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

LiDAR Surveys and Flood Mapping of Tumaga River

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

JULY 2017

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

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

M. Rodriguez, E. Epino, L.P. Balicanta, C. Cruz, L.G. Acuña, G. Hipolito, For. Ma. Verlina Tonga, J. Alviar, J.S. Caballero, P.P. dela Cruz, D.T. Lozano, D.C. Tajora, E.B. Salvador, R.C. Alberto, C.C. Atacador, L.R. Taguse, M.R. Ang, J.D. Fabila, S.D. Samalburo, G.M. Apat, H.F. Santos, M.A. Olanda, A.V. Araneta, C.T. Lubiano , J.P. Ballori, J.L. Paterno, A.M. Lagmay, C. Uichanco, S. Sueno, M. Moises, H. Ines, M. del Rosario, K. Punay, N. Tingin, G. Sumajit (2017), LiDAR Surveys and Flood Mapping of Tumaga River, in Enrico C. Paringit, (Ed.), Flood Hazard Mapping of the Philippines using LIDAR, Quezon City: University of the Philippines Training Center for Applied Geodesy and Photogrammetry (UP TCAGP). 164 pp.

For questions/queries regarding this report, contact:

Mr. Mario S. Rodriguez
Project Leader, Phil-LiDAR 1 Program
Ateneo de Zamboanga University
Zamboanga City, Philippines 7000
rodriguezmars@adzu.edu.ph

Enrico C. Paringit, Dr. Eng.
Program Leader, Phil-LiDAR 1 Program
University of the Philippines Diliman
Quezon City, Philippines 1101
E-mail: ecparingit@up.edu.ph

Table of Contents

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS AND ABBREVIATIONS

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

Chapter 1: OVERVIEW OF THE PROGRAM AND TUMAGA RIVER

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

1.1 Background of the Phil-LIDAR 1 Program

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

Also, the program was aimed at producing an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through DOST. The methods applied in this report are thoroughly described in a separate publiction entitled "FLOOD MAPING OF RIVERS IN THE PHILIPPINES USING AIRBORNE LIDAR: METHODS (Paringit, et al., 2017) available separately."

The implementing partner university for the Phil-LiDAR 1 Program is the Ateneo de Zamboanga (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 Zamboanga Peninsula. The university is located in Zamboanga City.

1.2 Overview of Tumaga River Basin

Tumaga River is one of the biggest and most locally known rivers in the Zamboanga Peninsula. Its more or less thirty-kilometer reach, extends from Lumayang in the north to Arena Blanco in the south and traverses the following barangays of Zamboanga City: Dulian, Pasonanca, Sta Maria, Boalan, Tumaga, Zamboowood, Guiwan, Tetuan, Tugbungan,Talon-talon, and Mampang. Majority of these barangays are located in the urban parts of the city and are densely populated turning most of the downstream stretch of the river into a seemingly manmade semi-concrete creek and dumpsite. On the other hand, the watershed in the upstream part, more locally known as the Pasonanca Watershed or Pasonanca Natural Park, is heavily forested with endemic trees and covers some parts of Dulian in the west and Lunzuran in the east. The riverhas a catchment area approximately equal to 140.50 sq.km and drains into a stretch of mangrove forest fronting Sacol Island.

Gifted with untainted scenic spots like the Carreon Falls and the Pasonanca Aviary and Butterfly Garden, the name "Tumaga" unsurprisingly came from a romantic expression of adoration from a Spanish commandant named Col. Pedro Real in the 1870s. In his admiration of the river's splendor, he wrote a poem with parts stating: "Tumaga triste na dita for crosar el mar distante como agua crystalante baniara cual quien bonita." Hence, the first word of the poem became the name of the river.

Figure 1. Carreon Falls of Zambanga City

Flood Incidence and Contamination

As a tropical city, Zamboanga has an annual average rainfall amounting to 1066.7mm, three times lower than Surigao's 3086.2mm (Climatemps, 2016). It's not frequently visited by strong typhoons but still experiences heavy rains all year round. Some rain events are remarkably intense enough to inundate the low-lying areas along the river.

Last October 2013, some areas of Zamboanga City, particulary those that are located near the river, experienced severe flooding due to a 28mm rainfall in just three hours (ASTI, 2013). According to the local authorities, the flood washed away a number of houses in the following barangays: Pasonanca, Sta. Maria, Sinunuc and Putik. Other barangays like Tugbungan, Baliwasan, San Jose Gusu, Guiwan, Tetuan, Boalan, Zambowood, Patalon, Ayala, Talon-talon, Vitali, Curuan and Lumayang were also seriously affected (Inquirer Mindanao, 2013).

Aside from flooding, the river is also in danger of contamination. The monthly water quality monitoring of the Environmental Management Bureau (EMB) of DENR conducted for the last quarter of 2015 revealed very alarming results. Tumaga, especially its downstream parts, contain high concentration of total and fecal coliform which makes its water not suitable for human use. Coliforms are bacteria present in human and animal wastes. This is an indication that people along the river are mindlessly throwing their wastes into the river. Regarded as one of the most important rivers in Zamboanga City, Tumaga deserves utmost care and protection.

Figure 2. Sewer pipes draining into the river

Chapter 2: LiDAR DATA ACQUISITION OF THE TUMAGA FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Gracia Acuña, Engr. Gerome Hipolito, Engr. Grace B. Sinadjan, Ms. Julie Pearl S. Mars, Ms. Kristine Joy P. Andaya

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 Tumaga Floodplain in Zamboanga. Each flight mission has an average of 16 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 3 shows the flight plans for Tumaga Floodplain.

Table 1. Flight planning parameters for Gemini LiDAR System

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)
BLK75F	1100	20	40	100	50	120	5

Table 2. Flight planning parameters for Pegasus LiDAR System

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)
BLK75E	800/1100/1200	30	50	200	30	130	5
BLK75C	800/1200	30	50	200	30	130	5
BLK75D	800/1200	30	50	200	30	130	5
Sacol Island	800/1200	30	50	200	30	130	5
BLK75AS	1000	30	50	200	30	130	5

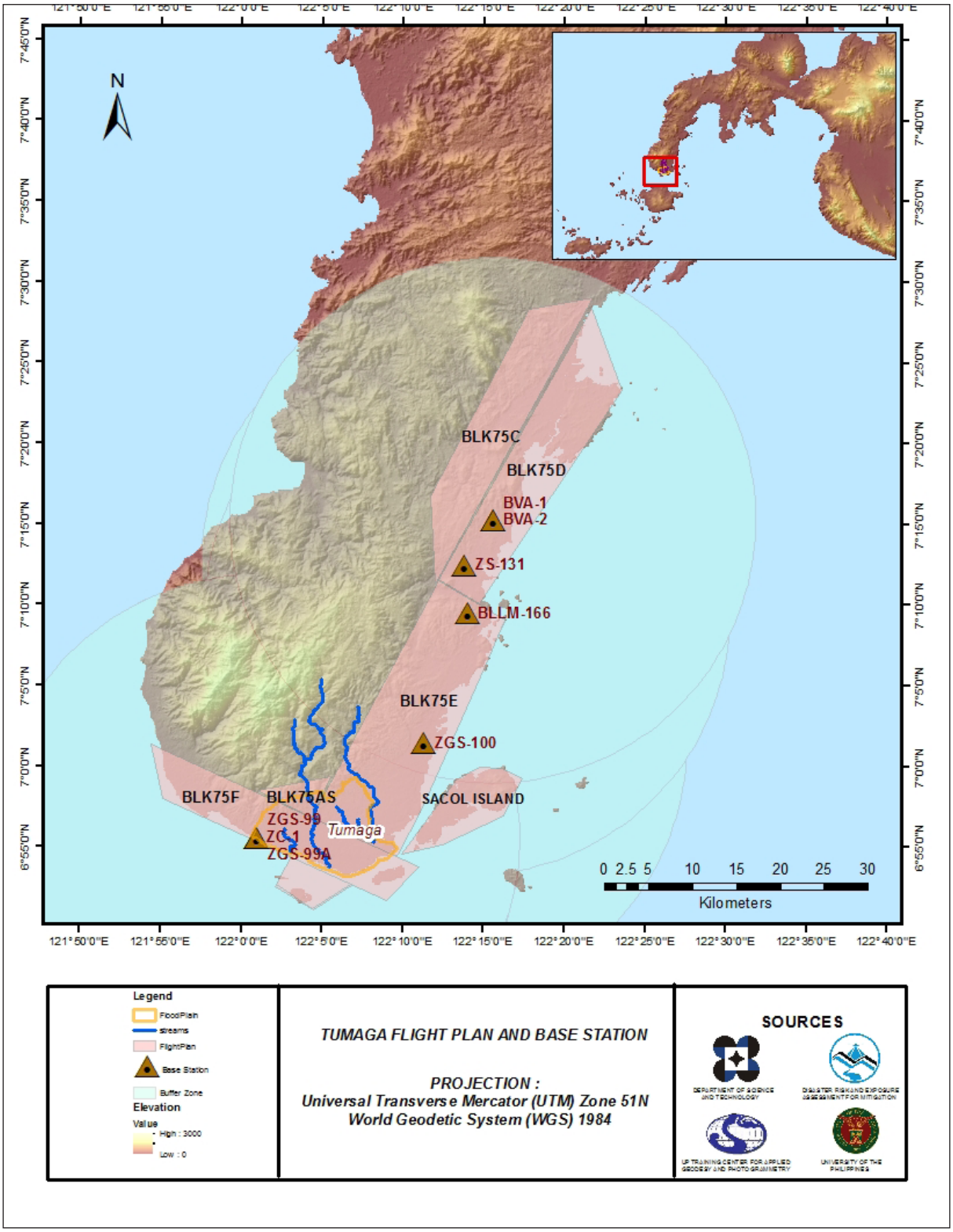


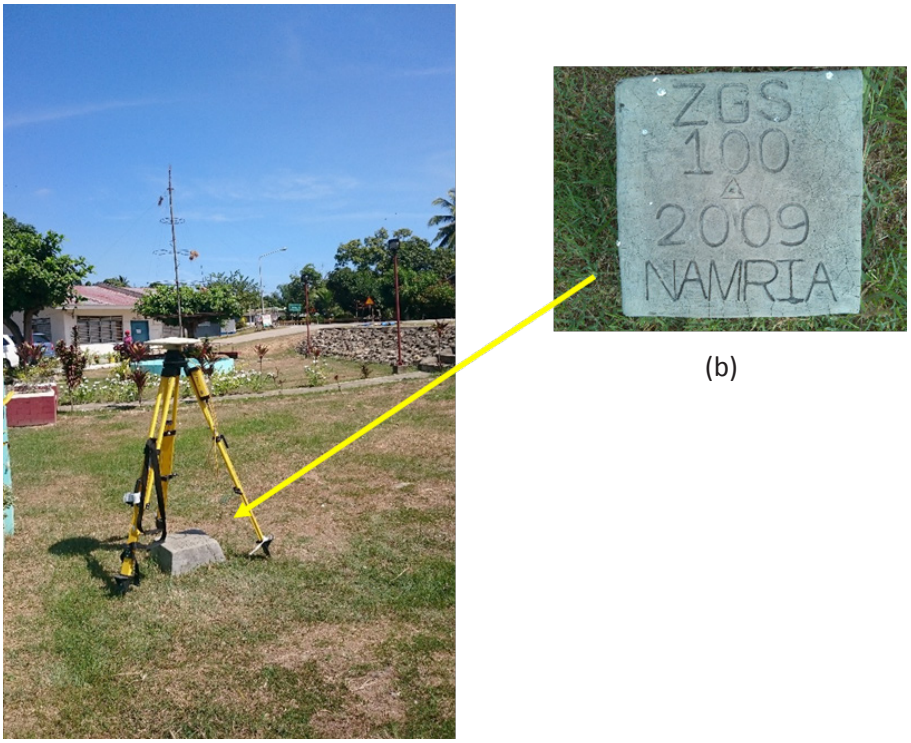
Figure 3. Flight plans used for Tumaga Floodplain

2.2 Ground Base Station

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) benchmark point: ZS-131 and four (4) established control points: ZC-1, BLLM-166, BVA-1 and ZG-99A. 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 (August 18-September 8, 2014; January 29-Febuary 12, 2015; May 19-31, 2016). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS

882, SPS 852, SPS 985, and TOPCON GR-5. Flight plans and location of base stations used during the aerial LiDAR acquisition in Tumaga Floodplain are also shown in Figure 4.

Figures 5 to 7 shows the recovered NAMRIA control stations within the area, in addition Tables 3 to 9 show the details about the following NAMRIA control stations and established points. Table 10 shows the list of all ground control points occupied during the acquisition together with the dates they are utilized during the survey.



(a) (b)

Figure 4. GPS set-up over ZGS-100 in Brgy. Manicahan, Zamboanga del Sur and (a) NAMRIA reference point ZGS-100 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point ZGS-100 used as base station for the LiDAR data acquisition

Station Name	ZGS-100	
Order of Accuracy	2nd Order	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	7° 1' 26.72368" North
	Longitude	122° 11' 12.74401" East
	Ellipsoidal Height	11.27 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting	410158.521 meters
	Northing	776712.542 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	7° 1' 23.30149" North
	Longitude	122° 11' 18.30044" East
	Ellipsoidal Height	75.603 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting	410189.97 meters
	Northing	776440.68 meters

(a) (b)

Figure 5. GPS set-up over ZS-131 in Curuan, Zamboanga City and (a) NAMRIA benchmark 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 data acquisition.

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

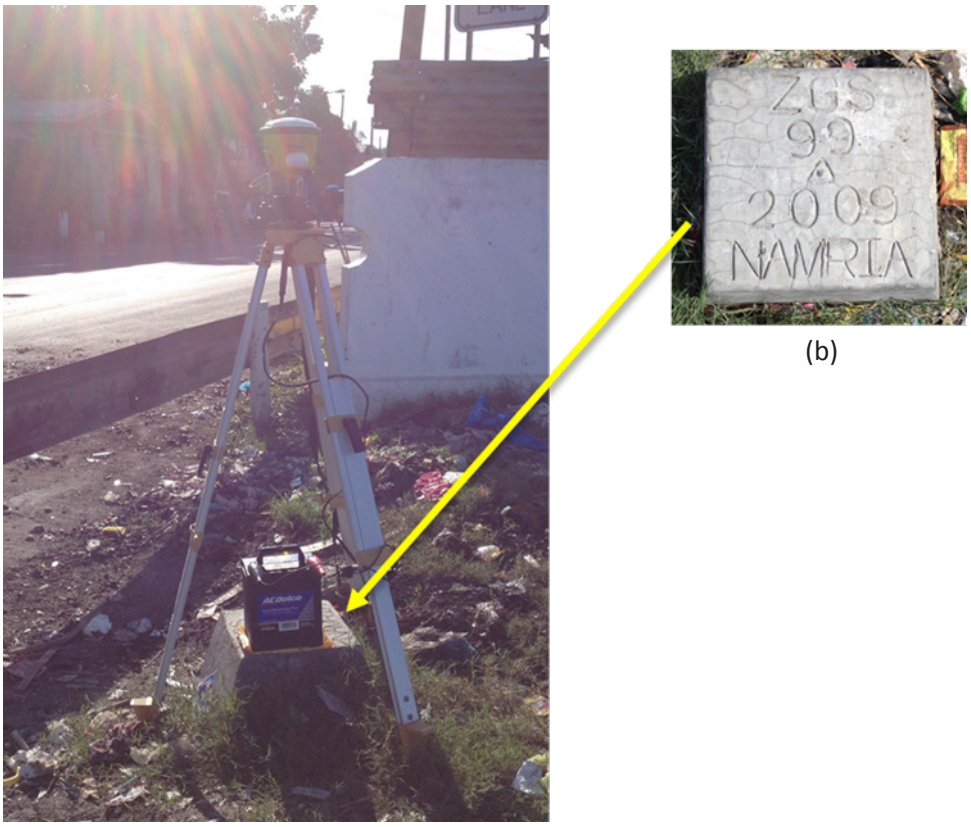
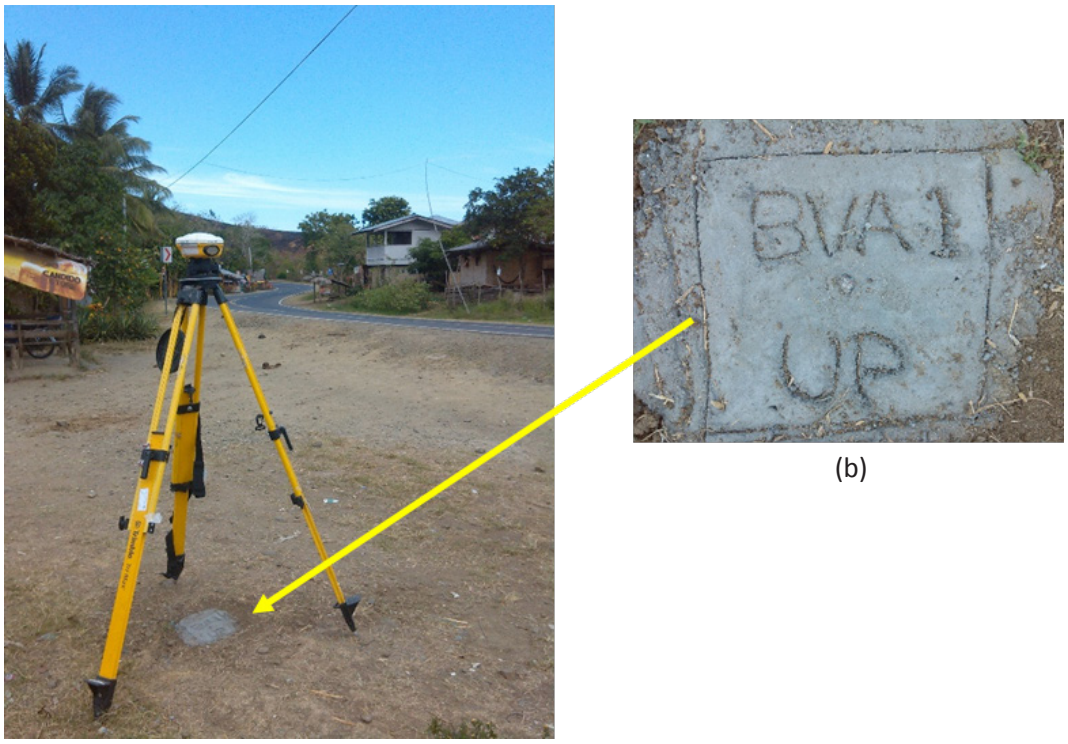


Figure 6. GPS set-up over ZGS-99 beside the seawall in Calarian, Zamboanga City and (a) NAMRIA reference point ZGS-99 (b) as recovered by the field team.

Table 5. Details of the recovered NAMRIA horizontal control point ZGS-99 used as base station for the LiDAR data acquisition.

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



(a) (b)

Figure 7. GPS set-up over BVA-1 established in Brgy. Buenavista, Zamboanga City and (a) Reference point BVA-1 (b) as established by the field team.

Table 6. Details of the established ground control point BVA-1 used as base station for the LiDAR data acquisition.

Station Name	BVA-1	
Order of Accuracy	2nd Order	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	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 7. Details of the established ground control point BLLM-161 used as base station for the LiDAR acquisition.

Station Name	BLLM
Order of Accuracy	2nd Order
Relative Error (horizontal positioning)	1 in 50,000

Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	7°09'33.60926" North
	Longitude	122°13'54.54820" East
	Ellipsoidal Height	124.333 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting	415179.269 meters
	Northing	791383.716 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	7°09'30.15553" North
	Longitude	122°14'00.09187" East
	Ellipsoidal Height	188.527 meters

Table 8. Details of the established ground control point ZC-1 used as base station for the LiDAR acquisition.

Station Name	ZC-1	
Order of Accuracy	2nd Order	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	6°55'37.81337" North
	Longitude	122°00'52.07695" East
	Ellipsoidal Height	7.666 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting	391123.456 meters
	Northing	765762.247 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	6°55'34.40099" North
	Longitude	122°00'57.64335" East
	Ellipsoidal Height	71.746 meters

Table 9. Details of the established ground 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	6° 55' 37.63895"North 122° 00' 52.48834"East
	Longitude	
	Ellipsoidal Height	7.850 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting	391136.071 meters
	Northing	765756.864 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	6° 55' 34.22659" North 122° 00' 58.05475" East
	Longitude	
	Ellipsoidal Height	71.931 meters

Table 10. Ground control points used during LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
August 23, 2014	7450GC	2BLKSF235A	ZGS-99 and ZC-1
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, 2106	23394P	1BLK75AS147B	ZGS-100 and ZS-131

2.3 Flight Missions

Five (5) missions were conducted to complete LiDAR data acquisition in Tumaga Floodplain, for a total of 18 hours and 25 minutes of flying time for RP-C9022. All missions were acquired using the Gemini and Pegasus Systems. Table 11 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 12 shows the actual parameters used during the LiDAR data acquisition.

Table 11. Flight missions for LiDAR data acquisition in Tumaga Floodplain

Date Surveyed	Flight Number	Flight Plan Area (km2)	Surveyed Area (km2)	Area Surveyed within the Floodplain (km^2)	Area Surveyed Outside the Floodplain (km^2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
August 23, 2014	7450GC	155.5	166.89	63.47	62.11	NA	4	11
February 5, 2015	2535P	137.24	331.7	-	133.04	715	3	53
February 8, 2015	2545P	906.64	318.38	10.08	227.05	608	4	11
February 11, 2015	2557P	234.33	228.21	8.34	124.82	474	4	23
May 26, 2106	23394P	8.52	54.57	33.04	2	NA	1	47
TOTAL		1442.23	1101.75	114.93	549.02	1797	18	25

Table 12. 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)

7450GC	1100	20	40	100	50	120	5
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

2.4 Survey Coverage

Tumaga Floodplain is located in the Province of Zamboanga del Sur with the floodplain situated within Zamboanga City. The list of municipalities and cities surveyed with at least one (1) square kilometer coverage, is shown in Table 13. The actual coverage of the LiDAR acquisition for Tumaga Floodplain is presented in Figure 8.

Table 13. List of municipalities and cities surveyed in Tumaga 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 Norte	Kalawit	329.51	5.03	2%
Zamboanga del sur	Zamboanga City	1461.05	522.74	36%
Zamboanga Sibugay	Ipil	130.90	60	46%
	Roseller Lim	272.39	9.61	4%
	Titay	176.50	58.4	33%
	Tungawan	441.86	26.7	6%
Total		2812.21	682.48	24.27%

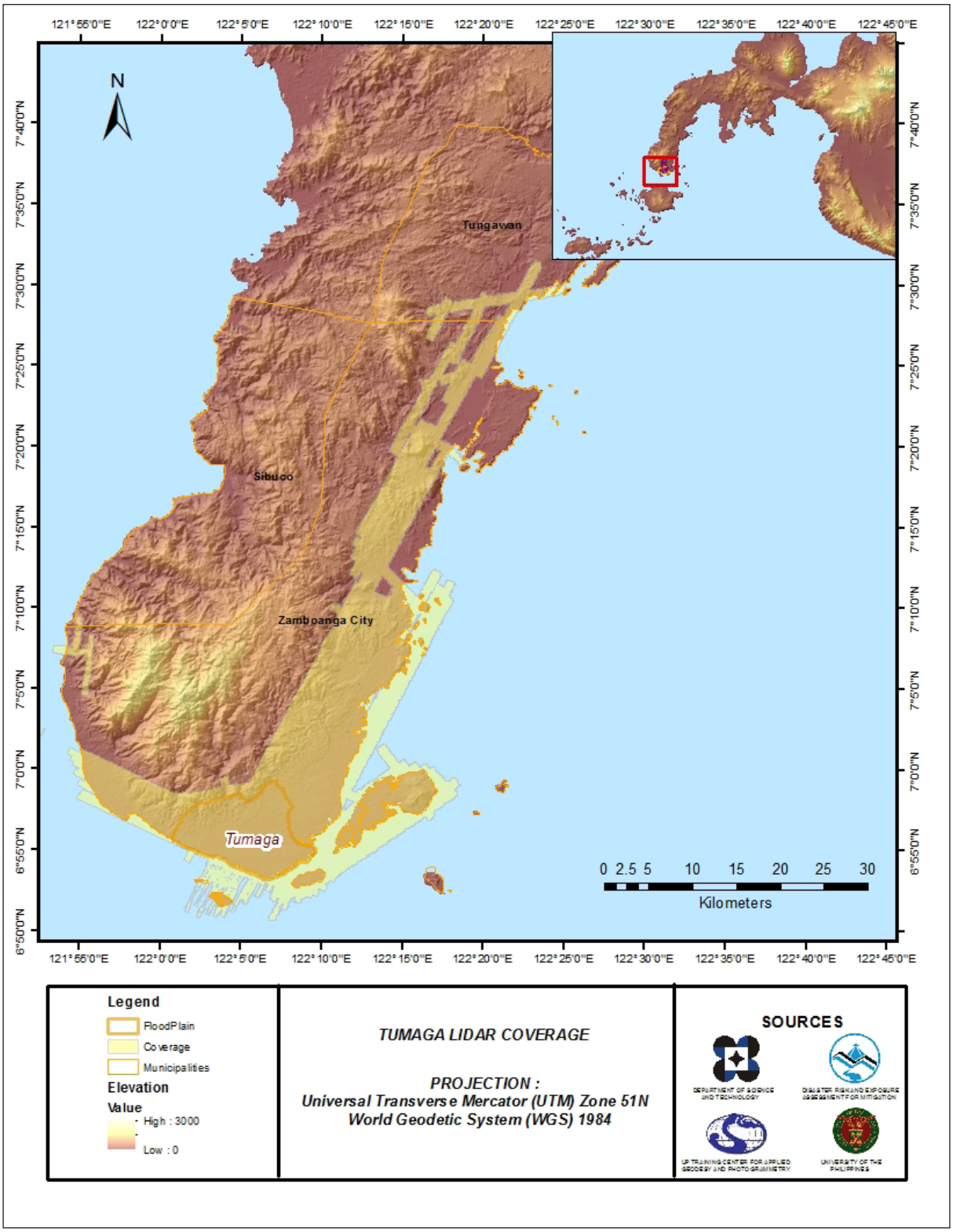


Figure 8. Actual LiDAR surver coverage for Tumaga Floodplain

Chapter 3: DATA PROCESSING FOR THE TUMAGA FLOODPLAIN

Engr. Ma. Rosario Concepcion O. Ang, Engr. John Louie D. Fabila, Engr. Sarah Jane D. Samalburo , Engr. Gladys Mae Apat , Engr. Ma. Ailyn L. Olanda , Engr. Don Matthew B. Banatin, Engr. Jovelle Anjeanette S. Canlas, Engr. Christy Lubiano , Deane Leonard M. Bool, Eriasha Loryn C. Tong

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

3.1 Overview of the LiDAR Data Pre-Processing

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

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

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

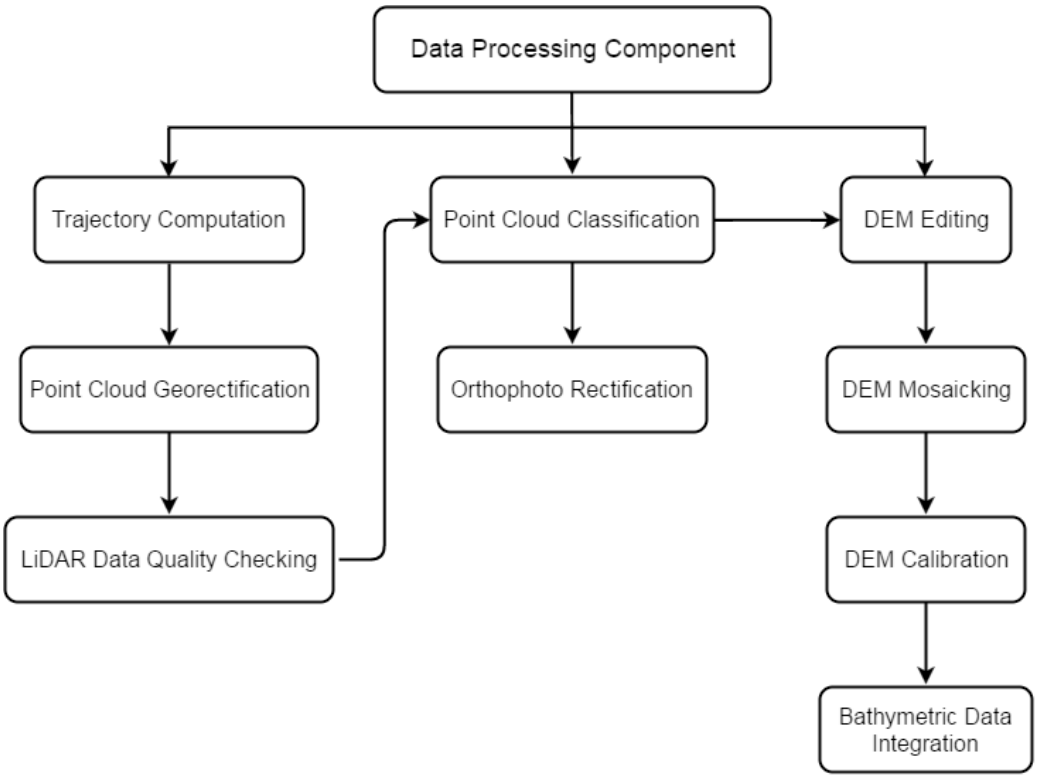


Figure 9. Schematic Diagram for Data Pre-Processing Component

3.2. Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Tumaga Floodplain can be found in Annex 5. Missions flown during the first survey conducted on August 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Gemini System, while missions acquired during the second and third survey on February 2015 and May 2016 were flown using the Pegasus System over Zamboanga City. The Data Acquisition Component (DAC) transferred a total of 103.83 gigabytes of range data, 1.099 gigabytes of POS data, 162.71 megabytes of GPS base station data, and 120.2 gigabytes of raw image data to the data server on August 23, 2014 for the first survey, February 11, 2015 for the second survey and May 26, 2014 for the third survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Tumaga was fully transferred on July 14, 2016, as indicated on the Data Transfer Sheets for Tumaga Floodplain.

3.3. Trajectory Computation

The *Smoothed Performance Metric* parameters of the computed trajectory for Flight 7450G, one of the Tumaga flights, which is the North, East, and Down position RMSE values are shown in Figure 10. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on August 23, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

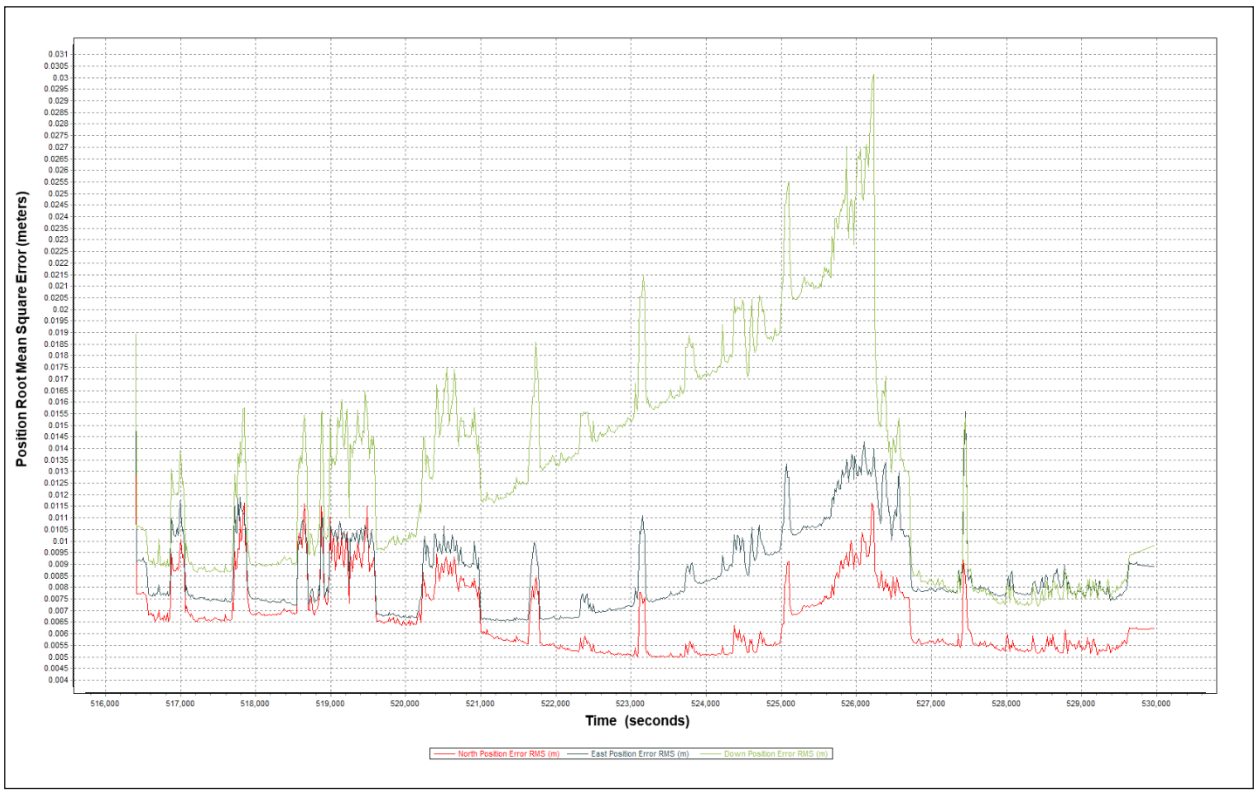


Figure 10. Smoothed Performance Metric Parameters of a Tumaga Flight 7450G.

The time of flight was from 516400 seconds to 530000 seconds, which corresponds to morning of August 23, 2014. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 10 shows that the North position RMSE peaks at 1.15 centimeters, the East position RMSE peaks at 1.55 centimeters, and the Down position RMSE peaks at 3.0 centimeters, which are within the prescribed accuracies described in the methodology.

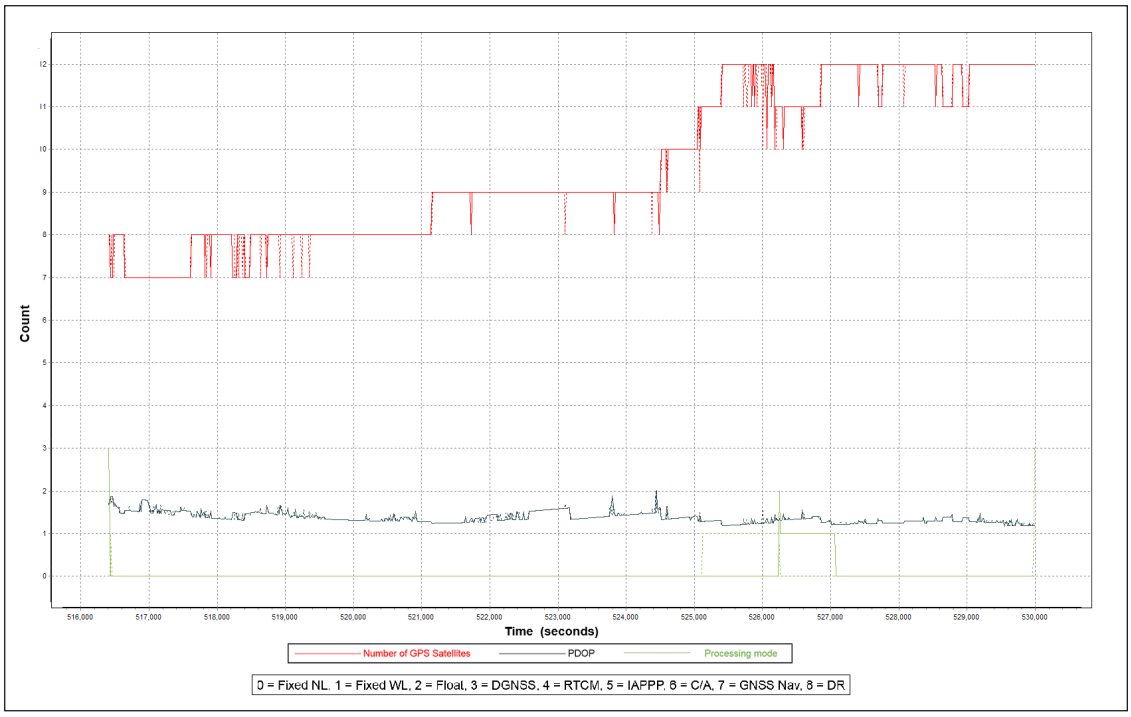


Figure 11. Solution Status Parameters of Tumaga Flight 7450G.

The *Solution Status* parameters of Flight 7450G, one of the Tumaga flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 11. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Majority of the time, the number of satellites tracked was between 7 and 12. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 2 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 Tumaga flights is shown in Figure 12.

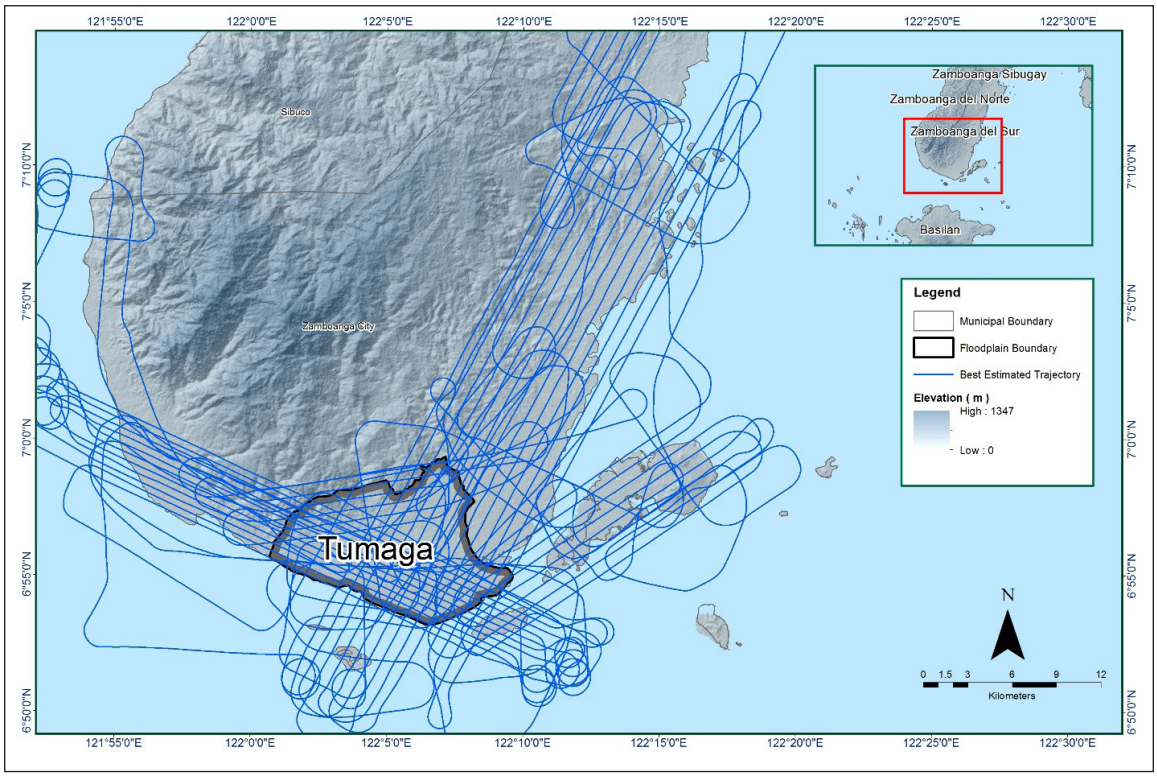


Figure 12. Best Estimated Trajectory of the LiDAR missions conducted over the Tumaga Floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 55 flight lines, with each flight line containing one channel for Gemini System and two channels for Pegasus System. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Tumaga Floodplain are given in Table 14.

Table 14. Self-Calibration Results values for Tumaga flights.

Parameter		Value
Boresight Correction stdev	(<0.001degrees)	0.000318
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.000807
GPS Position Z-correction stdev	(<0.01meters)	0.0096

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

3.5 LiDAR Data Quality Checking

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

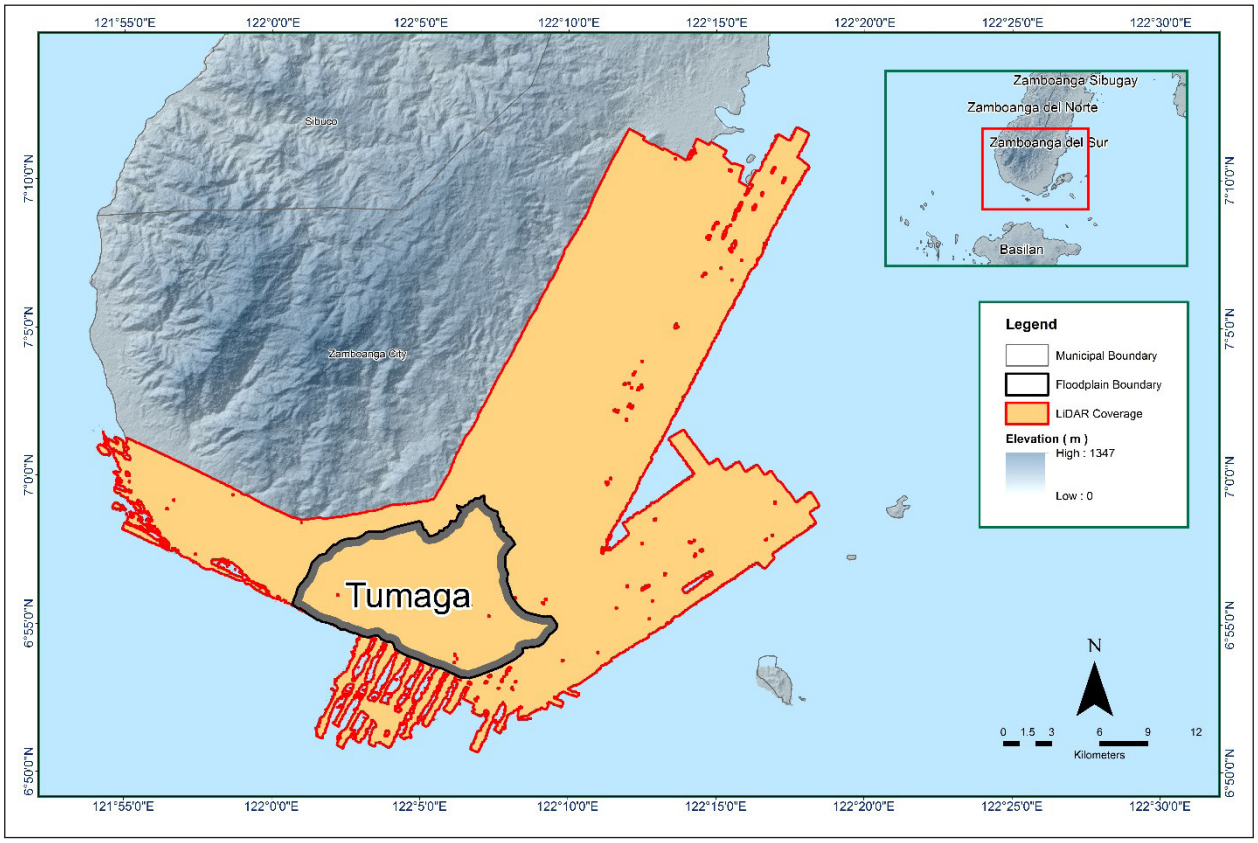


Figure 13. Boundary of the processed LiDAR data over Tumaga Floodplain

The total area covered by the Tumaga missions is 700.08 sq.km that is comprised of five (5) flight acquisitions grouped and merged into six (6) blocks as shown in Table 15.

Table 15. List of LiDAR blocks for Tumaga Floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Zamboanga_Blk75E	2535P	394.93
	2545P	
Zamboanga_Blk75F	7450G	146.15
Zamboanga_Blk75F_additional	2557P	2.48
Zamboanga_Sacol	2557P	96.90
Zamboanga_reflights_Blk75AS	23394P	35.24
Zamboanga_reflights_Blk75F_supplement	23394P	24.38
	TOTAL	700.08 sq.km

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 14. Since the Gemini System employs one channel, we would expect an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines. While the Pegasus System employs two channels, we would expect an average value of 2 (blue) for areas where there is limited overlap, and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines.

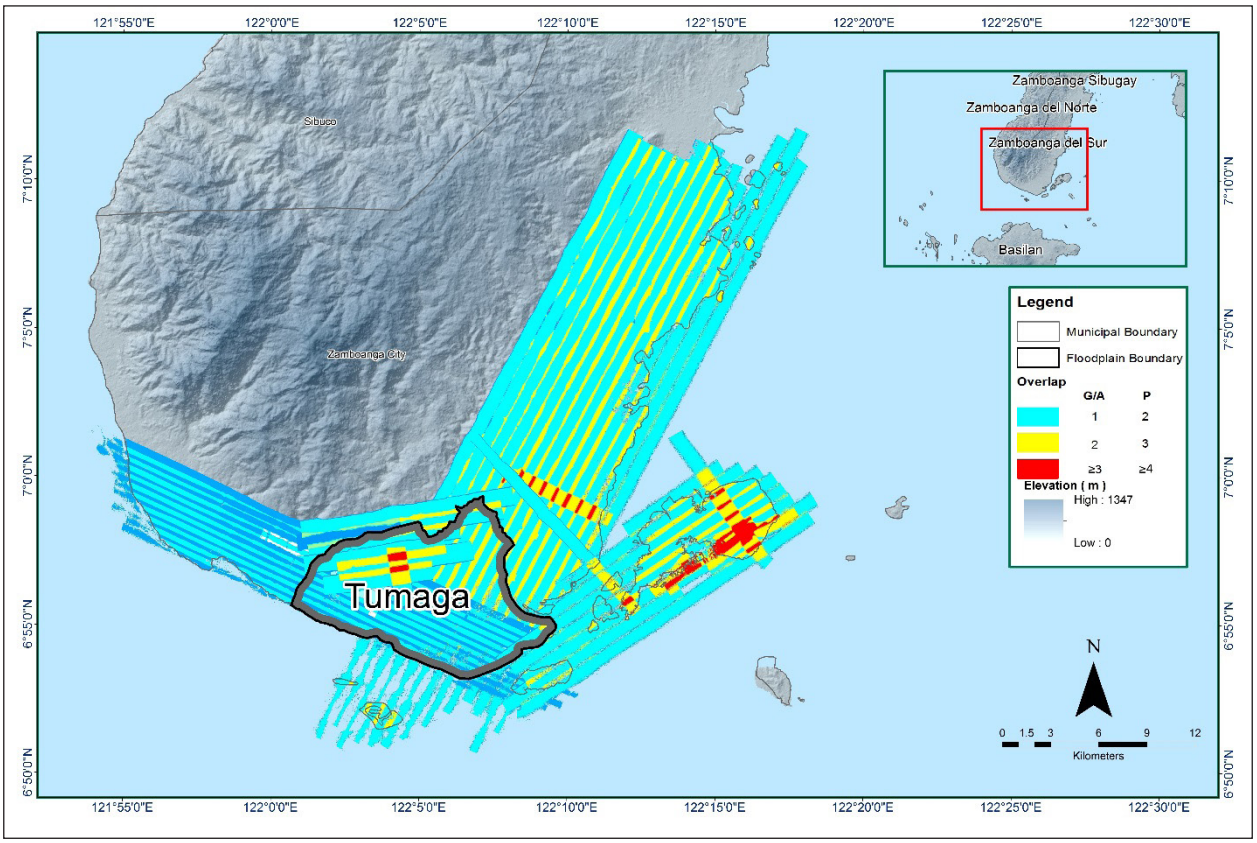


Figure 14. Image of data overlap for Tumaga Floodplain.

The overlap statistics per block for the Tumaga Floodplain can be found in Annex 8. One pixel corresponds to 25.0 sq.km. on the ground. For this area, the minimum and maximum percent overlaps are 26.46% and 90.58% respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 15. It was determined that all LiDAR data for Tumaga Floodplain satisfy the point density requirement, and the average density for the entire survey area is 2.78 points per square meter.

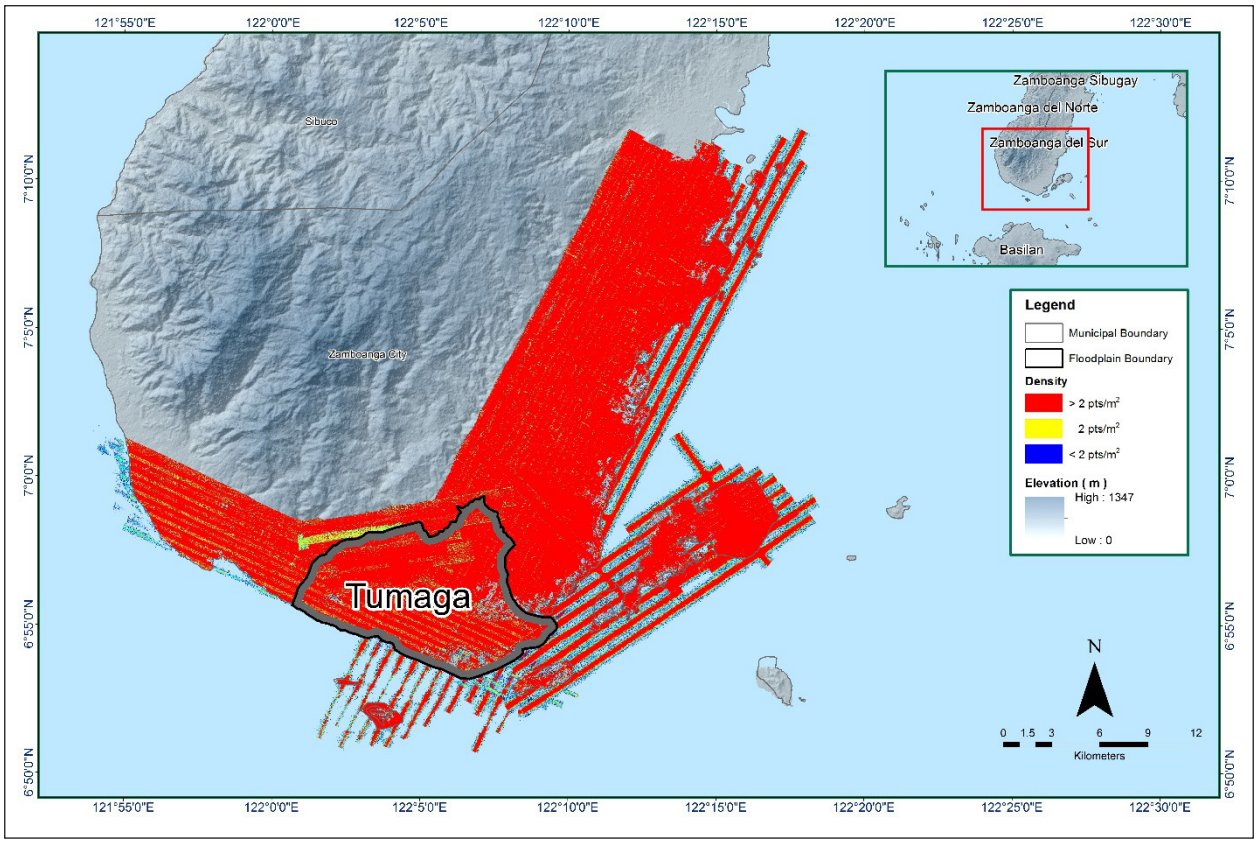


Figure 15. Pulse density map of merged LiDAR data for Tumaga Floodplain.

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

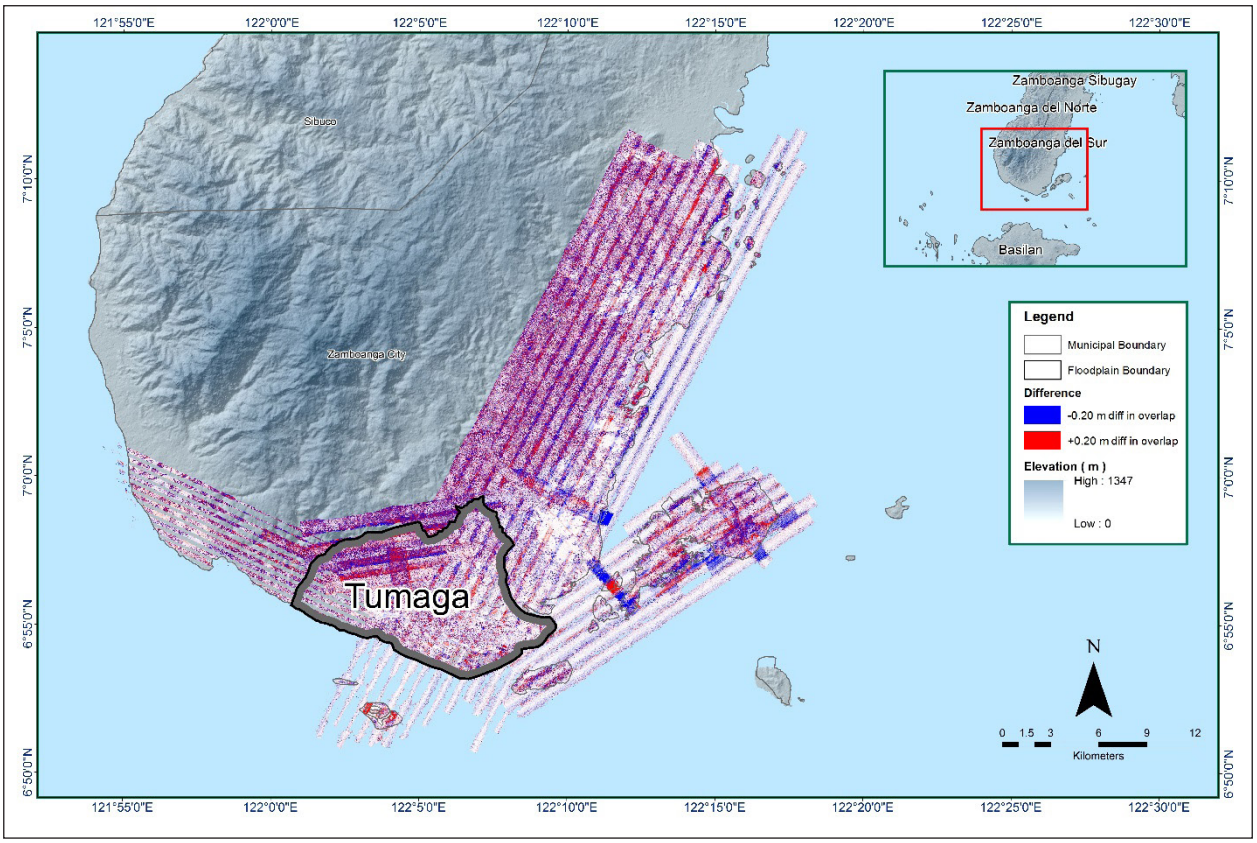


Figure 16. Elevation difference map between flight lines for Tumaga Floodplain.

A screen capture of the processed LAS data from a Tumaga Flight 7450G loaded in QT Modeler is shown in Figure 17. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed yellow line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

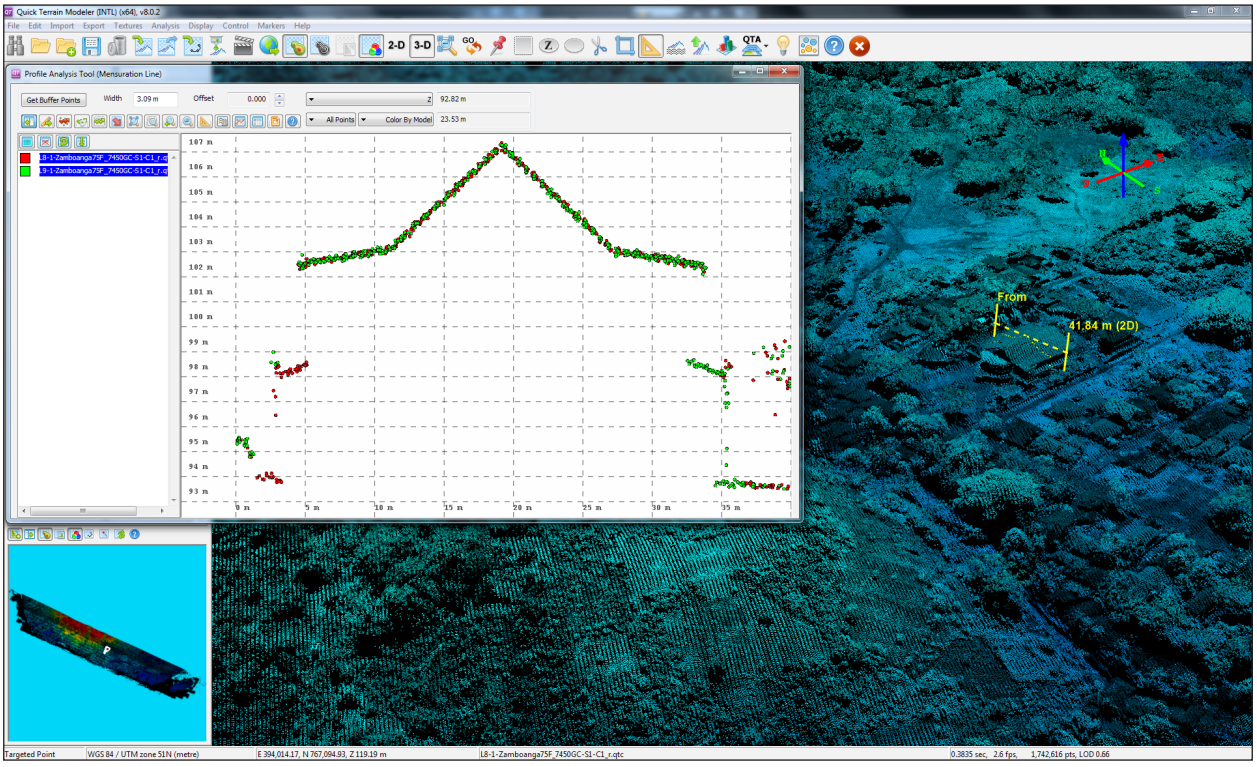


Figure 17. Quality checking for a Tumaga flight 7450G using the Profile Tool of QT Modeler.

3.6 LIDAR Point Cloud Classification and Rasterization

Table 16. Tumaga classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	574,137,102
Low Vegetation	452,634,231
Medium Vegetation	680,777,952
High Vegetation	1,284,794,811
Building	73,546,016

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Tumaga floodplain is shown in Figure 18. A total of 1,026 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 16. The point cloud has a maximum and minimum height of 588.90 meters and 64.94 meters respectively.

