5 GB
POS data size	265 MB
Base data size	9.83 MB
Image	n/a
Transfer date	June 23, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	0.95
RMSE for East Position (<4.0 cm)	1.04
RMSE for Down Position (<8.0 cm)	1.8
Boresight correction stdev (<0.001deg)	0.000228
IMU attitude correction stdev (<0.001deg)	0.0493
GPS position stdev (<0.01m)	0.0318
Minimum % overlap (>25)	44.22
Ave point cloud density per sq.m. (>2.0)	6.30
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	171
Maximum Height	794.05 m
Minimum Height	66.1 m
Classification (# of points)	
Ground	131,200,834
Low vegetation	154,620,486
Medium vegetation	308,219,562
High vegetation	343,529,636
Building	16,708,805
Orthophoto	
Processed by	Engr. Jennifer Saguran, Engr. Harmond Santos, Engr. Gladys Mae Apat

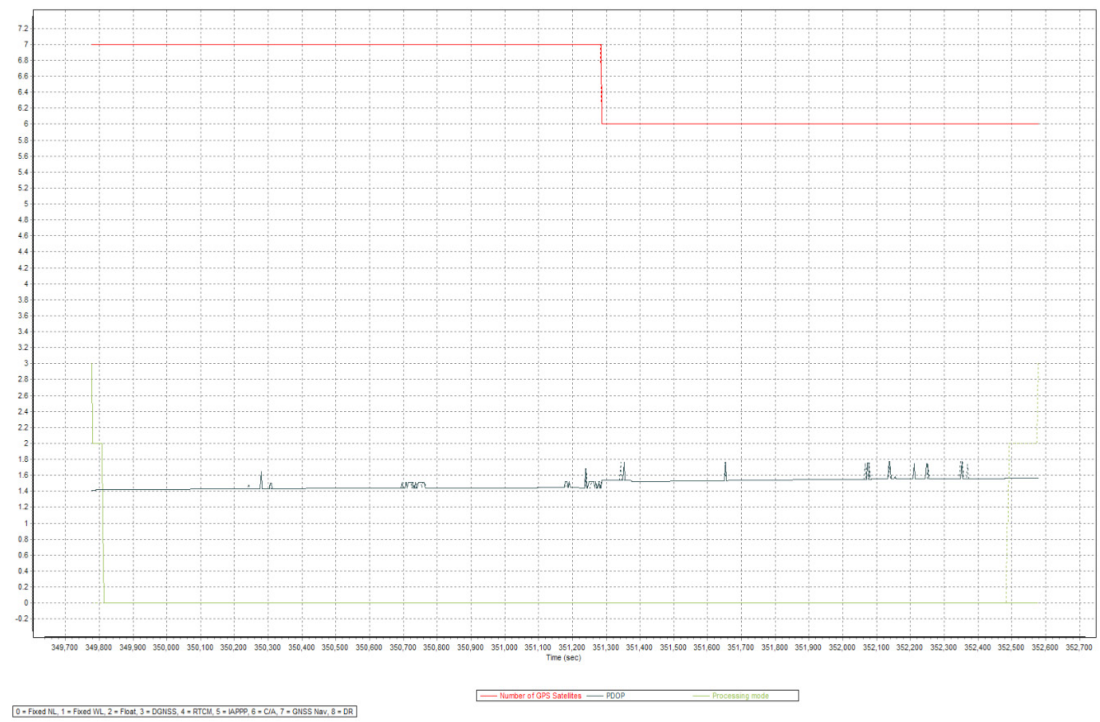

Figure A-8.1 Solution Status

Figure A-8.2 Smoothed Performance Metric Parameters

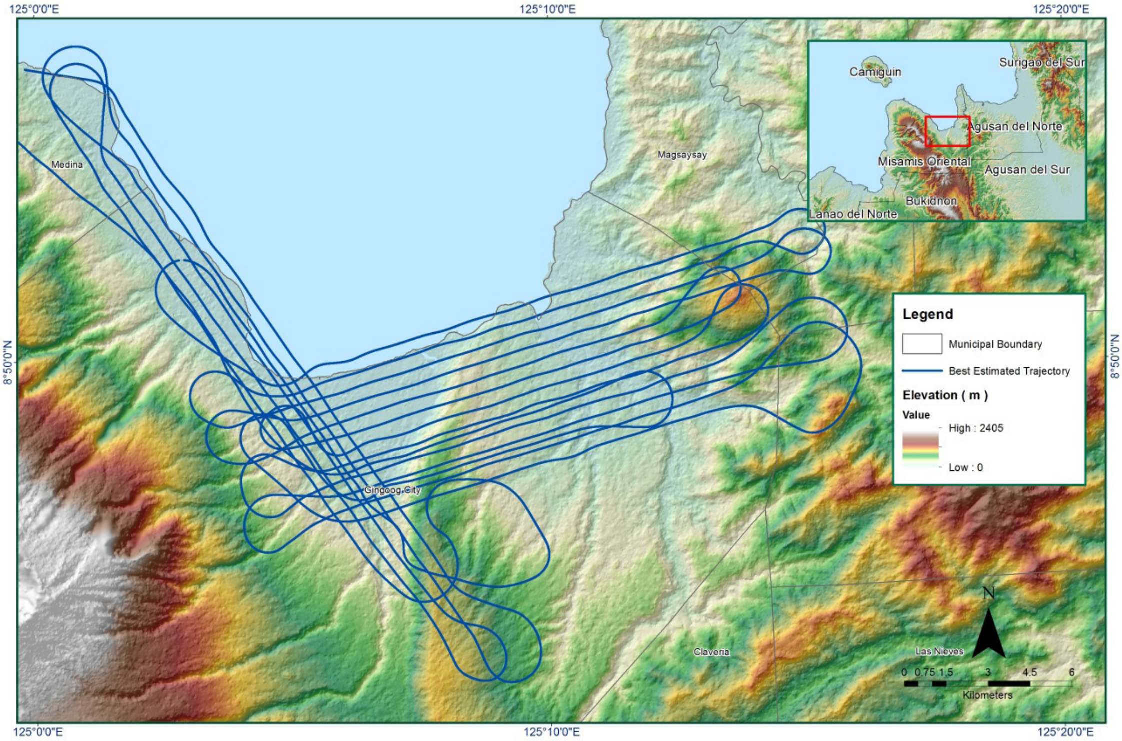

Figure A-8.3 Best Estimated Trajectory

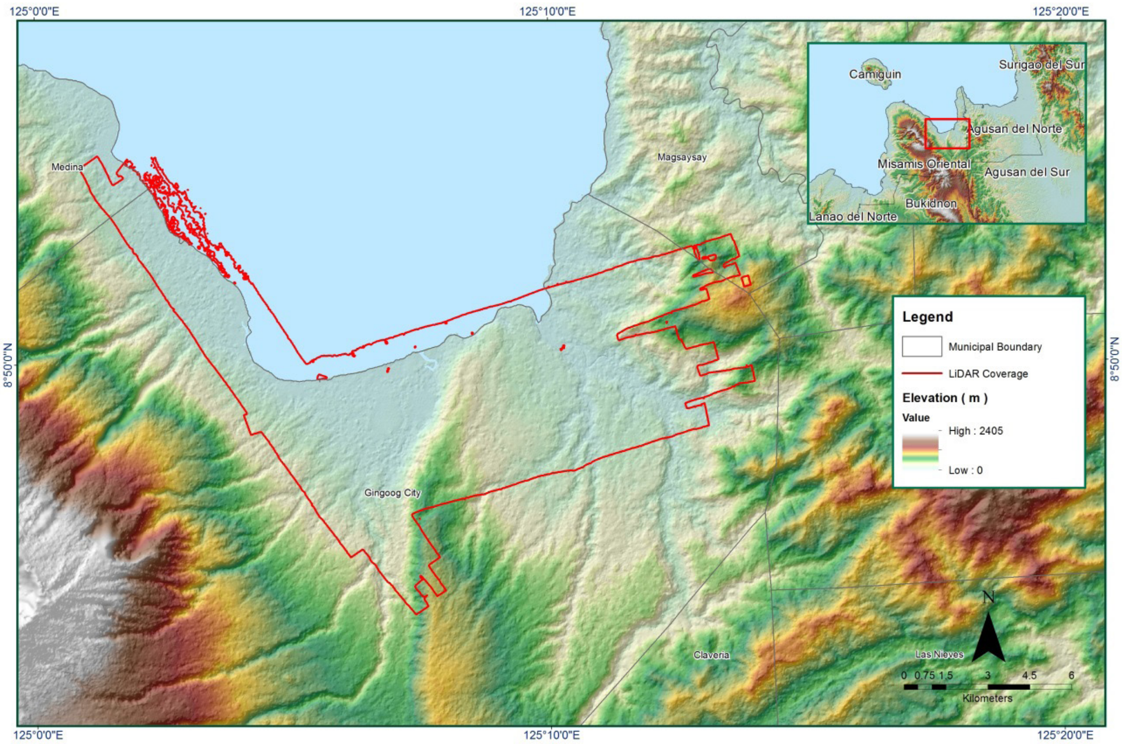

Figure A-8.4 *Coverage of LiDAR data*

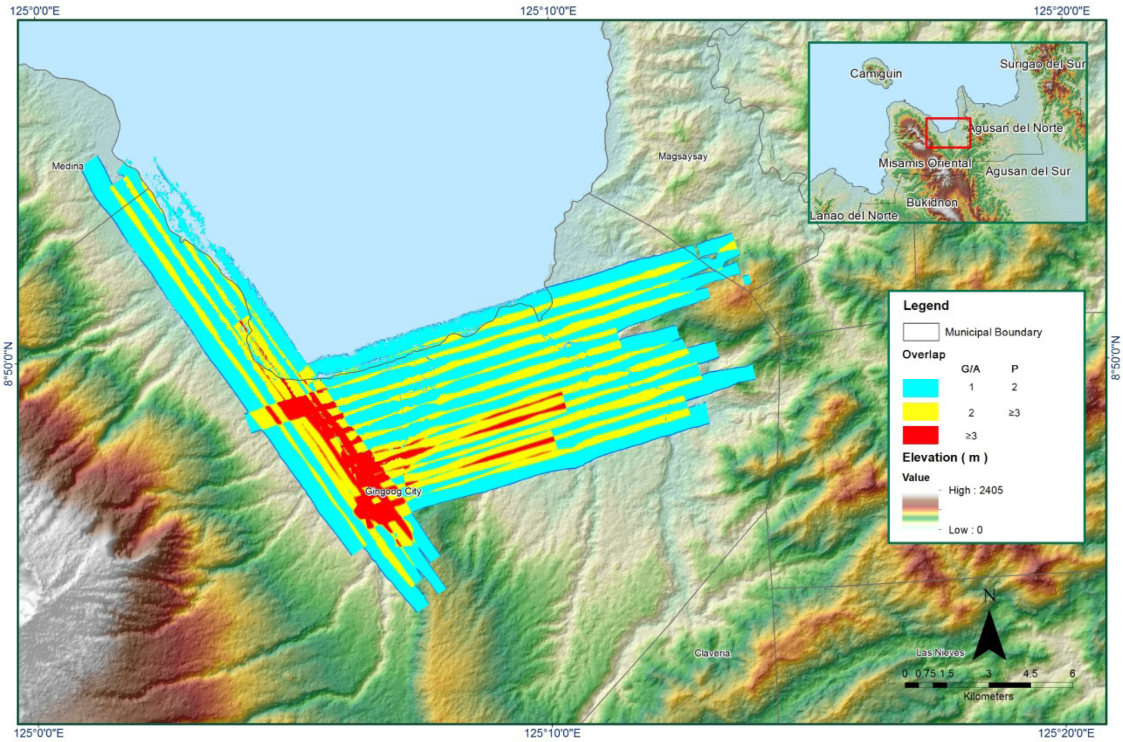

__Figure A-8.5__ Image of data overlap

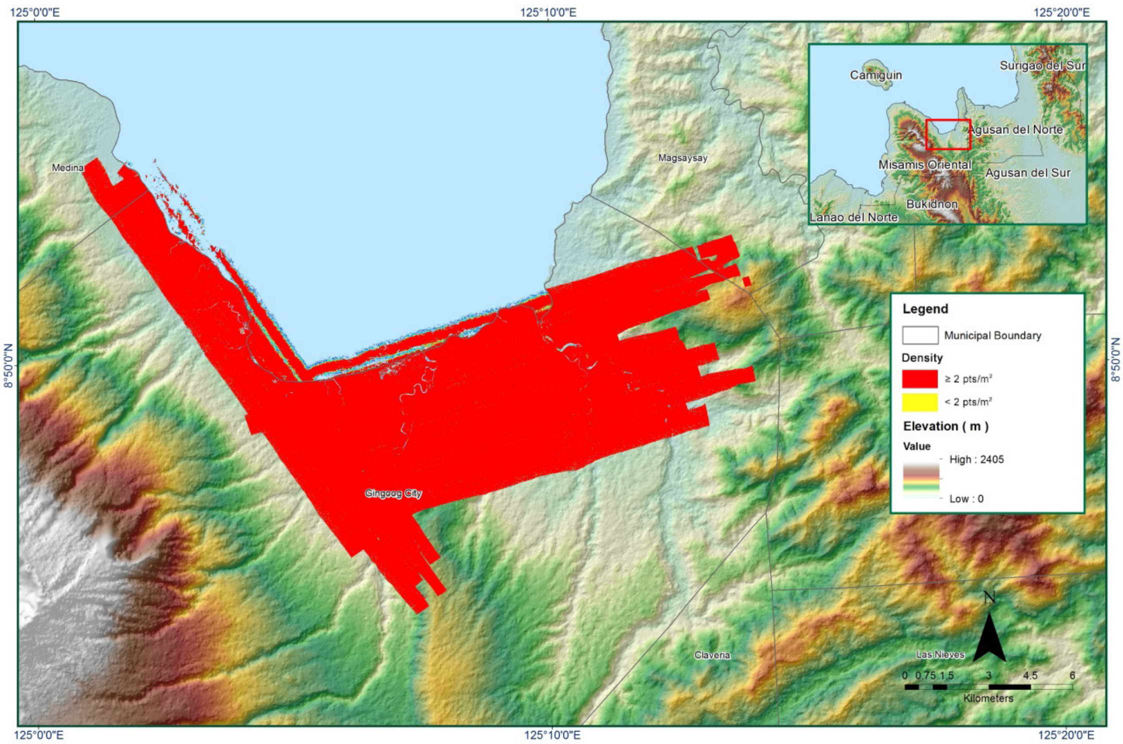

Figure A-8.6 Density map of merged LiDAR data

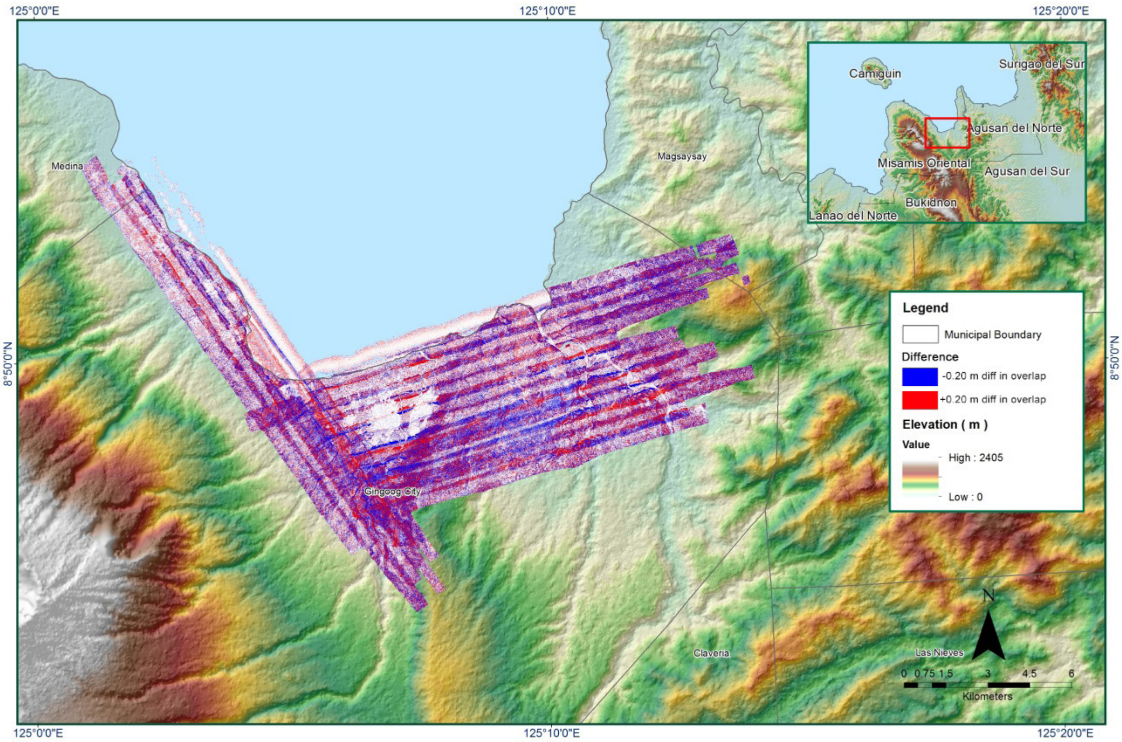

Figure A-8.7 *Elevation difference between flight lines*

Table A-8.2 Mission Summary Report for Mission RX_A

Flight Area	Northern Mindanao
Mission Name	RX_A
Inclusive Flights	1521P
Range data size	28 GB
POS data size	252 MB
Base data size	5.54 MB
Image	n/a
Transfer date	June 10, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.05
RMSE for East Position (<4.0 cm)	1.6
RMSE for Down Position (<8.0 cm)	2.7
Boresight correction stdev (<0.001deg)	0.000202
IMU attitude correction stdev (<0.001deg)	0.000646
GPS position stdev (<0.01m)	0.0027
Minimum % overlap (>25)	50.40
Ave point cloud density per sq.m. (>2.0)	3.98
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	114
Maximum Height	469.96 m
Minimum Height	34.79 m
Classification (# of points)	
Ground	70,130,753
Low vegetation	91,556,121
Medium vegetation	150,469,617
High vegetation	201,117,199
Building	13,619,682
Orthophoto	
Processed by	Engr. Irish Cortez, Engr. Christy Lubiano, Engr. Gladys Mae Apat

