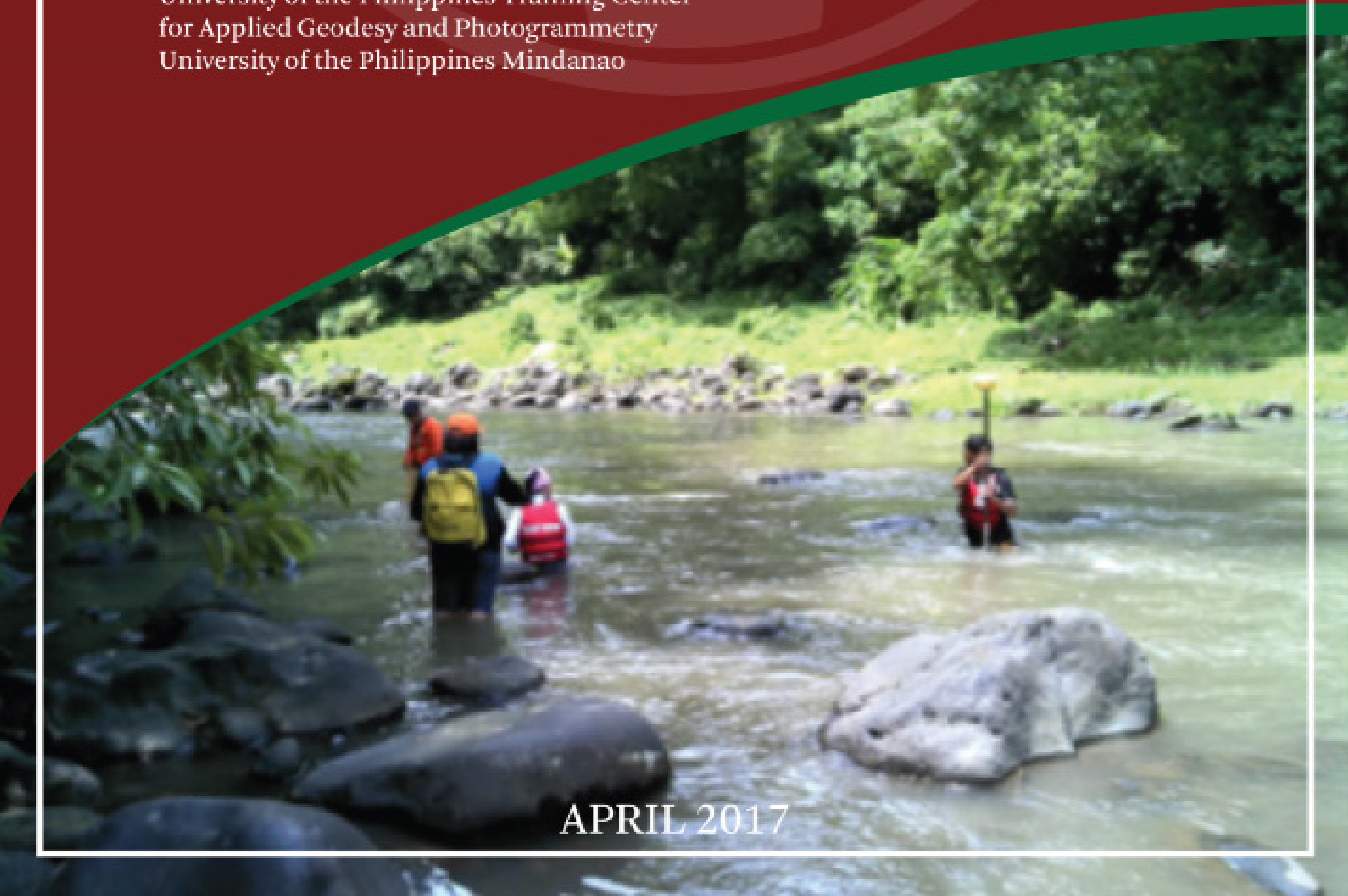
HAZARD MAPPING OF THE PHILIPPINES USING LIDAR ( PHIL-LIDAR 1 )

# LiDAR Surveys and Flood Mapping of Talomo River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
University of the Philippines Mindanao



APRIL 2017

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

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

E.C. Paringit, and J.E. Acosta, (Eds.). (2017), LiDAR Surveys and Flood Mapping of Talomo River. Quezon City: University of the Philippines Training Center for Applied Geodesy and Photogrammetry-161 pp.



For questions/queries regarding this report, contact:

**Dr. Joseph E. Acosta**
Project Leader, Phil-LiDAR 1 Program
University of the Philippines Mindanao
Davao City, Davao del Sur, 8000
E-mail: jacosta_96140@yahoo.com

**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

National Library of the Philippines
ISBN: 987-621-430-174-4

# TABLE OF CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

# LIST OF ACRONYMS AND ABBREVIATIONS

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

# CHAPTER 1: OVERVIEW OF THE PROGRAM AND TALOMO RIVER

Enrico C. Paringit, Dr. Eng., Dr. Joseph E. Acosta, and Dr. Ruth James

## 1.1 Background of the Phil-LiDAR 1 Program

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

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

The implementing partner university for the Phil-LiDAR 1 Program is the University of the Philippines Mindanao (USC) is in charge of processing LiDAR data and conducting data validation reconnaissance, cross section, bathymetric survey, validation, river flow measurements, flood height and extent data gathering, flood modeling, and flood map generation for the 13 river basins in the Southern Mindanao Region. The university is located in Davao City in the province of Davao del Sur.

## 1.2 Overview of the Talomo River Basin

The Talomo River is a stream in the province of Davao del Sur, on the southeastern side of Mindanao. It traverses Davao City and drains into Talomo Bay in the Davao Gulf (Mines and Geosciences Bureau, 2014). It is part of the three (3) major rivers that provide major drainage way in Davao City and primary drainage system in Mt. Talomo area. It is a waterway connecting Mt. Talomo and Apo Range and is part of the thirteen (13) river systems in the Davao Region.

The upstream portion of Talomo River is characterized by rapids and rocky terrain while its banks have dense of canopy cover. Although shallow, downstream portion of the river could still be navigable by a rubber boat but its banks are still characterized by dense canopy covers.

Talomo River Basin is located in the eastern portion of Davao City, Davao del Sur. It has a drainage area of 244 km2 and an estimated 488 million cubic meter (MCM) annual run-off according to DENR-RCBO. The Talomo River has a total watershed area of 230.07 square kilometers with a river length of 51.2 kilometers. It has 71 subbasins, 35 junctions, and 35 reaches. It is also among the eight (8) river basins in Davao City.

Along the Talomo river lives a population of 138,840 which is composed of (6) barangays namely; Tacunan, Mintal, Catalunan Grande, Catalunan Pequeño, Bago Gallera and Talomo Proper, which are all part of Davao City.

Davao City is the largest city in the Philippines in terms of land area. It is bounded by Davao del Norte in the north, Davao Gulf and Samal City on the east, the province of Cotabato on the west, and Digos City and the municipality of Sta. Cruz on the south.

Davao serves as the main trade, commerce, and industry hub of the island of Mindanao. Being the regional center of Davao Region, the highly urbanized City of Davao is bustling with rich cultural heritage. It has also played a part in various historical events including the Second World War (Dacumos, 2012; City Government of Davao, 2011).

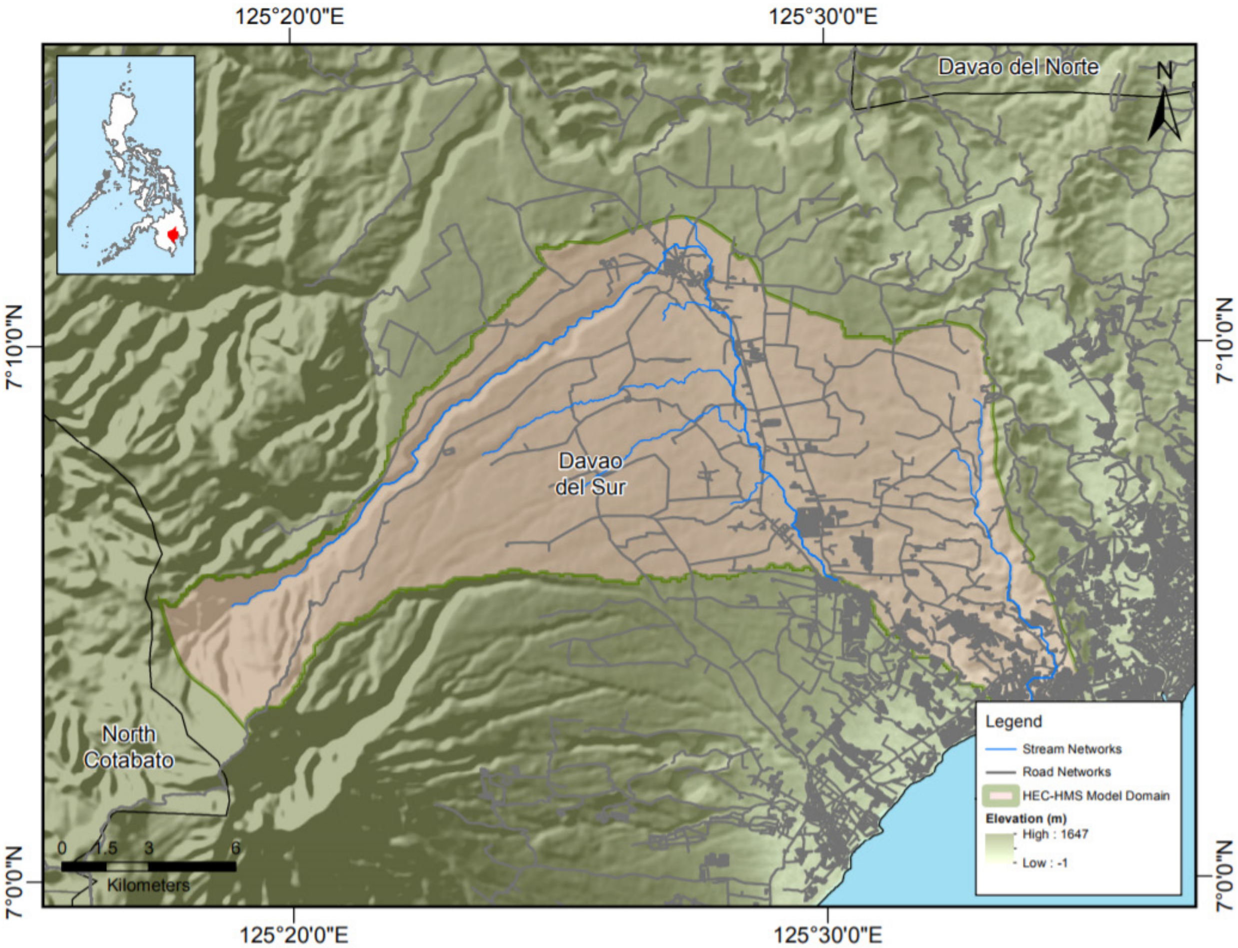



Figure 1. Map of Talomo River Basin (in brown)

During World War II in 1945, the allied forces of the United States and the Philippines started a campaign to recapture and liberate Mindanao from the Japanese forces. Davao City was the last major Philippine City under the Japanese control (Battad, 2011). The Battle of Davao was fought with the American-Filipino troops and the Japanese soldiers on either side. The Talomo River was utilized by the Americans in an attempt to cut off the Japanese who retreated into the highlands (Bell, 1999; Smith, 2005).

Talomo River serves as one of the major drainage systems of Mt. Talomo in the eastern part of Mt. Apo along with Lipadas and Sibulan Rivers (GreedyPeg, 2016). Davao City's drinking water is sourced from the Talomo-Lipadas Watersheds which originates from Mt. Talomo (Mallare, 2016). Five (5) run-of-the-river hydropower systems managed by Hedcor also utilizes the said river as a source of renewable energy for the country (Hedcor, 2015; MindanaoTimes, 2017).

River Tubing, locally known as Paanod, is a recreational activity that utilizes an inner tube to navigate the Talomo River (ABS-CBN, 2015; Cairo, 2016). An ancestral domain of the Obu-Manuvu tribe can be found in the upper part of the Talomo River (EuroGenerics, 2011).
Pollution is the primary problem identified in Talomo Watershed (Mallare, 2016). Other issues include deforestation, land use conflict, and improper cultivation of hilly lands (PCEEM, 2017). Population increase near Talomo River also increases the demand for water, food, and shelter resulting to depletion of groundwater resources, increase in volume of wastewater, and increase in risk of agricultural runoff (Sherbinin, 1998; Abayon et.al., 2013).

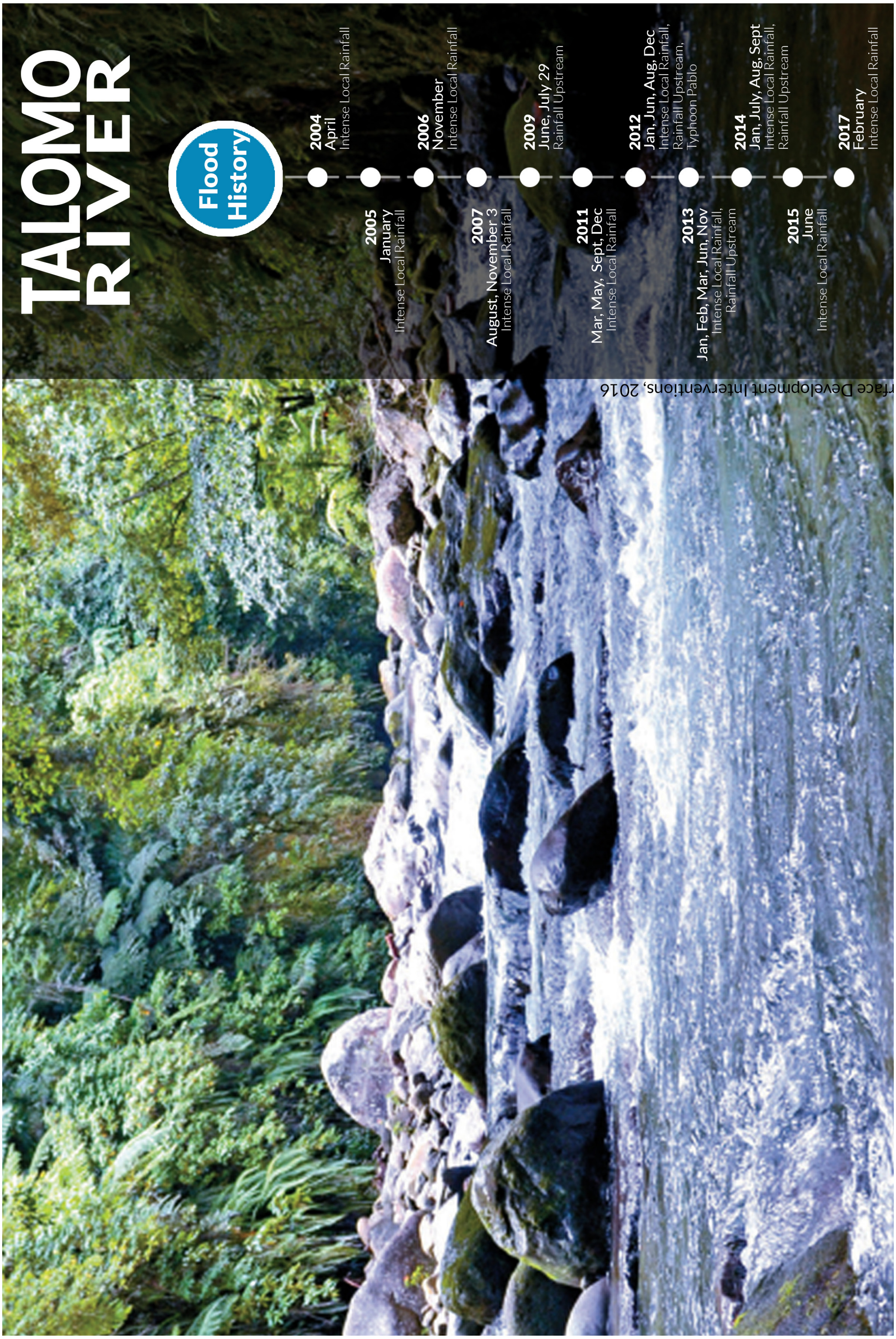



Figure 2. Talomo River flood history

A study by the World Wildlife Fund (WWF) in 2011 found that areas near the rivers in Davao City are susceptible to floods even though it is located in a typhoon-free zone. This includes the two biggest rivers that run through the city: Davao and Talomo Rivers (Carillo, 2016).

According to locals, from the year 2004 to 2017, local rainfall and upstream rainfall are the usual cause of flooding near the river. However, PAGASA only noted typhoon events such as Typhoon Pablo in 2012. The recent flooding events caused Talomo River to overflow on June 5, 2013 where 371 families were affected in Davao city. The two (2) hour heavy rains triggered floods in some areas in Davao City caused evacuation of some residents along the riverbanks.

# CHAPTER 2: LIDAR DATA ACQUISITION OF THE TALOMO FLOODPLAIN

*Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Acuna, Engr. Gerome Hipolito, Ms. Sandra C. Poblete, and Engr. Grace Sinadjan*

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 Talomo floodplain in Davao del Sur. These missions were planned for 12 lines that run for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR system is found in Table 1. Figure 1 shows the flight plan for Talomo floodplain survey.

Table 1. Flight planning parameters for the Gemini LiDAR system.

| Block Name | Flying Height (m AGL) | Overlap (%) | Field of view (ø) | Pulse Repetition Frequency (PRF) (kHz) | Scan Frequency (Hz) | Average Speed (kts) | Average Turn Time (Minutes) |
|---|---|---|---|---|---|---|---|
| BLK82A | 850, 1000 | 30, 35 | 40, 50 | 125 | 40, 50 | 130 | 5 |
| BLK82B | 850, 1000 | 30, 35 | 40, 50 | 125 | 40, 50 | 130 | 5 |
| BLK82C | 850, 1000 | 30, 35 | 40, 50 | 125 | 40, 50 | 130 | 5 |
| BLK82D | 1000 | 35 | 40 | 125 | 50 | 130 | 5 |
| BLK82E | 850, 1000 | 30 | 40, 50 | 125 | 40, 50 | 130 | 5 |
| BLK82F | 850, 1000 | 30, 35 | 40, 50 | 125 | 40, 50 | 130 | 5 |
| BLK82G | 850, 1000 | 30, 35 | 40, 50 | 125 | 40, 50 | 130 | 5 |
| BLK82H | 850 | 30 | 50 | 125 | 40 | 130 | 5 |

[1] The explanation of the parameters used are in the volume "LiDAR Surveys and Flood Mapping in the Philippines: Methods."

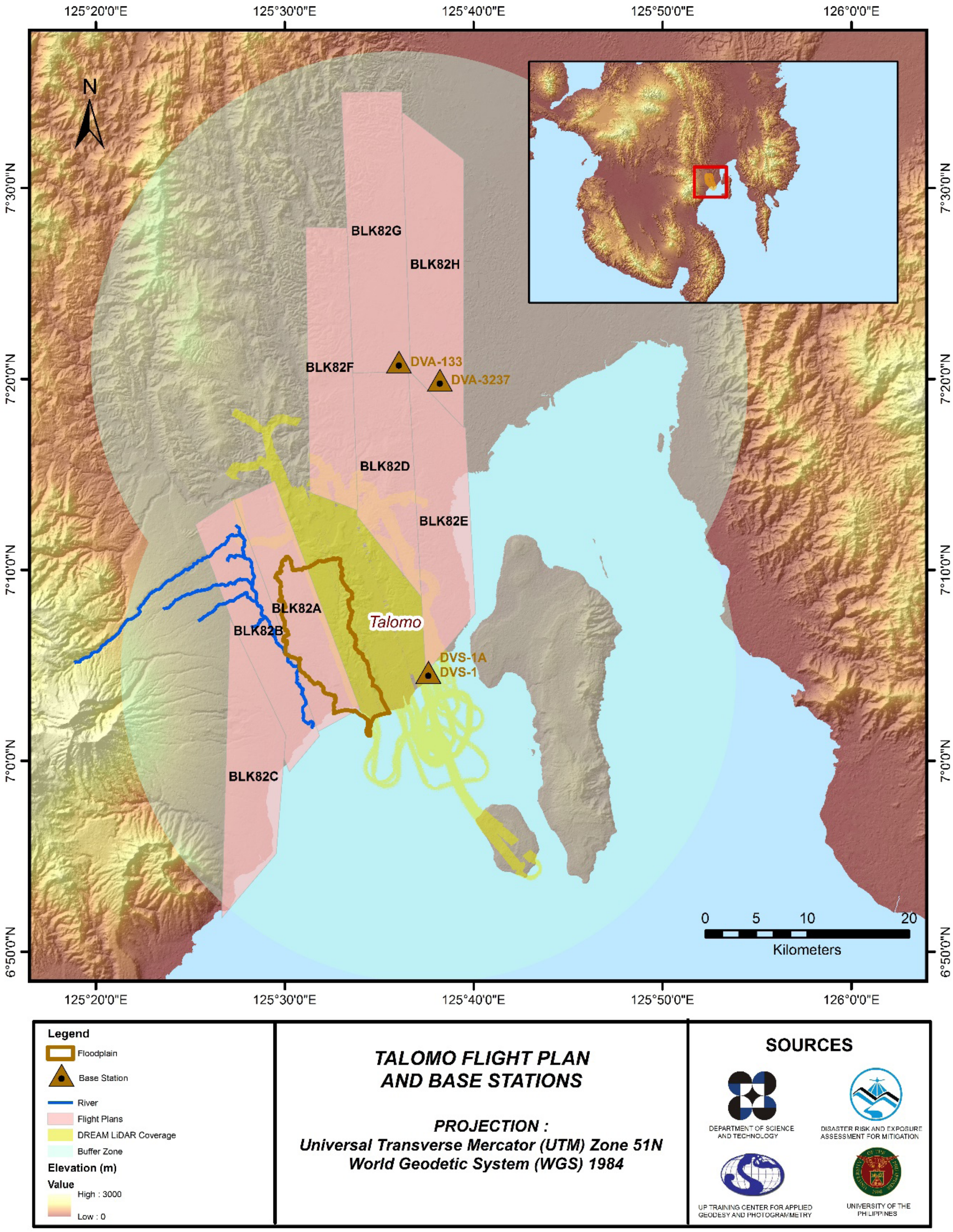



Figure 3. Flight Plan and base station used for the Talomo Floodplain survey.

## 2.2 Ground Base Stations

The project team was able to recover three (3) NAMRIA ground control points: DVS-1, DVA-133, DVA-3237, which are of first (1st), second (2nd) and fourth (4th) order accuracy, respectively. The project team also established one (1) ground control point, DVS-1A. The certifications for the NAMRIA reference points are found in Annex 2 while the baseline processing reports for the established control point are found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey (July 18 to August 11, 2014). Base stations were observed using dual frequency GPS receivers: TRIMBLE SPS 852, TRIMBLE SPS 882 and TRIMBLE SPS 985. Flight plans and location of base stations used during the aerial LiDAR acquisition in Talomo floodplain are shown in Figure 3.

Figure 4 to Figure 7 show the recovered NAMRIA reference points within the area. In addition, Table 2 to Table 5 show the details about the following NAMRIA control stations and established points, while Table 6 shows the list of all ground control points occupied during the acquisition together with the corresponding dates of utilization. The list of team members are found in Annex 4.

(a)

(b)

Figure 4. GPS set-up over DVS-1 at Sta. Ana Wharf, Davao City (a) and NAMRIA reference point DVS-1 (b) as recovered by the field team.

Table 2. Details of the recovered NAMRIA horizontal control point DVS-1 used as base station for the LiDAR acquisition.

| **Station Name** | **DVS-1** | |
|---|---|---|
| **Order of Accuracy** | **1st** | |
| **Relative Error (Horizontal positioning)** | **1 in 50,000** | |
| Geographic Coordinates, Philippine Reference 0f 1992 Datum (PRS 92) | Latitude<br>Longitude<br>Ellipsoidal Height | 7° 4’ 41.48387” North<br>125° 37’ 31.24815” East<br>-4.50700 meters |
| Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92) | Easting<br>Northing | 569,084.935 meters<br>782,663.345 meters |
| Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84) | Latitude<br>Longitude<br>Ellipsoidal Height | 7° 4’ 38.36201” North<br>125° 37’ 36.77094” East<br>68.27510 meters |
| Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992) | Easting<br>Northing | 790,026.11 meters<br>783162.17 meters |

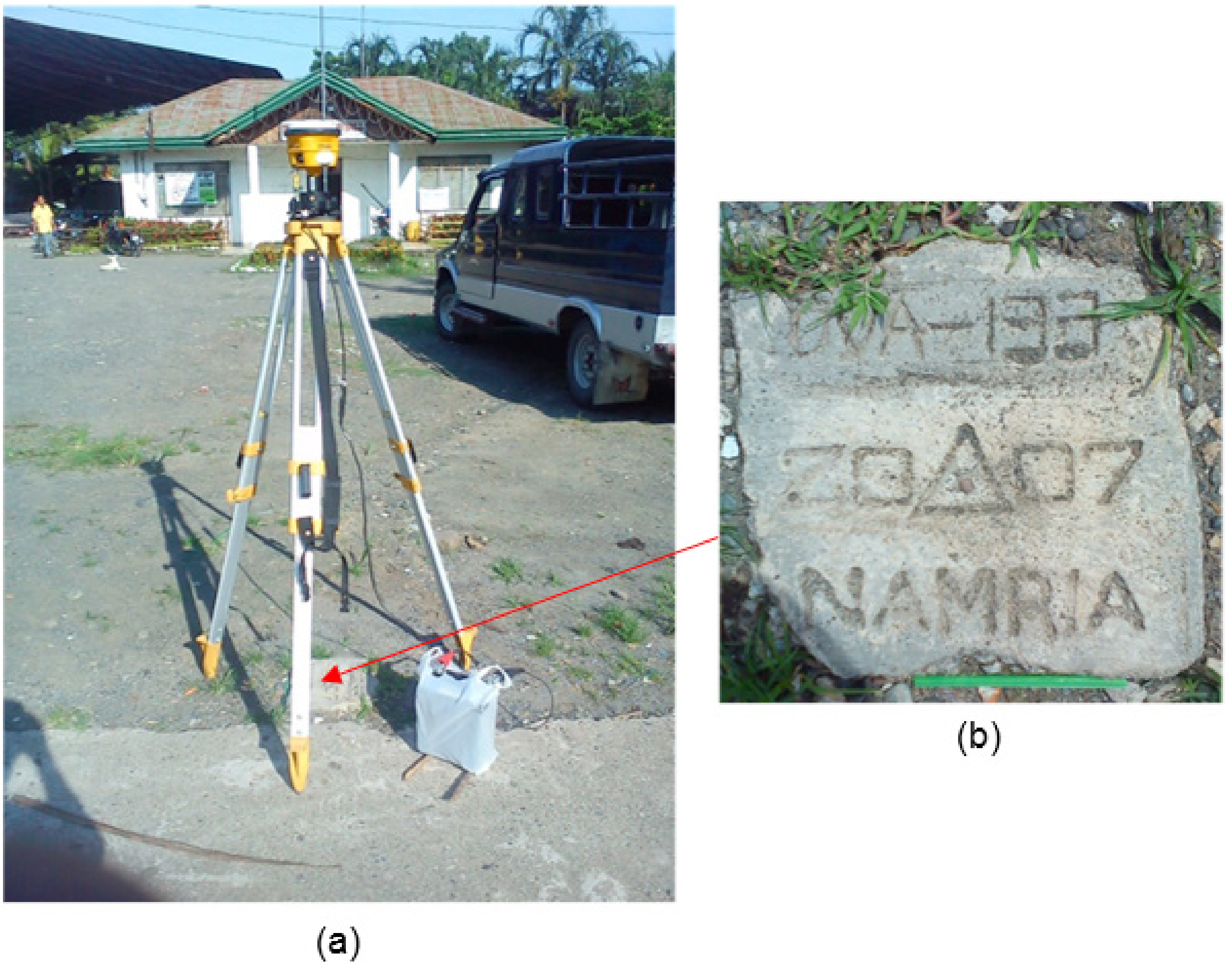



Figure 5. GPS set-up over DVA-133 at Barangay Manay, Panabo in Davao del Norte (a) and NAMRIA reference point DVA-133 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point DVA-133 used as base station for the LiDAR acquisition.

| **Station Name** | **DVA-133** | |
|---|---|---|
| **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° 20' 57.02014" North<br>125° 35' 57.50044" East<br>23.957 meters |
| Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92) | Easting<br>Northing | 566,168.597 meters<br>812,626.211 meters |
| Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84) | Latitude<br>Longitude<br>Ellipsoidal Height | 7° 20' 53.82313" North<br>125° 36' 2.99870" East<br>96.163 meters |
| Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992) | Easting<br>Northing | 786,976.44 meters<br>813,130.63 meters |


(a) (b)

Figure 6. GPS set-up over DVA-3237 at Barangay Nanyo, Panabo in Davao del Norte (a) and NAMRIA reference point DVA-3237 (b) as recovered by the field team.

Table 4. Details of the recovered NAMRIA horizontal control point DVA-133 used as base station for the LiDAR acquisition.

| Station Name | DVA-3237 | |
|---|---|---|
| **Order of Accuracy** | **4th** | |
| **Relative Error (horizontal positioning)** | **1 in 50,000** | |
| Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92) | Latitude<br>Longitude<br>Ellipsoidal Height | 7° 19' 59.93670" North<br>125° 38' 7.27962" East<br>16.912 meters |
| Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92) | Easting<br>Northing | 570,151.447 meters<br>810,878.179 meters |
| Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84) | Latitude<br>Longitude<br>Ellipsoidal Height | 7° 19' 56.74722" North<br>125° 38' 12.77896" East<br>89.238 meters |
| Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 52N PRS 1992) | Easting<br>Northing | 791,135.56 meters<br>811,353.56 meters |

(a)

(b)

Figure 7. GPS set-up over DVS-1A in the town proper of Davao City, Davao del Sur (a) and NAMRIA reference point DVS-1A (b) as recovered by the field team.

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

| Station Name | DVS-1A | |
|---|---|---|
| Order of Accuracy | 2nd (established point) | |
| Relative Error (horizontal positioning) | 1 in 50,000 | |
| Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92) | Latitude<br>Longitude<br>Ellipsoidal Height | 7° 4’ 42.20000” North<br>125° 37’ 32.82000” East<br>-4.50 meters |
| Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92) | Easting<br>Northing | 569,133.093 meters<br>782,685.309 meters |
| Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84) | Latitude<br>Longitude<br>Ellipsoidal Height | 7° 4’ 38.34585” North<br>125° 37’ 36.60874” East<br>68.265 meters |
| Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 52N PRS 1992) | Easting<br>Northing | 790,187.943 meters<br>783,116.18 meters |

Table 6. Ground control points used during the LiDAR data acquisition.

| Date Surveyed | Flight Number | Mission Name | Ground Control Points |
|---|---|---|---|
| July 18, 2014 | 7378GC | 2BLK82A199A | DVS-1, DVS-1A |
| July 23, 2014 | 7388GC | 2BLK82DAB204A | DVS-1, DVS-1A |
| July 29, 2014 | 7401GC | 2BLK87EFGHS210B | DVS-1, DVS-1A |
| August 11, 2014 | 7426GC | 2BLK82V223A | DVA-133, DVA-3237; DVS-1, DVS-1A |
| August 11, 2014 | 7427GC | 2BLK82V223B | DVA-133, DVA-3237; DVS-1, DVS-1A |

## 2.3 Flight Missions

Two (2) missions under DREAM program covered around seventy-six (76) square kilometers (Table 7) within Talomo floodplain. Five (5) missions under Phil-LiDAR program were conducted to complete the LiDAR data acquisition in Talomo floodplain, for a total of fifteen hours and nineteen minutes (15+19) of flying time for RP-C9322. The missions were acquired using the Gemini LiDAR system. Table 8 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 9 presents the actual parameters used during the LiDAR data acquisition.

Table 7. Flight missions under the DREAM Program covering the Talomo Floodplain.

| Flight Number | Mission Name | Area Surveyed within the Floodplain (sq. km.) |
|---|---|---|
| 94P | 1DV017B | 32.36 |
| 115P | 1DV029A | 43.15 |
| TOTAL | | 75.51 |

Table 8. Flight missions for the LiDAR data acquisition in Talomo Floodplain.

| Date Surveyed | Flight Number | Flight Plan Area (km2) | Surveyed Area (km2) | Area Surveyed within the Floodplain (km2) | Area Surveyed Outside the Floodplain (km2) | No. of Images (Frames) | Flying Hours | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Hr | Min |
| July 18, 2014 | 7378GC | 326.51 | 177.79 | 58.49 | 119.3 | NA | 4 | 05 |
| July 23, 2014 | 7388GC | 338.75 | 208.11 | 4.46 | 203.65 | NA | 4 | 05 |
| July 29, 2014 | 7401GC | 534.84 | 83.43 | 0 | 83.43 | NA | 1 | 59 |
| August 11, 2014 | 7426GC | 486.08 | 97.12 | 2.59 | 94.53 | NA | 2 | 41 |
| August 11, 2014 | 7427GC | 326.51 | 48.56 | 0.2 | 48.36 | NA | 2 | 29 |
| **TOTAL** | | **2,012.69** | **615.01** | **65.74** | **549.27** | **NA** | **15** | **19** |

Table 9. Actual parameters used during the LiDAR data acquisition of the Talomo Floodplain.

| Flight Number | Flying Height (m AGL) | Overlap (%) | FOV (θ) | PRF (khz) | Scan Frequency (Hz) | Average Speed (kts) | Average Turn Time (Minutes) |
|---|---|---|---|---|---|---|---|
| 7378GC | 850 | 30 | 50 | 125 | 40 | 130 | 5 |
| 7388GC | 1000 | 30 | 40 | 125 | 50 | 130 | 5 |
| 7401GC | 850 | 30 | 50 | 125 | 40 | 130 | 5 |
| 7426GC | 1000 | 35 | 40 | 125 | 50 | 130 | 5 |
| 7427GC | 1000 | 35 | 40 | 125 | 50 | 130 | 5 |

## 2.4 Survey Coverage

Talomo floodplain is located along the province of Davao del Sur with majority of the floodplain situated within the municipality of Davao City. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 10. The actual coverage of the LiDAR acquisition for Talomo floodplain is presented in Figure 8.

Table 10. List of municipalities and cities surveyed during the Talomo Floodplain LiDAR acquisition.

| Province | Municipality/ City | Area of Municipality/City (km2) | Total Area Surveyed (km2) | Percentage of Area Surveyed |
|---|---|---|---|---|
| Davao del Norte | Panabo City | 301.68 | 114.94 | 38.10% |
| | Braulio E. Dujali | 119.23 | 6.85 | 5.75% |
| Davao del Sur | Davao City | 2,224.82 | 340.16 | 15.29% |
| | Santa Cruz | 267.54 | 11.8 | 4.41% |
| **Total** | | **2913.27** | **473.75** | **16.26%** |

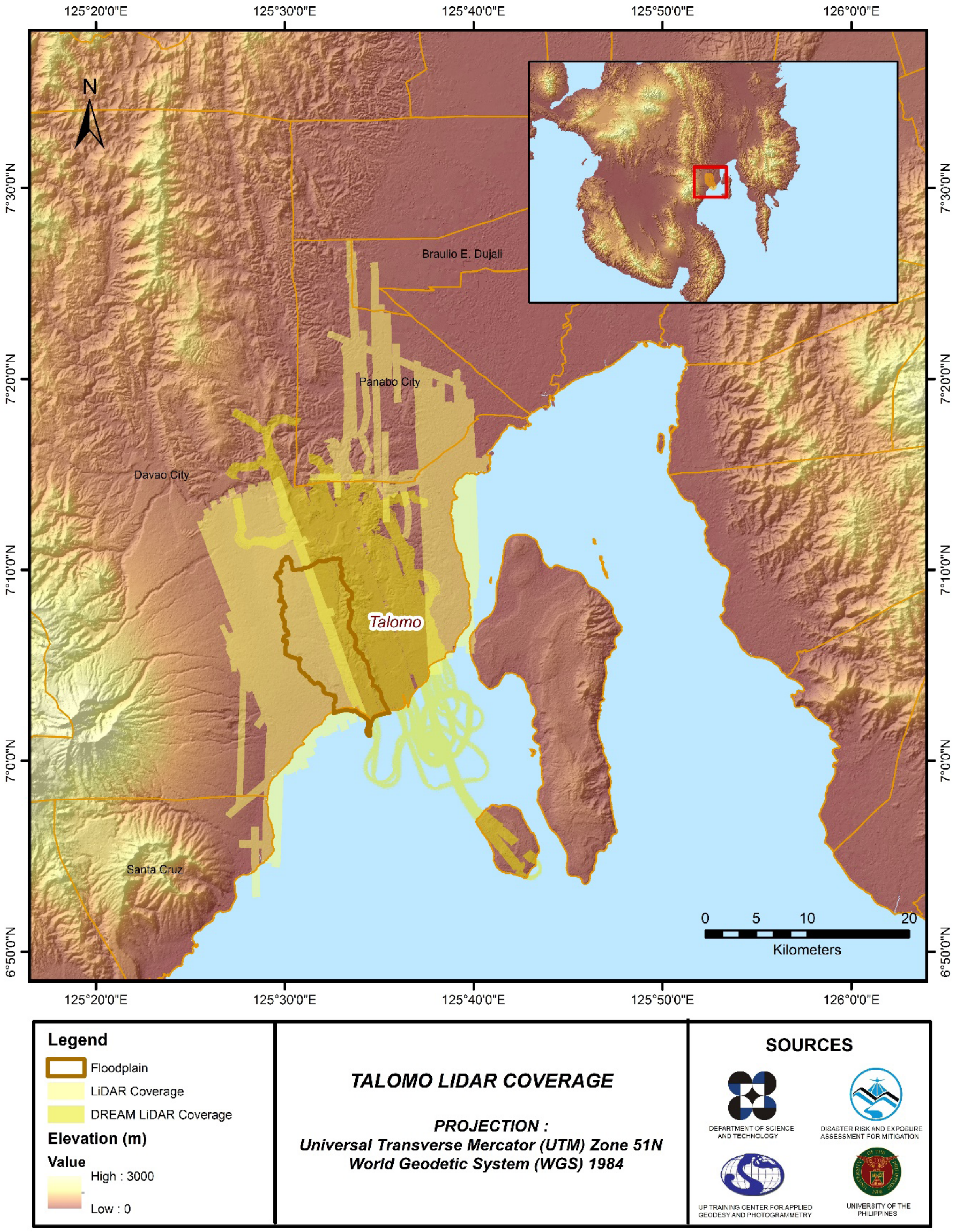



Figure 8. Actual LiDAR survey coverage of the Talomo Floodplain.

# CHAPTER 3: LIDAR DATA PROCESSING OF THE TALOMO FLOODPLAIN

*Engr. Ma. Rosario Concepcion O. Ang, Engr. John Louie D. Fabila, Engr. Sarah Jane D. Samalburo, Engr. Harmond F. Santos , Engr. John Dill P. Macapagal , Engr. Ma. Ailyn L. Olanda, Engr. Merven Mattew D. Natino, Engr. Melissa F. Fernandez , Engr. Ben Joseph J. Harder, Engr. Karl Adrian P. Vergara*

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

## 3.1 Overview of the LiDAR Data Pre-Processing

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

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

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

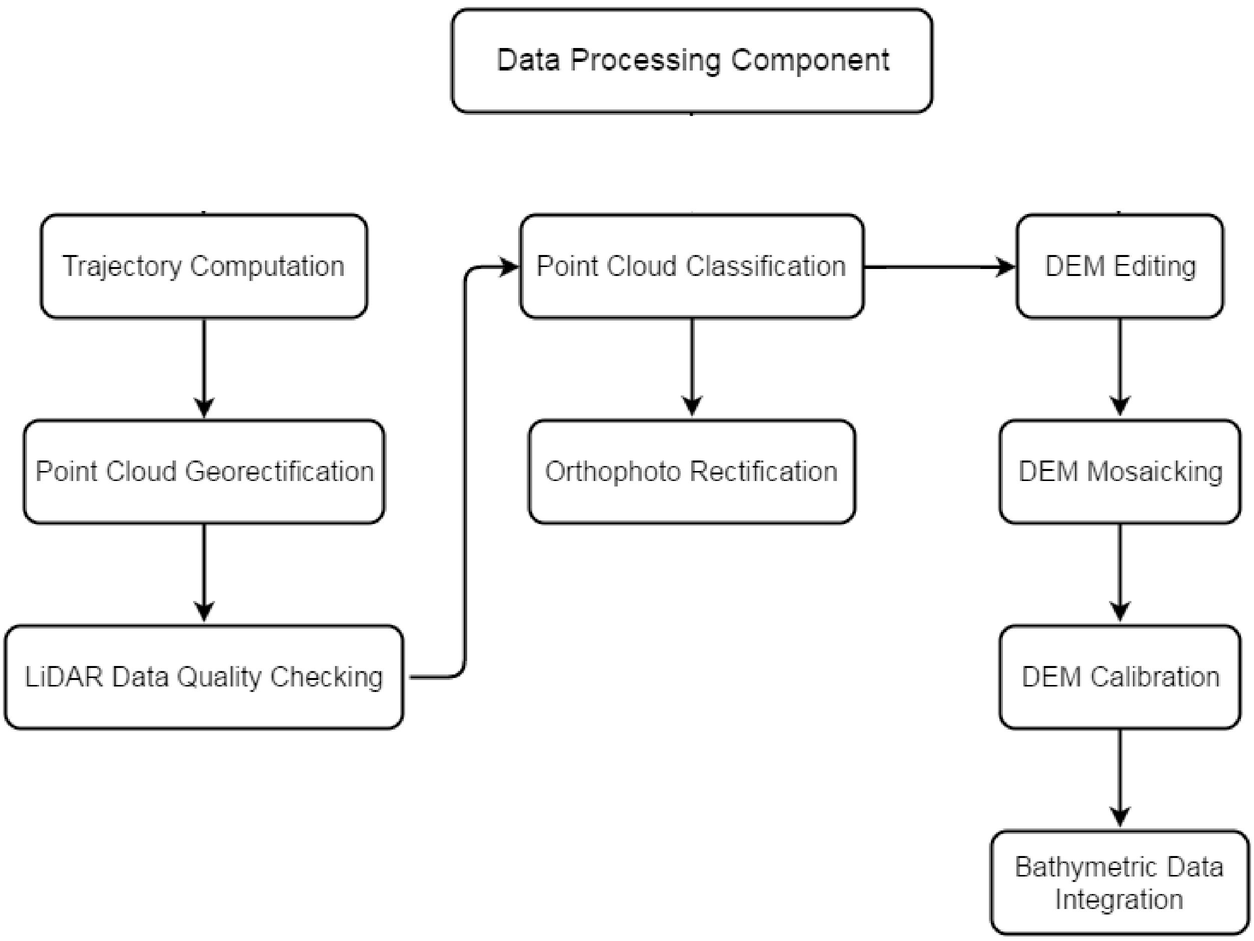



Figure 9. Schematic diagram for Data Pre-Processing Component.

## 3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Talomo floodplain can be found in Annex 5. Missions flown during the first survey conducted on January 2013 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Gemini system while missions acquired during the second survey on August 2014 were flown using the Gemini system over Sta. Rita, Samar.

The Data Acquisition Component (DAC) transferred a total of 136.91 Gigabytes of Range data, 1.37 Gigabytes of POS data, 66.32 Megabytes of GPS base station data, and 126.3 Gigabytes of raw image data to the data server on January 23, 2013 for the first survey and August 2, 2014 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Talomo was fully transferred on August 29, 2014, as indicated on the Data Transfer Sheets for Talomo floodplain.

## 3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 7388GC, one of the Talomo flights, which is the North, East, and Down position RMSE values are shown in Figure 10. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on July 23, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

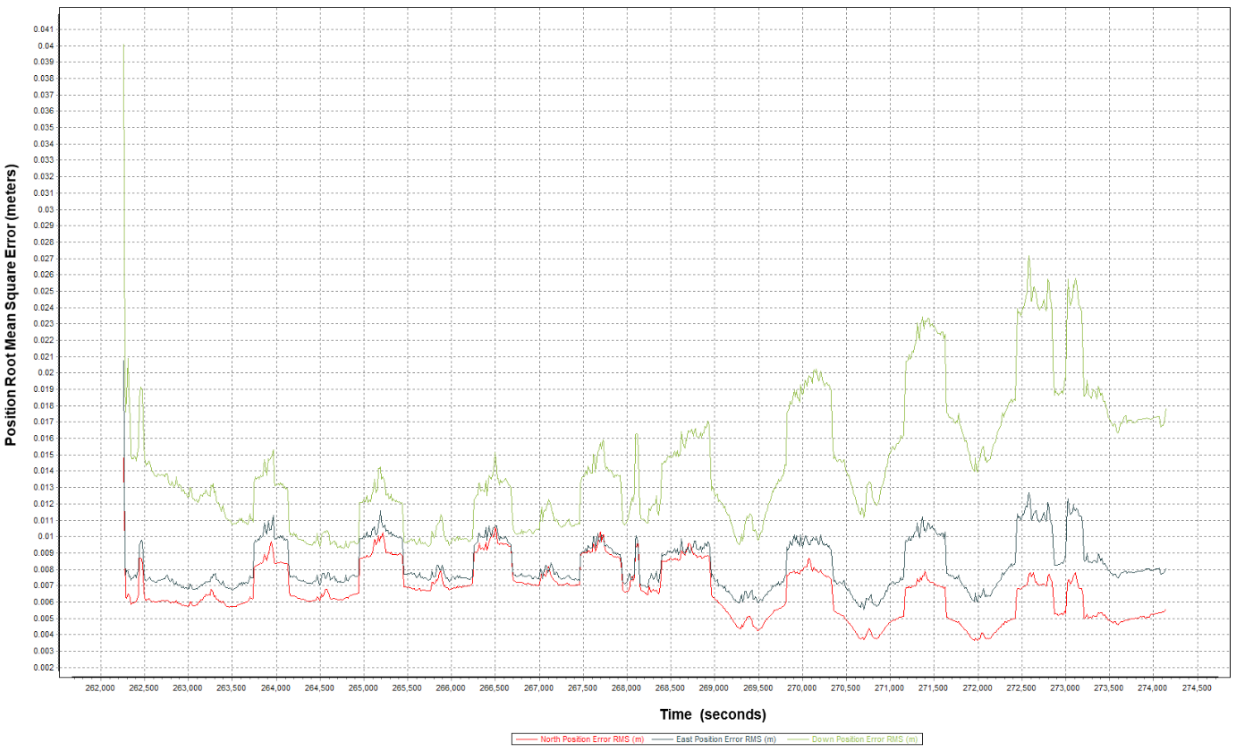



Figure 10. Smoothed Performance Metrics of Talomo Flight 7388GC.

The time of flight was from 262000 seconds to 274500 seconds, which corresponds to morning of July 23, 2014. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft.

Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 11 shows that the North position RMSE peaks at 1.00 centimeters, the East position RMSE peaks at 1.42 centimeters, and the Down position RMSE peaks at 2.2 centimeters, which are within the prescribed accuracies described in the methodology.

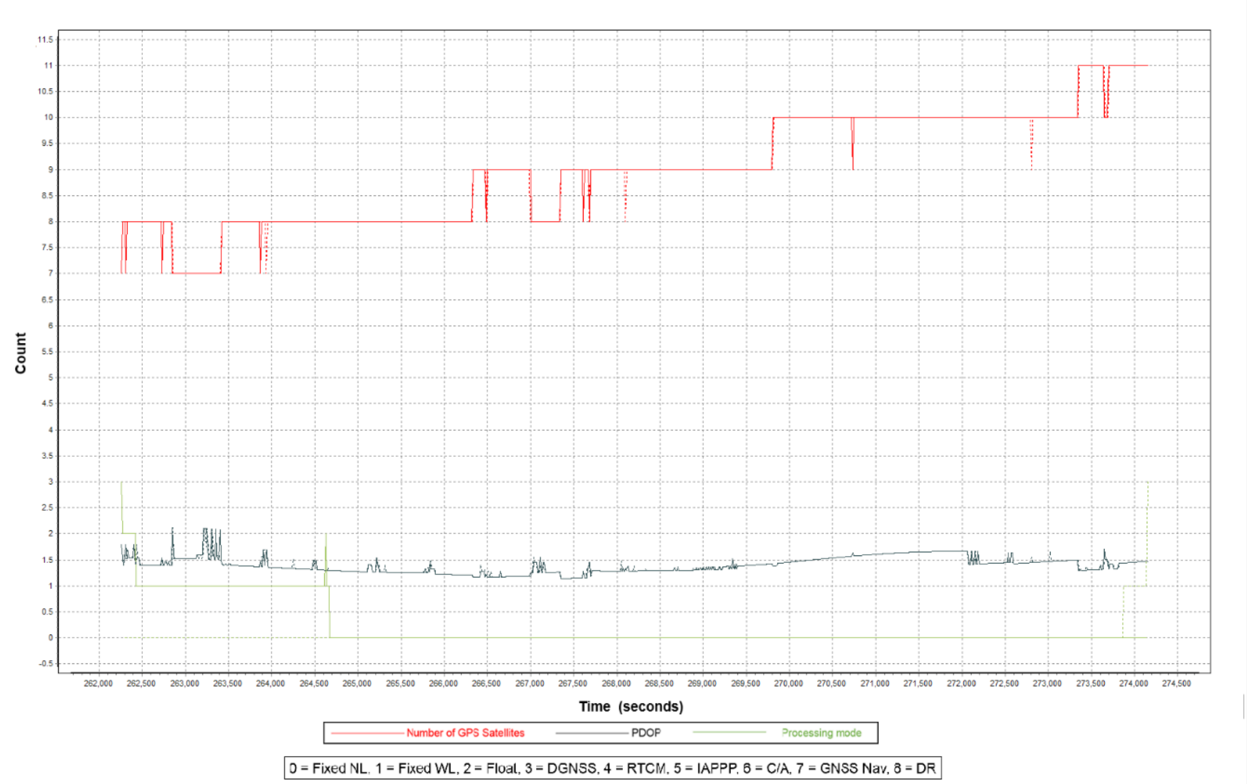



Figure 11. Solution Status Parameters of Talomo Flight 7388GC.

The Solution Status parameters of flight 7388GC, one of the Talomo flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure B-3. The graphs indicate that the number of satellites during the acquisition did not go down to 7. Majority of the time, the number of satellites tracked was between 7 and 11.  The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 1 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Talomo flights is shown in Figure 12.

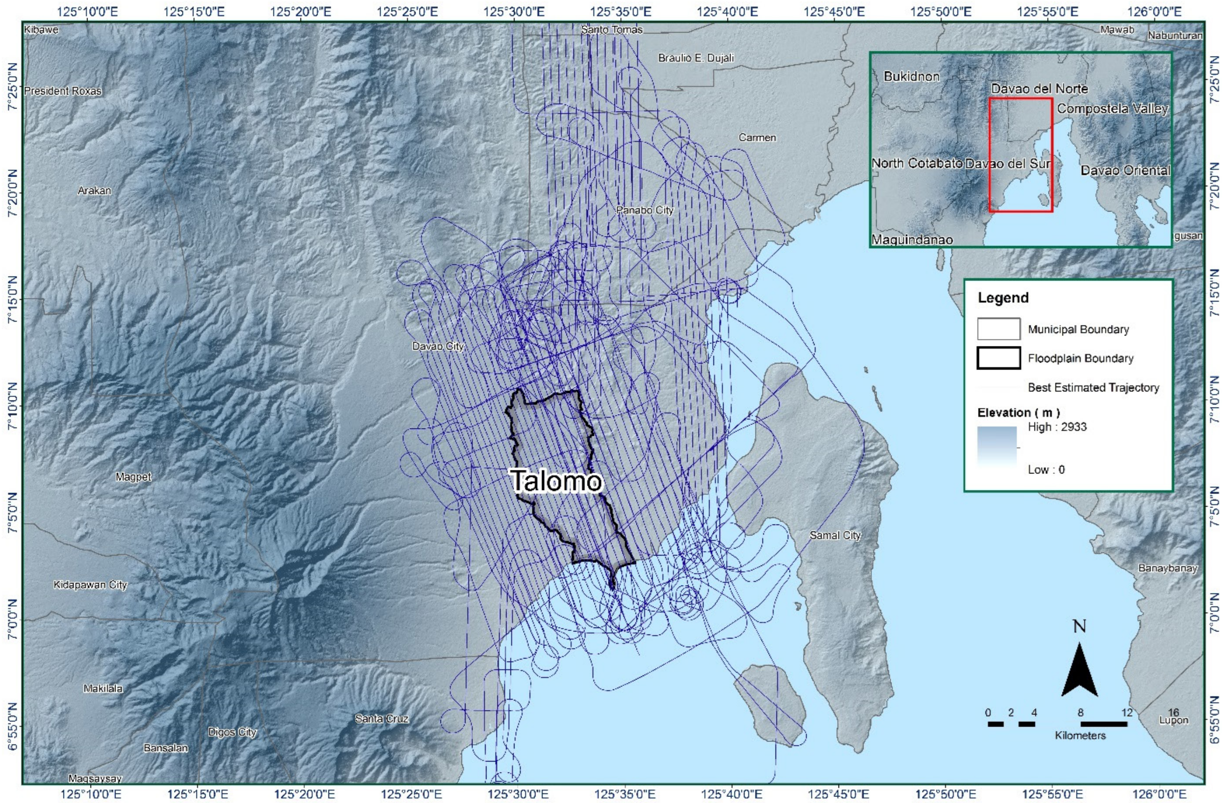



Figure 12. Best Estimated Trajectory of the LiDAR missions conducted over the Talomo Floodplain.

## 3.4 LiDAR Point Cloud Computation

The produced LAS data contains 71 flight lines, , with each flight line containing one channel, since the Gemini and Aquarius systems both contain one channel only. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Talomo floodplain are given in Table 11.

Table 11. Self-calibration Results values for Talomo flights.

| Parameter | Acceptable Value | Computed Value |
|---|---|---|
| Boresight Correction stdev | <0.001degrees | 0.000857 |
| IMU Attitude Correction Roll and Pitch Correction stdev | <0.001degrees | 0.002434 |
| GPS Position Z-correction stdev | <0.01meters | 0.0169 |

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

## 3.5 LiDAR Data Quality Checking

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

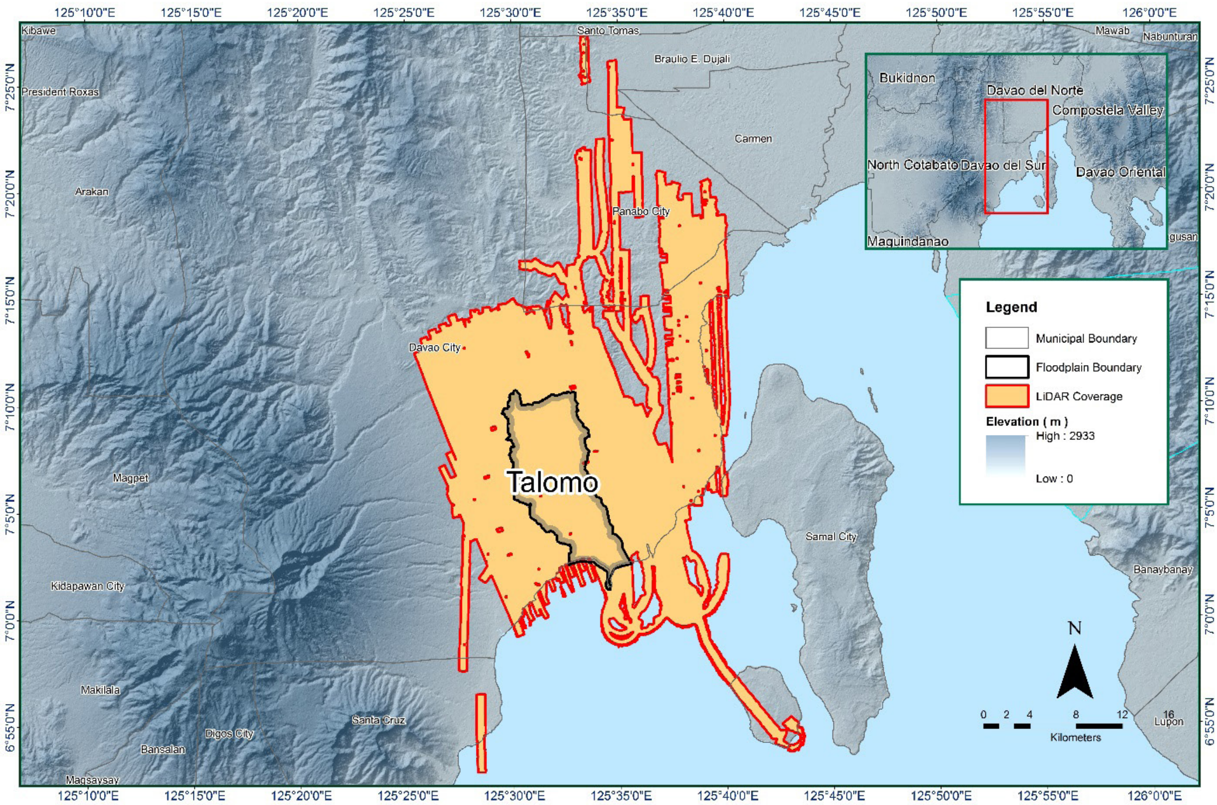



Figure 13. Boundary of the processed LiDAR data over Talomo Floodplain

The total area covered by the Talomo missions is 853.54 sq.km that is comprised of eight (8) flight acquisitions grouped and merged into seven (7) blocks as shown in Table 12.

Table 12. List of LiDAR blocks for Talomo Floodplain.

| LiDAR Blocks | Flight Numbers | Area (sq. km) |
|---|---|---|
| DavaoDelSur_Blk82A | 7378GC | 105.58 |
| DavaoDelSur_Blk82B | 7388GC | 120.5 |
| DavaoDelSur_Blk82_voids | 7426GC | 116.99 |
| | 7427GC | |
| DavaoDelSur_Blk82E | 7388GC | 228.68 |
| | 7401GC | |
| Davao City | 115P | 281.79 |
| | 94P | |
| | 96P | |
| **TOTAL** | | **853.54 sq. km** |

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 14. Since the Gemini and Aquarius systems both employ 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.

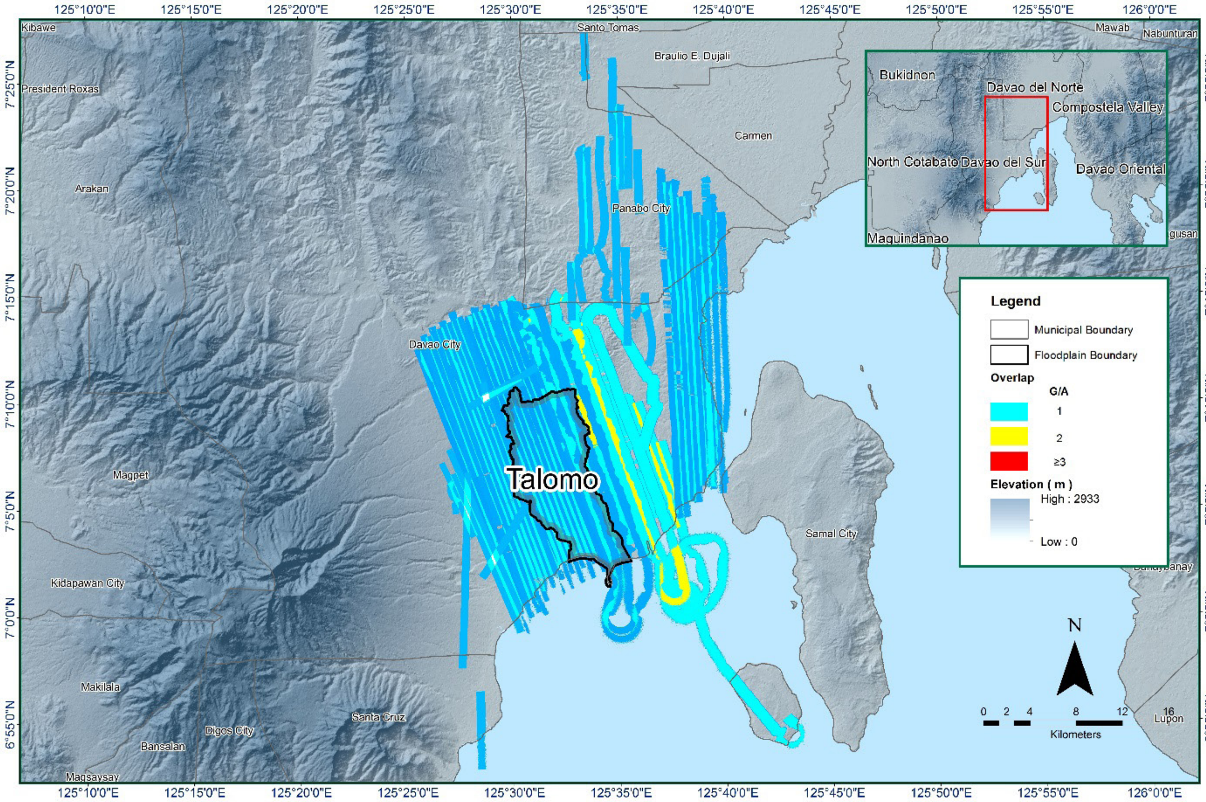



Figure 14. Image of data overlap for Talomo Floodplain.

The overlap statistics per block for the Talomo floodplain can be found in Annex 8: Mission Summary Reports. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 27.93% and 29.34% respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 15. It was determined that all LiDAR data for Talomo floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.86 points per square meter.

