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

LiDAR Surveys and Flood Mapping of Guinabasan River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
University of San Carlos

APRIL 2017

Published by the UP Training Center for Applied Geodesy and Photogrammetry (TCAGP)
College of Engineering
University of the Philippines – Diliman
Quezon City
1101 PHILIPPINES

This research project is supported by the Department of Science and Technology (DOST) as part of its Grants-in-Aid Program and is to be cited as:

E. C. Paringit and R. S. Otadoy (eds.) (2017), LiDAR Surveys and Flood Mapping of Guinabasan River, Quezon City: University of the Philippines Training Center for Applied Geodesy and Photogrammetry-170pp.

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National Library of the Philippines
ISBN: 978-621-430-179-9

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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 GUINABASAN RIVER

Enrico C. Paringit, Dr. Eng., Dr. Roland Emerito S. Otadoy, and Engr. Aure Flo Oraya

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 in 2014" or Phil-LiDAR 1, supported by the Department of Science and Technology (DOST) Grants-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) available separately.

The implementing partner university for the Phil-LiDAR 1 Program is the University of San Carlos (USC). USC 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 17 river basins in the Central Visayas Region. The university is located in Cebu City in the province of Cebu.

1.2 Overview of the Guinabasan River Basin

Guinabasan River Basin covers two (2) Municipalities in Cebu, namely: Asturias and Tuburan, as well as the City of Danao. The DENR- RCBO identified the basin to have a drainage area of 120 km2 and an estimated 72 million cubic meter (MCM) annual run-off. The catchment is located in the central part of the Province of Cebu. It is classified under Type III weather in the Corona climate classification with dry season from November to April and wet season for the other months of the year. Asturias is a 3rd income class municipality with a population of 47,857. Tuburan is a 2nd income class municipality with a population of 63,866.

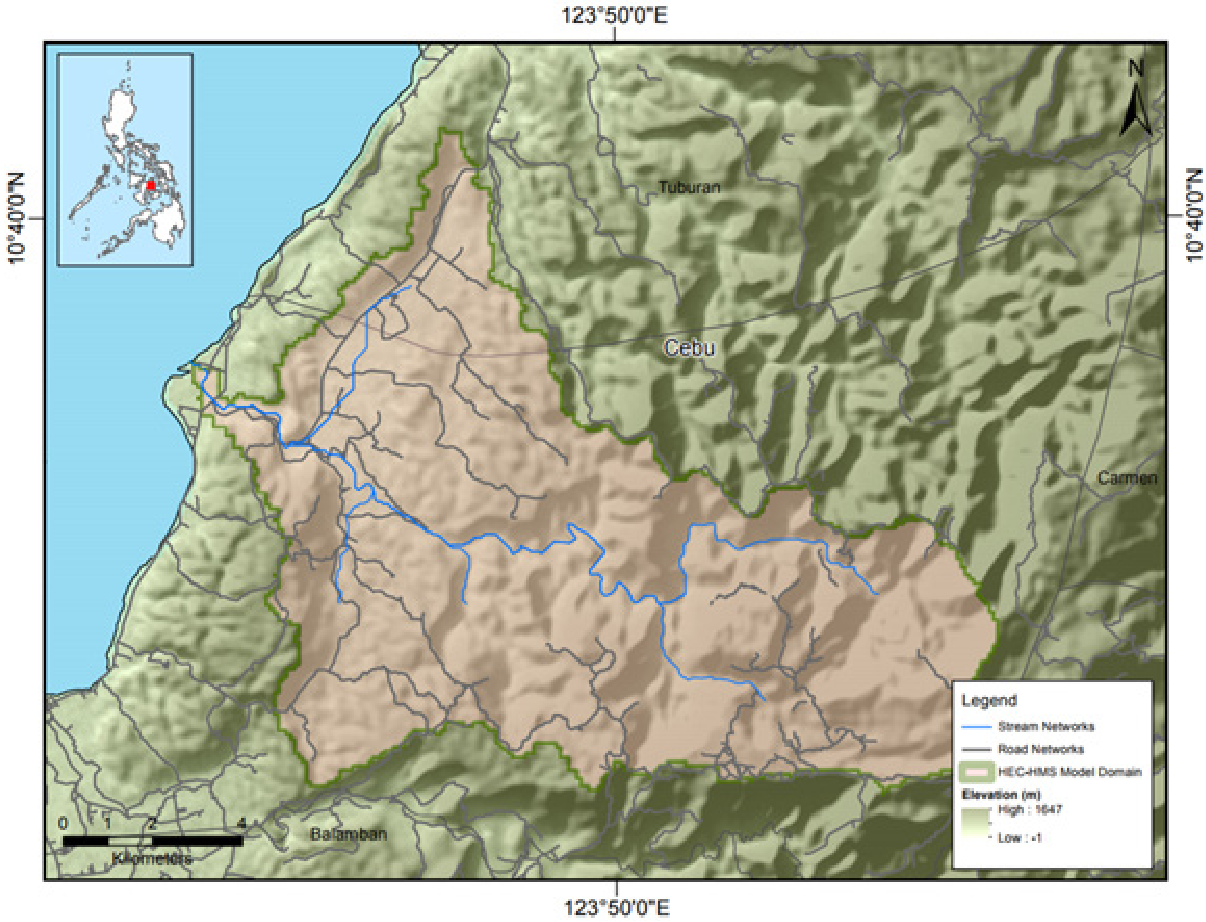

Figure 1. Map of Guinabasan River Basin (in brown).

Its main stream, Guinabasan River, passes along Barangays Agtugop, Bog-O, Bago, New Bago, Santa Lucia, and Tubigagmanok, all within the Municipality of Asturias. It is part of the river systems in Central Visayas Region. There is a total of 12,384 people residing within the immediate vicinity of the river which is distributed among six (6) barangays, namely: Agtugop, Bago, Bog-O, New Bago, Tubigagmanok, and Santa Lucia (NSO, 2010). Most of the livelihood of the population in Western Cebu are the extraction, consumption, and management of coastal and marine resources found in their province. Recently, Typhoon Seniang, brought about immense flooding and landslides to Municipalities such as Sibonga, Ronda, and Dumanjung in Cebu in December 2014.

CHAPTER 2: LIDAR DATA ACQUISITION OF THE GUINABASAN 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).

2.1 Flight Plans

To initiate the LiDAR acquisition survey of the Guinabasan floodplain, the Data Acquisition Component (DAC) created flight plans within the delineated priority area for Guinabasan Floodplain in Cebu. These flight missions were planned for 16 lines and ran for at most four and a half hours (4.5) including take-off, landing and turning time. The flight planning parameters for the LiDAR system are outlined in Table 1. Figure 2 shows the flight plan for Guinabasan floodplain survey.

Table 1. Flight planning parameters for the 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)
BLK36A	1200, 1000	30	50	200	30	130	5
BLK36B	1000	30	50	200	30	130	5
BLK36C	1200	30	50	200	30	130	5
BLK36D	1200	30	50	200	30	130	5
BLK36A	1200, 1000	30	50	200	30	130	5

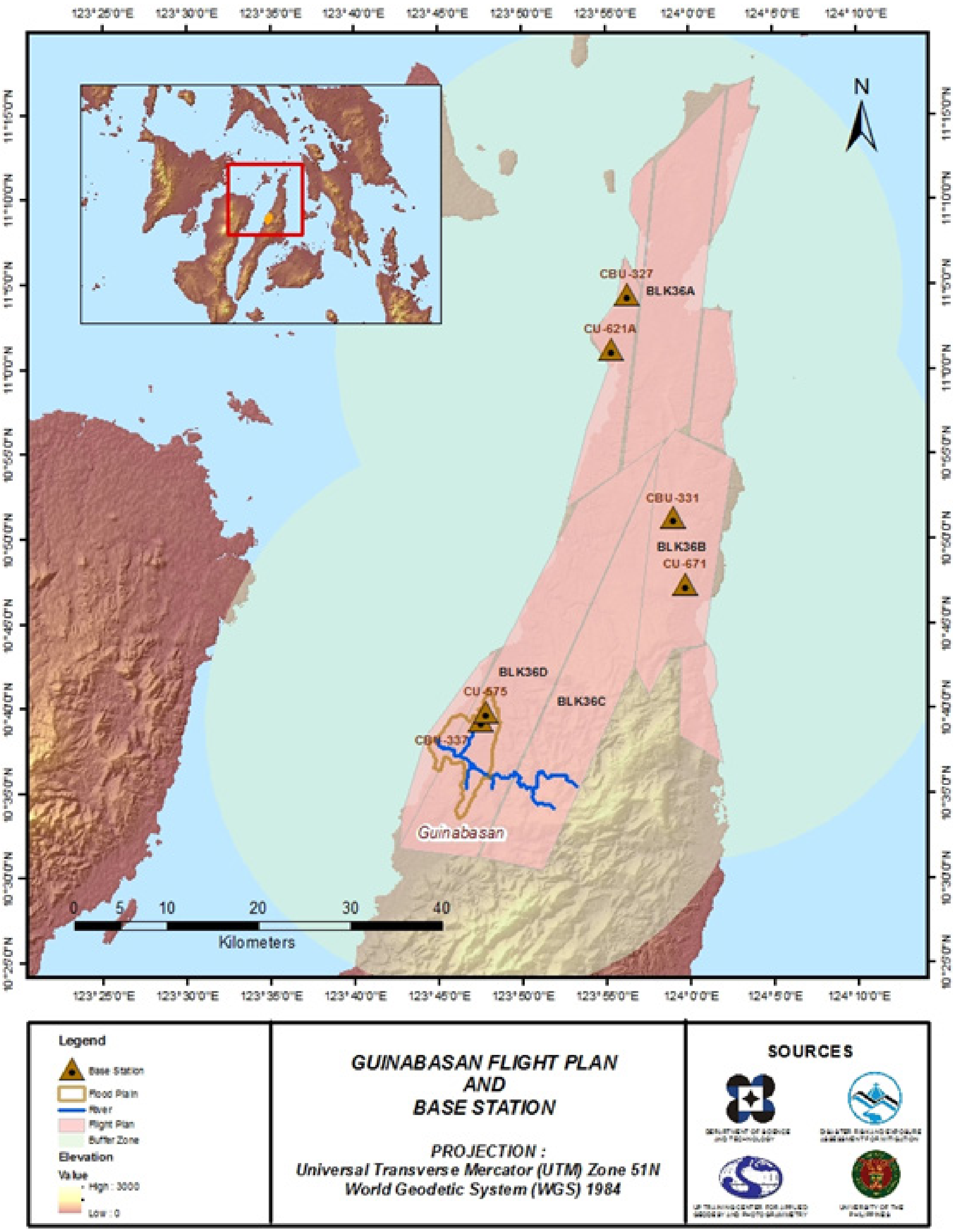


Figure 2. Flight plans and base stations used for Guinabasan floodplain using Pegasus LiDAR system.

2.2 Ground Base Stations

The project team was able to recover three (3) NAMRIA horizontal ground control point: CBU-327, CBU-331, and CBU-337 which are of first (2nd) order accuracy. ree (3) NAMRIA benchmarks were also recovered: CU-575, CU-621A and CU-671 which are of first (1st) order accuracy. These benchmarks were used as vertical reference points and were also established as ground control points.

The certifications for the base stations are found in Annex 2 while the baseline processing reports for the established control points are found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey on July 18, July 28, and July 30, 2014. Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 882 and SPS 852. Flight plans and location of base stations used during the aerial LiDAR acquisition in Guinabasan floodplain are shown in Figure 2.

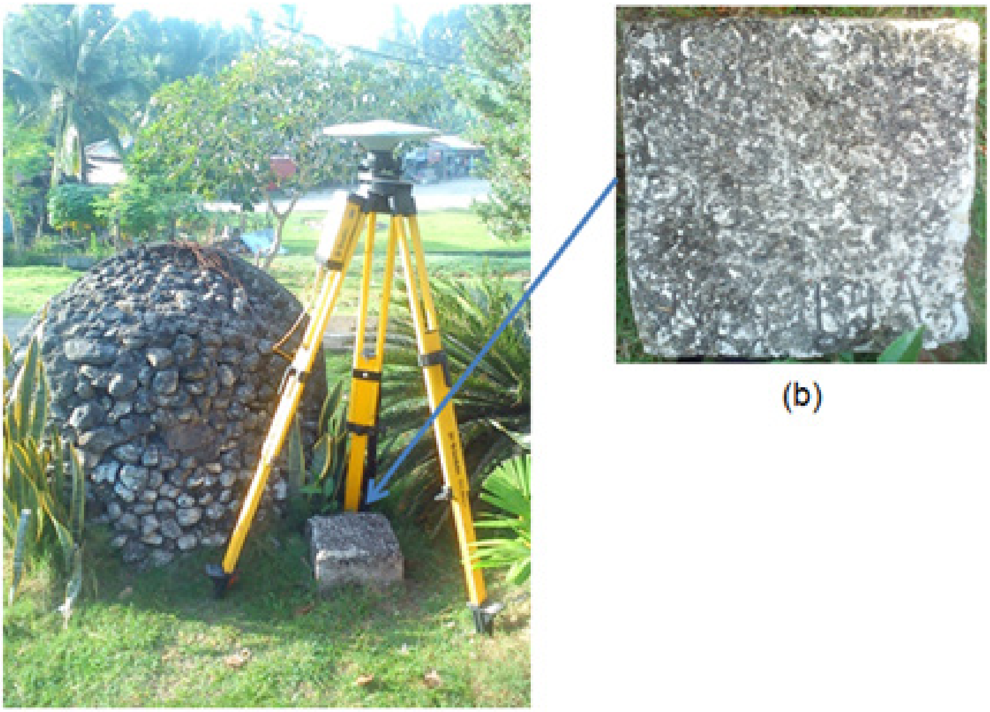
The succeeding sections depict the sets of reference points, control stations and established points, and the ground control points for the entire Guinabasan Floodplain LiDAR Survey. Figure 3 to Figure 8 show the recovered NAMRIA reference points within the area of the floodplain, while Table 2 to Table 7 show the details about the following NAMRIA control stations and established points. Table 8, on the other hand, shows the list of all ground control points occupied during the acquisition together with the corresponding dates of utilization.

(a) (b)

Figure 3. GPS set-up over CBU-327 on a bridge adjacent to San Remigio Cemetery in Barangay Poblacion, San Remigio, Cebu (a) and NAMRIA reference point CBU-327 (b) as recovered by the field team.

Table 2. Details of the recovered NAMRIA horizontal control point CBU-327 used as base station for the LiDAR acquisition.

Station Name	CBU-327	
Order of Accuracy	2nd Order	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11° 4' 30.20546" 123° 56' 10.33433" 3.541 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	602,289.857 meters 1,224,791.193 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 4' 25.88934" North 123° 56' 15.51412" East 63.574 meters
Grid Coordinates, Universal Transverse Mercator Zone 52 North (UTM 52N PRS 92)	Easting Northing	602,254.06 meters 1,224,362.49 meters



(a) (b)

Figure 4. GPS set-up over CBU-331 beside the Grotto in Barangay Sagay, Borbon, Cebu (a) and NAMRIA reference point CBU-331 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point CBU-331 used as base station for the LiDAR acquisition.

Station Name	CBU-331	
Order of Accuracy	2nd Order	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 51' 20.15600" 123° 58' 52.36488" 114.16 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 51' 15.89918" North 123° 58' 57.56330" East 175.074 meters
Grid Coordinates, Universal Transverse Mercator Zone 52 North (UTM 52N PRS 92)	Easting Northing	607,249.46 meters 1,200,110.89 meters

(a) (b)

Figure 5. GPS set-up over CBU-337 outside Colonia Central School in Barangay Colonia, Tuburan, Cebu (a) and NAMRIA reference point CBU-337 (b) as recovered by the field team.

Table 4.Details of the recovered NAMRIA horizontal control point CBU-337 used as base station for the LiDAR data acquisition.

Station Name	CBU-337	
Order of Accuracy	2nd Order	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 39' 23.68236" 123° 47' 24.66142" 29.987 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	586,455.051 meters 1,178,456.495 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 39' 19.45980" 123° 47' 29.88199" 90.660 meters
Grid Coordinates, Universal Transverse Mercator Zone 52 North (UTM 52N PRS 92)	Easting Northing	586,424.79 meters 1,178,044.01 meters

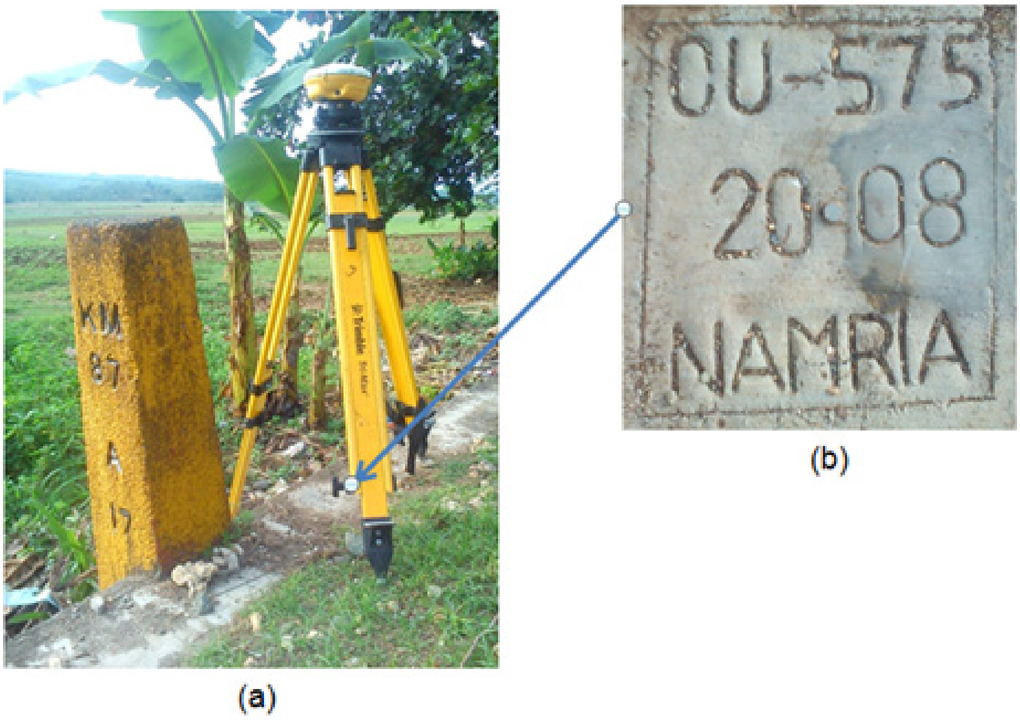
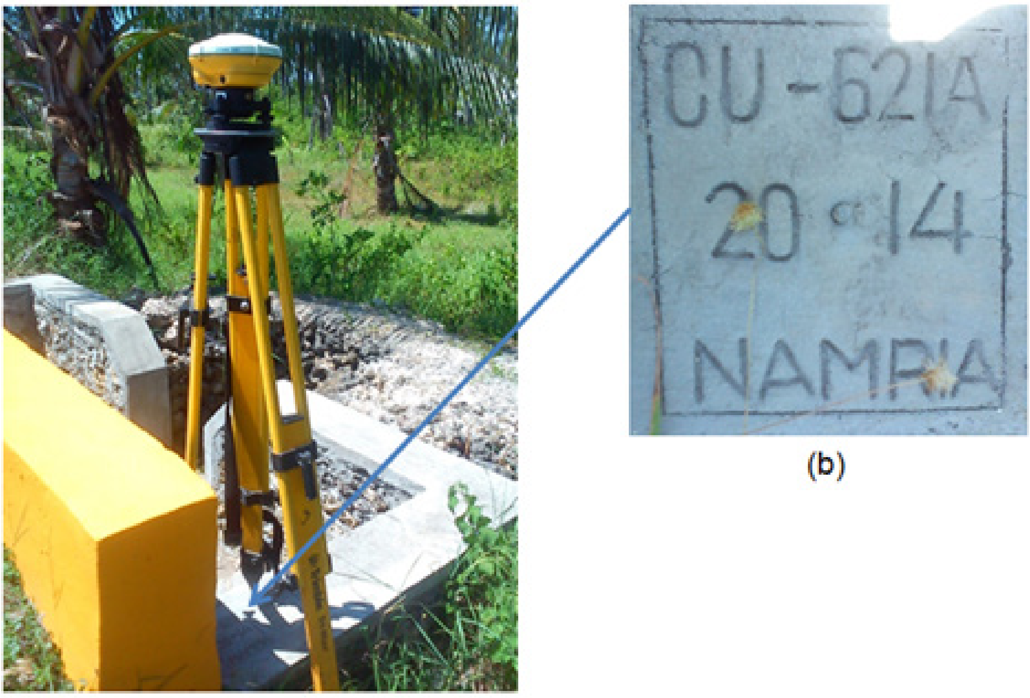


Figure 6. GPS set-up over CU-575 at the right side of the National Road going to Tuburan Town Proper, near KM Post No. 87 in Barangay Colonia, Tuburan, Cebu (a) and NAMRIA reference point CU-575 (b) as recovered by the field team.

Table 5. Details of the recovered NAMRIA horizontal control point CU-575 used as base station for the LiDAR data acquisition.

Station Name	CU-575	
Order of Accuracy	2nd Order	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 39’ 54.85976” 123° 47’ 43.61537” 28.568 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	587,058.76 meters 1,179,426.958 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 39’ 50.63546” North 123° 47’ 48.83243” East 89.233 meters
Grid Coordinates, Universal Transverse Mercator Zone 52 North (UTM 52N PRS 92)	Easting Northing	586,498.1305 meters 1,179,003.08 meters



(a) (b)

Figure 7. GPS set-up over CU-621A located 20 m NE of KM Post No. 133 and beside the head wall of the box culvert in Barangay Tambongon, San Remigio, Cebu (a) and NAMRIA reference point CU-621A (b) as recovered by the field team.

Table 6. Details of the recovered NAMRIA horizontal control point CU-621A used as base station for the LiDAR data acquisition.

Station Name	CU-621A	
Order of Accuracy	2nd Order	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11° 01’ 11.40721” 123° 55’ 20.28470” 15.6595 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	600,817.462 meters 1,218,689.898 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 01’ 07.10388” North 123° 55’ 25.46947” East 75.791 meters
Grid Coordinates, Universal Transverse Mercator Zone 52 North (UTM 52N PRS 92)	Easting Northing	600,754.2895 meters 1,218,251.478 meters

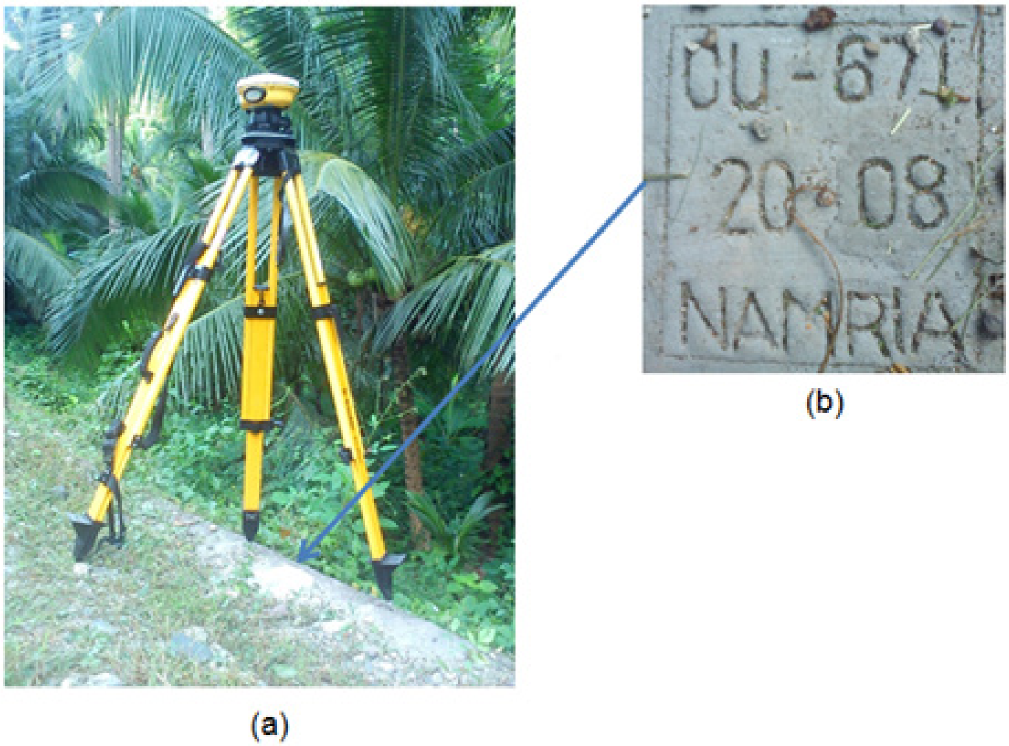


Figure 8. GPS set-up over CU-671 at the right side of the National Road going to Argao Town Proper in Barangay Liki, Sogod, Cebu (a) and NAMRIA reference point CU-671 (b) as recovered by the field team.

Table 7. Details of the recovered NAMRIA horizontal control point CU-671 used as base station for the LiDAR data acquisition.

Station Name	CU-671	
Order of Accuracy	2nd Order	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 47’ 20.40000” 123° 59’ 42.04388” 113.6205 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	608,849.434 m 1,193,181.364 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 47’ 16.16154” North 123° 59’ 47.24832” East 174.484 m
Grid Coordinates, Universal Transverse Mercator Zone 52 North (UTM 52N PRS 92)	Easting Northing	608,781.9745 m 1,192,751.406 m

Table 8. Ground control points used during the LiDAR data acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
July 23, 2014	1747P	1BLK36A204B	CBU-327 and CU-621A
July 24, 2014	1749P	1BLK36AS205A	CBU-327 and CU-621A
August 6, 2014	1801P	1BLK36D218A	CBU-337 and CU-575
August 6, 2014	1803P	1BLK36C218B	CBU-337 and CU-575
August 7, 2014	1805P	1BLK36B219A	CBU-331 and CU-671
August 11, 2014	1821P	1BLK36AS223A	CBU-327 and CU-621A
August 12, 2014	1825P	1BLK36ABC224A	CBU-331 and CU-671

2.3 Flight Missions

Seven (7) missions were conducted to complete the LiDAR data acquisition in Guinabasan floodplain, for a total of twenty-five hours and thirty-five minutes (25+35) of flying time for RP-C9022 (See Annex 6). All missions were acquired using Pegasus LiDAR system. As shown below, the total area of actual coverage per mission and the corresponding flying hours are depicted in Table 9, while the actual parameters used during the LiDAR data acquisition are presented in Table 10.

Table 9. Flight missions for LiDAR data acquisition in Guinabasan floodplain.

Date Surveyed	Flight Number	Flight Plan Area (km2)	Surveyed Area (km2)	Area Surveyed within the Floodplain (km2)	Area Surveyed Outside the Floodplain (km2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
July 23, 2014	1747P	233.03	258.43	NA	258.43	NA	3	35
July 24, 2014	1749P	49.22	96.59	NA	96.59	NA	3	7
August 6, 2014	1801P	316.09	347.35	45.21	302.14	NA	4	18
August 6, 2014	**1803P**	257.90	306.81	NA	306.81	NA	3	35
August 7, 2014	**1805P**	183.55	318.85	NA	318.85	NA	4	23
August 11, 2014	1821P	233.03	170.46	NA	170.46	NA	3	40
August 12, 2014	1825P	183.55	129.83	NA	129.83	NA	2	57
TOTAL		1456.37	625.63	32.63	590.98	NA	25	35

Table 10. 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)
BLK36A	1200, 1000	30	50	200	30	130	5
BLK36B	1000	30	50	200	30	130	5
BLK36C	1200	30	50	200	30	130	5
BLK36D	1200	30	50	200	30	130	5

2.4 Survey Coverage

This certain LiDAR acquisition survey covered the Guinabasan floodplain (See Annex 7). It is located in the province of Cebu with majority of the floodplain situated within the municipalities Asturias and Tuburan. Municipality of Tabuelan 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 11. Figure 9, on the other hand, shows the actual coverage of the LiDAR acquisition for the Guinabasan floodplain.

Table 11. List of municipalities and cities surveyed during Guinabasan floodplain LiDAR survey.

Province	Municipality/City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Cebu	Asturias	252.52	188.42	74.62%
	Balamban	236.29	51.5	21.80%
	Bogo City	86.17	86.13	99.95%
	Borbon	**91.56**	**91.54**	**99.98%**
	Carmen	**58.44**	**1.62**	**2.77%**
	Catmon	**92.99**	**58.79**	**63.22%**
	Daanbantayan	**94.98**	**90.95**	**95.76%**
	Medellin	**75.7**	**73.34**	**96.88%**
	San Remigio	**97.13**	**97.09**	**99.96%**
	Sogod	75.1	75.09	99.99%
	Tabogon	91.49	91.46	99.97%
	Tabuelan	85.94	85.94	100%
	Tuburan	242.78	241.44	99.45%
Total		1581.09	1233.31	78%

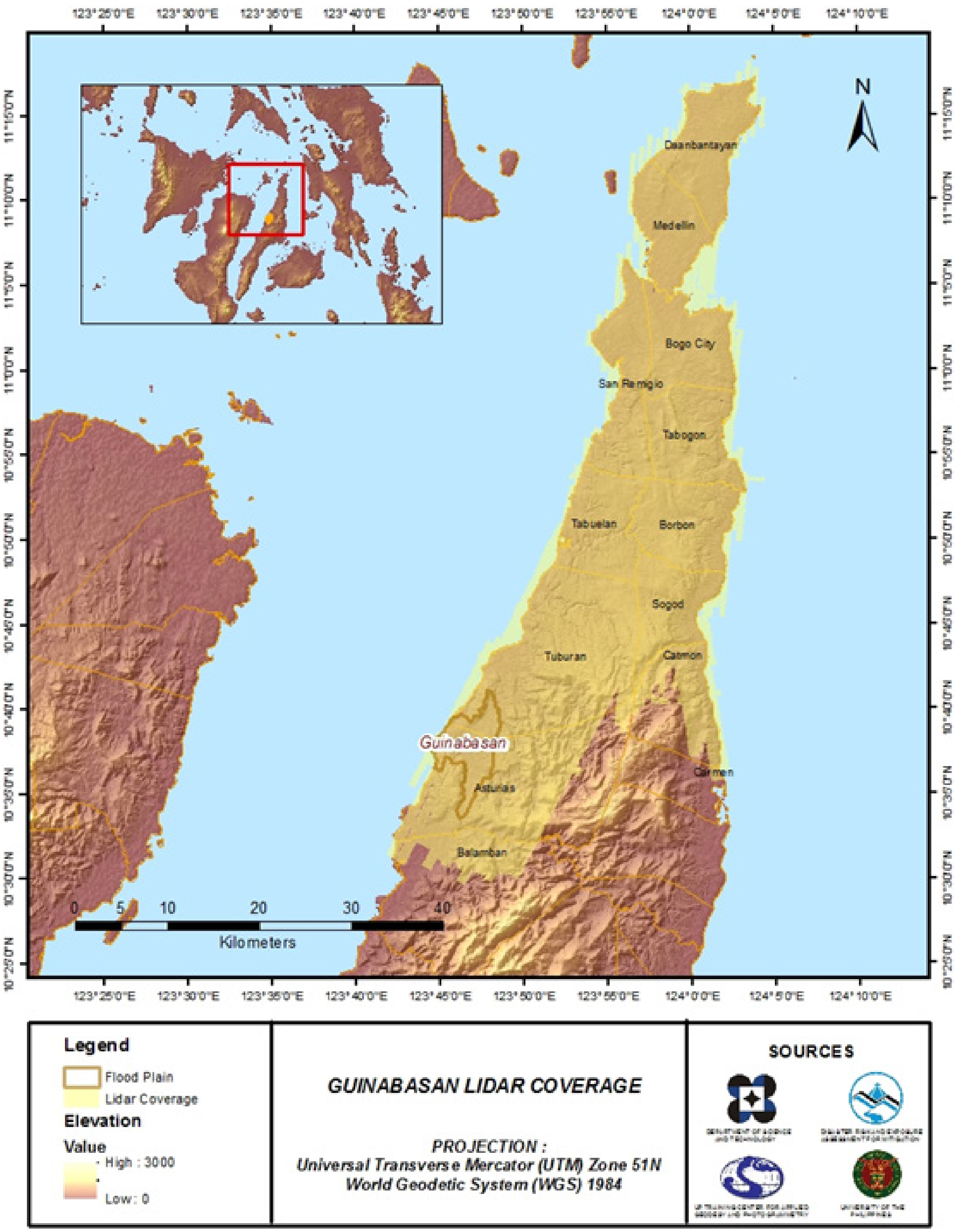


Figure 9. Actual LiDAR survey coverage for Guinabasan floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE GUINABASAN FLOODPLAIN

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

3.1 Overview of the LIDAR Data Pre-Processing

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

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

These processes are summarized in the flowchart shown in Figure 10.

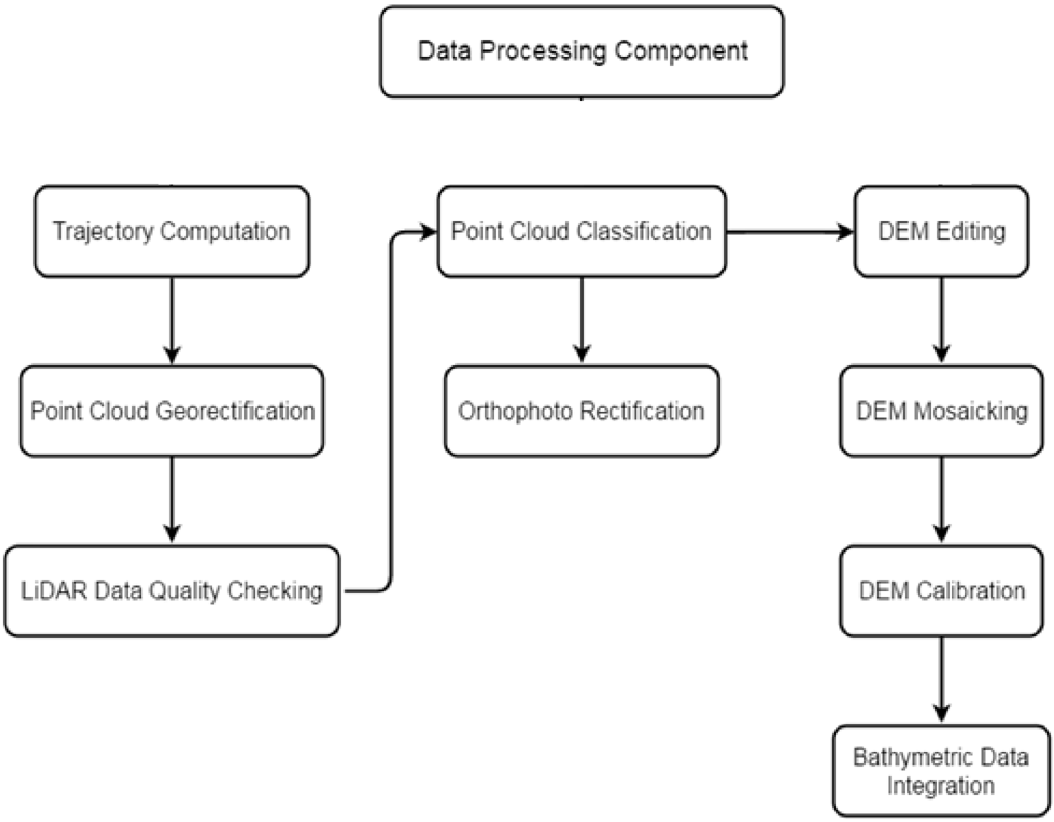

Figure 10. Schematic diagram for the data pre-processing.

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions of the Guinabasan Floodplain can be found in Annex 5. The missions flown during the first survey in December 2013 and second survey on June 2014 utilized the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system over Guinabasan, Cebu.

The Data Acquisition Component (DAC) transferred a total of 138.6 Gigabytes of Range data, 1.27 Gigabytes of POS data, 42.08 Megabytes of GPS base station data, and no raw image data to the data server on August 4, 2014 for the first survey which was verified for accuracy and completeness by the DPPC. The whole dataset for the Guinabasan Floodplain was fully transferred on September 2014, as indicated on the Data Transfer Sheets for the Guinabasan floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for Flight 1825P, one of the Guinabasan flights, which is the North, East, and Down position RMSE values are shown in Figure 11Figure 11. The x-axis corresponds to the time of the flight, which was measured by the number of seconds from the midnight of the start of the GPS week, which fell on the date and time of June 20, 2014 00:00AM. The y-axis, on the other hand, represents the RMSE value for that particular position.

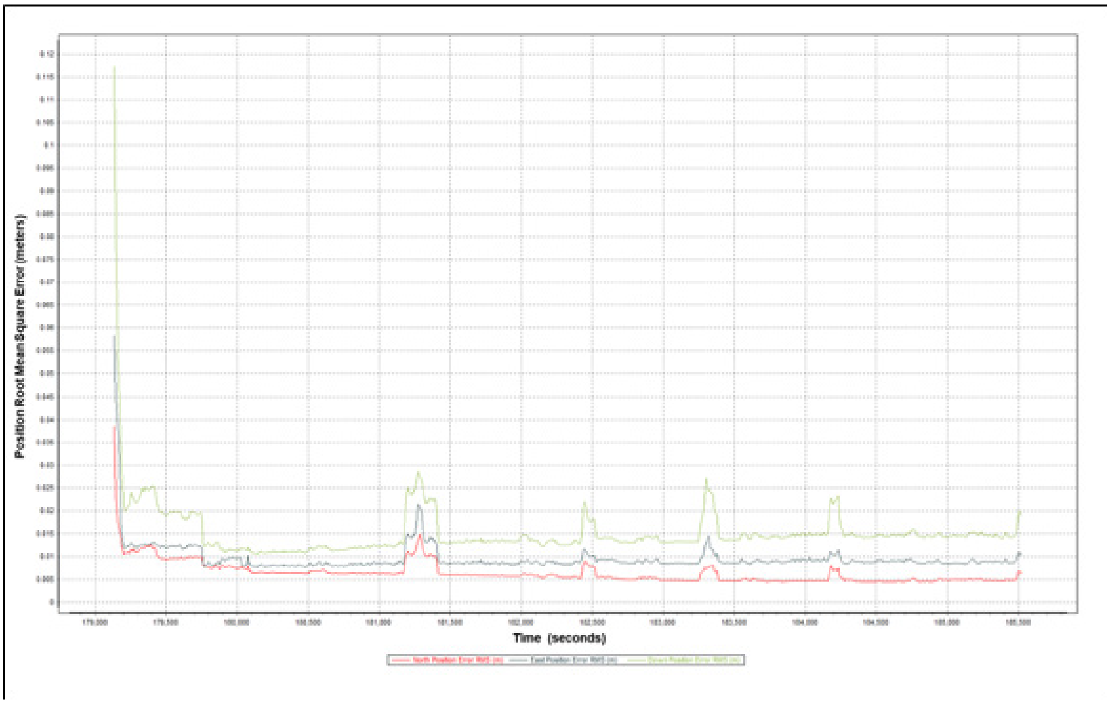

Figure 11. Smoothed Performance Metrics of Guinabasan Flight 1825.

The time of flight was from 179,000 seconds to 185,500 seconds, which corresponds to afternoon of August 12, 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 minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 12 shows that the North position RMSE peaks at 3.00 centimeter, the East position RMSE peaks at 3.50 centimeters, and the Down position RMSE peaks at 6.20 centimeters, which are within the prescribed accuracies described in the methodology.

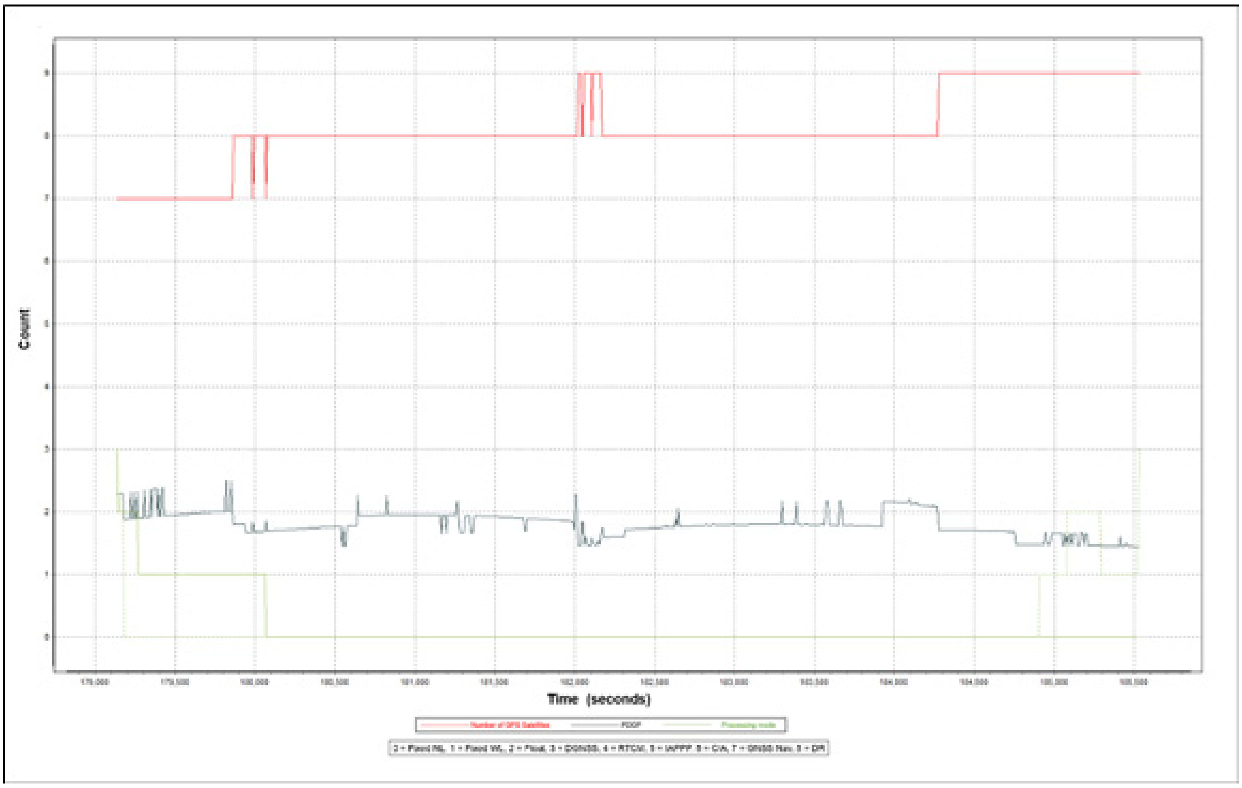

Figure 12. Solution Status Parameters of Guinabasan Flight

The Solution Status parameters, which indicate the number of GPS satellites; Positional Dilution of Precision (PDOP); and the GPS processing mode used for Guinabasan Flight 1825P are shown in Figure 12. For the Solution Status parameters, the figure above signifies that the number of satellites utilized and tracked during the acquisition were between 7 and 9, not going lower than 7. Similarly, the PDOP value did not go above the value of 3, which indicates optimal GPS geometry. The processing mode also remained at 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 the POSPAC MMS. Fundamentally, 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 Guinabasan flights is shown in Figure 13.

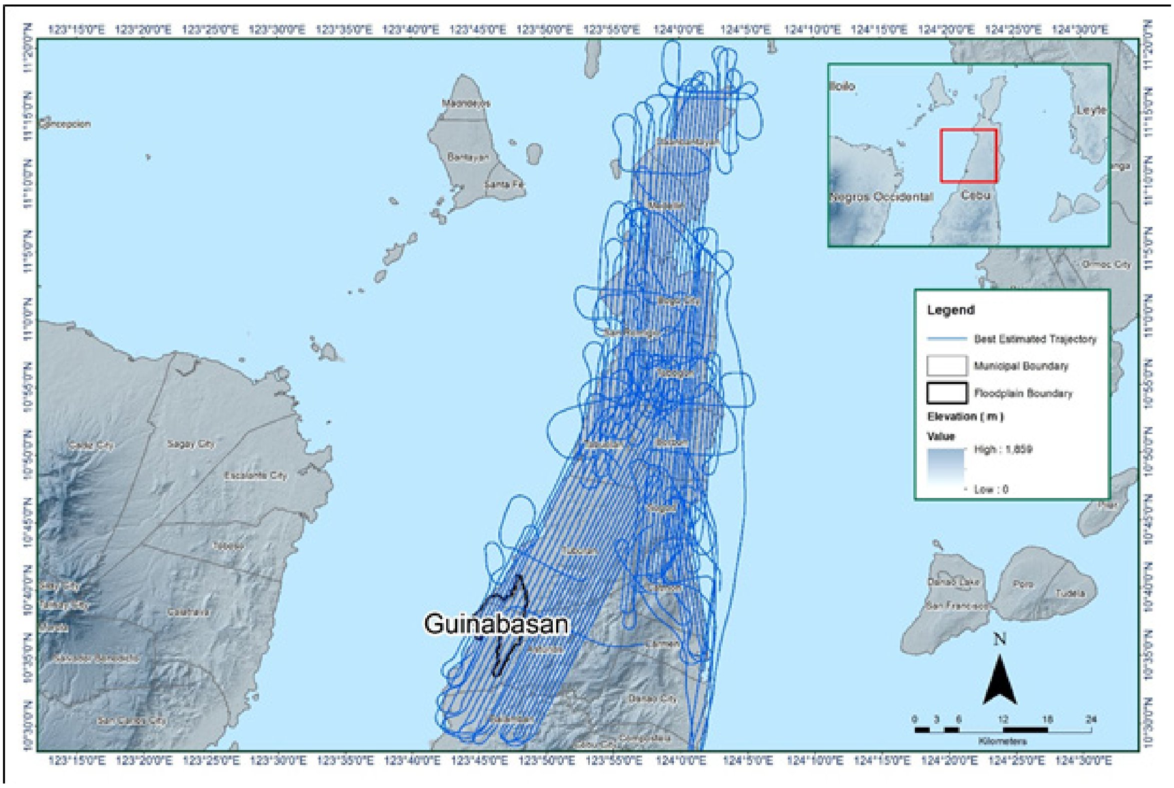

Figure 13. Best estimated trajectory of the LiDAR missions conducted over the Guinabasan

3.4 LiDAR Point Cloud Computation

The produced LAS contains 107 flight lines, with each flight line contains two channels, since the Pegasus system contains two channels. The summary of the self-calibration results obtained from LiDAR processing in the LiDAR Mapping Suite (LMS) software for all flights over the Guinabasan floodplain are given in Table 9.

Table 12. Self-calibration Results values for Guinabasan flights.

Parameter	Acceptable Value	Computed Value
Boresight Correction stdev)	<0.001degrees	0.001156
IMU Attitude Correction Roll and Pitch Corrections stdev)	<0.001degrees	0.004014
GPS Position Z-correction stdev)	<0.01meters	0.0078

The optimum accuracy values for all Guinabasan flights were also calculated, which are based on the computed standard deviations of the corrections of the orientation parameters. The standard deviation values for individual blocks are presented in the Mission Summary Reports (Annex 8).

3.5 LiDAR Quality Checking

The boundary of the processed LiDAR data is shown in Figure 14. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

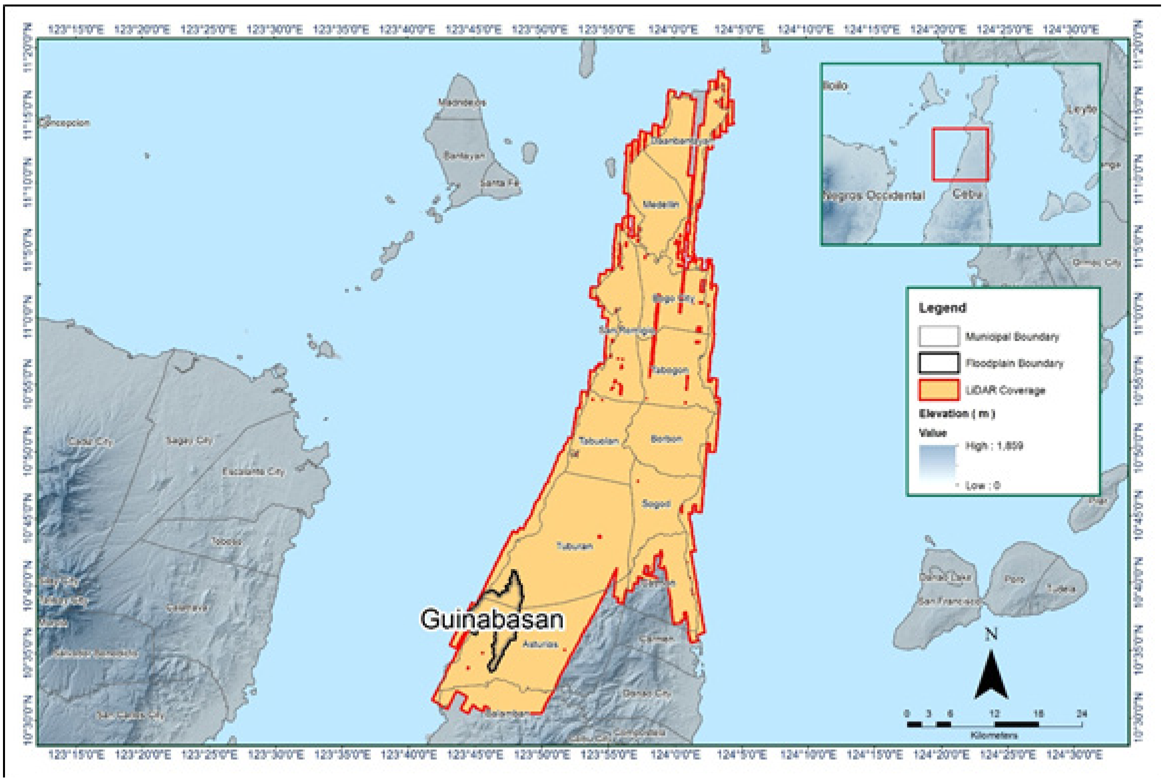

Figure 14. Boundary of the processed LiDAR data on top of the SAR Elevation Data over the Guinabasan Floodplain.

A total area of 1,524.882 square kilometers (sq. kms.) were covered by the Guinabasan flight missions as a result of six (6) flight acquisitions, which were grouped and merged into five (5) block accordingly, as portrayed in Table 13.

Table 13. List of LiDAR blocks for the Guinabasan floodplain.

LiDAR Blocks	Flight Numbers	Area (sq.km)
Cebu Blk36A	1747P	450.768
	1749P	
	1821P	
Cebu Blk36B	1825P	395.82
	1805P	
Cebu Blk36B additional	1805P	30.97
Cebu Blk36C	1803P	286.861
Cebu Blk36D	1803P	360.463
TOTAL		**1,524.882 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 12. 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.

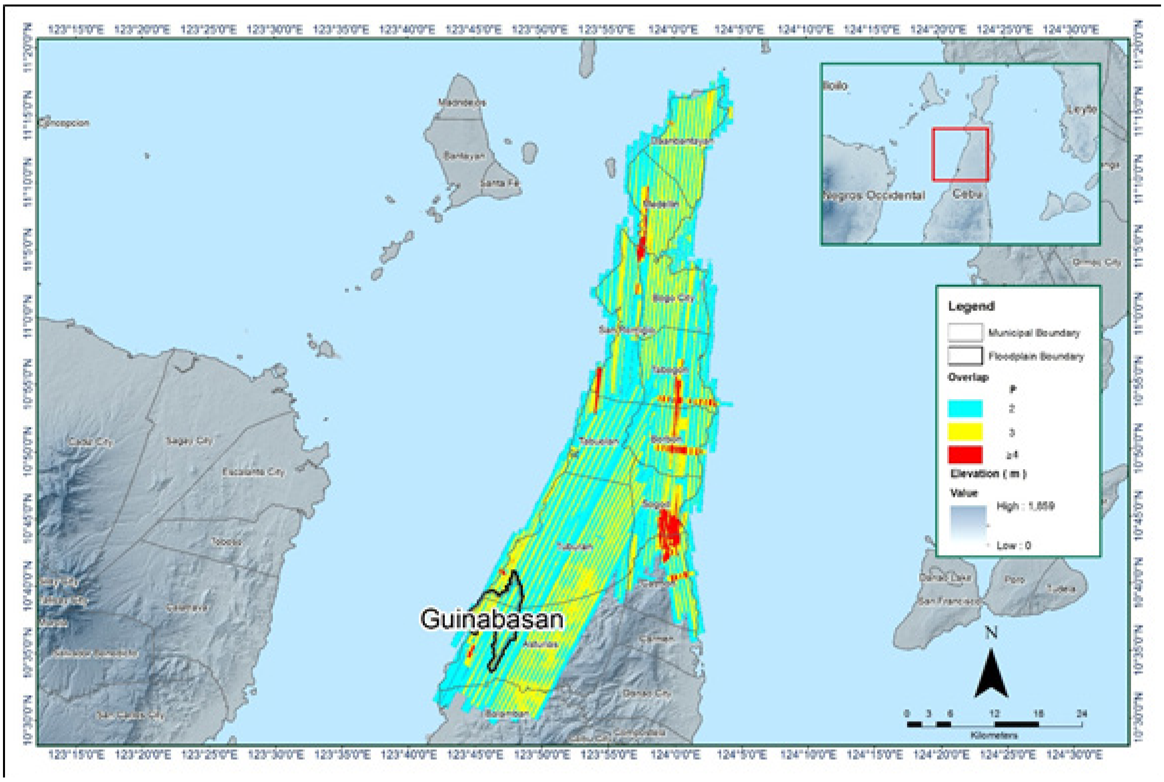

Figure 15. Image of data overlap for Guinabasan floodplain

The overlap statistics per block for the Guinabasan floodplain can be found in the Mission Summary Reports (Annex 8). One pixel corresponds to 25.0 square meters on the ground. For this area, the percent overlaps are 26.55% and 45.30% which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the two (2) points per square meter criterion is shown in Figure 16. As seen in the figure below, it was determined that all LiDAR data for the Guinabasan Floodplain Survey satisfy the point density requirement, as the average density for the entire survey area is 3.11 points per square meter.

