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

# LiDAR Surveys and Flood Mapping of San Jose River

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

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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 |
| ADNU | 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: INTRODUCTION

## 1.1 Background of the Phil-LiDAR 1 Program

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

The program also aimed to produce an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through DOST. The methods applied in this report are thoroughly described in a separate publication titled *Flood Mapping of Rivers in the Philippines Using Airborne LiDAR: Methods* (Paringit et al., 2017) available separately.

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

## 1.2 Overview of the San Jose River Basin

The San Jose River Basin covers Zamboanga City in Zamboanga Peninsula. The DENR River Basin Control Office identified the basin to have a drainage area of 127.44 km$^2$. It has an estimated 163 million cubic meter (MCM) annual run-off according to PHIL-LIDAR 1 partner HEI, Ateneo de Zamboanga University (AdZu) and UPD FMC.

Its main stem, San Jose River, is part of the 18 river systems in the Zamboanga Penisula Region. It is an urban river basin lying beside Tumaga River. It has a catchment area of 37.87 sq.km, enough to fully or partially cover 11 barangays of Zamboanga City. These barangays include Dulian, Capisan, Pasonanca, Sta Maria, Cabatangan, San Roque, Malagutay, Calarian, San Jose-Gusu, Canelar, and Baliwasan.


Figure 1. Concrete banks of San Jose River

According to the 2015 national census of NSO, a total of 74,998 persons are residing within the immediate vicinity of the river which is distributed among four (4) barangays in the Zamboanga City, namely San Roque, Campo Islam, Canelar, and Baliwasan.

Because it is not much forested in the upstream, the river is sometimes dry especially in dry seasons. The river only produces as little as 2, 160 cubic meters per day on normal weather conditions. This flow rate was measured at a footbridge (6.944259 E, 122.042434 N) on a small Muslim compound called Townsville in June 2016, a month after an El Niño struck the city. More than half of the river's stretch has concrete banks and runs through the most populated areas of the city making it a natural garbage pit. It passes beneath the runway of the Zamboanga International Airport and drains into the city's old and tarnished fishing docks in Baliwasan.

Local small-scale quarrymen therefore exploit the not much forested upstream riverbeds. Small-scale sand and gravel quarry has been an alternative means of livelihood for people living in the upstream parts of San Jose River. Quarrying takes place specifically in Brgy. San Roque and extensive enough to disrupt the natural course of the river. Although the local government issues environmental certification or clearance to local quarry establishments, most small-scale quarries are illegal.

There have been many cases of landslides particularly during rainy seasons due to excessive digging at the base of the river's banks. In May 2012, two were buried alive when a quarry caved in (Inquirer.net, 2012). That same month, a city resolution was passed mandating pertinent officials to earnestly monitor the ongoing quarries in San Roque.

In June 2015, Mayor Beng Climaco-Salazar ordered to stop all illegal quarrying operations in Zamboaga City.

Aside from landslide, with deforested uplands and clogged waterways downstream because of garbage accumulation, San Jose River easily gets flooded during rain events. Floods are even aggravated by the lack of open and unpaved ground surfaces which would supposedly absorbed some of the water. And even making it worse, houses are built along its riverbanks or even atop the concrete dikes.

Figure 2. Human wastes along San Jose River

Aside from the damages floods cause to the residents, they also disrupt the regular flights at the airport.

Last September 2012, Typhoon Lawin, internationally known as *Jelawat*, caused flooding and heavy rains for three days in Zamboanga City. A number of 171 families were evacuated in the city (http://newsinfo.inquirer.net/276310/1-missing-hundreds-evacuated-due-to-typhoon-lawin).

During a heavy rain in October 2013, the same rain event that flooded Tumaga River, the runway was flooded and flights were cancelled until the next day. These incidents somehow led to the plan of transferring the airport somewhere in Mercedes, Taluksangay, and Talabaan, which are located along Mercedes River.

San Jose was part of the Adopt-an-Estero/River Program of the Environmental Management Bureau of DENR 9 which was launched in June 2012. This program was implemented to encourage the local residents to take responsibility in cleaning the waterways in urban areas to mitigate flooding and contamination.

Sometimes referred to as San Jose-Gusu, the river got its name from the patron saint Joseph, the husband of Mary, the mother of Jesus. Gusu is the Spanish word for joy, "gozo." This term was used in the Spanish era to describe its inhabitants' simple and easy lifestyle.

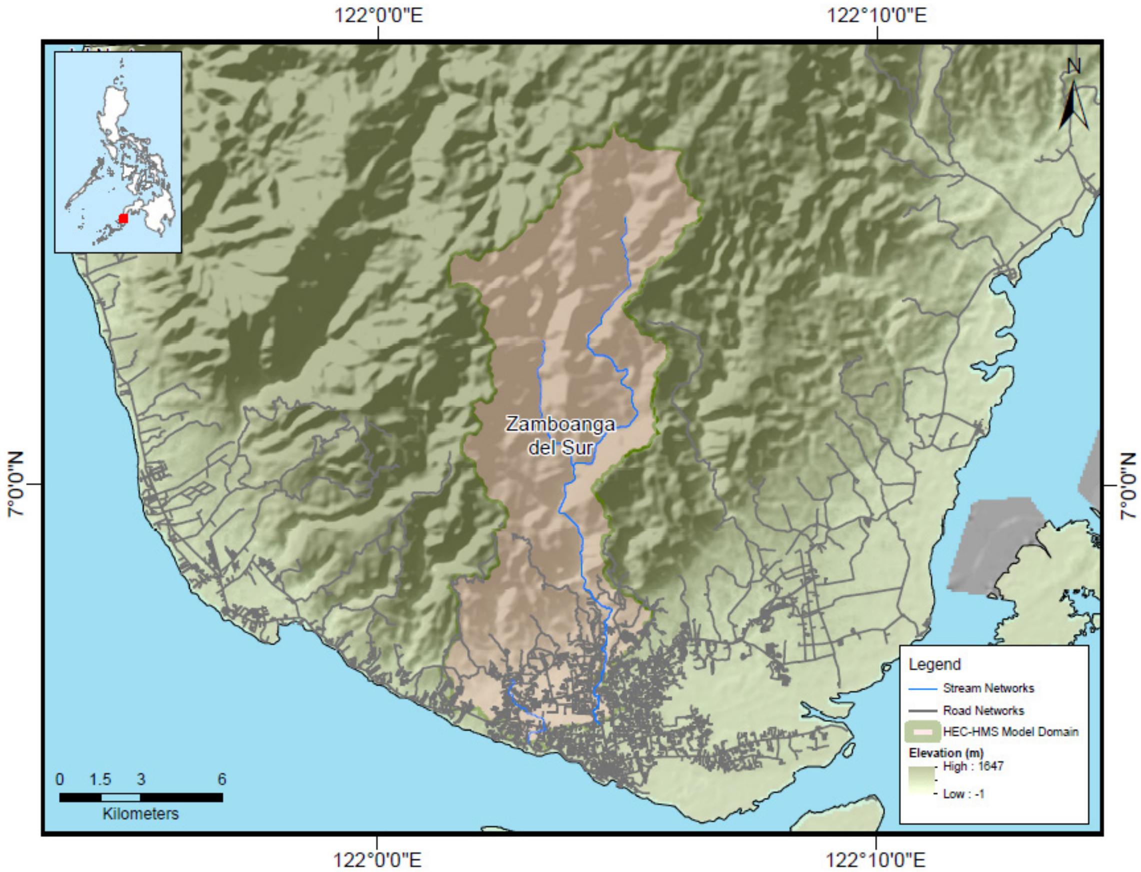



Figure 3. Map of San Jose River Basin (in brown)

# Chapter 2: LiDAR Acquisition in San Jose Floodplain

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Gracia Acuña, Engr. Gerome Hipolito,
Engr. Iro Niel D. Roxas, Ms. Rowena M. Gabua

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 San Jose Floodplain in Zamboanga. These missions were planned for16 lines that 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 and Table 2. Figure 4 shows the flight plans for San Jose 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 |

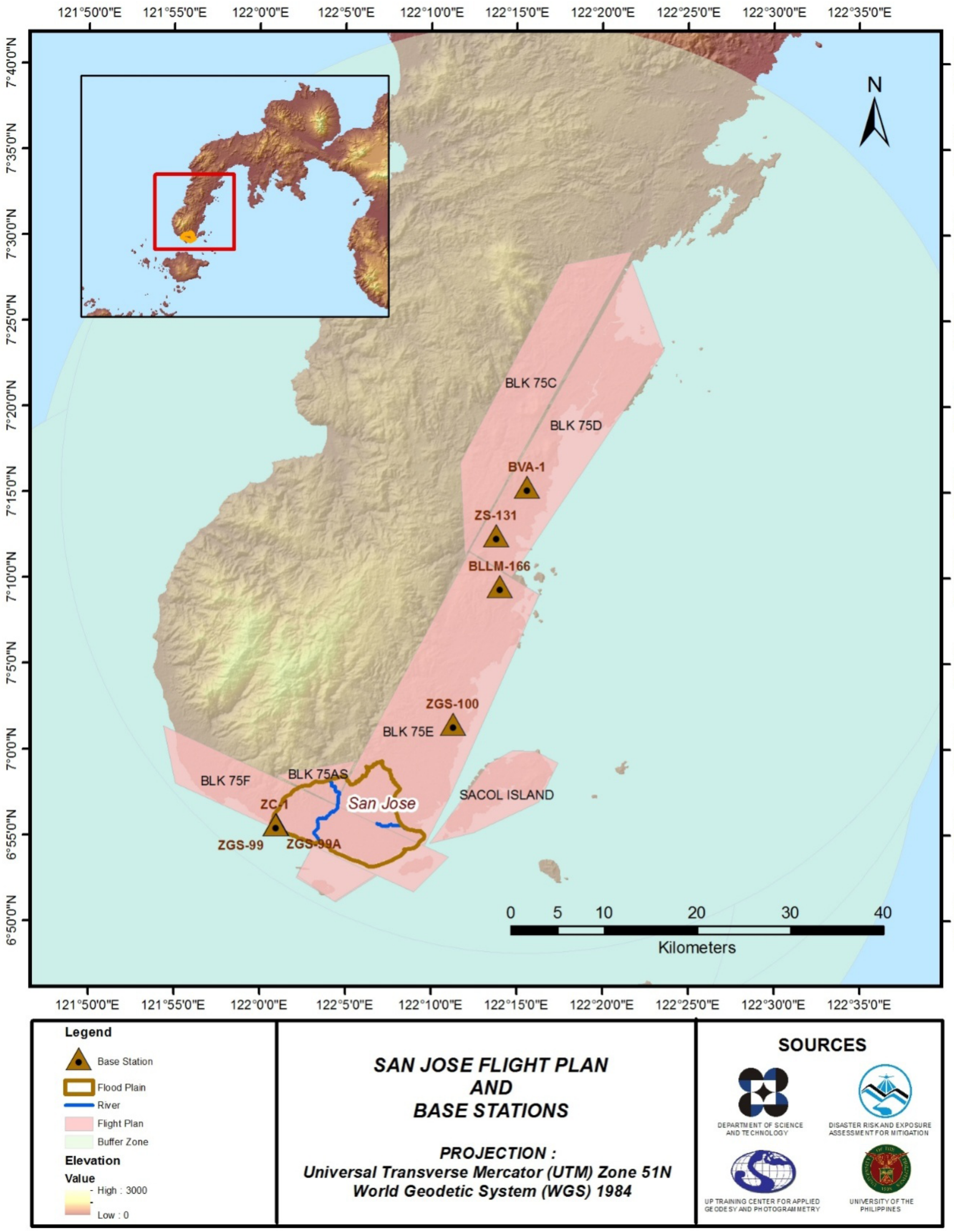
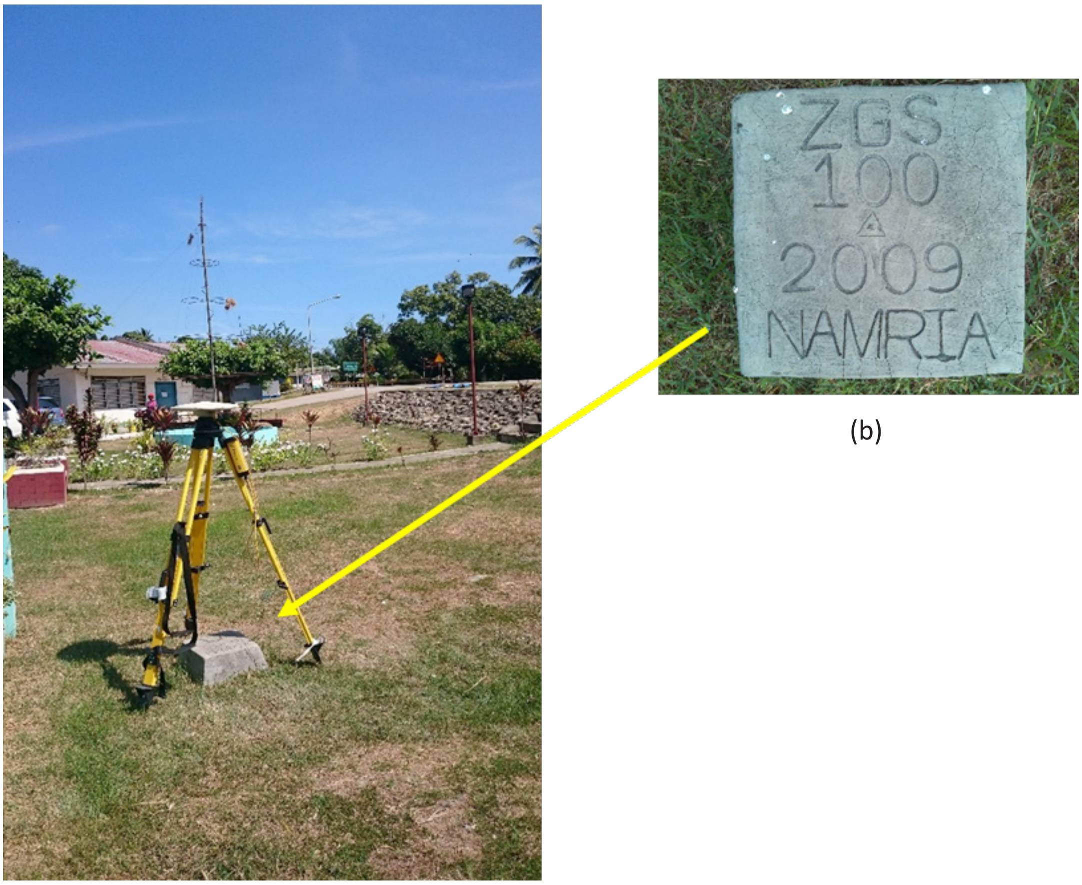



Figure 4. Flight plan and base stations used for San Jose Floodplain.

## 2.2 Ground Base Station

The project team was able to recover two (2) NAMRIA horizontal ground control points: ZGS-100 and ZGS-99 which are of second (2nd) order accuracy, and one (1) NAMRIA benchmark, ZS-131. This benchmark was used as vertical reference point and was also established as a ground control point. The project team also established four (4) reference points: ZC-1, BLLM-166, BVA-1 and ZG-99A. The certifications for the NAMRIA reference points are found in Annex 2 while the baseline processing reports for the established ground control points are found in Annex 3. 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 San Jose floodplain are shown in Figure 4.

Figure 5 to Figure 8 show the recovered NAMRIA reference points within the area. Table 3 to Table 9 present the details about the following NAMRIA control stations and established points while Table 10 lists all ground control points occupied during the acquisition with the corresponding dates of utilization.




(b)

(a)

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

Table 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 | |
| Relative Error (horizontal positioning) | 1:50,000 | |
| Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92) | Latitude<br>Longitude<br>Ellipsoidal Height | 7° 1’ 26.72368” North<br>122° 11’ 12.74401” East<br>11.27 meters |
| Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92) | Easting<br>Northing | 410158.521 meters<br>776712.542 meters |
| Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84) | Latitude<br>Longitude<br>Ellipsoidal Height | 7° 1’ 23.30149” North<br>122° 11’ 18.30044” East<br>75.603 meters |
| Grid Coordinates, Universal Transverse Mercator Zone 51 North<br>(UTM 51N PRS 1992) | Easting<br>Northing | 410189.97 meters<br>776440.68 meters |


(a) (b)

Figure 6. GPS set-up over ZS-131 in Curuan, Zamboanga City(a) and NAMRIA benchmark reference point ZS-131 (b) as recovered by the field team

Table 4. Details of the recovered NAMRIA BenchmarkZS-131with processed coordinates used as base station for the LiDAR data acquisition

| | | |
|---|---|---|
| Station Name | ZS-131 | |
| Order of Accuracy | 2nd | |
| Relative Error (horizontal positioning) | 1:50,000 | |
| 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 |

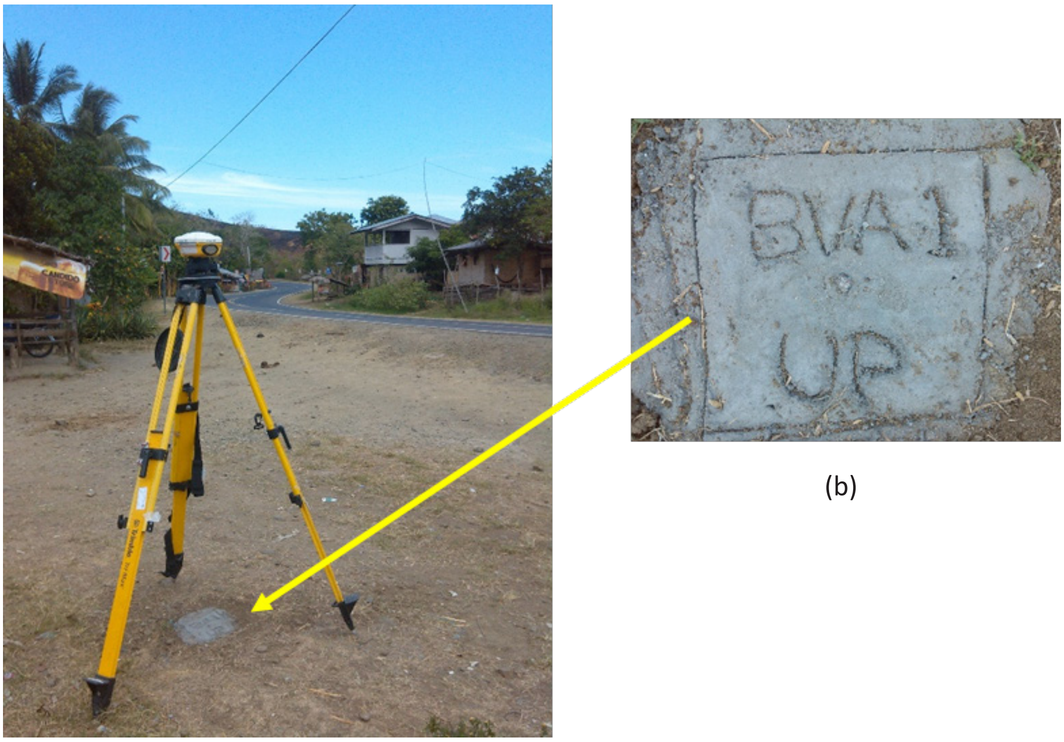

(a) (b)

Figure 7. GPS set-up overZGS-99beside the seawall in Calarian, Zamboanga City(a) and 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 | |
| Relative Error (horizontal positioning) | 1:50,000 | |
| 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 (WGS84) | 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 |

| Station Name | ZGS-100 | |
|---|---|---|
| Order of Accuracy | 2rd | |
| Relative Error (horizontal positioning) | 1 in 50,000 | |
| Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92) | Latitude | 7° 1' 26.72368" North |
| | Longitude | 122° 11' 12.74401" East |
| | Ellipsoidal Height | 11.27 meters |
| Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 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 |




(b)

(a)

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

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

| | | |
|---|---|---|
| Station Name | BVA-1 | |
| Order of Accuracy | 2nd | |
| Relative Error (horizontal positioning) | 1 in 50,000 | |
| Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92) | Latitude<br>Longitude<br>Ellipsoidal Height | 7° 15’ 19.31910” North122°<br>15’ 28.78738” East<br>82.446 meters |
| Grid Coordinates, Universal Transverse Mercator Zone 51 North<br>(UTM 51N PRS 1992) | Easting<br>Northing | 417939.856 meters<br>802333.522 meters |
| Geographic Coordinates, World Geodetic System 1984 Datum<br>(WGS 84) | Latitude<br>Longitude<br>Ellipsoidal Height | 7° 15’ 15.84241” North122°<br>15’ 34.32212” East<br>146.526 meters |

Table 7. Details of the established point BLLM-161 used as base station for the LiDAR acquisition

| | | |
|---|---|---|
| Station Name | BLLM-161 | |
| Order of Accuracy | 2nd | |
| Relative Error (horizontal positioning) | 1 in 50,000 | |
| Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92) | Latitude<br>Longitude<br>Ellipsoidal Height | 7°09'33.60926" North<br>122°13'54.54820" East<br>124.333 meters |
| Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992) | Easting<br>Northing | 415179.269 meters<br>791383.716 meters |
| Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84) | Latitude<br>Longitude<br>Ellipsoidal Height | 7°09'30.15553" North<br>122°14'00.09187" East<br>188.527 meters |

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

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

Table 9. Details of the established control point ZGS-99A used as base station for the LiDAR acquisition

| Station Name | ZGS-99A | |
|---|---|---|
| Order of Accuracy | 2nd | |
| Relative Error (horizontal positioning) | 1 in 50,000 | |
| Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92) | Latitude<br>Longitude<br>Ellipsoidal Height | 6° 55' 37.63895"North122° 00' 52.48834"East<br>7.850 meters |
| Grid Coordinates, Universal Transverse Mercator Zone 51 North<br>(UTM 51N PRS 1992) | Easting<br>Northing | 391136.071 meters<br>765756.864 meters |
| Geographic Coordinates, World Geodetic System 1984 Datum<br>(WGS 84) | Latitude<br>Longitude<br>Ellipsoidal Height | 6° 55' 34.22659" North122° 00' 58.05475" East<br>71.931 meters |

Table 10. Ground control points used during LiDAR data acquisition

| Date Surveyed | Flight Number | Mission Name | Ground Control Points |
|---|---|---|---|
| 23-Aug-14 | 7450GC | 2BLK75F235A | ZGS-99 and ZC-1 |
| 5-Feb-15 | 2535P | 1BLK75E36A | BLLM-166 and ZGS-100 |
| 8-Feb-15 | 2545P | 1BLK75S39A | BVA-1 and ZGS-100 |
| 11-Feb-15 | 2557P | 1BLK75S42A | ZGS-99 and ZGS-99A |
| 26-May-16 | 23394P | 1BLK75AS147B | ZGS-100 and ZS-131 |

## 2.3 Flight Missions

Five (5) missions were conducted to complete LiDAR data acquisition in San Josefloodplain, for a total of 18 hours and 25 minutes of flying time (18+25) for RP-C9022 and RP-C9122.All missions were acquired using the Gemini and Pegasus LiDAR systems. Table 11 shows the total area of actual coverage and the corresponding flying hours per mission while Table 12 presents the actual parameters used during the LiDAR data acquisition.

Table 11. Flight missions for LiDAR data acquisition in San Jose Floodplain.

| Date Surveyed | Flight Number | Flight Plan Area ($km^2$) | Surveyed Area ($km^2$) | Area Surveyed within the Floodplain ($km^2$) | Area Surveyed Outside the Floodplain ($km^2$) | No. of Images (Frames) | Flying Hours | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Hr | Min |
| 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.

| Flight Number | Flying Height (m AGL) | Overlap (%) | FOV (θ) | 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

This certain LiDAR acquisition survey covered the San Jose Floodplain (See Annex 7). San Jose Floodplain is located in the province of Zamboanga del Sur, with the floodplain situated within the municipality of 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 San Jose floodplain is presented in Figure 9.

Table 13. List of municipalities and cities surveyed in San Jose floodplain LiDAR survey.

| Province | Municipality/City | Area of Municipality/City (km²) | Total Area Surveyed (km²) | Percentage of Area Surveyed |
|---|---|---|---|---|
| Zamboanga del Norte | Kalawit | 329.51 | 5.03 | 1.53% |
| Zamboanga del Sur | Zamboanga City | 1461.05 | 522.74 | 35.78% |
| Zamboanga Sibugay | Ipil | 130.9 | 60 | 45.84% |
| | Roseller Lim | 272.39 | 9.61 | 3.53% |
| | Titay | 176.5 | 58.4 | 33.09% |
| | Tungawan | 441.86 | 26.7 | 6.04% |
| Total | | 2812.21 | 682.48 | 20.97% |

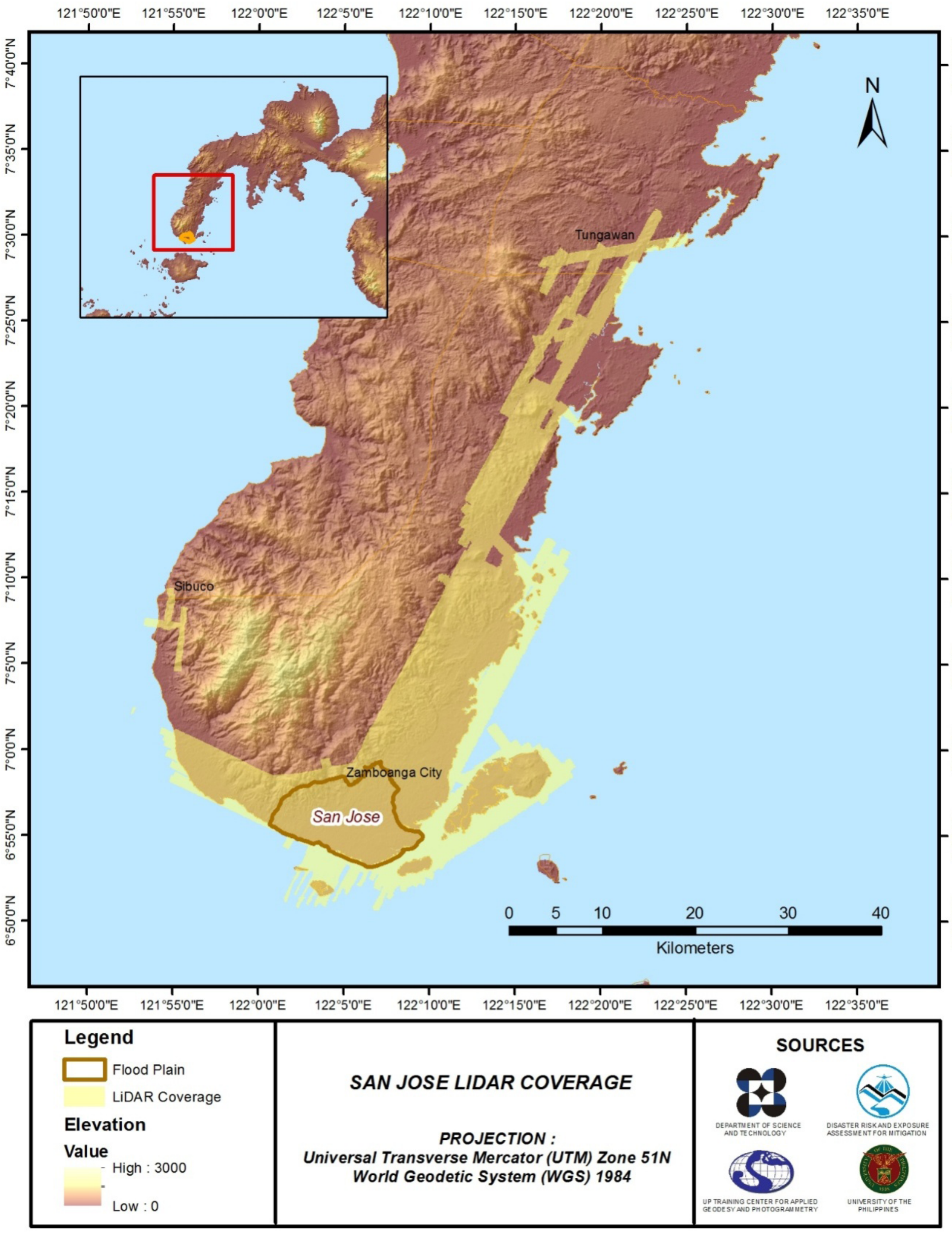



Figure 9. LiDAR coverage for San Jose Floodplain

# Chapter 3: LiDAR Data Processing for San Jose 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. Ma. Joanne I. Balaga, 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 were checked for completeness based on the list of raw files required to proceed with the pre-processing of the LiDAR data. Upon acceptance of the LiDAR field data, georeferencing of the flight trajectory was done to obtain the exact location of the LiDAR sensor when the laser was shot.

Point cloud georectification was performed to incorporate correct position and orientation for each point acquired. The georectified LiDAR point clouds were 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 were then classified into various classes before generating Digital Elevation Models such as Digital Terrain Model and Digital Surface Model.

Using the elevation of points gathered in the field, the LiDAR-derived digital models were calibrated. Portions of the river that are barely penetrated by the LiDAR system were replaced by the actual river geometry measured from the field by the Data Validation and Bathymetry Component. LiDAR acquired temporally were then mosaicked to completely cover the target river systems in the Philippines.

Orthorectification of images acquired simultaneously with the LiDAR data was done through the help of the georectified point clouds and the metadata containing the time the image was captured.

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

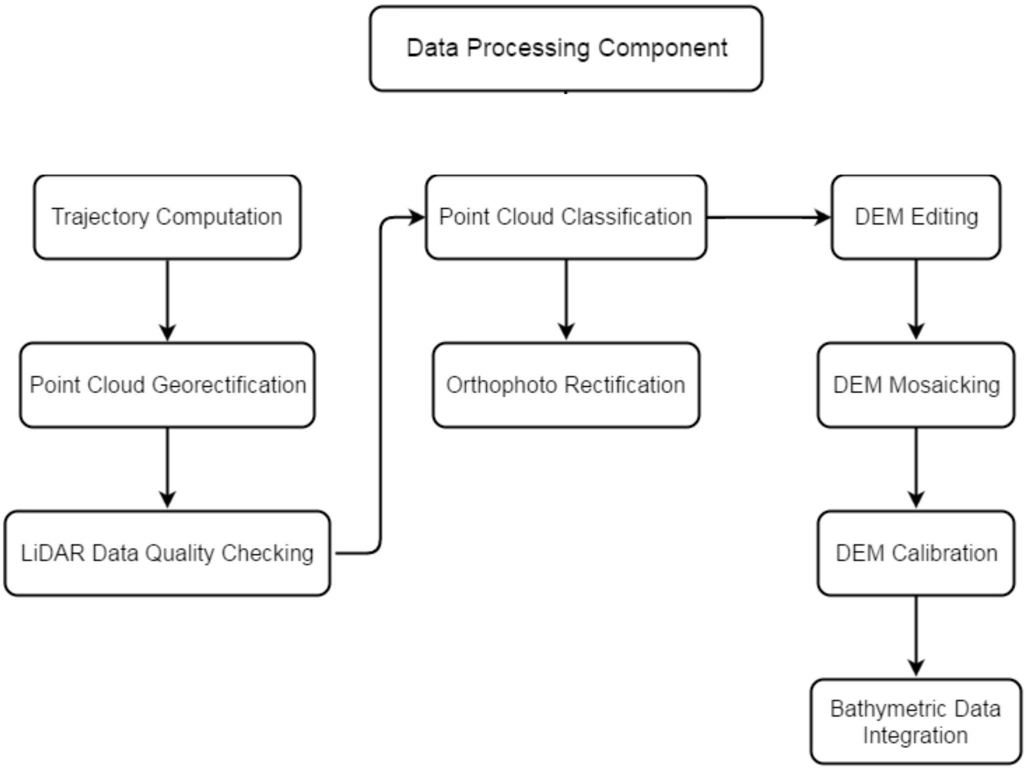



Figure 10. Schematic Diagram for Data Pre-Processing Component

## 3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for San Jose floodplain can be found in Annex 5. Missions flown during the first survey conducted in September 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Gemini system while missions acquired during the second and third survey were flown using the Pegasus system over Zamboanga City. The Data Acquisition Component (DAC) transferred a total of 103.43 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 September 23, 2014 for the first survey, February 24, 2015 for the second survey and July 11, 2016 for the third survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for San Jose was fully transferred on July 14, 2016, as indicated in the Data Transfer Sheets for San Jose Floodplain.

## 3.3 Trajectory Computation

The *Smoothed Performance Metrics* of the computed trajectory for flight 23394P, one of the San Jose flights, which is the North, East, and Down position RMSE values are shown in Figure 11. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on May 26, 2016 00:00AM. The y-axis is the RMSE value for that particular position.

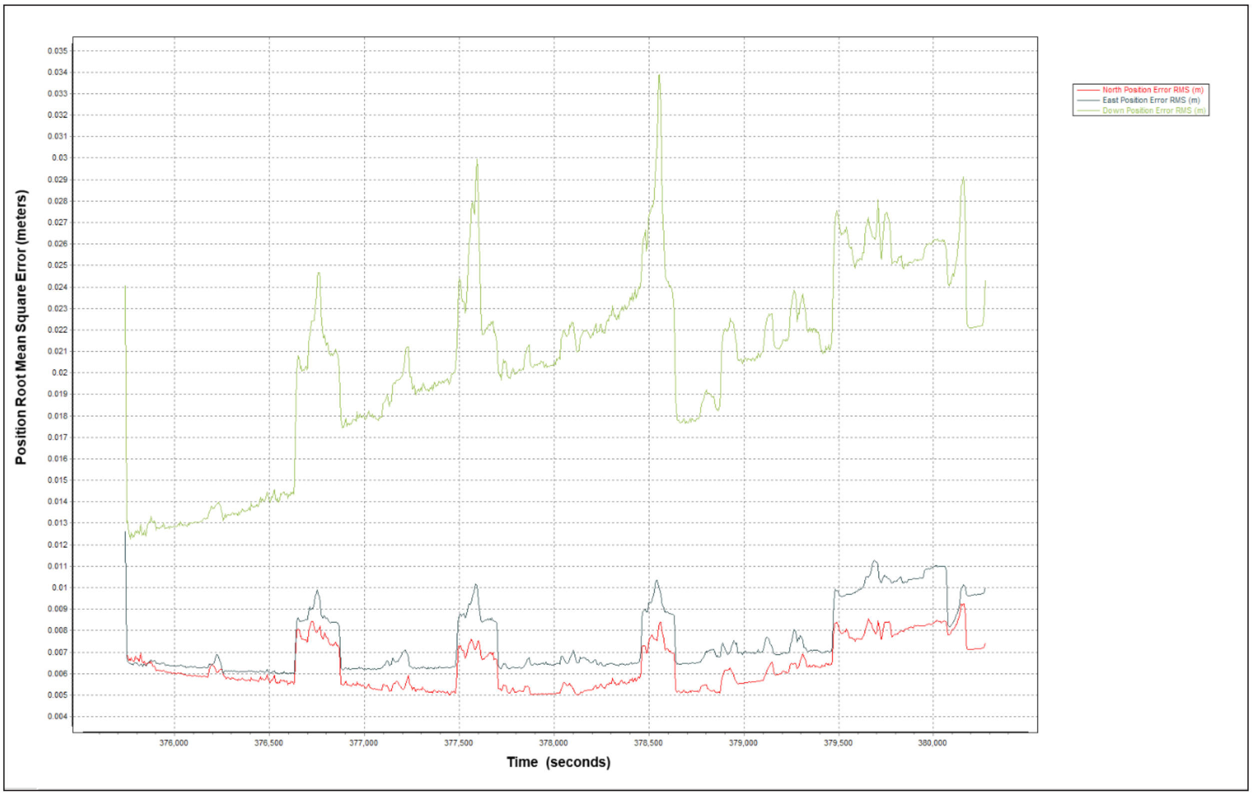



Figure 11. Smoothed Performance Metrics of San Jose Flight 23394P

The time of flight was from 376000 seconds to 380000 seconds, which corresponds to afternoon of May 26, 2016. 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 9 shows that the North position RMSE peaks at 0.92 centimeters, the East position RMSE peaks at 1.14centimeters, and the Down position RMSE peaks at 3.39centimeters, which are within the prescribed accuracies described in the methodology.

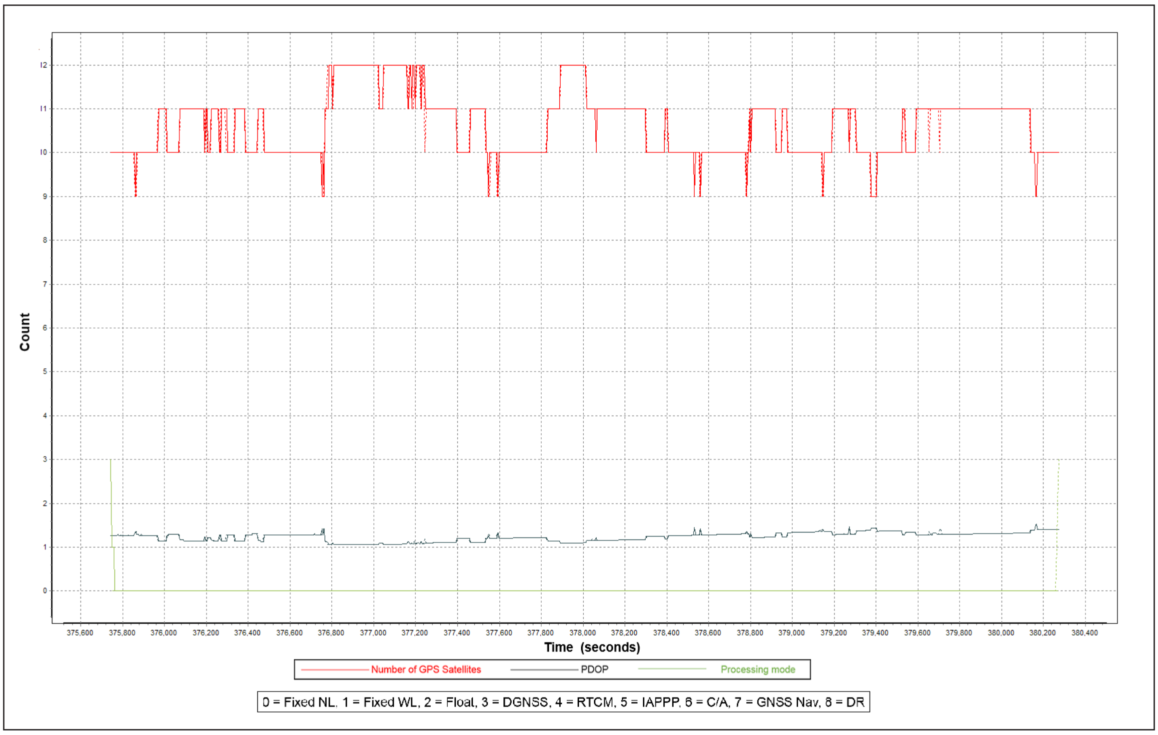



Figure 12. Solution Status Parameters of San Jose Flight 23394P

The *Solution Status* parameters of flight 23394P, one of the San Jose flights, which indicate the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 12. The graphs indicate that the number of satellites during the acquisition did not go down to 9. Most of the time, the number of satellites tracked was between 9 and 12. The PDOP value also did not go above the value of 2, which indicates optimal GPS geometry. The processing mode remained at 0 for majority of the survey. 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 San Jose flights is shown in Figure 13.

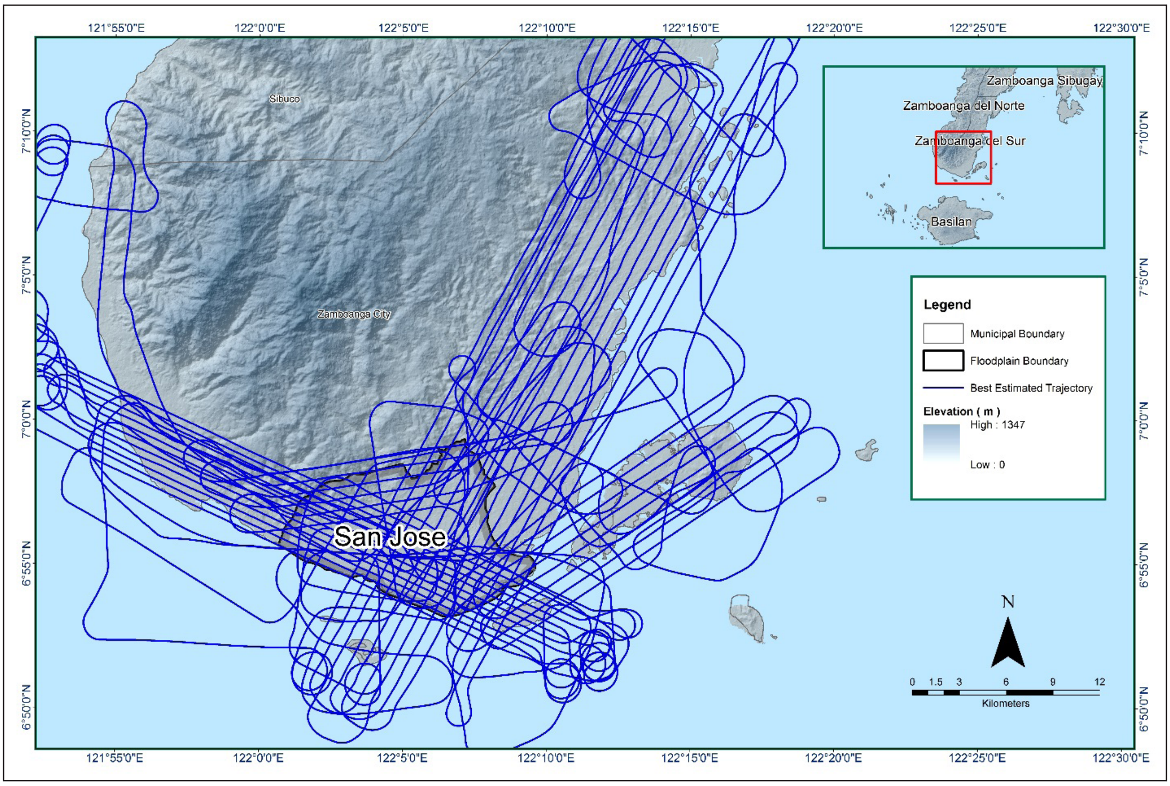



Figure 13. Best estimated trajectory for San Jose Floodplain

## 3.4 LiDAR Point Cloud Computation

The produced LAS data contains 54 flight lines, with each flight line containing one channel for the Gemini system and two channels for the Pegasus system. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over San Jose Floodplain are given in Table 14.

Table 14. Self-Calibration Results values for San Jose flights.

| Parameter | Value |
|---|---|
| Boresight Correction stdev(<0.001degrees) | 0.000190 |
| IMU Attitude Correction Roll and Pitch Corrections stdev(<0.001degrees) | 0.000887 |
| GPS Position Z-correction stdev(<0.01meters) | 0.0028 |

The optimum accuracy was obtained for all San Jose flights based on the computed standard deviations of the corrections of the orientation parameters. Standard deviation values for individual blocks are available in the Annex 8.

## 3.5 LiDAR Data Quality Checking

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

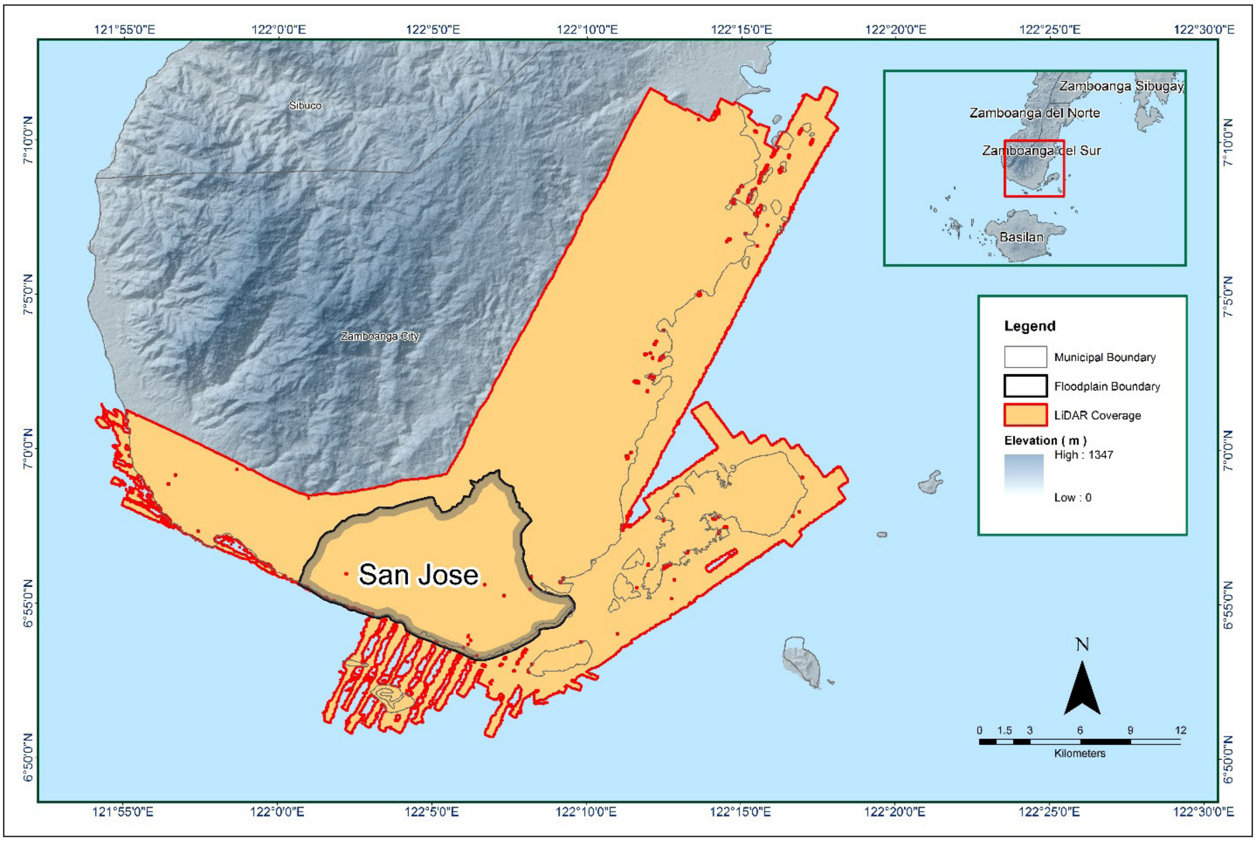



Figure 14. Boundary of the processed LiDAR data on top of a SAR Elevation Data over San Jose Floodplain.

The total area covered by the San Jose missions is 758.24 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 San Jose floodplain.

| LiDAR Blocks | Flight Numbers | Area (sq. km) |
|---|---|---|
| Zamboanga_Blk75E | 2535P | 422.89 |
| | 2545P | |
| Zamboanga_Blk75F | 7450G | 140.87 |
| Zamboanga_Blk75F_additional | 2557P | 2.48 |
| Zamboanga_Sacol | 2557P | 132.22 |
| Zamboanga_reflights_Blk75AS | 23394P | 35.31 |
| Zamboanga_reflights_Blk75F_supplement | 23394P | 24.47 |
| | TOTAL | 758.24 sq.km. |

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 15. Since the 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 for the Pegasus system which employs two channels, we would expect an average value of 2 (blue) for areas where there is limited overlap and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines.

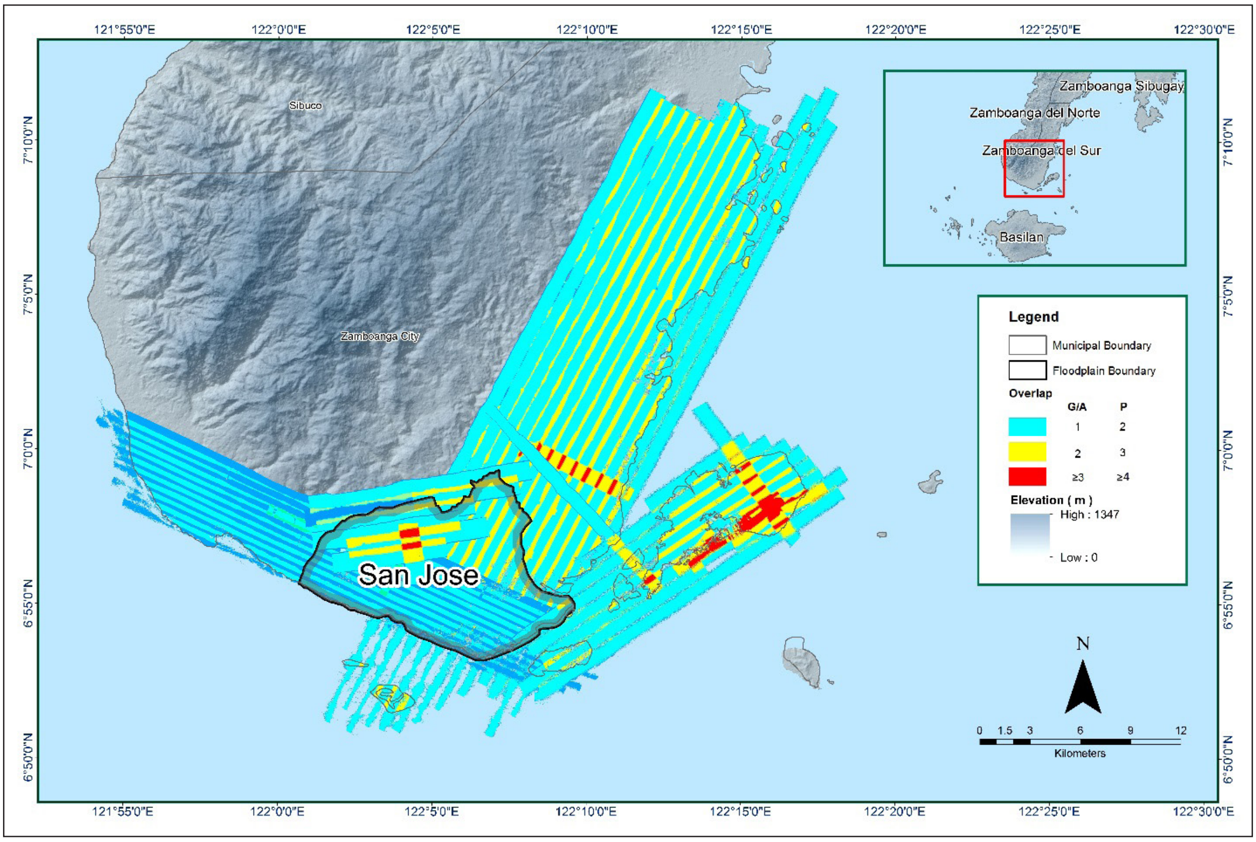



Figure 15. Image of data overlap for San Jose Floodplain

The overlap statistics per block for the San Jose Floodplain can be found in Annex 8. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are26.46% 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 16. It was determined that all LiDAR data for San Jose Floodplain satisfy the point density requirement, and the average density for the entire survey area is 2.77 points per square meter.

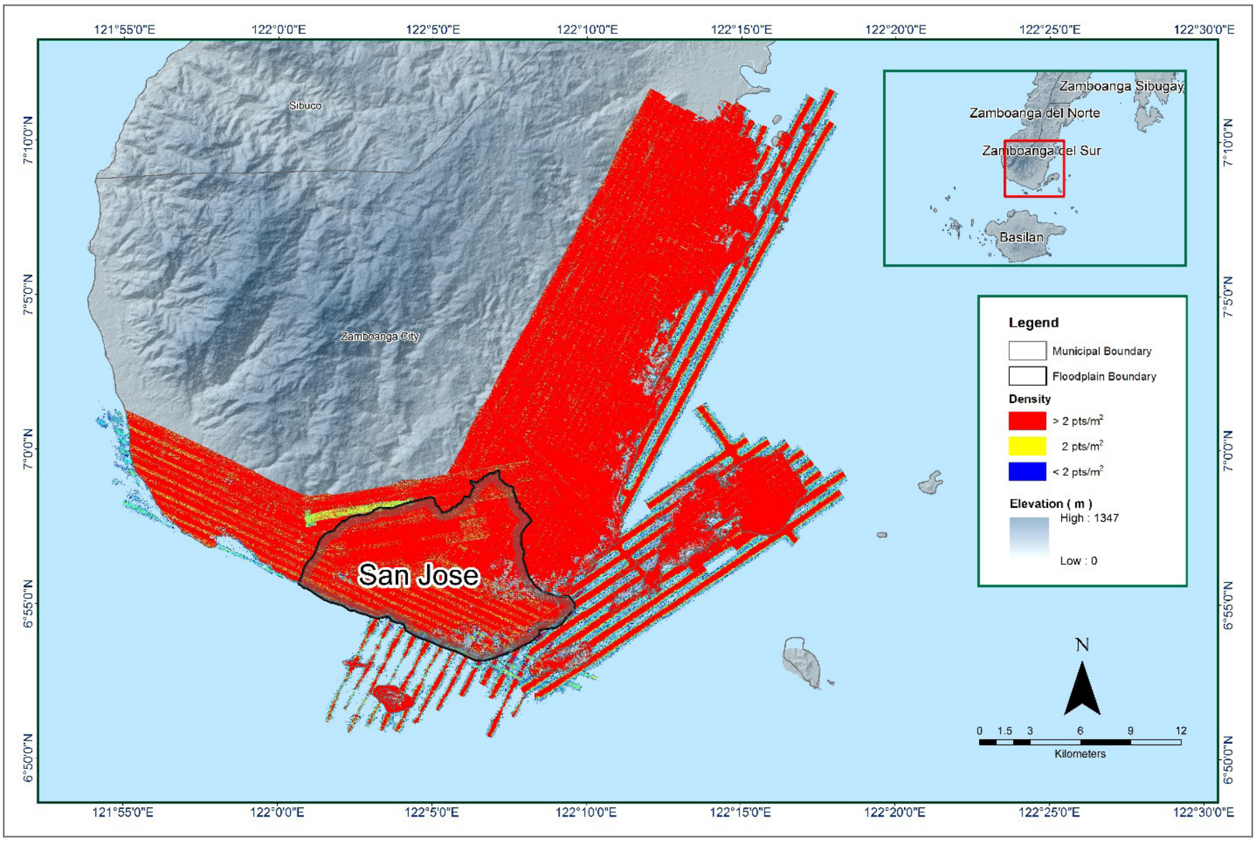



Figure 16. Pulse Density map of merged LiDAR data for San Jose Floodplain.