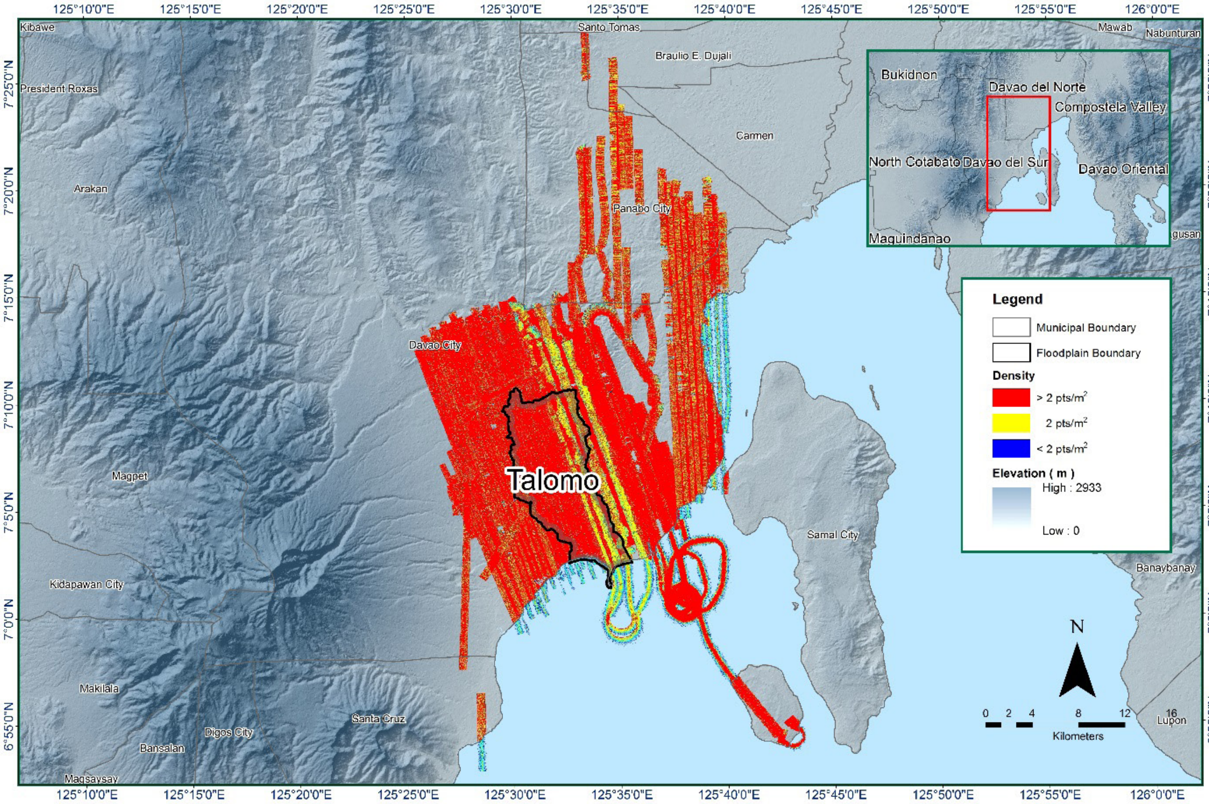



Figure 15. Pulse density map of merged LiDAR data for Talomo Floodplain.

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

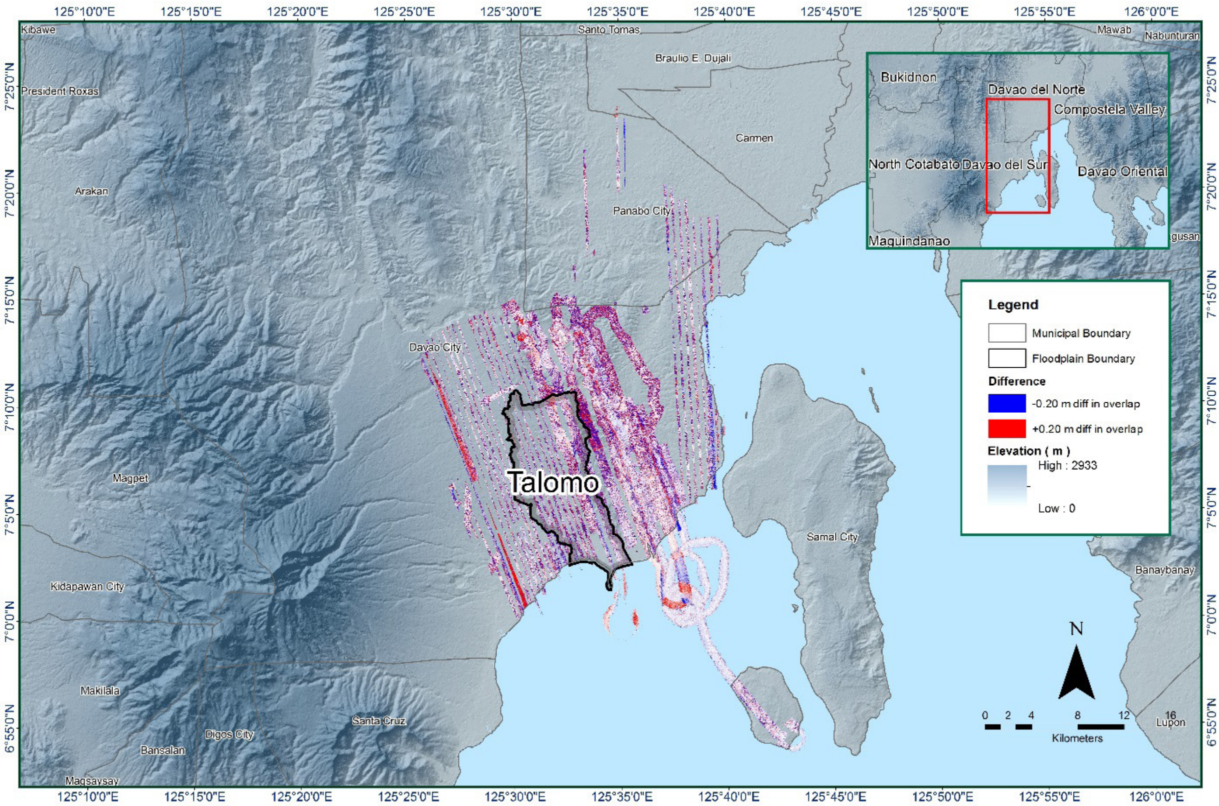



Figure 16. Elevation Difference Map between flight lines for Talomo Floodplain Survey.

A screen capture of the processed LAS data from a Talomo flight 7388GC loaded in QT Modeler is shown in Figure 17. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed yellow line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

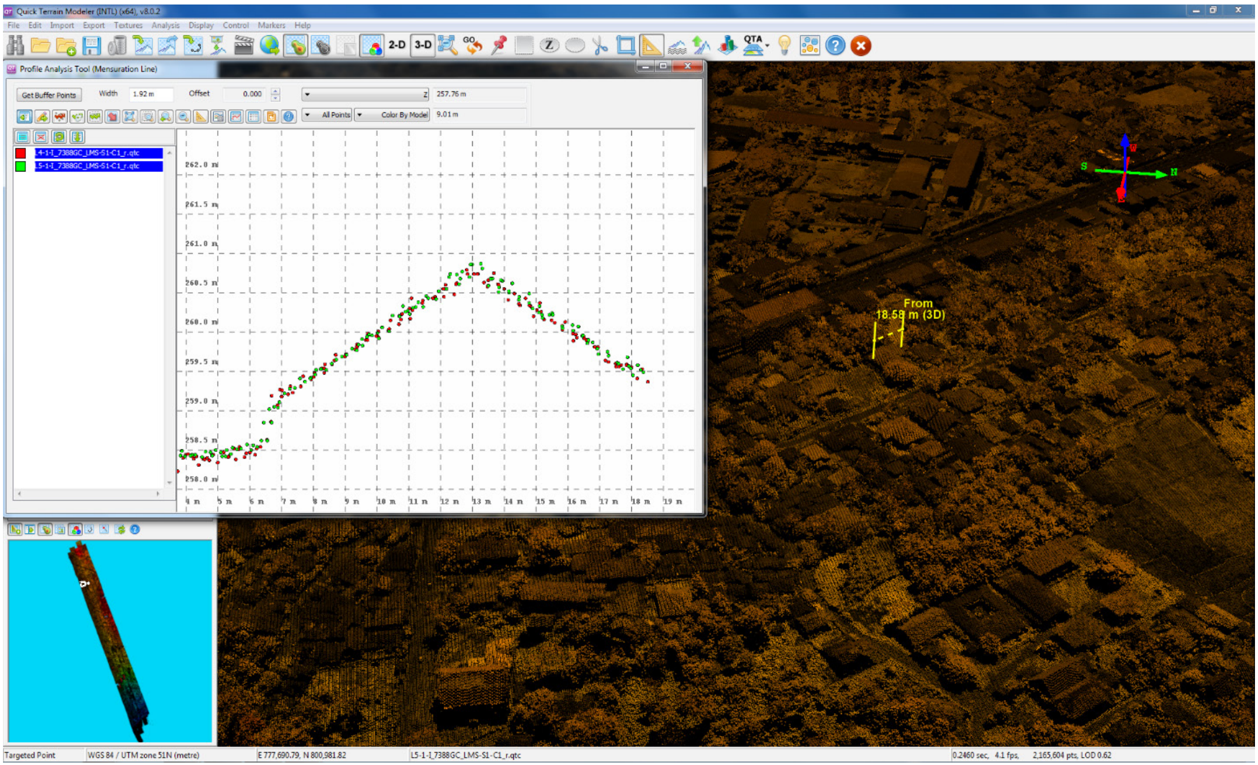


Figure 17. Quality checking for Talomo Flight 7388GC using the Profile Tool of QT Modeler.

## 3.6 LiDAR Point Cloud Classification and Rasterization

Table 13. Talomo classification results in TerraScan

| Pertinent Class | Total Number of Points |
|---|---|
| Ground | 377,651,908 |
| Low Vegetation | 369,217,896 |
| Medium Vegetation | 706,614,815 |
| High Vegetation | 1,135,809,855 |
| Building | 91,351,661 |

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Talomo floodplain is shown in Figure 18. A total of 1,314 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 13. The point cloud has a maximum and minimum height of 883.49 meters and 38.75 meters, respectively.

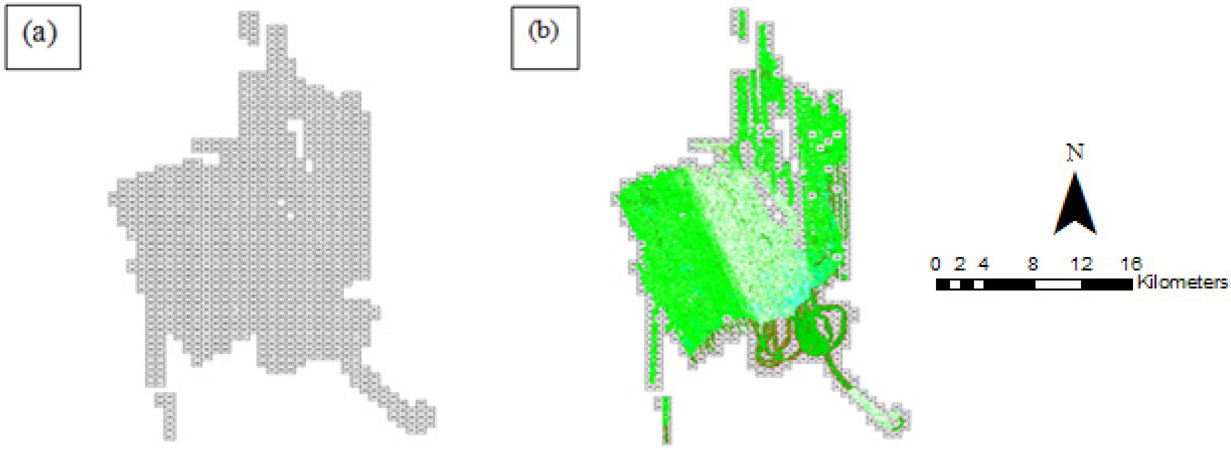



Figure 18. Tiles for Talomo Floodplain (a) and classification results (b) in TerraScan.

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

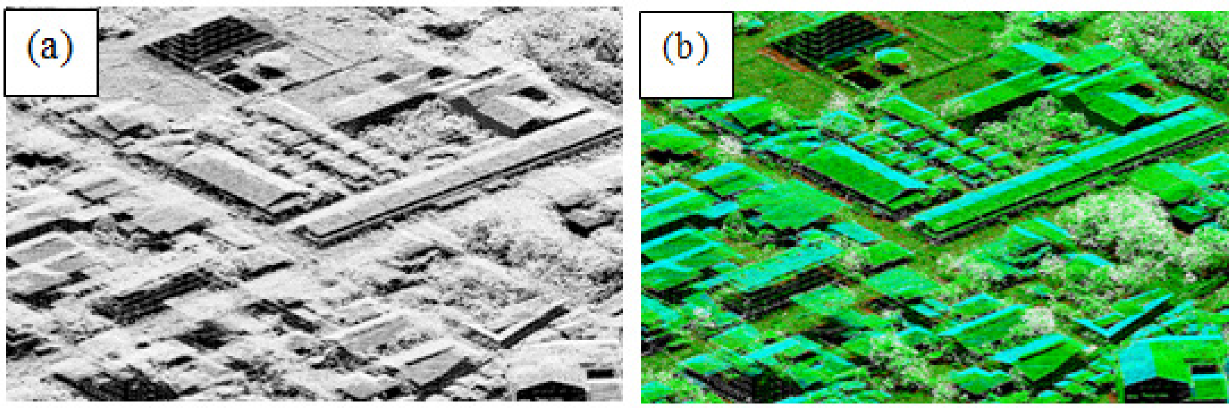



Figure 19. Point cloud before (a) and after (b) classification

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

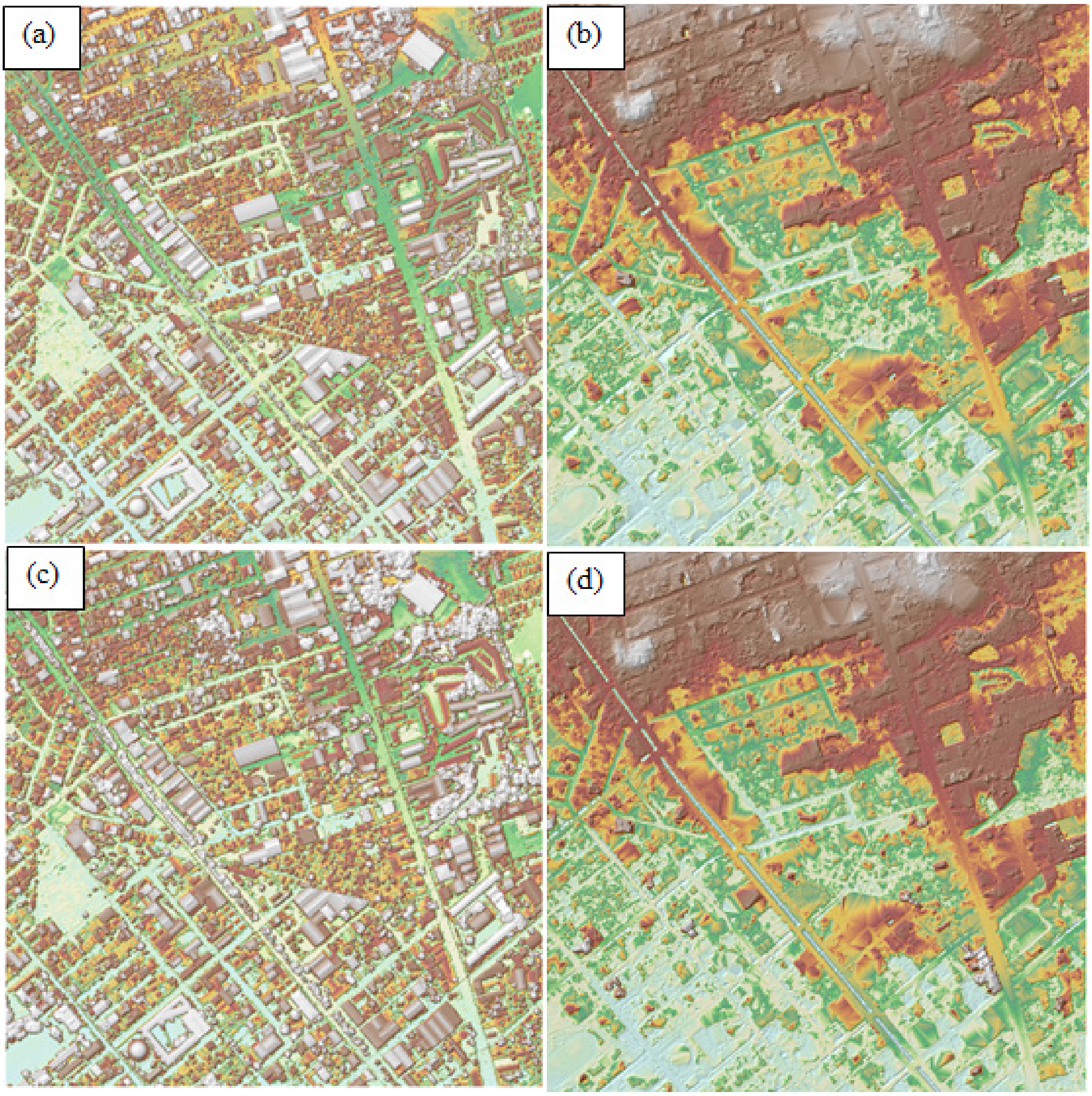



Figure 20. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Talomo Floodplain.

## 3.7 LiDAR Image Processing and Orthophotograph Rectification

The 321 1km by 1km tiles area covered by Talomo floodplain is shown in Figure 21. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Talomo floodplain has a total of 216.47 sq.km orthophotogaph coverage comprised of 1,544 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 22.

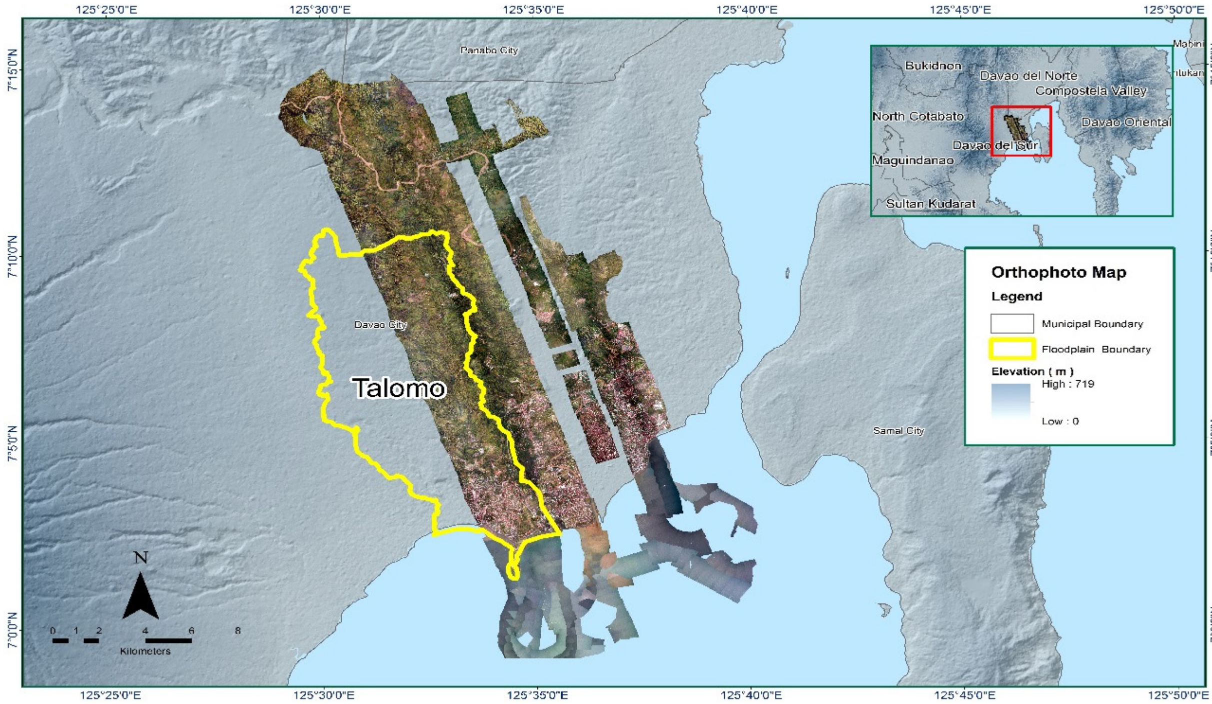



Figure 21. Talomo Floodplain with available orthophotographs

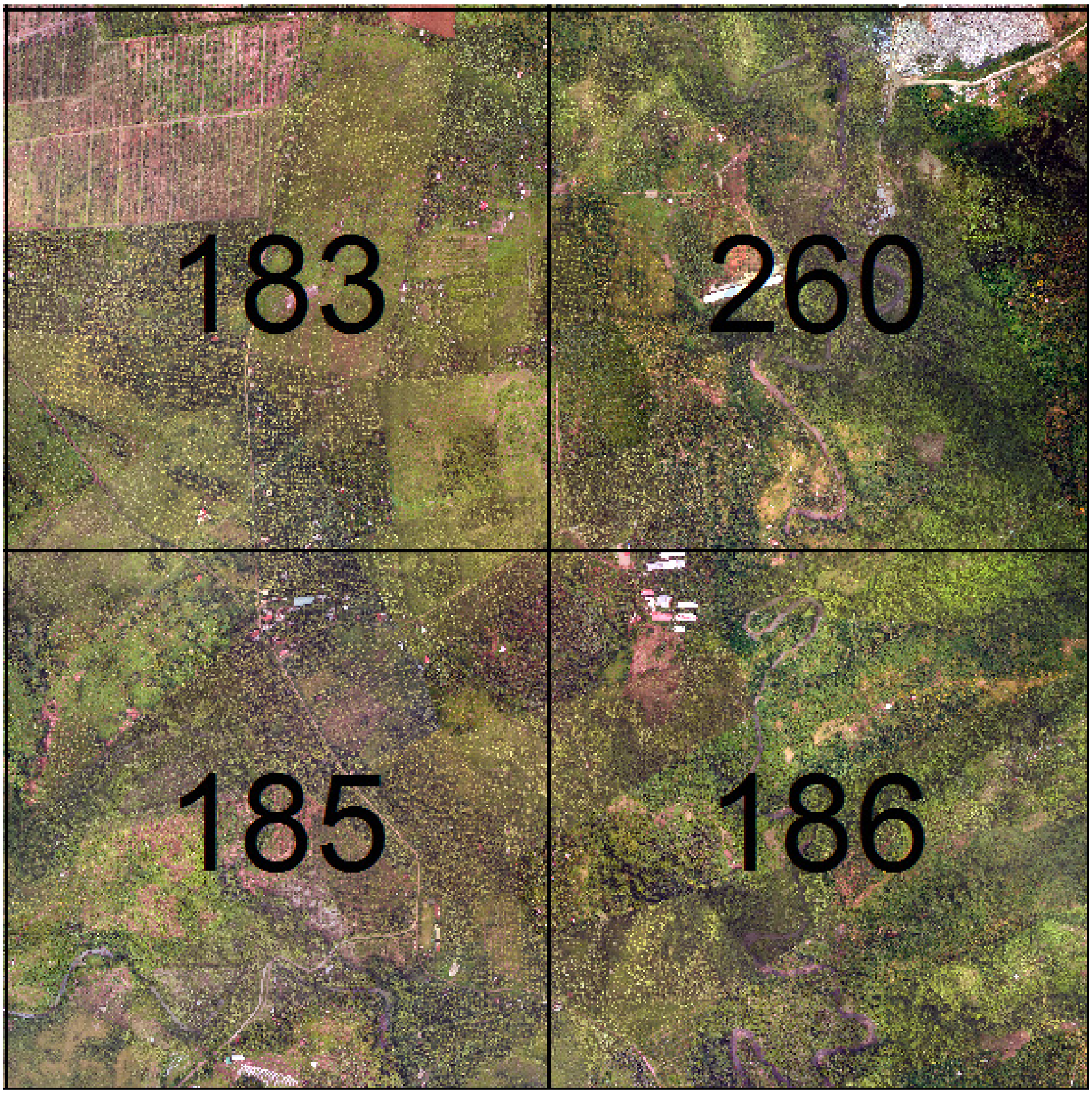



Figure 22. Sample orthophotograph tiles for Talomo Floodplain.

## 3.8 DEM Editing and Hydro-Correction

Seven (7) mission blocks were processed for Talomo flood plain. These blocks are composed of Davao City and DavaoDelSur blocks with a total area of 853.54 square kilometers. Table 14 shows the name and corresponding area of each block in square kilometers.

Table 14. LiDAR blocks with its corresponding areas.

| LiDAR Blocks | Area (sq.km) |
|---|---|
| DavaoDelSur_Blk82A | 105.58 |
| DavaoDelSur_Blk82B | 120.5 |
| DavaoDelSur_Blk82_voids | 116.99 |
| DavaoDelSur_Blk82E | 228.68 |
| Davao City_115P | 228.68 |
| Davao City_94P | |
| Davao City_96P | |
| **TOTAL** | **853.54 sq. km** |

Portions of DTM before and after manual editing are shown in Figure 23. The bridge (Figure 23a) is also considered to be an impedance to the flow of water along the river and has to be removed (Figure 23b) in order to hydrologically correct the river. Another example is a building that is still present in the DTM after classification (Figure 23c) and has to be removed through manual editing (Figure 23d).

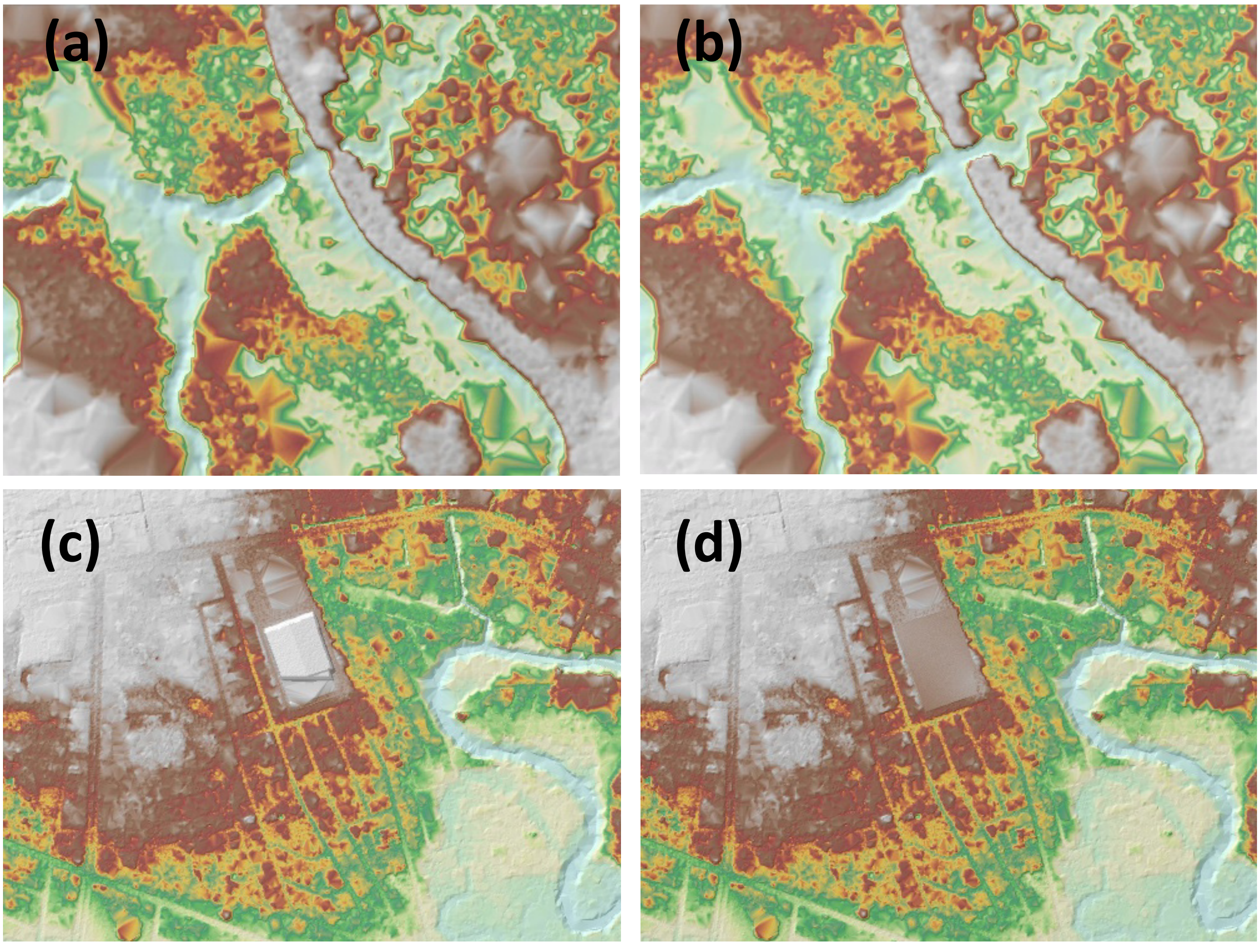



Figure 23. Portions in the DTM of Talomo Floodplain – a bridge before (a) and after (b) manual editing; and a building before (c) and after (d) manual editing

## 3.9 Mosaicking of Blocks

DavaoDelSur_Blk82A was used as the reference block at the start of mosaicking because it was referred to a base station with an acceptable order of accuracy. Table 15 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Talomo floodplain is shown in Figure 24. It can be seen that the entire Talomo floodplain is 99.8% covered by LiDAR data.

Table 15. Shift values of each LiDAR block of Talomo Floodplain.

| Mission Blocks | Shift Values (meters) | | |
|---|---|---|---|
| | x | y | z |
| DavaoDelSur_Blk82A | 0.00 | 0.00 | 0.00 |
| DavaoDelSur_Blk82B | 0.00 | 0.00 | -0.63 |
| DavaoDelSur_Blk82_voids | 0.50 | 0.50 | 0.00 |
| DavaoDelSur_Blk82E | 0.00 | 0.00 | 0.00 |
| Davao City_115P | 0.00 | 0.00 | 0.00 |
| Davao City_94P | 0.00 | 0.00 | 0.00 |
| Davao City_96P | 0.00 | 0.00 | 0.00 |

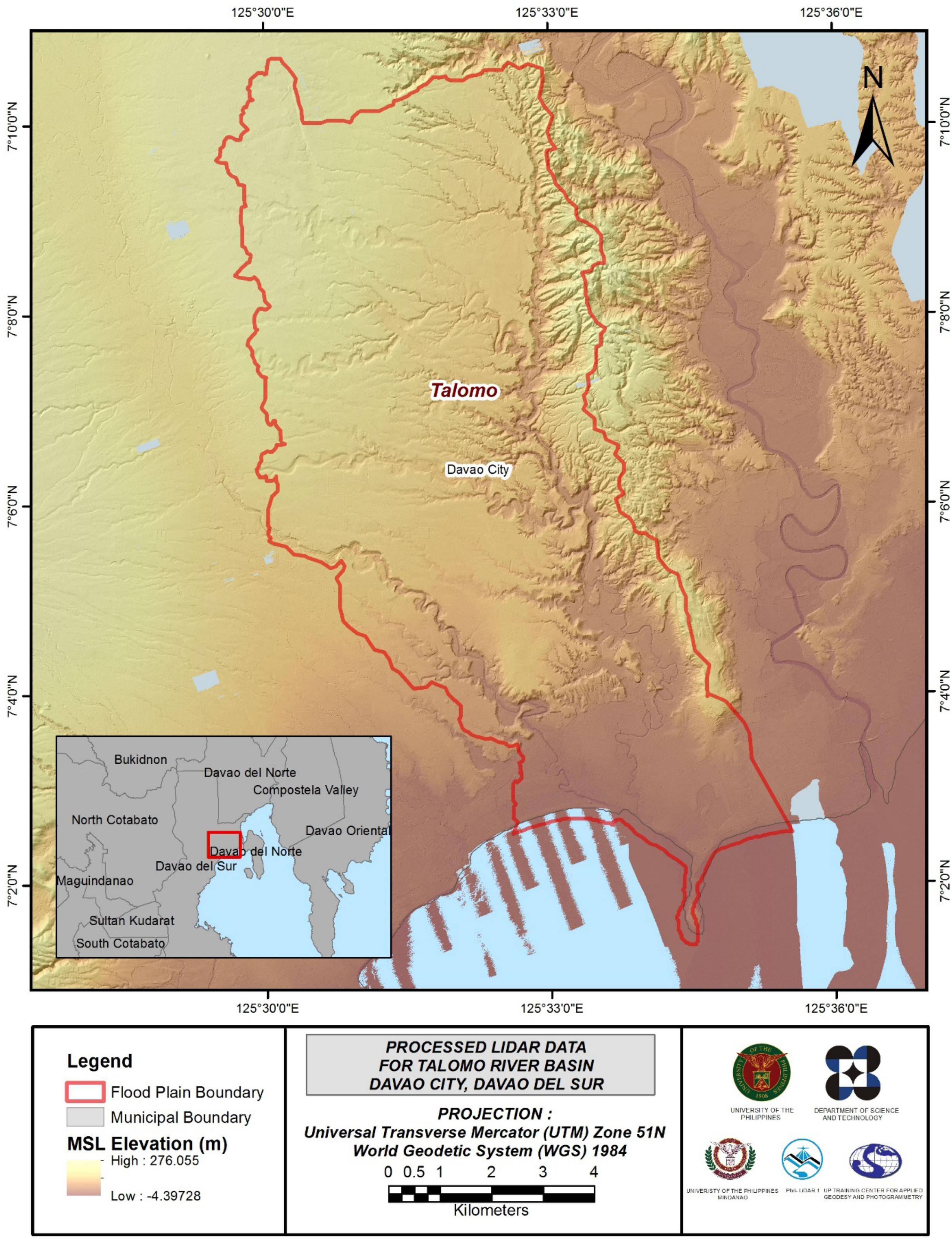



Figure 24. Map of Processed LiDAR Data for Talomo Floodplain

## 3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model (DEM)

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Talomo to collect points with which the LiDAR dataset is validated is shown in Figure 25. A total of 2,364 survey points were used for calibration and validation of Talomo LiDAR data. Random selection of 80% of the survey points, resulting to 1,891 points, were used for calibration.

A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure 26. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration elevation values is 1.81 meters with a standard deviation of 0.15 meters. Calibration of Talomo LiDAR data was done by adding the height difference value, 1.81 meters, to Talomo mosaicked LiDAR data. Table 16 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

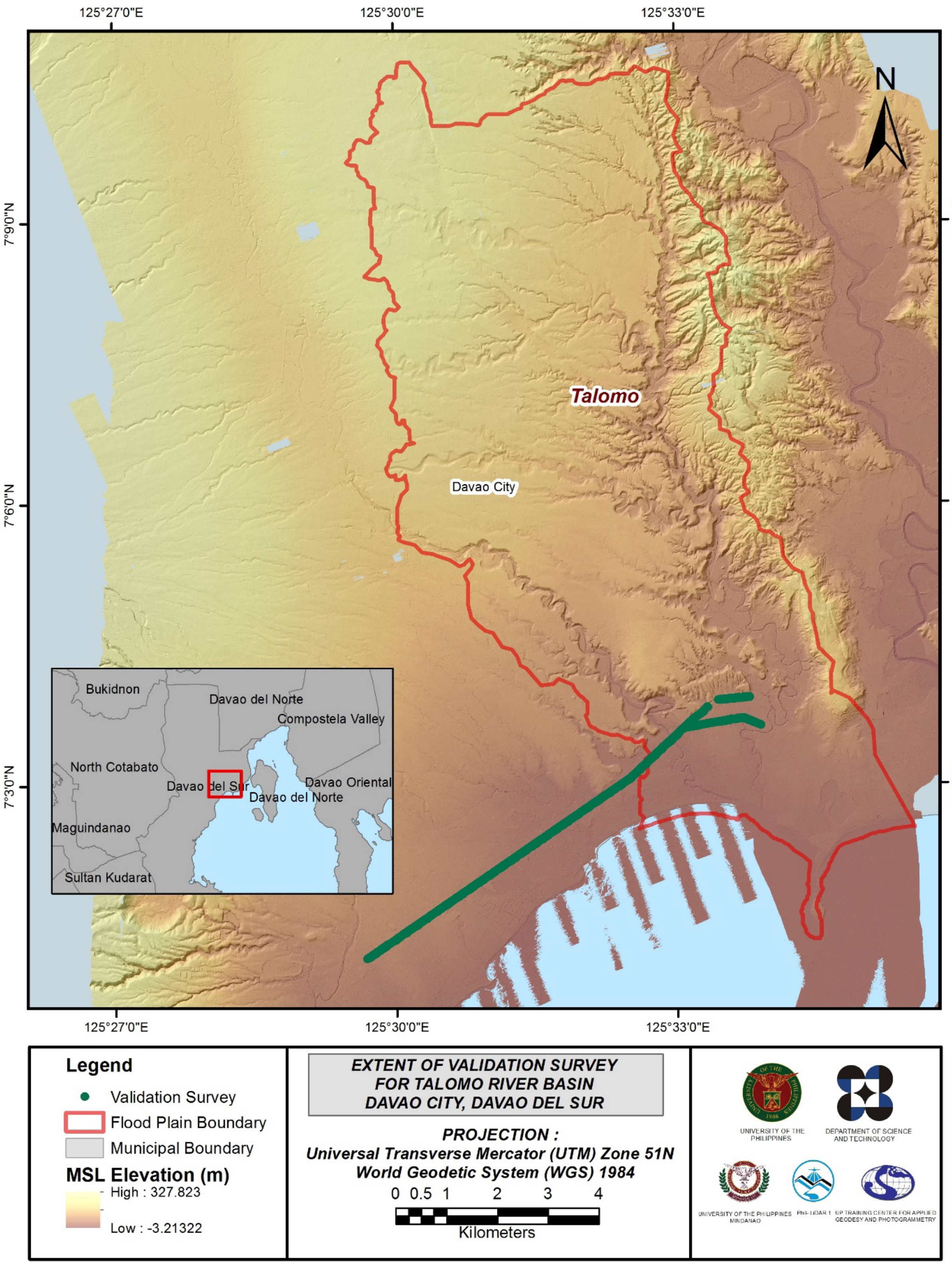



Figure 25. Map of Talomo Floodplain with validation survey points in green.

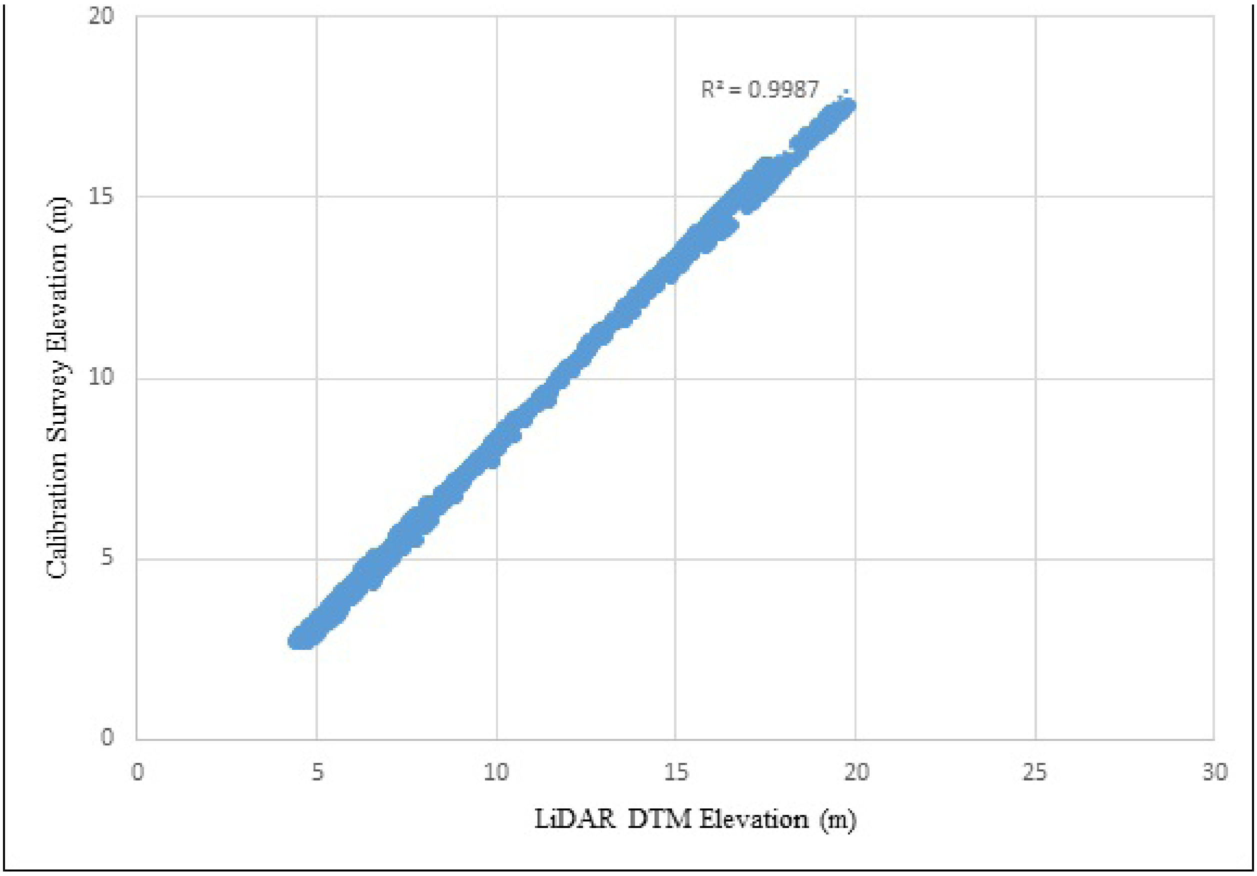



Figure 26. Correlation plot between calibration survey points and LiDAR data.

Table 16. Calibration Statistical Measures

| Calibration Statistical Measures | Value (meters) |
|---|---|
| Height Difference | 1.81 |
| Standard Deviation | 0.15 |
| Average | 1.80 |
| Minimum | 1.50 |
| Maximum | 2.11 |

The remaining 20% of the total survey points, resulting to 472 points, were used for the validation of calibrated Talomo DTM. A good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM is shown in Figure 27. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.17 meters with a standard deviation of 0.17 meters, as shown in Table 17.

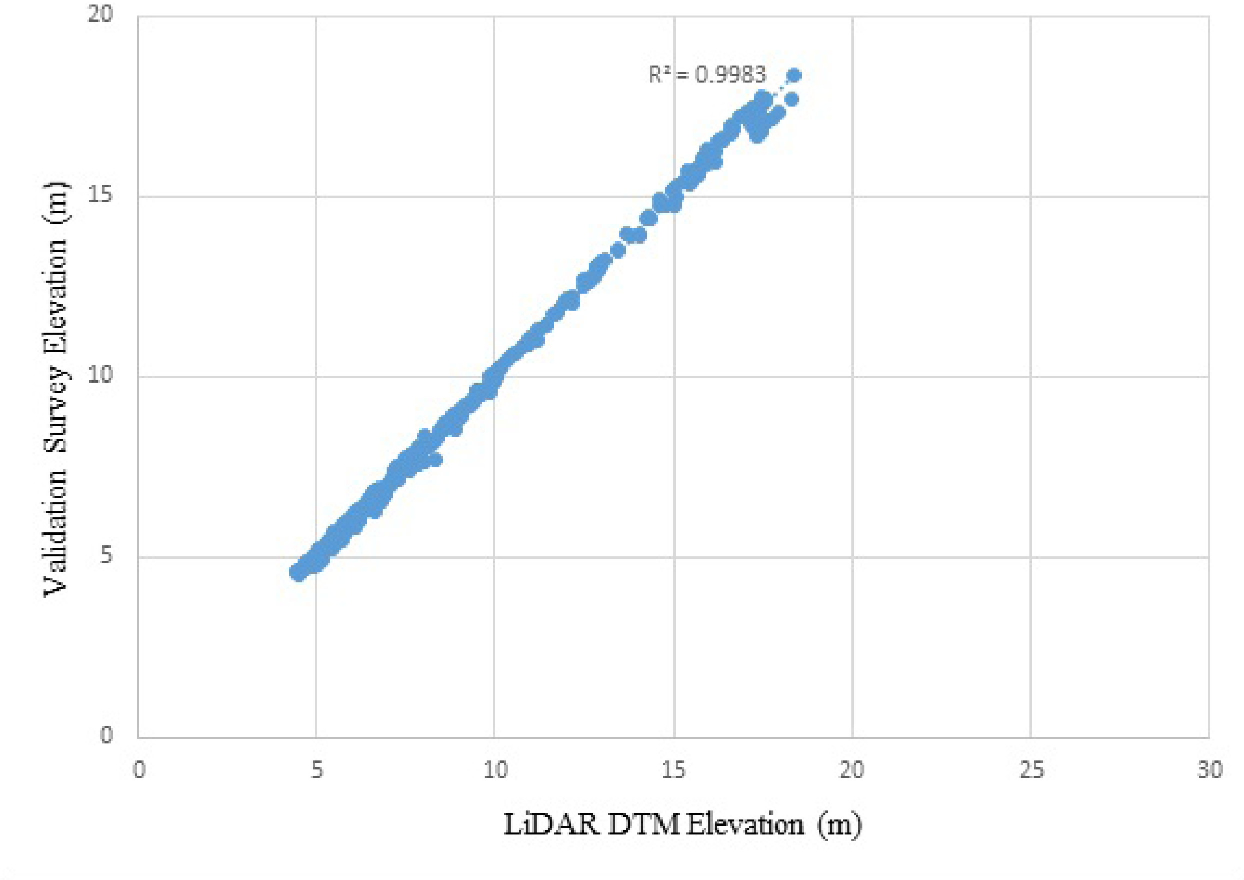



Figure 27. Correlation plot between validation survey points and LiDAR data.

Table 17. Validation Statistical Measures

| Validation Statistical Measures | Value (meters) |
|---|---|
| RMSE | 0.17 |
| Standard Deviation | 0.17 |
| Average | 0.00 |
| Minimum | -0.35 |
| Maximum | 0.34 |

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

For bathy integration, only centerline and cross-section data were available for Talomo with 716 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 0.11 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Talomo integrated with the processed LiDAR DEM is shown in Figure 28.

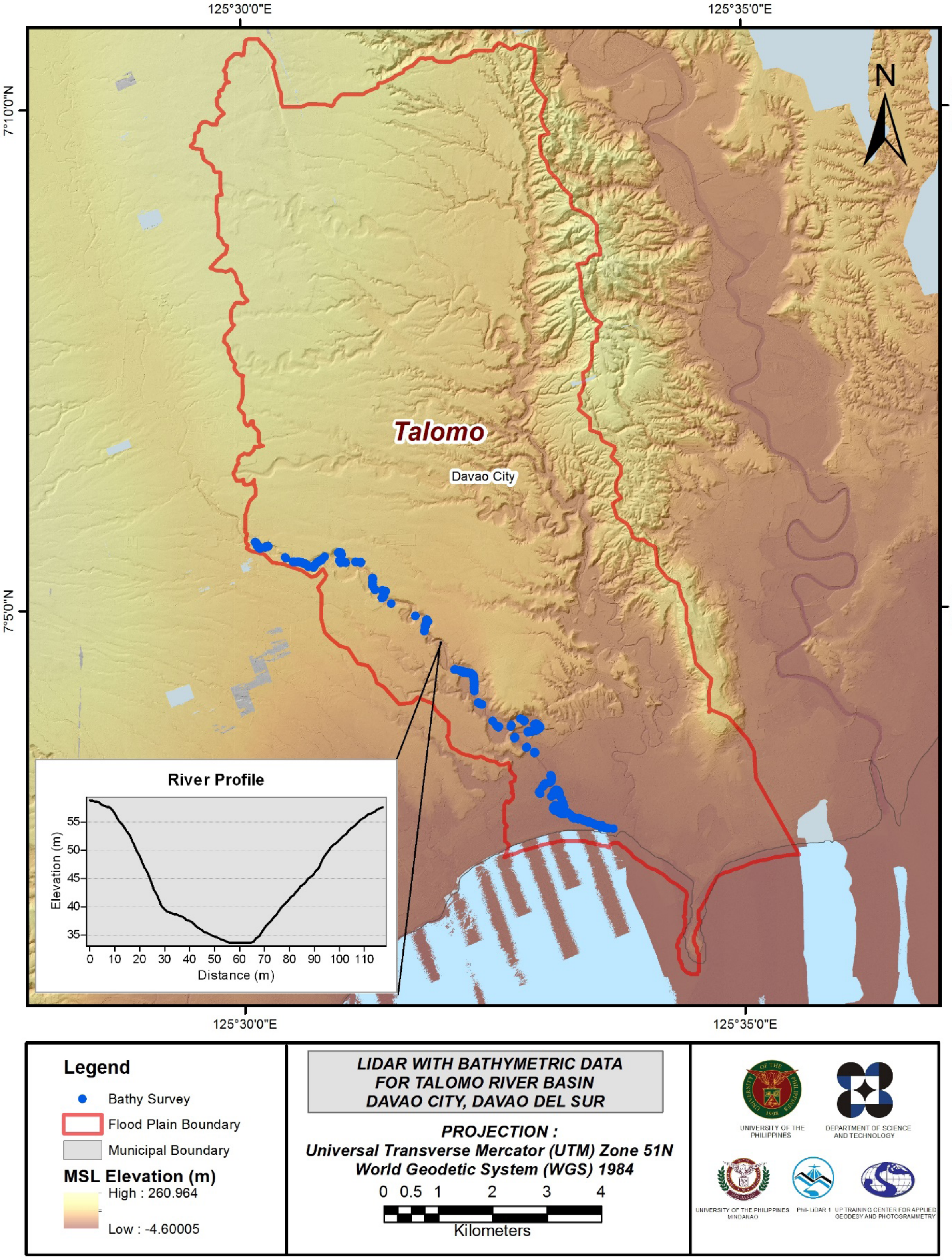



Figure 28. Map of Talomo Floodplain with bathymetric survey points shown in blue.

## 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

Talomo floodplain, including its 200 m buffer, has a total area of 102.10 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 4207 building features, are considered for QC. Figure 29 shows the QC blocks for Talomo floodplain.

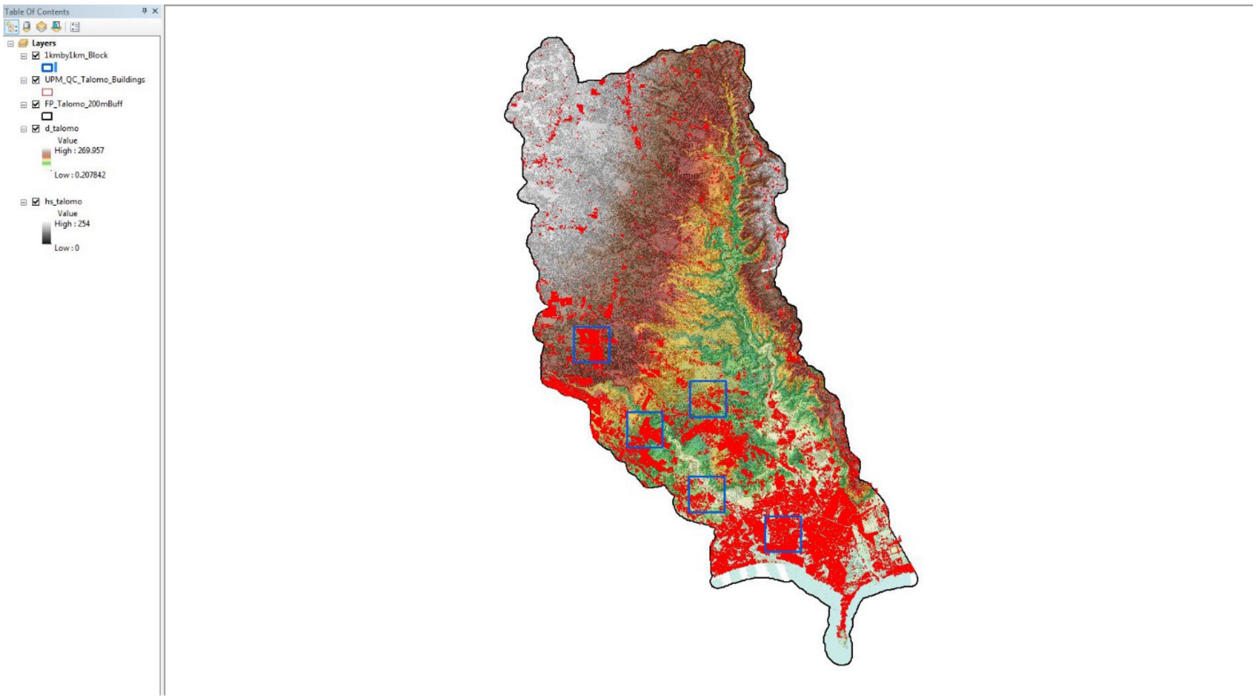



Figure 29. Blocks (in blue) of Talomo building features subjected to QC

Quality checking of Talomo building features resulted in the ratings shown in Table 18.

Table 18. Quality Checking Ratings for Talomo Building Features

| FLOODPLAIN | COMPLETENESS | CORRECTNESS | QUALITY | REMARKS |
|---|---|---|---|---|
| Talomo | 99.74 | 100.00 | 96.60 | PASSED |

### 3.12.2 Height Extraction

Height extraction was done for 53,621 building features in Talomo floodplain. Of these building features, 12,859 were filtered out after height extraction, resulting to 40,762 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 17.10m.

### 3.12.3 Feature Attribution

Field validation for Talomo floodplain has already been completed last November 13-25, 2015. However, in November of the same year, there were changes in the Feature Extraction Manual given by UP Diliman Data Pre-Processing Component, which then prompted for the conduct of the another field work on September 5-22, 2016 for the digitized features in the additional area scope.

Before the actual field validation, courtesy calls were conducted to seek permission and assistance from the Local Government Units of each barangay. This was done to ensure the safety and security in the area for the field validation process to go smoothly. Verification of barangay boundaries was also done to finalize the distribution of features for each barangay.

Barangay Health Workers (BHWs) were requested and hired to guide the University of the Philippines Mindanao Phil-LiDAR1 field enumerators during validation. The local hires deployed by the barangay captains were given a brief orientation by the field enumerators before the actual field work. The team surveyed the twenty-one (21) barangays covered by the floodplain namely New Carmen, New Valencia, Biao Escuela, Matina Biao, Langub, Tacunan, Catalunan Grande, Matina Pangi, Ma-a, Matina Crossing, Matina Aplaya, Bucana, Talomo Proper, Catalunan Pequeno, Biao Guianga, Biao Joacquin, Ula, Talandang, and some parts of Mintal, Tugbok, and Sto. Nino, Davao City.

Table 19 summarizes the number of building features per type. On the other hand, Table 20 shows the total length of each road type, while Table 21 shows the number of water features extracted per type.

Table 19. Building Features Extracted for Talomo Floodplain.

| Facility Type | No. of Features |
|---|---|
| Residential | 38,099 |
| School | 448 |
| Market | 43 |
| Agricultural/Agro-Industrial Facilities | 245 |
| Medical Institutions | 52 |
| Barangay Hall | 10 |
| Military Institution | 0 |
| Sports Center/Gymnasium/Covered Court | 66 |
| Telecommunication Facilities | 17 |
| Transport Terminal | 20 |
| Warehouse | 50 |
| Power Plant/Substation | 8 |
| NGO/CSO Offices | 31 |
| Police Station | 6 |
| Water Supply/Sewerage | 4 |
| Religious Institutions | 359 |
| Bank | 18 |
| Factory | 44 |
| Gas Station | 48 |
| Fire Station | 1 |
| Other Government Offices | 57 |
| Other Commercial Establishments | 1,136 |
| **Total** | **40,762** |

Table 20. Total Length of Extracted Roads for Talomo Floodplain.

| Floodplain | Road Network Length (km) | | | | | Total |
|---|---|---|---|---|---|---|
| | Barangay Road | City/Municipal Road | Provincial Road | National Road | Others | |
| Talomo | 409.62 | 54.35 | 0.00 | 55.33 | 0.00 | 519.29 |

Table 21. Number of Extracted Water Bodies for Talomo Floodplain.

| Floodplain | Water Body Type | | | | | Total |
|---|---|---|---|---|---|---|
| | Rivers/Streams | Lakes/Ponds | Sea | Dam | Fish Pen | |
| Talomo | 2 | 1 | 0 | 0 | 0 | 3 |

A total of 13 bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

## 3.12.4 Final Quality Checking of Extracted Features

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

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

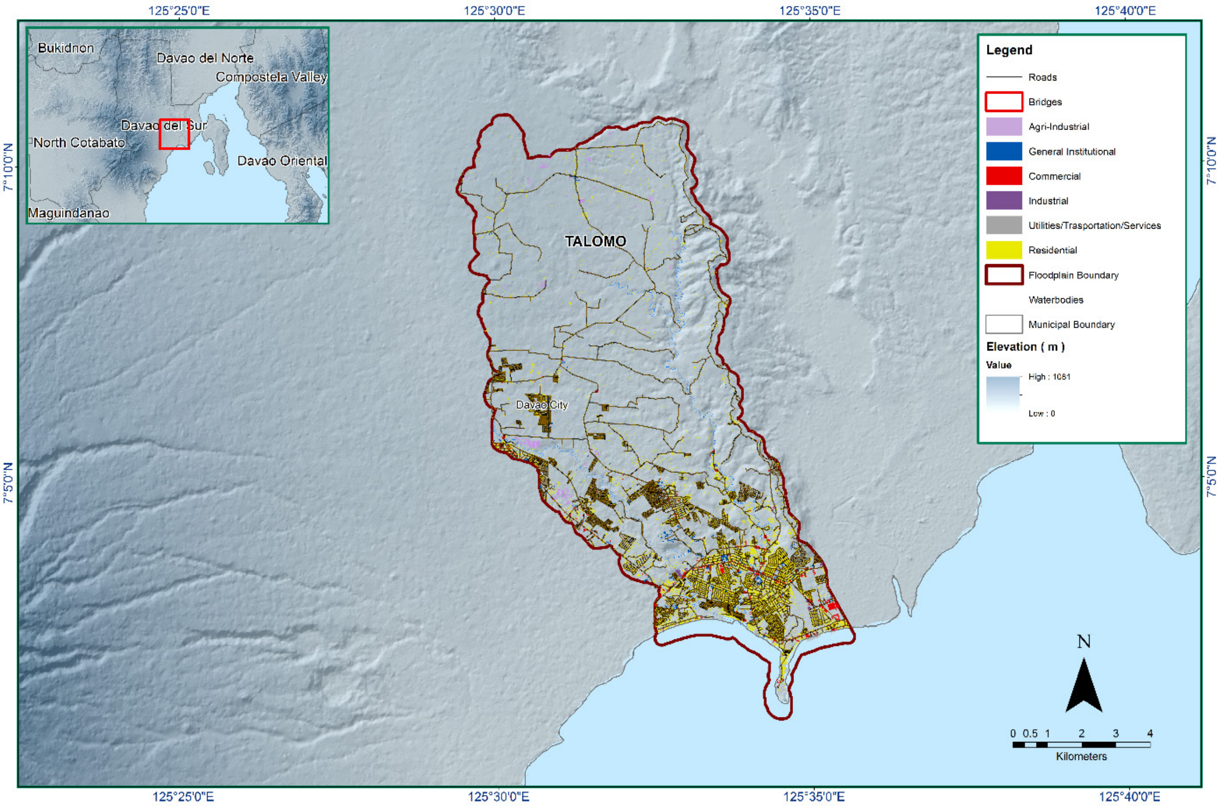



Figure 30. Extracted features for Talomo Floodplain.

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

Engr. Louie P. Balicanta, Engr. Joemarie Caballero, Patrizcia Mae. P. dela Cruz, Engr. Kristine Ailene B. Borromeo, Ms. Jeline M. Amante, Marie Angelique R. Estipona, Charie Mae V. Manliguez, Engr. Janina Jupiter, and Vie Marie Paola M. Rivera

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

## 4.1 Summary of Activities

The Data Validation and Bathymetry Component (DVBC) conducted static and establishment of control points, bridge cross-section, as-built and MSL-based elevation markings, ground validation, and bathymetric surveys in Talomo River from October 15 to 27, 2014. This is to capture the actual geomorphology of the river. Bridge cross-section and water level elevation data shall be used to calculate the cross-sectional area. Furthermore, the cross-sectional area will be used in computing for stream discharge which is necessary for flood modelling. These models will serve to augment the early flood warning system for the communities in the floodplain areas of Davao City. The entire survey extent is illustrated in Figure 31.

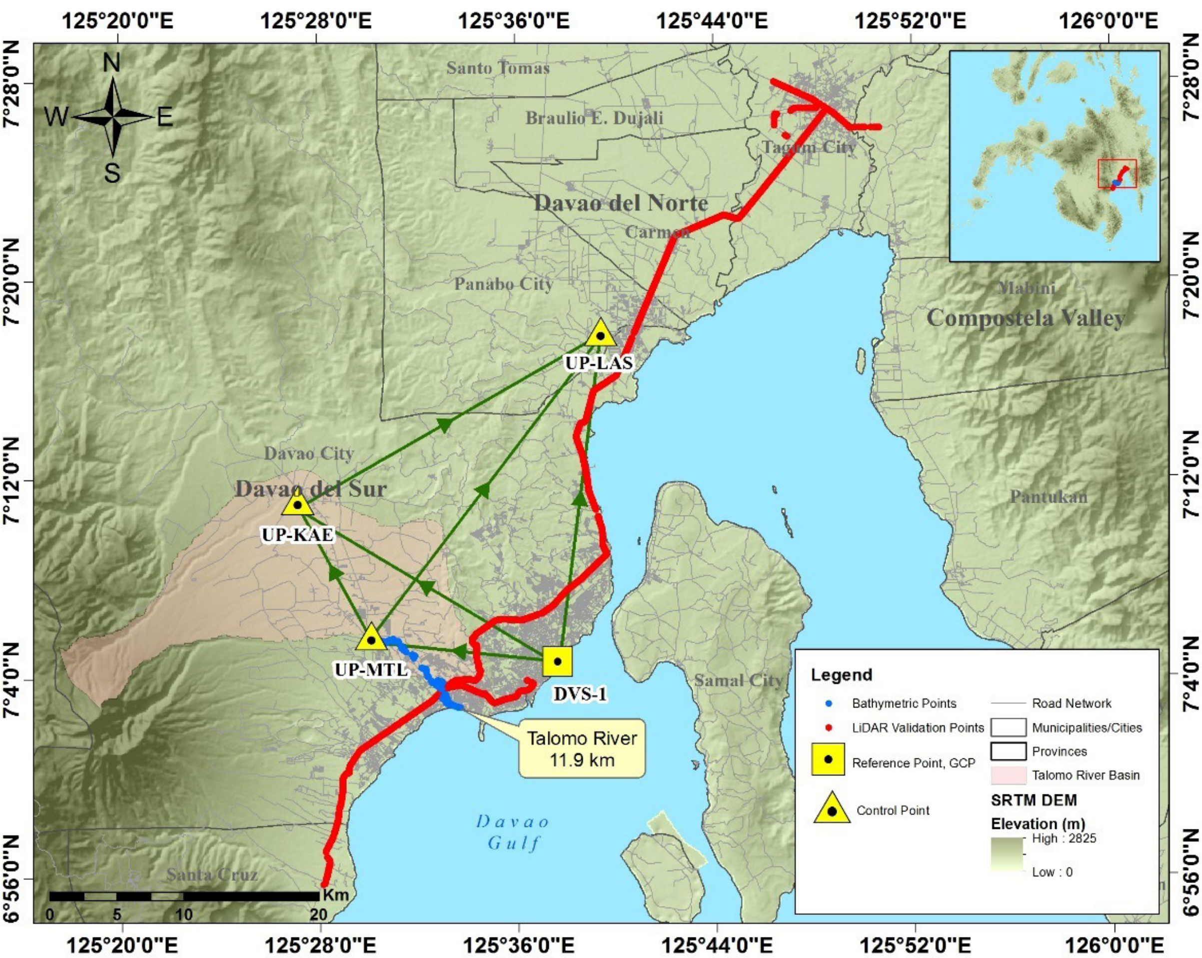



Figure 31. Extent of the bathymetric survey (in blue line) in Talomo River and the LiDAR data validation survey (in red).

