HAZARD MAPPING OF THE PHILIPPINES USING LIDAR (PHIL-LIDAR 1)

LiDAR Surveys and Flood Mapping of Mercedes River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
Ateneo de Zamboanga University

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LIST OF ACRONYMS AND ABBREVIATIONS

AAC	Asian Aerospace Corporation
Ab	abutment
ADZU	Ateneo de Zamboanga University
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
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
UP-TCAGP	University of the Philippines – Training Center for Applied Geodesy and Photogrammetry
UTM	Universal Transverse Mercator
WGS	World Geodetic System

CHAPTER 1: OVERVIEW OF THE PROGRAM AND MERCEDES RIVER

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1.1 Background of the Phil-LiDAR 1 Program

The University of the Philippines Training Center for Applied Geodesy and Photogrammetry (UP-TCAGP) launched a research program entitled "Nationwide Hazard Mapping using LiDAR" or Phil-LiDAR 1, 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).

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

1.2 Overview of the Mercedes River Basin

The Mercedes (also known as Culianan) River Basin covers six (6) barangays of Zamboanga City, namely: Brgy. Tolosa, Salaan, Pasobolong, Culianan, Mercedes and Zambowood with a total population estimate of 37,925, according to the May 2010 census. It has a catchment approximate area of 50.36 km2 according to DENR-RCBO.

Its main stem, Culianan River is part of the 18 river systems in the Zamboanga Peninsula. It is also among the rivers which contributed to the flooding on a large part of Zamboanga City during Typhoon Quedan on October 4, 2013, which left a trail of destruction in many areas that affected thousands of people. Nevertheless, the river is significant in the area as source of water for agricultural lands in the barangays of Tolosa, Salaan, Pasobolong, Culianan and Mercedes. Brgy. Zambowood is the home of Zamboanga wood products and use portions of Culianan River as log ponds since their saw mill is found in the area.

Named after one of the barangays in Zamboanga City, Mercedes lies connected to Tumaga River. It has a catchment area of 49.02 sq.km, almost three times smaller than Tumaga. The main river acts as the boundary between the barangays of Zambowood, Pasobolong, Salaan in the west and the barangays of Tolosa, Lanzones, Culianan, and Mercedes in the east.

The name Mercedes, originally Las Mercedes, was used to honor the Patron Saint of Mercedarian who was responsible for the rescue of Christian captives from the Moors in Spain during the reign of Don Jaime de Aragon. It was given by a Jesuit missionary in the 1870s to a place that was formerly known as Paso Caña because of the abundance of bamboo trees along its river banks. Technically, Culianan and Mercedes are the same rivers, but the city local government stated to use the name Mercedes for consistency purposes.

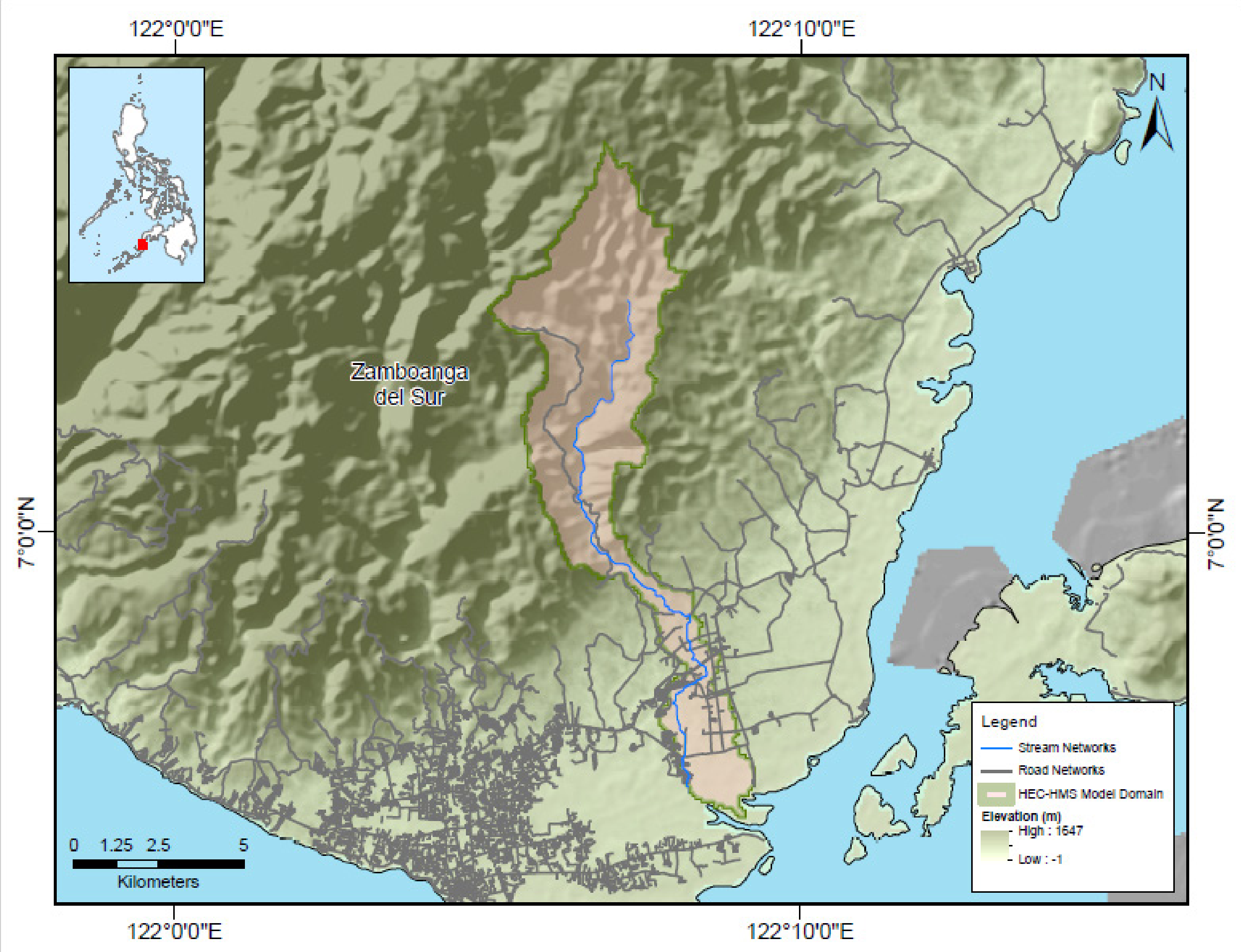

Figure 1. Map of the Mercedes River Basin (in brown)

Flood Incidence

Areas along Mercedes River are identified by the Mines and Geosciences Bureau of Region 9 to be under low to moderate susceptibility against floods. In the increasing intensity of rain events in Zamboanga City brought about by climate change, the bureau recommends the improvement of storm water drainage networks and the strengthening of the built-up areas along the river banks to mitigate flood damages.

Figure 2. ARG and WLMS at Culianan Bridge

In October of 2006, Zamboanga City experienced torrential rains which flooded many villages and destroyed rice paddies and several aquatic resources particularly seaweed farms and fishponds. Tumaga and Culianan were among the most affected areas (The Mindanao Examiner, 2006).

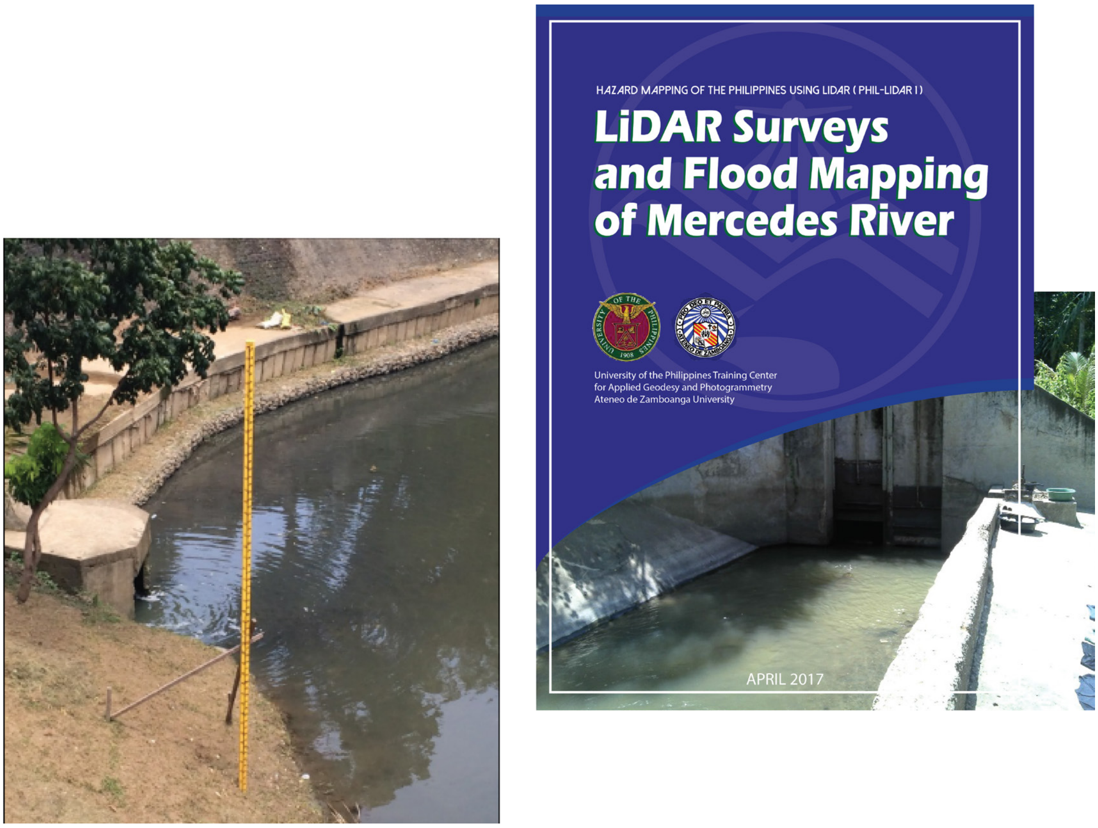

Figure 3. The gate of the diversion dam in Culianan

In the hopes of mitigating these adverse effects of floods, Mercedes River was included in the nationwide Deployment of Early Warning Systems (DEWS) program of the Department of Science and Technology (DOST). A tandem sensor which consists of an Automated Rain Gauge (ARG) and a Water Level Monitoring System (WLMS) was installed in Culianan Bridge in 2013.

Agriculture and Fishery

Mercedes normally produces 17, 158.40 cubic meters of water per day. This volume was measured at the Culianan Bridge (6.971554°E, 122.138069°N) on April 2015.This provides supply for the irrigation of rice fields in the nearby barangays. A controlled mini dam is installed at Barangay Culianan intended to divert the water from the river to irrigation channels during rainy seasons.

It also partially supports majority of the fishponds in the coastlines of Mercedes and Zambowood.

CHAPTER 2: LIDAR DATA ACQUISITION OF THE MERCEDES FLOODPLAIN

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

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Mercedes floodplain in Zamboanga. Each flight mission has an average of 12 lines and run for at most four and a half (4.5) hours including take-off, landing and turning time. The parameter used in the LiDAR system for acquisition is found in Table 1. Figure 1 shows the flight plans for Mercedes floodplain.shows the flight plan for the Silaga Floodplain survey.

Table 1. Flight planning parameters for Pegasus LiDAR system

Block Name	Flying Height (m AGL)	Overlap (%)	Field of view (ø)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK75E	1100	30	50	200	30	130	5
Sacol Island	800/1200	30	50	200	30	130	5
BLK75AS	1000	30	50	200	30	130	5

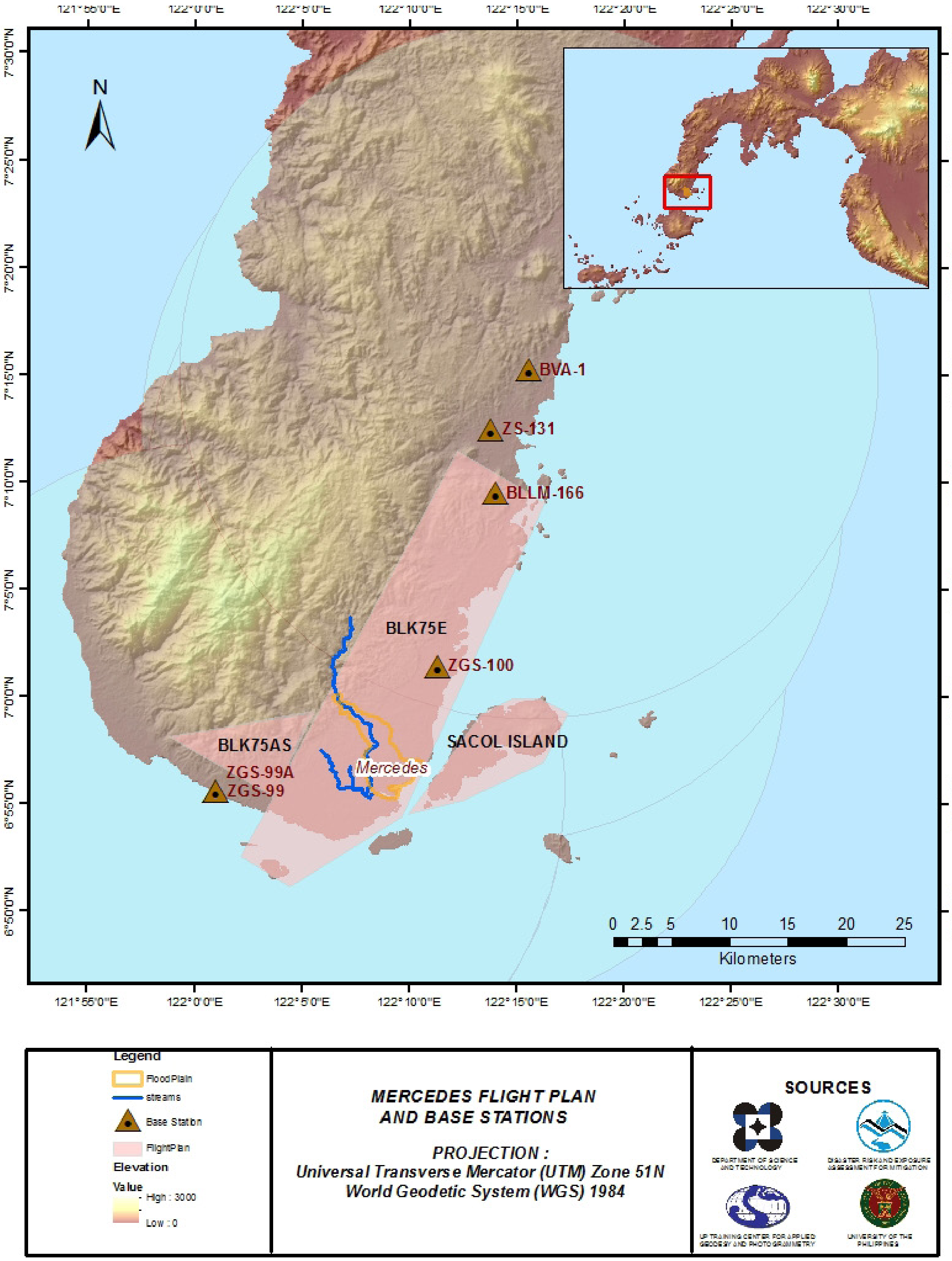

Figure 4. Flight plan and base stations used for Mercedes Floodplain survey

2.2 Ground Base Stations

The project team was able to recover two (2) NAMRIA ground control points: ZGS-100 and ZGS-99 which are of second (2nd) order accuracy, one (1) Bench Mark point: ZS-131, and three (2) established control point: ZG-99A, BLLM-166 and BVA-1. The certifications for the NAMRIA reference points and processing report for the established points are found in Annex 2. These were used as base stations during flight operations for the entire duration of the survey (January 29-Febuary 12, 2015; May 19-31, 2016). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 882, SPS 852 and SPS 985. Flight plans and location of base stations used during the aerial LiDAR acquisition in Mercedes floodplain are also shown in Figure 4.

Figures 5-8 show the recovered NAMRIA control stations within the area, in addition Table 2 to Table 7 show the details about the following NAMRIA control stations and established points, Table 8 shows the list of all ground control points occupied during the acquisition together with the dates they are utilized during the survey.

Figure 5. GPS set-up over ZGS-100 in Brgy. Manicahan, Zamboanga del Sur (a) and NAMRIA reference point ZGS-100 (b) as recovered by the field team.

Table 2. Details of the recovered NAMRIA horizontal control point ZGS-100 used as base station for the LiDAR acquisition

Station Name	**ZGS-100**	
Order of Accuracy	**2rd**	
Relative Error (horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	7° 1' 26.72368" North 122° 11' 12.74401" East 11.27 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	410158.521 meters 776712.542 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7° 1' 23.30149" North 122° 11' 18.30044" East 75.603 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	410189.97 meters 776440.68 meters

Figure 6. GPS set-up over ZGS-99 beside the seawall in Calarian, Zamboanga City (a) and NAMRIA reference point ZGS-99 (b) as recovered by the field team

Table 3. Details of the recovered NAMRIA horizontal control point ZGS-99 used as base station for the LiDAR acquisition

Station Name	**ZGS-99**	
Order of Accuracy	**2rd**	
Relative Error (horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	5° 55’ 37.48971” North 122° 0’ 52.66431” East 8.14900 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 5 PRS 92)	Easting Northing	766020.391 meters 391103.346 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	6° 55’ 34.07737” North 122° 0’ 58.23072” East 72.23000 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	765752.27 meters 391141.46 meters

Figure 7. GPS set-up over ZS-131 in Curuan, Zamboanga City (a) and NAMRIA reference point ZS-131 (b) as recovered by the field team

Table 4. Details of the recovered NAMRIA horizontal control point ZS-131 used as base station for the LiDAR acquisition

Station Name	**ZS-131**	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	7°12’31.51602” North 122°13’42.69458” East 15.557 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Latitude Longitude Ellipsoidal Height	414824.878 meters 796847.561 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7°12’28.04890” North 122°13’48.23382” East 79.651 meters

Figure 8. GPS set-up over BVA-1 established in Brgy. Buenavista, Zamboanga City and (a) and Reference point BVA-1 (b) as established by the field team

Table 5. Details of the established control point BVA-1 used as base station for the LiDAR acquisition

Station Name	**BVA-1**	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	67° 15’ 19.31910”North 122° 15’ 28.78738”East 82.446 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	417939.856 meters 802333.522 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7° 15’ 15.84241” North 122° 15’ 34.32212” East 146.526 meters

Table 6. Details of the established point BLLM-166 used as base station for the LiDAR acquisition

Station Name	BLLM-166	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	7°09’33.60926” North 122°13’54.54820” East 124.333 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	415179.269 meters 791383.716 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	77°09’30.15553” North 122°14’00.09187” East 188.527 meters

Table 7. Details of the established control point ZGS-99A used as base station for the LiDAR acquisition

Station Name	ZGS-99A	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	6° 55’ 37.63895”North 122° 00’ 52.48834”East 7.850 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	391136.071 meters 765756.864 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	6° 55’ 34.22659” North 122° 00’ 58.05475” East 71.931 meters

Table 8. Ground control points used during LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
February 5, 2015	2535P	1BLK75E36A	BLLM-166 and ZGS-100
February 8, 2015	2545P	1BLK75S39A	BVA-1 and ZGS-100
February 11, 2015	2557P	1BLK75S42A	ZGS-99 and ZGS-99A
May 26, 2016	23394P	1BLK75AS147B	ZGS-100 and ZS-131

2.3 Flight Missions

Four (4) missions were conducted to complete LiDAR data acquisition in Mercedes floodplain, for a total of 14 hours and 14 minutes of flying time for RP-C9022. All missions were acquired using the Pegasus system. Table 9 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 10 presents the actual parameters used during the LiDAR data acquisition.

Table 9. Flight missions for LiDAR data acquisition in Mercedes Floodplain

Date Surveyed	Flight Number	Flight Plan Area (km^2)	Surveyed Area (km^2)	Area Surveyed within the Floodplain (km^2)	Area Surveyed Outside the Floodplain (km^2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
February 5, 2015	2535P	357.52	331.7	16.54	315.16	715	3	53
February 8, 2015	2545P	906.64	318.38	7.48	310.9	608	4	11
February 11, 2015	2557P	234.33	228.21	2.16	226.05	474	4	23
May 26, 2016	23394P	13.39	54.57	1.99	52.58	NA	1	47
TOTAL		1511.88	932.86	28.17	904.69	715	14	14

Table 10. Actual parameters used during LiDAR data acquisition

Block Name	Flying Height (AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
2535P	1100	30	50	200	30	130	5
2545P	1100	30	50	200	30	130	5
2557P	800/1200	30	50	200	30	130	5
23394P	1000	30	50	200	30	130	5

Mercedes floodplain is located in the provinces of Zamboanga del Sur the floodplain situated within the City of Zamboanga. The list of municipalities and cities surveyed with at least one (1) square kilometer coverage is shown in Table 11. The actual coverage of the LiDAR acquisition for Mercedes floodplain is presented in Figure 6.

Table 11. List of Municipalities/Cities Surveyed in Mercedes Floodplain LiDAR survey

Province	Municipality/City	Area of Municipality/City (km^2)	Total Area Surveyed (km^2)	Percentage of Area Surveyed =(Total Area covered/ Area of Municipality)*100
Zamboanga del Sur	Zamboanga City	1461.04	691.32	47%
Zamboanga Sibugay	Tungawan	441.86	26.7	6%
Total		1902.9	718.02	37.73%

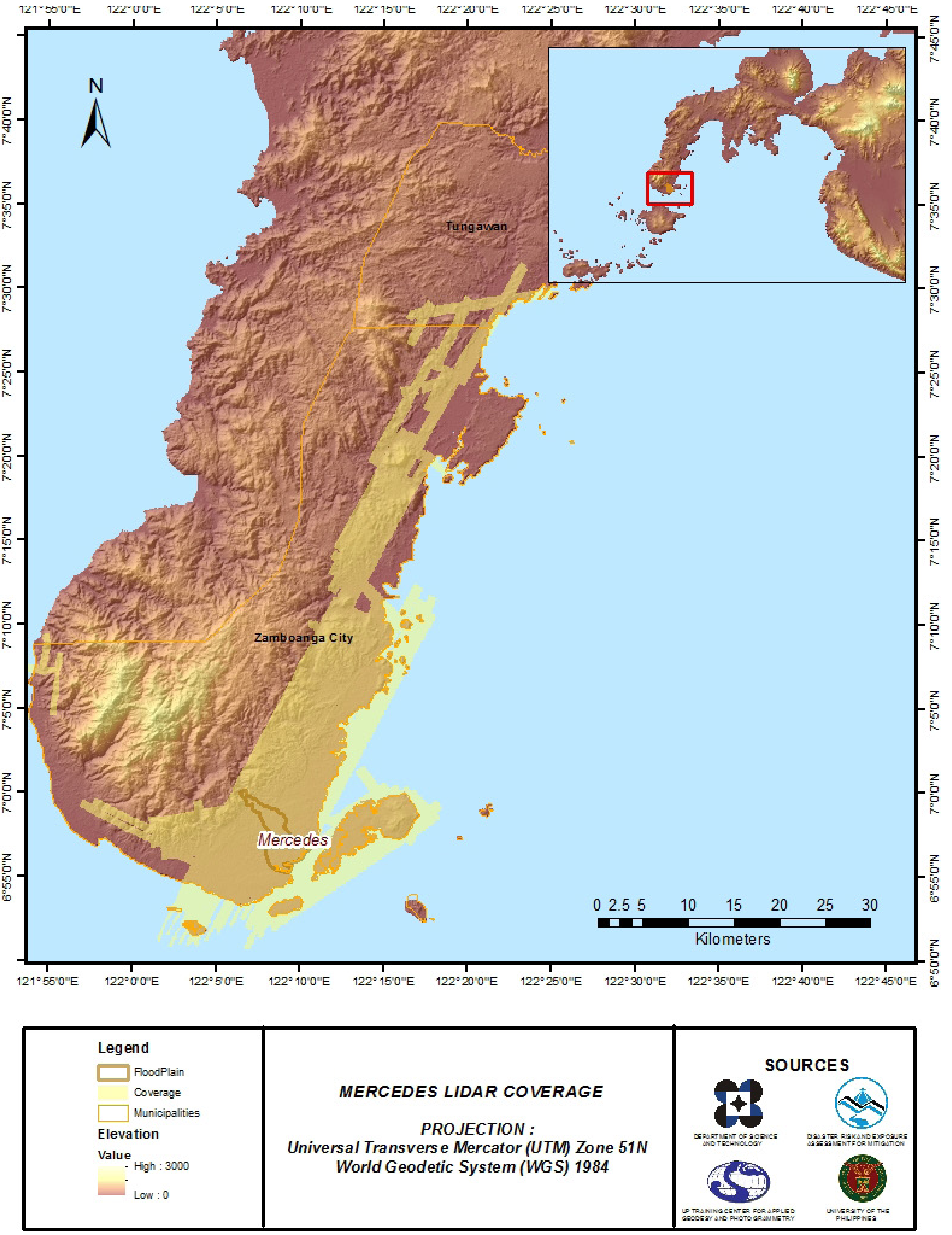

Figure 9. Actual LiDAR survey coverage for Mercedes Floodplain

CHAPTER 3: LIDAR DATA PROCESSING OF THE MERCEDES 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.

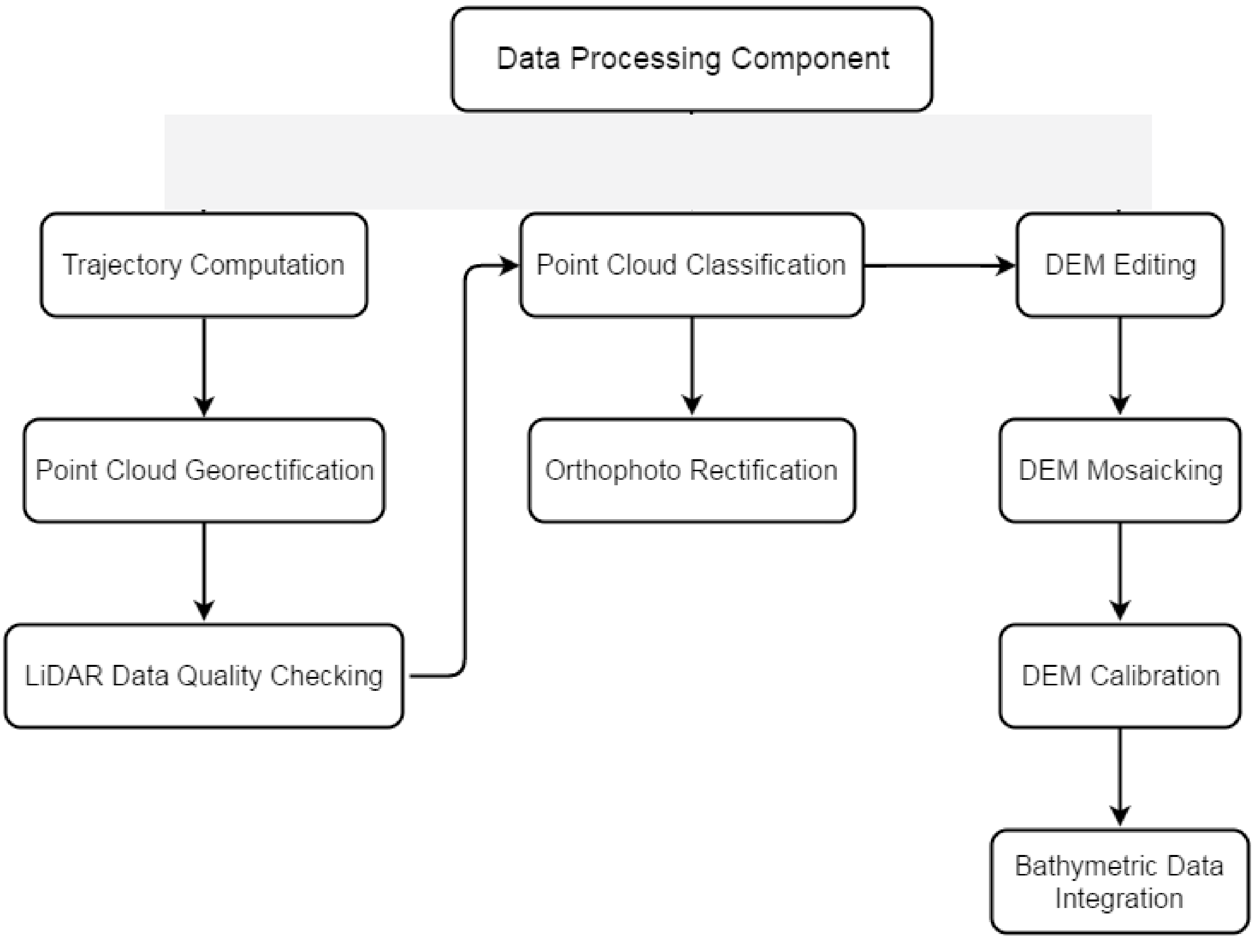


Figure 10. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Mercedes floodplain can be found in Annex 5. Missions flown during the first survey conducted on February 2015 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system while missions the second survey on May 2016 were flown using the same system over Zamboanga City.

The Data Acquisition Component (DAC) transferred a total of 82.53 Gigabytes of Range data, 847 Megabytes of POS data, 156.77 Megabytes of GPS base station data, and 120.20 Gigabytes of raw image data to the data server on June 3, 2015 for the first survey and July 14, 2016 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Mercedes was fully transferred on July 14, 2016, as indicated on the Data Transfer Sheets for Mercedes floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 2535P, one of the Mercedes flights, which is the North, East, and Down position RMSE values are shown in Figure 11. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on February 5, 2015 00:00AM. The y-axis is the RMSE value for that particular position.

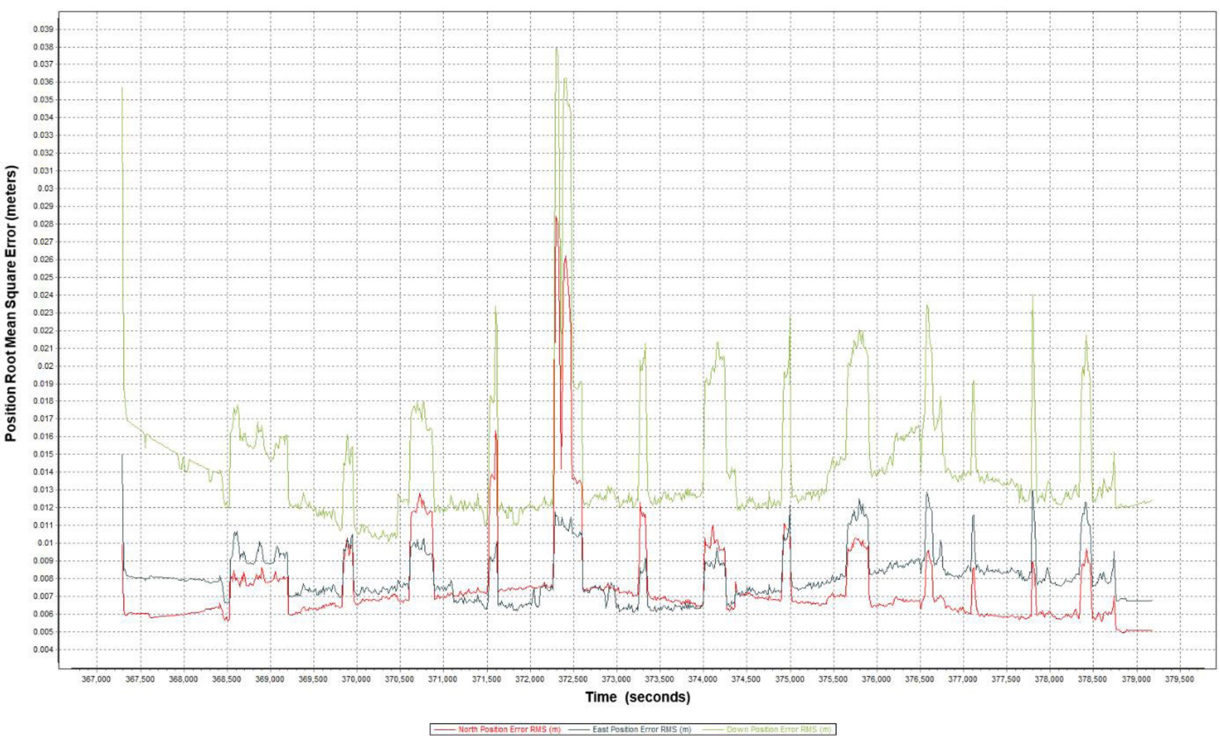


Figure 11. Smoothed Performance Metrics of a Mercedes Flight 2535P.

The time of flight was from 367000 seconds to 379500 seconds, which corresponds to morning of February 5, 2015. 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 11 shows that the North position RMSE peaks at 2.85 centimeters, the East position RMSE peaks at 1.26 centimeters, and the Down position RMSE peaks at 3.80 centimeters, which are within the prescribed accuracies described in the methodology.

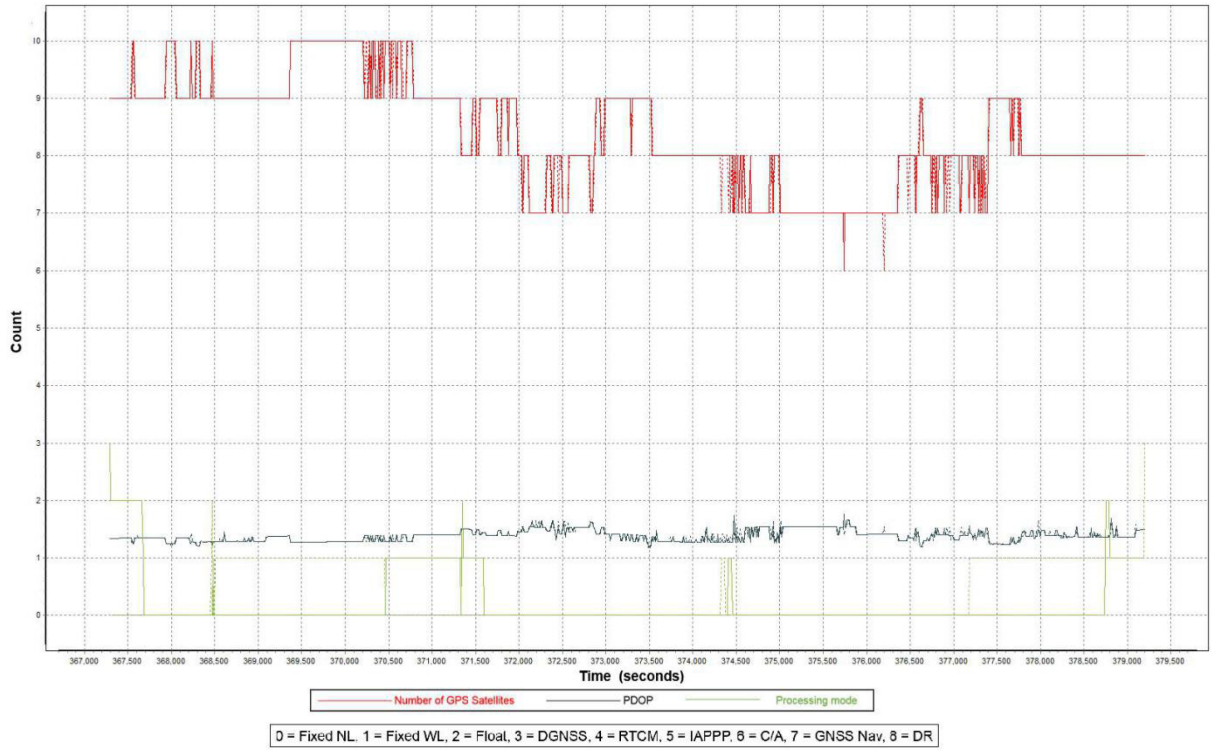


Figure 12. Solution Status Parameters of Mercedes Flight 2535P

The Solution Status parameters of flight 2535P, one of the Mercedes flights, which indicate the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 12. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Most of the time, the number of satellites tracked was between 6 and 10. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode 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 POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Mercedes flights is shown in Figure 13.

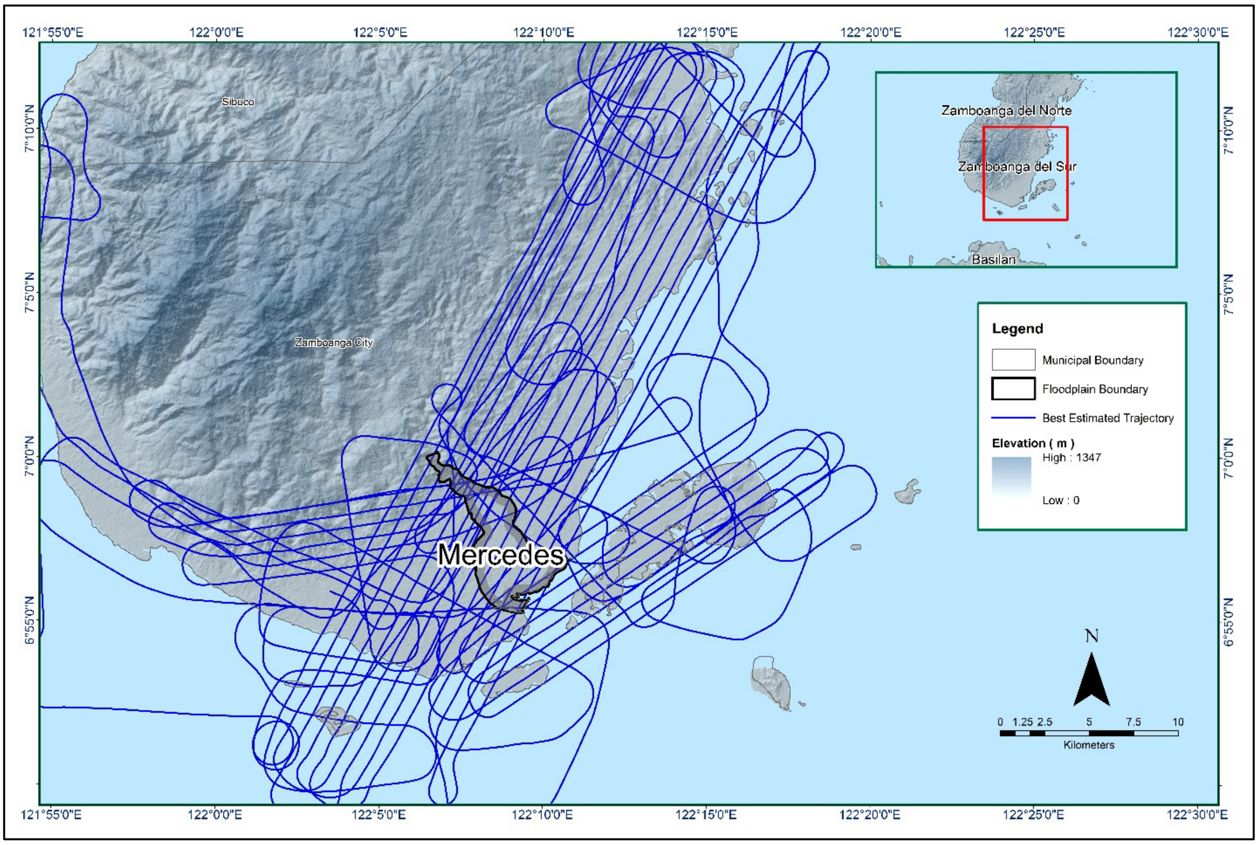


Figure 13. Best estimated trajectory for Mercedes Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 36 flight lines, with each flight line containing two channels, since the Pegasus system was used. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Mercedes floodplain are given in Table 12.

Table 12. Self-calibration results values for Mercedes flights.

Parameter	Acceptable Value	Value
Boresight Correction stdev)	<0.001degrees	0.000223
IMU Attitude Correction Roll and Pitch Correction stdev)	<0.001degrees	0.000328
GPS Position Z-correction stdev)	<0.01meters	0.0061

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

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data is shown in Figure 14. The map shows no gaps in the LiDAR coverage.

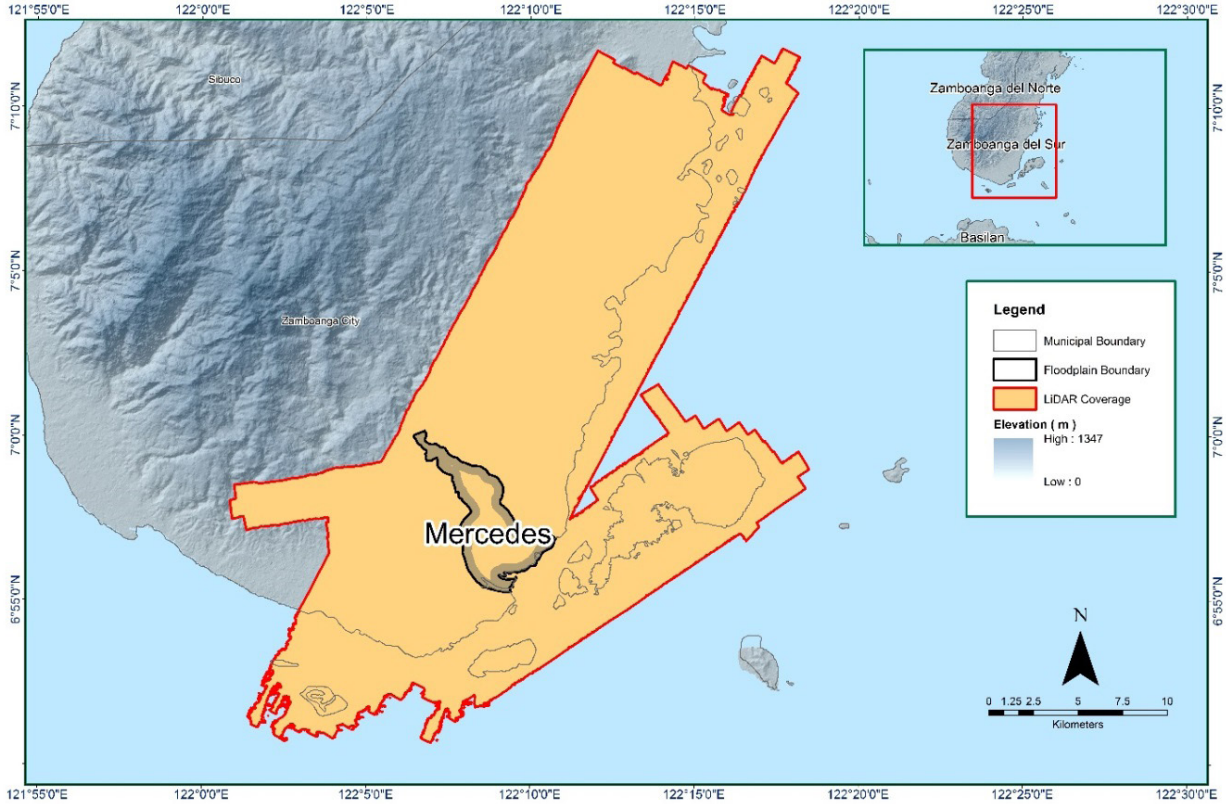


Figure 14. Boundary of the processed LiDAR on top of a SAR Elevation Data over Mercedes Floodplain.

The total area covered by the Mercedes missions is 527.27 sq.km that is comprised of four (4) flight acquisitions grouped and merged into three (3) blocks as shown in Table 13.

Table 13. List of LiDAR blocks for Mercedes floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Zamboanga_Blk75E	2535P	394.93
	2545P	
Zamboanga_Sacol	2557P	96.90
Zamboanga_reflights_Blk75AS	23394P	35.24
	TOTAL	527.27 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 15. Since the Pegasus system covered all of the area, 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.

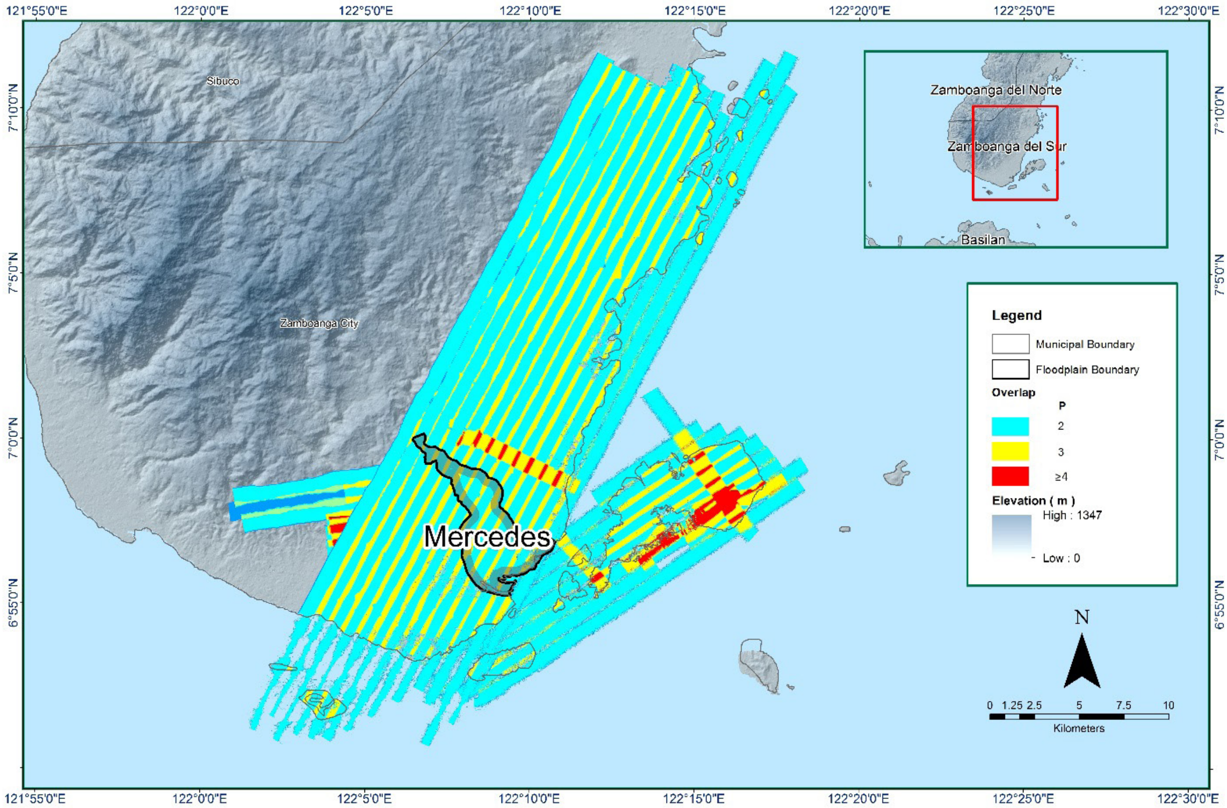


Figure 15. Image of data overlap for Mercedes Floodplain

The overlap statistics per block for the Mercedes floodplain can be found in Annex 8. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 26.46% and 27.08% respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 16. It was determined that all LiDAR data for Mercedes floodplain satisfy the point density requirement, and the average density for the entire survey area is 2.56 points per square meter.

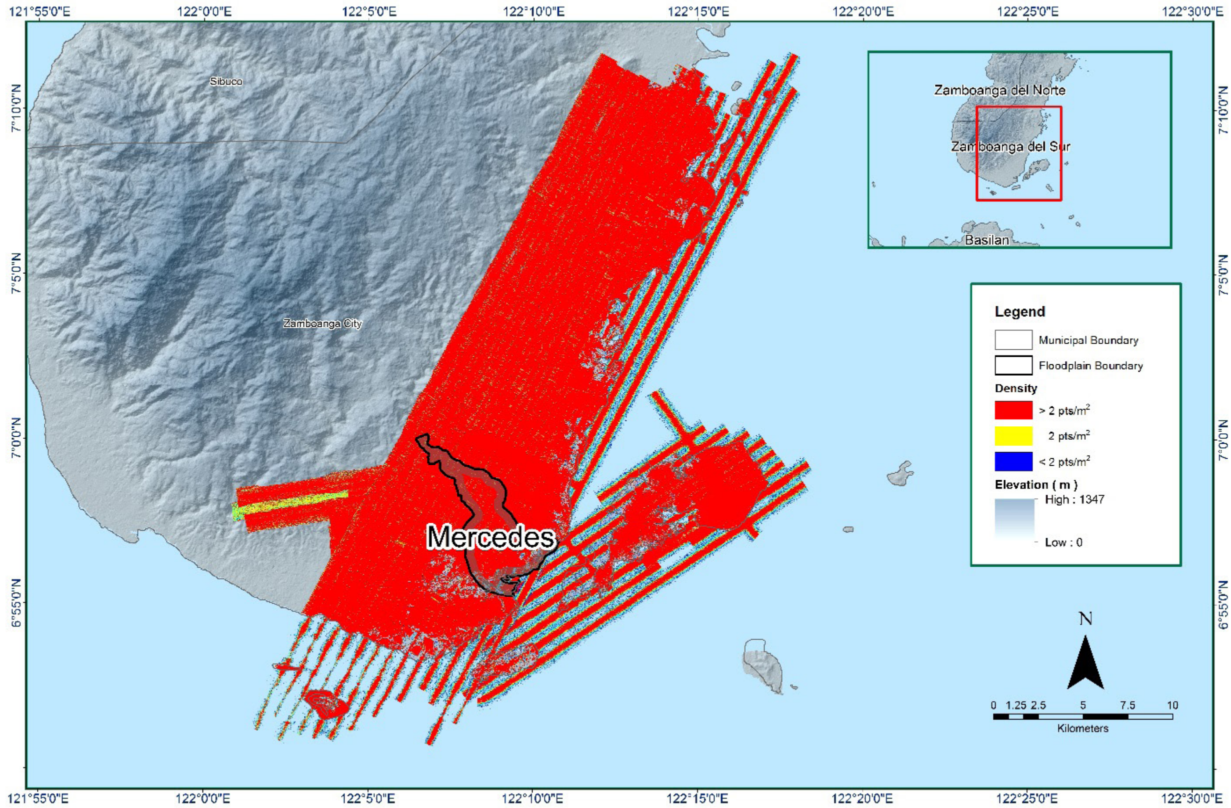


Figure 16. Pulse density map of merged LiDAR data for Mercedes Floodplain

The elevation difference between overlaps of adjacent flight lines is shown in Figure 17. The default color range is from blue to red, where bright blue areas correspond to portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.20m relative to elevations of its adjacent flight line. Bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20m relative to elevations of its adjacent flight line. Areas with bright red or bright blue need to be investigated further using Quick Terrain Modeler software.

