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

# LiDAR Surveys and Flood Mapping of Inagauan River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
University of the Philippines Los Baños

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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 |
| UTM | Universal Transverse Mercator |
| WGS | World Geodetic System |

# CHAPTER 1: OVERVIEW OF THE PROGRAM AND INAGAUAN RIVER

Enrico C. Paringit, Dr. Eng., Asst. Prof. Edwin R. Abucay, and Ms. Sandra S. Samantela

## 1.1 Background of the Phil-LIDAR 1 Program

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

Also, the program was aimed at producing an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through DOST.

The implementing partner university for the Phil-LiDAR 1 Program is the University of the Philippines Los Baños (UPLB). UPLB 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 45 river basins in the Southern Luzon region. The university is located in Los Baños in the province of Laguna.

## 1.2 Overview of the Inagauan River Basin

The Inagauan River Basin is a 16,885-ha watershed covering a small portion of the City of Puerto Princesa in the province of Palawan. It encompasses barangay Aporawan, and Sagpangan in the municipality of Aborlan; Inagawan, Napsan, Inagawan Sub-Colony in Puerto Princesa City. The DENR River Basin Control Office (RBCO) states that the Inagauan River Basin has a drainage are of 171 km$^2$ and an estimated 274 cubic meter (MCM) annual run-off (RBCO, 2015).

The Inagauan River Basin's main stem, the Inagauan River, is part of the forty-five (45) river systems under the PHIL-LIDAR 1 Program partner State University and College (SUC), University of the Philippines Los Baños. The Inagauan River Basin passes through Napsan, Inagawan Sub-colony, and Inagawan. According to the 2015 national census of Philippine Statistics Authority (PSA), a total of 4,052 persons are residing in Brgy. Inagawan Sub-Colony in Puerto Princesa City, which is within the immediate vicinity of the river. The economic activities of the people in the Inagauan River Basin of the province of Palawan is primarily agriculture-based, with fishing, tourism, trade, commerce, and mineral extraction as the major sources of income (Palawan Knowledge Platform for Biodiversity and Sustainable Development, 2007).

Within a tropical region, Climate Type I and III prevails in the Inagauan River Basin based on the Modified Corona Classification of climate. Type I has two pronounced seasons, dry from November to April, and wet the rest of the year with maximum rain period from June to September. On the other hand, Type III has no very pronounced maximum rain period and with short dry season lasting only from one to three months, during the period from December to February or from March to May. The same climate type prevails in the Mindoro, Marinduque, Romblon, and Palawan (MIMAROPA) region, where the Inagauan River Basin is located.

In terms of geology, the basin area is classified as predominatly Undifferentiated (Sedimentary & Metamorphic Rocks) and Cretaceous-Paleogene. Other areas area classified as Basement Complex (pre-jurassic), Pliocene-pleistocene and Recent. Generally, the slope in the area can be classified as gently sloping to steep with elevation ranging from 50 to more than 300 meters above sea level (masl). The soil in the large extent of rough mountainous land is still unclassified. However, other areas have Taburos clay and Aborlan loam. Dense vegetation of closed forest (broadleaved) dominates the basin area along with other wooded land (shrubs), other wooded land (wooded grassland), and other land (cultivated perennial).

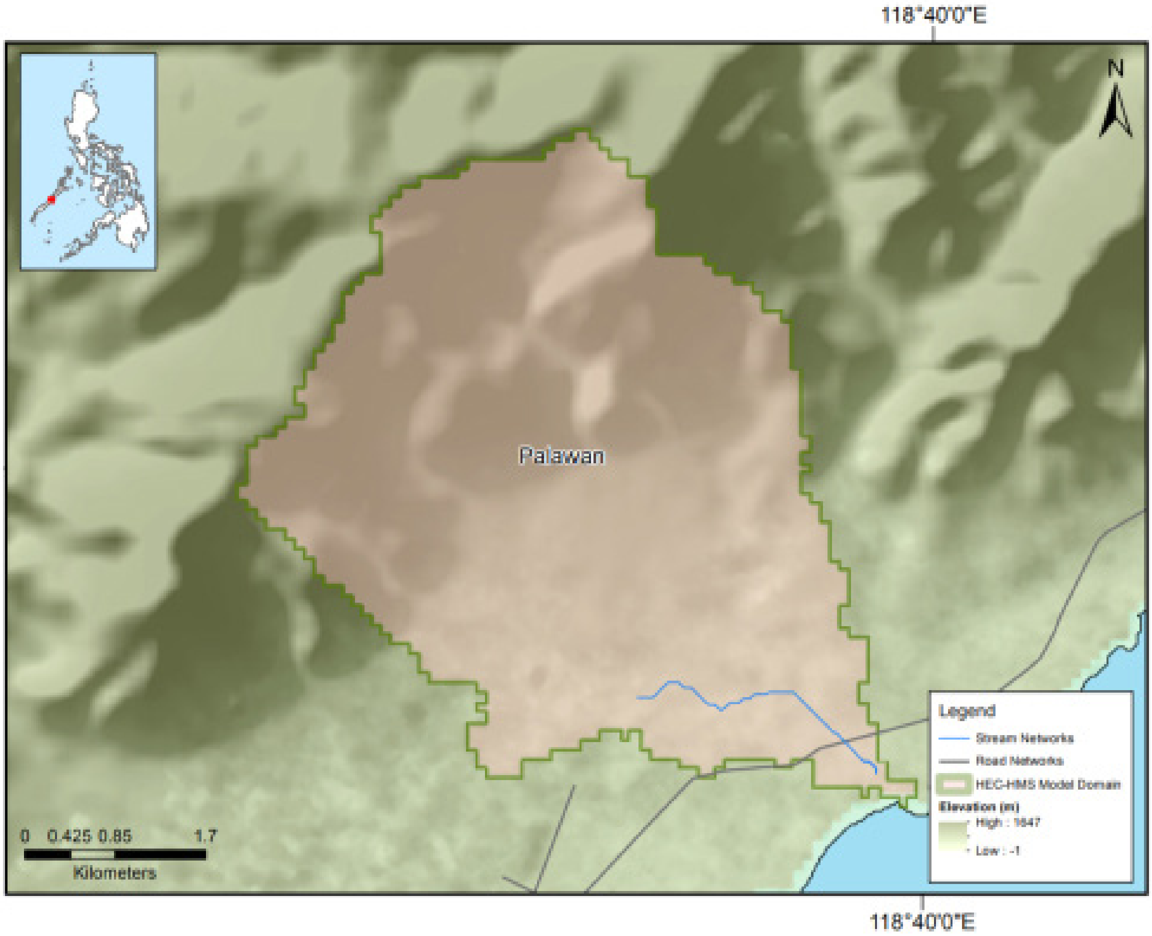


Figure 1. Map of Inagauan River Basin (in brown)

Based on the study conducted by the Mines and Geosciences Bureau, generally the barangays in the basin area have no susceptibility to flooding except for the portion of barangay Inagauan that has moderate to high susceptibility. The field surveys conducted by the PHIL-LiDAR 1 validation team showed that there were several notable weather disturbances that caused flooding in 2000 (Seniang), 2004 (Rolly), 2005 (Quedan), 2008 (Frank), 2013 (Yolanda), 2015 (Nona and Lando) and 2016 (Lawin). Meanwhile, due to the continuous rains brought about by the tail-end of a cold front, flooding incidents occurred in the Municipality of Narra and Puerto Princesa City on January 2011 as per NDRRMC report (National Disaster Risk Reduction and Management Council, 2011). For landslide risk susceptibility, barangay Napsan and Aporawan has moderate to high while Inagawan Sub-Colony has moderate susceptibility.

# CHAPTER 2: LIDAR DATA ACQUISITION IN INAGAUAN FLOODPLAIN

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

## 2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Inagauan floodplain in Palawan. These missions were planned for 12 lines and ran 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 Inagauan floodplain.

Table 1. Flight planning parameters for Aquarius LiDAR system

| Block Name | Flying Height (AGL) | Overlap (%) | Field of View | Pulse Repetition Frequency (PRF) (kHz) | Scan Frequency | Average Speed | Average Turn Time (Minutes) |
|---|---|---|---|---|---|---|---|
| BLK42A | 800 | 30 | 50 | 200 | 30 | 130 | 5 |
| BLK42E | 800 | 30 | 50 | 200 | 30 | 130 | 5 |
| BLK42F | 800 | 30 | 50 | 200 | 30 | 130 | 5 |

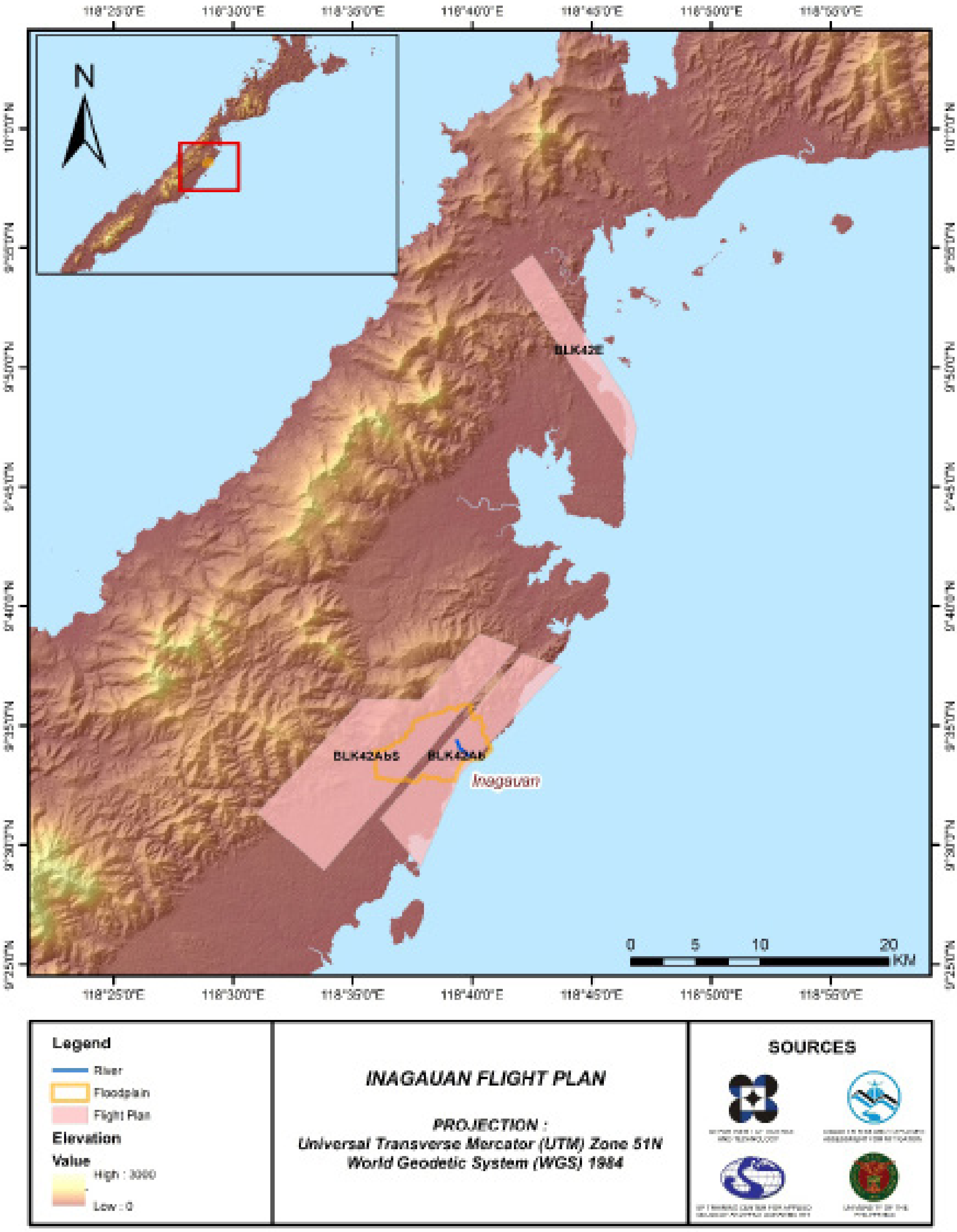


Figure 2. Flight plans used for Inagauan Floodplain

## 2.2 Ground Base Station

The project team was able to recover one (1) NAMRIA ground control point (GCP), PLW-50 which is of second (2nd) order accuracy, and one (1) NAMRIA benchmark, PL-92. The certifications for the NAMRIA GCP and benchmark are found in Annex 2, while the baseline processing report for the established GCP is found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey (June 14 and 17, 2015). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 882 and SPS 852. Flight plans and location of base stations used during the aerial LiDAR acquisition in Inagauan floodplain are shown in Figure 2. The list of team members are shown in Annex 4.

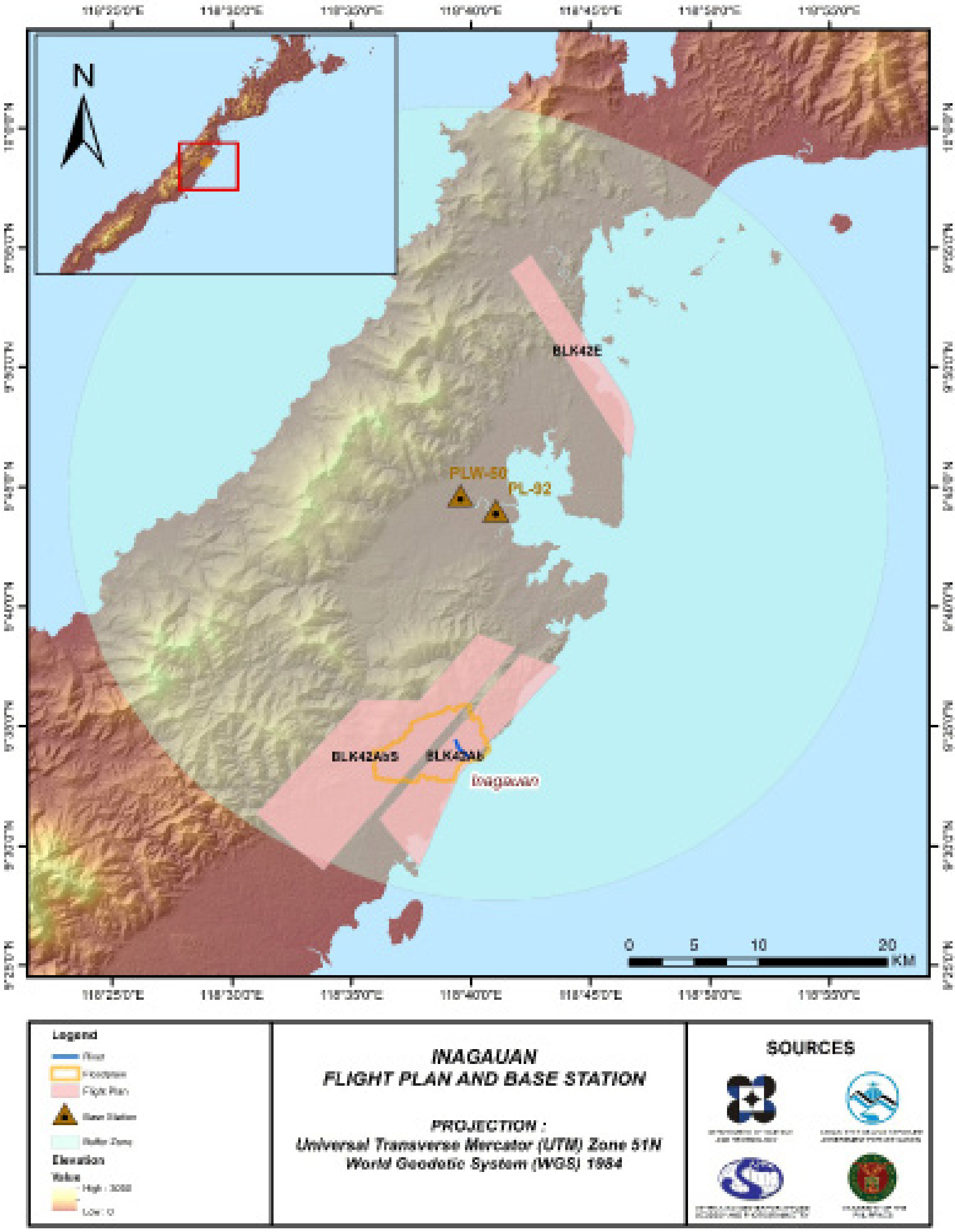


Figure 3. Flight plans and base stations for Inagauan Floodplain.

Figure 4 shows the recovered NAMRIA reference points within the area. In addition, Table 2 and Table 3 show the details about the following NAMRIA control stations. Table 4 shows the list of all ground control points occupied during the acquisition together with the corresponding dates of utilization.


(b)

(a)

Figure 4. GPS set-up over PLW-50 within the vicinity of Ihawig Prison and Penal Farm at the fountain in front of Quarter 1, Brgy. Iwahig Puerto Princesa City (a) and NAMRIA reference point PLW-50 (b) as recovered by the field team.

Table 2. Details of the recovered NAMRIA horizontal control point PLW-50 used as base station for the LiDAR acquisition.

| Station Name | PLW-50 | |
|---|---|---|
| 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 | 9° 44’ 42.16318” North<br>118° 39’ 28.02050” East<br>16.81300 meters |
| Grid Coordinates, Philippine Transverse Mercator Zone 1A (PTM Zone 1A PRS 92) | Easting<br>Northing | 517311.956 meters<br>1077537.527 meters |
| Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84) | Latitude<br>Longitude<br>Ellipsoidal Height | 9° 44’ 37.72390” North<br>118° 39’ 33.34598” East<br>66.85300 meters |
| Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRD 1992) | Easting<br>Northing | 681,851.72 meters<br>1,077,601.73 meters |

Table 3. Details of the recovered NAMRIA vertical control point PL-92 used as base station for the LiDAR acquisition with re-processed coordinates.

| Station Name | PL-92 | |
|---|---|---|
| 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 | 9° 44' 04.01581" North<br>118° 40' 58.28065" East<br>8.218 meters |
| Grid Coordinates, Philippine Transverse Mercator Zone 1A (PTM Zone 1A PRS 92) | Easting<br>Northing | 26049.752 meters<br>1079008.192 meters |
| Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84) | Latitude<br>Longitude<br>Ellipsoidal Height | 99° 43' 59.58138" North<br>118° 41' 3.60701" East<br>58.344 meters |

Table 4. Ground control points used during LiDAR data acquisition

| Date Surveyed | Flight Number | Mission Name | Ground Control Points |
|---|---|---|---|
| June 14, 2015 | 3049P | 1BLK42S165A | PL-92, PLW-50 |
| June 17, 2015 | 3061P | 1BLK42Ab168A | PL-92, PLW-50 |

## 2.3 Flight Missions

Two (2) missions were conducted to complete LiDAR data acquisition in Inagauan floodplain, for a total of six hours and four minutes (6+04) of flying time for RP-C9022. All missions were acquired using the Pegasus LiDAR systems. Table 5 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 6 presents the actual parameters used during the LiDAR data acquisition.