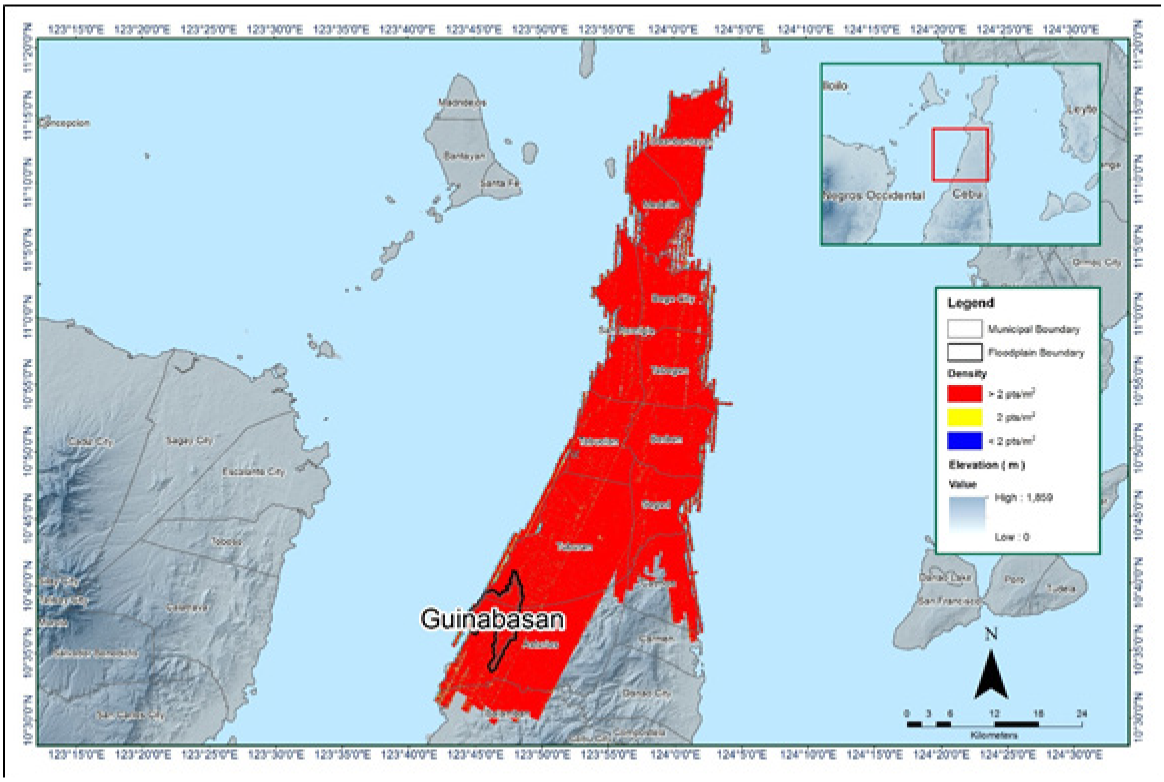

Figure 16. Pulse density map of the merged LiDAR data for Guinabasan floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 17. The default color range is blue to red, where bright blue areas correspond to portions where elevations of a previous flight line are higher by more than 0.20m, as identified by its acquisition time; which is relative to the elevations of its adjacent flight line. Similarly, bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20m, relative to the elevations of its adjacent flight line. Areas highlighted in bright red or bright blue necessitate further investigation using the Quick Terrain Modeler software.

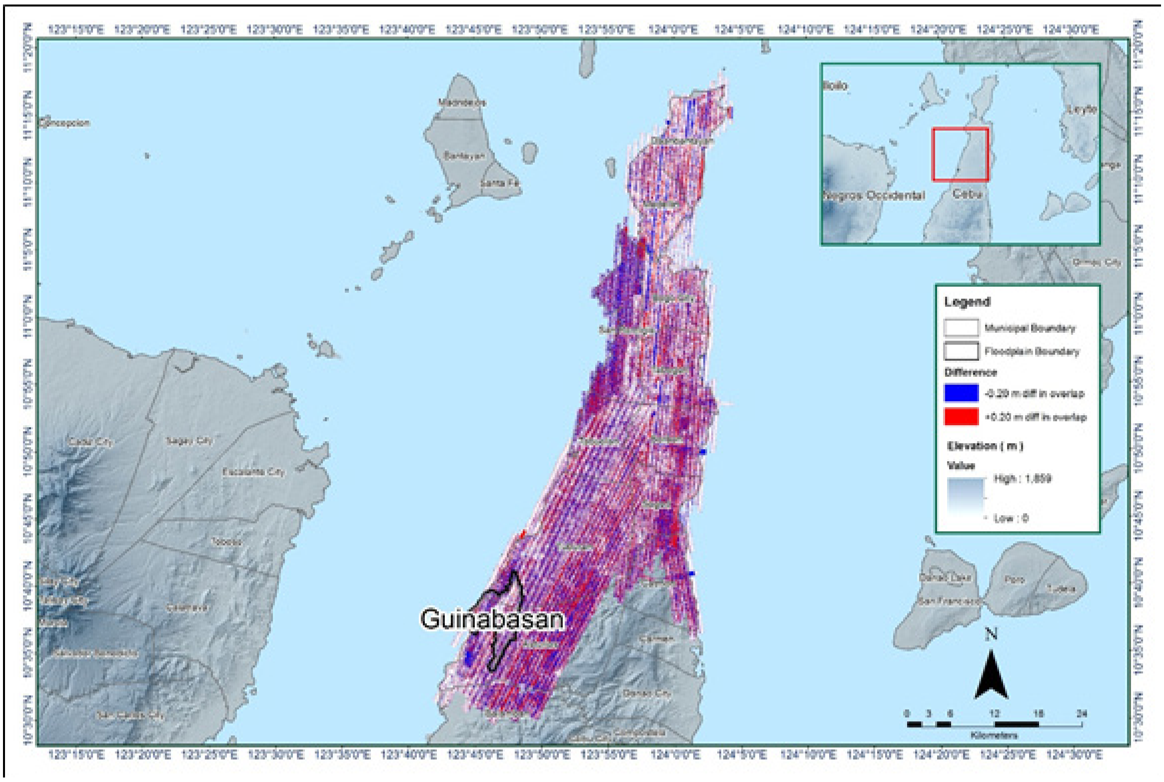

Figure 17. Elevation difference Map between flight lines for the Guinabasan Floodplain Survey.

A screen-capture of the processed LAS data from Guinabasan flight 1825P loaded in QT Modeler is shown in Figure 18. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data generated satisfactory results. No reprocessing was done for this LiDAR dataset.

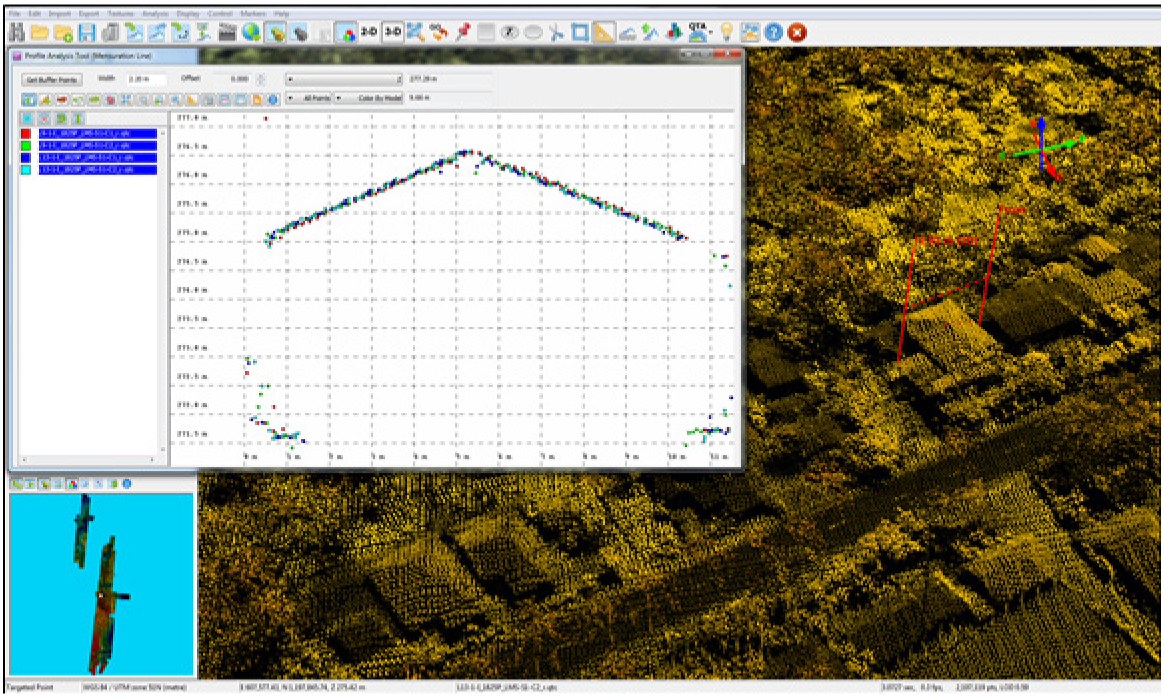

Figure 18. Quality checking for Guinabasan flight 1825P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 14. Guinabasan classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	1,157,172,657
Low Vegetation	1,042,381,165
Medium Vegetation	2,833,588,589
High Vegetation	1,268,915,135
Building	39,054,915

The tile system that TerraScan employed for the LiDAR data as well as the final classification image for a block of the Guinabasan floodplain is shown in Figure 19. A total of 1,987 tiles with 1 km. X 1 km. (one kilometer by one kilometer) size were produced. Correspondingly, Table 14 summarizes the number of points classified to the pertinent categories. The point cloud has a maximum and minimum height of 725.61 meters and 60.43 meters respectively.

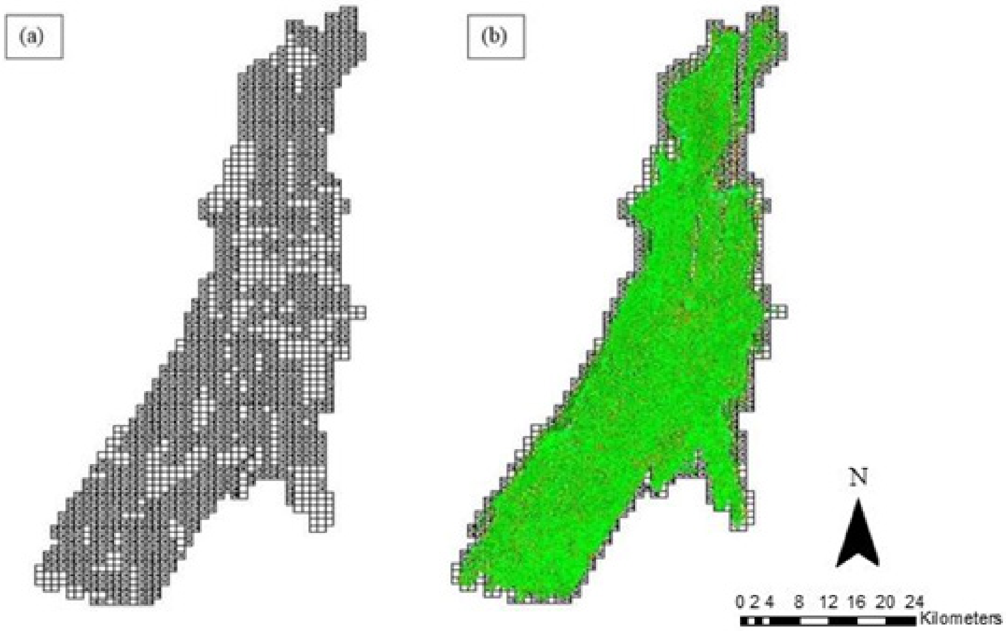

Figure 19. Tiles for Guinabasan floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 20. The ground points are highlighted in orange, while 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 the canopy are classified correctly, due to the density of the LiDAR data.

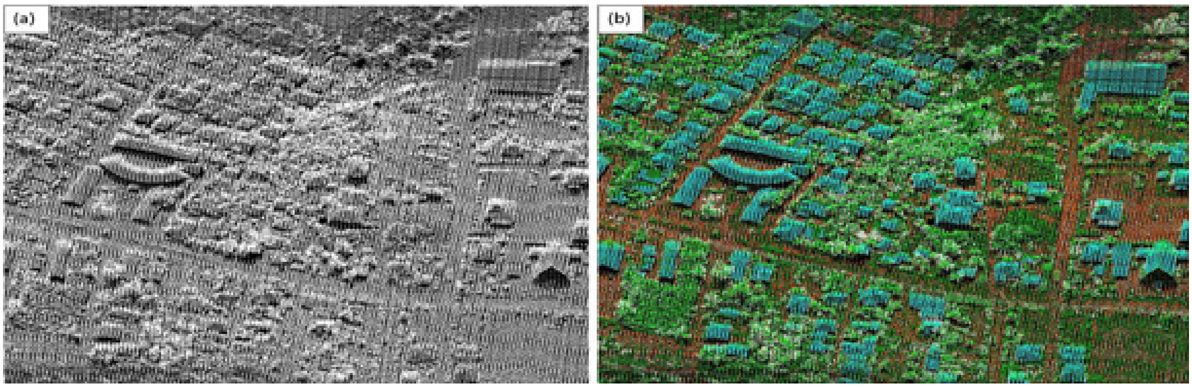

Figure 20. Point cloud before (a) and after (b) classification.

The production of the last return (V_ASCII) and secondary (T_ ASCII) DTM as well as the first (S_ ASCII) and last (D_ ASCII) return DSM of the area in top view display are shown in Figure 21. It shows that DTMs are the representation of the bare earth, while on the DSMs, all features are present, such as buildings and vegetation.

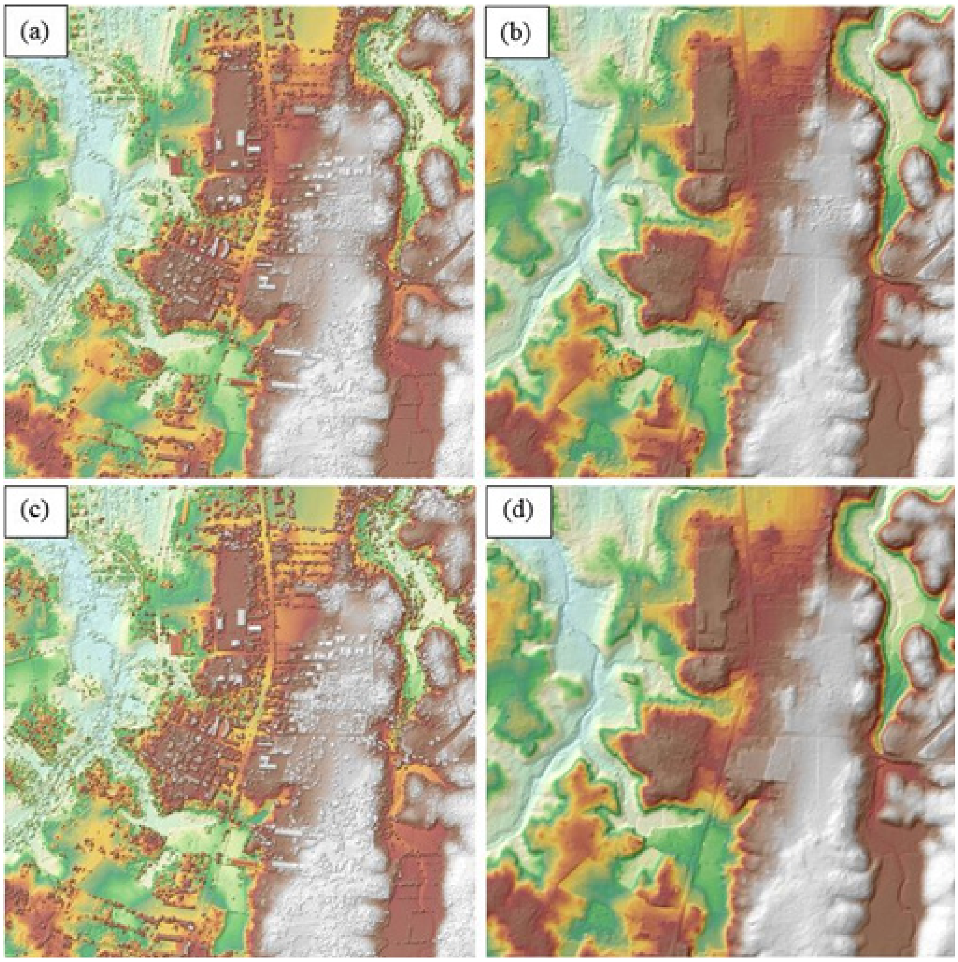

Figure 21. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Guinabasan floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 1,914 1km by 1km tiles area covered by Guinabasan floodplain is shown in Figure 22. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Guinabasan floodplain has a total of 1399.09 sq.km orthophotogaph coverage comprised of 4,190 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 23.

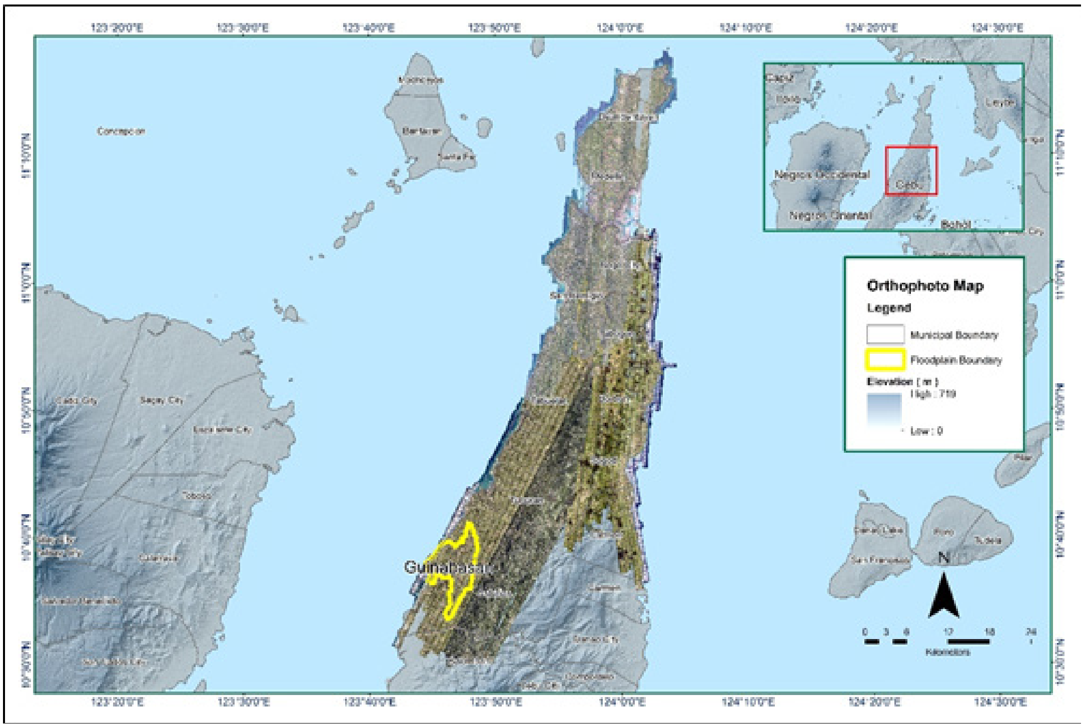

Figure 22. Guinabasan floodplain with available orthophotographs

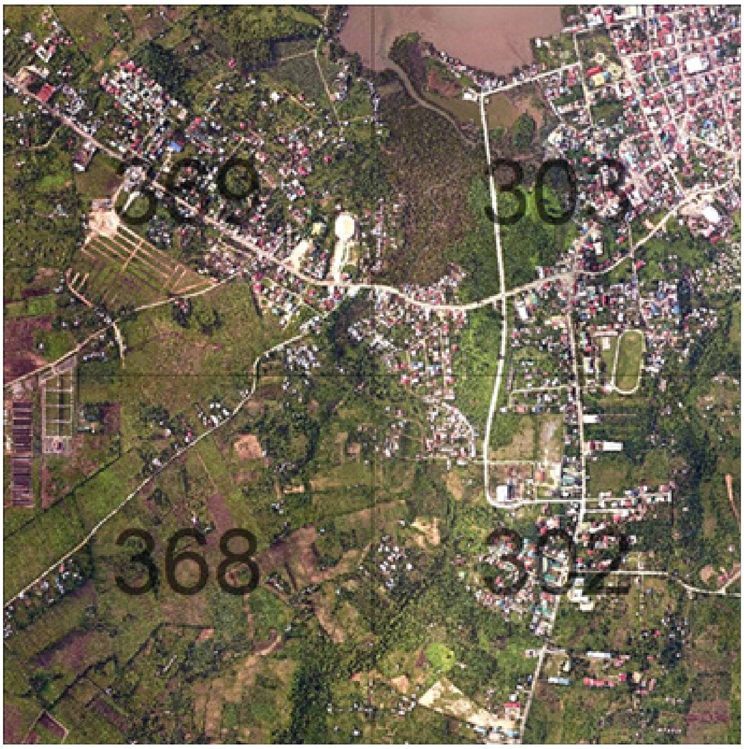

Figure 23. Sample orthophotograph tiles for Guinabasan floodplain.

3.8 DEM Editing and Hydro-Correction

Five (5) mission blocks were processed for the Guinabasan Floodplain Survey. The block is from the Cebu mission with a total area of 1,524.882 square kilometers. Table 15 shows the name and corresponding area of each block in square kilometers.

Table 15. LiDAR blocks with its corresponding areas.

LiDAR Blocks	Area (sq. km.)
Cebu_Blk36A	450.768
Cebu_Blk36B	395.82
Cebu_Blk36C	286.861
Cebu_Blk36D	360.463
Cebu_Blk36B_additional	30.97
TOTAL	1,524.882 sq.km

Figure 24 shows portions of a DTM before and after manual editing. As evident in the figure, the bridge (Figure 24a) has obstructed the flow of water along the river. To correct the river hydrologically, the bridge was removed through manual editing (Figure 24b). A part of river (Figure 24c) has obstructed the flow of water and has to be removed through manual editing (Figure 24d).

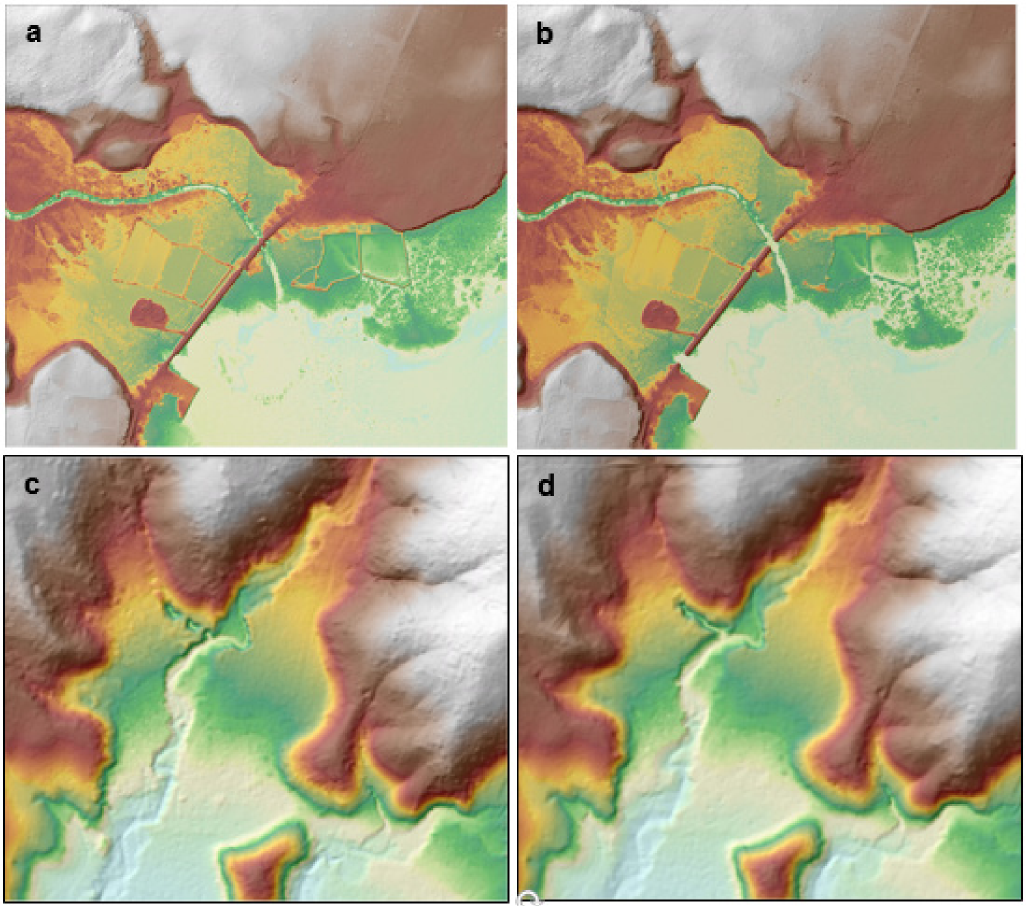

Figure 24. Portions in the DTM of the Guinabasan Floodplain – a bridge before (a) and after (b) manual editing; a part of the river before (c) and after (d) manual editing.

3.9 Mosaicking of Blocks

Cebu_Blk36G was used as the reference block at the start of mosaicking because the identified reference for shifting was an existing calibrated Cebu DEM overlapping with the blocks to be mosaicked. Table 16 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Guinabasan Floodplain is shown in Figure 19. It can be seen that the entire Guinabasan floodplain is 100% covered by LiDAR data.

Table 16. Shift values of each LiDAR block of Guinabasan Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Cebu_Blk36A	0.00	0.00	-0.63
Cebu_Blk36B	0.00	0.00	0.37
Cebu_Blk36B_additional	0.00	0.00	0.85
Cebu_Blk36C	0.00	0.00	-0.30
Cebu_Blk36D	0.00	0.00	-0.25
Cebu_Blk36A	0.00	0.00	-0.63

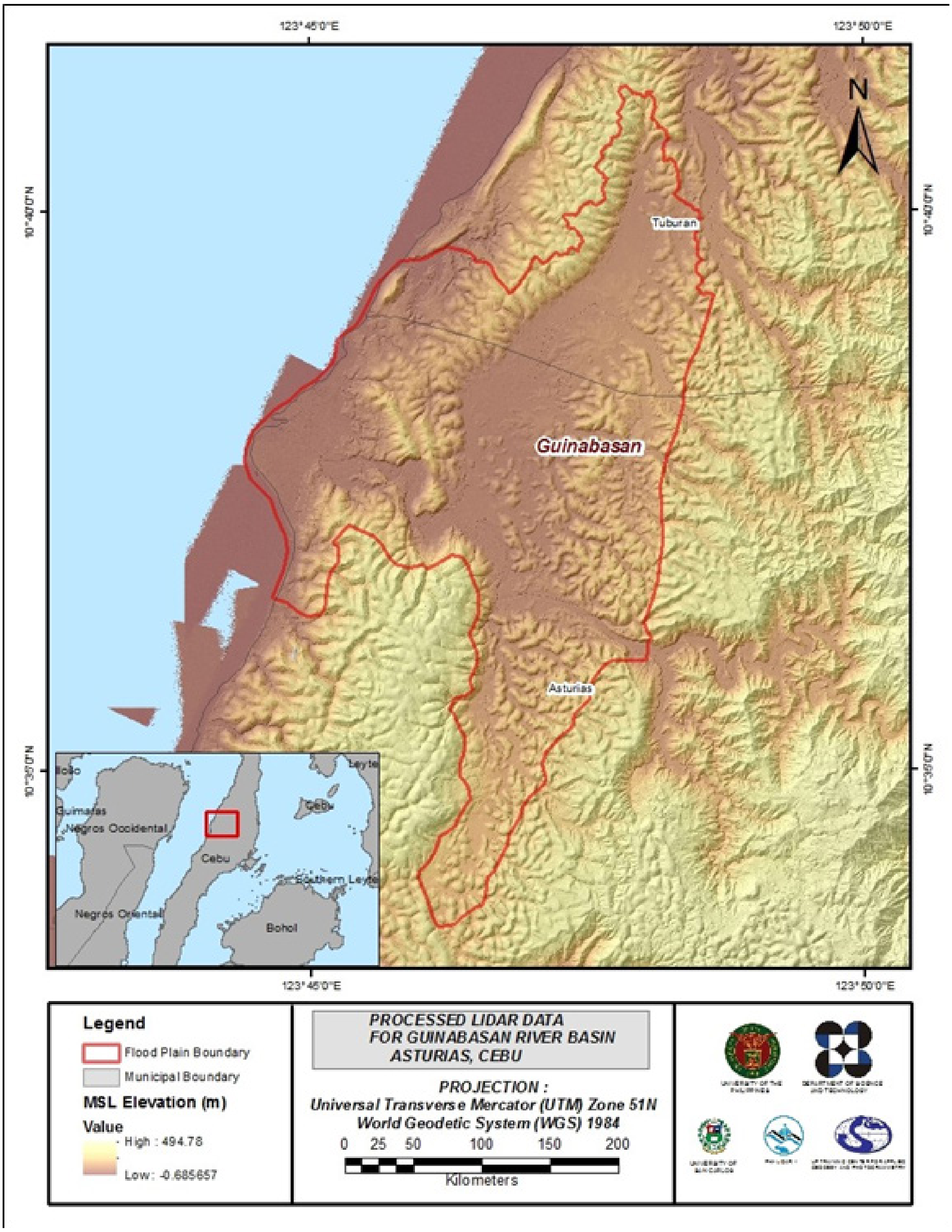

Figure 25. Map of processed LiDAR data for the Guinabasan Floodplain.

3.10 Calibration and Validation of Mosaicked LiDAR DEM

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Guinabasan to collect points with which the LiDAR dataset is validated is shown in Figure 26. A total of 22,471 survey points were gathered for all the flood plains within the province of Cebu wherein the Guinabasan floodplain is located. Random selection of 80% of the survey points, resulting to 17,977 points, was used for calibration.

A good correlation between the uncalibrated mosaicked LiDAR DTM and ground survey elevation values is shown in Figure 27. 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 0.55 meters with a standard deviation of 0.20 meters. Calibration of the LiDAR data was done by subtracting the height difference value, 0.55 meters, to the mosaicked LiDAR data. Table 17 shows the statistical values of the compared elevation values between the LiDAR data and calibration data.

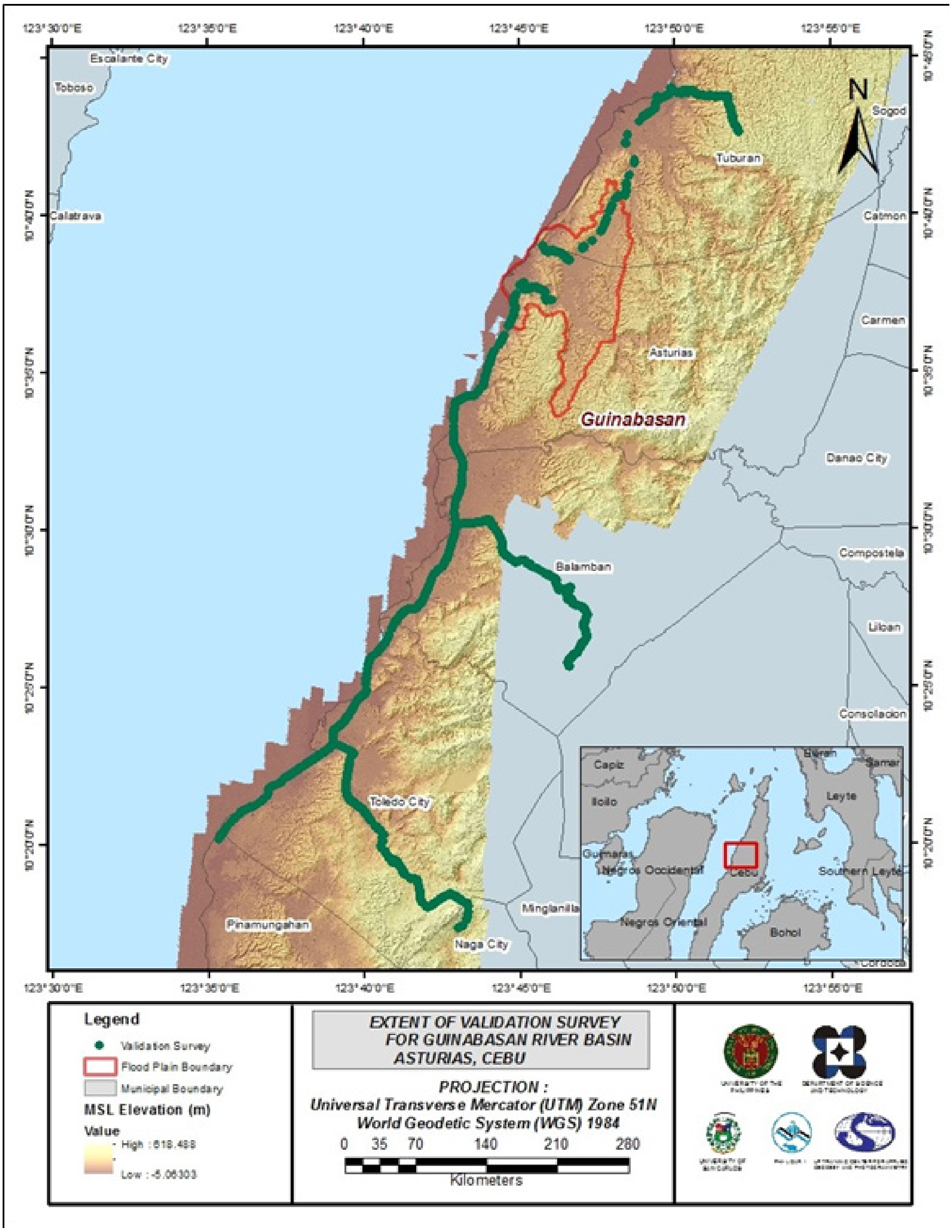

Figure 26. Map of Guinabasan Floodplain with validation survey points in green.

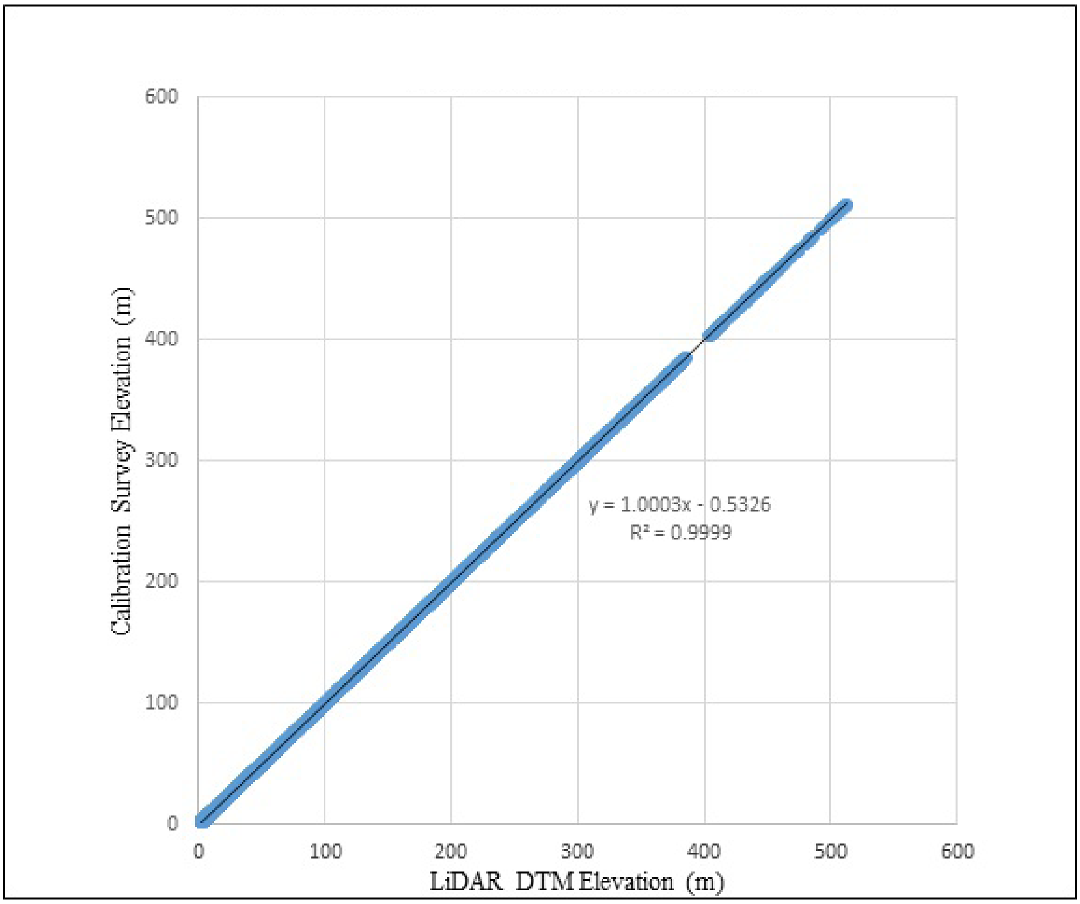

Figure 27. Correlation plot between calibration survey points and LiDAR data.

Table 17. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	0.55
Standard Deviation	0.20
Average	-0.51
Minimum	-1.01
Maximum	-0.00005

The remaining 20% of the total survey points were intersected to the flood plain, resulting to 365 points, were used for the validation of calibrated Guinabasan DTM. A good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM, is shown in Figure 28. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.15 meters with a standard deviation of 0.09 meters, as shown in Table 18.

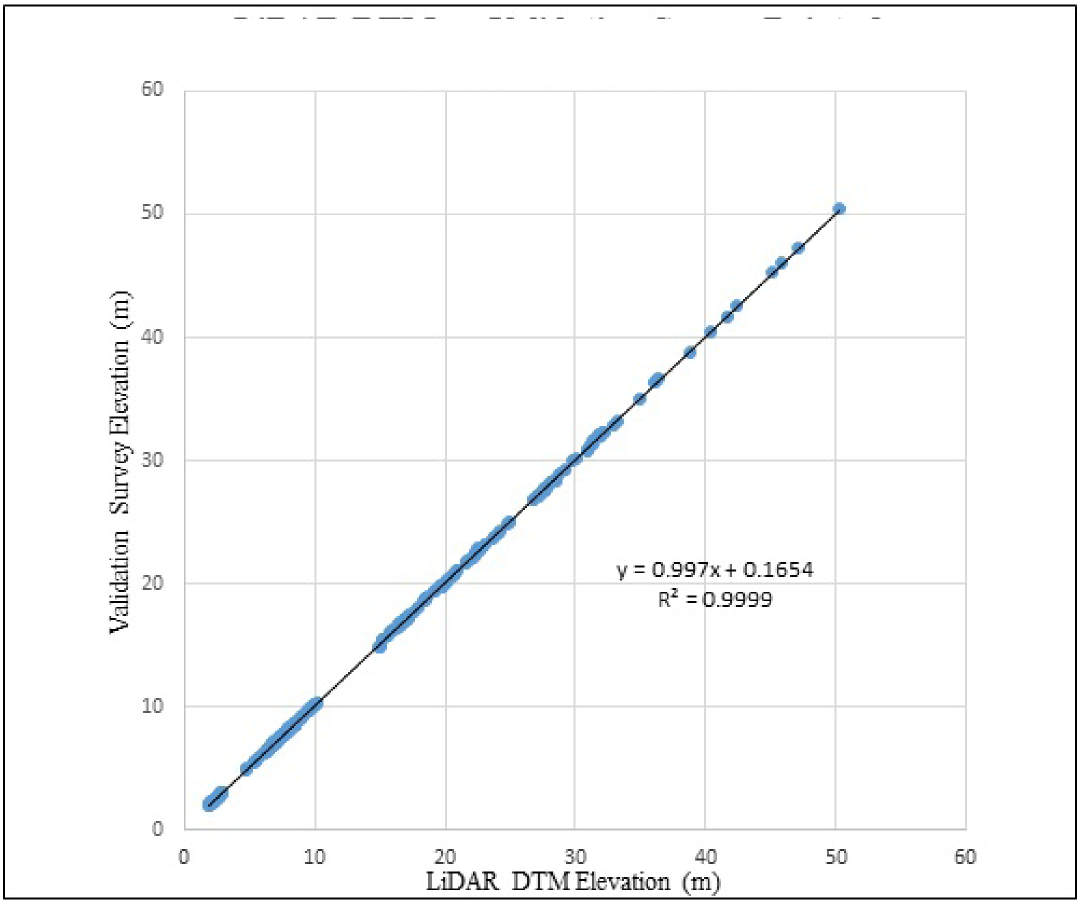

Figure 28. Correlation plot between the validation survey points and the LiDAR data.

Table 18. Validation Statistical Measures

Validation Statistical Measures	Value (meters)
RMSE	0.15
Standard Deviation	0.09
Average	0.12
Minimum	-0.25
Maximum	0.40

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and zigzag data were available for Guinabasan with a total of 15,322 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 0.002 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Guinabasan integrated with the processed LiDAR DEM is shown in Figure 29.

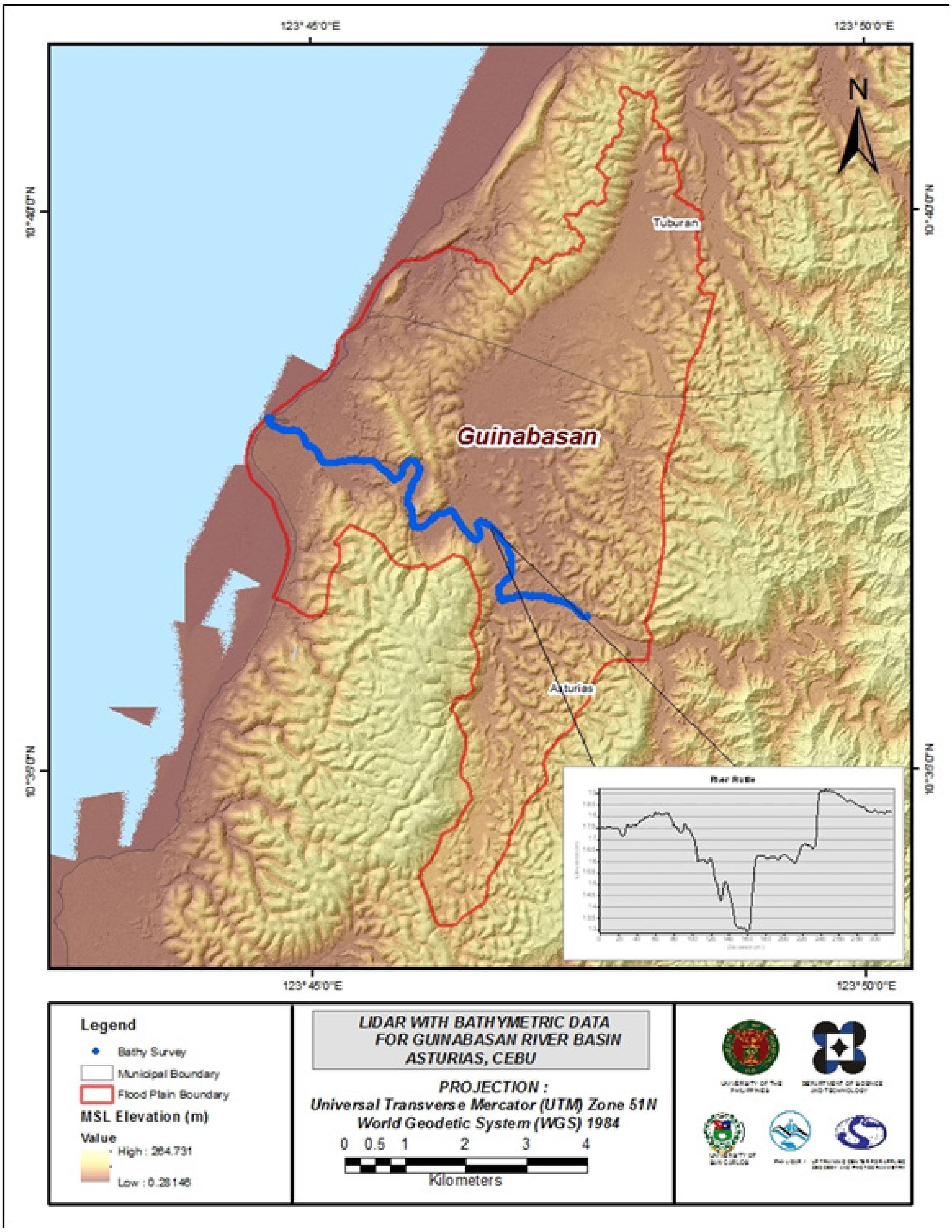

Figure 29. Map of Guinabasan floodplain with bathymetric survey points in blue.

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 a 200-meter buffer zone. Mosaicked LiDAR DEMs with a 1-m resolution were used to delineate footprints of building features, which comprised 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 the routing of disaster response efforts. These features are represented by network of road centerlines.

3.12.1 Quality Checking (QC) of Digitized Features' Boundary

Guinabasan floodplain, including its 200-m buffer, has a total area of 53.95 sq km. For this area, a total of 5.0 sq. km., corresponding to a total of 1085 building features, were considered for QC. Figure 30 shows the QC block for the Guinabasan floodplain.

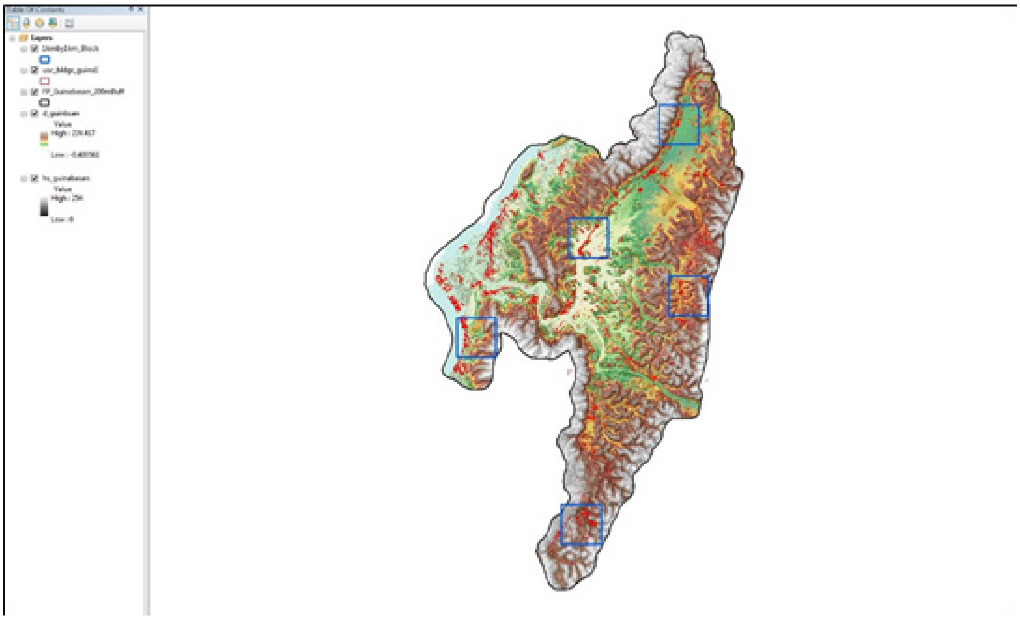

Figure 30. Block (in blue) of Guinabasan building features that was subjected to QC.

Quality checking of Guinabasan building features resulted in the ratings shown in Table 19.

Table 19. Details of the quality checking ratings for the building features extracted for the Guinabasan River Basin

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Guinabasan	99.82	99.91	97.79	PASSED

3.12.2 Height Extraction

Height extraction was done for 6,144 building features in Guinabasan floodplain. Of these building features, 1,344 were filtered out after height extraction, resulting to 4,800 buildings with height attributes. The lowest building height is at 2.00 meters, while the highest building is at 6.40 meters.

3.12.3 Feature Attribution

In attribution, combination of participatory mapping and actual field validation was done. Representatives from LGU were invited to assist in the determination of the features. The remaining unidentified features were then validated on the field.

Table 20 summarizes the number of building features per type, while Table 21 shows the total length of each road type. Table 22, on the other hand, shows the number of water features extracted per type.

Table 20. Building features extracted for Guinabasan Floodplain.

Facility Type	No. of Features
Residential	4,745
School	10
Market	2
Agricultural/Agro-Industrial Facilities	1
Medical Institutions	2
Barangay Hall	2
Military Institution	0
Sports Center/Gymnasium/Covered Court	2
Telecommunication Facilities	0
Transport Terminal	0
Warehouse	0
Power Plant/Substation	0
NGO/CSO Offices	1
Police Station	0
Water Supply/Sewerage	0
Religious Institutions	5
Bank	0
Factory	19
Gas Station	2
Fire Station	0
Other Government Offices	1
Other Commercial Establishments	8
Total	**4,800**

Table 21. Total length of extracted roads for Guinabasan Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/ Municipal Road	Provincial Road	National Road	Others	
Guinabasan	76.59	13.22	0.00	14.46	0.00	104.27

Table 22. Number of extracted water bodies for Guinabasan Floodplain.

Floodplain	Water Body Type					Total
	Rivers/ Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Guinabasan	2	14	0	0	24	40

A total of three (3) bridges over small culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

All extracted ground features were given the complete required attributes. Respectively, all these output features comprise the flood hazard exposure database for the floodplain. The final quality checking completes the feature extraction phase of the project.

Figure 31 shows the completed Digital Surface Model (DSM) of the Guinabasan floodplain overlaid with its ground features.

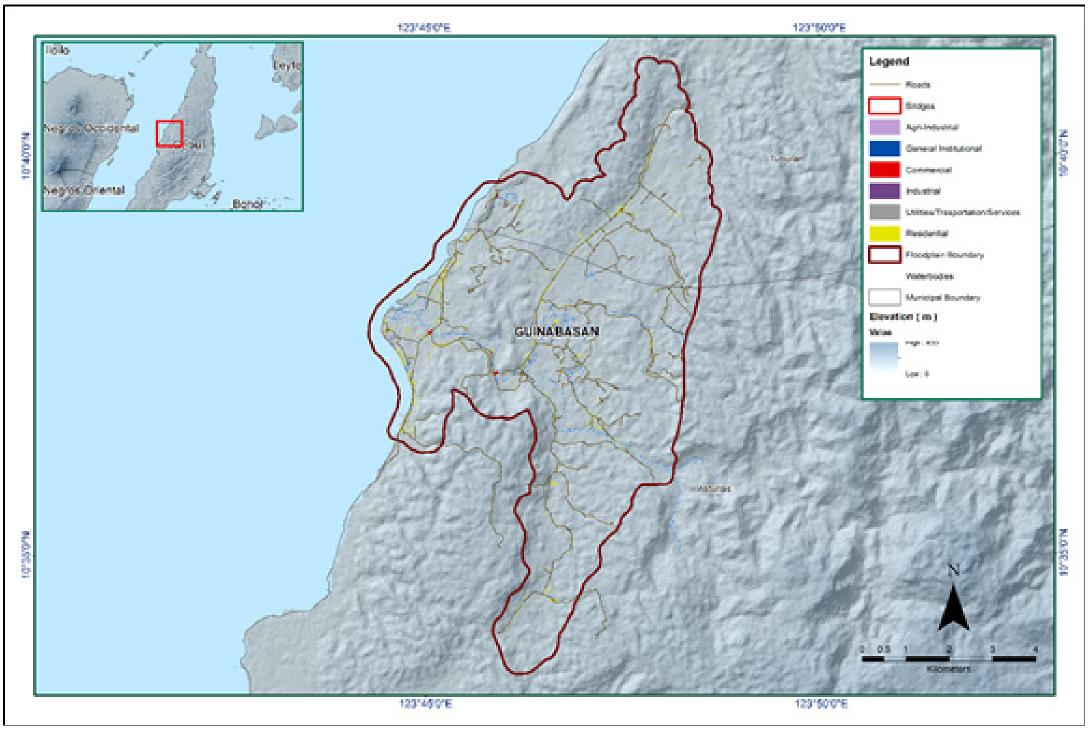

Figure 31. Extracted features of the Guinabasan Floodplain.