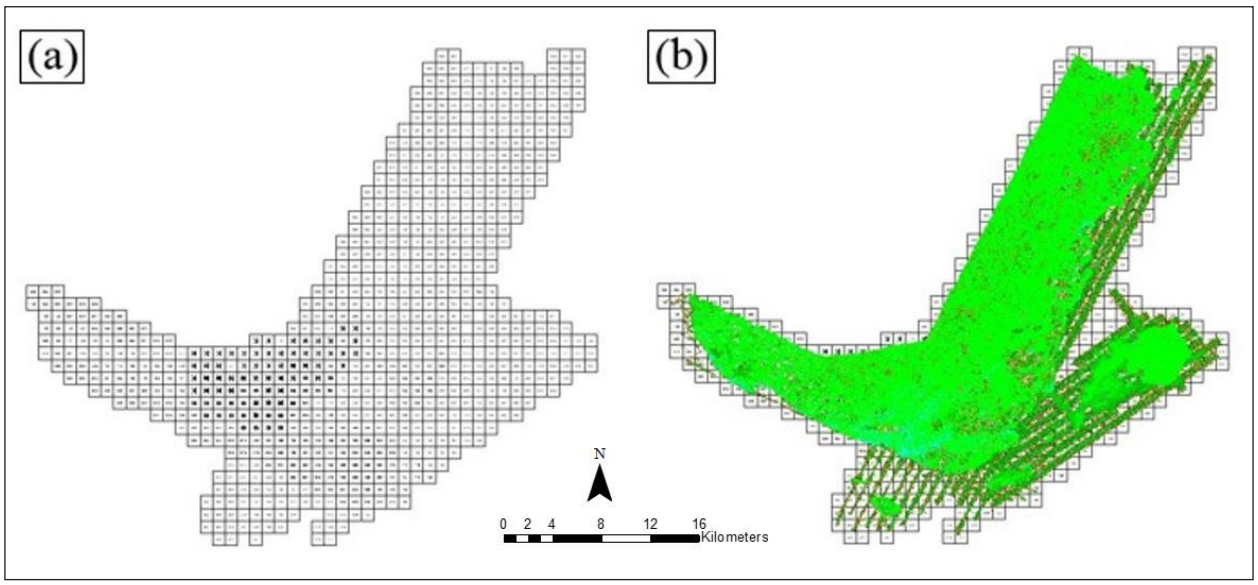


Figure 18. Tiles for Tumaga Floodplain (a) and classification results (b) in TerraScan.

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

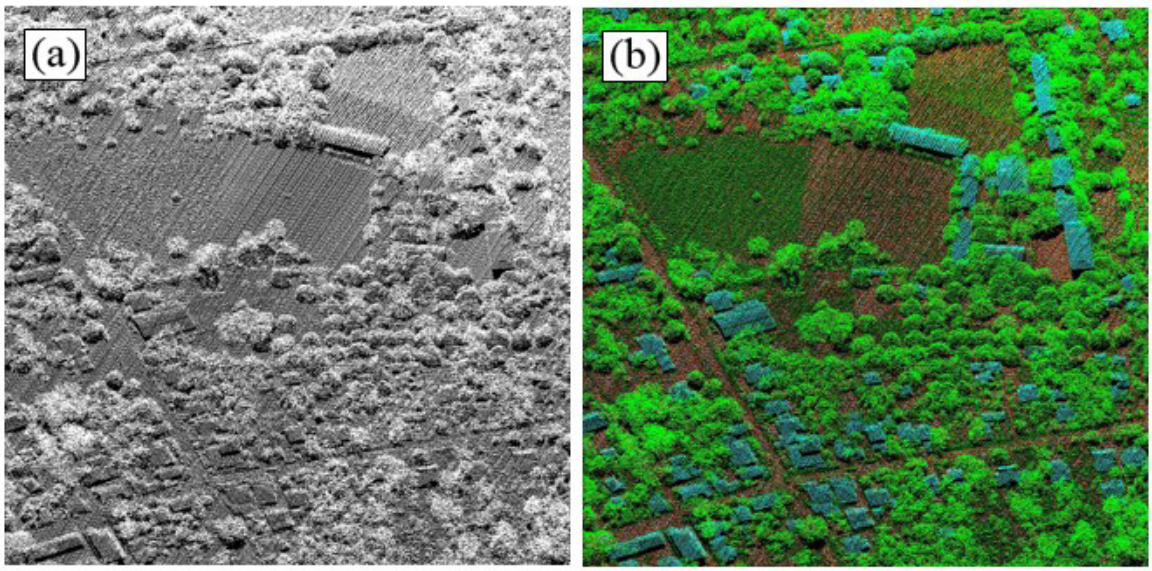


Figure 19. Point cloud before (a) and after (b) classification.

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

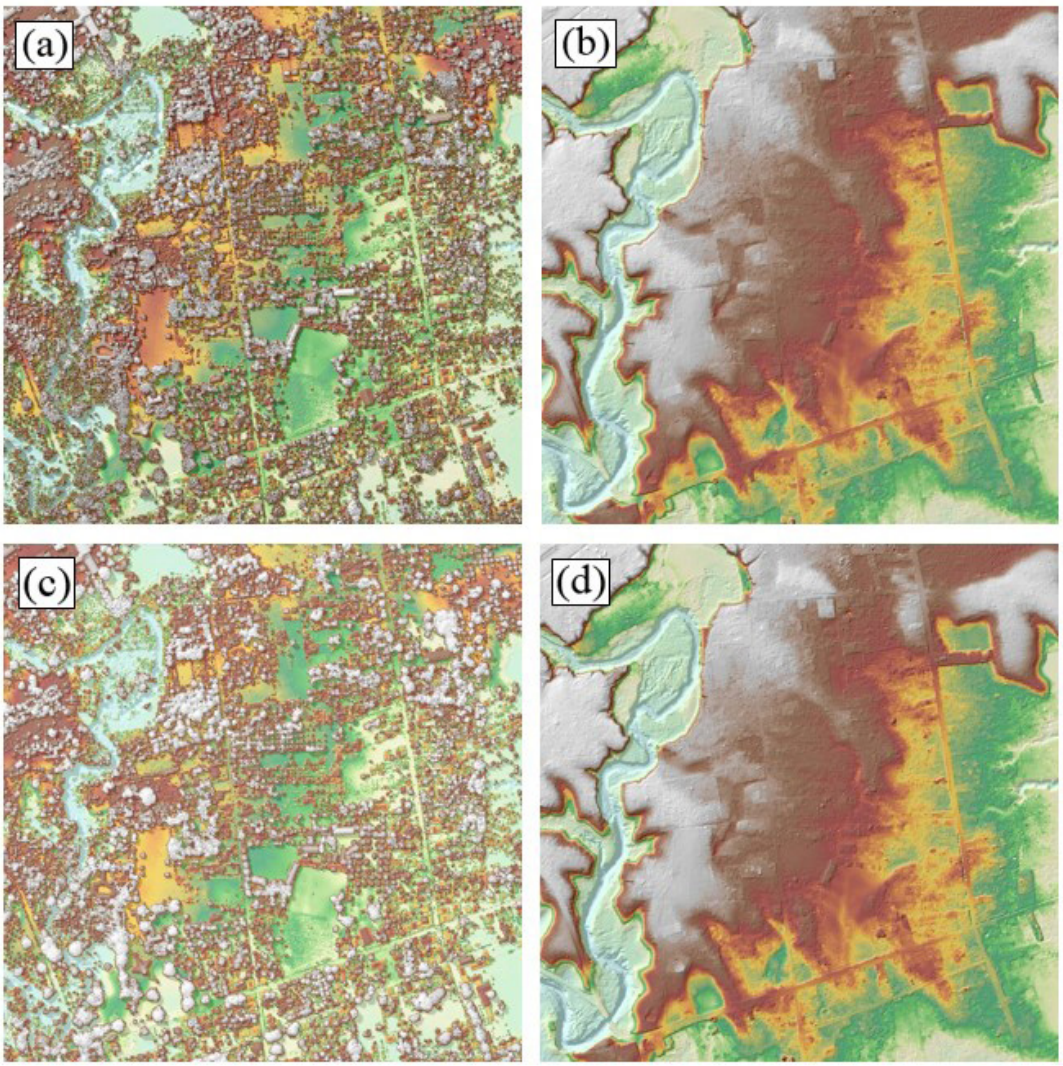


Figure 20. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Tumaga Floodplain.

3.7 LIDAR Image Processing and Orthophotograph Rectification

The 697 1km by 1km tiles area covered by Tumaga Floodplain is shown in Figure 21. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Tumaga Floodplain has a total of 552.42 sq.km 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 22.

Figure 21. Tumaga Floodplain with available orthophotographs.

Figure 22. Sample orthophotograph tiles for Tumaga Floodplain.

3.8 DEM Editing and Hydro-Correction

Six (6) mission blocks were processed for Tumaga Floodplain. These blocks are composed of Zamboanga and Zamboanga reflights blocks with a total area of 700.08 square kilometers. Table 17 shows the name and corresponding area of each block in square kilometers.

Table 17. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq.km)
Zamboanga_Blk75F	146.15
Zamboanga_Blk75E	394.93
Zamboanga_Blk75F_additiional	2.48
Zamboanga_Sacol	96.90
Zamboanga_reflights_BLK75AS	35.24
Zamboanga_reflights_BLK75F_supplement	24.38
TOTAL	**700.08 sq.km**

Figure 23 shows portions of DTM before and after manual editing. The river embankment (Figure 23a) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 23b) to allow the correct flow of water. The bridge (Figure 23c) 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. Another example is a building that is still present in the DTM after classification (Figure 23e) and has to be removed through manual editing (Figure 23f).

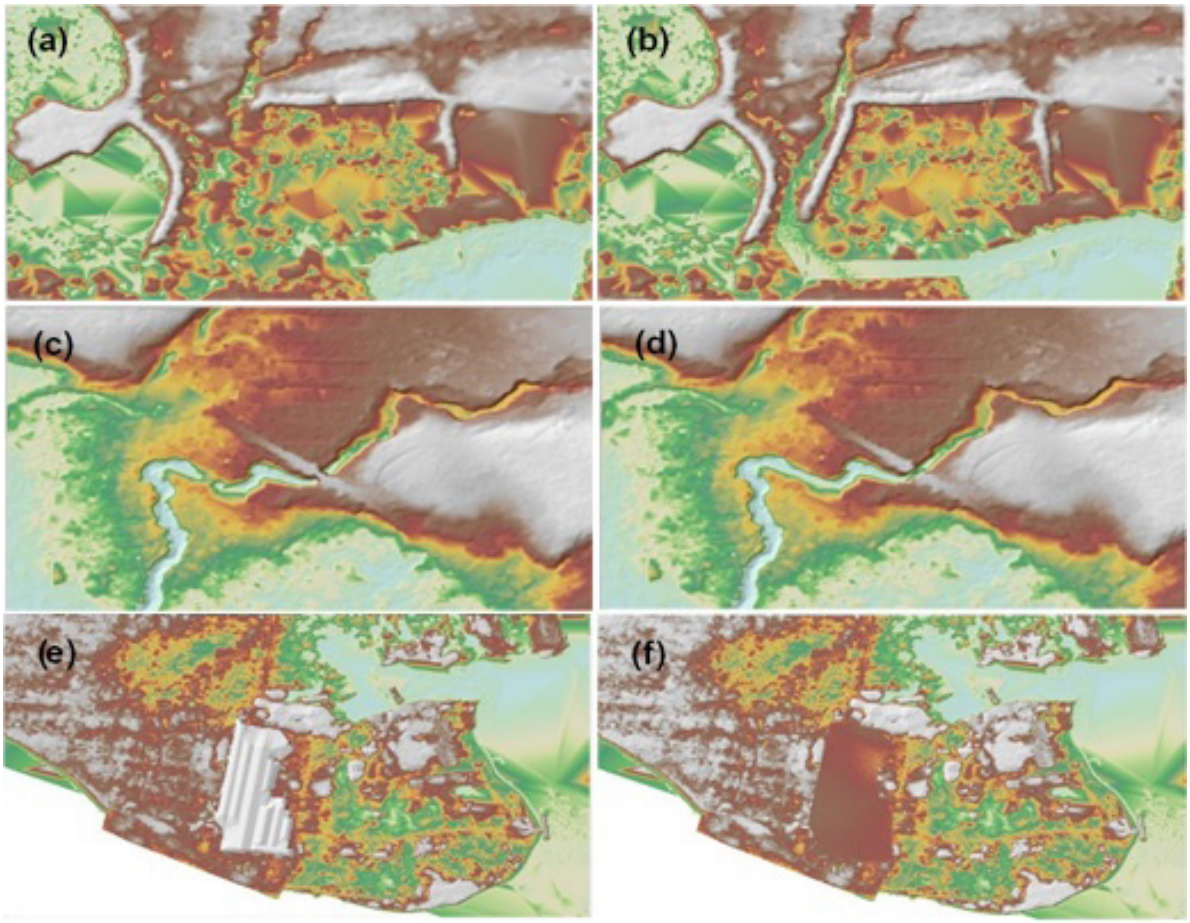


Figure 23. Portions in the DTM of Tumaga Floodplain – a paddy field before (a) and after (b) data retrieval; a road before (c) and after (d) manual editing; a building before (e) and after (f) manual editing.

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. Table 18 shows the shift values applied to each LiDAR block during mosaicking.

Table 18. Shift Values of each LiDAR Block of Tumaga Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Zamboanga_Blk75F	0.31	0.30	0.90
Zamboanga_Blk75E	0.00	0.00	0.47
Zamboanga_Blk75F_additional	0.00	0.00	0.90
Zamboanga_Sacol	0.00	0.00	0.47
Zamboanga_reflights_Blk75AS	0.00	0.00	0.44
Zamboanga_reflights_Blk75F_supplement	0.00	0.00	0.44

Mosaicked LiDAR DTM for Tumaga Floodplain is shown in Figure 24. It can be seen that the entire Tumaga Floodplain is 100% covered by LiDAR data.

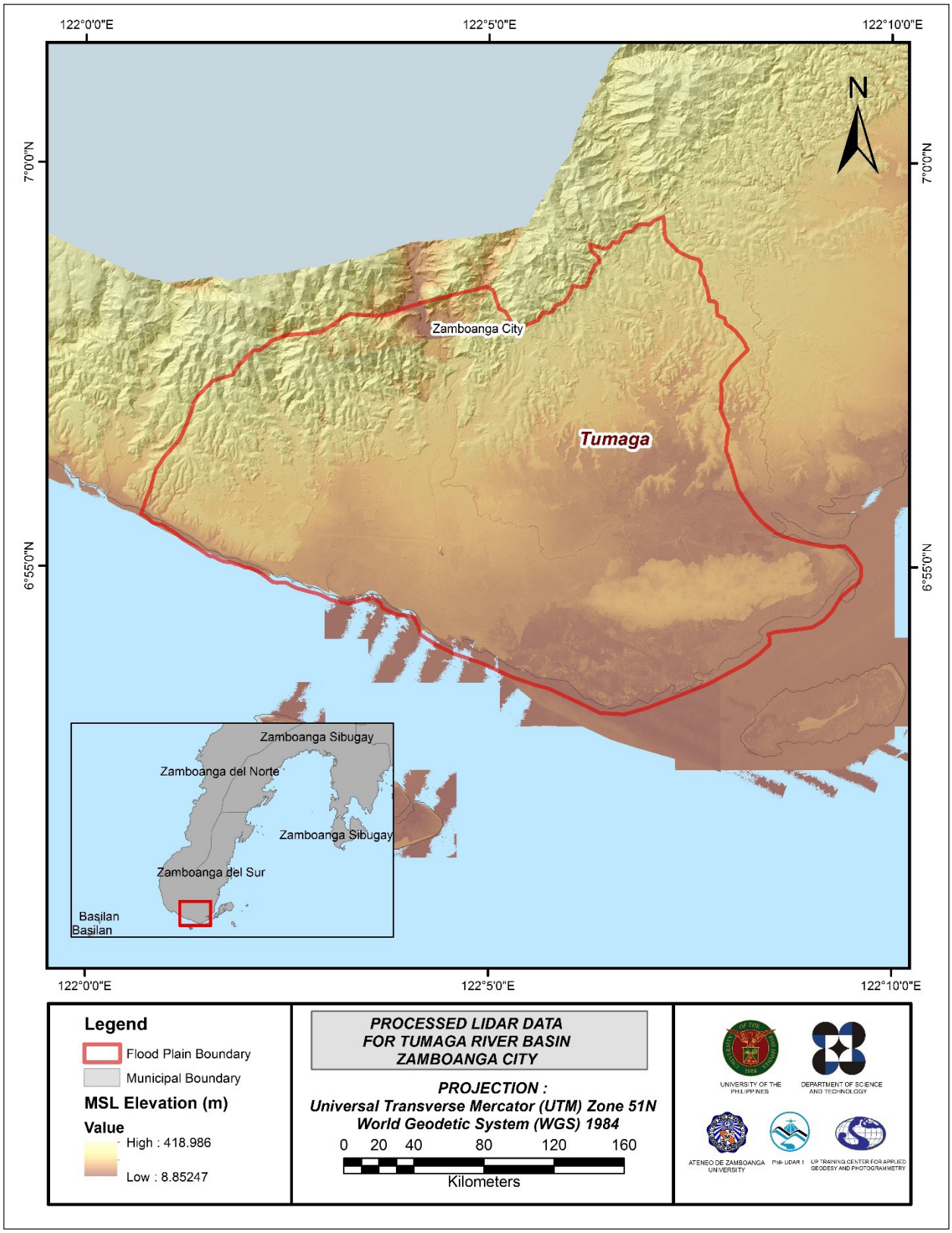


Figure 24. Map of Processed LiDAR Data for Tumaga Floodplain.

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Tumaga to collect points with which the LiDAR dataset is validated is shown in Figure 25. A total of 1,739 survey points were used for calibration and validation of Tumaga 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

26. 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 of Tumaga LiDAR data was done by adding the height difference value, 8.06 meters, to Tumaga mosaicked LiDAR data. Table 19 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

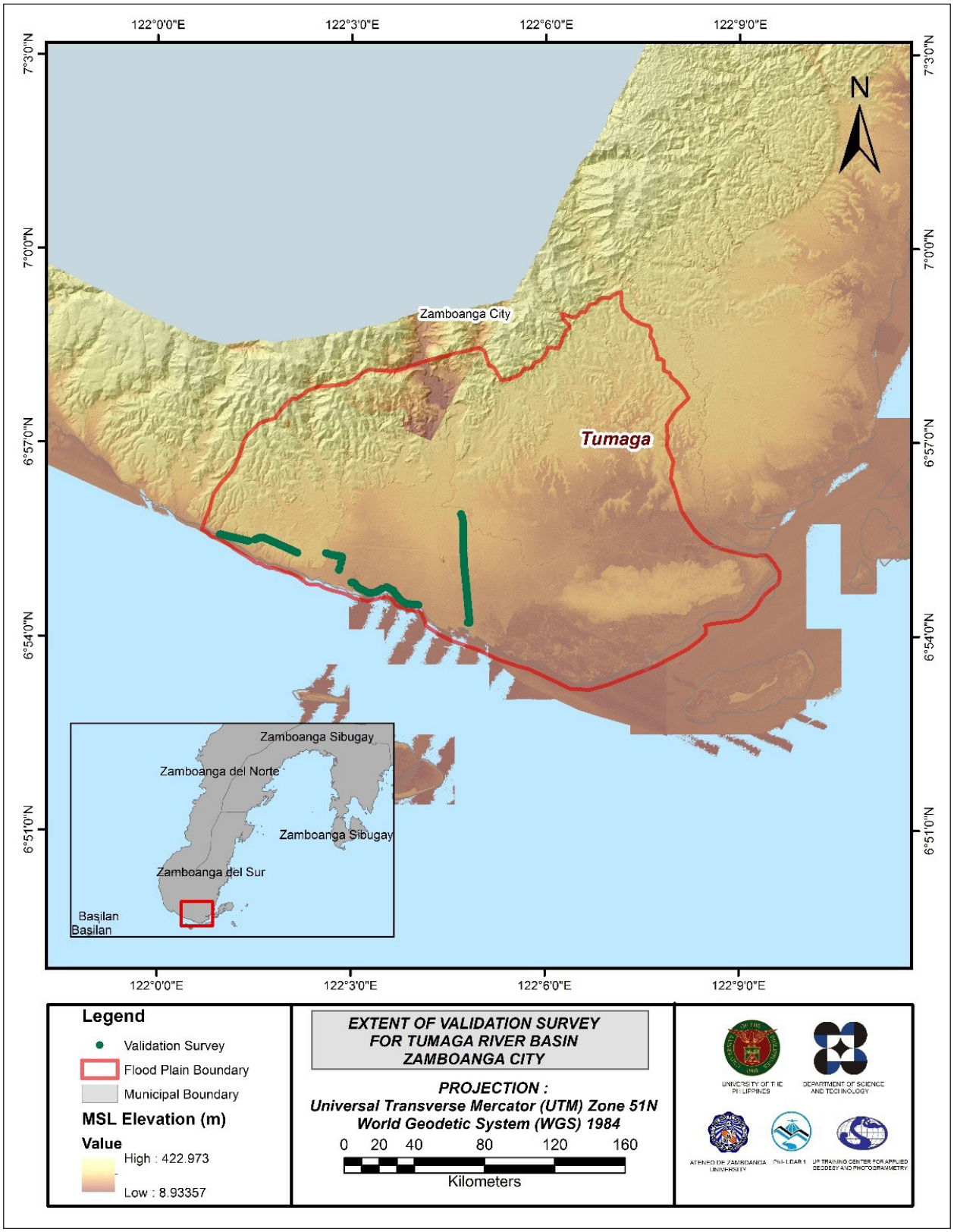


Figure 25. Map of Tumaga Floodplain with validation survey points in green.

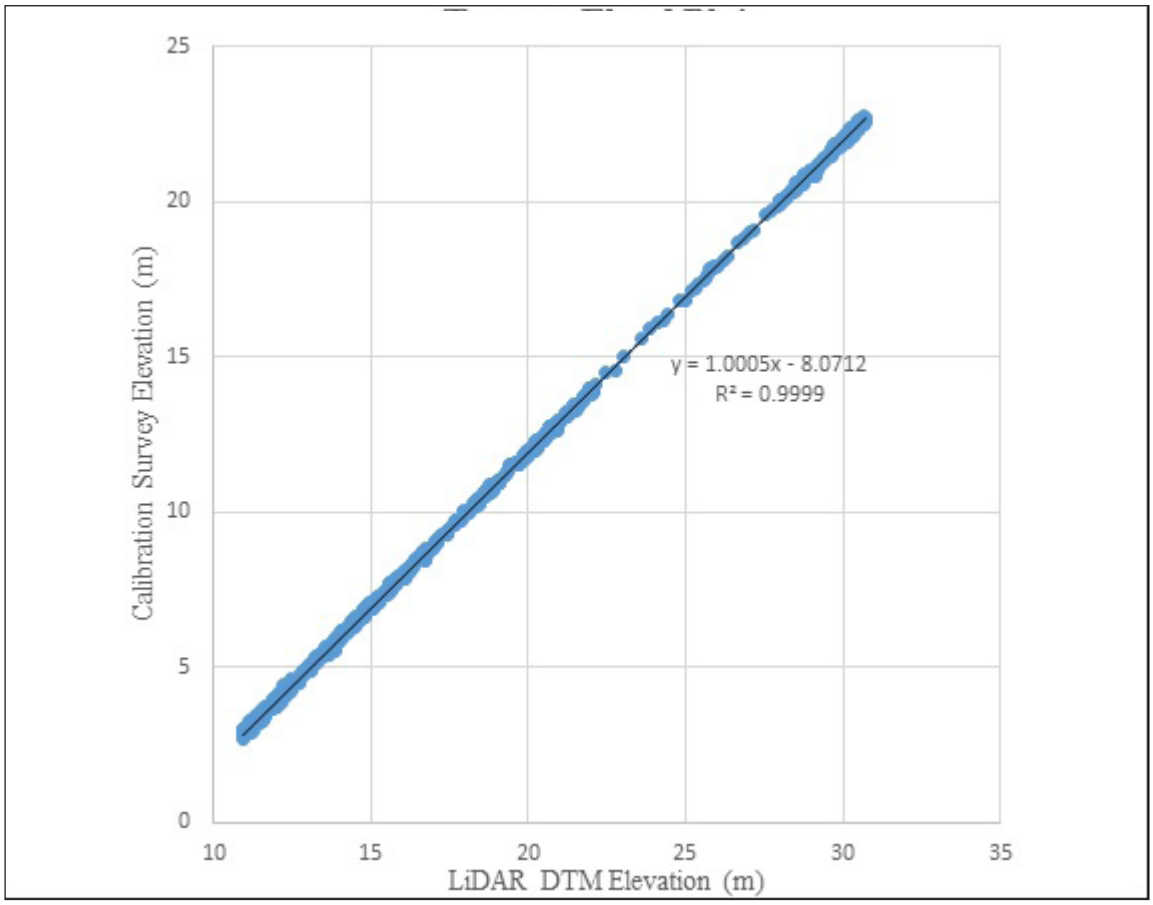


Figure 26. Correlation plot between calibration survey points and LiDAR data.

Table 19. 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 remaining 20% of the total survey points, resulting to 347 points, were used for the validation of calibrated Tumaga DTM. A good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM is shown in Figure 27. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 8.06 meters with a standard deviation of 0.07 meters, as shown in Table 20.

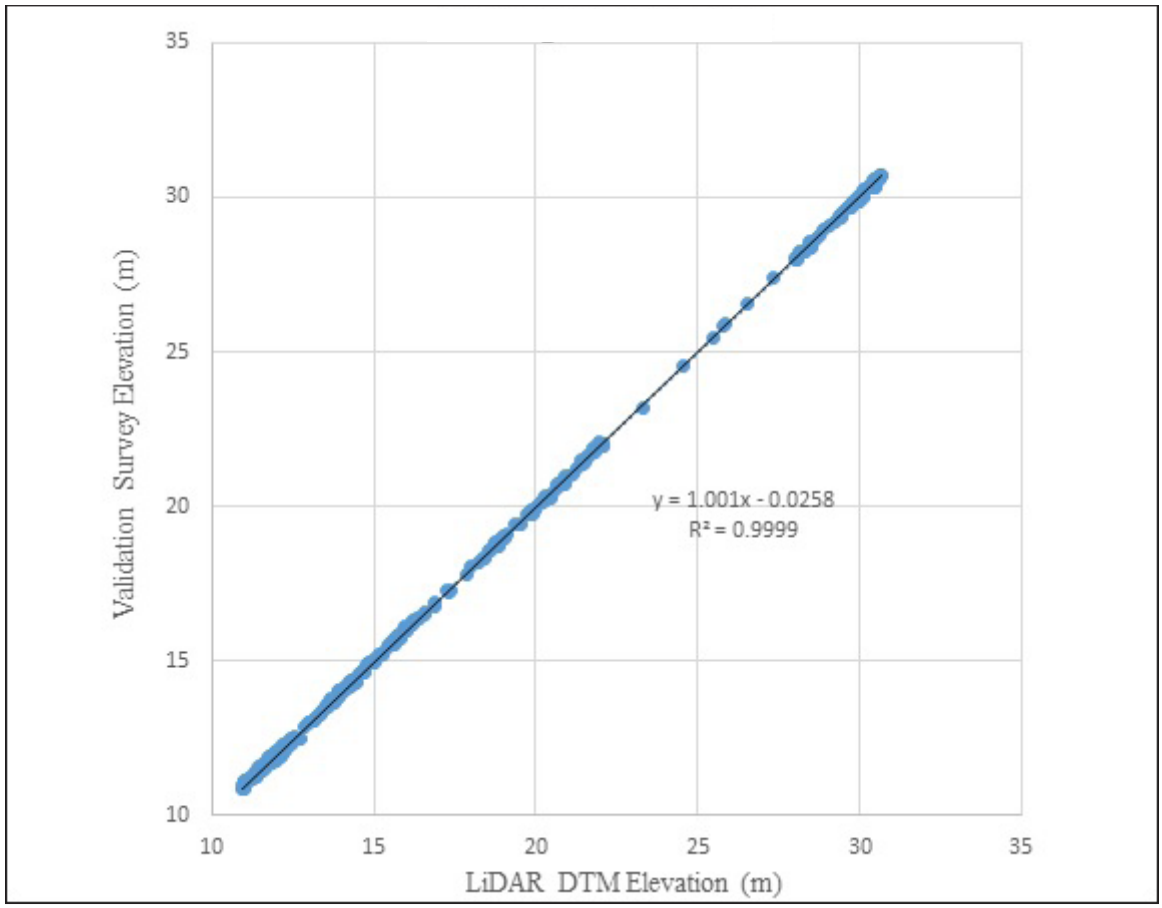


Figure 27. Correlation plot between validation survey points and LiDAR data.

Table 20. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.07
Standard Deviation	0.07
Average	0.008
Minimum	-0.13
Maximum	0.15

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data was available for Tumaga with 592 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 0.24 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Tumaga integrated with the processed LiDAR DEM is shown in Figure 28.

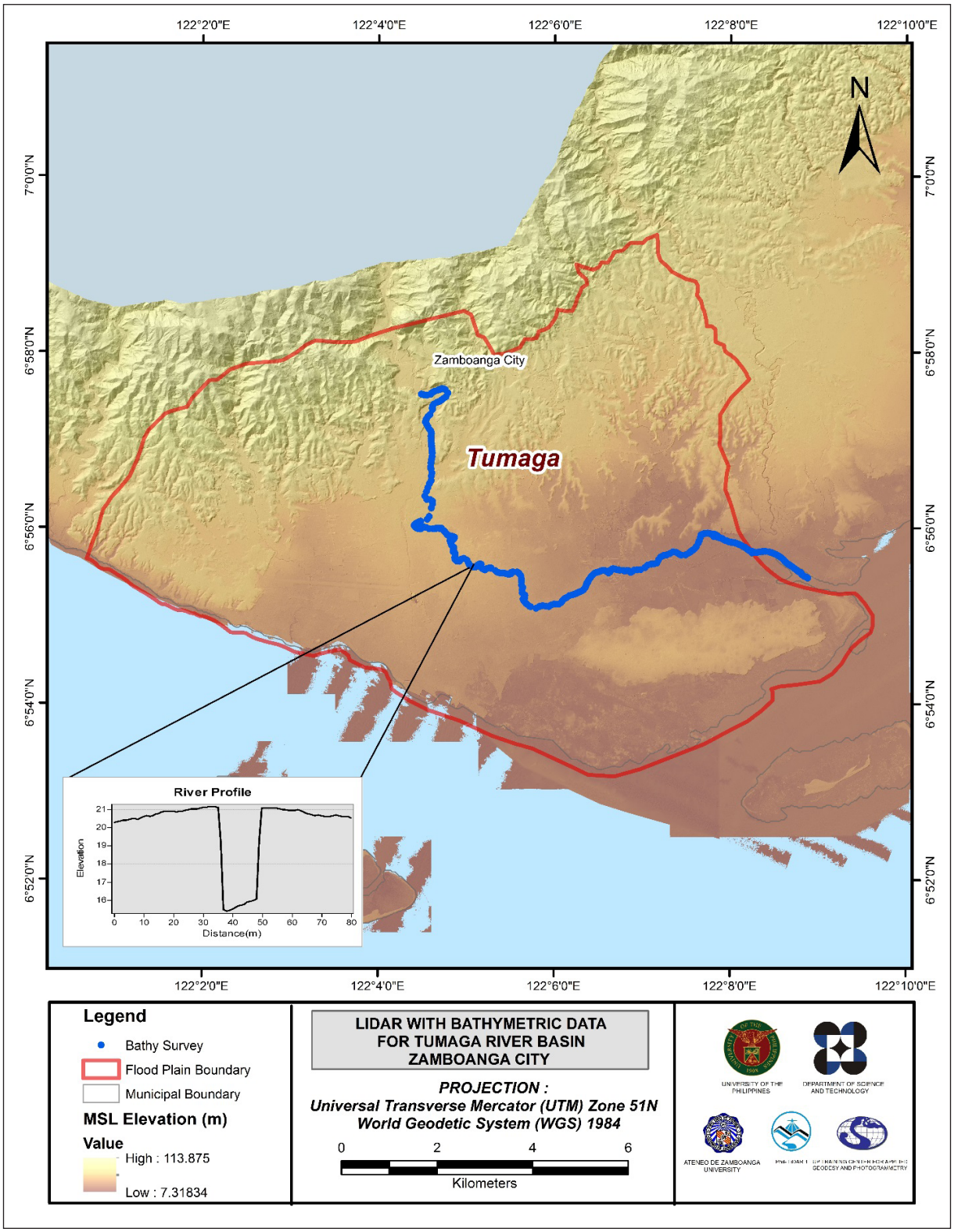


Figure 28. Map of Tumaga Floodplain with bathymetric survey points shown in blue.

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

Tumaga Floodplain, including its 200 m buffer, has a total area of 112.78 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 6,918 building features, are considered for QC. Figure 29 shows the QC blocks for Tumaga Floodplain.

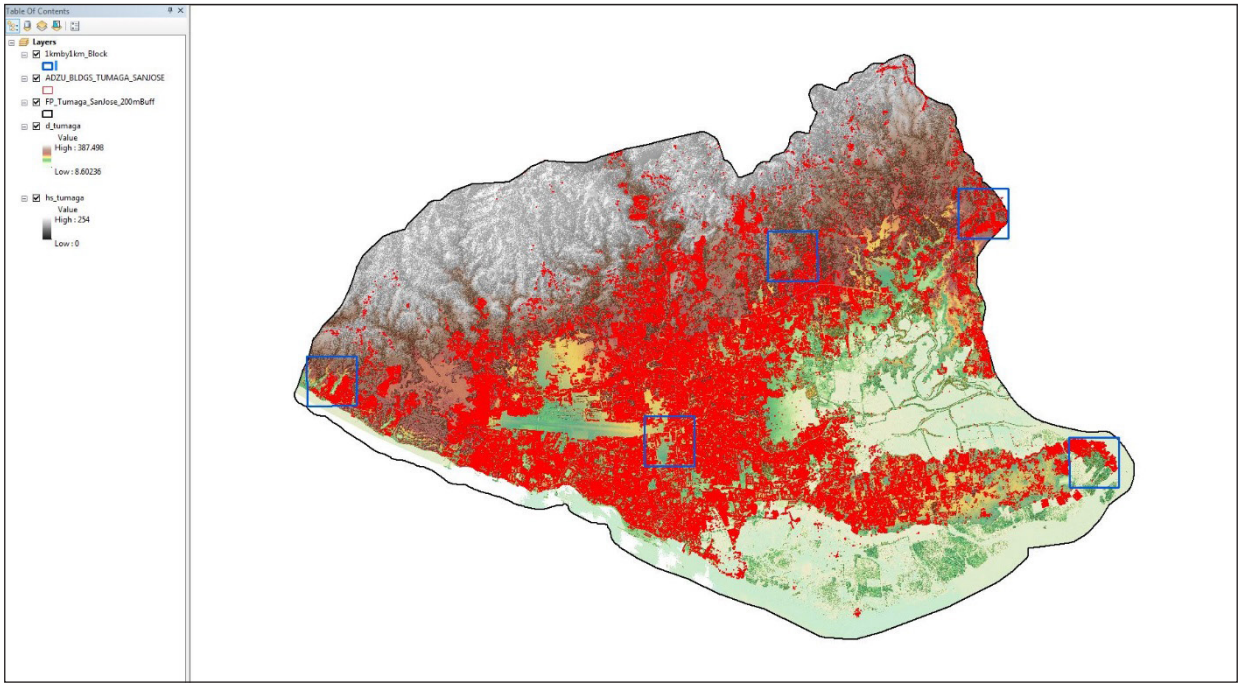


Figure 29. QC blocks for Tumaga building features.

Quality checking of Tumaga building features resulted in the ratings shown in Table 21.

Table 21. Quality Checking Ratings for Tumaga Building Features.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Tumaga	97.63	99.79	90.80	PASSED

3.12.2 Height Extraction

Height extraction was done for 80,920 building features in Tumaga Floodplain. Of these building features, 892 was filtered out after height extraction, resulting to 80,028 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 17.85 m.

3.12.3 Feature Attribution

One of the research associates 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 floodplain of the riverbasin; likewise, the number of enumerators are also dependent on the availability of the tablet and the number of features of the floodplain.

Table 22 summarizes the number of building features per type. On the other hand, Table 23 shows the total length of each road type, while Table 24 shows the number of water features extracted per type.

Table 22. Number of Building Features Extracted for Tumaga Floodplain.

Facility Type	No. of Features
Residential	74,440
School	750
Market	1,949
Agricultural/Agro-Industrial Facilities	89
Medical Institutions	86
Barangay Hall	29
Military Institution	406
Sports Center/Gymnasium/Covered Court	52
Telecommunication Facilities	9
Transport Terminal	25
Warehouse	184
Power Plant/Substation	6
NGO/CSO Offices	8
Police Station	21
Water Supply/Sewerage	41
Religious Institutions	163
Bank	20
Factory	215
Gas Station	45
Fire Station	4
Other Government Offices	138
Other Commercial Establishments	1,114
N/A	234
Total	**80,028**

Table 23. Total Length of Extracted Roads for Tumaga Floodplain

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Tumaga	376.36	137.81	0.00	50.29	0.00	**564.46**

Table 24. Number of Extracted Water Bodies for Tumaga Floodplain

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Tumaga	28	0	1	0	152	**181**

A total of 19 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 30 shows the Digital Surface Model (DSM) of Tumaga Floodplain overlaid with its ground features.

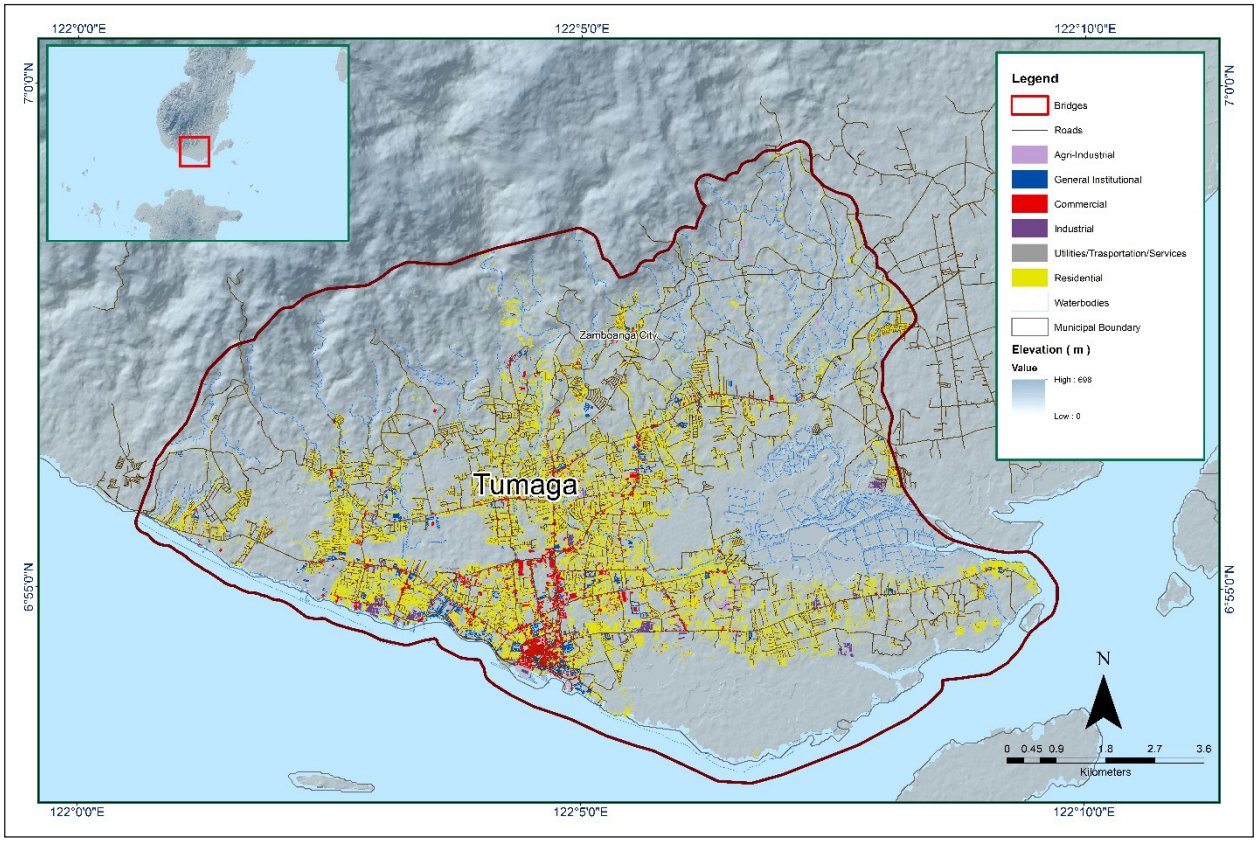


Figure 30. Extracted features for Tumaga Floodplain.

Chapter 4: SURVEY AND MEASUREMENTS IN THE TUMAGA RIVER BASIN SURVEY

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

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

4.1 Summary of Activities

The Tumaga River Basin is located in Zamboanga City, Zamboanga Peninsula. It covers the southernmost part of the city and is a part of the larger Pasonaca Watershed which covers 10,560 ha of the southern half of Zamboanga. The Tumaga River Basin alone has a catchment area of 10,100 ha.

The Tumaga River, is one of the river systems in the Zamboanga Peninsula. It encompasses 14 barangays, namely: Lumayang, Lunzuran, Lumbangan, Pasobolong, Boalan, Tumaga, Divisoria, Guiwan, Putik, Tugbungan, Mampang, Arena Blanco, Zambowood and Talon-Talon. Barangays Lumayang, Lunzuran, Lumbangan, Pasobolong and Boalan are known to be agricultural areas with livelihoods consisting of coconut, corn and mango orchard plantations. On the other hand, barangays Divisoria, Guiwan, Putik and Tugbungan are commercial and residential areas. Aquaculture is common for coastal barangays such as Talon-Talon, Zambowood, Arena Blanco and Mampang.

The areas near Tumaga River have a population of 186,736 people according to the 2010 NSO census data. Settlements in the area are in constant threat of flooding due to heavy rainfall. On October 8, 2013, floods due to intermittent heavy rains since October 4, 2013 submerged parts of the city, with 2,869 families (8,848 persons) had been displaced by the floods. With damaged agricultural crops of 640 ha of riceland; 1,243 has corn; 200 ha of assorted vegetables. About 2,000 ha of fishpond and 900 ha of seaweed were also among those flooded.

The Data Validation and Bathymetry Component (DVBC) conducted a field survey in Tumaga River from September 19 to 22, 2014 (Phase 1) and from January 20 to February 1, 2015. The scope of work covered reconnaissance, control survey for the establishment of control points, cross-section survey with bridge as-built and water level marking, and validation points acquisition survey. Bathymetric survey with a length of 15.6 km from the upstream Brgy. Dulian down to the mouth of the river in Brgy. Zambowood in Zamboanga City was conducted during the second phase of the survey as shown in Figure .

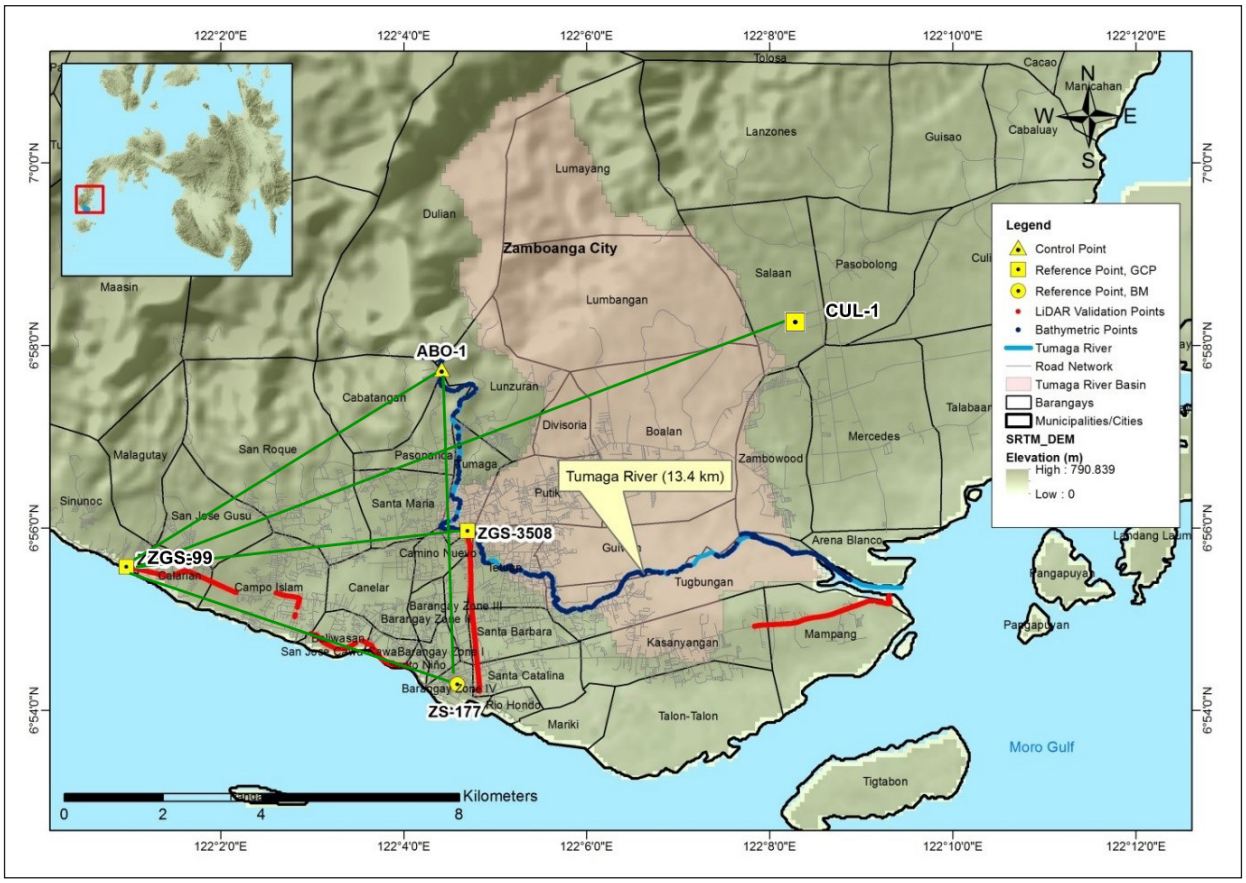


Figure 31. Extent of the bathymetric survey (in blue line) in Tumaga River and the LiDAR data validation survey (red)

4.2 Control Survey

The GNSS network used for Tumaga 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 25, while the GNSS network is illustrated in Figure 32.

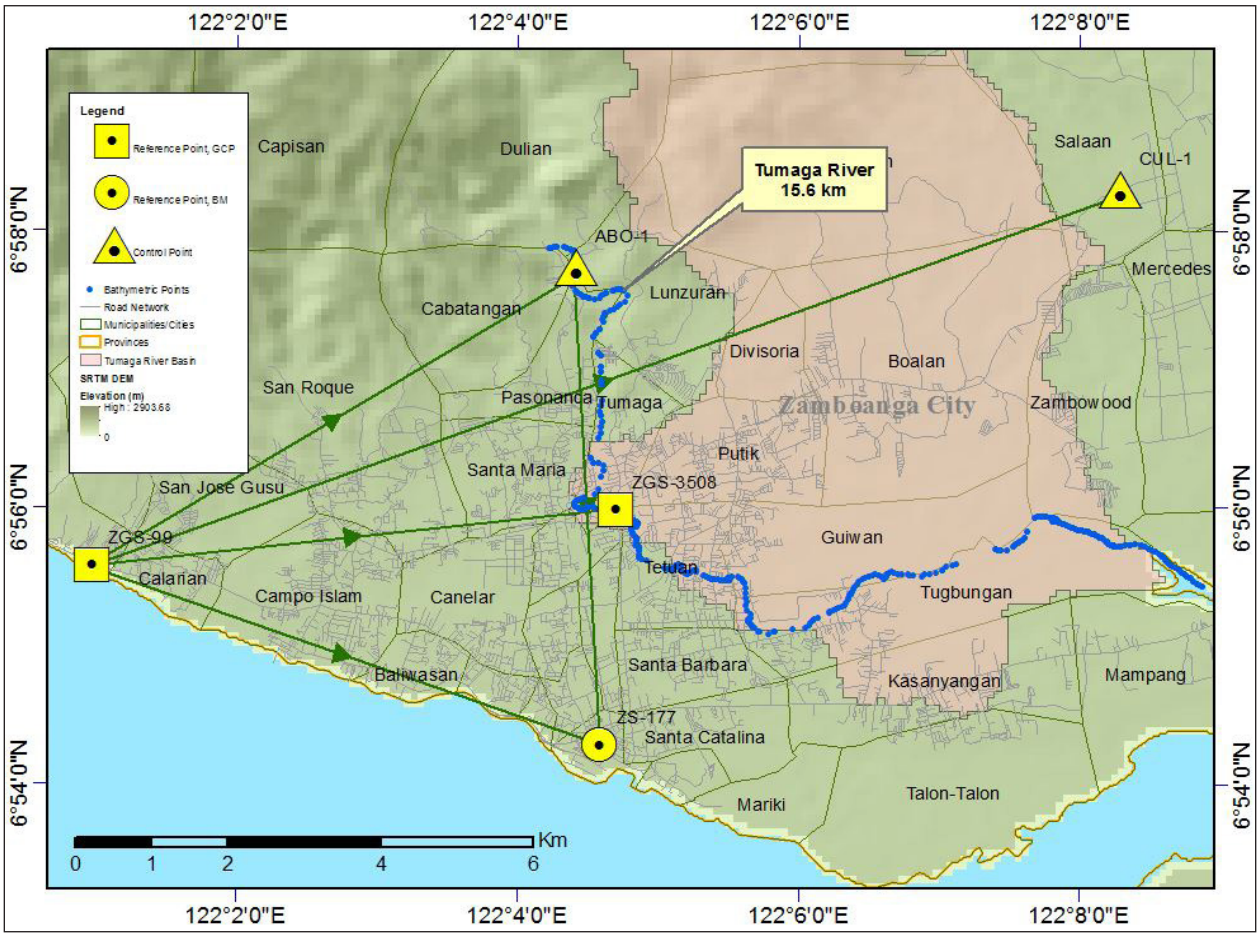


Figure 32. GNSS Network of Tumaga River Basin Survey

Table 25. References used and control points established in Tumaga 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 Figure 37.

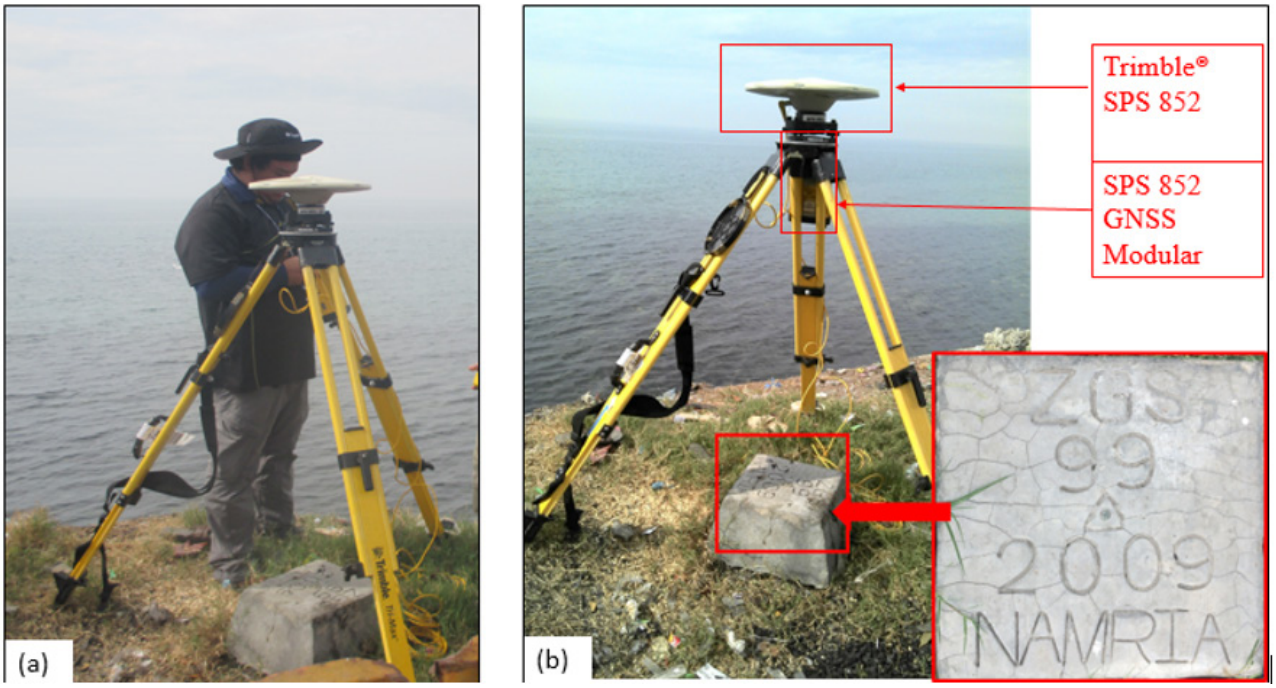


Figure 33. GNSS base receiver setup, Trimble® SPS 852 at ZGS-99 in Brgy. Sinunoc, Zamboanga City, Zamboanga Del Sur

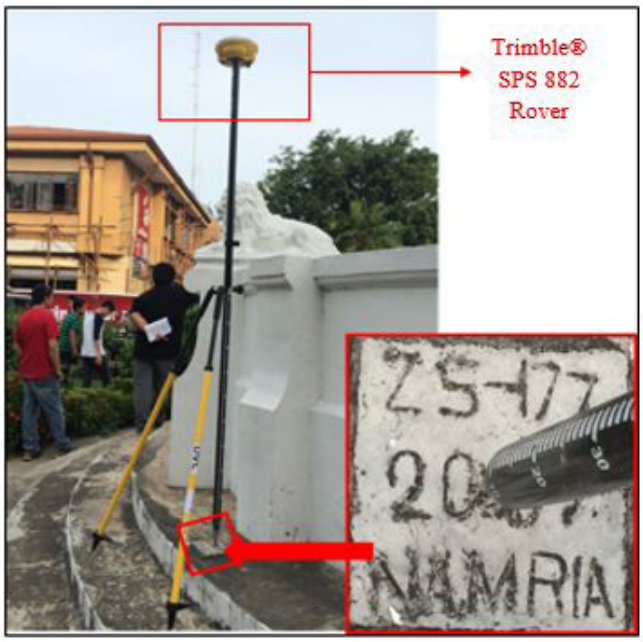


Figure 34. GNSS receiver setup, Trimble® SPS 882 at ZS-177, located in Rizal Park in Brgy. Zone IV, Zamboanga City, Zamboanga Del Sur

Figure 35. GNSS receiver occupation, Trimble® SPS 852 at ABO-1 located along approach of Abong Bridge, in Brgy. Dulian, Zamboanga City, Zamboanga Del Sur

Figure 36. GNSS base receiver setup, Trimble® SPS 882 at CUL-1 along approach of Culianan Bridge in Brgy. Culianan, Zamboanga City, Zamboanga Del Sur

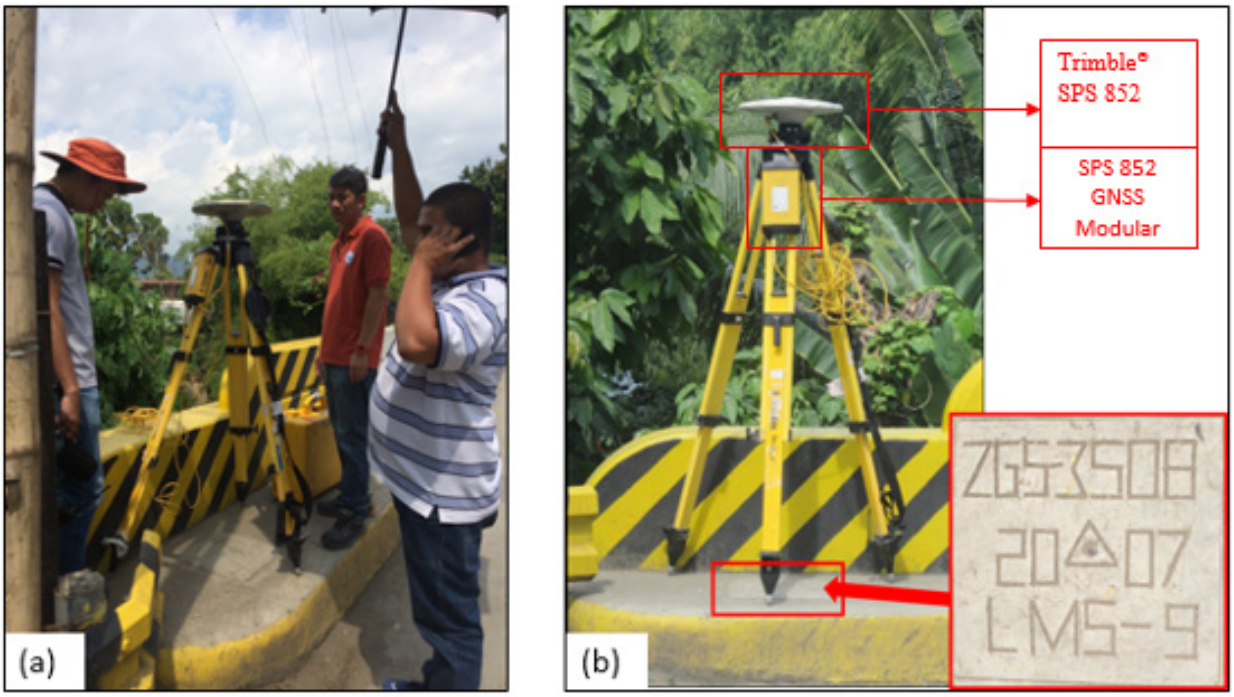


Figure 37. GNSS base receiver setup, Trimble® SPS 852 at ZGS-3508 along Tumaga Bridge in Brgy. Tumaga, Zamboanga City, Zamboanga Del Sur

4.3 Baseline Processing

The GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within ± 20 cm and ± 10 cm requirement, respectively. In cases when one or more baselines did not meet all of these criteria, masking is performed. Masking is the removal or covering portions of the baseline data using the same processing software. The data is then repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, a resurvey is initiated. Table 26 presents the baseline processing result of control points in Tumaga River Basin, as generated by TBC software.

Table 26. Baseline Processing Report for Tumaga 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 26, 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, the network adjustment is performed using the TBC software. Looking at the Adjusted Grid Coordinates table of the TBC-generated Network Adjustment Report, it is observed that the square root of the sum of the squares of x and y must be less than 20cm and z less than 10 cm, in equation from:

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

Where:

x_e is the Easting error,

y_e is the Northing error, and

z_e is the Elevation error

For complete details, see the Network Adjustment Report shown in Tables 27 to 30:

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 27. Through these reference points, the coordinates and elevation of the unknown control points were computed.

Table 27. 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)					

Likewise, the list of adjusted grid coordinates, (i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network) is indicated in Table 28. All fixed control points have no values for grid and elevation values.

Table 28. 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

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 29. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	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 Based on the result of the computation, the equation is satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table 30.

Table 30. 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

A GNSS receiver Trimble® SPS 882 using PPK survey technique was utilized to get the cross-section of Tumaga Bridge and Abong Abong Bridge from September 19 to 21, 2014 as shown in Figure 38 and Figure 39, respectively.

In addition to 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 a GNSS receiver Trimble® SPS 882 to get the high cord and meter tapes to get its low chord elevation.