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

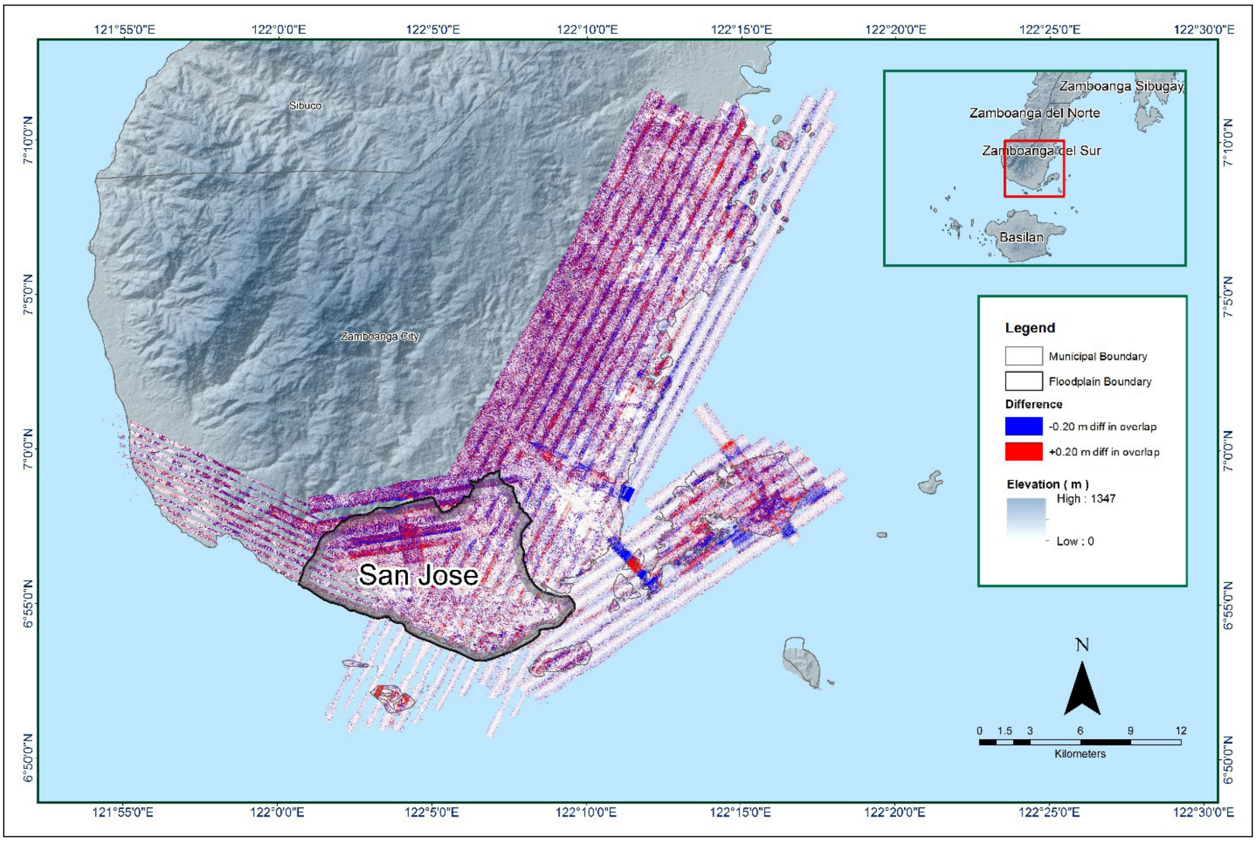



Figure 17. Elevation difference map between flight lines for San Jose Floodplain.

A screen capture of the processed LAS data from a San Jose flight 23394P loaded in QT Modeler is shown in Figure 18. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

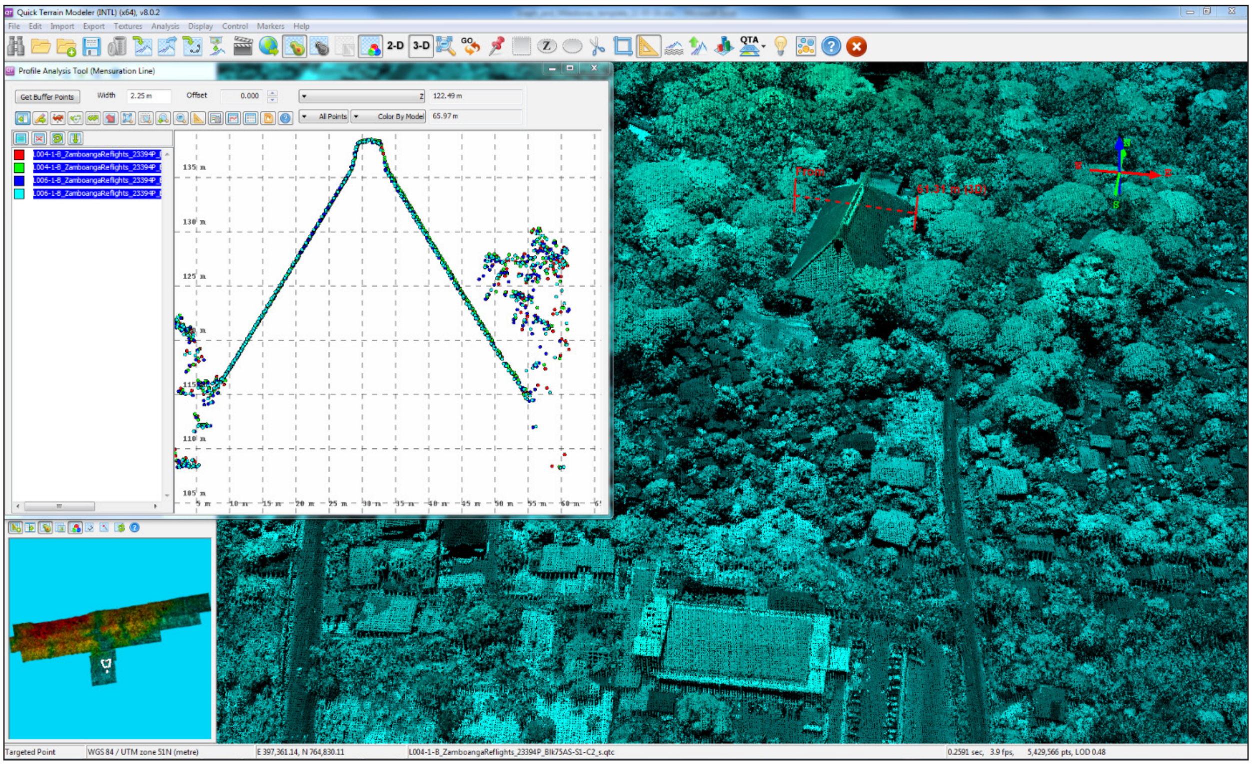


Figure 18. Quality checking for San Jose flight 23394P using the Profile Tool of QT Modeler.

## 3.6 LiDAR Point Cloud Classification and Rasterization

Table 16. San Jose 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 San Jose Floodplain is shown in Figure 19. A total of 1,035 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.

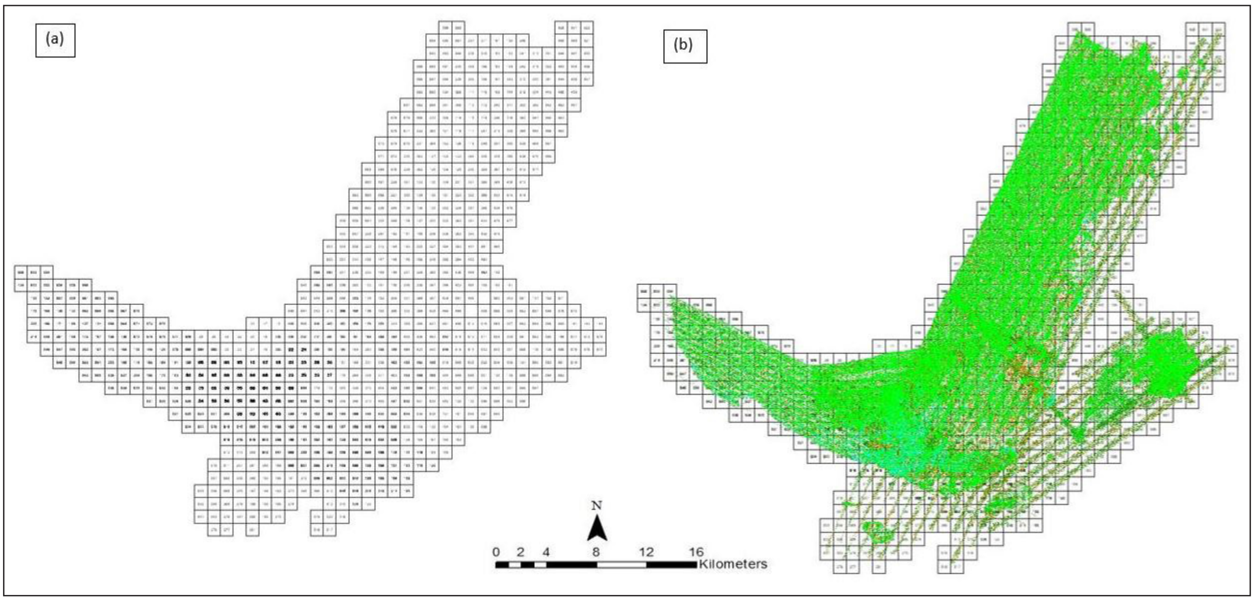



Figure 19. Tiles for San Jose Floodplain (a) and classification results (b) in TerraScan.

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

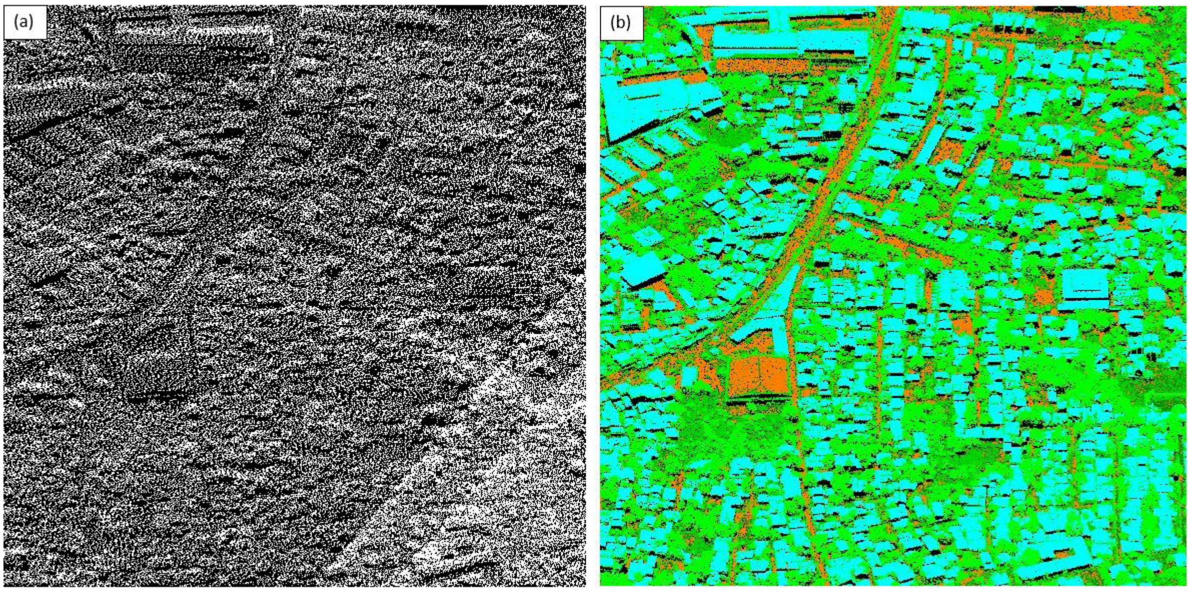



Figure 20. Point cloud before (a) and after (b) classification.

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

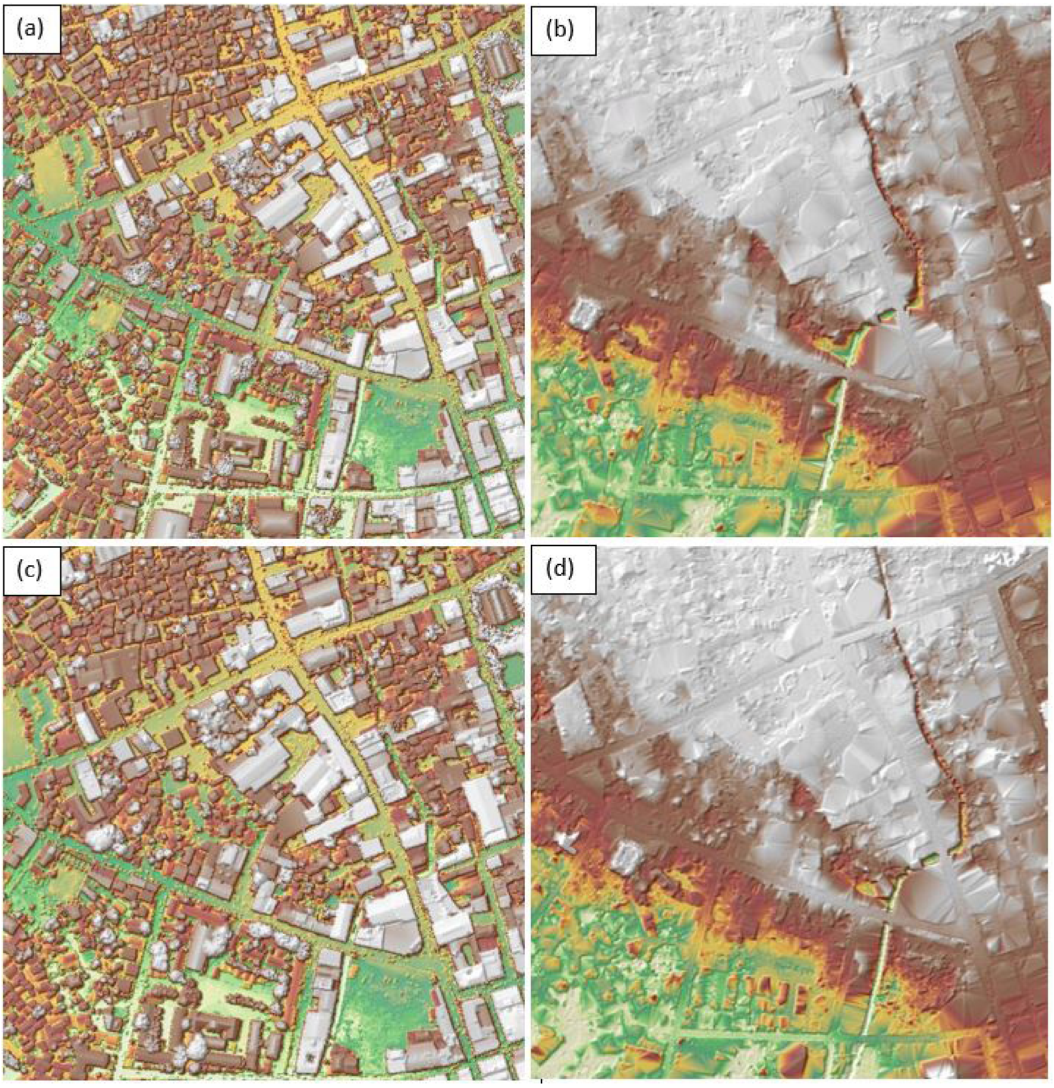



Figure 21. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of San Jose Floodplain.

## 3.7 LiDAR Image Processing and Orthophotograph Rectification

The 697 1km by 1km tiles area covered by San Jose Floodplain is shown in Figure 22. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The San Jose Floodplain has a total of 573.57 sq.km orthophotogaph coverage comprised of1,319 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 23.

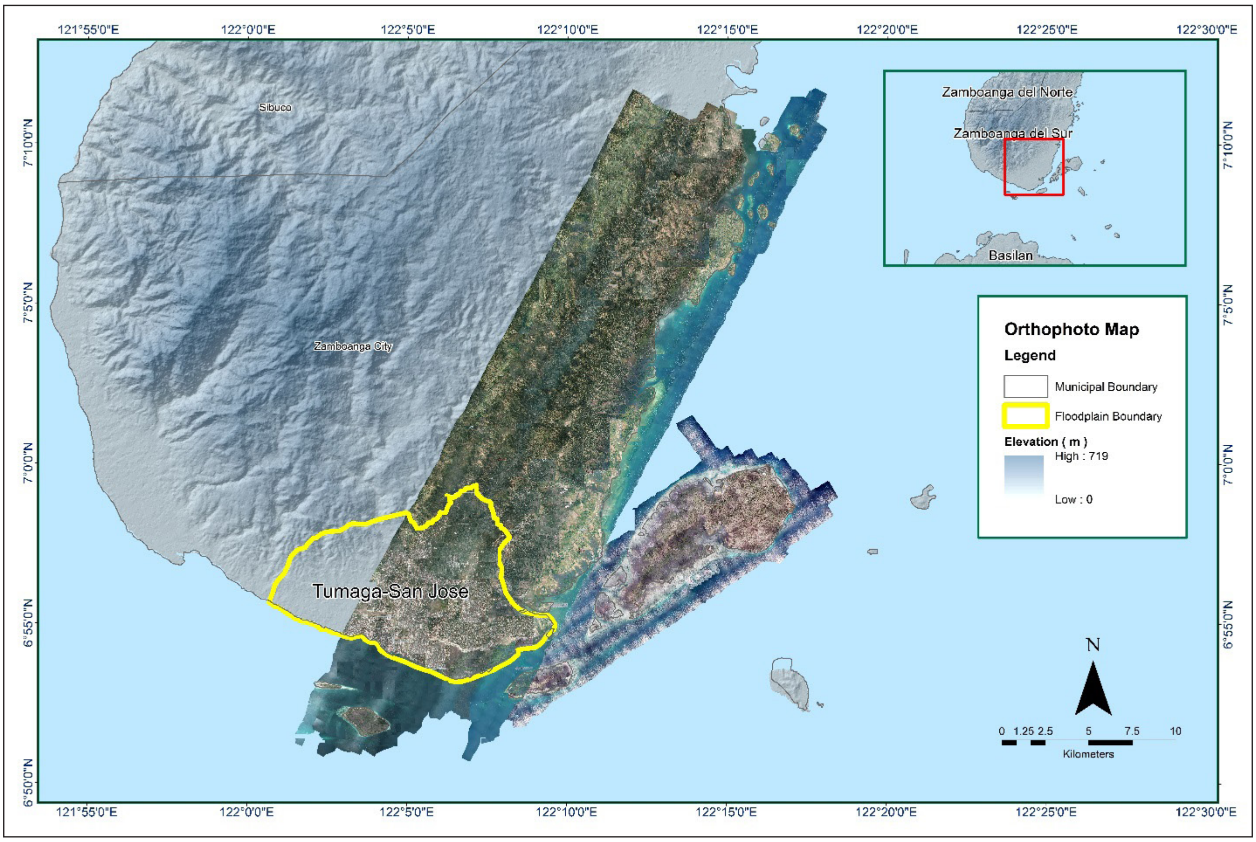



Figure 22. San Jose floodplain with available orthophotographs

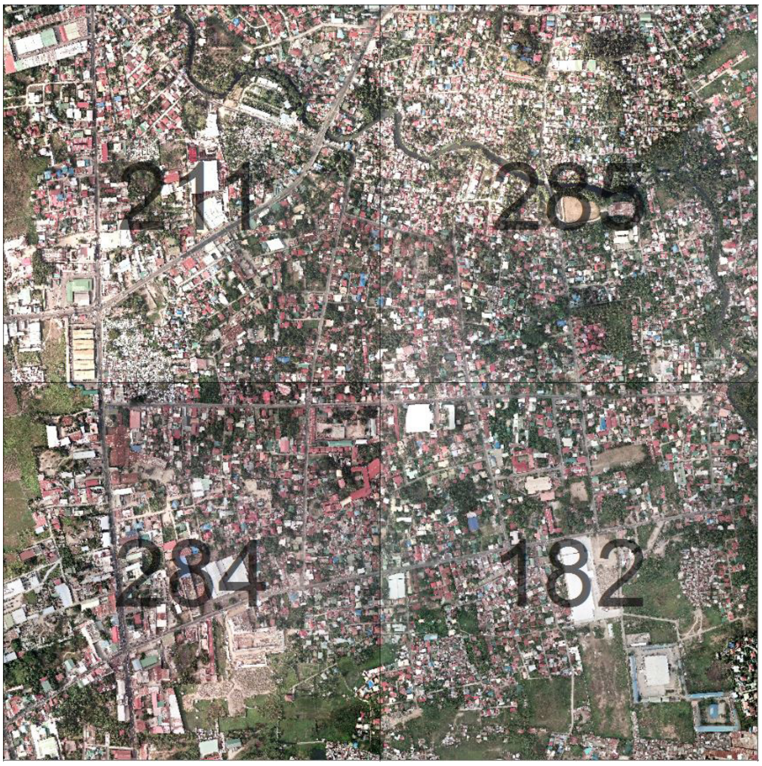



Figure 23. Sample orthophotograph tiles for San Jose Floodplain

## 3.8 DEM Editing and Hydro-Correction

Six (6) mission blocks were processed for San Jose Floodplain. These blocks are composed of Samar Leyte and Leyte blocks with a total area of 758.24 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_Blk75E | 422.89 |
| Zamboanga_Blk75F | 140.87 |
| Zamboanga_Blk75F_additional | 2.48 |
| Zamboanga_Sacol | 132.22 |
| Zamboanga_reflights_Blk75AS | 35.31 |
| Zamboanga_reflights_Blk75F_supplement | 24.47 |
| **TOTAL** | 758.24 sq.km |

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

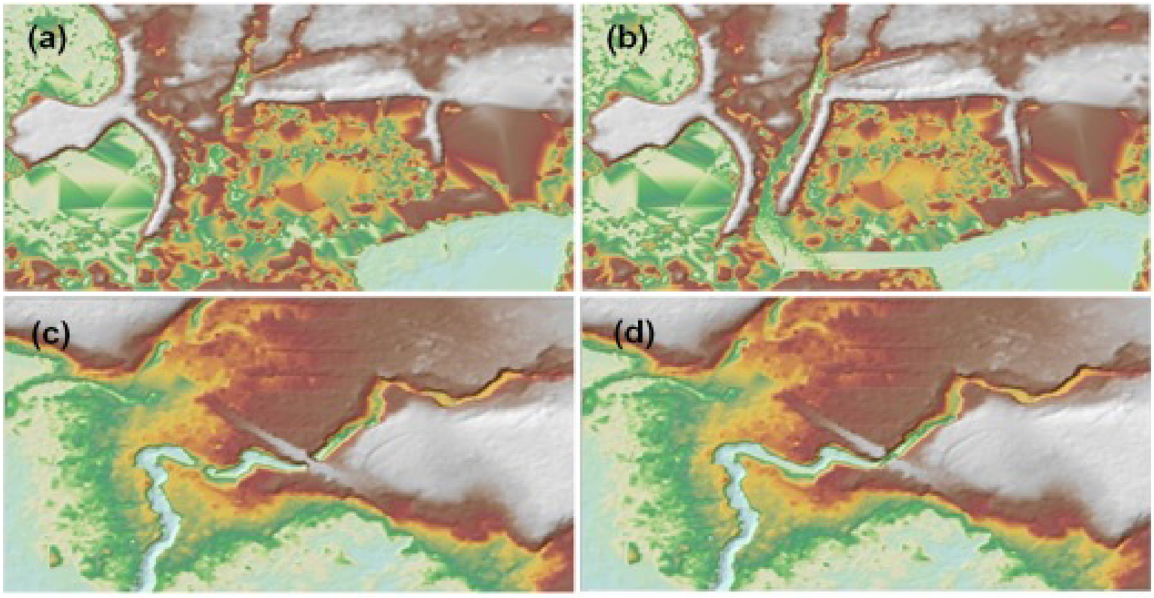



Figure 24. Portions in the DTM of San Jose Floodplain– a river embankment field before (a) and after (b) data retrieval; a bridge before (c) and after (d) manual editing

## 3.9 Mosaicking of Blocks

Simultaneous mosaicking was done to all the available LiDAR data covering San Jose Floodplain, which are, in the order of being mosaicked, 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 was the first available LiDAR data. The shift values applied to each LiDAR block during mosaicking is shown in Table 18.

Mosaicked LiDAR DTM for San Jose Floodplainis shown in Figure 25. It can be seen that the entire San Jose Floodplainis 100% covered by LiDAR data.

Table 18.Shift Values of each LiDAR Block of San Jose 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 |

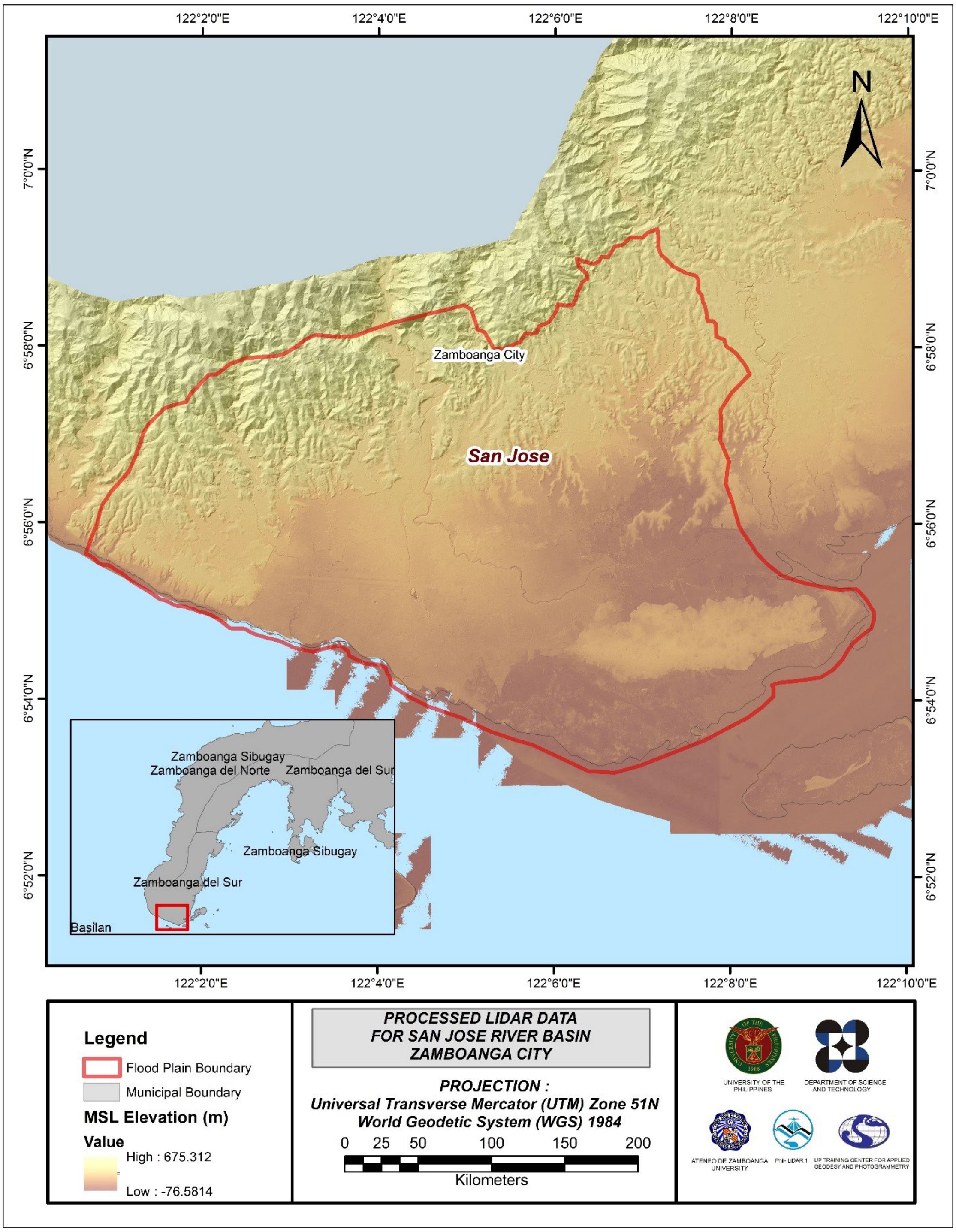



Figure 25. Map of Processed LiDAR Data for San Jose Floodplain

## 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 San Jose Floodplains to collect points with which the LiDAR dataset is validated is shown in Figure 26.

Simultaneous mosaicking was done for the Zamboanga LiDAR blocks and the only available data that time was for Tumaga. The San Jose Floodplain is included in the set of blocks previously mosaicked. Therefore, the Tumaga calibration data and methodology were used.

A total of 1,739 survey points from Tumaga data were used for calibration and validation of all the blocks of Zamboanga LiDAR data. Eighty (80) % of the survey points, resulting in 1,391 points, were used for calibration. A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure 27. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration elevation values is 8.06 meters with a standard deviation of 0.07 meters. Calibration for Zamboanga LiDAR data was done by adding the height difference value, 8.06 meters, to Zamboanga mosaicked LiDAR data. Table 19 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

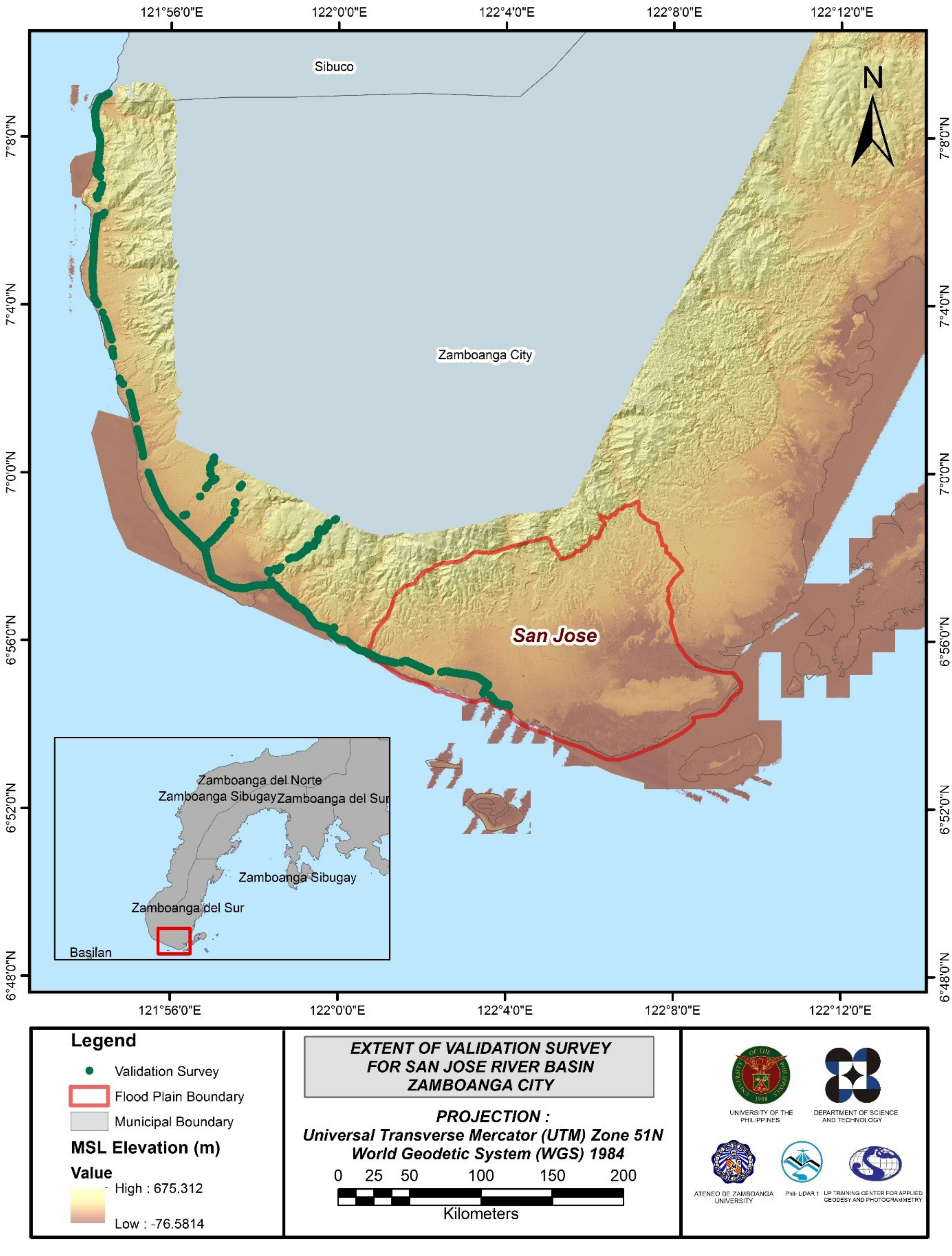



Figure 26. Map of San Jose Floodplain with validation survey points in green

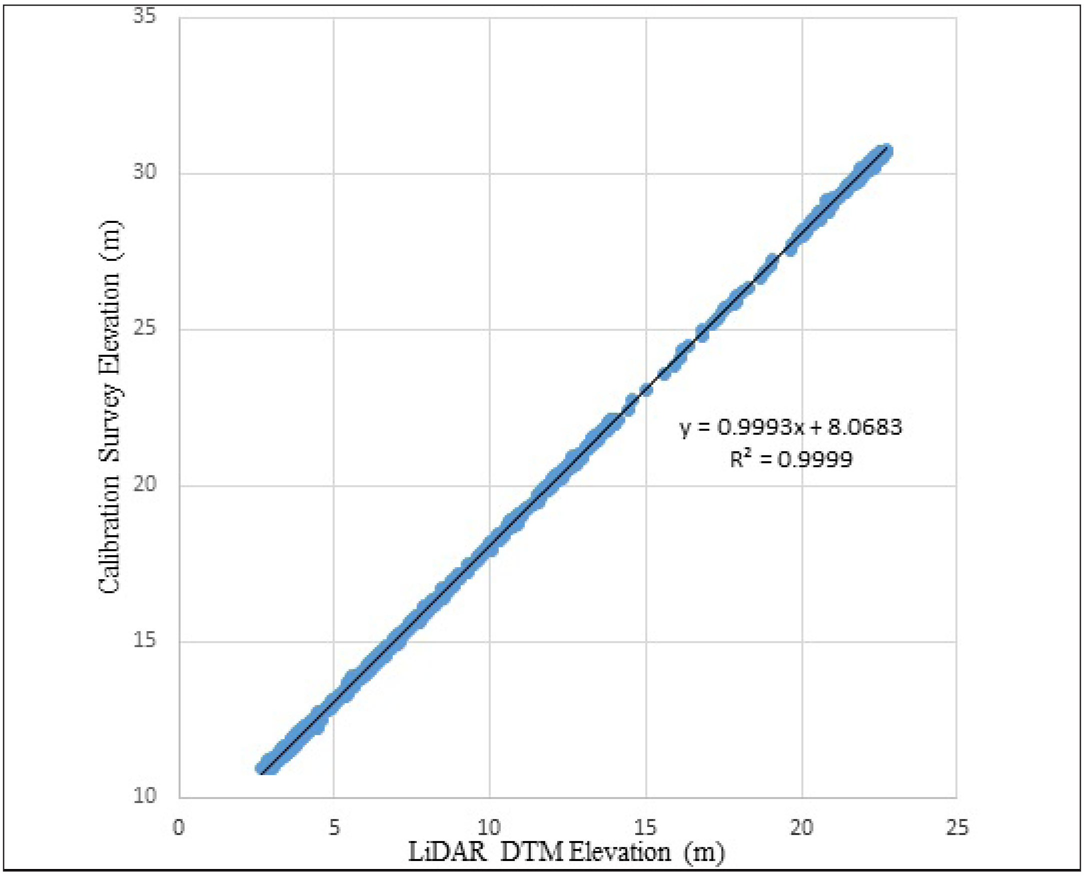



Figure 27. Correlation plot between calibration survey points and LiDAR data

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 in 944 points, were used for the validation of calibrated San Jose DTM. A good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM is shown in Figure 28. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.16meters with a standard deviation of 0.15meters, as shown in Table 20.

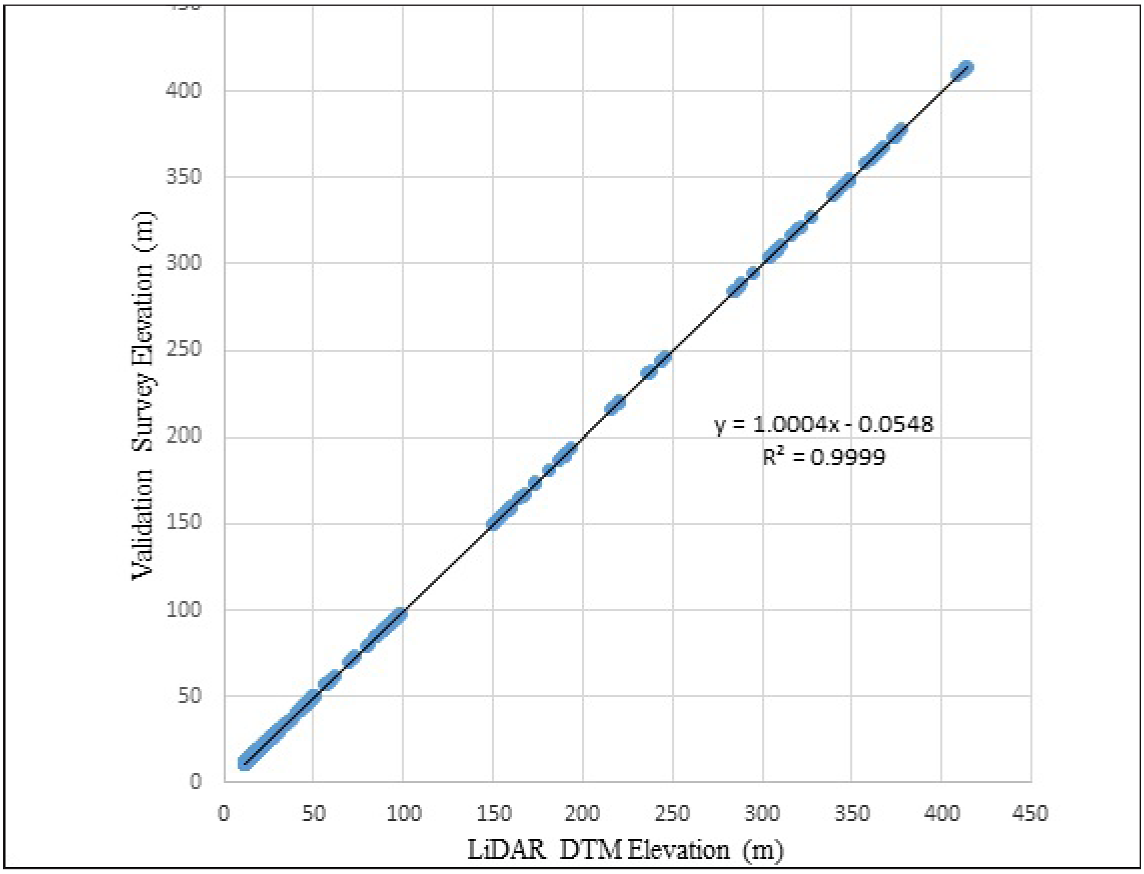



Figure 28. Correlation plot between validation survey points and LiDAR data.

Table 20. Validation Statistical Measures.

| Validation Statistical Measures | Value (meters) |
|---|---|
| RMSE | 0.16 |
| Standard Deviation | 0.15 |
| Average | -0.04 |
| Minimum | -0.34 |
| Maximum | 0.27 |

## 3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and zigzag data were available for San Jose with 2,470 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 0.18 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in San Jose integrated with the processed LiDAR DEM is shown in Figure 29.

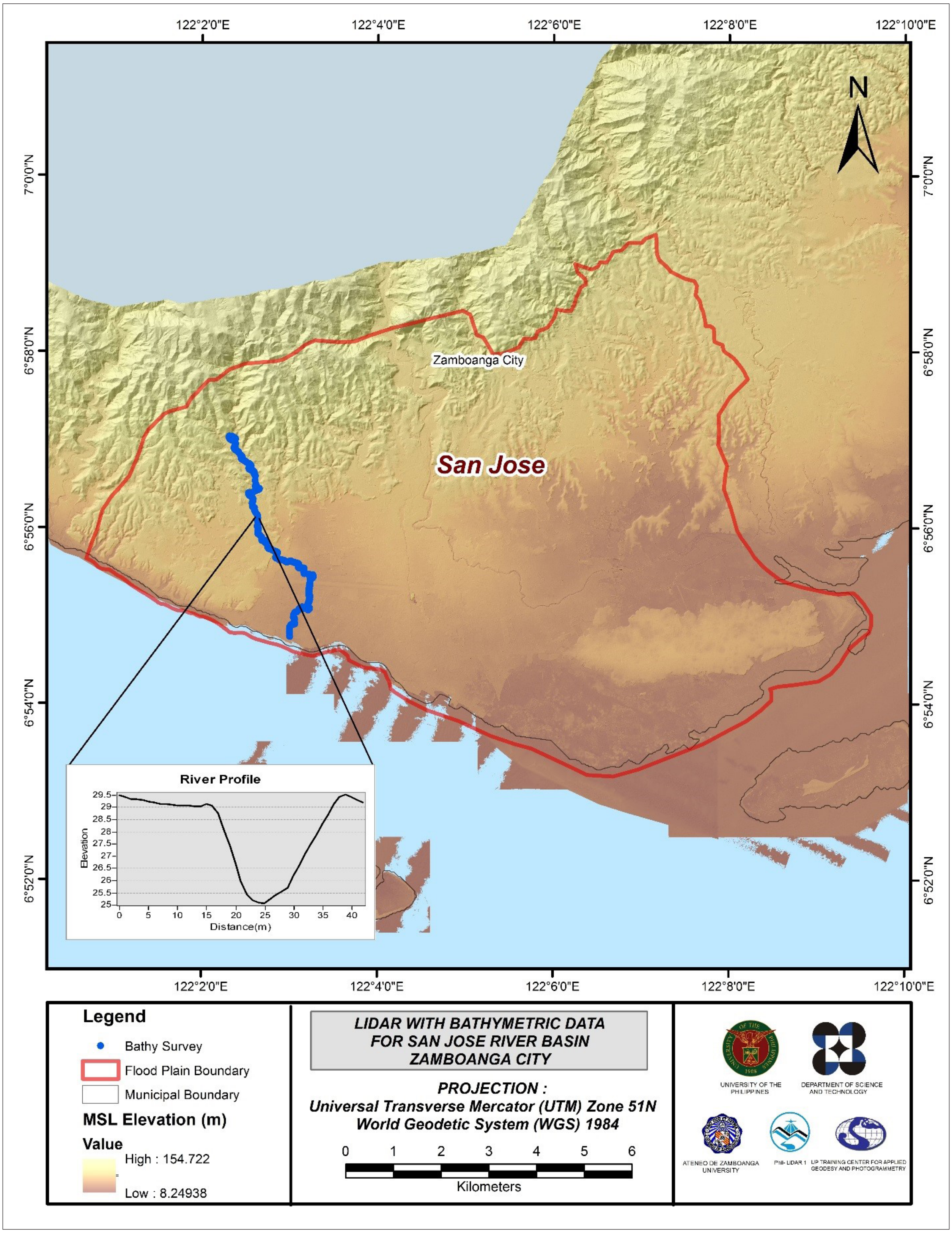



Figure 29. Map of San Jose Floodplain with bathymetric survey points shown in blue

## 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

San Jose Floodplain, including its 200 m buffer, has a total area of 112.78sq km. For this area, a total of 5.00sq km, corresponding to a total of 6, 918 building features, are considered for QC. Figure 30 shows the QC blocks for San Jose floodplain.

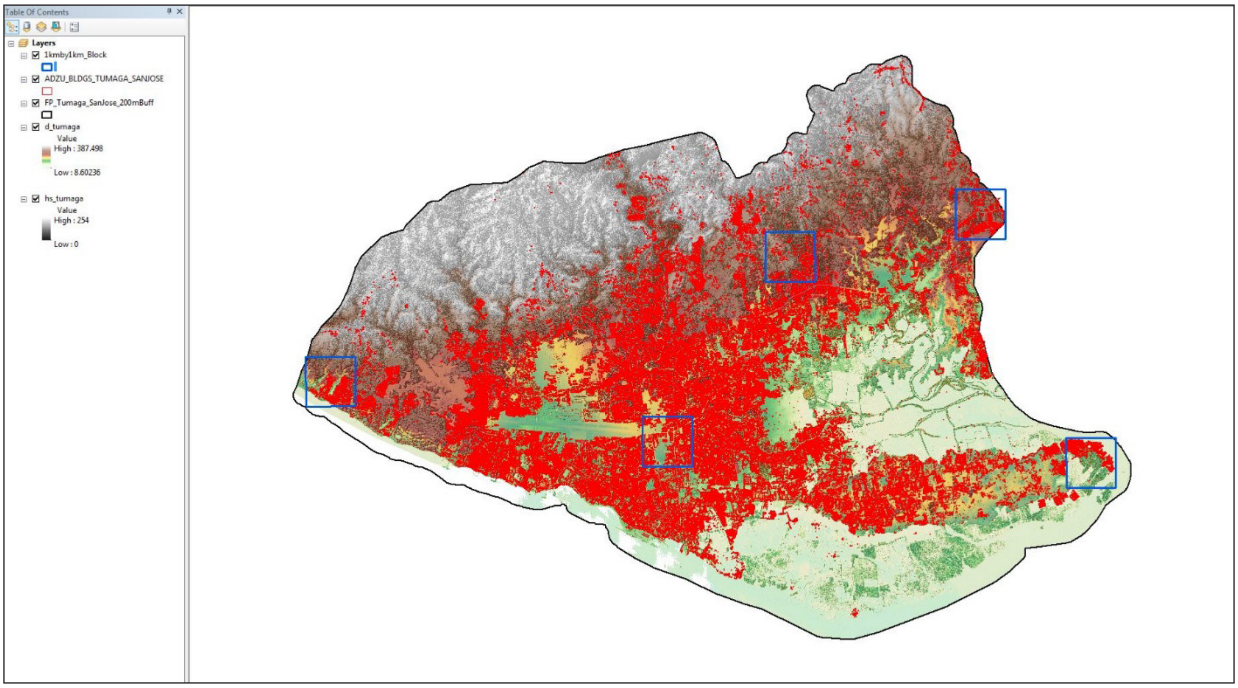


Figure 30. Blocks (in blue) of San Jose building features that were subjected in QC

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

Table 21. Quality Checking Ratings for San Jose Building Features.

| FLOODPLAIN | COMPLETENESS | CORRECTNESS | QUALITY | REMARKS |
|---|---|---|---|---|
| San Jose | 97.63 | 99.79 | 90.80 | PASSED |

### 3.12.2 Height Extraction

Height extraction was done for 80,920 building features in San Jose Floodplain. Of these building features, 892 were filtered out after height extraction, resulting in 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, through 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 river basin; likewise, the number of enumerators is 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. Building Features Extracted for San Jose Floodplain

| Facility Type | No. of Features |
|---|---|
| Residential | 74,4440 |
| 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 San Jose Floodplain

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

Table 24. Number of Extracted Water Bodies for San Jose Floodplain

| Floodplain | Water Body Type | | | | | Total |
|---|---|---|---|---|---|---|
| | Rivers/Streams | Lakes/Ponds | Sea | Dam | Fish Pen | |
| San Jose | 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 31 shows the Digital Surface Model (DSM) of San Jose floodplain overlaid with its ground features.

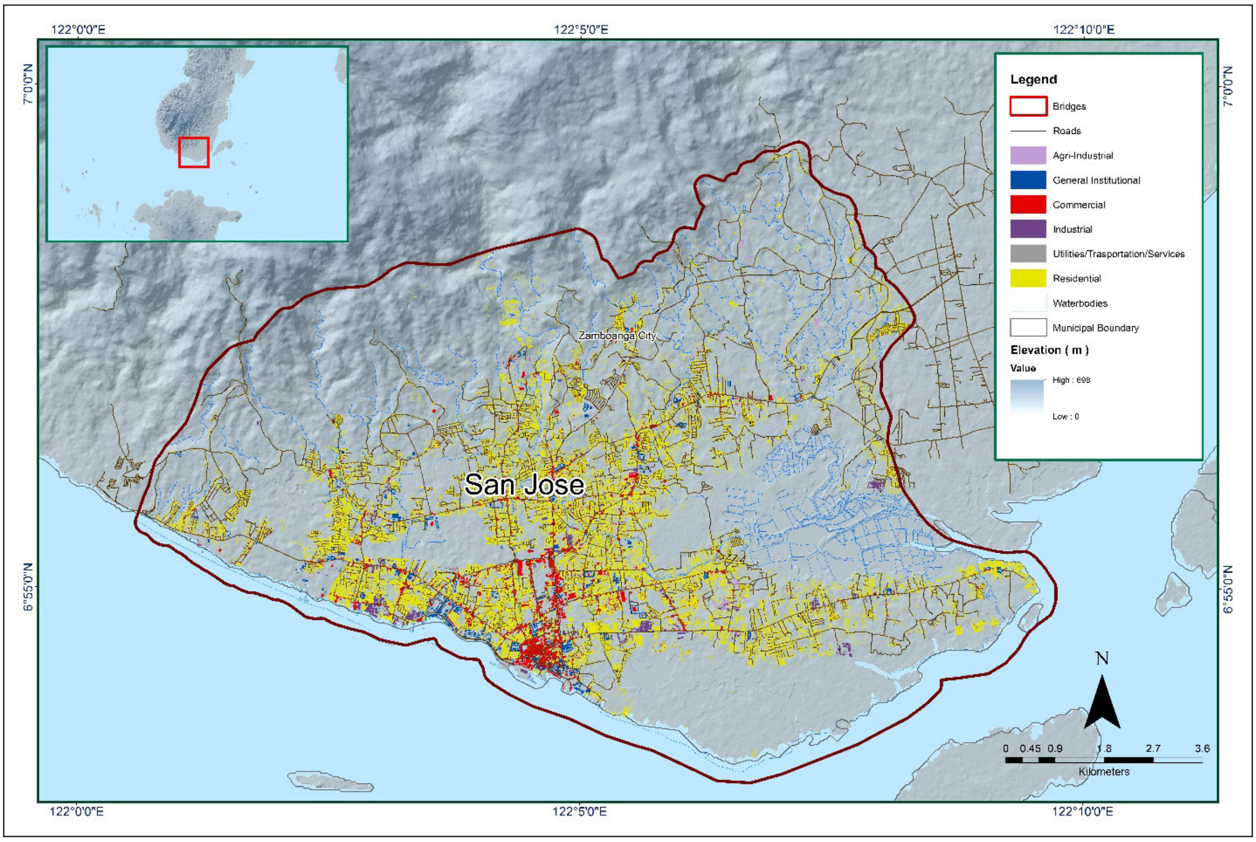



Figure 31. Extracted features for San Jose floodplain.

# CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS OF THE SAN JOSE RIVER BASIN

*Engr. Louie P. Balicanta, Engr. Joemarie S. Caballero, Ms. Patrizcia Mae. P. dela Cruz, Engr. Kristine Ailene B. Borromeo, 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 DVBC conducted a field survey in San Jose River on August 12 to 20, 2016 with the following scope of work: reconnaissance; control survey; cross-section and as-built survey at Townsville Bridge in Brgy. San Roque, Zamboanga City, Zamboanga Peninsula; validation points acquisition of about 49.545 km covering the San Jose River Basin area; and bathymetric survey from its upstream in Brgy. San Roque, down to the mouth of the river located in Brgy. Baliwasan, both in Zamboanga City, with an approximate total length of 7.241 km using Hi™ single beam echo sounder and Trimble® SPS 985 GNSS PPK survey technique as shown in Figure 32.

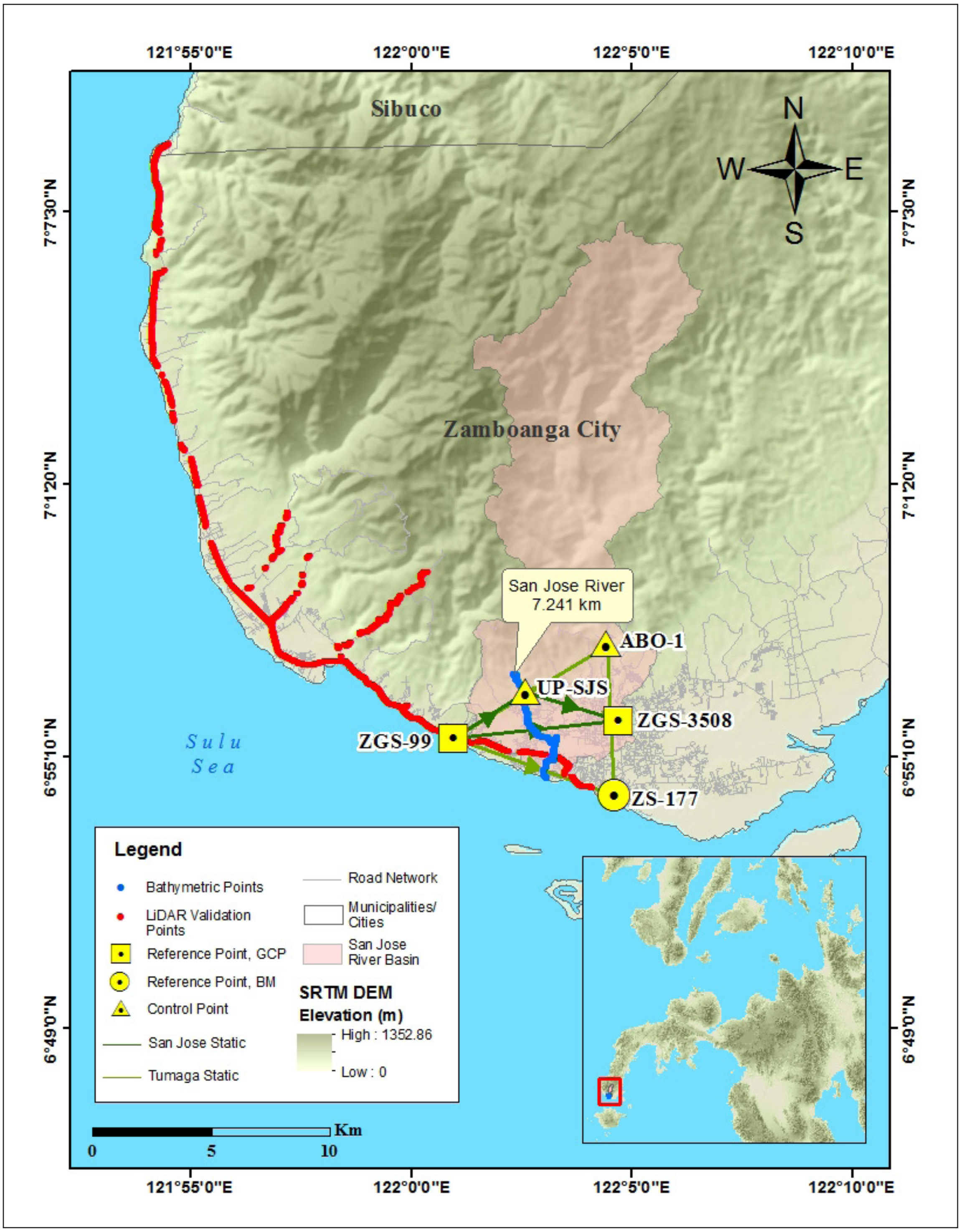



Figure 32. San JoseRiver Survey Extent

## 4.2 Control Survey

A GNSS network from Tumaga River Survey was established on September 19, 2015 occupying the control points ZGS-99, a second-order GCP, in Brgy. Sinunoc, Zamboanga City; and ZS-177, a first-order BM, in Brgy. Zone 4, Zamboanga City; both in Zamboanga Del Sur.