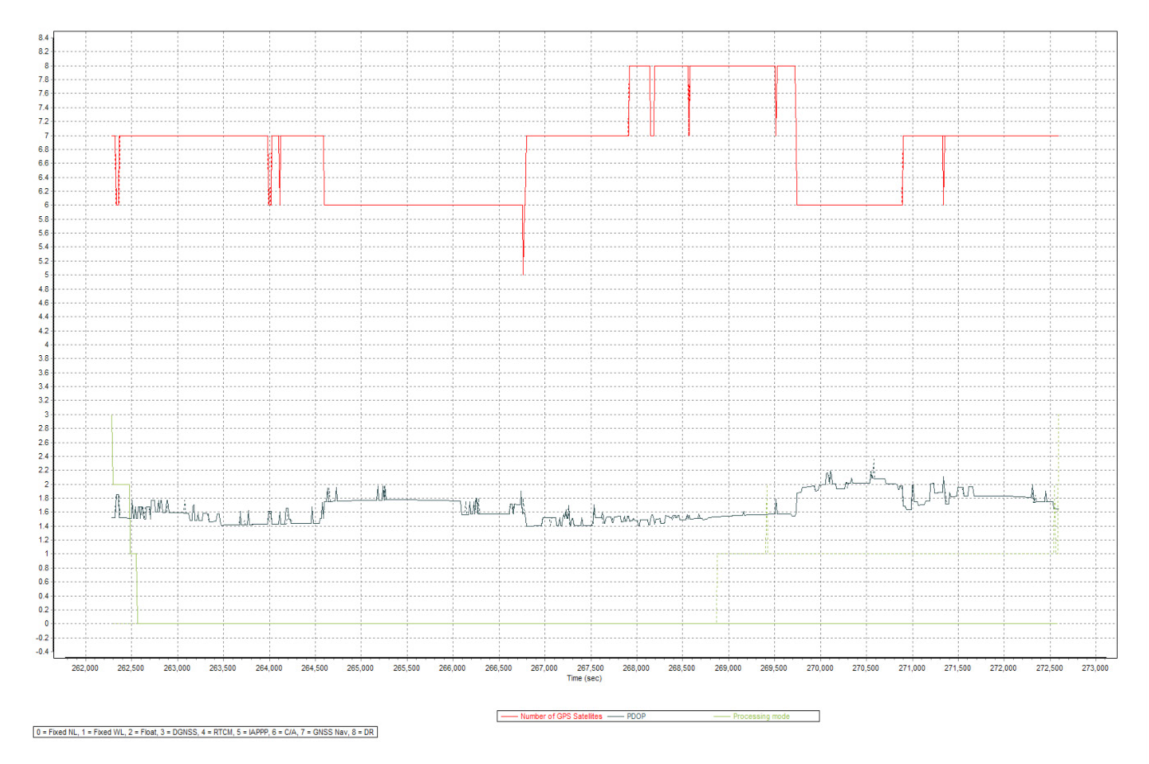

Figure A-8.8 Solution Status

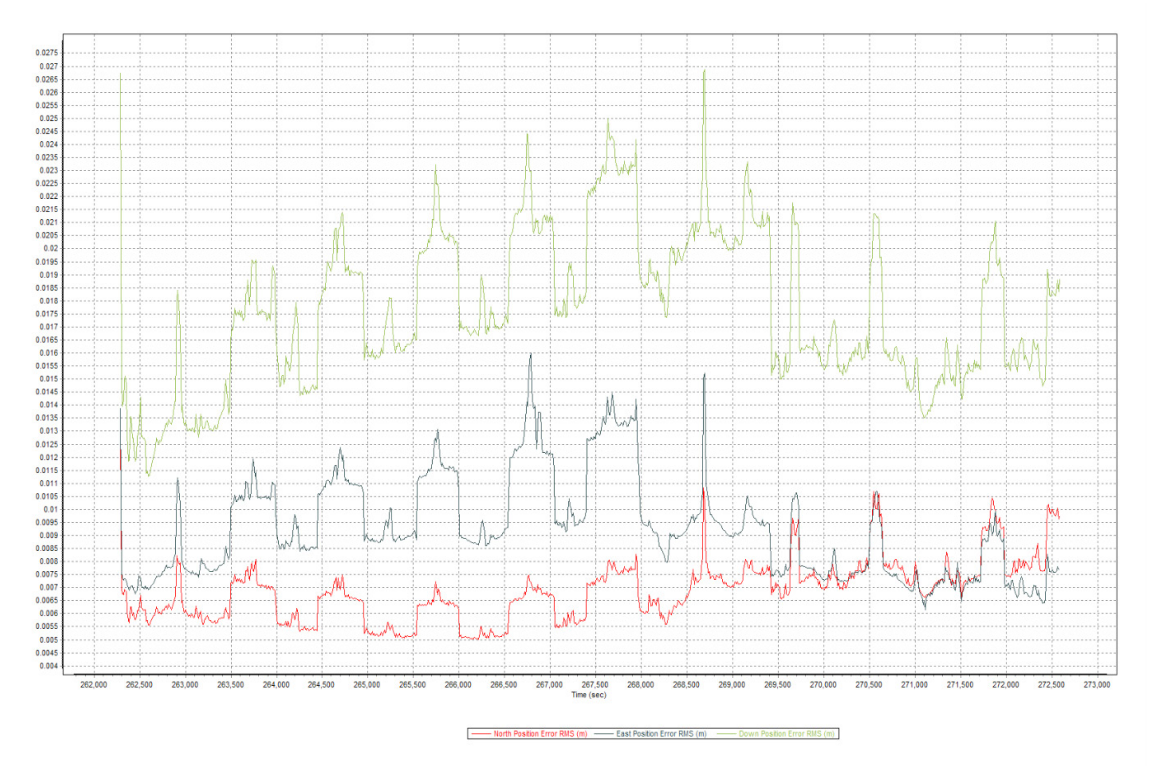

Figure A-8.9 Smoothed Performance Metric Parameters

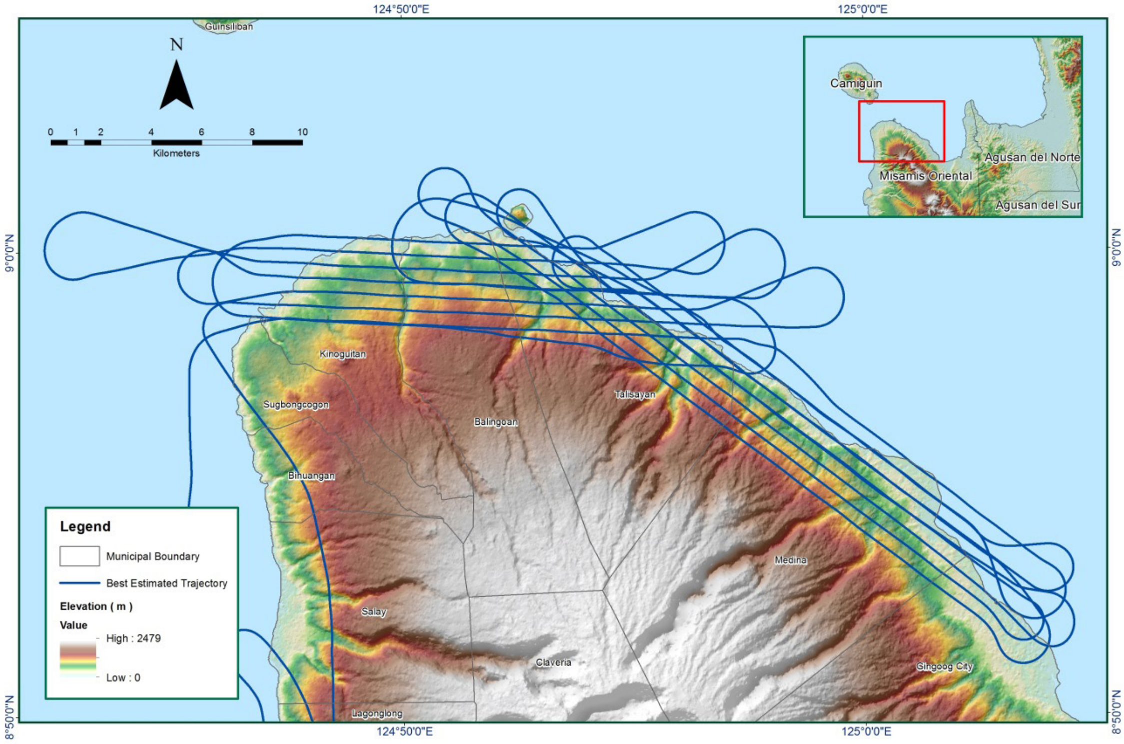

Figure A-8.10 Best Estimated Trajectory

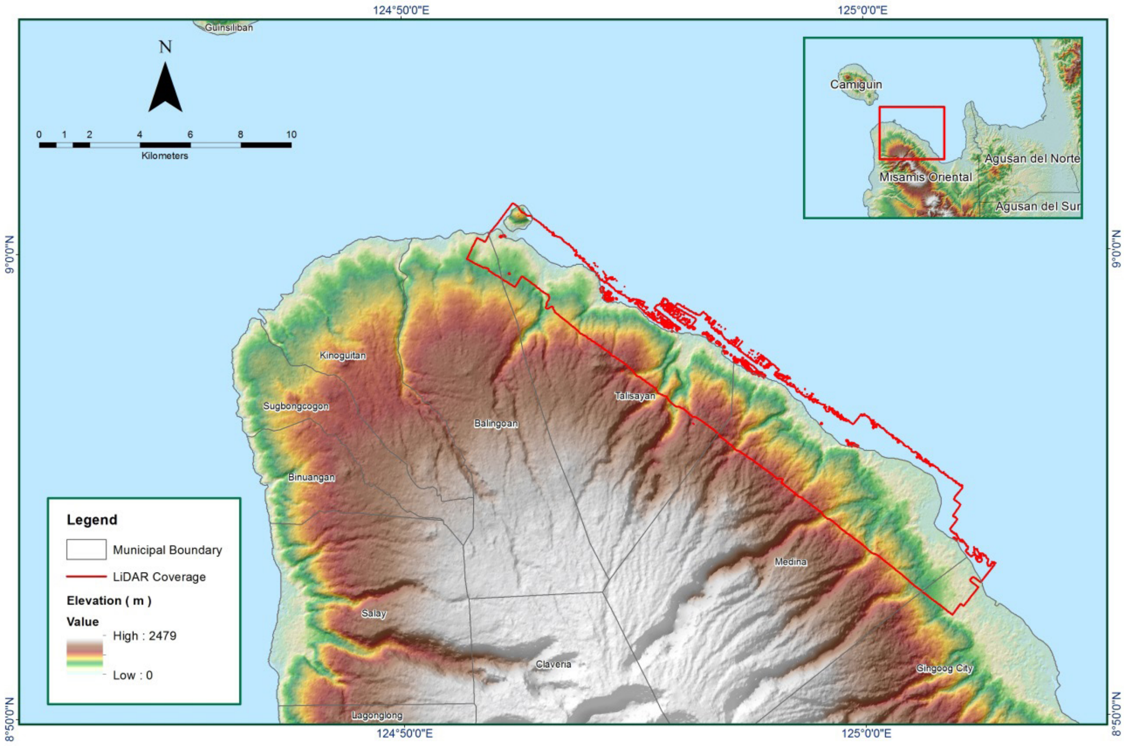

Figure A-8.11 *Coverage of LiDAR data*

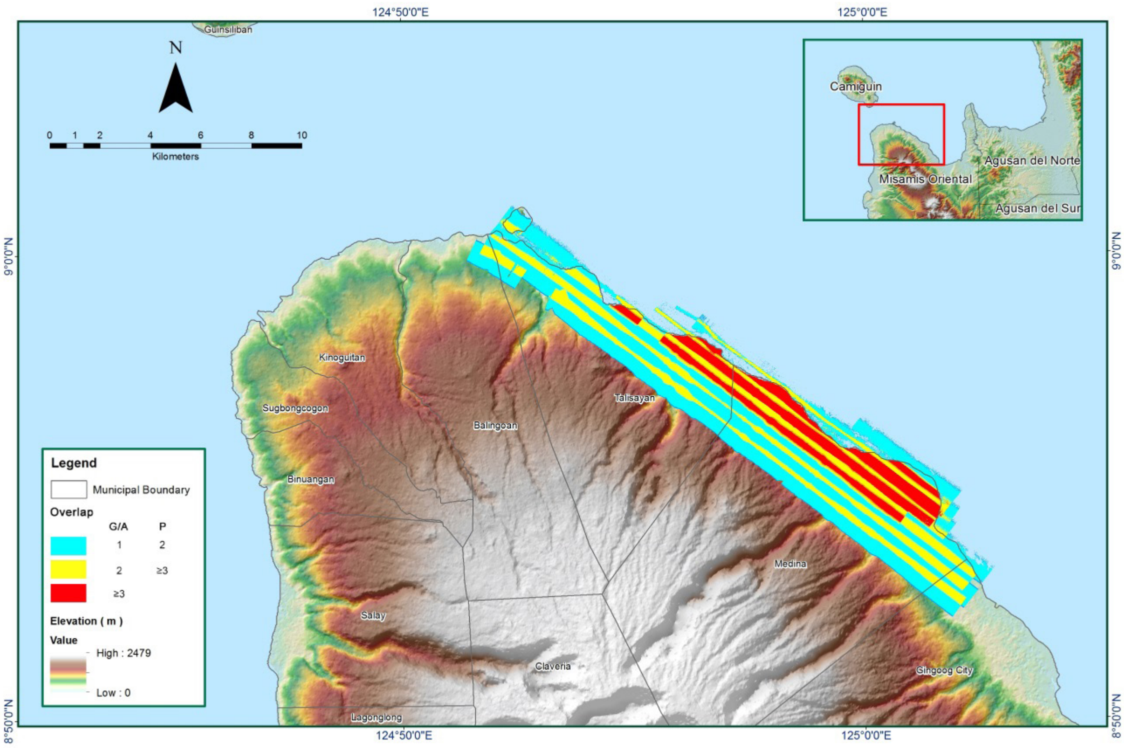

Figure A-8.12 *Image of data overlap*

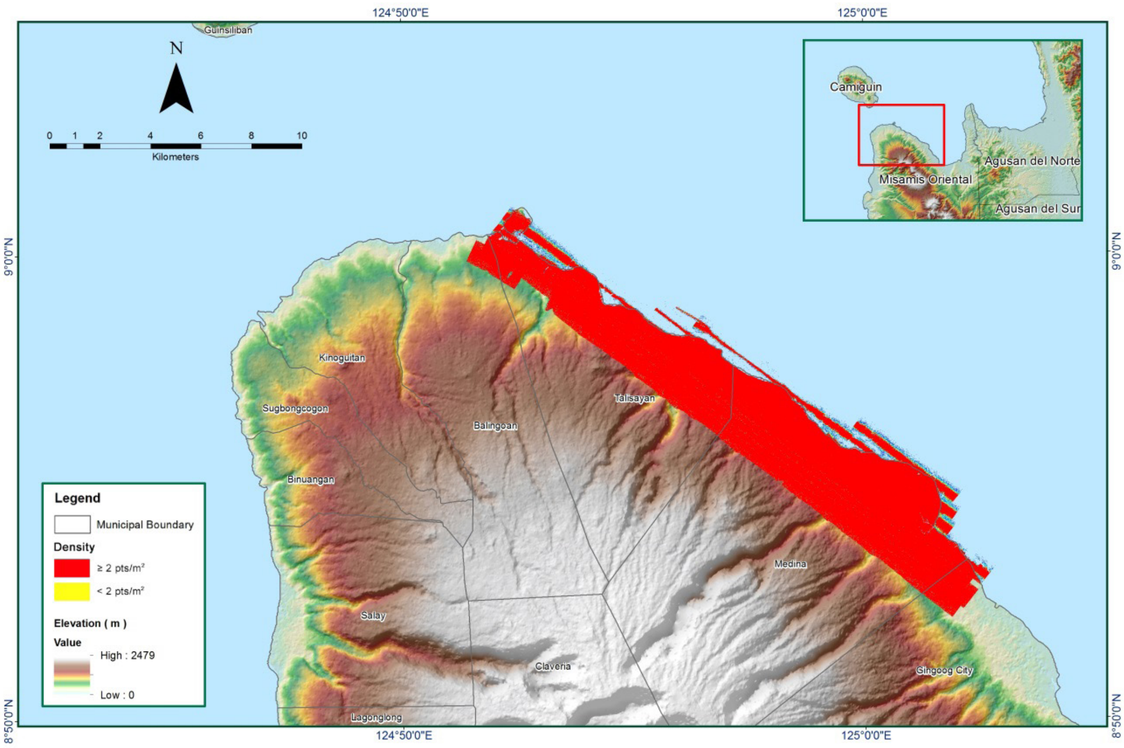

Figure A-8.13 Density map of merged LiDAR data

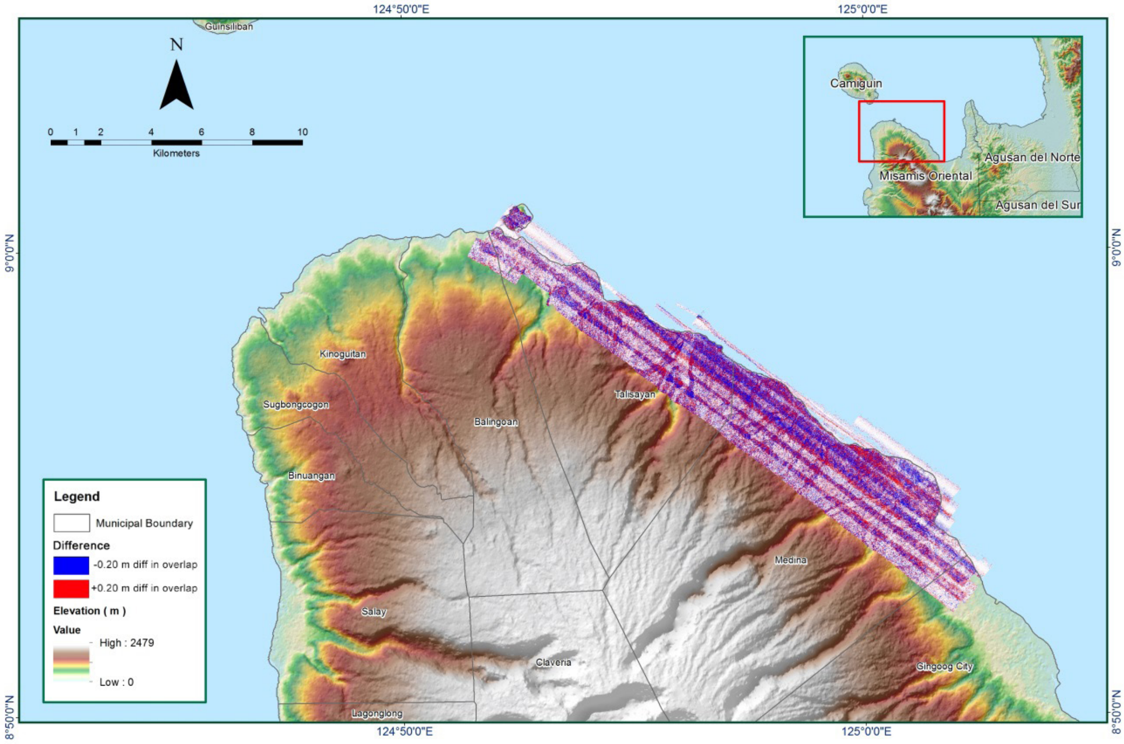

Figure A-8.14 Elevation difference between flight lines

Table A-8.3 Mission Summary Report for Mission RX_B

Flight Area	Northern Mindanao
Mission Name	RX_B
Inclusive Flights	1521P
Range data size	28 GB
POS data size	252 MB
Base data size	5.54 MB
Image	n/a
Transfer date	June 10, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.05
RMSE for East Position (<4.0 cm)	1.6
RMSE for Down Position (<8.0 cm)	2.7
Boresight correction stdev (<0.001deg)	0.000202
IMU attitude correction stdev (<0.001deg)	0.000646
GPS position stdev (<0.01m)	0.0027
Minimum % overlap (>25)	38.03
Ave point cloud density per sq.m. (>2.0)	5.47
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	97
Maximum Height	709.41
Minimum Height	65.52
Classification (# of points)	
Ground	90,111,761
Low vegetation	70,011,011
Medium vegetation	111,473,867
High vegetation	142,777,830
Building	5,556,604
Orthophoto	
Processed by	Engr. Irish Cortez, Engr. Harmond Santos, Engr. Gladys Mae Apat