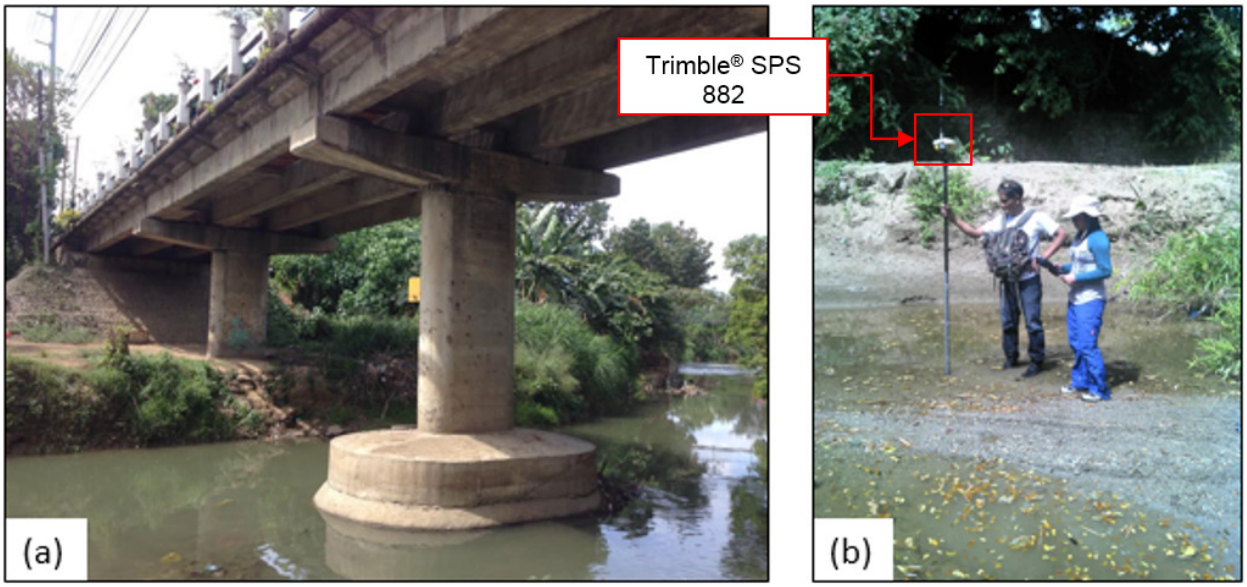


Figure 38. (a) Tumaga Bridge, and (b) cross-section survey at Tumaga Bridge, Brgy. Tumaga, Zamboanga City

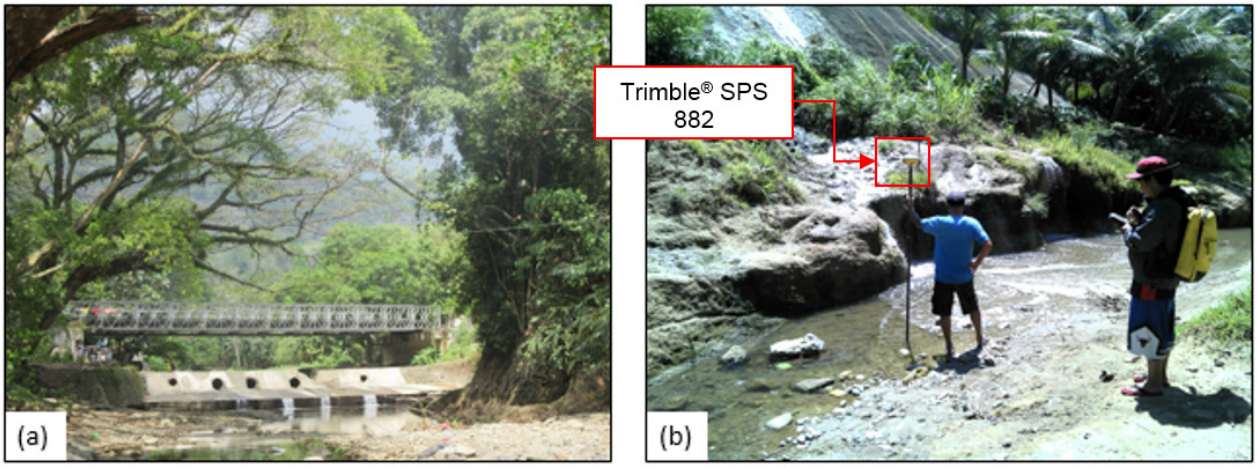


Figure 39. (a) Abong Abong Bridge, and (b) cross-section survey at Abong Abong Bridge, Brgy Dulian, Zamboanga City

The cross-sectional line for the Tumaga Bridge is about 162.95 m, composed of 31 points and acquired on September 20, 2014. On the other hand, about 131.47 m composed of 15 points were gathered for Abong-abong Bridge on September 21, 2014. The cross-section diagram, planimetric map, and bridge as-built form for Tumaga Bridge are shown in Figure to Figure 42, while Figure 43 to Figure 45, for Abong-abong bridge.

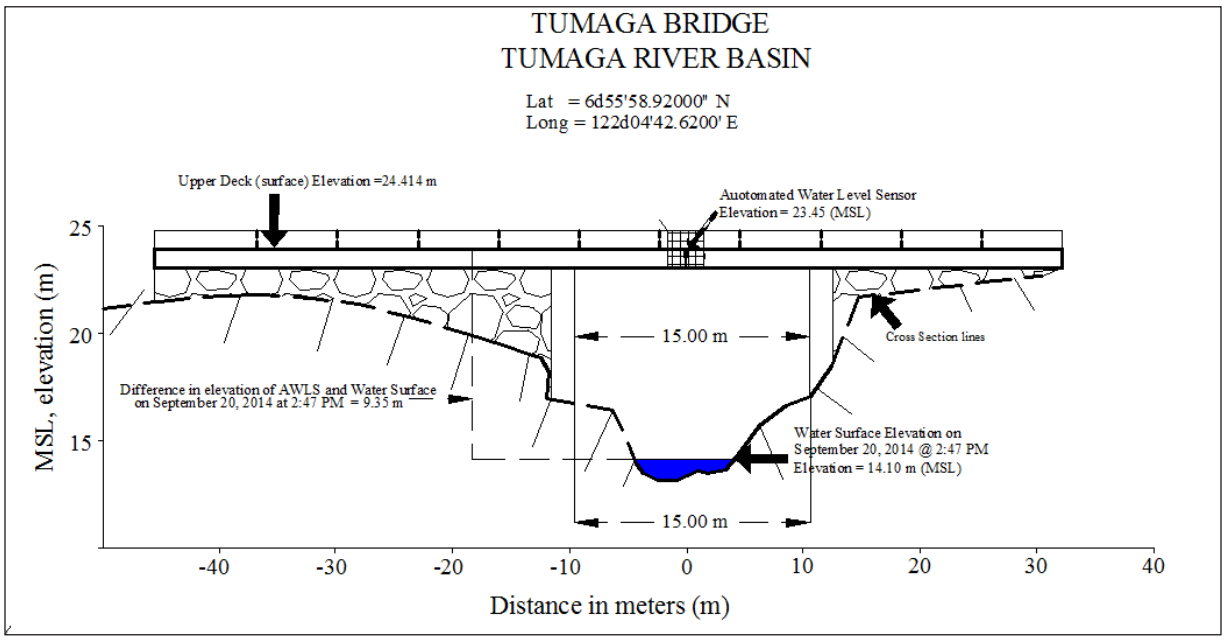


Figure 40. Tumaga Bridge cross-sectional diagram

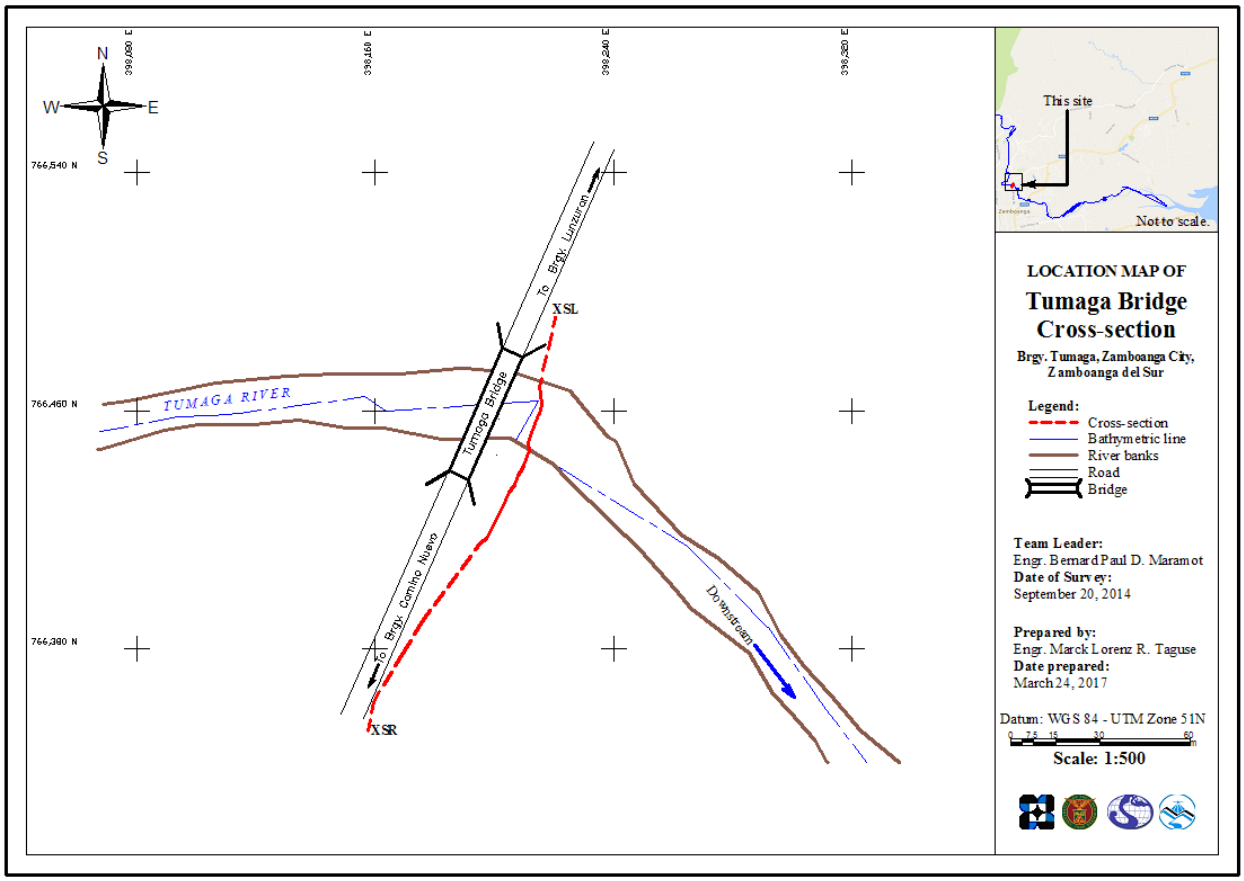


Figure 41. Tumaga Bridge cross-section planimetric map

Bridge Data Form

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

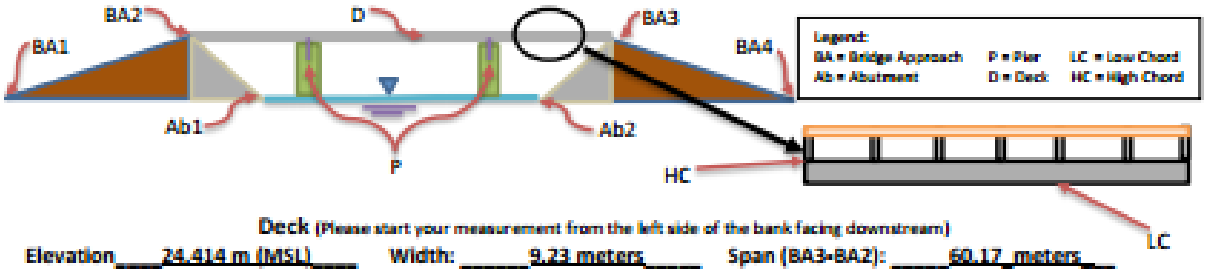
River Name: TUMAGA RIVER **Time:** 2:09 pm

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

Survey Team: DVBC Zamboanga City Survey Team

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

Latitude: 6d55'58.03334" N **Longitude:** 122d04'41.85627" E



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

Elevation 24.414 m (MSL) **Width:** 9.23 meters **Span (BA3-BA2):** 60.17 meters

	Station	High Chord Elevation	Low Chord Elevation
1		24.359	23.007
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	22.593	BA3	82.547	24.398
BA2	27.405	23.114	BA4	152.209	22.581

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

	Station (Distance from BA1)	Elevation
Ab1	30.758	18.423
Ab2	78.183	17.603

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

Shape: Cylindrical **Number of Piers:** 4 **Height of column footing:**

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	69.66323	24.398	
Pier 2	84.64783	24.397	
Pier 3	99.71156	24.432	
Pier 4	110.788	24.432	

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

Figure 42. Tumaga Bridge Data Form

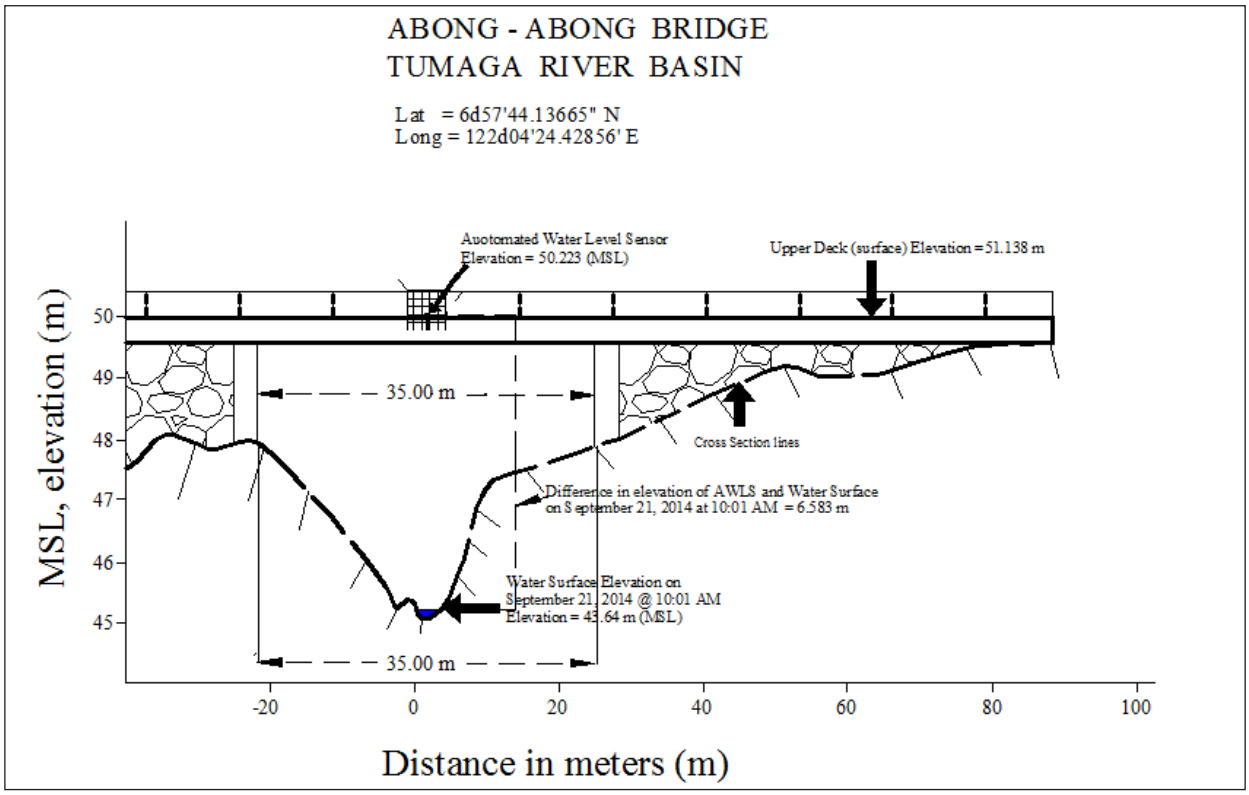


Figure 43. Abong-abong Bridge cross-sectional diagram

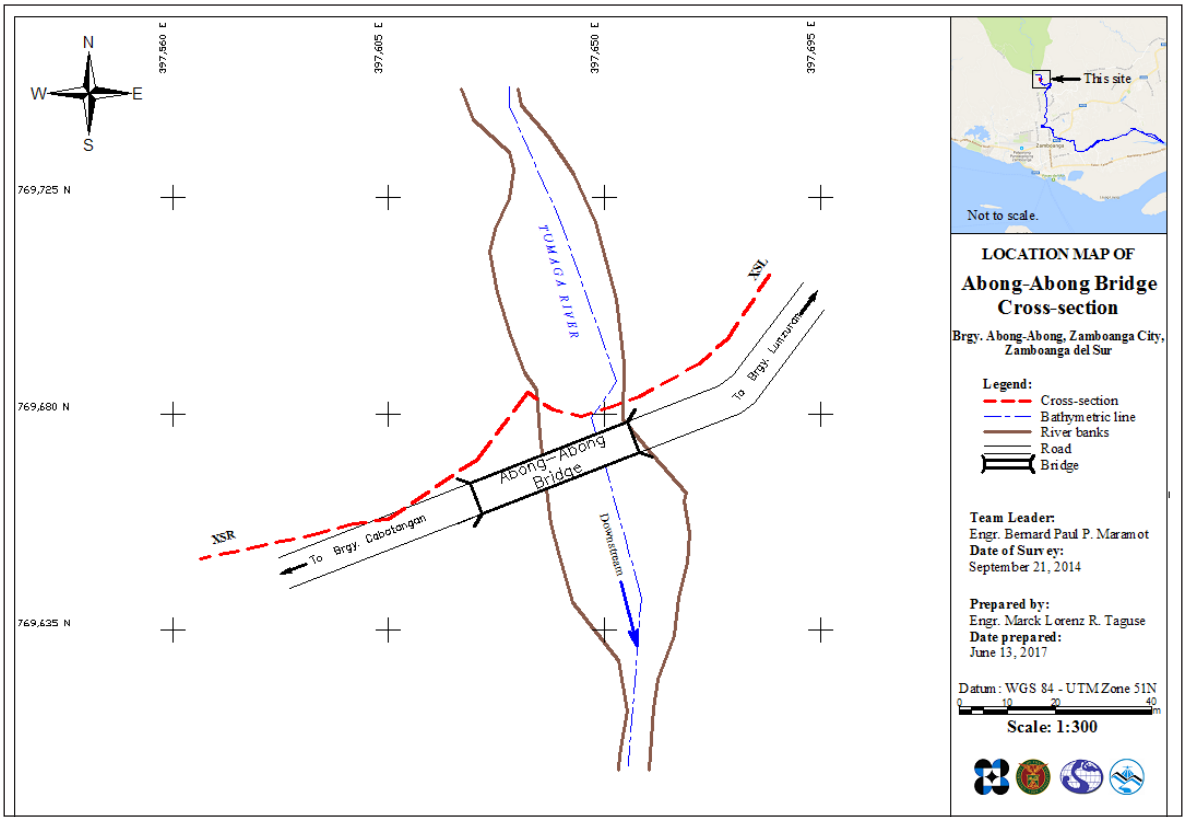


Figure 44. Abong-abong bridge cross-section planimetric map

Bridge Data Form

Bridge Name: ABONG-ABONG BRIDGE Date: September 21, 2014

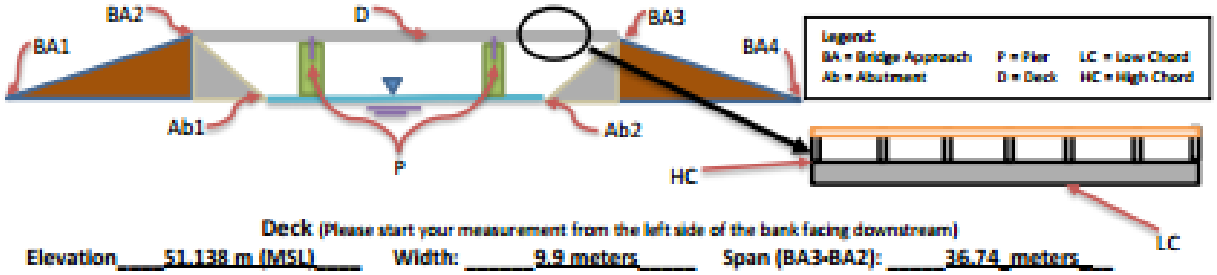
River Name: TUMAGA RIVER Time: 9:36 am

Location (Brgy, City, Region): Brgy. Abong-Abong, Zamboanga City

Survey Team: DVBC Zamboanga Survey Team

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

Latitude: 6d57'44.11463" N Longitude: 122d04'25.00914" E



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

Elevation 51.138 m (MSL) Width: 9.9 meters Span (BA3-BA2): 36.74 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	49.106	BA3	62.251	51.013
BA2	27.045	51.068	BA4	129.118	49.878

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 45. Abong-abong Bridge Data form

Figure 46. Water Marking on the Water Post near Tumaga Bridge

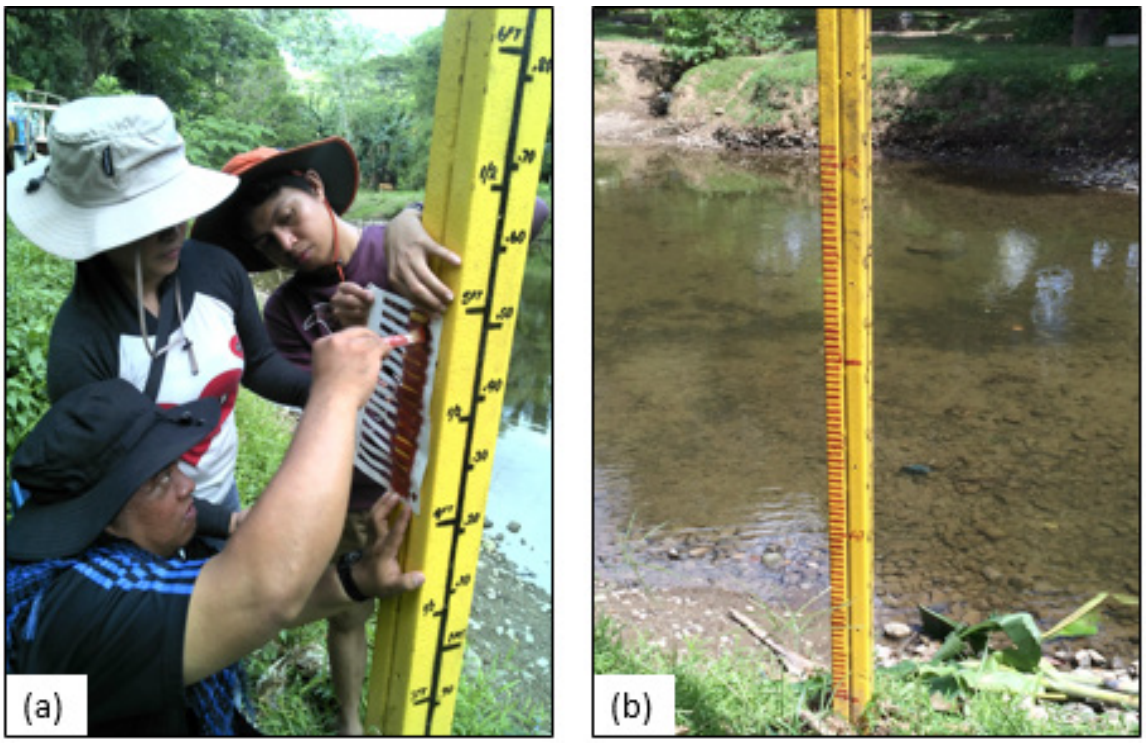


Figure 47. (a) Marking on the existing water post in Abong-abong Bridge, and (b) the finished water level markings in MSL

Water surface elevation of Tumaga River was determined using Trimble® SPS 882 in PPK mode on September 21, 2014 at 2:47 PM along the banks of Tumaga Bridge. Water surface elevation along Abong-abong Bridge was observed and recorded on September 21, 2014 at 10:01 AM. Both water surface elevations were then translated on bridge piers in MSL using a Digital Level. The marked pier will serve as 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 20, 2014 and January 28, 2015 using a survey grade GNSS Rover receiver, Trimble® SPS 882, mounted on a pole which was attached at the side of a vehicle. It was secured with a cable tie to ensure that it was horizontally and vertically balanced. The antenna height was measured as 2.602 m from the ground up to the bottom of the notch of the GNSS Rover receiver. The survey was conducted using PPK survey technique on a continuous topography mode.

Ground validation survey conducted on September 20, 2014 started near its base station at ZGS-99 in Calarian, Zamboanga City to ZGS-3508 at Tumaga Bridge, Brgy. Tumaga, Zamboanga City. The survey acquired 1,764 validation points within 11.81 km road distance. Additional validation points were acquired on January 28, 2015, which gathered 1,058 points within 2.90 km road distance using ZGS-3508 as base station. Figure 48 shows all acquired validation points. Data gaps in the survey were due to canopy cover along the roads.

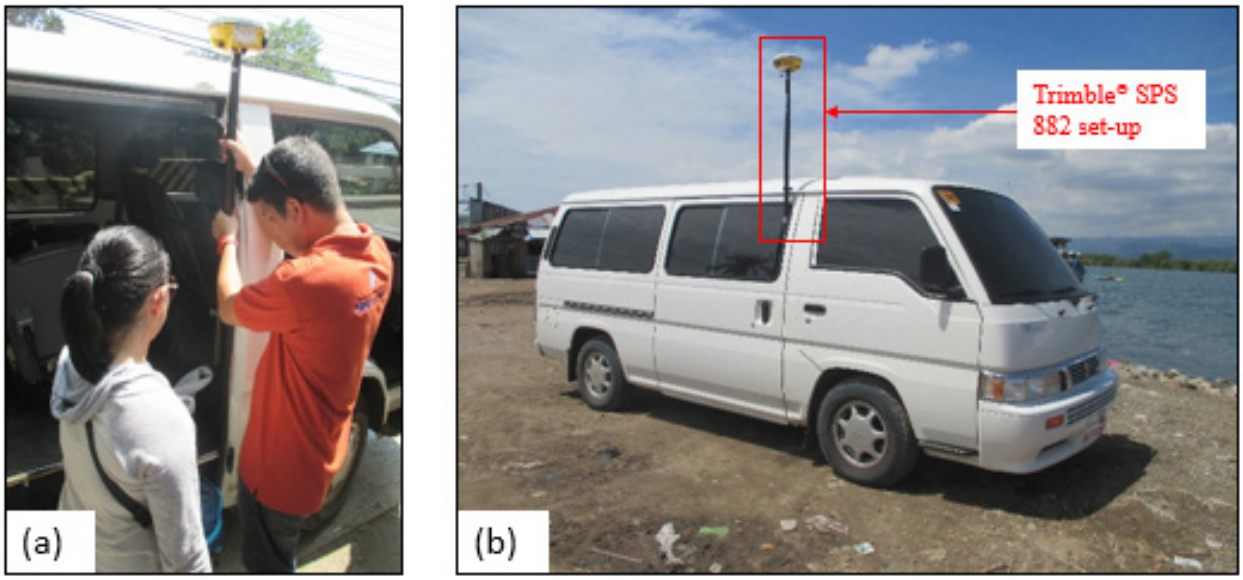


Figure 48. (a) Ground validation set-up by the survey team: A Trimble® SPS 882 attached to the side of the vehicle

Figure 49. LiDAR Ground Validation Survey along Tumaga River Basin

4.7 Bathymetric Survey

Bathymetric survey was conducted on January 26 and 30, 2015 using Trimble® SPS 882 in GNSS PPK survey technique and an OHMEX™ Single Bean echo sounder mounted on a boat as shown in Figure 50. The survey started in Brgy. Tumaga with coordinates 6°55'57.94036" 122°04'44.68689", down to its mouth in Brgy. Arena Blanco with coordinates 6°55'25.93272" 122°08'53.00195".

Manual Bathymetric survey on the other hand was conducted on January 23, 27 and 28, 2015 using Trimble® SPS 882 in GNSS PPK survey technique as shown in Figure 51. The survey started in the upstream part of the river in Brgy. Dulian, with coordinates 6°57'52.09403" 122°04'13.42916" traversed the river y foot and ended at the starting point of bathymetric survey using boat. Both ZGS-99 and ZGS-3508 were used as base stations for the survey.

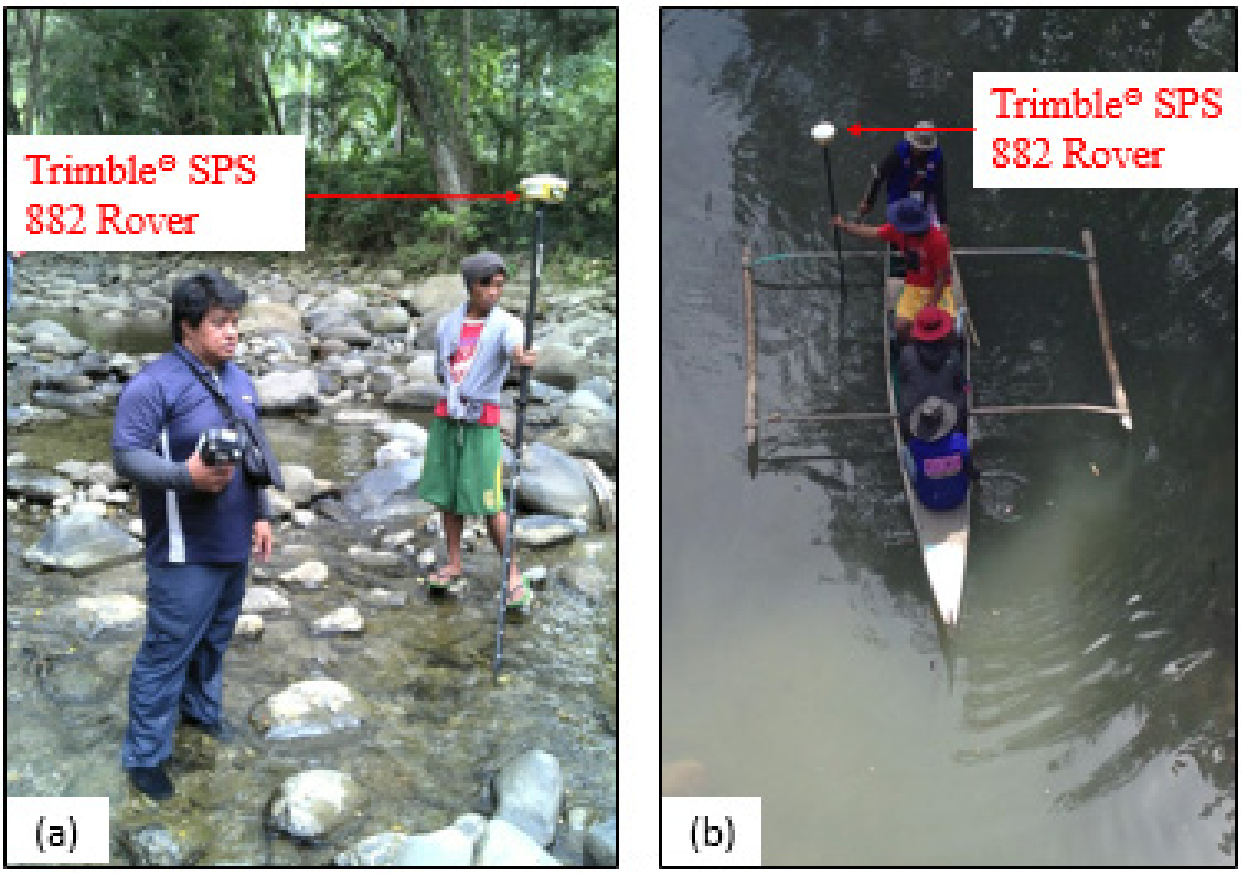


Figure 50. Bathymetric survey in Tumaga River: (a) upstream and (b) downstream

Figure 51. Bathymetric survey of Tumaga River

Bathymetric line length is 15.6 km with total of 612 bathymetric points gathered covering at least four (4) barangay boundaries: Brgys. Dulian, Guiwan, Tugbungan and Arena Blanco. A CAD drawing was also produced to illustrate the Tumaga riverbed profile as shown in Figure 52. An elevation drop of 42.7 m (MSL) was observed within 15.6 km. The highest elevation observed was 51.11 m in MSL located in Brgy. Dulian, while the lowest elevation observed was 6.55 m in MSL located in Brgy. Tugbungan, Zamboanga City.

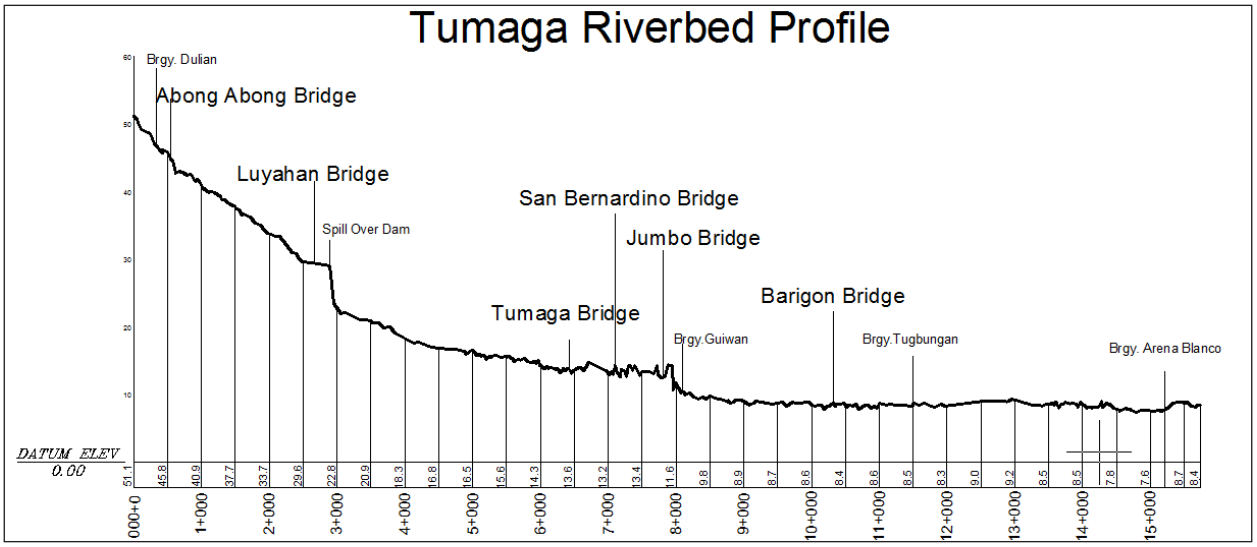


Figure 52. Riverbed profile of Tumaga River

Chapter 5: FLOOD MODELING AND MAPPING

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

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

Components and data that affect the hydrologic cycle of the river basin was monitored, collected, and analyzed. These include the rainfall, water level, and flow in a certain period of time.

5.1.2 Precipitation

Precipitation data was taken from an automatic rain gauge (ARG) installed by the Department of Science and Technology of Region 9 (DOST-IX). The ARG was installed in the Tandem Station in the Upper Pasonanca Spillway at Brgy. Pasonanca, Zamboanga City (Figure 53). The precipitation data collection started from September 30, 2013 at 08:10 AM to October 2, 2013 at 11:40 PM with 10 minutes recording interval.

The total precipitation for this event in Cabonegro Repeater Station ARG was 28.194 mm. It has a peak rainfall of 6.096 mm. on October 1, 2013 at 11:40 AM. The lag time between the peak rainfall and discharge is 2 hours and 40 minutes.

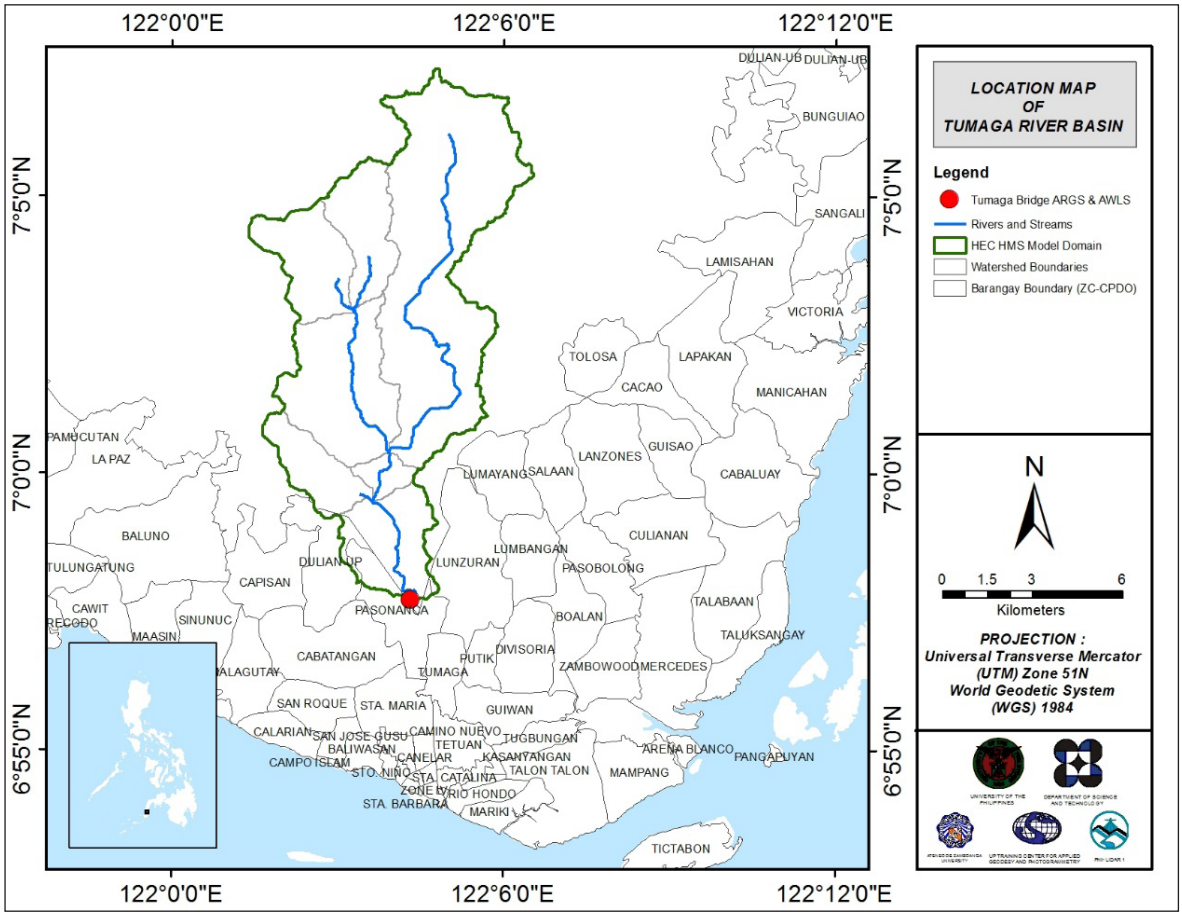


Figure 53. The location map of Tumaga HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Upper Pasonanca Spillway (Abong-abong Bridge), Pasonanca, Zamboanga City (6° 57' 51.97" N, 122° 4' 33.6" E). It gives the relationship between the observed water levels at Upper Pasonanca Spillway and outflow of the watershed at this location.

For Abong-abong Bridge, the rating curve is expressed as $Q = 9E\text{-}35e^{1.7924h}$ as shown in Figure 55.

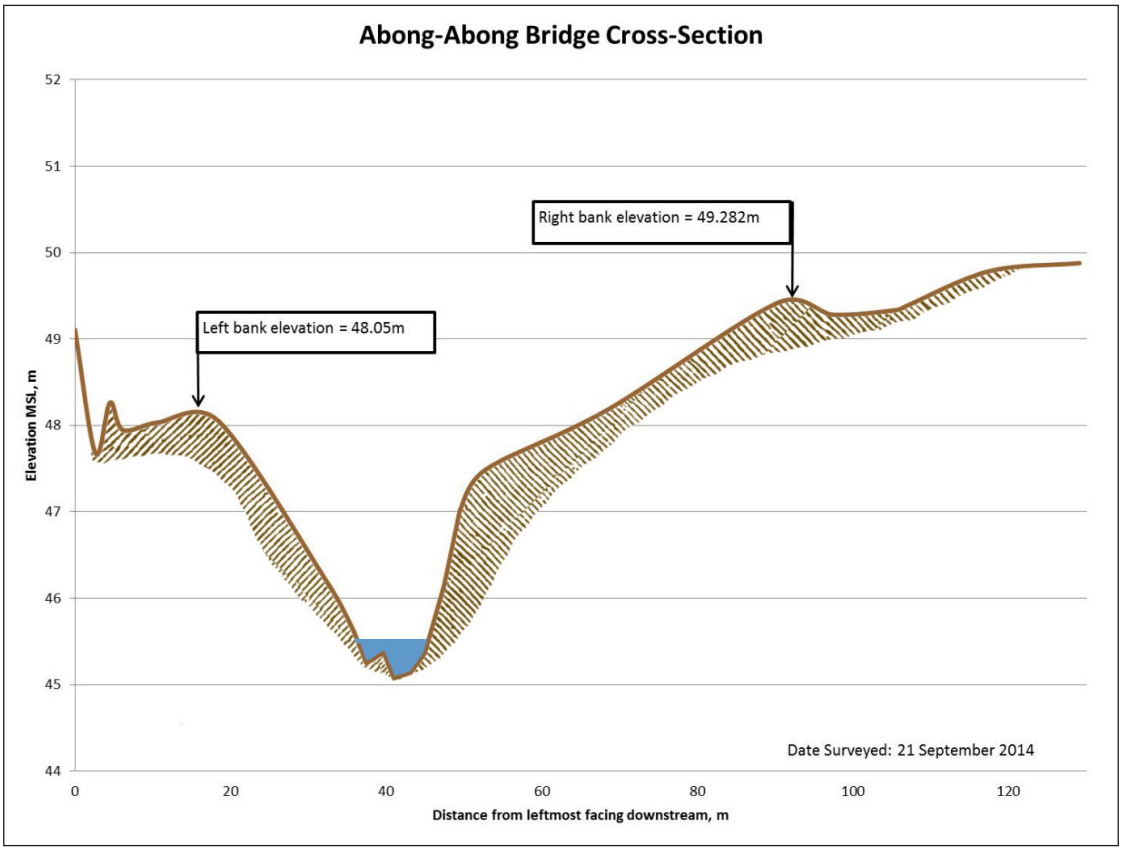


Figure 54. Cross-Section Plot of Abong-Abong Bridge

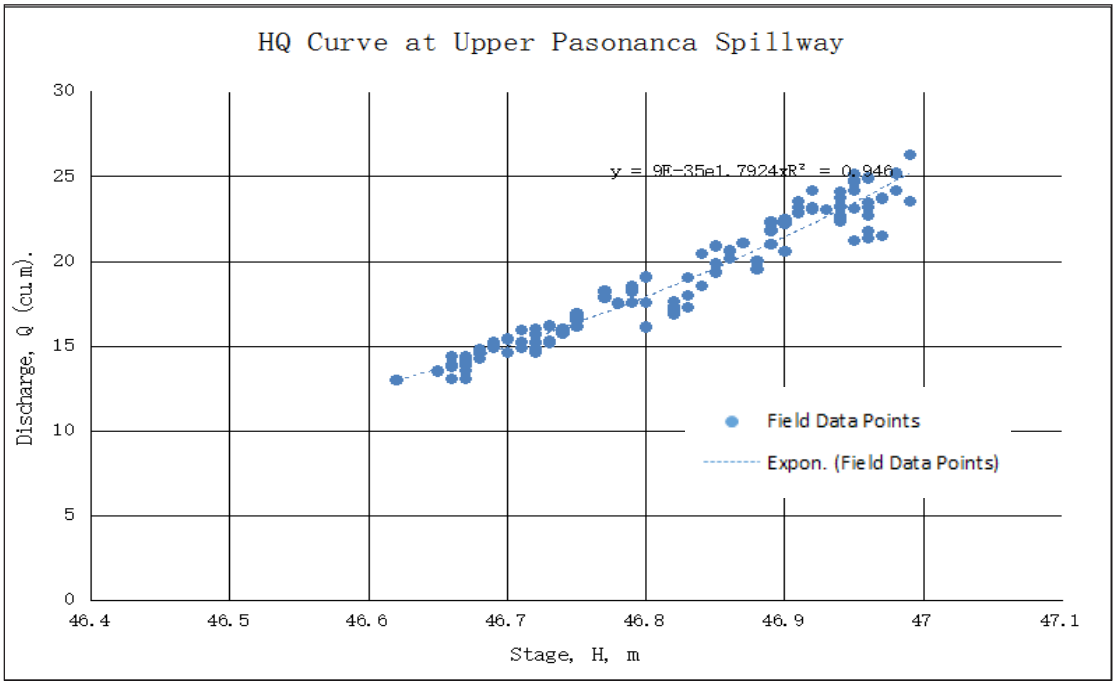


Figure 55. The rating curve at Upper Pasonanca Spillway (Abong-abong Bridge), Pasonanca, Zamboanga City

This rating curve equation was used to compute the river outflow at Upper Pasonanca Spillway for the calibration of the HEC-HMS model shown in Figure 56. Peak discharge is 7.14 cubic meters per second at 2:20 PM, October 1, 2013.

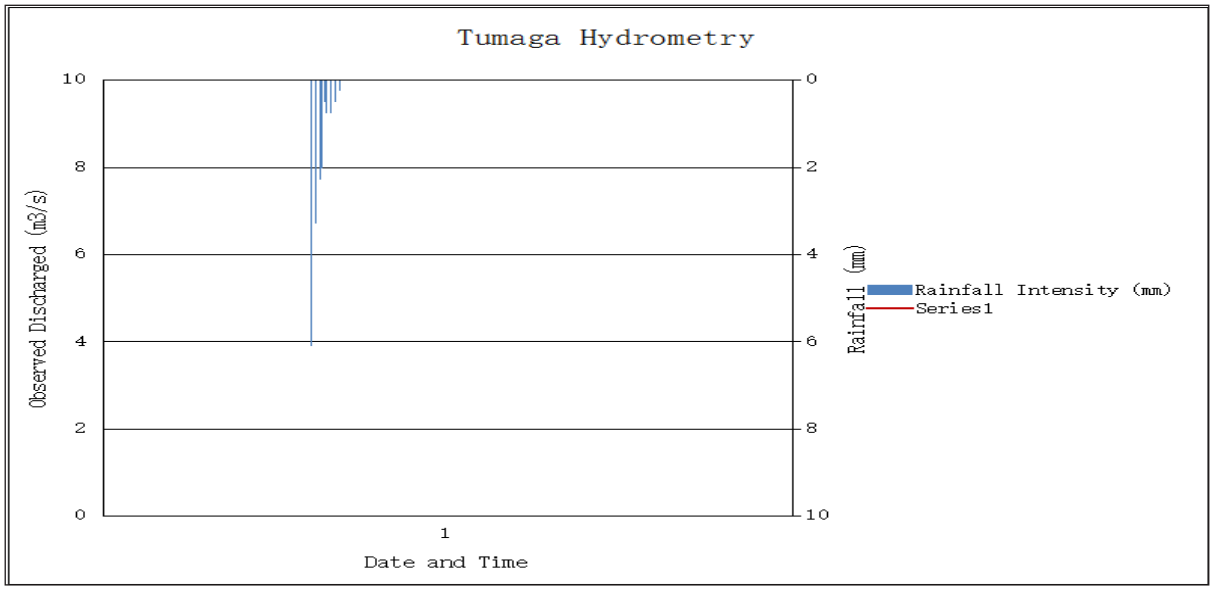


Figure 56. Rainfall and outflow data at Upper Pasonanca Spillway (Abong-abong Bridge) used for modeling

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Zamboanga City RIDF (Figure 57). 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 (Figure 58). This station was selected based on its proximity to the Tumaga watershed. The extreme values for this watershed were computed based on a 59-year record.

Table 31. 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

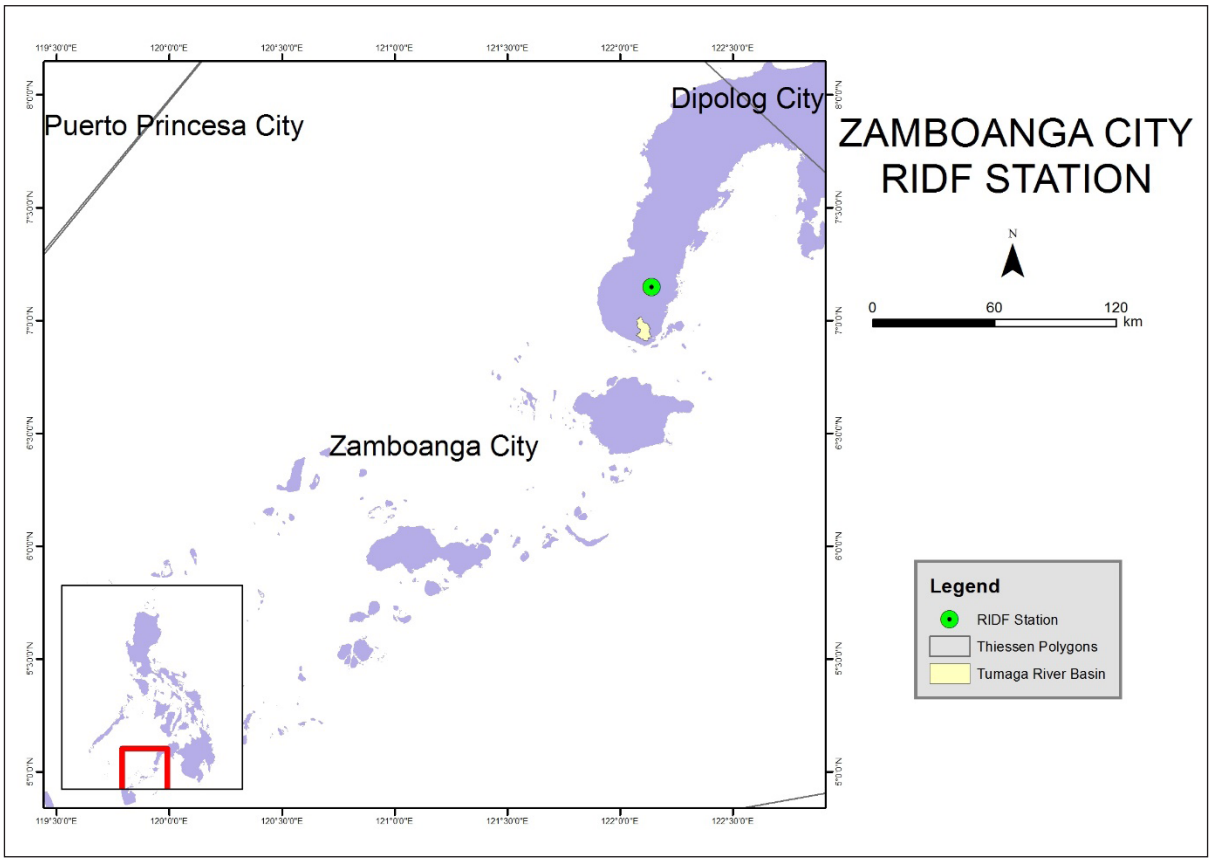


Figure 57. Zamboanga City RIDF location relative to Tumaga River Basin

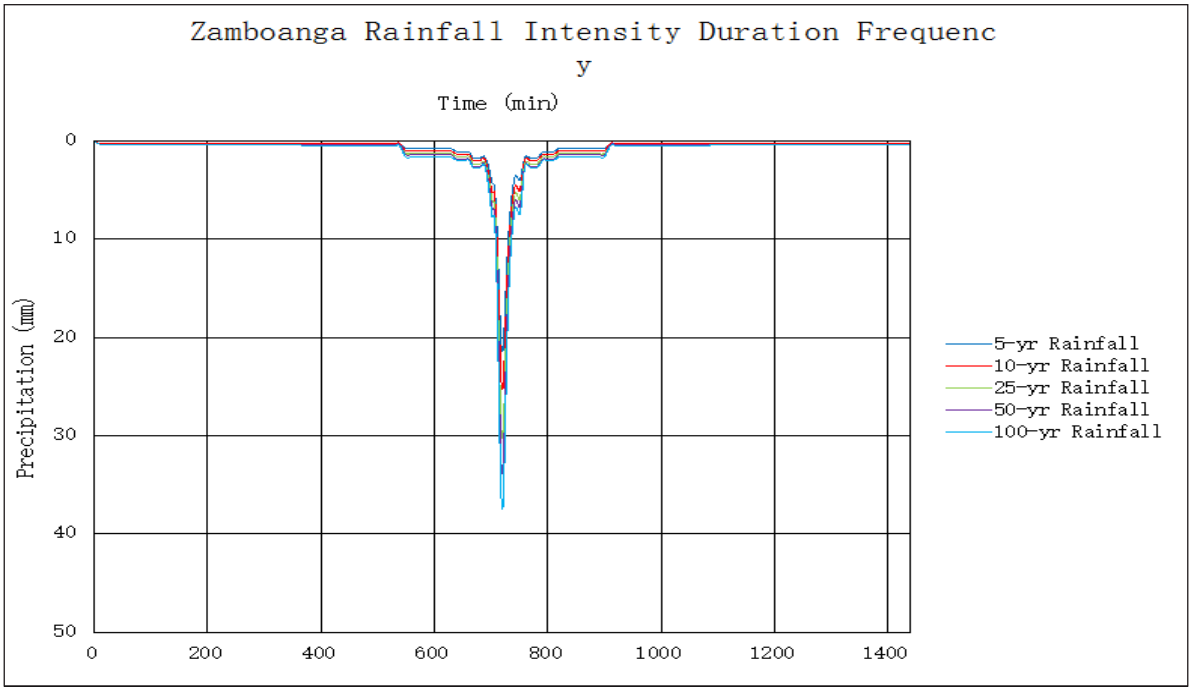


Figure 58. Synthetic storm generated for a 24-hr period rainfall for various return periods

5.3 HMS Model

The soil shapefile was taken in 2004 from the Bureau of Soils and Water Management (BSWM) under the Department of Environment and Natural Resources Management (DENR). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Tumaga River Basin are shown in Figures 59 and 60, respectively.

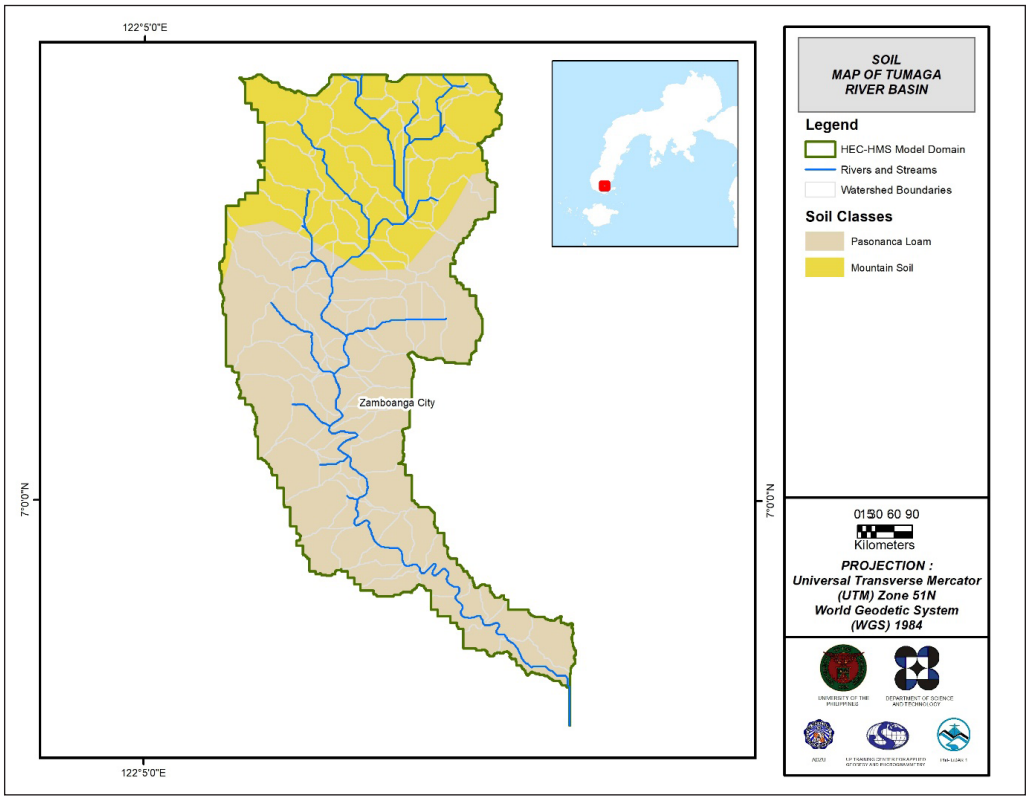


Figure 59. Soil Map of Tumaga River Basin

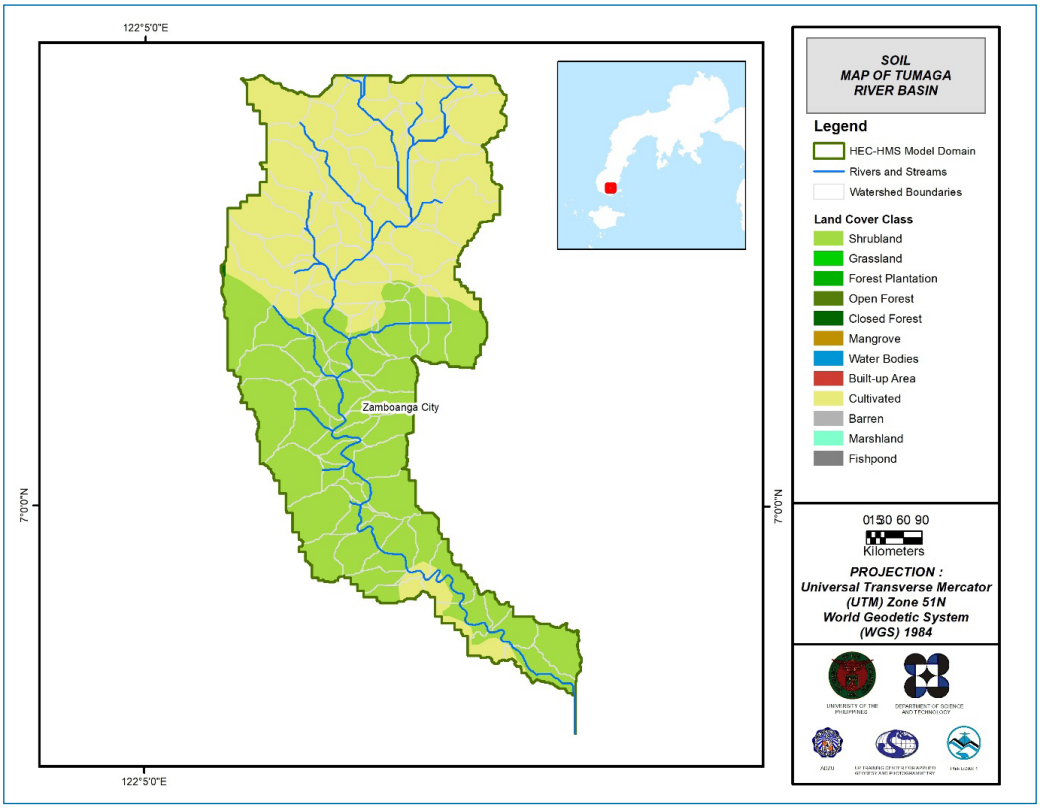


Figure 60. Land Cover Map of Tumaga River Basin

For Tumaga, the soil classes identified were loam and mountain soil. The land cover types identified were cultivated areas and shrubland.