Table 5. Flight missions for LiDAR data acquisition in Inagauan 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 14, 2015 | 3049P | 128.25 | 149.83 | 20.14 | 128.98 | 501 | 2 | 50 |
| June 17, 2015 | 3061P | 208.16 | 173.22 | 18.67 | 153.69 | 603 | 3 | 14 |
| TOTAL | | 236.41 | 323.05 | 38.82 | 282.67 | 1104 | 6 | 4 |

Table 6. Actual parameters used during LiDAR data acquisition.

| Flight Number | Flying Height (AGL) | Overlap (%) | Field of View (θ) | Pulse Repetition Frequency (PRF) (kHz) | Scan Frequency (Hz) | Average Speed (kts) | Average Turn Time (Minutes) |
|---|---|---|---|---|---|---|---|
| 3049P | 800 | 30 | 50 | 200 | 30 | 130 | 5 |
| 3061P | 800 | 30 | 50 | 200 | 30 | 130 | 5 |

## 2.4 Survey Coverage

Inagauan floodplain is located in the province of Palawan. The list of municipalities and cities, with at least one (1) square kilometer coverage, is shown in Table 7. The actual coverage of the LiDAR acquisition for Inagauan floodplain is shown in Figure 5.

Table 7. List of municipalities and cities surveyed during Inagauan Floodplain LiDAR survey.

| Province | Municipality/City | Area of Municipality/City (km2) | Total Area Surveyed (km2) | Percentage of Area Surveyed |
|---|---|---|---|---|
| Palawan | Aborlan | 645.11 | 77.72 | 12% |
| | Puerto Princesa City | 2186.36 | 206.72 | 9% |
| Total | | 2831.47 | 284.44 | 10.05% |

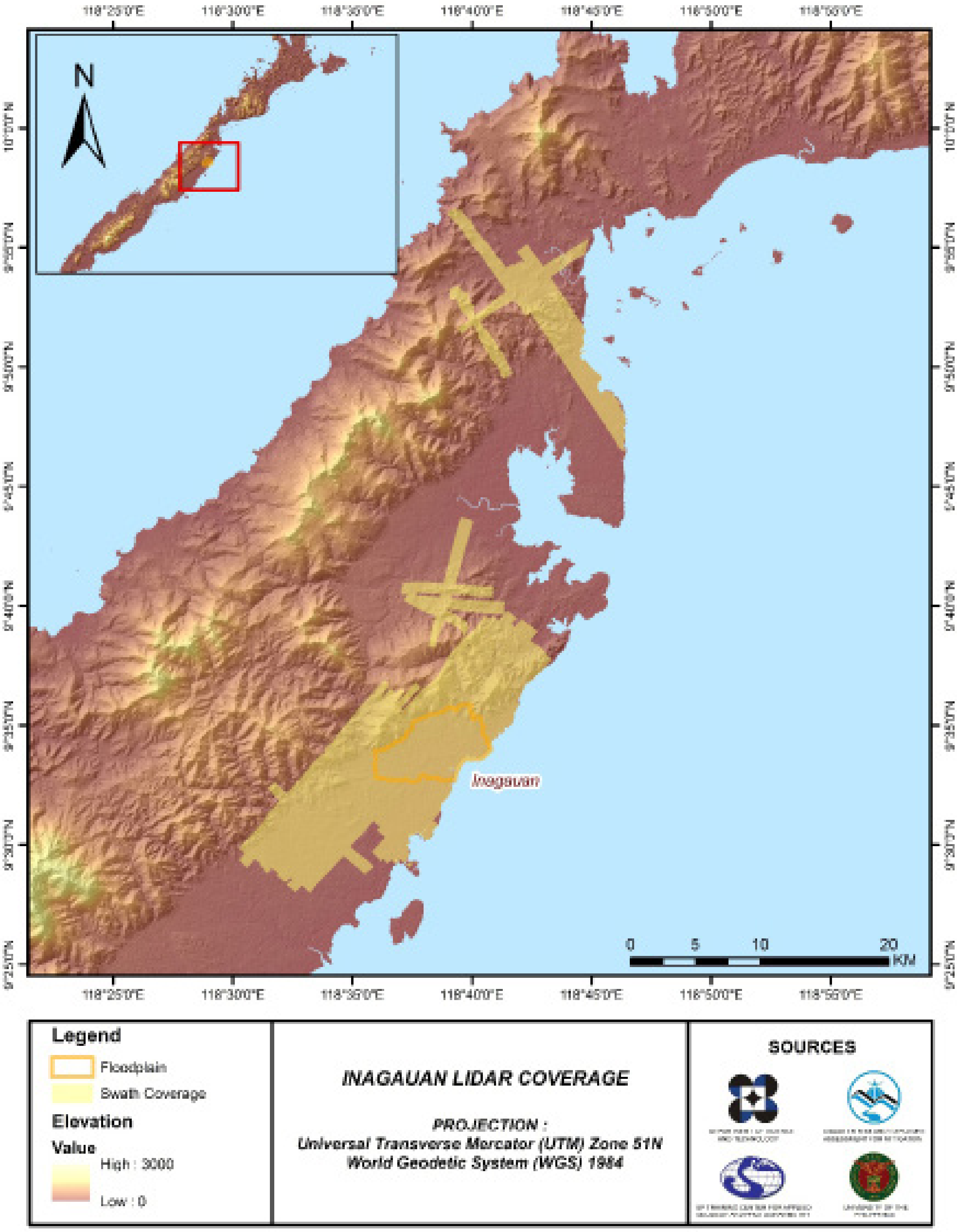


Figure 5. Actual LiDAR data acquisition for Inagauan floodplain.

# CHAPTER 3: LIDAR DATA PROCESSING FOR INAGAUAN FLOODPLAIN

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

## 3.1 Overview of LiDAR Data Pre-Processing

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

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

These processes are summarized in the flowchart shown in Figure 6.

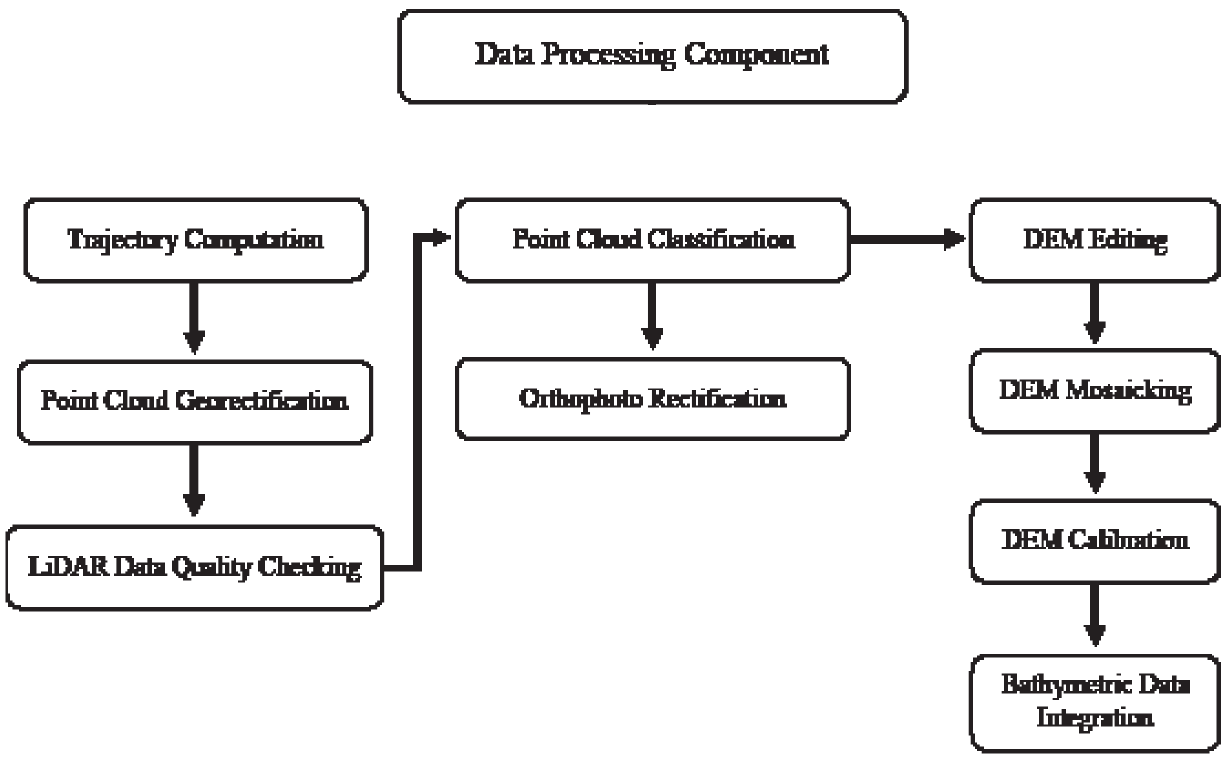


Figure 6. Schematic Diagram for Data Pre-Processing Component

## 3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Inagauan floodplain can be found in Annex 5. Missions flown during the first survey conducted on June 2015 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system while missions acquired during the second survey on July 2015 were flown using the Aquarius system over Puerto Princesa, Palawan.

The Data Acquisition Component (DAC) transferred a total of 42.70 Gigabytes of Range data, 367 Megabytes of POS data, 21.33 Megabytes of GPS base station data, and 70.9 Gigabytes of raw image data to the data server on July 13, 2015 for the first survey and August 3, 2015 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Babuyan was fully transferred on August 5, 2015, as indicated on the Data Transfer Sheets for Inagauan floodplain.

## 3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 3061P, one of the Inagauan flights, which is the North, East, and Down position RMSE values are shown in Figure 7. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on June 17, 2015 00:00AM. The y-axis is the RMSE value for that particular position.

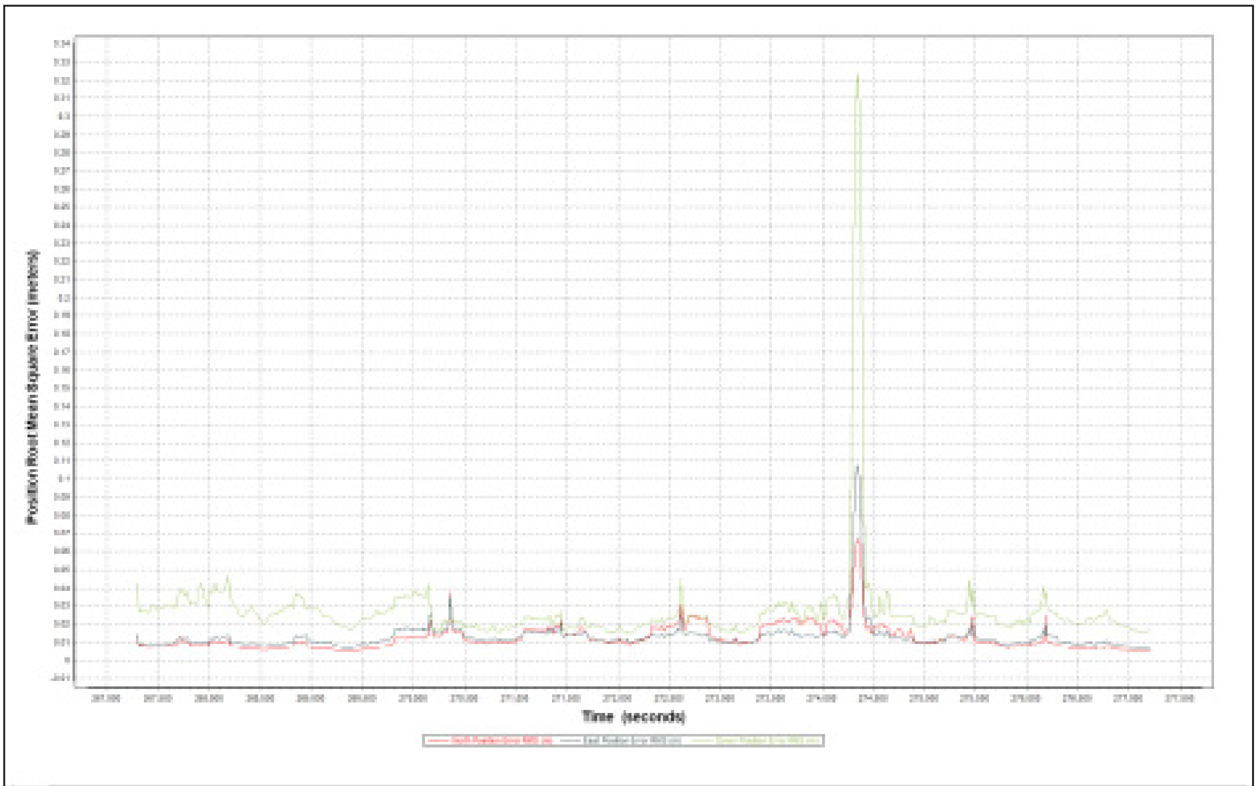


Figure 7. Smoothed Performance Metrics of Inagauan Flight 3061P.

The time of flight was from 267000 seconds to 277500 seconds, which corresponds to morning of June 17, 2015. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 8 shows that the North position RMSE peaks at 1.10 centimeters, the East position RMSE peaks at 0.70 centimeters, and the Down position RMSE peaks at 3.20 centimeters, which are within the prescribed accuracies described in the methodology.

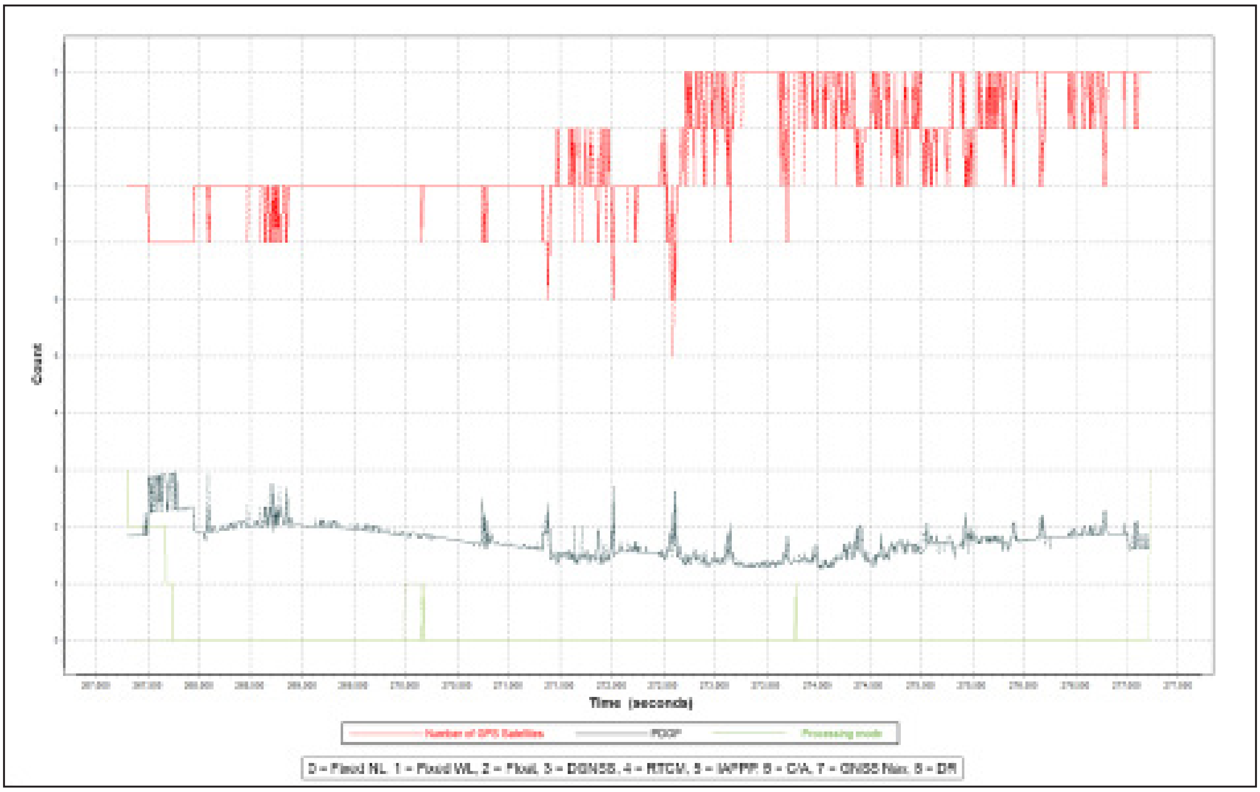


Figure 8. Solution Status Parameters of Inagauan Flight 3061P.

The Solution Status parameters of flight 3061P, one of the Inagauan flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 8. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Majority of the time, the number of satellites tracked was between 6 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 1 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Inagauan flights is shown in Figure 9.

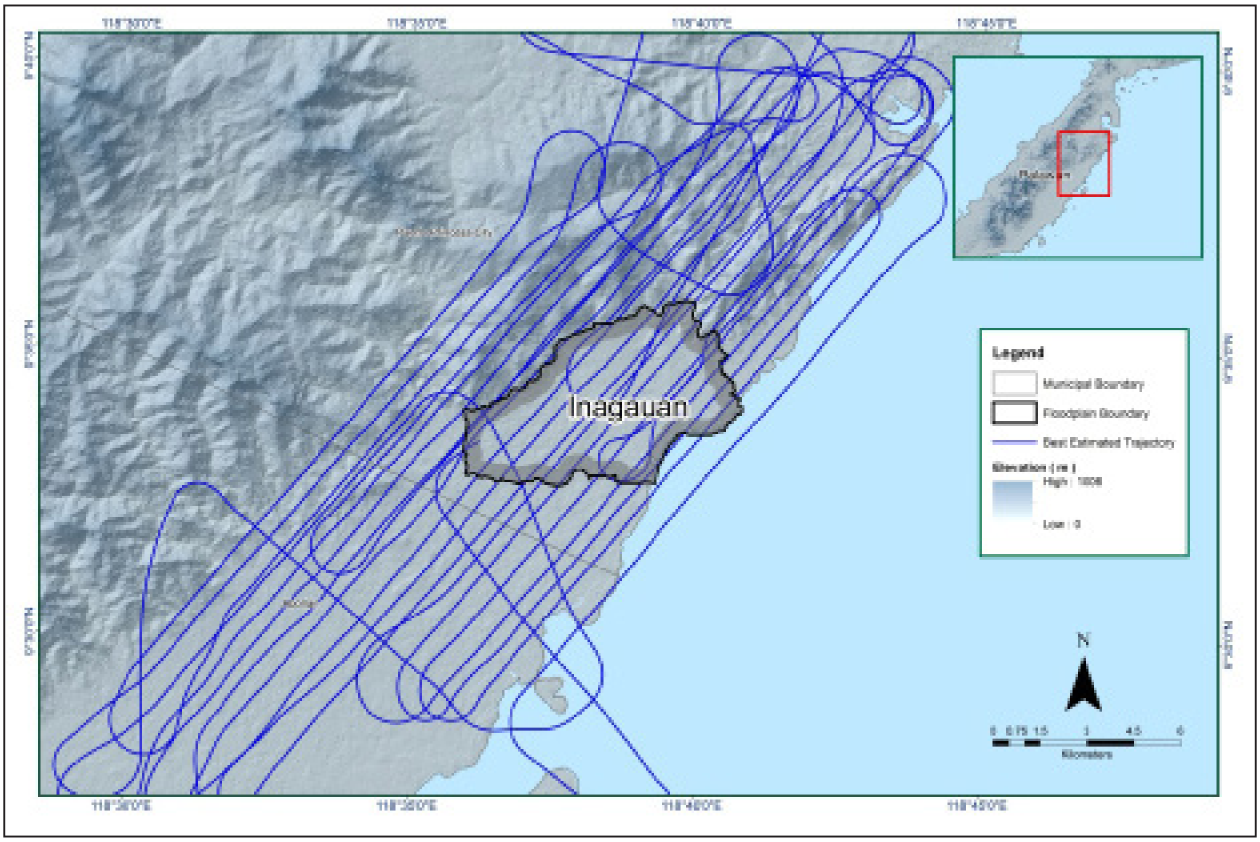


Figure 9. Best Estimated Trajectory for Inagauan Floodplain.

