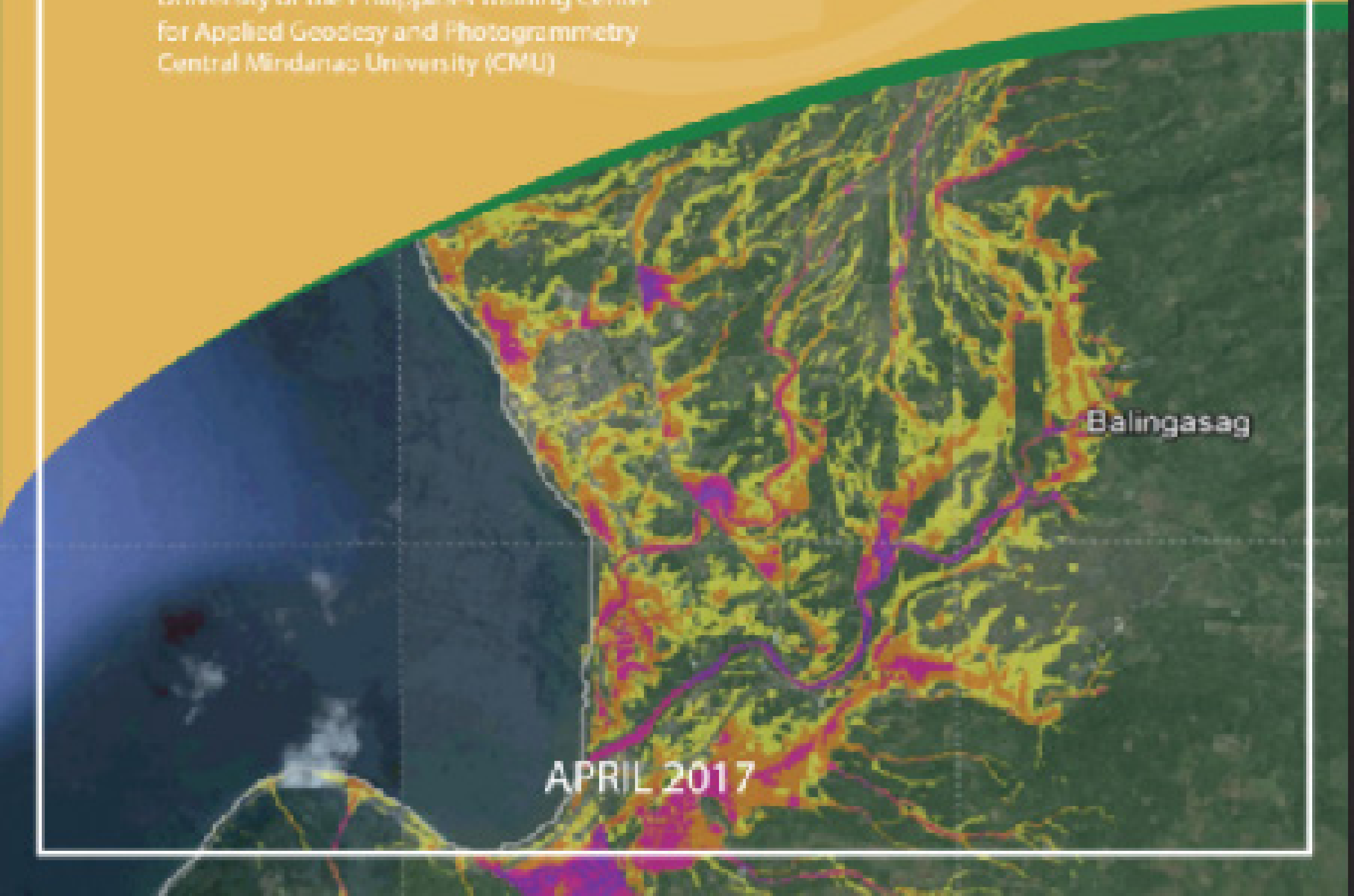
Hazard Mapping of the Philippines Using LIDAR (Phil-LIDAR 1)

LiDAR Surveys and Flood Mapping of Musi-Musi River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
Central Mindanao University (CMU)



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LIST OF ACRONYMS AND ABBREVIATIONS

AAC	Asian Aerospace Corporation
Ab	abutment
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
ATQ	Antique
AWLS	Automated Water Level Sensor
BA	Bridge Approach
BM	benchmark
CAD	Computer-Aided Design
CN	Curve Number
CSRS	Chief Science Research Specialist
DAC	Data Acquisition Component
DEM	Digital Elevation Model
DENR	Department of Environment and Natural Resources
DOST	Department of Science and Technology
DPPC	Data Pre-Processing Component
DREAM	Disaster Risk and Exposure Assessment for Mitigation [Program]
DRRM	Disaster Risk Reduction and Management
DSM	Digital Surface Model
DTM	Digital Terrain Model
DVBC	Data Validation and Bathymetry Component
FMC	Flood Modeling Component
FOV	Field of View
GiA	Grants-in-Aid
GCP	Ground Control Point
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HEC-HMS	Hydrologic Engineering Center - Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center - River Analysis System
HC	High Chord
IDW	Inverse Distance Weighted [interpolation method]
IMU	Inertial Measurement Unit
kts	knots
LAS	LiDAR Data Exchange File format
LC	Low Chord
LGU	local government unit
LiDAR	Light Detection and Ranging
LMS	LiDAR Mapping Suite
m AGL	meters Above Ground Level
MMS	Mobile Mapping Suite
MSL	mean sea level
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
UPC	University of the Philippines Cebu
UP-TCAGP	University of the Philippines – Training Center for Applied Geodesy and Photogrammetry

CHAPTER 1. OVERVIEW OF THE PROGRAM AND DIGOS RIVER

1.1 Background of the Phil-LiDAR 1 Program

The University of the Philippines Training Center for Applied Geodesy and Photogrammetry (UP-TCAGP) launched a research program entitled "Nationwide Hazard Mapping using LiDAR" or Phil-LiDAR 1 in 2014, supported by the Department of Science and Technology (DOST) Grant-in-Aid (GiA) Program. The program was primarily aimed at acquiring a national elevation and resource dataset at sufficient resolution to produce information necessary to support the different phases of disaster management. Particularly, it targeted to operationalize the development of flood hazard models that would produce updated and detailed flood hazard maps for the major river systems in the country.

Also, the program was 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 entitled "Flood Mapping of Rivers in the Philippines Using Airborne LiDAR: Methods." (Paringit, et. Al. 2017)

The implementing partner university for the Phil-LiDAR 1 Program is the Central Mindanao State 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 13 river basins in the ______ Mindanao Region. The university is located in the municipality of Maramag in the province of Bukidnon.

1.2 Overview of the Musi-Musi River Basin

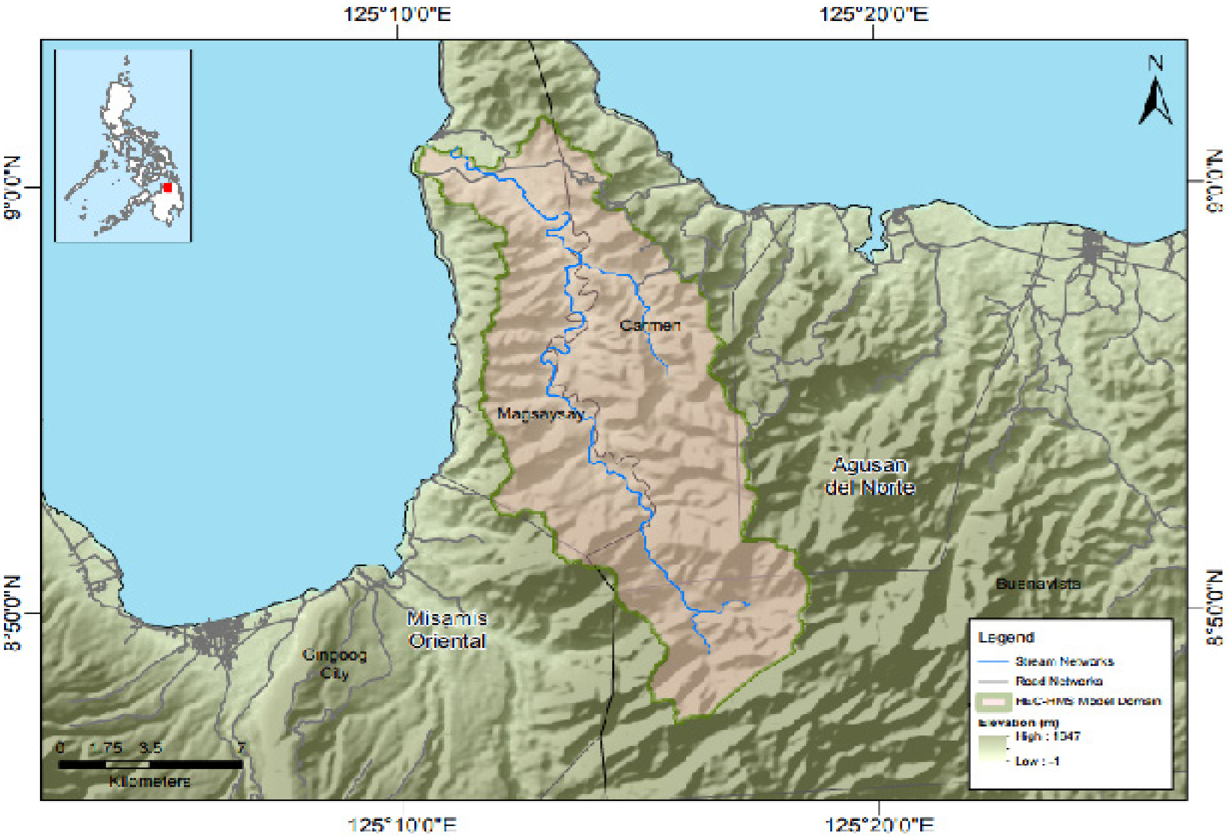

Figure 1. Map of Musi-Musi River Basin.

Musi-musi river is situated in the Municipality of Balingasag, Province of Misamis Oriental, Philippines. It lies between the geographical coordinates of 8°41’ to 8°48 north latitudes and 124°45’ to 124°54’ east longitudes. It has a total area of 7,772 hectares and comprises 16 barangay local government units. Its head water emanates from the hinterlands of the Municipalities of Balingasag and Claveria.

Significant socio-economic uses are contributed by the river to the Municipality of Balingasag. The river provides a classified major III water system supplying 18 barangays. It also supports irrigational needs to over 500-hectare rice fields. However, the small size of Musi-musi River is also occasionally overflowed with flood waters inundating houses and cultivated lands. According to the locals during the conducted focused group discussions, earliest accounted flood incident was on 1990 during Typhoon Ruping which destroyed two (2) houses carried along by the rapids of flood water. Among the other flood occurrences which hit the area were on 2000, 2011 (Typhoon Sendong), 2012 (Typhoon Pablo), 2013, and on 2014 (Typhoon Seniang) which placed several affected barangays under state of calamity.

Under the Phil-LiDAR1 Program, Musi-musi river was among the 13 rivers modeled and generated with up-to-date and detailed 3D flood hazard maps by Central Mindanao University (CMU) using Light Detection and Ranging (LiDAR) Technology. Maps were derived through flood modeling comprised of hydrologic and hydraulic models. The former which is responsible for simulating discharge based on a particular rainfall event was developed using the computer software Hydrologic Modeling System - Hydrologic Engineering Center (HEC-HMS). It was calibrated using the actual collected hydrologic and meteorologic data of Typhoon Seniang on December 29–30, 2014. Statistical tests employed to measure the model efficiency revealed a satisfactory model performance. Using the calibrated HMS model and Rainfall Intensity Duration Frequency (RIDF) data of the Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) based on a 26-year record of Lumbia Rain Gauge, hypothetical discharge amounts were simulated. Using these discharge hydrographs as inputs, water movement was simulated using Hydrologic Engineering Centre’s – Hydrologic River Analysis System (HEC-RAS) software over the LiDAR Digital Terrain Model (DTM) showing flood extent and depth information. Generated flood hazard maps show the 5-, 25-, and 100-year return period flood scenarios in Musi-musi river.

CHAPTER 2. LIDAR ACQUISITION OF THE MUSI-MUSI

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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 Musi-musi floodplain in Misamis Oriental. These missions were planned for 12 lines that 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 Musi-musi floodplain.

Table 1. Flight planning parameters for Pegasus LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
RX_BLKC	850	30	50	200	30	130	5
RX_BLKD	850	30	50	200	30	130	5
RX_BLKE	900	30	50	200	30	130	5
BLK64A	1200	30	50	200	30	130	5

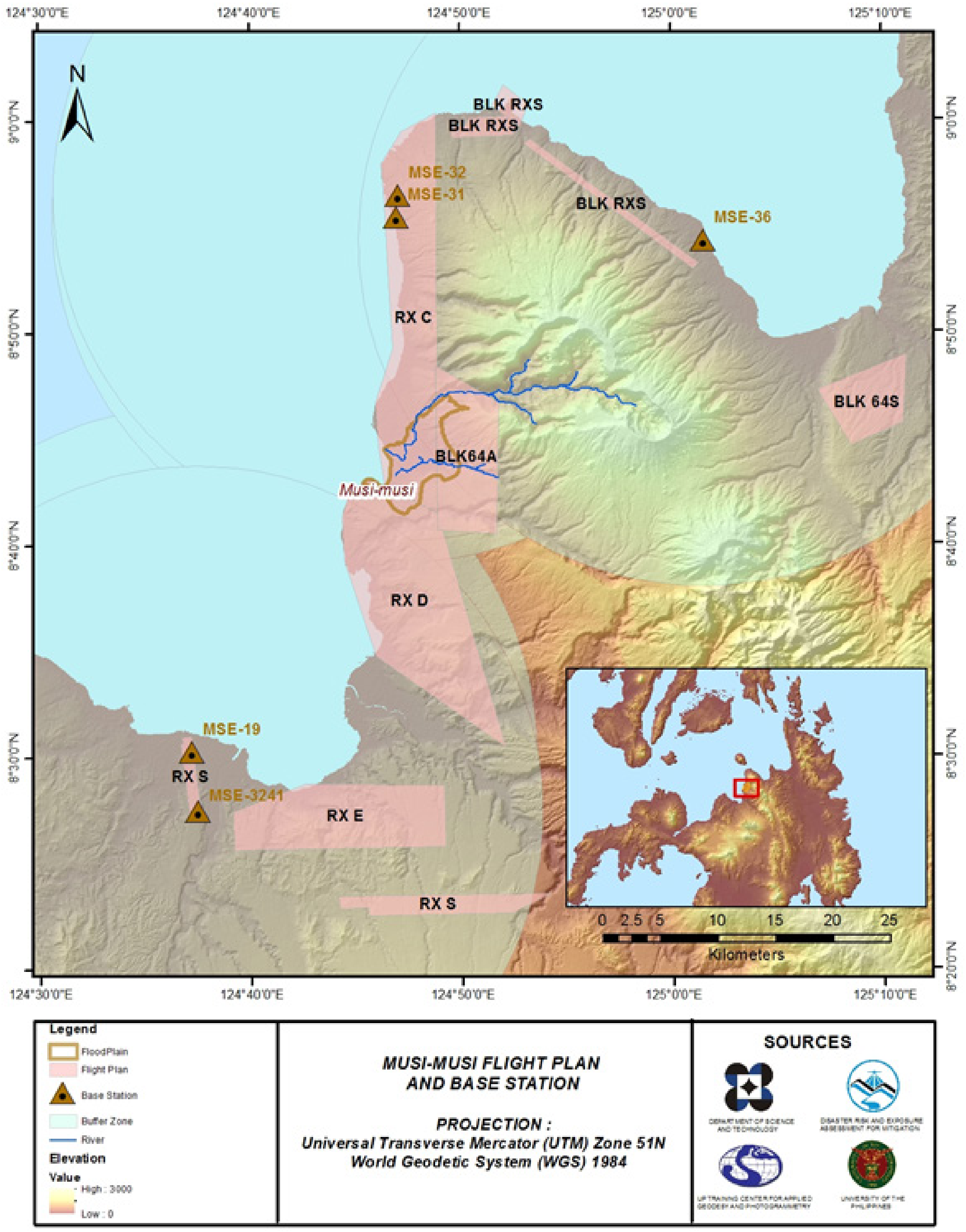
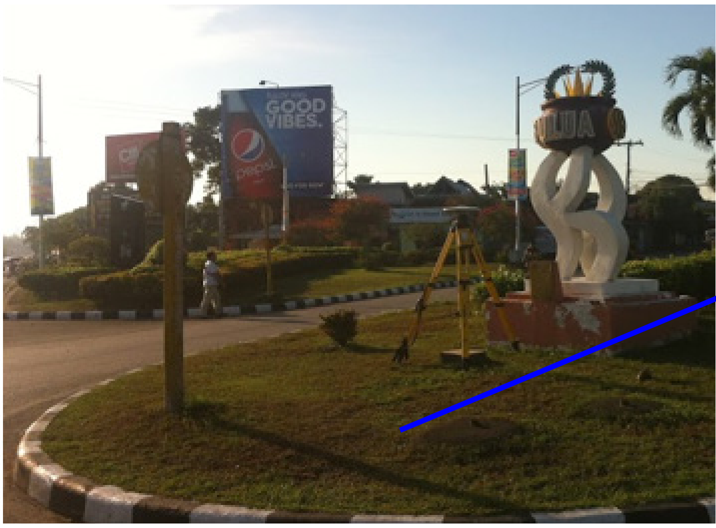


Figure 2. Flight plans and base stations used for Musi-Musi Floodplain.

2.2 Ground Base Stations

The project team was able to recover five (5) NAMRIA ground control points: MSE-19, MSE-31, MSE-32, MSE-36 which are of second (2nd) order accuracy and MSE-3241, which is of 3rd order accuracy. The certifications for the NAMRIA reference points are found in Annex 2. These were used as base stations during flight operations for the entire duration of the survey (May 25 – June 19, 2014) and November 15, 2016. 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 Musi-musi floodplain are shown in Figure 2.

Figure 3 to Figure 7 show the recovered NAMRIA reference points within the area. In addition, Table 2 to Table 6 show the details about the following NAMRIA control stations, while Table 7 shows the list of all ground control points occupied during the acquisition together with the corresponding dates of utilization.



(b)

(a)

Figure 3.GPS set-up over MSE-19 at the center island located at the road intersections going to Cagayan de Oro, Butuan City and Iligan City (a) and NAMRIA reference point MSE-16 (b) as recovered by the field team.

Table 2. Details of the recovered NAMRIA horizontal control point MSE-19 used as base station for the LiDAR acquisition.

Station Name	MSE-19	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	8° 30’ 19.11464” North
	Longitude	124° 37’ 6.46518” East
	Ellipsoidal Height	11.24200 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting	457,992.786 meters
	Northing	940,451.853 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	8° 30’ 15.52234” North
	Longitude	124° 37’ 11.86795” East
	Ellipsoidal Height	78.72200 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting	678,151.65 meters
	Northing	940,474.22 meters

(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 3. Details of the recovered NAMRIA horizontal control 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	8°55’28.57032” North
	Longitude	124°46’55.456” East
	Ellipsoidal Height	59.48400 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting	476032.898 meters
	Northing	986806.828 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	8°55’24.88251” North
	Longitude	124°47’0.81947” East
	Ellipsoidal Height	126.4900 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting	696109.62 meters
	Northing	986876.83 meters

(a) (b)

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 4. 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	2^{nd}	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	8°56'30.44605" North
	Longitude	124°46'58.97104" East
	Ellipsoidal Height	132.12900 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting	476141.401 meters
	Northing	988707.53 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	8°56'26.75387" North
	Longitude	124°47'4.33290" East
	Ellipsoidal Height	199.10100 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting	696045.73 meters
	Northing	988828.70 meters

(a) (b)

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 5. 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

(a)

(b)

Figure 7.GPS set-up over MSE-3241 on a center island near a gasoline station beside SM Cagayan de Oro (a) and NAMRIA reference point MSE-3241 (b) as recovered by the field team.

Table 6. Details of the recovered NAMRIA horizontal control point MSE-3241used as base station for the LiDAR acquisition.

Station Name	MSE-3241	
Order of Accuracy	3rd	
Relative Error (horizontal positioning)	1 in 10,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8° 27’ 31.07607” North 124° 37’ 23.18891” East 109.46700 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting Northing	458499.251 meters 935289.375 meters 458499.251 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8° 27’ 27.49608” North 124° 37’ 28.59587” East 177.055 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	678684.71 meters 935314.30 meters

Table 7. Ground control points used during LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
May 25,2014	1509P	1RDXE145A	MSE-31 & MSE-32
May 27,2014	1517P	1RXE147A	MSE-19 & MSE-3241
June 7, 2014	1561P	1RXE158A	MSE-19 & MSE-3241
June 16, 2014	1597P	1BLKRXE167A	MSE-19 & MSE-3241
June 19,2014	1609P	1RXS170A	MSE-31 & MSE-36
November 15,2016	23552P	BLK64A	MSE-31 & MSE-32

2.3 Flight Missions

Six (6) missions were conducted to complete the LiDAR data acquisition in Musi-musi floodplain, for a total of twenty four hours and fifty minutes (24+50) of flying time for RP-C9022. All missions were acquired using the Pegasus LiDAR system. Table 8 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 9 presents the actual parameters used during the LiDAR data acquisition.

Table 8. Flight missions for LiDAR data acquisition in Musi-musi floodplain

Date Surveyed	Flight Number	Flight Plan Area (km^2)	Surveyed Area (km^2)	Area Surveyed within the Floodplain (km^2)	Area Surveyed outside the Floodplain (km^2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
May 25,2014	1509P	145.49	146.09	13.73	132.36	766	4	17
May 27,2014	1517P	256.68	164.99	0	164.99	NA	4	23
June 7, 2014	1561P	161.42	193.69	3.25	190.44	NA	3	41
June 16, 2014	1597P	256.68	165.7	0	165.7	NA	4	0
June 19, 2014	1609P	145.49	141.10	1.92	139.18	618	4	18
November 15,2016	23552P	68.32	131.50	3.41	128.09	NA	4	11
TOTAL		1034.08	943.07	22.31	920.76	1384	24	50

Table 9. Actual parameters used during LiDAR data acquisition

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
1509P	800	30	50	200	30	130	5
1517P	900	30	50	200	30	130	5
1561P	1000	30	50	200	30	130	5
1597P	800	30	50	200	30	130	5
1609P	900	30	50	200	30	130	5
23552P	1200	30	50	200	30	130	5

2.4 Survey Coverage

Musi-musi floodplain is located in the provinces of Misamis Oriental with majority of the floodplain situated within the municipality of Balingasag. The municipality of Jasaan is fully covered by the survey. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 10. The actual coverage of the LiDAR acquisition for Musi-musi floodplain is presented in Figure 8.

Table 10. List of municipalities and cities surveyed during Musi-musi floodplain LiDAR survey.

Province	Municipality/City	Area of Municipality/City (km^2)	Total Area Surveyed (km^2)	Percentage of Area Surveyed
Misamis Oriental	Jasaan	68.33	68.33	100 %
	Binuangan	15.32	12.91	84 %
	Villanueva	46.05	38.71	84 %
	Sugbongcogon	21.35	14.59	68 %
	Kinoguitan	36.19	18.57	51 %
	Lagonglong	46.62	20.64	44 %
	Balingasag	125.59	54.01	43 %
	Salay	56.46	24.07	43 %
	Tagoloan	55.72	15.58	28 %
	Cagayan de Oro City	440.17	108.83	25 %
	Talisayan	65.14	11.99	18 %
	Balingoan	62.65	10.12	16 %
	Gingoog City	538.03	53.04	10 %
	Medina	118.64	7.55	6 %
	Claveria	768.95	44.47	6 %
Bukidnon	Manolo Fortich	350.15	59.80	17 %
	Libona	282.23	26.72	10 %
	Malitbog	359.59	27.29	8 %

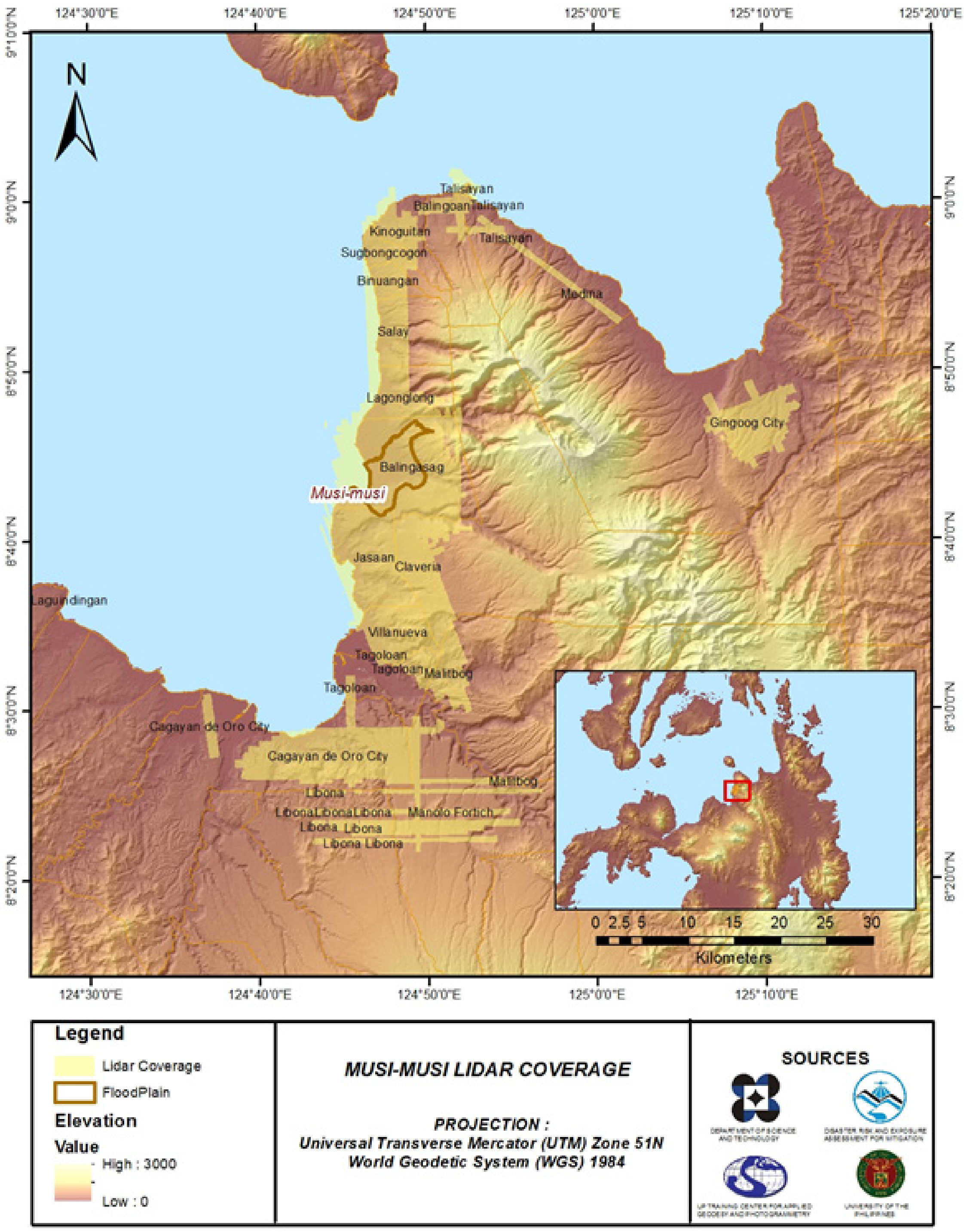


Figure 8. Actual LiDAR survey coverage for Musi-musi floodplain.

CHAPTER 3. LIDAR DATA PROCESSING OF THE DIGOS 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

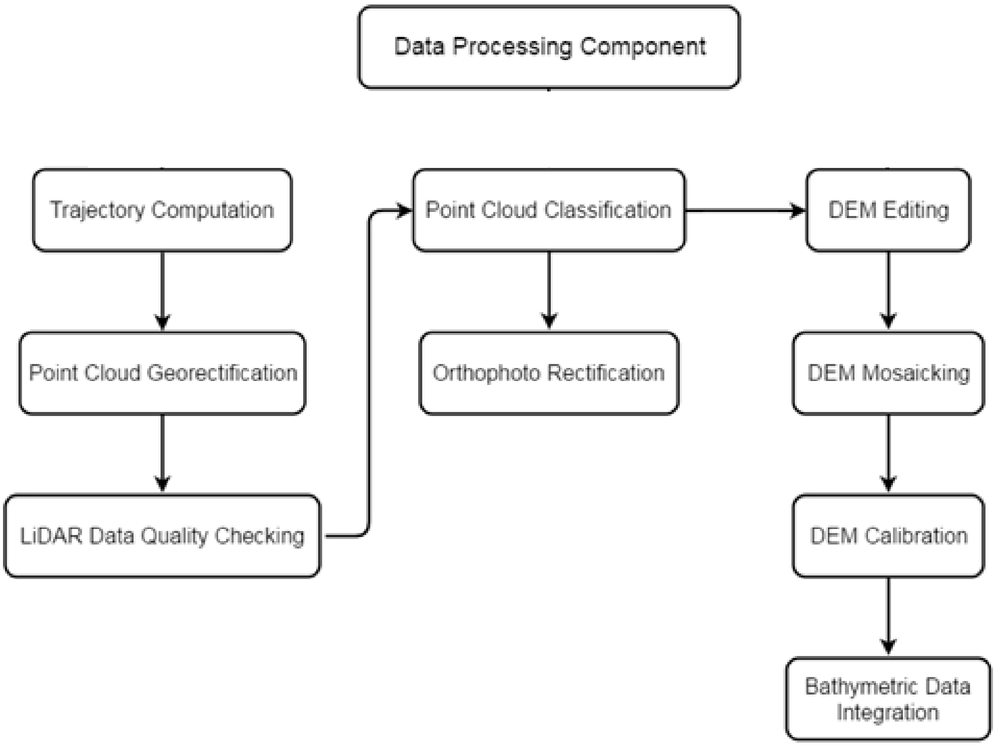


Figure 9. Schematic Diagram for Data Pre-Processing Component

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

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

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

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Musi-musi floodplain can be found in Annex 5. Data Transfer Sheets. Missions flown during the first survey conducted on May 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system over Municipality of Balingasag, Misamis Oriental. The Data Acquisition Component (DAC) transferred a total of 139.9 Gigabytes of Range data, 1.43 Gigabytes of POS data, 168.35 Megabytes of GPS base station data, and 98.9 Gigabytes of raw image data to the data server on June 23, 2014 for the first survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Musi-musi was fully transferred on July 28, 2014, as indicated on the Data Transfer Sheets for Musi-musi floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for flight 1609P, one of the Musi-musi flights, which is the North, East, and Down position RMSE values are shown in Figure 10. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on June 19, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

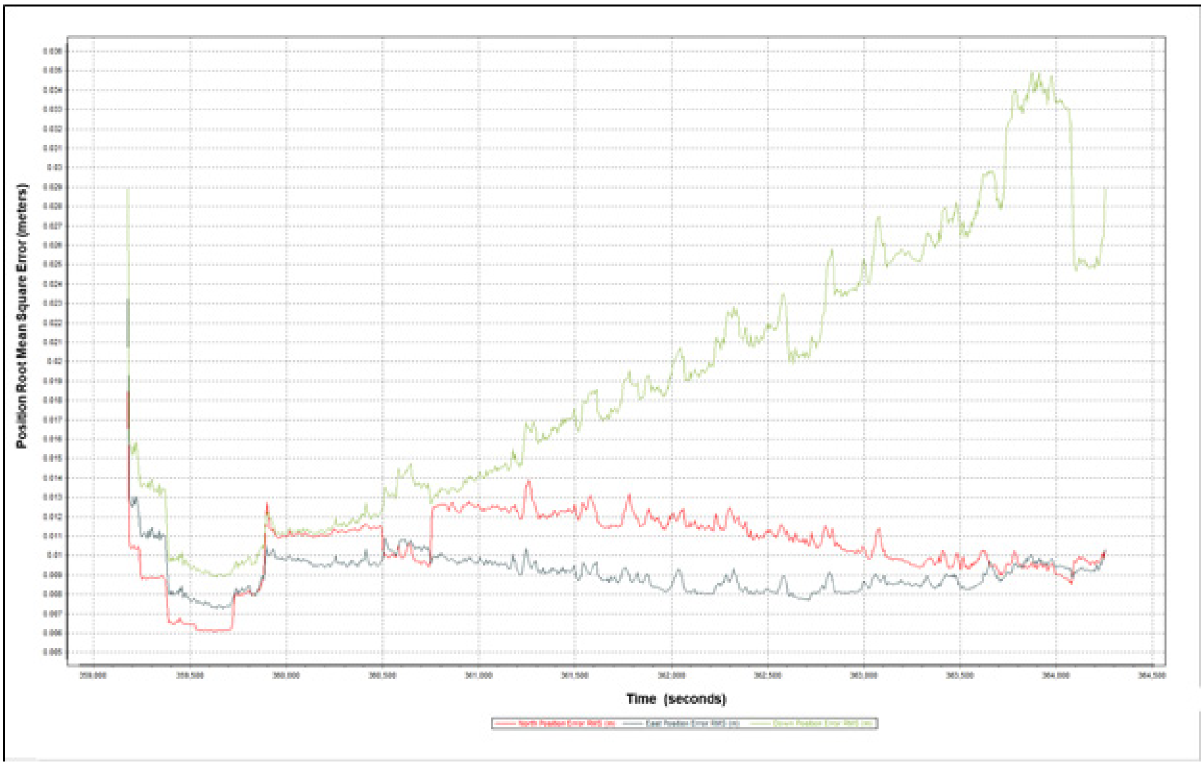


Figure 10. Smoothed Performance Metric Parameters of a Musi-musi Flight 1609P.

The time of flight was from 359200 seconds to 364200 seconds, which corresponds to morning of June 19, 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 POS system starts computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimize the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 10 shows that the North position RMSE peaks at 1.40 centimeters, the East position RMSE peaks at 1. 30 centimeters, and the Down position RMSE peaks at 3.50 centimeters, which are within the prescribed accuracies described in the methodology.

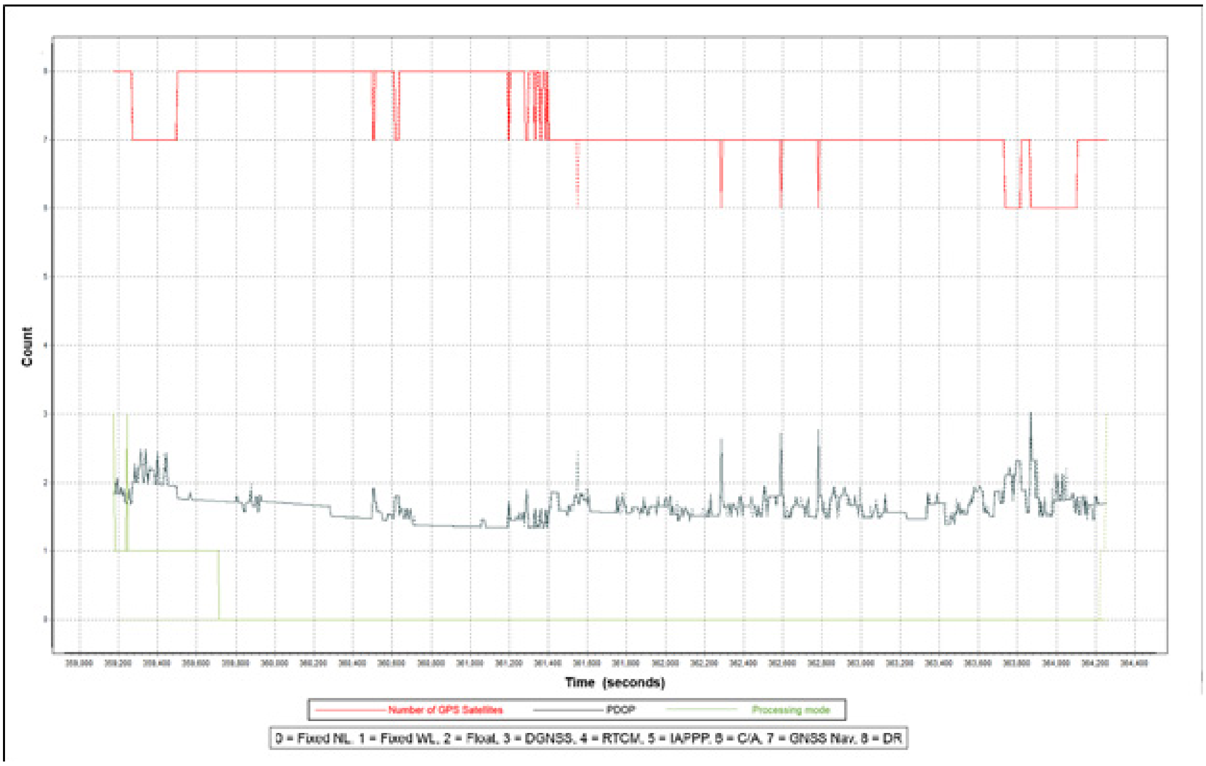


Figure 11. Solution Status Parameters of Musi-musi Flight 1609P.

The Solution Status parameters of flight 1609P, one of the Musi-musi flights, which are the number of GPS satellites, Positional Dilution of Precision, and the GPS processing mode used are shown in Figure 11. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Majority of the time, the number of satellites tracked was between 6 and 10. 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 Musi-musi flights is shown in Figure 12.

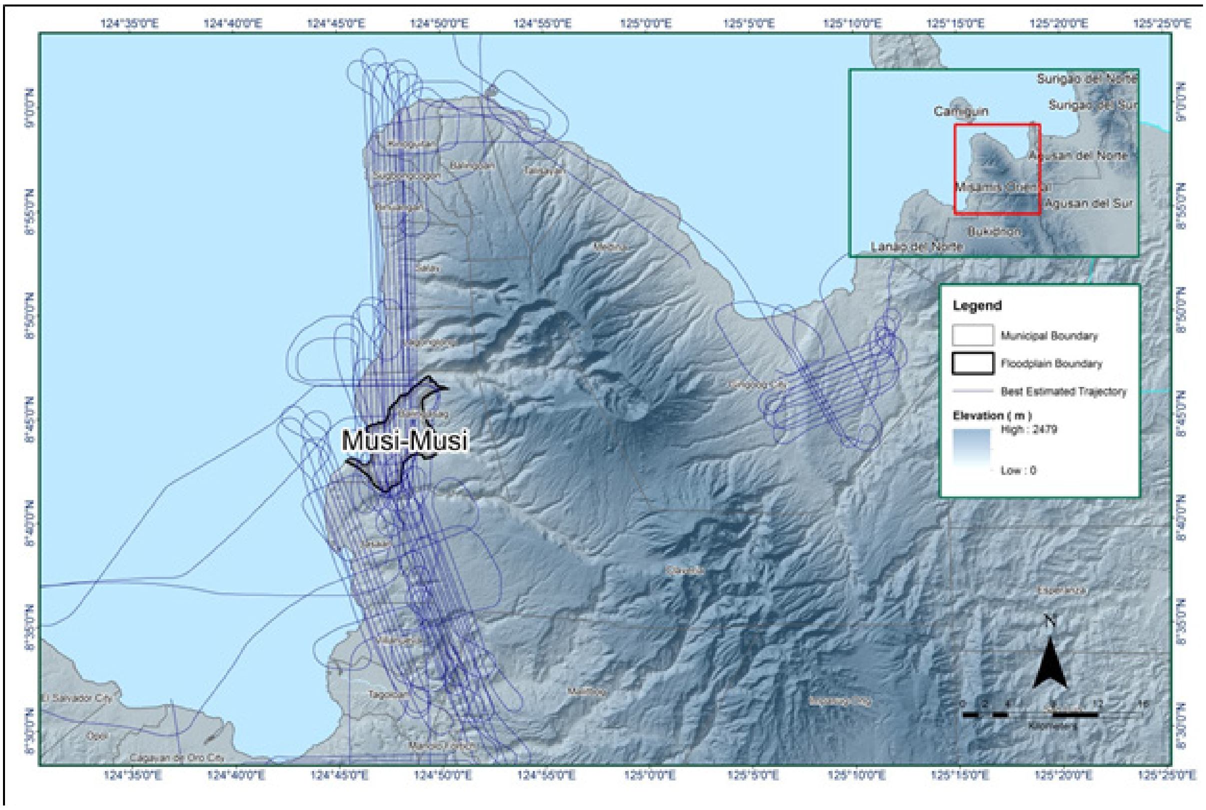


Figure 12. Best Estimated Trajectory of the lidar missions conducted over the Musi-Musi floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 72 flight lines, with each flight line containing two channels, since the Pegasus system contain two channels. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Musi-musi floodplain are given in Table 11.

Table 11. Self-Calibration Results values for Musi-musi flights.

Parameter	Value
Boresight Correction stdev (<0.001degrees)	0.000220
IMU Attitude Correction Roll and Pitch Corrections stdev (<0.001degrees)	0.00368
GPS Position Z-correction stdev (<0.01meters)	0.0026

The optimum accuracy is obtained for all Musi-musi flights based on the computed standard deviations of the corrections of the orientation parameters. Standard deviation values for individual blocks are available in the Annex 8. Mission Summary Reports.

3.5 LiDAR Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Musi-musi Floodplain is shown in Figure B-5. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

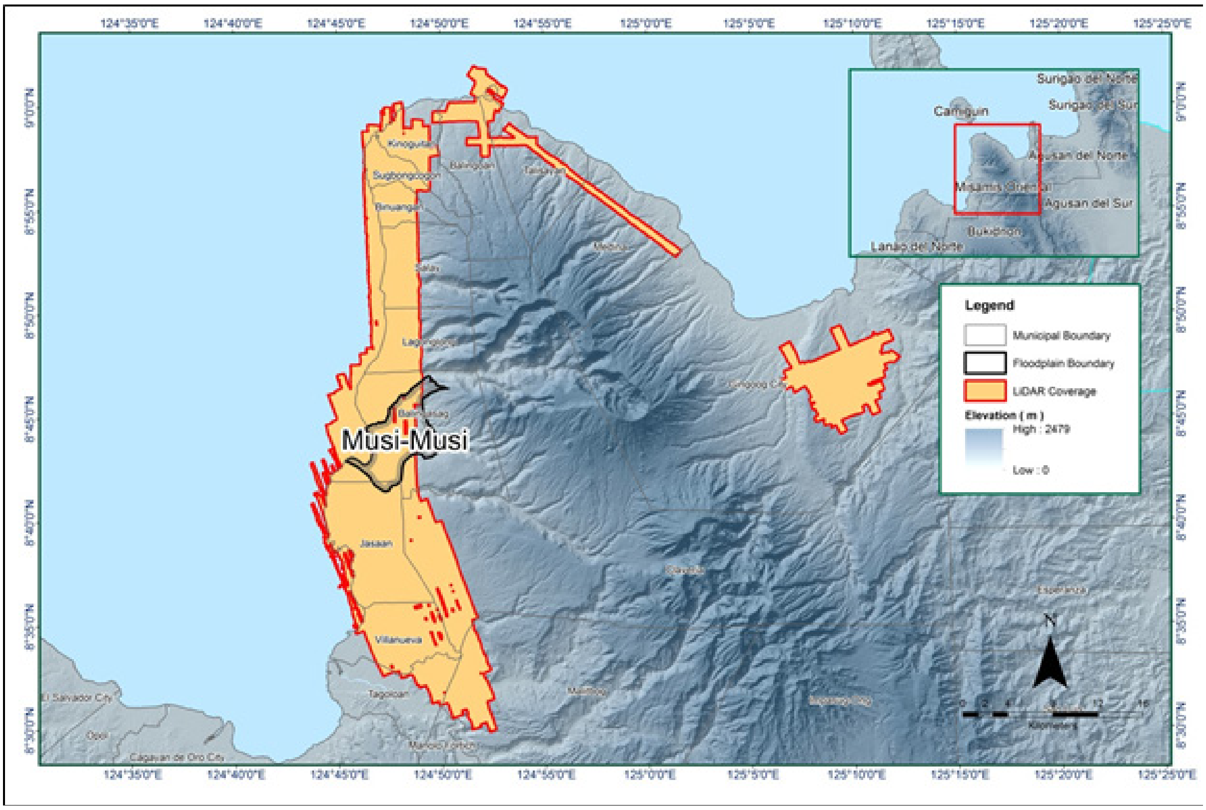


Figure 13. Boundary of the processed LiDAR data over Musi-musi Floodplain

The total area covered by the Musi-musi missions is 633.48 sq.km that is comprised of five (5) flight acquisitions grouped and merged into five (5) blocks as shown in Table 12.

Table 12. List of LiDAR blocks for Musi-musi floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
NorthernMindanao_RX_BlkC_supplement	1609P	76.89
NorthernMindanao_RX_supplement	1609P	50.42
NorthernMindanao_RX_BlkC	1509P	138.78
NorthernMindanao_RX_BlkD	1517P	241.20
	1561P	
	1597P	
Bukidnon_Blk64F	23552P	126.19
	TOTAL	**633.48 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 14. Since the Pegasus system employs two channels, we would expect an average value of 2 (blue) for areas where there is limited overlap, and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines.

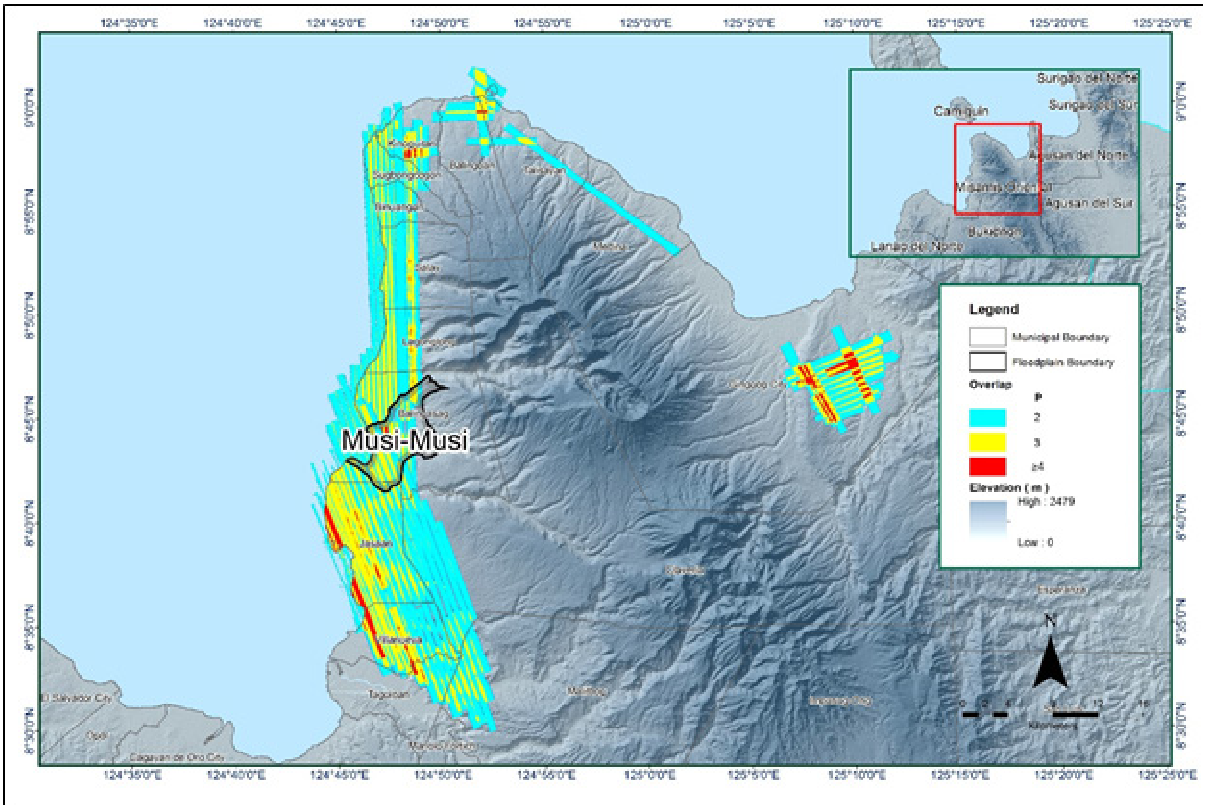


Figure 14. Image of data overlap for Musi-musi floodplain.

The overlap statistics per block for the Musi-musi floodplain can be found in Annex 8. Mission Summary Reports. It should be noted that one pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 30.50% and 38.61% respectively, which passed the 25% requirement.

The density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 15. It was determined that all LiDAR data for Musi-musi floodplain satisfy the point density requirement, and the average density for the entire survey area is 4.63 points per square meter.

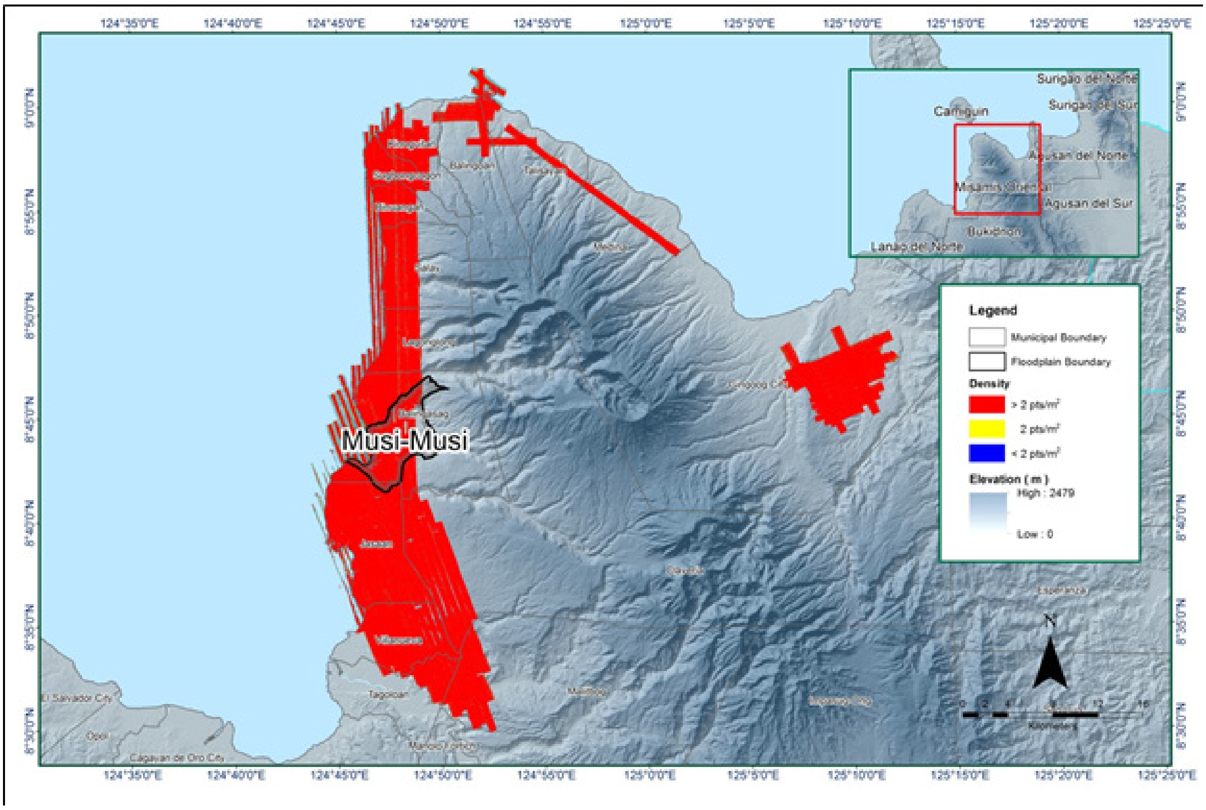


Figure 15. Density map of merged LiDAR data for Musi-musi floodplain.

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

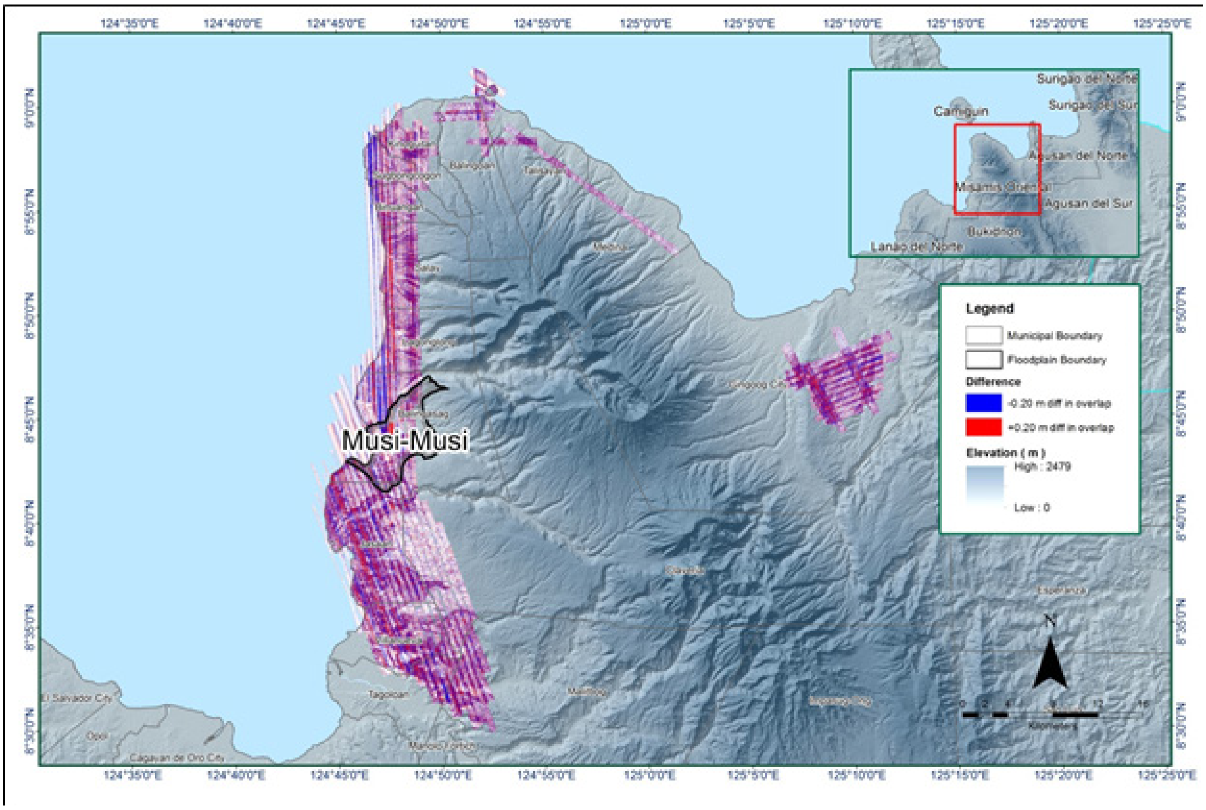


Figure 16. Elevation difference map between flight lines for Musi-musi floodplain.