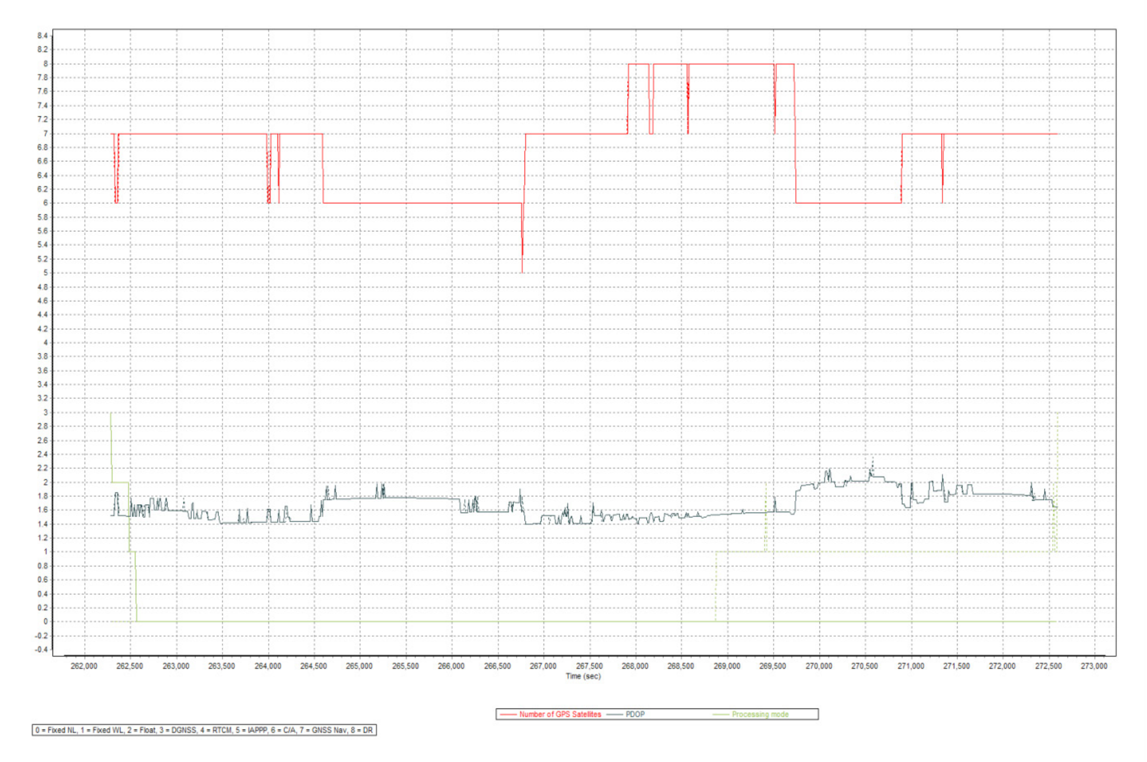

Figure A-8.15 Solution Status

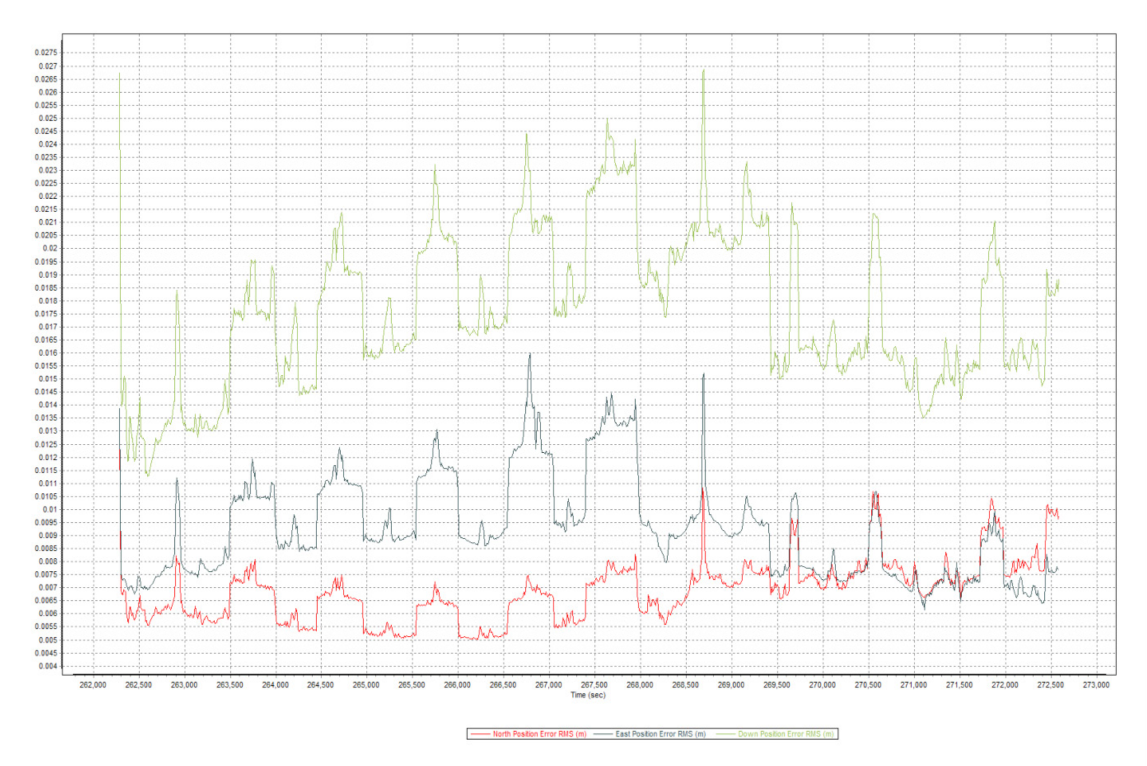

Figure A-8.16 Smoothed Performance Metric Parameters

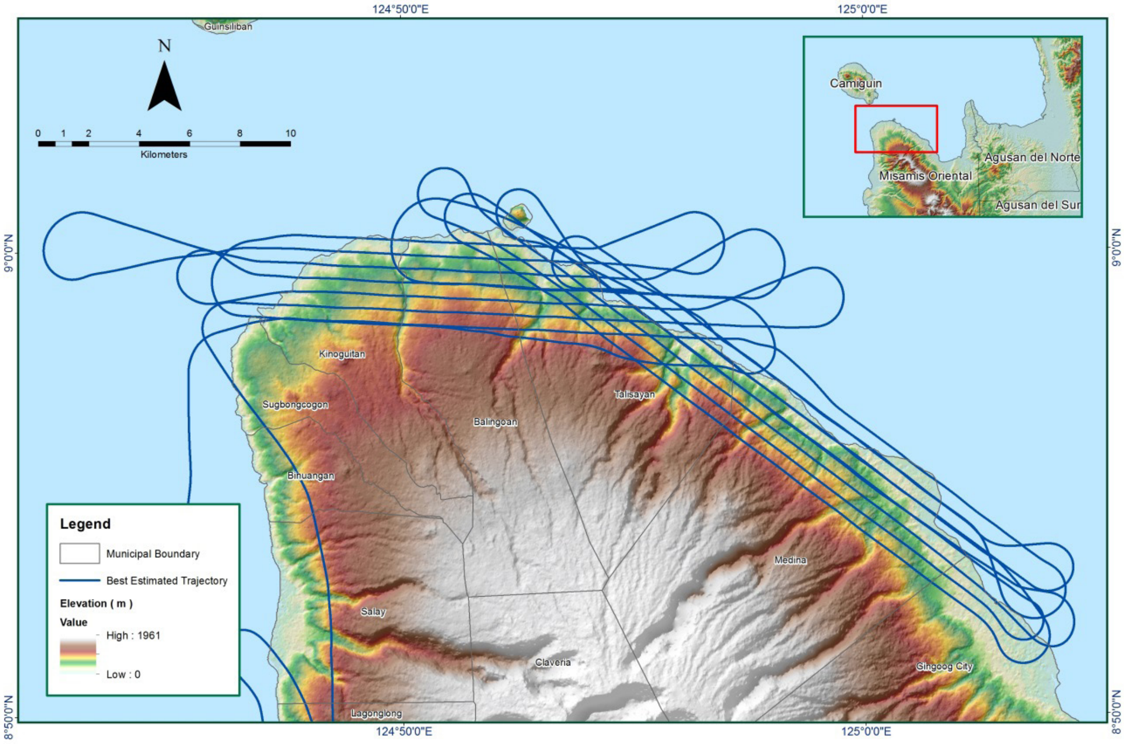

Figure A-8.17 Best Estimated Trajectory

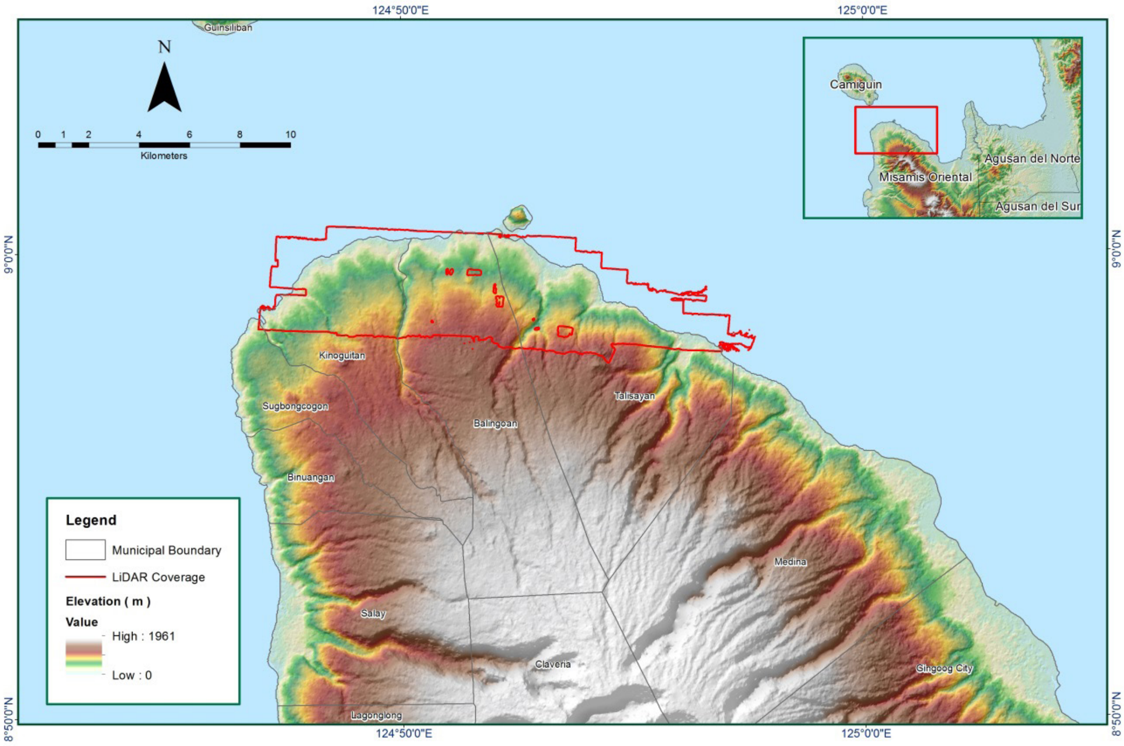

Figure A-8.18 Coverage of LiDAR data

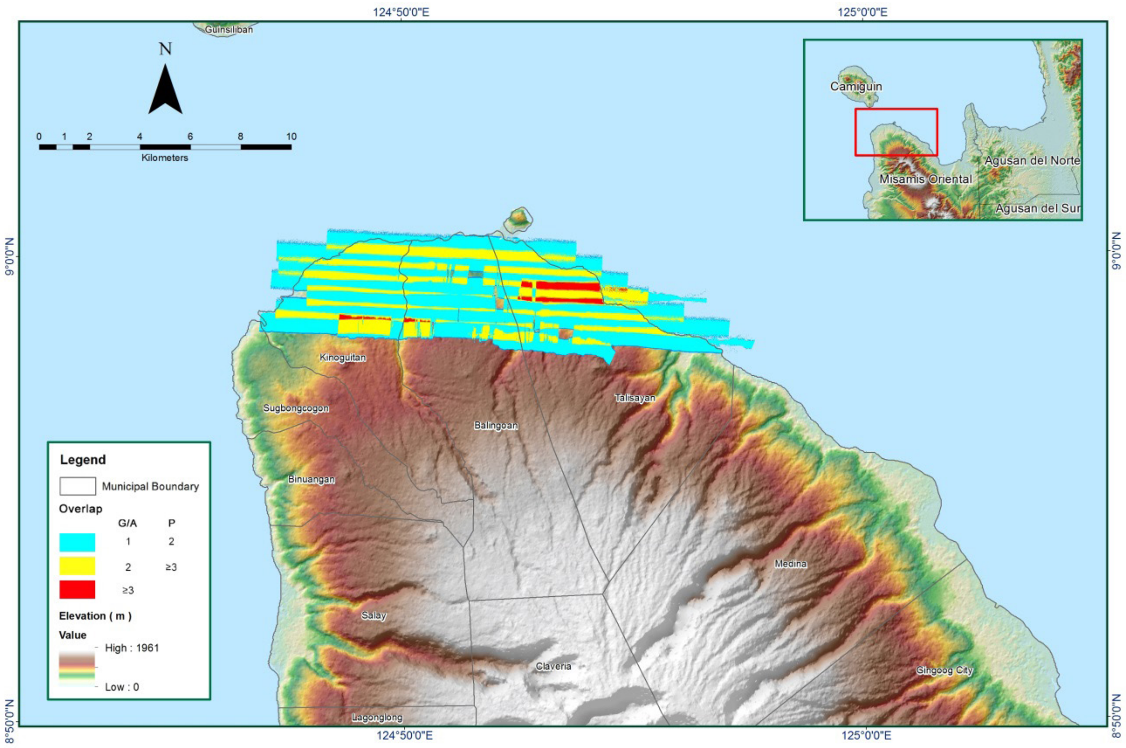

Figure A-8.19 Image of data overlap

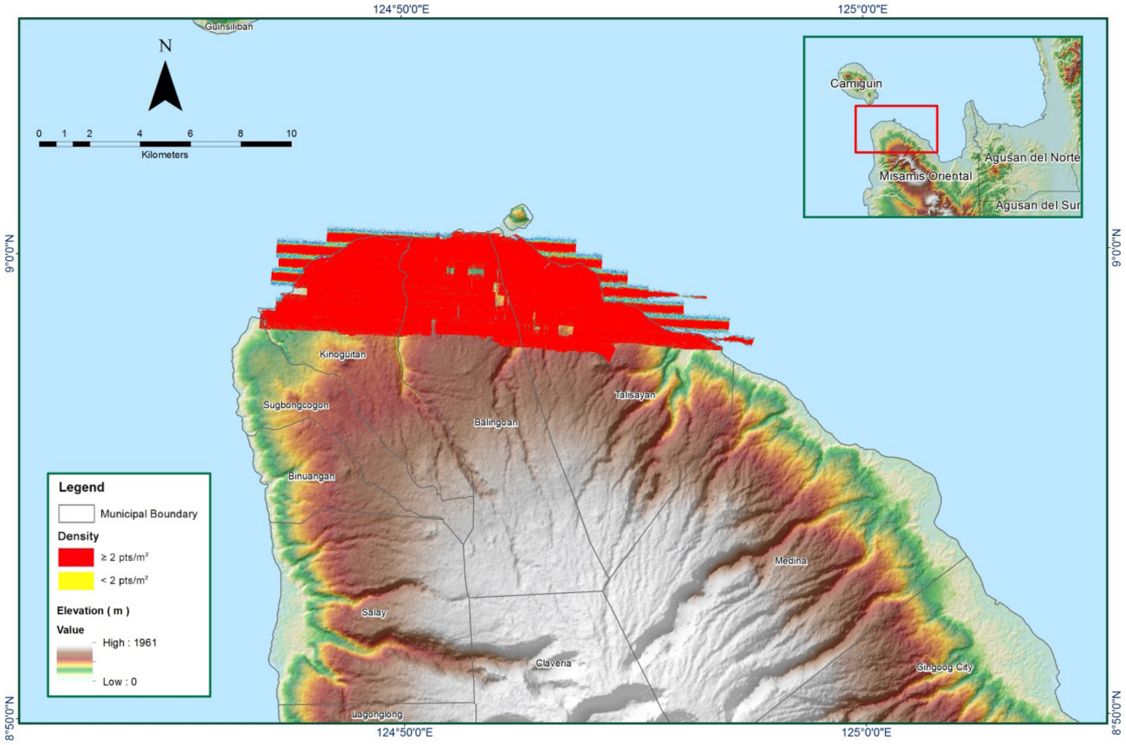

Figure A-8.20 Density map of merged LiDAR data

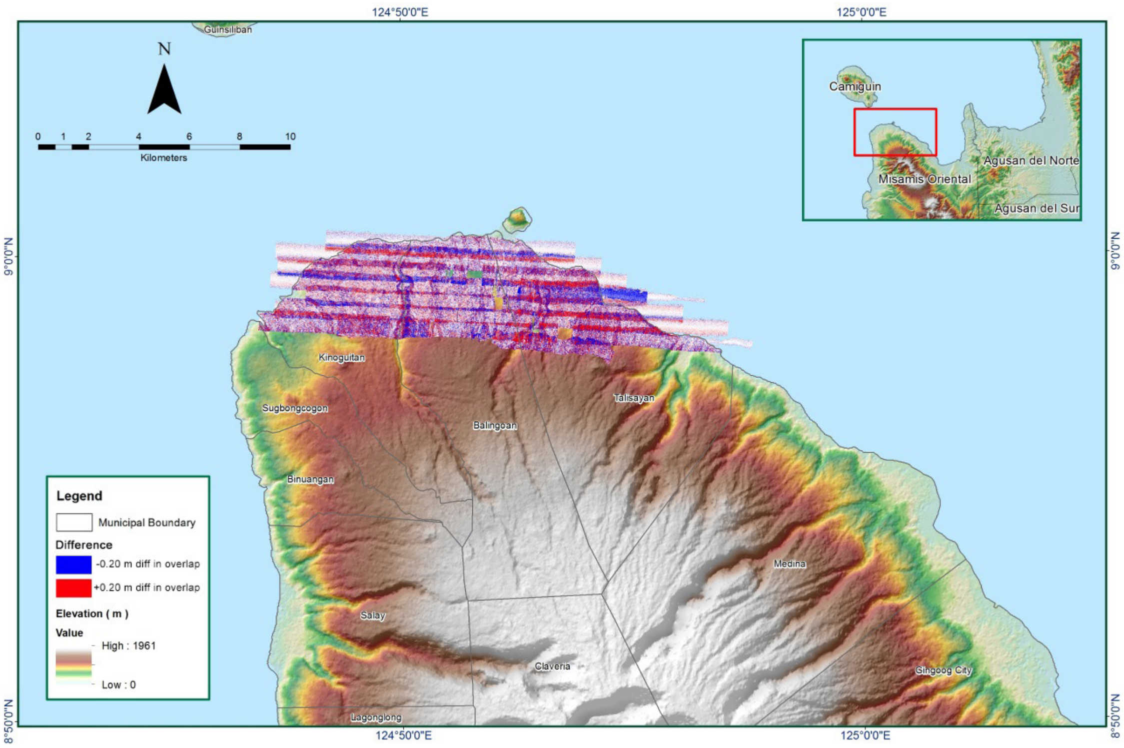

Figure A-8.21 Elevation difference between flight lines

Annex 9. Gahub Model Basin Parameters

Table A-9.1 Gahub 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
57B	4.68	74.73	0	0.56	1.0021	Discharge	0.23146	0.33333	Ratio to Peak	0.016
56B	4.53	72	0	0.51	0.9196	Discharge	0.11703	0.33333	Ratio to Peak	0.016
52B	4.83	73	0	0.61	1.1	Discharge	0.12022	0.33333	Ratio to Peak	0.016
51B	4.74	73	0	0.58	1.0373	Discharge	0.1002056	0.33333	Ratio to Peak	0.016
48B	6.51	75.88	0	1.17	2.0999	Discharge	0.4967589	0.33333	Ratio to Peak	0.016
47B	4.86	83.21	0	0.62	1.1088	Discharge	0.1632488	0.33333	Ratio to Peak	0.016
62B	4.62	77.33	0	0.54	0.9768	Discharge	0.2181102	0.33333	Ratio to Peak	0.016
61B	4.95	77.9	0	0.65	1.1627	Discharge	0.21091	0.33333	Ratio to Peak	0.016
60B	3.84	79.56	0	0.28	0.4994	Discharge	0.0438652	0.33333	Ratio to Peak	0.016
59B	4.89	77.07	0	0.63	1.1396	Discharge	0.2385284	0.33333	Ratio to Peak	0.016
55B	4.92	73.3	0	0.64	1.1495	Discharge	0.11711	0.33333	Ratio to Peak	0.016
54B	3.51	81	0	0.17	0.3124	Discharge	0.0038642	0.33333	Ratio to Peak	0.016
58B	5.46	75.48	0	0.82	1.4696	Discharge	0.2074479	0.33333	Ratio to Peak	0.016
53B	5.1	73.06	0	0.7	1.2529	Discharge	0.2293566	0.33333	Ratio to Peak	0.016
50B	6.3	82.62	0	1.1	1.9668	Discharge	0.51770	0.33333	Ratio to Peak	0.016
49B	5.79	76.28	0	0.93	1.6753	Discharge	0.18988	0.33333	Ratio to Peak	0.016