CHAPTER 4 LIDAR VALIDATION SURVEY AND MEASUREMENT OF THE GUINABASAN RIVER BASIN

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

4.1 Summary of Activities

The Data Validation and Bathymetry Component (DVBC) conducted a field survey in Guinabasan River on December 5 to 17, 2015. Generally, the scope of work was comprised of (i) initial reconnaissance; (ii) control point survey for the establishment of a control point; (iii) the cross section survey and bridge as-built survey, and water level marking in the Mean Sea Level (MSL) of the Guinabasan Bridge in Brgy. Bago, Municipality of Asturias; (iv) validation points acquisition of about 97.43 km covering Municipalities of Asturias and Balamban, and Toledo City; and (v) bathymetric survey from Brgy. Agtugop down to Brgy. Tubigagmanok, Municipality of Asturias, with an approximate length of 9.52 km using Trimble® SPS 882 GNSS PPK survey technique. Figure 32 illustrates the extent of the entire survey in Guinabasan River.

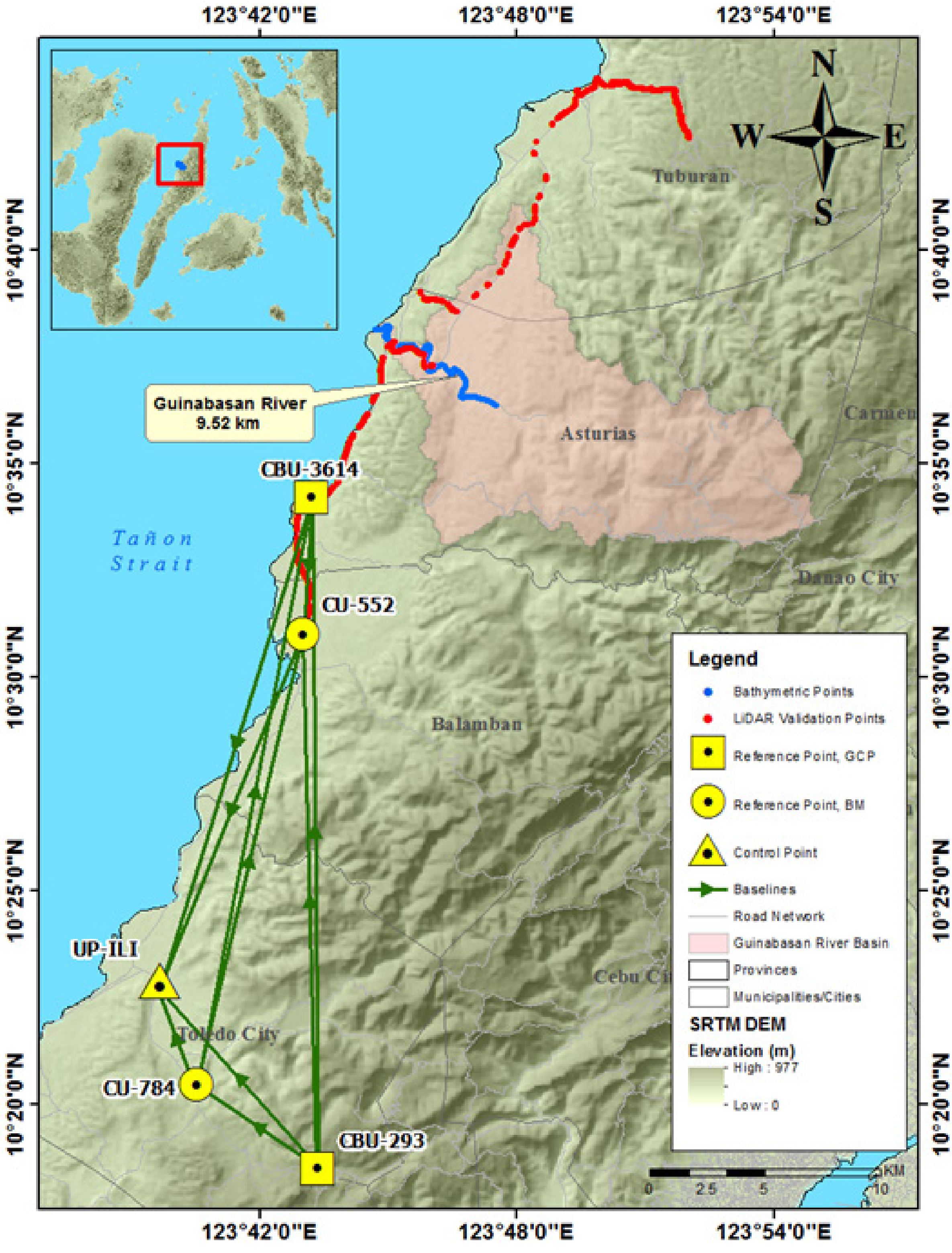


Figure 32. Guinabasan River Survey Extent.

4.2 Control Survey

The GNSS network utilized for the Guinabasan River Basin is composed of seven (7) loops established on December 7 and 14, 2015, which occupied the following reference points: CBU-293, a second order GCP located inside Cantabaco National High School in Brgy. Cantabaco, Toledo City; and, CU-784, a first order BM in Brgy. Balud, Toldeo City.

A control point was established along the approach of bridges, namely: UP-ILI at Ilihan Bridge in Brgy. Ilihan, Toledo City. The DPWH control point DPWHECS, in Brgy. Bago, Astrias; and the NAMRIA established control points CBU-3614, in Brgy. Poblacion, Municipality of Asturias; CU-552, in Brgy. Cantu-Od, Municipality of Balamban; and CBU-3015, in Brgy. Sta. Lucia, Municipality of Asturias, were also occupied to use as markers for the network.

Table 23 depicts the summary of reference and control points utilized, with their corresponding locations, while Figure 31 shows the GNSS network established in the Guinabasan River Survey.

Table 23. List of reference and control points used during the survey in Guinabasan River (Source: NAMRIA, UP-TCAGP).

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (m)	MSL Elevation (m)	Date of Establishment
CBU-293	**2nd order**	**10°18'28.70835"**	**123°43'20.76082"**	**350.838**	**-**	**2007**
CU-784	1st order	-	-	121.354	58.767	2014
CBU-3614	Used as marker	-	-	-	-	2007
CU-552	Used as marker	-	-	-	-	2003
UP-ILI	UP Established	-	-	-	-	12-7-2015
CBU-3015	Used as marker	-	-	-	-	2007
DPWHECS	Used as marker	-	-	-	-	2010

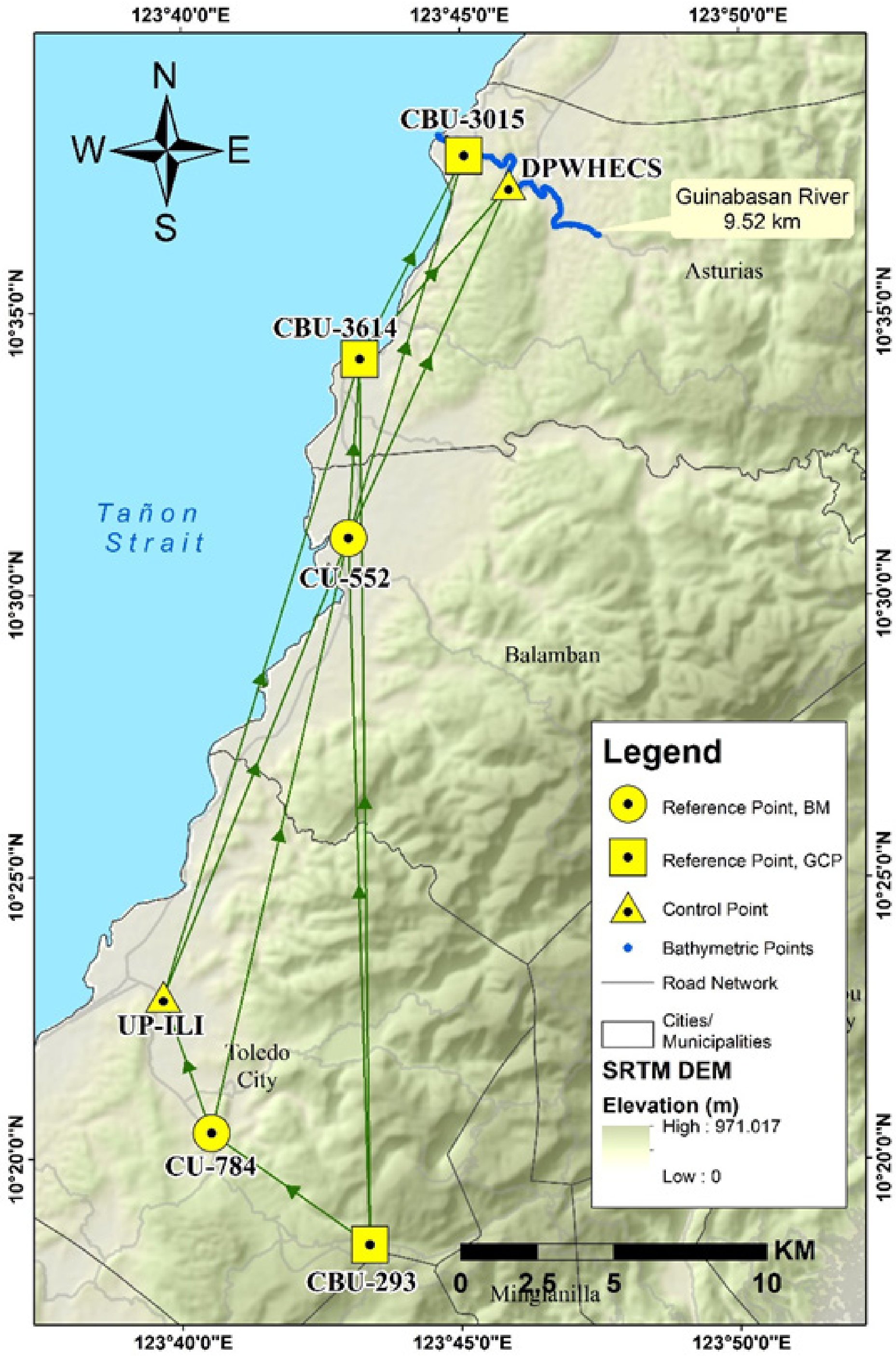


Figure 33. Guinabasan River Basin Control Survey Extent.

Figure 34 to Figure 40 depict the setup of the GNSS on recovered reference points and established control points in the Guinabasan River.

Figure 34. GNSS receiver set-up, Trimble® SPS 852, at CBU-293 in front of Cantabaco National High School in Brgy. Cantabaco, Toledo City, Cebu.

Figure 35. GNSS receiver setup, Trimble® Zephyr ™ Model 2, at CU-784 Balud Bridge approach in Brgy. Balud, Toledo City, Cebu.

Figure 36. GNSS base receiver setup, Trimble® Zephyr ™ Model 2, at CBU-3614, Lapu-Lapu Bridge approach in Brgy. Poblacion, Municipality of Asturias, Cebu.

Figure 37. GNSS base setup, Trimble® Zephyr ™ Model 2, at CU-552 in Brgy. Cantu-od, Municipality of Balamban.

Figure 38. GNSS base receiver setup, Trimble® Zephyr ™ Model 2, at the established point, UP-ILI in the approach of Ilihan Footbridge in Brgy. Ilihan, Toledo City.

Figure 39. GNSS base setup, Trimble® Zephyr ™ Model 2, at CBU-3015 in Santa Lucia Bridge, Brgy. Santa Lucia, Municipality of Asturias.

Figure 40. GNSS base receiver setup, Trimble® Zephyr ™ Model 2, at DPWHECS in Brgy. Bago, Municipality of Asturias.

4.3 Baseline Processing

The GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement respectively. In cases where one or more baselines did not meet all of these criteria, masking was performed. Masking is the removal or covering of portions of the baseline data using the same processing software. The data is then repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, a resurvey is initiated. Table 24 presents the baseline processing results of control points in the Guinabasan River Basin, as generated by the TBC software.

Table 24. The Baseline processing report for the Guinabasan River GNSS static observation survey.

Observation	Date of Observation	Solution Type	H.Prec	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)
CU-784 --- UP-ILI (B1)	12-7-2015	Fixed	0.006	0.034	340°45'16"	4741.533
CU-552 --- UP-ILI (B9)	12-7-2015	Fixed	0.004	0.022	202°05'36"	16152.939
CBU-293 --- CU-784 (B3)	12-7-2015	Fixed	0.006	0.028	305°11'33"	6328.249
CU-784 --- CBU--3614 (B6)	12-7-2015	Fixed	0.006	0.042	10°56'41"	25772.836
CU784 --- CU-552 (B10)	12-7-2015	Fixed	0.004	0.021	13°03'37"	19960.518
CBU-3614 --- CU-552 (B7)	12-7-2015	Fixed	0.005	0.026	183°44'41"	5872.324
CBU-293 --- CBU-3614 (B4)	12-7-2015	Fixed	0.008	0.035	359°27'24"	28951.752
CBU-293 --- CU-552 (B8)	12-7-2015	Fixed	0.006	0.022	358°22'03"	23100.039
CBU-293 --- UP-ILI (B2)	12-7-2015	Fixed	0.004	0.019	320°20'42"	10551.869
CBU-3614 --- UP-ILI (B5)	12-7-2015	Fixed	0.004	0.027	197°13'50"	21805.194
DPWHECS --- CBU-3015 (B12)	12-14-2015	Fixed	0.006	0.010	303°29'12"	1750.592
CU-552 --- DPWHECS (B10)	12-14-2015	Fixed	0.006	0.033	24°32'17"	12684.190
CBU-3614 --- DPWHECS (B11)	12-14-2015	Fixed	0.006	0.035	40°41'55"	7490.309
CBU-3614 --- CBU-3015 (B7)	12-14-2015	Fixed	0.003	0.016	27°15'49"	7474.835
CU-552 --- CBU-3614 (B8)	12-14-2015	Fixed	0.004	0.016	183°44'41"	5872.328

As shown in Table 24, a total of fifteen (15) baselines were processed with the coordinates of CBU-293 and CU-784 held fixed for coordinate and elevation values; it is apparent that all baselines passed the required accuracy.

4.4 Network Adjustment

After the baseline processing procedure, the network adjustment is performed using the TBC software. 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 for each control point; or in equation form:

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

where:

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

For complete details, see the Network Adjustment Report shown in Table 25 to Table 28.

The seven (7) control points, CBU-293, CU-784, CBU-3614, CU-552, CBU-3015, DPWHECS and UP-ILI were occupied and observed simultaneously to form a GNSS loop. Coordinates of CBU-293 and elevation value of CU-784 were held fixed during the processing of the control points as presented in Table 25. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 25. Constraints applied to the adjustment of the control points.

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
CBU-293	Global	Fixed	Fixed		
CU-784	Grid				Fixed
Fixed = 0.000001(Meter)					

Likewise, 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 26. The fixed control point CBU-293 has no values for standard errors.

Table 26. Adjusted grid coordinates for the control points used in the Guinabasan River flood plain survey.

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
CBU-293	579101.757	?	1139552.798	?	287.891	0.028	LL
CBU-3614	578761.189	0.004	1168493.192	0.004	3.267	0.033	
CU-552	578391.244	0.004	1162634.434	0.003	4.293	0.026	
CU-784	573923.645	0.004	1143187.034	0.004	58.767	?	e
UP-ILI	572351.798	0.004	1147658.769	0.003	13.024	0.029	
CBU-3015	582168.859	0.011	1175143.391	0.009	8.929	0.036	
DPWHECS	583630.791	0.012	1174181.419	0.010	18.930	0.039	

With the mentioned equation, $\sqrt{((x_e)^2+(y_e)^2)}<20cm$ for horizontal and $z^e<10$ cm for the vertical; the computation for the accuracy are as follows:

a. CBU-293 = fixed
= 2.8 < 10 cm

b. CU-784
horizontal accuracy = √((0.4)² + (0.3)²
= √(0.16 + 0.9)
= 1.03 cm < 20 cm
vertical accuracy = fixed

c. CBU-3614
horizontal accuracy = √((0.4)² + (0.4)²
= √(0.16 + 0.16)
= 0.57 cm < 20 cm
vertical accuracy = 3.3 < 10 cm

d. CU-552
horizontal accuracy = √((0.4)² + (0.3)²
= √(0.16 +0.9)
= 1.03 cm < 20 cm
vertical accuracy = 2.6 < 10 cm

e. UP-ILI
horizontal accuracy = √((0.4)² + (0.3)²
= √(0.16 + 0.9)
= 1.03 cm < 20 cm
vertical accuracy = 2.9 < 10 cm

f. CBU-3015
horizontal accuracy = √((1.1)² + (0.9)²
= √(1.21 + 0.81)
= 1.42 cm < 20 cm
vertical accuracy = 3.6 < 10 cm

g. DPWHECS
horizontal accuracy = √((1.2)² + (1.0)²
= √(1.44 + 1.0)
= 1.56 cm < 20 cm
vertical accuracy = 3.9 < 10 cm

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

Table 27. Adjusted geodetic coordinates for control points used in the Guinabasan River Flood Plain validation.

Point ID	Latitude	Longitude	Ellipsoid Height (Meter)	Height Error (Meter)	Constraint
CBU-293	N10°18'28.70835"	E123°43'20.76082"	350.838	0.028	LL
CBU-3614	N10°34'10.94597"	E123°43'11.73023"	64.969	0.033	
CU-552	N10°31'00.23116"	E123°42'59.11634"	66.222	0.026	
CU-784	N10°20'27.39811"	E123°40'30.77220"	121.354	?	e
UP-ILI	N10°22'53.09406"	E123°39'39.39389"	75.336	0.029	
CBU-3015	N10°37'47.19160"	E123°45'04.38488"	70.553	0.036	
DPWHECS	N10°37'15.75721"	E123°45'52.41992"	80.663	0.039	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 27. Based on the results of the computation, the accuracy conditions are satisfied; hence, the required accuracy for the program was met. The computed coordinates of the reference and control points utilized in the Guinabasan River GNSS Static Survey are seen in Table 28

Table 28. The reference and control points utilized in the Guinabasan River Static Survey, with their corresponding locations (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
CBU-293	2nd order GCP	10°18'28.70835"	123°43'20.76082"	350.838	1139553	579101.8	287.844
CU-784	1st order BM	10°20'27.39811"	123°40'30.77220"	121.354	1143187	573923.6	58.767
CBU-3614	Used as Marker	10°34'10.94597"	123°43'11.73023"	64.969	1168493	578761.2	3.317
CU-552	Used as Marker	10°31'00.23116"	123°42'59.11634"	66.222	1162634	578391.2	4.332
UP-ILI	UP Established	10°22'53.09406"	123°39'39.39389"	75.336	1147659	572351.8	13.001
CBU-3015	Used as Marker	10°37'47.19160"	123°45'04.38488"	70.553	1175143	582168.9	8.929
DPWHECS	Used as Marker	10°37'15.75721"	123°45'52.41992"	80.663	1174181	583630.8	18.93

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

The bridge cross-section and as-built survey were conducted on December 15, 2015 at the upstream portion of Guinabasan River in Guinabasan Bridge, Brgy. Bago, Municipality of Asturias using GNSS receiver Trimble® SPS 882 in PPK survey technique (Figure 41).

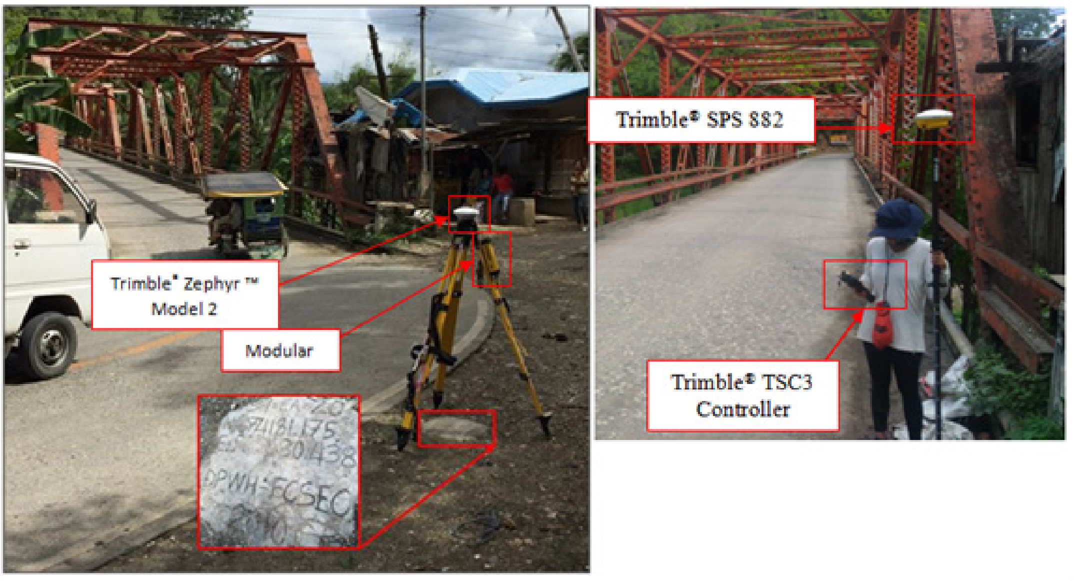


Figure 41. Bridge as-built and cross-section survey of Guinabasan Bridge.

The length of the cross-sectional line surveyed at Guinabasan Bridge is about 101.680 m. (Figure 42) with eighty-one (81) cross-sectional points using the control point DPWHECS as the GNSS base station. The location map, cross-section diagram, and the accomplished bridge data form are shown in Figure 42 to Figure 44.

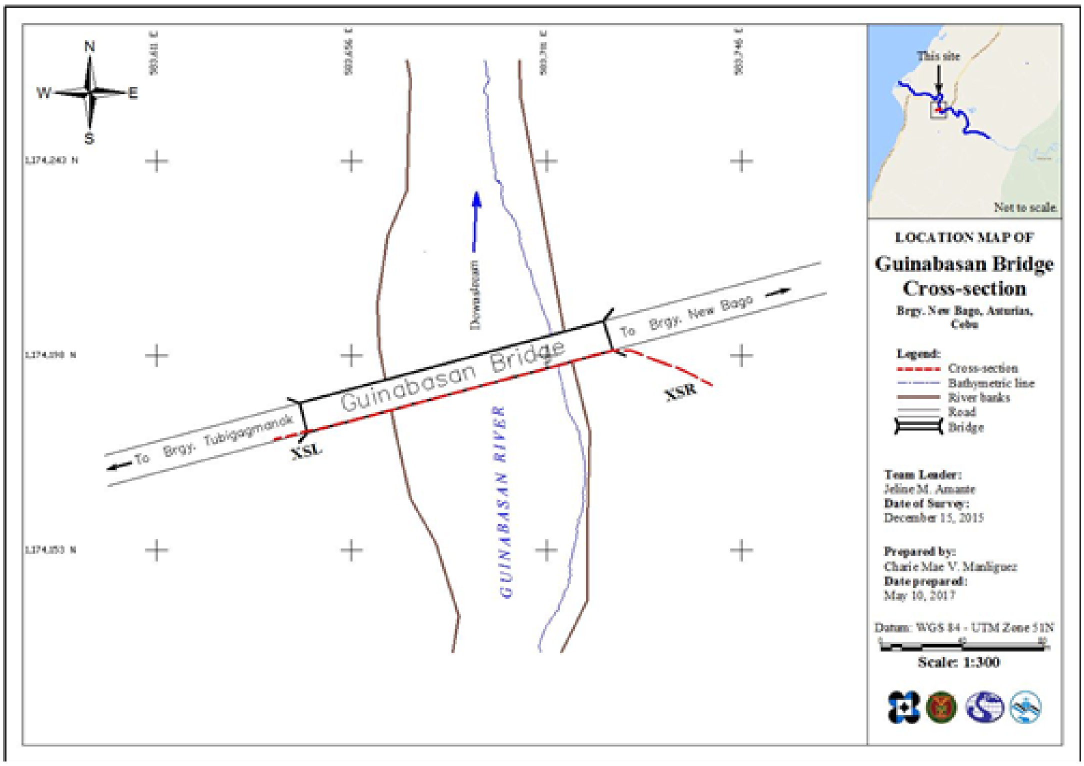


Figure 42. Location map of the Guinabasan Bridge Cross Section.

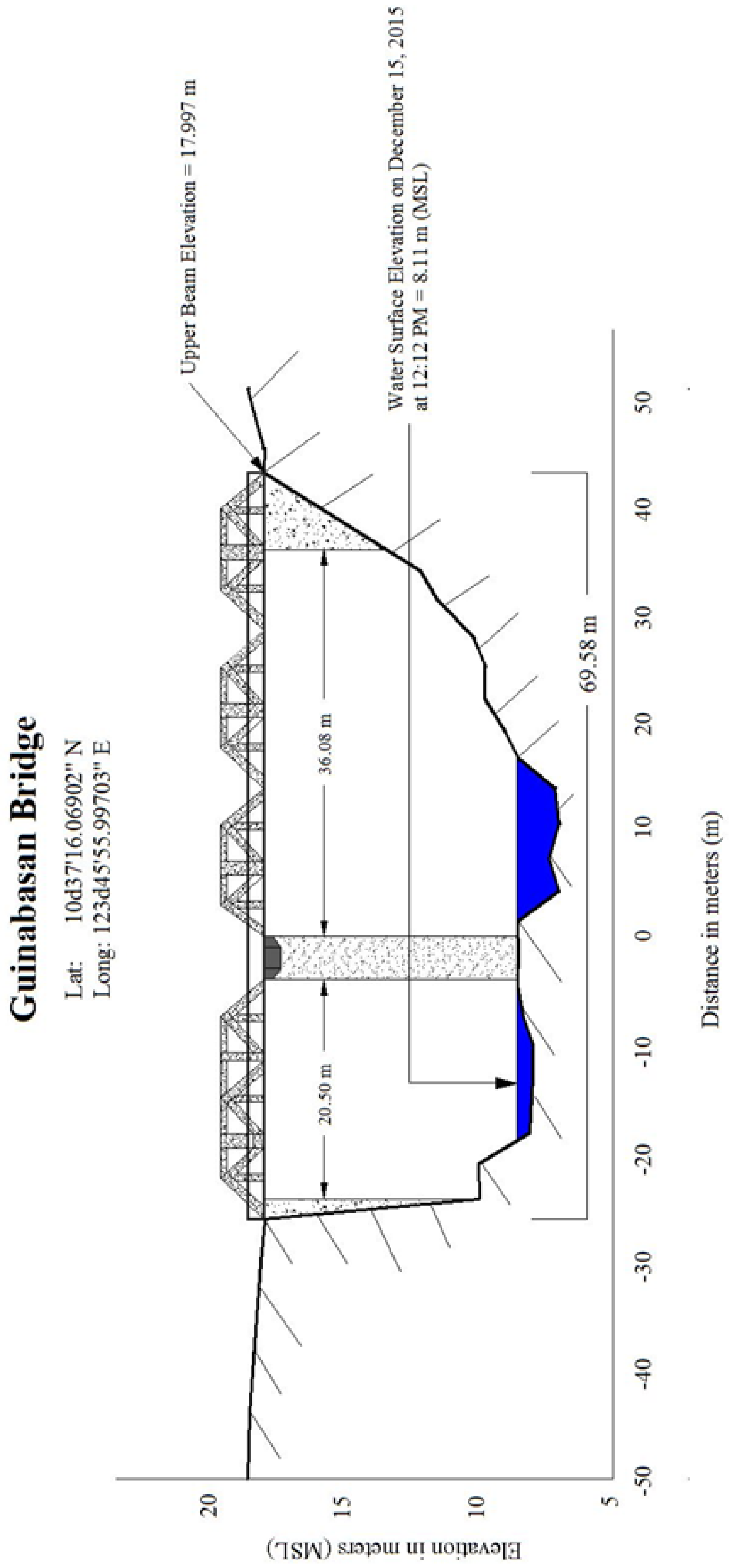


Figure 43. The Guinabasan Bridge cross-section survey drawn to scale.

Bridge Data Form

Bridge Name: Guinabasan Bridge — Date: December 15, 2015

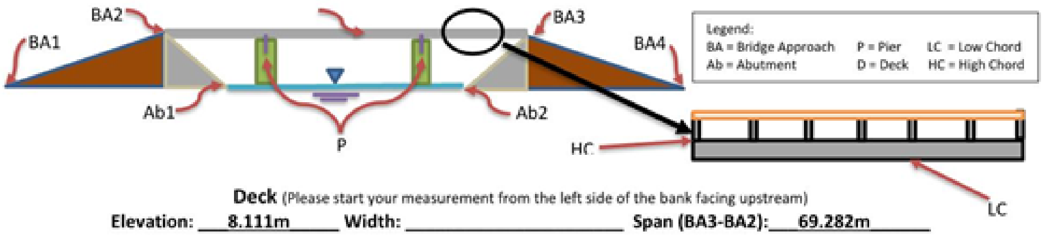
River Name: Guinabasan River — Time: 12:12 PM

Location (Brgy, City,Region): Brgy. New Bago, Municipality of Asturias, Cebu

Survey Team: Amante, Alberto, Salvador, Tort

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

Latitude: 10d37'16.06902" — Longitude: 123d45'55.99703"



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

Elevation: 8.111m Width: ______ Span (BA3-BA2): 69.282m

	Station	High Chord Elevation	Low Chord Elevation
1			
2			
3			
4			

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	18.647m	BA3	93.864m	18.005m
BA2	24.220m	17.937m	BA4	96.068m	17.997m

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

	Station (Distance from BA1)	Elevation
Ab1		
Ab2		

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

Shape: rectangular Number of Piers: 1 Height of column footing: ______

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	32.280m	8.111m	
Pier 2			
Pier 3			
Pier 4			
Pier 5			

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

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure 44. The Guinabasan Bridge as-built survey data.

The water surface elevation of Guinabasan River was determined using a survey grade GNSS receiver Trimble® SPS 882 in PPK survey technique on December 15, 2015 at 12:12 PM with a value of 8.111 m above MSL. This was translated into marking on the bridge's pier using the same technique as shown in Figure 45. It now serves as the reference for flow data gathering and depth gauge deployment of the University of San Carlos (USC), the partner HEI responsible for the monitoring of Guinabasan River.

Figure 45. Water level marking on Guinabasan Bridge

4.6 Validation Points Acquisition Survey

The validation points acquisition survey was conducted on December 12 and 14, 2015 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted at the side of a vehicle as shown in Figure 46. It was secured with cable ties to ensure that it was horizontally and vertically balanced. The antenna height was 2.170 m measured from the ground up to the bottom of notch of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with CBU-3015, CBU-3614, CU-552, DPWHECS, UP-ILI occupied as the GNSS base stations in the conduct of the survey.

Figure 46. GNSS Receiver Trimble® SPS 882 installed on a vehicle for Ground Validation Survey.

The validation points acquisition survey for the Guinabasan River Basin traversed the Municipalities of Tuburan, Asturias, and Balamban. The route of the survey aims to traverse LiDAR flight strips perpendicularly for the basin. The survey gathered a total of 12,473 points with approximate length of 97.43 km for the entire extent validation points acquisition survey as illustrated in the map in Figure 47.

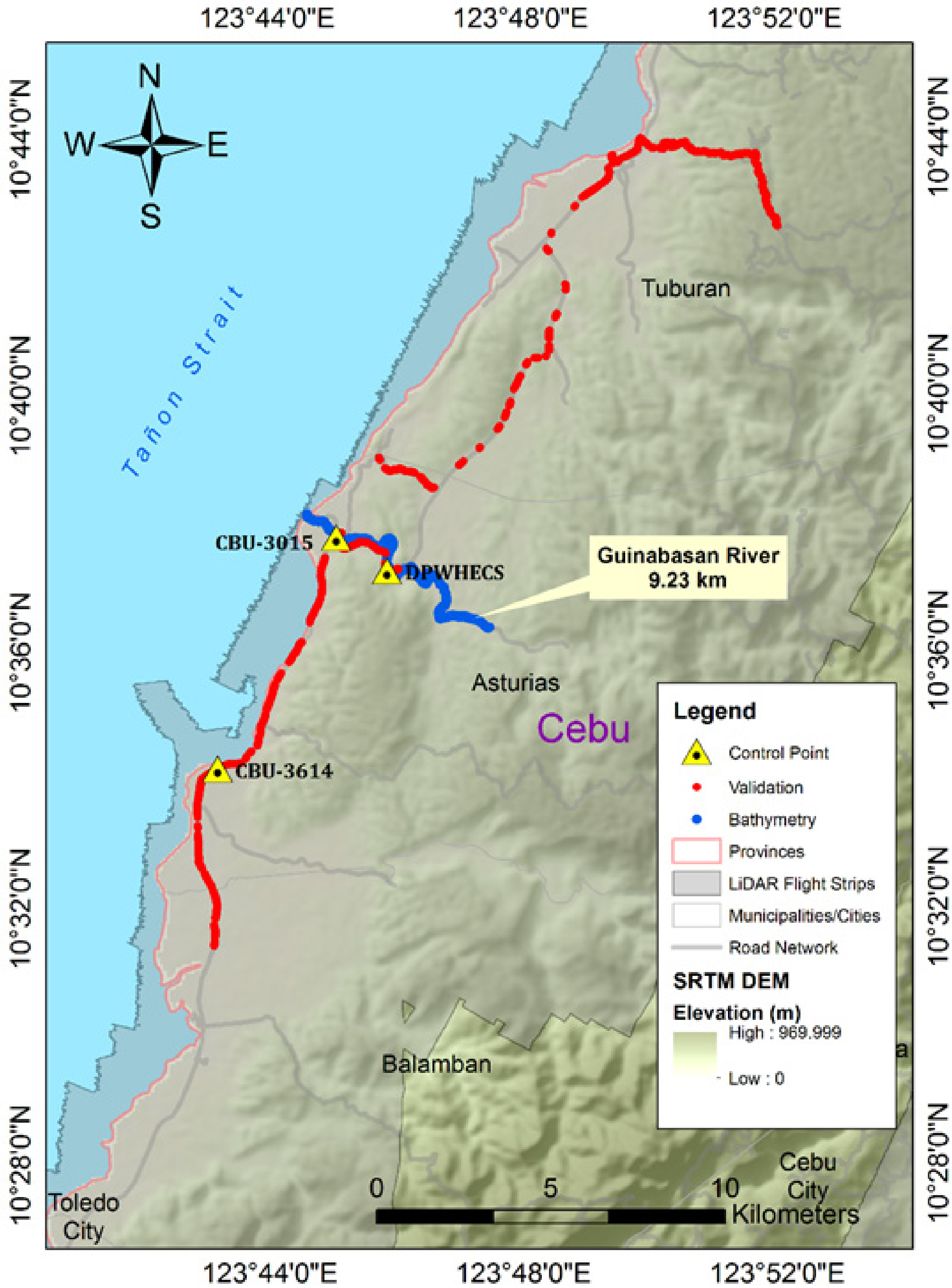


Figure 47. The extent of the LiDAR ground validation survey (in red) for Guinabasan River Basin.

4.7 River Bathymetric Survey

A manual bathymetric survey was performed on December 9, 2015 using a Trimble® SPS 882 in GNSS PPK survey technique in continuous topo mode as illustrated in Figure 48. The survey team was divided in to two (2) groups – the first group began upstream in Brgy. Agtugop, Municipality of Asturias, with coordinates 10°36'22.57096"N 123°47'29.55609"E, up to the boundary of Brgy. New Bago, Municipality of Asturias. Meanwhile, the second group started from Brgy. New Bago, Municipality of Asturias, with coordinates 10°37'09.34070"N 123°46'30.46167"E, going to the mouth of the river to Brgy. Tubigagmanok, Municipality of Asturias. The survey was conducted with the assistance of personnel from the University of San Carlos. Portions of the river with data gaps were resurveyed on December 15, 2015. The control point CBU-3015 was used as base station for the whole conduct of the survey.

Figure 48. Set up of the bathymetric survey at Guinabasan River.

The extent of the bathymetric survey for Guinabasan River is shown in Figure 49. There was a slight deviation from the delineated bathymetric lines in Brgy. Santa Lucia due to the river branching out into two. The survey team chose the branch that has a wider riverbed. To further illustrate this, a CAD drawing of the riverbed centerline profile of the Guinabasan River was produced. As seen in Figure 50, there is about a 23.31-m change in elevation observed within the whole extent of the bathymetric data from its upstream in Brgy. Agtugop down to the mouth of the river in Brgy. Tubigagmanok in the Municipality of Asturias

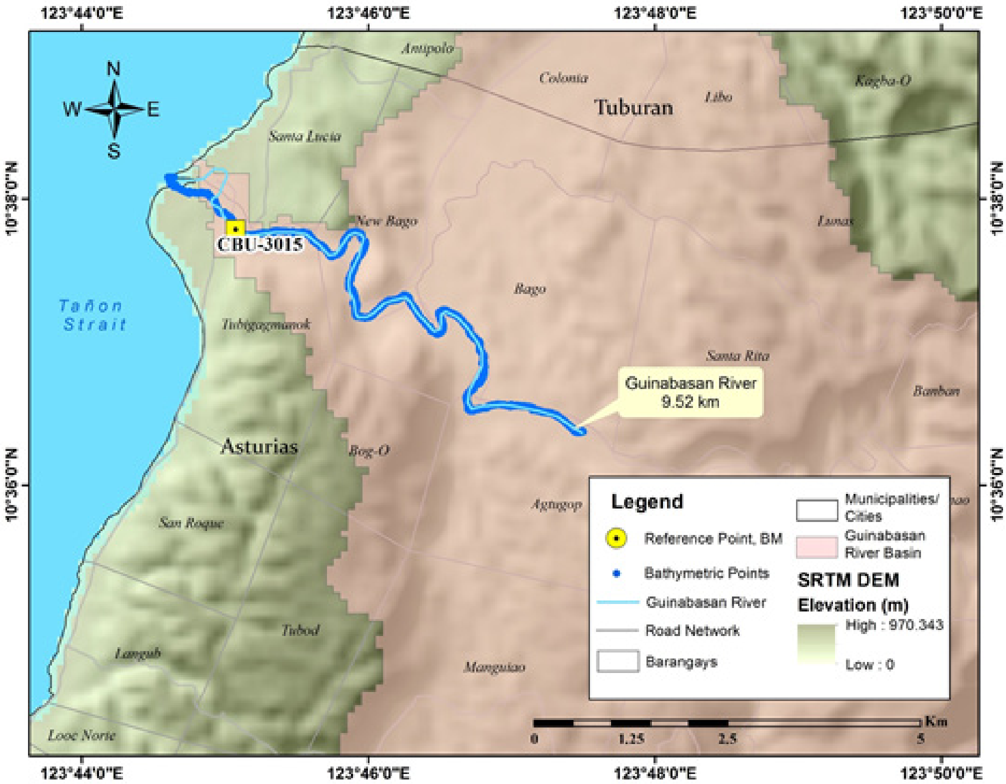


Figure 49. The extent of the Guinabasan River Bathymetry Survey.

Overall, the bathymetric survey for Libertad River gathered a total of 3,477 points, covering 8.023 km of the river. The extent of the bathymetric survey for the Libertad River is shown in Figure 42. To further illustrate this, a CAD drawing of the riverbed profile of the Libertad River was produced. As seen in Figure 43, the highest and lowest elevation has a 40-m difference. The highest elevation observed was 37.575 m in MSL located at Brgy. Cangabo, Libertad; while the lowest was -3.217 m below MSL located in Brgy. Poblacion also in Libertad.

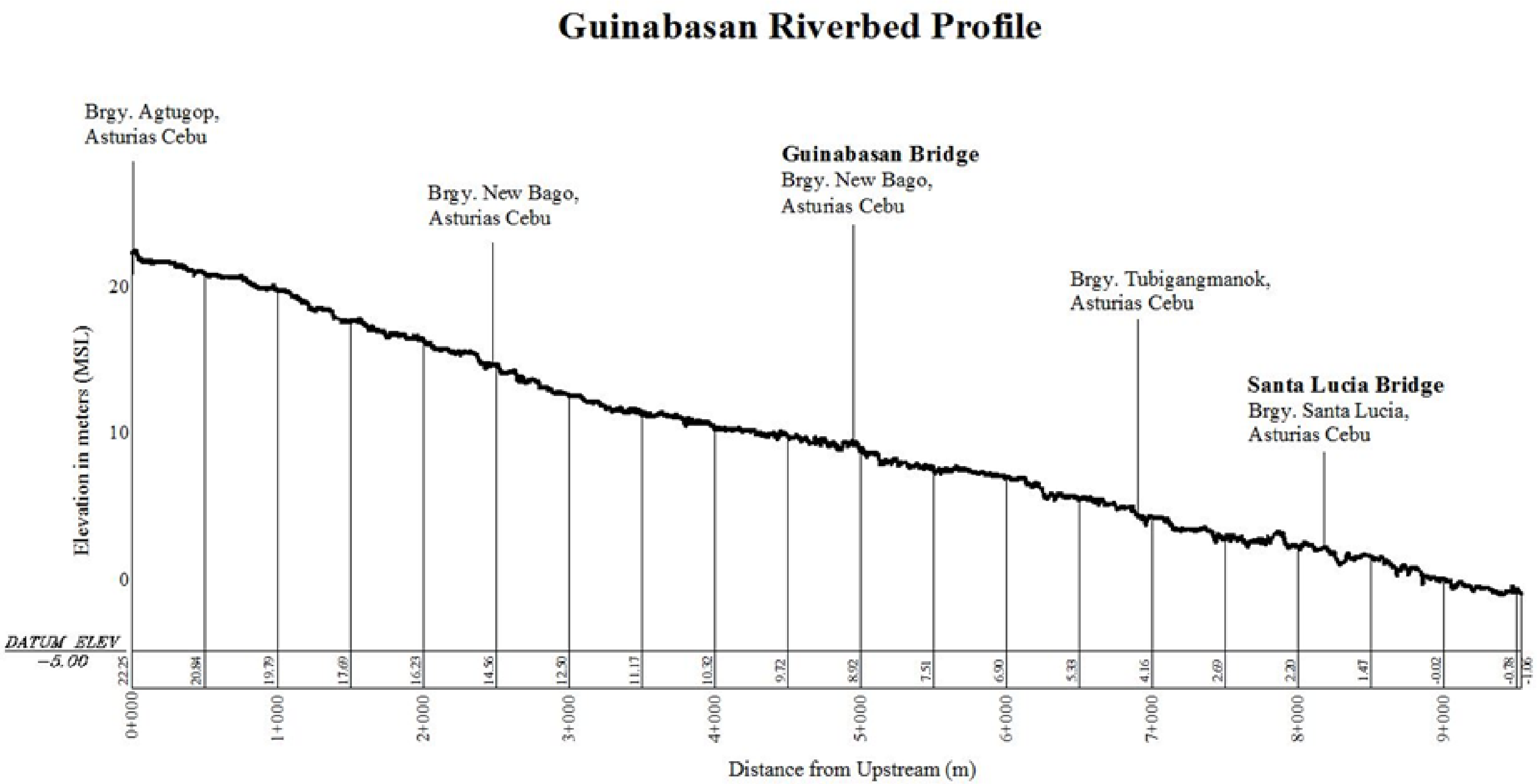


Figure 50. Guinabasan Riverbed Profile.

CHAPTER 5: FLOOD MODELING AND MAPPING

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

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

All components and data, such as rainfall, water level, and flow in a certain period of time, which may affect the hydrologic cycle of the Guinabasan River Basin were monitored, collected, and analyzed.

5.1.2 Precipitation

Precipitation data was taken from an automatic rain gauge (ARG) installed by the Department of Science and Technology – Advanced Science and Technology Institute (DOST-ASTI). This rain gauge was installed in in Brgy. Agbanga, Asturias with geographic coordinates of 10.5911° N and 123.803°E as illustrated in Figure 51.

The total precipitation for this event in Brgy. Agbanga, Asturias ARG was 6 mm. It has a peak rainfall of 1.4 mm on January 2, 2017 at 6:50 AM. The lag time between the peak rainfall and discharge is 1 hour and 50 minutes.

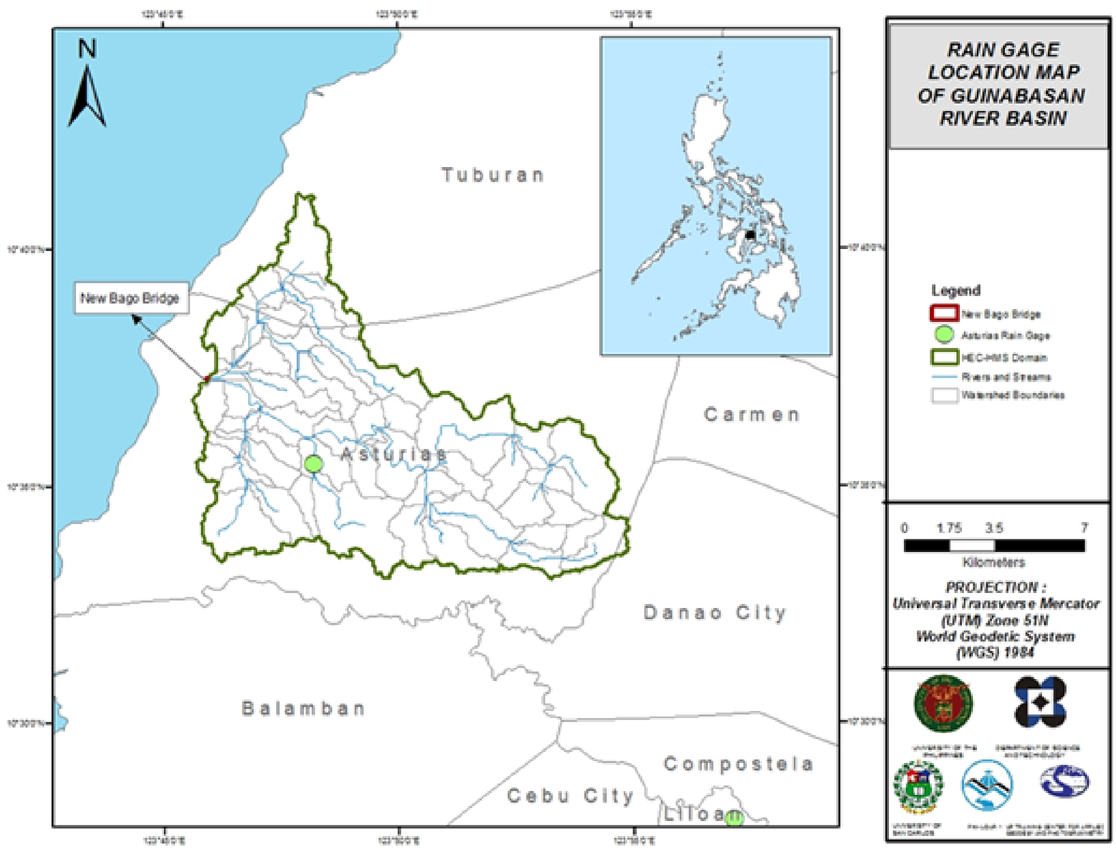


Figure 51. Location Map of the Guinabasan HEC-HMS model used for calibration.

5.1.3 Rating Curves and River Outflow

A rating curve was computed using the prevailing cross-section (Figure 52) at New Bago Bridge (10.6212°N, 123.765°E). It gives the relationship between the observed water levels and outflow of the watershed at this location.

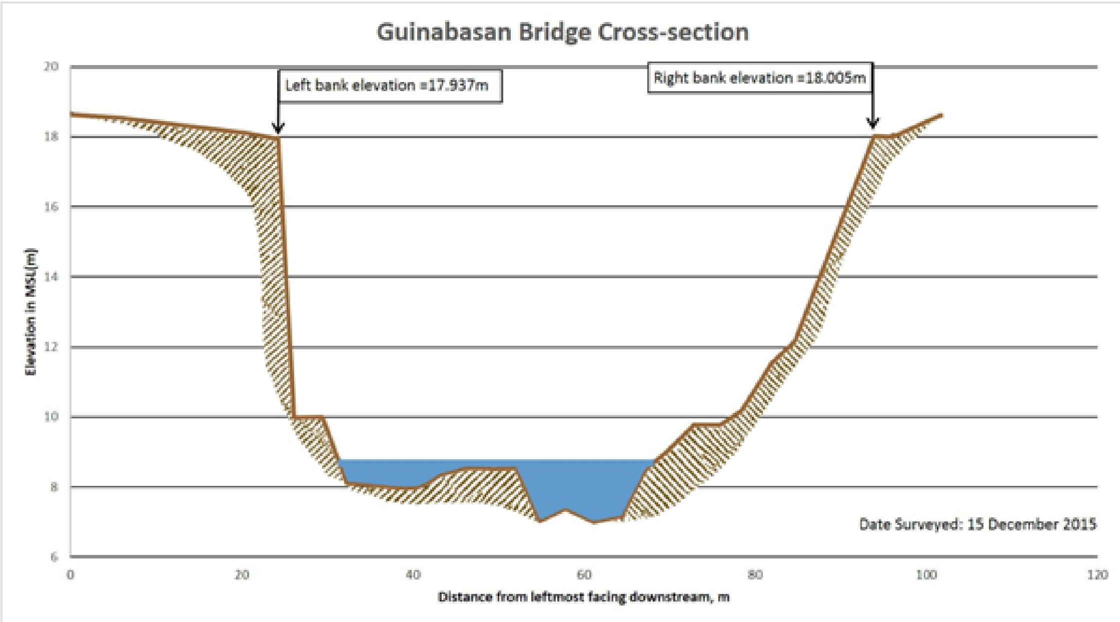


Figure 52. Cross-Section Plot of New Bago Bridge.

For New Bago Bridge, the rating curve is expressed y=1E-14e^4.4196x as shown in Figure 53.

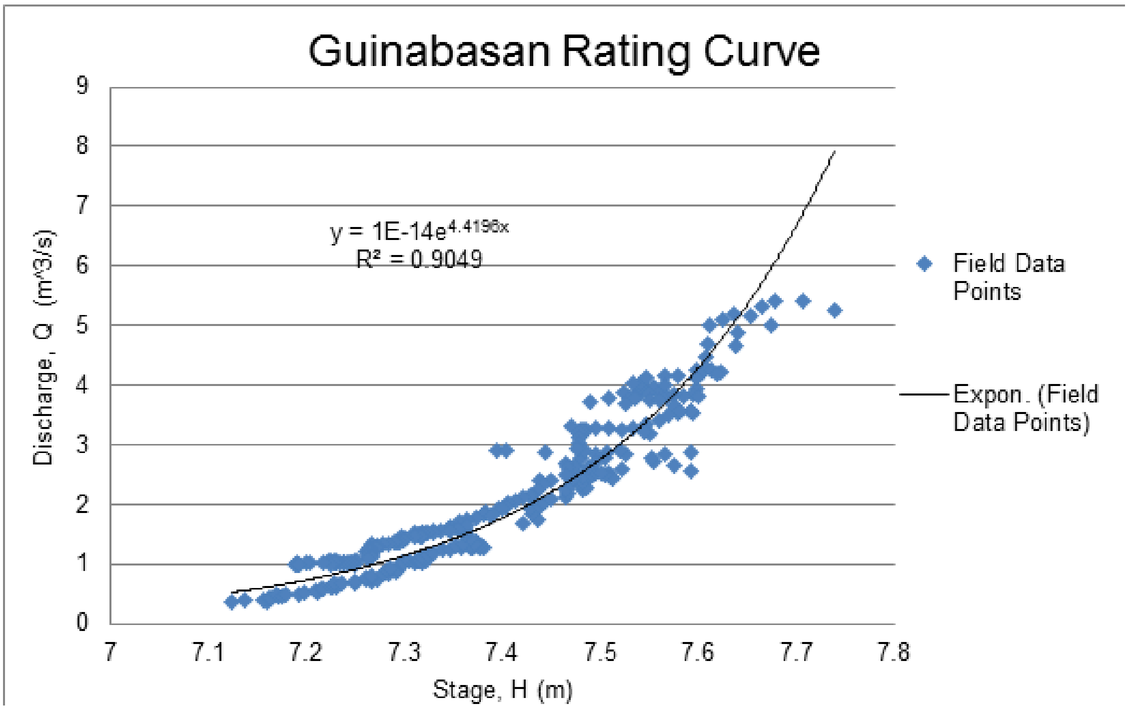


Figure 53. The rating curve at New Bago Bridge, Asturias, Cebu.

This rating curve equation was used to compute the river outflow at New Bago Bridge for the calibration of the HEC-HMS model shown in Figure 54. The total rainfall for this event is 6 mm and the peak discharge is 5.4 m3/s at 7:40 PM of January 2, 2017.