[insert Slope Map]

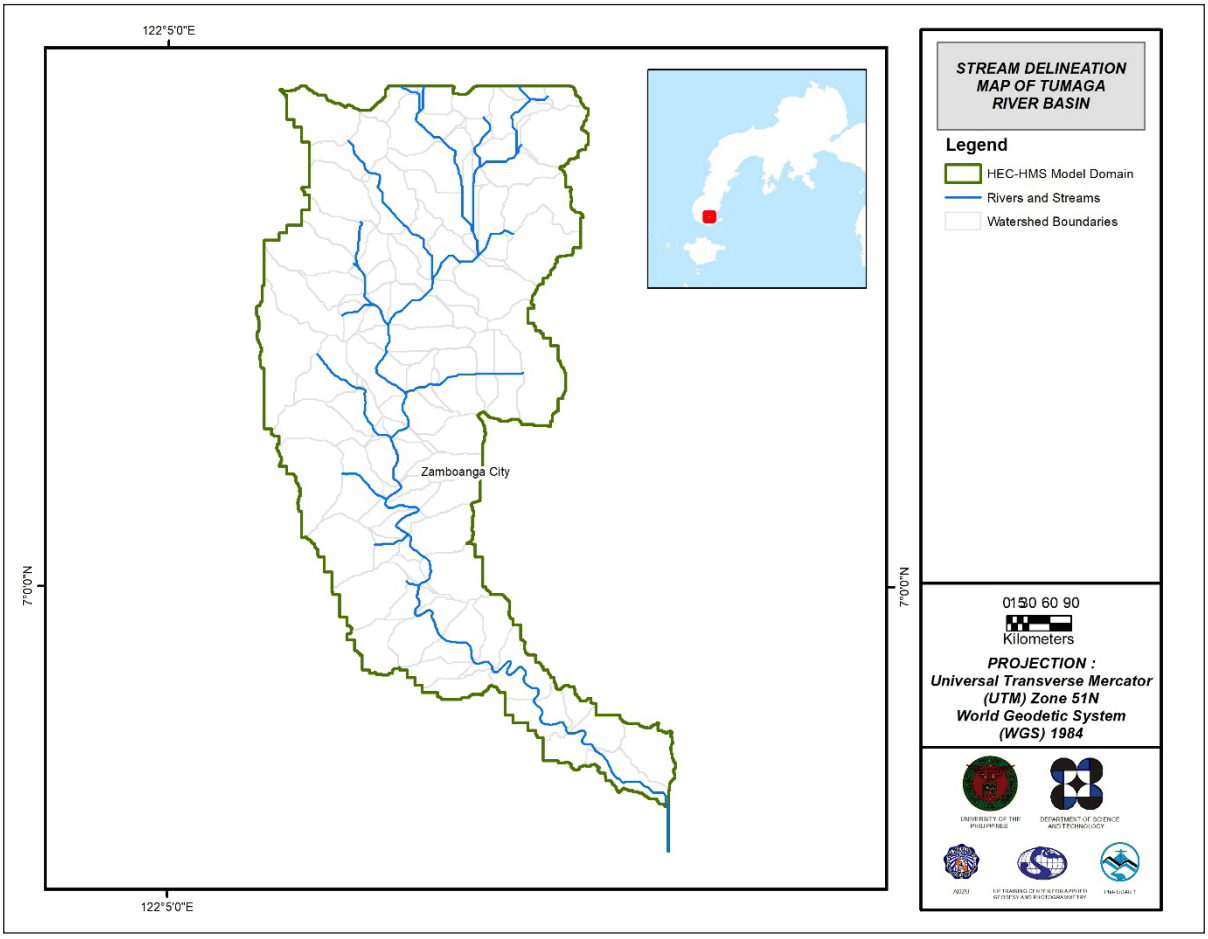


Figure 61. Stream delineation map of Tumaga river basin

Using the SAR-based DEM, the Tumaga basin was delineated and further subdivided into subbasins. The model consists of 7 sub basins, 3 reaches, and 3 junctions as shown in Figure 62 (See Annex 10). The main outlet is at Upper Pasonanca Spillway.

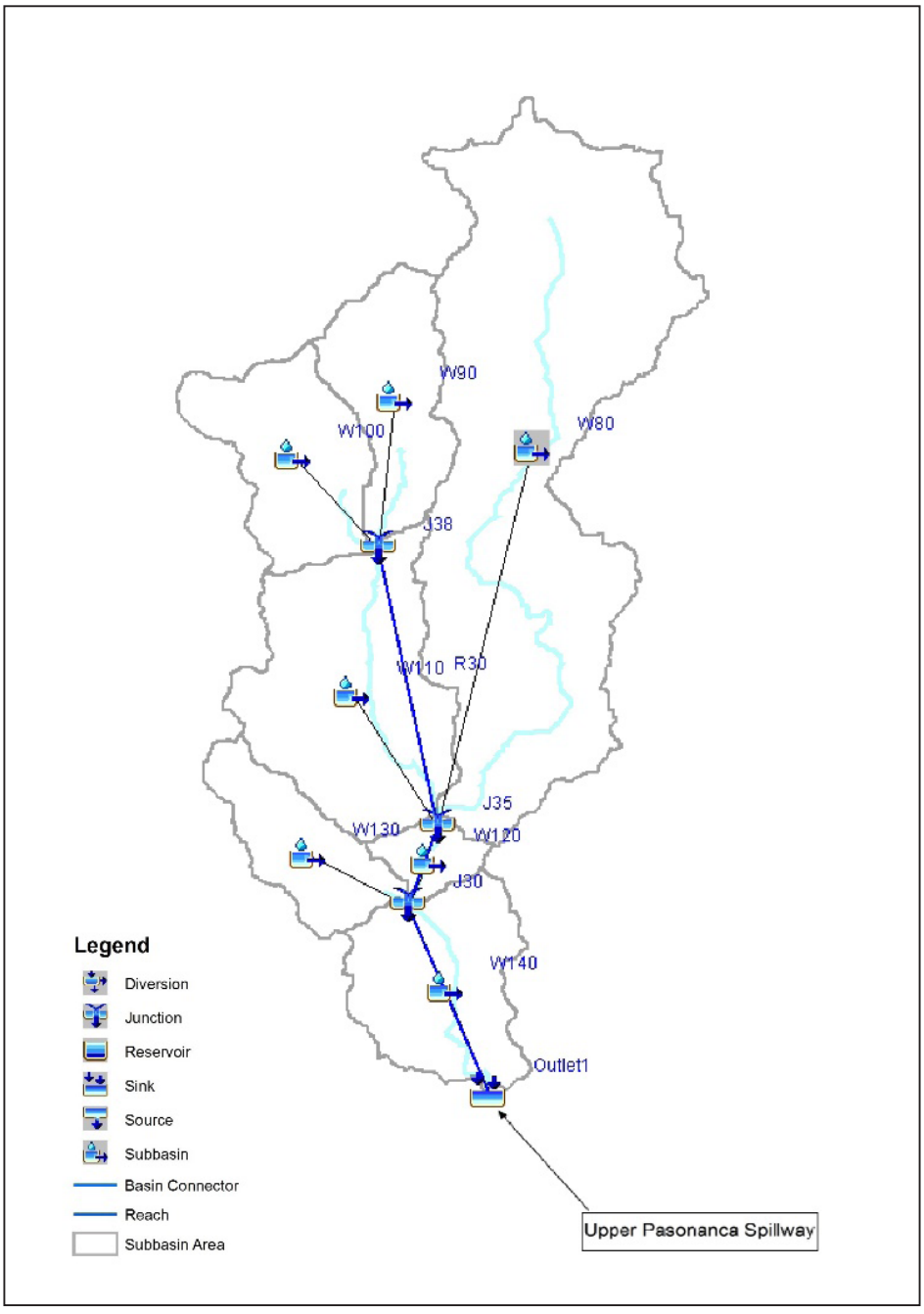


Figure 62. The Tumaga river basin model generated using HEC-HMS

5.4 Cross-Section Data

The riverbed cross-sections of the watershed were necessary in the HEC-RAS model setup. The cross-section data for the HEC-RAS model was derived ffrom the LiDAR DEM data. It was defined using the Arc GeoRAS tool and was post-processed in ArcGIS (Figure 63).

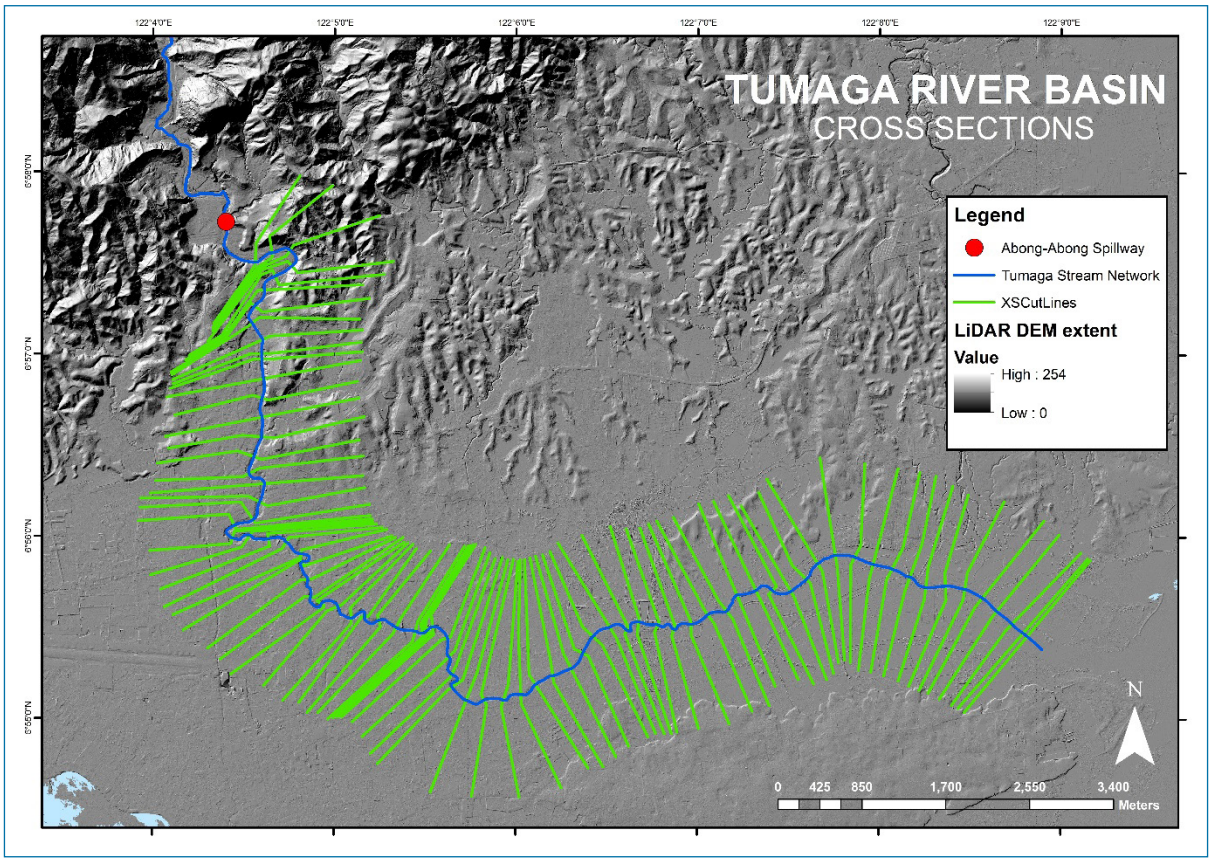


Figure 63. River cross-section of Tumaga River generated through Arcmap HEC GeoRAS tool

5.5 Flo-2D Model

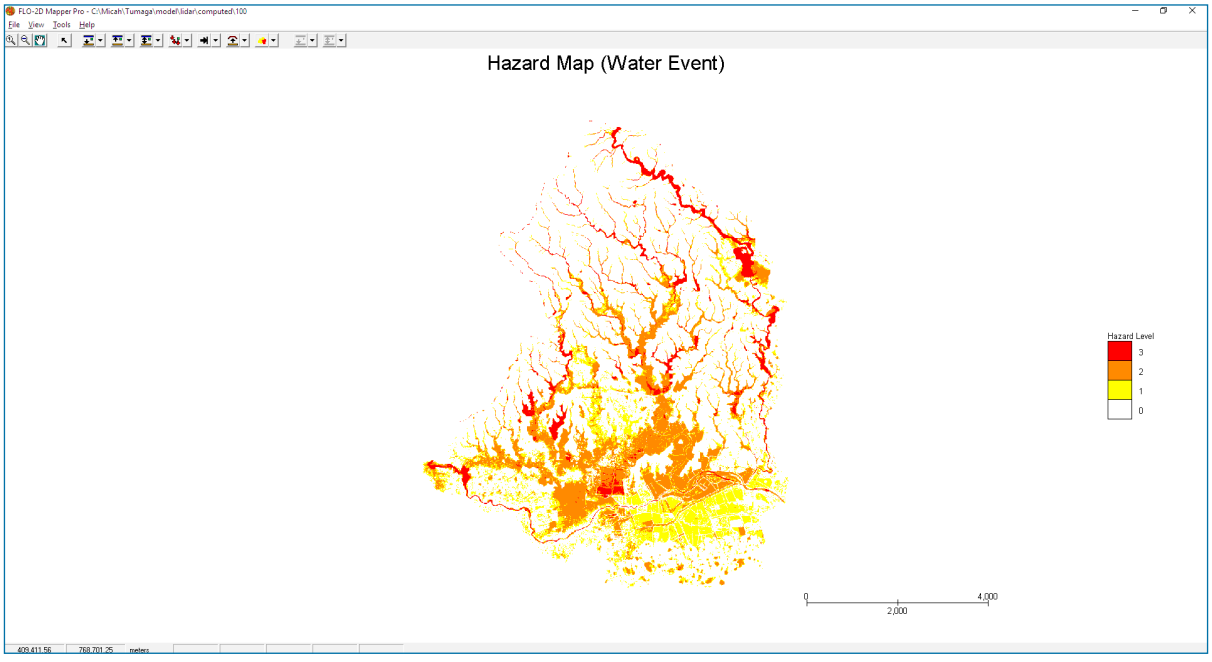


Figure 64. Generated 100-year rain return hazard map from FLO-2D Mapper

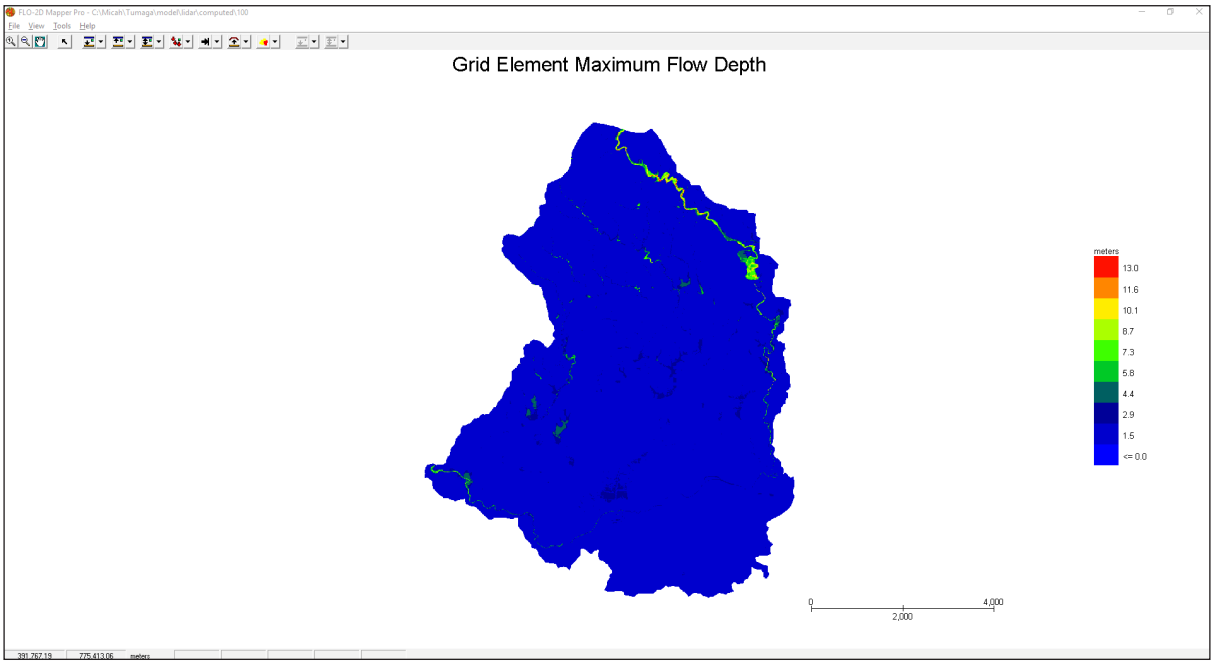


Figure 65. Generated 100-year rain return flow depth map from FLO-2D Mapper

5.6 Results of HMS Calibration

After calibrating the Tumaga HEC-HMS river basin model (See Annex 9), its accuracy was measured against the observed values. Figure 66 shows the comparison between the two discharge data.

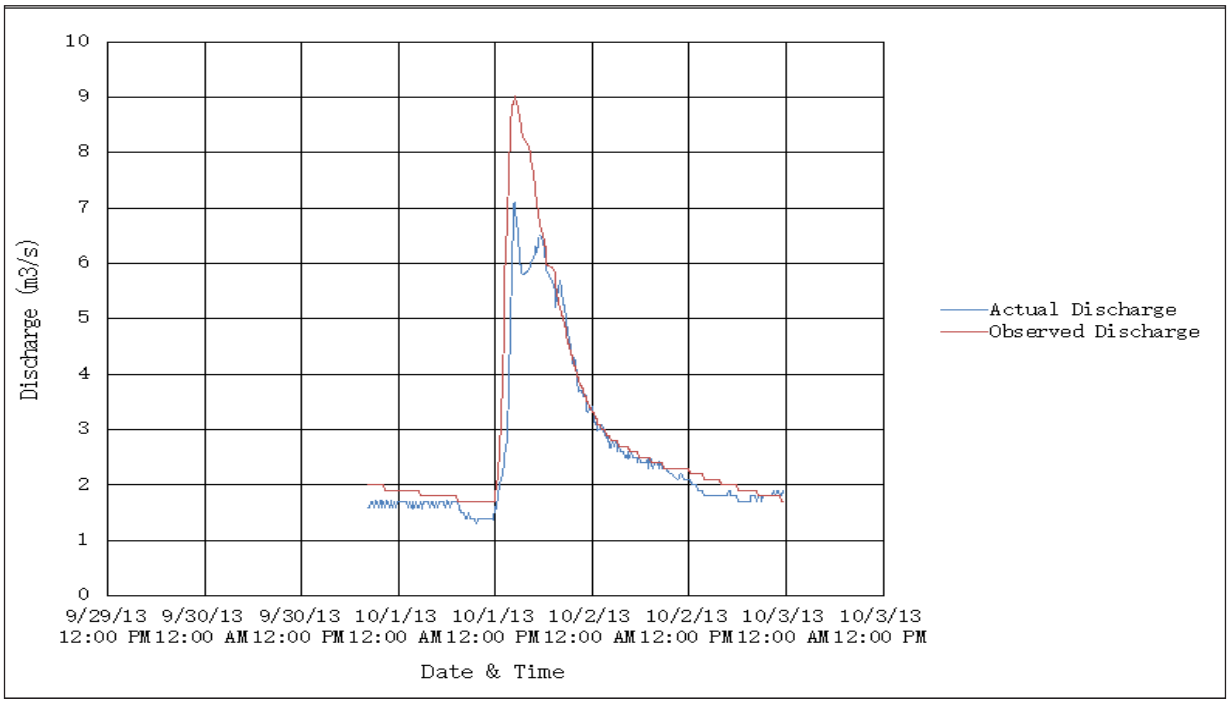


Figure 66. Outflow hydrograph of Tumaga produced by the HEC-HMS model compared with observed outflow

Table 32 shows are the adjusted ranges of values of the parameters used in calibrating the model.

Table 32. Range of Calibrated Values for Tumaga

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	7.27 – 8.19
			Curve Number	58.29 – 61.6
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.05 – 0.29
			Storage Coefficient (hr)	1.99 – 12.49
	Baseflow	Recession	Recession Constant	0.75
			Ratio to Peak	0.2
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.018

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 7.27mm to 8.19mm means that there is a moderate 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 58.29 to 61.6 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For Tumaga, the basin mostly consists of built-up, brushland and closed canopy forests and the soil consists of loams and mountain soil.

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.05 hours to 12.49 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events, while ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.75 indicates that the basin is moderately likely to quickly go back to its original discharge. Ratio to peak of 0.2 indicates a steeper receding limb of the outflow hydrograph.

Table 33. ummary of the Efficiency Test of Tumaga HMS Model

RMSE	12.20041
r^2	0.946
NSE	0.749342
PBIAS	-11.5329
RSR	0.500658

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 12.20041 (m3/s).

The Pearson correlation coefficient (r^2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.946.

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 0.749342.

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 -11.5329.

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 0.500658.

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 67) shows the Tumaga 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 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.

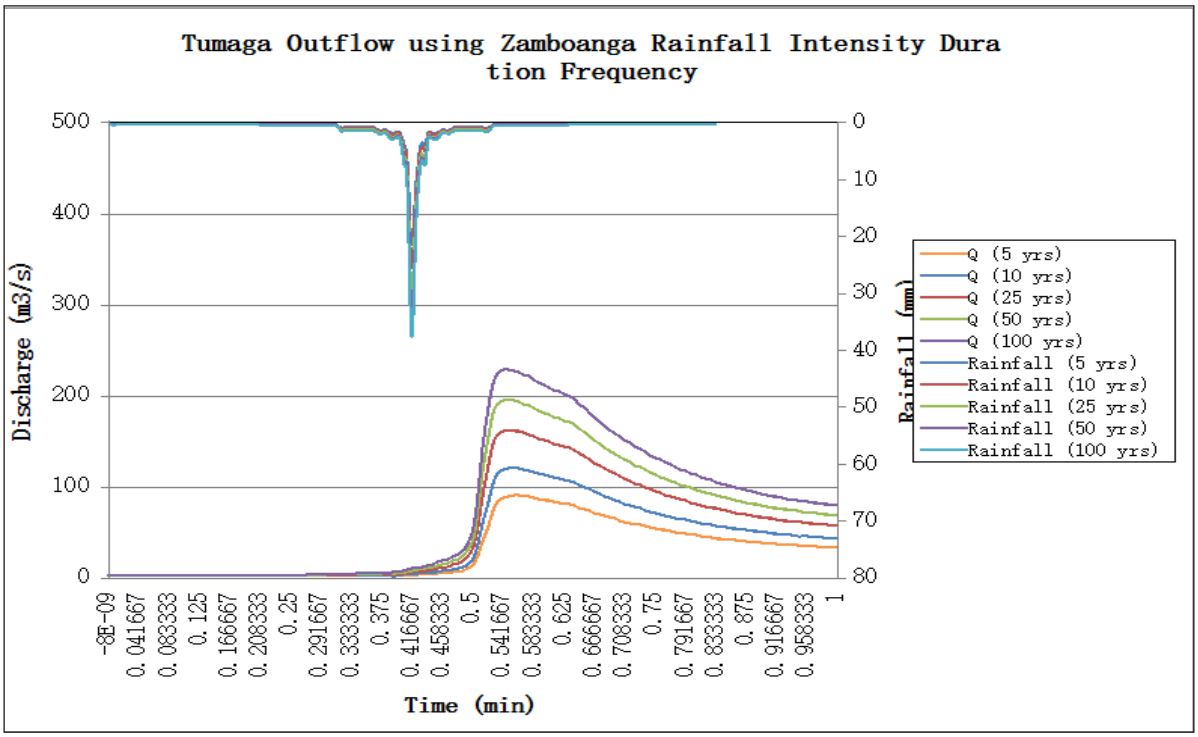


Figure 67. The Outflow hydrograph at Tumaga Station, generated using Zamboanga City RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Tumaga discharge using the Zamboanga City Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 34.

Table 34. Peak values of the Tumaga 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	90.60	1 hour, 20 minutes
10-Year	127.90	25.30	120.40	1 hour, 20 minutes
25-Year	153.40	30.20	162.20	1 hour, 20 minutes
50-Year	172.30	33.90	195.30	1 hour, 20 minutes
100-Year	191.10	37.50	228.90	1 hour, 20 minutes

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. For this publication, only a sample output map river was to be shown. The sample generated map of Tumaga River using the calibrated HMS base flow is shown in Figure 68.

Figure 68. Sample output of Tumaga RAS Model

5.9 Flood Depth and Flood Hazard Maps

The resulting hazard and flow depth maps have a 10 m resolution. Figures 69 to Figure 74 show the 5-, 25-, and 100-year rain return scenarios of the Tumaga Floodplain.

The generated flood hazard maps for the Tumaga 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 35. Municipalities affected in Tumaga-San Jose Floodplain

Municipality	Total Area	Area Flooded	% Flooded
Zamboanga City	1496.29	124.38	8%

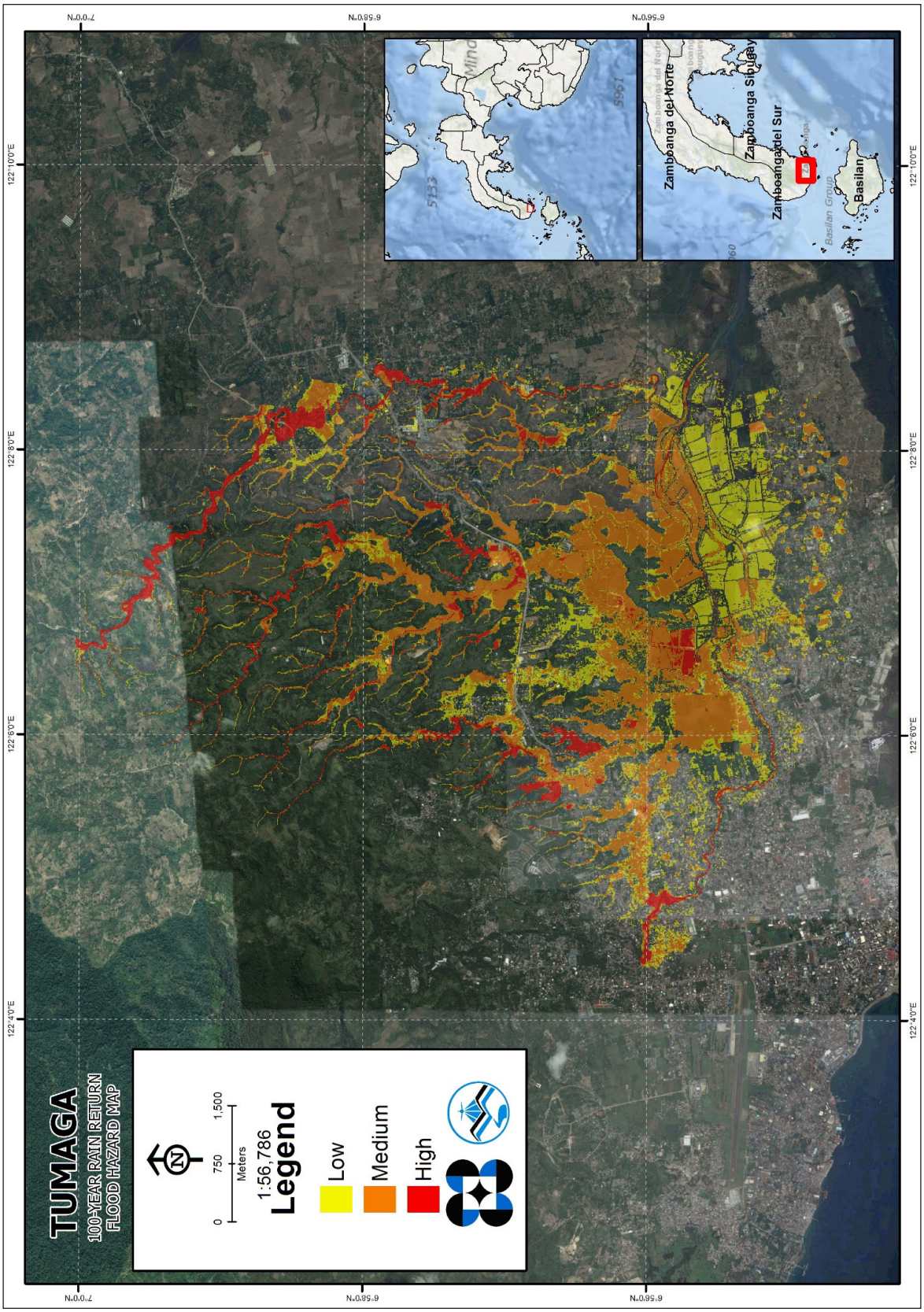


Figure 69. A 100-year flood hazard map for the Tumaga Floodplain

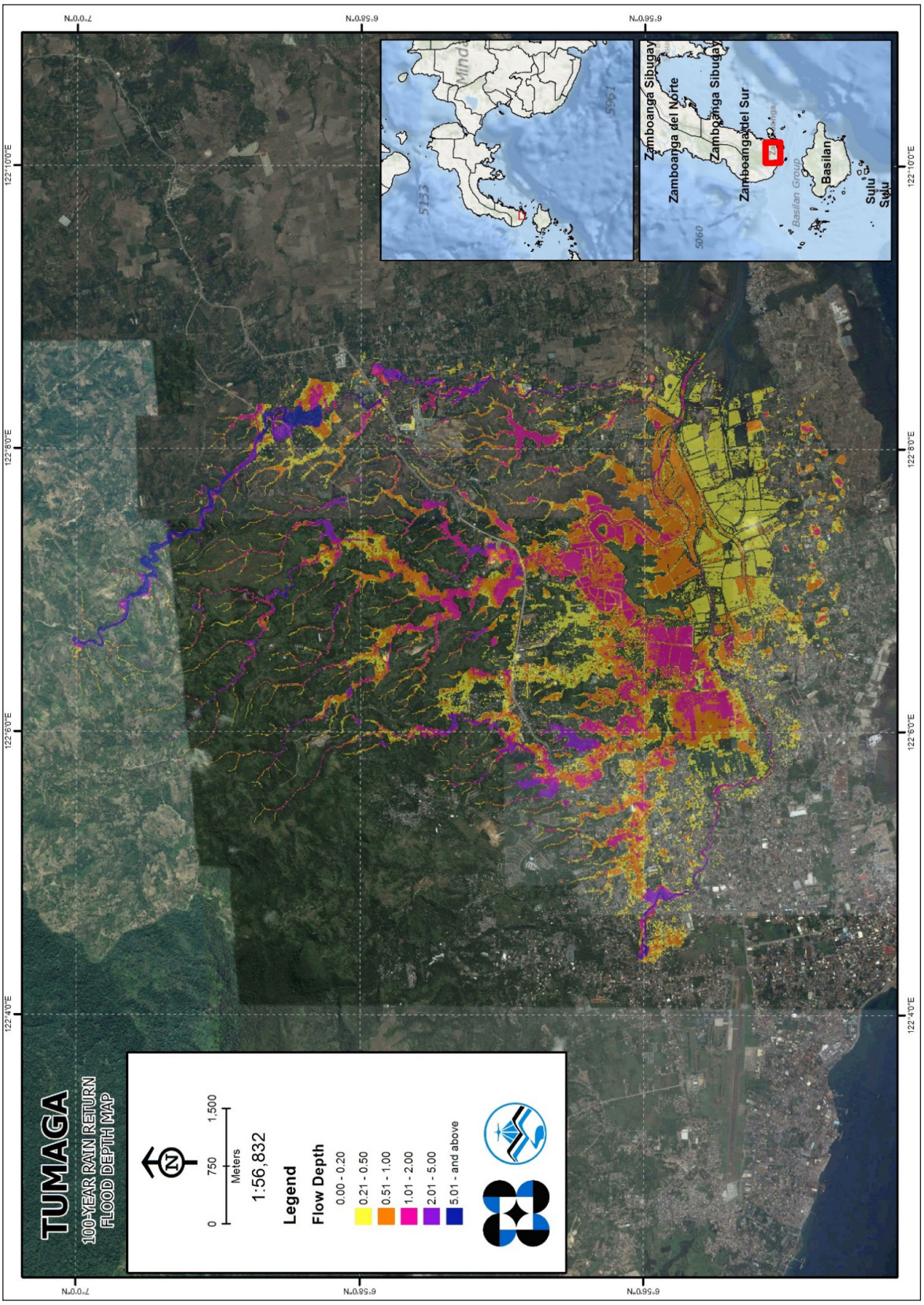


Figure 70. A 100-year flow depth map for Tumaga Floodplain

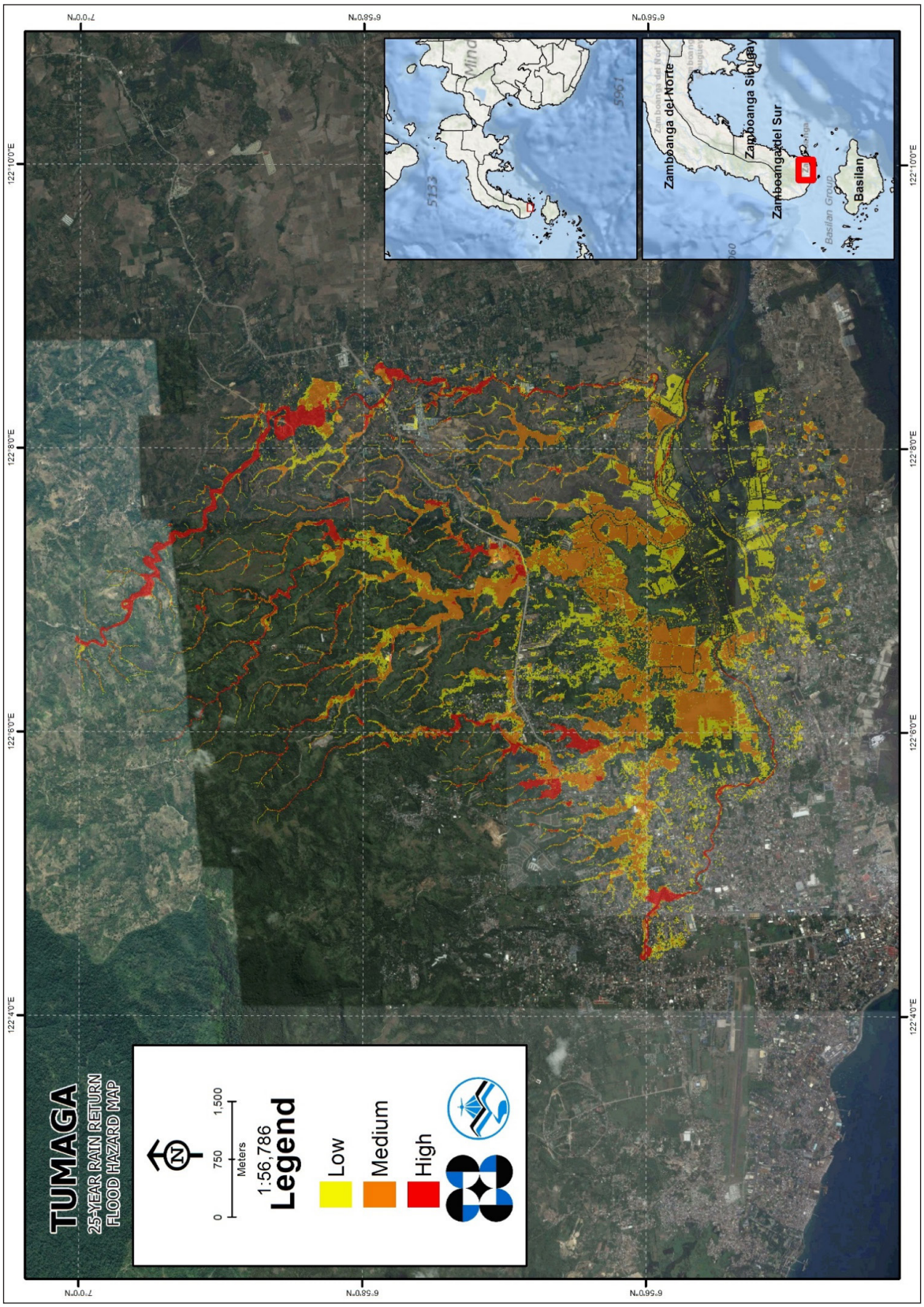


Figure 71. A 25-year flood hazard map for Tumaga Floodplain

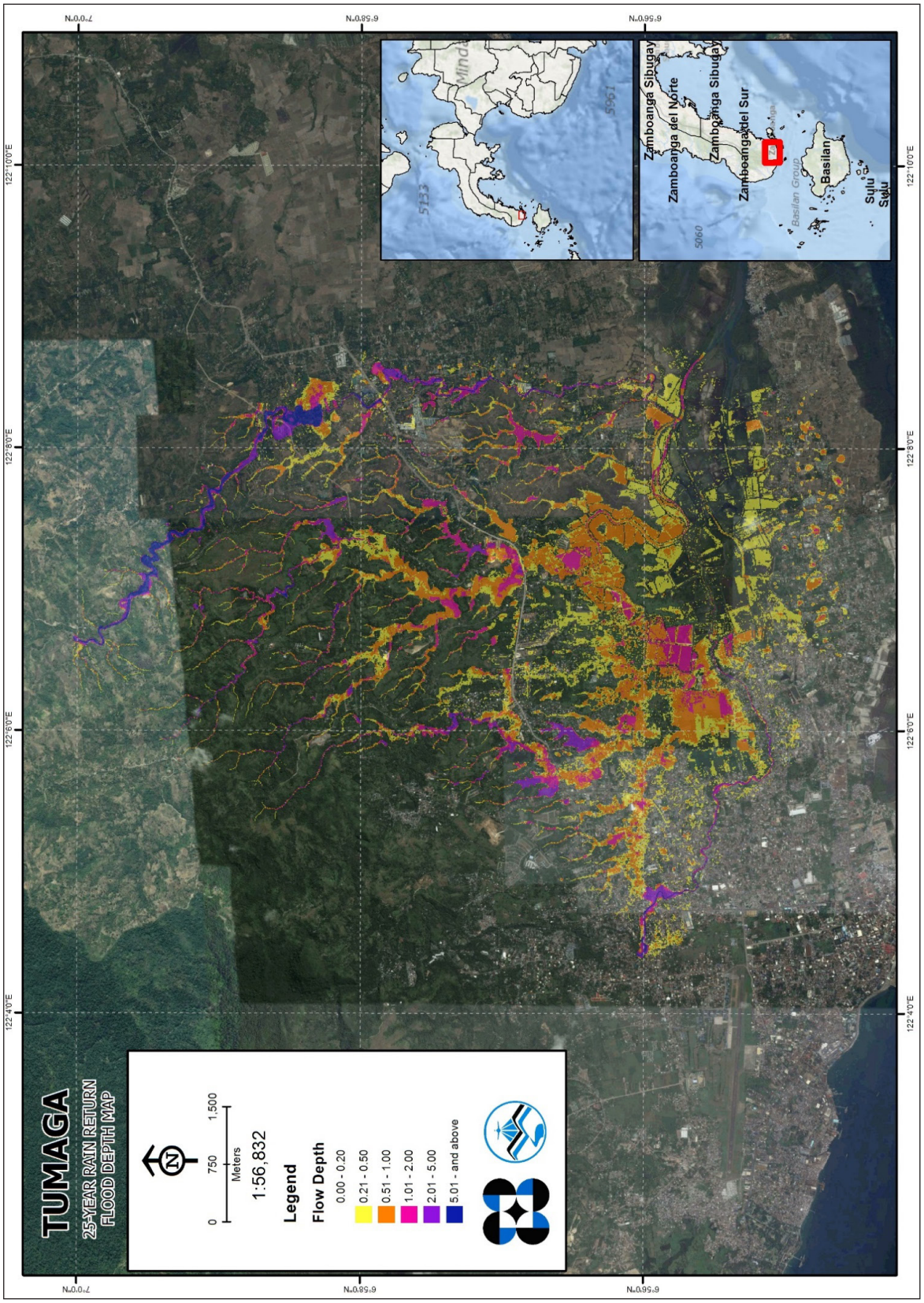


Figure 72. A 25-year flow depth map for Tumaga Floodplain

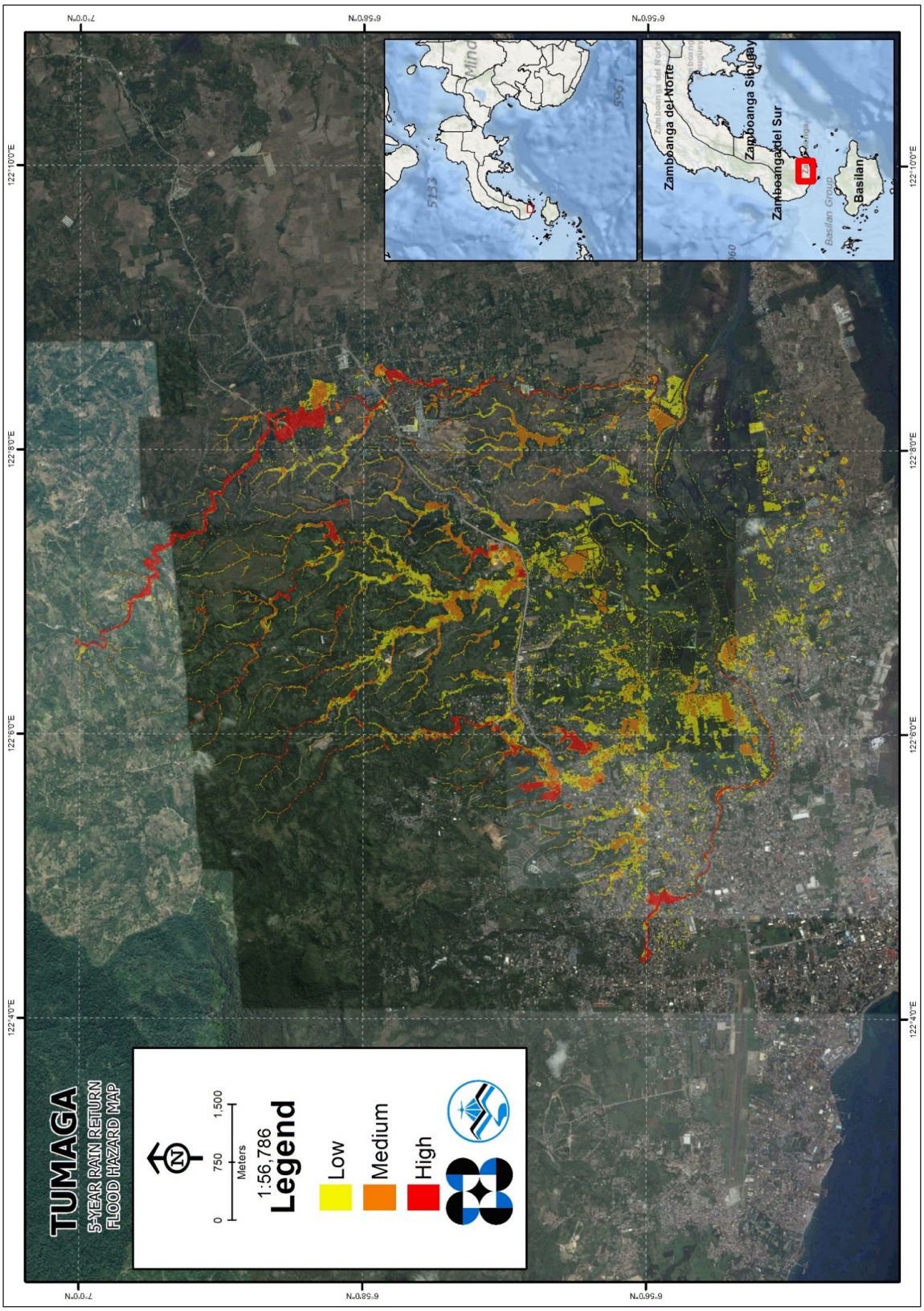


Figure 73. A 5-year flood hazard map for Tumaga Floodplain

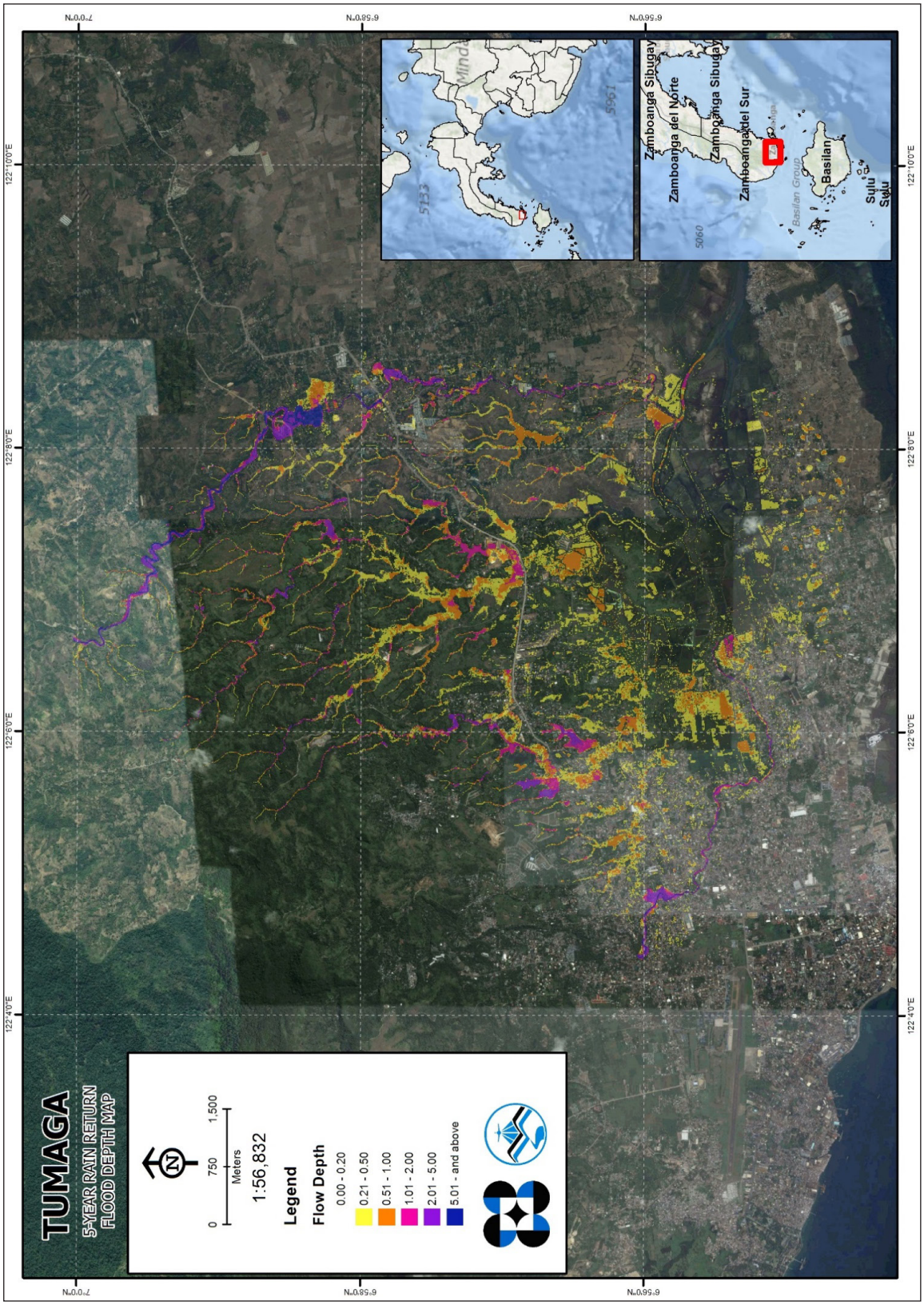


Figure 74. A 5-year flood depth map for Tumaga Floodplain

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Salug River Basin, grouped by municipality, are listed below. For the said basin, 11 barangays in two municipalities are expected to experience flooding when subjected to the flood hazard scenarios.

For the 5-year return period, 6.82% of the municipalities of Zamboanga City with an area of 1496.293 sq. km. will experience flood levels of less than 0.20 meters. 0.76% of the area will experience flood levels of 0.21 to 0.50 meters while 0.42%, 0.20%, 0.09%, 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 Tables 36 to 39 are the affected areas in square kilometers by flood depth per barangay.

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

TUMAGA-SAN JOSE BASIN		Affected Barangays in Zamboanga City										
		Arena Blanco	Baliwasan	Barangay Zone I	Barangay Zone II	Barangay Zone III	Barangay Zone IV	Boalan	Cabatangan	Calarian	Camino Nuevo	Campo Islam
Affected Area (sq. km.)	1	1.025293	0.70861	0.520313	0.620465	0.625355	0.544432	7.206508	3.433914	0.986504	0.445678	3.12852
	2	0.493011	0.114796	0.040038	0.056534	0.093055	0.044288	1.389019	0.12652	0.052328	0.129612	0.530001
	3	0.017093	0.020657	0.002655	0.01396	0.0715	0.00159	1.122207	0.098665	0.044173	0.188435	0.164384
	4	0.000852	0.009613	0.0002	0.00106	0.060406	0.0005	0.266264	0.093199	0.001037	0.099897	0.027598
	5	0.002467	0.00254	0	0	0	0	0.032181	0.040215	0	0.009994	0.010114
	6	0	0	0	0	0	0	0.00306	0.001898	0	0.00079	0

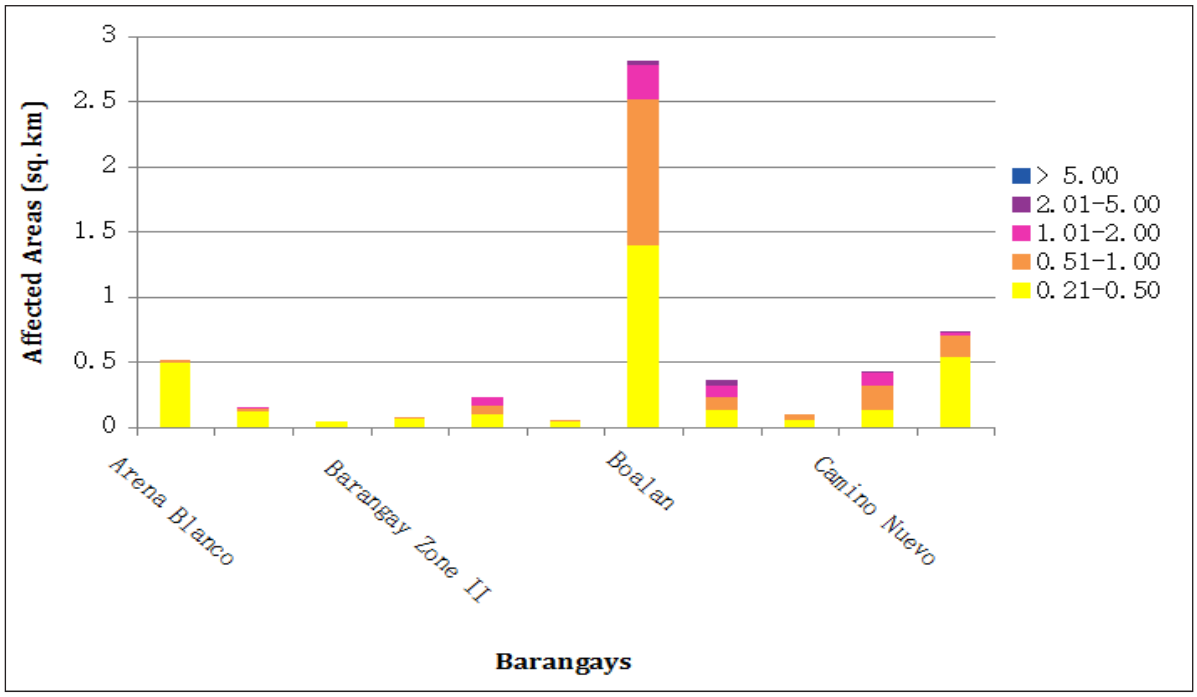


Figure 75. Affected Areas in Zamboanga City during 5-Year Rainfall Return Period

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

TUMAGA-SAN JOSE BASIN		Affected Barangays in Zamboanga City										
		Canelar	Capisan	Divisoria	Dulian	Guiwan	Kasanyangan	Lumayang	Lumbangan	Lunzuran	Maasin	Malagutay
Affected Area (sq. km.)	1	1.968468	3.409108	1.206391	5.85675	2.137196	4.038134	0.811814	10.34449	3.641315	0.178466	0.150556
	2	0.315573	0.067812	0.057952	0.151995	0.61057	0.442212	0.015957	0.426386	0.171321	0.004166	0.000265
	3	0.197749	0.038521	0.060934	0.101397	0.697935	0.065204	0.009798	0.267604	0.122181	0.0026	0.0002
	4	0.056783	0.022546	0.054552	0.12303	0.590583	0.0016	0.00769	0.194679	0.147404	0.0016	0.0001
	5	0.0025	0.01192	0.038129	0.198622	0.010111	0	0.003819	0.13981	0.095921	0.000265	0
	6	0	0.0009	0.00034	0.031566	0.0006	0	0.0003	0.0235	0.023643	0	0

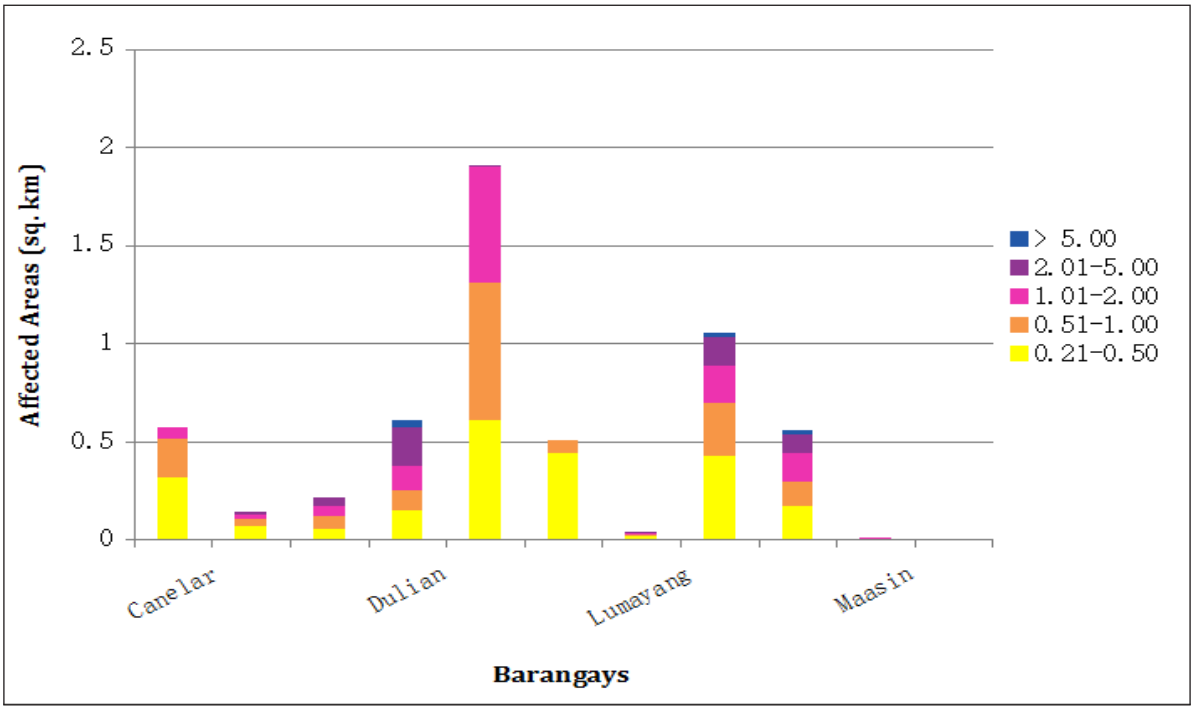


Figure 76. Affected Areas in Zamboanga City during 5-Year Rainfall Return Period

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

TUMAGA-SAN JOSE BASIN		Affected Barangays in Zamboanga City										
		Mampang	Mariki	Mercedes	Pasobolong	Pasonanca	Putik	Rio Hondo	Salaan	San Jose Cawa-Cawa	San Jose Gusu	San Roque
Affected Area (sq. km.)	1	4.051447	1.265641	4.072397	0.012413	1.388451	2.027187	0.478533	3.204667	0.422482	2.538761	8.74361
	2	0.386695	0.121199	0.453707	0	0.134143	0.392965	0.074811	0.228496	0.056607	0.396566	0.629015
	3	0.053421	0.0002	0.082053	0	0.117659	0.457668	0.002	0.13793	0.006	0.129486	0.493795
	4	0.0034	0	0.053071	0	0.120941	0.227064	0	0.073103	0	0.020731	0.178777
	5	0	0	0.057577	0	0.107536	0.032598	0	0.148341	0	0.0059	0.075823
	6	0	0	0.012923	0	0.015457	0	0	0.1355	0	0.0002	0.0062

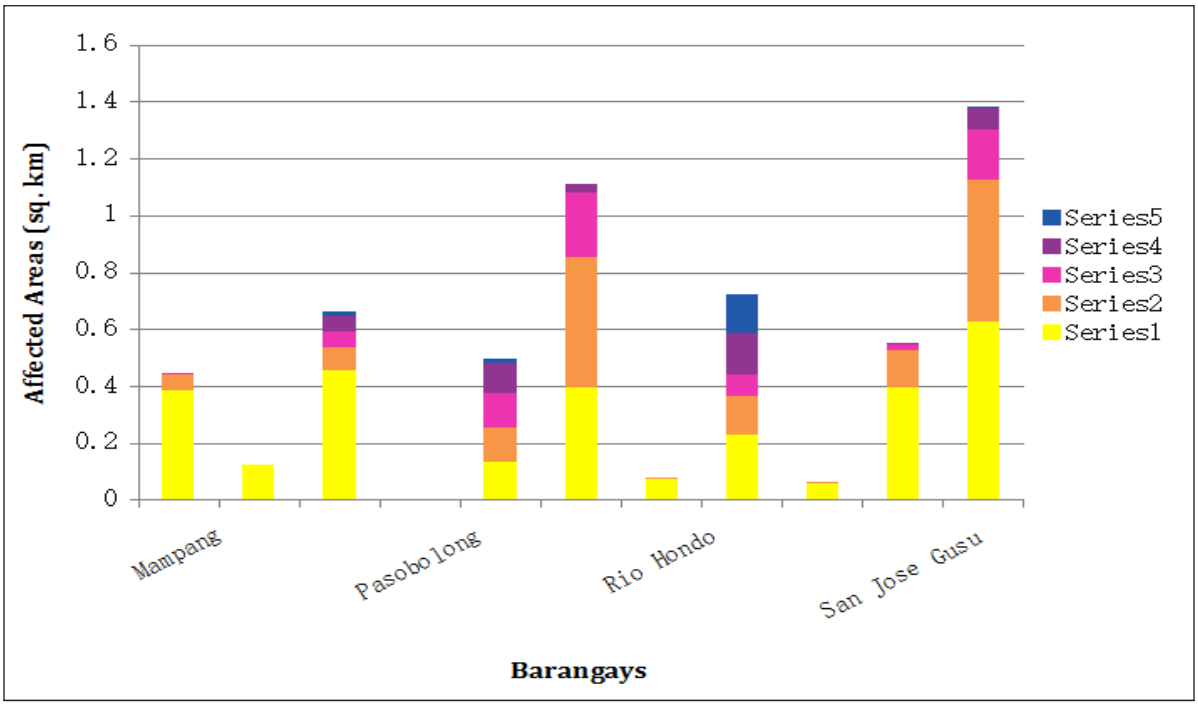


Figure 77. Affected Areas in Zamboanga City during 5-Year Rainfall Return Period

Table 39. Affected Areas in Zamboanga City during 5-Year Rainfall Return Period

TUMAGA-SAN JOSE BASIN		Affected Barangays in Zamboanga City									
		Santa Barbara	Santa Catalina	Santa Maria	Santo Niño	Sinunoc	Talon-Talon	Tetuan	Tugbungan	Tumaga	Zambowood
Affected Area (sq. km.)	1	1.308469	1.67878	1.2771	0.197955	0.073385	5.071679	1.769732	4.674742	0.909947	3.903953
	2	0.311894	0.240244	0.591457	0.030006	0.001154	0.510002	0.343891	0.648353	0.174099	0.330376
	3	0.148482	0.027795	0.369783	0.0002	0.001197	0.019374	0.178517	0.265248	0.18475	0.22755
	4	0.00691	0.0003	0.143492	0	0.000363	0.0007	0.05832	0.065405	0.198905	0.05931
	5	0.000071	0	0.04611	0	0	0	0.070234	0.035227	0.163853	0.025614
	6	0	0	0	0	0	0	0.011978	0.0008	0.096067	0.005977

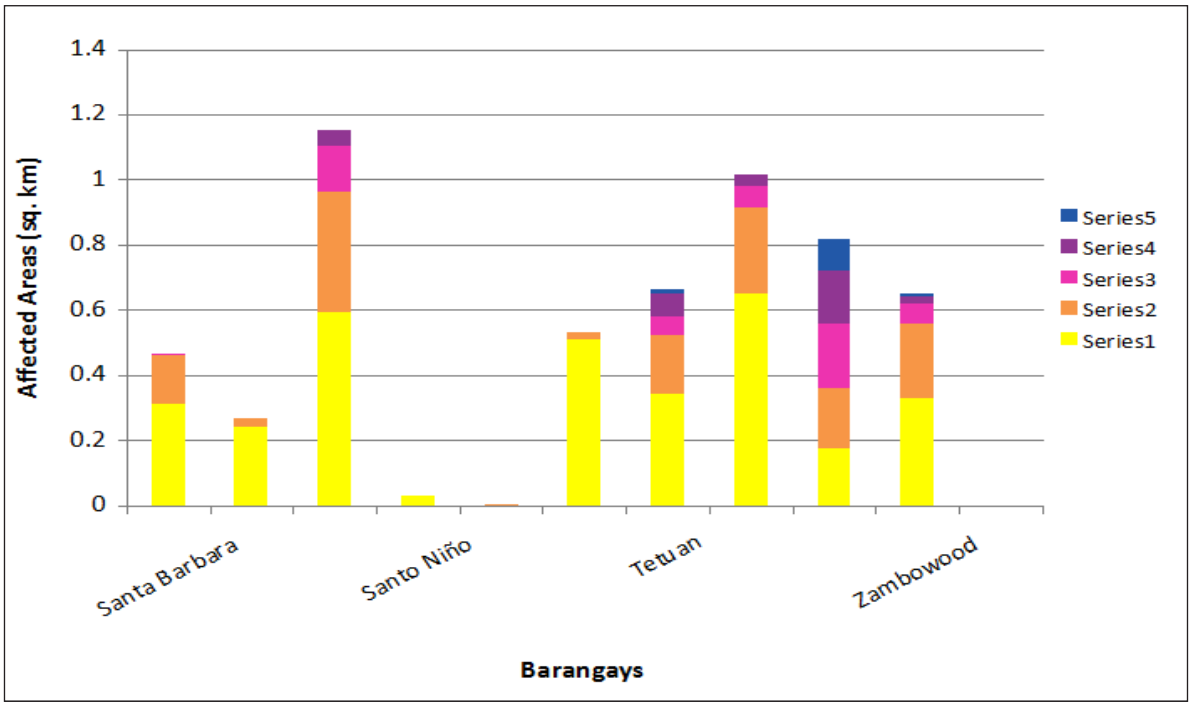


Figure 78. Affected Areas in Zamboanga City during 5-Year Rainfall Return Period

For the 25-year return period, 6.08% of the municipalities of Zamboanga City with an area of 1496.293 sq. km. will experience flood levels of less than 0.20 meters. 0.99% of the area will experience flood levels of 0.21 to 0.50 meters while 0.70%, 0.36%, 0.13%, and 0.04% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Tables 40 to 43 are the affected areas in square kilometers by flood depth per barangay.