46B	6.42	82.44	0	1.14	2.0372	Discharge	0.3716031	0.33333	Ratio to Peak	0.016
45B	5.4	79.63	0	0.8	1.4278	Discharge	0.1827364	0.33333	Ratio to Peak	0.016
44B	6.06	84.68	0	1.02	1.8348	Discharge	0.1819972	0.33333	Ratio to Peak	0.016
43B	3.42	95	0	0.14	0.2508	Discharge	0.0072633	0.33333	Ratio to Peak	0.016
42B	4.23	70	0	0.41	0.7403	Discharge	.00031008	0.33333	Ratio to Peak	0.016

Annex 10. Gahub Model Reach Parameters

Table A-10.1 Gahub Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Man-ning's n	Shape	Width	Side Slope
70R	Automatic Fixed Interval	2932.827	0.121830	0.0004	Trapezoid	15	0.05
65R	Automatic Fixed Interval	5115.322	0.098140	0.0004	Trapezoid	15	0.05
72R	Automatic Fixed Interval	2210.804	0.103530	0.0004	Trapezoid	15	0.05
61R	Automatic Fixed Interval	7418.965	0.077530	0.0003	Trapezoid	15	0.05
57R	Automatic Fixed Interval	6133.003	0.055870	0.0004	Trapezoid	15	0.05
56R	Automatic Fixed Interval	1657.898	0.025150	0.0004	Trapezoid	15	0.05
68R	Automatic Fixed Interval	2684.719	0.167590	0.0004	Trapezoid	15	0.05
67R	Automatic Fixed Interval	2698.432	0.167780	0.0004	Trapezoid	15	0.05
71R	Automatic Fixed Interval	17503.128	0.100530	0.0004	Trapezoid	15	0.05
69R	Automatic Fixed Interval	4986.573	0.209290	0.0004	Trapezoid	15	0.05
64R	Automatic Fixed Interval	99.977	0.139360	0.0004	Trapezoid	15	0.05
63R	Automatic Fixed Interval	9159.641	0.087380	0.0004	Trapezoid	15	0.05
66R	Automatic Fixed Interval	14289.442	0.092180	0.0004	Trapezoid	15	0.05
62R	Automatic Fixed Interval	6610.106	0.085550	0.0004	Trapezoid	15	0.05
60R	Automatic Fixed Interval	14125.441	0.049460	0.0004	Trapezoid	15	0.05
31R	Automatic Fixed Interval	8467.220	0.043500	0.0004	Trapezoid	15	0.05
55R	Automatic Fixed Interval	6365.248	0.031600	0.0004	Trapezoid	15	0.05
54R	Automatic Fixed Interval	7469.190	0.009400	0.0004	Trapezoid	15	0.05
53R	Automatic Fixed Interval	880.421	0.001750	0.0004	Trapezoid	15	0.05
51R	Automatic Fixed Interval	122.339	0.002930	0.0004	Trapezoid	15	0.05

