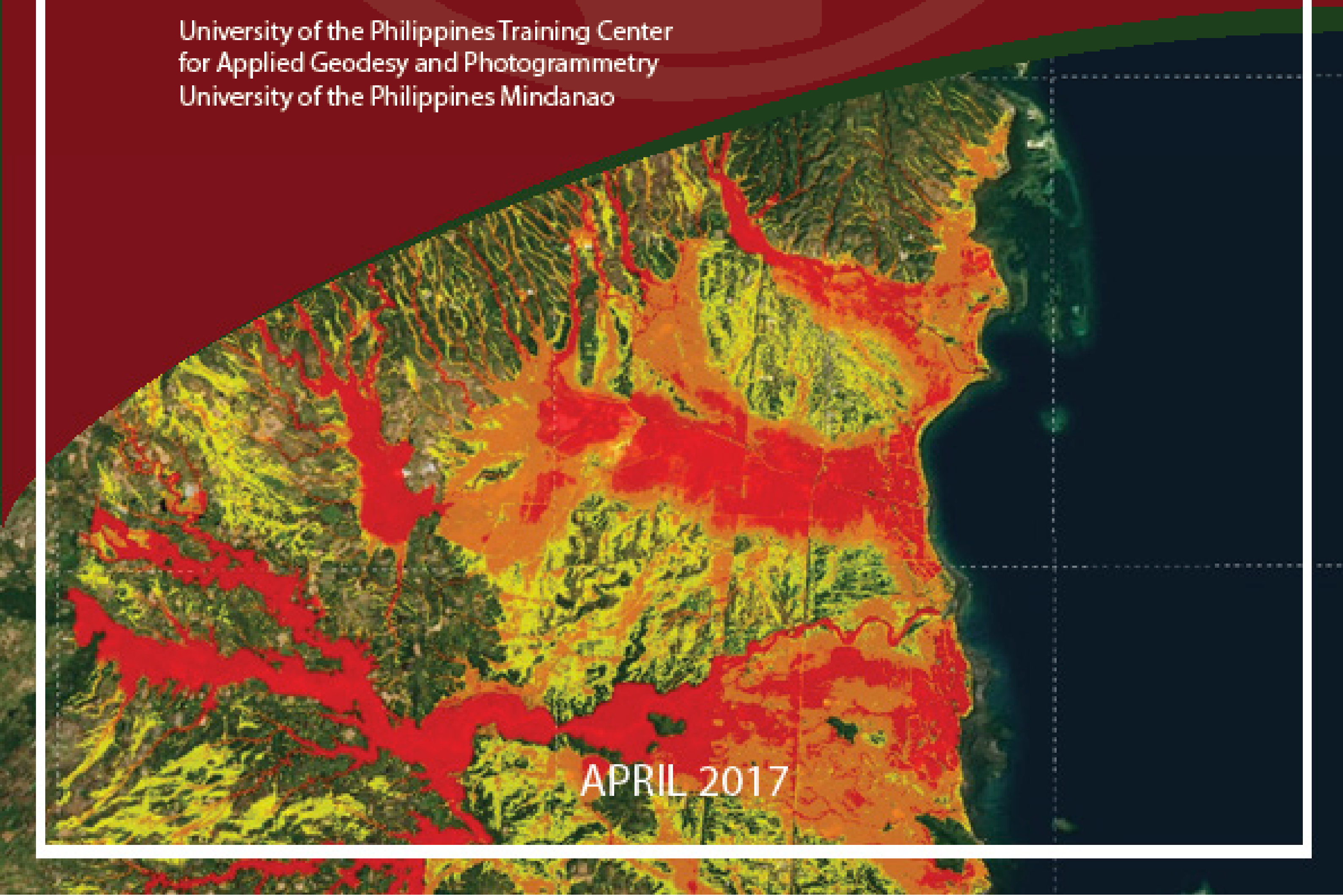
Hazard Mapping of the Philippines Using LIDAR ( Phil-LIDAR 1 )

# LiDAR Surveys and Flood Mapping of Sumlog River

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



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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, DREAM Program
University of the Philippines Diliman
Quezon City, Philippines 1101
E-mail: ecparingit@up.edu.ph

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# LIST OF ACRONYMS AND ABBREVIATIONS

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

# CHAPTER 1. OVERVIEW OF THE PROGRAM AND SUMLOG RIVER

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

## 1.1 Background of the Phil-LIDAR 1 Program

The University of the Philippines Training Center for Applied Geodesy and Photogrammetry (UP-TCAGP) launched a research program entitled "Nationwide Hazard Mapping using LiDAR" or Phil-LiDAR 1, supported by the Department of Science and Technology (DOST) 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 implementing partner University for the Phil-LiDAR 1 Program is the University of the Philippines Mindanao (UP MIN). UP MIN 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 10 river basins in the ____________. The university is located in ___________.

## 1.2 Overview of the Sumlog River Basin

Sumlog is called as the majestic river in the Municipality of Lupon which is largely part of the town's rich history. Lupon is said to have derived its name from the native word "naluponan," which means a body of land accumulated at the mouth of a river resulting from years of continued accretion. The settlers shortened the word "naluponan" in to what is called now "Lupon". This "naluponan" area was then applied to the mouth of the Sumlog River in the Municipality of Lupon of today (NSCB, 2016).

Sumlog Rver is one of the most important water channels within the gulf town municipalities covering District II, Province of Davao Oriental. It is invaluable because of its water service in the irrigable rice land of the Municipalities of Banaybanay and Lupon estimated to have about 3,100 hectares for the two (2) municipalities or 1,955.00 hectares for Banaybanay and 1,145.00 hectares for Lupon. Historically, the plain areas of Lupon in its creation as a municipality in 1949 were mostly developed with coconut plantation and only small areas were cultivated into rice land (ISRWMDP, 2016).

The Sumlog Watershed area is pre-occupied by the Mandaya, Mansaka and native Kalagan. The indigenous people had long engaged in farming activities, cleaning-up some parcel of forest land for agricultural purposes and wandering in other places starting anew for their planting activities. The natives have the common notion that all lands of public domain are alienable, disposable and can cultivate for such purposes. The coming of logging industries became the critical issues and problems that were identified in the Sumlog Watershed (ISRWMDP, 2016).

Today, Sumlog River is invaluable and essential to the lives of many people of Lupon and Banaybanay being the main source of water for irrigation. Domestic use has a huge contribution to the economic and socio cultural functions of the people, thus, the Sumlog River greatly affects the lives of many people (ISRWMDP, 2016).

Sumlog Watershed has a drainage area of 381 sq. km. and is located in Lupon and San Isidro, Davao Oriental. It then empties into the Davao Gulf. The watershed area is 472 and its river length is 58 kilometers with 51 sub basins, 25 reaches, and 25 junctions. According to locals, from the year 1984 to 2015, buhawi, intense local rainfall and upstream rainfall usually causedf flooding near the river. However, PAGASA only noted typhoon events such as Pablo in 2012, Yolanda in 2013 and Agaton in 2014. The Sumlog flooding usually happen due to siltation problems emanating from the Sumlog Watershed area where sands, stones, boulders and debris stuck-up making the waterways narrower which results to the spread of water in other farm areas (ISRWMDP, 2016).

The location map of Sumlog River Basin is shown in Figure 1.

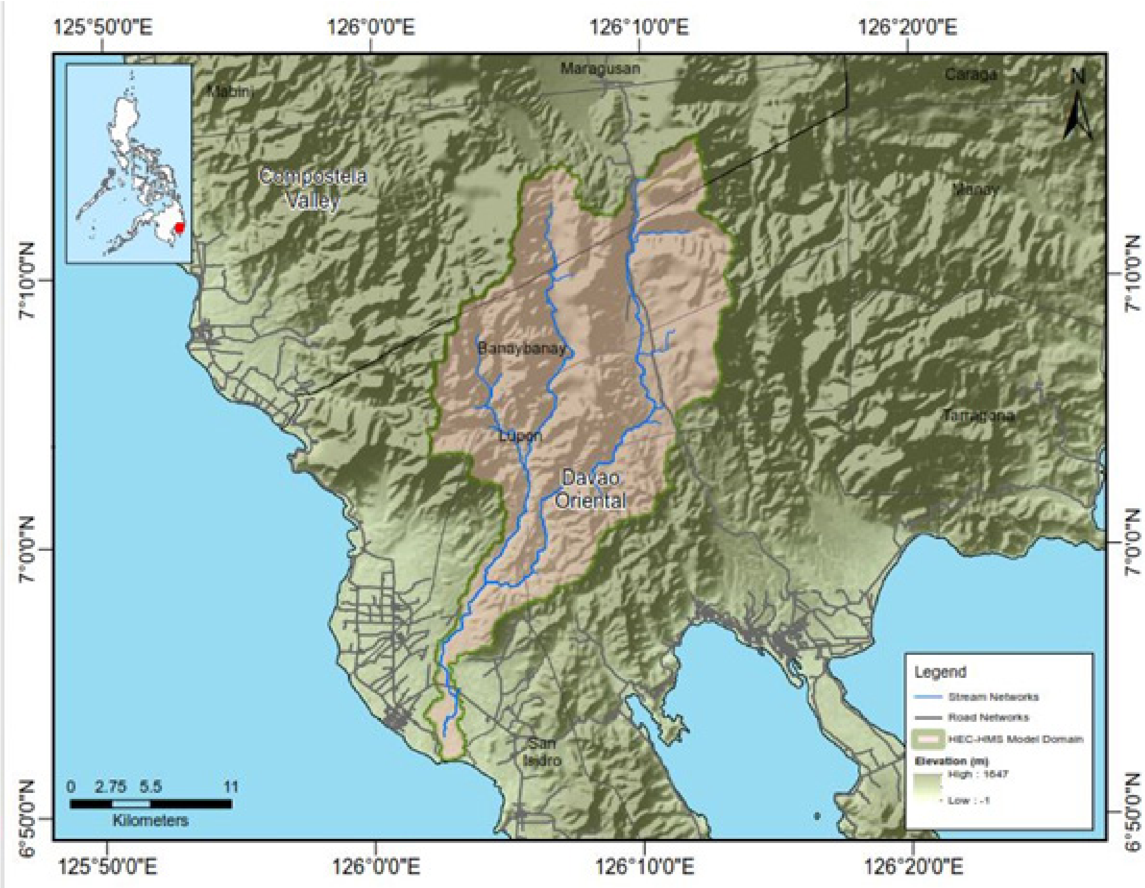



Figure 1. Map of the Sumlog River Basin (in brown)

# CHAPTER 2: LIDAR DATA ACQUISITION OF THE SUMLOG FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Gracia Acuña, Engr. Gerome Hipolito, Ms. Pauline Joanne G. Arceo, Engr. Kenneth A. Quisado

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

## 2.1 Flight Plans

In order to acquire LiDAR data, the Data Acquisition Component (DAC) created flight plans within the delineated priority area of the Sumlog Floodplain in the Province of Davao Oriental. These missions were planned for fourteen (14) 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 2 shows the flight plan for Sumlog Floodplain.

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

| Block Name | Flying Height (m AGL) | Overlap (%) | Field of View (θ) | Pulse Repetition Frequency (PRF) (kHz) | Scan Frequency (Hz) | Average Speed (kts) | Average Turn Time (Minutes) |
|---|---|---|---|---|---|---|---|
| BLK83A | 1100 | 30 | 40 | 100 | 50 | 130 | 5 |
| BLK84B | 1100 | 30 | 40 | 100 | 50 | 130 | 5 |
| BLK85A | 1300 | 40 | 24 | 70 | 60 | 130 | 5 |
| BLK86A | 1000 | 30 | 40 | 100 | 50 | 130 | 5 |
| BLK86B | 1000 | 30 | 40 | 100 | 50 | 130 | 5 |
| BLK86C | 1000 | 30 | 40 | 100 | 50 | 130 | 5 |

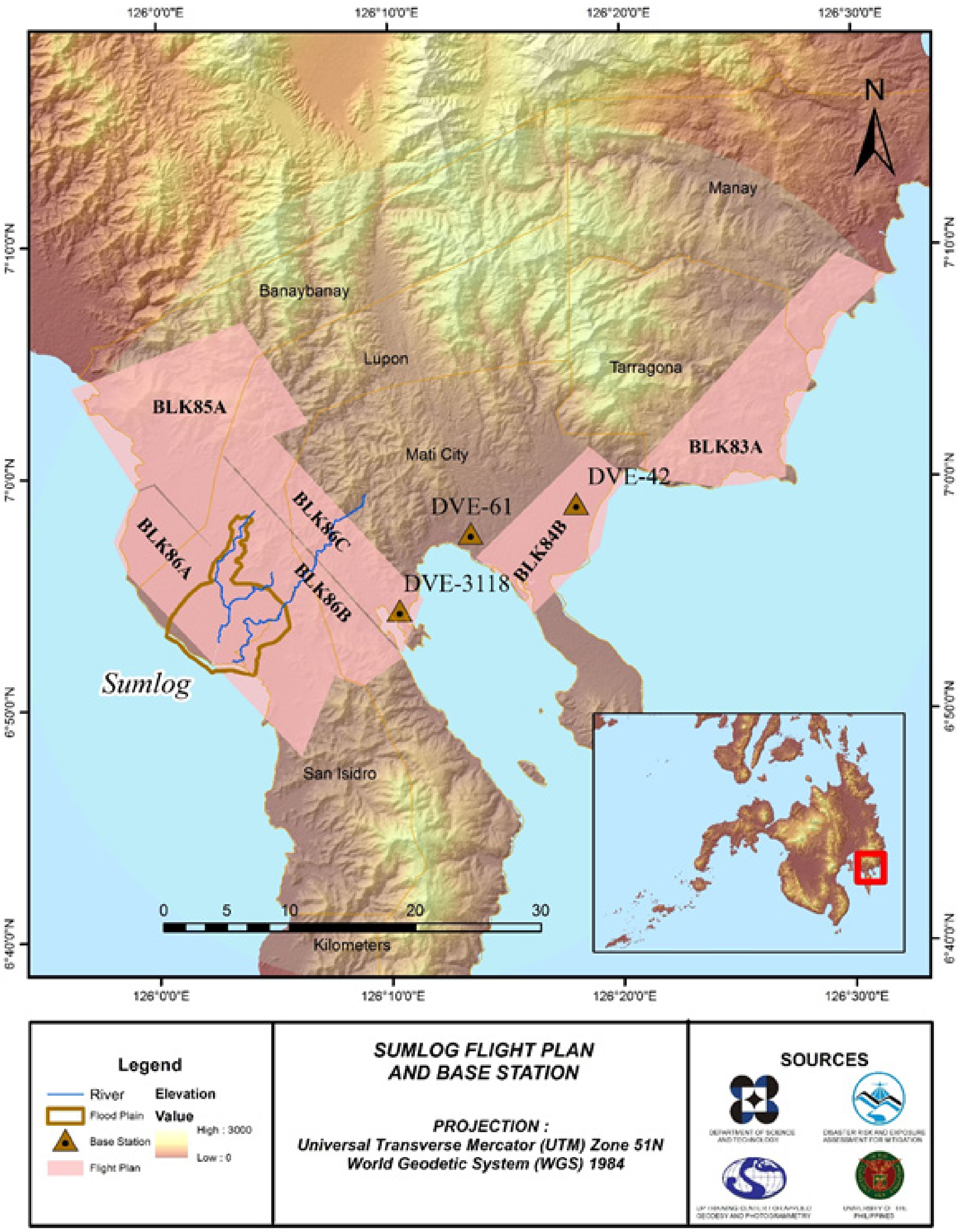



Figure 2. Flight plans and base stations used for Sumlog Floodplain Survey

## 2.2 Ground Base Stations

The Project Team was able to recover four (4) NAMRIA ground control points: DVE-42 and DVE-61 which are of second (2nd) order accuracy, and DVE-3088 and DVE-3118 which are of fourth (4th) order accuracy. Fourth (4th) order ground control points where then re-processed to obtain coordinates of second (2nd) order accuracy. The certifications for the NAMRIA reference points are found in Annex 2 while the baseline processing reports for the re-processed control points are found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey (June 20 – July 11, 2014). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 882 and SPS 985. Flight plans and location of base stations used during the aerial LiDAR acquisition in Sumlog Floodplain are shown in Figure 2.

Figures 3 to 6 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 with the corresponding dates of utilization.

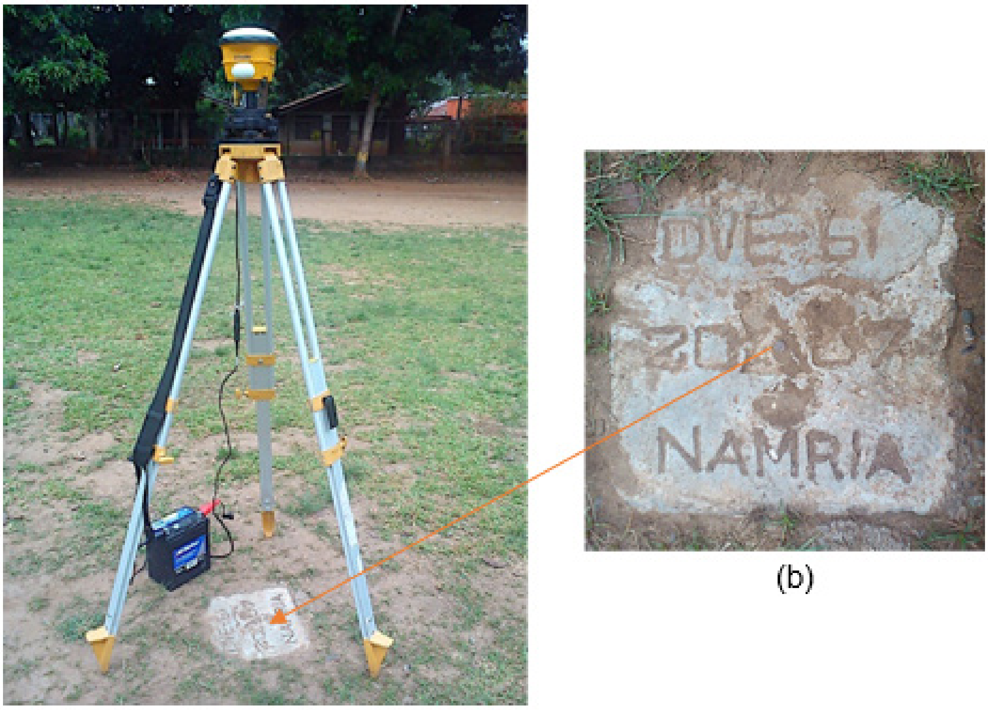

(b)

(a)

Figure 3. Photo (a) shows the GPS set-up over DVE-42 located in front of the flagpole inside the premises of Don Enrique Elementary School, while Photo (b) depicts a close-up view of NAMRIA reference point DVE-42 as recovered by the field team.

Table 2. Description of the recovered NAMRIA horizontal control point DVE-42 used as base station for the LiDAR acquisition.

| Station Name | DVE-42 | |
|---|---|---|
| Order of Accuracy | $2^{nd}$ | |
| Relative Error (horizontal positioning) | 1 in 50,000 | |
| Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92) | Latitude<br>Longitude<br>Ellipsoidal Height | 6°58’54.82726” North<br>126°17’56.05259” East<br>6.395 meters |
| Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92) | Easting<br>Northing | 643534.636 meters<br>772166.69 meters |
| Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84) | Latitude<br>Longitude<br>Ellipsoidal Height | 6°58’51.79295” North<br>126°18’1.57690” East<br>81.025 meters |
| Grid Coordinates, Universal Transverse Mercator Zone 52 North (UTM 52N PRS 92) | Easting<br>Northing | 201538.20 meters<br>772554.34 meters |

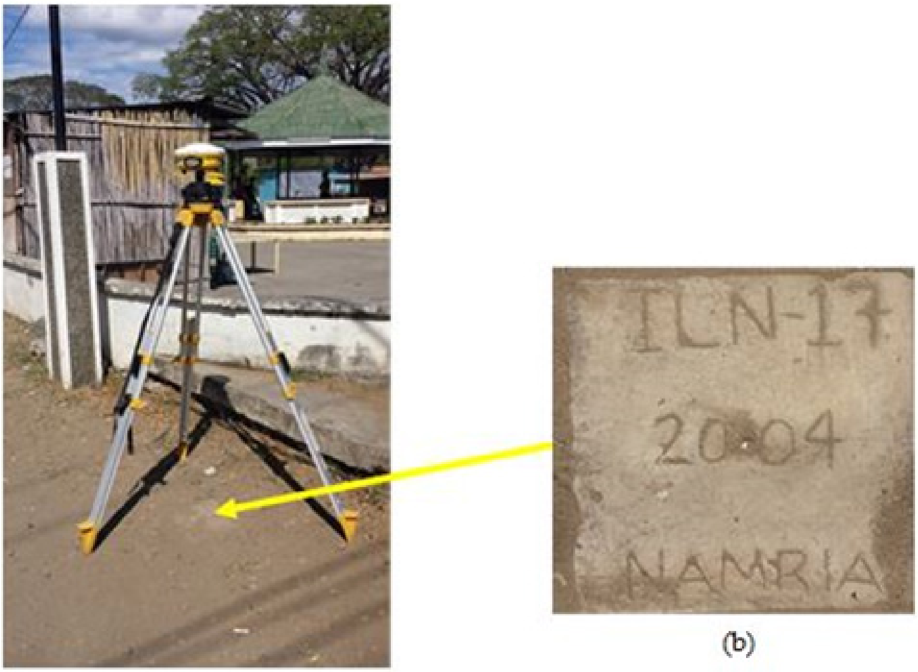



(a) (b)

Figure 4. Photo (a) shows the GPS set-up over DVE-61 located at the center of the playground of Zign Elementary School, while Photo (b) depicts a close-up view of NAMRIA reference point DVE-61 as recovered by the field team.

Table 3. Description of the recovered NAMRIA horizontal control point DVE-61 used as base station for the LiDAR acquisition.

| Station Name | DVE-61 | |
|---|---|---|
| Order of Accuracy | 2nd | |
| Relative Error (horizontal positioning) | 1 in 50,000 | |
| Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92) | Latitude<br>Longitude<br>Ellipsoidal Height | 6°57’39.37336” North<br>126°13’22.44550” East<br>48.474 meters |
| Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92) | Easting<br>Northing | 635140.8 meters<br>769826.046 meters |
| Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84) | Latitude<br>Longitude<br>Ellipsoidal Height | 6°57’36.33777” North<br>126°13’27.97256” East<br>122.953 meters |
| Grid Coordinates, Universal Transverse Mercator Zone 52 North (UTM 52N PRS 92) | Easting<br>Northing | 193120.25 meters<br>770283.71 meters |




(a) (b)

Figure 5. GPS set-up over ILN-17 located inside the park in front of Pasuquin Municipal Hall in Pasuquin Ilocos Norte (a) and NAMRIA reference point ILN-17 (b) as recovered by the field team.

Table 4. Details of the recovered NAMRIA horizontal control point ILN-17 used as base station for the LiDAR data acquisition.

| | | |
|---|---|---|
| Station Name | ILN-17 | |
| Order of Accuracy | 2nd Order | |
| Relative Error (horizontal positioning) | 1:50,000 | |
| Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92) | Latitude<br>Longitude<br>Ellipsoidal Height | 18°20'6.62958" North<br>120°37'1.30945" East<br>16.73900 meters |
| Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92) | Easting<br>Northing | 459,520.118 meters<br>2,027,898.996 meters |
| Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84) | Latitude<br>Longitude<br>Ellipsoidal Height | 18°20'0.3524" North<br>120°37'5.89113" East<br>47.87100 meters |
| Grid Coordinates, Universal Transverse Mercator Zone 52 North (UTM 52N PRS 92) | Easting<br>Northing | 248,151.17 meters<br>2,028,794.85 meters |


(a) (b)

Figure 6. GPS set-up over ILN-3234 located in front of the Administration Building of Mariano Marcos Memorial University in Batac Ilocos Norte (a) and NAMRIA reference point ILN-3234 (b) as recovered by the field team.

Table 5. Details of the recovered NAMRIA horizontal control point ILN-3234 used as base station for the LiDAR data acquisition.

| Station Name | ILN-3234 | |
|---|---|---|
| Order of Accuracy | 4th Order | |
| Relative Error (horizontal positioning) | 1:10,000 | |
| Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92) | Latitude<br>Longitude<br>Ellipsoidal Height | 18°3'41.82025" North<br>120°32'3.1072" East<br>22.632 meters |
| Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92) | Easting<br>Northing | 452,075.694 meters<br>1,997,640.111 meters |
| Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84) | Latitude<br>Longitude<br>Ellipsoidal Height | 18°3'35.59528" North<br>120°32'54.91553" East<br>54.492 meters |
| Grid Coordinates, Universal Transverse Mercator Zone 52 North (UTM 52N PRS 92) | Easting<br>Northing | 240,373.73 meters<br>1,998,605.86 meters |

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

| Date Surveyed | Flight Number | Mission Name | Ground Control Points |
|---|---|---|---|
| June 20, 2014 | 7322GC | 2BLK84AS&86B171A (BLK83A instead of BLK84A) | DVE-42 & DVE-3088 |
| June 20, 2014 | 7323GC | 2BLK86C&83A171B (additional BLK84B) | DVE-42 & DVE-3088 |
| June 27 2014 | 7337GC | 2BLK86A178A | DVE-61 & DVE-3118 |
| July 11, 2014 | 7364GC | 2BLK85V192A (covered BLK85A and voids of BLK84A and BLK83A) | DVE-61 & DVE-3118 |

## 2.3 Flight Missions

Four (4) missions were conducted to complete the LiDAR data acquisition in Sumlog Floodplain, for a total of fifteen hours and forty eight minutes (15+48) of flying time for RP-C9322. All missions were acquired using the Gemini LiDAR System. Table 7 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 8 presents the actual parameters used during the LiDAR data acquisition.

Table 7. Flight missions for LiDAR data acquisition in Sumlog 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 |
| June 20, 2014 | 7322GC | 252.00 | 209.19 | 13.64 | 195.55 | NA | 4 | 11 |
| June 20, 2014 | 7323GC | 210.29 | 214.08 | 0 | 214.08 | NA | 4 | 9 |
| June 27 2014 | 7337GC | 137.98 | 176.23 | 50.35 | 125.88 | NA | 3 | 53 |
| July 11, 2014 | 7364GC | 138.00 | 195.19 | 0 | 195.19 | NA | 3 | 35 |
| **TOTAL** | | 738.27 | 794.69 | 63.99 | 730.7 | NA | 15 | 48 |

Table 8. Actual parameters used during LiDAR data acquisition

| Flight Number | Flying Height (m AGL) | Overlap (%) | FOV (θ) | PRF (KHz) | Scan Frequency (Hz) | Average Speed (kts) | Average Turn Time (Minutes) |
|---|---|---|---|---|---|---|---|
| 7322GC | 1100 | 30 | 40 | 100 | 50 | 130 | 5 |
| 7323GC | 1100 | 30 | 40 | 100 | 50 | 130 | 5 |
| | 1250 | 30 | 36 | 100 | 50 | 130 | 5 |
| 7337GC | 1100 | 30 | 40 | 100 | 50 | 130 | 5 |
| 7364GC | 1600 | 40 | 40 | 70 | 50 | 130 | 5 |
| | | 40 | 24 | 70 | 60 | 130 | 5 |

## 2.4 Survey Coverage

The Sumlog Floodplain is located in the Province of Davao Oriental, specifically within the City of Mati. The list of municipalities/cities surveyed, with at least one (1) square kilometer coverage is shown in Table 9. The actual coverage of the LiDAR acquisition for Sumlog floodplain is presented in Figure 7.

Table 9. List of municipalities and cities surveyed during Sumlog Floodplain LiDAR survey.

| Province | Municipality/City | Area of Municipality/City (km2) | Total Area Surveyed (km2) | Percentage of Area Surveyed |
|---|---|---|---|---|
| Davao Oriental | Lupon | 356.28 | 168.19 | 47.21% |
| | Banaybanay | 385.28 | 150.20 | 38.99% |
| | San Isidro | 224.84 | 69.43 | 30.88% |
| | Tarragona | 277.90 | 58.22 | 20.95% |
| | Mati City | 797.38 | 139.24 | 17.46% |
| | Manay | 430.89 | 30.16 | 7.00% |
| **Total** | | **2,472.57** | **615.44** | **24.89%** |

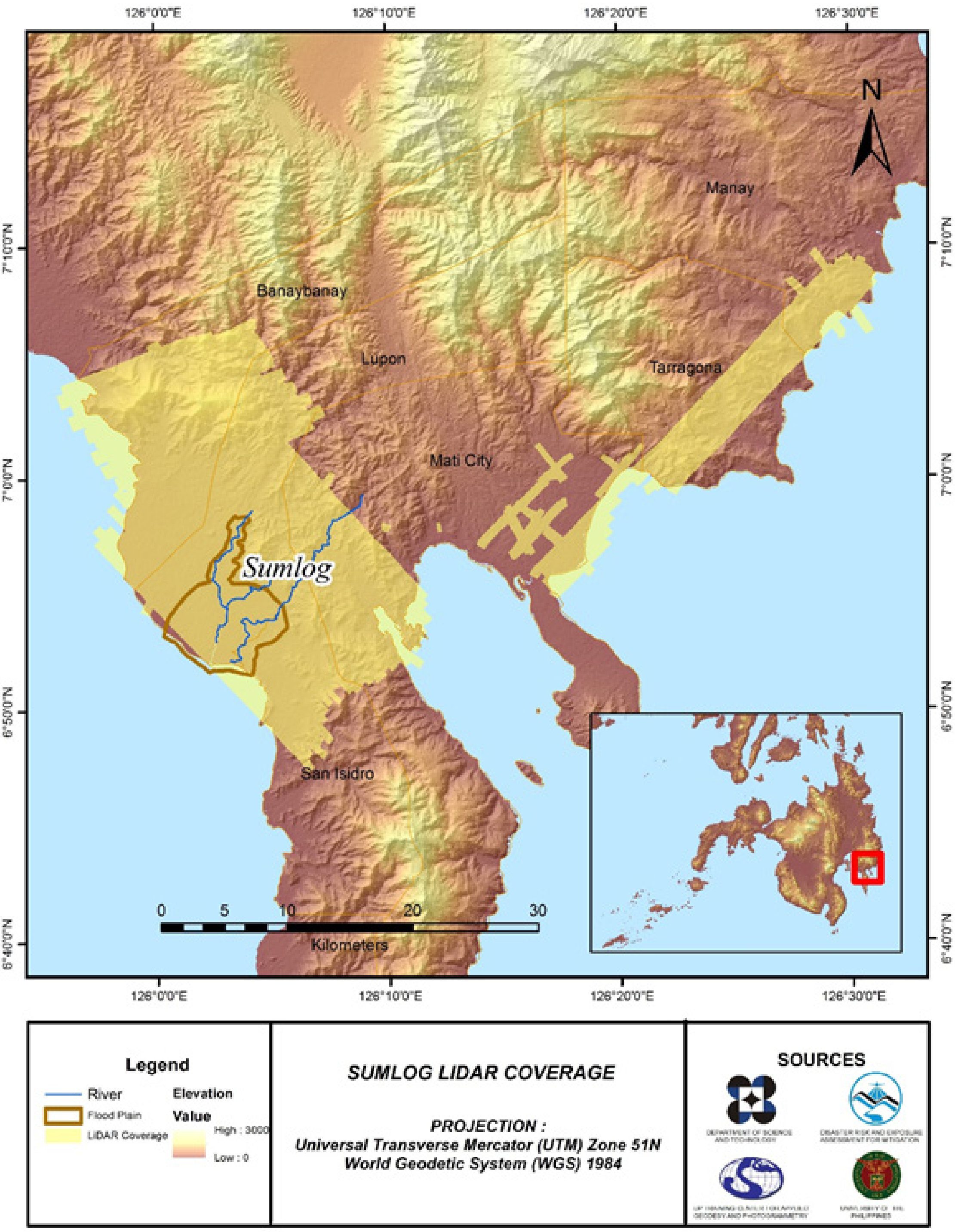



Figure 7. Actual LiDAR survey coverage for Sumlog Floodplain.

# CHAPTER 3: LIDAR DATA PROCESSING OF THE SUMLOG 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. Velina Angela S. Bemida, 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 were checked for completeness based on the list of raw files required to proceed with the pre-processing of the LiDAR data. Upon acceptance of the LiDAR field data, georeferencing of the flight trajectory was done in order to obtain the exact location of the LiDAR sensor when the laser was shot. Point cloud georectification was performed to incorporate correct position and orientation for each point acquired. The georectified LiDAR point clouds were subjected to quality check in order to ensure that the required accuracies of the program, which are the minimum point density, vertical and horizontal accuracies, were met. The point clouds were then classified into various classes before generating Digital Elevation Models such as Digital Terrain Model and Digital Surface Model.

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

These processes are summarized in the flowchart shown in Figure 8.

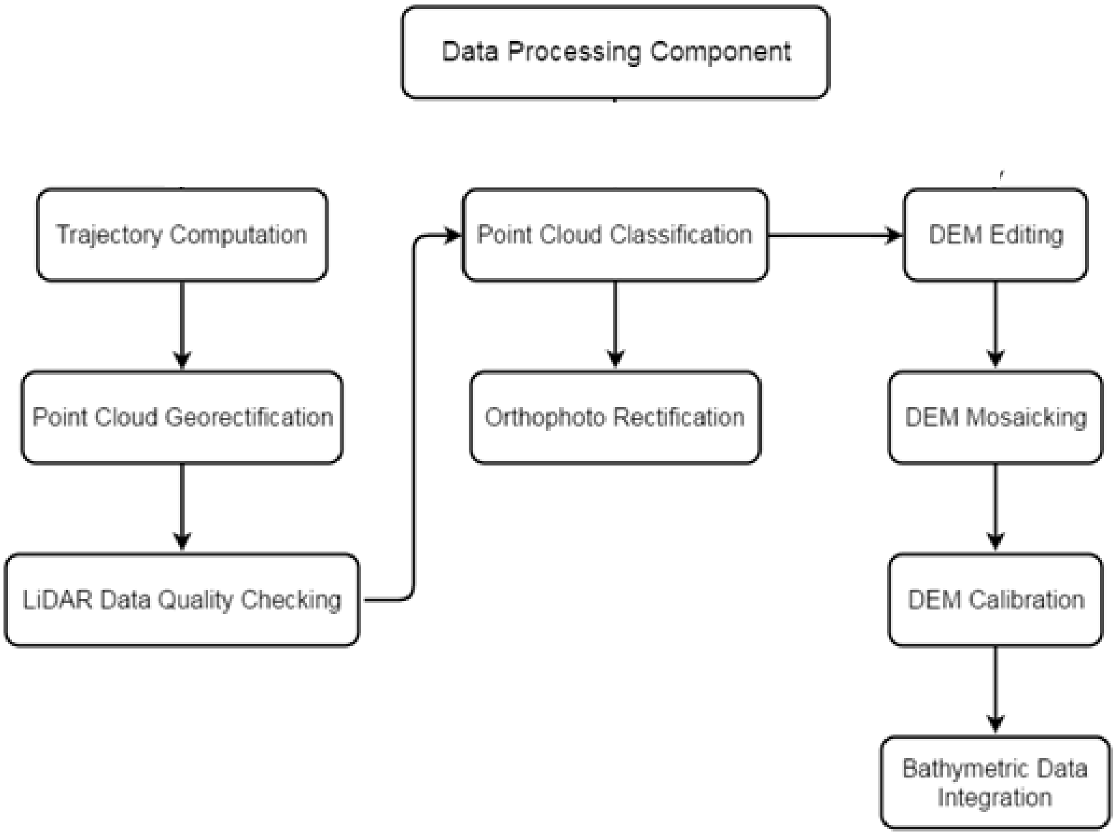



Figure 8. Schematic Diagram for Data Pre-Processing Component

## 3.2 Transmittal of Acquired LiDAR Data

The Data Transfer Sheets for all the LiDAR missions for Sumlog Floodplain can be found in Annex 5. Missions flown during most of the surveys conducted used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Gemini System over Davao Oriental. The Data Acquisition Component (DAC) transferred a total of 87.6 Gigabytes of Range data, .86 Gigabytes of POS data, 23.31 Megabytes of GPS base station data, and 0 Gigabytes of raw image data to the data server on July 2, 2014 for the first survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Sumlog was fully transferred on July 28, 2014, as indicated on the Data Transfer Sheets for Sumlog Floodplain.

## 3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for flight 7337GC, one of the Sumlog flights, which is the North, East, and Down position RMSE values are shown in Figure 9. The x-axis corresponds to the time of flight, which was measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on July 8, 2014 00:00AM. The y-axis is the RMSE value for that particular position.


Figure 9. Smoothed Performance Metric of Sumlog Flight 7337GC.

The time of flight was from 452,200 seconds to 461,100 seconds, which corresponds to morning of July 8, 2014. The initial spike seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and when the POS system started 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 made a turn to start a new flight line. Figure 9 shows that the North position RMSE peaks at 1.20 centimeters, the East position RMSE peaks at 1.85 centimeters, and the Down position RMSE peaks at 2.55 centimeters, which are within the prescribed accuracies described in the methodology.

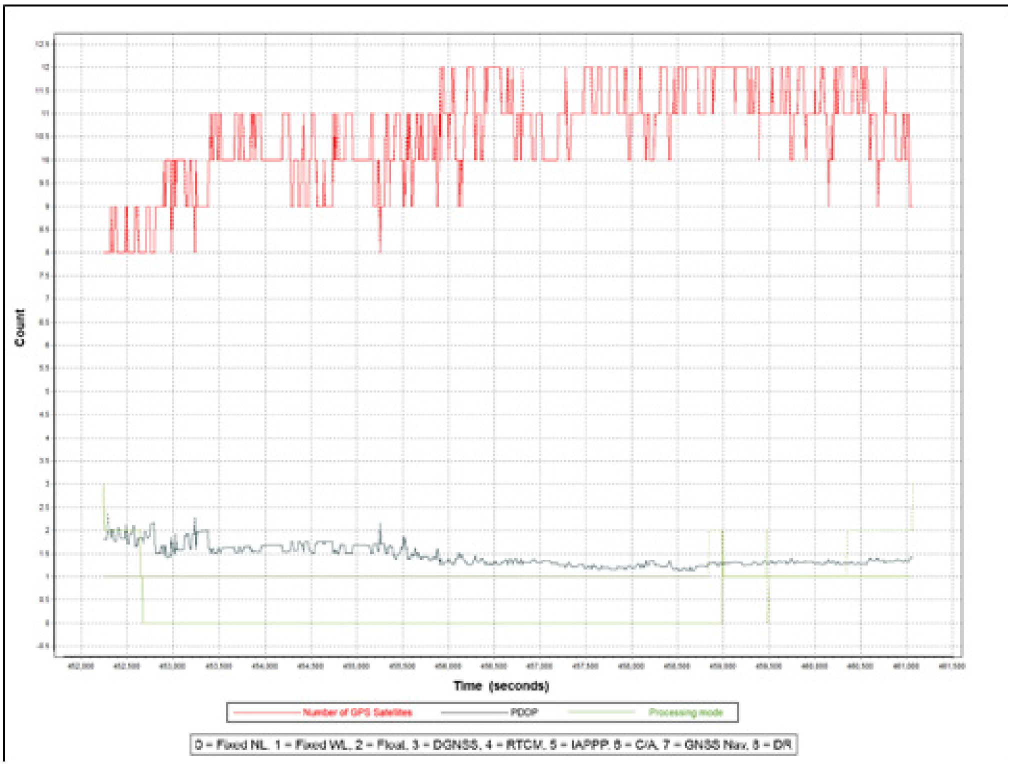



Figure 10. Solution Status Parameters of Aunugay Flight 7337GC

The Solution Status parameters of flight 7337GC, one of the Sumlog flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 10. The graphs indicate that the number of satellites during the acquisition did not go down to 8. Majority of the time, the number of satellites tracked was between 8 and 10. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 2 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Sumlog flights is shown in Figure 11.

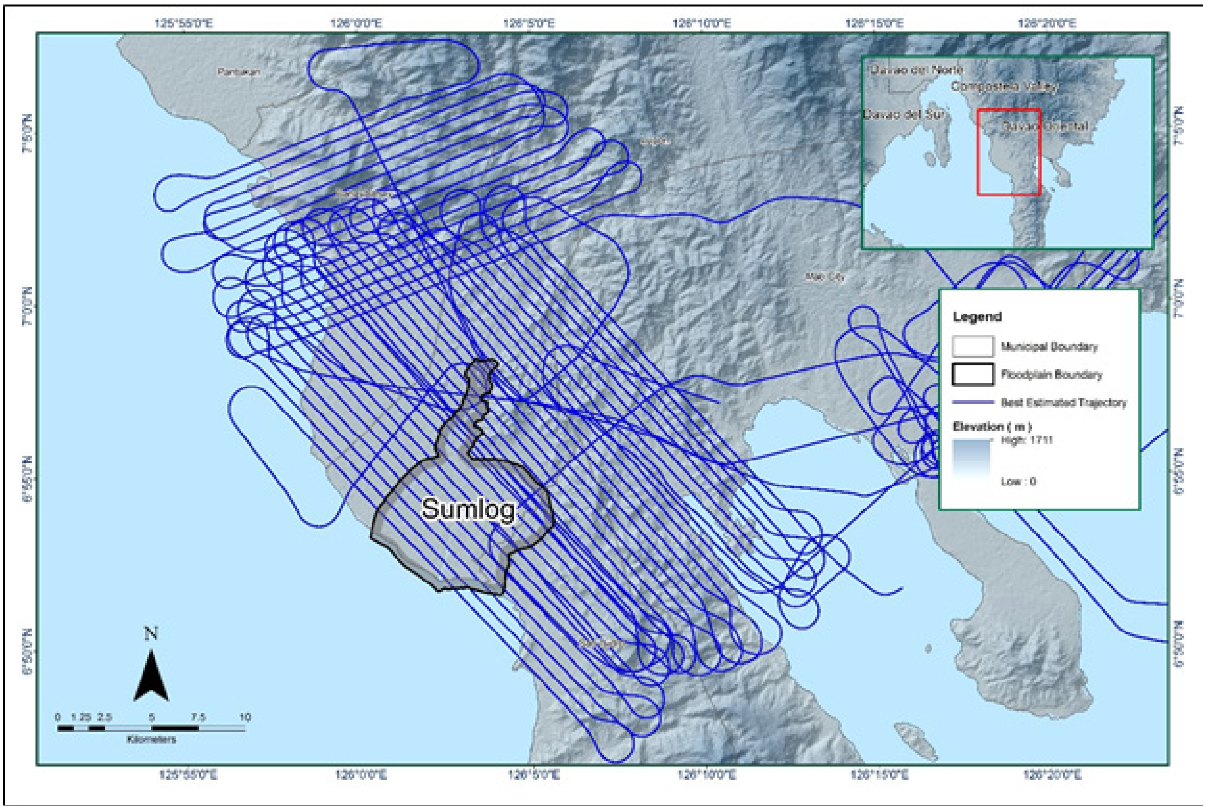



Figure 11. Best Estimated Trajectory for Sumlog Floodplain.

## 3.4 LiDAR Point Cloud Computation

The produced LAS data contain 49 flight lines, with each flight line containing one channel, since the Gemini System contained one channel only. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Sumlog Floodplain are given in Table 10.

Table 10. Self-Calibration Results values for Sumlog flights

| Parameter | Acceptable Value | Computed Value |
|---|---|---|
| Boresight Correction stdev) | <0.001degrees | 0.000467 |
| IMU Attitude Correction Roll and Pitch Corrections stdev) | <0.001degrees | 0.000774 |
| GPS Position Z-correction stdev) | <0.01meters | 0.0020 |

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

## 3.5 LiDAR Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Aunugay Floodplain is shown in Figure 12. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

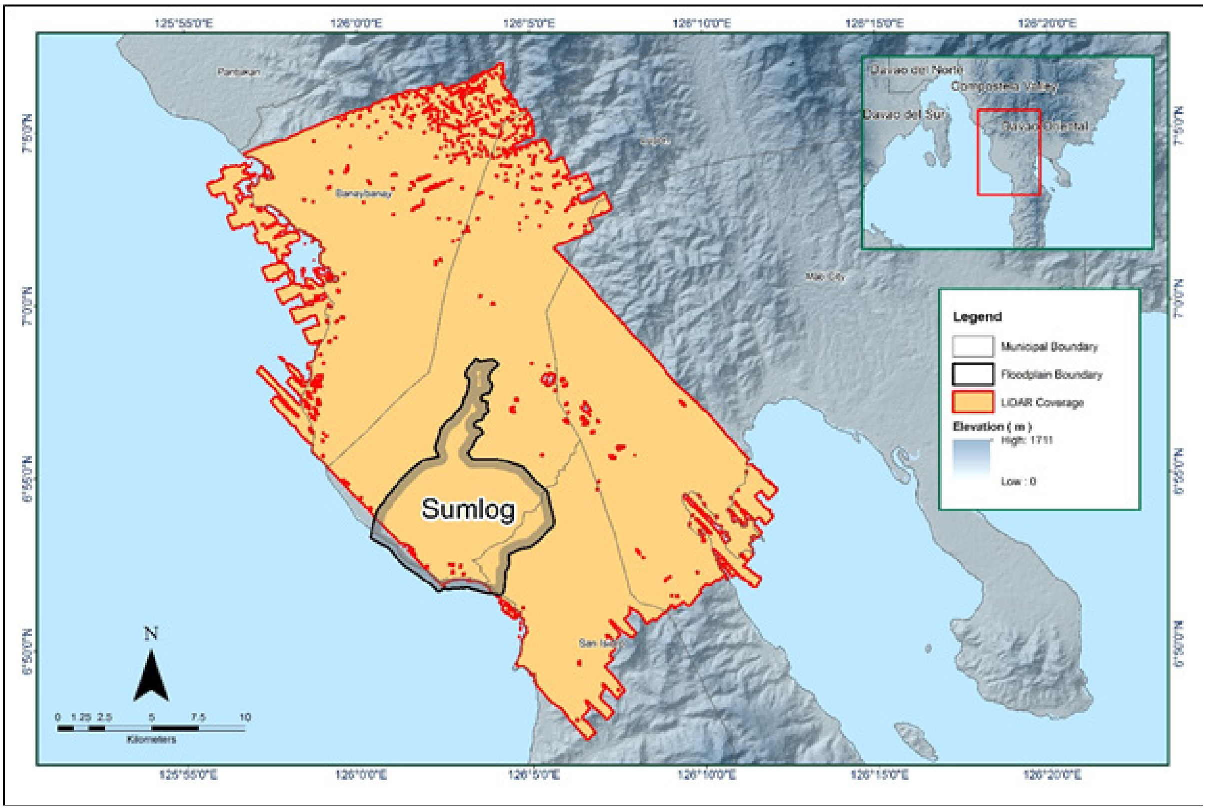



Figure 12. Boundary of the processed LiDAR data over Sumlog Floodplain.

The total area covered by the Sumlog missions is 589.81 sq.km that comprised of four (4) flight acquisitions grouped and merged into four (4) blocks as shown in Table 11.

Table 11. List of LiDAR blocks for Sumlog Floodplain.

| LiDAR Blocks | Flight Numbers | Area (sq.km) |
|---|---|---|
| DavaoOriental_Blk86A | 7337GC | 158.52 |
| DavaoOriental_Blk86B | 7322GC | 160.46 |
| DavaoOriental_Blk86C | 7323GC | 97.23 |
| DavaoOriental_Blk86A_additional | 7364GC | 173.60 |
| **TOTAL** | | **589.81 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 13. Since the Gemini System employs one channel, we could 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.

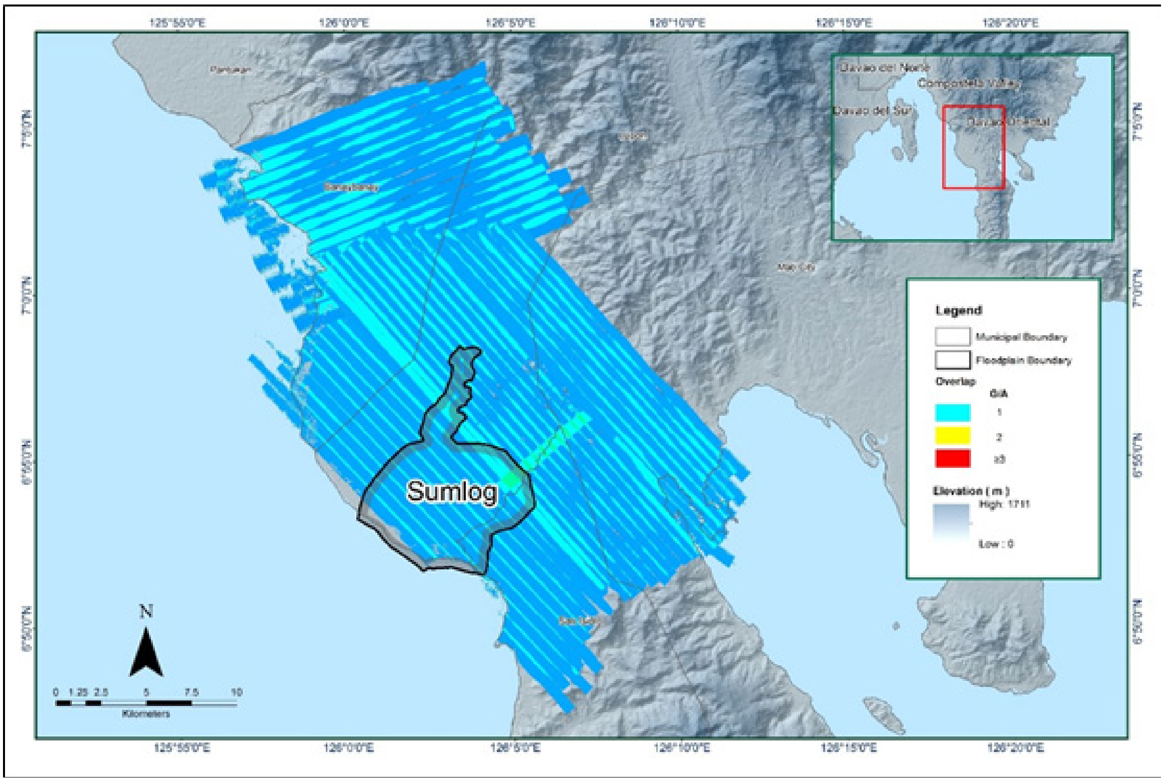



Figure 13. Image of data overlap for Sumlog Floodplain.

The overlap statistics per block for the Sumlog Floodplain can be found in Annex 5. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 33.62% and 35.88% respectively, which passed the 25% requirement.

The 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 14. It was determined that all LiDAR data for Sumlog Floodplain satisfied the point density requirement, and the average density for the entire survey area is 2.95 points per square meter.

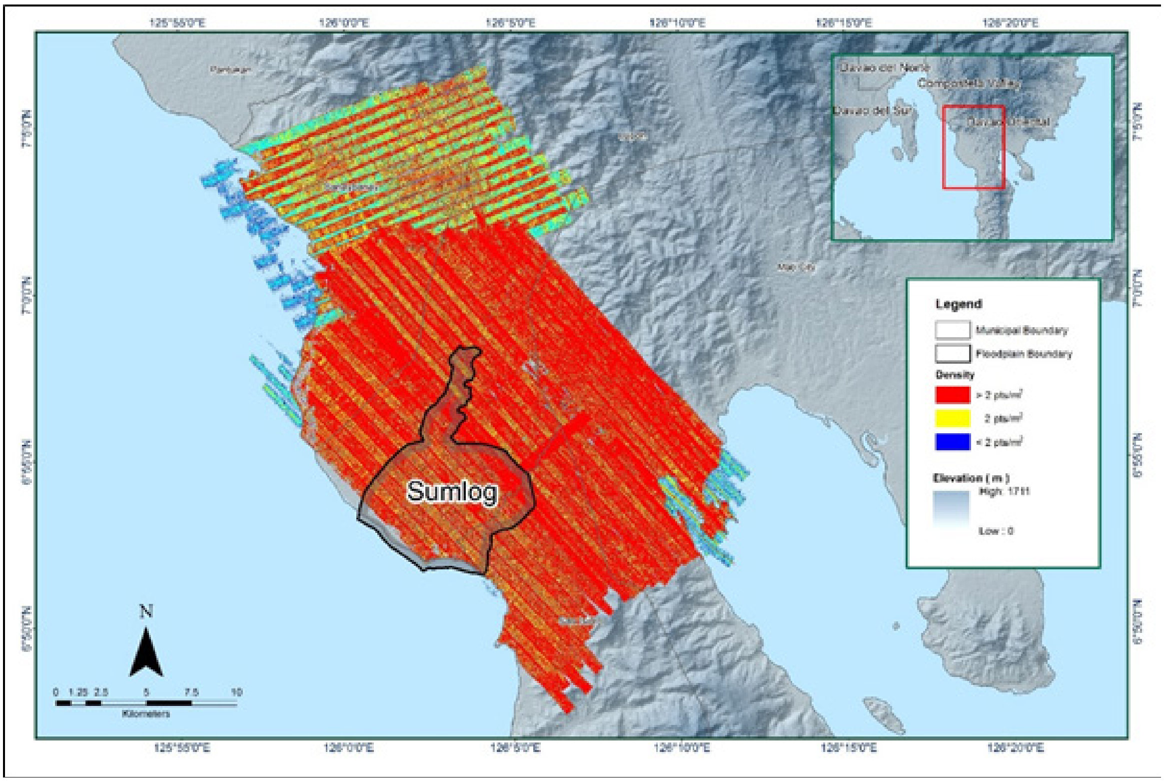



Figure 14. Density map of merged LiDAR data for Sumlog Floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 15. 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.