Table 40. Affected Areas in Zamboanga City during 25-Year Rainfall Return Period

TUMAGA-SAN JOSE BASIN		Affected Barangays in Zamboanga City										
		Arena Blanco	Baliwasan	Barangay Zone I	Barangay Zone II	Barangay Zone III	Barangay Zone IV	Boalan	Cabatangan	Calarian	Camino Nuevo	Campo Islam
Affected Area (sq. km.)	1	0.729205	0.484226	0.486412	0.578867	0.543528	0.497467	6.076987	3.358161	0.954262	0.379797	2.667151
	2	0.662959	0.198871	0.069409	0.085779	0.129862	0.086828	1.231017	0.103027	0.062692	0.123466	0.599789
	3	0.142659	0.136057	0.006785	0.023658	0.083099	0.005816	1.70345	0.125544	0.037918	0.181006	0.454233
	4	0.001325	0.03015	0.0006	0.003917	0.093727	0.0007	0.930136	0.120129	0.02917	0.178864	0.123602
	5	0.002567	0.006912	0	0	0	0	0.072289	0.084806	0	0.011682	0.015842
	6	0	0	0	0	0	0	0.00536	0.003044	0	0.00079	0

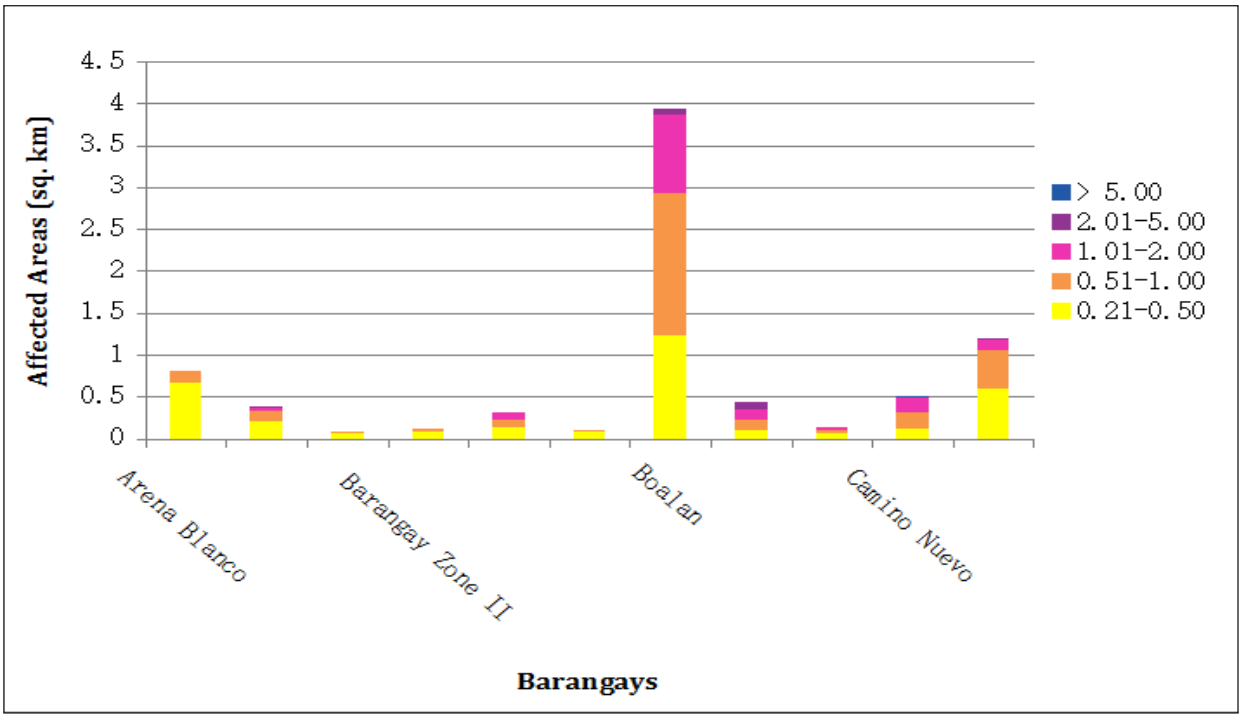


Figure 79. Affected Areas in Zamboanga City during 25-Year Rainfall Return Period

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

TUMAGA-SAN JOSE BASIN		Affected Barangays in Zamboanga City										
		Canelar	Capisan	Divisoria	Dulian	Guiwan	Kasanyangan	Lumayang	Lumbangan	Lunzuran	Maasin	Malagutay
Affected Area (sq. km.)	1	1.537594	3.379485	1.166717	5.764327	1.32283	3.677343	0.803513	10.09004	3.553325	0.177566	0.150356
	2	0.484663	0.074907	0.062265	0.149263	0.557454	0.691334	0.017886	0.435399	0.160179	0.004166	0.000365
	3	0.255622	0.047657	0.065676	0.090823	1.171269	0.164587	0.011649	0.357359	0.15508	0.0027	0.0002
	4	0.252994	0.029564	0.06338	0.116431	0.982351	0.013887	0.009994	0.261196	0.127456	0.0021	0.0002
	5	0.0102	0.017893	0.058121	0.230218	0.012492	0	0.00553	0.210371	0.16399	0.000565	0
	6	0	0.0015	0.00214	0.113999	0.0006	0	0.0008	0.042106	0.041755	0	0

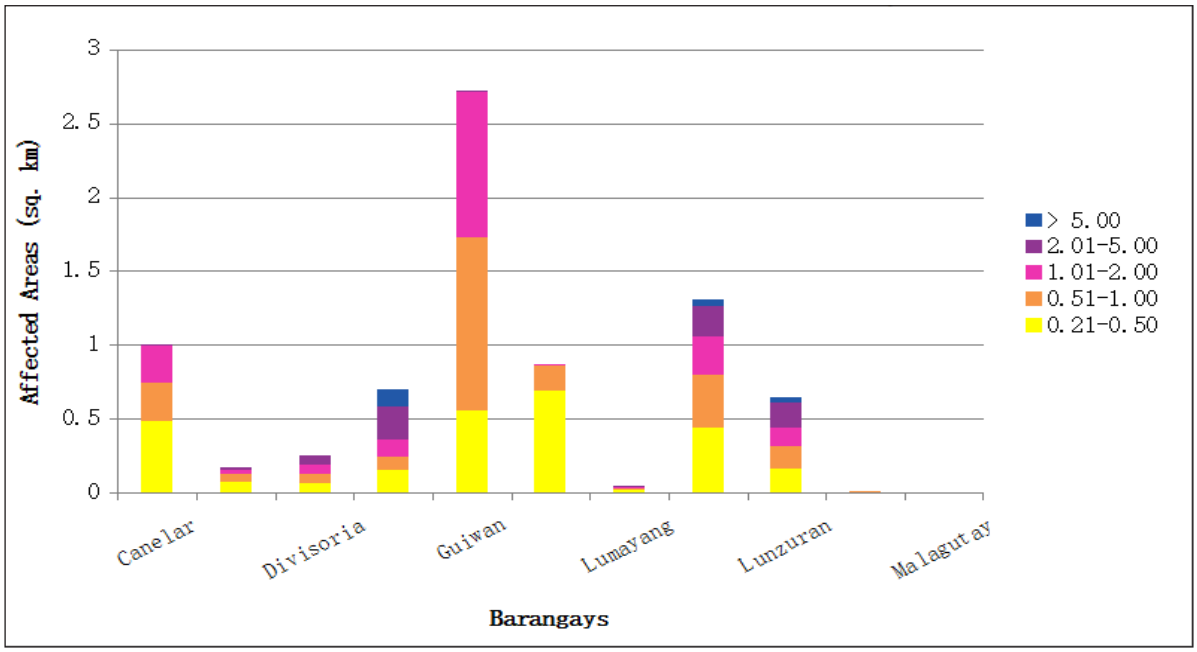


Figure 80. Affected Areas in Zamboanga City during 25-Year Rainfall Return Period

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

TUMAGA-SAN JOSE BASIN		Affected Barangays in Zamboanga City										
		Mampang	Mariki	Mercedes	Pasobolong	Pasonanca	Putik	Rio Hondo	Salaan	San Jose Cawa-Cawa	San Jose Gusu	San Roque
Affected Area (sq. km.)	**1**	3.669075	1.08513	3.747959	0.012413	1.28493	1.812623	0.329449	2.934301	0.374387	2.396627	8.361439
	2	0.678397	0.300111	0.650794	0	0.10581	0.290541	0.117851	0.301784	0.093846	0.19777	0.565527
	3	0.13119	0.0018	0.185882	0	0.161455	0.569121	0.106444	0.232838	0.016856	0.428745	0.693312
	4	0.0163	0	0.064381	0	0.132849	0.355911	0.0016	0.120093	0	0.058102	0.380295
	5	0	0	0.065594	0	0.1715	0.109286	0	0.154121	0	0.0102	0.114547
	6	0	0	0.017118	0	0.028043	0	0	0.1853	0	0.0002	0.0121

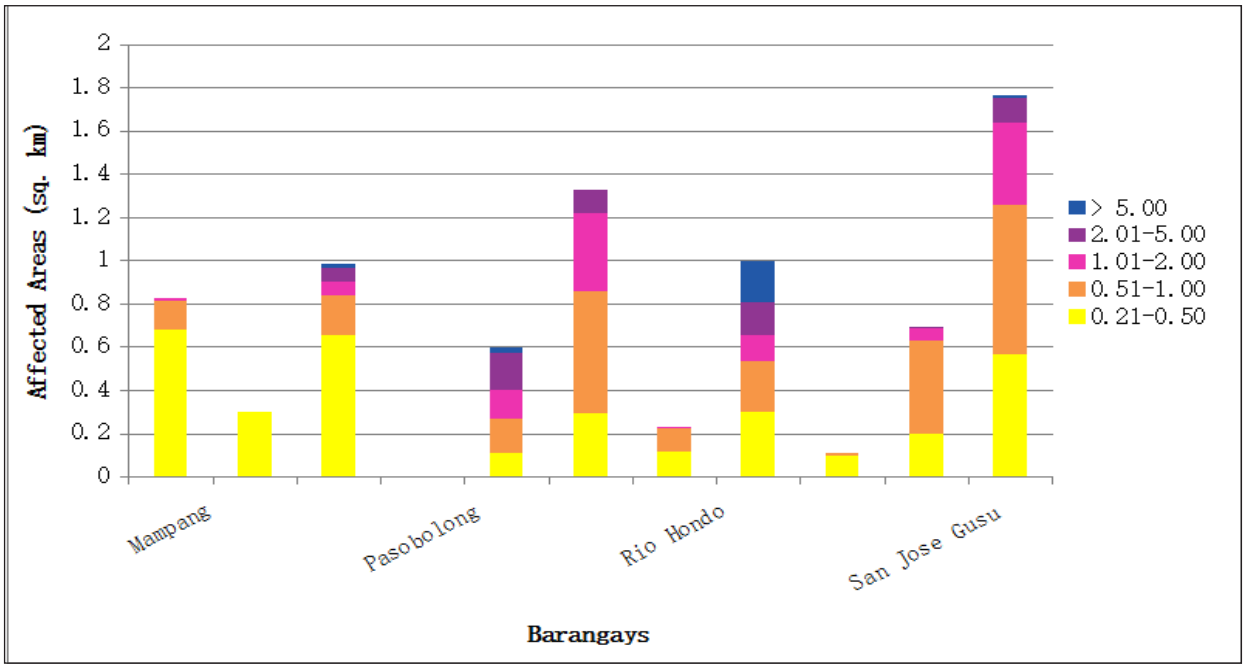


Figure 81. Affected Areas in Zamboanga City during 25-Year Rainfall Return Period

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

TUMAGA-SAN JOSE BASIN		Affected Barangays in Zamboanga City										
		Santa Barbara	Santa Catalina	Santa Maria	Santo Niño	Sinunoc	Talon-Talon	Tetuan	Tugbungan	Tumaga	Zambowood	
Affected Area (sq. km.)	1	1.154432	1.372735	0.908451	0.174648	0.073085	4.253943	1.622686	2.581191	0.823404	3.650124	0
	2	0.409268	0.489025	0.514552	0.052213	0.001054	1.297814	0.430097	1.884029	0.101946	0.326565	0
	3	0.198945	0.084858	0.626528	0.0013	0.000997	0.044885	0.204178	1.051795	0.226829	0.347072	0
	4	0.01311	0.0005	0.305825	0	0.000963	0.005113	0.091701	0.126429	0.216046	0.179022	0
	5	0.000071	0	0.075787	0	0	0	0.071634	0.04553	0.245137	0.041514	0
	6	0	0	0	0	0	0	0.012378	0.0008	0.114259	0.008482	0

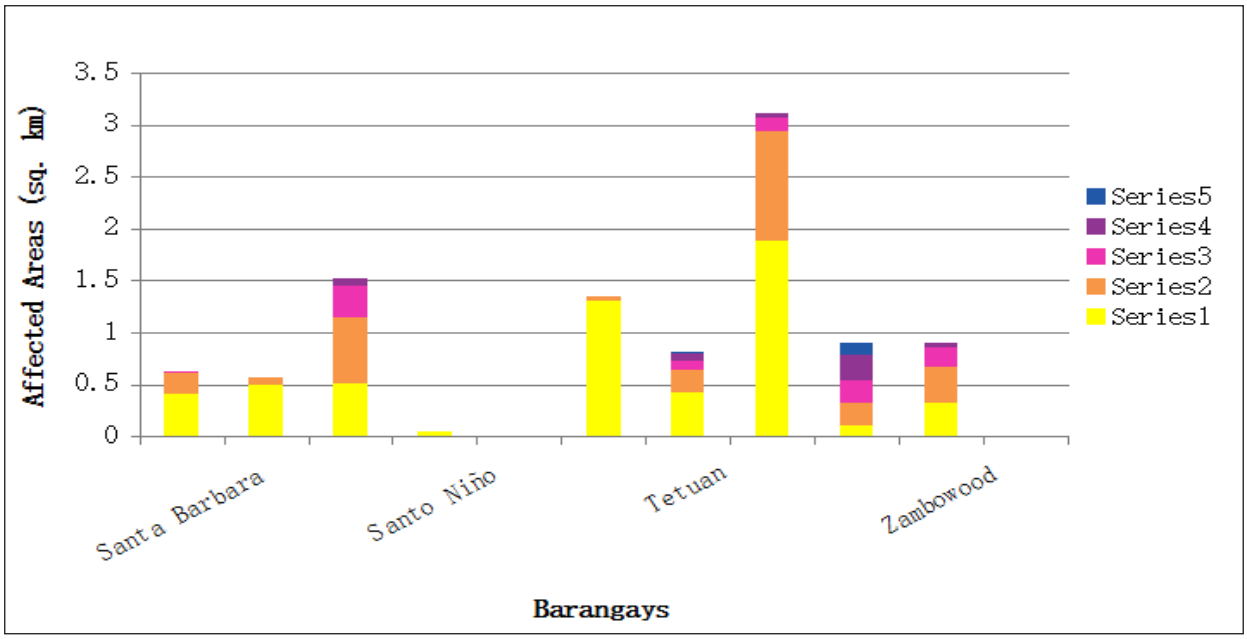


Figure 82. Affected Areas in Zamboanga City during 25-Year Rainfall Return Period

For the 100-year return period, 6.46% of the municipality of Liloy with an area of 122.4937 sq. km. will experience flood levels of less than 0.20 meters. 0.38% of the area will experience flood levels of 0.21 to 0.50 meters while 0.45%, 0.93%, 0.50%, and 0.06% 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 Tables 44 to 47 are the affected areas in square kilometers by flood depth per barangay.

Table 44. Affected Areas in Zamboanga City during 100-Year Rainfall Return Period

TUMAGA-SAN JOSE BASIN		Affected Barangays in Zamboanga City										
		Arena Blanco	Baliwasan	Barangay Zone I	Barangay Zone II	Barangay Zone III	Barangay Zone IV	Boalan	Cabatangan	Calarian	Camino Nuevo	Campo Islam
Affected Area (sq. km.)	1	0.635194	0.335158	0.463535	0.551517	0.481245	0.465294	5.649828	3.325582	0.932817	0.346199	2.415739
	2	0.560746	0.210184	0.089403	0.103494	0.162754	0.110611	0.95825	0.089219	0.069949	0.122079	0.603537
	3	0.338683	0.238461	0.009568	0.031174	0.09079	0.014005	1.727314	0.120444	0.04037	0.165563	0.568765
	4	0.001526	0.061024	0.0007	0.005816	0.115545	0.0009	1.552527	0.122965	0.040906	0.228094	0.250673
	5	0.002567	0.011389	0	0.0002	0	0	0.12396	0.129733	0	0.012846	0.021904
	6	0	0	0	0	0	0	0.00736	0.007167	0	0.000924	0

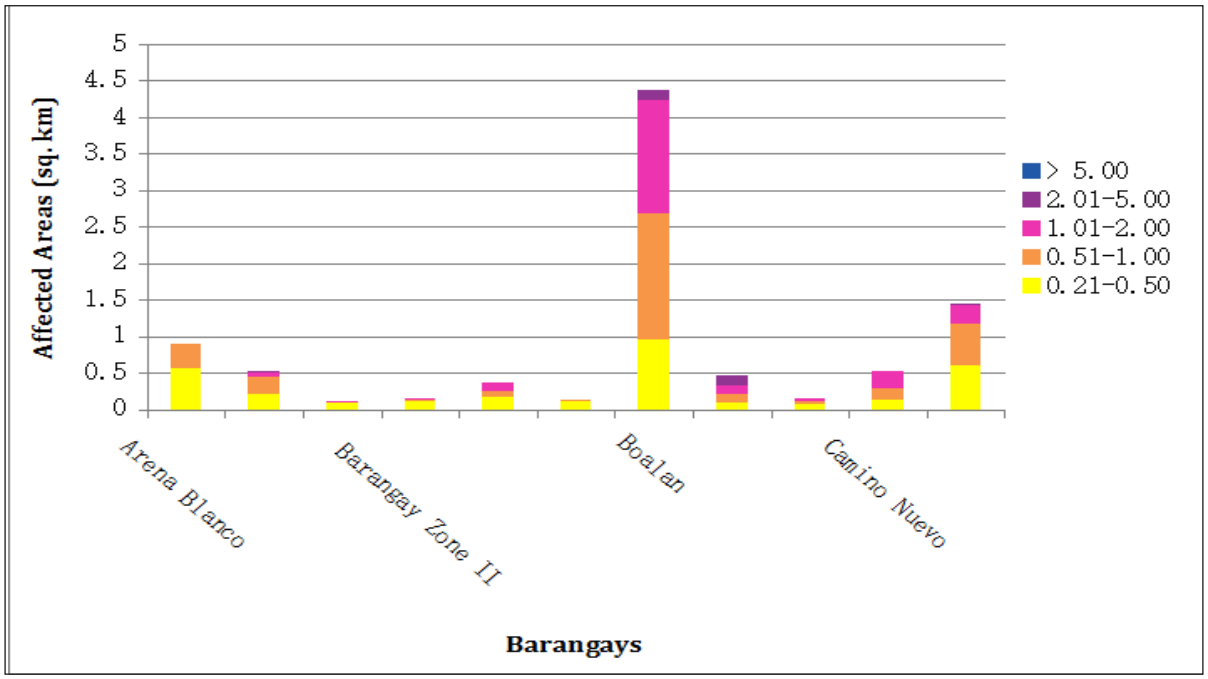


Figure 83. Affected Areas in Zamboanga City during 100-Year Rainfall Return Period

Table 45. Affected Areas in Zamboanga City during 100-Year Rainfall Return Period

TUMAGA-SAN JOSE BASIN		Affected Barangays in Zamboanga City										
		Canelar	Capisan	Divisoria	Dulian	Guiwan	Kasanyangan	Lumayang	Lumbangan	Lunzuran	Maasin	Malagutay
Affected Area (sq. km.)	1	1.286994	3.36235	1.142243	5.700953	1.105597	3.333783	0.798402	9.959194	3.506855	0.176766	0.149917
	2	0.564556	0.077538	0.068856	0.16334	0.45052	0.642129	0.019441	0.408348	0.154857	0.004185	0.000804
	3	0.341686	0.052195	0.063752	0.079238	1.051286	0.53057	0.012097	0.416616	0.168958	0.003182	0.0002
	4	0.324424	0.03533	0.073721	0.113224	1.382779	0.04057	0.011268	0.298282	0.124724	0.0021	0.0002
	5	0.023414	0.022193	0.066287	0.222709	0.056212	0.0001	0.007265	0.251396	0.182348	0.000865	0
	6	0	0.0018	0.00344	0.186996	0.0006	0	0.0013	0.062636	0.064044	0	0

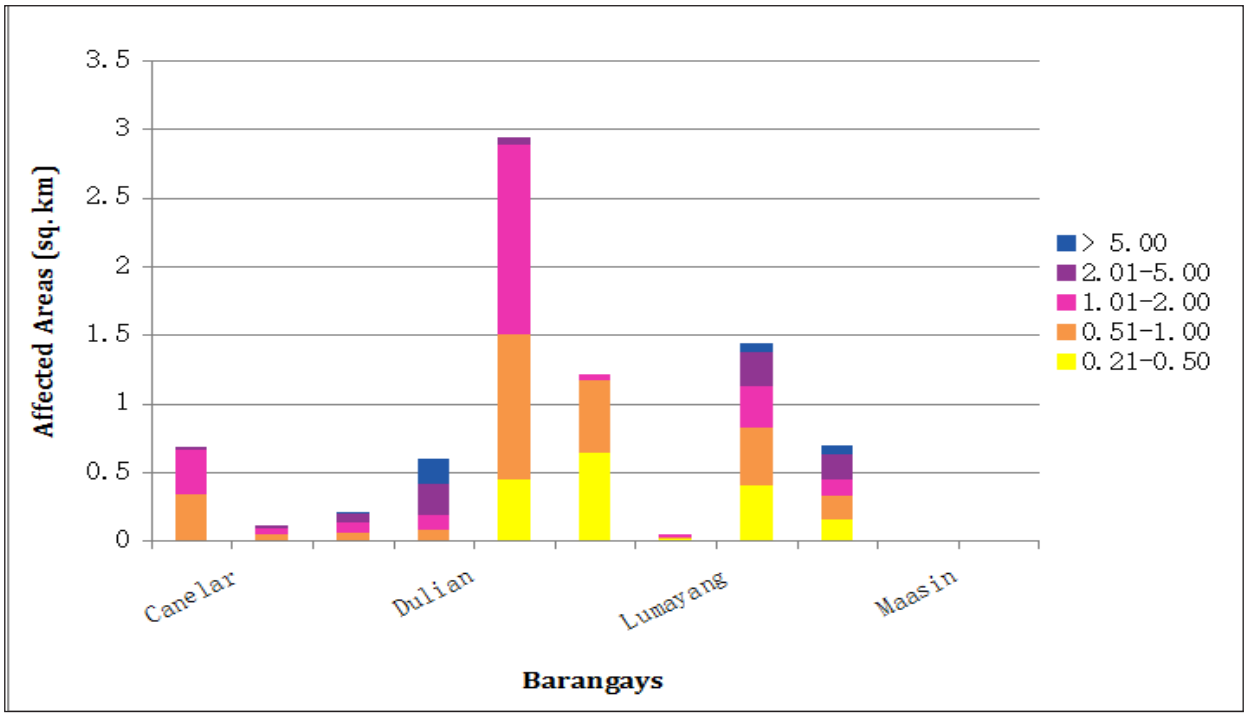


Figure 84. Affected Areas in Zamboanga City during 100-Year Rainfall Return Period

Table 46. Affected Areas in Zamboanga City during 100-Year Rainfall Return Period

TUMAGA-SAN JOSE BASIN		Affected Barangays in Zamboanga City										
		Mampang	Mariki	Mercedes	Pasobolong	Pasonanca	Putik	Rio Hondo	Salaan	San Jose Cawa-Cawa	San Jose Gusu	San Roque
Affected Area (sq. km.)	1	3.24532	0.920024	3.531272	0.012413	1.239682	1.714168	0.271654	2.76601	0.343318	2.320483	8.154021
	2	0.967348	0.450228	0.774769	0	0.094872	0.251438	0.144311	0.329366	0.113851	0.176106	0.546334
	3	0.250494	0.016788	0.253575	0	0.14027	0.4942	0.13618	0.309027	0.02792	0.356193	0.713061
	4	0.0316	0	0.079446	0	0.16157	0.54909	0.0032	0.155553	0	0.225167	0.551854
	5	0.0002	0	0.073619	0	0.194603	0.128586	0	0.164701	0	0.013295	0.14265
	6	0	0	0.019048	0	0.053691	0	0	0.20378	0	0.0004	0.0193

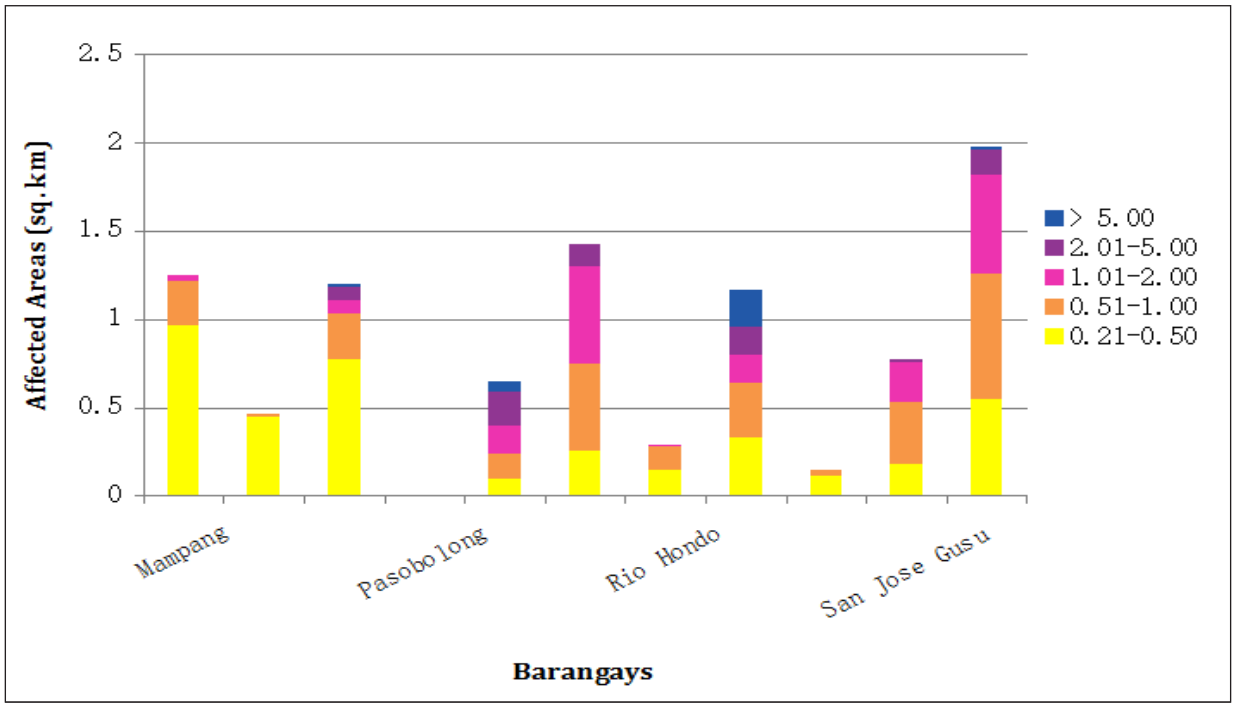


Figure 85. Affected Areas in Zamboanga City during 100-Year Rainfall Return Period

Table 47. Affected Areas in Zamboanga City during 100-Year Rainfall Return Period

TUMAGA-SAN JOSE BASIN		Affected Barangays in Zamboanga City									
		Santa Barbara	Santa Catalina	Santa Maria	Santo Niño	Sinunoc	Talon-Talon	Tetuan	Tugbungan	Tumaga	Zambowood
Affected Area (sq. km.)	1	1.039073	1.05156	0.762173	0.157552	0.072585	3.652149	1.484194	1.691951	0.789006	3.537432
	2	0.474042	0.762939	0.432479	0.065997	0.001543	1.850505	0.50029	0.889264	0.073545	0.327058
	3	0.244383	0.129019	0.663693	0.004612	0.000807	0.089888	0.227709	2.672787	0.205755	0.372981
	4	0.018256	0.0036	0.459309	0	0.001163	0.009213	0.131566	0.379262	0.242681	0.251167
	5	0.000071	0	0.112611	0	0	0	0.076269	0.055709	0.291939	0.054389
	6	0	0	0.000477	0	0	0	0.012644	0.0008	0.124694	0.009752

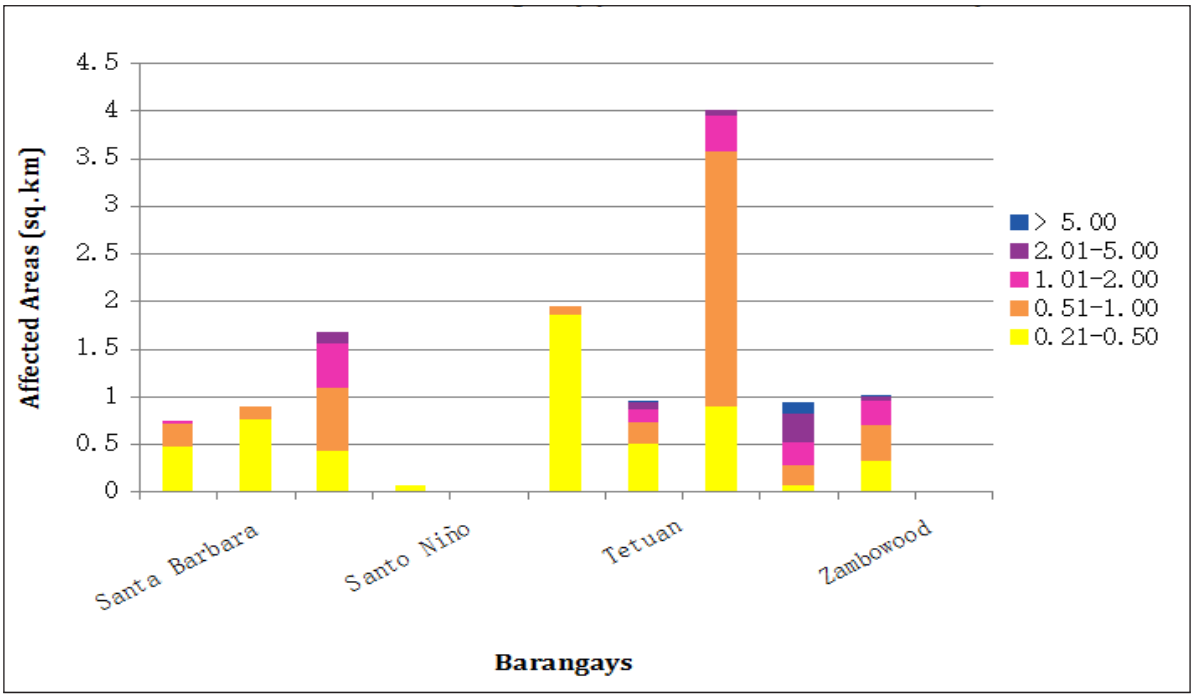


Figure 86. Affected Areas in Zamboanga City during 100-Year Rainfall Return Period

Moreover, the generated flood hazard maps for the Tumaga-San Jose 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 48. Area covered by each warning level with respect to the rainfall scenario

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	1.7086	1.9279	1.9625
Medium	1.3254	1.9483	2.2505
High	0.6145	0.9432	1.1749

Of the 89 identified educational institutions in Tumaga-San Jose Floodplain, 42, 10 and 2 institutions were exposed to low, medium and high flood levels for the 5-year scenZario. 34, 24 and 6 institutions were exposed to the same flood levels for the 25-year scenario. 33, 28 and 6 institutions were exposed to the same flood levels for the 100-year scenario. 22 institutions were assessed as not exposed to any flooding for all the scenarios.

Of the 22 identified medical institutions in Tumaga-San Jose Floodplain, 5 institutions were exposed to low flood levels for the 5-year scenario. 7 and 1 institutions were exposed to low and medium flood levels for the 25-year scenario, respectively. 9 and 1 institutions were exposed to low and medium flood levels for the 100-year scenario, respectively. 12 institutions were assessed as not exposed to any flooding.

5.11 Flood Validation

The flood validation consists of 211 points randomly selected all over the Tumaga Floodplain. It has an RMSE value of 0.33.

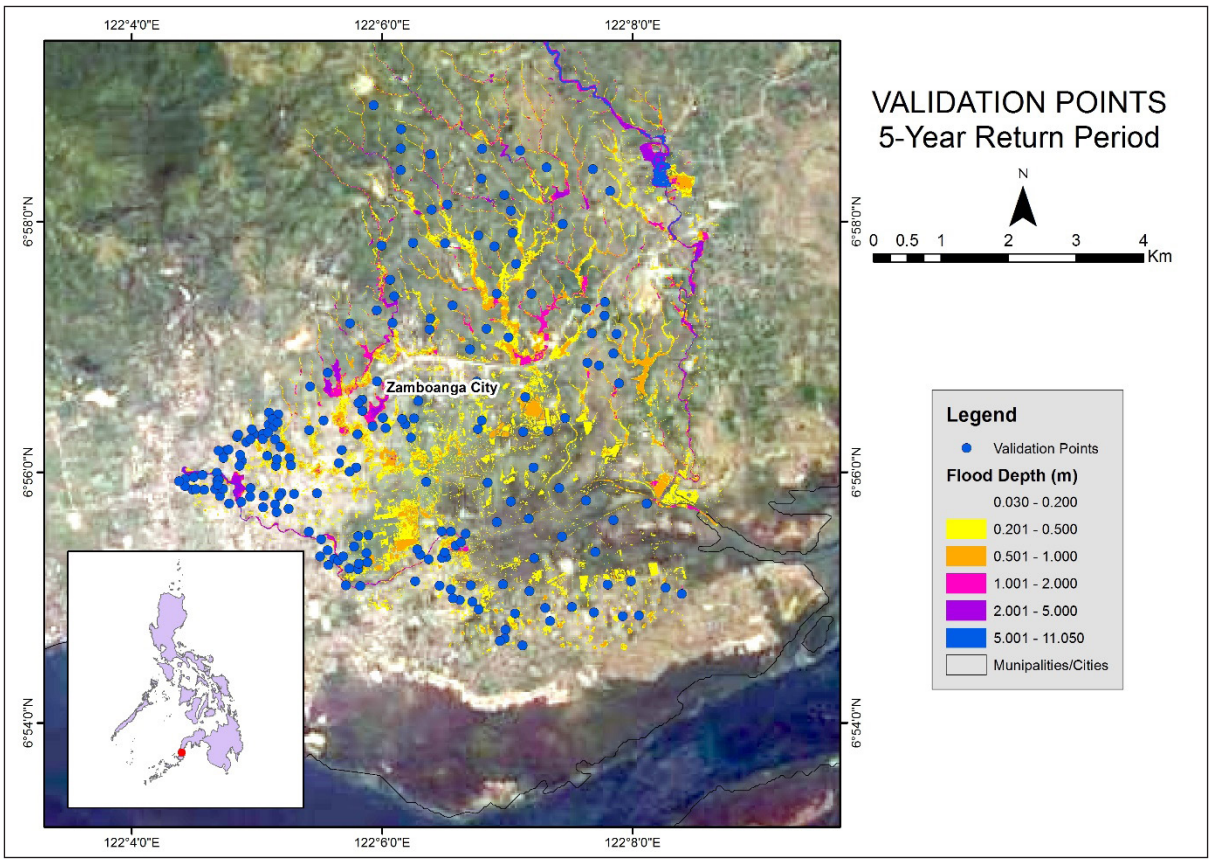


Figure 87. Validation points for 5-year flood depth map of Tumaga Floodplain

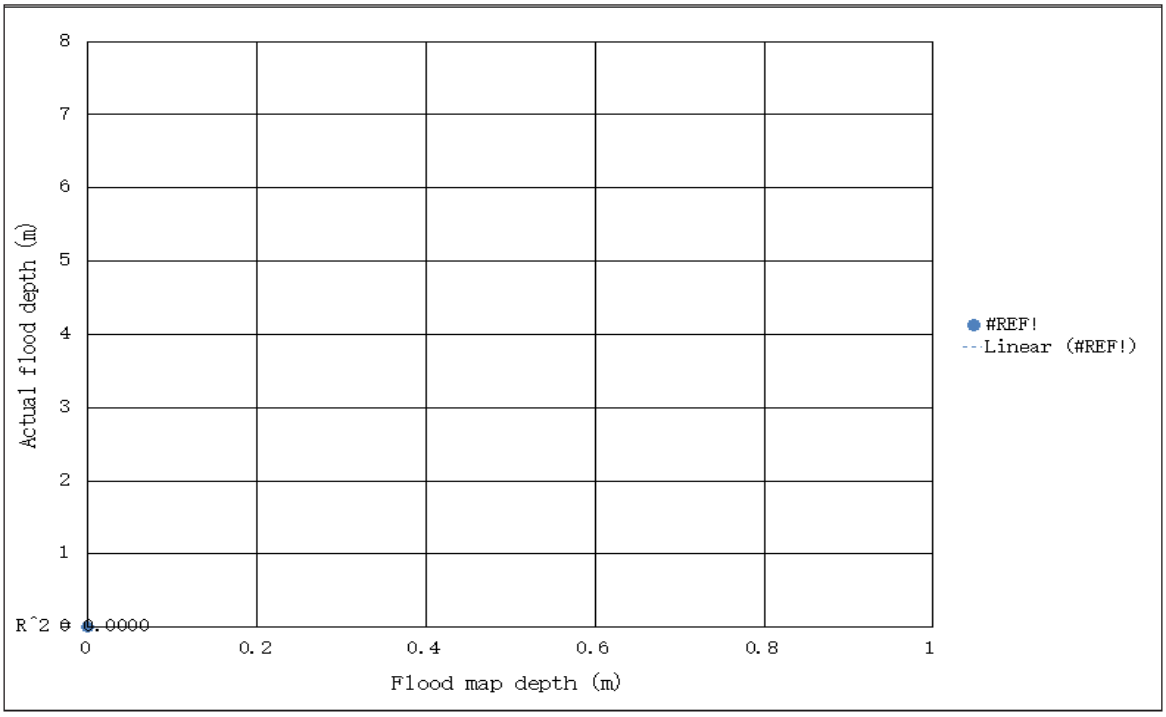


Figure 88. Flood map depth vs actual flood dept

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.

Environmental Management Bureau, DENR 9

Inquirer.net

Zamboanga.climatemps.com

Zamboangacity.gov.ph

Zamboangatimes.ph

Zamboanga City Water District

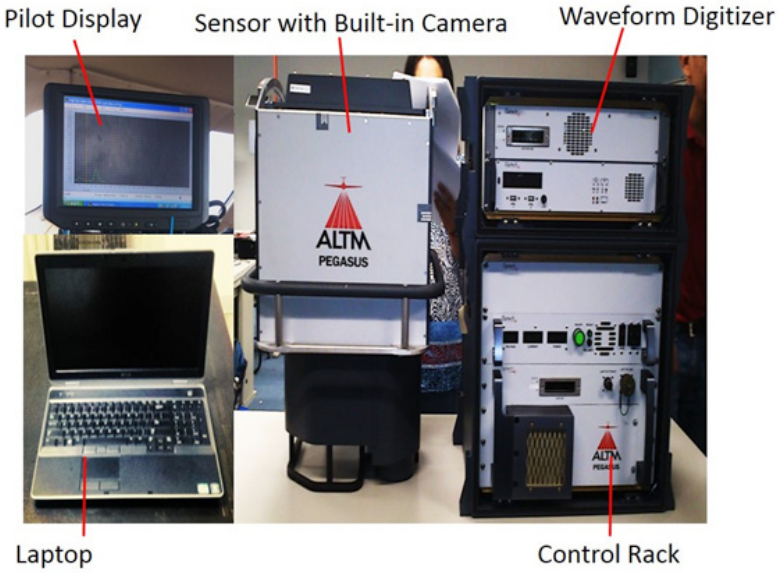
ANNEXES

Annex 1. Technical Specifications of the LiDAR Sensors used in the Tumaga Floodplain Survey

1. GEMINI SENSOR

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

2. PEGASUS SENSOR



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

1 Target reflectivity ≥20%

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

3 Angle of incidence ≤20˚

4 Target size ≥ laser footprint5 Dependent on system configuration

OPTECH TECHNICAL SPECIFICATION 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 Certification 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

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' 59.23072"** 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 96
www.namria.gov.ph

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Annex 3. Baseline Procesing Reports 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

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

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. ZC-1

ZGS-99 - ZC-1 (7:04:04 AM-12:01:44 PM) (S1)

Baseline observation:	ZGS-99 --- ZC-1 (B1)
Processed:	9/18/2014 4:08:50 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:	1.777
Ephemeris used:	Broadcast
Antenna model:	Trimble Relative
Processing start time:	8/23/2014 7:04:14 AM (Local: UTC+8hr)
Processing stop time:	8/23/2014 12:01:44 PM (Local: UTC+8hr)
Processing duration:	04:57:30
Processing interval:	5 seconds

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:	ZC-1				
Grid		Local		Global	
Easting	391123.456 m	Latitude	N6°55'37.81337"	Latitude	N6°55'34.40099"
Northing	765762.247 m	Longitude	E122°00'52.07695"	Longitude	E122°00'57.64335"
Elevation	4.170 m	Height	7.666 m	Height	71.746 m

Vector					
ΔEasting	-18.006 m	NS Fwd Azimuth	298°52'19"	ΔX	16.179 m
ΔNorthing	9.977 m	Ellipsoid Dist.	20.590 m	ΔY	8.136 m
ΔElevation	-0.483 m	ΔHeight	-0.483 m	ΔZ	9.811 m

Standard Errors

Vector errors:					
σ ΔEasting	0.000 m	σ NS fwd Azimuth	0°00'02"	σ ΔX	0.000 m
σ ΔNorthing	0.000 m	σ Ellipsoid Dist.	0.000 m	σ ΔY	0.000 m
σ ΔElevation	0.001 m	σ ΔHeight	0.001 m	σ ΔZ	0.000 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000001675		
Y	-0.0000000621	0.0000002067	
Z	-0.0000000118	0.0000000230	0.0000000431

4. 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

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

5. 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

Annex 4. The LiDAR Survery Team Composition

Data Acquisition Component Sub -Team	Designation	Name	Agency / Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	UP-TCAGP
		LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	JULIE PEARL MARS	UP-TCAGP
	SSRS	JASMINE ALVIAR	UP-TCAGP
	SSRS	ENGR. IRO NIEL ROXAS	UP-TCAGP
	Research Associate (RA)	ENGR. LARAH KRISTINA PARAGAS	UP-TCAGP
	RA	FOR. MA. VERLINA TONGA	UP-TCAGP
	RA	KRISTINE ANDAYA	UP-TCAGP
	RA	ENGR. RENAN PUNTO	UP-TCAGP
	RA	SANDRA POBLETE	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	JERIEL PAUL ALAMBAN, GEOL.	UP-TCAGP
	RA	FRANK NICOLAS ILEJAY	UP-TCAGP
	RA	JONATHAN ALMALVEZ	UP-TCAGP
LiDAR Operation	Airborne Security	SSG. JULIUS RENDON	PHILIPPINE AIR FORCE (PAF)
		SSG. ERWIN DELOS SANTOS	PAF
		SSG. JAYCO MANZANO	PAF
	Pilot	CAPT. BRYAN DONGUINES	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. NEIL ACHILLES AGAWIN	AAC
		CAPT. SHERWIN CESAR ALFONSO	AAC
		CAPT. ANTON DAYO	AAC

Annex 5. Data Transfer Sheet for Tumaga Floodplain

DATA TRANSFER SHEET
09/23/2014(Zamboanga ready)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
8/23/2014	7450G	2BLK75F235A	Gemini	12.2	247	493	252	NA	NA	20.9	NA	5.94	1KB	1KB	4	8	Z:\DAC\RAWDATA
8/24/2014	7452G	2BLK75G236A	Gemini	5.29	131	262	138	NA	NA	11	NA	3.07	1KB	1KB	4	NA	Z:\DAC\RAWDATA

Received from

Name C. JOAQUIN
Position RA
Signature

Received by

Name JOIDA PRIETO
Position SSRS
Signature 9/23/14

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 Ar Bongat 3/13/15
Position GSRS
Signature

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

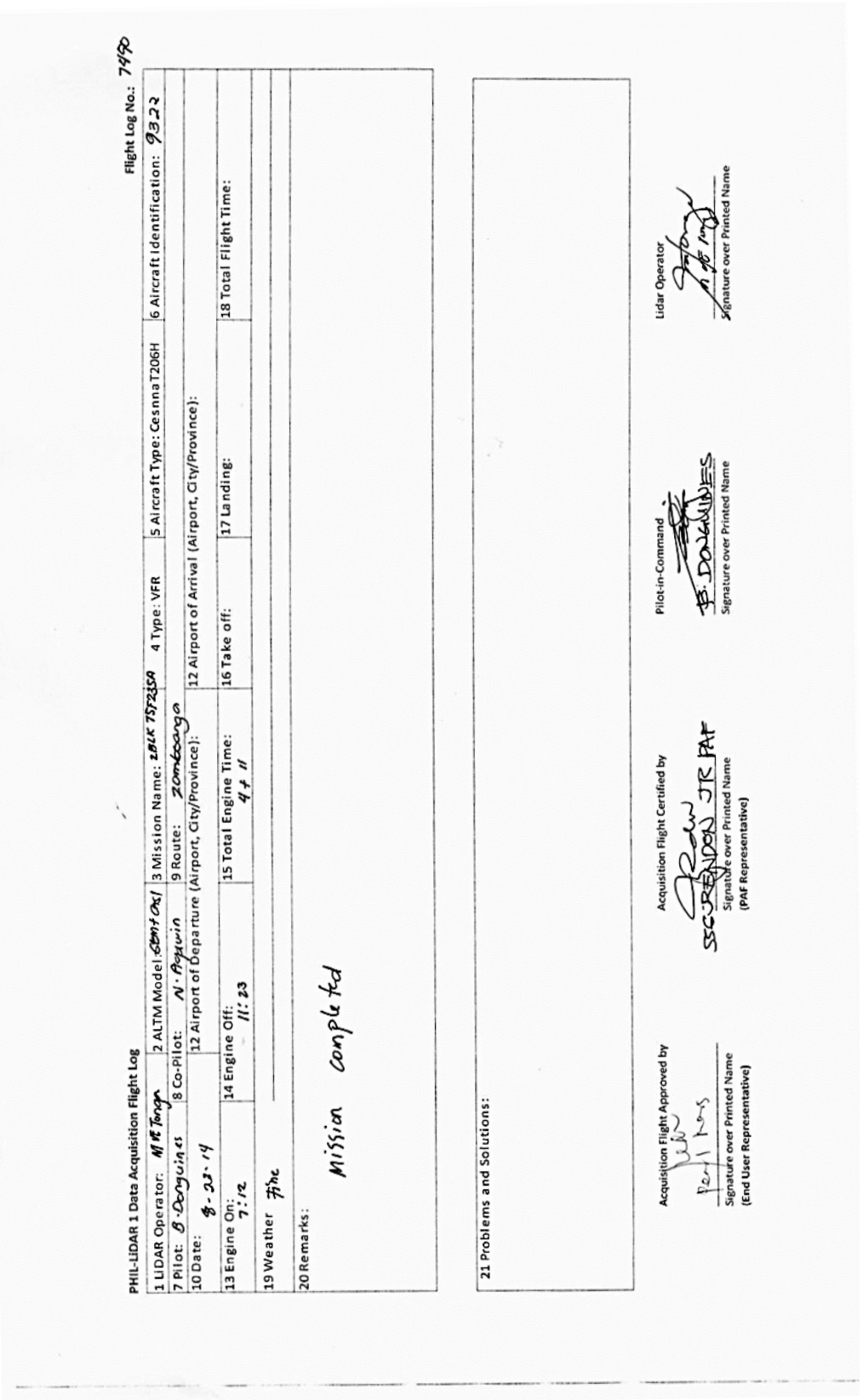
Name R. PUNTO
Position RA
Signature

Received by

Name AC Bongat
Position SSES
Signature 7/14/16

Annex 6. Flight logs for the flight missions

1. Flight Log for 7450GC Mission



PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 7490

1 LiDAR Operator: M.E Tongo	2 ALTM Model: Gemini Os/	3 Mission Name: zbuk 7572350	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: B. Dequinas	8 Co-Pilot: N. Aquino	9 Route: Zambanga		
10 Date: 8-23-14	11 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):	
13 Engine On: 7:12	14 Engine Off: 11:23	15 Total Engine Time: 4 + 11	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather Fine					
20 Remarks: Mission completed					
21 Problems and Solutions:					

Acquisition Flight Approved by

Signature over Printed Name
(End User Representative)

Acquisition Flight Certified by

SSG. REYNALDO JR. PAF

Signature over Printed Name
(PAF Representative)

Pilot-in-Command

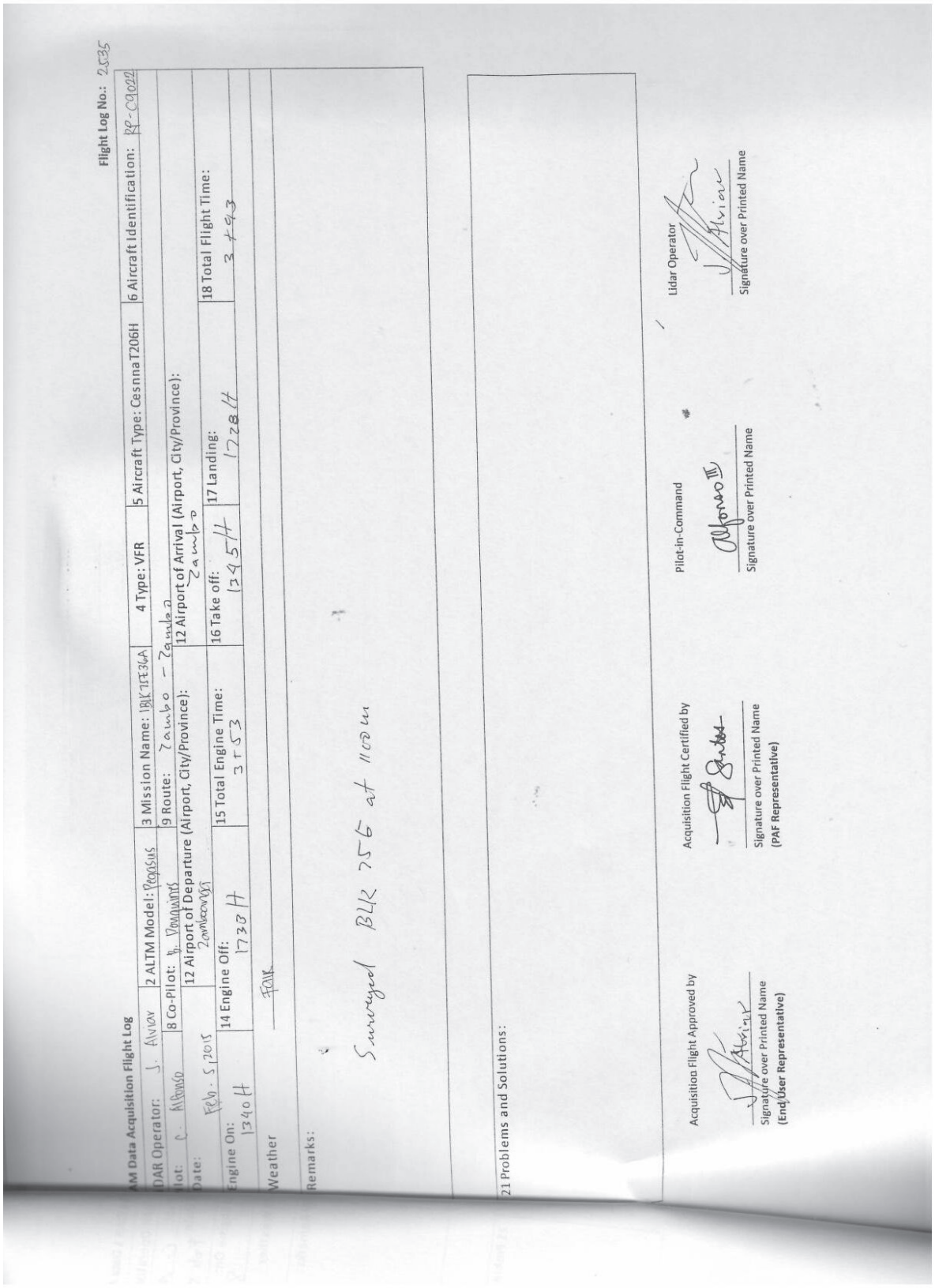
B. DEQUINAS

Signature over Printed Name

Lidar Operator

Signature over Printed Name

2. 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: BLK12E30A	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RP-C9022
Pilot: C. Alfonso	8 Co-Pilot: R. Pamaong	9 Route: Zamboanga - Zamboanga			
Date: Feb. 5, 2015	12 Airport of Departure (Airport, City/Province): Zamboanga		12 Airport of Arrival (Airport, City/Province): Zamboanga		
Engine On: 1340 H	14 Engine Off: 1730 H	15 Total Engine Time: 3+53	16 Take off: 1345 H	17 Landing: 1728 H	18 Total Flight Time: 3+43

Weather: Fair

Remarks:

Surveyed BLK 25E 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)