The GNSS network used for San Jose River Basin is composed of a single loop established on August 13, 2016 occupying the reference point with fixed elevation and coordinate values from Tumaga Survey, ZGS-99, a second-order GCP in Brgy. Sinunoc, Zamboanga City, Zamboanga Del Sur.

A control point was established at the approach of Townsville Bridge namely; UP-SJS, in Brgy. San Roque; and aNAMRIA-established control pointnamely ZGS-3508, located at the approach of Tumaga Bridge, in

Brgy. Tumaga; both in Zamboanga City, Zamboanga Del Sur, were also occupied and used as marker.

The summary of reference and control points and its location is summarized in Table 25 while the GNSS network established is illustrated in Figure 33.

Table 25. List of Reference and Control Points occupied for San Jose River Survey
Source: NAMRIA; UP-TCAGP)

| Control Point | Order of Accuracy | Geographic Coordinates (WGS 84) | | | | |
|---|---|---|---|---|---|---|
| | | Latitude | Longitude | Ellipsoidal Height (m) | MSL Elevation (m) | Date Established |
| Control Survey on August 13, 2016 | | | | | | |
| ZGS-99 | 2nd order, GCP | 6°55'34.07738"N | 122°00'58.23071"E | 81.385 | 13.808 | 2014 |
| ZGS-3508 | Used as Marker | - | - | - | - | 08-13-16 11:48 AM |
| UP-SJS | UP-Established | - | - | - | - | 08-13-16 11:48AM |
| Control Survey on September 19, 2014 | | | | | | |
| ZGS-99 | 2nd order, GCP | 6°55'34.07737"N | 122°00'58.23072"E | 72.230 | 13.808 | 2014 |
| ZS-177 | 1st order, BM | 6°54'16.64510"N | 122°04'35.11998"E | 70.847 | 12.311 | 2014 |
| ABO-1 | UP-Established | 6°57'43.70228"N | 122°04'25.00909"E | 109.733 | 51.125 | 9-19-14 3:46 PM |


Figure 33. GNSS Network covering San JoseRiver

The GNSS set-ups on recovered reference points and established control points in San Jose River are shown in Figure 34 to Figure 36.


Figure 34. .GNSS base set-up, Trimble® SPS 852, atZGS-99located beside a seawall at Airforce Beach, Brgy. Sinunoc, Zamboanga City, Zamboanga Del Sur


Figure 35. GNSS receiver set-up, Trimble® SPS 985, atZGS-3508 located at the approach of Tumaga Bridge, Brgy. Tumaga, Zamboanga City, Zamboanga Del Sur


Figure 36. GNSS receiver set-up, Trimble® SPS 852, at UP-SJS located at the approach Townsville Bridge, Brgy. San Roque, Zamboanga City, Zamboanga Del Sur

## 4.3 Baseline Processing

GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement, respectively. In case where one or more baselines did not meet all of these criteria, masking was performed. Masking is done by removing/masking portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. Baseline processing result of control points in San Jose River Basin is summarized in Table 26 generated by TBC software.

Table 26. Baseline Processing Summary Report for San JoseRiver Survey

| Observation | Date of Observation | Solution Type | H.Prec. (Meter) | V.Prec. (Meter) | Geodetic Az. | Ellipsoid Dist. (Meter) | Height (Meter) |
|---|---|---|---|---|---|---|---|
| UPSJS --- ZGS99 | 08-13-2016 | Fixed | 0.005 | 0.017 | 56°21'54" | 3576.307 | 28.119 |
| UPSJS --- ZGS3508 | 08-13-2016 | Fixed | 0.006 | 0.025 | 107°30'54" | 4076.059 | -17.345 |
| ZGS99 --- ZGS3508 | 08-13-2016 | Fixed | 0.004 | 0.013 | 83°43'42" | 6906.058 | 10.786 |

As shown Table 26, a total of three (3) baselines were processed with reference point ZGS-99 held fixed for coordinate value;and its fixed value from Tumaga fieldwork for elevation values. All of them passed the required accuracy.

## 4.4 Network Adjustment

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

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

Where:

$x_e$ is the Easting error,

$y_e$ is the Northing error, and

$z_e$ is the Elevation error

for each control point. See the Network Adjustment Report shown in Table 27 to Table 30 for complete details.

The three (3) control points, ZGS-99, ZGS-3508, and UP-SJSwere occupied and observed simultaneously to form a GNSS loop. Coordinates of ZGS-99; and its elevation valuefixed from Tumaga control surveywere 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 | Grid | Fixed | Fixed | | Fixed |
| **Fixed = 0.000001 (Meter)** | | | | | |

The list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 28. The fixed control ZGS-99has no value for grid error elevation error.

Table 28. Adjusted Grid Coordinates

| Point ID | Easting (Meter) | Easting Error (Meter) | Northing (Meter) | Northing Error (Meter) | Elevation (Meter) | Elevation Error (Meter) | Constraint |
|---|---|---|---|---|---|---|---|
| ZGS-99 | 391313.321 | ? | 765695.628 | ? | 13.808 | ? | ENe |
| ZGS-3508 | 398177.791 | 0.002 | 766435.635 | 0.002 | 24.450 | 0.011 | |
| UP-SJS | 394294.224 | 0.002 | 767669.863 | 0.002 | 41.835 | 0.012 | |

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

**ZGS-99**

horizontal accuracy = Fixed

vertical accuracy = Fixed

**ZGS-3508**

| | | |
|---|---|---|
| horizontal accuracy | = | $\sqrt{((0.2)^2 + (0.2)^2}$ |
| | = | $\sqrt{(0.04 + 0.04)}$ |
| | = | 0.28< 20 cm |
| vertical accuracy | = | 1.1 < 10 cm |

**MQ-120**

| | | |
|---|---|---|
| horizontal accuracy | = | $\sqrt{((0.2)^2 + (0.2)^2}$ |
| | = | $\sqrt{(0.04 + 0.04)}$ |
| | = | 0.28< 20 cm |
| vertical accuracy | = | 1.2 cm < 10 cm |

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

Table 29. Adjusted Geodetic Coordinates

| Point ID | Latitude | Longitude | Ellipsoidal Height (Meter) | Height Error (Meter) | Constraint |
|---|---|---|---|---|---|
| ZGS-99 | N6°55'34.07738" | E122°00'58.23071" | 81.385 | ? | ENe |
| ZGS-3508 | N6°55'58.62125" | E122°04'41.85581" | 92.169 | 0.011 | |
| UP-SJS | N6°56'38.55865" | E122°02'35.23021" | 109.507 | 0.012 | |

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 29. 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) |
| Control Survey on August 13, 2016 | | | | | | | |
| ZGS-99 | 2nd order, GCP | 6°55'34.07738" | 122°00'58.23071" | 81.385 | 765695.628 | 391313.321 | 13.808 |
| ZGS-3508 | Used as Marker | 6°55'58.62125" | 122°04'41.85581" | 92.169 | 766435.635 | 398177.791 | 24.45 |
| UP-SJS | UP Established | 6°56'38.55865" | 122°02'35.23021" | 109.507 | 767669.863 | 394294.224 | 41.835 |
| Control Survey on September 19, 2014 | | | | | | | |
| ZGS-99 | 2nd order, GCP | 6°55'34.07737" | 122°00'58.23072" | 72.230 | 765695.628 | 391313.321 | 13.808 |
| ZS-177 | 1st order, BM | 6°54'16.64510" | 122°04'35.11998" | 70.847 | 763304.231 | 397964.993 | 3.156 |
| ABO-1 | UP Established | 6°57'43.70228" | 122°04'25.00909" | 109.733 | 769663.809 | 397667.093 | 51.125 |

## 4.5 Cross-section and Bridge As-Built Survey and Water Level Marking

Cross-section and as-built survey were conducted on August 15, 2016 at the downstream side of Townsville Bridge in Brgy. San Roque,Zamboanga City, Zamboanga Del Sur as shown in Figure 37. A Total Station and Trimble® SPS 985 GNSS PPK survey technique were utilized for this survey as shown in Figure 38.

Figure 37. Townsville Bridge facing upstream


Figure 38. Bridge As-Built Survey using PPK Technique.

The cross-sectional line of Townsville Bridge is about 12.318m withseven (7)cross-sectional points using the control point UP-SJSas the GNSS base station. The cross-section diagram, location map, and the bridge data form are shown in  Figure 39 to Figure 41, respectively.

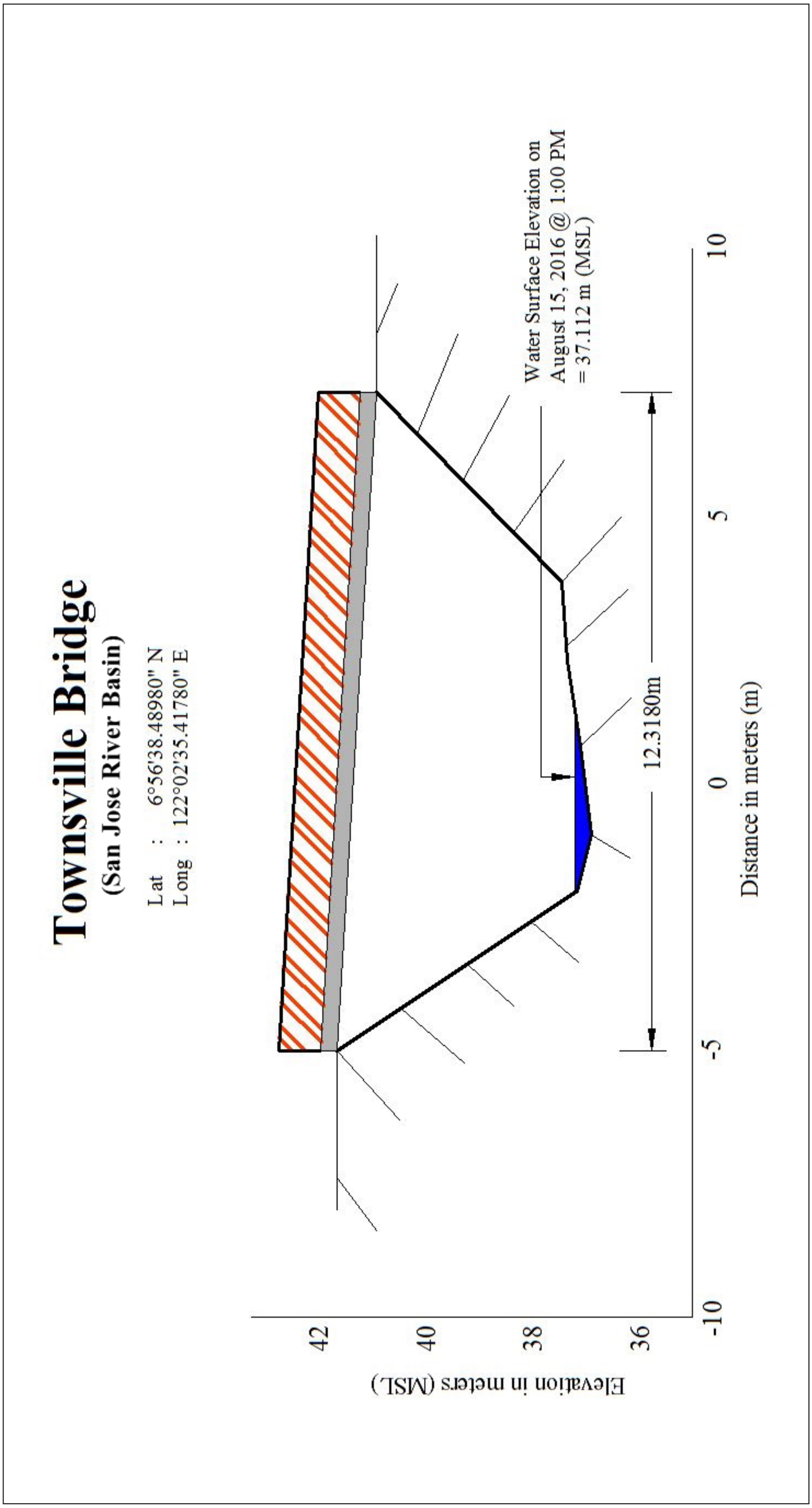



Figure 39. Townsville Bridge cross-section diagram

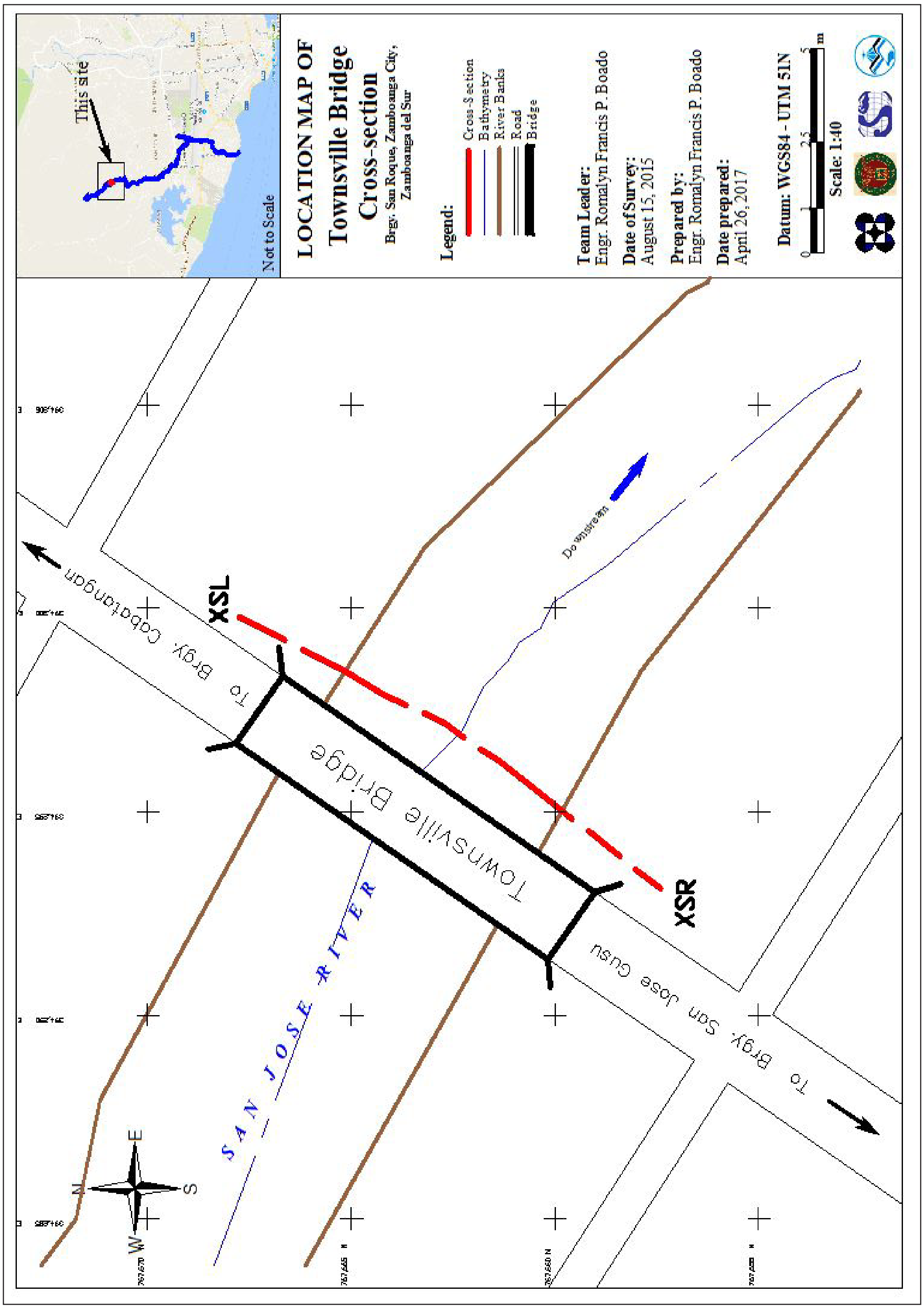
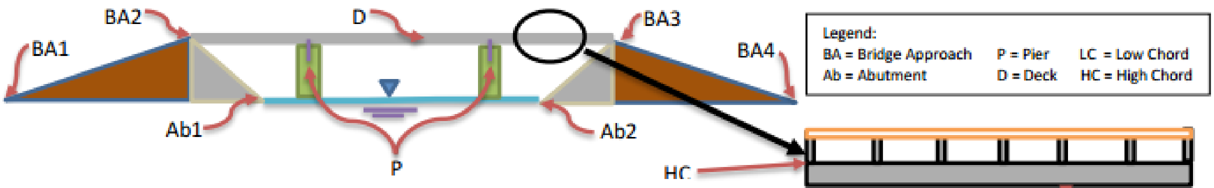



Figure 40. Townsville bridge cross-section location map

**Bridge Data Form**

| | |
|---|---|
| **Bridge Name:** **Townsville Bridge** | **Date:** **August 15, 2016** |
| **River Name:** **San Jose River** | **Time:** **1:00 PM** |
| **Location (Brgy, City,Region):** **Brgy. San Roque, Zamboanga City, Zamboanga del Sur** | |
| **Survey Team:** **Romalyn Boado, Cybil Atacador** | |
| **Flow condition:** normal | **Weather Condition:** fair |
| **Latitude:** **06˚56'38.48980" N** | **Longitude:** **122˚02'35.41780" E** |




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

**Elevation:** **Not available** **Width:** **Not available** **Span (BA3-BA2):** **Not available**

| | Station | High Chord Elevation | Low Chord Elevation |
|---|---|---|---|
| 1 | Not available | Not available | Not available |

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

| | Station(Distance from BA1) | Elevation | | Station(Distance from BA1) | Elevation |
|---|---|---|---|---|---|
| BA1 | 0 | 41.643 m | BA3 | 10.903 m | 40.896 m |
| BA2 | 1.819 m | 41.489 | BA4 | 12.318 m | 40.899 m |

**Abutment:** Is the abutment sloping? **Yes**; If yes, fill in the following information:

| | Station (Distance from BA1) | Elevation |
|---|---|---|
| Ab1 | Not available | Not available |
| Ab2 | Not available | Not available |

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

Shape: Not available Number of Piers: Not available Height of column footing: Not available

| | Station (Distance from BA1) | Elevation | Pier Diameter |
|---|---|---|---|
| Not available | Not available | Not available | Not available |

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

Figure 41. Bridge as-built form of Townsville Bridge

Water surface elevation of Townsville River was determined using a Total Station on August 15, 2016 at 1:00PM with a value of 37.112m in MSL as shown in Figure C-8. This was translated into marking on the wall under the bridge using the same technique as shown in Figure 42. The markings will serve as reference for flow data gathering and depth gauge deployment of partner HEI responsible for San Jose River, the ADZU.


Figure 42. Water-level markings on TownsvilleBridge

## 4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on August 13, 15 and 19, 2016 using a survey-grade GNSS Rover receiver, Trimble® SPS 985, mounted in front of a vehicle as shown in Figure 43. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna heightswere1.9 m and 2.34 m and measured from the ground up to the bottom of notch of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with ZGS-99 occupied as the GNSS base station.


Figure 43. Validation points acquisition survey set up along San JoseRiver Basin

The survey started from Tawiran Bridge in Brgy. Limpapa, Municipality of Sibuco; going south it traversed twenty (20) Barangays in Zamboanga City and ended in Brgy. Sto. Niño, also in Zamboanga City.Atotal of 6,266points were gathered with approximate length of 49.545km using ZGS-99 as GNSS base station for the entire extent validation points acquisition survey as illustrated in the map in Figure 44.

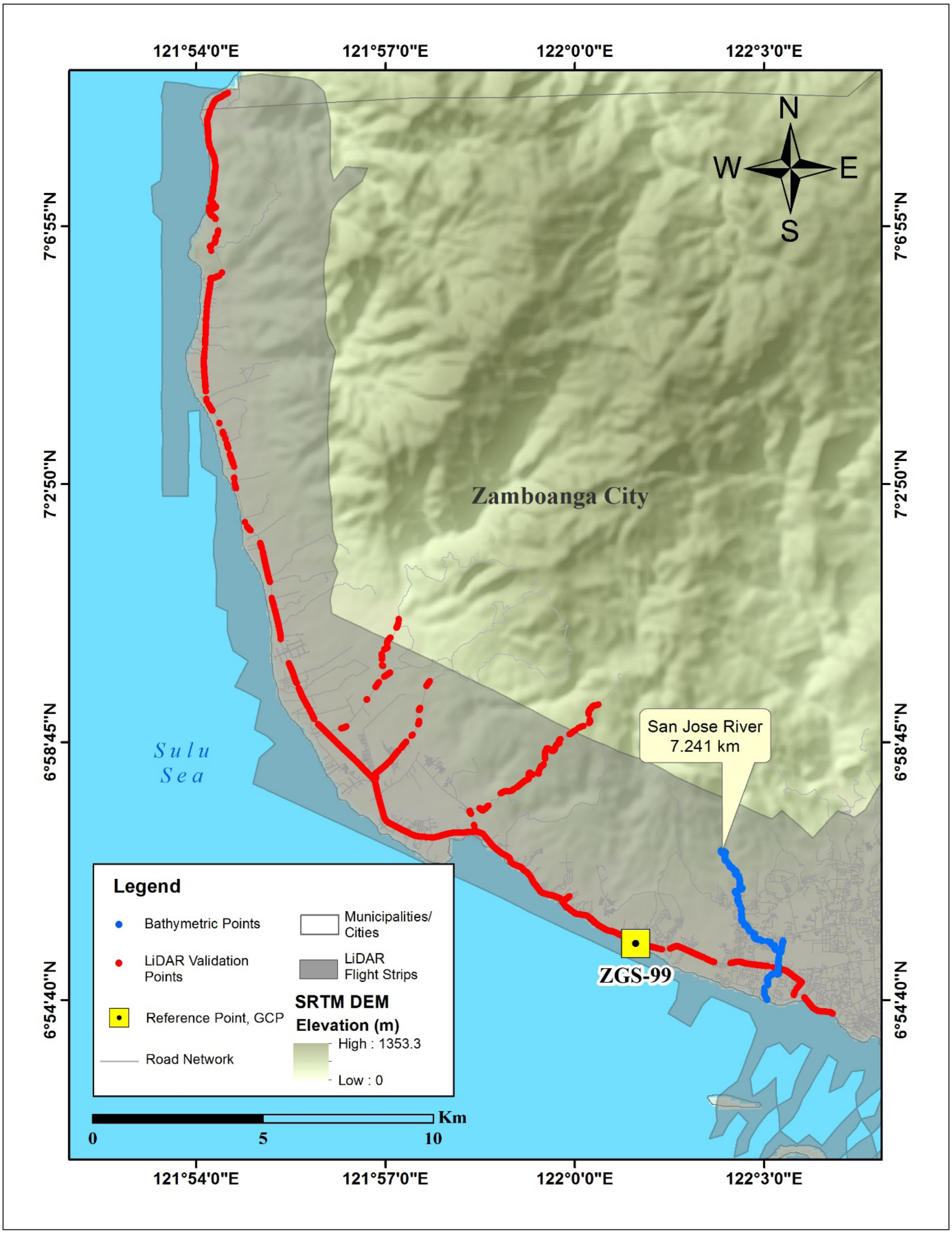



Figure 44. Validation point acquisition survey of San Jose River Basin

## 4.7 Bathymetric Survey

Bathymetric survey was executed on August 16 and 19, 2016 using an Ohmex ™ single beam echosounder and Trimble® SPS 985 in GNSSPPK survey technique in continuous topo mode as illustrated in Figure C-14. The survey was done by patch: one 200-m length at Brgy. Baliwasan with coordinates6°54'42.42621"N, 122°03'01.77140"E; and another 200-m at Brgy. Canelar with coordinates6°55'04.82940"N, 122°03'08.40959"E.


Figure 45. Bathymetric survey using OHMEX™ single beam echo sounder in San Jose River

Manual bathymetric survey was executed on August 14, 15 and 18, 2016 using Trimble® SPS 985 in GNSS PPK survey technique in continuous topo mode as shown in Figure 46. The survey was done in three locations. First started in Brgy. San Roque, with coordinates 6°57'02.13715"N, 122°02'18.94037"E, and ended at 6°56'25.03753"N, 122°02'37.30398"E. The second is a 300m strip in Brgy. Campo Islam with coordinates 6°55'53.43788"N, 122°02'40.79317"E. The third started from Brgy. Campo Islam with coordinates 6°55'37.41742"N, 122°02'5.42997"E and ended in Brgy. Canelar with coordinates 6°55'06.47533"N, 122°03'12.69133"E.


Figure 46. Bathymetric survey using Trimble® SPS 985 in GNSS PPK survey technique in Townsville River

Another technique using Total Station was used for bathymetric survey on August 17, 2016 as shown in Figure 47. The survey started from Brgy. San Roque with coordinates 6°57'27.06020"N, 122°02'37.61304"E, and ended at Brgy. Campo Islam with coordinates 6°55'50.89743"N, 122°02'41.28283"E. The control point UP-SJS was used as the GNSS base station throughout the entire survey.

Figure 47. Bathymetric Survey using Total Station

The bathymetric survey for San Jose River gathered a total of 2,925 points covering a total estimated length of 7.241 km of the river traversing Barangays San Roque, Campo Islam, Canelar and Baliwasan, in Zamboanga City. A CAD drawing was also produced to illustrate the riverbed profile of San Jose River. As shown in Figure 49 and Figure 50, the highest and lowest elevation has a 47-m difference. The highest elevation observed was 54.673 m in MSL located in Brgy. San Roque while the lowest was 7.131 m below MSL located at the downstream portion of the river located in Brgy. Baliwasan, both in Zamboanga and Tagum.


Figure 48. Bathymetric survey of San Jose River

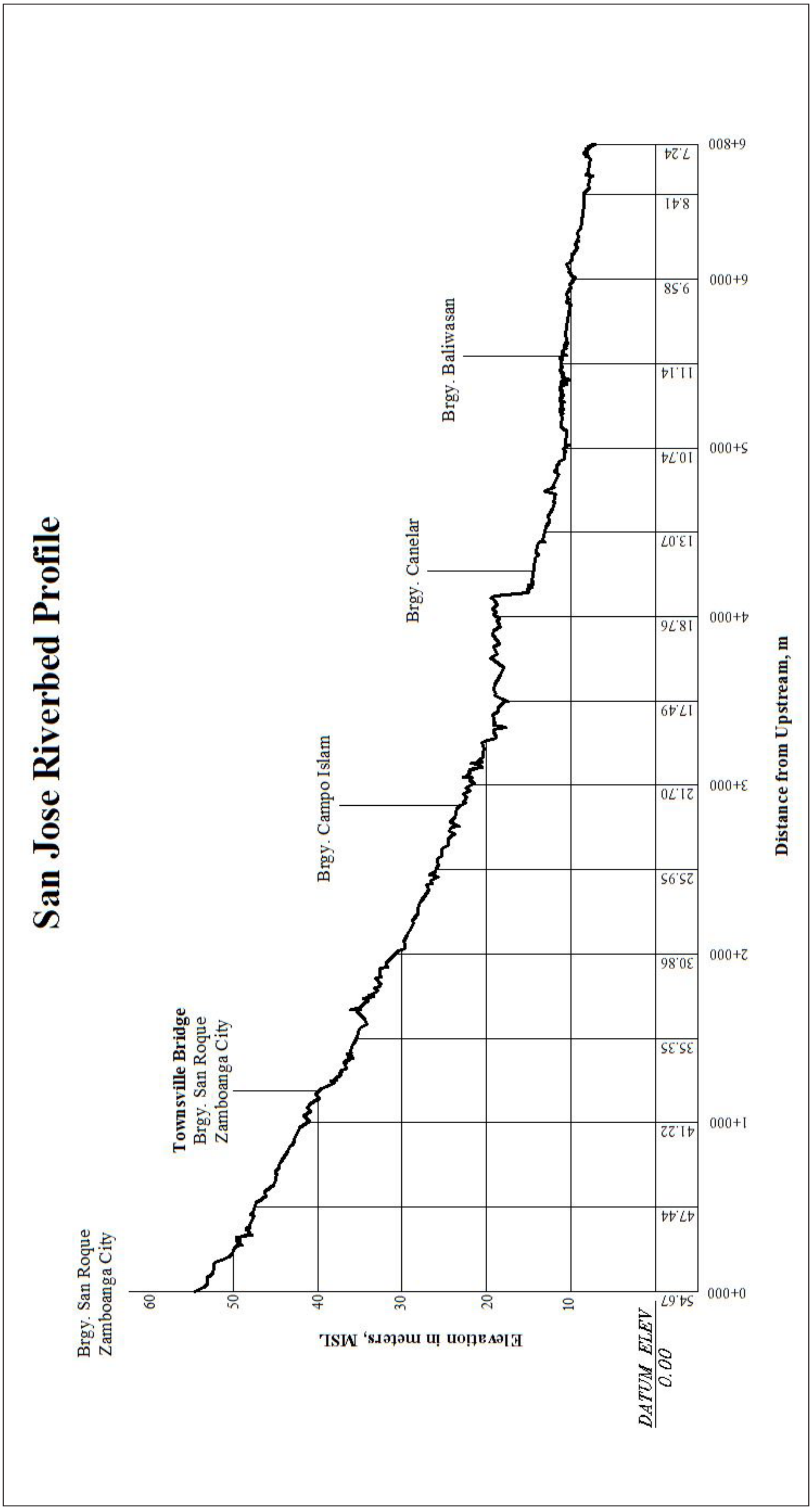



Figure 49. San Jose Riverbed Profile, from Brgy. San Roque upstream

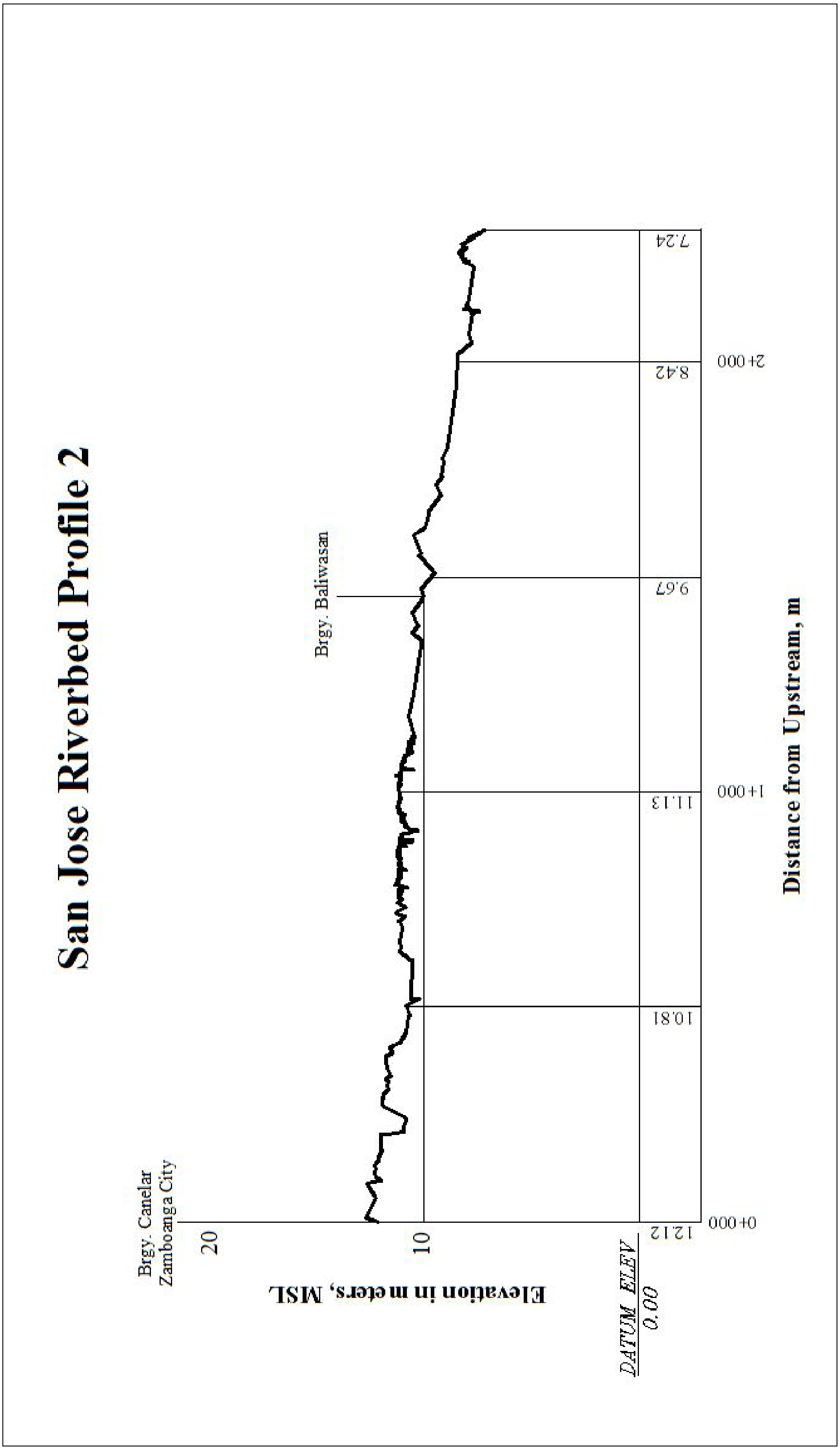



Figure 50. San Jose Riverbed Profile, from Brgy. Canelar upstream

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

### 5.1.2 Precipitation

Precipitation data was taken from a manually read Rain Gauge at Brgy. Cabatangan, Zamboanga City(6° 57' 6.34" N, 122° 2' 22.46" E). (Figure 51). The precipitation data collection started from September26, 2016 at 4:45PM to September27, 2016 at 10:25PM with 10 minutes recording interval.

The total precipitation for this event in Brgy. Cabatangan was 17.5mm. It has a peak rainfall of 12 mm on September 26, 2016 at 08:00 PM. The lag time between the peak rainfall and discharge is 4 hours and 15 minutes.

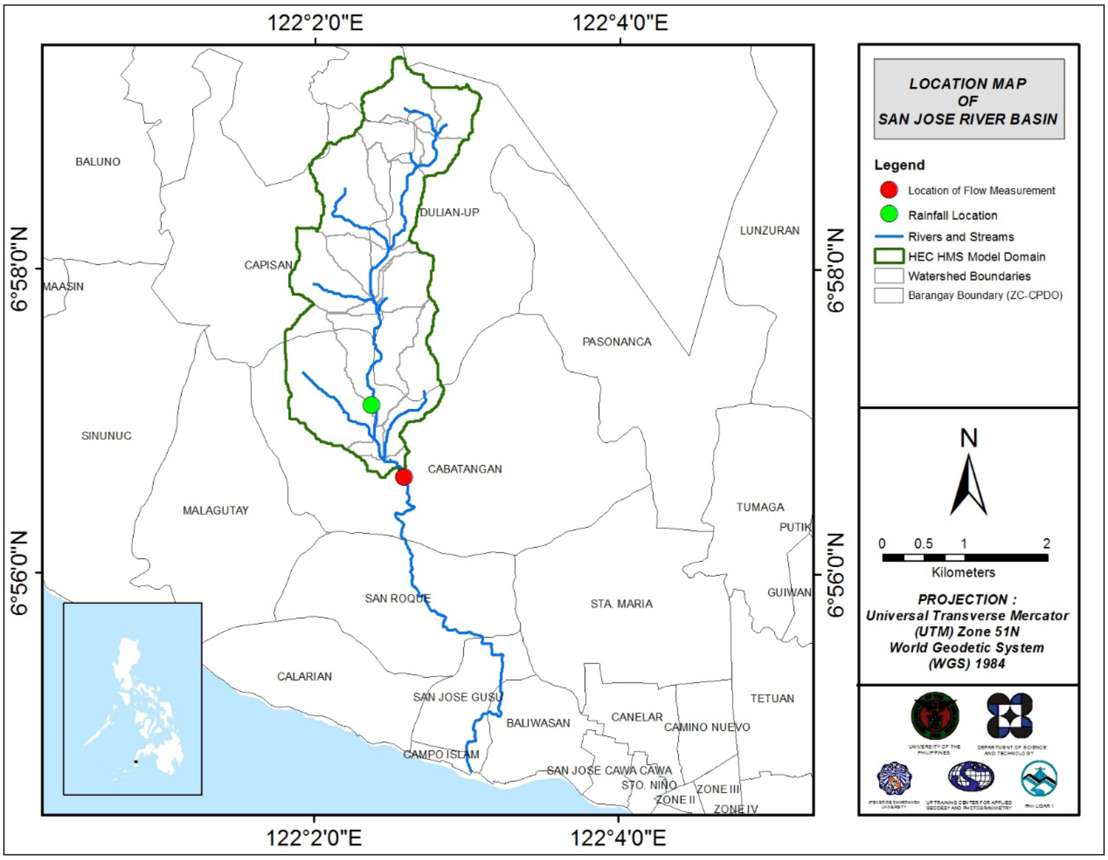



Figure 51. The location map of San Jose HEC-HMS model used for calibration

### 5.1.3 Rating Curves and River Outflow

A rating curve was developed at Townsville Footbridge, Brgy. San Roque, Zamboanga City(6° 56' 38.42" N, 122° 2' 35.06" E). It gives the relationship between the observed water levels at Townsville Footbridge and outflow of the watershed at this location.

For Townsville Footbridge, the rating curve is expressed as $Q = 5E\text{-}62e^{1.2569h}$ as shown in Figure 53.

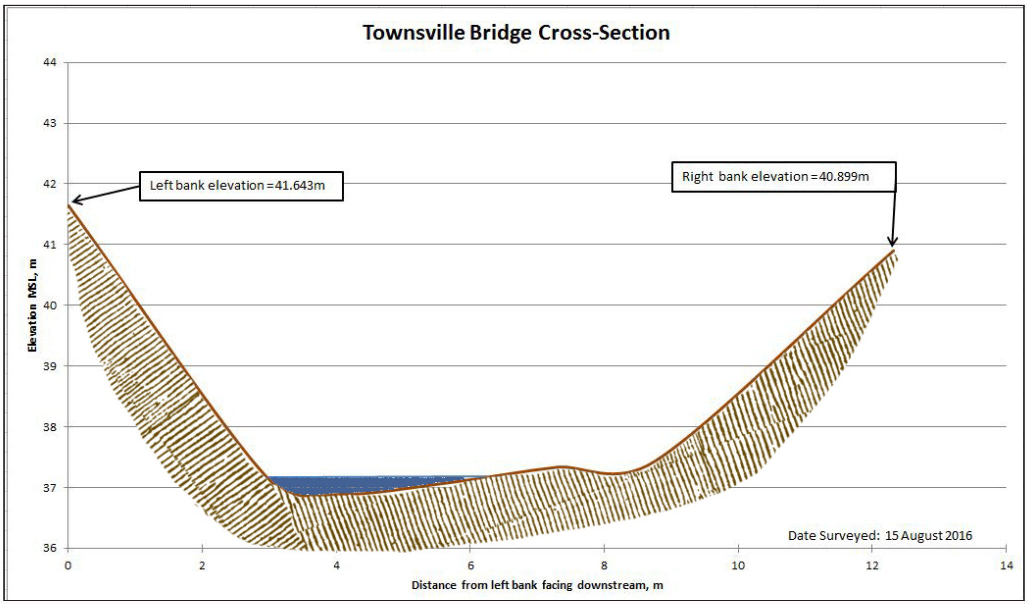



Figure 52. Cross-Section Plot of Townsville Footbridge

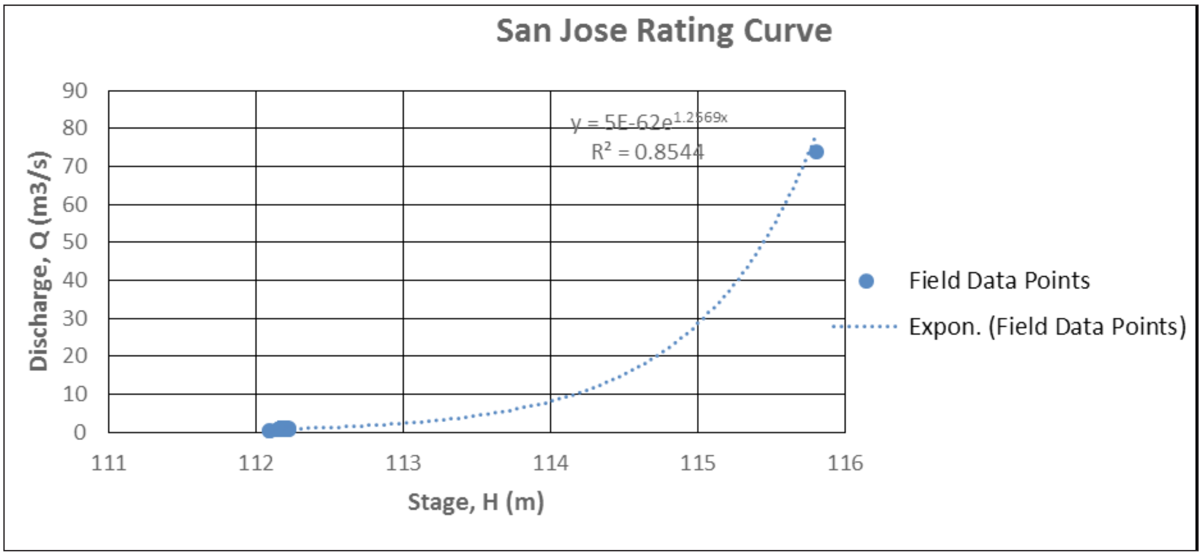



Figure 53. Rating Curve at Townsville Footbridge, San Jose, Zamboanga del Norte

This rating curve equation was used to compute the river outflow at Townsville Footbridge for the calibration of the HEC-HMS model shown in Figure 54. Peak discharge is 1.14 cubic meters per second at 12:15AM, September27, 2016.

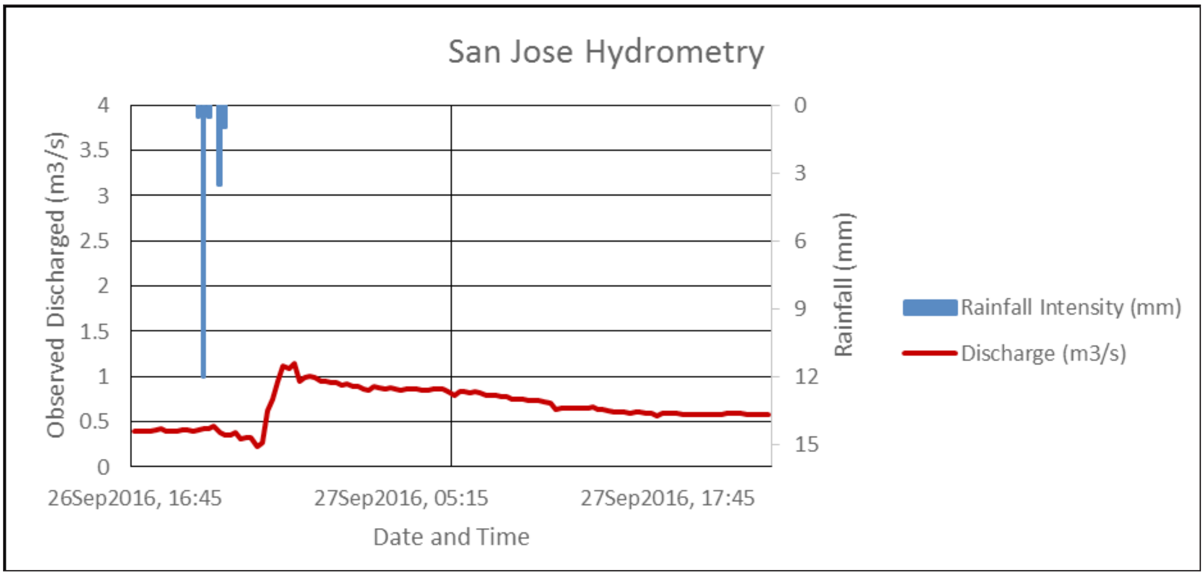



Figure 54. Rainfall and outflow data at Townsville Footbridge used for modeling

## 5.2 RIDF Station

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

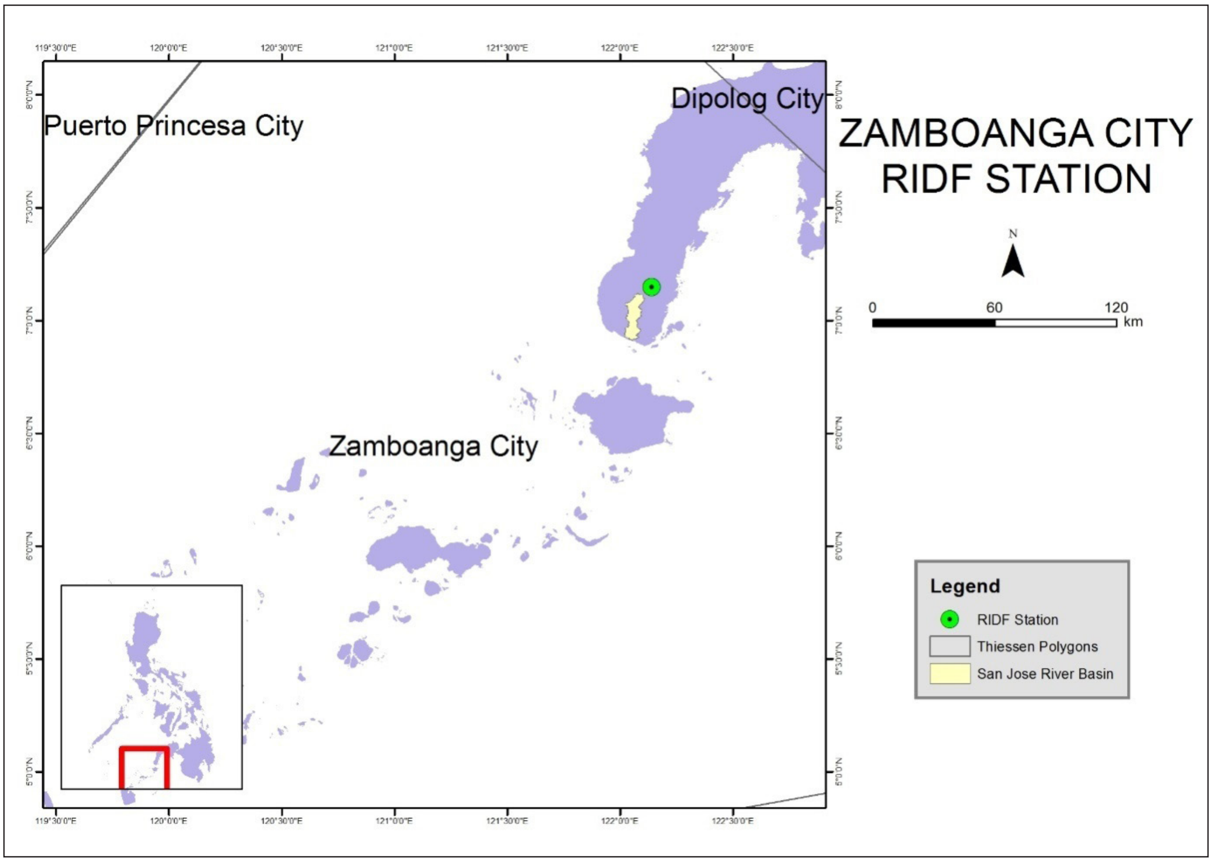



Figure 55. Dipolog City RIDF location relative to San Jose River Basin

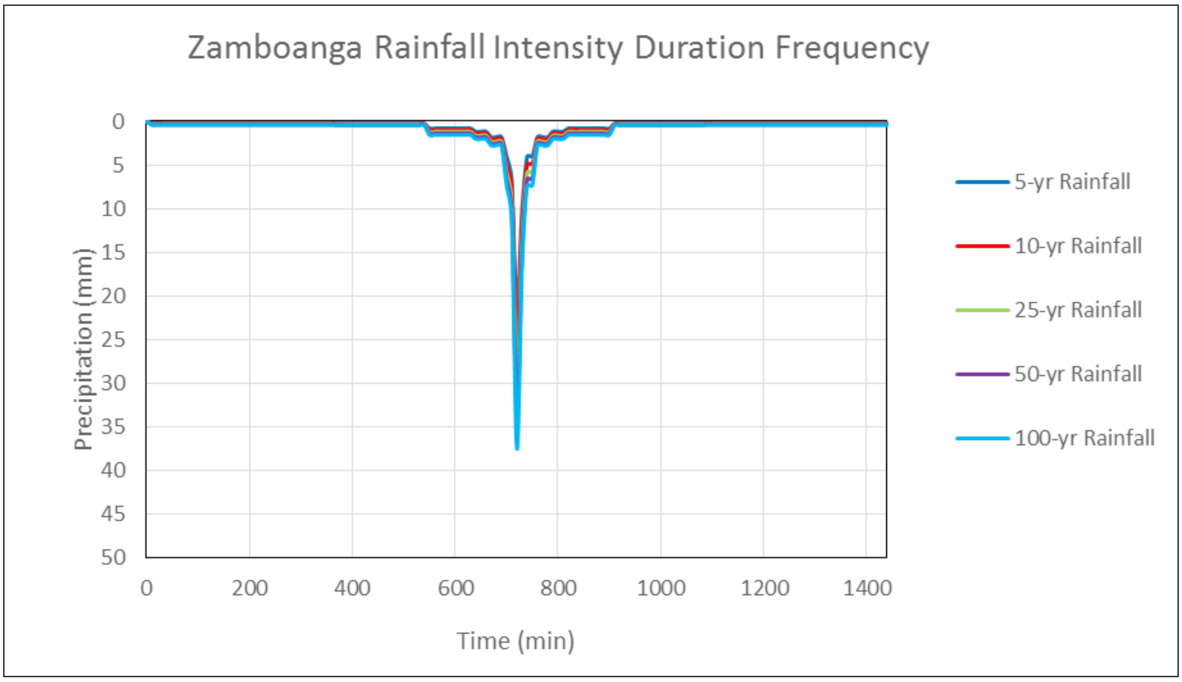



Figure 56. Synthetic storm generated for a 24-hr period rainfall for various return periods

## 5.3 HMS Model

The soil dataset was generated before 2004 by the Bureau of Soils under the Department of Agriculture (DA). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the San Jose River Basin are shown in Figures 57 and 58, respectively.

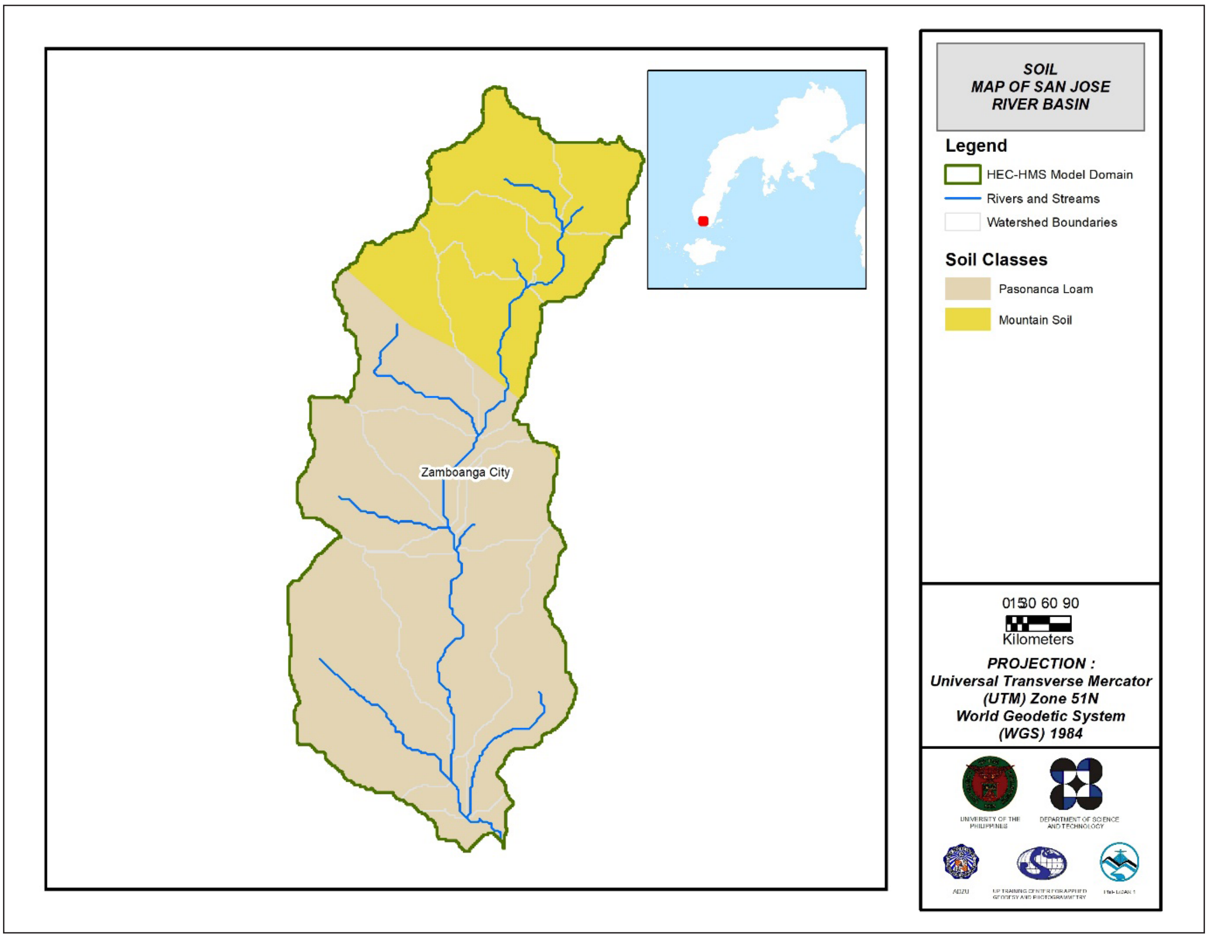



Figure 57. Soil Map of San Jose River Basin

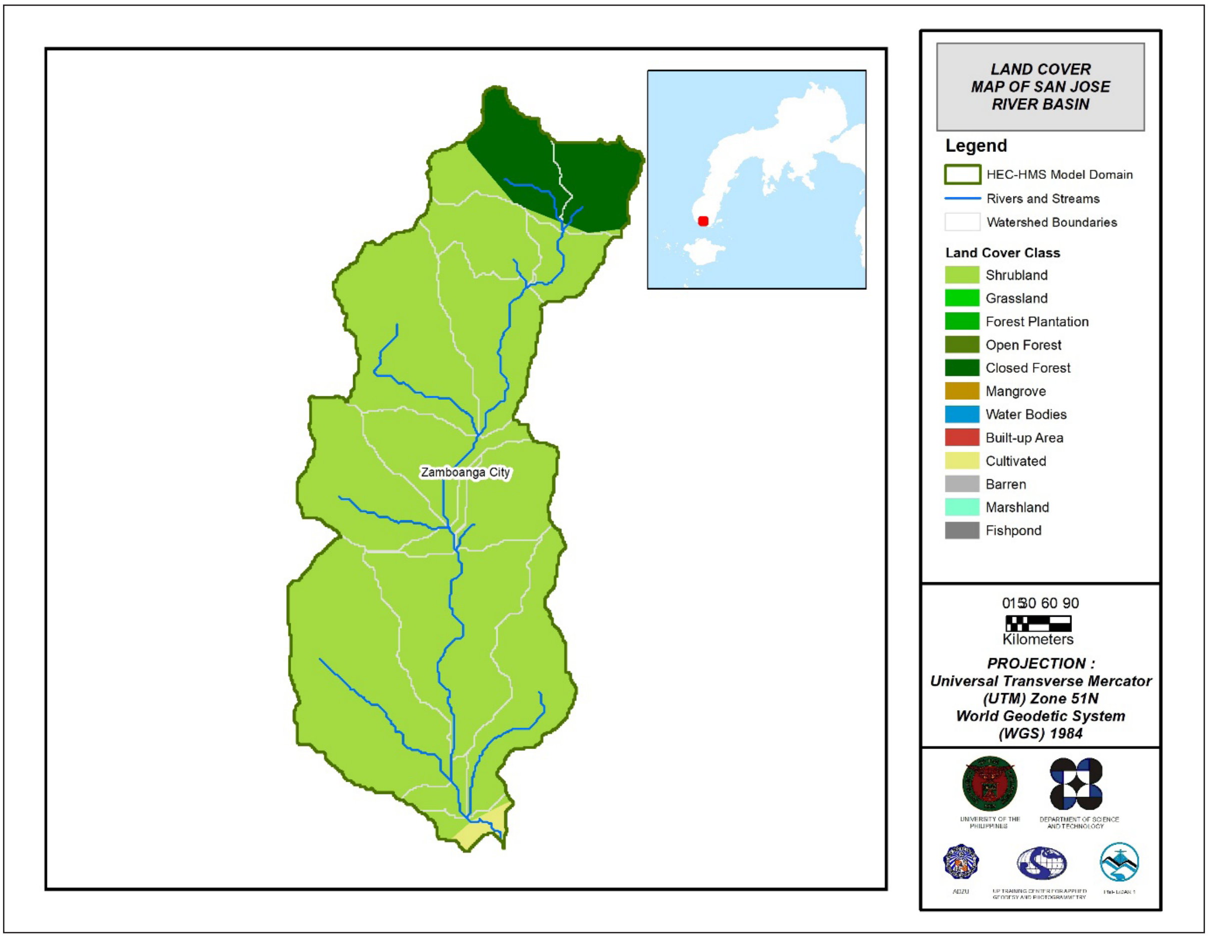



Figure 58. Land Cover Map of San Jose River Basin

For San Jose, the soil classes identified were loam and mountain soil. The land cover types identified were cultivated areas, shrubland, and closed canopy forests.