A screen capture of the processed LAS data from a Musi-musi flight 1609P loaded in QT Modeler is shown in Figure 17. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed yellow line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

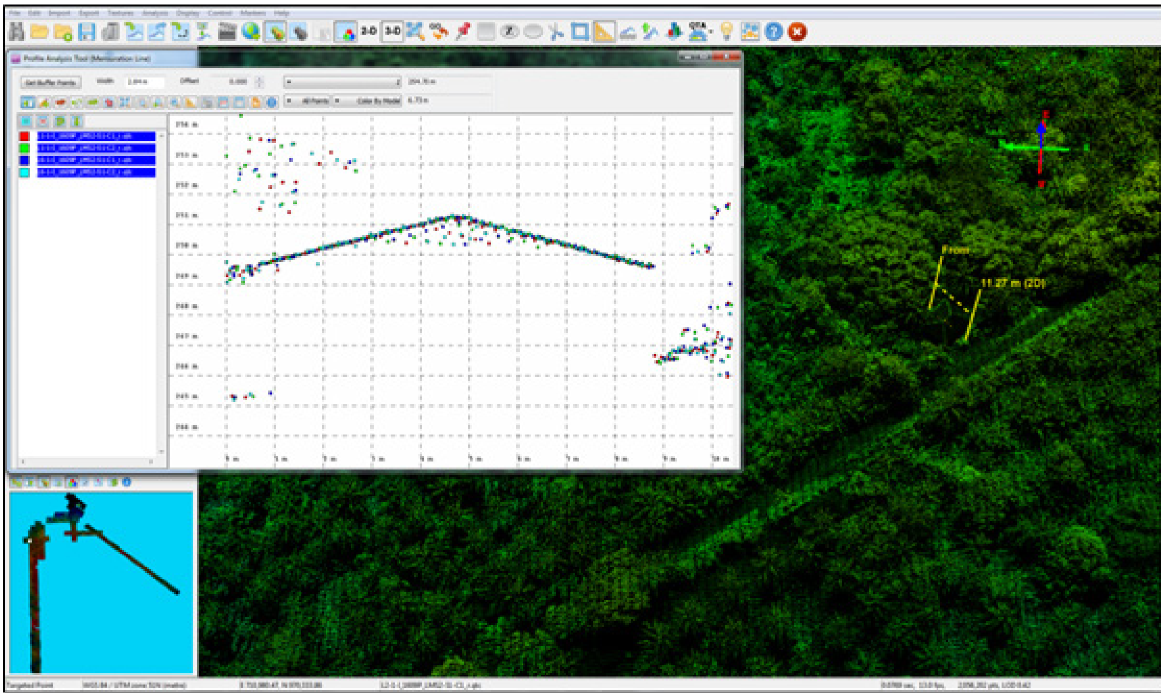


Figure 17. Quality checking for a Musi-musi flight 1609P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 13. Musi-musi classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	490,007,179
Low Vegetation	481,160,815
Medium Vegetation	892,464,071
High Vegetation	829,322,362
Building	30,305,024

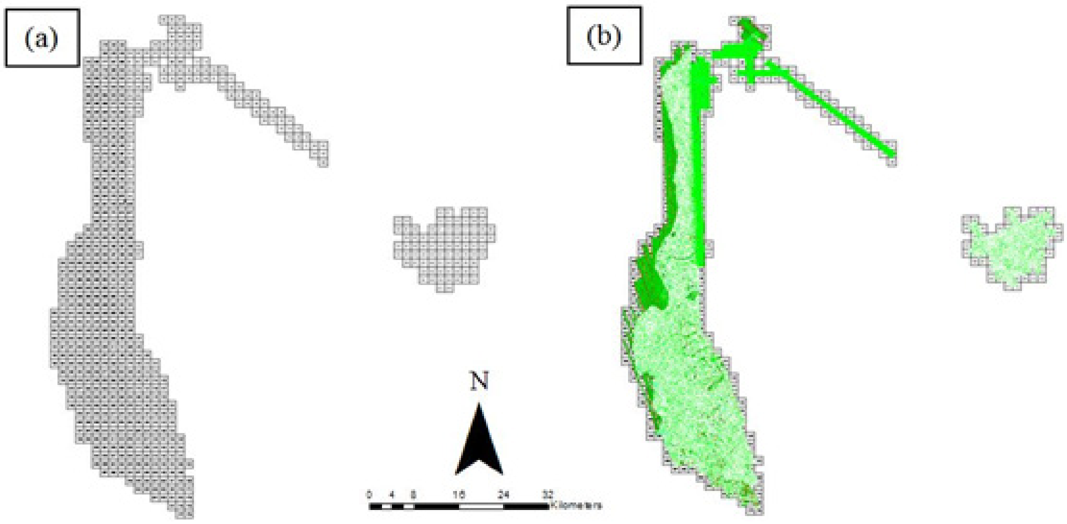


Figure 18. Tiles for Musi-musi floodplain (a) and classification results (b) in TerraScan.

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

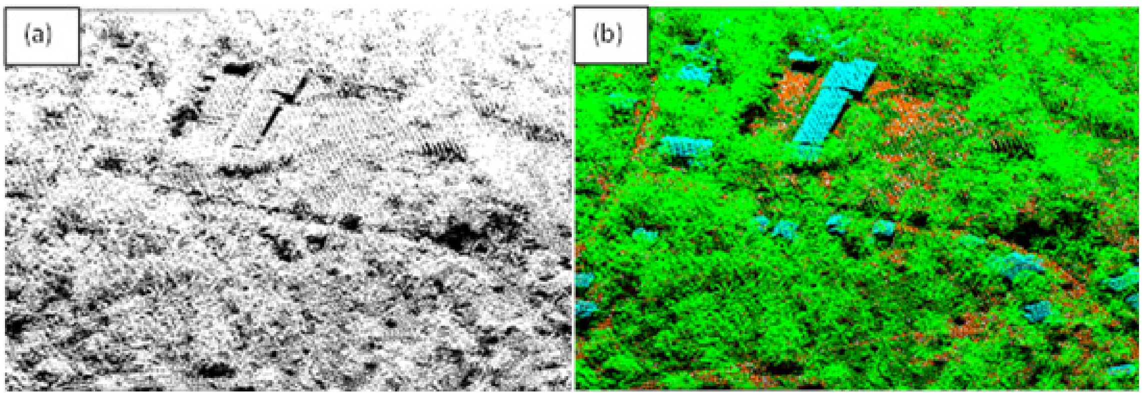


Figure 19. Point cloud before (a) and after (b) classification.

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

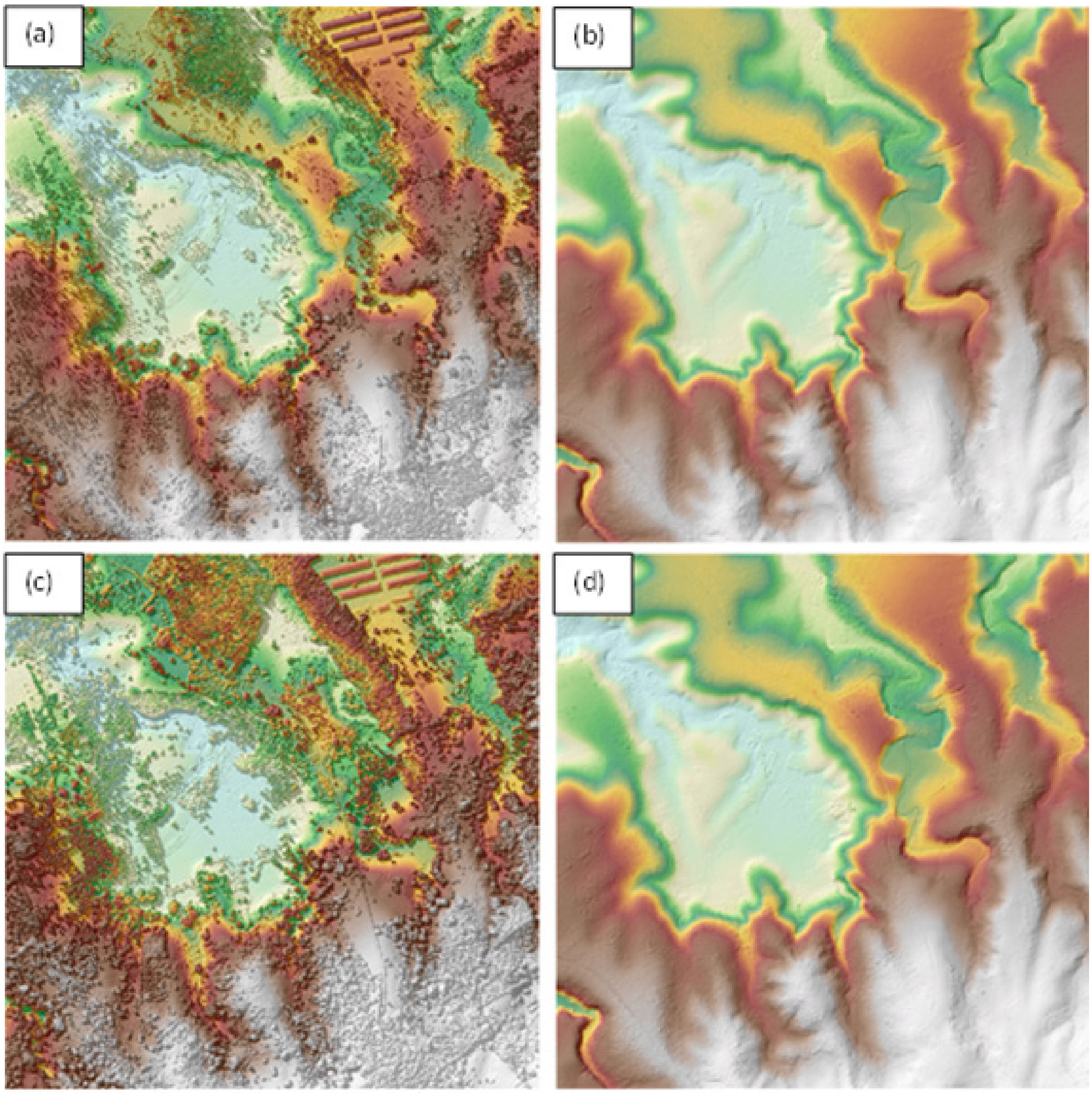


Figure 20. The Production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Musi-musi floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 267 1km by 1km tiles area covered by Musi-musi floodplain is shown in Figure 21. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Musi-musi floodplain has a total of 140.62 sq.km orthophotogaph coverage comprised of 614 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 22.

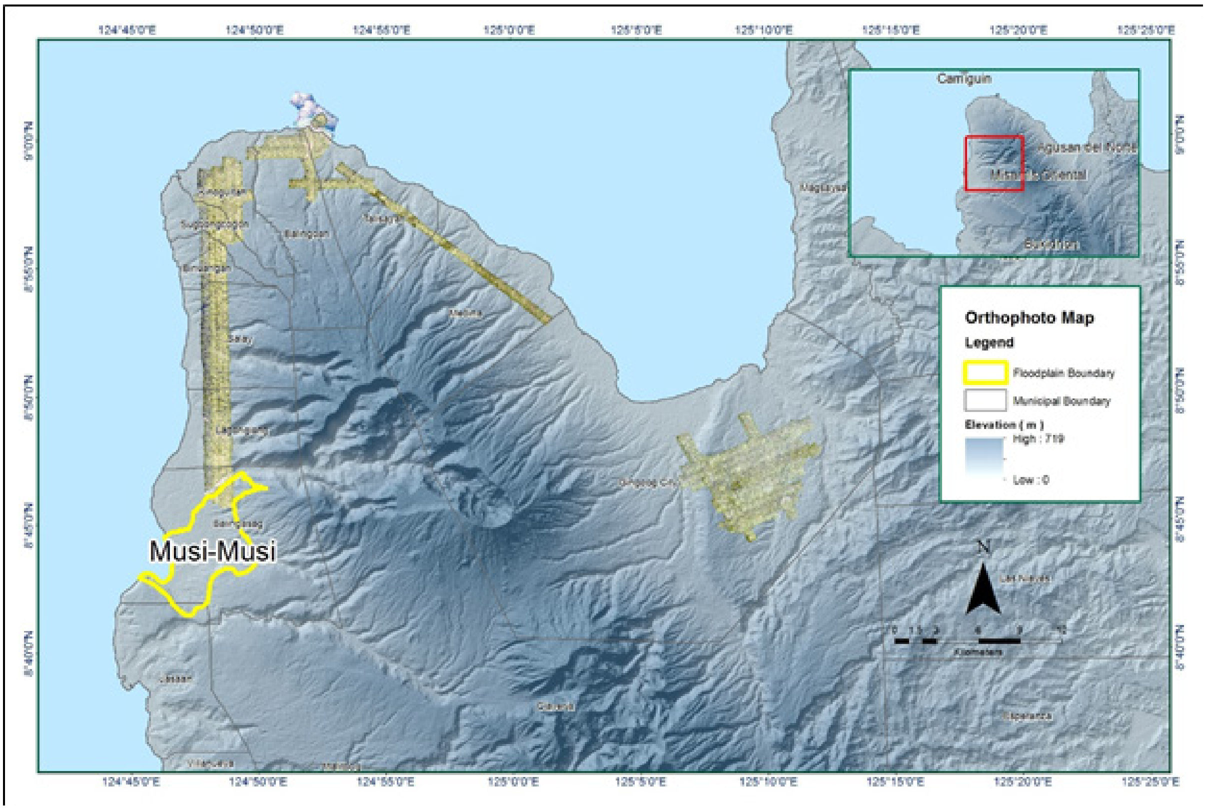


Figure 21. Musi-musi floodplain with available orthophotographs.

Figure 22. Sample orthophotograph tiles for Musi-musi floodplain.

3.8 DEM Editing and Hydro-Correction

Four (4) mission blocks were processed for Musi-musi flood plain. These blocks are composed of NorthernMindanao_RX_C, Northern Mindanao RX_supplement NorthernMindanao, RX_C_supplement and NorthernMindanao_RX_D with a total area of 507.29 square kilometers. Table 14 shows the name and corresponding area of each block in square kilometers.

Table 14. LiDAR blocks with its corresponding area

LiDAR Blocks	Area (sq.km)
NorthernMindanao_RX_BlkC_supplement	76.89
NorthernMindanao_RX_supplement	50.42
NorthernMindanao_RX_BlkC	138.78
NorthernMindanao_RX_BlkD	241.20
Bukidnon_Blk64F	126.19
TOTAL	633.48 sq.km

Portions of DTM before and after manual editing are shown in Figure 23. The bridge (Figure 23a) is considered to be an impedance to the flow of water along the river and has to be removed (Figure 23b) in order to hydrologically correct the river. This was done through interpolation process wherein 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 areas such as paddies (Figure 23c) which have been removed during classification process and have to be retrieved to complete the surface (Figure 23d). Portion of hill also (Figure 23e) has been misclassified that needs to be retrieved to retain the correct terrain (Figure 23f). Object retrieval uses the secondary DTM (t_layer) to fill in to these areas.

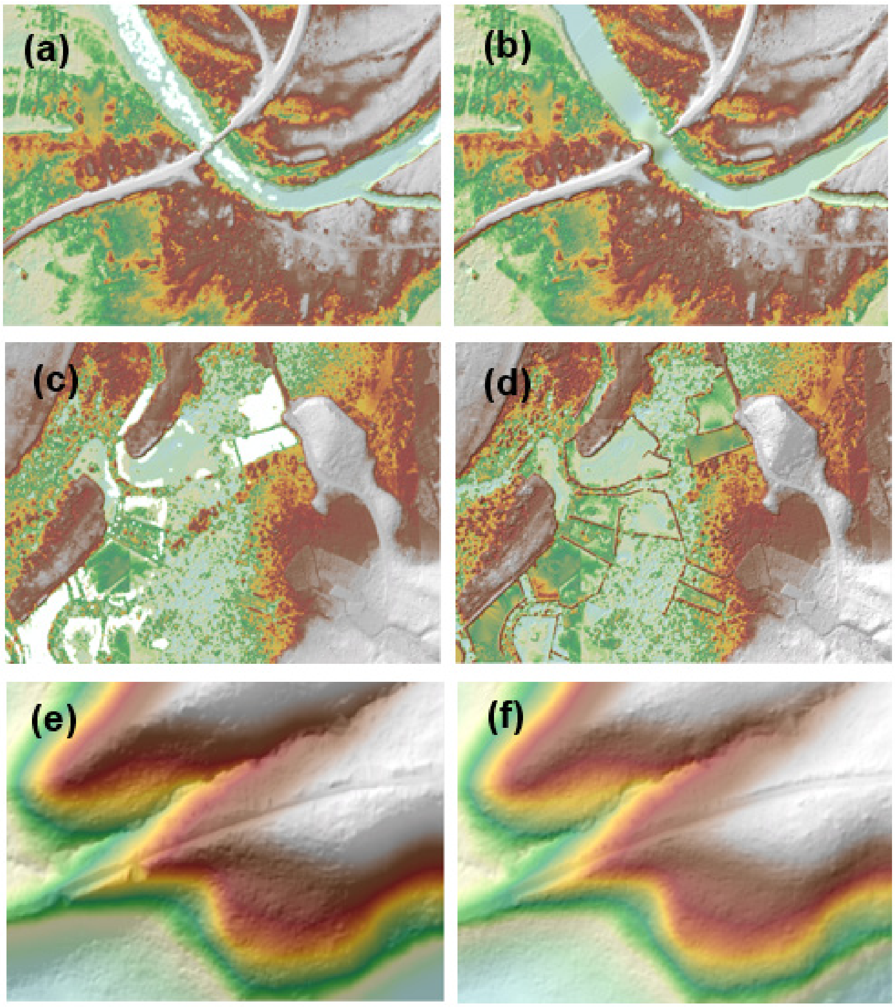


Figure 23.Portions in the DTM of Musi-musi floodplain – bridges before (a) and after (b) manual editing; a paddy field before (c) and after (d) data retrieval; and a misclassified hill before (e) and after (f) data retrieval

3.9 Mosaicking of Blocks

The Musi-musi flood plain lies within the NorthernMindanao_RX_C block. It was used as the reference block at the start of mosaicking and calibration. Table 15 shows the area of each LiDAR blocks and the shift values applied during mosaicking. Shifting values were derived from the height difference of the calibrated block and the overlapping adjacent block.

Mosaicked LiDAR DTM for Balatucan floodplain is shown in Figure 24. It can be seen that the entire Musi-musi floodplain is 100% covered by LiDAR data.

Table 15. Shift Values of each LiDAR Block of Musi-musi floodplain

Mission Blocks	Shift Values (meters)		
	x	y	z
NorthernMindanao_RX_BlkC_supplement	0.00	0.00	-0.18
NorthernMindanao_RX_supplement	0.00	0.00	-0.16
NorthernMindanao_RX_BlkC	0.00	0.00	0.00
NorthernMindanao_RX_BlkD	0.00	0.00	-0.12
Bukidnon_Blk64F	0.00	0.00	0.01

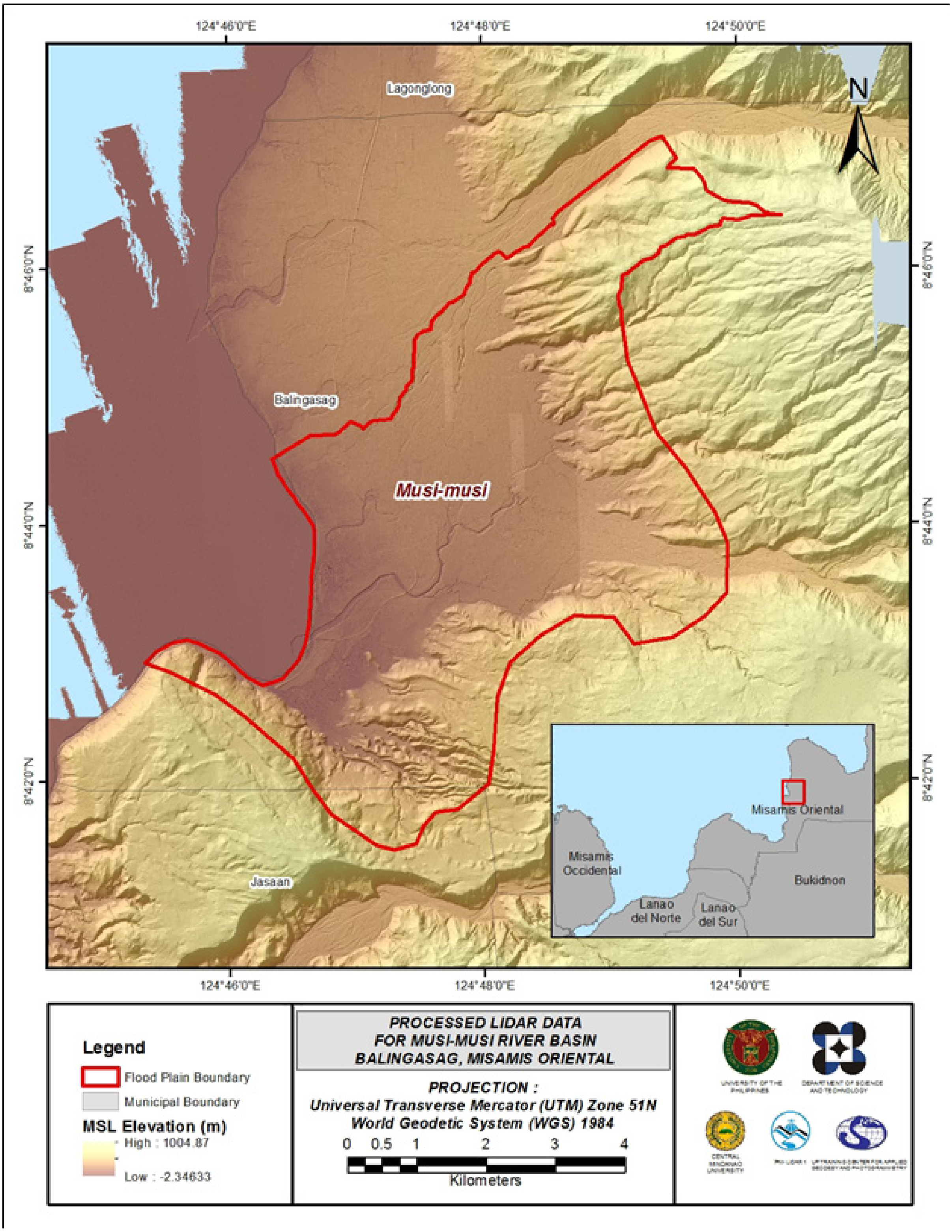


Figure 24. Map of Processed LiDAR Data for Musi-musi Flood Plain

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Musi-musi to collect points with which the LiDAR dataset is validated is shown in Figure 25. A total of 1,755 survey points were gathered for the Musi-musi flood plain. However, the point dataset was not used for the calibration of the LiDAR data for Musi-musi because during the mosaicking process, each LiDAR block were referred to the calibrated Gingoog DEM. Therefore, the mosaicked DEMs of Musi-musi can already be considered as a calibrated DEM.

A good correlation between the uncalibrated Gingoog LiDAR DTM and ground survey elevation values is shown in Figure 24. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration points is 0.64 meters with a standard deviation of 0.10 meters. Calibration of Gingoog LiDAR data was done by subtracting the height difference value, 0.64 meters, to Gingoog mosaicked LiDAR data. Table 16 shows the statistical values of the compared elevation values between Gingoog LiDAR data and calibration data. These values were also applicable to the Musi-musi DEM.

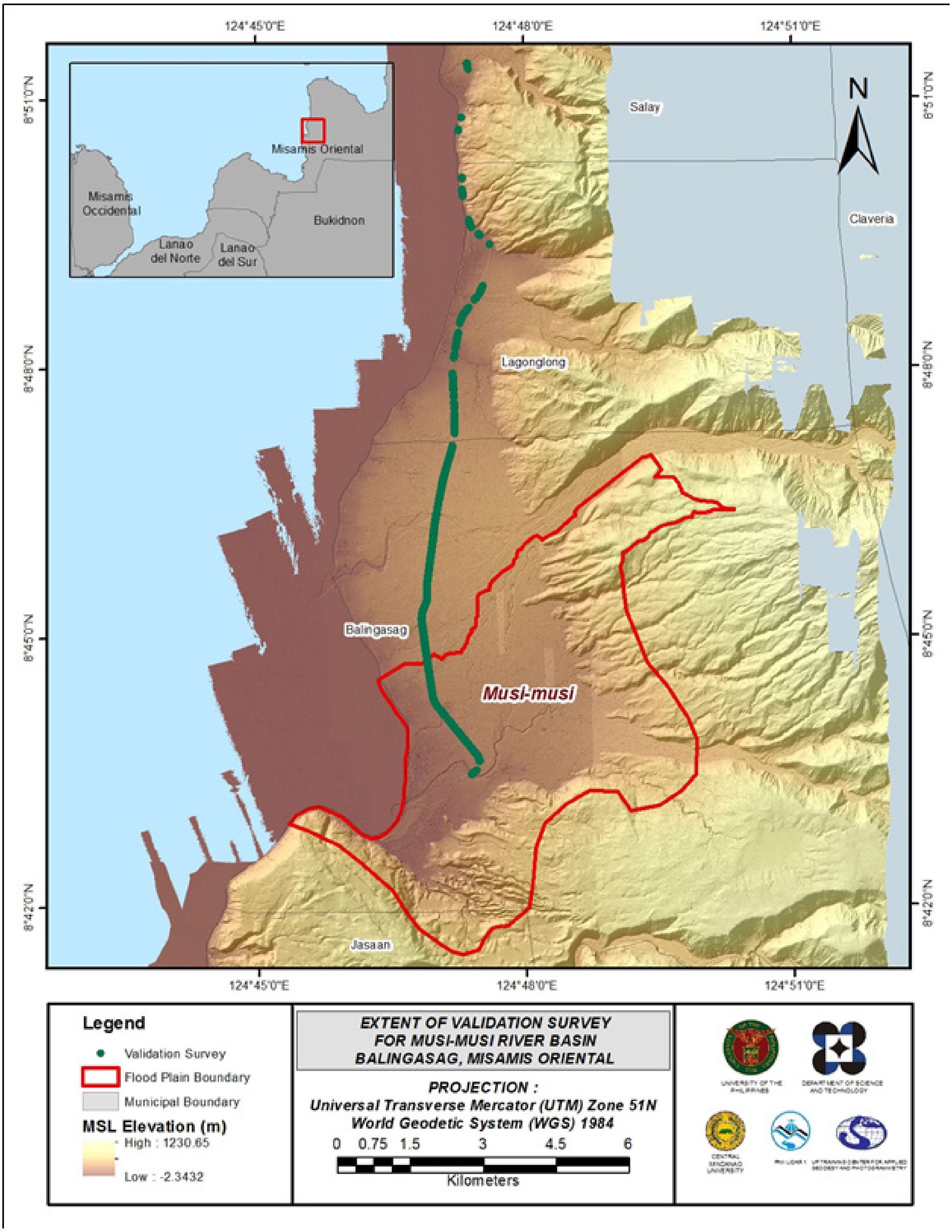


Figure 25. Map of Musi-musi Flood Plain with validation survey points in green

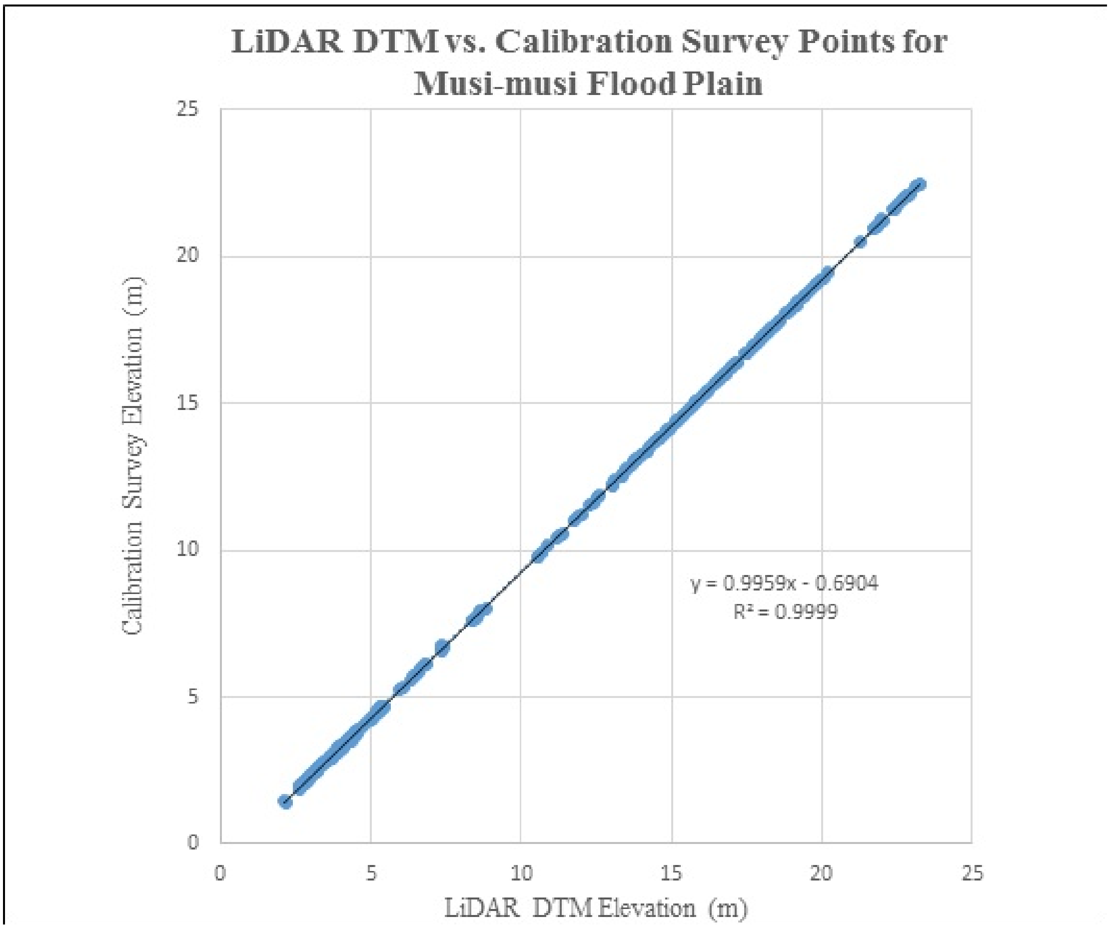


Figure 26. Correlation plot between calibration survey points and LiDAR data

Table 16. Calibration Statistical Measures

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

All survey points of the Musi-musi floodplain were used for the validation of calibrated Musi-musi DTM. The 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 27. The computed height difference between the calibrated LiDAR DTM and validation elevation values is 0.13 meters with a standard deviation of 0.13 meters, as shown in Table17.

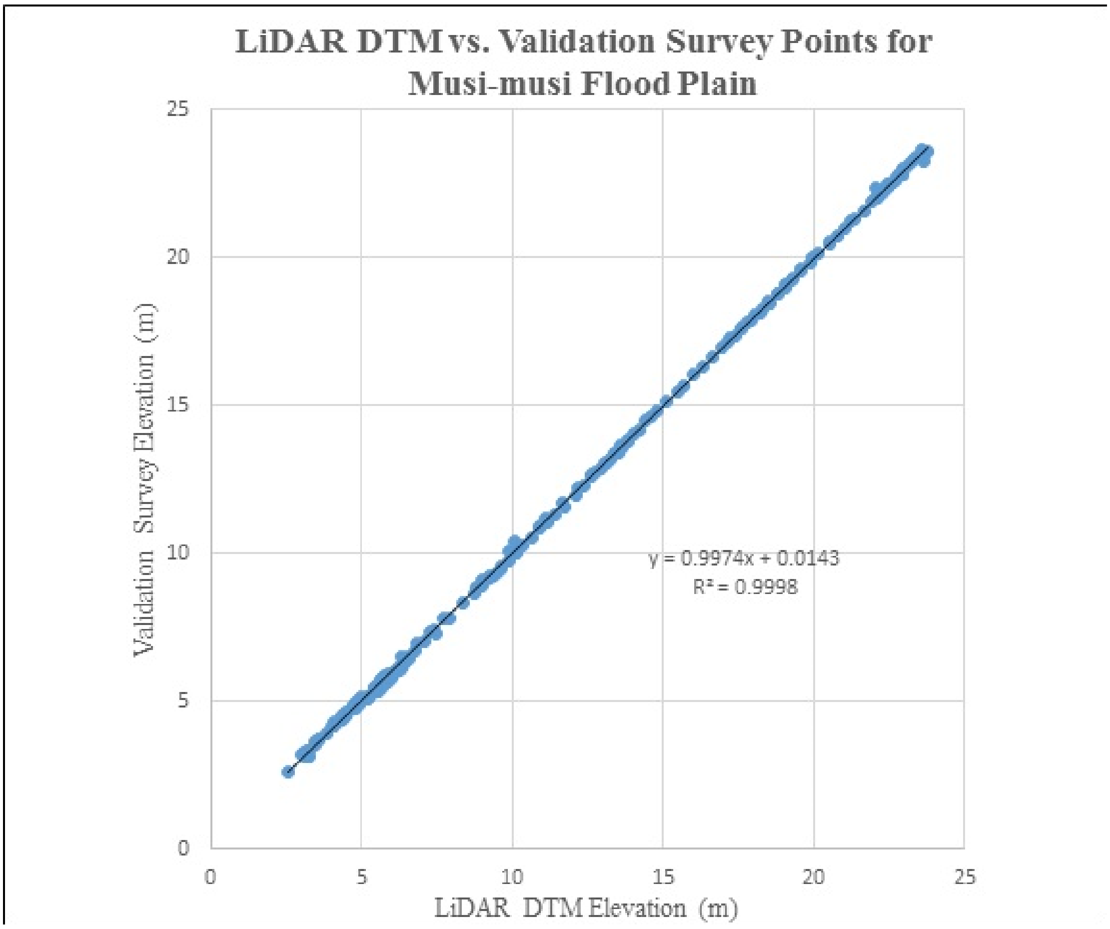


Figure 27. Correlation plot between validation survey points and LiDAR data

Table 17. Validation Statistical Measures.

Validation Statistical Measures	Value (m)
Height Difference	0.13
Standard Deviation	0.13
Average	-0.02
Minimum	-0.42
Maximum	0.47

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline data was available for Musi-musi with 144 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 0.35 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Musi-musi integrated with the processed LiDAR DEM is shown in Figure 28.

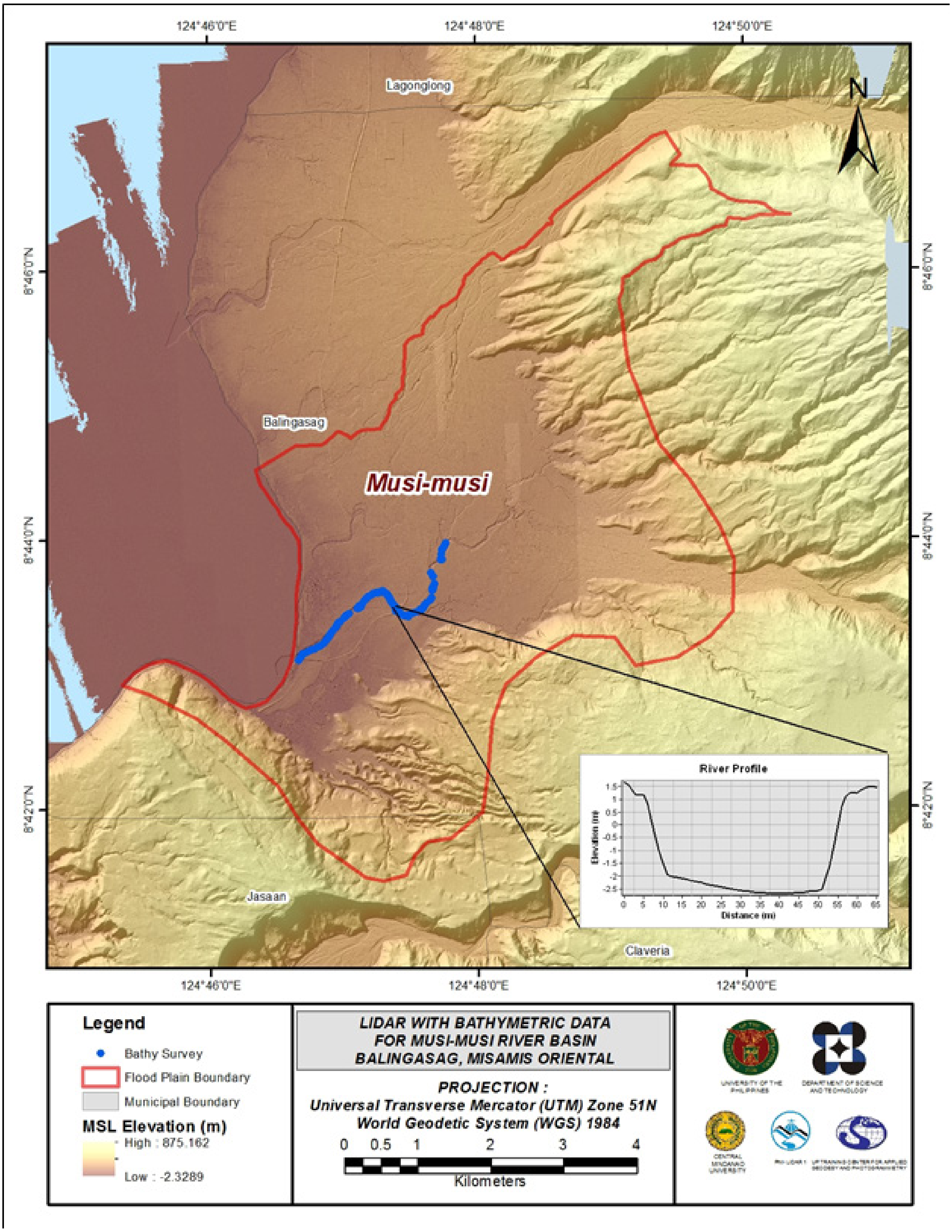


Figure 28. Map of Musi-musi Flood Plain with bathymetic survey points shown in blue

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

Musi-musi floodplain, including its 200 m buffer, has a total area of 43.45 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 1031 building features, are considered for QC. Figure 29 shows the QC blocks for Musi-musi floodplain.

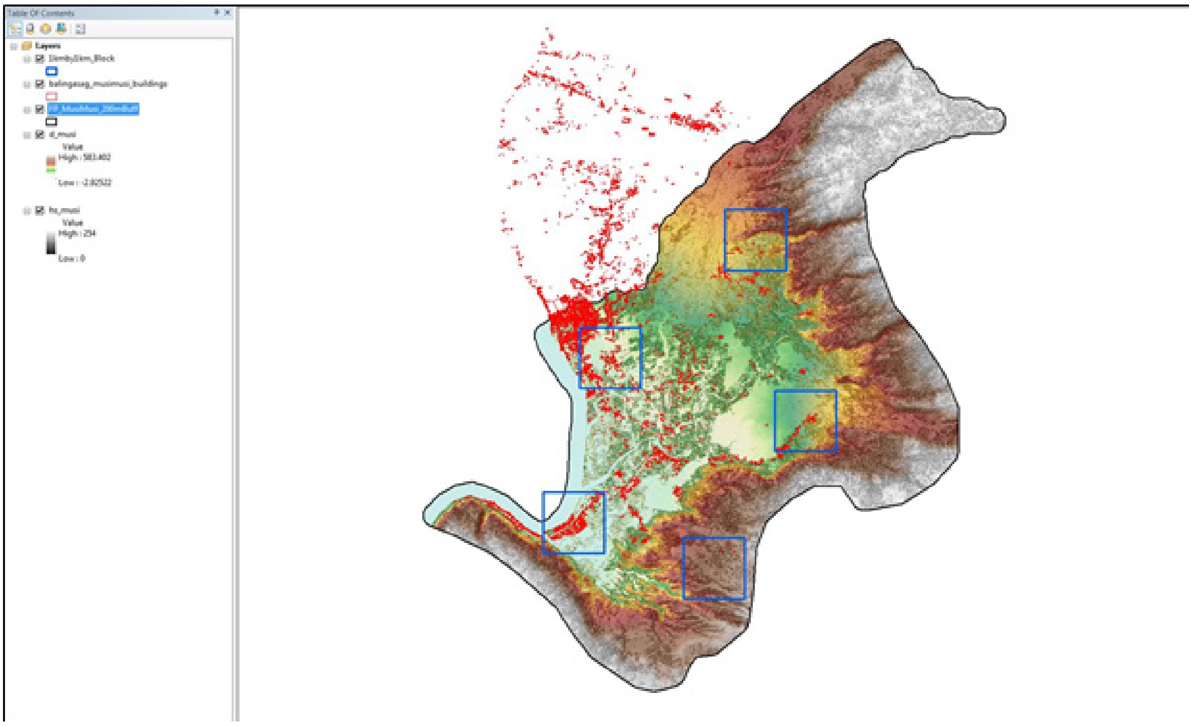


Figure 29. Blocks (in blue) of Musi-musi building features that were subjected to QC

Quality checking of Musi-musi building features resulted in the ratings shown in Table 18.

Table 18. Quality Checking Ratings for Musi-musi Building Features

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Musi-musi	90.73	99.07	86.55	PASSED

3.12.2 Height Extraction

Height extraction was done for 5, 297 building features in Musi-musi floodplain. Of these building features, none was filtered out after height extraction, resulting to 5,297 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 10.57 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 19 summarizes the number of building features per type. From the total features identified, approximately 4, 943 of it are residential establishments while the commercial establishments are the most common in non-residential features. On the other hand, Table 20 shows the total length of each road type. However, road networks other than the national road (NA) were considered unclassified (Others). Table 21 shows the number of water features extracted.

Table 19. Number of Building Features Extracted for Musi-musi Floodplain

Facility Type	No. of Features
Residential	4, 943
School	72
Market	9
Agricultural/Agro-Industrial Facilities	0
Medical Institutions	7
Barangay Hall	9
Military Institution	0
Sports Center/Gymnasium/Covered Court	5
Telecommunication Facilities	0
Transport Terminal	0
Warehouse	3
Power Plant/Substation	0
NGO/CSO Offices	0
Police Station	0
Water Supply/Sewerage	0
Religious Institutions	19
Bank	1
Factory	0
Gas Station	4
Fire Station	1
Other Government Offices	13
Other Commercial Establishments	210
Municipal Hall	1
Total	5, 297

Table 20. Total Length of Extracted Roads for Musi-musi Floodplain

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/ Municipal Road	Provincial Road	National Road	Others	
Musi-musi	46.85		3.24	7.63	0	54.49

Table 21. Number of Extracted Water Bodies for Musi-musi Floodplain

Floodplain	Road Network Length (km)					Total
	Rivers/ Streams	Lakes/Ponds	sea	Dam	Fish Pen	
Musi-musi	5	0	0	0	0	5

A total of 10 bridges that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

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

Figure 30 shows the Digital Surface Model (DSM) of Musi-musi floodplain overlaid with its ground features.

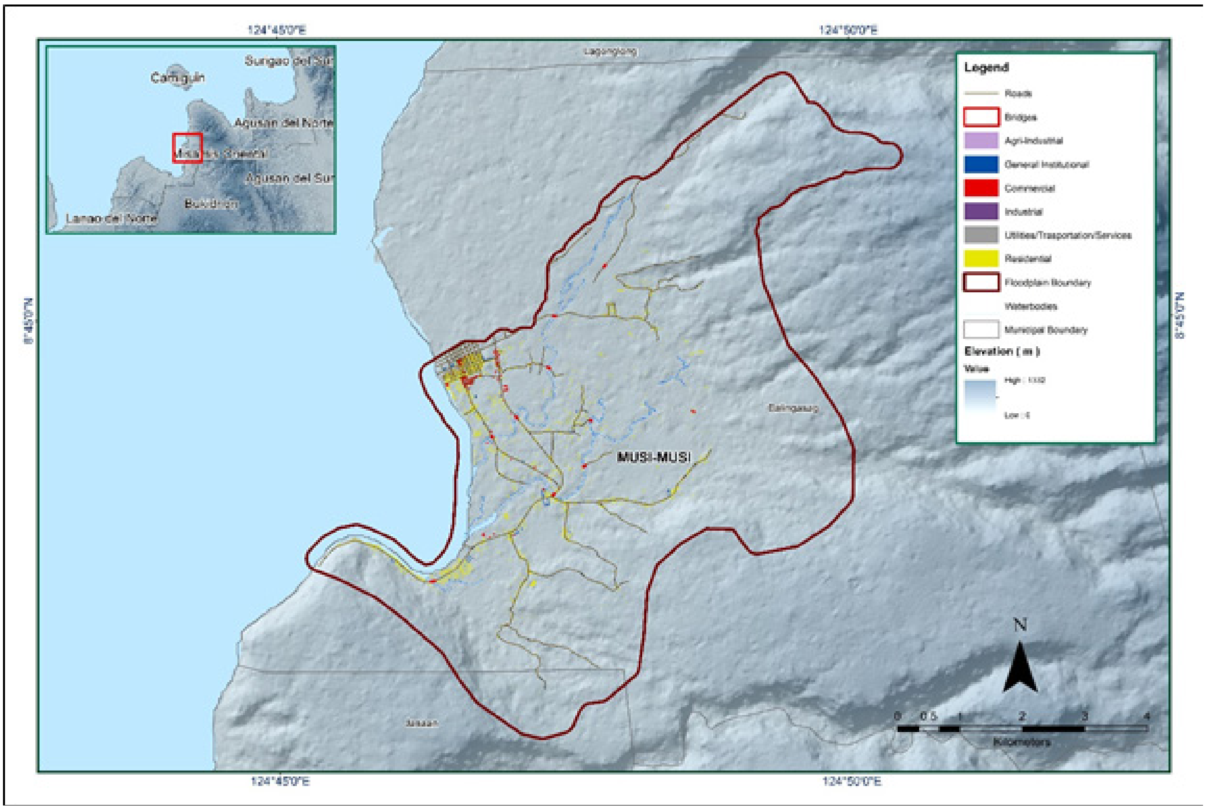


Figure 30. Extracted features for Musi-musi floodplain

CHAPTER 4. LIDAR VALIDATION SURVEY AND MEASUREMENTS OF THE MUSI-MUSI 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 Musi-Musi Watershed is located in the Province of Misamis Oriental in Mindanao. The watershed covers the municipalities of Balingasag and Claveria. It has a total of area of 7,736.12 ha and a perimeter of 284.32 m.

Its main stem, the Musi-Musi River, is one of the 13 river systems Central Mindanao Region. It has an approximate length of 23 km and empties towards Macalajar Bay. The river encompasses 14 barangays namely: Baliwagan, Talusan, Linabu, San Isidro, Camuayan, Blanco, Dumarait, San Juan, Quezon, Rosario, Balagnan, Calawag, San Francisco in the Municipality of Balingasag, and a single barangay from Claveria named Brgy. Tiplohon. Livelihoods near the river consist mostly of crop production, rice irrigation, aquaculture and poultry raising. The total population of these barangays within the watershed is 21,943 according to the 2010 NSO census data. These barangays were inundated when Typhoon Seniang hit on December 2014, causing damage to property and partially damaging the Camuayan and Rosario spillway.

In line with this, DVBC conducted a field survey in Musi-Musi River from September 25 to October 09, 2014 with the following scope of work: reconnaissance; control survey for the establishment of a control point; cross-section, bridge as-built and water level elevation marking tied with MSL of Musi-Musi Bridge pier; ground validation data acquisition of about 36 km; and bathymetric survey from Brgy. Talusan to Brgy. Waterfall, Balingasag, Misamis Oriental with an estimated length 2.6 km in accordance to the advisory of the partner HEI.

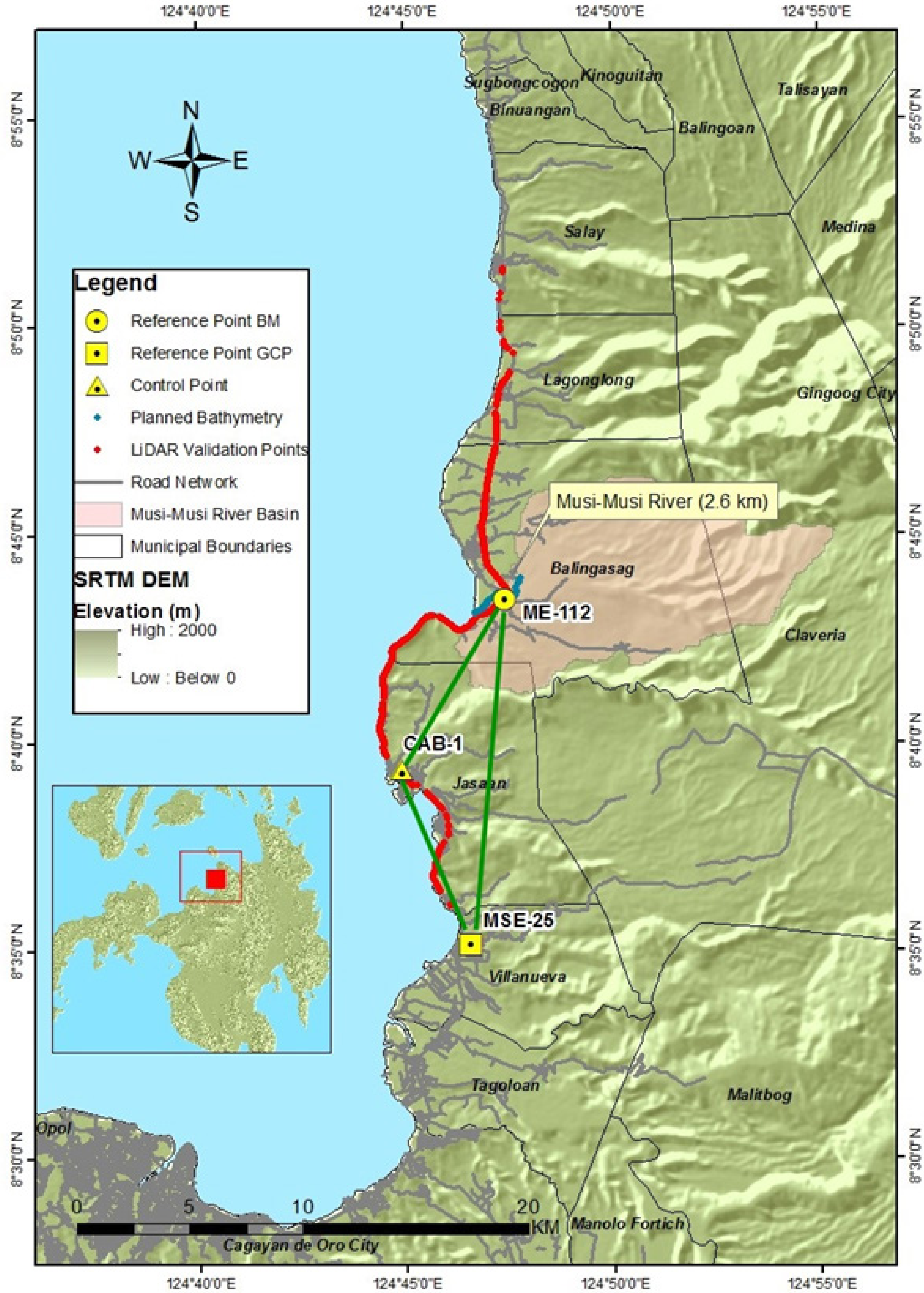


Figure 31. Musi-Musi River survey extent

4.2 Control Survey

The GNSS network used for Musi-musi River Basin is composed of a single loop established on September 29, 2014 occupying the reference points MSE-25, a second order GCP in Brgy. Poblacion 1, Municipality of Villanueva, Misamis Oriental, fixed from previous PHIL-LIDAR survey in Misamis Occidental with elevation derived from TGBM.

A control point was established along the approach of bridge, namely: CAB-1, located at Cabulig Bridge in Brgy. Bobontugan, Municipality of Jasaan, Misamis Oriental. A NAMRIA established control point namely ME-112, in Brgy. Talusan, Municipality of Balingasag, Misamis Oriental was also occupied to use as marker.

The summary of references and control points and its location is summarized in Table 22 while the GNSS network established is illustrated in Figure 32.

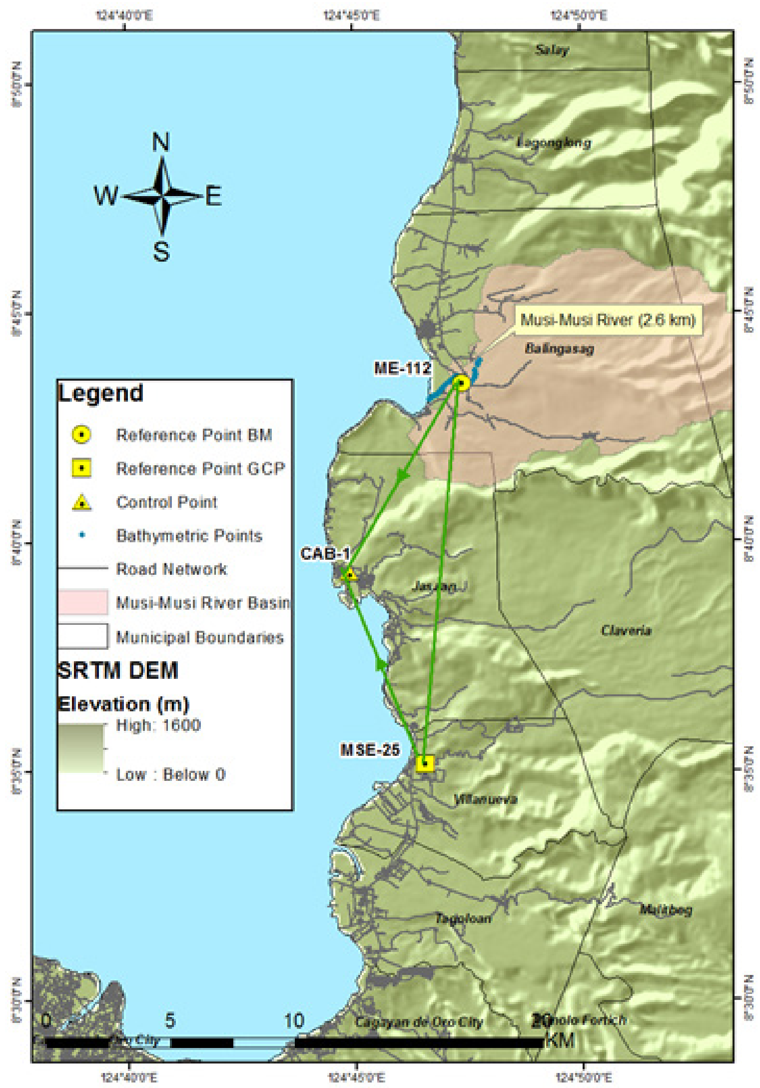


Figure 32. GNSS Network covering the Musi-Musi River

Table 22. List of Reference and Control points used in Musi-Musi River Basin Survey. (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoid Height (m)	Elevation in MSL (m)	Date Established
MSE-25	2nd order, GCP	8°35'09.60584"	124°46'32.43073"	76.139	6.528	2003
ME-112	1st order, BM	-	-	-	-	2007
CAB-1	UP Established	-	-	-	-	2014

The GNSS set ups made in the location of the reference and control points are exhibited in Figure 33 to Figure 35.

Figure 33. GNSS base receiver setup, Trimble® SPS 852 at MSE-25 in Brgy. Poblacion 1, Municipality of Villanueva, Misamis Oriental

Figure 34. GNSS base receiver setup, Trimble® SPS 852 at ME-112 at Musi-Musi Bridge in Brgy. Talusan, Municipality of Balingasag, Misamis Oriental.

Figure 35. GNSS base occupation, Trimble® SPS 882 at CAB-1 along Iligan-Cagayan de Oro-Butuan Road at the approach of Cabulig Bridge in Brgy. Bobontugan, Municipality of Jasaan, Misamis Oriental.

4.2.1 Baseline Processing

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

Table 23. Baseline processing report for Musi-Musi River

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
MSE-25 --- CAB-1	09-29-2014	Fixed	0.003	0.016	338°15'59"	8315.309	0.636
CAB-1 --- ME-112	09-29-2014	Fixed	0.007	0.030	31°26'18"	8885.787	-1.253
MSE-25 --- ME-112	09-29-2014	Fixed	0.006	0.020	5°48'19"	15384.161	-0.688

As shown in Table 23, a total of three (3) baselines were processed and all of them passed the required accuracy set by the project.

4.2.2 Network Adjustment

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

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

Where:

Xe is the Easting Error,
Ye is the Northing Error, and
Ze is the Elevation Error

The three (3) control points, MSE-25, ME-112 and CAB-1 were occupied and observed simultaneously to form a GNSS loop. Coordinates and elevation values of MSE-25 were held fixed during the processing of the control points as presented in Table 24. Through this reference point, the coordinates and elevation of the unknown control points were computed.

Table 24. Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
MSE-25	Grid				Fixed
MSE-25	Global	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 25. All fixed control points have no values for grid and elevation errors.