## 3.4 LiDAR Point Cloud Computation

The produced LAS data contains 60 flight lines, with each flight line containing two channels, since the Pegasus system contains two one channels. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Babuyan floodplain are given in Table 8.

Table 8. Self-Calibration Results values for Inagauan flights.

| Parameter | Acceptable Value | Value |
|---|---|---|
| Boresight Correction stdev | (<0.001degrees) | 0.000288 |
| IMU Attitude Correction Roll and Pitch Corrections stdev | (<0.001degrees) | 0.0021 |
| GPS Position Z-correction stdev | (<0.01meters) | 0.0024 |

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

## 3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Inagauan Floodplain is shown in Figure 10. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

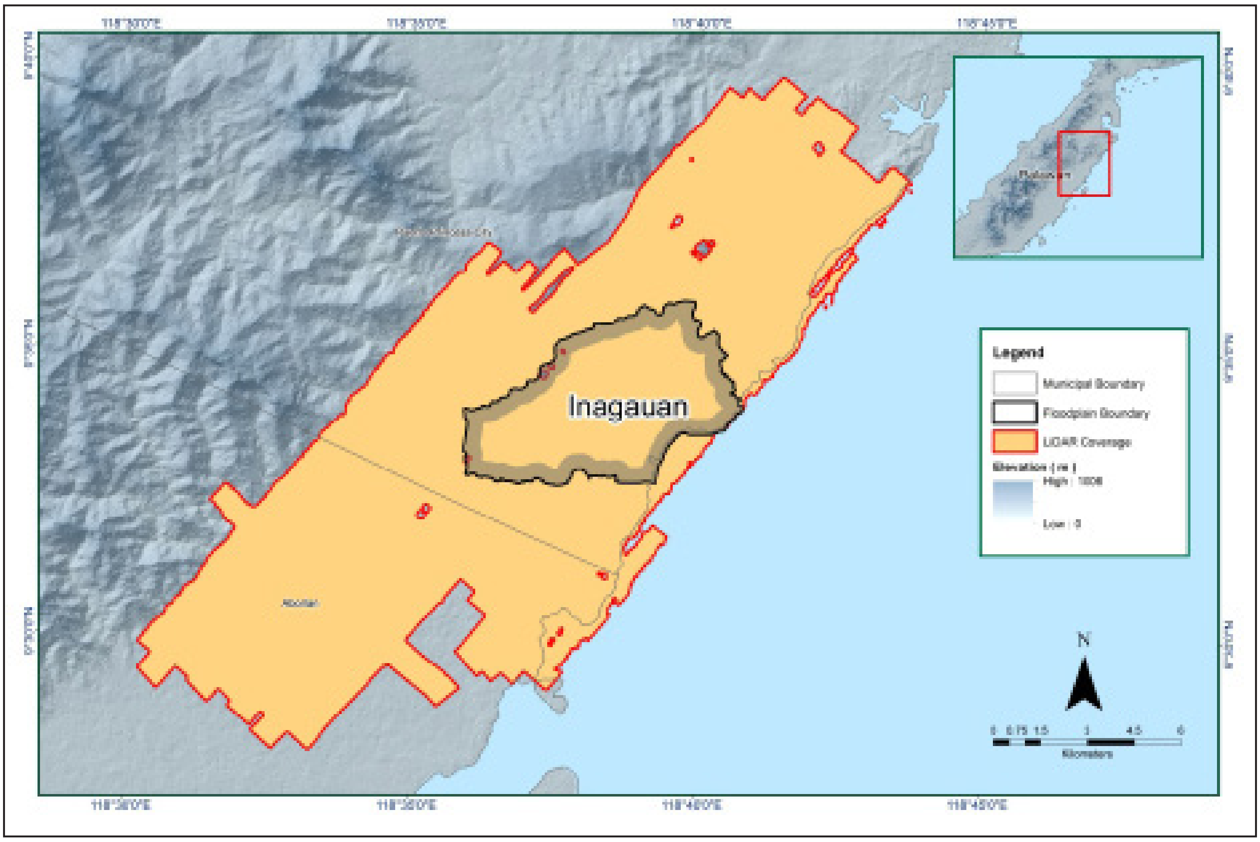


Figure 10. Boundary of the processed LiDAR data over Inagauan Floodplain

The total area covered by the Inagauan missions is 227.70 sq.km that is comprised of two (2) flight acquisitions grouped and merged into two (2) blocks as shown in Table 9.

Table 9. List of LiDAR blocks for Inagauan Floodplain.

| LiDAR Blocks | Flight Numbers | Area (sq. km) |
|---|---|---|
| Palawan_Blk42AB | 3061P | 148.98 |
| Palawan_Blk42AB_supplement | 3049P | 78.72 |
| TOTAL | | 227.70 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 11. Since the Pegasus system employs two channels, we would expect an average value of 2 (blue) for areas where there is limited overlap, and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines.

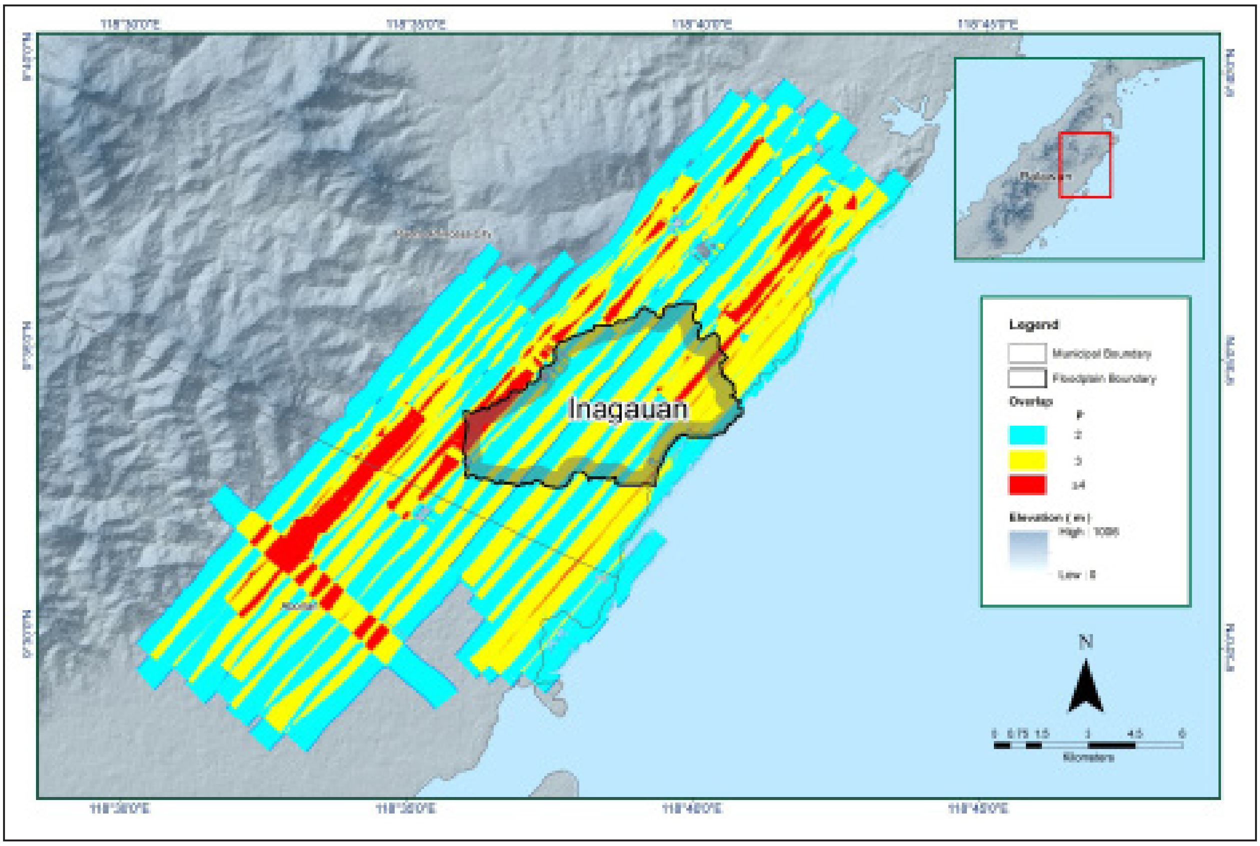


Figure 11. Image of data overlap for Inagauan floodplain.

The overlap statistics per block for the Inagauan floodplain can be found in Annex 8. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 47.37% and 56.02% respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 12. It was determined that all LiDAR data for Inagauan floodplain satisfy the point density requirement, and the average density for the entire survey area is 4.79 points per square meter.

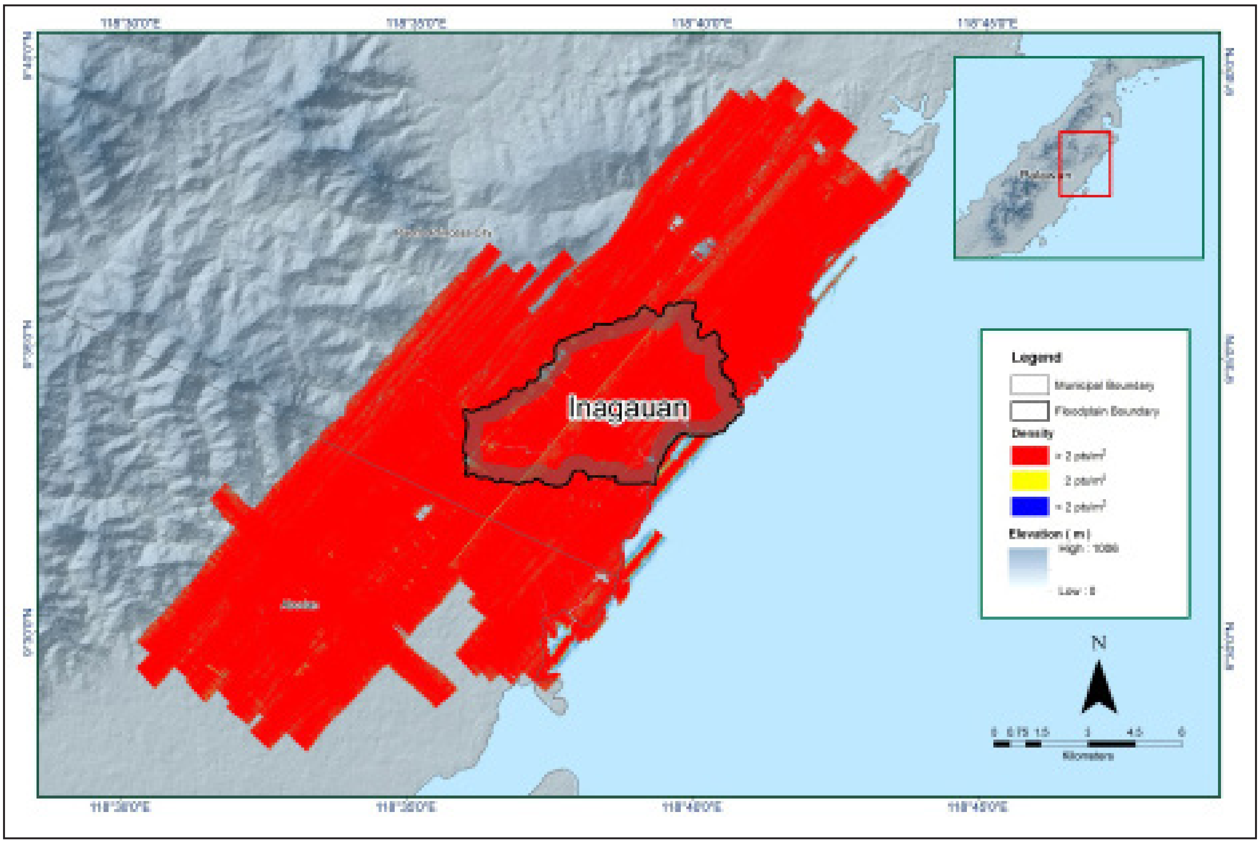


Figure 12. Pulse density map of merged LiDAR data for Inagauan Floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 13. 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.

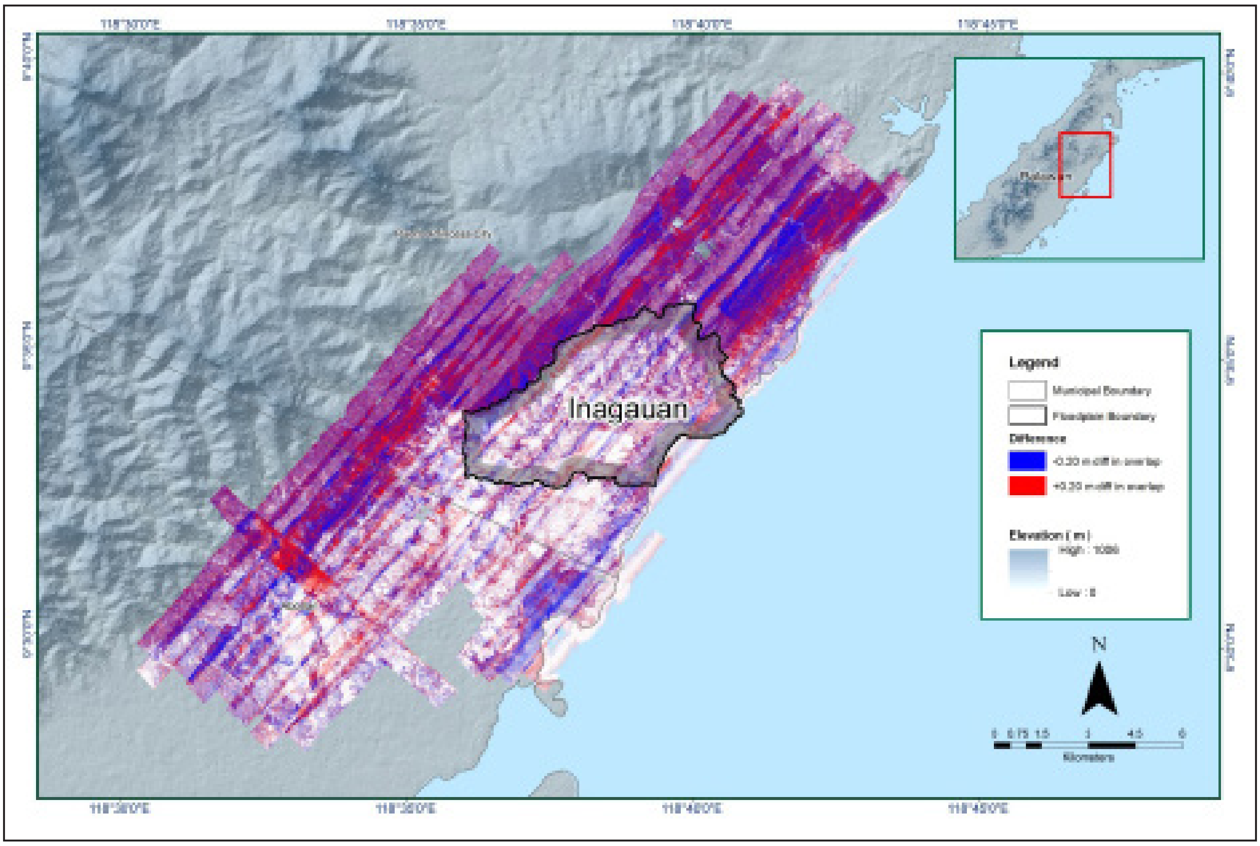


Figure 13. Elevation difference map between flight lines for Inagauan Floodplain.

A screen capture of the processed LAS data from a Babuyan flight 3061P loaded in QT Modeler is shown in Figure 14. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

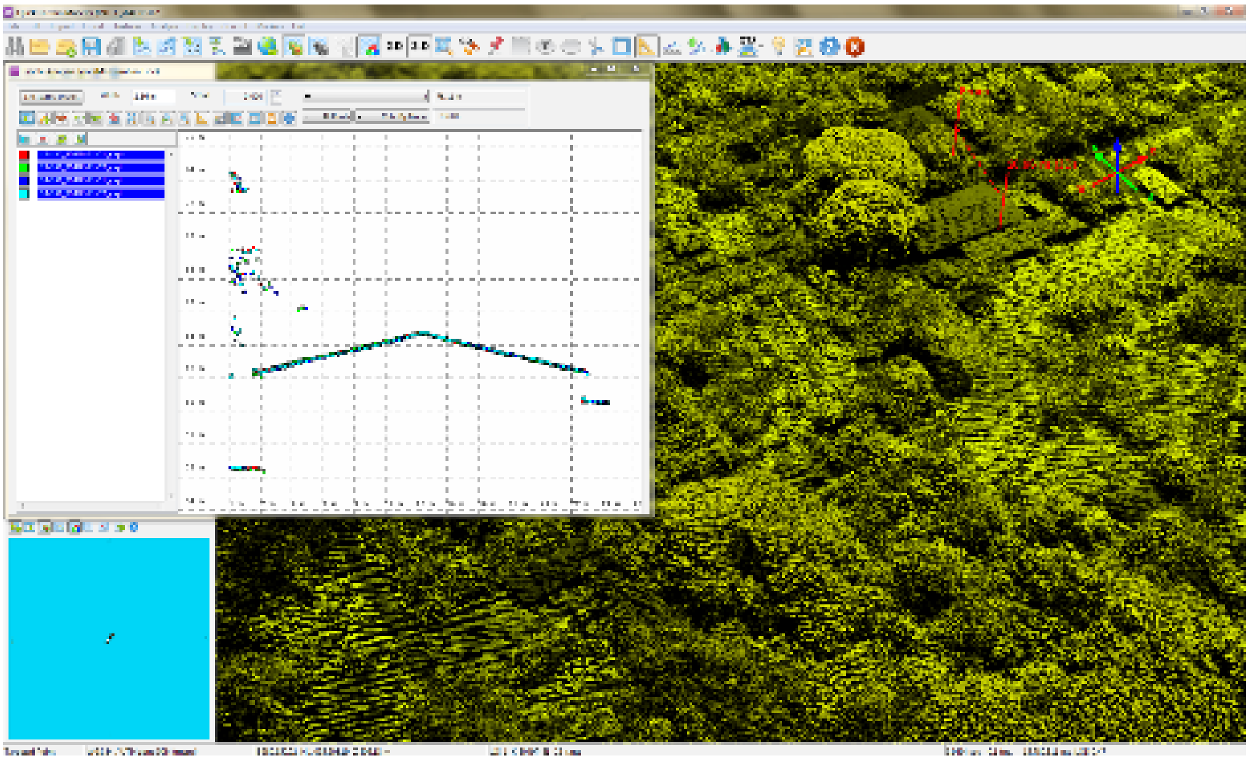

Figure 14. Quality checking for Inagauan flight 3061P using the Profile Tool of QT Modeler.