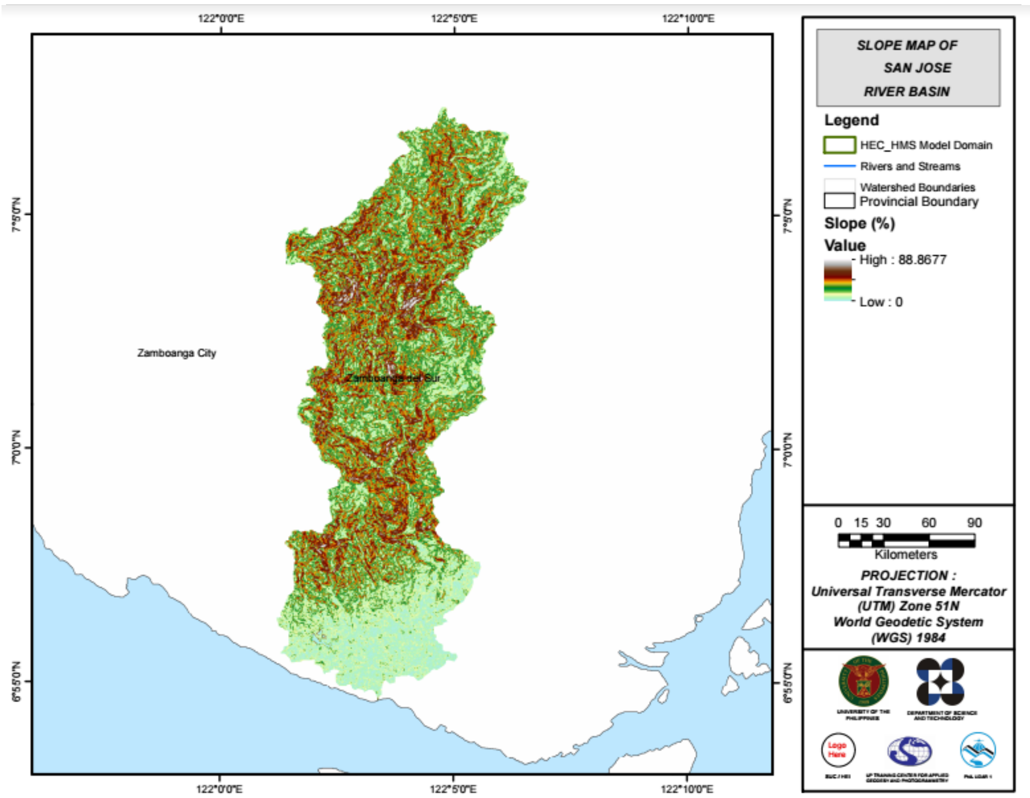



Figure 59. Slope Map of San Jose River Basin

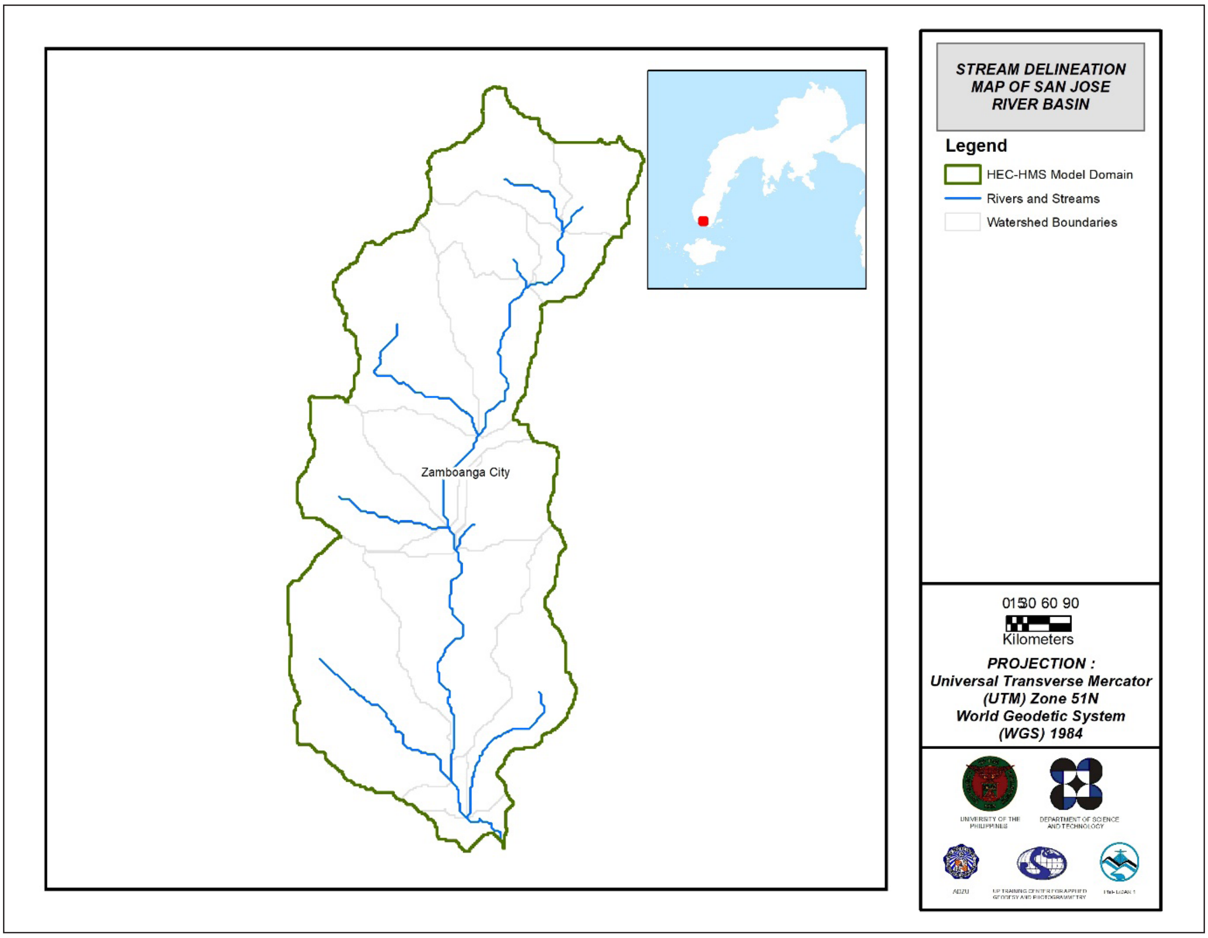



Figure 60. Stream delineation map of San Jose river basin

Using the SAR-based DEM, the San Jose basin was delineated and further subdivided into subbasins. The model consists of 15 sub basins, 7 reaches, and 7 junctions as shown in Figure 61 (See Annex 10). The main outlet is at Townsville Footbridge, Brgy. San Roque, Zamboanga City.

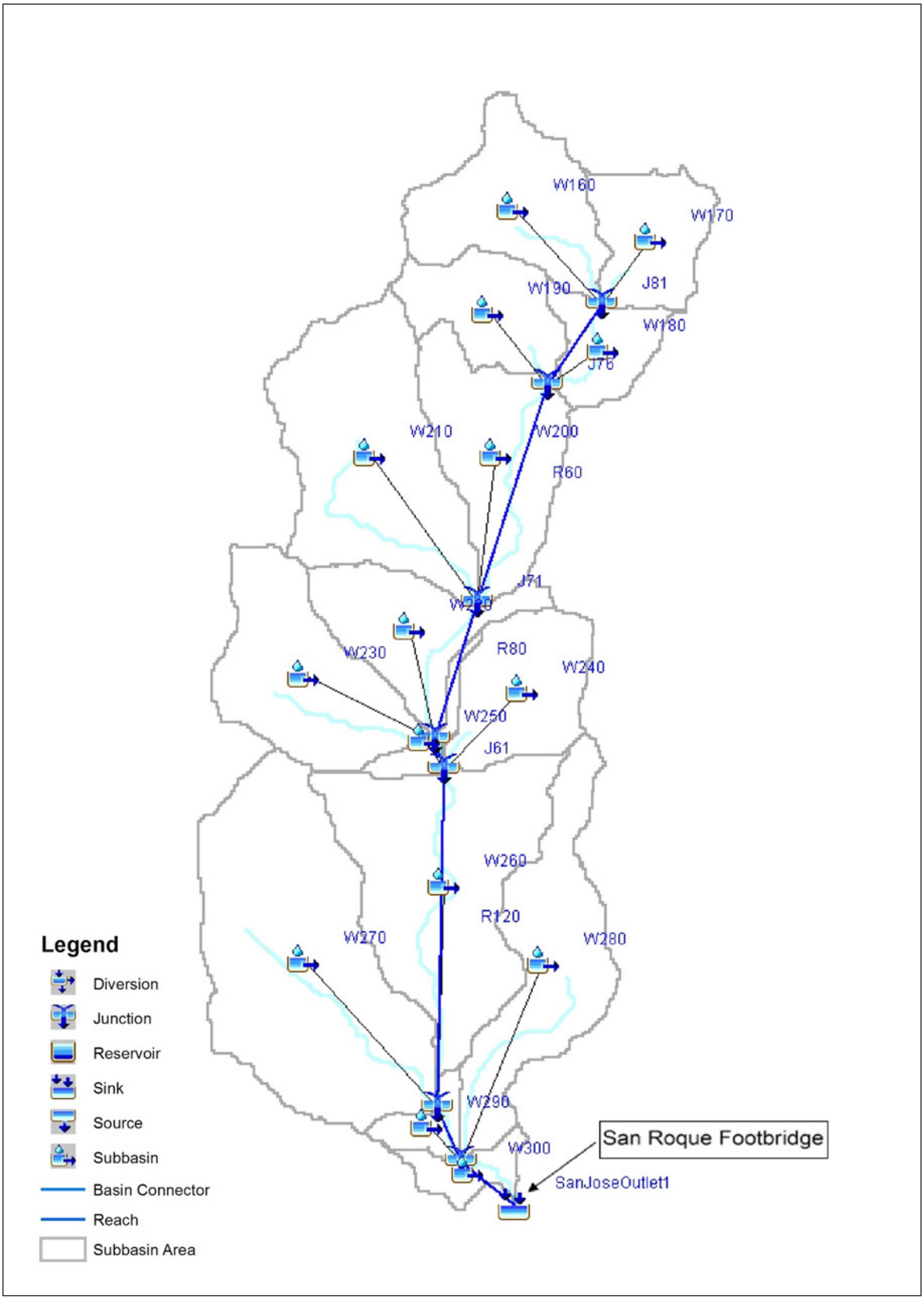



Figure 61. The San Jose river basin model generated using HEC-HMS

## 5.4 Cross-section Data

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

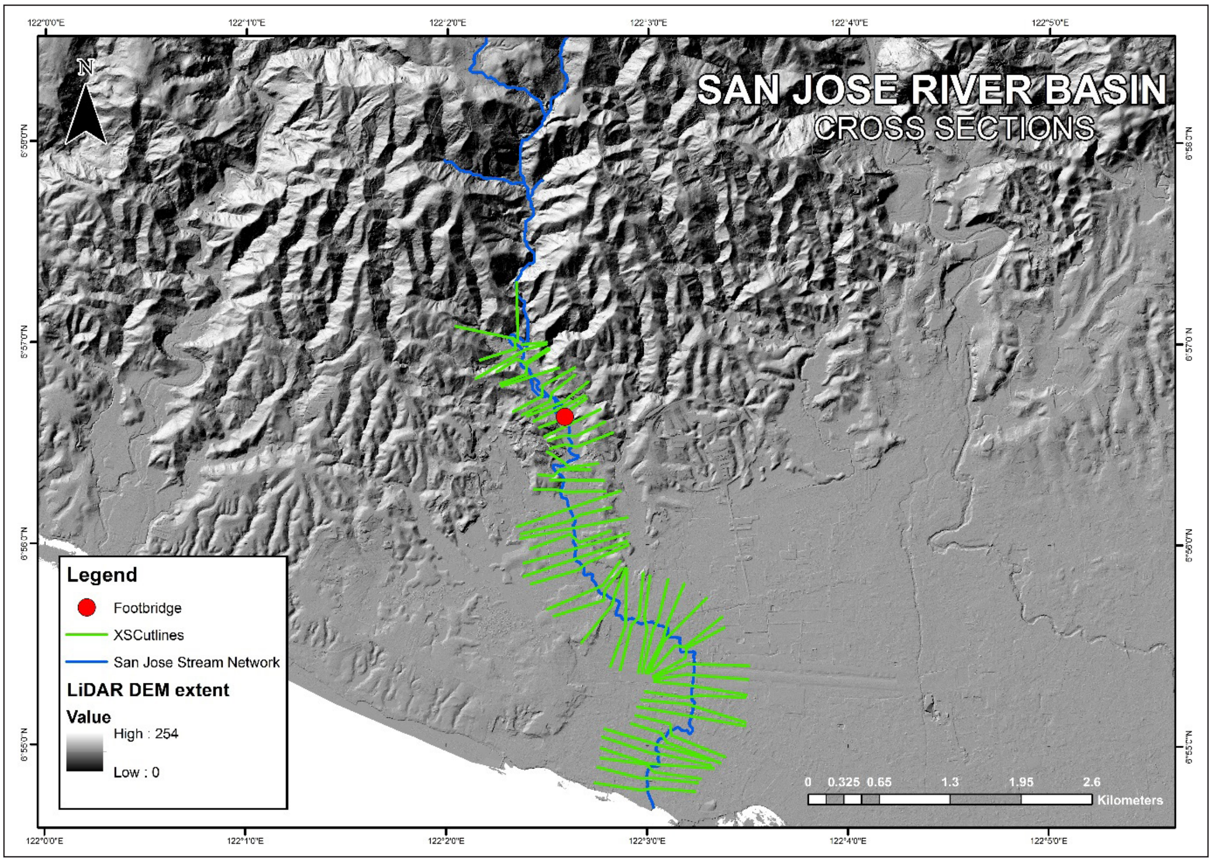



Figure 62. River cross-section of San Jose River generated through Arcmap HEC GeoRAS tool

## 5.5 Flo 2D Model

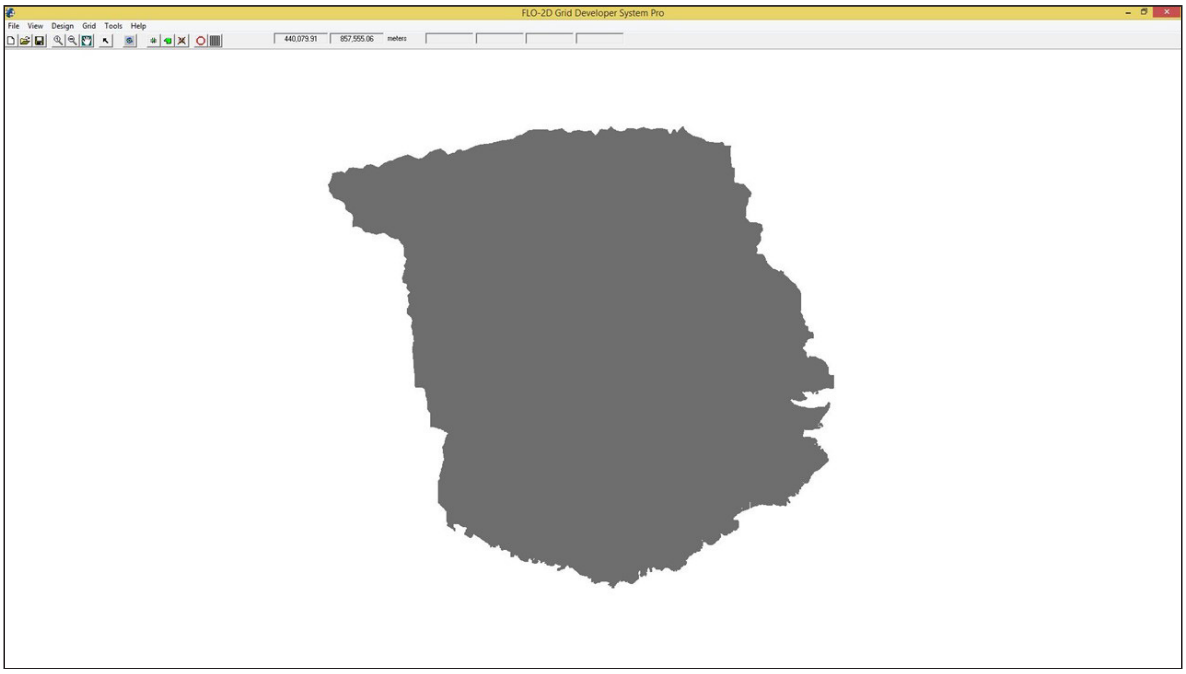



Figure 63. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

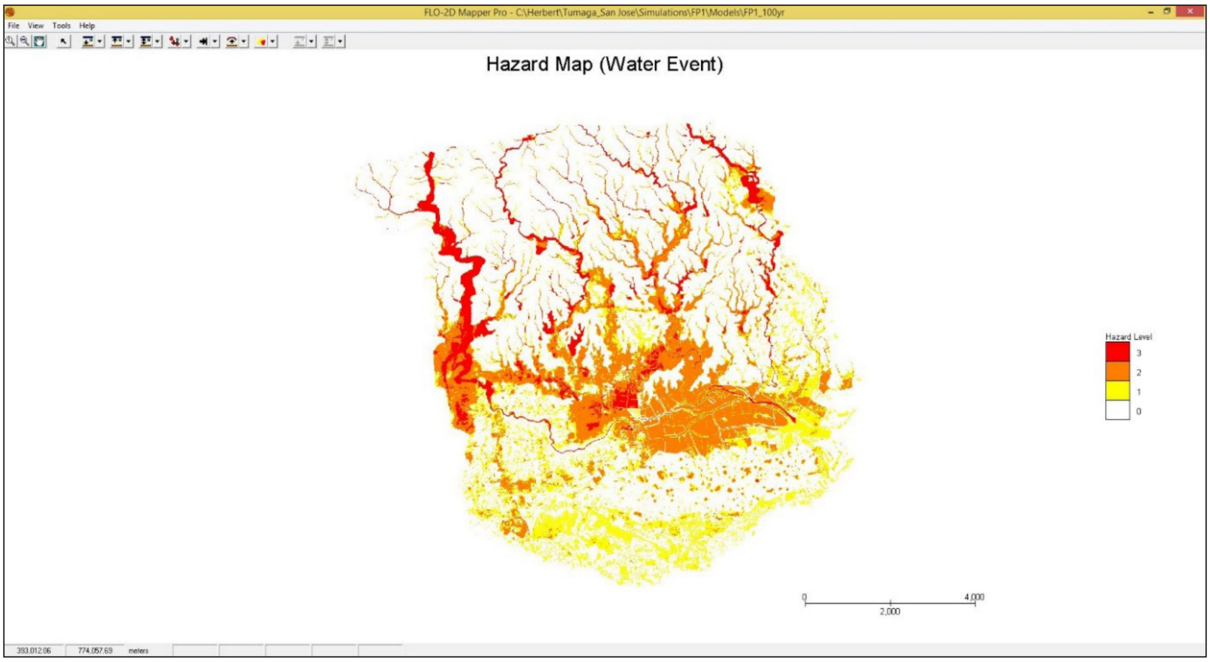



Figure 64. Generated 100-year rain return hazard map from FLO-2D Mapper

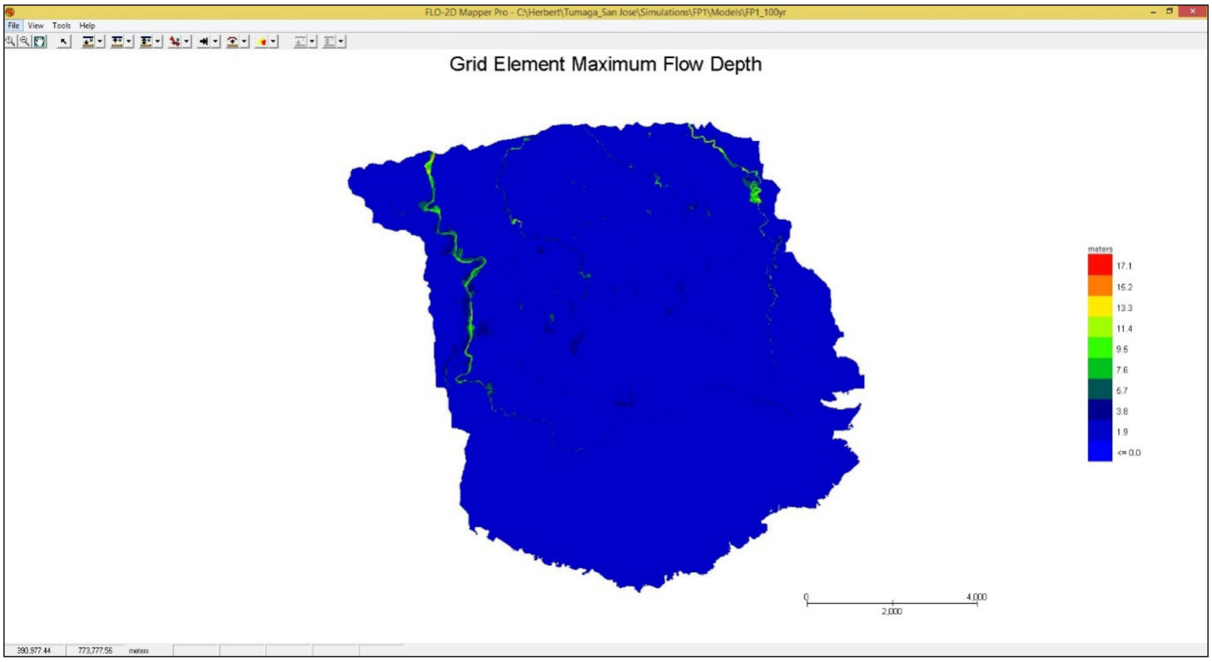



Figure 65. Generated 100-year rain return flow depth map from FLO-2D Mapper

## 5.6 Results of HMS Calibration

After calibrating the San Jose 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.

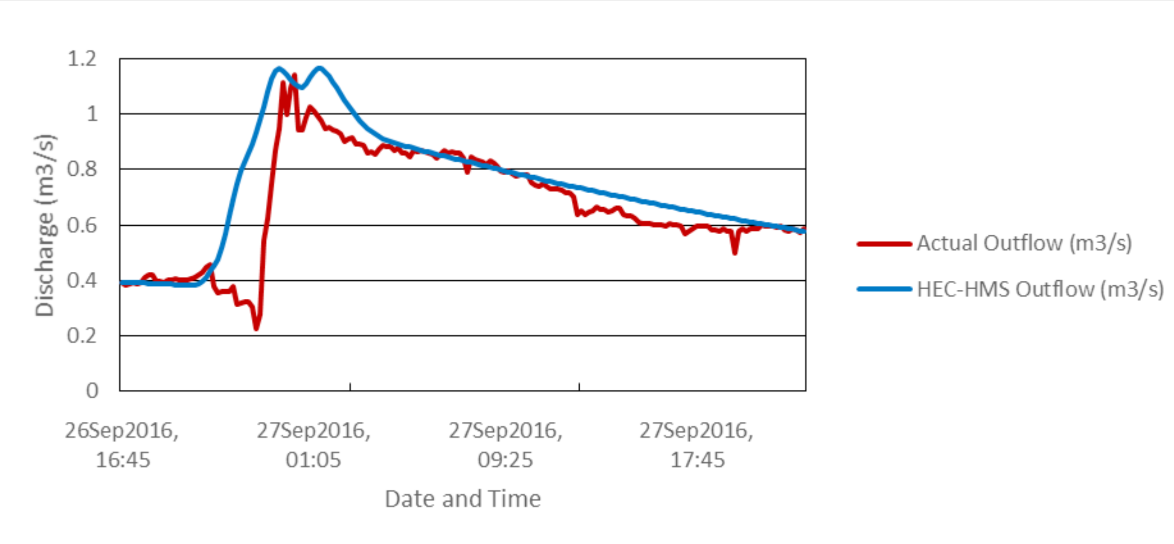



Figure 66. Outflow Hydrograph of San Jose River Basin produced by the HEC-HMS model compared with observed outflow

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

Table 32. Range of Calibrated Values for San Jose

| Hydrologic Element | Calculation Type | Method | Parameter | Range of Calibrated Values |
|---|---|---|---|---|
| Basin | Loss | SCS Curve number | Initial Abstraction (mm) | 0.0042 – 0.0055 |
| | | | Curve Number | 67 – 77 |
| | Transform | Clark Unit Hydrograph | Time of Concentration (hr) | 0.39 – 1.41 |
| | | | Storage Coefficient (hr) | 0.64 – 2.29 |
| | Baseflow | Recession | Recession Constant | 0.55 |
| | | | Ratio to Peak | 0.5 |
| Reach | Routing | Muskingum-Cunge | Manning's Coefficient | 0.215 |

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 0.0042 – 0.0055mm means that there is a minimal 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 67-77 fo curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For San Jose, the basin mostly consists of built-up, brushland and closed canopy forests and the soil consists of loams and undifferentiated 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 0.39 hours to 2.29 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.55 indicates that the basin is moderately unlikely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.5 indicates a steeper receding limb of the outflow hydrograph.

Table 33. Summary of the Efficiency Test of San Jose HMS Model

| | |
|---|---|
| **RMSE** | 1.979888 |
| **$r^2$** | 0.8544 |
| **NSE** | 0.510597 |
| **PBIAS** | -10.6761 |
| **RSR** | 0.699574 |

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as1.979888 (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 0.8544.

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 0.510597.

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 -10.6761.

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 0.699574.

## 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 San Jose 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 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.

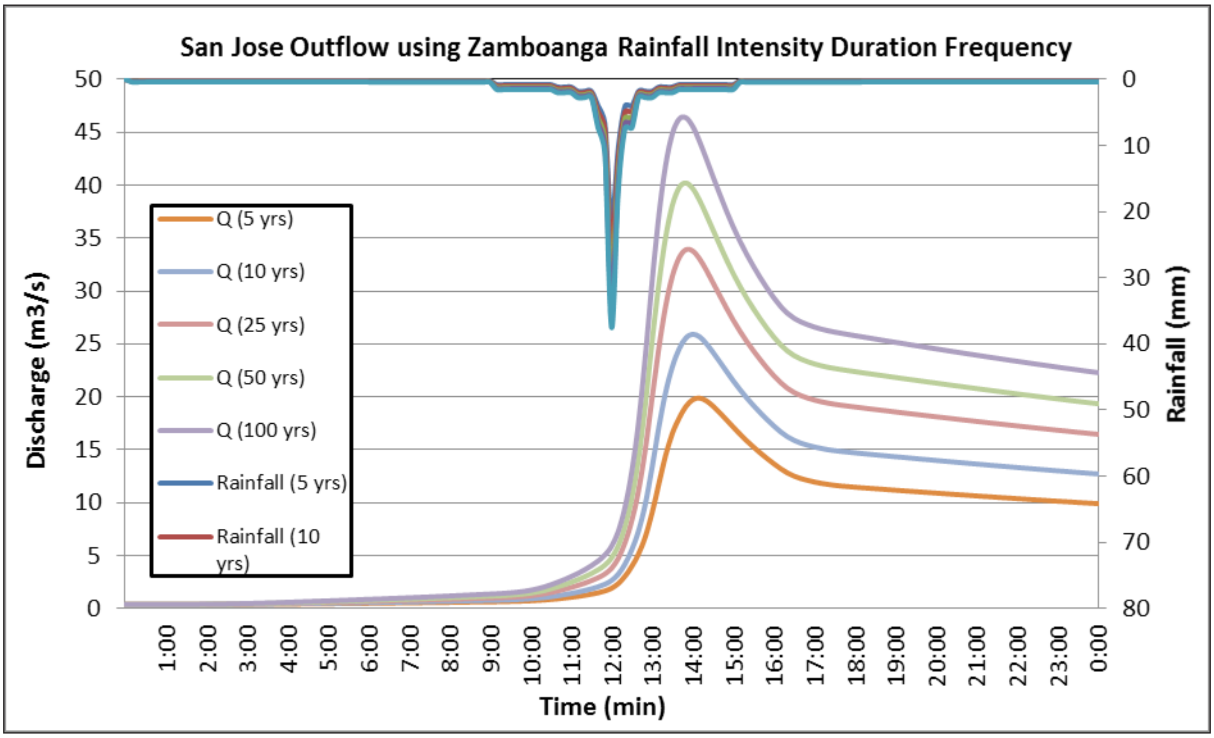



Figure 67. Outflow hydrograph at Townsville Footbridge Station generated using Zamboanga City RIDF simulated in HEC-HMS

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

Table 34. Peak values of the San Jose HEC-HMS Model outflow using the Zamboanga CityRIDF

| RIDF Period | Total Precipitation (mm) | Peak rainfall (mm) | Peak outflow ($m^3/s$) | Time to Peak |
|---|---|---|---|---|
| 5-Year | 107.8 | 21.4 | 19.89 | 14 hours 10 minutes |
| 10-Year | 127.9 | 25.3 | 25.92 | 14 hours |
| 25-Year | 153.4 | 30.2 | 33.90 | 13 hours 50 minutes |
| 50-Year | 172.3 | 33.9 | 40.21 | 13 hours 50 minutes |
| 100-Year | 191.1 | 37.5 | 46.37 | 13 hours 50 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 was used in determining the flooded areas within the model. The simulated model was an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. The sample generated map of San Jose River using the calibrated HMS base flow is shown in Figure 68.

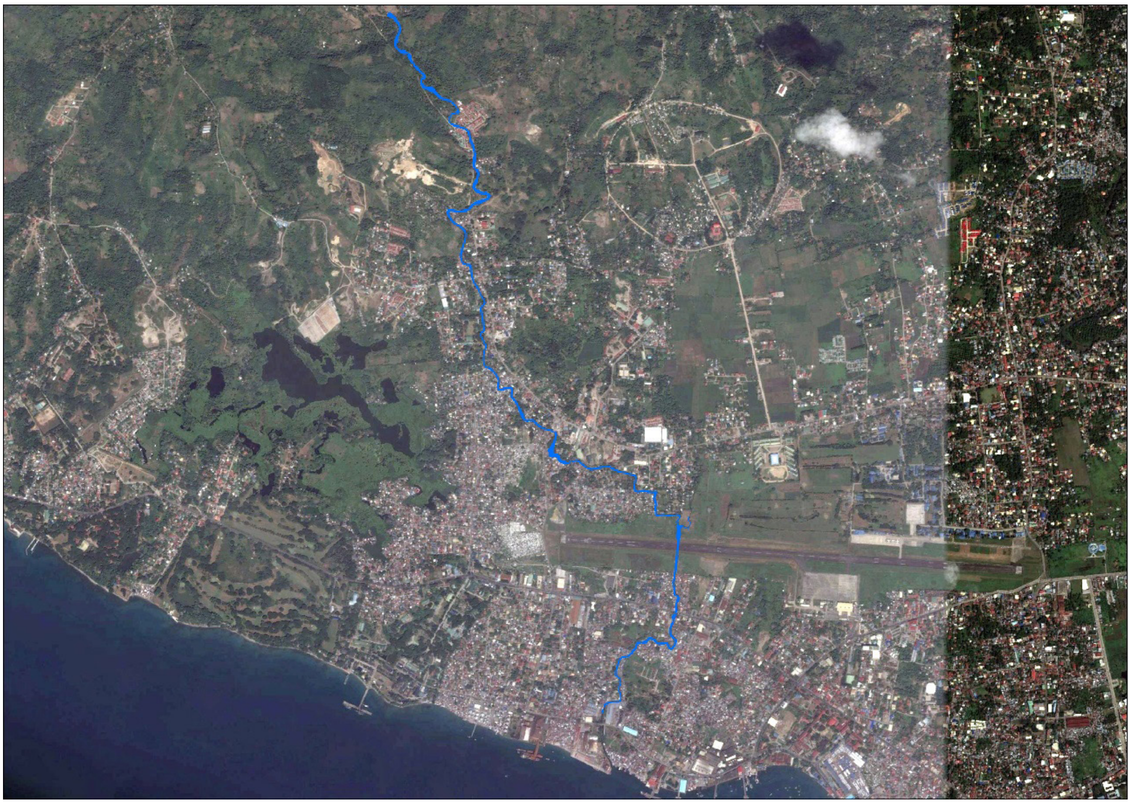


Figure 68. Sample output of San Jose RAS Model

## 5.9 Flood Hazard and Flow Depth

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

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 35. Municipalities affected in Tumaga-San Jose floodplain

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

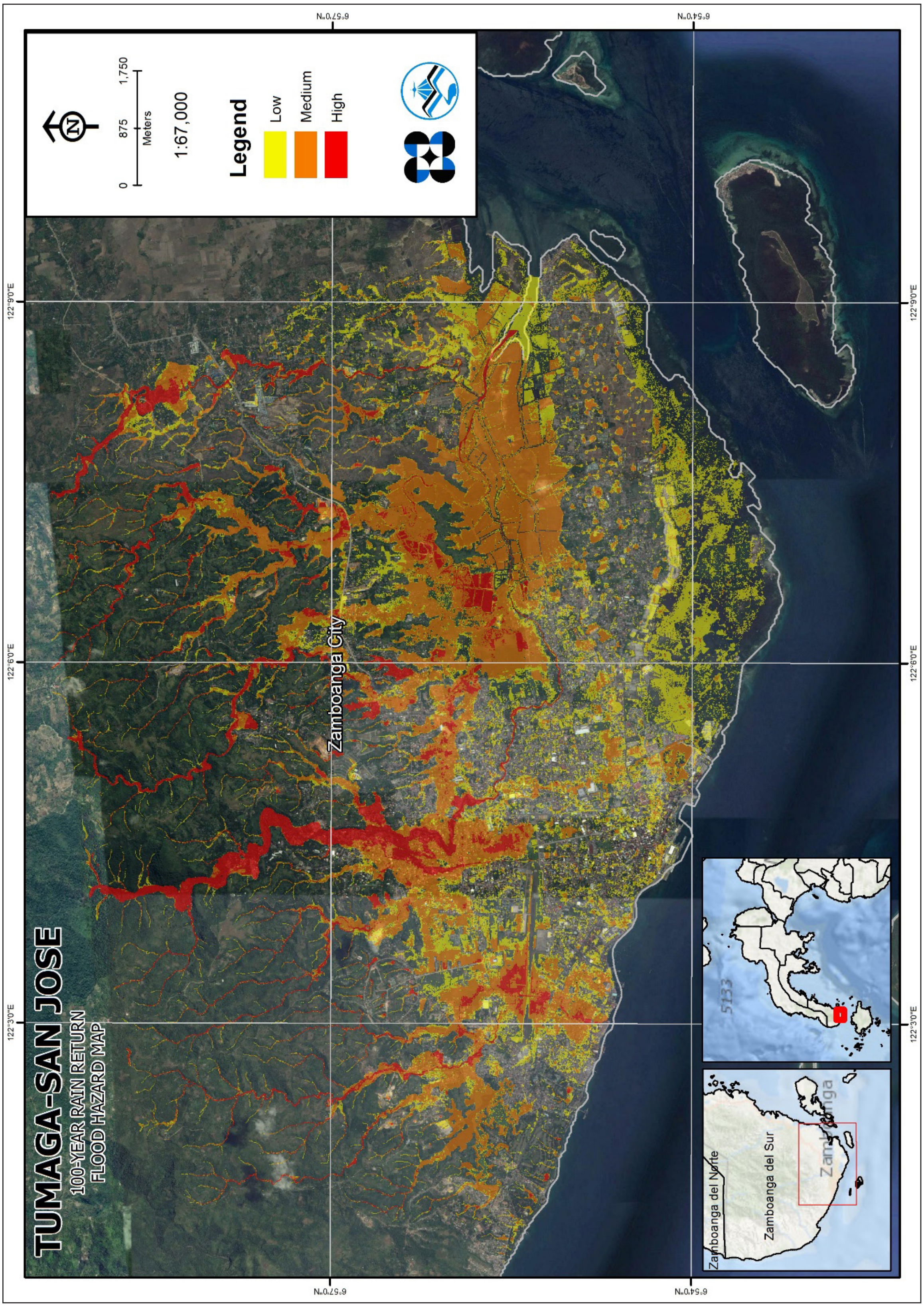



Figure 69. 100-year Flood Hazard Map for Tumaga-San Jose Floodplain

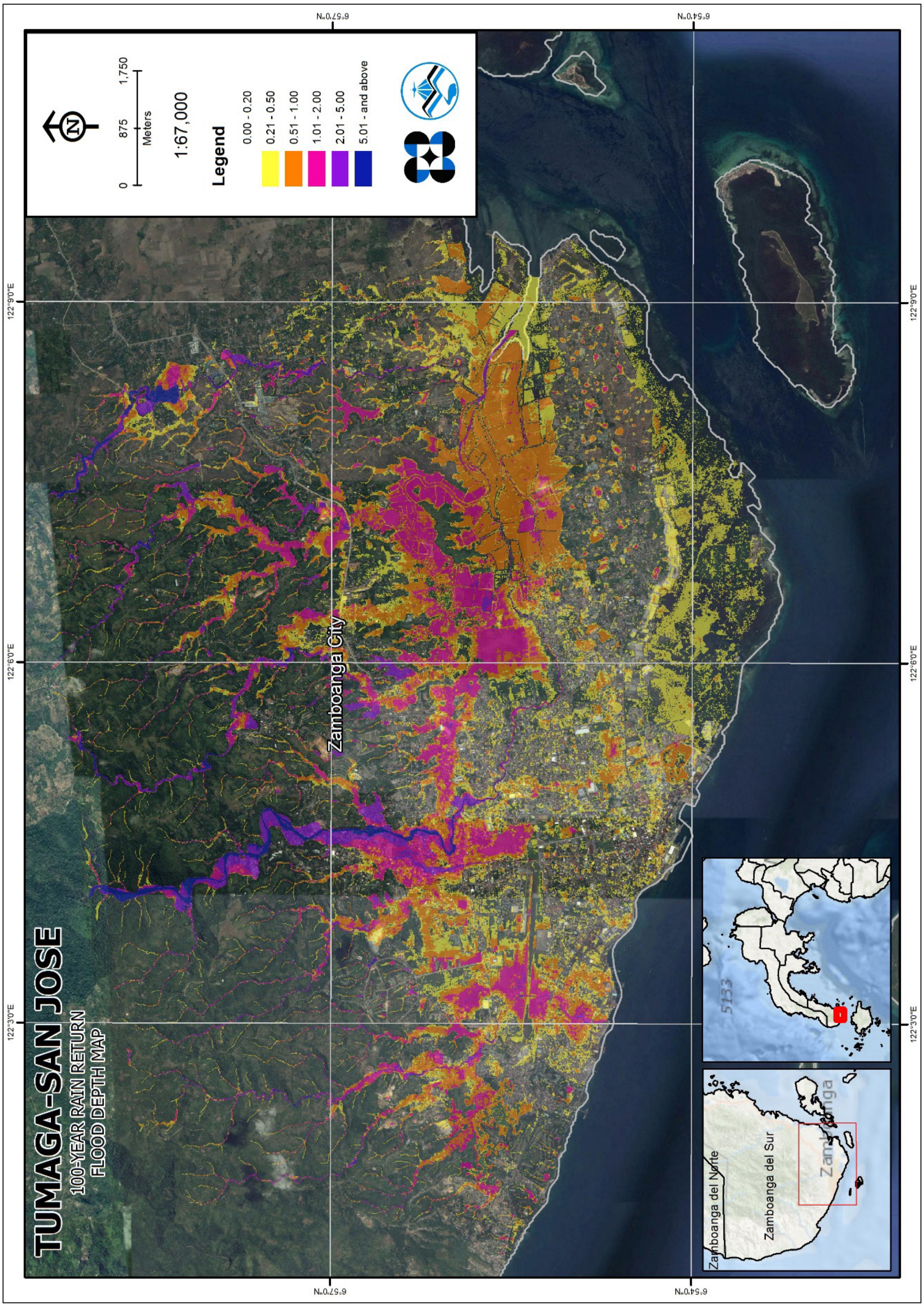



Figure 70. 100-year Flow Depth Map for Tumaga-San Jose Floodplain

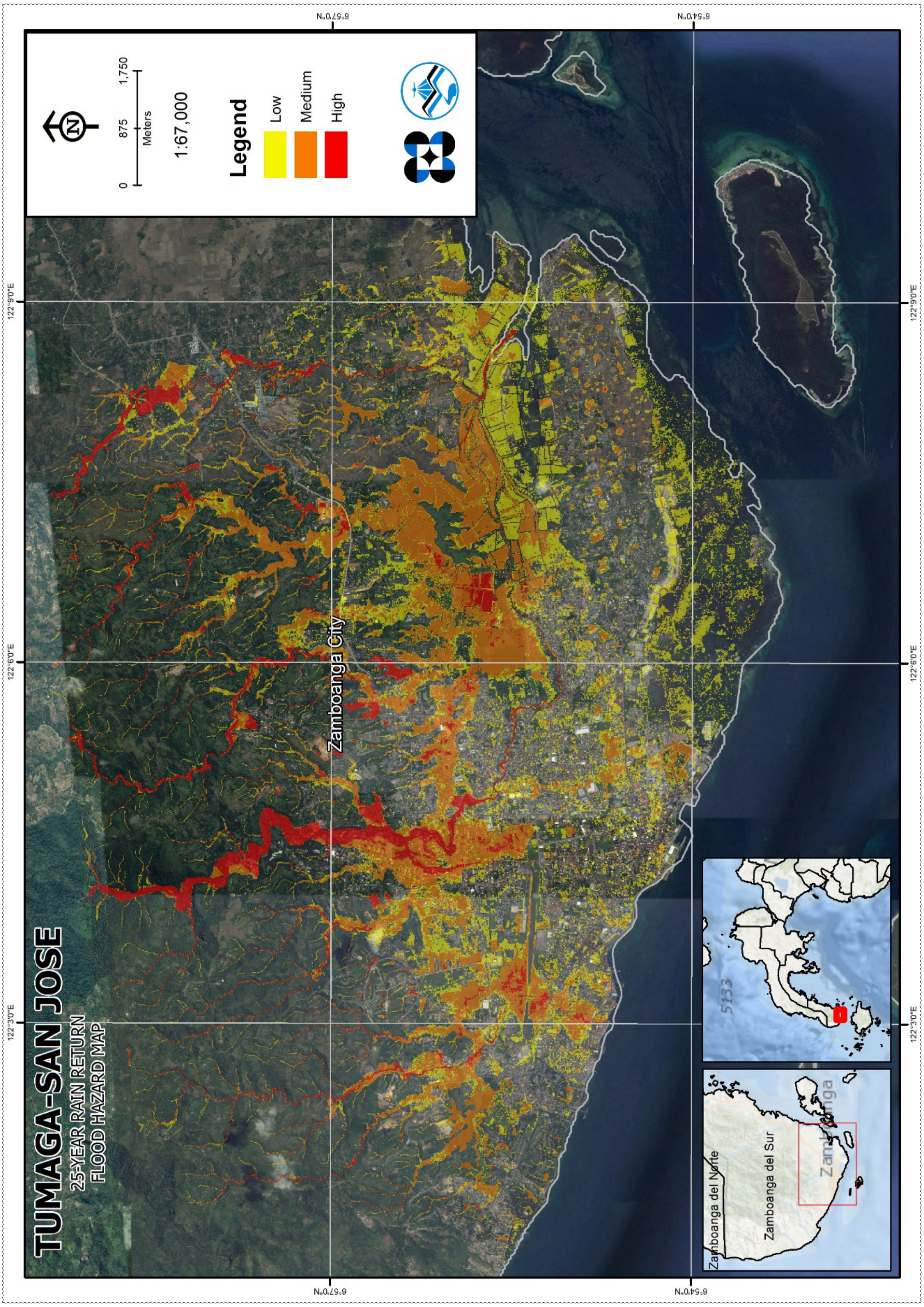



Figure 71. 25-year Flood Hazard Map for Tumaga-San Jose Floodplain

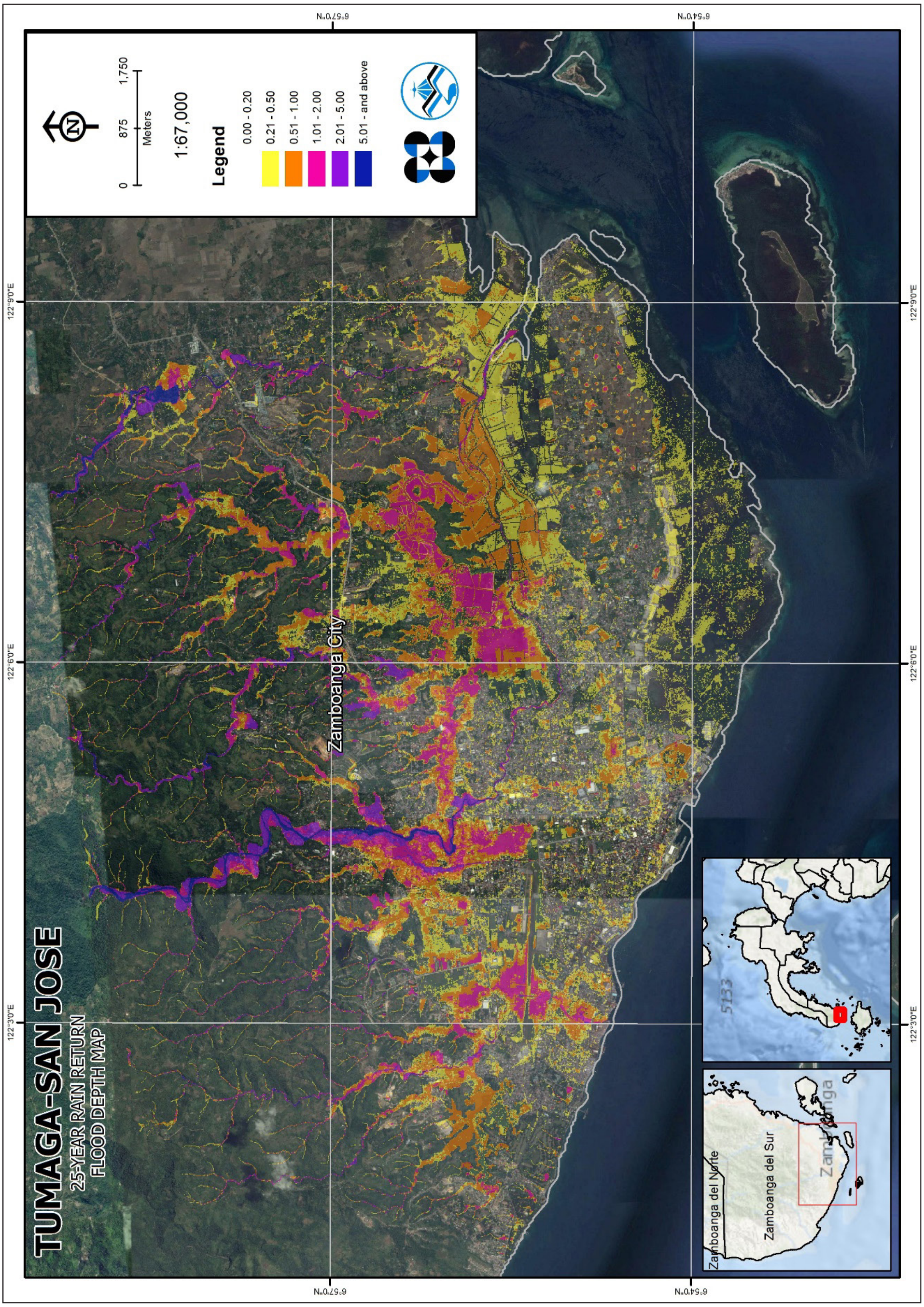



Figure 72. 25-year Flow Depth Map for Tumaga-San Jose Floodplain

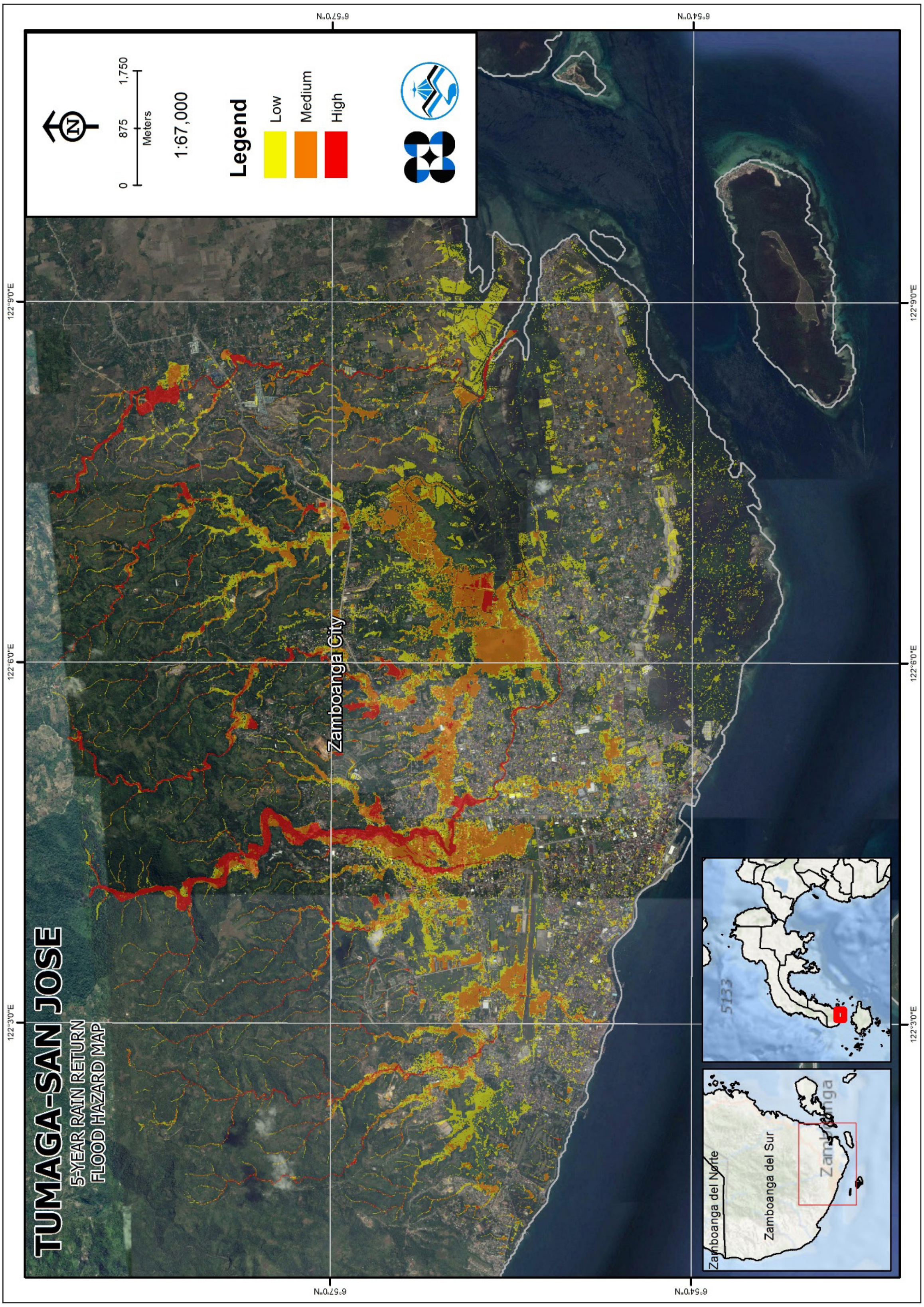



Figure 73. 5-year Flood Hazard Map for Tumaga-San Jose Floodplain

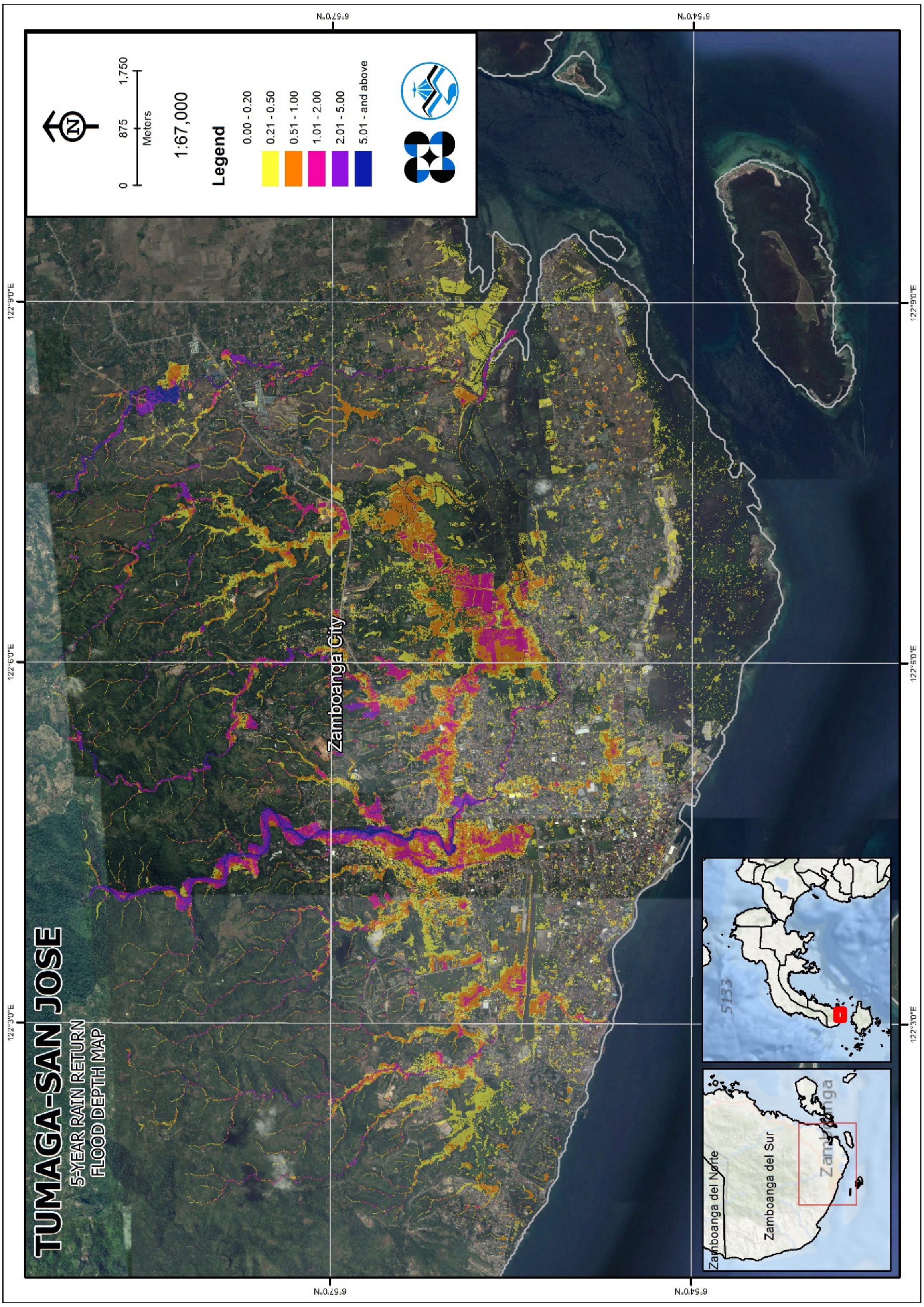



Figure 74. 5-year Flood Depth Map for Tumaga-San Jose Floodplain

## 5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Tumaga-San Jose Rive r 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 municipality 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 the table are the affected areas in square kilometers by flood depth per barangay. Annex 12 and Annex 13 show the educational and health institutions exposed to flooding,