## 4.2 Control Survey

The GNSS network used in Tagulaya-Sibulan River survey was composed of six (6) loops established on July 4 and 5, 2015 with the following reference points: DVS-1, a first order GCP in Brgy. Leon Garcia Sr, Davao City, Davao Del Sur; and DV-76, a first order benchmark located Brgy. Guadalupe, Municipality of Carmen, Davao Del Norte.

A GSS network was established on July 4 and 5, 2015 for a previous Phil-LiDAR survey in Digos River occupying the refence points: DVS-1, a first order GCP in Brgy. Leon Garcia Sr., Davai City, Dava Del Sur; and DV-76, a first order benchmark located in Brgy. Guadalupe, Municipality of Carmen, Davao Del Norte.

The GNSS network used in the survey is composed of three loops established on October 16, 2014 occupying the control point DVS-1, a first order GCP in Brgy. Leon Garcia Sr, Davao City, Davao Del Sur, with fixed coordinates and elevation values from the previous Davao field work.

Three control points were established along approach of bridges namely: UP-KAE at Kalye Apike Bridge in Brgy. Calinan, Davao City, Davao Del Norte; UP-LAS at Lasang Bridge in Brgy. Maduao, Panabo City, Davao Del Norte; and UP-MTL at Mintal Bridge in Brgy. Mintal, Davao City, Davao Del Sur; to use as reference points for the survey as shown in Figure 32. The summary of reference and control points and its location is summarized in Table 22.

Table 22. List of Reference and Control Points occupied for Talomo River Survey

(Source: NAMRIA; UP-TCAGP)

| Control Point | Order of Accuracy | Geographic Coordinates (WGS 84) | | | | |
|---|---|---|---|---|---|---|
| | | Latitude | Longitude | Ellipsoidal Height (Meter) | Elevation in MSL (Meter) | Date Established |
| DVS-1 | 1st Order, GCP | 7°04'38.36202" | 125°37'36.77094" | 68.500 | 0.771 | 2013 |
| UP-KAE | UP Established | - | - | - | - | October 16, 2014 |
| UP-LAS | UP Established | - | - | - | - | October 16, 2014 |
| UP-MTL | UP Established | - | - | - | - | October 16, 2014 |

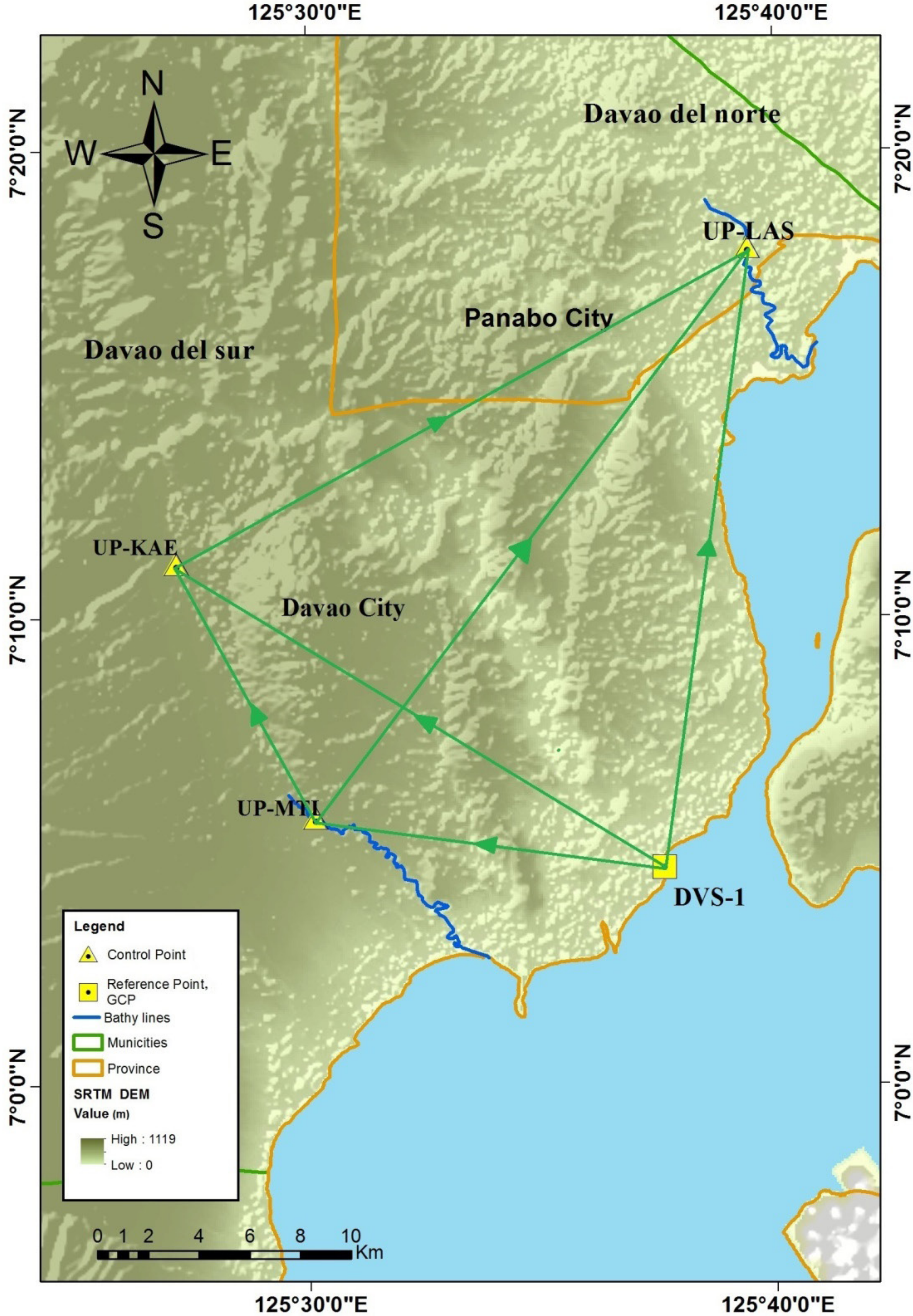



Figure 32. The GNSS Network established in the Talomo River Survey.

The GNSS set up made in the location of the reference and control points are exhibited in Figure 33 to Figure 36.

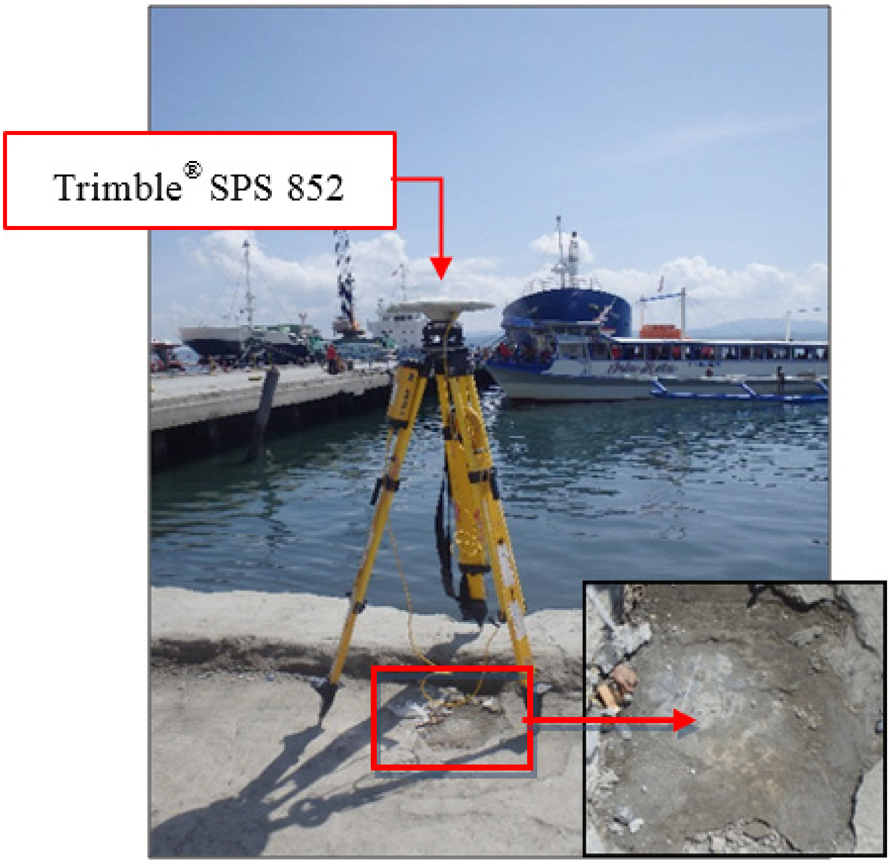



Figure 33. GNSS base receiver set up, Trimble® SPS 852 at DVS-1 in Sta. Ana Wharf, Davao City


Figure 34. GNSS receiver occupation set up, Trimble® SPS 882 at control point UP-KAE, Kalye Apike Bridge in Brgy. Calinan, Davao City

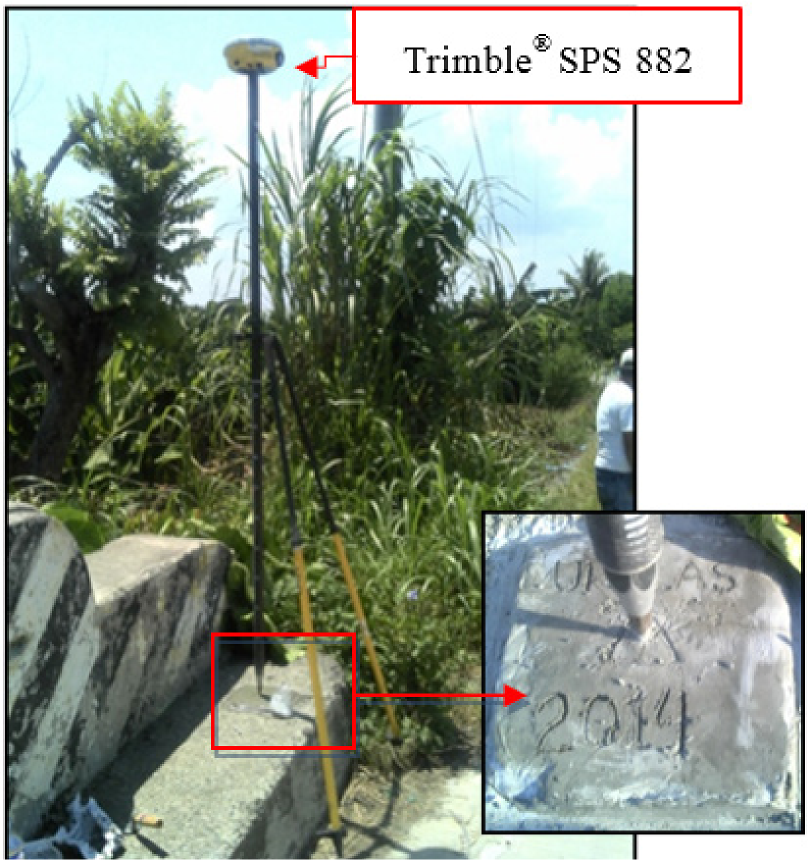



Figure 35. GNSS receiver occupation set up, Trimble® SPS 882 at control point UP-LAS in Brgy. Little Panay, Panabo City


Figure 36. GNSS receiver occupation set up, Trimble® SPS 882 at control point UP-MTL, Mintal Bridge in Brgy. Mintal, Davao City

## 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 is performed. Masking is done by removing/masking portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. Baseline processing result of control points in Talomo River Basin is summarized in Table 23 generated by TBC software.

Table 23. Baseline Processing Summary Report for Talomo River Static Survey

| Observation | Date of Observation | Solution Type | H. Prec. (Meter) | V. Prec. (Meter) | Geodetic Az. | Ellipsoid Dist. (Meter) | ΔHeight (Meter) |
|---|---|---|---|---|---|---|---|
| DVS1 --- UPKAE (B3) | 10-6-2014 | Fixed | 0.003 | 0.018 | 301°56'03" | 22698.648 | -8.798 |
| DVS1 --- UPMTL (B6) | 10-6-2014 | Fixed | 0.003 | 0.020 | 278°05'36" | 13963.237 | -1.723 |
| DVS1 --- UPLAS (B1) | 10-6-2014 | Fixed | 0.003 | 0.013 | 7°42'04" | 24652.588 | -229.449 |
| UPKAE --- UPMTL (B4) | 10-6-2014 | Fixed | 0.003 | 0.018 | 151°31'59" | 11419.131 | -7.064 |
| UPKAE --- UPLAS (B2) | 10-6-2014 | Fixed | 0.005 | 0.030 | 61°08'38" | 25760.778 | -55.135 |
| UPMTL --- UPLAS (B5) | 10-6-2014 | Fixed | 0.003 | 0.020 | 37°18'28" | 28249.074 | -7.047 |

As shown in Table 23, a total of six (6) baselines were processed with reference points DVS-1 held fixed for grid and elevation values, respectively. 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 C-C-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:

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

for each control point. See the Network Adjustment Report shown in Table 24 to Table 26 for the complete details.

The four (4) control points, DVS-1, UP-KAE, UP-LAS, and UP-MTL were occupied and observed simultaneously to form a GNSS loop. The coordinates and elevation values of point DVS-1 were held fixed during the processing of the control points as presented in Table 24. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 24.  Constraints applied to the adjustment of the control points.

| Point ID | Type | East σ (Meter) | North σ (Meter) | Height σ (Meter) | Elevation σ (Meter) |
|---|---|---|---|---|---|
| DVS-1 | 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 25. The fixed control points LYT-101 has no values for grid errors; and LY-106, for elevation error.

Table 25.  Adjusted grid coordinates for the control points used in the Talomo River Floodplain survey.

| Point ID | Easting (Meter) | Easting Error (Meter) | Northing (Meter) | Northing Error (Meter) | Elevation (Meter) | Elevation Error (Meter) | Constraint |
|---|---|---|---|---|---|---|---|
| DVS1 | 790192.921 | ? | 783116.705 | ? | 0.771 | ? | ENe |
| UPKAE | 770850.418 | 0.007 | 795019.989 | 0.006 | 197.198 | 0.052 | |
| UPLAS | 793358.273 | 0.006 | 807581.490 | 0.006 | 12.404 | 0.046 | |
| UPMTL | 776349.630 | 0.006 | 785005.363 | 0.006 | 110.718 | 0.051 | |

The network is fixed at reference point DVS-1 with known coordinates and elevation. With the mentioned equation, $\sqrt{((x_e)^2 + (y_e)^2)}$ <20cm and $z_e < 10\ cm$ for horizontal for the vertical, respectively; the computation for the accuracy are as follows:

| | | | |
|---|---|---|---|
| a. | DVS-1 | | |
| | horizontal accuracy | = | Fixed |
| | vertical accuracy | = | Fixed |
| b. | UP-KAE | | |
| | horizontal accuracy | = | $\sqrt{((0.07)^2 + (0.06)^2)}$ |
| | | = | $\sqrt{(0.49 + 0.36)}$ |
| | | = | 0.92 cm < 20 cm |
| | vertical accuracy | = | 5.2 cm < 10 cm |
| c. | UP-LAS | | |
| | horizontal accuracy | = | $\sqrt{((0.06)^2 + (0.06)^2)}$ |
| | | = | $\sqrt{(0.36 + 0.36)}$ |
| | | = | 0.85 cm < 20 cm |
| | vertical accuracy | = | 4.6 cm < 10 cm |
| d. | UP-MTL | | |
| | horizontal accuracy | = | $\sqrt{((0.06)^2 + (0.06)^2)}$ |
| | | = | $\sqrt{(0.36 + 0.36)}$ |
| | | = | 0.85 cm < 20 cm |
| | vertical accuracy | = | 5.1 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 26. Adjusted geodetic coordinates for control points used in the Talomo River Floodplain validation.

| Point ID | Latitude | Longitude | Ellipsoid | Height | Constraint |
|---|---|---|---|---|---|
| DE-160 | N6°59'41.20398" | E126°19'30.03464" | 71.754 | ? | e |
| DVE-42 | N6°58'51.79295" | E126°18'01.57690" | 80.539 | 0.023 | LL |
| UP_BIT-1 | N6°57'46.30507" | E126°17'35.96635" | 80.537 | 0.025 | |
| UP_MAY-1 | N6°59'26.93722" | E126°19'18.72092" | 73.478 | 0.009 | |
| UP_QUI-1 | N7°05'25.95862" | E126°27'58.08622" | 70.854 | 0.034 | |

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

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

Table 27. Reference and control points utilized in the Talomo River Static Survey, with their corresponding locations (Source: NAMRIA, UP-TCAGP)

| Control Point | Order of Accuracy | Geographic Coordinates (WGS 84) | | | UTM ZONE 51 N | | | |
|---|---|---|---|---|---|---|---|---|
| | | Latitude | Longitude | Ellipsoidal Height (m) | Northing (m) | Easting (m) | EGM Ortho (m) | BM Ortho (m) |
| DVS1 | 1st Order, GCP | 7°04'38.36202" | 125°37'36.77094" | 68.500 | 783116.705 | 790192.921 | 0.771 | 287.844 |
| UPKAE | UP Established | 7°11'09.07739" | 125°27'08.90858" | 266.926 | 795019.989 | 770850.418 | 197.198 | 58.767 |
| UPLAS | UP Established | 7°17'53.61604" | 125°39'24.47345" | 80.420 | 807581.490 | 793358.273 | 12.404 | 3.317 |
| UPMTL | UP Established | 7°05'42.29301" | 125°30'06.27926" | 179.729 | 785005.363 | 776349.630 | 110.718 | 4.332 |

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

Cross-section and as-built survey were conducted on October 16, 2014 along the downstream side of Kalye-Apike Bridge in Brgy. Calinan, Davao City and October 22 and 25, 2014 at the downstream side of Mintal Bridge in Brgy. Mintal, Davao City using GNSS receiver, Trimble® SPS 882 in PPK survey technique as shown in Figure 37.


Figure 37. Cross-section Survey at Mintal Bridge

The length of cross-sectional lines for Kalye Apike Bridge is 123.58 m with thirteen points; while of Mintal Bridge is 204 m with a total of sixteen (16) points, both acquired using the cotrol point DVS-1 as the GNSS base station, respectively. Their location maps, cross-section diagrams, and bridge as-built form of the two bridges are shown in Figure 38 to Figure 43.

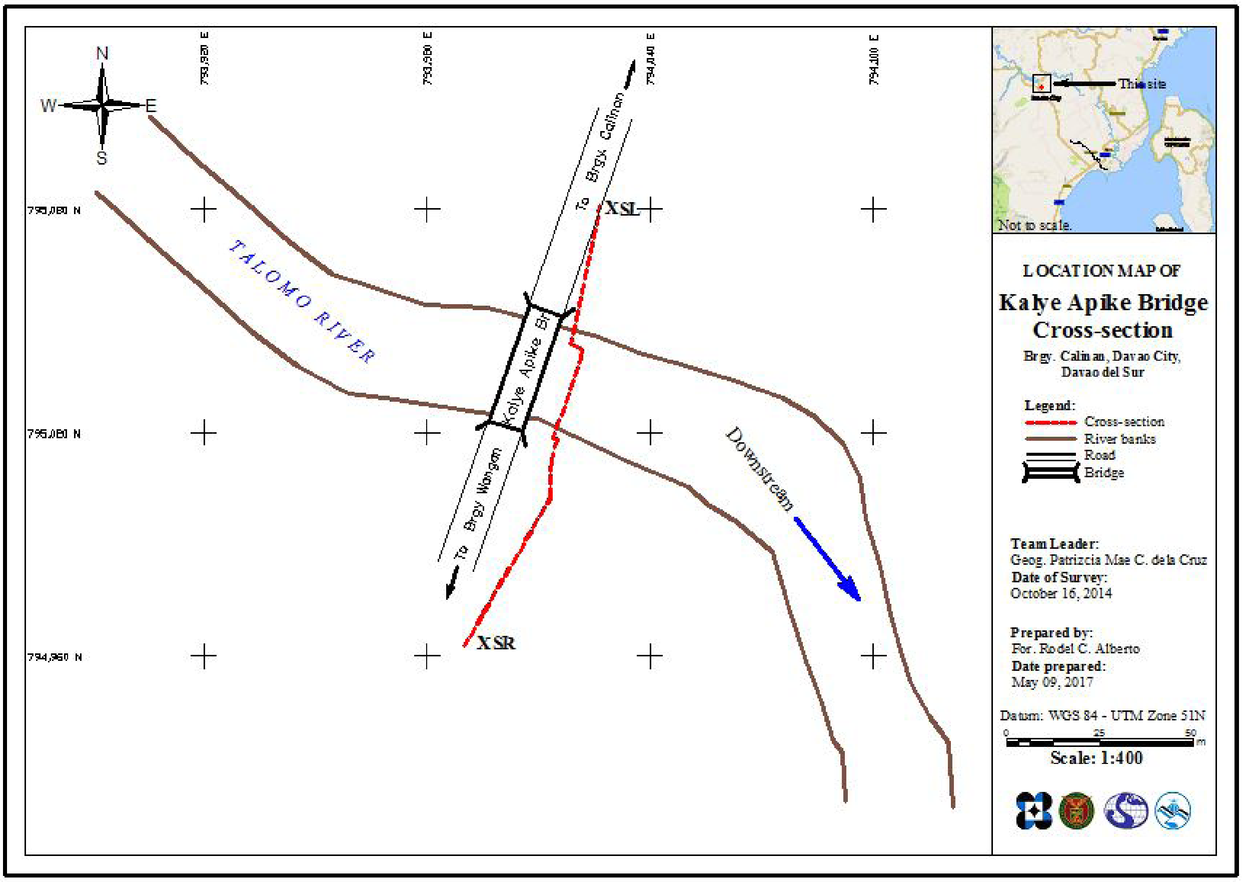



Figure 38. Location map of Kalye-Apike Bridge cross-section survey

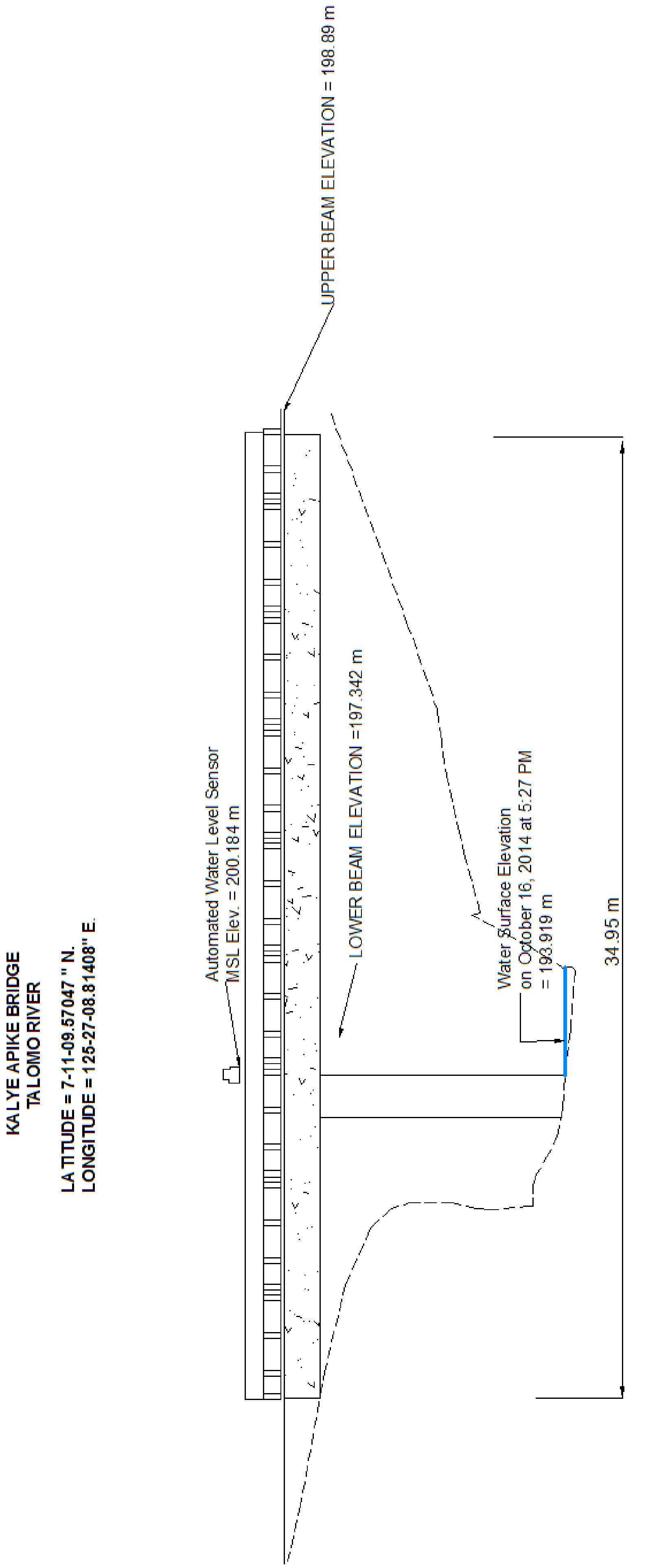



Figure 39. Kalye-Apike Bridge cross-section diagram

**Bridge Data Form**

Bridge Name: Kalye Apike Bridge Date: 10-16-2014

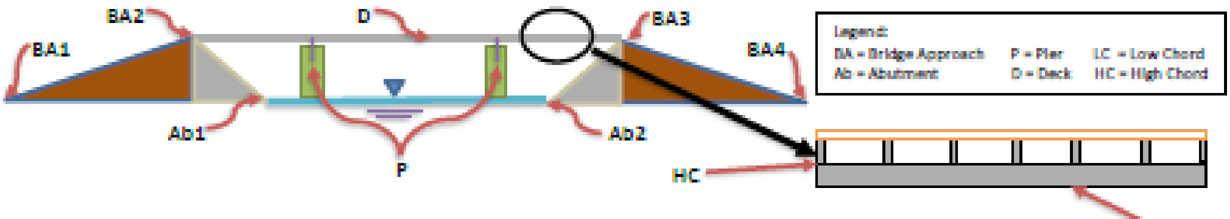
River Name: Talomo River Time: 5:29 PM

Location (Brgy, City, Region): Brgy. Wangan and Calinan Davao City Region XI

Survey Team: Team Patrizcia Dela Cruz - DVBC

Flow condition: low normal high Weather Condition: fair rainy

Latitude: 7 – 11 – 09.57047 " N Longitude: 125 -27 – 08.81408 " E




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

Elevation: 198.8892 m Width: 7.774 m Span (BA3-BA2): 34.957 m

| | Station | High Chord Elevation | Low Chord Elevation |
|---|---|---|---|
| 1 | BA2 | 198.8892 m | 197.3242 m |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |

**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 | 198.5672 | BA3 | 67.347 m | 198.8472 |
| BA2 | 32.396 m | 198.8872 | BA4 | 123.580 m | 197.8292 |

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

| | Station (Distance from BA1) | Elevation |
|---|---|---|
| Ab1 | | |
| Ab2 | | |

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

Shape: Oblique Number of Piers: 1 Height of column footing: N/A

| | Station (Distance from BA1) | Elevation | Pier Width |
|---|---|---|---|
| Pier 1 | 49.709 m | 193.9192 m | |
| Pier 2 | | | |
| Pier 3 | | | |
| Pier 4 | | | |
| Pier 5 | | | |
| Pier 6 | | | |

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

Figure 40. Kalye-Apike Bridge Data Form

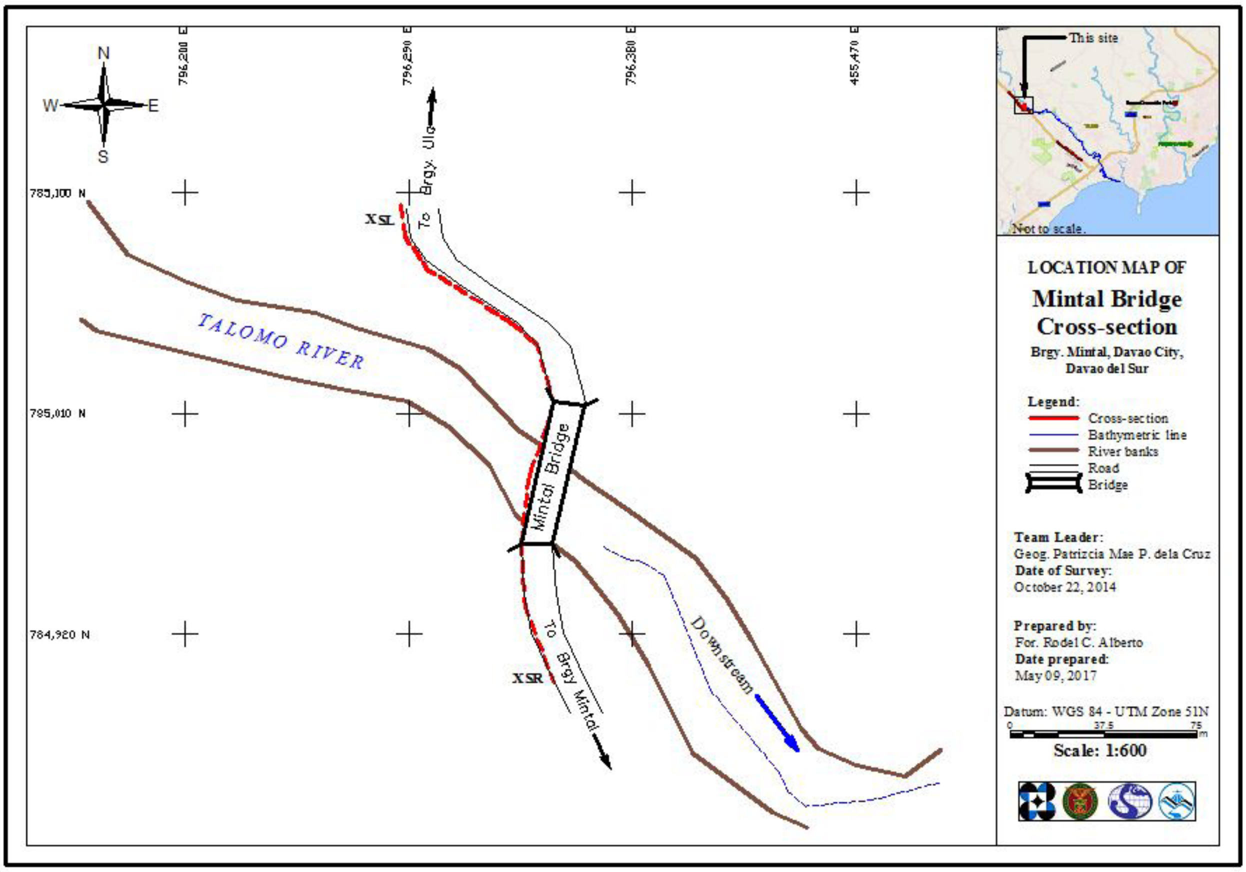



Figure 41. Location map of Mintal Bridge cross-section survey

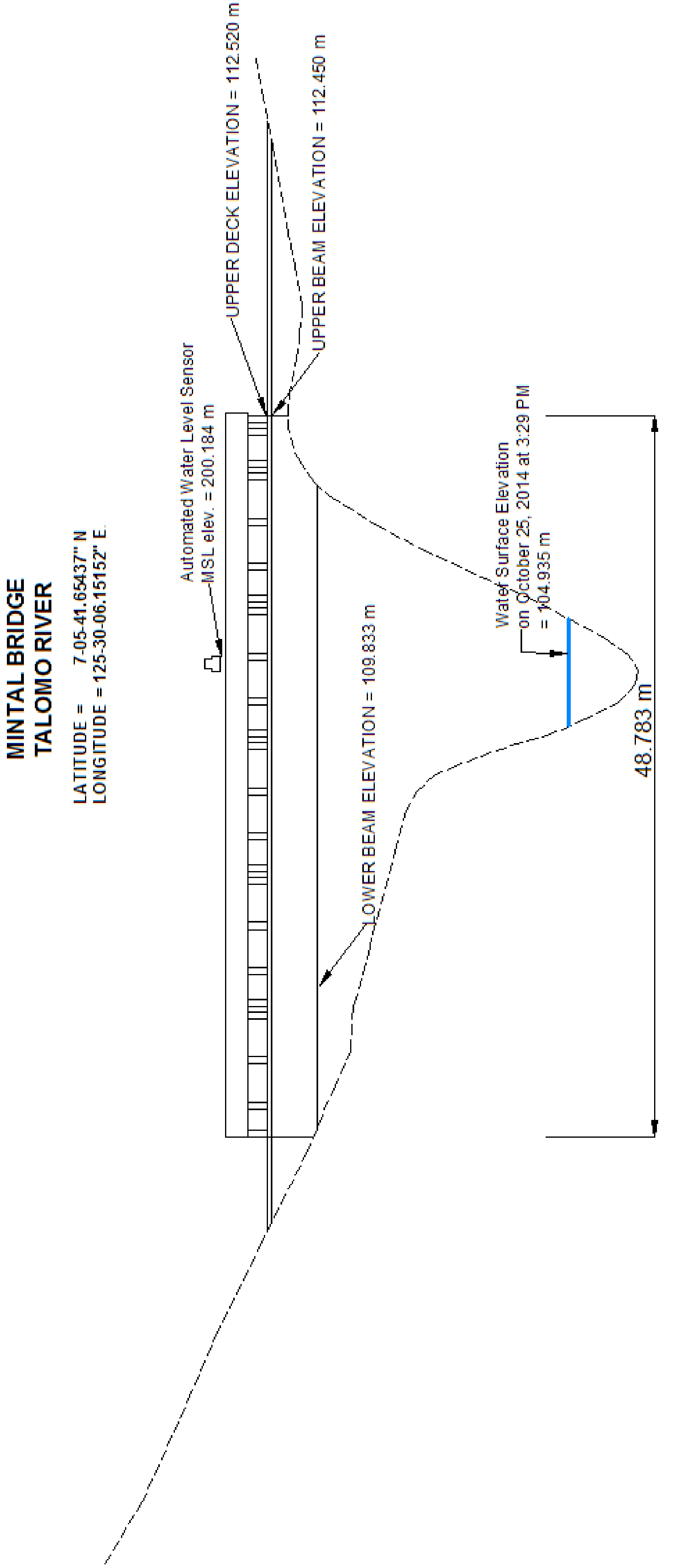
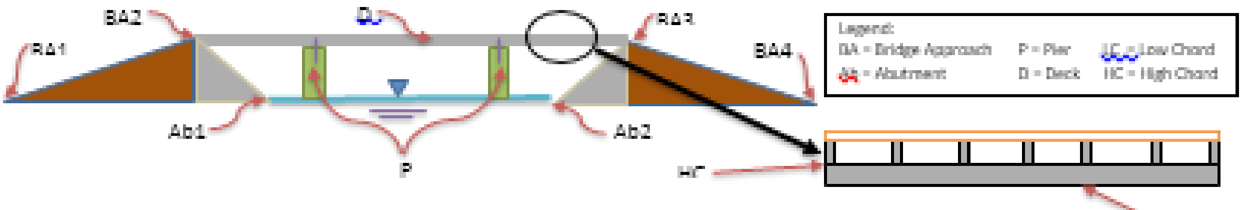



Figure 39. Mintal Bridge cross-section diagram

**Bridge Data Form**

| | | | |
|---|---|---|---|
| Bridge Name: | MINTAL BRIDGE | Date: | 10-22-2014 |
| River Name: | TALOMO RIVER | Time: | 10:42:05 AM |
| Location (Brgy, City,Region): | BRGY MINTAL DAVAO CITY | | |
| Survey Team: | PATRIZCIA MAE DELA RUZ-DBVC | | |
| Flow condition: | low normal high | Weather Condition: | fair rainy |
| Latitude: | 7-05-41.65437" N | Longitude: | 125-30-06.15152" E. |




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

Elevation: 112.5202 M Width: 8.347 M. Span (BA3-BA2): 48.783 M

| | Station | High Chord Elevation | Low Chord Elevation |
|---|---|---|---|
| 1 | BA2 | 112.4532 M | 109.8332 M |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |

**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 | 116.1262 | BA3 | 152.613 | 112.4492 |
| BA2 | 116.457 | 112.4522 | BA4 | 204.022 | 112.4982 |

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

| | Station (Distance from BA1) | Elevation |
|---|---|---|
| Ab1 | | |
| Ab2 | | |

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

Shape: ____________ Number of Piers: N/A Height of column footing: N/A

| | Station (Distance from BA1) | Elevation | Pier Width |
|---|---|---|---|
| Pier 1 | | | |
| Pier 2 | | | |
| Pier 3 | | | |
| Pier 4 | | | |
| Pier 5 | | | |

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

Figure 43. Mintal Bridge Data Form

The water surface elevation in Kalye Apike Bridge is 193.919 m (MSL) acquired on October 16, 2014 at 5:27 PM. These markings on the bridge piers (Figure 44) shall also serve as a reference for flow data gathering and depth gauge deployment of UP Mindanao PHIL-LIDAR 1.

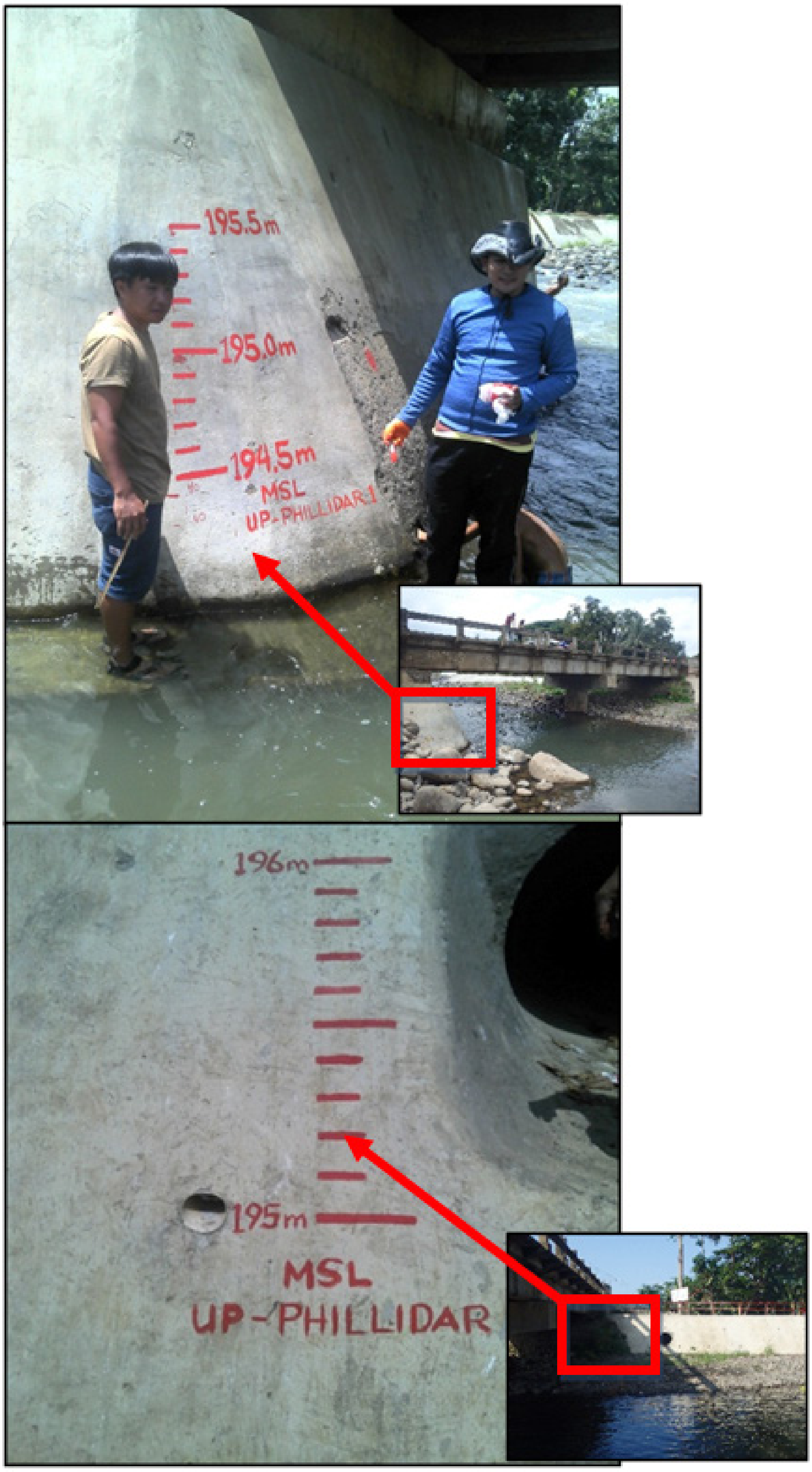



Figure 44. Water level markings on Talomo Bridge

Meanwhile, the water surface elevation of Talomo River at Mintal Bridge at the left and right banks was acquired using PPK survey technique on October 25, 2014 at 3:29 PM. The resulting water surface elevation data of 104.935 m (MSL) was applied as markings on the right and left abutments of the bridge facing downstream as shown in Figure 45. This will be used as reference for the flow measurement and depth gauge deployment of partner HEI, UP Mindanao.

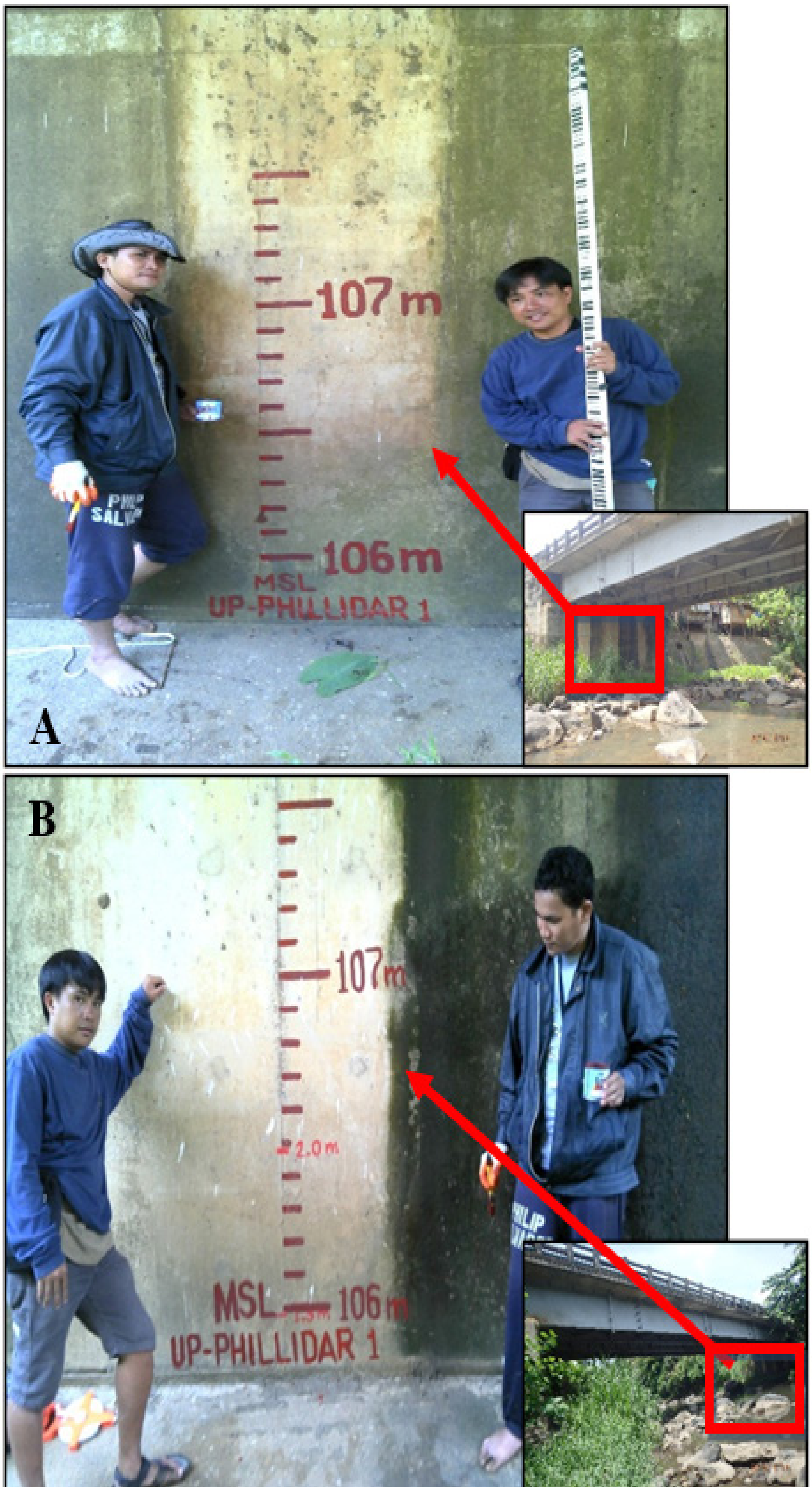



Figure 45. Water Level marking at the left (A) and right pier (B) of the bridge facing downstream of Mintal Bridge

## 4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on October 21 and 23, 2015 using a survey grade GNSS Rover receiver mounted on a pole which was attached in front of the vehicle as shown in Figure 46. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna height was measured from the ground up to the bottom of the notch of the GNSS Rover receiver. The survey was conducted using PPK technique on a continuous topography mode.

The first day of ground validation started from Brgy. Toril, Davao City and traversed major roads going to Brgy. Magugpo Poblacion in Tagum City. Meanwhile, the second day of survey started from Brgy. 4-A in Davao City along Maharlika Highway, and ended in Brgy. Darong Santa Cruz, Davao del Sur. Point DVS-1 was used as base station all throughout the conduct of the survey.

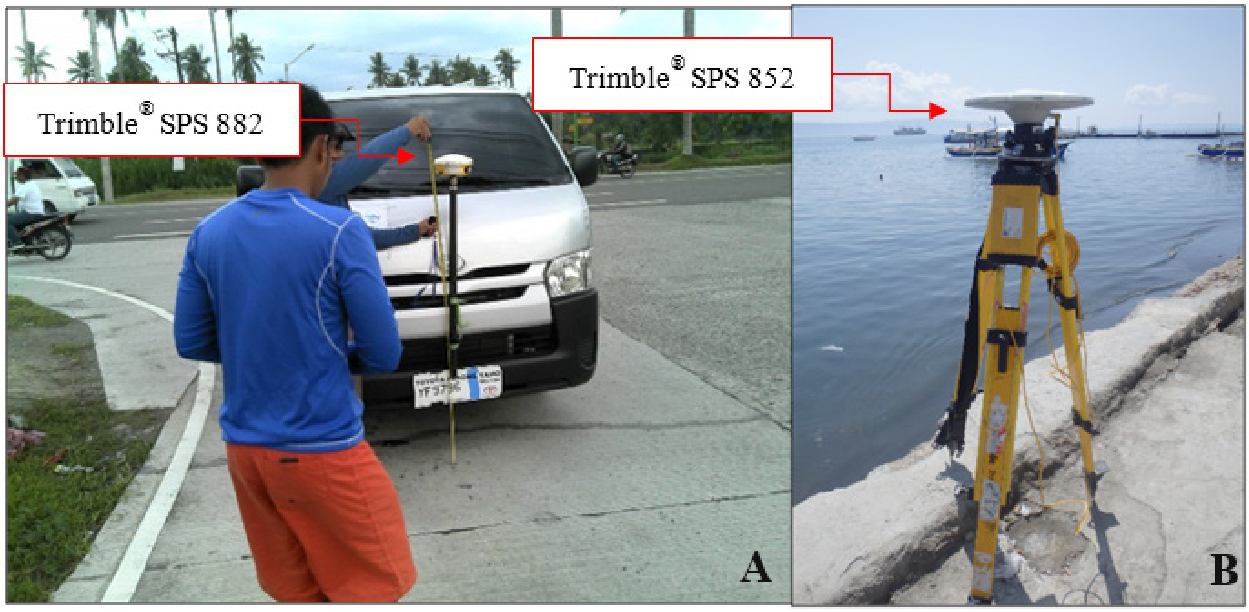



Figure 46. Ground Validation Set-up (A) and (B) GPS base receiver set up, Trimble® SPS 852 at DVS-1, in Sta. Ana Port

The survey acquired 13,126 ground validation points with an approximate length of 94 km using the base station DVS-1, as shown in the map in Figure 47.

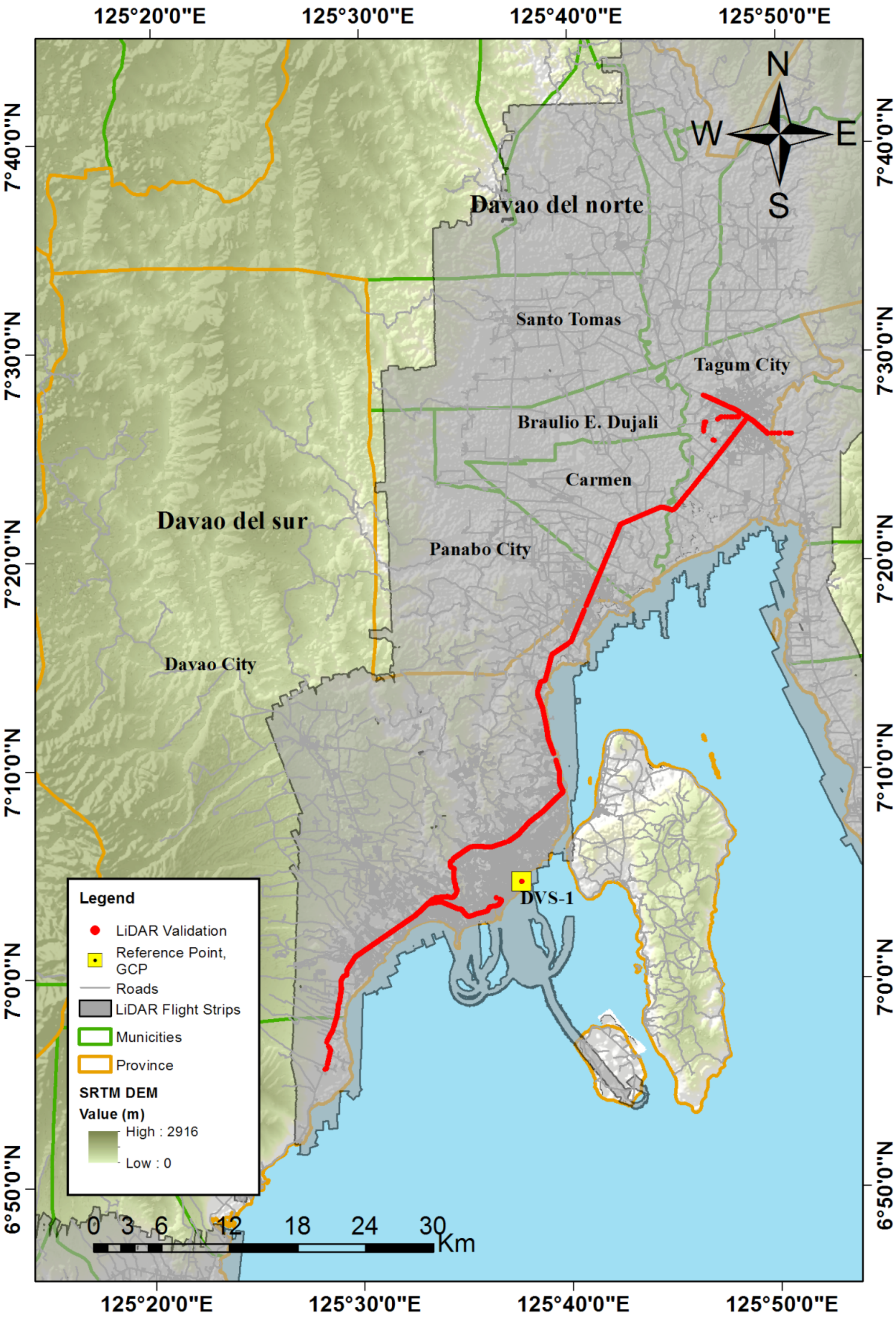



Figure 47. Validation point acquisition survey of Talomo River basin

## 4.7 River Bathymetric Survey

Manual bathymetric survey was conducted on October 17 to 21, 2014 using a Trimble® SPS 882 GNSS receiver in a PPK survey technique as shown in Figure 48. The survey started in the upstream part of the river in Brgy. Mintal, Davao City, Davao Del Sur with coordinates 7˚05'40.66644" 125˚30'06.88067", traversed down the river by foot and ended at the mouth of it in Brgy. Maina Aplaya, also in Davao City with coordinates 7˚02'47.89194" 125˚33'40.86268".


Figure 48. Actual Execution of Manual Bathymetry in Talomo River

The bathymetric survey covered a total length of approximately 11.90 km with a total of 717 points gathered using DVS-1 as GNSS base station all throughout the survey. Canopy cover along the river prohibited GPS signals to penetrate; thus, resulting in float data. The processed data were generated into a map using GIS software as shown in Figure 49.

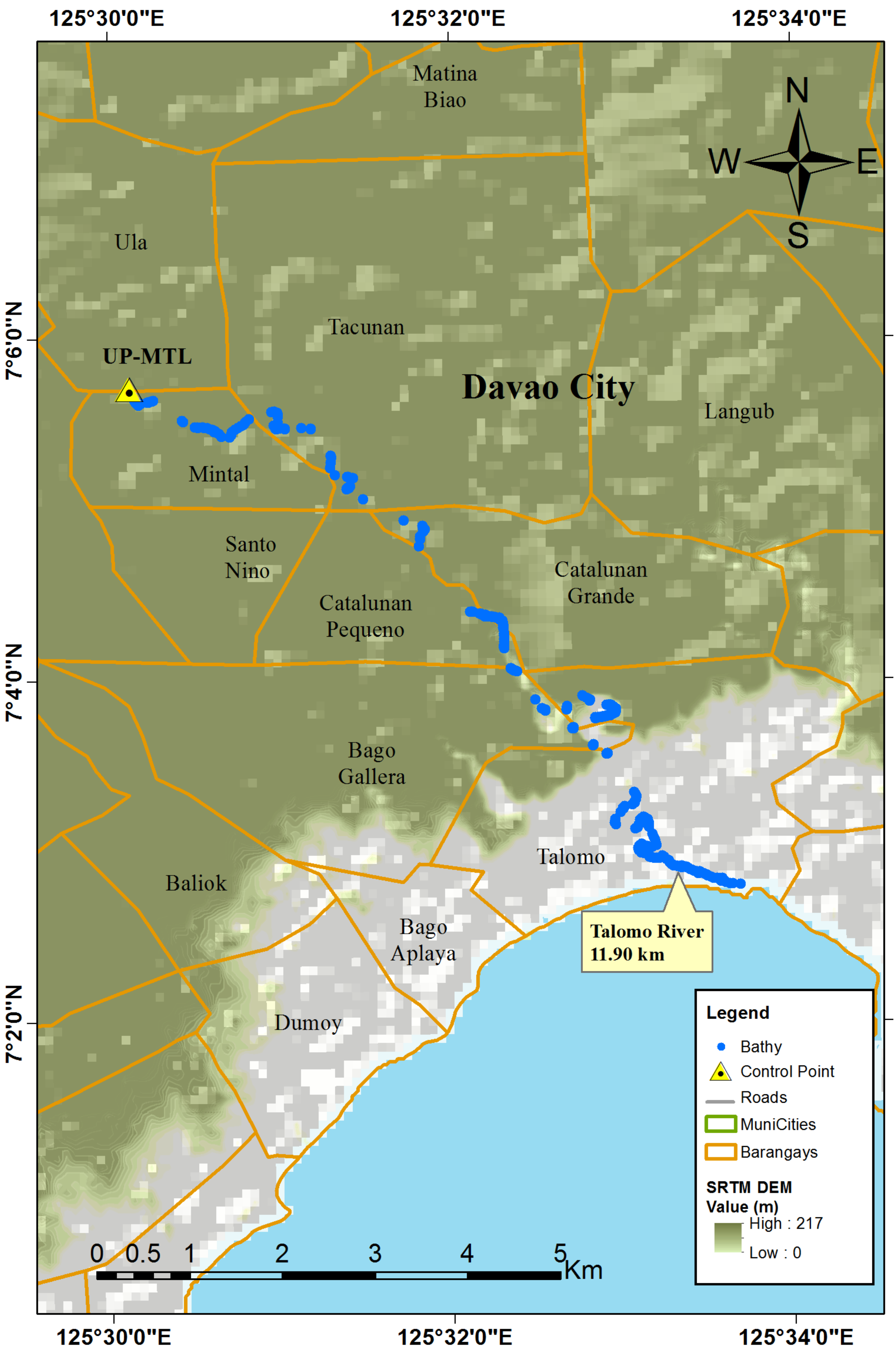



Figure 49. Extent of the Talomo River Bathymetry Survey in Davao City, Davao del Sur

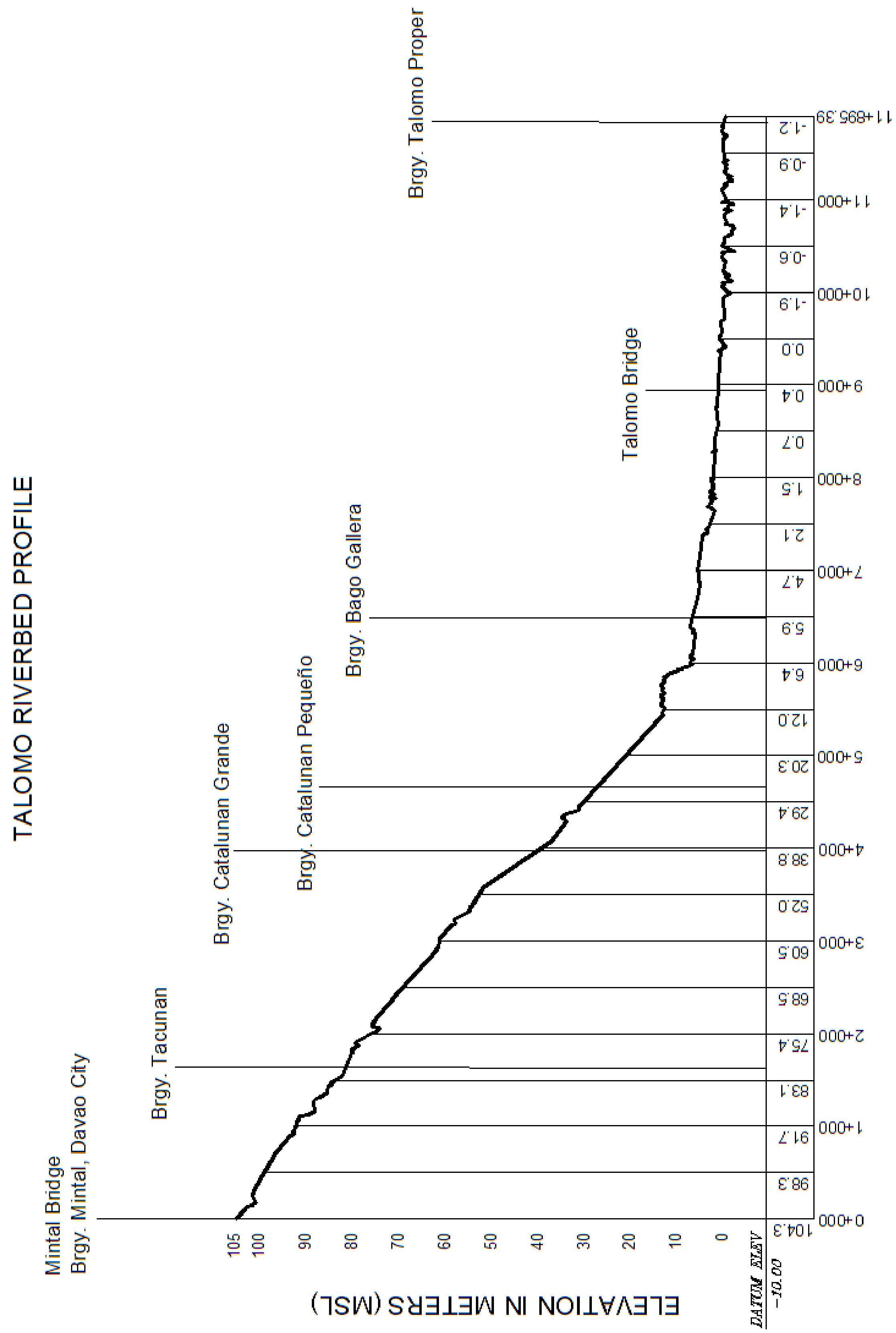



Figure 50. Talomo riverbed profile.

# CHAPTER 5: FLOOD MODELING AND MAPPING

*Alfredo Mahar Francisco A. Lagmay, Enrico C. Paringit, Dr. Eng., Christopher Noel L. Uichanco, Sylvia Sueno, Marc Moises, Hale Ines, Miguel del Rosario, Kenneth Punay, Neil R. Tingin, Narvin Clyd Tan, and Hannah Aventurado*

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

## 5.1 Data Used for Hydrologic Modeling

### 5.1.1 Hydrometry and Rating Curves

All data that affect the hydrologic cycle of the Talomo 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 Talomo River Basin were monitored, collected, and analyzed.

### 5.1.2 Precipitation

Precipitation data was taken from automatic rain gauge (ARG) installed by the Department of Science and Technology – Advanced Science and Technology Institute (DOST-ASTI). This rain gauge is the Baguio District ARG located in Barangay Baguio, Davao, Davao del Sur with the following coordinates: 7° 10’ 19.31” N, 125° 24’ 12.24” E (Figure 51). The precipitation data collection started from July 31, 2015 at 1:00 PM to August 2, 2015 at 2:30 PM with a 15-minute recording interval.

The total precipitation for this event in the installed rain gauge was 14.37 mm. It has a peak rainfall of 3.33 mm. on July 31, 2015 at 6:45 PM. The lag time between the peak rainfall and discharge is 12 hours and 25 minutes.