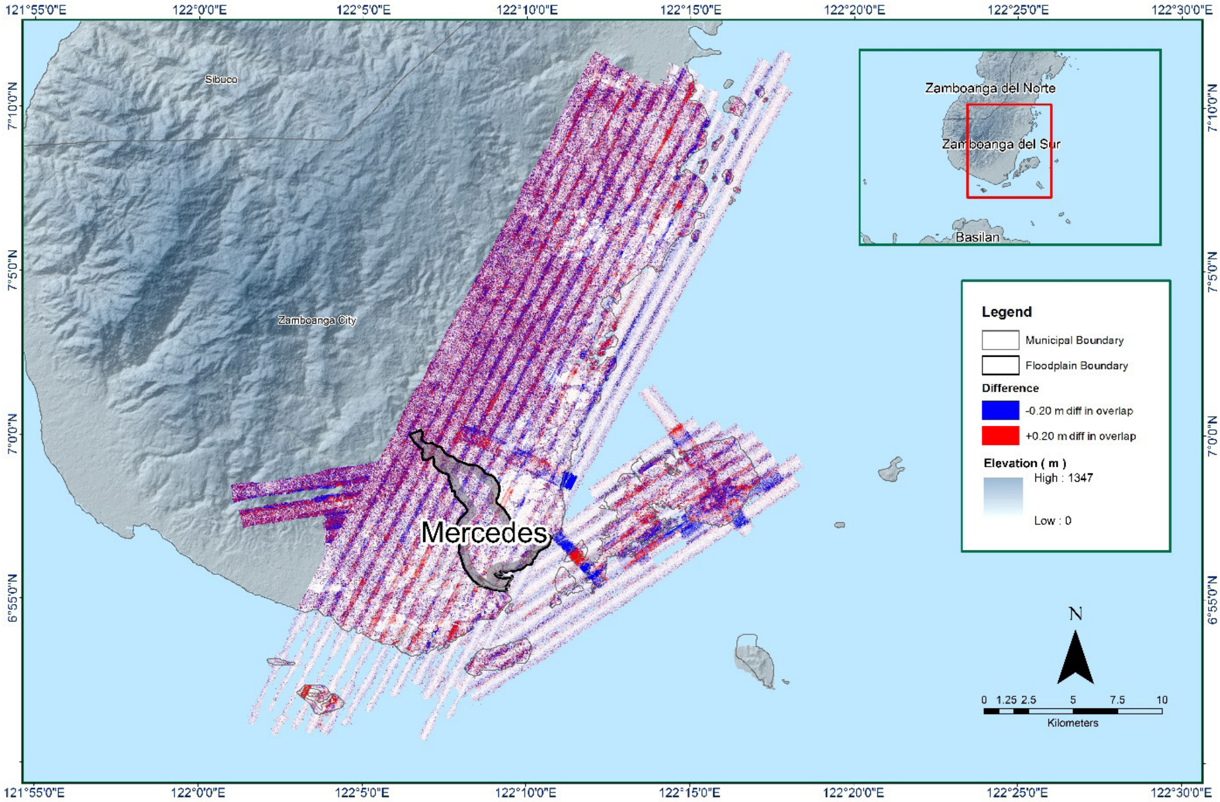


Figure 17. Elevation difference map between flight lines for Mercedes Floodplain

A screen capture of the processed LAS data from a Mercedes flight 2535P 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 yellow line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

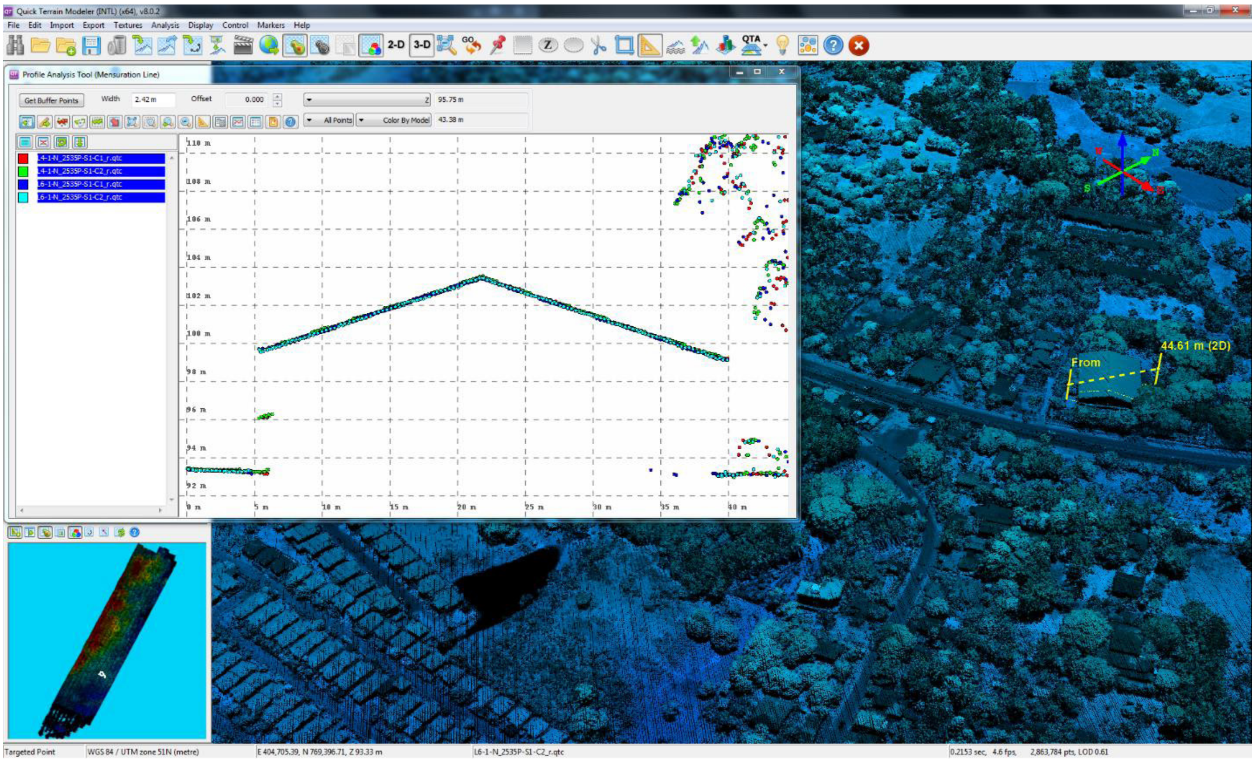


Figure 18. Quality checking for a Mercedes flight 2535P using the Profile Tool of QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 14. Mercedes classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	503,251,800
Low Vegetation	385,239,703
Medium Vegetation	542,828,825
High Vegetation	1,061,362,902
Building	42,820,674

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Mercedes floodplain is shown in Figure 19. A total of 765 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 14. The point cloud has a maximum and minimum height of 588.90 meters and 65.50 meters respectively.

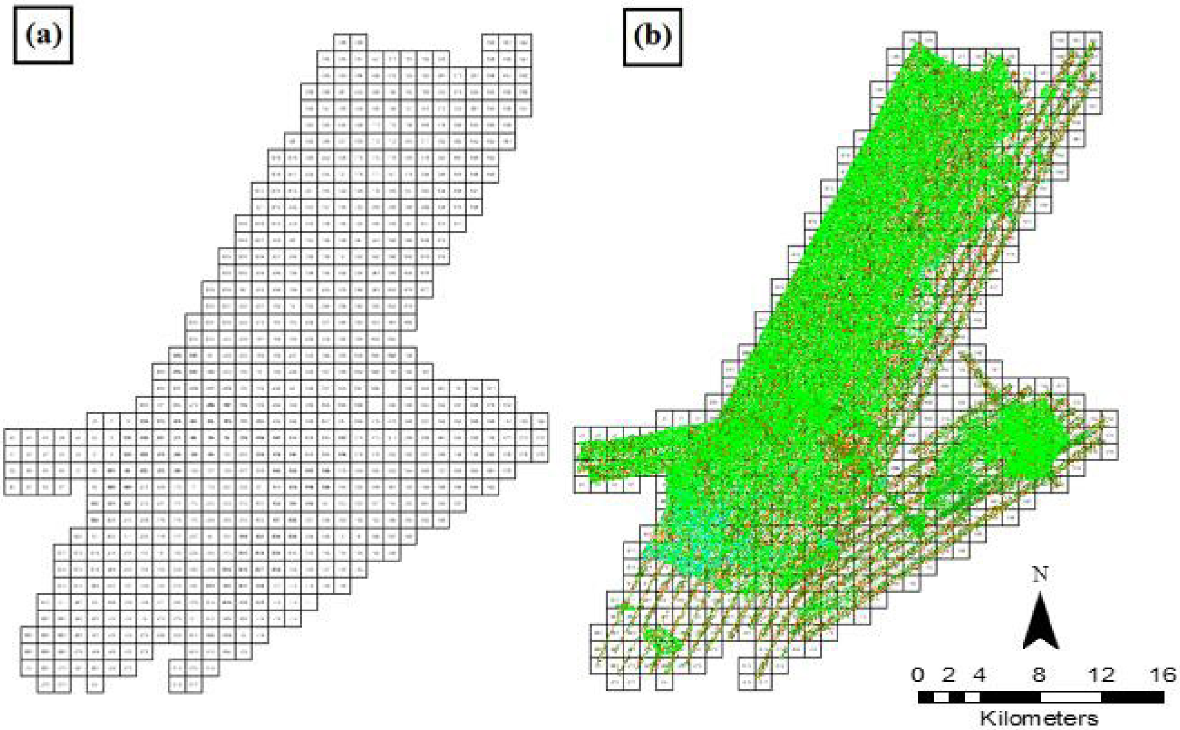


Figure 19. Tiles for Mercedes Floodplain (a) and classification results (b) in TerraScan

An isometric view of an area before and after running the classification routines is shown in Figure 20. The ground points are in orange, the vegetation is in different shades of green, and the buildings are in cyan. It can be seen that residential structures adjacent or even below canopy are classified correctly, due to the density of the LiDAR data.

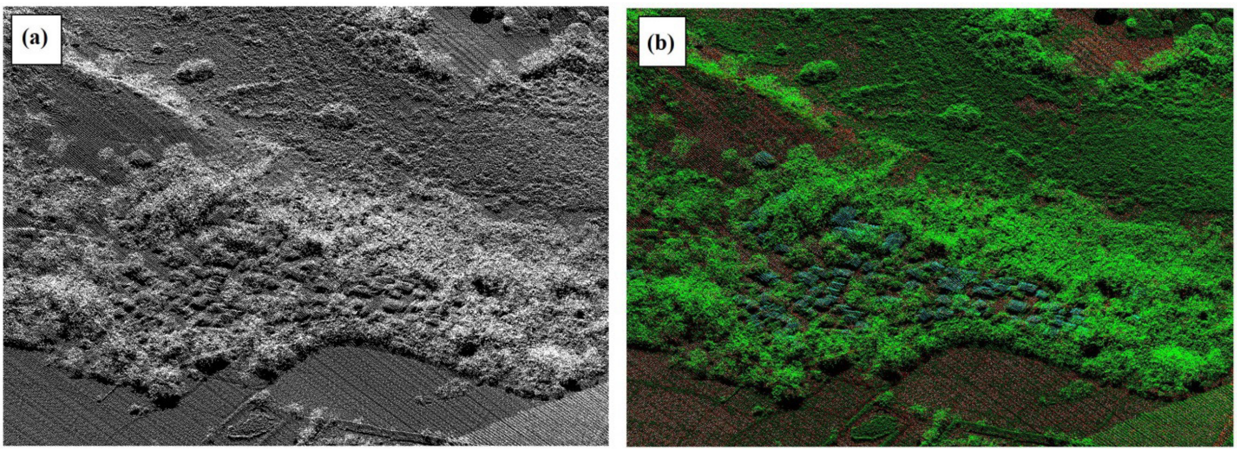


Figure 20. Point cloud before (a) and after (b) classification

The production of last return (V_ASCII) and the secondary (T_ ASCII) DTM, first (S_ ASCII) and last (D_ ASCII) return DSM of the area in top view display are shown in Figure 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.

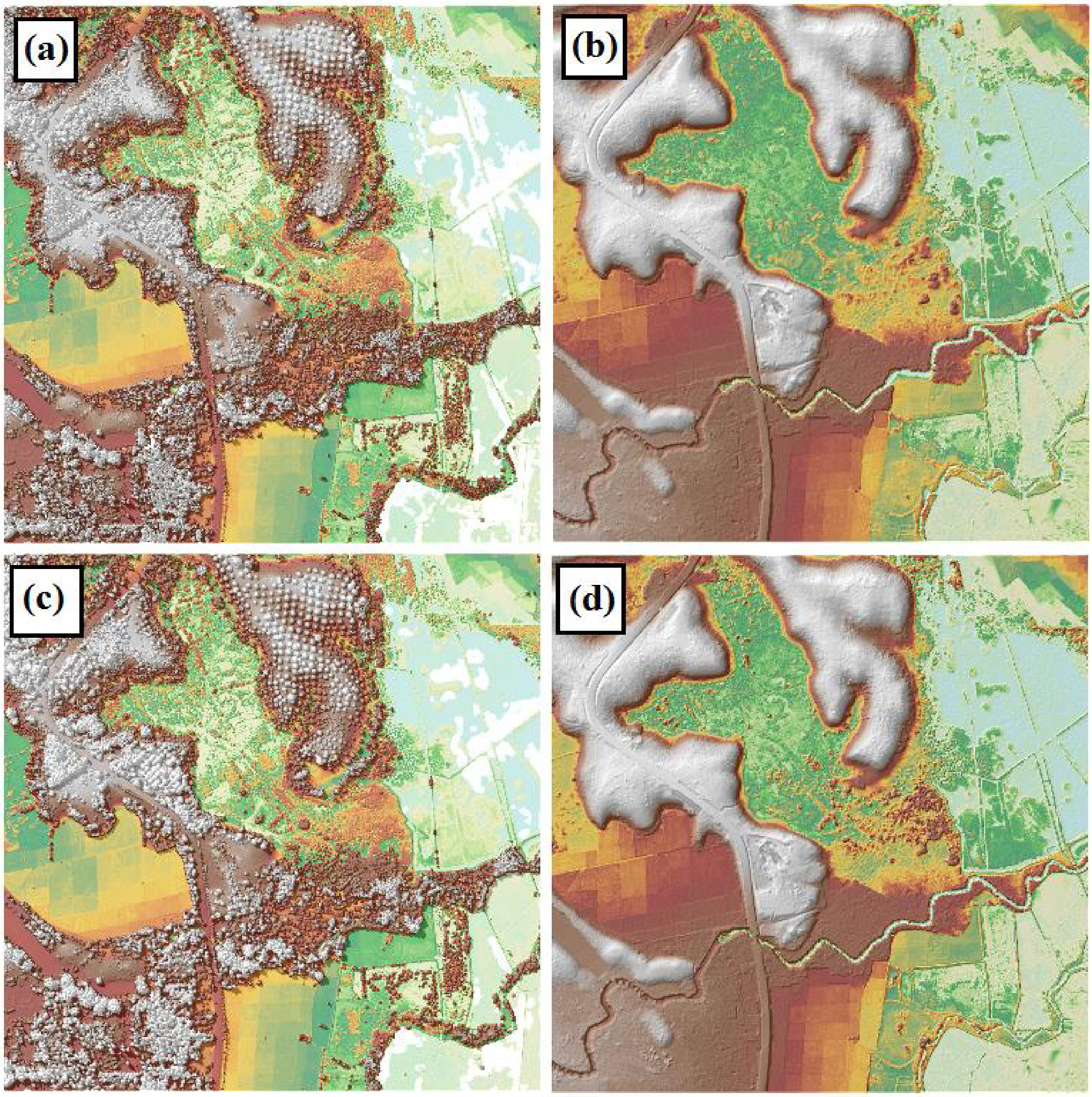


Figure 21. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Mercedes Floodplain

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 697 1km by 1km tiles area covered by Mercedes 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 Mercedes floodplain has a total of 552.42 km2 in orthophotogaph coverage comprised of 1,319 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 23.

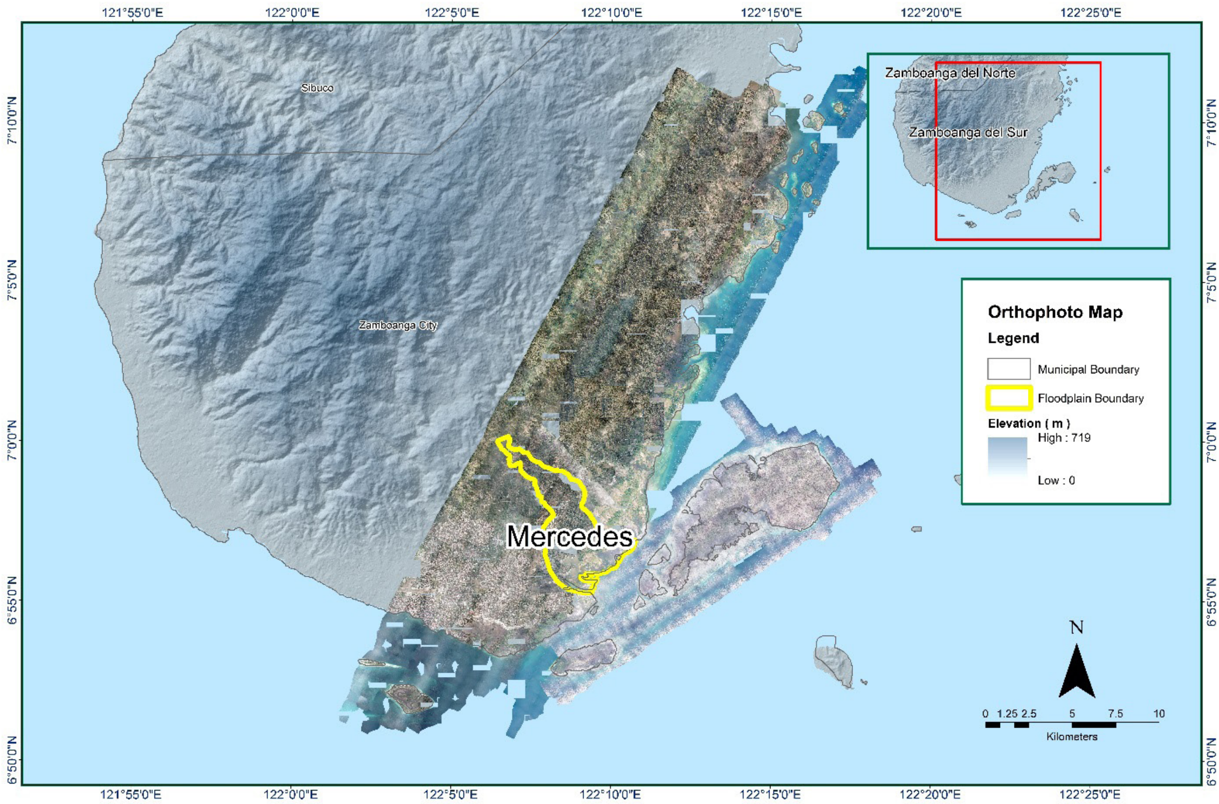


Figure 22. Mercedes Floodplain with available orthophotographs

Figure 23. Sample orthophotograph tiles for Mercedes floodplain

3.8 DEM Editing and Hydro-Correction

Three (3) mission blocks were processed for Mercedes flood plain. These blocks are composed of Zamboanga and Zamboanga_reflight blocks with a total area of 527.27 square kilometers. Table 15 shows the name and corresponding area of each block in square kilometers.

Table 15. LiDAR blocks with its corresponding area

LiDAR Blocks	Area (sq.km)
Zamboanga_Blk75E	394.93
Zamboanga_Sacol	96.90
Zamboanga_reflights_Blk75AS	35.24
TOTAL	527.27 sq.km

Portions of DTM before and after manual editing are shown in Figure 24. The river embankment (Figure 24a) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 24b) to allow the correct flow of water. The bridge (Figure 24c) is also considered to be an impedance to the flow of water along the river and has to be removed (Figure 24d) in order to hydrologically correct the river.

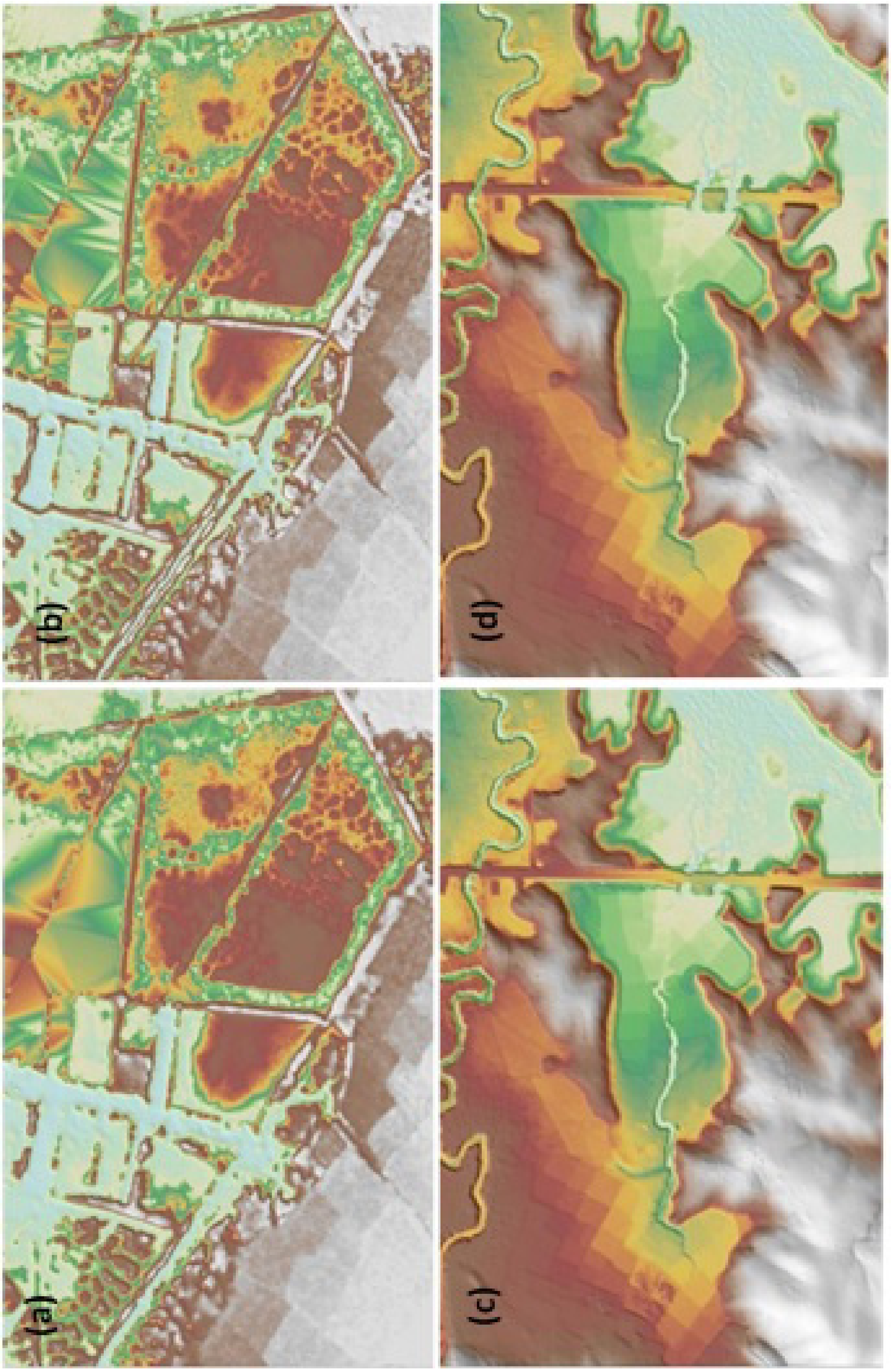


Figure 24. Portions in the DTM of Mercedes Floodplain – a paddy field before (a) and after (b) data retrieval; a bridge before (c) and after (d) manual editing.

3.9 Mosaicking of Blocks

Simultaneous mosaicking was done to all the available LiDAR data (Zamboanga_Blk75G, Zamboanga_Blk75F, Zamboanga_Blk75E, Zamboanga_Blk75F_additional, Zamboanga_Blk75D, Zamboanga_Blk75C and Zamboanga_Sacol). Zamboanga_Blk75G was used as the reference block at the start of mosaicking because it is the first available LiDAR data. Zamboanga_reflights_Blk75AS was mosaicked to the available LiDAR data by directly incorporating the height difference to its Z value. Table 16 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Mercedes floodplain is shown in Figure 25. It can be seen that the entire Mercedes floodplain is 100% covered by LiDAR data.

Table 16. Shift Values of each LiDAR Block of Mercedes floodplain

Mission Blocks	Shift Values (meters)		
	x	y	z
Zamboanga_Blk75E	0.00	0.00	0.47
Zamboanga_Sacol	0.00	0.00	0.47
Zamboanga_reflights_Blk75AS	0.00	0.00	0.44

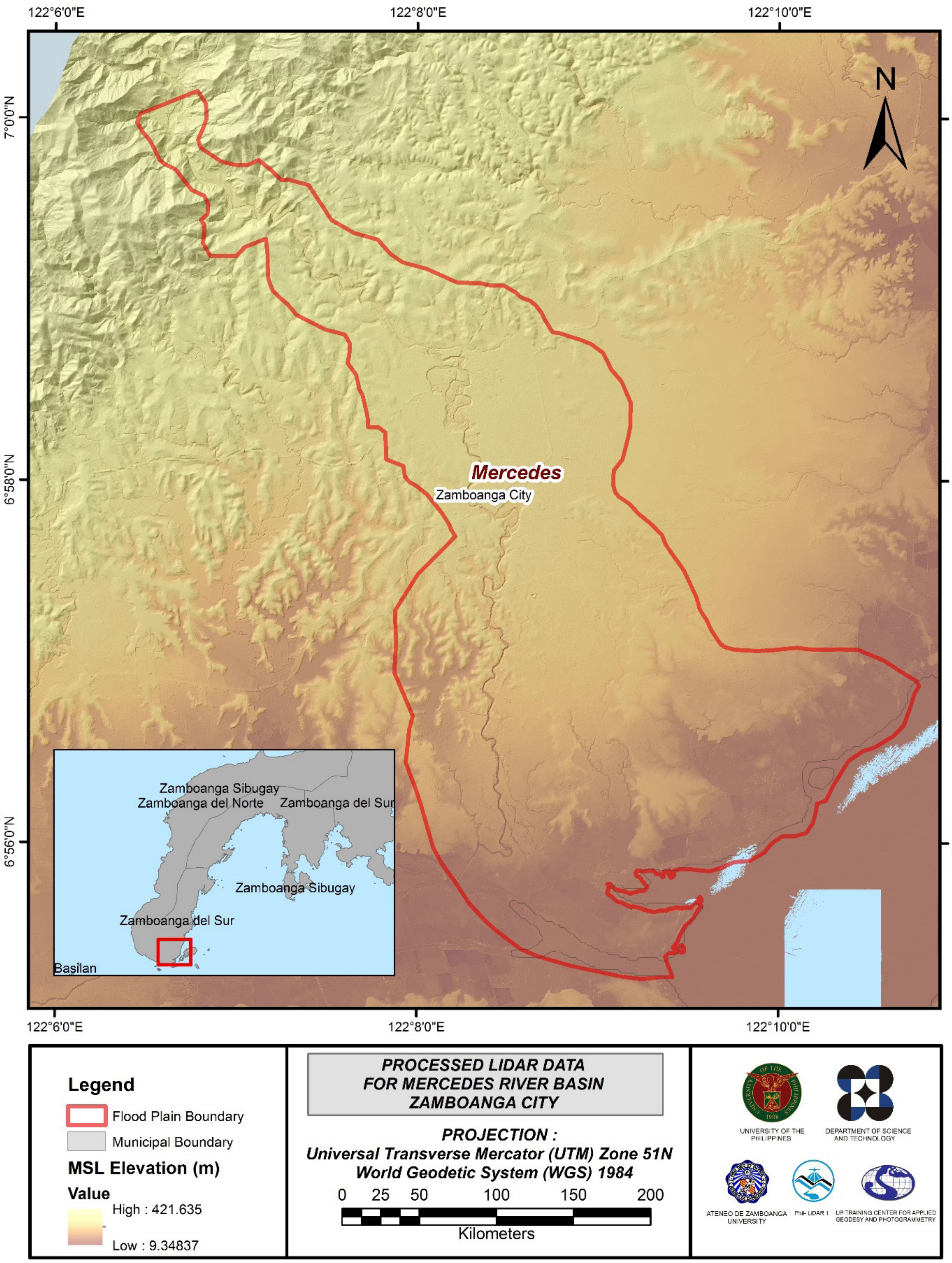


Figure 25. Map of Processed LiDAR Data for Mercedes Floodplain

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 Mercedes to collect points with which the LiDAR dataset is validated is shown in Figure 26. Simultaneous mosaicking was done for the Zamboanga LiDAR blocks and the only available data that time was for Tumaga. The Mercedes flood plain is included in the set of blocks previously mosaicked, therefore, the Tumaga calibration data and methodology was used.

A total of 1,739 survey points from Tumaga data were used for calibration and validation of all the blocks of Zamboanga LiDAR data. Random selection of 80% of the survey points, resulting to 1,391 points, were used for calibration. A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure 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 elevation values is 8.06 meters with a standard deviation of 0.07 meters. Calibration for Zamboanga LiDAR data was done by adding the height difference value, 8.06 meters, to Zamboanga mosaicked LiDAR data. Table 17 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

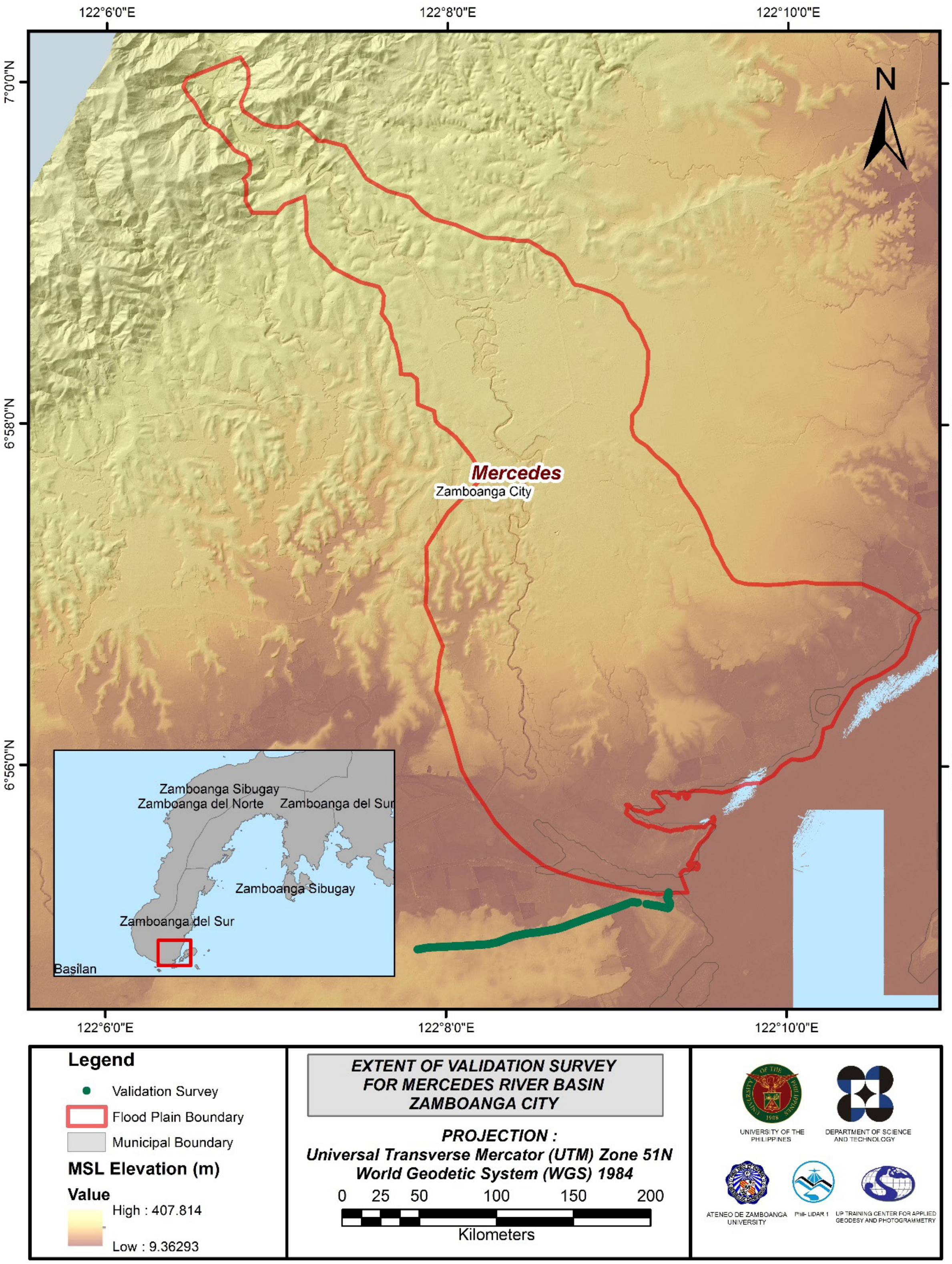


Figure 26. Map of Mercedes Floodplain with validation survey points in green

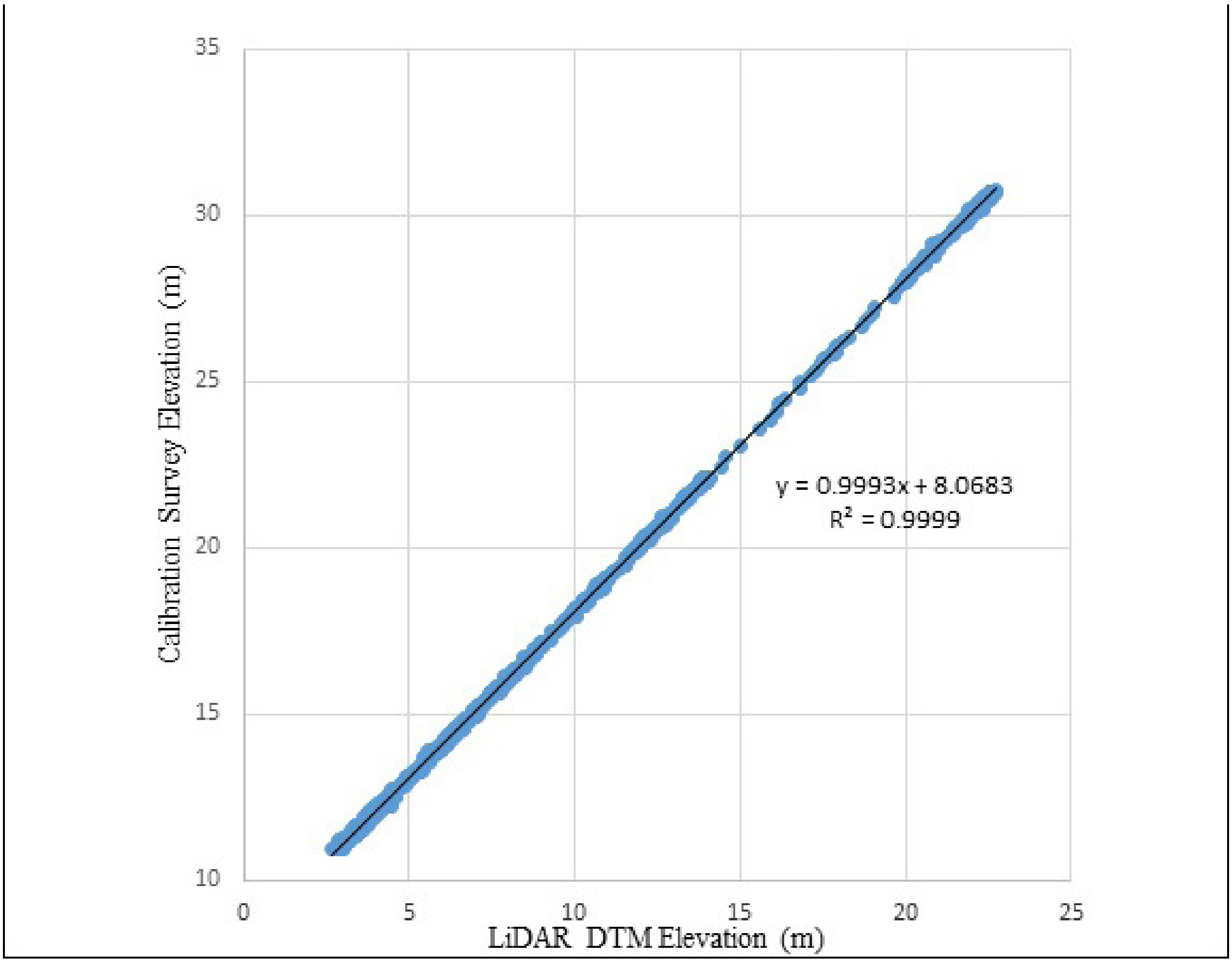


Figure 27. Correlation plot between calibration survey points and LiDAR data

Table 17. Calibration Statistical Measures

Calibration Statistical Measures	Value (meters)
Height Difference	8.06
Standard Deviation	0.07
Average	8.06
Minimum	7.91
Maximum	8.20

The Mercedes floodplain has a total of 1029 survey points and only 20% of the total survey points, resulting to 206 points, were randomly selected and used for the validation of calibrated Mercedes DTM. The good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM is shown in 28. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.12 meters with a standard deviation of 0.08 meters, as shown in Table 18.

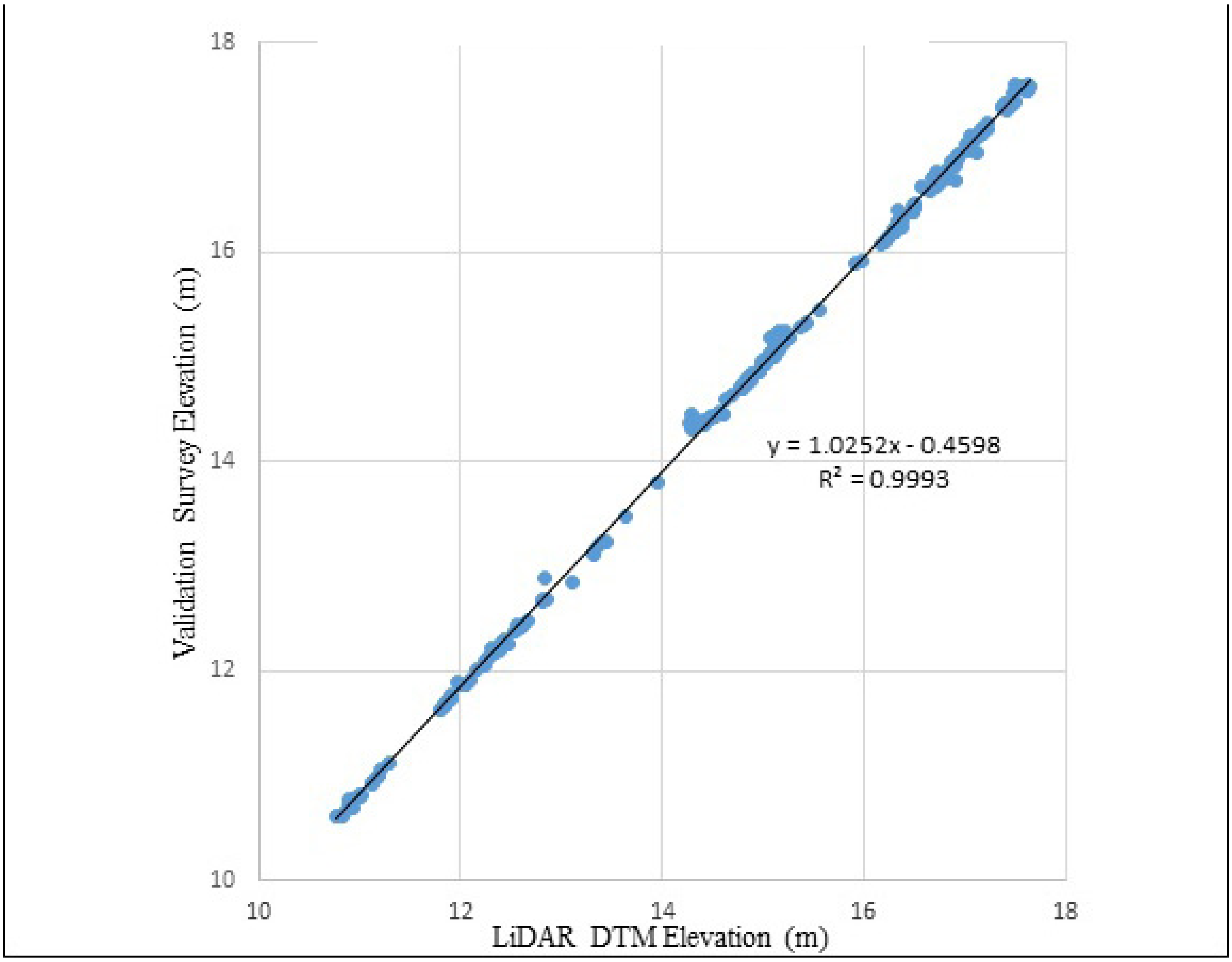


Figure 28. Correlation plot between validation survey points and LiDAR data

Table 18. Validation Statistical Measures

Validation Statistical Measures	Value (meters)
RMSE	0.12
Standard Deviation	0.08
Average	-0.09
Minimum	-0.25
Maximum	0.07

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data was available for Mercedes with 362 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 0.04 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Mercedes integrated with the processed LiDAR DEM is shown in Figure 29.

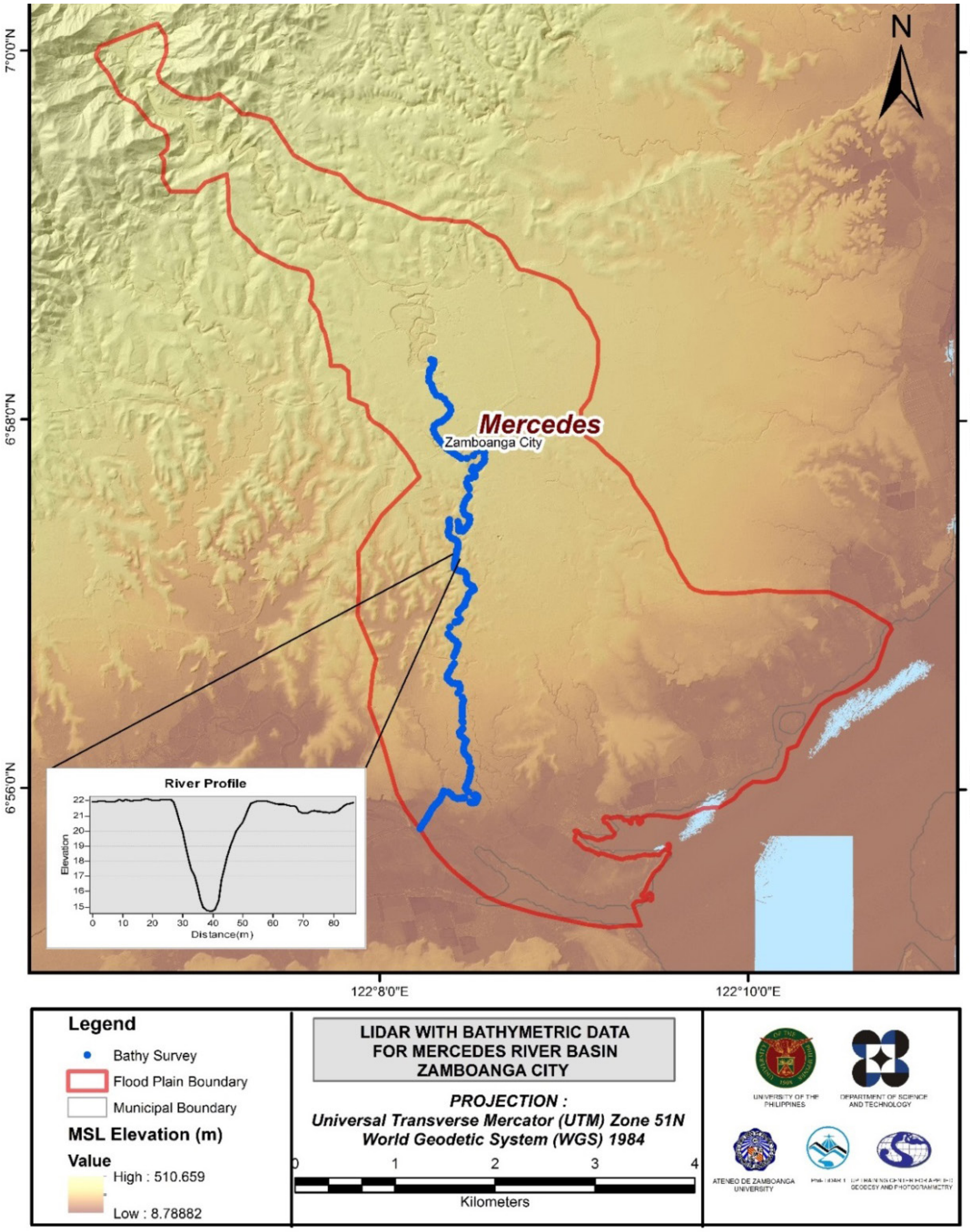


Figure 29. Map of Mercedes Floodplain with bathymetric survey points shown in blue

3.12 Feature Extraction

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

3.12.1 Quality Checking of Digitized Features' Boundary

Mercedes floodplain, including its 200 m buffer, has a total area of 29.39 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 2,740 building features, are considered for QC. Figure 30 shows the QC blocks for Mercedes floodplain.

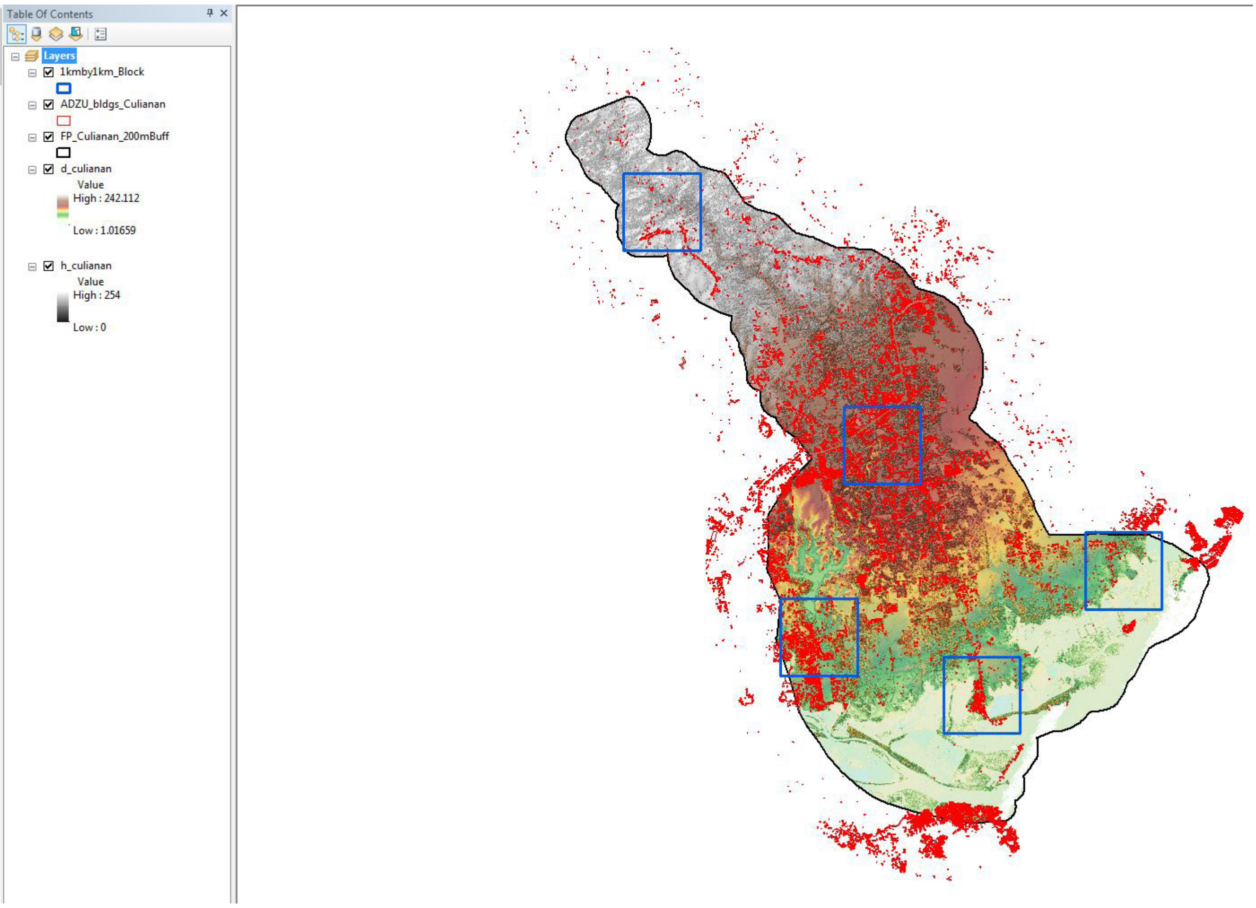


Figure 30. Blocks (in blue) of Mercedes building features that were subjected to QC blocks

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

Table 19. Quality Checking Ratings for Mercedes Building Features

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Mercedes	99.71	100.00	96.57	PASSED

3.12.2 Height Extraction

Height extraction was done for 12,207 building features in Mercedes floodplain. Of these building features, 169 was filtered out after height extraction, resulting to 12,038 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 6.86 m.