Table 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 |

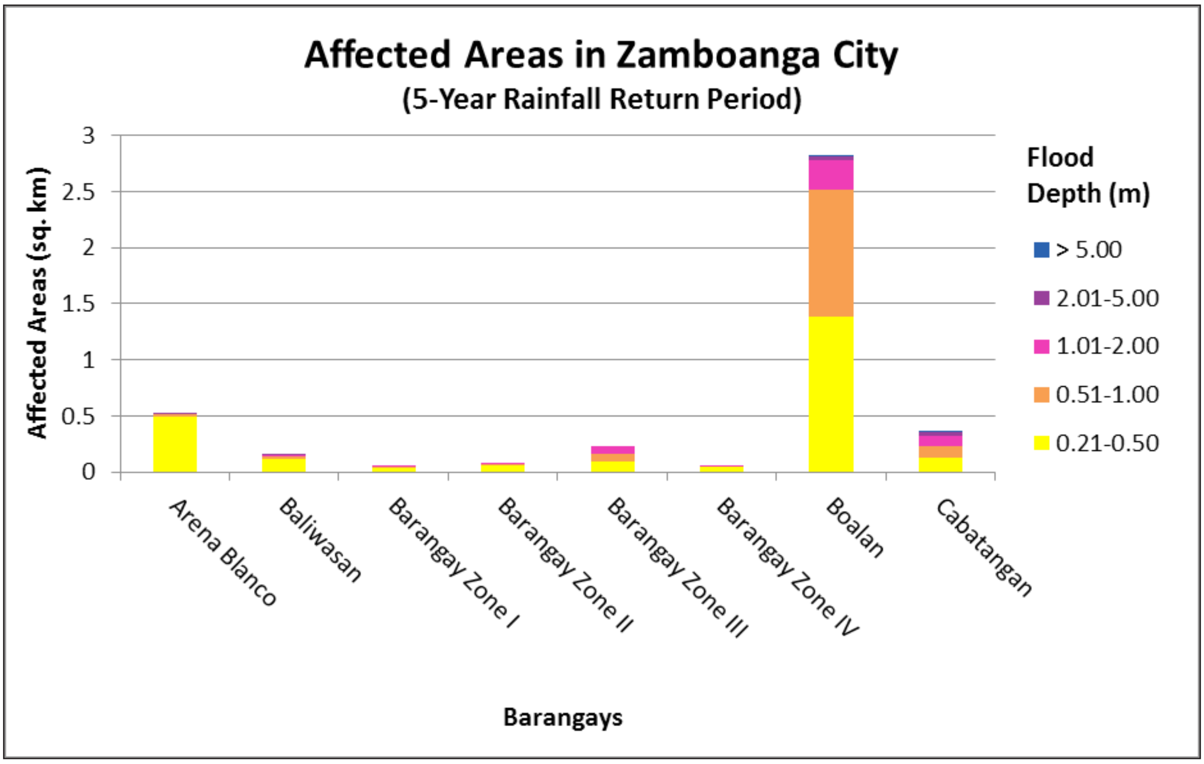



Figure 75. Affected Areas in Zamboanga City during 5-Year Rainfall Return Period

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 |

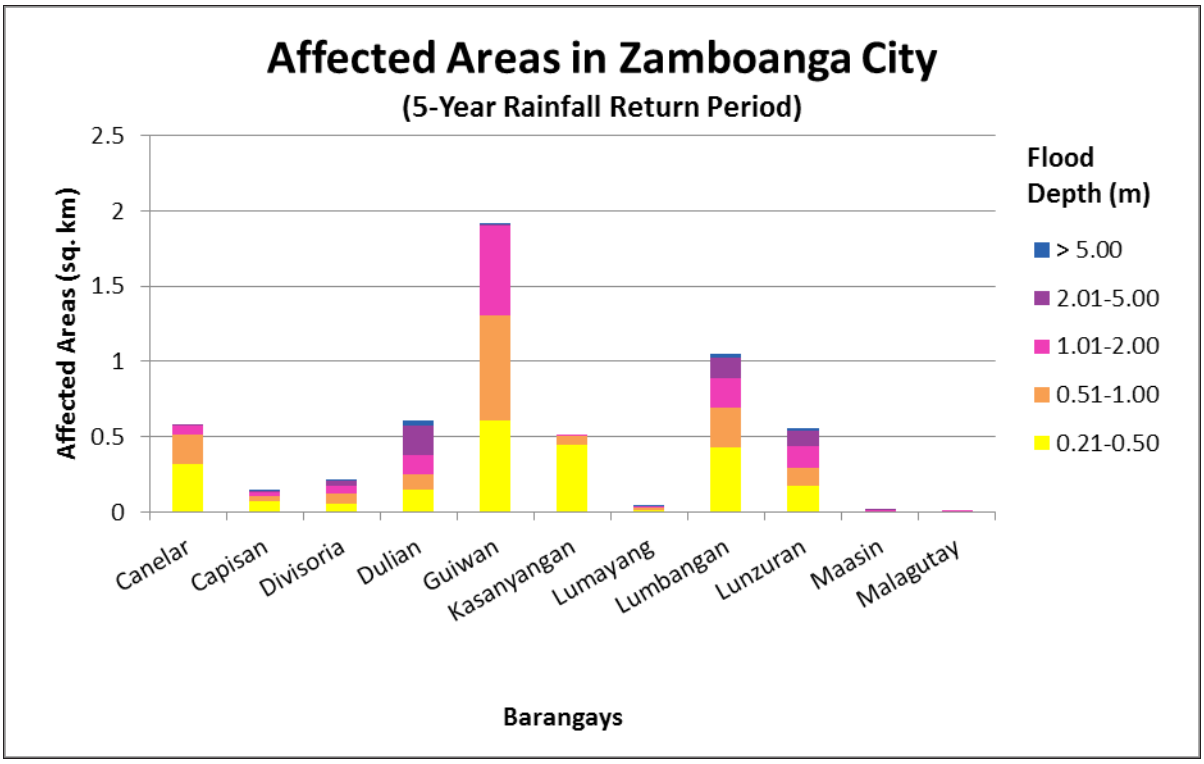



Figure 76. Affected Areas in Zamboanga City during 5-Year Rainfall Return Period

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 |

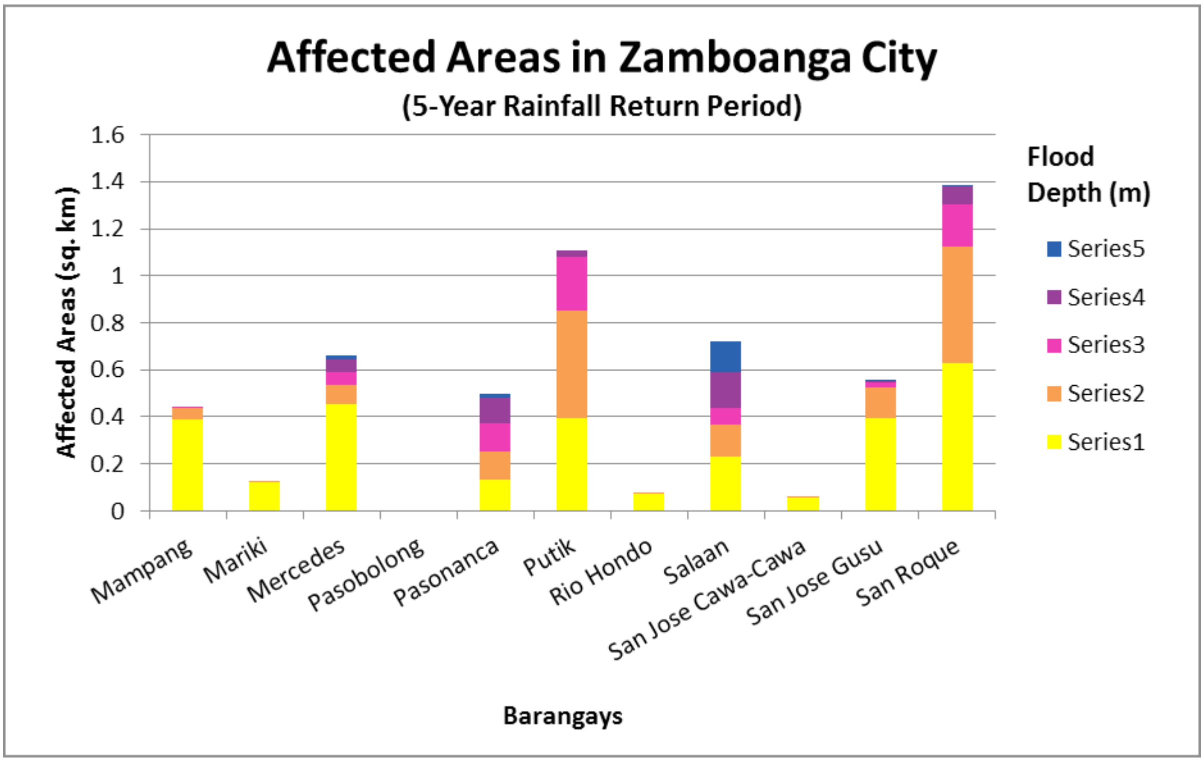



Figure 77. Affected Areas in Zamboanga City during 5-Year Rainfall Return Period

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 |

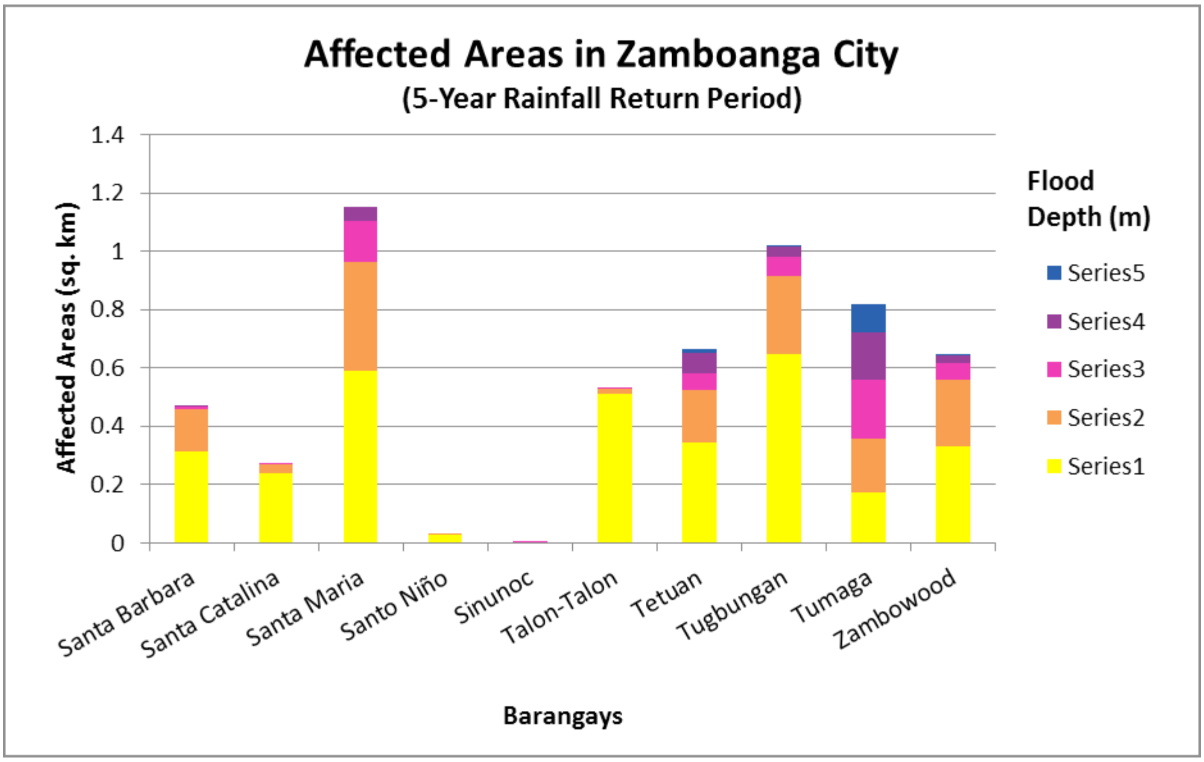



Figure 78. Affected Areas in Zamboanga City during 5-Year Rainfall Return Period

For the 25-year return period, 6.08% of the municipality 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 the table 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 |

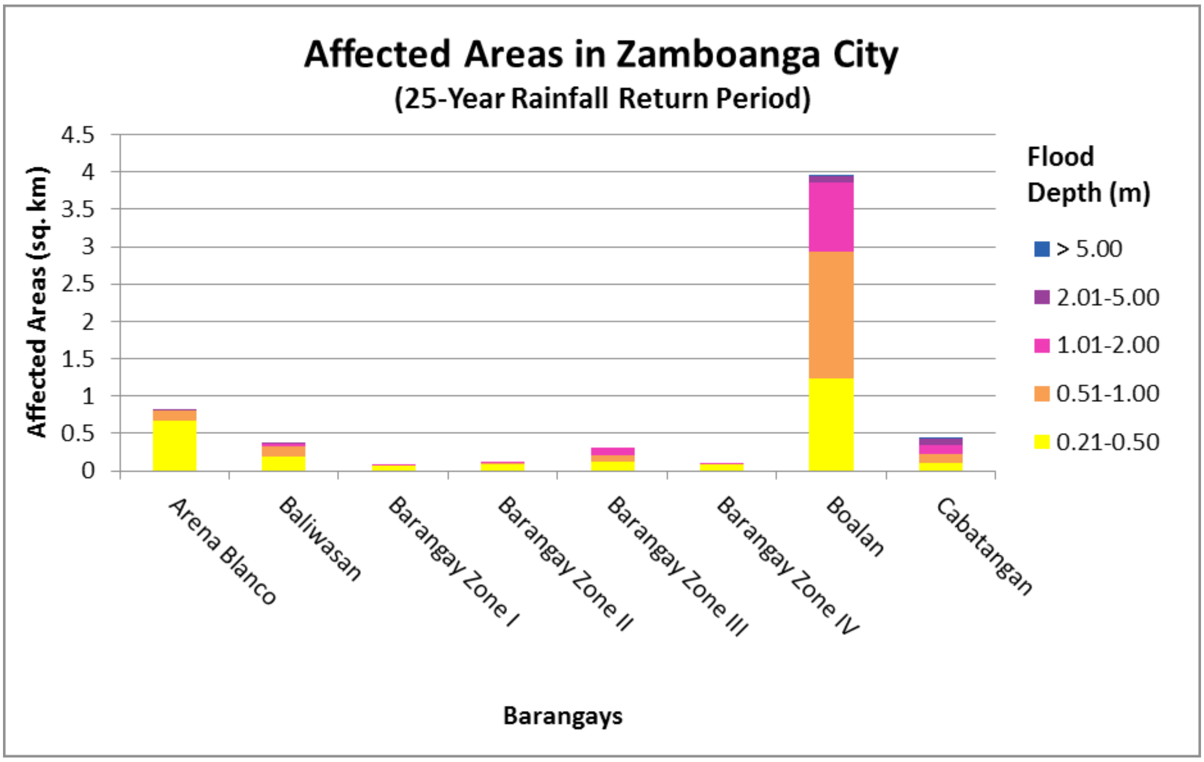



Figure 79. Affected Areas in Zamboanga City during 25-Year Rainfall Return Period

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 |

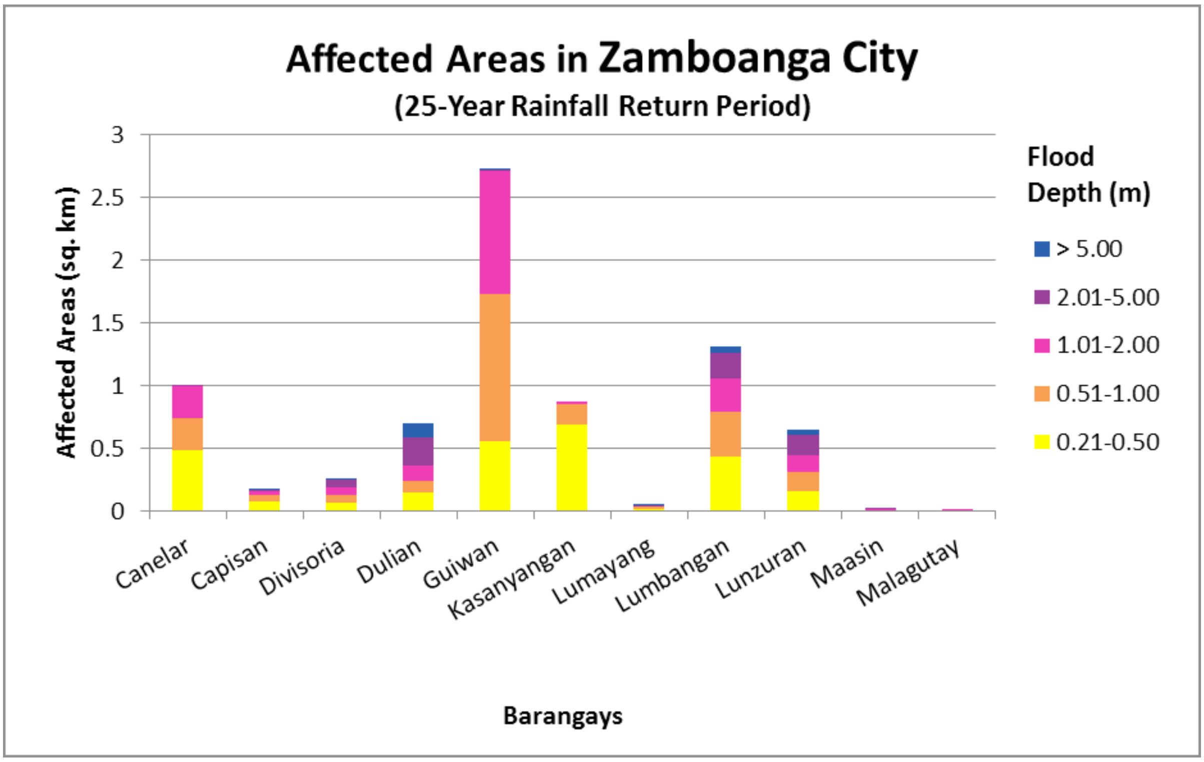



Figure 80. Affected Areas in Zamboanga City during 25-Year Rainfall Return Period

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 |

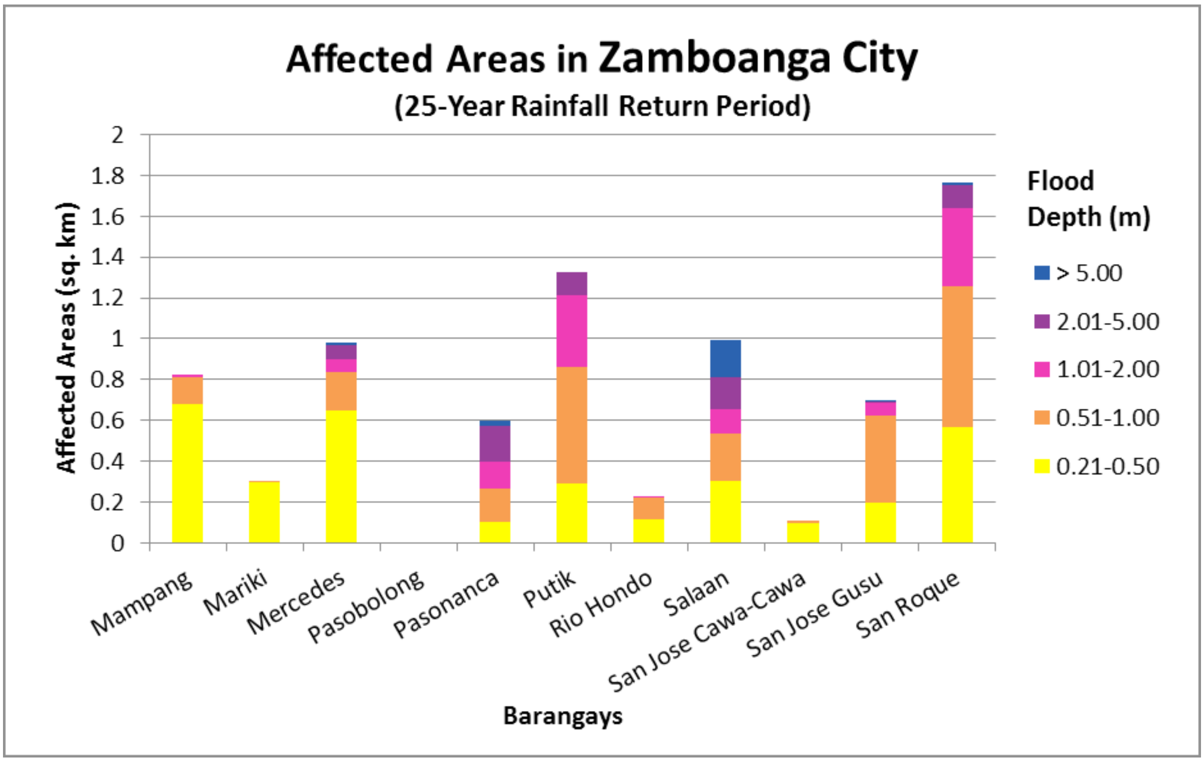



Figure 81. Affected Areas in Zamboanga City during 25-Year Rainfall Return Period

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 |

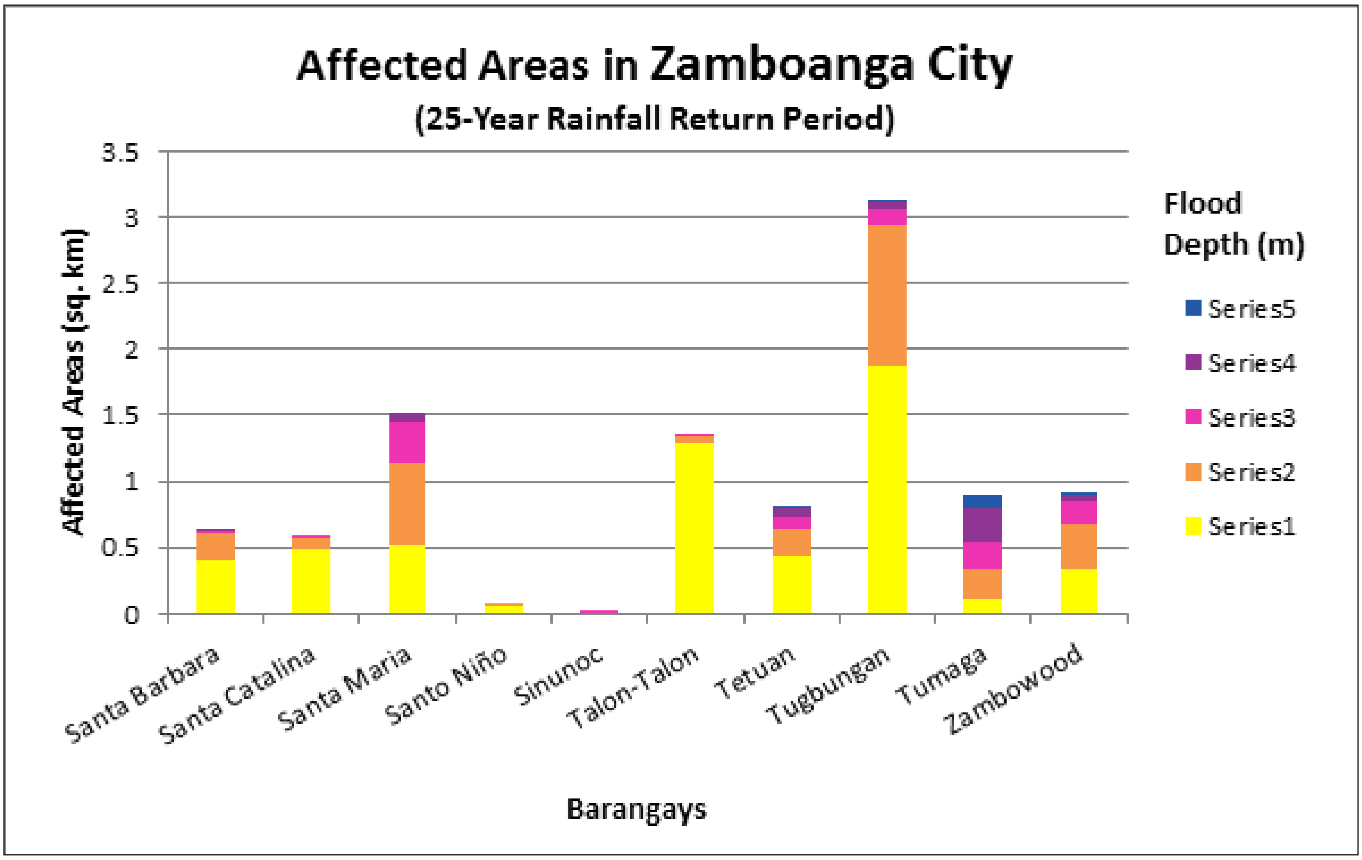



Figure 82. Affected Areas in Zamboanga City during 25-Year Rainfall Return Period

Table 44. 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 |

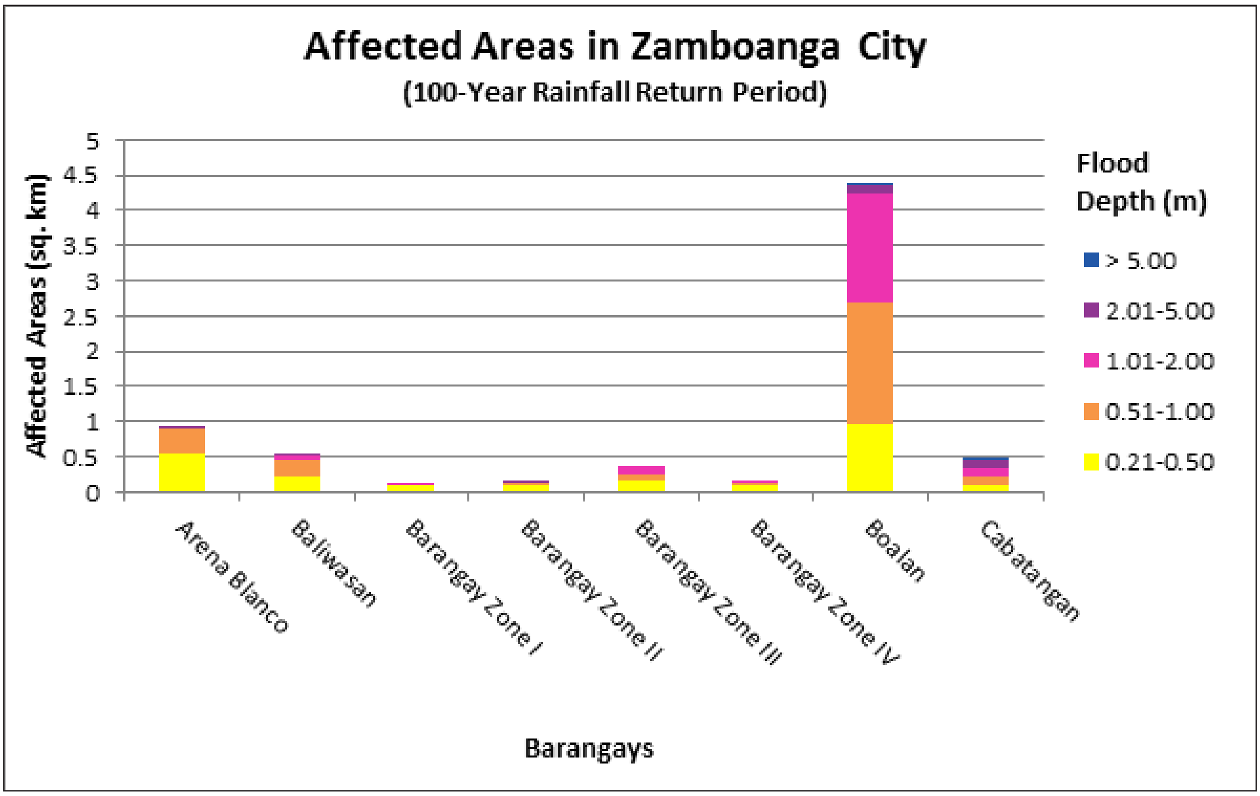



Figure 83. Affected Areas in Zamboanga City during 25-Year Rainfall Return Period

Table 45. 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 |

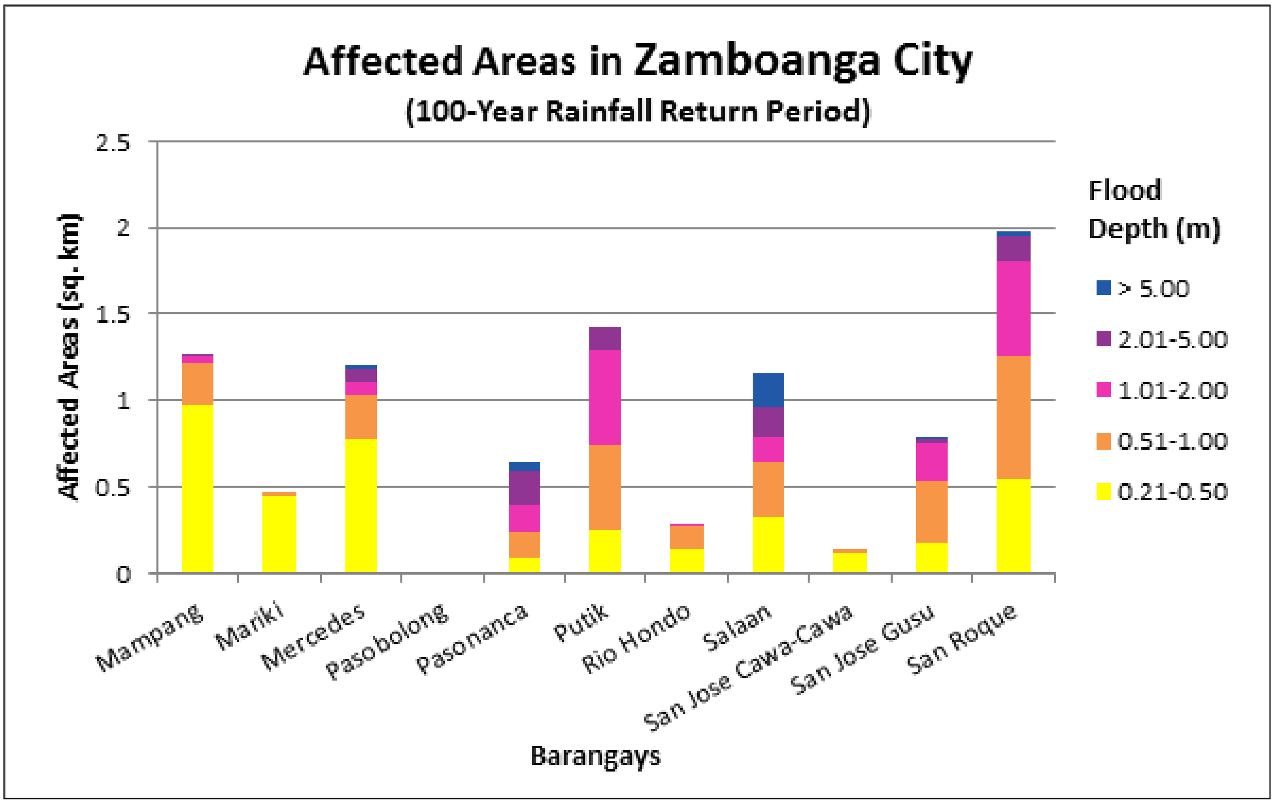



Figure 84. Affected Areas in Zamboanga City during 25-Year Rainfall Return Period

Table 46. 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 |

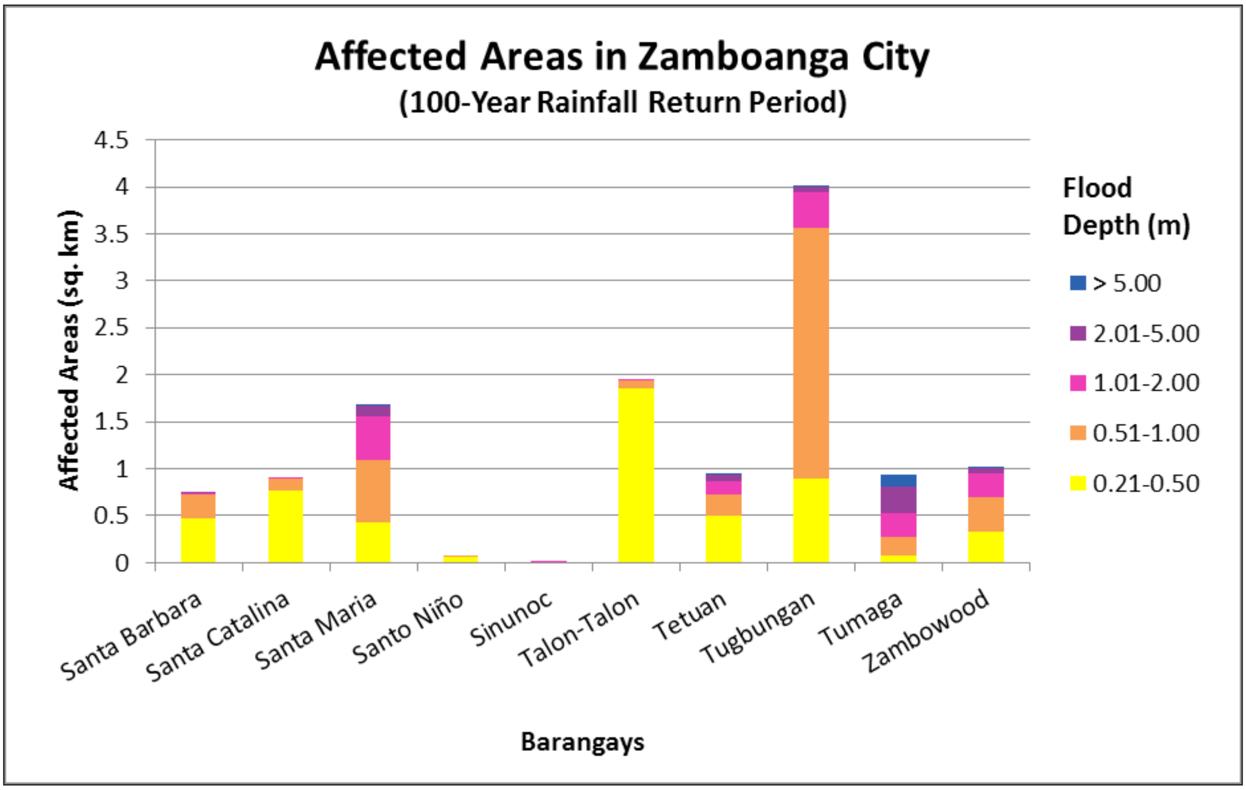



Figure 85. Affected Areas in Zamboanga City during 100-Year Rainfall Return Period

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 47. 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 scenario. 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; and 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; and 12 institutions were assessed as not exposed to any flooding for all the scenarios.

## 5.11 Flood Validation

The flood validation consists of 190 points randomly selected all over the San Jose Floodplain. It has an RMSE value of 0.91. The validation points are found in Annex 11.

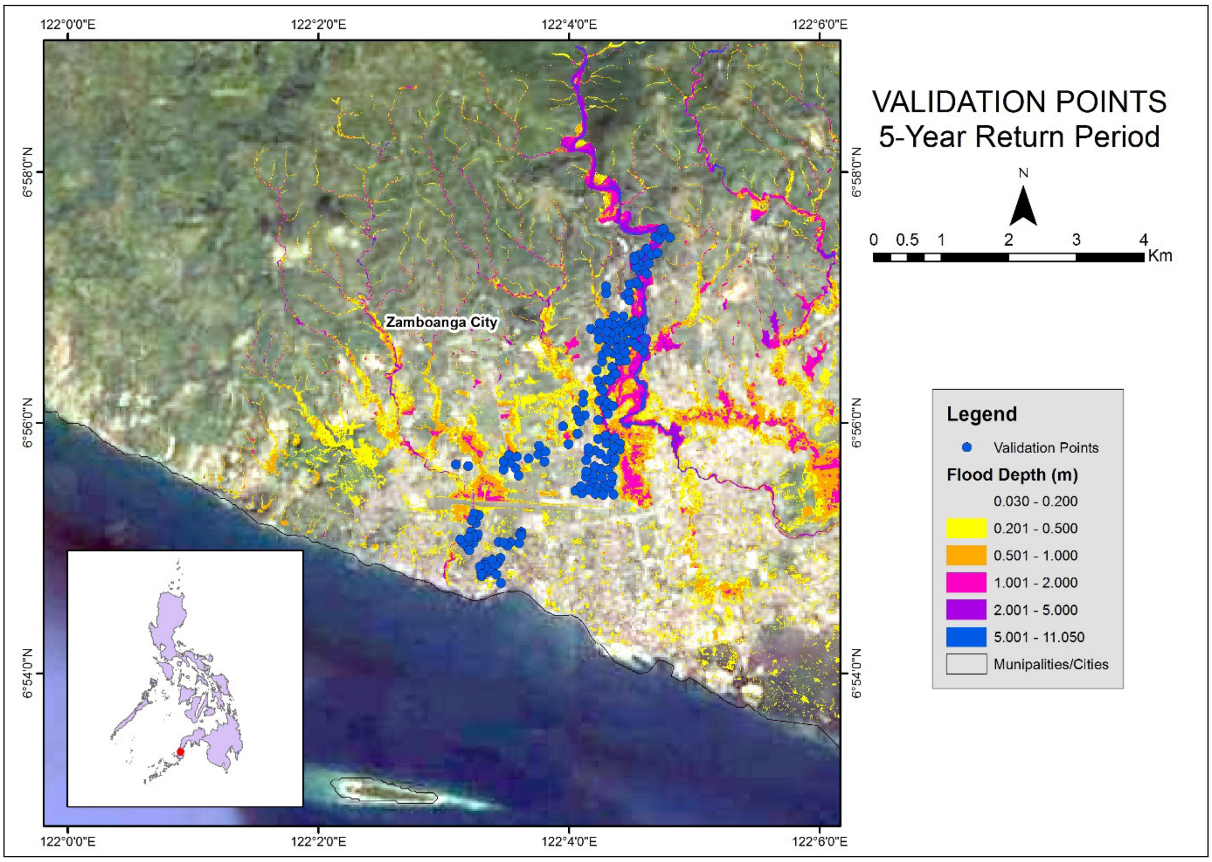



Figure 86. Validation points for 5-year Flood Depth Map of San Jose Floodplain

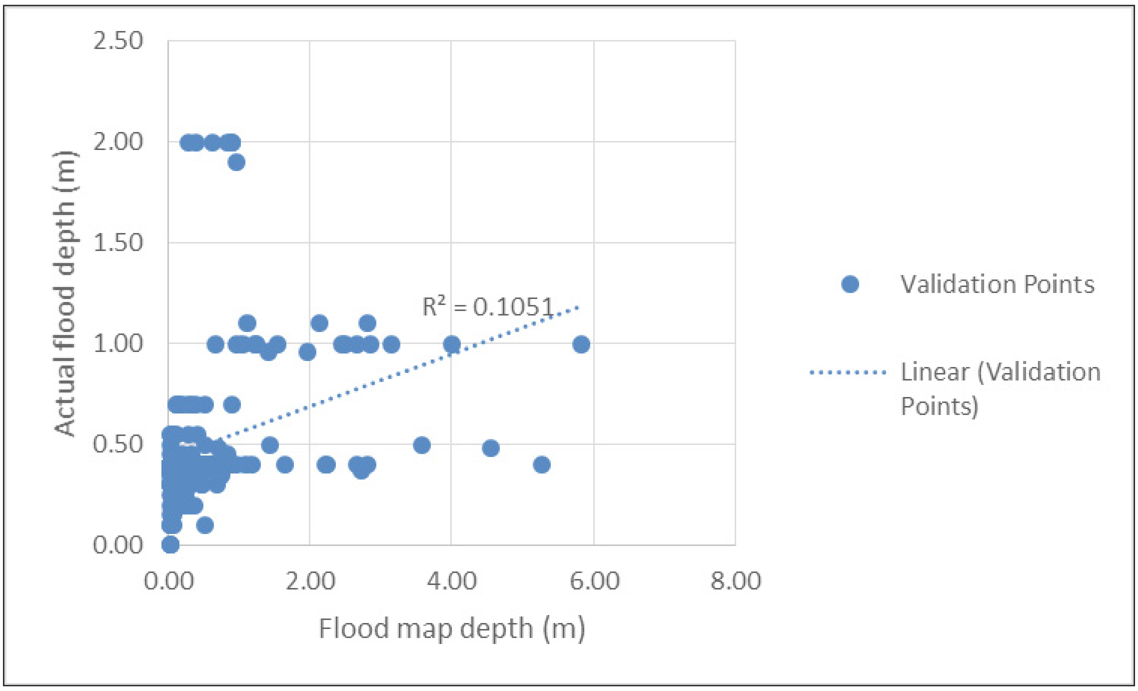



Figure 87. Flood map depth vs actual flood depth

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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 IX, DENR*

*Inquirer.net*

*National Disaster Risk Reduction and Management Council*

*Sunstar Zamboanga*

*Zamboanga Today Online*

*Zamboangacity.gov.ph*

Brunner, 2010

# Annexes

## Annex 1. Technical Specifications of the LIDAR Sensors used in the San Jose Floodplain Survey

**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);<br><br>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<br><br>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 |

**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.<br>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<br>computers with AMD TurionTM 64 X2 CPU<br>4 GB RAM, 4 GB flash disk local storage<br>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<br>8 or 16 bits per channel (180 MB or 360 MB per image) |

**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 |

# 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

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

CIP/4701/12/09/814

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 98
www.namria.gov.ph

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

# Annex 3. Baseline Processing 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

### 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)

3. ZC-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: | 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

**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

**Vector Components (Mark to Mark)**

| From: | ZGS100 | | | | |
|---|---|---|---|---|---|
| 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: | BVA1 | | | | |
|---|---|---|---|---|---|
| Grid | | Local | | Global | |
| Easting | 418087.142 m | Latitude | N7°15'19.31910" | Latitude | N7°15'15.84241" |
| Northing | 801995.112 m | Longitude | E122°15'28.78738" | Longitude | E122°15'34.32212" |
| Elevation | 78.652 m | Height | 82.446 m | Height | 146.526 m |

| Vector | | | | | |
|---|---|---|---|---|---|
| ΔEasting | 7897.175 m | NS Fwd Azimuth | 17°04'19" | ΔX | -4988.546 m |
| ΔNorthing | 25554.433 m | Ellipsoid Dist. | 26755.117 m | ΔY | -6818.290 m |
| ΔElevation | 70.906 m | ΔHeight | 71.176 m | ΔZ | 25386.506 m |

## Annex 4. The LIDAR Survey Team Composition

| Data Acquisition Component Sub -Team | Designation | Name | Agency / Affiliation |
|---|---|---|---|
| **PHIL-LIDAR 1** | Program Leader | ENRICO C. PARINGIT, D.ENG | UP-TCAGP |
| **Data Acquisition Component Leader** | Data Component Project Leader – I | ENGR. CZAR JAKIRI 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 San Jose 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 [signature]

Received by

Name JOIDA PRIETO
Position SSRS
Signature [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 [signature]

Received by

Name AC BONGAT 3/13/15

Position SSRS

Signature [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 [signature]

Received by

Name AC, Bongat
Position SSRS
Signature [signature] 7/14/16

# Annex 6. Flight Logs for the Flight Missions

Flight Log for 7450GC Mission

PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 7450

| | | | | | |
|---|---|---|---|---|---|
| 1 LiDAR Operator: M V Tonga | 2 ALTM Model: Gemini | 3 Mission Name: 2BLK 75F235A | 4 Type: VFR | 5 Aircraft Type: Cesnna T206H | 6 Aircraft Identification: 9322 |
| 7 Pilot: B. Donguines | 8 Co-Pilot: N. Aquino | 9 Route: Zamboanga | | | |
| 10 Date: 8-23-14 | 12 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 | Acquisition Flight Certified by | Pilot-in-Command | Lidar Operator |
|---|---|---|---|
| Pearl Kays | SSG Rendon Jr PAF | B. Donguines | M V Tonga |
| Signature over Printed Name (End User Representative) | Signature over Printed Name (PAF Representative) | Signature over Printed Name | Signature over Printed Name |

Flight Log for 2535P Mission

Flight Log No.: 2535

AM Data Acquisition Flight Log

| | | | | | |
|---|---|---|---|---|---|
| 1 LiDAR Operator: J. Alviar | 2 ALTM Model: Pegasus | 3 Mission Name: 1BLK75E36A | 4 Type: VFR | 5 Aircraft Type: Cesnna T206H | 6 Aircraft Identification: RP-C9022 |
| 7 Pilot: C. Alfonso | 8 Co-Pilot: B. Donguines | 9 Route: Zambo - Zambo | | | |
| 10 Date: Feb. 5, 2015 | 12 Airport of Departure (Airport, City/Province): Zamboanga | | 12 Airport of Arrival (Airport, City/Province): Zambo | | |
| 13 Engine On: 1340H | 14 Engine Off: 1733H | 15 Total Engine Time: 3+53 | 16 Take off: 1345H | 17 Landing: 1728H | 18 Total Flight Time: 3+43 |
| 19 Weather: Fair | | | | | |

20 Remarks:

Surveyed BLK 75E at 1100m

21 Problems and Solutions:

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

Flight Log for 2545P Mission

**DREAM Data Acquisition Flight Log** — Flight Log No.: 2545

| | | | | | |
|---|---|---|---|---|---|
| 1 LiDAR Operator: J. Alviar | 2 ALTM Model: Pegasus | 3 Mission Name: 1BLK75S39A | 4 Type: VFR | 5 Aircraft Type: CesnnaT206H | 6 Aircraft Identification: RP-C9022 |
| 7 Pilot: C. Alfonso | 8 Co-Pilot: B. Donguines | 9 Route: | | | |
| 10 Date: Feb. 8, 2015 | 12 Airport of Departure (Airport, City/Province): Zamboanga | | 12 Airport of Arrival (Airport, City/Province): | | |
| 13 Engine On: 0833H | 14 Engine Off: 1244H | 15 Total Engine Time: 4+11 | 16 Take off: 0838H | 17 Landing: 1239H | 18 Total Flight Time: 4+01 |
| 19 Weather: partly cloudy | | | | | |

20 Remarks:

successful flight

21 Problems and Solutions:

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

Flight Log for 2557P Mission

Data Acquisition Flight Log

Flight Log No.: 2557

| | | | | | |
|---|---|---|---|---|---|
| R Operator: J. Alviar | 2 ALTM Model: IBLK75S4A | 3 Mission Name: IBLK75S4A | 4 Type: VFR | 5 Aircraft Type: Cesnna T206H | 6 Aircraft Identification: RP-C9022 |
| t: C. Alfonso | 8 Co-Pilot: B. Dongulnes | 9 Route: Zambo - Zambo | | | |
| te: Feb. 11, 2015 | 12 Airport of Departure (Airport, City/Province): Zamboanga | | 12 Airport of Arrival (Airport, City/Province): Zambo | | |
| gine On: 0902 | 14 Engine Off: 1325H | 15 Total Engine Time: 4+23 | 16 Take off: 0907H | 17 Landing: 1320H | 18 Total Flight Time: 4+13 |
| eather | Partly cloudy | | | | |

emarks:

Surveyed remaining gaps in BLK 75C, D, E, 65, 75, Sacol Island

Problems and Solutions:

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

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

Pilot-in-Command
Alfonso III
Signature over Printed Name

Lidar Operator
J. Alviar
Signature over Printed Name

Flight Log for 23394P Mission

**Data Acquisition Flight Log** — **Flight Log No.:** 23394 P

| | | | | | |
|---|---|---|---|---|---|
| 1 LiDAR Operator: I. ROXAS & S. POBLETE | 2 ALTM Model: PEGASUS | 3 Mission Name: 1BLK75AS147B | 4 Type: VFR | 5 Aircraft Type: 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 Reports

**FLIGHT STATUS REPORT**

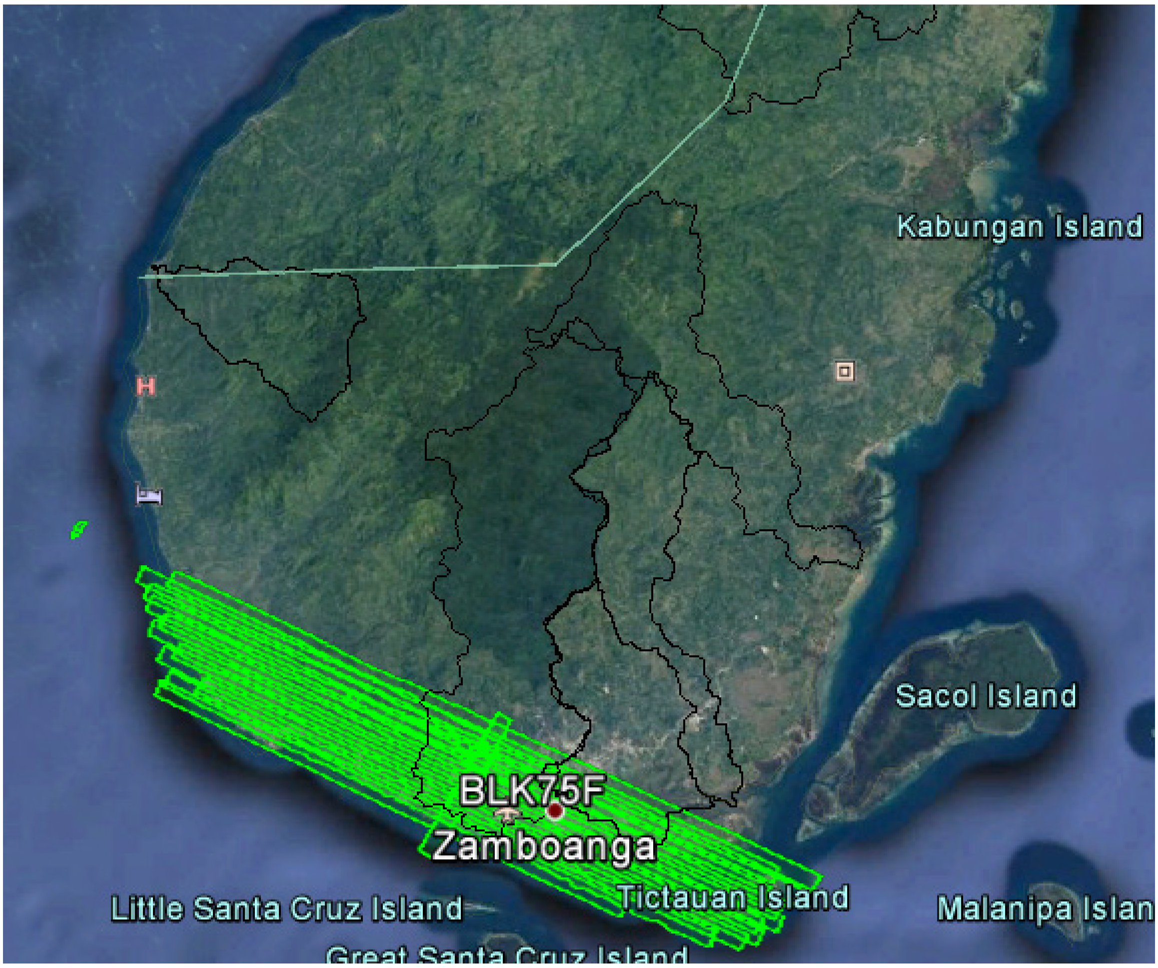
San Jose Floodplain

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

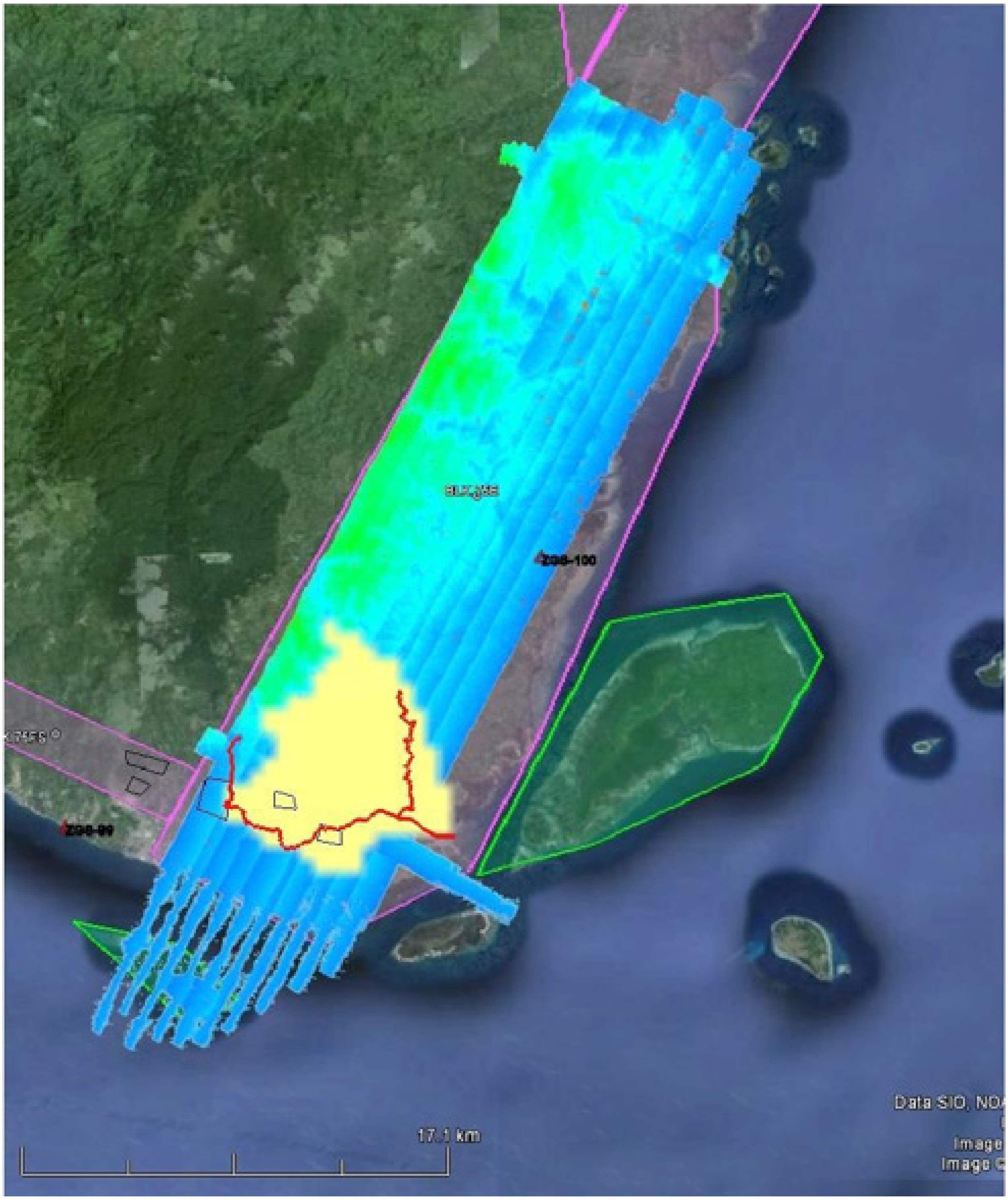
| FLIGHT NO | AREA | MISSION | OPERATOR | DATE FLOWN | REMARKS |
|---|---|---|---|---|---|
| 7450GC | BLK75F | 2BLK75F235A | M.V.E. TONGA | Aug. 23, 2014 | COMPLETED BLK75F;FAST CLOUD BUILD UP |
| 2535P | BLK75E | 1BLK75E36A | J. ALVIAR | Feb. 5, 2015 | FOR COMPLETION AND SOME GAP FILLING (TERRAIN) |
| 2545P | BLK75C<br>BLK75D<br>BLK75E<br>BLK75FS | 1BLK75C39A | J. ALVIAR | Feb. 7, 2015 | ABNORMAL PROGRAM TERMINATION (AVPOS) |
| 2557P | BLK75C<br>BLK75D<br>BLK75GS<br>BLK75FS<br>SACOL IS. | 1BLK75S42A | J. ALVIAR | Feb. 11, 2015 | SURVEY 6 DESCENDED TO 1000 DUE<br>TO CLOUDS;RETURNED TO 1100M FOR SURVEY<br>OVER SACOL;GAPS DUE TO CLOUDS, DESCENDED<br>TO 1000M TO FILL UP VOIDS IN<br>SACOL AND BLK 75EFG;ADDED 1 SMALL LINE (CORRIDOR<br>18), DESCENDED TO 800M;CORRIDOR 16 WHICH SHOULD<br>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