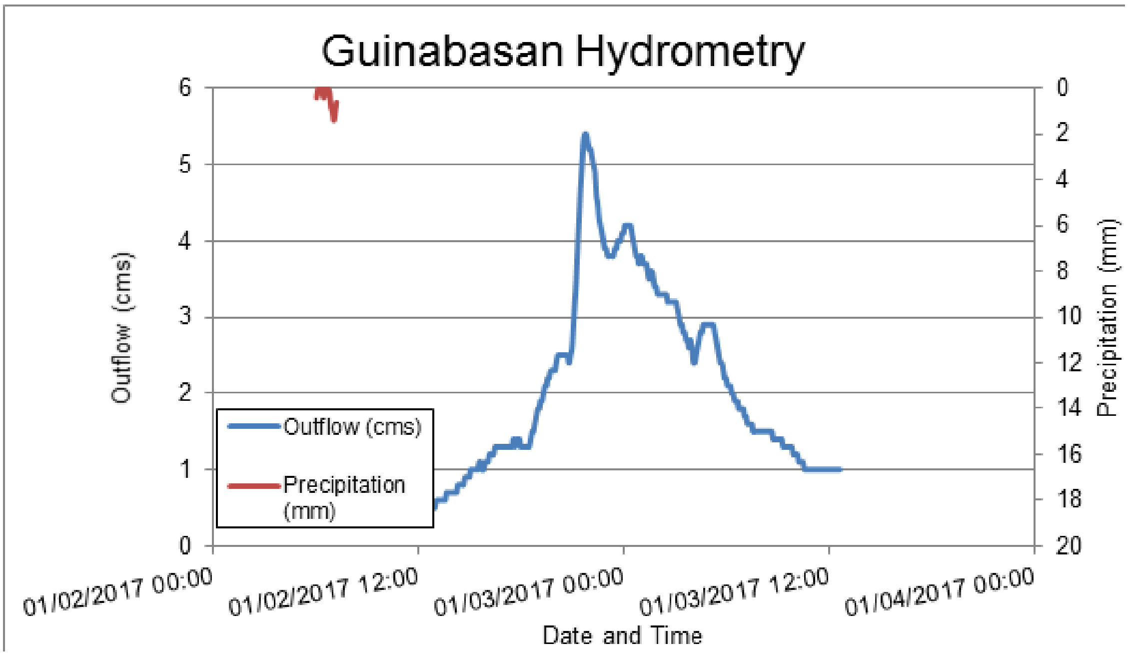


Figure 54. Rainfall and outflow data at New Bago Bridge, which was used for modeling.

5.2 RIDF Station

PAGASA computed the Rainfall Intensity Duration Frequency (RIDF) values for the Laoag Rain Gauge (Table 29). The RIDF rainfall amount for 24 hours was converted into a synthetic storm by interpolating and re-arranging the values in such a way that certain peak values will be attained at a certain time (Figure 56). This station was selected based on its proximity to the Guinabasan watershed. The extreme values for this watershed were computed based on a 37-year record.

Table 29. RIDF values for the Mactan Point Rain Gauge, as computed by PAGASA

COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION									
T (yrs)	10 mins	20 mins	30 mins	1 hr	2 hrs	3 hrs	6 hrs	12 hrs	24 hrs
2	15.9	24.7	31.4	41.4	53.7	60.5	73.1	83.4	92.8
5	21.9	34	43.2	58.4	74.9	84	105.2	122.6	139.1
10	25.8	40.2	51.1	69.7	88.9	99.6	126.3	148.6	169.7
15	28.1	43.6	55.5	76	96.8	108.4	138.3	163.3	187
20	29.6	46.1	58.6	80.5	102.3	114.5	146.7	173.5	199.1
25	30.9	48	61	83.9	106.6	119.3	153.1	181.4	208.5
50	34.6	53.8	68.3	94.4	119.7	133.9	173	205.8	237.2
100	38.3	59.5	75.6	104.9	132.7	148.4	192.7	230	265.7

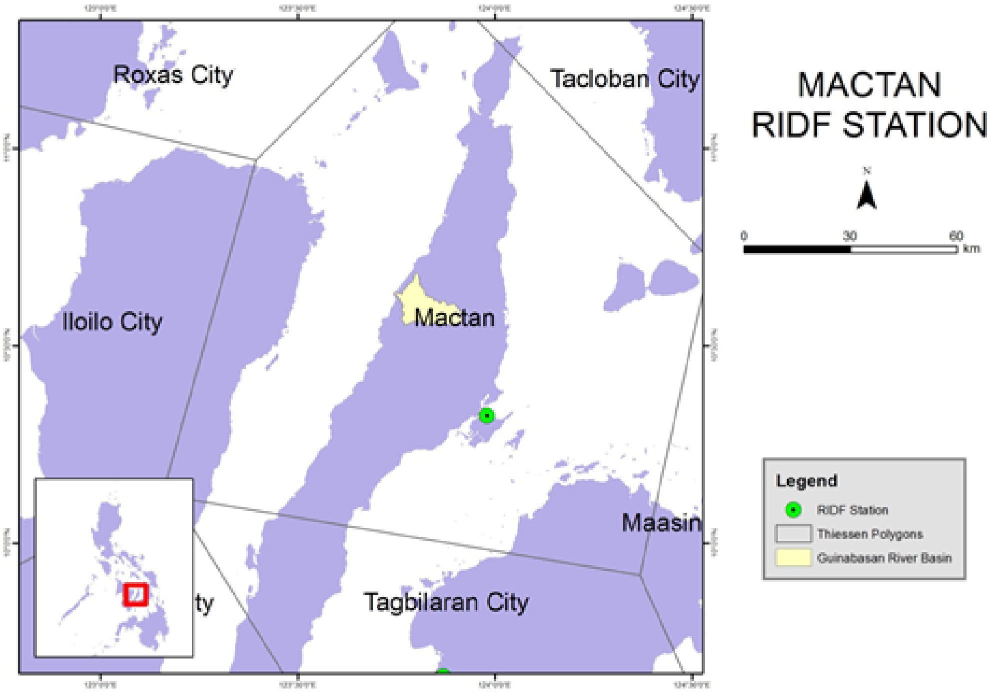


Figure 55. Location of Mactan RIDF Station relative to Guinabasan River Basin.

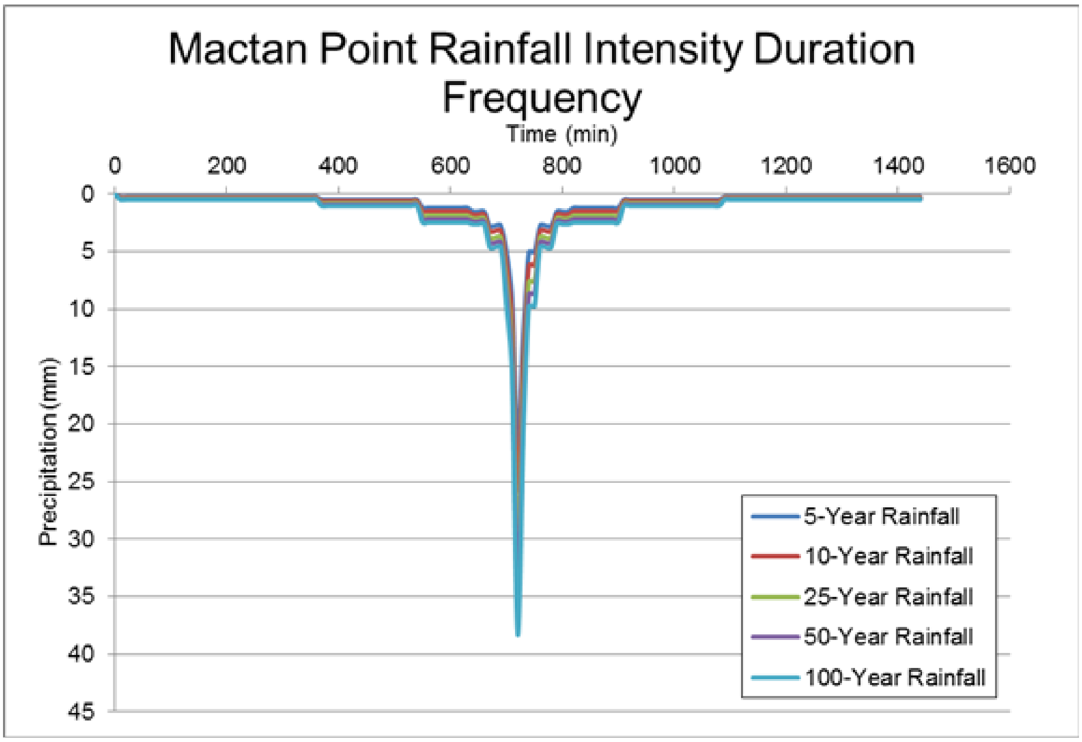


Figure 56. Synthetic storm generated for a 24-hr period rainfall for various return periods.

5.3 HMS Model

The soil dataset was generated before 2004 from the Bureau of Soils under the Department of Environment and Natural Resources Management. The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Guinabasan River Basin are shown in Figure 57 and Figure 58, respectively.

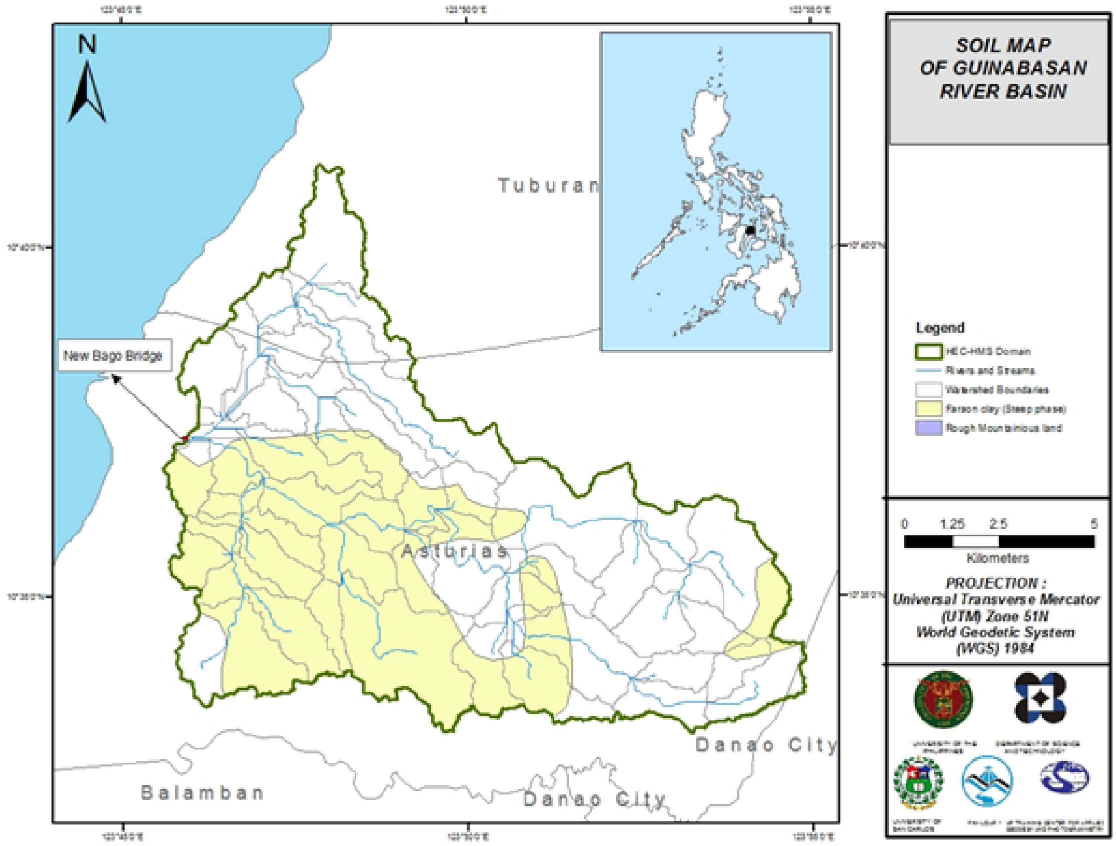


Figure 57. Soil Map of Guinabasan River Basin.

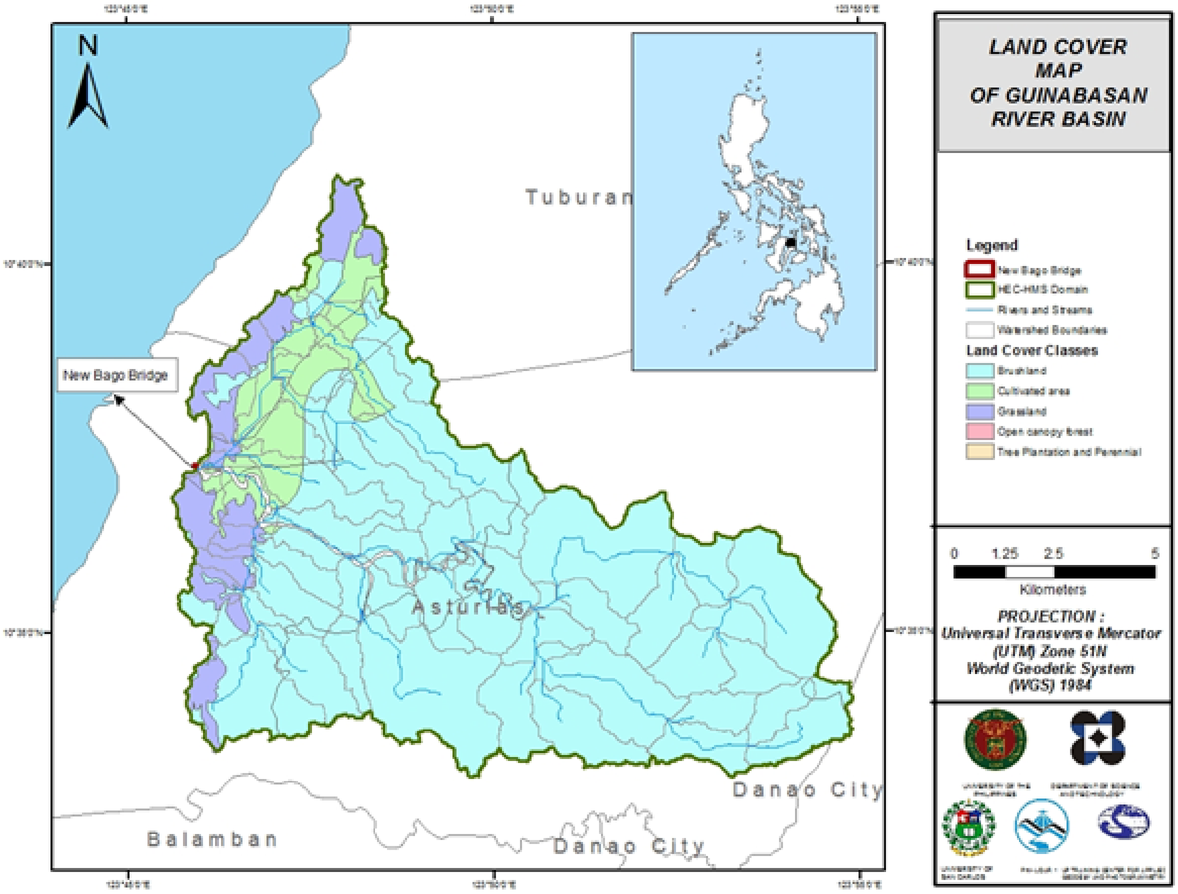


Figure 58. Land Cover Map of Guinabasan River Basin.

For Guinabasan, four (4) soil classes were identified. These are clay, clay loam, silt loam and undifferentiated land. Moreover, seven (7) land cover classes were identified. These are brushlands, built-up areas, cultivated areas, inland water, open areas, open canopy forests, and tree plantations.

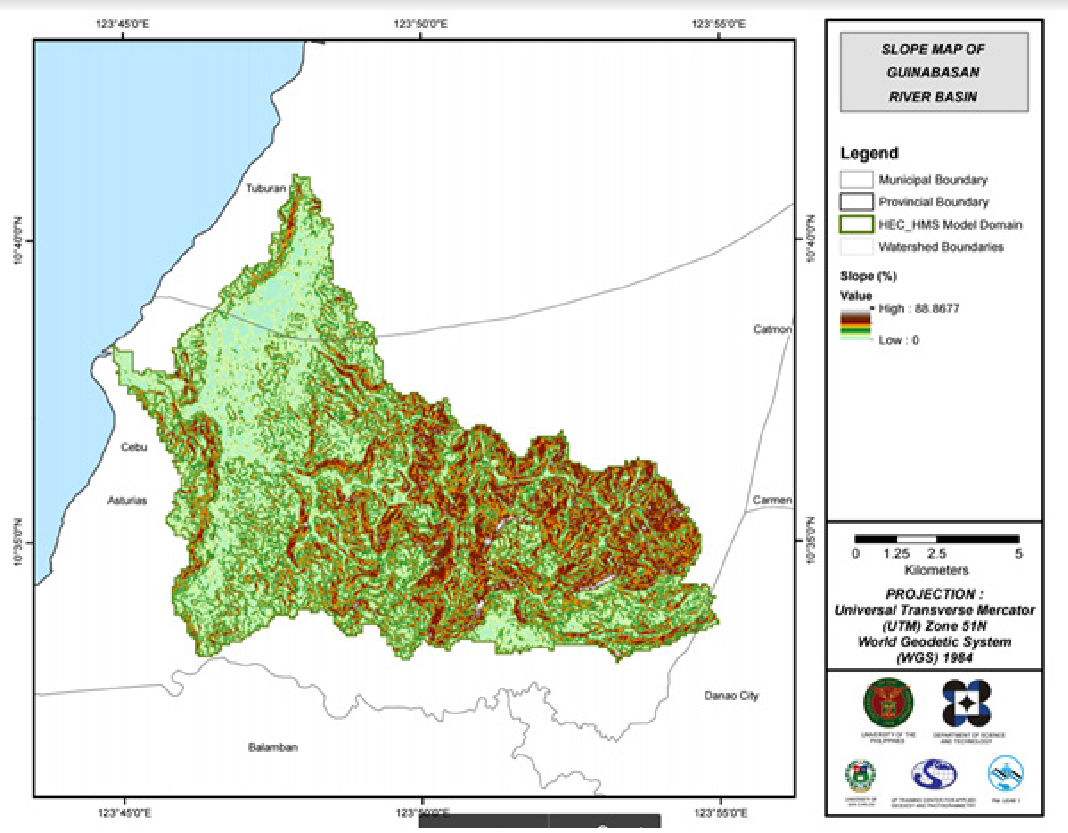


Figure 59. Slope Map of the Guinabasan River Basin.

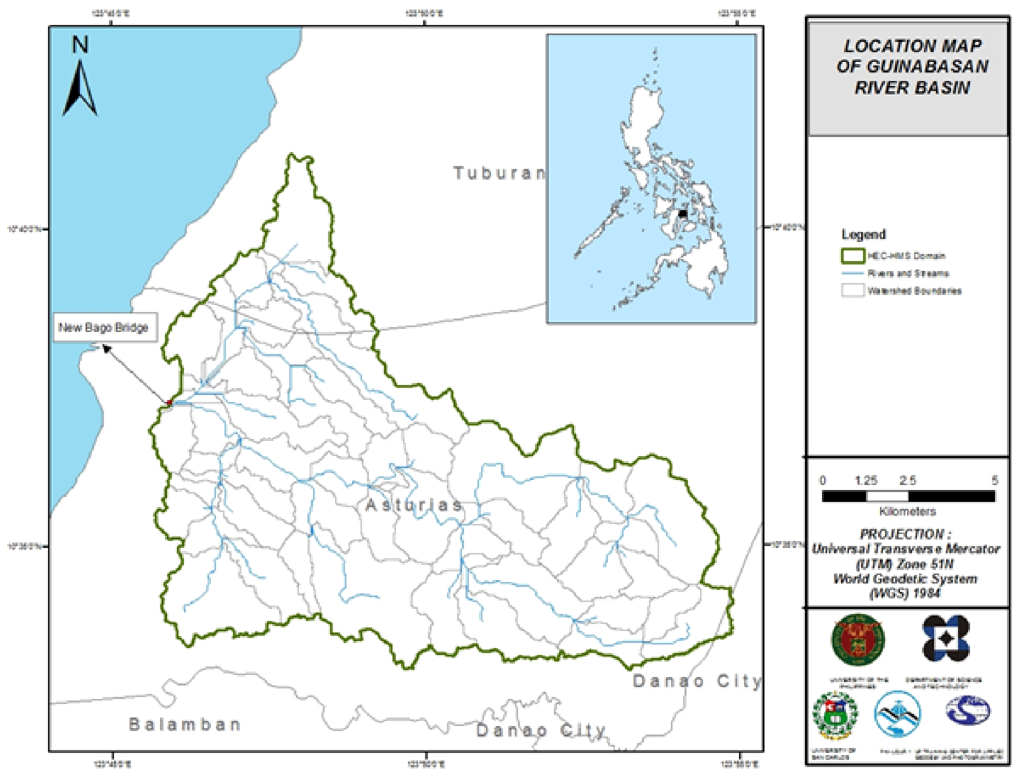


Figure 60. Stream Delineation Map of Guinabasan River Basin

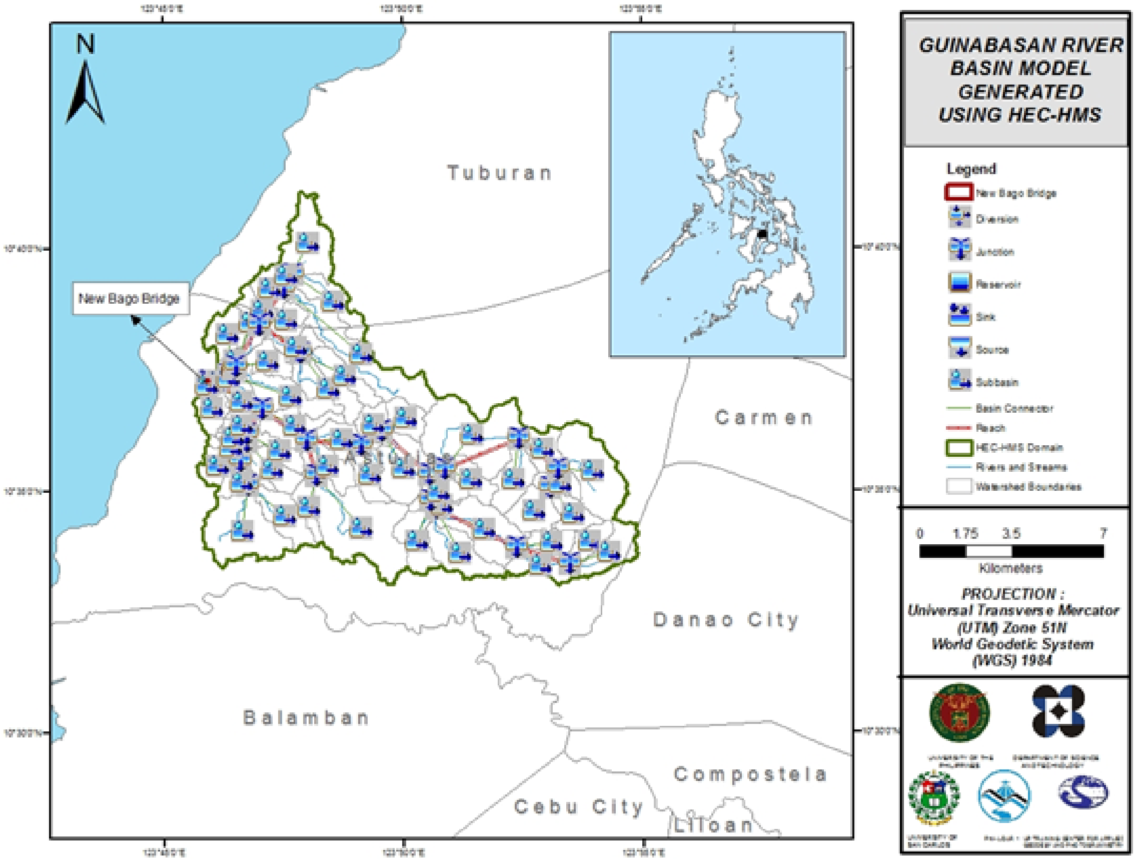


Figure 61. Guinabasan river basin model generated in HEC-HMS.

Using the SAR-based DEM, the Guinabasan basin was delineated and further subdivided into subbasins. The model consists of 57 sub basins and 28 reaches as shown in Figure 61 (See Annex 10).

5.4 Cross-section Data

The riverbed cross-sections of the watershed were necessary in the HEC-RAS model setup. The cross-section data for the HEC-RAS model was derived from the LiDAR DEM data, which was defined using the Arc GeoRAS tool and was post-processed in ArcGIS (Figure 62).

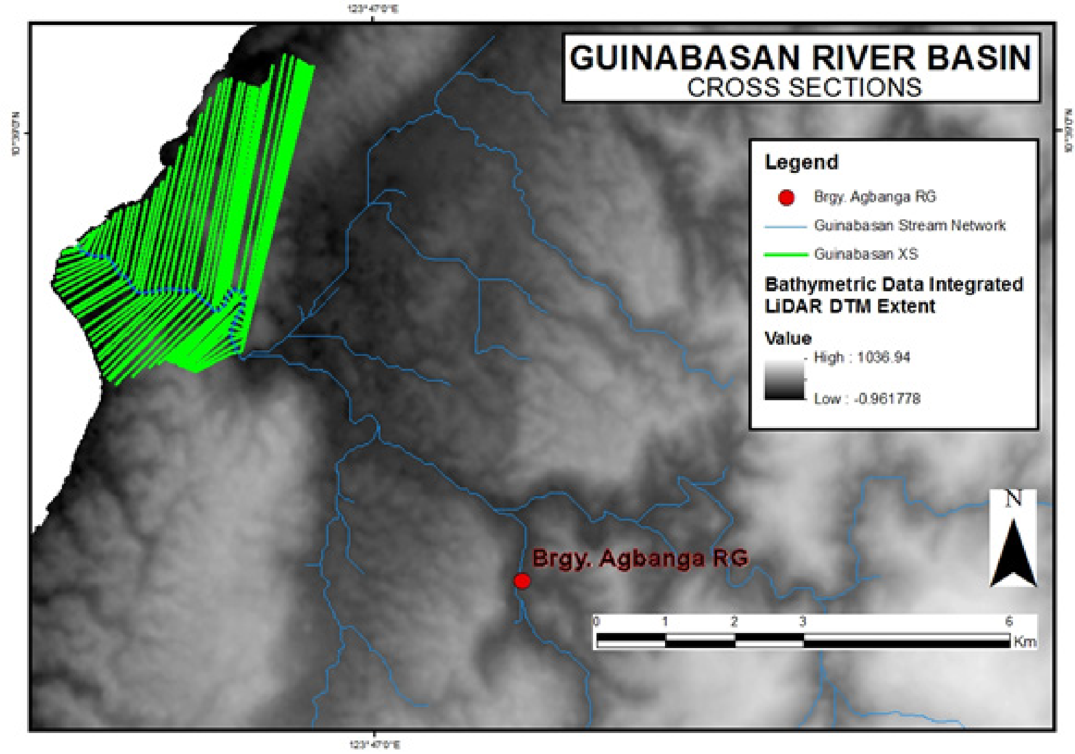


Figure 62. River cross-section of the Guinabasan River through the ArcMap HEC GeoRas tool.

5.5 Flo 2D Model

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

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

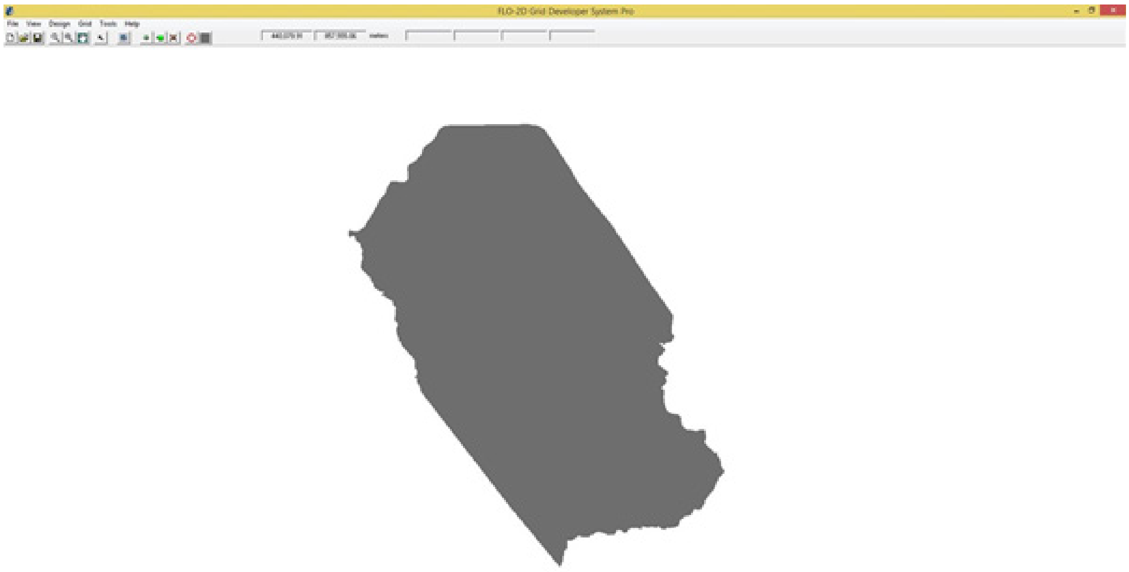


Figure 63. A screenshot of the river sub-catchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro).

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 100.06329 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 generated hazard maps for Guinabasan are in Figure 68, 70, and 72.

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 63 792 800.00 m2. The generated flood depth maps for Guinabasan are in Figure 69, 71, and 73.

There is a total of 465 228 177.98 m3 of water entering the model. Of this amount, 25 253 779.51 m3 is due to rainfall while 439 974 398.47 m3 is inflow from other areas outside the model. 11 329 565.00 m3 of this water is lost to infiltration and interception, while 24 641 579.81 m3 is stored by the flood plain. The rest, amounting up to 429 257 024.59 m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Guinabasan HEC-HMS river basin model (See Annex 9), its accuracy was measured against the observed values. Figure 64 shows the comparison between the two discharge data.

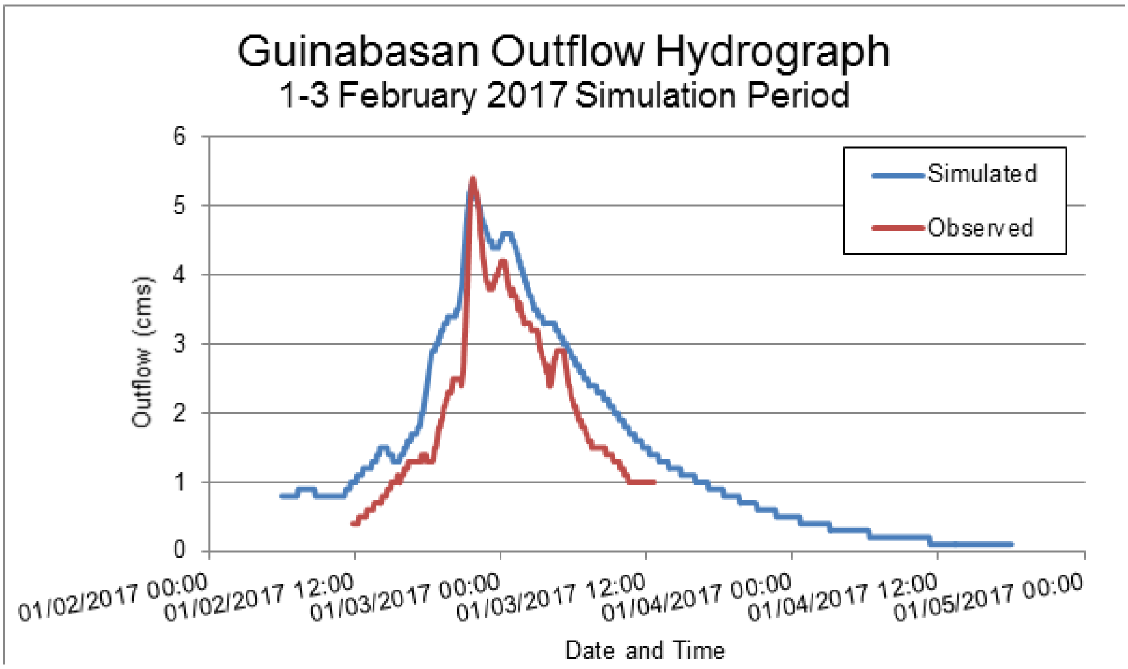


Figure 64. Outflow Hydrograph of Guinabasan produced by the HEC-HMS model compared with observed outflow.

Table 30 shows the adjusted ranges of values of the parameters used in calibrating the model.

Table 30. Range of calibrated values for the Guinabasan River Basin.

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	1.15-6.22
			Curve Number	59.07-83.33
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0-70
			Storage Coefficient (hr)	0.51-7.63
	Baseflow	Recession	Recession Constant	0.02-27.85
			Ratio to Peak	0-0.10
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.17-0.40

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 1.15 to 6.22 mm means that there is minimal to average 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 65 to 90 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). Since the soil type is mostly clay, the curve number values for Guinabasan range from 59.07 to 83.33.

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 0.51 to 7.63 minutes 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 to 0.10 indicates that the basin will quickly go back to its original discharge. Ratio to peak of 0.17 to 0.40 indicates a steeper receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.01 to 0.90 corresponds to the common roughness in Guinabasan, which is determined to be mostly brushland (Brunner, 2010).

Table 31. Summary of the Efficiency Test of the Guinabasan HMS Model

Accuracy measure	Value
RMSE	0.6774
r2	0.9684
NSE	0.8596
PBIAS	-24
RSR	0.3747

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 0.6774

.

The Pearson correlation coefficient (r^2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.9684.

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 0.8596.

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 -24.

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 0.3747.

1.

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

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph (Figure 63) shows the Guinabasan outflow using the Mactan 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 show increasing outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

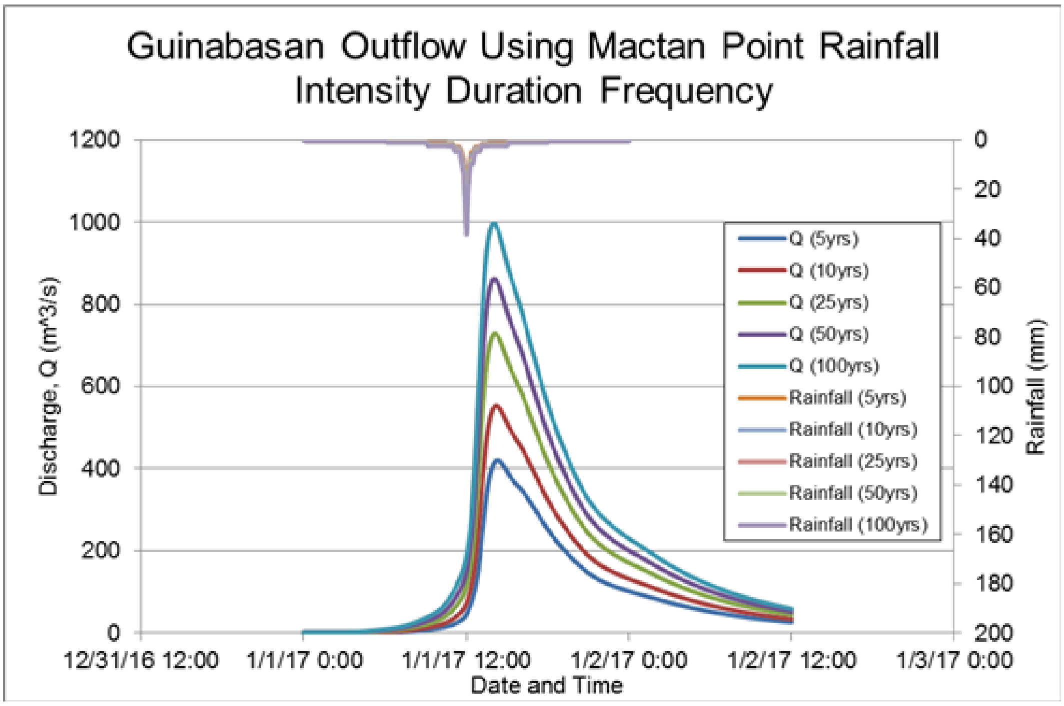


Figure 65. The Outflow hydrograph at the Guinabasan Station, generated using the Mactan RIDF simulated in HEC-HMS.

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Guinabasan discharge using the Mactan Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 33.

Table 32. The peak values of the Guinabasan HEC-HMS Model outflow using the Mactan RIDF.

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	139.1	21.9	420.206	2 hour, 20 minutes
10-Year	169.7	25.8	552.835	2 hour, 10 minutes
25-Year	208.5	30.9	728.715	2 hour, 10 minutes
50-Year	237.2	34.6	861.084	2 hour, 00 minutes
100-Year	265.7	38.3	997.209	2 hour, 00 minutes

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model 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. Figure 66 shows a generated sample map of the Guinabasan River using the calibrated HMS base flow.

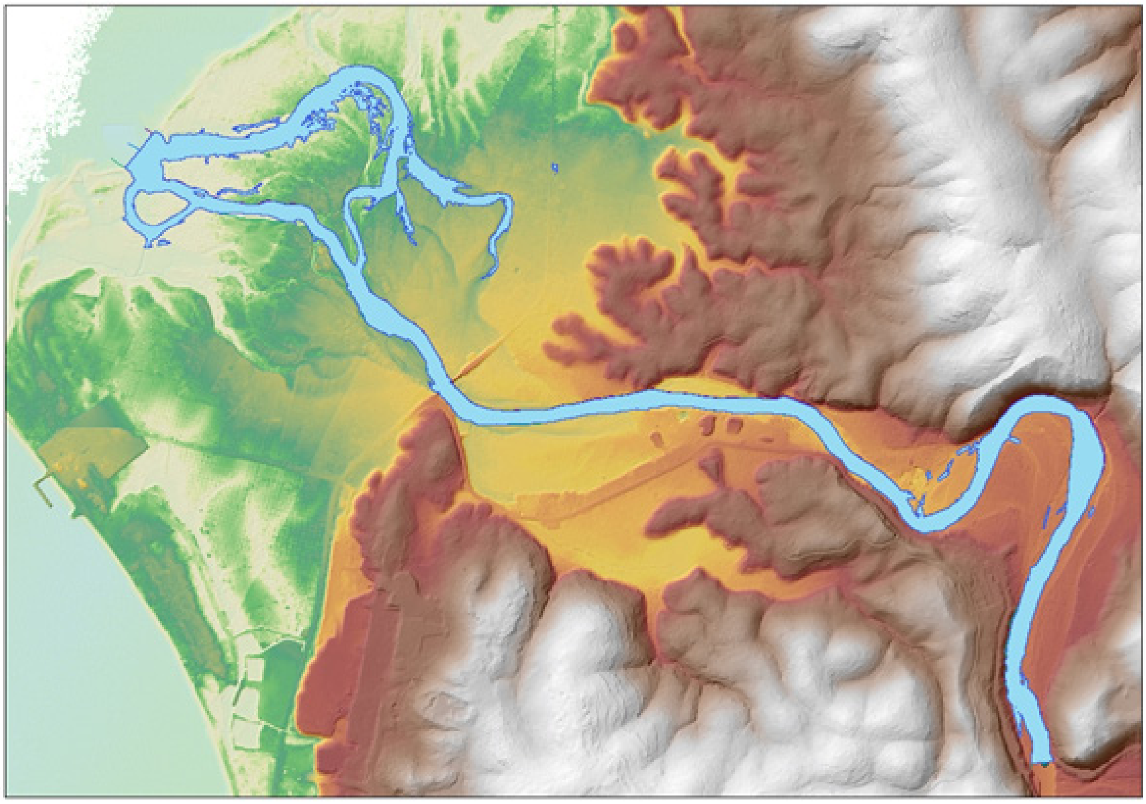


Figure 66. Sample output map of the Guinabasan RAS Model.

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figure 67 to Figure 72 show the 5-, 25-, and 100-year rain return scenarios of the Guinabasan floodplain. The floodplain, with an area of 566.21 sq. km., covers 16 municipalities from three provinces. Table 37 shows the percentage of area affected by flooding per municipality.

Table 33. Municipalities affected in Guinabasan floodplain.

Province	Municipality	Total Area	Area Flooded	% Flooded
Abra	San Quintin	62.29	44.19	70.94%
Abra	Bangued	123.75	30.88	24.96%
Abra	Langiden	98.70	87.67	88.82%
Abra	Pidigan	58.13	45.00	77.41%
Ilocos Norte	Nueva Era	619.00	3.54	0.57%
Ilocos Sur	Bantay	71.06	71.06	100.00%
Ilocos Sur	Caoayan	21.20	20.08	94.73%
Ilocos Sur	Magsingal	78.90	75.66	95.90%
Ilocos Sur	Narvacan	97.18	0.30	0.31%
Ilocos Sur	San Ildefonso	13.21	13.21	100.00%
Ilocos Sur	San Juan	59.88	42.08	70.28%
Ilocos Sur	San Vicente	12.20	12.20	100.00%
Ilocos Sur	Santa Catalina	10.83	8.09	74.65%
Ilocos Sur	Santa	57.20	35.91	62.78%
Ilocos Sur	Santo Domingo	50.36	50.36	99.99%
Ilocos Sur	Vigan City	24.01	23.44	97.66%

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Figure 67. A 100-year Flood Hazard Map for Guinabasan Floodplain overlaid on Google Earth imagery.

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Figure 68. A 100-year Flow Depth Map for Guinabasan Floodplain overlaid on Google Earth imagery.

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Figure 69. A 25-year Flood Hazard Map for Guinabasan Floodplain overlaid on Google Earth imagery.

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Figure 70. A 25-year Flow Depth Map for Guinabasan Floodplain overlaid on Google Earth imagery.

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Figure 71. A 5-year Flood Hazard Map for Guinabasan Floodplain overlaid on Google Earth imagery.

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Figure 72. A 5-year Flood Depth Map for Guinabasan Floodplain overlaid on Google Earth imagery.

5.10 Inventory of Areas Exposed to Flooding

Listed below are the affected barangays in the Guinabasan River Basin, grouped accordingly by municipality. For the said basin, four municipalities consisting of 26 barangays are expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 42% of the municipality of Asturias with an area of 140.45 sq. km. will experience flood levels of less 0.20 meters. 1.9% of the area will experience flood levels of 0.21 to 0.50 meters while 1.8%, 1.5%, 1.01, and 0.31% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters respectively. Listed in Table 34 are the affected areas in square kilometers by flood depth per barangay. Annex 12 and Annex 13 show the educational and health institutions exposed to flooding.

Table 34. Affected Areas in Asturias, Cebu during 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Asturias (in sq. km.)								
	Agbanga	Agtugop	Bago	Bairan	Bog-O	Lunas	Magcalape	Manguiao	New Bago
0.03-0.20	2.39	5.49	5.7	1.98	2.86	3.56	3.41	8.46	5.17
0.21-0.50	0.047	0.21	0.35	0.049	0.064	0.12	0.078	0.34	0.44
0.51-1.00	0.063	0.26	0.3	0.025	0.041	0.053	0.04	0.23	0.72
1.01-2.00	0.1	0.32	0.35	0.025	0.016	0.056	0.06	0.18	0.56
2.01-5.00	0.2	0.26	0.27	0.037	0.0021	0.062	0.051	0.13	0.28
> 5.00	0.08	0.14	0.027	0.011	0.000003	0.012	0.012	0.0072	0.094

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Asturias (in sq. km.)							
	San Isidro	San Roque	Santa Lucia	Santa Rita	Tag-Amakan	Tubigagmanok	Tubod	Ubogon
0.03-0.20	0.93	1.39	2.89	5.86	0.4	4.67	1.95	1.87
0.21-0.50	0.016	0.037	0.33	0.14	0.007	0.37	0.043	0.036
0.51-1.00	0.014	0.023	0.27	0.11	0.0048	0.28	0.026	0.019
1.01-2.00	0.019	0.028	0.059	0.087	0.0036	0.2	0.019	0.017
2.01-5.00	0.019	0.018	0.017	0.087	0.0083	0.073	0.0098	0.014
> 5.00	0.0014	0.0066	0.00032	0.017	0.0041	0.018	0.0009	0.0003

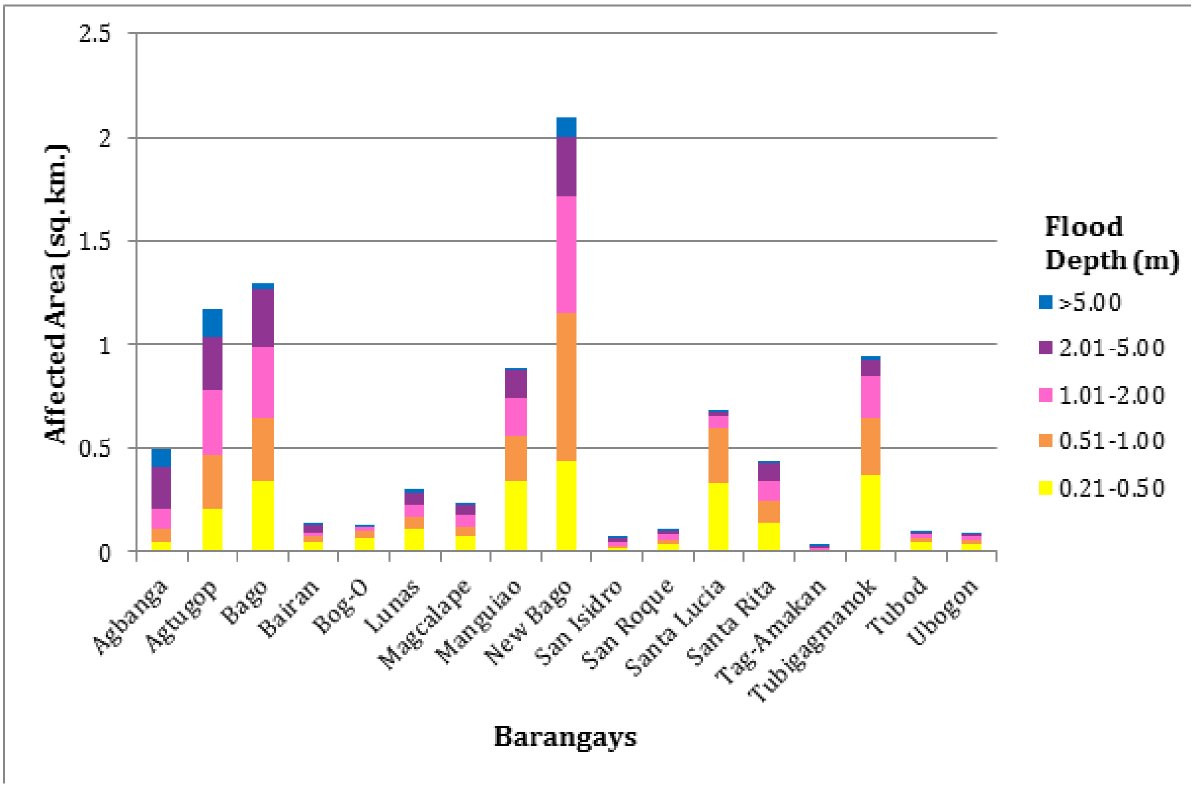

Figure 73. Affected Areas in Asturias, Cebu during 5-Year Rainfall Return Period.

For the municipality of Tuburan, with an area of 243.8 sq. km., 7.04% will experience flood levels of less 0.20 meters. 0.49% of the area will experience flood levels of 0.21 to 0.50 meters while 0.35%, 0.28%, 0.04%, and 0.0004% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 35 are the affected areas in square kilometers by flood depth per barangay.

Table 35. Affected Areas in Tuburan, Cebu during 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tuburan (in sq. km.)				
	Antipolo	Bakyawan	Caridad	Colonia	Fortaliza
0.03-0.20	5.25	0.17	0.085	3.58	1.18
0.21-0.50	0.14	0.0079	0.0021	0.66	0.066
0.51-1.00	0.15	0.0005	0.00029	0.43	0.059
1.01-2.00	0.28	0.0002	0	0.19	0.12
2.01-5.00	0.014	0	0	0.011	0.025
> 5.00	0	0	0	0.0001	0

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tuburan (in sq. km.)				
	Kagba-O	Libo	Molobolo	Santo Niño	
0.03-0.20	0.17	2.92	0.082	3.72	
0.21-0.50	0.0022	0.19	0.0043	0.11	
0.51-1.00	0.00064	0.14	0.002	0.074	
1.01-2.00	0.0003	0.044	0.00091	0.035	
2.01-5.00	0	0.029	0.0004	0.012	
> 5.00	0	0.0007	0	0.0001	

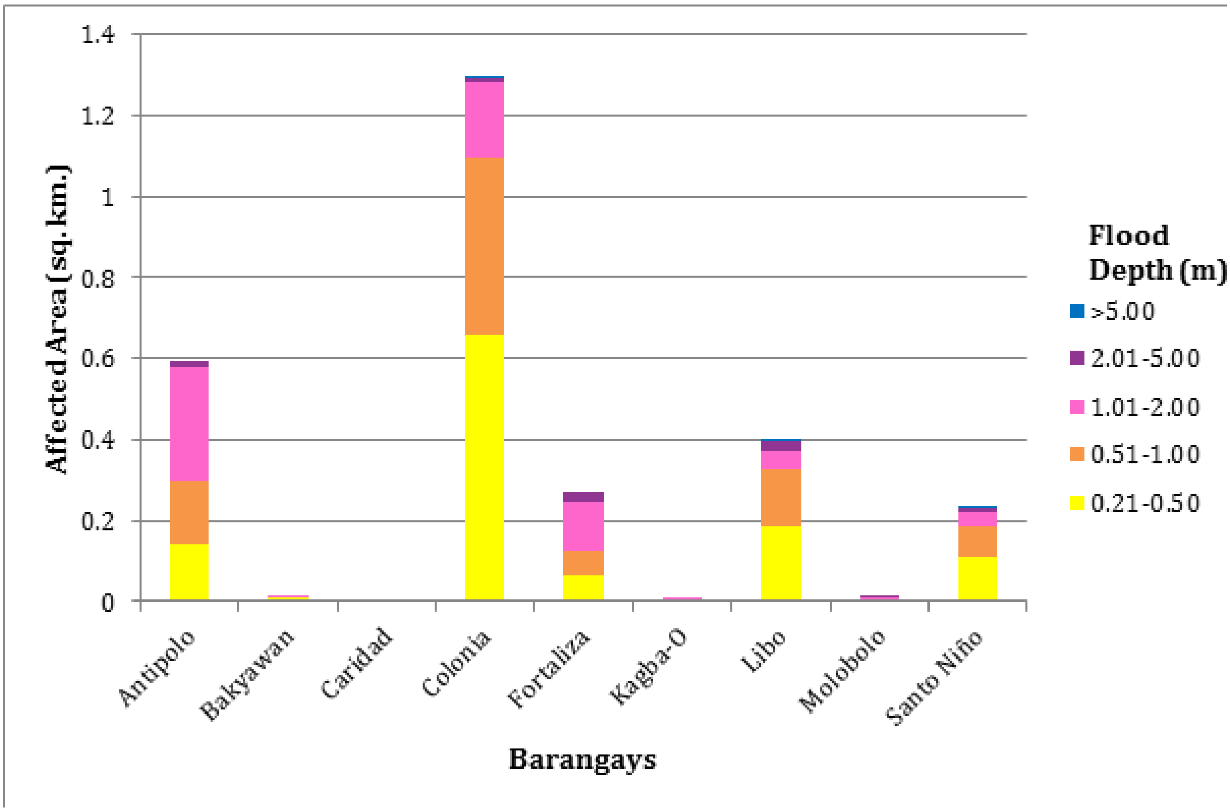

Figure 74. Affected Areas in Tuburan, Cebu during 5-Year Rainfall Return Period.

For the 25-year return period, 40.7% of the municipality of Asturias with an area of 140.45 sq. km. will experience flood levels of less 0.20 meters. 1.87% of the area will experience flood levels of 0.21 to 0.50 meters while 1.78%, 1.82%, 1.087, and 0.72% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters respectively. Listed in Table 36 are the affected areas in square kilometres by flood depth per barangay.