Table 25. Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
CAB-1	692303.312	0.006	957244.697	0.005	7.759	0.036	
ME-112	696903.266	0.009	964847.889	0.008	6.695	0.042	
MSE-25	695418.468	?	949534.368	?	6.528	?	LLe

The network is fixed at reference points. The list of adjusted grid coordinates of the network is shown in Table 26.Using the equation $\sqrt{((x_e)^2+(y_e)^2)}<20cm$ for horizontal and $z_e<10$ cm for the vertical; below is the computation for accuracy that passed the required precision:

a. **MSE-25**
Horizontal accuracy = Fixed
Vertical accuracy = Fixed

b. **ME-112**
Horizontal accuracy = $\sqrt{((0.9)^2 + (0.8)^2}$
= $\sqrt{(0.81 + 0.64)}$
= 1.20 cm < 20 cm
Vertical accuracy = 4.2 cm < 10 cm

c. **CAB-1**
Horizontal accuracy = $\sqrt{((0.6)^2 + (0.5)^2}$
= $\sqrt{(0.36 + 0.25)}$
= 0.78 cm < 20 cm
Vertical accuracy = 3.6 cm < 10 cm

Table 26. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
CAB-1	N8°39'21.02516"	E124°44'51.71530"	76.762	0.036	
ME-112	N8°43'27.78957"	E124°47'23.33936"	75.468	0.042	
MSE-25	N8°35'09.60584"	E124°46'32.43073"	76.139	?	LLe

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 26. Based on the result of the computation, the accuracy conditions are satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table 27.

Table 27. References 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	Ellipsoid Height (m)	Northing	Easting	BM Ortho
MSE-25	2nd order, GCP	8°35'09.60584"	124°46'32.43073"	76.139	949534.368	695418.468	6.528
ME-112	1st order, BM	8°43'27.78957"	124°47'23.33936"	75.468	964847.889	696903.266	6.695
CAB-1	UP Estab-lished	8°39'21.02516"	124°44'51.71530"	76.762	957244.697	692303.312	7.759

4.3 Cross-section and Bridge As-Built Survey, and Water Level Marking

GNSS receiver Trimble® SPS 882 in PPK survey technique was used to acquire the cross-section of the river. Cross-section survey across Musi-Musi River was conducted along Musi-Musi Bridge in Balingasag, Misamis Oriental on September 29, 2014, as shown in Figure 36. Bridge as-built features determination was performed to get the distance of piers and abutments from the bridge approach. The bridge deck was measured using GNSS receiver Trimble® SPS 882 to get the high chord and meter tapes to get its low chord elevation.

However, the controller used for the cross-section survey was damaged and its data gathered was partially lost. Another team led by Engr. JMSon Calalang was requested to redo the survey on October 24, 2014 to complete the cross-section data.

Figure 36. Cross-section and bridge as-built survey for Musi-Musi Bridge

The cross-sectional line for the Musi-Musi Bridge is about 90.338 m with 16 cross-sectional points. The summary of gathered cross-section, planimetric map, and as-built data are shown in Figure 37 to Figure 39 respectively.

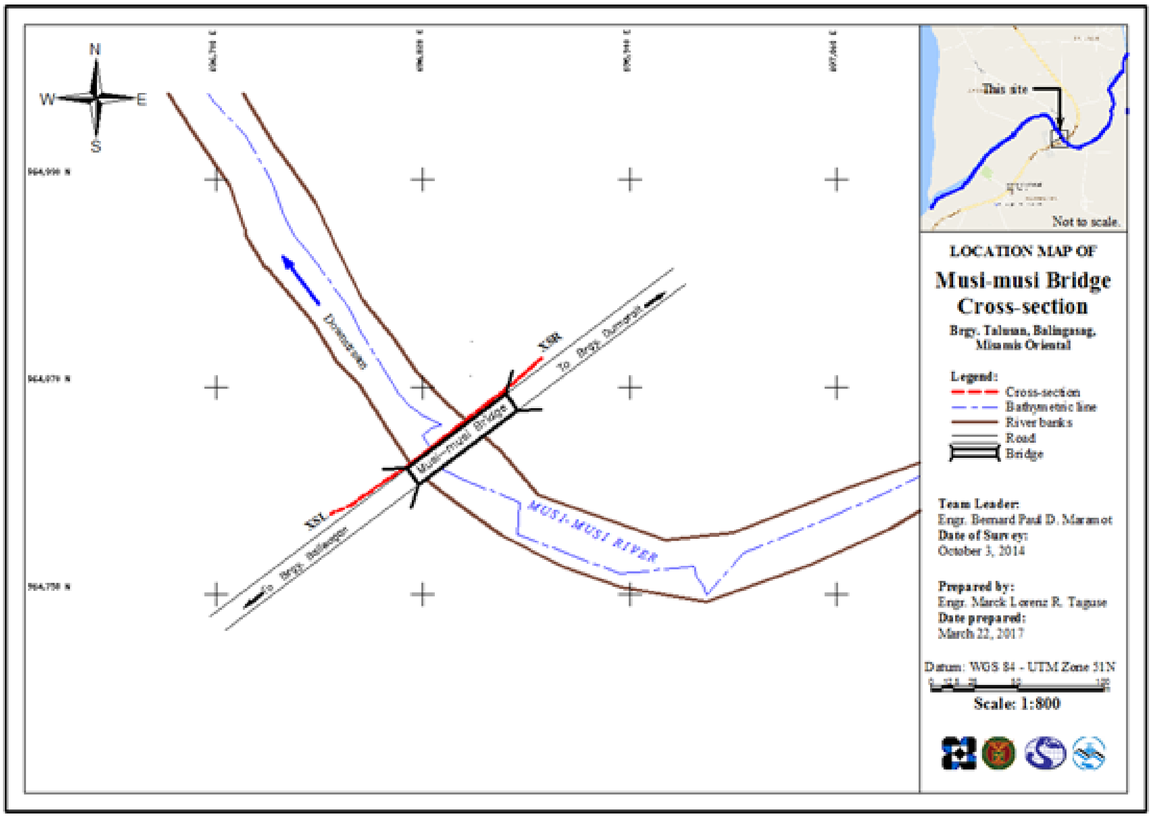


Figure 37. Musi-musi bridge cross-section planimetric map

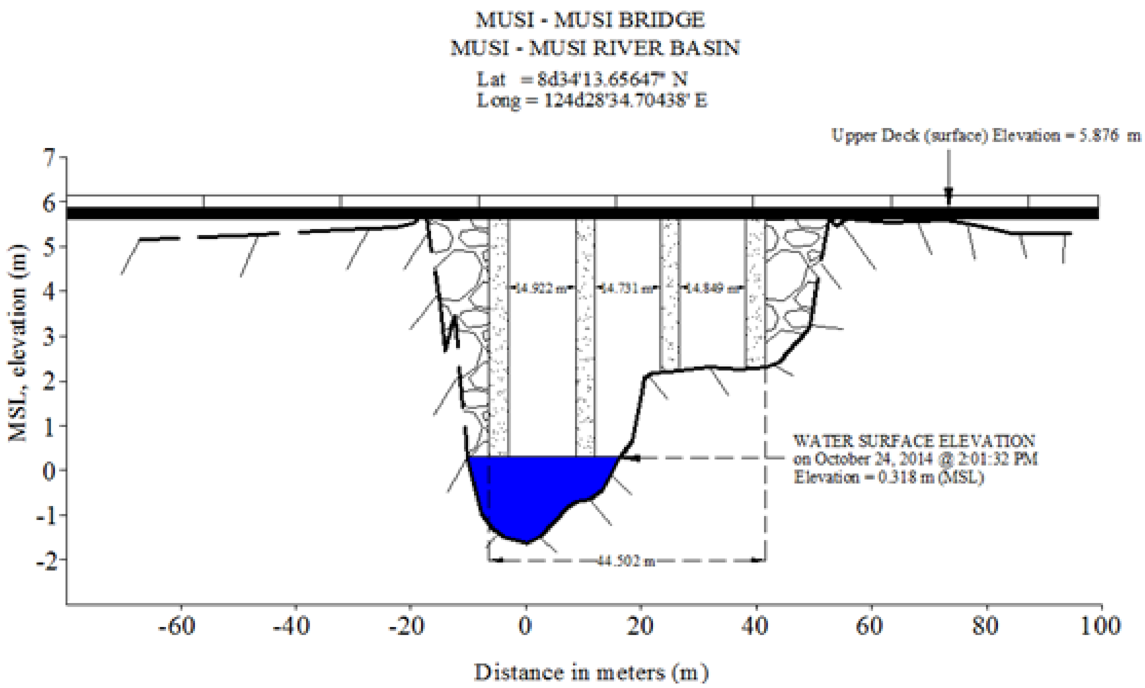


Figure 38. Musi-Musi Bridge cross-section diagram

Bridge Data Form

Bridge Name: Musi-Musi Bridge **Date:** October 7, 2015

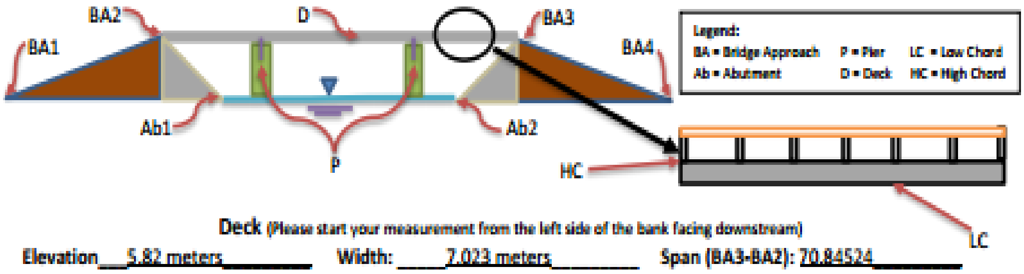
River Name: Musi-Musi River **Time:** 2:30 P.M.

Location (Brgy, City, Region): Barangay Talusan, Municipality of Balingasag, Misamis Oriental

Survey Team: Bernard's Team

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

Latitude: 8d34'13.65647" N **Longitude:** 124d28'34.70438" E



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

Elevation 5.82 meters **Width:** 7.023 meters **Span (BA3-BA2):** 70.84524

	Station	High Chord Elevation	Low Chord Elevation
1	Pier 1	5.798	4.695
2	Pier 2	5.882	4.595
3	Pier 3	5.88	4.565
4	Pier 4	5.873	4.534
5			

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	5.134	BA3	120.0659	5.941
BA2	49.22066	5.814	BA4	161.7155	5.27

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

	Station (Distance from BA1)	Elevation
Ab1	53.10264	2.651
Ab2	116.2894	3.087

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

Shape: Rectangular Cylinder **Number of Piers:** 4 **Height of column footing:** ____________

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	62.31441	5.88	
Pier 2	77.23706	5.873	
Pier 3	91.96838	5.882	
Pier 4	106.8178	5.876	
Pier 5			
Pier 6			

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

Figure 39. Musi-Musi Bridge Data Form

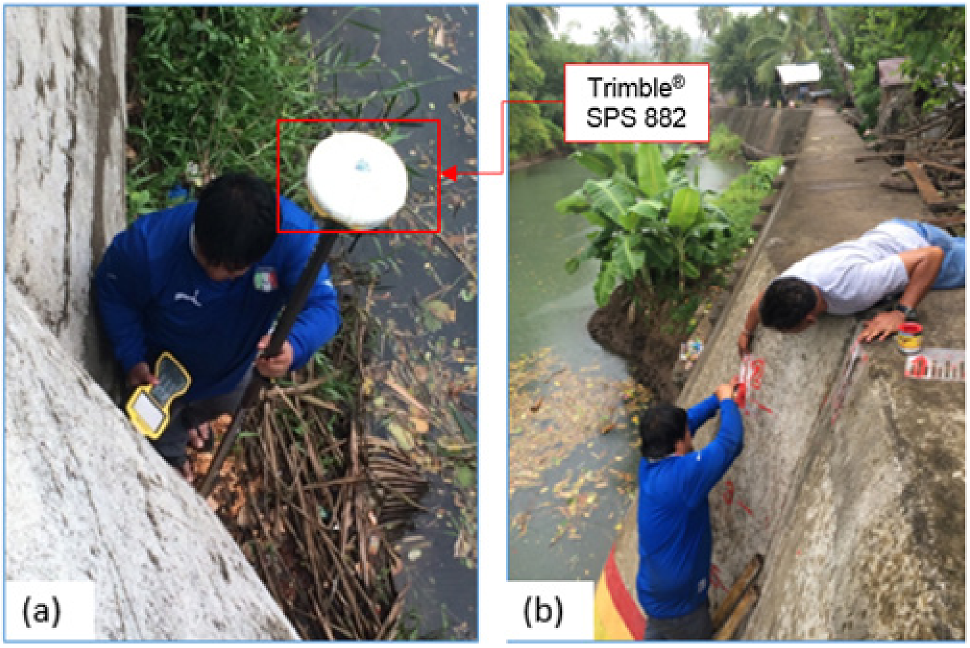


Figure 40. (a) Water level data acquisition and (b) marking of water level reference for Musi-Musi Bridge

Figure 41. Water level marking on the side of the Musi-Musi Bridge

Water surface elevation of Musi-Musi River was determined using Trimble® SPS 882 in PPK mode survey on October 24, 2014 at 2:01 P.M, shown in Figure 40. The elevation was referred to MSL equal to 0.318 m was reflected to the markings painted on the dike (Figure 41). The marked dike shall serve as reference for flow data gathering and depth gauge deployment of the accompanying HEI.

4.3.1 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on September 29, 2014 using a survey grade GNSS Rover receiver, Trimble® SPS 882, mounted on a pole which was attached at the side of a vehicle, shown in Figure 42. It was secured using a cable tie making sure it was horizontally and vertically balanced. The antenna height was measured 2.25 m from the ground up to the bottom of the notch of the GNSS Rover receiver. The survey was conducted using PPK survey technique utilizing continuous topography mode.

Figure 42. Ground validation set-up

The survey started in the Municipality of Jasaan and traversed major roads going to the boundary of Villanueva Municipality. 1,942 ground validation points were acquired with an approximate length of 30 km using CAB-1 as the GNSS base station, shown in Figure 43.

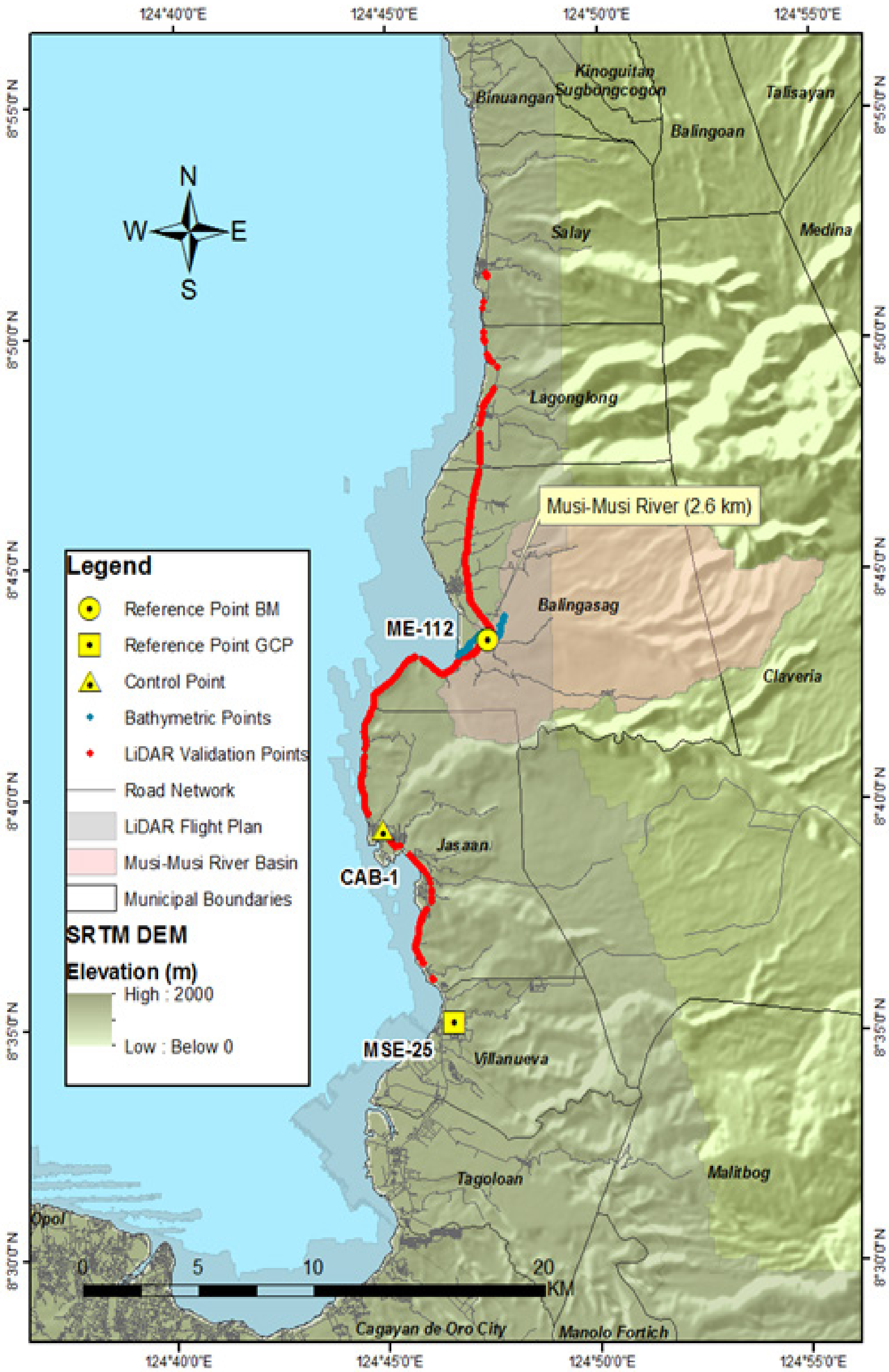


Figure 43. Validation points acquisition survey covering Musi-Musi River Basin

4.3.2 River Bathymetric Survey

Manual bathymetry was performed on October 4 to 5, 2014 using a GNSS rover receiver, Trimble® SPS 882, in PPK survey technique as shown in Figure C-14. The survey started in Brgy. Talusan, Municipality of Balingasag with coordinates 8°43'57.88198" 124°47'45.84650", traversed down the river by foot and ended in Brgy. Binitinan, also in Municipality of Balingasag with coordinates 8°43'06.10503" 124°46'39.69605". The control point ME-112 was used as the GNSS base station all throughout the survey.

Figure 44. Bathymetric survey: (a) upstream in Barangay Talusan and (b) downstream bathymetry near Barangay Waterfall.

Approximately 2.6 k of bathymetry line with a total of 142 points were acquired. Dense canopy was observed north in Brgy.Talusan which prohibited GPS signals to penetrate. This resulted to float data which are shown as gaps in Figure 45.

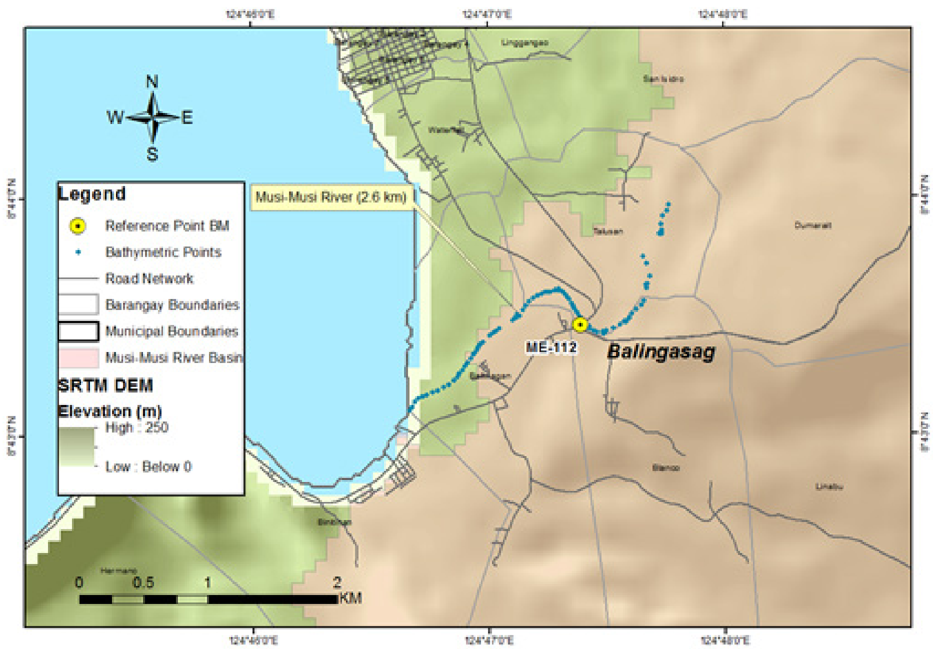


Figure 45. Bathymetric survey of Musi-Musi River

A CAD drawing was produced to illustrate the Musi-Musi riverbed profile as shown in Figure 46. An elevation drop of 2.75 m in MSL was observed within the approximate distance of 2.6 km.

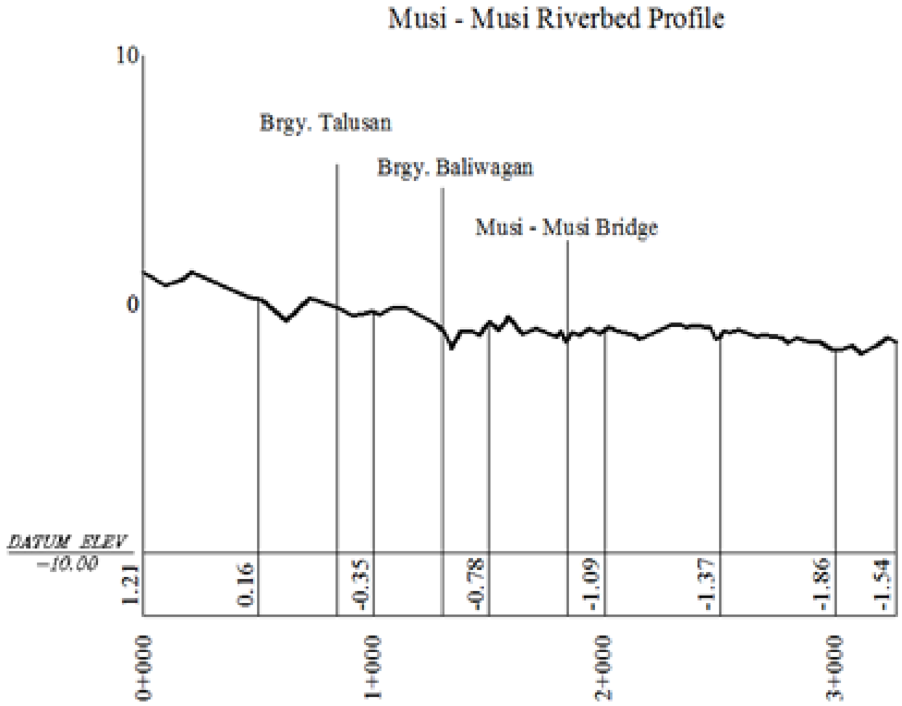


Figure 46. Riverbed profile of Musi-Musi River

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

Components and data that affect the hydrologic cycle of the river basin was monitored, collected, and analyzed. Rainfall, water level, and flow in a certain period of time, which may affect the hydrologic cycle of the Musi-Musi River Basin were monitored, collected, and analyzed.

5.1.1.1 Precipitation

Precipitation data is one input requirement for the HMS calibration. Data was taken from an automatic rain gauge (ARG) installed by the Department of Science and Technology – Advanced Science and Technology Institute (DOST-ASTI) at Quezon, Balingasag. The location of the rain gauge is shown in Figure 47.

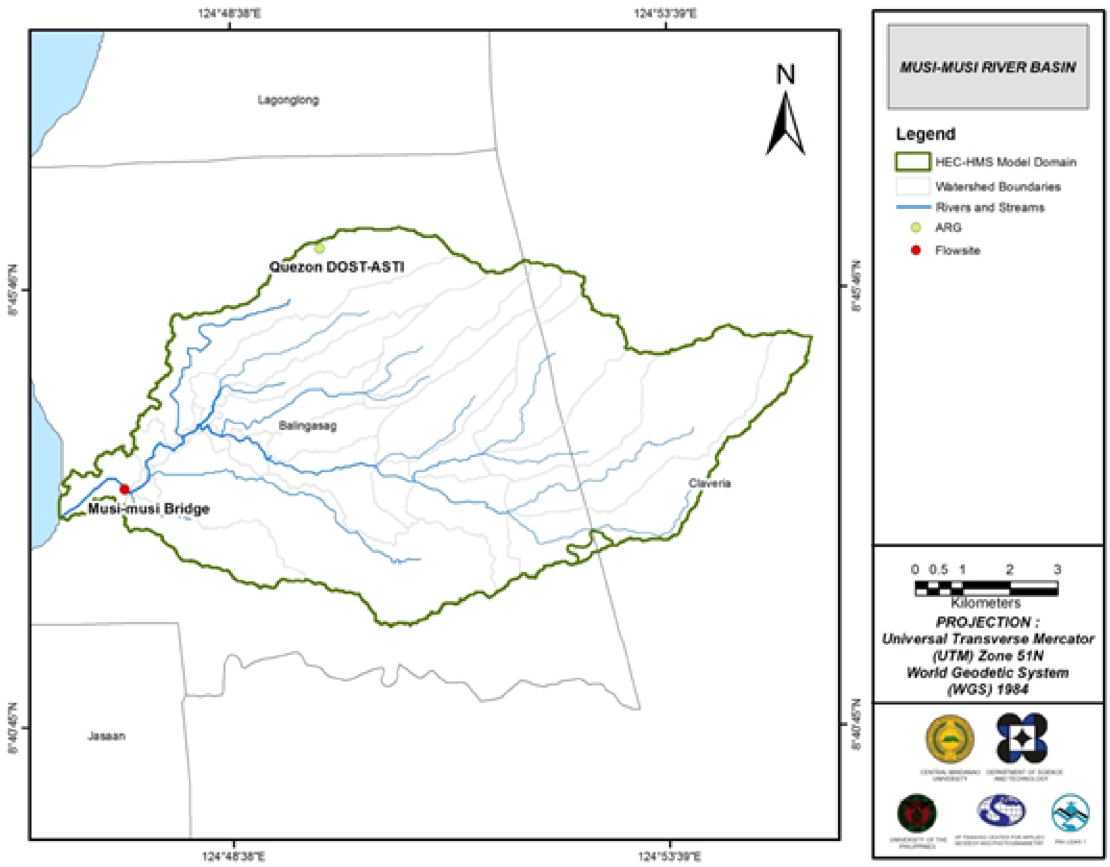


Figure 47. Location map of Musi-Musi HEC-HMS model used for calibration

5.1.1.2 Rating Curves and River Outflow

The river velocity and water level change were used for the calculation of discharge, the other input data requirement for HMS model calibration. Both were measured at Musi-musi bridge along the National Highway of Barangay Baliwagan, Balingasag using a mechanical flow meter and digital depth gauge, respectively during the onslaught of Typhoon Seniang from 0740 to 0250 of December 29-30, 2014. Peak discharge is 27.87 m3/s on December 29, 2014 at 13:10.

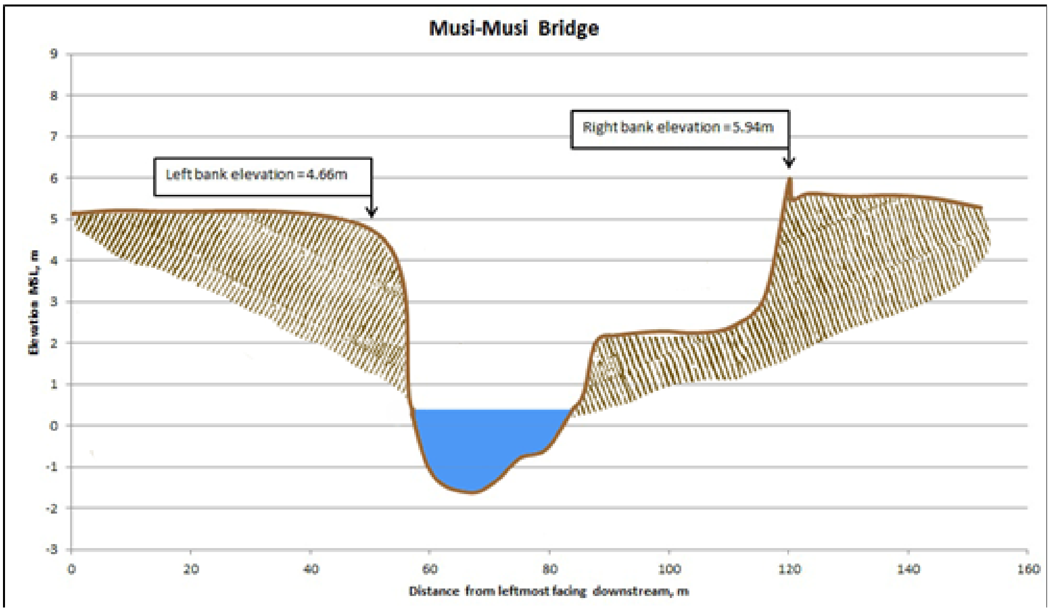


Figure 48. Cross-Section Plot of Musi-Musi Bridge

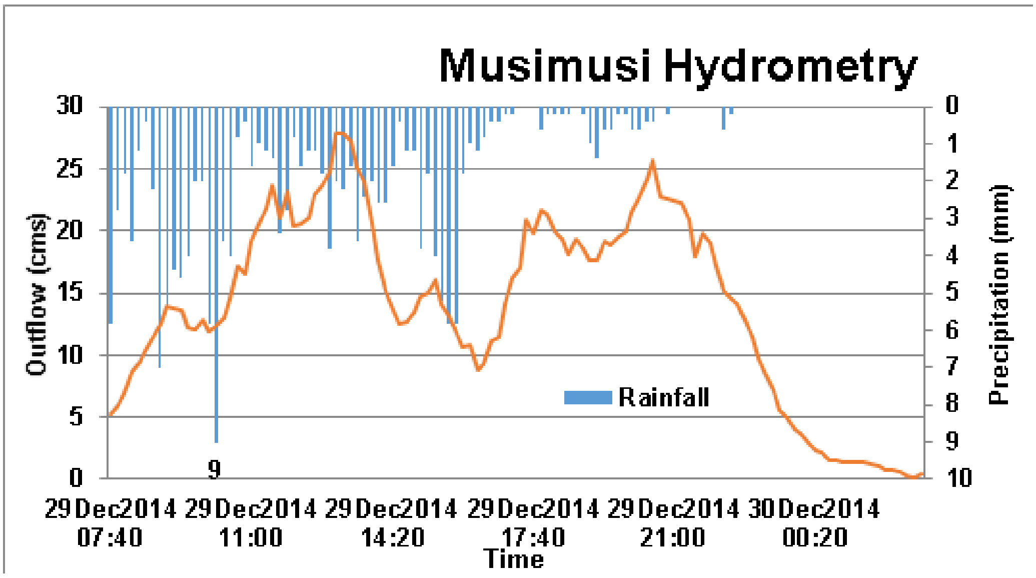


Figure 49. Rainfall and outflow data used for modeling.

Using the gathered stage and discharge data, a rating curve was developed to illustrate its relationship. Stage was determined by the tying up the water surface elevation and water level change measured using a digital depth gauge. Meanwhile, discharge was calculated using the cross section area, stage, and river velocity measured using a mechanical flow meter. The relationship is expressed in the form of the equation below. For Musi-musi Bridge, the rating curve is expressed as Q = 0.3896e5.2118h as shown in Figure 50.

Q=anh

where, Q : Discharge (m3/s),
h : Gauge height (reading from Musi-musi Bridge AWLS), and
a and n : Constants.

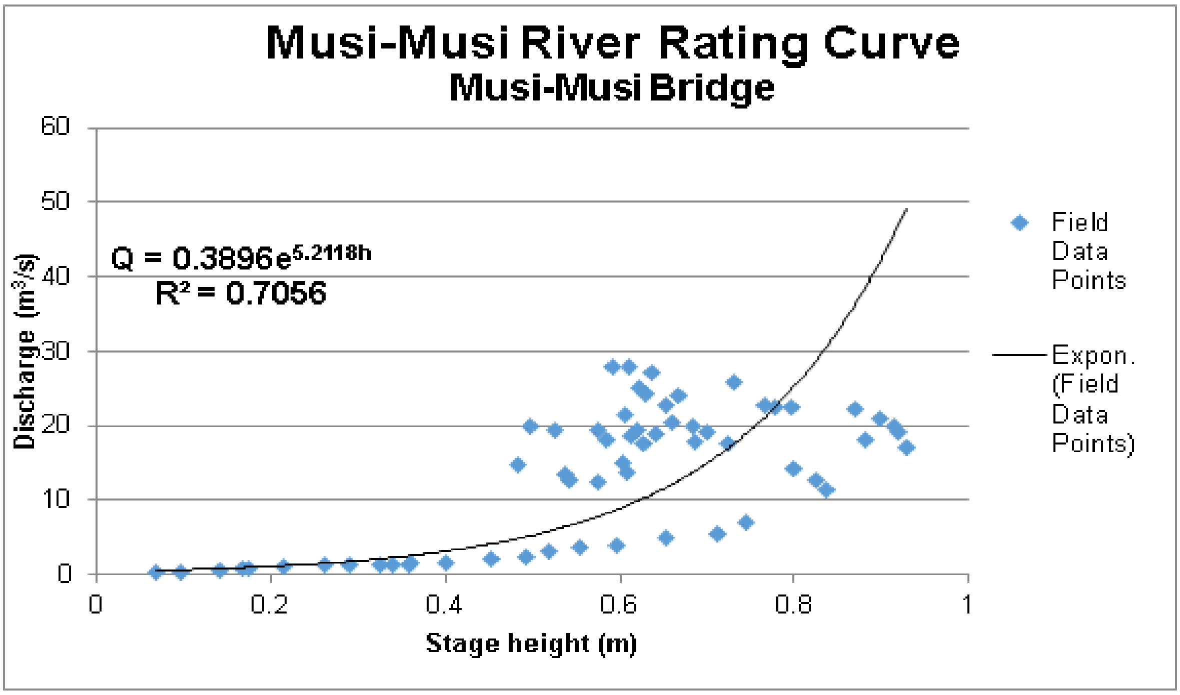


Figure 50. HQ Curve of HEC-HMS Model

5.1.2 RIDF Station

Discharge simulations based on historical data were performed in the calibrated hydrologic model. Among the readily available datasets is the Rainfall Intensity Duration Frequency (RIDF) which is a probability that a particular average rainfall intensity will occur in a specific time frame. Data is usually being utilized to create representation on the estimates of the return period of an observed rainfall event. The RIDF used was based on a 26-year record of Lumbia Rain Gauge of the Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA). The Lumbia station was chosen for the simulation due to its proximity to the Musi-musi river basin. Five return periods data namely, 5, 10, 25, 50 and 100-year RIDFs were used for the simulation.

Table 28. RIDF values for Lumbia 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	22.3	32.5	42	56.6	68.1	74.1	82.1	85.1	88.8
5	27.1	39.9	52.7	74	91.5	96.5	104.8	110.4	129.2
10	30.2	44.9	59.8	85.4	107.1	111.4	119.9	127.1	156
15	32	47.6	63.8	91.9	115.8	119.7	128.4	136.5	171.1
20	33.3	49.6	66.6	96.4	122	125.6	134.4	143.1	181.6
25	34.2	51.1	68.7	99.9	126.7	130.1	139	148.2	189.8
50	37.2	55.7	75.4	110.7	141.3	144	153.1	163.9	214.8
100	40.2	60.3	82	121.3	155.7	157.8	167.2	179.4	239.7

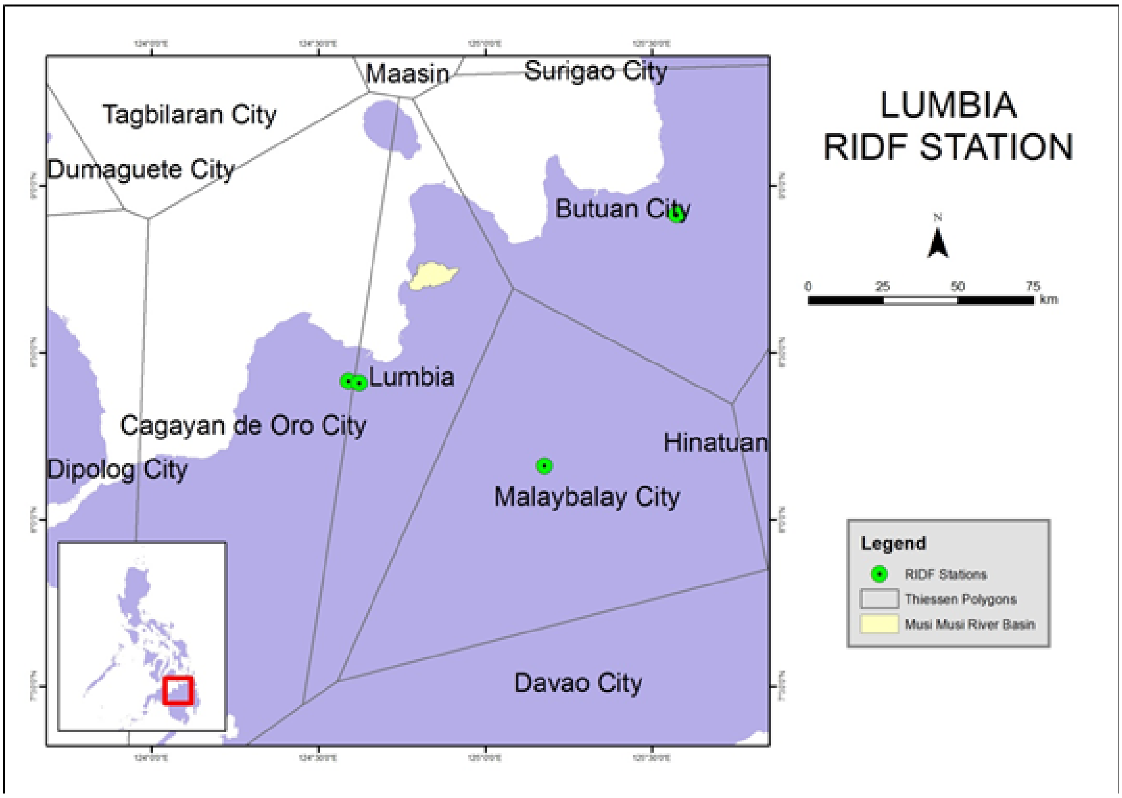


Figure 51. Location of Lumbia RIDF Station relative to Musi-Musi River Basin

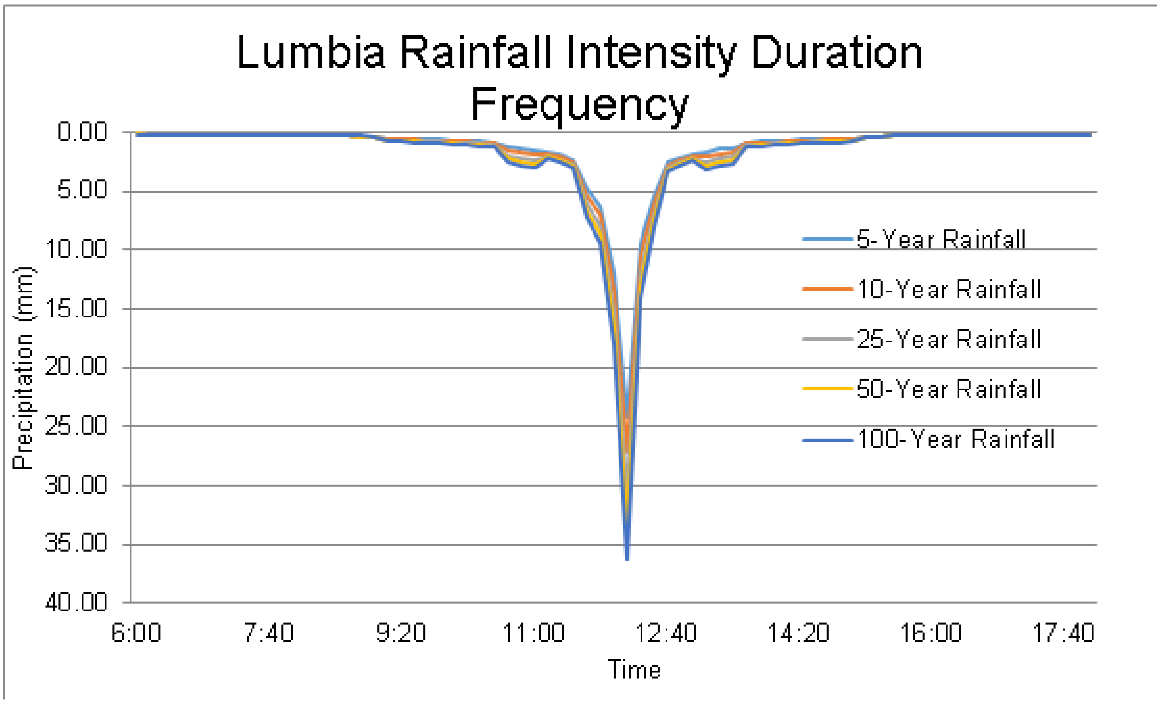


Figure 52. Synthetic storm generated for a 24-hr period rainfall for various return periods

5.1.3 HMS Model

The soil dataset was taken before 2004 by the Bureau of Soils and Water Management (BSWM), under the Department of Agriculture (DA). The land cover dataset file is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Musi-Musi River Basin are shown in Figures 53 and 54, respectively.

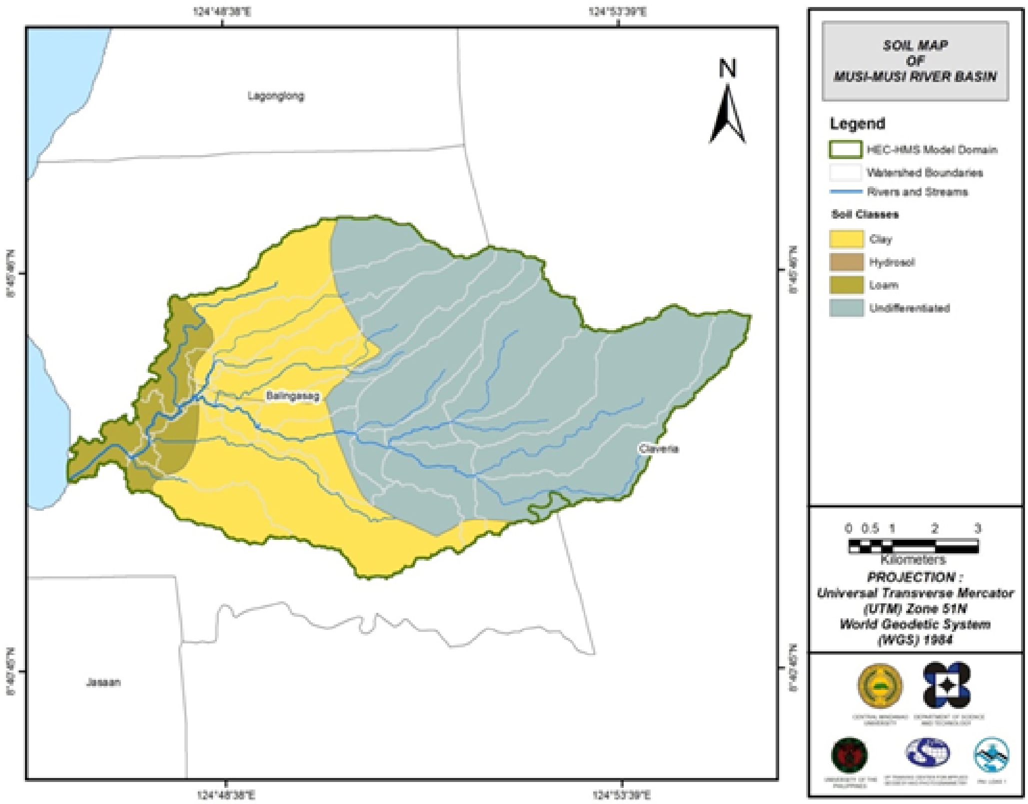


Figure 53. The soil map of the Musi-musi River Basin

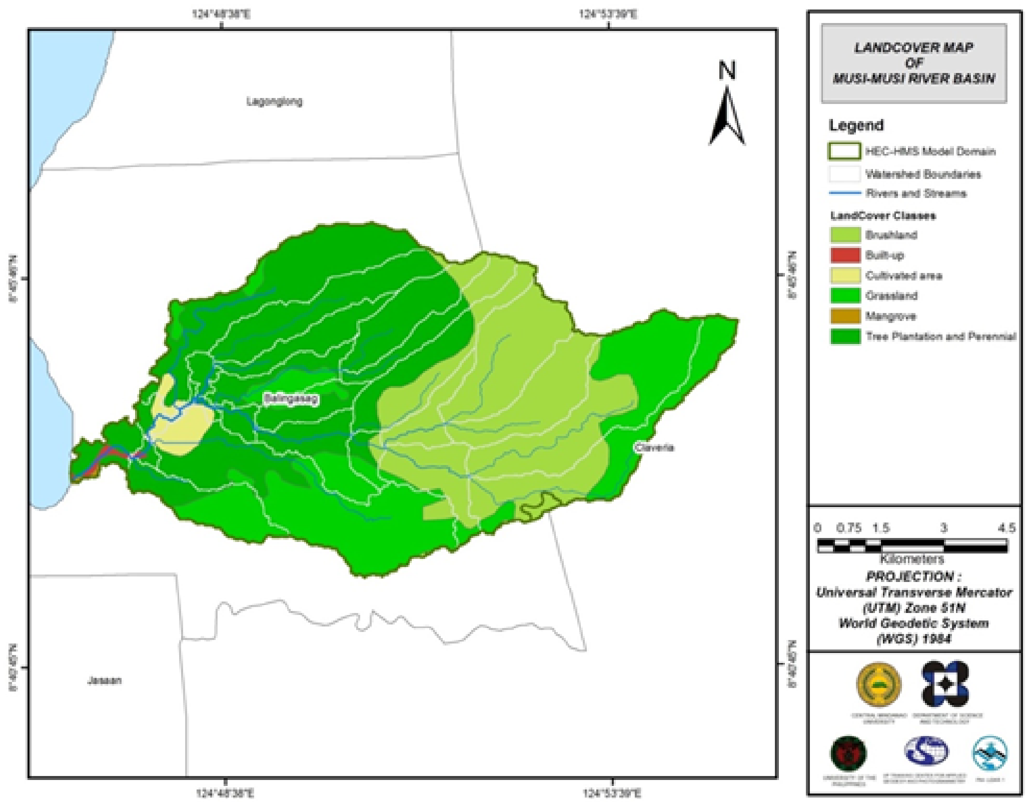


Figure 54. The land cover map of the Musi-musi River Basin (Source: NAMRIA)

For Musi-Musi, four soil classes were identified. These are loam, clay, hydrosol, and undifferentiated soil. Moreover, six land cover classes were identified. These are brushland, built-up, cultivated areas, grassland, mangrove, and tree plantation and perennial.

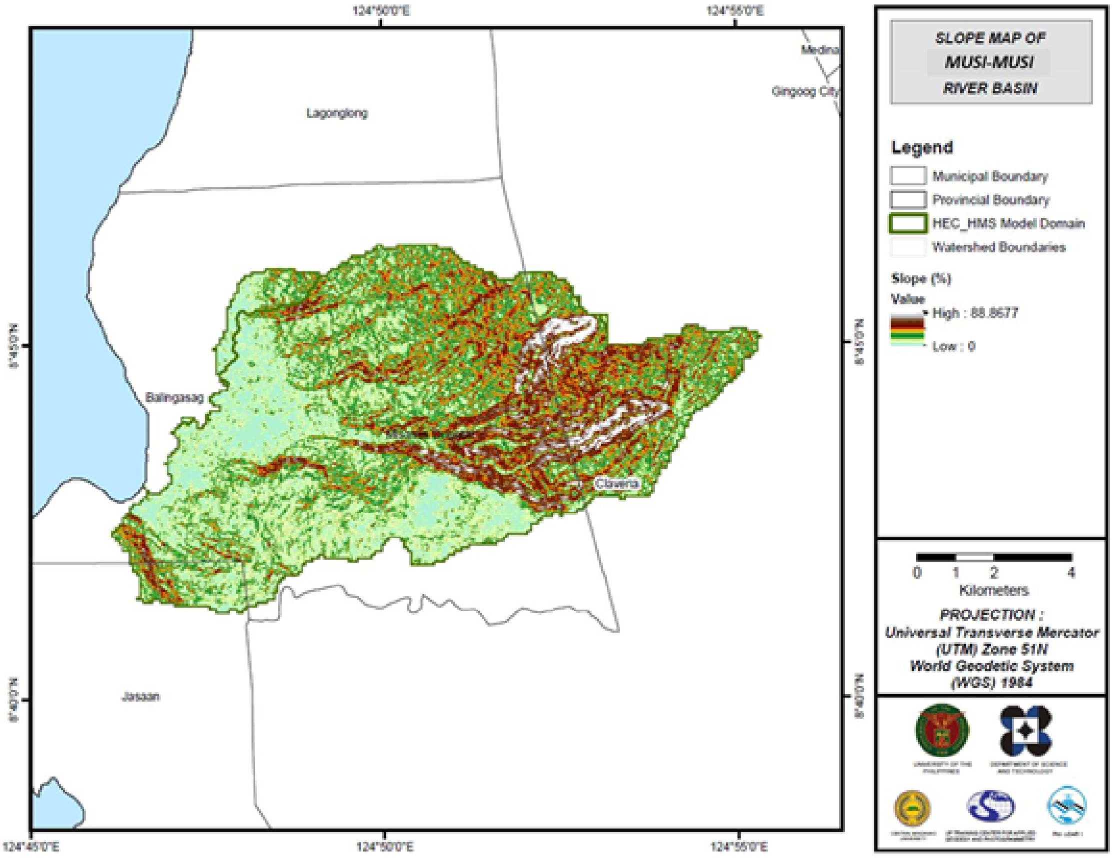


Figure 55. Slope map of Musi-Musi River Basin

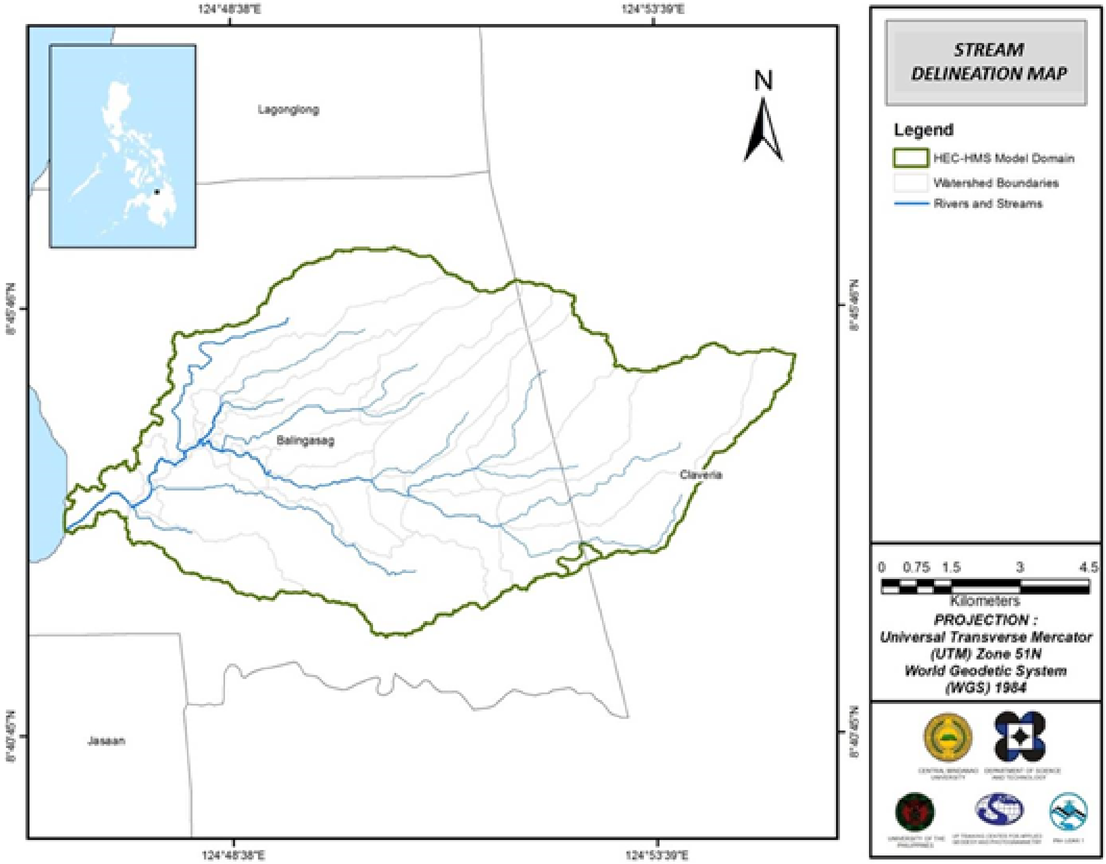


Figure 56. Stream delineation map of Musi-Musi river basin

The basin model of Musi-musi with delineated basin and subbasins was generated using Synthetic Aperture Radar (SAR) 10m Digital Elevation Model (DEM) and digitized river centerline extracted from Google Earth through ArcGIS10.1 extension tool GeoHMS10.1.

The basin model consists of 27 sub basins, 14 reaches, and 12 junctions. The main outlet is assigned at the estuary. The basins were identified based on soil and land cover characteristics of the area. Precipitation from the 29-30 December 2014 (Typhoon Seniang) was taken from DOST rain gauge. Finally, it was calibrated using discharge data gathered at the Musi-musi Bridge using mechanical flow meter and deployed digital depth gauge.

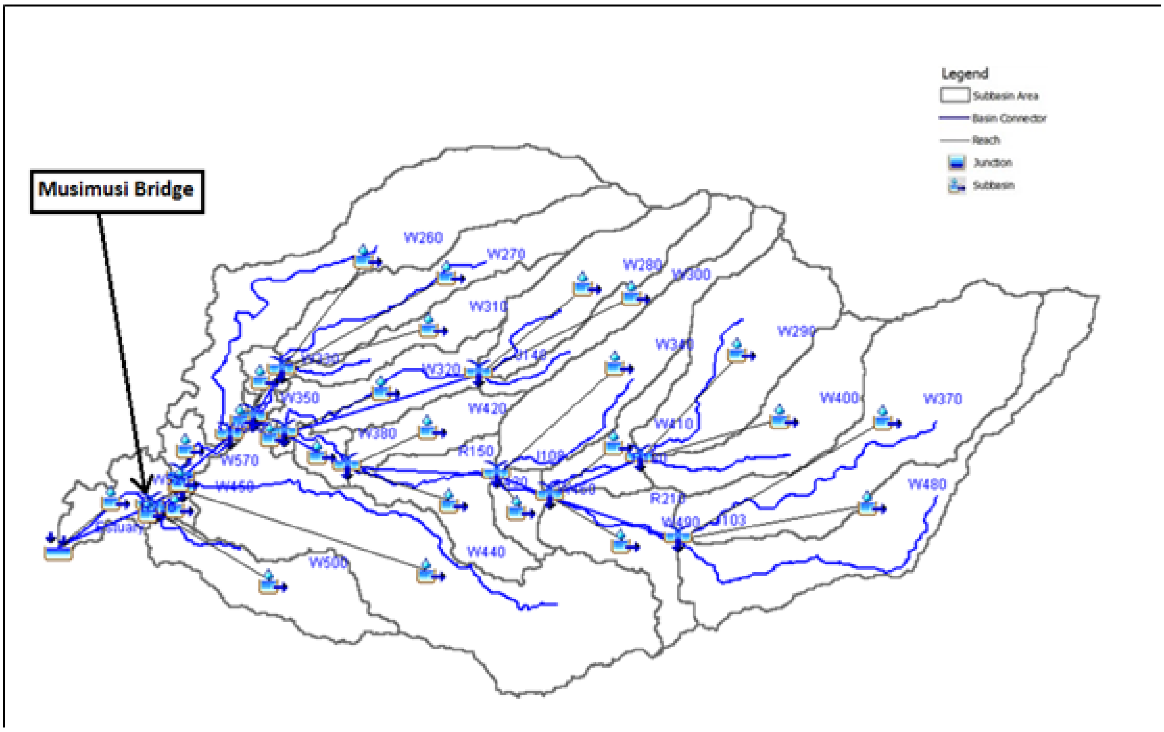


Figure 57. The Musi-Musi river basin model generated using HEC-HMS

5.1.4 Cross-Section Data

Riverbed cross-sections of the watershed are necessary in the HEC-RAS model setup and in an important composition of the river geometry. 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. The river geometry of Musi-musi consists of one (1) river centerline, two (2) banks, three (3) flowpaths, and 16 cross section polylines RAS layers.