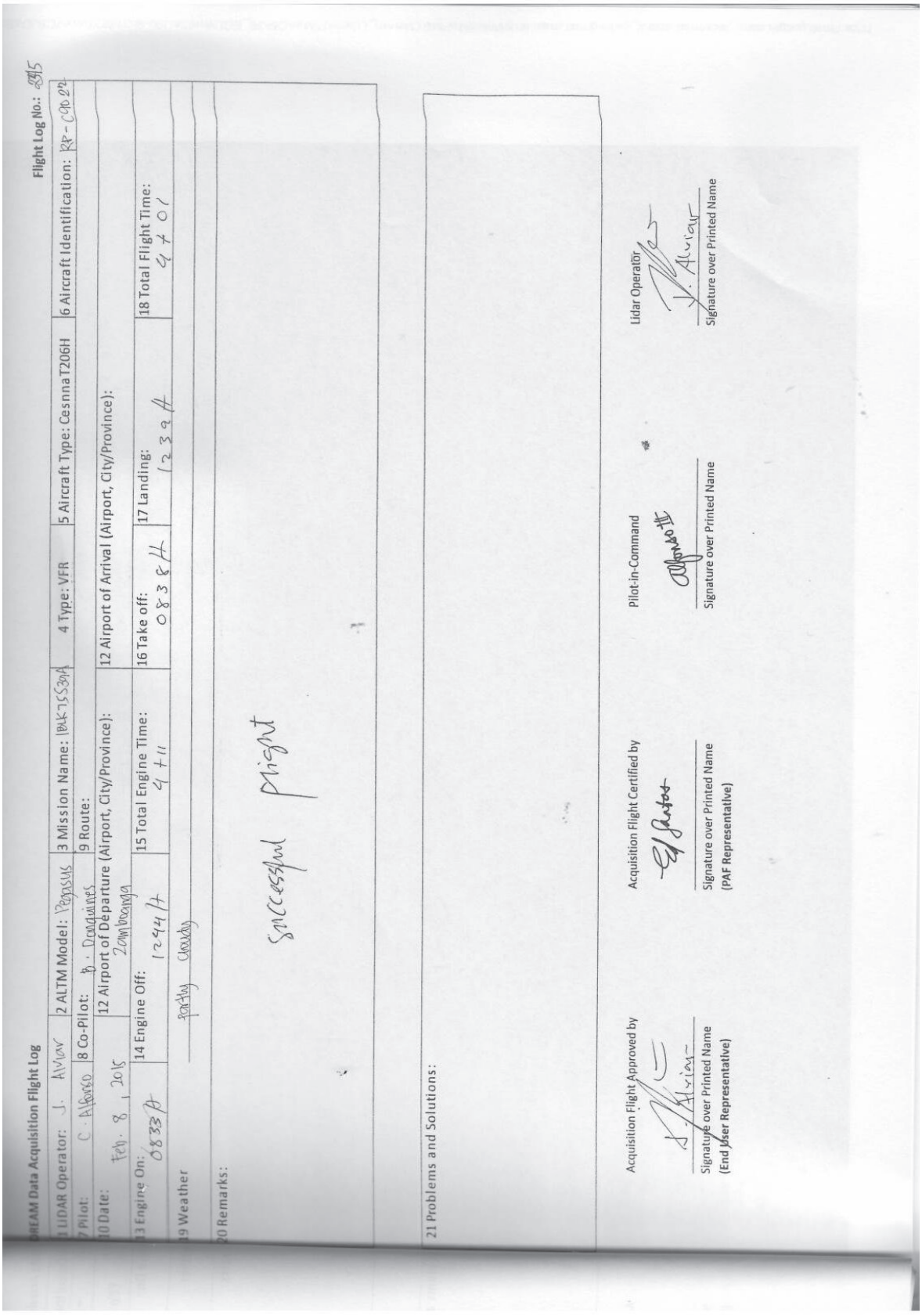
Pilot-in-Command

Signature over Printed Name

Lidar Operator

Signature over Printed Name

3. Flight Log for 2545P Mission



NAMRIA Data Acquisition Flight Log

Flight Log No.: 2545

1 LiDAR Operator: J. Alviar	2 ALTM Model: Pegasus	3 Mission Name: BAK15S30A	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: C. Alcovendo	8 Co-Pilot: B. Dequinones	9 Route:			
10 Date: Feb. 8, 2015	11 Airport of Departure (Airport, City/Province): Zamboanga		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0833H	14 Engine Off: 1249H	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

Signature over Printed Name
(End User Representative)

Acquisition Flight Certified by

Signature over Printed Name
(PAF Representative)

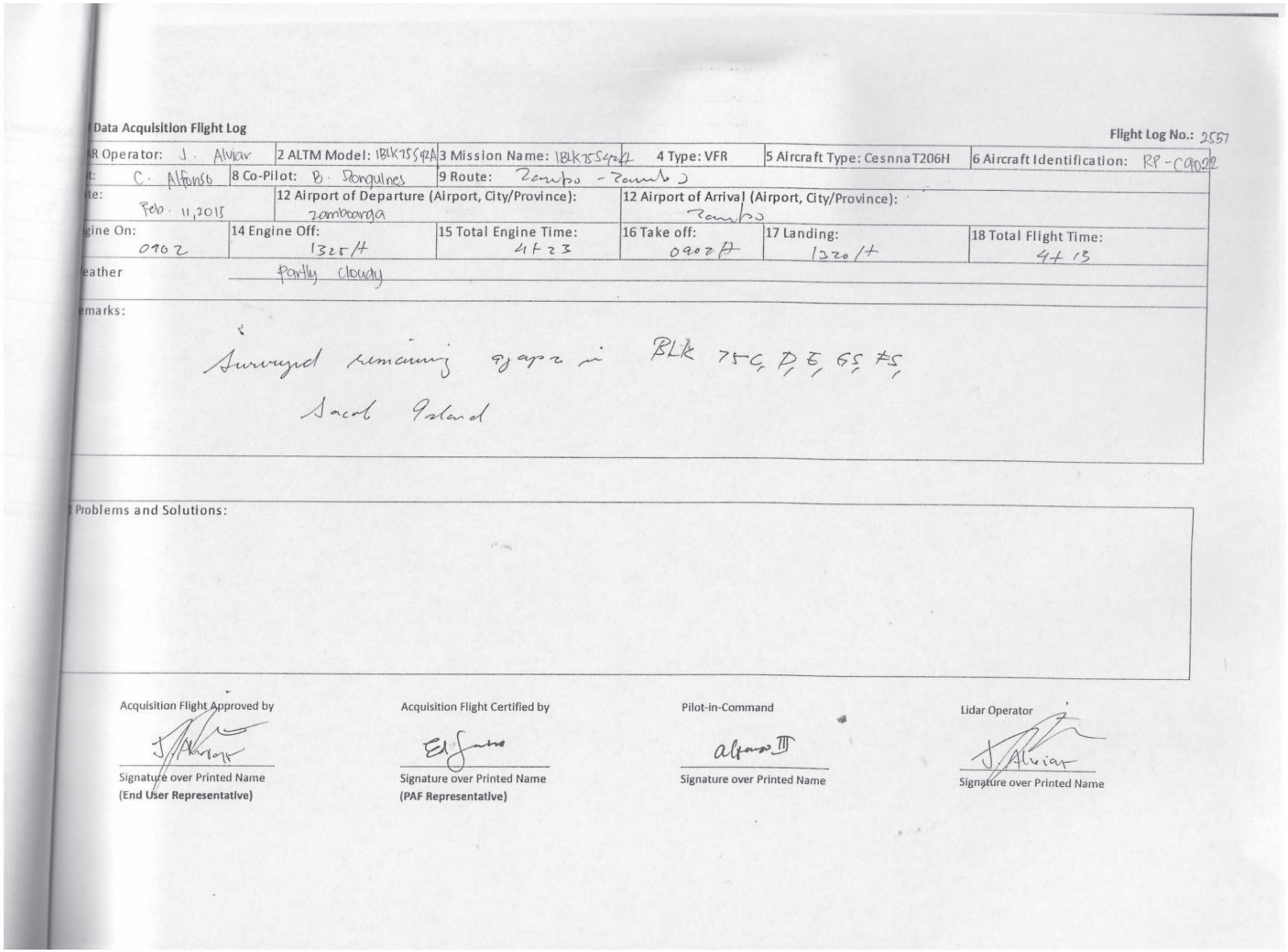
Pilot-in-Command

Signature over Printed Name

Lidar Operator

J. Alviar

Signature over Printed Name



Data Acquisition Flight Log

Flight Log No.: 2557

R Operator: J. Alviar	2 ALTM Model: 1BLK75S92A	3 Mission Name: 1BLK75S42A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
t: C. Alfonso	8 Co-Pilot: B. Dongulines	9 Route: Zamboa - Zamboa			
te: Feb. 11, 2015	12 Airport of Departure (Airport, City/Province): Zamboanga		12 Airport of Arrival (Airport, City/Province): Zamboa		
gine On: 0902	14 Engine Off: 1325/H	15 Total Engine Time: 4+23	16 Take off: 0902 P	17 Landing: 1320/H	18 Total Flight Time: 4+13
eather	Partly cloudy				

emarks:

Surveyed remaining areas in BLK 75C, D, E, 65, #5, Jacob Island

1 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

5. Flight LoZg 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: CesnnaT206H	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	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator	Aircraft Mechanic/ Technician
I. ROXAS	A1C JAYCO C MANZANO PAF	C. ALFONSO III	S. POBLETE / I. ROXAS	—
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Annex 7. Flight Status Report

FLIGHT STATUS REPORT

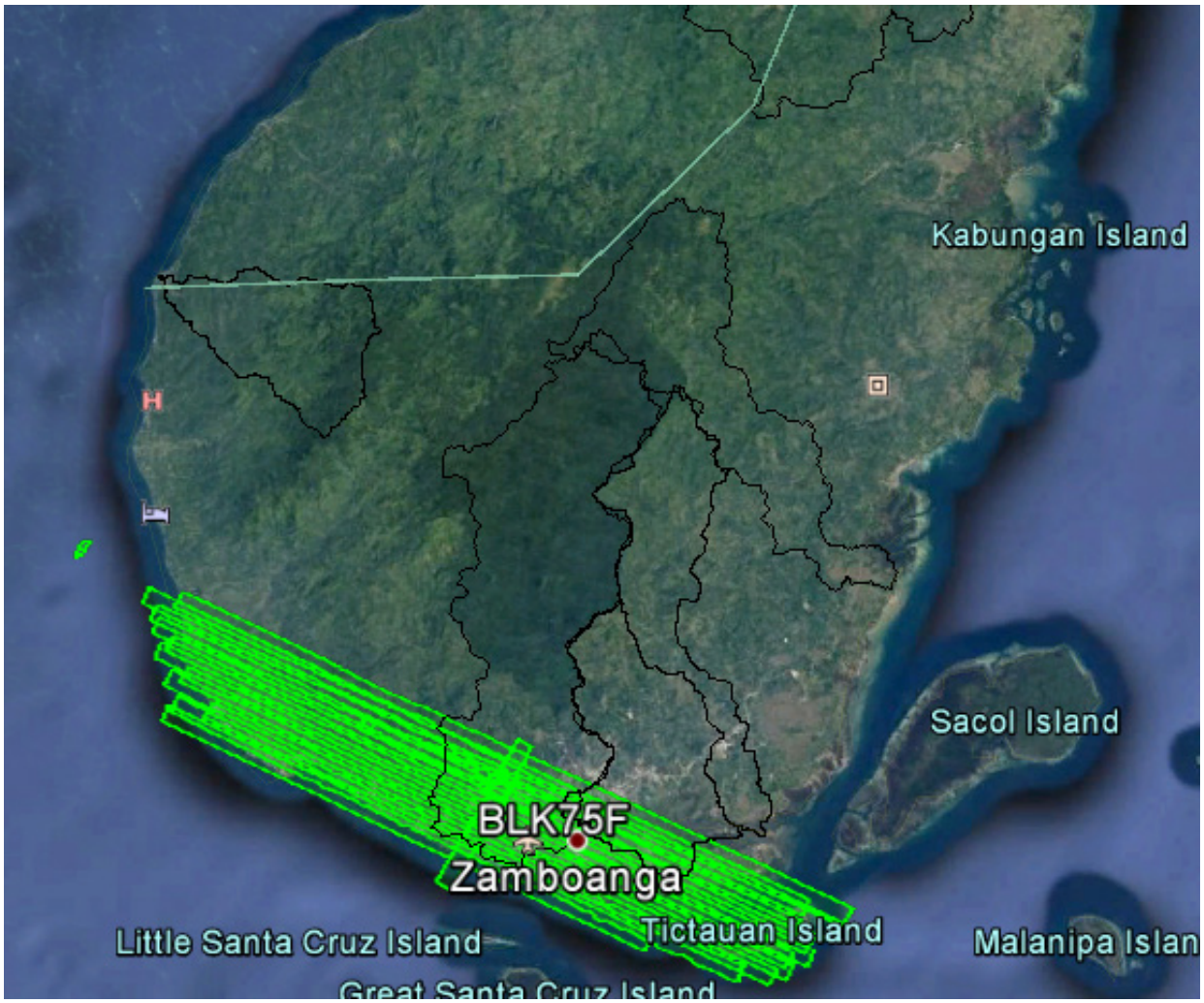
Zamboanga-Zamboanga Sibugay

August 23, 2014;February 5,8 and 11 2015; May 26, 2016

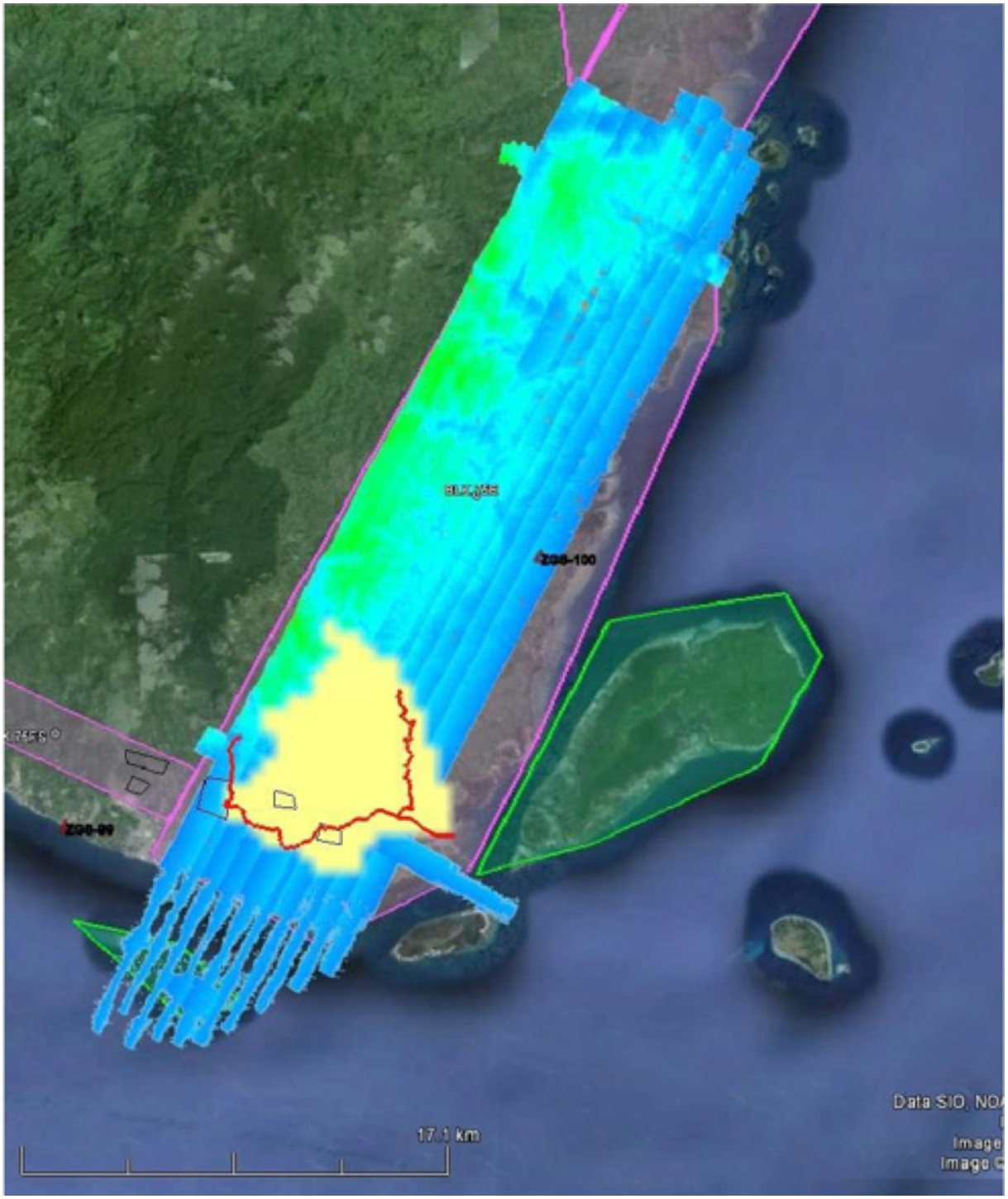
FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
7450GC	BLK75F	2BLK75F235A	M.V.E. TONGA	Aug. 23, 2014	COMPLETED BLK75F;FAST CLOUD BUILD UP
2535P	BLK75E	1BLK75E36A	J. ALVIAR	Feb. 5, 2015	FOR COMPLETION AND SOME GAP FILLING (TERRAIN)
2545P	BLK75C BLK75D BLK75E BLK75FS	1BLK75C39A	J. ALVIAR	Feb. 7, 2015	ABNORMAL PROGRAM TERMINATION (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 (CORRIDOR 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

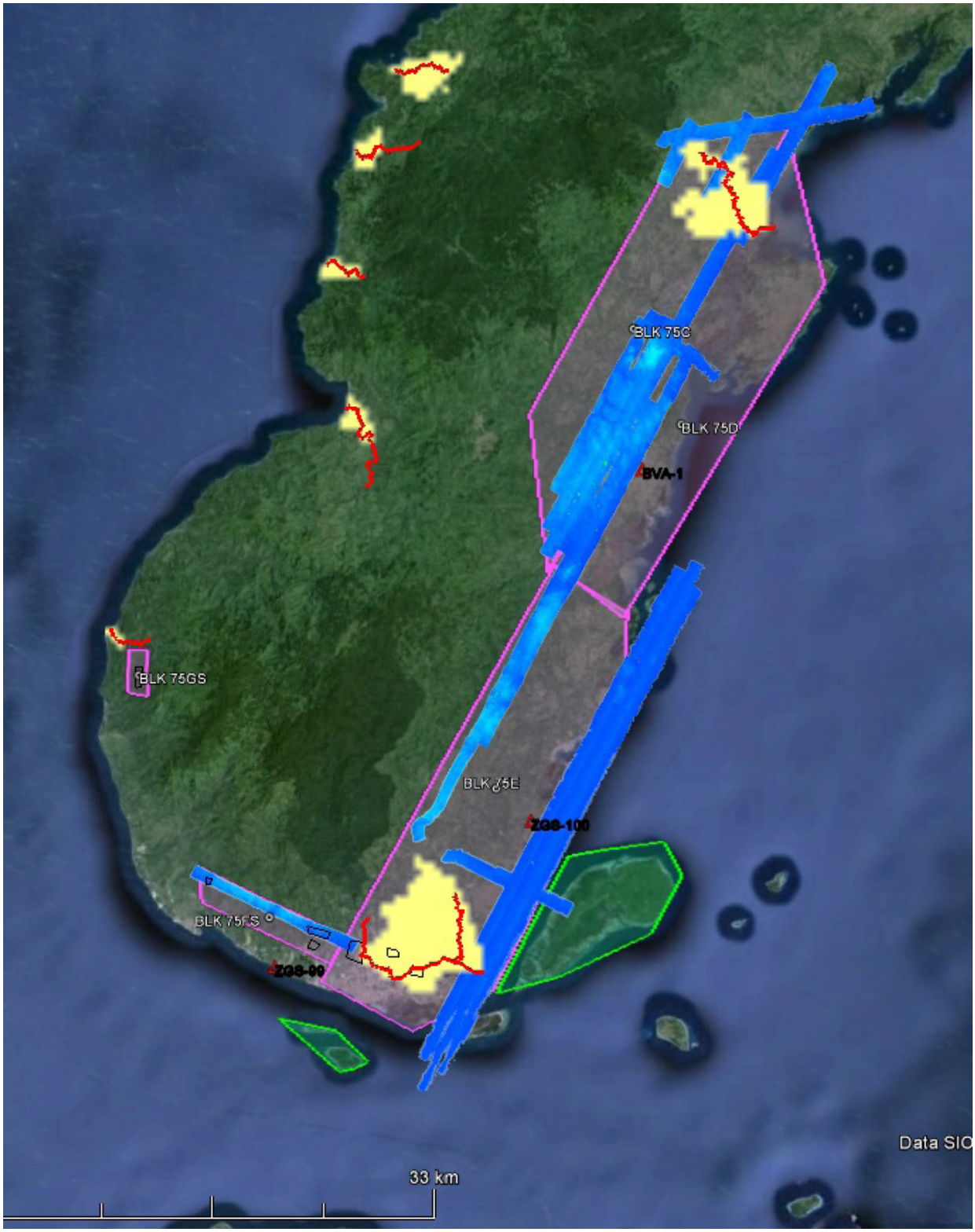
Flight No.: 7450GC
Area: BLK75F
Mission Name: 2BLK75F235A
Parameters: Altitude: 1100m; Scan Frequency: 50; Scan Angle: 40



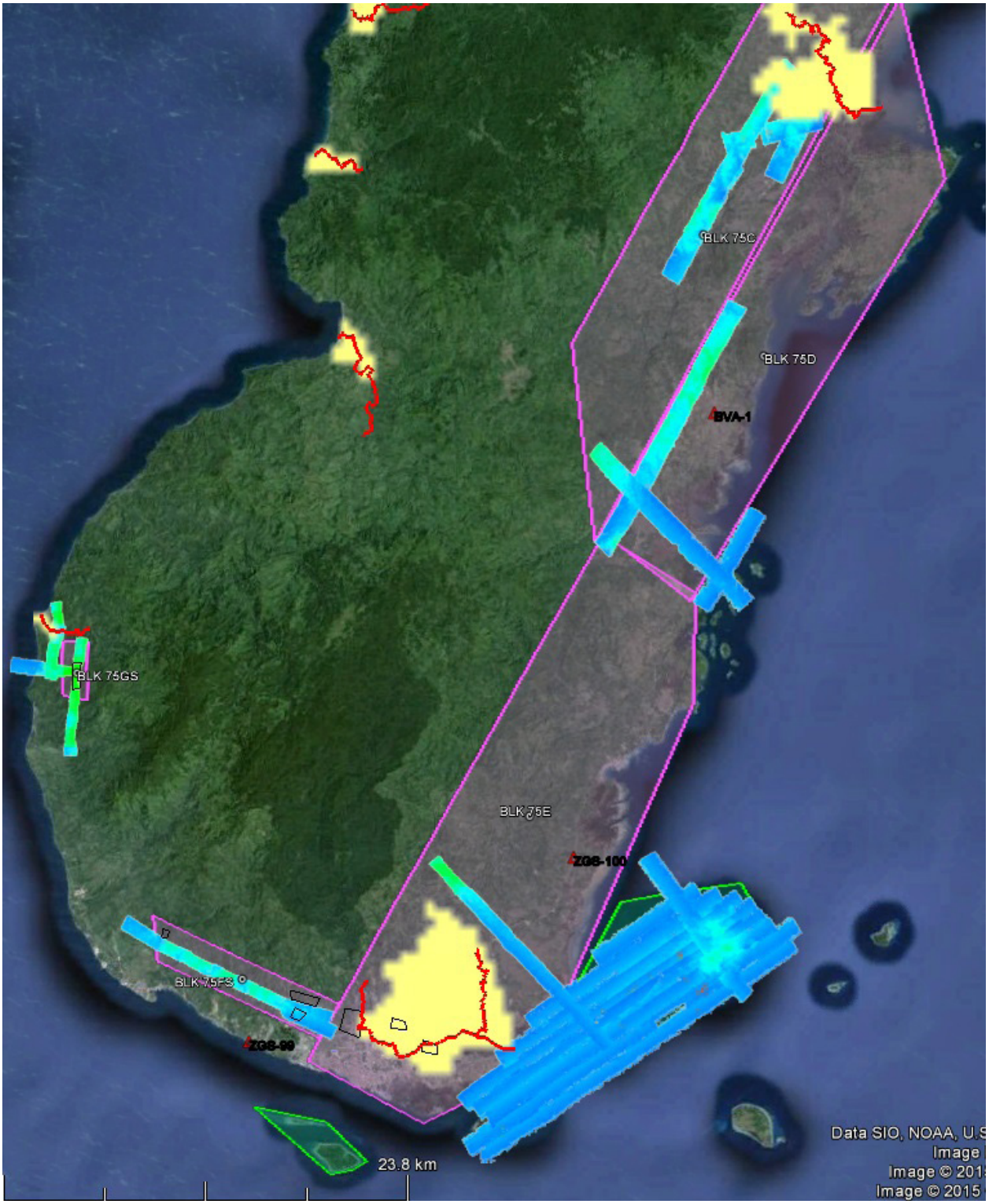
Flight No.: 2535P
Area: BLK75E
Mission Name: 1BLK75E36A
Parameters: Altitude: 1100m; Scan Frequency: 30; Scan Angle: 50



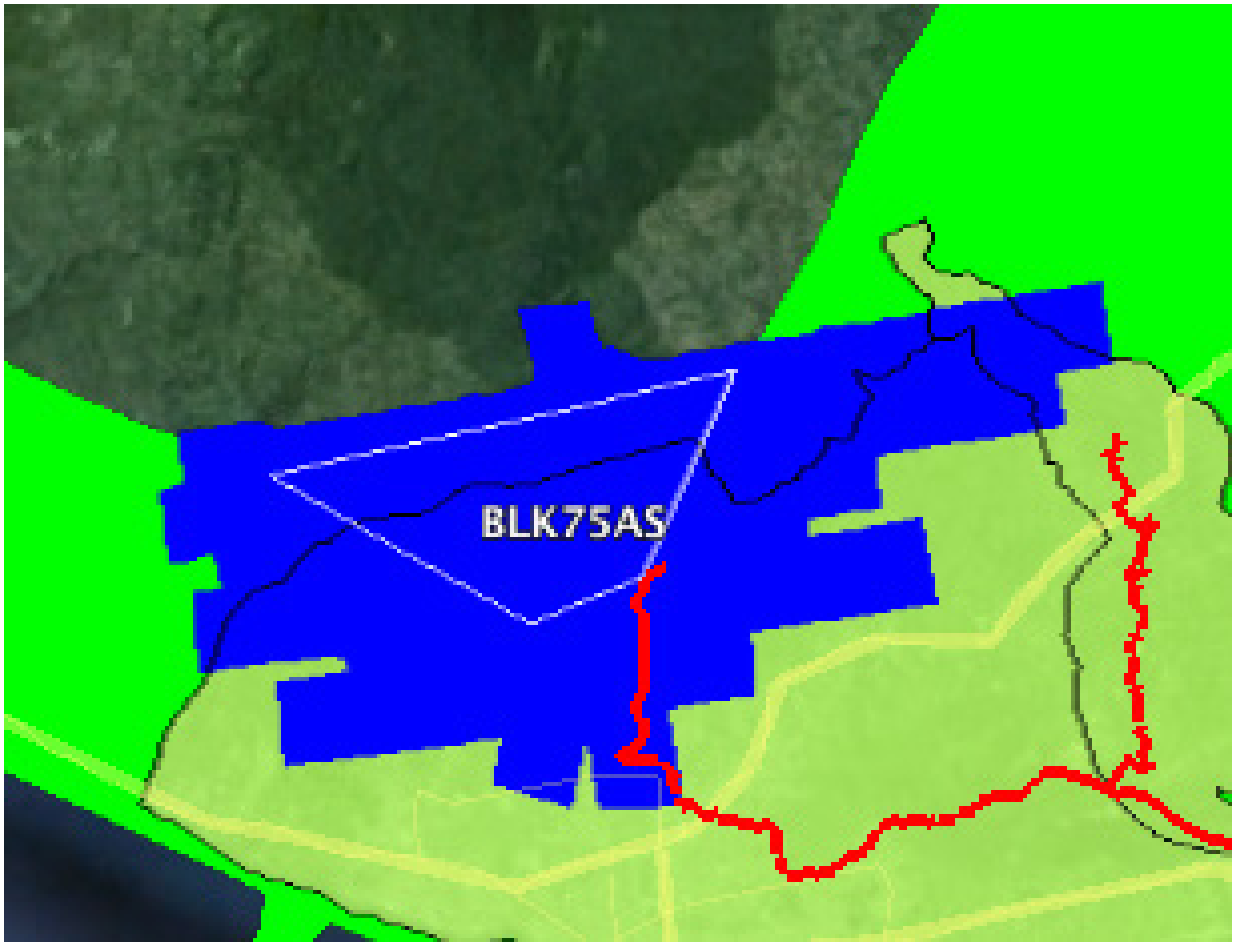
Flight No. : 2545P
Area: BLK 75C
Mission Name: 1BLK75C39A
Parameters: Altitude: 1100m; Scan Frequency: 30; Scan Angle: 50



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



Flight No.: 23394P
Area: BLK75AS
Mission Name: 1BLK75AS147B
Parameters: Altitude: 1000m; Scan Frequency: 30; Scan Angle: 50



Annex 8. Mission Summary Reports

Flight Area	Zamboanga
Mission Name	**Block 75E**
Inclusive Flights	2535P, 2545P
Range data size	56.9 GB
Base data size	7.77 MB
POS	491 MB
Image	85.3 GB
Transfer date	February 27 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 (<0.20 m)	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. Velina Angela Bemida, Alex John Escobido

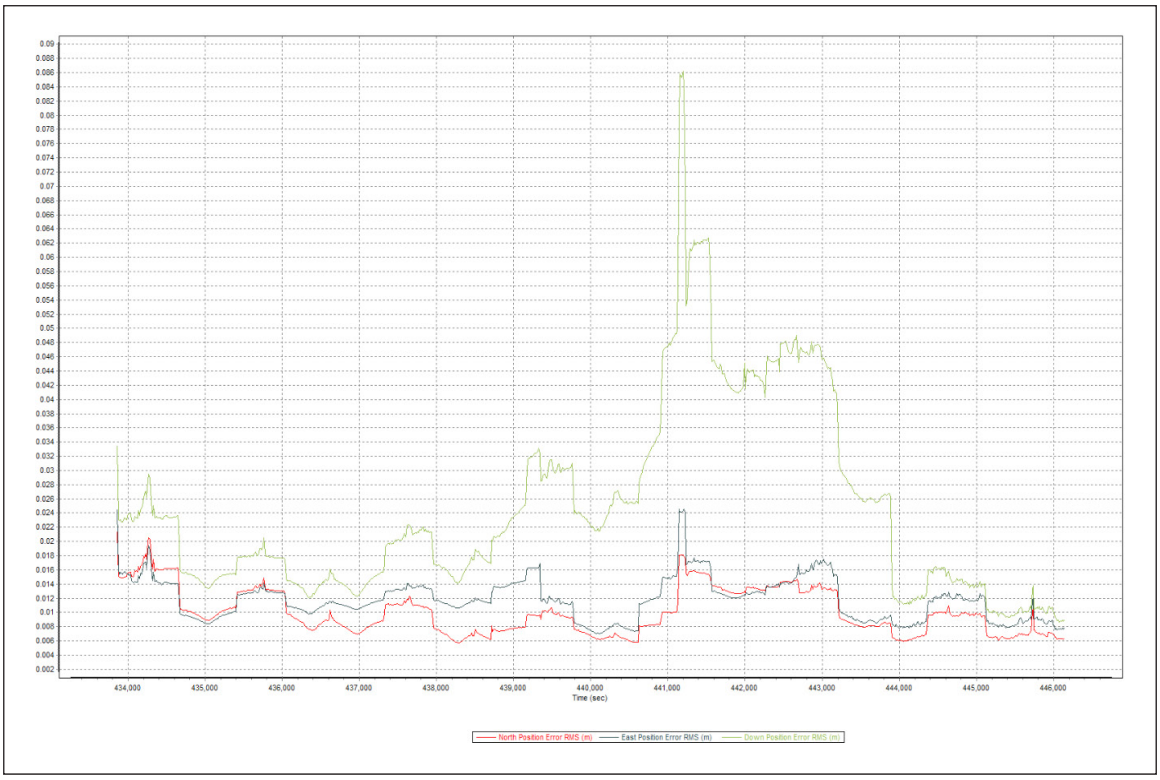


Figure 1.1.1 Solution Status

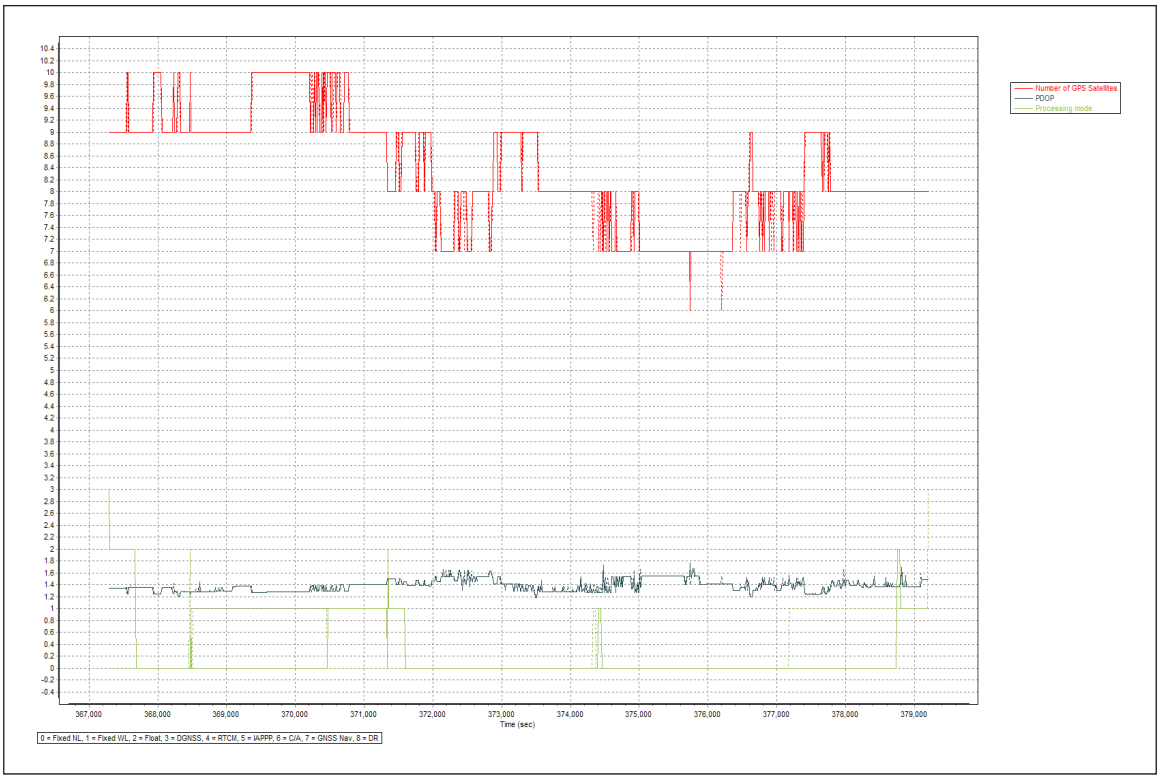


Figure 1.1.2 Smoothed Performance Metric Parameters

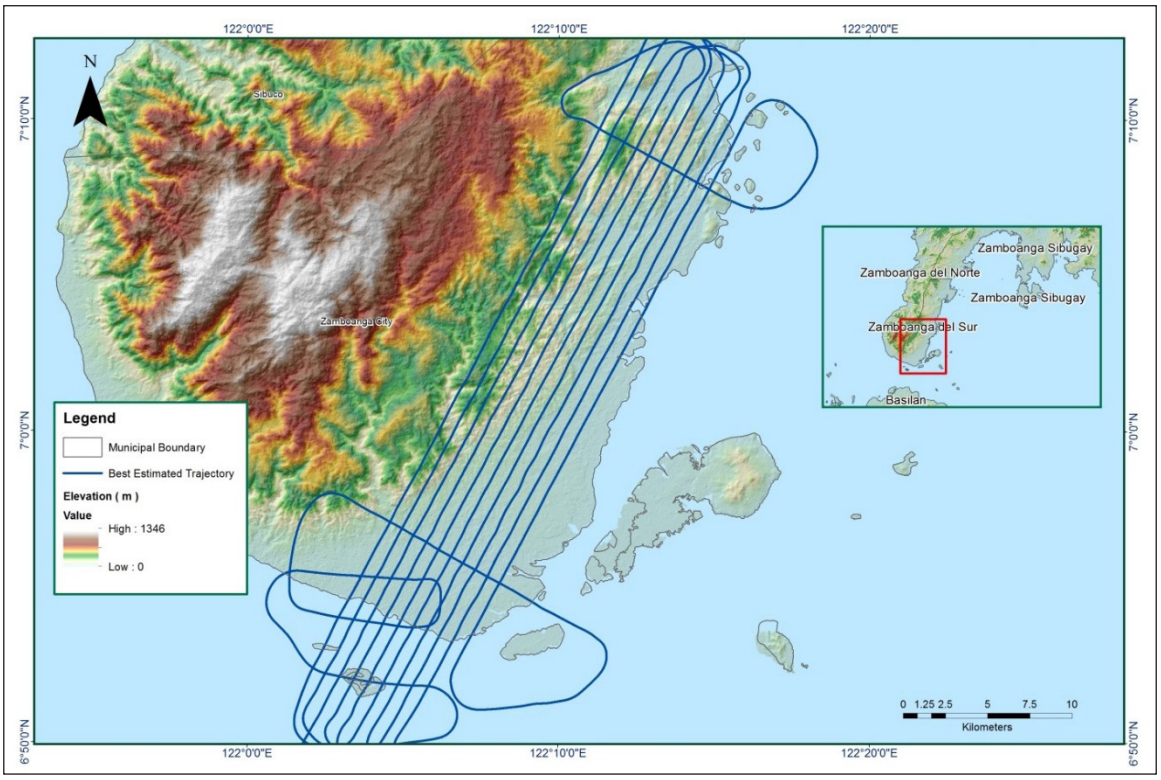


Figure 1.1.3 Best Estimated Trajectory

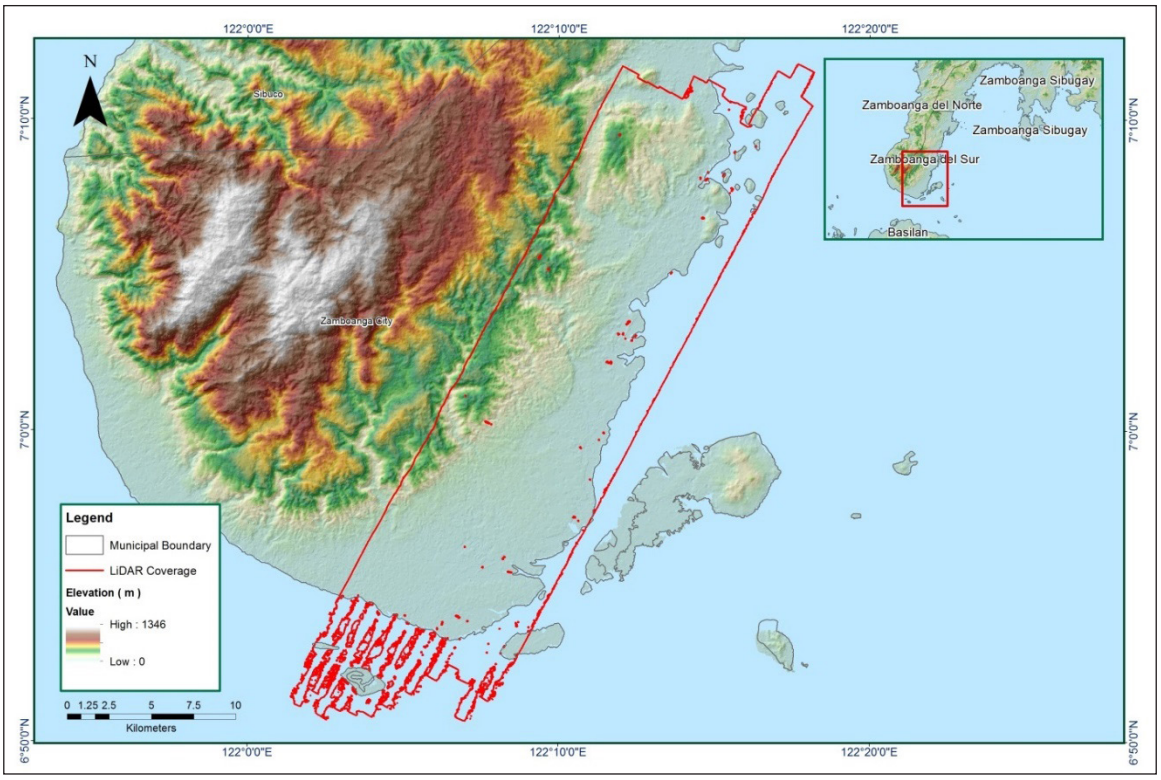


Figure 1.1.4 Coverage of LiDAR data

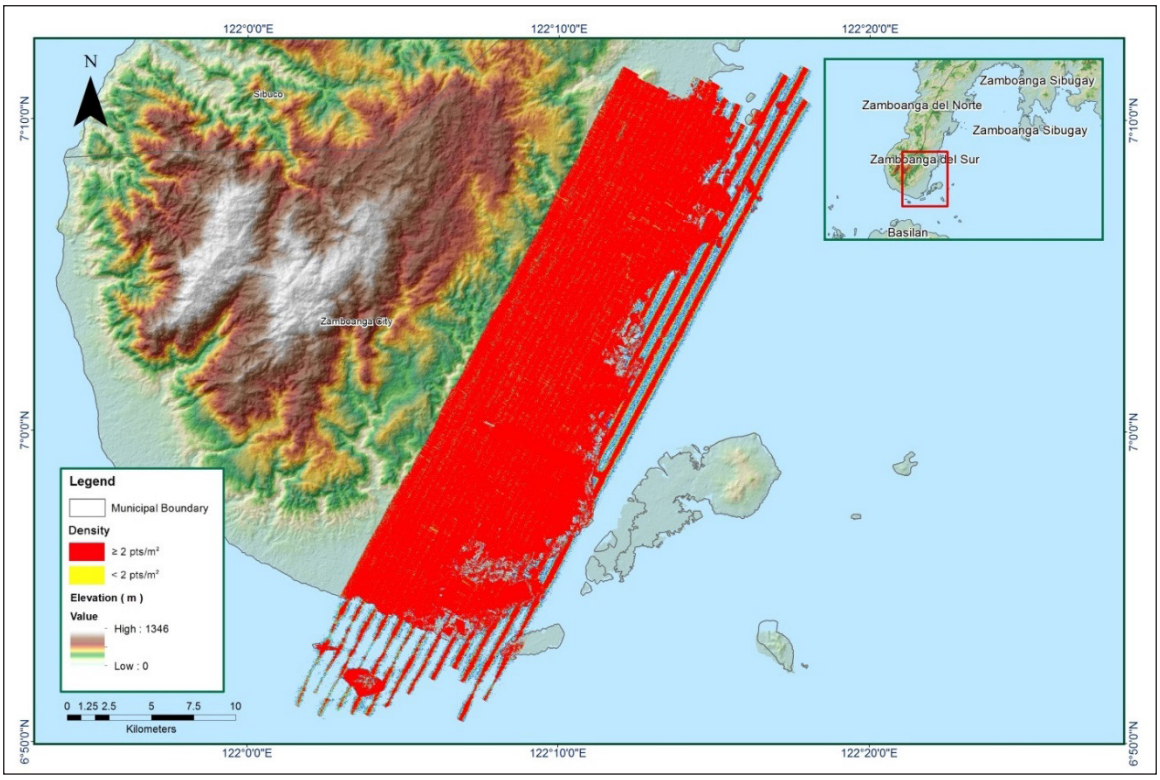


Figure 1.1.5 Image of data overlap

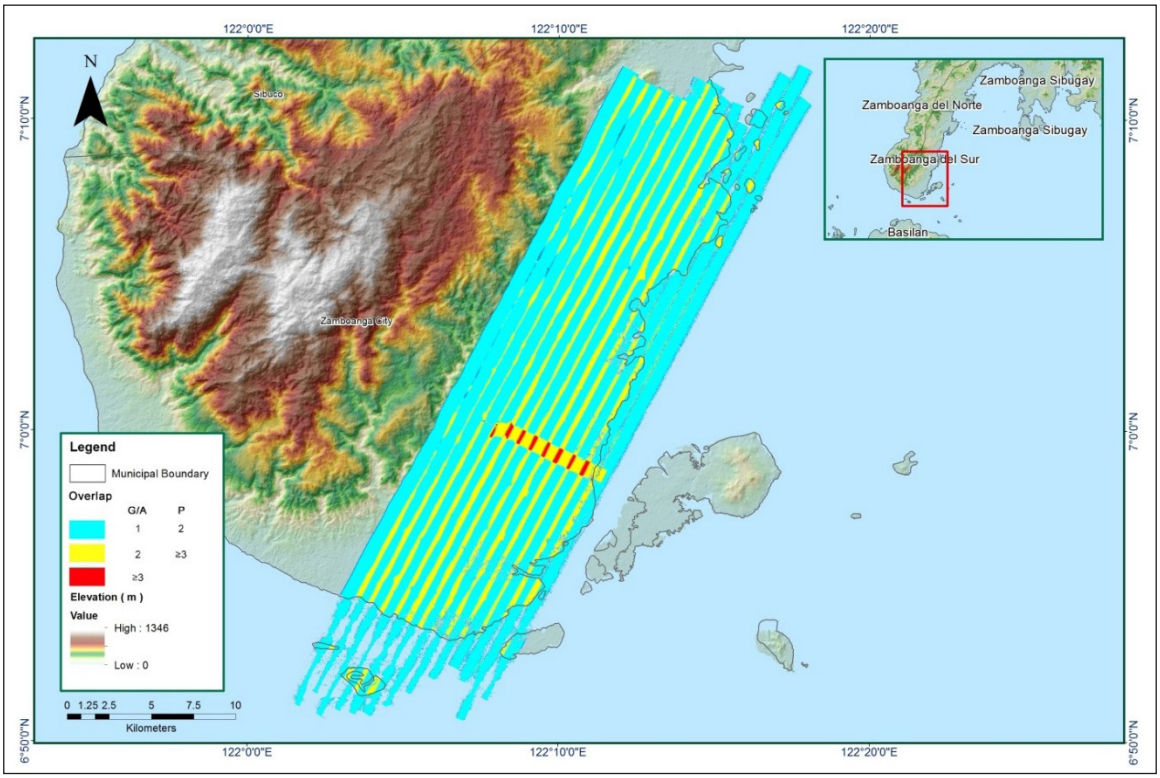


Figure 1.1.6 Density map of merged LiDAR data

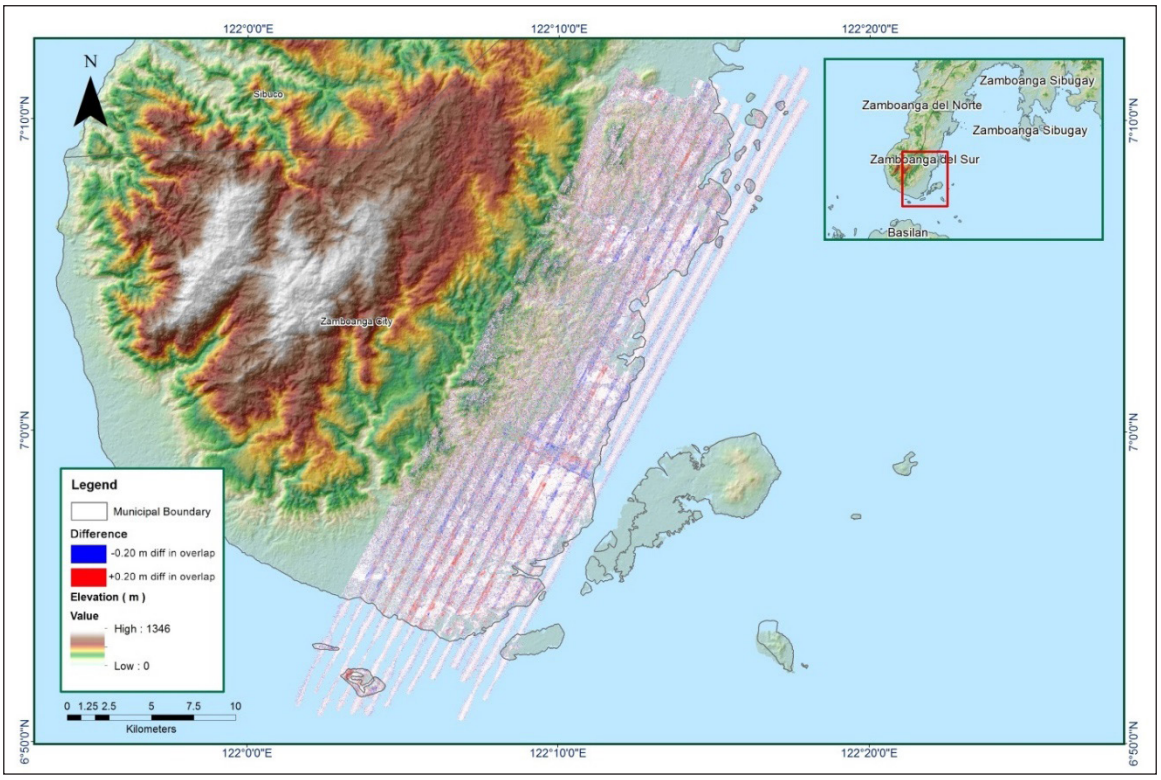


Figure 1.1.7 Elevation difference between flight lines

Flight Area	Zamboanga
Mission Name	**Blk75F**
Inclusive Flights	7450GC, 2557P
Range data size	20.9 GB
Base data size	8.47 MB
POS	252 MB
Image	0 GB
Transfer date	September 23 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.16
RMSE for East Position (<4.0 cm)	1.43
RMSE for Down Position (<8.0 cm)	3.02
Boresight correction stdev (<0.001deg)	0.000318
IMU attitude correction stdev (<0.001deg)	0.000664
GPS position stdev (<0.01m)	0.0096
Minimum % overlap (>25)	45.16%
Ave point cloud density per sq.m. (>2.0)	3.30
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	208
Maximum Height	505.54 m
Minimum Height	64.94 m
Classification (# of points)	
Ground	46,501,319
Low vegetation	53,336,315
Medium vegetation	110,540,939
High vegetation	159,255,533
Building	24,154,268
Orthophoto	No
Processed by	Engr. Jommer Medina, Engr. Harmond Santos, Engr. Ma. Ailyn Olanda