Annex 11. Gahub-Gingoog Flood Validation Data

Table A-11.1 Gahub-Gingoog Flood Validation Data

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
1	8.81668700000	125.09850600000	3.73	0.10	-3.63	Ondoy/29Nov2009	5YR
2	8.81355200100	125.09886200000	0.06	0.00	-0.06	Ondoy/29Nov2009	5YR
3	8.81167500000	125.09786400000	2.19	0.10	-2.09	Ondoy/29Nov2009	5YR
4	8.81134700000	125.09898300000	0.05	0.00	-0.05	Ondoy/29Nov2009	5YR
5	8.81109100000	125.10063600000	0.06	0.05	-0.01	Ondoy/29Nov2009	5YR
6	8.81106000000	125.10289100000	0.66	0.00	-0.66	Ondoy/29Nov2009	5YR
7	8.81099999900	125.10264100000	0.05	1.15	1.10	Ondoy/29Nov2009	5YR
8	8.81378999900	125.10341300000	0.06	0.00	-0.06	Ondoy/29Nov2009	5YR
9	8.81478199900	125.10379900000	0.06	0.00	-0.06	Ondoy/29Nov2009	5YR
10	8.82237100000	125.09894300000	0.28	0.00	-0.28	Ondoy/29Nov2009	5YR
11	8.82194399900	125.09858600000	0.25	0.25	0.00	Ondoy/29Nov2009	5YR
12	8.82100600000	125.09917800000	0.06	0.00	-0.06	Ondoy/29Nov2009	5YR
13	8.82066200000	125.09940300000	6.48	1.70	-4.78	Ondoy/29Nov2009	5YR
14	8.82060800100	125.09917900000	0.47	0.00	-0.47	Ondoy/29Nov2009	5YR
15	8.82058200000	125.09875200000	0.15	0.00	-0.15	Ondoy/29Nov2009	5YR
16	8.82057399900	125.09856300000	0.14	0.00	-0.14	Ondoy/29Nov2009	5YR
17	8.81979700000	125.09828000000	2.13	0.00	-2.13	Ondoy/29Nov2009	5YR
18	8.81979300100	125.09829800000	2.13	0.05	-2.08	Ondoy/29Nov2009	5YR
19	8.81969400100	125.09818300000	1.28	0.00	-1.28	Ondoy/29Nov2009	5YR
20	8.81965800000	125.09817200000	1.28	0.40	-0.88	Ondoy/29Nov2009	5YR
21	8.81953900000	125.09831500000	1.45	0.05	-1.40	Ondoy/29Nov2009	5YR
22	8.81935700000	125.09780500000	0.12	5.00	4.88	Ondoy/29Nov2009	5YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
23	8.81872299900	125.09828500000	0.65	5.00	4.35	Ondoy/29Nov2009	5YR
24	8.81807300000	125.09860300000	6.32	5.00	-1.32	Ondoy/29Nov2009	5YR
25	8.81786200000	125.09870700000	5.42	5.00	-0.42	Ondoy/29Nov2009	5YR
26	8.81780400000	125.09867400000	5.99	5.00	-0.99	Ondoy/29Nov2009	5YR
27	8.81777000000	125.09849500000	2.84	0.00	-2.84	Ondoy/29Nov2009	5YR
28	8.81774200000	125.09853500000	2.84	0.05	-2.79	Ondoy/29Nov2009	5YR
29	8.81777500000	125.09840600000	2.84	0.00	-2.84	Ondoy/29Nov2009	5YR
30	8.80519100000	125.10621500000	0.79	0.90	0.11	Ondoy/29Nov2009	5YR
31	8.80496300000	125.10652800000	0.05	1.00	0.95	Ondoy/29Nov2009	5YR
32	8.80569500000	125.10651000000	0.63	2.00	1.37	Ondoy/29Nov2009	5YR
33	8.80612900000	125.10648000000	0.46	2.00	1.54	Ondoy/29Nov2009	5YR
34	8.80598000000	125.10647600000	0.61	2.00	1.39	Ondoy/29Nov2009	5YR
35	8.80632600000	125.10609400000	0.63	0.40	-0.23	Ondoy/29Nov2009	5YR
36	8.80682300000	125.10642900000	0.28	1.00	0.72	Ondoy/29Nov2009	5YR
37	8.80706600000	125.10569300000	0.05	0.40	0.35	Ondoy/29Nov2009	5YR
38	8.80788600000	125.10623300000	0.09	0.40	0.31	Ondoy/29Nov2009	5YR
39	8.80771000000	125.10596900000	0.17	0.40	0.23	Ondoy/29Nov2009	5YR
40	8.80878000000	125.10572600000	0.21	0.00	-0.21	Ondoy/29Nov2009	5YR
41	8.81091800000	125.10560100000	0.06	0.00	-0.06	Ondoy/29Nov2009	5YR
42	8.81192600000	125.10491200000	0.06	0.00	-0.06	Ondoy/29Nov2009	5YR
43	8.81275900000	125.10552100000	0.05	0.00	-0.05	Ondoy/29Nov2009	5YR
44	8.81263200000	125.10474500000	0.17	0.00	-0.17	Ondoy/29Nov2009	5YR
45	8.81358700000	125.10445000000	0.09	0.00	-0.09	Ondoy/29Nov2009	5YR
46	8.81661000000	125.09936100000	0.34	0.00	-0.34	Ondoy/29Nov2009	5YR
47	8.81816100000	125.09885700000	0.38	0.00	-0.38	Ondoy/29Nov2009	5YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
48	8.81831800000	125.09874000000	0.29	0.00	-0.29	Ondoy/29Nov2009	5YR
49	8.81888900000	125.09878300000	0.41	0.00	-0.41	Ondoy/29Nov2009	5YR
50	8.81960399900	125.09877600000	0.55	0.00	-0.55	Ondoy/29Nov2009	5YR
51	8.81988900100	125.09885100000	0.85	0.40	-0.45	Ondoy/29Nov2009	5YR
52	8.82015400000	125.09937400000	0.63	2.50	1.87	Ondoy/29Nov2009	5YR
53	8.82045100000	125.09963500000	1.58	2.50	0.92	Ondoy/29Nov2009	5YR
54	8.82139600000	125.09950800000	1.79	0.00	-1.79	Ondoy/29Nov2009	5YR
55	8.82167700000	125.09933300000	2.68	0.00	-2.68	Ondoy/29Nov2009	5YR
56	8.82270100000	125.09914900000	1.52	0.00	-1.52	Ondoy/29Nov2009	5YR
57	8.81736000000	125.10262300000	0.24	0.00	-0.24	Ondoy/29Nov2009	5YR
58	8.81839700000	125.10272200000	0.05	0.00	-0.05	Ondoy/29Nov2009	5YR
59	8.81906200000	125.10347400000	0.63	1.00	0.37	Ondoy/29Nov2009	5YR
60	8.81865100000	125.10395800000	0.29	0.00	-0.29	Ondoy/29Nov2009	5YR
61	8.81929300000	125.10475700000	0.41	1.80	1.39	Ondoy/29Nov2009	5YR
62	8.82096500000	125.10540400000	0.17	0.00	-0.17	Ondoy/29Nov2009	5YR
63	8.82181100000	125.10535400000	0.18	0.00	-0.18	Ondoy/29Nov2009	5YR
64	8.82265700000	125.10515000000	0.25	0.00	-0.25	Ondoy/29Nov2009	5YR
65	8.82220800000	125.10335700000	0.17	0.00	-0.17	Ondoy/29Nov2009	5YR
66	8.82031800000	125.10352600000	0.05	0.00	-0.05	Ondoy/29Nov2009	5YR
67	8.80747600000	125.09891000000	0.39	0.00	-0.39	Ondoy/29Nov2009	5YR
68	8.80700900000	125.09904800000	0.27	0.00	-0.27	Ondoy/29Nov2009	5YR
69	8.80891200000	125.10063500000	0.05	3.00	2.95	Ondoy/29Nov2009	5YR
70	8.80953400000	125.10006200000	0.05	1.50	1.45	Ondoy/29Nov2009	5YR
71	8.80977200000	125.10021200000	0.14	1.50	1.36	Ondoy/29Nov2009	5YR
72	8.81016200000	125.10036300000	0.15	0.00	-0.15	Ondoy/29Nov2009	5YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
73	8.81060799900	125.10071100000	0.16	0.00	-0.16	Ondoy/29Nov2009	5YR
74	8.81086000100	125.10113200000	0.29	2.30	2.01	Ondoy/29Nov2009	5YR
75	8.81093200000	125.10181700000	0.12	0.00	-0.12	Ondoy/29Nov2009	5YR
76	8.81093600000	125.10221000000	0.28	1.20	0.92	Ondoy/29Nov2009	5YR
77	8.81190800000	125.10268400000	0.05	0.67	0.62	Ondoy/29Nov2009	5YR
78	8.81225500000	125.10257500000	0.05	0.50	0.45	Ondoy/29Nov2009	5YR
79	8.81258600000	125.10227400000	0.06	0.00	-0.06	Ondoy/29Nov2009	5YR
80	8.81349000100	125.10324400000	0.06	0.00	-0.06	Ondoy/29Nov2009	5YR
81	8.82392700100	125.09908700000	0.06	0.00	-0.06	Ondoy/29Nov2009	5YR
82	8.82400500000	125.09840400000	0.05	0.00	-0.05	Ondoy/29Nov2009	5YR
83	8.82518800000	125.09873000000	0.05	0.00	-0.05	Ondoy/29Nov2009	5YR
84	8.82555700000	125.09864100000	0.05	0.00	-0.05	Ondoy/29Nov2009	5YR
85	8.82580499900	125.09891800000	0.14	1.00	0.86	Ondoy/29Nov2009	5YR
86	8.82600800000	125.09888400000	0.18	0.00	-0.18	Ondoy/29Nov2009	5YR
87	8.82617900000	125.09860500000	0.05	0.00	-0.05	Ondoy/29Nov2009	5YR
88	8.82645200000	125.09811200000	0.05	0.00	-0.05	Ondoy/29Nov2009	5YR
89	8.82605300000	125.09666400000	0.16	0.20	0.04	Ondoy/29Nov2009	5YR
90	8.82535000100	125.09626200000	0.12	0.00	-0.12	Ondoy/29Nov2009	5YR
91	8.82461199900	125.09695400000	0.51	0.00	-0.51	Ondoy/29Nov2009	5YR
92	8.82408700000	125.09762200000	0.05	0.30	0.25	Ondoy/29Nov2009	5YR
93	8.82387300000	125.09562800000	0.05	0.00	-0.05	Ondoy/29Nov2009	5YR
94	8.82487400000	125.09389200000	0.12	0.00	-0.12	Ondoy/29Nov2009	5YR
95	8.82586400000	125.09381900000	0.16	0.00	-0.16	Ondoy/29Nov2009	5YR
96	8.82569500100	125.09292300000	0.06	0.00	-0.06	Ondoy/29Nov2009	5YR
97	8.82722599900	125.09263600000	0.43	0.00	-0.43	Ondoy/29Nov2009	5YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
98	8.82756600000	125.09273600000	0.55	0.00	-0.55	Ondoy/29Nov2009	5YR
99	8.82689500000	125.09227600000	0.23	1.00	0.77	Ondoy/29Nov2009	5YR
100	8.82452900000	125.09889000000	0.14	0.00	-0.14	Ondoy/29Nov2009	5YR
101	8.82732099900	125.10946500000	0.48	0.00	-0.48	Ondoy/29Nov2009	5YR
102	8.82726900000	125.11055100000	1.06	0.00	-1.06	Ondoy/29Nov2009	5YR
103	8.82711700000	125.11056400000	1.15	1.00	-0.15	Ondoy/29Nov2009	5YR
104	8.82694900100	125.11125300000	1.16	0.00	-1.16	Ondoy/29Nov2009	5YR
105	8.82827600000	125.11130100000	1.22	1.50	0.28	Ondoy/29Nov2009	5YR
106	8.82713800000	125.10830800000	0.60	1.30	0.70	Ondoy/29Nov2009	5YR
107	8.82818500000	125.10795000000	1.23	0.00	-1.23	Ondoy/29Nov2009	5YR
108	8.82898200000	125.10856700000	0.96	0.00	-0.96	Ondoy/29Nov2009	5YR
109	8.83000400000	125.11018500000	0.72	0.00	-0.72	Ondoy/29Nov2009	5YR
110	8.82872400000	125.11008600000	0.90	0.80	-0.10	Ondoy/29Nov2009	5YR
111	8.82857800000	125.11073800000	0.88	1.50	0.62	Ondoy/29Nov2009	5YR
112	8.82681100000	125.11025200000	0.63	0.00	-0.63	Ondoy/29Nov2009	5YR
113	8.82664900000	125.11286300000	0.66	0.00	-0.66	Ondoy/29Nov2009	5YR
114	8.82666300000	125.11285300000	0.66	0.00	-0.66	Ondoy/29Nov2009	5YR
115	8.82828300000	125.11405900000	0.88	1.60	0.72	Ondoy/29Nov2009	5YR
116	8.82930200000	125.11522800000	1.58	0.00	-1.58	Ondoy/29Nov2009	5YR
117	8.82953200000	125.11502300000	1.38	0.00	-1.38	Ondoy/29Nov2009	5YR
118	8.82954800000	125.11640500000	1.42	0.00	-1.42	Ondoy/29Nov2009	5YR
119	8.82767499900	125.11595200000	0.38	1.40	1.02	Ondoy/29Nov2009	5YR
120	8.82922800000	125.11834100000	0.88	0.00	-0.88	Ondoy/29Nov2009	5YR
121	8.83008800100	125.11963700000	0.23	1.10	0.87	Ondoy/29Nov2009	5YR
122	8.83079200000	125.11896400000	0.85	1.20	0.35	Ondoy/29Nov2009	5YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