## 3.6 LiDAR Point Cloud Classification and Rasterization

Table 10. Inagauan classification results in TerraScan.

| Pertinent Class | Total Number of Points |
|---|---|
| Ground | 203,865,061 |
| Low Vegetation | 163,178,413 |
| Medium Vegetation | 332,054,303 |
| High Vegetation | 1,244,112,706 |
| Building | 10,395,438 |

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Inagauan floodplain is shown in Figure 15. A total of 309 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 10. The point cloud has a maximum and minimum height of 695 meters and 42.29 meters respectively.

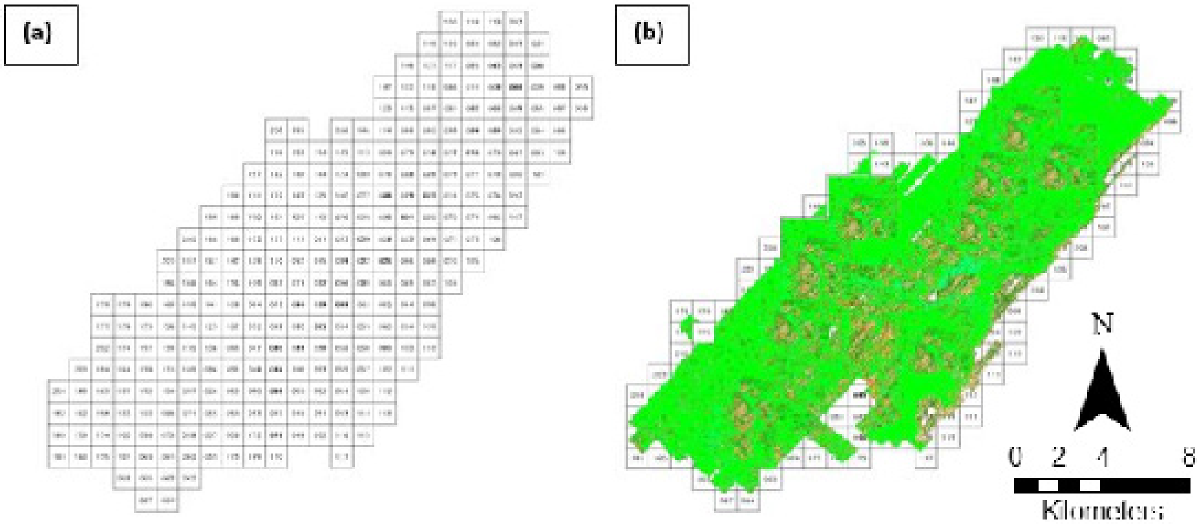


Figure 15. Tiles for Inagauan Floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 16. 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.

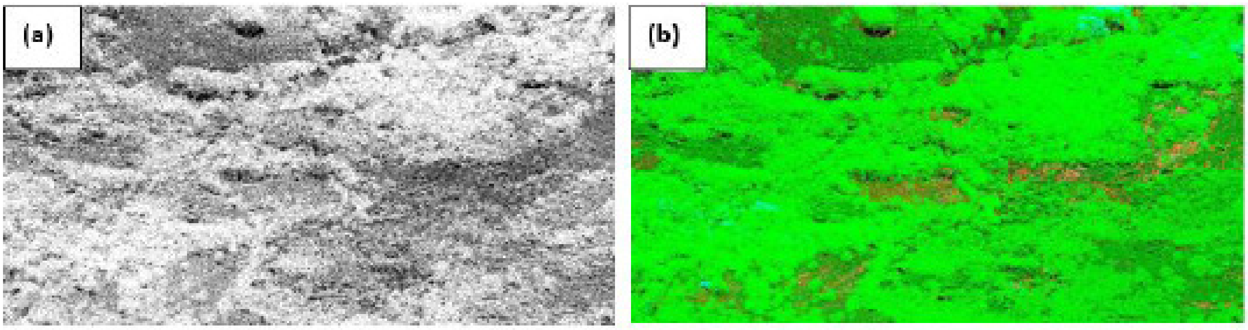


Figure 16. Point cloud before (a) and after (b) classification.

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

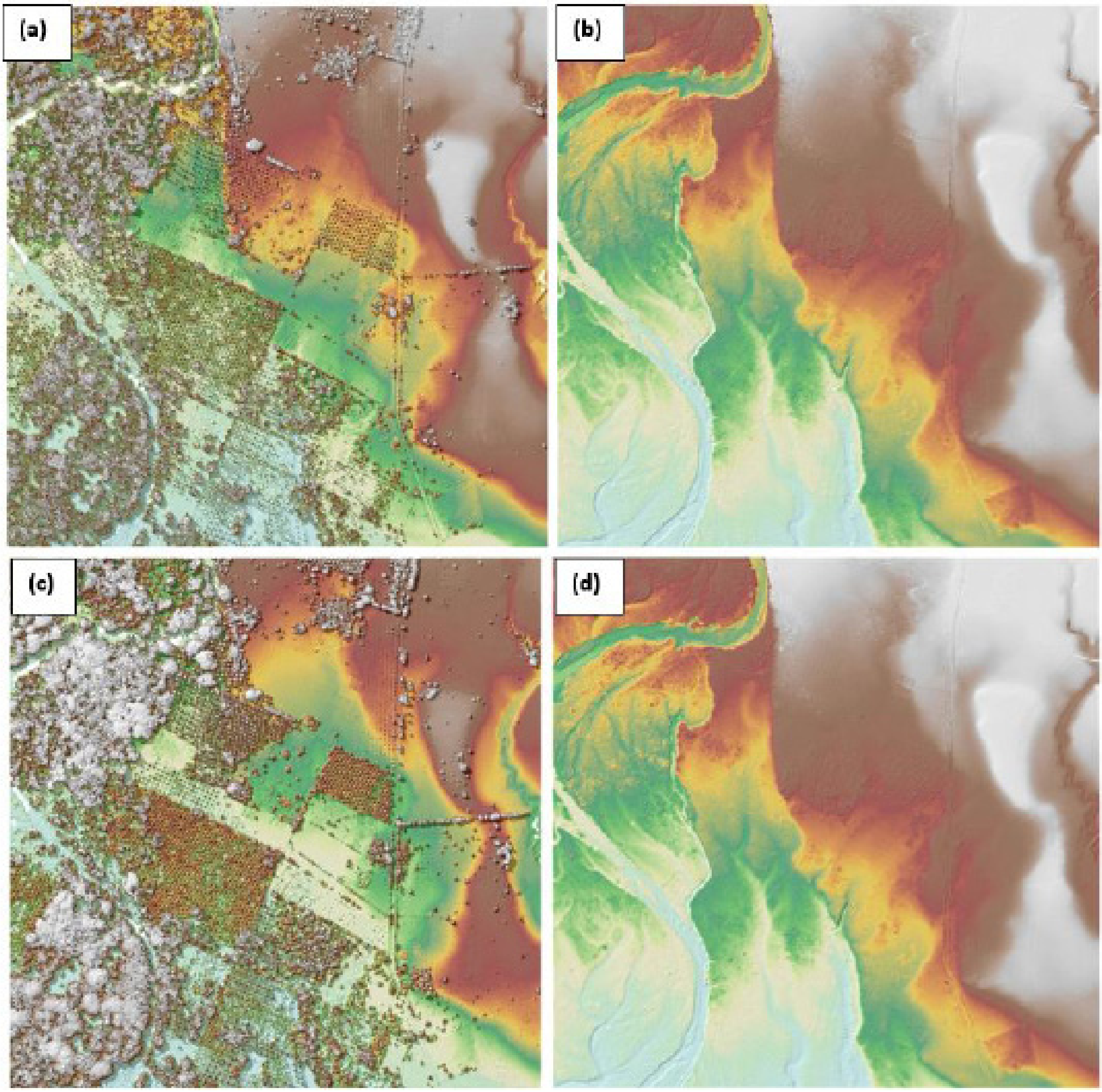


Figure 17. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Inagauan Floodplain.

## 3.7 LiDAR Image Processing and Orthophotograph Rectification

The 311 1km by 1km tiles area covered by Inagauan floodplain is shown in Figure 18. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Inagauan floodplain has a total of 202.97 sq.km orthophotogaph coverage comprised of 1,014 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 19.

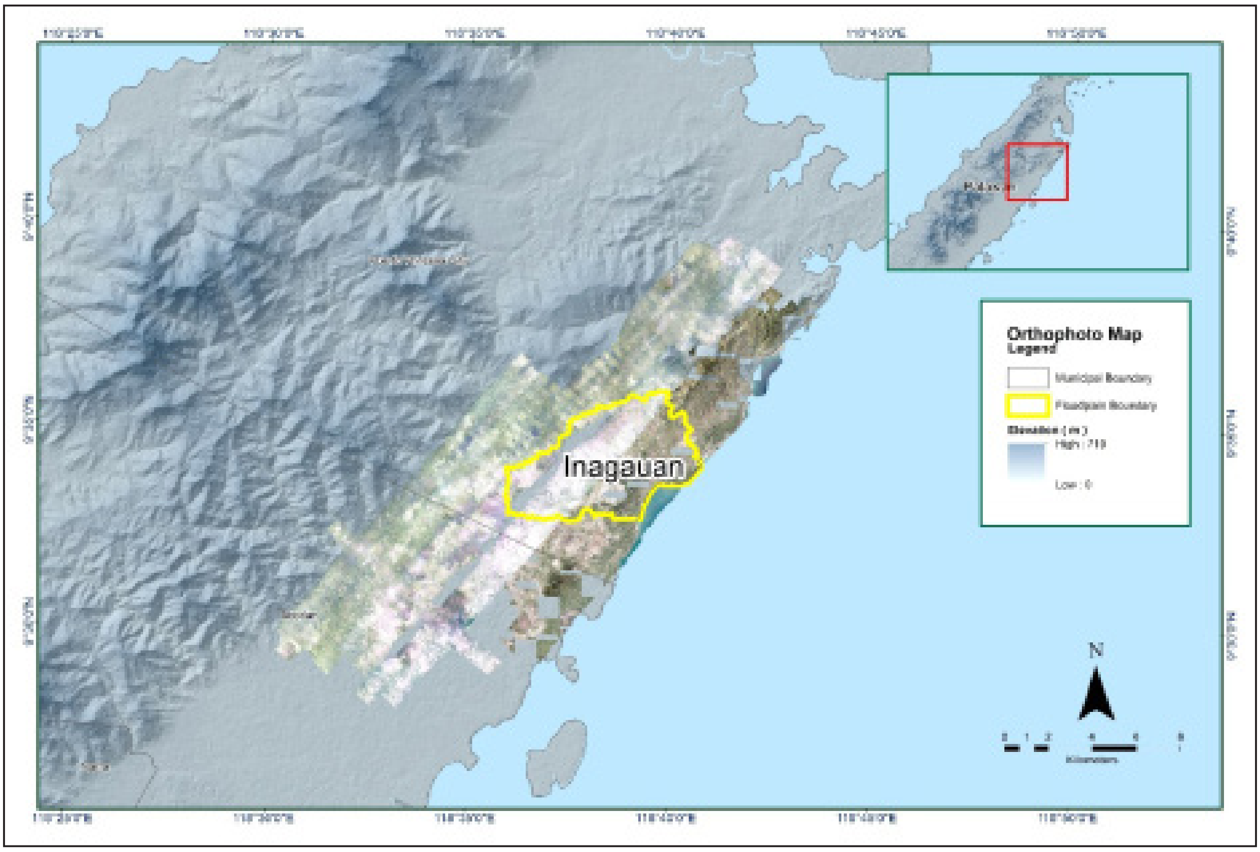


Figure 18. Inagauan Floodplain with available orthophotographs.

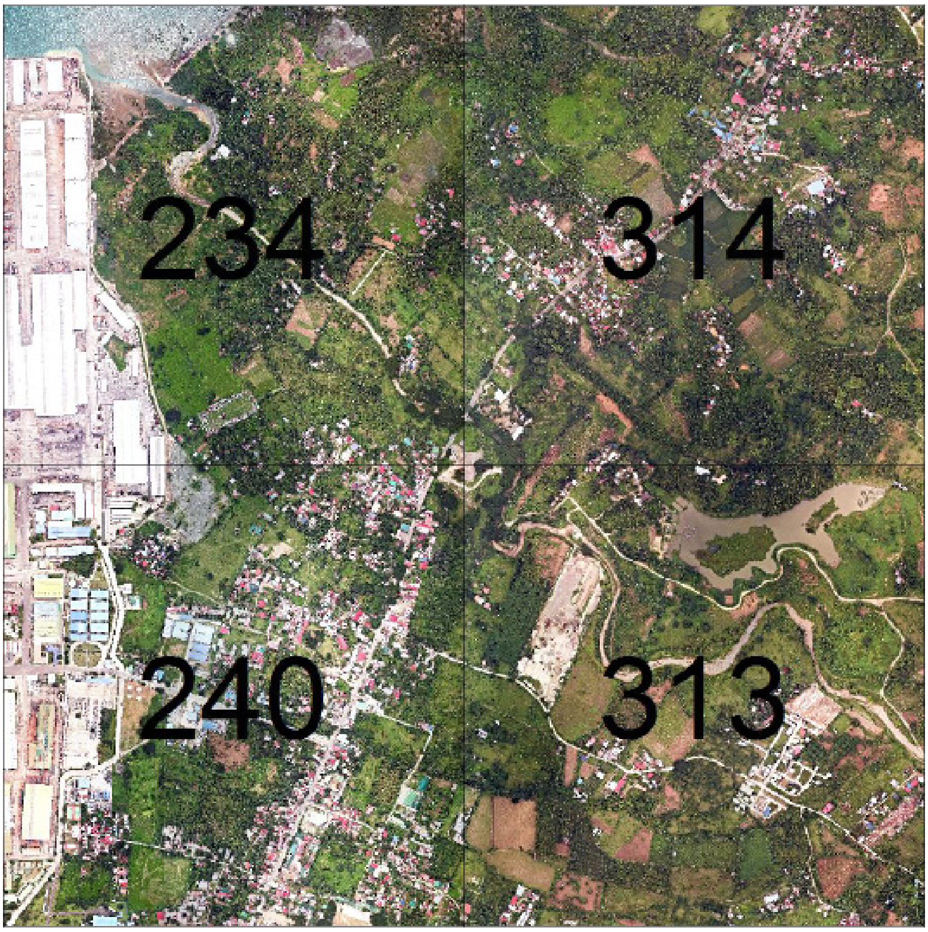


Figure 19. Sample orthophotograph tiles for Inagauan Floodplain.

## 3.8 DEM Editing and Hydro-Correction

Two (2) mission blocks were processed for Inagauan floodplain. These blocks are composed of Palawan blocks with a total area of 227.70 square kilometers. Table 11 shows the name and corresponding area of each block in square kilometers.

Table 11. LiDAR blocks with its corresponding area.

| LiDAR Blocks | Area (sq.km) |
|---|---|
| Palawan_Blk42AB | 148.98 |
| Palawan_Blk42AB_supplement | 78.72 |
| **TOTAL** | **227.70 sq.km** |

Portions of DTM before and after manual editing are shown in Figure 20. The bridge in Figure 20a would be an impedance to the flow of water along the river and was removed in order to hydrologically correct the river, as done in Figure 20b. Another portion of the DTM presented in Figure 20c shows the part of the river which have data gaps. This part was filled as done in Figure 20d.

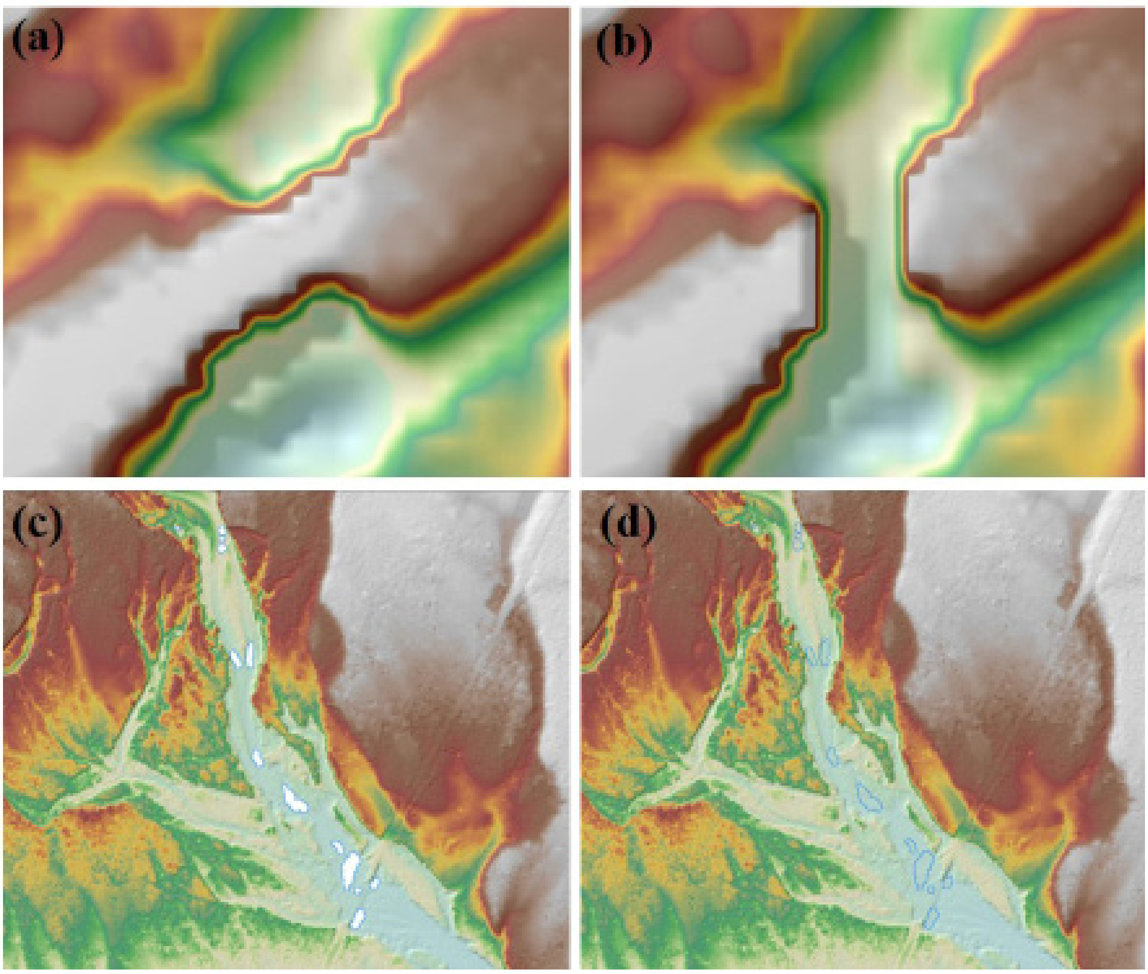


Figure 20. Figure 20. Portions in the DTM of Inagauan Floodplain – a bridge before (a) and and after (b) manual data editing and a part of the river with no data before (c) and after (d) filling data gaps.