3.12.3 Feature Attribution

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

The team, thru the endorsement of the Local Government Units of the Municipality/ City hired a number of enumerators who conducted the house-to-house survey of the features using the GEONYT application. The team provided the enumerators smart tablets where the GEONYT is integrated. The number of days by which the survey was conducted was dependent on the number of features of the flood plain of the riverbasin; likewise, the number of enumerators are also dependent on the availability of the tablet and the number of features of the flood plain.

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

Table 20. Building Features Extracted for Mercedes Floodplain

Facility Type	No. of Features
Residential	11,262
School	136
Market	383
Agricultural/Agro-Industrial Facilities	80
Medical Institutions	11
Barangay Hall	4
Military Institution	1
Sports Center/Gymnasium/Covered Court	9
Telecommunication Facilities	1
Transport Terminal	0
Warehouse	12
Power Plant/Substation	0
NGO/CSO Offices	0
Police Station	2
Water Supply/Sewerage	4
Religious Institutions	13
Bank	0
Factory	85
Gas Station	0
Fire Station	0
Other Government Offices	8
Other Commercial Establishments	27
Total	12,038

Table 21. Total Length of Extracted Roads for Mercedes Floodplain

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Mercedes	57.93	22.69	0.00	6.33	0.00	86.95

Table 22. Number of Extracted Water Bodies for Mercedes Floodplain

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Mercedes	8	0	1	0	84	93

A total of 9 bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

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

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

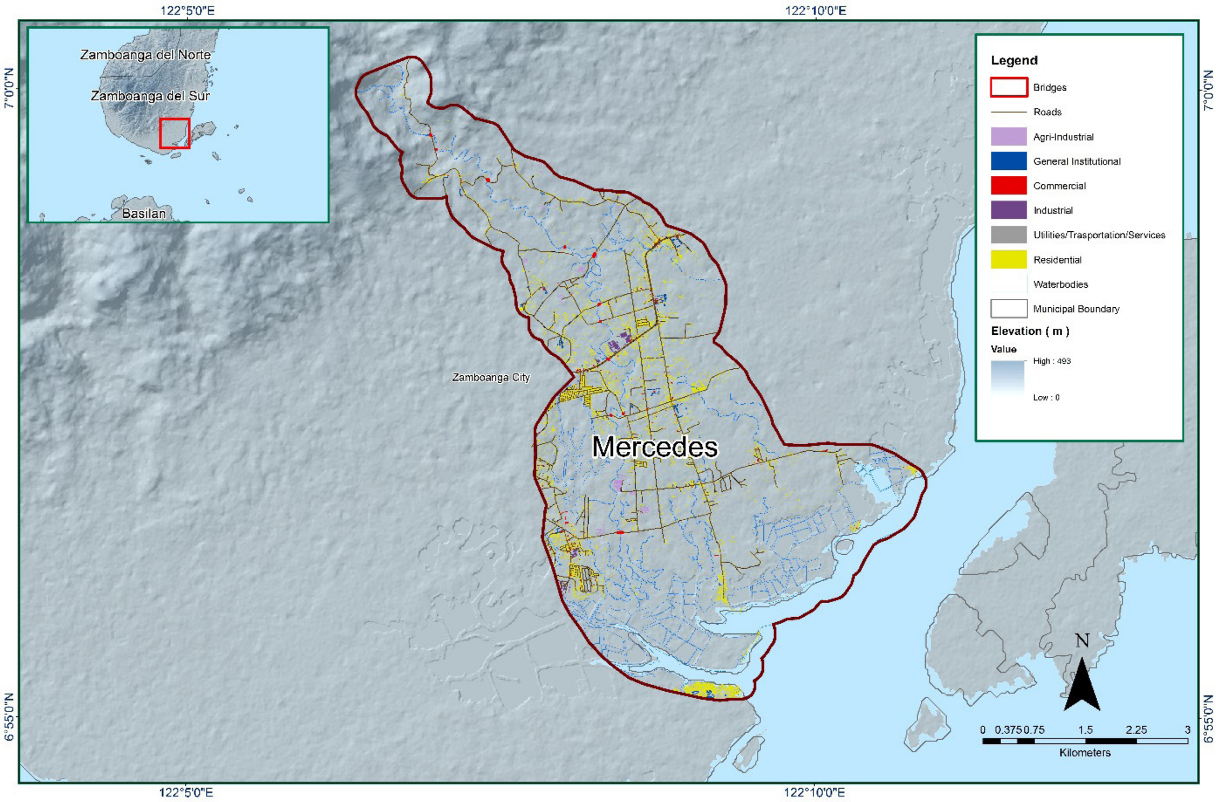


Figure 31. Extracted features for Mercedes Floodplain

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

Engr. Louie P. Balicanta, Engr. Joemarie S. Caballero, Ms. Patrizcia Mae. P. dela Cruz, Engr. Dexter T. Lozano

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 Bathymentry Component (DVBC) conducted a field survey in Culianan River from January 20 to February 1, 2015 with the following scope of work: control survey; cross-section survey and bridge as-built and water level marking of Culianan Bridge; LiDAR ground validation with an estimated length of 19.06 km; and manual bathymetric survey of the river starting from the upstream at Brgy. Salaan down to Brgy. Arena Blanco with an approximate distance of 6.68 km.

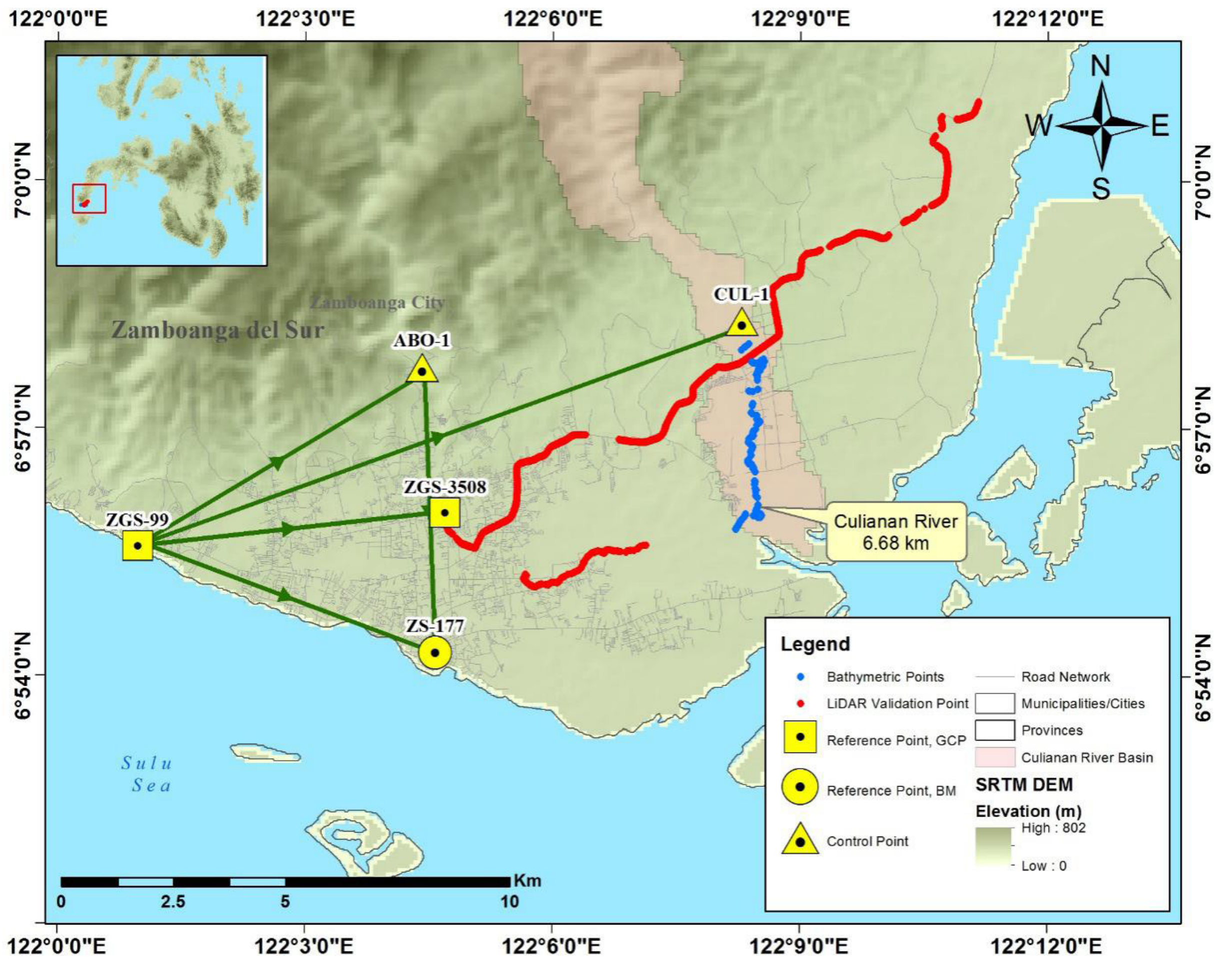


Figure 32. Extent of the Bathymetric survey (in blue line) in Mercedes River and the LiDAR data validation survey (in red)

4.2 Control Survey

The GNSS network used for Culianan River Basin is composed of a single loop and two baseline established on September 19 – 22, 2014 occupying the following reference points: ZGS-99, a second-order GCP, located off-road near the highway in Sinunoc, Zamboanga City; and ZS-177, a first-order benchmark located at the Rizal Park in Brgy. Zone IV, Zamboanga City.

Two control points were established along approach of bridges namely: ABO-1, located in Abong Bridge in Brgy. Dulian, Zamboanga City; and CUL-1, in Culianan Bridge in Brgy. Culianan, Zamboanga City. A NAMRIA established control point, namely ZGS-3508, in Brgy. Tumaga, also in Zamboanga City, was also occupied to use as marker during the survey.

The summary of reference and control points used in the survey is summarized in Table 23, while the GNSS network is illustrated in Figure 33.

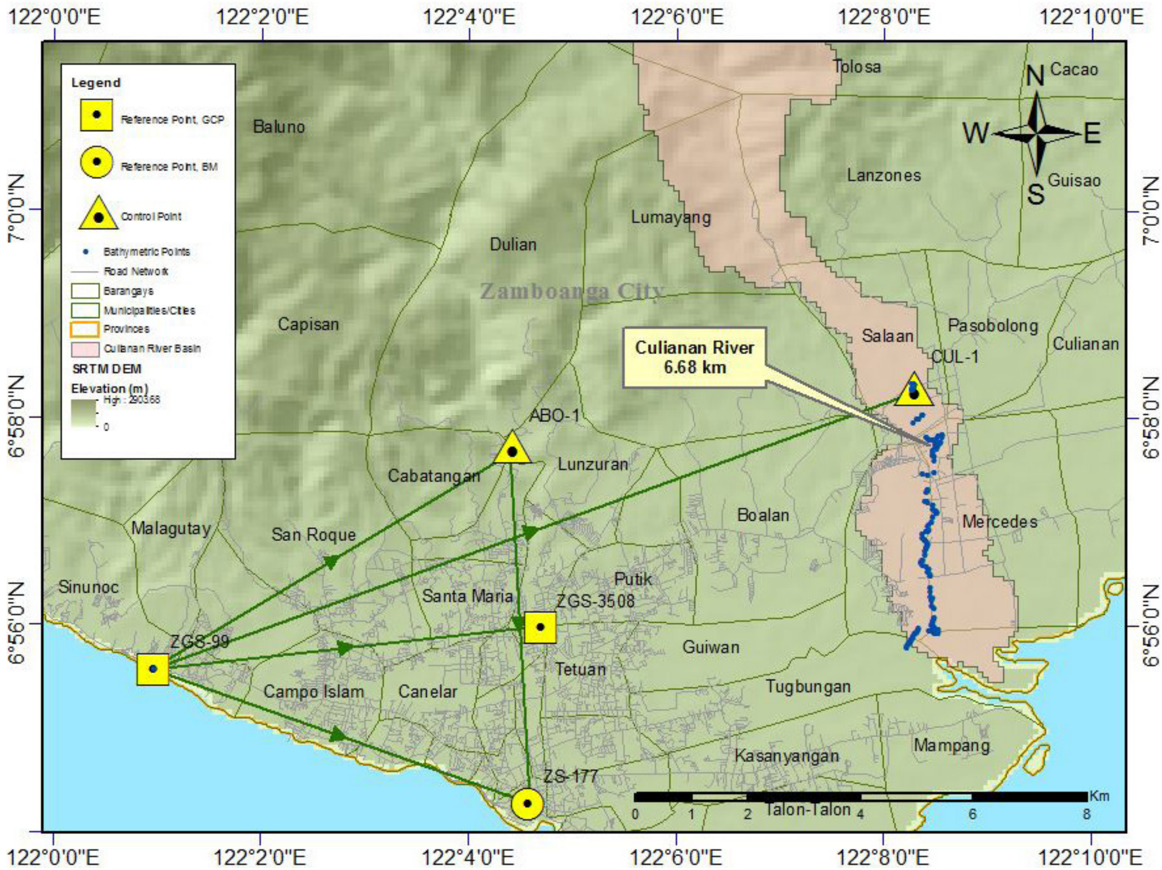


Figure 33. GNSS Network covering Mercedes (Culianan) River

Table 23. List of references and control points used in Mercedes (Culianan) River Basin

(Source: NAMRIA, UP-TCAGP)

Control Point Name	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoid Height, (m)	Elevation in MSL (m)	Date Established
ZGS-99	2nd Order, GCP	6°55’34.07737”N	122°00’58.23072”E	81.427	-	2009
ZS-177	1st Order, BM	-	-	80.002	12.311	2009
ABO-1	UP Established	-	-	-	-	9-19-2014
CUL-1	UP Established	-	-	-	-	9-20-2014
ZGS-3508	Used as Marker	-	-	-	-	9-20-2014

The GNSS set ups made in the location of the reference and control points are exhibited in Figures 34 to 38.

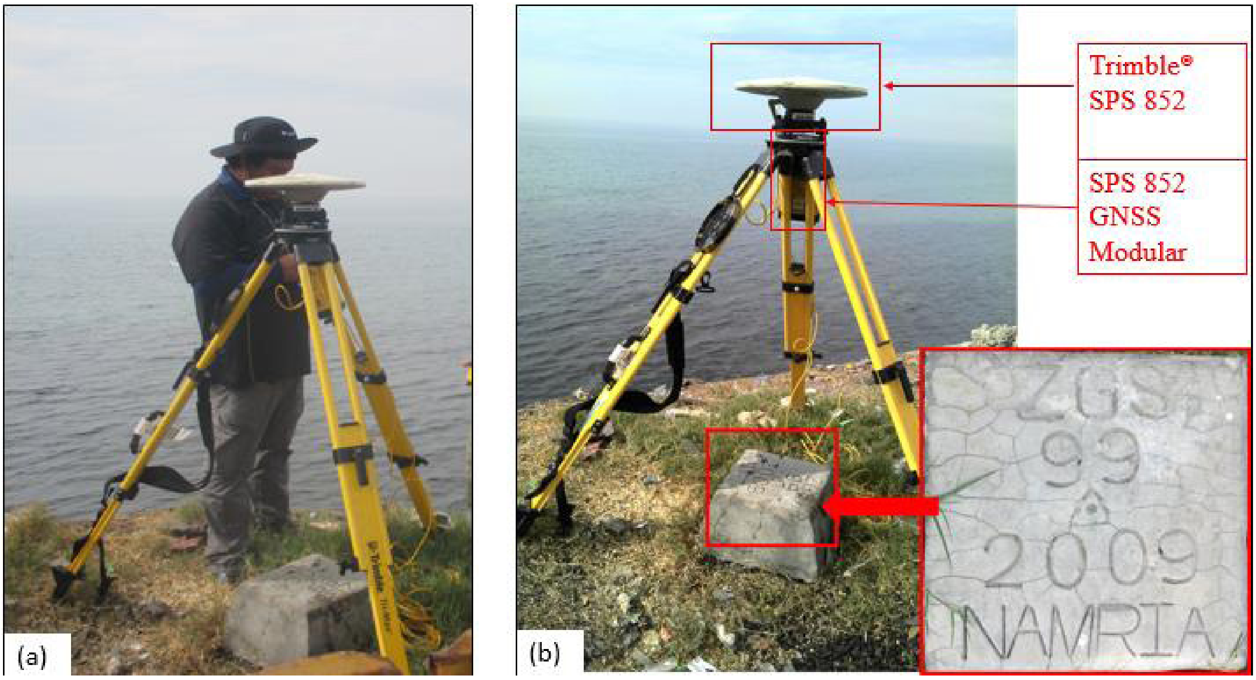


Figure 34. GNSS base receiver setup, Trimble® SPS 852 at ZGS-99
in Brgy. Sinunoc, Zamboanga City, Zamboanga Del Sur

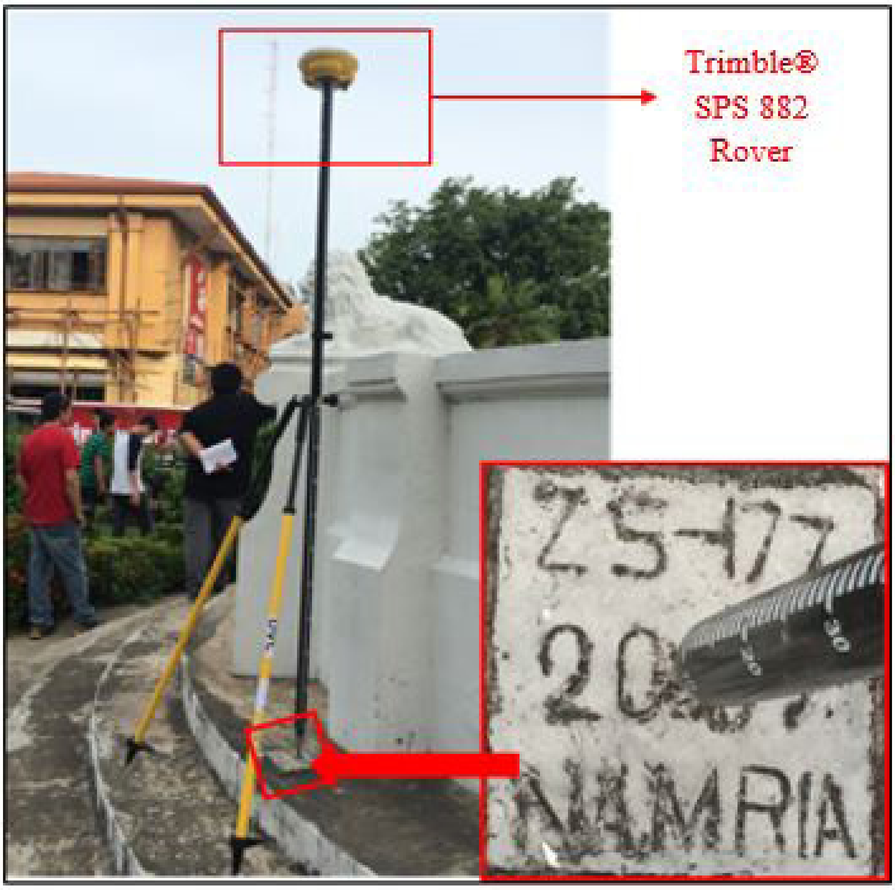


Figure 35. GNSS receiver setup, Trimble® SPS 882 at ZS-177, located in Rizal Park
in Brgy. Zone IV, Zamboanga City, Zamboanga Del Sur

Figure 36. GNSS receiver occupation, Trimble® SPS 852 at ABO-1 located along approach of Abong Bridge, in Brgy. Dulian, Zamboanga City, Zamboanga Del Sur

Figure 37. GNSS base receiver setup, Trimble® SPS 882 at CUL-1 along approach of Culianan Bridge in Brgy. Culianan, Zamboanga City, Zamboanga Del Sur

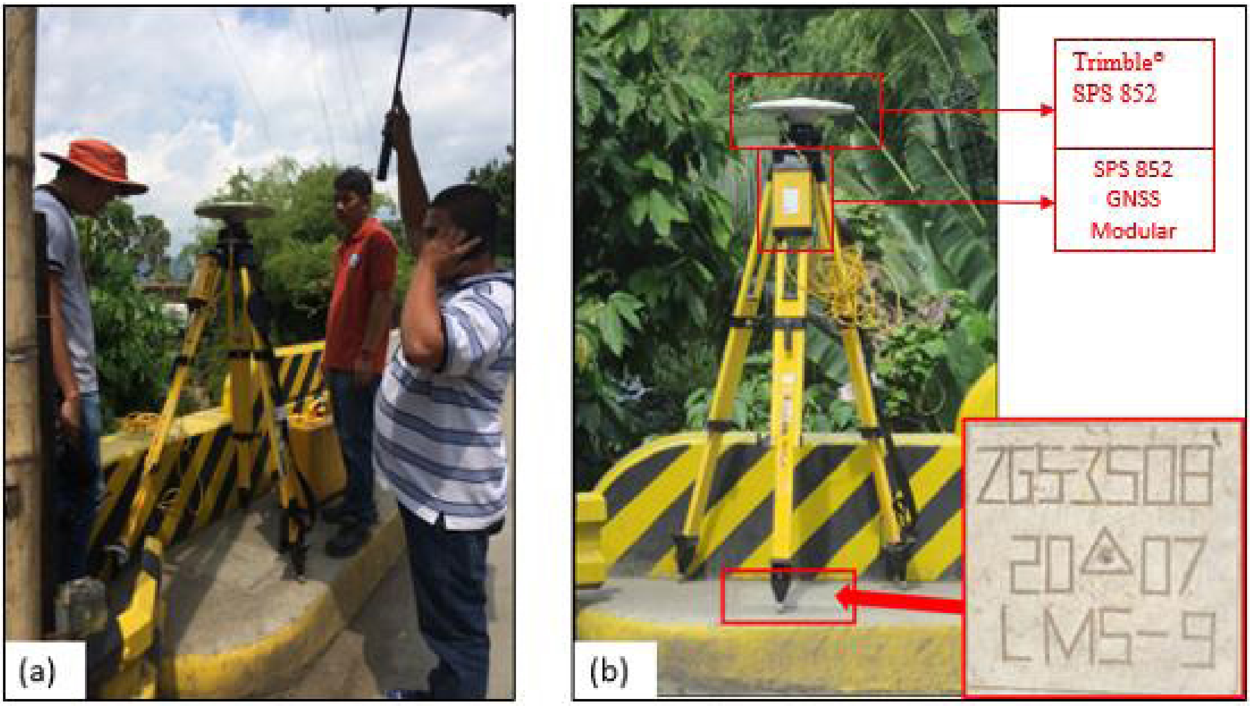


Figure 38. GNSS base receiver setup, Trimble® SPS 852 at ZGS-3508 along Tumaga Bridge in Brgy. Tumaga, Zamboanga City, Zamboanga Del Sur

4.3 Baseline Processing

GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement, respectively. In cases where one or more baselines did not meet all of these criteria, masking is performed. Masking is done by removing/masking portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. Baseline processing result of control points in Mercedes (Culianan) River Basin is summarized in Table 24 generated by TBC software.

Table 24. Baseline Processing Report for Mercedes (Culianan) River static survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
ZGS-99 --- ABO-1	9-19-2014	Fixed	0.004	0.028	57°53'41"	7493.070	37.518
ZGS-99 --- ZS-177	9-19-2014	Fixed	0.004	0.019	109°39'22"	7070.332	-1.438
ZGS-99 --- CUL-1	9-20-2014	Fixed	0.011	0.062	69°32'00"	14392.717	19.213
ZGS-99 --- ZGS-3508	9-20-2014	Fixed	0.006	0.020	83°43'43"	6906.042	10.778
ABO-1 --- ZS-177	9-19-2014	Fixed	0.006	0.030	177°12'23"	6368.267	-38.883

As shown in Table 24, a total of nine (9) baselines were processed with reference point ZGS-99 held fixed for coordinate values; and ZS-177 fixed for elevation values. All of them passed the required accuracy.

4.4 Network Adjustment

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

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

where:

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

For complete details, see the Network Adjustment Report shown in Table 25 to Table 27.

The five (5) control points, ZGS-99, ZS-177, ABO-1, CUL-1 and ZGS-3508 were occupied and observed simultaneously to form a GNSS loop. Coordinates of ZGS-99 and elevation values of ZS-177 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 were computed.

Table 25. Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
ZGS-99	Local	Fixed	Fixed		
ZS-177	Grid				Fixed
Fixed = 0.000001(Meter)					

The list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 26. All fixed control points have no values for grid and elevation values.

Table 26. Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
BO-1	397667.079	0.006	769663.801	0.005	51.156	0.045	
ZGS-99	391313.321	?	765695.628	?	13.851	0.035	LL
ZS-177	397964.978	0.006	763304.232	0.005	12.311	?	e

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

a. ZGS-99

horizontal accuracy	=	Fixed
vertical accuracy	=	cm < 10 cm

b. ZS-177

horizontal accuracy	=	$\sqrt{(0.8)^2 + (0.7)^2}$
	=	$\sqrt{(0.64 + 0.49)}$
	=	1.06 cm < 20 cm
vertical accuracy	=	Fixed

c. ABO-1

horizontal accuracy	=	$\sqrt{(1.2)^2 + (0.9)^2}$
	=	$\sqrt{(1.44 + 0.81)}$
	=	1.50cm < 20 cm
vertical accuracy	=	Fixed

d. CUL-1

horizontal accuracy	=	$\sqrt{(1.1)^2 + (1.0)^2}$
	=	$\sqrt{((1.21 + 1)}$
	=	1.49 cm < 20 cm
vertical accuracy	=	8.3 cm < 10 cm

e. ZGS-3508

horizontal accuracy	=	$\sqrt{(1.1)^2 + (0.9)^2}$
	=	$\sqrt{(1.21 + 0.81)}$
	=	1.42 cm < 20 cm
vertical accuracy	=	8.2 cm < 10 cm

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

Table 27. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Ellipsoid	Height	Constraint
ABO-1	N6°57'43.70202"	E122°04'25.00864"	118.918	0.045	
ZGS-99	N6°55'34.07737"	E122°00'58.23072"	81.427	0.035	LL
ZS-177	N6°54'16.64514"	E122°04'35.11948"	80.002	?	e

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 27. Based on the result of the computation, the accuracy condition is satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table 28.

Table 28. Reference and control points used and its location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
ZGS-99	2nd Order, GCP	6°55'34.07737"N	122°00'58.23072"E	81.427	765695.6	391313.3	13.851
ZS-177	1st Order, BM	6°54’16.64514”N	122°04'35.11948"E	80.002	763304.2	397965	12.311
ABO-1	UP Established	6°57'43.70202"N	122°04'25.00864"E	118.918	769663.8	397667.1	51.156
CUL-1	UP Established	6°58'17.84390"N	122°08'17.52714"E	100.641	770698.8	404804.3	32.832
ZGS-3508	Used as Marker	6°55'58.62095"N	122°04'41.85531"E	92.206	766435.6	398177.8	24.486

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

Cross-section survey was done on September 20, 2014 along the downstream side of Culianan bridge Brgy. Salaan, Zamboanga City, Zamboanga Del Sur. A GNSS receiver Trimble® SPS 882 in GNSS PPK survey technique was used as shown in Figure 39. Control point CUL-1 was used as base station during the survey.

In addition to the cross-section survey, bridge as-built features determination was performed to get the distance of piers and abutments from the bridge approach. The bridge deck was measured using GNSS receiver Trimble® SPS 882 to get the high chord and meter tapes to get its low chord elevation.

Figure 39. (a) Culianan Bridge and (b) Cross-section and bridge as-built survey for Culianan Bridge

The cross-sectional line for the Culianan Bridge is about 120.29 m with 37 cross-section points. Figure 40 to Figure 42 show the summary of gathered cross-section location map, cross-section bridge in a diagram, and as-built data form.

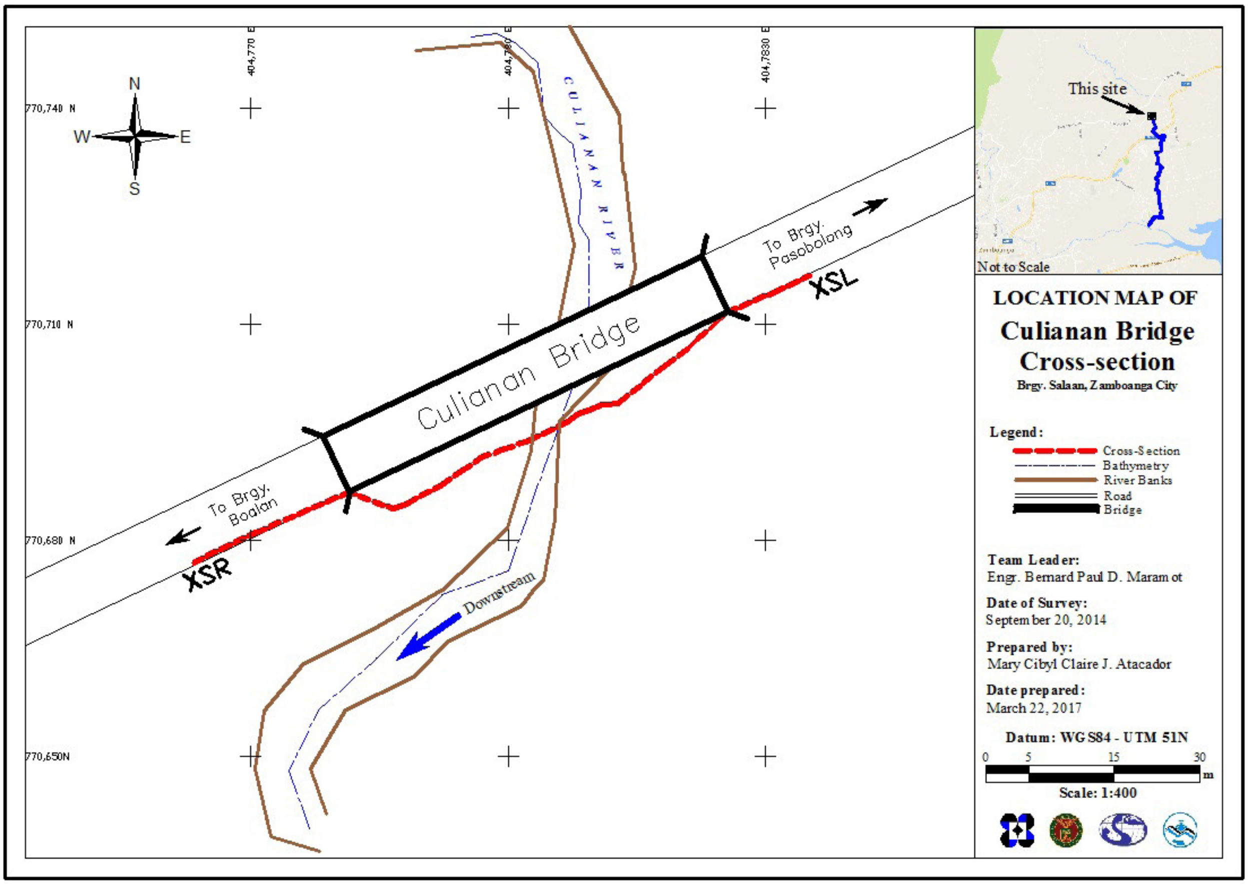


Figure 40. Culianan bridge cross-section location map

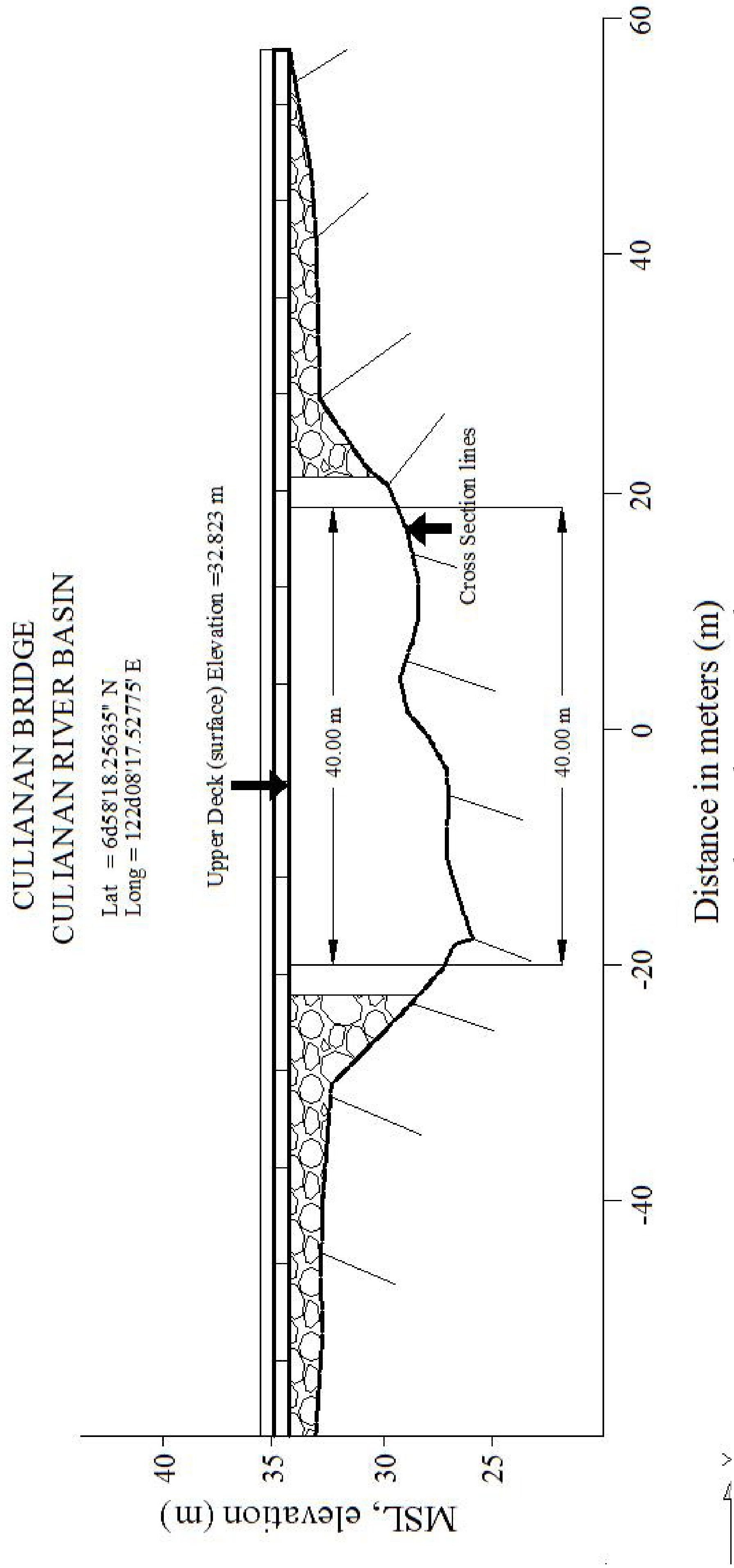


Figure 41 Culianan Bridge cross-section diagram

Bridge Data Form

Bridge Name: CULIANAN BRIDGE **Date:** September 20, 2014

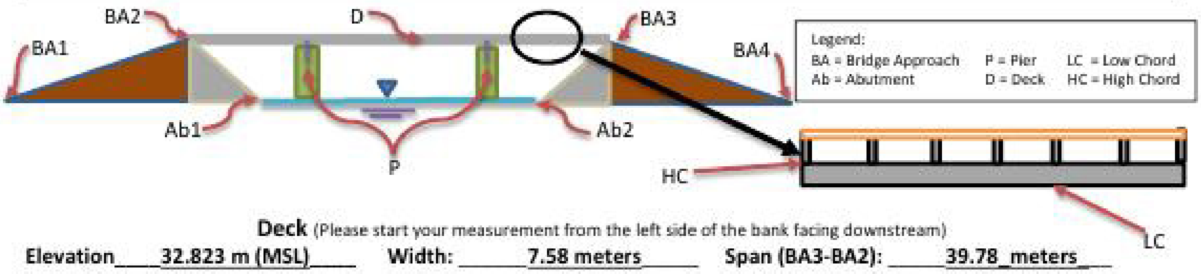
River Name: CULIANAN RIVER **Time:** 10:48 am

Location (Brgy, City, Region): Brgy. Culianan, Zamboanga City

Survey Team: DVBC Zamboanga City Survey Team

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

Latitude: 6d58'18.25635" N **Longitude:** 122d08'17.52775" E



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

Elevation 32.823 m (MSL) **Width:** 7.58 meters **Span (BA3-BA2):** 39.78 meters

	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 downstream)

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	31.064	BA3	70.472	32.609
BA2	7.464	31.091	BA4	117.150	33.981

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 downstream)

Shape: ______ **Number of Piers:** 0 **Height of column footing:** ______

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1			
Pier 2			
Pier 3			
Pier 4			
Pier 5			
Pier 6			
Pier 7			

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

Figure 42. The Culianan Bridge as-built survey data.

Figure 43. (a) Existing water level post near Culianan Bridge and (b) Water level marking

Water surface elevation of Culianan River was determined using Trimble® SPS 882 in PPK mode survey on January 21, 2015 at 11:00 A.M. The elevation referred to MSL was translated to the bridge pier using a Digital Level. This shall serve as a reference for flow data gathering and depth gauge deployment by the accompanying HEI, Ateneo de Zamboanga University.

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on September 21, 2014 using a survey grade GNSS Rover receiver, Trimble® SPS 882, mounted on a pole which was attached on the side of the vehicle. It was secured with a cable tie to ensure that it was horizontally and vertically balanced. The antenna height was measured from the ground up to the bottom of the notch of the GNSS Rover receiver. The measured height of the bottom of the notch is 2.602 m from the ground. The survey was conducted using PPK technique on a continuous topography mode.

The activity started from the ZGS-3508 in Tumaga Bridge to Brgy. Manicahan with an approximate distance of 19.06 km with a total of 2,380 validation points covering the barangays of Calarian, Campo Islam, Baliwasan, Cawa-cawa, Sto. Nino, Sta. Catalina and Tumaga. Control point ZGS-3508 was used as base station for the survey.

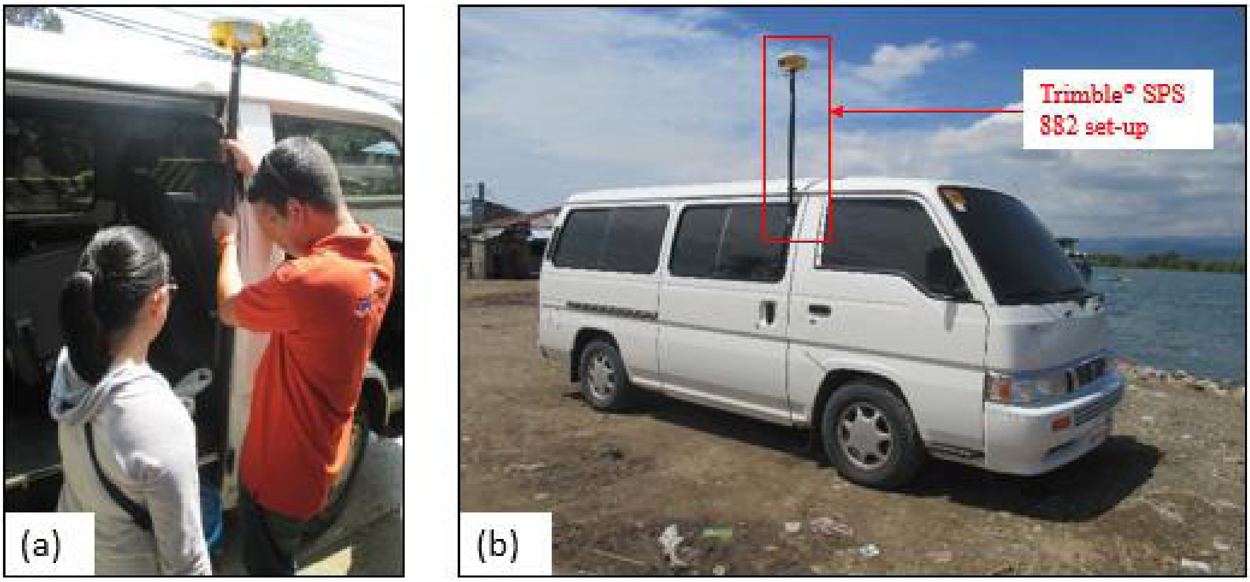


Figure 44. (a) Ground validation set-up by: Trimble® SPS 882 mounted on a pole attached on the side of the vehicle

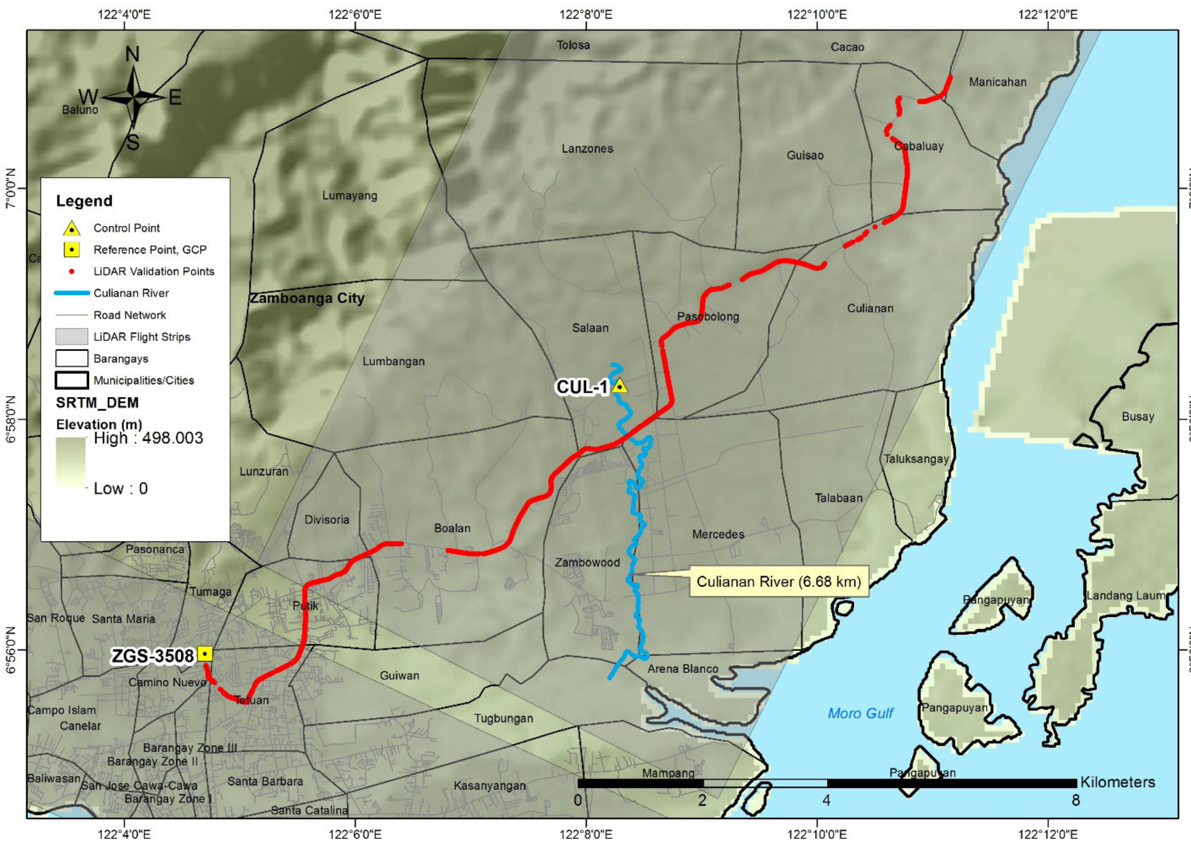


Figure 45. Validation acquisition points survey covering Mercedes (Culianan) River

4.7 River Bathymetric Survey

Bathymetric survey was done on January 21, 29 and 30, 2015 using Trimble® SPS 882 in GNSS PPK survey technique as shown in Figure 46. The survey started at the upstream part of the river in Brgy. Salaan, Zamboanga City with coordinates 6°58'16.76773" 122°08'16.84301", traversed down by foot and ended at the mouth of the river in Brgy. Arena Blanco, Zamboanga City with coordinates 6°55'47.99488" 122°08'13.77668". The control point CUL-1 was used as the GNSS base station all throughout the survey.

Figure 46. Bathymetric survey in Culianan River: (a) upstream and (b) downstream

The bathymetric line surveyed has an estimated length of 6.68 km with 269 bathynetric points covering Barangays Arena Blaco, Mercedes, Zambowood and Salaan in Zamboanga City as shown in Figure 47. Additionally, a CAD drawing was also produced to illustrate the Culianan riverbed profile as shown in Figure 48. An elevation drop of 18.7 m in MSL was observed within the approximate distance of 6.68 km. The highest elevation observed was 27.657 m in MSL located at the upstream part of the river, while the lowest elevation observed was 7.896 m in MSL located at the mouth of the river. Data gaps present were due to canopy cover along the banks of the river.

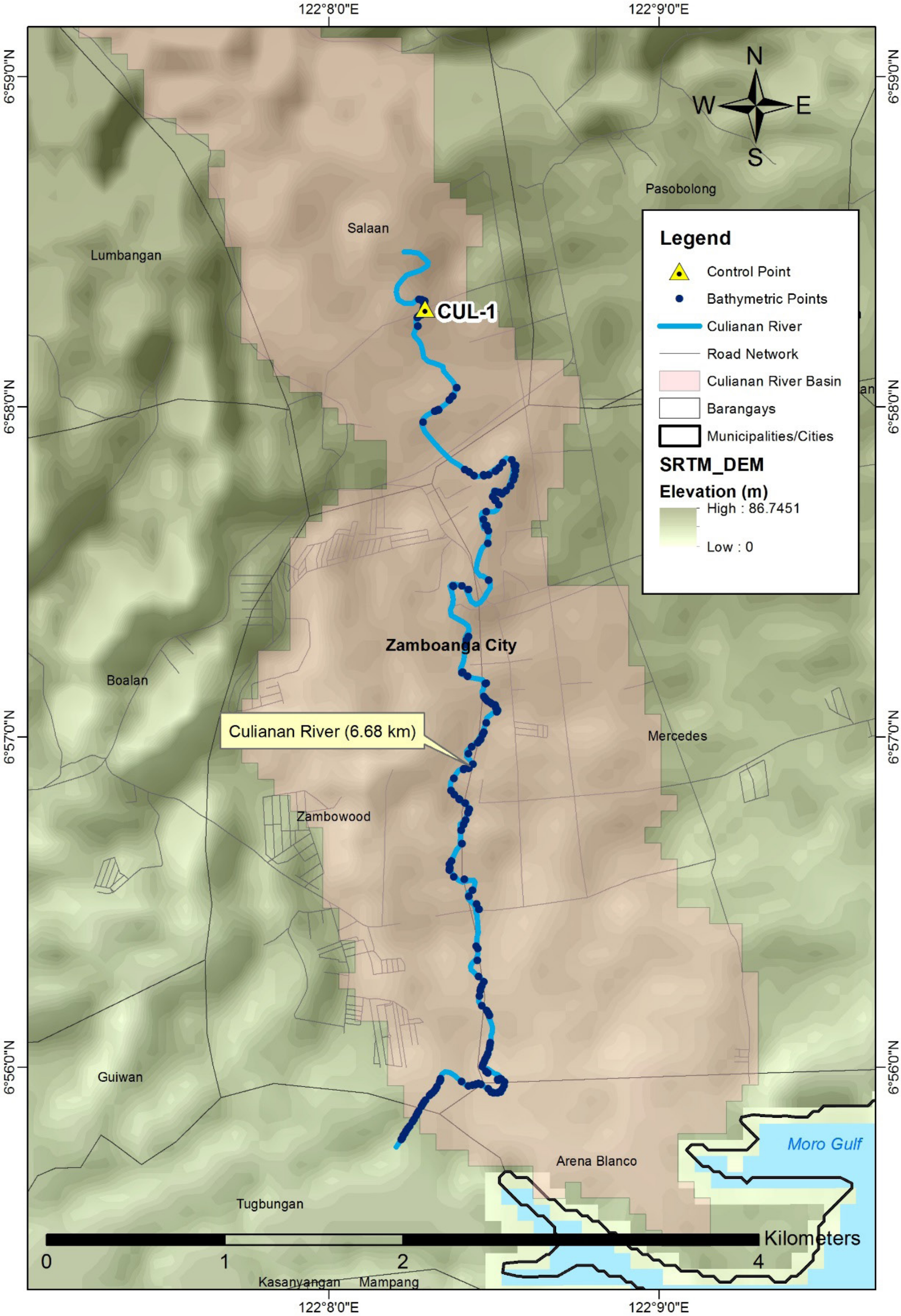


Figure 47. Bathymetric survey of Culianan River

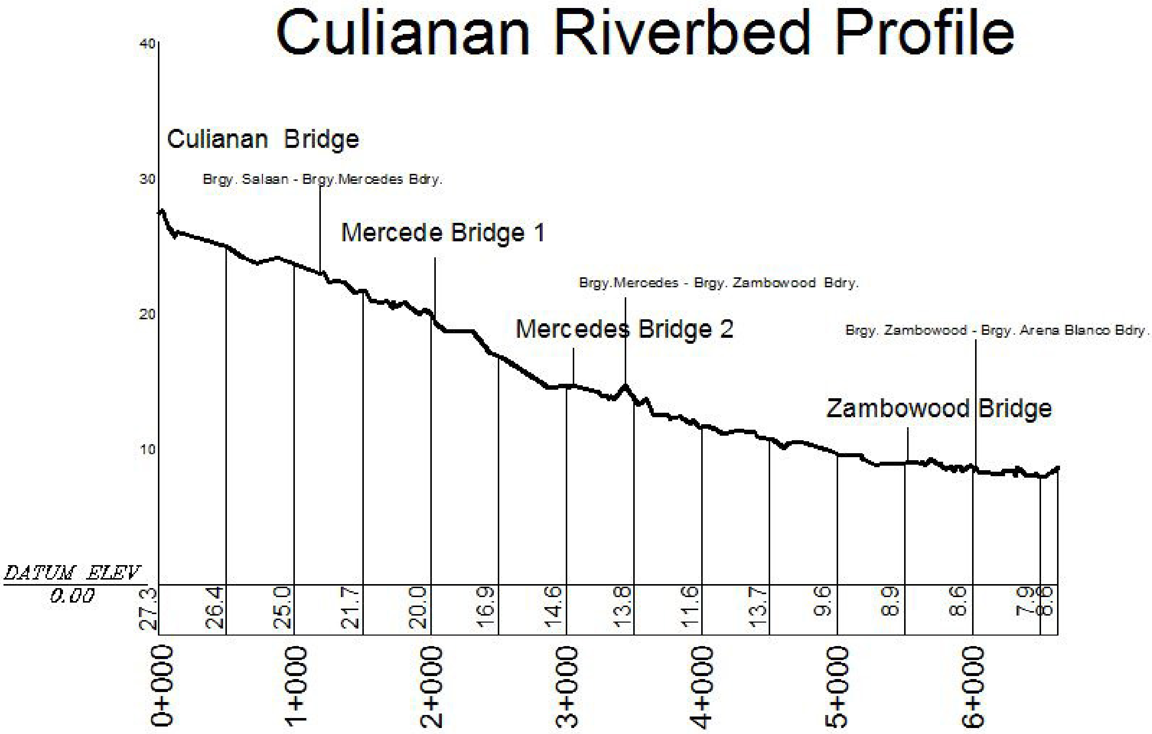


Figure 48. Riverbed profile of Culianan River

CHAPTER 5: FLOOD MODELING AND MAPPING

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

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

Rainfall, water level, and flow in a certain period of time, which may affect the hydrologic cycle of the Mercedes River Basin were monitored, collected, and analysed.