123	8.83014700000	125.11802700000	0.61	0.00	-0.61	Ondoy/29Nov2009	5YR
124	8.82949000000	125.11733400000	1.19	2.00	0.81	Ondoy/29Nov2009	5YR
125	8.83118300000	125.11791800000	1.02	0.00	-1.02	Ondoy/29Nov2009	5YR
126	8.82934500000	125.11946900000	0.61	0.00	-0.61	Ondoy/29Nov2009	5YR
127	8.82866500100	125.11879100000	0.79	1.00	0.21	Ondoy/29Nov2009	5YR
128	8.82725600000	125.11593000000	0.60	1.20	0.60	Ondoy/29Nov2009	5YR
129	8.82995699900	125.12390500000	0.28	0.00	-0.28	Ondoy/29Nov2009	5YR
130	8.82964900000	125.12357300000	0.06	0.00	-0.06	Ondoy/29Nov2009	5YR
131	8.83140700000	125.12319100000	0.75	0.00	-0.75	Ondoy/29Nov2009	5YR
132	8.83281400000	125.12581400000	0.47	0.00	-0.47	Ondoy/29Nov2009	5YR
133	8.82980300000	125.12528700000	0.51	0.00	-0.51	Ondoy/29Nov2009	5YR
134	8.82915600000	125.12470000000	1.04	0.00	-1.04	Ondoy/29Nov2009	5YR
135	8.82788600100	125.12391800000	0.75	2.00	1.25	Ondoy/29Nov2009	5YR
136	8.82770800000	125.12276200000	0.85	0.00	-0.85	Ondoy/29Nov2009	5YR
137	8.82815000000	125.12243300000	0.88	0.00	-0.88	Ondoy/29Nov2009	5YR
138	8.82823799900	125.12235300000	0.69	0.00	-0.69	Ondoy/29Nov2009	5YR
139	8.82877700100	125.12114900000	0.06	0.00	-0.06	Ondoy/29Nov2009	5YR
140	8.82834400000	125.12032900000	0.88	0.00	-0.88	Ondoy/29Nov2009	5YR
141	8.82421000000	125.11638200000	1.09	0.00	-1.09	Ondoy/29Nov2009	5YR
142	8.80680200100	125.11040400000	0.35	1.00	0.65	Ondoy/29Nov2009	5YR
143	8.80695700100	125.11072100000	0.25	0.00	-0.25	Ondoy/29Nov2009	5YR
144	8.80710100000	125.11136500000	0.31	0.00	-0.31	Ondoy/29Nov2009	5YR
145	8.80768299900	125.10968300000	0.50	0.40	-0.10	Ondoy/29Nov2009	5YR
146	8.80769600100	125.10951400000	0.72	1.00	0.28	Ondoy/29Nov2009	5YR
147	8.80675900000	125.10903600000	1.02	0.20	-0.82	Ondoy/29Nov2009	5YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
148	8.80723400100	125.10835700000	0.28	0.00	-0.28	Ondoy/29Nov2009	5YR
149	8.80614100100	125.10888600000	0.72	0.00	-0.72	Ondoy/29Nov2009	5YR
150	8.80595100000	125.10907500000	0.35	0.00	-0.35	Ondoy/29Nov2009	5YR
151	8.80515300000	125.10821100000	0.69	0.00	-0.69	Ondoy/29Nov2009	5YR
152	8.80455700100	125.10821500000	0.31	0.00	-0.31	Ondoy/29Nov2009	5YR
153	8.80454400000	125.10872500000	0.28	0.00	-0.28	Ondoy/29Nov2009	5YR
154	8.80405900000	125.10876600000	0.05	0.40	0.35	Ondoy/29Nov2009	5YR
155	8.80462900000	125.10649900000	1.65	0.40	-1.25	Ondoy/29Nov2009	5YR
156	8.80729300000	125.11265200000	0.62	0.00	-0.62	Ondoy/29Nov2009	5YR
157	8.80704900000	125.11274300000	0.55	2.00	1.45	Ondoy/29Nov2009	5YR
158	8.80792400000	125.11419500000	0.48	0.00	-0.48	Ondoy/29Nov2009	5YR
159	8.80807100100	125.11435100000	0.69	0.00	-0.69	Ondoy/29Nov2009	5YR
160	8.80828000000	125.11472600000	0.90	1.50	0.60	Ondoy/29Nov2009	5YR
161	8.80850400000	125.11705100000	1.30	0.00	-1.30	Ondoy/29Nov2009	5YR
162	8.80865000000	125.11749800000	1.41	0.00	-1.41	Ondoy/29Nov2009	5YR
163	8.80859700000	125.11791600000	1.64	0.80	-0.84	Ondoy/29Nov2009	5YR
164	8.80843200000	125.11827900000	1.40	0.00	-1.40	Ondoy/29Nov2009	5YR
165	8.80870200000	125.11895500000	1.97	1.50	-0.47	Ondoy/29Nov2009	5YR
166	8.82585700100	125.12853300000	1.20	0.00	-1.20	Ondoy/29Nov2009	5YR
167	8.79905200000	125.10918500000	0.05	0.00	-0.05	Ondoy/29Nov2009	5YR
168	8.79843000000	125.10830900000	0.63	0.00	-0.63	Ondoy/29Nov2009	5YR
169	8.79853000000	125.10838500000	1.33	0.45	-0.88	Ondoy/29Nov2009	5YR
170	8.79797600000	125.10834400000	0.67	0.00	-0.67	Ondoy/29Nov2009	5YR
171	8.79861800000	125.10830800000	2.94	3.00	0.06	Ondoy/29Nov2009	5YR
172	8.79787800000	125.10866900000	0.05	0.00	-0.05	Ondoy/29Nov2009	5YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
173	8.80100900000	125.11549500000	1.52	1.00	-0.52	Ondoy/29Nov2009	5YR
174	8.80299700100	125.11725200000	1.92	0.00	-1.92	Ondoy/29Nov2009	5YR
175	8.80354500000	125.11711200000	3.66	0.00	-3.66	Ondoy/29Nov2009	5YR
176	8.80386300000	125.11838000000	0.62	0.00	-0.62	Ondoy/29Nov2009	5YR
177	8.80398700000	125.11844400000	0.95	0.00	-0.95	Ondoy/29Nov2009	5YR
178	8.80409699900	125.11827100000	1.75	1.30	-0.45	Ondoy/29Nov2009	5YR
179	8.80406000000	125.11862900000	0.29	0.70	0.41	Ondoy/29Nov2009	5YR
180	8.80376800000	125.11903900000	0.12	0.20	0.08	Ondoy/29Nov2009	5YR
181	8.80367400000	125.11890300000	0.51	0.20	-0.31	Ondoy/29Nov2009	5YR
182	8.80784400000	125.12056600000	0.51	0.00	-0.51	Ondoy/29Nov2009	5YR
183	8.80794900000	125.12020100000	1.36	0.00	-1.36	Ondoy/29Nov2009	5YR
184	8.80782100000	125.12111900000	0.24	0.00	-0.24	Ondoy/29Nov2009	5YR
185	8.80981900000	125.12127600000	1.19	2.00	0.81	Ondoy/29Nov2009	5YR
186	8.80998000000	125.12111800000	1.29	1.00	-0.29	Ondoy/29Nov2009	5YR
187	8.81007800000	125.12088100000	1.48	2.00	0.52	Ondoy/29Nov2009	5YR
188	8.81018200000	125.12077700000	1.60	1.50	-0.10	Ondoy/29Nov2009	5YR
189	8.81210200000	125.12057000000	1.42	0.00	-1.42	Ondoy/29Nov2009	5YR
190	8.81408400000	125.12084600000	1.48	1.00	-0.48	Ondoy/29Nov2009	5YR
191	8.81367700000	125.12059900000	1.48	0.40	-1.08	Ondoy/29Nov2009	5YR
192	8.81569600000	125.12113000000	1.16	1.00	-0.16	Ondoy/29Nov2009	5YR
193	8.81767800000	125.12170800000	1.65	1.00	-0.65	Ondoy/29Nov2009	5YR
194	8.81865500000	125.12234300000	0.88	0.00	-0.88	Ondoy/29Nov2009	5YR
195	8.81943600000	125.12287500000	0.88	0.40	-0.48	Ondoy/29Nov2009	5YR
196	8.81954100000	125.12287900000	0.88	1.00	0.12	Ondoy/29Nov2009	5YR
197	8.82651000000	125.12913500000	0.05	0.00	-0.05	Ondoy/29Nov2009	5YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
198	8.82503000000	125.12754600000	0.37	0.00	-0.37	Ondoy/29Nov2009	5YR
199	8.82358500000	125.12637400000	0.41	0.40	-0.01	Ondoy/29Nov2009	5YR
200	8.82320599900	125.12582500000	0.39	2.00	1.61	Ondoy/29Nov2009	5YR
201	8.82286700000	125.12537400000	0.71	2.00	1.29	Ondoy/29Nov2009	5YR
202	8.82240700000	125.12479500000	0.63	0.40	-0.23	Ondoy/29Nov2009	5YR
203	8.82400900000	125.12397700000	1.02	0.00	-1.02	Ondoy/29Nov2009	5YR
204	8.82429800000	125.12392400000	0.87	0.00	-0.87	Ondoy/29Nov2009	5YR
205	8.82338100000	125.12348900000	1.29	0.60	-0.69	Ondoy/29Nov2009	5YR
206	8.82259100000	125.12456300000	1.70	2.00	0.30	Ondoy/29Nov2009	5YR
207	8.82141100000	125.12395100000	0.88	2.50	1.62	Ondoy/29Nov2009	5YR
208	8.82255900000	125.11216200000	0.35	0.00	-0.35	Ondoy/29Nov2009	5YR
209	8.82131699900	125.11233700000	0.88	1.25	0.37	Ondoy/29Nov2009	5YR
210	8.82058000000	125.11237600000	0.66	0.55	-0.11	Ondoy/29Nov2009	5YR
211	8.82051100000	125.11188900000	0.65	0.40	-0.25	Ondoy/29Nov2009	5YR
212	8.82224600000	125.11194100000	0.60	0.05	-0.55	Ondoy/29Nov2009	5YR
213	8.80722700000	125.11238200000	0.61	0.98	0.37	Ondoy/29Nov2009	5YR
214	8.80768200000	125.11395500000	0.50	0.55	0.05	Ondoy/29Nov2009	5YR
215	8.80885299900	125.11545300000	1.02	0.75	-0.27	Ondoy/29Nov2009	5YR
216	8.80818500000	125.11689400000	1.38	0.00	-1.38	Ondoy/29Nov2009	5YR
217	8.80817300000	125.11689000000	1.38	1.40	0.02	Ondoy/29Nov2009	5YR
218	8.80762100000	125.11701700000	1.58	1.35	-0.23	Ondoy/29Nov2009	5YR
219	8.80744999900	125.11686300000	1.58	1.40	-0.18	Ondoy/29Nov2009	5YR
220	8.83698900000	125.12520400000	0.05	0.40	0.35	Ondoy/29Nov2009	5YR
221	8.83704900100	125.12572500000	0.05	0.75	0.70	Ondoy/29Nov2009	5YR
222	8.83709599900	125.12566600000	0.05	0.25	0.20	Ondoy/29Nov2009	5YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
223	8.83747000000	125.12621900000	0.05	0.25	0.20	Ondoy/29Nov2009	5YR
224	8.83736100000	125.12645800000	0.18	0.40	0.22	Ondoy/29Nov2009	5YR
225	8.83731300000	125.12720700000	0.05	0.75	0.70	Ondoy/29Nov2009	5YR
226	8.83692500000	125.12707300000	0.05	0.40	0.35	Ondoy/29Nov2009	5YR
227	8.83764500000	125.12905200000	0.05	0.40	0.35	Ondoy/29Nov2009	5YR
228	8.83755200000	125.12910700000	0.05	0.98	0.93	Ondoy/29Nov2009	5YR
229	8.83860300000	125.12999700000	0.05	0.07	0.02	Ondoy/29Nov2009	5YR
230	8.83829200000	125.13018000000	0.05	0.75	0.70	Ondoy/29Nov2009	5YR
231	8.83794700100	125.13040200000	0.48	0.55	0.07	Ondoy/29Nov2009	5YR
232	8.83850100000	125.13113200000	0.61	0.98	0.37	Ondoy/29Nov2009	5YR
233	8.83801100000	125.13140800000	0.65	0.75	0.10	Ondoy/29Nov2009	5YR
234	8.83849300000	125.13201900000	0.35	0.80	0.45	Ondoy/29Nov2009	5YR
235	8.83814799900	125.13248900000	0.06	0.55	0.49	Ondoy/29Nov2009	5YR
236	8.83816600000	125.13256400000	0.06	0.20	0.14	Ondoy/29Nov2009	5YR
237	8.83740200000	125.13293600000	0.06	0.00	-0.06	Ondoy/29Nov2009	5YR
238	8.83704100000	125.13277600000	0.27	0.00	-0.27	Ondoy/29Nov2009	5YR
239	8.83727100000	125.13231800000	0.66	0.75	0.09	Ondoy/29Nov2009	5YR
240	8.83650800000	125.13257200000	0.05	0.00	-0.05	Ondoy/29Nov2009	5YR
241	8.83616500000	125.13239600000	0.05	0.00	-0.05	Ondoy/29Nov2009	5YR
242	8.83439200000	125.13160000000	0.06	0.00	-0.06	Ondoy/29Nov2009	5YR
243	8.83330200000	125.13119200000	0.12	0.00	-0.12	Ondoy/29Nov2009	5YR
244	8.83158500000	125.13008100000	0.05	0.55	0.50	Ondoy/29Nov2009	5YR