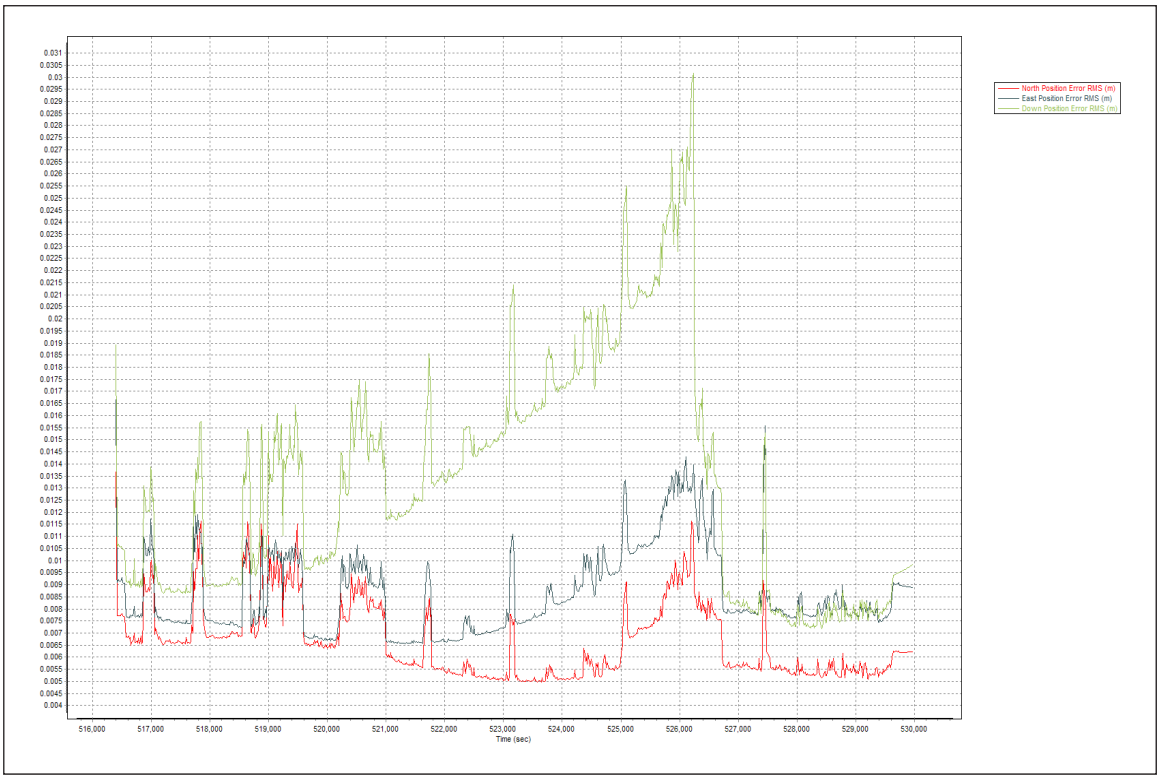


Figure 1.2.1 Solution Status

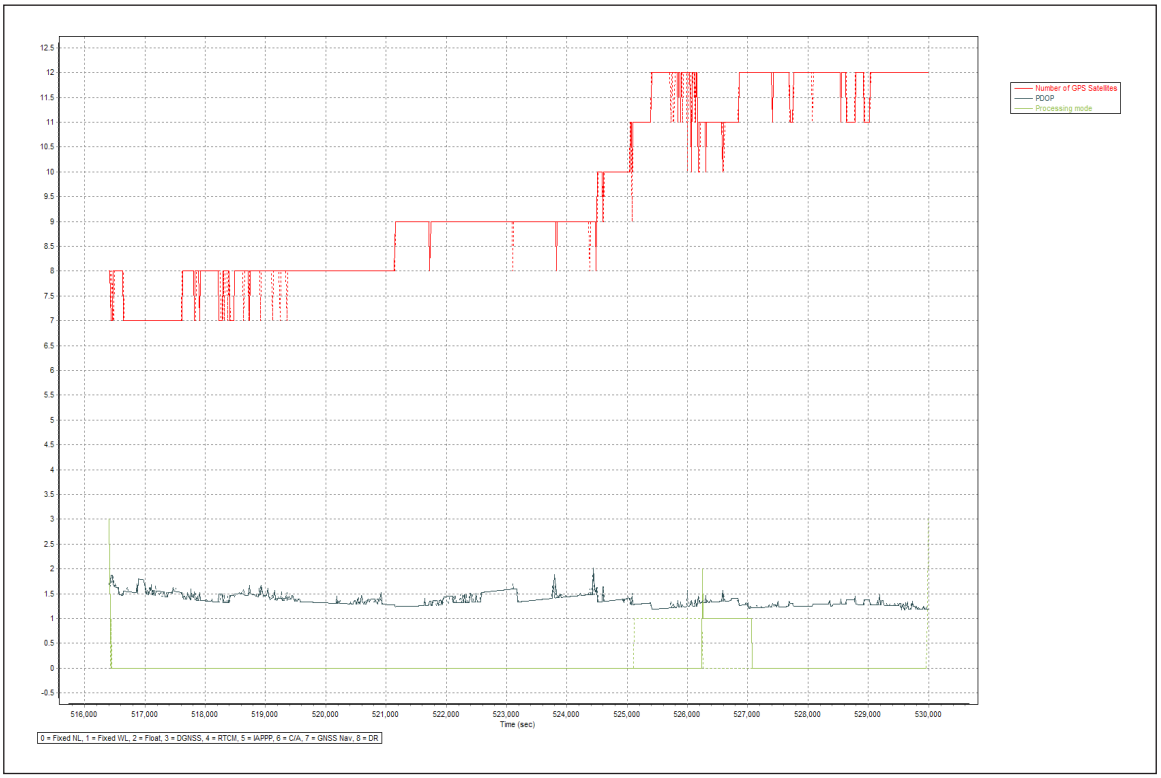


Figure 1.2.2 Smoothed Performance Metric Parameters

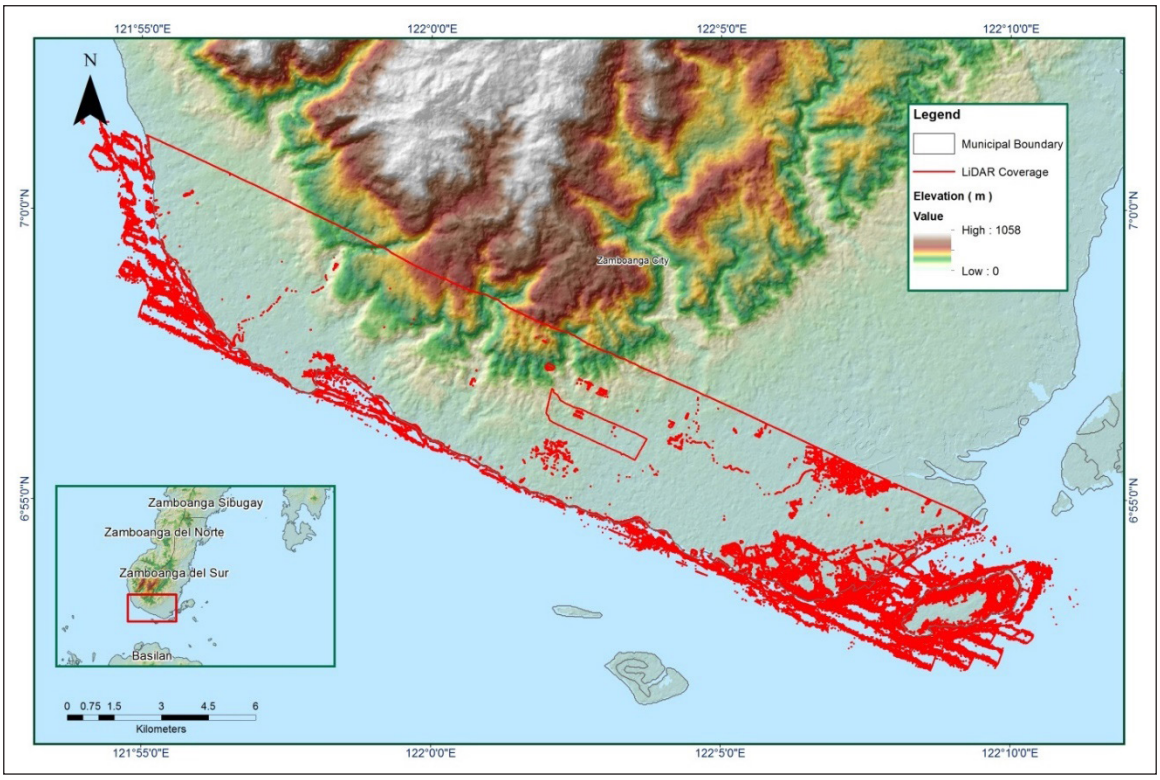


Figure 1.2.5 Image of data overlap

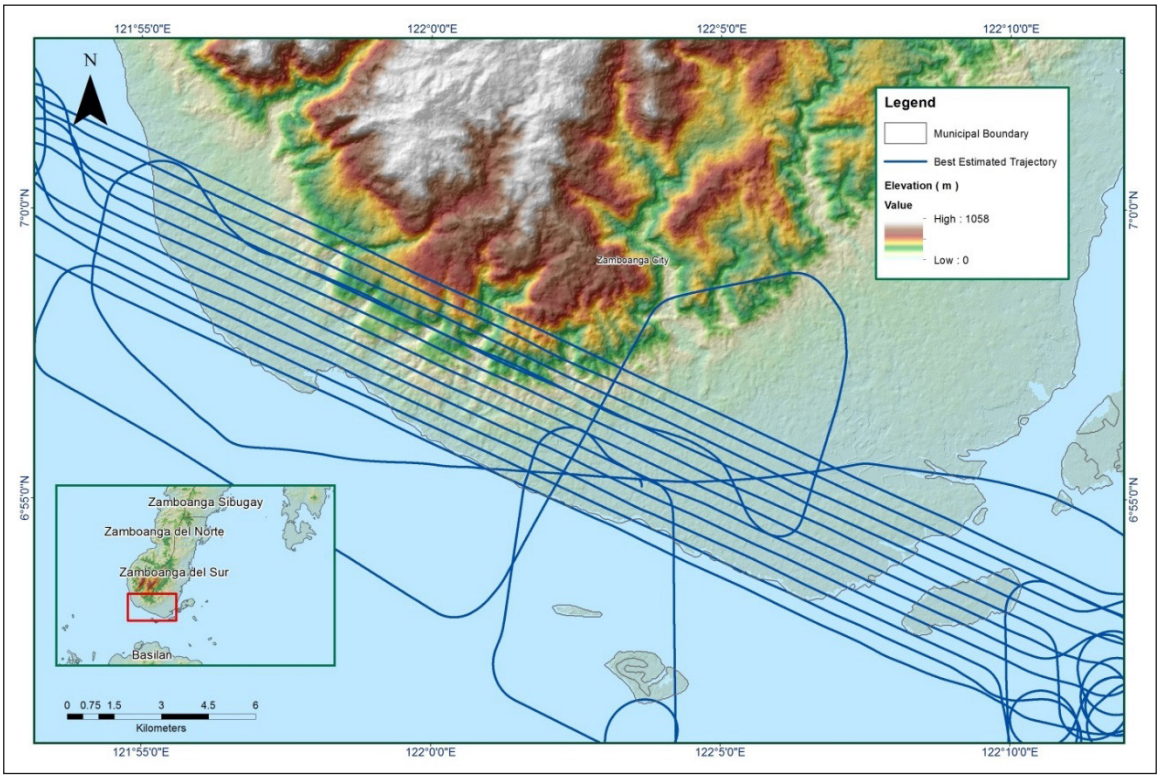


Figure 1.2.4 Coverage of LiDAR data

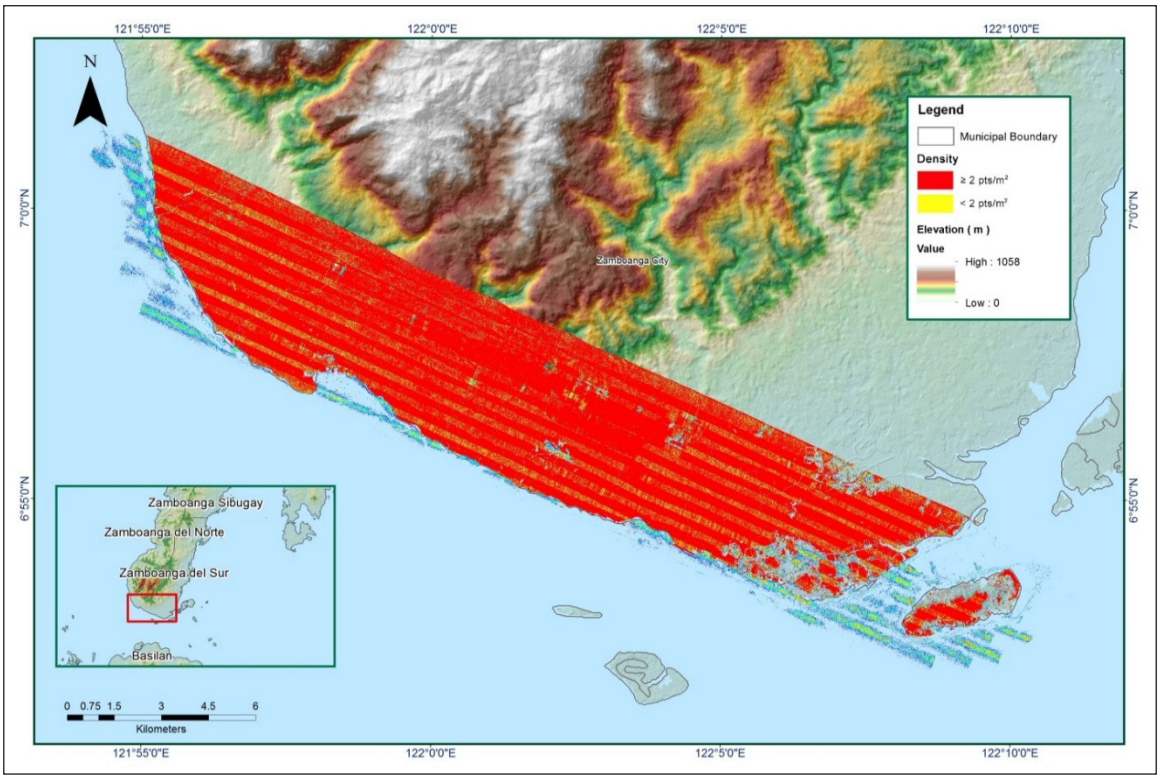


Figure 1.2.5 Image of data overlap

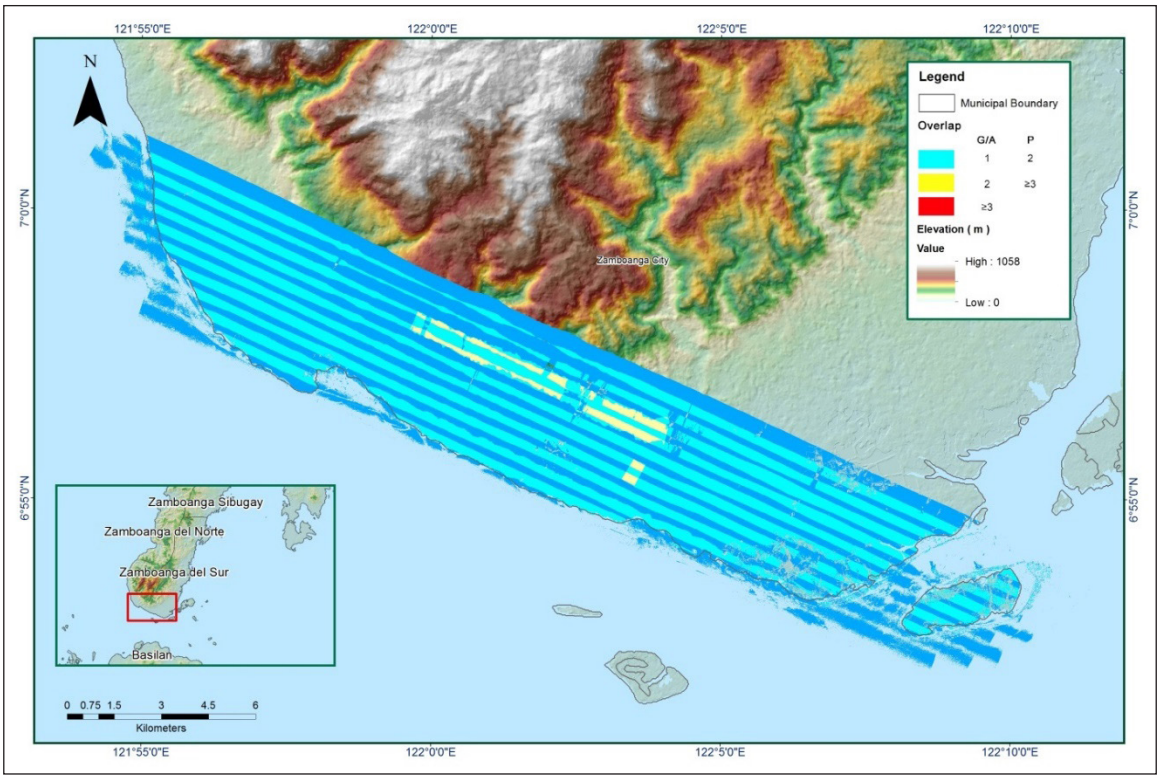


Figure 1.2.6 Density map of merged LiDAR data

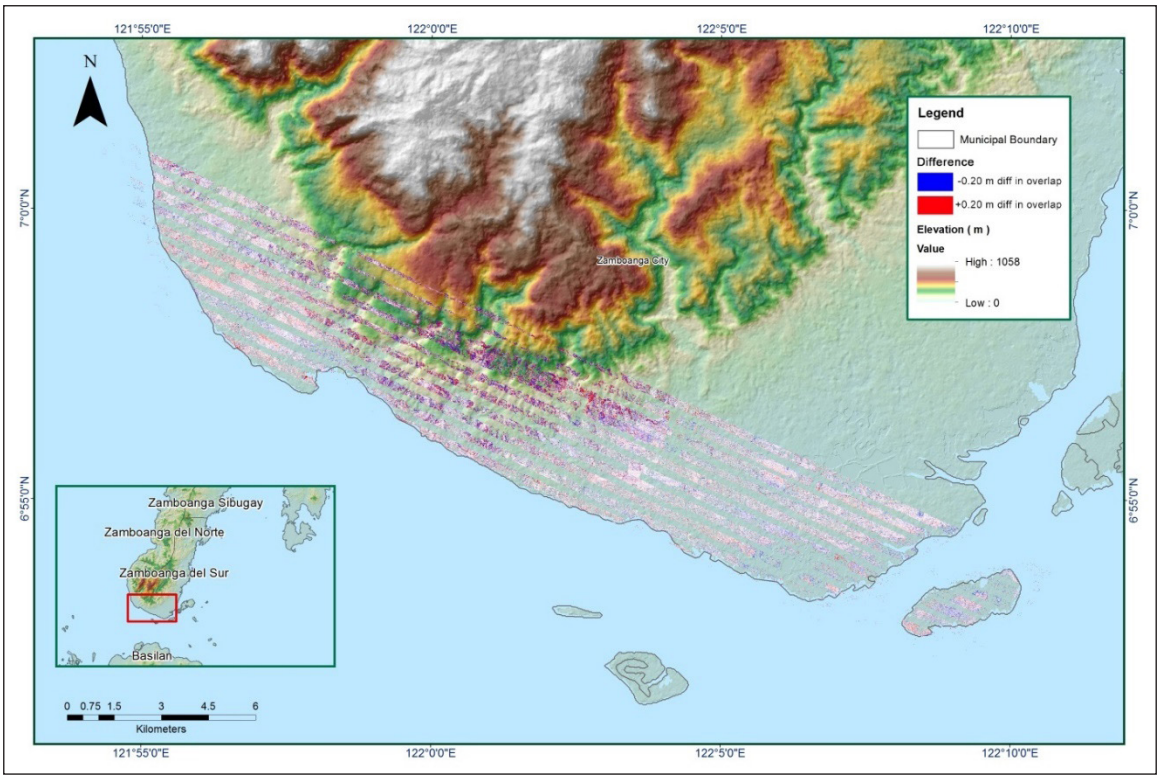


Figure 1.2.7 Elevation difference between flight lines

Flight Area	Zamboanga
Mission Name	**Block 75F_additional**
Inclusive Flights	2557P
Range data size	20.5 GB
Base data size	8.47 MB
POS	255 MB
Image	34.9 GB
Transfer date	February 27 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)	1.141
RMSE for East Position (<4.0 cm)	1.744
RMSE for Down Position (<8.0 cm)	3.620
Boresight correction stdev (<0.001deg)	0.000683
IMU attitude correction stdev (<0.001deg)	0.001812
GPS position stdev (<0.01m)	0.0094
Minimum % overlap (>25)	90.58%
Ave point cloud density per sq.m. (>2.0)	3.12
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	10
Maximum Height	211.78 m
Minimum Height	71.72 m
Classification (# of points)	
Ground	4,965,841
Low vegetation	1,517,124
Medium vegetation	2,161,688
High vegetation	5,531,337
Building	767,278
Orthophoto	No
Processed by	Engr. Jommer Medina, Engr. Melanie Hingpit, Kathryn Claudyn Zarate

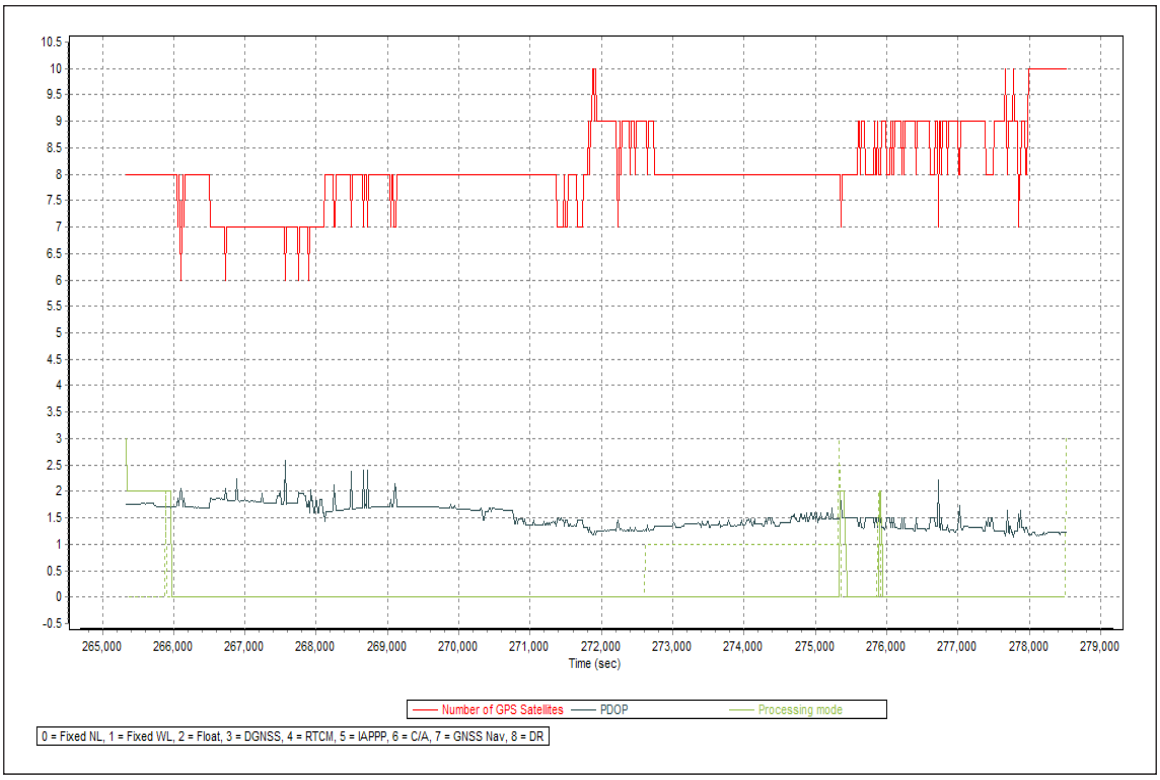


Figure 1.3.1 Solution Status

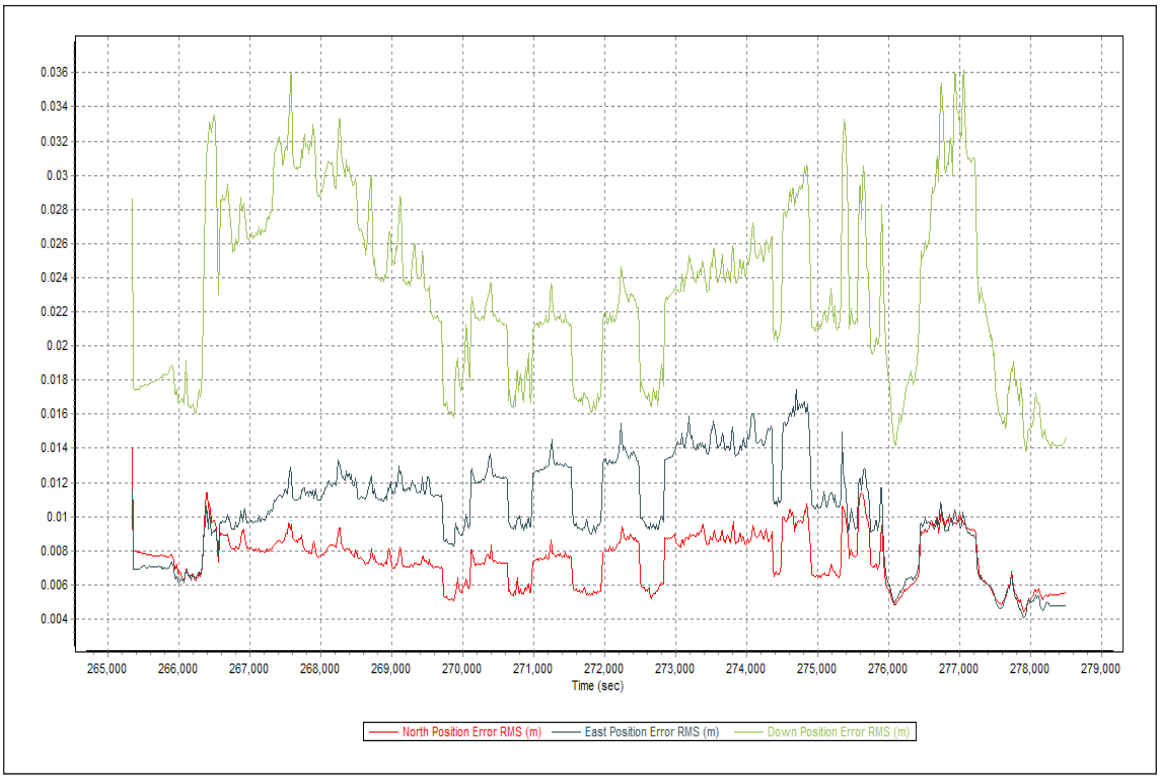


Figure 1.3.2 Smoothed Performance Metric Parameters

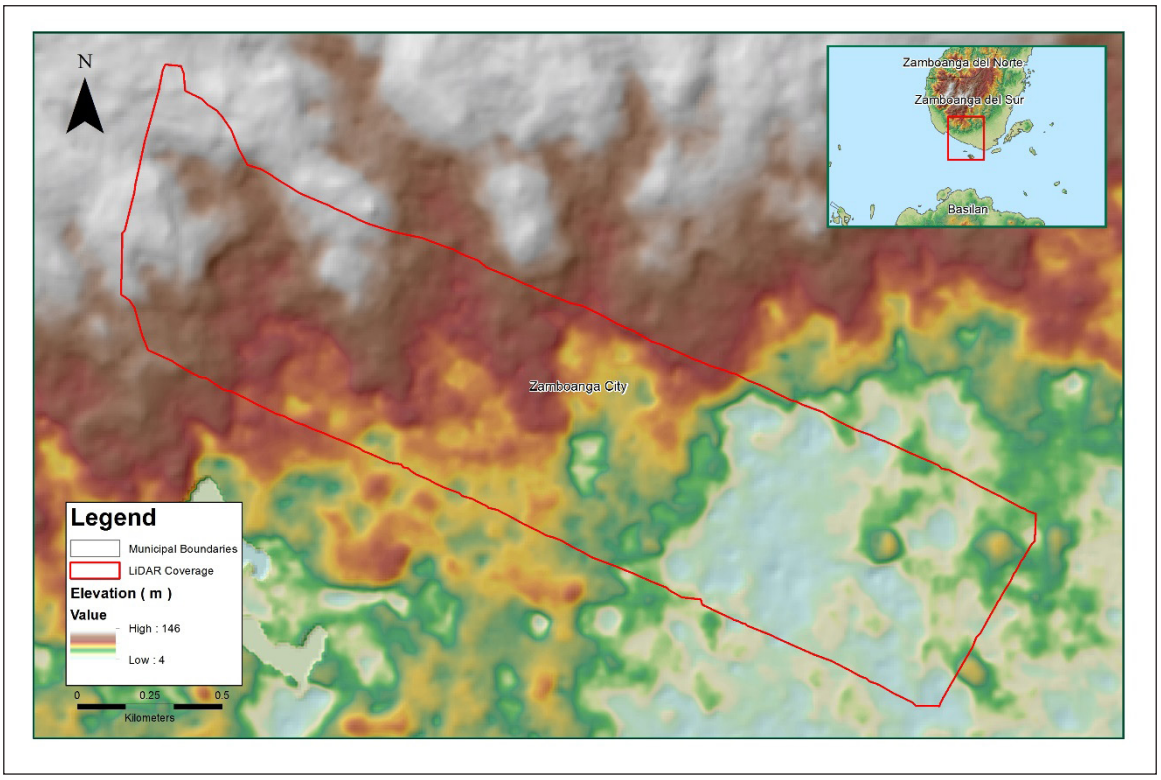


Figure 1.3.3 Best Estimated Trajectory

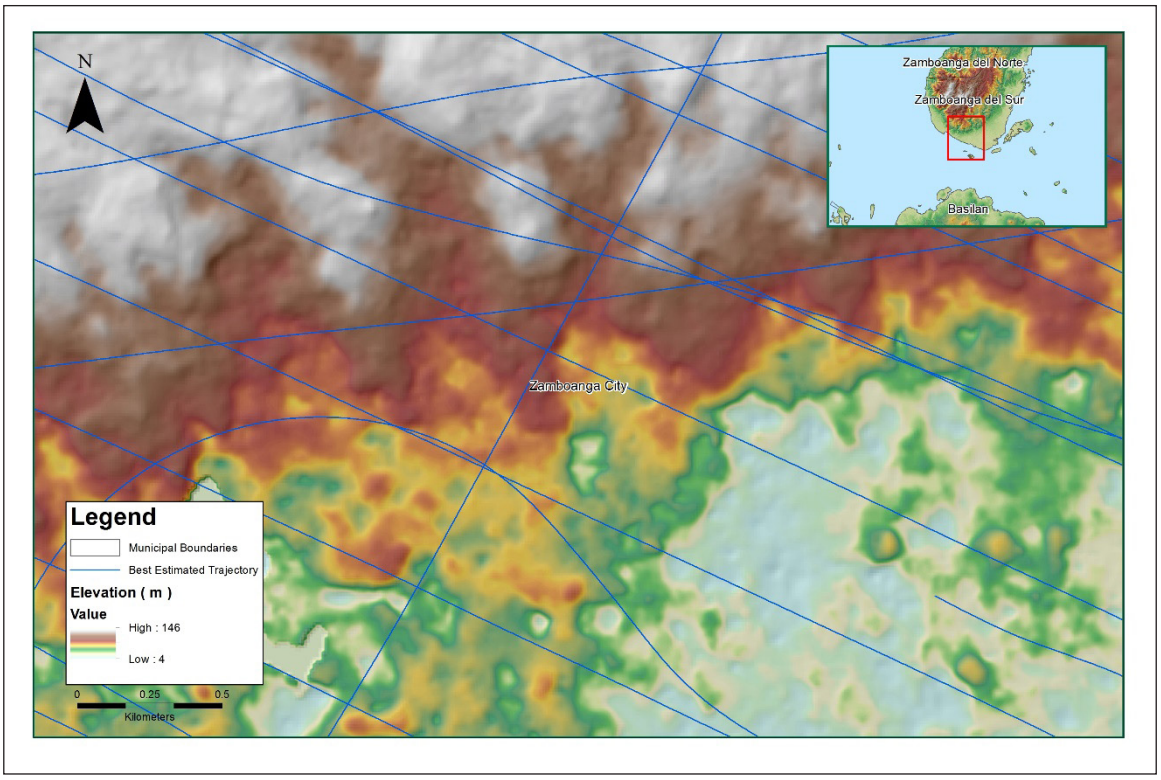


Figure 1.3.4 Coverage of LiDAR data

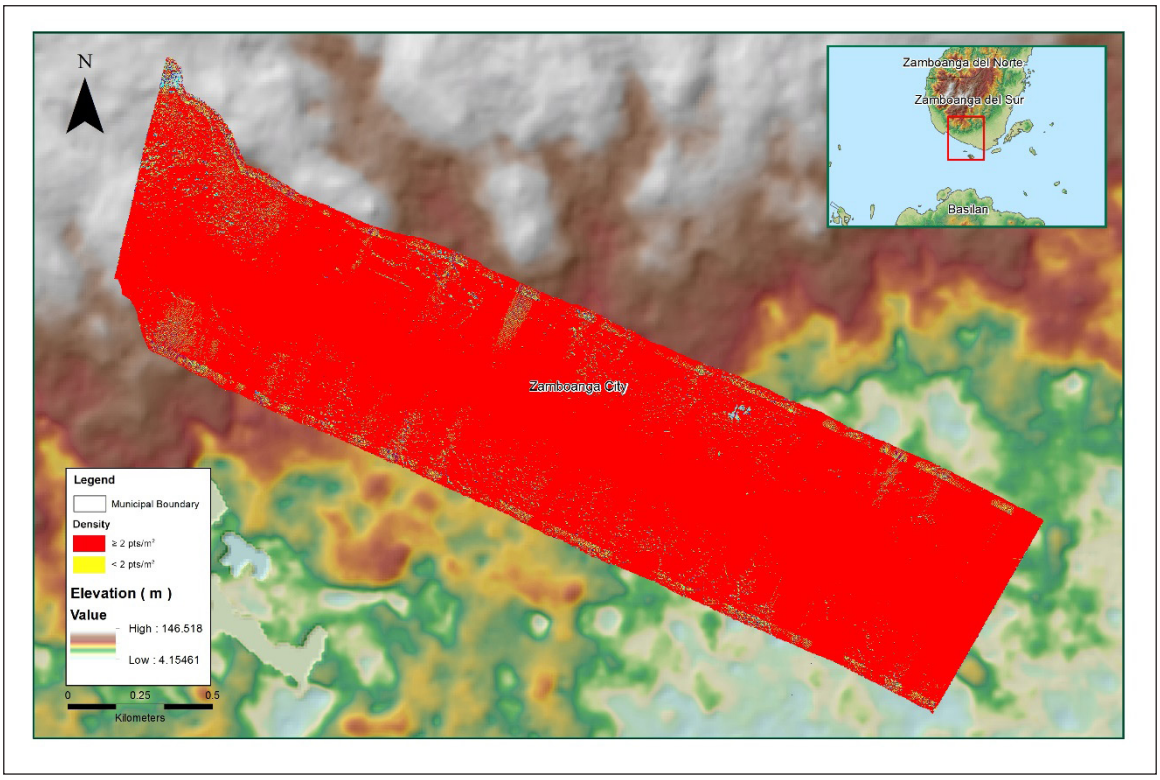


Figure 1.3.5 Image of data overlap

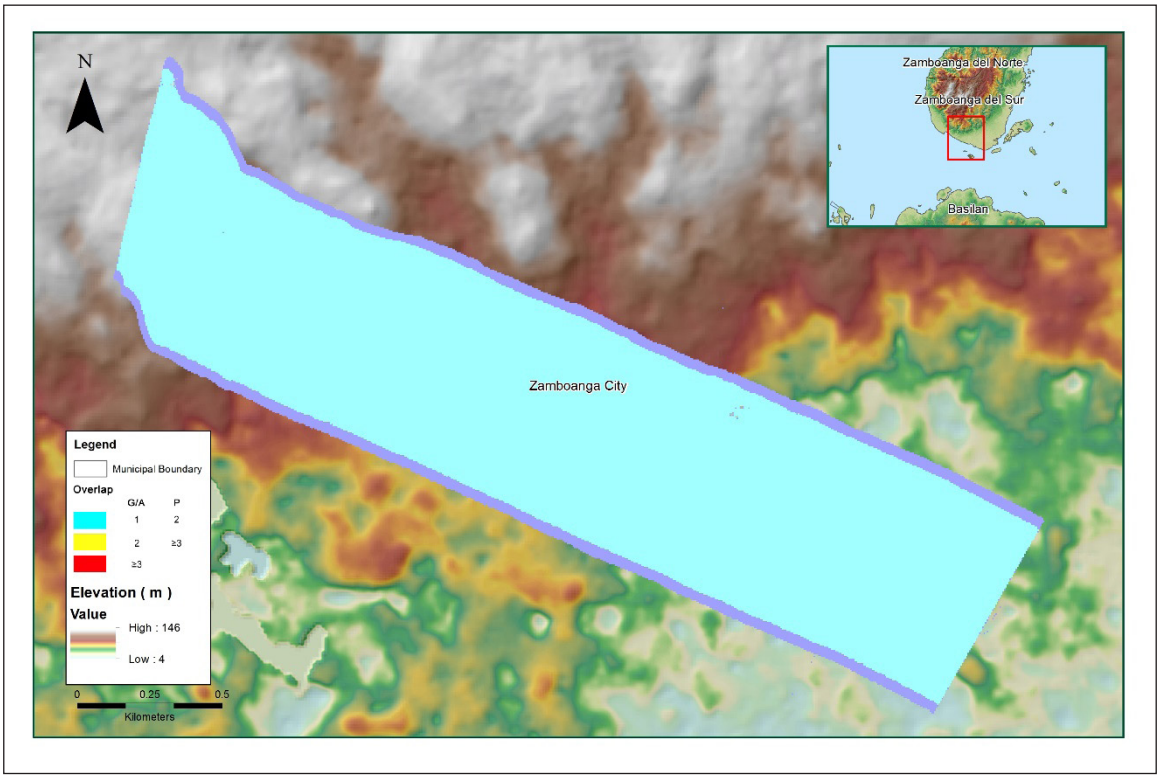


Figure 1.3.6 Density map of merged LiDAR data

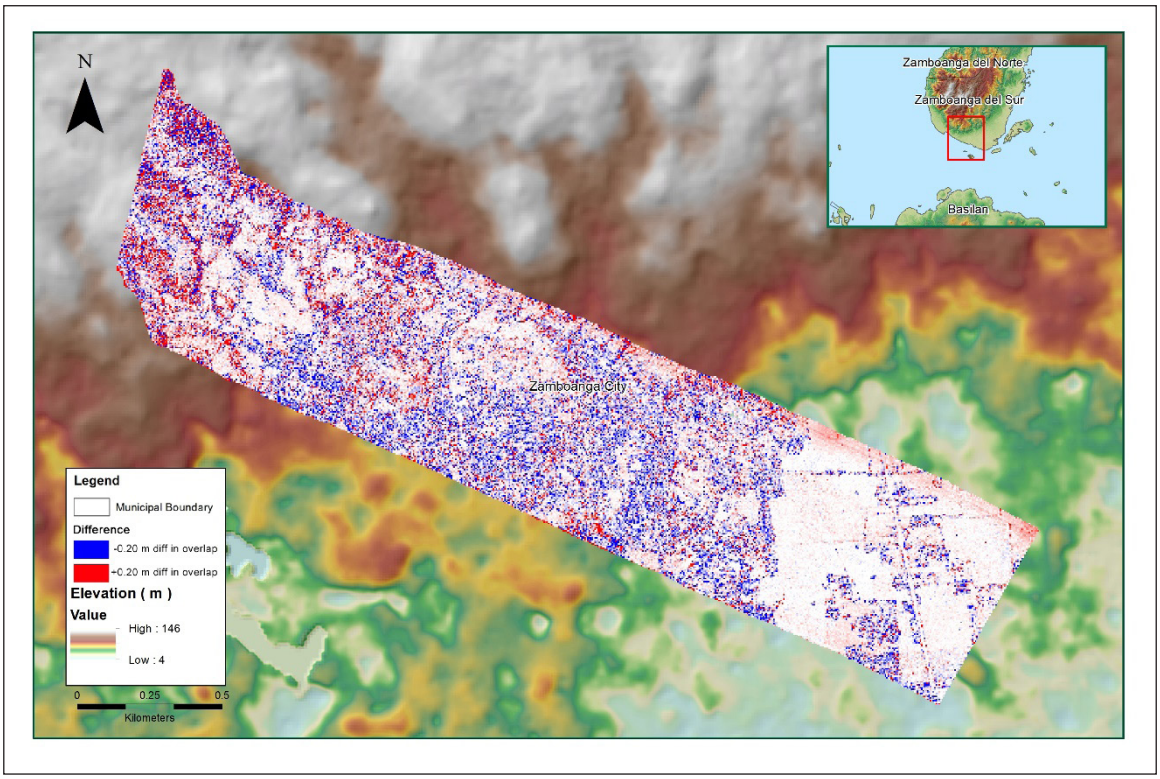


Figure 1.3.7 Elevation difference between flight lines

Flight Area	Zamboanga
Mission Name	**Sacol**
Inclusive Flights	2557P
Range data size	20.5 GB
Base data size	8.47 MB
POS	255 MB
Image	34.9 GB
Transfer date	February 27 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 (<0.20 m)	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 John Escobido

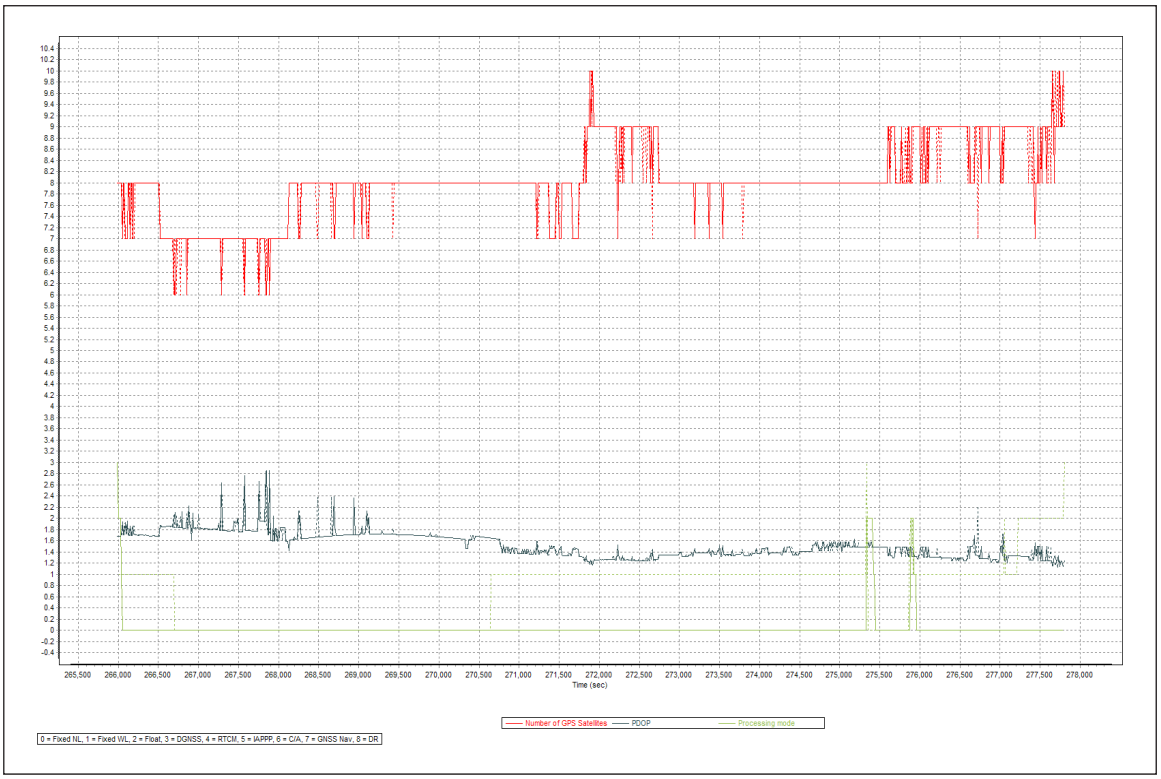


Figure 1.4.1 Solution Status

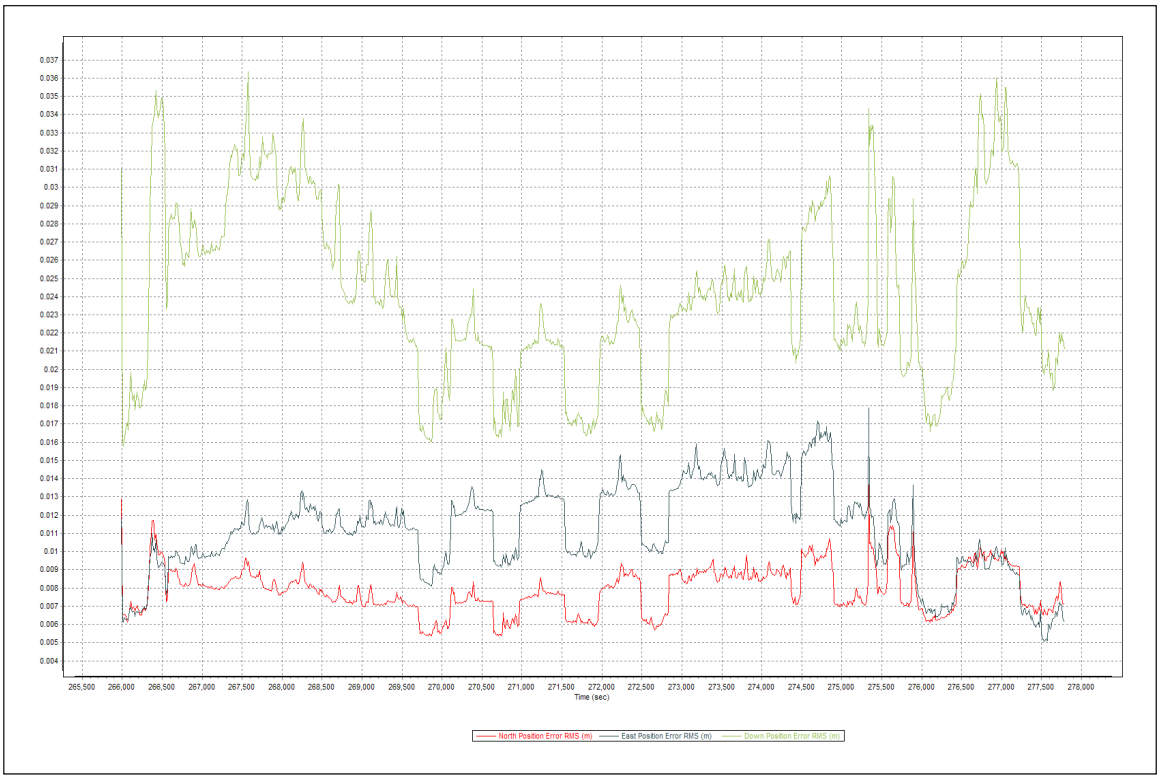


Figure 1.4.2 Smoothed Performance Metric Parameters

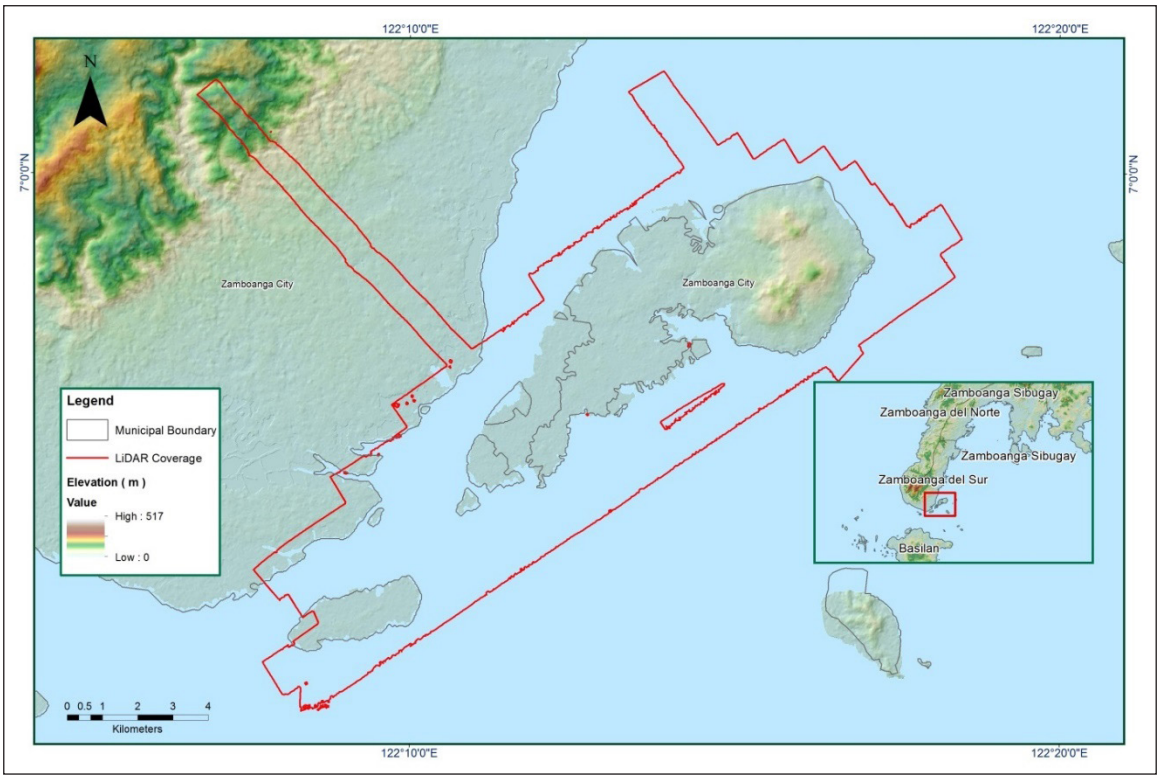


Figure 1.4.3 Best Estimated Trajectory

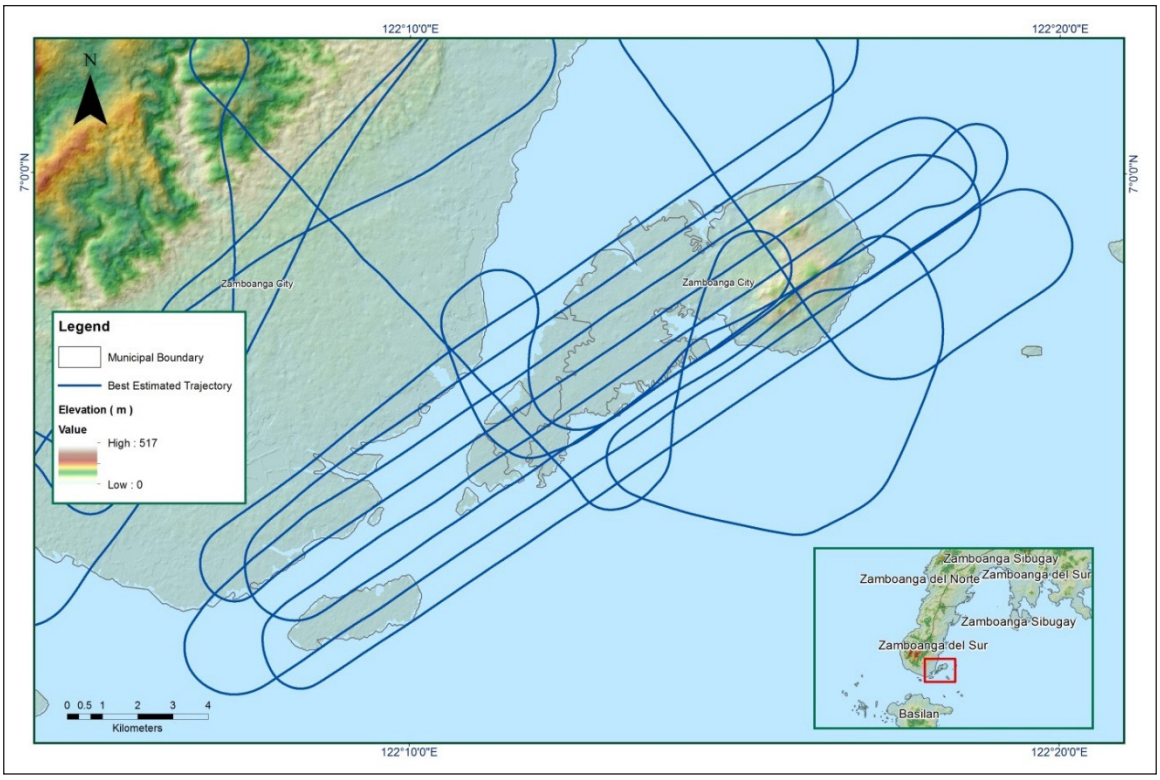


Figure 1.4.4 Coverage of LiDAR data

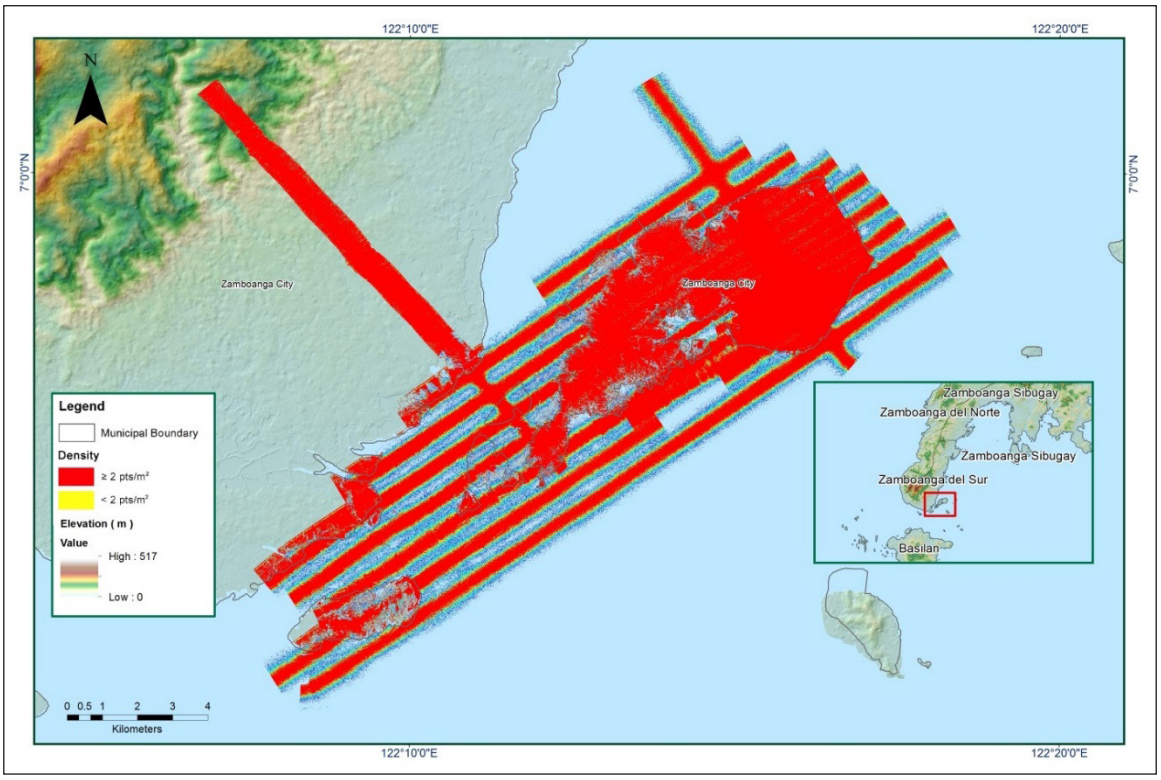


Figure 1.4.5 Image of data overlap

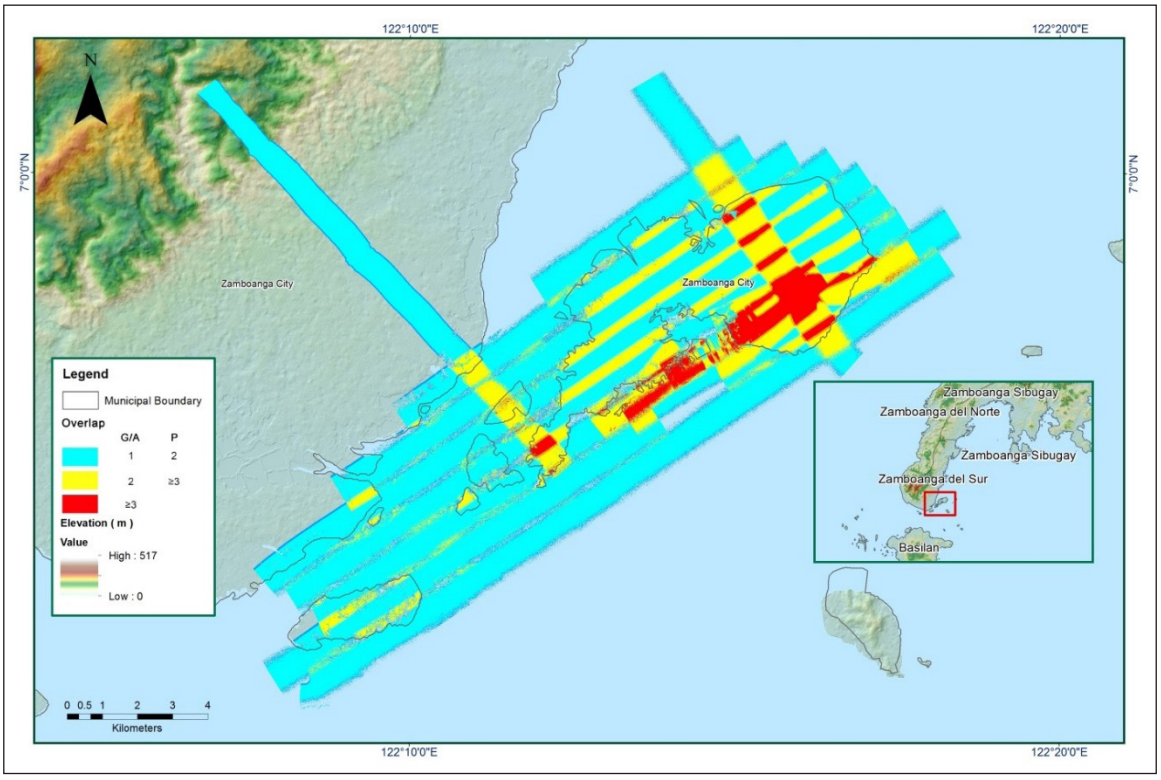


Figure 1.4.6 Density map of merged LiDAR data

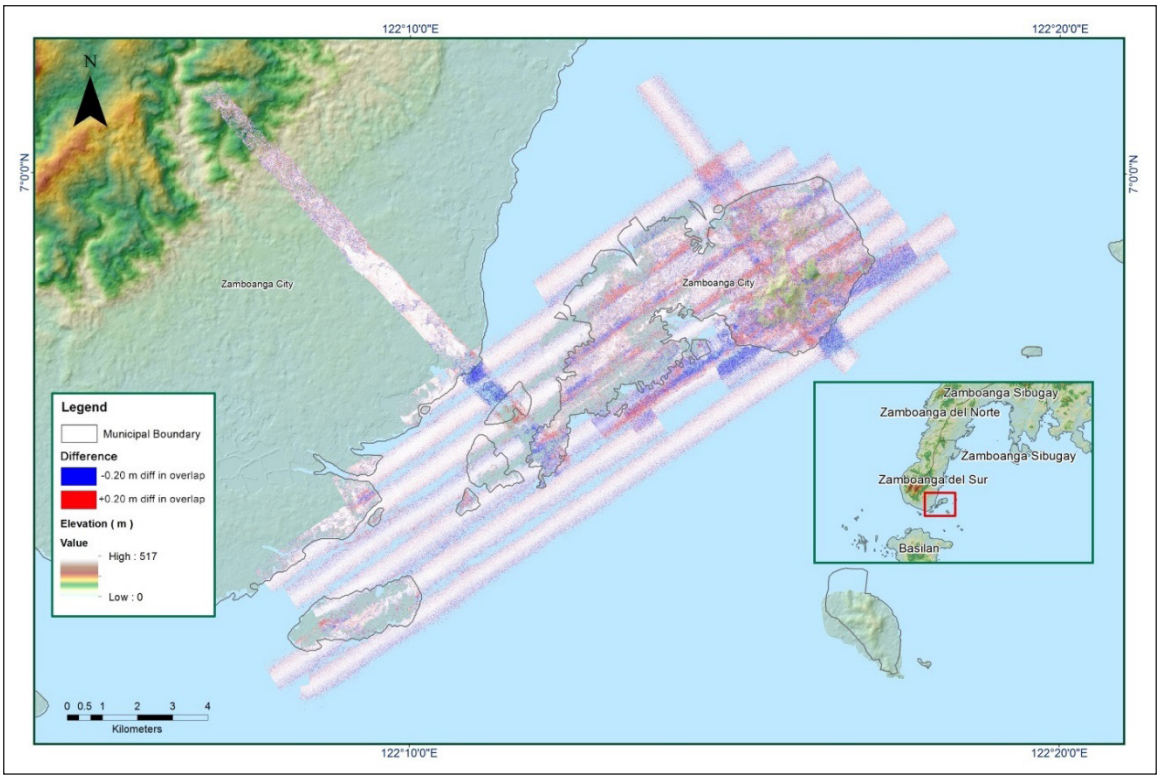


Figure 1.4.7 Elevation difference between flight lines

Flight Area	Zamboanga Reflights
Mission Name	**Blk75AS**
Inclusive Flights	23394P
Range data size	5.13 GB
Base data size	133 MB
POS	101 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 Harder, Erica Erin Elazequi, Engr. Jeffrey Delica

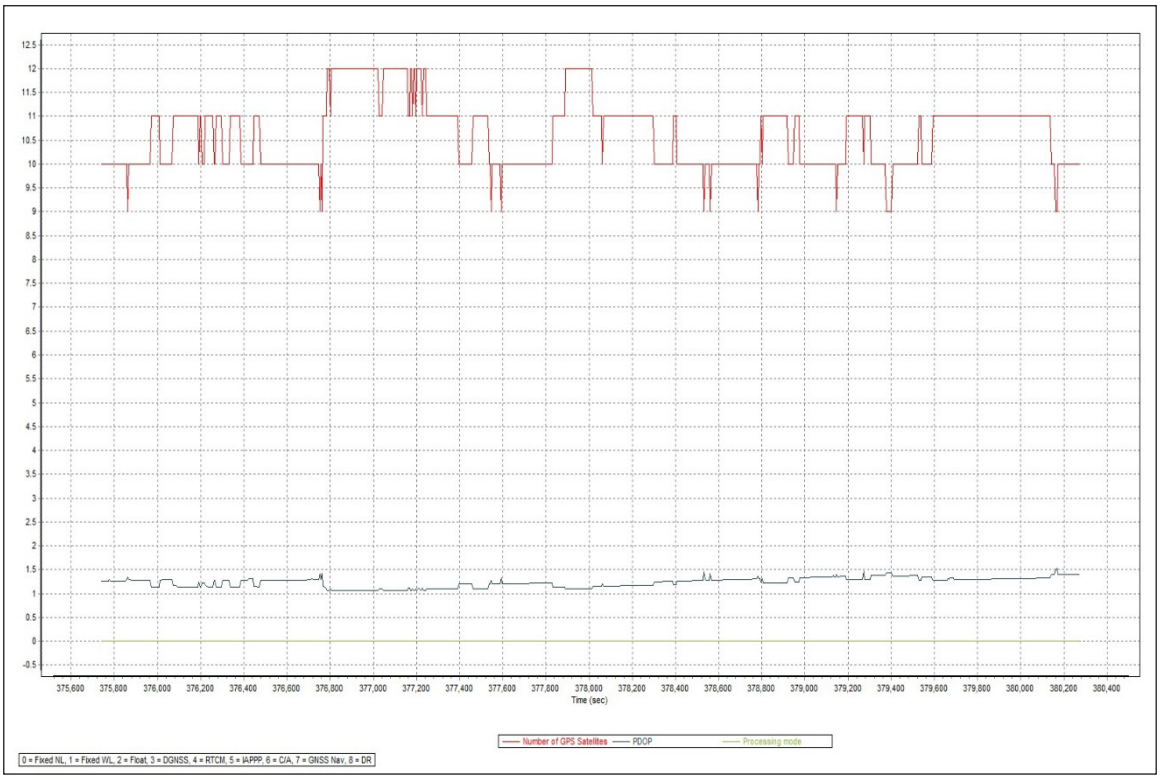


Figure 1.5.1 Solution Status

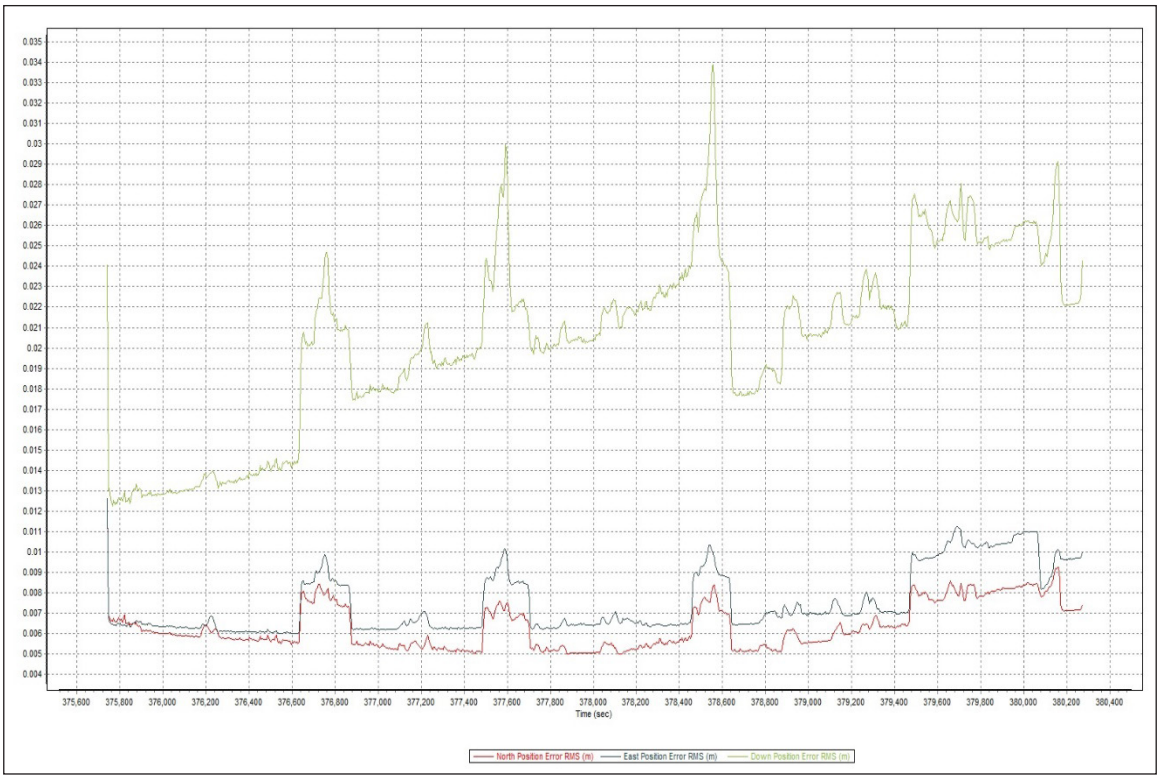
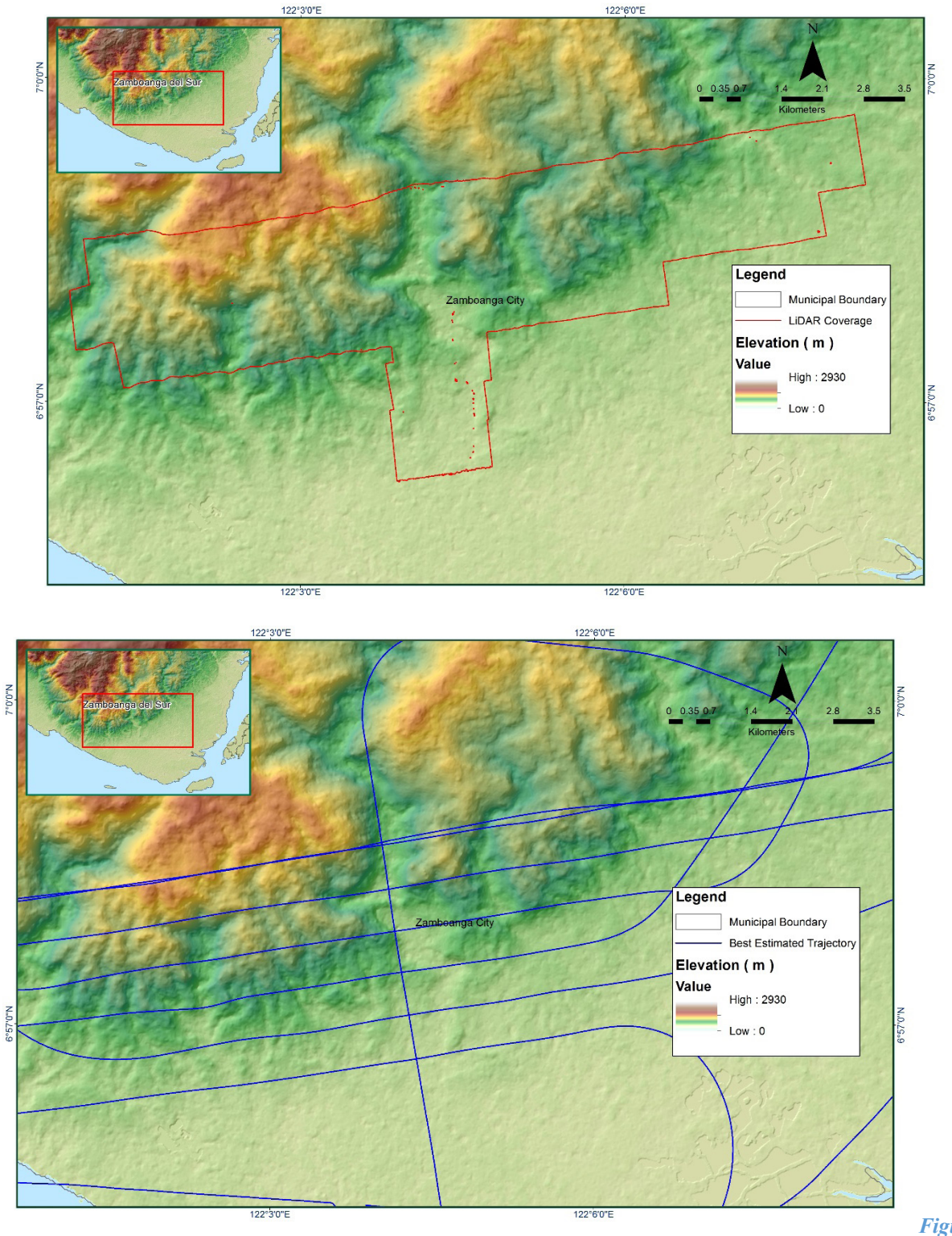