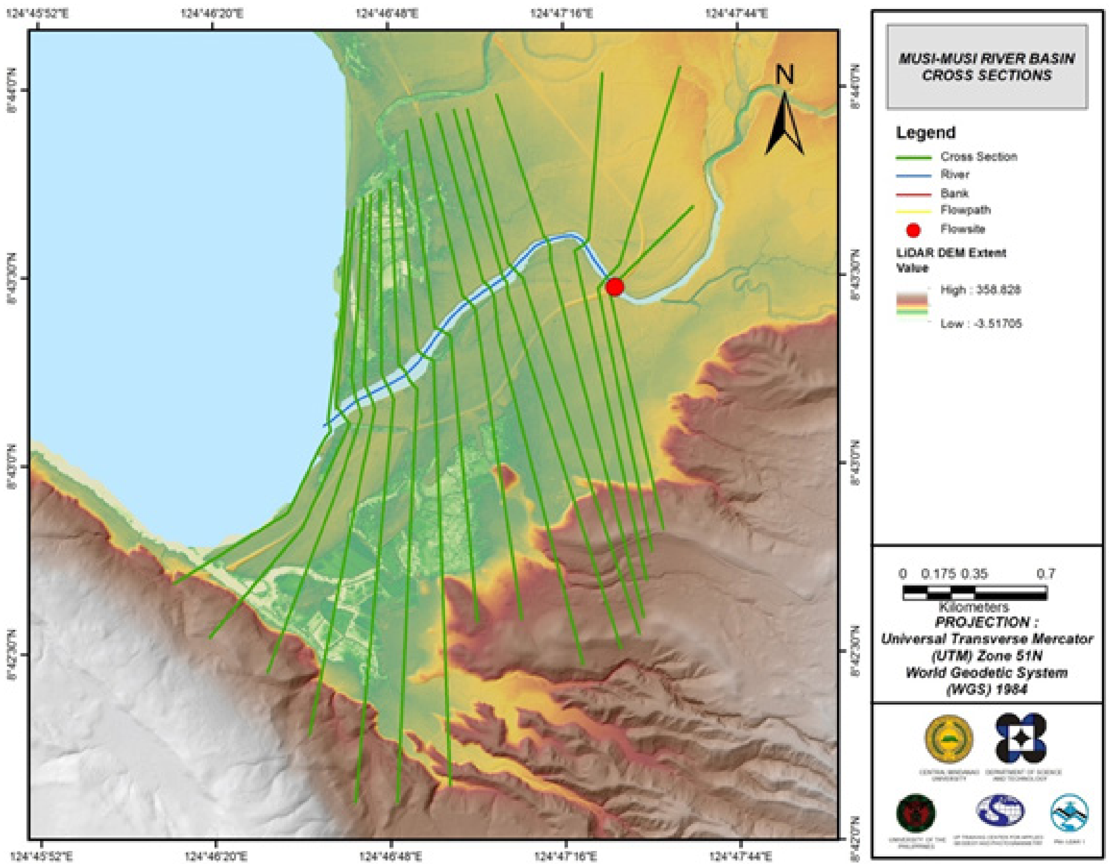


Figure 58. Musi-musi River Cross-section generated using HEC GeoRAS tool

5.1.5 Flo 2D Model

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

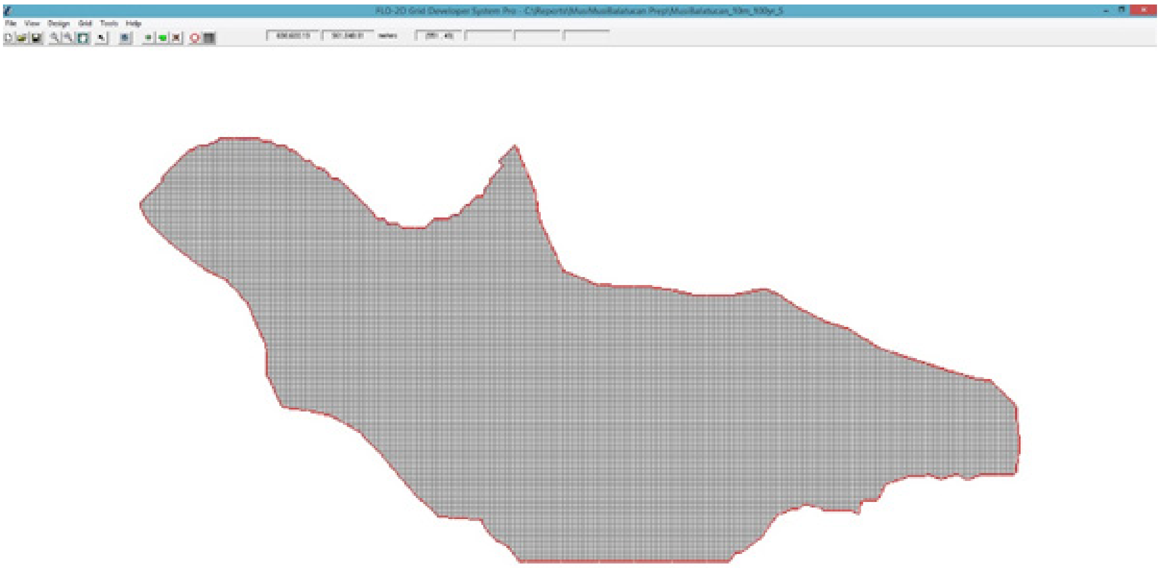


Figure 59. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 39.55225 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h) is set at 0 m2/s.

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 39 385 900.00 m2.

There is a total of 18 419 757.72 m3 of water entering the model. Of this amount, 10 725 727.85 m3 is due to rainfall while 7 694 029.87 m3 is inflow from other areas outside the model. 3 960 626.75 m3 of this water is lost to infiltration and interception, while 12 447 417.07 m3 is stored by the flood plain. The rest, amounting up to 2 011 714.06 m3, is outflow.

5.2 Results of HMS Calibration

After calibrating the Musi-Musi HEC-HMS river basin model, its accuracy was measured against the observed values (See Annex 9). Figure 60 shows the comparison between the two discharge data.

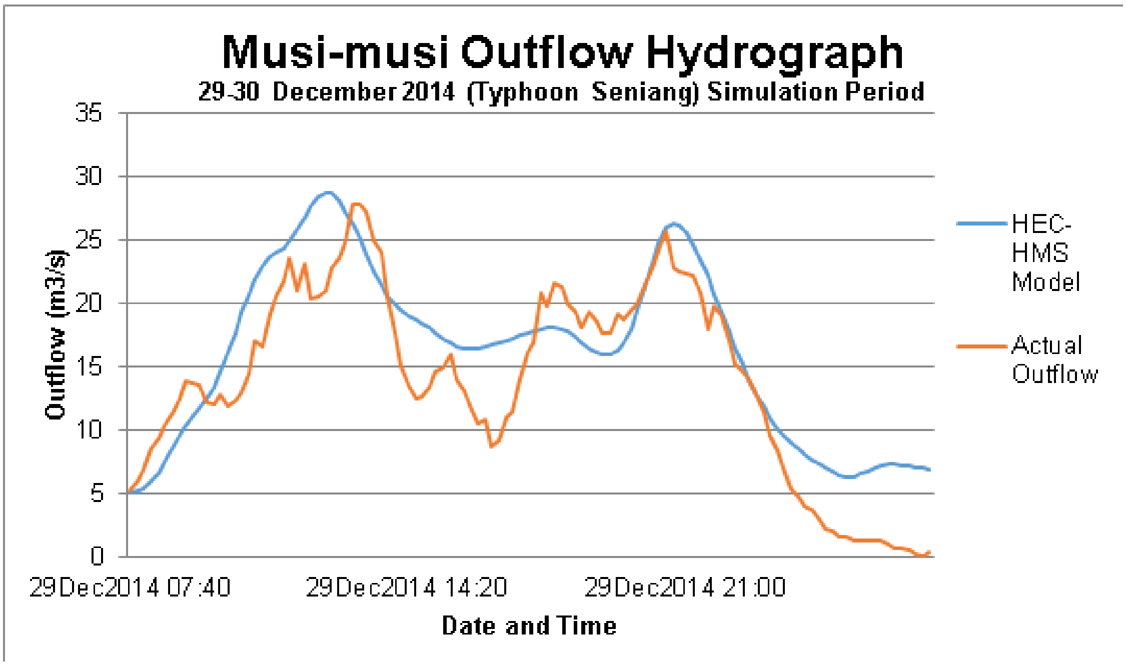


Figure 60. Outflow Hydrograph of Musi-Musi produced by the HEC-HMS model compared with observed outflow.

Enumerated in Table 29 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 29. Range of Calibrated Values for Musi-Musi

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	100 - 275
			Curve Number	38 - 73.837
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.158 - 2.774
			Storage Coefficient (hr)	0.114 - 2.012
	Baseflow	Recession	Recession Constant	0.5
			Ratio to Peak	0.01

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 100mm to 275mm means that there is a high amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 38 to 73.837 for curve number is lower than the advisable range for Philippine watersheds depending on the soil and land cover of the area. For Musi-Musi, the basin mostly consists of brushlands, grasslands, tree plantation and perennial, and the soil consists of clay, loam, and undifferentiated soil.

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.114 hours to 2.774 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.5 indicates that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.01 indicates a steeper receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.001 – 0.003 is lower than the usual Manning's n value in the Philippines.

Table 30. Summary of the Efficiency Test of Musi-Musi HMS Model

Accuracy measure	Value
RMSE	4.0
r^2	0.90
NSE	0.71
PBIAS	20.96
RSR	0.54

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 4.0 (m3/s).

The Pearson correlation coefficient (r2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.90.

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 0.71.

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 20.96.

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 0.54.

5.3 Calculated Outflow Hydrographs and Discharge Values for Different Rainfall Return Models

5.3.1 Hydrograph Using the Rainfall Runoff Model

The summary graph (Figure 61) shows the Musi-Musi outflow using the Lumbia Rainfall Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on 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.

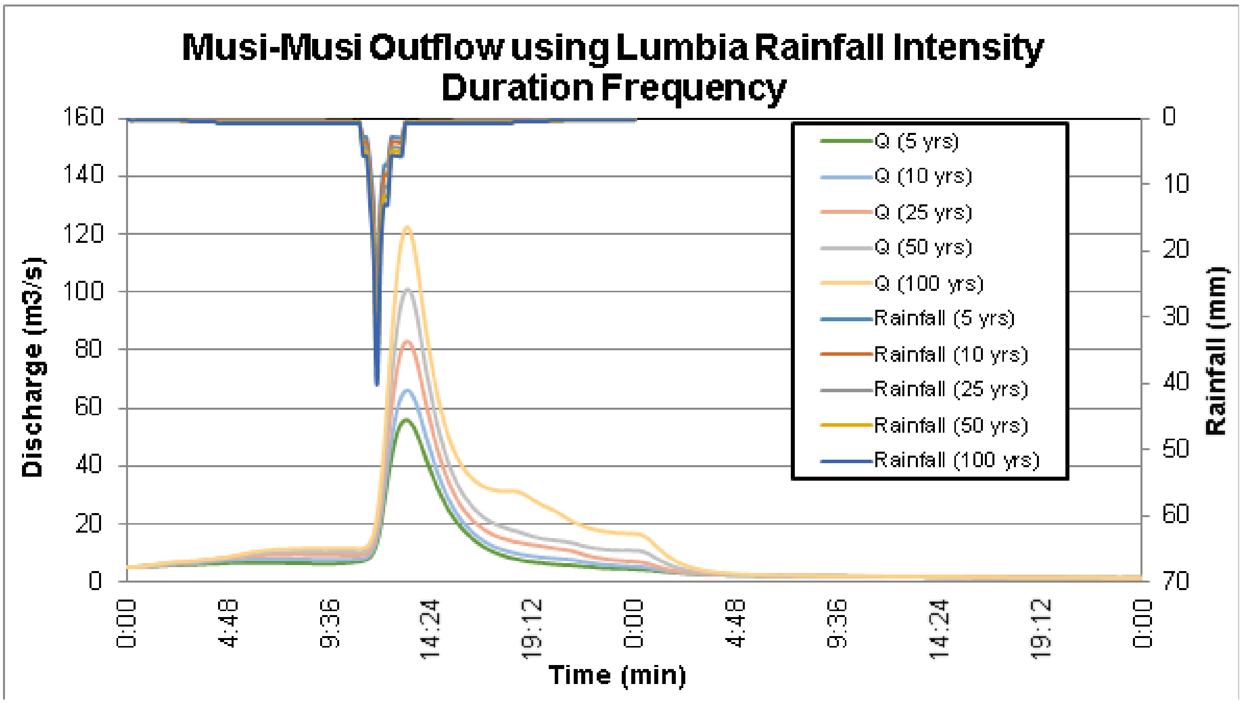


Figure 61. Outflow hydrograph at Musi-Musi Station generated using Lumbia RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Musi-Musi discharge using the Lumbia Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 31.

Table 31. Peak values of the Musi-Musi HECHMS Model outflow using the Lumbia RIDF

RIDF Period	Total Precipitation (mm)	Peak Rainfall (mm)	Peak Outflow (m^3/s)	Time to Peak
5-Year	110.4	27.1	54.3	1 hour, 30 minutes
10-Year	127.1	30.2	66.6	1 hour, 30-40 minutes
25-Year	148.2	34.2	83.5	1 hour, 30 minutes
50-Year	163.9	37.2	101.1	1 hour, 30 minutes
100-Year	179.4	40.2	122.5	1 hour, 30 minutes

5.3.2 Hydrograph Using the Rainfall Runoff Model

The river discharges for the three rivers entering the floodplain are shown in Figure 62 to Figure 63 and the peak values are summarized in Table 32 to Table 33.

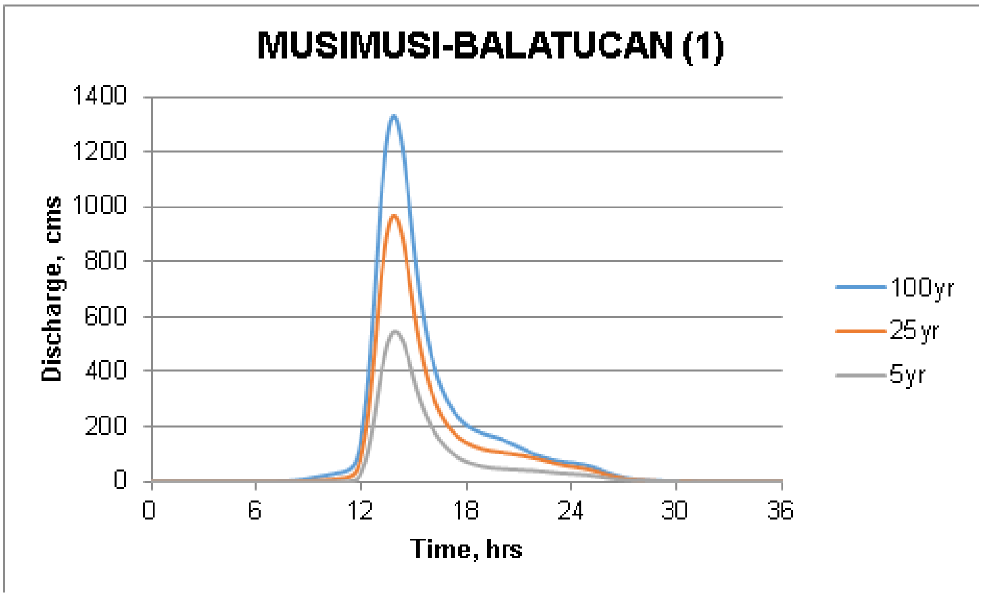


Figure 62. Musi-Musi and Balatucan river (1) generated discharge using 5-, 25-, and 100-year Lumbia rainfall intensity-duration-frequency (RIDF) in HEC-HMS

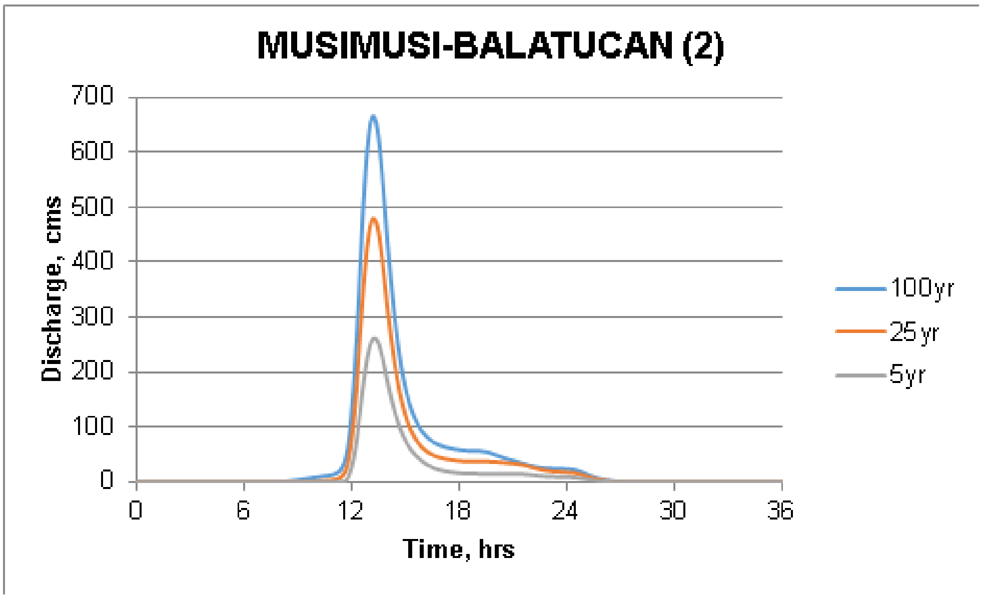


Figure 63. Musi-Musi and Balatucan river (2) generated discharge using 5-, 25-, and 100-year Lumbia rainfall intensity-duration-frequency (RIDF) in HEC-HMS

Table 32. Summary of Musi-Musi and Balatucan river (1) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	1331.9	13 hours, 50 minutes
25-Year	969.0	13 hours, 50 minutes
5-Year	545.1	13 hours, 50 minutes

Table 33. Summary of Musi-Musi and Balatucan river (2) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	665.9	13 hours, 10 minutes
25-Year	479.3	13 hours, 10 minutes
5-Year	260.2	13 hours, 10 minutes

The comparison of the discharge results using Dr. Horritt's recommended hydrological method against the bankful and specific discharge estimates is shown in Table 34.

Table 34. Validation of river discharge estimates

Discharge Point	$Q_{MED(SCS)}$, cms	$Q_{BANKFUL}$, cms	$Q_{MED(SPEC)}$, cms	VALIDATION	
				Bankful Discharge	Specific Discharge
Musi-Musi and Balatucan (1)	479.688	471.303	355.125	Pass	Pass
Musi-Musi and Balatucan (2)	228.976	320.892	193.706	Pass	Pass

The two values from the HEC-HMS river discharge estimates were able to satisfy the conditions for validation using the bankful and specific discharge methods. The calculated values are based on theory but are supported using other discharge computation methods so they were good to use flood modeling. However, these values will need further investigation for the purpose of validation. It is therefore recommended to obtain actual values of the river discharges for higher-accuracy modeling.

5.5 River Analysis 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 to be shown. The sample generated map of Musi-Musi River using the calibrated HMS base flow is shown in Figure 64.

Figure 64. Sample output of Balatucan - Musi-Musi RAS Model

5.6 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figure 65 to Figure 70 shows the 5-, 25-, and 100-year rain return scenarios of the Musi-Balatucan floodplain. The floodplain, with an area OF 46.31 sq. km., covers four municipalites namely Balingasa, Claveria, Jasaan and Lagonglong. Table shows the percentage of area affected by flooding per municipality.

Table 35. Municipalities affected in Musi-Balatucan floodplain

Municipality	Total Area	Area Flooded	% Flooded
Balingasag	165.73	39.29	23.71%
Claveria	622.22	0.09	0.01%
Jasaan	64.84	2.47	3.81%
Lagonglong	47.38	3.56	7.51%

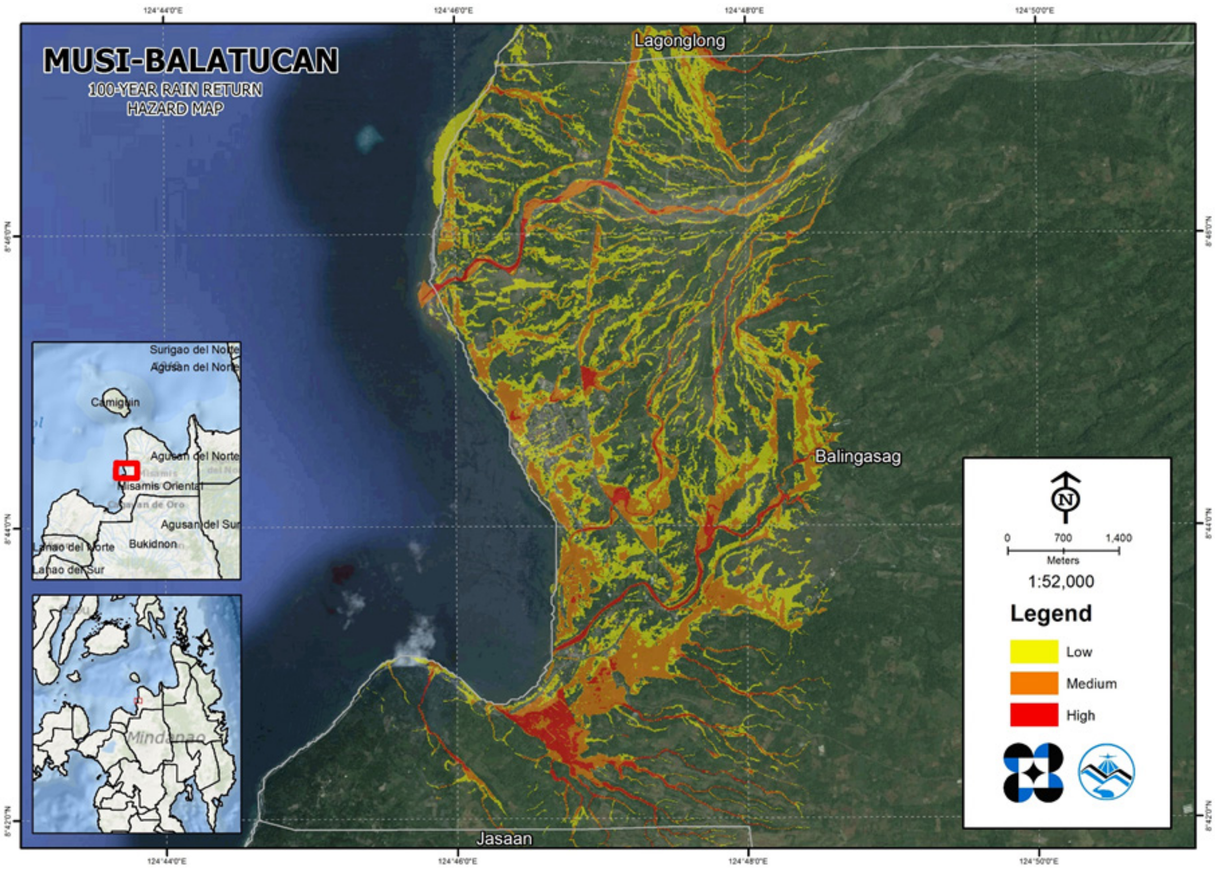


Figure 65. 100-year Flood Hazard Map for Musi-Musi-Balatucan Floodplain

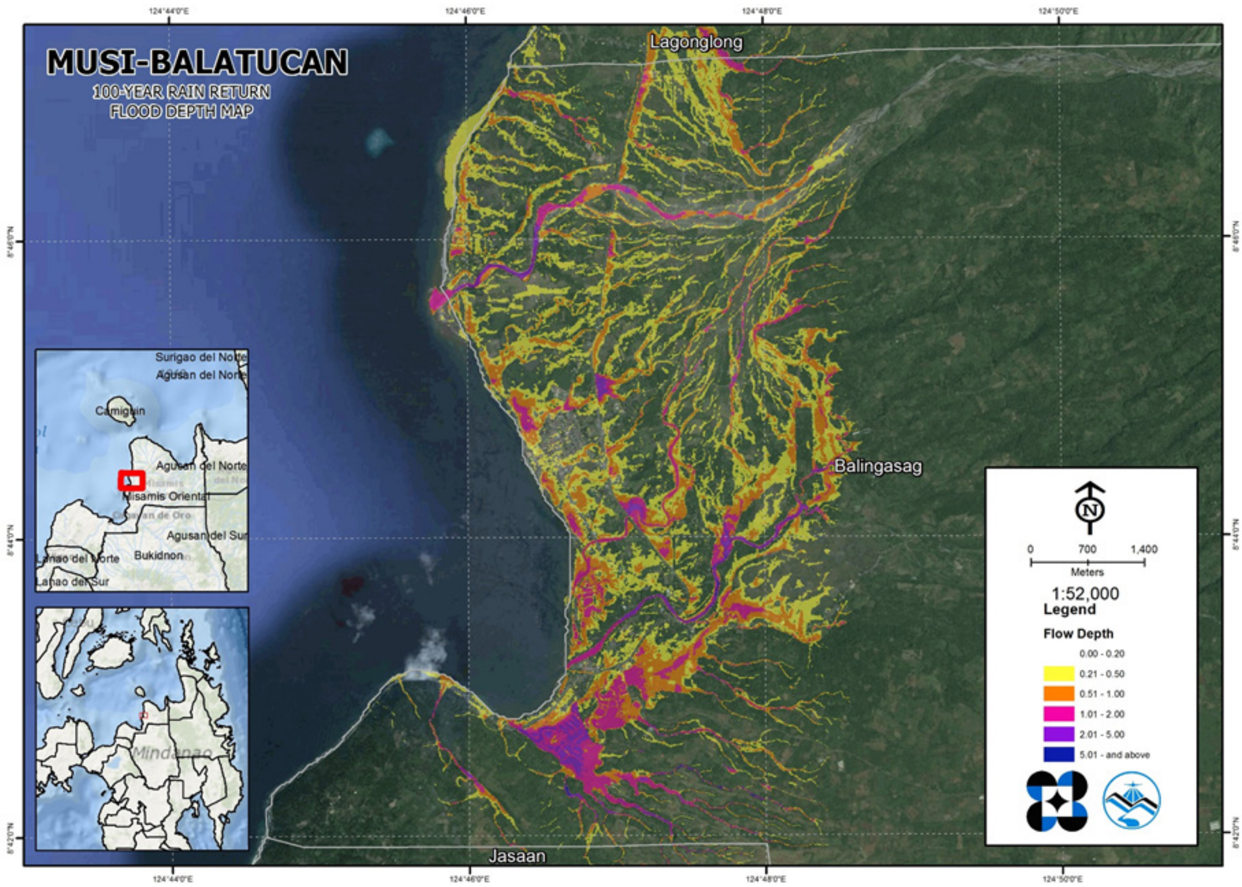


Figure 66. 100-year Flow Depth Map for Musi-Musi-Balatucan Floodplain

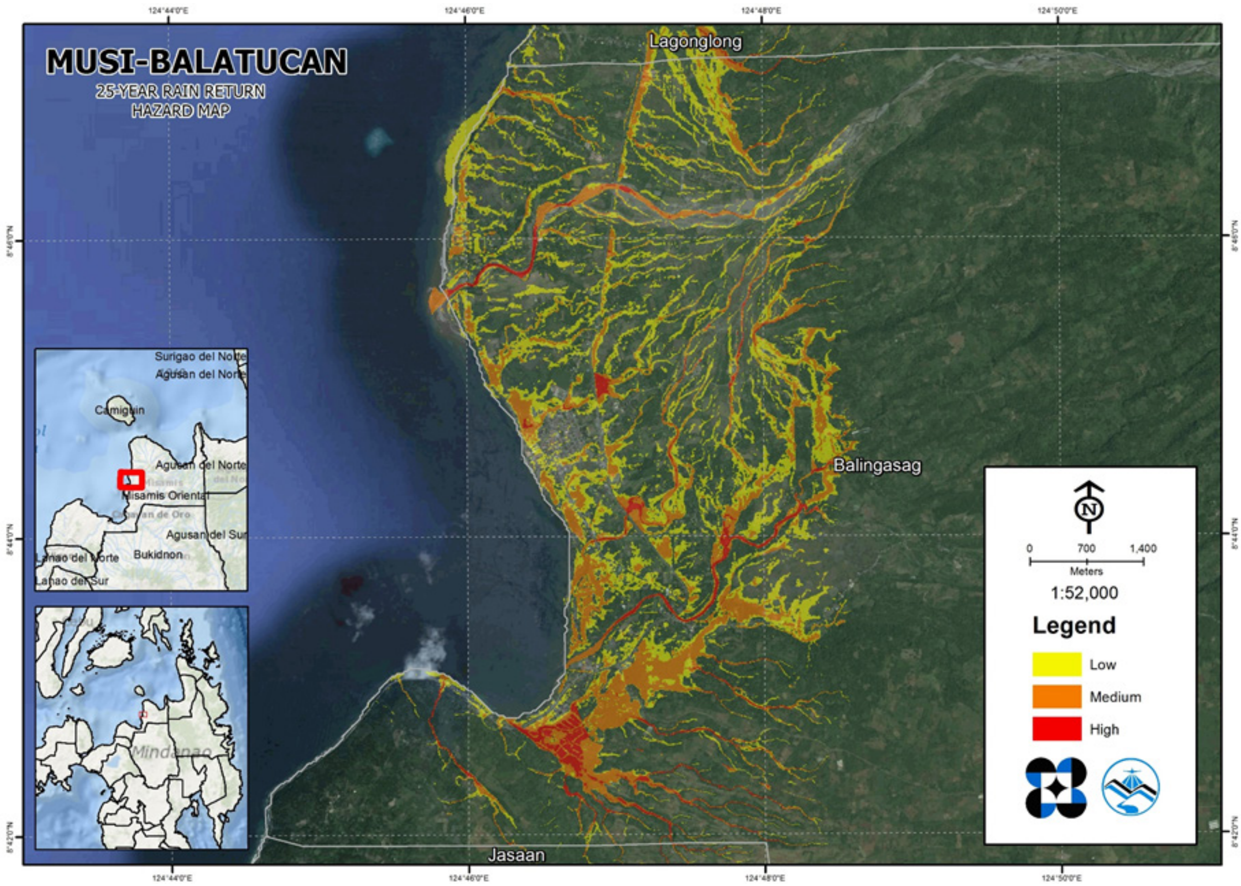


Figure 67. 25-year Flood Hazard Map for Musi-Musi-Balatucan Floodplain

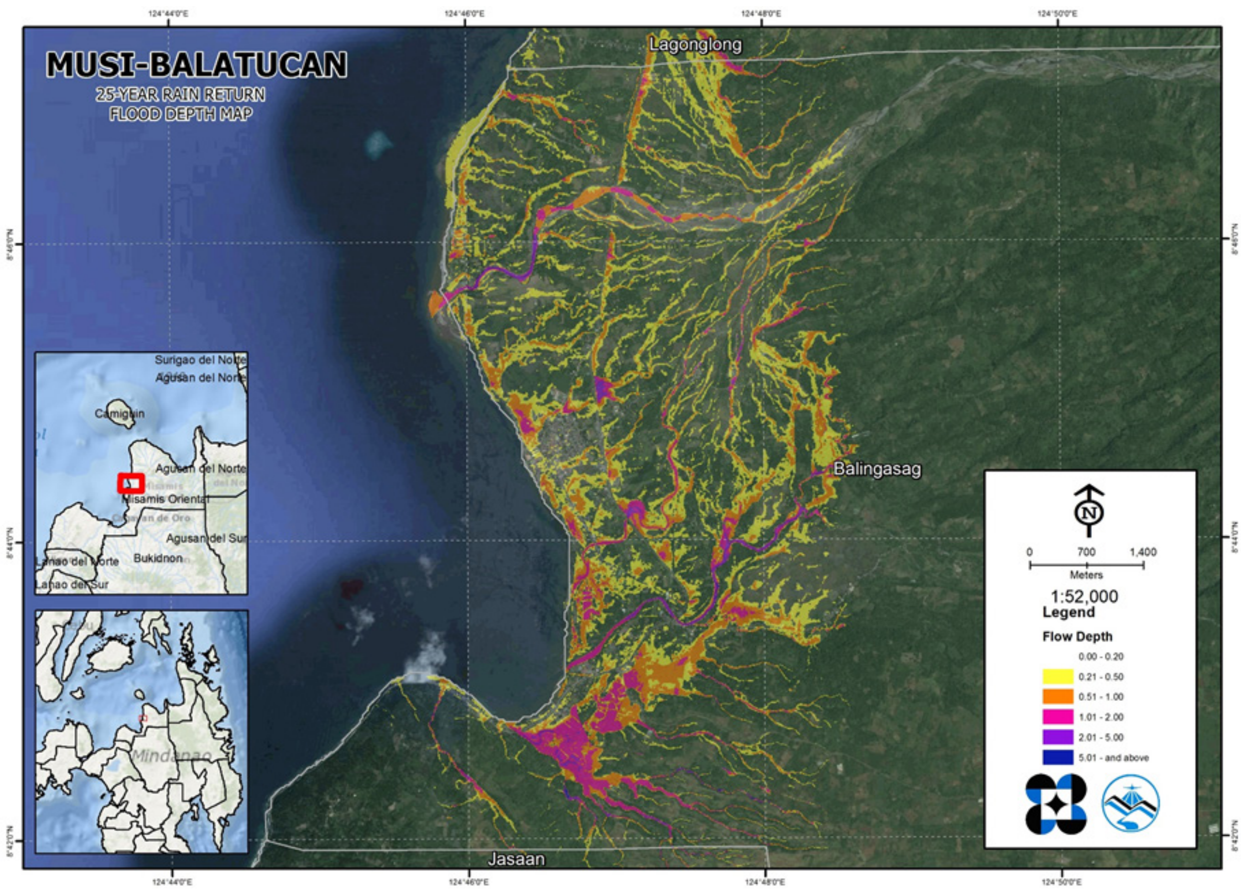


Figure 68. 25-year Flow Depth Map for Musi-Musi-Balatucan Floodplain

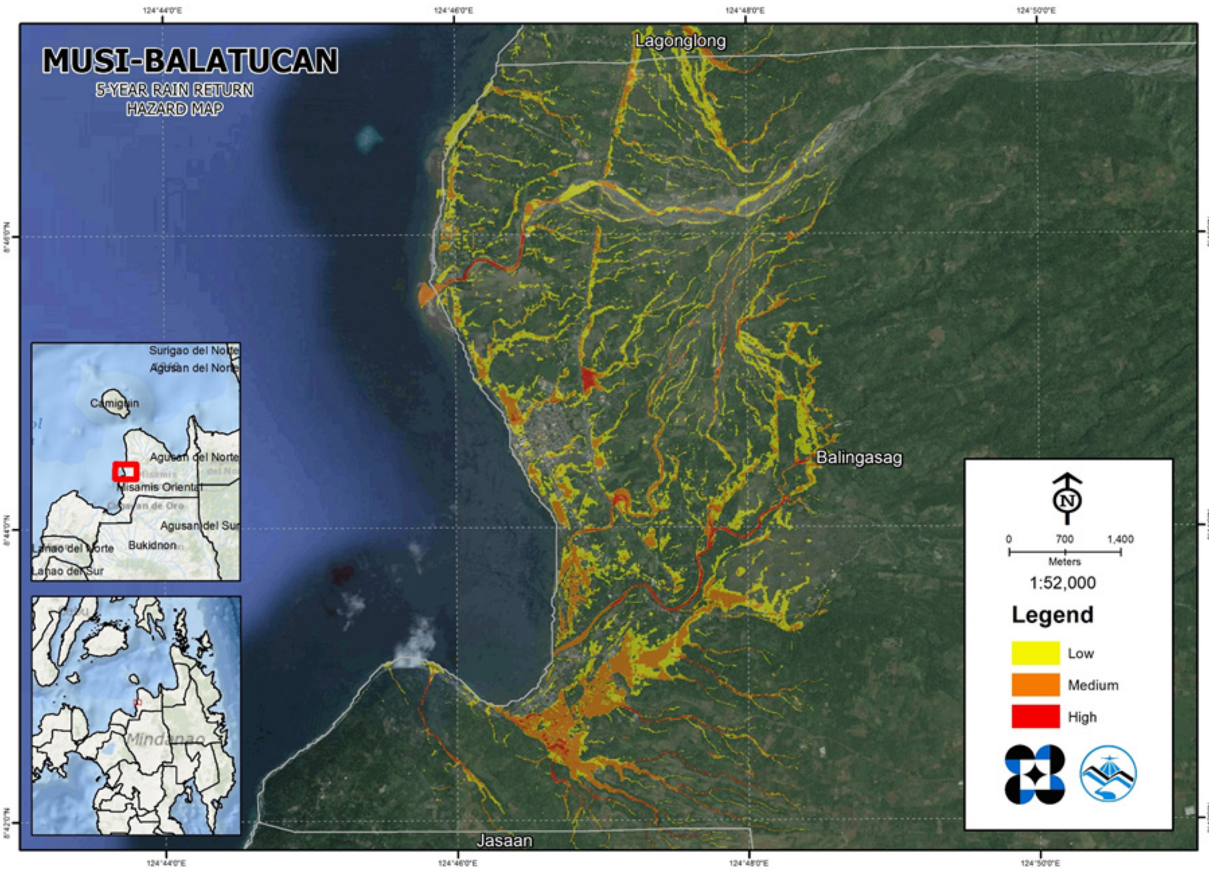


Figure 69. 5-year Flood Hazard Map for Musi-Musi-Balatucan Floodplain

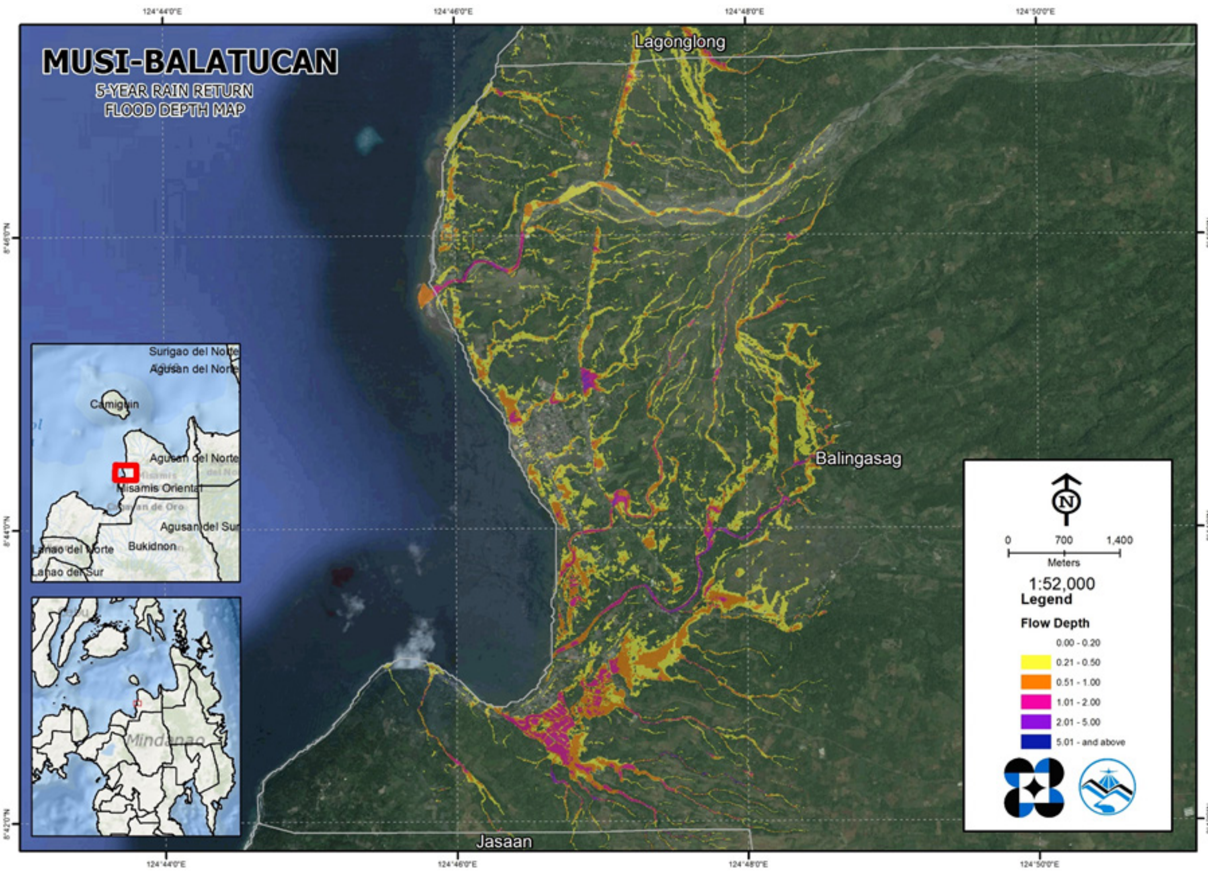


Figure 70. 5-year Flood Depth Map for MusiMusi-Balatucan Floodplain

5.6.1 Inventory of Areas Exposed to Flooding

Areas exposed to flooding in the barangays in Balatucan – Musi-Musi river basin, grouped by municipality, are listed below. For the said basin, three municipalities consisting of 26 barangays are expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 27.95% of the municipality of Balingasag with an area of 125.591 sq. km. will experience flood levels of less than 0.20 meters. 3.91% of the area will experience flood levels of 0.21 to 0.50 meters while 1.67%, 0.59%, and 0.09%, of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 36. Affected Areas in Balingasag during 5-Year Rainfall Return Period

BALATUCAN – MUSI-MUSI BASIN		Affected Barangays in Balingasag							
		Baliwagan	Barangay 1	Barangay 2	Barangay 3	Barangay 4	Barangay 5	Barangay 6	Binitinan
Affected Area (sq. km.)	**0.03-0.20**	2.52917	0.077572	0.07775	0.048659	0.144833	0.093553	0.09747	3.22456
	0.21-0.50	0.512744	0.011576	0.011419	0.023431	0.013699	0.011243	0.018073	0.281563
	0.51-1.00	0.475933	0.006549	0.005997	0.014429	0.004904	0.001116	0.002405	0.301411
	1.01-2.00	0.159511	0.00379	0	0.006416	0.00026	0	0	0.248385
	2.01-5.00	0.005681	0	0	0	0	0	0	0.006
	> 5.00	0.0005	0	0	0	0	0	0	0.0006

Table 37. Affected Areas in Balingasag during 5-Year Rainfall Return Period

BALATUCAN – MUSI-MUSI BASIN		Affected Barangays in Balingasag							
		Blanco	Cogon	Dumarait	Hermano	Kibanban	Linabu	Linggangao	Mambayaan
Affected Area (sq. km.)	**0.03-0.20**	2.91012	3.01164	1.761579	0.370308	0.763646	2.00165	1.441179	2.860419
	0.21-0.50	0.265792	0.554912	0.304966	0.005953	0.03327	0.051018	0.170755	0.390089
	0.51-1.00	0.217801	0.138026	0.085591	0.001992	0.002882	0.012323	0.054122	0.110657
	1.01-2.00	0.041439	0.049031	0.023291	0.000654	0	0.001598	0.018505	0.012099
	2.01-5.00	0.012256	0.013981	0.012448	0	0	0.000099	0.003928	0
	> 5.00	0.0019	0	0	0	0	0	0	0

Table 38. Affected Areas in Balingasag during 5-Year Rainfall Return Period

BALATUCAN – MUSI-MUSI BASIN		Affected Barangays in Balingasag					
Mandangoa		Napaliran	Quezon	San Isidro	Talusan	Waterfall	
Affected Area (sq. km.)	**0.03-0.20**	3.078219	3.88907	1.69419	2.836359	1.483829	0.706759
	0.21-0.50	0.403697	0.532742	0.18872	0.576995	0.321471	0.228413
	0.51-1.00	0.132493	0.10631	0.072866	0.150885	0.101337	0.091266
	1.01-2.00	0.034695	0.013968	0.011612	0.02961	0.06008	0.026081
	2.01-5.00	0.004197	0.000899	0.001992	0.003108	0.040393	0.003911
	> 5.00	0	0	0	0	0.0004	0

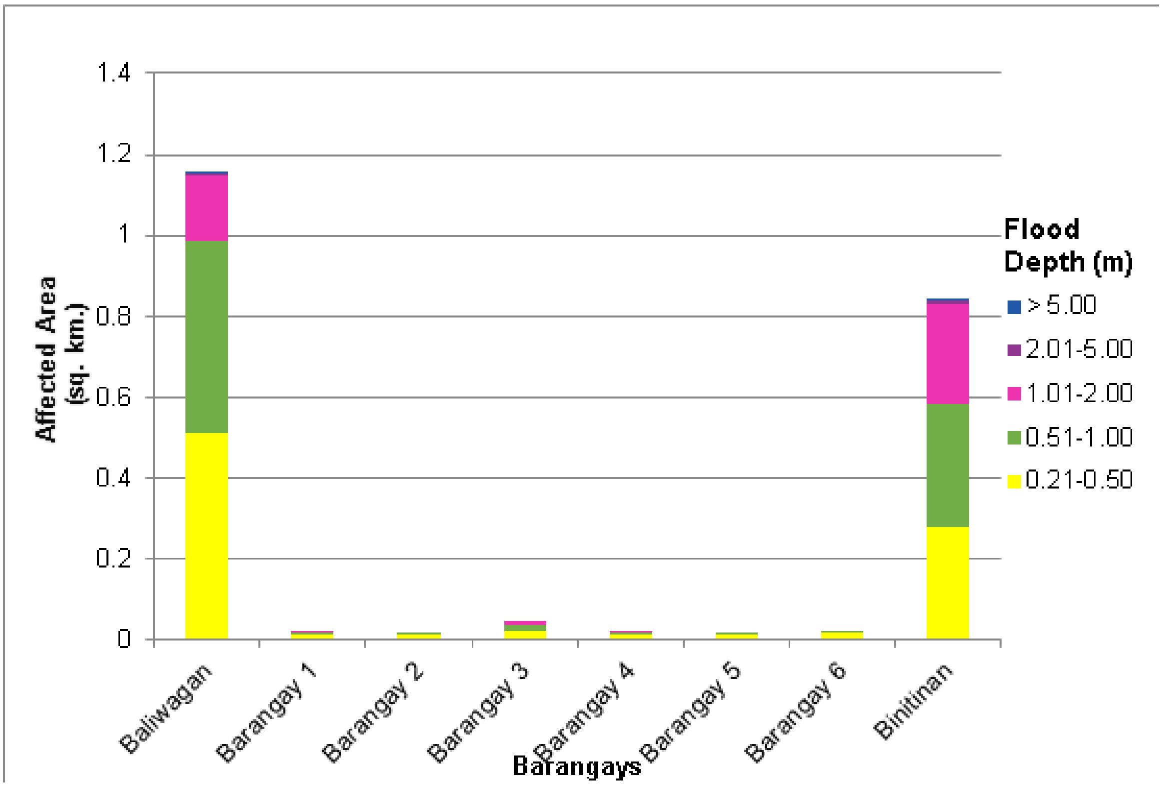


Figure 71. Affected Areas in Balingasag, Misamis Oriental during 5-Year Rainfall Return Period

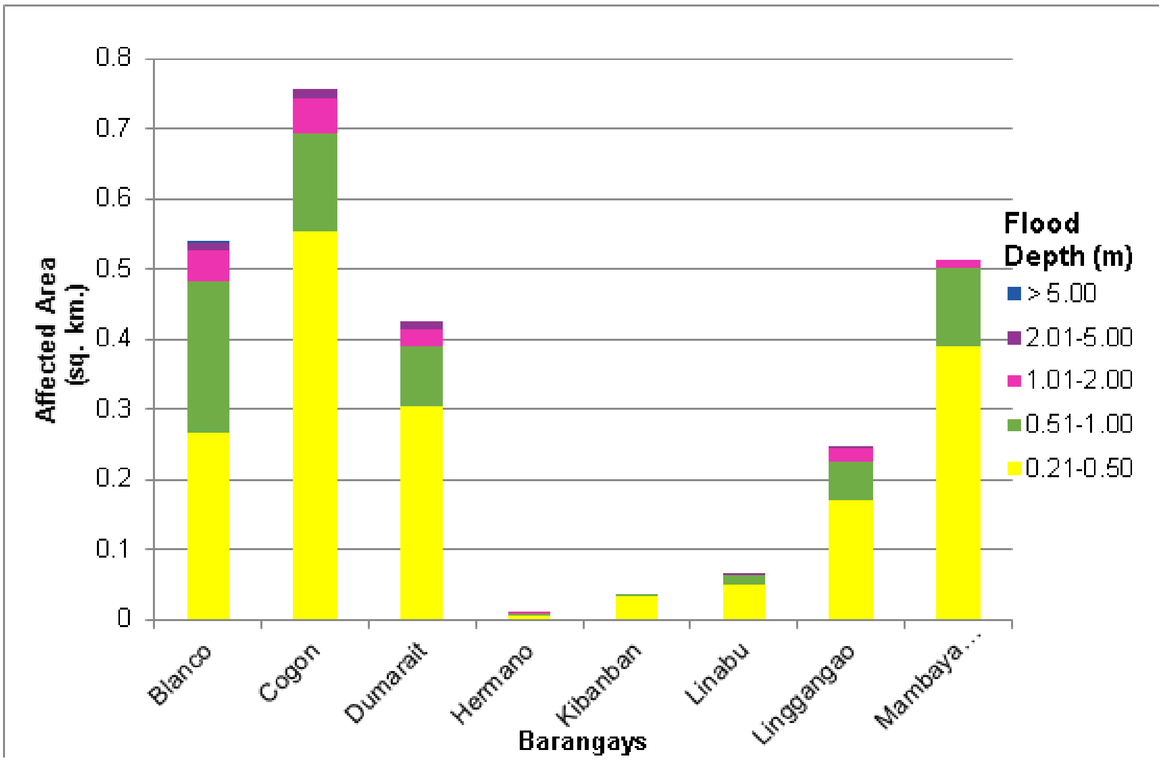


Figure 72. Affected Areas in Balingasag, Misamis Oriental during 5-Year Rainfall Return Period

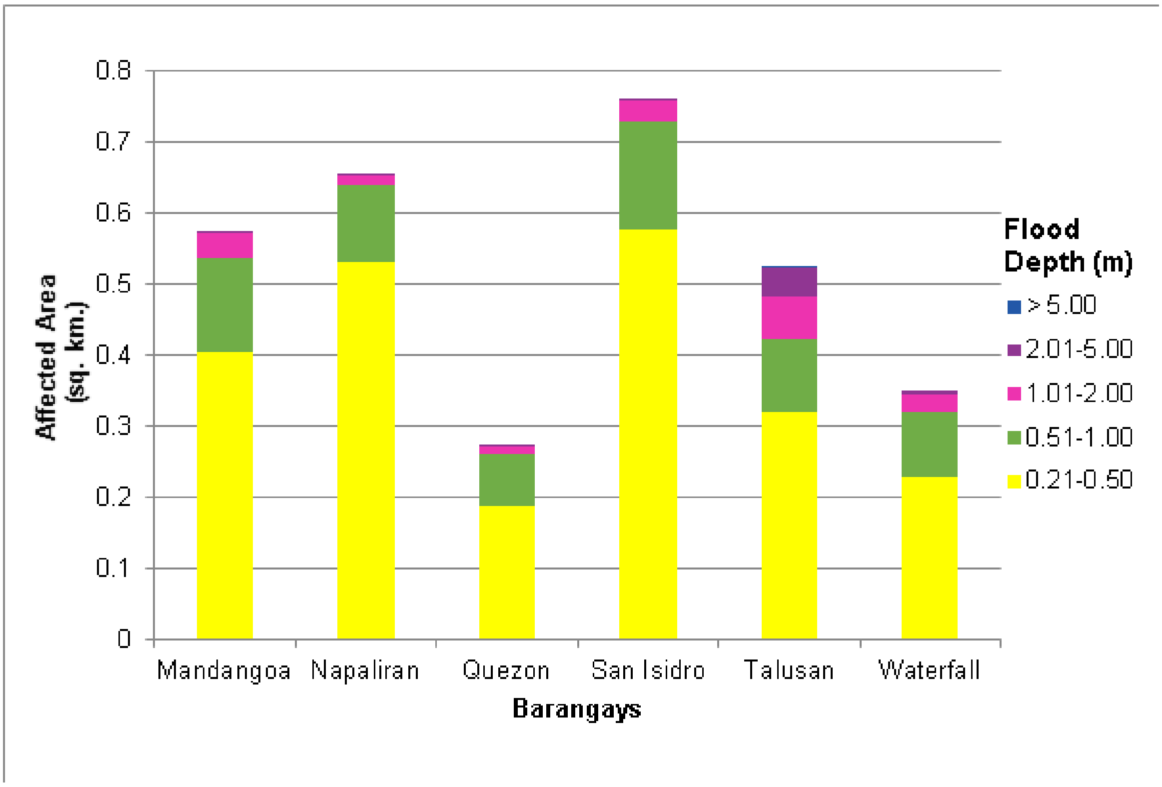


Figure 73. Affected Areas in Balingasag, Misamis Oriental during 5-Year Rainfall Return Period

For the 5-year return period, 2.17% of the municipality of Jasaan with an area of 68.327103 sq. km. will experience flood levels of less than 0.20 meters. 0.06% of the area will experience flood levels of 0.21 to 0.50 meters while 0.03%, and 0.02% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 39. Affected Areas in Jasaan, Misamis Oriental during 5-Year Rainfall Return Period

BALATUCAN – MUSI-MUSI BASIN		Affected Barangays in Jasaan	
		Danao	I. S. Cruz
Affected Area (sq. km.)	**0.03-0.20**	0.044131	1.43929
	0.21-0.50	0.000163	0.039839
	0.51-1.00	0	0.019582
	1.01-2.00	0	0.013992
	2.01-5.00	0	0.001599
	> 5.00	0	0

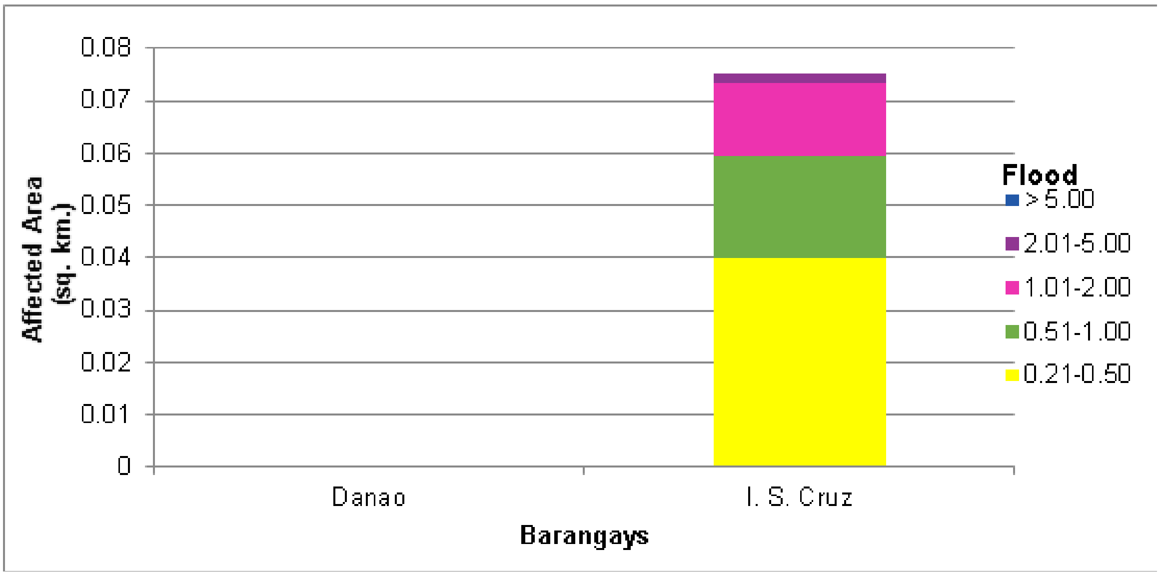


Figure 74. Affected Areas in Jasaan, Misamis Oriental during 5-Year Rainfall Return Period