245	8.83161700000	125.12978700000	1.40	0.98	-0.42	Ondoy/29Nov2009	5YR
246	8.83156300000	125.12972800000	1.42	0.98	-0.44	Ondoy/29Nov2009	5YR
247	8.83151400000	125.12970400000	1.42	1.40	-0.02	Ondoy/29Nov2009	5YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
248	8.83144100000	125.12982100000	1.41	1.40	-0.01	Ondoy/29Nov2009	5YR
249	8.83151200000	125.13035600000	0.06	0.00	-0.06	Ondoy/29Nov2009	5YR
250	8.83065600000	125.12977900000	0.05	0.00	-0.05	Ondoy/29Nov2009	5YR
251	8.82652100000	125.11582400000	1.04	0.00	-1.04	Ondoy/29Nov2009	5YR
252	8.82690600000	125.11699000000	1.04	0.00	-1.04	Ondoy/29Nov2009	5YR
253	8.82696500000	125.11702900000	1.15	1.50	0.35	Ondoy/29Nov2009	5YR
254	8.82696300000	125.11693800000	1.04	1.55	0.51	Ondoy/29Nov2009	5YR
255	8.82694700000	125.11698000000	1.04	0.00	-1.04	Ondoy/29Nov2009	5YR
256	8.82590600000	125.11733200000	1.15	1.80	0.65	Ondoy/29Nov2009	5YR
257	8.82445300000	125.11854500000	0.21	0.55	0.34	Ondoy/29Nov2009	5YR
258	8.82458600000	125.11875300000	0.46	0.55	0.09	Ondoy/29Nov2009	5YR
259	8.82361799900	125.11793700000	0.28	0.40	0.12	Ondoy/29Nov2009	5YR
260	8.82268800000	125.11738500000	0.29	0.55	0.26	Ondoy/29Nov2009	5YR
261	8.82167200000	125.11743100000	0.36	0.55	0.19	Ondoy/29Nov2009	5YR
262	8.81922999900	125.11784700000	0.38	0.55	0.17	Ondoy/29Nov2009	5YR
263	8.80296100000	125.11720000000	1.76	1.00	-0.76	Ondoy/29Nov2009	5YR
264	8.80791100000	125.12024000000	1.36	0.60	-0.76	Ondoy/29Nov2009	5YR
265	8.80726100000	125.11951000000	5.07	0.90	-4.17	Ondoy/29Nov2009	5YR
266	8.80974200000	125.12018000000	3.22	1.05	-2.17	Ondoy/29Nov2009	5YR
267	8.81419400000	125.12090000000	1.71	0.50	-1.21	Ondoy/29Nov2009	5YR
268	8.81475800000	125.11965000000	0.12	0.70	0.58	Ondoy/29Nov2009	5YR
269	8.81897300000	125.12252000000	0.88	0.65	-0.23	Ondoy/29Nov2009	5YR
270	8.81962800000	125.12173000000	0.05	0.40	0.35	Ondoy/29Nov2009	5YR
271	8.82004600000	125.11860000000	1.00	0.45	-0.55	Ondoy/29Nov2009	5YR
272	8.82096100000	125.11856000000	0.12	0.55	0.43	Ondoy/29Nov2009	5YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
273	8.82056700000	125.12307000000	1.75	0.70	-1.05	Ondoy/29Nov2009	5YR
274	8.82240000000	125.12477000000	0.63	0.60	-0.03	Ondoy/29Nov2009	5YR
275	8.82262900000	125.12425000000	1.82	0.82	-1.00	Ondoy/29Nov2009	5YR
276	8.82377200000	125.12547000000	3.46	1.52	-1.94	Ondoy/29Nov2009	5YR
277	8.82324700000	125.12677000000	2.11	0.60	-1.51	Ondoy/29Nov2009	5YR
278	8.82491700000	125.12667000000	1.06	1.41	0.35	Ondoy/29Nov2009	5YR
279	8.82474600000	125.12681000000	1.31	0.68	-0.63	Ondoy/29Nov2009	5YR
280	8.82562200000	125.12898000000	2.09	0.85	-1.24	Ondoy/29Nov2009	5YR
281	8.82720800000	125.12987000000	0.06	0.75	0.69	Ondoy/29Nov2009	5YR
282	8.82899300000	125.12894000000	2.24	1.72	-0.52	Ondoy/29Nov2009	5YR
283	8.82986000000	125.12785000000	1.57	1.61	0.04	Ondoy/29Nov2009	5YR
284	8.83007000000	125.12892000000	0.16	1.48	1.32	Ondoy/29Nov2009	5YR
285	8.83001400000	125.12616000000	1.01	1.40	0.39	Ondoy/29Nov2009	5YR
286	8.82972400000	125.12593000000	2.06	1.00	-1.06	Ondoy/29Nov2009	5YR
287	8.82920200000	125.12536000000	1.69	1.25	-0.44	Ondoy/29Nov2009	5YR
288	8.82959000000	125.12514000000	1.87	0.00	-1.87	Ondoy/29Nov2009	5YR
289	8.81387600000	125.11769000000	1.10	0.65	-0.45	Ondoy/29Nov2009	5YR
290	8.81083000000	125.11784000000	1.48	1.02	-0.46	Ondoy/29Nov2009	5YR
291	8.81916200000	125.11812000000	1.65	0.45	-1.20	Ondoy/29Nov2009	5YR
292	8.82154200000	125.11678000000	0.73	0.73	0.00	Ondoy/29Nov2009	5YR
293	8.82113300000	125.11608000000	1.07	0.65	-0.42	Ondoy/29Nov2009	5YR
294	8.82248700000	125.11755000000	1.92	0.55	-1.37	Ondoy/29Nov2009	5YR
295	8.82310300000	125.11772000000	0.05	0.45	0.40	Ondoy/29Nov2009	5YR
296	8.82496500000	125.11734000000	0.88	1.87	0.99	Ondoy/29Nov2009	5YR
297	8.82836800000	125.11853000000	0.67	0.55	-0.12	Ondoy/29Nov2009	5YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
298	8.82926900000	125.12250000000	0.05	0.30	0.25	Ondoy/29Nov2009	5YR
299	8.82832900000	125.11953000000	0.23	0.40	0.17	Ondoy/29Nov2009	5YR
300	8.82436100000	125.11506000000	0.54	0.45	-0.09	Ondoy/29Nov2009	5YR
301	8.82255200000	125.11369000000	0.05	0.65	0.60	Ondoy/29Nov2009	5YR
302	8.82283700000	125.11222000000	0.38	0.50	0.12	Ondoy/29Nov2009	5YR
303	8.82028800000	125.10970000000	0.05	0.00	-0.05	Ondoy/29Nov2009	5YR
304	8.81691600000	125.10906000000	0.09	0.00	-0.09	Ondoy/29Nov2009	5YR
305	8.81924600000	125.10858000000	0.05	0.00	-0.05	Ondoy/29Nov2009	5YR
306	8.81550700000	125.10517000000	0.12	0.00	-0.12	Ondoy/29Nov2009	5YR
307	8.81781300000	125.10552000000	0.12	0.00	-0.12	Ondoy/29Nov2009	5YR
308	8.81796100000	125.10559000000	0.06	0.00	-0.06	Ondoy/29Nov2009	5YR
309	8.82702000000	125.11517000000	0.62	0.00	-0.62	Ondoy/29Nov2009	5YR
310	8.82685500000	125.11394000000	0.38	0.40	0.02	Ondoy/29Nov2009	5YR
311	8.82487900000	125.11009000000	0.64	0.00	-0.64	Ondoy/29Nov2009	5YR
312	8.82407200000	125.10852000000	0.09	0.00	-0.09	Ondoy/29Nov2009	5YR
313	8.82210000000	125.10736000000	0.34	0.00	-0.34	Ondoy/29Nov2009	5YR
314	8.82012000000	125.10533000000	0.35	0.00	-0.35	Ondoy/29Nov2009	5YR
315	8.81628900000	125.09948000000	0.28	0.00	-0.28	Ondoy/29Nov2009	5YR
316	8.83926100000	125.13213000000	0.38	1.20	0.82	Ondoy/29Nov2009	5YR
317	8.83993900000	125.13292000000	0.62	1.20	0.58	Ondoy/29Nov2009	5YR
318	8.83702300000	125.12689000000	0.21	0.50	0.29	Ondoy/29Nov2009	5YR
319	8.83604800000	125.12870000000	0.05	0.50	0.45	Ondoy/29Nov2009	5YR
320	8.83739500000	125.12924000000	0.50	0.50	0.00	Ondoy/29Nov2009	5YR
321	8.83874800000	125.13242000000	0.29	0.50	0.21	Ondoy/29Nov2009	5YR
322	8.83141400000	125.12956000000	1.24	1.50	0.26	Ondoy/29Nov2009	5YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
323	8.83141400000	125.12956000000	1.24	1.50	0.26	Ondoy/29Nov2009	5YR
324	8.83109000000	125.12940000000	1.15	1.50	0.35	Ondoy/29Nov2009	5YR
325	8.83043100000	125.12898000000	0.05	1.50	1.45	Ondoy/29Nov2009	5YR
326	8.83055400000	125.12785000000	0.05	0.50	0.45	Ondoy/29Nov2009	5YR
327	8.83068400000	125.12658000000	0.88	0.50	-0.38	Ondoy/29Nov2009	5YR
328	8.83064500000	125.12618000000	1.19	1.20	0.01	Ondoy/29Nov2009	5YR
329	8.82989900000	125.12484000000	0.05	1.20	1.15	Ondoy/29Nov2009	5YR
330	8.82965600000	125.12179000000	0.23	0.00	-0.23	Ondoy/29Nov2009	5YR
331	8.82867600000	125.11882000000	0.79	0.60	-0.19	Ondoy/29Nov2009	5YR
332	8.83022400000	125.11997000000	0.43	0.50	0.07	Ondoy/29Nov2009	5YR
333	8.83491500000	125.12283000000	0.60	0.00	-0.60	Ondoy/29Nov2009	5YR
334	8.83402800000	125.11668000000	0.67	0.00	-0.67	Ondoy/29Nov2009	5YR
335	8.83394300000	125.11630000000	0.50	0.00	-0.50	Ondoy/29Nov2009	5YR
336	8.82690000000	125.11463000000	0.43	0.00	-0.43	Ondoy/29Nov2009	5YR
337	8.82783100000	125.11345000000	0.80	2.00	1.20	Ondoy/29Nov2009	5YR
338	8.82755700000	125.11109000000	0.69	1.50	0.81	Ondoy/29Nov2009	5YR
339	8.82770200000	125.10972000000	0.63	1.50	0.87	Ondoy/29Nov2009	5YR
340	8.83189600000	125.11262000000	1.45	0.50	-0.95	Ondoy/29Nov2009	5YR
341	8.83264200000	125.11242000000	0.52	0.00	-0.52	Ondoy/29Nov2009	5YR
342	8.83123100000	125.10895000000	0.31	0.00	-0.31	Ondoy/29Nov2009	5YR
343	8.83089600000	125.10899000000	0.88	1.50	0.62	Ondoy/29Nov2009	5YR
344	8.82920700000	125.10769000000	1.19	1.50	0.31	Ondoy/29Nov2009	5YR
345	8.82773100000	125.10701000000	0.64	0.70	0.06	Ondoy/29Nov2009	5YR
346	8.82947000000	125.10422000000	0.67	0.90	0.23	Ondoy/29Nov2009	5YR
347	8.82855600000	125.10255000000	0.60	0.00	-0.60	Ondoy/29Nov2009	5YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
348	8.82806300000	125.10418000000	0.79	0.90	0.11	Ondoy/29Nov2009	5YR
349	8.82751700000	125.10282000000	0.50	0.90	0.40	Ondoy/29Nov2009	5YR
350	8.82756100000	125.10303000000	0.60	1.50	0.90	Ondoy/29Nov2009	5YR
351	8.82662600000	125.10362000000	0.06	0.50	0.44	Ondoy/29Nov2009	5YR
352	8.82635600000	125.10313000000	0.35	0.50	0.15	Ondoy/29Nov2009	5YR
353	8.82571600000	125.10263000000	0.21	0.50	0.29	Ondoy/29Nov2009	5YR
354	8.82469800000	125.10153000000	0.28	0.50	0.22	Ondoy/29Nov2009	5YR
355	8.82704200000	125.09955000000	0.09	0.00	-0.09	Ondoy/29Nov2009	5YR
356	8.82923700000	125.09938000000	0.12	0.00	-0.12	Ondoy/29Nov2009	5YR
357	8.82866000000	125.10117000000	0.67	0.90	0.23	Ondoy/29Nov2009	5YR
358	8.82695400000	125.10145000000	0.40	1.20	0.80	Ondoy/29Nov2009	5YR
359	8.82609900000	125.10091000000	0.12	0.90	0.78	Ondoy/29Nov2009	5YR
360	8.82895700000	125.09642000000	0.63	0.90	0.27	Ondoy/29Nov2009	5YR
361	8.82691400000	125.09699000000	0.47	0.00	-0.47	Ondoy/29Nov2009	5YR
362	8.82772100000	125.09626000000	0.69	0.50	-0.19	Ondoy/29Nov2009	5YR
363	8.82716200000	125.09398000000	0.43	0.25	-0.18	Ondoy/29Nov2009	5YR
364	8.82591400000	125.09519000000	0.12	0.00	-0.12	Ondoy/29Nov2009	5YR
365	8.82519200000	125.09695000000	0.28	0.00	-0.28	Ondoy/29Nov2009	5YR
366	8.82542100000	125.09696000000	0.31	0.00	-0.31	Ondoy/29Nov2009	5YR