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). The ARG was installed in the Cabonegro Repeater Station at Brgy. Bungulao, Zamboanga City (Figure 49). The precipitation data collection started from June 29, 2015 at 12:00 AM to July 4, 2015 at 11:00 PM with 10 minutes recording interval.

The total precipitation for this event in Cabonegro Repeater Station ARG was 44.6 mm. It has a peak rainfall of 13.2 mm. on July 2, 2015 at 08:00 AM. The lag time between the peak rainfall and discharge is 5 hours and 15 minutes.

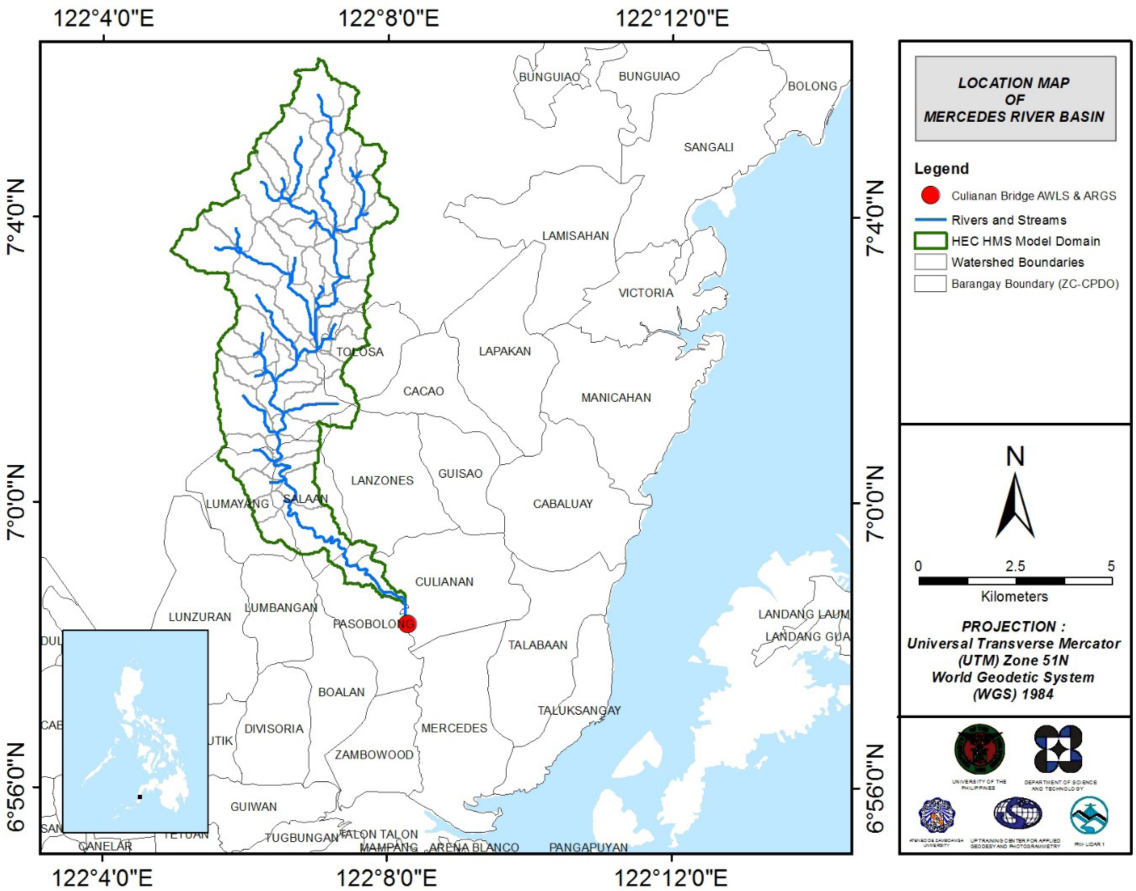


Figure 49. Location map of Mercedes HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Culianan Bridge, Salaan, Zamboanga City (6°58'18.26"N, 122° 8'17.52"E). It gives the relationship between the observed water levels at Culianan Bridge and outflow of the watershed at this location.

For Culianan Bridge, the rating curve is expressed as Q = 2E-50e4.2552h as shown in Figure 51.

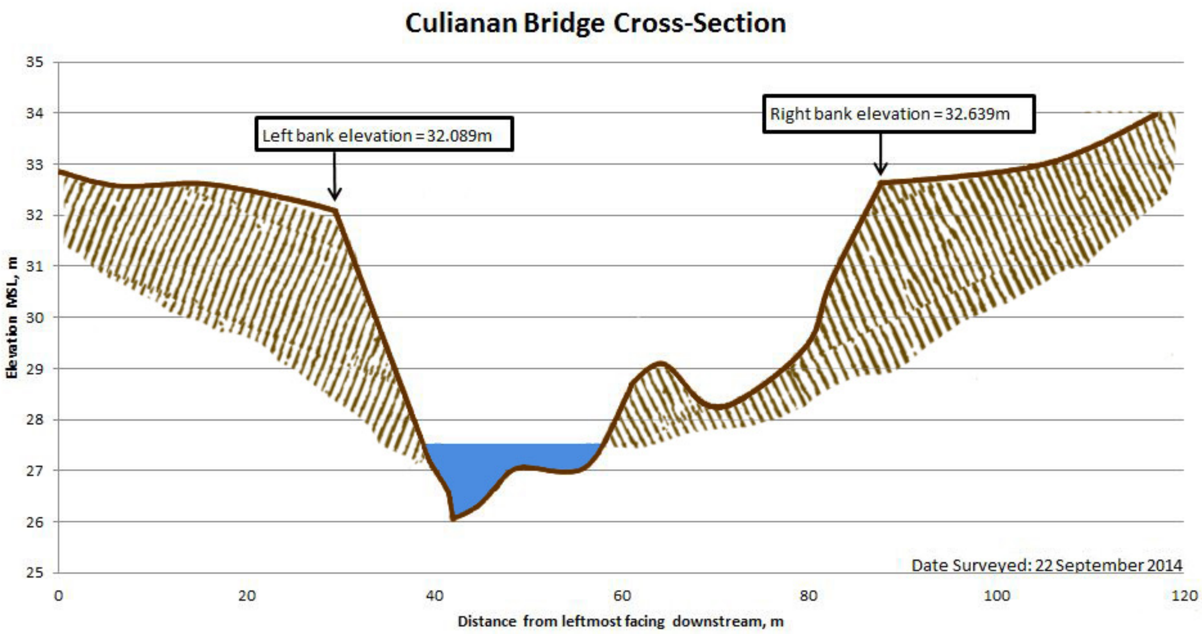


Figure 50. Cross-Section Plot of Culianan Bridge

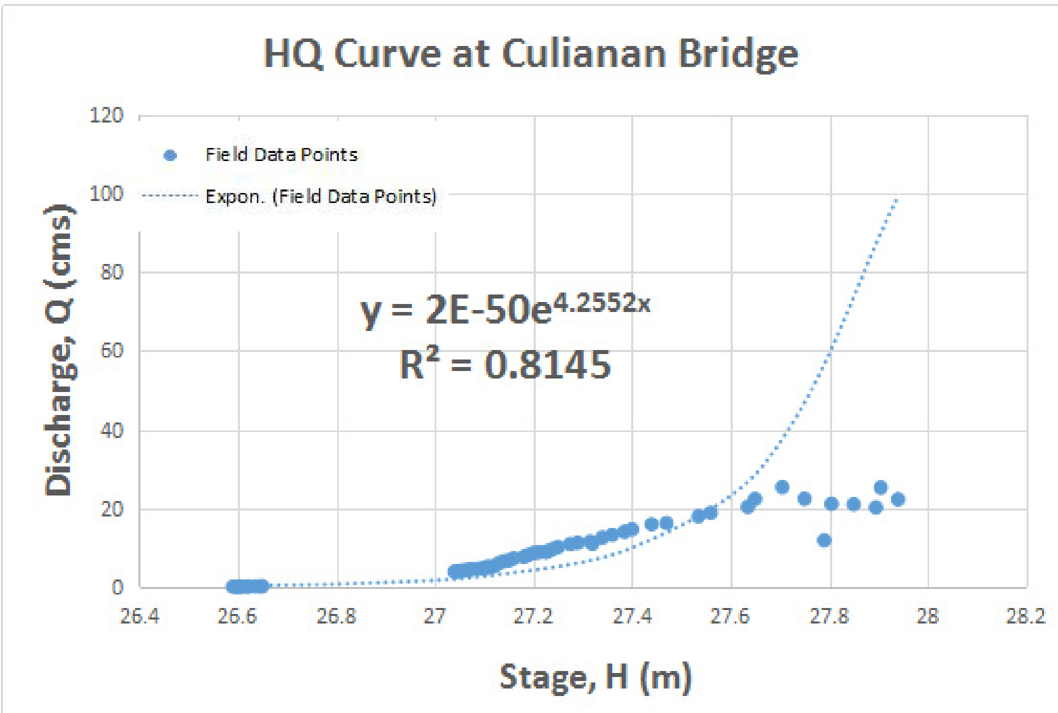


Figure 51. Hydrometry rating curve of Culianan Bridge

This rating curve equation was used to compute the river outflow at Culianan Bridge for the calibration of the HEC-HMS model shown in Figure 52. Peak discharge is 25.4 cubic meters per second at 1:15 PM, July 2, 2015.

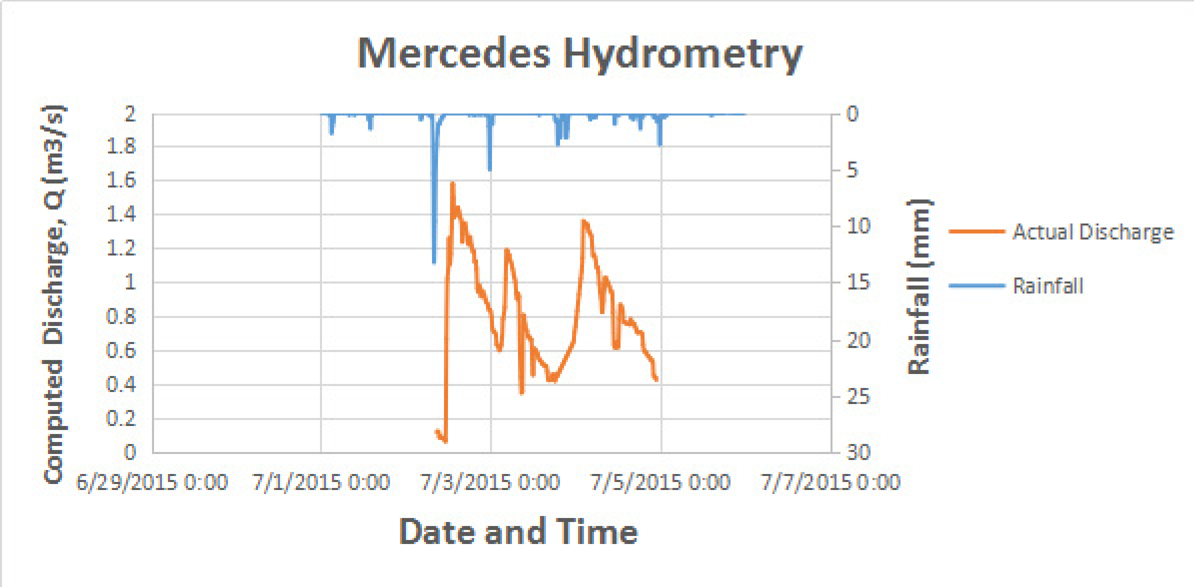


Figure 52. Rainfall and outflow data at Mercedes used for modeling

5.2 RIDF Station

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

Table 29. RIDF values for Zamboanga City Rain Gauge computed by PAGASA

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

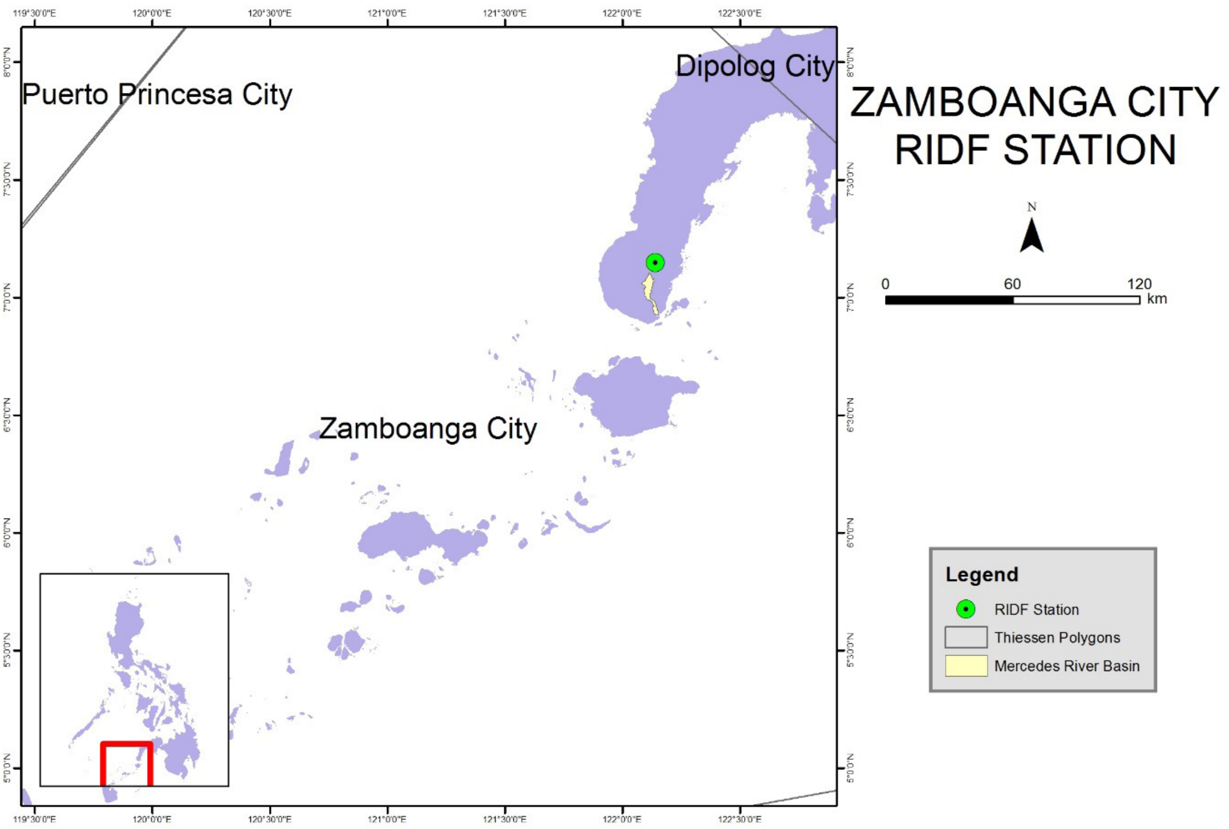


Figure 53. Zamboanga City RIDF location relative to Mercedes River Basin

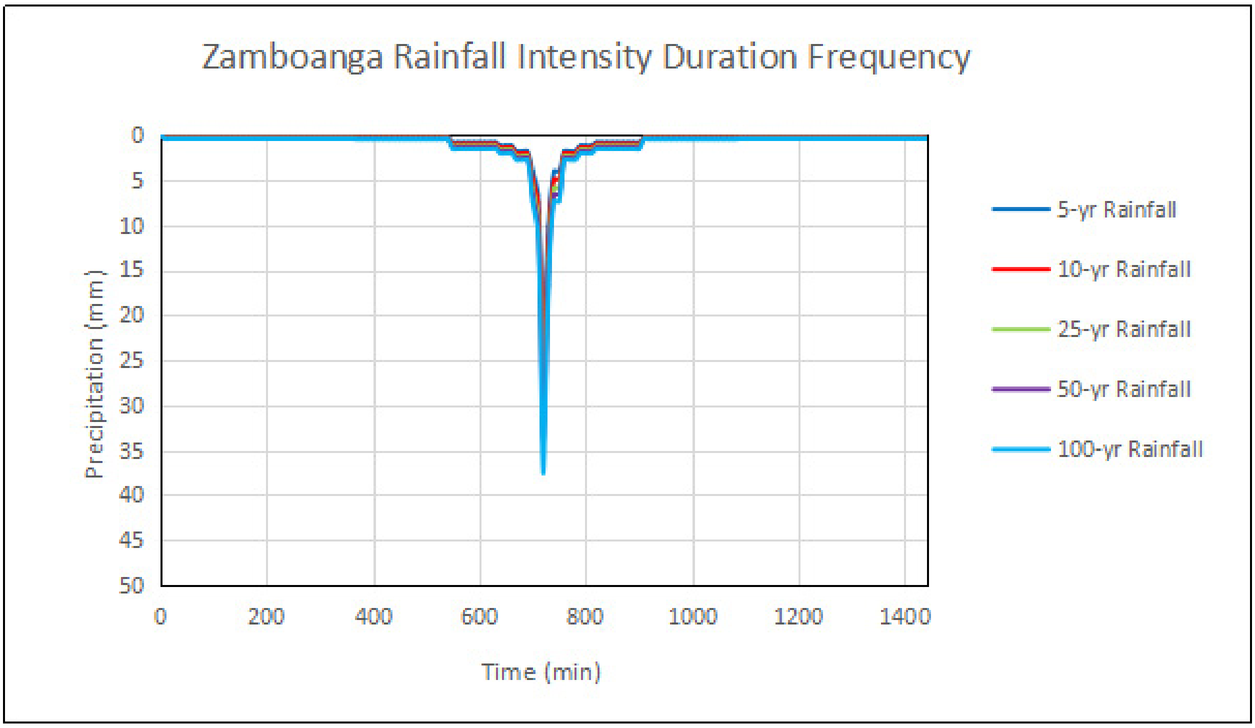


Figure 54. Synthetic storm generated for a 24-hr period rainfall for various return periods

5.3 HMS Model

The soil shapefile was taken before 2004 from the Bureau of Soils under the Department of Agriculture. The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Mercedes River Basin are shown in Figures 55 and 56, respectively.

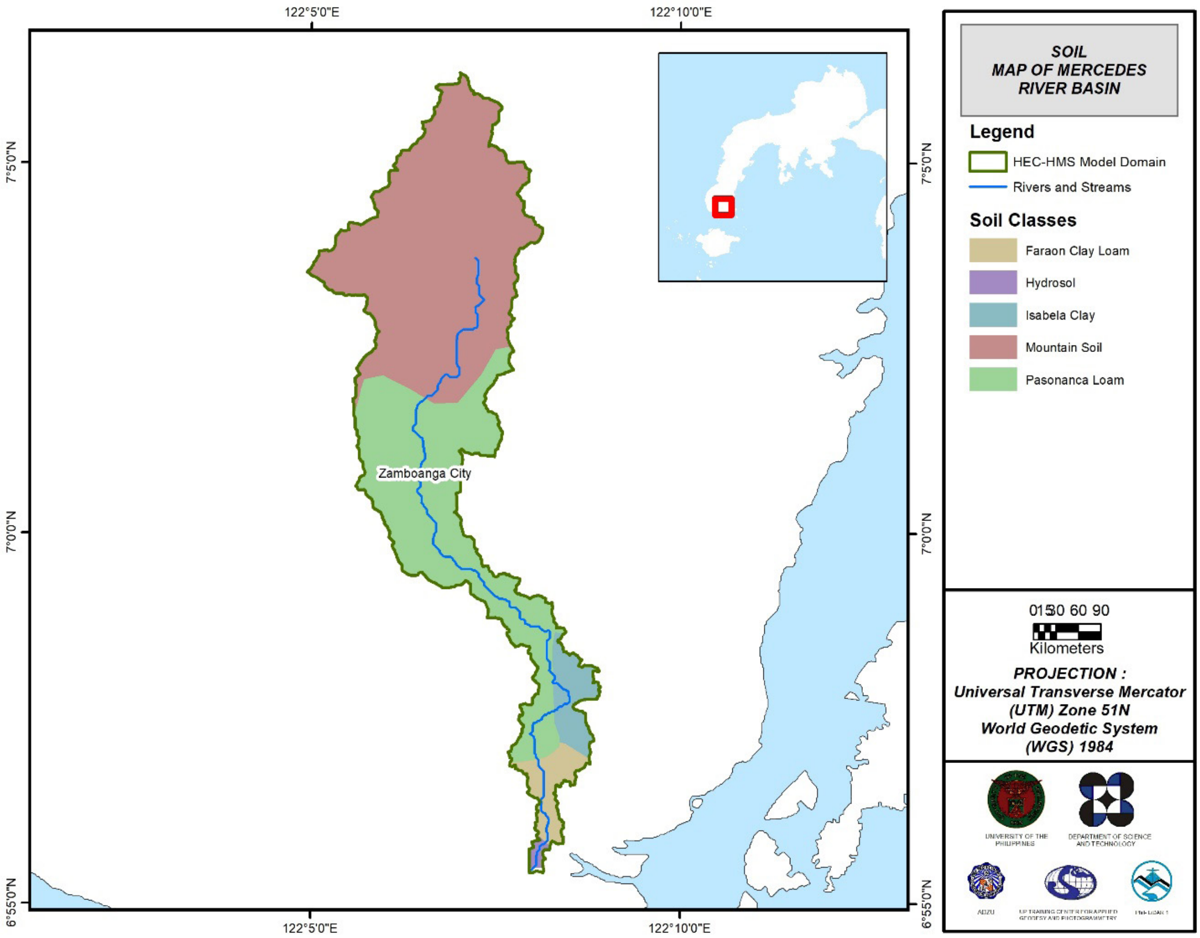


Figure 55. Soil Map of Mercedes River Basin

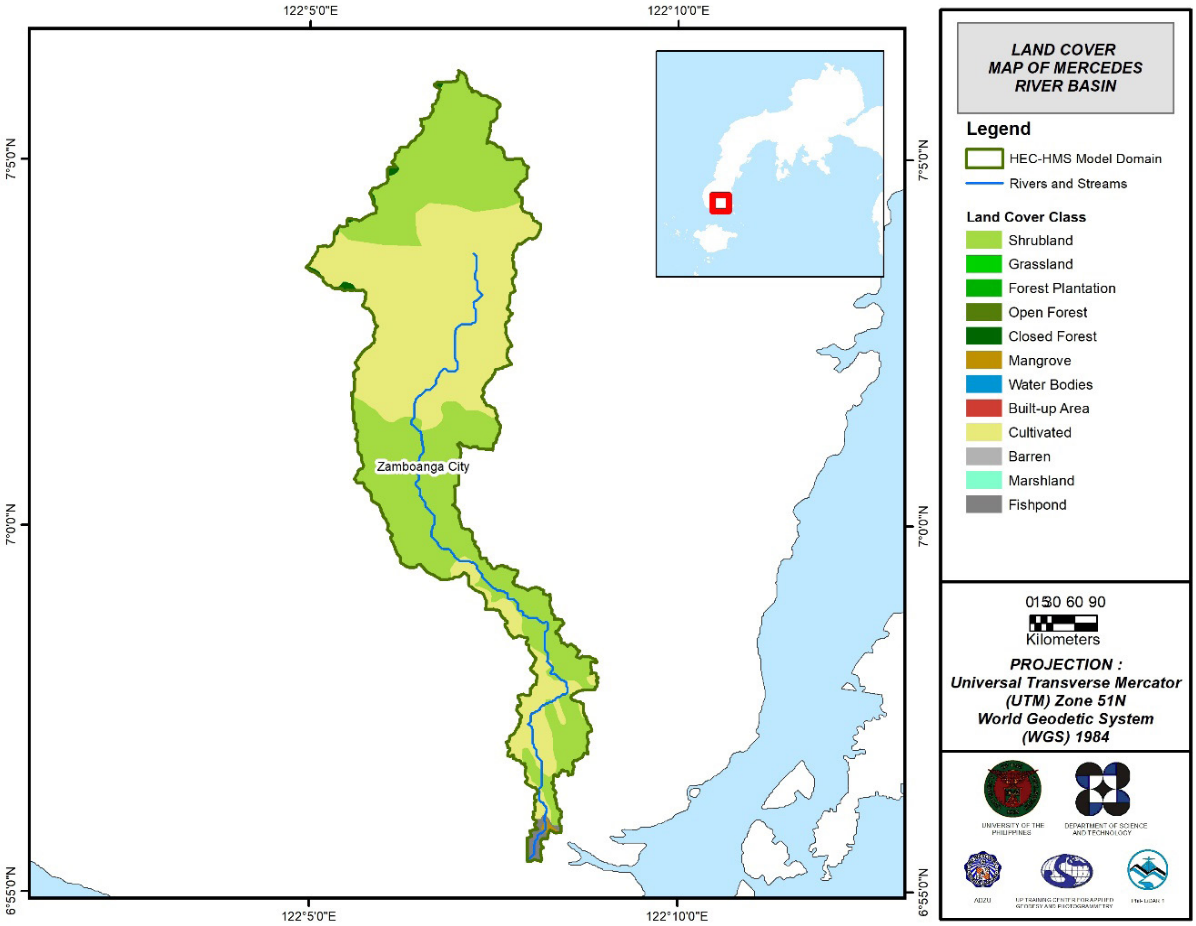


Figure 56. Land Cover Map of Mercedes River Basin (Source: NAMRIA)

For Mercedes, the soil classes identified were loam, clay, clay loam, hydrosols, and mountain soil. The land cover types identified were mangrove forests, grassland, cultivated areas, fishponds and closed canopy forests.

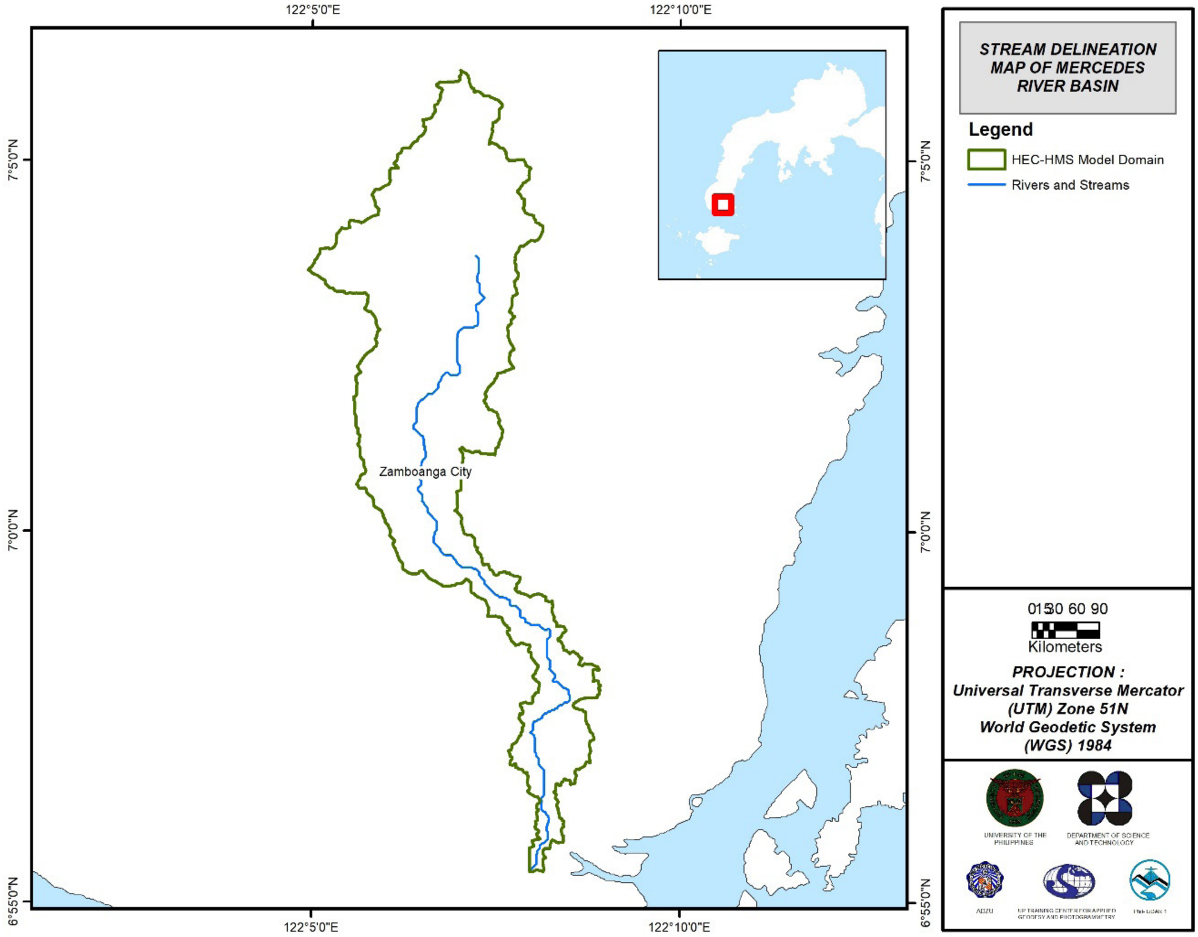


Figure 57. Stream Delineation Map of Mercedes River Basin

Using the SAR-based DEM, the Mercedes basin was delineated and further subdivided into subbasins. The model consists of 53 sub basins, 26 reaches, and 26 junctions as shown in Figure 58. The main outlet is at Culianan Bridge.

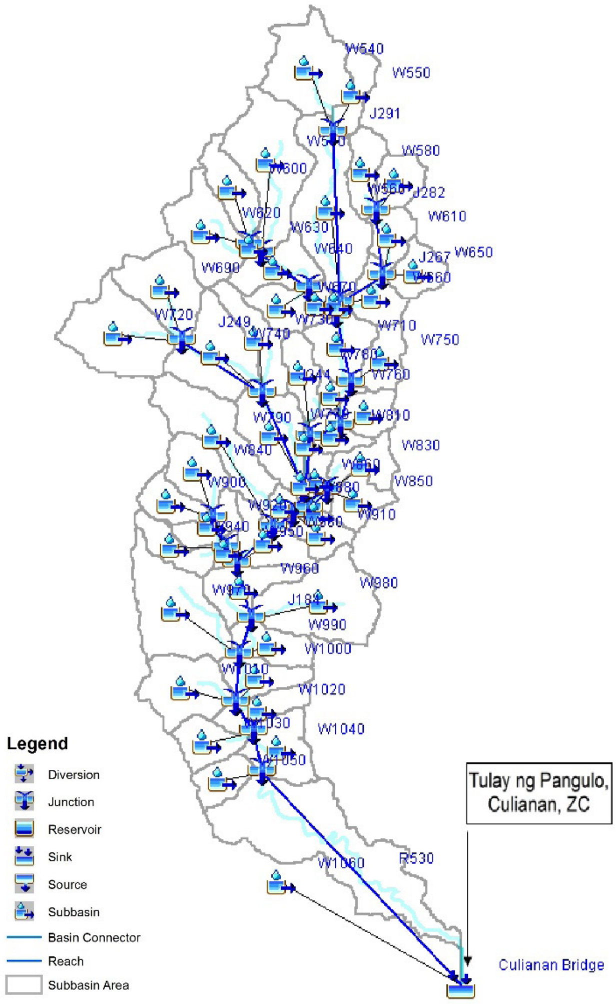


Figure 58. The Mercedes river basin model generated using HEC-HMS

5.4 Cross-section Data

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

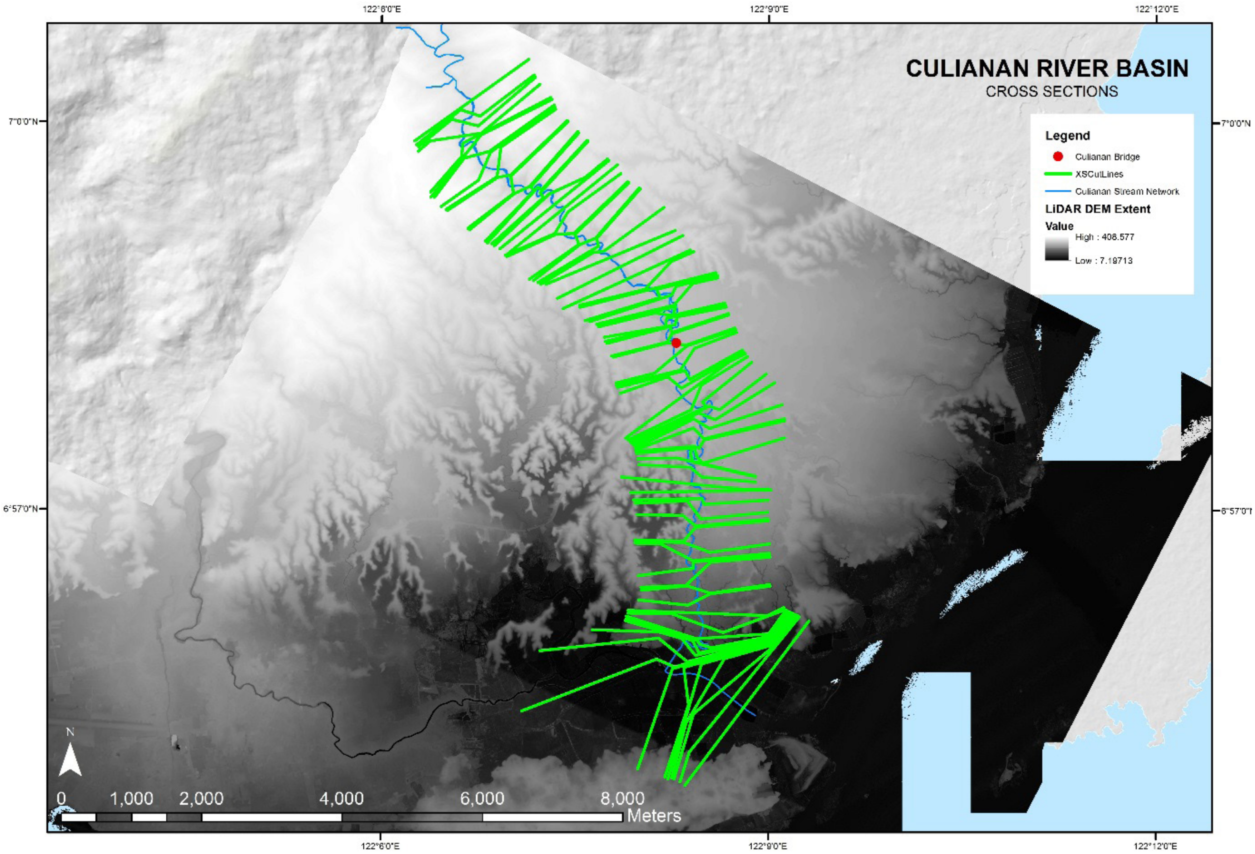


Figure 59. River cross-section of Mercedes River generated through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

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

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

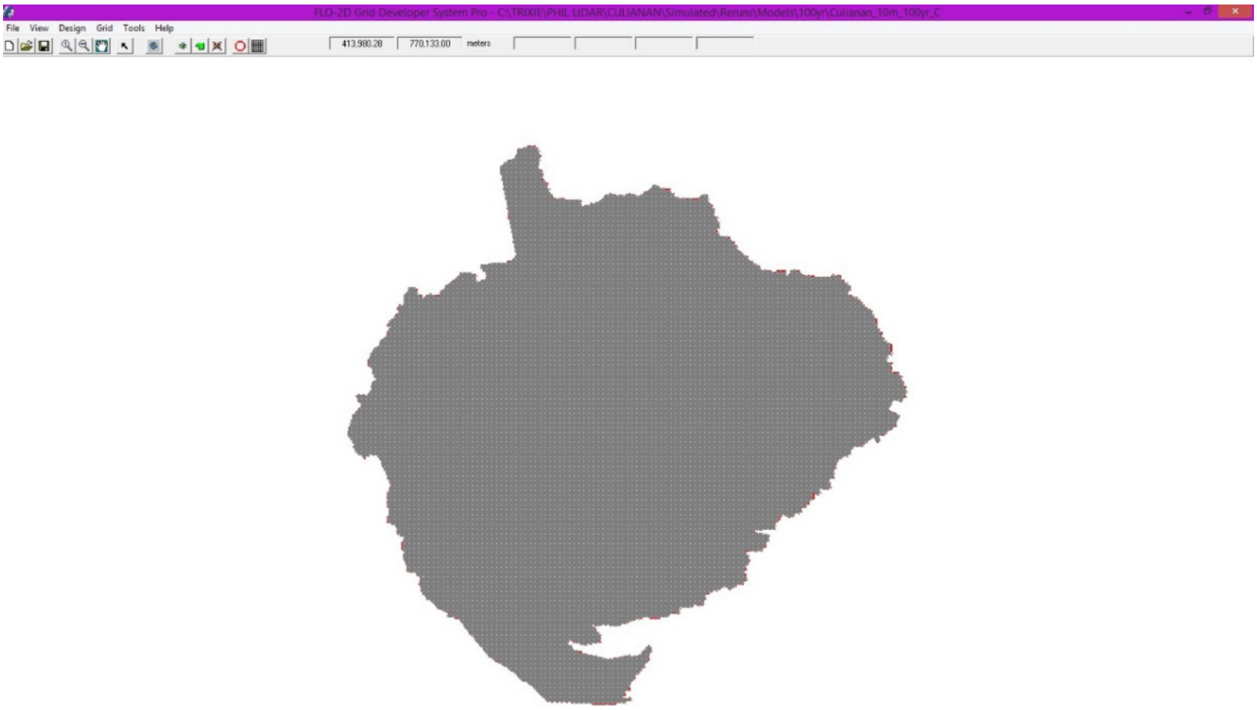


Figure 60. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 15.90259 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 flood hazard map (Figure 61). 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 sq.m./s.

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element (Figure 62). 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 23 180 200.00 sq. m.

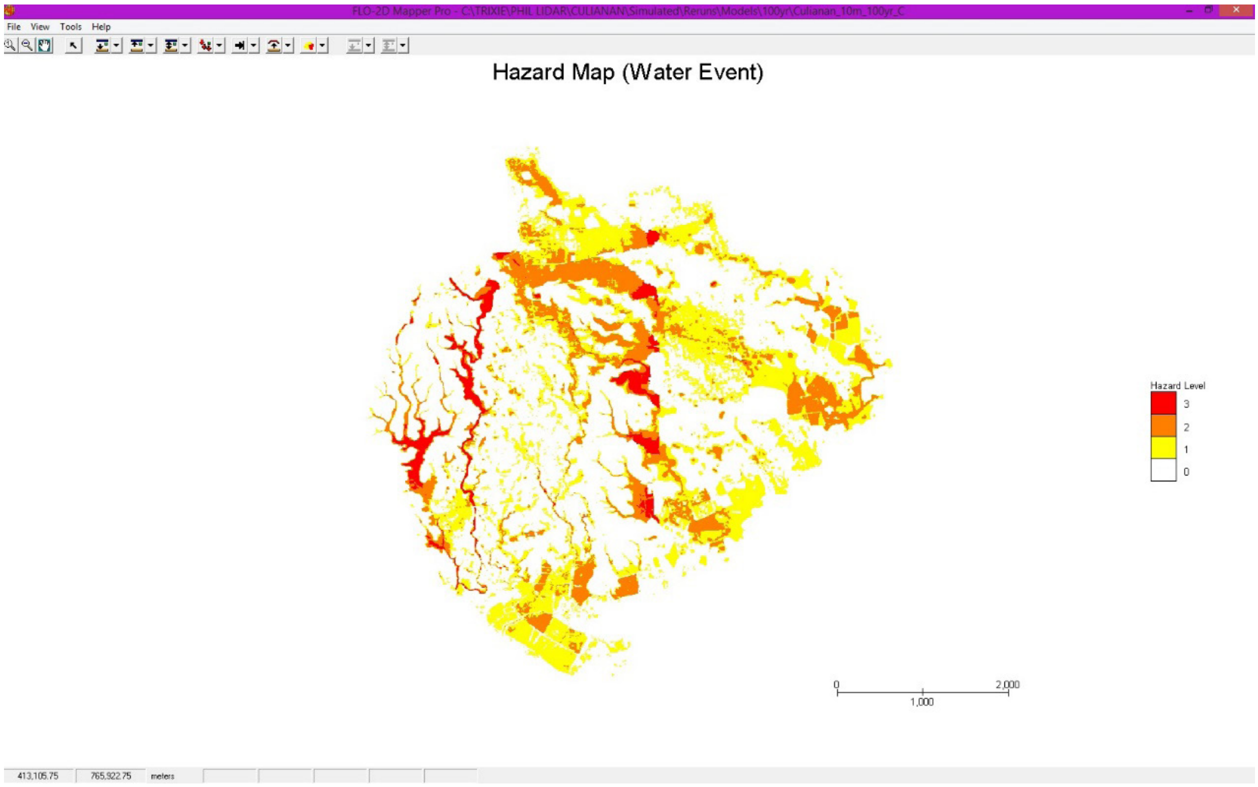


Figure 61. Generated 100-year rain return hazard map from FLO-2D Mapper

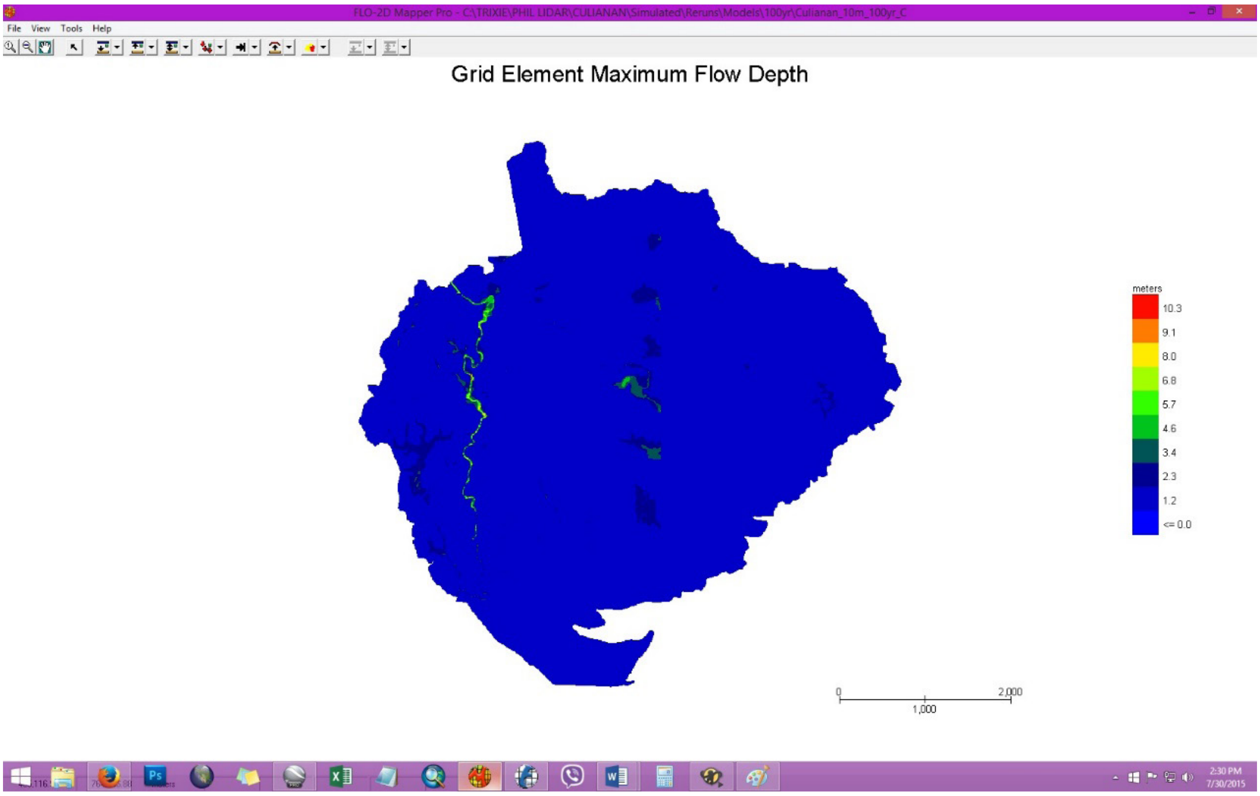


Figure 62. Generated 100-year rain return flow depth map from FLO-2D Mapper

There is a total of 8 609 872.07 cu.m. of water entering the model. Of this amount, 4 390 784.43 cu.m. is due to rainfall while 4 219 087.65 m3 is inflow from other areas outside the model. 2 476 688.75 cu.m. of this water is lost to infiltration and interception, while 2 389 605.22 cu.m. is stored by the floodplain. The rest, amounting up to 3 743 578.46 cu. m., is outflow.

5.6 Results of HMS Calibration

After calibrating the Mercedes HEC-HMS river basin model (see Annex 8: Mercedes Model Basin Parameters), its accuracy was measured against the observed values. Figure 63 shows the comparison between the two discharge data.

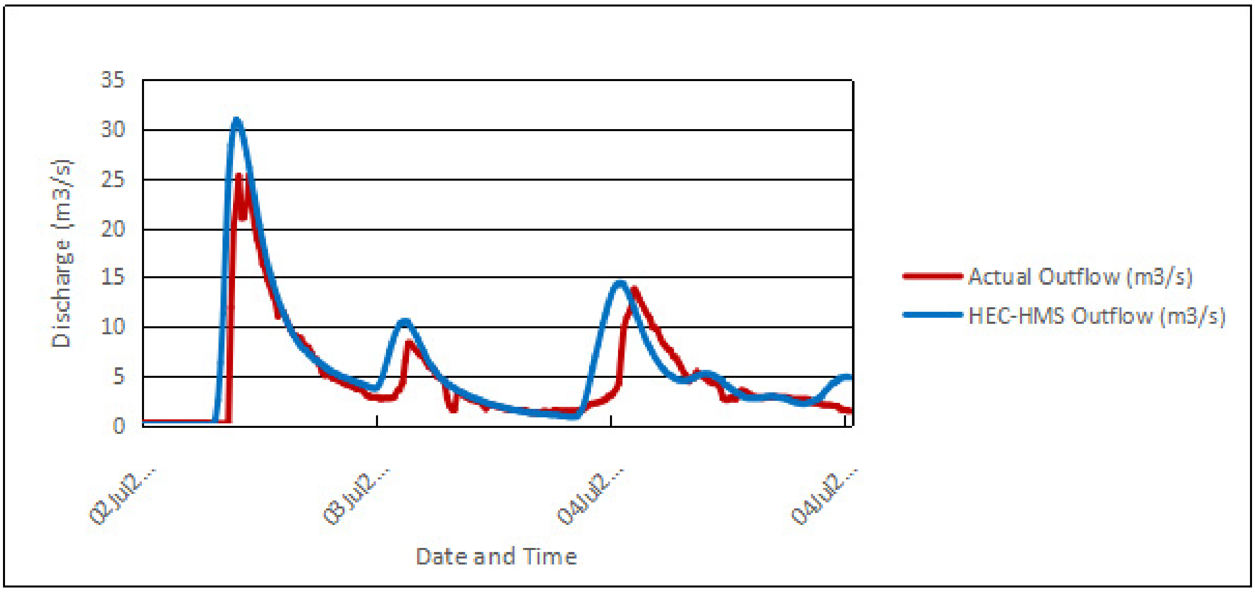


Figure 63. Outflow Hydrograph of Mercedes produced by the HEC-HMS model compared with observed outflow

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

Table 30. Range of Calibrated Values for Mercedes

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	25.98 – 99.80
			Curve Number	60 – 98
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	1.24 – 33.24
			Storage Coefficient (hr)	0.02 – 0.61
	Baseflow	Recession	Recession Constant	0.02 – 0.09
			Ratio to Peak	0.3
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.06 – 3211.50

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 25.98mm to 99.80mm means that there is a large 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 60 to 98 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For Mercedes, the basin mostly consists of cultivated areas and brushlands and the soil consists of loam and clay.