For the 5-year return period, 2.48% of the municipality of Lagonglong with an area of 46.624699 sq. km. will experience flood levels of less than 0.20 meters. 0.34% of the area will experience flood levels of 0.21 to 0.50 meters while 0.10%, and 0.02%of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 40. Affected Areas in Lagonglong, Misamis Oriental during 5-Year Rainfall Return Period

BALATUCAN – MUSI-MUSI BASIN		Affected Barangays in Lagonglong	
		Kauswagan	Manaol
Affected Area (sq. km.)	**0.03-0.20**	0.458871	0.696308
	0.21-0.50	0.10429	0.052608
	0.51-1.00	0.012596	0.035014
	1.01-2.00	0	0.009628
	2.01-5.00	0	0.000099
	> 5.00	0	0

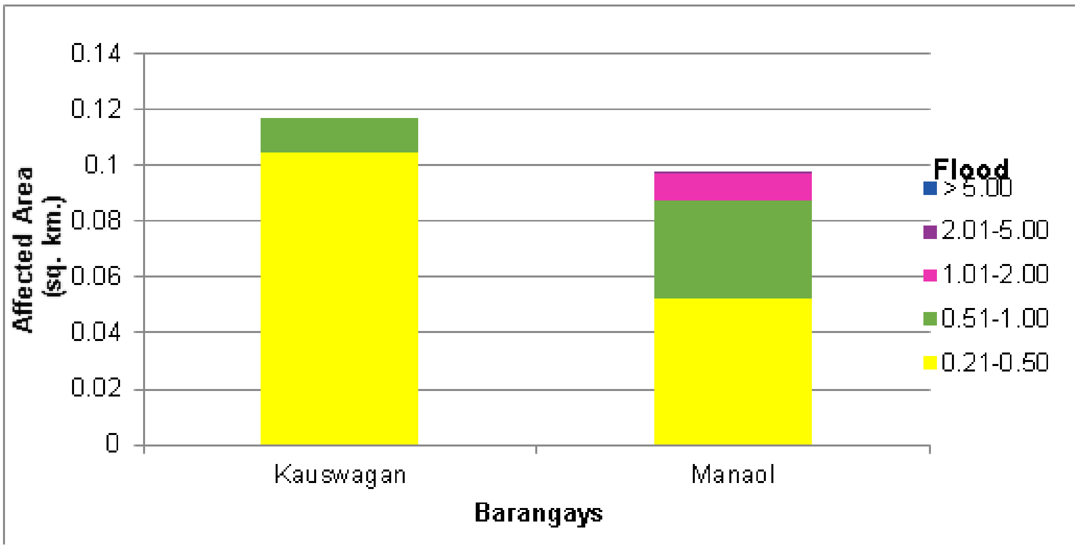


Figure 75. Affected Areas in Lagonglong, Misamis Oriental during 5-Year Rainfall Return Period

For the 25-year return period, 25.10% of the municipality of Balingasag with an area of 125.591 sq. km. will experience flood levels of less than 0.20 meters. 5.21% of the area will experience flood levels of 0.21 to 0.50 meters while 2.56%, 1.13%, 0.22%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 41. Affected Areas in Balingasag during 25-Year Rainfall Return Period

BALATUCAN – MUSI-MUSI BASIN		Affected Barangays in Balingasag							
		Baliwagan	Barangay 1	Barangay 2	Barangay 3	Barangay 4	Barangay 5	Barangay 6	Binitinan
Affected Area (sq. km.)	0.03-0.20	2.2455	0.069474	0.06959	0.028571	0.139612	0.082176	0.079685	3.03149
	0.21-0.50	0.535166	0.015178	0.013204	0.027263	0.014649	0.021767	0.034371	0.275858
	0.51-1.00	0.548842	0.008805	0.011499	0.025758	0.008686	0.001968	0.003792	0.262522
	1.01-2.00	0.335319	0.00603	0.000873	0.011242	0.00075	0	0.000099	0.445719
	2.01-5.00	0.019111	0	0	0.000099	0	0	0	0.045126
	> 5.00	0.0007	0	0	0	0	0	0	0.002799

Table 42. Affected Areas in Balingasag during 25-Year Rainfall Return Period

BALATUCAN – MUSI-MUSI BASIN		Affected Barangays in Balingasag							
		Blanco	Cogon	Dumarait	Hermano	Kibanban	Linabu	Linggangao	Mambayaan
Affected Area (sq. km.)	0.03-0.20	2.775389	2.5848	1.48306	0.365404	0.726619	1.96851	1.323469	2.58924
	0.21-0.50	0.254615	0.832705	0.467954	0.009553	0.066797	0.069967	0.233345	0.501248
	0.51-1.00	0.305765	0.278017	0.173353	0.002595	0.006682	0.02459	0.092033	0.235933
	1.01-2.00	0.096078	0.057887	0.039033	0.001354	0	0.00461	0.032828	0.049551
	2.01-5.00	0.018367	0.029049	0.025568	0	0	0.000099	0.007585	0.000099
	> 5.00	0.002599	0	0	0	0	0	0	0

Table 43. Affected Areas in Balingasag during 25-Year Rainfall Return Period

BALATUCAN – MUSI-MUSI BASIN		Affected Barangays in Balingasag					
		Mandangoa	Napaliran	Quezon	San Isidro	Talusan	Waterfall
Affected Area (sq. km.)	0.03-0.20	2.762769	3.52707	1.5769	2.36998	1.175089	0.554645
	0.21-0.50	0.602774	0.720233	0.236941	0.855853	0.457899	0.295349
	0.51-1.00	0.194842	0.240884	0.120176	0.303074	0.214629	0.154825
	1.01-2.00	0.056348	0.052895	0.032097	0.065825	0.096508	0.040235
	2.01-5.00	0.041293	0.001799	0.003271	0.004765	0.062991	0.011877
	> 5.00	0	0	0	0	0.002	0

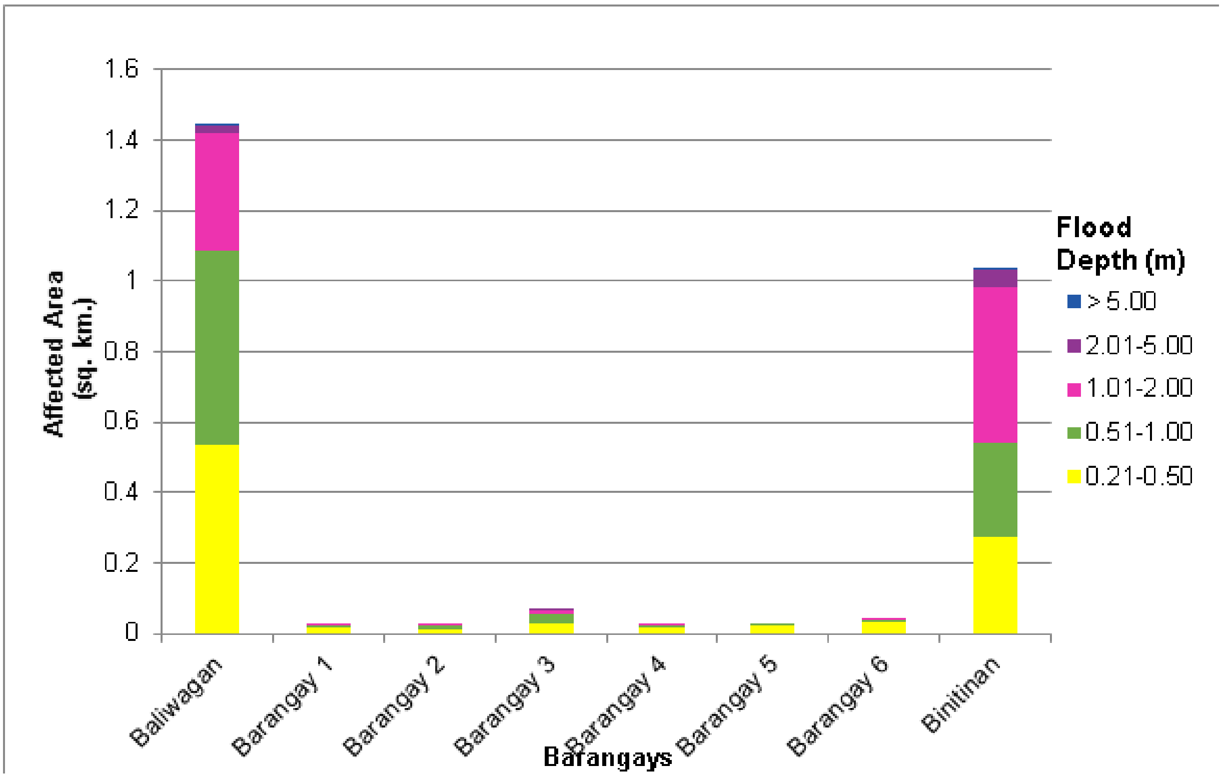


Figure 76. Affected Areas in Balingasag, Misamis Oriental during 25-Year Rainfall Return Period

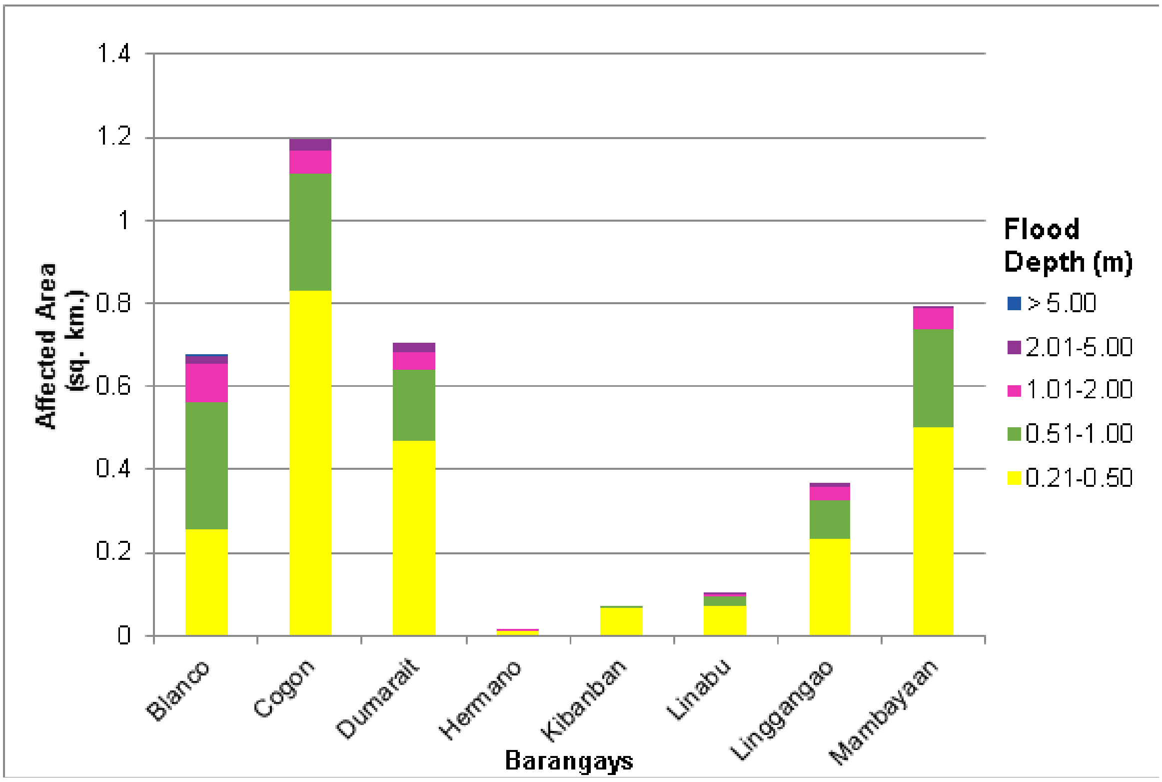


Figure 77. Affected Areas in Balingasag, Misamis Oriental during 25-Year Rainfall Return Period

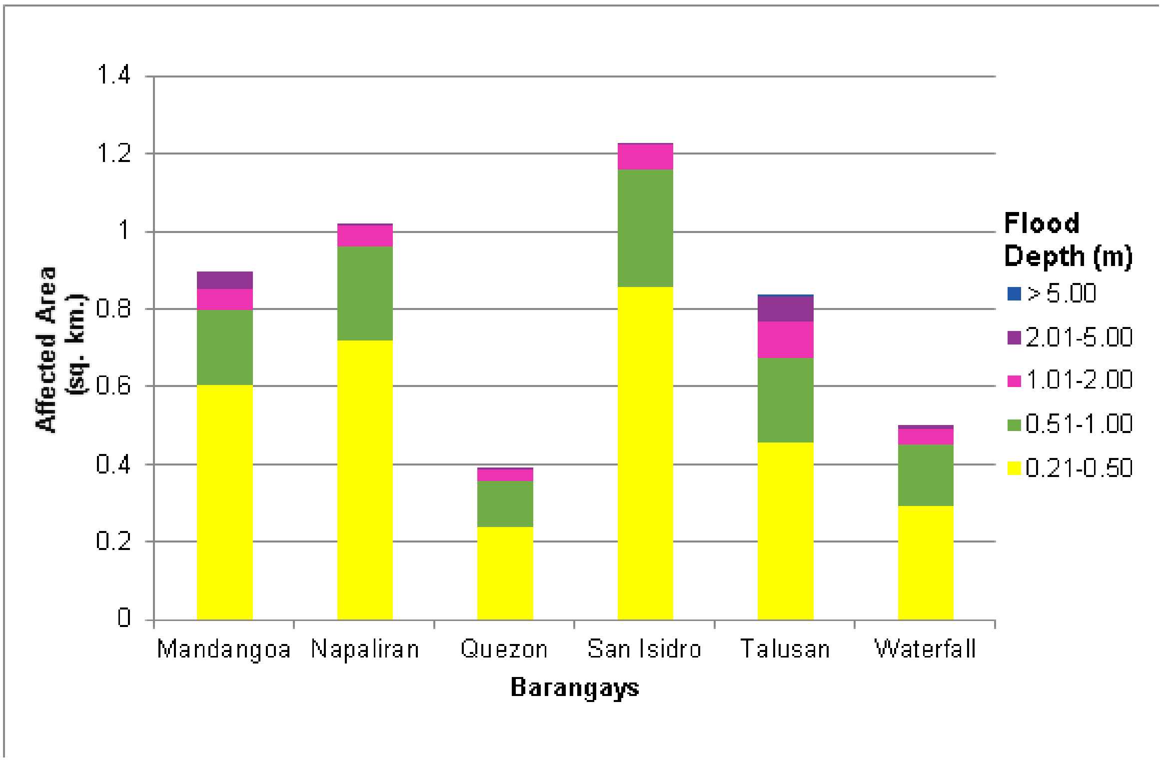


Figure 78. Affected Areas in Balingasag, Misamis Oriental during 25-Year Rainfall Return Period

For the 25-year return period, 2.14% of the municipality of Jasaan with an area of 68.327103 sq. km. will experience flood levels of less than 0.20 meters. 0.07% of the area will experience flood levels of 0.21 to 0.50 meters while 0.04%, 0.03%, 0.00%, and 0.00% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 44. Affected Areas in Jasaan, Misamis Oriental during 25-Year Rainfall Return Period

BALATUCAN – MUSI-MUSI BASIN		Affected Barangays in Jasaan	
		Danao	I. S. Cruz
Affected Area (sq. km.)	0.03-0.20	0.04413	1.41582
	0.21-0.50	0.000163	0.048891
	0.51-1.00	0	0.024278
	1.01-2.00	0	0.021922
	2.01-5.00	0	0.003393
	> 5.00	0	0

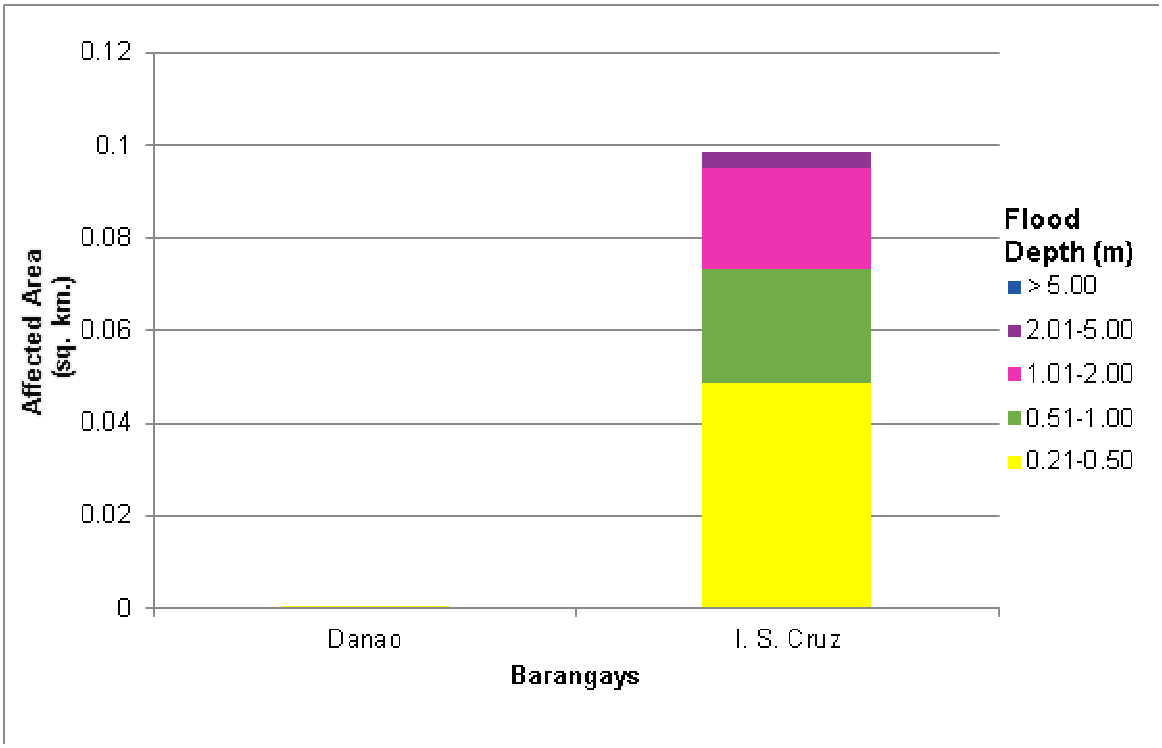


Figure 79. Affected Areas in Pinabacdao, Samar during 25-Year Rainfall Return Period

For the 25-year return period, 2.26% of the municipality of Lagonglong with an area of 46.624699 sq. km. will experience flood levels of less than 0.20 meters. 0.44% of the area will experience flood levels of 0.21 to 0.50 meters while 0.19%, 0.04%, 0.00%, and 0.00% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 45. Affected Areas in Lagonglong, Misamis Oriental during 25-Year Rainfall Return Period

BALATUCAN – MUSI-MUSI BASIN		Affected Barangays in Lagonglong	
		Kauswagan	Manaol
Affected Area (sq. km.)	0.03-0.20	0.386808	0.668852
	0.21-0.50	0.151103	0.055185
	0.51-1.00	0.037546	0.050922
	1.01-2.00	0.0003	0.017898
	2.01-5.00	0	0.0008
	> 5.00	0	0

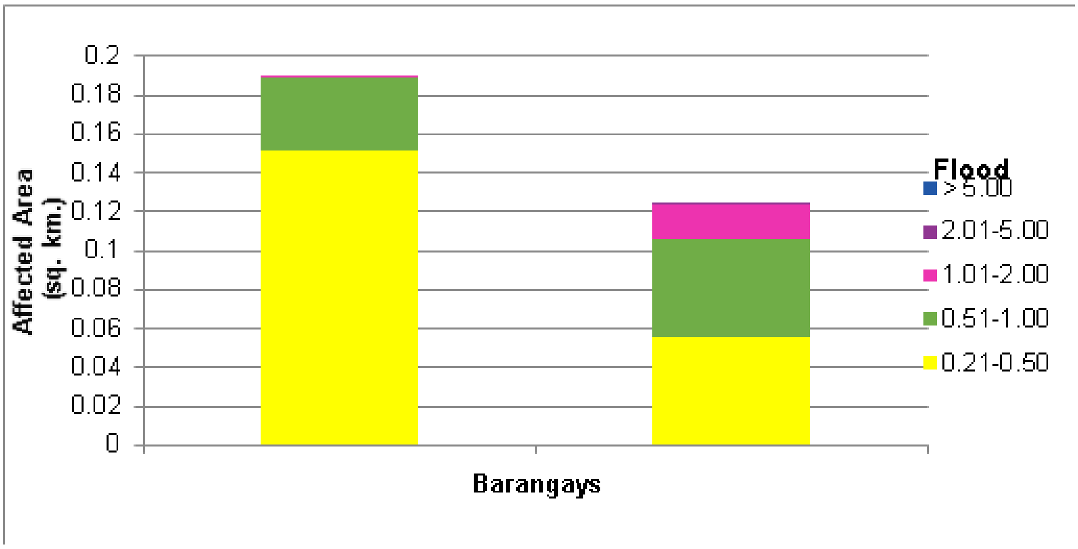


Figure 80. Affected Areas in Lagonglong, Misamis Oriental during 25-Year Rainfall Return Period

For the 100-year return period, 23.15% of the municipality of Balingasag with an area of 125.591 sq. km. will experience flood levels of less than 0.20 meters. 6.06% of the area will experience flood levels of 0.21 to 0.50 meters while 3.15%, 1.47%, 0.41%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 46. Affected Areas in Balingasag, Misamis Oriental during 100-Year Rainfall Return Period

BALATUCAN – MUSI-MUSI BASIN		Affected Barangays in Balingasag							
		Baliwagan	Barangay 1	Barangay 2	Barangay 3	Barangay 4	Barangay 5	Barangay 6	Binitinan
Affected Area (sq. km.)	0.03-0.20	2.07082	0.063571	0.062722	0.021423	0.130817	0.072149	0.067537	2.911839
	0.21-0.50	0.532414	0.018881	0.016492	0.024867	0.019744	0.030879	0.043979	0.294788
	0.51-1.00	0.589016	0.009854	0.014086	0.031063	0.011899	0.002883	0.005749	0.240714
	1.01-2.00	0.448228	0.006882	0.001866	0.014582	0.001235	0	0.000682	0.41525
	2.01-5.00	0.043965	0.0003	0	0.001	0	0	0	0.199926
	> 5.00	0.0013	0	0	0	0	0	0	0.003299

Table 47. Affected Areas in Balingasag, Misamis Oriental during 100-Year Rainfall Return Period

BALATUCAN – MUSI-MUSI BASIN		Affected Barangays in Balingasag							
		Blanco	Cogon	Dumarait	Hermano	Kibanban	Linabu	Linggangao	Mambayaan
Affected Area (sq. km.)	0.03-0.20	2.6798	2.266309	1.296429	0.360967	0.709298	1.94349	1.2403	2.378959
	0.21-0.50	0.280757	1.015229	0.551716	0.012958	0.079953	0.085651	0.271207	0.636215
	0.51-1.00	0.307372	0.396075	0.253538	0.003111	0.010563	0.031131	0.121807	0.267765
	1.01-2.00	0.158178	0.074496	0.056375	0.001867	0.000282	0.00741	0.04679	0.091439
	2.01-5.00	0.027608	0.037749	0.03191	0	0	0.0003	0.009351	0.003199
	> 5.00	0.003499	0	0	0	0	0	0	0

Table 48. Affected Areas in Balingasag, Misamis Oriental during 100-Year Rainfall Return Period

BALATUCAN – MUSI-MUSI BASIN		Affected Barangays in Balingasag					
		Mandangoa	Napaliran	Quezon	San Isidro	Talusan	Waterfall
Affected Area (sq. km.)	0.03-0.20	2.517299	3.30445	1.488	2.05287	0.980551	0.457913
	0.21-0.50	0.763426	0.827383	0.270761	0.990029	0.515121	0.32376
	0.51-1.00	0.241756	0.314575	0.151703	0.458321	0.289658	0.205485
	1.01-2.00	0.083545	0.093171	0.054151	0.097184	0.141077	0.053935
	2.01-5.00	0.053493	0.0035	0.004766	0.006084	0.07831	0.017538
	> 5.00	0.000099	0	0	0	0.005599	0

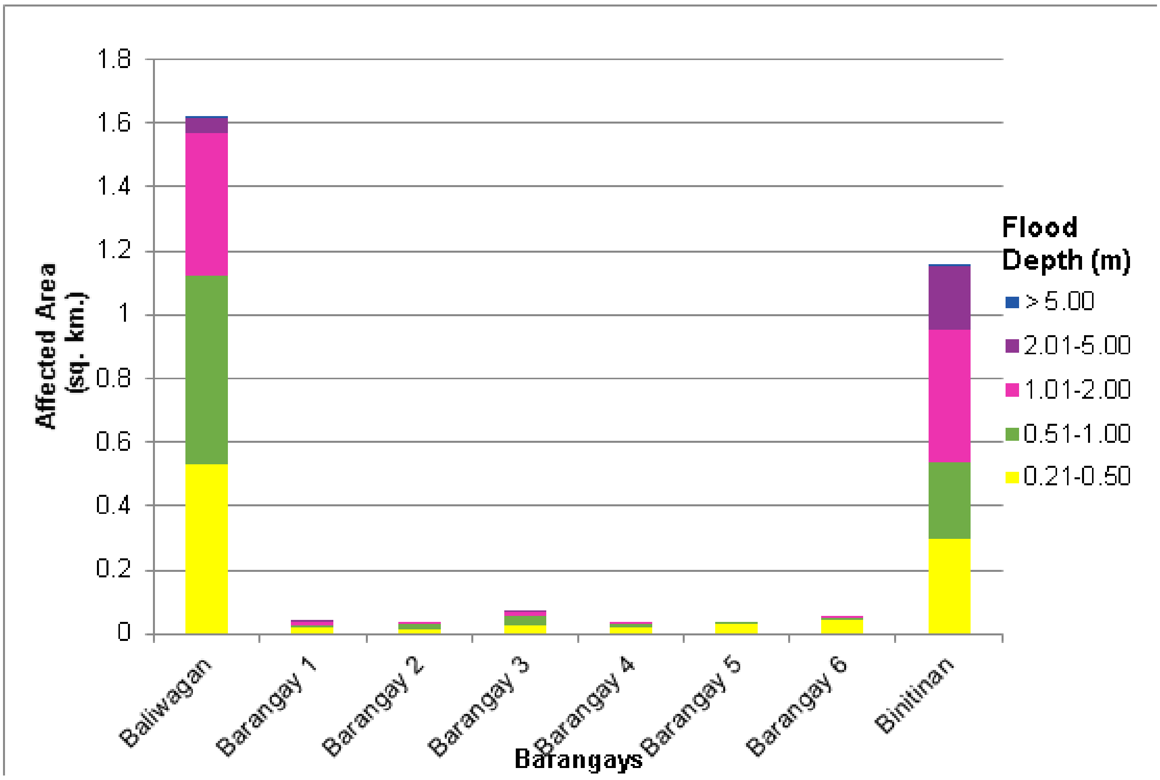


Figure 81. Affected Areas in Balingasag, Misamis Oriental during 100-Year Rainfall Return Period

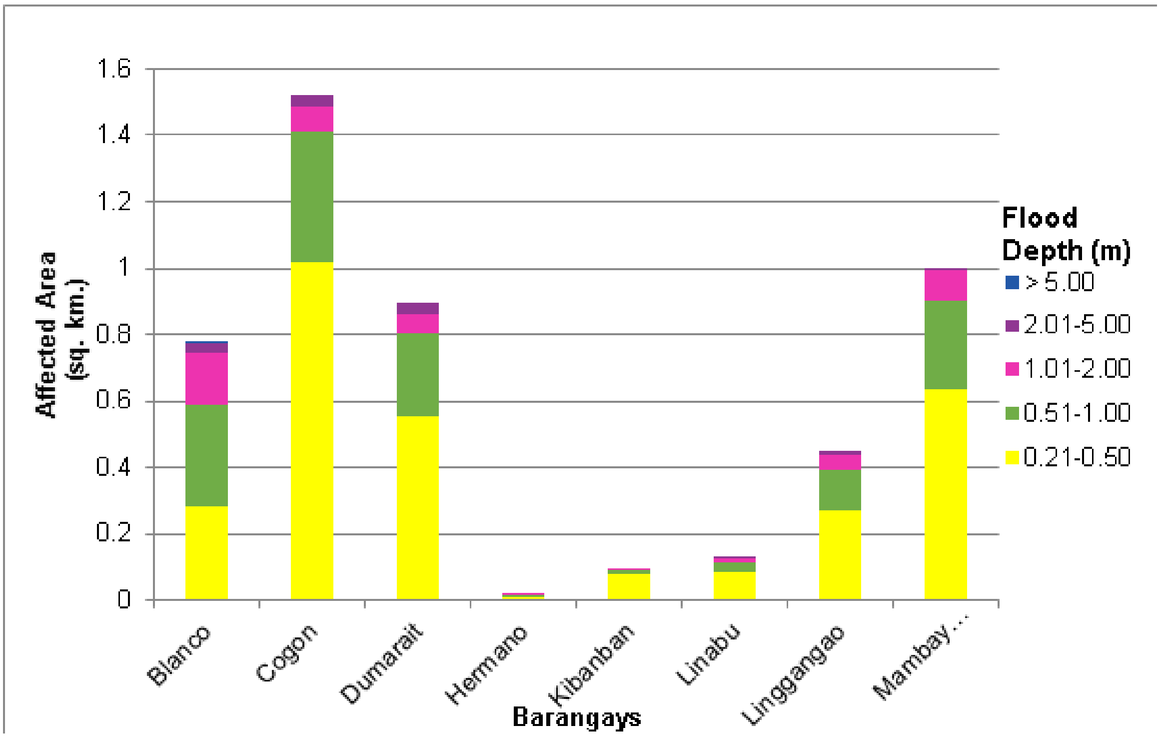


Figure 82. Affected Areas in Balingasag, Misamis Oriental during 100-Year Rainfall Return Period

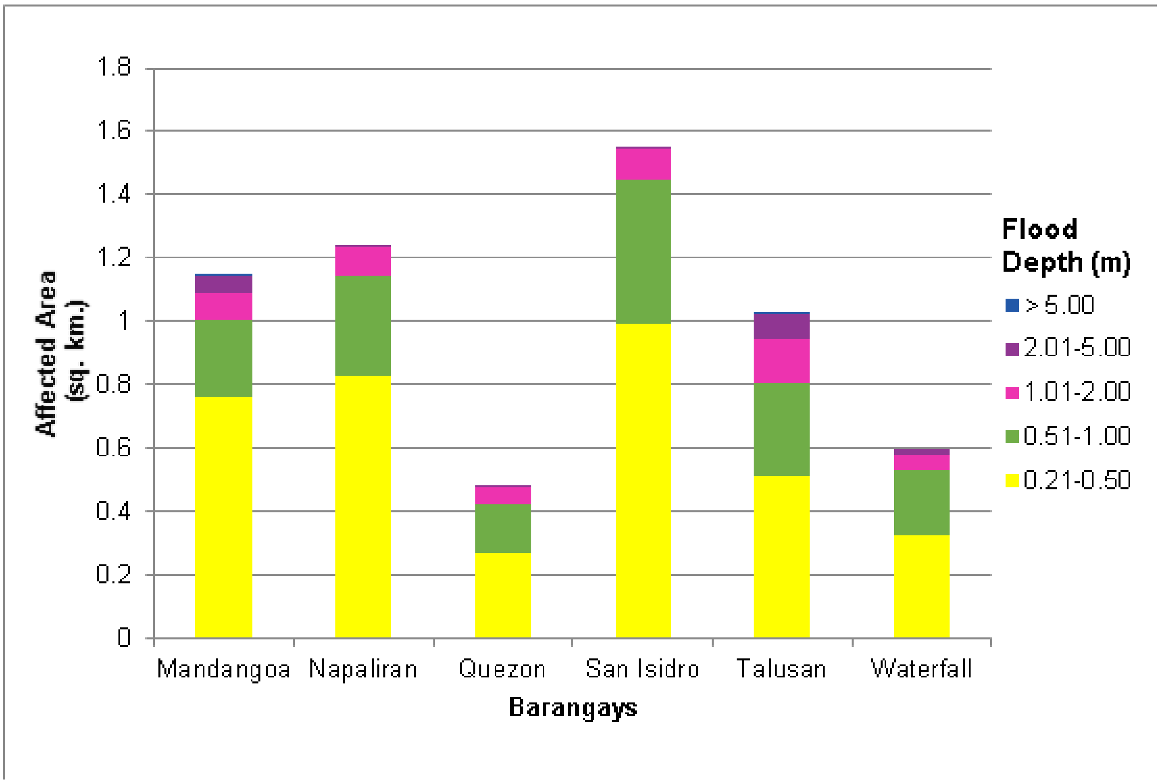


Figure 83. Affected Areas in Balingasag, Misamis Oriental during 100-Year Rainfall Return Period

For the 100-year return period, 2.12% of the municipality of Jasaan with an area of 68.327103 sq. km. will experience flood levels of less than 0.20 meters. 0.08% of the area will experience flood levels of 0.21 to 0.50 meters while 0.04%, 0.04%, 0.01%, and 0.00% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 49. Affected Areas in Jasaan, Misamis Oriental during 100-Year Rainfall Return Period

BALATUCAN – MUSI-MUSI BASIN		Affected Barangays in Jasaan	
		Danao	I. S. Cruz
Affected Area (sq. km.)	0.03-0.20	0.044129	1.402379
	0.21-0.50	0.000163	0.051441
	0.51-1.00	0	0.028861
	1.01-2.00	0	0.026922
	2.01-5.00	0	0.004593
	> 5.00	0	0.000099

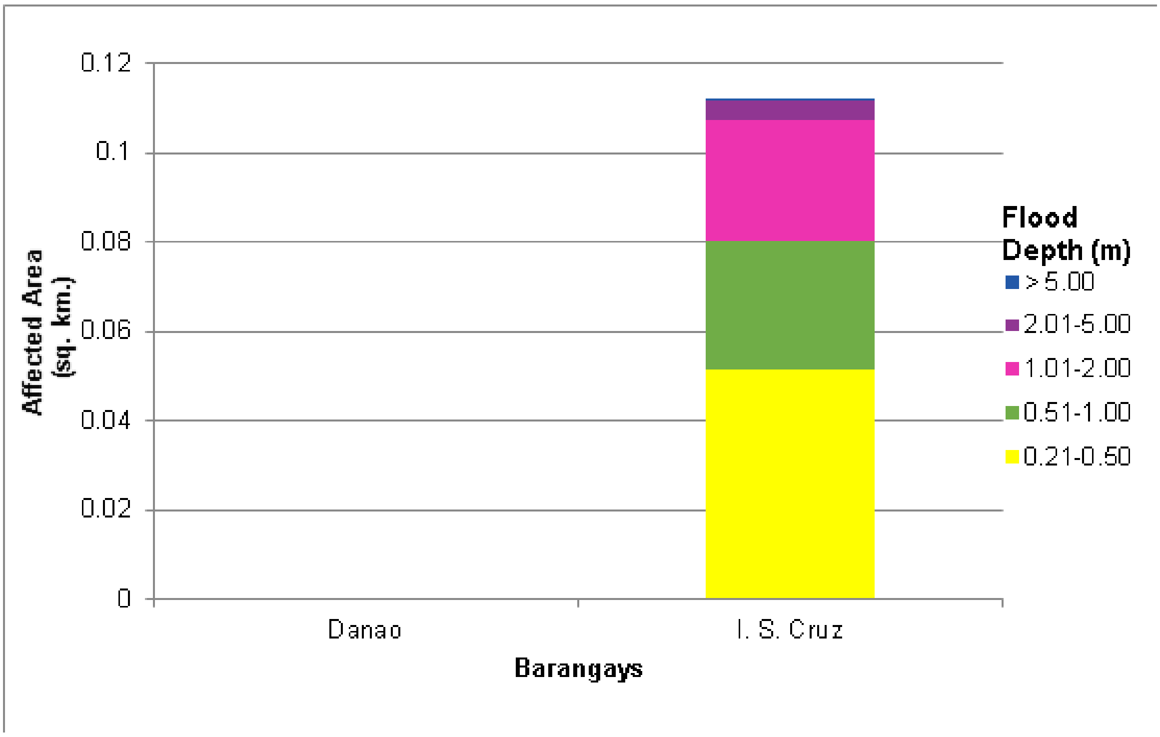


Figure 84. Affected Areas in Jasaan, Misamis Oriental during 100-Year Rainfall Return Period

For the 100-year return period, 2.13% of the municipality of Lagonglong with an area of 46.624699 sq. km. will experience flood levels of less than 0.20 meters. 0.50% of the area will experience flood levels of 0.21 to 0.50 meters while 0.23%, 0.07%, 0.00%, and 0.00% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 50. Affected Areas in Lagonglong, Misamis Oriental during 100-Year Rainfall Return Period

BALATUCAN – MUSI-MUSI BASIN		Affected Barangays in Lagonglong	
		Kauswagan	Manaol
Affected Area (sq. km.)	0.03-0.20	0.341212	0.651848
	0.21-0.50	0.172683	0.05945
	0.51-1.00	0.061363	0.047111
	1.01-2.00	0.0005	0.033755
	2.01-5.00	0	0.0015
	> 5.00	0	0

Among the barangays in the municipality of Balingasag, Napaliran is projected to have the highest percentage of area that will experience flood levels at 3.62%. Meanwhile, Binitinan posted the second highest percentage of area that may be affected by flood depths at 3.24%.
Among the barangays in the municipality of Jasaan, I. S. Cruz is projected to have the highest percentage of area that will experience flood levels at 2.22%. Meanwhile, Danao posted the second highest percentage of area that may be affected by flood depths at 0.065%.
Among the barangays in the municipality of Lagonglong, Manaol is projected to have the highest percentage of area that will experience flood levels of at 1.70%. Meanwhile, Kauswagan posted the percentage of area that may be affected by flood depths of at 1.23%.
Moreover, the generated flood hazard maps for the Balatucan – Musi-Musi 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 yr, 25 yr, and 100 yr).

Table 51. Area covered by each warning level with respect to the rainfall scenario

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	5.32	5.18	5.37
Medium	2.89	9.02	8.66
High	0.40	11.09	13.15
TOTAL	8.61	25.29	27.17

Of the 15 identified Education Institute in Musi-Musi Flood plain, two school were assessed to be exposed to Low level flooding and one was assessed to be exposed to medium level flooding during a 5 year rain scenario. In the 25 year scenario, four schools were assessed to be exposed to low level flooding and one was assessed to medium level flooding. For the 100 year scenario, five schools were assessed to be exposed to low level flooding and two were assessed to medium level flooding. See Annex 12 for a detailed enumeration of schools in the Musi-Musi floodplain.
Six (6) Medical Institutions were identified in Musi-Musi Floodplain and two health centers will be exposed to low level flooding during a 100 year rain scenario. See Annex 13 for a detailed enumeration of hospitals and clinics in the Musi-Musi floodplain.

5.7 Flood Validation

In order to check and validate the extent of flooding in different river systems, there was 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 flood depth maps produced by Phil-LiDAR 1 Program, multiple points representing the different flood depths for different scenarios were identified for validation.

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

The actual data from the field were compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed.
The flood validation consists of 221 points randomly selected all over the Balatucan - Musi-Musi flood plain. It has an RMSE value of 0.66. The validation points are found in ANNEX 11.

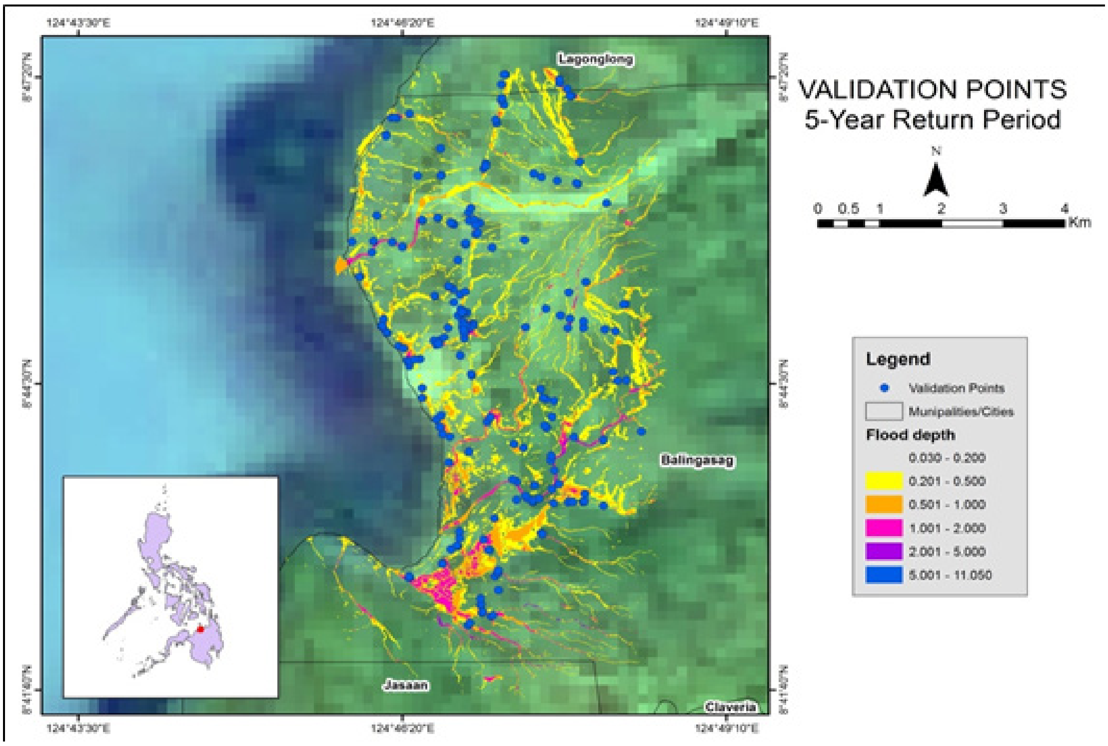


Figure 85. MusiMusi-Balatucan Flood Validation Points

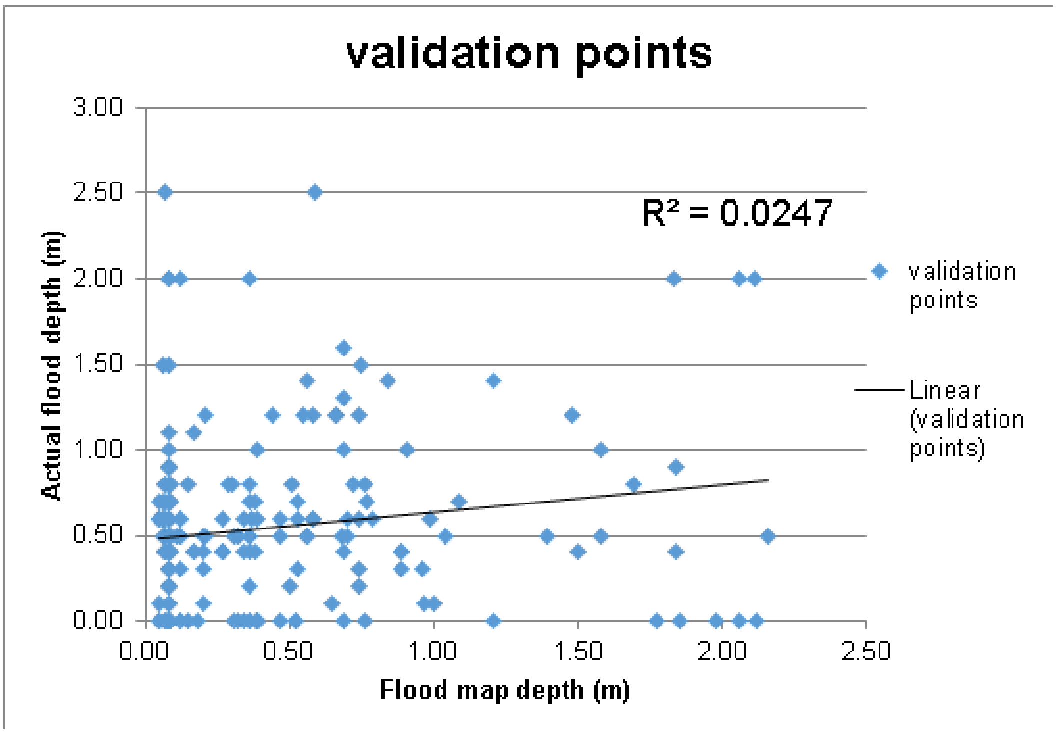


Figure 86. Flood map depth vs actual flood depth

Table 52. Actual Flood Depth vs Simulated Flood Depth in Balatucan – Musi-Musi Floodplain

BALATUCAN – MUSI-MUSI BASIN		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
Actual Flood Depth (m)	0-0.20	39	13	8	4	2	0	66
	0.21-0.50	31	13	11	5	1	0	61
	0.51-1.00	37	12	14	4	0	0	67
	1.01-2.00	7	3	10	3	2	0	25
	2.01-5.00	1	0	1	0	0	0	2
	> 5.00	0	0	0	0	0	0	0
	Total	115	41	44	16	5	0	221

The overall accuracy generated by the flood model is estimated at 31.22%, with 69 points correctly matching the actual flood depths. In addition, there were 83 points estimated one level above and below the correct flood depths while there were 54 points and 15 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 50 points were overestimated while a total of 102 points were underestimated in the modelled flood depths of Balatucan – Musi-Musi Floodplain.

Table 53. Summary of Accuracy Assessment in Balatucan – Musi-Musi Floodplain

	No. of Points	%
Correct	69	**31.22**
Overestimated	50	**22.62**
Underestimated	102	**46.15**
Total	221	**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.

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

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˚

ANNEX 2. NAMRIA CERTIFICATES OF REFERENCE POINTS USED

1. MSE-19

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-19**
Order: **2nd**

Island: **MINDANAO**
Municipality: **CAGAYAN DE ORO**
Barangay: **BULUA**

PRS92 Coordinates

Latitude: **8° 30' 19.11464"**	Longitude: **124° 37' 6.46518"**	Ellipsoidal Hgt: **11.24200 m.**

WGS84 Coordinates

Latitude: **8° 30' 15.52234"**	Longitude: **124° 37' 11.86795"**	Ellipsoidal Hgt: **78.72200 m.**

PTM Coordinates

Northing: **940451.853 m.**	Easting: **457992.786 m.**	Zone: **5**

UTM Coordinates

Northing: **940,474.22**	Easting: **678,151.65**	Zone: **51**

Location Description

MSE-19
The station is located at the intersection of roads going to Cagayan de Oro City, Butuan City and Iligan City. It is situated on the center island between two triangular islands, about 14.5 m E of Bulua marker, about 21m W of black-tiled peace marker, about 10m S of road centerline, and about 3.5m S of the N end of the arc-shaped curb of the island. Statio mark is the head of a 4" copper nail set on the center of a 30cm. x 30 cm. x 60cm. concrete monument protruding by about 12cm. above the ground, with inscriptions, MSE-19, 2003 NAMRIA.

Requesting Party: **Engr. Cruz**
Pupose: **Reference**
OR Number: **8796376 A**
T.N.: **2014-1437**

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

9906242014111459

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

2. 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**
Order: **2nd**

Island: **MINDANAO** Municipality: **BINUANGAN**		Barangay: **SITIO: NARATULAN**
	PRS92 Coordinates	
Latitude: **8° 55' 28.57032"**	Longitude: **124° 46' 55.45680"**	Ellipsoidal Hgt: **59.48400 m.**
	WGS84 Coordinates	
Latitude: **8° 55' 24.88251"**	Longitude: **124° 47' 0.81947"**	Ellipsoidal Hgt: **125.49000 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 80cm 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.: [illegible]
Branch: [illegible]
www.namria.gov.ph

ISO 9001 : 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

3. 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**	Order: **2nd**	Barangay: **ALICOMOHAN**
Municipality: **SUGBONGCOGON**		
	PRS92 Coordinates	
Latitude: **8° 56' 30.44606"**	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: **988787.53 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

4. 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**	
Island: **MINDANAO**	Order: **2nd**	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: **68.61700 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 16cm 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

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5. MSE-3241

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

April 18, 2013

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-3241**
Order: **3rd**

Island: **MINDANAO**
Municipality: **CAGAYAN DE ORO CITY (CAPITAL)**
Barangay: **BARANGAY 10 (POB.)**

	PRS92 Coordinates	
Latitude: **8° 27' 31.07607"**	Longitude: **124° 37' 23.18891"**	Ellipsoidal Hgt: **109.46700 m.**
	WGS84 Coordinates	
Latitude: **8° 27' 27.49608"**	Longitude: **124° 37' 28.59587"**	Ellipsoidal Hgt: **177.05500 m.**
	PTM Coordinates	
Northing: **935289.375 m.**	Easting: **458499.251 m.**	Zone: **5**
	UTM Coordinates	
Northing: **935,314.30**	Easting: **678,684.71**	Zone: **51**

Location Description

MSE-3241
Is located at the center island along Macapagal Rd., Brgy. 10 (Pob.). Cagayan de Oro City. It is situated between Sungolo Bldg. and Super Mart Mall, about 20 m. facing the mall entrance. Mark is the head of a 4 in. copper nail embedded on a 25 cm. x 25 cm. concrete block, with inscriptions "MSE-3241 2007 NAMRIA".