## 3.9 Mosaicking of Blocks

Palawan Block 42AB was used as the reference block at the start of mosaicking because it was the first block mosaicked to the larger DTM of West Coast Palawan. Upon inspection of the blocks mosaicked for the Inagauan floodplain, it was concluded that there is no need to adjust the elevation of the DTM for all of the blocks merged, as presented in Table 12.

Mosaicked LiDAR DTM for Inagauan floodplain is shown in Figure 21. It can be seen that the entire Inagauan floodplain is 99.70% covered by LiDAR data.

Table 12. Shift Values of each LiDAR Block of Inagauan Floodplain

| Mission Blocks | Shift Values (meters) | | |
|---|---|---|---|
| | x | y | z |
| Palawan_Blk42AB | 0.00 | 0.00 | 0.00 |
| Palawan_Blk42AB_supplement | 0.00 | 0.00 | 0.00 |

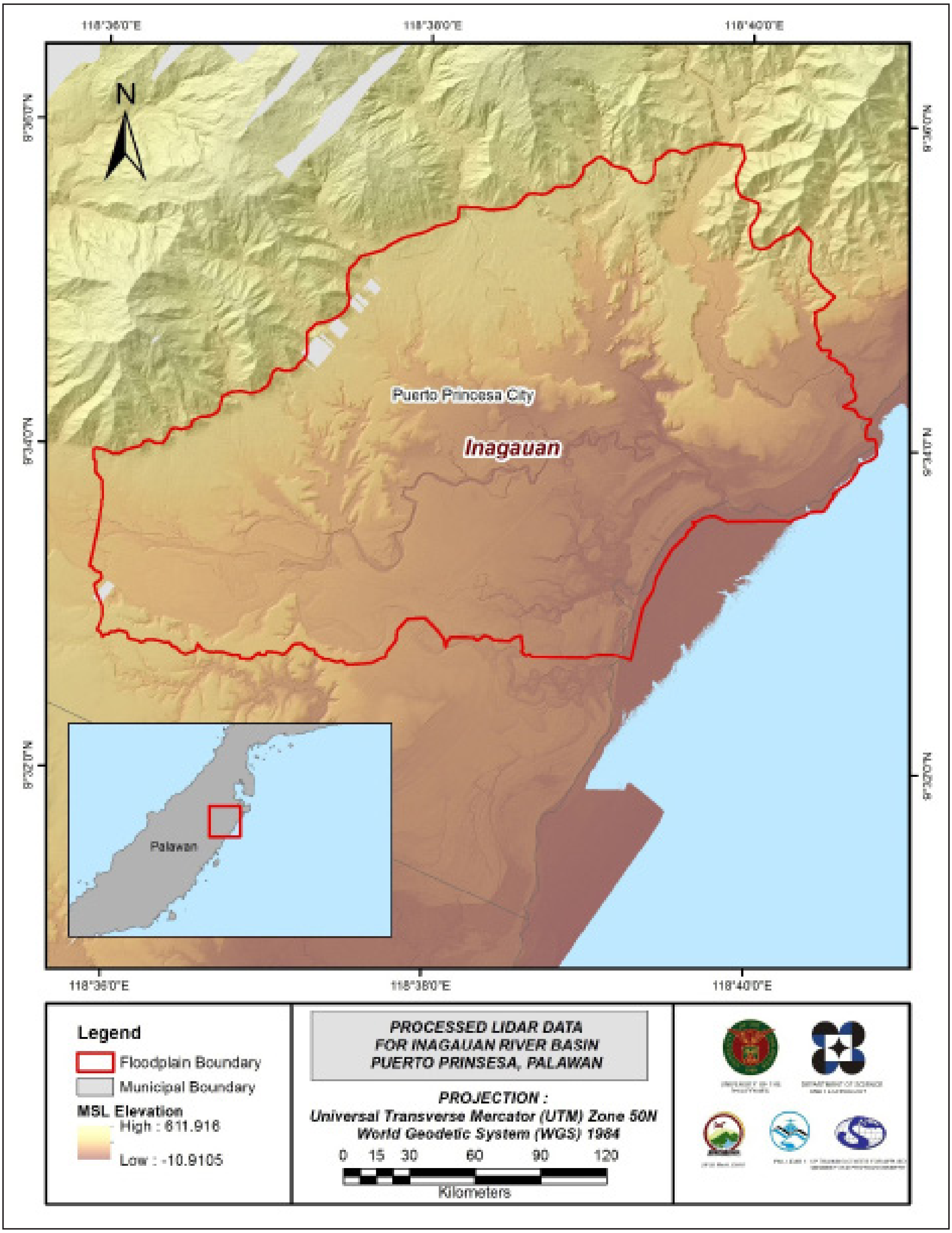


Figure 21. Map of Processed LiDAR Data for Inagauan Flood Plain.

## 3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Inagauan to collect points with which the LiDAR dataset is validated is shown in Figure 22. A total of 3,498 survey points were used for calibration and validation of Inagauan LiDAR data. Random selection of 80% of the survey points, resulting to 2,794 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 23. 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 9.61 meters with a standard deviation of 0.15 meters. Calibration of Inagauan LiDAR data was done by adding the height difference value, 9.61 meters, to Inagauan mosaicked LiDAR data. Table 13 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

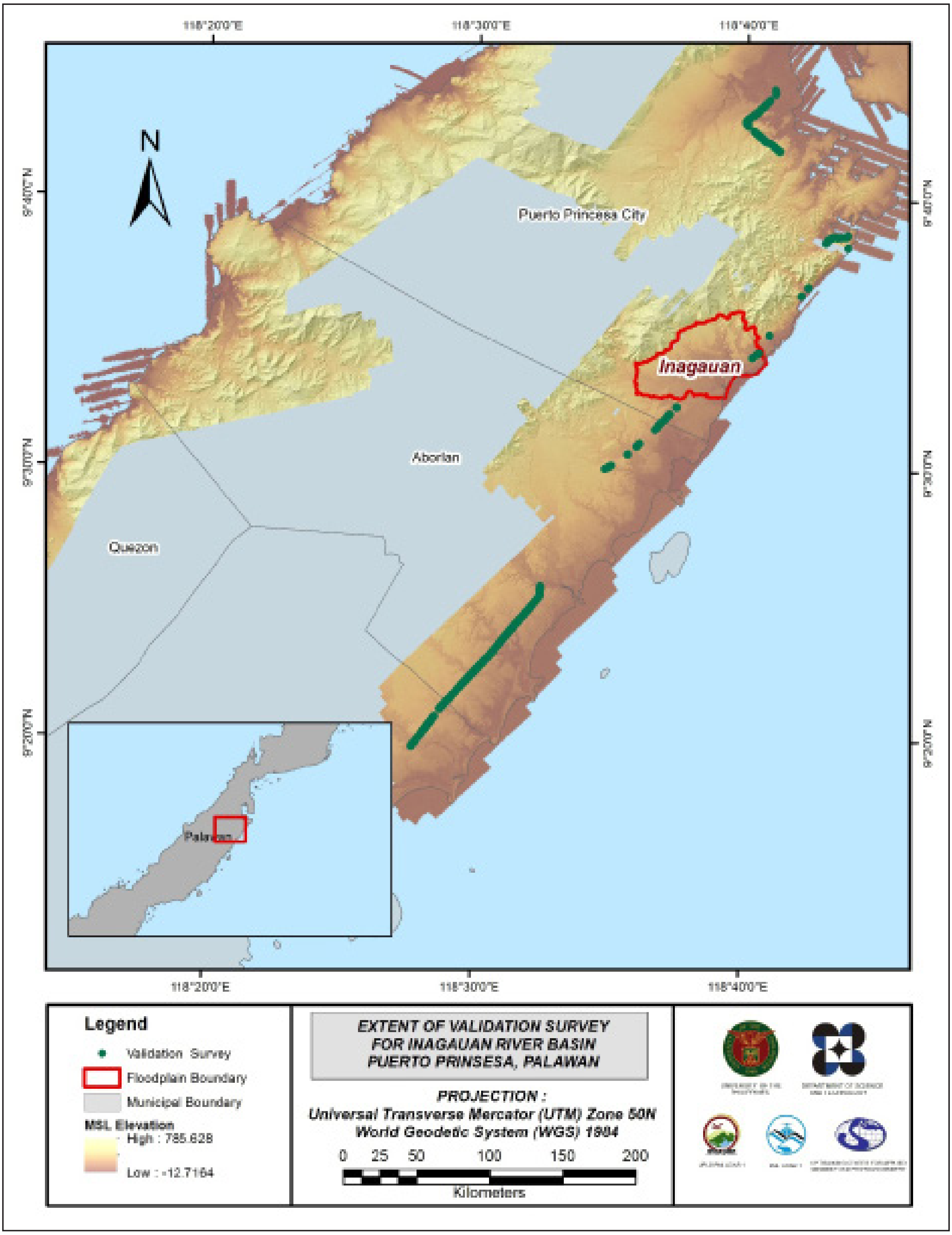


Figure 22. Map of Inagauan Floodplain with validation survey points in green.

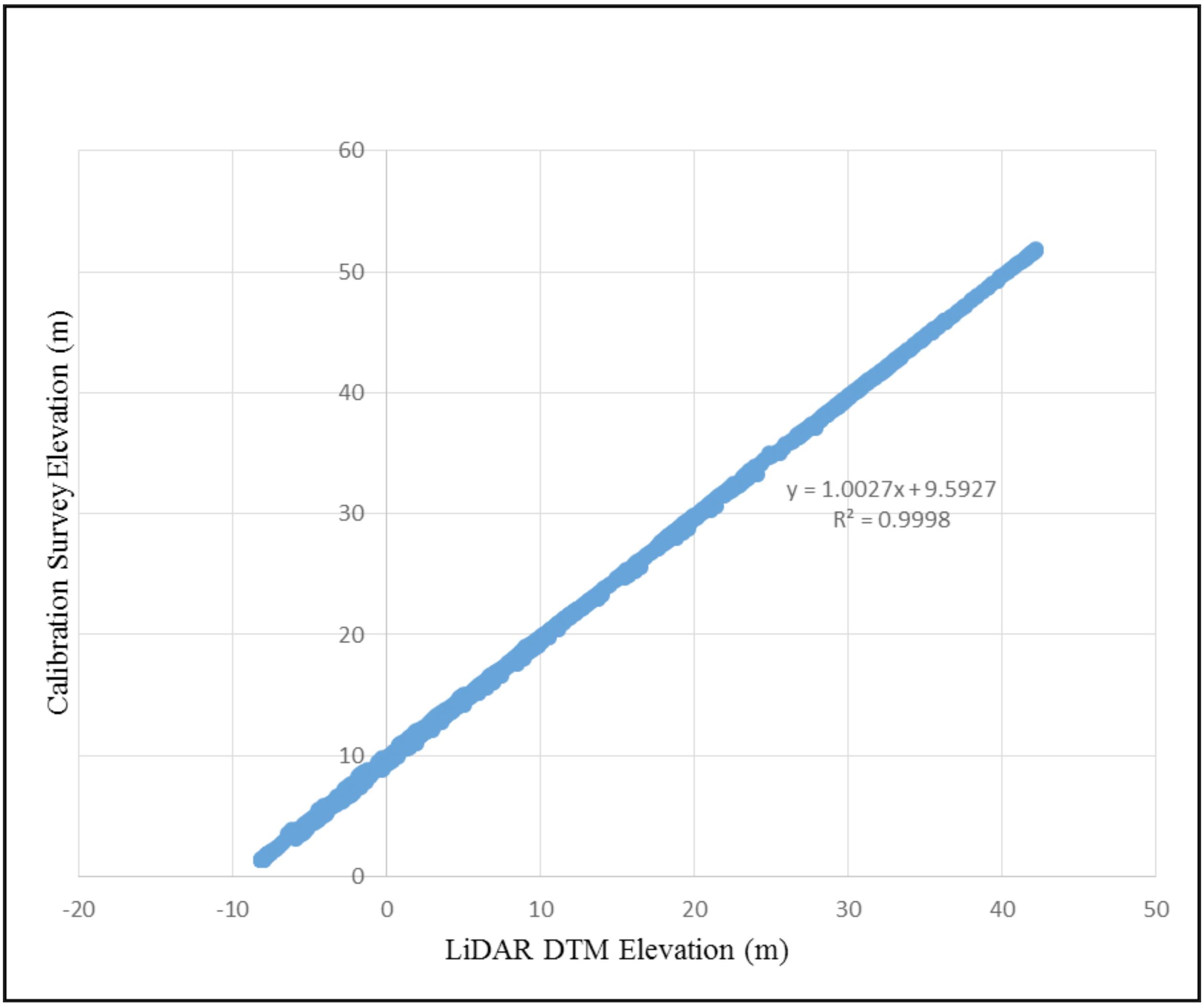


Figure 23. Correlation plot between calibration survey points and LiDAR data.

Table 13. Calibration Statistical Measures.

| Calibration Statistical Measures | Value (meters) |
|---|---|
| Height Difference | 9.61 |
| Standard Deviation | 0.15 |
| Average | 9.61 |
| Minimum | 9.30 |
| Maximum | 9.92 |

The remaining 20% of the total survey points, resulting to 701 points, were used for the validation of calibrated Inagauan 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 0.15 meters with a standard deviation of 0.15 meters, as shown in Table 14.

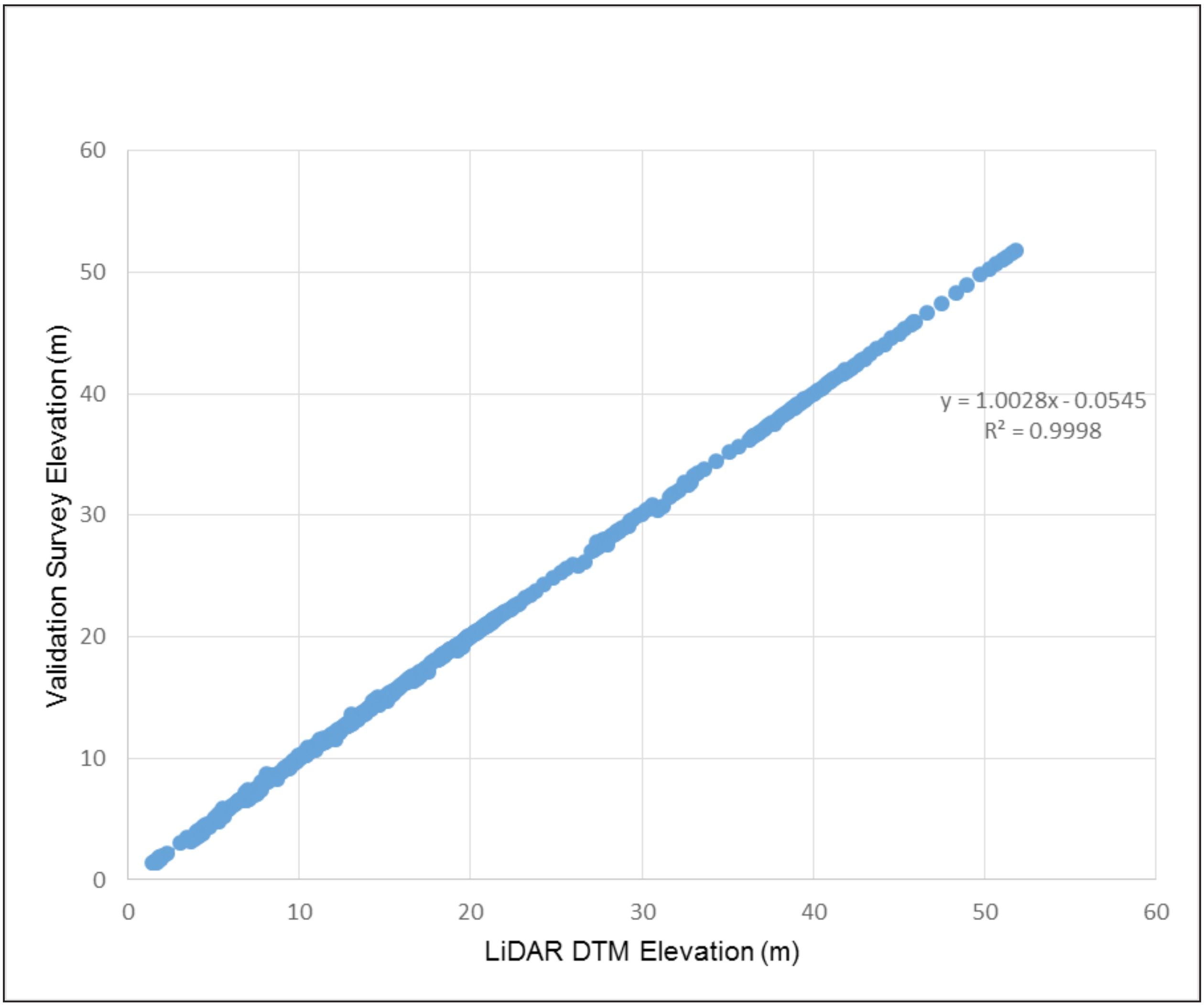


Figure 24. Correlation plot between validation survey points and LiDAR data.

Table 14. Validation Statistical Measures.

| Validation Statistical Measures | Value (meters) |
|---|---|
| RMSE | 0.15 |
| Standard Deviation | 0.15 |
| Average | -0.005 |
| Minimum | -0.31 |
| Maximum | 0.30 |

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

For bathy integration, centerline and zigzag data were available for Inagauan with 2,487 and 417 bathymetric survey points, respectively. The resulting raster surface produced was done by Kernel Interpolation with Barriers method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.44 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Inagauan integrated with the processed LiDAR DEM is shown in Figure 25.