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 1.24 hours to 33.24 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.02 to 0.09 indicates that the basin is moderately likely to quickly go back to its original discharge. Ratio to peak of 0.3 indicates a steeper receding limb of the outflow hydrograph.

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

Accuracy measure	Value
RMSE	23.078995
r2	0.8145
NSE	0.59
PBIAS	-24.98
RSR	0.64

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 23.078995 (m3/s).

The Pearson correlation coefficient (r2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.8145.

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 0.59.

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 -24.98.

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 0.64.

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 64) shows the Mercedes outflow using the Zamboanga City Rainfall Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAG-ASA) data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

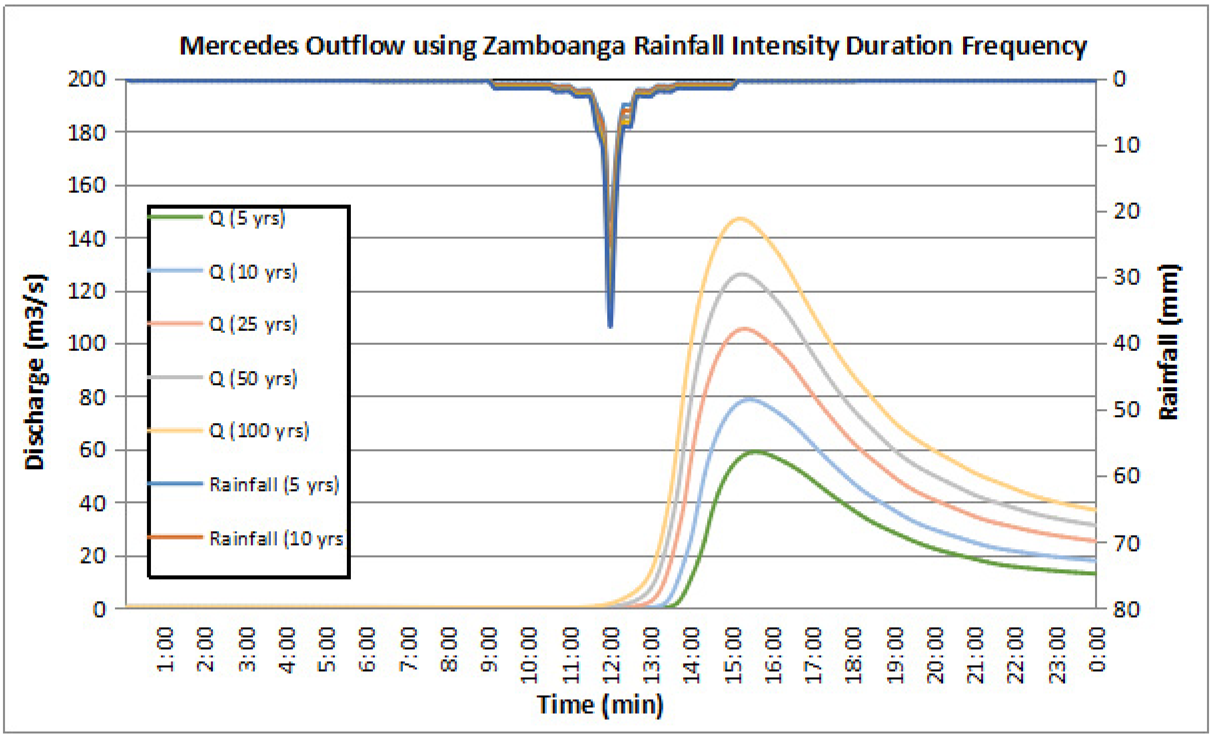


Figure 64. Outflow hydrograph at Mercedes Station generated using Zamboanga City RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Mercedes discharge using the Zamboanga City Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 32.

Table 32. Peak values of the Mercedes HECHMS Model outflow using the Zamboanga City RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	107.80	21.40	58.80	3 hours, 40 minutes
10-Year	127.90	25.30	78.60	3 hours, 30 minutes
25-Year	153.40	30.20	105.20	3 hours, 20 minutes
50-Year	172.30	33.90	125.8	3 hours, 20 minutes
100-Year	191.10	37.50	146.8	3 hours, 10 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. The sample generated map of Mercedes River using the calibrated HMS base flow is shown in Figure 65.

Figure 65. Sample output of Mercedes RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figure 66 to Figure 71 shows the 5-, 25-, and 100-year rain return scenarios of the Mercedes floodplain. The floodplain, with an area of 23.22 sq. km., covers the Zamboanga City. Table 33 shows the percentage of area affected by flooding per municipality.

Table 33. Municipalities affected in Mercedes Floodplain

Municipality	Total Area	Area Flooded	% Flooded
Zamboanga City	146.29	21.77	15%

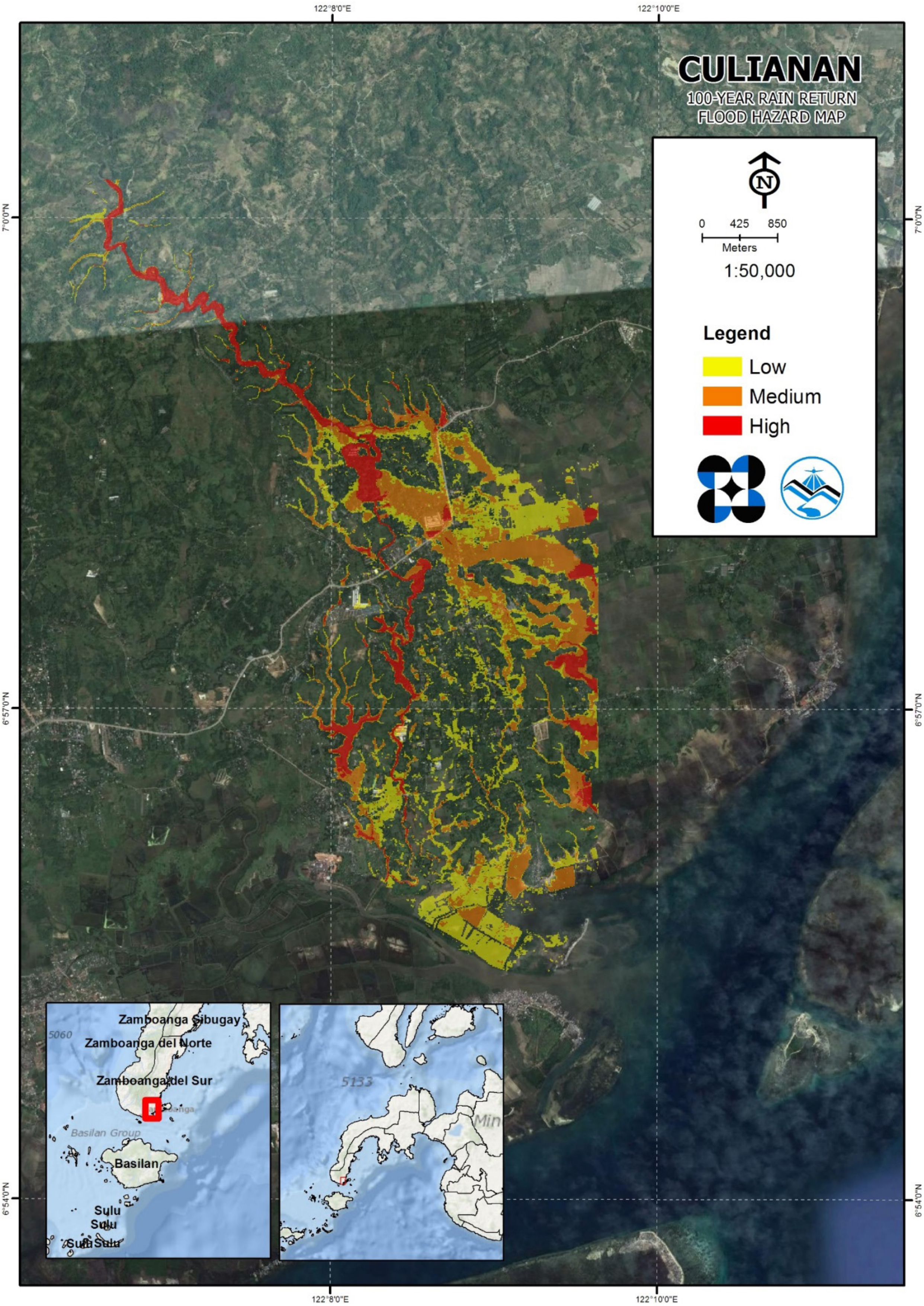


Figure 66. 100-year Flood Hazard Map for Mercedes (also known as Culianan) Floodplain

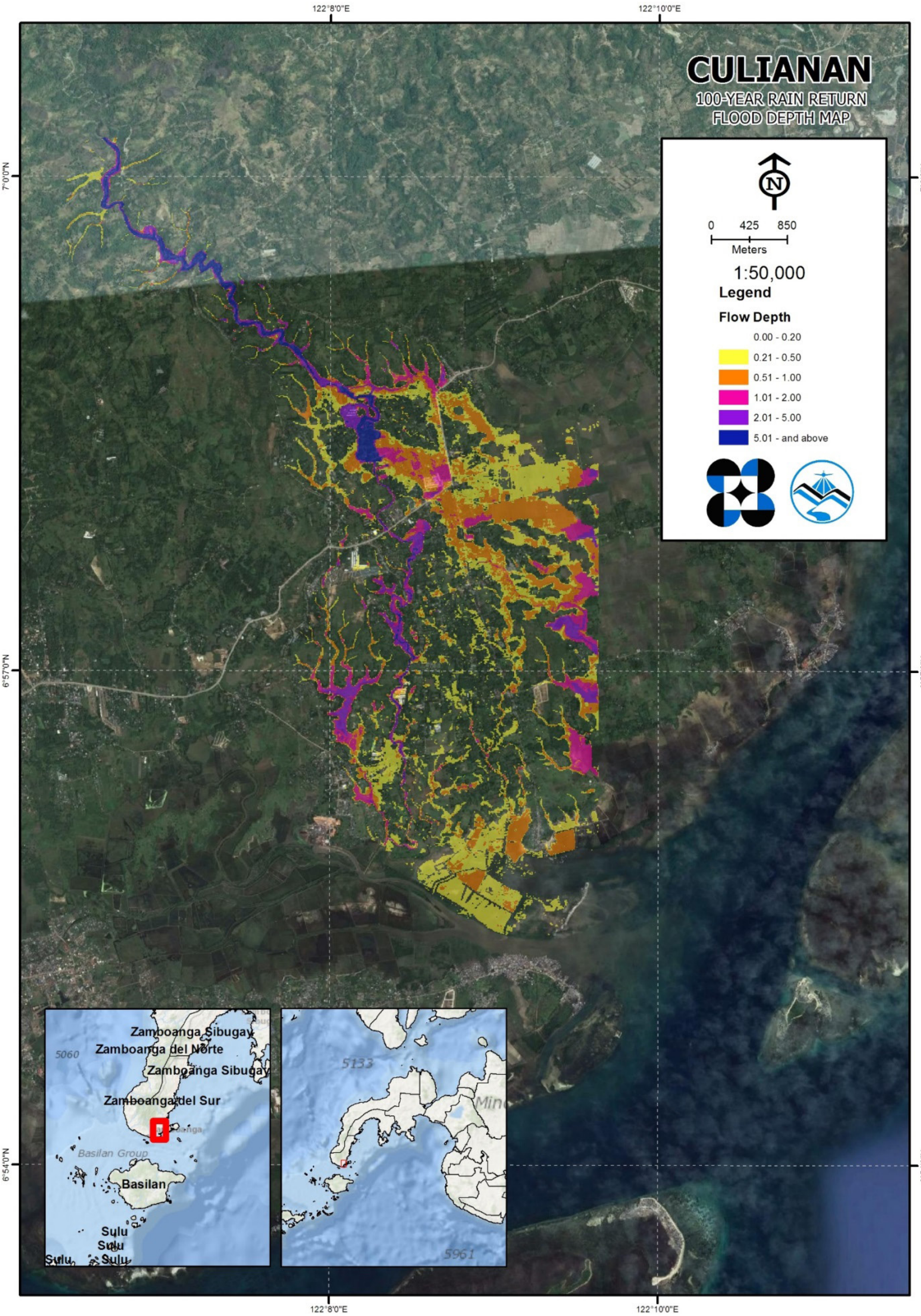


Figure 67. 100-year Flow Depth Map for Mercedes (also known as Culianan) Floodplain

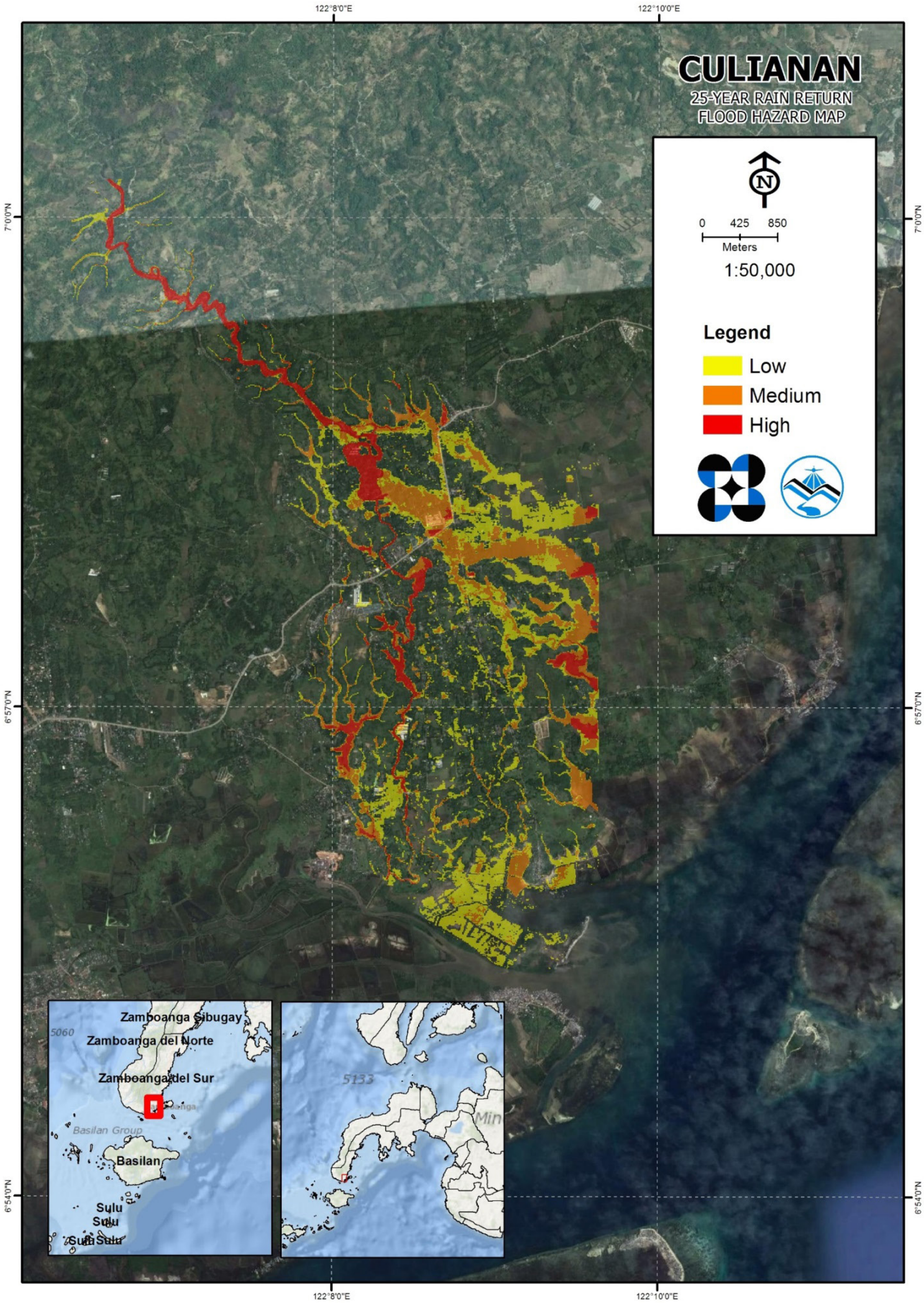


Figure 68. 25-year Flood Hazard Map for Mercedes (also known as Culianan) Floodplain

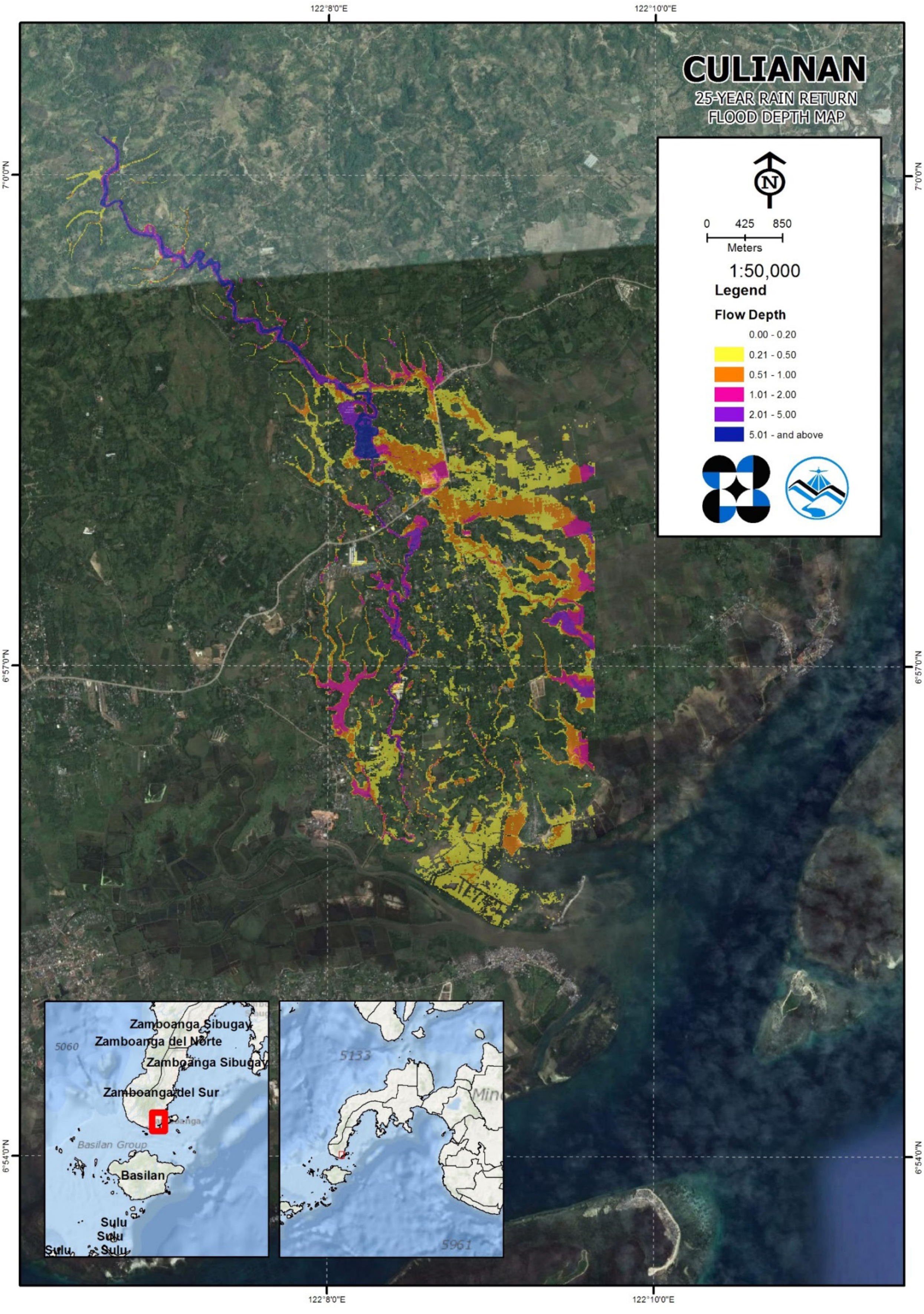


Figure 69. 25-year Flow Depth Map for Mercedes (also known as Culianan) Floodplain

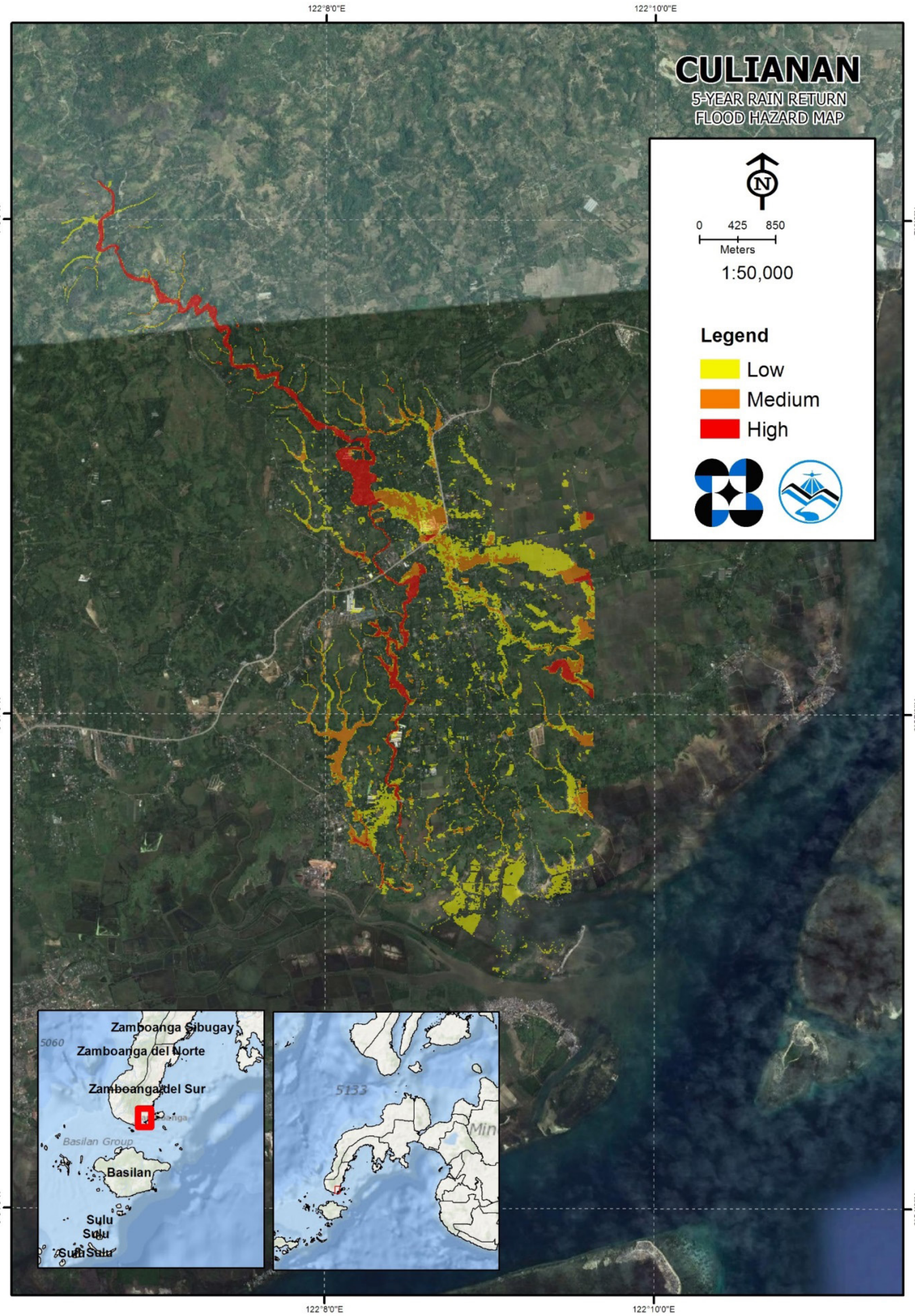


Figure 70. 5-year Flood Hazard Map for Mercedes (also known as Culianan) Floodplain

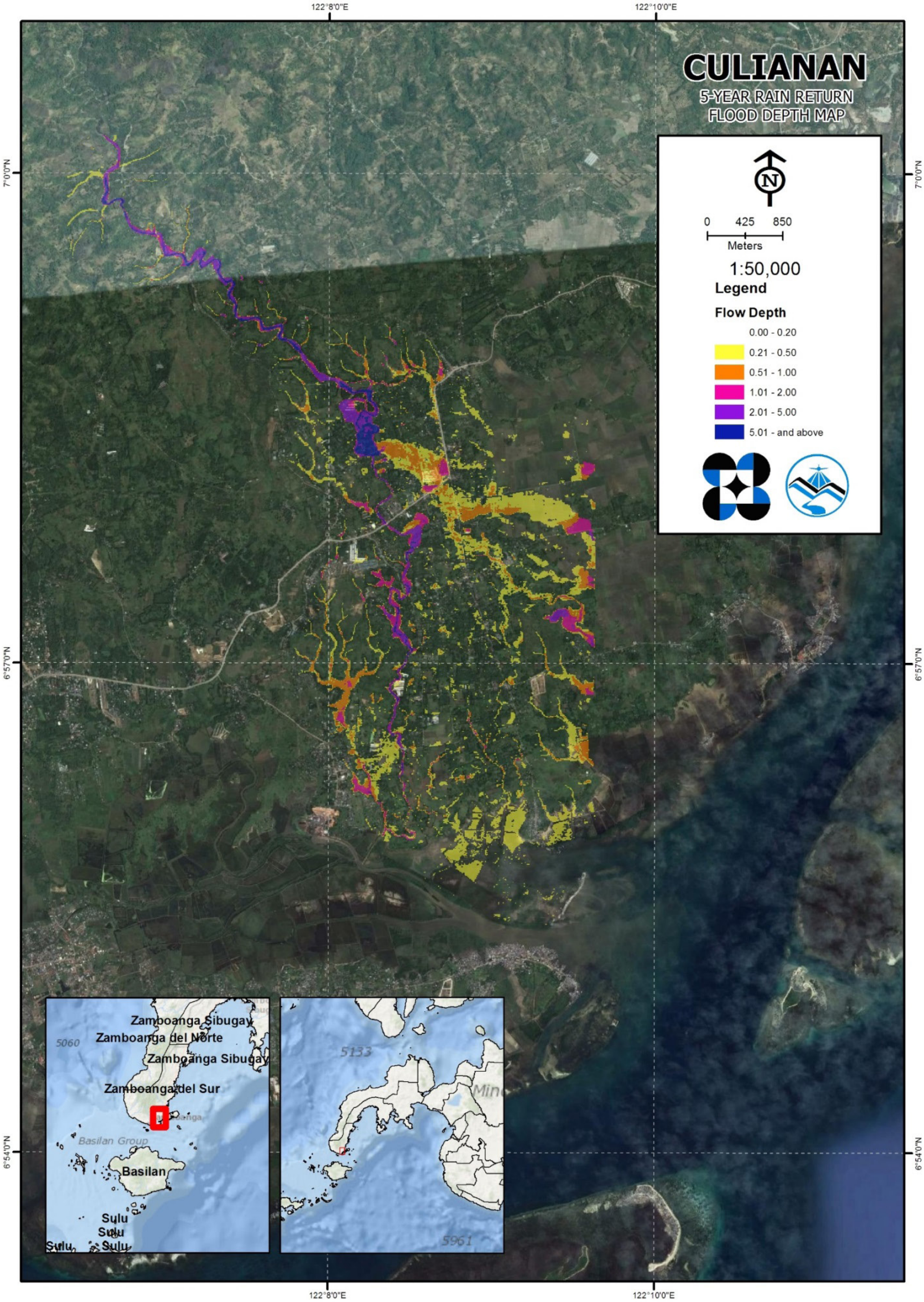


Figure 71. 5-year Flow Depth Map for Mercedes (also known as Culianan) Floodplain

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Mercedes river basin in Zamboanga City are listed below. For the said basin, 10 barangays are expected to experience flooding when subjected to to the three rainfall events.

For the 5-year return period, 1.36% of Zamboanga City with an area of 1496.293 sq. km. will experience flood levels of less than 0.20 meters. 0.16% of the area will experience flood levels of 0.21 to 0.50 meters while 0.07%, 0.03%, 0.03%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 34 are the affected areas in square kilometers by flood depth per barangay.

Table 34. Affected Areas in Zamboanga City during 5-Year Rainfall Return Period

Affected Areas (in sq. km.) by flood depth (in m.)	Affected Barangays in Zamboanga City									
	Arena Blan-co	Culianan	Lanzones	Lumayang	Lumbangan	Mercedes	Pasobolong	Salaan	Talabaan	Zambowood
< 0.21	1.3	0.44	0.81	1.28	0.047	6.69	1.35	3.57	0.0065	2.39
0.21 - 0.50	0.21	0.041	0.016	0.056	0.0011	1.11	0.17	0.27	0	0.26
0.51 - 1.00	0.0016	0.013	0.0078	0.011	0	0.33	0.07	0.18	0	0.19
1.01 - 2.00	0.0015	0.017	0.0085	0.013	0	0.14	0.025	0.084	0	0.096
2.01 - 5.00	0.00073	0	0.024	0.038	0	0.089	0.00048	0.19	0	0.037
> 5.00	0	0	0.0061	0.017	0	0.01	0	0.14	0	0.0064

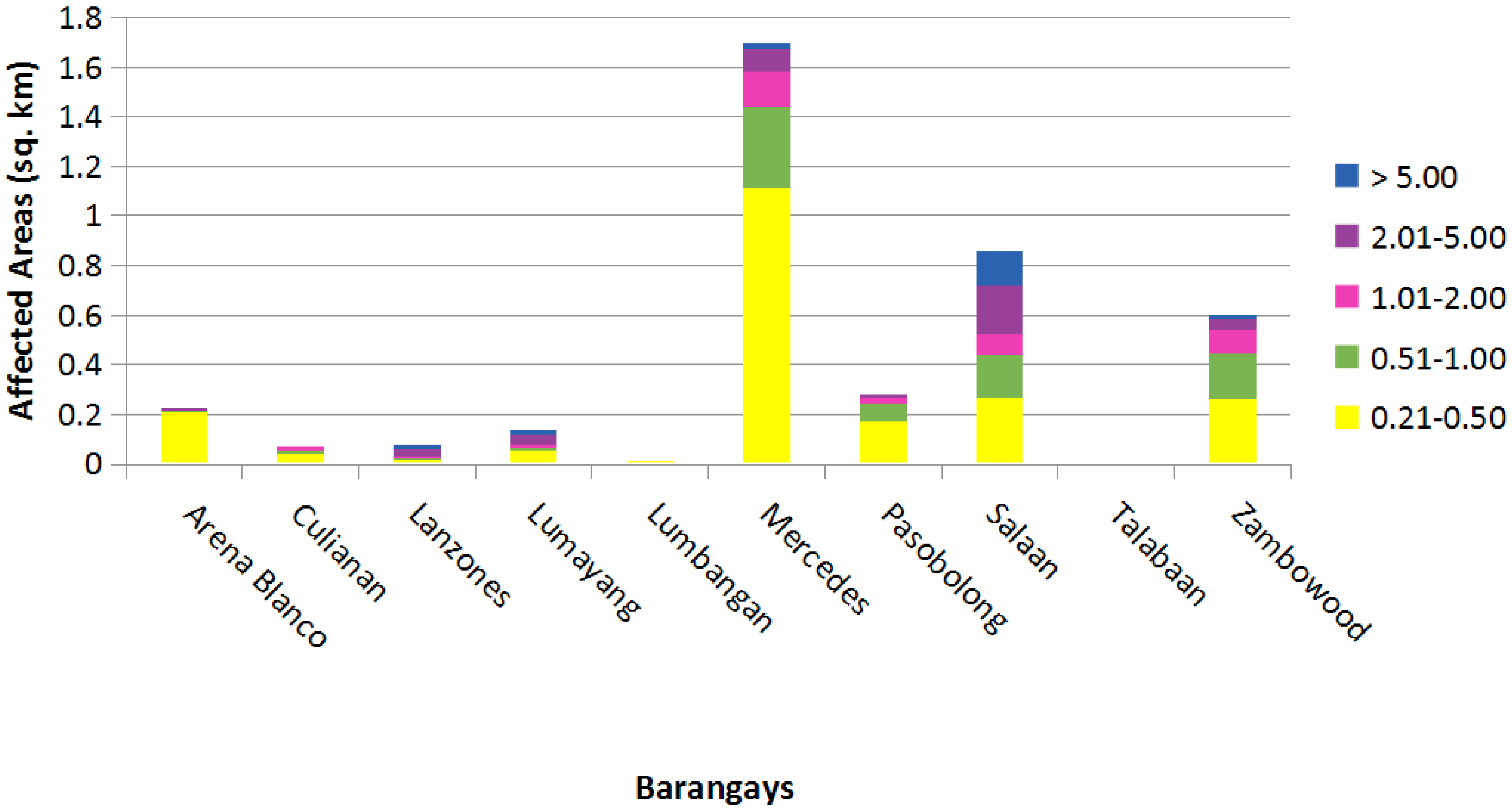


Figure 72. Affected Areas in Zamboanga City during 5-Year Rainfall Return Period

For the 25-year return period, 1.20% of Zamboanga City with an area of 1496.293 sq. km. will experience flood levels of less than 0.20 meters. 0.22% of the area will experience flood levels of 0.21 to 0.50 meters while 0.12%, 0.06%, 0.03%, and 0.02% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 35. Affected Areas in Zamboanga City during 25-Year Rainfall Return Period

Affected Areas (in sq. km.) by flood depth (in m.)	Affected Barangays in Zamboanga City									
	Arena Blanco	Culianan	Lanzones	Lumayang	Lumbangan	Mercedes	Pasobolong	Salaan	Talabaan	Zambowood
< 0.21	0.92	0.28	0.8	1.24	0.047	5.92	0.93	3.23	0.0065	2.27
0.21 - 0.50	0.54	0.17	0.018	0.068	0.0019	1.2	0.47	0.35	0	0.28
0.51 - 1.00	0.059	0.041	0.0092	0.015	0	0.82	0.15	0.31	0	0.17
1.01 - 2.00	0.0014	0.02	0.0073	0.011	0	0.27	0.064	0.13	0	0.2
2.01 - 5.00	0.00091	0.0036	0.023	0.038	0	0.15	0.0043	0.18	0	0.056
> 5.00	0	0	0.021	0.044	0	0.012	0	0.21	0	0.0079

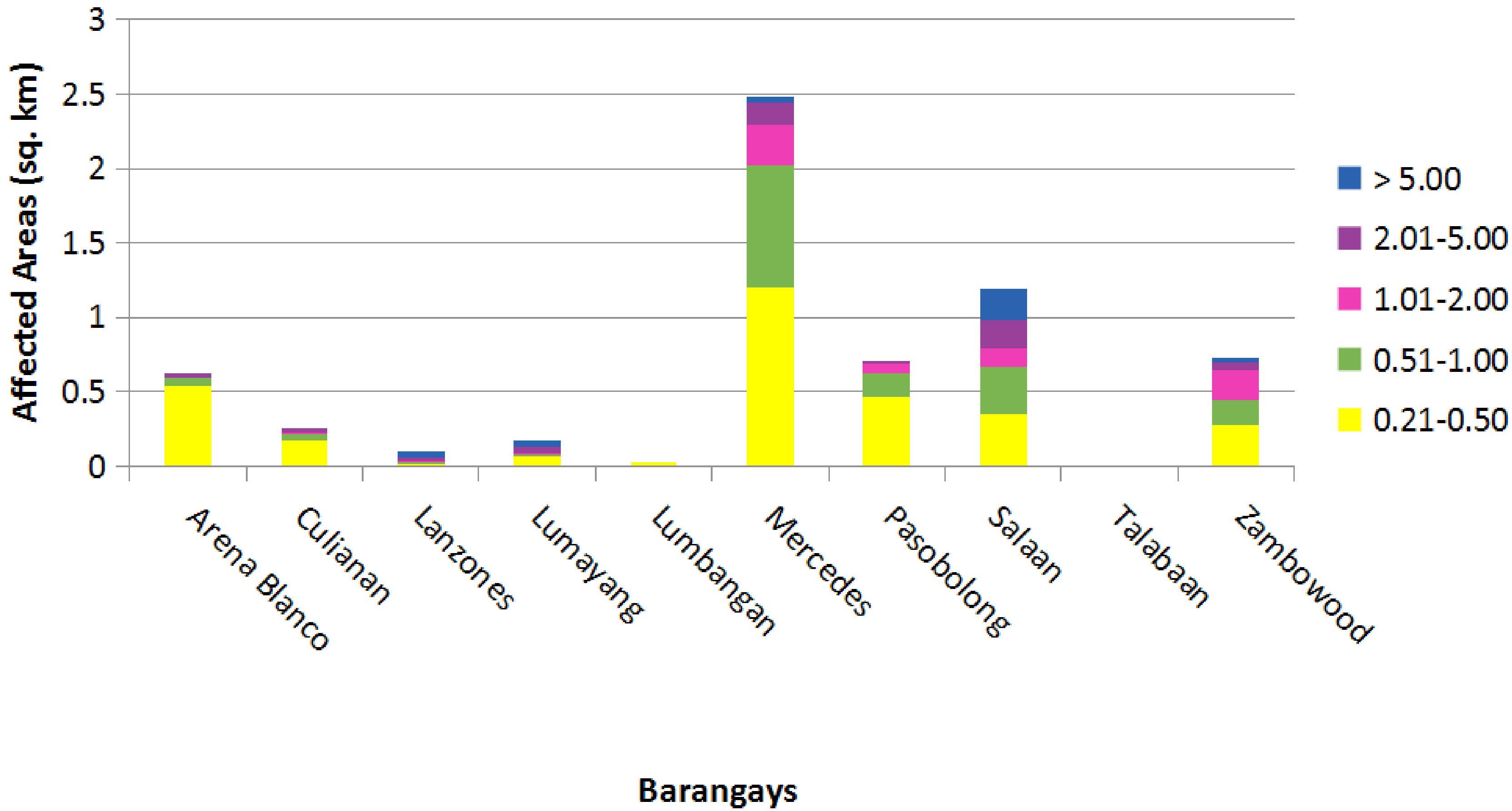


Figure 73. Affected Areas in Zamboanga City during 25-Year Rainfall Return Period

For the 100-year return period, 1.12% of Zamboanga City with an area of 1496.293 sq. km. will experience flood levels of less than 0.20 meters. 0.23% of the area will experience flood levels of 0.21 to 0.50 meters while 0.15%, 0.07%, 0.05%, and 0.03% 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 kilometers by flood depth per barangay.

Table 36. Affected Areas in Zamboanga City during 100-Year Rainfall Return Period

Affected Areas (in sq. km.) by flood depth (in m.)	**Affected Barangays in Zamboanga City**									
	Arena Blanco	Culianan	Lanzones	Lumayang	Lumbangan	Mercedes	Pasobolong	Salaan	Talabaan	Zambowood
< 0.21	0.77	0.22	0.79	1.21	0.046	5.55	0.77	3.06	0.0065	2.18
0.21 - 0.50	0.58	0.17	0.018	0.073	0.0024	1.19	0.5	0.38	0	0.28
0.51 - 1.00	0.17	0.084	0.0094	0.021	0	1.03	0.27	0.38	0	0.17
1.01 - 2.00	0.0014	0.023	0.0053	0.013	0	0.4	0.082	0.18	0	0.19
2.01 - 5.00	0.00097	0.0074	0.017	0.034	0	0.18	0.0081	0.19	0	0.14
> 5.00	0	0	0.04	0.064	0	0.015	0	0.24	0	0.0084

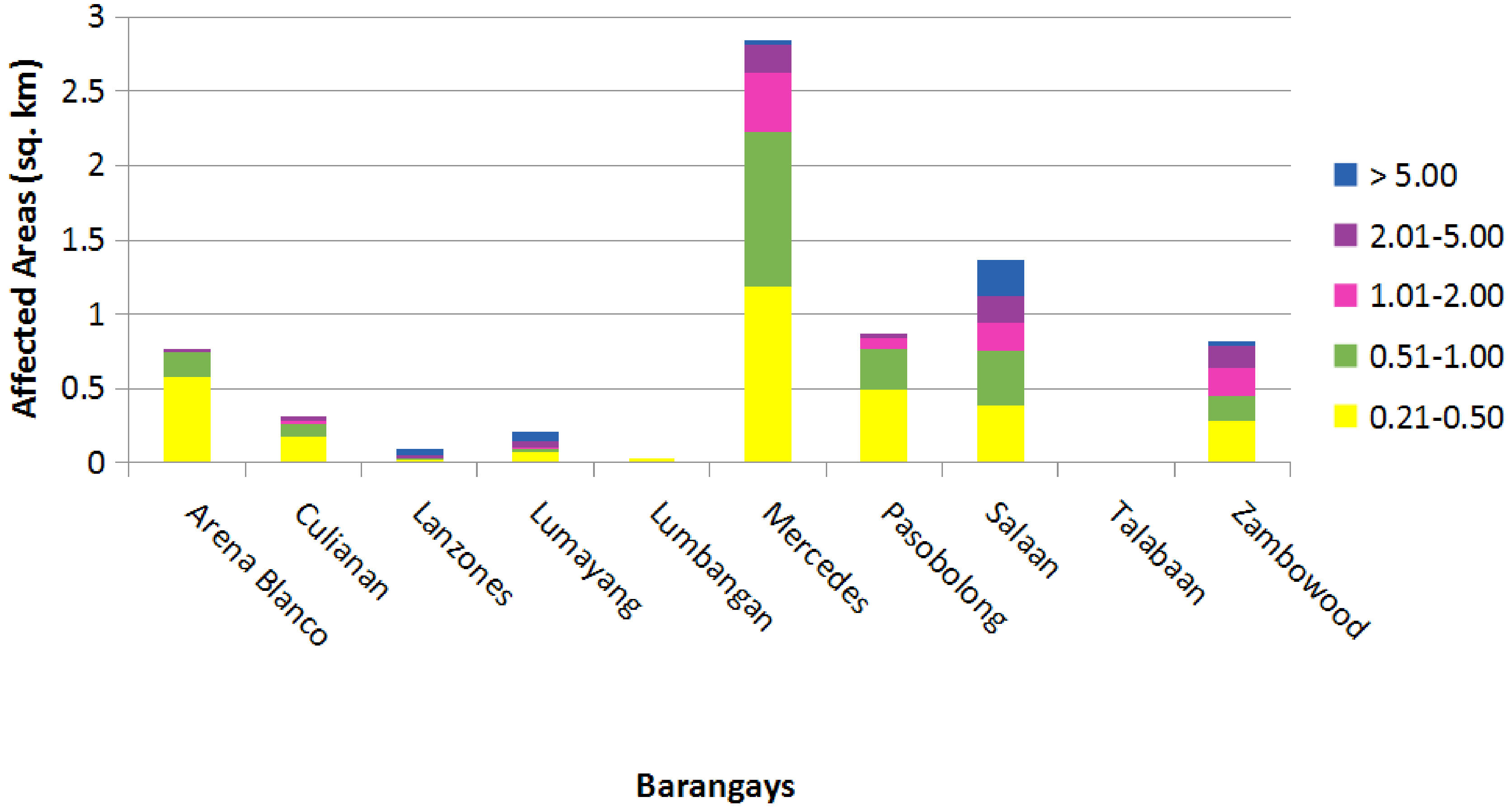


Figure 74. Affected Areas in Zamboanga City during 100-Year Rainfall Return Period

Moreover, the generated flood hazard maps for the Mercedes 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 37. Summary of the Accuracy Assessment in the Mercedes River Basin Survey

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	3.73	5.96	6.48
Medium	1.53	3.02	4.18
High	1.41	1.98	2.33
Total	6.67	10.96	12.99

Of the 14 identified Education Institutes in Mercedes floodplain, 1 school was assessed to be exposed to the Low level flooding during a 5 year scenario. In the 25 year scenario, 2 schools were assessed to be exposed to the Low level flooding. For the 100 year scenario, 3 schools were assessed for Low level flooding. The educational institutions exposed to flooding in the Mercedes floodplain are found in Annex 12.

Seven (7) Medical Institutions were identified in Mercedes floodplain, none were assessed to be exposed to any of the flood hazard levels at any of the rainfall scenarios.

5.11 Flood Validation

In order to check and validate the extent of flooding in different river systems, a validation survey work was performed. 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 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 and interviews from some residents with knowledge of or have had experienced flooding in a particular area. The flood validation data were obtained on September 24, 2016.

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

The flood validation consists of 128 points randomly selected all over the Mercedes floodplain. It has an RMSE value of 0.70.

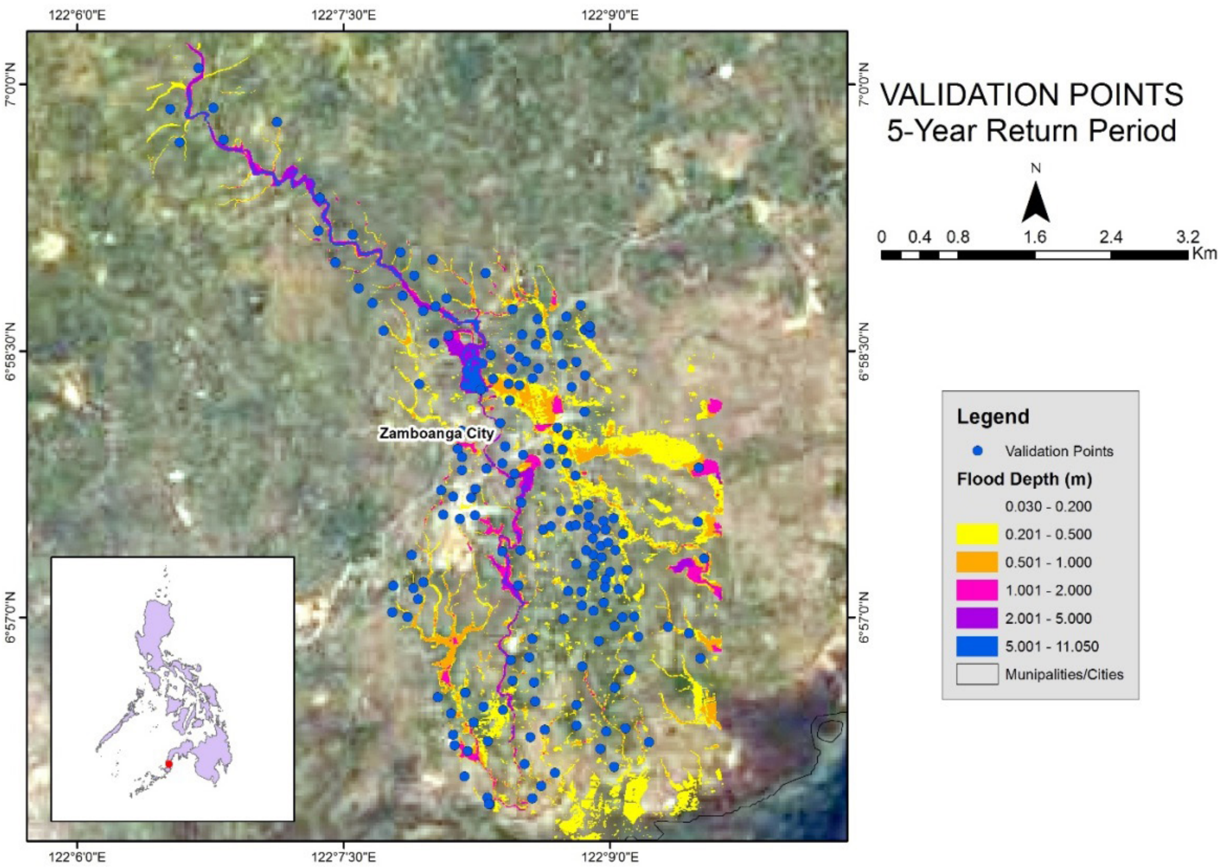


Figure 75. Validation points for 5-year Flood Depth Map of Mercedes Floodplain

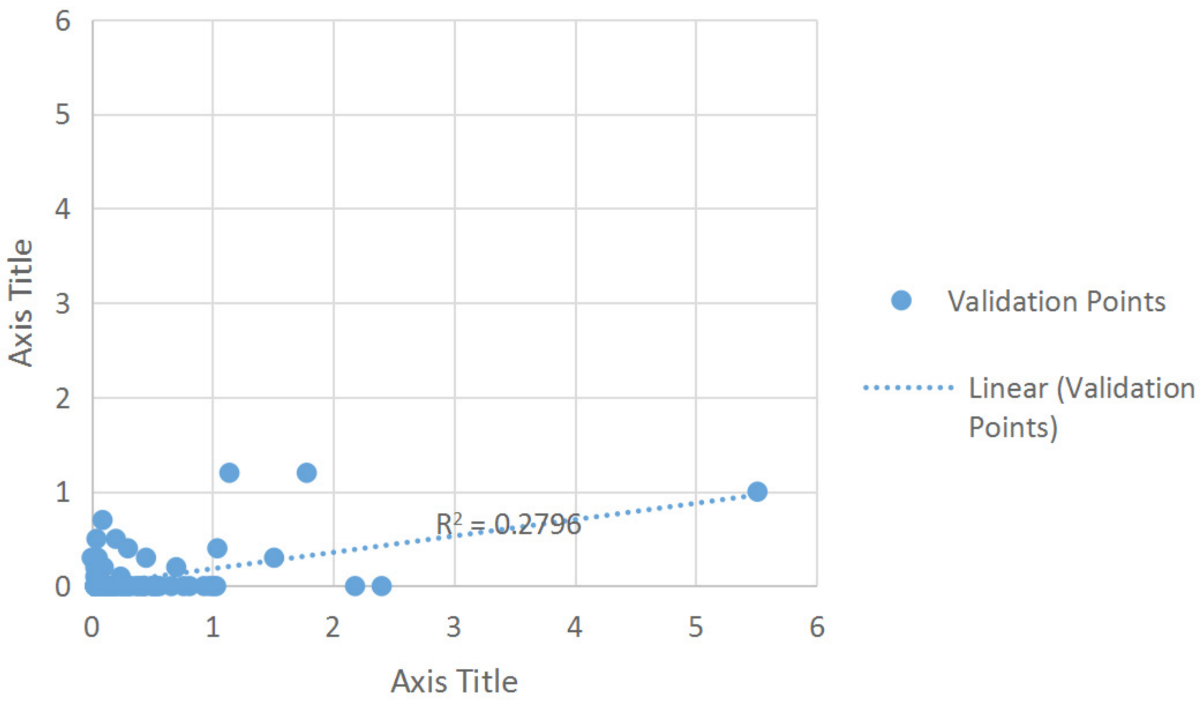


Figure 76. Flood map depth vs actual flood depth

Table 38. Actual Flood Depth vs Simulated Flood Depth in Mercedes

Actual Flood Depth (m)	Modeled Flood Depth (m)						
	0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
0-0.20	30	5	4	0	0	0	39
0.21-0.50	35	7	3	4	1	0	50
0.51-1.00	1	3	11	3	1	0	19
1.01-2.00	0	1	4	3	1	1	10
2.01-5.00	0	0	0	4	6	0	10
> 5.00	0	0	0	0	0	0	0
Total	66	16	22	14	9	1	128

The overall accuracy generated by the flood model is estimated at 44.53%, with 57 points correctly matching the actual flood depths. In addition, there were 55 points estimated one level above and below the correct flood depths while there were 12 points and 1 point estimated two levels above and below, and three or more levels above and below the correct flood. A total of 23 points were overestimated while a total of 48 points were underestimated in the modelled flood depths of Mercedes.