Requesting Party: **UP DREAM/ Melchor Nery**
Pupose: **Reference**
OR Number: **3943540 B**
T.N.: **2013-0311**

RUEL DM. BELEN, MNSA
Director, Mapping and Geodesy Department

ANNEX 3. BASELINE PROCESSING REPORTS OF REFERENCE POINTS USED

The Musi Musi Technical Report has no BASELINE PROCESSING REPORTS OF REFERENCE POINTS USED

ANNEX 4. THE SURVEY TEAM

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
		ENGR. LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	JULIE PEARL MARS	UP-TCAGP
	SSRS	PAULINE JOANNE ARCEO	UP-TCAGP
	Research Associate (RA)	ENGR. IRO NIEL ROXAS	UP-TCAGP
	RA	REGINA FELISMINO	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	LANCE KERWIN CINCO	UP-TCAGP
		BRYLLE ADAM DE CASTRO	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 MUSI-MUSI 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	~~31.828~~ 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

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

DATA TRANSFER SHEET
07/28/2014(Northern Mindanao - ready)

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	
6/8/2014	1565P	1BLK71B159A	Pegasus	NA	16	6.93	168	NA	NA	13.3	NA	7.75	1KB	1KB	36	NA	Z:\Airborne_Raw
6/9/2014	1569P	1BLKRXE160A	Pegasus	4.16	832	16.5	290	8.86	62	38.5	NA	10	1KB	1KB	85	NA	Z:\Airborne_Raw
6/16/2014	1597P	1BLKRXE167A	Pegasus	2.18	332	10.5	237	NA	NA	21.3	NA	7.52	1KB	1KB	68	NA	Z:\Airborne_Raw
6/19/2014	1609P	1RXS170A	Pegasus	2.16	526	11.2	259	45.3	309	22.1	NA	7.07	1KB	1KB	77/76	NA	Z:\Airborne_Raw
6/20/2014	1613P	1BLK71G171A	Pegasus	3.44	177	13.7	258	67.3	437	33.2	NA	5.92	1KB	1KB	46	NA	Z:\Airborne_Raw
6/23/2014	1625P	1BLK67BC174A	Pegasus	3.09	1112	11.7	212	60.3	415	29.4	86.6	4.97	1KB	1KB	52/56	NA	Z:\Airborne_Raw
6/24/2014	1629P	1BLKRXES175A	Pegasus	2.79	370	10.7	187	36.3	268	26.1	NA	4.45	1KB	1KB	73	NA	Z:\Airborne_Raw
6/27/2014	1641P	1BLK68A178A	Pegasus	2.94	1995	12.6	268	57.4	398	28.9	57.2	7.7	1KB	1KB	65/65/60/58	NA	Z:\Airborne_Raw
6/27/2014	1643P	1BLK67ABS178B	Pegasus	532	95	4.33	119	NA	NA	5.65	NA	7.7	1KB	1KB	48	NA	Z:\Airborne_Raw
6/28/2014	1645P	1BLK71C179A	Pegasus	2.84	NA	11.4	242	51.8	375	27.4	NA	6.25	1KB	1KB	59/68	NA	Z:\Airborne_Raw

Received from

Name TIN ANDAYA
Position RA
Signature [signature]

Received by

Name JOIDA PRIETO
Position SSRS
Signature [signature] 7/28/14

DATA TRANSFER SHEET
BUKIDNON 11/21/2016

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	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	
November 10, 2016	23534P	1BKNG315A	PEGASUS	1.61	NA	8	255	NA	NA	16.6	NA	136	1KB	1KB	NA	NA	Z:\DAC\RAW DATA
November 11, 2016	23536P	1BKNDE316A	PEGASUS	2.45	NA	10.6	235	NA	NA	22.9	NA	146	1KB	1KB	595	5KB	Z:\DAC\RAW DATA
November 12, 2016	23540P	1BKNE317A	PEGASUS	2.3	NA	9.76	263	NA	NA	21.4	NA	131	1KB	1KB	646	NA	Z:\DAC\RAW DATA
November 13, 2016	23544P	1BKNE318A	PEGASUS	2.61	NA	10.8	230	NA	NA	24.3	NA	299	1KB	1KB	595	NA	Z:\DAC\RAW DATA
November 13, 2016	23546P	1BKNG318B	PEGASUS	1.95	NA	9.55	262	NA	NA	18.1	NA	299	1KB	1KB	554	NA	Z:\DAC\RAW DATA
November 14, 2016	23548P	1BKNEF319A	PEGASUS	2.86	NA	12	268	NA	NA	26.7	NA	208	1KB	1KB	554	NA	Z:\DAC\RAW DATA
November 15, 2016	23552P	1BLK64A320A	PEGASUS	2.1	NA	10.5	261	NA	NA	20.6	NA	131	1KB	1KB	174	NA	Z:\DAC\RAW DATA

Received from

Name R. PANTO
Position RA
Signature [signature]

Received by

Name AC. Bongat
Position SSRS
Signature [signature] 11/24/2016

ANNEX 6. FLIGHT LOGS

1. Flight Log for 1509P Mission


DREAM Data Acquisition Flight Log

Flight Log No.: 1509P

1 LiDAR Operator: J. Alviar
2 ALTM Model: Pegasus
3 Mission Name: [illegible]
4 Type: VFR
5 Aircraft Type: Cessna T206H
6 Aircraft Identification:
7 Pilot: J. Alajar
8 Co-Pilot: C. Alfonso
9 Route: Cagayan de Oro
10 Date: May 25, 2014
12 Airport of Departure (Airport, City/Province): Cagayan de Oro
12 Airport of Arrival (Airport, City/Province): Cagayan de Oro
13 Engine On: 0744 H
14 Engine Off: 1201 H
15 Total Engine Time: 4+17
16 Take off:
17 Landing:
18 Total Flight Time:
19 Weather
20 Remarks: successful flight
21 Problems and Solutions:

Acquisition Flight Approved by — Signature over Printed Name (End User Representative)
Acquisition Flight Certified by — SSg LDE [illegible] — Signature over Printed Name (PAF Representative)
Pilot-in-Command — J. [illegible] — Signature over Printed Name
Lidar Operator — Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

2. Flight Log for 1517P Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1517P

1 LiDAR Operator: I. Roxas	2 ALTM Model: Pegasus	3 Mission Name: 1RXE147A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: J. Alajar	8 Co-Pilot: C. Alfonso	9 Route: CDO			
10 Date: May 27, 2014	12 Airport of Departure (Airport, City/Province): CDO		12 Airport of Arrival (Airport, City/Province): CDO		
13 Engine On: 0702H	14 Engine Off: 1125H	15 Total Engine Time: 4+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Very cloudy					
20 Remarks: surveyed half of RXD and half of RXE at 800m, 1000m then 900m; camera stylus malfunctioned					

21 Problems and Solutions:

Acquisition Flight Approved by: J. Alajar — Signature over Printed Name (End User Representative)

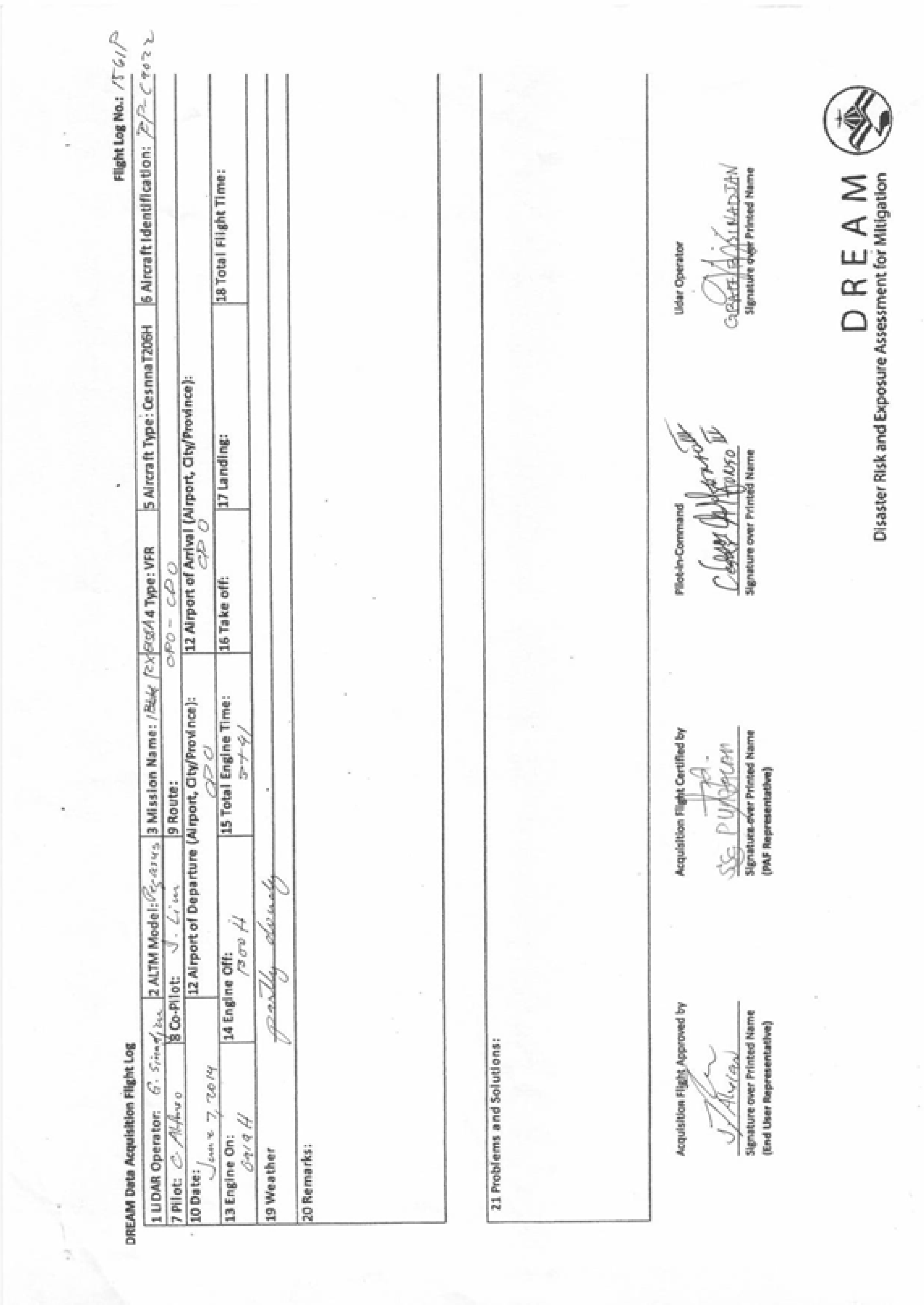
Acquisition Flight Certified by: SSg Lee Jay Punzalan — Signature over Printed Name (PAF Representative)

Pilot-in-Command: Signature over Printed Name

Lidar Operator: Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

3. Flight Log for 1561P Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1561P

1 LIDAR Operator: G. Sinadjan	2 ALTM Model: Pegasus	3 Mission Name: [illegible]	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9022
7 Pilot: C. Alfonso	8 Co-Pilot: J. Lim	9 Route: CPO - CPO			
10 Date: June 7, 2014	12 Airport of Departure (Airport, City/Province): CPO		12 Airport of Arrival (Airport, City/Province): CPO		
13 Engine On: 0919H	14 Engine Off: 1300H	15 Total Engine Time: 3+41	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: partly cloudy					
20 Remarks:					
21 Problems and Solutions:					

Acquisition Flight Approved by: J. Alviar — Signature over Printed Name (End User Representative)

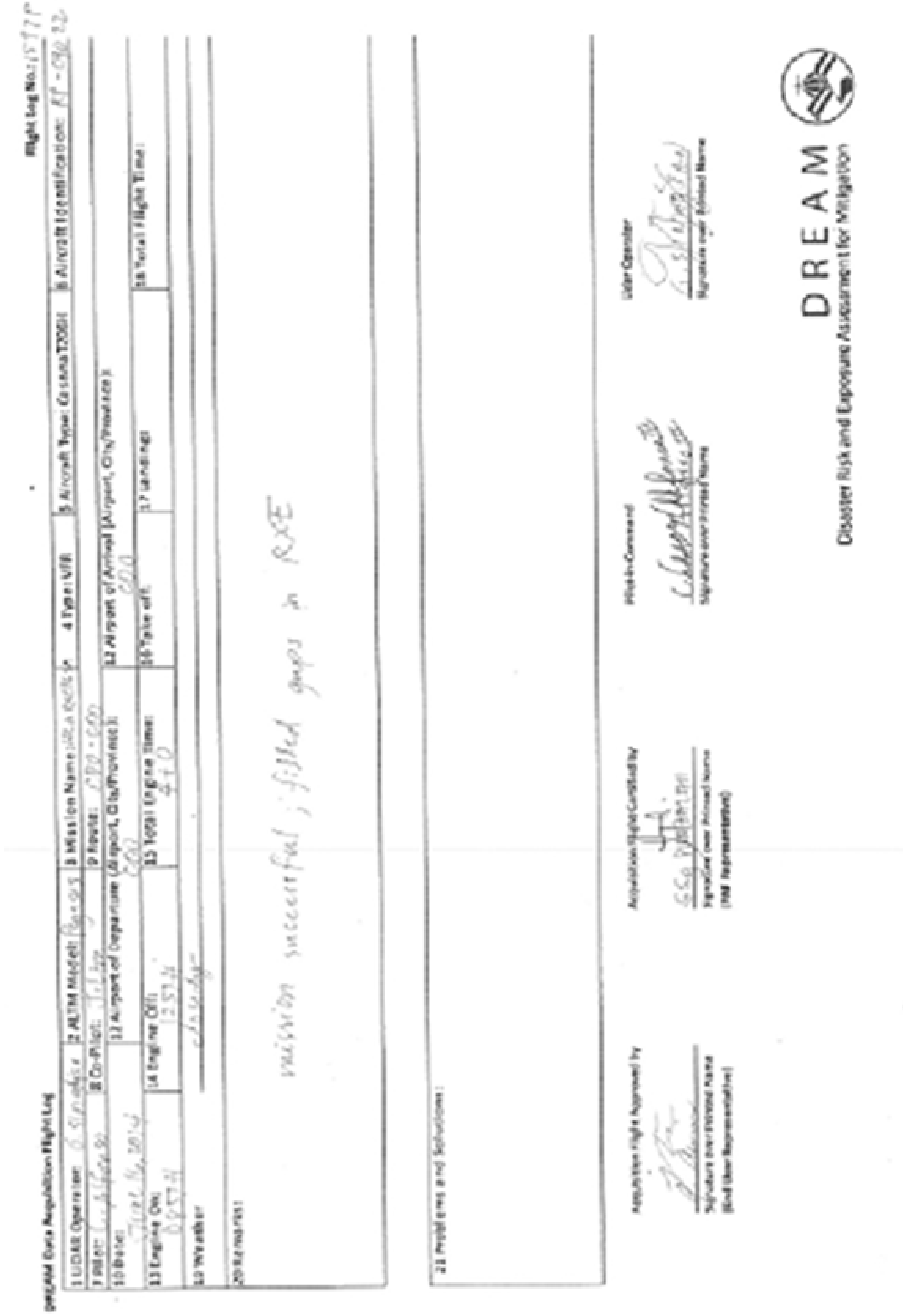
Acquisition Flight Certified by: SS Publico — Signature over Printed Name (PAF Representative)

Pilot-in-Command: C. Alfonso IV — Signature over Printed Name

Lidar Operator: G. Sinadjan — Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

4. Flight Log for 1597P Mission


DREAM Data Acquisition Flight Log

Flight Log No.: 1597P

1 LiDAR Operator: G. Sinadjan	2 ALTM Model: Pegasus	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: Alfonso	8 Co-Pilot:	9 Route: CDO-CDO			
10 Date: June 16, 2014	12 Airport of Departure (Airport, City/Province): CDO		12 Airport of Arrival (Airport, City/Province): CDO		
13 Engine On: 0857H	14 Engine Off: 1257H	15 Total Engine Time: 4+0	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: cloudy					

20 Remarks:

mission successful; filled gaps in RXE

21 Problems and Solutions:

Acquisition Flight Approved by — Signature over Printed Name (End User Representative)

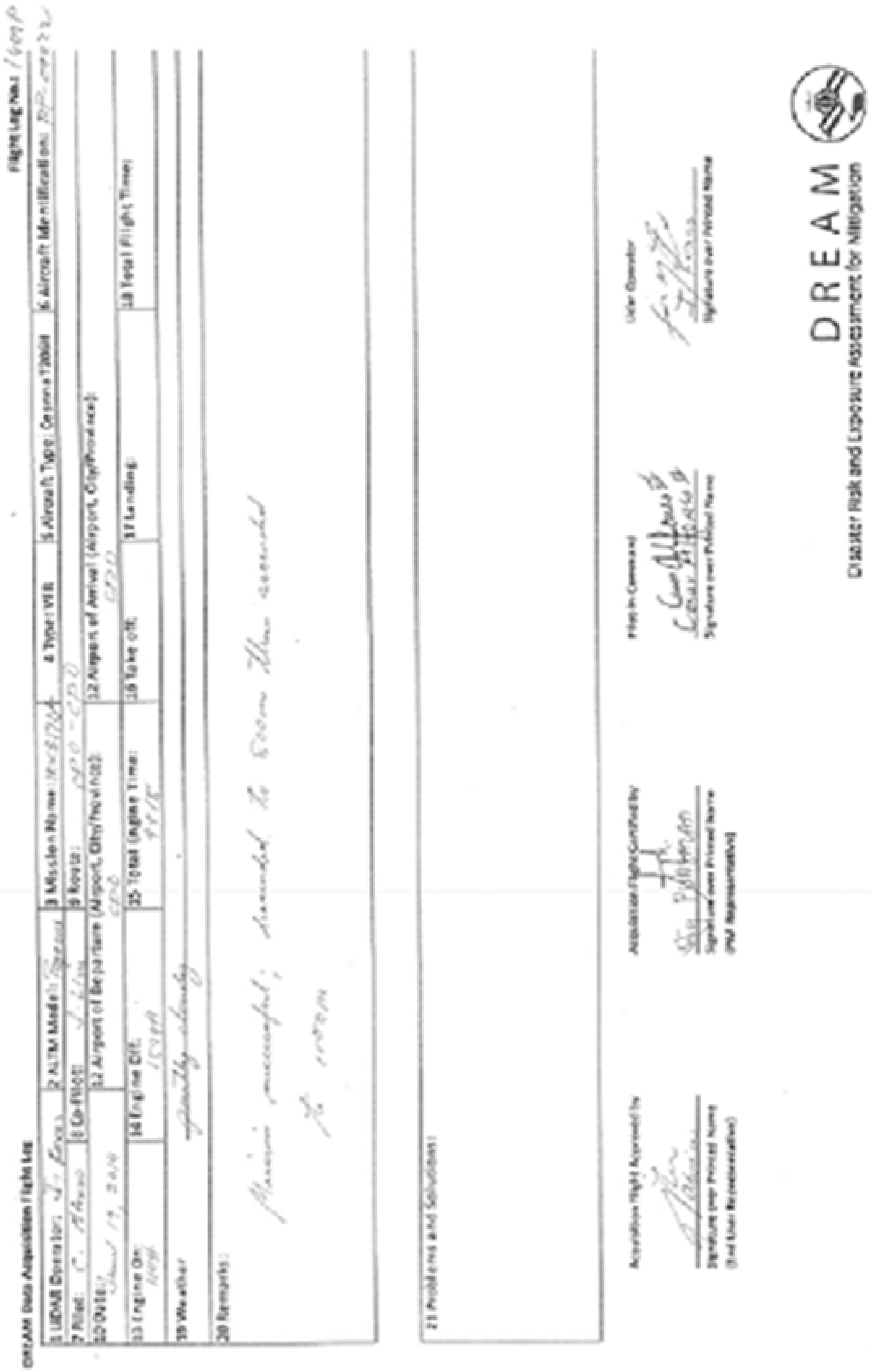
Acquisition Flight Certified by — Signature over Printed Name (PAF Representative)

Pilot-in-Command — Signature over Printed Name

Lidar Operator — Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

5. Flight Log for 1609P Mission


DREAM Data Acquisition Flight Log

Flight Log No.: 1609P

1 LIDAR Operator: J. Roxas	2 ALTM Model: Pegasus	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: C. Alfonso	8 Co-Pilot:	9 Route: CPD - CPD			
10 Date: June 19, 2014	12 Airport of Departure (Airport, City/Province): CPD		12 Airport of Arrival (Airport, City/Province): CPD		
13 Engine On:	14 Engine Off:	15 Total Engine Time:	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: partly cloudy					

20 Remarks:

Mission successful; descended to 800m then ascended to 1000m

21 Problems and Solutions:

Acquisition Flight Approved by — Signature over Printed Name (End User Representative)

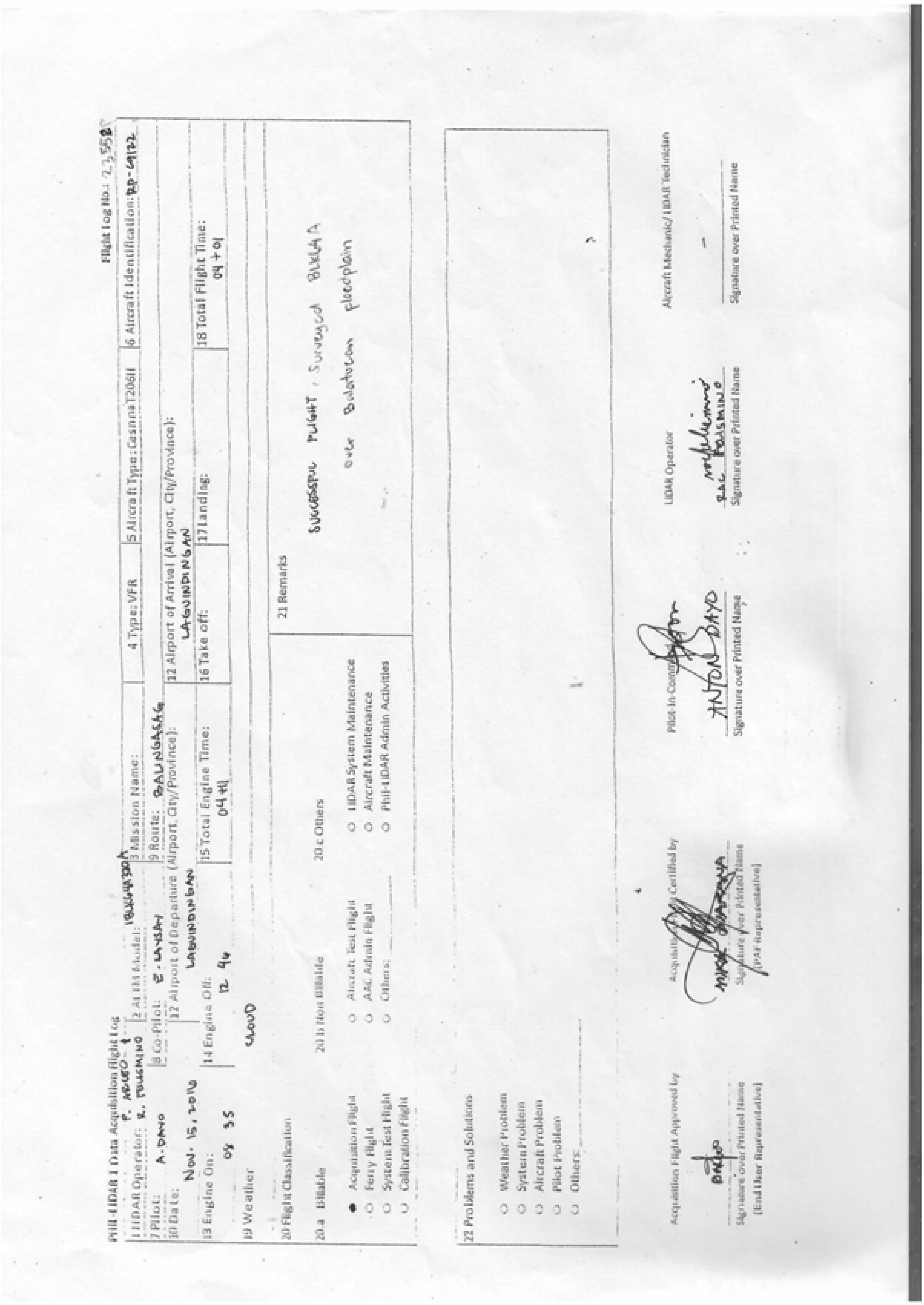
Acquisition Flight Certified by — Signature over Printed Name (PAF Representative)

Pilot-in-Command — Cesar Alfonso III — Signature over Printed Name

Lidar Operator — J. Roxas — Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

6. Flight Log for 23552P Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 23552P

1 LiDAR Operator: P. ABUGO-I R. PUNSIMINO
2 ALTM Model: [illegible]
3 Mission Name: [illegible]
4 Type: VFR
5 Aircraft Type: Cesnna T206H
6 Aircraft Identification: RP-C9122
7 Pilot: A. DAVO
8 Co-Pilot: E. LAYSAY
9 Route: BALINGASAG
10 Date: NOV. 15, 2016
12 Airport of Departure (Airport, City/Province): LAGUINDINGAN
12 Airport of Arrival (Airport, City/Province): LAGUINDINGAN
13 Engine On: 08 35
14 Engine Off: 12 46
15 Total Engine Time: 04+11
16 Take off:
17 Landing:
18 Total Flight Time: 04+01
19 Weather: CLOUD

20 Flight Classification

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

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

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

21 Remarks

SUCCESSFUL FLIGHT, Surveyed BLK47A over Balatukan floodplain

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

Acquisition Flight Approved by: BAHJO — Signature over Printed Name (End User Representative)

Acquisition Flight Certified by: MIKE [illegible] — Signature over Printed Name (PAF Representative)

Pilot-in-Command: ANTON DAYO — Signature over Printed Name

LiDAR Operator: RAC PUNSIMINO — Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician — Signature over Printed Name

Phil-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 23558

1 LIDAR Operator: P. ARCEO + R. FOLISMINO	2 ALTM Model: 1BLK64A330A	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9122
7 Pilot: A. DAYO	8 Co-Pilot: E. LAYSAY	9 Route: BALINGASAG			
10 Date: NOV. 15, 2016	12 Airport of Departure (Airport, City/Province): LAGUINDINGAN		12 Airport of Arrival (Airport, City/Province): LAGUINDINGAN		
13 Engine On: 08 35	14 Engine Off: 12 46	15 Total Engine Time: 04 11	16 Take off:	17 Landing:	18 Total Flight Time: 04 + 01
19 Weather: CLOUD					

20 Flight Classification

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

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

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

21 Remarks

SUCCESSFUL FLIGHT, Surveyed BLK64A over Balatucan floodplain

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LIDAR Operator	Aircraft Mechanic/ LIDAR Technician
BAGO	MIKE GUARENA	ANTON DAYO	RAC FOLISMINO	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

ANNEX 7. FLIGHT STATUS REPORT

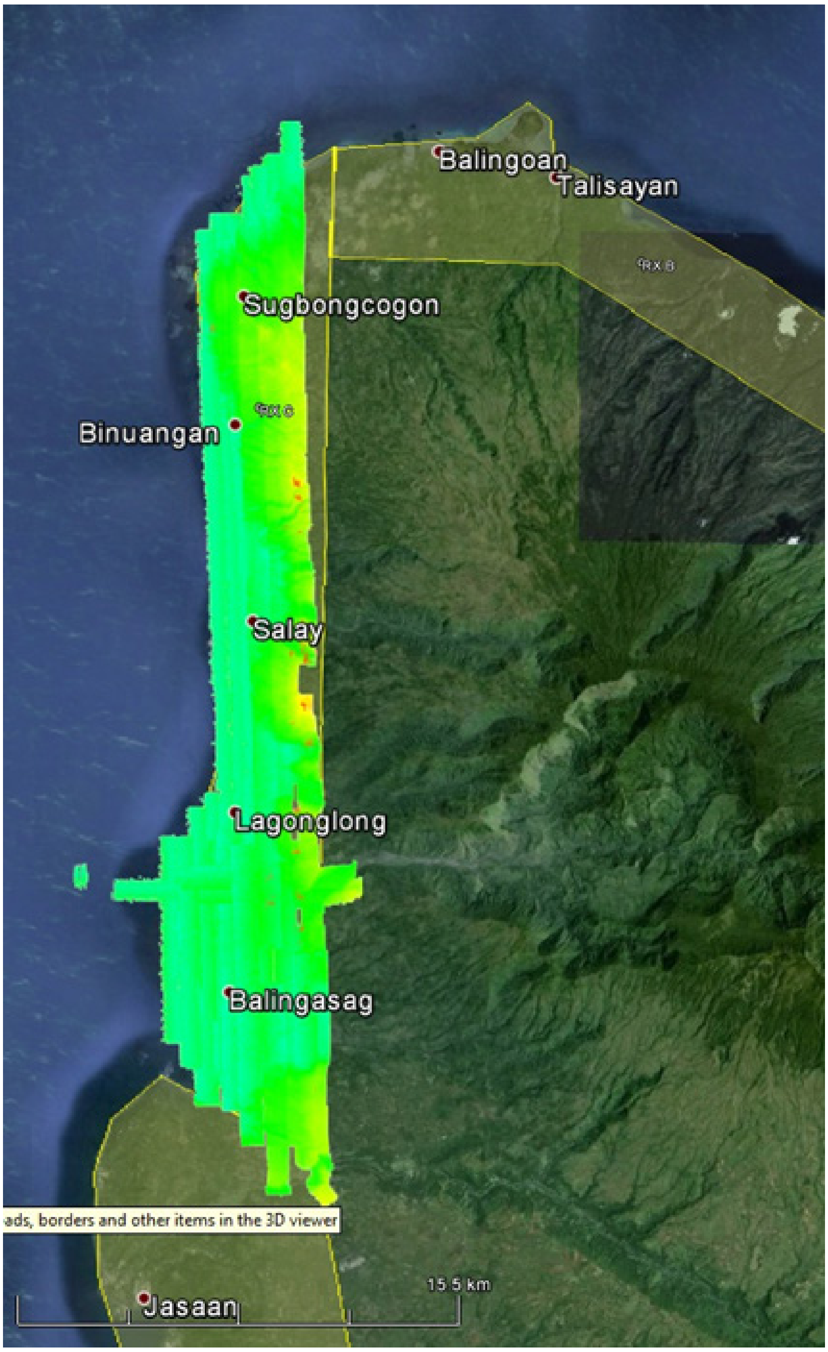
NORTHERN MINDANAO
(May 25 - June 19, 2014 & November 15,2016)

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1509P	RX BLKC	1RDXE145A	J.Alviar	May 25, 2014	Mission done at 800m with voids east of the area; camera assertion failed 2x; no cam mission log; to be renamed to 1RXC145A;
1517P	RX BLKD,E	1RXE147A	I. Roxas	May 27, 2014	Surveyed half of RX D and half of RX E at 800m, 1000m then 900m; cam stylus malfunctioned
1561P	RX BLKD	1RXE158A	G.Sinadjan	June 7, 2014	Mission successful; gaps due to high terrain
1597P	RX BLKD,E	1BLKRXE167A	G.Sinadjan	June 16, 2014	Mission successful; filled gaps in RX E
1609P	RX A,B,C, BLK 64	1RXS170A	I. Roxas	June 19, 2014	Mission successful; descended to 800m then ascended to 1000m
23552P	BLK64A	1BLK64A320A	R. Felismino	November 15, 2016	Surveyed BLK64A over Musi-musi floodplain

LAS BOUNDARIES PER FLIGHT

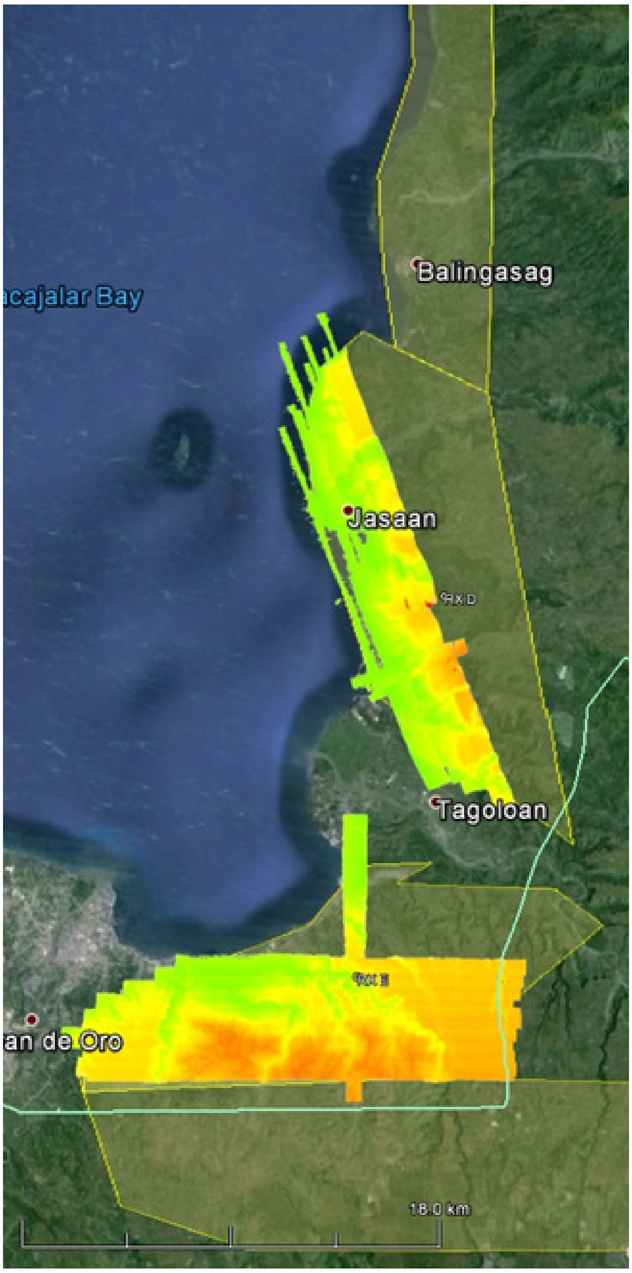
Flight No. : 1509P
Area: RX C
Mission Name: 1RDXE145A
Parameters: Altitude: 800m; Scan Frequency: 30Hz;
Scan Angle: 25deg; Overlap: 30%

LAS



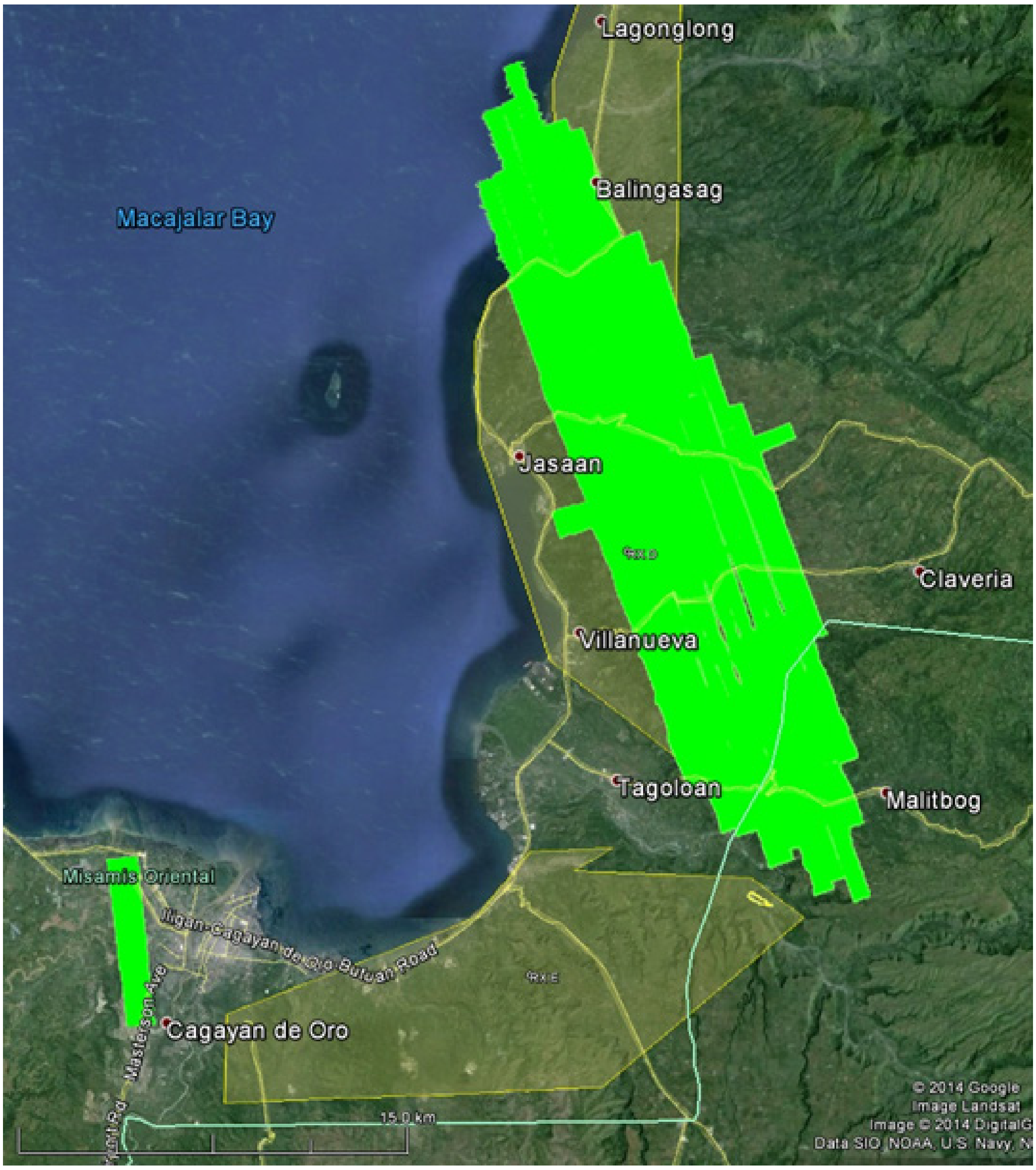
Flight No. : 1517P
Area: RX D, RX E
Mission Name: 1RXE147A
Parameters: Altitude: 900m; Scan Frequency: 30Hz;
Scan Angle: 25deg; Overlap: 30%

LAS



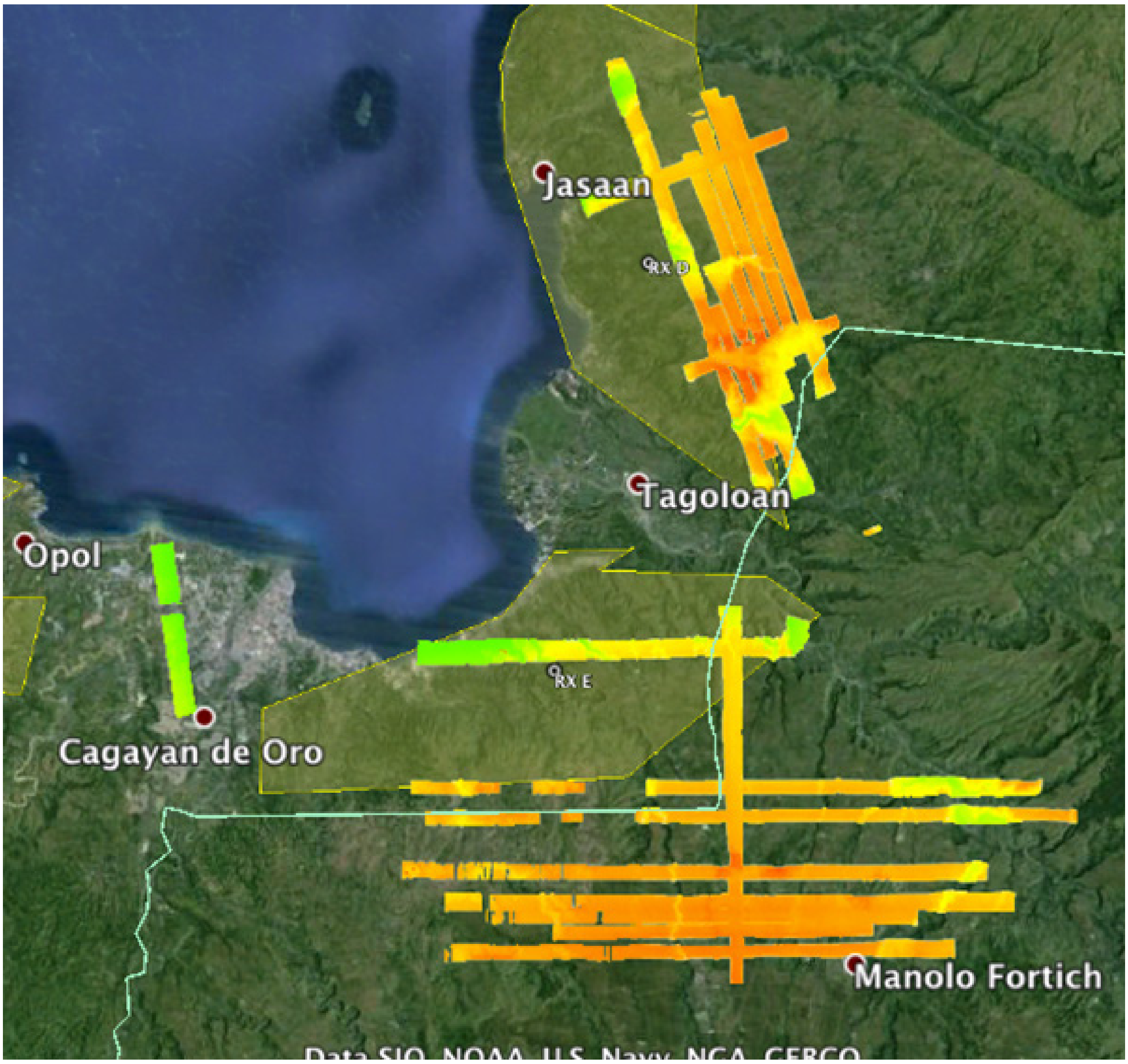
Flight No. : 1561P
Area: RX D
Mission Name: 1RXE158A
Parameters: Altitude: 1000 m; Scan Frequency: 30Hz;
Scan Angle: 25deg; Overlap: 30%

LAS



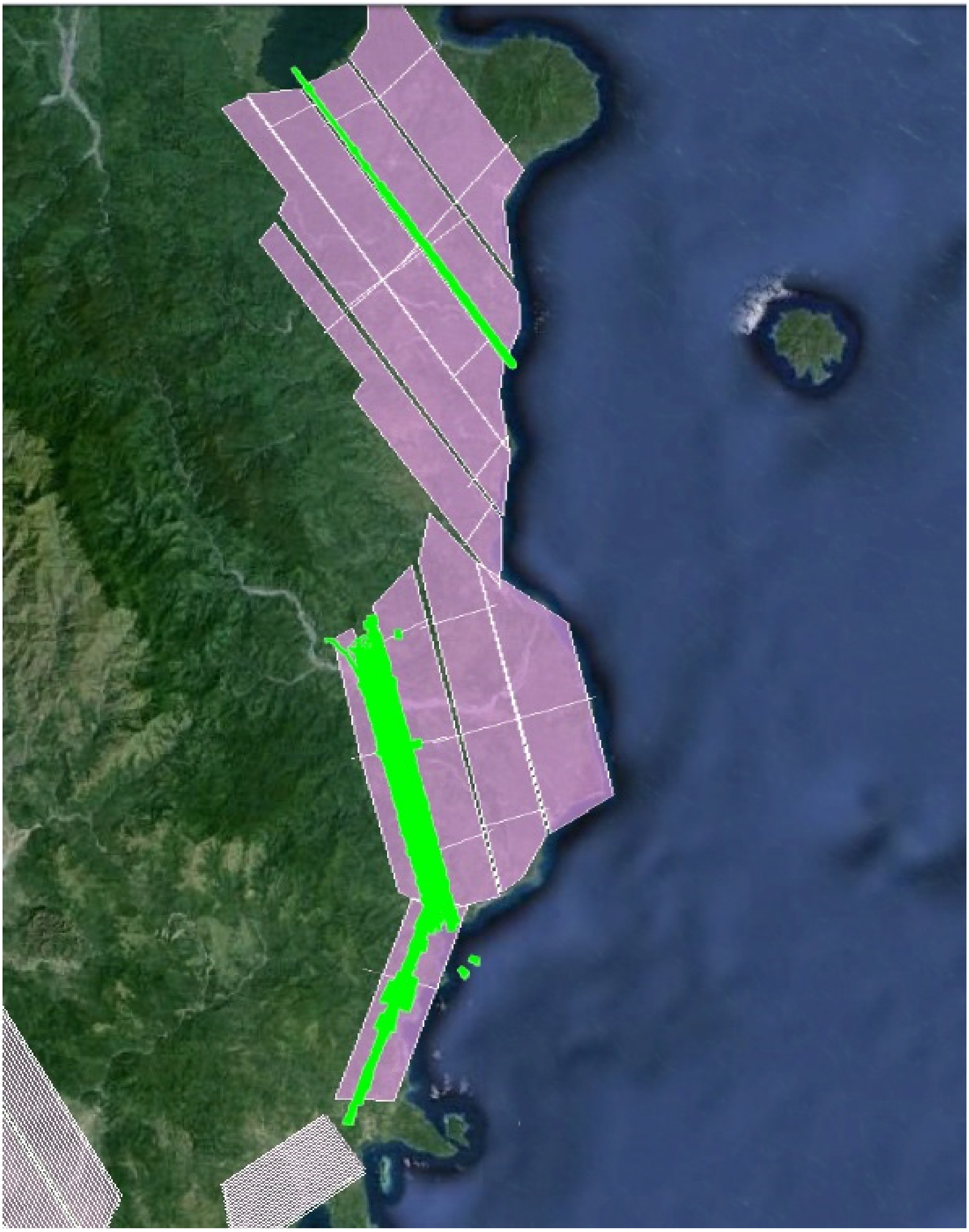
Flight No. : 1597P
Area: RX D, RX E
Mission Name: 1BLKRXE167A
Parameters: Altitude: 800m; Scan Frequency: 30Hz;
Scan Angle:25 deg; Overlap: 30%

LAS



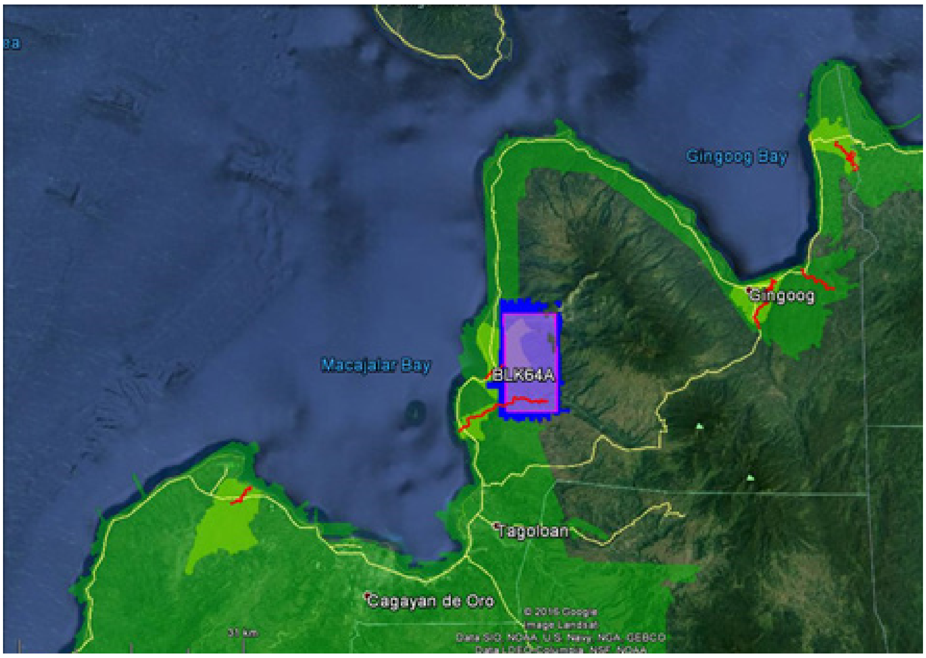
Flight No. : 1609P
Area: RX A, B, C
Mission Name: 1RXS170A
Parameters: Altitude: 900m; Scan Frequency: 30 kHz;
Scan Angle: 25 deg Overlap: 30%

LAS



Flight No. : 23552P
Area: BLK 64A
Mission Name: 1BLK64A320A
Parameters: Altitude: 1200m; Scan Frequency: 30 kHz;
Scan Angle: 25 deg Overlap: 30%

LAS



ANNEX 8. MISSION SUMMARY REPORTS

Flight Area	Northern Mindanao
Mission Name	Blk RX_C_supplement
Inclusive Flights	1609P
Range data size	22.1 GB
Base data size	7.07 MB
POS	259 MB
Image	45.3 GB
Transfer date	July 28, 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)	1.2
RMSE for East Position (<4.0 cm)	2.1
RMSE for Down Position (<8.0 cm)	3.4
Boresight correction stdev (<0.001deg)	0.000218
IMU attitude correction stdev (<0.001deg)	0.000460
GPS position stdev (<0.01m)	0.0010
Minimum % overlap (>25)	30.50%
Ave point cloud density per sq.m. (>2.0)	4.28
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	148
Maximum Height	610.04 m
Minimum Height	65.41 m
Classification (# of points)	
Ground	74,863,357
Low vegetation	68,810,625
Medium vegetation	154,140,328
High vegetation	140,551,764
Building	2,051,193
Orthophoto	
Processed by	Engr. Irish Cortez, Engr. Melanie Hingpit, Engr. Krisha Marie Bautista

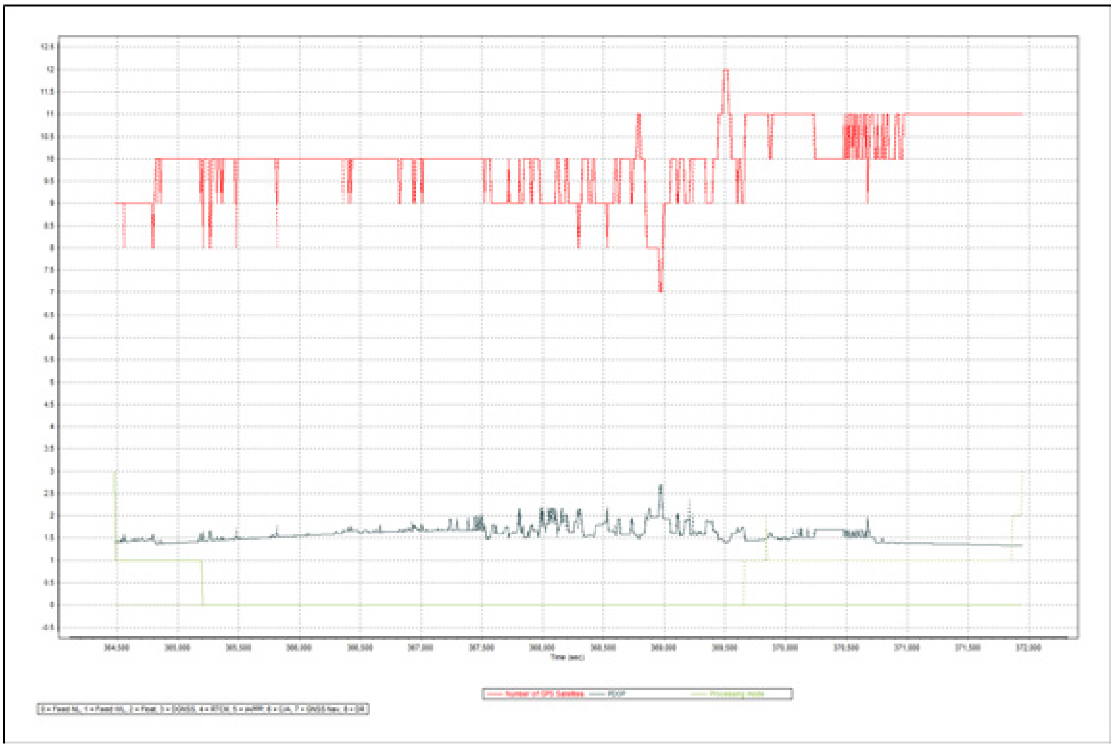


Figure 1.1.1 Solution Status

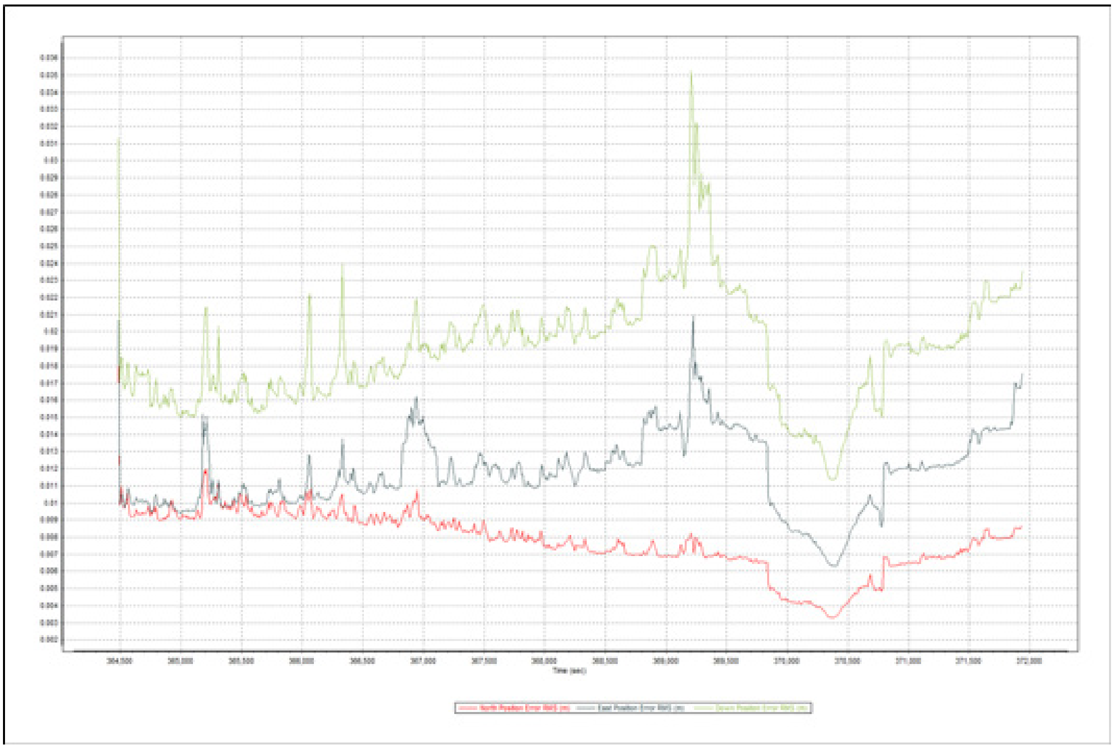


Figure 1.1.2 Smoothed Performance Metric Parameters

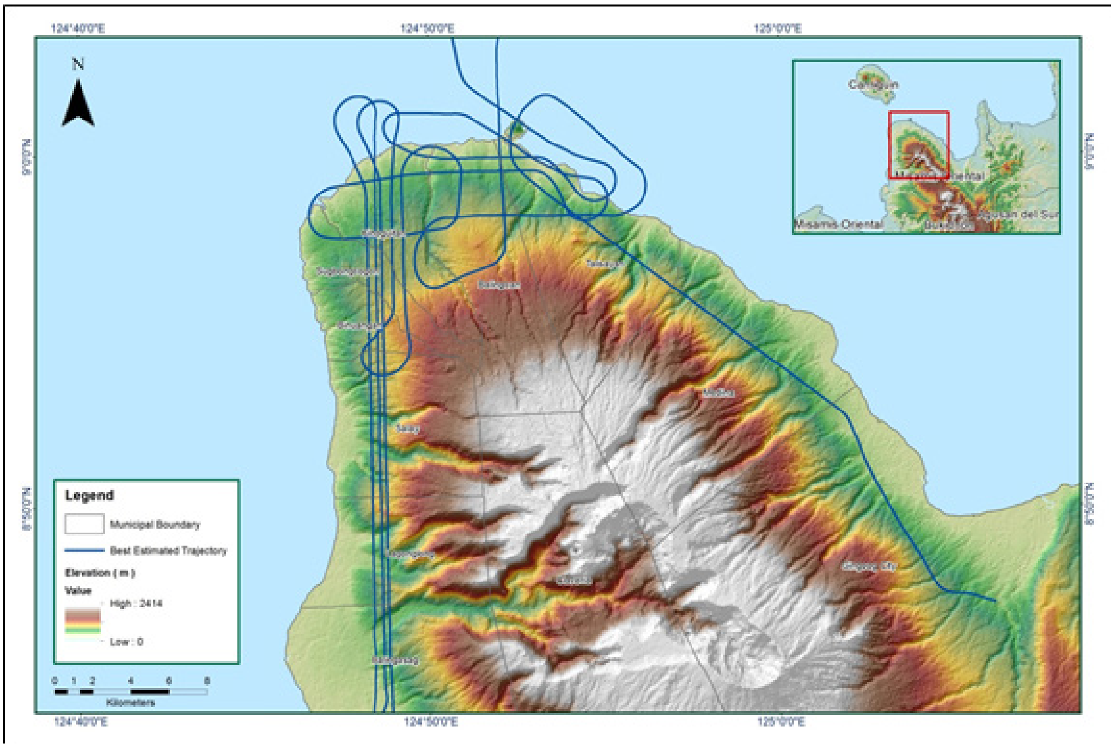


Figure 1.1.3 Best Estimated Trajectory

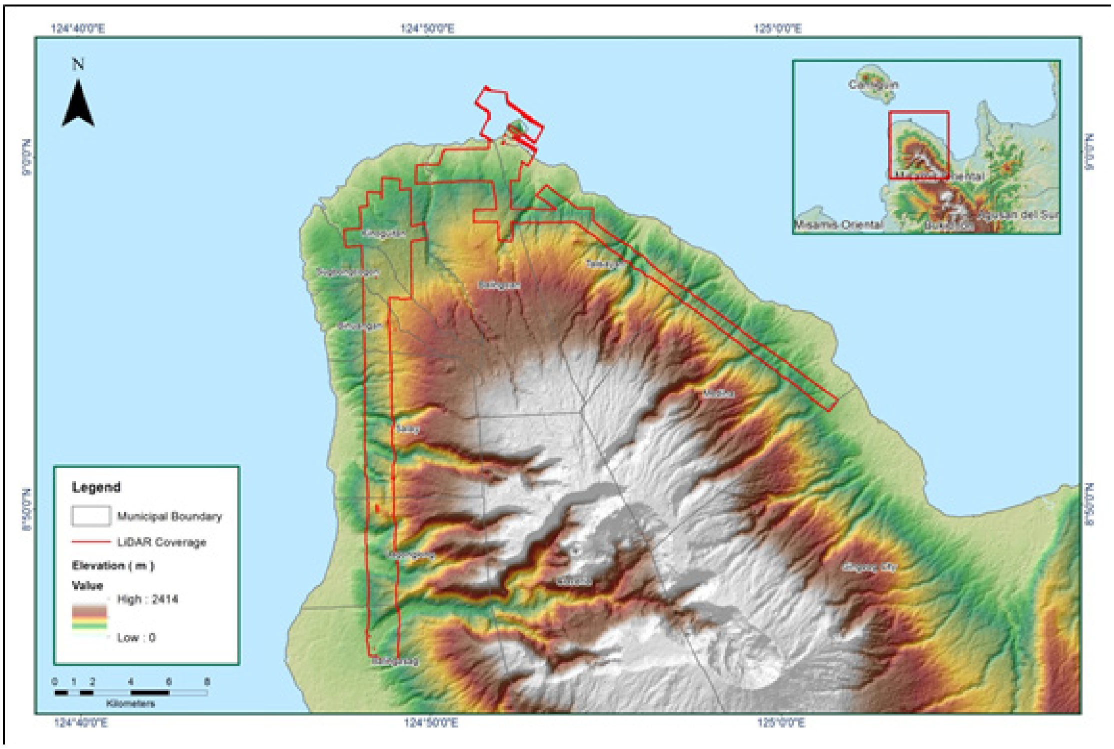


Figure 1.1.4 Coverage of LiDAR data

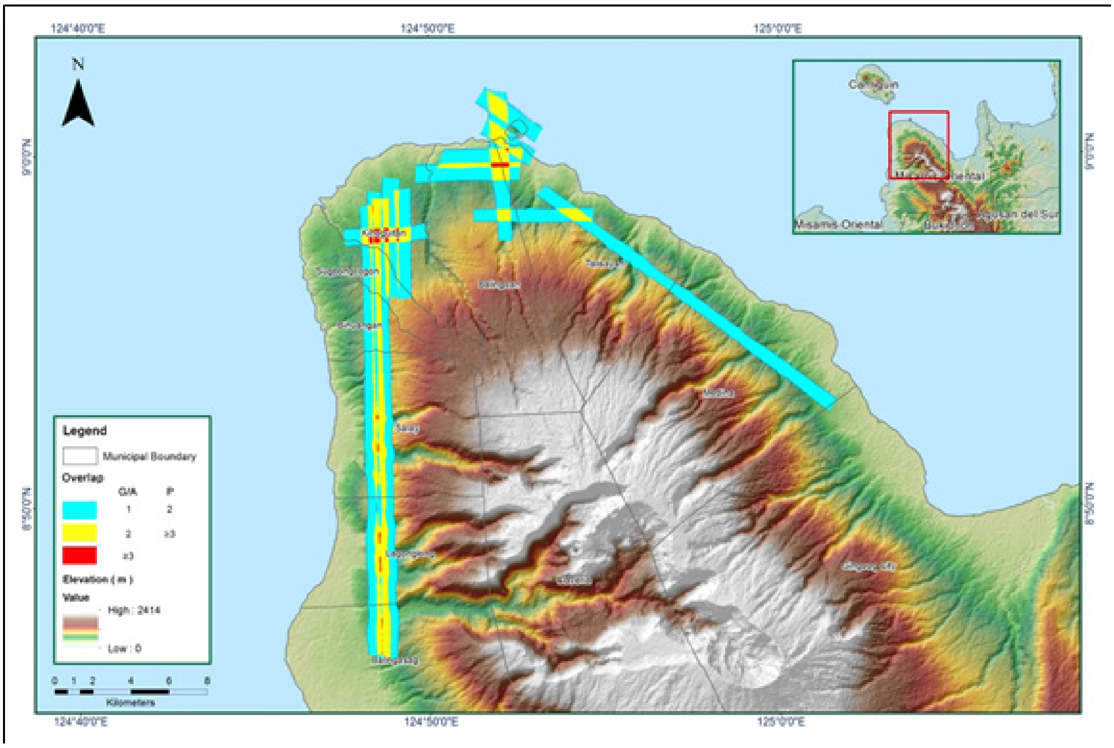


Figure 1.1.5 Image of data overlap

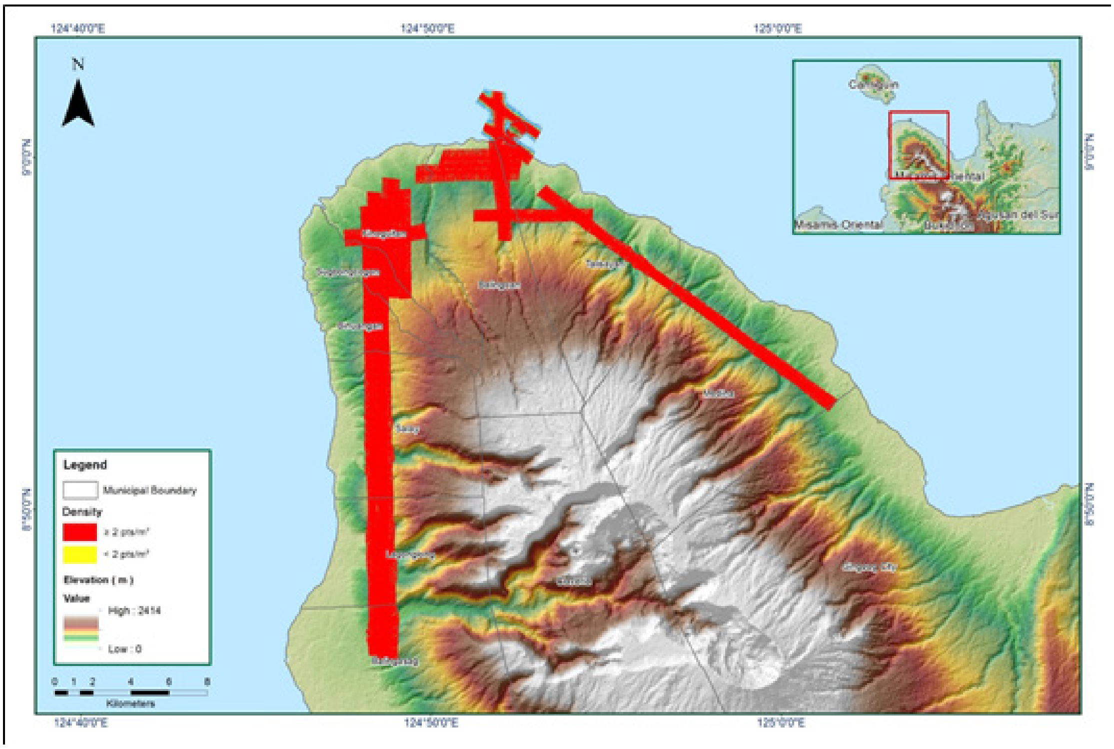


Figure 1.1.6 Density map of merged LiDAR data

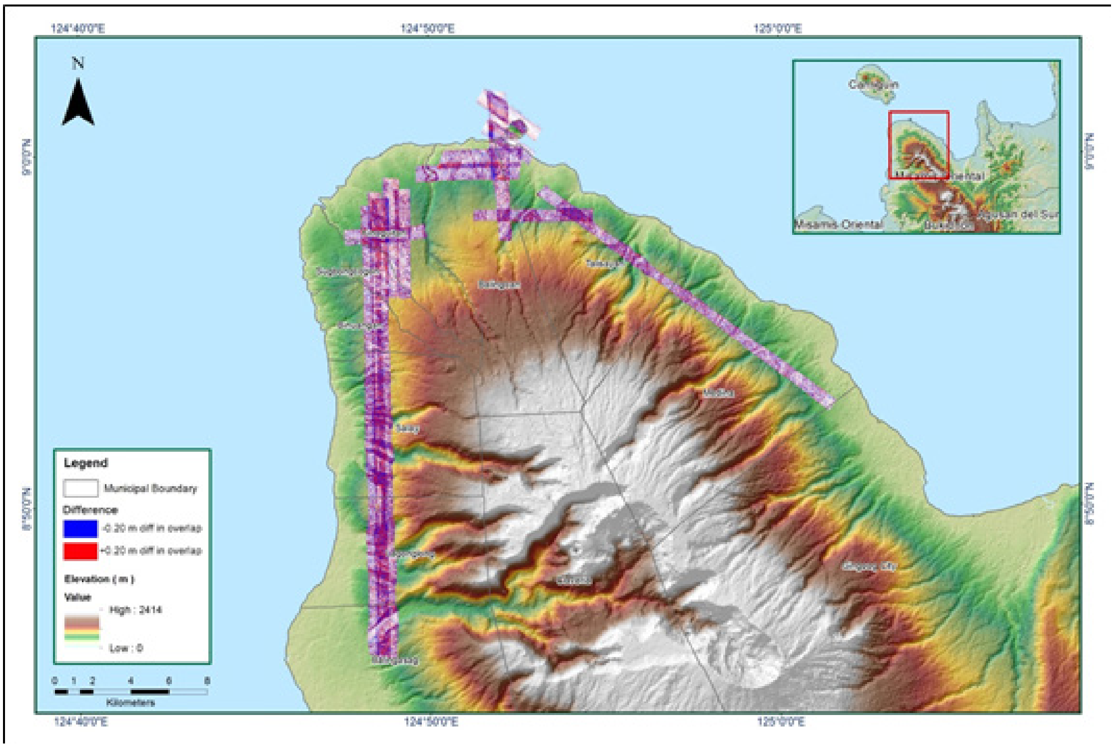


Figure 1.1.7 Elevation difference between flight lines

Flight Area	Northern Mindanao
Mission Name	Blk RX_supplement
Inclusive Flights	1609P
Range data size	22.1 GB
Base data size	7.07 MB
POS	259 MB
Image	45.3 GB
Transfer date	July 28, 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)	1.2
RMSE for East Position (<4.0 cm)	2.1
RMSE for Down Position (<8.0 cm)	3.5
Boresight correction stdev (<0.001deg)	0.000218
IMU attitude correction stdev (<0.001deg)	0.000460
GPS position stdev (<0.01m)	0.0010
Minimum % overlap (>25)	33.39%
Ave point cloud density per sq.m. (>2.0)	5.40
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	132
Maximum Height	678.91 m
Minimum Height	68.96 m
Classification (# of points)	
Ground	50,885,013
Low vegetation	47,864,075
Medium vegetation	170,807,118
High vegetation	161,481,667
Building	1,560,519
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Analyn Naldo, Engr. Chelou Prado, Engr. Gladys Mae Apat