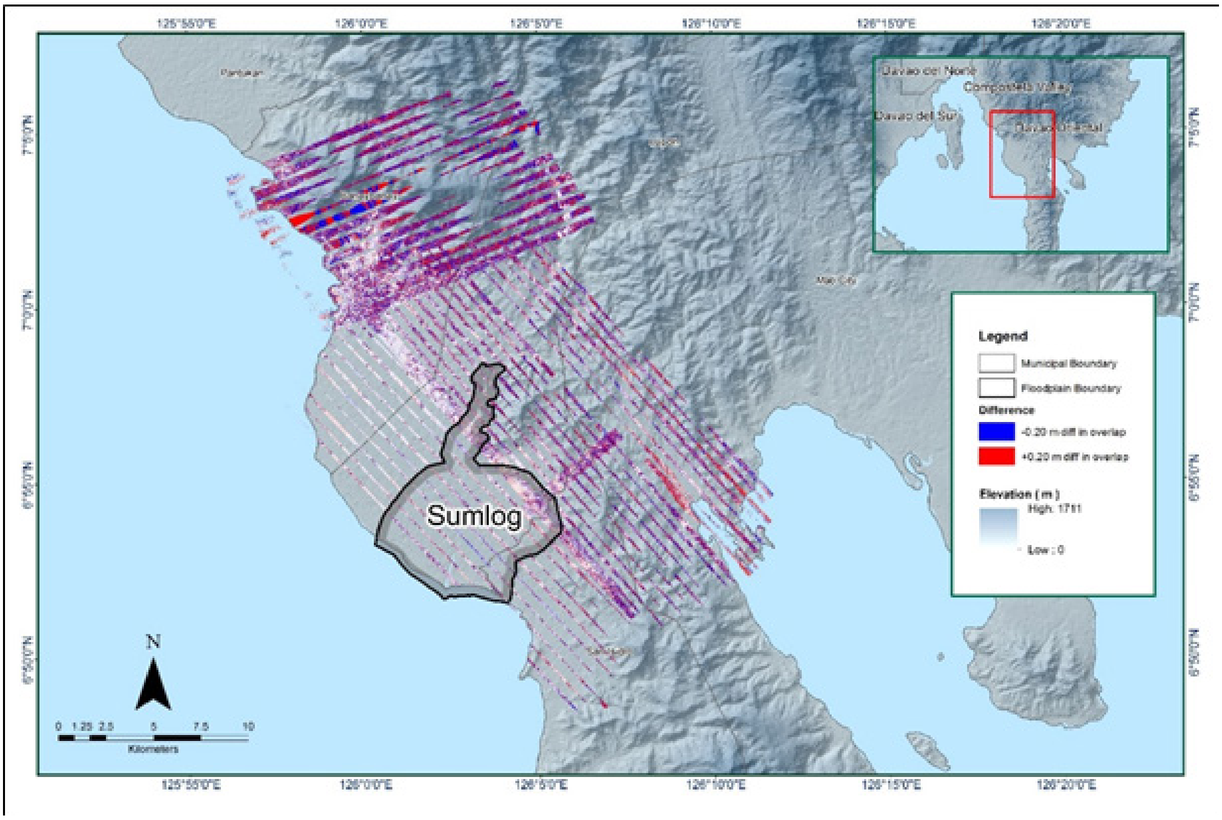



Figure 15. Elevation difference map between flight lines for Sumlog Floodplain.

A screen capture of the processed LAS data from a Sumlog flight 7337GC loaded in QT Modeler is shown in Figure 16. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there were differences in elevation, but the differences did 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.

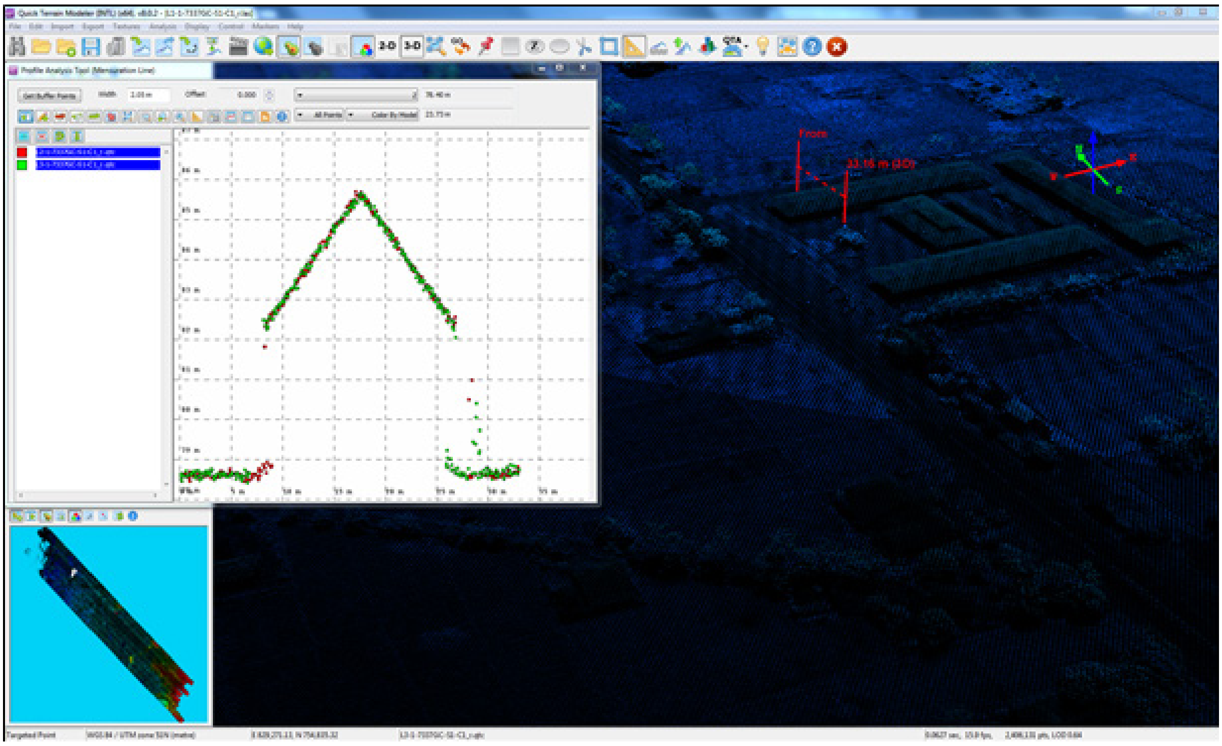


Figure 16. Quality checking for Aunugay flight 3981G using the Profile Tool of QT Modeler.

## 3.6 LiDAR Point Cloud Classification and Rasterization

Table 12. Sumlog classification results in TerraScan.

| Pertinent Class | Total Number of Points |
|---|---|
| Ground | 166,470,503 |
| Low Vegetation | 150,178,023 |
| Medium Vegetation | 266,900,575 |
| High Vegetation | 703,353,898 |
| Building | 5,757,965 |

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Sumlog Floodplain is shown in Figure 17. A total of 670 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 12. The point cloud has a maximum and minimum height of 773.03 meters and 47.95 meters respectively.

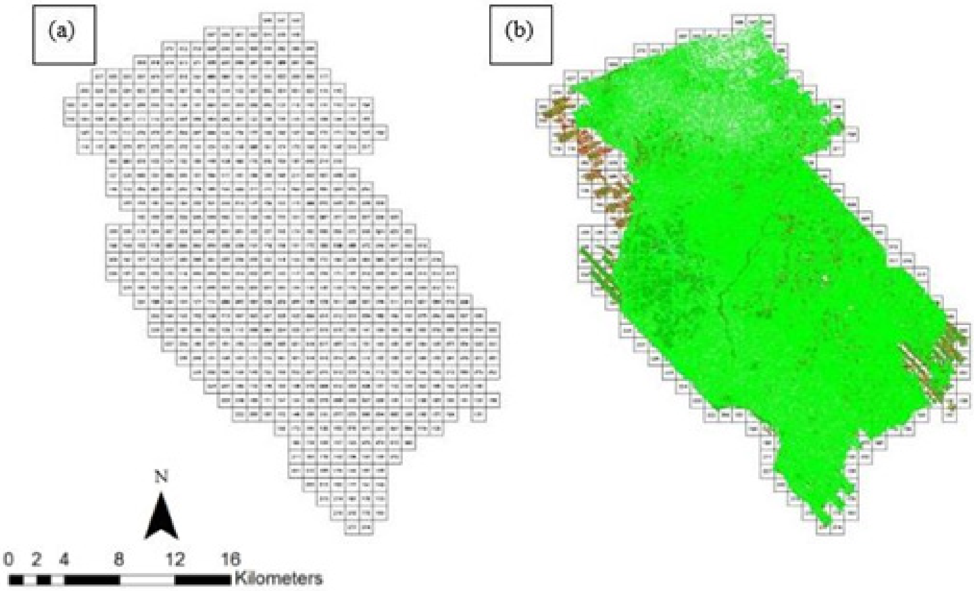



Figure 17. Tiles for Sumlog Floodplain (a) and classification results (b) in TerraScan

An isometric view of an area before and after running the classification routines is shown in Figure 18. 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.

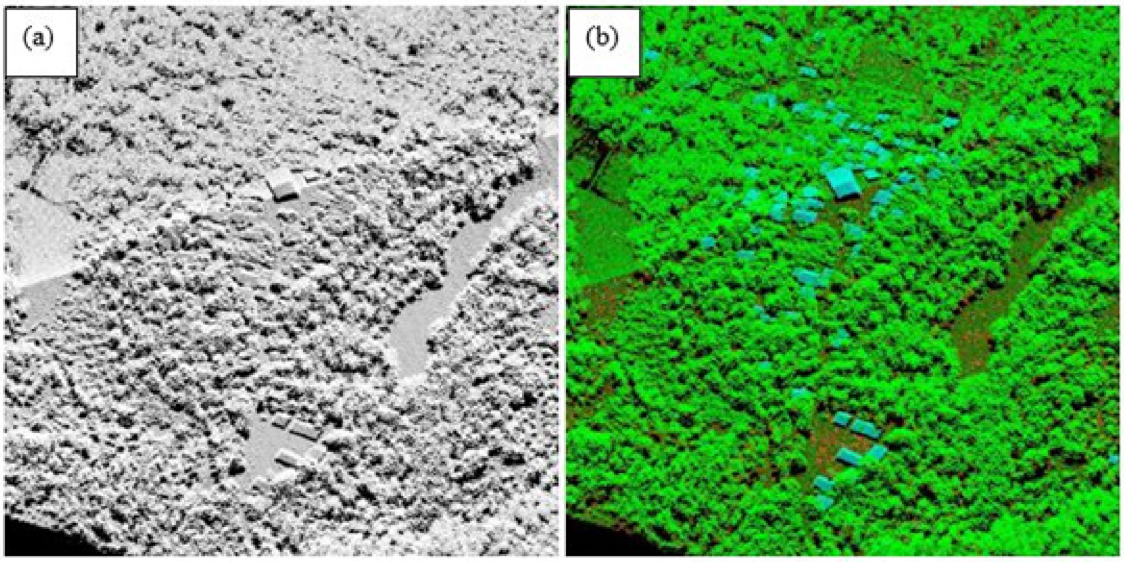



Figure 18. Point cloud before (a) and after (b) classification.

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 19. It shows that DTMs are the representation of the bare earth while on the DSMs, all features are present such as buildings and vegetation.

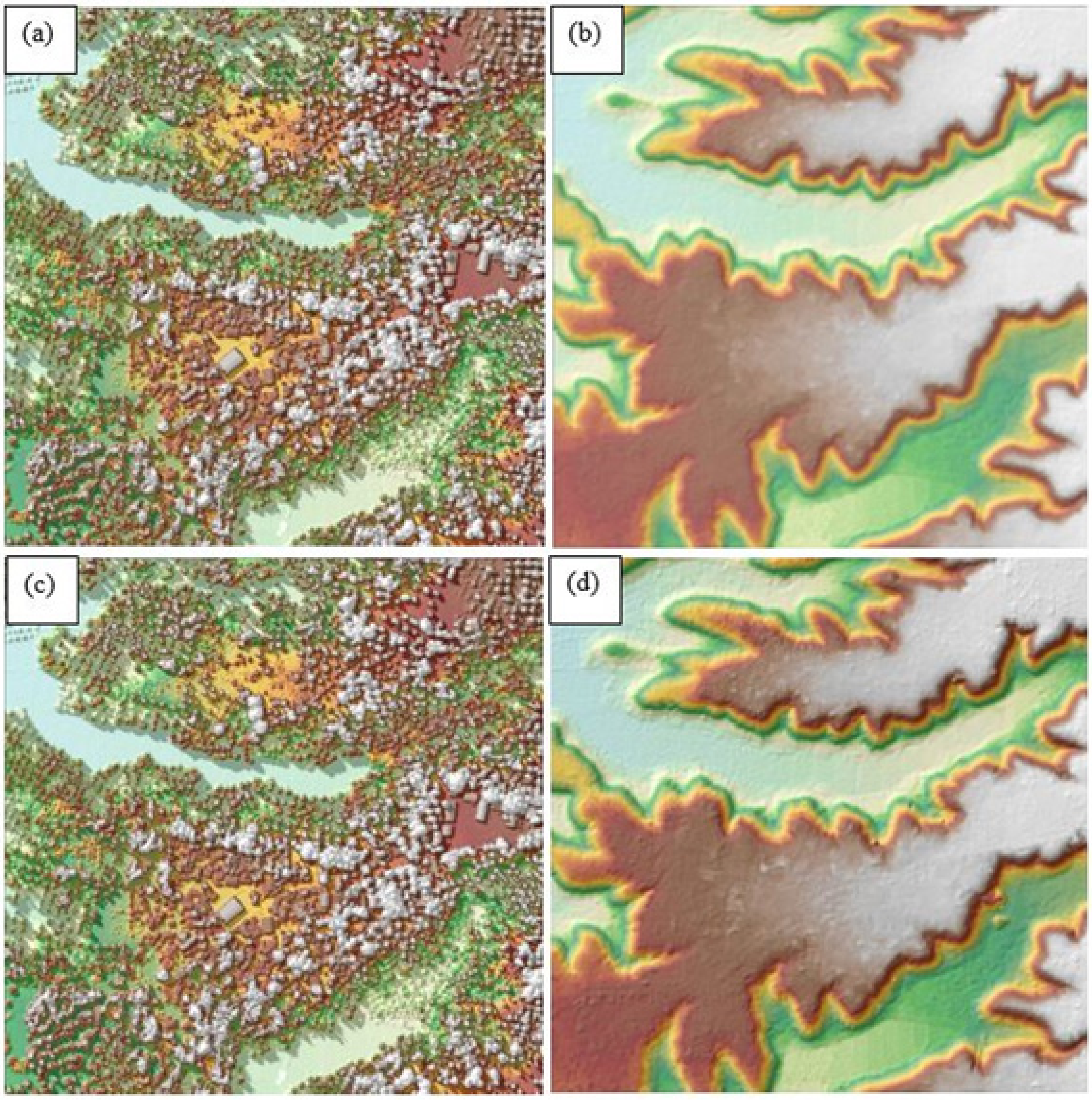



Figure 19. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Sumlog Floodplain.

## 3.7 LiDAR Image Processing and Orthophotograph Rectification

There are no available orthophotographs for the Sumlog floodplain.

## 3.8 DEM Editing and Hydro-Correction

Four (4) mission blocks were processed for Sumlog Floodplain. These blocks are comprised of DavaoOriental blocks with a total area of 589.81 square kilometers. Table 13 shows the name and corresponding area of each block in square kilometers.

Table 13. LiDAR blocks with its corresponding area.

| LiDAR Blocks | Area (sq. km.) |
|---|---|
| DavaoOriental_Blk86A | 158.52 |
| DavaoOriental_Blk86B | 160.46 |
| DavaoOriental_Blk86C | 97.23 |
| DavaoOriental_Blk86A_additional | 173.60 |
| **TOTAL** | **589.81 sq.km** |

Portions of DTM before and after manual editing are shown in Figure B-13. The river embankment (Figure B-13a) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure B-13b) to allow the correct flow of water. The bridge (Figure B-13c) is also considered to be an impedance to the flow of water along the river and has to be removed (Figure B-13d) in order to hydrologically correct the river.

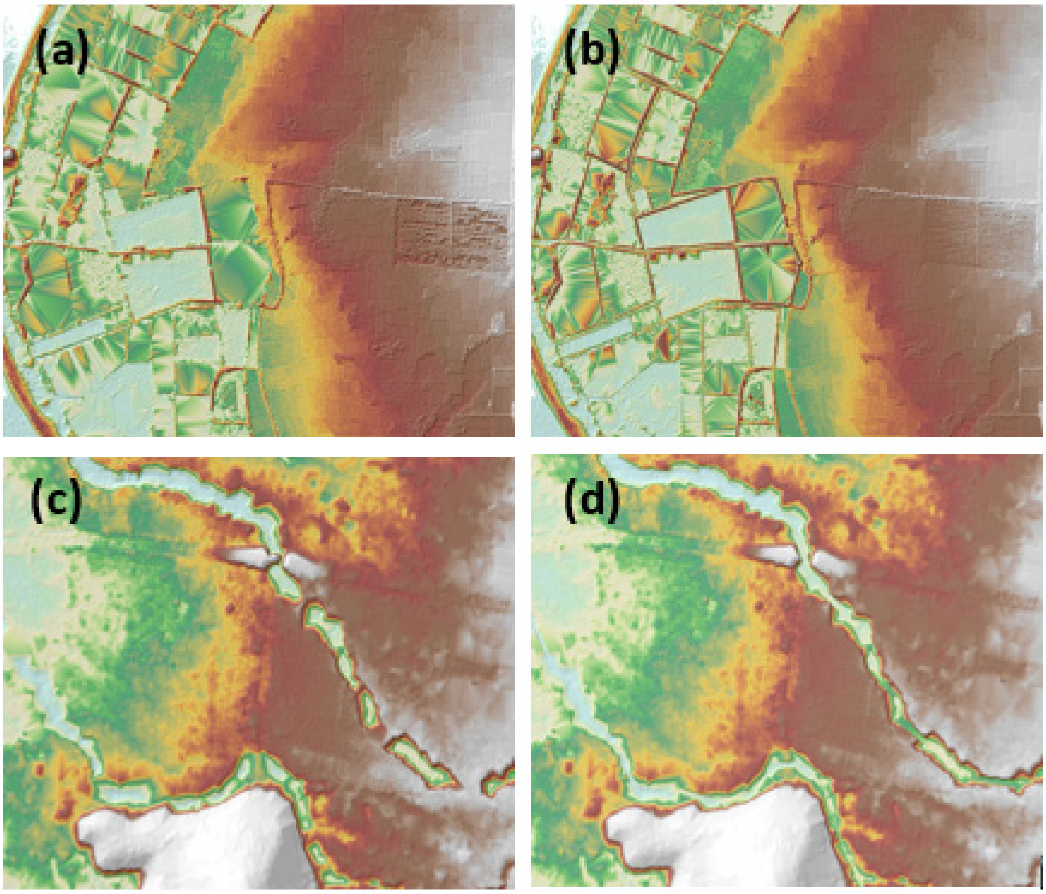



Figure 20. Portions in the DTM of Sumlog Floodplain – a paddy field before (a) and after (b) data retrieval; a bridge before (c) and after (d) manual editing.

## 3.9 Mosaicking of Blocks

DavaoOriental_Blk86A 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 14 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Sumlog Floodplain is shown in Figure 20. It can be seen that the entire Sumlog Floodplain is 94.95% covered by LiDAR data.

Table 14. Shift Values of each LiDAR Block of Sumlog Floodplain.

| Mission Blocks | Shift Values (meters) | | |
|---|---|---|---|
| | x | y | z |
| DavaoOriental_Blk86A | 0.00 | 0.00 | 0.00 |
| DavaoOriental_Blk86B | 2.00 | 1.00 | 0.73 |
| DavaoOriental_Blk86C | 0 | 0 | -0.16 |
| DavaoOriental_Blk86A_additional | -1.3 | 0 | -1.03 |

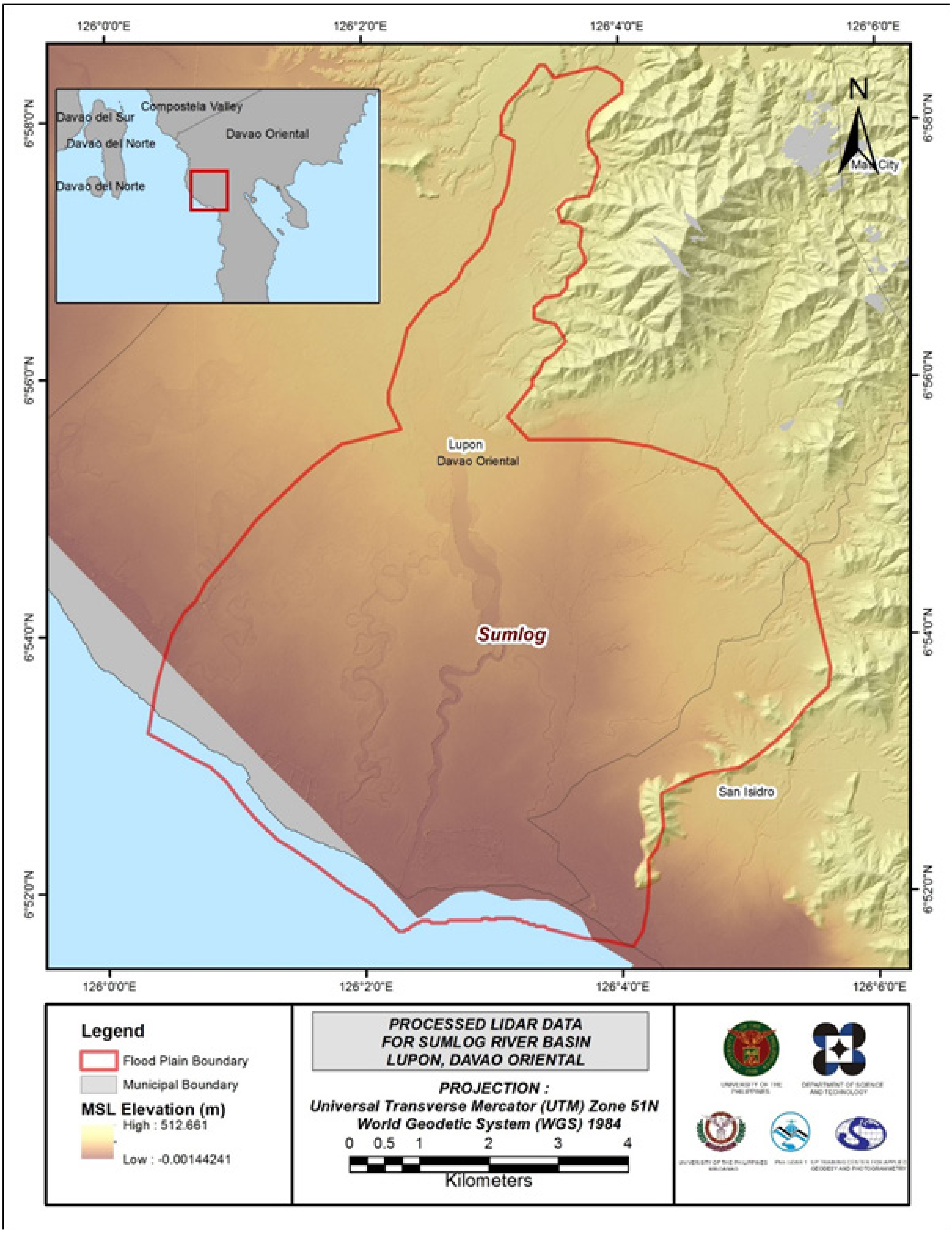



Figure 21. Map of Processed LiDAR Data for Sumlog Floodplain.

## 3.10 Calibration and Validation of Mosaicked LiDAR DEM

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Sumlog to collect points with which the LiDAR dataset is validated is shown in Figure 21. A total of 3,432 survey points were used for calibration and validation of Sumlog LiDAR data. Random selection of 80% of the survey points, resulting to 2,746 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 22. 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 0.70 meters with a standard deviation of 0.17 meters. Calibration of Sumlog LiDAR data was done by subtracting the height difference value, 0.70 meters, to Sumlog mosaicked LiDAR data. Table 15 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

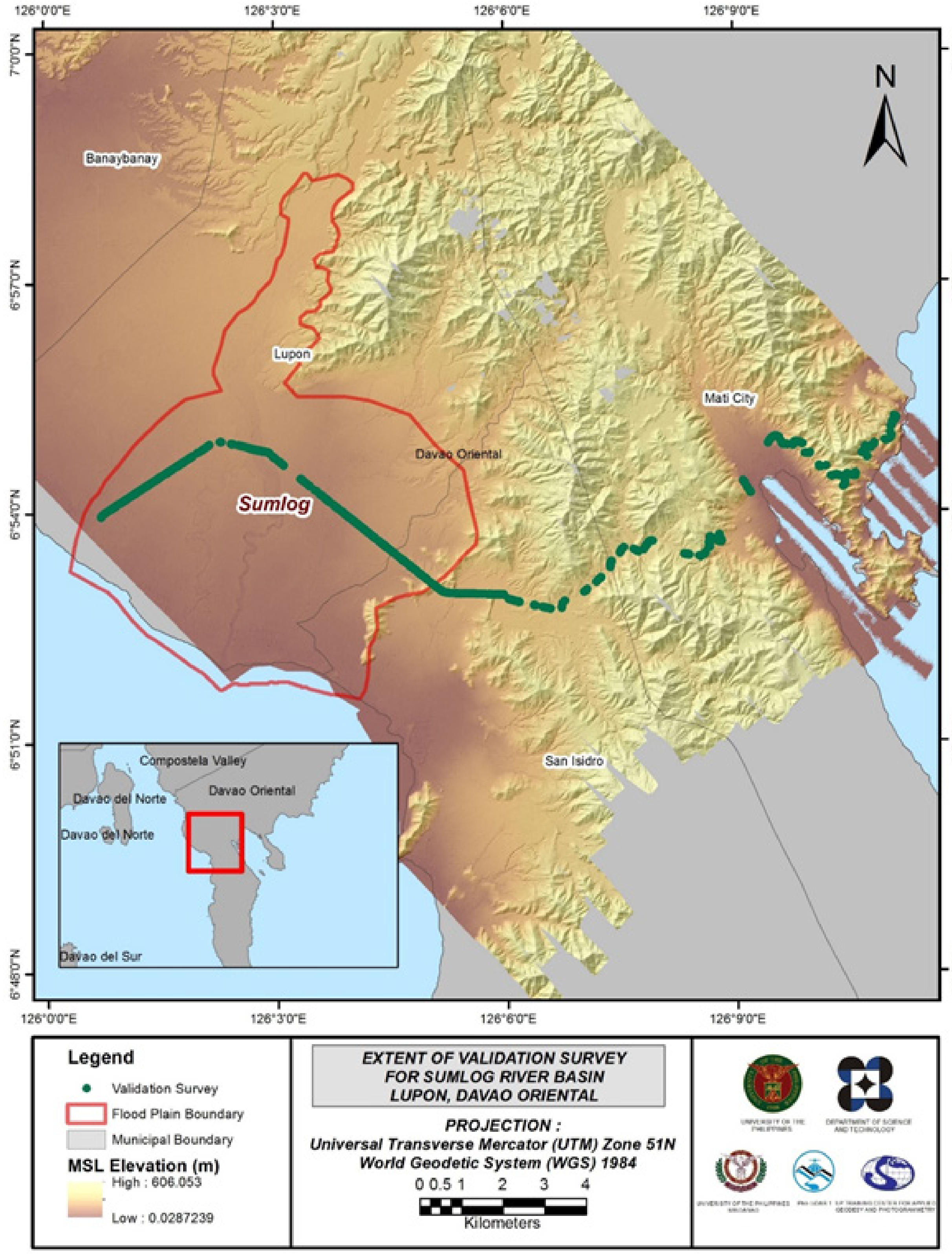



Figure 22. Map of Sumlog Floodplain with validation survey points in green.

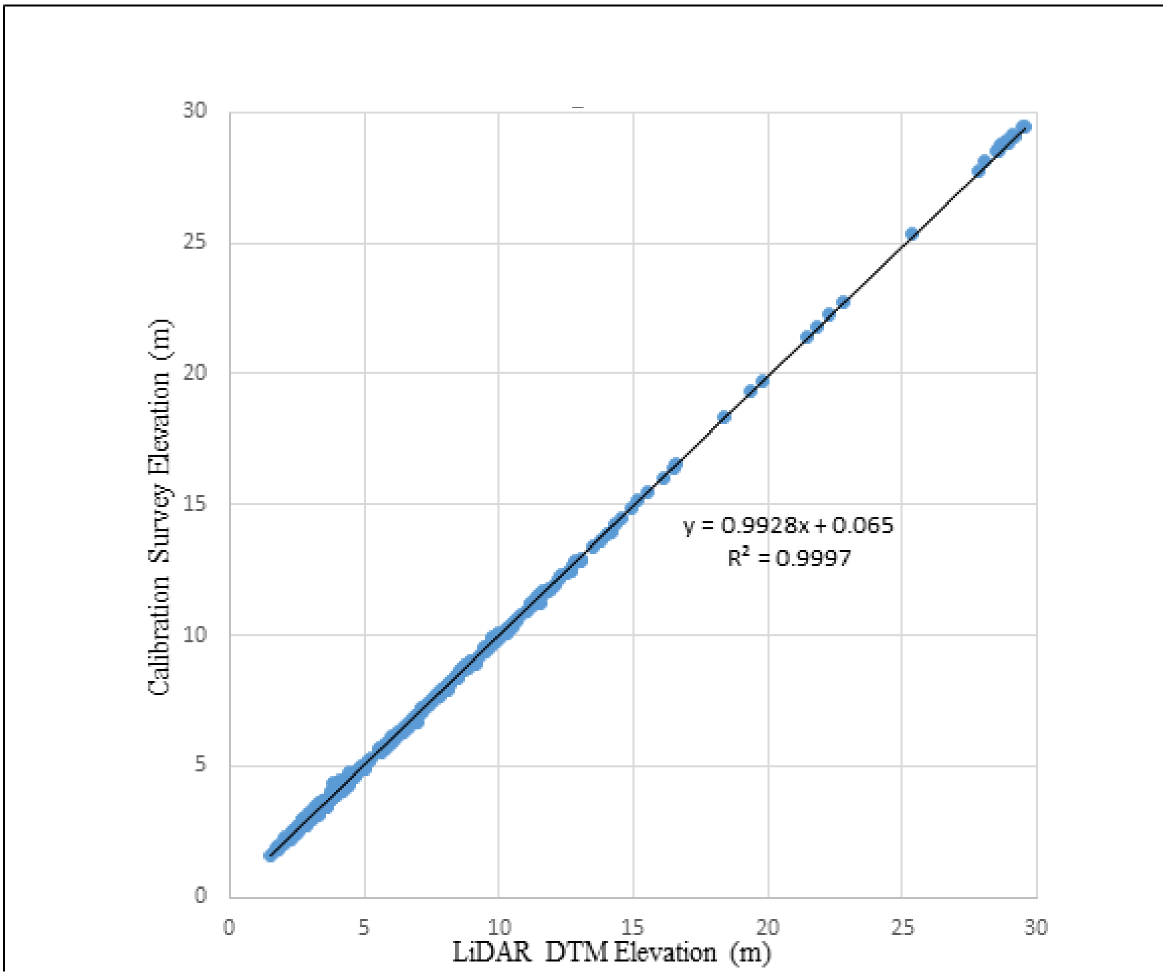



Figure 23. Correlation plot between calibration survey points and LiDAR data.

Table 15. Calibration Statistical Measures

| Calibration Statistical Measures | Value (meters) |
|---|---|
| Height Difference | 0.70 |
| Standard Deviation | 0.17 |
| Average | -0.68 |
| Minimum | -1.01 |
| Maximum | -0.35 |

The remaining 20% of the total survey points, resulting to 686 points, were used for the validation of calibrated Sumlog 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 24. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.19 meters with a standard deviation of 0.18 meters, as shown in Table 16.

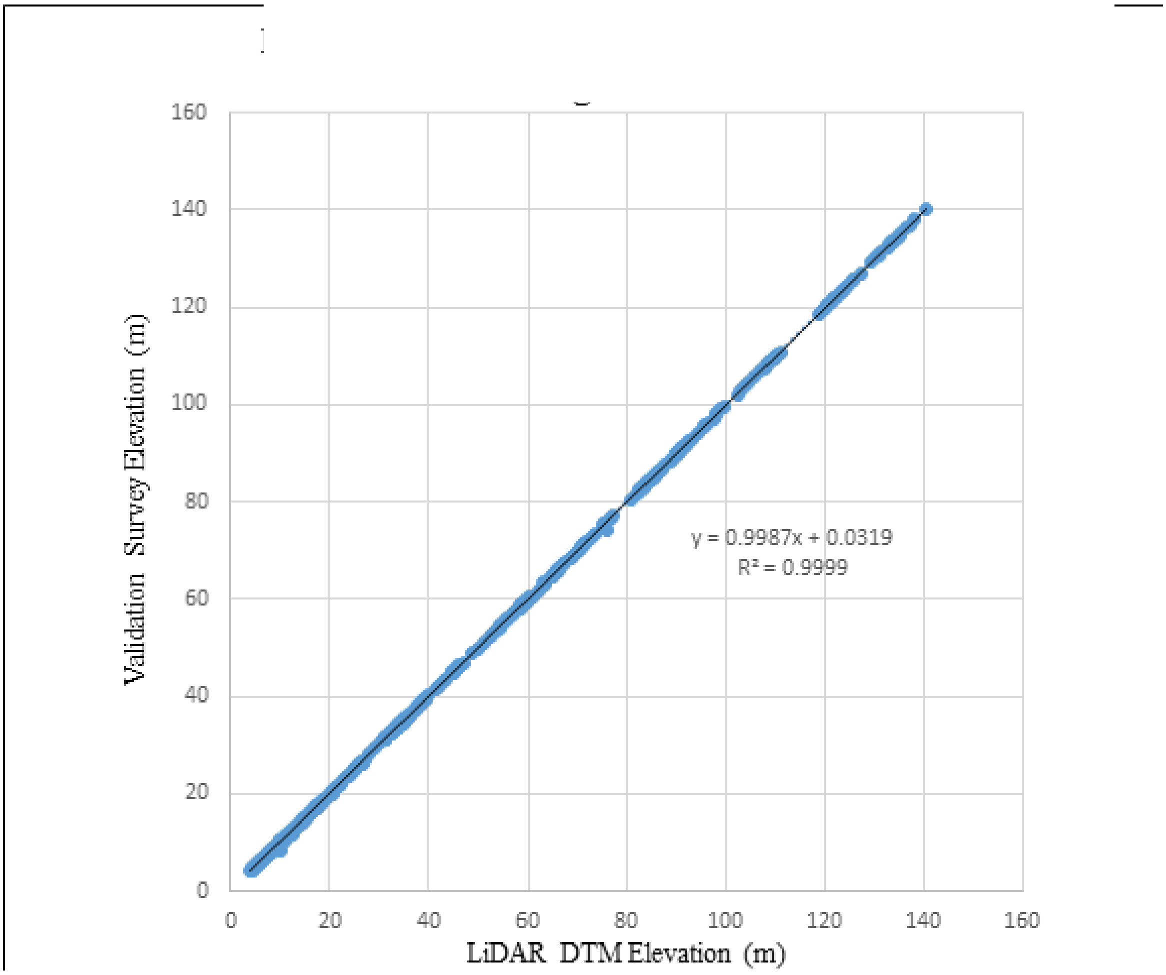



Figure 24. Correlation plot between validation survey points and LiDAR data.

Table 16. Validation Statistical Measures.

| Validation Statistical Measures | Value (meters) |
|---|---|
| RMSE | 0.19 |
| Standard Deviation | 0.18 |
| Average | 0.02 |
| Minimum | -0.35 |
| Maximum | 0.39 |

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

For bathy integration, only centerline data was available for Sumlog with 7,231 bathymetric survey points. The resulting raster surface produced was done by Kernel Interpolation with Barriers interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.50 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Sumlog integrated with the processed LiDAR DEM is shown in Figure 25.

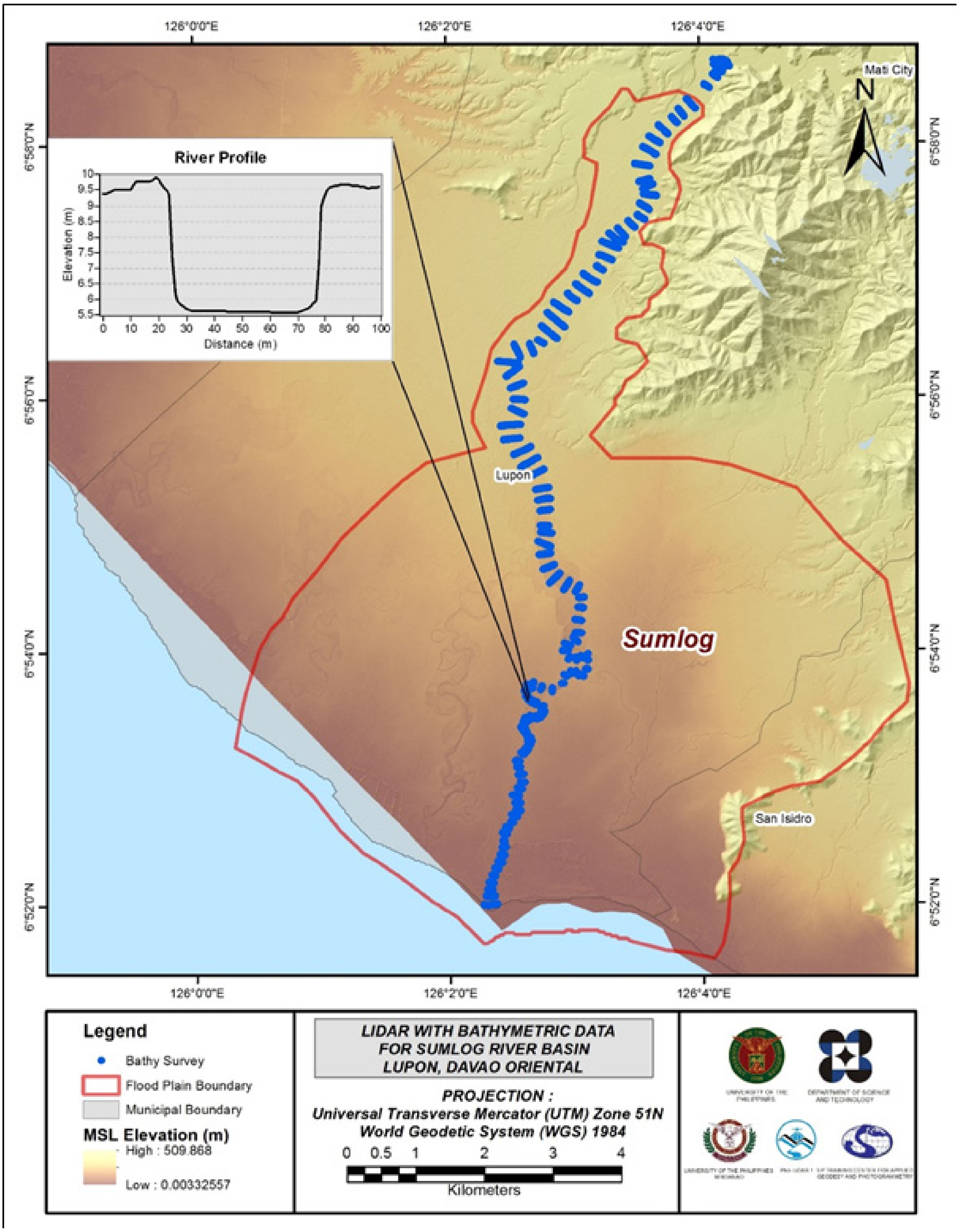



Figure 25. Map of Sumlog Floodplain with bathymetric survey points shown in blue.

## 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, consist of residential buildings, government offices, medical facilities, religious institutions, and commercial establishments, among others. Road networks, comprised 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 (QC) of Digitized Features' Boundary

The Sumlog Floodplain, including its 200 m buffer, has a total area of 66.79 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 776 building features, are considered for QC. Figure B-19 shows the QC blocks for Sumlog Floodplain.

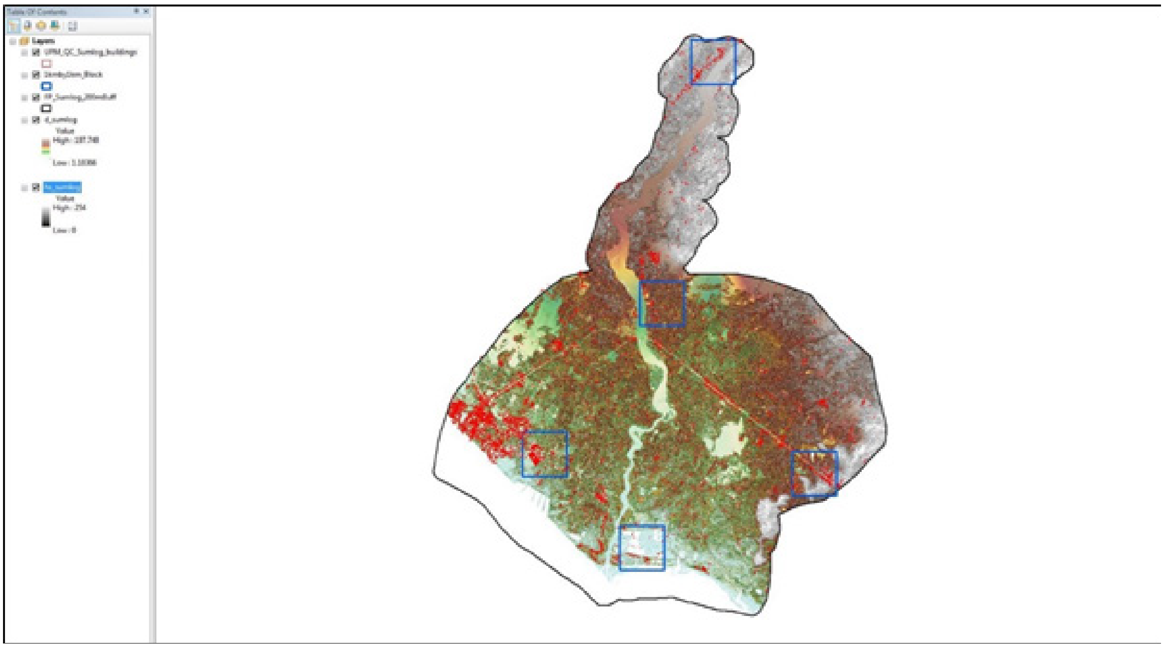


Figure 26. QC blocks for Sumlog building features.

Quality checking of Sumlog building features resulted in the ratings shown in Table 17.

Table 17. Quality Checking Ratings for Sumlog Building Features.

| FLOODPLAIN | COMPLETENESS | CORRECTNESS | QUALITY | REMARKS |
|---|---|---|---|---|
| Sumlog | 99.43 | 99.81 | 80.44 | PASSED |

### 3.12.2 Height Extraction

Height extraction was done for 7,270 building features in Sumlog Floodplain. Of these building features, 228 were filtered out after height extraction, resulting to 7,042 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 18.31 m.

### 3.12.3 Feature Attribution

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. Verification of barangay boundaries were also done to finalize the distribution of features for each barangay.

The courtesy calls and project presentations were done last April 25 - 26, 2016. Barangay Health Workers (BHWs) were requested and hired to guide the University of the Philippines Mindanao Phil-LiDAR1 field enumerators during validation. The field work activity was conducted from May 2 - 26, 2016. The local hires deployed by the barangay captains were given a brief orientation by the field enumerators before the actual field work. Some of the personnel volunteered to use their own motorcycle vehicles during the validation proper. The team surveyed the fifteen (15) barangays covered by the floodplain namely Poblacion, Corporacion, Ilangay, Cabandiangan, Lanka, Tagugpo, Cocornon, Macangao, San Jose, Limbanhan, Magsaysay and Tagboa, Lupon Municipality; barangays San Roque, Lapu-lapu and Manikling, San Isidro Municipality.

The locals from Municipalities of Lupon and San Isidro raised concerns on nearby rivers such as Cuabo, Quinonoan, Mayo, Talisay, Maug, Bitaogan, and Magtalinga. Cuabo River marks the political boundaries of Lupon and San Isidro where it causes flood to adjacent barangays, specifically in the southern areas of San Isidro. Its tributaries contribute to flooding, sending waters towards Brgy. Iba, then into Brgy. Dugmanon, and lastly into Brgy. Manikling. Both Quinonoan and Mayo River cause floods in the upper areas of the Municipality of Lupon known to locals as the DonCaMar area. This area consists of Barangays Don Mariano Marcos, Calapagan, and Marayag. Other nearby rivers such as Talisay River affects Brgy. Talisay of San Isidro when it overflows. Likewise, Maug River affects Brgy. La Union of San Isidro. Moreover, Bitaogan and Magtalinga are known to overflow during heavy rain to San Isidro.

During field validation, there had been issues regarding the political boundaries of barangays San Jose, Corporacion and Bagumbayan. Despite this, the field validation process went well according to schedule. Some areas were steep and elevated, which made field work more difficult. Some teams encountered buildings which were reported by the local guides as “dangerous place(s)”. They also encountered security issues in some areas which then led to pursuing field validation directly using only the maps with the help of the local assistants.

Table 18 summarizes the number of building features per type. On the other hand, Table 19 shows the total length of each road type, while Table 20 shows the number of water features extracted per type.

Table 18. Building Features Extracted for Sumlog Floodplain.

| Facility Type | No. of Features |
|---|---|
| Residential | 6304 |
| School | 206 |
| Market | 10 |
| Agricultural/Agro-Industrial Facilities | 129 |
| Medical Institutions | 20 |
| Barangay Hall | 13 |
| Military Institution | 19 |
| Sports Center/Gymnasium/Covered Court | 21 |
| Telecommunication Facilities | 2 |
| Transport Terminal | 1 |
| Warehouse | 6 |
| Power Plant/Substation | 0 |
| NGO/CSO Offices | 1 |
| Police Station | 0 |
| Water Supply/Sewerage | 1 |
| Religious Institutions | 98 |
| Bank | 1 |
| Factory | 20 |
| Gas Station | 6 |
| Fire Station | 1 |
| Other Government Offices | 28 |
| Other Commercial Establishments | 155 |
| **Total** | 7,042 |

Table 19. Total Length of Extracted Roads for Sumlog Floodplain.

| **Floodplain** | **Road Network Length (km)** | | | | | **Total** |
|---|---|---|---|---|---|---|
| | **Barangay Road** | **City/ Municipal Road** | **Provincial Road** | **National Road** | **Others** | |
| Sumlog | 106.87 | 14.46 | 0.00 | 12.29 | 0.00 | 133.62 |

Table 20. Number of Extracted Water Bodies for Sumlog Floodplain.

| Floodplain | Water Body Type | | | | | Total |
|---|---|---|---|---|---|---|
| | Rivers/ Streams | Lakes/Ponds | Sea | Dam | Fish Pen | |
| Sumlog | 6 | 0 | 0 | 0 | 7 | 13 |

A total of twelve (12) 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 comprised the flood hazard exposure database for the floodplain. This completed the feature extraction phase of the project.

Figure 27 shows the Digital Surface Model (DSM) of Sumlog Floodplain overlaid with its ground features.

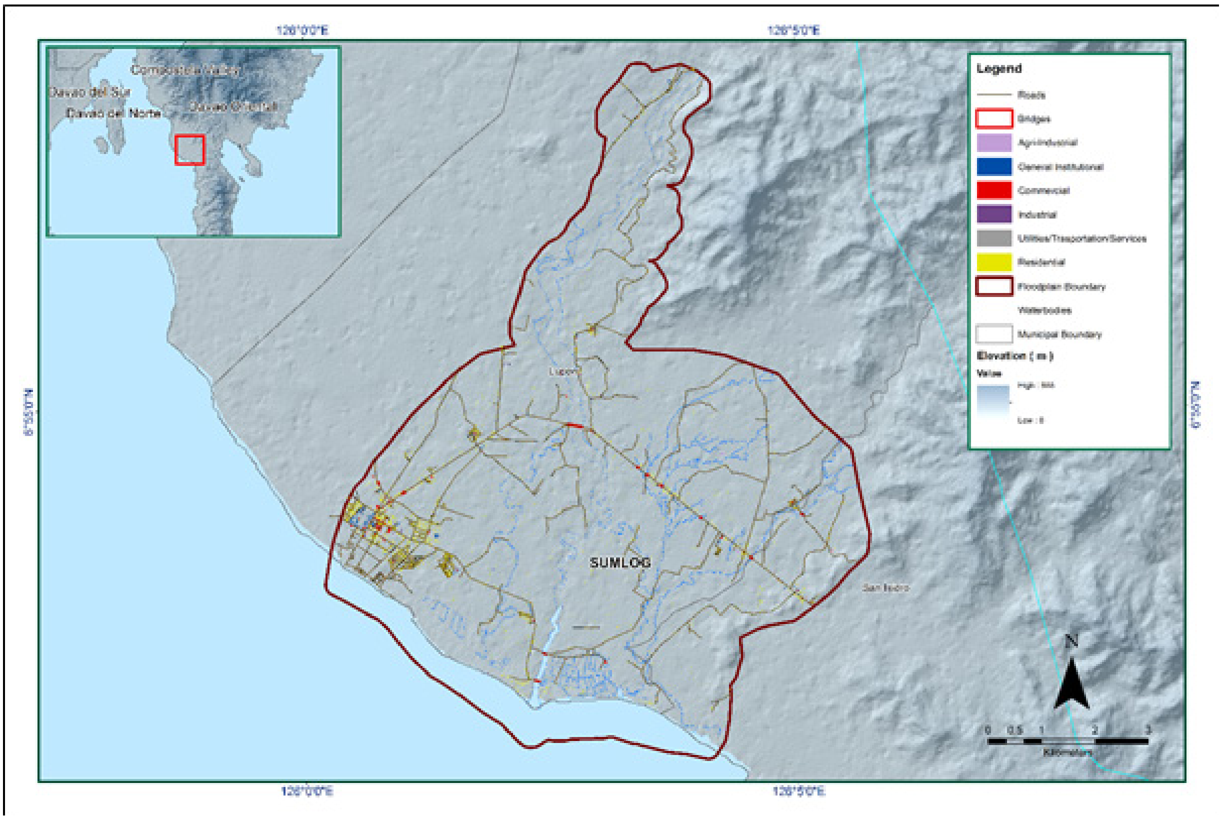



Figure 27. Extracted features for Sumlog Floodplain.

# CHAPTER 4 LIDAR VALIDATION SURVEY AND MEASUREMENT OF THE SUMLOG RIVER BASIN

Engr. Louie P. Balicanta, Engr. Joemarie S. Caballero, Ms. 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, Vie Marie Paola M. Rivera

**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).**

## 4.1 Summary of Activities

The AB Surveying and Development (ABSD) conducted a field survey in Sumlog River on March 15-20, 2016 and March 27, 2016 with the following scope: reconnaissance; control survey; cross-section and as-built survey at Sumlog Bridge in Brgy. Ilangay, Lupon, Davao Oriental; and bathymetric survey from its upstream in Brgy. New Visayas, Lupon, Davao Oriental to the mouth of the river located in Brgy. Macangao, Lupon, Davao Oriental, with an approximate length of 15.5 km using a Nikon® Total Station. Random checking points for the contractor's cross-section and bathymetry data were gathered by DVBC on May 10-24, 2016 using a survey grade GNSS receiver Trimble® SPS 985 GNSS PPK survey technique. In addition to this, validation points acquisition survey was conducted covering the Sumlog River Basin area. The entire survey extent is illustrated in Figure 28 .

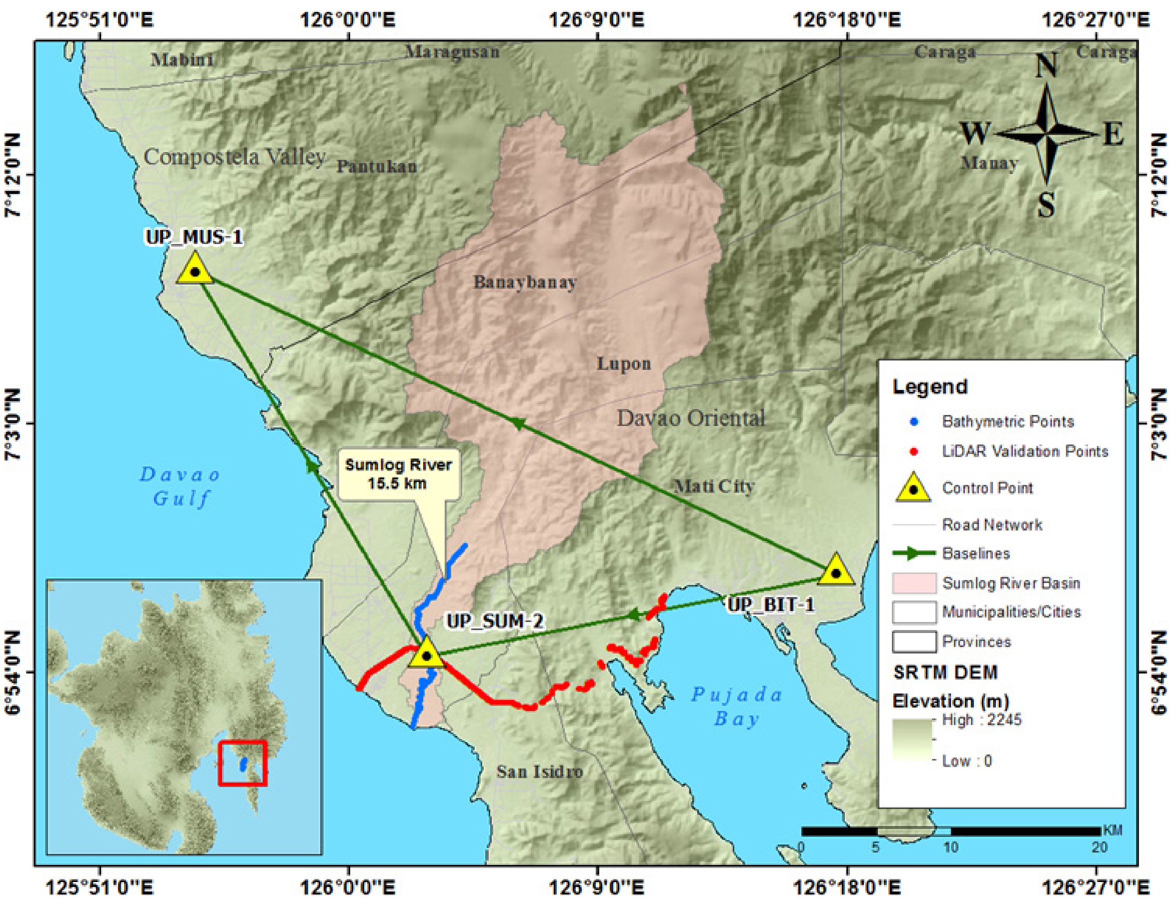



Figure 28. Extent of the bathymetric survey (in blue line) in Sumlog River and the LiDAR Data Validation Survey (in red).