Table 39. Summary of Accuracy Assessment in Mercedes

	No. of Points	%
Correct	73	31.06
Overestimated	25	10.64
Underestimated	137	58.30
Total	235	100

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 Mercedes Floodplain Survey

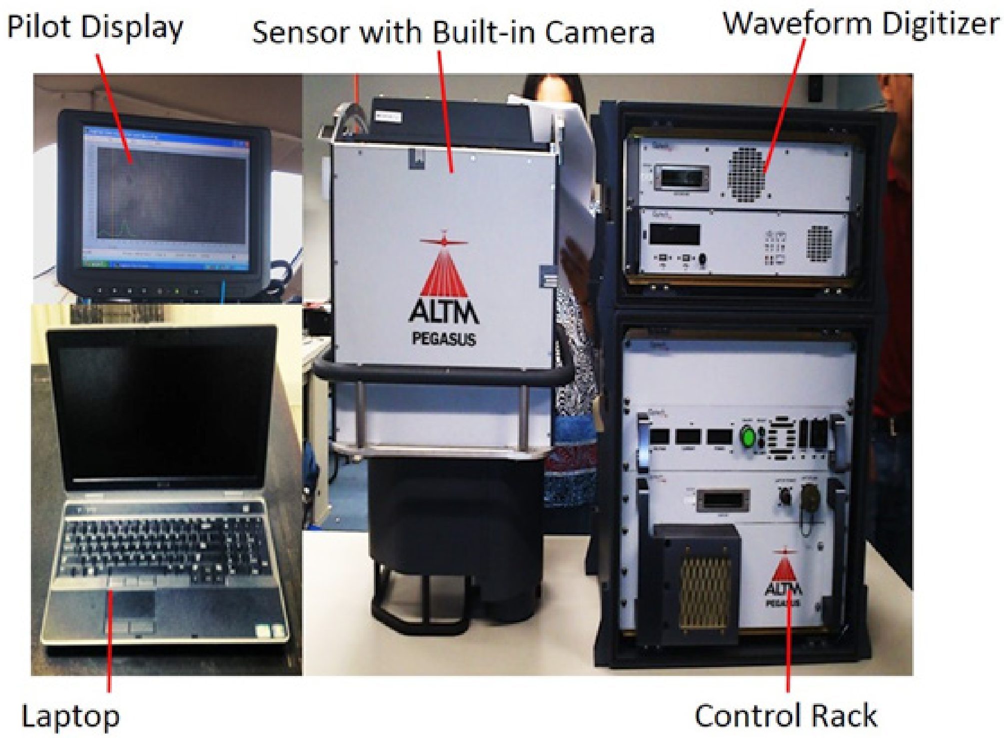


Figure A1. Parameters and Specification of Sensor

Table A1-1. Parameters and Specification of Sensor

Parameter	Specification
Operational envelope (1,2,3,4)	150-5000 m AGL, nominal
Laser wavelength	1064 nm
Horizontal accuracy (2)	1/5,500 x altitude, 1σ
Elevation accuracy (2)	< 5-20 cm, 1σ
Effective laser repetition rate	Programmable, 100-500 kHz
Position and orientation system	POS AV ™AP50 (OEM)
Scan width (FOV)	Programmable, 0-75 ˚
Scan frequency (5)	Programmable, 0-140 Hz (effective)
Sensor scan product	800 maximum
Beam divergence	0.25 mrad (1/e)
Roll compensation	Programmable, ±37˚ (FOV dependent)
Vertical target separation distance	<0.7 m
Range capture	Up to 4 range measurements, including 1st, 2nd, 3rd, and last returns
Intensity capture	Up to 4 intensity returns for each pulse, including last (12 bit)

Image capture	5 MP interline camera (standard); 60 MP full frame (optional)
Full waveform capture	12-bit Optech IWD-2 Intelligent Waveform Digitizer
Data storage	Removable solid state disk SSD (SATA II)
Power requirements	28 V, 800 W, 30 A
Dimensions and weight	Sensor: 630 x 540 x 450 mm; 65 kg;
	Control rack: 650 x 590 x 490 mm; 46 kg
Operating Temperature	-10°C to +35°C
Relative humidity	0-95% non-condensing

1 Target reflectivity ≥20%

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

3 Angle of incidence ≤20°

4 Target size ≥ laser footprint5 Dependent on system configuration

Table A1-2. Parameters and Specifications of the D-8900 Aerial Digital Camera

Parameter	Specification
Camera Head	
Sensor type	60 Mpix full frame CCD, RGB
Sensor format (H x V)	8, 984 x 6, 732 pixels
Pixel size	6µm x 6 µm
Frame rate	1 frame/2 sec.
FMC	Electro-mechanical, driven by piezo technology (patented)
Shutter	Electro-mechanical iris mechanism 1/125 to 1/500++ sec. f-stops: 5.6, 8, 11, 16
Lenses	50 mm/70 mm/120 mm/210 mm
Filter	Color and near-infrared removable filters
Dimensions (H x W x D)	200 x 150 x 120 mm (70 mm lens)
Weight	~4.5 kg (70 mm lens)
Controller Unit	
Computer	Mini-ITX RoHS-compliant small-form-factor embedded computers with AMD TurionTM 64 X2 CPU 4 GB RAM, 4 GB flash disk local storage IEEE 1394 Firewire interface
Removable storage unit	~500 GB solid state drives, 8,000 images
Power consumption	~8 A, 168 W
Dimensions	2U full rack; 88 x 448 x 493 mm
Weight	~15 kg
Image Pre-Processing Software	
Capture One	Radiometric control and format conversion, TIFF or JPEG
Image output	8,984 x 6,732 pixels 8 or 16 bits per channel (180 MB or 360 MB per image)

Annex 2. NAMRIA Certificates of Reference Points used in the LIDAR Survey

1. ZGS-100

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: **ZAMBOANGA DEL SUR**
Station Name: **ZGS-100**
Order: **2nd**

Island: **MINDANAO** | Barangay: **MANICAHAN**
Municipality: **ZAMBOANGA CITY** | MSL Elevation:

PRS92 Coordinates

Latitude:	**7° 1' 26.72368"**	Longitude:	**122° 11' 12.74401"**	Ellipsoidal Hgt:	**11.27000 m.**

WGS84 Coordinates

Latitude:	**7° 1' 23.30149"**	Longitude:	**122° 11' 18.30044"**	Ellipsoidal Hgt:	**75.60300 m.**

PTM / PRS92 Coordinates

Northing:	**776712.542 m.**	Easting:	**410158.521 m.**	Zone:	**4**

UTM / PRS92 Coordinates

Northing:	**776,440.68**	Easting:	**410,189.97**	Zone:	**51**

Location Description

The station is marked by an 4" copper nail with its head flushed at the center of an cement putty on a concrete open canal with inscription " ZGS-100, 2009 NAMRIA".Located at Manicahan Barangay Hal 7 meters South from the flag pole 7 meters km post 1916-ZC22

Requesting Party: **ENGR. CHRISTOPHER CRUZ**
Purpose: **Reference**
OR Number: **8799780 A**
T.N.: **2014-1902**

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

9 9 0 8 2 9 2 0 1 4 1 5 4 2 2 5

CIP/4701/12/09/814

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 A2-1. ZGS-100

2. ZGS-99

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: **ZAMBOANGA DEL SUR**
Station Name: **ZGS-99**
Order: **2nd**

Island: **MINDANAO**		Barangay: **CALARIAN**			
Municipality: **ZAMBOANGA CITY**		MSL Elevation:			
		PRS92 Coordinates			
Latitude:	**6° 55' 37.48971"**	Longitude:	**122° 0' 52.66431"**	Ellipsoidal Hgt:	**8.14900 m.**
		WGS84 Coordinates			
Latitude:	**6° 55' 34.07737"**	Longitude:	**122° 0' 58.23072"**	Ellipsoidal Hgt:	**72.23000 m.**
		PTM / PRS92 Coordinates			
Northing:	**766020.391 m.**	Easting:	**391103.346 m.**	Zone:	**4**
		UTM / PRS92 Coordinates			
Northing:	**765,752.27**	Easting:	**391,141.46**	Zone:	**51**

Location Description

ZGS-99

The station is located beside a seawall, 10 m from the centerline and 50 m from the Airforce Beach, in Brgy. Upper Calarian. It is marked by a 4" copper nail flushed at the center of a cement putty on a concrete open canal with inscriptions " ZGS-99, 2009, NAMRIA".

Requesting Party: **ENGR. CHRISTOPHER CRUZ**
Purpose: **Reference**
OR Number: **8799780 A**
T.N.: **2014-1901**

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 A2-1. ZGS-99

Annex 3. Base Processing Report of Control Points used in the LIDAR Survey

1. ZS-131

Vector Components (Mark to Mark)

From:	ZGS-100				
Grid		Local		Global	
Easting	410189.967 m	Latitude	N7°01'26.72367"	Latitude	N7°01'23.30149"
Northing	776440.678 m	Longitude	E122°11'12.74401"	Longitude	E122°11'18.30044"
Elevation	7.745 m	Height	11.271 m	Height	75.603 m

To:	ZS-131				
Grid		Local		Global	
Easting	414826.524 m	Latitude	N7°12'31.41328"	Latitude	N7°12'27.94616"
Northing	796844.403 m	Longitude	E122°13'42.74840"	Longitude	E122°13'48.28765"
Elevation	7.052 m	Height	10.811 m	Height	74.904 m

Vector					
ΔEasting	4636.557 m	NS Fwd Azimuth	12°42'06"	ΔX	-2545.750 m
ΔNorthing	20403.725 m	Ellipsoid Dist.	20930.290 m	ΔY	-4593.707 m
ΔElevation	-0.693 m	ΔHeight	-0.460 m	ΔZ	20260.657 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.005 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.008 m
σ ΔElevation	0.009 m	σ ΔHeight	0.009 m	σ ΔZ	0.002 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000227893		
Y	-0.0000323435	0.0000634026	
Z	-0.0000043665	0.0000093098	0.0000024763

Figure A3-1. ZS-131

2. BLLM-166

ZGS 100 - BLLM166 (12:55:14 PM-5:24:39 PM) (S2)

Baseline observation:	ZGS 100 --- BLLM166 (B2)
Processed:	3/5/2015 5:24:48 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.004 m
Vertical precision:	0.017 m
RMS:	0.007 m
Maximum PDOP:	1.981
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	2/5/2015 12:55:34 PM (Local: UTC+8hr)
Processing stop time:	2/5/2015 5:24:39 PM (Local: UTC+8hr)
Processing duration:	04:29:05
Processing interval:	5 seconds

Figure A3-2. BLLM-166

Vector Components (Mark to Mark)

From:	ZGS 100				
Grid		Local		Global	
Easting	410189.967 m	Latitude	N7°01'26.72367"	Latitude	N7°01'23.30149"
Northing	776440.678 m	Longitude	E122°11'12.74401"	Longitude	E122°11'18.30044"
Elevation	7.745 m	Height	11.271 m	Height	75.603 m

To:	BLLM166				
Grid		Local		Global	
Easting	415179.269 m	Latitude	N7°09'33.60926"	Latitude	N7°09'30.15553"
Northing	791383.716 m	Longitude	E122°13'54.54820"	Longitude	E122°14'00.09187"
Elevation	120.669 m	Height	124.333 m	Height	188.527 m

Vector					
ΔEasting	4989.302 m	NS Fwd Azimuth	18°21'47"	ΔX	-3276.482 m
ΔNorthing	14943.038 m	Ellipsoid Dist.	15758.784 m	ΔY	-4113.808 m
ΔElevation	112.923 m	ΔHeight	113.062 m	ΔZ	14855.907 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.005 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.007 m
σ ΔElevation	0.009 m	σ ΔHeight	0.009 m	σ ΔZ	0.002 m

3. ZGS-99A

ZGS-99 - ZGS-99A (9:00:34 AM-1:46:19 PM) (S1)

Baseline observation:	ZGS-99 --- ZGS-99A (B1)
Processed:	3/6/2015 1:27:43 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.001 m
Vertical precision:	0.001 m
RMS:	0.000 m
Maximum PDOP:	4.130
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	2/11/2015 9:00:34 AM (Local: UTC+8hr)
Processing stop time:	2/11/2015 1:46:19 PM (Local: UTC+8hr)
Processing duration:	04:45:45
Processing interval:	5 seconds

1

Figure A3-3. ZGS-99A

Vector Components (Mark to Mark)

From:	ZGS-99				
Grid		Local		Global	
Easting	391141.462 m	Latitude	N6°55'37.48971"	Latitude	N6°55'34.07737"
Northing	765752.270 m	Longitude	E122°00'52.66432"	Longitude	E122°00'58.23072"
Elevation	4.653 m	Height	8.149 m	Height	72.230 m

To:	ZGS-99A				
Grid		Local		Global	
Easting	391136.071 m	Latitude	N6°55'37.63895"	Latitude	N6°55'34.22659"
Northing	765756.864 m	Longitude	E122°00'52.48834"	Longitude	E122°00'58.05475"
Elevation	4.354 m	Height	7.850 m	Height	71.931 m

Vector					
ΔEasting	-5.391 m	NS Fwd Azimuth	310°19'07"	ΔX	5.031 m
ΔNorthing	4.594 m	Ellipsoid Dist.	7.085 m	ΔY	2.144 m
ΔElevation	-0.299 m	ΔHeight	-0.299 m	ΔZ	4.515 m

Standard Errors

Vector errors:					
σ ΔEasting	0.000 m	σ NS fwd Azimuth	0°00'11"	σ ΔX	0.000 m
σ ΔNorthing	0.000 m	σ Ellipsoid Dist.	0.000 m	σ ΔY	0.001 m
σ ΔElevation	0.001 m	σ ΔHeight	0.001 m	σ ΔZ	0.000 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000002239		
Y	-0.0000001250	0.0000004533	
Z	-0.0000000277	0.0000000071	0.0000000770

4. BVA-1

BVA-1 - BVA-2 (2:54:04 PM-5:12:34 PM) (S1)

Baseline observation:	BVA-1 --- BVA-2 (B1)
Processed:	3/6/2015 3:31:41 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.001 m
Vertical precision:	0.002 m
RMS:	0.000 m
Maximum PDOP:	2.093
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	2/6/2015 2:54:04 PM (Local: UTC+8hr)
Processing stop time:	2/6/2015 5:12:34 PM (Local: UTC+8hr)
Processing duration:	02:18:30
Processing interval:	5 seconds

Vector Components (Mark to Mark)

From:	BVA-1				
Grid		**Local**		**Global**	
Easting	418087.142 m	**Latitude**	N7°15'19.31910"	**Latitude**	N7°15'15.84241"
Northing	801995.112 m	**Longitude**	E122°15'28.78739"	**Longitude**	E122°15'34.32212"
Elevation	78.652 m	**Height**	82.446 m	**Height**	146.526 m

To:	BVA-2				
Grid		**Local**		**Global**	
Easting	418085.472 m	**Latitude**	N7°15'19.25198"	**Latitude**	N7°15'15.77529"
Northing	801993.053 m	**Longitude**	E122°15'28.73303"	**Longitude**	E122°15'34.26776"
Elevation	78.729 m	**Height**	82.524 m	**Height**	146.603 m

Vector					
ΔEasting	-1.670 m	**NS Fwd Azimuth**	218°57'49"	**ΔX**	1.230 m
ΔNorthing	-2.059 m	**Ellipsoid Dist.**	2.652 m	**ΔY**	1.175 m
ΔElevation	0.077 m	**ΔHeight**	0.077 m	**ΔZ**	-2.036 m

Standard Errors

Vector errors:					
σ ΔEasting	0.000 m	**σ NS fwd Azimuth**	0°00'28"	**σ ΔX**	0.001 m
σ ΔNorthing	0.000 m	**σ Ellipsoid Dist.**	0.000 m	**σ ΔY**	0.001 m
σ ΔElevation	0.001 m	**σ ΔHeight**	0.001 m	**σ ΔZ**	0.000 m

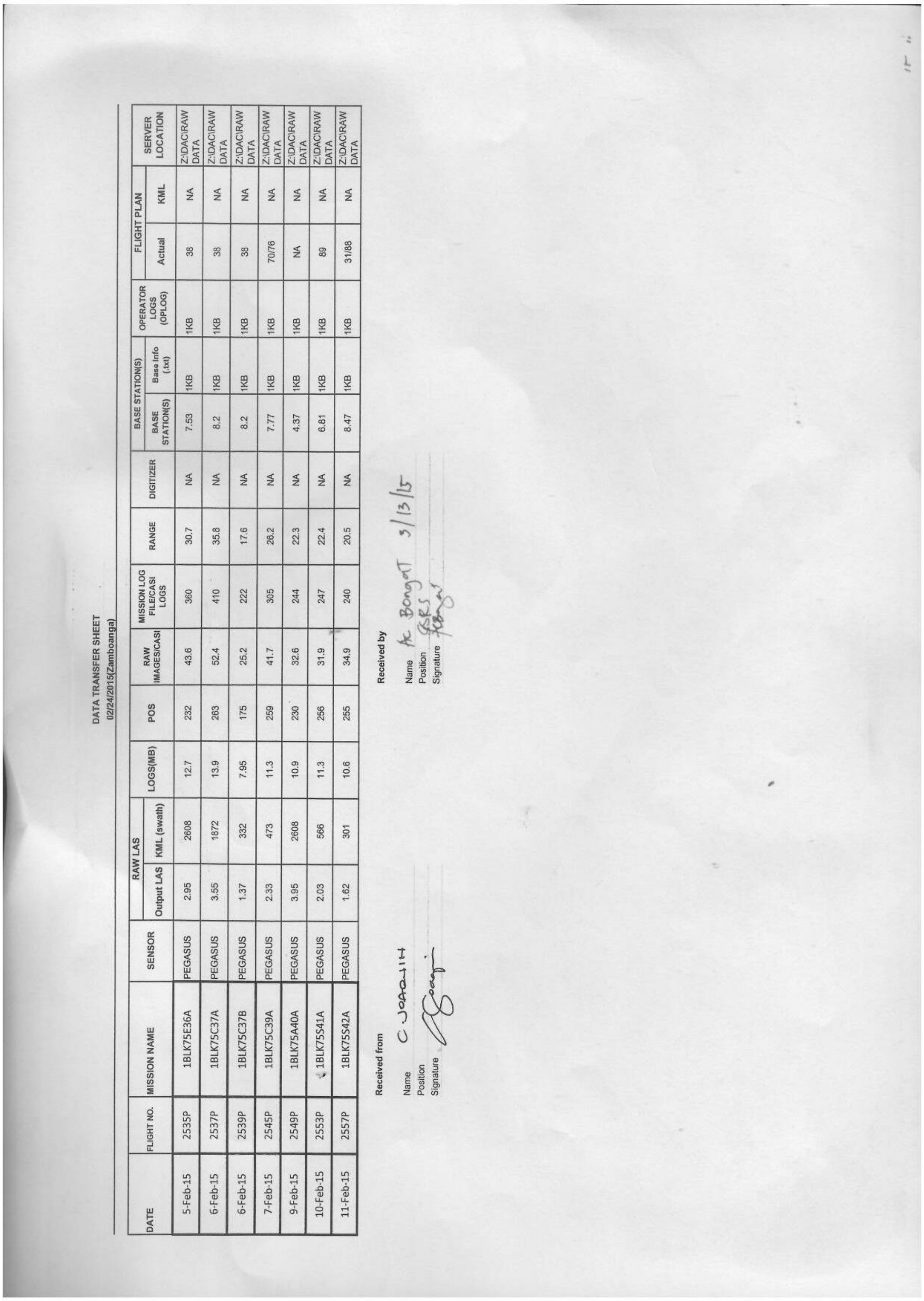
Figure A3-4. BVA-1

Annex 4. 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 S. SARMIENTO	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
LiDAR Operation	Senior Science Research Specialist (SSRS)	LOVELY GRACIA ACUNA	UP-TCAGP
LiDAR Operation	Senior Science Research Specialist (SSRS)	JASMINE ALVIAR	UP-TCAGP
LiDAR Operation	Senior Science Research Specialist (SSRS)	ENGR. IRO NIEL ROXAS	UP-TCAGP
LiDAR Operation	Research Associate (RA)	ENGR. RENAN PUNTO	UP-TCAGP
	RA	KRISTINE JOY ANDAYA	UP-TCAGP
LiDAR Operation	RA	JONATHAN ALMALVEZ	UP-TCAGP
	RA	SANDRA POBLETE	UP-TCAGP
Ground Survey	RA	FRANK NICOLAS ILEJAY	UP-TCAGP
LiDAR Operation	Airborne Security	ERWIN DELOS SANTOS	PILIPPINE AIR FORCE (PAF)
LiDAR Operation	Airborne Security	JAYCO MANZANO	PILIPPINE AIR FORCE (PAF)
LiDAR Operation	Pilot	CAPT. SHERWIN CESAR ALFONSO	ASIAN AEROSPACE COR-PORATION (AAC)
LiDAR Operation	Pilot	CAPT. BRYAN DONGUINES	AAC
LiDAR Operation	Pilot	CAPT. ANTON DAYO	AAC

Table A-4.1. The LiDAR Survey Team Composition

Annex 5. Data Transfer Sheet for Mercedes Floodplain



DATA TRANSFER SHEET
02/24/2015(Zamboanga)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
5-Feb-15	2535P	1BLK75E36A	PEGASUS	2.95	2608	12.7	232	43.6	360	30.7	NA	7.53	1KB	1KB	38	NA	Z:\DAC\RAW DATA
6-Feb-15	2537P	1BLK75C37A	PEGASUS	3.55	1872	13.9	263	52.4	410	35.8	NA	8.2	1KB	1KB	38	NA	Z:\DAC\RAW DATA
6-Feb-15	2539P	1BLK75C37B	PEGASUS	1.37	332	7.95	175	25.2	222	17.6	NA	8.2	1KB	1KB	38	NA	Z:\DAC\RAW DATA
7-Feb-15	2545P	1BLK75C39A	PEGASUS	2.33	473	11.3	259	41.7	305	26.2	NA	7.77	1KB	1KB	70/76	NA	Z:\DAC\RAW DATA
9-Feb-15	2549P	1BLK75A40A	PEGASUS	3.95	2608	10.9	230	32.6	244	22.3	NA	4.37	1KB	1KB	NA	NA	Z:\DAC\RAW DATA
10-Feb-15	2553P	1BLK75S41A	PEGASUS	2.03	566	11.3	256	31.9	247	22.4	NA	6.81	1KB	1KB	89	NA	Z:\DAC\RAW DATA
11-Feb-15	2557P	1BLK75S42A	PEGASUS	1.62	301	10.6	255	34.9	240	20.5	NA	8.47	1KB	1KB	31/88	NA	Z:\DAC\RAW DATA

Received from
Name C JOAQUIN
Position
Signature

Received by
Name AC Bongat 3/13/15
Position SSRS
Signature

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

DATA TRANSFER SHEET
ZAMBOANGA 7/11/2016

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
May 25, 2016	23390P	1BLK75BS146A	PEGASUS	518	NA	4.08	91	NA	NA	5.63	NA	95.8	1KB	NA	53	NA	Z:\DAC\RAW DATA
May 26, 2016	23392P	1BLK75FG147A	PEGASUS	2.28	NA	11	253	NA	NA	24.7	NA	133	1KB	NA	89	NA	Z:\DAC\RAW DATA
May 26, 2016	23394P	1BLK75AS147B	PEGASUS	506	NA	3.37	101	NA	NA	5.13	NA	133	1KB	NA	NA	NA	Z:\DAC\RAW DATA
May 27, 2016	23398P	1BLK75CSDE148B	PEGASUS	2.09	NA	11.6	281	30	274	22.6	NA	153	1KB	NA	NA	NA	Z:\DAC\RAW DATA
May 30, 2016	23408P	1BLK75HI151A	PEGASUS	546	NA	6.09	173	8.73	69	7.88	NA	171	1KB	NA	NA	NA	Z:\DAC\RAW DATA
May 30, 2016	23410P	1BLK75CS151B	PEGASUS	1.1	NA	6.75	192	15.3	139	12.6	NA	171	1KB	NA	NA	NA	Z:\DAC\RAW DATA

Received from

Name R. PUNTO
Position RA
Signature

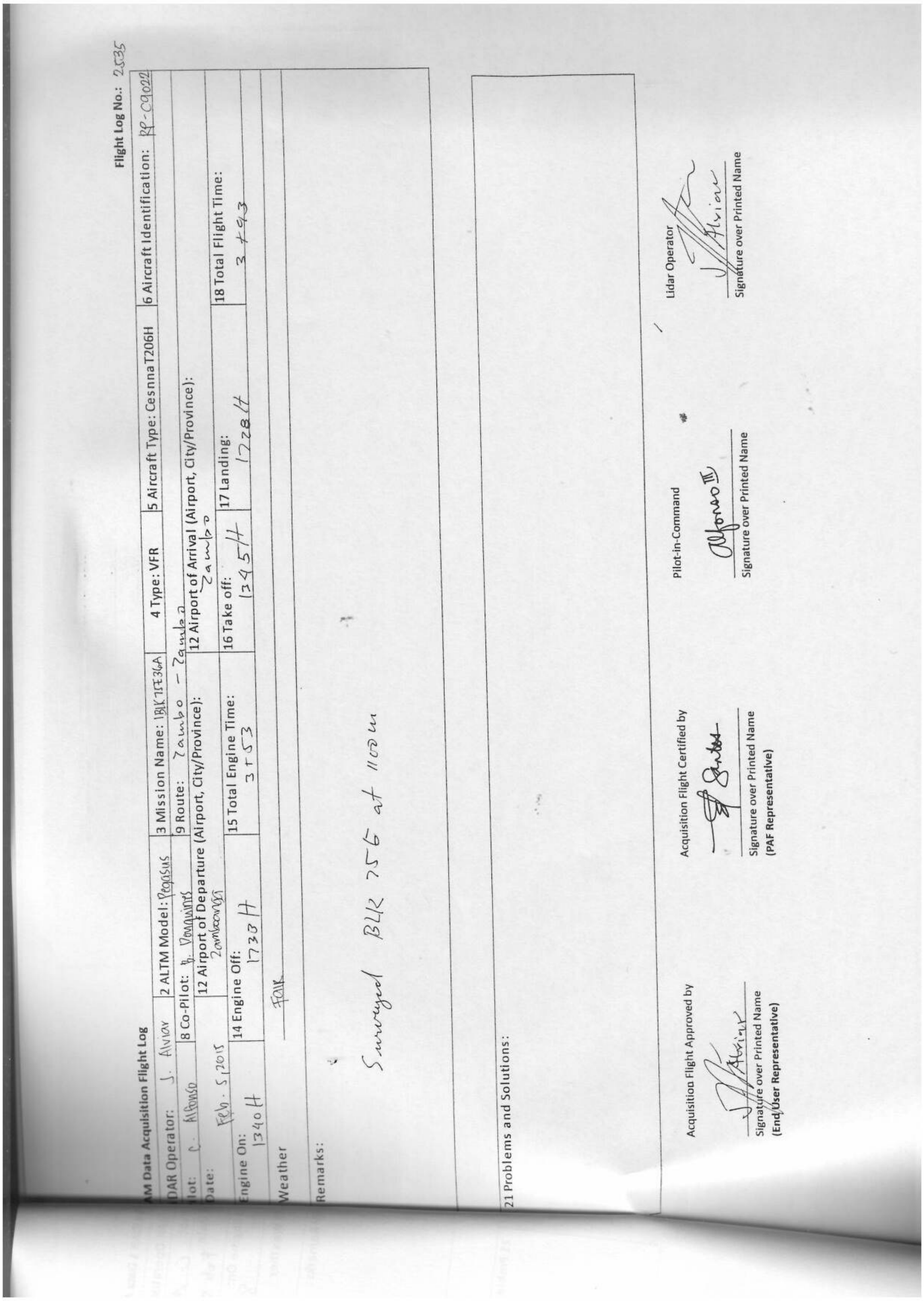
Received by

Name AC Bongat
Position SSRS
Signature 7/14/16

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

Annex 6. Flight Logs for the Flight Missions

1. Flight Log for 2535P Mission



...AM Data Acquisition Flight Log

Flight Log No.: 2535

...DAR Operator: J. Alviar	2 ALTM Model: Pegasus	3 Mission Name: 1BLK75E36A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
...lot: C. Alfonso	8 Co-Pilot: B. Dongwines	9 Route: Zambo - Zambo			
Date: Feb. 5, 2015	12 Airport of Departure (Airport, City/Province): Zamboanga		12 Airport of Arrival (Airport, City/Province): Zambo		
Engine On: 1340H	14 Engine Off: 1733H	15 Total Engine Time: 3+53	16 Take off: 1345H	17 Landing: 1728H	18 Total Flight Time: 3+43

Weather: Fair

Remarks:

Surveyed BLK 75G at 1100 m

21 Problems and Solutions:

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

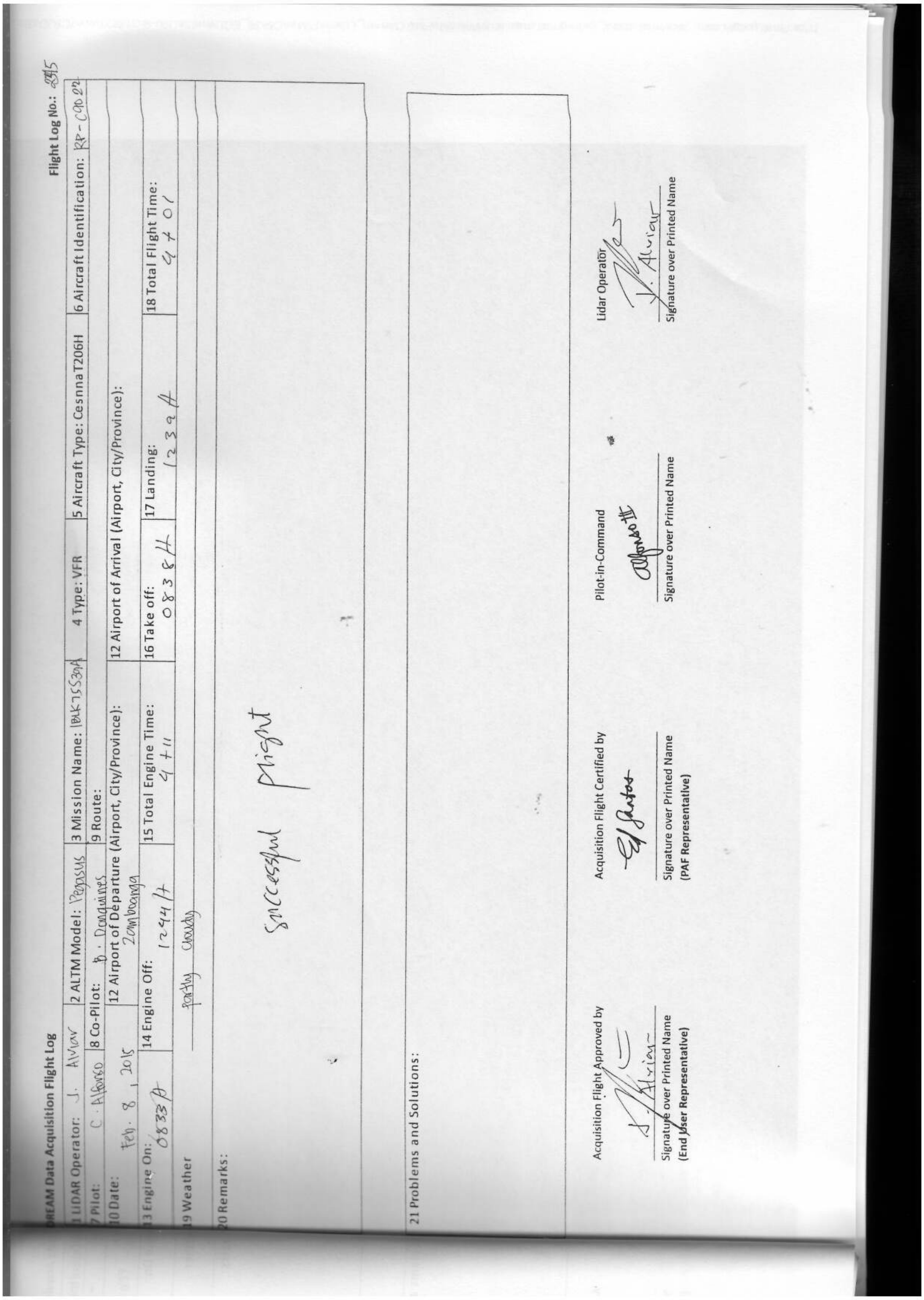
Acquisition Flight Certified by — Signature over Printed Name (PAF Representative)

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

Lidar Operator — J. Alviar — Signature over Printed Name

Figure A-6.1. Flight Log for 2535P Mission

2. Flight Log for 2545P Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 2545

1 LiDAR Operator: J. Alviar	2 ALTM Model: Pegasus	3 Mission Name: 1BLK75S39A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: C. Alfonso	8 Co-Pilot: B. Donguines	9 Route:			
10 Date: Feb. 8, 2015	12 Airport of Departure (Airport, City/Province): Zamboanga		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0833H	14 Engine Off: 1244H	15 Total Engine Time: 4+11	16 Take off: 0838H	17 Landing: 1239H	18 Total Flight Time: 4+01
19 Weather: partly cloudy					

20 Remarks:

Successful flight

21 Problems and Solutions:

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

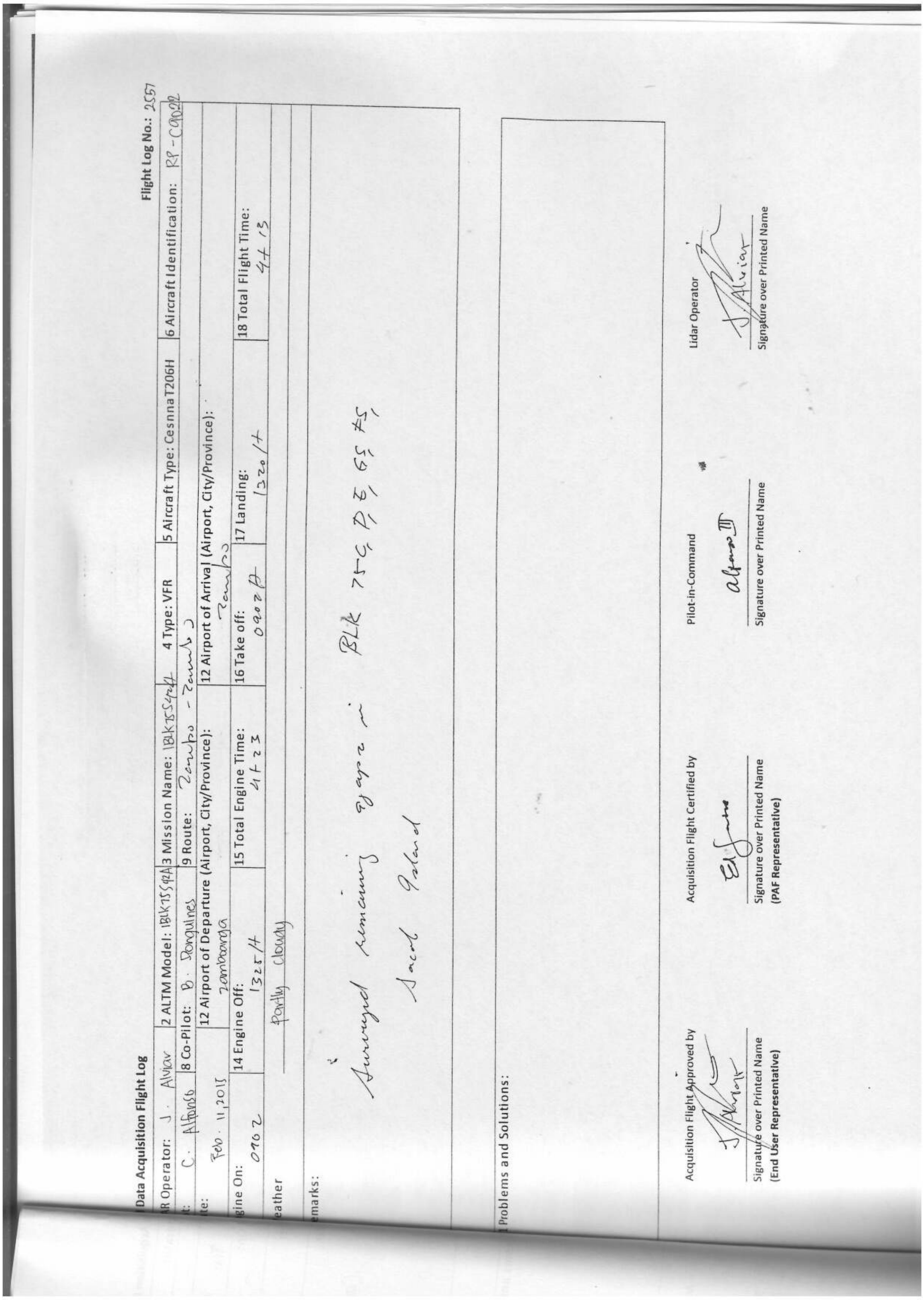
Acquisition Flight Certified by: El Santos — Signature over Printed Name (PAF Representative)

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

Lidar Operator: J. Alviar — Signature over Printed Name

Figure A-6.2. Flight Log for 2545P Mission

3. Flight Log for 2557P Mission


Data Acquisition Flight Log

Flight Log No.: 2557

R Operator: J. Alviar | 2 ALTM Model: 1BLK75S42A | 3 Mission Name: 1BLK75S42A | 4 Type: VFR | 5 Aircraft Type: Cesnna T206H | 6 Aircraft Identification: RP-C9022

t: C. Alfonso | 8 Co-Pilot: B. Dongulnes | 9 Route: Zambo - Zambo

te: Feb. 11, 2015 | 12 Airport of Departure (Airport, City/Province): Zamboanga | 12 Airport of Arrival (Airport, City/Province): Zambo

gine On: 0902 | 14 Engine Off: 1325H | 15 Total Engine Time: 4+23 | 16 Take off: 0907H | 17 Landing: 1320H | 18 Total Flight Time: 4+13

eather: partly cloudy

emarks: Surveyed remaining gaps in BLK 75C, D, E, G5, F5, Sacol Island

Problems and Solutions:

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

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

Pilot-in-Command — Signature over Printed Name

Lidar Operator — Signature over Printed Name

Figure A-6.3 Flight Log for 2557P Mission

4. Flight Log for 23394P Mission

Data Acquisition Flight Log

Flight Log No.: 23394 P

1 LiDAR Operator: I. ROXAS & S. POBLETE	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK75AS147B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9122
7 Pilot: C. ALFONSO III	8 Co-Pilot: A. DAYO	9 Route: ZAMBOANGA CITY - ZAMBOANGA CITY			
10 Date: MAY 26, 2016	12 Airport of Departure (Airport, City/Province): ZAMBOANGA CITY		12 Airport of Arrival (Airport, City/Province): ZAMBOANGA CITY		
13 Engine On: 1605 H	14 Engine Off: 1752 H	15 Total Engine Time: 1 + 47	16 Take off: 1610 H	17 Landing: 1747 H	18 Total Flight Time: 1 + 37
19 Weather	CLOUDY				

20 Flight Classification

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

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

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

21 Remarks

Successful flight

Completed BLK 75AS

22 Problems and Solutions

- ○ Weather Problem
- ○ System Problem
- ○ Aircraft Problem
- ○ Pilot Problem
- ○ Others: ____________

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

Acquisition Flight Certified by: A1C JAYSON C MANZANO PAF — Signature over Printed Name (PAF Representative)

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

Lidar Operator: S. POBLETE / I. ROXAS — Signature over Printed Name

Aircraft Mechanic/ Technician: — Signature over Printed Name

Figure A-6.4. Flight Log for 23394P Mission

Annex 7. Flight Status Reports

Zamboanga-Zamboanga Sibugay Mission
February 5,8 and 11 2015; May 26, 2016

Table A-7. 1 Flight Status Report

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
2535P	BLK75E	1BLK75E36A	J. ALVIAR	Feb. 5, 2015	FOR COMPLETION AND SOME GAP FILLING (TER-RAIN)
2545P	BLK75C BLK75D BLK75E BLK75FS	1BLK75C39A	J. ALVIAR	Feb. 7, 2015	ABNORMAL PROGRAM TER-MINATION (AVPOS)
2557P	BLK75C BLK75D BLK75GS-BLK75FS-SACOL IS.	1BLK75S42A	J. ALVIAR	Feb. 11, 2015	SURVEY 6 DESCENDED TO 1000 DUE TO CLOUDS; RETURNED TO 1100M FOR SURVEY OVER SACOL; GAPS DUE TO CLOUDS, DESCENDED TO 1000M TO FILL UP VOIDS IN SACOL AND BLK 75EFG; ADDED 1 SMALL LINE (COR-RIDOR 18), DESCENDED TO 800M; CORRIDOR 16 WHICH SHOULD COVER GAP IN BLK75E, UP TO ALL
23394P	BLK75AS	1BLK75AS147B	I. ROXAS and S. POBLETE	May 26, 2016	COMPLETED BLK 75AS