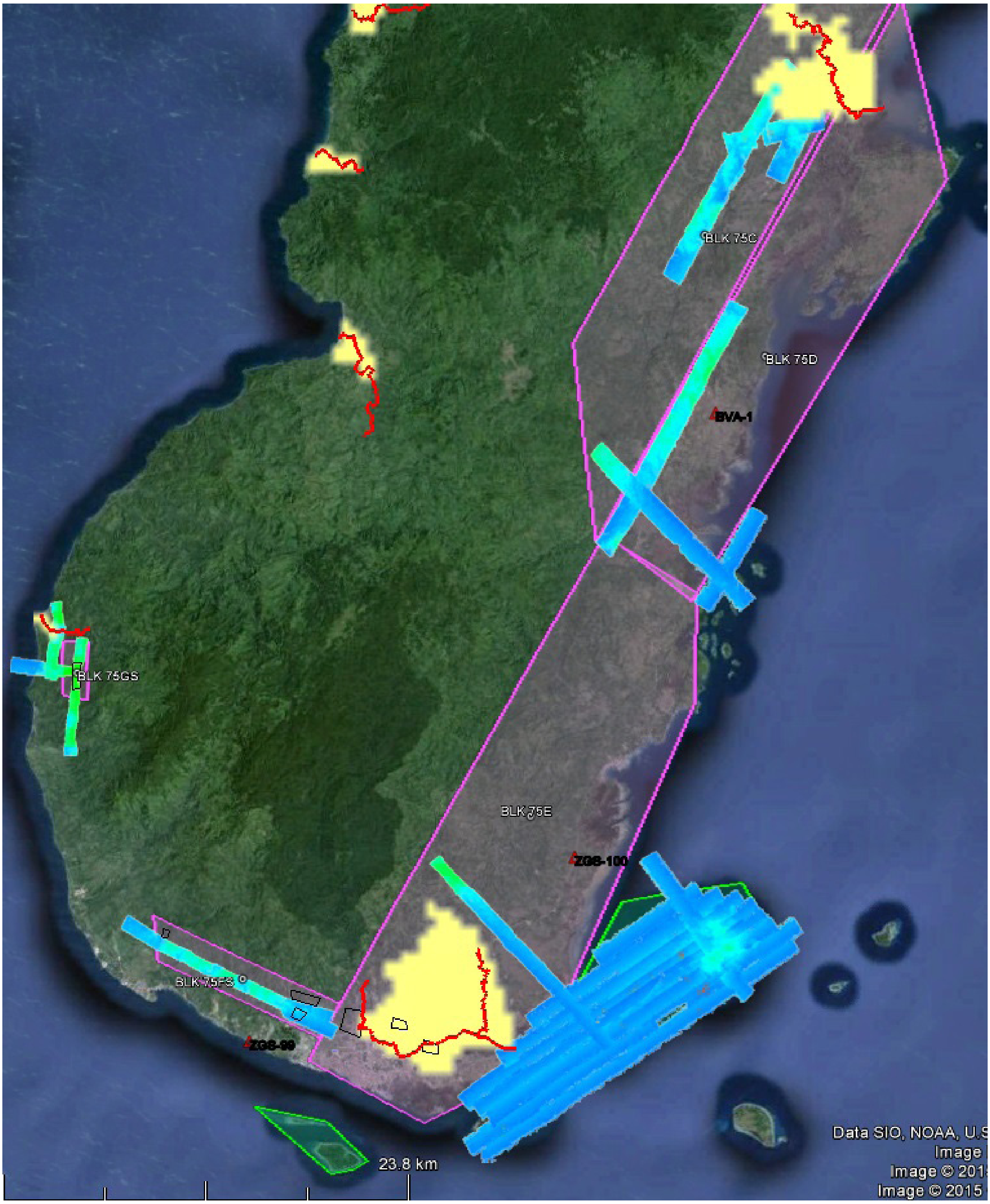
| | |
|---|---|
| Flight No. : | 2545P |
| Area: | BLK 75C |
| Mission Name: | 1BLK75C39A |
| Parameters: | Altitude: 1100m; Scan Frequency: 30; Scan Angle: 50 |

Flight No. : 2557P

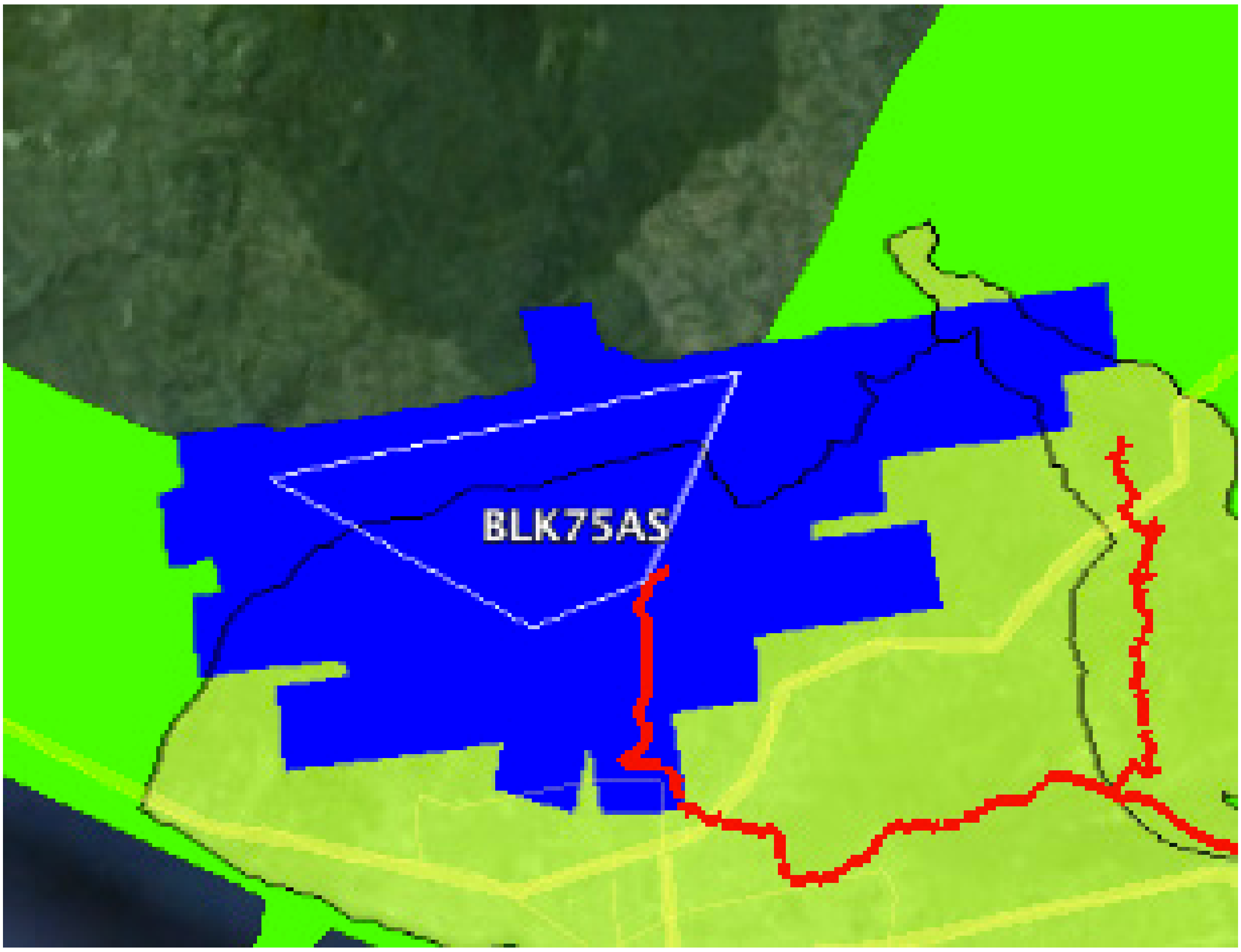
Area: BLK 75C, D, E, GS, FS, Sacol island

Mission Name: 1BLK75S42

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

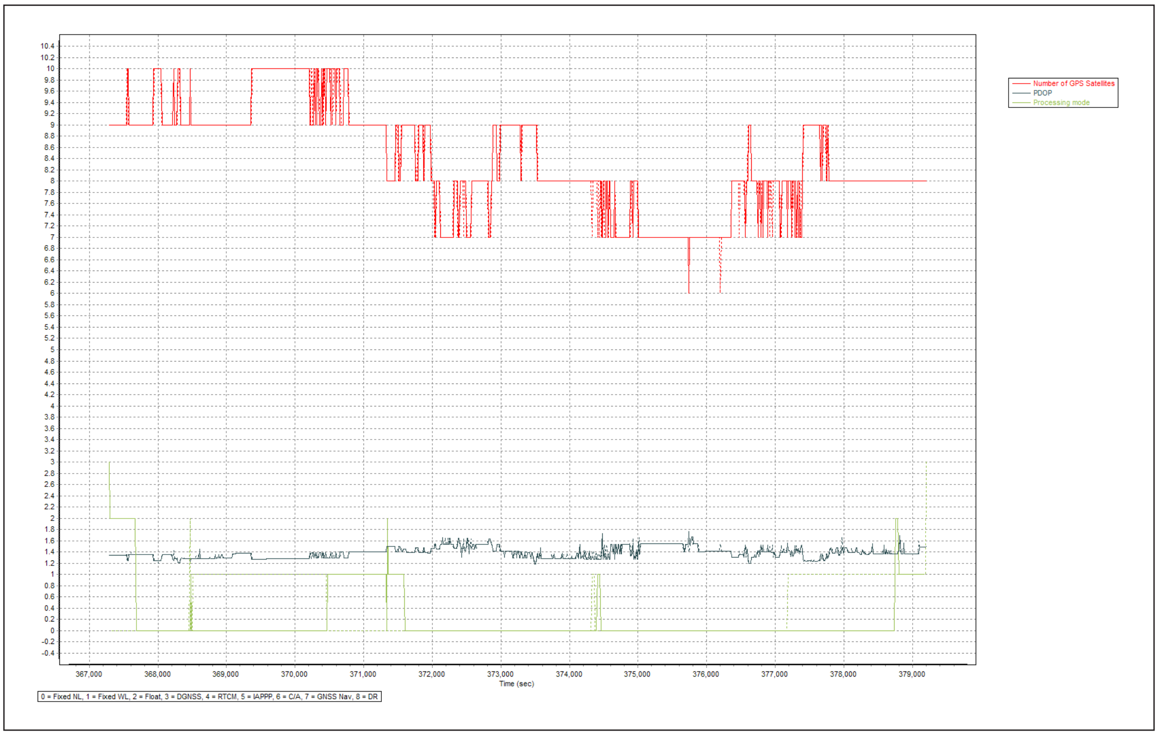


| | |
|---|---|
| Flight No.: | 23394P |
| Area: | BLK75AS |
| Mission Name: | 1BLK75AS147B |
| Parameters: | Altitude: 1000m; Scan Frequency: 30; Scan Angle: 50 |

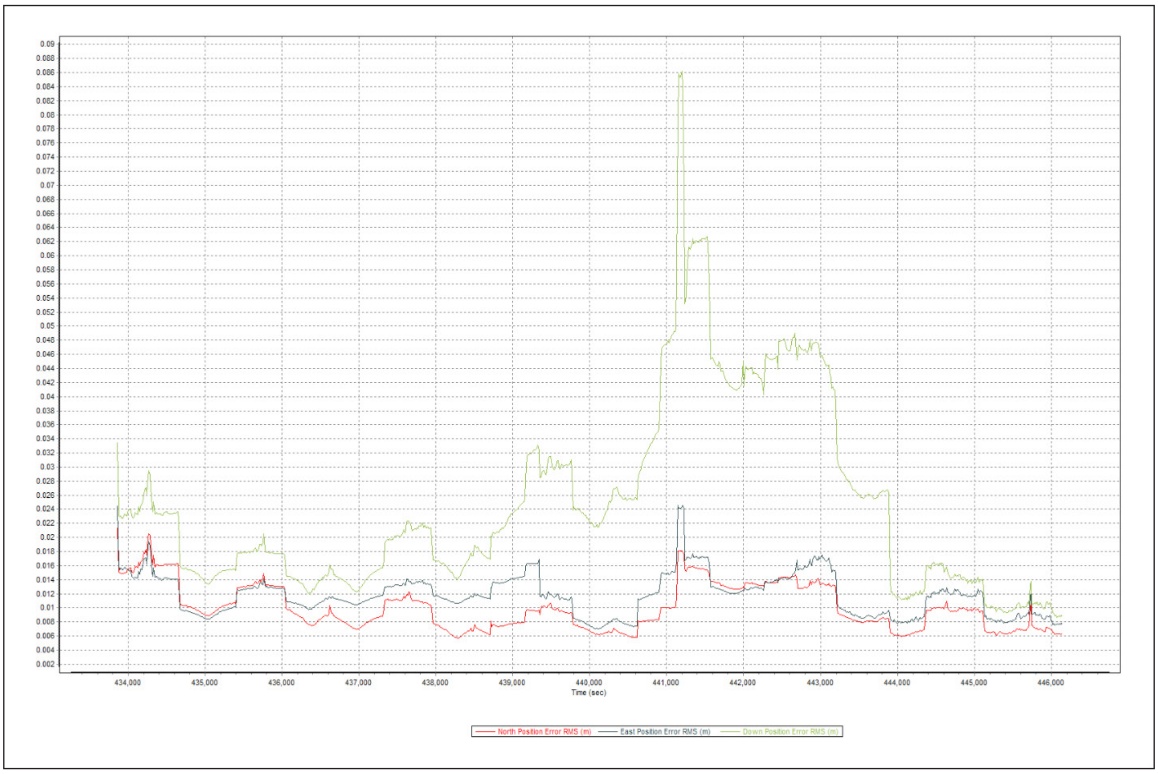


# ANNEX 8. Mission Summary Reports

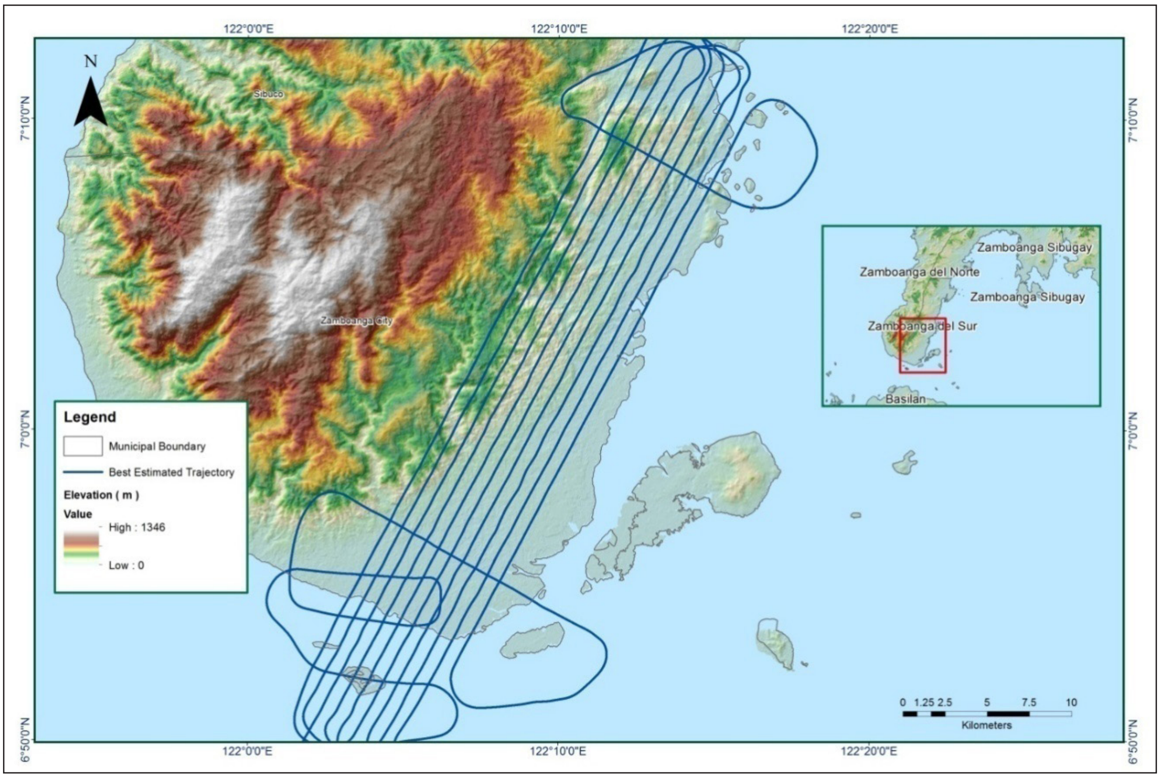
| Flight Area | Zamboanga |
|---|---|
| Mission Name | **Blk75E** |
| Inclusive Flights | 2535P, 2545P |
| Range data size | 56.9 GB |
| POS data size | 491 MB |
| Base data size | 15.3 MB |
| Image | 85.3 GB |
| Transfer date | February 27, 2015 |
| | |
| Solution Status | |
| Number of Satellites (>6) | 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 (<0.20m) | Yes |
| | |
| Number of 1km x 1km blocks | 522 |
| Maximum Height | 498.00 m |
| Minimum Height | 65.50 m |
| | |
| Classification (# of points) | |
| Ground | 369,443,876 |
| Low vegetation | 268,989,359 |
| Medium vegetation | 403,829,240 |
| High vegetation | 815,604,498 |
| Building | 37,951,116 |
| Orthophoto | YES |
| Processed by | Engr. Analyn Naldo, Engr. Velina Angela Bemida, Alex John Escobido |



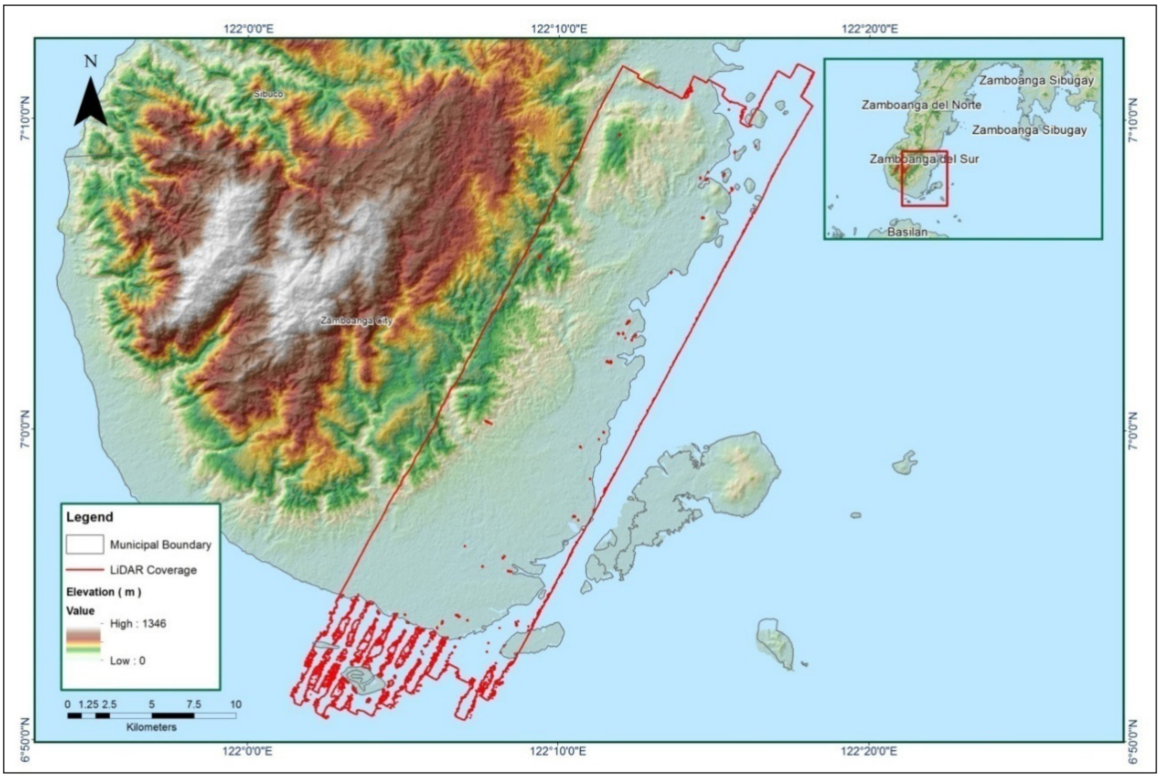

Solution Status




Smoothed Performance Metric Parameters




Best Estimated Trajectory




Coverage of LiDAR data

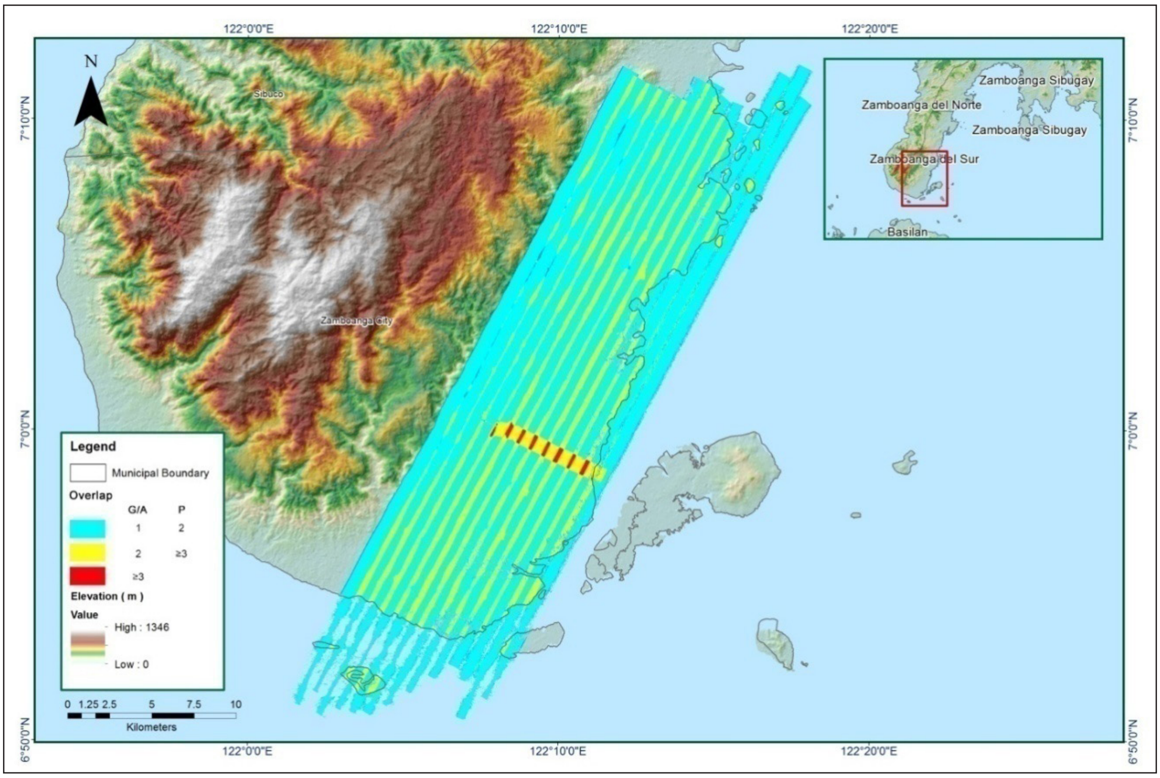
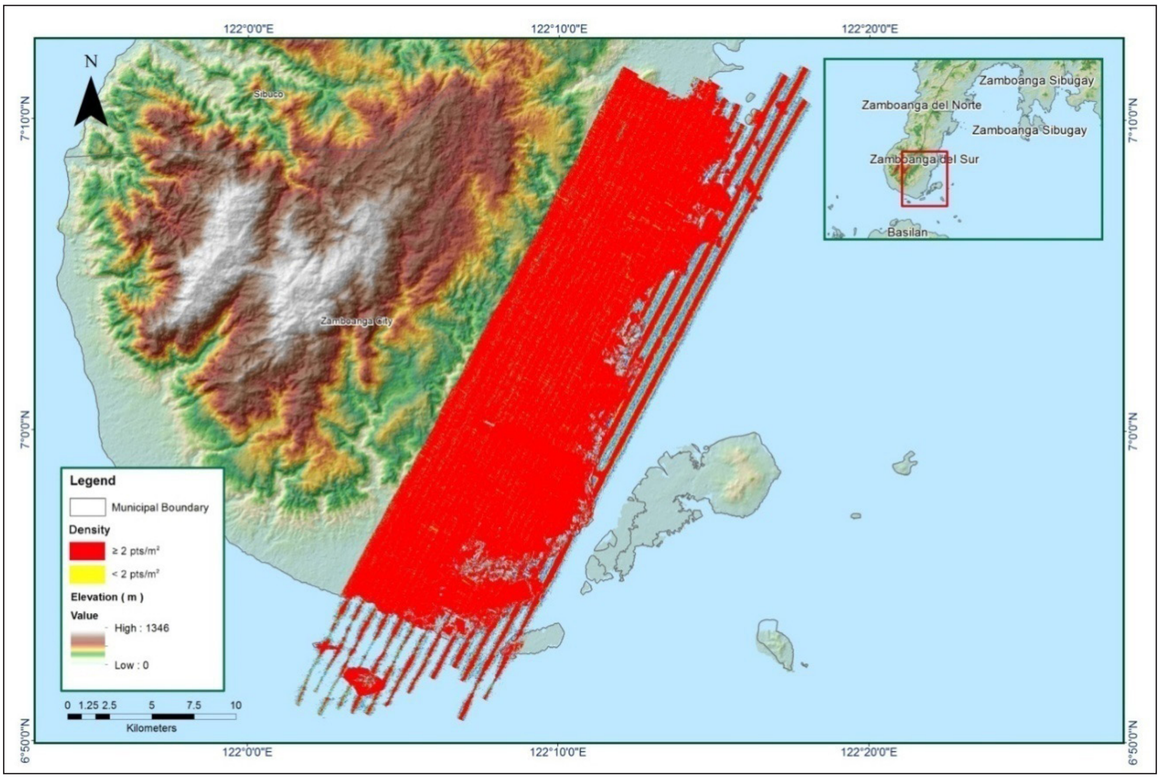
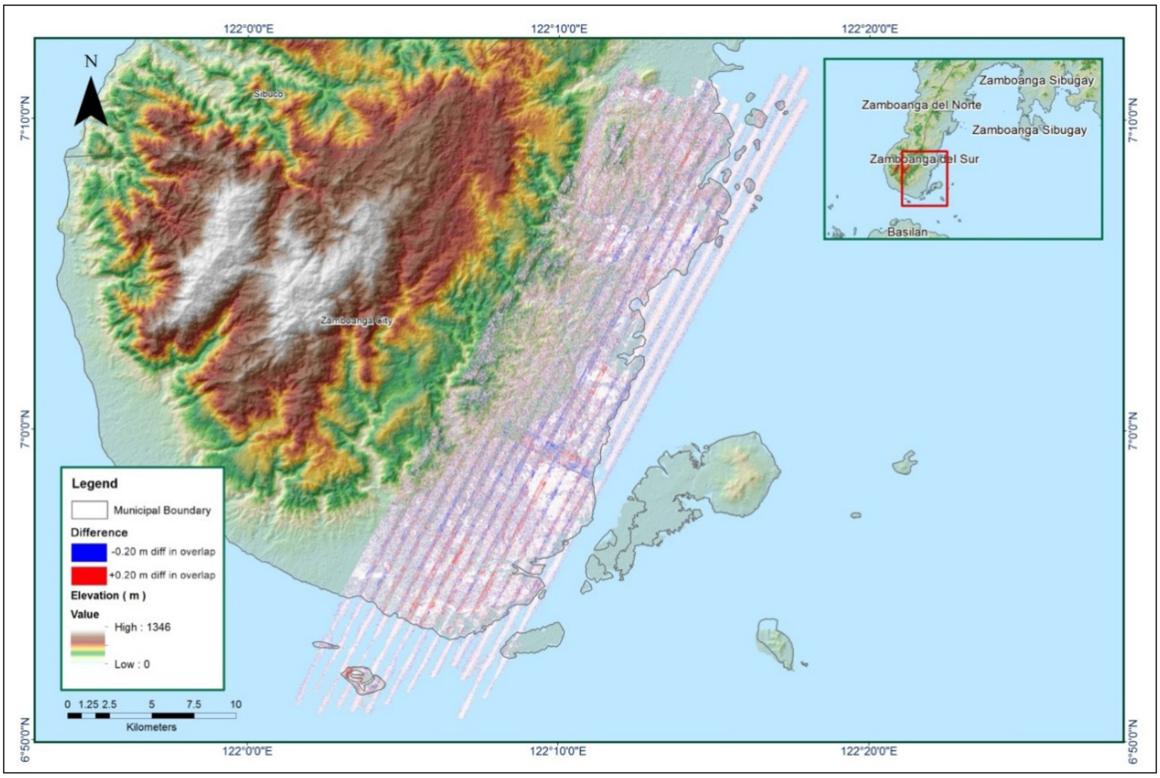



Image of data overlap

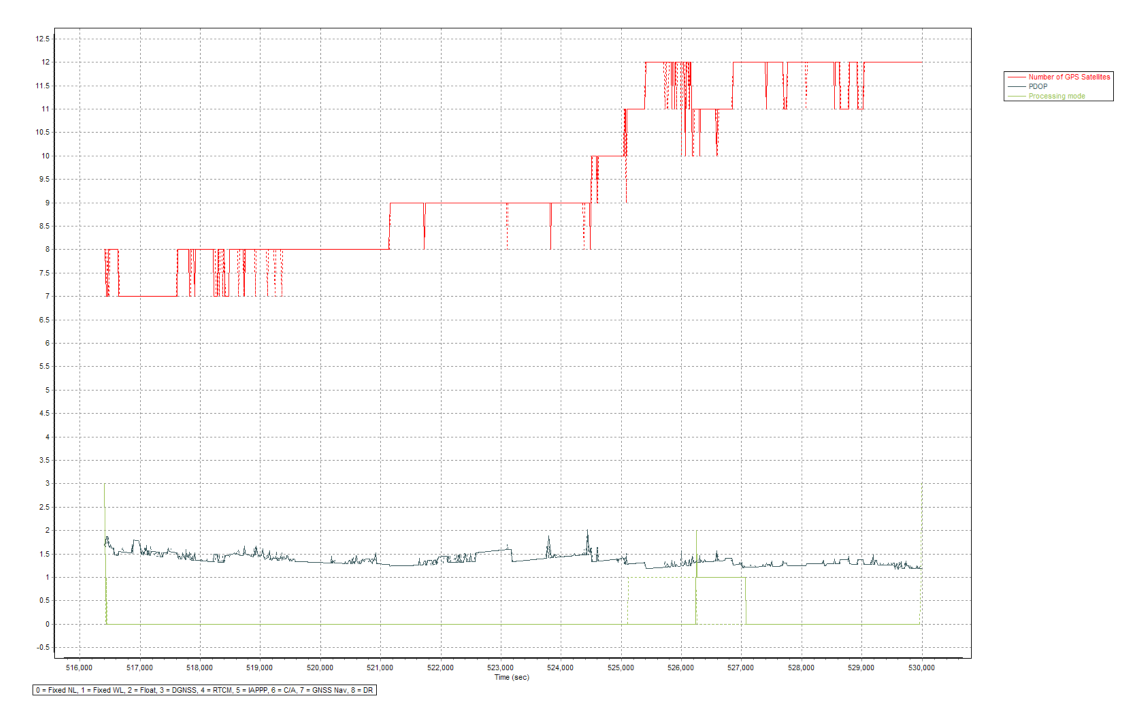



Density map of merged LiDAR data

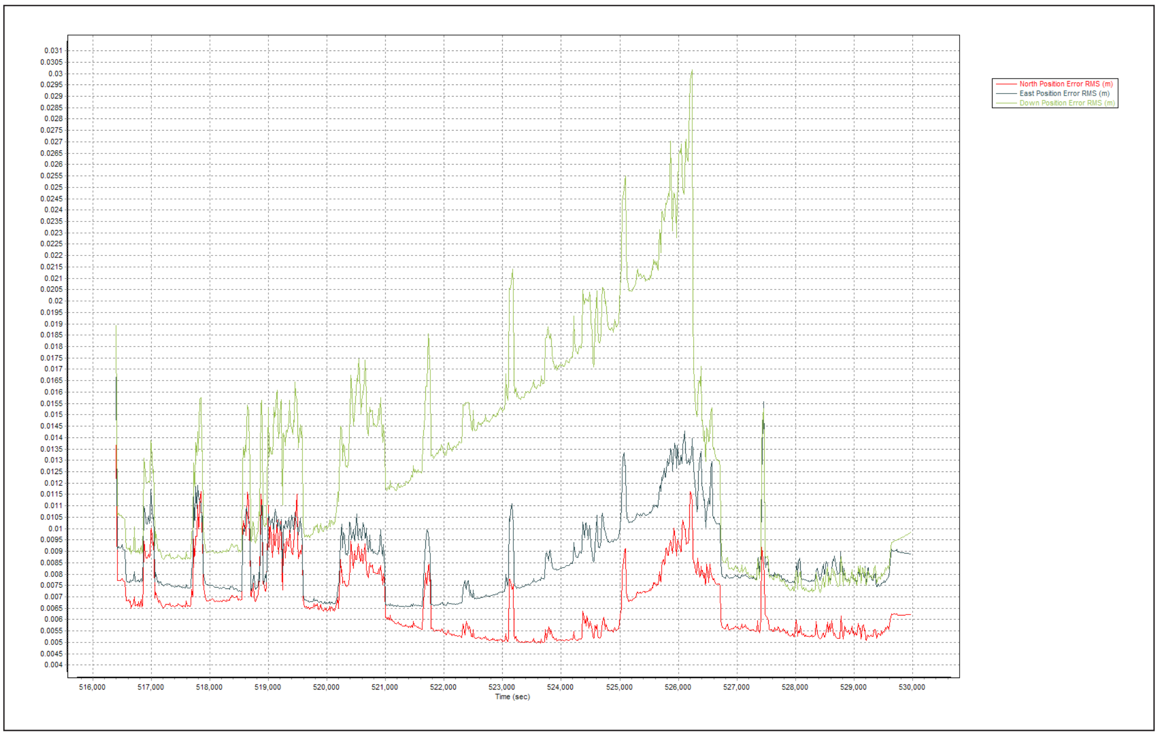



Elevation difference between flight lines

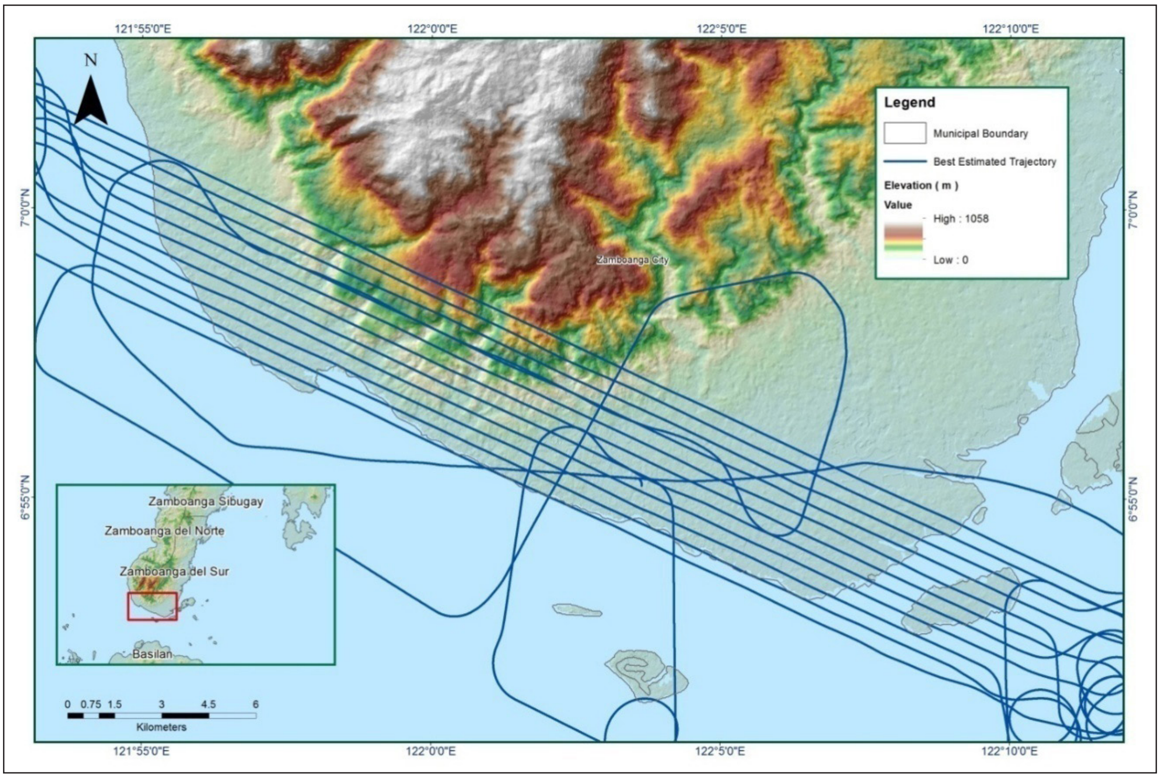
| Flight Area | Zamboanga |
|---|---|
| Mission Name | **Blk75F** |
| Inclusive Flights | 7450GC, 2557P |
| Range data size | 20.9 GB |
| POS data size | 252 MB |
| Base data size | 14.41 MB |
| Image | 0 GB |
| Transfer date | September 23, 2014 |
| | |
| *Solution Status* | |
| Number of Satellites (>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 (<0.20m) | 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 |



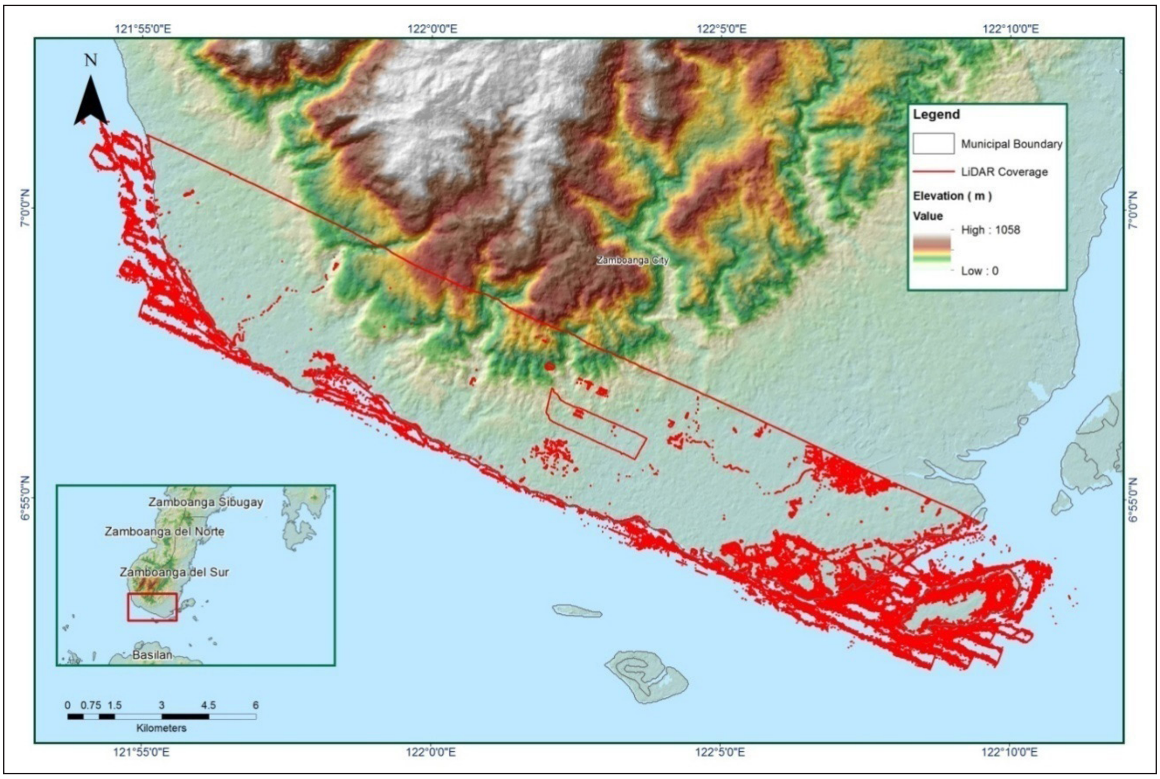

Solution Status




.Smoothed Performance Metric Parameters




Best Estimated Trajectory




Coverage of LiDAR data

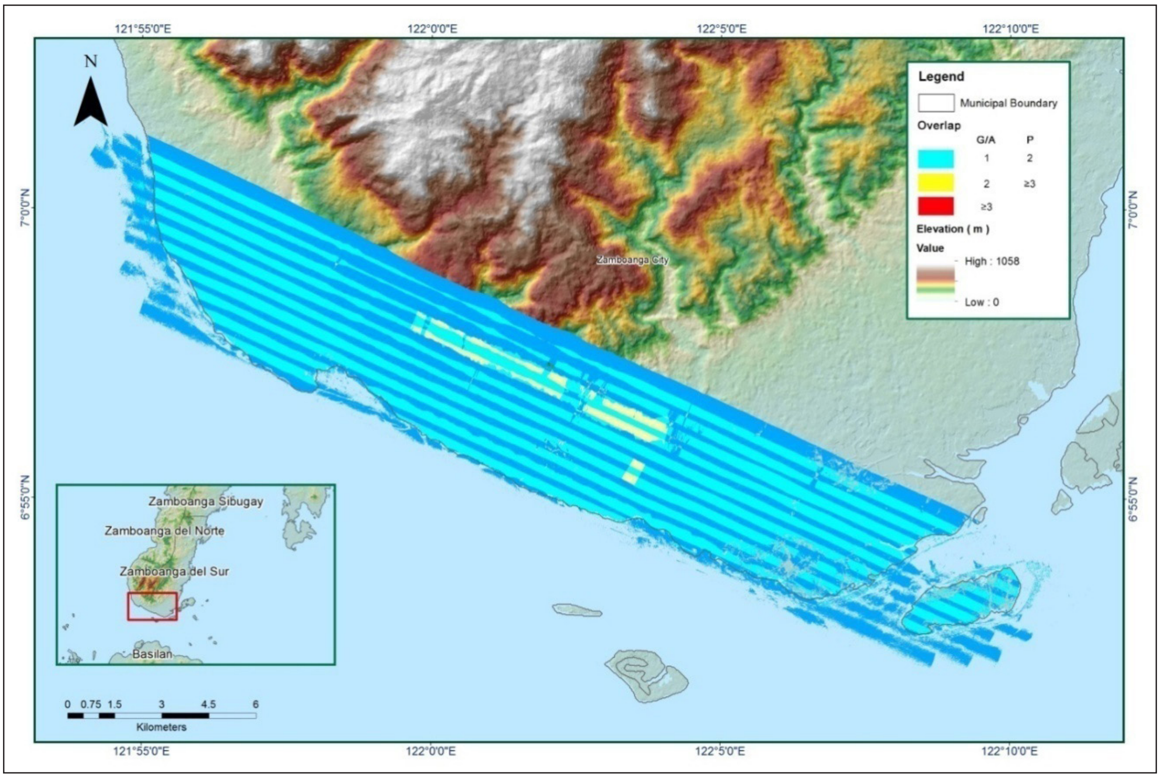
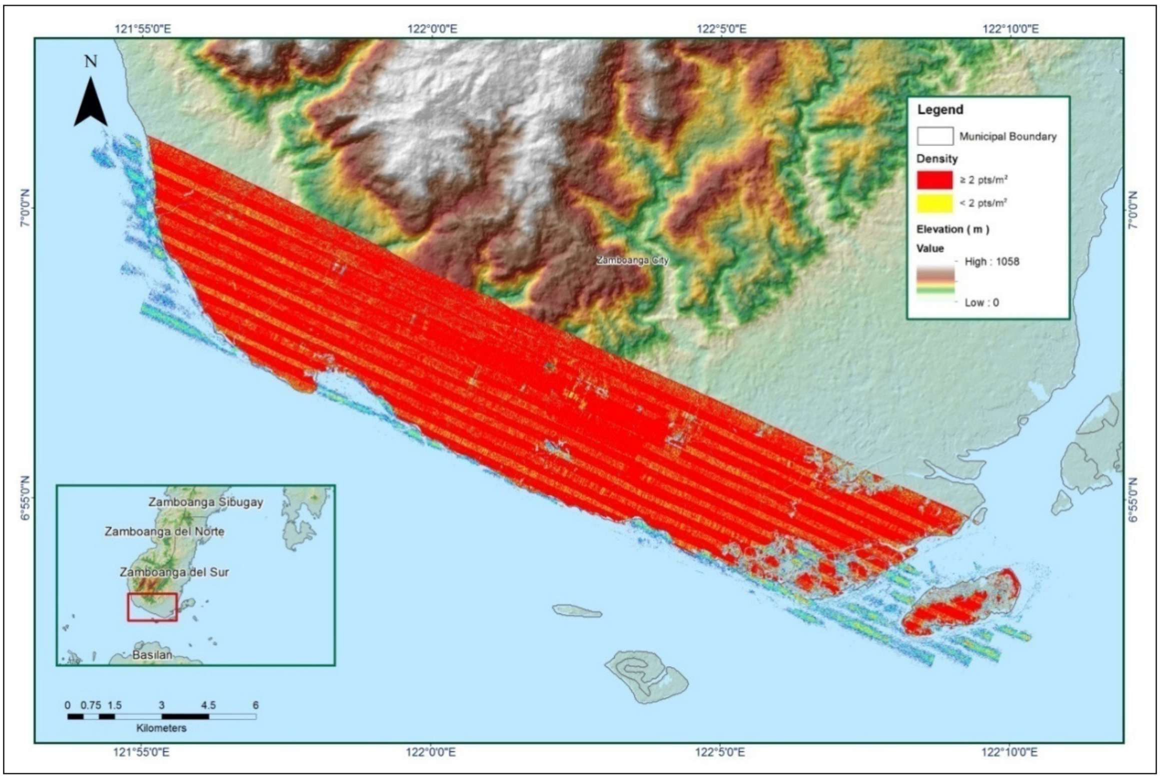
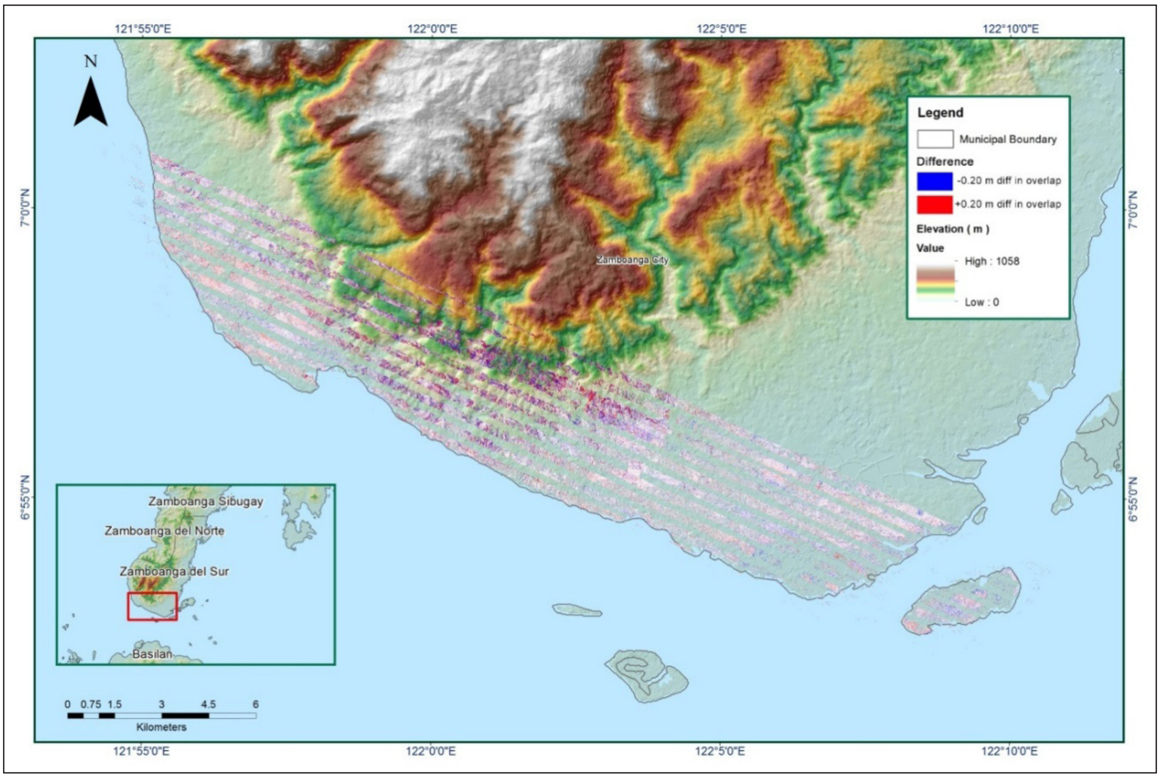