## 4.2 Control Survey

The GNSS network used for Sumlog River is composed of one (1) loop established on May 20, 2016 occupying the following reference point: UP_BIT-1, an established control point that was referred from the static survey of Bitanayan River on May 10-24, 2016, in Brgy. Don Enrique Lopez, Mati City, Davao Oriental.

Two (2) control points established in the area by ABSD were also occupied: UP_MUS-1 at the approach of Musahamat Bridge in Brgy. Kingking, Pantukan, Province of Compostela Valley and UP_SUM-2 located beside the approach of Sumlog Bridge in Brgy. Ilangay, Lupon, Davao Oriental.

The summary of reference and control points and its location is summarized in Table 21 while GNSS network established is illustrated in Figure 29.

Table 21. List of reference and control points used during the survey in Sumlog River (Source: NAMRIA, UP-TCAGP).

| Control Point | Order of Accuracy | Geographic Coordinates (WGS 84) | | | | |
|---|---|---|---|---|---|---|
| | | Latitude | Longitude | Ellipsoid Height (m) | Elevation (MSL) (m) | Date of Establishment |
| Control Survey on December 10, 2016 | | | | | | |
| UP_BIT-1 | Established | 6°57'46.30507"N | 126°17'35.96635"E | 80.537 | 15.21 | 2-26-16 |
| UP_MUS-1 | Established | 7°08'40.27743"N | 125°54'27.05429"E | 82.138 | 14.547 | 3-23-16 |
| UP_SUM-2 | Established | 6°54'48.60496"N | 126°02'48.52278"E | 84.364 | 18.125 | 3-17-16 |

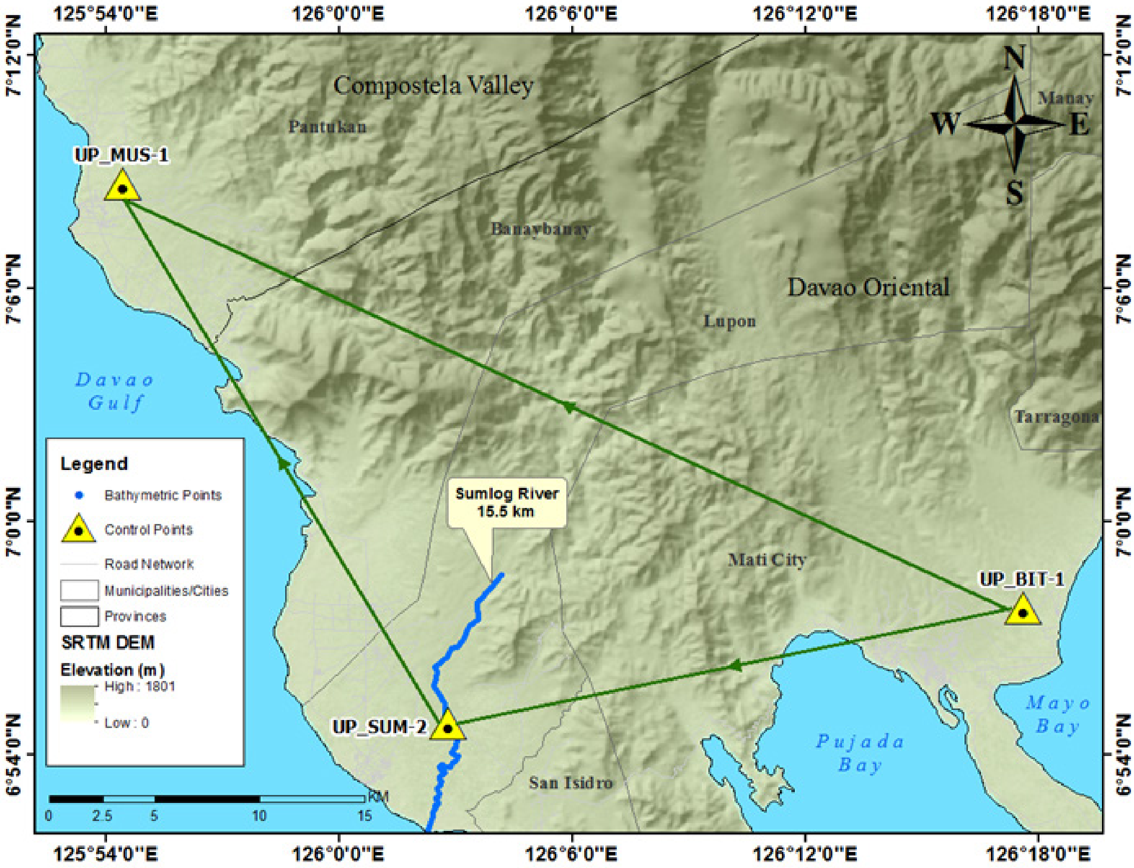



Figure 29. Sumlog River Basin Control Survey Extent.

The GNSS set-ups on recovered reference points and established control points in Sumlog River are shown from Figures 30 to 32.


Figure 30. GNSS receiver set up, Trimble® SPS 852, at UP_BIT-1, located at the side of the railing near the approach of Bitanagan Bridge in Brgy. Don Enrique Lopez, City of Mati, Davao Oriental.

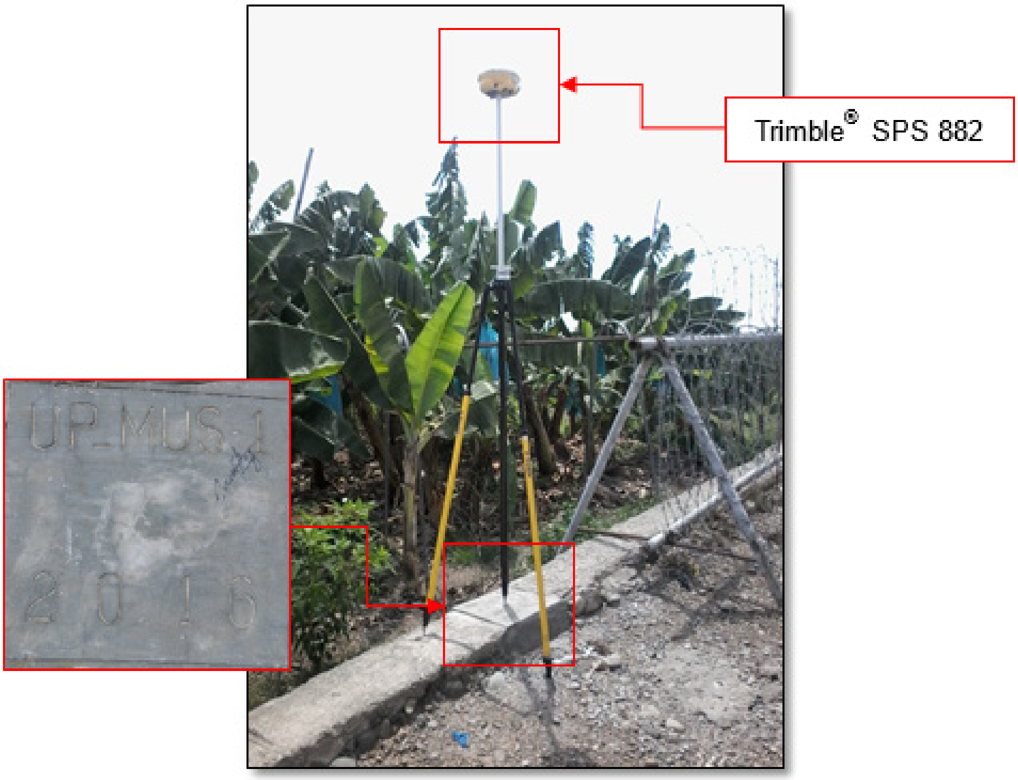



Figure 31. GNSS receiver set up, Trimble® SPS 882, at UP_MUS-1, located at the approach of Musahamat Bridge in Brgy. Kingking, Pantukan, Province of Compostela Valley.

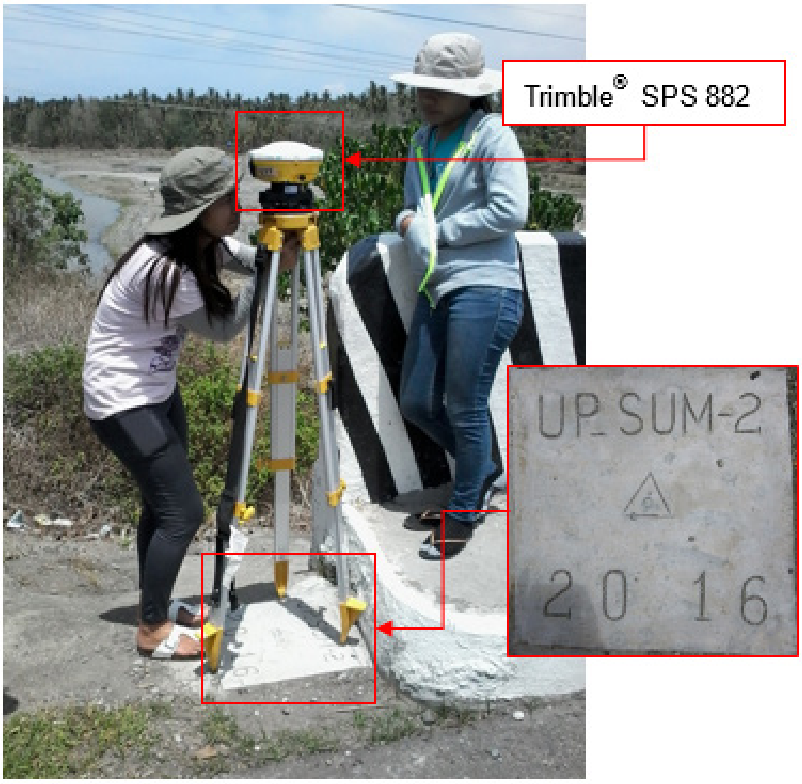



Figure 32. GNSS receiver set up, Trimble® SPS 882, at UP_SUM-2, located beside the approach of Sumlog Bridge in Brgy. Ilangay, Municipality of Lupon, Province of Davao Oriental.

## 4.3 Baseline Processing

GNSS Baselines were processed simultaneously in TBC. It was observed 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 fails to meet all of these criteria, masking was performed. Masking is the process of 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. The Baseline processing result of control points in Sumlog River Basin is summarized in Table 22 generated by TBC software.

Table 22. Baseline Processing Report for Sumlog River Static Survey.

| Observation | Date of Observation | Solution Type | H. Prec. (Meter) | V. Prec. (Meter) | Geodetic Az. | Ellipsoid Dist. (Meter) | ΔHeight (Meter) |
|---|---|---|---|---|---|---|---|
| UP_BIT-1 --- UP_MUS-1 | 5-20-2016 | Fixed | 0.210 | 0.112 | 295°15'31" | 47122.295 | 1.549 |
| UP_MUS-1 – UP_SUM-2 | 5-20-2016 | Fixed | 0.007 | 0.011 | 328°56'37" | 29826.325 | -2.222 |
| UP_MUS-1 – UP_SUM-2 | 5-20-2016 | Fixed | 0.005 | 0.040 | 328°56'37" | 29826.333 | -2.228 |
| UP_BIT-1 --- UP_SUM-2 | 5-20-2016 | Fixed | 0.009 | 0.028 | 258°41'02" | 27783.534 | 3.833 |

As shown Table 22 a total of four (4) baselines were processed with coordinate and elevation values of UP_BIT-1 held fixed. All of them passed the required accuracy.

## 4.4 Network Adjustment

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

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

where:

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

for each control point. See the Network Adjustment Report shown from Tables 23 to 25 for the complete details. Refer to Appendix C for the computation for the accuracy of ABSD.

The three (3) control points, UP-BIT-1, UP_MUS-1, and UP-SUM-2 were occupied and observed simultaneously to form a GNSS loop. The coordinate values of DVE-42 and elevation of DE-160 were held fixed during the processing of the control points as presented in Table 23. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 23. Constraints applied to the adjustment of the control points

| Point ID | Type | East σ (Meter) | North σ (Meter) | Height σ (Meter) | Elevation σ (Meter) |
|---|---|---|---|---|---|
| UP_BIT-1 | Global | 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 24. All fixed control points have no values for grid errors and elevation error.

Table 24. Adjusted Grid Coordinates for the control points used in the Sumlog River.

| Point ID | Easting (Meter) | Easting Error (Meter) | Northing (Meter) | Northing Error (Meter) | Elevation (Meter) | Elevation Error (Meter) | Constraint |
|---|---|---|---|---|---|---|---|
| UP_BIT-1 | 770500.332 | ? | 200912.560 | ? | 15.210 | ? | LLh |
| UP_MUS-1 | 790872.748 | 0.005 | 158376.175 | 0.010 | 14.547 | 0.041 | |
| UP_SUM-2 | 765199.921 | 0.006 | 173616.342 | 0.009 | 18.125 | 0.040 | |

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

**a.** **UP_BIT-1**

| | | |
|---|---|---|
| horizontal accuracy | = | Fixed |
| vertical accuracy | = | Fixed |

**b.** **UP_MUS-1**

| | | |
|---|---|---|
| horizontal accuracy | = | $\sqrt{((0.3)^2 + (1.0)^2}$ |
| | = | $\sqrt{(0.09 + 1.00)}$ |
| | = | 1.09 < 20 cm |
| vertical accuracy | = | 4.1 < 10 **cm** |

**c.** **UP_SUM-2**

| | | |
|---|---|---|
| horizontal accuracy | = | $\sqrt{((0.6)^2 + (0.9)^2}$ |
| | = | $\sqrt{(0.36 + 0.81)}$ |
| | = | 1.17 < 20 cm |
| vertical accuracy | = | 4.0 < 10 cm |

Following the given formula, the horizontal and vertical accuracy result of the two (2) occupied control points are within the required precision.

Table 25. Adjusted geodetic coordinates for control points used in the Sumlog River Floodplain Validation.

| Point ID | Latitude | Longitude | Ellipsoid Height (Meter) | Height Error (Meter) | Constraint |
|---|---|---|---|---|---|
| UP_BIT-1 | N6°57'46.30507" | E126°17'35.96635" | 80.537 | ? | LLh |
| UP_MUS-1 | N7°08'40.27743" | E125°54'27.05429" | 82.138 | 0.041 | |
| UP_SUM-2 | N6°54'48.60496" | E126°02'48.52278" | 84.364 | 0.040 | |

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 25. Based on the result of the computation, the equation is satisfied; hence, the required accuracy for the program was met.

The summary of reference control points used is indicated in Table 26.

Table 26. The reference and control points utilized in the Sumlog River Static Survey, with their corresponding location (Source: NAMRIA, UP-TCAGP).

| Control Point | Order of Accuracy | Geographic Coordinates (WGS 84) | | | UTM ZONE 51 N | | |
|---|---|---|---|---|---|---|---|
| | | Latitude | Longitude | Ellipsoidal Height (m) | Northing (m) | Easting (m) | BM Ortho (m) |
| UP_BIT-1 | Established | 6°57'46.30507"N | 126°17'35.96635"E | 80.537 | 770500.332 | 200912.56 | 15.21 |
| UP_MUS-1 | Established | 7°08'40.27743"N | 125°54'27.05429" E | 82.138 | 790872.748 | 158376.175 | 14.547 |

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

Cross-section and as-built surveys were conducted on March 27, 2016 at the downstream side of Sumlog Bridge in Brgy. Ilangay, Municipality of Lupon as shown in Figure 33. A Nikon® Total Station was utilized for this survey as shown in Figure 34.

Figure 33. Upstream side of the Sumlog Bridge.


Figure 34. The cross-section survey conducted at the Sumlog Bridge.

The cross-sectional line of Sumlog Bridge is about 400 m with two hundred twenty-seven (227) cross-sectional points using the control points UP_SUM-1 and UP_SUM-2 as the GNSS base stations. The cross-section diagram and the bridge data form are shown in Figures 36 and 37. Gathering of random points for the checking of ABSD's bridge cross-section and bridge points data was performed by DVBC on May 18, 2016 using a survey grade GNSS Rover receiver attached to a 2-m pole.

Linear square correlation (R2) and RMSE analysis were performed on the two (2) datasets. The linear square coefficient range is determined to ensure that the submitted data of the contractor is within the accuracy standard of the project which is ±20 cm and ±10 cm for horizontal and vertical, respectively. The R2 value must be within 0.85 to 1. An R2 approaching 1 signifies a strong correlation between the vertical (elevation values) of the two datasets. A computed R2 value of 1.00 was obtained by comparing the data of the contractor and DVBC; signifying a strong correlation between the two (2) datasets.

In addition to the Linear Square Correlation, Root Mean Square (RMSE) analysis is also performed in order to assess the difference in elevation between the DVBC checking points and the contractor's. The RMSE value should only have a maximum radial distance of 5 m and the difference in elevation within the radius of 5 meters should not be beyond 0.50 m. For the bridge cross-section data, a computed value of 0.290 was acquired. The computed R2 and RMSE values are within the accuracy requirement of the program.

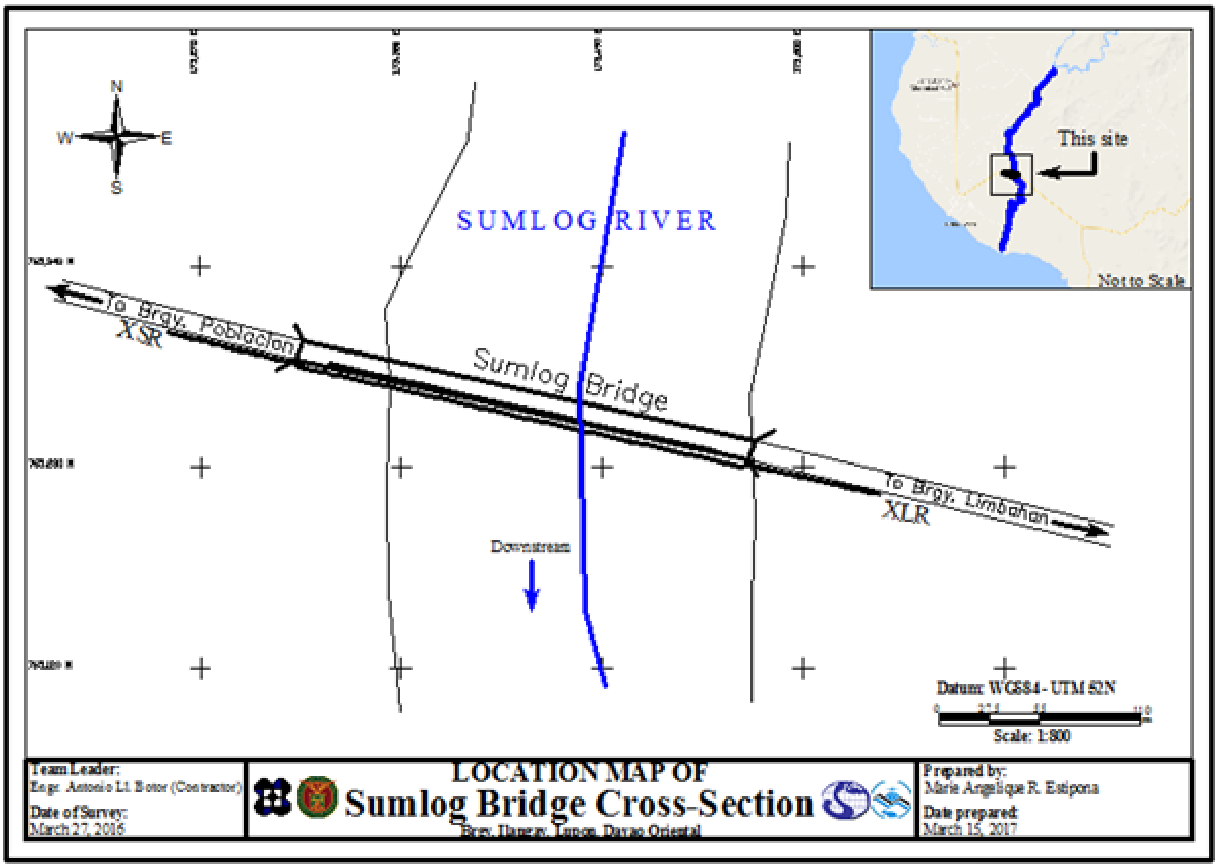



Figure 35. Location map of Sumlog Bridge Cross Section.

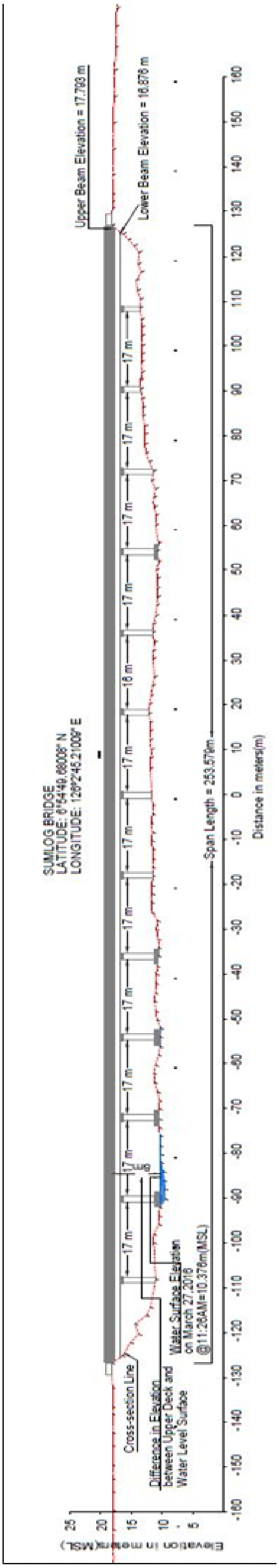



Figure 36. The Sumlog Bridge cross-section survey drawn to scale.

**Bridge Data Form**

Bridge Name: Sumlog Bridge

River Name: Sumlog River

Location (Brgy, City, Region): Brgy. Ilangay, Lupon, Davao Oriental

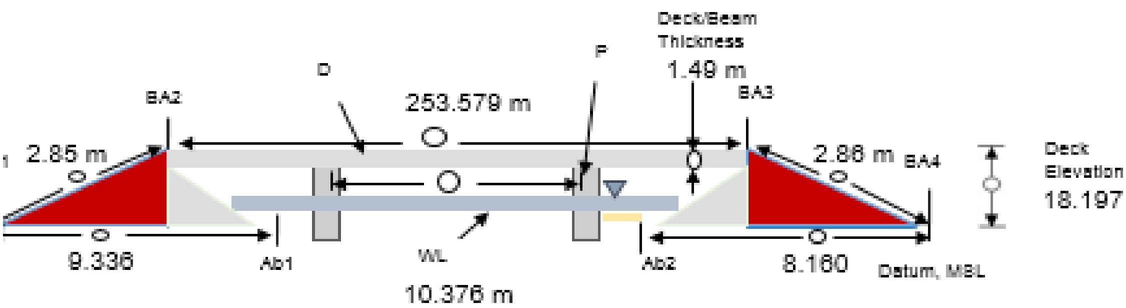
Survey Team: Jayson Ilustre, Ryan Antonio

Date and Time: March 27, 2016, 11:26 A.M.

Flow Condition: low ✔normal high

Weather Condition: ✔fair rainy

Cross-sectional View (not to scale)




Legend:
BA = Bridge Approach
P = Pier
Ab = Abutment
D = Deck
WL = Water Level/Surface
MSL = Mean Sea Level
◯ = Measurement Value

| Line Segment | Measurement (m) | Remarks |
|---|---|---|
| 1. BA1-BA2 | 2.85 m | |
| 2. BA2-BA3 | 253.579 m | |
| 3. BA3-BA4 | 2.86 m | |
| 4. BA1-Ab1 | 9.336 m | |
| 5. Ab2-BA4 | 8.160 m | |
| 6. Deck/beam thickness | 1.49 m | |
| 7. Deck elevation | 18.197 m | |

*Note: Observer should be facing downstream*

Figure 37. The Sumlog Bridge as-built survey data.

Water surface elevation of Sumlog River was determined by a Nikon® Total Station on March 27, 2016 at 11:26 AM at Sumlog Bridge area with a value of 10.376 m in MSL as shown in Figure 36. This was translated into marking on the bridge's pier as shown in Figure 38. The marking will serve as reference for flow data gathering and depth gauge deployment of the partner HEI responsible for Sumlog River, UP Mindanao.


Figure 38. Painting of water level markings on Sumlog Bridge.

## 4.6 Validation Points Acquisition Survey

The Validation Points Acquisition survey was conducted by DVBC on May 18, 2016 using a survey grade GNSS Rover receiver, Trimble® SPS 985, mounted on a range pole which was attached on the front of the vehicle as shown in Figure 39. It was secured with cable ties and ropes to ensure that it was horizontally and vertically balanced. The antenna height was 2.476 m and measured from the ground up to the bottom of the quick release of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with UP_SUM-2 occupied as the GNSS base station in the conduct of the survey.

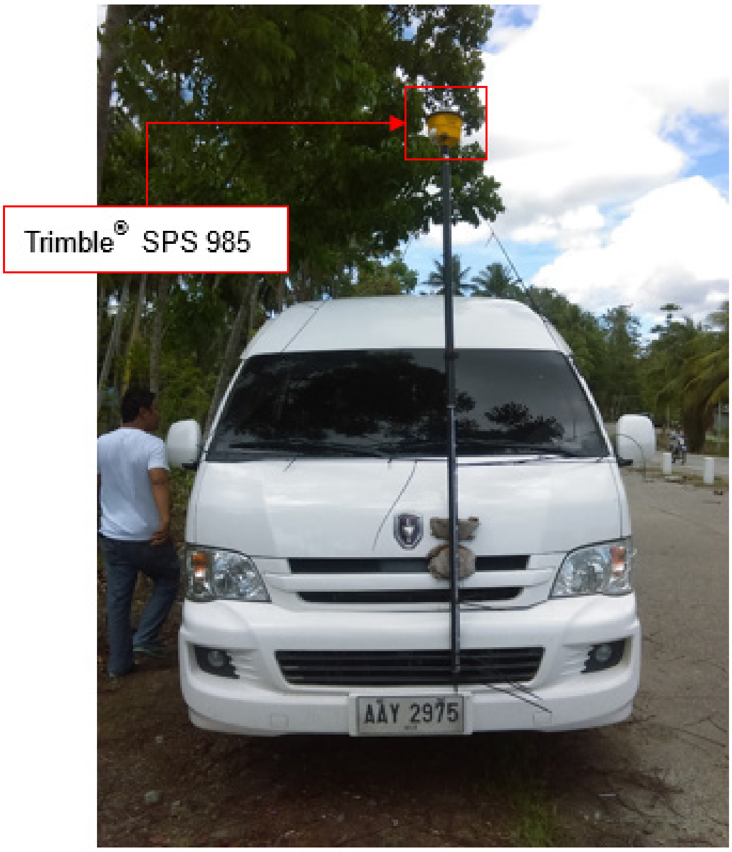



Figure 39. The Validation Points Acquisition survey set-up using a GNSS receiver fixed in a van along the Sumlog River Basin.

The survey started from Brgy. Poblacion, Lupon, Davao Oriental going east along the national highway, traversing three (3) barangays in the Municipality of Lupon, two (2) barangays in the Municipality of San Isidro, two (2) barangays in Mati City, and in Brgy. Sanghay, Mati City, Davao Oriental. The survey gathered a total of 3,430 points with approximate length of 33.13 km using UP_SUM-2 as GNSS base station for the entire extent of validation points acquisition survey as illustrated in the map in Figure 40.

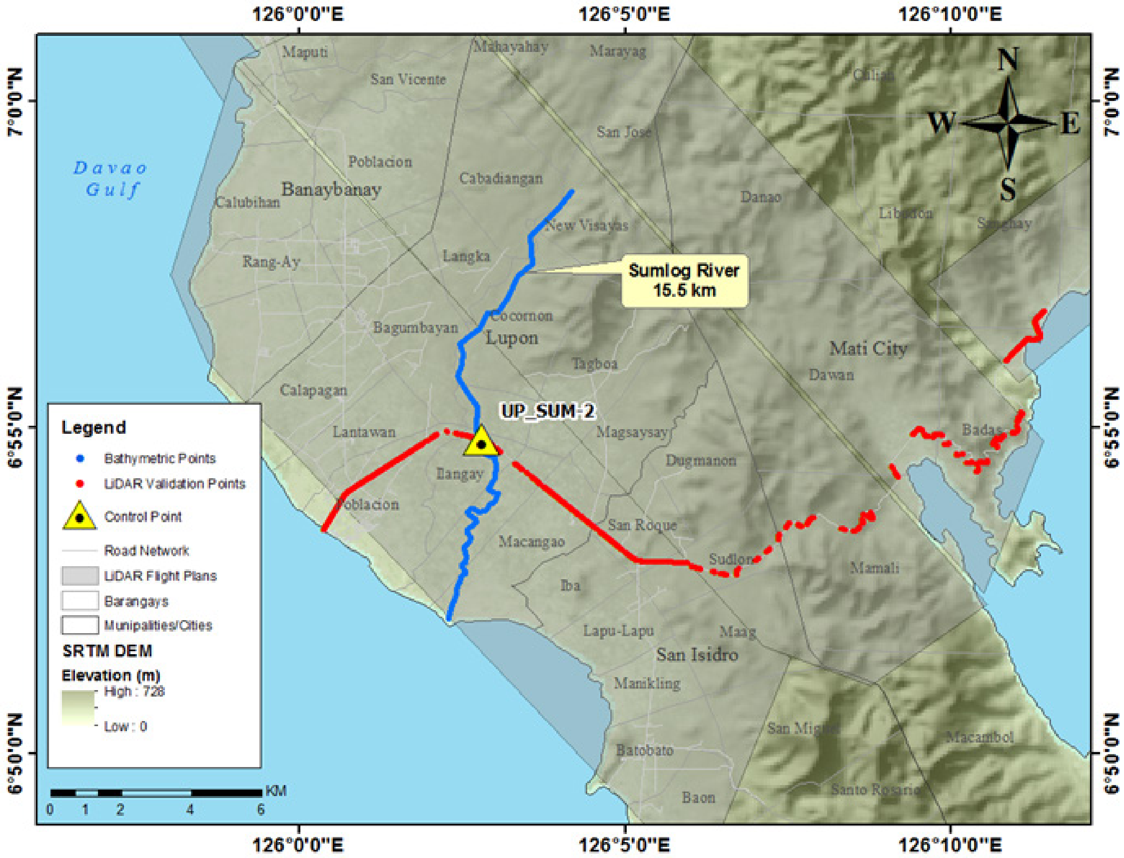



Figure 40. Extent of the LiDAR ground validation survey along Samar and Eastern Samar.

## 4.7 River Bathymetric Survey

Bathymetric survey was executed manually on March 15, 2016 and March 18-20, 2016 using a Nikon® Total Station as seen in Figure C- 13. The survey started in Brgy. New Visayas, Lupon, Davao Oriental with coordinates 6° 58’ 39.45634”N, 126° 4’ 11.60372”E and ended at the mouth of the river in Brgy. Macangao, Lupon, Davao oriental, with coordinates 6° 51’ 59.49757”N, 126° 2’ 16.42555”E. The control points UP_SUM-1 and UP_SUM-2, served as the GNSS base stations all throughout the survey.


Figure 41. Manual bathymetric survey of ABSD at Sumlog River using Nikon® Total Station.

Gathering of random points for the checking of ABSD's bathymetric data was performed by DVBC on May 18, 2016 using a GNSS Rover receiver, Trimble® SPS 985 attached to a 2-m pole, see Figure 42. A map showing the DVBC bathymetric checking points is shown in Figure 44.


Figure 42. Gathering of random bathymetric points along Sumlog River.

Linear square correlation (R2) and RMSE analysis were also performed on the two (2) datasets and a computed R2 value of 0.90 is within the required range for R2, which is 0.85 to 1. Additionally, an RMSE value of 0.199 was obtained. Both the computed R2 and RMSE values are within the accuracy required by the program.

The bathymetric survey for Sumlog River gathered a total of 8,003 points covering 15.5 km of the river traversing barangays Macangao, Limbahan, Ilangay, Corporacion, Cocornon, Cabadiangan, and New Visayas in the Municipality of Lupon, Davao Oriental. A CAD drawing was also produced to illustrate the riverbed profile of Sumlog River. As shown in Figure 45, the highest and lowest elevation has a 48-m difference. The highest elevation observed was 47.528 m above MSL located in Brgy. New Visayas, Lupon while the lowest was -0.266 m below MSL located in Brgy. Macangao, Lupon.

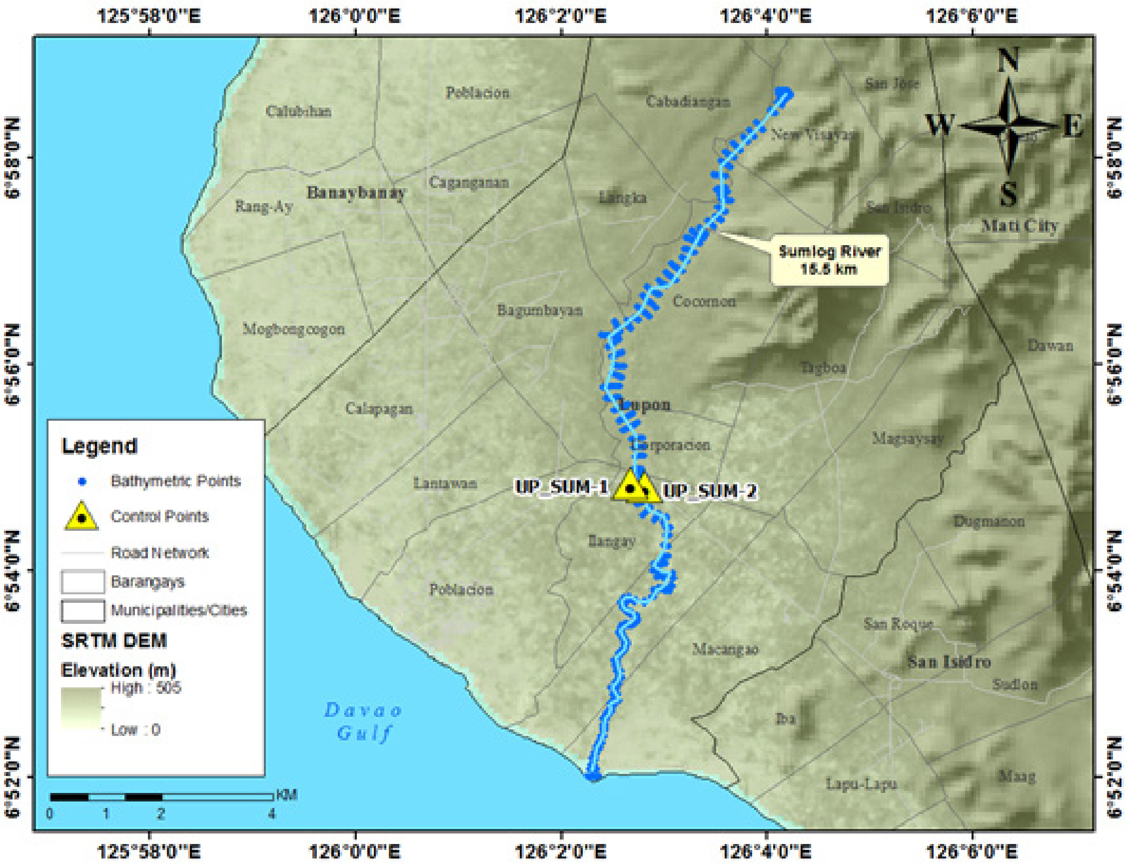



Figure 43. Extent of the Sumlog River bathymetric survey.

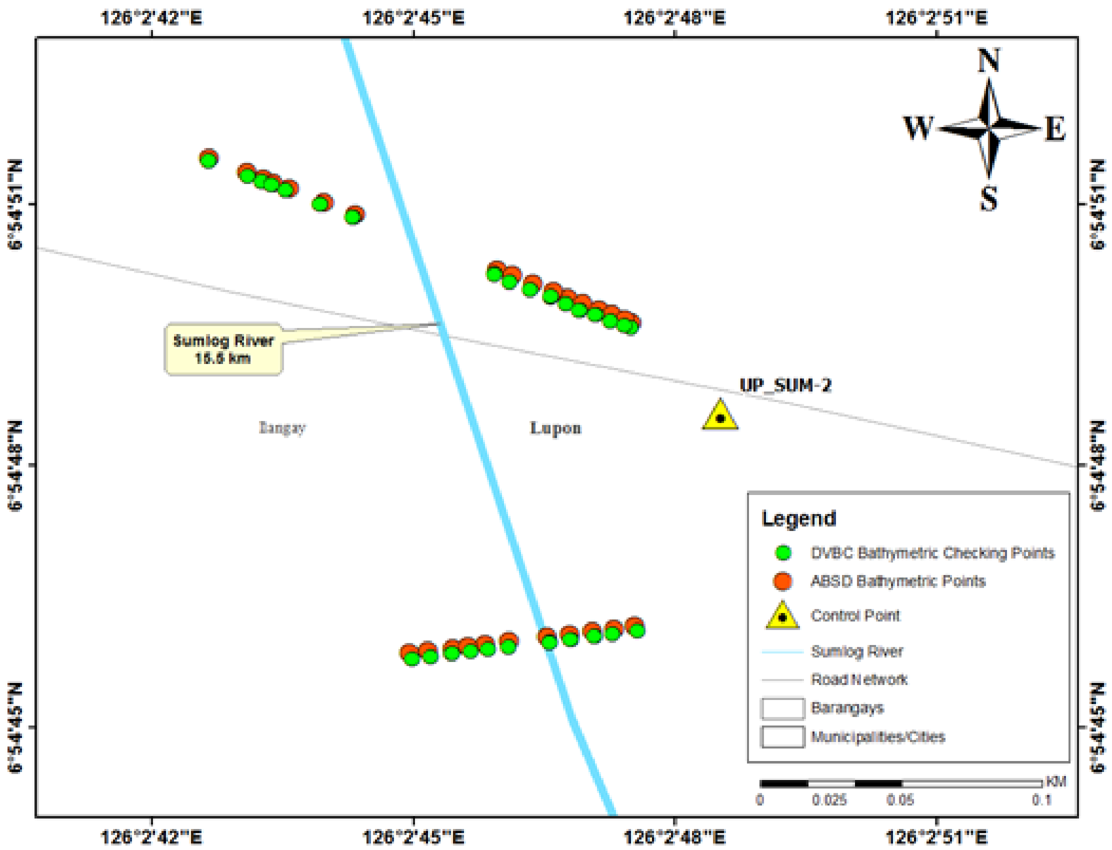



Figure 44. Quality checking points gathered along Sumlog River by DVBC.

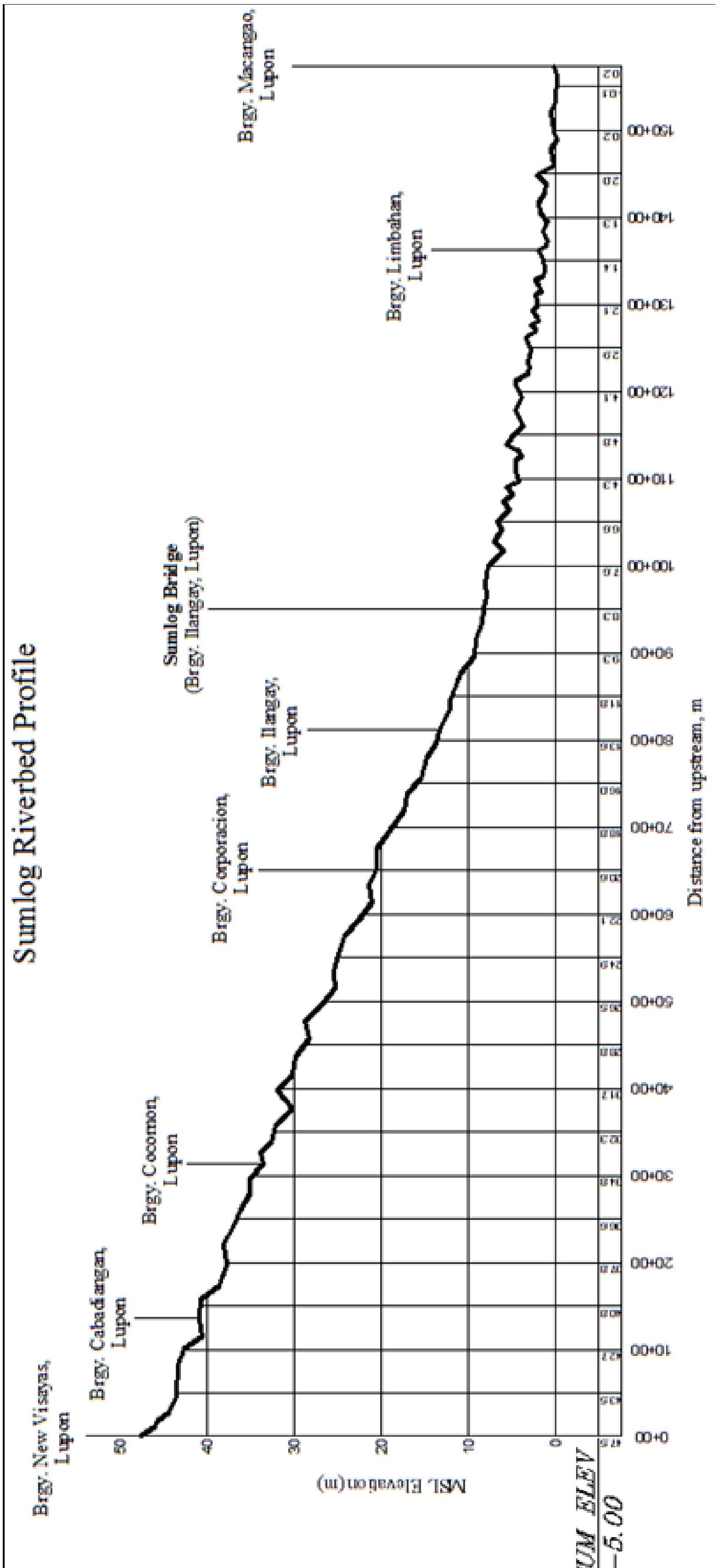



Figure 45. The Sumlog Riverbed Profile.

# CHAPTER 5: FLOOD MODELING AND MAPPING

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

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).

## 5.1 Data Used for Hydrologic Modeling

### 5.1.1 Hydrometry and Rating Curves

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

### 5.1.2 Precipitation

Precipitation data was taken from the rain gauge installed by the University of the Philippines Mindanao Phil. LiDAR 1. This rain gauge is located in Barangay Maragatas, Lupon, Davao Oriental with the following coordinates: 7° 9' 18.07" N, 126° 9' 47.38" E (Figure 1). The precipitation data collection started from November 21, 2015 at 1:00 PM to November 23, 2015 at 3:20 PM with a 10-minute recording interval.

The total precipitation for this event in the installed rain gauge was 18.8 mm. It has a peak rainfall of 9 mm. on November 21, 2015 at 1:20 PM. The lag time between the peak rainfall and discharge is 8 hours and 20 minutes.

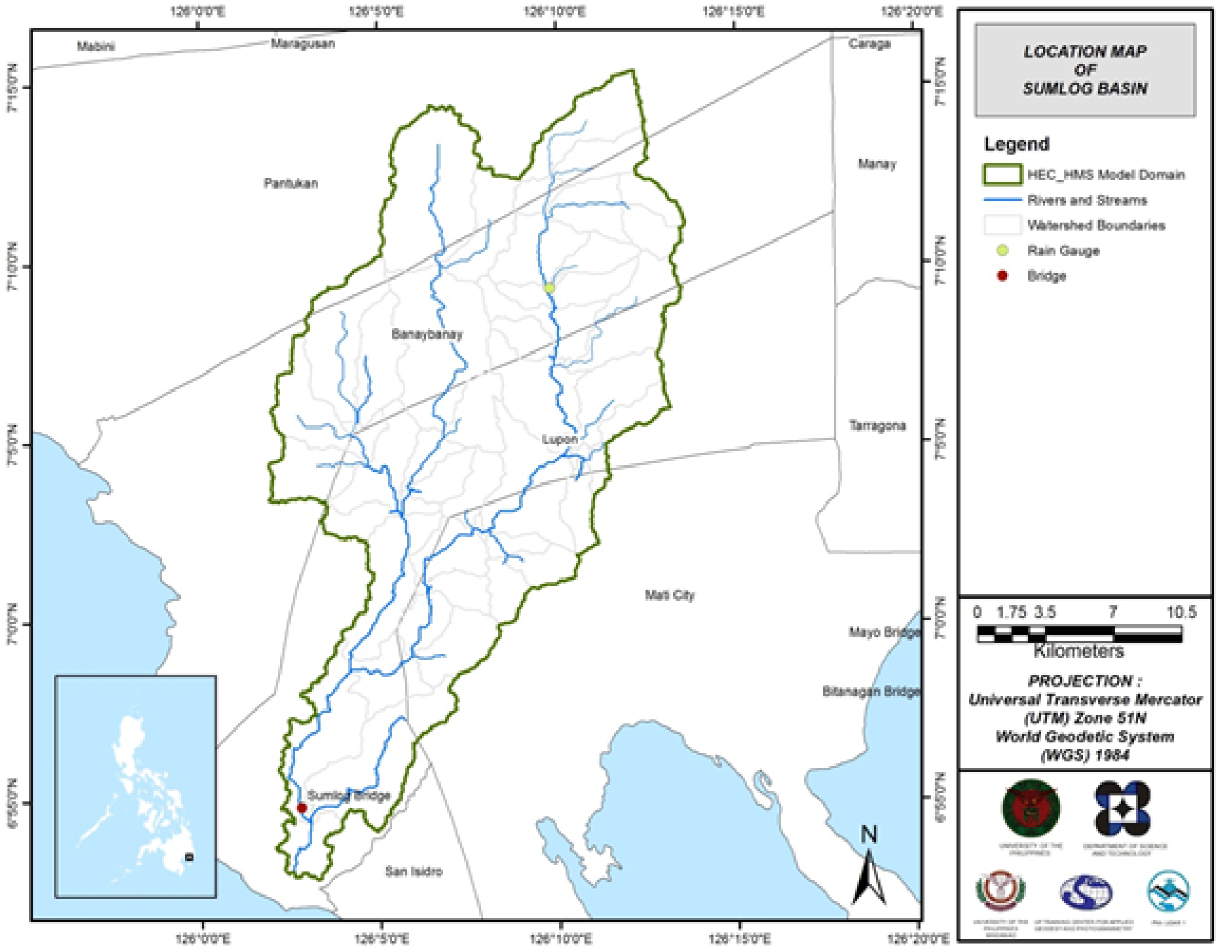



Figure 46. The location map of Sumlog HEC-HMS model used for calibration.

## 5.1.3 Rating Curves and River Outflow

A rating curve was developed at Sumlog Bridge, Barangay Cocornon, Lupon, Davao Oriental (6° 54’ 48.92” N, 126° 2’ 47.33” E). It gives the relationship between the observed water level at the Sumlog Bridge and outflow of the watershed at this location.

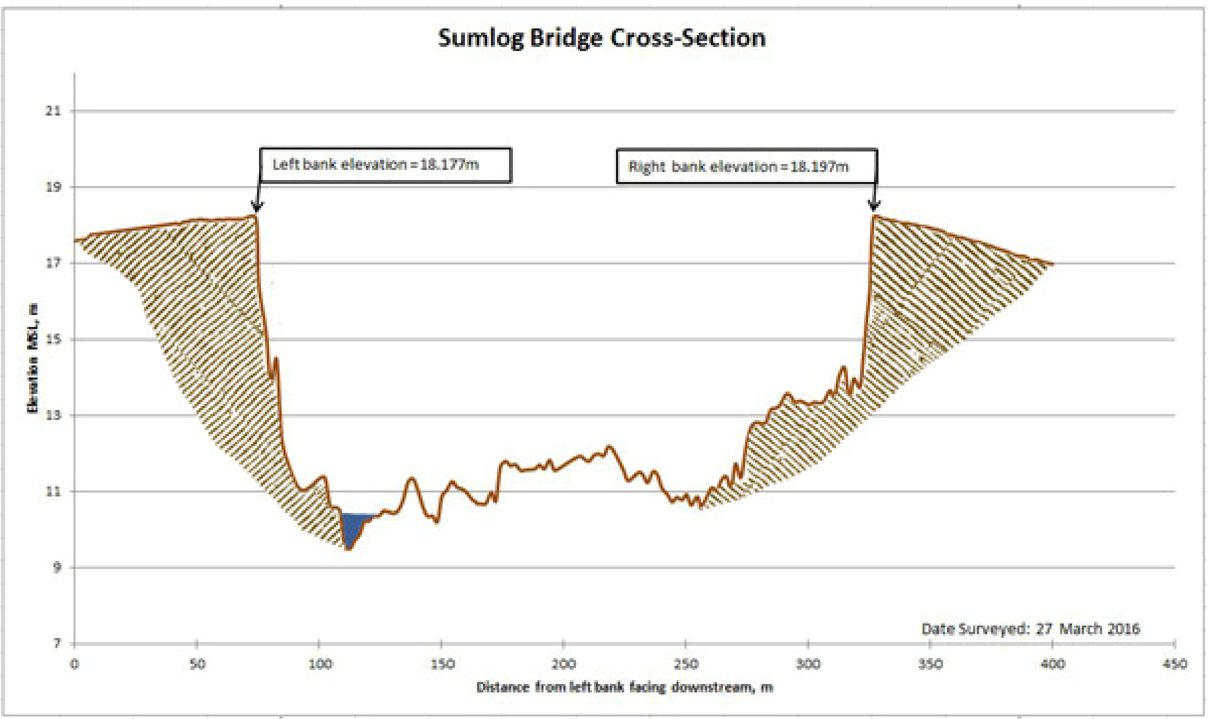



Figure 47. Cross-Section Plot of Sumlog Bridge

For Bacarra Bridge, the rating curve is expressed as Q = 0.094e0.3989h as shown in Figure 48.

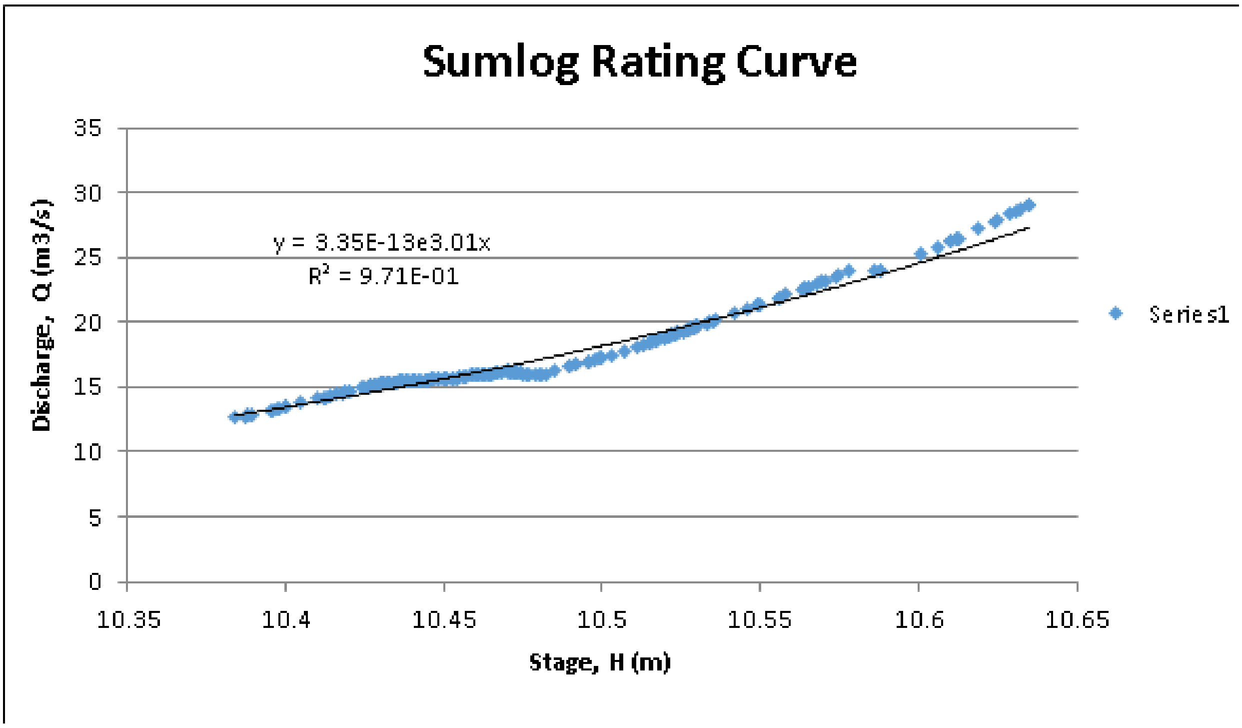



Figure 48. Rating Curve at Sumlog Bridge, Lupon, Davao Oriental.