LAS/SWATH BOUNDARIES PER MISSION FLIGHT

Flight No.: 2535P

Area: BLK75E

Mission Name: 1BLK75E36A

Parameters: Altitude: 1100m; Scan Frequency: 30; Scan Angle: 50

LAS/SWATH

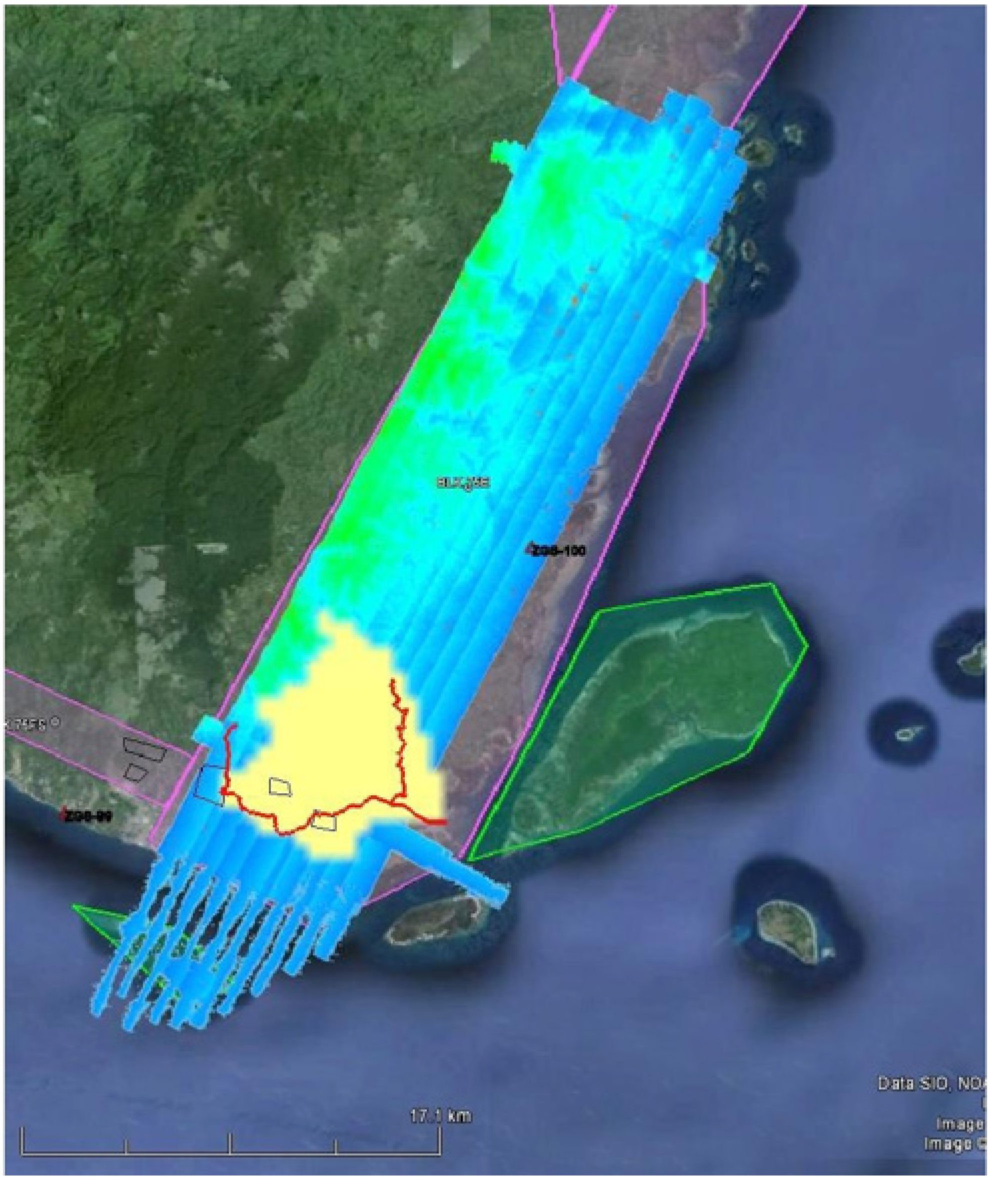


Figure A-7.1. Swath for Flight No. 2535P

Flight No. : 2545P

Area: BLK 75C

Mission Name: 1BLK75C39A

Parameters: Altitude: 1100m; Scan Frequency: 30; Scan Angle: 50

Figure A-7.2. Swath for Flight No. 2545P

Flight No. : 2557P

Area: BLK 75C, D, E, GS, FS, Sacol island

Mission Name: 1BLK75S42

Parameters: Altitude: 800-1200m; Scan Frequency: 30; Scan Angle: 50

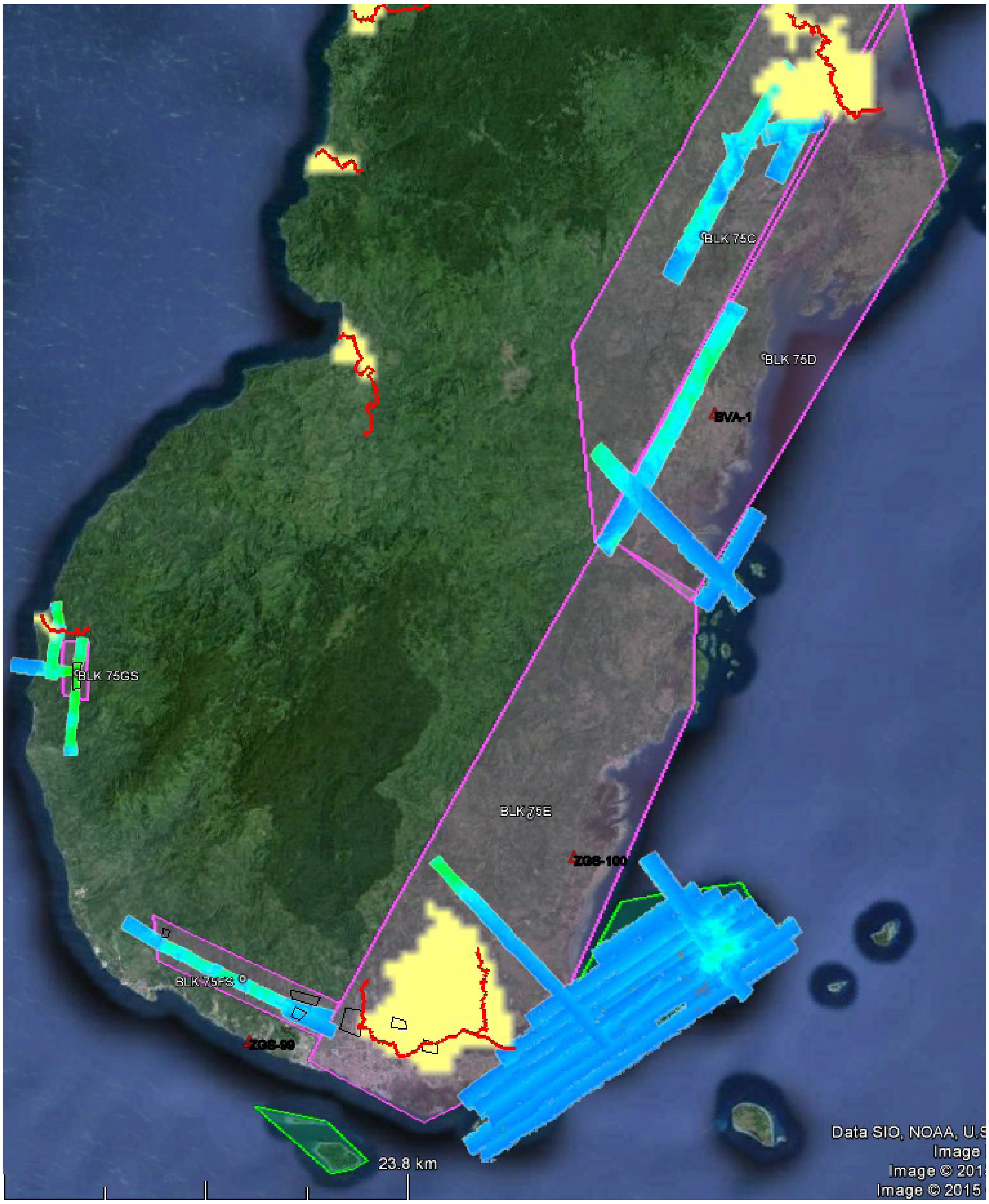


Figure A-7.3. Swath for Flight No. 2557P

Flight No.: 23394P

Area: BLK75AS

Mission Name: 1BLK75AS147B

Parameters: Altitude: 1000m; Scan Frequency: 30; Scan Angle: 50

LAS/SWATH

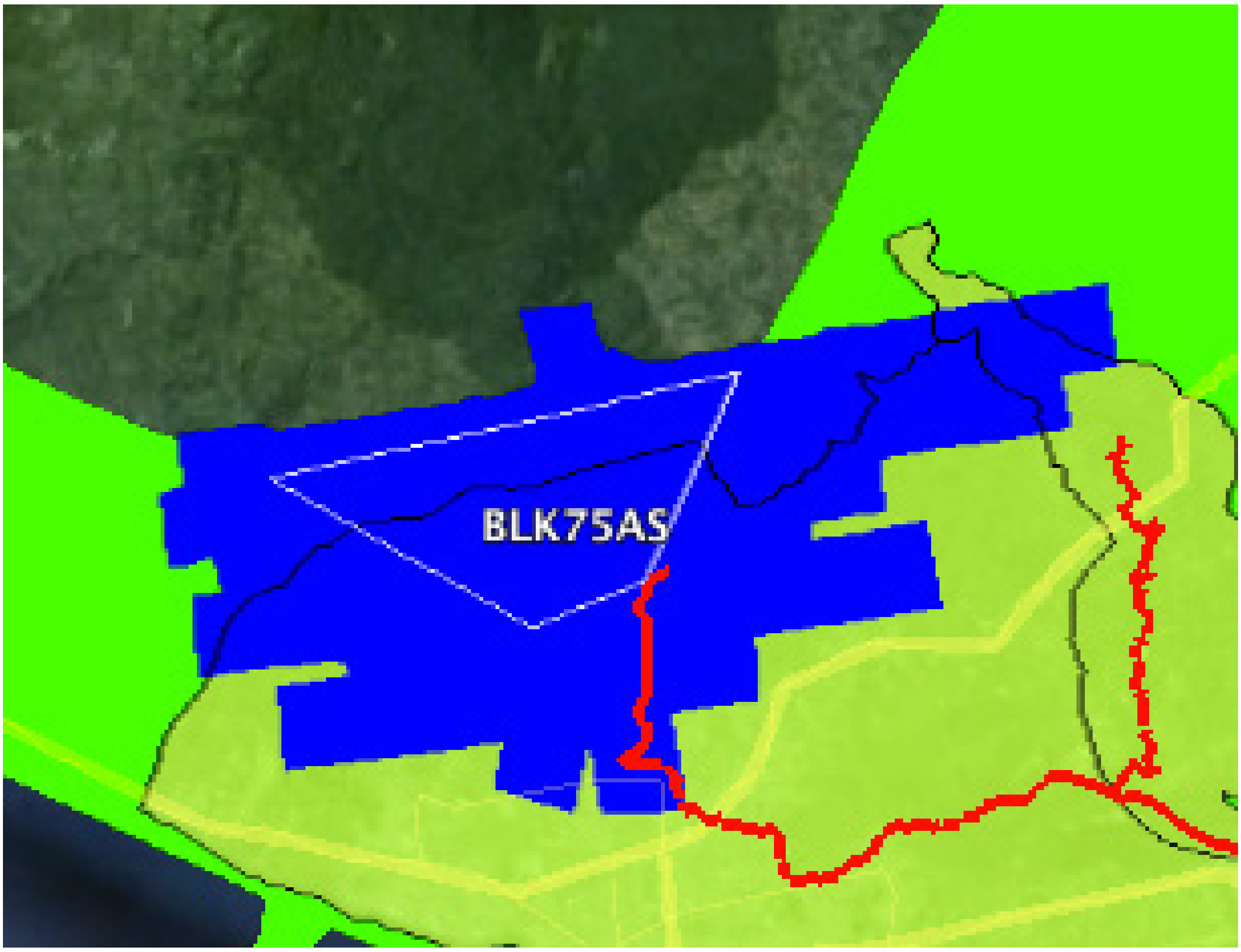


Figure A-7.4. Swath for Flight No. 23394P

Annex 8. Mission Summary Reports

Figure A-8.1. Mission summary report for Blk75E

Flight Area	Zamboanga
Mission Name	**Blk75E**
Inclusive Flights	2535P, 2545P
Mission Name	1BLK75E36A, 1BLK75C39A
Range data size	56.9 GB
Base data size	15.3 MB
POS	491 MB
Image	85.3 GB
Transfer date	March 13 2015
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)	1.08
RMSE for East Position (<4.0 cm)	1.42
RMSE for Down Position (<8.0 cm)	2.94
Boresight correction stdev (<0.001deg)	0.000223
IMU attitude correction stdev (<0.001deg)	0.000328
GPS position stdev (<0.01m)	0.0061
Minimum % overlap (>25)	96.73%
Ave point cloud density per sq.m. (>2.0)	5.11
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	522
Maximum Height	498.00 m
Minimum Height	65.50 m
Classification (# of points)	
Ground	369,443,876
Low vegetation	268,989,359
Medium vegetation	403,829,240
High vegetation	815,604,498
Building	37,951,116
Orthophoto	Yes
Processed by	Engr. Analyn Naldo, Engr. Cherlou Prado, Alex John Escobido

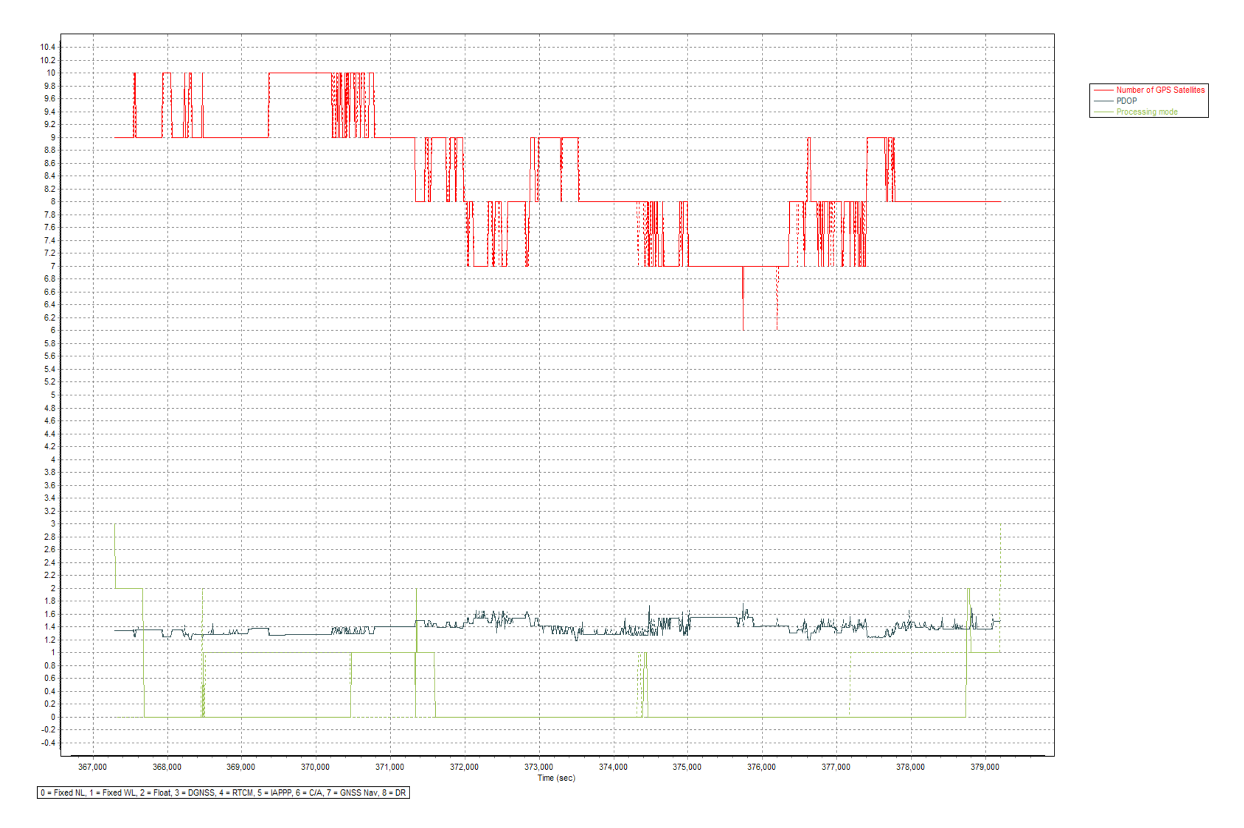


Figure A-8.1 Solution Status

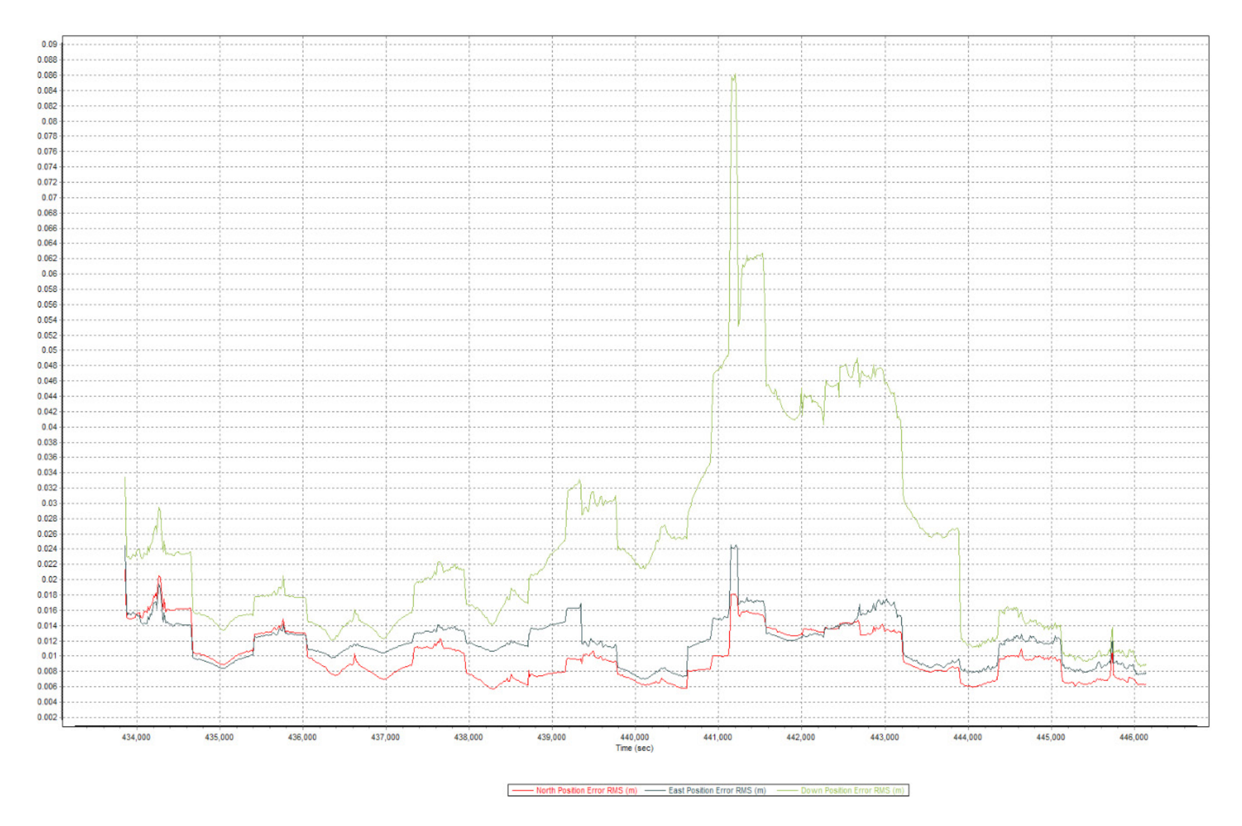


Figure A-8.2 Smoothed Performance Metric Parameters

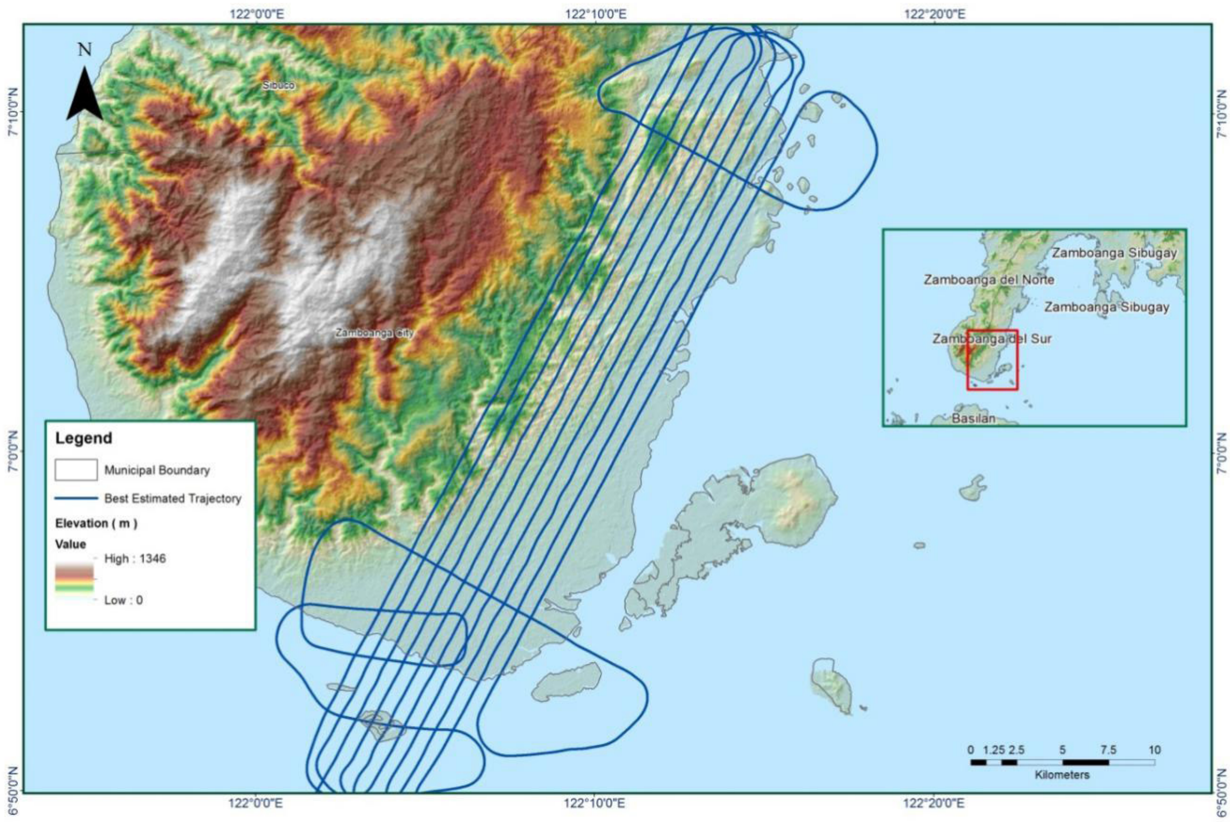


Figure A-8.3 Best Estimated Trajectory

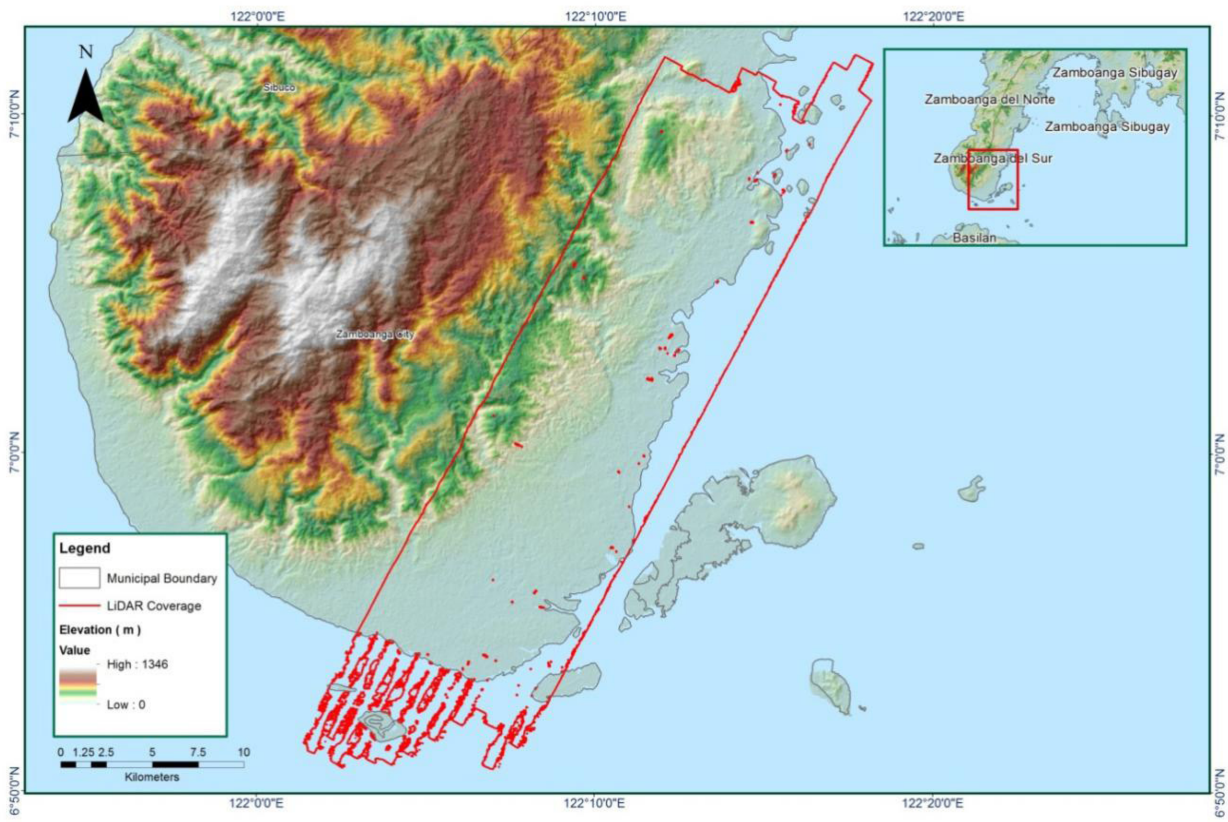


Figure A-8.4 Coverage of LiDAR data

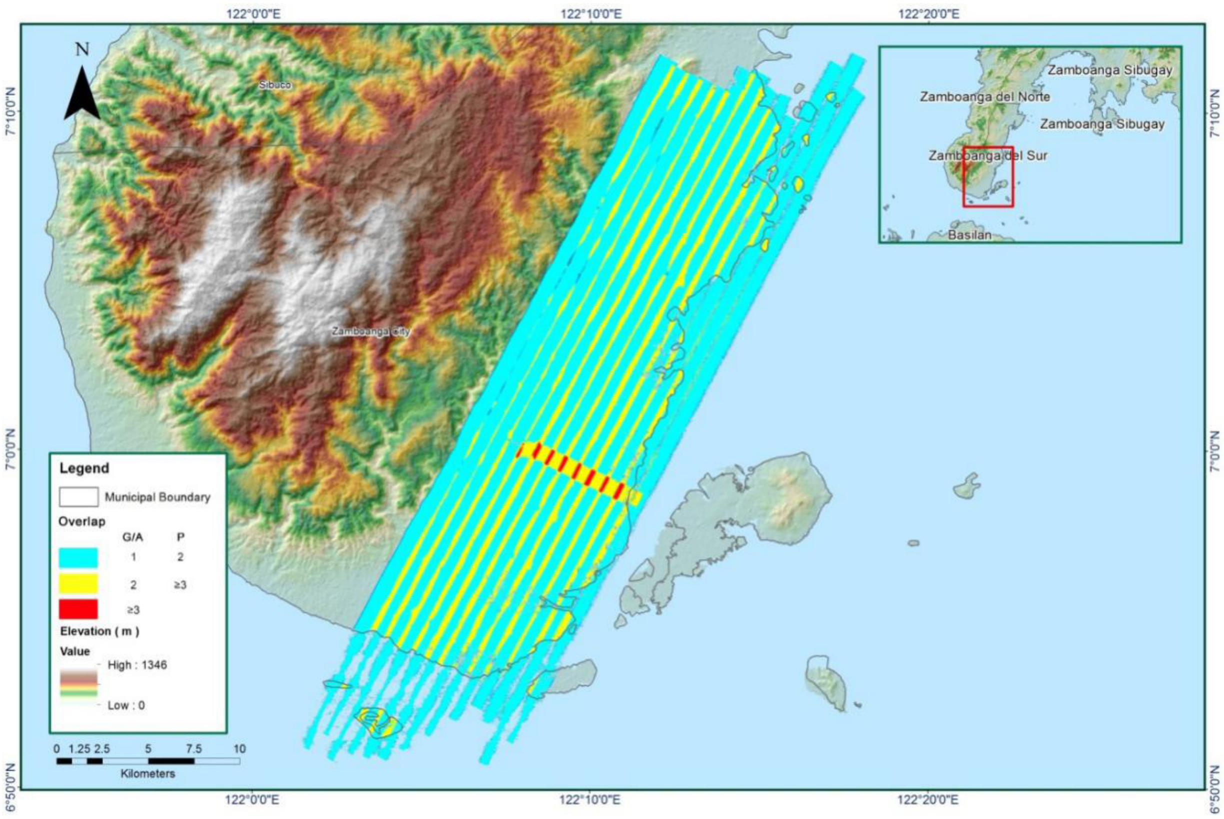


Figure A-8.5 Image of data overlap

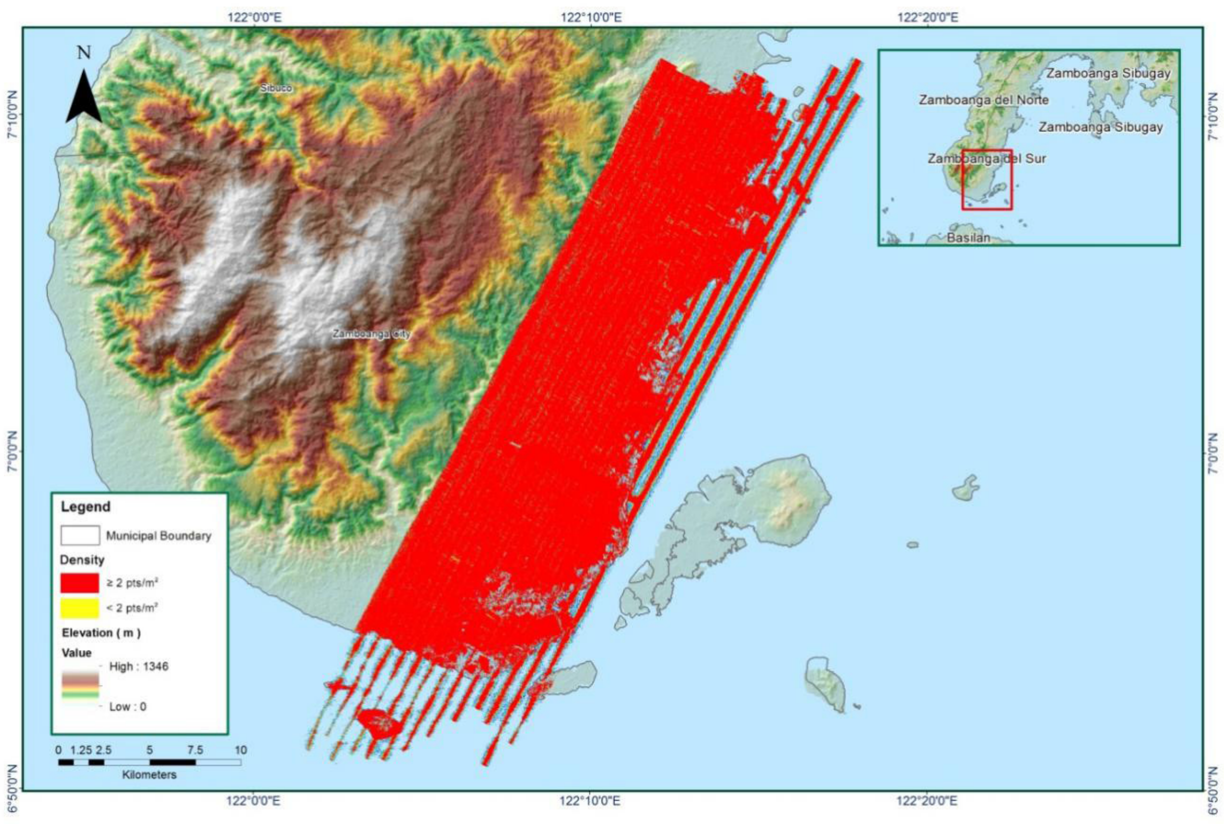


Figure A-8.6 Density map of merged LiDAR data

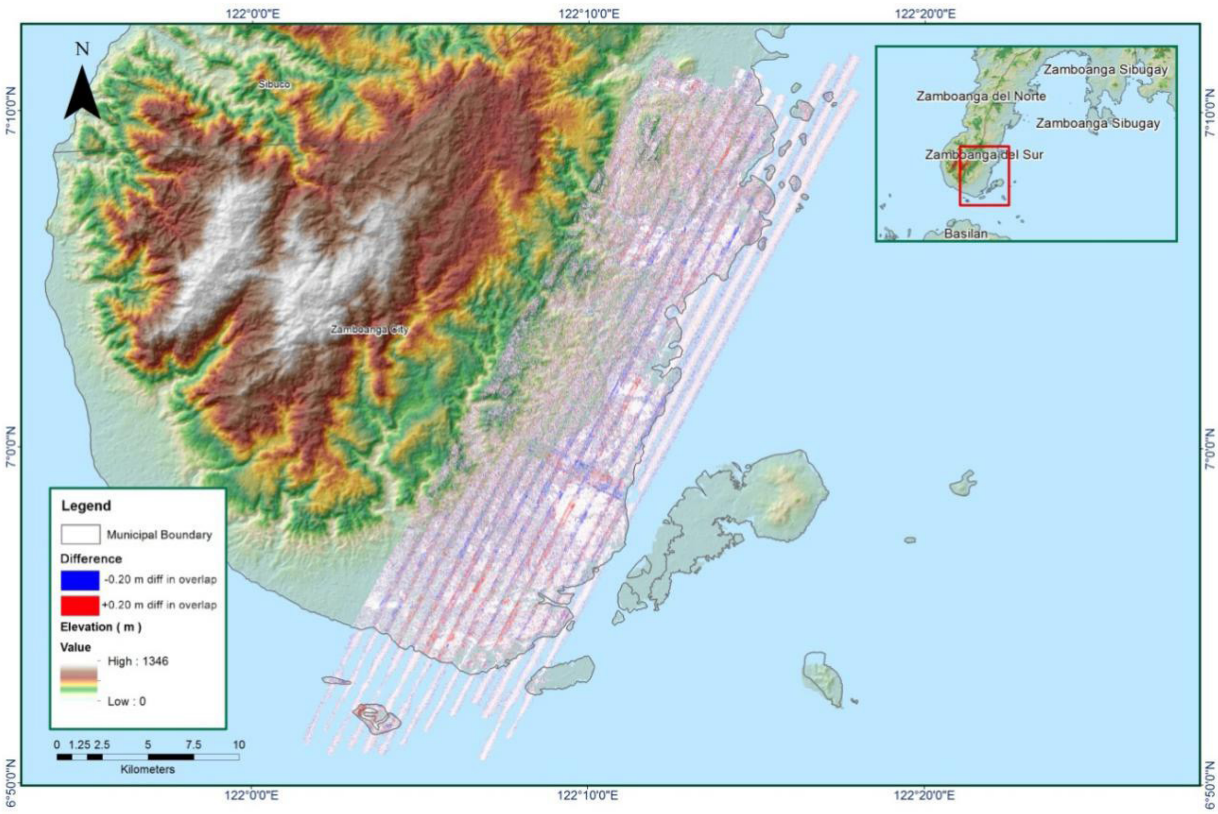


Figure A-8.7 Elevation difference between flight lines

Table A-8.2. Mission summary report for Sacol

Flight Area	Zamboanga
Mission Name	**Sacol**
Inclusive Flights	2557P
Mission Name	1BLK75S42A
Range data size	20.5 GB
Base data size	8.47 MB
POS	255 MB
Image	34.9 GB
Transfer date	March 3 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics(in cm)	
RMSE for North Position (<4.0 cm)	1.07
RMSE for East Position (<4.0 cm)	1.72
RMSE for Down Position (<8.0 cm)	3.35
Boresight correction stdev (<0.001deg)	0.000189
IMU attitude correction stdev (<0.001deg)	0.001474
GPS position stdev (<0.01m)	0.0028
Minimum % overlap (>25)	93.75%
Ave point cloud density per sq.m. (>2.0)	4.29
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	183
Maximum Height	422.16 m
Minimum Height	67.62 m
Classification (# of points)	
Ground	102,448,806
Low vegetation	102,238,659
Medium vegetation	104,811,352
High vegetation	138,074,781
Building	1,942,211
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Melanie Hingpit, Alex Escobido

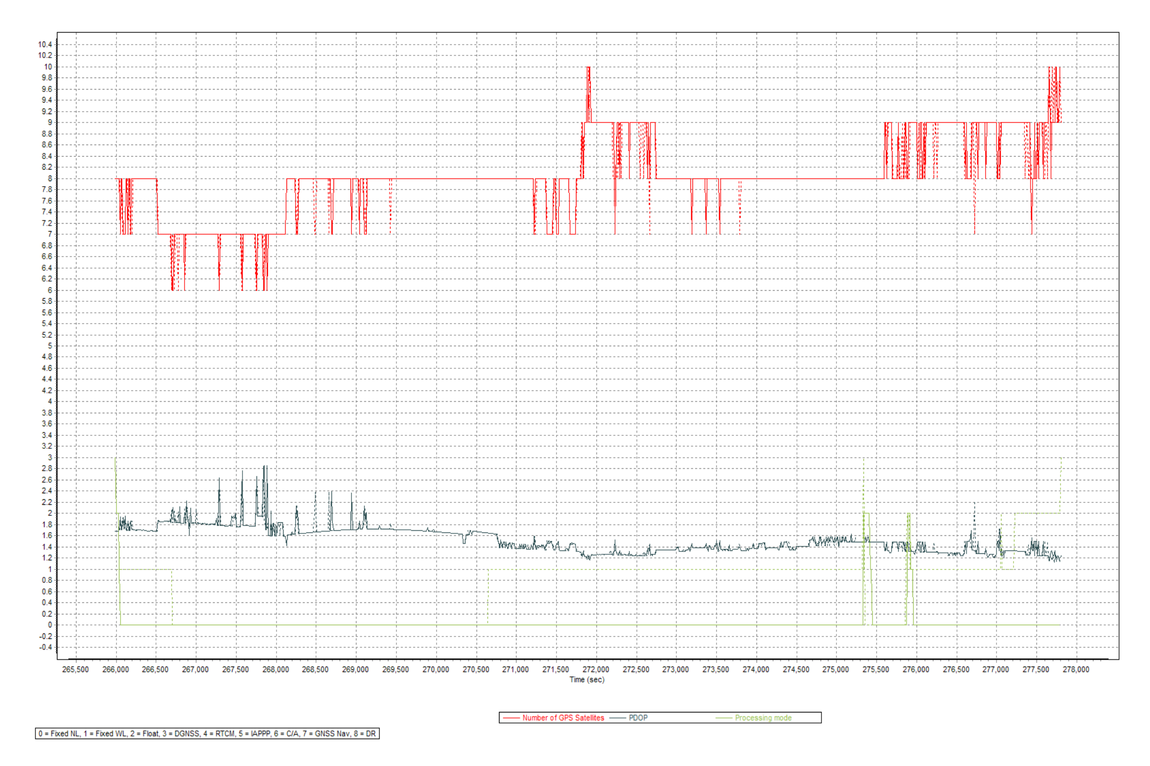


Figure A-8.8 Solution Status

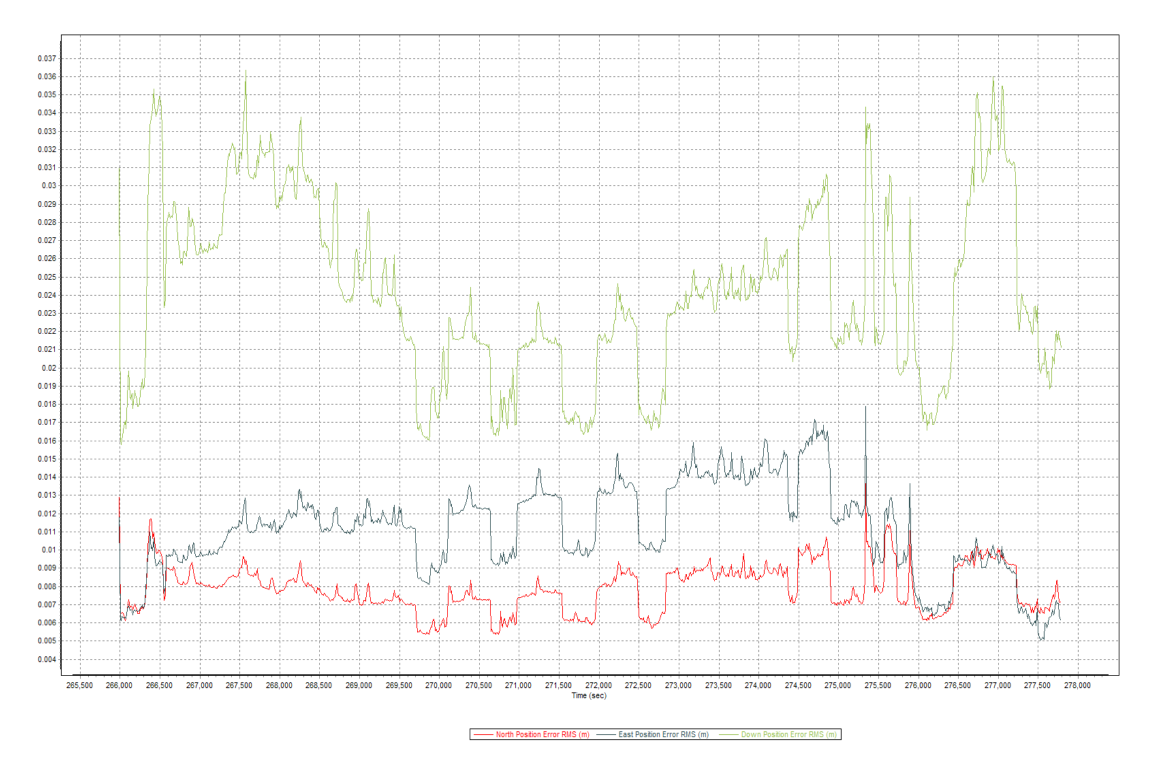


Figure A-8.9 Smoothed Performance Metric Parameters

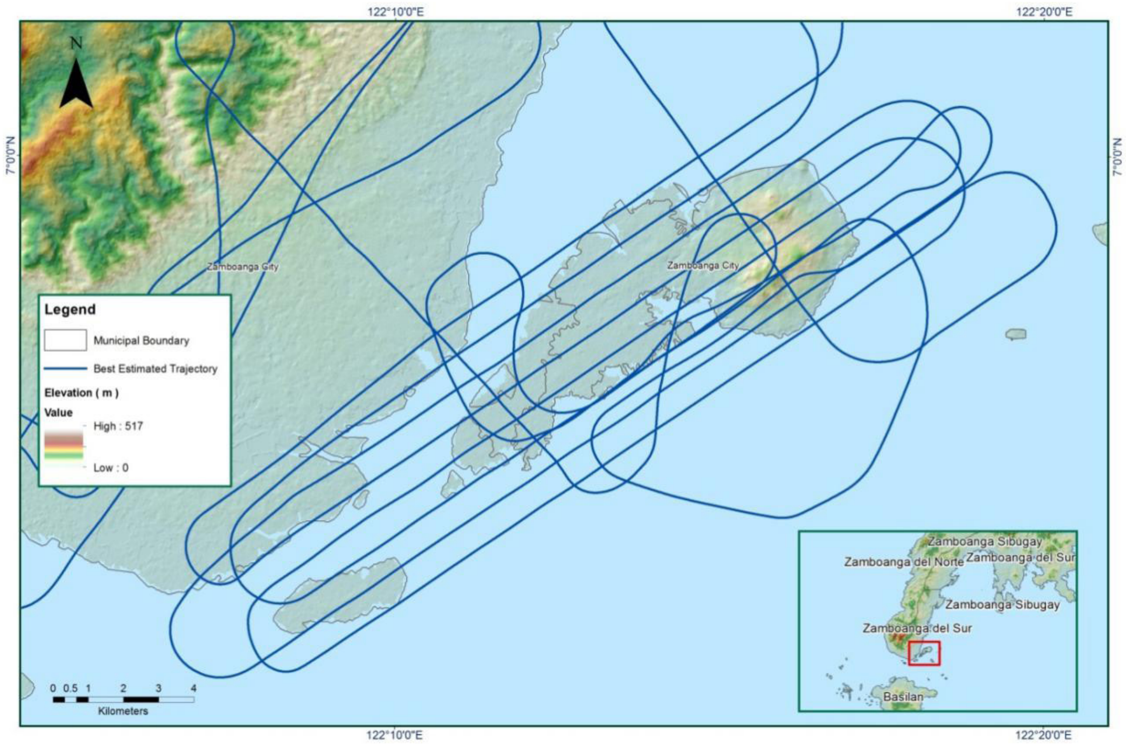


Figure A-8.10 Best Estimated Trajectory

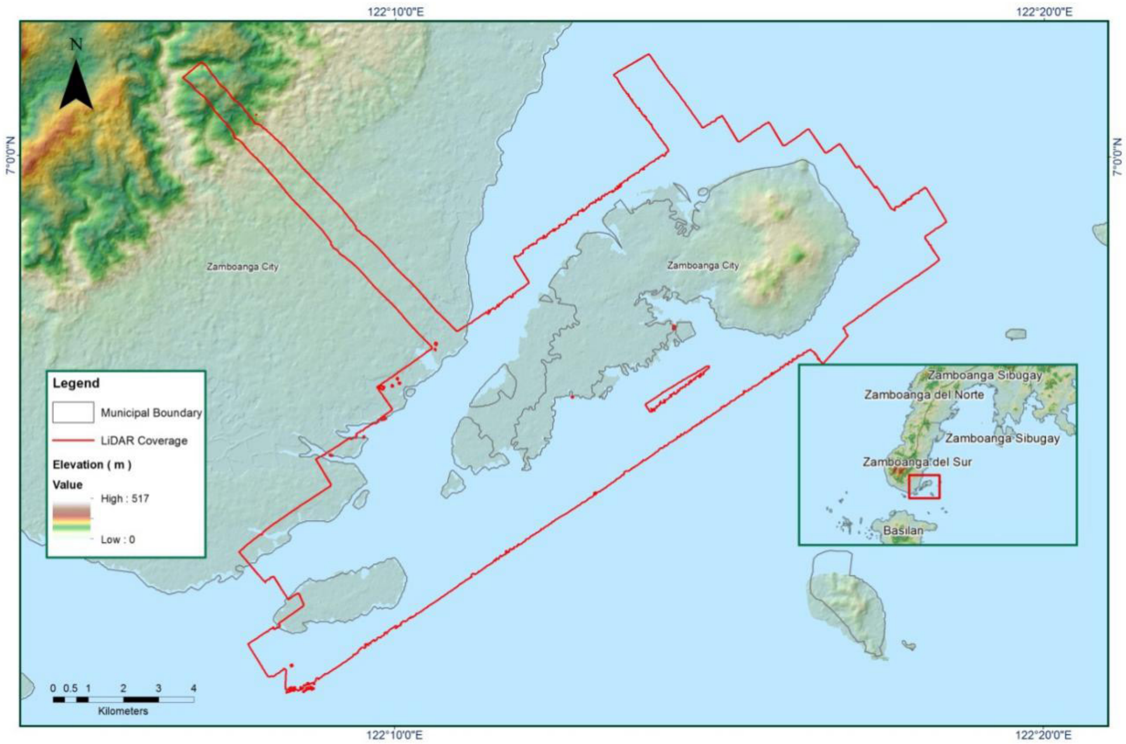


Figure A-8.11 Coverage of LiDAR data

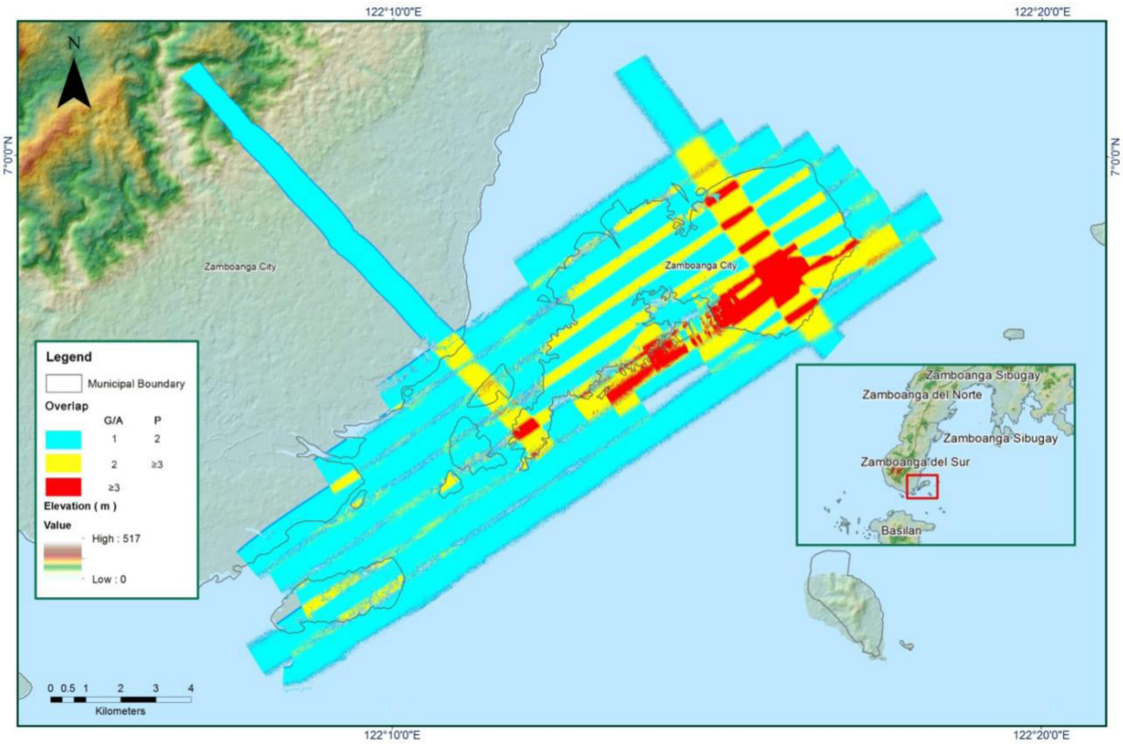


Figure A-8.12 Image of data overlap

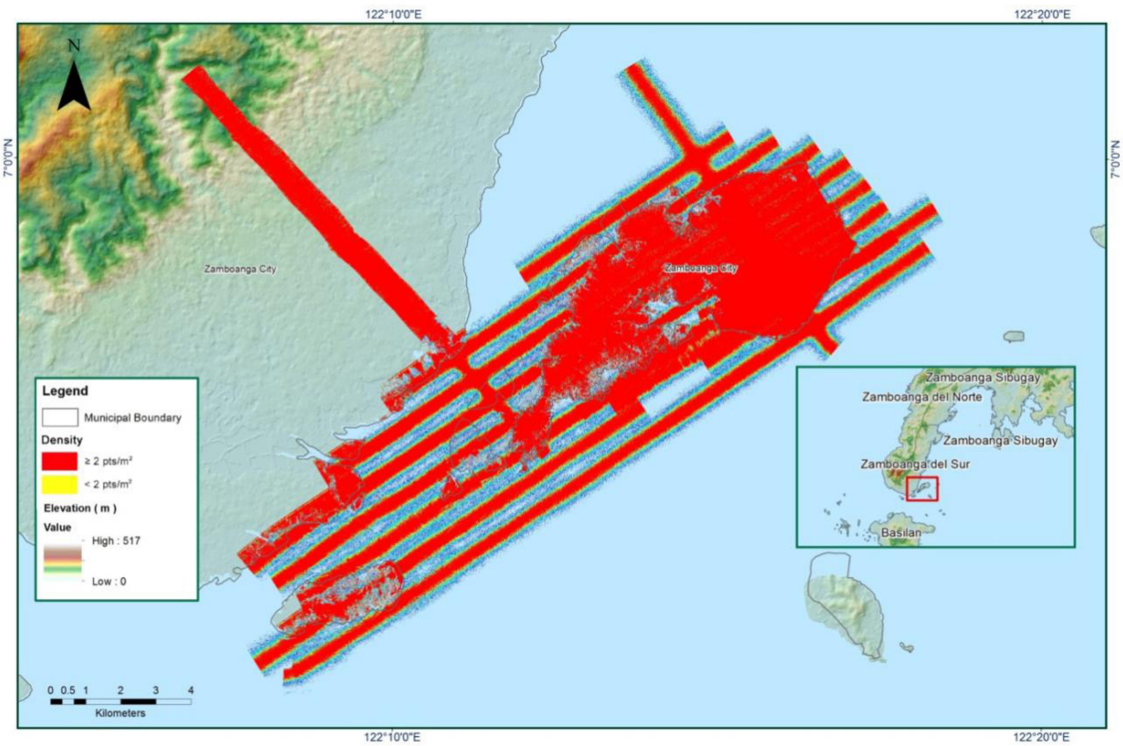


Figure A-8.13 Density map of merged LiDAR data

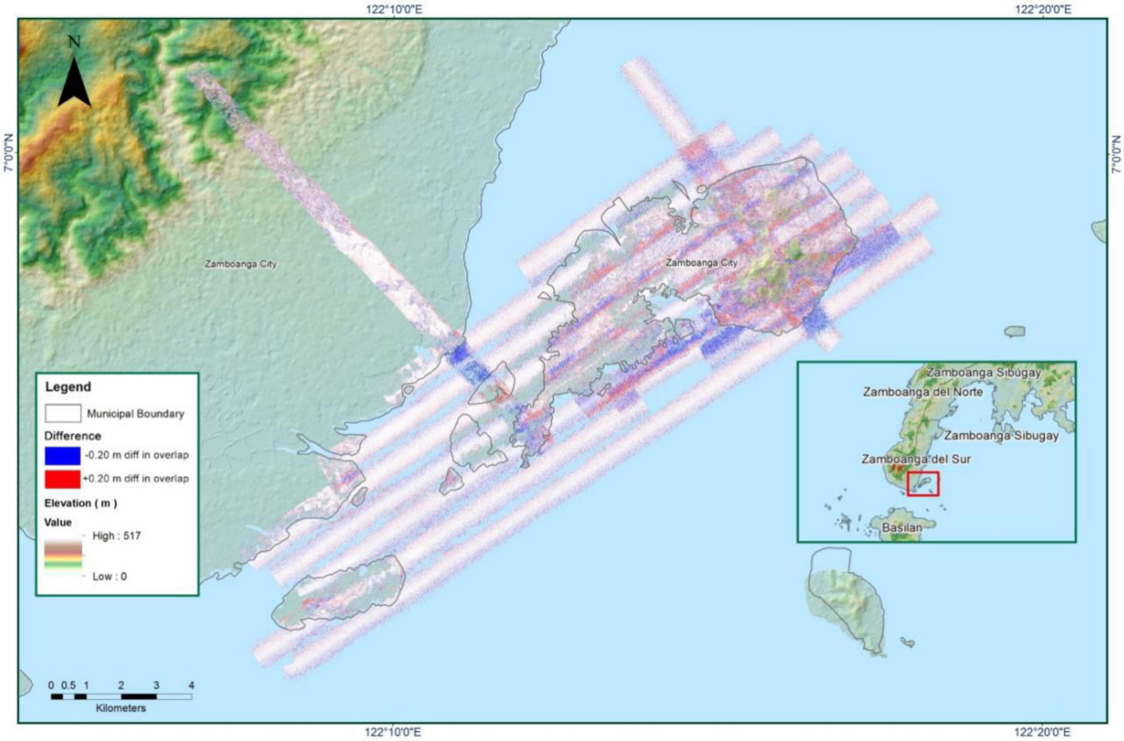


Figure A-8.14 Elevation difference between flight lines

Table A-8.3 Mission summary report for Blk75AS

Flight Area	Zamboanga Reflights
Mission Name	**Blk75AS**
Inclusive Flights	23394P
Range data size	5.13 GB
POS data size	101 MB
Base data size	133 MB
Image	n/a
Transfer date	July 14, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	0.9
RMSE for East Position (<4.0 cm)	1.1
RMSE for Down Position (<8.0 cm)	3.4
Boresight correction stdev (<0.001deg)	n/a
IMU attitude correction stdev (<0.001deg)	n/a
GPS position stdev (<0.01m)	n/a
Minimum % overlap (>25)	27.08
Ave point cloud density per sq.m. (>2.0)	2.98
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	60
Maximum Height	588.90 m
Minimum Height	77.48 m
Classification (# of points)	
Ground	31,359,118
Low vegetation	14,011,685
Medium vegetation	34,188,233
High vegetation	107,683,623
Building	2,927,347
Orthophoto	No
Processed by	Ben Joseph J. Harder, Engr. Christy Lubiano, Engr. Jeffrey Delica