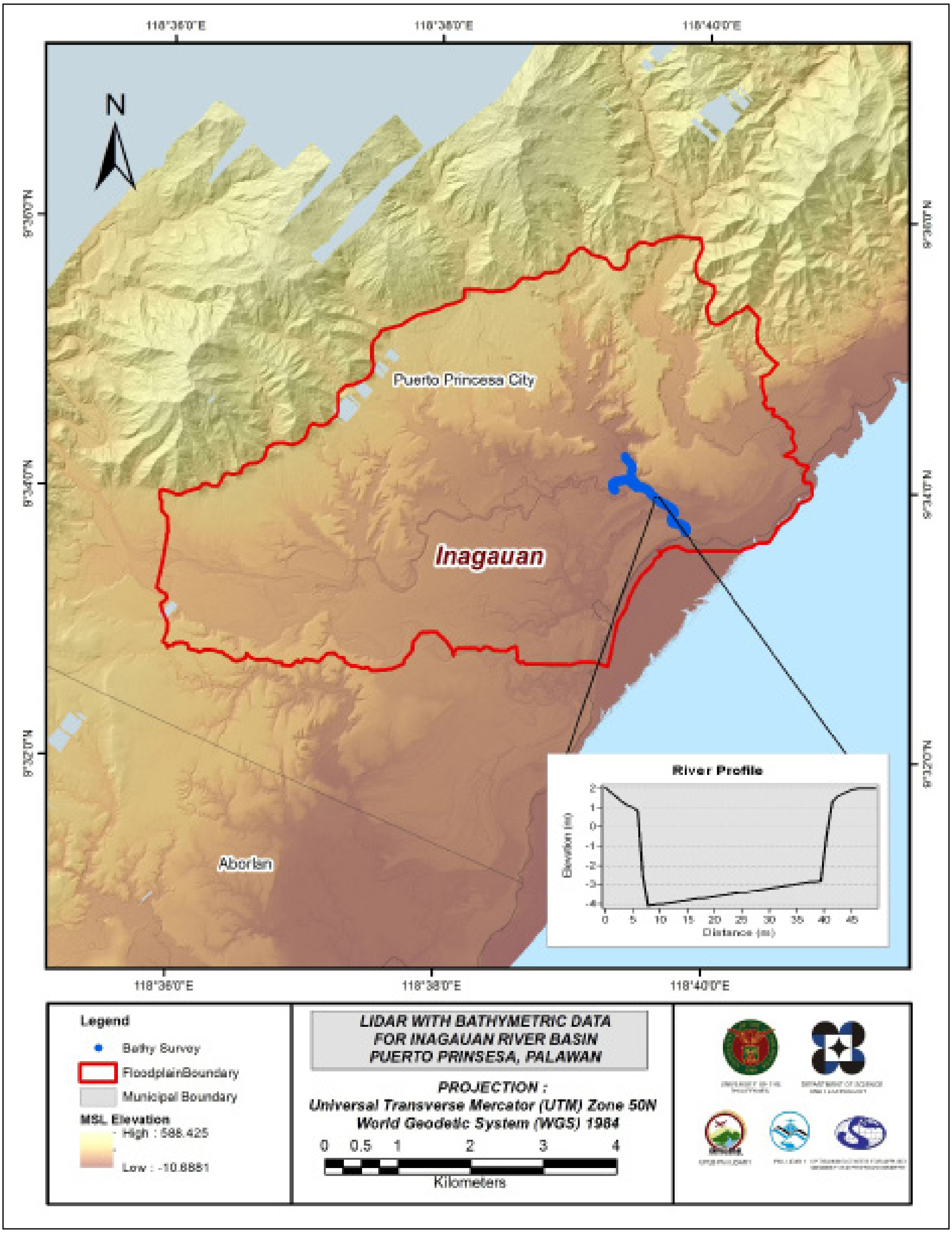


Figure 25. Map of Inagauan Floodplain with bathymetric survey points shown in blue.

## 3.12 Feature Extraction

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

### 3.12.1 Quality Checking (QC) of Digitized Features' Boundary

Inagauan floodplain, including its 200 m buffer, has a total area of 39.33 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 539 building features, are considered for QC. Figure 26 shows the QC blocks for Inagauan floodplain.

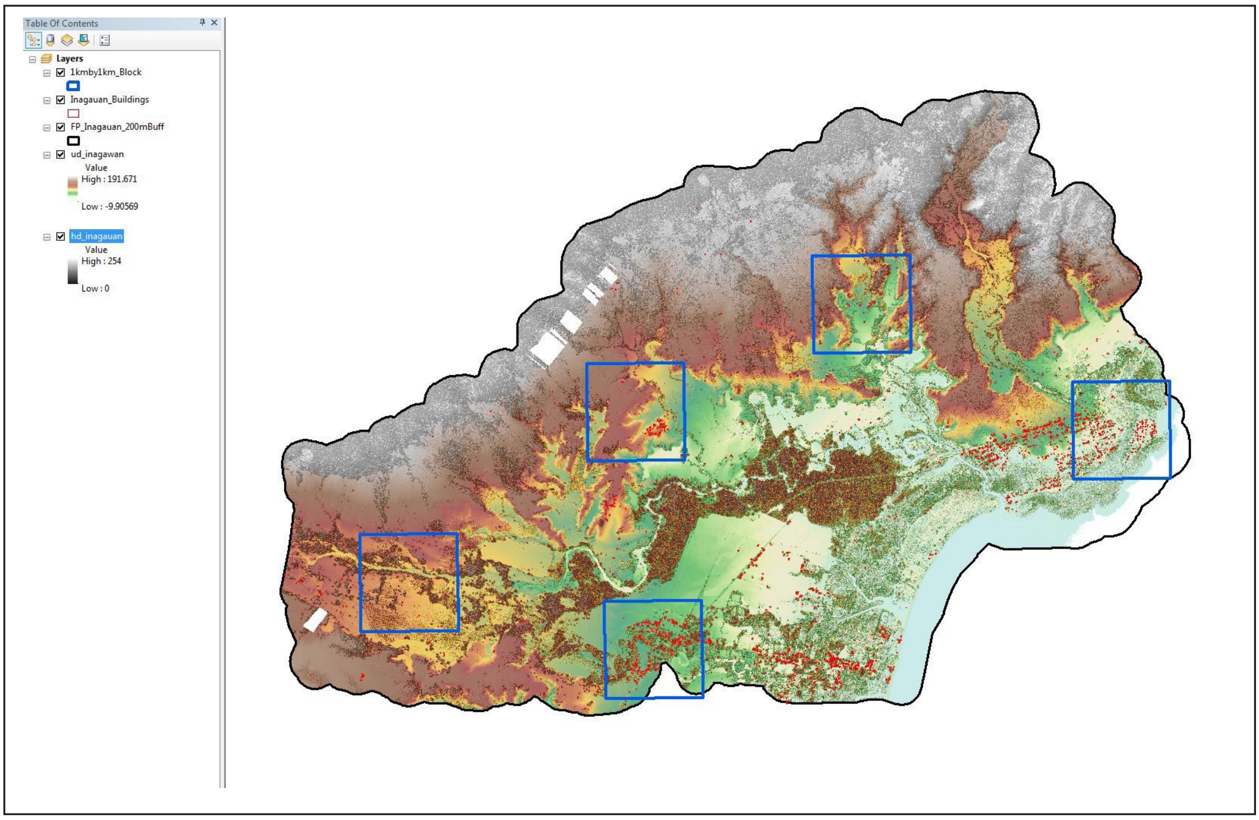


Figure 26. QC blocks for Inagauan building features.

Quality checking of Inagauan building features resulted in the ratings shown in Table 15.

Table 15. Quality Checking Ratings for Inagauan Building Features.

| FLOODPLAIN | COMPLETENESS | CORRECTNESS | QUALITY | REMARKS |
|---|---|---|---|---|
| Inagauan | 87.62 | 99.81 | 82.19 | PASSED |

### 3.12.2 Height Extraction

Height extraction was done for 5,690 building features in Inagauan floodplain. Of these building features, none was filtered out after height extraction, resulting to 5,690 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 8.74 m.

### 3.12.3 Feature Attribution

The digitized features were marked and coded in the field using handheld GPS receivers. The attributes of non-residential buildings were first identified; all other buildings were then coded as residential. An nDSM was generated using the LiDAR DEMs to extract the heights of the buildings. A minimum height of 2 meters was used to filter out the terrain features that were digitized as buildings. Buildings that were not yet constructed during the time of LiDAR acquisition were noted as new buildings in the attribute table.

Table 16 summarizes the number of building features per type. On the other hand, Table 17 shows the total length of each road type, while Table 18 shows the number of water features extracted per type.

Table 16. Building Features Extracted for Inagauan Floodplain.

| Facility Type | No. of Features |
|---|---|
| Residential | 1470 |
| School | 26 |
| Market | 0 |
| Agricultural/Agro-Industrial Facilities | 1 |
| Medical Institutions | 0 |
| Barangay Hall | 1 |
| Military Institution | 0 |
| Sports Center/Gymnasium/Covered Court | 2 |
| Telecommunication Facilities | 0 |
| Transport Terminal | 0 |
| Warehouse | 2 |
| Power Plant/Substation | 0 |
| NGO/CSO Offices | 0 |
| Police Station | 8 |
| Water Supply/Sewerage | 0 |
| Religious Institutions | 16 |
| Bank | 0 |
| Factory | 0 |
| Gas Station | 0 |
| Fire Station | 0 |
| Other Government Offices | 2 |
| Other Commercial Establishments | 51 |
| **Total** | 1579 |

Table 17. Total Length of Extracted Roads for Inagauan Floodplain.

| Floodplain | Road Network Length (km) | | | | | Total |
|---|---|---|---|---|---|---|
| | Barangay Road | City/Municipal Road | Provincial Road | National Road | Others | |
| Inagauan | 6.9 | 0.00 | 0.00 | 7.01 | 0.00 | 13.91 |

Table 18. Number of Extracted Water Bodies for Inagauan Floodplain.

| Floodplain | Water Body Type | | | | | Total |
|---|---|---|---|---|---|---|
| | Rivers/Streams | Lakes/Ponds | Sea | Dam | Fish Pen | |
| Inagauan | 3 | 5 | 0 | 0 | 0 | 8 |

A total of 6 bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

## 3.12.4 Final Quality Checking of Extracted Features

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

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

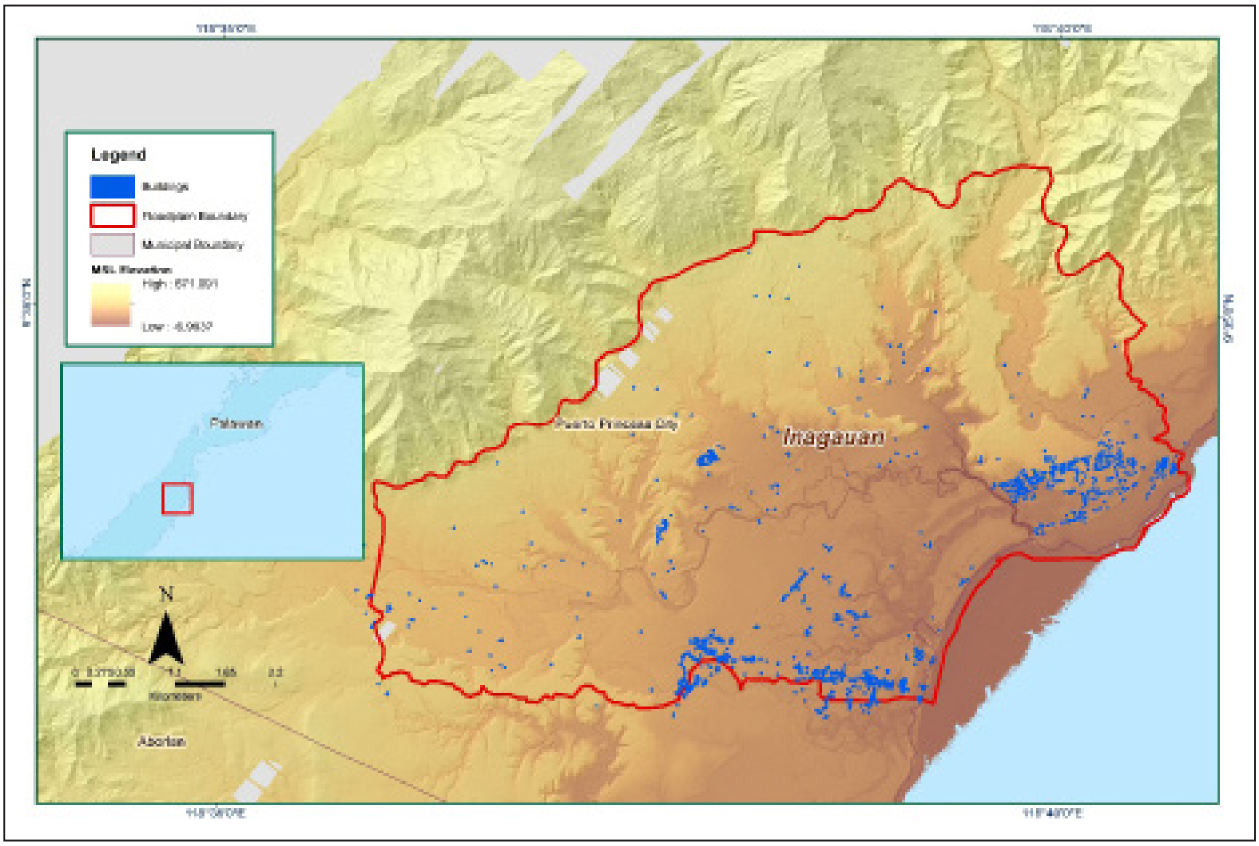


Figure 27. Extracted features for Inagauan Floodplain.

# CHAPTER 4: DATA VALIDATION SURVEY AND MEASUREMENTS IN THE INAGAUAN RIVER BASIN

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

## 4.1 Summary of Activities

AB Surveying and Development (ABSD) conducted a field survey in Inagauan River on November 27 and 28, 2015, and February 6, 2016 with the following scope: reconnaissance; control survey; and cross-section and as-built survey at Inagauan Bridge in Brgy. Inagawan Sub-Colony, Puerto Princesa City, Palawan. Random checking points for the contractor's cross-section and bathymetry data were gathered by DVBC on August 16-28, 2016 using an Ohmex™ Single Beam Echo Sounder and Trimble® SPS 985 GNSS PPK survey technique. In addition to this, validation points acquisition survey was conducted covering the Inagauan River Basin area. The entire survey extent is illustrated in Figure 28.

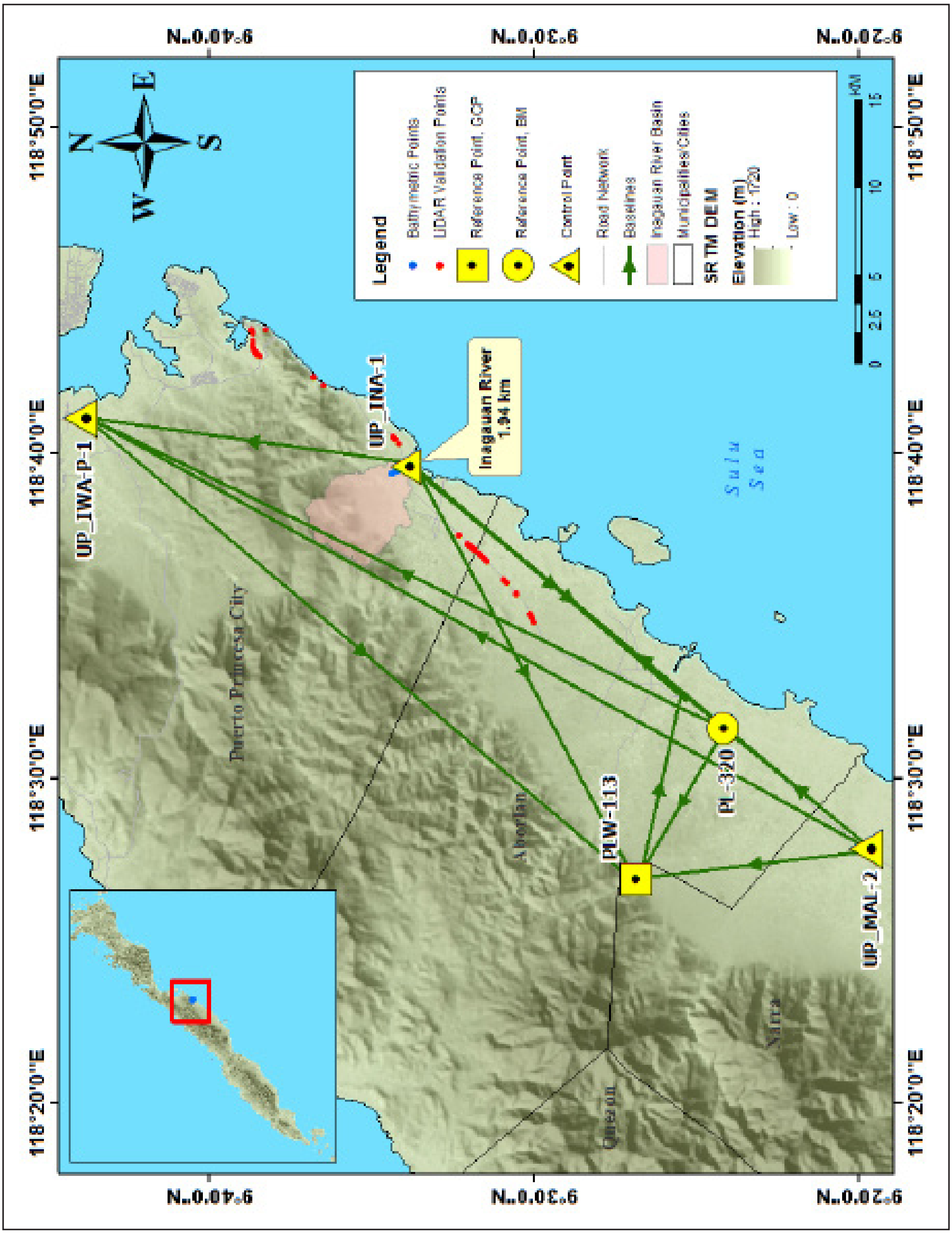



Figure 28. Inagauan River Survey Extent

## 4.2 Control Survey

The GNSS network used for Inagauan River is composed of nine (9) loops established on August 25, 2016 occupying the following reference points: PLW-113 a second-order GCP, in Brgy. Dumagueña, Narra, Palawan and PL-320, a first-order BM, in Brgy. Ramon Magsaysay, Aborlan, Palawan.

Four (4) control points established in the area by ABSD were also occupied: UP_MAL-2 at the approach of Malatgao Bridge in Brgy. Tinagong Dagat, Narra, Province of Palawan, UP_IWA-P-1 at the approach of Iwahig Penal Bridge in Brgy. Iwahig, Puerto Princesa City, Palawan, UP_ABO-1 located beside the approach of Aborlan Bridge in Brgy. Gogognan, Aborlan, Palawan, and UP_INA-1 located beside the approach of Inagauan Bridge in Brgy. Inagauan Sub-Colony, Puerto Princesa City, Palawan.

The summary of reference and control points and its location is summarized in Table 19 while GNSS network established is illustrated in Figure 29.