Annex 12. Educational Institutions Affected by Flooding in Gahub Floodplain

Table A-12.1 Educational institutions in Gingoog City, Misamis Oriental affected by flooding in Gahub Floodplain

Misamis Oriental				
Gingoog City				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Don Manuel Lugod Central School	Barangay 10	Low	Low	Low
Don Manuel Lugod Central School	Barangay 11	Low	Low	Medium
Don Manuel Lugod Central School	Barangay 14	Low	Low	Medium
Guevara Institute of Technology	Barangay 14		Low	Low
Don Manuel Lugod Central School	Barangay 15	Low	Low	Medium
Guevara Institute of Technology	Barangay 15			
Gingoog Charismatic Foundation	Barangay 16		Low	Low
Goodwill Technical Skills and Computer Col.	Barangay 16			
Gingoog City National High School	Barangay 2	Medium	Medium	Medium
Nursery School	Barangay 22-A			
Christ The King College	Barangay 23	Low	Medium	Medium
Gingoog Christian College	Barangay 23		Medium	Medium
Gingoog City Elementary School	Barangay 23		Low	Medium
Gingoog City National High School	Barangay 23	Medium	Medium	Medium
School	Barangay 23		Low	Medium
Talisay Elementary School	Barangay 23		Low	Low
TESDA	Barangay 23		Low	Low
Magallanes Elementary School	Barangay 24	Low	Medium	Medium
Magallanes Integrated School	Barangay 24			
GINCITU-TSC	Barangay 24-A		Low	Low
Pundasan National High School	Barangay 24-A	Low	Medium	Medium
Christ The King College	Barangay 3	Medium	Medium	Medium
Goodwill Technical Skills and Computer Col.	Barangay 9			
Magallanes Integrated School	Barangay 9			Low
San Juan Central School	San Juan			
Don Manuel Lugod Central School	Barangay 10	Low	Low	Low

Annex 13. Medical Institutions Affected by Flooding in Gahub Floodplain

Table A-13.1 Medical Institutions in Gingoog City, Misamis Oriental affected by flooding in Gahub Floodplain

Misamis Oriental				
Gingoog City				
Building Name	Barangay	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
City Family Health Center	Barangay 15			
City Family Health Center	Barangay 16			
Hospital	Barangay 21	Low	Low	Medium
Lipunan Hospital Inc.	Barangay 24			Low
Lipunan Hospital Inc.	Barangay 24-A			Low