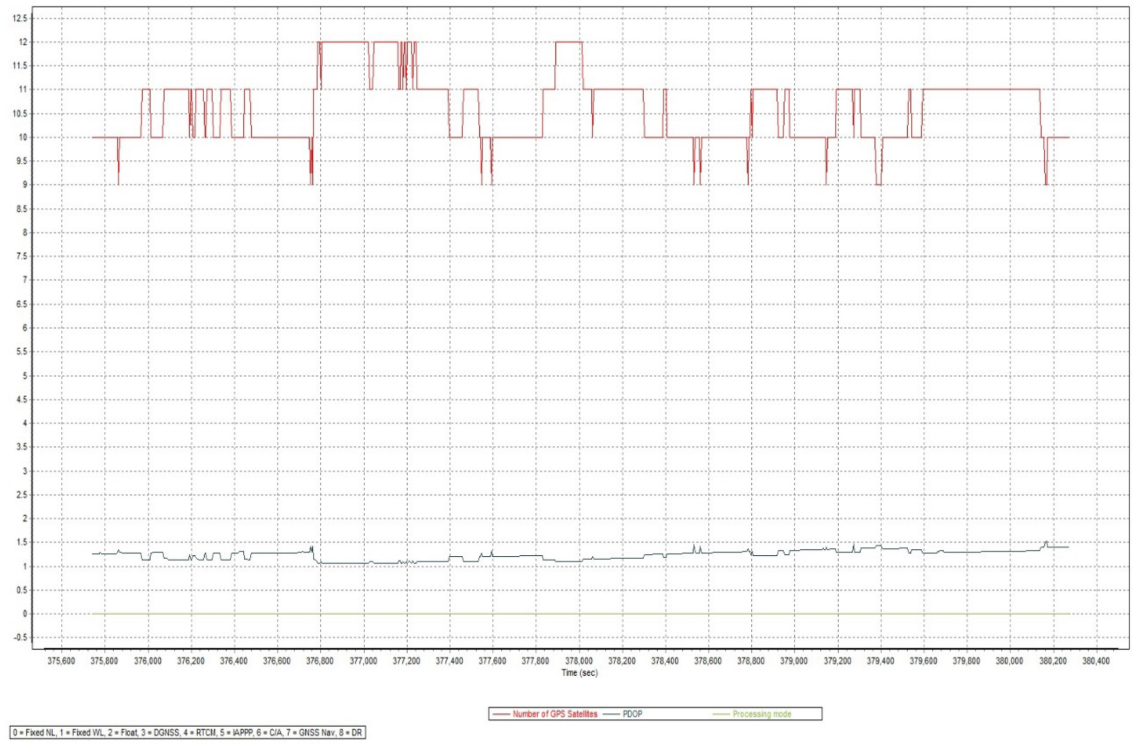


Figure A-8.15 Solution Status

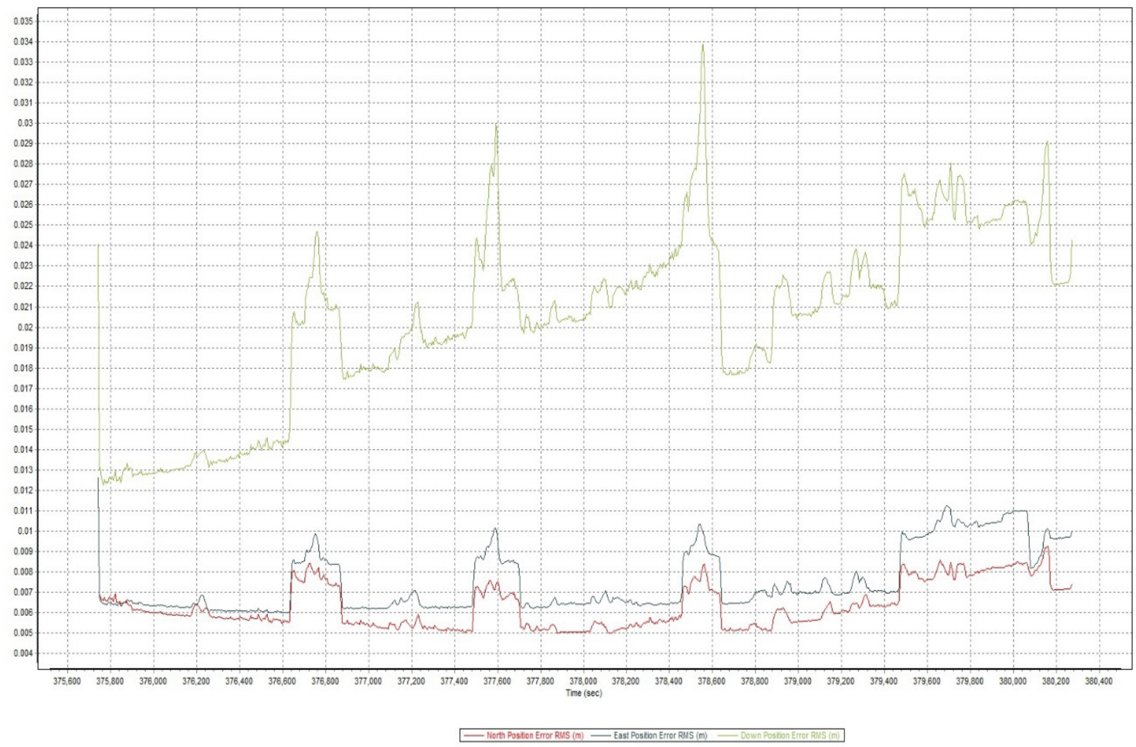


Figure A-8.16 Smoothed Performance Metric Parameters

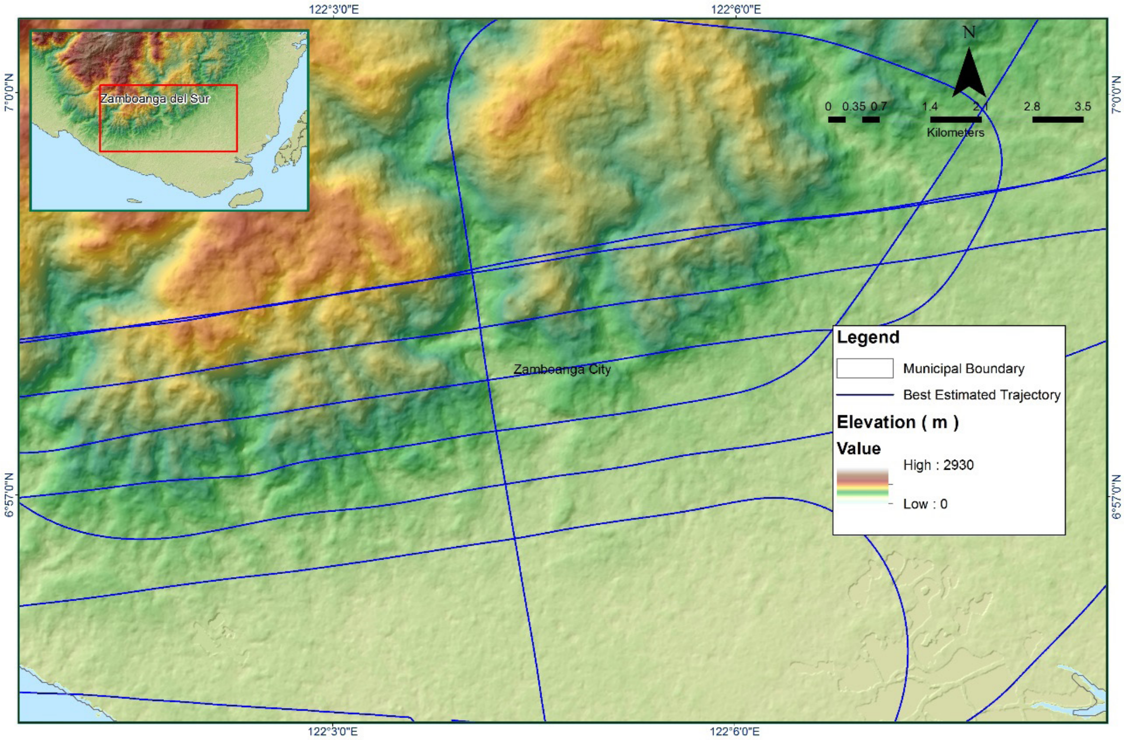


Figure A-8.17 Best Estimated Trajectory

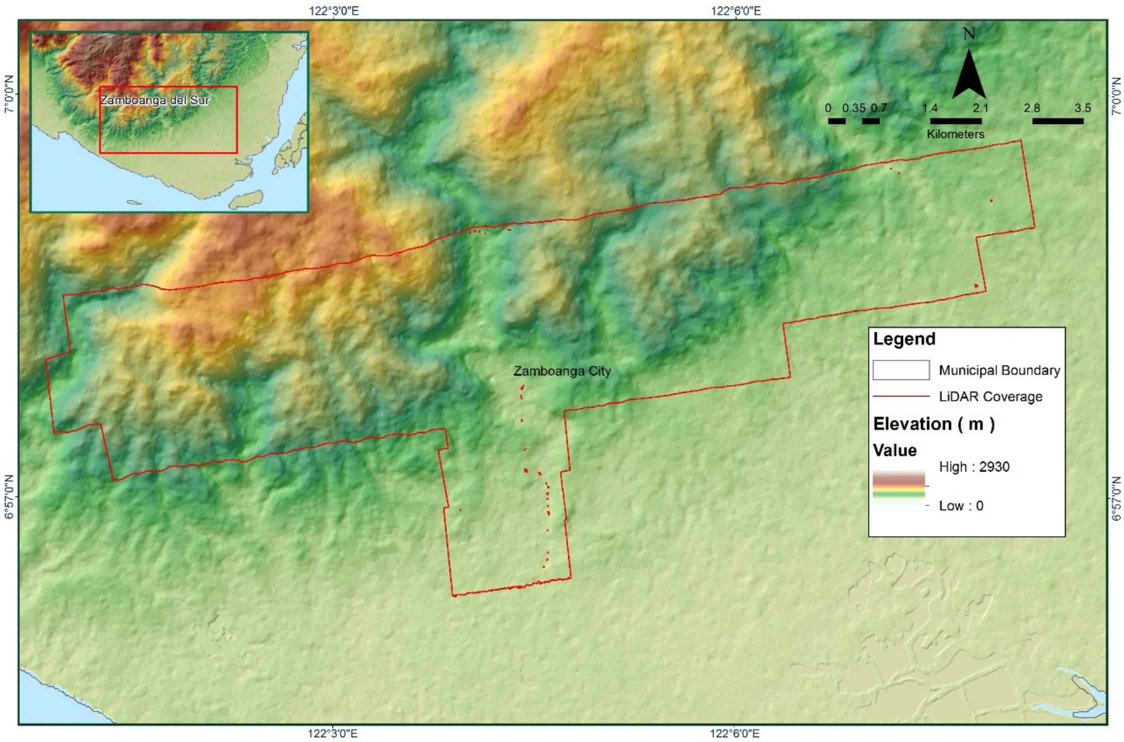


Figure A-8.18 Coverage of LiDAR data

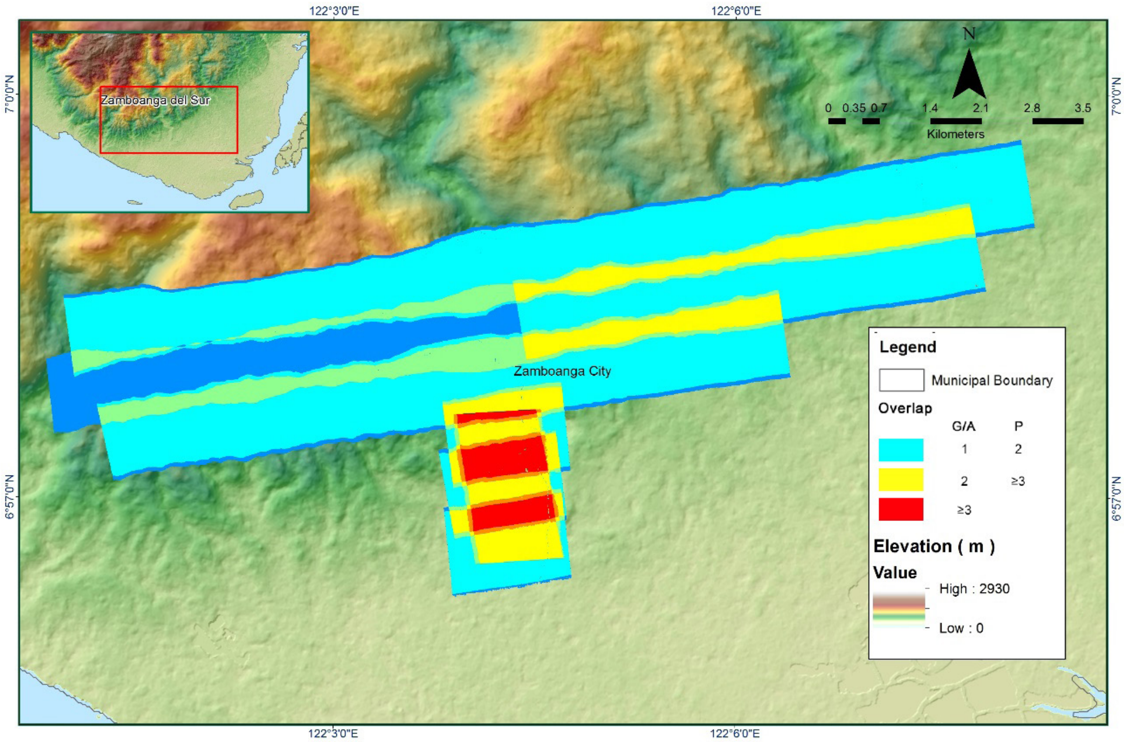


Figure A-8.19 Image of data overlap

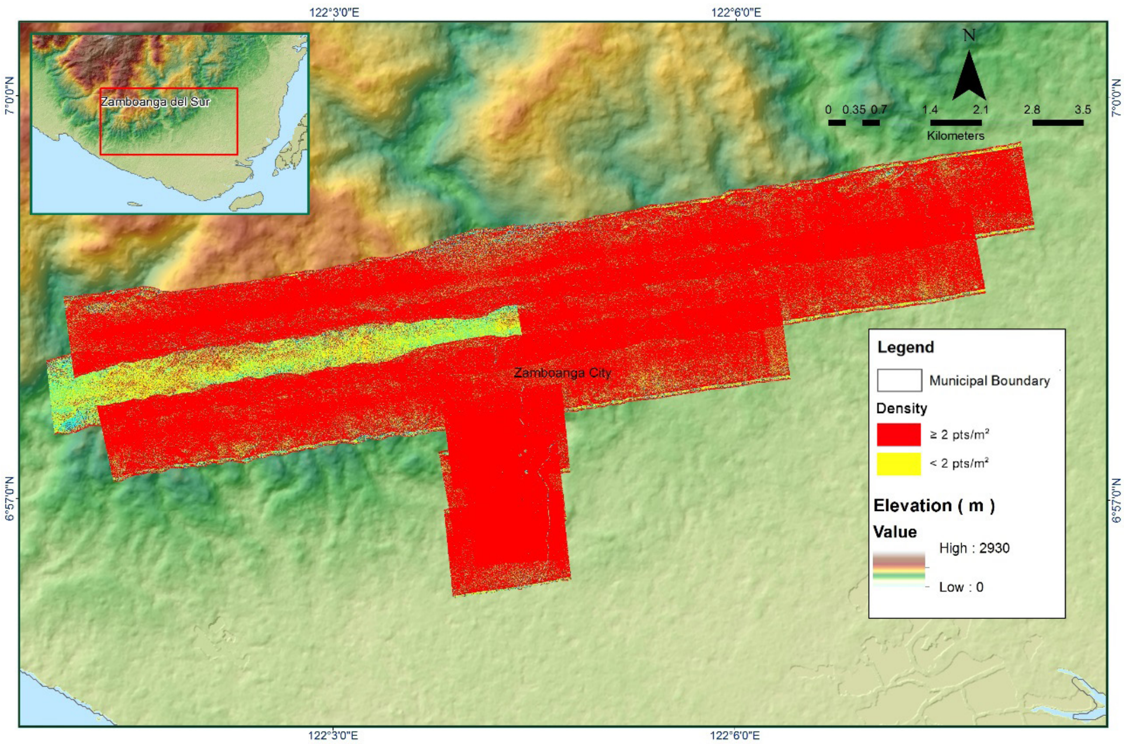


Figure A-8.20 Density map of merged LiDAR data

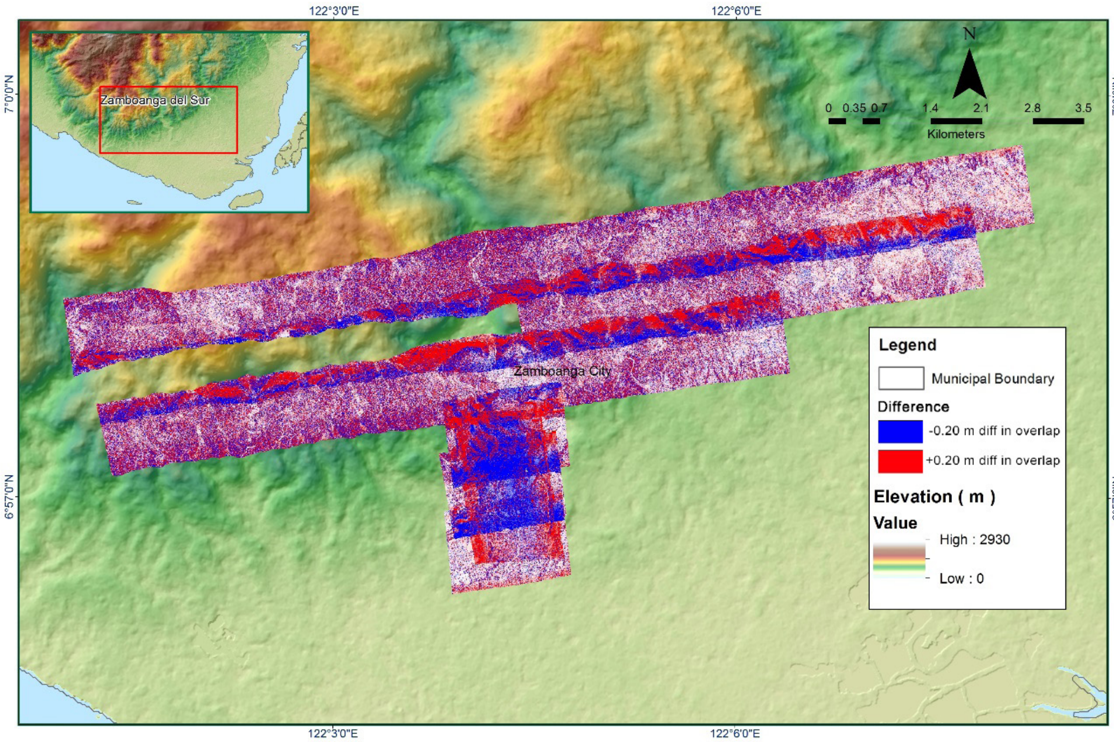


Figure A-8.21 Elevation difference between flight lines

Annex 9. Mercedes Model Basin Parameters

Table A-9.1. Mercedes Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W1060	89.4762765	65.24625	0	33.2352	0.6102	Discharge	0.0170781	0.0850453	Ratio to Peak	0.3
W1050	99.8023455	60	0	5.33168	0.0978903	Discharge	0.0023982	0.0177778	Ratio to Peak	0.3
W1040	99.8023455	60	0	7.12128	0.13075	Discharge	0.0042494	0.0177778	Ratio to Peak	0.3
W1030	99.8023455	60	0	6.17512	0.11337	Discharge	0.0027858	0.0177778	Ratio to Peak	0.3
W1020	99.8023455	60	0	7.1932	0.13207	Discharge	0.002686	0.0177778	Ratio to Peak	0.3
W1010	99.8023455	60	0	9.144	0.1678887	Discharge	0.0055049	0.0261333	Ratio to Peak	0.3
W1000	99.8023455	60	0	6.64904	0.12208	Discharge	0.0030129	0.0118519	Ratio to Peak	0.3
W990	99.6826545	60.06125	0	6.1552	0.11301	Discharge	0.003054	0.0177778	Ratio to Peak	0.3
W980	64.8163035	77.77375	0	8.9952	0.16515	Discharge	0.0087509	0.0177778	Ratio to Peak	0.3
W970	85.140198	66.94625	0	12.8256	0.23548	Discharge	0.0086802	0.0177778	Ratio to Peak	0.3
W960	34.5417345	93.1525	0	5.15568	0.0946588	Discharge	0.0038322	0.0177778	Ratio to Peak	0.3
W950	25.983828	97.5	0	1.46896	0.0269706	Discharge	0.00067037	0.0177778	Ratio to Peak	0.3
W940	34.0738515	92.79125	0	4.7124	0.0865201	Discharge	0.0026143	0.0177778	Ratio to Peak	0.3
W930	25.983828	97.5	0	3.94808	0.0724862	Discharge	0.0035329	0.0177778	Ratio to Peak	0.3
W920	25.983828	97.5	0	2.81568	0.0516956	Discharge	0.0023997	0.0261333	Ratio to Peak	0.3
W910	25.983828	97.5	0	2.82496	0.0518658	Discharge	0.0021405	0.0261333	Ratio to Peak	0.3
W900	40.081977	89.29375	0	4.3912	0.0806226	Discharge	0.0024559	0.0177778	Ratio to Peak	0.3
W890	25.983828	97.5	0	1.49448	0.0274384	Discharge	0.000146408	0.0177778	Ratio to Peak	0.3
W880	25.983828	97.5	0	2.76432	0.0507525	Discharge	0.0011116	0.0177778	Ratio to Peak	0.3
W1060	89.4762765	65.24625	0	33.2352	0.6102	Discharge	0.0170781	0.0850453	Ratio to Peak	0.3

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W1050	99.8023455	60	0	5.33168	0.0978903	Discharge	0.0023982	0.0177778	Ratio to Peak	0.3
W870	25.983828	97.5	0	3.12456	0.0573674	Discharge	0.0014054	0.0177778	Ratio to Peak	0.3
W860	25.983828	97.5	0	4.46288	0.0819383	Discharge	0.000353486	0.0177778	Ratio to Peak	0.3
W850	25.983828	97.5	0	3.82056	0.0701454	Discharge	0.0025556	0.0177778	Ratio to Peak	0.3
W840	30.474054	94.88625	0	4.69288	0.086162	Discharge	0.0036296	0.0177778	Ratio to Peak	0.3
W830	25.983828	97.5	0	6.2492	0.11474	Discharge	0.0026233	0.0177778	Ratio to Peak	0.3
W820	25.983828	97.5	0	3.274	0.0601103	Discharge	0.00026173	0.0177778	Ratio to Peak	0.3
W810	25.983828	97.5	0	2.98528	0.0548098	Discharge	0.0017654	0.0177778	Ratio to Peak	0.3
W800	25.983828	97.5	0	3.46144	0.0635522	Discharge	0.0024804	0.0177778	Ratio to Peak	0.3
W790	27.2659725	96.75375	0	7.75112	0.14231	Discharge	0.00736	0.0177778	Ratio to Peak	0.3
W780	25.983828	97.5	0	4.52408	0.0830624	Discharge	0.0025993	0.0177778	Ratio to Peak	0.3
W770	25.983828	97.5	0	5.86728	0.10772	Discharge	0.0057761	0.0177778	Ratio to Peak	0.3
W760	25.983828	97.5	0	3.27296	0.0600909	Discharge	0.0011221	0.0177778	Ratio to Peak	0.3
W750	25.983828	97.5	0	3.7292	0.0684681	Discharge	0.0025476	0.0177778	Ratio to Peak	0.3
W740	33.7038975	93.5775	0	5.34456	0.0981256	Discharge	0.00664	0.0177778	Ratio to Peak	0.3
W730	48.794031	85.9125	0	6.42424	0.11795	Discharge	0.0036005	0.0177778	Ratio to Peak	0.3
W720	39.1988025	89.83375	0	5.27096	0.0967748	Discharge	0.008066	0.0177778	Ratio to Peak	0.3
W710	25.983828	97.5	0	3.75648	0.0689691	Discharge	0.0040182	0.0177778	Ratio to Peak	0.3
W700	25.983828	97.5	0	1.24272	0.0228171	Discharge	6.17E-05	0.0177778	Ratio to Peak	0.3
W690	80.5284675	68.6425	0	7.20248	0.13224	Discharge	0.0058303	0.0177778	Ratio to Peak	0.3
W680	25.983828	97.5	0	2.17104	0.0398601	Discharge	0.0012008	0.0177778	Ratio to Peak	0.3
W670	36.1339875	92.34375	0	3.15808	0.0579824	Discharge	0.0024177	0.0177778	Ratio to Peak	0.3
W660	27.336699	96.8125	0	4.05248	0.0744029	Discharge	0.002874	0.0261333	Ratio to Peak	0.3
W650	32.9966325	93.9375	0	3.72744	0.0684355	Discharge	0.002502	0.0830131	Ratio to Peak	0.3

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W640	53.9534385	83.29125	0	5.56528	0.10218	Discharge	0.0036472	0.0177778	Ratio to Peak	0.3
W630	99.8023455	60	0	2.60632	0.0478523	Discharge	0.000317887	0.0177778	Ratio to Peak	0.3
W620	91.897299	62.8325	0	7.82472	0.14366	Discharge	0.0059426	0.0177778	Ratio to Peak	0.3
W610	92.205594	63.86	0	8.396	0.15415	Discharge	0.0024017	0.0177778	Ratio to Peak	0.3
W600	93.6001755	62.22125	0	8.3048	0.15247	Discharge	0.0035409	0.0177778	Ratio to Peak	0.3
W590	99.8023455	60	0	8.6	0.1579	Discharge	0.0025	0.0177778	Ratio to Peak	0.3
W580	99.8023455	60	0	8.3472	0.15326	Discharge	0.0027742	0.0261333	Ratio to Peak	0.3
W570	98.806734	60.3575	0	14.232	0.2613	Discharge	0.0088707	0.038416	Ratio to Peak	0.3
W560	86.8031775	66.60375	0	16.632	0.30536	Discharge	0.0099934	0.0177778	Ratio to Peak	0.3
W550	99.8023455	60	0	9.208	0.16906	Discharge	0.0022959	0.038416	Ratio to Peak	0.3
W540	92.321658	62.68	0	11.52	0.21151	Discharge	0.007167	0.0177778	Ratio to Peak	0.3

Annex 10. Mercedes Model Reach Parameters

Table A-10.1. Mercedes Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R70	Automatic Fixed Interval	241.42	0.0555019	241.42	Trapezoid	30	1
R90	Automatic Fixed Interval	1084.3	0.0245221	1084.3	Trapezoid	30	1
R110	Automatic Fixed Interval	1153.3	0.039488	1153.3	Trapezoid	30	1
R130	Automatic Fixed Interval	3211.5	0.0556812	3211.5	Trapezoid	30	1
R140	Automatic Fixed Interval	987.7	0.0544809	987.7	Trapezoid	30	1
R150	Automatic Fixed Interval	647.7	0.0512279	647.7	Trapezoid	30	1
R160	Automatic Fixed Interval	206.57	0.0408191	206.57	Trapezoid	30	1
R190	Automatic Fixed Interval	1140.1	0.0086207	1140.1	Trapezoid	30	1
R210	Automatic Fixed Interval	1664.4	0.0405305	1664.4	Trapezoid	30	1
R230	Automatic Fixed Interval	795.27	0.011228	795.27	Trapezoid	30	1
R260	Automatic Fixed Interval	513.85	0.0111499	513.85	Trapezoid	30	1
R270	Automatic Fixed Interval	1834.4	0.0184486	1834.4	Trapezoid	30	1
R280	Automatic Fixed Interval	823.14	0.0038411	823.14	Trapezoid	30	1
R310	Automatic Fixed Interval	304.85	0.0001	304.85	Trapezoid	30	1
R320	Automatic Fixed Interval	446.27	0.0581721	446.27	Trapezoid	30	1
R330	Automatic Fixed Interval	258.99	0.0901284	258.99	Trapezoid	30	1
R380	Automatic Fixed Interval	517.7	0.0001	517.7	Trapezoid	30	1
R390	Automatic Fixed Interval	548.7	0.15237	548.7	Trapezoid	30	1
R410	Automatic Fixed Interval	322.13	0.0497242	322.13	Trapezoid	30	1
R420	Automatic Fixed Interval	841.54	0.0292951	841.54	Trapezoid	30	1
R430	Automatic Fixed Interval	1100.5	0.0359817	0.055	Trapezoid	30	1
R460	Automatic Fixed Interval	720.12	0.0106701	0.055	Trapezoid	30	1
R480	Automatic Fixed Interval	926.69	0.0079047	0.055	Trapezoid	30	1
R490	Automatic Fixed Interval	1085.7	0.0102168	0.055	Trapezoid	30	1
R520	Automatic Fixed Interval	840.83	0.0209252	0.055	Trapezoid	30	1
R530	Automatic Fixed Interval	6254.1	0.0069262	0.055	Trapezoid	30	1

Annex 11. Mercedes Field Validation Points

Table A-11.1. Mercedes Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
1	6.976665	122.143505	0.03	0	0.03	Not Defined	5 -Year
2	6.976443	122.145085	0.03	0	0.03	Not Defined	5 -Year
3	6.977991	122.143201	0.03	0	0.03	Not Defined	5 -Year
4	6.97558	122.143046	0.07	0	0.07	Not Defined	5 -Year
5	6.959618	122.13433	0.03	0	0.03	Not Defined	5 -Year
6	6.95924	122.135899	0.03	0	0.03	Not Defined	5 -Year
7	6.961229	122.136953	0.03	0	0.03	Not Defined	5 -Year
8	6.976423	122.134849	2.4	0	2.4	Not Defined	5 -Year
9	6.971876	122.132071	0.03	0	0.03	Not Defined	5 -Year
10	6.976897	122.128723	0.03	0	0.03	Not Defined	5 -Year
11	6.978754	122.132458	1.04	0.4	0.64	Not Defined	5 -Year
12	6.963961	122.1384	0.09	0	0.09	Not Defined	5 -Year
13	6.959974	122.14538	0.12	0	0.12	Not Defined	5 -Year
14	6.97573	122.133466	0.03	0	0.03	Not Defined	5 -Year
15	6.976993	122.147619	0.04	0.5	-0.46	24-09-2016	5 -Year
16	6.977125	122.147955	0.03	0.2	-0.17	24-09-2016 12:00	5 -Year
17	6.976631	122.148146	0.1	0.2	-0.1	24-09-2016 12:00	5 -Year
18	6.977236	122.148097	0.03	0.3	-0.27	24-09-2016 12:00	5 -Year
19	6.977328	122.148079	0.03	0.3	-0.27	24-09-2016 12:00	5 -Year
20	6.979267	122.147259	0.03	0.1	-0.07	24-09-2016	5 -Year
21	6.985896	122.125847	0.03	0	0.03	Not Defined	5 -Year
22	6.935078	122.136338	0.03	0	0.03	Not Defined	5 -Year
23	6.937477	122.136629	0.98	0	0.98	Not Defined	5 -Year
24	6.958621	122.147919	0.05	0	0.05	Not Defined	5 -Year
25	6.959433	122.148016	0.05	0	0.05	Not Defined	5 -Year
26	6.960551	122.147955	0.25	0	0.25	Not Defined	5 -Year
27	6.96012	122.14699	0.39	0	0.39	Not Defined	5 -Year
28	6.963291	122.146748	0.03	0	0.03	Not Defined	5 -Year
29	6.957424	122.148369	0.03	0	0.03	Not Defined	5 -Year
30	6.955897	122.148411	0.04	0	0.04	Not Defined	5 -Year
31	6.954823	122.148533	0.09	0	0.09	Not Defined	5 -Year
32	6.953963	122.148341	0.06	0	0.06	Not Defined	5 -Year
33	6.958259	122.148559	0.11	0	0.11	Not Defined	5 -Year
34	6.959304	122.150327	0.07	0	0.07	Not Defined	5 -Year
35	6.959021	122.149355	0.05	0	0.05	Not Defined	5 -Year
36	6.958224	122.149578	0.07	0	0.07	Not Defined	5 -Year
37	6.956278	122.147747	0.04	0	0.04	Not Defined	5 -Year
38	6.954977	122.146799	0.03	0	0.03	Not Defined	5 -Year
39	6.956702	122.149089	0.03	0	0.03	Not Defined	5 -Year
40	6.957809	122.15122	0.12	0	0.12	Not Defined	5 -Year
41	6.956317	122.150502	0.06	0	0.06	Not Defined	5 -Year
42	6.95563	122.149202	0.03	0	0.03	Not Defined	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
43	6.957007	122.149818	0.05	0	0.05	Not Defined	5 -Year
44	6.954257	122.150001	0.03	0	0.03	Not Defined	5 -Year
45	6.953566	122.149583	0.03	0	0.03	Not Defined	5 -Year
46	6.954442	122.151587	0.43	0	0.43	Not Defined	5 -Year
47	6.960753	122.141674	0.03	0	0.03	Not Defined	5 -Year
48	6.958233	122.143733	0.03	0	0.03	Not Defined	5 -Year
49	6.958525	122.144438	0.09	0	0.09	Not Defined	5 -Year
50	6.956174	122.139885	1.01	0	1.01	Not Defined	5 -Year
51	6.956328	122.141591	0.03	0	0.03	Not Defined	5 -Year
52	6.953001	122.141358	0.03	0	0.03	Not Defined	5 -Year
53	6.947972	122.142702	0.03	0	0.03	Not Defined	5 -Year
54	6.946268	122.142414	0.16	0	0.16	Not Defined	5 -Year
55	6.945994	122.140669	0.03	0	0.03	Not Defined	5 -Year
56	6.943915	122.142858	0.03	0	0.03	Not Defined	5 -Year
57	6.94408	122.140836	0.03	0	0.03	Not Defined	5 -Year
58	6.952821	122.149529	0.25	0	0.25	Not Defined	5 -Year
59	6.942131	122.142963	0.03	0	0.03	Not Defined	5 -Year
60	6.952642	122.150789	0.03	0	0.03	Not Defined	5 -Year
61	6.951375	122.149419	0.18	0	0.18	Not Defined	5 -Year
62	6.949184	122.150419	0.03	0	0.03	Not Defined	5 -Year
63	6.950001	122.15117	0.06	0	0.06	Not Defined	5 -Year
64	6.950089	122.152264	0.03	0	0.03	Not Defined	5 -Year
65	6.948201	122.152621	0.03	0	0.03	Not Defined	5 -Year
66	6.952477	122.146069	0.03	0	0.03	Not Defined	5 -Year
67	6.952422	122.147321	0.03	0	0.03	Not Defined	5 -Year
68	6.951106	122.147332	0.03	0	0.03	Not Defined	5 -Year
69	6.950606	122.148442	0.06	0	0.06	Not Defined	5 -Year
70	6.949852	122.145655	0.11	0	0.11	Not Defined	5 -Year
71	6.947785	122.148927	0.03	0	0.03	Not Defined	5 -Year
72	6.945411	122.147364	0.07	0	0.07	Not Defined	5 -Year
73	6.945059	122.151743	0.03	0	0.03	Not Defined	5 -Year
74	6.943398	122.150438	0.03	0	0.03	Not Defined	5 -Year
75	6.938752	122.142516	0.03	0	0.03	Not Defined	5 -Year
76	6.939455	122.143878	0.26	0	0.26	Not Defined	5 -Year
77	6.935419	122.144819	0.07	0	0.07	Not Defined	5 -Year
78	6.936236	122.141962	0.03	0	0.03	Not Defined	5 -Year
79	6.934196	122.143523	0.06	0	0.06	Not Defined	5 -Year
80	6.933027	122.142687	0.07	0	0.07	Not Defined	5 -Year
81	6.939857	122.146849	0.03	0	0.03	Not Defined	5 -Year
82	6.941786	122.146858	0.03	0	0.03	Not Defined	5 -Year
83	6.938288	122.153636	0.03	0	0.03	Not Defined	5 -Year
84	6.937655	122.149076	0.04	0	0.04	Not Defined	5 -Year
85	6.939285	122.149639	0.03	0	0.03	Not Defined	5 -Year
86	6.939583	122.151442	0.03	0	0.03	Not Defined	5 -Year
87	6.935978	122.150372	0.3	0	0.3	Not Defined	5 -Year
88	6.941308	122.139958	0.42	0	0.42	Not Defined	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
89	6.938397	122.138509	0.32	0	0.32	Not Defined	5 -Year
90	6.940123	122.137204	0.27	0	0.27	Not Defined	5 -Year
91	6.966029	122.14016	0.03	0	0.03	Not Defined	5 -Year
92	6.964448	122.139866	0.07	0	0.07	Not Defined	5 -Year
93	6.963469	122.141059	0.3	0	0.3	Not Defined	5 -Year
94	6.967778	122.145041	0.56	0	0.56	Not Defined	5 -Year
95	6.965845	122.14422	0.03	0	0.03	Not Defined	5 -Year
96	6.964424	122.144334	0.03	0	0.03	Not Defined	5 -Year
97	6.964484	122.145935	0.26	0	0.26	Not Defined	5 -Year
98	6.96575	122.145511	0.66	0	0.66	Not Defined	5 -Year
99	6.967131	122.145999	0.53	0	0.53	Not Defined	5 -Year
100	6.971625	122.146374	0.03	0	0.03	Not Defined	5 -Year
101	6.94163	122.138121	0.12	0	0.12	Not Defined	5 -Year
102	6.942931	122.136408	0.2	0	0.2	Not Defined	5 -Year
103	6.968223	122.139693	0.03	0	0.03	Not Defined	5 -Year
104	6.972438	122.142737	0.03	0	0.03	Not Defined	5 -Year
105	6.965251	122.141832	0.08	0	0.08	Not Defined	5 -Year
106	6.996449	122.118734	0.03	0	0.03	Not Defined	5 -Year
107	6.989367	122.122751	0.03	0	0.03	Not Defined	5 -Year
108	6.986279	122.122634	0.03	0	0.03	Not Defined	5 -Year
109	6.94912	122.155436	0.03	0	0.03	Not Defined	5 -Year
110	6.946171	122.15846	0.03	0	0.03	Not Defined	5 -Year
111	6.948526	122.157406	0.44	0	0.44	Not Defined	5 -Year
112	6.983564	122.133331	0.03	0	0.03	Not Defined	5 -Year
113	6.984256	122.130329	0.03	0	0.03	Not Defined	5 -Year
114	6.933099	122.138495	0.05	0.3	-0.25	11-11-2013	5 -Year
115	6.932495	122.138721	0.2	0.5	-0.3	30-11-2013	5 -Year
116	6.9325	122.138608	0.24	0.1	0.14	30-11-2013	5 -Year
117	6.978198	122.145875	0.04	0	0.04	Not Defined	5 -Year
118	6.982306	122.138333	0.03	0	0.03	Not Defined	5 -Year
119	6.997796	122.11279	0.03	0	0.03	Not Defined	5 -Year
120	6.9948	122.113754	0.08	0	0.08	Not Defined	5 -Year
121	6.950482	122.129556	0.06	0	0.06	Not Defined	5 -Year
122	6.950052	122.131003	0.03	0	0.03	Not Defined	5 -Year
123	6.952973	122.129661	0.03	0	0.03	Not Defined	5 -Year
124	6.952719	122.131538	0.03	0	0.03	Not Defined	5 -Year
125	6.953282	122.132497	0.03	0	0.03	Not Defined	5 -Year
126	6.951705	122.131995	0.03	0	0.03	Not Defined	5 -Year
127	7.001533	122.11137	0.03	0	0.03	Not Defined	5 -Year
128	6.994564	122.109631	0.04	0	0.04	Not Defined	5 -Year
129	6.997674	122.108713	0.03	0	0.03	Not Defined	5 -Year
130	6.955529	122.158841	0.19	0	0.19	Not Defined	5 -Year
131	6.958985	122.158215	0.03	0	0.03	Not Defined	5 -Year
132	6.964046	122.158299	1.03	0	1.03	Not Defined	5 -Year
133	6.979925	122.134648	0.03	0	0.03	Not Defined	5 -Year
134	6.979183	122.133613	0.03	0	0.03	Not Defined	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
135	6.979485	122.127717	0.03	0	0.03	Not Defined	5 -Year
136	6.980868	122.126401	0.03	0	0.03	Not Defined	5 -Year
137	6.983293	122.124213	0.03	0	0.03	Not Defined	5 -Year
138	6.967503	122.136075	0.03	0	0.03	Not Defined	5 -Year
139	6.971353	122.137853	5.51	1	4.51	Not Defined	5 -Year
140	6.955852	122.131395	0	0.3	-0.3	Not Defined	5 -Year
141	6.966973	122.138063	0.03	0	0.03	Not Defined	5 -Year
142	6.965798	122.135711	0.03	0	0.03	Not Defined	5 -Year
143	6.965036	122.136111	0.03	0	0.03	Not Defined	5 -Year
144	6.958537	122.146235	0.03	0	0.03	Not Defined	5 -Year
145	6.958625	122.146771	0.06	0	0.06	Not Defined	5 -Year
146	6.980178	122.130518	0.03	0	0.03	Not Defined	5 -Year
147	6.982058	122.131628	0.03	0	0.03	Not Defined	5 -Year
148	6.973729	122.145516	0.03	0	0.03	Not Defined	5 -Year
149	6.973954	122.146803	0.03	0	0.03	Not Defined	5 -Year
150	6.973325	122.143263	0.16	0	0.16	Not Defined	5 -Year
151	6.974004	122.142061	0.1	0	0.1	Not Defined	5 -Year
152	6.976519	122.141733	0.06	0	0.06	Not Defined	5 -Year
153	6.978902	122.140837	0.03	0	0.03	Not Defined	5 -Year
154	6.974436	122.141442	0.03	0	0.03	Not Defined	5 -Year
155	6.962057	122.137346	0.03	0	0.03	Not Defined	5 -Year
156	6.962605	122.140661	0.03	0	0.03	Not Defined	5 -Year
157	6.959574	122.137314	0.05	0	0.05	Not Defined	5 -Year
158	6.961916	122.134126	0.2	0	0.2	Not Defined	5 -Year
159	6.971787	122.141462	0.37	0	0.37	Not Defined	5 -Year
160	6.970341	122.140569	0.51	0	0.51	Not Defined	5 -Year
161	6.971906	122.140463	0.5	0	0.5	Not Defined	5 -Year
162	6.963814	122.136105	0.03	0	0.03	Not Defined	5 -Year
163	6.942524	122.133858	0.06	0	0.06	Not Defined	5 -Year
164	6.969298	122.14762	0.14	0	0.14	Not Defined	5 -Year
165	6.968217	122.139697	0.03	0	0.03	Not Defined	5 -Year
166	6.972709	122.147659	0.11	0	0.11	Not Defined	5 -Year
167	6.940994	122.135066	0.03	0	0.03	Not Defined	5 -Year
168	6.94293	122.136413	0.03	0	0.03	Not Defined	5 -Year
169	6.972387	122.139033	0.76	0	0.76	Not Defined	5 -Year
170	6.974624	122.138792	0.08	0	0.08	Not Defined	5 -Year
171	6.975167	122.140635	0.03	0	0.03	Not Defined	5 -Year
172	6.973312	122.140772	0.03	0	0.03	Not Defined	5 -Year
173	6.93899	122.135254	0.03	0	0.03	Not Defined	5 -Year
174	6.938003	122.135391	0.03	0	0.03	Not Defined	5 -Year
175	6.961319	122.135267	0.03	0	0.03	Not Defined	5 -Year
176	6.993646	122.115714	1.14	1.2	-0.06	Not Defined	5 -Year
177	6.991944	122.117007	1.78	1.2	0.58	Not Defined	5 -Year
178	6.94236	122.136286	0.09	0.7	-0.61	Not Defined	5 -Year
179	6.932817	122.138572	0.3	0.4	-0.1	Ruby/ December 06,2014	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
180	6.978675	122.134152	1.51	0.3	1.21	Ruby/ December 06,2014	5 -Year
181	6.977465	122.144019	0.45	0.3	0.15	Ruby/ December 06,2014	5 -Year
182	6.979123	122.14496	0.7	0.2	0.5	Ruby/ December 06,2014	5 -Year
183	6.934351	122.139277	0.03	0	0.03	Ruby/ December 06,2014	5 -Year
184	6.933169	122.139119	0.54	0	0.54	Ruby/ December 06,2014	5 -Year
185	6.9368	122.135257	0.04	0	0.04	Ruby/ December 06,2014	5 -Year
186	6.964494	122.139094	0.93	0	0.93	Ruby/ December 06,2014	5 -Year
187	6.978336	122.137671	2.18	0	2.18	Ruby/ December 06,2014	5 -Year
188	6.953255	122.158881	0.81	0	0.81	Ruby/ December 06,2014	5 -Year
189	6.950491	122.159461	0.03	0	0.03	Ruby/ December 06,2014	5 -Year
190	6.938185	122.144237	0.14	0	0.14	Ruby/ December 06,2014	5 -Year
				RMSE	0.48		

Annex 12. Educational Institutions Affected in Mercedes Floodplain

Table A-12.1 Educational Institutions Affected in Mercedes Floodplain

Zamboanga City				
Barangay	Building Name	Rainfall Scenario		
		5-year	25-year	100-year
Lumbangan	Salaan Elementary School	None	None	None
Mampang	Arena Blanco East Elementary School	None	None	None
Mampang	Arena Blanco National High School	None	None	None
Mampang	Arena Blanco West Elementary School	None	None	None
Mercedes	Mercedes Central School	None	Low	Low
Mercedes	Mercedes National High School	Low	Low	Low
Mercedes	MERCEDES SCHOOL	None	None	None
Pasobolong	Culianan Learning Center	None	None	None
Pasobolong	Culianan National High School	None	None	Low
Salaan	Buenakapok Elementary School	None	None	None
Salaan	Pasobolong Elementary School	None	None	None
Salaan	Salaan Elementary School	None	None	None
Tugbungan	Arena Blanco National High School	None	None	None
Zambowood	Zambowood Elementary School	None	None	None

Annex 13. Medical Institutions Affected in Mercedes Floodplain

Table A-13.1 Medical Institutions Affected in Mercedes Floodplain

Zamboanga City				
Barangay	Building Name	Rainfall Scenario		
		5-year	25-year	100-year
Lumayang	Salaan Health Center	None	None	None
Mercedes	Mercedes Health Center	None	None	None
Pasobolong	Culianan Health Center	None	None	None
Salaan	LANZONES HEALTH CENTER	None	None	None
Salaan	Mancao Medical Clinic	None	None	None
Salaan	Minadanao Central Sanitarium General Hospital	None	None	None
Salaan	Pasobolong Health Center	None	None	None