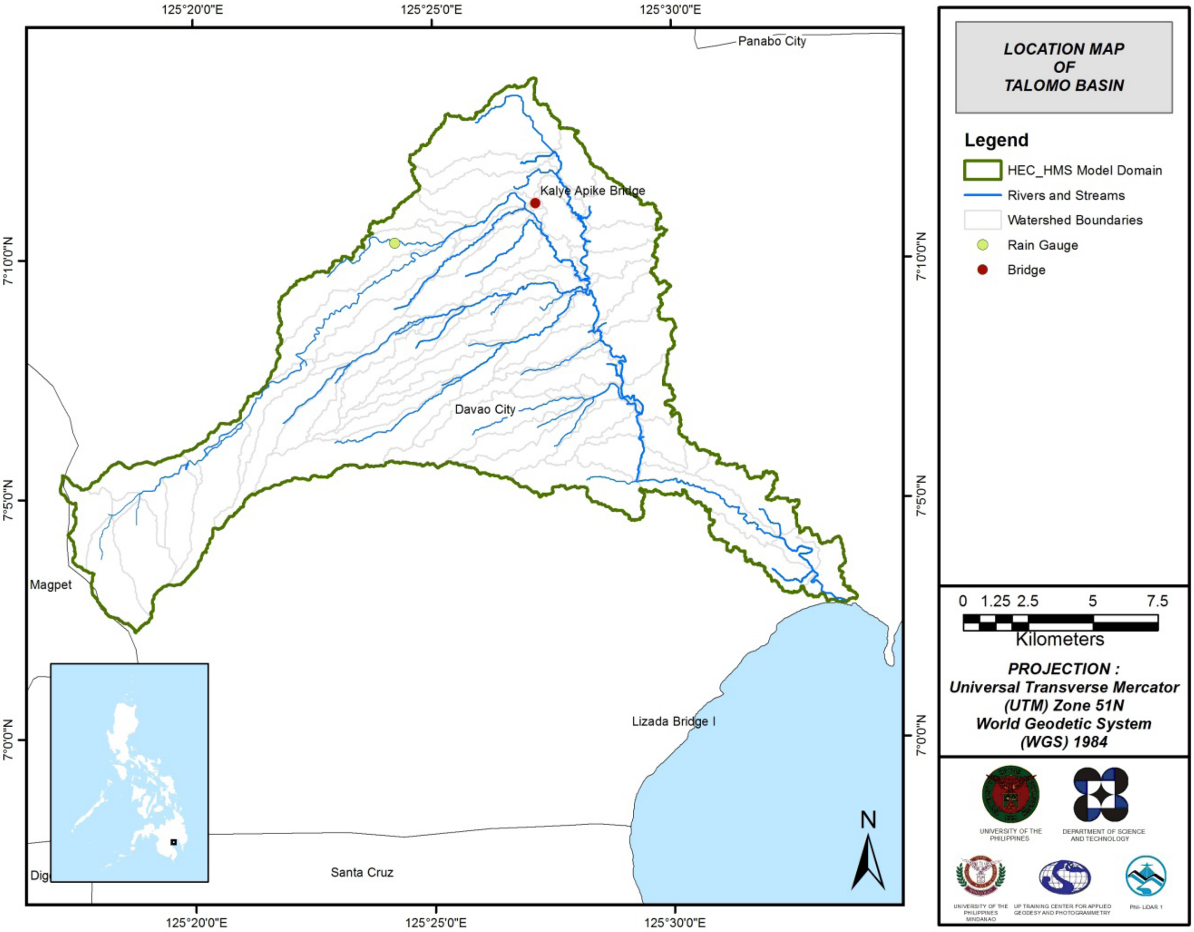



Figure 51. Location map of the Talomo HEC-HMS model used for calibration.

### 5.1.3 Rating Curves and River Outflow

A rating curve was developed at Kalye Apike Bridge, Barangay Calinan, Davao, Davao del Sur (7° 11’ 9.13” N, 125° 27’ 9” E). It gives the relationship between the observed water level at the Kalye Apike Bridge and outflow of the watershed at this location.

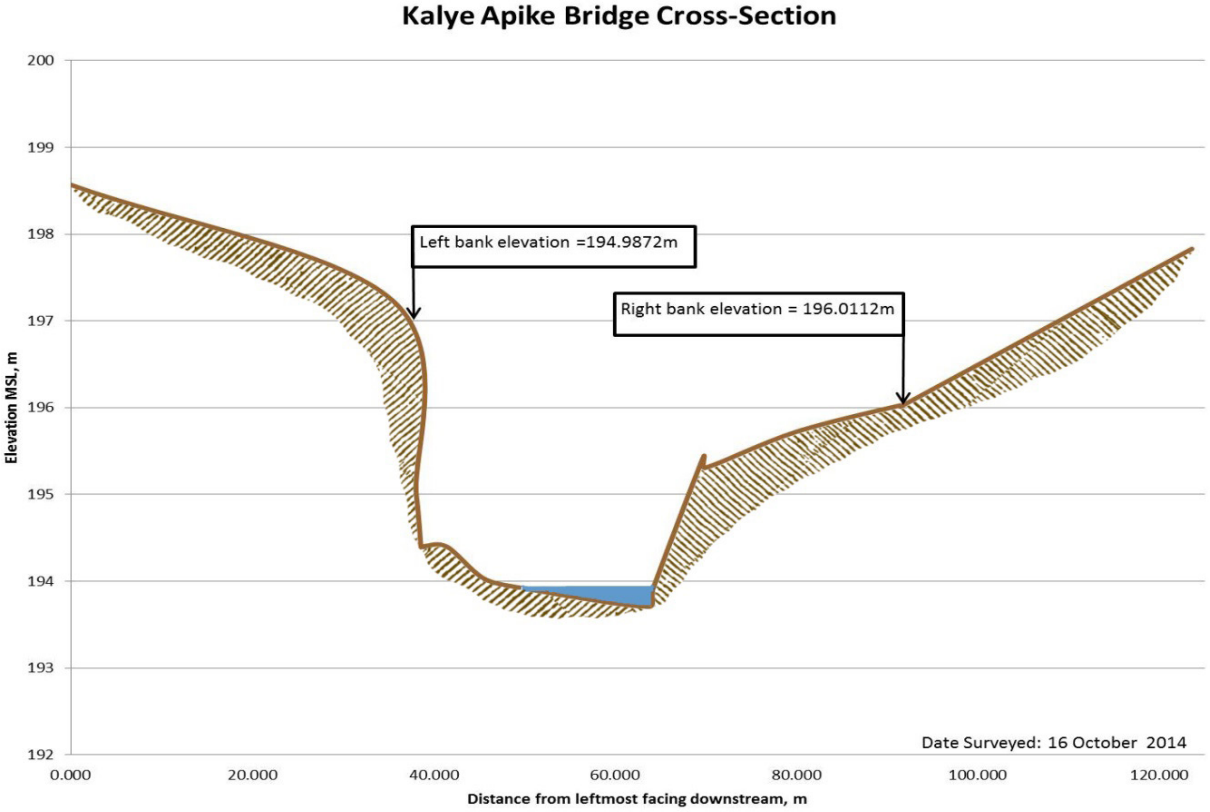



Figure 52. Cross-section plot of Kalye Apike Bridge

For Kalye Apike Bridge, the rating curve is expressed as Q = 1.00E-306e3.65x as shown in Figure 53.

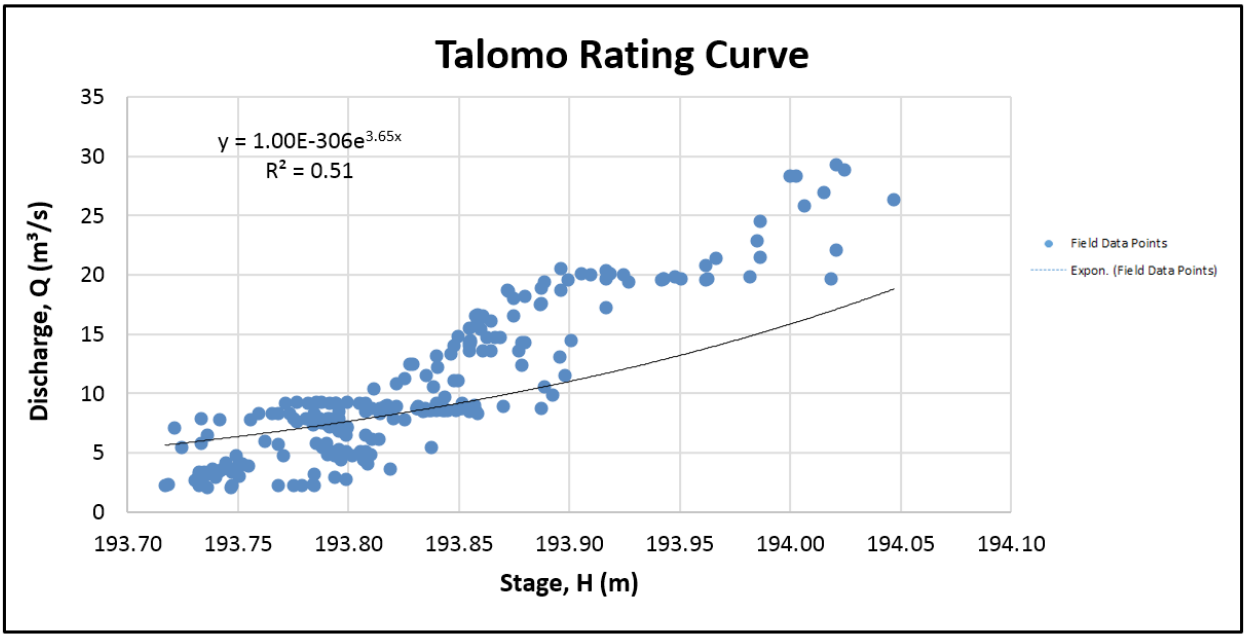



Figure 53. Rating curve at Kalye Apike Bridge, Davao, Davao del Sur

The rating curve equation was used to compute for the river outflow at Kalye Apike Bridge for the calibration of the HEC-HMS model for Talomo, as shown in Figure 54. The total rainfall for this event is 14.37 mm and the peak discharge is 29.2 m3/s at 7:10 AM of August 1, 2015.

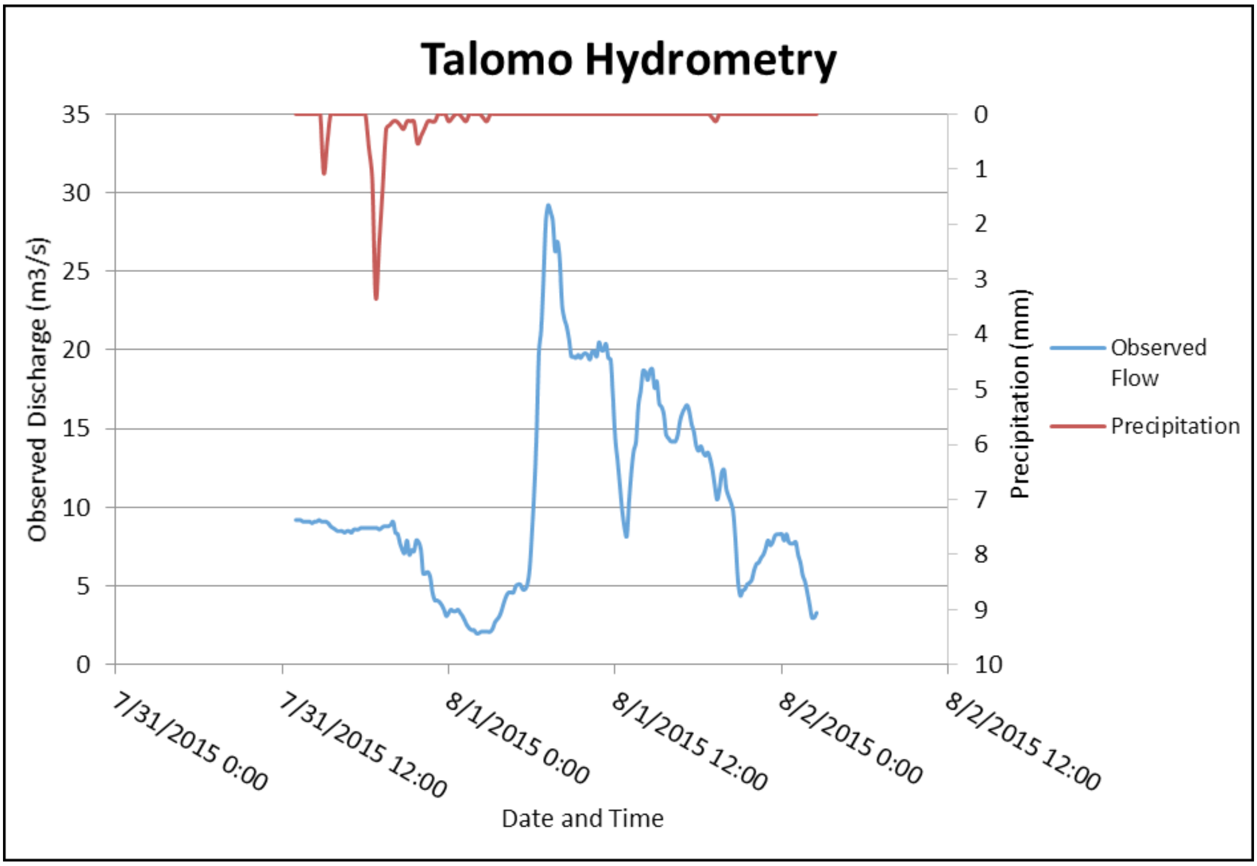



Figure 54. Rainfall and outflow data at Kalye Apike Bridge used for modeling

## 5.2 RIDF Station

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

Table 28. RIDF values for Davao 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 | 19.5 | 30 | 38.2 | 53.2 | 65.2 | 71.6 | 80.3 | 85.8 | 91.4 |
| 5 | 25.1 | 39.3 | 51 | 73.2 | 88.8 | 96.4 | 108.7 | 114.9 | 121.1 |
| 10 | 28.8 | 45.4 | 59.4 | 86.5 | 104.5 | 112.8 | 127.5 | 134.1 | 140.7 |
| 15 | 30.9 | 48.9 | 64.2 | 94 | 113.3 | 122.1 | 138.1 | 145 | 151.8 |
| 20 | 32.4 | 51.3 | 67.6 | 99.3 | 119.5 | 128.6 | 145.5 | 152.6 | 159.5 |
| 25 | 33.5 | 53.2 | 70.1 | 103.3 | 124.2 | 133.6 | 151.2 | 158.5 | 165.5 |
| 50 | 37 | 59 | 78.1 | 115.8 | 138.9 | 149 | 168.8 | 176.5 | 183.9 |
| 100 | 40.5 | 64.7 | 85.9 | 128.1 | 153.5 | 164.2 | 186.3 | 194.4 | 202.1 |

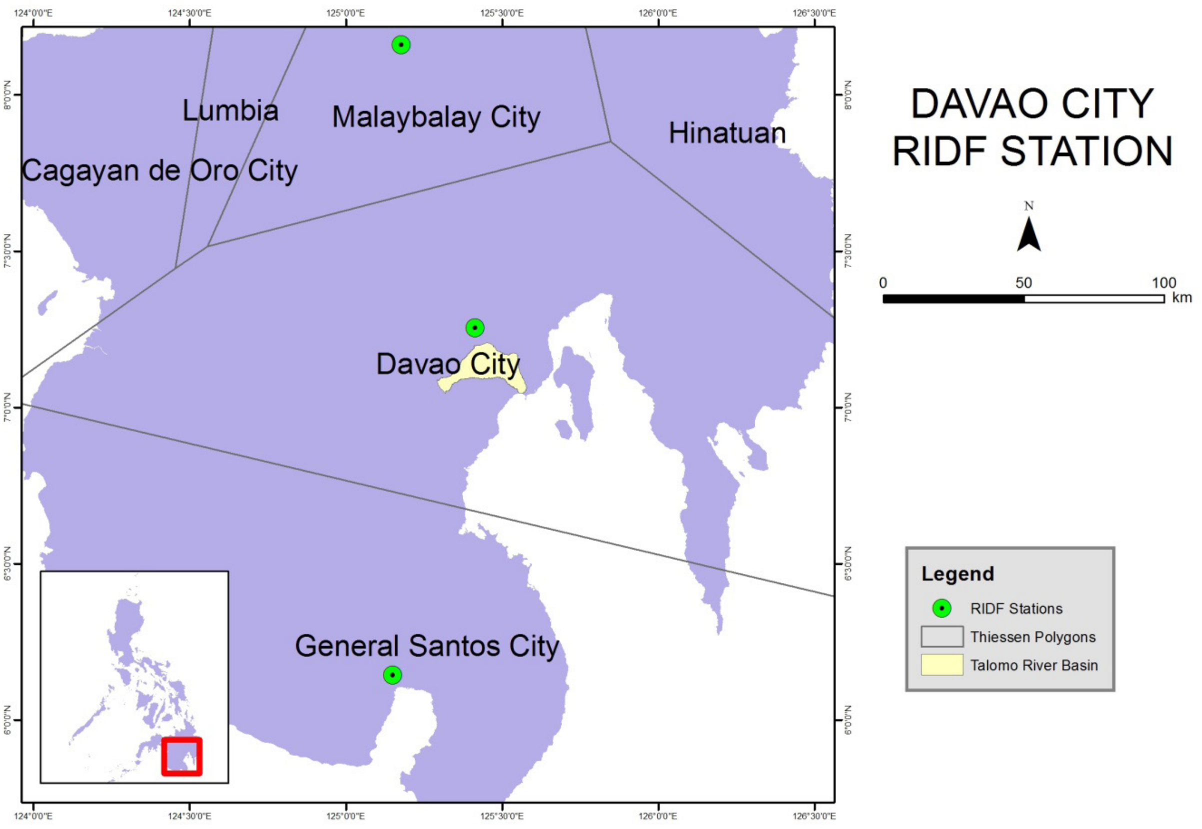



Figure 55. Location of Davao RIDF Station relative to Talomo River Basin

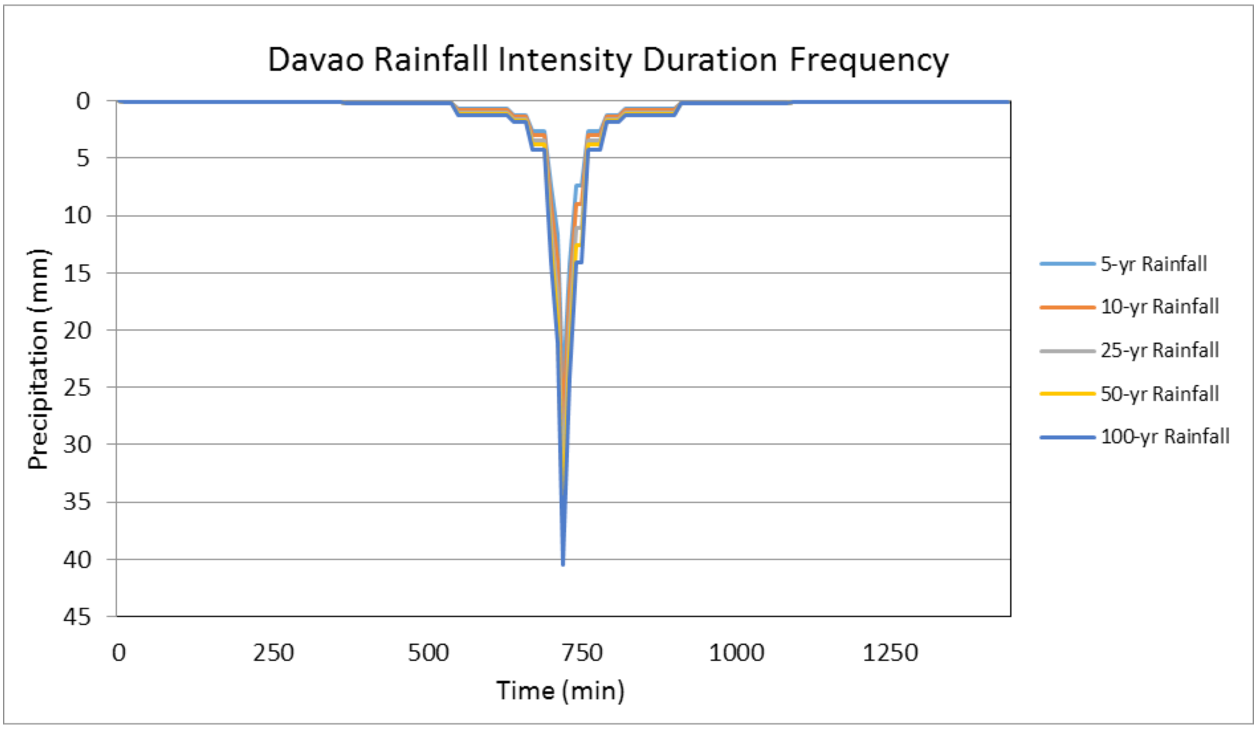



Figure 56. Synthetic storm generated for a 24-hr period rainfall for various return periods.

## 5.3 HMS Model

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

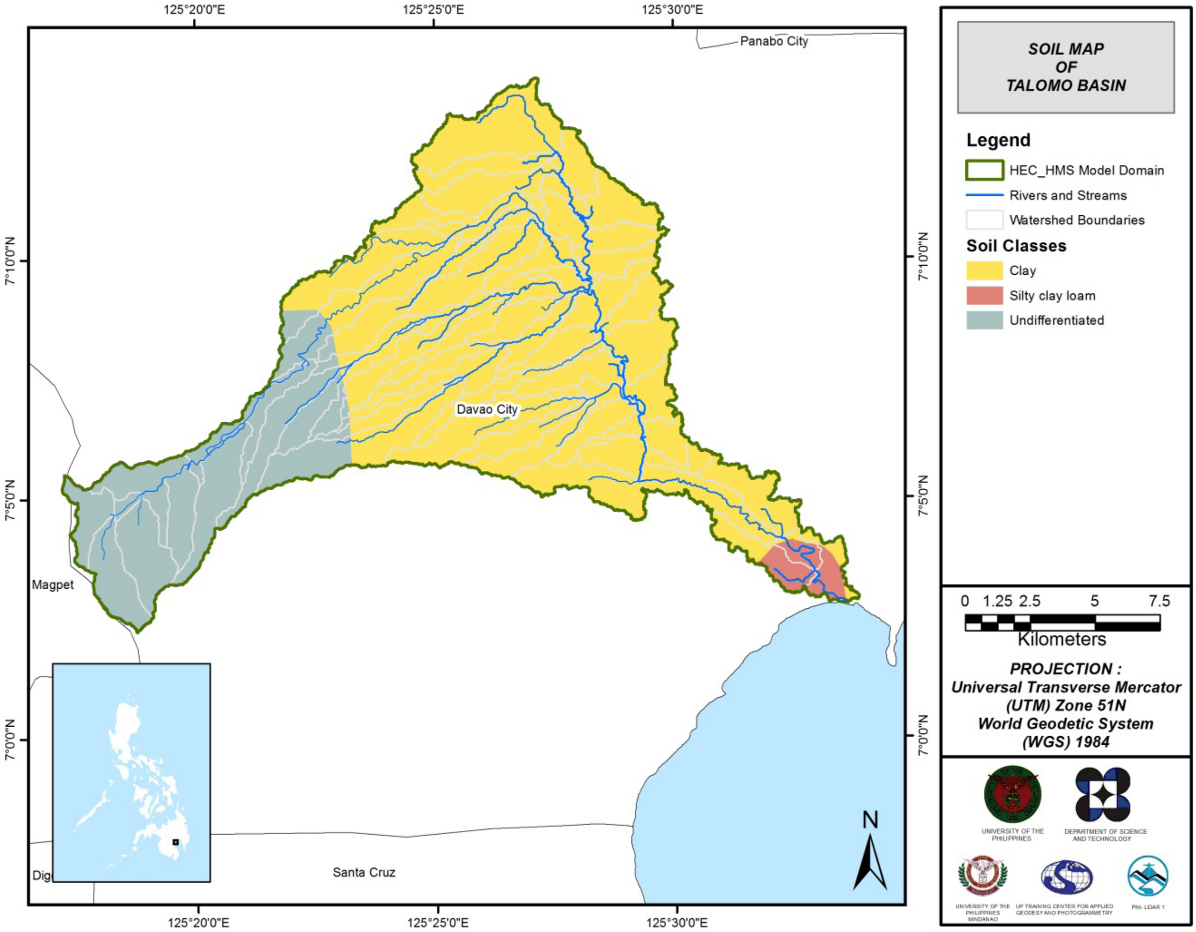



Figure 57. Soil Map of Talomo River Basin used for the estimation of the CN parameter.

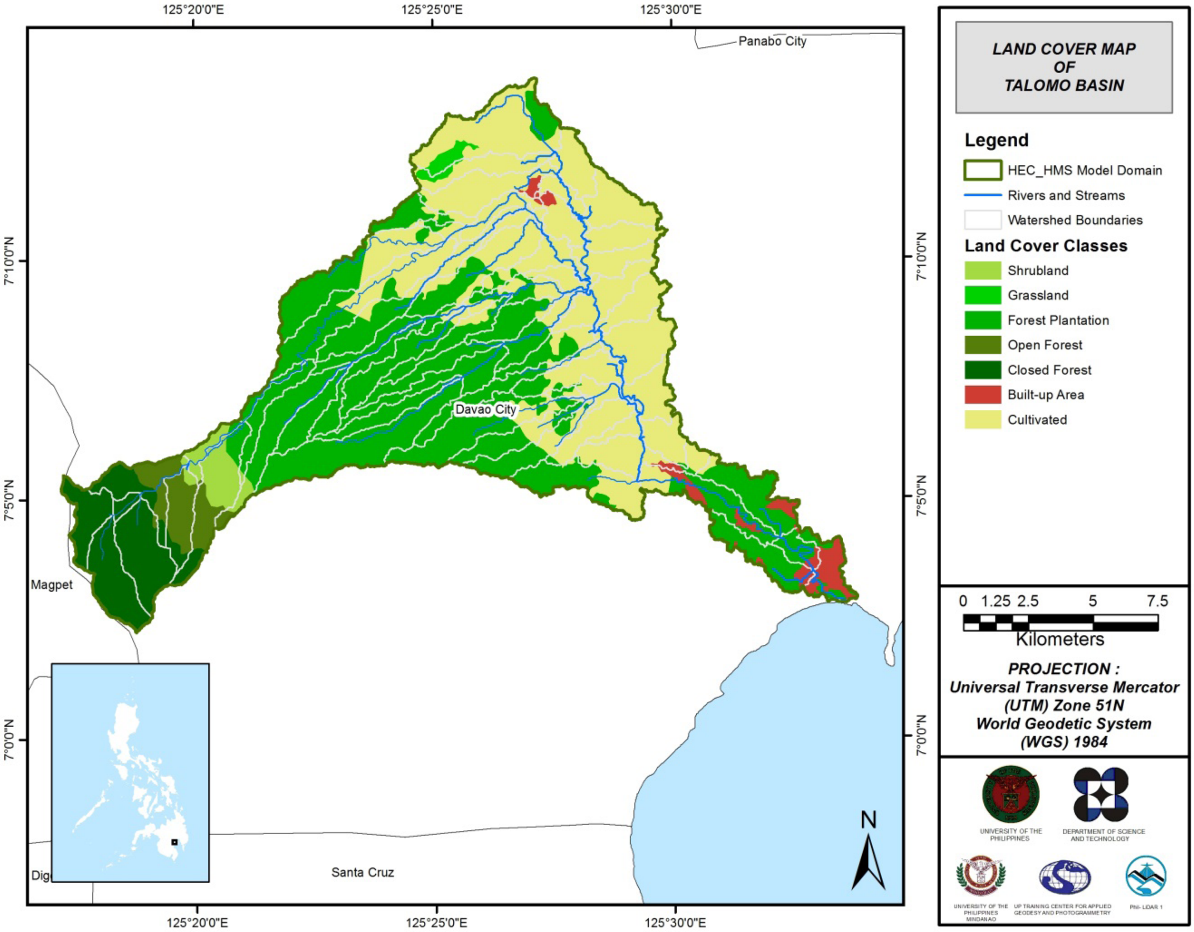



Figure 58. Land Cover Map of Talomo River Basin used for the estimation of the Curve Number (CN) and the watershed lag parameters of the rainfall-runoff model.

For Talomo, three (3) soil classes were identified. These are clay, silty clay loam and undifferentiated land. Moreover, seven (7) land cover classes were identified. These are shrublands, grasslands, forest plantations, open forests, closed forests, built-up areas, and cultivated areas.

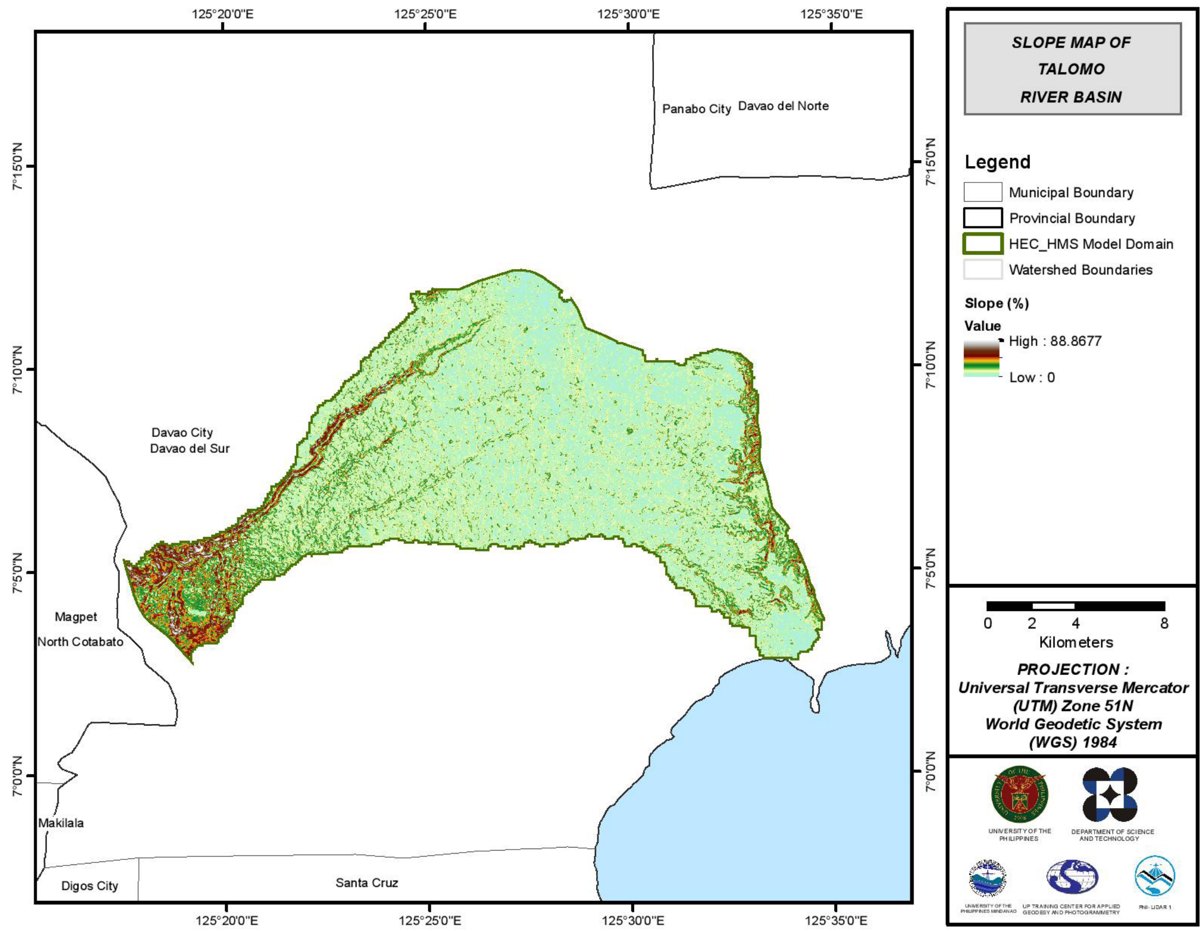



Figure 59. Slope Map of Talomo River Basin

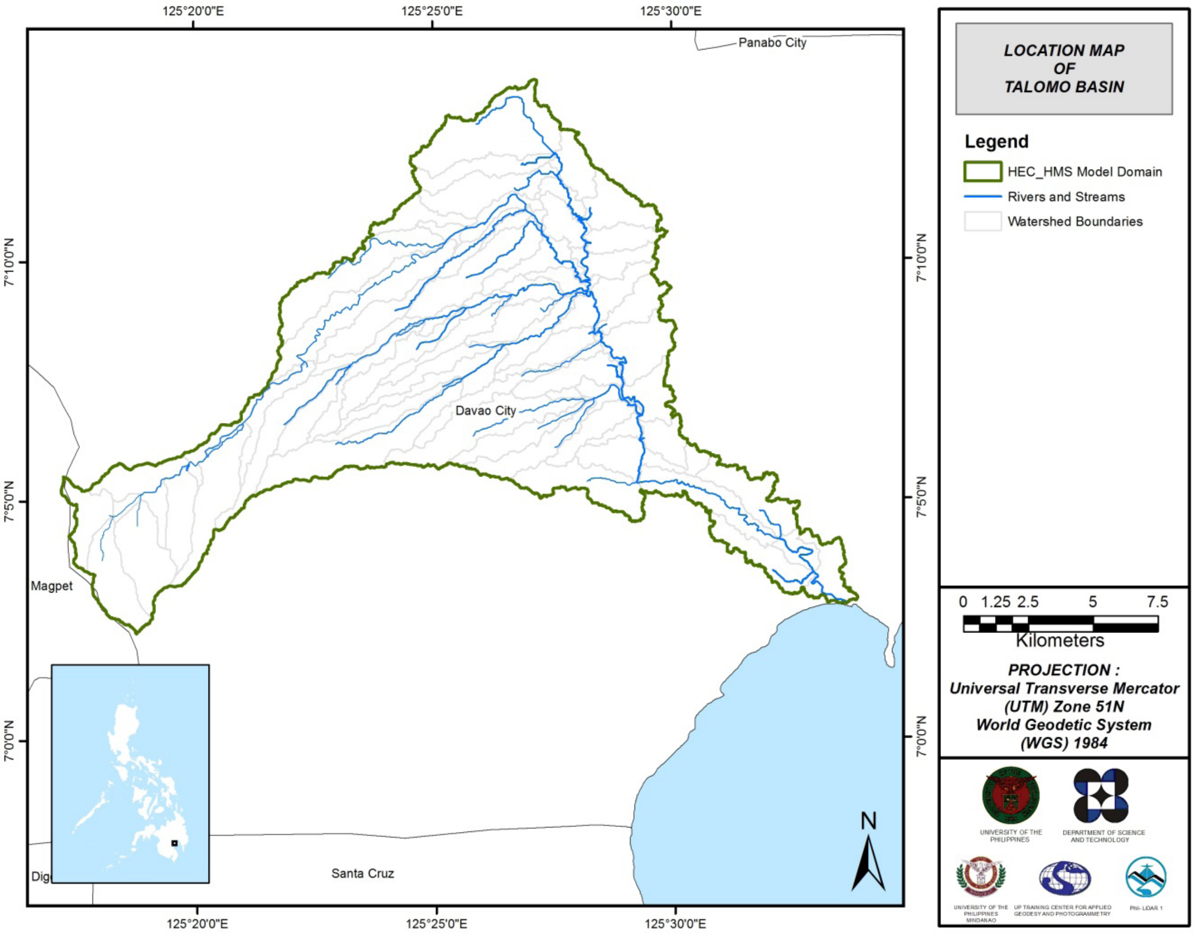



Figure 60. Stream Delineation Map of Talomo River Basin

Using the SAR-based DEM, the Talomo basin was delineated and further subdivided into subbasins. The model consists of 71 sub basins, 35 reaches, and 35 junctions, as shown in Figure 61. The main outlet is at Kalye Apike Bridge.

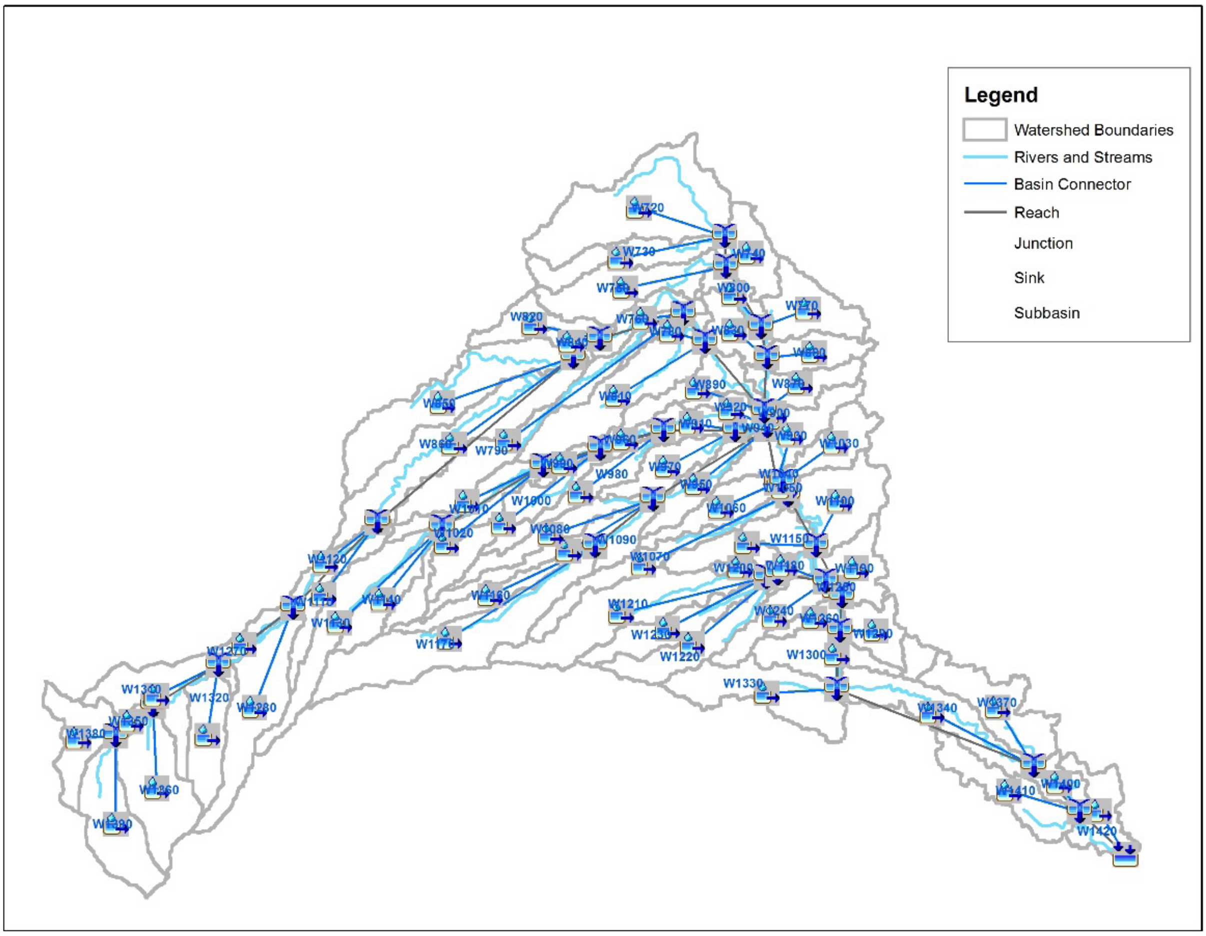



Figure 61. Talomo River Basin model generated in HEC-HMS

## 5.4 Cross-section Data

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

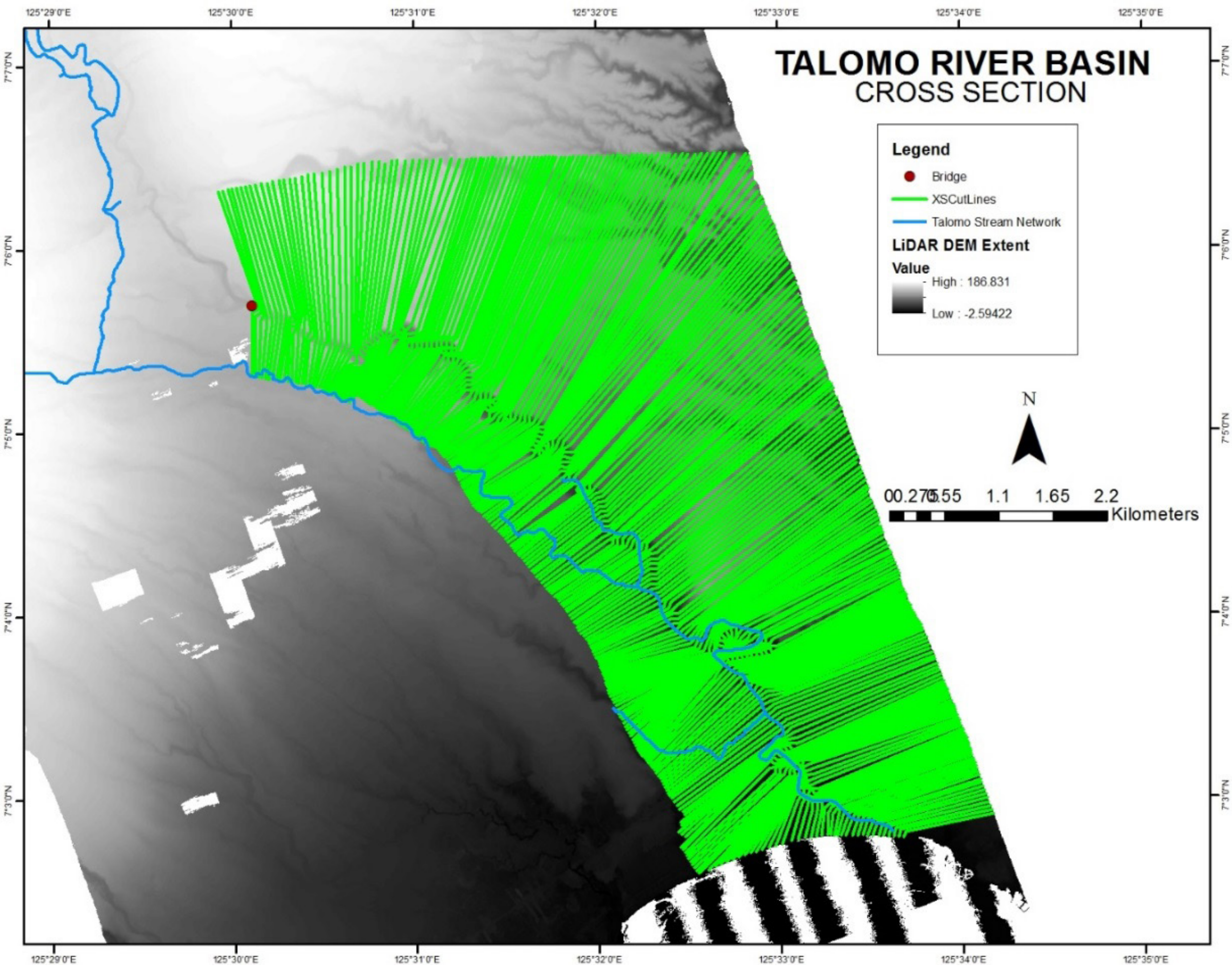



Figure 62. River cross-section of Talomo River generated through Arcmap HEC GeoRAS tool

## 5.5 Flo 2D Model

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

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

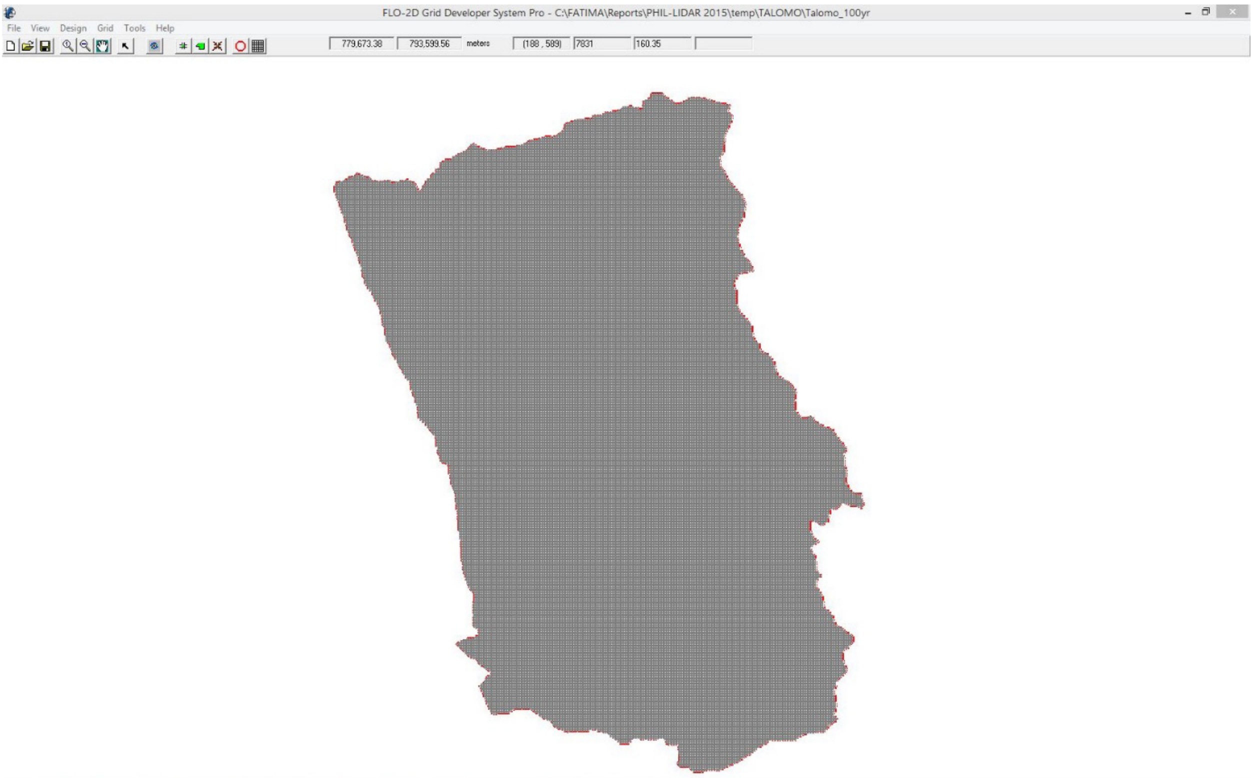



Figure 60. Screenshot of the river sub-catchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro)

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 14.54883 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m2/s. The generated hazard maps for Talomo are in Figures Figure 67, Figure 69, and Figure 71.

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 12824400.00 m2. The generated flood depth maps for Talomo are in Figures Figure 68, Figure 70, and Figure 72.

There is a total of 4156394.14 m3 of water entering the model. Of this amount, 4156394.14 m3 is due to rainfall while 0 m3 is inflow from other areas outside the model. 984200.00 m3 of this water is lost to infiltration and interception, while 878971.22 m3 is stored by the flood plain. The rest, amounting up to 2293222.86 m3, is outflow.

## 5.6 Results of HMS Calibration

After calibrating the Talomo HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 64 shows the comparison between the two discharge data.

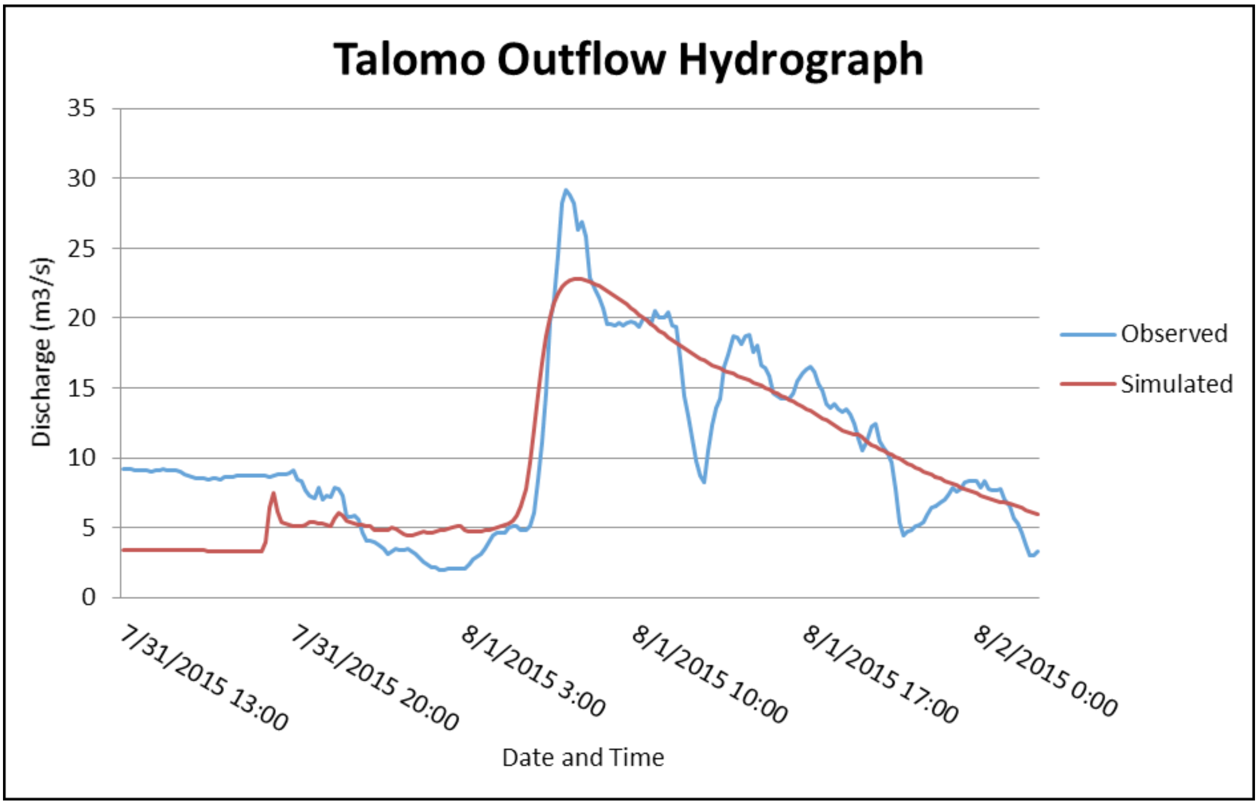



Figure 64. Outflow hydrograph of Talomo produced by the HEC-HMS model compared with observed outflow

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

Table 29. Range of calibrated values for the Talomo River Basin.

| Hydrologic Element | Calculation Type | Method | Parameter | Range of Calibrated Values |
|---|---|---|---|---|
| Basin | Loss | SCS Curve number | Initial Abstraction (mm) | 1.86 – 19.726 |
| | | | Curve Number | 37.68 – 99 |
| | Transform | Clark Unit Hydrograph | Time of Concentration (hr) | 0.02 – 0.07 |
| | | | Storage Coefficient (hr) | 0.024 – 0.069 |
| | Baseflow | Recession | Recession Constant | 0.0044 – 0.015 |
| | | | Ratio to Peak | 0.327 – 0.75 |
| Reach | Routing | Muskingum-Cunge | Manning's Coefficient | 0.19012 |

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 1.86 mm to 19.726 mm means that there is a small initial fraction of the storm depth after which runoff begins, increasing the river outflow.

The curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 65 to 90 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For Talomo, the basin consists mainly of forest plantations and cultivated areas and the soil consists of mostly undifferentiated land and clay.

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.02 hours to 0.07 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 values within the range of 0.0044 to 0.015 indicate that the basin is highly likely to quickly go back to its original discharge. Values of ratio to peak within the range of 0.327 to 0.75 indicate an average receding limb of the outflow hydrograph.

Manning's roughness coefficients correspond to the common roughness of Philippine watersheds. Talomo river basin reaches' Manning's coefficient is 0.19012, showing that the catchment is filled with rough surfaces that impede flow and runoff. (Brunner, 2010).

Table 30. Summary of the Efficiency Test of the Talomo HMS Model

| Accuracy measure | Value |
|---|---|
| RMSE | 3.3 |
| r2 | 0.751 |
| NSE | 0.73 |
| PBIAS | 5.61 |
| RSR | 0.52 |

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 3.3 m3/s.

The Pearson correlation coefficient (r2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.751.

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 0.73

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 5.61.

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 0.52.

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

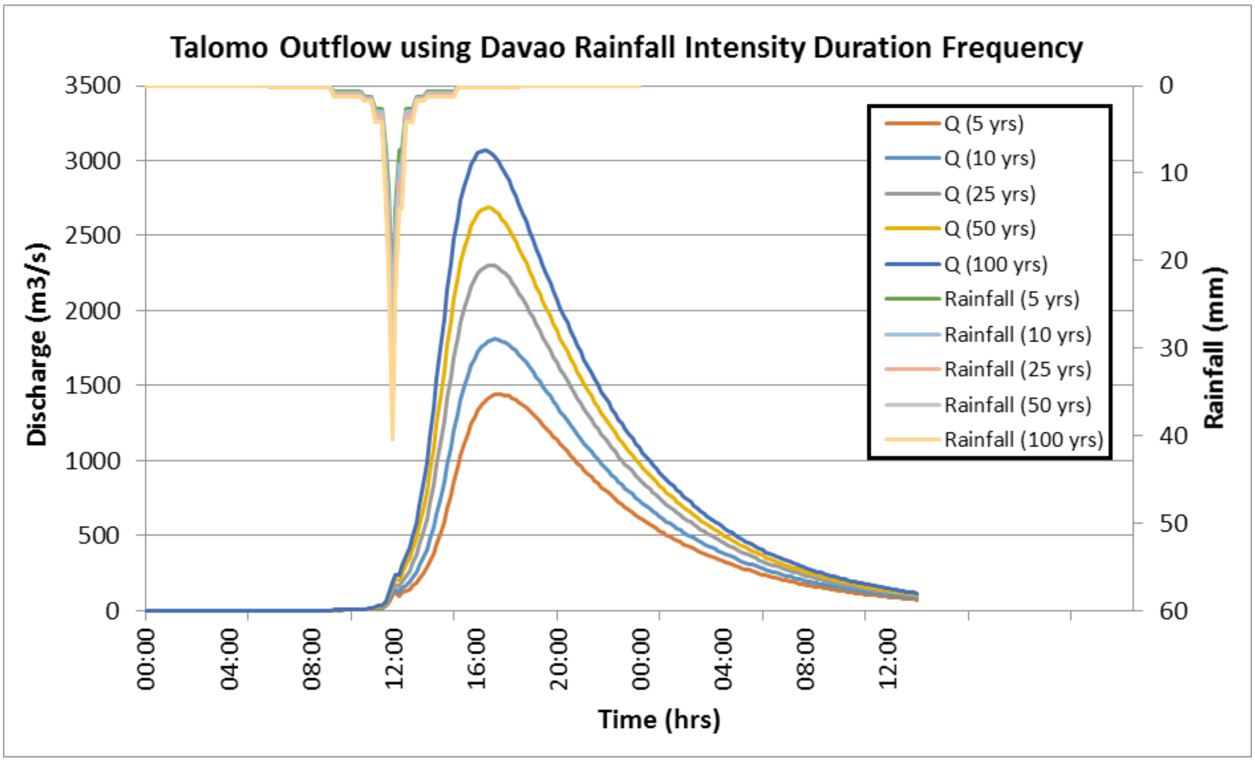



Figure 65. Outflow hydrograph at Talomo Station generated using the Davao RIDF simulated in HEC-HMS.

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

Table 31. Peak values of the Talomo HEC-HMS Model outflow using the Davao RIDF 24-hour values.

| RIDF Period | Total Precipitation (mm) | Peak rainfall (mm) | Peak outflow (m 3/s) | Time to Peak |
|---|---|---|---|---|
| 5-Year | 121.1 | 25.1 | 1442.7 | 5 hours, 10 minutes |
| 10-Year | 140.7 | 28.8 | 1810.3 | 5 hours |
| 25-Year | 165.5 | 33.5 | 2304.8 | 4 hours, 50 minutes |
| 50-Year | 183.9 | 37 | 2686.3 | 4 hours, 40 minutes |
| 100-Year | 202.1 | 40.5 | 3070.5 | 4 hour, 30 minutes |

## 5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. For this publication, only a sample output map river was to be shown. The sample generated map of Talomo River using the calibrated HMS base flow is shown in Figure 66.

Figure 66. Sample output map of Talomo RAS Model

## 5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. The 5-, 25-, and 100-year rain return scenarios of the Talomo floodplain are shown in Figure 67 to Figure 72. The floodplain, with an area of 31.24 sq. km., covers only one muncipality. Table 32 shows the percentage of area affected by flooding per municipality/ city.