The rating curve equation was used to compute for the river outflow at Sumlog Bridge for the calibration of the HEC-HMS model for Sumlog, as shown in Figure 49. The total rainfall for this event is 18.8 mm and the peak discharge is 29.1 m3/s at 9:40 PM of November 21, 2015.

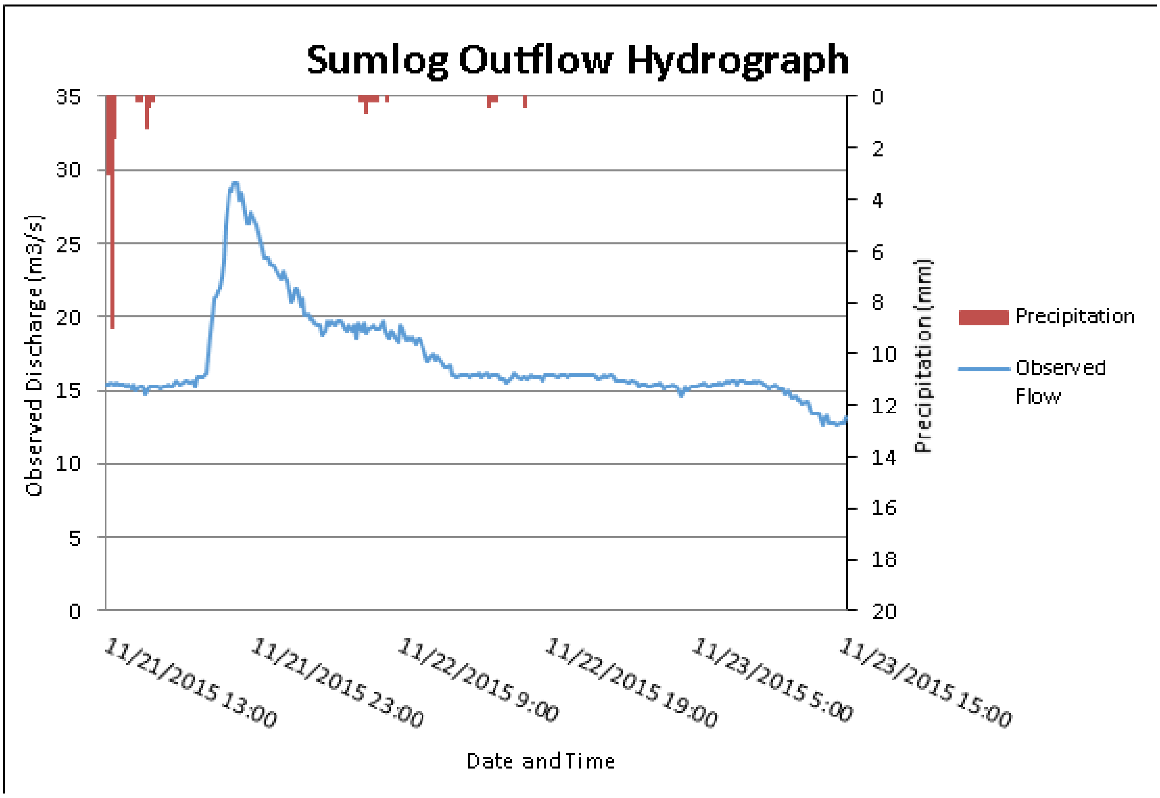



Figure 49. Rainfall and outflow data at Sumlog Bridge used for modeling.

## 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 Sumlog watershed. The extreme values for this watershed were computed based on a 59-year record.

Table 27. 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 |

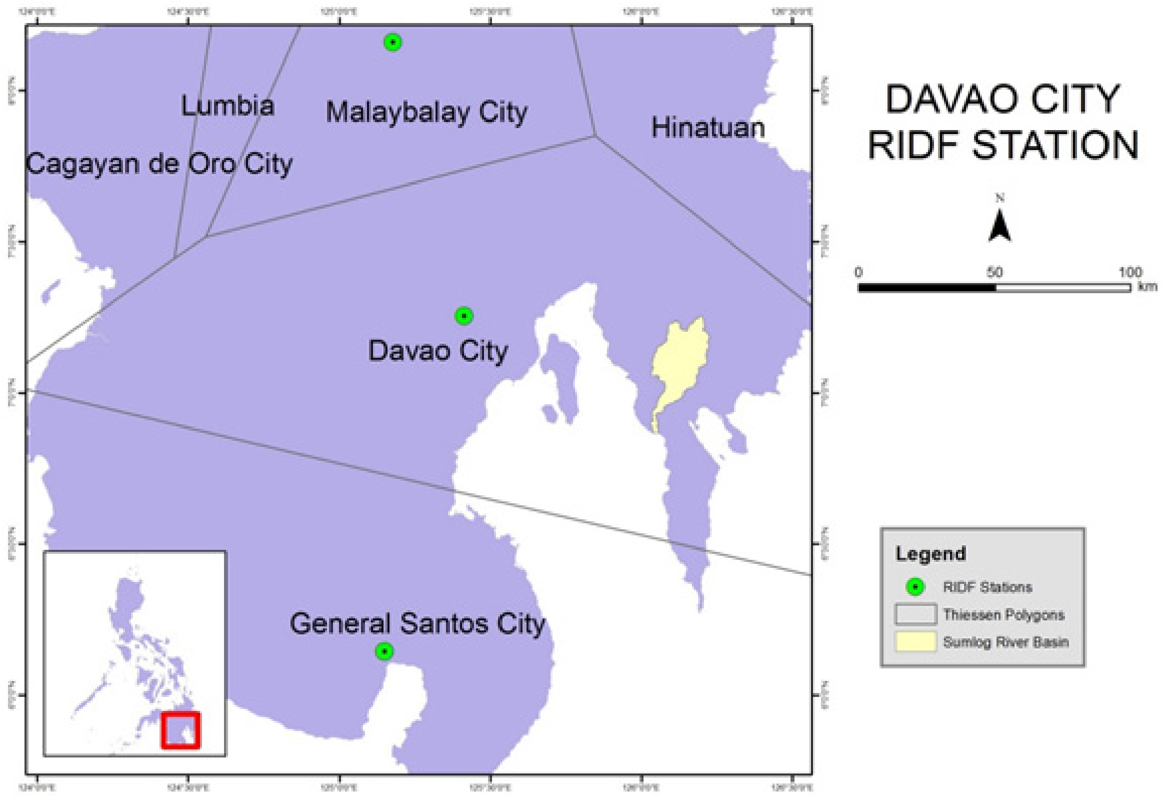



Figure 50. Location of Davao RIDF Station relative to Sumlog River Basin.

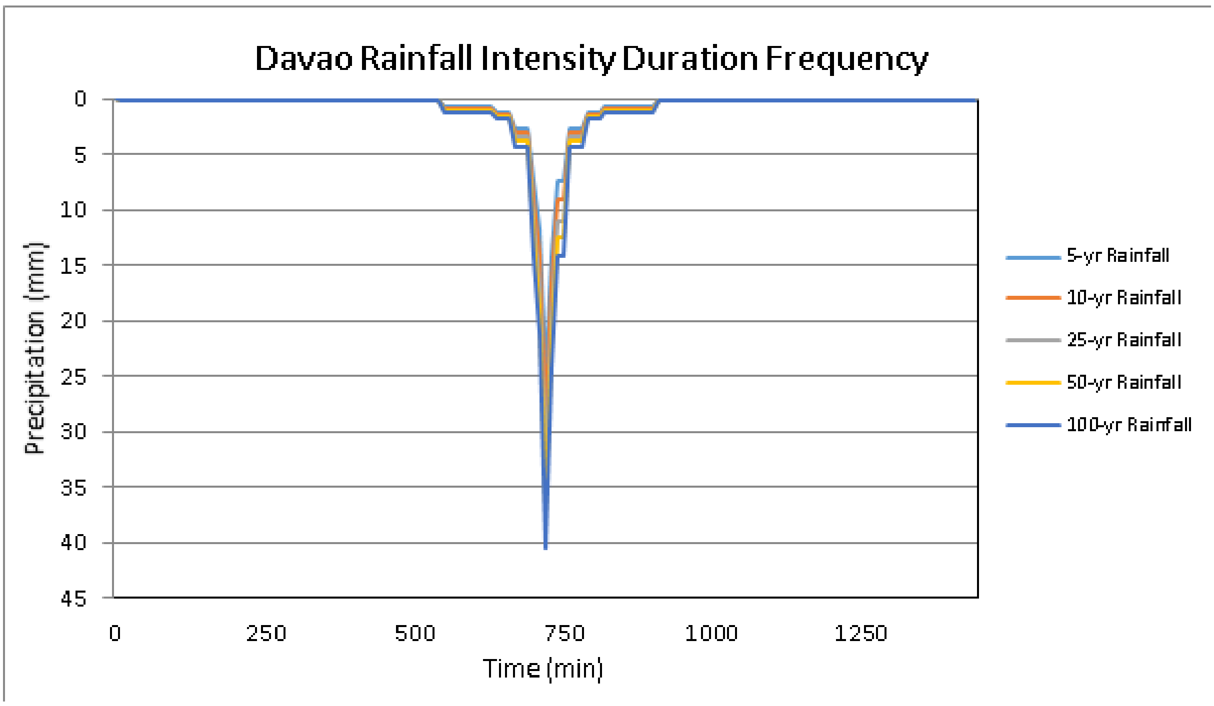



Figure 51. Synthetic storm generated for a 24-hr period rainfall for various return periods.

## 5.3 HMS Model

The soil dataset, taken in 2004, was sourced out from the Bureau of Soils under the Department of Agriculture. The land cover data, on the other hand, was taken from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Sumlog River Basin are shown in Figures 52 and 53, respectively.

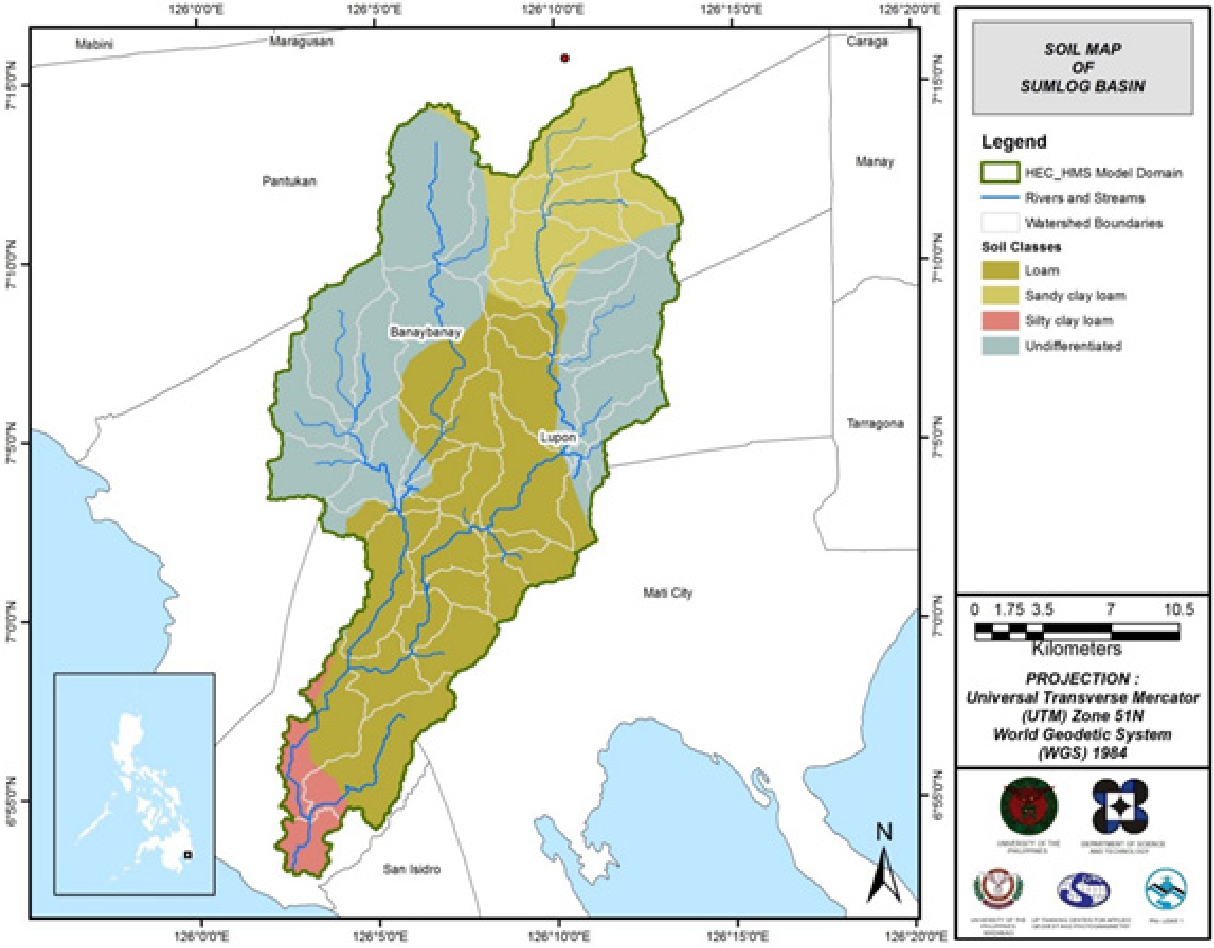



Figure 52. The soil map of the Sumlog River Basin.

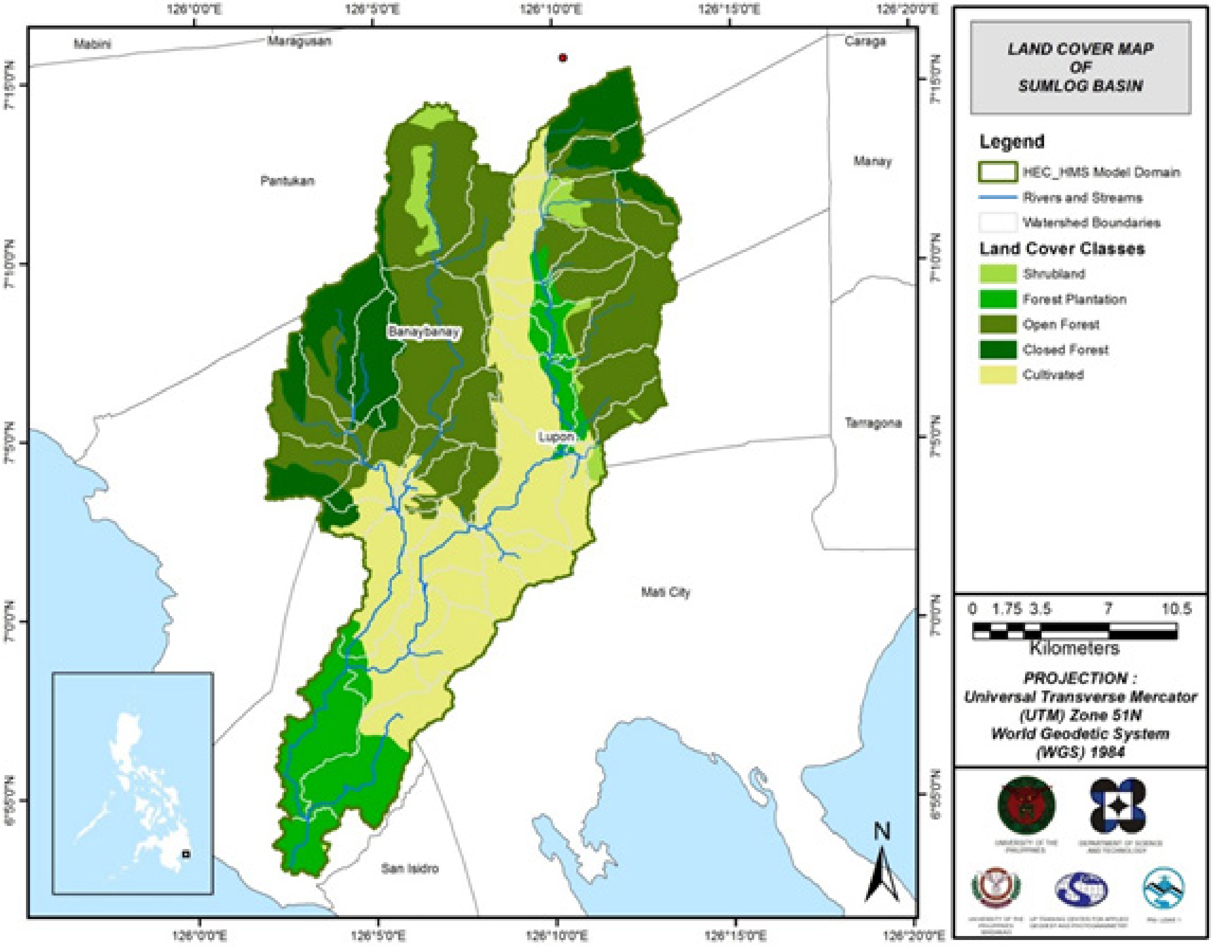



Figure 53. The land cover map of the Sumlog River Basin.

For Sumlog, four soil classes were identified. These are loam, sandy clay loam, silty clay loam and undifferentiated land. Moreover, five land cover classes were identified. These are shrublands, forest plantations, open forests, closed forests, and cultivated areas.

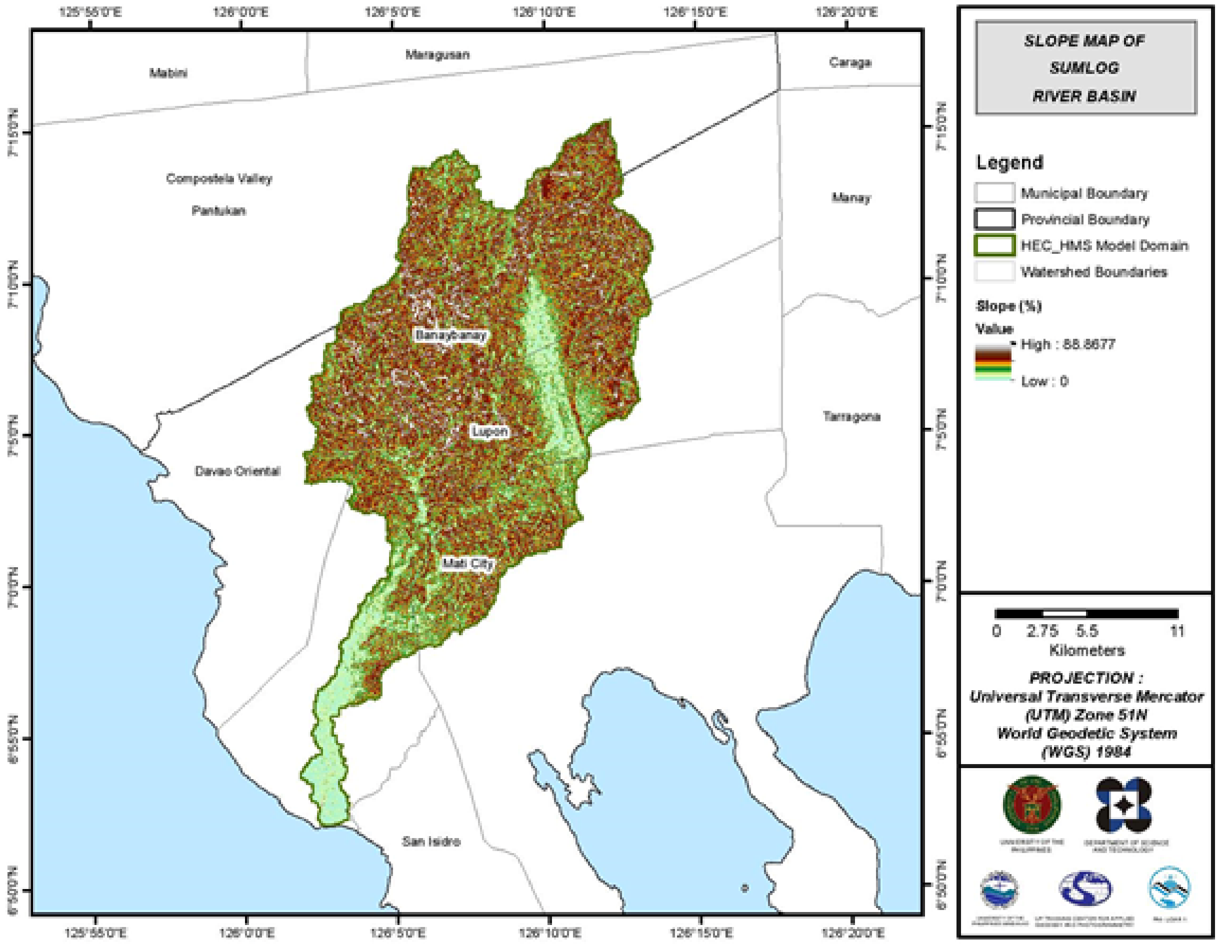



Figure 54. The slope map of the Sumlog River Basin.

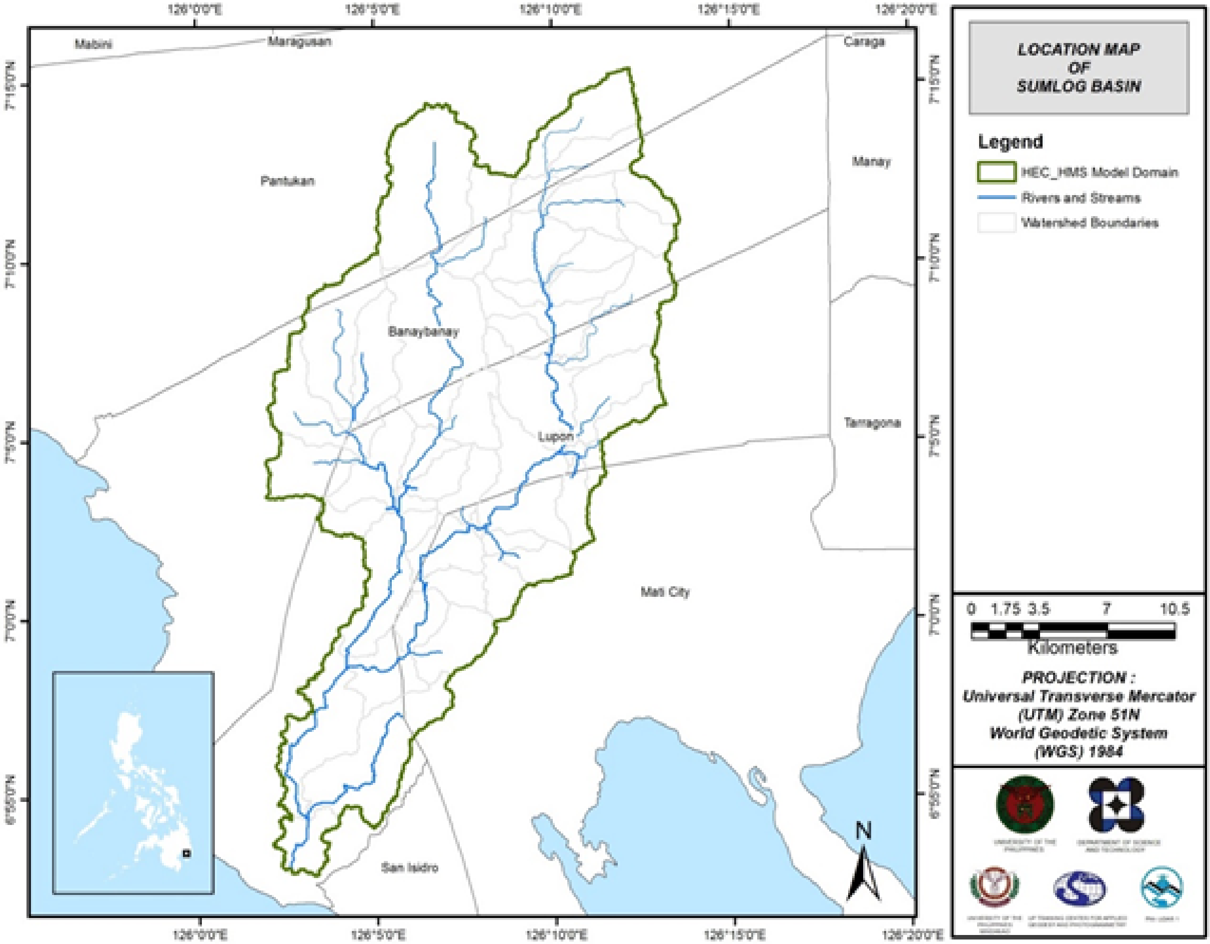



Figure 55. Stream delineation map of Sumlog River Basin.

Using the SAR-based DEM, the Sumlog basin was delineated and further subdivided into subbasins. The model consists of 51 sub basins, 25 reaches, and 25 junctions, as shown in Figure 56. The main outlet is at Sumlog Bridge.

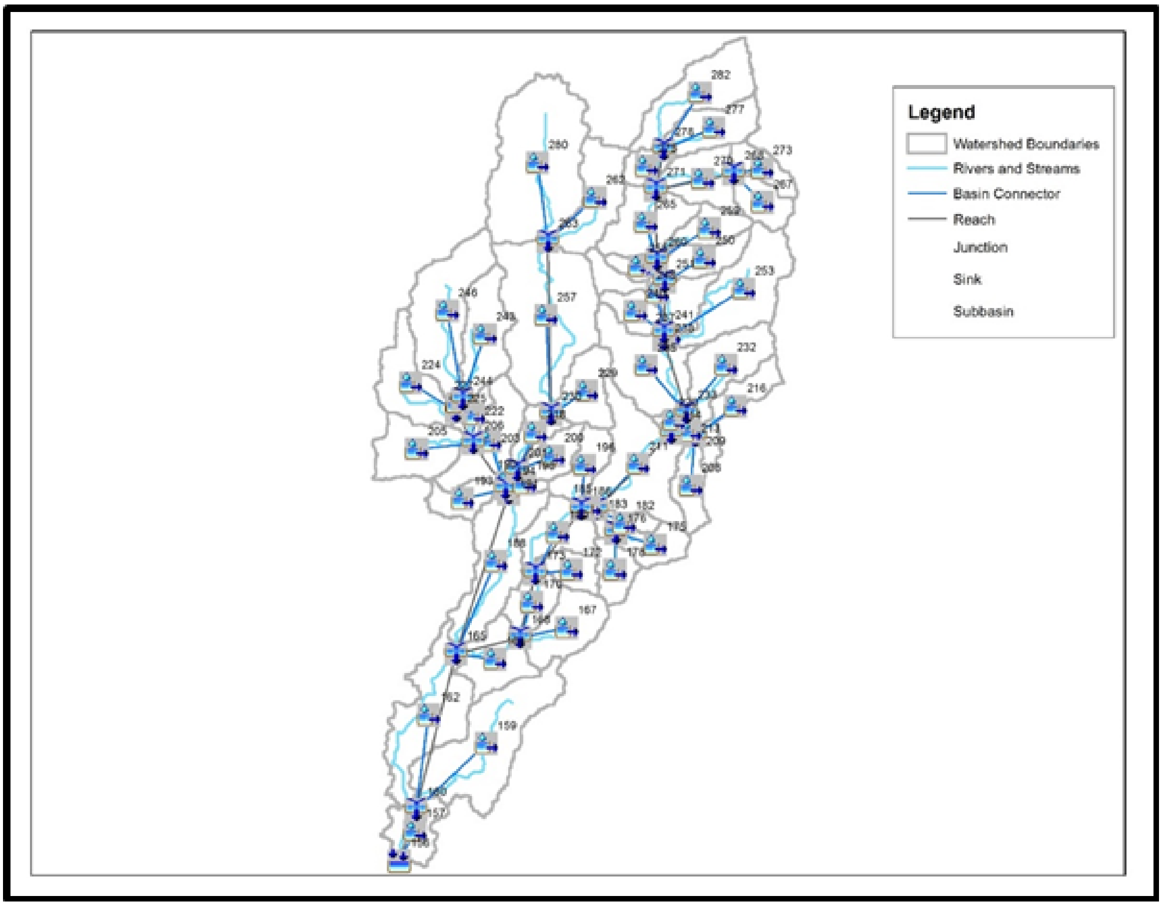



Figure 56. The Sumlog River Basin model generated in HEC-HMS.

## 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.

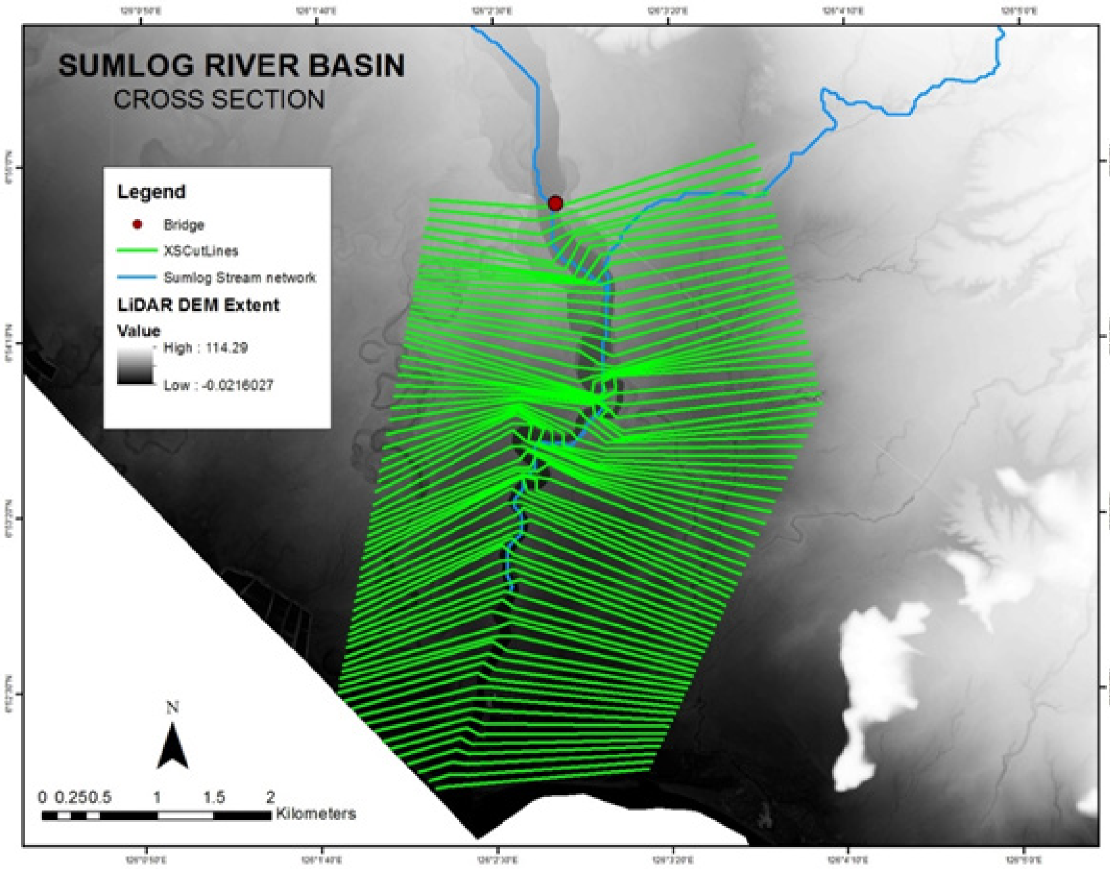



Figure 57. River Cross-section of the Sumlog River generated through Arcmap HEC GeoRAS tool.

## 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 south of the model to the north, following the main channel. As such, boundary elements in those particular regions of the model are assigned as inflow and outflow elements respectively.

Figure 58. A Screenshot of subcatchment 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 58.36890 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 Sumlog are in Figures __, __, and __.

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 43894900.00 m2. The generated flood depth maps for Sumlog are in Figures __, __, and __.

There is a total of 34088534.89 m3 of water entering the model. Of this amount, 15257043.87 m3 is due to rainfall while 18831491.02 m3 is inflow from other areas outside the model. 6156764.50 m3 of this water is lost to infiltration and interception, while 19224428.46 m3 is stored by the flood plain. The rest, amounting up to 8707324.78 m3, is outflow.

## 5.6 Results of HMS Calibration

After calibrating the Sumlog HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 59 shows the comparison between the two discharge data.

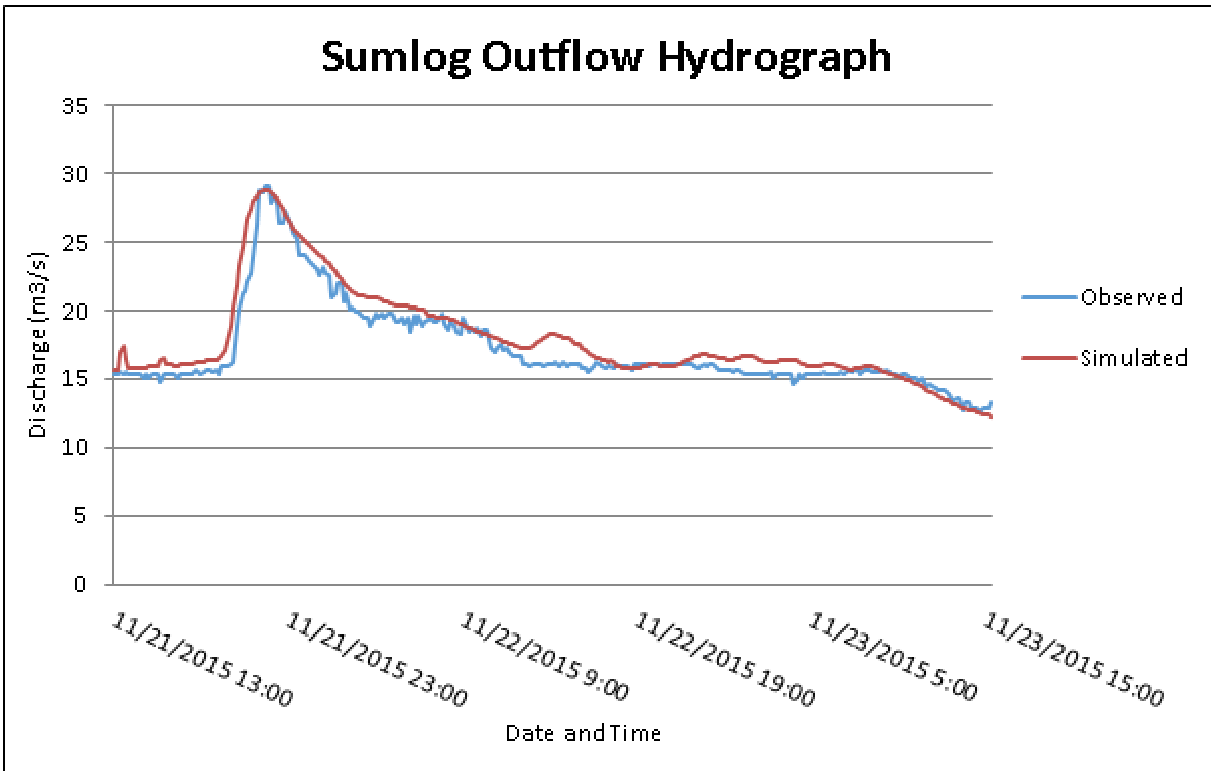



Figure 59. Outflow Hydrograph of Sumlog produced by the HEC-HMS model compared with observed outflow.

Enumerated in Table 28 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 28. Range of Calibrated Values for Sumlog.

| Hydrologic Element | Calculation Type | Method | Parameter | Range of Calibrated Values |
|---|---|---|---|---|
| Basin | Loss | SCS Curve Number | Initial Abstraction (mm) | 2.73 – 24.07 |
| | | | Curve Number | 36.56 – 99 |
| | Transform | Clark Unit Hydrograph | Time of Concentration (hr) | 0.022 – 0.226 |
| | | | Storage Coefficient (hr) | 0.017 – 0.135 |
| | Baseflow | Recession | Recession Constant | 0.029 - 1 |
| | | | Ratio to Peak | 0.21 – 0.995 |
| Reach | Routing | Muskingum-Cunge | Manning's Coefficient | 0.011 – 0.129 |

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 2.73 mm to 24.07 mm means that there is an average initial fraction of the storm depth after which runoff begins.

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 Sumlog, the basin consists mainly of open forests and cultivated areas and the soil consists of mostly undifferentiated land and loam.

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 0.017 hours to 0.226 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 0.029 to 1 indicate that the discharge leaving every subbasin within Sumlog recede differ significantly. Values of ratio to peak within the range of 0.21 to 0.995 indicate an average receding limb of the outflow hydrograph.

Manning's roughness coefficients correspond to the common roughness of Philippine watersheds. Sumlog river basin reaches' Manning's coefficients range from 0.011 to 0.129, showing that there is variety in surface roughness all over the catchment (Brunner, 2010).

Table 29. Summary of the Efficiency Test of Sumlog HMS Model.

| Accuracy measure | Value |
|---|---|
| RMSE | 1.1 |
| r2 | 0.944 |
| NSE | 0.88 |
| PBIAS | -3.93 |
| RSR | 0.34 |

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 1.1 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 0.944.

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 0.88.

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 -3.93.

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 0.34.

## 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 60) shows the Sumlog 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.

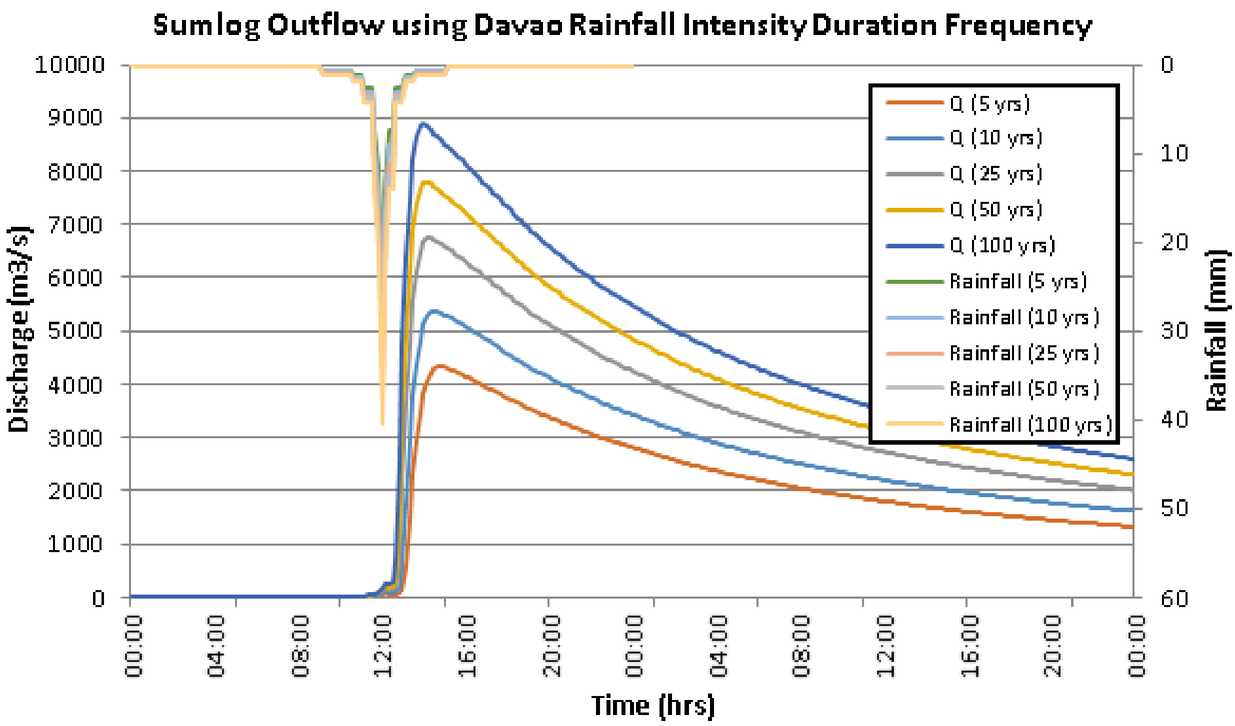



Figure 60. The Outflow hydrograph at Sumlog Station generated using Cagayan de Oro RIDF simulated in HEC-HMS.

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Sumlog discharge using the Davao Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 30. A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Sumlog discharge using the Davao Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 30.

Table 30. Peak values of the Sumlog HEC-HMS Model outflow using the Davao RIDF.

| RIDF Period | Total Precipitation (mm) | Peak rainfall (mm) | Peak outflow (m 3/s) | Time to Peak |
|---|---|---|---|---|
| 5-Year | 121.1 | 25.1 | 4334.1 | 2 hours, 40 minutes |
| 10-Year | 140.7 | 28.8 | 5374.5 | 2 hours, 30 minutes |
| 25-Year | 165.5 | 33.5 | 6748.9 | 2 hours, 20 minutes |
| 50-Year | 183.9 | 37 | 7798.9 | 2 hours, 10 minutes |
| 100-Year | 202.1 | 40.5 | 8876.4 | 2 hours |

## 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 Sumlog River using the calibrated HMS base flow is shown in Figure 61.

Figure 61. . Sample output of Sumlog 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 Sumlog floodplain are shown in Figures 15 to 20. The floodplain, with an area of 97.22 sq. km., covers two municipalities. Table 31 shows the percentage of area affected by flooding per municipality.

Table 31. Municipalities affected in Sumlog Floodplain.

| Province | Municipality | Total Area | Area Flooded | % Flooded |
|---|---|---|---|---|
| Davao Oriental | Lupon | 356.28 | 84.46 | 23.71 % |
| Davao Oriental | San Isidro | 224.84 | 12.70 | 5.65% |

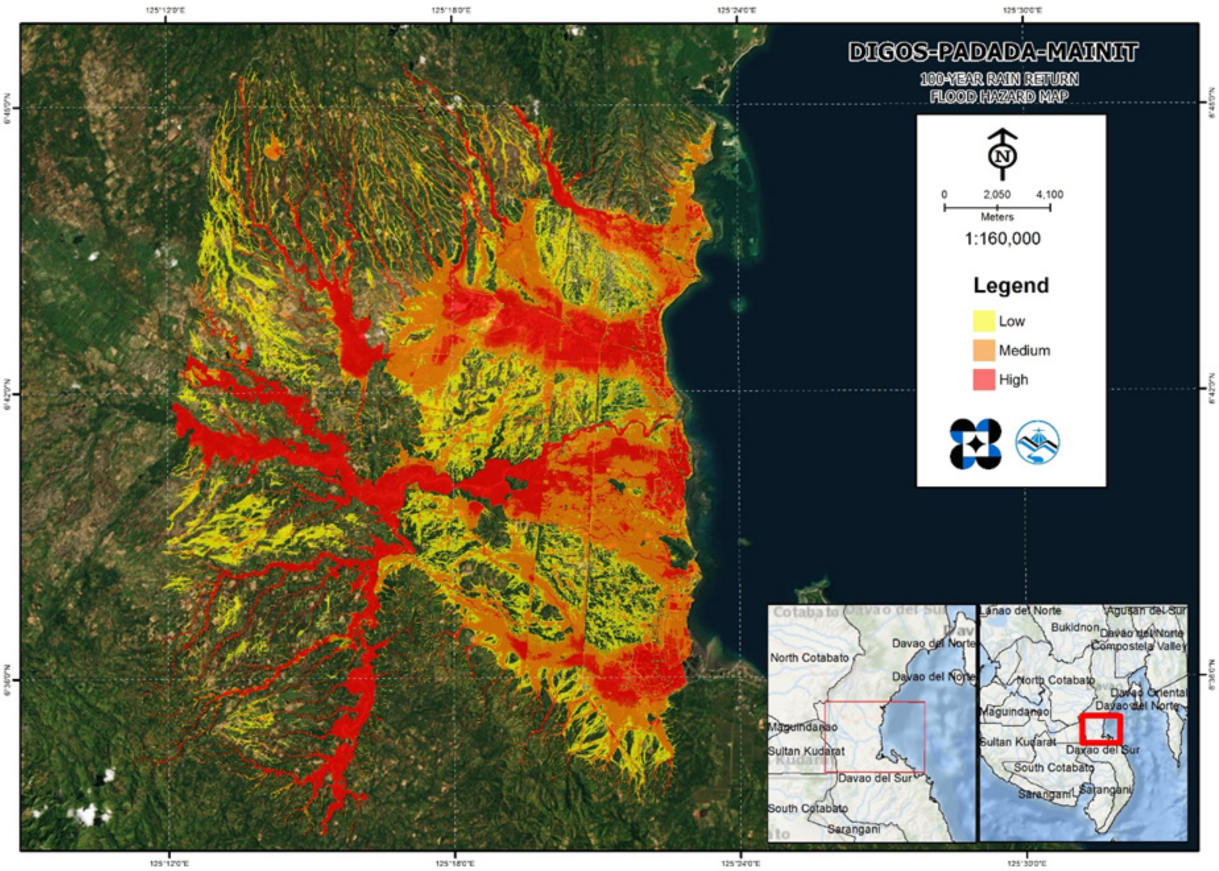



Figure 62. 100-year Flood Hazard Map for Sumlog Floodplain.

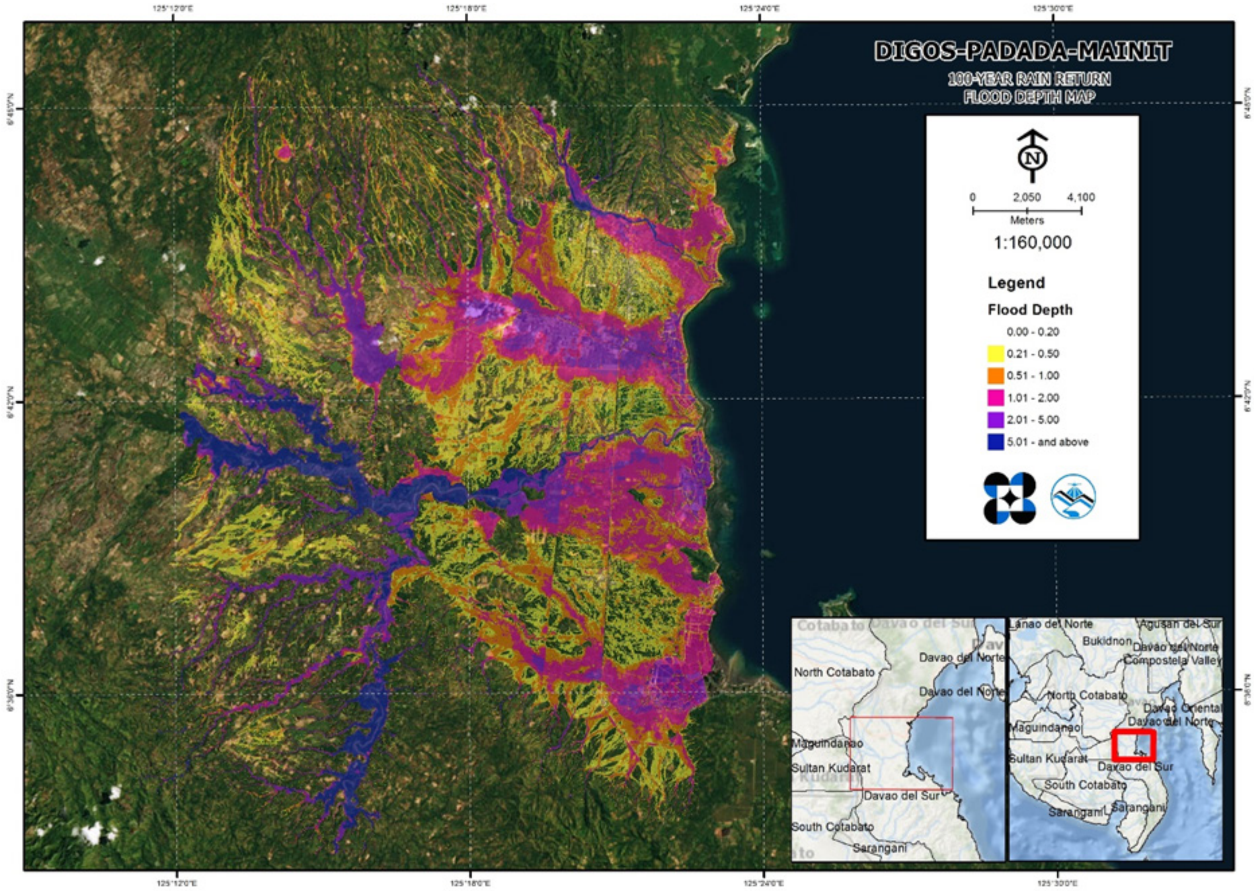



Figure 63. 100-year Flow Depth Map for Sumlog Floodplain.

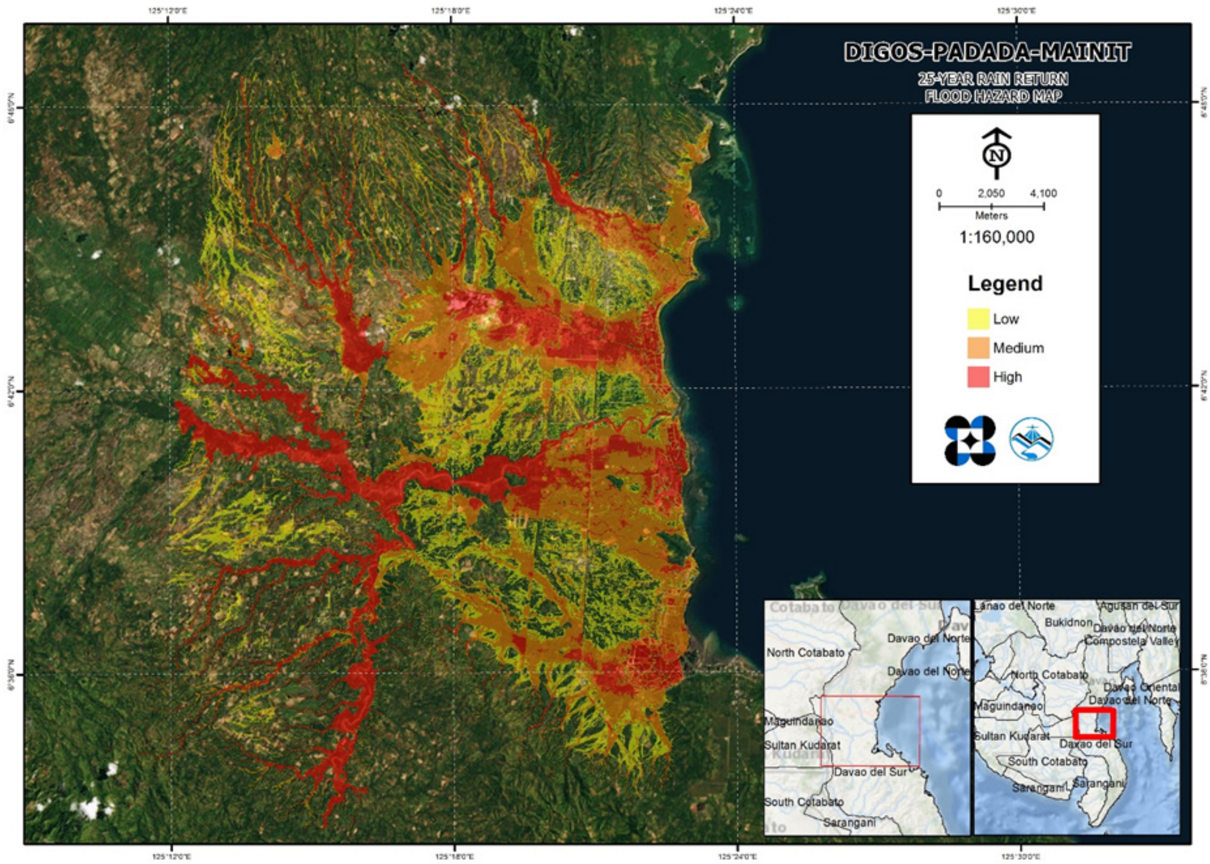



Figure 64. 25-year Flood Hazard Map for Sumlog Floodplain.