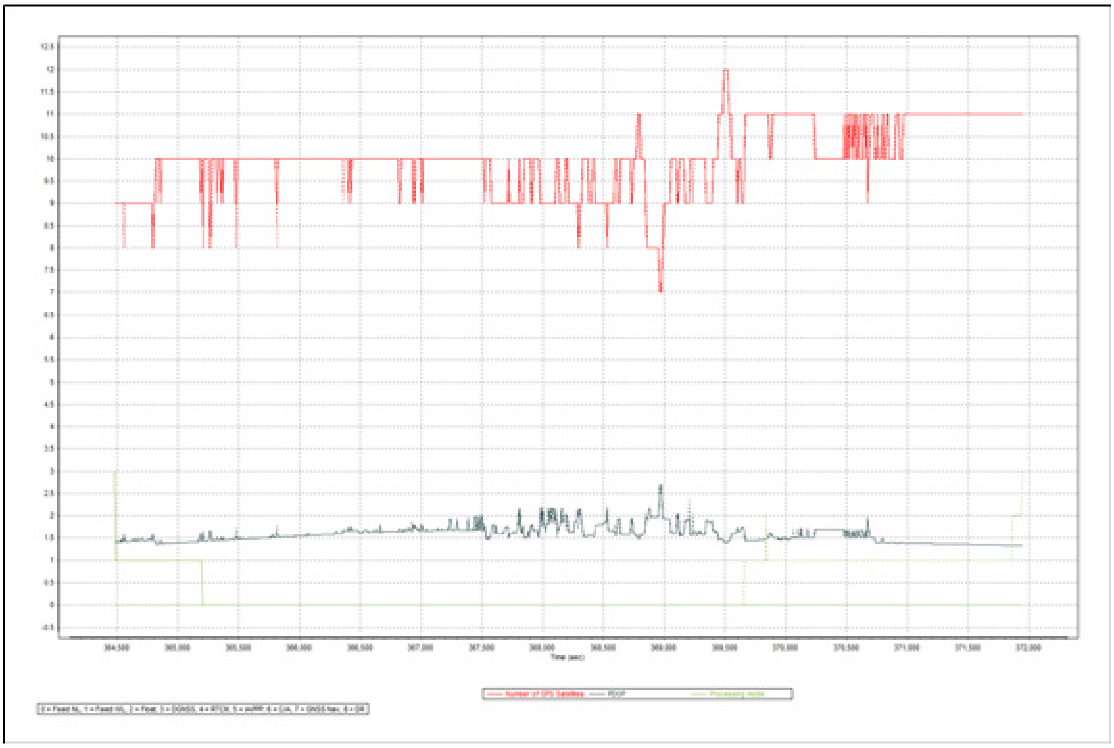


Figure 1.2.1 Solution Status

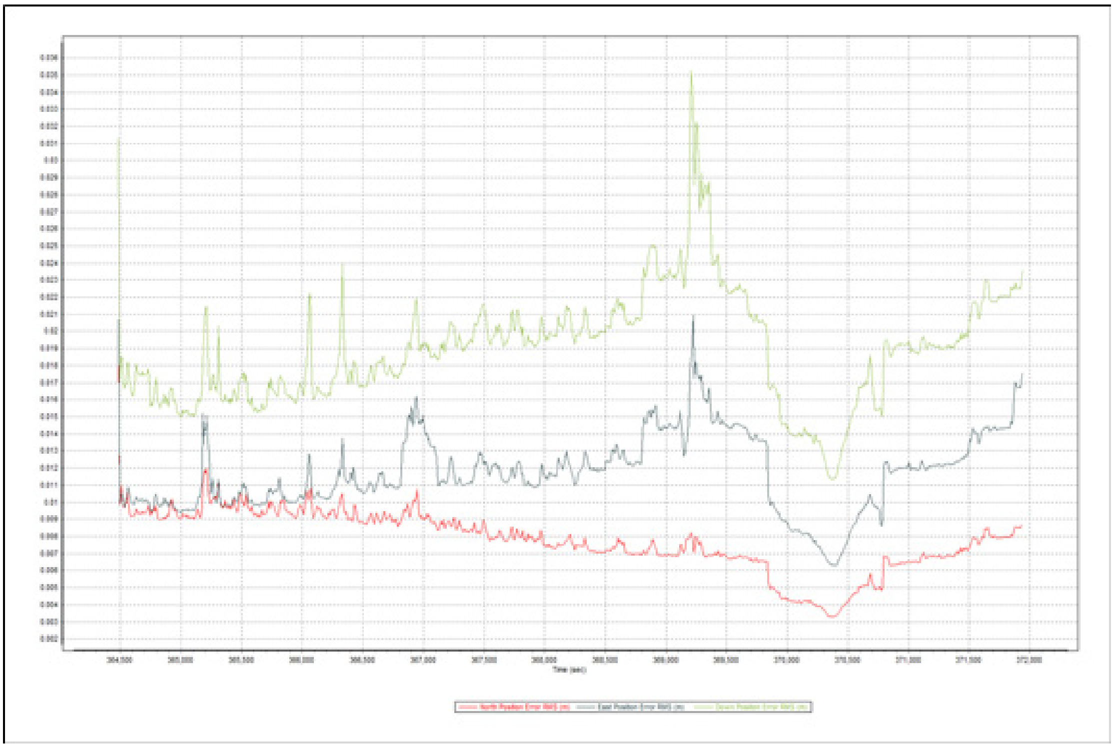


Figure 1.2.2 Smoothed Performance Metric Parameters

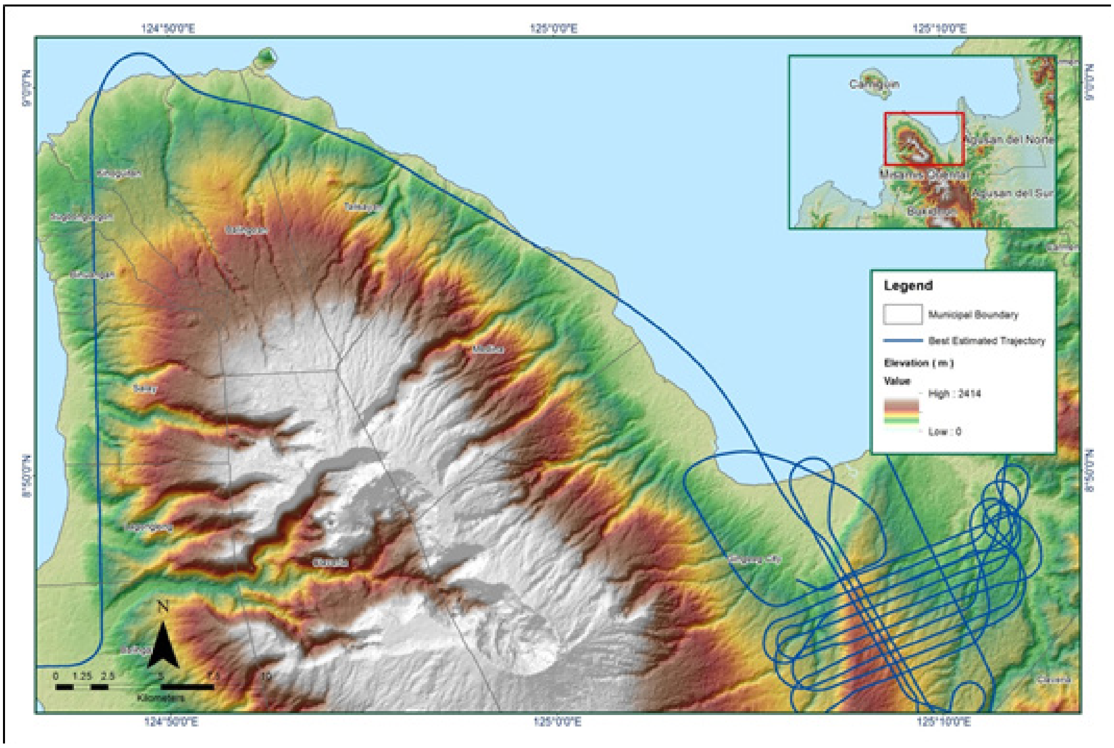


Figure 1.2.3 Best Estimated Trajectory

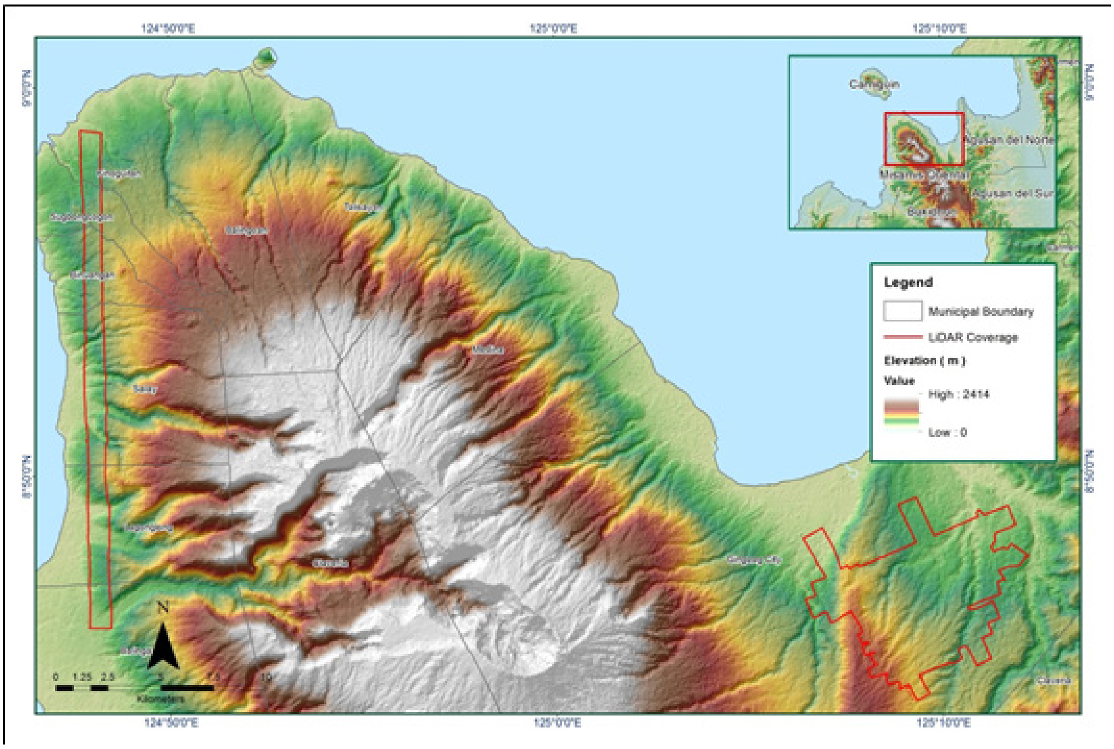


Figure 1.2.4 Coverage of LiDAR data

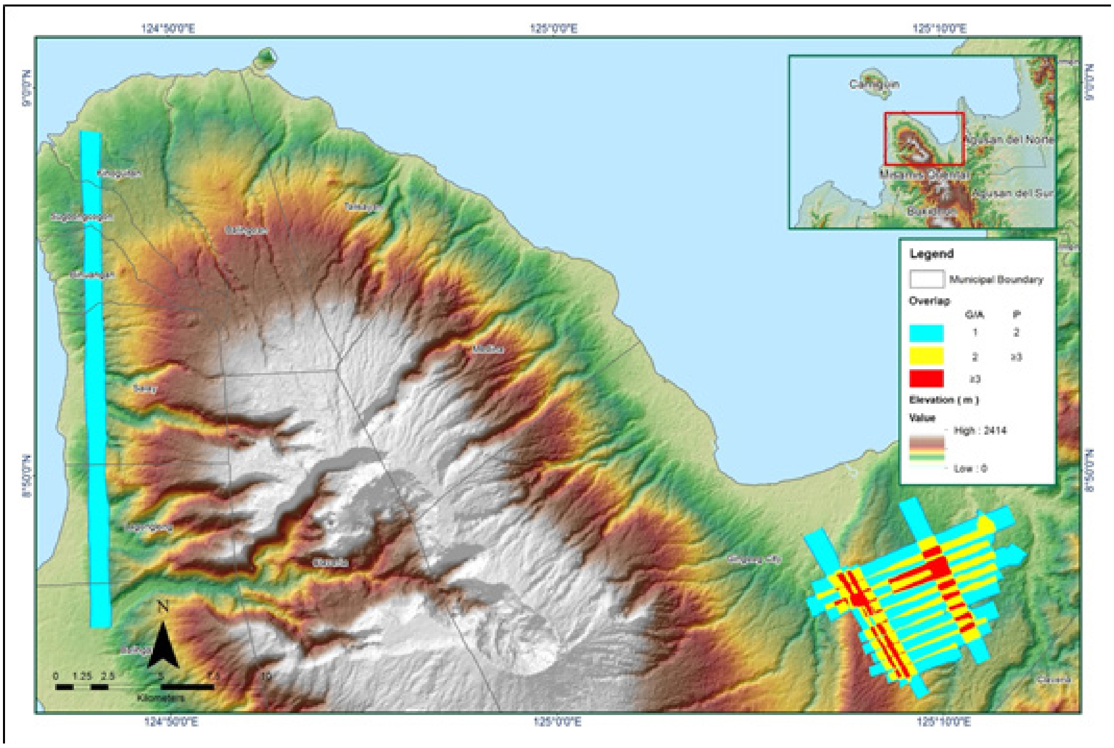


Figure 1.2.5 Image of data overlap

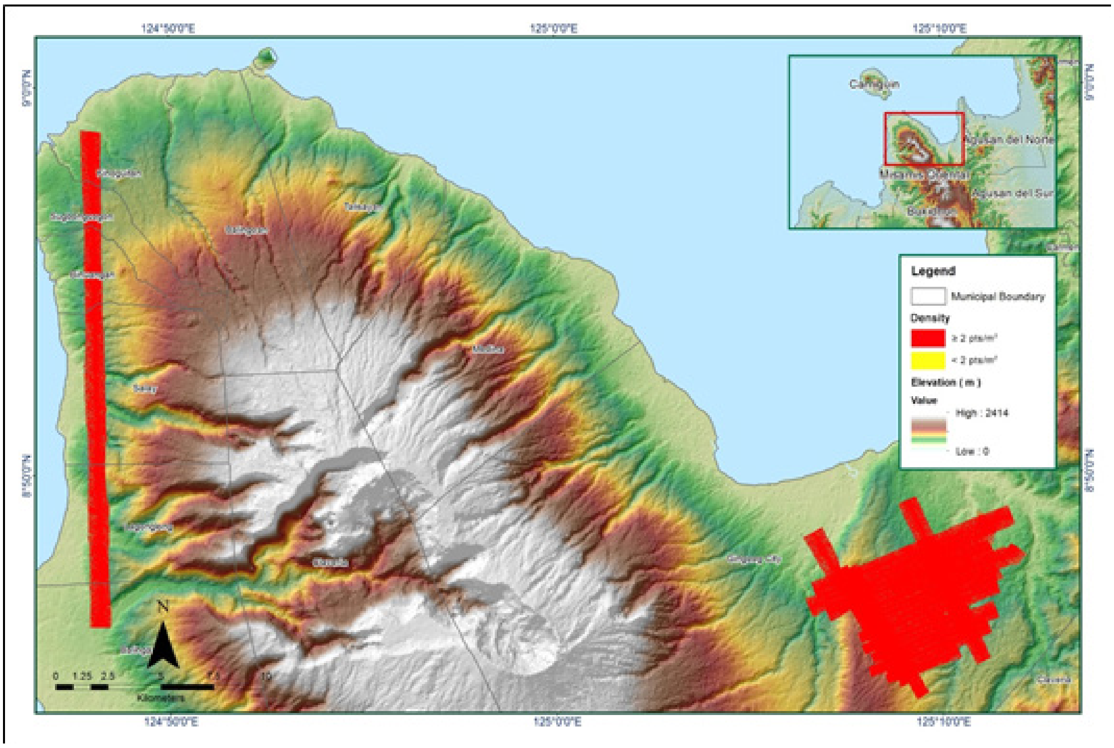


Figure 1.2.6 Density map of merged LiDAR data

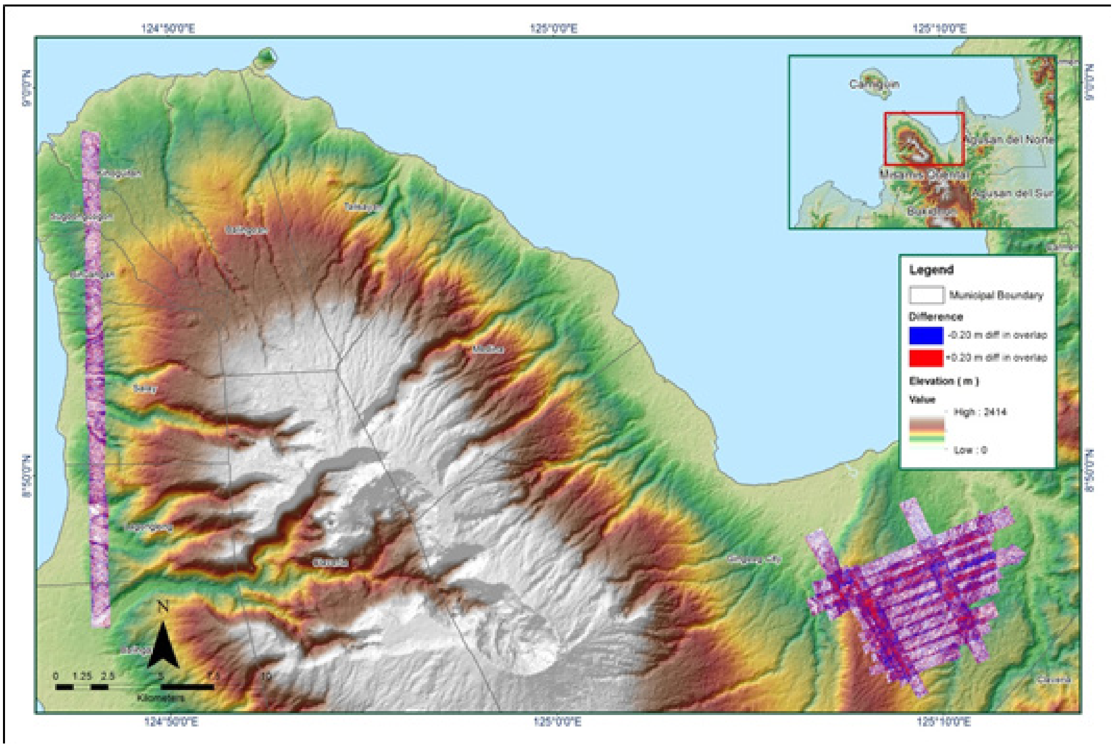


Figure 1.2.7 Elevation difference between flight lines

Flight Area	Northern Mindanao
Mission Name	RX_C
Inclusive Flights	1509P
Range data size	26.2 GB
Base data size	4.96 MB
POS	254 MB
Image	53.6 GB
Transfer date	June 10, 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)	1.4
RMSE for East Position (<4.0 cm)	1.8
RMSE for Down Position (<8.0 cm)	3.0
Boresight correction stdev (<0.001deg)	0.000264
IMU attitude correction stdev (<0.001deg)	0.004243
GPS position stdev (<0.01m)	0.0069
Minimum % overlap (>25)	38.61%
Ave point cloud density per sq.m. (>2.0)	4.28
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	185
Maximum Height	531.69 m
Minimum Height	65.50 m
Classification (# of points)	
Ground	122,191,837
Low vegetation	148,368,596
Medium vegetation	208,375,236
High vegetation	193,794,857
Building	10,741,701
Orthophoto	No
Processed by	Victoria Rejuso, Engr. Melanie Hingpit, Engr. Roa Shalemar Redo

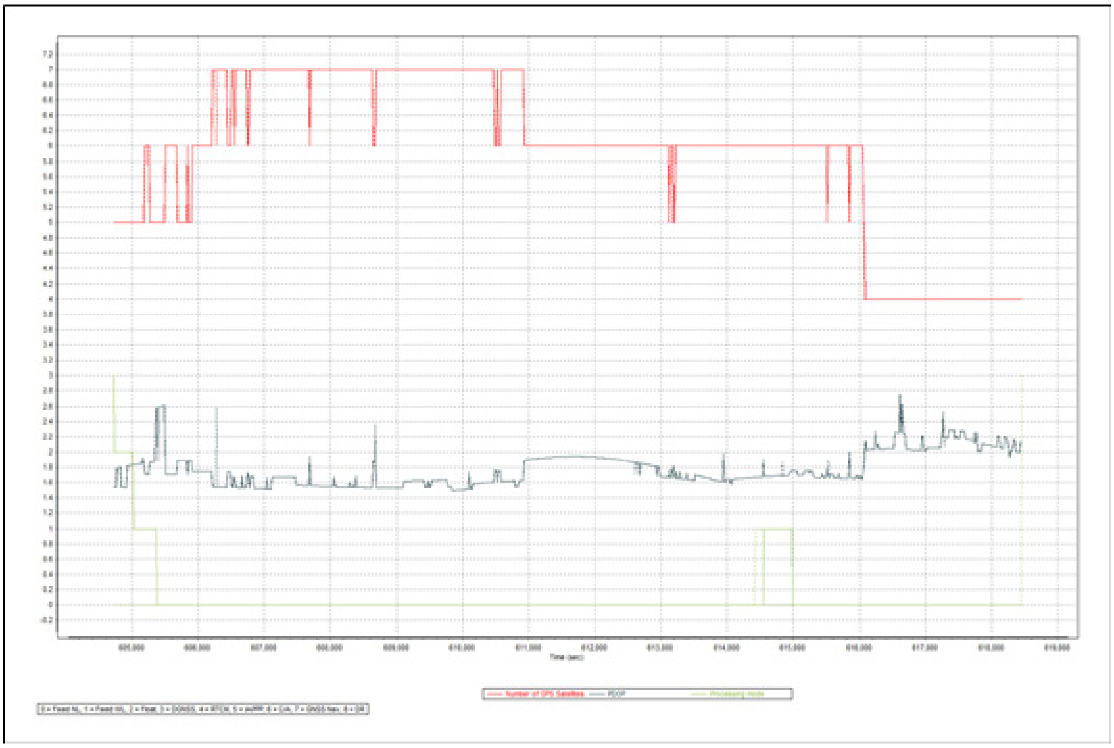


Figure 1.3.1 Solution Status

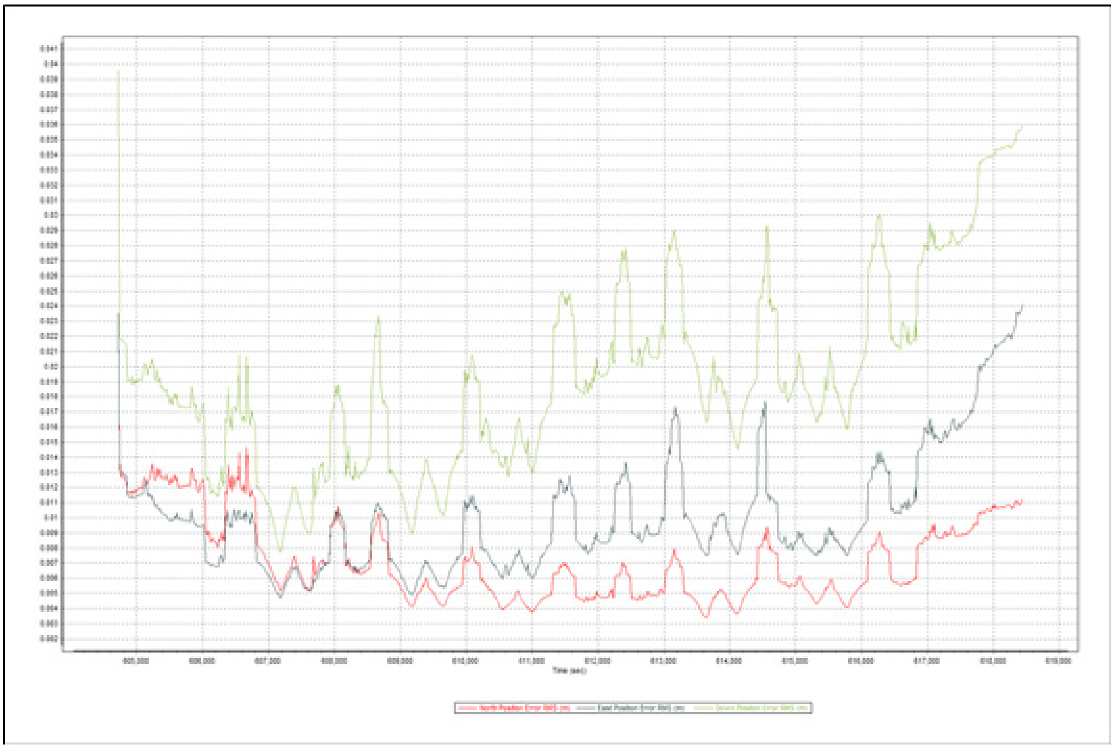


Figure 1.3.2 Smoothed Performance Metric Parameters

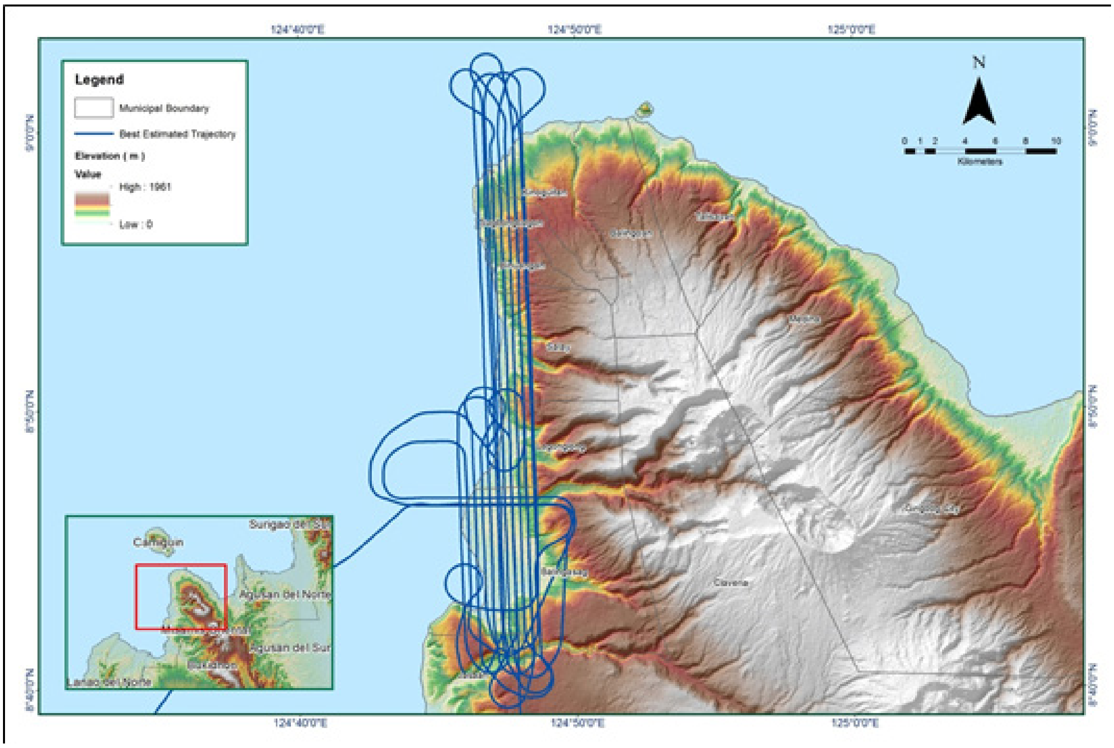


Figure 1.3.3 Best Estimated Trajectory

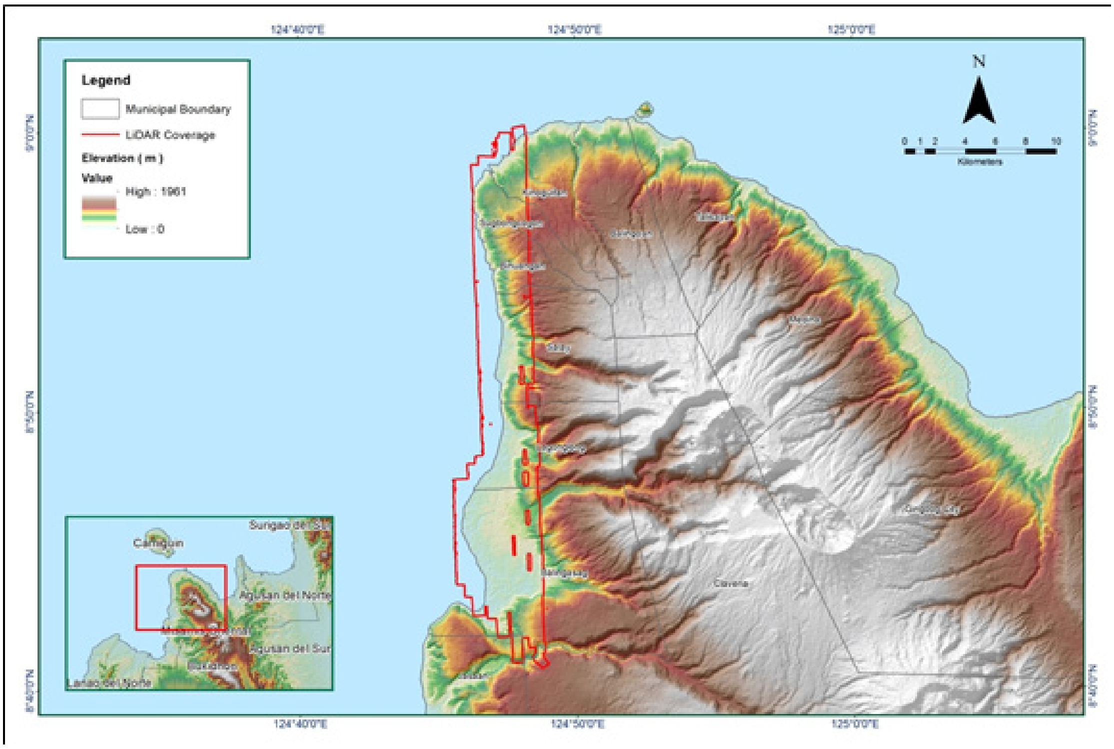


Figure 1.3.4 Coverage of LiDAR data

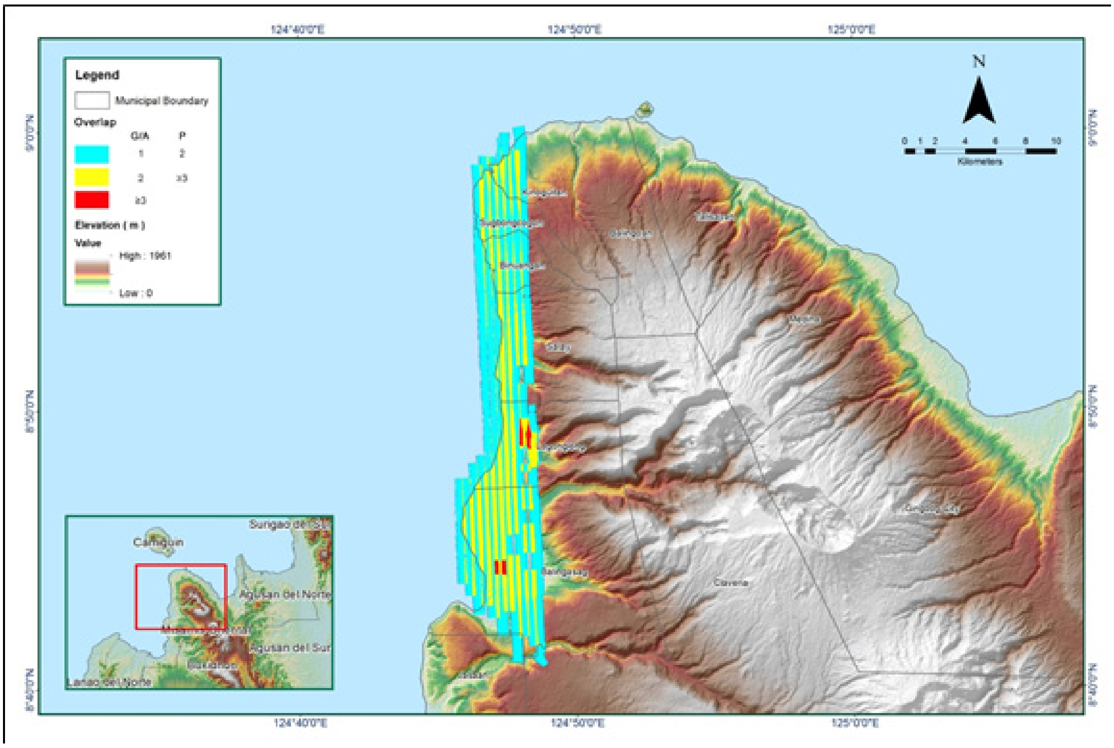


Figure 1.3.5 Image of data overlap

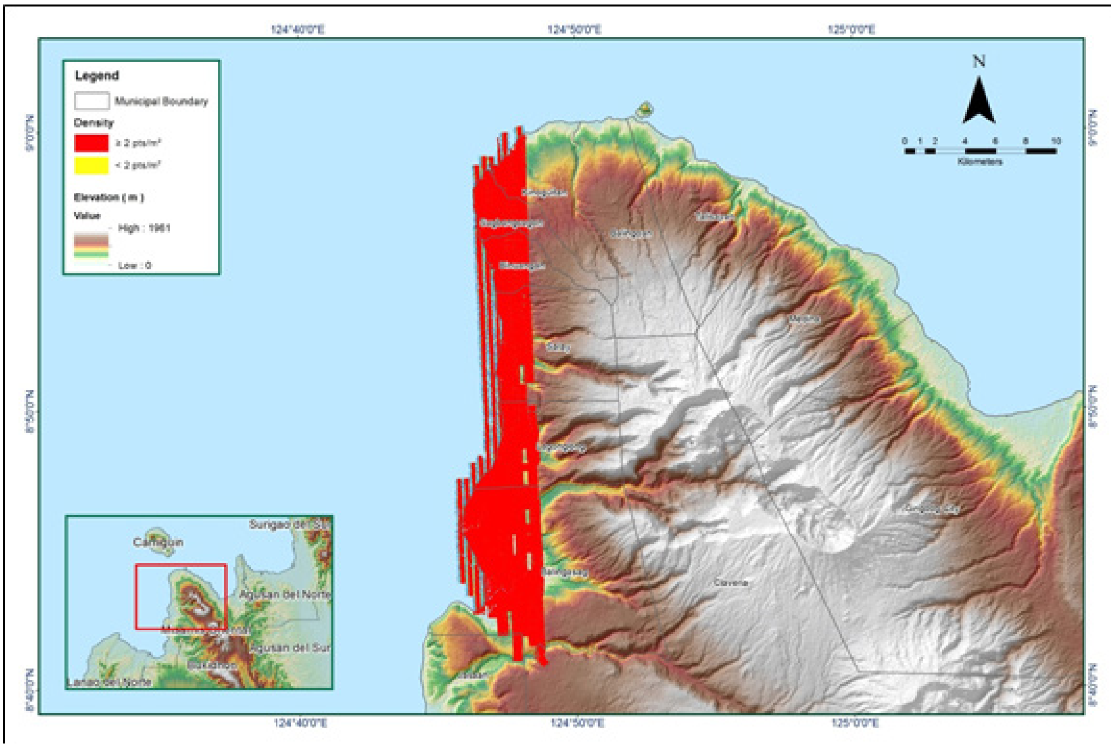


Figure 1.3.6 Density map of merged LiDAR data

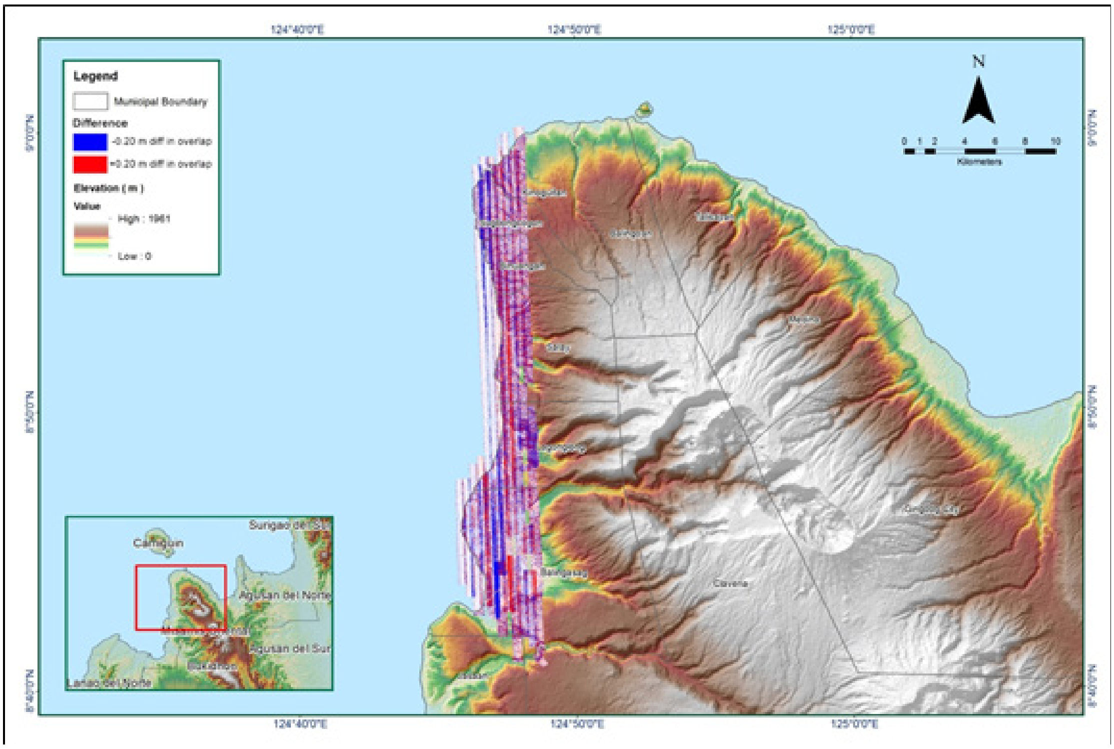


Figure 1.3.7 Elevation difference between flight lines

Flight Area	Northern Mindanao
Mission Name	RX_D
Inclusive Flights	1561P
Range data size	22 GB
Base data size	8.1 MB
POS	187 MB
Image	n/a
Transfer date	June 23, 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)	1.3
RMSE for East Position (<4.0 cm)	1.05
RMSE for Down Position (<8.0 cm)	3.2
Boresight correction stdev (<0.001deg)	0.000179
IMU attitude correction stdev (<0.001deg)	0.001266
GPS position stdev (<0.01m)	0.0058
Minimum % overlap (>25)	33.38%
Ave point cloud density per sq.m. (>2.0)	3.85
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	297
Maximum Height	747.65 m
Minimum Height	66.39
Classification (# of points)	
Ground	242,066,972
Low vegetation	216,117,519
Medium vegetation	359,141,389
High vegetation	333,494,074
Building	15,951,611
Orthophoto	
Processed by	Engr. Jommer Medina, Engr. Kenneth Solidum, Engr. Christy Lubiano, Engr. Gladys Apat

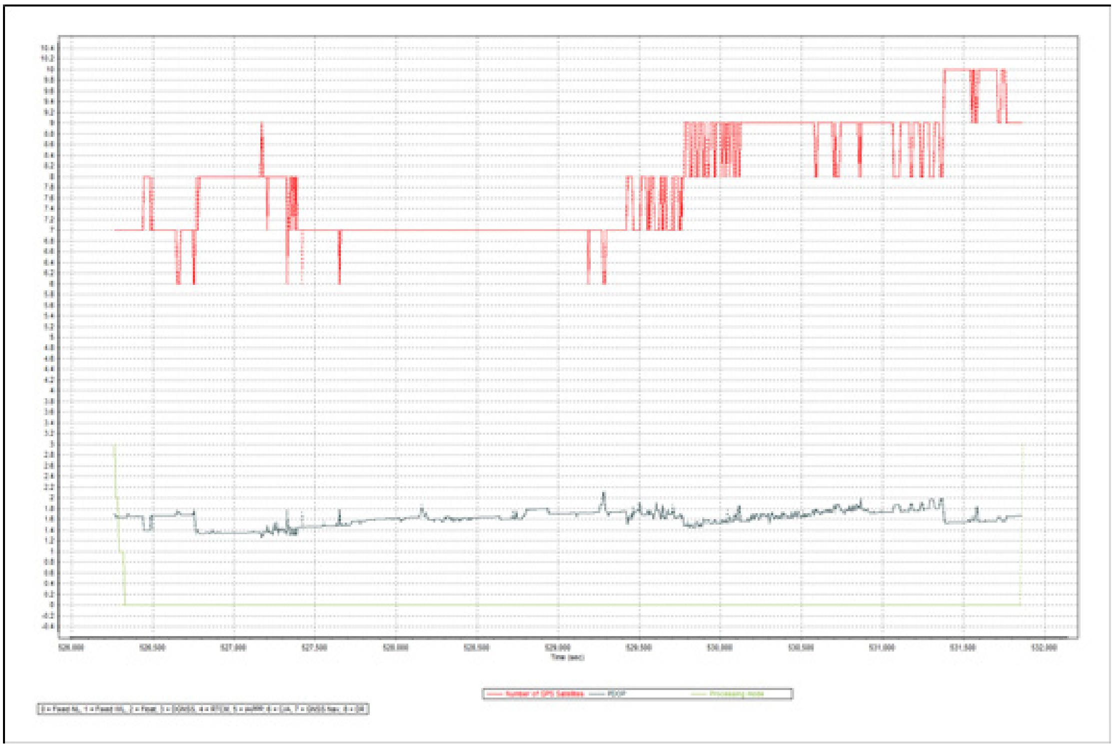


Figure 1.4.1 Solution Status

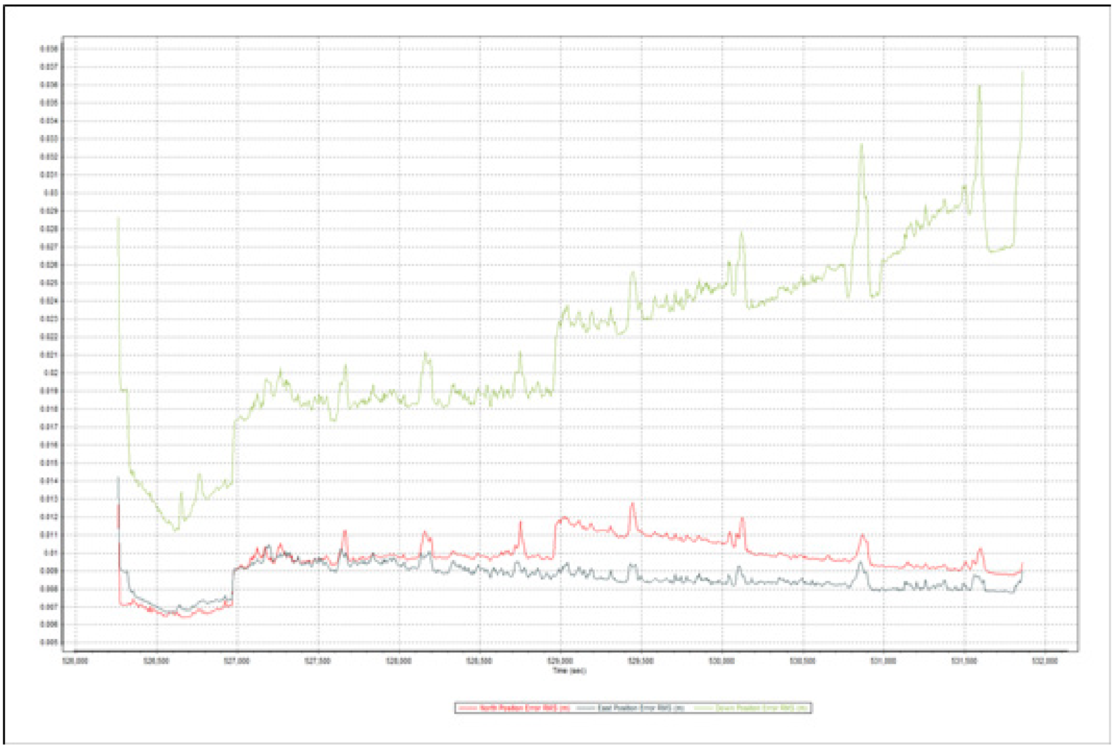


Figure 1.4.2 Smoothed Performance Metric Parameters

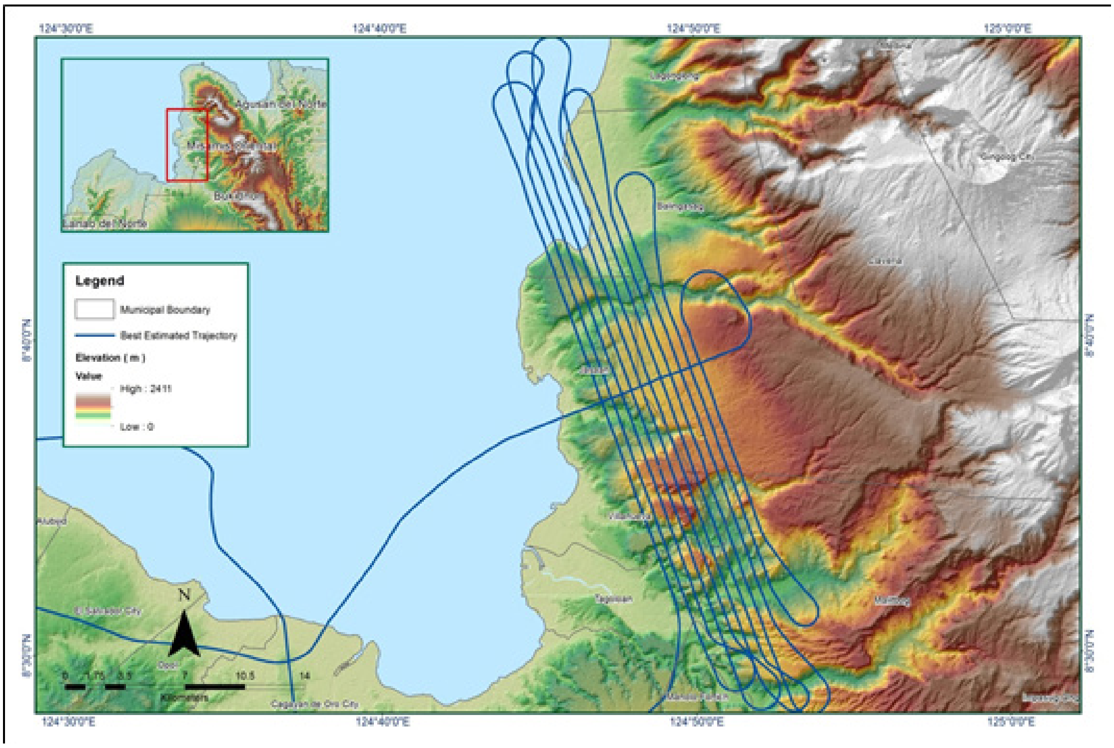


Figure 1.4.3 Best Estimated Trajectory

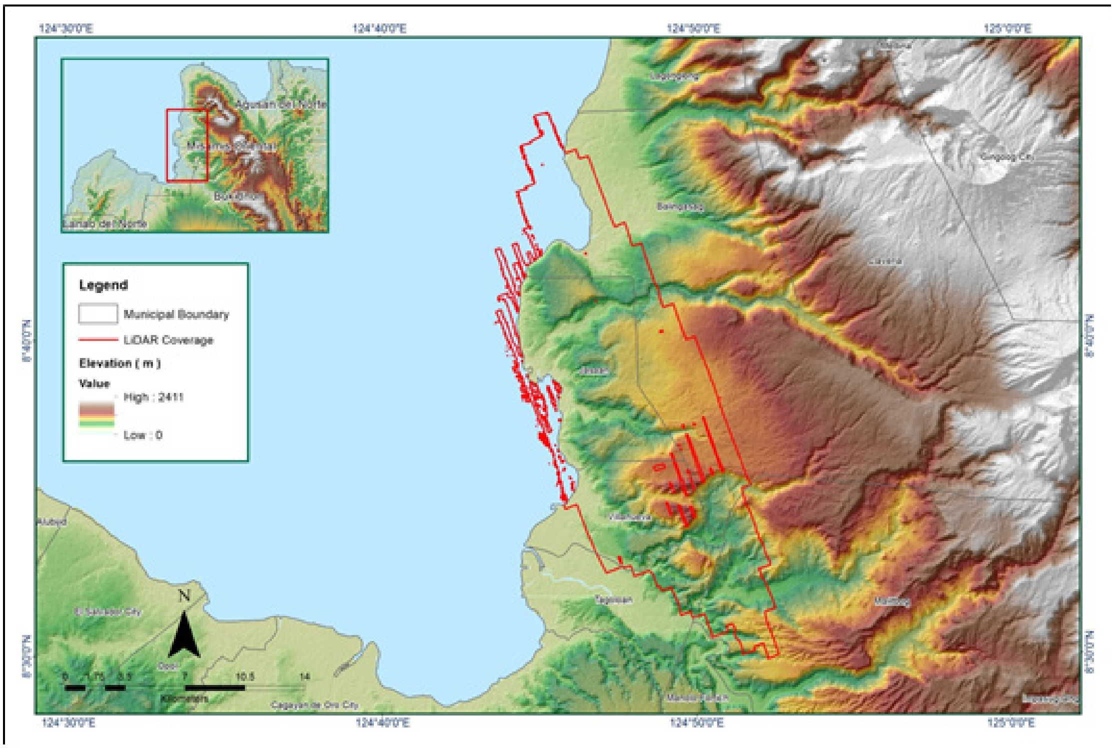


Figure 1.4.4 Coverage of LiDAR data

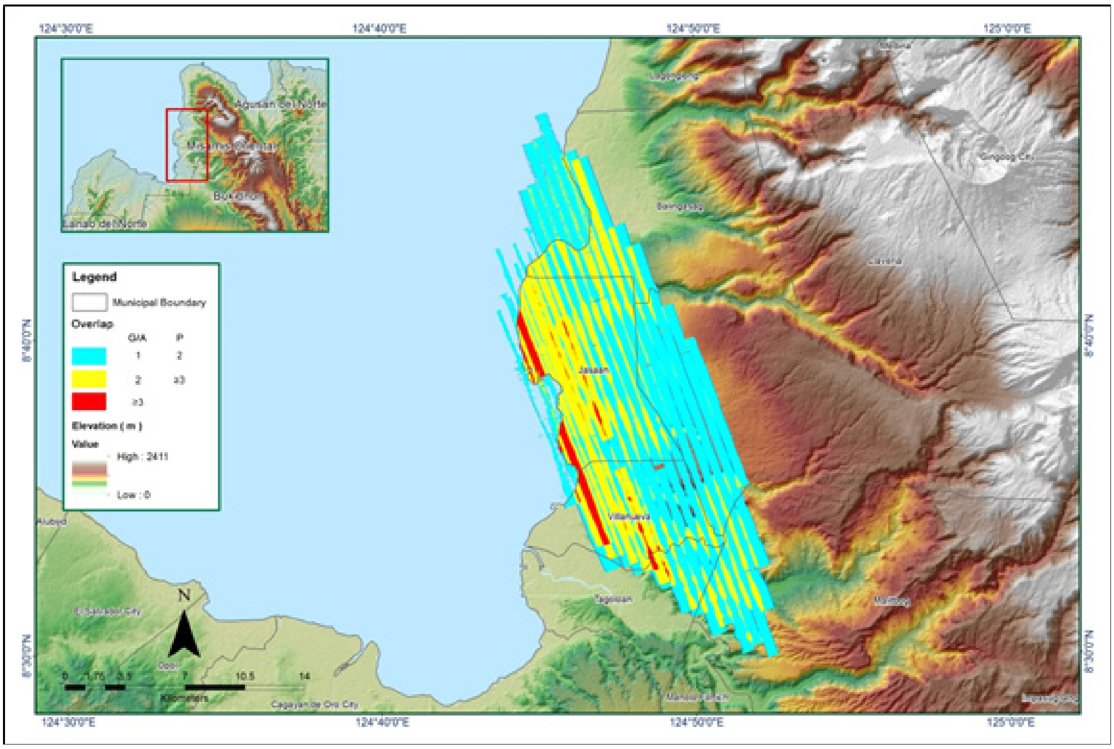


Figure 1.4.5 Image of data overlap

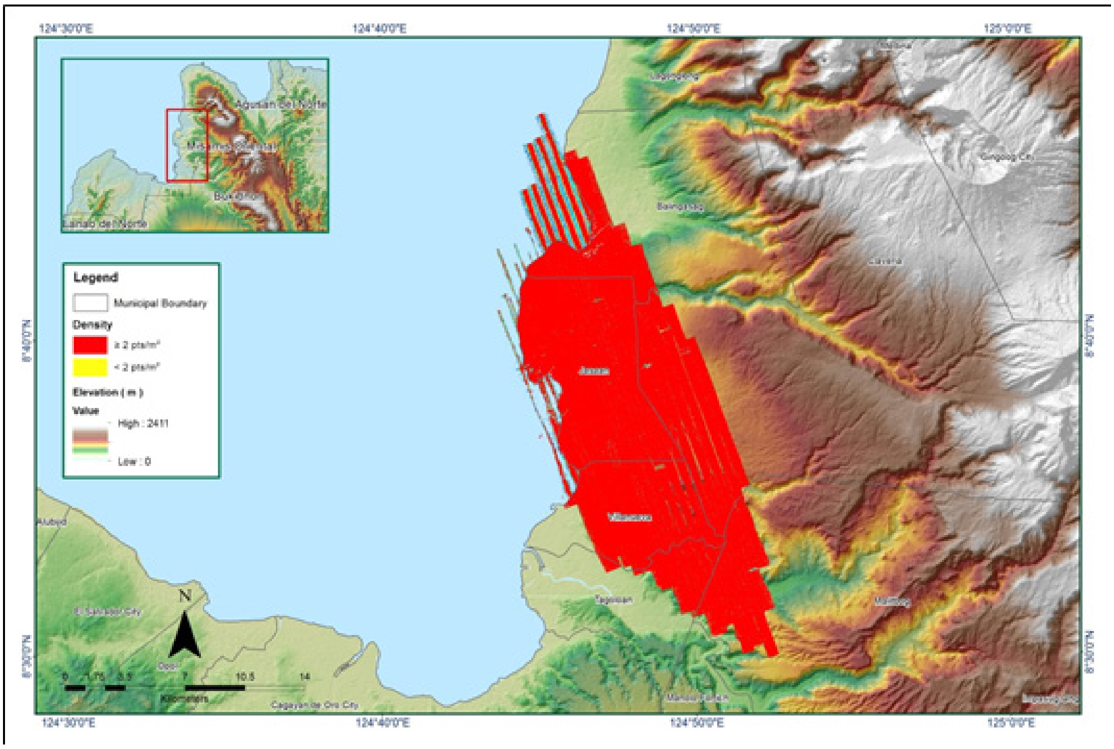


Figure 1.4.6 Density map of merged LiDAR data

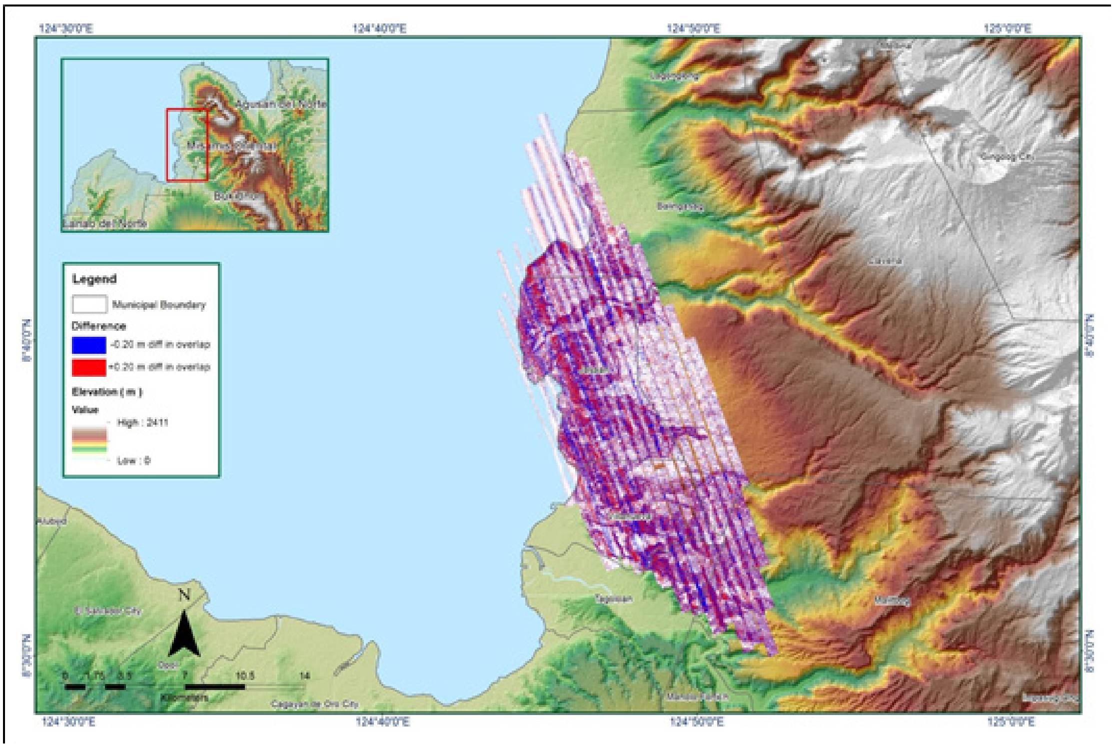


Figure 1.4.7 Elevation difference between flight lines

Flight Area	Bukidnon
Mission Name	Block 64F
Inclusive Flights	23552P
Range data size	20.6 GB
Base data size	131 MB
POS	261 MB
Image	N/A
Transfer date	November 24, 2016
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)	1.492
RMSE for East Position (<4.0 cm)	1.474
RMSE for Down Position (<8.0 cm)	3.170
Boresight correction stdev (<0.001deg)	0.000182
IMU attitude correction stdev (<0.001deg)	0.010301
GPS position stdev (<0.01m)	0.0027
Minimum % overlap (>25)	54.18
Ave point cloud density per sq.m. (>2.0)	5.01
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	156
Maximum Height	1396.06 m
Minimum Height	68.22 m
Classification (# of points)	
Ground	124,368,997
Low vegetation	128,062,833
Medium vegetation	343,670,586
High vegetation	634,413,336
Building	35,123,927
Orthophoto	No
Processed by	Engr. Irish Cortez, Ma. Joanne Balaga, Engr. Monalyne Rabino