Table 32. Municipalities/ cities affected in Talomo Floodplain

| Province | Municipality/ City | Total Area | Area Flooded | % Flooded |
|---|---|---|---|---|
| Davao del Sur | Davao City | 2224.82 | 31.24 | 1.4% |

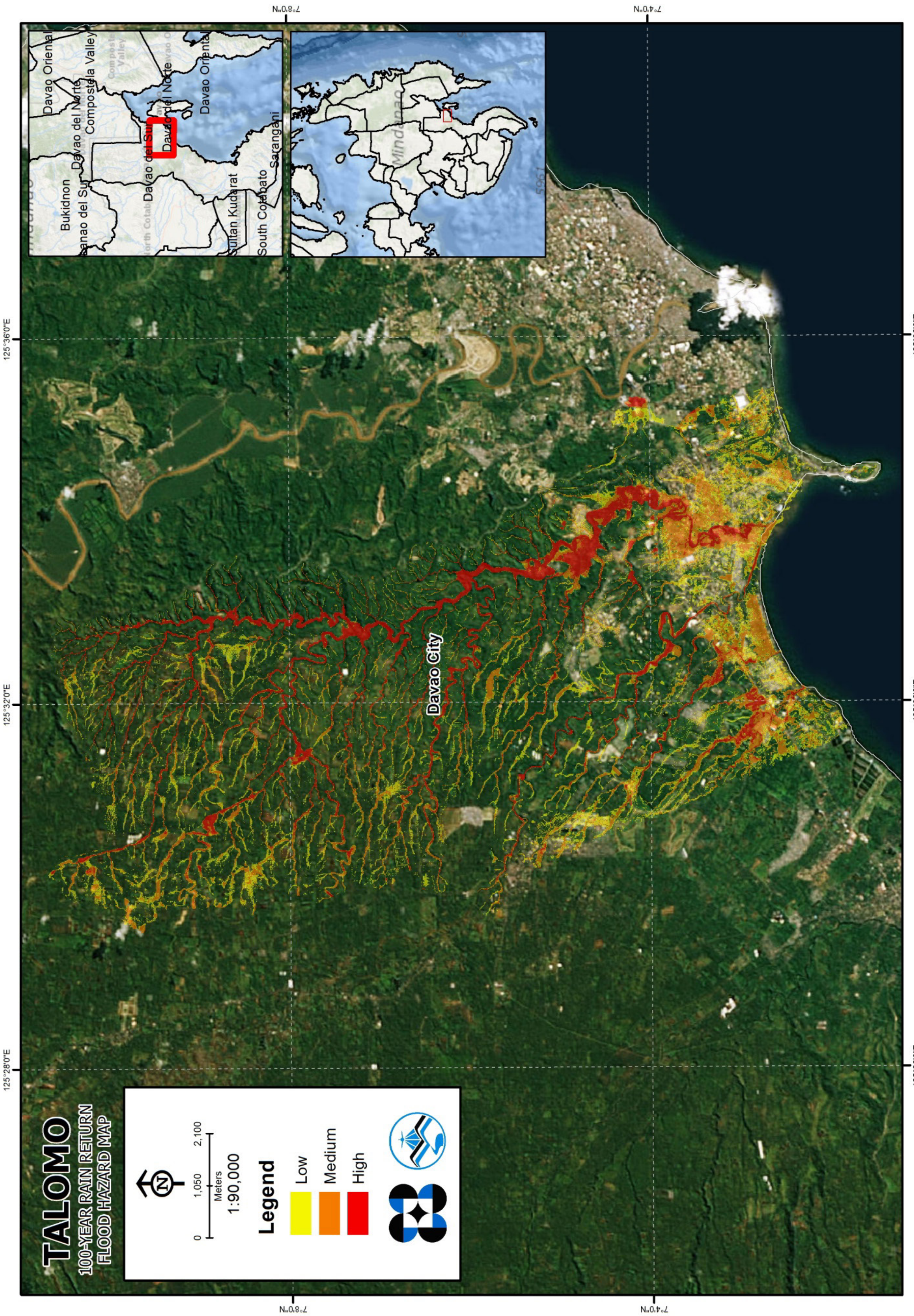



Figure 67. 100-year Flood Hazard Map for Talomo Floodplain overlaid on Google Earth imagery

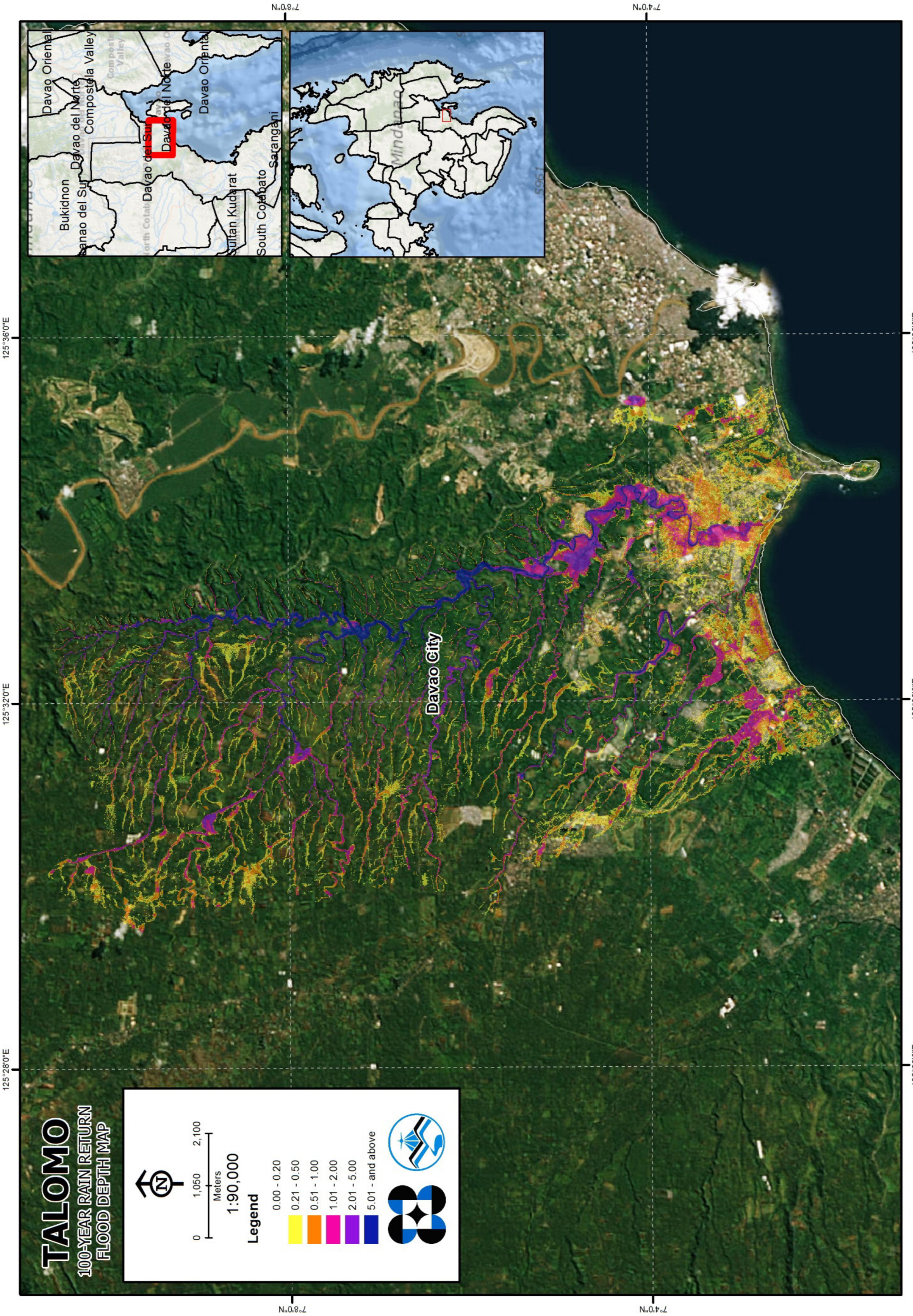



Figure 68. 100-year Flow Depth Map for Talomo Floodplain overlaid on Google Earth imagery

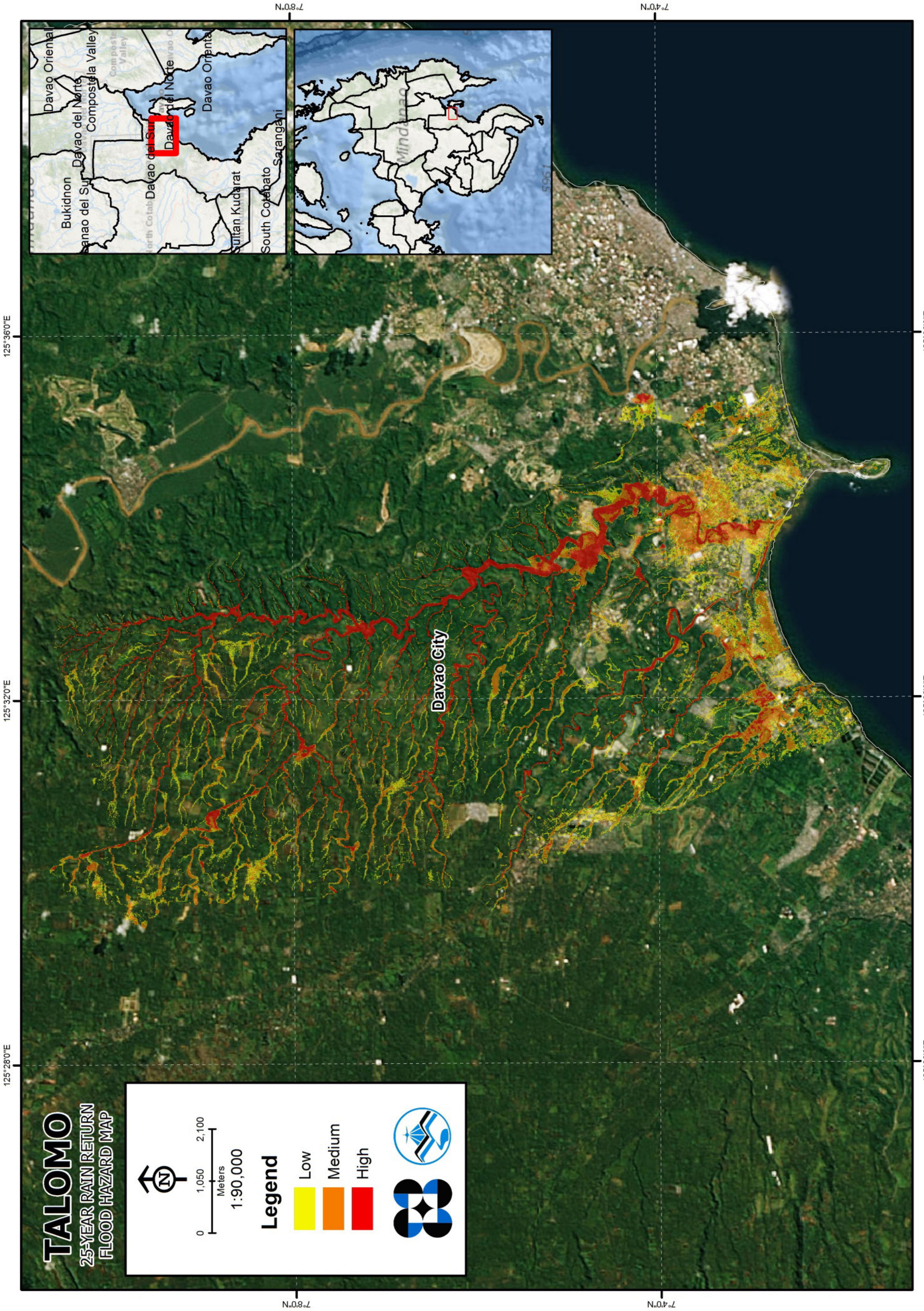



Figure 69. 25-year Flood Hazard Map for Talomo Floodplain overlaid on Google Earth imagery

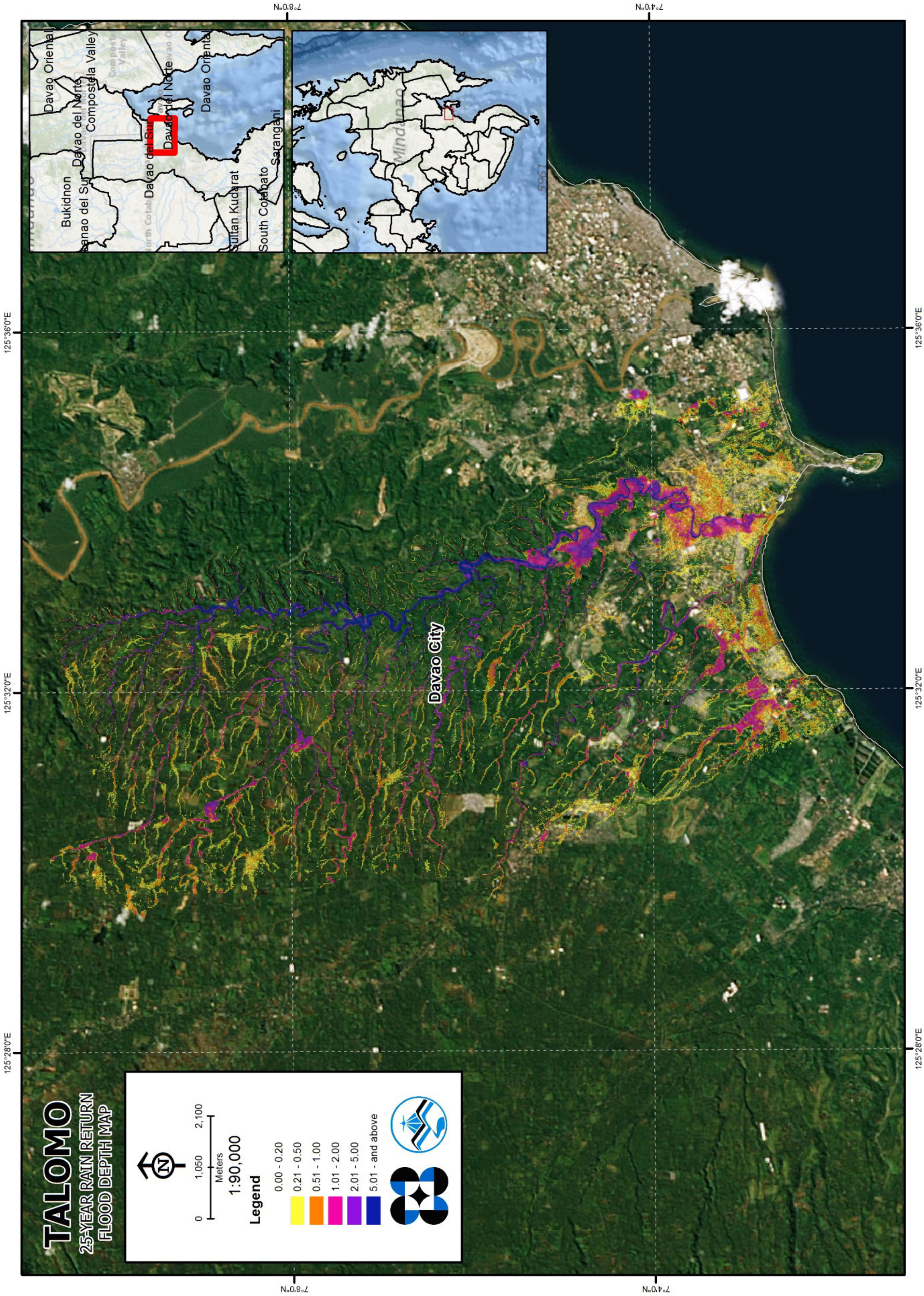



Figure 70. 25-year Flow Depth Map for Talomo Floodplain overlaid on Google Earth imagery

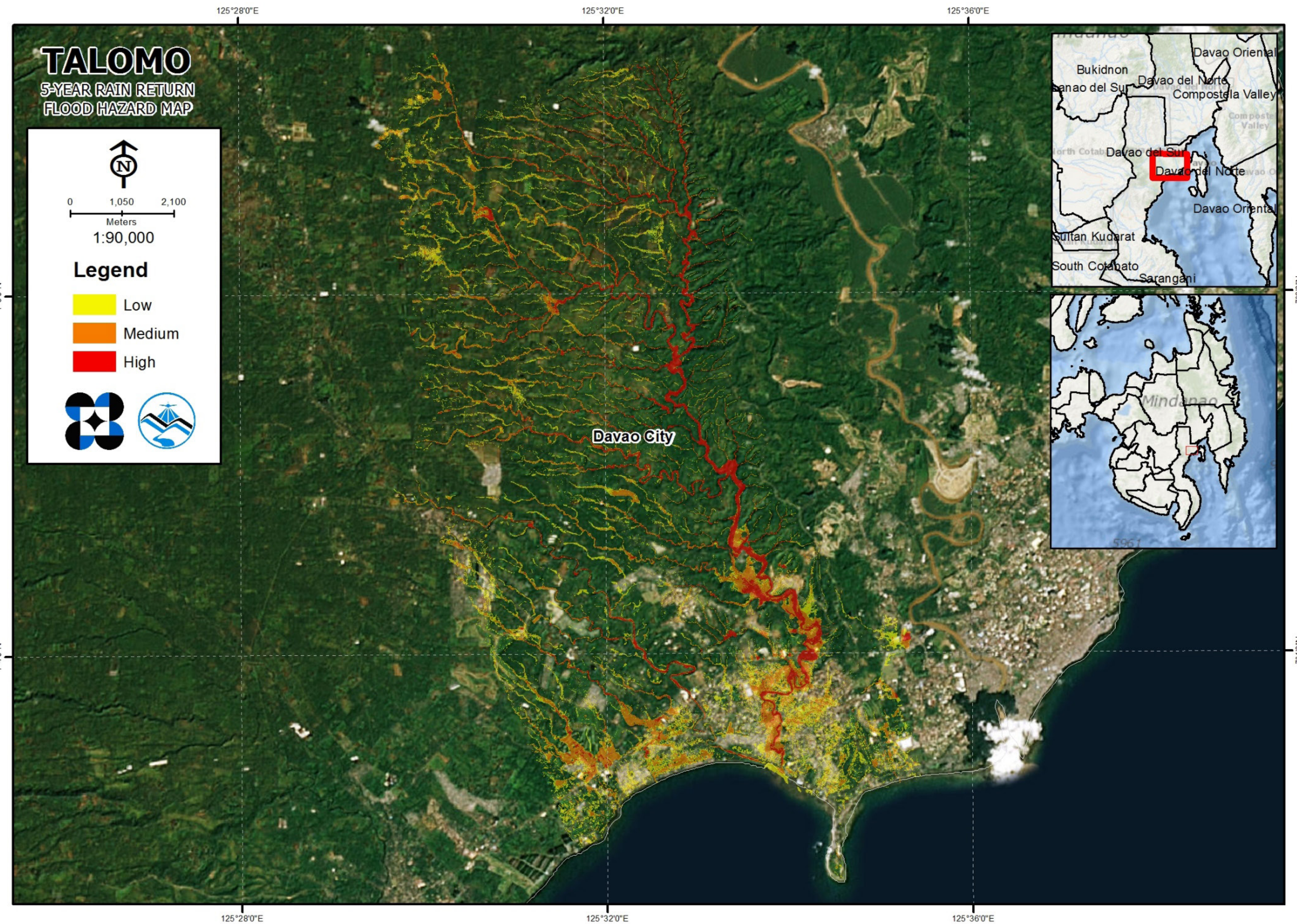



Figure 71. 5-year Flood Hazard Map for Talomo Floodplain overlaid on Google Earth imagery

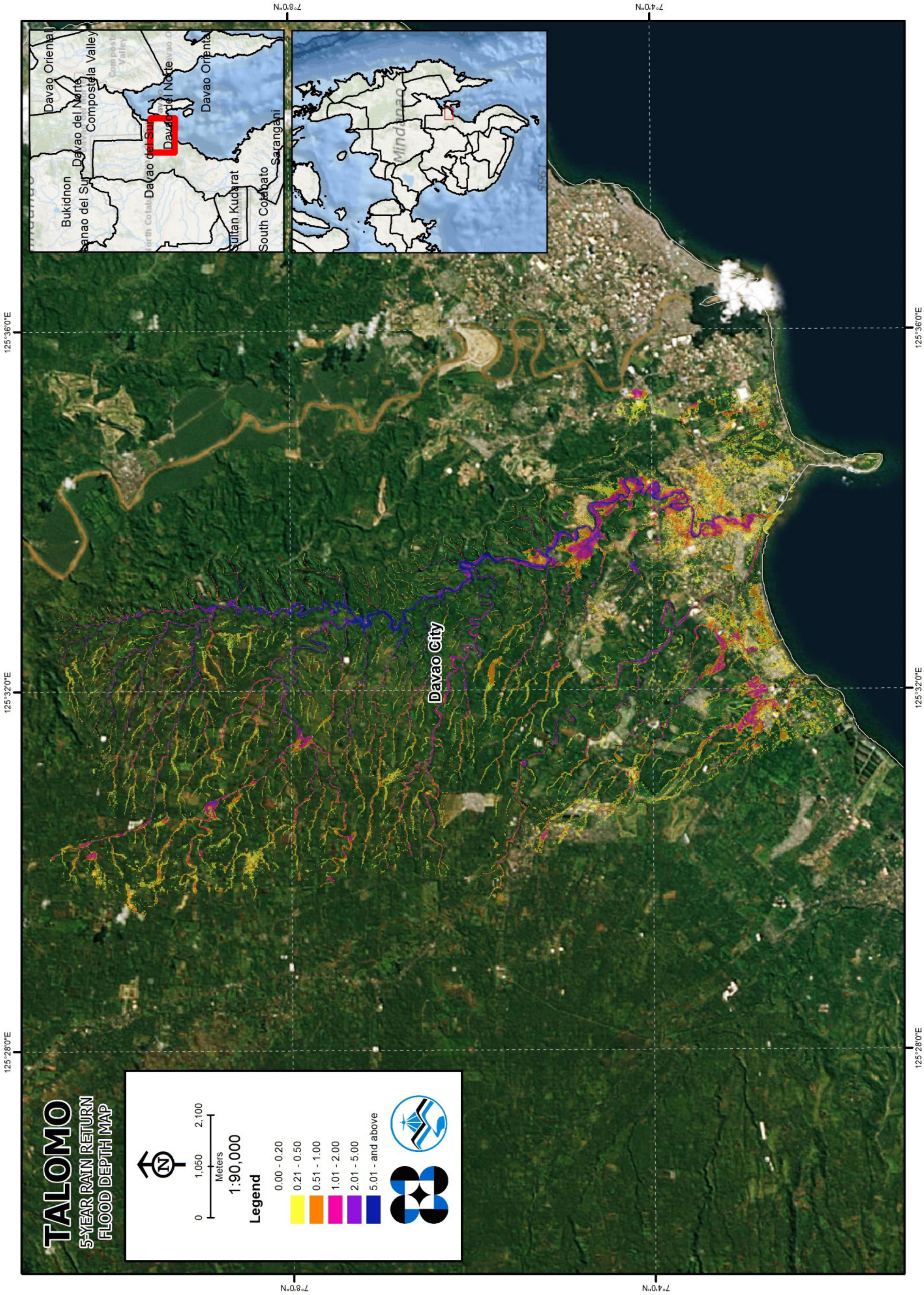



Figure 72. 5-year Flood Depth Map for Talomo Floodplain overlaid on Google Earth imagery

## 5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Talomo river basin, grouped by municipality, are listed below. For the said basin, only one municipality consisting of 22 barangays are expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 2.69% of the municipality of Davao City with an area of 2224.82 sq. km. will experience flood levels of less than 0.20 meters. 0.18% of the area will experience flood levels of 0.21 to 0.50 meters while 0.08%, 0.06%, 0.04%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 33 and Table 34, and shown in Figure 73 and Figure 74 are the affected areas in square kilometres by flood depth per barangay.

Table 33. Affected areas in Davao City, Davao del Sur during a 5-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth (in m.) | Area of affected barangays in Davao City (in sq. km.) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Bago Gallera | Bago Oshiro | Callawa | Catalunan Grande | Catalunan Pequeño | Langub | Ma-A | Mandug | Matina Aplaya | Matina Biao | Matina Crossing |
| **0.03-0.20** | 0.9 | 0.084 | 4.93 | 4.69 | 2.28 | 5.7 | 0.74 | 0.19 | 2.69 | 2.29 | 2.29 |
| **0.21-0.50** | 0.047 | 0.0037 | 0.2 | 0.2 | 0.11 | 0.25 | 0.13 | 0.003 | 0.43 | 0.083 | 0.39 |
| **0.51-1.00** | 0.016 | 0.0023 | 0.092 | 0.15 | 0.072 | 0.19 | 0.03 | 0.0021 | 0.066 | 0.06 | 0.07 |
| **1.01-2.00** | 0.015 | 0.00066 | 0.067 | 0.12 | 0.054 | 0.14 | 0.03 | 0.0019 | 0.0031 | 0.051 | 0.012 |
| **2.01-5.00** | 0.036 | 0 | 0.046 | 0.046 | 0.03 | 0.21 | 0.0017 | 0.0003 | 0 | 0.034 | 0.00078 |
| **> 5.00** | 0.00036 | 0 | 0.0042 | 0.0015 | 0.0031 | 0.054 | 0 | 0 | 0 | 0.0052 | 0 |

Table 34. Affected areas in Davao City, Davao del Sur during a 5-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth (in m.) | Area of affected barangays in Davao City (in sq. km.) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Matina Pangi | Mintal | New Carmen | New Valencia | Pangyan | Santo Niño | Tacunan | Talandang | Talomo | Ula | Waan |
| **0.03-0.20** | 1.55 | 1.27 | 5.95 | 3.08 | 0.12 | 0.45 | 10.99 | 0.95 | 4.01 | 0.49 | 4.14 |
| **0.21-0.50** | 0.18 | 0.051 | 0.26 | 0.12 | 0.0017 | 0.024 | 0.58 | 0.038 | 0.76 | 0.022 | 0.11 |
| **0.51-1.00** | 0.11 | 0.024 | 0.099 | 0.077 | 0.0006 | 0.012 | 0.33 | 0.019 | 0.32 | 0.0078 | 0.066 |
| **1.01-2.00** | 0.12 | 0.018 | 0.11 | 0.046 | 0.0001 | 0.0039 | 0.18 | 0.0067 | 0.21 | 0.0033 | 0.053 |
| **2.01-5.00** | 0.068 | 0.0024 | 0.089 | 0.022 | 0 | 0 | 0.081 | 0 | 0.13 | 0.0002 | 0.12 |
| **> 5.00** | 0.0036 | 0 | 0.001 | 0.00025 | 0 | 0 | 0.019 | 0 | 0.0067 | 0 | 0.046 |

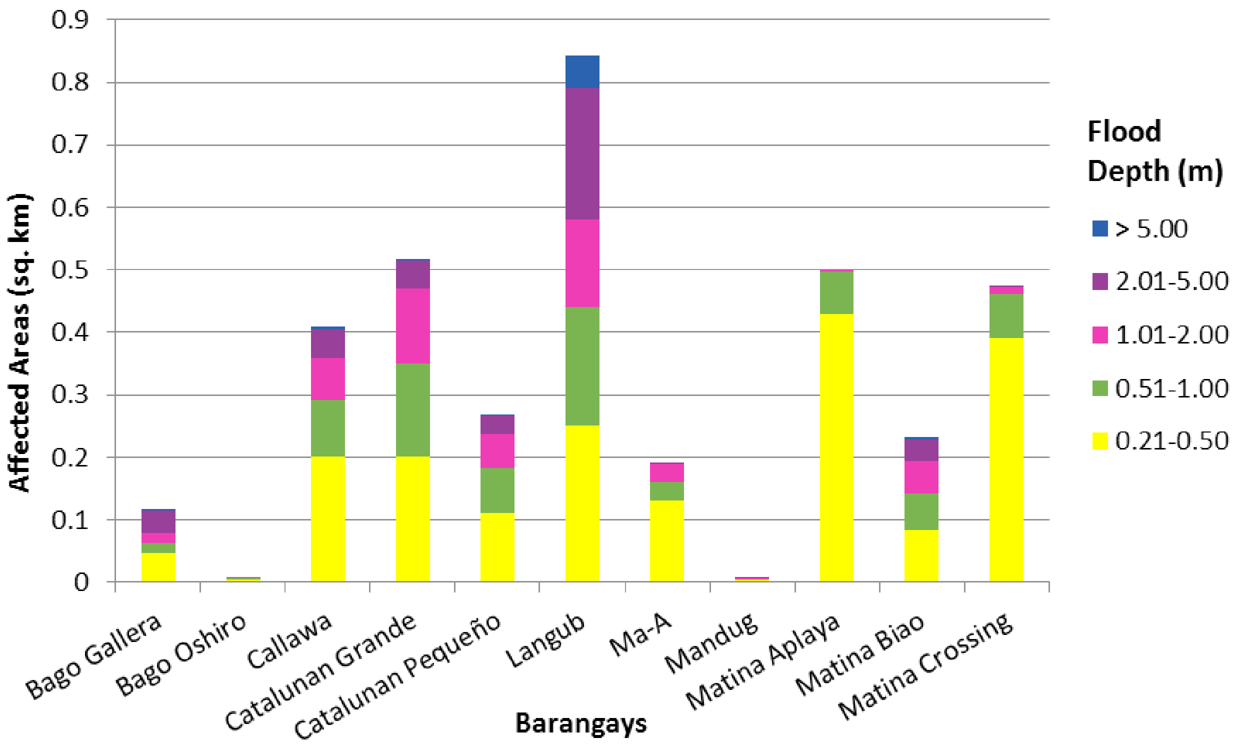



Figure 73. Affected Areas in Davao City, Davao del Sur during 5-Year Rainfall Return Period

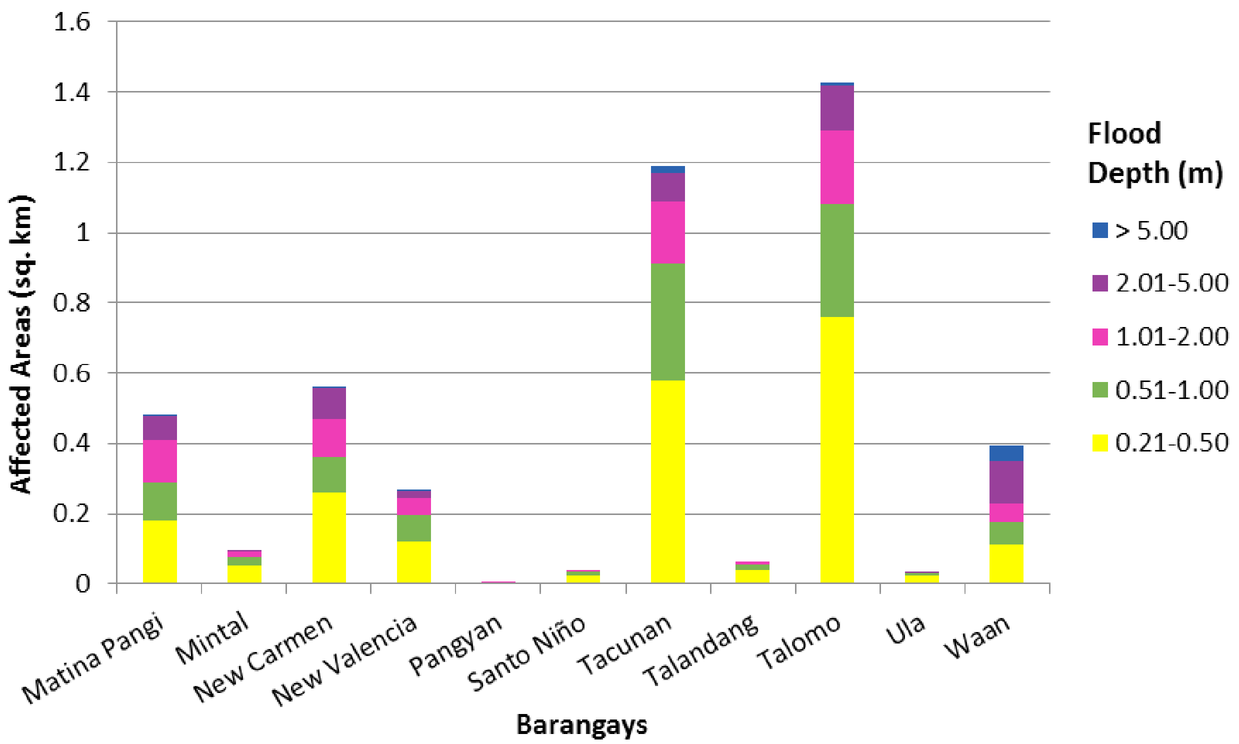



Figure 74. Affected Areas in Davao City, Davao del Sur during 5-Year Rainfall Return Period

For the 25-year return period, 2.57% of the municipality of Davao City with an area of 2224.82 sq. km. will experience flood levels of less than 0.20 meters. 0.22% of the area will experience flood levels of 0.21 to 0.50 meters while 0.11%, 0.08%, 0.06%, 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 Table 35 and Table 36, and shown in Figure 75 and Figure 76 are the affected areas in square kilometres by flood depth per barangay.

Table 35. Affected areas in Davao City, Davao del Sur during a 25-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth (in m.) | Area of affected barangays in Davao City (in sq. km.) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Bago Gallera | Bago Oshiro | Callawa | Catalunan Grande | Catalunan Pequeño | Langub | Ma-A | Mandug | Matina Aplaya | Matina Biao | Matina Crossing |
| **0.03-0.20** | 0.84 | 0.082 | 4.84 | 4.55 | 2.18 | 5.48 | 0.67 | 0.19 | 2.39 | 2.25 | 2.09 |
| **0.21-0.50** | 0.063 | 0.0042 | 0.24 | 0.25 | 0.16 | 0.26 | 0.16 | 0.0036 | 0.67 | 0.089 | 0.51 |
| **0.51-1.00** | 0.029 | 0.0032 | 0.1 | 0.16 | 0.076 | 0.27 | 0.04 | 0.0019 | 0.12 | 0.066 | 0.14 |
| **1.01-2.00** | 0.028 | 0.00066 | 0.083 | 0.16 | 0.083 | 0.19 | 0.039 | 0.0023 | 0.012 | 0.058 | 0.027 |
| **2.01-5.00** | 0.041 | 0.000099 | 0.069 | 0.072 | 0.049 | 0.26 | 0.02 | 0.0003 | 0 | 0.053 | 0.0029 |
| **> 5.00** | 0.014 | 0 | 0.009 | 0.0075 | 0.0087 | 0.095 | 0 | 0 | 0 | 0.012 | 0 |

Table 36. Affected areas in Davao City, Davao del Sur during a 25-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth (in m.) | Area of affected barangays in Davao City (in sq. km.) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Matina Pangi | Mintal | New Carmen | New Valencia | Pangyan | Santo Niño | Tacunan | Talandang | Talomo | Ula | Waan |
| **0.03-0.20** | 1.45 | 1.24 | 5.78 | 3.02 | 0.12 | 0.44 | 10.71 | 0.94 | 3.42 | 0.48 | 4.07 |
| **0.21-0.50** | 0.17 | 0.064 | 0.33 | 0.14 | 0.0022 | 0.03 | 0.64 | 0.043 | 0.98 | 0.028 | 0.13 |
| **0.51-1.00** | 0.14 | 0.03 | 0.11 | 0.085 | 0.00051 | 0.018 | 0.41 | 0.026 | 0.56 | 0.011 | 0.069 |
| **1.01-2.00** | 0.17 | 0.027 | 0.11 | 0.064 | 0.00029 | 0.0065 | 0.26 | 0.0087 | 0.28 | 0.0041 | 0.062 |
| **2.01-5.00** | 0.1 | 0.0076 | 0.12 | 0.035 | 0 | 0 | 0.13 | 0.0005 | 0.19 | 0.001 | 0.12 |
| **> 5.00** | 0.011 | 0 | 0.042 | 0.0014 | 0 | 0 | 0.037 | 0 | 0.022 | 0 | 0.099 |

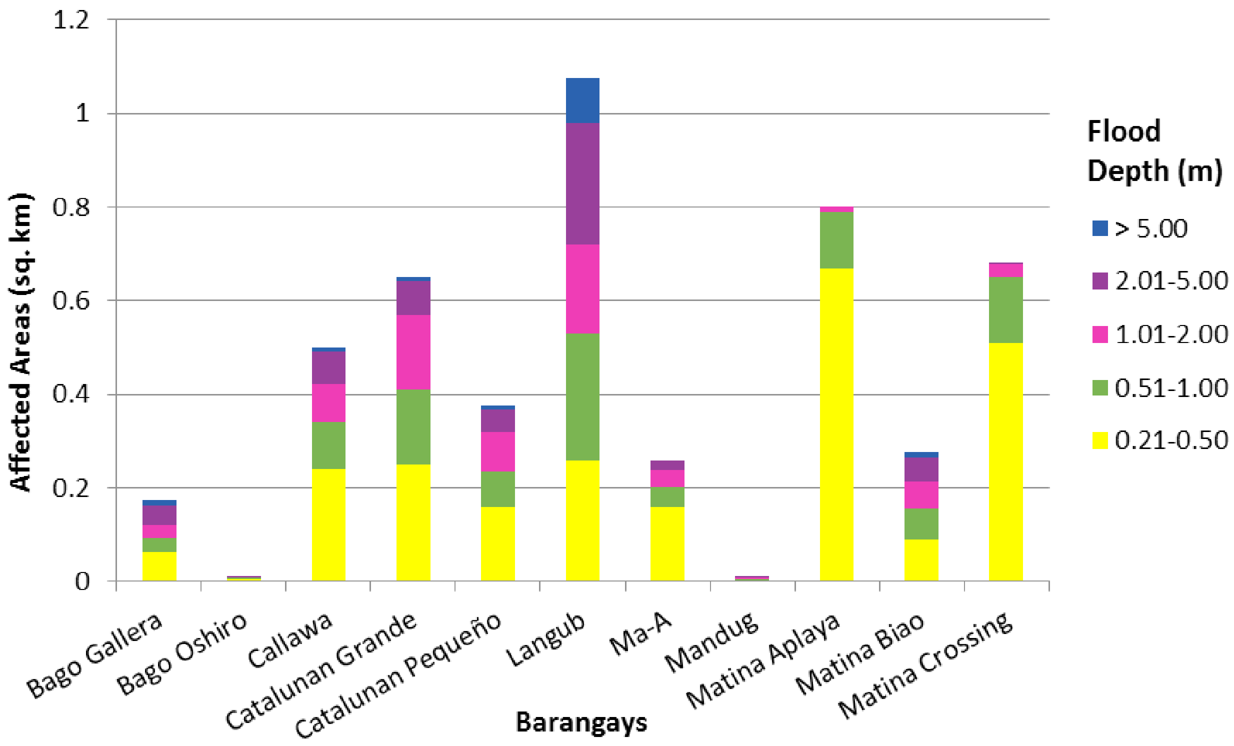



Figure 75. Affected Areas in Davao City, Davao del Sur during 25-Year Rainfall Return Period

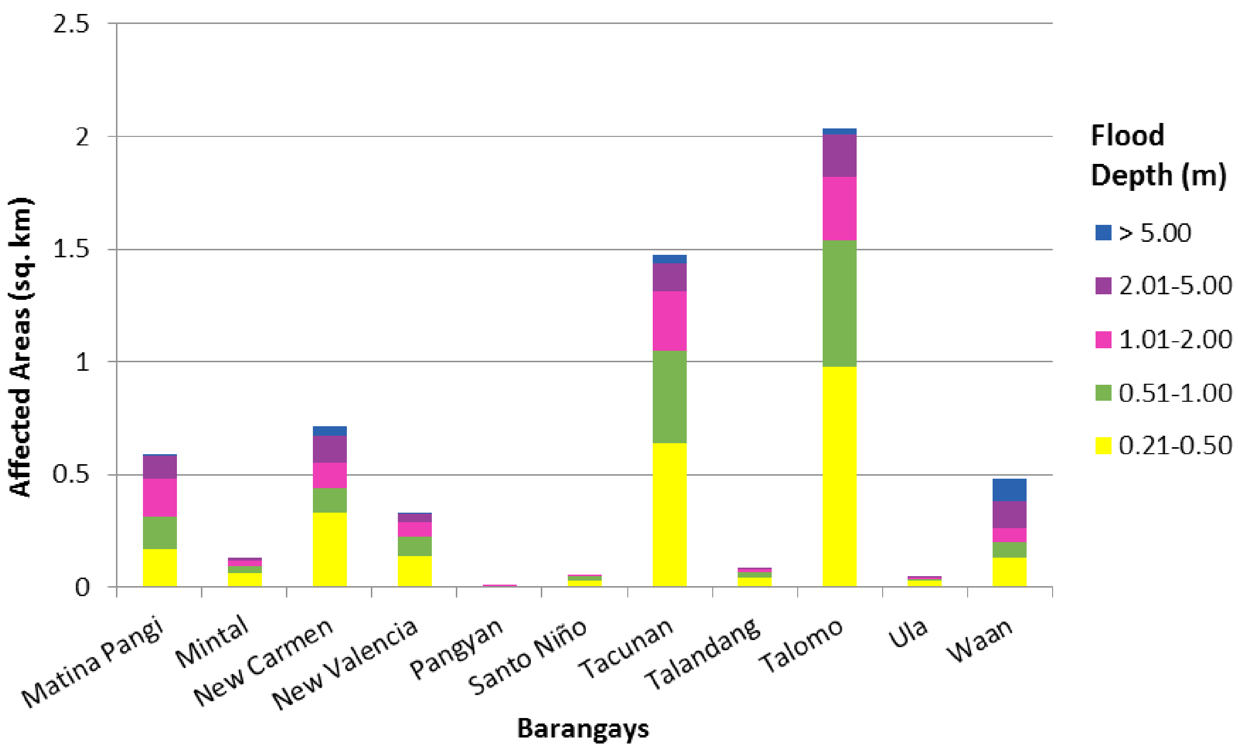



Figure 76. Affected Areas in Davao City, Davao del Sur during 25-Year Rainfall Return Period

For the 100-year return period, 2.50% of the municipality of Davao City with an area of 2224.82 sq. km. will experience flood levels of less than 0.20 meters. 0.24% of the area will experience flood levels of 0.21 to 0.50 meters while 0.13%, 0.09%, 0.07%, and 0.03% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 37 and Table 38, and shown in Figure 77 and Figure 78 are the affected areas in square kilometres by flood depth per barangay.

Table 37. Affected areas in Davao City, Davao del Sur during a 100-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth (in m.) | Area of affected barangays in Davao City (in sq. km.) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Bago Gallera | Bago Oshiro | Callawa | Catalunan Grande | Catalunan Pequeño | Langub | Ma-A | Mandug | Matina Aplaya | Matina Biao | Matina Crossing |
| **0.03-0.20** | 0.78 | 0.08 | 4.77 | 4.45 | 2.12 | 5.37 | 0.63 | 0.19 | 2.18 | 2.22 | 1.97 |
| **0.21-0.50** | 0.066 | 0.006 | 0.27 | 0.28 | 0.18 | 0.24 | 0.18 | 0.0044 | 0.82 | 0.089 | 0.55 |
| **0.51-1.00** | 0.045 | 0.003 | 0.11 | 0.18 | 0.085 | 0.26 | 0.048 | 0.0017 | 0.18 | 0.073 | 0.21 |
| **1.01-2.00** | 0.047 | 0.0012 | 0.085 | 0.18 | 0.089 | 0.24 | 0.04 | 0.0026 | 0.021 | 0.06 | 0.036 |
| **2.01-5.00** | 0.051 | 0.000099 | 0.086 | 0.099 | 0.066 | 0.29 | 0.035 | 0.0003 | 0 | 0.063 | 0.004 |
| **> 5.00** | 0.023 | 0 | 0.015 | 0.019 | 0.014 | 0.13 | 0 | 0 | 0 | 0.02 | 0 |

Table 38. Affected areas in Davao City, Davao del Sur during a 100-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth (in m.) | Area of affected barangays in Davao City (in sq. km.) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Matina Pangi | Mintal | New Carmen | New Valencia | Pangyan | Santo Niño | Tacunan | Talandang | Talomo | Ula | Waan |
| **0.03-0.20** | 1.4 | 1.21 | 5.67 | 2.99 | 0.11 | 0.42 | 10.53 | 0.93 | 3.07 | 0.47 | 4.02 |
| **0.21-0.50** | 0.16 | 0.076 | 0.39 | 0.15 | 0.0023 | 0.037 | 0.68 | 0.044 | 0.97 | 0.031 | 0.13 |
| **0.51-1.00** | 0.11 | 0.035 | 0.12 | 0.087 | 0.00071 | 0.021 | 0.45 | 0.031 | 0.76 | 0.013 | 0.071 |
| **1.01-2.00** | 0.21 | 0.028 | 0.11 | 0.077 | 0.00029 | 0.0082 | 0.3 | 0.01 | 0.38 | 0.0048 | 0.066 |
| **2.01-5.00** | 0.14 | 0.014 | 0.13 | 0.041 | 0 | 0.0005 | 0.17 | 0.0012 | 0.23 | 0.0014 | 0.1 |
| **> 5.00** | 0.018 | 0 | 0.087 | 0.0042 | 0 | 0 | 0.054 | 0 | 0.033 | 0 | 0.15 |

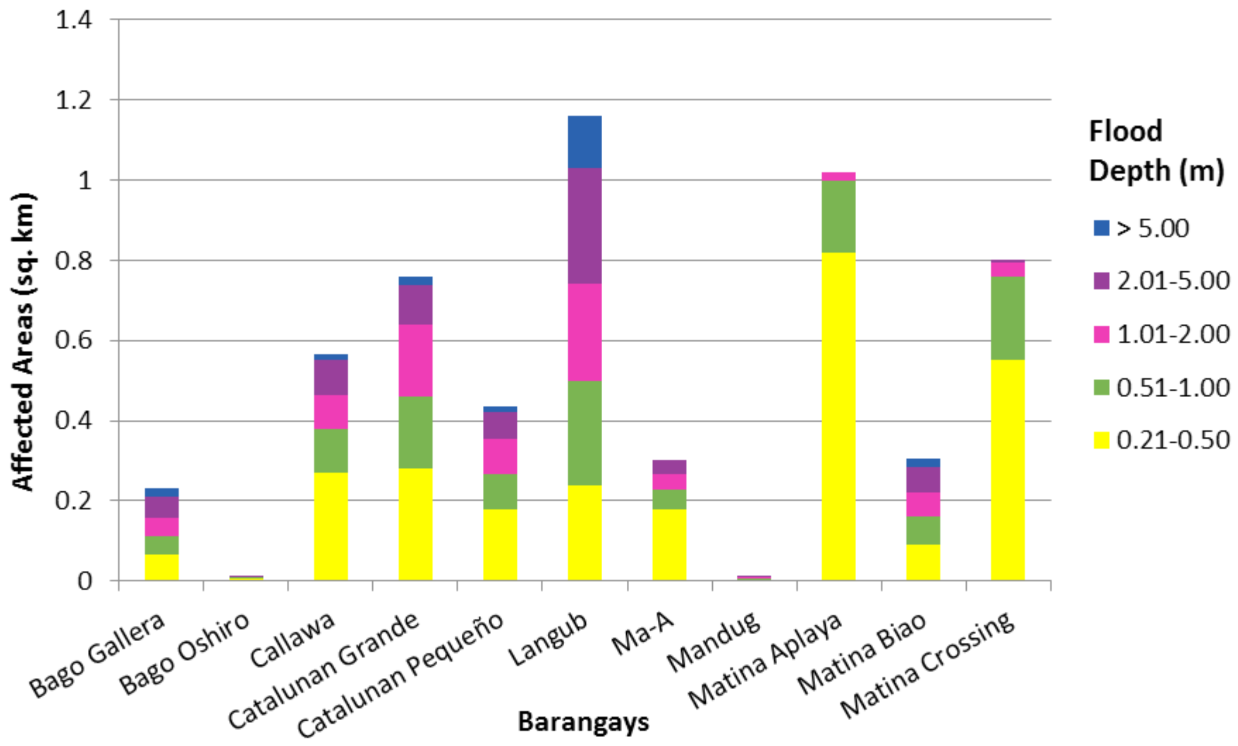



Figure 77. Affected Areas in Davao City, Davao del Sur during 100-Year Rainfall Return Period

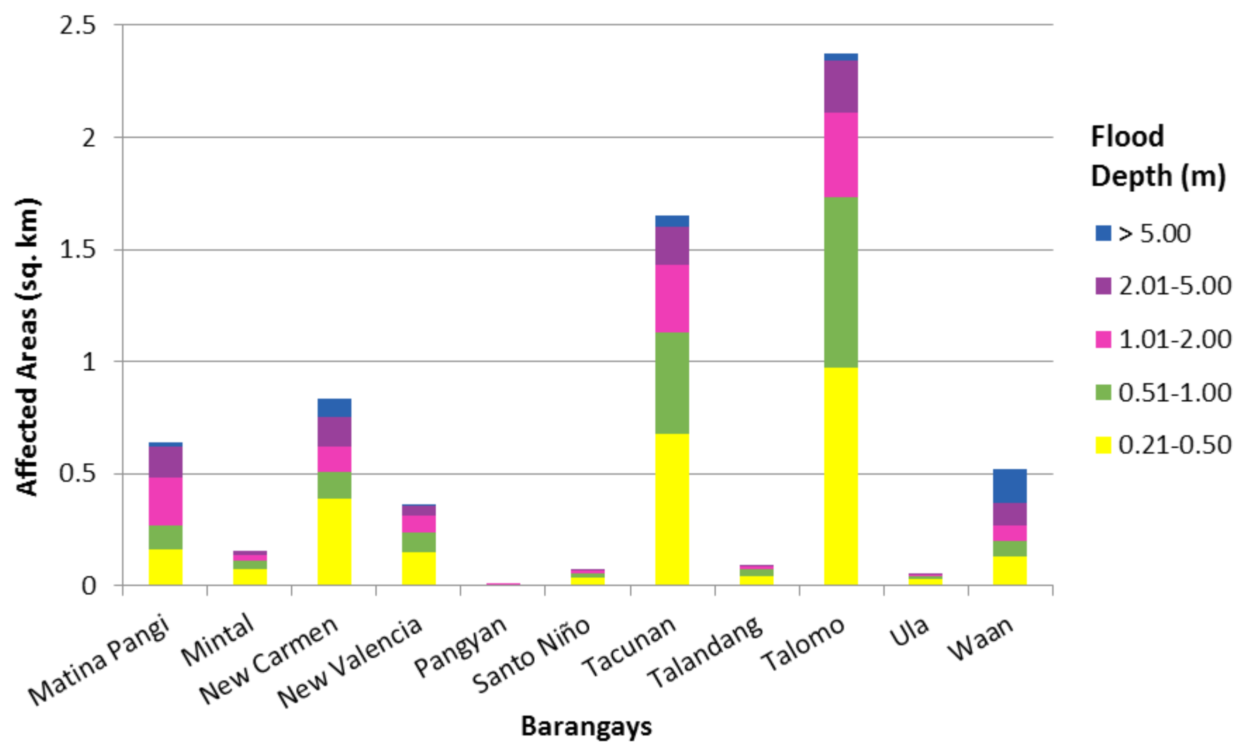



Figure 78. Affected Areas in Davao City, Davao del Sur during 100-Year Rainfall Return Period

Among the barangays in the municipality of Davao City in Davao del Sur, Tacunan is projected to have the highest percentage of area that will experience flood levels at 0.55%. Meanwhile, Langub posted the second highest percentage of area that may be affected by flood depths at 0.29%.

Moreover, the generated flood hazard maps for the Talomo Floodplain were used to assess the vulnerability of the educational and medical institutions in the floodplain. Using the flood depth units of PAGASA 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 39. Areas covered by each warning level with respect to the rainfall scenarios

| Warning Level | Area Covered in sq. km. | | |
|---|---|---|---|
| | 5 year | 25 year | 100 year |
| Low | 4.21 | 5.15 | 5.58 |
| Medium | 2.51 | 3.40 | 4.04 |
| High | 1.75 | 2.53 | 3.13 |
| **TOTAL** | **8.46** | **11.07** | **12.76** |

Of the 60 identified educational institutions in the Talomo floodplain, eight schools were assessed to be relatively prone to flooding as they are exposed to the Medium level flooding for all three rainfall scenarios. Four other institutions were found to be also susceptible to flooding, experiencing Low level flooding in the 5-year return period, and Medium level flooding in the 25- and 100-year rainfall scenarios. The educational institutions exposed to flooding are shown in Annex 12.

15 medical institutions were identified in the Talomo floodplain. 318 Phamacia King Inc. in Brgy. Matina Aplaya and Amboy Dental Clinic, Central Park Veterinary Clinic, and Farmacia Rowems in Brgy. Talomo were found to be relatively prone to flooding, having Low level flooding in all three rainfall scenarios. The medical institutions exposed to flooding are shown in Annex 13.

## 5.11 Flood Validation

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

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

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

After which, the actual data from the field was compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what was needed.

The flood validation survey was conducted on December 4-8, 2015. The flood validation consisted of 180 points randomly selected all over the Talomo flood plain. It had an RMSE value of 0.93.

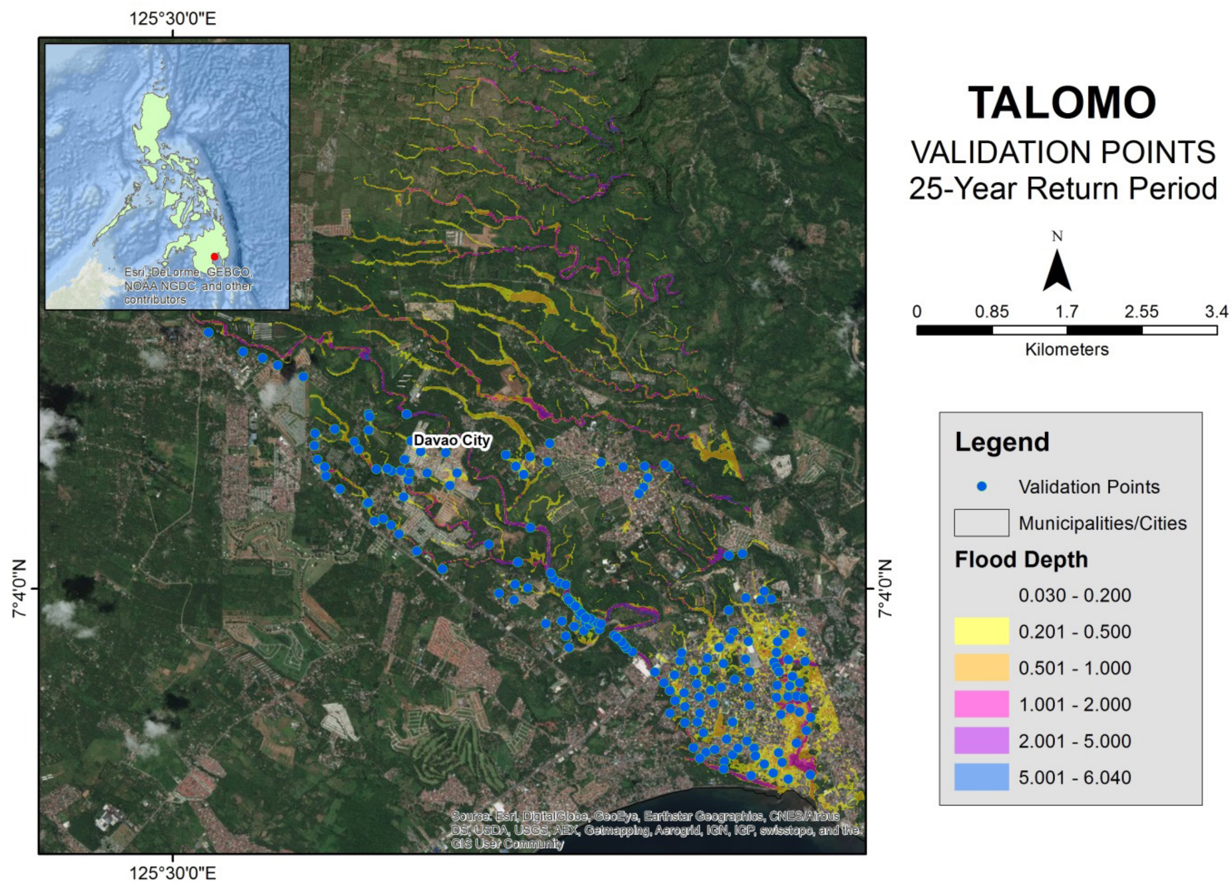



Figure 79. Talomo Flood Validation Points

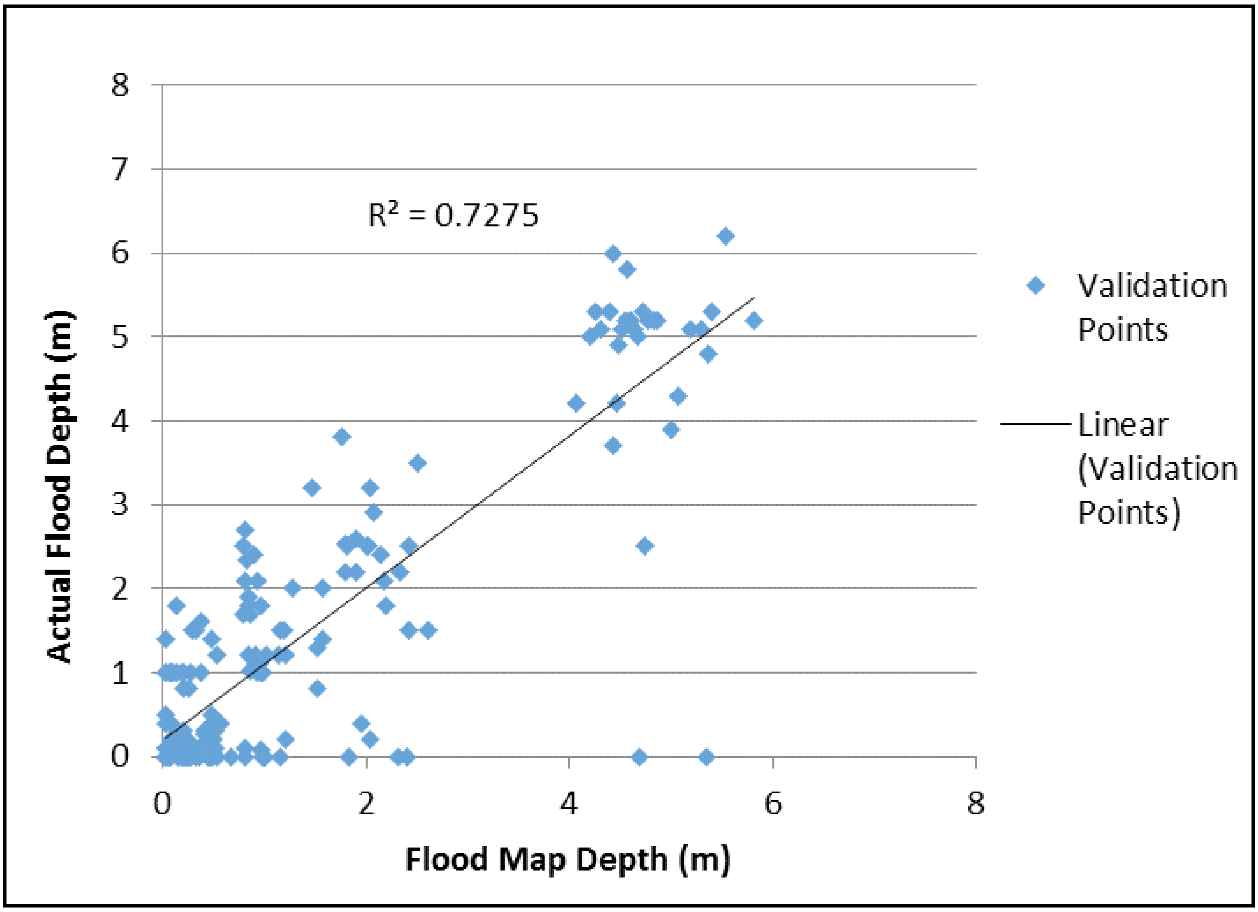



Figure 80. Flood map depth vs. actual flood depth

Table 40. Actual flood vs simulated flood depth at different levels in the Talomo River Basin.

| Actual Flood Depth (m) | Modeled Flood Depth (m) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0-0.20 | 0.21-0.50 | 0.51-1.00 | 1.01-2.00 | 2.01-5.00 | > 5.00 | Total |
| 0-0.20 | 27 | 25 | 8 | 4 | 4 | 1 | 69 |
| 0.21-0.50 | 4 | 8 | 2 | 1 | 0 | 0 | 15 |
| 0.51-1.00 | 8 | 5 | 3 | 1 | 0 | 0 | 17 |
| 1.01-2.00 | 2 | 4 | 11 | 9 | 3 | 0 | 29 |
| 2.01-5.00 | 0 | 0 | 6 | 7 | 16 | 3 | 32 |
| > 5.00 | 0 | 0 | 0 | 0 | 13 | 5 | 18 |
| Total | 41 | 42 | 30 | 22 | 36 | 9 | 180 |

The overall accuracy generated by the flood model is estimated at 37.78%, with 68 points correctly matching the actual flood depths. In addition, there were 74 points estimated one level above and below the correct flood depths while there were 27 points and 11 points estimated two levels above and below, and three or more levels above and below the correct flood depth. A total of 52 points were overestimated while a total of 60 points were underestimated in the modelled flood depths of Talomo. The summary of the accuracy assessment is presented in Table 41.

Table 41. Summary of the Accuracy Assessment in the Talomo River Basin Survey

| | No. of Points | % |
|---|---|---|
| Correct | 68 | 37.78 |
| Overestimated | 52 | 28.89 |
| Underestimated | 60 | 33.33 |
| Total | 180 | 100 |

# REFERENCES


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

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

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

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

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

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

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

# ANNEXES

## Annex 1. Optech Technical Specification of the Gemini Sensor


Figure A-1.1. Parameters and Specification of the Gemini Sensor

Table A-1.1. Parameters and Specification of the Gemini Sensor

| Parameter | Specification |
|---|---|
| Operational envelope (1,2,3,4) | 150-4000 m AGL, nominal |
| Laser wavelength | 1064 nm |
| Horizontal accuracy (2) | 1/5,500 x altitude, (m AGL) |
| Elevation accuracy (2) | <5-35 cm, 1 σ |
| Effective laser repetition rate | Programmable, 33-167 kHz |
| Position and orientation system | POS AV™ AP50 (OEM); |
| 220-channel dual frequency GPS/GNSS/ Galileo/L-Band receiver | Programmable, 0-75 ˚ |
| Scan width (WOV) | Programmable, 0-50˚ |
| Scan frequency (5) | Programmable, 0-70 Hz (effective) |
| Sensor scan product | 1000 maximum |
| Beam divergence | Dual divergence: 0.25 mrad (1/e) and 0.8 mrad (1/e), nominal |
| Roll compensation | Programmable, ±5˚ (FOV dependent) |
| Range capture | Up to 4 range measurements, including 1st, 2nd, 3rd, and last returns |
| Intensity capture | Up to 4 intensity returns for each pulse, including last (12 bit) |
| Video Camera | Internal video camera (NTSC or PAL) |
| Image capture | Compatible with full Optech camera line (optional) |
| Full waveform capture | 12-bit Optech IWD-2 Intelligent Waveform Digitizer (optional) |
| Data storage | Removable solid state disk SSD (SATA II) |
| Power requirements | 28 V; 900 W;35 A(peak) |
| Dimensions and weight | Sensor: 260 mm (w) x 190 mm (l) x 570 mm (h); 23 kg |
| Control rack: 650 mm (w) x 590 mm (l) x 530 mm (h); 53 kg | -10°C to +35°C |
| Operating temperature | -10˚C to +35˚C (with insulating jacket) |
| Relative humidity | 0-95% no-condensing |

1 Target reflectivity ≥20%
2 Dependent on selected operational parameters using nominal FOV of up to 40° in standard atmospheric conditions with 24-km visibility
3 Angle of incidence ≤20˚
4 Target size ≥ laser footprint5 Dependent on system configuration

# Annex 2. NAMRIA Certification of Reference Points Used in the LIDAR Survey

1. DVS-1

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

April 26, 2013

**CERTIFICATION**

To whom it may concern:

This is to certify that according to the records on file in this office, the requested survey information is as follows -

Province: **DAVAO DEL SUR**
Station Name: **DVS-1**
Order: **1st**

| | | |
|---|---|---|
| Island: **MINDANAO** | | Barangay: **TOWN PROPER** |
| Municipality: **DAVAO CITY** | | |
| | *PRS92 Coordinates* | |
| Latitude: **7° 4' 41.48387"** | Longitude: **125° 37' 31.24815"** | Ellipsoidal Hgt: **-4.50700 m.** |
| | *WGS84 Coordinates* | |
| Latitude: **7° 4' 38.36201"** | Longitude: **125° 37' 36.77094"** | Ellipsoidal Hgt: **68.27510 m.** |
| | *PTM Coordinates* | |
| Northing: **782663.345 m.** | Easting: **569084.935 m.** | Zone: **5** |
| | *UTM Coordinates* | |
| Northing: **783,162.17** | Easting: **790,026.11** | Zone: **51** |

Location Description

DVS-1
From Davao City hall travel southeast along San Pedro street for 400 meters. Upon reaching the "T" intersection of San Pedro street and Quezon boulevard travel for 2.1 kms. up to the cross intersection of roads at Monteverde street, Leon Garcia street and Quezon boulevard. From this intersection turn right to Sta. Ana pier. The station is located on the east side of the new pier; 94 meters Northeast of coast guard house and north of the old pier. Station mark is 0.15 m x 0.01 m in diameter brass rod with cross cut on top, set in a drill hole, centered in a 30 cm x 30 cm cement patty on top of concrete pavement of wharf. Inscribed on top with the station name. All reference marks are 0.15 m x 0.01 m in diameter brass rods with cross cut on top, set in drill holes, centered in cement patty on concrete pavement of wharf. Inscribed on top with the reference mark numbers and arrow pointing to the station.

Requesting Party: **UP-TCAGP**
Pupose: **Reference**
OR Number: **3943584 B**
T.N.: **2013-0366**

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

9 9 0 4 2 6 2 0 1 3 1 6 3 5 1 3

CERTIFICATION INTERNATIONAL ISO 9001:2008
CIP/4701/12/09/814

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

Figure A-2.1. DVS-1

2. DVA-133

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

July 25, 2014

CERTIFICATION

To whom it may concern:

This is to certify that according to the records on file in this office, the requested survey information is as follows -

Province: **DAVAO DEL NORTE**
Station Name: **DVA-133**
Order: **2nd**

| | | |
|---|---|---|
| Island: **MINDANAO** | | Barangay: **MANAY** |
| Municipality: **CITY OF PANABO** | | MSL Elevation: |
| | *PRS92 Coordinates* | |
| Latitude: **7° 20' 57.02014"** | Longitude: **125° 35' 57.50044"** | Ellipsoidal Hgt: **23.95700 m.** |
| | *WGS84 Coordinates* | |
| Latitude: **7° 20' 53.82313"** | Longitude: **125° 36' 2.99870"** | Ellipsoidal Hgt: **96.16300 m.** |
| | *PTM / PRS92 Coordinates* | |
| Northing: **812626.211 m.** | Easting: **566168.597 m.** | Zone: **5** |
| | *UTM / PRS92 Coordinates* | |
| Northing: **813,130.63** | Easting: **786,976.44** | Zone: **51** |

Location Description

DVA-133
"DVA-133" is in Barangay Manay, Municipality of Panabo. To reach the station travel for about 9 kms. from the intersection of National Highway and barangay road turn right going to Barangay Manay. Station is located infront of the Barangay Hall 15 m. from the flagpole and "NW" of volleyball court. Mark is the head of 4" copper nail embedded in a 30 x 30 cm. concrete monument with the inscription "DVA-133 2007 NAMRIA".

Requesting Party: **UP-TCAGP / Engr. Christopher Cruz**
Pupose: **Reference**
OR Number: **8799582 A**
T.N.: **2014-1736**

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

9 9 0 7 2 5 2 0 1 4 1 3 2 0 4 6

CIP/4701/12/09/814

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.2. DVA-133

3. DVA-3237

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

July 25, 2014

## CERTIFICATION

To whom it may concern:

This is to certify that according to the records on file in this office, the requested survey information is as follows -

Province: **DAVAO DEL NORTE**
Station Name: **DVA-3237**
Order: **4th**

| | | |
|---|---|---|
| Island: **MINDANAO** | | Barangay: **NANYO** |
| Municipality: **CITY OF PANABO** | | MSL Elevation: |
| | ***PRS92 Coordinates*** | |
| Latitude: **7° 19' 59.93670"** | Longitude: **125° 38' 7.27962"** | Ellipsoidal Hgt: **16.91200 m.** |
| | ***WGS84 Coordinates*** | |
| Latitude: **7° 19' 56.74722"** | Longitude: **125° 38' 12.77896"** | Ellipsoidal Hgt: **89.23800 m.** |
| | ***PTM / PRS92 Coordinates*** | |
| Northing: **810878.179 m.** | Easting: **570151.447 m.** | Zone: **5** |
| | ***UTM / PRS92 Coordinates*** | |
| Northing: **811,399.31** | Easting: **790,969.56** | Zone: **51** |

Location Description

DVA-3237

The station is located beside the flagpole inside the compound of Nanyo Elementary School.