Table 36. Affected Areas in Asturias, Cebu during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Asturias (in sq. km.)								
	Agbanga	Agtugop	Bago	Bairan	Bog-O	Lunas	Magcalape	Manguiao	New Bago
0.03-0.20	2.35	5.34	5.2	1.96	2.84	3.5	3.36	8.27	4.86
0.21-0.50	0.045	0.19	0.38	0.056	0.064	0.12	0.09	0.33	0.28
0.51-1.00	0.043	0.19	0.37	0.031	0.05	0.073	0.045	0.27	0.55
1.01-2.00	0.083	0.33	0.45	0.027	0.022	0.064	0.053	0.25	0.7
2.01-5.00	0.21	0.37	0.56	0.041	0.0055	0.077	0.077	0.2	0.74
> 5.00	0.15	0.24	0.04	0.017	0.000003	0.022	0.019	0.023	0.13

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Asturias (in sq. km.)							
	San Isidro	San Roque	Santa Lucia	Santa Rita	Tag-Amakan	Tubigagmanok	Tubod	Ubogon
0.03-0.20	0.91	1.36	2.72	5.79	0.4	4.49	1.93	1.85
0.21-0.50	0.016	0.044	0.38	0.14	0.0068	0.4	0.047	0.041
0.51-1.00	0.014	0.025	0.33	0.11	0.0045	0.33	0.031	0.022
1.01-2.00	0.021	0.029	0.11	0.11	0.0041	0.26	0.022	0.017
2.01-5.00	0.031	0.025	0.024	0.12	0.0085	0.11	0.017	0.02
> 5.00	0.0055	0.012	0.0014	0.024	0.0079	0.02	0.0023	0.0029

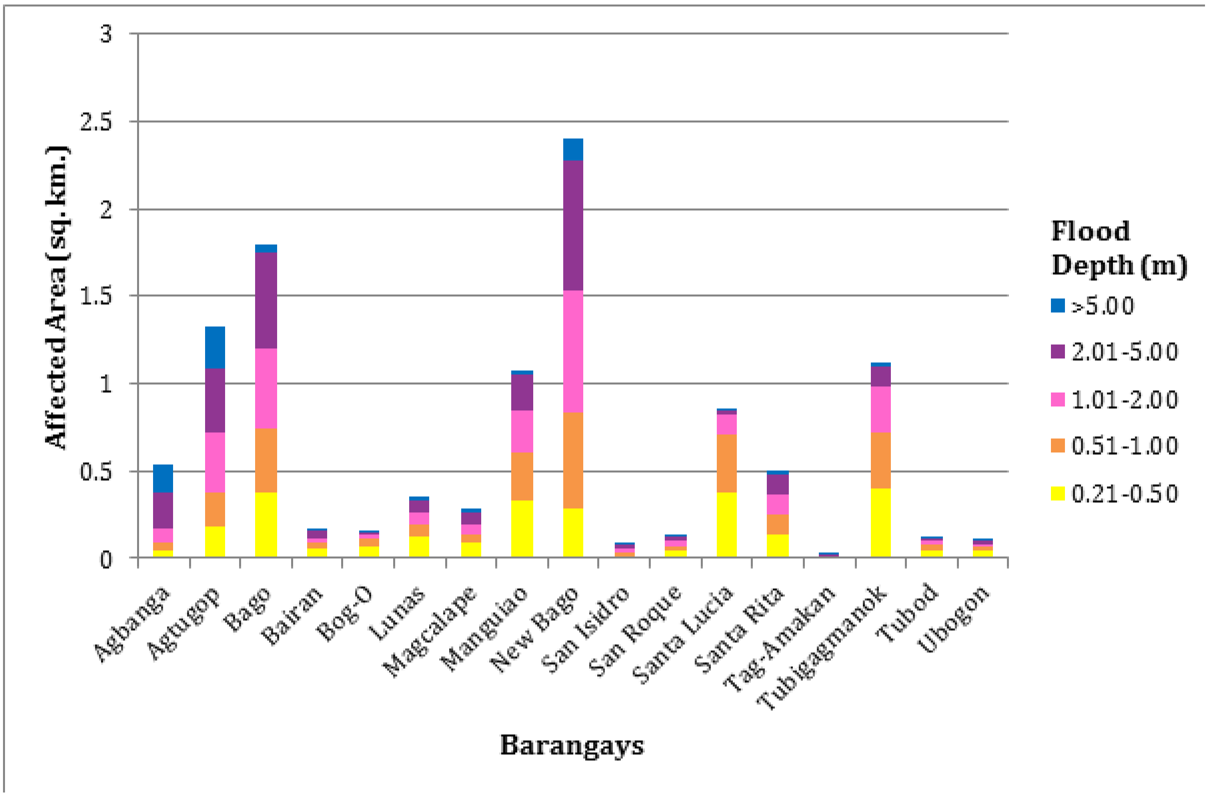

Figure 75. Affected Areas in Asturias, Cebu during 25-Year Rainfall Return Period.

For the municipality of Tuburan, with an area of 243.8 sq. km., 6.85% will experience flood levels of less 0.20 meters. 0.45% of the area will experience flood levels of 0.21 to 0.50 meters while 0.4%, 0.32%, 0.14%, and 0.0008% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 37 are the affected areas in square kilometers by flood depth per barangay.

Table 37. Affected Areas in Tuburan, Cebu during 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tuburan (in sq. km.)				
	Antipolo	Bakyawan	Caridad	Colonia	Fortaliza
0.03-0.20	5.19	0.17	0.084	3.31	1.15
0.21-0.50	0.14	0.011	0.0024	0.58	0.069
0.51-1.00	0.12	0.001	0.00036	0.61	0.054
1.01-2.00	0.31	0.0001	0.00013	0.28	0.062
2.01-5.00	0.079	0.0002	0	0.091	0.12
> 5.00	0	0	0	0.0002	0

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tuburan (in sq. km.)			
	Kagba-O	Libo	Molobolo	Santo Niño
0.03-0.20	0.17	2.86	0.08	3.68
0.21-0.50	0.0023	0.17	0.0041	0.12
0.51-1.00	0.00084	0.18	0.0028	0.081
1.01-2.00	0.0004	0.073	0.0016	0.054
2.01-5.00	0	0.038	0.0005	0.017
> 5.00	0	0.0016	0	0.0002

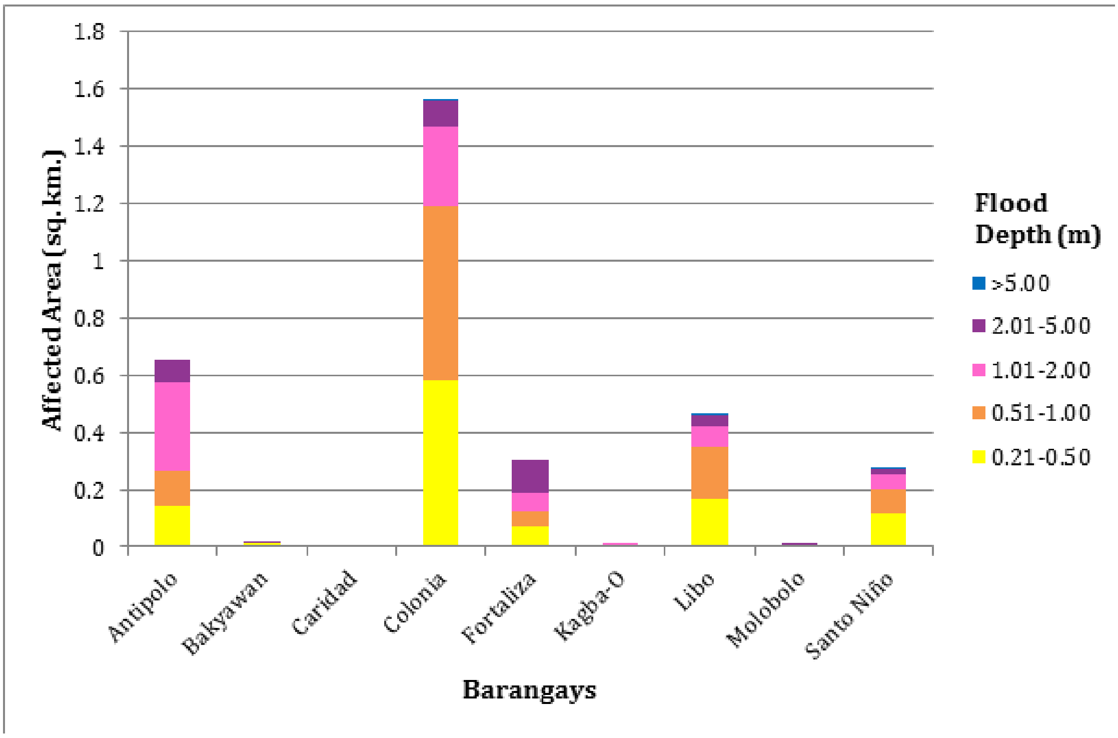

Figure 76. Affected Areas in Tuburan, Cebu during 25-Year Rainfall Return Period.

For the 100-year return period, 40.05% of the municipality of Asturias with an area of 140.45 sq. km. will experience flood levels of less 0.20 meters. 1.73% of the area will experience flood levels of 0.21 to 0.50 meters while 1.78%, 1.9%, 2.37, and 0.72% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters respectively. Listed in Table are the affected areas in square kilometers by flood depth per barangay.

Table 38. Affected Areas in Asturias, Cebu during 100-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Asturias (in sq. km.)								
	Agbanga	Agtugop	Bago	Bairan	Bog-O	Lunas	Magcalape	Manguiao	New Bago
0.03-0.20	2.32	5.25	5.04	1.94	2.83	3.46	3.34	8.15	4.74
0.21-0.50	0.045	0.18	0.24	0.061	0.068	0.11	0.099	0.33	0.22
0.51-1.00	0.038	0.18	0.42	0.035	0.052	0.094	0.05	0.27	0.38
1.01-2.00	0.07	0.29	0.46	0.029	0.027	0.065	0.043	0.3	0.73
2.01-5.00	0.17	0.44	0.77	0.045	0.0077	0.09	0.094	0.26	1.03
> 5.00	0.24	0.32	0.051	0.023	0.000003	0.029	0.027	0.038	0.16

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Asturias (in sq. km.)							
	San Isidro	San Roque	Santa Lucia	Santa Rita	Tag-Amakan	Tubigagmanok	Tubod	Ubogon
0.03-0.20	0.9	1.35	2.62	5.76	0.39	4.39	1.92	1.84
0.21-0.50	0.015	0.047	0.37	0.14	0.0089	0.39	0.05	0.043
0.51-1.00	0.015	0.027	0.38	0.11	0.0038	0.37	0.034	0.026
1.01-2.00	0.022	0.032	0.16	0.13	0.0045	0.28	0.024	0.02
2.01-5.00	0.036	0.028	0.03	0.13	0.0089	0.15	0.02	0.021
> 5.00	0.01	0.015	0.002	0.033	0.01	0.022	0.003	0.0053

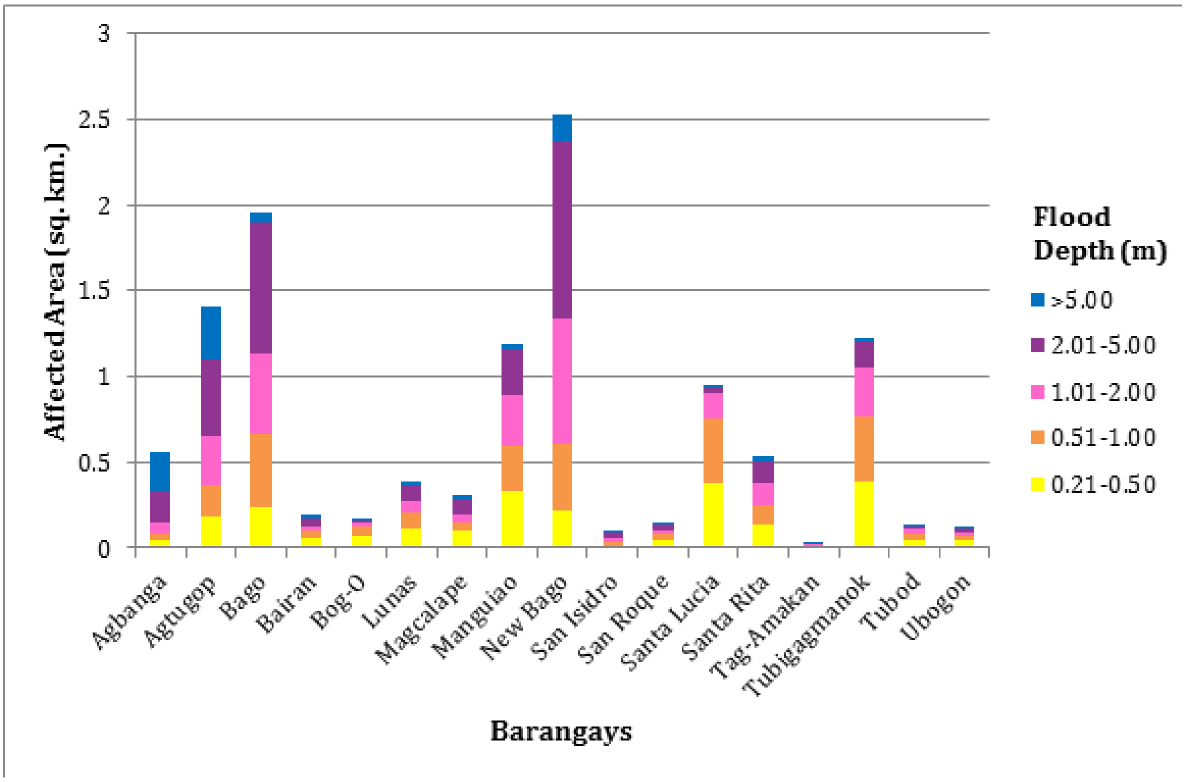

Figure 77. Affected Areas in Asturias, Cebu during 100-Year Rainfall Return Period.

For the municipality of Tuburan, with an area of 243.8 sq. km., 6.74% will experience flood levels of less 0.20 meters. 0.43% of the area will experience flood levels of 0.21 to 0.50 meters while 0.45%, 0.34%, 0.24%, and 0.002% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 39 are the affected areas in square kilometers by flood depth per barangay.

Table 39. Affected Areas in Tuburan, Cebu during 100-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tuburan (in sq. km.)				
	Antipolo	Bakyawan	Caridad	Colonia	Fortaliza
0.03-0.20	5.15	0.17	0.084	3.16	1.13
0.21-0.50	0.15	0.013	0.0023	0.53	0.075
0.51-1.00	0.13	0.0019	0.0003	0.65	0.052
1.01-2.00	0.2	0.0002	0.00029	0.38	0.056
2.01-5.00	0.22	0.0002	0	0.15	0.14
> 5.00	0	0	0	0.0002	0

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tuburan (in sq. km.)			
	Kagba-O	Libo	Molobolo	Santo Niño
0.03-0.20	0.17	2.83	0.08	3.66
0.21-0.50	0.0026	0.14	0.0037	0.12
0.51-1.00	0.00094	0.19	0.0034	0.086
1.01-2.00	0.0004	0.11	0.0017	0.065
2.01-5.00	0	0.044	0.0006	0.022
> 5.00	0	0.003	0	0.0006

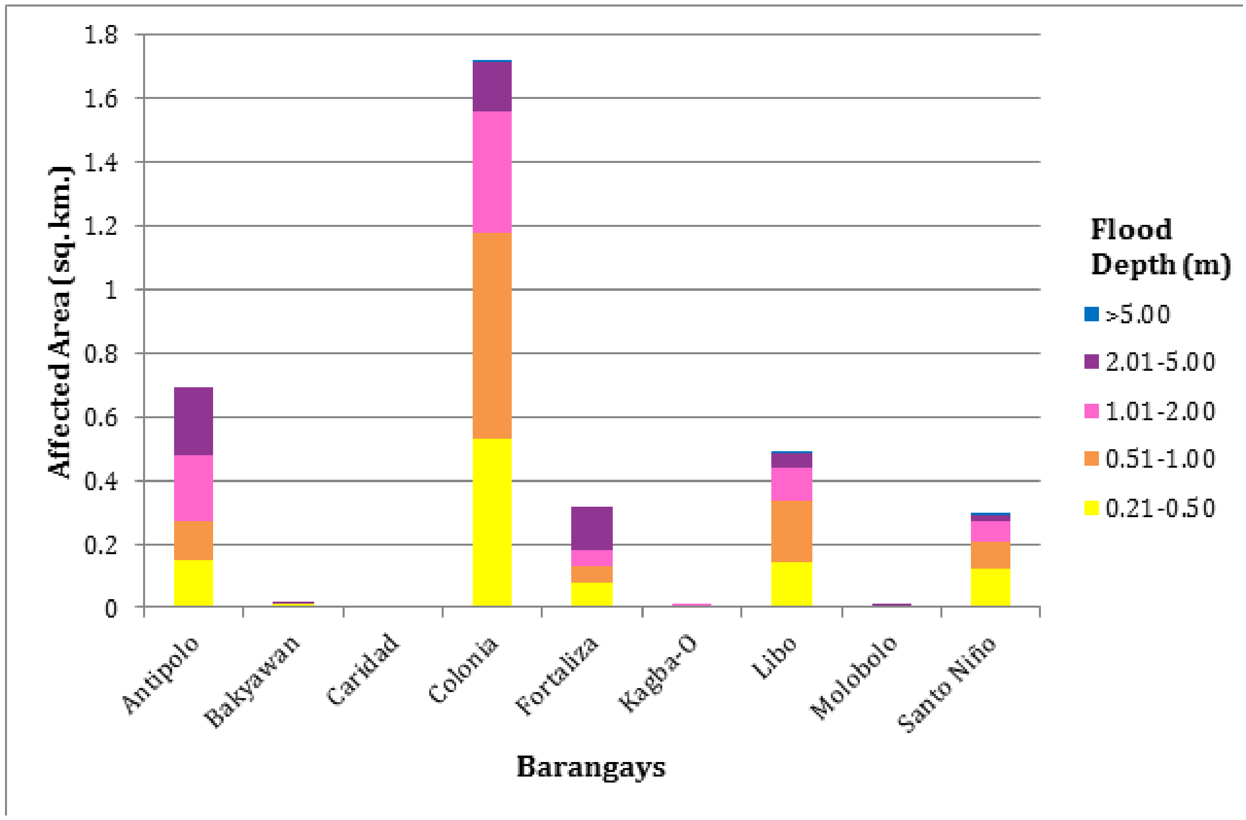

Figure 78. Affected Areas in Tuburan, Cebu during 100-Year Rainfall Return Period.

Among the barangays in the municipality of Asturias, Manguiao is projected to have the highest percentage of area that will experience flood levels at 6.65%. Meanwhile, New Bago posted the second highest percentage of area that may be affected by flood depths at 5.17%.

Among the barangays in the municipality of Tuburan, Antipolo is projected to have the highest percentage of area that will experience flood levels at 2.4%. Meanwhile, Colonia posted the second highest percentage of area that may be affected by flood depths at 2%.

Moreover, the generated flood hazard maps for the Guinabasan 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 40. Area covered by each warning level with respect to the rainfall scenarios.

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	3.73	3.62	3.36
Medium	4.96	5.25	5.45
High	3.51	5.61	6.83

Of the 2 identified Education Institutions in the Guinabasan Flood plain, no schools were assessed to be exposed to any of the flooding scenarios.

Of the 2 identified Medical Institutions in the Guinabasan Flood Plain, one medical institution was assessed to be exposed to Low level flooding in both 25 and 100 year scenarios.

5.11 Flood Validation

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

From the flood depth maps produced by Phil-LiDAR 1 Program, multiple points representing the different flood depths for different scenarios were identified for validation.

The validation personnel then went to the specified points identified in a river basin and gathered data regarding the actual flood level in each location. Data gathering was done through a local DRRM office to obtain maps or situation reports about the past flooding events or by interviewing some residents with knowledge of or have 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 the results of the flood map. The points in the flood map versus its corresponding validation depths are shown in Figure 80.

Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 3.15 m. Table 41 shows a contingency matrix of the comparison. The validation points are found in Annex 11.

The flood validation data were gathered on Jan 13-15, 2016

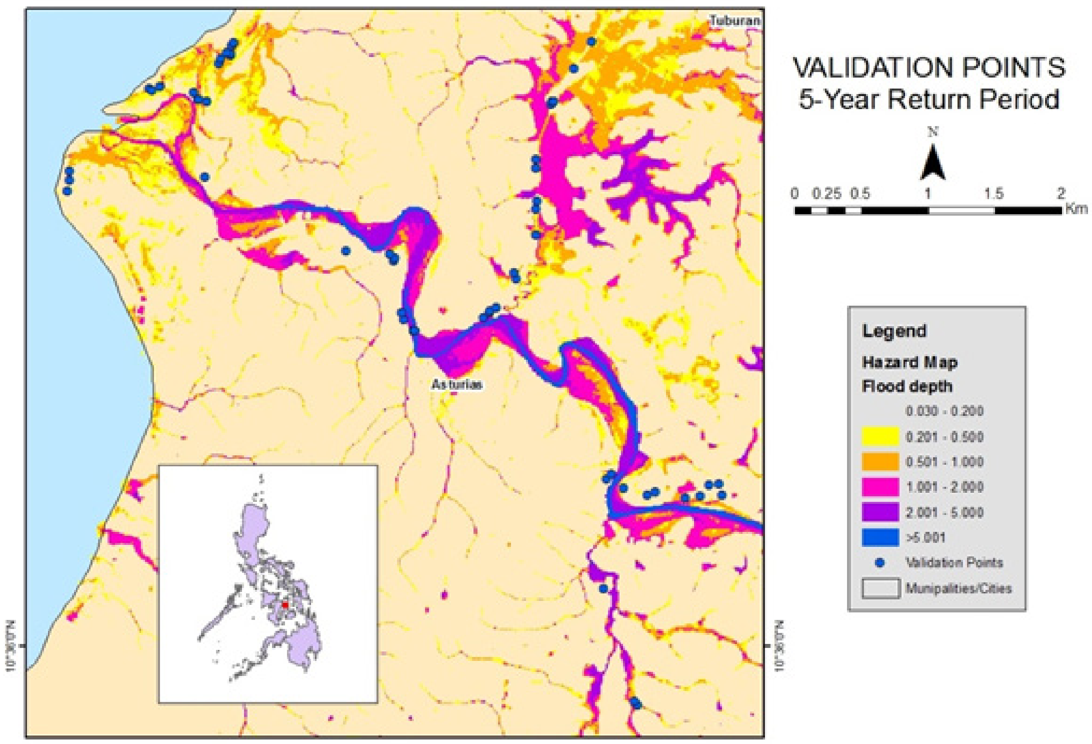

Figure 79. Validation points for a 5-year Flood Depth Map of the Guinabasan Flood Plain.

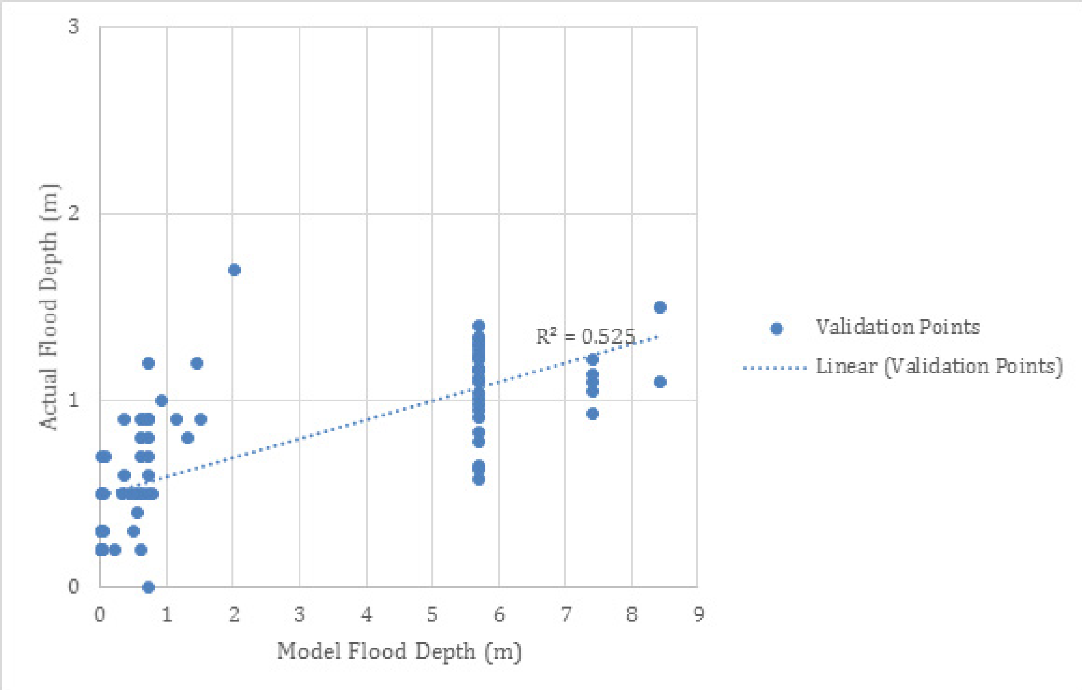

Figure 80. Flood Map depth versus Actual Flood Depth.

Table 41. Actual Flood Depth versus Simulated Flood Depth at different levels in the Guinabasan River Basin.

GUINABASAN 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**	11	1	2	0	0	0	14
	0.21-0.50	9	3	6	0	0	0	18
	0.51-1.00	2	2	11	3	0	9	27
	1.01-2.00	0	0	1	1	1	23	26
	2.01-5.00	0	0	0	0	0	0	0
	> 5.00	0	0	0	0	0	0	0
	Total	22	6	20	4	1	32	85

On the whole, the overall accuracy generated by the flood model is estimated at 30.59% with 26 points correctly matching the actual flood depths. In addition, there were 21 points estimated one level above and below the correct flood depths while there were 27 points and 9 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 4 points were overestimated while a total of 14 points were underestimated in the modelled flood depths of Guinabasan. Table 42 depicts the summary of the Accuracy Assessment in the Guinabasan River Basin Flood Depth Map.

Table 42. Summary of the Accuracy Assessment in the Guinabasan River Basin Survey.

	No. of Points	%
Correct	26	30.59
Overestimated	45	52.94
Underestimated	14	16.47
Total	85	100.00

REFERENCES

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

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

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

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

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

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

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

ANNEXES

Annex 1. Technical Specifications of the LIDAR Sensors used in the Guinabasan Floodplain Survey

1. PEGASUS SENSOR

Table A-1.1 Parameters and Specifications of Pegasus Sensor

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

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

1. CBU-327

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

July 25, 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: **CEBU**
Station Name: **CBU-327**
Order: **2nd**

Island: **VISAYAS**
Municipality: **SAN REMIGIO**
Barangay: **POBLACION**
MSL Elevation:

	PRS92 Coordinates	
Latitude: **11° 4' 30.20546"**	Longitude: **123° 56' 10.33433"**	Ellipsoidal Hgt: **3.54100 m.**
	WGS84 Coordinates	
Latitude: **11° 4' 25.88934"**	Longitude: **123° 56' 15.51412"**	Ellipsoidal Hgt: **63.57400 m.**
	PTM / PRS92 Coordinates	
Northing: **1224791.193 m.**	Easting: **602289.857 m.**	Zone: **4**
	UTM / PRS92 Coordinates	
Northing: **1,224,362.49**	Easting: **602,254.06**	Zone: **51**

Location Description

CBU-327

Station is located at San Remegio. It is situated on the bridge adjacent to San Remegio Public Cemetery.

Mark is the head of a 3 in. copper nail embedded and centered on a 30 cm x 30 cm x 1.20 cm concrete monument, protruding about 20 cm above the ground with inscriptions, "CBU-327, 2007, NAMRIA".

Requesting Party: **UP-TCAGP / Engr. Christopher Cruz**
Pupose: **Reference**
OR Number: **8799582 A**
T.N.: **2014-1733**

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.1. CBU-327

2. CBU-331

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

July 25, 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: **CEBU**	
	Station Name: **CBU-331**	
Island: **Visayas**	Order: **4th**	Barangay: **SAGAY**
Municipality: **BORBON**		MSL Elevation:
	PRS92 Coordinates	
Latitude: **10° 51' 20.15600"**	Longitude: **123° 58' 52.36448"**	Ellipsoidal Hgt: **114.16500 m.**
	WGS84 Coordinates	
Latitude: **10° 51' 15.89918"**	Longitude: **123° 58' 57.56330"**	Ellipsoidal Hgt: **175.07400 m.**
	PTM / PRS92 Coordinates	
Northing: **1200531.095 m.**	Easting: **607287.007 m.**	Zone: **4**
	UTM / PRS92 Coordinates	
Northing: **1,200,110.89**	Easting: **607,249.46**	Zone: **51**

Location Description

CBU-331
From Cebu City, travel N to Brgy. Sagay. When you reach Brgy. Sagay turn right at the road going to Borbon town. The monument is located beside the Grotto, 10 m SW from the chapel, 6 m away from the center of the provincial road, and 20 m SW from the brgy. hall of Sagay. Mark is the head of a 3 in. copper nail embedded and centered on a 30 cm x 30 cm x 1.20 cm concrete monument, protruding about 20 cm above the ground with inscriptions, "CBU-331, 2007, NAMRIA".

Requesting Party: **UP-TCAGP / Engr. Christopher Cruz**
Pupose: **Reference**
OR Number: **8799582 A**
T.N.: **2014-1732**

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

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Figure A-2.2. CBU-331

3. CBU-337

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

July 25, 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: **CEBU**	
	Station Name: **CBU-337**	
Island: **VISAYAS**	Order: **2nd**	Barangay: **COLONIA**
Municipality: **TUBURAN**		MSL Elevation:
	PRS92 Coordinates	
Latitude: **10° 39' 23.68236"**	Longitude: **123° 47' 24.66412"**	Ellipsoidal Hgt: **29.98700 m.**
	WGS84 Coordinates	
Latitude: **10° 39' 19.45980"**	Longitude: **123° 47' 29.88199"**	Ellipsoidal Hgt: **90.66000 m.**
	PTM / PRS92 Coordinates	
Northing: **1178456.495 m.**	Easting: **586455.051 m.**	Zone: **4**
	UTM / PRS92 Coordinates	
Northing: **1,178,044.01**	Easting: **586,424.79**	Zone: **51**

Location Description

CBU-337

To reach the station, travel along S road to Naga City then turn W to the junction road leading to Toledo City and travel for one and a half hrs., after you reach Toledo City, turn N to Sangi junction leading to the Mun. of Tuburan and travel again for one and a half hrs. to reach the station. You will pass the Municipalities of Balamban and Asturias. After reaching Asturias Proper, continue travelling to Sta. Lucia Junction. When you reach the junction, turn right going to a concrete road and continue travelling to another junction leading to Brgy. Colonia and Brgy. Manguiao. After you reach the other junction, turn left to the road to reach Brgy. Colonia. The station is located aoutside the Colonia Central School compound near the concrete fence infront of the school.

Mark is the head of a 3 in. copper nail embedded and centered on a 30 cm x 30 cm x 1.20 m concrete monument, protruding about 20 cm above the ground with inscriptions, "CBU-337, 2007, NAMRIA".

Requesting Party: **UP-TCAGP / Engr. Christopher Cruz**
Pupose: **Reference**
OR Number: **8799582 A**
T.N.: **2014-1731**

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

9 9 0 7 2 5 2 0 1 4 1 3 1 8 3 2

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Main : Lawton Avenue, Fort Bonifacio, 1634 Taguig City, Philippines Tel. No.: (632) 810-4831 to 41
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Figure A-2.3. CBU-337

4. CU-575

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

August 29, 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: **CEBU**
Station Name: **CU-575**

Island: **CEBU**	Municipality: **TUBURAN**	Barangay: **FORTALIZA**
Elevation: **28.7137 +/- 0.00 m.**	Order: **1st Order**	Datum: **Mean Sea Level**
Latitude:	Longitude:	

Location Description

BM CU-575 is located along the national highway of barangay Fortaliza, Tuburan 13 m NE of deep well, 20 m SE of Jessie Quer Residence, 25 m SE of Renante Quer residence, 0.20 m NW of km post 87. It is set on a drilled hole centered with a copper nail on a 0.20 m x 0.20 m cement putty, 0.02 m above a concrete surface of a riprap wall with inscription of CU-575.

Requesting Party: **ENGR. CHRISTOPHER CRUZ**
Purpose: **Reference**
OR Number: **8799780 A**
T.N.: **2014-1903**

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

9908292014154248

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Figure A-2.4. CU-575

5. CU-621A

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

July 25, 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: **CEBU**
Station Name: **CU-621**

Island: **CEBU**	Municipality: **SAN REMIGIO**	Barangay: **TAMBONGON**
Elevation: **19.8770 m.**	Order: **1st Order**	Datum: **Mean Sea Level**

Location Description

Station mark is in Municipality of San Remigio, Barangay Tambongon. From the town proper travel 20 m NE of km post 133, 15 m SW of Diodito Pabona Residence, 18 m NW of Urnilio Ursaez Residence and 65 m NE of Daring's Building.

Is a head of 4" copper nail centered on a 0.20 x 0.20 cm concrete monument with projection of 0.20 m above the ground surface. Inscription "CU-621, 2008, NAMRIA".

Requesting Party: **UP-TCAGP / Engr. Christopher Cruz**
Pupose: **Reference**
OR Number: **8799582 A**
T.N.: **2014-1735**

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

9907252014132024

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Figure A-2.5. CU-621A

6. CU-671

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

August 15, 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: **CEBU**
Station Name: **CU-671**

Island: **CEBU**	Municipality: **SOGOD**	Barangay: **DAMOLOG**
Elevation: **112.9312 m.**	Order: **1st Order**	Datum: **Mean Sea Level**

Location Description

BM CU-671 is located along the national highway of brgy. Damolog, municipality of Sogod, 8 m SE of a concrete riprap wall, 35 m SE of a steel concrete post railings and 10 m SW of km post 65. Mark is set on a drilled hole centered with 3" copper nail on top of a concrete riprap wall embedded with concrete cement putty, 0.20 m x 0.20 m x 0.03 m with inscription of "CU-671 2008 NAMRIA".

Requesting Party: **Engr. Cristopher Cruz**
Pupose: **Reference**
OR Number: **8799719 A**
T.N.: **2014-1850**

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

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Figure A-2.6. CU-671

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

1. CU-575

Table A-3.1. CU-575

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
CBU-337 --- CU-575 (B1)	CBU-337	CU-575	Fixed	0.003	0.004	31°01'03"	1117.714	-1.414
CBU-337 --- CU-575 (B2)	CBU-337	CU-575	Fixed	0.002	0.003	31°01'04"	1117.719	-1.424

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

Vector Components (Mark to Mark)

From:	CBU-337				
Grid		Local		Global	
Easting	586424.790 m	Latitude	N10°39'23.68236"	Latitude	N10°39'19.45981"
Northing	1178044.015 m	Longitude	E123°47'24.66412"	Longitude	E123°47'29.88199"
Elevation	28.962 m	Height	29.987 m	Height	90.659 m

To:	CU-575				
Grid		Local		Global	
Easting	586998.127 m	Latitude	N10°39'54.85973"	Latitude	N10°39'50.63543"
Northing	1179003.079 m	Longitude	E123°47'43.61525"	Longitude	E123°47'48.83231"
Elevation	27.560 m	Height	28.573 m	Height	89.238 m

Vector					
ΔEasting	573.336 m	NS Fwd Azimuth	31°01'03"	ΔX	-379.302 m
ΔNorthing	959.064 m	Ellipsoid Dist.	1117.714 m	ΔY	-468.760 m
ΔElevation	-1.402 m	ΔHeight	-1.414 m	ΔZ	941.111 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.001 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.002 m
σ ΔElevation	0.002 m	σ ΔHeight	0.002 m	σ ΔZ	0.001 m

2. CU-621A

Table A-3.2. CU-621A

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
CBU-327 --- CU-621A (B1)	CBU-327	CU-621A	Fixed	0.004	0.014	193°58'06"	6294.070	12.113
CBU-327 --- CU-621A (B2)	CBU-327	CU-621A	Fixed	0.003	0.012	193°58'06"	6294.084	12.124

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

Vector Components (Mark to Mark)

From:	CBU-327				
Grid		Local		Global	
Easting	602254.054 m	Latitude	N11°04'30.20546"	Latitude	N11°04'25.88935"
Northing	1224362.494 m	Longitude	E123°56'10.33433"	Longitude	E123°56'15.51412"
Elevation	2.863 m	Height	3.541 m	Height	63.573 m

To:	CU-621A				
Grid		Local		Global	
Easting	600754.296 m	Latitude	N11°01'11.40740"	Latitude	N11°01'07.10407"
Northing	1218251.484 m	Longitude	E123°55'20.28492"	Longitude	E123°55'25.46968"
Elevation	15.098 m	Height	15.654 m	Height	75.785 m

Vector					
ΔEasting	-1499.757 m	NS Fwd Azimuth	193°58'06"	ΔX	600.402 m
ΔNorthing	-6111.011 m	Ellipsoid Dist.	6294.070 m	ΔY	1828.859 m
ΔElevation	12.235 m	ΔHeight	12.113 m	ΔZ	-5992.519 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.004 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.006 m
σ ΔElevation	0.007 m	σ ΔHeight	0.007 m	σ ΔZ	0.002 m

3. CU-671

Table A-3.3. CU-671

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
CU-671 --- CBU-331 (B1)	CBU-331	CU-671	Fixed	0.011	0.027	168°25'16"	7519.275	-0.549
CBU-331 --- CU-671 (B2)	CBU-331	CU-671	Fixed	0.011	0.028	168°25'16"	7519.276	-0.540

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

Vector Components (Mark to Mark)

From:	CBU-331				
Grid		Local		Global	
Easting	607249.455 m	Latitude	N10°51'20.15600"	Latitude	N10°51'15.89943"
Northing	1200110.888 m	Longitude	E123°58'52.36448"	Longitude	E123°58'57.56315"
Elevation	113.315 m	Height	114.165 m	Height	174.835 m

To:	CU-671				
Grid		Local		Global	
Easting	608781.977 m	Latitude	N10°47'20.40004"	Latitude	N10°47'16.16158"
Northing	1192751.407 m	Longitude	E123°59'42.04397"	Longitude	E123°59'47.24841"
Elevation	112.679 m	Height	113.616 m	Height	174.479 m

Vector					
ΔEasting	1532.523 m	NS Fwd Azimuth	168°25'16"	ΔX	-2024.349 m
ΔNorthing	-7359.481 m	Ellipsoid Dist.	7519.275 m	ΔY	302.655 m
ΔElevation	-0.636 m	ΔHeight	-0.549 m	ΔZ	-7235.455 m

Standard Errors

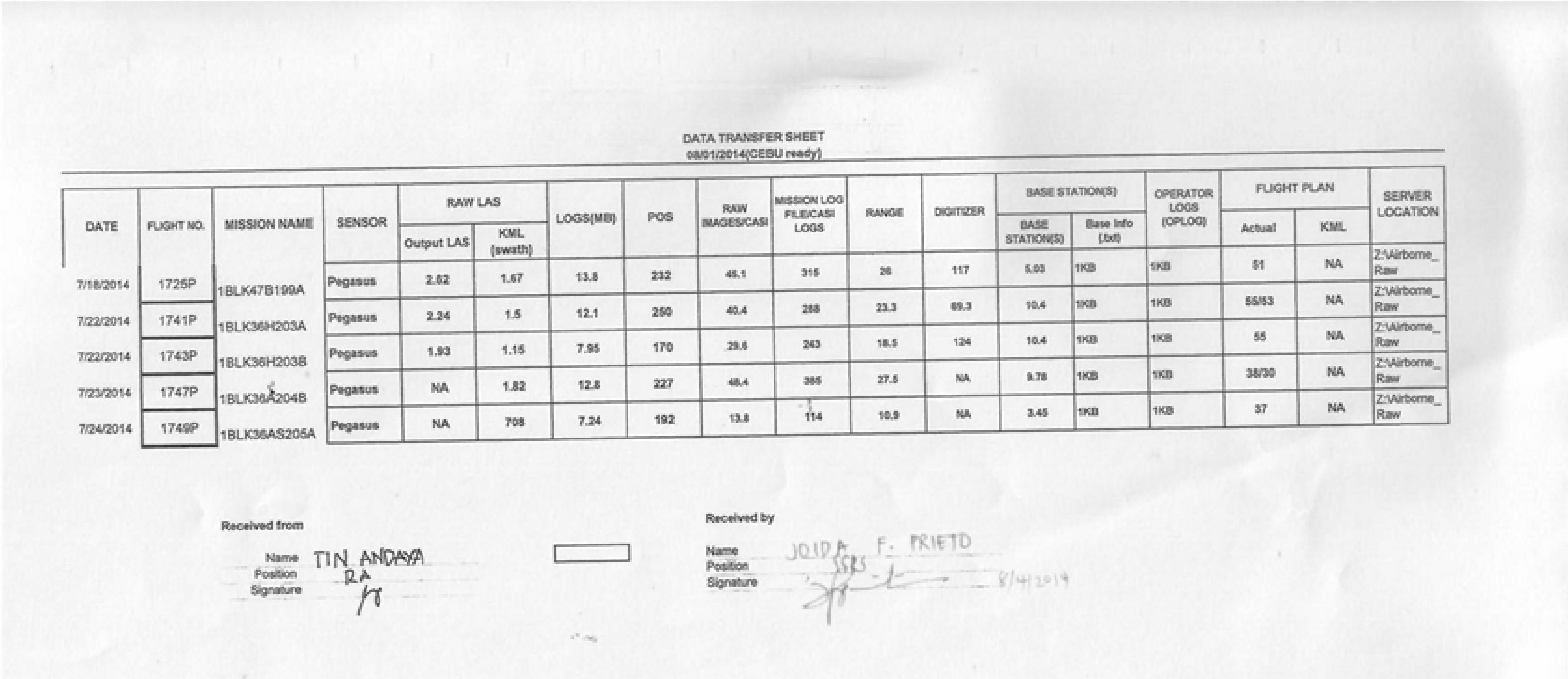
Vector errors:					
σ ΔEasting	0.005 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.009 m
σ ΔNorthing	0.002 m	σ Ellipsoid Dist.	0.002 m	σ ΔY	0.011 m
σ ΔElevation	0.014 m	σ ΔHeight	0.014 m	σ ΔZ	0.004 m

Annex 4. The LiDAR Survey Team Composition

Table A-4.1. The LiDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	UP-TCAGP
		ENGR. LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	ENGR. GEROME HIPOLITO	UP-TCAGP
	Research Associate (RA)	GRACE SINADJAN	UP-TCAGP
		ENGR. IRO NIEL ROXAS	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	JERIEL PAUL ALAMBAN, GEOL.	UP-TCAGP
		KENNETH QUISADO	UP-TCAGP
LiDAR Operation	Airborne Security	SSG. RAYMUND DOMINE	PILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. CESAR ALFONSO III	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. FERDINAND DE OCAMPO	AAC

Annex 5. Data Transfer Sheet for Guinabasan Floodplain



DATA TRANSFER SHEET
08/01/2014(CEBU 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	
7/18/2014	1725P	1BLK47B199A	Pegasus	2.62	1.67	13.8	232	45.1	315	26	117	5.03	1KB	1KB	51	NA	Z:\Airborne_Raw
7/22/2014	1741P	1BLK36H203A	Pegasus	2.24	1.5	12.1	250	40.4	288	23.3	69.3	10.4	1KB	1KB	55/53	NA	Z:\Airborne_Raw
7/22/2014	1743P	1BLK36H203B	Pegasus	1.93	1.15	7.95	170	29.6	243	18.5	124	10.4	1KB	1KB	55	NA	Z:\Airborne_Raw
7/23/2014	1747P	1BLK36A204B	Pegasus	NA	1.82	12.8	227	48.4	385	27.5	NA	9.78	1KB	1KB	38/30	NA	Z:\Airborne_Raw
7/24/2014	1749P	1BLK36AS205A	Pegasus	NA	708	7.24	192	13.8	114	10.9	NA	3.45	1KB	1KB	37	NA	Z:\Airborne_Raw

Received from
Name TIN ANDAYA
Position RA
Signature

Received by
Name JOIDA F. PRIETO
Position SSRS
Signature 8/4/2014

Figure A-5.1. Transfer Sheet for Guinabasan Floodplain - A

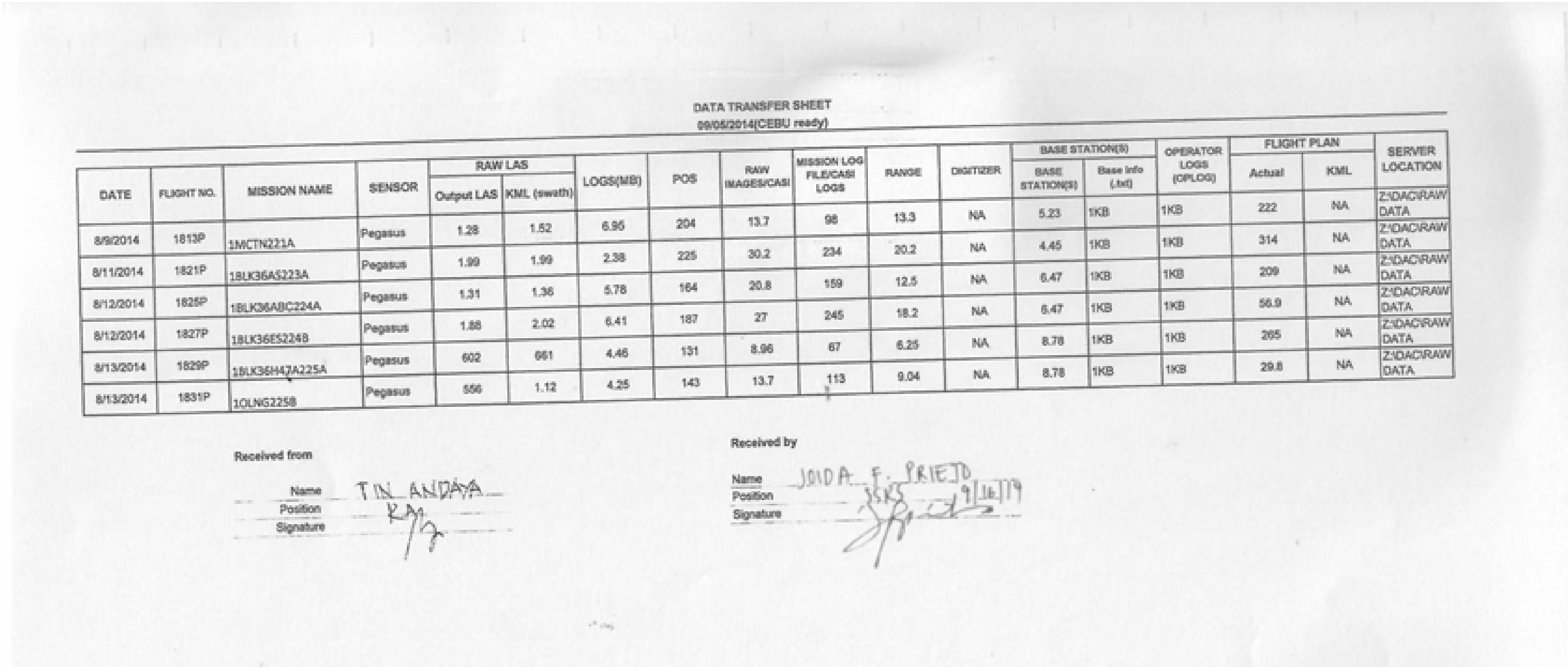
DATA TRANSFER SHEET
08/15/2014(CEBU ready)

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	
7/29/2014	1769P	1BLK47A210A	Pegasus	931	0.99	3.45	95.7	10.5	85	9.18	NA	6.47	1KB	1KB	495	NA	Z:\DAC\RAWDATA
7/30/2014	1773P	1BLK47A211A	Pegasus	2.31	2.06	8.4	238	38.5	318	22.9	NA	8.16	1KB	1KB	97.7	NA	Z:\DAC\RAWDATA
7/30/2014	1775P	1BLK47A211B	Pegasus	1.61	1.67	7.96	141	22.5	200	15.1	NA	8.16	1KB	1KB	1	NA	Z:\DAC\RAWDATA
7/31/2014	1777P	1BLK36E213A	Pegasus	3.37	3.82	9.71	262	59.6	442	32.4	NA	9.13	1KB	1KB	45	NA	Z:\DAC\RAWDATA
7/31/2014	1779P	1BLK36EF212B	Pegasus	2.64	3.04	8.87	239	41.3	359	25.8	NA	9.13	1KB	1KB	96.4	NA	Z:\DAC\RAWDATA
8/01/2014	1781P	1BLK36F213A	Pegasus	2.57	2.94	9.09	215	41.7	340	25.5	NA	6.61	1KB	1KB	33	NA	Z:\DAC\RAWDATA
8/02/2014	1785P	1BLK36GF214A	Pegasus	3.36	3.78	9.87	250	46.2	335	32.7	NA	10.9	1KB	1KB	163	NA	Z:\DAC\RAWDATA
8/02/2014	1787P	1BLK36G214B	Pegasus	3.07	3.41	9.24	250	48.3	45/57/270	29.5	NA	10.9	1KB	1KB	40	NA	Z:\DAC\RAWDATA
8/03/2014	1789P	1MCTN215A	Pegasus	732	1.02	7.16	250	13.4	105	9.33	NA	8.84	1KB	1KB	612	NA	Z:\DAC\RAWDATA
8/03/2014	1791P	1MCTN215B	Pegasus	517	736	5.44	167	7.61	69	6.52	NA	8.84	1KB	1KB	624	NA	Z:\DAC\RAWDATA
8/04/2014	1793P	1BLK36EFGS216A	Pegasus	NA	746	5.12	144	11	77	6.7	NA	2.11	1KB	1KB	189	NA	Z:\DAC\RAWDATA
8/06/2014	1801P	1BLK36D218A	Pegasus	NA	3.6	9.62	258	54	384	32.1	NA	8.9	1KB	1KB	59.3	NA	Z:\DAC\RAWDATA
8/06/2014	1803P	1BLK36C218B	Pegasus	3.58	3.83	12.1	224	22.7/37.1	153/1/275	33	NA	8.9	1KB	1KB	93.8	NA	Z:\DAC\RAWDATA
8/07/2014	1805P	1BLK36B219A	Pegasus	3.41	3.91	10,945	280	60.4	441	34.5	NA	7.01	1KB	1KB	121	NA	Z:\DAC\RAWDATA

Received from
Name TIN ANDAYA
Position
Signature

Received by
Name JOIDA PRIETO
Position SSRS
Signature
8/20/14

Figure A-5.2. Transfer Sheet for Libertad Floodplain - B



DATA TRANSFER SHEET
09/05/2014(CEBU 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	
8/9/2014	1813P	1MCTN221A	Pegasus	1.28	1.52	6.95	204	13.7	98	13.3	NA	5.23	1KB	1KB	222	NA	Z:\DAC\RAW DATA
8/11/2014	1821P	1BLK36AS223A	Pegasus	1.99	1.99	2.38	225	30.2	234	20.2	NA	4.45	1KB	1KB	314	NA	Z:\DAC\RAW DATA
8/12/2014	1825P	1BLK36ABC224A	Pegasus	1.31	1.36	5.78	164	20.8	159	12.5	NA	6.47	1KB	1KB	209	NA	Z:\DAC\RAW DATA
8/12/2014	1827P	1BLK36ES224B	Pegasus	1.88	2.02	6.41	187	27	245	18.2	NA	6.47	1KB	1KB	56.9	NA	Z:\DAC\RAW DATA
8/13/2014	1829P	1BLK36H47A225A	Pegasus	602	661	4.46	131	8.96	67	6.25	NA	8.78	1KB	1KB	265	NA	Z:\DAC\RAW DATA
8/13/2014	1831P	1OLNG225B	Pegasus	556	1.12	4.25	143	13.7	113	9.04	NA	8.78	1KB	1KB	29.8	NA	Z:\DAC\RAW DATA

Received from

Name T.N. ANDAYA
Position RA
Signature

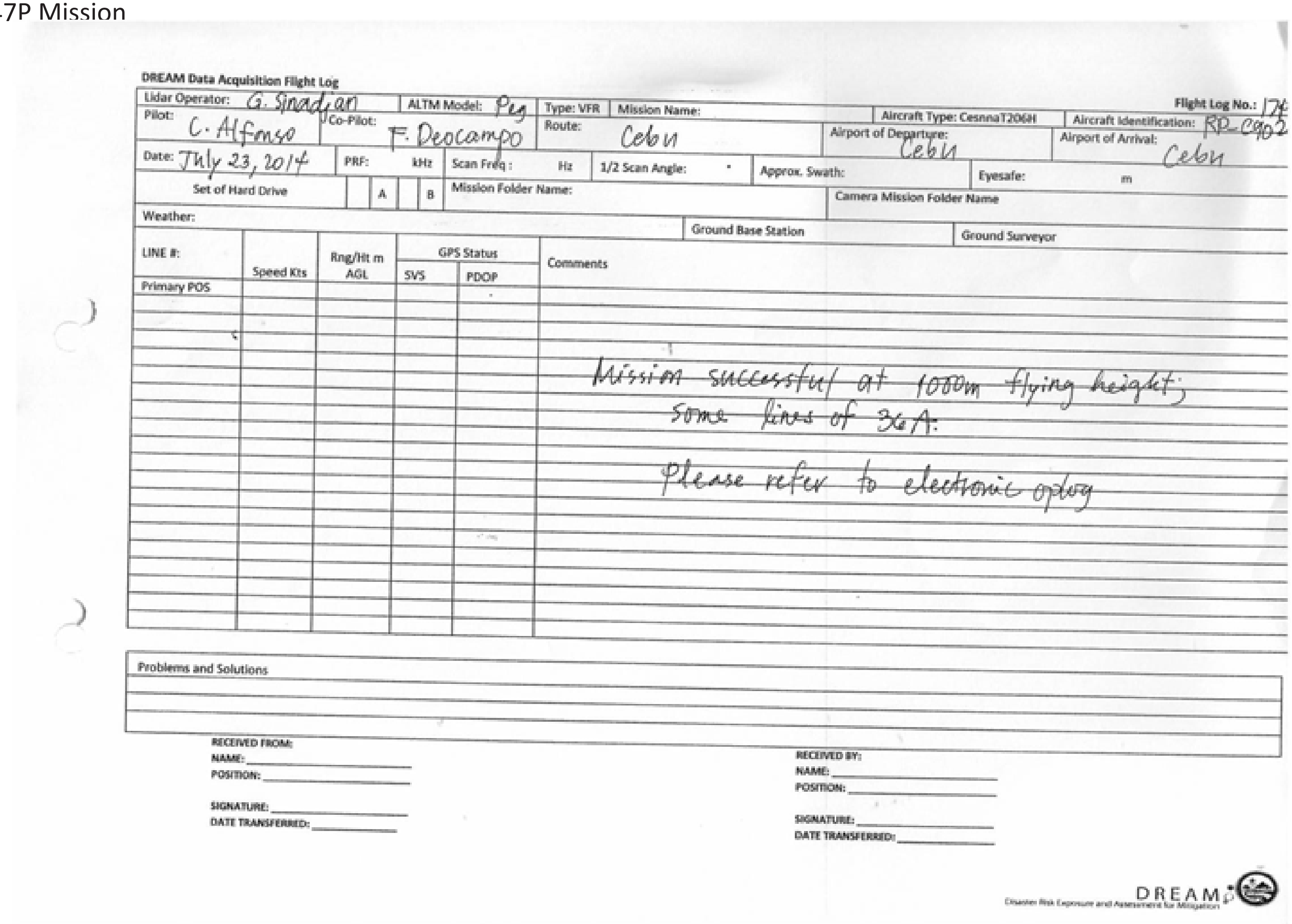
Received by

Name JOIDA F. PRIETO
Position SSRS 9/16/14
Signature

Figure A-5.3. Transfer Sheet for Guinabasan Floodplain – C

Annex 6. Flight logs for the flight missions

1. Flight Log for 1747P Mission



DREAM Data Acquisition Flight Log

Lidar Operator: G. Sinadjan | ALTM Model: Peg | Type: VFR | Mission Name: | Aircraft Type: CesnnaT206H | Aircraft Identification: RP-C9022 | Flight Log No.: 174

Pilot: C. Alfonso | Co-Pilot: F. Deocampo | Route: Cebu | Airport of Departure: Cebu | Airport of Arrival: Cebu

Date: July 23, 2014 | PRF: kHz | Scan Freq: Hz | 1/2 Scan Angle: ° | Approx. Swath: | Eyesafe: m

Set of Hard Drive: A | B | Mission Folder Name: | Camera Mission Folder Name

Weather: | Ground Base Station | Ground Surveyor

LINE #:	Speed Kts	Rng/Ht m AGL	GPS Status SVS	GPS Status PDOP	Comments
Primary POS					
					Mission successful at 1000m flying height; some lines of 36A.
					Please refer to electronic oplog

Problems and Solutions

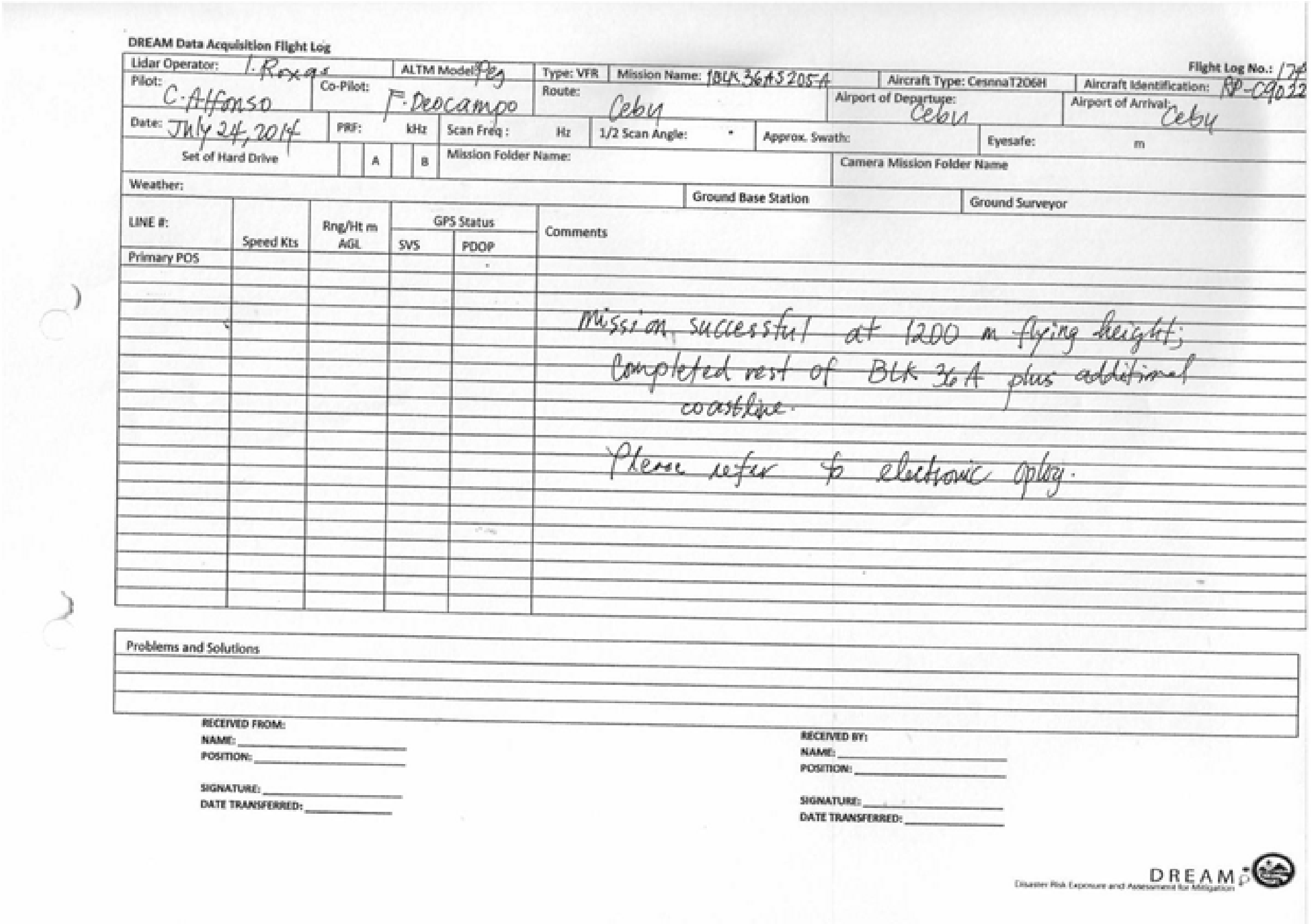
RECEIVED FROM:
NAME:
POSITION:
SIGNATURE:
DATE TRANSFERRED:

RECEIVED BY:
NAME:
POSITION:
SIGNATURE:
DATE TRANSFERRED:

DREAM Disaster Risk Exposure and Assessment for Mitigation

Figure A-6.1. Flight Log for Mission1747P

2. Flight Log for 1749P Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 17

Lidar Operator: I. Roxas	ALTM Model: Peg	Type: VFR	Mission Name: 1BLK36AS205A	Aircraft Type: CesnnaT206H	Aircraft Identification: RP-C9022
Pilot: C. Alfonso	Co-Pilot: F. Deocampo	Route: Cebu	Airport of Departure: Cebu	Airport of Arrival: Cebu
Date: July 24, 2014	PRF: kHz	Scan Freq: Hz	1/2 Scan Angle: °	Approx. Swath:	Eyesafe: m
Set of Hard Drive: A B	Mission Folder Name:		Camera Mission Folder Name	
Weather:		Ground Base Station	Ground Surveyor	

LINE #:	Speed Kts	Rng/Ht m AGL	GPS Status SVS	GPS Status PDOP	Comments
Primary POS					
					Mission successful at 1200 m flying height; Completed rest of BLK 36A plus additional coastline.
					Please refer to electronic oplog.