Image of data overlap

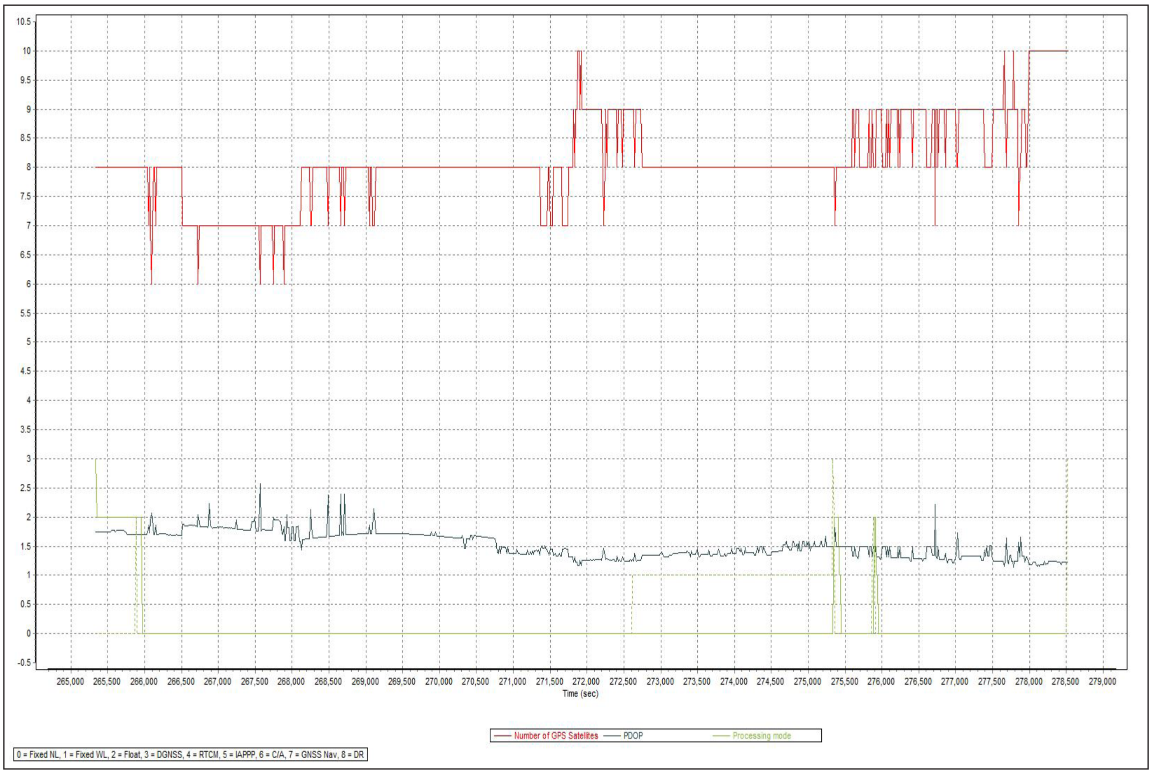



Density map of merged LiDAR data

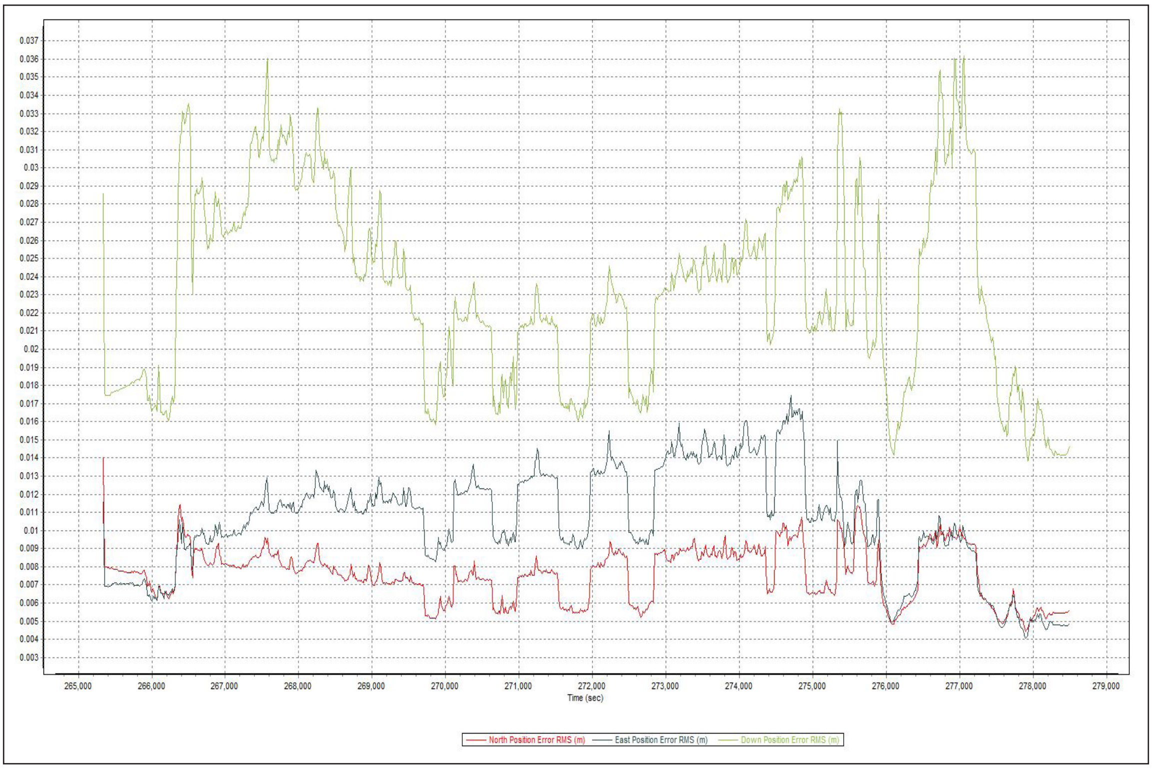



Elevation difference between flight lines

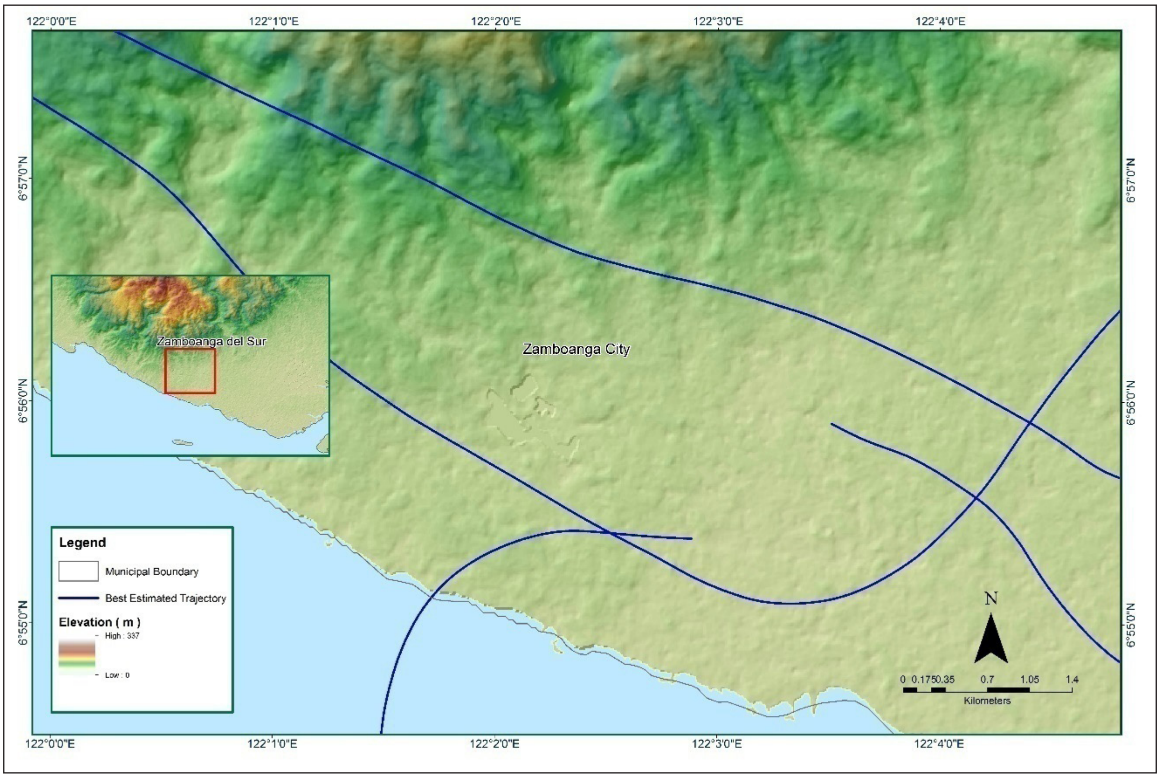
| Flight Area | Zamboanga |
|---|---|
| Mission Name | Blk 75F_additional |
| Inclusive Flights | 2557P |
| Range data size | 20.5 GB |
| POS data size | 255 MB |
| Base data size | 8.47 MB |
| Image | 34.9 GB |
| Transfer date | February 27 2015 |
| | |
| Solution Status | |
| Number of Satellites (>6) | Yes |
| PDOP (<3) | Yes |
| Baseline Length (<30km) | No |
| Processing Mode (<=1) | No |
| | |
| Smoothed Performance Metrics(in cm) | |
| RMSE for North Position (<4.0 cm) | 1.14 |
| RMSE for East Position (<4.0 cm) | 1.74 |
| RMSE for Down Position (<8.0 cm) | 3.62 |
| | |
| 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) | 6.24 |
| Elevation difference between strips (<0.20m) | 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 |



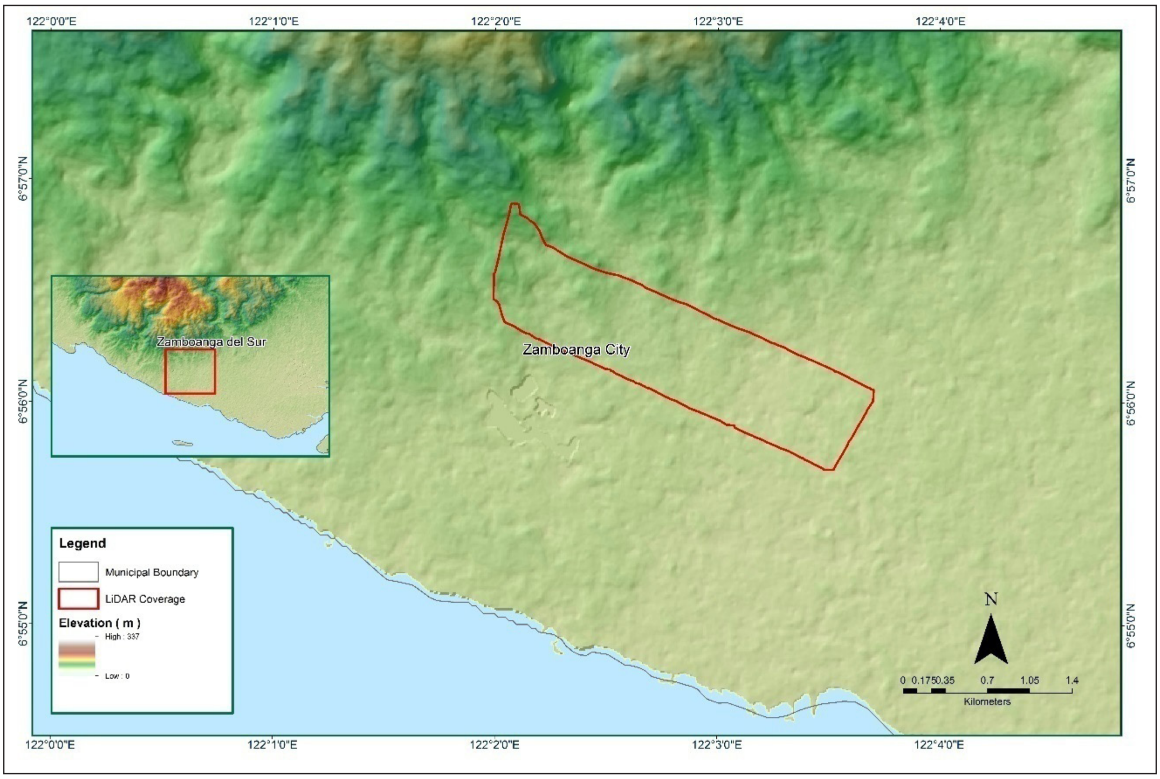

Solution Status




Smoothed Performance Metric Parameters




Best Estimated Trajectory




Coverage of LiDAR data

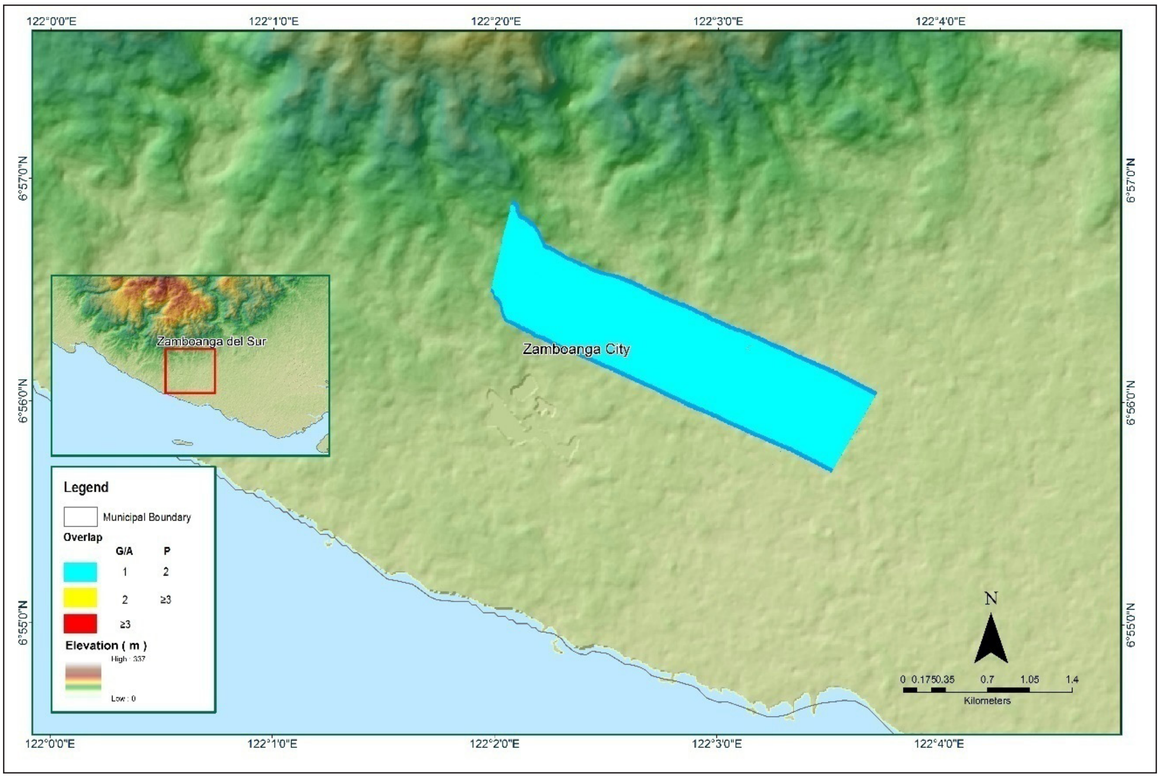
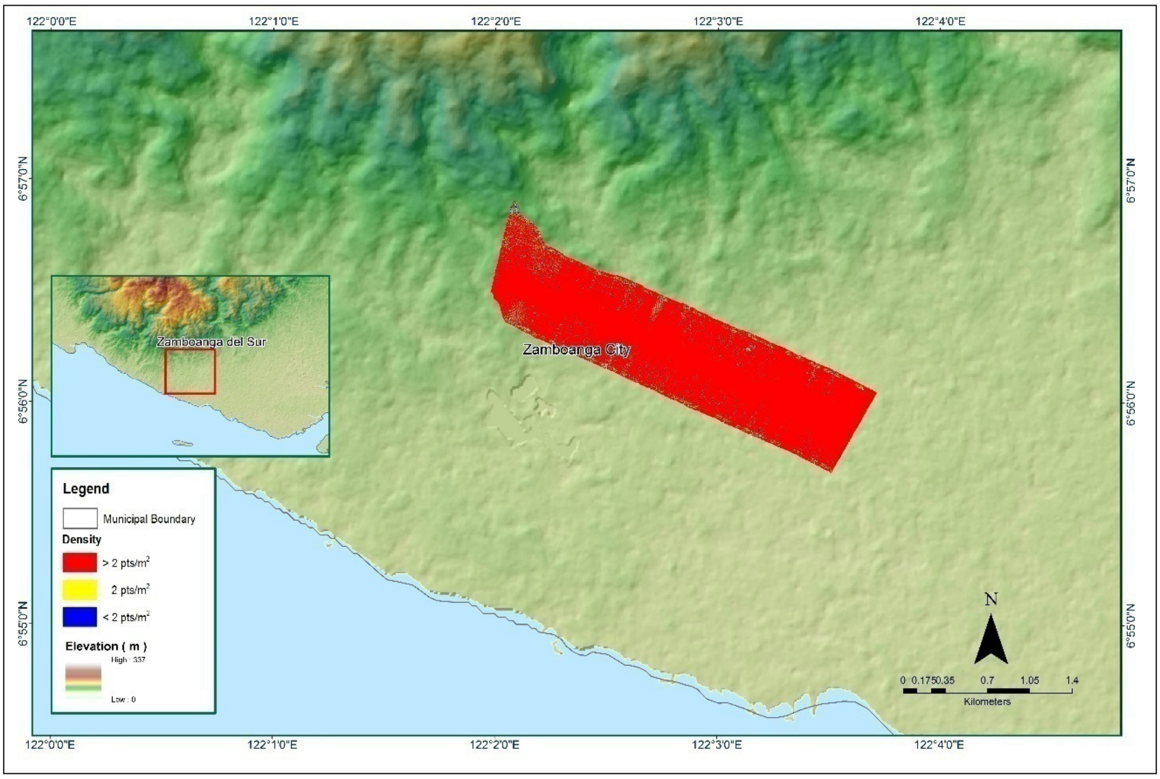
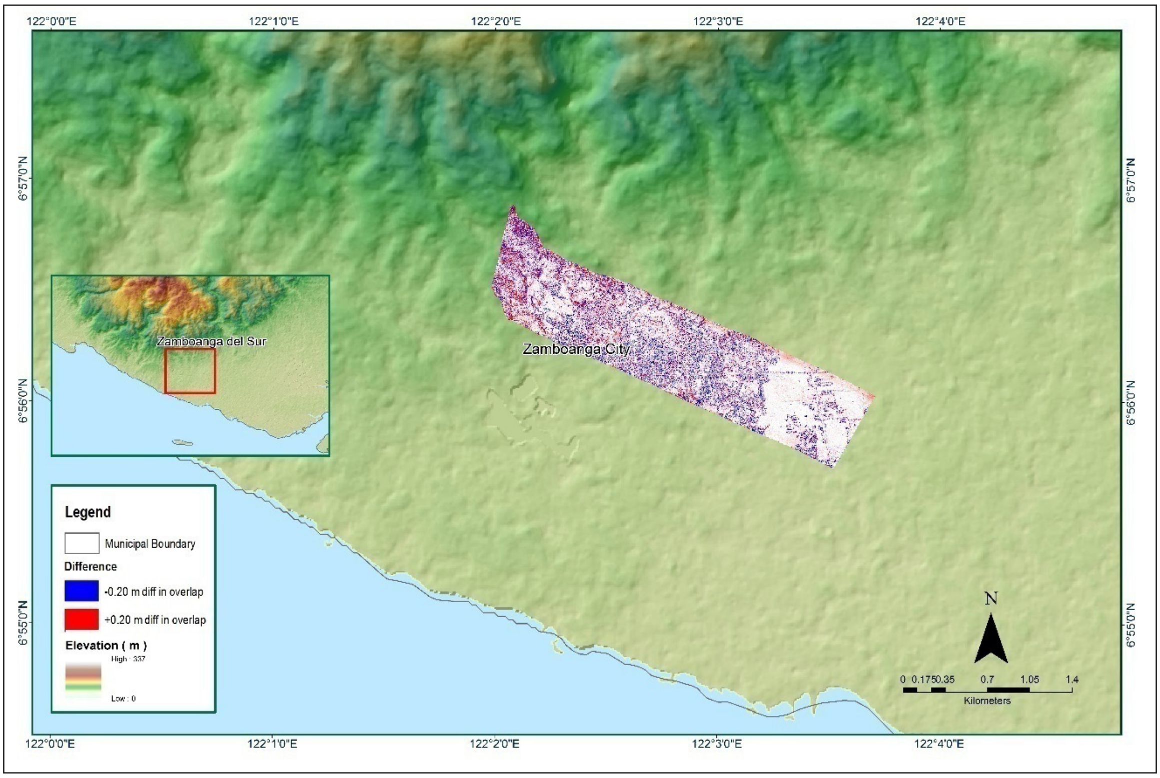



Image of data overlap

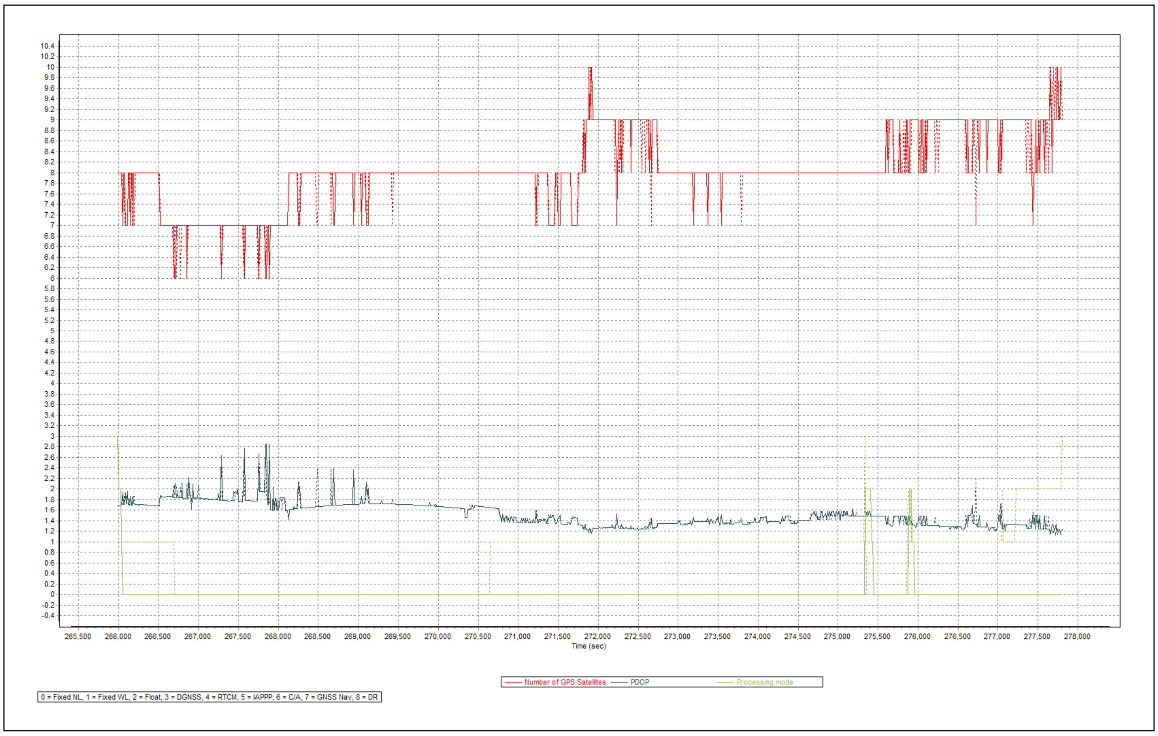



Density map of merged LiDAR data

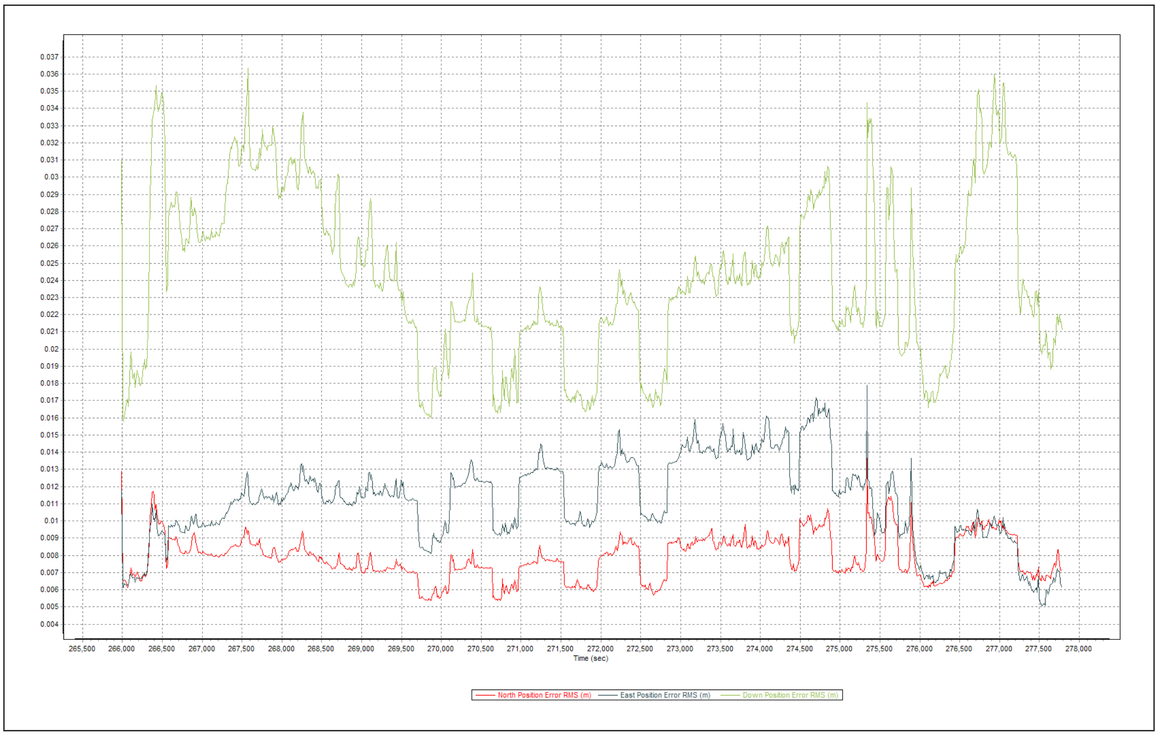



Elevation difference between flight lines

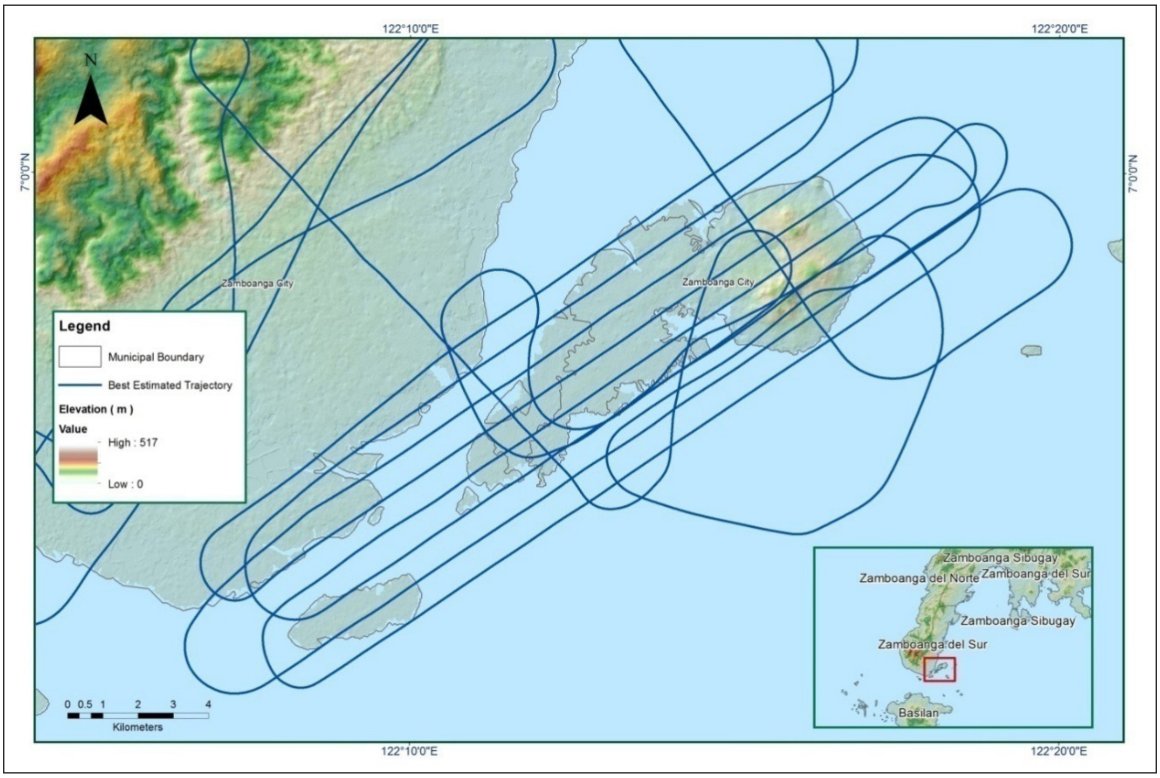
| Flight Area | Zamboanga |
|---|---|
| Mission Name | Sacol |
| Inclusive Flights | 2557P |
| Range data size | 20.5 GB |
| POS data size | 255 MB |
| Base data size | 8.47 MB |
| Image | 34.9 GB |
| Transfer date | February 27 2015 |
| | |
| Solution Status | |
| Number of Satellites (>6) | Yes |
| 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 (<0.20m) | Yes |
| | |
| Number of 1km x 1km blocks | 183 |
| Maximum Height | 422.16 m |
| Minimum Height | 67.62 m |
| | |
| Classification (# of points) | |
| Ground | 102,448,806 |
| Low vegetation | 102,238,659 |
| Medium vegetation | 104,811,352 |
| High vegetation | 138,074,781 |
| Building | 1,942,211 |
| Orthophoto | YES |
| Processed by | Engr. Irish Cortez, Engr. Melanie Hingpit, Alex John Escobido |



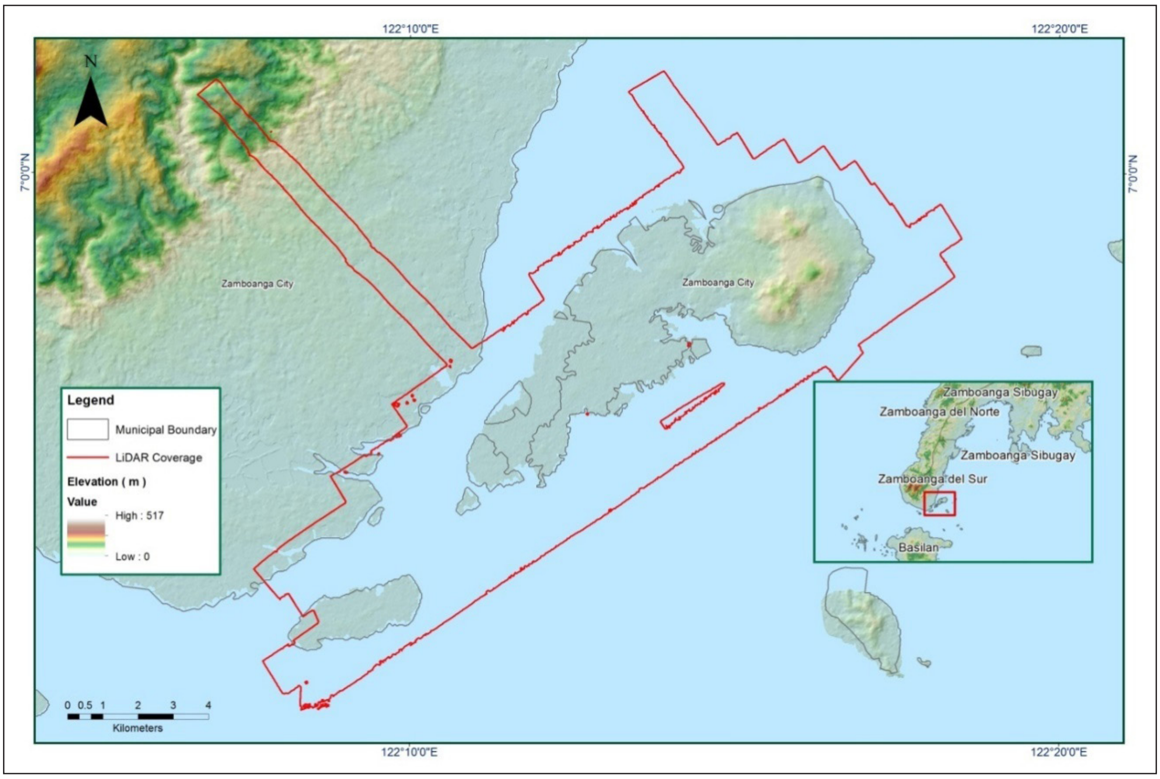

Solution Status



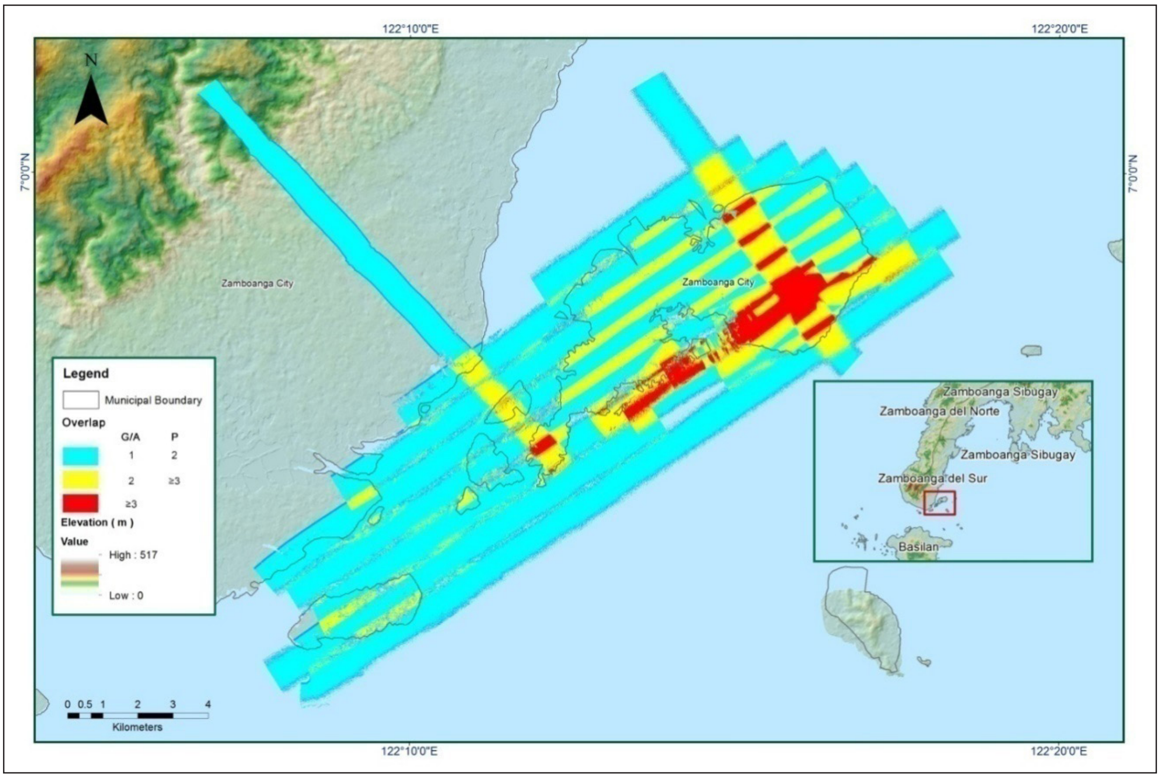

Smoothed Performance Metric Parameters



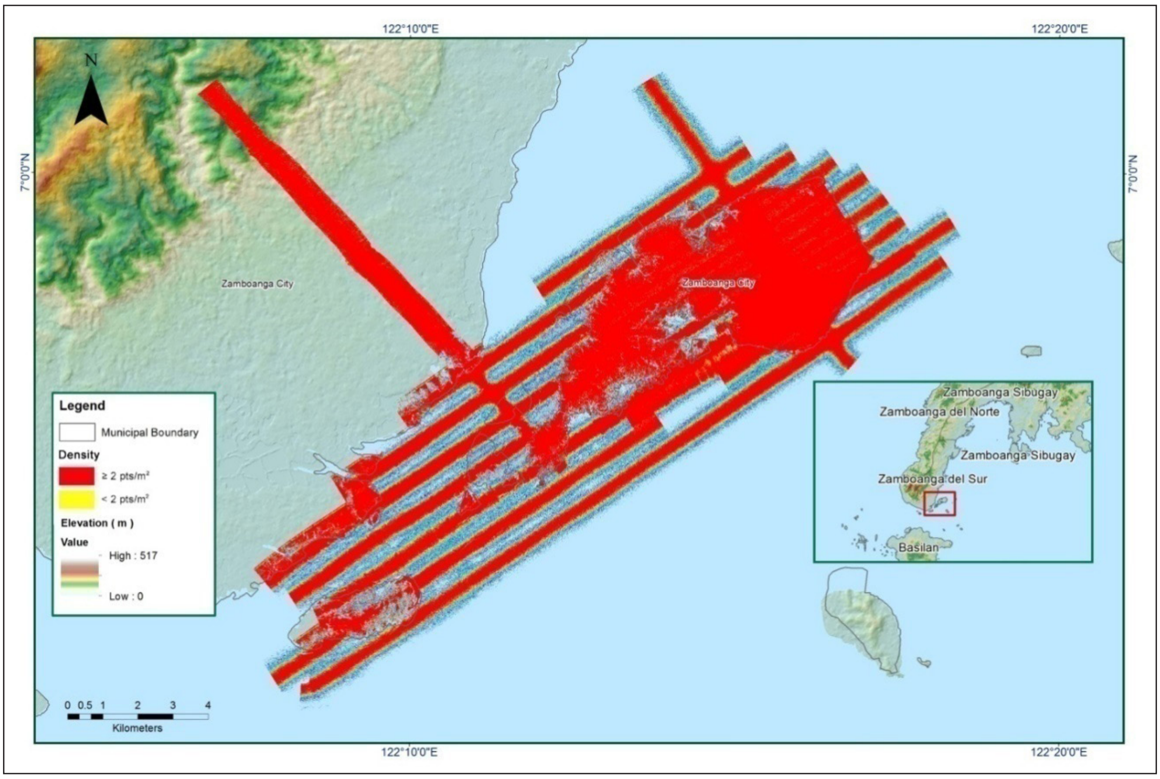

Best Estimated Trajectory



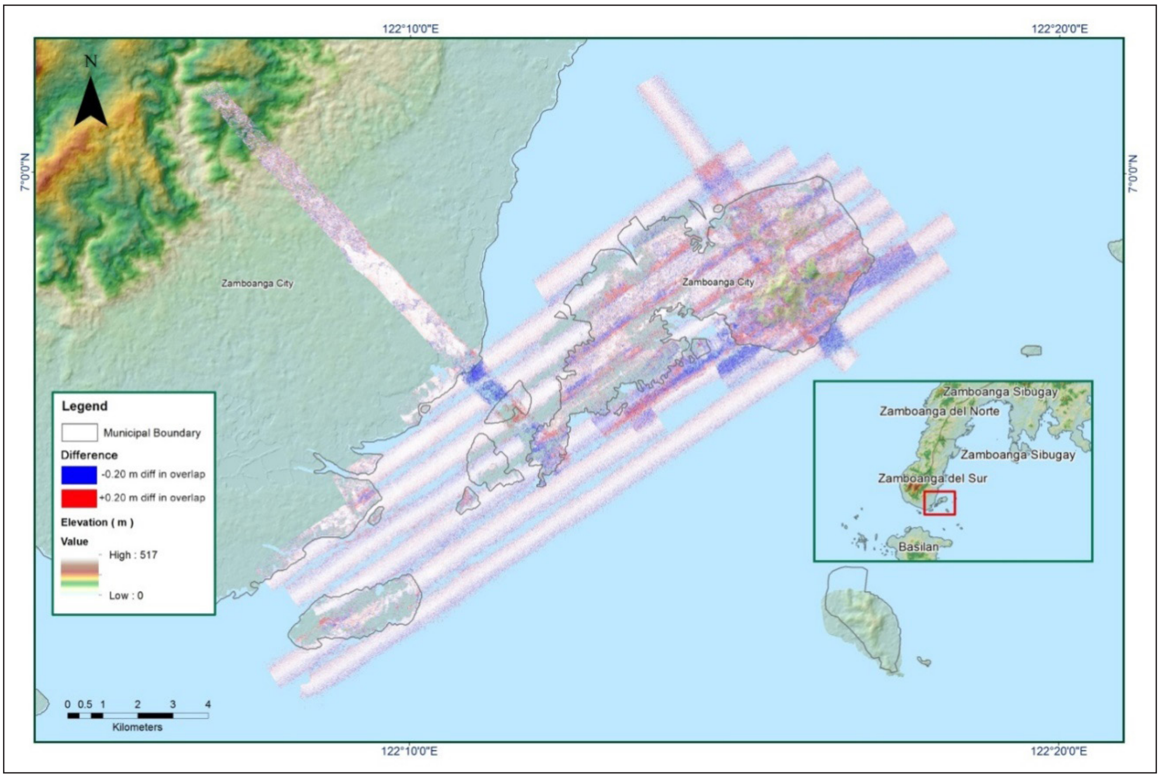

Coverage of LiDAR Data




Im Elevation difference between flight lines age of data overlap

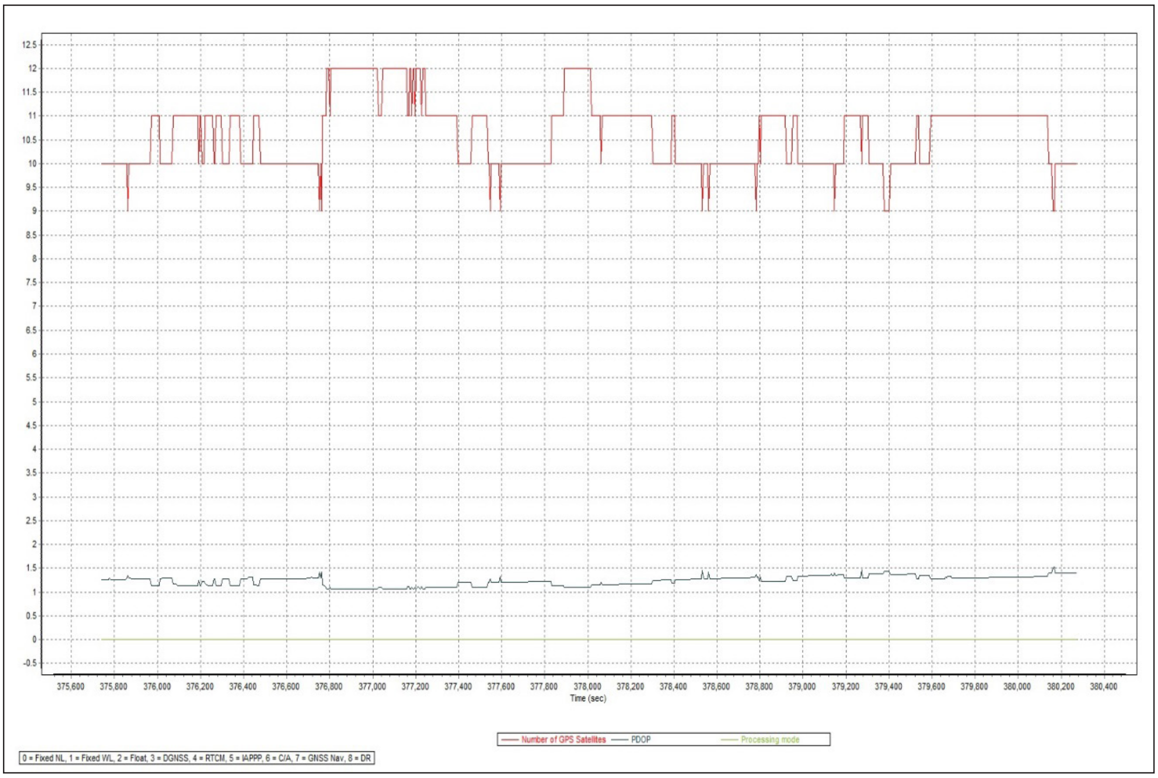



Density map of merged LiDAR data

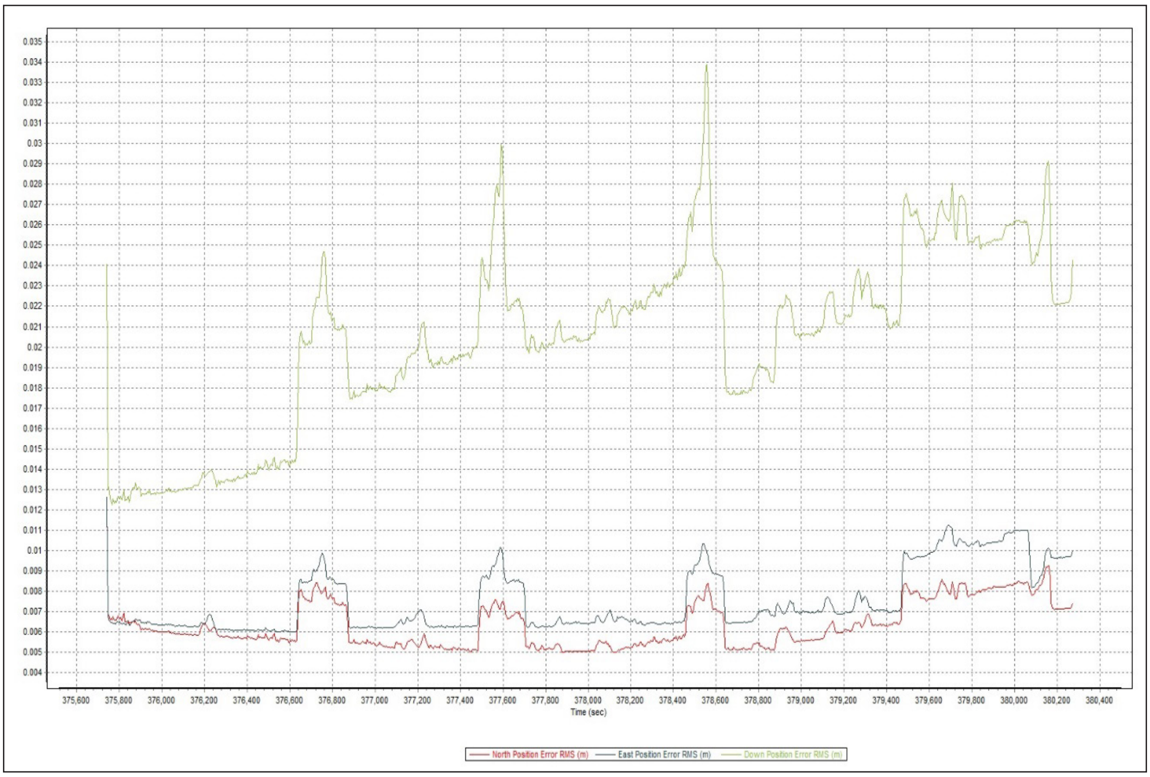



Elevation difference between flight lines

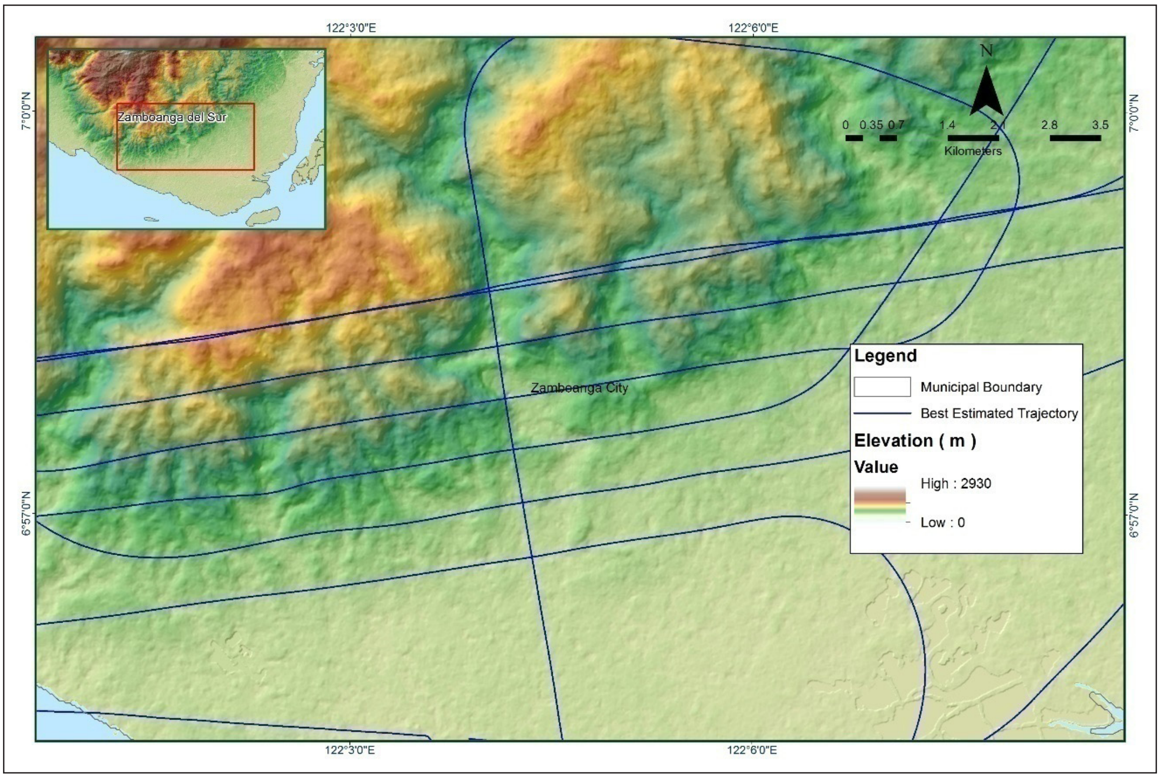
| Flight Area | Zamboanga Reflights |
|---|---|
| Mission Name | **Blk75AS** |
| Inclusive Flights | 23394P |
| Range data size | 5.13 GB |
| POS data size | 101 MB |
| Base data size | 133 MB |
| Image | n/a |
| Transfer date | July 14, 2016 |
| | |
| Solution Status | |
| Number of Satellites (>6)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



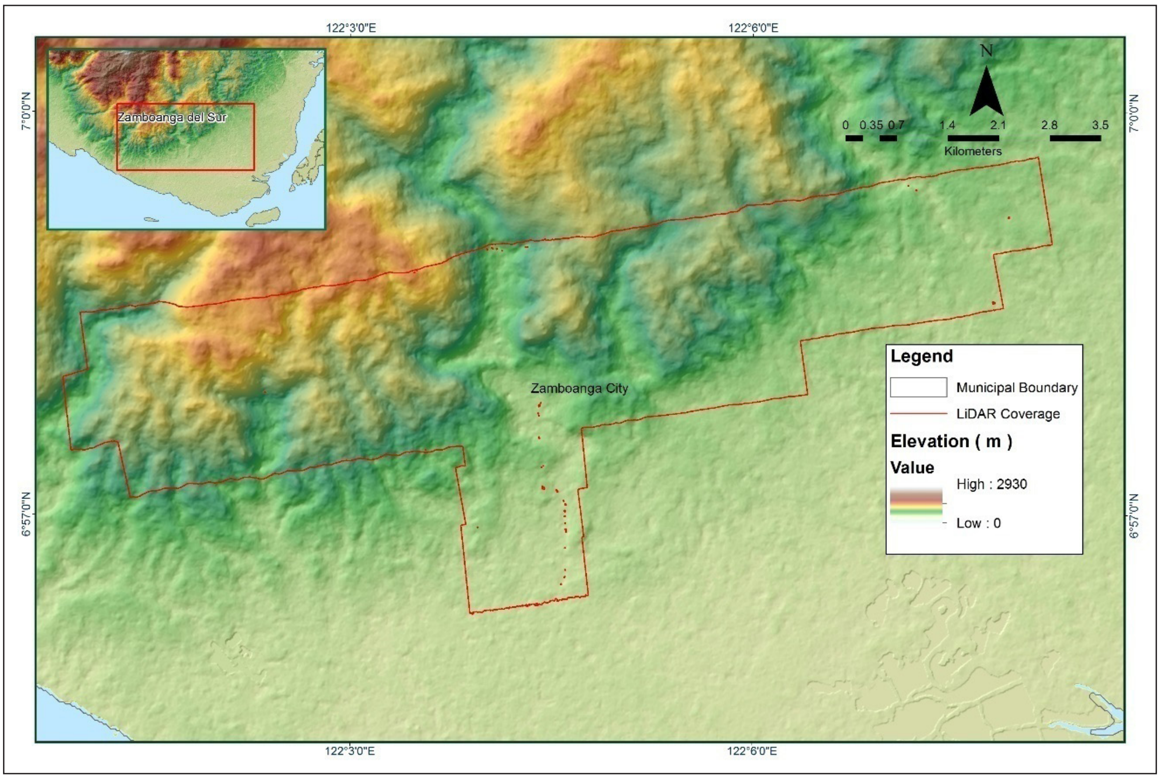

Solution Status




Smoothed Performance Metric Parameters




Best Estimated Trajectory




Coverage of LiDAR Data

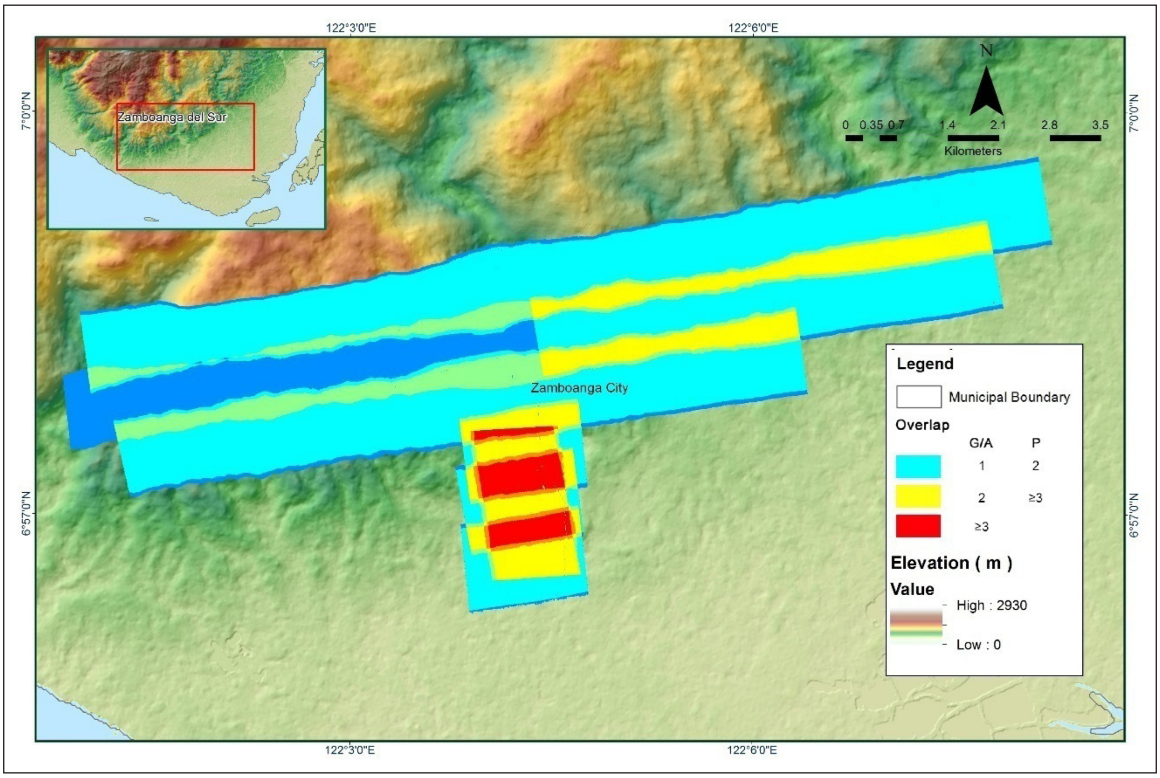
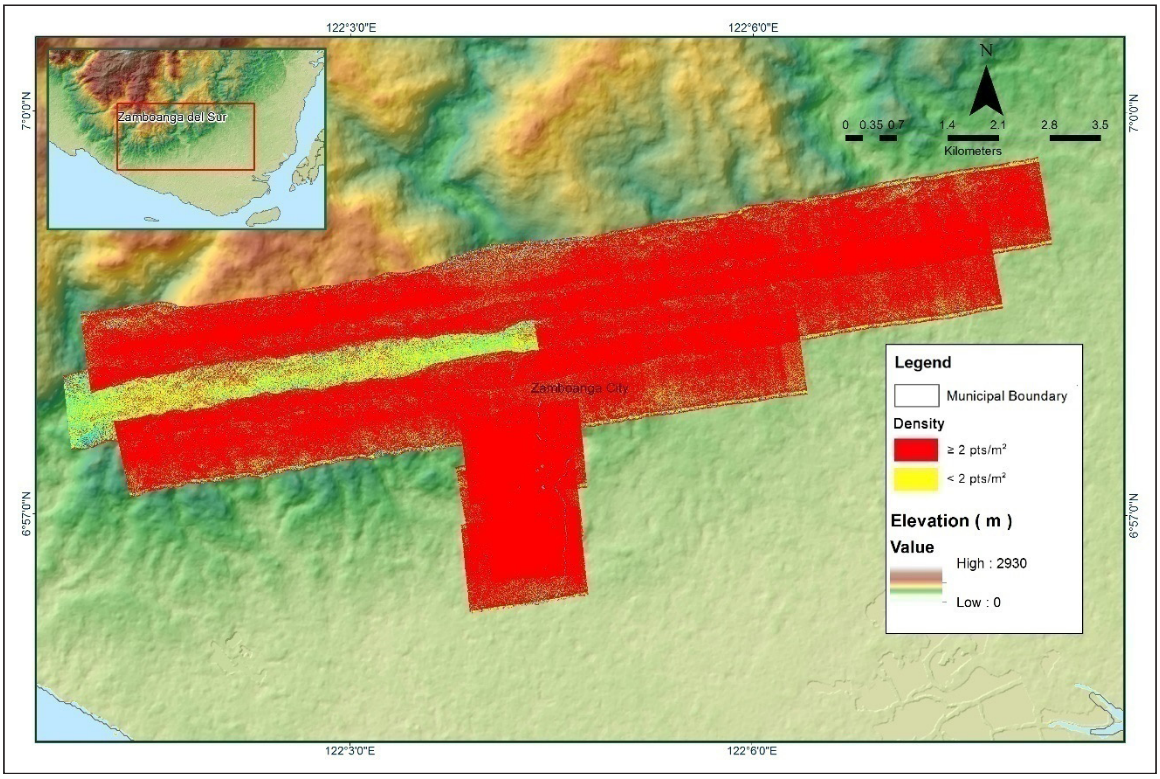
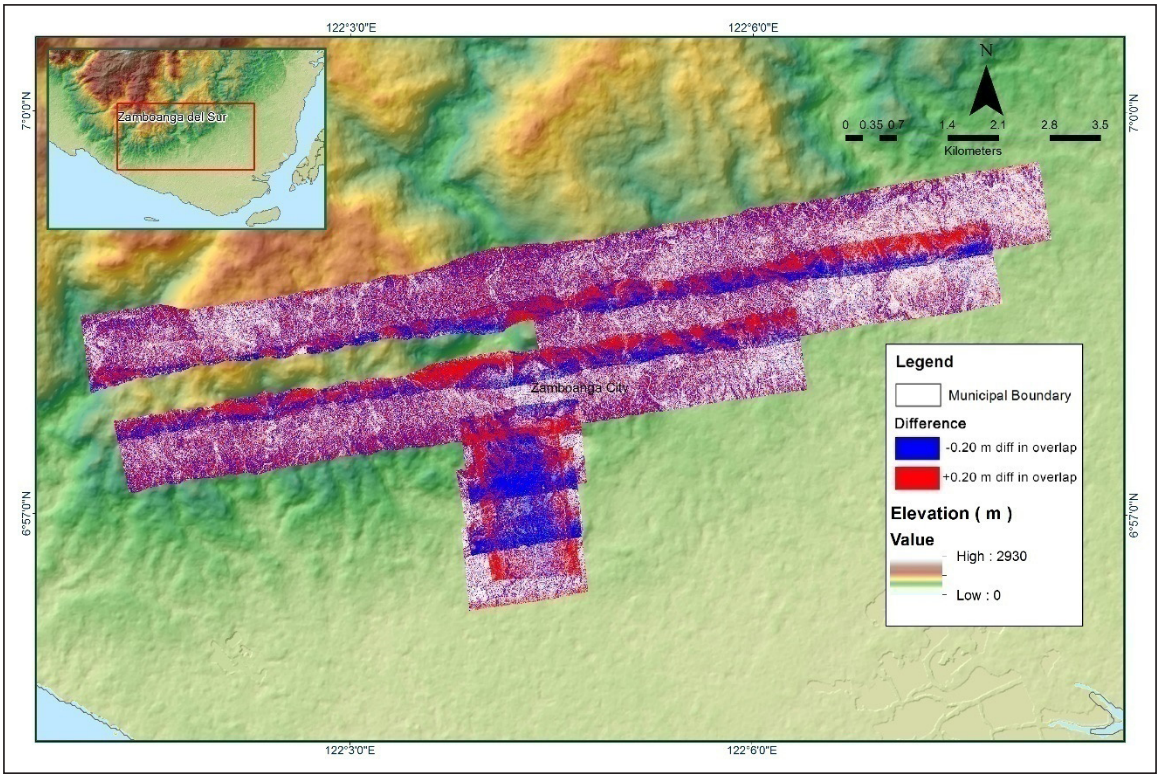