Marked is the head of a 4" copper nail embedded and centered on a 0.25cm. x 0.25cm. x 1.00m. concrete monument with inscriptions "DVA-3237; 2008; LMS XI."

Requesting Party: **UP-TCAGP / Engr. Christopher Cruz**
Pupose: **Reference**
OR Number: **8799582 A**
T.N.: **2014-1737**

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

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

CIF/4701/12/09/814

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.3. DVA-3237

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

1. DVS-1A

Table A-3.1. DVS-1A

**DVS-01 18 - DVS-01A 18 (9:38:44 AM-2:08:59 PM) (S1)**

| | |
|---|---|
| Baseline observation: | DVS-01 18 --- DVS-01A 18 (B1) |
| Processed: | 7/23/2014 10:09:22 PM |
| Solution type: | Fixed |
| Frequency used: | Dual Frequency (L1, L2) |
| Horizontal precision: | 0.001 m |
| Vertical precision: | 0.001 m |
| RMS: | 0.000 m |
| Maximum PDOP: | 1.748 |
| Ephemeris used: | Broadcast |
| Antenna model: | Trimble Relative |
| Processing start time: | 7/18/2014 9:38:44 AM (Local: UTC+8hr) |
| Processing stop time: | 7/18/2014 2:08:59 PM (Local: UTC+8hr) |
| Processing duration: | 04:30:15 |
| Processing interval: | 5 seconds |

**Vector Components (Mark to Mark)**

| From: | DVS-01 18 | | | | |
|---|---|---|---|---|---|
| Grid | | Local | | Global | |
| Easting | 790192.921 m | Latitude | N7°04'38.36201" | Latitude | N7°04'38.36201" |
| Northing | 783116.705 m | Longitude | E125°37'36.77094" | Longitude | E125°37'36.77094" |
| Elevation | 0.546 m | Height | 68.275 m | Height | 68.275 m |

| To: | DVS-01A 18 | | | | |
|---|---|---|---|---|---|
| Grid | | Local | | Global | |
| Easting | 790187.943 m | Latitude | N7°04'38.34585" | Latitude | N7°04'38.34585" |
| Northing | 783116.180 m | Longitude | E125°37'36.60874" | Longitude | E125°37'36.60874" |
| Elevation | 0.535 m | Height | 68.265 m | Height | 68.265 m |

| Vector | | | | | |
|---|---|---|---|---|---|
| ΔEasting | -4.978 m | NS Fwd Azimuth | 264°18'12" | ΔX | 4.016 m |
| ΔNorthing | -0.525 m | Ellipsoid Dist. | 5.002 m | ΔY | 2.941 m |
| ΔElevation | -0.011 m | ΔHeight | -0.010 m | ΔZ | -0.494 m |

# Annex 4. The LIDAR Survey Team Composition

Table A-4.1. The LiDAR Survey Team Composition

| Data Acquisition Component Sub-Team | Designation | Name | Agency/ Affiliation |
|---|---|---|---|
| PHIL-LIDAR 1 | Program Leader | ENRICO C. PARINGIT, DR.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 |
| | Research Associate (RA) | ENGR. LARAH KRISELLE PARAGAS | UP-TCAGP |
| | RA | FOR. MA. VERLINA TONGA | UP-TCAGP |
| Ground Survey, Data Download and Transfer | RA | ENGR. KENNETH QUISADO | UP-TCAGP |
| LiDAR Operation | Airborne Security | TSG. MIKE DIAPANA | PHILIPPINE AIR FORCE (PAF) |
| | Pilot | CAPT. RAUL CZ SAMAR II | ASIAN AEROSPACE CORPORATION (AAC) |
| | | CAPT. JOHN BRYAN DONGUINES | AAC |

# Annex 5. Data Transfer Sheet for Talomo Floodplain

DATA TRANSFER SHEET
07/08/2014(Davao Oriental - ready)

| DATE | FLIGHT NO. | MISSION NAME | SENSOR | RAW LAS | | LOGS(MB) | POS | RAW IMAGES/CASI | MISSION LOG FILE/CASI LOGS | RANGE | DIGITIZER | BASE STATION(S) | | OPERATOR LOGS (OPLOG) | FLIGHT PLAN | | SERVER LOCATION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Output LAS | KML (swath) | | | | | | | BASE STATION(S) | Base Info (.txt) | | Actual | KML | |
| 7/18/2014 | 7378GC | 2BLK82A199A | Gemini | NA | 242 | 493 | 243 | NA | NA | 24.1 | NA | 8.53 | 1KB | 1KB | 7/7 | 16 | Z:\DAC\RAW_DATA |
| 7/22/2014 | 7386GC | 2BLK82CSD203A | Gemini | NA | 141/159 | 637 | 267 | NA | NA | 29.2 | NA | 8.87 | 1KB | 1KB | 3/3 | NA | Z:\DAC\RAW_DATA |
| 7/23/2014 | 7388GC | 2BLK82AB204A | Gemini | NA | 89 | 488 | 228 | NA | NA | 21.4 | NA | 8.69 | 1KB | 1KB | 4/3 | 10 | Z:\DAC\RAW_DATA |
| 7/24/2014 | 7390GC | 2BLK82FH205A | Gemini | NA | 93 | 591 | 241 | NA | NA | 29 | NA | 17.6 | 1KB | 1KB | 2/4 | NA | Z:\DAC\RAW_DATA |
| 7/27/2014 | 7396GC | 2BLK82GSH208A | Gemini | NA | 280 | 769 | 214 | NA | NA | 27.1 | NA | 5.65 | 1KB | 1KB | 4/4 | NA | Z:\DAC\RAW_DATA |
| 7/29/2014 | 7401GC | 2BLK82EFGHS210B | Gemini | NA | 83 | 339 | 104 | NA | NA | 8.25 | NA | 7.1 | 1KB | 1KB | 12/12/12 | NA | Z:\DAC\RAW_DATA |

Received from

Name TIN ANDAYA
Position RA
Signature

Received by

Name JOIDA F. PRIETO
Position SSRS
Signature

8/7/2014

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

DATA TRANSFER SHEET
08/28/2014(Davao- 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) | QUICK PROCESS (kml (Boundary) | FLIGHT PLAN | | SERVER LOCATION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Output LAS | KML (swath) | | | | | | | BASE STATION(S) | Base Info (.txt) | | | Actual | KML | |
| 8/4/2014 | 7412GC | 2BLK87CSD216A | Gemini | 21 | 310 | 537 | 165 | NA | NA | 24.2 | NA | 4.99 | 1KB | 1KB | 3382 | 3/3/7/3/3 | NA | Z:\DAC\RAWDATA |
| 8/5/2014 | 7414GC | 2BLK87E217A | Gemini | 3.68 | 88 | 158 | 146 | NA | NA | 7.62 | NA | 3.11 | 1KB | 1KB | 786 | 5/5 | NA | Z:\DAC\RAWDATA |
| 8/6/2014 | 7416GC | 2BLK87F218A | Gemini | 5.39 | 184 | 194 | 148 | NA | NA | 8.31 | NA | 3.55 | 1KB | 1KB | 1616 | 5 | 11 | Z:\DAC\RAWDATA |
| 8/7/2014 | 7418GC | 2BLK87FV219A | Gemini | 12.7 | 181 | 355 | 180 | NA | NA | 14.4 | NA | 3.49 | 1KB | 1KB | 1233 | 9/10 | NA | Z:\DAC\RAWDATA |
| 7/9/2014 | 7422GC | 2COMA221A | Gemini | 16.5 | 248 | 423 | 219 | NA | NA | 19.8 | NA | 9.95 | 1KB | 1KB | 2848 | 5 | 12 | Z:\DAC\RAWDATA |
| 8/9/2014 | 7423GC | 2COMBSCD221B | Gemini | 11 | 210 | 395 | 175 | NA | NA | 16.6 | NA | 9.95 | 1KB | 1KB | 1090 | 7/5/3 | NA | Z:\DAC\RAWDATA |
| 8/10/2014 | 7424GC | 2COMDS222A | Gemini | 8.44 | 39 | 236 | 157 | NA | NA | 9.69 | NA | 4.38 | 1KB | 1KB | 1064 | 3/3 | 8 | Z:\DAC\RAWDATA |
| 8/11/2014 | 7426GC | 2BLK82V223A | Gemini | 8.44 | 119 | 279 | 135 | NA | NA | 9.61 | NA | 7.83 | 1KB | 1KB | 1813 | 7/11 | NA | Z:\DAC\RAWDATA |
| 8/11/2014 | 7427GC | 2BLK82V223B | Gemini | 4.32 | 64 | 184 | 132 | NA | NA | 5.65 | NA | 7.83 | 1KB | 1KB | 434 | 8 | 6 | Z:\DAC\RAWDATA |
| 8/12/2014 | 7428GC | 2TAGV224A | Gemini | 20.1 | 287 | 530 | 223 | NA | NA | 22.6 | NA | 4.44 | 1KB | 1KB | 2667 | 23/23 | NA | Z:\DAC\RAWDATA |
| 8/13/2014 | 7430GC | 2TAGV225A | Gemini | 5.95 | 34 | 326 | 179 | NA | NA | 9.38 | NA | 3.58 | 1KB | 1KB | 1283 | 18/18 | NA | Z:\DAC\RAWDATA |

Received from

Name TIN ANDAYA
Position RA
Signature M

Received by

Name JOIDA PRIETO
Position SSRS
Signature 8/29/14

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

# Annex 6. Flight Logs for the Flight Missions

1. Flight Log for Mission 2BLK82A199A

DREAM Data Acquisition Flight Log

Flight Log No.: 7378

| | | | | | |
|---|---|---|---|---|---|
| 1 LiDAR Operator: MV Fonga | 2 ALTM Model: GHC | 3 Mission Name: 2BLK82A199A | 4 Type: VFR | 5 Aircraft Type: CesnnaT206H | 6 Aircraft Identification: RP C9322 |
| 7 Pilot: Samar V | 8 Co-Pilot: Pangmiu | 9 Route: | | | |
| 10 Date: 7-18-14 | 12 Airport of Departure (Airport, City/Province): RPMD | | 12 Airport of Arrival (Airport, City/Province): RPMD | | |
| 13 Engine On: 10+39 | 14 Engine Off: 14+44 | 15 Total Engine Time: 4+5 | 16 Take off: | 17 Landing: | 18 Total Flight Time: |
| 19 Weather | | | | | |

20 Remarks:

Surveyed 12 lines of Blk 82 (ABC) without CASI

21 Problems and Solutions:

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

Figure A-6.1. Flight Log for Mission 2BLK82A199A

2. Flight Log for 2BLK82DAB204A Mission

**DREAM Data Acquisition Flight Log** — Flight Log No.: 7388

| | | | | | |
|---|---|---|---|---|---|
| 1 LIDAR Operator: M V Tonga | 2 ALTM Model: GTC | 3 Mission Name: 2BLK82DAB204A | 4 Type: VFR | 5 Aircraft Type: CesnnaT206H | 6 Aircraft Identification: RPC9322 |
| 7 Pilot: Dongumes | 8 Co-Pilot: Agawin | 9 Route: | | | |
| 10 Date: 7-23-14 | 12 Airport of Departure (Airport, City/Province): RPMD | | 12 Airport of Arrival (Airport, City/Province): RPMD | | |
| 13 Engine On: 8+19 | 14 Engine Off: 12+24 | 15 Total Engine Time: 4+5 | 16 Take off: | 17 Landing: | 18 Total Flight Time: |
| 19 Weather | | | | | |

20 Remarks:

Surveyed the Rest of BlK82AB & 6 lines of BLK82D (without CASI)

21 Problems and Solutions:

| Acquisition Flight Approved by | Acquisition Flight Certified by | Pilot-in-Command | Lidar Operator |
|---|---|---|---|
| Signature over Printed Name (End User Representative) | Signature over Printed Name (PAF Representative) | E. DONGUIMES<br>Signature over Printed Name | Signature over Printed Name |

Figure A-6.2. Flight Log for Mission 2BLK82DAB204A

3. Flight Log for 2BLK87EFGHS210B Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 7401

| | | | | | |
|---|---|---|---|---|---|
| 1 LiDAR Operator: LK Paragas | 2 ALTM Model: GMC | 3 Mission Name: 2BLK82 EFGHS 210B | 4 Type: VFR | 5 Aircraft Type: CesnnaT206H | 6 Aircraft Identification: RPC9322 |
| 7 Pilot: B. Donguines | 8 Co-Pilot: N. Aragwin | 9 Route: | | | |
| 10 Date: 7-29-14 | 12 Airport of Departure (Airport, City/Province): RPMD | | 12 Airport of Arrival (Airport, City/Province): RPMD | | |
| 13 Engine On: 14+41 | 14 Engine Off: 16+40 | 15 Total Engine Time: 1+59 | 16 Take off: | 17 Landing: | 18 Total Flight Time: |
| 19 Weather | | | | | |
| 20 Remarks: completed Blk 82G and voids of Blocks 82E, F, H | | | | | |

21 Problems and Solutions:

| | | | |
|---|---|---|---|
| Acquisition Flight Approved by | Acquisition Flight Certified by | Pilot-in-Command | Lidar Operator |
| Signature over Printed Name (End User Representative) | Signature over Printed Name (PAF Representative) | B. DONGUINES Signature over Printed Name | LK Paragas Signature over Printed Name |

Figure A-6.3. Flight Log for Mission 2BLK87EFGHS210B

4. Flight Log for 2BLK82V223A Mission

**DREAM Data Acquisition Flight Log**

Flight Log No.: 7426

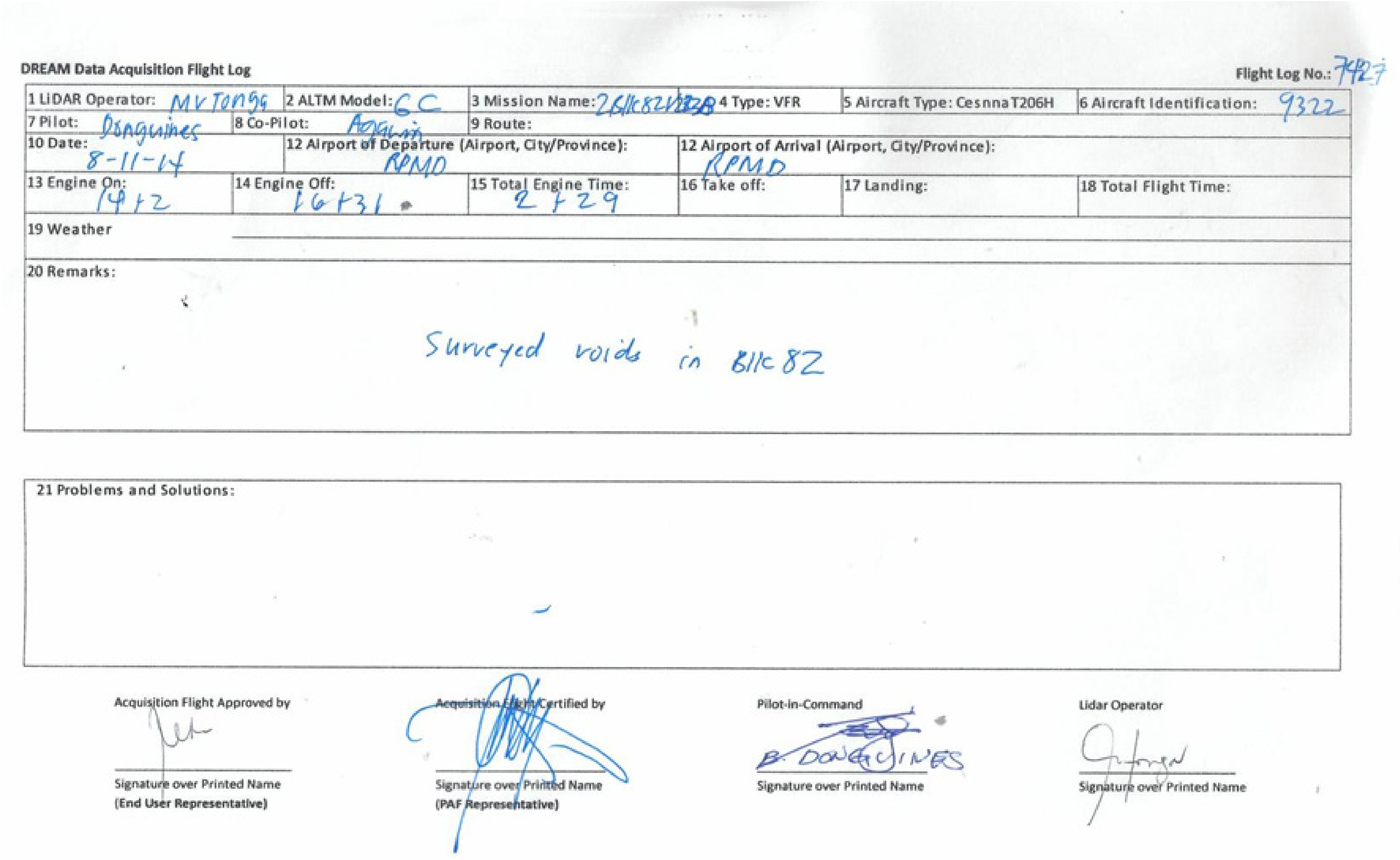
| | | | | | |
|---|---|---|---|---|---|
| 1 LiDAR Operator: LK Paragas | 2 ALTM Model: 6C | 3 Mission Name: 2BLK82V223A | 4 Type: VFR | 5 Aircraft Type: Cesnna T206H | 6 Aircraft Identification: 9322 |
| 7 Pilot: Dongwines | 8 Co-Pilot: Agawin | 9 Route: | | | |
| 10 Date: 8-11-14 | 12 Airport of Departure (Airport, City/Province): RPMD | | 12 Airport of Arrival (Airport, City/Province): RPMD | | |
| 13 Engine On: 9431 | 14 Engine Off: 1242 | 15 Total Engine Time: 2+41 | 16 Take off: | 17 Landing: | 18 Total Flight Time: |
| 19 Weather | | | | | |
| 20 Remarks: Surveyed voids in Blk 82 | | | | | |

21 Problems and Solutions:

| Acquisition Flight Approved by | Acquisition Flight Certified by | Pilot-in-Command | Lidar Operator |
|---|---|---|---|
| Signature over Printed Name (End User Representative) | Signature over Printed Name (PAF Representative) | B. DONGUINES<br>Signature over Printed Name | Signature over Printed Name |

Figure A-6.4. Flight Log for Mission 2BLK82V223A

4. Flight Log for 2BLK82V223B Mission



**DREAM Data Acquisition Flight Log**

Flight Log No.: 7427

| | | | | | |
|---|---|---|---|---|---|
| 1 LiDAR Operator: MV Tongo | 2 ALTM Model: GC | 3 Mission Name: 2BLK82V223B | 4 Type: VFR | 5 Aircraft Type: Cesnna T206H | 6 Aircraft Identification: 9322 |
| 7 Pilot: Donguines | 8 Co-Pilot: Aguirre | 9 Route: | | | |
| 10 Date: 8-11-14 | 12 Airport of Departure (Airport, City/Province): RPMD | | 12 Airport of Arrival (Airport, City/Province): RPMD | | |
| 13 Engine On: 1412 | 14 Engine Off: 1631 | 15 Total Engine Time: 2+29 | 16 Take off: | 17 Landing: | 18 Total Flight Time: |
| 19 Weather | | | | | |
| 20 Remarks: Surveyed voids in Blk 82 | | | | | |

21 Problems and Solutions:

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

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

Pilot-in-Command — B. DONGUINES — Signature over Printed Name

Lidar Operator — Signature over Printed Name

Figure A-6.4. Flight Log for Mission 2BLK82V223B

# Annex 7. Flight Status Reports

DAVAO CITY
(July 16 - August 13, 2014

Table A-7.1. Flight Status Report

| FLIGHT NO. | AREA | MISSION | OPERATOR | DATE FLOWN | REMARKS |
|---|---|---|---|---|---|
| 7378GC | BLK82A, 82B, 82C | 2BLK82A199A | MV Tonga | July 18, 2014 | Flown BLK82ABC and surveyed 12 lines without CASI @ 850 AGL |
| 7388GC | BLK82A,82B, 82E | 2BLK82DAB204A | MV Tonga | July 23, 2014 | Completed the remaining lines of BLK82AB (8 lines) and proceed to BLK82E (6 lines) without CASI @ 1000 AGL |
| 7401GC | BLK82E, 82F, 82G, 82H | 2BLK87EFGHS210B | LK Paragas | July 29, 2014 | Surveyed BLK87EFGH (7 lines) without CASI @ 850 AGL |
| 7426GC | BLK82A, 82D, 82F, 82G | 2BLK82V223A | LK Paragas | August 11, 2014 | 14 lines that filled up BLK 82 voids |
| 7427GC | BLK82A, 82B, 82C | 2BLK82V223B | MV Tonga | August 11, 2014 | Filled up voids in BLK 82@1000m |

**LAS BOUNDARIES PER FLIGHT**

| | | | |
|---|---|---|---|
| Flight No.: | 7378GC | | |
| Area: | BLK82A, BLK82B, BLK82C | | |
| Mission Name: | 2BLK82A199A | | |
| Parameters: | Altitude: | 850 m; | Scan Frequency: 40 Hz; |
| Scan Angle: | 25 deg; | Overlap: 30% | |

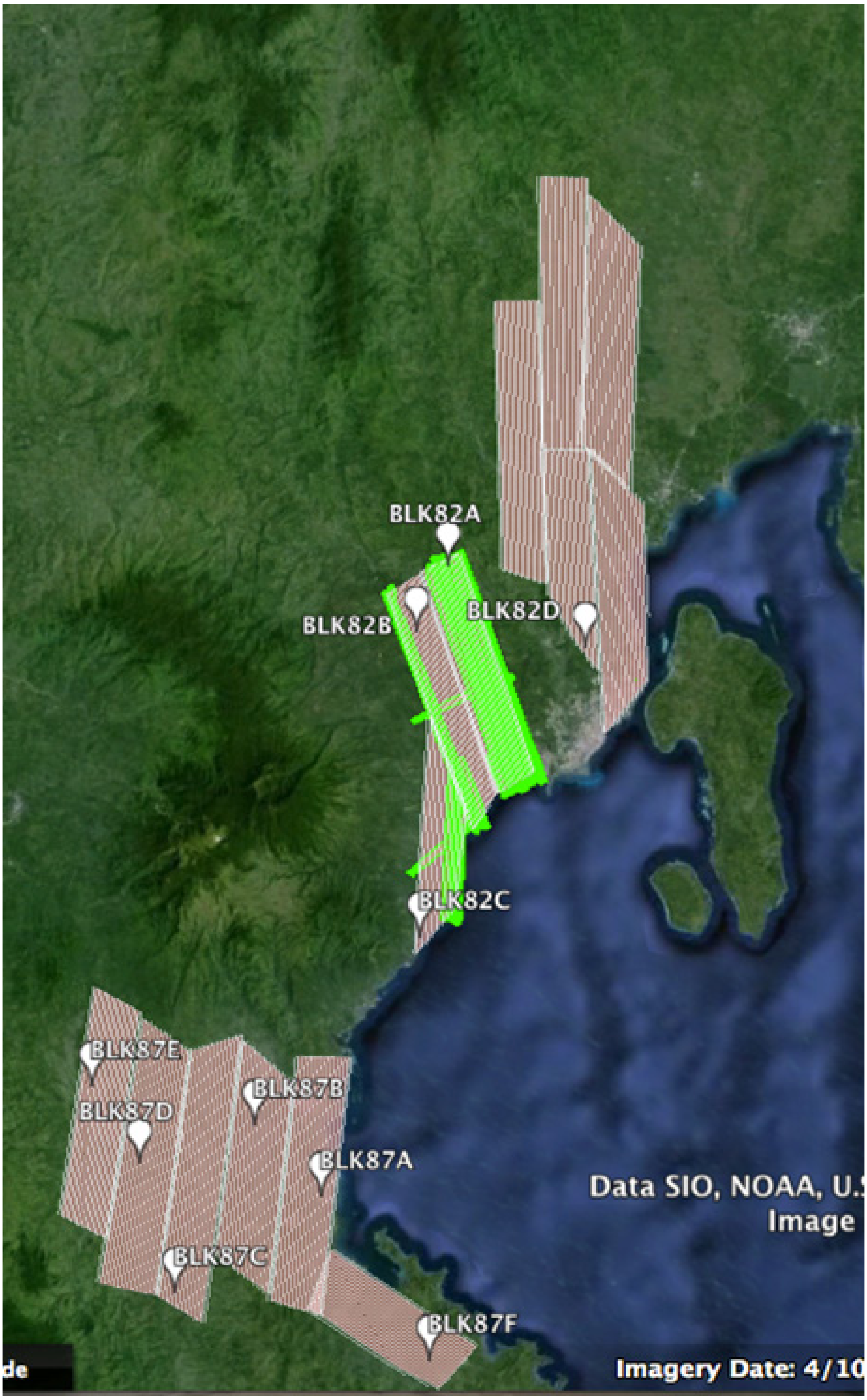



Figure A-7.1. Swath for Flight No. 7378GC

| | | | |
|---|---|---|---|
| Flight No.: | 7401GC | | |
| Area: | BLK82E, BLK82F, BLK82G, BLK82H | | |
| Mission Name: | 2BLK87EFGHS210B | | |
| Parameters: | Altitude: | 850 m; | Scan Frequency: 40 Hz; |
| Scan Angle: | 25 deg; | Overlap: 30% | |


Figure A-7.2. Swath for Flight No. 7401GC

| | | | |
|---|---|---|---|
| Flight No.: | 7426GC | | |
| Area: | BLK82A, BLK82D, BLK82F, BLK82G | | |
| Mission Name: | 2BLK82V223A | | |
| Parameters: | Altitude: | 1000 m; | Scan Frequency: 50 Hz; |
| Scan Angle: | 20 deg; | Overlap: 35% | |

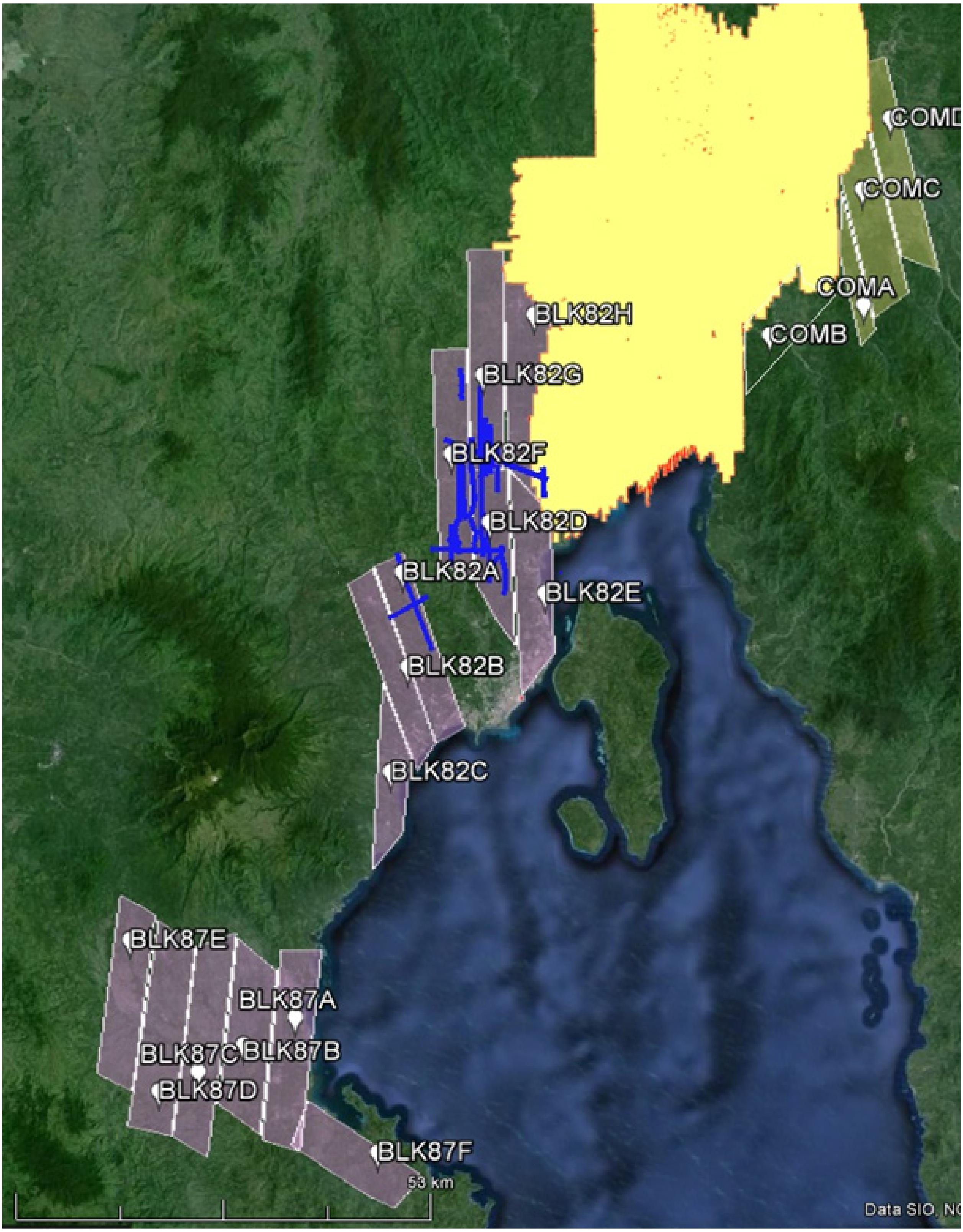



Figure A-7.3. Swath for Flight No. 7426GC

| | | | |
|---|---|---|---|
| Flight No.: | 7427GC | | |
| Area: | BLK82A, BLK82B, BLK82C | | |
| Mission Name: | 2BLK82V223B | | |
| Parameters: | Altitude: | 1000 m; | Scan Frequency: 50 Hz; |
| Scan Angle: | 20 deg; | Overlap: 35% | |

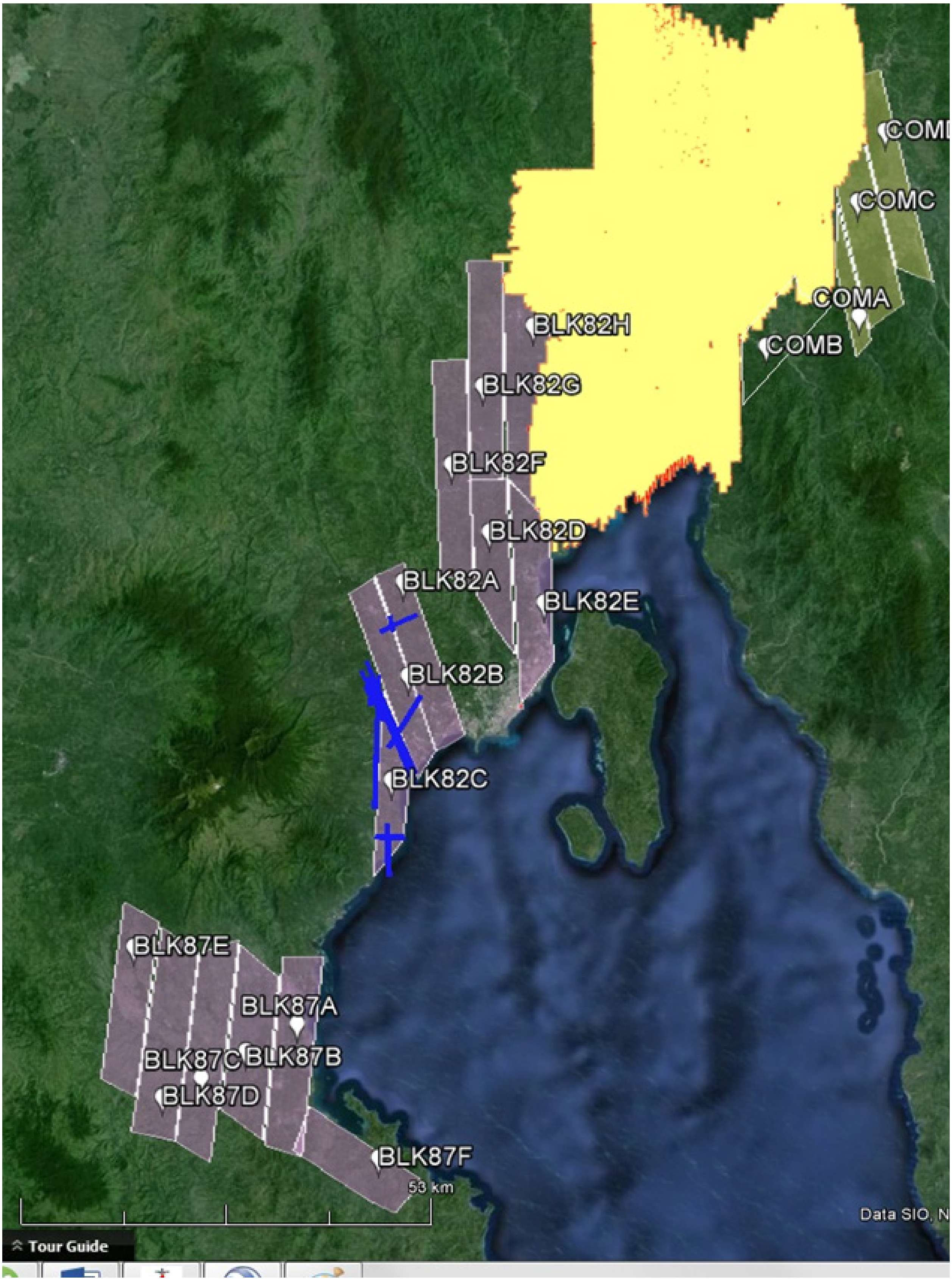



Figure A-7.4. Swath for Flight No. 7427GC

# Annex 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Blk82A

| Flight Area | Davao Del Sur |
|---|---|
| Mission Name | Blk82A |
| Inclusive Flights | 7378G |
| Range data size | 48.3 GB |
| POS data size | 243 MB |
| Base data size | 8.53 MB |
| Image | na |
| Transfer date | August 7, 2014 |
| | |
| Solution Status | |
| Number of Satellites (>6) | Yes |
| PDOP (<3) | Yes |
| Baseline Length (<30km) | Yes |
| Processing Mode (<=1) | Yes |
| | |
| Smoothed Performance Metrics (in cm) | |
| RMSE for North Position (<4.0 cm) | 1.0 |
| RMSE for East Position (<4.0 cm) | 1.42 |
| RMSE for Down Position (<8.0 cm) | 2.2 |
| | |
| Boresight correction stdev (<0.001deg) | 0.000857 |
| IMU attitude correction stdev (<0.001deg) | 0.002434 |
| GPS position stdev (<0.01m) | 0.0169 |
| | |
| Minimum % overlap (>25) | 27.93% |
| Ave point cloud density per sq.m. (>2.0) | 3.86 |
| Elevation difference between strips (<0.20 m) | Yes |
| | |
| Number of 1km x 1km blocks | 149 |
| Maximum Height | 883.49 m |
| Minimum Height | 66.48 m |
| | |
| Classification (# of points) | |
| Ground | 29,381,439 |
| Low vegetation | 32,643,635 |
| Medium vegetation | 115,735,540 |
| High vegetation | 209,802,627 |
| Building | 3,579,878 |
| | |
| Orthophoto | No |
| Processed By | Engr. Carlyn Ann Ibañez, Engr. Harmond Santos, Engr. Jeffrey Delica |

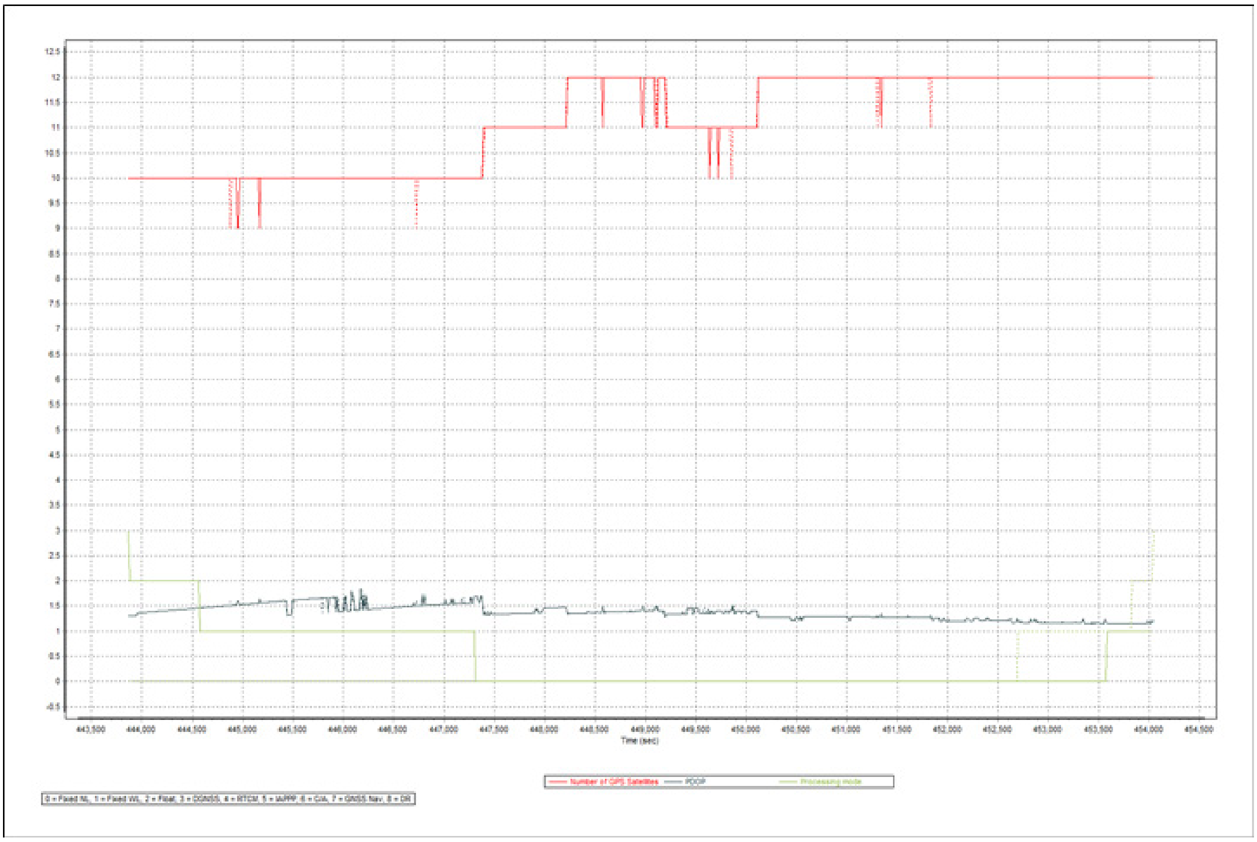



Figure A-8.1. Solution Status

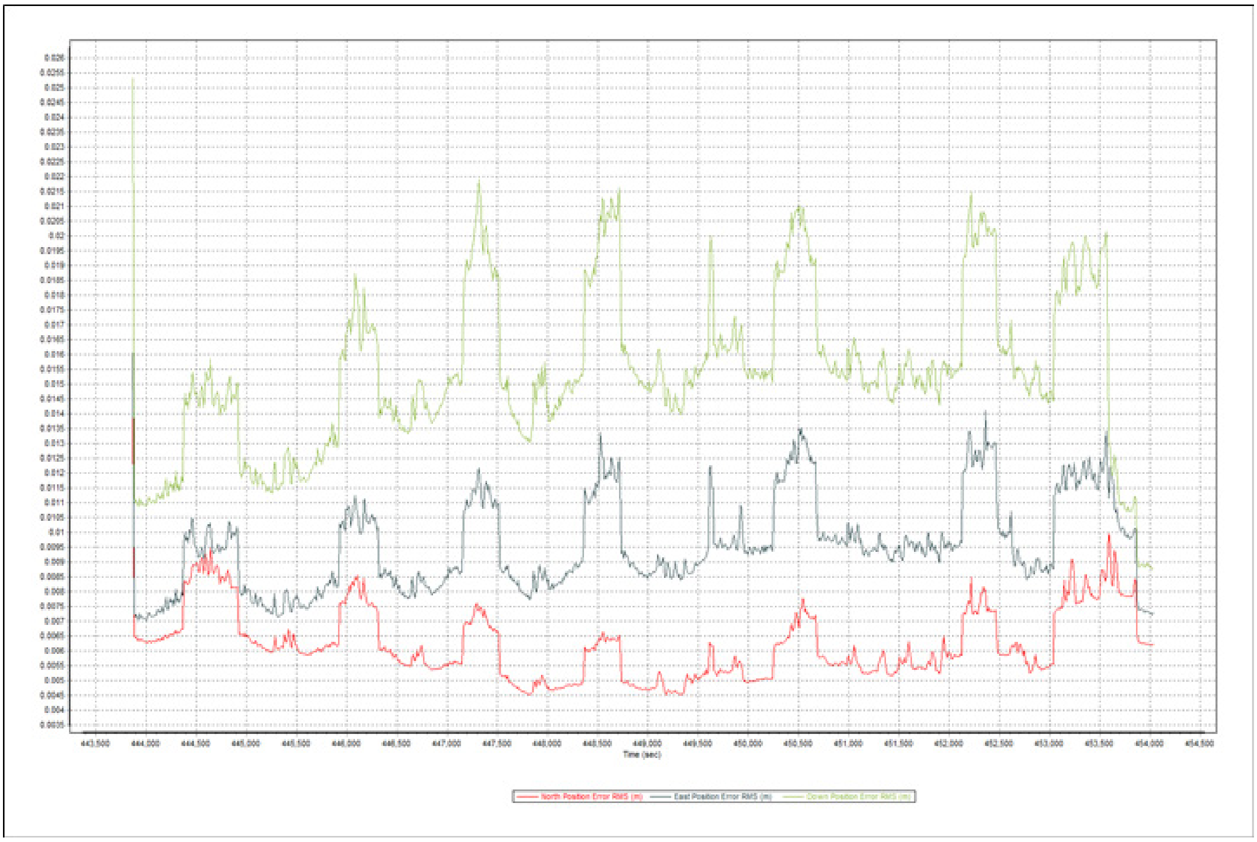



Figure A-8.2. Smoothed Performance Metrics Parameters

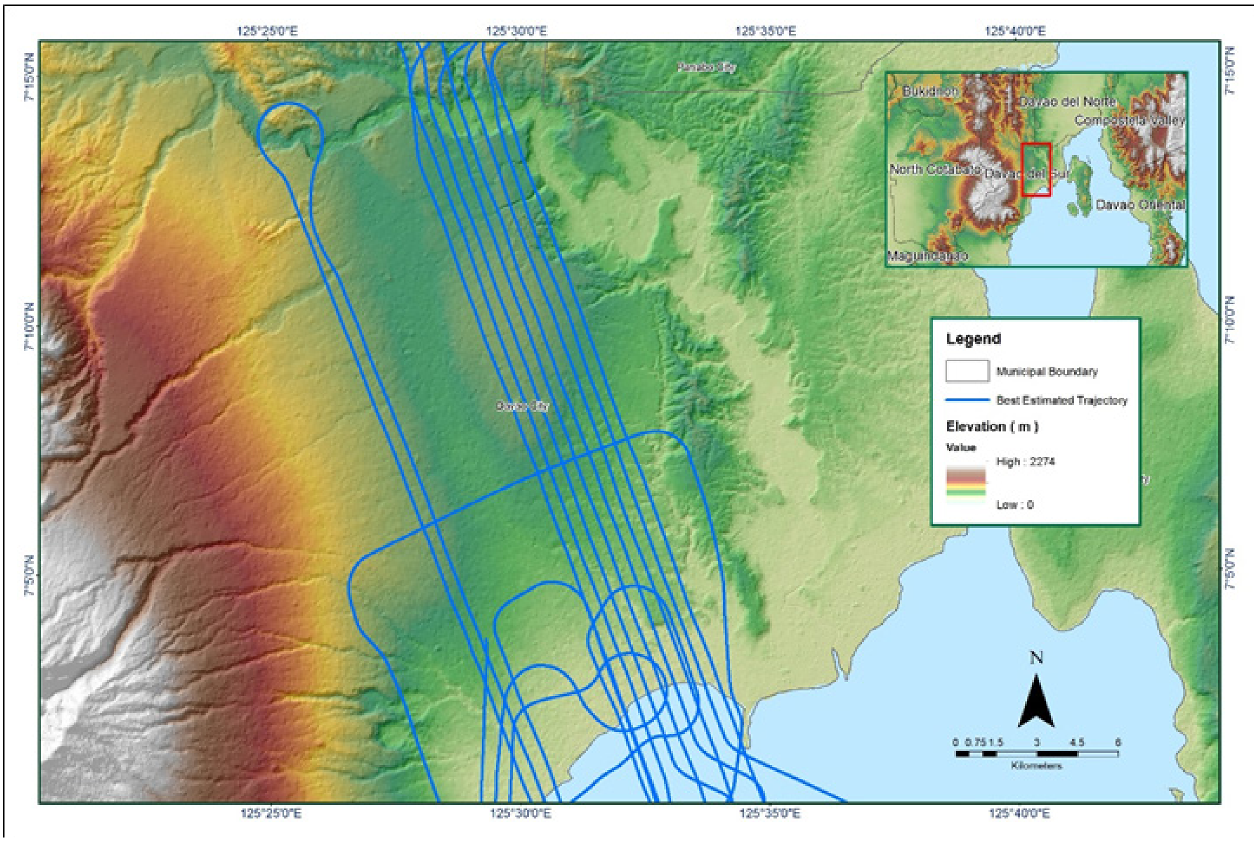



Figure A-8.3. Best Estimated Trajectory

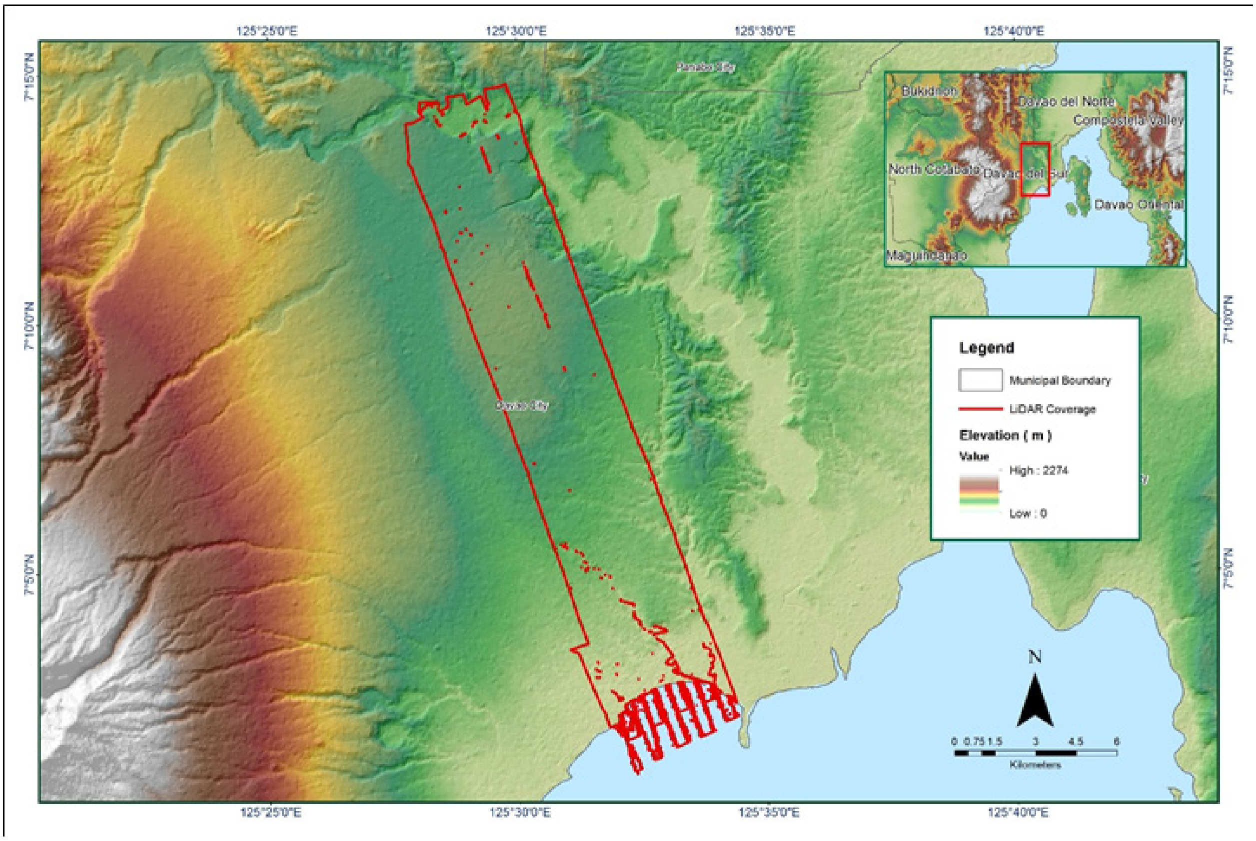



Figure A-8.4. Coverage of LiDAR data

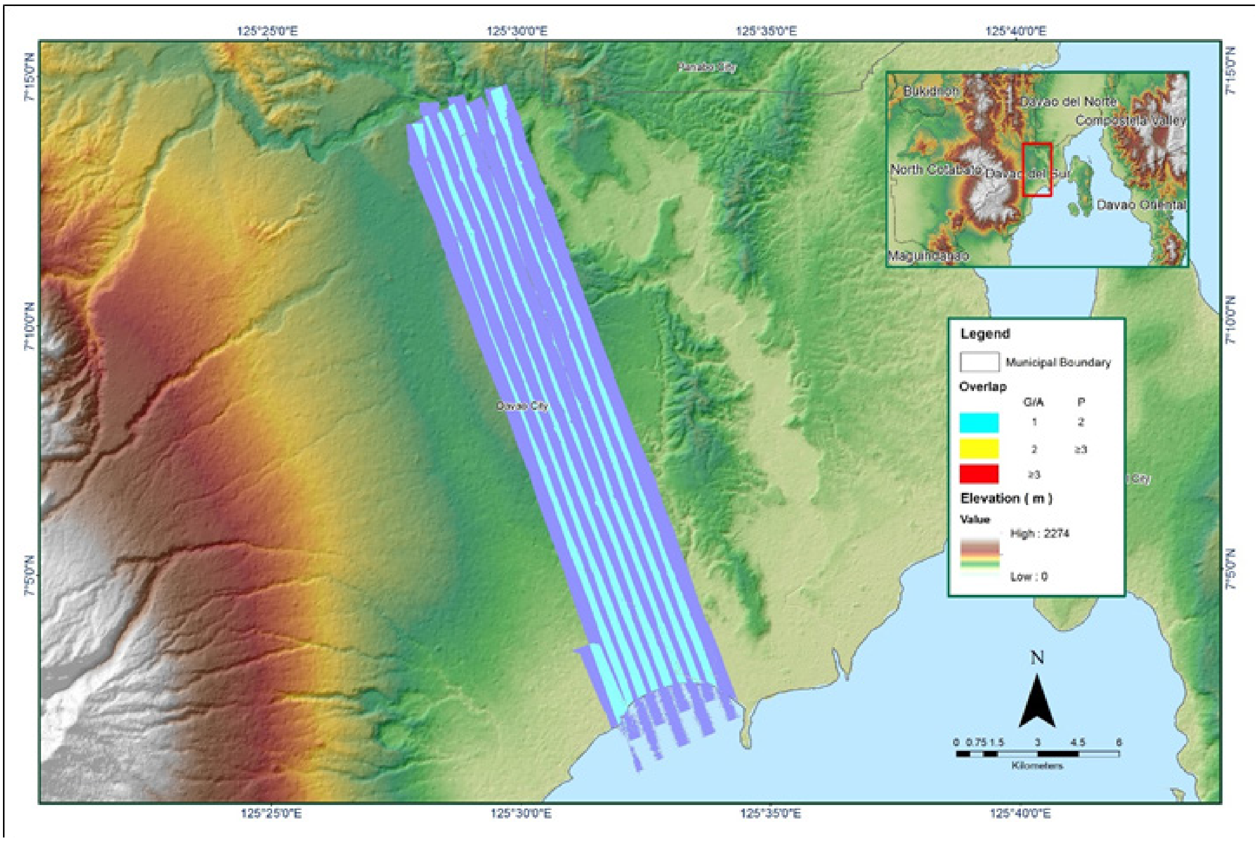



Figure A-8.5. Image of Data Overlap

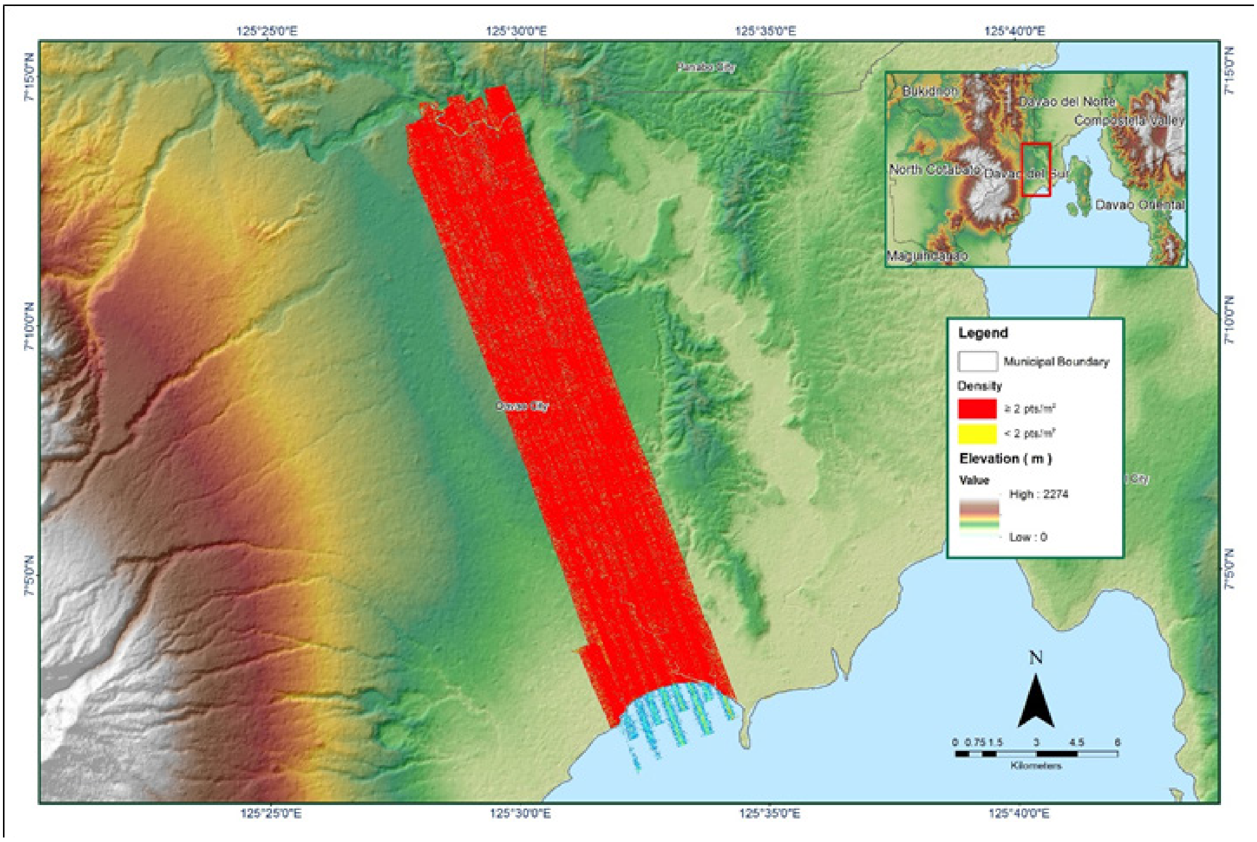



Figure A-8.6. Density map of merged LiDAR data

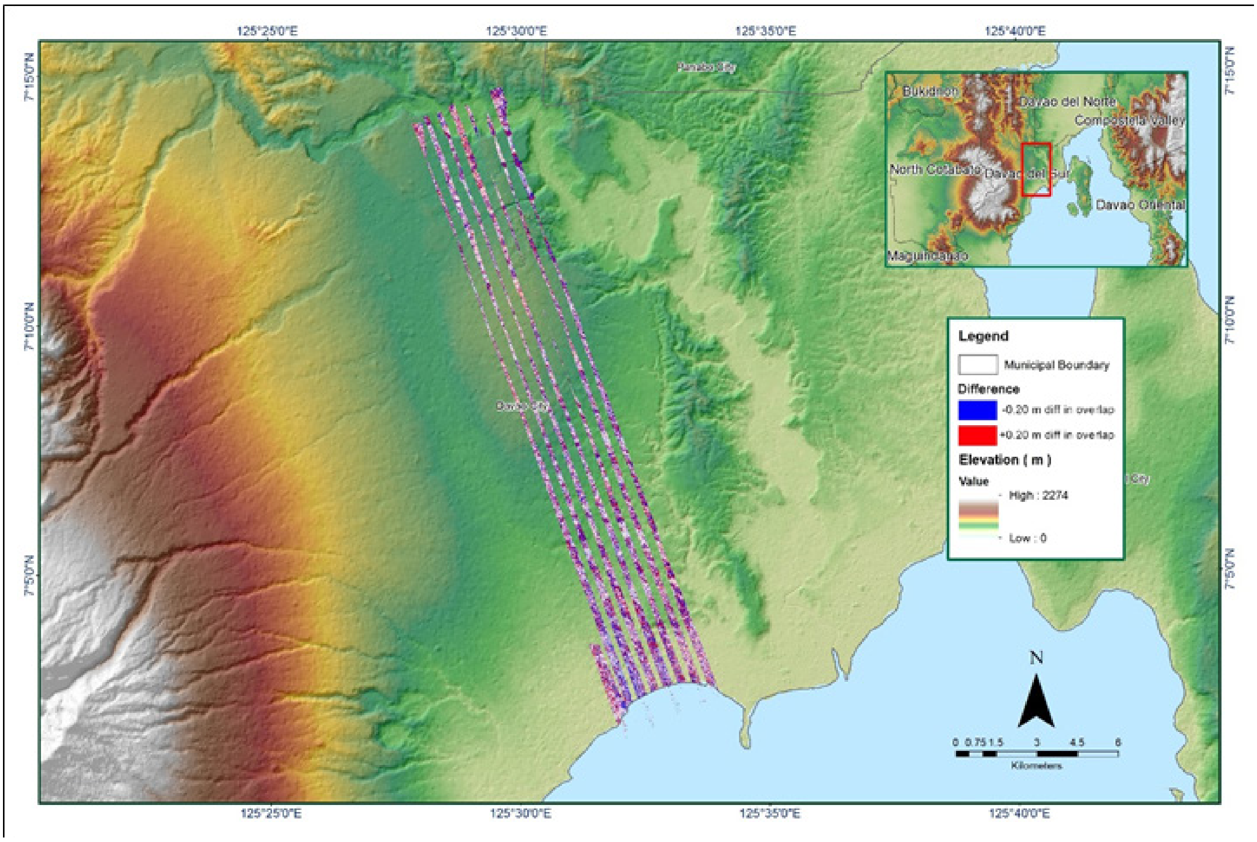



Figure A-8.7. Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Blk82B

| Flight Area | Davao Del Sur |
|---|---|
| Mission Name | Blk82B |
| Inclusive Flights | 7378G,7388G |
| Range data size | 69.7 GB |
| POS data size | 471 MB |
| Base data size | 17.22 MB |
| Image | na |
| Transfer date | August 7, 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) | 1.06 |
| RMSE for East Position (<4.0 cm) | 1.25 |
| RMSE for Down Position (<8.0 cm) | 2.6 |
| | |
| Boresight correction stdev (<0.001deg) | 0.000555 |
| IMU attitude correction stdev (<0.001deg) | 0.002846 |
| GPS position stdev (<0.01m) | 0.0102 |
| | |
| Minimum % overlap (>25) | 10.46% |
| Ave point cloud density per sq.m. (>2.0) | 2.79 |
| Elevation difference between strips (<0.20 m) | Yes |
| | |
| Number of 1km x 1km blocks | 164 |
| Maximum Height | 460.63 m |
| Minimum Height | 66.77 m |
| | |
| Classification (# of points) | |
| Ground | 42,418,988 |
| Low vegetation | 48,280,364 |
| Medium vegetation | 94,050,611 |
| High vegetation | 197,058,041 |
| Building | 10,388,900 |
| | |
| Orthophoto | No |
| Processed By | Engr. Carlyn Ann Ibañez, Engr. Harmond Santos, Engr. Jeffrey Delica |