Problems and Solutions

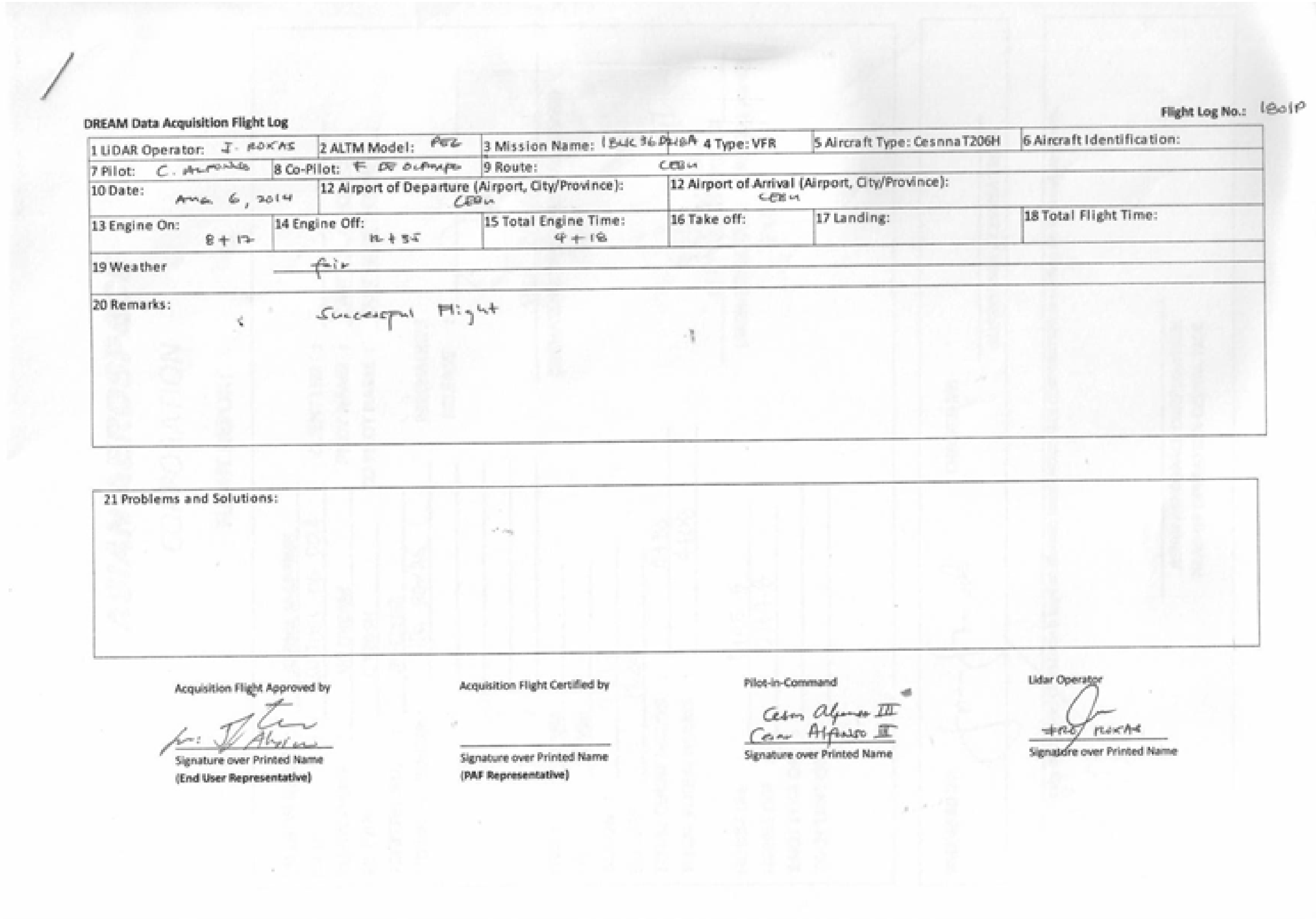
RECEIVED FROM:
NAME:
POSITION:
SIGNATURE:
DATE TRANSFERRED:

RECEIVED BY:
NAME:
POSITION:
SIGNATURE:
DATE TRANSFERRED:

DREAM Disaster Risk Exposure and Assessment for Mitigation

Figure A-6.2. Flight Log for Mission1749P

3. Flight Log for 1801P Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1801P

1 LiDAR Operator: J. ROXAS	2 ALTM Model: PEG	3 Mission Name: 1BLK36DHGA	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification:
7 Pilot: C. ALFONSO	8 Co-Pilot: F. DE OCAMPO	9 Route: CEBU			
10 Date: Aug. 6, 2014		12 Airport of Departure (Airport, City/Province): CEBU	12 Airport of Arrival (Airport, City/Province): CEBU		
13 Engine On: 8+12	14 Engine Off: 12+35	15 Total Engine Time: 4+18	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: fair					
20 Remarks: Successful Flight					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Cesar Alfonso III Signature over Printed Name	J. ROXAS Signature over Printed Name

Figure A-6.3. Flight Log for Mission1801P

4. Flight Log for 1803P Mission

DREAM Data Acquisition Flight Log — Flight Log No.: 1803P

1 LiDAR Operator: G. Sinadjan	2 ALTM Model: PEG	3 Mission Name: 1BLK26C218B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9022
7 Pilot: C. Alfonso	8 Co-Pilot: F. De Ocampo	9 Route: Cebu			
10 Date: Aug. 6, 2014	12 Airport of Departure (Airport, City/Province): Cebu		12 Airport of Arrival (Airport, City/Province): Cebu		
13 Engine On: 1230	14 Engine Off: 1745	15 Total Engine Time: 3+35	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: cloudy					
20 Remarks: Successful flight					

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 — Grace Sinadjan — Signature over Printed Name

Figure A-6.4. Flight Log for Mission 8464AC

5. Flight Log for 1805P Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1805P

1 LIDAR Operator: I. Roxas	2 ALTM Model: Pegasus	3 Mission Name: 1BLK36B218A	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: C. Alfonso	8 Co-Pilot: F. Delcampo	9 Route: Cebu			
10 Date: August 7, 2014	12 Airport of Departure (Airport, City/Province): Cebu		12 Airport of Arrival (Airport, City/Province): Cebu		
13 Engine On: 0916H	14 Engine Off: 1339H	15 Total Engine Time: 4+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: fair					

20 Remarks:

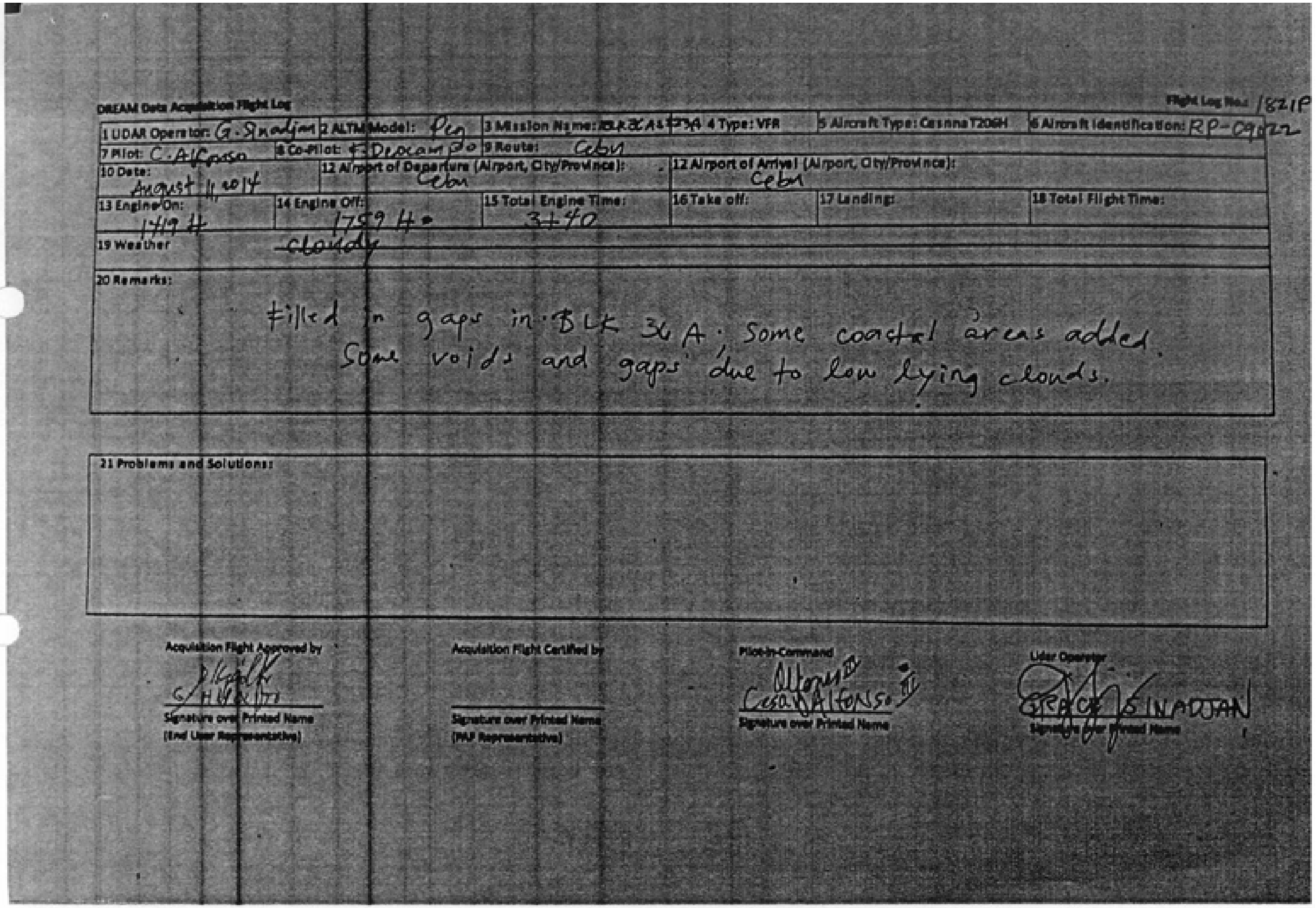
Mission successful at 1000-1200 m flying heights; completed BLK 36B and added shore between BLK 36B and 47B; some voids

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Cesar Alfonso III Signature over Printed Name	I. Roxas Signature over Printed Name

Figure A-6.5. Flight Log for Mission1805P

6. Flight Log for 1821P Mission


DREAM Data Acquisition Flight Log

Flight Log No.: 1821P

1 LiDAR Operator: G. Sinadjan	2 ALTM Model: Peg	3 Mission Name: 3BLK36A223A	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: C. Alfonso	8 Co-Pilot: F. Deocampo	9 Route: Cebu			
10 Date: August 11, 2014	12 Airport of Departure (Airport, City/Province): Cebu		12 Airport of Arrival (Airport, City/Province): Cebu		
13 Engine On: 1419 H	14 Engine Off: 1759 H	15 Total Engine Time: 3+40	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: cloudy					

20 Remarks:

Filled in gaps in BLK 36A. Some coastal areas added. Some voids and gaps due to low lying clouds.

21 Problems and Solutions:

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

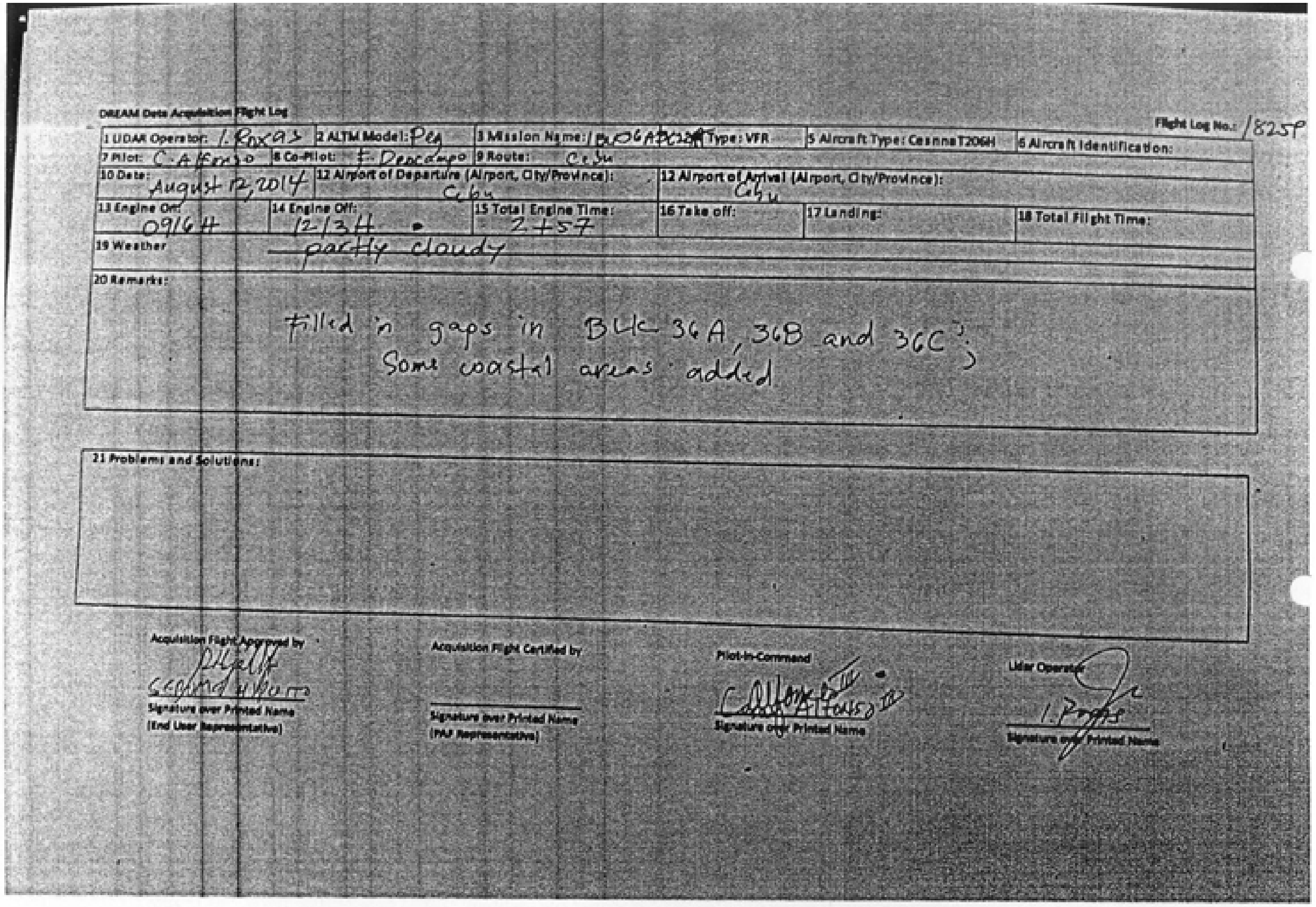
Acquisition Flight Certified by: Signature over Printed Name (PAF Representative)

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

Lidar Operator: Grace Sinadjan — Signature over Printed Name

Figure A-6.6. Flight Log for Mission1821P

7. Flight Log for 1825P Mission


DREAM Data Acquisition Flight Log

Flight Log No.: 1825P

1 LIDAR Operator: I. Roxas	2 ALTM Model: Peg	3 Mission Name: 1BLK36ABC224	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification:
7 Pilot: C. Alfonso	8 Co-Pilot: E. Deocampo	9 Route: Cebu			
10 Date: August 12, 2014	12 Airport of Departure (Airport, City/Province): Cebu		12 Airport of Arrival (Airport, City/Province): Cebu		
13 Engine On: 0916H	14 Engine Off: 1213H	15 Total Engine Time: 2+57	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: partly cloudy					

20 Remarks:

Filled in gaps in BLK 36A, 36B and 36C; Some coastal areas added

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: C. Alfonso III, Signature over Printed Name

Lidar Operator: I. Roxas, Signature over Printed Name

Figure A-6.7. Flight Log for Mission1825P

Annex 7. Flight status reports

Table A-7.1. Flight Status Report

Cebu Mission
July 23-24, 2014, August 6-7, 2014, and August 11-12, 2014

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1747P	BLK36A	1BLK36A204B	G. Sinadjan	July 23	Surveyed 10 lines of BLK36A; 258.43 km2
1749P	BLK36A	1BLK36AS205A	I. Roxas	July 24	Mission successful. Plan extended to cover shoreline; 96.59 km2
1801P	BLK36D	1BLK36D218A	I. Roxas	August 6	Completed BLK36D; 347.35 km2
1803P	BLK36C	1BLK36C218B	G. Sinadjan	August 6	Completed BLK36C; 306.81 km2
1805P	BLK36B	1BLK36B219A	I. Roxas	August 7	Data acquired in BLK36B; Survey area exended to cover coastal areas; 318.85 km2
1821P	BLK36A	1BLK36AS223A	G. Sinadjan	August 11	Filled in gaps in BLK 36A; Some coastal areas added. Some voids and gaps due to low lying clouds; 170.46 km2
1825P	BLK36A, BLK36B	1BLK36ABC224A	I. Roxas	August 12	Filled in gaps in BLK 36A, 36B and 36 C; Some coastal areas added; 129.83 km2

SWATH PER FLIGHT MISSION

Flight No. : 1747P

Area: BLK36A

Mission Name: 1BLK36A204B

Parameters: Altitude: 1200m; Scan Frequency: 30Hz;

Scan Angle: 25deg; Overlap: 30%

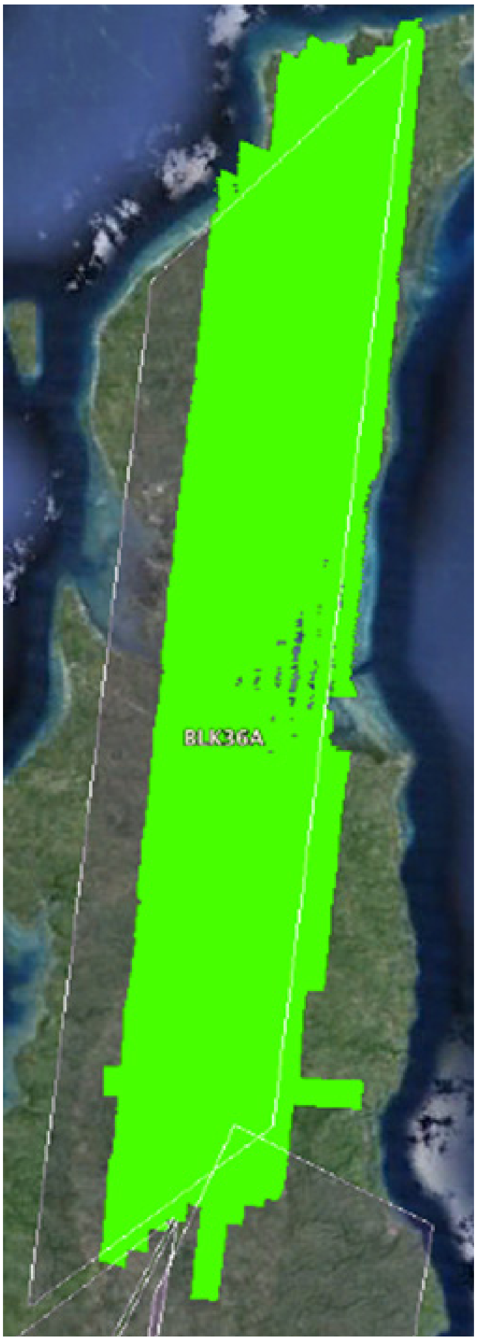


Figure A-7.1. Swath for Flight No. 1747P

Flight No. :	1749P		
Area:	BLK36A		
Mission Name:	1BLK36AS205A		
Parameters:	Altitude:	1200m; Scan Frequency:	30Hz;
	Scan Angle:	25deg; Overlap:	30%

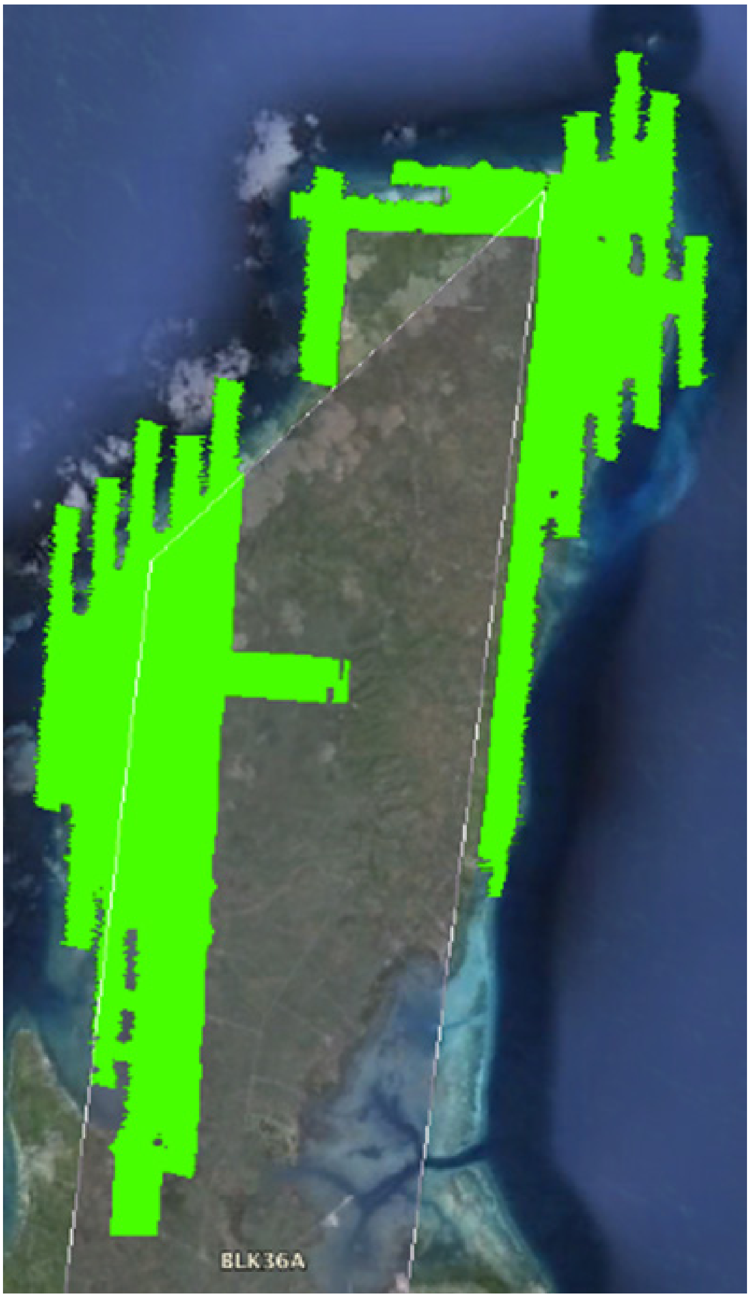


Figure A-7.2. Swath for Flight No. 1749P

Flight No. : 1801P
Area: BLK36D
Mission Name: 1BLK47A211A
Parameters: Altitude: 1200m; Scan Frequency: 30Hz;
Scan Angle: 25deg; Overlap: 30%

Figure A-7.3. Swath for Flight No. 8462AC

Flight No. :	1803P			
Area:	BLK36C			
Mission Name:	1BLK36C218B			
Parameters:	Altitude:	1200m; Scan Frequency:		30Hz;
	Scan Angle:	25deg;	Overlap:	30%

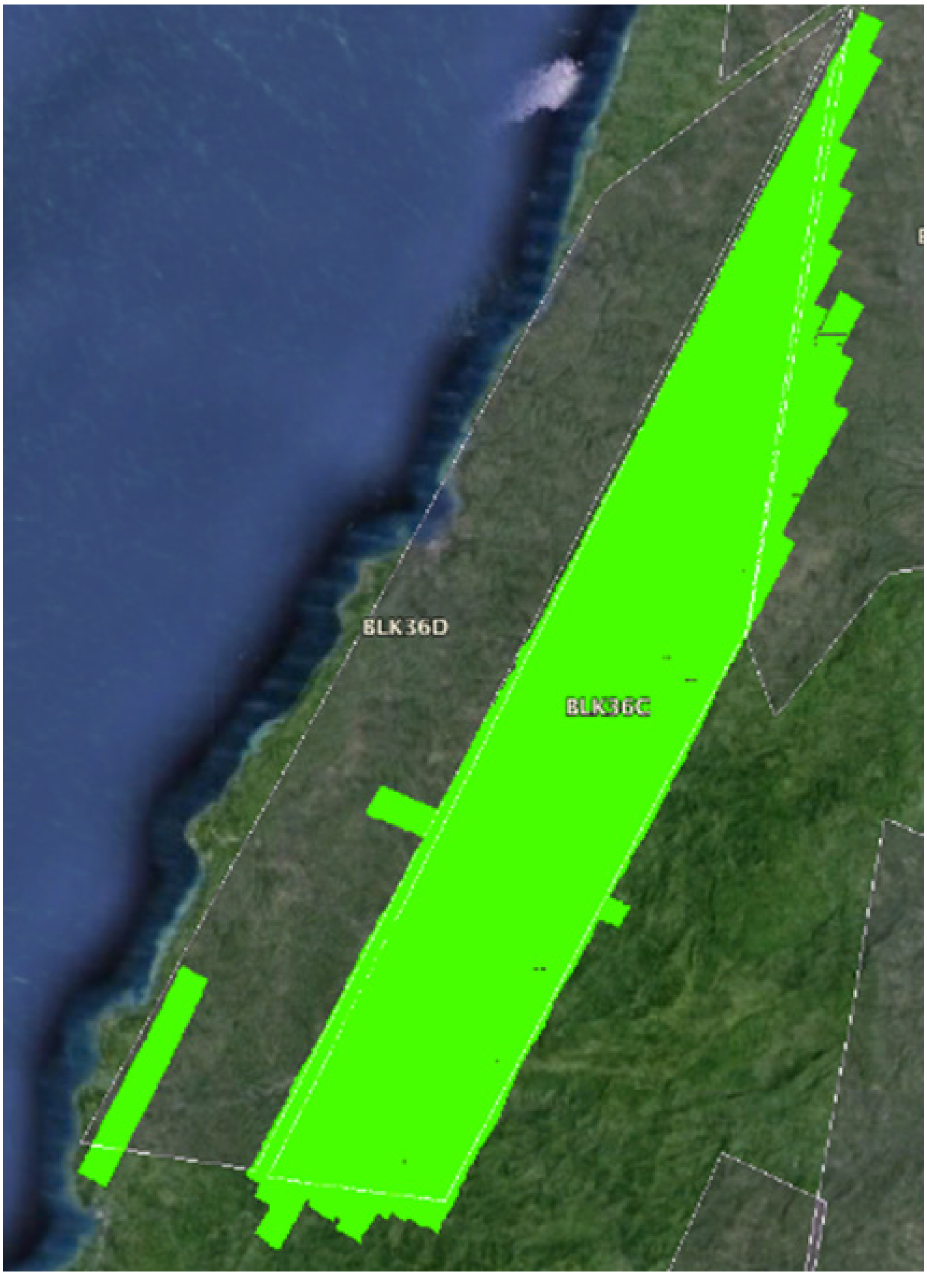


Figure A-7.4. Swath for Flight No. 8464AC

Flight No. : 1805P

Area: BLK36B

Mission Name: 1BLK36B219A

Parameters:	Altitude:	1000m;	Scan Frequency:	30Hz;
	Scan Angle:	25deg;	Overlap:	30%

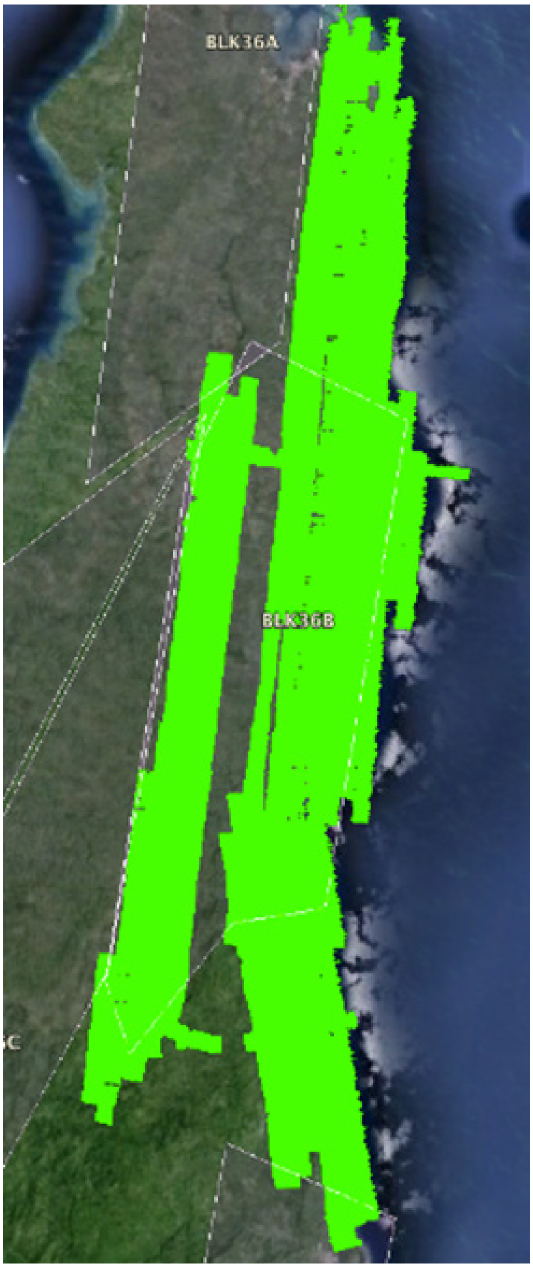


Figure A-7.5. Swath for Flight No. 1805P

Flight No. : 1821P
Area: BLK36A
Mission Name: 1BLK36AS223A
Parameters: Altitude: 1000m; Scan Frequency: 30Hz;
Scan Angle: 25deg; Overlap: 30%

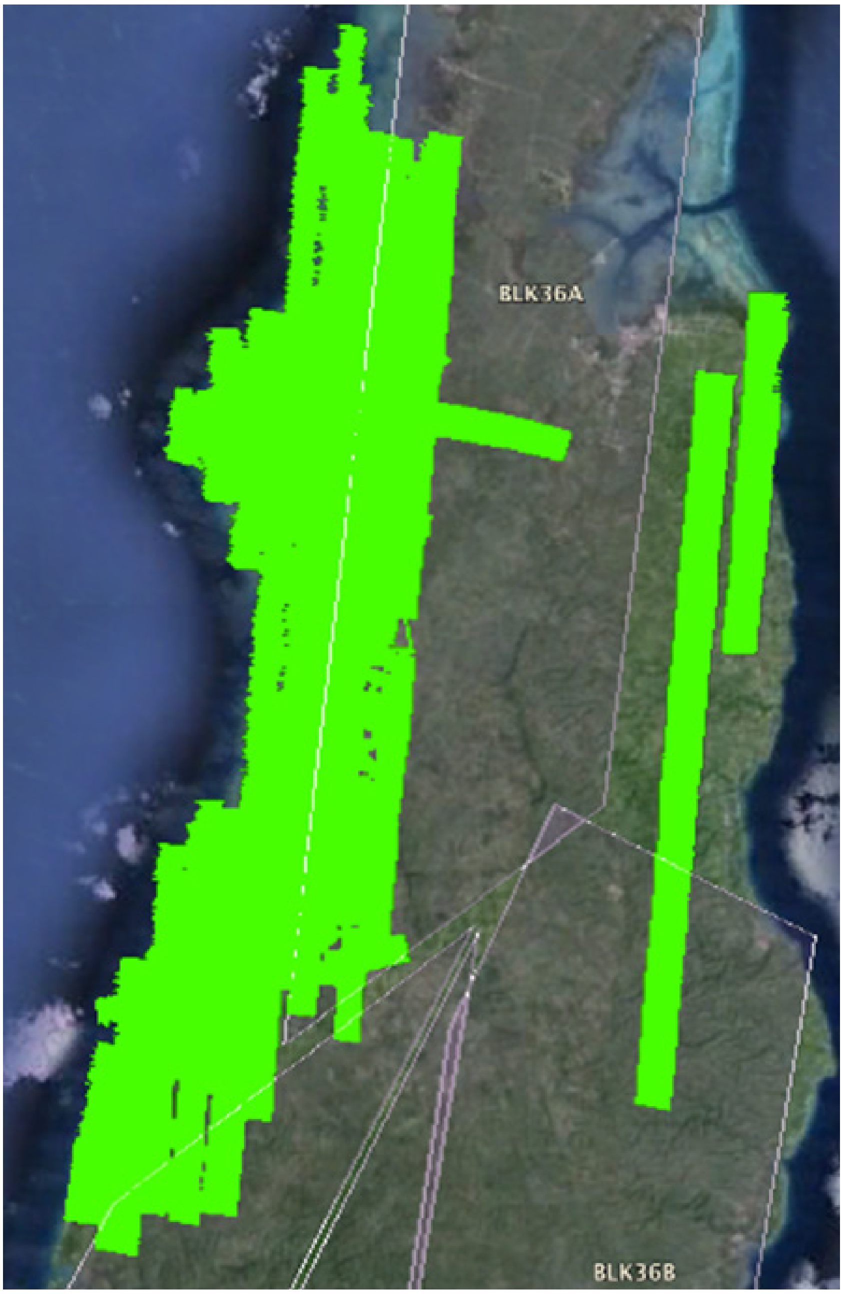


Figure A-7.6. Swath for Flight No. 1821P

Flight No. : 1825P
Area: BLK36B
Mission Name: 1BLK36ABC224A
Parameters: Altitude: 1000m; Scan Frequency: 30Hz;
Scan Angle: 25deg; Overlap: 30%

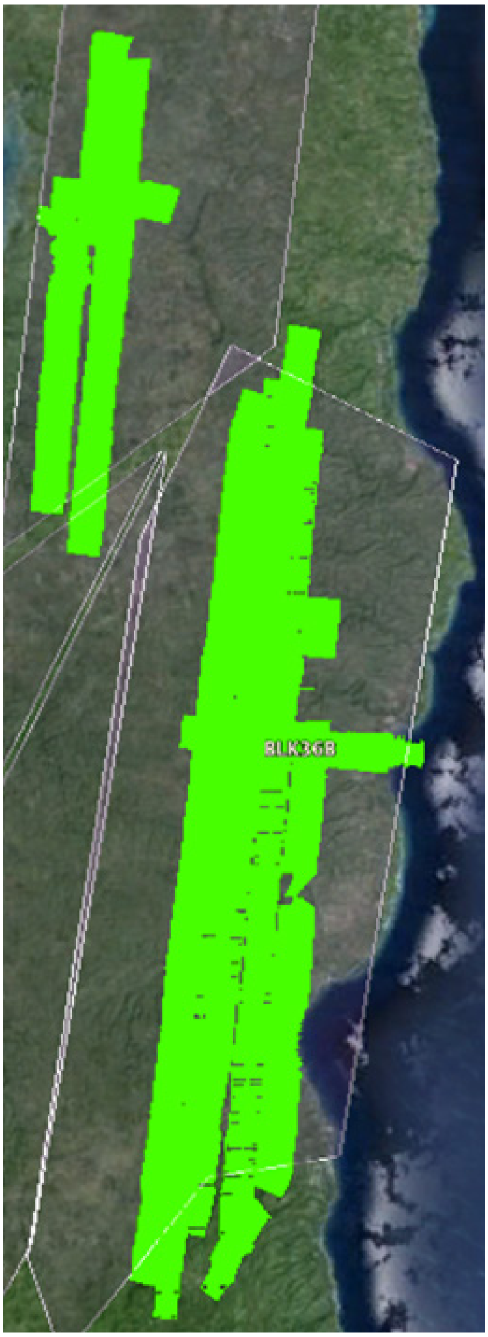


Figure A-7.7. Swath for Flight No. 1825P

ANNEX 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Blk26D

Flight Area	Cebu
Mission Name	Blk36D
Inclusive Flights	1801P
Range data size	32.1 GB
Base data size	8.9 MB
POS	258 MB
Image	54.0 GB
Transfer date	August 20, 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)	1.4
RMSE for Down Position (<8.0 cm)	2.8
Boresight correction stdev (<0.001deg)	0.000153
IMU attitude correction stdev (<0.001deg)	0.000411
GPS position stdev (<0.01m)	0.0068
Minimum % overlap (>25)	32.62%
Ave point cloud density per sq.m. (>2.0)	5.31
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	451
Maximum Height	358.11 m
Minimum Height	60.66 m
Classification (# of points)	
Ground	287,792,916
Low vegetation	214,914,170
Medium vegetation	546,398,318
High vegetation	258,444,081
Building	5,935,580
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Harmond Santos, Engr. Jeffrey Delica