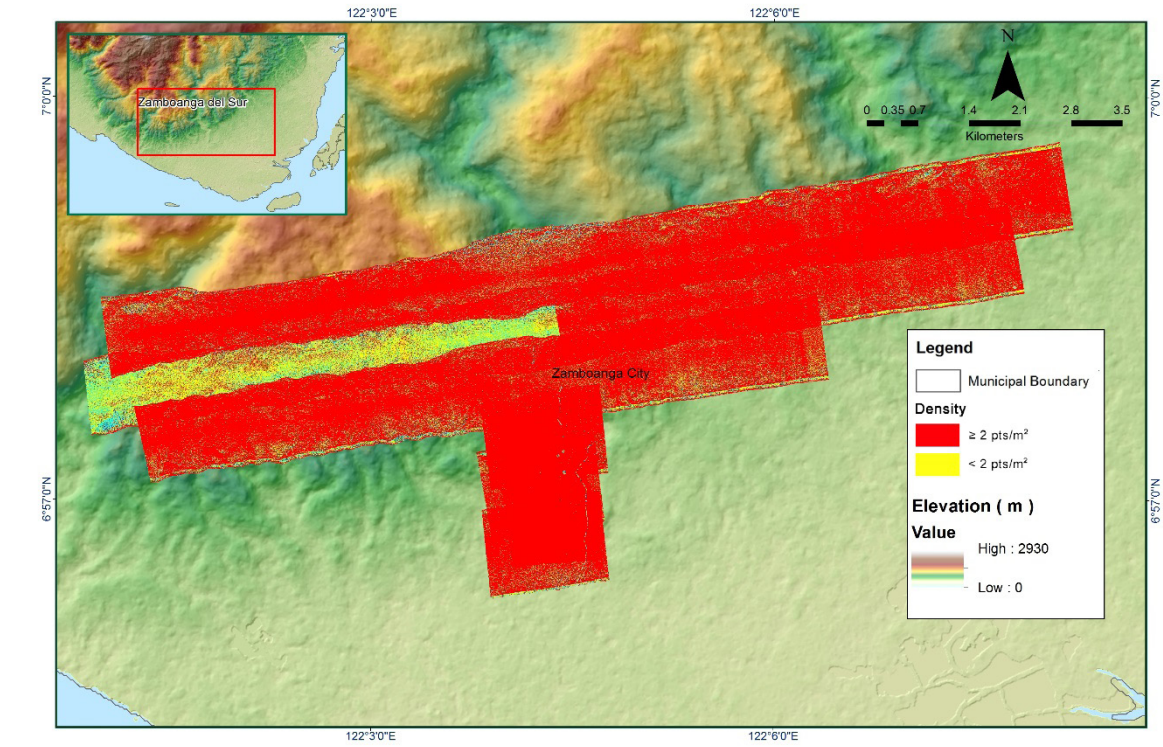
Figure 1.5.2 Smoothed Performance Metric Parameters

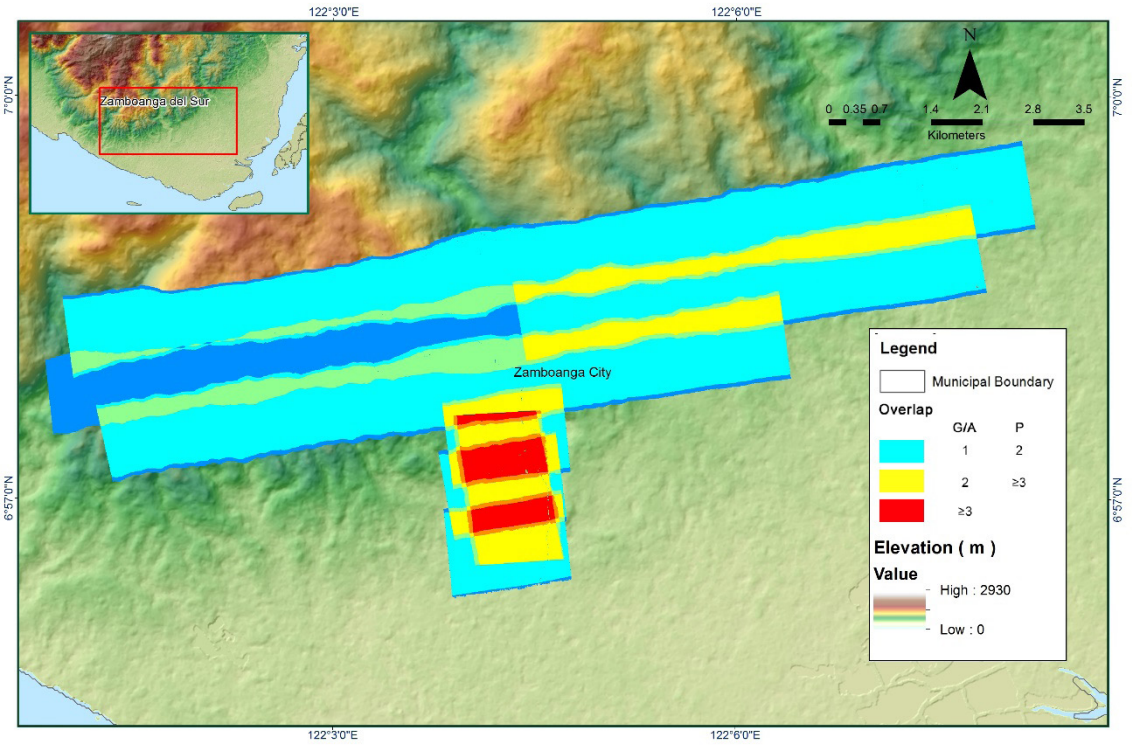


Figure

1.5.3 Best Estimated Trajectory

Figure 1.5.4 Coverage of LiDAR data





Figure

1.5.5 Image of data overlap

Figure 1.5.6 Density map of merged LiDAR data

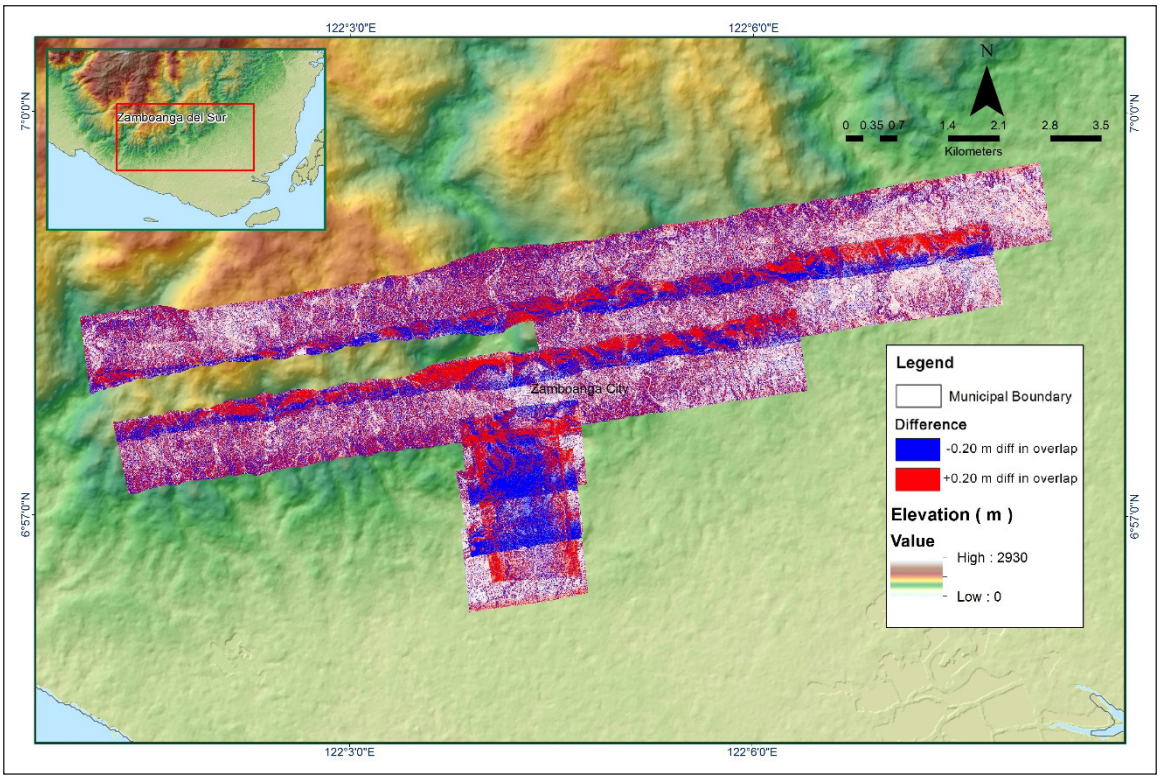


Figure 1.5.7 Elevation difference between flight lines

Mission Name	Block 75F_supplement
Inclusive Flights	23394P
Range data size	5.13 GB
Base data size	133 MB
POS	101 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)	0.926
RMSE for East Position (<4.0 cm)	1.126
RMSE for Down Position (<8.0 cm)	3.388
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)	32.76
Ave point cloud density per sq.m. (>2.0)	2.57
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	43
Maximum Height	377.09 m
Minimum Height	73.58 m
Classification (# of points)	
Ground	19,418,142
Low vegetation	12,541,089
Medium vegetation	25,246,500
High vegetation	58,645,039
Building	5,803,796
Orthophoto	No
Processed by	Ben Joseph Harder, Engr. Harmond Santos, Maria Tamsyn Malabanan

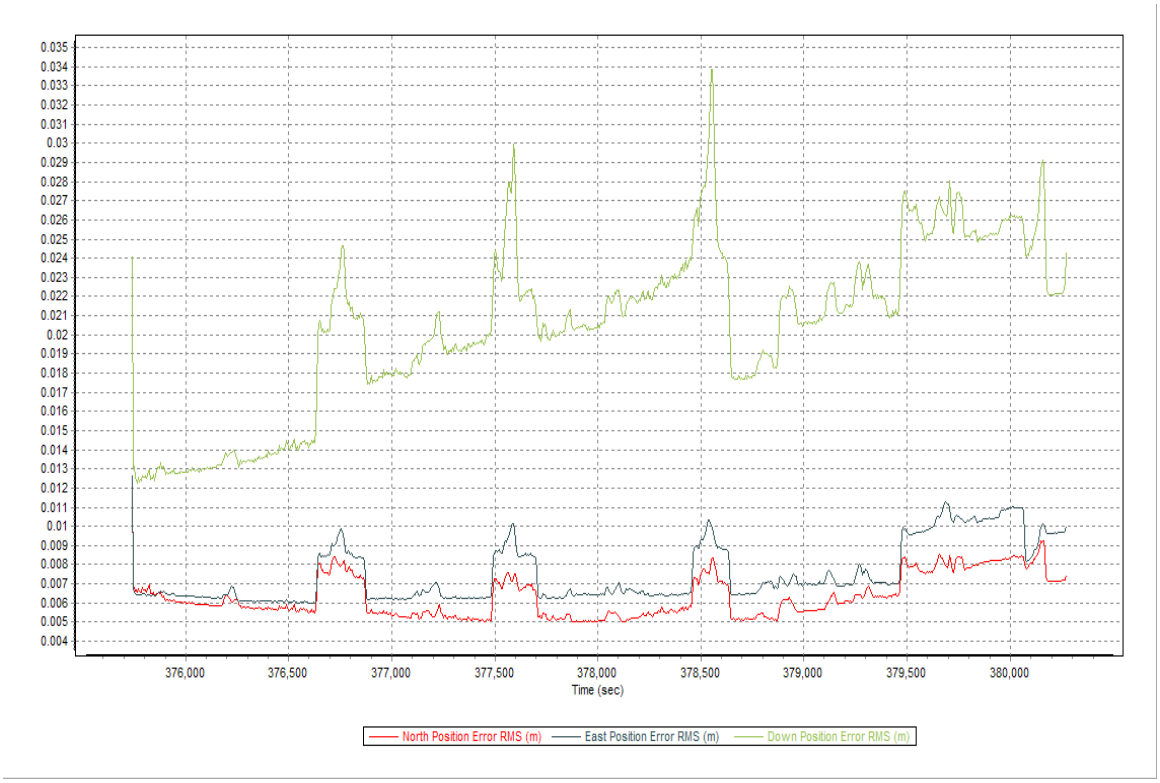


Figure 1.6.1 Solution Status

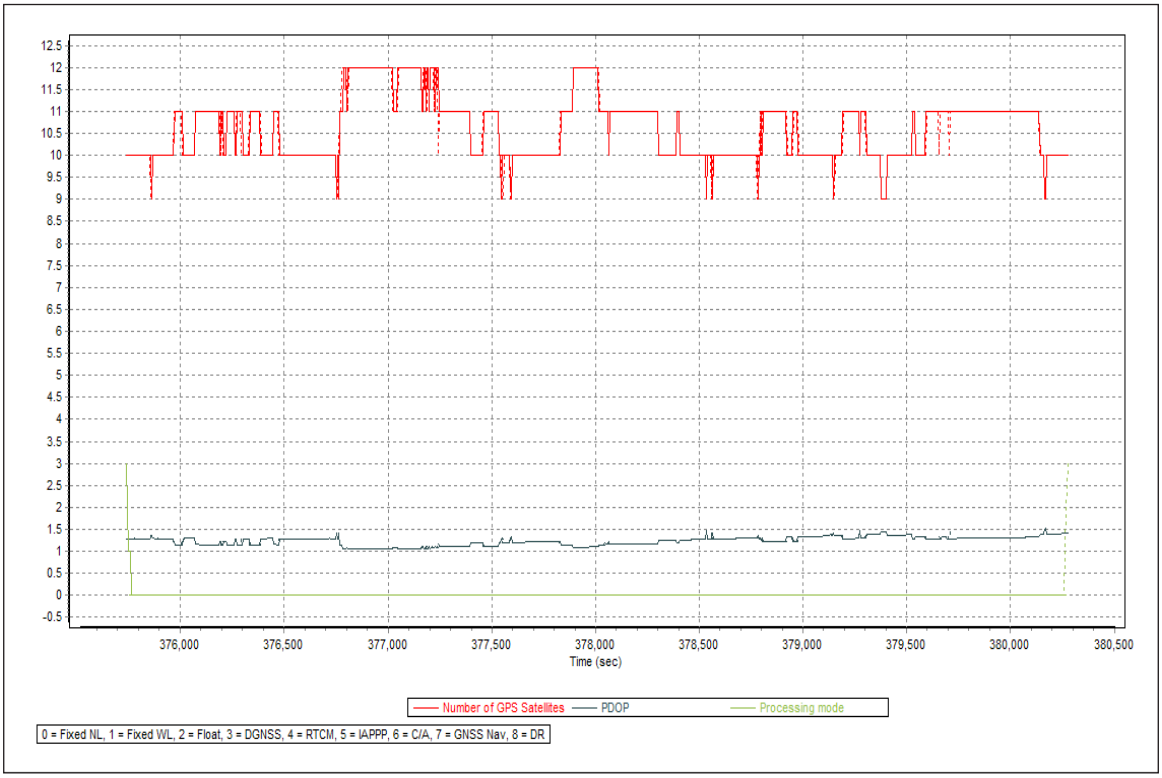


Figure 1.6.2 Smoothed Performance Metric Parameters

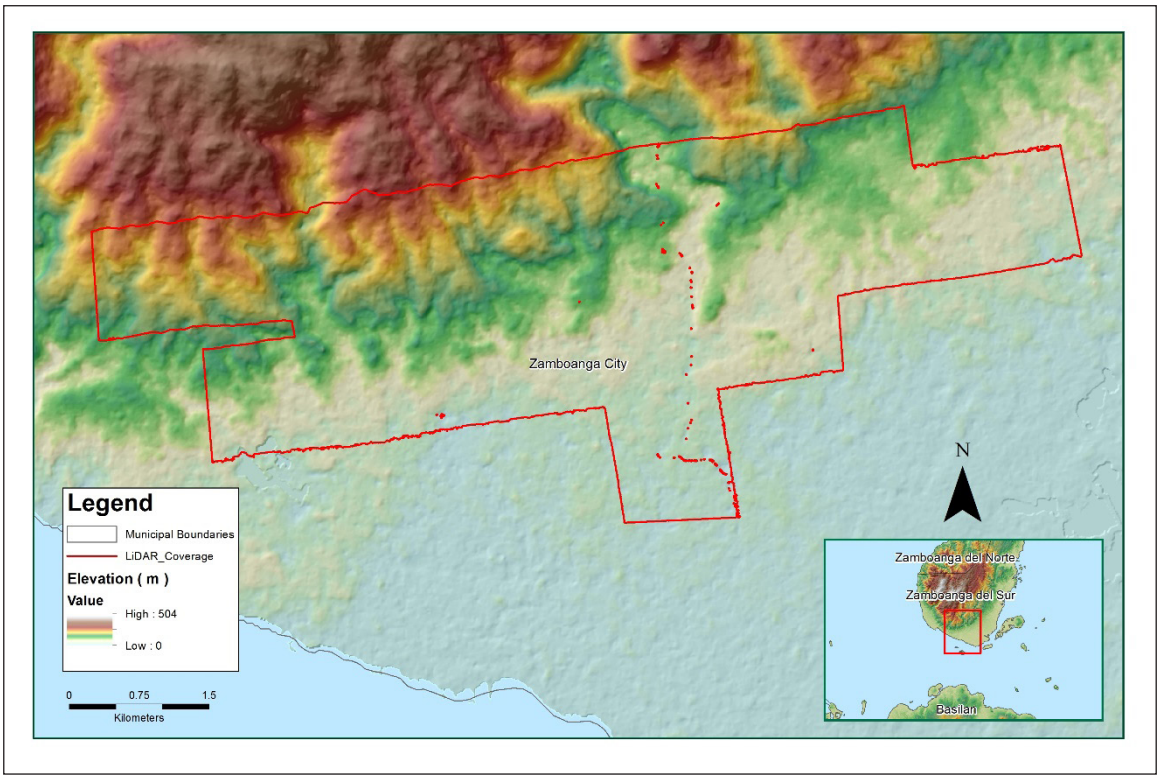


Figure 1.6.3 Best Estimated Trajectory

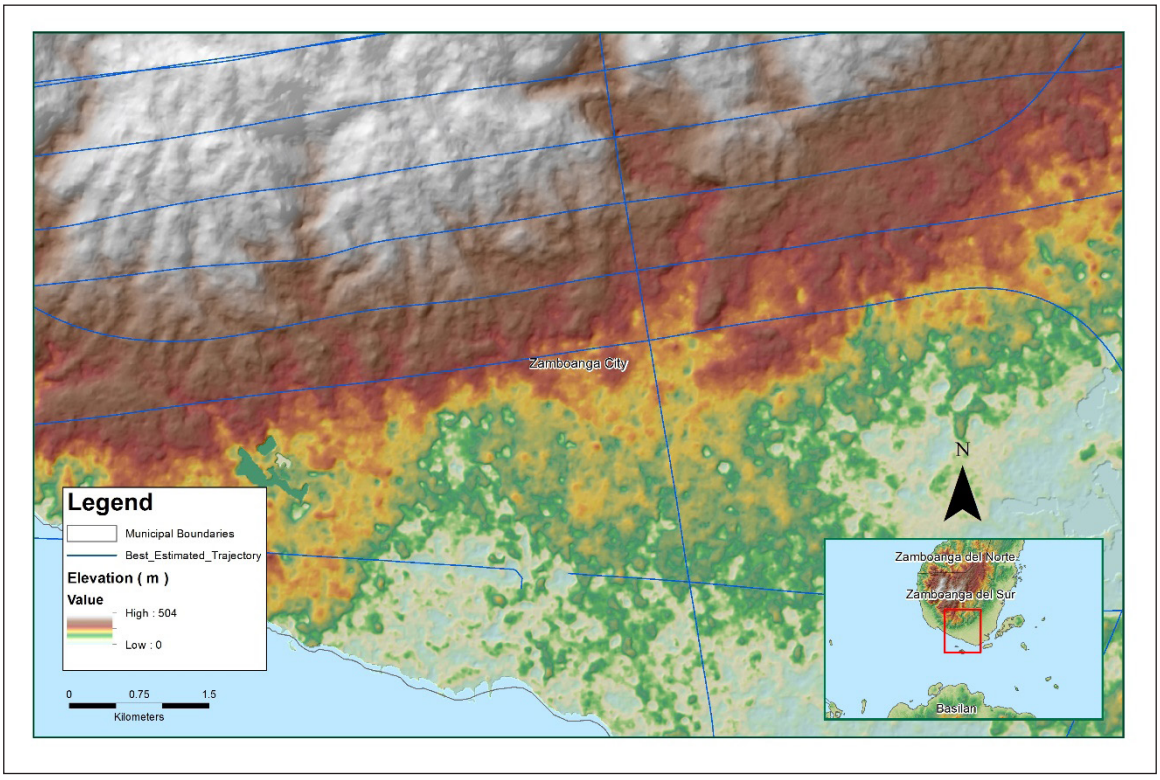


Figure 1.6.4 Coverage of LiDAR data

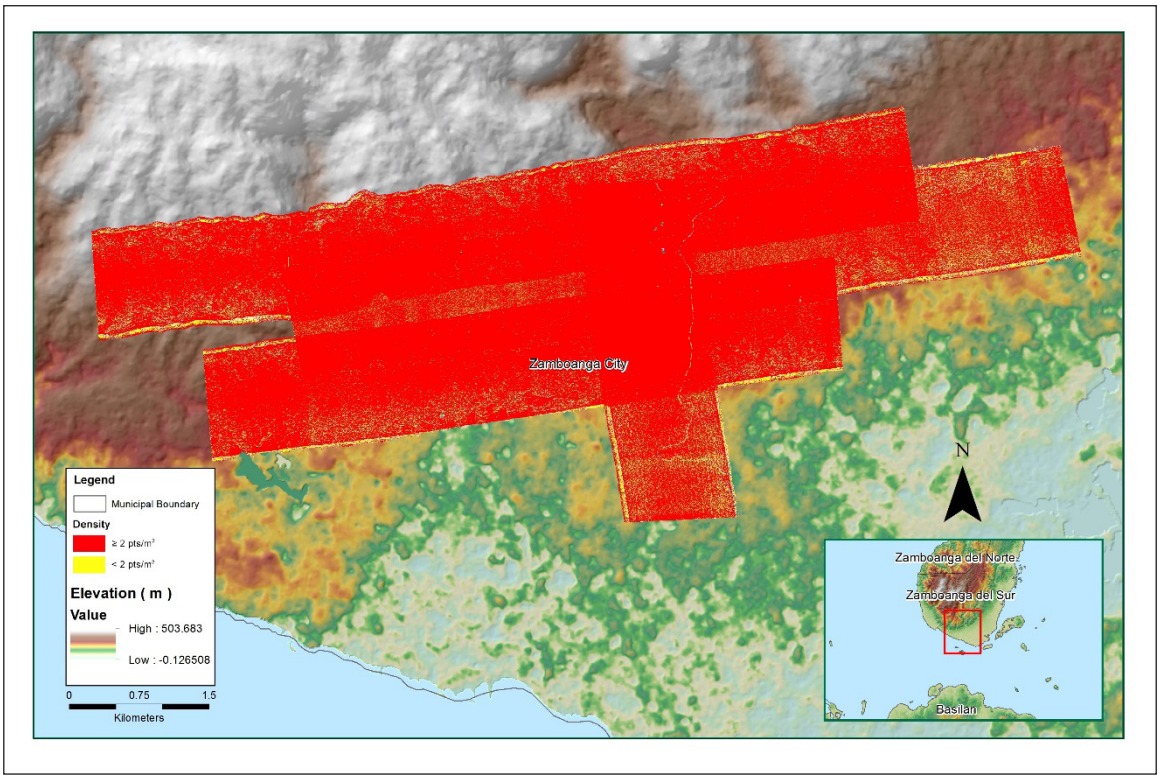


Figure 1.6.5 Image of data overlap

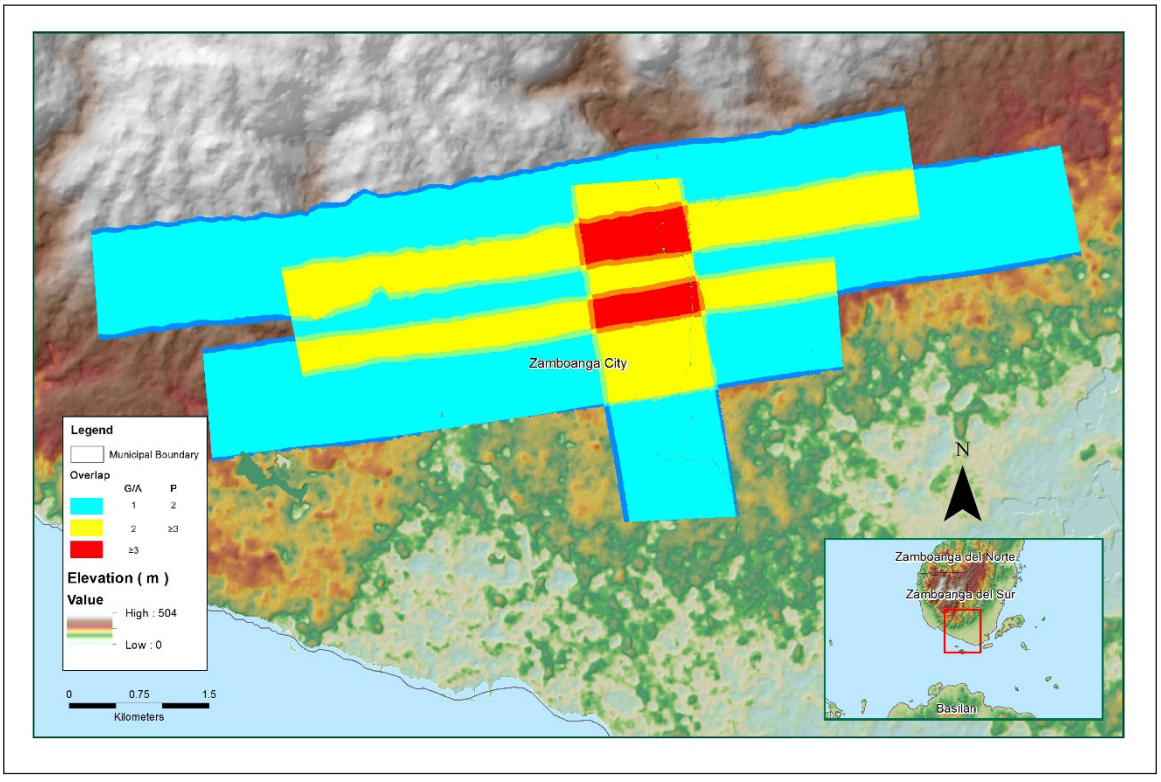


Figure 1.6.6 Density map of merged LiDAR data

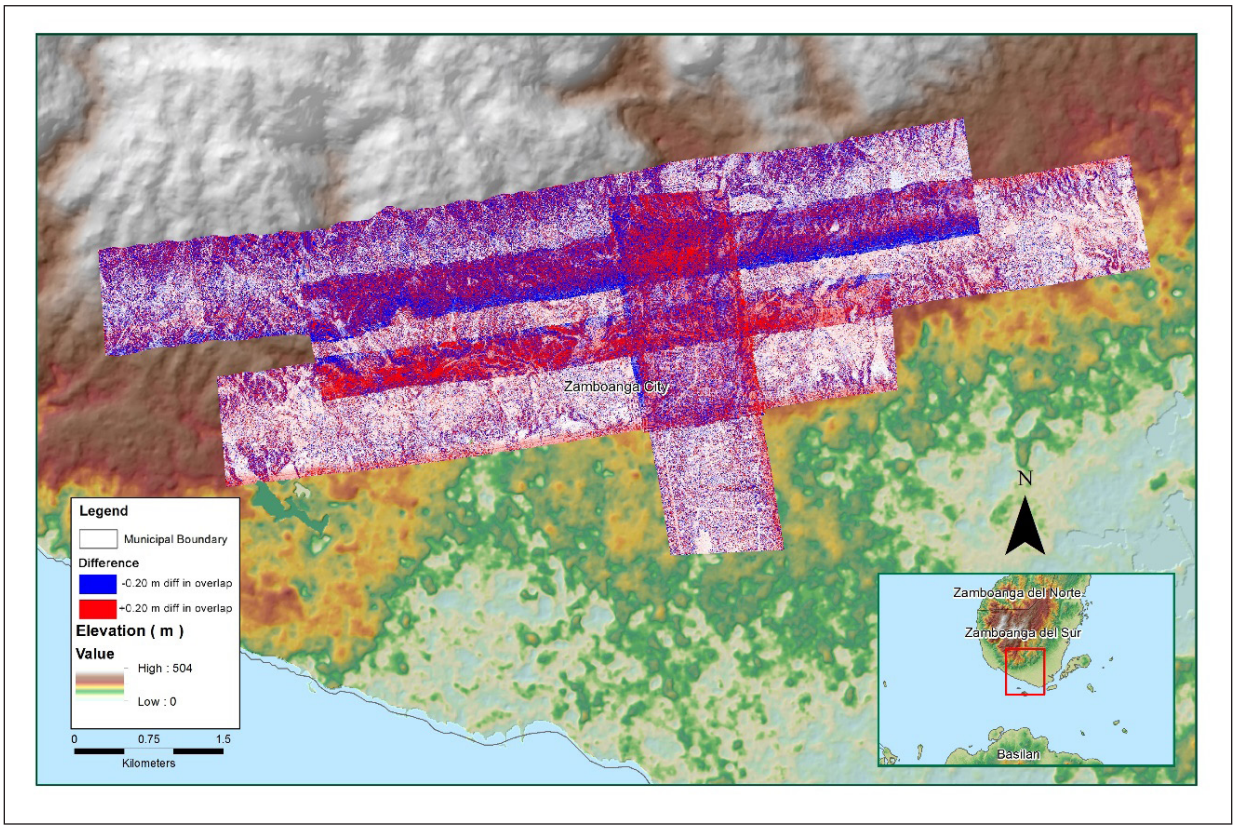


Figure 1.6.7 Elevation difference between flight lines

ANNEX 9. Tumaga 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
W100	7.2736	61.6	0	0.076245	3.3181808	Discharge	0.18974	0.75	Ratio to Peak	0.2
W110	7.3013	61.49472	0	0.095883	4.1728392	Discharge	0.3437	0.75	Ratio to Peak	0.2
W120	7.2736	61.6	0	0.04569	1.9883728	Discharge	0.0441795	0.75	Ratio to Peak	0.2
W130	7.3923	61.15088	0	0.069843	3.0395352	Discharge	0.12877	0.75	Ratio to Peak	0.2
W140	8.1914	58.2904	0	0.091284	3.9726896	Discharge	0.20521	0.75	Ratio to Peak	0.2
W80	7.3721	61.22704	0	0.286995	12.4899584	Discharge	0.89669	0.75	Ratio to Peak	0.2
W90	7.2736	61.6	0	0.079554	3.462212	Discharge	0.16935	0.75	Ratio to Peak	0.2

ANNEX 10. Tumaga Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R30	Automatic Fixed Interval	5830.4	0.0420993	0.018	Trapezoid	35	1
R60	Automatic Fixed Interval	2026.1	0.0234658	0.018	Trapezoid	35	1
R70	Automatic Fixed Interval	4641.5	0.0204807	0.018	Trapezoid	35	1

ANNEX 11. Tumaga Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Lat	Long					
1	401544.5115	770406.9969	0.03	0	0.03	Not Defined	5 -Year
2	401313.2583	770329.7103	0.031	0	0.03	Not Defined	5 -Year
3	401994.8154	769947.7683	0.03	0	0.03	Not Defined	5 -Year
4	402234.7911	769786.4539	0.03	0	0.03	Not Defined	5 -Year
5	400109.1224	768660.4425	0.03	0	0.03	Not Defined	5 -Year
6	400504.4382	768852.0631	0.03	0	0.03	Not Defined	5 -Year
7	398446.5421	766996.1707	0.03	0	0.03	Not Defined	5 -Year
8	398637.9542	766113.5273	0.03	0	0.03	Not Defined	5 -Year
9	398640.2963	766239.23	0.04	0	0.04	Not Defined	5 -Year
10	398503.6875	766040.1536	0.034	0	0.03	Not Defined	5 -Year
11	398514.9066	766642.2445	0.183	0	0.18	Not Defined	5 -Year
12	398481.5097	766568.7864	0.209	0	0.21	Not Defined	5 -Year
13	398459.7517	767028.4287	0.03	0	0.03	Not Defined	5 -Year
14	398493.2	766729.2976	0.03	0	0.03	Not Defined	5 -Year
15	398280.6442	766790.6286	0.03	0	0.03	Not Defined	5 -Year
16	398175.2515	766793.4867	0.03	0	0.03	Not Defined	5 -Year
17	401514.647	765220.806	0.602	0.4	0.20	Not Defined	5 -Year
18	401803.9813	765564.6573	0.177	0.3	-0.12	Not Defined	5 -Year
19	401451.3933	765602.1344	0.041	0.15	-0.11	Not Defined	5 -Year
20	401588.0415	765592.591	2.287	1.5	0.79	Not Defined	5 -Year
21	402467.7505	766037.1668	0.07	0	0.07	Not Defined	5 -Year
22	402125.1158	766315.0882	0.03	0	0.03	Not Defined	5 -Year
23	404061.6194	767768.6777	0.03	0	0.03	Not Defined	5 -Year
24	403664.1639	768510.1542	0.03	0	0.03	Not Defined	5 -Year
25	403576.6673	768869.4119	0.03	0	0.03	Not Defined	5 -Year
26	403848.3487	768762.7746	0.03	0	0.03	Not Defined	5 -Year
27	403856.8999	768967.1827	0.03	0	0.03	Not Defined	5 -Year
28	403983.3301	768211.1682	0.03	0	0.03	Not Defined	5 -Year
29	404026.8329	768498.7631	0.079	0	0.08	Not Defined	5 -Year
30	403766.8027	768033.7869	0.035	0	0.04	Not Defined	5 -Year
31	403594.9728	768072.3567	0.03	0	0.03	Not Defined	5 -Year
32	402525.0188	764391.6054	0.03	0	0.03	Not Defined	5 -Year
33	404466.1705	766003.528	0.082	0	0.08	Not Defined	5 -Year
34	403891.4798	764811.7566	0.279	0	0.28	Not Defined	5 -Year
35	402972.7419	764473.9177	0.03	0	0.03	Not Defined	5 -Year
36	398321.7747	766807.0223	0.034	0	0.03	Not Defined	5 -Year
37	398584.6007	766917.8475	0.273	0	0.27	Not Defined	5 -Year
38	398700.8291	767033.9323	0.03	0	0.03	Not Defined	5 -Year
39	398643.7954	766963.2839	0.056	0	0.06	Not Defined	5 -Year
40	398662.2935	767102.3332	0.031	0	0.03	Not Defined	5 -Year
41	402352.8028	764823.4382	0.133	0	0.13	Not Defined	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Lat	Long					
42	402809.3652	765206.343	0.03	0	0.03	Not Defined	5 -Year
43	402728.6786	765784.0543	0.031	0	0.03	Not Defined	5 -Year
44	403220.276	765520.6778	0.03	0	0.03	Not Defined	5 -Year
45	403707.8555	765293.0246	0.068	0	0.07	Not Defined	5 -Year
46	403975.8608	765763.1834	0.03	0	0.03	Not Defined	5 -Year
47	403573.3514	766048.9428	0.03	0	0.03	Not Defined	5 -Year
48	404467.0535	766003.0841	0.062	0	0.06	Not Defined	5 -Year
49	401900.7719	764563.4703	0.03	0	0.03	Not Defined	5 -Year
50	401712.7771	764589.6925	0.036	0	0.04	Not Defined	5 -Year
51	398329.0773	766014.9522	0.118	0	0.12	Not Defined	5 -Year
52	397683.6921	766380.8363	0.046	0	0.05	Not Defined	5 -Year
53	404979.3734	764672.7957	0.03	0	0.03	Not Defined	5 -Year
54	404107.7366	764350.2202	0.03	0	0.03	Not Defined	5 -Year
55	403040.1112	764280.2042	0.03	0	0.03	Not Defined	5 -Year
56	404738.9131	764767.4271	0.03	0	0.03	Not Defined	5 -Year
57	403361.4487	764487.3532	0.122	0	0.12	Not Defined	5 -Year
58	402385.2629	764157.1471	0.056	0	0.06	Not Defined	5 -Year
59	402638.8349	763923.6181	0.03	0	0.03	Not Defined	5 -Year
60	401991.0491	764451.3052	0.03	0	0.03	Not Defined	5 -Year
61	399095.3417	766167.7045	0.042	0	0.04	Not Defined	5 -Year
62	399281.0318	766152.5325	0.03	0	0.03	Not Defined	5 -Year
63	398838.6094	766124.1959	0.04	0	0.04	Not Defined	5 -Year
64	399005.7583	766004.3581	0.046	0	0.05	Not Defined	5 -Year
65	399065.99	766129.1754	0.03	0	0.03	Not Defined	5 -Year
66	402740.5146	764718.13	0.03	0	0.03	Not Defined	5 -Year
67	400216.604	767032.0185	0.484	0	0.48	Not Defined	5 -Year
68	400286.9703	767375.5052	0.03	0	0.03	Not Defined	5 -Year
69	400629.5265	767122.7773	0.157	0	0.16	Not Defined	5 -Year
70	400281.0945	767538.8136	0.054	0	0.05	Not Defined	5 -Year
71	400232.614	767491.0335	0.036	0	0.04	Not Defined	5 -Year
72	400195.5664	766543.4936	0.214	0	0.21	Not Defined	5 -Year
73	400591.6915	767270.4467	0.031	0	0.03	Not Defined	5 -Year
74	400916.8685	767173.9751	0.541	0	0.54	Not Defined	5 -Year
75	400871.3918	767253.7748	0.03	0	0.03	Not Defined	5 -Year
76	400101.0988	766481.8705	0.178	0	0.18	Not Defined	5 -Year
77	399945.4458	766604.9996	0.03	0	0.03	Not Defined	5 -Year
78	399983.3826	766800.7292	0.246	0	0.25	Not Defined	5 -Year
79	398916.988	767351.5972	0.127	0	0.13	Not Defined	5 -Year
80	398909.796	767174.2721	0.03	0	0.03	Not Defined	5 -Year
81	399049.9588	767327.7914	0.079	0	0.08	Not Defined	5 -Year
82	401874.9283	764805.3122	0.189	0	0.19	Not Defined	5 -Year
83	401584.0267	764747.1491	0.092	0	0.09	Not Defined	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Lat	Long					
84	401616.3756	764616.9599	0.133	0	0.13	Not Defined	5 -Year
85	398831.9742	767036.8852	0.03	0	0.03	Not Defined	5 -Year
86	398825.4261	766964.2596	0.03	0	0.03	Not Defined	5 -Year
87	398982.4255	767140.0794	0.03	0	0.03	Not Defined	5 -Year
88	398898.416	767059.4218	0.03	0	0.03	Not Defined	5 -Year
89	399006.0431	766955.1769	0.047	0	0.05	Not Defined	5 -Year
90	398887.2565	766715.3793	0.146	0	0.15	Not Defined	5 -Year
91	399013.1462	766570.6341	0.03	0	0.03	Not Defined	5 -Year
92	399031.2231	766663.5806	0.039	0	0.04	Not Defined	5 -Year
93	399082.6201	766848.0069	0.46	0	0.46	Not Defined	5 -Year
94	400216.604	767032.0185	0.166	0	0.17	Not Defined	5 -Year
95	400286.9703	767375.5052	0.03	0	0.03	Not Defined	5 -Year
96	400436.5687	767148.5725	1.048	0	1.05	Not Defined	5 -Year
97	400629.5265	767122.7773	0.157	0	0.16	Not Defined	5 -Year
98	400281.0945	767538.8136	0.054	0	0.05	Not Defined	5 -Year
99	400232.614	767491.0335	0.036	0	0.04	Not Defined	5 -Year
100	400195.5664	766543.4936	0.214	0	0.21	Not Defined	5 -Year
101	400591.6915	767270.4467	0.031	0	0.03	Not Defined	5 -Year
102	400916.8685	767173.9751	0.541	0	0.54	Not Defined	5 -Year
103	400871.3918	767253.7748	0.03	0	0.03	Not Defined	5 -Year
104	400101.0988	766481.8705	0.178	0	0.18	Not Defined	5 -Year
105	399945.4458	766604.9996	0.03	0	0.03	Not Defined	5 -Year
106	399983.3826	766800.7292	0.246	0	0.25	Not Defined	5 -Year
107	398177.5504	766213.7024	0.043	0.37	-0.33	Not Defined	5 -Year
108	398192.3003	766128.6526	0.03	0.4	-0.37	Not Defined	5 -Year
109	398148.3247	766467.938	6.165	3	3.17	Not Defined	5 -Year
110	398151.0748	766348.0849	0.03	0.1	-0.07	Not Defined	5 -Year
111	398120.2401	766228.9605	0.03	0.4	-0.37	Not Defined	5 -Year
112	398235.5923	766233.8223	0.142	0.4	-0.26	Not Defined	5 -Year
113	398177.5058	766361.4114	0.03	0.4	-0.37	Not Defined	5 -Year
114	398164.6592	766288.6875	0.03	0.35	-0.32	Not Defined	5 -Year
115	397961.5689	766218.8762	0.03	0.3	-0.27	Not Defined	5 -Year
116	397788.01	766222.8627	0.03	0.35	-0.32	Not Defined	5 -Year
117	397842.1601	766230.0542	0.07	0.37	-0.30	Not Defined	5 -Year
118	397676.6365	766275.3751	0.106	0.3	-0.19	Not Defined	5 -Year
119	397590.7038	766343.206	0.03	0.37	-0.34	Not Defined	5 -Year
120	398964.4174	767254.6547	0.031	0	0.03	Not Defined	5 -Year
121	399043.426	767205.6347	0.03	0	0.03	Not Defined	5 -Year
122	400254.6787	764802.2822	0.03	0	0.03	Not Defined	5 -Year
123	399783.5013	765111.1992	0.082	0	0.08	Not Defined	5 -Year
124	399664.7429	765232.8209	0.03	0	0.03	Not Defined	5 -Year
125	399219.3029	766685.5518	0.361	0	0.36	Not Defined	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Lat	Long					
126	399236.2124	766573.7428	0.342	0	0.34	Not Defined	5 -Year
127	399868.524	765201.1435	0.031	0	0.03	Not Defined	5 -Year
128	399930.7894	765176.3699	0.03	0	0.03	Not Defined	5 -Year
129	400000.8366	765234.8333	0.057	0	0.06	Not Defined	5 -Year
130	402436.6733	768451.6224	0.311	0	0.31	Not Defined	5 -Year
131	402117.9641	768576.7081	0.031	0	0.03	Not Defined	5 -Year
132	402268.511	769091.7447	0.918	0	0.92	Not Defined	5 -Year
133	402777.0192	769089.1377	0.03	0	0.03	Not Defined	5 -Year
134	401110.9721	767520.9873	0.03	0	0.03	Not Defined	5 -Year
135	401004.773	766979.2235	0.03	0	0.03	Not Defined	5 -Year
136	403179.9422	766234.8542	0.03	0	0.03	Not Defined	5 -Year
137	402803.5395	766534.6134	0.03	0	0.03	Not Defined	5 -Year
138	402652.8257	767059.3868	0.03	0	0.03	Not Defined	5 -Year
139	402043.297	767226.9151	0.128	0	0.13	Not Defined	5 -Year
140	403020.5294	767076.2838	0.29	0	0.29	Not Defined	5 -Year
141	403270.1106	767261.4513	0.03	0	0.03	Not Defined	5 -Year
142	402681.622	767573.6557	0.344	0	0.34	Not Defined	5 -Year
143	401987.9323	767100.7596	0.475	0	0.48	Not Defined	5 -Year
144	401047.0693	767262.5085	0.031	0	0.03	Not Defined	5 -Year
145	401279.9938	768569.8811	0.044	0	0.04	Not Defined	5 -Year
146	400506.8661	767805.3865	0.031	0	0.03	Not Defined	5 -Year
147	400761.9057	769058.2103	0.03	0	0.03	Not Defined	5 -Year
148	401038.3596	769840.3399	0.03	0	0.03	Not Defined	5 -Year
149	401506.205	769836.1382	0.039	0	0.04	Not Defined	5 -Year
150	400859.8222	771228.3178	0.03	0	0.03	Not Defined	5 -Year
151	400867.8753	771512.663	0.03	0	0.03	Not Defined	5 -Year
152	400464.5644	771866.672	0.03	0	0.03	Not Defined	5 -Year
153	401298.4509	771144.4545	0.03	0	0.03	Not Defined	5 -Year
154	402055.9809	771222.407	0.03	0	0.03	Not Defined	5 -Year
155	402616.4549	771195.7066	0.03	0	0.03	Not Defined	5 -Year
156	403682.0853	770918.5438	0.03	0	0.03	Not Defined	5 -Year
157	403935.2389	770595.0226	0.03	0	0.03	Not Defined	5 -Year
158	403002.9675	770947.0008	0.03	0	0.03	Not Defined	5 -Year
159	402381.7017	770544.2863	0.03	0	0.03	Not Defined	5 -Year
160	403237.4975	770114.3843	0.03	0	0.03	Not Defined	5 -Year
161	399026.0814	765886.6827	0.314	0	0.31	Not Defined	5 -Year
162	399201.6251	765937.8663	0.663	0	0.66	Not Defined	5 -Year
163	402261.5841	765735.6126	0.81	0.2	0.61	17 October 2016	5 -Year
164	401059.1306	764871.0773	0.285	1.105	-0.82	Not Defined	5 -Year
165	401419.9488	764800.9676	0.182	0.53	-0.35	Not Defined	5 -Year
166	401257.1672	765191.549	0.03	0.72	-0.69	Not Defined	5 -Year
167	401454.9691	765211.631	0.183	1.102	-0.92	Not Defined	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Lat	Long					
168	401492.5726	765291.495	0.113	0.92	-0.81	Not Defined	5 -Year
169	401656.3897	765394.2295	0.976	1.103	-0.13	Not Defined	5 -Year
170	401732.3706	765436.7633	0.586	1.101	-0.52	Not Defined	5 -Year
171	401135.206	765256.5664	0.125	0.49	-0.37	6 October 2013	5 -Year
172	401093.263	765336.6907	0.07	0.1	-0.03	Not Defined	5 -Year
173	399619.0112	766161.3927	0.03	0.75	-0.72	Not Defined	5 -Year
174	399498.2802	765597.6562	0.114	0.54	-0.43	Not Defined	5 -Year
175	402376.9529	764025.3758	0.324	0.92	-0.60	Not Defined	5 -Year
176	402305.0737	763990.9042	0.202	0.92	-0.72	Not Defined	5 -Year
177	400860.2156	770912.4469	0.036	0	0.04	Not Defined	5 -Year
178	399719.1711	767234.1879	0.031	0	0.03	Not Defined	5 -Year
179	399507.8865	767093.6285	0.03	0	0.03	Not Defined	5 -Year
180	399779.5068	767934.1397	0.03	0	0.03	Not Defined	5 -Year
181	399522.4802	767732.4178	0.03	0	0.03	Not Defined	5 -Year
182	397808.3616	766404.6954	0.07	0.2	-0.13	Not Defined	5 -Year
183	397937.2407	766434.5169	0.03	0.22	-0.19	18 September 2013	5 -Year
184	399677.0517	765487.7491	0.03	0	0.03	Not Defined	5 -Year
185	399776.2833	765323.5989	0.24	0	0.24	Not Defined	5 -Year
186	400376.1881	765547.3363	0.03	0	0.03	Not Defined	5 -Year
187	400222.2562	765531.5974	0.03	0	0.03	Not Defined	5 -Year
188	400165.0676	765379.0228	0.056	0	0.06	Not Defined	5 -Year
189	400343.3166	765283.8237	0.03	0	0.03	Not Defined	5 -Year
190	400358.4156	765147.8063	0.525	0	0.53	Not Defined	5 -Year
191	400223.7623	765045.02	0.1	0	0.10	Not Defined	5 -Year
192	400232.762	765129.8024	0.03	0	0.03	Not Defined	5 -Year
193	400091.6472	765057.2116	0.03	0	0.03	Not Defined	5 -Year
194	400042.014	764811.1994	0.03	0.1	-0.07	Not Defined	5 -Year
195	401974.9858	767797.9728	0.03	0	0.03	Not Defined	5 -Year
196	400575.6204	769799.6486	0.559	0	0.56	Not Defined	5 -Year
197	400697.7402	769301.4537	0.03	0	0.03	Not Defined	5 -Year
198	400733.3161	768663.3443	0.03	0	0.03	Not Defined	5 -Year
199	401222.8429	766325.8459	0.489	0	0.49	Not Defined	5 -Year
200	398829.118	765957.4891	0.03	0	0.03	Not Defined	5 -Year
201	404231.1981	764863.3201	0.04	0	0.04	Not Defined	5 -Year
202	403684.5698	764403.1776	0.038	0	0.04	Not Defined	5 -Year
203	404346.179	764360.289	0.09	0	0.09	Not Defined	5 -Year
204	398241.889	766688.8775	0.291	0	0.29	Not Defined	5 -Year
205	402475.5001	770312.3778	0.03	0	0.03	Not Defined	5 -Year
206	402042.9987	770780.5241	0.03	0	0.03	Not Defined	5 -Year
207	401289.9081	768730.2847	0.116	0	0.12	Not Defined	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Lat	Long					
208	401616.1694	768921.0486	0.321	0	0.32	Not Defined	5 -Year
209	402549.0453	769527.7098	0.302	0	0.30	Not Defined	5 -Year
210	401873.9123	768276.2221	0.03	0	0.03	Not Defined	5 -Year
211	402502.5019	769982.6387	0.144	0	0.14	Not Defined	5 -Year
				RMSE	0.33		

ANNEX 12. Educational Institutions affected in Tumaga-San Jose Floodplain

Zamboanga City				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Spinola Child Learning Center	Tetuan	Low	Low	Low
Putik elementary school	Putik	Low	Low	Low
LUNZURAN ELEM. SCHOOL	Lunzuran	Low	Low	Low
ATENEO DE ZAMBOANGA UNIVERSITY	Barangay Zone I	Low	Low	Low
ATENEO DE ZAMBOANGA UNIVERSITY	Barangay Zone III	Low	Low	Low
TUMAGA ELEM. SCHOOL	Tumaga	Low	Low	Low
ARENA BLANCO ELEM. SCHOOL -WEST	Mampang	Low	Low	Low
Talon talon national highschool	Kasanyangan	Low	Low	Low
CENTRAL ELEMENTARY SCHOOL	Barangay Zone I	Low	Low	Low
CENTRAL ELEMENTARY SCHOOL	Barangay Zone IV	Low	Low	Low
SAINT JOSEPH SCHOOL	Canelar	Low	Low	Low
RIO HONDO	Rio Hondo	Low	Low	Low
sti	Barangay Zone IV	Low	Low	Low
ZSCMST college	Rio Hondo	Low	Low	Low
STA. BARBARA	Barangay Zone IV	Low	Low	Low
STA. BARBARA	Rio Hondo	Low	Low	Low
STA. BARBARA	Santa Catalina	Low	Low	Low
Icas	Santa Barbara	Low	Low	Low
Icas	Tetuan	Low	Low	Low
Pastor bonus semenary	Santa Barbara	Low	Low	Low
SOUTHCOM NATIONAL HIGH SCHOOL	Campo Islam	None	Low	Low
Southcom elem. School	Campo Islam	None	Low	Low
uz Senior high	Barangay Zone III	None	Low	Low
uz Senior high	Santa Barbara	None	Low	Low
Early childhood prep learning center	Putik	None	Low	Low
STA. MARIA ELEMENTARY SCHOOL	Camino Nuevo	None	Low	Low
Tetuan central school	Santa Barbara	None	Low	Low
Tetuan central school	Tetuan	None	Low	Low
BALIWASAN	Baliwasan	None	Low	Low
BALIWASAN	San Jose Cawa-Cawa	None	Low	Low
ZAMBOWOOD ELEM. SCHOOL	Zambowood	None	None	Low
MAMPANG ELEM. SCHOOL	Mampang	None	None	Low
chongwa school	Barangay Zone IV	None	None	Low
POLYTECHNIC SCHOOL	Baliwasan	Low	Low	Medium
POLYTECHNIC SCHOOL	San Jose Cawa-Cawa	Low	Low	Medium
Canelar elementary	Barangay Zone II	Low	Low	Medium
BRENT	Santo Niño	Low	Low	Medium
Ateneo de Zamboanga university	Lunzuran	Low	Medium	Medium

Zamboanga City				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Ateneo de Zamboanga university	Tumaga	Low	Medium	Medium
Smart lkids learning center	Putik	Low	Medium	Medium
PHILIPPINE ISLAMIC COLLEGE HMIJ	Baliwasan	Low	Medium	Medium
PHILIPPINE ISLAMIC COLLEGE HMIJ	Canelar	Low	Medium	Medium
COMPUTER TECHNOLOGIES INSTITUTE INC.	Baliwasan	Low	Medium	Medium
Southern city College	Canelar	Low	Medium	Medium
Southern city College	Santa Catalina	Low	Medium	Medium
DON PABLO LORENZO MEMORIAL HIGH SCHOOL	Canelar	Low	Medium	Medium
Sto nino village school	Putik	Low	Medium	Medium
Sto nino village school	Tetuan	Low	Medium	Medium
REGIONAL SCIENCE HIGH SCHOOL	San Roque	Low	Medium	Medium
Jong. Spirit senior memorial	Campo Islam	Low	Medium	Medium
TUGBUNGAN CENTRAL SCHOOL	Tugbungan	Low	Medium	Medium
PILAR COLLEGE	San Jose Cawa-Cawa	Low	Medium	Medium
WMSU	Baliwasan	Low	Medium	Medium
WMSU	San Jose Cawa-Cawa	Low	Medium	Medium
a.b simpson alliance school	Santa Barbara	Low	Medium	Medium
Chinese abalo	Camino Nuevo	Medium	Medium	Medium
Chinese abalo	Santa Barbara	Medium	Medium	Medium
SAN ROQUE ELEMENTARY SCHOOL	San Roque	Medium	Medium	Medium
Infancia	Santa Maria	Medium	Medium	Medium
STA. CATALINA	Santa Catalina	Medium	Medium	Medium
zchs main	Santa Barbara	Medium	Medium	Medium
maria clara lorenzo lobregat national high school	Putik	Medium	High	High
SAN JOSE GUSE ELEM. SCHOOL	Campo Islam	Medium	High	High
SAN JOSE GUSE ELEM. SCHOOL	Canelar	Medium	High	High
Bethany	Tumaga	Medium	High	High
UPPER PASONANCA ELEM. SCHOOL	Cabatangan	High	High	High
boalan elem.school	Boalan	High	High	High
imaculate elem school	Tetuan	None	None	None
LUYAHAN ELEM. SCHOOL	Lunzuran	None	None	None
DIVISORIA ELEM. SCHOOL	Boalan	None	None	None
day care center divisoria	Boalan	None	None	None
WES. MIN. COM	Campo Islam	None	None	None
SARANG BANGUN LEARNING CENTER AND HIGH SCHOOL	Baliwasan	None	None	None
avalokitesvara	Santa Barbara	None	None	None
Bahay bulilit	Barangay Zone II	None	None	None
yogi school	Tumaga	None	None	None

Zamboanga City				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
ARENA BLANCO NATIONAL HIGH SCHOOL	Mampang	None	None	None
ARENA BLANCO NATIONAL HIGH SCHOOL	Tugbungan	None	None	None
School of masjid	Talon-Talon	None	None	None
boalal cindee	Boalan	None	None	None
kinder garden school and extension	Kasanyangan	None	None	None
UPPER CALARIAN 2	Calarian	None	None	None
UPPER CALARIAN 2	Sinunoc	None	None	None
UPPER CALARIAN	Calarian	None	None	None
Malagutay elementary school	Malagutay	None	None	None
west high school	San Jose Cawa-Cawa	None	None	None
INIVERSIDAD DE ZAMBOANGA	Barangay Zone IV	None	None	None
daycare center	Rio Hondo	None	None	None
Uz	Tetuan	None	None	None

ANNEX 13. Health Institutions affected in Tumaga-San Jose Floodplain

Zamboanga City				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Memorial hospital	Tetuan	Low	Low	Low
Zamboanga doctors hospital	Santa Barbara	Low	Low	Low
BRENT HOSPITAL	Santo Niño	Low	Low	Low
ZCMC HOSPITAL	Santa Catalina	Low	Low	Low
West metro medical center	Tetuan	None	Low	Low
Wes.min.com hospital	Campo Islam	None	Low	Low
catalina health center	Santa Catalina	None	Low	Low
Dampen hospital	Putik	None	None	Low
Health Center	Baliwasan	None	None	Low
CAMP NAVARRO	Campo Islam	Low	Medium	Medium
CIUDAD MEDICAL	Barangay Zone III	None	None	None
Generika	Tetuan	None	None	None
Oro	Tetuan	None	None	None
Generics pharmacy	Barangay Zone III	None	None	None
Generics pharmacy	Tetuan	None	None	None
Aleli tan dental clinic	Camino Nuevo	None	None	None
Cabato dental clinic	Tetuan	None	None	None
healt center mampang	Mampang	None	None	None
BALIWASAN	Baliwasan	None	None	None
RedCross	Barangay Zone IV	None	None	None
RedCross	Santa Catalina	None	None	None
health center	Santa Catalina	None	None	None