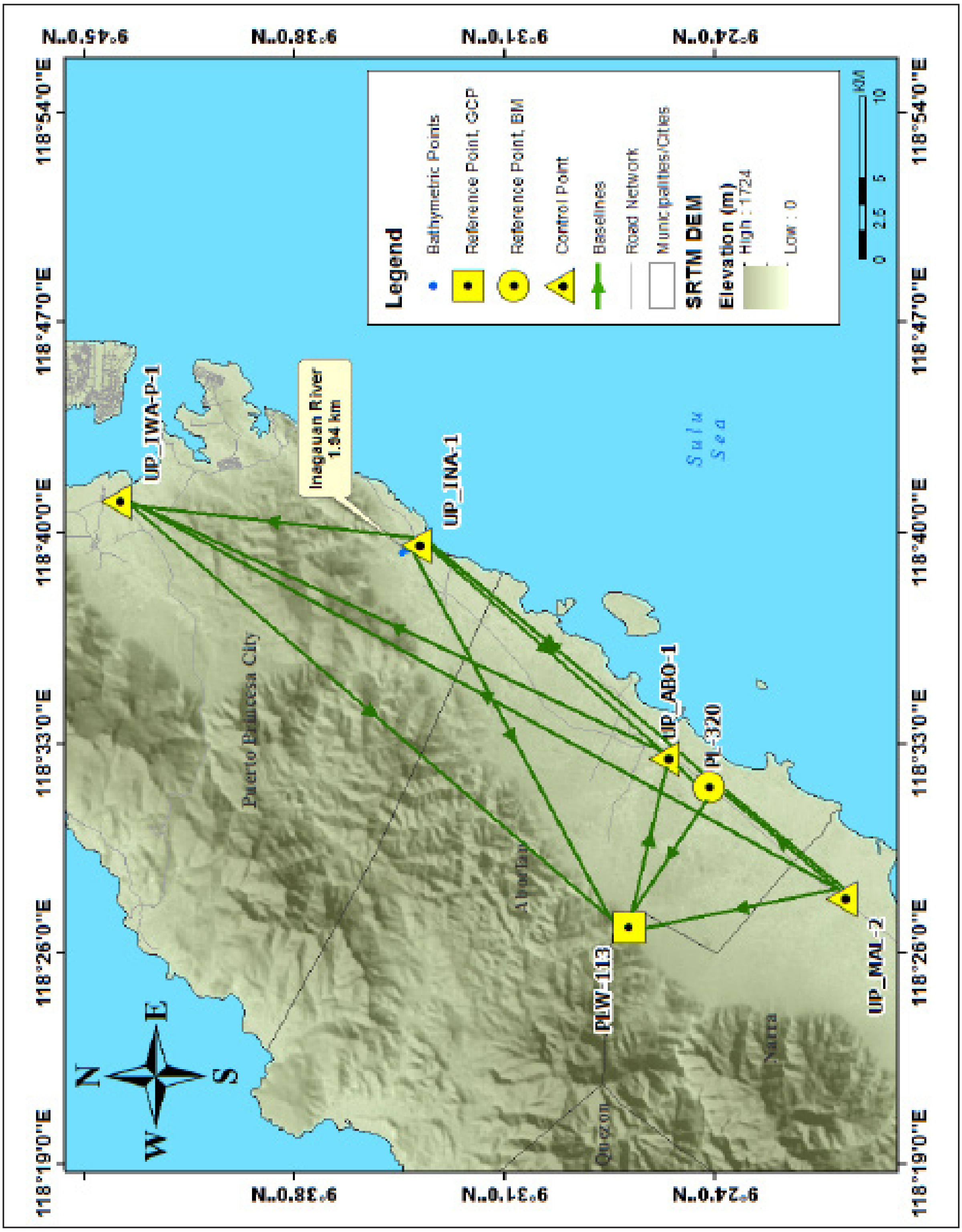



Figure 29. GNSS Network covering Inagauan River

Table 19. List of reference and control points used during the survey in Inagauan River (Source: NAMRIA, UP-TCAGP)

| Control Point | Order of Accuracy | Geographic Coordinates (WGS 84) | | | | |
|---|---|---|---|---|---|---|
| | | Latitude | Longitude | Ellipsoidal Height (Meter) | Elevation in MSL (Meter) | Date Established |
| PLW-113 | 2nd order, GCP | 9° 26' 50.78624" N | 118° 26' 52.23491"E | 144.388 | 93.784 | 2007 |
| PL-320 | 1st order, BM | 9° 24' 10.67926" N | 118° 31' 31.30061"E | 58.025 | 7.089 | 2008 |
| UP_MAL-2 | Established | 9° 19' 47.08536"N | 118° 27' 48.23703"E | 67.449 | 16.469 | 11-27-15 |
| UP_IWA-P-1 | Established | 9° 43' 58.38961"N | 118° 41' 03.58218"E | 55.529 | 5.044 | 11-25-15 |
| UP_ABO-1 | Established | 9° 25' 39.66712"N | 118° 32' 29.34660"E | 59.322 | 8.415 | 11-26-15 |
| UP_INA-1 | Established | 9° 33' 58.62160"N | 118° 39' 34.84567"E | 56.382 | 5.672 | 11-27-15 |

The GNSS set-ups on recovered reference points and established control points in Inagauan River are shown from Figure 30 to Figure 35.


Figure 30. GNSS base set up, Trimble® SPS 852, at PLW-113, located southwest of the Aborlan Water System in Brgy. Dumagueña, Narra, Province of Palawan

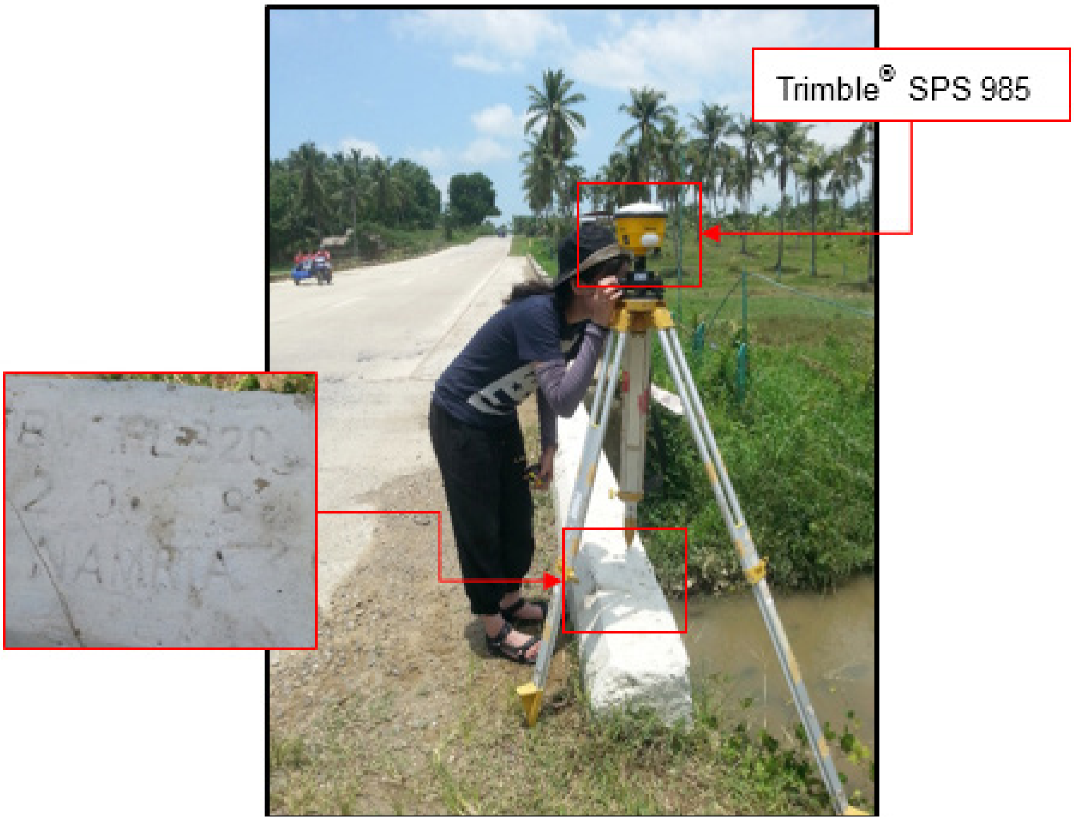



Figure 31. GNSS receiver set up, Trimble® SPS 985, at PL-320, located on top of a culvert headwall along the National Road in Brgy. Ramon Magsaysay, Aborlan, Province of Palawan


Figure 32. GNSS receiver set up, Trimble® SPS 882, at UP_MAL-2, located at the approach of Malatgao Bridge in Brgy. Tinagong Dagat, Narra, Province of Palawan

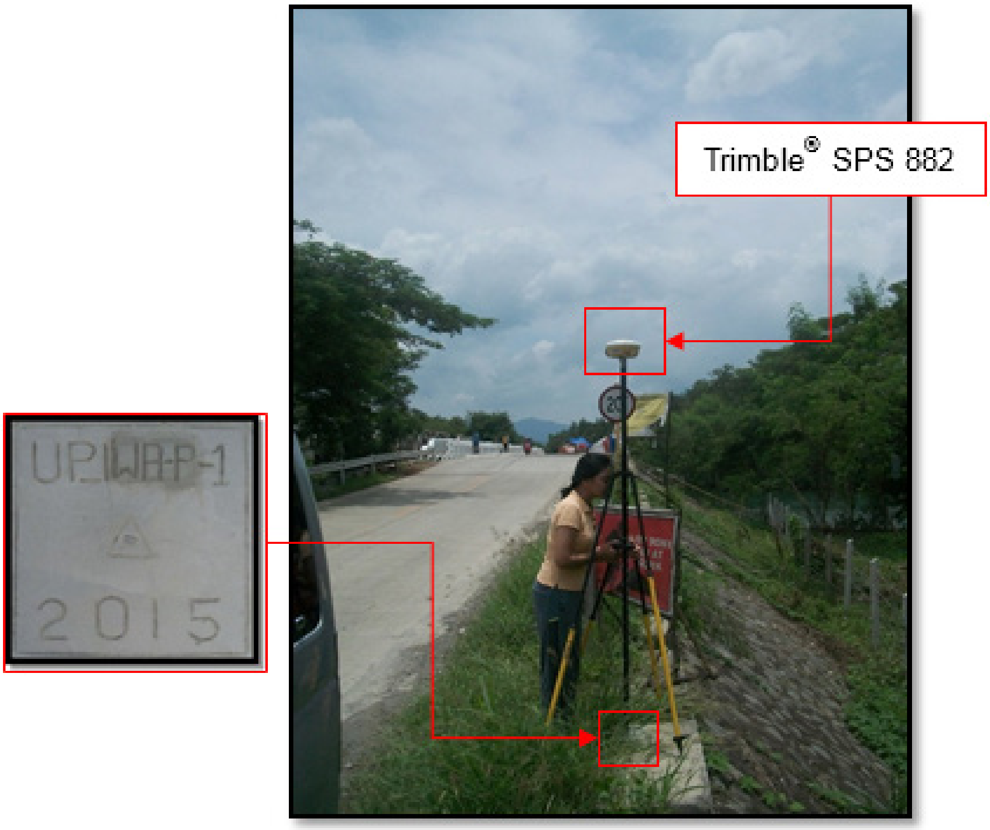



Figure 33. GNSS receiver set up, Trimble® SPS 982, at UP_IWA-P-1, located at the approach of Iwahig Penal Bridge in Brgy. Iwahig, Puerto Princesa City, Palawan


Figure 34. GNSS receiver set-up, Trimble® SPS 852, at UP_ABO-1, an established control point, beside the approach of Aborlan Bridge in Brgy. Gogognan, Aborlan, Palawan


Figure 35. GNSS receiver set up, Trimble® SPS 882, at UP_INA-1, located beside the approach of Inagauan Bridge in Brgy. Inagauan Sub-Colony, Puerto Princesa City, Palawan

## 4.3 Baseline Processing

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

Table 20. Baseline Processing Report for Inagauan River Static Survey
(Source: NAMRIA, UP-TCAGP)

| Observation | Date of Observation | Solution Type | H. Prec. (Meter) | V. Prec. (Meter) | Geodetic Az. | Ellipsoid Dist. (Meter) | ΔHeight (Meter) |
|---|---|---|---|---|---|---|---|
| PLW-113 --- UP_ ABO-1 | 8-25-2016 | Fixed | 0.009 | 0.023 | 101°59'15" | 10513.593 | -85.092 |
| UP_IWA-P-1 --- PLW-113 | 8-25-2016 | Fixed | 0.004 | 0.024 | 219°26'55" | 40874.066 | 88.833 |
| PL-320 --- PLW-113 | 8-25-2016 | Fixed | 0.018 | 0.029 | 300°01'31" | 9832.467 | 86.391 |
| PL-320 --- UP_ IWA-P-1 | 8-25-2016 | Fixed | 0.004 | 0.018 | 205°34'21" | 40449.118 | 2.530 |
| UP_MAL-2 --- PL-320 | 8-25-2016 | Fixed | 0.010 | 0.021 | 220°02'59" | 10578.751 | 9.435 |
| UP_INA-1 --- UP_ ABO-1 | 8-25-2016 | Fixed | 0.008 | 0.025 | 220°15'41" | 20085.570 | 2.974 |
| UP_INA-1 --- PLW-113 | 8-25-2016 | Fixed | 0.005 | 0.025 | 240°32'45" | 26716.978 | 88.012 |
| UP_INA-1 --- PL-320 | 8-25-2016 | Fixed | 0.010 | 0.019 | 219°14'35" | 23320.185 | 1.618 |
| UP_INA-1 --- UP_ IWA-P-1 | 8-25-2016 | Fixed | 0.005 | 0.019 | 188°21'15" | 18624.653 | 0.847 |
| UP_MAL-2 --- UP_INA-1 | 8-25-2016 | Fixed | 0.005 | 0.014 | 39°28'10" | 33898.188 | -11.058 |
| UP_MAL-2 --- UP_ IWA-P-1 | 8-25-2016 | Fixed | 0.024 | 0.024 | 208°33'52" | 50759.890 | 11.894 |
| UP_MAL-2 --- PLW-113 | 8-25-2016 | Fixed | 0.005 | 0.021 | 352°31'24" | 13129.154 | 76.935 |

As shown Table 20 a total of twelve (12) baselines were processed with coordinate and elevation values of UP_IWA-P-1 and the coordinate values of PLW-113 held fixed. All of them passed the required accuracy.

## 4.4 Network Adjustment

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

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

Where:

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

for each control point. See the Network Adjustment Report shown in Table 21 to Table 24 for complete details.

The six (6) control points, PLW-113, PL-320, UP-MAL-2, UP-IWA-P-1, UP_ABO-1, and UP_INA-1 were occupied and observed simultaneously to form a GNSS loop. The coordinates and elevation of UP_IWA-P-1 and the coordinates of PLW-113 were held fixed during the processing of the control points as presented in Table 21. Through these reference points, the coordinates and elevations of the unknown control points will be computed.

Table 21. Control Point Constraints

| Point ID | Type | East σ (Meter) | North σ (Meter) | Height σ (Meter) | Elevation σ (Meter) |
|---|---|---|---|---|---|
| PLW-113 | Global | Fixed | Fixed | | |
| UP_IWA-P-1 | Grid | | | | Fixed |
| UP_IWA-P-1 | Global | 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 22. All fixed control points have no values for grid and elevation errors.

Table 22. Adjusted Grid Coordinates

| Point ID | Easting | Easting Error (Meter) | Northing (Meter) | Northing Error (Meter) | Elevation (Meter) | Elevation Error (Meter) | Constraint |
|---|---|---|---|---|---|---|---|
| PL-320 | 667487.736 | 0.013 | 1039767.829 | 0.008 | 7.089 | 0.049 | |
| PLW-113 | 658953.945 | ? | 1044650.284 | ? | 93.784 | 0.054 | LL |
| UP_ABO-1 | 669246.540 | 0.018 | 1042509.427 | 0.016 | 8.415 | 0.080 | |
| UP_INA-1 | 682153.657 | 0.009 | 1057898.445 | 0.007 | 5.672 | 0.047 | |
| UP_IWA-P-1 | 684768.852 | ? | 1076338.886 | ? | 5.044 | ? | LLe |
| UP_MAL-2 | 660716.408 | 0.012 | 1031641.078 | 0.009 | 16.469 | 0.047 | |

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

a. PL-320
horizontal accuracy = $\sqrt{((1.3)^2 + (0.8)^2}$
= $\sqrt{(1.69 + 0.64)}$
= 2.33 < 20 cm
vertical accuracy = 4.9 < 10 cm

b. PLW-113
horizontal accuracy = Fixed
vertical accuracy = Fixed

c. UP_ABO-1
horizontal accuracy = $\sqrt{((1.8)^2 + (1.6)^2}$
= $\sqrt{(3.24 + 2.56)}$
= 5.8 < 20 cm
vertical accuracy = 8.0 < 10 cm

d. UP_INA-1
horizontal accuracy = $\sqrt{((0.9)^2 + (0.7)^2}$
= $\sqrt{(0.81 + 0.49)}$
= 1.30 < 20 cm
vertical accuracy = 4.7 < 10 cm

e. UP_IWA-P-1
horizontal accuracy = Fixed
vertical accuracy = Fixed

f. UP_MAL-2
horizontal accuracy = $\sqrt{((1.2)^2 + (0.9)^2}$
= $\sqrt{(1.44 + 0.81)}$
= 2.25 < 20 cm
vertical accuracy = 4.7 < 10 cm

Following the given formula, the horizontal and vertical accuracy result of the four (4) occupied control points are within the required precision.

Table 23. Adjusted Geodetic Coordinates

| Point ID | Latitude | Longitude | Height (Meter) | Height Error (Meter) | Constraint |
|---|---|---|---|---|---|
| PL-320 | N9°24'10.67926" | E118°31'31.30061" | 58.025 | 0.049 | |
| PLW-113 | N9°26'50.78624" | E118°26'52.23491" | 144.388 | 0.054 | LL |
| UP_ABO-1 | N9°25'39.66712" | E118°32'29.34660" | 59.322 | 0.080 | |
| UP_INA-1 | N9°33'58.62160" | E118°39'34.84567" | 56.382 | 0.047 | |
| UP_IWA-P-1 | N9°43'58.38961" | E118°41'03.58218" | 55.529 | ? | LLe |
| UP_MAL-2 | N12°57'27.19115" | E120°53'33.54442" | 88.823 | 0.091 | LL |

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 23. 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 24.

Table 24. Reference and control points used and its location (Source: NAMRIA, UP-TCAGP)

| Control Point | Order of Accuracy | Geographic Coordinates (WGS 84) | | | UTM ZONE 51 N | | |
|---|---|---|---|---|---|---|---|
| | | Latitude | Longitude | Ellipsoidal Height (m) | Northing | Easting | MSL Elevation (m) |
| PLW-113 | 2nd order, GCP | 9° 26' 50.78624" N | 118° 26' 52.23491"E | 144.388 | 1044650.284 | 658953.945 | 93.784 |
| PL-320 | 1st order, BM | 9° 24' 10.67926" N | 118° 31' 31.30061"E | 58.025 | 1039767.829 | 667487.736 | 7.089 |
| UP_ MAL-2 | Established | 9° 19' 47.08536"N | 118° 27' 48.23703"E | 67.449 | 1031641.078 | 660716.408 | 16.469 |
| UP_ IWA-P-1 | Established | 9° 43' 58.38961"N | 118° 41' 03.58218"E | 55.529 | 1076338.886 | 684768.852 | 5.044 |
| UP_ ABO-1 | Established | 9° 25' 39.66712"N | 118° 32' 29.34660"E | 59.322 | 1042509.427 | 669246.54 | 8.415 |
| UP_INA-1 | Established | 9° 33' 58.62160"N | 118° 39' 34.84567"E | 56.382 | 1057898.445 | 682153.657 | 5.672 |

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

Cross-section and as-built surveys were conducted on November 27, 2015 at the downstream side of Inagauan Bridge in Brgy. Inagawan Sub-Colony, Puerto Princesa City as shown in Figure 36. A total station was utilized for this survey as shown in Figure 37.