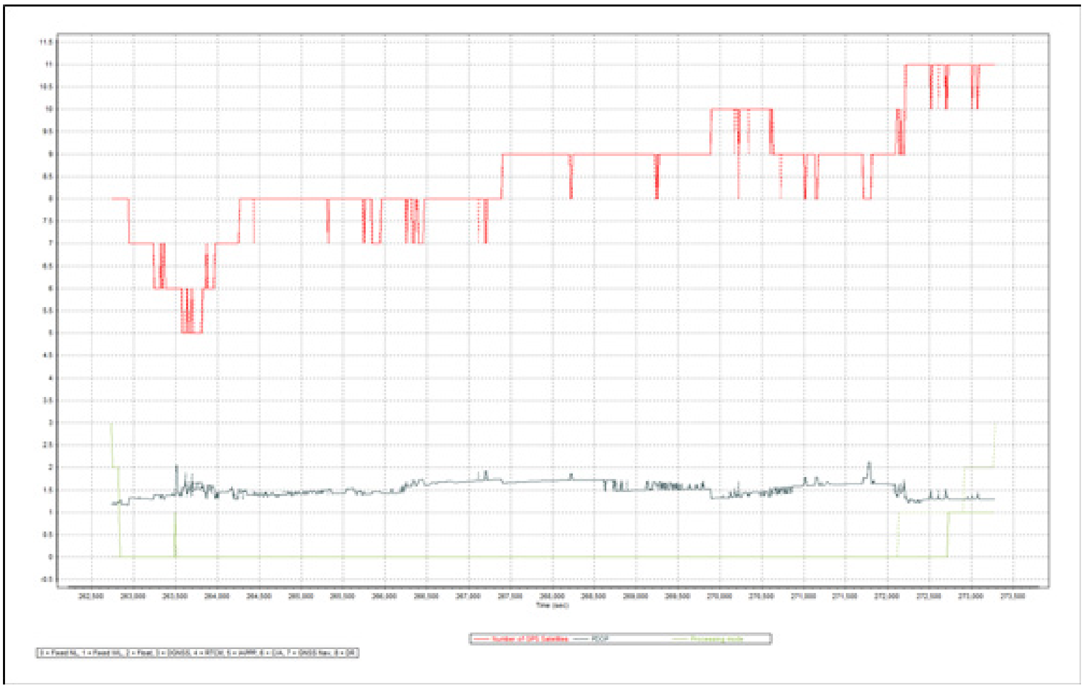


Figure A-8.1 Solution Status

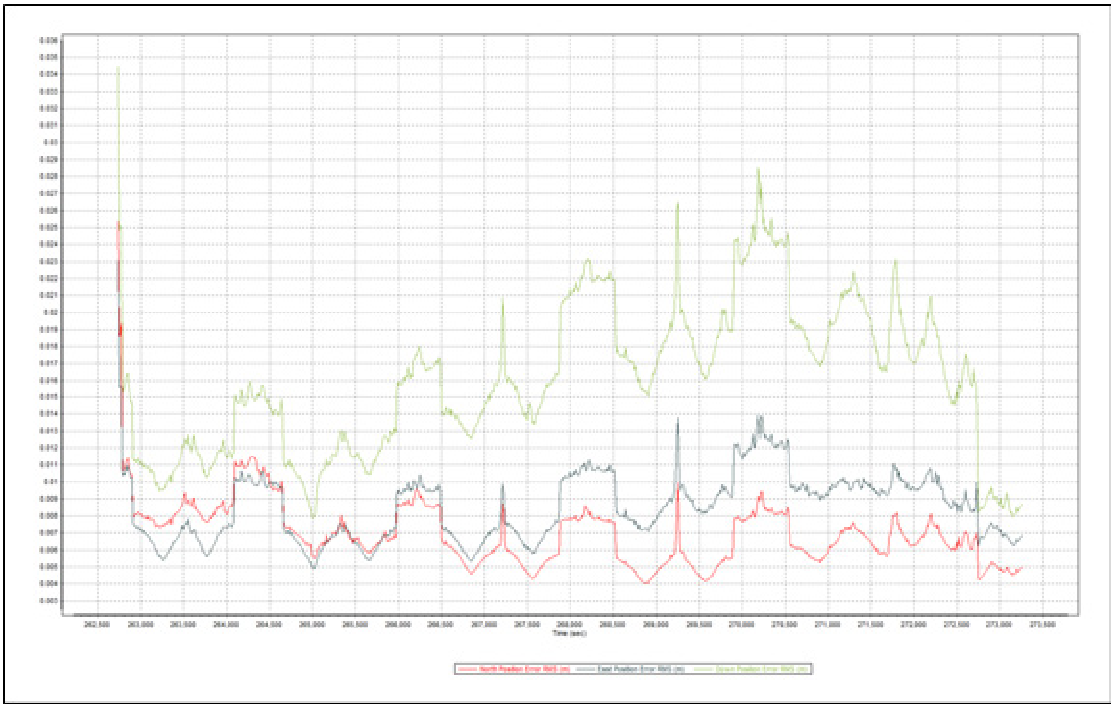


Figure A-8.2. Smoothed Performance Metric Parameters

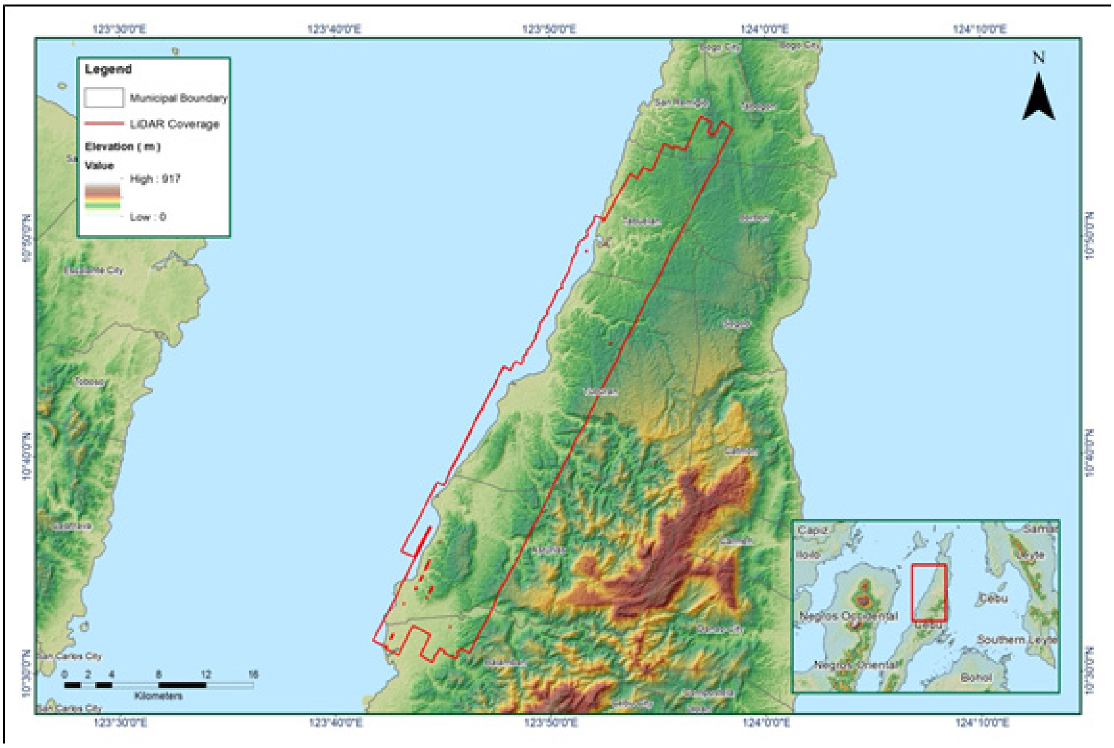


Figure A-8.3. Best Estimated Trajectory

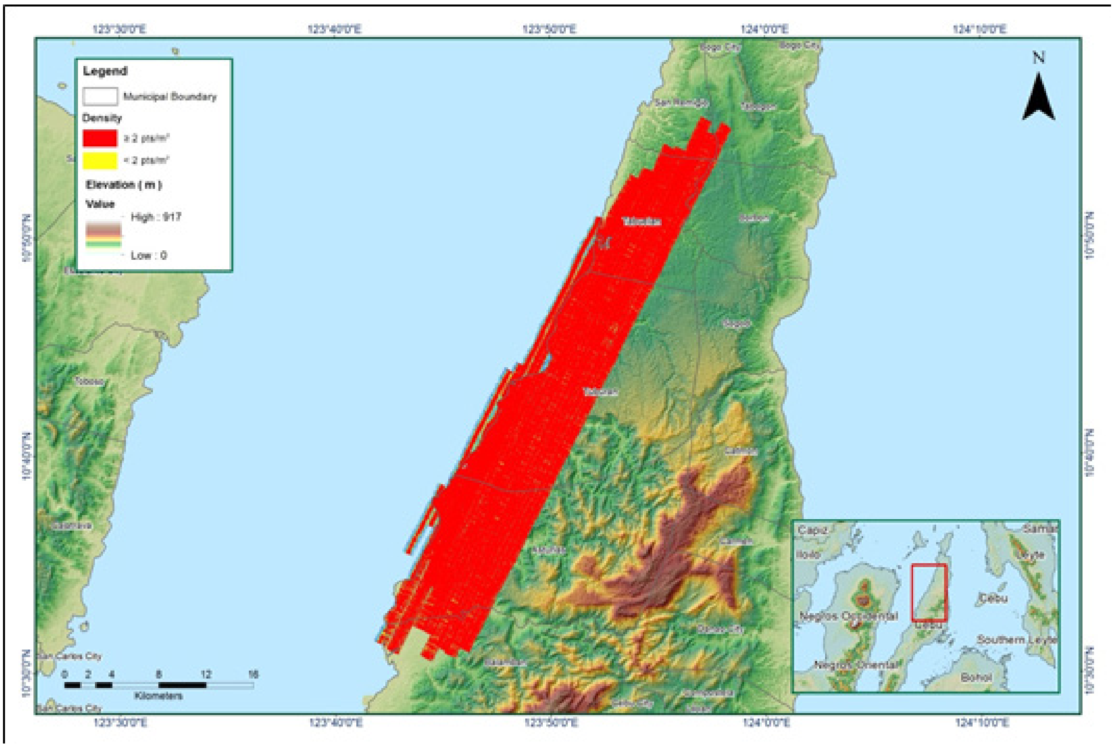


Figure A-8.4. Coverage of LiDAR data

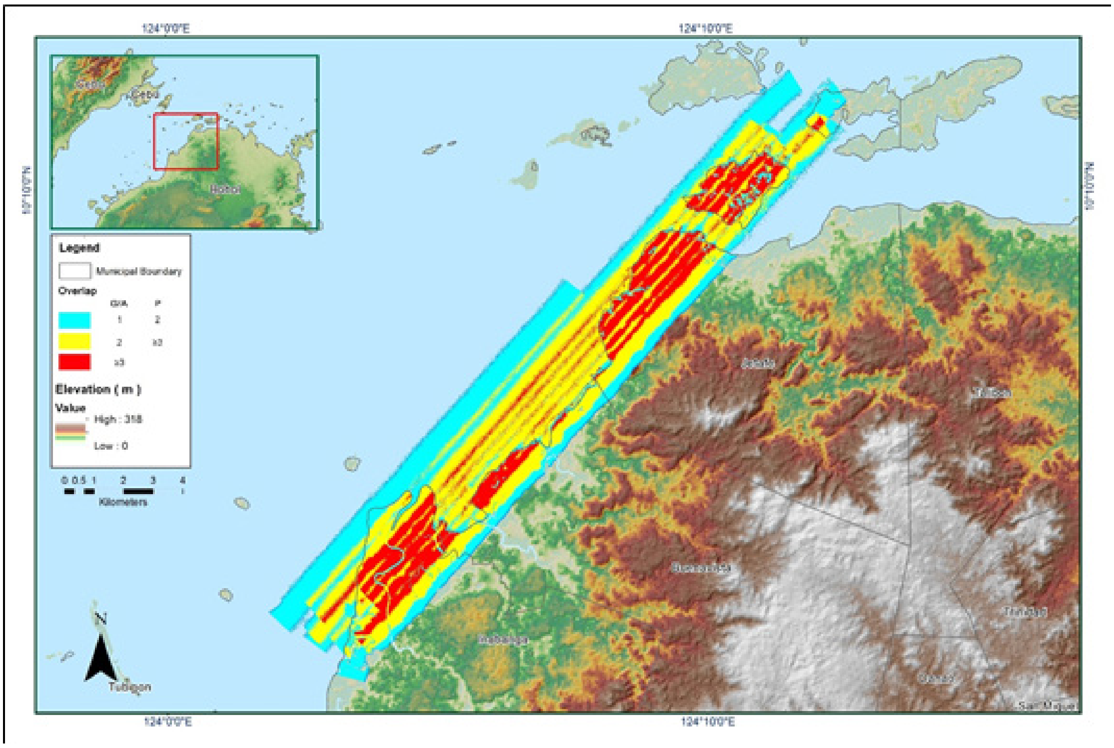


Figure A-8.5. Image of data overlap

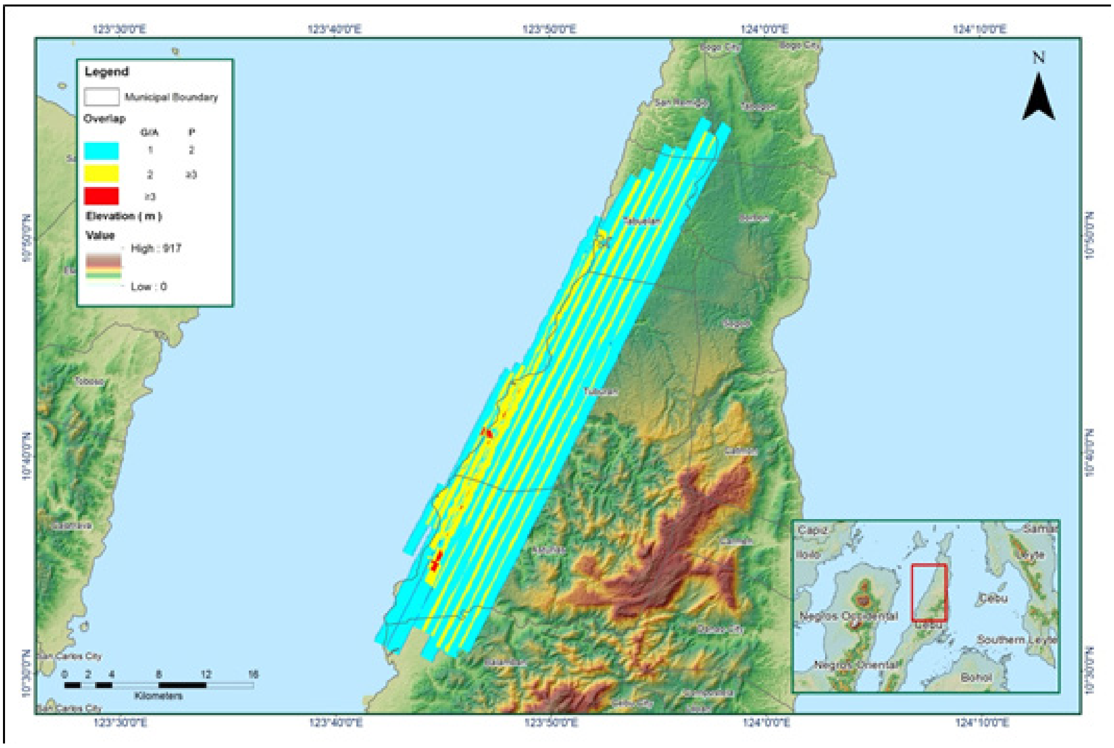


Figure A-8.6. Density map of merged LiDAR data

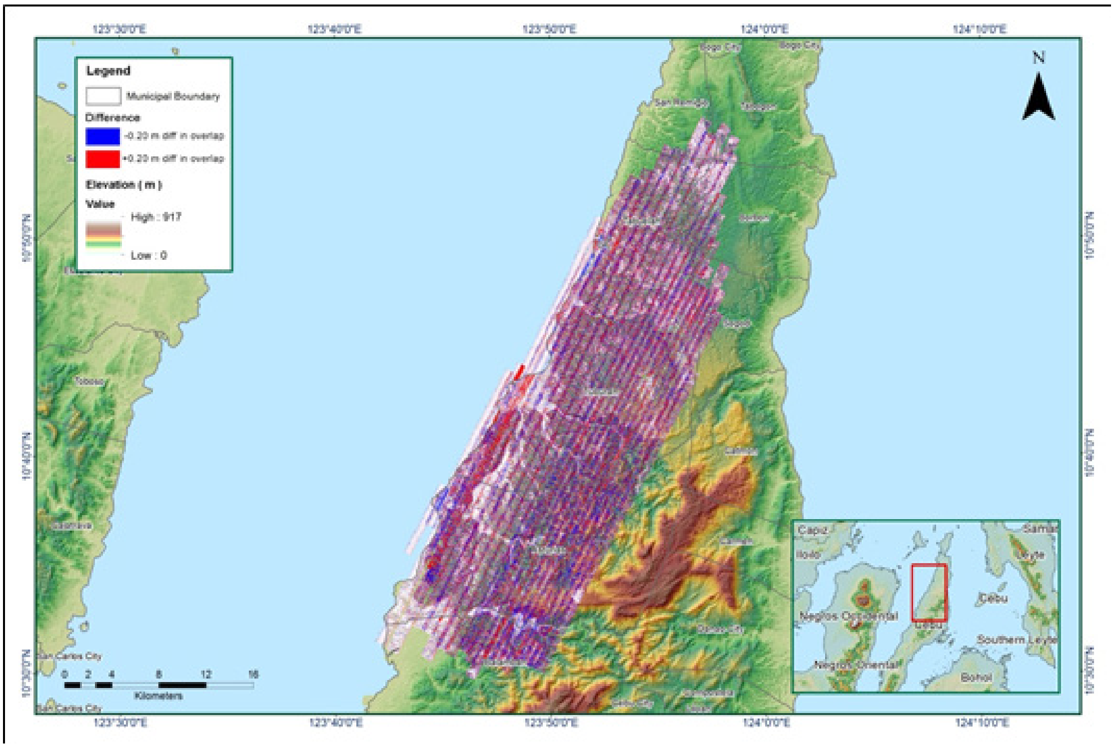


Figure A-8.7. Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Blk36A

Flight Area	Cebu
Mission Name	Blk36A
Inclusive Flights	1747P, 1749P, 1821P
Range data size	58.60 GB
Base data size	4.45 MB
POS	644 MB
Image	92.4 GB
Transfer date	September 16, 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)	3.0
RMSE for East Position (<4.0 cm)	3.5
RMSE for Down Position (<8.0 cm)	6.2
Boresight correction stdev (<0.001deg)	0.001156
IMU attitude correction stdev (<0.001deg)	0.004014
GPS position stdev (<0.01m)	0.0078
Minimum % overlap (>25)	45.30%
Ave point cloud density per sq.m. (>2.0)	5.67
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	630
Maximum Height	399.43 m
Minimum Height	49.55 m
Classification (# of points)	
Ground	407,980,203
Low vegetation	367,986,481
Medium vegetation	942,528,392
High vegetation	224,684,474
Building	19,336,751
Orthophoto	Yes
Processed by	Engr. Jommer Medina, Aljon Rie Araneta, Jovy Narisma

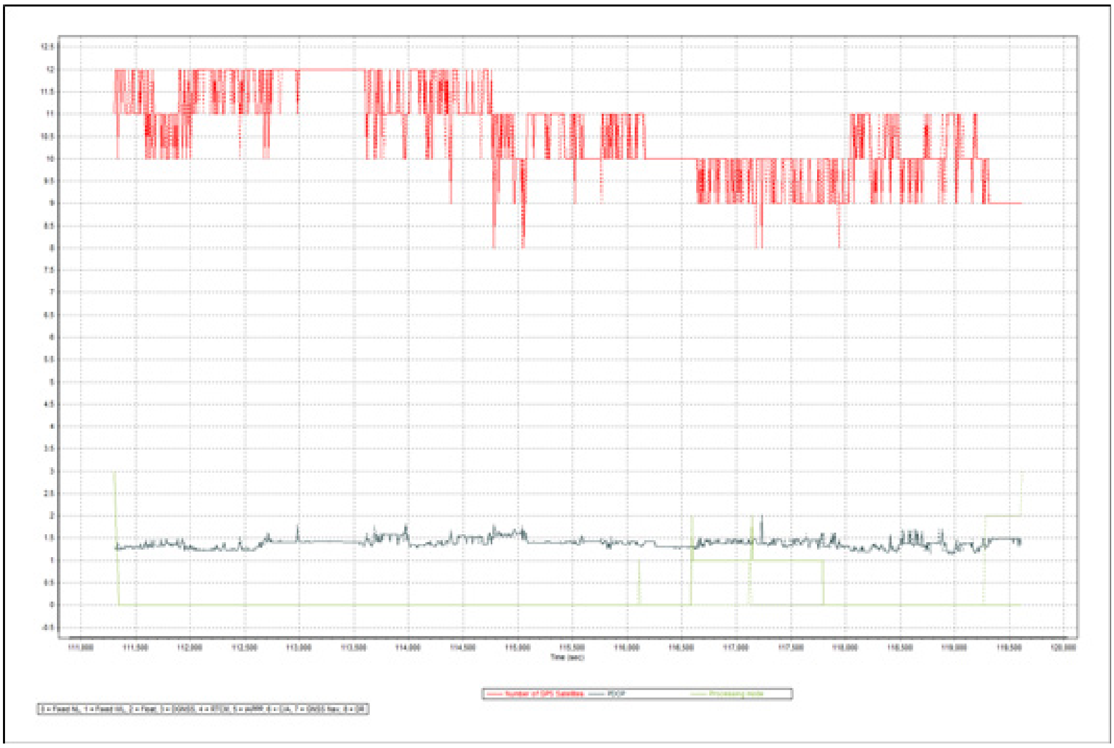


Figure A-8.8. Solution Status

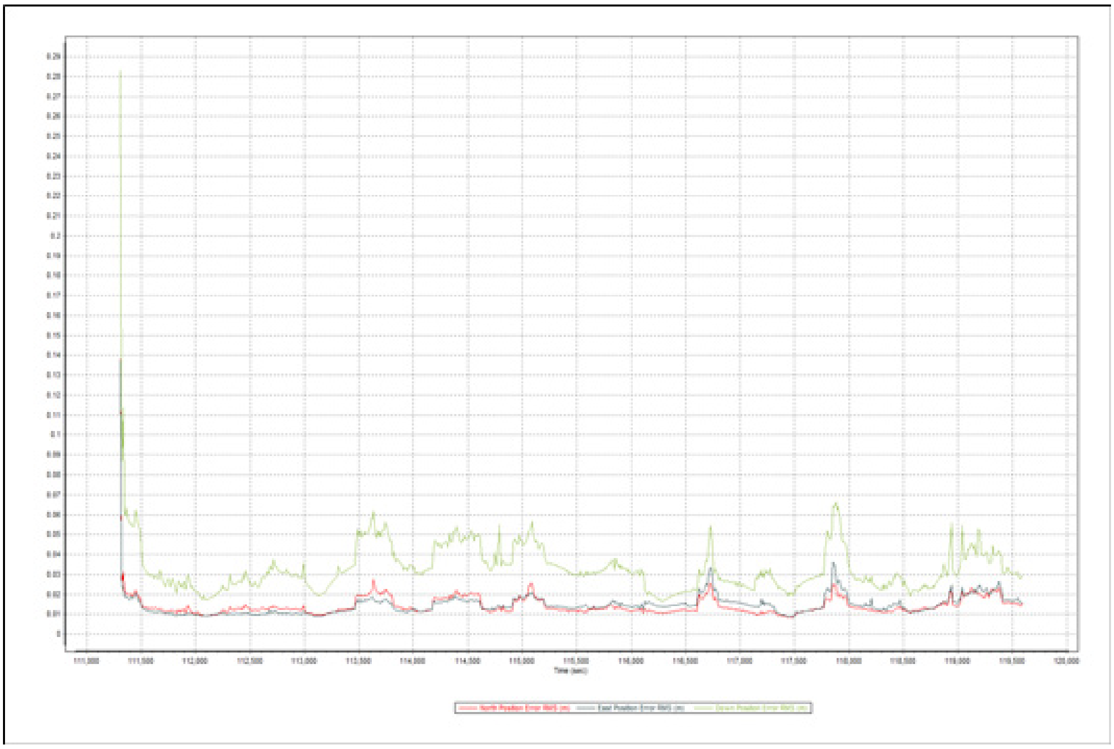


Figure A-8.9. Smoothed Performance Metric Parameters

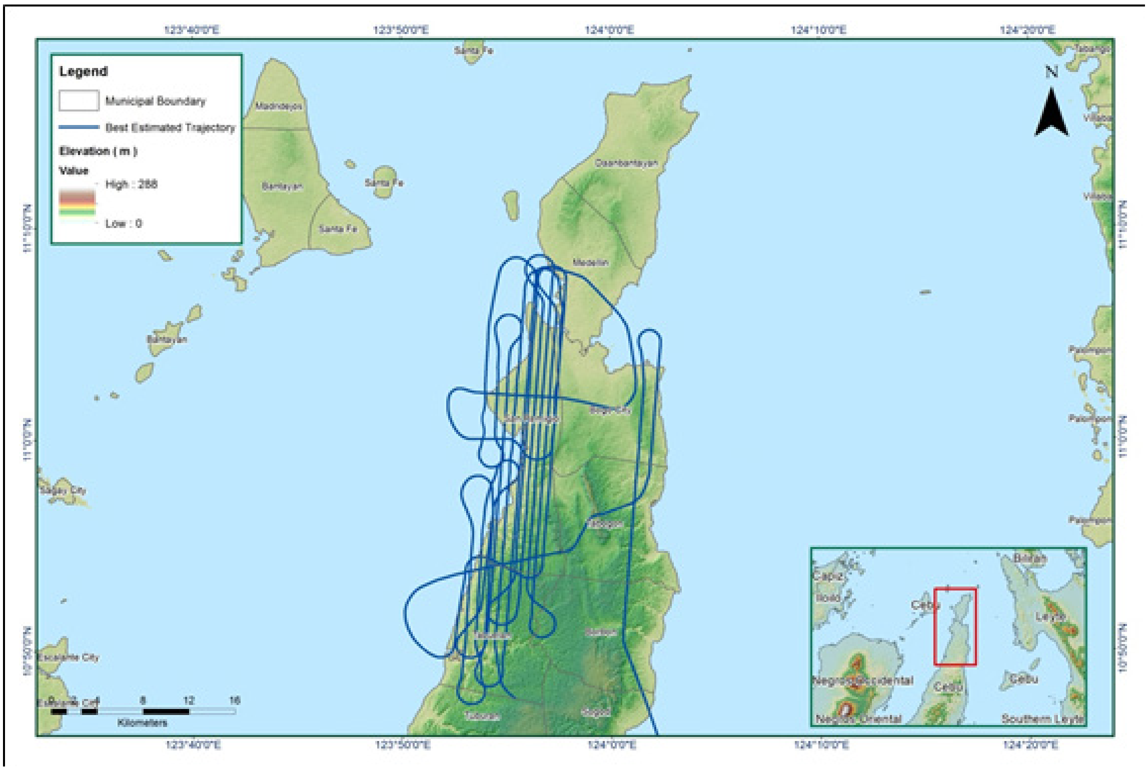


Figure A-8.10. Best Estimated Trajectory

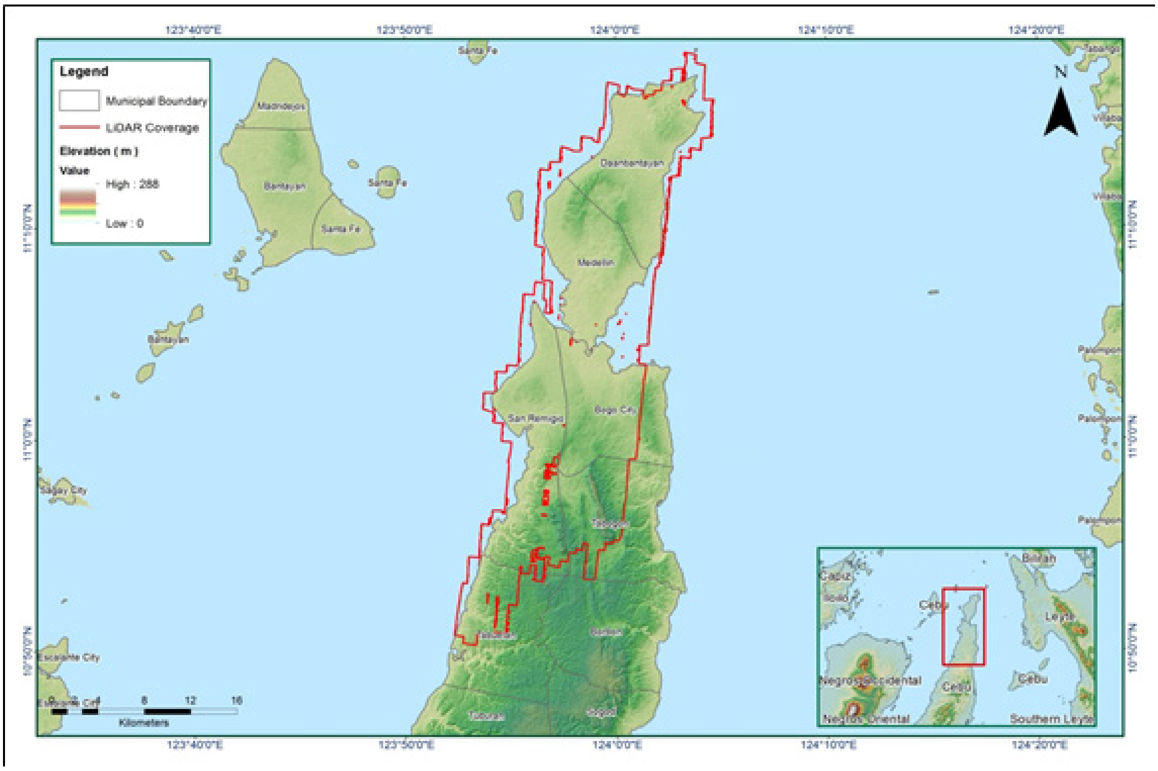


Figure A-8.11. Coverage of LiDAR data

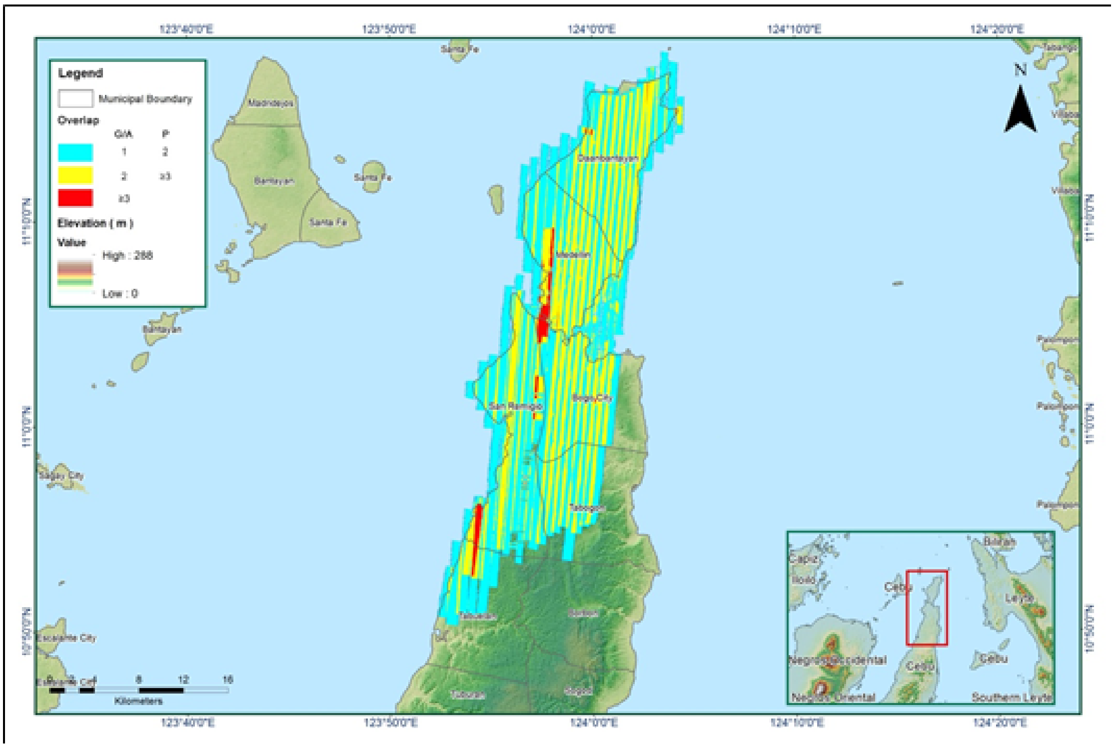


Figure A-8.12. Image of data overlap

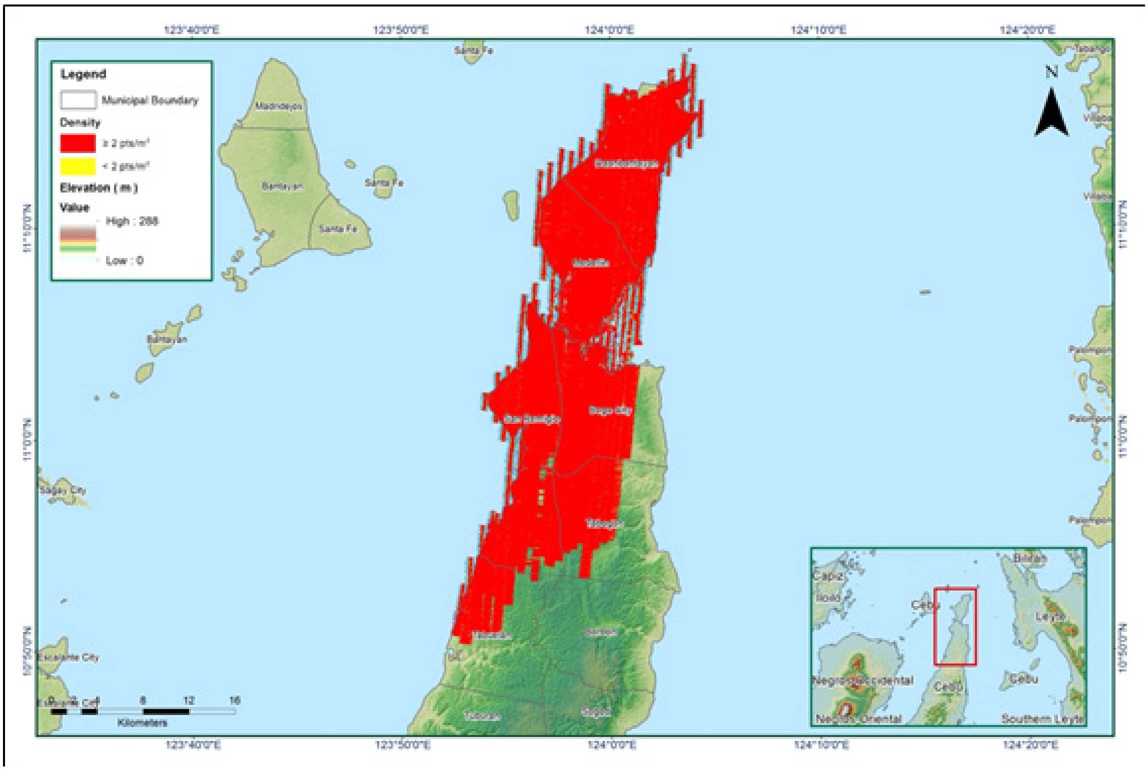


Figure A-8.13. Density map of merged LiDAR data

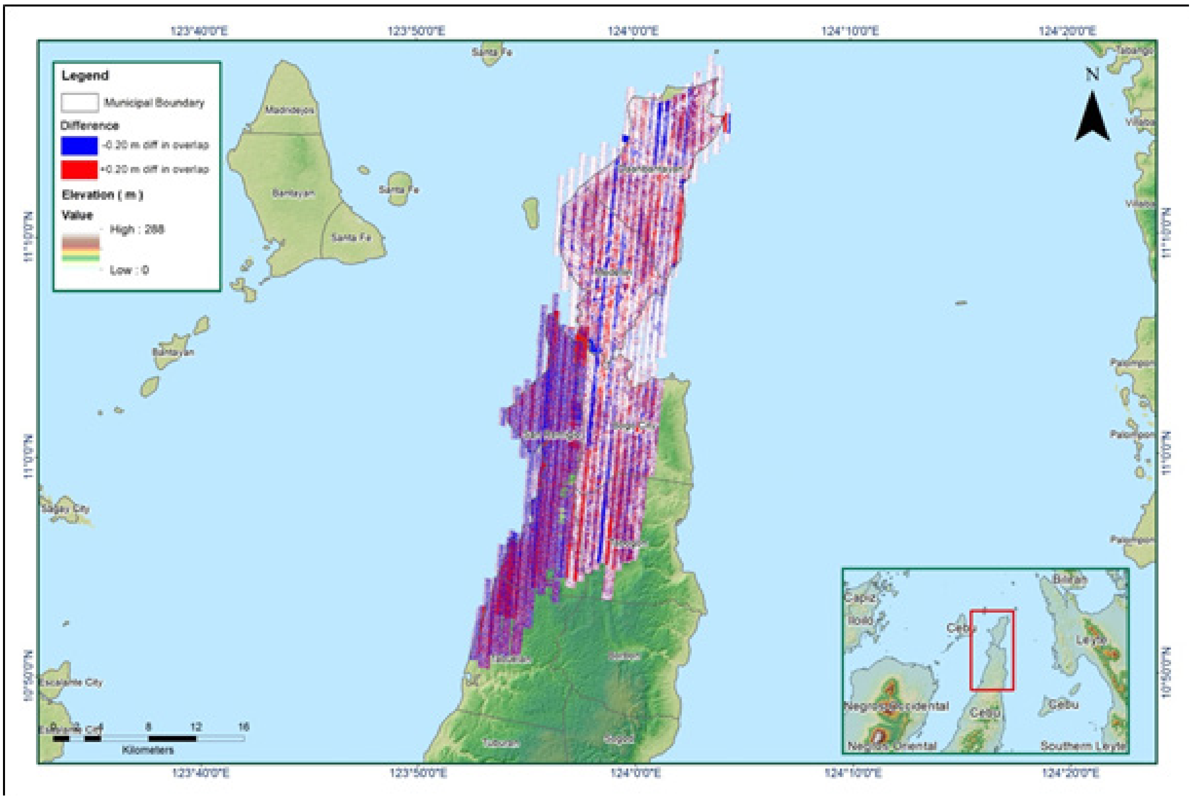


Figure A-8.14. Elevation difference between flight lines

Table A-8.3. Mission Summary Report for Mission Blk36B

Flight Area	Cebu
Mission Name	Blk36B
Inclusive Flights	1805P, 1825P
Range data size	47 GB
Base data size	6.47 MB
POS	444 MB
Image	81.2 GB
Transfer date	August 20, 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)	2.2
RMSE for East Position (<4.0 cm)	1.6
RMSE for Down Position (<8.0 cm)	2.5
Boresight correction stdev (<0.001deg)	0.000168
IMU attitude correction stdev (<0.001deg)	0.002433
GPS position stdev (<0.01m)	0.0029
Minimum % overlap (>25)	41.07%
Ave point cloud density per sq.m. (>2.0)	6.81
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	519
Maximum Height	731.74 m
Minimum Height	60.43 m
Classification (# of points)	
Ground	372,118,756
Low vegetation	310,445,965
Medium vegetation	818,595,739
High vegetation	364,539,463
Building	11,845,876
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Edgardo Gubatanga Jr., Engr. John Dill Macapagal

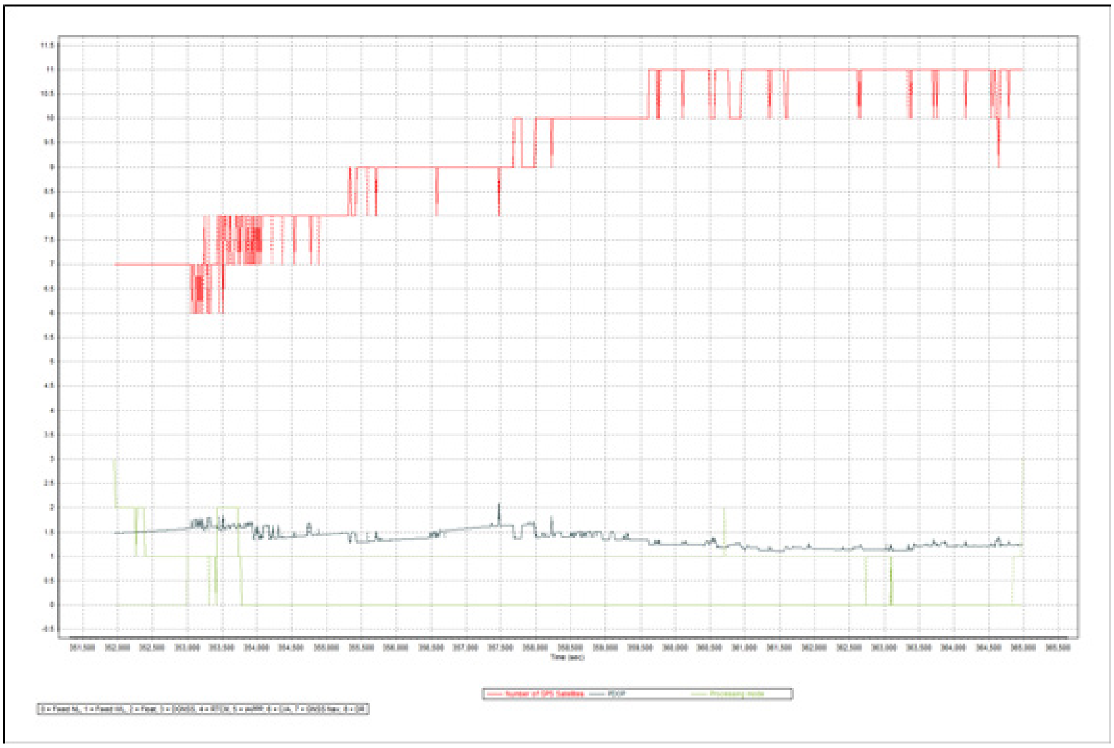


Figure A-8.15. Solution Status

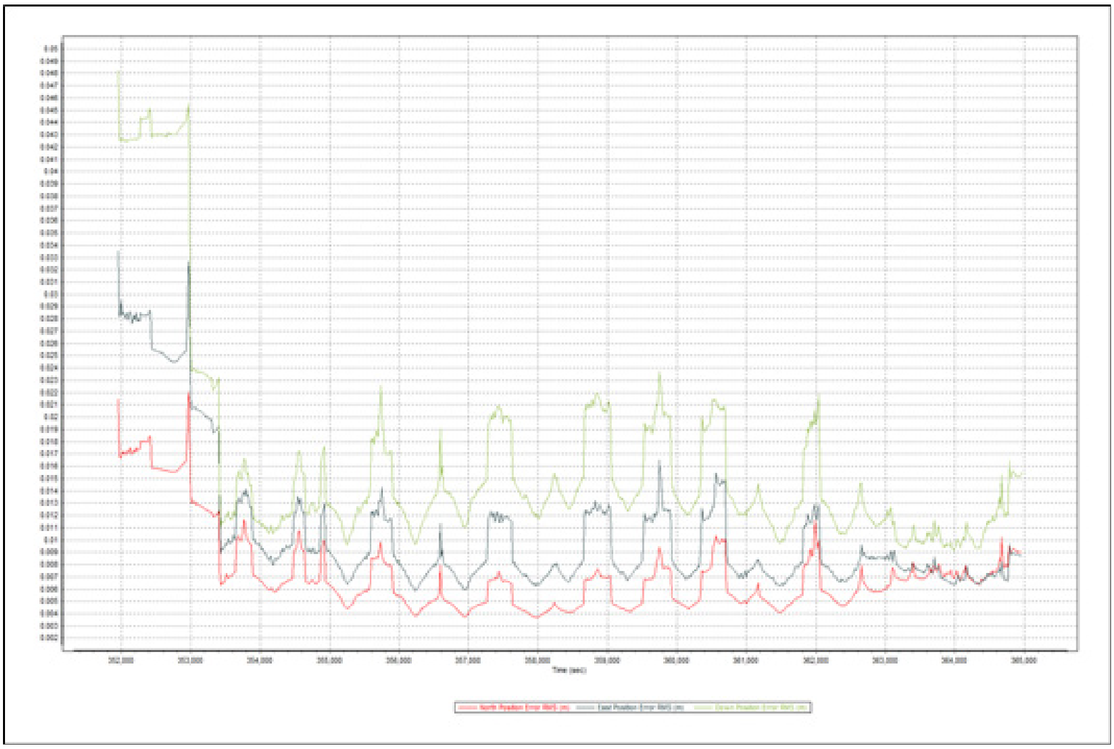


Figure A-8.16. Smoothed Performance Metric Parameters

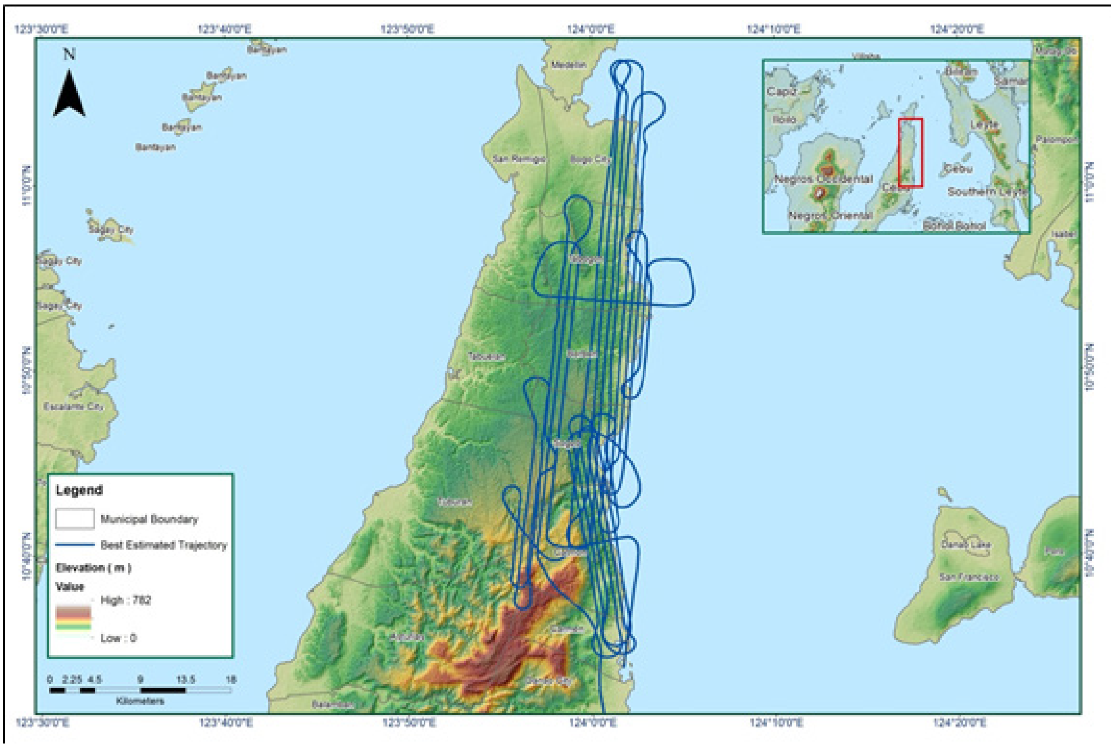


Figure A-8.17. Best Estimated Trajectory

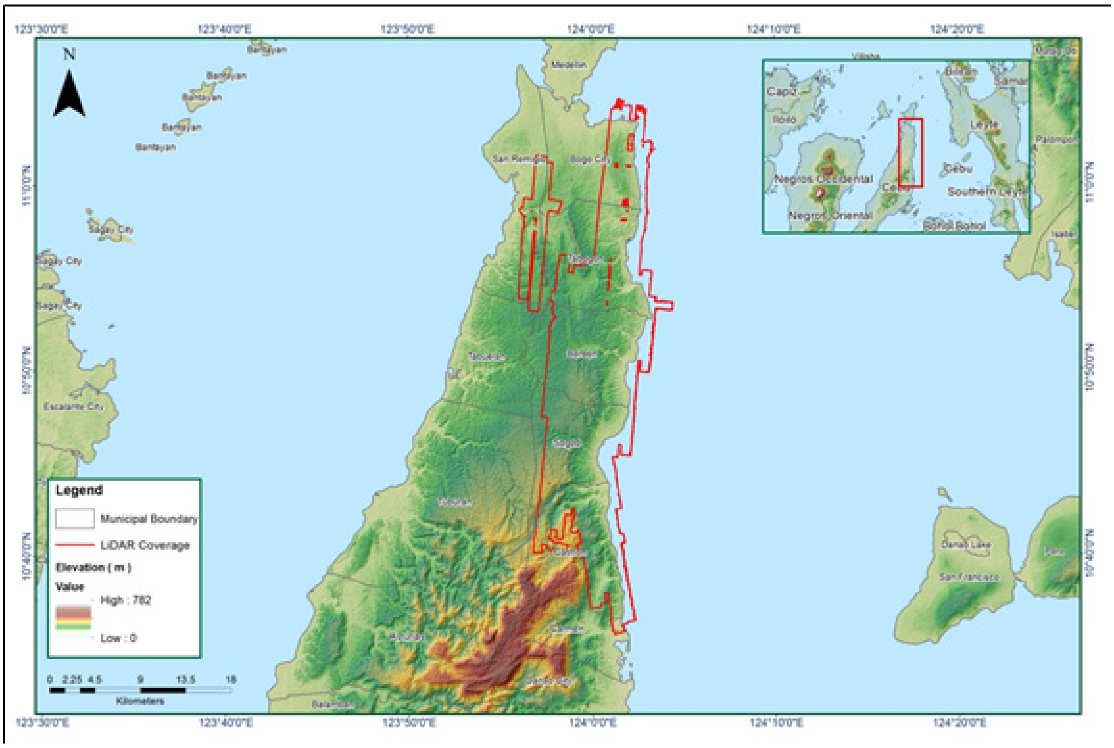


Figure A-8.18. Coverage of LiDAR data

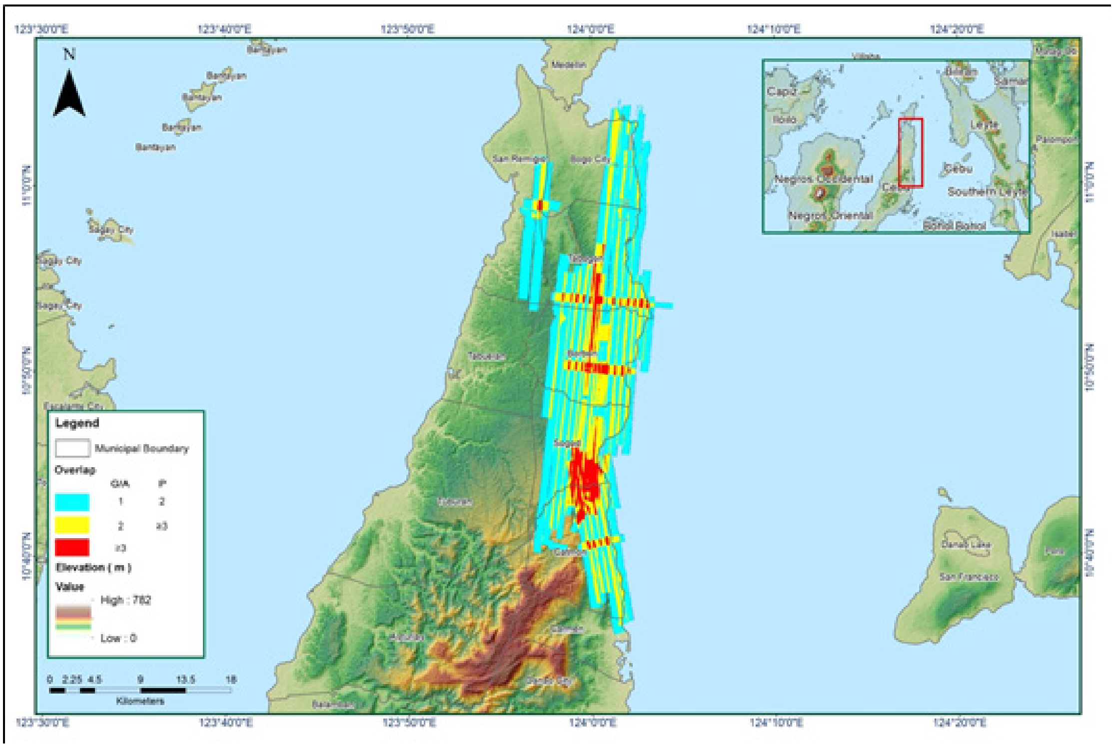


Figure A-8.19. Image of data overlap

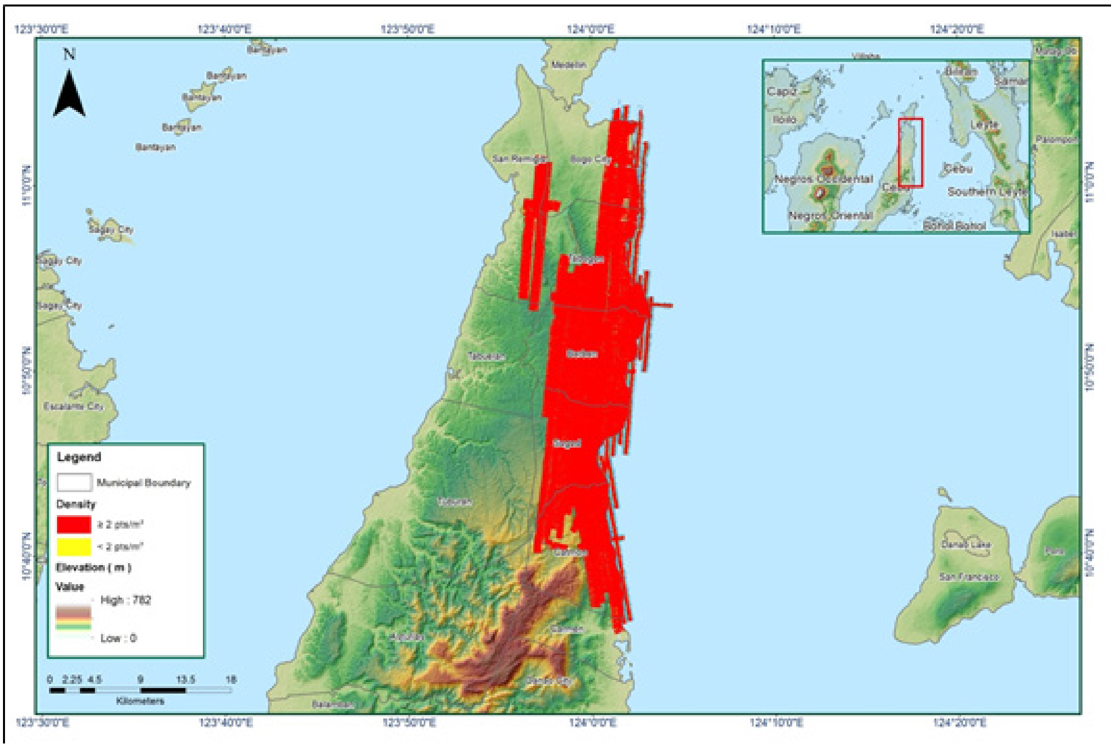


Figure A-8.20. Density map of merged LiDAR data

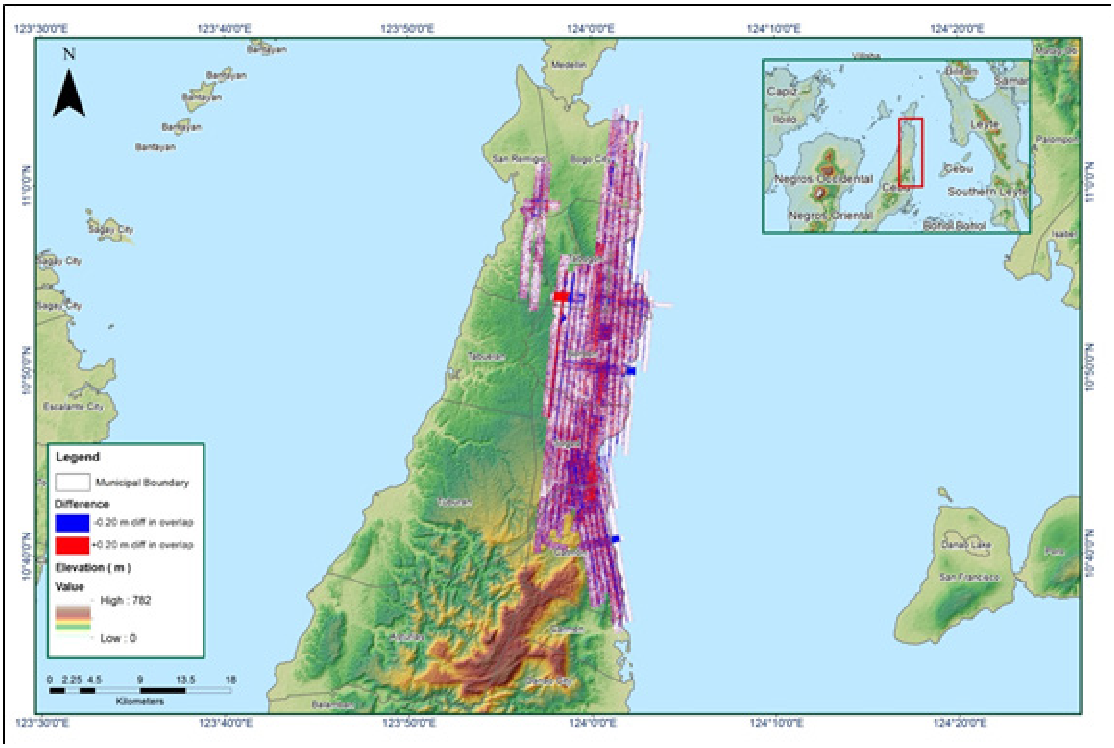


Figure A-8.21. Elevation difference between flight lines

Table A-8.4. Mission Summary Report for Mission Blk36C

Flight Area	Cebu
Mission Name	Blk36C
Inclusive Flights	1803P
Range data size	33.0 GB
Base data size	8.9 MB
POS	224 MB
Image	59.8 GB
Transfer date	September 16, 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)	1.0
RMSE for East Position (<4.0 cm)	1.6
RMSE for Down Position (<8.0 cm)	3.25
Boresight correction stdev (<0.001deg)	0.000153
IMU attitude correction stdev (<0.001deg)	0.000411
GPS position stdev (<0.01m)	0.0068
Minimum % overlap (>25)	55.29%
Ave point cloud density per sq.m. (>2.0)	6.97
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	376
Maximum Height	692.74 m
Minimum Height	84.17 m
Classification (# of points)	
Ground	238,048,848
Low vegetation	174,614,136
Medium vegetation	588,737,226
High vegetation	388,155,860
Building	3,659,537
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Edgardo Gubatanga Jr., Engr. Monalyne Rabino