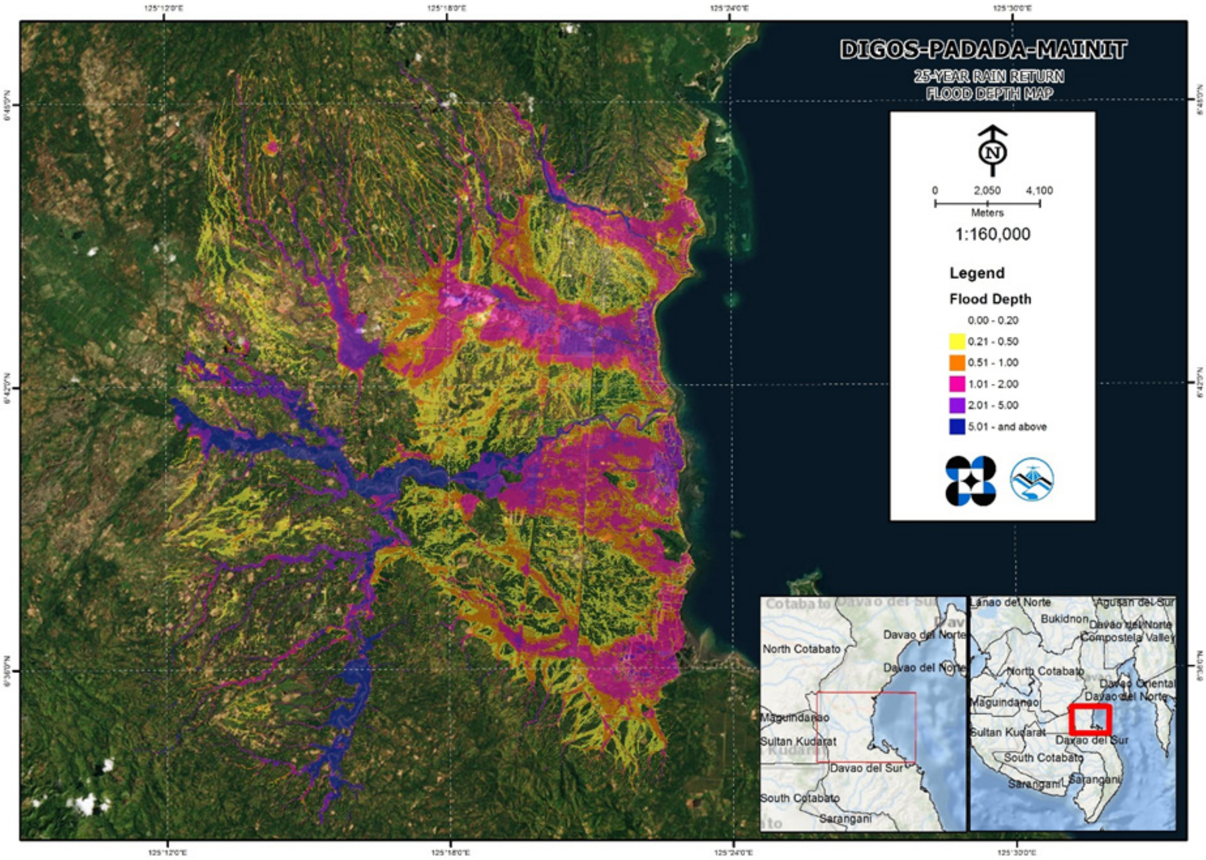



Figure 65. 25-year Flow Depth Map for Sumlog Floodplain.

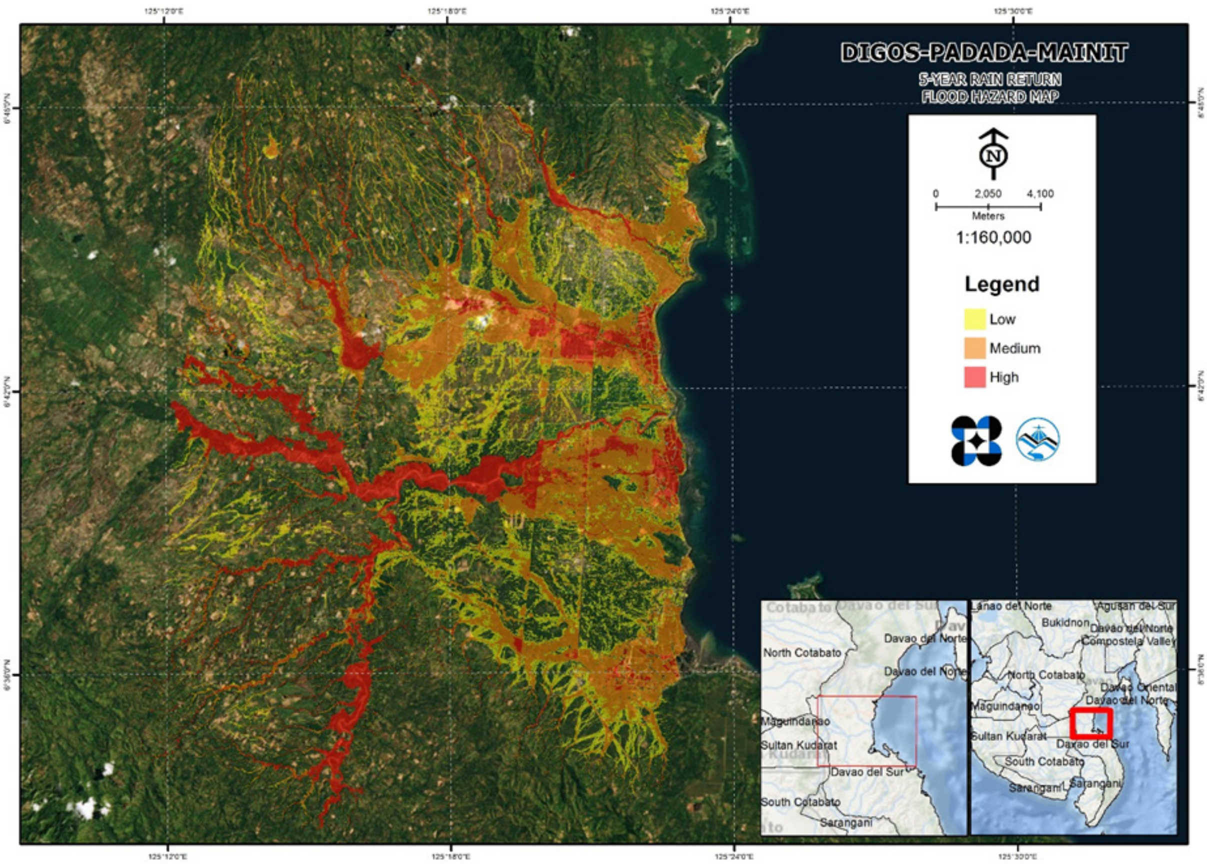



Figure 66. 5-year Flood Hazard Map for Sumlog Floodplain

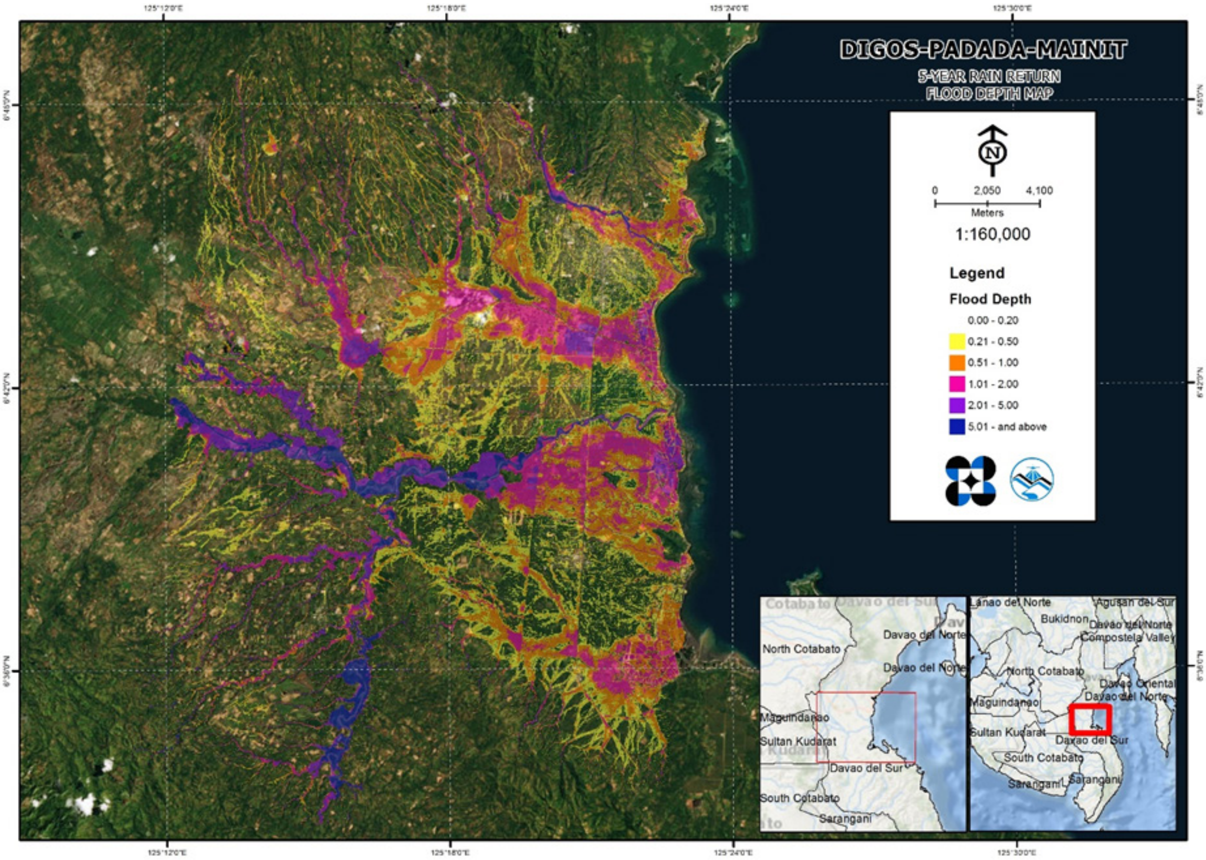



Figure 67. 5-year Flood Depth Map for Sumlog Floodplain.

## 5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Sumlog River Basin, grouped by municipality, are listed below. For the said basin, two municipalities consisting of 20 barangays are expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 9.90% of the municipality of Lupon with an area of 356.28 sq. km. will experience flood levels of less than 0.20 meters. 3.65% of the area will experience flood levels of 0.21 to 0.50 meters while 3.88%, 3.71%, 2.39%, and 0.17% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 32. Affected Areas in Lupon, Davao Oriental during 5-Year Rainfall Return Period.

| Affected Area (sq. km.) by flood depth (in m.) | Area of affected barangays in Lupon (in sq. km) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Bagum-bayan | Cabad-iangan | Calap-agan | Cocor-non | Corpo-racion | Don Mariano Marcos | Ilangay | Langka |
| 0.03-0.20 | 0.48 | 2 | 0.24 | 6.58 | 0.95 | 0.0057 | 1.55 | 1.01 |
| 0.21-0.50 | 0.86 | 0.1 | 0.82 | 0.5 | 0.73 | 0.0002 | 0.92 | 0.033 |
| 0.51-1.00 | 1.42 | 0.059 | 1.11 | 0.6 | 0.21 | 0.00019 | 1 | 0.081 |
| 1.01-2.00 | 2.51 | 0.086 | 0.69 | 0.83 | 0.21 | 0 | 0.58 | 0.8 |
| 2.01-5.00 | 1.29 | 1.08 | 0.026 | 2.11 | 0.44 | 0 | 0.56 | 1.29 |
| > 5.00 | 0 | 0.11 | 0 | 0.023 | 0.015 | 0 | 0.058 | 0.024 |

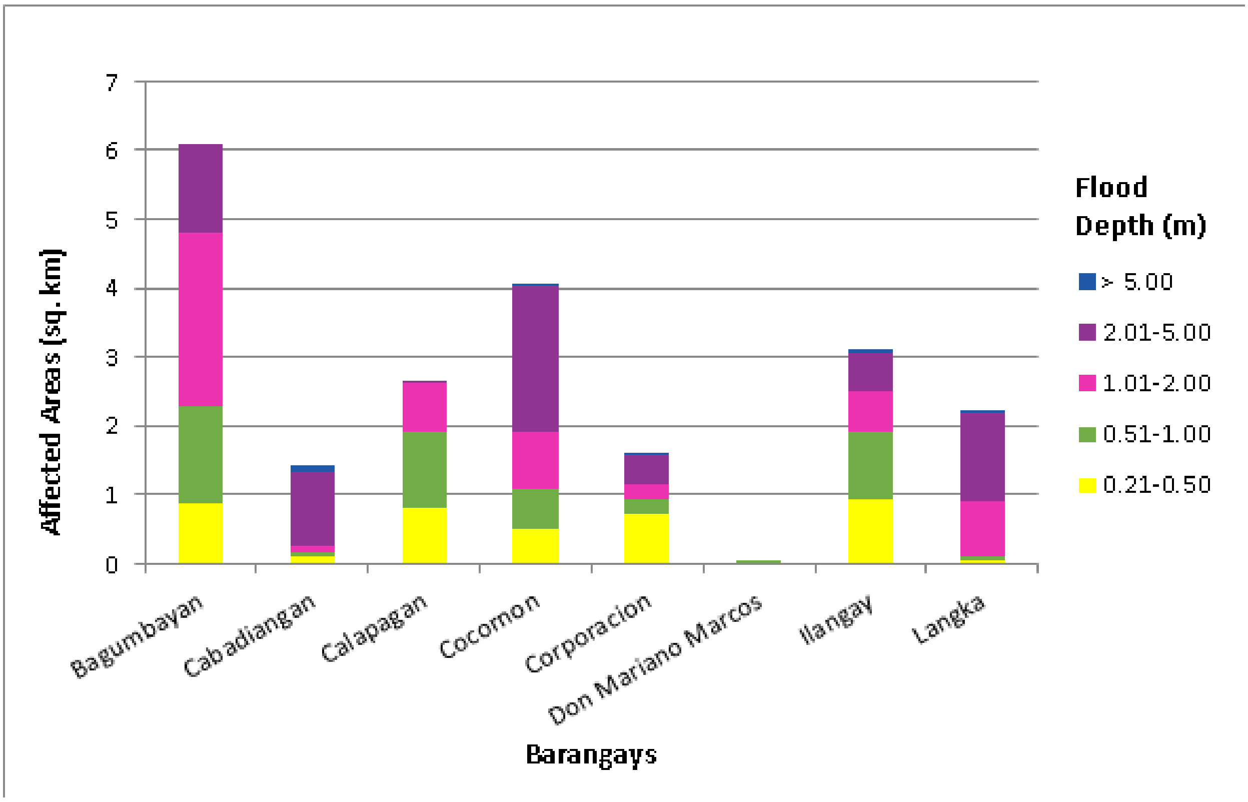



Figure 68. Affected Areas in Lupon, Davao Oriental during 5-Year Rainfall Return Period.

Table 33. Affected Areas in Lupon, Davao Oriental during 5-Year Rainfall Return Period.

| Affected Area (sq. km.) by flood depth (in m.) | Area of affected barangays in Lupon (in sq. km) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Lanta-wan | Limba-han | Maca-ngao | Magsay-say | New Visayas | Poblacion | San Isidro | Tagboa |
| 0.03-0.20 | 0.38 | 0.47 | 1.91 | 5.6 | 1.24 | 4.46 | 1.06 | 7.32 |
| 0.21-0.50 | 1.71 | 0.56 | 1.87 | 0.96 | 0.032 | 2.66 | 0.026 | 1.24 |
| 0.51-1.00 | 2.67 | 1.74 | 1.65 | 0.79 | 0.026 | 1.12 | 0.021 | 1.34 |
| 1.01-2.00 | 0.36 | 2.28 | 3.54 | 0.3 | 0.017 | 0.4 | 0.017 | 0.6 |
| 2.01-5.00 | 0.0001 | 0.39 | 0.87 | 0.11 | 0.087 | 0.029 | 0.02 | 0.21 |

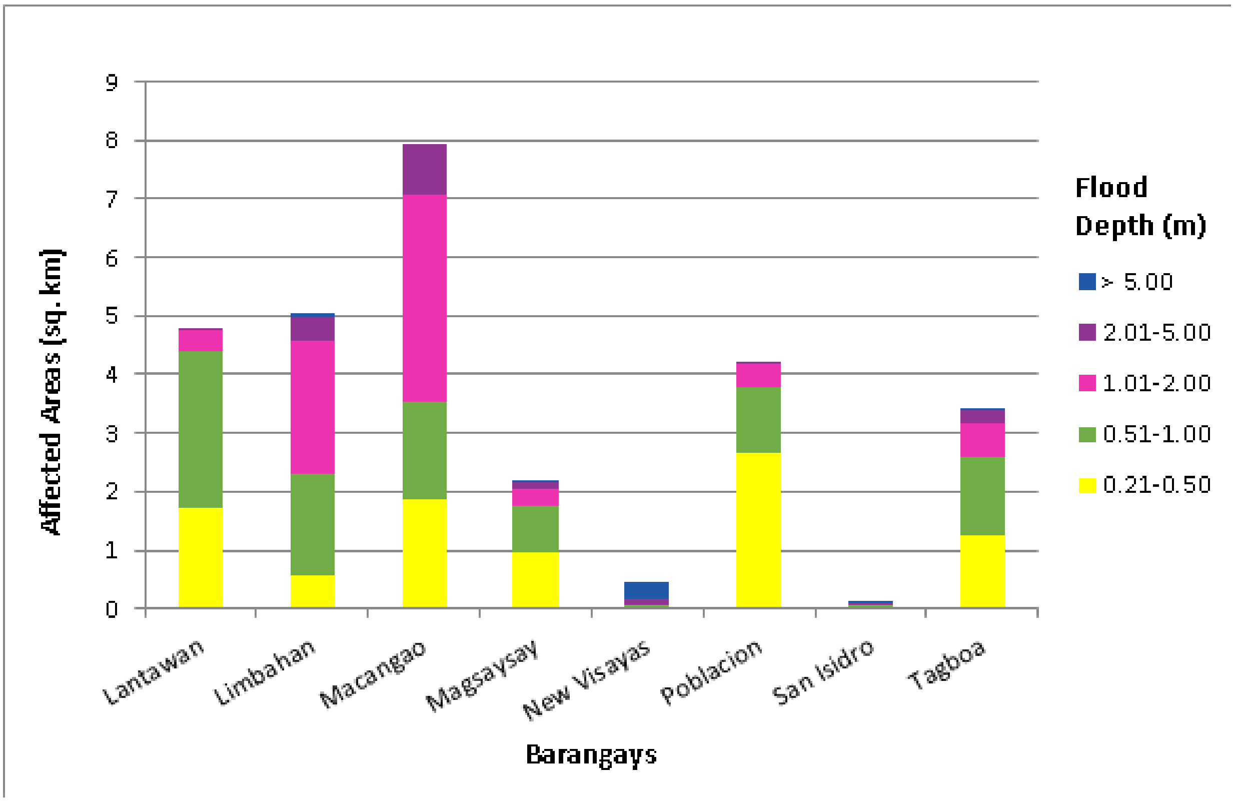



Figure 69. Affected Areas in Lupon, Davao Oriental during 5-Year Rainfall Return Period.

For the 5-year return period, 3.69% of the municipality of San Isidro with an area of 224.84 sq. km. will experience flood levels of less than 0.20 meters. 0.91% of the area will experience flood levels of 0.21 to 0.50 meters while 0.72%, 0.25%, and 0.08% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 34. Affected Areas in San Isidro, Davao Oriental during 5-Year Rainfall Return Period.

| Affected Area (sq. km.) by flood depth (in m.) | Area of affected barangays in San Isidro (in sq. km) | | | |
|---|---|---|---|---|
| | Dugmanon | Iba | Lapu-Lapu | San Roque |
| 0.03-0.20 | 3.71 | 2 | 0.14 | 2.45 |
| 0.21-0.50 | 0.23 | 1.37 | 0.066 | 0.39 |
| 0.51-1.00 | 0.27 | 0.97 | 0.025 | 0.36 |
| 1.01-2.00 | 0.16 | 0.094 | 0.0031 | 0.3 |
| 2.01-5.00 | 0.07 | 0 | 0 | 0.1 |

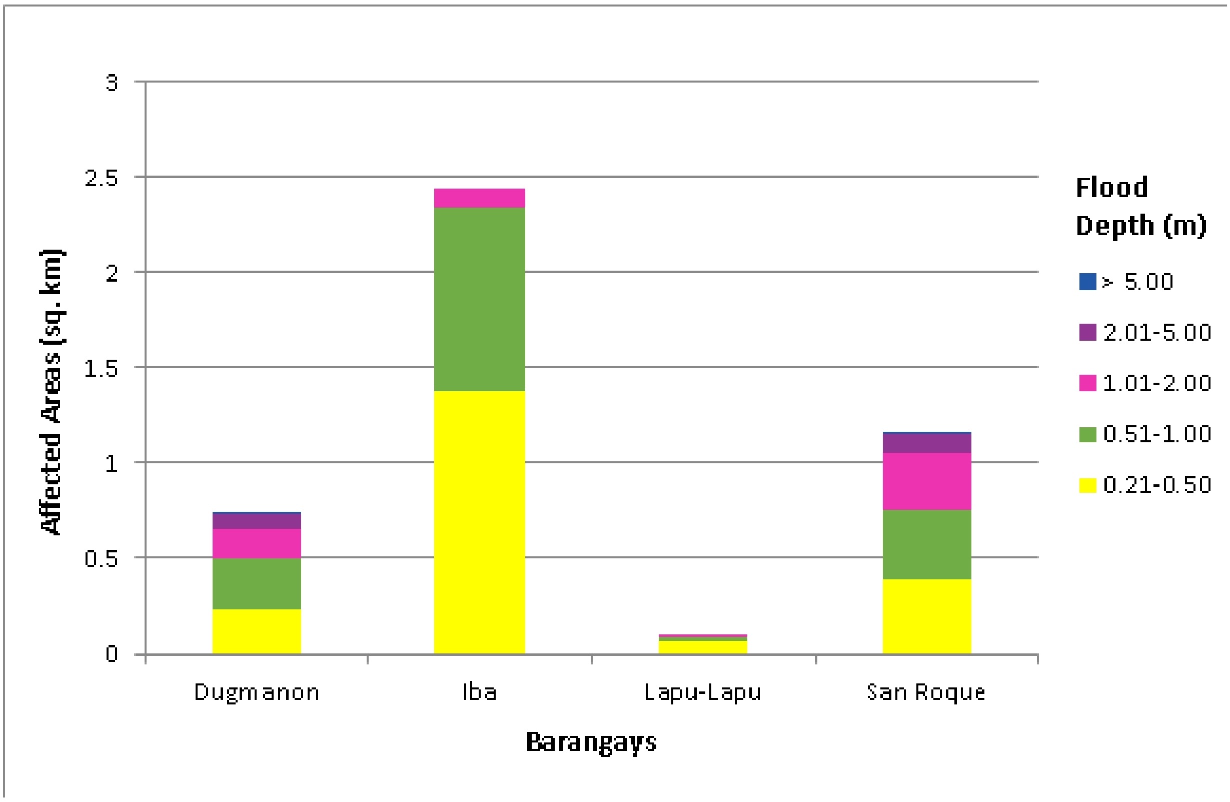



Figure 70. Affected Areas in San Isidro, Davao Oriental during 5-Year Rainfall Return Period.

For the 25-year return period, 7.92% of the municipality of Lupon with an area of 356.28 sq. km. will experience flood levels of less than 0.20 meters. 3.15% of the area will experience flood levels of 0.21 to 0.50 meters while 4.16%, 4.77%, 3.23%, and 0.48% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 35. Affected Areas in Lupon, Davao Oriental during 25-Year Rainfall Return Period.

| Affected Area (sq. km.) by flood depth (in m.) | Area of affected barangays in Lupon (in sq. km) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Bagum-bayan | Cabad -iangan | Calap-agan | Cocor-non | Corpo-racion | Don Mariano Marcos | Ilangay | Langka |
| 0.03-0.20 | 0.091 | 1.84 | 0.094 | 6.27 | 0.42 | 0.0057 | 0.76 | 0.95 |
| 0.21-0.50 | 0.38 | 0.16 | 0.37 | 0.48 | 0.95 | 0.0002 | 0.96 | 0.032 |
| 0.51-1.00 | 1.27 | 0.067 | 1.36 | 0.53 | 0.44 | 0.00019 | 1.39 | 0.031 |
| 1.01-2.00 | 2.1 | 0.093 | 0.84 | 0.88 | 0.23 | 0 | 0.89 | 0.22 |
| 2.01-5.00 | 2.71 | 0.8 | 0.22 | 2.04 | 0.5 | 0 | 0.57 | 1.84 |
| > 5.00 | 0 | 0.47 | 0 | 0.46 | 0.021 | 0 | 0.087 | 0.16 |

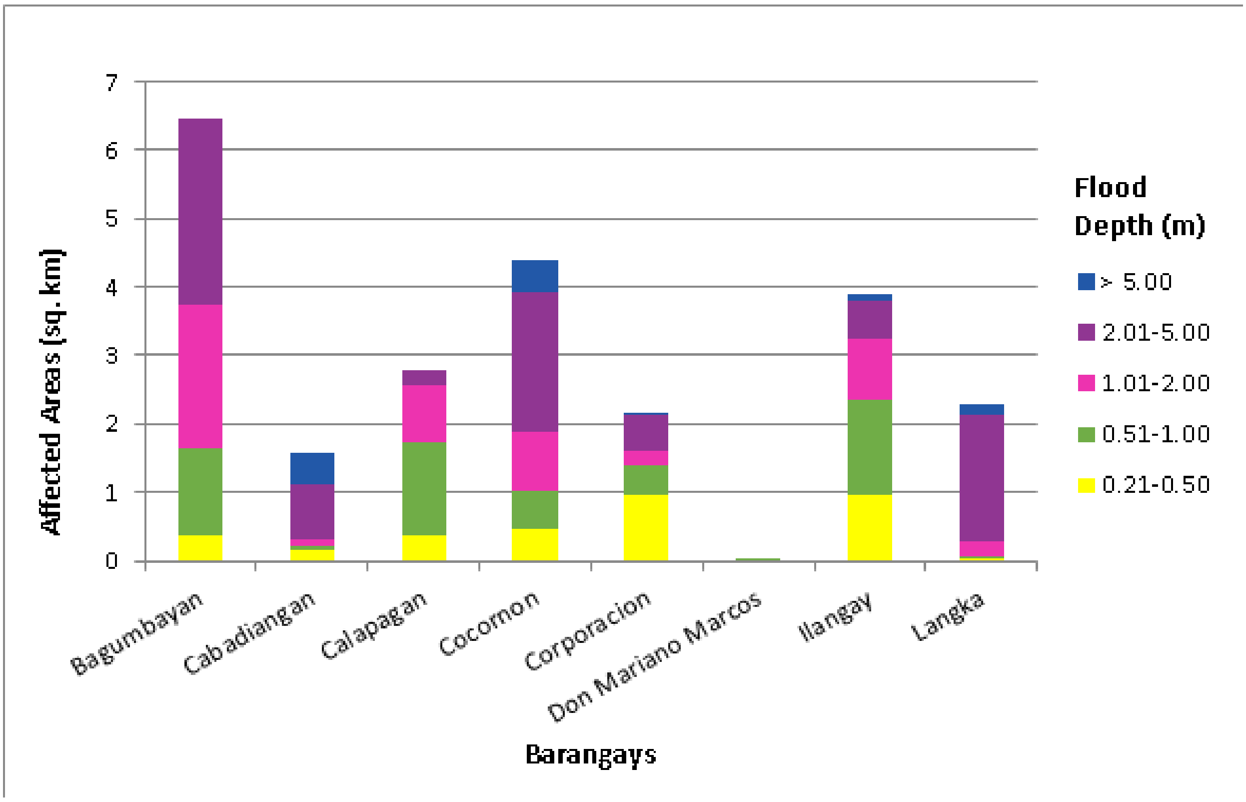



Figure 71. Affected Areas in Lupon, Davao Oriental during 25-Year Rainfall Return Period.

Table 36. Affected Areas in Lupon, Davao Oriental during 25-Year Rainfall Return Period.

| Affected Area (sq. km.) by flood depth (in m.) | Area of affected barangays in Lupon (in sq. km) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Lanta-wan | Limba-han | Maca-ngao | Magsay-say | New Visayas | Poblacion | San Isidro | Tagboa |
| 0.03-0.20 | 0.036 | 0.29 | 1.23 | 5.05 | 1.22 | 2.25 | 1.04 | 6.68 |
| 0.21-0.50 | 0.22 | 0.4 | 1.82 | 0.86 | 0.035 | 3.23 | 0.026 | 1.3 |
| 0.51-1.00 | 2.31 | 1.37 | 1.8 | 1.15 | 0.028 | 1.91 | 0.022 | 1.13 |
| 1.01-2.00 | 2.52 | 2.71 | 3.57 | 0.5 | 0.022 | 1.15 | 0.023 | 1.23 |
| 2.01-5.00 | 0.025 | 0.64 | 1.43 | 0.21 | 0.028 | 0.13 | 0.022 | 0.35 |
| > 5.00 | 0 | 0.084 | 0 | 0.0011 | 0.36 | 0 | 0.0079 | 0.044 |

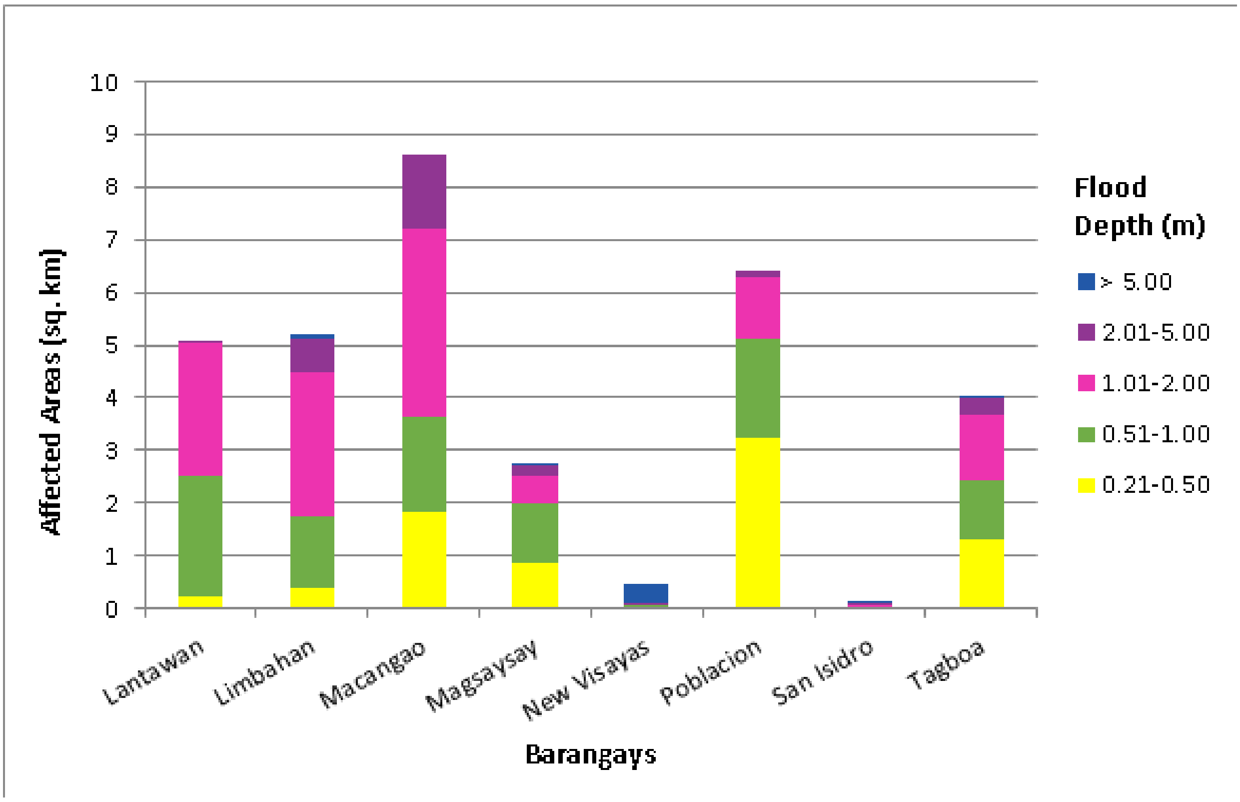



Figure 72. Affected Areas in Lupon, Davao Oriental during 25-Year Rainfall Return Period.

For the 25-year return period, 3.38% of the municipality of San Isidro with an area of 224.84 sq. km. will experience flood levels of less than 0.20 meters. 0.79% of the area will experience flood levels of 0.21 to 0.50 meters while 0.95%, 0.40%, 0.12%, 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 the table are the affected areas in square kilometers by flood depth per barangay.

Table 37. Affected Areas in San Isidro, Davao Oriental during 25-Year Rainfall Return Period.

| Affected Area (sq. km.) by flood depth (in m.) | Area of affected barangays in San Isidro (in sq. km) | | | |
|---|---|---|---|---|
| | Dugmanon | Iba | Lapu-Lapu | San Roque |
| 0.03-0.20 | 3.58 | 1.62 | 0.12 | 2.27 |
| 0.21-0.50 | 0.22 | 1.11 | 0.075 | 0.37 |
| 0.51-1.00 | 0.27 | 1.45 | 0.036 | 0.38 |
| 1.01-2.00 | 0.25 | 0.25 | 0.0057 | 0.4 |
| 2.01-5.00 | 0.1 | 0.0002 | 0 | 0.18 |
| > 5.00 | 0.0007 | 0 | 0 | 0.012 |

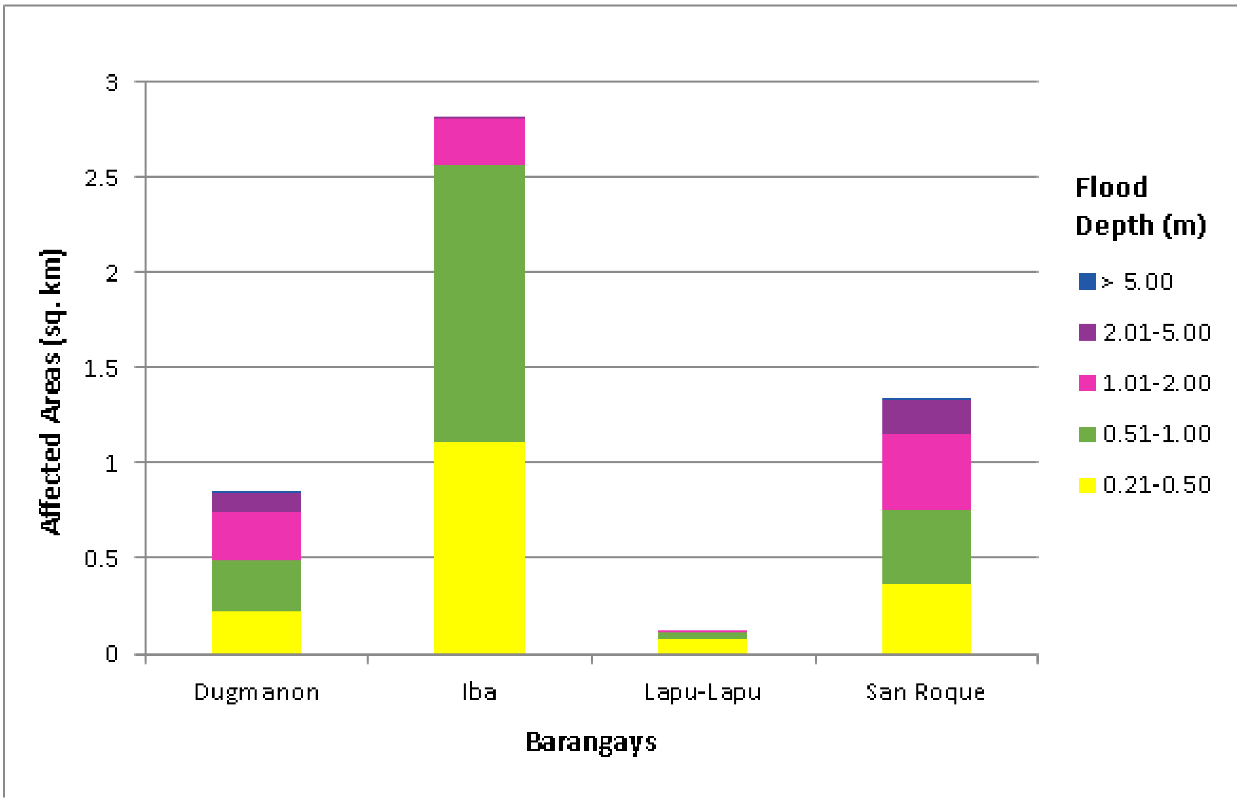



Figure 73. Affected Areas in San Isidro, Davao Oriental during 25-Year Rainfall Return Period.

For the 100-year return period, 7.01% of the municipality of Lupon with an area of 356.28 sq. km. will experience flood levels of less than 0.20 meters. 2.63% of the area will experience flood levels of 0.21 to 0.50 meters while 3.92%, 5.61%, 3.77%, and 0.77% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 38. Affected Areas in Lupon, Davao Oriental during 100-Year Rainfall Return Period.

| Affected Area (sq. km.) by flood depth (in m.) | Area of affected barangays in Lupon (in sq. km) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Bagum-bayan | Cabad-iangan | Calap-agan | Cocor-non | Corpo-racion | Don Mariano Marcos | Ilangay | Langka |
| 0.03-0.20 | 0.026 | 1.75 | 0.06 | 6.05 | 0.19 | 0.0056 | 0.57 | 0.91 |
| 0.21-0.50 | 0.092 | 0.2 | 0.2 | 0.49 | 0.96 | 0.00022 | 0.89 | 0.044 |
| 0.51-1.00 | 0.77 | 0.058 | 1.16 | 0.44 | 0.56 | 0.00019 | 1.37 | 0.029 |
| 1.01-2.00 | 2.24 | 0.089 | 1.16 | 0.86 | 0.25 | 0 | 1.09 | 0.096 |
| 2.01-5.00 | 3.42 | 0.48 | 0.3 | 1.98 | 0.57 | 0 | 0.59 | 1.84 |
| > 5.00 | 0.0058 | 0.86 | 0 | 0.83 | 0.013 | 0 | 0.15 | 0.32 |

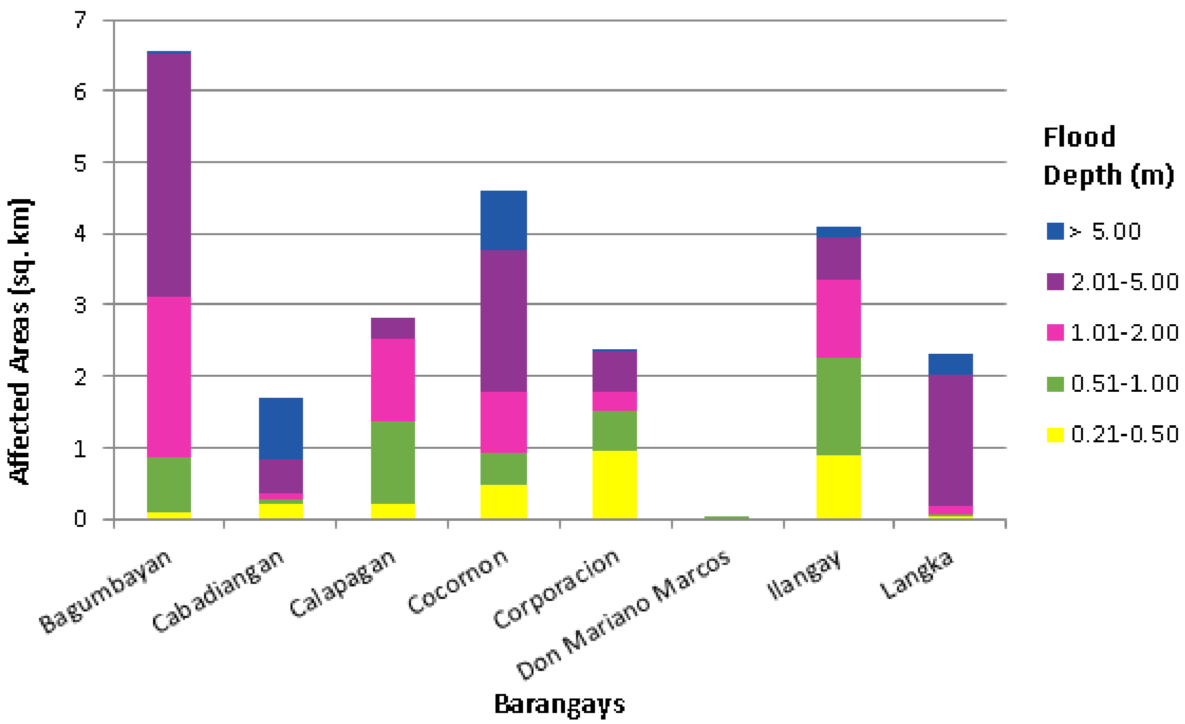



Figure 74. Affected Areas in Lupon, Davao Oriental during 100-Year Rainfall Return Period.

Table 39. Affected Areas in Lupon, Davao Oriental during 100-Year Rainfall Return Period.

| Affected Area (sq. km.) by flood depth (in m.) | Area of affected barangays in Lupon (in sq. km) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Lanta-wan | Limba-han | Maca-ngao | Magsay-say | New Visayas | Poblacion | San Isidro | Tagboa |
| 0.03-0.20 | 0.012 | 0.19 | 0.83 | 4.74 | 1.21 | 1.12 | 1.03 | 6.28 |
| 0.21-0.50 | 0.037 | 0.29 | 1.49 | 0.77 | 0.038 | 2.46 | 0.031 | 1.39 |
| 0.51-1.00 | 0.9 | 1.13 | 2.16 | 1.21 | 0.029 | 3.07 | 0.023 | 1.05 |
| 1.01-2.00 | 4.01 | 2.83 | 3.34 | 0.77 | 0.025 | 1.72 | 0.025 | 1.47 |
| 2.01-5.00 | 0.15 | 0.95 | 2.04 | 0.28 | 0.021 | 0.31 | 0.026 | 0.48 |
| > 5.00 | 0 | 0.12 | 0 | 0.0029 | 0.37 | 0 | 0.0097 | 0.062 |

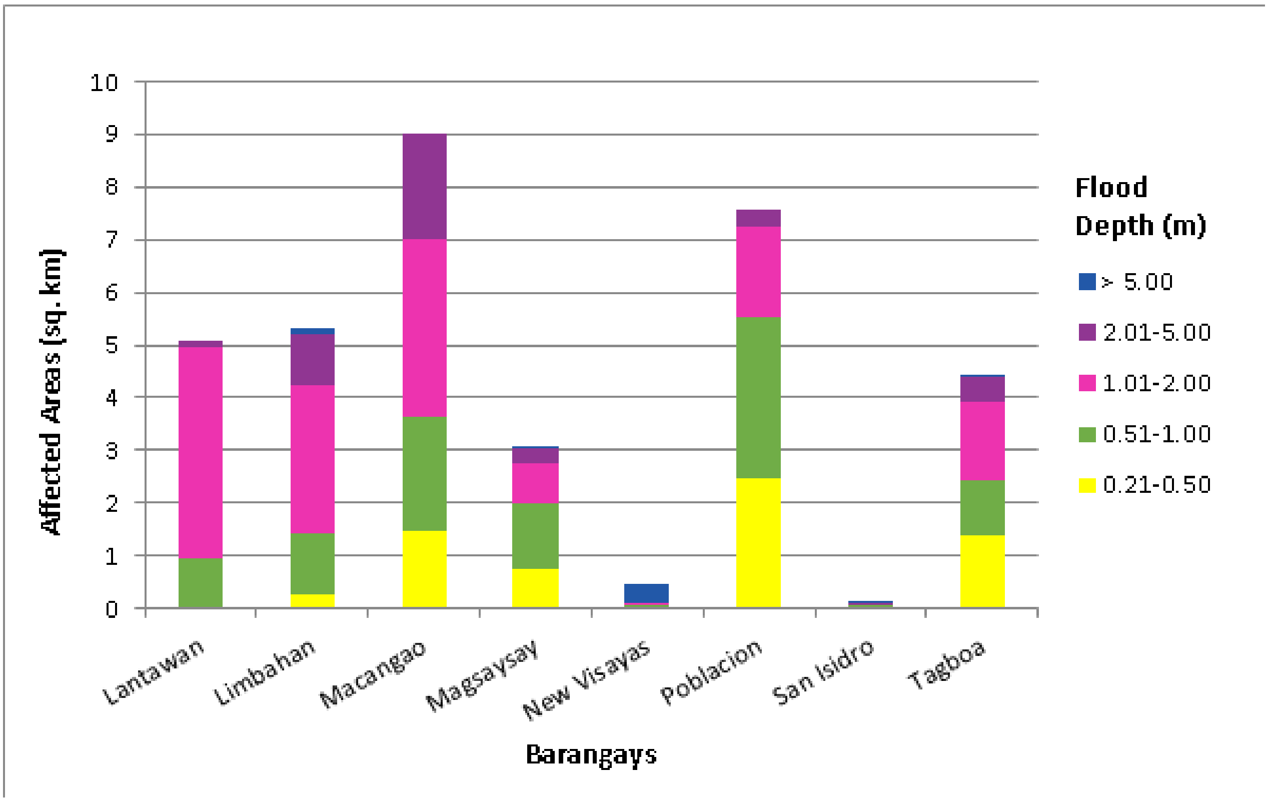



Figure 75. Affected Areas in Pasuquin, Ilocos Norte during 5-Year Rainfall Return Period.

For the 100-year return period, 3.19% of the municipality of San Isidro with an area of 224.84 sq. km. will experience flood levels of less than 0.20 meters. 0.73% of the area will experience flood levels of 0.21 to 0.50 meters while 0.97%, 0.57%, 0.17%, 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 the table are the affected areas in square kilometers by flood depth per barangay.

Table 40. Affected Areas in San Isidro, Davao Oriental during 100-Year Rainfall Return Period.

| Affected Area (sq. km.) by flood depth (in m.) | Area of affected barangays in San Isidro (in sq. km) | | | |
|---|---|---|---|---|
| | Dugmanon | Iba | Lapu-Lapu | San Roque |
| 0.03-0.20 | 3.51 | 1.44 | 0.1 | 2.13 |
| 0.21-0.50 | 0.2 | 0.99 | 0.079 | 0.38 |
| 0.51-1.00 | 0.26 | 1.51 | 0.045 | 0.37 |
| 1.01-2.00 | 0.32 | 0.49 | 0.0072 | 0.46 |
| 2.01-5.00 | 0.14 | 0.0009 | 0 | 0.25 |

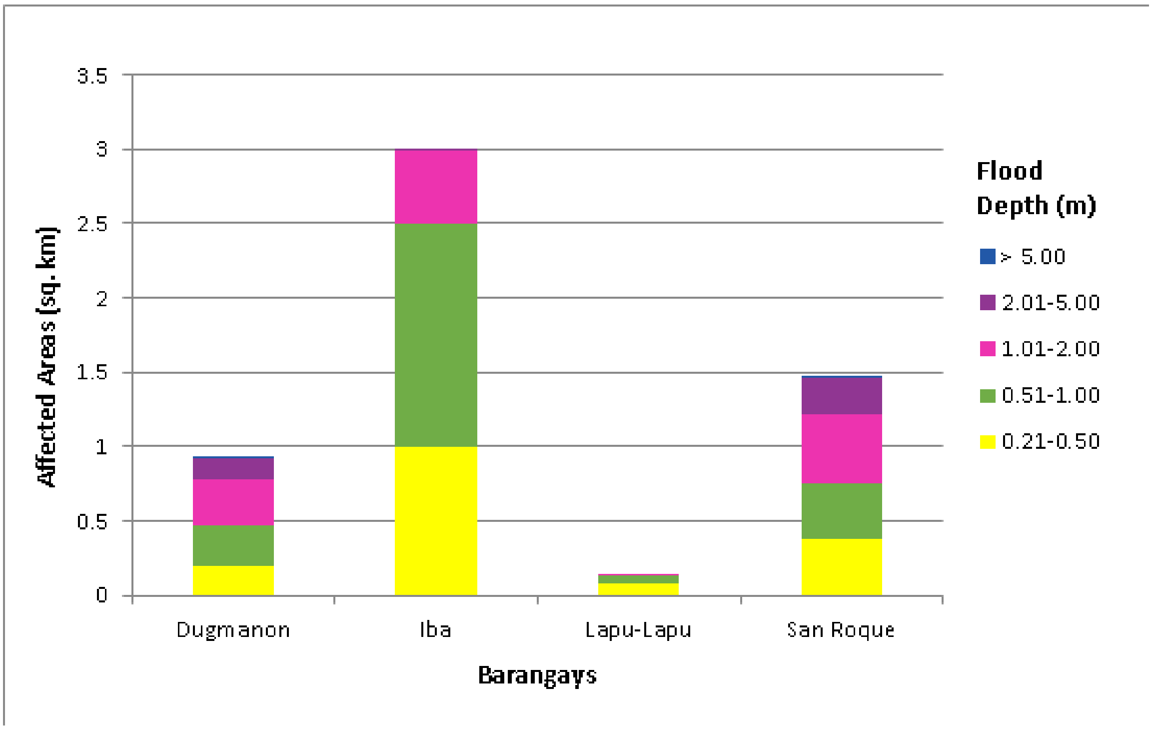



Figure 76. Affected Areas in San Isidro, Davao Oriental during 100-Year Rainfall Return Period.

Among the barangays in the municipality of Lupon in Davao Oriental, Tagboa is projected to have the highest percentage of area that will experience flood levels at 3.01%. Meanwhile, Cocornon posted the second highest percentage of area that may be affected by flood depths at 2.99%.

Among the barangays in the municipality of San Isidro in Davao Oriental, Dugmanon is projected to have the highest percentage of area that will experience flood levels at 1.97%. Meanwhile, Iba posted the second highest percentage of area that may be affected by flood depths at 1.97%.

Moreover, the generated flood hazard maps for the Sumlog 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 41. Area covered by each warning level with respect to the rainfall scenario.

| Warning Level | Area Covered in sq. km. | | |
|---|---|---|---|
| | 5 year | 25 year | 100 year |
| Low | 15.22 | 13.06 | 11.01 |
| Medium | 23.30 | 27.96 | 28.56 |
| High | 15.74 | 20.82 | 25.84 |

Of the 34 identified educational institutions in the Sumlog floodplain, six schools were assessed to be highly prone to flooding as they are exposed to the High level flooding for all three rainfall scenarios. Another institution was found to be also susceptible to flooding, experiencing Medium level flooding in the 5-year return period, and High level flooding in the 25- and 100-year rainfall scenarios. See Appendix D for a detailed enumeration of schools in the Sumlog floodplain.

Fourteen (14) medical institutions were identified in the Sumlog floodplain. The Barangay Health Center in Brgy. Limbahan was found to be highly prone to flooding, having High level flooding in all three rainfall scenarios. See Appendix E for a detailed enumeration of hospitals and clinics in the Sumlog Floodplain.

## 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 gather 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 are identified for validation.

The validation personnel will then go to the specified points identified in a river basin and will gather data regarding the actual flood level in each location. Data gathering can be 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 have had experienced flooding in a particular area.

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

The flood validation survey was conducted on November 15-18, 2016. The flood validation consists of 180 points randomly selected all over the Sumlog Floodplain. It has an RMSE value of 1.59.

The vlidation data were obtained November 15-18, 2016.

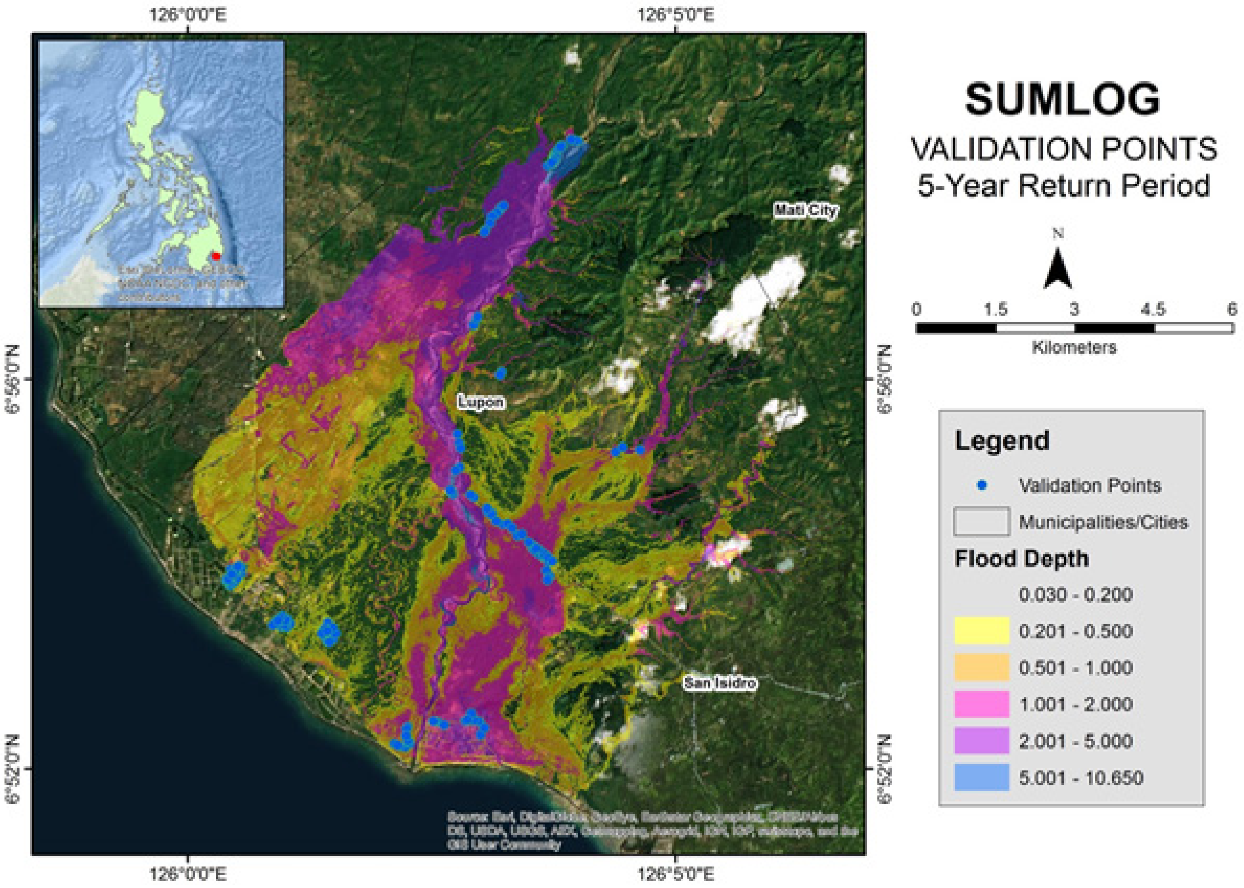



Figure 77. Sumlog Flood Validation Points.