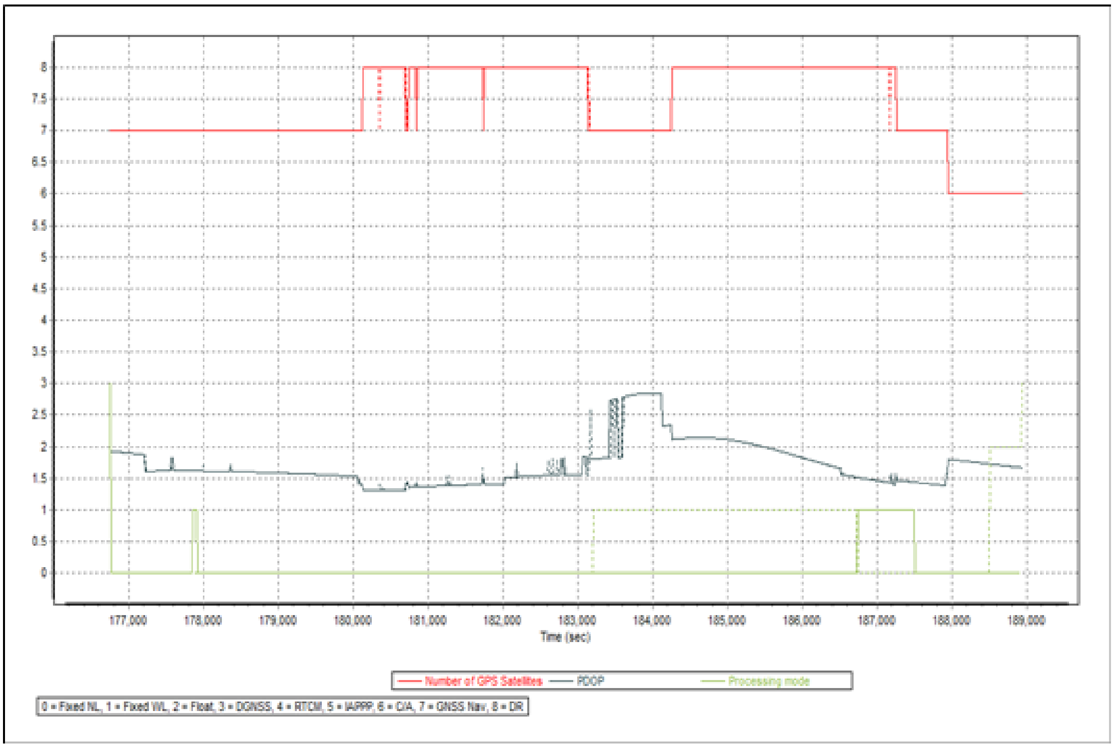


Figure 1.5.1 Solution Status

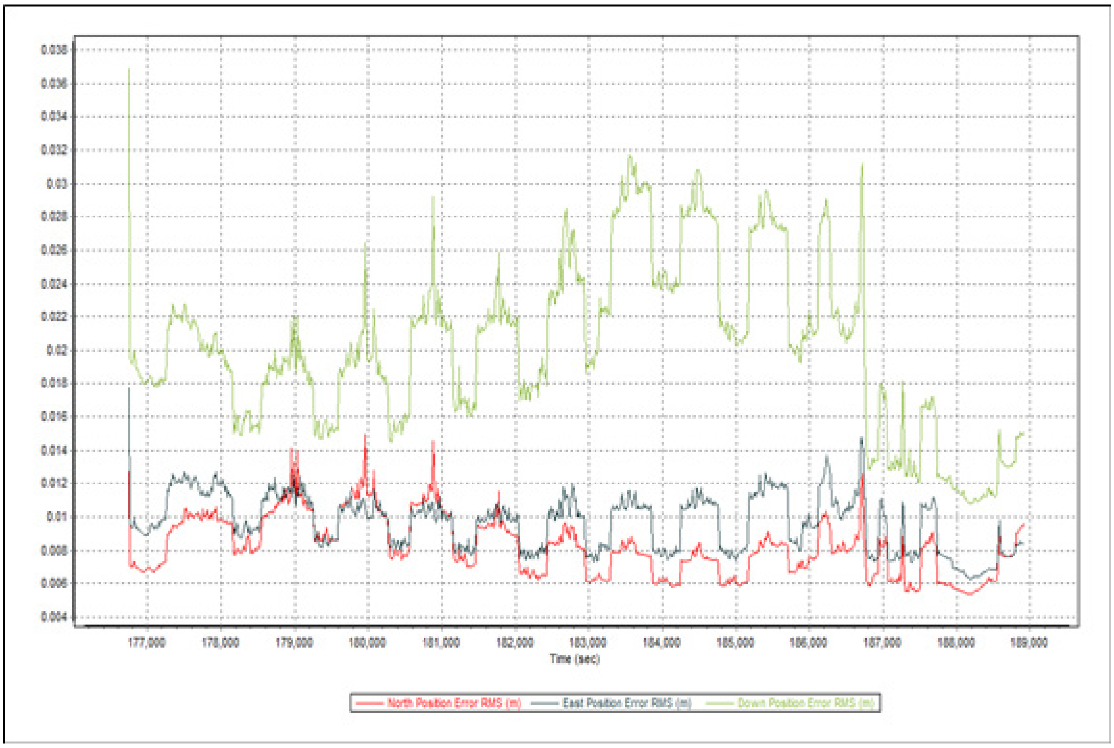


Figure 1.5.2 Smoothed Performance Metric Parameters

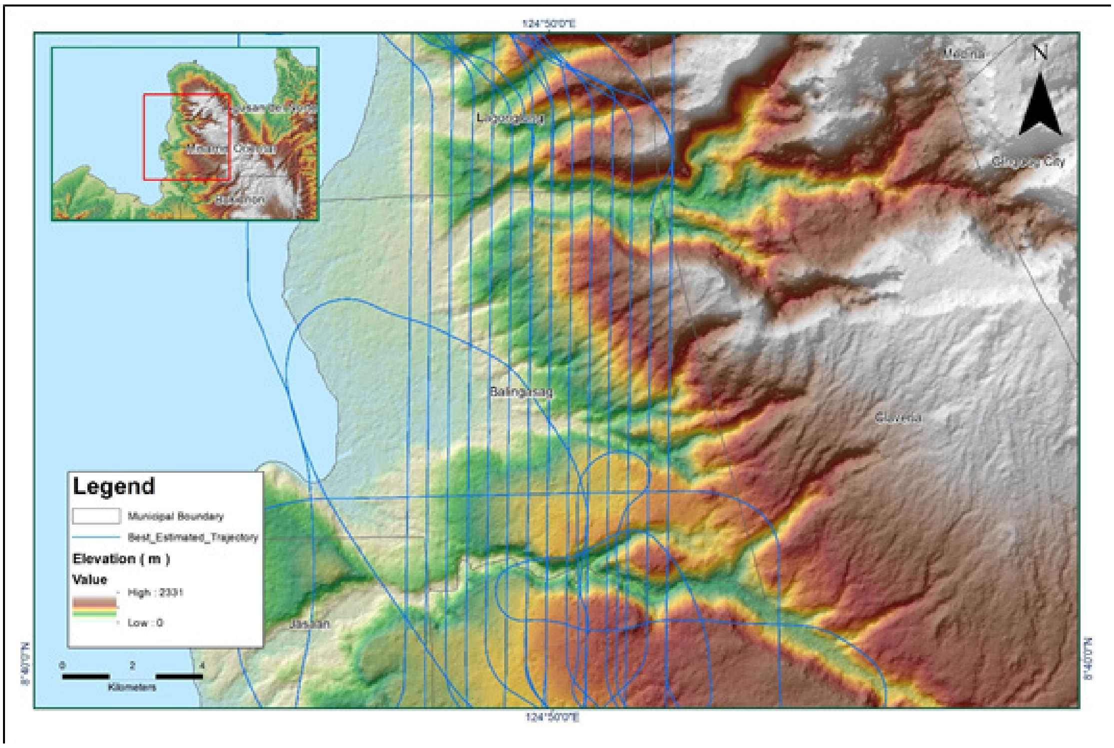


Figure 1.5.3 Best Estimated Trajectory

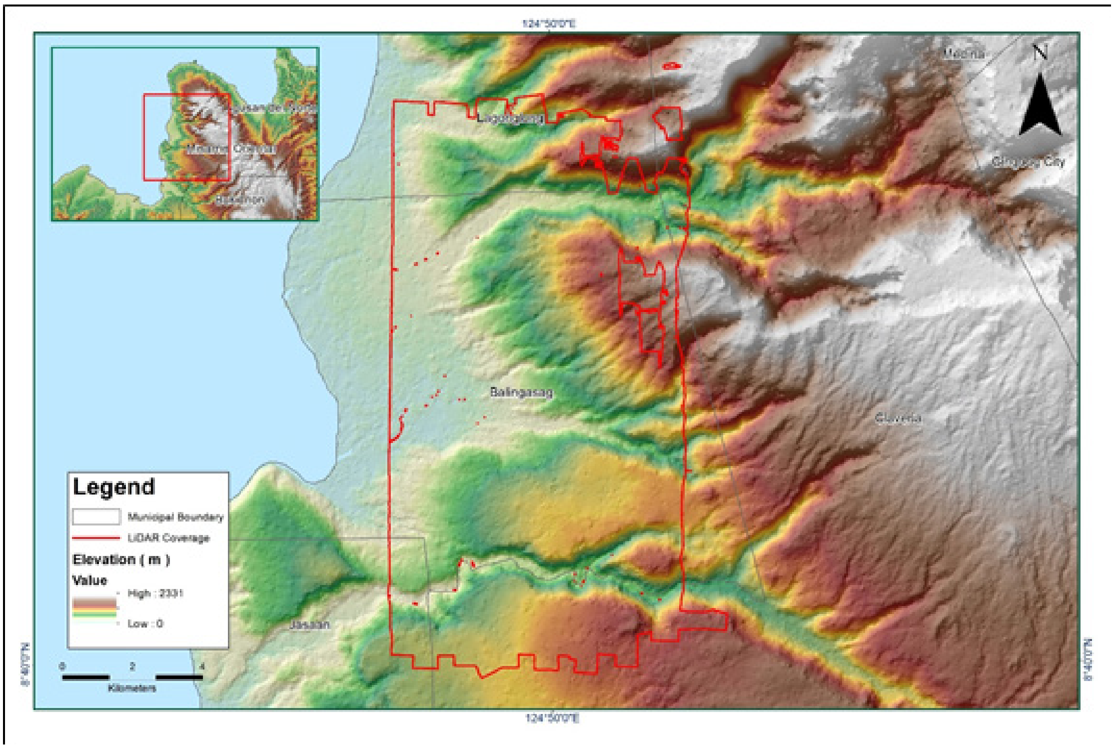


Figure 1.5.4 Coverage of LiDAR data

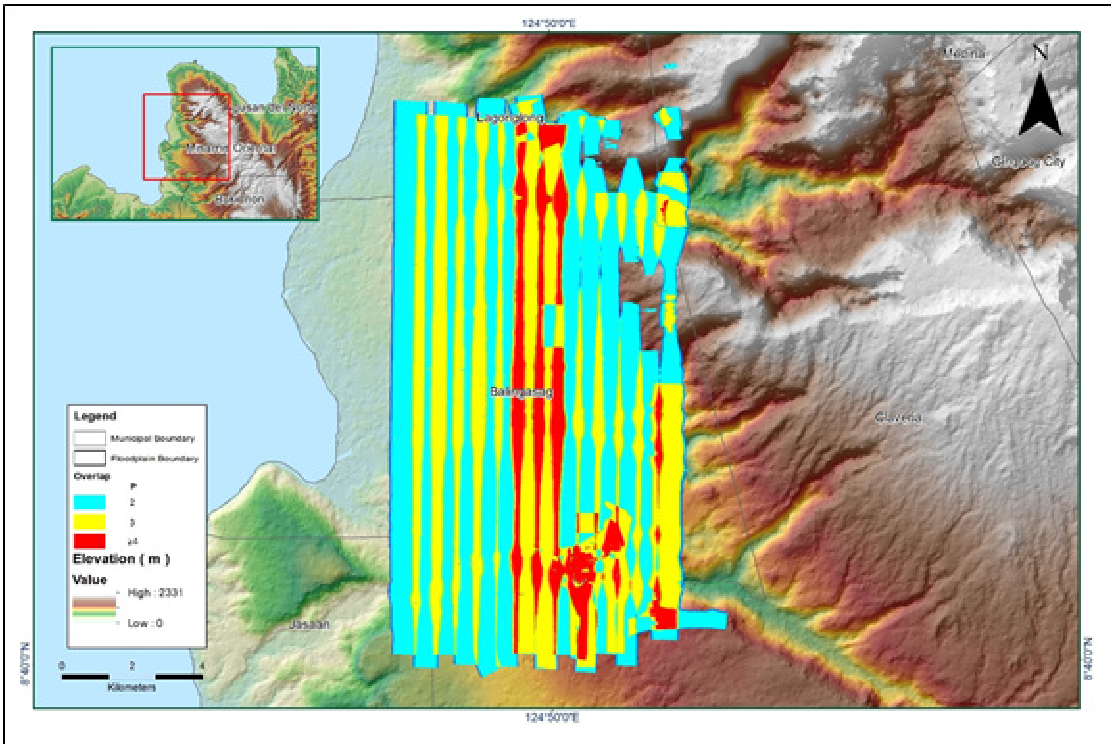


Figure 1.5.5 Image of data overlap

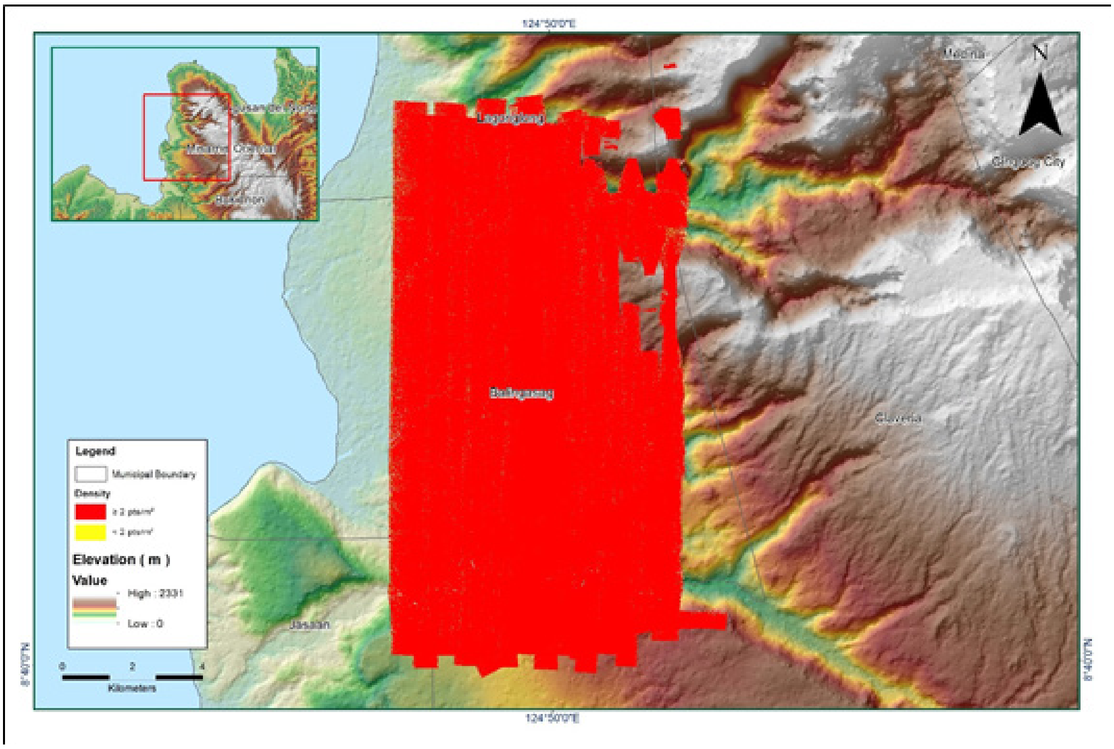


Figure 1.5.6 Density map of merged LiDAR data

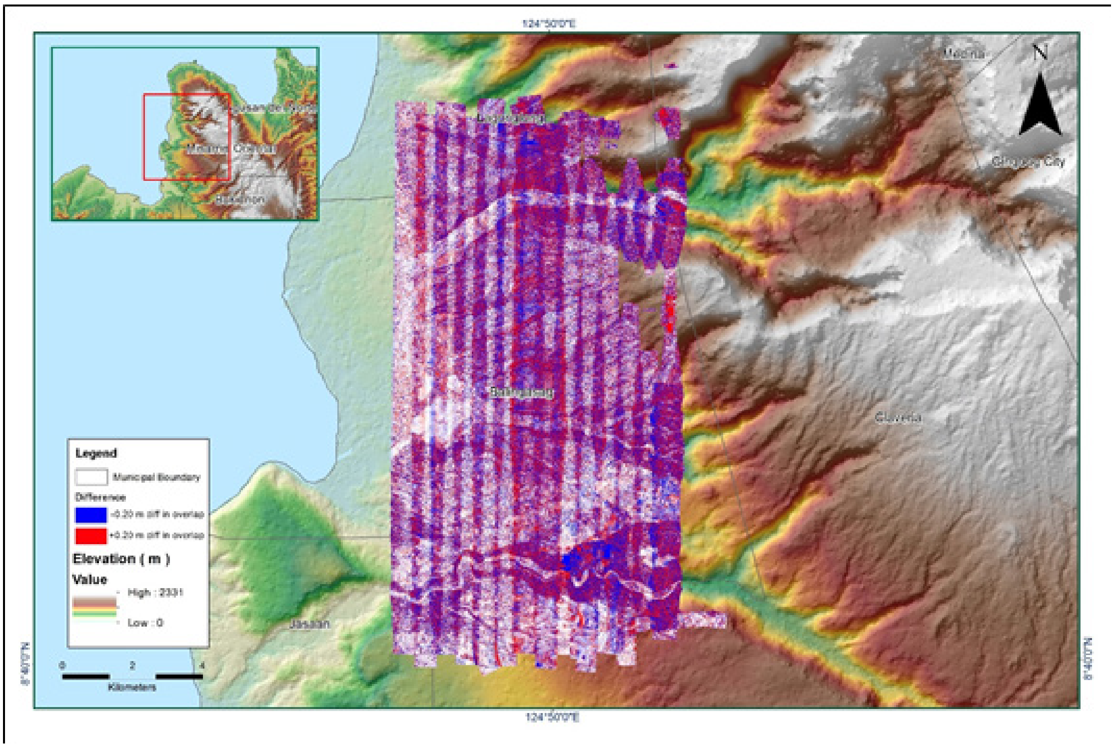


Figure 1.5.7 Elevation difference between flight lines

ANNEX 9. MUSI-MUSI 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 (m^3/s)	Recession Constant	Threshold Type	Ratio to Peak
W260	200	63.594	8	1.960875	1.4223	Discharge	0.52754	0.5	Ratio to Peak	0.01
W270	200	65.315	8	1.144875	0.8304	Discharge	0.29756	0.5	Ratio to Peak	0.01
W280	200	55.589	8	1.06845	0.77499	Discharge	0.22103	0.5	Ratio to Peak	0.01
W290	268.84	38.58	8	1.456725	1.0566	Discharge	0.34906	0.5	Ratio to Peak	0.01
W300	171.79	49.654	8	1.38255	1.0028	Discharge	0.14251	0.5	Ratio to Peak	0.01
W310	200	69.429	8	0.855375	0.62044	Discharge	0.14368	0.5	Ratio to Peak	0.01
W320	200	72.355	8	0.929625	0.67427	Discharge	0.17071	0.5	Ratio to Peak	0.01
W330	200	68.355	10	0.812025	0.58897	Discharge	0.037184	0.5	Ratio to Peak	0.01
W340	200	51.276	10	1.56735	1.1369	Discharge	0.30095	0.5	Ratio to Peak	0.01
W350	200	57.423	10	0.82515	0.59852	Discharge	0.009082	0.5	Ratio to Peak	0.01
W360	200	73.837	0.05	0.666773	0.48363	Discharge	0.013856	0.5	Ratio to Peak	0.01
W370	239.04	41.518	0	2.38365	1.7289	Discharge	0.5702	0.5	Ratio to Peak	0.01
W380	200	73.191	0.05	0.539085	0.39102	Discharge	0.043091	0.5	Ratio to Peak	0.01
W400	275	38	0.05	1.566825	1.1365	Discharge	0.25955	0.5	Ratio to Peak	0.01
W410	251.36	40.262	0.05	1.189575	0.86284	Discharge	0.10627	0.5	Ratio to Peak	0.01
W420	150	63.869	0.05	0.8613	0.62473	Discharge	0.11377	0.5	Ratio to Peak	0.01
W430	150	66.181	0.05	0.846375	0.613881	Discharge	0.18497	0.5	Ratio to Peak	0.01
W440	200	66.636	15	1.969125	1.4283	Discharge	0.76725	0.5	Ratio to Peak	0.01
W450	150	58.225	10	0.49431	0.35854	Discharge	0.017737	0.5	Ratio to Peak	0.01
W460	200	53.701	10	0.567323	0.4115	Discharge	0.059255	0.5	Ratio to Peak	0.01
W480	232.54	42.206	10	2.7744	2.0123	Discharge	0.41573	0.5	Ratio to Peak	0.01
W490	237.82	41.645	10	1.67535	1.2152	Discharge	0.18804	0.5	Ratio to Peak	0.01
W500	110	68.641	5	0.954975	0.69268	Discharge	0.21353	0.5	Ratio to Peak	0.01
W520	100	57.137	8	2.046375	1.4843	Discharge	0.095364	0.5	Ratio to Peak	0.01
W530	100	57.106	8	0.157628	0.11433	Discharge	0.000969	0.5	Ratio to Peak	0.01
W570	110	56	8	0.18675	0.13546	Discharge	0.001216	0.5	Ratio to Peak	0.01
W580	200	57.339	8	1.780125	1.2912	Discharge	0.042961	0.5	Ratio to Peak	0.01

ANNEX 10. MUSI-MUSI MODEL REACH PARAMETERS

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R 110	Automatic Fixed Interval	1328.7	0.01979	0.003	Trapezoid	10	0.5
R 150	Automatic Fixed Interval	2621	0.027471	0.003	Trapezoid	10	0.5
R 160	Automatic Fixed Interval	187.38	0.023032	0.001	Trapezoid	10	0.5
R 170	Automatic Fixed Interval	996.13	0.042782	0.003	Trapezoid	10	0.5
R 180	Automatic Fixed Interval	1849.9	0.048172	0.003	Trapezoid	10	0.5
R 190	Automatic Fixed Interval	620.37	0.006493	0.003	Trapezoid	10	0.5
R 210	Automatic Fixed Interval	2400.3	0.039656	0.001	Trapezoid	10	0.5
R 220	Automatic Fixed Interval	1821.6	0.0001	0.001	Trapezoid	10	0.5
R 50	Automatic Fixed Interval	955.66	0.00996	0.001	Trapezoid	10	0.5
R 540	Automatic Fixed Interval	95.263	0.043205	0.001	Trapezoid	10	0.5
R 60	Automatic Fixed Interval	747.49	0.00127	0.001	Trapezoid	10	0.5
R 600	Automatic Fixed Interval	1448.9	0.000827	0.001	Trapezoid	10	0.5
R 70	Automatic Fixed Interval	3954.1	0.050851	0.001	Trapezoid	10	0.5

ANNEX X. Musi-Musi-Balatucan Flood Validation Data

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
1	8.70447800000	124.78178400000	0.36	0.00	-0.36	Seniang/29Dec2014	5YR
2	8.70448400000	124.78178500000	0.36	2.00	1.64	Seniang/29Dec2014	5YR
3	8.70479752800	124.78203100000	0.77	0.70	-0.07	Seniang/29Dec2014	5YR
4	8.70636800000	124.78375800000	0.72	0.80	0.08	Seniang/29Dec2014	5YR
5	8.70752200000	124.78360800000	0.08	0.00	-0.08	Seniang/29Dec2014	5YR
6	8.70771000000	124.78367100000	0.08	0.00	-0.08	Seniang/29Dec2014	5YR
7	8.70858076800	124.78360710000	0.12	0.50	0.38	Seniang/29Dec2014	5YR
8	8.70988241400	124.78617430000	0.08	0.80	0.72	Seniang/29Dec2014	5YR
9	8.71200100000	124.78569900000	0.20	0.30	0.10	Seniang/29Dec2014	5YR
10	8.71202700100	124.78569800000	0.20	0.50	0.30	Seniang/29Dec2014	5YR
11	8.71255300000	124.78613300000	0.32	0.50	0.18	Seniang/29Dec2014	5YR
12	8.71293600000	124.78613500000	0.34	0.60	0.26	Seniang/29Dec2014	5YR
13	8.71601900000	124.78480000000	0.08	0.00	-0.08	Seniang/29Dec2014	5YR
14	8.71603200000	124.78479300000	0.08	0.00	-0.08	Seniang/29Dec2014	5YR
15	8.71615900100	124.77931800000	0.05	0.70	0.65	Seniang/29Dec2014	5YR
16	8.71666400100	124.78031400000	0.12	2.00	1.88	Seniang/29Dec2014	5YR
17	8.71668899900	124.78026900000	0.12	0.30	0.18	Seniang/29Dec2014	5YR
18	8.71673299900	124.78019200000	0.08	0.00	-0.08	Seniang/29Dec2014	5YR
19	8.71791200000	124.78055200000	0.08	0.60	0.52	Seniang/29Dec2014	5YR
20	8.71889600000	124.78054800000	0.09	0.70	0.61	Seniang/29Dec2014	5YR
21	8.72323700000	124.79423300000	0.39	1.00	0.61	Seniang/29Dec2014	5YR
22	8.72341600100	124.79637500000	0.08	1.00	0.92	Seniang/29Dec2014	5YR
23	8.72344600000	124.79702700000	0.08	0.00	-0.08	Seniang/29Dec2014	5YR
24	8.72344800000	124.79115800000	0.08	0.00	-0.08	Seniang/29Dec2014	5YR
25	8.72347499900	124.79852800000	0.08	0.80	0.72	Seniang/29Dec2014	5YR
26	8.72348100000	124.79858800000	0.08	0.70	0.62	Seniang/29Dec2014	5YR
27	8.72354700000	124.79869000000	0.08	0.80	0.72	Seniang/29Dec2014	5YR
28	8.72363900000	124.79115500000	0.08	0.00	-0.08	Seniang/29Dec2014	5YR
29	8.72365500000	124.79113400000	0.08	0.00	-0.08	Seniang/29Dec2014	5YR
30	8.72376300000	124.78881900000	0.08	0.30	0.22	Seniang/29Dec2014	5YR
31	8.72468899900	124.79878700000	0.51	0.80	0.29	Seniang/29Dec2014	5YR
32	8.72600400000	124.79145200000	0.37	0.60	0.23	Seniang/29Dec2014	5YR
33	8.72603100000	124.79146700000	0.37	0.60	0.23	Seniang/29Dec2014	5YR
34	8.73177200000	124.78982200000	0.08	0.40	0.32	Seniang/29Dec2014	5YR
35	8.73237099900	124.78848700000	0.36	0.50	0.14	Seniang/29Dec2014	5YR
36	8.73352400000	124.77913600000	0.56	0.50	-0.06	Seniang/29Dec2014	5YR
37	8.73392100000	124.77808400000	0.08	0.20	0.12	Seniang/29Dec2014	5YR
38	8.73489493600	124.79319960000	0.17	0.40	0.23	Seniang/29Dec2014	5YR
39	8.73517542000	124.79290780000	0.05	0.00	-0.05	Seniang/29Dec2014	5YR
40	8.73614900100	124.77716800000	0.08	0.00	-0.08	Seniang/29Dec2014	5YR
41	8.73654599900	124.79399300000	0.07	0.60	0.53	Seniang/29Dec2014	5YR
42	8.73673648100	124.77783920000	0.47	0.60	0.13	Seniang/29Dec2014	5YR
43	8.73904900000	124.79426800000	0.09	0.40	0.31	Seniang/29Dec2014	5YR
44	8.73928600000	124.79311800000	0.20	0.40	0.20	Seniang/29Dec2014	5YR
45	8.73950300100	124.79265400000	0.07	0.70	0.63	Seniang/29Dec2014	5YR
46	8.74079299900	124.79230900000	0.07	0.80	0.73	Seniang/29Dec2014	5YR
47	8.74100500000	124.77511700000	0.15	0.00	-0.15	Seniang/29Dec2014	5YR
48	8.74444000000	124.77322500000	0.32	0.50	0.18	Seniang/29Dec2014	5YR
49	8.74546600100	124.77475200000	0.07	0.50	0.43	Seniang/29Dec2014	5YR
50	8.74548500100	124.77476100000	0.07	0.60	0.53	Seniang/29Dec2014	5YR
51	8.74603500000	124.78060800000	0.07	0.00	-0.07	Seniang/29Dec2014	5YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
52	8.74746800000	124.77169300000	0.08	0.20	0.12	Seniang/29Dec2014	5YR
53	8.74800500100	124.77739900000	0.58	0.60	0.02	Seniang/29Dec2014	5YR
54	8.74802800000	124.77746200000	0.89	0.40	-0.49	Seniang/29Dec2014	5YR
55	8.74804200000	124.77750800000	0.89	0.40	-0.49	Seniang/29Dec2014	5YR
56	8.74806000000	124.77746500000	0.89	0.30	-0.59	Seniang/29Dec2014	5YR
57	8.74812499900	124.77735000000	0.09	0.50	0.41	Seniang/29Dec2014	5YR
58	8.74837900000	124.77760800000	0.70	0.60	-0.10	Seniang/29Dec2014	5YR
59	8.74863900000	124.78126000000	0.36	0.00	-0.36	Seniang/29Dec2014	5YR
60	8.74949700000	124.76993800000	0.06	0.60	0.54	Seniang/29Dec2014	5YR
61	8.74949800000	124.76999600000	0.06	0.60	0.54	Seniang/29Dec2014	5YR
62	8.74965400000	124.76984700000	0.06	0.50	0.44	Seniang/29Dec2014	5YR
63	8.74975400000	124.80323500000	0.27	0.40	0.13	Seniang/29Dec2014	5YR
64	8.75003000000	124.80168200000	0.07	2.50	2.43	Seniang/29Dec2014	5YR
65	8.75024000000	124.79625600000	1.58	1.00	-0.58	Seniang/29Dec2014	5YR
66	8.75027299900	124.79857600000	0.08	0.50	0.42	Seniang/29Dec2014	5YR
67	8.75031000000	124.77883100000	0.68	0.50	-0.18	Seniang/29Dec2014	5YR
68	8.75033300000	124.76934900000	0.47	0.50	0.03	Seniang/29Dec2014	5YR
69	8.75033600000	124.78118300000	2.16	0.50	-1.66	Seniang/29Dec2014	5YR
70	8.75040600000	124.79010200000	0.06	1.50	1.44	Seniang/29Dec2014	5YR
71	8.75045500000	124.78099400000	0.08	0.70	0.62	Seniang/29Dec2014	5YR
72	8.75058100000	124.78185600000	1.84	0.40	-1.44	Seniang/29Dec2014	5YR
73	8.75061100000	124.76918000000	0.08	0.60	0.52	Seniang/29Dec2014	5YR
74	8.75092500000	124.78249100000	0.76	0.80	0.04	Seniang/29Dec2014	5YR
75	8.75127600000	124.79855100000	0.15	0.80	0.65	Seniang/29Dec2014	5YR
76	8.75160900100	124.76948700000	0.39	0.60	0.21	Seniang/29Dec2014	5YR
77	8.75215700000	124.79522400000	0.05	0.00	-0.05	Seniang/29Dec2014	5YR
78	8.75265400000	124.78160700000	0.08	0.00	-0.08	Seniang/29Dec2014	5YR
79	8.75272200000	124.78117800000	0.39	0.00	-0.39	Seniang/29Dec2014	5YR
80	8.75320100000	124.78069000000	0.36	0.20	-0.16	Seniang/29Dec2014	5YR
81	8.75391900000	124.80469900000	0.59	2.50	1.91	Seniang/29Dec2014	5YR
82	8.75393300000	124.80438700000	0.36	0.80	0.44	Seniang/29Dec2014	5YR
83	8.75421500000	124.77971100000	0.17	0.40	0.23	Seniang/29Dec2014	5YR
84	8.75516000000	124.77690800000	0.08	0.60	0.52	Seniang/29Dec2014	5YR
85	8.75519800000	124.77686300000	0.08	0.70	0.62	Seniang/29Dec2014	5YR
86	8.75535400000	124.78059800000	0.08	0.00	-0.08	Seniang/29Dec2014	5YR
87	8.75582500000	124.78136000000	0.11	0.50	0.39	Seniang/29Dec2014	5YR
88	8.75625800000	124.77962100000	0.69	0.40	-0.29	Seniang/29Dec2014	5YR
89	8.75663700000	124.77893400000	0.27	0.40	0.13	Seniang/29Dec2014	5YR
90	8.75664600000	124.77891100000	0.27	0.60	0.33	Seniang/29Dec2014	5YR
91	8.75669200000	124.77894600000	0.27	0.40	0.13	Seniang/29Dec2014	5YR
92	8.75732700000	124.79893700000	0.08	0.60	0.52	Seniang/29Dec2014	5YR
93	8.75814000000	124.76604600000	0.08	0.40	0.32	Seniang/29Dec2014	5YR
94	8.75817099900	124.76602600000	0.08	0.60	0.52	Seniang/29Dec2014	5YR
95	8.76069200000	124.78031500000	0.07	0.50	0.43	Seniang/29Dec2014	5YR
96	8.76263700000	124.78527400000	0.09	0.80	0.71	Seniang/29Dec2014	5YR
97	8.76314300000	124.78140600000	0.07	0.80	0.73	Seniang/29Dec2014	5YR
98	8.76337167100	124.78137780000	0.07	0.40	0.33	Seniang/29Dec2014	5YR
99	8.76354000000	124.76489500000	0.08	0.00	-0.08	Seniang/29Dec2014	5YR
100	8.76361200000	124.76798700000	0.12	0.00	-0.12	Seniang/29Dec2014	5YR
101	8.76365400000	124.76798900000	0.12	0.60	0.48	Seniang/29Dec2014	5YR
102	8.76381000000	124.78998500000	0.08	0.70	0.62	Seniang/29Dec2014	5YR
103	8.76620660400	124.77968620000	0.34	0.40	0.06	Seniang/29Dec2014	5YR
104	8.76636700000	124.77941900000	0.12	0.60	0.48	Seniang/29Dec2014	5YR
105	8.76640300000	124.78348700000	0.08	2.00	1.92	Seniang/29Dec2014	5YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
106	8.76644900000	124.77926600000	0.29	0.80	0.51	Seniang/29Dec2014	5YR
107	8.76676800000	124.78196400000	0.08	2.00	1.92	Seniang/29Dec2014	5YR
108	8.76684799900	124.77509500000	0.53	0.30	-0.23	Seniang/29Dec2014	5YR
109	8.76691700000	124.78272000000	0.08	0.70	0.62	Seniang/29Dec2014	5YR
110	8.76692600000	124.77511600000	0.53	0.60	0.07	Seniang/29Dec2014	5YR
111	8.76719200000	124.77736000000	0.58	0.60	0.02	Seniang/29Dec2014	5YR
112	8.76726400000	124.77735000000	0.31	0.50	0.19	Seniang/29Dec2014	5YR
113	8.76805500100	124.78183500000	0.05	0.60	0.55	Seniang/29Dec2014	5YR
114	8.76876400000	124.78217800000	0.05	0.60	0.55	Seniang/29Dec2014	5YR
115	8.76948800000	124.80195900000	0.08	0.50	0.42	Seniang/29Dec2014	5YR
116	8.77244900000	124.79773700000	0.08	0.20	0.12	Seniang/29Dec2014	5YR
117	8.77258500000	124.79755200000	0.07	0.40	0.33	Seniang/29Dec2014	5YR
118	8.77293400000	124.79474000000	0.07	0.40	0.33	Seniang/29Dec2014	5YR
119	8.77351400000	124.79242500000	0.05	0.60	0.55	Seniang/29Dec2014	5YR
120	8.77374100000	124.77444300000	0.12	0.00	-0.12	Seniang/29Dec2014	5YR
121	8.77375800000	124.77784000000	0.39	0.00	-0.39	Seniang/29Dec2014	5YR
122	8.77375800000	124.77784000000	0.39	0.00	-0.39	Seniang/29Dec2014	5YR
123	8.77375800000	124.77784000000	0.39	0.00	-0.39	Seniang/29Dec2014	5YR
124	8.77375800000	124.77784000000	0.39	0.00	-0.39	Seniang/29Dec2014	5YR
125	8.77404200000	124.79136200000	0.07	0.40	0.33	Seniang/29Dec2014	5YR
126	8.77479400000	124.78404400000	0.69	1.00	0.31	Seniang/29Dec2014	5YR
127	8.77518400000	124.78429300000	0.08	0.40	0.32	Seniang/29Dec2014	5YR
128	8.77558700000	124.78435400000	0.30	0.80	0.50	Seniang/29Dec2014	5YR
129	8.77581899900	124.79800600000	0.36	0.70	0.34	Seniang/29Dec2014	5YR
130	8.77792800000	124.77775800000	0.08	0.20	0.12	Seniang/29Dec2014	5YR
131	8.78008600000	124.76986000000	0.36	0.40	0.04	Seniang/29Dec2014	5YR
132	8.78176700000	124.78593300000	0.70	0.50	-0.20	Seniang/29Dec2014	5YR
133	8.78232800000	124.78582400000	0.38	0.40	0.02	Seniang/29Dec2014	5YR
134	8.78235099900	124.78578100000	0.38	0.70	0.32	Seniang/29Dec2014	5YR
135	8.78256700000	124.77138000000	0.08	0.00	-0.08	Seniang/29Dec2014	5YR
136	8.78264400000	124.77057700000	0.06	0.70	0.64	Seniang/29Dec2014	5YR
137	8.78268699900	124.77103300000	0.08	0.00	-0.08	Seniang/29Dec2014	5YR
138	8.78320500000	124.77320900000	0.76	0.00	-0.76	Seniang/29Dec2014	5YR
139	8.78462600100	124.78699500000	0.91	1.00	0.09	Seniang/29Dec2014	5YR
140	8.78534300000	124.78662800000	0.08	0.50	0.42	Seniang/29Dec2014	5YR
141	8.78600700000	124.79688300000	1.09	0.70	-0.39	Seniang/29Dec2014	5YR
142	8.78778500000	124.78666100000	0.08	0.00	-0.08	Seniang/29Dec2014	5YR
143	8.78796800000	124.79509600000	0.74	0.60	-0.14	Seniang/29Dec2014	5YR
144	8.78927699900	124.78730700000	0.53	0.70	0.17	Seniang/29Dec2014	5YR
145	8.78929300000	124.78699600000	0.08	0.70	0.62	Seniang/29Dec2014	5YR
146	8.75165900000	124.79660000000	0.08	1.10	1.02	Seniang/29Dec2014	5YR
147	8.75575900000	124.79640000000	0.07	0.00	-0.07	Seniang/29Dec2014	5YR
148	8.75324900000	124.79310000000	0.32	0.00	-0.32	Seniang/29Dec2014	5YR
149	8.71177900000	124.77330000000	0.69	1.60	0.91	Seniang/29Dec2014	5YR
150	8.71174400000	124.77310000000	0.84	1.40	0.56	Seniang/29Dec2014	5YR
151	8.71397600000	124.77800000000	0.08	0.30	0.22	Seniang/29Dec2014	5YR
152	8.70654400000	124.78390000000	0.79	0.60	-0.19	Seniang/29Dec2014	5YR
153	8.70585500000	124.78510000000	0.96	0.30	-0.66	Seniang/29Dec2014	5YR
154	8.70596400000	124.78540000000	0.74	0.20	-0.54	Seniang/29Dec2014	5YR
155	8.71768200000	124.78400000000	0.17	1.10	0.93	Seniang/29Dec2014	5YR
156	8.72093700000	124.78560000000	0.08	0.40	0.32	Seniang/29Dec2014	5YR
157	8.72288900000	124.80150000000	0.31	0.00	-0.31	Seniang/29Dec2014	5YR
158	8.71868100000	124.79240000000	0.69	1.30	0.61	Seniang/29Dec2014	5YR
159	8.71848900000	124.79260000000	0.99	0.60	-0.39	Seniang/29Dec2014	5YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
160	8.72395300000	124.79210000000	0.47	0.00	-0.47	Seniang/29Dec2014	5YR
161	8.72365900000	124.79110000000	0.08	0.00	-0.08	Seniang/29Dec2014	5YR
162	8.72400800000	124.79040000000	1.98	0.00	-1.98	Seniang/29Dec2014	5YR
163	8.72442500000	124.79010000000	1.85	0.00	-1.85	Seniang/29Dec2014	5YR
164	8.72660400000	124.78890000000	0.08	0.90	0.82	Seniang/29Dec2014	5YR
165	8.72984300000	124.79380000000	0.08	0.00	-0.08	Seniang/29Dec2014	5YR
166	8.73057400000	124.79390000000	0.08	0.90	0.82	Seniang/29Dec2014	5YR
167	8.72830500000	124.79430000000	0.08	0.40	0.32	Seniang/29Dec2014	5YR
168	8.72621900000	124.79500000000	0.50	0.20	-0.30	Seniang/29Dec2014	5YR
169	8.72543600000	124.79400000000	0.08	0.30	0.22	Seniang/29Dec2014	5YR
170	8.73434700000	124.80700000000	0.08	0.00	-0.08	Seniang/29Dec2014	5YR
171	8.74349300000	124.80290000000	0.20	0.10	-0.10	Seniang/29Dec2014	5YR
172	8.74212500000	124.80350000000	0.18	0.00	-0.18	Seniang/29Dec2014	5YR
173	8.74219800000	124.80480000000	0.05	0.10	0.05	Seniang/29Dec2014	5YR
174	8.73345100000	124.79720000000	0.08	0.90	0.82	Seniang/29Dec2014	5YR
175	8.73298600000	124.80150000000	0.08	0.40	0.32	Seniang/29Dec2014	5YR
176	8.73580400000	124.78460000000	1.69	0.80	-0.89	Seniang/29Dec2014	5YR
177	8.73653100000	124.78500000000	1.84	0.90	-0.94	Seniang/29Dec2014	5YR
178	8.74289800000	124.78230000000	1.21	1.40	0.19	Seniang/29Dec2014	5YR
179	8.74320200000	124.78220000000	0.74	1.20	0.46	Seniang/29Dec2014	5YR
180	8.75125300000	124.78100000000	0.69	0.00	-0.69	Seniang/29Dec2014	5YR
181	8.74941600000	124.78120000000	1.50	0.40	-1.10	Seniang/29Dec2014	5YR
182	8.75219800000	124.78030000000	0.08	0.00	-0.08	Seniang/29Dec2014	5YR
183	8.71198900000	124.77320000000	0.08	0.90	0.82	Seniang/29Dec2014	5YR
184	8.71393500000	124.77800000000	0.08	1.50	1.42	Seniang/29Dec2014	5YR
185	8.72695200000	124.78830000000	0.08	0.50	0.42	Seniang/29Dec2014	5YR
186	8.73118600000	124.78190000000	0.21	0.50	0.29	Seniang/29Dec2014	5YR
187	8.72953000000	124.77900000000	0.56	1.40	0.84	Seniang/29Dec2014	5YR
188	8.73501600000	124.77770000000	0.08	0.00	-0.08	Seniang/29Dec2014	5YR
189	8.73947200000	124.77510000000	0.66	1.20	0.54	Seniang/29Dec2014	5YR
190	8.75058900000	124.76930000000	0.75	1.50	0.75	Seniang/29Dec2014	5YR
191	8.74710300000	124.77240000000	0.55	1.20	0.65	Seniang/29Dec2014	5YR
192	8.74525600000	124.77290000000	0.08	0.10	0.02	Seniang/29Dec2014	5YR
193	8.74512500000	124.77330000000	0.65	0.10	-0.55	Seniang/29Dec2014	5YR
194	8.74539900000	124.77400000000	0.56	0.50	-0.06	Seniang/29Dec2014	5YR
195	8.74832500000	124.77680000000	0.08	0.00	-0.08	Seniang/29Dec2014	5YR
196	8.74771600000	124.77710000000	0.21	1.20	0.99	Seniang/29Dec2014	5YR
197	8.74779000000	124.77750000000	1.48	1.20	-0.28	Seniang/29Dec2014	5YR
198	8.74879600000	124.77830000000	0.34	0.00	-0.34	Seniang/29Dec2014	5YR
199	8.77982900000	124.76980000000	0.44	1.20	0.76	Seniang/29Dec2014	5YR
200	8.76756500000	124.76850000000	0.08	0.10	0.02	Seniang/29Dec2014	5YR
201	8.76189800000	124.76780000000	1.83	2.00	0.17	Seniang/29Dec2014	5YR
202	8.76351700000	124.77070000000	2.06	2.00	-0.06	Seniang/29Dec2014	5YR
203	8.76275500000	124.77220000000	2.11	2.00	-0.11	Seniang/29Dec2014	5YR
204	8.76608100000	124.78290000000	0.66	1.20	0.54	Seniang/29Dec2014	5YR
205	8.76467600000	124.78290000000	0.58	1.20	0.62	Seniang/29Dec2014	5YR
206	8.76489800000	124.78320000000	0.97	0.10	-0.87	Seniang/29Dec2014	5YR
207	8.78563500000	124.78670000000	1.00	0.10	-0.90	Seniang/29Dec2014	5YR
208	8.78598900000	124.79660000000	0.74	0.30	-0.44	Seniang/29Dec2014	5YR
209	8.78710700000	124.79620000000	0.12	0.50	0.38	Seniang/29Dec2014	5YR
210	8.78851100000	124.79510000000	1.04	0.50	-0.54	Seniang/29Dec2014	5YR
211	8.77520300000	124.78430000000	0.08	0.00	-0.08	Seniang/29Dec2014	5YR
212	8.77583100000	124.79800000000	0.36	0.50	0.14	Seniang/29Dec2014	5YR
213	8.75254500000	124.78090000000	0.52	0.00	-0.52	Seniang/29Dec2014	5YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
214	8.75262000000	124.78090000000	0.52	0.00	-0.52	Seniang/29Dec2014	5YR
215	8.75068300000	124.78220000000	1.58	0.50	-1.08	Seniang/29Dec2014	5YR
216	8.75068600000	124.78260000000	1.39	0.50	-0.89	Seniang/29Dec2014	5YR
217	8.75031600000	124.78210000000	1.77	0.00	-1.77	Seniang/29Dec2014	5YR
218	8.75037800000	124.78160000000	2.06	0.00	-2.06	Seniang/29Dec2014	5YR
219	8.75068200000	124.78150000000	2.12	0.00	-2.12	Seniang/29Dec2014	5YR
220	8.75076800000	124.78110000000	1.21	0.00	-1.21	Seniang/29Dec2014	5YR
221	8.74992900000	124.78110000000	0.08	0.90	0.82	Seniang/29Dec2014	5YR

ANNEX 12. EDUCATIONAL INSTITUTIONS AFFECTED IN MUSI-MUSI FLOOD PLAIN

Misamis Oriental				
Balingasag				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Baliwagan Elementary School	Baliwagan		Low	Low
Baliwagan High School	Baliwagan			
Waterfall Elementary School	Baliwagan		Low	Low
Central School	Barangay 4			Low
Holy Child's School	Barangay 4			
School	Barangay 5			
St. Rita's College	Barangay 6	Low	Low	Medium
Binitinan Elementary School	Binitinan	Low	Low	Low
Elementary School	Binitinan			
Baliwagan Elementary School	Blanco			
Blanco Elementary School	Blanco	Medium	Medium	Medium
Dumarait Elementary School	Dumarait			
Talusan Day Care Center	Talusan			
Talusan Elementary School	Talusan			Low
Waterfall Day Care Center	Waterfall			

ANNEX 13. MEDICAL INSTITUTIONS AFFECTED IN MUSI-MUSI FLOOD

Misamis Oriental				
Balingasag				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Baliwagan Health Center	Baliwagan			Low
Health Center	Barangay 6			
Barangay Health Center	Binitinan			
Barangay Health Center	Blanco			Low
Barangay Health Center	Dumarait			
Waterfall Health Center	Waterfall			