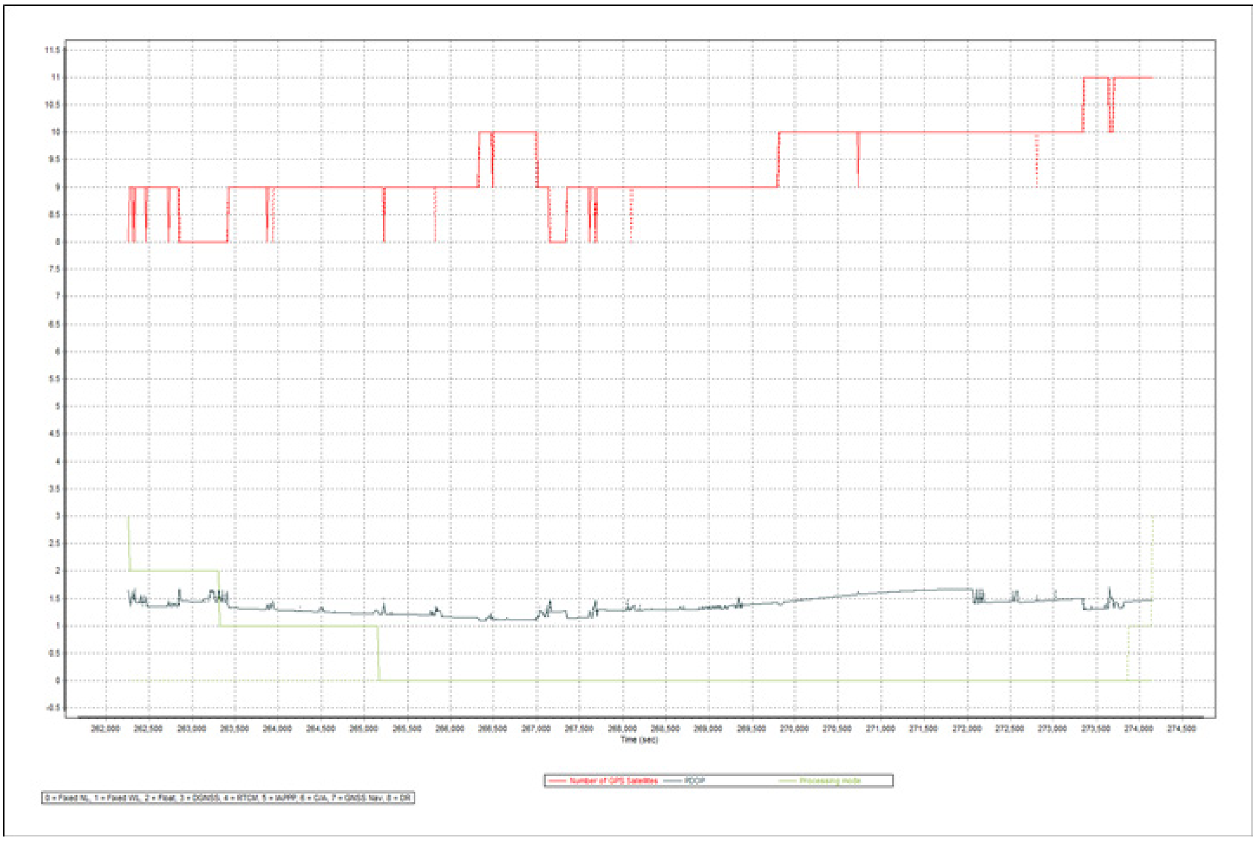


Figure A-8.8. Solution Status Parameters

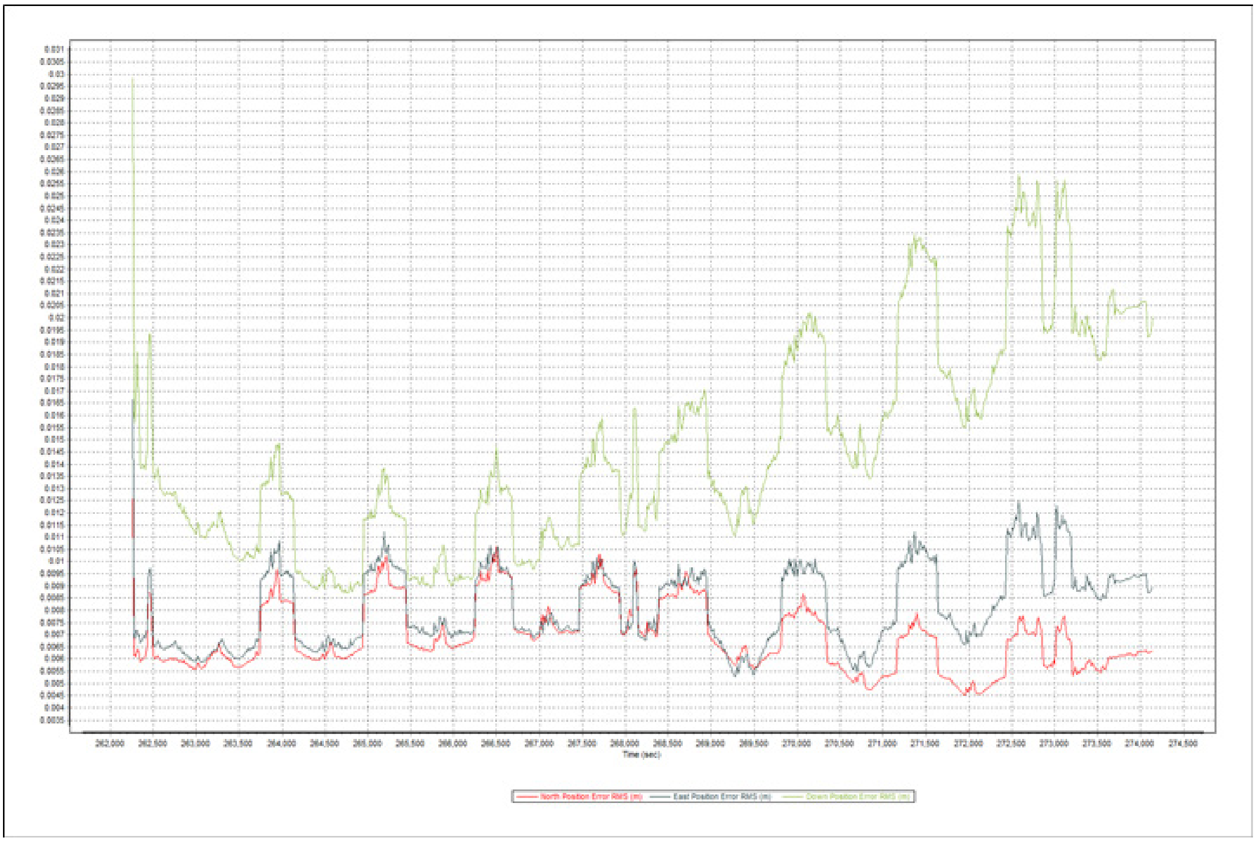


Figure A-8.9. Smoothed Performance Metrics Parameters

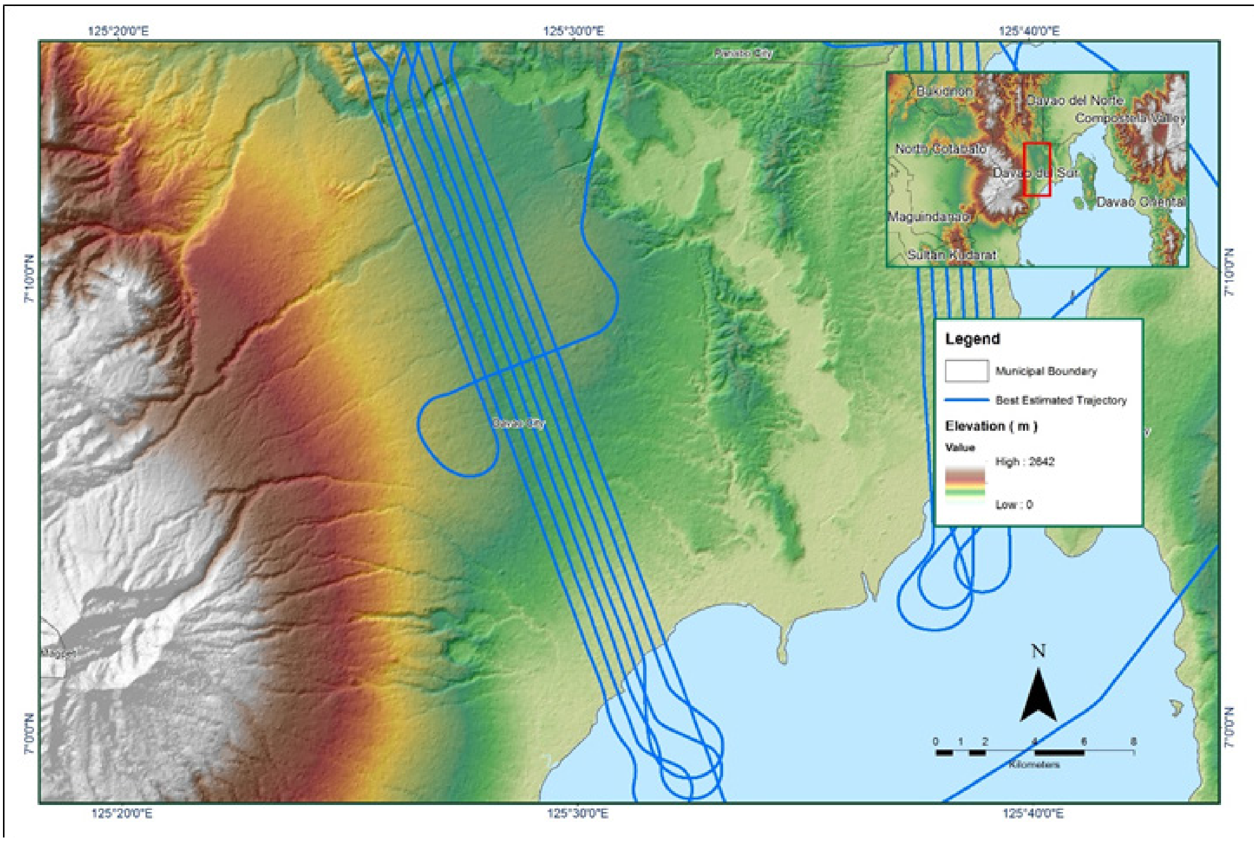



Figure A-8.10. Best Estimated Trajectory

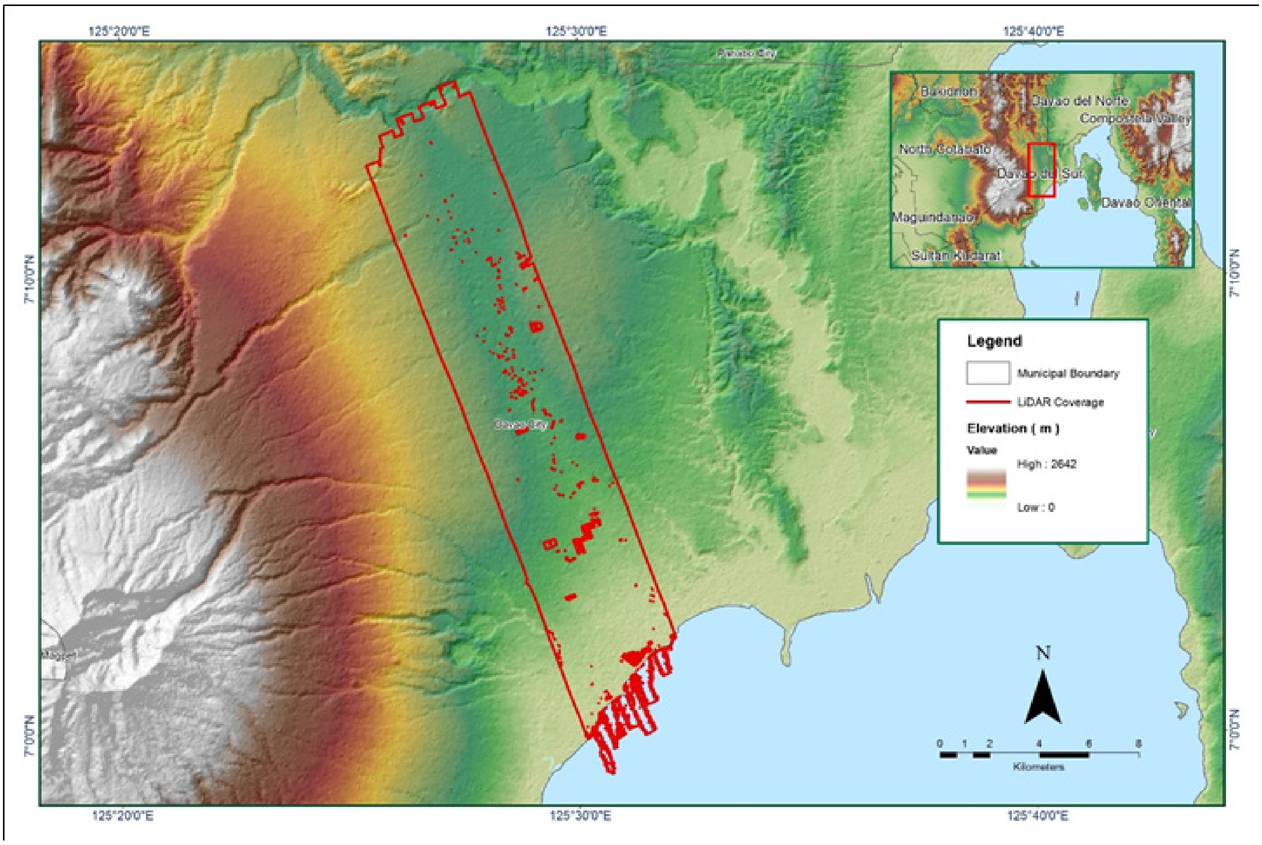



Figure A-8.11. Coverage of LiDAR data

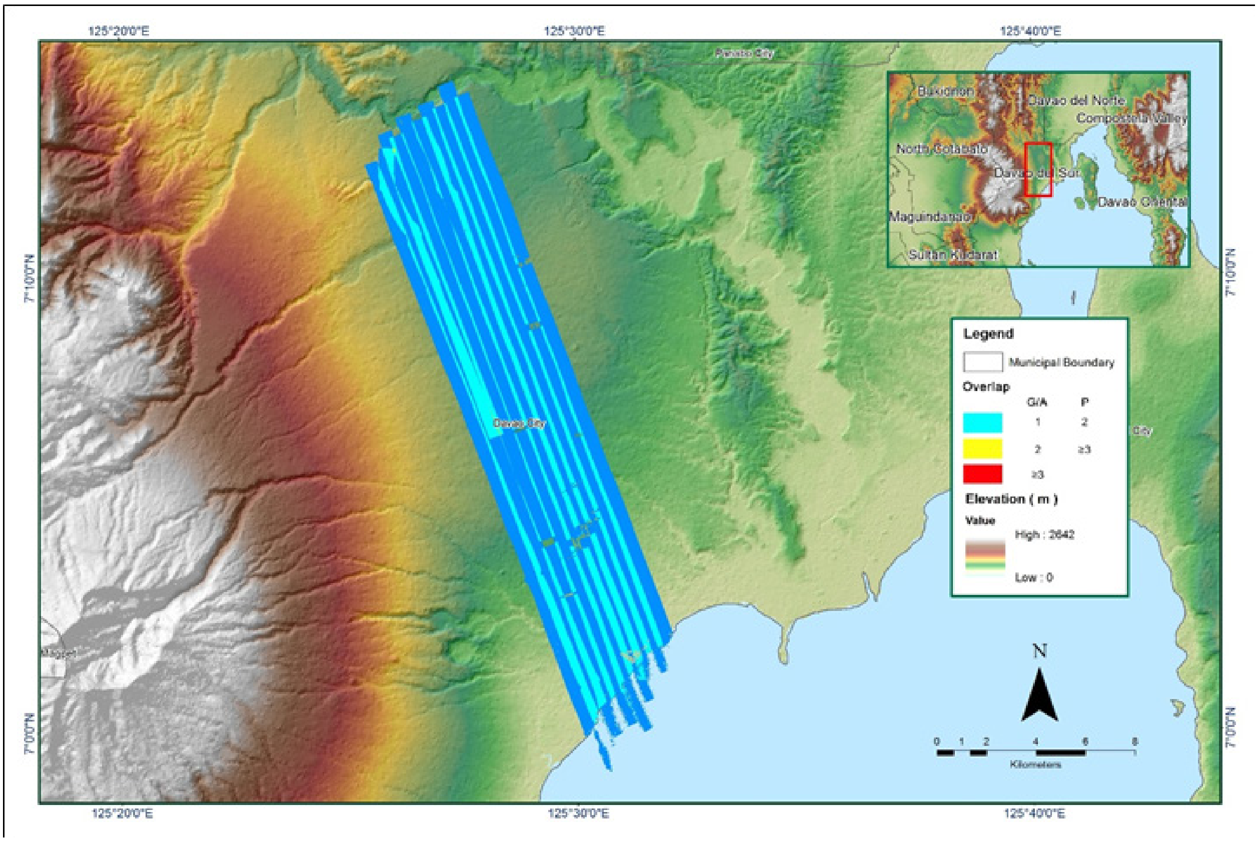



Figure A-8.12. Image of Data Overlap

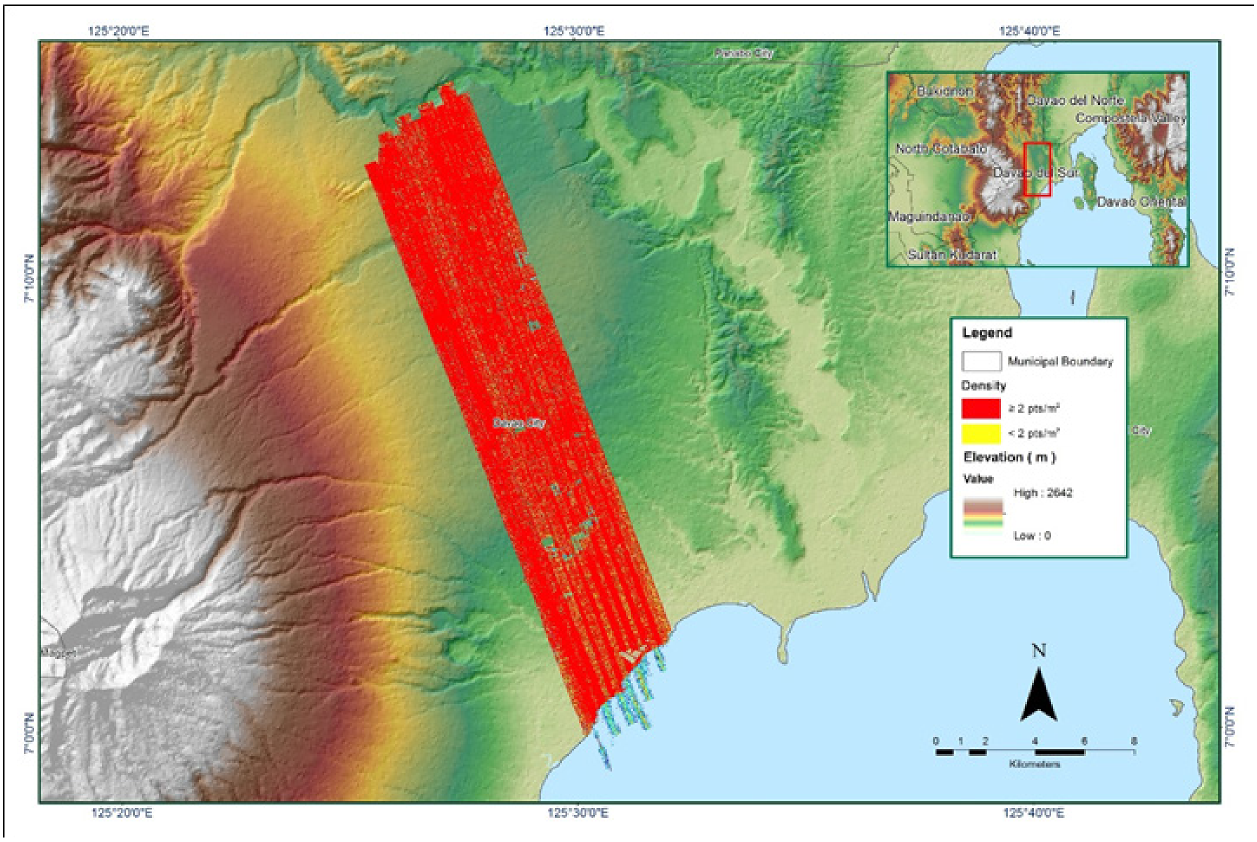



Figure A-8.13. Density map of merged LiDAR data

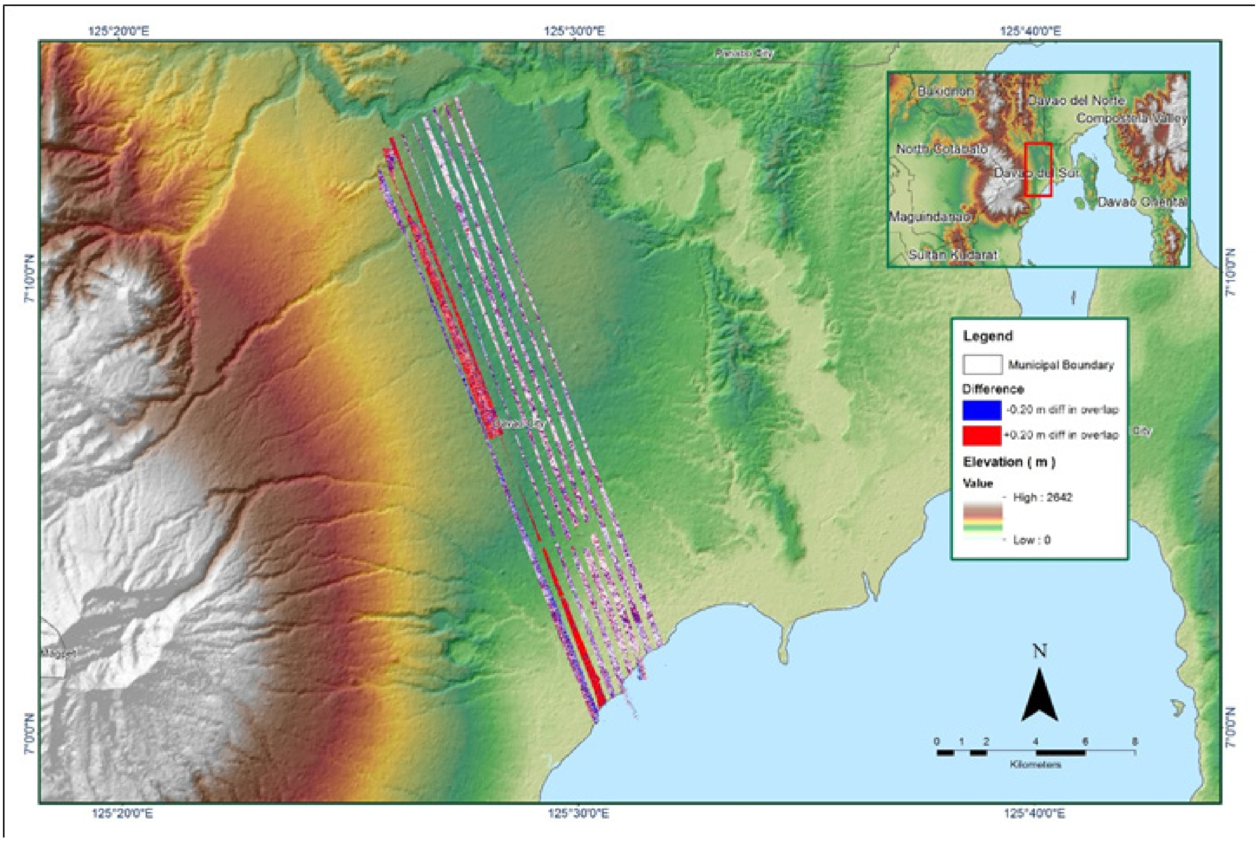



Figure A-8.14. Elevation difference between flight lines

Table A-8.3. Mission Summary Report for Mission Blk82 Voids

| Flight Area | Davao Del Sur |
|---|---|
| Mission Name | Blk82 Voids |
| Inclusive Flights | 7427G,7426G |
| Range data size | 15.26 GB |
| POS data size | 267 MB |
| Base Data Size | 15.66 MB |
| Image | na |
| Transfer date | August 29, 2014 |
| | |
| Solution Status | |
| Number of Satellites (>6) | Yes |
| PDOP (<3) | Yes |
| Baseline Length (<30km) | Yes |
| Processing Mode (<=1) | Yes |
| | |
| Smoothed Performance Metrics (in cm) | |
| RMSE for North Position (<4.0 cm) | 2.5 |
| RMSE for East Position (<4.0 cm) | 3.1 |
| RMSE for Down Position (<8.0 cm) | 7.4 |
| | |
| Boresight correction stdev (<0.001deg) | 0.001127 |
| IMU attitude correction stdev (<0.001deg) | 0.016683 |
| GPS position stdev (<0.01m) | 0.0248 |
| | |
| Minimum % overlap (>25) | 10.46% |
| Ave point cloud density per sq.m. (>2.0) | 2.79 |
| Elevation difference between strips (<0.20 m) | Yes |
| | |
| Number of 1km x 1km blocks | 272 |
| Maximum Height | 421.89 m |
| Minimum Height | 67.51 m |
| | |
| Classification (# of points) | |
| Ground | 40,594,810 |
| Low vegetation | 34,398,304 |
| Medium vegetation | 58,498,265 |
| High vegetation | 166,572,237 |
| Building | 4,853,133 |
| | |
| Orthophoto | No |
| Processed By | Engr. Analyn Naldo, Engr. Harmond Santos, Ailyn Biñas |

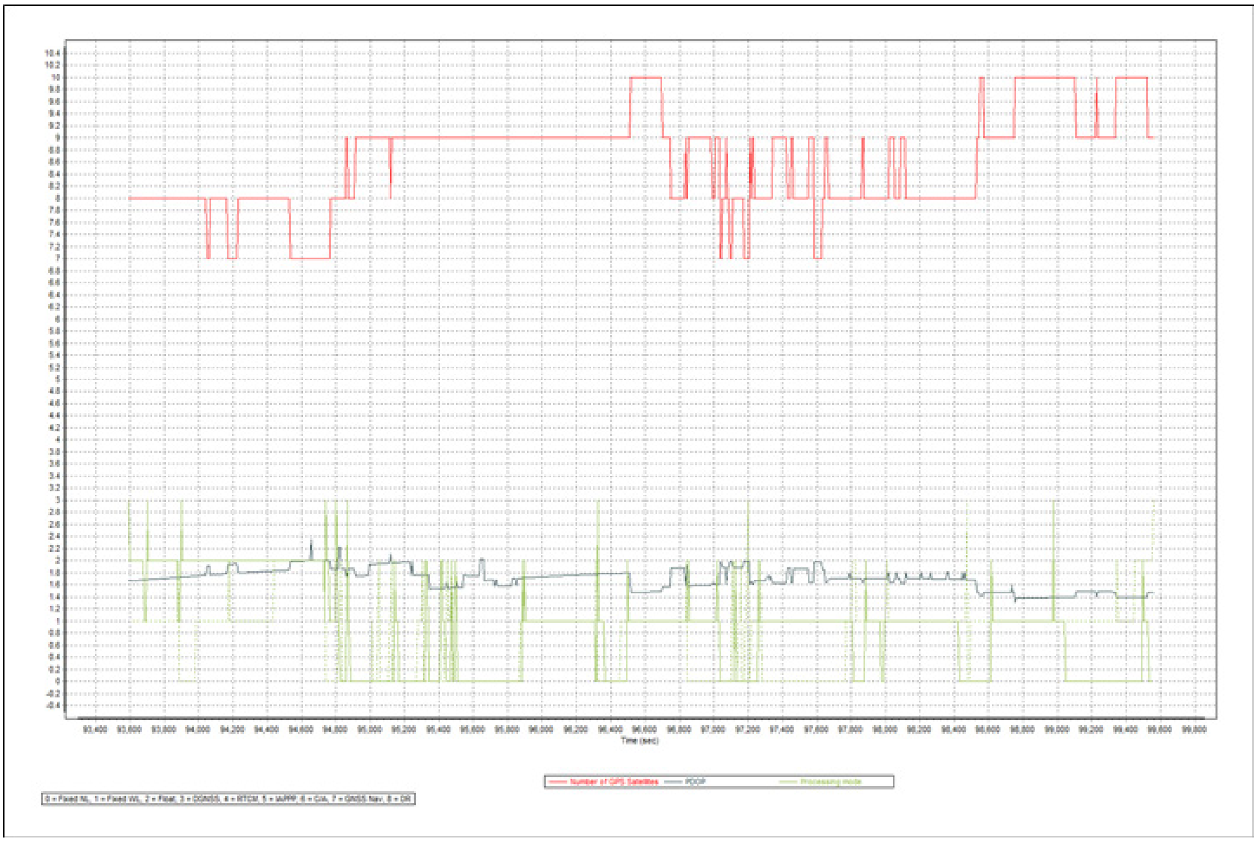



Figure A-8.15. Solution Status

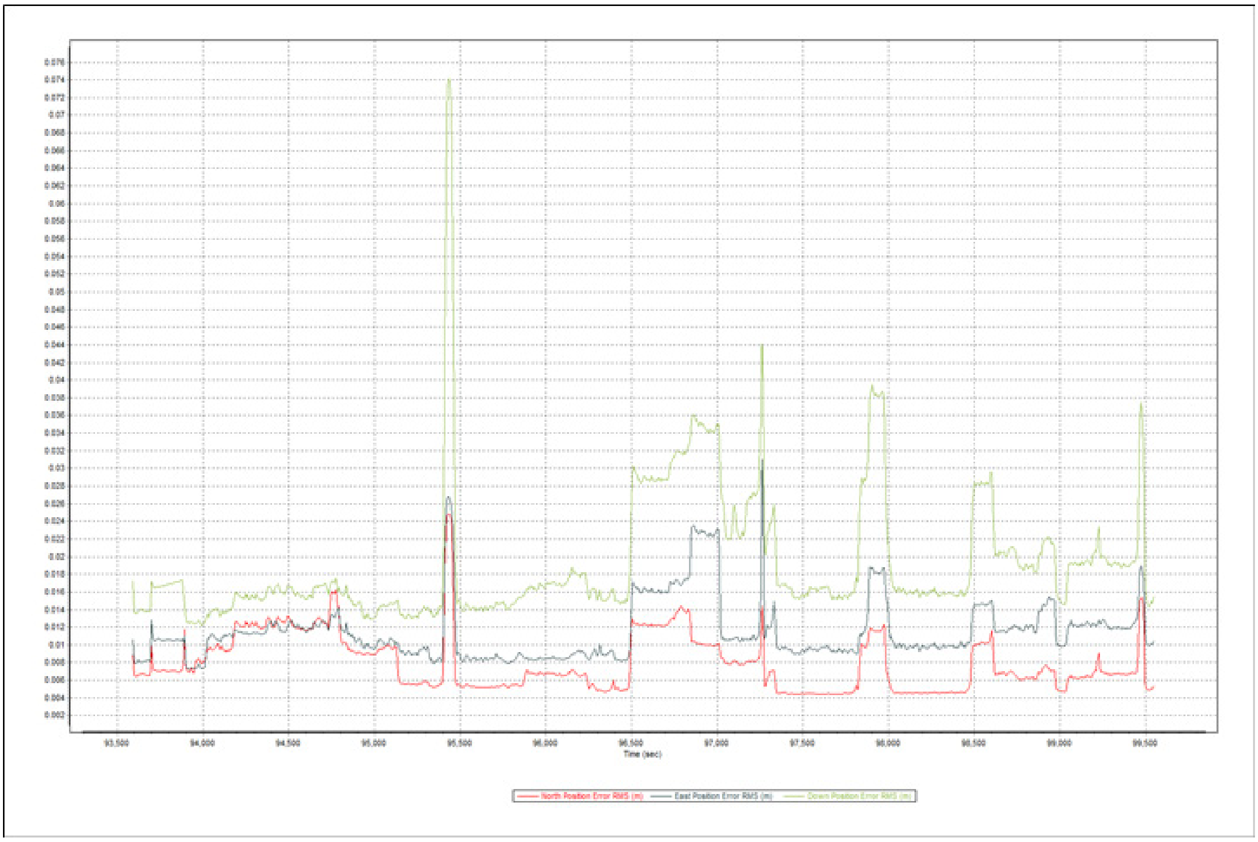



Figure A-8.16. Smoothed Performance Metric Parameters

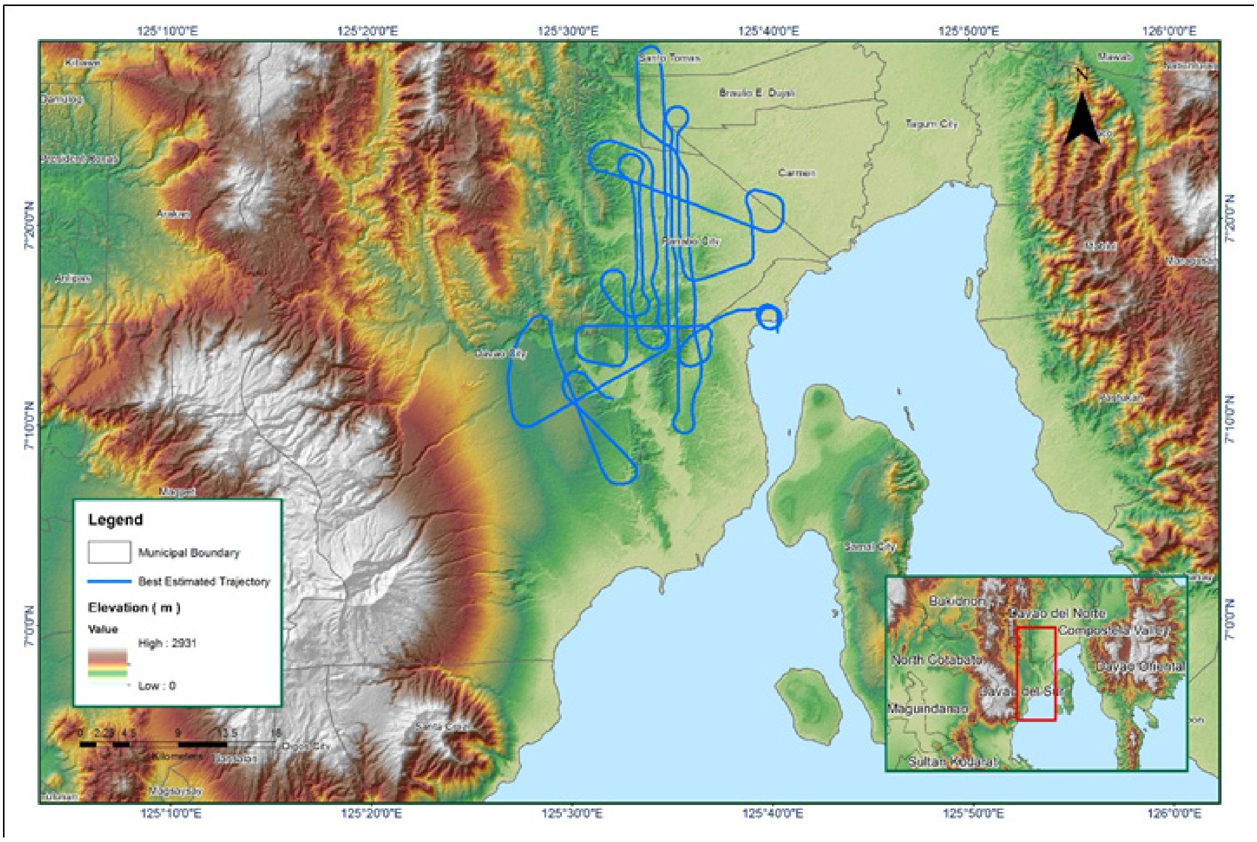



Figure A-8.17. Best Estimated Trajectory

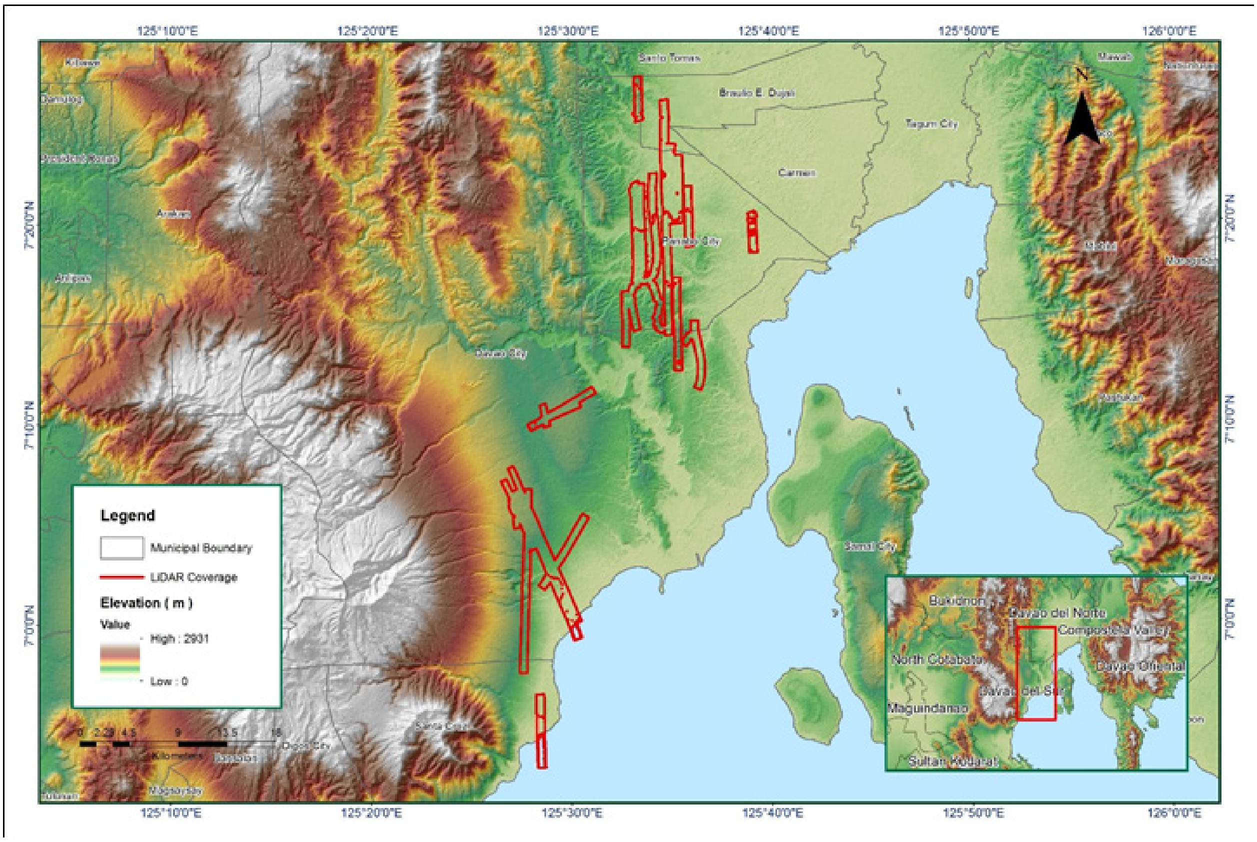



Figure A-8.18. Coverage of LiDAR data

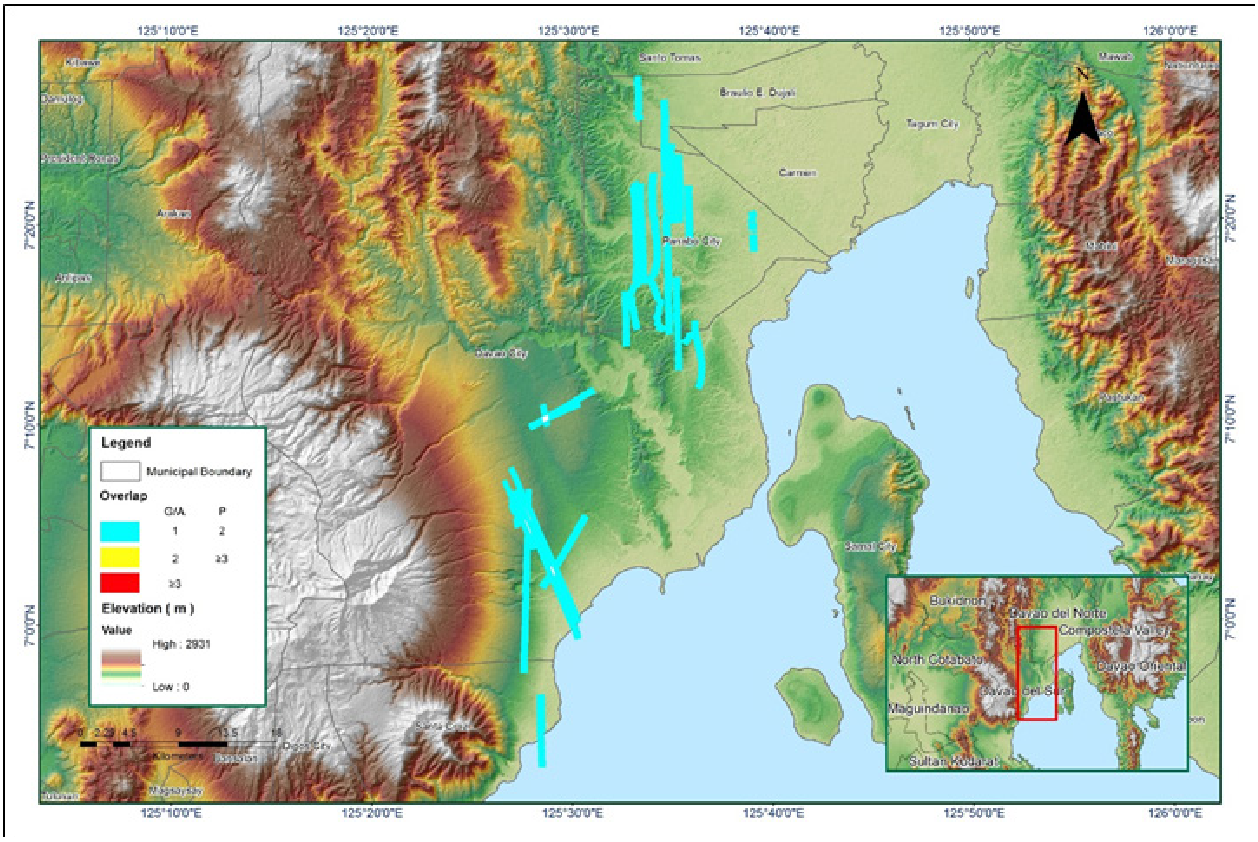



Figure A-8.19. Image of Data Overlap

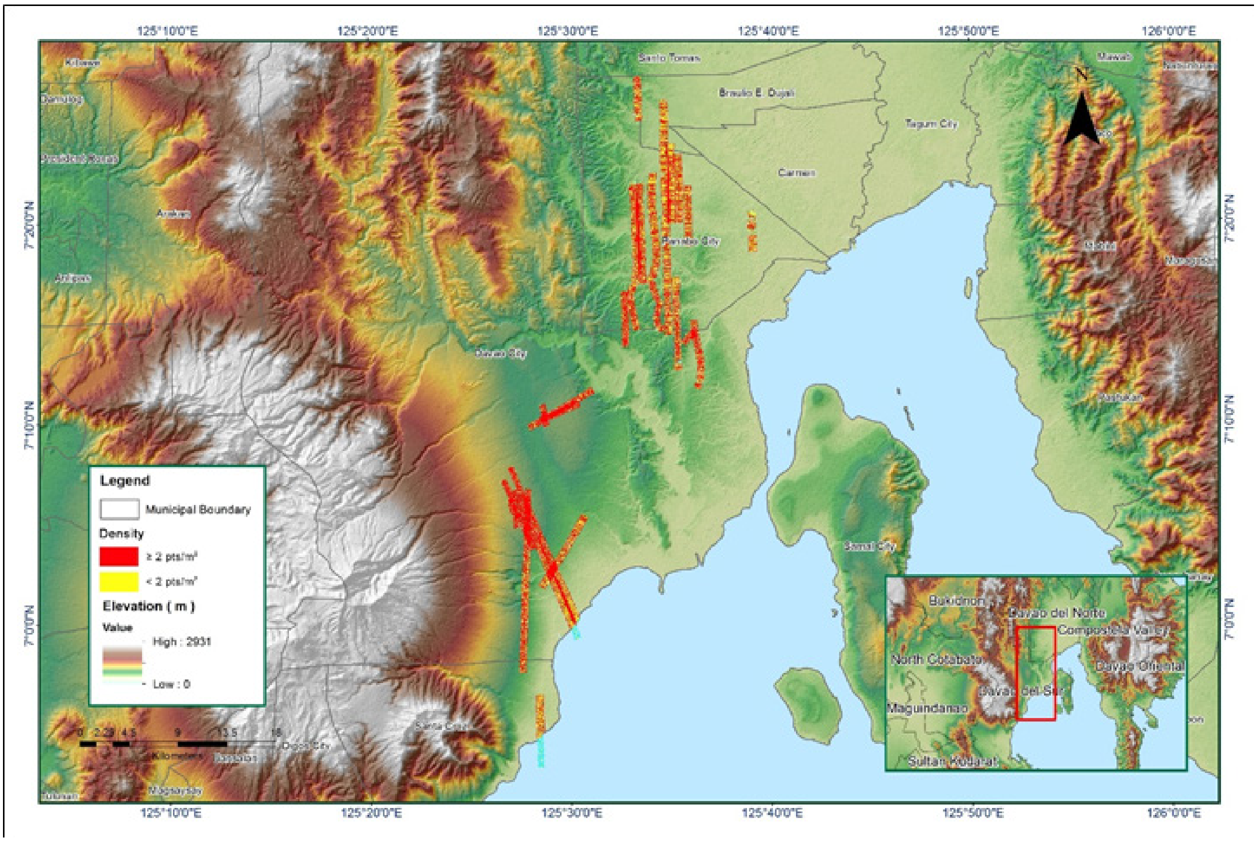



Figure A-8.20. Density map of merged LiDAR data

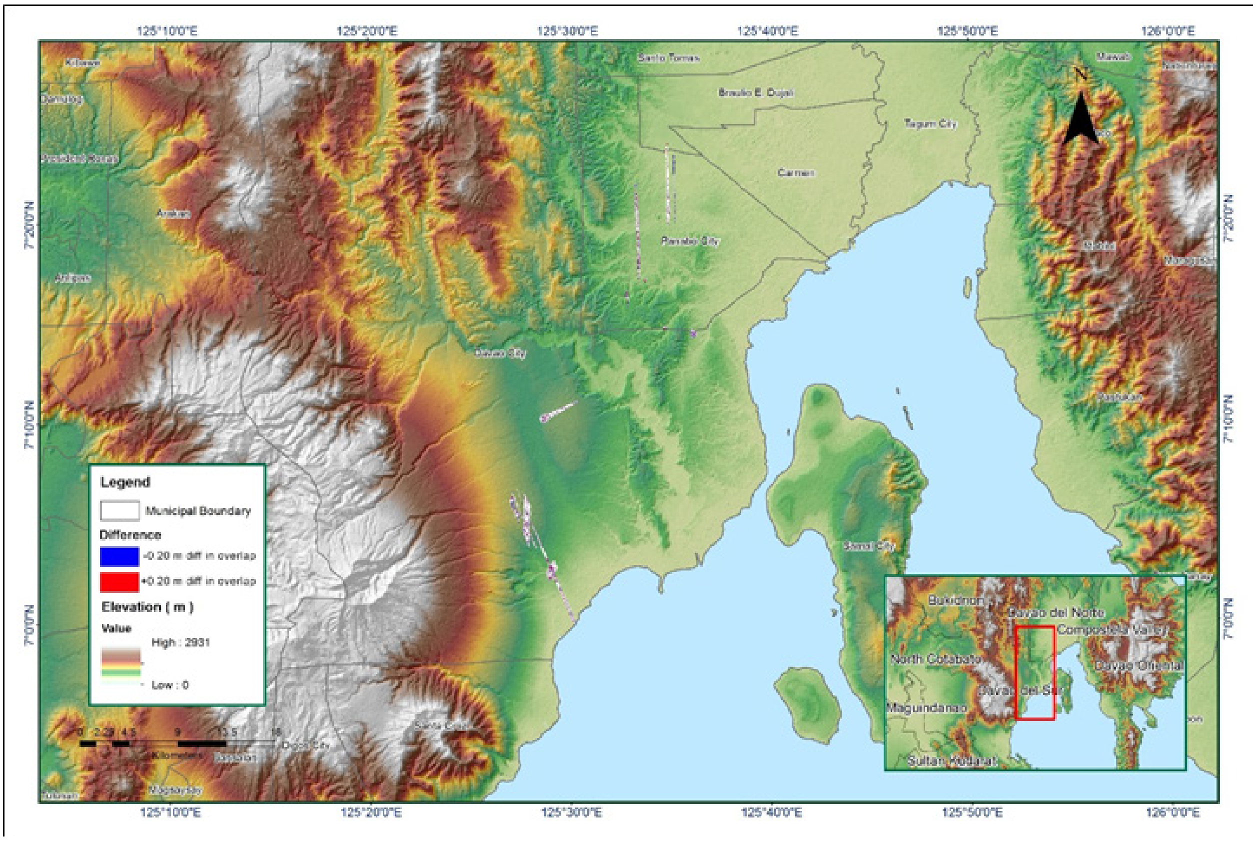


Figure A-8.21. Elevation difference between flight lines

Table A-8.4. Mission Summary Report for Mission Blk82E

| Flight Area | Davao Del Sur |
|---|---|
| Mission Name | Blk82E |
| Inclusive Flights | 7388G,7401G |
| Range data size | 29.65 GB |
| POS data size | 332 MB |
| Base Data Size | 15.79 MB |
| Image | na |
| Transfer date | August 7, 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) | 1.05 |
| RMSE for East Position (<4.0 cm) | 1.25 |
| RMSE for Down Position (<8.0 cm) | 2.7 |
| | |
| Boresight correction stdev (<0.001deg) | 0.000183 |
| IMU attitude correction stdev (<0.001deg) | 0.633546 |
| GPS position stdev (<0.01m) | 0.0028 |
| | |
| Minimum % overlap (>25) | 24.76% |
| Ave point cloud density per sq.m. (>2.0) | 2.92 |
| Elevation difference between strips (<0.20 m) | Yes |
| | |
| Number of 1km x 1km blocks | 318 |
| Maximum Height | 403.82 m |
| Minimum Height | 62.44 m |
| | |
| Classification (# of points) | |
| Ground | 75,679,213 |
| Low vegetation | 78,983,338 |
| Medium vegetation | 146,928,343 |
| High vegetation | 282,014,947 |
| Building | 24,716,788 |
| | |
| Orthophoto | No |
| Processed By | Engr. Irish Cortez, Engr. Harmond Santos, Ailyn Biñas |