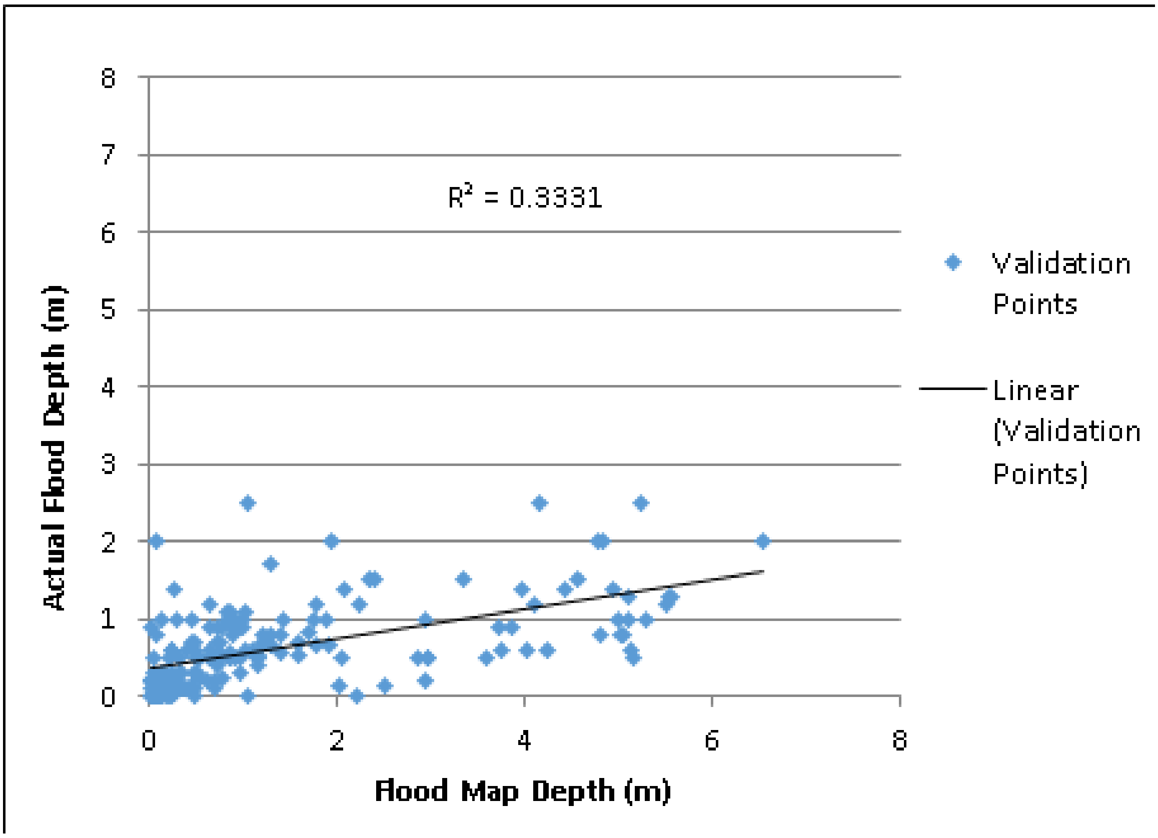



Figure 78. Flood map depth vs. actual flood depth.

Table 42. Actual Flood Depth vs Simulated Flood Depth in Sumlog.

| SUMLOG BASIN | | Modeled Flood Depth (m) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 0-0.20 | 0.21-0.50 | 0.51-1.00 | 1.01-2.00 | 2.01-5.00 | > 5.00 | Total |
| Actual Flood Depth (m) | 0-0.20 | 29 | 18 | 3 | 1 | 4 | 0 | 55 |
| | 0.21-0.50 | 4 | 6 | 17 | 2 | 4 | 1 | 34 |
| | 0.51-1.00 | 3 | 8 | 16 | 21 | 8 | 6 | 62 |
| | 1.01-2.00 | 1 | 1 | 3 | 4 | 12 | 5 | 26 |
| | 2.01-5.00 | 0 | 0 | 0 | 1 | 1 | 1 | 3 |
| | > 5.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total | 37 | 33 | 39 | 29 | 29 | 13 | 180 |

The overall accuracy generated by the flood model is estimated at 31.11%, with 56 points correctly matching the actual flood depths. In addition, there were 85 points estimated one level above and below the correct flood depths while there were 22 points and 17 points estimated two levels above and below, and three or more levels above and below the correct flood depth. A total of 103 points were overestimated while a total of 21 points were underestimated in the modelled flood depths of Sumlog.

Table 43. Summary of Accuracy Assessment in Sumlog.

| | No. of Points | % |
|---|---|---|
| Correct | 56 | 31.11 |
| Overestimated | 103 | 57.22 |
| Underestimated | 21 | 11.67 |
| Total | 180 | 100 |

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

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

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

# ANNEXES

## ANNEX 1. Technical Specifications of the Lidar Sensors Used In The Sumlog Floodplain Survey

1. GEMINI SENSOR


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

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

1. DVE-42

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

June 24, 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 ORIENTAL**
Station Name: **DVE-42**
Order: **2nd**

| | | |
|---|---|---|
| Island: **MINDANAO**<br>Municipality: **MATI (CAPITAL)** | | Barangay: **DON ENRIQUE LOPEZ** |
| | ***PRS92 Coordinates*** | |
| Latitude: **6° 58' 54.82726"** | Longitude: **126° 17' 56.05259"** | Ellipsoidal Hgt: **6.39500 m.** |
| | ***WGS84 Coordinates*** | |
| Latitude: **6° 58' 51.79295"** | Longitude: **126° 18' 1.57690"** | Ellipsoidal Hgt: **81.02500 m.** |
| | ***PTM Coordinates*** | |
| Northing: **772166.69 m.** | Easting: **643534.636 m.** | Zone: **5** |
| | ***UTM Coordinates*** | |
| Northing: **772,554.34** | Easting: **201,538.20** | Zone: **52** |

Location Description

DVE-42
"DVE-42" is in Barangay Don Enrique Lopez, Mati City, Davao Oriental. From Mati Proper, travel south for about 12 km. then turn left and continue travel for about 2.3 km. towards the Don Enrique Elem. School. Station is located at the Don Enrique Elem. School, 5 cm "SW" of the flagpole. Mark is the head of 4" copper nail embedded in a .30x0.30x1.0 m. concrete monument with inscription "DVE-42 2007 NAMRIA".

Requesting Party: **Engr. Cruz**
Pupose: **Reference**
OR Number: **8796376 A**
T.N.: **2014-1446**

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

2. DVE-61

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

July 11, 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 ORIENTAL**
Station Name: **DVE-61**
Order: **2nd**

Island: **MINDANAO**
Municipality: **MATI (CAPITAL)**
Barangay: **UPPER BLISS**
MSL Elevation:

***PRS92 Coordinates***

Latitude: **6° 57' 39.37336"** Longitude: **126° 13' 22.44550"** Ellipsoidal Hgt: **48.47400 m.**

***WGS84 Coordinates***

Latitude: **6° 57' 36.33777"** Longitude: **126° 13' 27.97256"** Ellipsoidal Hgt: **122.95300 m.**

***PTM / PRS92 Coordinates***

Northing: **769826.046 m.** Easting: **635140.8 m.** Zone: **5**

***UTM / PRS92 Coordinates***

Northing: **770,283.71** Easting: **193,120.25** Zone: **52**

Location Description

DVE-61
"DVE-61" is in Barangay Upper Bliss, Gov. Mati City, Davao Oriental. To reach the station travel for about 2.5 kms. from City Hall of mati, going east towards brgy. Zign, Mati City. Station is located at the center of the playground of Zign Elem. School, about 10 m "W" of school flagpole. Mark is the head of 4" copper nail embedded in a 0.30x0.30x1.0 m. concrete monument with inscription "DVE-61 2007 NAMRIA".

Requesting Party: **UP TCAGP / Engr. Christopher Cruz**
Pupose: **Reference**
OR Number: **8796507 A**
T.N.: **2014-1586**

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

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

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

1. DVE-3088

Processing Summary

| Observation | From | To | Solution Type | H. Prec. (Meter) | V. Prec. (Meter) | Geodetic Az. | Ellipsoid Dist. (Meter) | ΔHeight (Meter) |
|---|---|---|---|---|---|---|---|---|
| DVE-3088 --- DVE-42 (B1) | DVE-42 | DVE-3088 | Fixed | 0.001 | 0.002 | 160°37'05" | 8.200 | -0.026 |
| DVE-3088 --- DVE-42 (B2) | DVE-42 | DVE-3088 | Fixed | 0.001 | 0.002 | 160°36'35" | 8.199 | -0.029 |
| DVE-42 --- DVE-3088 (B3) | DVE-42 | DVE-3088 | Fixed | 0.001 | 0.002 | 160°36'48" | 8.202 | -0.036 |
| DVE-3088 --- DVE-42 (B4) | DVE-42 | DVE-3088 | Fixed | 0.001 | 0.002 | 160°40'50" | 8.200 | -0.031 |
| DVE-3088 --- DVE-42 (B5) | DVE-42 | DVE-3088 | Fixed | 0.001 | 0.001 | 160°40'52" | 8.202 | -0.036 |
| DVE-42 --- DVE-3088 (B6) | DVE-42 | DVE-3088 | Fixed | 0.001 | 0.001 | 160°40'53" | 8.203 | -0.034 |

Vector Components (Mark to Mark)

| From: | DVE-42 | | | | |
|---|---|---|---|---|---|
| Grid | | Local | | Global | |
| Easting | 201638.187 m | Latitude | N6°58'54.82727" | Latitude | N6°58'51.79296" |
| Northing | 772654.341 m | Longitude | E126°17'56.05259" | Longitude | E126°18'01.57690" |
| Elevation | 15.607 m | Height | 6.396 m | Height | 81.025 m |

| To: | DVE-3088 | | | | |
|---|---|---|---|---|---|
| Grid | | Local | | Global | |
| Easting | 201642.172 m | Latitude | N6°58'54.69466" | Latitude | N6°58'51.66037" |
| Northing | 772647.168 m | Longitude | E126°17'56.18365" | Longitude | E126°18'01.70797" |
| Elevation | 15.582 m | Height | 6.370 m | Height | 80.999 m |

| Vector | | | | | |
|---|---|---|---|---|---|
| ΔEasting | 3.986 m | NS Fwd Azimuth | 160°37'05" | ΔX | -3.741 m |
| ΔNorthing | -7.173 m | Ellipsoid Dist. | 8.200 m | ΔY | -1.703 m |
| ΔElevation | -0.026 m | ΔHeight | -0.026 m | ΔZ | -7.096 m |

Standard Errors

| Vector errors: | | | | | |
|---|---|---|---|---|---|
| σ ΔEasting | 0.001 m | σ NS fwd Azimuth | 0°00'12" | σ ΔX | 0.001 m |
| σ ΔNorthing | 0.000 m | σ Ellipsoid Dist. | 0.000 m | σ ΔY | 0.001 m |
| σ ΔElevation | 0.001 m | σ ΔHeight | 0.001 m | σ ΔZ | 0.000 m |

Aposteriori Covariance Matrix (Meter²)

| | X | Y | Z |
|---|---|---|---|
| X | 0.0000004144 | | |
| Y | -0.0000001656 | 0.0000005443 | |
| Z | -0.0000000528 | 0.0000000816 | 0.0000000908 |

2. DVE-3118

Processing Summary

| Observation | From | To | Solution Type | H. Prec. (Meter) | V. Prec. (Meter) | Geodetic Az. | Ellipsoid Dist. (Meter) | ΔHeight (Meter) |
|---|---|---|---|---|---|---|---|---|
| DVE-61 --- DVE-3118 (B7) | DVE-61 | DVE-3118 | Fixed | 0.017 | 0.060 | 222°57'30" | 8321.258 | 81.606 |
| DVE-61 --- DVE-3118 (B10) | DVE-61 | DVE-3118 | Fixed | 0.013 | 0.039 | 222°57'30" | 8321.245 | 81.578 |
| DVE-61 --- DVE-3118 (B11) | DVE-61 | DVE-3118 | Fixed | 0.017 | 0.043 | 222°57'29" | 8321.266 | 81.487 |

Vector Components (Mark to Mark)

| From: | DVE-61 | | | | |
|---|---|---|---|---|---|
| Grid | | Local | | Global | |
| Easting | 193120.234 m | Latitude | N6°57'39.37336" | Latitude | N6°57'36.33777" |
| Northing | 770283.711 m | Longitude | E126°13'22.44551" | Longitude | E126°13'27.97256" |
| Elevation | 57.158 m | Height | 48.473 m | Height | 122.953 m |

| To: | DVE-3118 | | | | |
|---|---|---|---|---|---|
| Grid | | Local | | Global | |
| Easting | 187409.531 m | Latitude | N6°54'21.10869" | Latitude | N6°54'18.08333" |
| Northing | 764222.331 m | Longitude | E126°10'17.73142" | Longitude | E126°10'23.26403" |
| Elevation | 138.503 m | Height | 129.978 m | Height | 204.433 m |

| Vector | | | | | |
|---|---|---|---|---|---|
| ΔEasting | -5710.703 m | NS Fwd Azimuth | 222°57'30" | ΔX | 4093.802 m |
| ΔNorthing | -6061.381 m | Ellipsoid Dist. | 8321.258 m | ΔY | 4007.271 m |
| ΔElevation | 81.345 m | ΔHeight | 81.505 m | ΔZ | -6036.086 m |

Standard Errors

| Vector errors: | | | | | |
|---|---|---|---|---|---|
| σ ΔEasting | 0.007 m | σ NS fwd Azimuth | 0°00'00" | σ ΔX | 0.015 m |
| σ ΔNorthing | 0.005 m | σ Ellipsoid Dist. | 0.006 m | σ ΔY | 0.021 m |
| σ ΔElevation | 0.025 m | σ ΔHeight | 0.025 m | σ ΔZ | 0.006 m |

Aposteriori Covariance Matrix (Meter²)

| | X | Y | Z |
|---|---|---|---|
| X | 0.0002242317 | | |
| Y | -0.0002729544 | 0.0004576374 | |
| Z | -0.0000517484 | 0.0000689019 | 0.0000341757 |

# Annex 4. The LiDAR Survey Team Composition

Table A-4.1. The LiDAR Survey Team Composition

| Data Acquisition Component Sub-Team | Designation | Name | Agency/ Affiliation |
|---|---|---|---|
| PHIL-LIDAR 1 | Program Leader | ENRICO C. PARINGIT, D.ENG | UP-TCAGP |
| Data Acquisition Component Leader | Data Component Project Leader – I | ENGR. CZAR JAKIRI SARMIENTO | UP-TCAGP |
| | Chief Science Research Specialist (CSRS) | ENGR. CHRISTOPHER CRUZ | UP-TCAGP |
| Survey Supervisor | Supervising Science Research Specialist (Supervising SRS) | ENGR. LOVELYN ASUNCION | UP-TCAGP |
| | | LOVELY GRACIA ACUÑA | UP-TCAGP |
| FIELD TEAM | | | |
| LiDAR Operation | Senior Science Research Specialist (SSRS) | JULIE PEARL MARS | UP-TCAGP |
| | Research Associate (RA) | FOR. MA. VERLINA TONGA | UP-TCAGP |
| | RA | ENGR. LARAH KRISELLE PARAGAS | UP-TCAGP |
| Ground Survey, Data Download and Transfer | RA | ENGR. KENNETH QUISADO | PHILIPPINE AIR FORCE (PAF) |
| LiDAR Operation | Airborne Security | TSG. MIKE DIAPANA | ASIAN AEROSPACE CORPORATION (AAC) |
| | Pilot | CAPT. RAUL CZ SAMAR II | AAC |
| | | CAPT. BRYAN JOHN DONGUINES | |

# ANNEX 5. Data Transfer Sheet for Sumlog Floodplain

DATA TRANSFER SHEET
06/28/2014DAVAO ORIENTAL - rearly1

| 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 | |
| 6/18/2014 | 7318GC* | 2BLK84A169A | GEMINI | NA | 217 | 6.21 | 217 | 17.3 | 106KB | 17.8 | NA | 4.86 | 1KB | 2KB | 3 | 9 | Z:\Airborne_Raw\7318GC |
| 6/19/2014 | 7320G | 2BLK83A8483170A | GEMINI | NA | 116/38 | 330 | 224 | na | na | 13.3 | NA | 3.82 | 1KB | 1KB | 4 | NA | Z:\Airborne_Raw\7320GC |
| 6/20/2014 | 7322G | 2BLK84AS86B171A | GEMINI | NA | 405 | 524 | 242 | na | na | 22 | NA | 4.86 | 1KB | 1KB | 6 | 9 | Z:\Airborne_Raw\7322GC |
| 6/20/2014 | 7323G | 2BLK86C83A171B | GEMINI | NA | 393/191 | 509 | 244 | na | na | 20.4 | NA | 5.26 | 1KB | 1KB | 4 | na | Z:\Airborne_Raw\7323GC |
| 6/22/2014 | 7326G | 2BLK80B173A | GEMINI | NA | 335 | 533 | 282 | na | na | 23.4 | NA | 7 | 1KB | 1KB | 4 | 9 | Z:\Airborne_Raw\7326G |
| 6/23/2014 | 7328GC* | 2BLK80A8174A | GEMINI | NA | na | 582 | 239 | 913 | 177kb | 20.9 | NA | 5.81 | 1KB | 1KB | 8 | na | Z:\Airborne_Raw\7328GC |

Received from:

Name: C. Joaquin
Position:
Signature:

Received by:

Name: LIDA F. PRIETO
Position:
Signature:
07/03/2014

*PRIORITY FLIGHTS WITH CASI DATA

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 | |
| 6/27/2014 | 7337GC | 2BLK86A178A | Gemini | NA | 209/70 | 366 | 163 | NA | NA | 16.9 | NA | 7.59 | 1KB | 1KB | 4/4/5/5/5/4 | 24 | Z:\Airborne_Raw\7337GC |
| 6/28/2014 | 7339GC | 2BLK79C179A | Gemini | NA | 179/11 | 367 | 74.8 | NA | NA | 14.3 | NA | 5.08 | 1KB | 1KB | 5 | 179/11 | Z:\Airborne_Raw\7339GC |
| 6/29/2014 | 7340GC | 2BLK79B180A | Gemini | NA | 119 | 580 | 265 | NA | NA | 28.2 | NA | 4.68 | 1KB | 1KB | 5 | 119 | Z:\Airborne_Raw\7339 |
| 7/1/2014 | 7344GC | 2BLK84B182A | Gemini | NA | 158/22 | 188 | 174 | NA | NA | 2.90/6.69 | NA | 6.95 | 1KB | 1KB | 9 | 158/22 | Z:\Airborne_Raw\1634A |
| 7/2/2014 | 7346GC | 2BLK79BSA183A | Gemini | NA | 376 | 612 | 279 | NA | NA | 29.7 | NA | 5.32 | 1KB | 1KB | 9 | 376 | Z:\Airborne_Raw\1636A |
| 7/3/2014 | 7348GC | 2BLK79V184A | Gemini | NA | 597 | 200 | 212 | NA | NA | 6.58 | NA | 6.49 | 1KB | 1KB | 14 | 597 | Z:\Airborne_Raw\1636A |
| 7/4/2014 | 7350GC | 2BLK85B185A | Gemini | NA | 300 | 499 | 258 | NA | NA | 23.8 | NA | 7.05 | 1KB | 1KB | 8 | 300 | Z:\Airborne_Raw\1636A |

Received from

Name Kristine Andaya
Position R.A.
Signature

Received by

Name ..IDA F. PRIETO
Position SSRS
Signature 7/14/14

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 | |
| 7/7/2014 | 7356GC | 2BLK80AS188A | Gemini | NA | 347/11 | 589 | 265 | NA | NA | 27.7 | NA | 9.58 | 1KB | 1KB | 4 | 374/11 | Z:\Airborne_Raw |
| 7/7/2014 | 7357GC | 2BLK80BS188B | Gemini | NA | 406 | 111 | 79.8 | NA | NA | 5.05 | NA | 7.68 | 1KB | 1KB | 4 | 406 | Z:\Airborne_Raw |
| 7/8/2014 | 7358GC | 2BLK80BS189A | Gemini | NA | 165/7/14 | 318 | 196 | NA | NA | 20.1 | | 4.83 | 1KB | 1KB | 7/3 | 165/7/14 | Z:\Airborne_Raw |
| 7/10/2014 | 7362GC | 2BLK85CS191A | Gemini | NA | 138 | 244 | 188 | NA | NA | 7.95 | NA | 4.7 | 1KB | 1KB | 8/5/4 | 138 | Z:\Airborne_Raw |
| 7/11/2014 | 7364GC | 2BLK85V192A | Gemini | NA | 234/9/12 | 488 | 207 | NA | NA | 27.3 | NA | 5.8 | 1KB | 1KB | 4/9 | 234/9/12 | Z:\Airborne_Raw |
| 7/12/2014 | 7366GC | 2BLK79D80BV193A | Gemini | NA | 60 | 409 | 241 | NA | NA | 12.2 | NA | 4.89 | 1KB | 1KB | 5/7 | 14/17 | Z:\Airborne_Raw |
| 7/15/2014 | 7372GC | 2BLK79E196A | Gemini | NA | 30/6 | 68.7 | 158 | NA | NA | 3.47 | NA | 4.56 | 1KB | 1KB | 3 | 30/6 | Z:\Airborne_Raw |
| 7/16/2014 | 7374GC | 2BLK79ES197A | Gemini | NA | 139 | 239 | 156 | NA | NA | 9.01 | NA | 3.42 | 1KB | 1KB | 3/4 | 139 | Z:\Airborne_Raw |

Received from

Name TIN ANYTANA
Position
Signature KAJ

Received by

Name JOIDA F. PRIETO
Position SSRS
Signature 7/28/14

# Annex 6. Flight logs for the flight missions

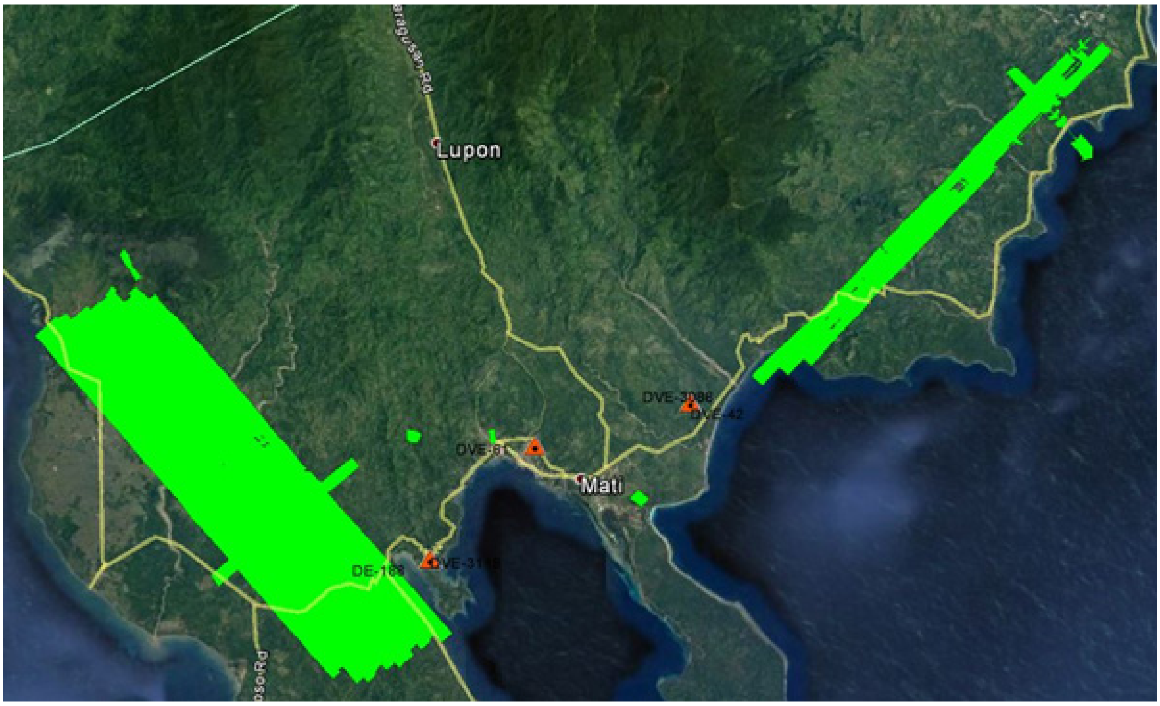
# Annex 7. Flight status reports

**DAVAO ORIENTAL**
**(June 16 - July 16, 2014)**

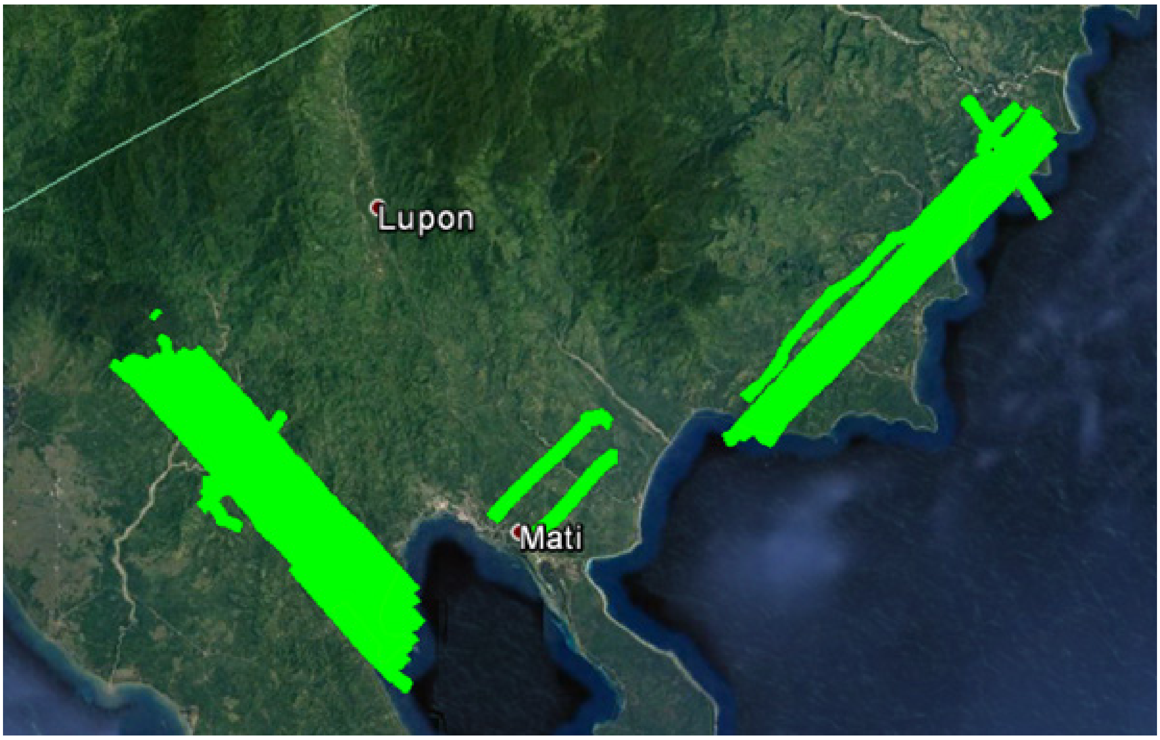
| FLIGHT NO. | AREA | MISSION | OPERATOR | DATE FLOWN | REMARKS |
|---|---|---|---|---|---|
| 7322GC | BLK83A, BLK86B | 2BLK84AS&-86B171A (BLK83A instead of BLK84A) | MV TONGA | June 20, 2014 | BLK 83A (3 lines). Moved to 86B (13 lines) |
| 7323GC | BLK86C, BLK83A BLK84B | 2BLK-86C&83A171B (additional BLK84B) | LK PARAGAS | June 20, 2014 | Surveyed BLK84B then moved to BLK86C due to rain, however; after surveying 10 lines, rain started to pour and moved to BLK83A. |
| 7337GC | BLK86A | 2BLK86A178A | LK PARAGAS | June 27, 2014 | Surveyed 12 lines at 1000m |
| 7364GC | BLK 85A | 2BLK85V192A | MV TONGA | July 11, 2014 | Covered BLK85A and voids of BLK84A and BLK83A |

**LAS BOUNDARIES PER FLIGHT**

Flight No. : 7322GC
Area: BLK83A & BLK86B
Mission name: 2BLK84AS86B171A (BLK83A instead of BLK84A)
Parameters: Altitude: 1100 m; Scan Frequency: 50 Hz;
FOV: 40 deg; Overlap: 30 %
Area covered: 209.19 km2

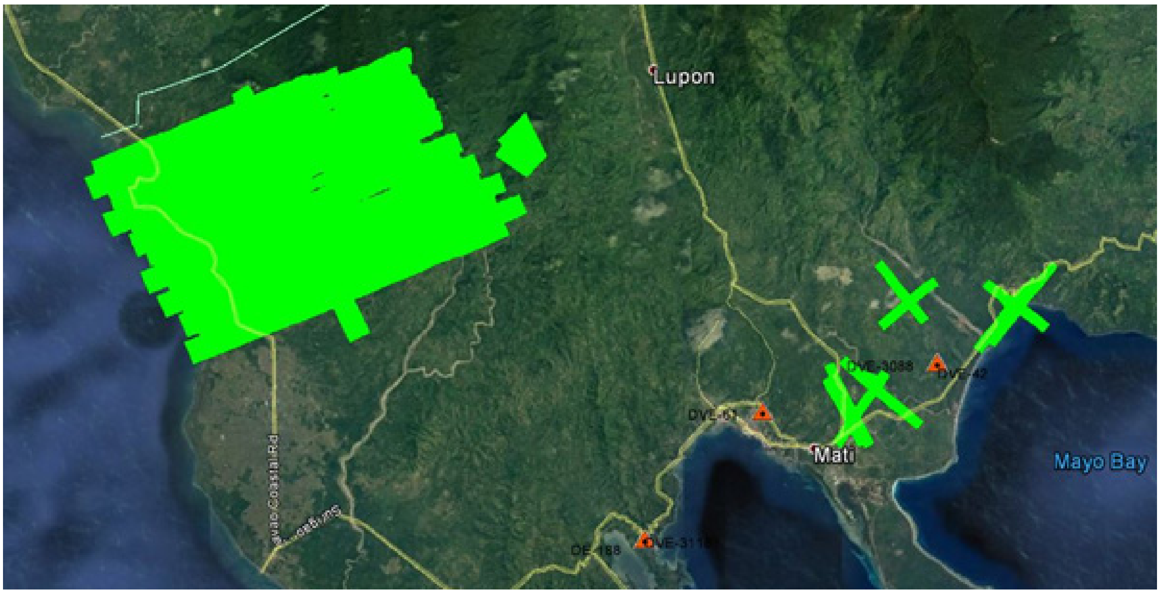


| | | |
|---|---|---|
| Flight No. : | 7323GC | |
| Area: | BLK86C, BLK83A & BLK84B | |
| Mission name: | 2BLK86C83A171B (additional BLK84B) | |
| Parameters: | Altitude: 1100 and 1250 m; | Scan Frequency: 50 Hz; |
| FOV: 40 and 36 deg; | Overlap: 30 % | |
| Area covered: | 214.08 km2 | |



| | | |
|---|---|---|
| Flight No. : | 7337GC | |
| Area: | BLK86A | |
| Mission name: | 2BLK86A178A | |
| Parameters: | Altitude: 1100 m; | Scan Frequency: 50 Hz; |
| FOV: 40 deg; | Overlap: 30 % | |
| Area covered: | 176.23 km2 | |

| | | |
|---|---|---|
| Flight No. : | 7364GC | |
| Area: | BLK85A | |
| Mission name: | 2BLK85V192A | |
| Parameters: | Altitude: 1600 and 1300 m; | Scan Frequency: 50 and 60 Hz; |
| FOV: 40 and 24 deg; | Overlap: 40 % | |
| Area covered: | 195.19 km2 | |



## ANNEX 8. Mission Summary Reports

| | |
|---|---|
| Flight Area | Davao Oriental |
| Mission Name | Blk86A |
| Inclusive Flights | 7337G |
| Range data size | 16.9 GB |
| POS | 163 MB |
| Image | na |
| Transfer date | July 14, 2014 |
| | |
| Solution Status | |
| Number of Satellites (>6) | Yes |
| PDOP (<3) | Yes |
| Baseline Length (<30km) | Yes |
| Processing Mode (<=1) | Yes |
| | |
| Smoothed Performance Metrics (in cm) | |
| RMSE for North Position (<4.0 cm) | 1.2 |
| RMSE for East Position (<4.0 cm) | 1.85 |
| RMSE for Down Position (<8.0 cm) | 2.55 |
| | |
| Boresight correction stdev (<0.001deg) | 0.000467 |
| IMU attitude correction stdev (<0.001deg) | 0.000774 |
| GPS position stdev (<0.01m) | 0.0020 |
| | |
| Minimum % overlap (>25) | 15.66% |
| Ave point cloud density per sq.m. (>2.0) | 2.66 |
| Elevation difference between strips (<0.20 m) | Yes |
| | |
| Number of 1km x 1km blocks | 230 |
| Maximum Height | 719.63 m |
| Minimum Height | 66.82 m |
| | |
| Classification (# of points) | |
| Ground | 101343254 |
| Low vegetation | 114062832 |
| Medium vegetation | 132213048 |
| High vegetation | 300594147 |
| Building | 3964197 |
| | |
| Orthophoto | No |
| Processed by | Engr. Kenneth Solidum, Engr. Angelo Carlo Bongat, Aljon Rei Araneta, Engr. Gladys Mae Apat |

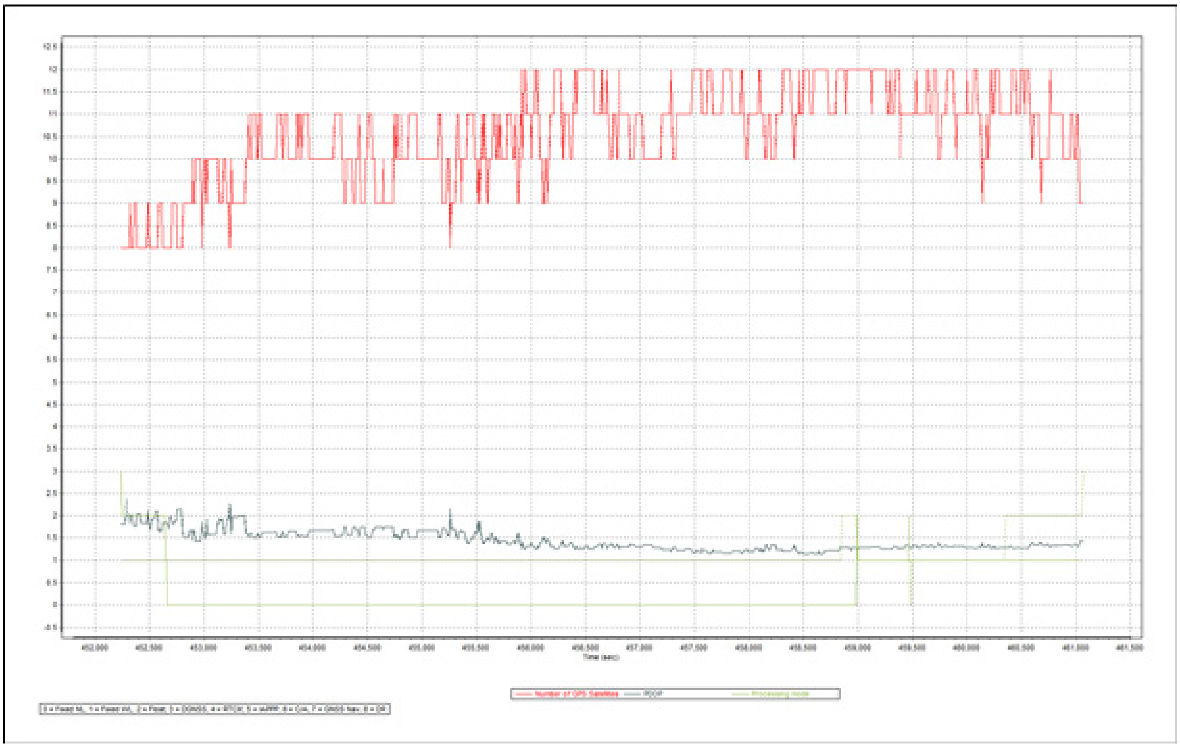


Figure 1.1.1 Solution Status

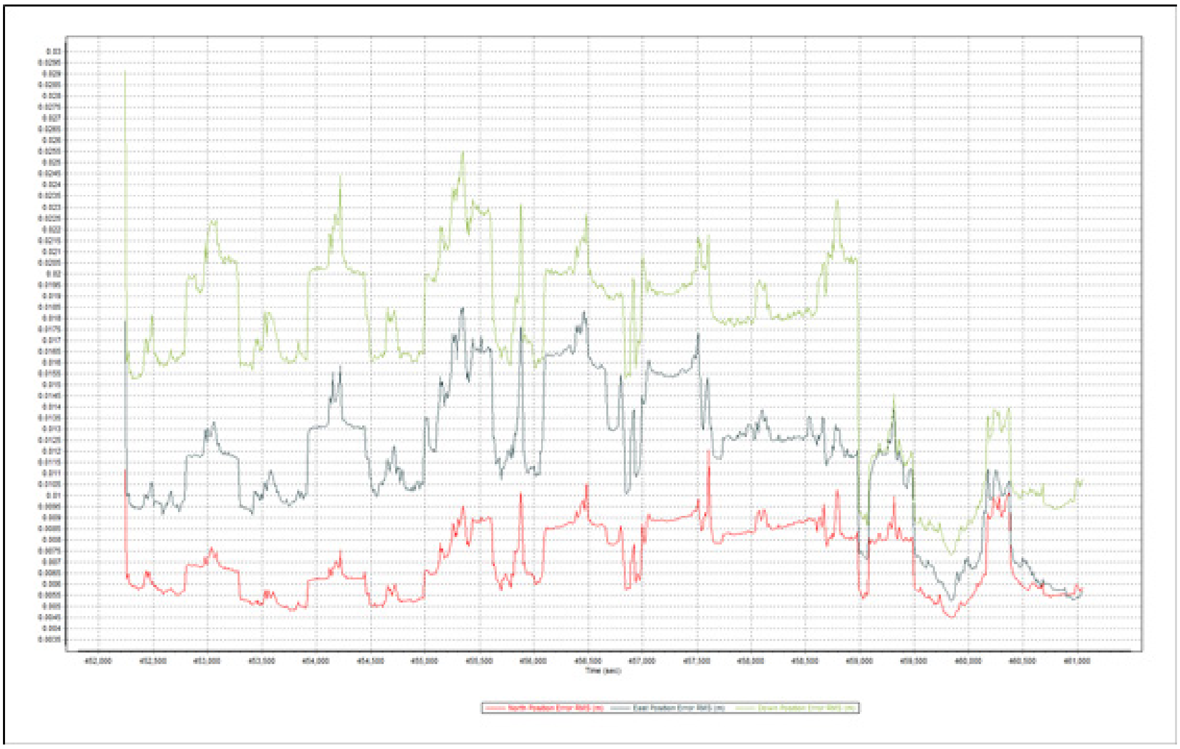


Figure 1.1.2 Smoothed Performance Metric Parameters

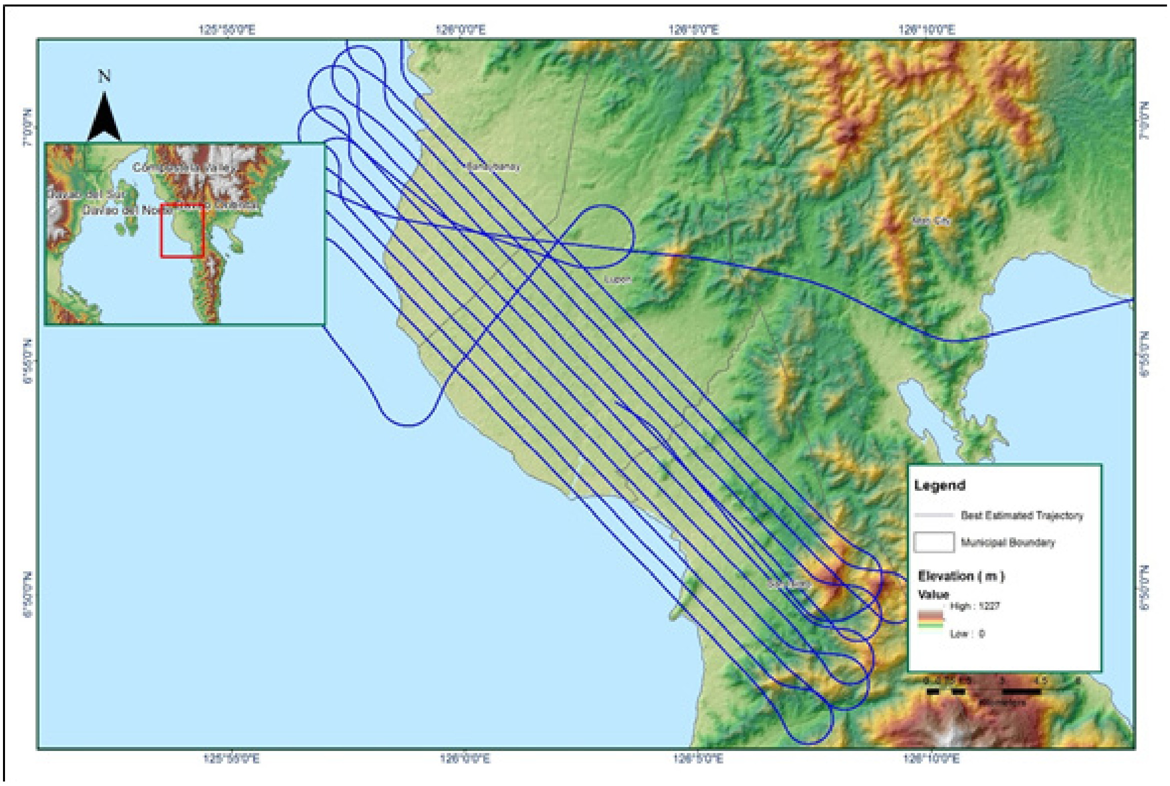



Figure 1.1.3 Best Estimated Trajectory

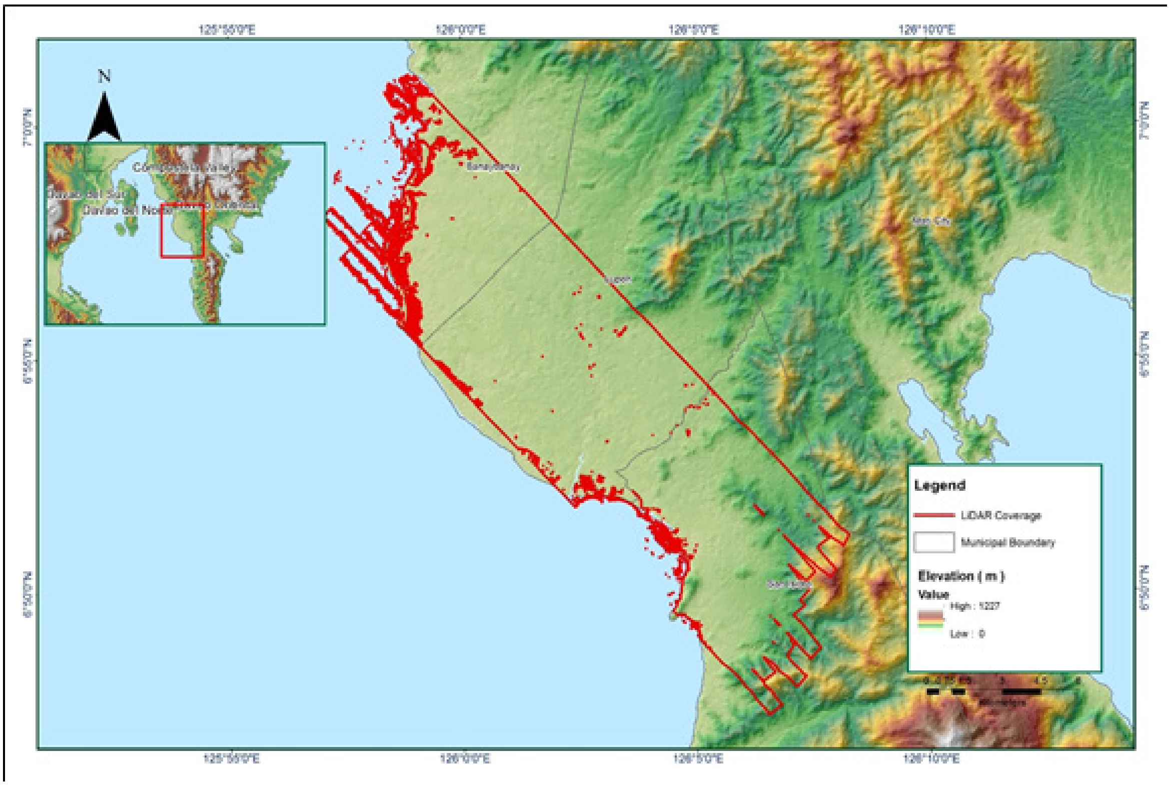



Figure 1.1.4 Coverage of LiDAR data

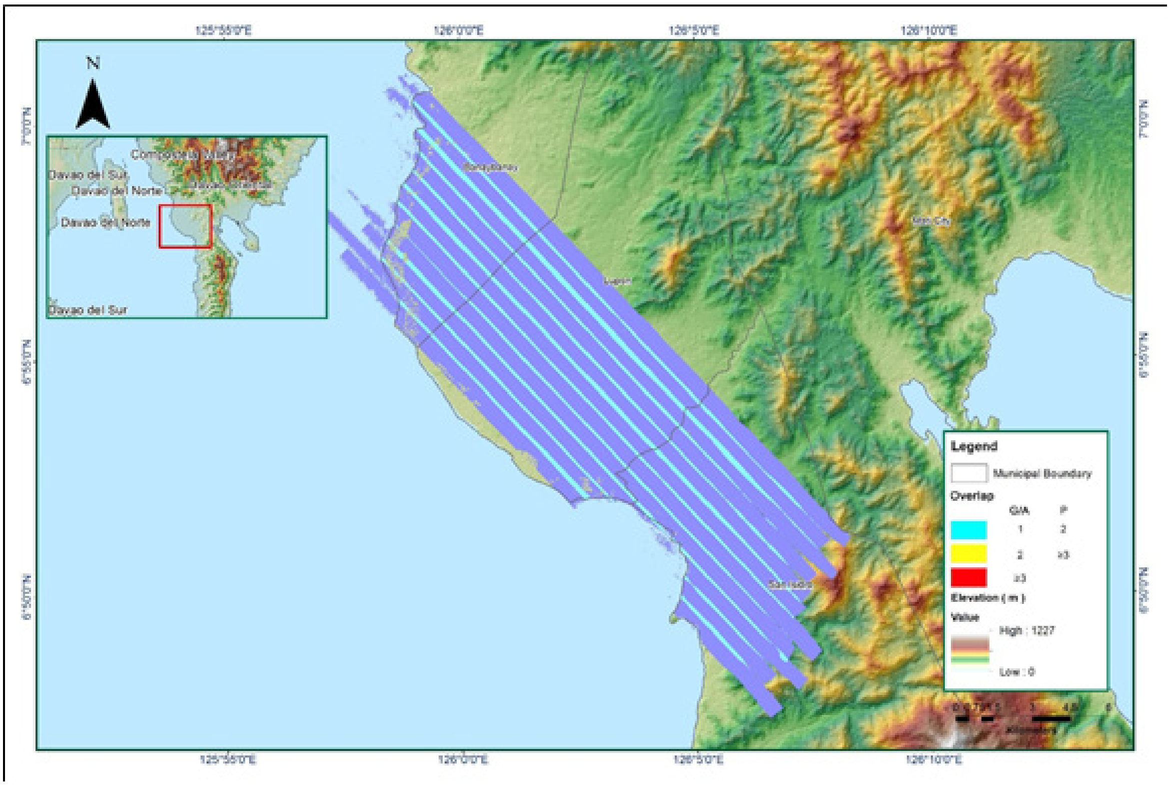


Figure 1.1.5 Image of data overlap

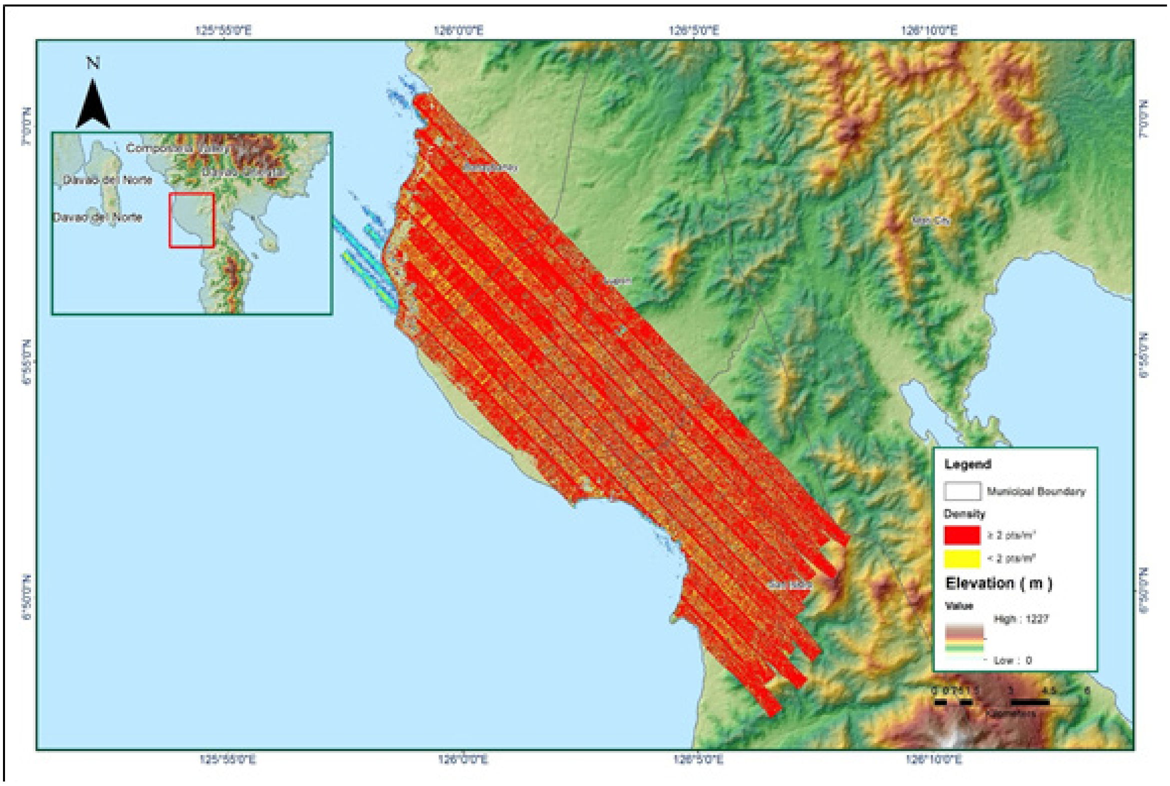


Figure 1.1.6 Density map of merged LiDAR data

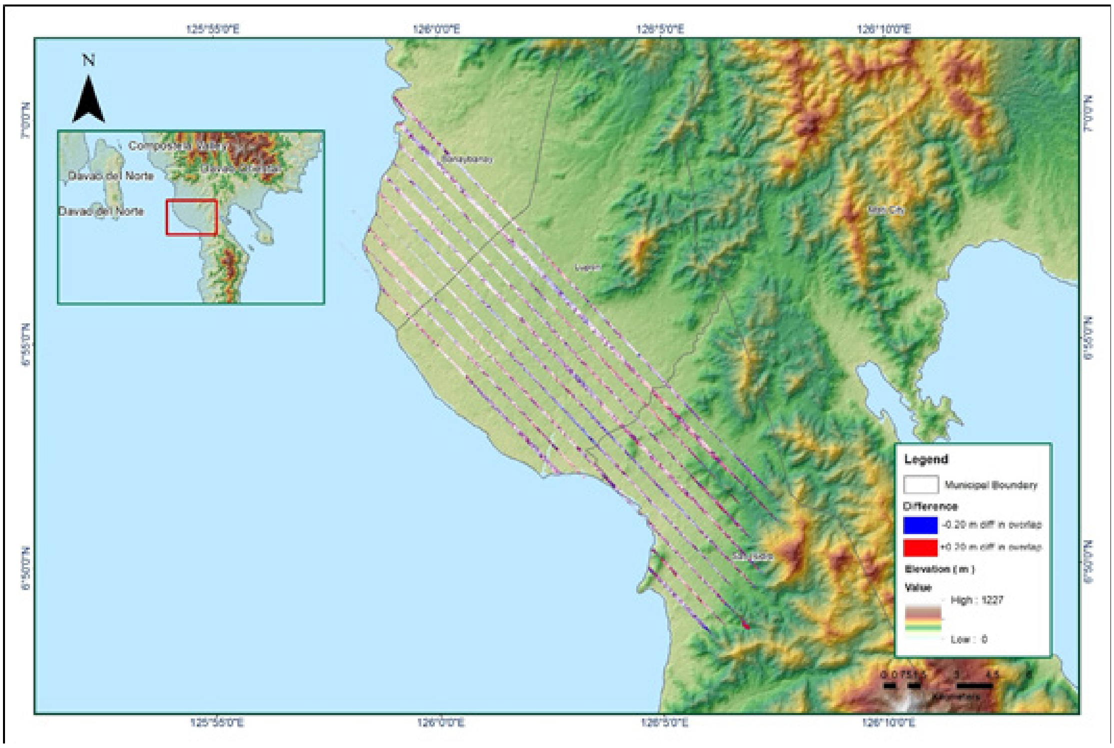



Figure 1.1.7 Elevation difference between flight lines

| | |
|---|---|
| Flight Area | Davao Oriental |
| Mission Name | Blk86A_additional |
| Inclusive Flights | 7364G |
| Range data size | 27.3 GB |
| POS | 207 MB |
| Image | na |
| Transfer date | July 28, 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) | 0.094 |
| RMSE for East Position (<4.0 cm) | 1.4 |
| RMSE for Down Position (<8.0 cm) | 3.1 |
| | |
| Boresight correction stdev (<0.001deg) | 0.000830 |
| IMU attitude correction stdev (<0.001deg) | 0.198724 |
| GPS position stdev (<0.01m) | 0.0294 |
| | |
| Minimum % overlap (>25) | 35.88% |
| Ave point cloud density per sq.m. (>2.0) | 1.96 |
| Elevation difference between strips (<0.20 m) | Yes |
| | |
| Number of 1km x 1km blocks | 217 |
| Maximum Height | 1040.91 m, |
| Minimum Height | 67.12 m |
| | |
| Classification (# of points) | |
| Ground | 20054320 |
| Low vegetation | 8107427 |
| Medium vegetation | 37709027 |
| High vegetation | 194858525 |
| Building | 872672 |
| | |
| Orthophoto | No |
| Processed by | Engr. Kenneth Solidum, Engr. Harmond Santos, Engr. Roa Shalemar Redo |