Image of data overlap

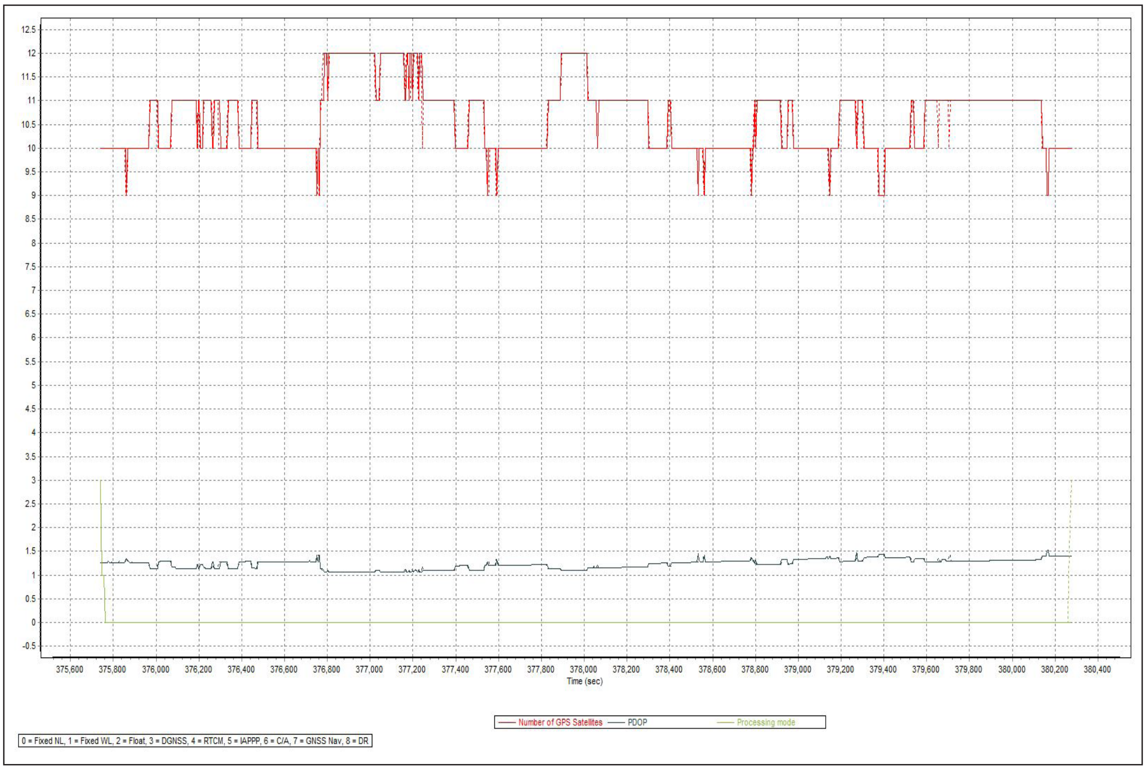



Density map of merged LiDAR data

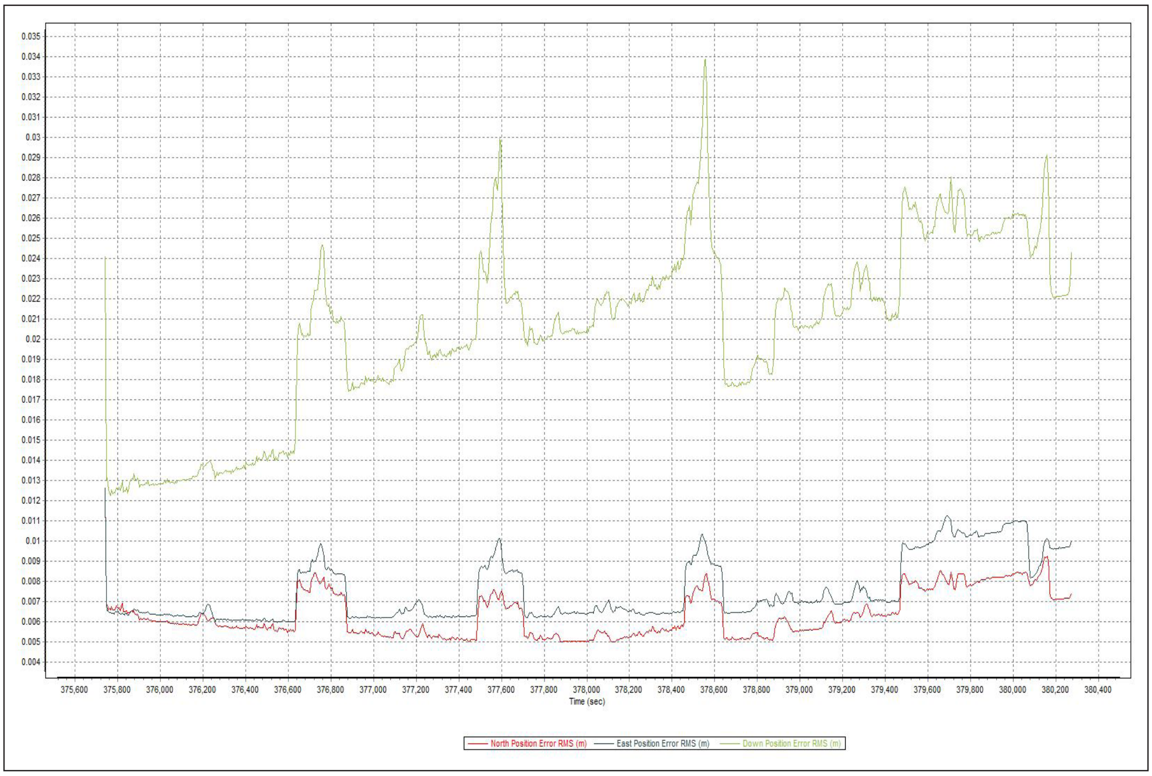



Elevation difference between flight lines

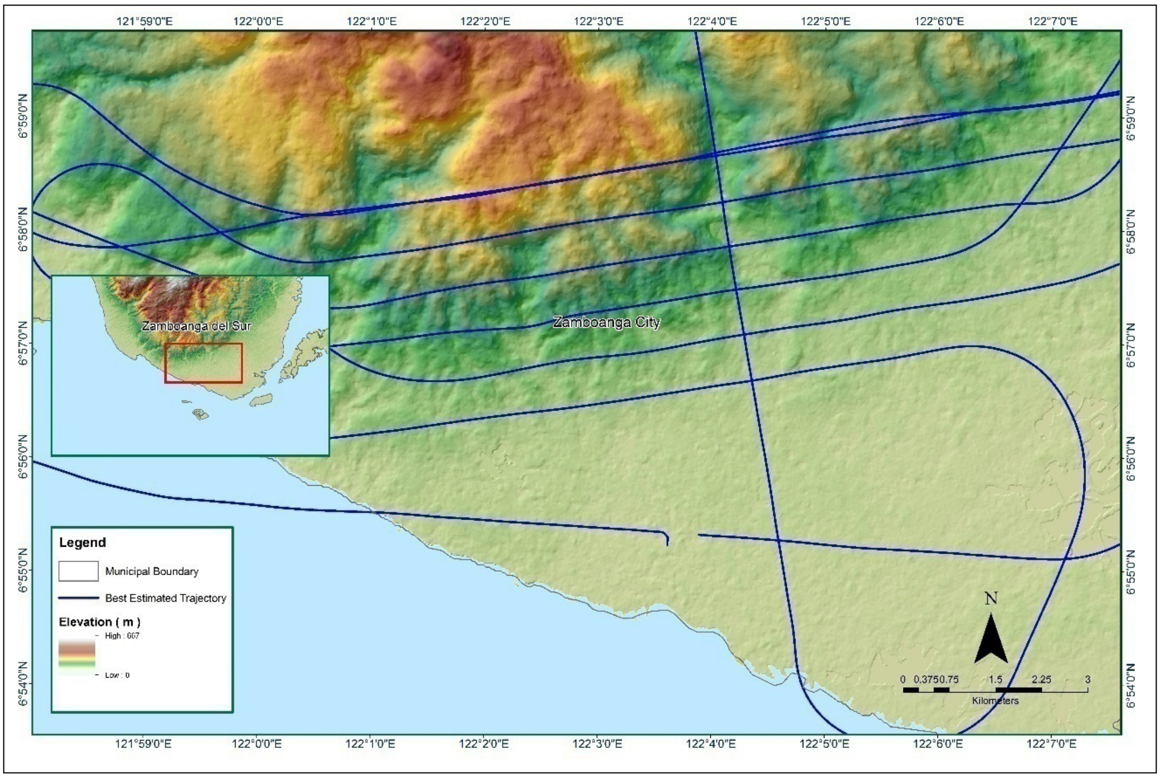
| Flight Area | Zamboanga |
|---|---|
| Mission Name | **Blk 75F_supplement** |
| Inclusive Flights | 23394P |
| Range data size | 5.13 GB |
| POS data size | 101 MB |
| Base data size | 133 MB |
| Image | n/a |
| Transfer date | July 14, 2016 |
| | |
| Solution Status | |
| Number of Satellites (>6) | Yes |
| PDOP (<3) | Yes |
| Baseline Length (<30km) | No |
| Processing Mode (<=1) | Yes |
| | |
| *Smoothed Performance Metrics*(in cm) | |
| RMSE for North Position (<4.0 cm) | 0.93 |
| RMSE for East Position (<4.0 cm) | 1.13 |
| RMSE for Down Position (<8.0 cm) | 3.39 |
| | |
| Boresight correction stdev (<0.001deg) | NA |
| IMU attitude correction stdev (<0.001deg) | NA |
| GPS position stdev (<0.01m) | NA |
| | |
| Minimum % overlap (>25) | 32.76 |
| Ave point cloud density per sq.m. (>2.0) | 2.57 |
| Elevation difference between strips (<0.20m) | 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 |



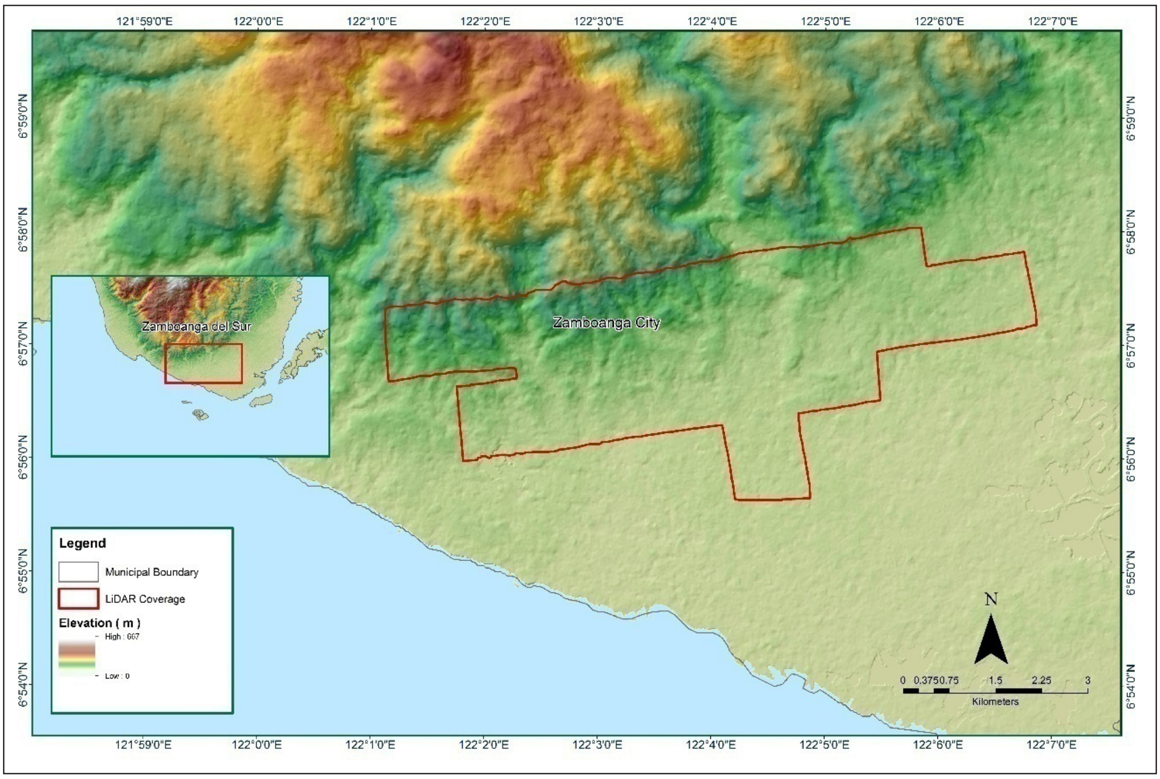

Solution Status




Smoothed Performance Metric Parameters




Best Estimated Trajectory




Coverage of LiDAR Data

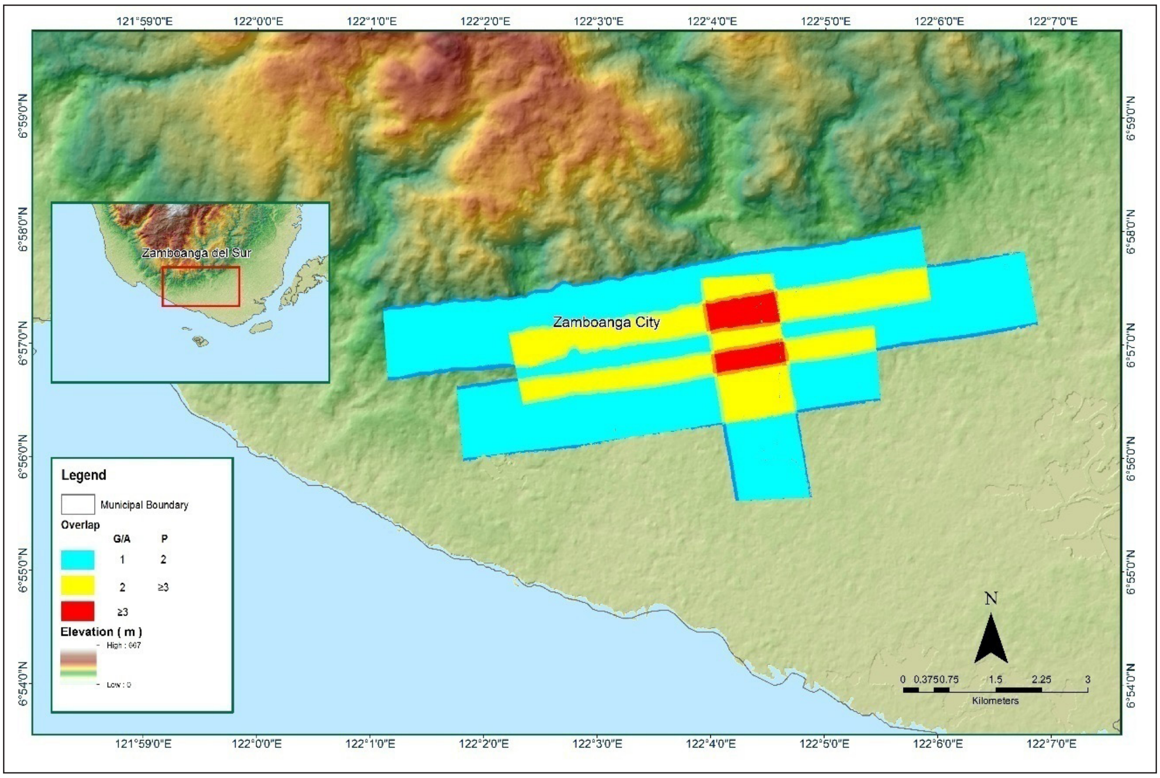
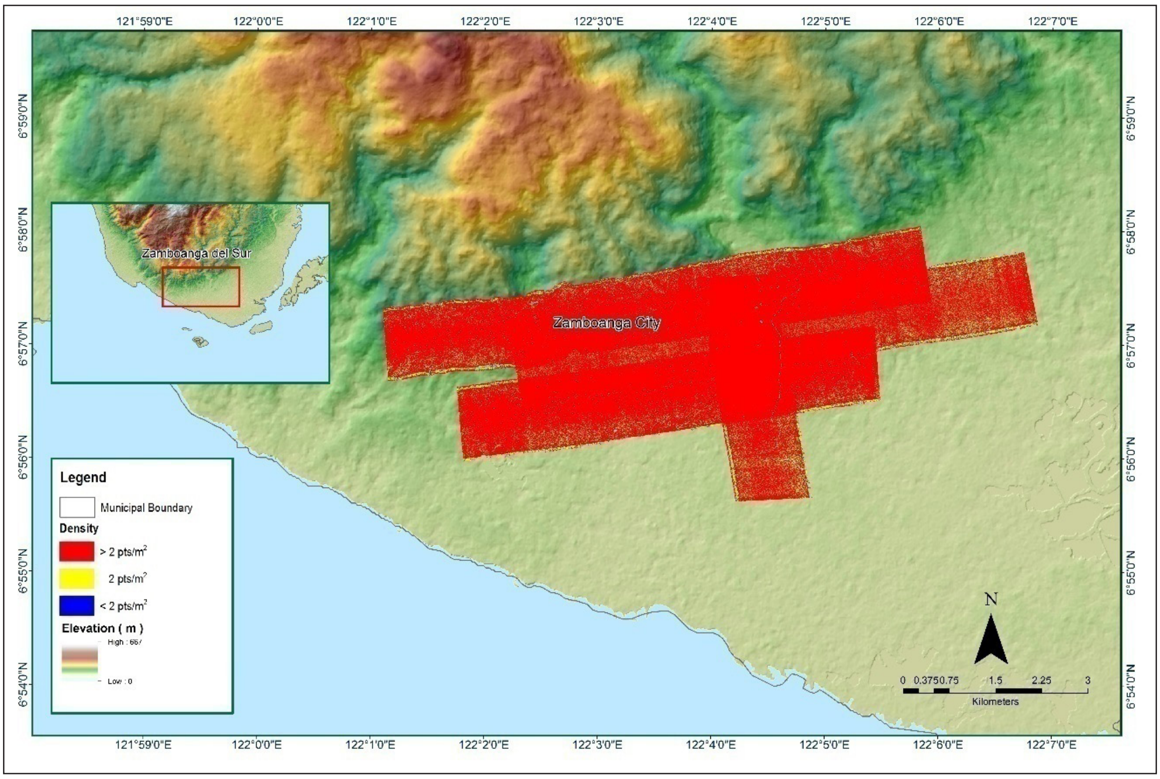
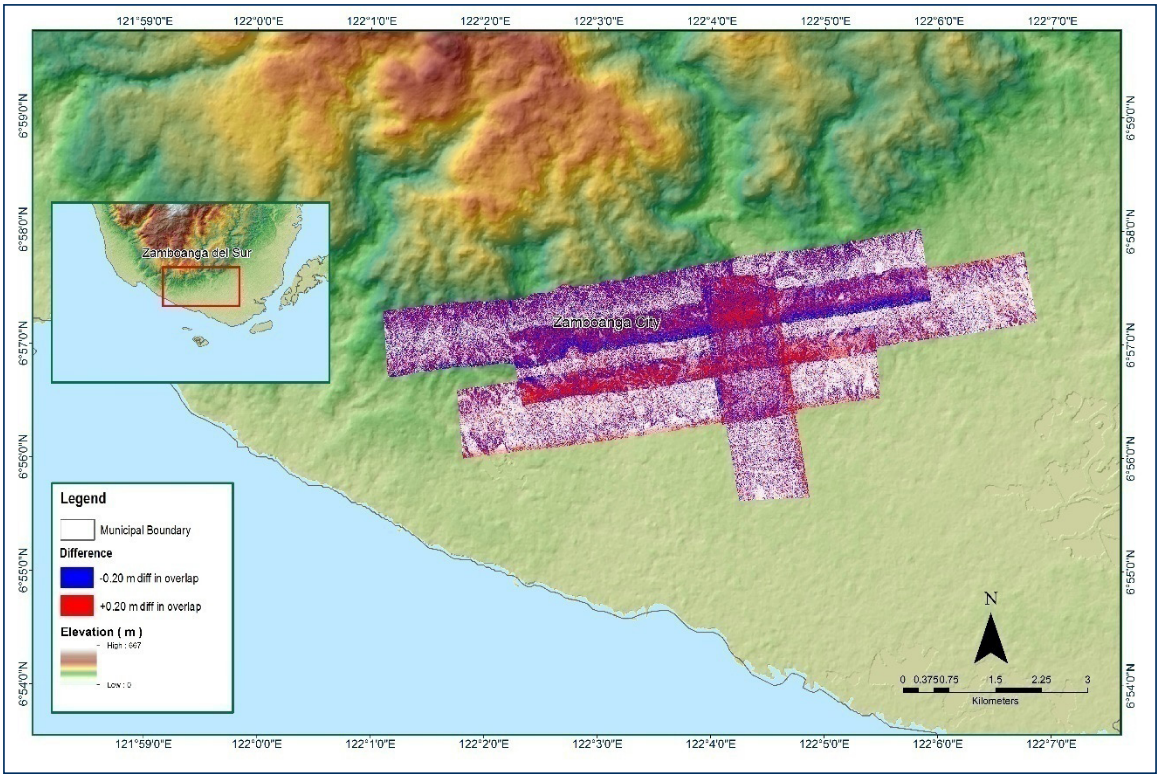



Image of data overlap




Density map of merged LiDAR data




Elevation difference between flight lines

## Annex 9. San Jose 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 |
| W300 | 0.0055033 | 67.2 | 0.0 | 0.68764 | 1.1222 | Discharge | 0.0057820 | 0.55 | Ratio to Peak | 0.5 |
| W290 | 0.0055033 | 67.2 | 0.0 | 0.50607 | 0.82591 | Discharge | 0.0050293 | 0.55 | Ratio to Peak | 0.5 |
| W280 | 0.0055033 | 67.2 | 0.0 | 1.4054 | 2.2936 | Discharge | 0.0335228 | 0.55 | Ratio to Peak | 0.5 |
| W270 | 0.0055033 | 67.2 | 0.0 | 1.2498 | 2.0396 | Discharge | 0.0676101 | 0.55 | Ratio to Peak | 0.5 |
| W260 | 0.0055033 | 67.2 | 0.0 | 1.3372 | 2.1823 | Discharge | 0.0516099 | 0.55 | Ratio to Peak | 0.5 |
| W250 | 0.0055033 | 67.2 | 0.0 | 0.39249 | 0.64054 | Discharge | 0.0042595 | 0.55 | Ratio to Peak | 0.5 |
| W240 | 0.0055033 | 67.2 | 0.0 | 0.5689 | 0.92845 | Discharge | 0.0211036 | 0.55 | Ratio to Peak | 0.5 |
| W230 | 0.0055033 | 67.2 | 0.0 | 0.77648 | 1.2672 | Discharge | 0.0318578 | 0.55 | Ratio to Peak | 0.5 |
| W220 | 0.0055033 | 67.2 | 0.0 | 0.52932 | 0.86385 | Discharge | 0.0213316 | 0.55 | Ratio to Peak | 0.5 |
| W210 | 0.0055033 | 67.2 | 0.0 | 1.3787 | 2.25 | Discharge | 0.0473219 | 0.55 | Ratio to Peak | 0.5 |
| W200 | 0.0055033 | 67.2 | 0.0 | 1.0057 | 1.6412 | Discharge | 0.0293659 | 0.55 | Ratio to Peak | 0.5 |
| W190 | 0.0055033 | 67.2 | 0.0 | 0.82207 | 1.3416 | Discharge | 0.0174485 | 0.55 | Ratio to Peak | 0.5 |
| W180 | 0.0051569 | 69.4736 | 0.0 | 0.63004 | 1.0282 | Discharge | 0.0112047 | 0.55 | Ratio to Peak | 0.5 |
| W170 | 0.0041564 | 77 | 0.0 | 0.82153 | 1.3407 | Discharge | 0.0165647 | 0.55 | Ratio to Peak | 0.5 |
| W160 | 0.0047521 | 72.3338 | 0.0 | 0.97255 | 1.5872 | Discharge | 0.0270680 | 0.55 | Ratio to Peak | 0.5 |

## Annex 10. San Jose Model Reach Parameters

| Reach Number | Muskingum Cunge Channel Routing | | | | | | |
|---|---|---|---|---|---|---|---|
| | Time Step Method | Length (m) | Slope | Manning's n | Shape | Width | Side Slope |
| R40 | Automatic Fixed Interval | 596.98 | 0.0435322 | 0.215 | Trapezoid | 30 | 0.01 |
| R60 | Automatic Fixed Interval | 1215.7 | 0.0778750 | 0.215 | Trapezoid | 30 | 0.01 |
| R80 | Automatic Fixed Interval | 755.27 | 0.26244 | 0.215 | Trapezoid | 30 | 0.01 |
| R90 | Automatic Fixed Interval | 156.57 | 0.0027507 | 0.215 | Trapezoid | 30 | 0.01 |
| R120 | Automatic Fixed Interval | 1806.4 | 0.0458446 | 0.215 | Trapezoid | 30 | 0.01 |
| R130 | Automatic Fixed Interval | 295.56 | 0.0027507 | 0.215 | Trapezoid | 30 | 0.01 |
| R150 | Automatic Fixed Interval | 410.56 | 0.0402350 | 0.215 | Trapezoid | 30 | 0.01 |
| R40 | Automatic Fixed Interval | 596.98 | 0.0435322 | 0.215 | Trapezoid | 30 | 0.01 |

# Annex 11. San Jose Field Validation Points

| Point Number | Validation Coordinates | | Model Var (m) | Validation Points (m) | Error | Event/ Date | Rain Return / Scenario |
|---|---|---|---|---|---|---|---|
| | Lat | Long | | | | | |
| 1 | 6.917288 | 122.06 | 0.21 | 0.45 | -0.24 | Habagat | 5 -Year |
| 2 | 6.917481 | 122.0573 | 0.03 | 0.30 | -0.27 | Habagat | 5 -Year |
| 3 | 6.91743 | 122.0589 | 0.03 | 0.45 | -0.42 | Habagat | 5 -Year |
| 4 | 6.918807 | 122.0603 | 0.03 | 0.25 | -0.22 | Habagat | 5 -Year |
| 5 | 6.918482 | 122.0601 | 0.23 | 0.25 | -0.02 | Habagat | 5 -Year |
| 6 | 6.918353 | 122.0604 | 0.18 | 0.25 | -0.07 | Habagat | 5 -Year |
| 7 | 6.911992 | 122.0576 | 0.05 | 0.15 | -0.10 | Habagat | 5 -Year |
| 8 | 6.916976 | 122.0585 | 0.03 | 0.15 | -0.12 | Habagat | 5 -Year |
| 9 | 6.917382 | 122.0579 | 0.07 | 0.15 | -0.08 | Habagat | 5 -Year |
| 10 | 6.914789 | 122.0555 | 0.11 | 0.55 | -0.44 | Habagat | 5 -Year |
| 11 | 6.913567 | 122.0559 | 0.41 | 0.55 | -0.14 | Habagat | 5 -Year |
| 12 | 6.914017 | 122.0552 | 0.11 | 0.70 | -0.59 | Habagat | 5 -Year |
| 13 | 6.918102 | 122.0544 | 0.30 | 0.55 | -0.25 | Habagat | 5 -Year |
| 14 | 6.917338 | 122.054 | 0.16 | 0.70 | -0.54 | Habagat | 5 -Year |
| 15 | 6.917448 | 122.0533 | 0.34 | 0.45 | -0.11 | Habagat | 5 -Year |
| 16 | 6.914413 | 122.0553 | 0.10 | 0.55 | -0.45 | Habagat | 5 -Year |
| 17 | 6.913778 | 122.0563 | 0.34 | 0.70 | -0.36 | Habagat | 5 -Year |
| 18 | 6.914406 | 122.0558 | 0.04 | 0.55 | -0.51 | Habagat | 5 -Year |
| 19 | 6.913408 | 122.055 | 0.39 | 0.70 | -0.31 | Habagat | 5 -Year |
| 20 | 6.918523 | 122.0545 | 0.03 | 0.55 | -0.52 | Habagat | 5 -Year |
| 21 | 6.913991 | 122.0555 | 0.20 | 0.70 | -0.50 | Habagat | 5 -Year |
| 22 | 6.913127 | 122.057 | 0.12 | 0.45 | -0.33 | Habagat | 5 -Year |
| 23 | 6.916888 | 122.0531 | 0.52 | 0.70 | -0.18 | Habagat | 5 -Year |
| 24 | 6.916361 | 122.0534 | 0.06 | 0.55 | -0.49 | Habagat | 5 -Year |
| 25 | 6.91418 | 122.0548 | 0.03 | 0.50 | -0.47 | Habagat | 5 -Year |
| 26 | 6.917392 | 122.0525 | 0.15 | 0.70 | -0.55 | Habagat | 5 -Year |
| 27 | 6.917812 | 122.0522 | 0.91 | 0.70 | 0.21 | Habagat | 5 -Year |
| 28 | 6.912892 | 122.055 | 0.11 | 0.70 | -0.59 | Habagat | 5 -Year |
| 29 | 6.913244 | 122.0551 | 0.29 | 0.70 | -0.41 | Habagat | 5 -Year |
| 30 | 6.915334 | 122.0576 | 0.03 | 0.20 | -0.17 | Habagat | 5 -Year |
| 31 | 6.91477 | 122.0572 | 0.25 | 0.25 | 0.00 | Habagat | 5 -Year |
| 32 | 6.914469 | 122.0569 | 0.06 | 0.20 | -0.14 | Habagat | 5 -Year |
| 33 | 6.915086 | 122.0564 | 0.15 | 0.25 | -0.10 | Habagat | 5 -Year |
| 34 | 6.91884 | 122.0536 | 0.90 | 2.00 | -1.10 | | 5 -Year |
| 35 | 6.918187 | 122.054 | 0.30 | 2.00 | -1.70 | | 5 -Year |
| 36 | 6.919982 | 122.0543 | 0.90 | 2.00 | -1.10 | | 5 -Year |
| 37 | 6.920569 | 122.0542 | 0.85 | 2.00 | -1.15 | | 5 -Year |
| 38 | 6.921024 | 122.0547 | 0.63 | 2.00 | -1.37 | | 5 -Year |
| 39 | 6.921205 | 122.0541 | 0.40 | 2.00 | -1.60 | | 5 -Year |
| 40 | 6.920355 | 122.0537 | 0.88 | 2.00 | -1.12 | | 5 -Year |
| 41 | 6.918109 | 122.0533 | 0.67 | 1.00 | -0.33 | | 5 -Year |
| 42 | 6.956439 | 122.077 | 5.83 | 1.00 | 4.83 | Typhoon | 5 -Year |

| Point Number | Validation Coordinates | | Model Var (m) | Validation Points (m) | Error | Event/ Date | Rain Return / Scenario |
|---|---|---|---|---|---|---|---|
| | Lat | Long | | | | | |
| 43 | 6.955689 | 122.0777 | 4.00 | 1.00 | 3.00 | Typhoon | 5 -Year |
| 44 | 6.955933 | 122.0784 | 1.06 | 1.00 | 0.06 | Typhoon | 5 -Year |
| 45 | 6.953532 | 122.0761 | 2.50 | 1.00 | 1.50 | Typhoon | 5 -Year |
| 46 | 6.953721 | 122.0765 | 1.22 | 1.00 | 0.22 | Typhoon | 5 -Year |
| 47 | 6.954078 | 122.0766 | 1.25 | 1.00 | 0.25 | Typhoon | 5 -Year |
| 48 | 6.955687 | 122.0761 | 1.12 | 1.10 | 0.02 | Typhoon | 5 -Year |
| 49 | 6.947485 | 122.0739 | 0.03 | 0.38 | -0.35 | Typhoon | 5 -Year |
| 50 | 6.943979 | 122.0729 | 0.16 | 0.40 | -0.24 | Typhoon | 5 -Year |
| 51 | 6.942518 | 122.0726 | 0.36 | 0.40 | -0.04 | Typhoon | 5 -Year |
| 52 | 6.944527 | 122.0729 | 0.08 | 0.40 | -0.32 | Typhoon | 5 -Year |
| 53 | 6.946519 | 122.0736 | 0.06 | 0.40 | -0.34 | Typhoon | 5 -Year |
| 54 | 6.940312 | 122.0703 | 0.19 | 0.40 | -0.21 | Typhoon | 5 -Year |
| 55 | 6.945776 | 122.0729 | 0.11 | 0.40 | -0.29 | Typhoon | 5 -Year |
| 56 | 6.954497 | 122.0759 | 2.14 | 1.10 | 1.04 | Typhoon | 5 -Year |
| 57 | 6.953992 | 122.0755 | 2.81 | 1.10 | 1.71 | Typhoon | 5 -Year |
| 58 | 6.95545 | 122.0753 | 1.96 | 0.96 | 1.00 | Typhoon | 5 -Year |
| 59 | 6.929621 | 122.0702 | 0.03 | 0.37 | -0.34 | Typhoon | 5 -Year |
| 60 | 6.931323 | 122.0727 | 0.47 | 0.37 | 0.10 | Typhoon | 5 -Year |
| 61 | 6.92454 | 122.0712 | 0.03 | 0.37 | -0.34 | Typhoon | 5 -Year |
| 62 | 6.924856 | 122.0703 | 0.03 | 0.37 | -0.34 | Typhoon | 5 -Year |
| 63 | 6.92521 | 122.0715 | 0.03 | 0.37 | -0.34 | Typhoon | 5 -Year |
| 64 | 6.925126 | 122.0695 | 0.03 | 0.37 | -0.34 | Typhoon | 5 -Year |
| 65 | 6.929264 | 122.0693 | 0.03 | 0.37 | -0.34 | Typhoon | 5 -Year |
| 66 | 6.92994 | 122.0692 | 0.04 | 0.35 | -0.31 | Typhoon | 5 -Year |
| 67 | 6.923879 | 122.0701 | 0.40 | 0.37 | 0.03 | Typhoon | 5 -Year |
| 68 | 6.923752 | 122.0712 | 0.03 | 0.37 | -0.34 | Typhoon | 5 -Year |
| 69 | 6.93115 | 122.0705 | 0.03 | 0.37 | -0.34 | Typhoon | 5 -Year |
| 70 | 6.927062 | 122.0719 | 0.08 | 0.37 | -0.29 | Typhoon | 5 -Year |
| 71 | 6.924664 | 122.072 | 0.03 | 0.37 | -0.34 | Typhoon | 5 -Year |
| 72 | 6.92435 | 122.0693 | 0.03 | 0.37 | -0.34 | Typhoon | 5 -Year |
| 73 | 6.925836 | 122.0699 | 0.03 | 0.37 | -0.34 | Typhoon | 5 -Year |
| 74 | 6.925386 | 122.0723 | 0.15 | 0.37 | -0.22 | Typhoon | 5 -Year |
| 75 | 6.926129 | 122.0724 | 0.15 | 0.37 | -0.22 | Typhoon | 5 -Year |
| 76 | 6.929143 | 122.0708 | 0.16 | 0.37 | -0.21 | Typhoon | 5 -Year |
| 77 | 6.928323 | 122.069 | 0.03 | 0.37 | -0.34 | Typhoon | 5 -Year |
| 78 | 6.943819 | 122.0738 | 0.28 | 0.40 | -0.12 | Typhoon | 5 -Year |
| 79 | 6.946431 | 122.0725 | 0.06 | 0.40 | -0.34 | Typhoon | 5 -Year |
| 80 | 6.945142 | 122.0739 | 0.59 | 0.40 | 0.19 | Typhoon | 5 -Year |
| 81 | 6.945209 | 122.0722 | 0.18 | 0.40 | -0.22 | Typhoon | 5 -Year |
| 82 | 6.955011 | 122.0753 | 1.42 | 0.96 | 0.46 | Typhoon | 5 -Year |
| 83 | 6.958047 | 122.0781 | 0.96 | 1.90 | -0.94 | Typhoon | 5 -Year |
| 84 | 6.957773 | 122.0787 | 1.55 | 1.00 | 0.55 | Typhoon | 5 -Year |
| 85 | 6.958649 | 122.0793 | 2.67 | 1.00 | 1.67 | Typhoon | 5 -Year |
| 86 | 6.958958 | 122.0789 | 2.85 | 1.00 | 1.85 | Typhoon | 5 -Year |

| Point Number | Validation Coordinates | | Model Var (m) | Validation Points (m) | Error | Event/ Date | Rain Return / Scenario |
|---|---|---|---|---|---|---|---|
| | Lat | Long | | | | | |
| 87 | 6.959128 | 122.0792 | 3.16 | 1.00 | 2.16 | Typhoon | 5 -Year |
| 88 | 6.930583 | 122.0734 | 0.72 | 0.37 | 0.35 | Typhoon | 5 -Year |
| 89 | 6.929747 | 122.0734 | 0.62 | 0.37 | 0.25 | Typhoon | 5 -Year |
| 90 | 6.957986 | 122.0801 | 2.46 | 1.00 | 1.46 | Typhoon | 5 -Year |
| 91 | 6.946413 | 122.0748 | 0.41 | 0.40 | 0.01 | Typhoon | 5 -Year |
| 92 | 6.945993 | 122.0743 | 0.22 | 0.40 | -0.18 | Typhoon | 5 -Year |
| 93 | 6.930561 | 122.0717 | 0.14 | 0.37 | -0.23 | Typhoon | 5 -Year |
| 94 | 6.929346 | 122.0723 | 2.73 | 0.37 | 2.36 | Typhoon | 5 -Year |
| 95 | 6.923935 | 122.0683 | 0.15 | 0.37 | -0.22 | Typhoon | 5 -Year |
| 96 | 6.924267 | 122.0675 | 0.03 | 0.30 | -0.27 | Typhoon | 5 -Year |
| 97 | 6.924869 | 122.0682 | 0.12 | 0.30 | -0.18 | Typhoon | 5 -Year |
| 98 | 6.927188 | 122.0709 | 0.27 | 0.30 | -0.03 | Typhoon | 5 -Year |
| 99 | 6.926451 | 122.0698 | 0.04 | 0.37 | -0.33 | Typhoon | 5 -Year |
| 100 | 6.926121 | 122.0689 | 0.08 | 0.37 | -0.29 | Typhoon | 5 -Year |
| 101 | 6.941461 | 122.071 | 0.03 | 0.35 | -0.32 | Typhoon | 5 -Year |
| 102 | 6.94235 | 122.0711 | 0.03 | 0.37 | -0.34 | Typhoon | 5 -Year |
| 103 | 6.946624 | 122.0718 | 0.91 | 0.40 | 0.51 | Typhoon | 5 -Year |
| 104 | 6.944142 | 122.072 | 0.03 | 0.40 | -0.37 | Typhoon | 5 -Year |
| 105 | 6.944527 | 122.0715 | 0.50 | 0.40 | 0.10 | Typhoon | 5 -Year |
| 106 | 6.947529 | 122.0726 | 0.04 | 0.37 | -0.33 | Typhoon | 5 -Year |
| 107 | 6.950249 | 122.0742 | 2.66 | 0.40 | 2.26 | Typhoon | 5 -Year |
| 108 | 6.95068 | 122.0746 | 0.03 | 0.40 | -0.37 | Typhoon | 5 -Year |
| 109 | 6.950545 | 122.0716 | 0.03 | 0.40 | -0.37 | Typhoon | 5 -Year |
| 110 | 6.951438 | 122.0716 | 0.03 | 0.40 | -0.37 | Typhoon | 5 -Year |
| 111 | 6.951657 | 122.0758 | 0.88 | 0.40 | 0.48 | Typhoon | 5 -Year |
| 112 | 6.951966 | 122.0755 | 0.82 | 0.40 | 0.42 | Typhoon | 5 -Year |
| 113 | 6.943168 | 122.0716 | 0.46 | 0.40 | 0.06 | Typhoon | 5 -Year |
| 114 | 6.942699 | 122.0718 | 0.13 | 0.40 | -0.27 | Typhoon | 5 -Year |
| 115 | 6.94204 | 122.0738 | 0.64 | 0.40 | 0.24 | Typhoon | 5 -Year |
| 116 | 6.941518 | 122.0734 | 0.43 | 0.40 | 0.03 | Typhoon | 5 -Year |
| 117 | 6.941561 | 122.0742 | 0.54 | 0.40 | 0.14 | Typhoon | 5 -Year |
| 118 | 6.942264 | 122.0733 | 0.33 | 0.40 | -0.07 | Typhoon | 5 -Year |
| 119 | 6.933674 | 122.0705 | 0.25 | 0.40 | -0.15 | Typhoon | 5 -Year |
| 120 | 6.930501 | 122.0666 | 0.34 | 0.30 | 0.04 | Typhoon | 5 -Year |
| 121 | 6.927548 | 122.0533 | 0.03 | 0.37 | -0.34 | Typhoon | 5 -Year |
| 122 | 6.927769 | 122.0516 | 0.03 | 0.40 | -0.37 | Typhoon | 5 -Year |
| 123 | 6.940778 | 122.0724 | 0.36 | 0.40 | -0.04 | Typhoon | 5 -Year |
| 124 | 6.939573 | 122.0725 | 0.76 | 0.40 | 0.36 | Typhoon | 5 -Year |
| 125 | 6.93982 | 122.0729 | 0.97 | 0.40 | 0.57 | Typhoon | 5 -Year |
| 126 | 6.946938 | 122.0754 | 0.41 | 0.40 | 0.01 | Typhoon | 5 -Year |
| 127 | 6.946958 | 122.0766 | 5.28 | 0.40 | 4.88 | Typhoon | 5 -Year |
| 128 | 6.94607 | 122.0753 | 0.19 | 0.40 | -0.21 | Typhoon | 5 -Year |
| 129 | 6.946304 | 122.0759 | 1.64 | 0.40 | 1.24 | Typhoon | 5 -Year |
| 130 | 6.945796 | 122.0759 | 2.25 | 0.40 | 1.85 | Typhoon | 5 -Year |

| Point Number | Validation Coordinates | | Model Var (m) | Validation Points (m) | Error | Event/ Date | Rain Return / Scenario |
|---|---|---|---|---|---|---|---|
| | Lat | Long | | | | | |
| 131 | 6.945464 | 122.0759 | 2.21 | 0.40 | 1.81 | Typhoon | 5 -Year |
| 132 | 6.945088 | 122.0753 | 0.38 | 0.40 | -0.02 | Typhoon | 5 -Year |
| 133 | 6.945532 | 122.0746 | 0.03 | 0.40 | -0.37 | Typhoon | 5 -Year |
| 134 | 6.944058 | 122.0746 | 0.52 | 0.40 | 0.12 | Typhoon | 5 -Year |
| 135 | 6.943169 | 122.0731 | 0.14 | 0.40 | -0.26 | Typhoon | 5 -Year |
| 136 | 6.943272 | 122.0738 | 0.03 | 0.40 | -0.37 | Typhoon | 5 -Year |
| 137 | 6.943911 | 122.0753 | 1.18 | 0.40 | 0.78 | Typhoon | 5 -Year |
| 138 | 6.94277 | 122.0766 | 4.55 | 0.48 | 4.07 | Typhoon | 5 -Year |
| 139 | 6.943418 | 122.0758 | 0.72 | 0.48 | 0.24 | Typhoon | 5 -Year |
| 140 | 6.942735 | 122.0741 | 1.10 | 0.40 | 0.70 | Typhoon | 5 -Year |
| 141 | 6.953137 | 122.077 | 0.97 | 1.00 | -0.03 | Typhoon | 5 -Year |
| 142 | 6.945848 | 122.0696 | 0.03 | 0.40 | -0.37 | Typhoon | 5 -Year |
| 143 | 6.945432 | 122.0704 | 0.03 | 0.40 | -0.37 | Typhoon | 5 -Year |
| 144 | 6.945783 | 122.071 | 0.03 | 0.40 | -0.37 | Typhoon | 5 -Year |
| 145 | 6.945447 | 122.0717 | 0.61 | 0.40 | 0.21 | Typhoon | 5 -Year |
| 146 | 6.944403 | 122.0706 | 0.11 | 0.40 | -0.29 | Typhoon | 5 -Year |
| 147 | 6.946548 | 122.0707 | 0.03 | 0.40 | -0.37 | Typhoon | 5 -Year |
| 148 | 6.949614 | 122.0747 | 0.03 | 0.40 | -0.37 | Typhoon | 5 -Year |
| 149 | 6.951737 | 122.0747 | 0.03 | 0.40 | -0.37 | Typhoon | 5 -Year |
| 150 | 6.954494 | 122.0773 | 0.04 | 0.40 | -0.36 | Typhoon | 5 -Year |
| 151 | 6.927106 | 122.0579 | 0.03 | 0.30 | -0.27 | Typhoon | 5 -Year |
| 152 | 6.927306 | 122.0596 | 0.16 | 0.40 | -0.24 | Typhoon | 5 -Year |
| 153 | 6.92804 | 122.0589 | 0.17 | 0.30 | -0.13 | Typhoon | 5 -Year |
| 154 | 6.928199 | 122.058 | 0.10 | 0.35 | -0.25 | Typhoon | 5 -Year |
| 155 | 6.9263 | 122.06 | 0.03 | 0.00 | 0.03 | Typhoon | 5 -Year |
| 156 | 6.929026 | 122.0586 | 0.52 | 0.50 | 0.02 | Typhoon | 5 -Year |
| 157 | 6.928777 | 122.0597 | 0.03 | 0.00 | 0.03 | Typhoon | 5 -Year |
| 158 | 6.928572 | 122.0613 | 0.09 | 0.20 | -0.11 | Typhoon | 5 -Year |
| 159 | 6.930278 | 122.0627 | 0.03 | 0.30 | -0.27 | Typhoon | 5 -Year |
| 160 | 6.929107 | 122.0626 | 0.05 | 0.30 | -0.25 | Typhoon | 5 -Year |
| 161 | 6.92947 | 122.0636 | 0.06 | 0.20 | -0.14 | Typhoon | 5 -Year |
| 162 | 6.928147 | 122.0634 | 0.05 | 0.40 | -0.35 | Typhoon | 5 -Year |
| 163 | 6.923772 | 122.0726 | 0.64 | 0.40 | 0.24 | Typhoon | 5 -Year |
| 164 | 6.928079 | 122.0726 | 0.80 | 0.40 | 0.40 | Typhoon | 5 -Year |
| 165 | 6.928529 | 122.0717 | 0.04 | 0.30 | -0.26 | Typhoon | 5 -Year |
| 166 | 6.928561 | 122.0728 | 0.23 | 0.20 | 0.03 | Typhoon | 5 -Year |
| 167 | 6.930071 | 122.0727 | 0.59 | 0.40 | 0.19 | Typhoon | 5 -Year |
| 168 | 6.926047 | 122.071 | 0.17 | 0.30 | -0.13 | Typhoon | 5 -Year |
| 169 | 6.927519 | 122.0701 | 0.26 | 0.35 | -0.09 | Typhoon | 5 -Year |
| 170 | 6.926854 | 122.069 | 0.04 | 0.10 | -0.06 | Typhoon | 5 -Year |
| 171 | 6.936239 | 122.0707 | 0.89 | 0.40 | 0.49 | Typhoon | 5 -Year |
| 172 | 6.938901 | 122.0705 | 0.47 | 0.30 | 0.17 | Typhoon | 5 -Year |
| 173 | 6.93909 | 122.0716 | 0.25 | 0.40 | -0.15 | Typhoon | 5 -Year |
| 174 | 6.938922 | 122.0721 | 0.76 | 0.35 | 0.41 | Typhoon | 5 -Year |

| Point Number | Validation Coordinates | | Model Var (m) | Validation Points (m) | Error | Event/ Date | Rain Return / Scenario |
|---|---|---|---|---|---|---|---|
| | Lat | Long | | | | | |
| 175 | 6.937963 | 122.0709 | 0.60 | 0.40 | 0.20 | Typhoon | 5 -Year |
| 176 | 6.937602 | 122.0712 | 0.69 | 0.30 | 0.39 | Typhoon | 5 -Year |
| 177 | 6.936361 | 122.0713 | 2.81 | 0.40 | 2.41 | Typhoon | 5 -Year |
| 178 | 6.935312 | 122.0715 | 3.58 | 0.50 | 3.08 | Typhoon | 5 -Year |
| 179 | 6.934493 | 122.0718 | 0.03 | 0.00 | 0.03 | Typhoon | 5 -Year |
| 180 | 6.936 | 122.0718 | 1.44 | 0.50 | 0.94 | Typhoon | 5 -Year |
| 181 | 6.935565 | 122.0725 | 0.49 | 0.30 | 0.19 | Typhoon | 5 -Year |
| 182 | 6.931611 | 122.0715 | 0.85 | 0.45 | 0.40 | ITCZ | 5 -Year |
| 183 | 6.937051 | 122.0686 | 0.03 | 0.10 | -0.07 | | 5 -Year |
| 184 | 6.931856 | 122.0678 | 0.03 | 0.10 | -0.07 | | 5 -Year |
| 185 | 6.93605 | 122.0685 | 0.52 | 0.10 | 0.42 | | 5 -Year |
| 186 | 6.934328 | 122.0687 | 0.08 | 0.10 | -0.02 | Heavy rain | 5 -Year |
| 187 | 6.934962 | 122.0676 | 0.43 | 0.40 | 0.03 | Heavy rain | 5 -Year |
| 188 | 6.93288 | 122.0659 | 0.03 | 0.40 | -0.37 | Heavy rain | 5 -Year |
| 189 | 6.934075 | 122.0678 | 0.32 | 0.20 | 0.12 | Heavy rain | 5 -Year |
| 190 | 6.933504 | 122.0681 | 0.38 | 0.20 | 0.18 | Heavy rain | 5 -Year |
| | | | | RMSE | 0.91 | | |

# Annex 12. Educational Institutions affected by flooding in 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 |
| 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 |

| Zamboanga City | | | | |
|---|---|---|---|---|
| Building Name | Barangay | Rainfall Scenario | | |
| | | 5-year | 25-year | 100-year |
| 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 |
| 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 |

| Zamboanga City | | | | |
|---|---|---|---|---|
| **Building Name** | **Barangay** | **Rainfall Scenario** | | |
| | | **5-year** | **25-year** | **100-year** |
| 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 by flooding in 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 |