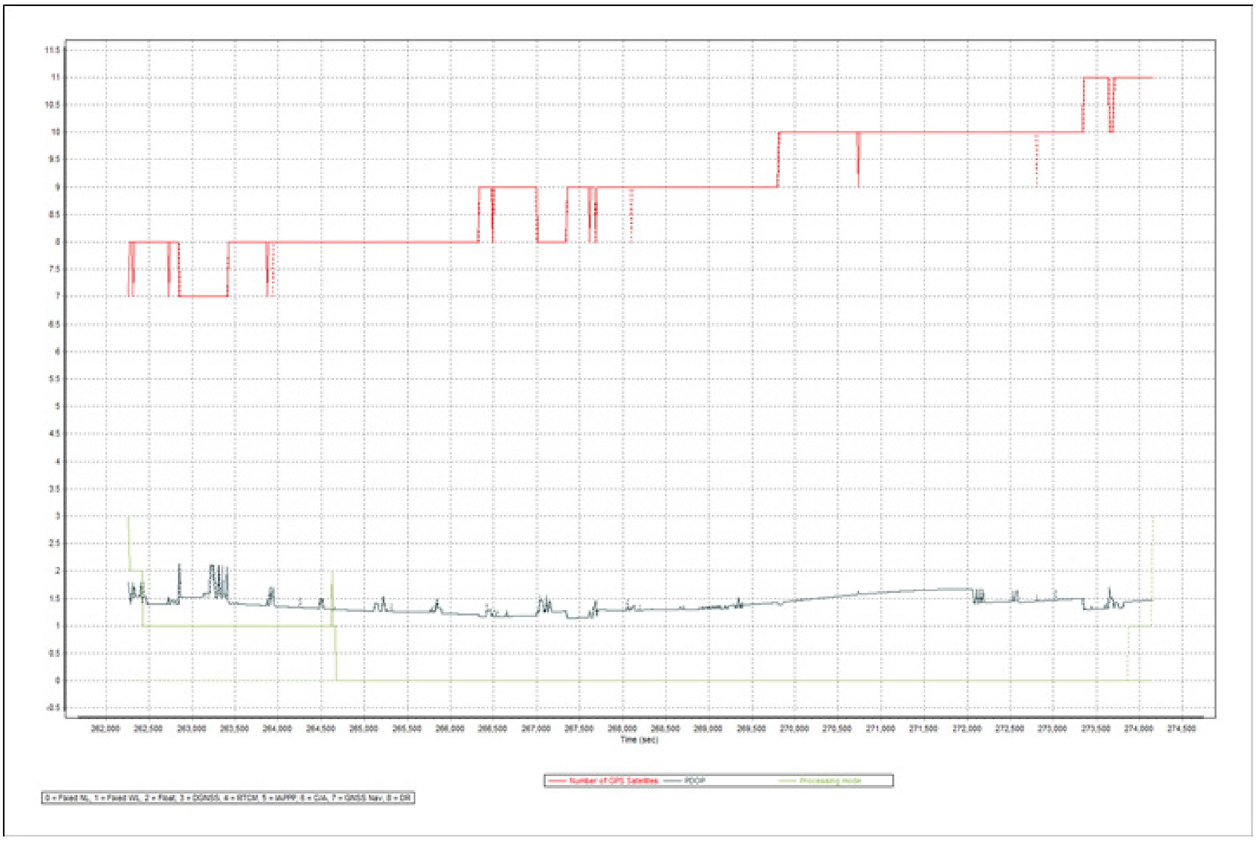


Figure A-8.22. Solution Status

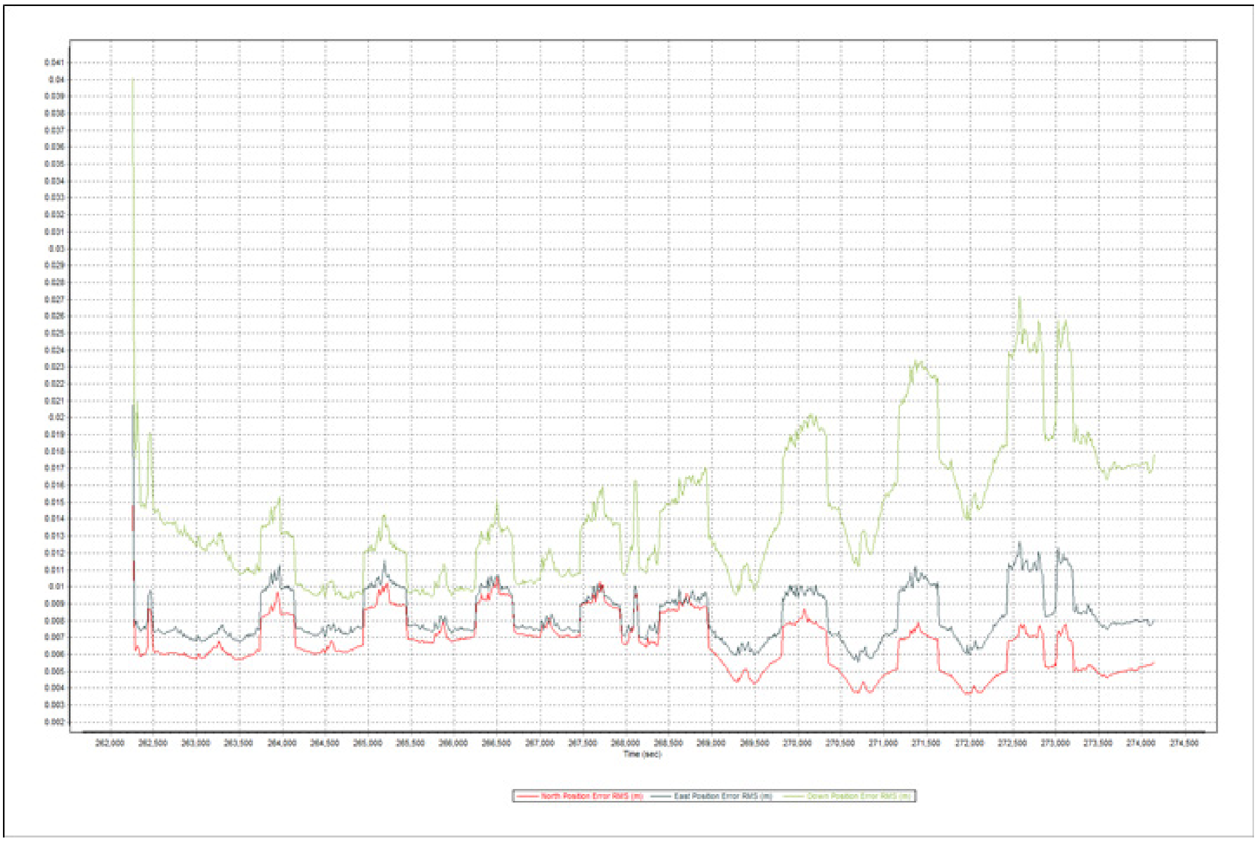


Figure A-8.23. Smoothed Performance Metric Parameters

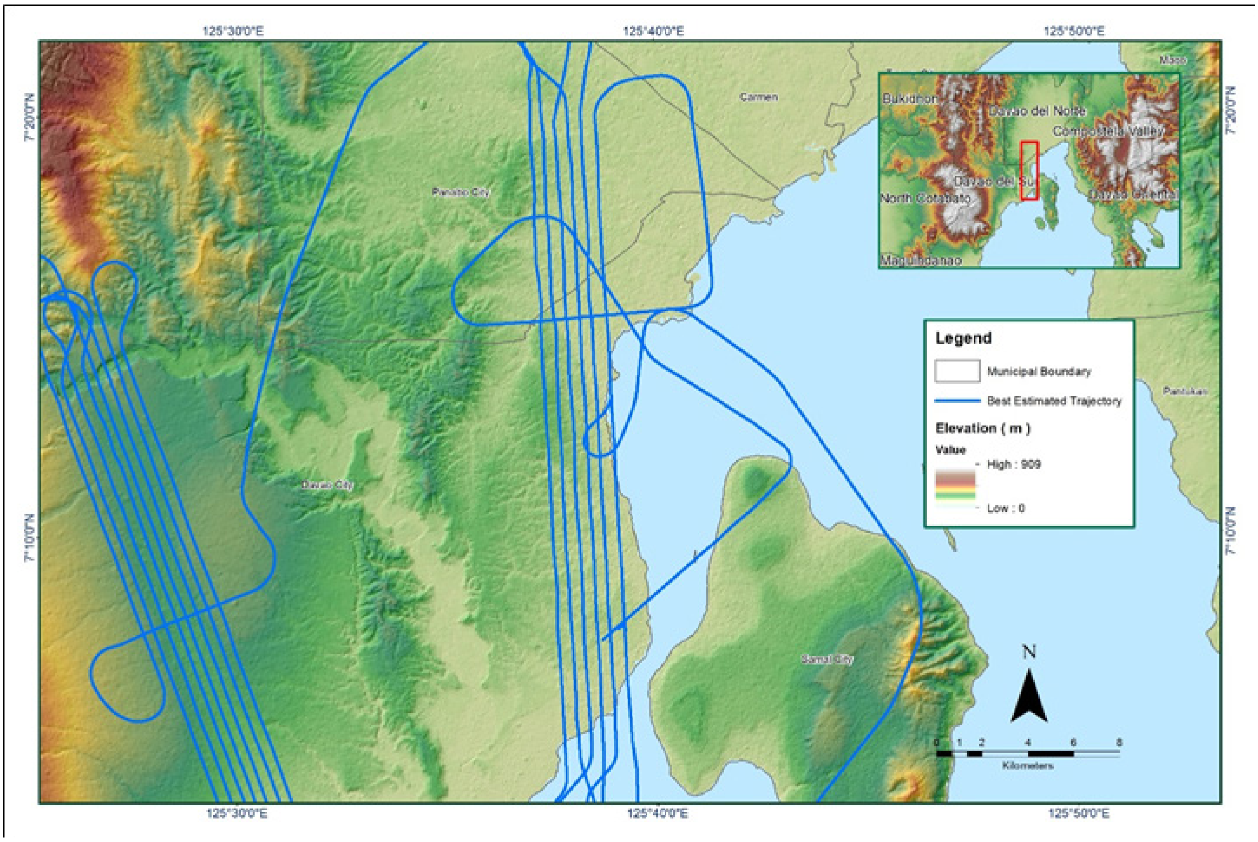



Figure A-8.24. Best Estimated Trajectory

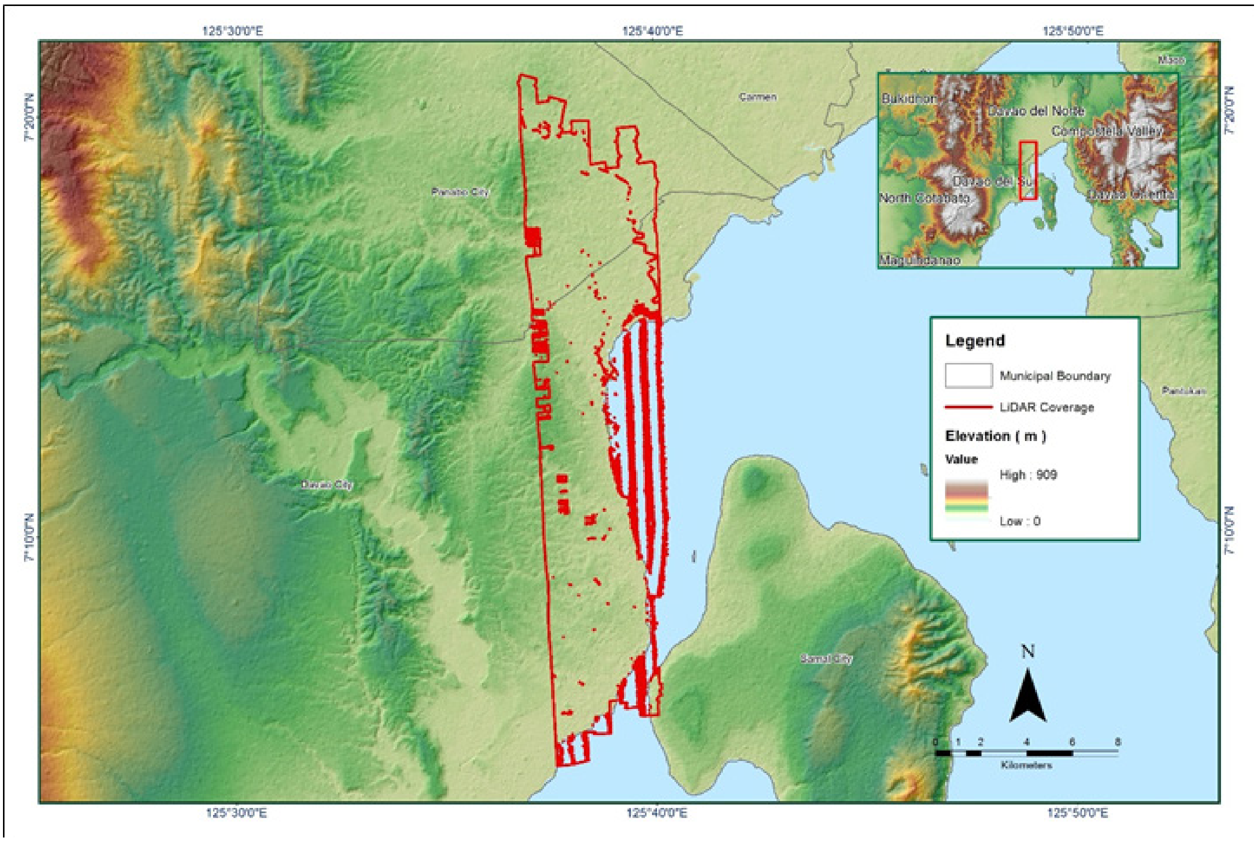



Figure A-8.25. Coverage of LiDAR data

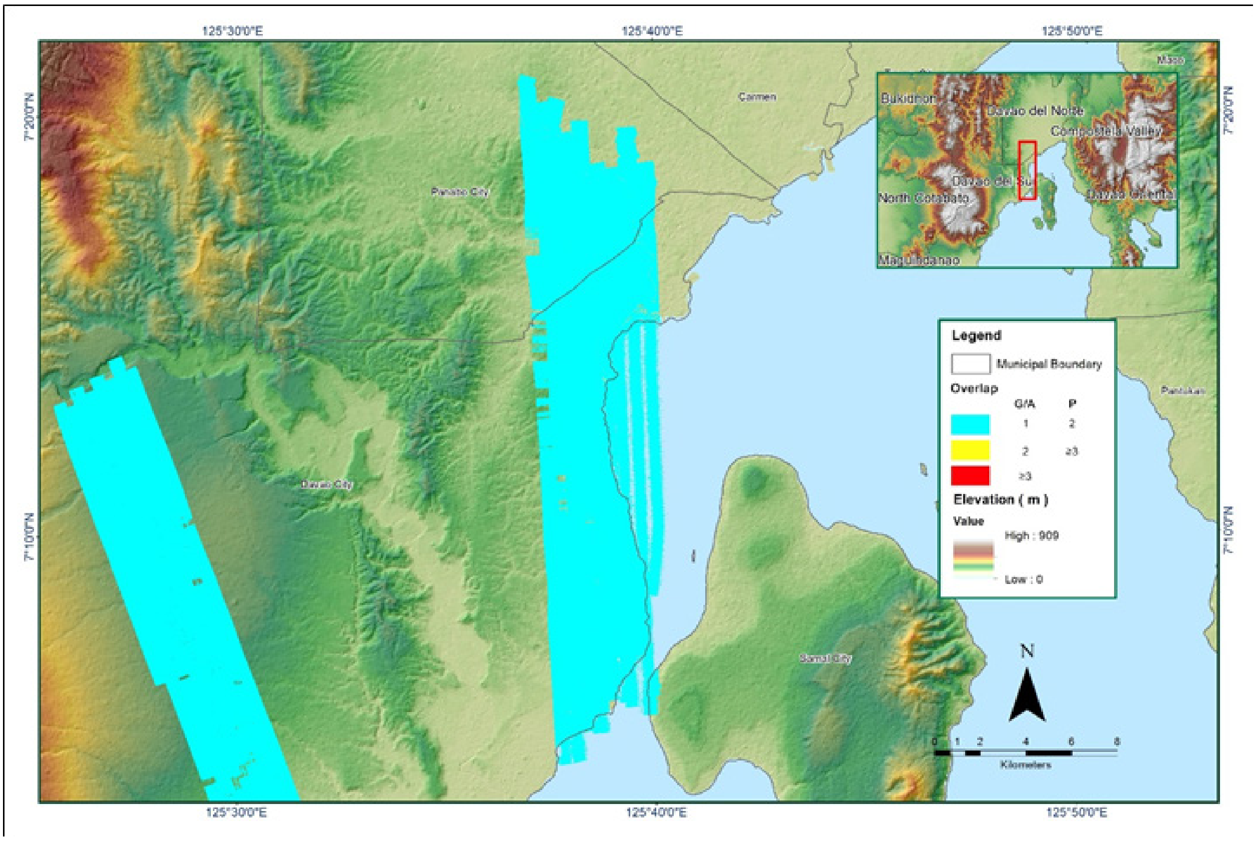



Figure A-8.26. Image of Data Overlap

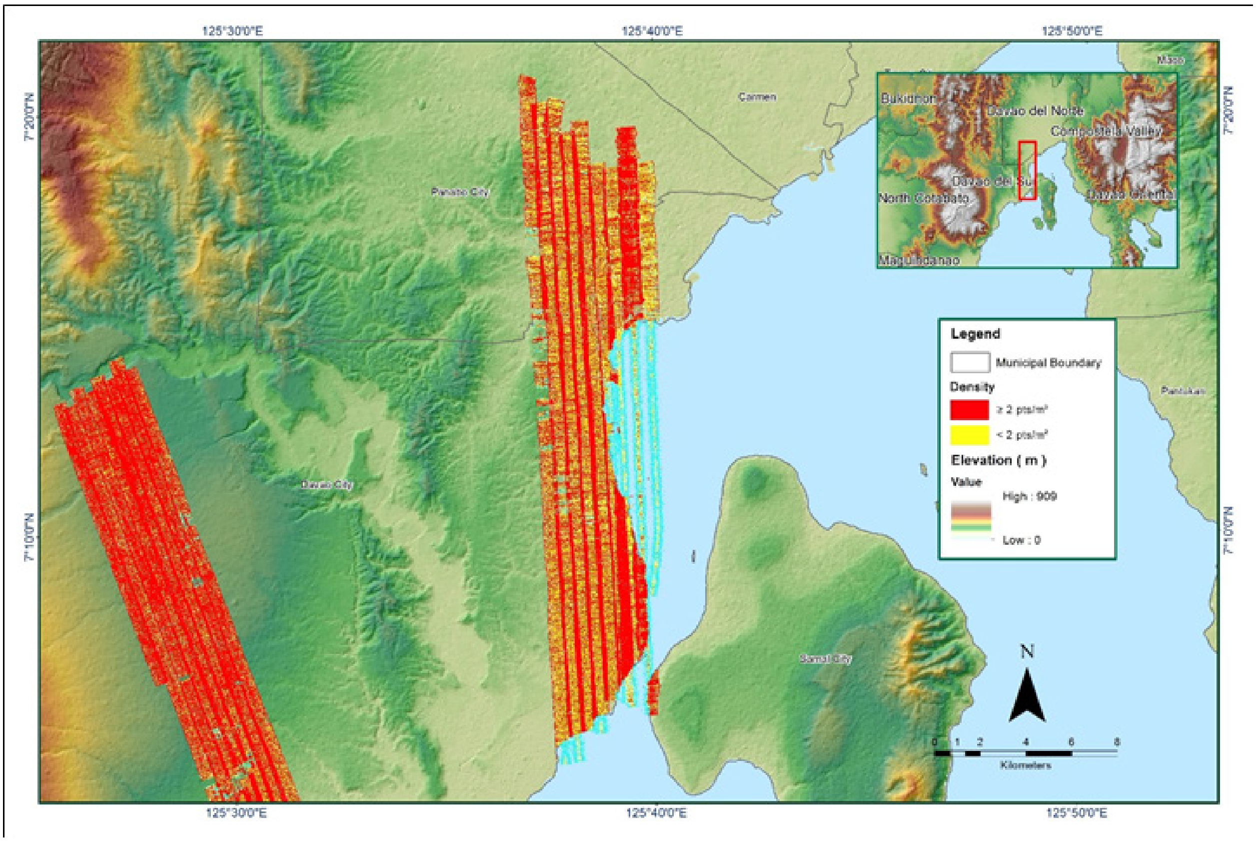



Figure A-8.27. Density map of merged LiDAR data

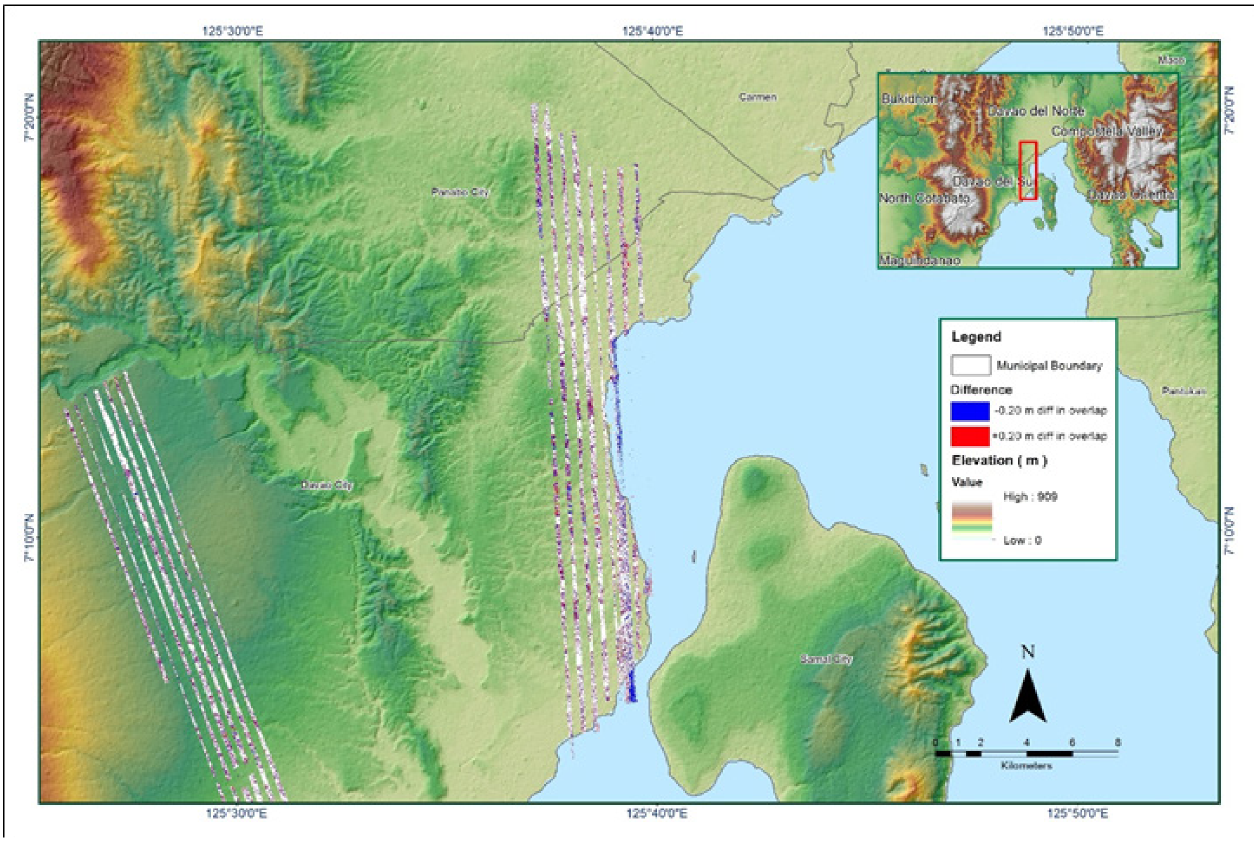



Figure A-8.28. Elevation difference between flight lines

# Annex 9. Talomo Model Basin Parameters

Table A-9.1. Talomo 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 |
| W1000 | 4.0218 | 99 | 0 | 0.046724 | 0.045751 | Discharge | 0.060103 | 0.009604 | Ratio to Peak | 0.50132 |
| W1010 | 7.4379 | 45.723 | 0 | 0.035392 | 0.034655 | Discharge | 0.027641 | 0.0147 | Ratio to Peak | 0.5 |
| W1020 | 9.4434 | 66.292 | 0 | 0.048278 | 0.047274 | Discharge | 0.038495 | 0.009845 | Ratio to Peak | 0.75 |
| W1030 | 2.3662 | 90.519 | 0 | 0.041036 | 0.040182 | Discharge | 0.040942 | 0.004445 | Ratio to Peak | 0.50243 |
| W1040 | 5.2978 | 99 | 0 | 0.02 | 0.024 | Discharge | 0.000545 | 0.004445 | Ratio to Peak | 0.49244 |
| W1050 | 5.2978 | 99 | 0 | 0.02 | 0.024 | Discharge | 0.001675 | 0.004445 | Ratio to Peak | 0.735 |
| W1060 | 4.9292 | 86.693 | 0 | 0.035256 | 0.034523 | Discharge | 0.04095 | 0.004445 | Ratio to Peak | 0.49242 |
| W1070 | 3.7768 | 82.858 | 0 | 0.055066 | 0.053921 | Discharge | 0.050203 | 0.004445 | Ratio to Peak | 0.49241 |
| W1080 | 3.9317 | 81.34 | 0 | 0.044682 | 0.043752 | Discharge | 0.041061 | 0.004445 | Ratio to Peak | 0.735 |
| W1090 | 4.0936 | 80.606 | 0 | 0.048812 | 0.047796 | Discharge | 0.059072 | 0.006533 | Ratio to Peak | 0.735 |
| W1100 | 2.3779 | 81.634 | 0 | 0.045406 | 0.044461 | Discharge | 0.071006 | 0.004445 | Ratio to Peak | 0.49225 |
| W1110 | 10.239 | 62.609 | 0 | 0.048796 | 0.047782 | Discharge | 0.035969 | 0.004445 | Ratio to Peak | 0.5 |
| W1120 | 9.9142 | 64.292 | 0 | 0.034198 | 0.033487 | Discharge | 0.010819 | 0.004445 | Ratio to Peak | 0.5 |
| W1130 | 16.364 | 61.001 | 0 | 0.070236 | 0.068775 | Discharge | 0.074744 | 0.004445 | Ratio to Peak | 0.5 |
| W1140 | 14.289 | 65.332 | 0 | 0.044242 | 0.043321 | Discharge | 0.039137 | 0.004445 | Ratio to Peak | 0.5 |
| W1150 | 4.3577 | 83.365 | 0 | 0.036556 | 0.035796 | Discharge | 0.051336 | 0.004445 | Ratio to Peak | 0.49244 |
| W1160 | 7.0033 | 52.441 | 0 | 0.040624 | 0.039779 | Discharge | 0.035591 | 0.009751 | Ratio to Peak | 0.5 |
| W1170 | 9.4899 | 73.569 | 0 | 0.061724 | 0.06044 | Discharge | 0.13658 | 0.0098 | Ratio to Peak | 0.575 |
| W1180 | 3.664 | 81.634 | 0 | 0.024358 | 0.024 | Discharge | 0.018514 | 0.004445 | Ratio to Peak | 0.49 |
| W1190 | 2.3781 | 81.634 | 0 | 0.03325 | 0.032558 | Discharge | 0.042467 | 0.004445 | Ratio to Peak | 0.4802 |
| W1200 | 4.5875 | 84.188 | 0 | 0.02 | 0.024 | Discharge | 0.007108 | 0.004445 | Ratio to Peak | 0.75 |
| W1210 | 5.6156 | 80.944 | 0 | 0.048664 | 0.047653 | Discharge | 0.11362 | 0.004445 | Ratio to Peak | 0.49241 |
| W1220 | 3.519 | 84.586 | 0 | 0.042612 | 0.041726 | Discharge | 0.053808 | 0.004445 | Ratio to Peak | 0.49243 |

| 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 | THreschold Type | Ratio to Peak |
| W1230 | 3.4466 | 84.81 | 0 | 0.040112 | 0.039277 | Discharge | 0.049258 | 0.004445 | Ratio to Peak | 0.49236 |
| W1240 | 3.7836 | 81.634 | 0 | 0.03558 | 0.03484 | Discharge | 0.041038 | 0.004445 | Ratio to Peak | 0.4802 |
| W1250 | 5.2978 | 81.634 | 0 | 0.02 | 0.024 | Discharge | 0.001728 | 0.004445 | Ratio to Peak | 0.49 |
| W1260 | 7.875 | 81.634 | 0 | 0.030666 | 0.030028 | Discharge | 0.015738 | 0.004445 | Ratio to Peak | 0.32667 |
| W1270 | 19.726 | 49.128 | 0 | 0.044628 | 0.043701 | Discharge | 0.019544 | 0.004445 | Ratio to Peak | 0.5 |
| W1280 | 16.212 | 54.024 | 0 | 0.059002 | 0.057775 | Discharge | 0.094323 | 0.004445 | Ratio to Peak | 0.5 |
| W1290 | 4.0272 | 76.832 | 0 | 0.059738 | 0.058496 | Discharge | 0.034233 | 0.004445 | Ratio to Peak | 0.4802 |
| W1300 | 6.0297 | 76.832 | 0 | 0.04072 | 0.039874 | Discharge | 0.065439 | 0.004445 | Ratio to Peak | 0.32667 |
| W1310 | 14.366 | 57.009 | 0 | 0.040834 | 0.039985 | Discharge | 0.066374 | 0.004445 | Ratio to Peak | 0.5 |
| W1320 | 13.482 | 58.559 | 0 | 0.032964 | 0.032279 | Discharge | 0.052379 | 0.004445 | Ratio to Peak | 0.5 |
| W1330 | 4.0397 | 76.832 | 0 | 0.038918 | 0.03811 | Discharge | 0.085804 | 0.004445 | Ratio to Peak | 0.4802 |
| W1340 | 15 | 78.4 | 0 | 0.064308 | 0.06297 | Discharge | 7.54E-02 | 0.010096 | Ratio to Peak | 0.5 |
| W1350 | 15.586 | 55 | 0 | 0.02 | 0.024 | Discharge | 9.15E-03 | 0.01 | Ratio to Peak | 0.5 |
| W1360 | 15.586 | 55 | 0 | 0.033468 | 0.032771 | Discharge | 0.086031 | 0.01 | Ratio to Peak | 0.5 |
| W1370 | 15 | 78.4 | 0 | 0.04976 | 0.048725 | Discharge | 0.06996 | 0.010096 | Ratio to Peak | 0.5 |
| W1380 | 15.586 | 55 | 0 | 0.03081 | 0.030168 | Discharge | 0.048522 | 0.01 | Ratio to Peak | 0.5 |
| W1390 | 15.586 | 55 | 0 | 0.037904 | 0.037116 | Discharge | 0.075651 | 0.01 | Ratio to Peak | 0.5 |
| W1400 | 6.7 | 72.03 | 0 | 0.032202 | 0.031532 | Discharge | 0.0231 | 0.010098 | Ratio to Peak | 0.33333 |
| W1410 | 6.6996 | 72.03 | 0 | 0.056462 | 0.055288 | Discharge | 0.057788 | 0.010099 | Ratio to Peak | 0.49 |
| W1420 | 6.5334 | 99 | 0 | 0.051818 | 0.05074 | Discharge | 0.04446 | 0.006533 | Ratio to Peak | 0.5047 |
| W720 | 2.6293 | 86.086 | 0 | 0.05684 | 0.055657 | Discharge | 0.15566 | 0.009847 | Ratio to Peak | 0.49216 |
| W730 | 2.0881 | 65.878 | 0 | 0.045044 | 0.044107 | Discharge | 0.050157 | 0.009837 | Ratio to Peak | 0.49242 |
| W740 | 2.3692 | 87.209 | 0 | 0.041434 | 0.040572 | Discharge | 0.042205 | 0.009983 | Ratio to Peak | 0.49239 |
| W750 | 3.5311 | 87.203 | 0 | 0.046414 | 0.045449 | Discharge | 0.075654 | 0.015062 | Ratio to Peak | 0.735 |

| 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 | THreschold Type | Ratio to Peak |
| W760 | 5.1576 | 58.317 | 0 | 0.033088 | 0.0324 | Discharge | 0.028119 | 0.006699 | Ratio to Peak | 0.32667 |
| W770 | 2.378 | 58.146 | 0 | 0.047046 | 0.046068 | Discharge | 0.056339 | 0.00882 | Ratio to Peak | 0.48736 |
| W780 | 3.514 | 89.049 | 0 | 0.029312 | 0.028702 | Discharge | 0.01517 | 0.004445 | Ratio to Peak | 0.33333 |
| W790 | 5.127 | 37.683 | 0 | 0.069848 | 0.068394 | Discharge | 0.084315 | 0.015072 | Ratio to Peak | 0.49 |
| W800 | 2.1963 | 86.2 | 0 | 0.070008 | 0.068551 | Discharge | 0.019594 | 0.006667 | Ratio to Peak | 0.32667 |
| W810 | 6.2469 | 84.985 | 0 | 0.058538 | 0.05732 | Discharge | 0.098238 | 0.006696 | Ratio to Peak | 0.32667 |
| W820 | 3.3961 | 55.499 | 0 | 0.030356 | 0.029724 | Discharge | 0.03431 | 0.004445 | Ratio to Peak | 0.50199 |
| W830 | 2.0685 | 99 | 0 | 0.15796 | 7.5333 | Discharge | 0.034373 | 0.010097 | Ratio to Peak | 0.5 |
| W840 | 3.5036 | 56.694 | 0 | 0.02 | 0.024 | Discharge | 0.011843 | 0.006533 | Ratio to Peak | 0.49244 |
| W850 | 4.0681 | 79.158 | 0 | 0.052126 | 0.051042 | Discharge | 0.12024 | 0.00882 | Ratio to Peak | 0.52988 |
| W860 | 6.9489 | 61.67 | 0 | 0.057378 | 0.056184 | Discharge | 0.12518 | 0.00882 | Ratio to Peak | 0.49242 |
| W870 | 2.3075 | 92.199 | 0 | 0.040028 | 0.039194 | Discharge | 0.038878 | 0.015074 | Ratio to Peak | 0.50245 |
| W880 | 2.3097 | 85.476 | 0 | 0.033172 | 0.032482 | Discharge | 0.036013 | 0.004445 | Ratio to Peak | 0.4802 |
| W890 | 2.4218 | 99 | 0 | 0.047244 | 0.046261 | Discharge | 0.044541 | 0.009536 | Ratio to Peak | 0.735 |
| W900 | 2.3004 | 99 | 0 | 0.02 | 0.024 | Discharge | 0.002942 | 0.009848 | Ratio to Peak | 0.49259 |
| W910 | 1.8613 | 89.82 | 0 | 0.024474 | 0.024 | Discharge | 0.02636 | 0.009847 | Ratio to Peak | 0.49 |
| W920 | 2.2614 | 89 | 0 | 0.026524 | 0.025972 | Discharge | 0.017639 | 0.009847 | Ratio to Peak | 0.4802 |
| W930 | 2.3659 | 85.466 | 0 | 0.048272 | 0.047267 | Discharge | 0.057659 | 0.006533 | Ratio to Peak | 0.4802 |
| W940 | 2.2614 | 99 | 0 | 0.02 | 0.024 | Discharge | 9.58E-05 | 0.010056 | Ratio to Peak | 0.49 |
| W950 | 3.3777 | 89.012 | 0 | 0.04466 | 0.043732 | Discharge | 0.040681 | 0.01008 | Ratio to Peak | 0.4802 |
| W960 | 3.0731 | 89.892 | 0 | 0.021528 | 0.024 | Discharge | 0.013414 | 0.010098 | Ratio to Peak | 0.48882 |
| W970 | 2.4889 | 83.659 | 0 | 0.037458 | 0.036678 | Discharge | 0.040674 | 0.010096 | Ratio to Peak | 0.48446 |
| W980 | 3.2267 | 83.816 | 0 | 0.046482 | 0.045516 | Discharge | 0.041154 | 0.010098 | Ratio to Peak | 0.48901 |
| W990 | 3.8046 | 99 | 0 | 0.022738 | 0.024 | Discharge | 0.011067 | 0.006698 | Ratio to Peak | 0.50238 |

# Annex 10. Talomo Model Reach Parameters

Table A-10.1. Talomo Model Reach Parameters

| Reach Number | Muskingum Cunge Channel Routing | | | | | | |
|---|---|---|---|---|---|---|---|
| | Time Step Method | Length (m) | Slope | Manning's n | Shape | Width | Side Slope |
| R100 | Automatic Fixed Interval | 972.91 | 0.015269 | 0.19012 | Trapezoid | 28.63 | 1 |
| R110 | Automatic Fixed Interval | 1397.7 | 0.000602 | 0.19012 | Trapezoid | 28.63 | 1 |
| R150 | Automatic Fixed Interval | 2247.8 | 0.001107 | 0.19012 | Trapezoid | 28.63 | 1 |
| R160 | Automatic Fixed Interval | 3722.1 | 0.003247 | 0.19012 | Trapezoid | 28.63 | 1 |
| R170 | Automatic Fixed Interval | 665.23 | 0.004304 | 0.19012 | Trapezoid | 28.63 | 1 |
| R180 | Automatic Fixed Interval | 88.279 | 0.007766 | 0.19012 | Trapezoid | 28.63 | 1 |
| R190 | Automatic Fixed Interval | 1101.5 | 0.011193 | 0.19012 | Trapezoid | 28.63 | 1 |
| R200 | Automatic Fixed Interval | 3069.6 | 0.028365 | 0.19012 | Trapezoid | 28.63 | 1 |
| R210 | Automatic Fixed Interval | 2424.4 | 0.031548 | 0.19012 | Trapezoid | 28.63 | 1 |
| R250 | Automatic Fixed Interval | 2188.6 | 0.022647 | 0.19012 | Trapezoid | 28.63 | 1 |
| R270 | Automatic Fixed Interval | 2284 | 0.003158 | 0.19012 | Trapezoid | 28.63 | 1 |
| R290 | Automatic Fixed Interval | 255.55 | 0.022736 | 0.19012 | Trapezoid | 28.63 | 1 |
| R30 | Automatic Fixed Interval | 1094.9 | 0.002208 | 0.19012 | Trapezoid | 28.63 | 1 |
| R310 | Automatic Fixed Interval | 522.1 | 0.018704 | 0.19012 | Trapezoid | 28.63 | 1 |
| R320 | Automatic Fixed Interval | 5275.2 | 0.026924 | 0.19012 | Trapezoid | 28.63 | 1 |
| R350 | Automatic Fixed Interval | 10089 | 0.03635 | 0.19012 | Trapezoid | 28.63 | 1 |
| R360 | Automatic Fixed Interval | 4559.1 | 0.047154 | 0.19012 | Trapezoid | 28.63 | 1 |
| R400 | Automatic Fixed Interval | 2681.6 | 0.005754 | 0.19012 | Trapezoid | 28.63 | 1 |
| R410 | Automatic Fixed Interval | 2830.2 | 0.025681 | 0.19012 | Trapezoid | 28.63 | 1 |
| R440 | Automatic Fixed Interval | 361.4 | 0.048253 | 0.19012 | Trapezoid | 28.63 | 1 |
| R450 | Automatic Fixed Interval | 2165.1 | 0.014418 | 0.19012 | Trapezoid | 28.63 | 1 |
| R470 | Automatic Fixed Interval | 789.36 | 0.002088 | 0.19012 | Trapezoid | 28.63 | 1 |

| Reach Number | Muskingum Cunge Channel Routing | | | | | | |
|---|---|---|---|---|---|---|---|
| | Time Step Method | Length (m) | Slope | Manning's n | Shape | Width | Side Slope |
| R480 | Automatic Fixed Interval | 2477.8 | 0.002369 | 0.19012 | Trapezoid | 28.63 | 1 |
| R490 | Automatic Fixed Interval | 4039.1 | 0.07225 | 0.19012 | Trapezoid | 28.63 | 1 |
| R530 | Automatic Fixed Interval | 1183.9 | 0.002041 | 0.19012 | Trapezoid | 28.63 | 1 |
| R580 | Automatic Fixed Interval | 3257 | 0.045634 | 0.19012 | Trapezoid | 28.63 | 1 |
| R60 | Automatic Fixed Interval | 2996 | 0.001572 | 0.19012 | Trapezoid | 28.63 | 1 |
| R600 | Automatic Fixed Interval | 1900.1 | 0.002901 | 0.19012 | Trapezoid | 28.63 | 1 |
| R620 | Automatic Fixed Interval | 2746.6 | 0.061437 | 0.19012 | Trapezoid | 28.63 | 1 |
| R640 | Automatic Fixed Interval | 1429.6 | 0.12659 | 0.19012 | Trapezoid | 28.63 | 1 |
| R660 | Automatic Fixed Interval | 7833.8 | 0.016456 | 0.19012 | Trapezoid | 28.63 | 1 |
| R690 | Automatic Fixed Interval | 3242.4 | 0.004075 | 0.19012 | Trapezoid | 28.63 | 1 |
| R710 | Automatic Fixed Interval | 2572.5 | 0.004075 | 0.19012 | Trapezoid | 28.63 | 1 |
| R80 | Automatic Fixed Interval | 3641.4 | 0.021156 | 0.19012 | Trapezoid | 28.63 | 1 |
| R90 | Automatic Fixed Interval | 1160.5 | 0.015523 | 0.19012 | Trapezoid | 28.63 | 1 |

# Annex 11. Talomo Field Validation Points

Table A-11.1. Talomo Field Validation Points

| Point Number | Validation Coordinates (in WGS84) | | Model Var (m) | Valid-ation Points (m) | Error | Event/Date | Rain Return / Scenario |
|---|---|---|---|---|---|---|---|
| | Lat | Long | | | | | |
| 1 | 7.066217 | 125.5333 | 0.05 | 0 | 0.0025 | 0 | 25-Year |
| 2 | 7.063377 | 125.5397 | 0.03 | 0 | 0.0009 | 0 | 25-Year |
| 3 | 7.060662 | 125.5404 | 0.04 | 0 | 0.0016 | 0 | 25-Year |
| 4 | 7.06674 | 125.5362 | 0.24 | 0.1 | 0.0196 | Intense local rainfall/ 2009 | 25-Year |
| 5 | 7.063115 | 125.538 | 0.17 | 0.1 | 0.0049 | Intense local rainfall/ 2009 | 25-Year |
| 6 | 7.06184 | 125.54 | 0.47 | 0 | 0.2209 | 0 | 25-Year |
| 7 | 7.067109 | 125.5349 | 0.48 | 0.5 | 0.0004 | Intense local rainfall/ June 2009 | 25-Year |
| 8 | 7.065526 | 125.5348 | 0.49 | 0 | 0.2401 | 0 | 25-Year |
| 9 | 7.063183 | 125.5421 | 0.03 | 0.4 | 0.1369 | Intense local rainfall/ June 2009 | 25-Year |
| 10 | 7.062371 | 125.5419 | 0.08 | 0.4 | 0.1024 | Intense local rainfall/ 2009 | 25-Year |
| 11 | 7.062828 | 125.5409 | 0.98 | 1 | 0.0004 | Intense local rainfall/ January 2015 | 25-Year |
| 12 | 7.065179 | 125.5407 | 2.62 | 1.5 | 1.2544 | Flash flood/ 2015 | 25-Year |
| 13 | 7.063001 | 125.5425 | 1.16 | 1.5 | 0.1156 | Flash flood/ June 1995 | 25-Year |
| 14 | 7.06391 | 125.5415 | 1.14 | 1.2 | 0.0036 | Buhawi/ June 29, 2009 | 25-Year |
| 15 | 7.062543 | 125.5435 | 1.28 | 2 | 0.5184 | Intense local rainfall/ 2012 | 25-Year |
| 16 | 7.067265 | 125.5394 | 1.57 | 1.4 | 0.0289 | Intense local rainfall/ May 24, 1990 | 25-Year |
| 17 | 7.06708 | 125.54 | 4.39 | 5.3 | 0.8281 | Flash flood/ 1995 | 25-Year |
| 18 | 7.065724 | 125.5402 | 4.25 | 5.3 | 1.1025 | Flash flood/ 1995 | 25-Year |
| 19 | 6.97602 | 126.309794 | 1.76 | 1.2 | 0.3136 | Pablo/ 2012 | 25-Year |
| 20 | 6.995603 | 126.305303 | 1.66 | 0.2 | 2.1316 | Pablo/ 2012 | 25-Year |
| 21 | 6.978806 | 126.312746 | 1.98 | 1 | 0.9604 | | 25-Year |
| 22 | 6.977517 | 126.311134 | 2.31 | 1 | 1.7161 | Typhoon/ 2014 | 25-Year |
| 23 | 6.988607 | 126.319967 | 0.72 | 0.4 | 0.1024 | Pablo and Yolanda/ 2012 and 2013 | 25-Year |
| 24 | 6.989011 | 126.320332 | 1 | 0.5 | 0.25 | Pablo/ 2012 | 25-Year |
| 25 | 7.010394 | 126.324075 | 0.03 | 0 | 0.0009 | | 25-Year |

| Point Number | Validation Coordinates (in WGS84) | | Model Var (m) | Valid-ation Points (m) | Error | Event/Date | Rain Return / Scenario |
|---|---|---|---|---|---|---|---|
| | Lat | Long | | | | | |
| 26 | 7.063451 | 125.5427 | 5.82 | 5.2 | 0.3844 | Flash flood/ 1995 | 25-Year |
| 27 | 7.061902 | 125.545 | 4.87 | 5.2 | 0.1089 | Intense local rainfall/ 2008-2009 | 25-Year |
| 28 | 7.063177 | 125.5433 | 4.07 | 4.2 | 0.0169 | Flash flood/ 1995 | 25-Year |
| 29 | 7.064906 | 125.541 | 4.2 | 5 | 0.64 | Flash flood/ 1995 | 25-Year |
| 30 | 7.060229 | 125.5469 | 4.57 | 5.8 | 1.5129 | Upstream rainfall/ 1994 | 25-Year |
| 31 | 7.060615 | 125.5462 | 4.46 | 4.2 | 0.0676 | Intense local rainfall/ 1992-1994 | 25-Year |
| 32 | 7.060893 | 125.546 | 4.48 | 4.9 | 0.1764 | Flash flood/ 1994 | 25-Year |
| 33 | 7.061518 | 125.5455 | 5.01 | 3.9 | 1.2321 | Flash flood/ 1995 | 25-Year |
| 34 | 7.061244 | 125.5458 | 5.07 | 4.3 | 0.5929 | Flash flood/ 1995 | 25-Year |
| 35 | 7.061702 | 125.5452 | 4.43 | 3.7 | 0.5329 | Intense local rainfall/ 2009 | 25-Year |
| 36 | 7.063606 | 125.5425 | 5.36 | 4.8 | 0.3136 | Flash flood/ 1995 | 25-Year |
| 37 | 7.063084 | 125.5436 | 4.43 | 6 | 2.4649 | Intense local rainfall/ 2012 | 25-Year |
| 38 | 7.0637 | 125.5421 | 4.6 | 5.2 | 0.36 | Intense local rainfall/ 1995 | 25-Year |
| 39 | 7.06552 | 125.5404 | 4.31 | 5.1 | 0.6241 | Intense local rainfall/ 1995 | 25-Year |
| 40 | 7.081459 | 125.5384 | 0.06 | 0 | 0.0036 | 0 | 25-Year |
| 41 | 7.080308 | 125.534 | 0.08 | 0.2 | 0.0144 | Intense local rainfall/ 2011 | 25-Year |
| 42 | 7.079128 | 125.535 | 0.07 | 0 | 0.0049 | 0 | 25-Year |
| 43 | 7.080114 | 125.5364 | 0.2 | 0 | 0.04 | 0 | 25-Year |
| 44 | 7.079562 | 125.5382 | 0.24 | 0 | 0.0576 | 0 | 25-Year |
| 45 | 7.079532 | 125.5436 | 0.32 | 0.1 | 0.0484 | Intense local rainfall/ 2015 | 25-Year |
| 46 | 7.079068 | 125.5459 | 0.82 | 0 | 0.6724 | 0 | 25-Year |
| 47 | 7.076978 | 125.548 | 0.49 | 0.2 | 0.0841 | Intense local rainfall/ 2011 | 25-Year |
| 48 | 7.076348 | 125.5475 | 0.52 | 0.3 | 0.0484 | Intense local rainfall/ 2015 | 25-Year |
| 49 | 7.07831 | 125.5358 | 0.48 | 0.3 | 0.0324 | Intense local rainfall/ 2015 | 25-Year |
| 50 | 7.07797 | 125.5484 | 0.95 | 1.1 | 0.0225 | Intense local rainfall/ 2011 | 25-Year |

| Point Number | Validation Coordinates (in WGS84) | | Model Var (m) | Valid-ation Points (m) | Error | Event/Date | Rain Return / Scenario |
|---|---|---|---|---|---|---|---|
| | Lat | Long | | | | | |
| 51 | 7.079043 | 125.5505 | 1.21 | 0.2 | 1.0201 | Intense local rainfall/ 2015 | 25-Year |
| 52 | 7.079147 | 125.5481 | 2.41 | 0 | 5.8081 | 0 | 25-Year |
| 53 | 7.079316 | 125.5502 | 2.04 | 0.2 | 3.3856 | Intense local rainfall/ 2015 | 25-Year |
| 54 | 7.070235 | 125.5581 | 1.52 | 0.8 | 0.5184 | Intense local rainfall/ 2011 | 25-Year |
| 55 | 7.070062 | 125.5567 | 4.69 | 0 | 21.9961 | 0 | 25-Year |
| 56 | 7.080522 | 125.5278 | 0.06 | 0 | 0.0036 | 0 | 25-Year |
| 57 | 7.079822 | 125.5236 | 0.04 | 0 | 0.0016 | 0 | 25-Year |
| 58 | 7.077176 | 125.5282 | 0.03 | 0 | 0.0009 | 0 | 25-Year |
| 59 | 7.081716 | 125.5243 | 0.33 | 0 | 0.1089 | 0 | 25-Year |
| 60 | 7.080626 | 125.5253 | 0.24 | 0.1 | 0.0196 | Intense local rainfall/ 2014 | 25-Year |
| 61 | 7.078454 | 125.5259 | 0.24 | 0.2 | 0.0016 | Intense local rainfall/ 2015 | 25-Year |
| 62 | 7.076027 | 125.5235 | 0.5 | 0.1 | 0.16 | Intense local rainfall/ 2015 | 25-Year |
| 63 | 7.073547 | 125.5205 | 0.53 | 1.2 | 0.4489 | Intense local rainfall/ 2014 | 25-Year |
| 64 | 7.075324 | 125.5198 | 0.81 | 0.1 | 0.5041 | Intense local rainfall/ 2015 | 25-Year |
| 65 | 7.077741 | 125.524 | 0.3 | 1.5 | 1.44 | Intense local rainfall/ June 7, 2015 | 25-Year |
| 66 | 7.078437 | 125.529 | 0.5 | 0.2 | 0.09 | Intense local rainfall/ 2014 | 25-Year |
| 67 | 7.078654 | 125.5223 | 1.01 | 0 | 1.0201 | 0 | 25-Year |
| 68 | 7.078463 | 125.5242 | 1.15 | 0 | 1.3225 | 0 | 25-Year |
| 69 | 7.075414 | 125.5199 | 0.91 | 1.2 | 0.0841 | Intense local rainfall/ June 2015 | 25-Year |
| 70 | 7.073142 | 125.5223 | 0.96 | 1 | 0.0016 | Intense local rainfall/ 2015 | 25-Year |
| 71 | 7.078844 | 125.5207 | 1.21 | 1.2 | 0.0001 | Intense local rainfall/ October 2015 | 25-Year |
| 72 | 7.078649 | 125.5233 | 0.92 | 1.1 | 0.0324 | Intense local rainfall/ 2015 | 25-Year |
| 73 | 7.070507 | 125.5249 | 1.58 | 2 | 0.1764 | Intense local rainfall/ June 7, 2015 | 25-Year |
| 74 | 7.073779 | 125.5214 | 0.94 | 2.1 | 1.3456 | Intense local rainfall/ June 7, 2015 | 25-Year |
| 75 | 7.072234 | 125.5231 | 2.33 | 2.2 | 0.0169 | Intense local rainfall/ 2015 | 25-Year |

| Point Number | Validation Coordinates (in WGS84) | | Model Var (m) | Valid-ation Points (m) | Error | Event/Date | Rain Return / Scenario |
|---|---|---|---|---|---|---|---|
| | Lat | Long | | | | | |
| 76 | 7.078928 | 125.5218 | 1.83 | 0 | 3.3489 | 0 | 25-Year |
| 77 | 7.068685 | 125.5275 | 1.9 | 2.2 | 0.09 | Intense local rainfall/ June 2015 | 25-Year |
| 78 | 7.072884 | 125.5365 | 4.67 | 5 | 0.1089 | Intense local rainfall/ June 7, 2015 | 25-Year |
| 79 | 7.07119 | 125.5322 | 4.83 | 5.2 | 0.1369 | Intense local rainfall/ 2015 | 25-Year |
| 80 | 7.069366 | 125.5352 | 4.64 | 5.1 | 0.2116 | Intense local rainfall/ 2015 | 25-Year |
| 81 | 7.068264 | 125.5385 | 5.54 | 6.2 | 0.4356 | Intense local rainfall/ June 7, 2015 | 25-Year |
| 82 | 7.092763 | 125.5036 | 0.03 | 0.1 | 0.0049 | Intense local rainfall/ 2014 | 25-Year |
| 83 | 7.090157 | 125.5092 | 0.07 | 0 | 0.0049 | 0 | 25-Year |
| 84 | 7.088259 | 125.5133 | 0.03 | 0 | 0.0009 | 0 | 25-Year |
| 85 | 7.090796 | 125.5072 | 0.22 | 0.2 | 0.0004 | Intense local rainfall/ 2014 | 25-Year |
| 86 | 7.089404 | 125.5107 | 0.25 | 0 | 0.0625 | 0 | 25-Year |
| 87 | 7.084451 | 125.52 | 0.18 | 0 | 0.0324 | 0 | 25-Year |
| 88 | 7.084179 | 125.5201 | 0.46 | 0 | 0.2116 | 0 | 25-Year |
| 89 | 7.08443 | 125.5239 | 5.34 | 0 | 28.5156 | 0 | 25-Year |
| 90 | 7.081227 | 125.5144 | 0.03 | 0.1 | 0.0049 | Intense local rainfall/ 2013 | 25-Year |
| 91 | 7.078162 | 125.5156 | 0.04 | 0 | 0.0016 | 0 | 25-Year |
| 92 | 7.076821 | 125.5171 | 0.03 | 0 | 0.0009 | 0 | 25-Year |
| 93 | 7.082933 | 125.5165 | 0.14 | 1.8 | 2.7556 | Intense local rainfall/ 2015 | 25-Year |
| 94 | 7.082824 | 125.52 | 0.19 | 0.1 | 0.0081 | Intense local rainfall/ 2013 | 25-Year |
| 95 | 7.082492 | 125.5145 | 0.41 | 0.15 | 0.0676 | Intense local rainfall/ 2008 | 25-Year |
| 96 | 7.079816 | 125.5147 | 0.68 | 0 | 0.4624 | 0 | 25-Year |
| 97 | 7.080842 | 125.519 | 0.97 | 0.08 | 0.7921 | Intense local rainfall/ 2013 | 25-Year |
| 98 | 7.079053 | 125.5155 | 1 | 0 | 1 | 0 | 25-Year |
| 99 | 7.081657 | 125.5185 | 1.95 | 0.4 | 2.4025 | Intense local rainfall/ 2014 | 25-Year |
| 100 | 7.048805 | 125.5603 | 0.37 | 1 | 0.3969 | Buhawi/ June 29, 2011 | 25-Year |
| 101 | 7.047255 | 125.5627 | 0.37 | 1.6 | 1.5129 | Buhawi/ June 29, 2011 | 25-Year |
| 102 | 7.058212 | 125.5588 | 0.57 | 0.4 | 0.0289 | Buhawi/ June 29, 2011 | 25-Year |

| Point Number | Validation Coordinates (in WGS84) | | Model Var (m) | Valid-ation Points (m) | Error | Event/Date | Rain Return / Scenario |
|---|---|---|---|---|---|---|---|
| | Lat | Long | | | | | |
| 103 | 7.059192 | 125.5613 | 0.8 | 1.7 | 0.81 | Buhawi/ June 29, 2011 | 25-Year |
| 104 | 7.053857 | 125.562 | 1.02 | 1.2 | 0.0324 | Buhawi/ June 29, 2011 | 25-Year |
| 105 | 7.050956 | 125.5636 | 0.84 | 1.2 | 0.1296 | Buhawi/ June 29, 2011 | 25-Year |
| 106 | 7.062078 | 125.5624 | 0.96 | 1.8 | 0.7056 | Buhawi/ June 29, 2011 | 25-Year |
| 107 | 7.06225 | 125.5641 | 0.86 | 1.7 | 0.7056 | Buhawi/ June 29, 2011 | 25-Year |
| 108 | 7.058174 | 125.5491 | 1.53 | 1.3 | 0.0529 | Buhawi/ June 2009 | 25-Year |
| 109 | 7.057736 | 125.5632 | 2.18 | 2.1 | 0.0064 | Buhawi/ June 29, 2011 | 25-Year |
| 110 | 7.0571 | 125.5639 | 2.07 | 2.9 | 0.6889 | Buhawi/ June 29, 2011 | 25-Year |
| 111 | 7.054009 | 125.5506 | 0.06 | 1 | 0.8836 | Heavy rainfall/ June 29, 2011 | 25-Year |
| 112 | 7.05309 | 125.5534 | 0.09 | 1 | 0.8281 | Heavy rainfall/ June 29, 2011 | 25-Year |
| 113 | 7.051357 | 125.5564 | 0.03 | 1.4 | 1.8769 | Heavy rainfall/ June 29, 2011 | 25-Year |
| 114 | 7.050438 | 125.5592 | 0.11 | 1 | 0.7921 | Heavy rainfall/ June 29, 2011 | 25-Year |
| 115 | 7.050012 | 125.5543 | 0.18 | 1 | 0.6724 | Heavy rainfall/ June 29, 2011 | 25-Year |
| 116 | 7.049727 | 125.557 | 0.03 | 0.5 | 0.2209 | Heavy rainfall/ June 29, 2011 | 25-Year |
| 117 | 7.058333 | 125.5531 | 0.42 | 0.26 | 0.0256 | Heavy rainfall/ June 29, 2011 | 25-Year |
| 118 | 7.057892 | 125.5511 | 0.2 | 0.25 | 0.0025 | Heavy rainfall/ June 29, 2011 | 25-Year |
| 119 | 7.054633 | 125.5522 | 0.21 | 0.8 | 0.3481 | Heavy rainfall/ June 29, 2011 | 25-Year |
| 120 | 7.053992 | 125.5537 | 0.25 | 0.8 | 0.3025 | Heavy rainfall/ June 29, 2011 | 25-Year |
| 121 | 7.050447 | 125.5576 | 0.27 | 1 | 0.5329 | Heavy rainfall/ June 29, 2011 | 25-Year |
| 122 | 7.050279 | 125.5552 | 0.21 | 1 | 0.6241 | Heavy rainfall/ June 29, 2011 | 25-Year |
| 123 | 7.049623 | 125.5594 | 0.13 | 1 | 0.7569 | Heavy rainfall/ June 29, 2011 | 25-Year |
| 124 | 7.059335 | 125.5517 | 0.21 | 0.3 | 0.0081 | Heavy rainfall/ June 29, 2011 | 25-Year |
| 125 | 7.05608 | 125.5521 | 0.49 | 1.4 | 0.8281 | Heavy rainfall/ June 29, 2011 | 25-Year |

| Point Number | Validation Coordinates (in WGS84) | | Model Var (m) | Valid-ation Points (m) | Error | Event/Date | Rain Return / Scenario |
|---|---|---|---|---|---|---|---|
| | Lat | Long | | | | | |
| 126 | 7.054778 | 125.5588 | 0.48 | 0.2 | 0.0784 | Heavy rainfall/ June 29, 2011 | 25-Year |
| 127 | 7.05307 | 125.5571 | 0.46 | 0.3 | 0.0256 | Heavy rainfall/ June 29, 2011 | 25-Year |
| 128 | 7.052002 | 125.5541 | 0.42 | 0.3 | 0.0144 | Heavy rainfall/ June 29, 2011 | 25-Year |
| 129 | 7.051164 | 125.5585 | 0.48 | 0.4 | 0.0064 | Heavy rainfall/ June 29, 2011 | 25-Year |
| 130 | 7.049098 | 125.5562 | 0.48 | 0.3 | 0.0324 | Heavy rainfall/ June 29, 2011 | 25-Year |
| 131 | 7.065715 | 125.5584 | 0.52 | 0.1 | 0.1764 | Heavy rainfall/ 1990's | 25-Year |
| 132 | 7.056268 | 125.5507 | 1.19 | 1.5 | 0.0961 | Heavy rainfall/ June 29, 2011 | 25-Year |
| 133 | 7.057085 | 125.55 | 2.19 | 1.8 | 0.1521 | Heavy rainfall/ June 29, 2011 | 25-Year |
| 134 | 7.055271 | 125.5512 | 2.42 | 1.5 | 0.8464 | Heavy rainfall/ June 29, 2011 | 25-Year |
| 135 | 7.053007 | 125.5522 | 2.03 | 2.5 | 0.2209 | Heavy rainfall/ June 29, 2011 | 25-Year |
| 136 | 7.050471 | 125.5531 | 2.42 | 2.5 | 0.0064 | Heavy rainfall/ June 29, 2011 | 25-Year |
| 137 | 7.049383 | 125.5537 | 1.81 | 2.5 | 0.4761 | Heavy rainfall/ June 29, 2011 | 25-Year |
| 138 | 7.048286 | 125.5561 | 2.01 | 2.5 | 0.2401 | Heavy rainfall/ June 29, 2011 | 25-Year |
| 139 | 7.058649 | 125.5615 | 4.74 | 2.5 | 5.0176 | Heavy rainfall/ June 29, 2011 | 25-Year |
| 140 | 7.061285 | 125.5586 | 0.13 | 0.2 | 0.0049 | Intense local rainfall/ June 29, 2011 | 25-Year |
| 141 | 7.059479 | 125.5584 | 0.47 | 0.2 | 0.0729 | Intense local rainfall/ June 28, 2011 | 25-Year |
| 142 | 7.061269 | 125.5616 | 0.85 | 1.9 | 1.1025 | Intense local rainfall/ June 29, 2011 | 25-Year |
| 143 | 7.056841 | 125.5616 | 1.47 | 3.2 | 2.9929 | Intense local rainfall/ June 29, 2011 | 25-Year |
| 144 | 7.054117 | 125.5639 | 0.83 | 2.35 | 2.3104 | Intense local rainfall/ June 29, 2011 | 25-Year |
| 145 | 7.060185 | 125.5615 | 0.82 | 2.1 | 1.6384 | Intense local rainfall/ June 29, 2011 | 25-Year |

| Point Number | Validation Coordinates (in WGS84) | | Model Var (m) | Valid-ation Points (m) | Error | Event/Date | Rain Return / Scenario |
|---|---|---|---|---|---|---|---|
| | Lat | Long | | | | | |
| 146 | 7.05566 | 125.5627 | 0.9 | 2.4 | 2.25 | Intense local rainfall/ June 29, 2011 | 25-Year |
| 147 | 7.054484 | 125.563 | 0.81 | 2.7 | 3.5721 | Intense local rainfall/ June 28, 2011 | 25-Year |
| 148 | 7.048976 | 125.5621 | 0.86 | 1.02 | 0.0256 | Intense local rainfall/ June 29, 2011 | 25-Year |
| 149 | 7.047695 | 125.565 | 0.93 | 1 | 0.0049 | Intense local rainfall/ June 28, 2011 | 25-Year |
| 150 | 7.059456 | 125.5627 | 2.14 | 2.4 | 0.0676 | Intense local rainfall/ June 29, 2011 | 25-Year |
| 151 | 7.058195 | 125.5618 | 1.9 | 2.6 | 0.49 | Intense local rainfall/ June 29, 2011 | 25-Year |
| 152 | 7.053569 | 125.565 | 1.8 | 2.2 | 0.16 | Intense local rainfall/ June 29, 2011 | 25-Year |
| 153 | 7.047638 | 125.5589 | 0.03 | 1 | 0.9409 | Intense local rainfall/ 2003 | 25-Year |
| 154 | 7.052216 | 125.5646 | 1.77 | 3.8 | 4.1209 | Intense local rainfall/ June 29, 2011 | 25-Year |
| 155 | 7.059265 | 125.5644 | 2.51 | 3.5 | 0.9801 | Intense local rainfall/ June 29, 2011 | 25-Year |
| 156 | 7.064459 | 125.5567 | 0.06 | 0 | 0.0036 | 0 | 25-Year |
| 157 | 7.062288 | 125.5571 | 0.18 | 0 | 0.0324 | 0 | 25-Year |
| 158 | 7.061567 | 125.5567 | 0.15 | 0 | 0.0225 | 0 | 25-Year |
| 159 | 7.057407 | 125.5573 | 0.07 | 0 | 0.0049 | 0 | 25-Year |
| 160 | 7.056586 | 125.5586 | 0.06 | 0 | 0.0036 | 0 | 25-Year |
| 161 | 7.055619 | 125.5536 | 0.06 | 0 | 0.0036 | 0 | 25-Year |
| 162 | 7.060148 | 125.5519 | 0.23 | 0 | 0.0529 | 0 | 25-Year |
| 163 | 7.05904 | 125.5561 | 0.36 | 0 | 0.1296 | 0 | 25-Year |
| 164 | 7.056976 | 125.5534 | 0.23 | 0 | 0.0529 | 0 | 25-Year |
| 165 | 7.056601 | 125.5559 | 0.28 | 0 | 0.0784 | 0 | 25-Year |
| 166 | 7.054979 | 125.5551 | 0.16 | 0 | 0.0256 | 0 | 25-Year |
| 167 | 7.060669 | 125.5557 | 0.45 | 0 | 0.2025 | 0 | 25-Year |
| 168 | 7.058327 | 125.5543 | 0.46 | 0 | 0.2116 | 0 | 25-Year |
| 169 | 7.056336 | 125.5548 | 0.48 | 0 | 0.2304 | 0 | 25-Year |
| 170 | 7.059591 | 125.5545 | 0.48 | 0 | 0.2304 | 0 | 25-Year |
| 171 | 7.066427 | 125.5603 | 0.53 | 0 | 0.2809 | 0 | 25-Year |
| 172 | 7.065526 | 125.5599 | 0.98 | 0 | 0.9604 | 0 | 25-Year |

| Point Number | Validation Coordinates (in WGS84) | | Model Var (m) | Valid-ation Points (m) | Error | Event/Date | Rain Return / Scenario |
|---|---|---|---|---|---|---|---|
| | Lat | Long | | | | | |
| 173 | 7.06561 | 125.561 | 2.31 | 0 | 5.3361 | 0 | 25-Year |
| 174 | 7.049972 | 125.5618 | 0.33 | 1.5 | 1.3689 | / June 28, 2011 | 25-Year |
| 175 | 7.047896 | 125.5612 | 0.09 | 1 | 0.8281 | Upstream rainfall/ June 29, 2011 | 25-Year |
| 176 | 7.047638 | 125.5589 | 0.03 | 1 | 0.9409 | Upstream rainfall/ June 29, 2011 | 25-Year |
| 177 | 7.055576 | 125.5615 | 0.84 | 1.8 | 0.9216 | Upstream rainfall/ June 29, 2011 | 25-Year |
| 178 | 7.056744 | 125.5629 | 0.8 | 2.5 | 2.89 | Upstream rainfall/ June 28, 2011 | 25-Year |
| 179 | 7.055745 | 125.5636 | 1.79 | 2.53 | 0.5476 | Upstream rainfall/ June 29, 2011 | 25-Year |
| 180 | 7.055561 | 125.5643 | 2.04 | 3.2 | 1.3456 | Upstream rainfall/ June 29, 2011 | 25-Year |
| | | | | | RMSE | 0.927134 | |

# Annex 12. Educational Institutions affected by flooding in Talomo Floodplain

Table A-12.1. Educational Institutions in Davao City, Davao del Sur affected by flooding in Talomo Floodplain

| Davao Del Sur | | | | |
|---|---|---|---|---|
| Davao City | | | | |
| Building Name | Barangay | Rainfall Scenario | | |
| | | 5-year | 25-year | 100-year |
| KEITH WILLIAMS BIBLE COLLEGE GYMNASIUM | Bago Gallera | | | Low |
| KEITH WILLIAMS BIBLE COLLEGE ROOM | Bago Gallera | | | Low |
| PROJECT HOPE | Bago Gallera | Medium | Medium | Medium |
| CATALUNAN GRANDE ELEMENTARY SCHOOL | Catalunan Grande | | | |
| EARLY CHILDHOOD CARE AND DEVELOPMENT (DAY CARE) | Catalunan Grande | | | |
| EVANGELICAL MISSION COLLEGE | Catalunan Grande | | | |
| EVANGELICAL MISSION COLLEGE (CANTEEN) | Catalunan Grande | | | |
| EVANGELICAL MISSION COLLEGE (DORM) | Catalunan Grande | | | |
| JESUS J. SORIANO NATIONAL HIGH SCHOOL | Catalunan Grande | | | |
| MODERN DAY MONTESSORI ACADEMY | Catalunan Grande | | | |
| SAINT FRANCIS XAVIER LEARNING CENTER | Catalunan Grande | | | |
| CASA CARMELITE SCHOOL OF DAVAO INC WITH MONTESSOR* | Catalunan Pequeño | | | |
| CASA CARMELITE SCHOOL OF DAVAO INC. | Catalunan Pequeño | | | |
| CASA CARMELITE SCHOOL OF DAVAO INC. WITH MONTESSO* | Catalunan Pequeño | | | |
| CATALUNAN PEQUEÑO ELEMENTARY SCHOOL | Catalunan Pequeño | | | |
| CATALUNAN PEQUEÑO NATIONAL HIGHSCHOOL | Catalunan Pequeño | | | |
| CHILD CENTER MINISTRY | Catalunan Pequeño | Low | Low | Low |
| WELLSPRING CENTRAL BAPTIST SCHOOL INC. | Catalunan Pequeño | | | |
| ARK LEARNING CENTER | Matina Aplaya | Low | Low | Low |
| ISKUL PANGANARAN SAGA BADJAO (BADJAO LEARNING CEN* | Matina Aplaya | | | |
| MATINA APLAYA ELEMENTARY SCHOOL | Matina Aplaya | Low | Low | Low |
| ACADEMIC LEARNING CENTER | Matina Crossing | Low | Medium | Medium |

| Davao del Sur | | | | |
|---|---|---|---|---|
| Davao City | | | | |
| Building Name | Barangay | Rainfall Scenario | | |
| | | 5-year | 25-year | 100-year |
| CATALUNAN GRANDE ELEMENTARY SCHOOL | Tacunan | | | |
| DAVAO VISION COLLEGES | Tacunan | | | |
| JESUS J. SORIANO NATIONAL HIGH SCHOOL | Tacunan | | | |
| SHEPERD MY LAMB CHRISTIAN ACADEMY, INC | Tacunan | | | |
| SKY LINE TUTORIAL CENTER | Tacunan | | | |
| UCCP RAINBOW CHILD DEVELOPMENT MINISTRY | Tacunan | | | |
| ABA SEA SCHOOL | Talomo | | Low | Low |
| ARK LEARNING CENTER | Talomo | | | |
| B.A.S.I.C. LEARNING CENTER | Talomo | | | |
| BANGKAL MISSION DAY CARE SCHOOL | Talomo | | | |
| DAVAO CITY MADRASAH COMPREHENSIVE DEVELOPMENT PRO* | Talomo | | | |
| DAVAO CITY SPECIAL NATIONAL HIGH SCHOOL | Talomo | Low | Low | Medium |
| DAVAO CITY SPECIAL NATIONAL HIGH SCHOOL (FACULTY) | Talomo | Low | Low | Low |
| DAVAO SPECIAL EDUCATION EARNING CENTER (ABANDONED) | Talomo | | | |
| DEAF MINISTRIES INTERNATIONAL PHILIPPINES | Talomo | Medium | Medium | Medium |
| DITE AUTOMOTIVE, DRIVING, MOTORCYCLE SCHOOL | Talomo | | Low | Medium |
| EVANGELICAL MISSION COLLEGE | Talomo | | | |
| GOLDEN CROWN TUTORIAL & MUSIC STUDIO | Talomo | | | Low |
| GOV. VICENTE DUTERTE NATIONAL HIGH SCHOOL | Talomo | Medium | Medium | Medium |
| GOV. VICENTE DUTERTE NATIONAL HIGH SCHOOL (UNDER * | Talomo | Medium | Medium | Medium |
| GOV. VICENTE DUTERTE NATIONAL HIGH SCHOOL COVERED* | Talomo | Medium | Medium | Medium |
| GOV. VICENTE DUTERTE NATIONAL HIGH SCHOOL GYM | Talomo | | Low | Medium |
| GOV. VICENTE DUTERTE NATIONAL HIGH SCHOOL PRINCIP* | Talomo | Low | Medium | Medium |
| INTL. CHRISTIAN SCHOOL OF DAVAO | Talomo | | Low | Low |
| ISLAMIC SCHOOL | Talomo | | | |
| KIDS CAMP | Talomo | | | |

| Davao del Sur | | | | |
|---|---|---|---|---|
| Davao City | | | | |
| Building Name | Barangay | Rainfall Scenario | | |
| | | 5-year | 25-year | 100-year |
| LEAP OF FAITH LEARNING CENTER | Talomo | | | |
| LEON GARCIA ELEMENTARY SCHOOL | Talomo | Medium | Medium | Medium |
| LEON GARCIA ELEMENTARY SCHOOL GYM | Talomo | Medium | Medium | Medium |
| MABINI ELEMENTARY SCHOOL | Talomo | Low | Medium | Medium |
| MABINI ELEMENTARY SCHOOL (COVERED COURT) | Talomo | Low | Medium | Medium |
| MABINI NATIONAL HIGH SCHOOL | Talomo | Low | Low | Low |
| MONTESSORI DE MANILA | Talomo | | | |
| PROJECT HOPE DAY CARE CENTER | Talomo | Medium | Medium | Medium |
| ROYAL VALLEY SDA ELEM. SCHOOL | Talomo | Low | Low | Low |
| SPED BANGKAL (ELEMENTARY) | Talomo | Low | Low | Low |
| SPED BANGKAL (ELEMENTARY) SOCIAL HALL | Talomo | | Low | Low |
| TALOMO ISLAMIC INSTITUTE | Talomo | | Low | Low |

# Annex 13. Health Institutions affected by flooding in Talomo Floodplain

Table A-13.1. Health Institutions in Davao City, Davao del Sur affected by flooding in Talomo Floodplain

| Davao Oriental | | | | |
|---|---|---|---|---|
| Mati City | | | | |
| Building Name | Barangay | Rainfall Scenario | | |
| | | 5-year | 25-year | 100-year |
| MEDICAL CLINIC | Catalunan Grande | | | |
| WELL FAMILY MID-WIFE CLINIC | Catalunan Grande | | | |
| 318 PHAMACIA KING INCORPORATION | Matina Aplaya | Low | Low | Low |
| FERNANDEZ MEDICAL CLINIC | Matina Aplaya | | | |
| MERCURY DRUG | Matina Aplaya | | | Low |
| AMBOY DENTAL CLINIC | Talomo | Low | Low | Low |
| ANTERIA MEDICAL EQUIPMENT | Talomo | | | |
| CENTRAL PARK VETERINARY CLINIC | Talomo | Low | Low | Low |
| DAVAO ADVENTIST HOSPITAL | Talomo | | | Low |
| DAVAO ANALYTICAL LABORATORIES INC. | Talomo | | Low | Low |
| FARMACIA ROWEMS | Talomo | Low | Low | Low |
| FRANCX-M PHARMACY | Talomo | | | |
| MERCURY DRUG | Talomo | | | |
| SAVE-ON DRUGSTORE | Talomo | | Low | Low |
| STAREX DRUG CENTER | Talomo | | Low | Low |