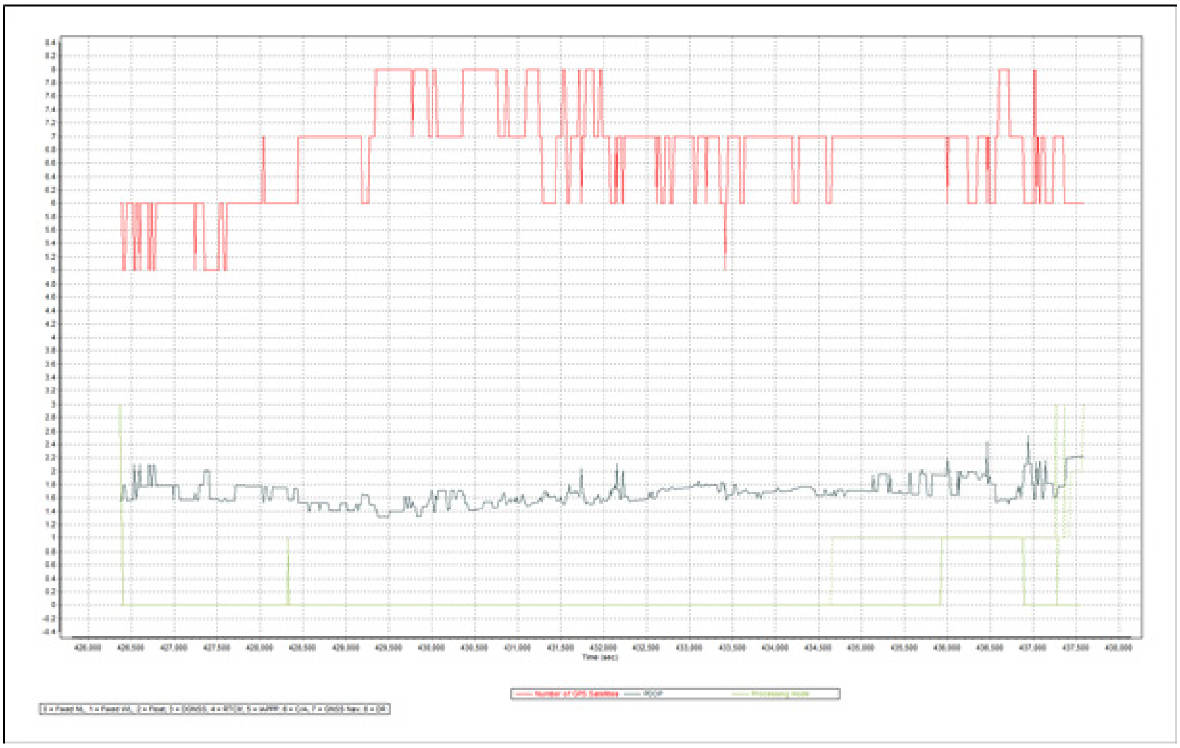


Figure 1.2.1 Solution Status

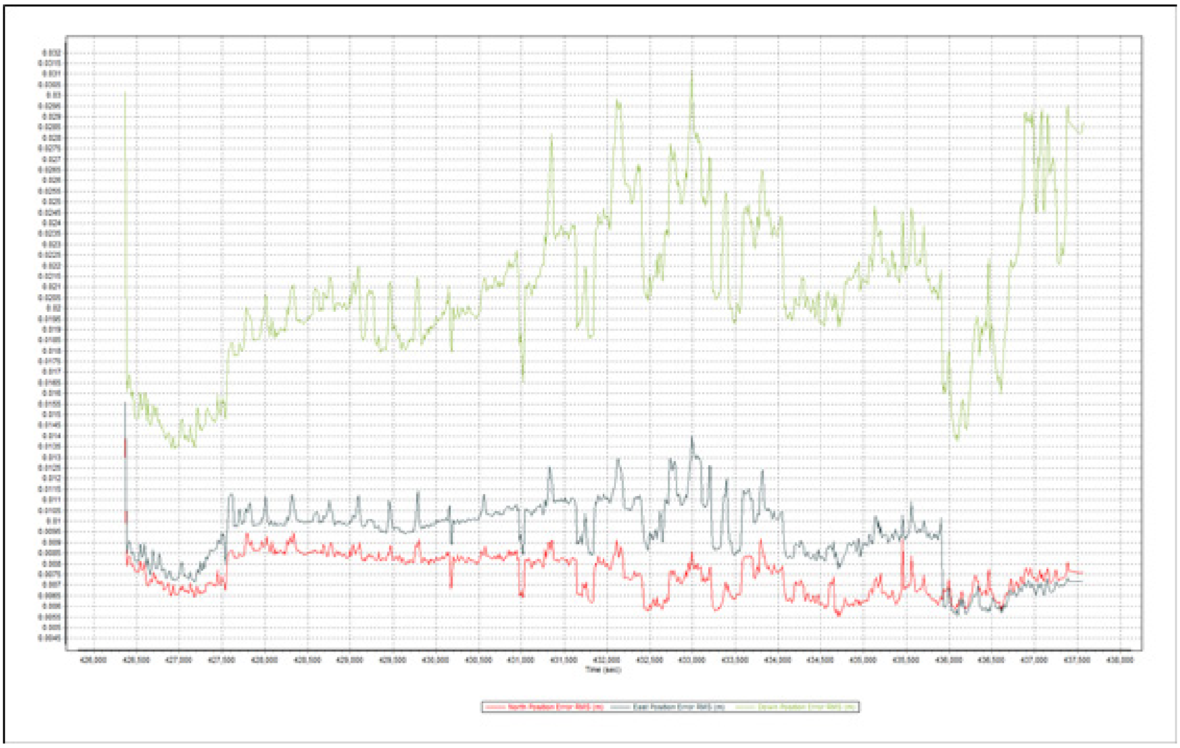


Figure 1.2.2 Smoothed Performance Metric Parameters

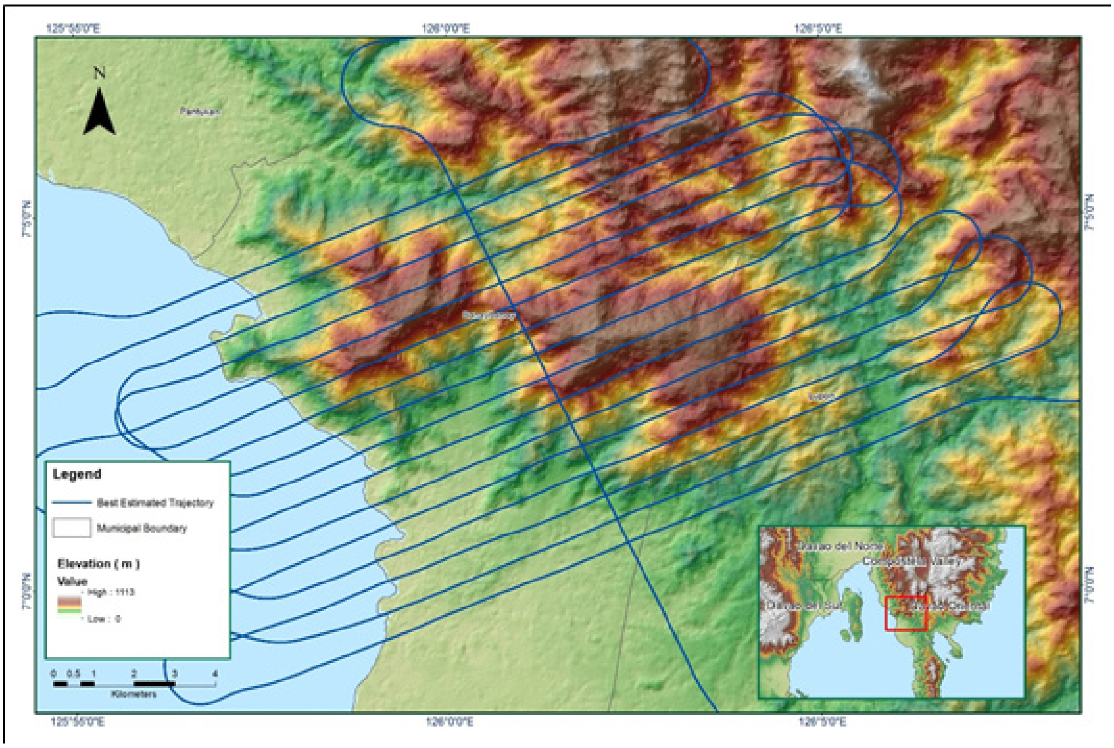



Figure 1.2.3 Best Estimated Trajectory

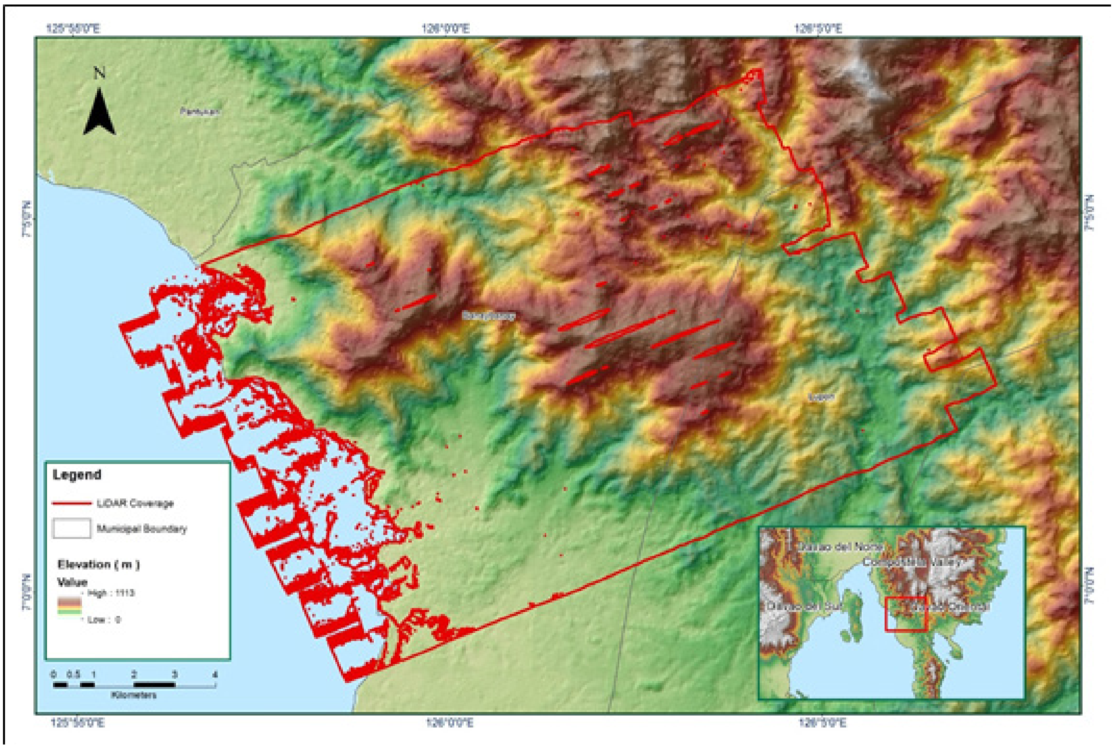



Figure 1.2.4 Coverage of LiDAR data

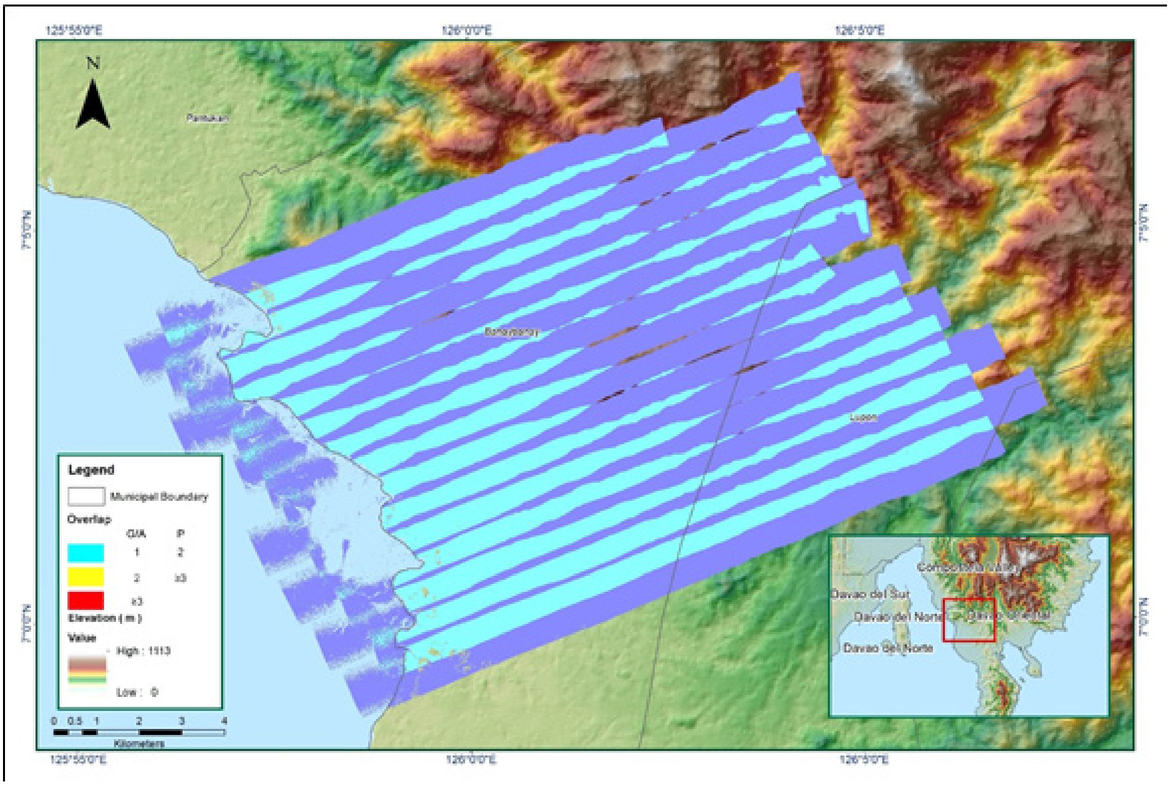



Figure 1.2.5 Image of data overlap

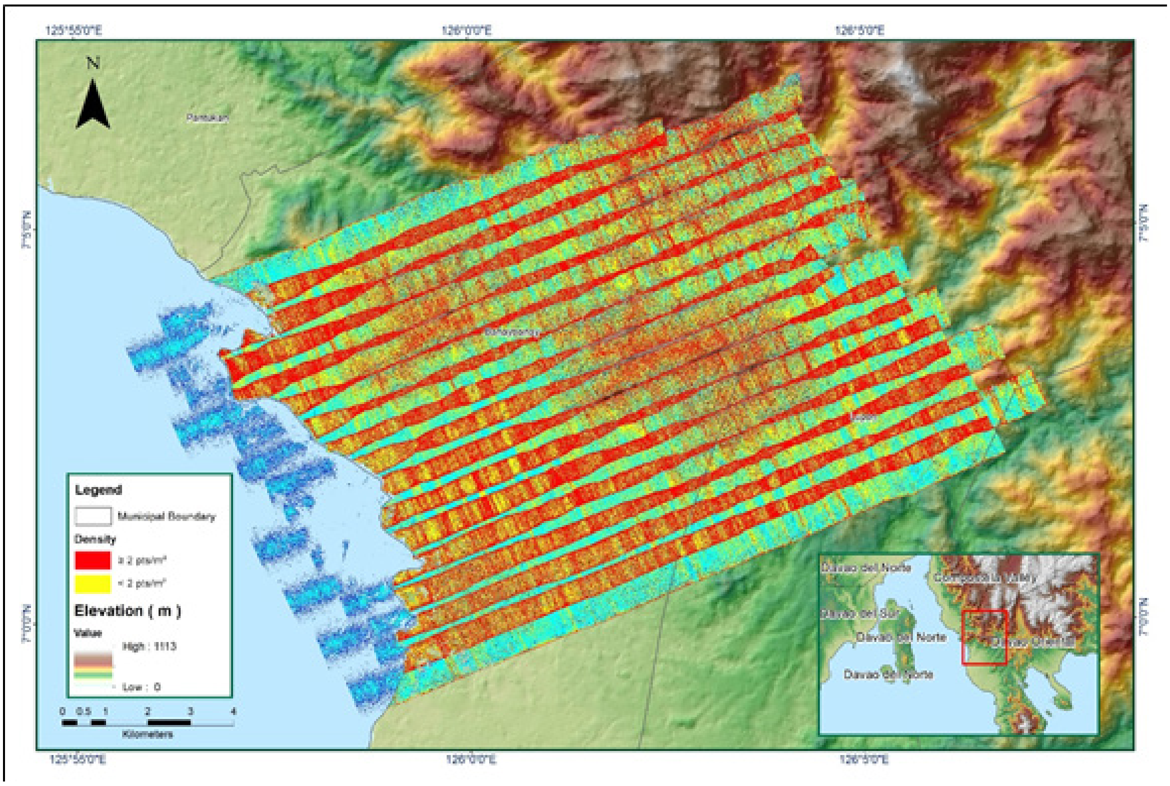



Figure 1.2.6 Density map of merged LiDAR data

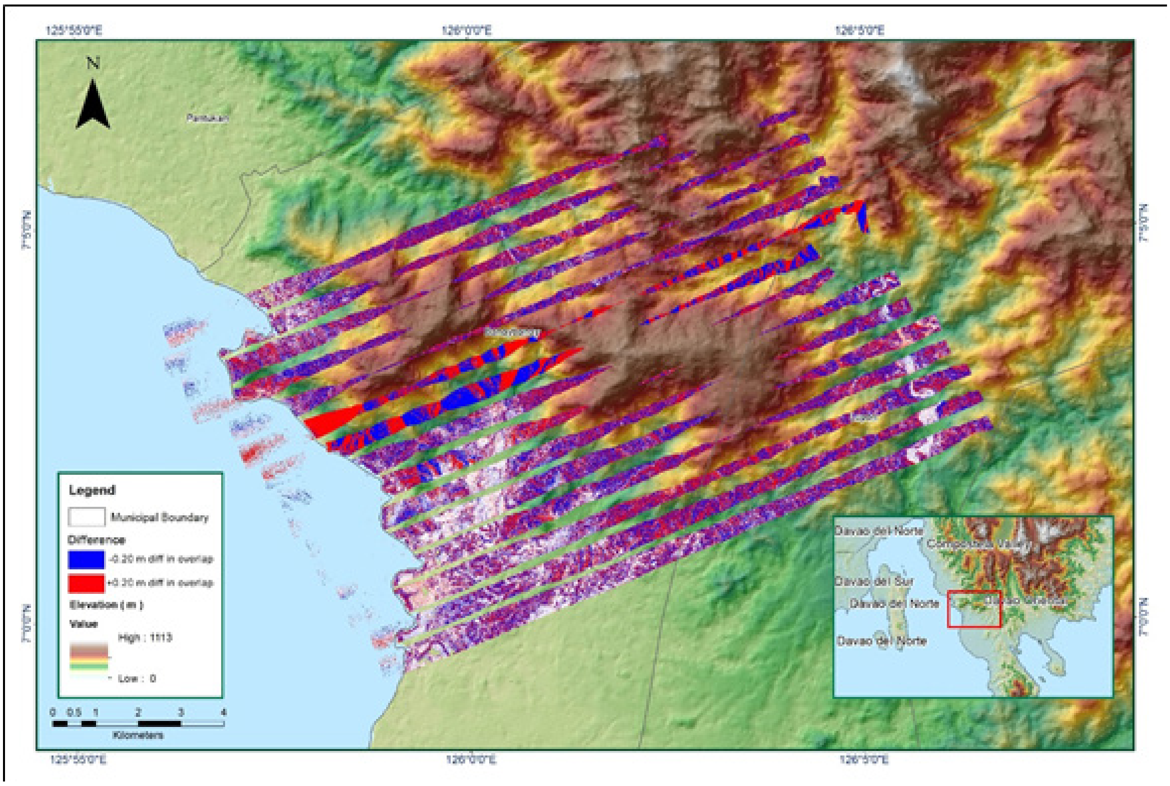



Figure 1.2.7 Elevation difference between flight lines

| | |
|---|---|
| Flight Area | Davao Oriental |
| Mission Name | Blk86B |
| Inclusive Flights | 7322G |
| Range data size | 23.0 GB |
| POS | 242 MB |
| Image | na |
| Transfer date | July 2, 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) | 1.1 |
| RMSE for East Position (<4.0 cm) | 1.46 |
| RMSE for Down Position (<8.0 cm) | 2.6 |
| | |
| Boresight correction stdev (<0.001deg) | 0.000188 |
| IMU attitude correction stdev (<0.001deg) | 0.001441 |
| GPS position stdev (<0.01m) | 0.0027 |
| | |
| Minimum % overlap (>25) | 33.62% |
| Ave point cloud density per sq.m. (>2.0) | 3.30 |
| Elevation difference between strips (<0.20 m) | Yes |
| | |
| Number of 1km x 1km blocks | 16 |
| Maximum Height | 374.79 m |
| Minimum Height | 88.63 m |
| | |
| Classification (# of points) | |
| Ground | 5850713 |
| Low vegetation | 5128592 |
| Medium vegetation | 8580789 |
| High vegetation | 23883495 |
| Building | 100524 |
| | |
| Orthophoto | No |
| Processed by | Engr. Irish Cortez, Engr. Melanie Hingpit, Engr. Analyn Naldo, Engr. Gladys Mae Apat |

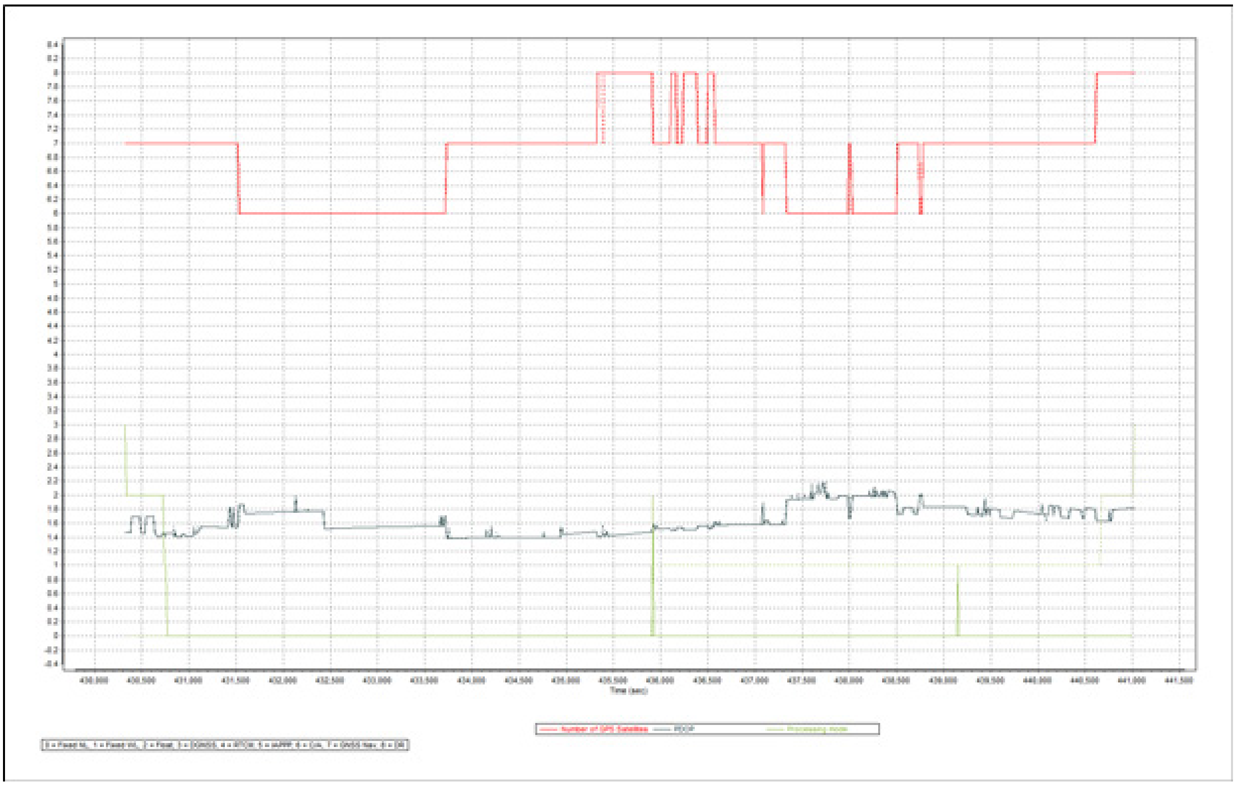


Figure 1.3.1 Solution Status

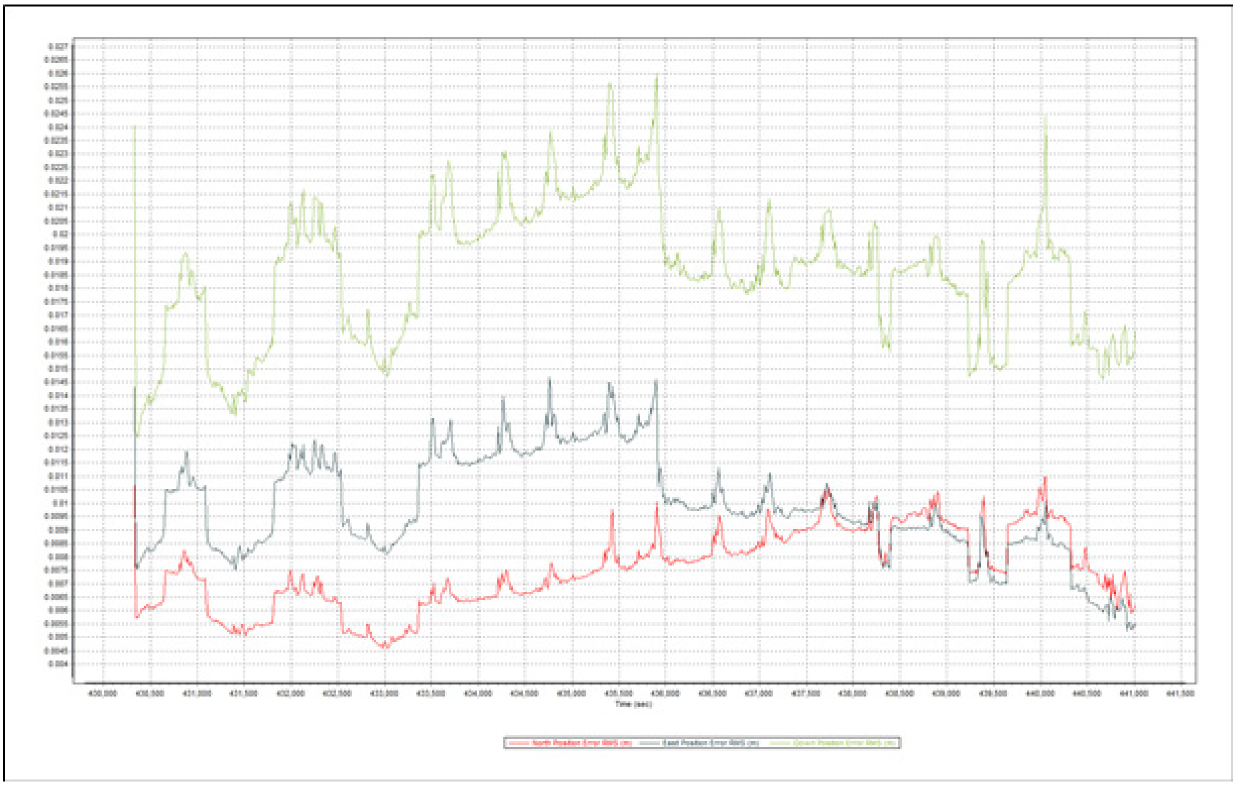


Figure 1.3.2 Smoothed Performance Metric Parameters

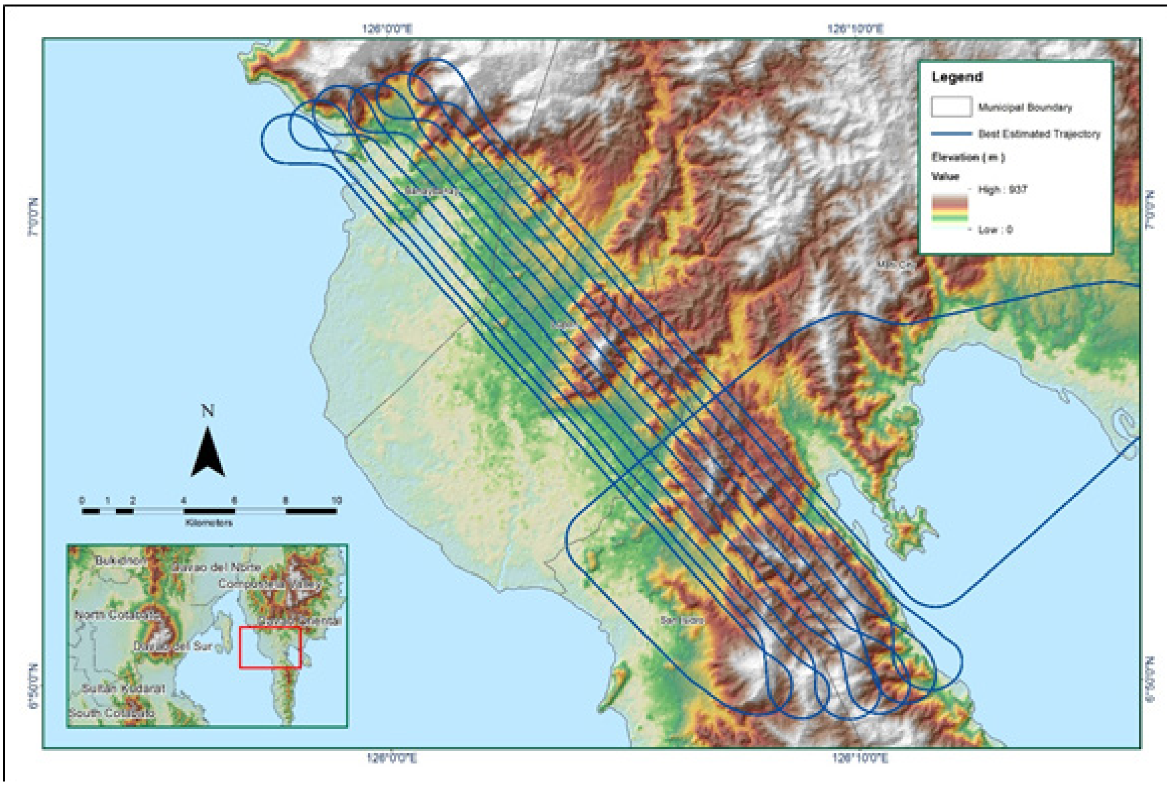



Figure 1.3.3 Best Estimated Trajectory

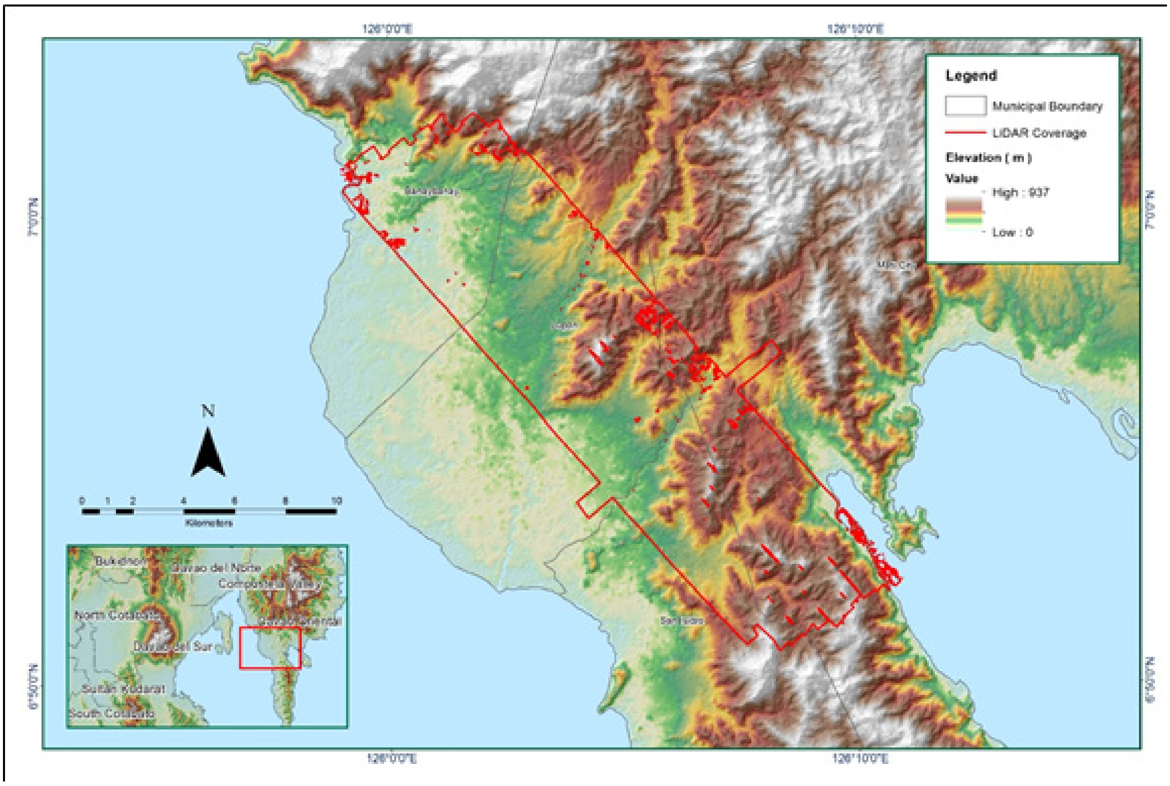



Figure 1.3.4 Coverage of LiDAR data

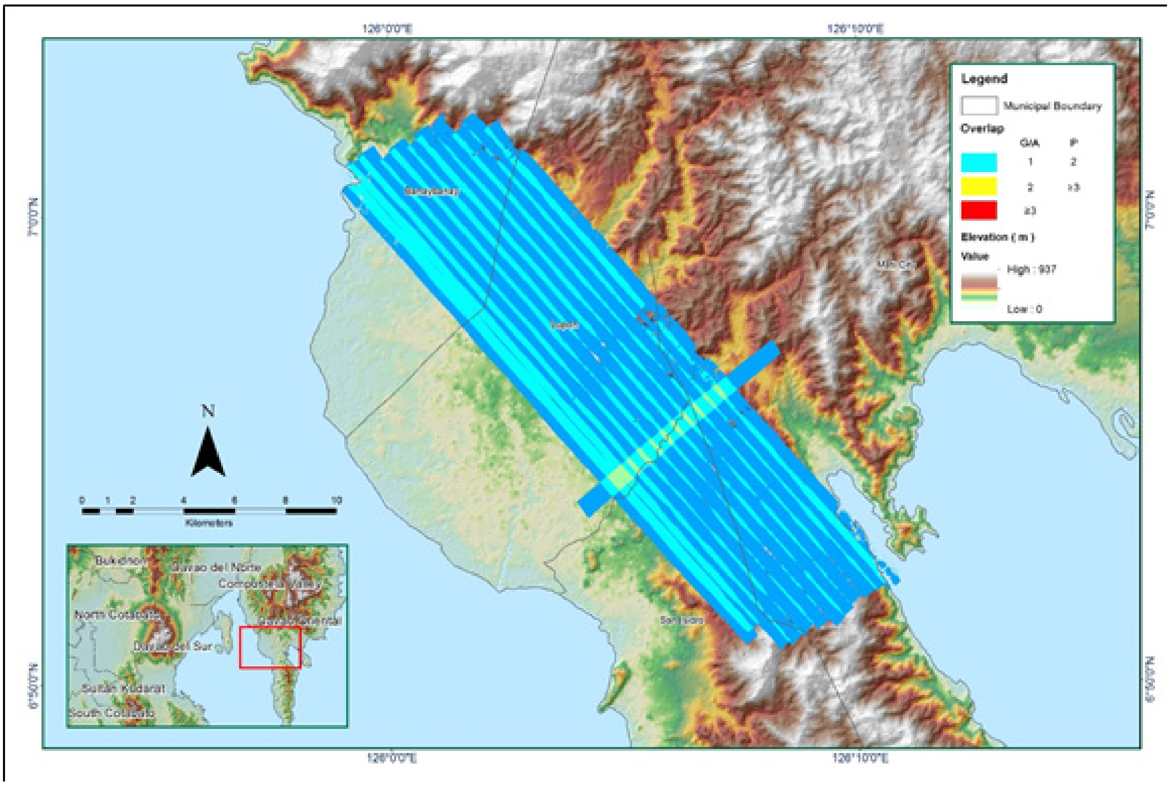



Figure 1.3.5 Image of data overlap

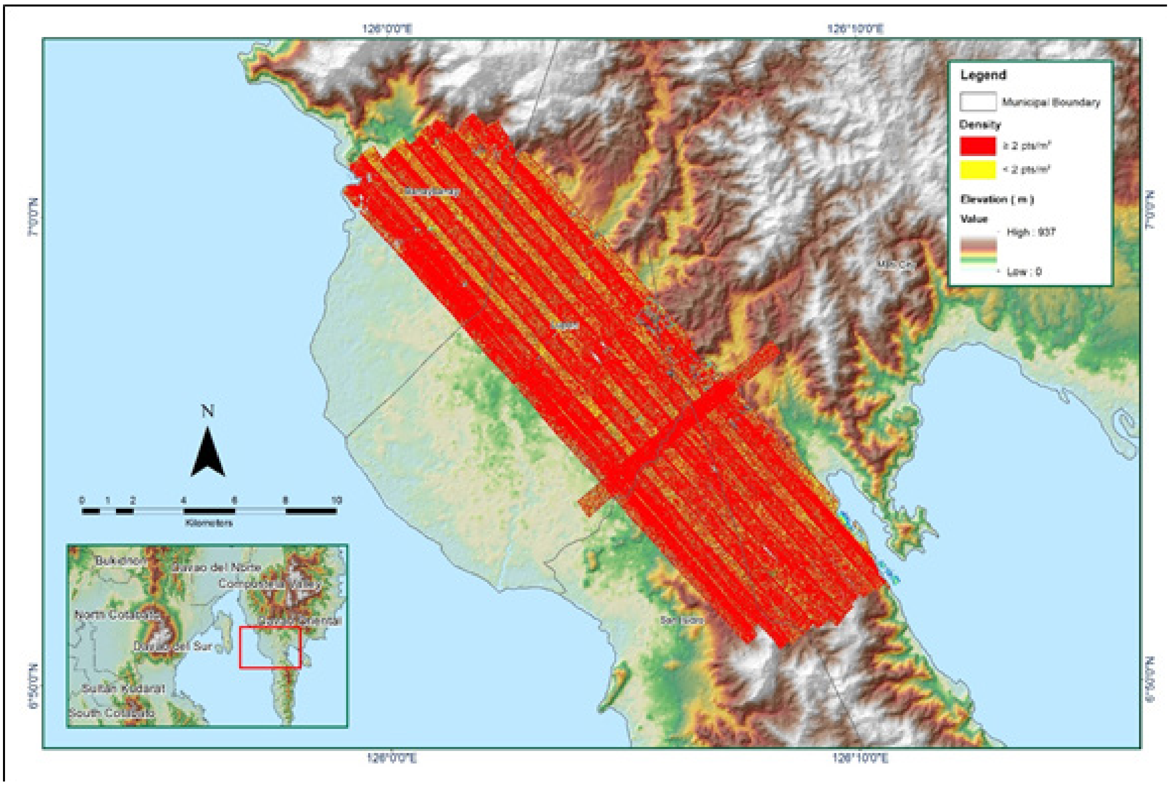



Figure 1.3.6 Density map of merged LiDAR data

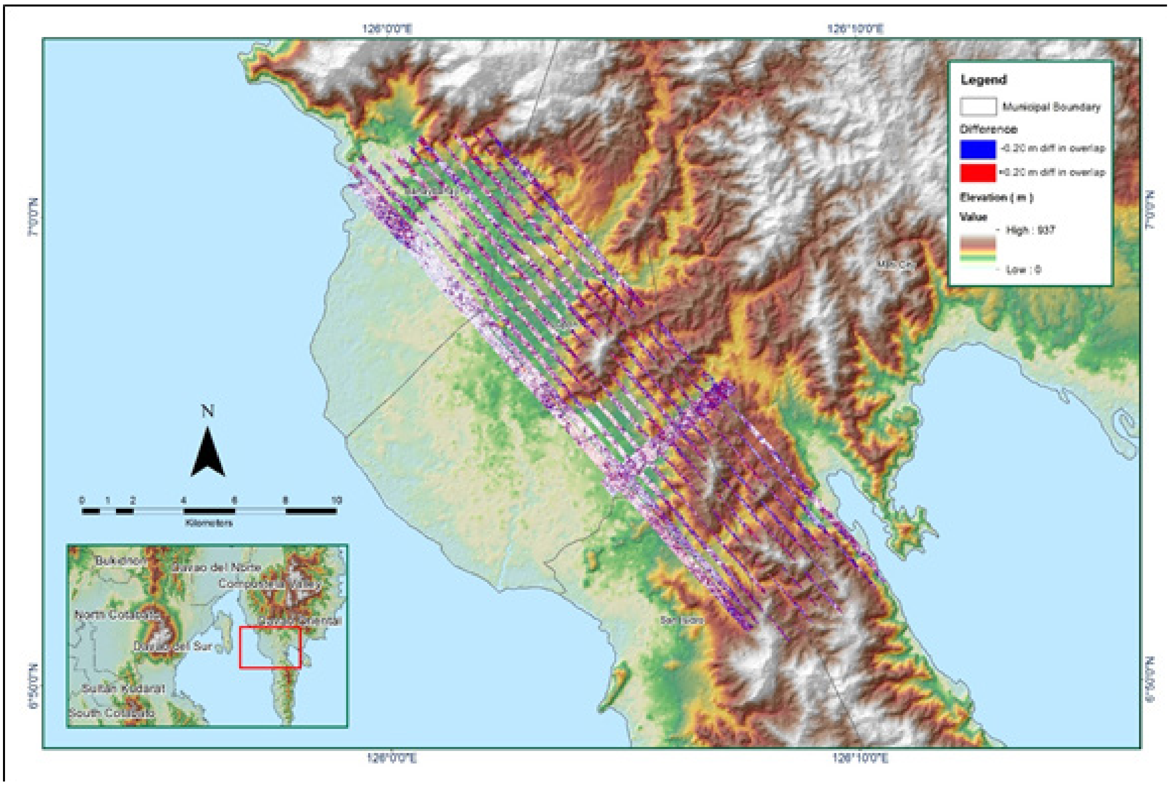



Figure 1.3.7 Elevation difference between flight lines

| | |
|---|---|
| Flight Area | Davao Oriental |
| Mission Name | Blk86C |
| Inclusive Flights | 7323G |
| Range data size | 20.4 GB |
| POS | 244 MB |
| Image | na |
| Transfer date | July 2, 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) | 0.094 |
| RMSE for East Position (<4.0 cm) | 1.28 |
| RMSE for Down Position (<8.0 cm) | 1.75 |
| | |
| Boresight correction stdev (<0.001deg) | 0.000523 |
| IMU attitude correction stdev (<0.001deg) | 0.003956 |
| GPS position stdev (<0.01m) | 0.0152 |
| | |
| Minimum % overlap (>25) | 22.94% |
| Ave point cloud density per sq.m. (>2.0) | 3.89 |
| Elevation difference between strips (<0.20 m) | Yes |
| | |
| Number of 1km x 1km blocks | 137 |
| Maximum Height | 667.86 m |
| Minimum Height | 65.73 m |
| | |
| Classification (# of points) | |
| Ground | 39222216 |
| Low vegetation | 22879172 |
| Medium vegetation | 88397711 |
| High vegetation | 184017731 |
| Building | 820572 |
| | |
| Orthophoto | No |
| Processed by | Engr. Analyn Naldo, Engr. Chelou Prado, Engr. Krisha Marie Bautista |