Figure A-8.22. Solution Status

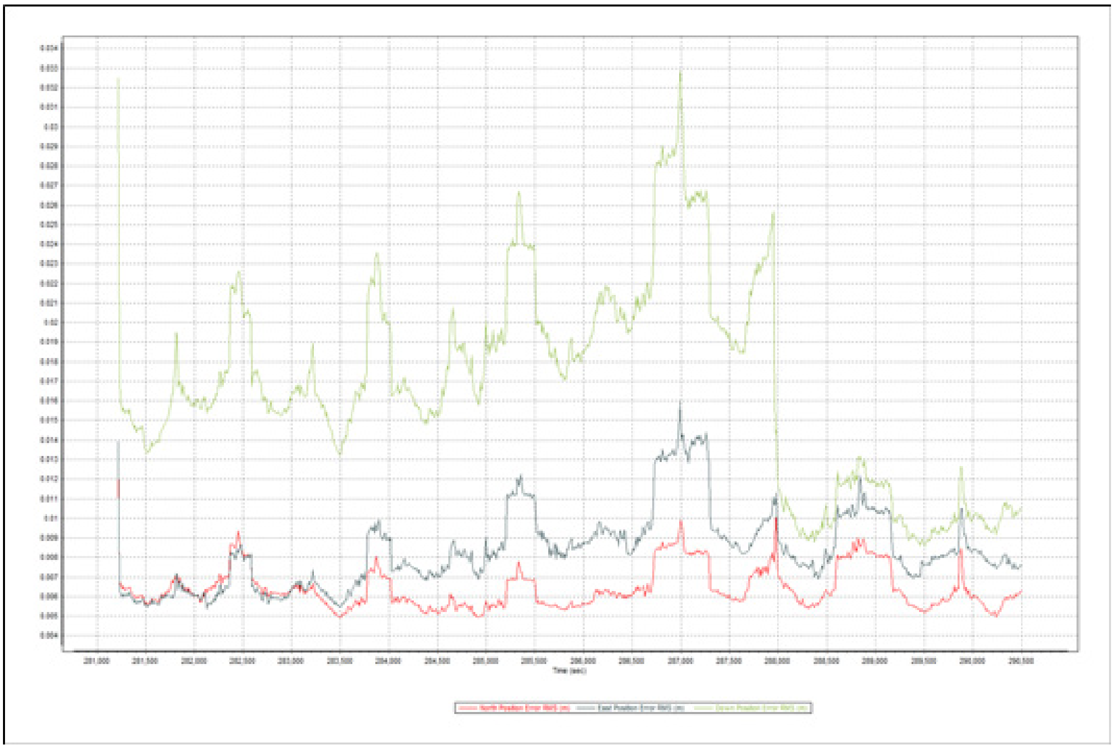


Figure A-8.23. Smoothed Performance Metric Parameters

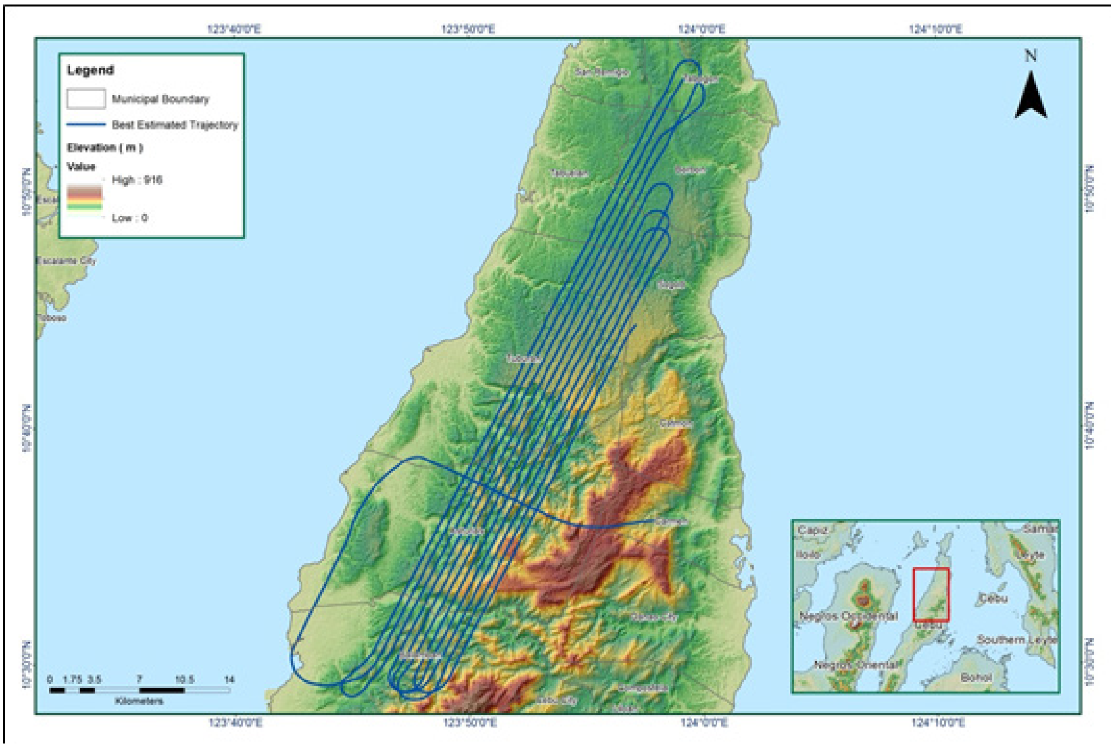


Figure A-8.24. Best Estimated Trajectory

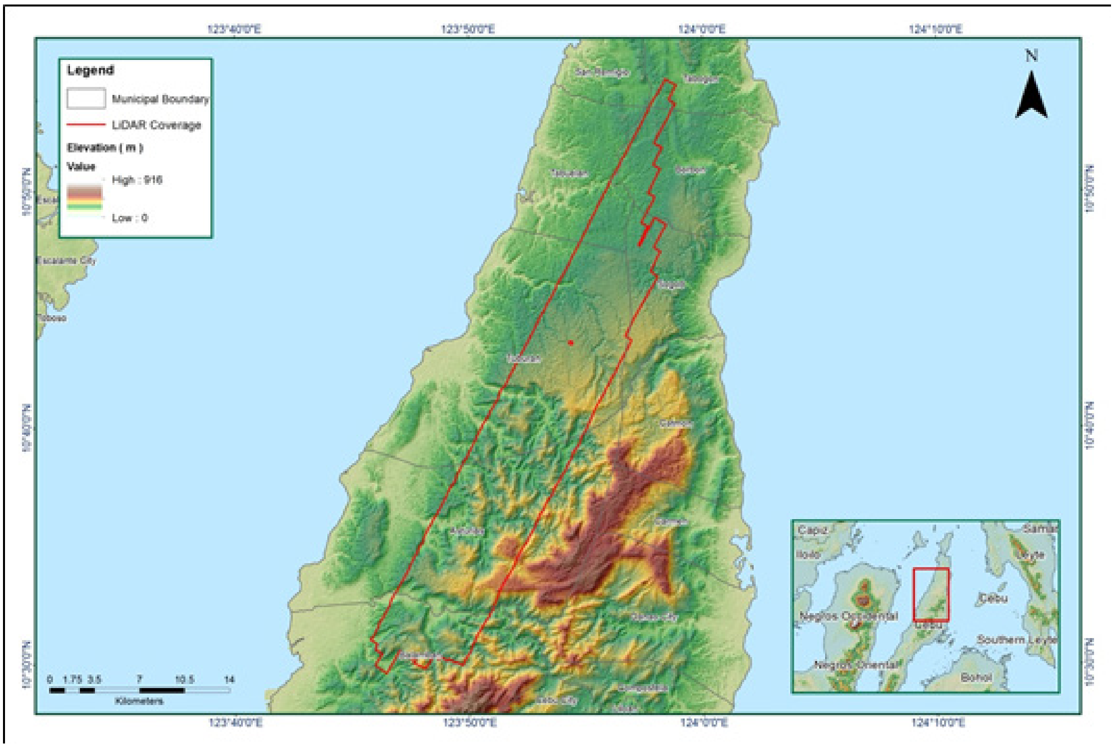


Figure A-8.25. Coverage of LiDAR data

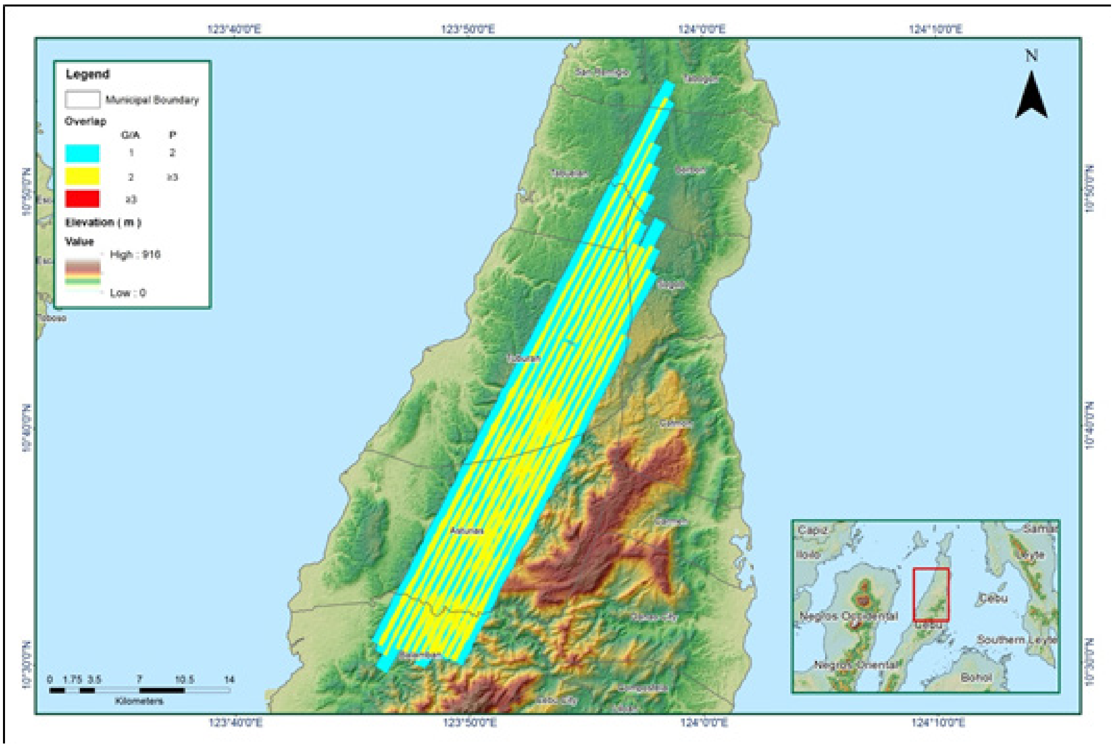


Figure A-8.26. Image of data overlap

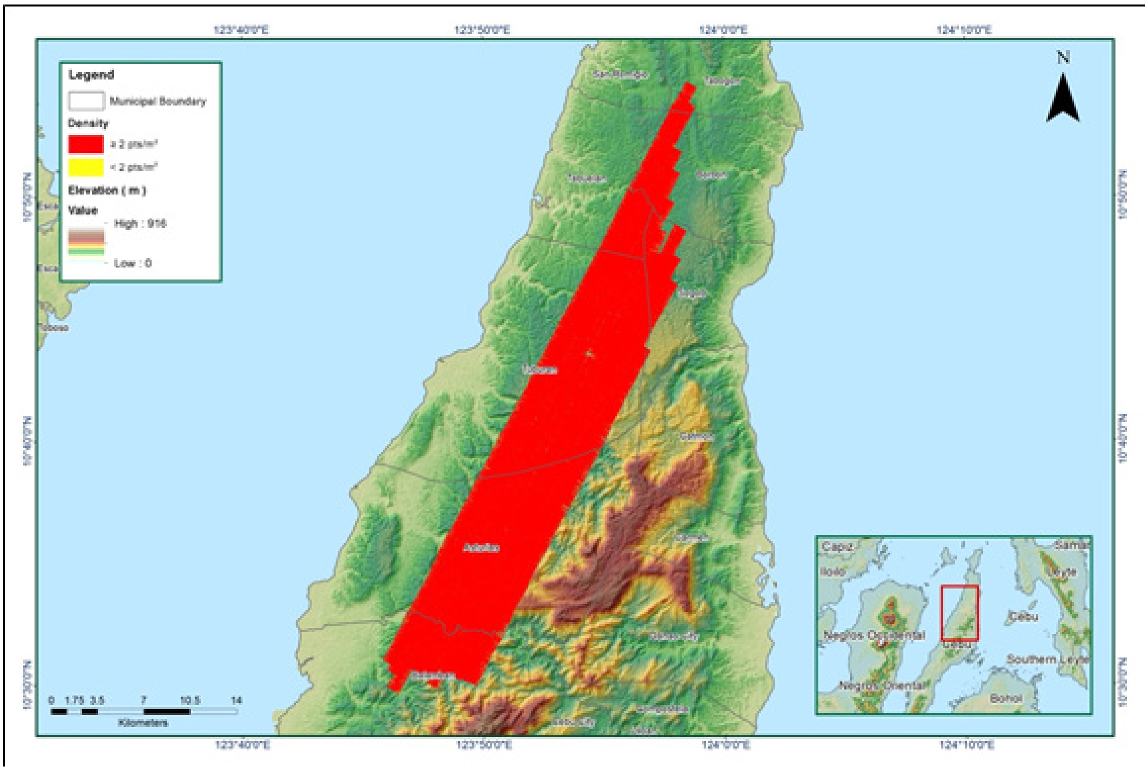


Figure A-8.27. Density map of merged LiDAR data

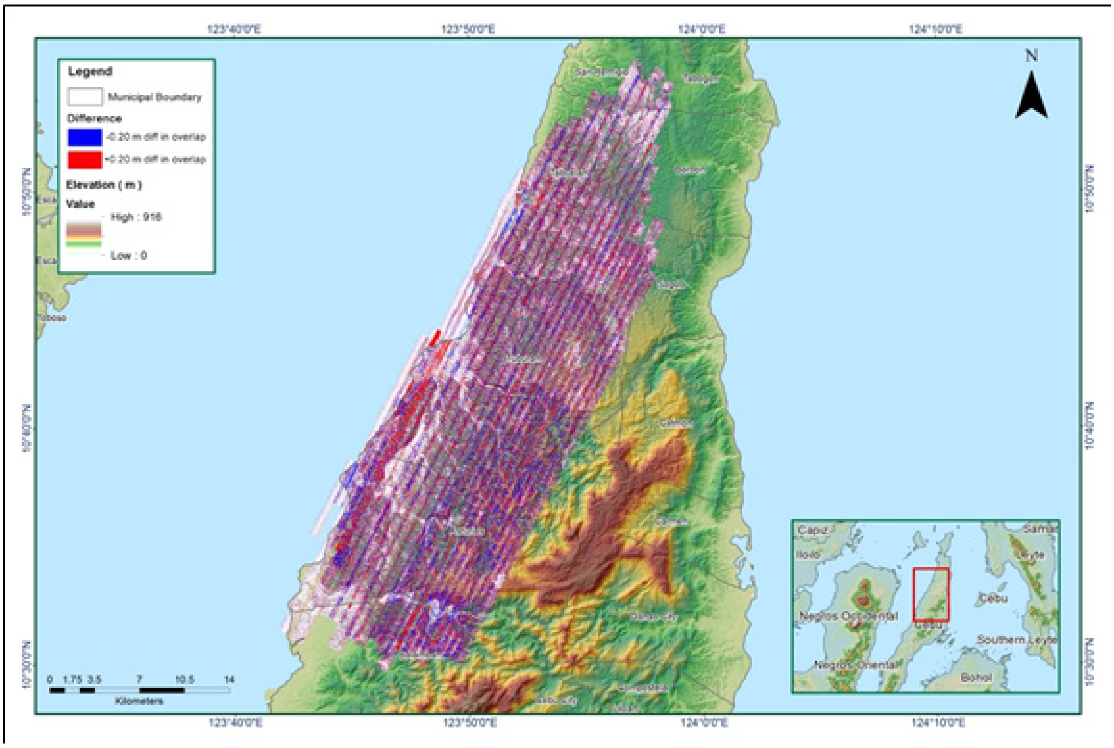


Figure A-8.28. Elevation difference between flight lines

Table A-8.5. Mission Summary Report for Mission Blk36B_additional

Flight Area	Cebu
Mission Name	Blk36B_additonal
Inclusive Flights	1805P
Range data size	34.5 GB
Base data size	7.01 MB
POS	280 MB
Image	60.4 GB
Transfer date	August 20, 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)	2.2
RMSE for East Position (<4.0 cm)	1.6
RMSE for Down Position (<8.0 cm)	2.5
Boresight correction stdev (<0.001deg)	0.000168
IMU attitude correction stdev (<0.001deg)	0.002433
GPS position stdev (<0.01m)	0.0029
Minimum % overlap (>25)	26.55%
Ave point cloud density per sq.m. (>2.0)	6.34
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	54
Maximum Height	730.75 m
Minimum Height	207.94 m
Classification (# of points)	
Ground	35,198,409
Low vegetation	23,205,736
Medium vegetation	51,225,555
High vegetation	27,423,683
Building	319,205
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Antonio Chua Jr., Engr. Gladys Mae Apat

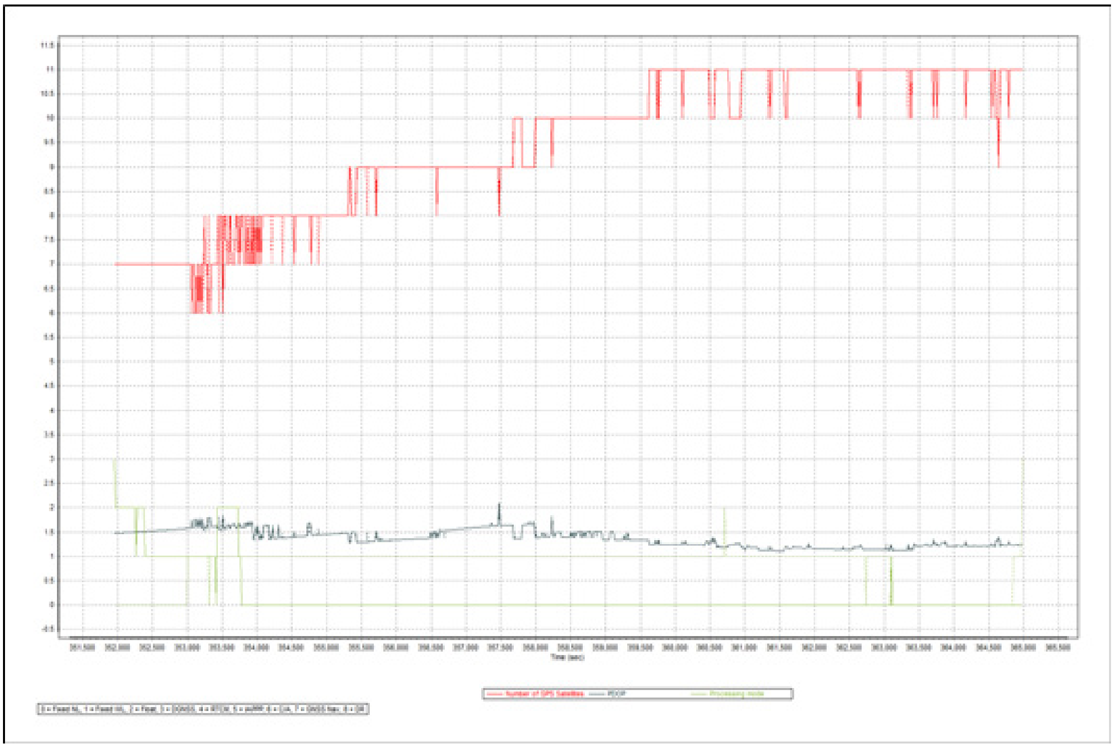


Figure A-8.29. Solution Status

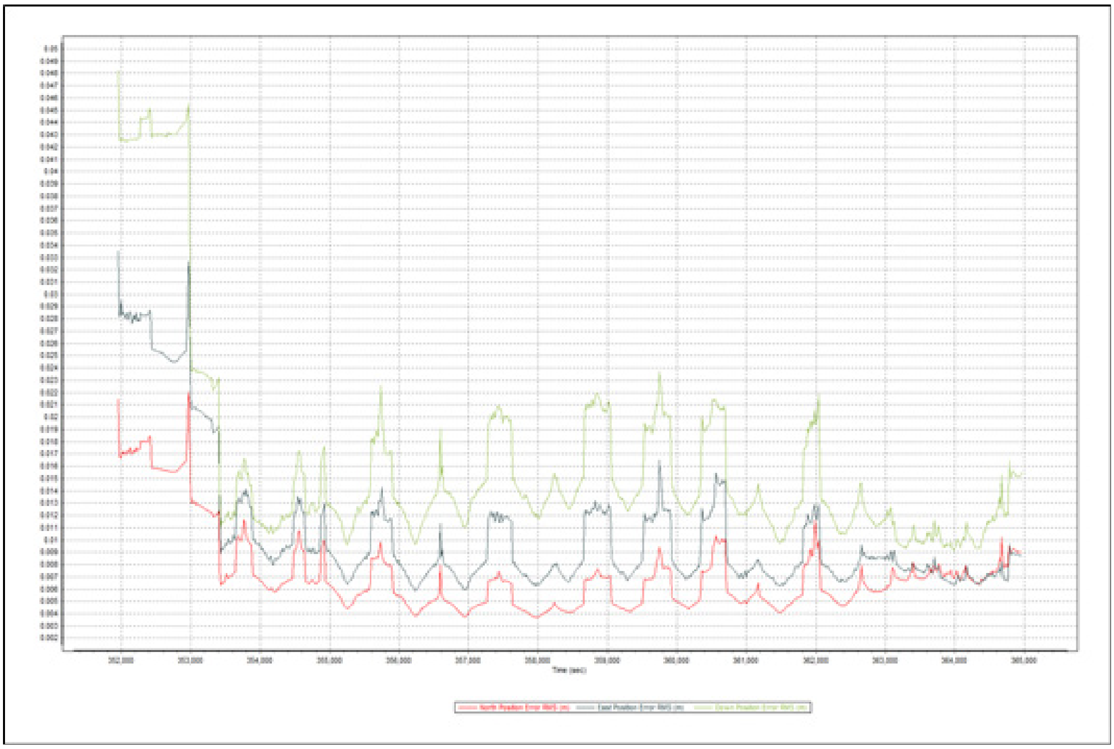


Figure A-8.30. Smoothed Performance Metric Parameters

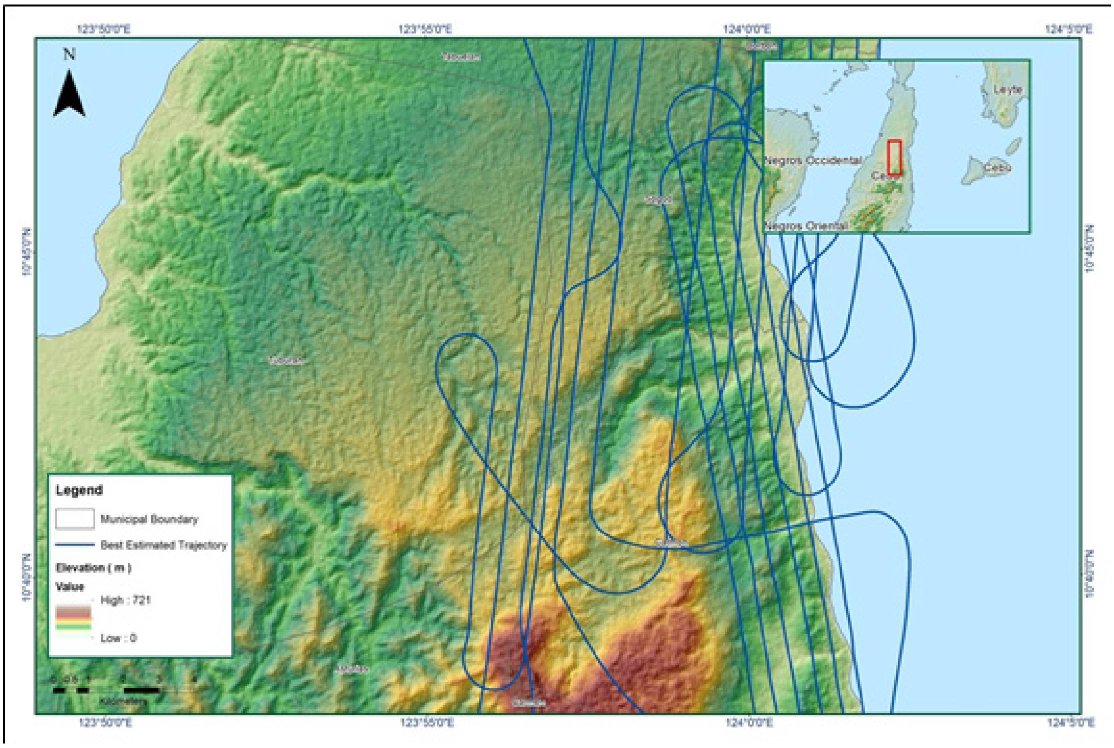


Figure A-8.31. Best Estimated Trajectory

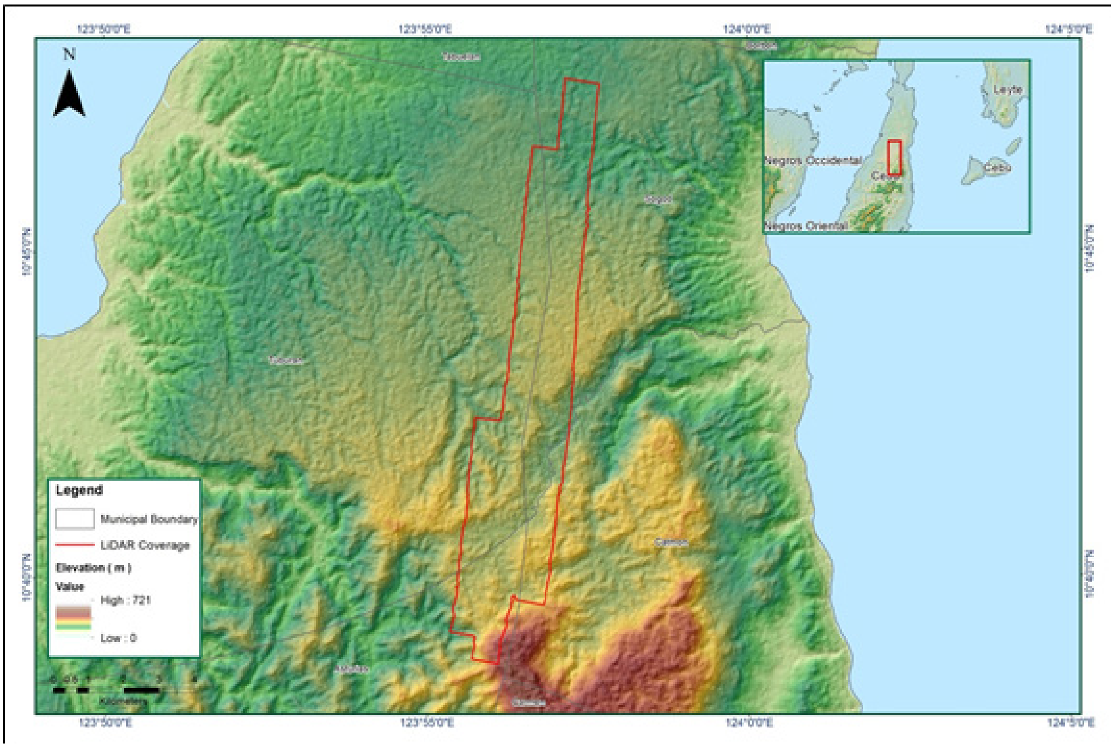


Figure A-8.32. Coverage of LiDAR data

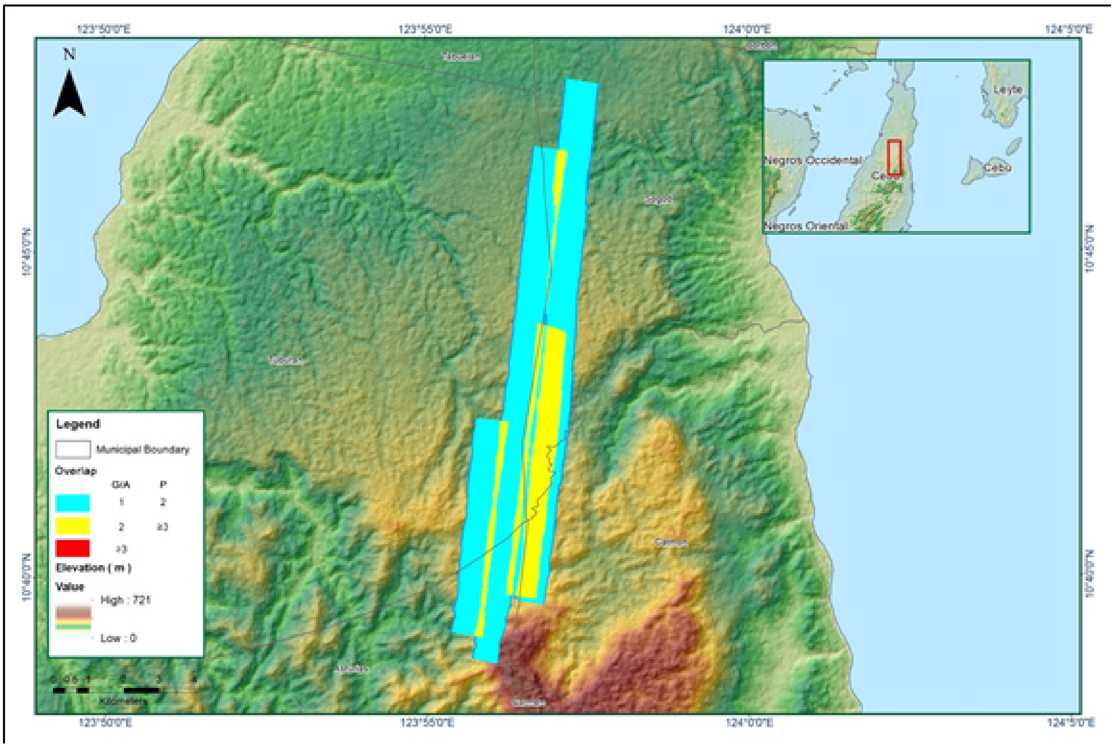


Figure A-8.33. Image of data overlap

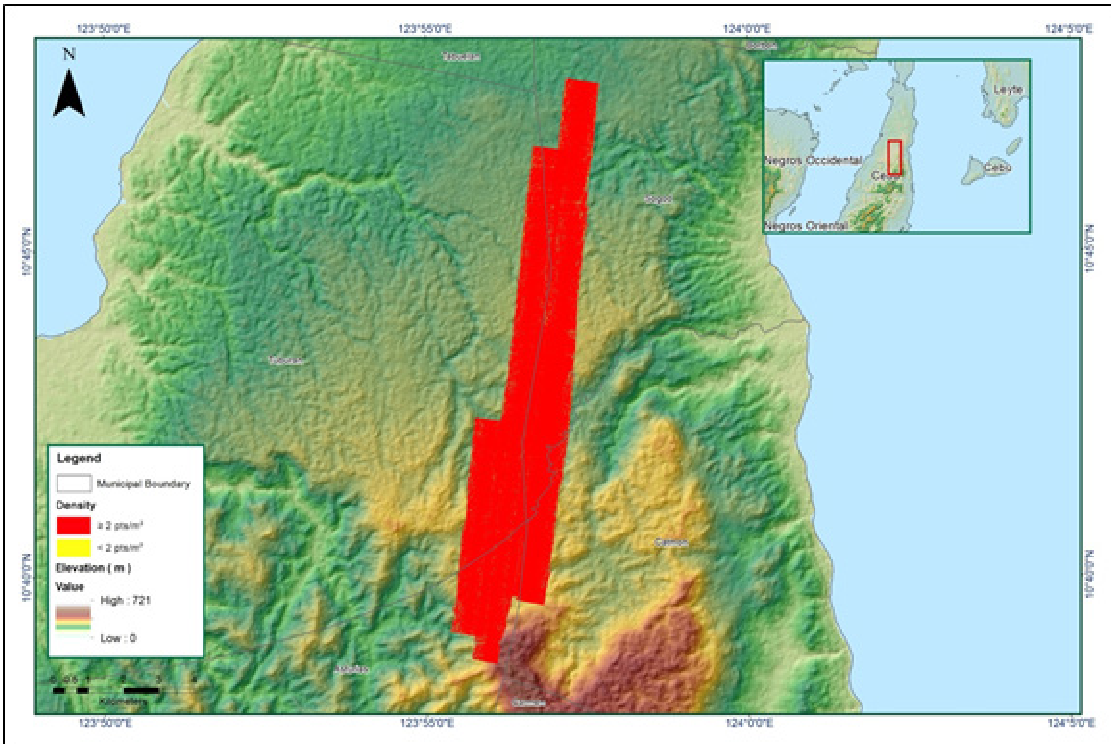


Figure A-8.34. Density map of merged LiDAR data

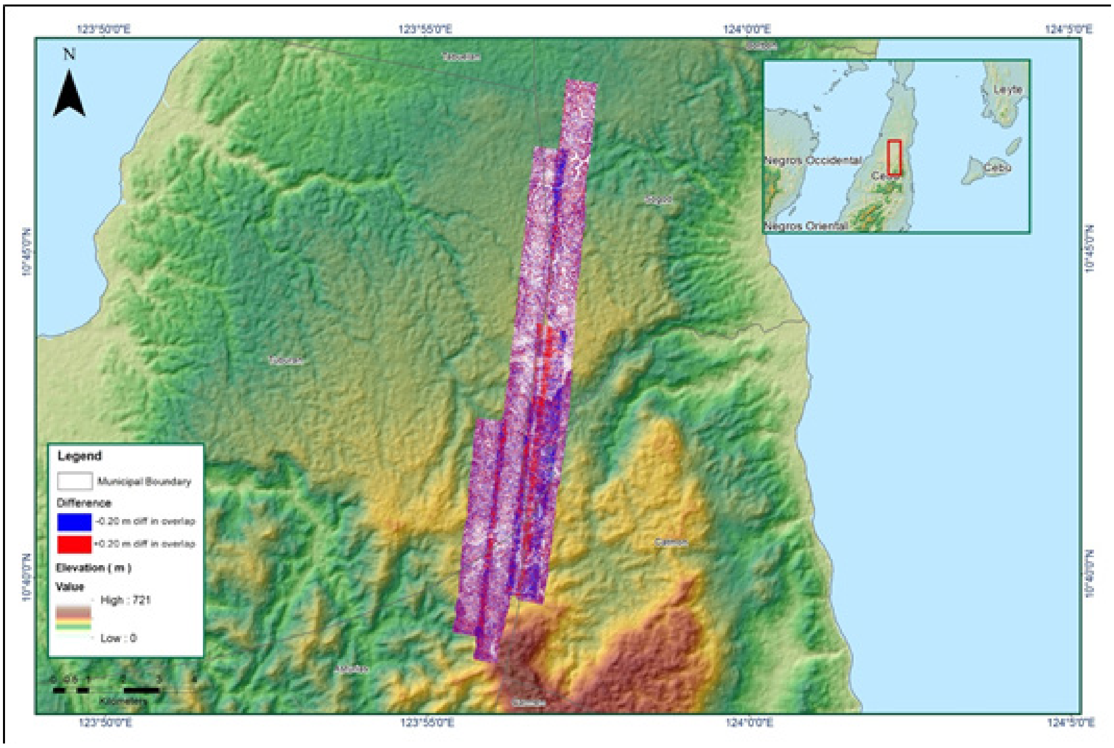


Figure A-8.35. Elevation difference between flight lines

Annex 9. Guinabasan Model Basin Parameters

Table A-9.1. Guinabasan Model Basin Parameters

Basin Number	SCS Curve Number Loss Model			Clark Transform Model		Recession Constant Baseflow Model				
	Initial Abstraction	Curve Number	Impervious	Time of Concentration	Storage Coefficient	Initial Type	Initial Discharge	Recession Constant	Threshold Type	Ratio to Peak
W1000	3.8303	68.9316	0	1.0468	0.051909	Discharge	0.0157891	0.00296	Ratio to Peak	0.25099
W1010	3.8668	68.7562	0	1.9305	0.51799	Discharge	0.0185673	0.02963	Ratio to Peak	0.17073
W1020	2.6305	68.7562	0	2.6795	0.03394	Discharge	0.0184327	0.02963	Ratio to Peak	0.25099
W1030	2.5077	69.6323	0	3.7999	1.8314	Discharge	0.0177757	0.02963	Ratio to Peak	0.25099
W1040	3.9526	68.7562	0	2.2029	0.061383	Discharge	0.0034036	0.06667	Ratio to Peak	0.17246
W1050	2.6305	68.7562	0	1.8662	0.040516	Discharge	0.0050386	0.098	Ratio to Peak	0.17422
W1060	2.6305	68.7562	0	2.5876	0.033517	Discharge	0.0164848	0.04356	Ratio to Peak	0.25098
W1070	2.6305	68.7562	0	0.98523	0.029473	Discharge	0.0039633	0.02963	Ratio to Peak	0.36895
W1080	3.8668	68.7562	0	3.5052	20.543	Discharge	0.0209253	0.02963	Ratio to Peak	0.25611
W1090	2.6305	68.7562	10	2.3909	2.5871	Discharge	0.0141977	0.04356	Ratio to Peak	0.2561
W1100	2.6277	68.7766	10	3.6441	2.0516	Discharge	0.0252962	0.04356	Ratio to Peak	0.17074
W1110	3.8668	68.7562	10	2.3742	2.5969	Discharge	0.0031089	0.02963	Ratio to Peak	0.37251
W1120	2.6305	68.7562	10	3.7128	1.235	Discharge	0.0178215	0.04356	Ratio to Peak	0.25098
W1130	3.8668	68.7562	50	1.8896	1.8382	Discharge	0.0042406	0.02963	Ratio to Peak	0.25611
W1140	2.6305	68.7562	70	2.2941	1.5056	Discharge	0.0019894	0.03968	Ratio to Peak	0.25099
W580	1.8183	75.0098	0	3.3939	1.5966	Discharge	0.0125604	0.02963	Ratio to Peak	0.18294
W590	2.6747	74.9986	0	0.7405	0.033115	Discharge	0.0014646	0.02963	Ratio to Peak	0.26134
W600	4.5648	65.5605	0	5.3304	0.031198	Discharge	0.0049299	0.02963	Ratio to Peak	0.18293
W610	2.2593	77.4496	0	2.5821	0.091046	Discharge	0.0047381	0.04356	Ratio to Peak	0.26891
W620	2.4729	69.8863	0	7.6318	0.041344	Discharge	0.0204198	0.02963	Ratio to Peak	0.3953
W630	2.5494	69.105	0	3.9028	1.9267	Discharge	0.0035144	0.02963	Ratio to Peak	0.26891
W640	3.963	83.8267	0	1.6657	0.55863	Discharge	0.0010039	0.04356	Ratio to Peak	0.26133

W650	2.8343	64.5099	0	3.4544	0.77228	Discharge	0.0054119	0.02963	Ratio to Peak	0.18293
W660	2.0204	79.0072	0	2.9282	4.7842	Discharge	0.0071399	0.02963	Ratio to Peak	0.26891
W670	4.6438	69.3325	0	2.9741	2.0992	Discharge	0.0063606	0.04356	Ratio to Peak	0.26891
W680	4.5579	68.2982	0	3.668	1.9836	Discharge	0.0052737	0.02963	Ratio to Peak	0.26891
W690	3.7983	74.0989	0	2.228	3.7492	Discharge	0.0108121	0.02963	Ratio to Peak	0.26134
W700	6.215	73.3492	0	1.3967	0.12651	Discharge	0.0015037	0.02963	Ratio to Peak	0.3953
W710	6.2149	65.2178	0	3.1043	0.31941	Discharge	0.0060643	0.02963	Ratio to Peak	0.3953
W720	2.2108	65.5911	0	2.2921	0.46058	Discharge	0.00546	0.02963	Ratio to Peak	0.3953
W730	3.1412	68.3543	0	3.1361	27.854	Discharge	0.0052029	0.02963	Ratio to Peak	0.27028
W740	2.8364	59.0713	0	0.51406	0.018	Discharge	0.0011689	0.02963	Ratio to Peak	0.3953
W750	1.1524	71.8508	0	1.9465	0.4972	Discharge	0.0012521	0.02963	Ratio to Peak	0.37837
W760	2.6635	72.4261	0	3.3376	4.0622	Discharge	0.0312462	0.02963	Ratio to Peak	0.36895
W770	3.6066	74.0867	0	1.2598	0.028619	Discharge	0.0256986	0.02963	Ratio to Peak	0.25099
W780	2.6305	81.0533	0	1.7336	0.36215	Discharge	0.0156641	0.02963	Ratio to Peak	0.36895
W790	3.3748	75.0638	0	1.0241	0.049269	Discharge	0.0081998	0.02963	Ratio to Peak	0.36895
W800	3.0555	70.0291	0	2.6359	0.087692	Discharge	0.0388571	0.04356	Ratio to Peak	0.36895
W810	2.6303	68.7562	0	1.1624	0.078563	Discharge	0.0164544	0.02963	Ratio to Peak	0.25611
W820	3.8668	69.3967	0	1.5985	0.16613	Discharge	0.0156405	0.02963	Ratio to Peak	0.36895
W830	3.8668	71.2021	0	2.8084	1.4828	Discharge	0.018312	0.04356	Ratio to Peak	0.1751
W840	3.8668	72.8861	0	0.64793	0.019198	Discharge	0.0044079	0.02963	Ratio to Peak	0.36895
W850	2.4766	68.7572	0	2.1089	0.28528	Discharge	0.0138142	0.04356	Ratio to Peak	0.36895
W860	3.0316	68.7562	0	3.3581	0.51616	Discharge	0.050745	0.06533	Ratio to Peak	0.2352
W870	3.857	68.7562	0	1.4894	3.426	Discharge	0.0060431	0.06533	Ratio to Peak	0.38416
W880	3.8057	68.7562	0	1.6398	21.876	Discharge	0.01901	0.098	Ratio to Peak	0.3953
W890	3.8668	69.8588	0	2.4323	0.43671	Discharge	0.0236683	0.04444	Ratio to Peak	0.38416
W900	3.3528	73.0147	0	0.98912	0.19252	Discharge	0.0102833	0.04444	Ratio to Peak	0.26133
W910	3.6452	68.8041	0	2.2864	0.24806	Discharge	0.0136931	0.04444	Ratio to Peak	0.38416
W920	3.7165	69.0509	0	1.7606	0.49972	Discharge	0.0270022	0.04444	Ratio to Peak	0.38416

W930	3.9457	68.7562	0	1.6328	0.030356	Discharge	0.0579544	0.1	Ratio to Peak	0.3953
W940	3.9307	71.3164	0	1.3146	0.028373	Discharge	0.0227569	0.06667	Ratio to Peak	0.26667
W950	3.9457	69.8363	0	1.4627	0.073848	Discharge	0.0219816	0.06667	Ratio to Peak	0.26133
W960	3.9457	69.8516	0	2.3234	0.041038	Discharge	0.0611436	0.06667	Ratio to Peak	0.26133
W970	3.2881	68.7562	0	1.1773	0.61831	Discharge	0.0186035	0.06667	Ratio to Peak	0.39259
W980	3.2881	68.8276	0	0.79812	0.035473	Discharge	0.0056459	0.06667	Ratio to Peak	0.26891
W990	3.2881	68.7562	0	0.82886	0.053849	Discharge	0.0135383	0.1	Ratio to Peak	0.26133

Annex 10. Libertad Model Reach Parameters

Table A-10.1. Guinabasan Model Reach Parameters

Reach Number	Muskingum Cunge Routing Model						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R120	Automatic Fixed Interval	127.28	0.001	0.04557	Trapezoid	20	0.1
R130	Automatic Fixed Interval	311.13	0.001	0.15139	Trapezoid	20	0.1
R140	Automatic Fixed Interval	685.98	0.001	0.10203	Trapezoid	20	0.1
R150	Automatic Fixed Interval	125.71	0.001	0.06035	Trapezoid	20	0.1
R160	Automatic Fixed Interval	120.71	0.001	0.01558	Trapezoid	20	0.1
R20	Automatic Fixed Interval	803.26	0.00614	0.029	Trapezoid	30	0.1
R210	Automatic Fixed Interval	2671.4	0.00235	0.07555	Trapezoid	20	0.1
R230	Automatic Fixed Interval	1368.1	0.00866	0.2216	Trapezoid	20	0.1
R250	Automatic Fixed Interval	2299.1	0.00455	0.06102	Trapezoid	20	0.1
R260	Automatic Fixed Interval	313.14	0.00134	0.06454	Trapezoid	20	0.1
R270	Automatic Fixed Interval	1556.8	0.00833	0.08122	Trapezoid	20	0.1
R280	Automatic Fixed Interval	2554.5	0.0047	0.04267	Trapezoid	20	0.1
R290	Automatic Fixed Interval	885.27	0.01391	0.10982	Trapezoid	20	0.1
R330	Automatic Fixed Interval	4936.6	0.01122	0.03246	Trapezoid	20	0.1
R350	Automatic Fixed Interval	2310.7	0.02222	0.02618	Trapezoid	20	0.1
R370	Automatic Fixed Interval	4052.4	0.01167	0.01873	Trapezoid	15	0.1
R380	Automatic Fixed Interval	685.27	0.001	0.10492	Trapezoid	15	0.1
R390	Automatic Fixed Interval	1725.4	0.00708	0.0345	Trapezoid	15	0.1
R410	Automatic Fixed Interval	1115.7	0.01264	0.00616	Trapezoid	15	0.1
R420	Automatic Fixed Interval	868.41	0.03949	0.04286	Trapezoid	15	0.1
R450	Automatic Fixed Interval	1097.7	0.02578	0.10891	Trapezoid	15	0.1
R470	Automatic Fixed Interval	378.7	0.001	0.86264	Trapezoid	15	0.1
R50	Automatic Fixed Interval	2068.5	0.00336	0.07517	Trapezoid	30	0.1

R520	Automatic Fixed Interval	3973.3	0.06508	0.9008	Trapezoid	15	0.1
R570	Automatic Fixed Interval	2561.7	0.04782	0.11469	Trapezoid	15	0.1
R60	Automatic Fixed Interval	70.711	0.001	0.15192	Trapezoid	30	0.1
R70	Automatic Fixed Interval	2257.9	0.01238	0.0342	Trapezoid	30	0.1
R90	Automatic Fixed Interval	1942.1	0.001	0.04435	Trapezoid	30	0.1

Annex 11. Guinabasan Field Validation Points

Table A-11.1. Guinabasan Field Validation Points

Point No.	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event / Date		Return Period of Event
	Longitude	Latitude						
1	10.63156	123.75099	0.36	0.9	0.2916	Basyang	January 2014	100 Year
2	10.6366383	123.75114	0.34	0.5	0.0256	Basyang	January 2014	100 Year
3	10.6367283	123.750542	0.71	0.9	0.0361	Basyang	January 2014	100 Year
4	10.6367583	123.750567	0.71	1.2	0.2401	Ruby	Dec 1-12, 2014	100 Year
5	10.6372117	123.750233	0.44	0.5	0.0036	Basyang	January 2014	100 Year
6	10.6376333	123.747965	0.49	0.3	0.0361	Basyang	January 2014	100 Year
7	10.637495	123.747223	0.63	0.5	0.0169	Basyang	January 2014	100 Year
8	10.6211744	123.765105	5.7	0.58	26.2144	Nona	10-Dec-15	5 Year
9	10.6211744	123.765105	5.7	0.83	23.7169	Onyok	Dec 14-19, 2015	5 Year
10	10.6211744	123.765105	5.7	1.33	19.0969	Kabayan	Ocotober 5, 2015	5 Year
11	10.6211744	123.765105	5.7	0.78	24.2064	Ineng	Aug 13-25, 2015	5 Year
12	10.6211744	123.765105	5.7	1.16	20.6116	LPA	July 22-25	5 Year
13	10.6211744	123.765105	5.7	0.63	25.7049	Hanna	29-Jul-15	5 Year
14	10.6211744	123.765105	5.7	0.65	25.5025	LPA	01-Jun-15	5 Year
15	10.6211744	123.765105	5.7	0.91	22.9441	Dodong	May 2-12, 2012	5 Year
16	10.6211744	123.765105	5.7	0.98	22.2784	Chedeng	Mar 26-Apr 7, 2015	5 Year
17	10.6211744	123.765105	5.7	1.24	19.8916	Neneng	04-Oct-15	5 Year
18	10.6211744	123.765105	5.7	1.12	20.9764	Ompong	07-Oct-15	5 Year
19	10.6211744	123.765105	5.7	1.3	19.36	Karding	06-Sep-14	5 Year
20	10.6211744	123.765105	5.7	1.17	20.5209	Luis	12-Sep-14	5 Year
21	10.6211744	123.765105	5.7	1.01	21.9961	Mario	17-Sep-14	5 Year
22	10.6211744	123.765105	5.7	1.34	19.0096	Jose	02-Aug-14	5 Year
23	10.6211744	123.765105	5.7	1.16	20.6116	Florita	05-Jul-14	5 Year
24	10.6211744	123.765105	5.7	1.04	21.7156	Glenda	15-Jul-14	5 Year
25	10.6211744	123.765105	5.7	1.22	20.0704	Henry	18-Jul-14	5 Year
26	10.6211744	123.765105	5.7	1.1	21.16	Inday	29-Jul-14	5 Year
27	10.6211744	123.765105	5.7	1.17	20.5209	Ester	14-Jun-14	5 Year
28	10.6211744	123.765105	5.7	1.3	19.36	Doming	06-Apr-14	5 Year
29	10.6211744	123.765105	5.7	1.27	19.6249	Caloy	21-Mar-14	5 Year

30	10.6211744	123.765105	5.7	1.4	18.49	Agaton	17-Jan-14	5 Year
31	10.6211744	123.765105	5.7	0.95	22.5625	Vinta	05-Nov-14	5 Year
32	10.6211744	123.765105	5.7	1.24	19.8916	Wilma	02-Nov-14	5 Year
33	10.6211948	123.76512	7.4	0.93	41.8609	Lando	Oct 12-21, 2015	100 Year
34	10.6211948	123.76512	7.4	1.05	40.3225	Egay	01-Jul-15	100 Year
35	10.6211948	123.76512	7.4	1.22	38.1924	Amang	13-Jan-15	100 Year
36	10.6211948	123.76512	7.4	1.14	39.1876	Basyang	January 2014	100 Year
37	10.6211948	123.76512	7.4	1.1	39.69	Zoraida	Nov 11-15, 2014	100 Year
38	10.5960144	123.780129	0.71	0.6	0.0121	Ruby	Dec 1-12, 2014	100 Year
39	10.5962457	123.779943	0.71	0.9	0.0361	Ruby	Dec 1-12, 2014	100 Year
40	10.6038549	123.777859	0.03	0.2	0.0289	Basyang	January 2014	100 Year
41	10.6099438	123.783363	0.61	0.7	0.0081	Basyang	January 2014	100 Year
42	10.6100872	123.784414	0.03	0.3	0.0729	Basyang	January 2014	100 Year
43	10.6101102	123.780824	0.03	0.2	0.0289	Seniang	Dec 29-30, 2014	100 Year
44	10.6101391	123.785866	0.04	0.5	0.2116	Seniang	Dec 29-30, 2014	100 Year
45	10.6103362	123.781396	0.03	0.5	0.2209	Seniang	Dec 29-30, 2014	100 Year
46	10.610641	123.7792	0.71	0.9	0.0361	Ruby	Dec 1-12, 2014	100 Year
47	10.6108061	123.784996	0.03	0.2	0.0289	Seniang	Dec 29-30, 2014	100 Year
48	10.6109035	123.78563	0.71	0	0.5041	Ruby	Dec 1-12, 2014	100 Year
49	10.6112195	123.778114	0.03	0.2	0.0289	Seniang	Dec 29-30, 2014	100 Year
50	10.6115779	123.778393	0.03	0.3	0.0729	Basyang	January 2014	100 Year
51	10.6211744	123.765105	8.41	1.1	53.4361	Seniang	Dec 29-30, 2014	100 Year
52	10.6211948	123.76512	8.41	1.5	47.7481	Seniang	Dec 29-30, 2014	100 Year
53	10.6219379	123.764395	0.03	0.2	0.0289	Seniang	Dec 29-30, 2014	100 Year
54	10.6221082	123.769759	0.03	0.2	0.0289	Seniang	Dec 29-30, 2014	100 Year
55	10.6223953	123.764263	0.03	0.2	0.0289	Seniang	Dec 29-30, 2014	100 Year
56	10.6223959	123.770153	0.64	0.9	0.0676	Seniang	Dec 29-30, 2014	100 Year
57	10.6225128	123.770245	0.93	1	0.0049	Seniang	Dec 29-30, 2014	100 Year
58	10.6227186	123.770613	0.71	0.8	0.0081	Ruby	Dec 1-12, 2014	100 Year

59	10.6247021	123.772011	1.51	0.9	0.3721	Seniang	Dec 29-30, 2014	100 Year
60	10.6251165	123.771838	0.71	0.5	0.0441	Ruby	Dec 1-12, 2014	100 Year
61	10.62592	123.763746	0.03	0.3	0.0729	Seniang	Dec 29-30, 2014	100 Year
62	10.6261297	123.763801	0.04	0.3	0.0676	Seniang	Dec 29-30, 2014	100 Year
63	10.6263418	123.763464	0.03	0.3	0.0729	Seniang	Dec 29-30, 2014	100 Year
64	10.626552	123.760548	0.03	0.2	0.0289	Seniang	Dec 29-30, 2014	100 Year
65	10.6276397	123.773288	2.02	1.7	0.1024	Seniang	Dec 29-30, 2014	100 Year
66	10.6293768	123.773312	0.35	0.6	0.0625	Basyang	January 2014	100 Year
67	10.6299293	123.773403	0.03	0.2	0.0289	Basyang	January 2014	100 Year
68	10.6306119	123.741736	0.03	0.2	0.0289	Seniang	Dec 29-30, 2014	100 Year
69	10.6313543	123.741884	0.03	0.3	0.0729	Seniang	Dec 29-30, 2014	100 Year
70	10.6319051	123.741866	0.03	0.7	0.4489	Seniang	Dec 29-30, 2014	100 Year
71	10.6321331	123.77335	0.03	0.5	0.2209	Basyang	January 2014	100 Year
72	10.6327221	123.773327	0.03	0.2	0.0289	Seniang	Dec 29-30, 2014	100 Year
73	10.6364394	123.774335	0.62	0.9	0.0784	Seniang	Dec 29-30, 2014	100 Year
74	10.636594	123.774374	0.09	0.7	0.3721	Seniang	Dec 29-30, 2014	100 Year
75	10.6366181	123.774527	0.62	0.8	0.0324	Seniang	Dec 29-30, 2014	100 Year
76	10.6373362	123.747465	0.56	0.4	0.0256	Seniang	Dec 29-30, 2014	100 Year
77	10.638819	123.775899	1.44	1.2	0.0576	Seniang	Dec 29-30, 2014	100 Year
78	10.639188	123.75191	0.73	0.7	0.0009	Seniang	Dec 29-30, 2014	100 Year
79	10.6394966	123.752043	0.57	0.5	0.0049	Seniang	Dec 29-30, 2014	100 Year
80	10.6396775	123.752767	0.62	0.2	0.1764	Seniang	Dec 29-30, 2014	100 Year
81	10.6398235	123.752736	1.15	0.9	0.0625	Seniang	Dec 29-30, 2014	100 Year
82	10.6399034	123.752444	0.22	0.2	0.0004	Seniang	Dec 29-30, 2014	100 Year
83	10.640378	123.752817	0.77	0.5	0.0729	Basyang	January 2014	100 Year
84	10.6406108	123.752967	0.52	0.5	0.0004	Basyang	January 2014	100 Year
85	10.6406301	123.777082	1.3	0.8	0.25	Basyang	January 2014	100 Year

Annex 12. Educational Institutions affected by flooding in Guinabasan Flood-plain

Table A-12.1. Educational Institutions in Guinabasan, Cebu affected by flooding in Guinabasan Flood Plain

Cebu				
Asturias				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Bago Elementary School	New Bago			
Sta Lucia National High School	Santa Lucia			

Annex 13. Medical Institutions affected by flooding in Guinabasan Floodplain

Table A-13.1. Medical Institutions in Guinabasan, Cebu affected by flooding in Guinabasan Flood Plain.

Cebu				
Asturias				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
New Bago Health Center	New Bago			
Sta Lucia Health Center	Santa Lucia		Low	Low