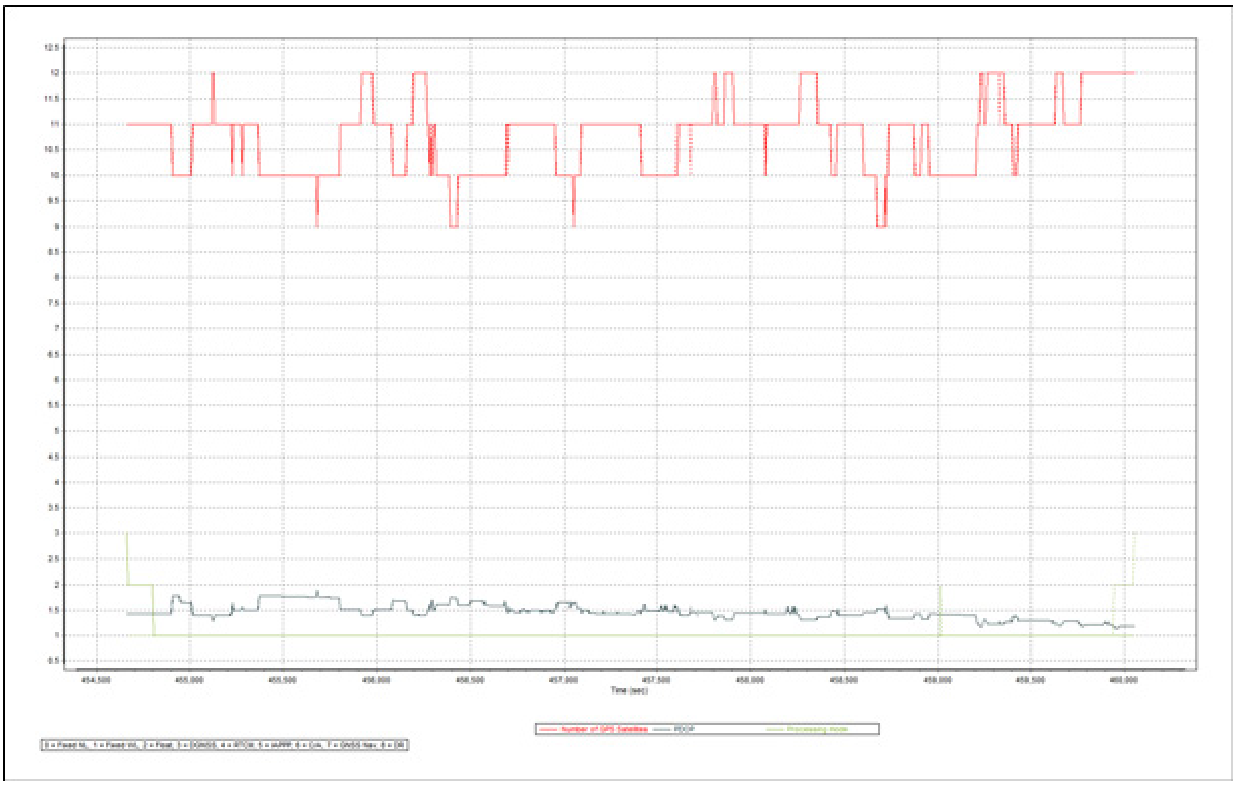


Figure 1.4.1 Solution Status

Figure 1.4.2 Smoothed Performance Metric Parameters

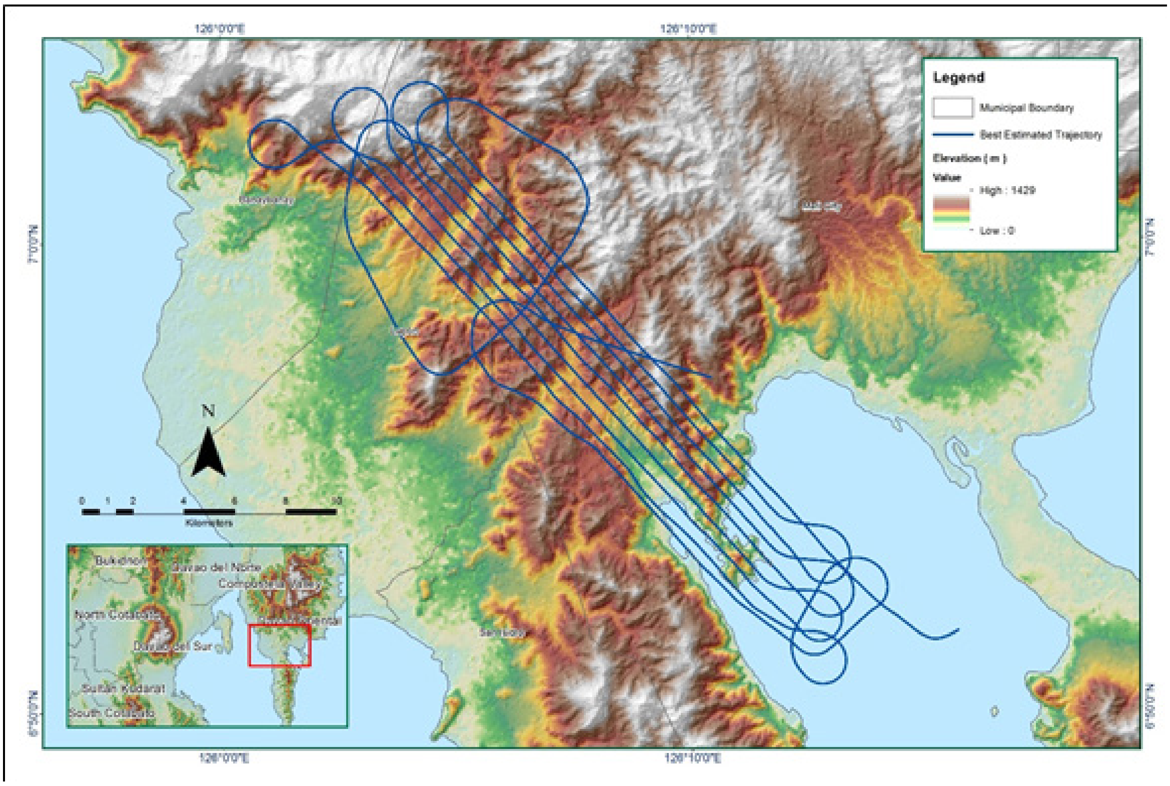



Figure 1.4.3 Best Estimated Trajectory

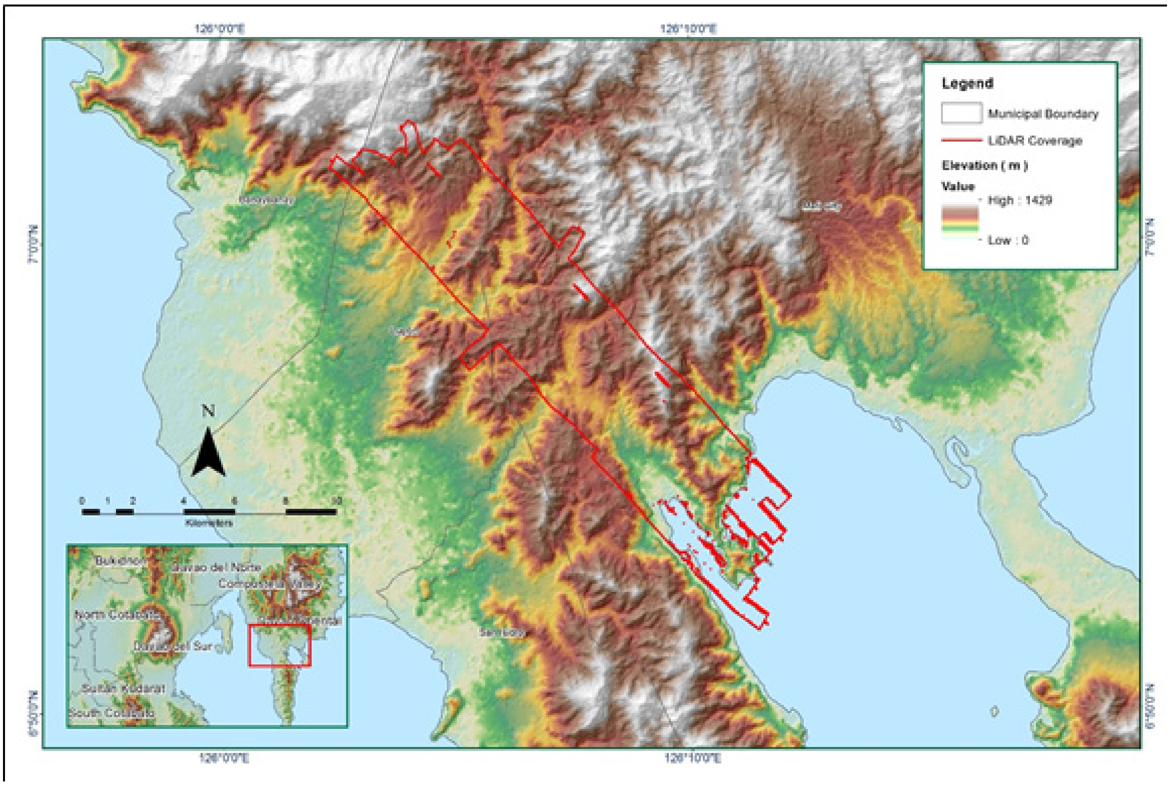



Figure 1.4.4 Coverage of LiDAR data

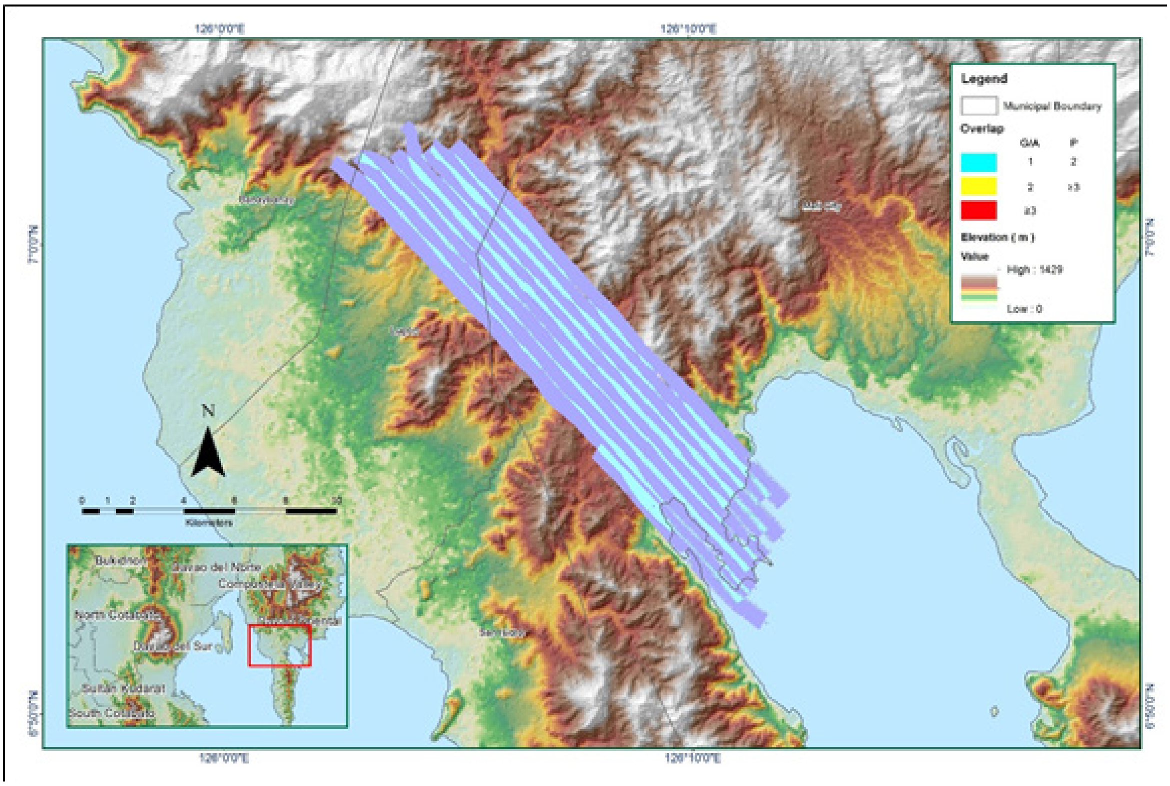



Figure 1.4.5 Image of data overlap

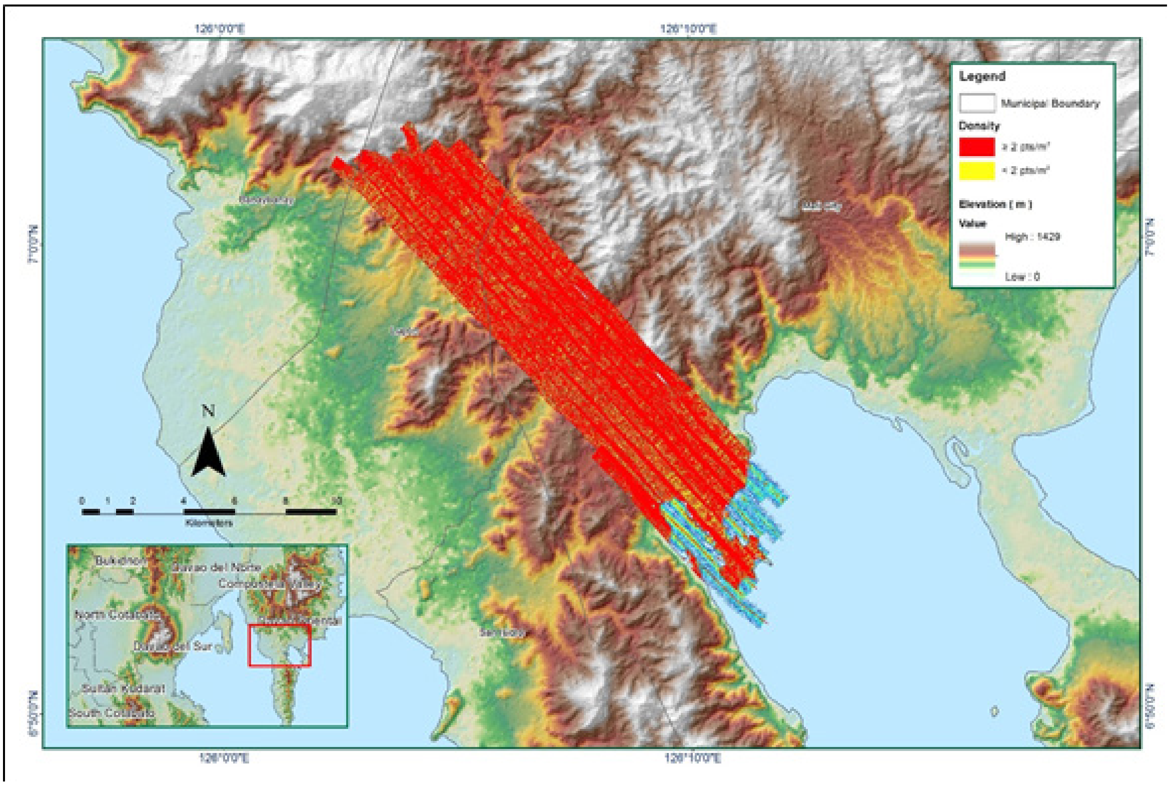



Figure 1.4.6 Density map of merged LiDAR data

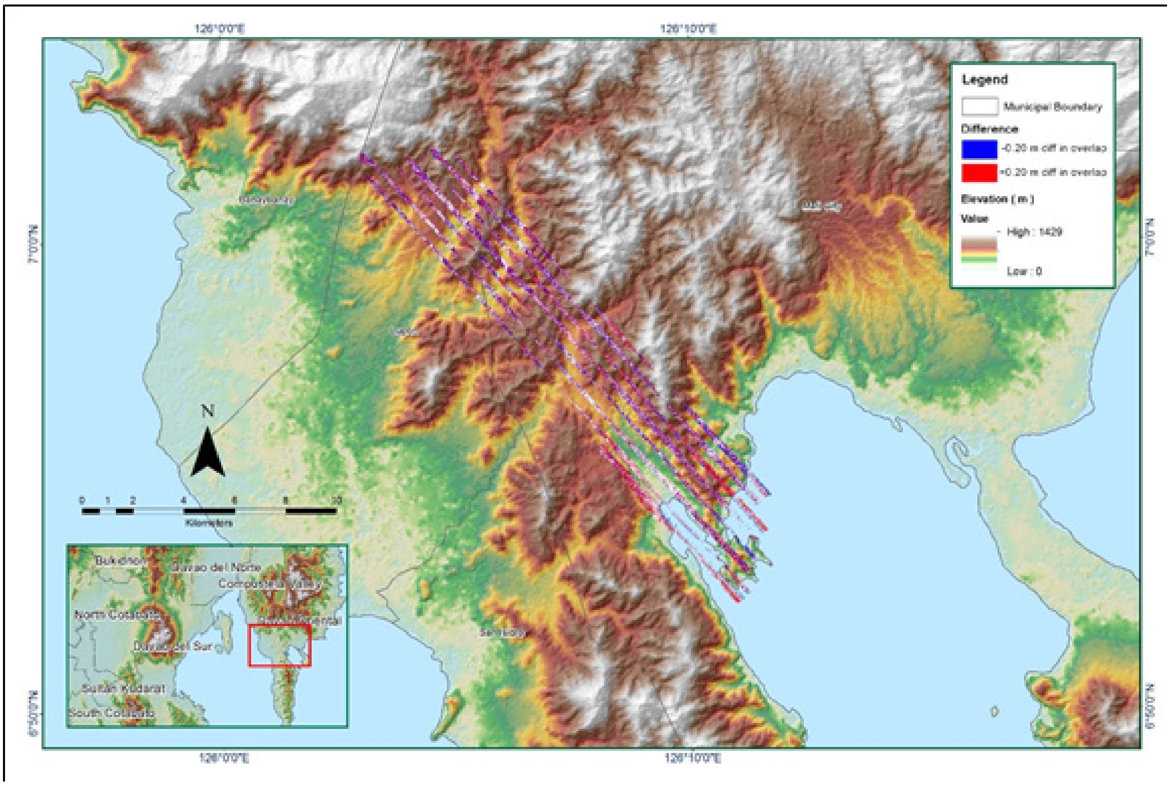



Figure 1.4.7 Elevation difference between flight lines

## Annex 9. Sumlog 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 Dis-charge (cms) | Recession Constant | Threshold Type | Ratio to Peak |
| W1000 | 7.6643 | 68.721 | 0 | 5.8932 | 0.63471 | Discharge | 0.64798 | 0.13665 | Ratio to Peak | 0.21633 |
| W1010 | 7.4459 | 73.023 | 0 | 10.594 | 0.58496 | Discharge | 0.83821 | 0.30269 | Ratio to Peak | 0.62544 |
| W1020 | 3.23092 | 42.942 | 0 | 0.15432 | 0.073875 | Discharge | 0.23477 | 0.45589 | Ratio to Peak | 0.44502 |
| W520 | 17.17 | 99 | 0 | 0.083668 | 0.039083 | Discharge | 0.47797 | 0.29236 | Ratio to Peak | 0.47341 |
| W530 | 24.074 | 98.682 | 0 | 0.2262 | 0.10566 | Discharge | 1.0982 | 0.56412 | Ratio to Peak | 0.5 |
| W540 | 19.628 | 59.177 | 0 | 0.070478 | 0.032921 | Discharge | 0.28697 | 0.33318 | Ratio to Peak | 0.5 |
| W550 | 11.286 | 95.629 | 0 | 0.028358 | 0.018924 | Discharge | 0.12322 | 0.32397 | Ratio to Peak | 0.4706 |
| W560 | 14.004 | 74.655 | 0 | 0.050003 | 0.023357 | Discharge | 0.15722 | 1 | Ratio to Peak | 0.99541 |
| W570 | 10.077 | 76.854 | 0 | 0.075919 | 0.035463 | Discharge | 0.30906 | 0.71922 | Ratio to Peak | 0.8145 |
| W580 | 14.792 | 97.248 | 0 | 0.058758 | 0.027447 | Discharge | 0.18351 | 1 | Ratio to Peak | 0.87581 |
| W590 | 8.0775 | 49.067 | 0 | 0.051016 | 0.02383 | Discharge | 0.39186 | 0.28236 | Ratio to Peak | 0.46453 |
| W600 | 13.699 | 93.418 | 0 | 0.12916 | 0.059124 | Discharge | 0.4007 | 0.076966 | Ratio to Peak | 0.69348 |
| W610 | 17.724 | 82.631 | 0 | 0.068307 | 0.031907 | Discharge | 0.18664 | 0.32013 | Ratio to Peak | 0.5 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| W620 | 14.259 | 81.603 | 0 | 0.12962 | 0.13469 | Discharge | 1.0632 | 0.057959 | Ratio to Peak | 0.56328 |
| W630 | 6.9069 | 36.557 | 0 | 0.038605 | 0.018033 | Discharge | 0.10273 | 0.32667 | Ratio to Peak | 0.32013 |
| W640 | 21.522 | 64.989 | 0 | 0.15642 | 0.073066 | Discharge | 0.56926 | 0.30673 | Ratio to Peak | 0.5 |
| 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 Dis-charge (cms) | Recession Constant | Threshold Type | Ratio to Peak |
| W650 | 12.014 | 78.145 | 0 | 0.073451 | 0.03431 | Discharge | 0.20362 | 0.36845 | Ratio to Peak | 0.6 |
| W660 | 12.915 | 73.469 | 0 | 0.10354 | 0.069655 | Discharge | 0.32387 | 0.30131 | Ratio to Peak | 0.21343 |
| W670 | 16.719 | 84.05 | 0 | 0.18279 | 0.074034 | Discharge | 0.65024 | 0.05948 | Ratio to Peak | 0.61127 |
| W680 | 15.433 | 87.46 | 0 | 0.1299 | 0.04045 | Discharge | 0.39696 | 0.13741 | Ratio to Peak | 0.50489 |
| W690 | 7.5494 | 41.215 | 0 | 0.056288 | 0.026293 | Discharge | 0.16037 | 0.9523 | Ratio to Peak | 0.43279 |
| W700 | 11.374 | 67.975 | 0 | 0.026005 | 0.017353 | Discharge | 0.006107 | 0.13391 | Ratio to Peak | 0.33333 |
| W710 | 11.333 | 48.151 | 0 | 0.11436 | 0.052499 | Discharge | 0.52644 | 0.12997 | Ratio to Peak | 0.70751 |
| W720 | 13.691 | 79.108 | 0 | 0.097312 | 0.044094 | Discharge | 0.39248 | 0.48014 | Ratio to Peak | 0.80284 |
| W730 | 14.042 | 78.887 | 0 | 0.10762 | 0.064874 | Discharge | 0.28729 | 0.32355 | Ratio to Peak | 0.74979 |
| W740 | 23.895 | 62.197 | 0 | 0.05425 | 0.025341 | Discharge | 0.017261 | 0.27 | Ratio to Peak | 0.5 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| W750 | 14.908 | 39.173 | 0 | 0.15664 | 0.050519 | Discharge | 0.37922 | 0.064528 | Ratio to Peak | 0.32168 |
| W760 | 14.546 | 80.971 | 0 | 0.066762 | 0.031185 | Discharge | 0.091462 | 0.21996 | Ratio to Peak | 0.81221 |
| W770 | 5.0359 | 50.458 | 0 | 0.0446 | 0.020833 | Discharge | 0.051433 | 1 | Ratio to Peak | 0.44056 |
| W780 | 15.382 | 97.156 | 0 | 0.077231 | 0.036076 | Discharge | 0.15284 | 0.2277 | Ratio to Peak | 0.74952 |
| W790 | 12.113 | 64.469 | 0 | 0.11166 | 0.044001 | Discharge | 0.22793 | 1 | Ratio to Peak | 0.6381 |
| W800 | 6.7615 | 46.107 | 0 | 0.054238 | 0.025335 | Discharge | 0.026175 | 1 | Ratio to Peak | 0.47258 |
| W810 | 11.42 | 66.043 | 0 | 0.12244 | 0.2958 | Discharge | 0.67857 | 0.14491 | Ratio to Peak | 0.41648 |
| W820 | 5.9611 | 64.648 | 0 | 0.079062 | 0.036931 | Discharge | 0.19306 | 0.245 | Ratio to Peak | 0.35177 |
| 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 Dis-charge (cms) | Recession Constant | Threshold Type | Ratio to Peak |
| W830 | 13.933 | 62.358 | 0 | 0.11431 | 0.052293 | Discharge | 3.71E-01 | 1 | Ratio to Peak | 0.87989 |
| W840 | 19.38 | 67.678 | 0 | 0.1125 | 0.05255 | Discharge | 3.98E-01 | 0.092959 | Ratio to Peak | 0.5 |
| W850 | 14.677 | 94.63 | 0 | 0.071138 | 0.03323 | Discharge | 0.17788 | 0.029264 | Ratio to Peak | 0.48258 |
| W860 | 5.166 | 89.392 | 0 | 0.031639 | 0.021113 | Discharge | 0.052983 | 0.029264 | Ratio to Peak | 0.31419 |
| W870 | 19.94 | 65.738 | 0 | 0.08382 | 0.039154 | Discharge | 0.21198 | 0.07534 | Ratio to Peak | 0.5 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| W880 | 2.8777 | 69.468 | 0 | 0.084921 | 0.039668 | Discharge | 0.16106 | 0.30746 | Ratio to Peak | 0.49434 |
| W890 | 5.7317 | 99 | 0 | 0.026796 | 0.017881 | Discharge | 0.007429 | 0.029264 | Ratio to Peak | 0.21019 |
| W900 | 6.3136 | 79.56 | 0 | 1.6412 | 0.074977 | Discharge | 0.60191 | 0.55261 | Ratio to Peak | 0.48594 |
| W910 | 21.434 | 73.871 | 0 | 0.021776 | 0.018164 | Discharge | 0.020227 | 0.039505 | Ratio to Peak | 0.32827 |
| W920 | 3.9005 | 91.158 | 0 | 0.051335 | 0.023979 | Discharge | 0.10496 | 0.82852 | Ratio to Peak | 0.36079 |
| W930 | 3.6648 | 81.851 | 0 | 0.081707 | 0.038167 | Discharge | 0.3015 | 0.085365 | Ratio to Peak | 0.27563 |
| W940 | 20.553 | 74.037 | 0 | 0.05493 | 0.025659 | Discharge | 0.17644 | 0.029264 | Ratio to Peak | 0.33333 |
| W950 | 20.916 | 50.847 | 0 | 0.055149 | 0.025761 | Discharge | 0.18218 | 0.096791 | Ratio to Peak | 0.47292 |
| W960 | 5.8191 | 76.86 | 0 | 0.052142 | 0.024356 | Discharge | 0.16163 | 0.87764 | Ratio to Peak | 0.48911 |
| W970 | 3.15406 | 84.131 | 0 | 0.080644 | 0.03767 | Discharge | 0.2049 | 0.20977 | Ratio to Peak | 0.5719 |
| W980 | 2.73371 | 80.716 | 0 | 0.063191 | 0.029518 | Discharge | 0.34169 | 0.47464 | Ratio to Peak | 0.42673 |
| W990 | 5.51628 | 58.257 | 0 | 0.091566 | 0.042772 | Discharge | 0.32228 | 0.21724 | Ratio to Peak | 0.23333 |

## Annex 10. Sumlog Model Reach Parameters

| Reach Number | Muskingum Cunge Channel Routing | | | | | | |
|---|---|---|---|---|---|---|---|
| | Time Step Method | Length (m) | Slope | Manning's n | Shape | Width | Side Slope |
| R110 | Automatic Fixed Interval | 1305.7 | 0.014951 | 0.082899 | Trapezoid | 45.75546 | 1 |
| R140 | Automatic Fixed Interval | 3230.8 | 0.015136 | 0.046676 | Trapezoid | 52.11182 | 1 |
| R150 | Automatic Fixed Interval | 374.85 | 0.026987 | 0.081323 | Trapezoid | 66.61429 | 1 |
| R190 | Automatic Fixed Interval | 780.83 | 0.09429 | 0.02422 | Trapezoid | 29.14583 | 1 |
| R200 | Automatic Fixed Interval | 4998.7 | 0.011439 | 0.054259 | Trapezoid | 60.03135 | 1 |
| R210 | Automatic Fixed Interval | 11796 | 0.028468 | 0.036181 | Trapezoid | 40.19901 | 1 |
| R250 | Automatic Fixed Interval | 1477.5 | 0.00653 | 0.12877 | Trapezoid | 57.41522 | 1 |
| R260 | Automatic Fixed Interval | 1323.6 | 0.006685 | 0.12891 | Trapezoid | 9.88333 | 1 |
| R280 | Automatic Fixed Interval | 2206.9 | 0.043565 | 0.024801 | Trapezoid | 14.66137 | 1 |
| R310 | Automatic Fixed Interval | 3860.4 | 0.027621 | 0.085413 | Trapezoid | 117.1018 | 1 |
| R330 | Automatic Fixed Interval | 4069.5 | 0.011191 | 0.055239 | Trapezoid | 82.77004 | 1 |
| R350 | Automatic Fixed Interval | 322.13 | 0.001 | 0.037773 | Trapezoid | 80.60591 | 1 |
| R360 | Automatic Fixed Interval | 1358.1 | 0.001 | 0.08312 | Trapezoid | 62.81199 | 1 |
| R370 | Automatic Fixed Interval | 6539.3 | 0.015757 | 0.086652 | Trapezoid | 24.26474 | 1 |
| R390 | Automatic Fixed Interval | 989.83 | 0.010958 | 0.057699 | Trapezoid | 25.85364 | 1 |
| R400 | Automatic Fixed Interval | 1818.9 | 0.032489 | 0.011134 | Trapezoid | 10.0025 | 1 |
| Reach Number | Muskingum Cunge Channel Routing | | | | | | |
| | Time Step Meth-od | Length (m) | Slope | Manning's n | Shape | Width | Side Slope |
| R430 | Automatic Fixed Interval | 5161.7 | 0.008608 | 0.0377 | Trapezoid | 46.66336 | 1 |
| R450 | Automatic Fixed Interval | 4004.2 | 0.009638 | 0.055091 | Trapezoid | 101.4683 | 1 |
| R470 | Automatic Fixed Interval | 9990.2 | 0.011238 | 0.023846 | Trapezoid | 151.4146 | 1 |
| R480 | Automatic Fixed Interval | 4056.9 | 0.008351 | 0.056506 | Trapezoid | 126.8871 | 1 |
| R490 | Automatic Fixed Interval | 10760 | 0.003022 | 0.057904 | Trapezoid | 196.4719 | 1 |
| R50 | Automatic Fixed Interval | 2312 | 0.051682 | 0.051717 | Trapezoid | 59.43071 | 1 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| R510 | Automatic Fixed Interval | 3248.4 | 0.001 | 0.056282 | Trapezoid | 86.98583 | 1 |
| R60 | Automatic Fixed Interval | 4859.5 | 0.066359 | 0.12875 | Trapezoid | 39.12024 | 1 |
| R90 | Automatic Fixed Interval | 4290.2 | 0.037384 | 0.055555 | Trapezoid | 62.06712 | 1 |

# Annex 11. Sumlog Field Validation Points

| Point Number | Validation Coordinates | | Model Var (m) | Validation Points (m) | Error (m) | Event/Date | Rain Return/ Scenario |
|---|---|---|---|---|---|---|---|
| | Lat | Long | | | | | |
| 1 | 6.898257 | 126.00739 | 0.51 | 0.5 | 0.0001 | Intense Local rainfall/ 2015 | 5-Year |
| 2 | 6.898706 | 126.007754 | 0.53 | 0.5 | 0.0009 | Intense Local rainfall/ August 2016 | 5-Year |
| 3 | 6.900053 | 126.009119 | 0.64 | 0.6 | 0.0016 | Intense Local rainfall/ 2015 | 5-Year |
| 4 | 6.901228 | 126.008946 | 0.54 | 0.25 | 0.0841 | Typhoon/ June 2016 | 5-Year |
| 5 | 6.898886 | 126.007936 | 0.65 | 0.5 | 0.0225 | Intense Local rainfall/ 2016 | 5-Year |
| 6 | 6.899604 | 126.008664 | 0.88 | 0.5 | 0.1444 | Buhawi/ December 2015 | 5-Year |
| 7 | 6.897988 | 126.007117 | 0.13 | 1 | 0.7569 | Intense Local rainfall/ 1990 | 5-Year |
| 8 | 6.897986 | 126.007298 | 0.3 | 1 | 0.49 | Intense Local rainfall/ 1990 | 5-Year |
| 9 | 6.89853 | 126.00703 | 0.73 | 0.9 | 0.0289 | Intense Local rainfall/ May 2016 | 5-Year |
| 10 | 6.898804 | 126.00658 | 0.65 | 0.9 | 0.0625 | Intense Local rainfall/ 2016 | 5-Year |
| 11 | 6.89889 | 126.007213 | 0.93 | 0.9 | 0.0009 | Intense Local rainfall/ 2016 | 5-Year |
| 12 | 6.898526 | 126.007663 | 0.63 | 0.2 | 0.1849 | Intense Local rainfall/ November 2015 | 5-Year |
| 13 | 6.898525 | 126.007844 | 0.7 | 0.2 | 0.25 | Intense Local rainfall/ 2015 | 5-Year |
| 14 | 6.900961 | 126.008401 | 1.02 | 0.6 | 0.1764 | Yolanda/ November 2013 | 5-Year |
| 15 | 6.901046 | 126.009216 | 0.79 | 0.5 | 0.0841 | Typhoon/ December 2015 | 5-Year |
| 16 | 6.899244 | 126.008391 | 0.7 | 0.5 | 0.04 | Upstream rainfall/ June 2016 | 5-Year |
| 17 | 6.90024 | 126.008126 | 0.77 | 0.7 | 0.0049 | Intense Local rainfall/ 2016 | 5-Year |
| 18 | 6.898712 | 126.006851 | 0.8 | 0.9 | 0.01 | Intense Local rainfall/ 2016 | 5-Year |
| 19 | 6.899255 | 126.006673 | 0.73 | 0.4 | 0.1089 | Typhoon/ November 2015 | 5-Year |
| 20 | 6.900785 | 126.007587 | 0.73 | 0.7 | 0.0009 | Pablo/ December 2012 | 5-Year |
| 21 | 6.900787 | 126.007225 | 1.22 | 0.7 | 0.2704 | Upstream rainfall/ June 2016 | 5-Year |
| 22 | 6.900787 | 126.007316 | 1.29 | 1.7 | 0.1681 | Upstream rainfall/ June 2016 | 5-Year |
| 23 | 6.901411 | 126.008676 | 0.79 | 0.25 | 0.2916 | Typhoon/ June 2016 | 5-Year |
| 24 | 6.900511 | 126.008037 | 0.4 | 0.6 | 0.04 | Upstream rainfall | 5-Year |
| 25 | 6.898528 | 126.007301 | 0.88 | 0.5 | 0.1444 | Intense Local rainfall/ 2015 | 5-Year |
| 26 | 6.899343 | 126.007126 | 0.83 | 1.1 | 0.0729 | Intense Local rainfall/ 2016 | 5-Year |
| 27 | 6.898799 | 126.007303 | 0.89 | 0.9 | 0.0001 | Intense Local rainfall/ May 2016 | 5-Year |
| 28 | 6.899162 | 126.007125 | 0.99 | 0.9 | 0.0081 | Intense Local rainfall/ 2016 | 5-Year |
| 29 | 6.899612 | 126.007399 | 0.88 | 1.1 | 0.0484 | Intense Local rainfall/ July 2016 | 5-Year |
| 30 | 6.899073 | 126.006943 | 0.93 | 0.9 | 0.0009 | Intense Local rainfall/ 2016 | 5-Year |
| 31 | 6.899969 | 126.008034 | 0.92 | 0.5 | 0.1764 | Upstream rainfall/ 2015 | 5-Year |
| 32 | 6.89979 | 126.007852 | 0.95 | 0.9 | 0.0025 | Upstream rainfall/ June 2016 | 5-Year |
| 33 | 6.900781 | 126.00822 | 1.12 | 0.6 | 0.2704 | Yolanda/ November 2013 | 5-Year |
| 34 | 6.901231 | 126.008494 | 0.99 | 0.3 | 0.4761 | Intense Local rainfall/ 2016 | 5-Year |
| 35 | 6.899883 | 126.0074 | 1.04 | 1.1 | 0.0036 | Intense Local rainfall/ July 2016 | 5-Year |
| 36 | 6.873856 | 126.037517 | 0.26 | 0.6 | 0.1156 | Intense Local rainfall/ 2013 | 5-Year |
| 37 | 6.873496 | 126.037334 | 0.24 | 0.6 | 0.1296 | Intense Local rainfall/ 2013 | 5-Year |
| 38 | 6.870336 | 126.037043 | 0.71 | 0.1 | 0.3721 | Intense Local rainfall/ January 2015 | 5-Year |
| 39 | 6.870963 | 126.03786 | 0.27 | 0.05 | 0.0484 | Intense Local rainfall/ 2013 | 5-Year |
| 40 | 6.871415 | 126.037773 | 0.45 | 0.7 | 0.0625 | Intense Local rainfall/ January 2015 | 5-Year |
| 41 | 6.870523 | 126.03605 | 0.71 | 0.5 | 0.0441 | Agaton/ June 2014 | 5-Year |
| 42 | 6.871507 | 126.037502 | 0.49 | 0.7 | 0.0441 | Intense Local rainfall/ January 2015 | 5-Year |
| 43 | 6.87098 | 126.035239 | 0.65 | 0.5 | 0.0225 | Intense Local rainfall/ November 28, 2011 | 5-Year |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 44 | 6.872322 | 126.037236 | 0.5 | 0.6 | 0.01 | Intense Local rainfall/ 2015 | 5-Year |
| 45 | 6.870705 | 126.03578 | 0.54 | 0.5 | 0.0016 | Agaton/ June 2014 | 5-Year |
| 46 | 6.890885 | 126.016021 | 0.05 | 0.5 | 0.2025 | Habagat/ 2012 | 5-Year |
| 47 | 6.891064 | 126.016294 | 0.33 | 0.5 | 0.0289 | Habagat/ 2012 | 5-Year |
| 48 | 6.890879 | 126.016925 | 0.03 | 0 | 0.0009 | | 5-Year |
| 49 | 6.891509 | 126.017381 | 0.03 | 0 | 0.0009 | | 5-Year |
| 50 | 6.891885 | 126.015033 | 0.15 | 0 | 0.0225 | | 5-Year |
| 51 | 6.891513 | 126.016658 | 0.1 | 0 | 0.01 | | 5-Year |
| 52 | 6.892325 | 126.016934 | 0.12 | 0 | 0.0144 | | 5-Year |
| 53 | 6.892418 | 126.016393 | 0.06 | 0 | 0.0036 | | 5-Year |
| 54 | 6.891338 | 126.015753 | 0.06 | 0 | 0.0036 | | 5-Year |
| 55 | 6.891334 | 126.016476 | 0.07 | 0 | 0.0049 | | 5-Year |
| 56 | 6.89197 | 126.015938 | 0.07 | 0 | 0.0049 | | 5-Year |
| 57 | 6.892781 | 126.016124 | 0.09 | 0 | 0.0081 | | 5-Year |
| 58 | 6.892055 | 126.016662 | 0.1 | 0 | 0.01 | | 5-Year |
| 59 | 6.892423 | 126.01567 | 0.21 | 0 | 0.0441 | | 5-Year |
| 60 | 6.891256 | 126.014487 | 0.14 | 0 | 0.0196 | | 5-Year |
| 61 | 6.891973 | 126.015396 | 0.2 | 0 | 0.04 | | 5-Year |
| 62 | 6.891286 | 126.023979 | 0.22 | 0.1 | 0.0144 | Intense Local rainfall/ 2008 | 5-Year |
| 63 | 6.888396 | 126.02387 | 0.14 | 0.2 | 0.0036 | Intense Local rainfall/ 2015 | 5-Year |
| 64 | 6.888663 | 126.024595 | 0.28 | 0.2 | 0.0064 | Intense Local rainfall/ 2015 | 5-Year |
| 65 | 6.890115 | 126.023429 | 0.36 | 0.3 | 0.0036 | Local rainfall/ 2016 | 5-Year |
| 66 | 6.888577 | 126.023781 | 0.24 | 0.2 | 0.0016 | Intense Local rainfall/ 2015 | 5-Year |
| 67 | 6.890297 | 126.023249 | 0.4 | 0.1 | 0.09 | Local rainfall/ | 5-Year |
| 68 | 6.890386 | 126.023431 | 0.17 | 0.3 | 0.0169 | Local rainfall/ 2016 | 5-Year |
| 69 | 6.891012 | 126.024429 | 0.14 | 0.1 | 0.0016 | Local rainfall/ | 5-Year |
| 70 | 6.890107 | 126.024785 | 0.03 | 0.2 | 0.0289 | Local rainfall/ | 5-Year |
| 71 | 6.890384 | 126.023883 | 0.24 | 0.3 | 0.0036 | Local rainfall/ 2016 | 5-Year |
| 72 | 6.891015 | 126.023977 | 0.24 | 0.1 | 0.0196 | Local rainfall/ | 5-Year |
| 73 | 6.890389 | 126.023069 | 0.15 | 0.1 | 0.0025 | Local rainfall/ | 5-Year |
| 74 | 6.889119 | 126.023784 | 0.27 | 0.2 | 0.0049 | Intense Local rainfall/ 2015 | 5-Year |
| 75 | 6.889576 | 126.023064 | 0.33 | 0.1 | 0.0529 | Intense Local rainfall/ | 5-Year |
| 76 | 6.890294 | 126.023701 | 0.34 | 0.3 | 0.0016 | Local rainfall/ 2016 | 5-Year |
| 77 | 6.890656 | 126.023703 | 0.1 | 0.1 | 0 | Local rainfall/ | 5-Year |
| 78 | 6.891648 | 126.023891 | 0.39 | 0.1 | 0.0841 | Intense Local rainfall/ 2008 | 5-Year |
| 79 | 6.888752 | 126.024776 | 0.17 | 0.2 | 0.0009 | Intense Local rainfall/ 2015 | 5-Year |
| 80 | 6.889833 | 126.025235 | 0.03 | 0.2 | 0.0289 | Intense Local rainfall/ 2015 | 5-Year |
| 81 | 6.889934 | 126.023518 | 0.14 | 0 | 0.0196 | | 5-Year |
| 82 | 6.888304 | 126.024141 | 0.18 | 0.2 | 0.0004 | Intense Local rainfall/ 2015 | 5-Year |
| 83 | 6.890026 | 126.023338 | 0.45 | 0.1 | 0.1225 | Intense Local rainfall/ | 5-Year |
| 84 | 6.89083 | 126.024789 | 0.3 | 0.2 | 0.01 | Intense Local rainfall/ 2015 | 5-Year |
| 85 | 6.890478 | 126.02325 | 0.36 | 0.1 | 0.0676 | Local rainfall/ | 5-Year |
| 86 | 6.890657 | 126.023432 | 0.03 | 0.1 | 0.0049 | Local rainfall/ | 5-Year |
| 87 | 6.889848 | 126.022885 | 0.5 | 0.1 | 0.16 | Intense Local rainfall/ | 5-Year |
| 88 | 6.890203 | 126.023791 | 0.13 | 0.3 | 0.0289 | Local rainfall/ 2016 | 5-Year |
| 89 | 6.934459 | 126.053543 | 3.36 | 1.5 | 3.4596 | Intense Local rainfall/ 2016 | 5-Year |
| 90 | 6.934009 | 126.053269 | 4.58 | 1.5 | 9.4864 | Intense Local rainfall/ 2016 | 5-Year |
| 91 | 6.923847 | 126.046062 | 2.21 | 0 | 4.8841 | | 5-Year |
| 92 | 6.92231 | 126.046324 | 0.03 | 0 | 0.0009 | | 5-Year |
| 93 | 6.921495 | 126.04659 | 0.26 | 0 | 0.0676 | | 5-Year |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 94 | 6.918154 | 126.046387 | 4.79 | 2 | 7.7841 | | 5-Year |
| 95 | 6.917707 | 126.045661 | 4.84 | 2 | 8.0656 | | 5-Year |
| 96 | 6.908441 | 126.053737 | 1.16 | 0.5 | 0.4356 | Intense Local rainfall/ 1980 | 5-Year |
| 97 | 6.91044 | 126.051942 | 0.03 | 0.2 | 0.0289 | Every rainy season/ | 5-Year |
| 98 | 6.910535 | 126.05122 | 1.01 | 0.9 | 0.0121 | Intense Local rainfall/ 2008 | 5-Year |
| 99 | 6.91308 | 126.048795 | 0.48 | 0 | 0.2304 | | 5-Year |
| 100 | 6.913535 | 126.048256 | 0.49 | 0.3 | 0.0361 | Intense Local rainfall/ 1990 | 5-Year |
| 101 | 6.91017 | 126.05185 | 0.03 | 0.9 | 0.7569 | Intense Local rainfall/ 2008 | 5-Year |
| 102 | 6.908526 | 126.054642 | 0.84 | 1 | 0.0256 | Intense Local rainfall/ 1963 & 2015 | 5-Year |
| 103 | 6.90899 | 126.052656 | 0.93 | 1 | 0.0049 | Buhawi/ 1980 | 5-Year |
| 104 | 6.911168 | 126.051043 | 0.03 | 0.2 | 0.0289 | Every rainy season/ | 5-Year |
| 105 | 6.913555 | 126.045183 | 5.02 | 1 | 16.1604 | | 5-Year |
| 106 | 6.914007 | 126.045095 | 5.31 | 1 | 18.5761 | | 5-Year |
| 107 | 6.91428 | 126.044826 | 5.12 | 1 | 16.9744 | | 5-Year |
| 108 | 6.902704 | 126.060932 | 1.17 | 0.41 | 0.5776 | Upstream rainfall/ 2016 | 5-Year |
| 109 | 6.903614 | 126.059853 | 1.22 | 0.67 | 0.3025 | Upstream rainfall/ June 2016 | 5-Year |
| 110 | 6.906528 | 126.056256 | 1.01 | 1 | 0.0001 | Buhawi/ 1980 | 5-Year |
| 111 | 6.903155 | 126.061025 | 1.61 | 0.71 | 0.81 | Upstream rainfall/ August 2016 | 5-Year |
| 112 | 6.90234 | 126.061291 | 0.87 | 0.55 | 0.1024 | Buhawi/ July 2016 | 5-Year |
| 113 | 6.903887 | 126.059493 | 1.4 | 0.81 | 0.3481 | Upstream rainfall/ 2016 | 5-Year |
| 114 | 6.904343 | 126.058864 | 1.16 | 0.51 | 0.4225 | Upstream rainfall/ June 2016 | 5-Year |
| 115 | 6.903158 | 126.060483 | 1.18 | 0.53 | 0.4225 | Upstream rainfall/ June 2016 | 5-Year |
| 116 | 6.902068 | 126.061561 | 0.76 | 0.56 | 0.04 | Upstream rainfall/ 2016 | 5-Year |
| 117 | 6.902427 | 126.061925 | 1.4 | 0.56 | 0.7056 | Upstream rainfall/ 2016 | 5-Year |
| 118 | 6.904612 | 126.059227 | 2.24 | 1.2 | 1.0816 | Upstream rainfall/ July 2016 | 5-Year |
| 119 | 6.903433 | 126.059942 | 1.29 | 0.65 | 0.4096 | Upstream rainfall/ June 2016 | 5-Year |
| 120 | 6.904977 | 126.058687 | 2.06 | 0.51 | 2.4025 | Upstream rainfall/ June 2016 | 5-Year |
| 121 | 6.907798 | 126.05536 | 1.44 | 1 | 0.1936 | Upstream rainfall/ 1980 | 5-Year |
| 122 | 6.903428 | 126.060756 | 1.59 | 0.53 | 1.1236 | Upstream rainfall/ June 2016 | 5-Year |
| 123 | 6.9027 | 126.061565 | 1.7 | 0.82 | 0.7744 | Upstream rainfall/ July 2016 | 5-Year |
| 124 | 6.905432 | 126.058147 | 1.8 | 0.65 | 1.3225 | Buhawi/ June 2016 | 5-Year |
| 125 | 6.904065 | 126.059947 | 1.93 | 0.67 | 1.5876 | Upstream rainfall/ June 2016 | 5-Year |
| 126 | 6.90398 | 126.059223 | 1.78 | 1.2 | 0.3364 | Upstream rainfall/ July 2016 | 5-Year |
| 127 | 6.904339 | 126.059496 | 0.66 | 1.2 | 0.2916 | Upstream rainfall/ July 2016 | 5-Year |
| 128 | 6.906794 | 126.056981 | 1.89 | 1 | 0.7921 | Buhawi/ 1980 | 5-Year |
| 129 | 6.874681 | 126.049815 | 0.03 | 0 | 0.0009 | | 5-Year |
| 130 | 6.874727 | 126.042584 | 0.06 | 0.3 | 0.0576 | Agaton/ January 2014 | 5-Year |
| 131 | 6.874863 | 126.049545 | 0.09 | 0 | 0.0081 | | 5-Year |
| 132 | 6.874961 | 126.048371 | 0.29 | 0.15 | 0.0196 | Upstream rainfall/ January 2014 | 5-Year |
| 133 | 6.874178 | 126.043756 | 2.04 | 0.15 | 3.5721 | Agaton/ January 2014 | 5-Year |
| 134 | 6.87482 | 126.042133 | 0.46 | 0.15 | 0.0961 | Pablo/ December 2012 | 5-Year |
| 135 | 6.875049 | 126.048733 | 0.18 | 0.15 | 0.0009 | Upstream rainfall/ January 2014 | 5-Year |
| 136 | 6.874877 | 126.047376 | 0.28 | 1.4 | 1.2544 | Pablo/ December 2012 | 5-Year |
| 137 | 6.874822 | 126.041862 | 0.52 | 0.3 | 0.0484 | Agaton/ January 2014 | 5-Year |
| 138 | 6.899627 | 126.061816 | 0.9 | 0.8 | 0.01 | Intense Local rainfall/ 1990 | 5-Year |
| 139 | 6.902154 | 126.062194 | 1.05 | 0 | 1.1025 | | 5-Year |
| 140 | 6.900534 | 126.061189 | 0.97 | 0.5 | 0.2209 | Upstream rainfall/ 2016 | 5-Year |
| 141 | 6.899268 | 126.061452 | 1.23 | 0.8 | 0.1849 | Intense Local rainfall/ 1990 | 5-Year |
| 142 | 6.898907 | 126.06136 | 1.3 | 0.8 | 0.25 | Intense Local rainfall/ 1990 | 5-Year |
| 143 | 6.872512 | 126.049982 | 1.76 | 1 | 0.5776 | Pablo/ 2012 | 5-Year |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 144 | 6.873682 | 126.050622 | 1.96 | 2 | 0.0016 | Sendong/ 2009 | 5-Year |
| 145 | 6.876136 | 126.048378 | 2.52 | 0.15 | 5.6169 | Upstream rainfall/ January 2014 | 5-Year |
| 146 | 6.875056 | 126.047739 | 2.09 | 1.4 | 0.4761 | Pablo/ December 2012 | 5-Year |
| 147 | 6.920783 | 126.072981 | 4.16 | 2.5 | 2.7556 | | 5-Year |
| 148 | 6.921678 | 126.074252 | 5.26 | 2.5 | 7.6176 | | 5-Year |
| 149 | 6.921208 | 126.077142 | 1.06 | 2.5 | 2.0736 | | 5-Year |
| 150 | 6.971978 | 126.062826 | 0.08 | 0.8 | 0.5184 | Pablo & Yolanda/ Dec 2012 & Nov 2013 | 5-Year |
| 151 | 6.971077 | 126.062368 | 3.88 | 0.9 | 8.8804 | Buhawi/ June 2014 | 5-Year |
| 152 | 6.962193 | 126.05327 | 2.88 | 0.5 | 5.6644 | Pablo/ December 2012 | 5-Year |
| 153 | 6.962644 | 126.053364 | 2.97 | 0.5 | 6.1009 | Pablo/ December 2012 | 5-Year |
| 154 | 6.962912 | 126.053908 | 2.99 | 0.5 | 6.2001 | Pablo & Yolanda/ Dec 2012 & Nov 2013 | 5-Year |
| 155 | 6.961655 | 126.052724 | 2.94 | 0.2 | 7.5076 | Intense Local rainfall/ 2015 | 5-Year |
| 156 | 6.972337 | 126.0631 | 2.96 | 1 | 3.8416 | Buhawi/ 2014 | 5-Year |
| 157 | 6.971708 | 126.062644 | 5.15 | 0.6 | 20.7025 | Buhawi/ June 2014 | 5-Year |
| 158 | 6.973236 | 126.063829 | 0.08 | 2 | 3.6864 | | 5-Year |
| 159 | 6.971348 | 126.062461 | 5.05 | 0.8 | 18.0625 | Upstream rainfall/ 2013 | 5-Year |
| 160 | 6.970806 | 126.062367 | 4.82 | 0.8 | 16.1604 | Buhawi/ July 2014 | 5-Year |
| 161 | 6.97394 | 126.066636 | 5.18 | 0.5 | 21.9024 | Upstream rainfall/ 2015 | 5-Year |
| 162 | 6.971347 | 126.062551 | 5.12 | 1.3 | 14.5924 | Upstream rainfall/ 2013 | 5-Year |
| 163 | 6.971076 | 126.062549 | 5.57 | 1.3 | 18.2329 | Buhawi/ June 2014 | 5-Year |
| 164 | 6.971164 | 126.062911 | 5.54 | 1.3 | 17.9776 | Buhawi/ June 2014 | 5-Year |
| 165 | 6.972966 | 126.063646 | 0.47 | 1 | 0.2809 | Buhawi/ 2014 | 5-Year |
| 166 | 6.974033 | 126.066185 | 6.56 | 2 | 20.7936 | | 5-Year |
| 167 | 6.974219 | 126.065372 | 3.6 | 0.5 | 9.61 | Upstream rainfall/ 2015 | 5-Year |
| 168 | 6.942529 | 126.048804 | 0.22 | 0.5 | 0.0784 | | 5-Year |
| 169 | 6.94352 | 126.049262 | 2.36 | 1.5 | 0.7396 | Pablo/ December 2012 | 5-Year |
| 170 | 6.94397 | 126.049446 | 2.4 | 1.5 | 0.81 | Pablo/ December 2012 | 5-Year |
| 171 | 6.961028 | 126.051907 | 3.73 | 0.9 | 8.0089 | Intense Local rainfall/ 2015 | 5-Year |
| 172 | 6.959945 | 126.051629 | 3.77 | 0.6 | 10.0489 | Intense Local rainfall/ 2015 | 5-Year |
| 173 | 6.958776 | 126.050807 | 4.04 | 0.6 | 11.8336 | Intense Local rainfall/ 2015 | 5-Year |
| 174 | 6.958416 | 126.050624 | 4.25 | 0.6 | 13.3225 | Intense Local rainfall/ 2015 | 5-Year |
| 175 | 6.970536 | 126.062275 | 4.43 | 1.4 | 9.1809 | Buhawi/ December 2014 | 5-Year |
| 176 | 6.970805 | 126.062548 | 5.04 | 0.8 | 17.9776 | Buhawi/ July 2014 | 5-Year |
| 177 | 6.970535 | 126.062455 | 4.95 | 1.4 | 12.6025 | Buhawi/ December 2014 | 5-Year |
| 178 | 6.969729 | 126.061365 | 4.12 | 1.2 | 8.5264 | Upstream rainfall/ December 25, 2015 | 5-Year |
| 179 | 6.969996 | 126.062 | 5.53 | 1.2 | 18.7489 | Upstream rainfall/ June 24, 2014 | 5-Year |
| 180 | 6.970266 | 126.062092 | 3.98 | 1.4 | 6.6564 | Buhawi/ December 2014 | 5-Year |
| | | | | **RMSE** | 1.585939 | | |

## Annex 12. Educational Institutions affected by flooding in Sumlog Flood Plain

| Davao Oriental | | | | |
|---|---|---|---|---|
| Lupon | | | | |
| Building Name | Barangay | Rainfall Scenario | | |
| | | 5-year | 25-year | 100-year |
| CABANDIANGAN ELEMENTARY SCHOOL | Bagumbayan | High | High | High |
| CABADIANGAN ELEMENTARY SCHOOL | Cabadiangan | High | High | High |
| DAY CARE CENTER | Cabadiangan | High | High | High |
| TAGUGPO NATIONAL HIGH SCHOOL | Cabadiangan | | Low | Medium |
| TAGUGPO NATIONAL HIGH SCHOOL PRINCIPAL'S OFFICE | Cabadiangan | | Medium | High |
| COCORNON ELEMENTARY SCHOOL | Cocornon | | | |
| PRESCHOOL | Cocornon | | | |
| SOMILDIA DAY CARE CENTER | Ilangay | | | Low |
| SUMLOG DAY CARE CENTER | Ilangay | Low | Medium | Medium |
| CABANDIANGAN ELEMENTARY SCHOOL | Langka | High | High | High |
| ROBERTO CEPULO SR. DAY CARE CENTER | Lantawan | High | High | High |
| DAY CARE CENTER | Limbahan | High | High | High |
| ILANGAY ELEMENTARY SCHOOL | Limbahan | Medium | Medium | High |
| ARABIC SCHOOL | Macangao | | Low | Medium |
| DAY CARE CENTER | Macangao | Medium | Medium | Medium |
| MACANGAO AGRICULTURAL VOCA-TIONAL HIGH SCHOOL | Macangao | Low | Low | Medium |
| MACANGAO CENTRAL ELEMENTARY SCHOOL | Macangao | Low | Low | Medium |
| MACANGAO DAY CARE CENTER | Macangao | | Low | Low |
| SAN JOSE ELEMENTARY SCHOOL | Magsaysay | Medium | Medium | Medium |
| BENITO BAROL SR. ELEMENTARY SCHOOL | Poblacion | Low | Medium | Medium |
| COMARRA MANUEL CENTRAL ELE-MENTARY SCHOOL | Poblacion | Medium | Medium | Medium |
| DAY CARE CENTER | Poblacion | | | Low |
| EASTERN DAVAO ISLAMIC INSTITUTE | Poblacion | Low | Medium | Medium |
| LUPON NATIONAL COMPREHENSIVE HIGH SCHOOL | Poblacion | Low | Low | Medium |
| LUPON VOCATIONAL HIGH SCHOOL | Poblacion | Medium | Medium | High |
| LYCEUM LUPON DAVAO ORIENTAL INCORPORATED COLLEGE | Poblacion | Low | Medium | Medium |

| | | | | |
|---|---|---|---|---|
| MAGDAGONDONG DAY CARE CENTER | Poblacion | Low | Medium | Medium |
| NATIONAL CHILD DEVELOPMENT CENTER (NCDC) | Poblacion | Low | Medium | Medium |
| ROBERTO CEPULO SR. DAY CARE CENTER | Poblacion | High | High | High |
| SMART MINDS | Poblacion | | | Low |
| TESDA LUPON SCHOOL OF FISHERIES | Poblacion | Medium | High | High |
| UCCP EARLY CHILDHOOD DEVELOPMENT CENTER | Poblacion | Low | Medium | Medium |
| | | | | |
| **San Isidro** | | | | |
| **Building Name** | **Barangay** | **Rainfall Scenario** | | |
| | | **5-year** | **25-year** | **100-year** |
| ARABIC SCHOOL | Iba | Low | Low | Medium |
| SAN ROQUE ELEMENTARY SCHOOL | San Roque | | | |

# Annex 13. Medical Institutions affected by flooding in Sumlog Flood Plain

| Davao Oriental | | | | |
|---|---|---|---|---|
| Lupon | | | | |
| Building Name | Barangay | Rainfall Scenario | | |
| | | 5-year | 25-year | 100-year |
| HEALTH CENTER | Cabadiangan | High | High | High |
| COCORNON HEALTH CENTER | Cocornon | | | |
| BARANGAY ILANGAY HEALTH STATION | Limbahan | Medium | High | High |
| BRGY HEALTH CENTER | Limbahan | High | High | High |
| MACANGAO HEALTH CENTER | Macangao | Low | Low | Medium |
| HEALTH CENTER | Magsaysay | Medium | Medium | Medium |
| DAVAO ORIENTAL PROVINCIAL HOSPI-TAL LUPON | Poblacion | | Low | Low |
| FLORES MATERNITY CLINIC | Poblacion | | Low | Low |
| GRACE MATERNITY & WELLNESS | Poblacion | Low | Medium | Medium |
| HEALTH CENTER | Poblacion | | | Low |
| MEDICAL CLINIC | Poblacion | Low | Low | Medium |
| MOM'S BIRTHING HOME & DENTAL CLINIC | Poblacion | | | |
| MUNICIPAL HEALTH CENTER | Poblacion | | | Low |
| HEALTH CENTER | Cabadiangan | High | High | High |
| COCORNON HEALTH CENTER | Cocornon | | | |
| BARANGAY ILANGAY HEALTH STATION | Limbahan | Medium | High | High |
| BRGY HEALTH CENTER | Limbahan | High | High | High |
| MACANGAO HEALTH CENTER | Macangao | Low | Low | Medium |
| HEALTH CENTER | Magsaysay | Medium | Medium | Medium |
| DAVAO ORIENTAL PROVINCIAL HOSPI-TAL LUPON | Poblacion | | Low | Low |
| FLORES MATERNITY CLINIC | Poblacion | | Low | Low |
| GRACE MATERNITY & WELLNESS | Poblacion | Low | Medium | Medium |
| HEALTH CENTER | Poblacion | | | Low |
| MEDICAL CLINIC | Poblacion | Low | Low | Medium |
| MOM'S BIRTHING HOME & DENTAL CLINIC | Poblacion | | | |
| MUNICIPAL HEALTH CENTER | Poblacion | | | Low |
| | | | | |
| San Isidro | | | | |
| Building Name | Barangay | Rainfall Scenario | | |
| | | 5-year | 25-year | 100-year |
| HEALTH CENTER | San Roque | | | |