Figure 36. Inagauan Bridge facing upstream

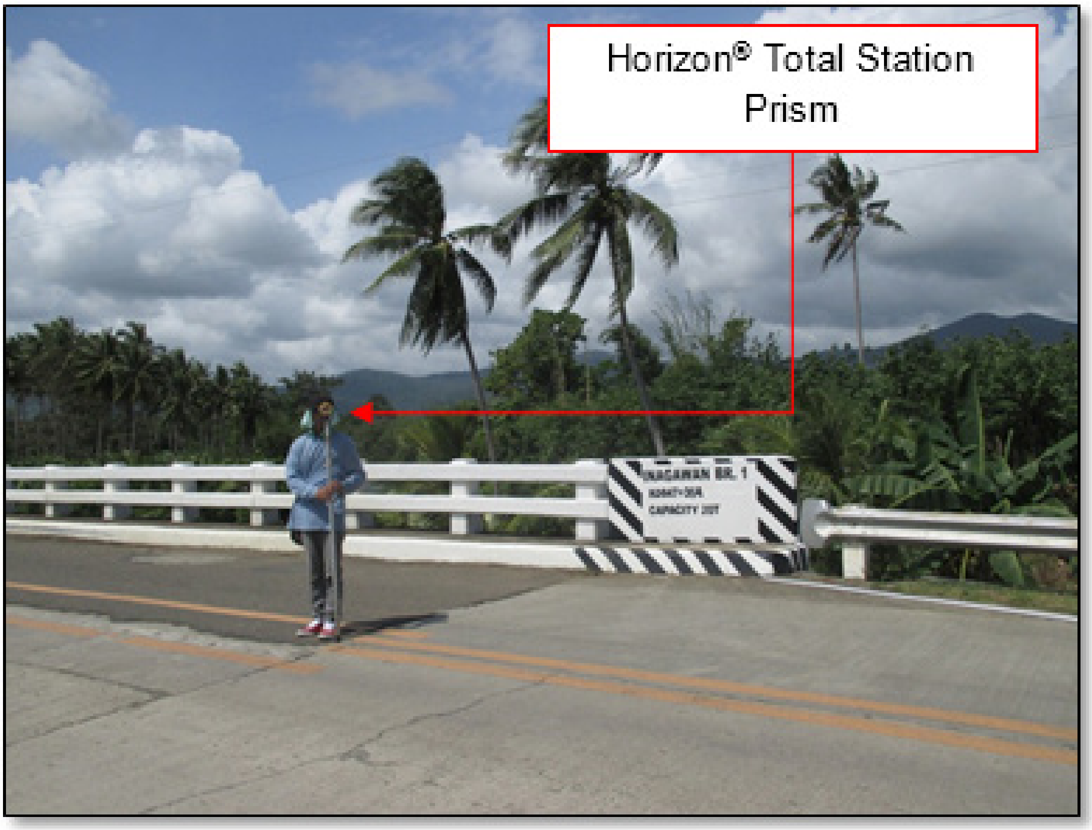



Figure 37. As-built survey of Inagauan Bridge

The cross-sectional line of Inagauan Bridge is about 227 m with sixty-two (62) cross-sectional points using the control points UP_INA-1 and UP_INA-2 as the GNSS base stations. The location map, cross-section diagram, and bridge data form are shown in Figure 38, Figure 39, and Figure 40.

Gathering of random points for the checking of ABSD's bridge cross-section and bridge points data was performed by DVBC on August 25, 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 0.997 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 0.219 was acquired. The computed R2 and RMSE values are within the accuracy requirement of the program.

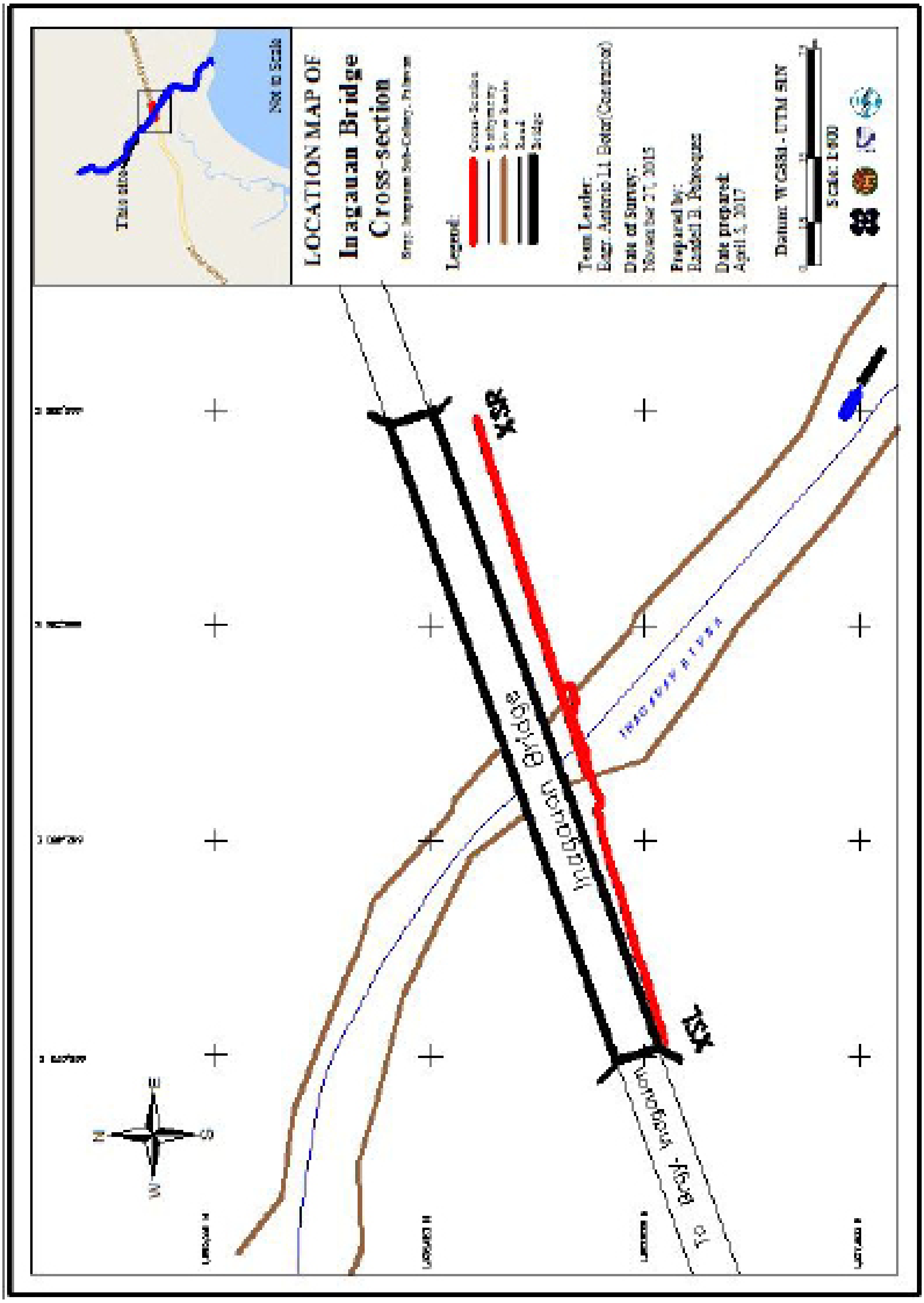



Figure 38. Location Map of Inagauan Bridge River Cross-Section survey

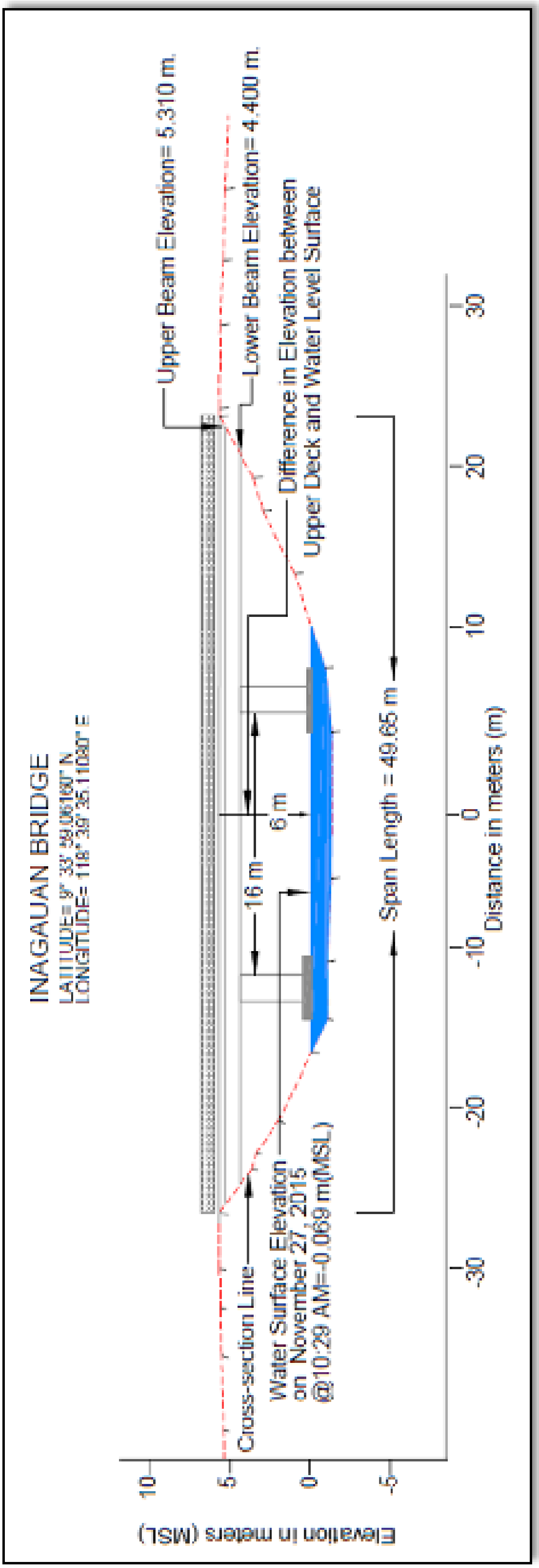



Figure 39. Inagauan Bridge cross-section diagram

**Bridge Data Form**

Bridge Name: INAGAUAN BRIDGE

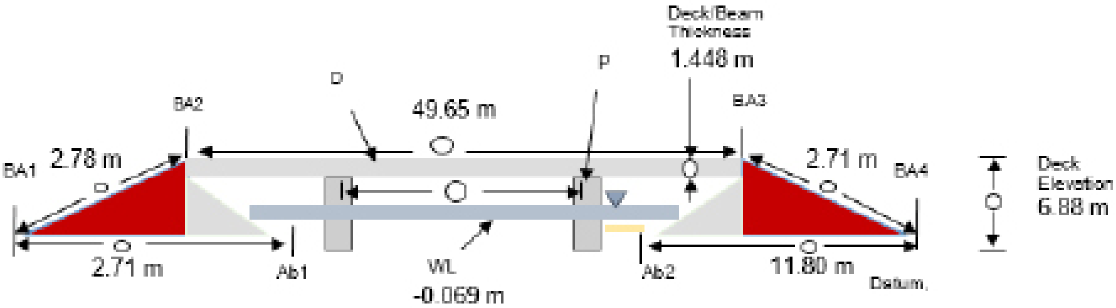
River Name: INAGAUAN RIVER
Location (Brgy, City, Region): Brgy. Inagauan Sub-Colony, Puerto Princesa, Palawan

Survey Team: Alpas Nilo
Date and Time: November 27, 2015 at 10:29 am

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 | 2.78 m | |
| 2. BA2-BA3 | 49.65 m | |
| 3. BA3-BA4 | 2.71 m | |
| 4. BA1-Ab1 | 2.71 m | |
| 5. Ab2-BA4 | 11.80 m | |
| 6. Deck/beam thickness | 1.448 m | |
| 7. Deck elevation | 6.88 m | |

Note: Observer should be facing downstream

Figure 40. Bridge as-built form of Inagauan Bridge

Water surface elevation of Inagauan River was determined by a Horizon® Total Station on November 27, 2015 at 10:29 AM at Inagauan Bridge area with a value of -0.069 m in MSL as shown in Figure 39. This was translated into marking on the bridge's pier as shown in Figure 41. The marking will serve as reference for flow data gathering and depth gauge deployment of the partner HEI responsible for Inagauan River, the University of the Philippines Los Baños.


Figure 41. Water-level markings on Inagauan Bridge

## 4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted by DVBC from August 16-28, 2016 using a survey grade GNSS Rover receiver, Trimble® SPS 985, mounted on a range pole which was attached on the side of the vehicle as shown in Figure 42.It was secured with cable ties and ropes to ensure that it was horizontally and vertically balanced. The antenna height was 2.590 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_INA-1 occupied as the GNSS base station in the conduct of the survey.


Figure 42. Validation Points Acquisition Set-up for Inagauan River

The survey started from Brgy. Tagburos, City of Puerto Princesa, Palawan going southwest along the national highway, covering three (3) barangays in the City of Puerto Princesa and and ended in Brgy. Isaub, Municipality of Aborlan, Palawan. The survey gathered a total of 344 points with approximate length of 26.46 km using UP_INA-1 as GNSS base station for the entire extent of validation points acquisition survey as illustrated in the map in Figure 43.  More than 60% of the surveyed area for validation has no data due to heavy canopy and absence of GNSS receiver signal because of the mountainous terrain in the area.

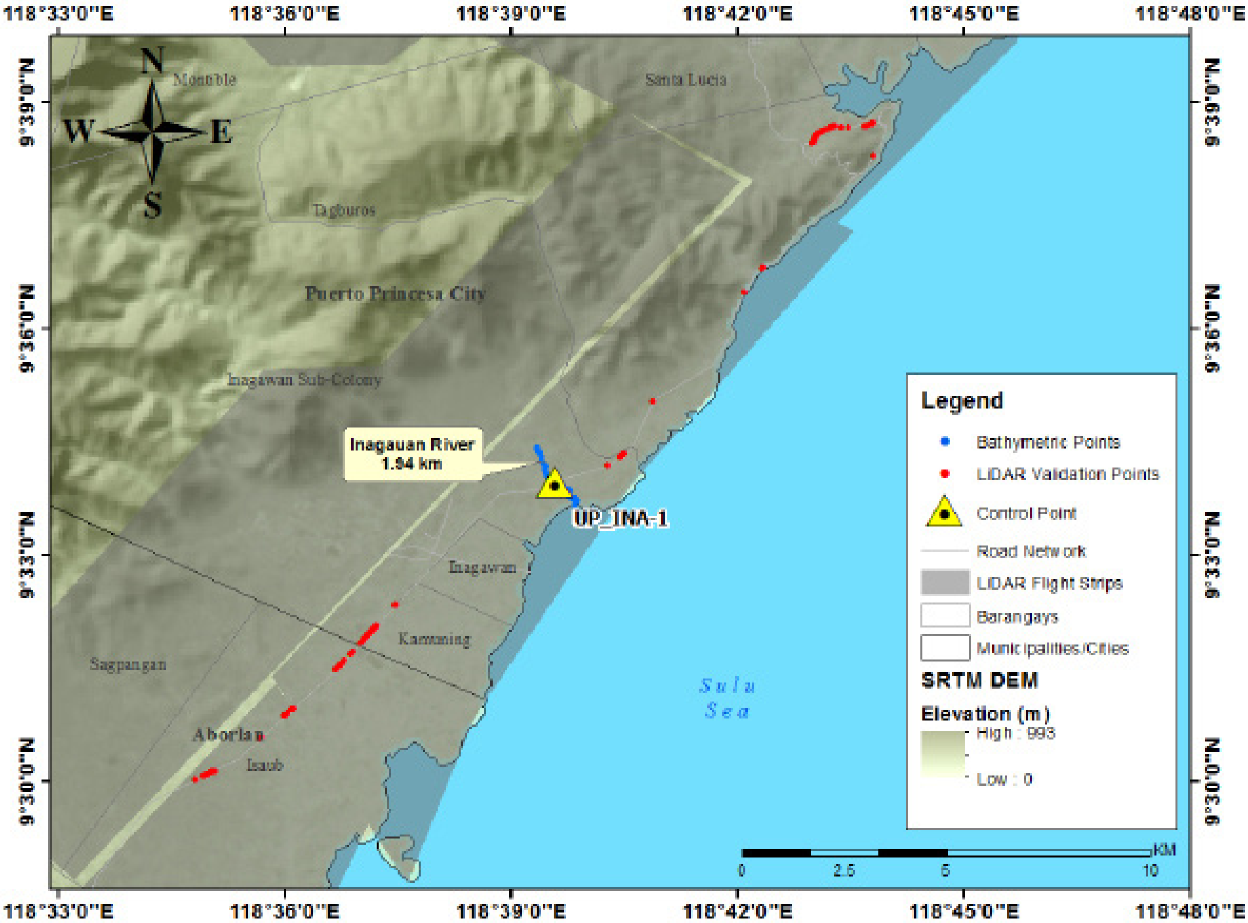



Figure 43. Validation point acquisition survey of Inagauan River Basin

## 4.7 Bathymetric Survey

Bathymetric survey was executed on November 28, 2016 using a single-beam echo sounder as illustrated in Figure 44. The survey started in Brgy. Inagawan Sub-Colony, Puerto Princesa City, Palawan with coordinates 9° 34' 15.43106"N, 118° 39' 24.05592"E and ended at the mouth of the river in Brgy. Inagawan Sub-Colony, Puerto Princesa City as well, with coordinates 9° 33' 41.99750"N, 118° 39' 51.07104"E. The control point UP_INA-1 was used as GNSS base station all throughout the entire survey.

Gathering of random points for the checking of ABSD's bathymetric data was performed by DVBC on August 26, 2016 using a survey grade GNSS Rover receiver attached to a boat as seen in Figure 45. A map showing the DVBC bathymetric checking points is shown in Figure 47 .

Linear square correlation (R2) and RMSE analysis were also performed on the two (2) datasets and a computed R2 values of 0.860 and 0.895 for the centerline and zigzag line bathymetric data, respectively, are within the required range for R2, which is 0.85 to 1. Additionally, an RMSE values of 0.304 and 0.314 for the centerline and zigzag line bathymetric data, respectively, were obtained. Both the computed R2 and RMSE values are within the accuracy required by the program.

Figure 44. Manual Bathymetric survey using a Trimble® SPS 985 in GNSS PPK survey technique in Caramay River

On the other hand, manual bathymetric survey was executed on November 9, 10, 11, and 14 2015 carrying a Trimble bag with installed Trimble® SPS 882 using GNSS PPK survey technique as shown in Figure 46. The survey started at the upstream part of the river in Brgy. Purnaga with coordinates 12°21’06.41749” 121°11’13.79163”, traversed down by foot and ended at the starting point of bathymetric survey using boat. The control points GPS 4 was used as base station on November 9, 10, and 14 while MC-200 was used on N0vember 13, 2015.


Figure 45. Gathering of random bathymetric points along Inagauan River

The bathymetric survey for Inagauan River gathered a total of 3,152 points covering 1.94 km of the river traversing Brgy. Inagawan Sub-Colony in Puerto Princesa City. Because of the narrow width of the river in the upstream, 0.34 km was not surveyed. Instead, 1.35 km was surveyed in the tributary of Inagauan River. (Figure 46).

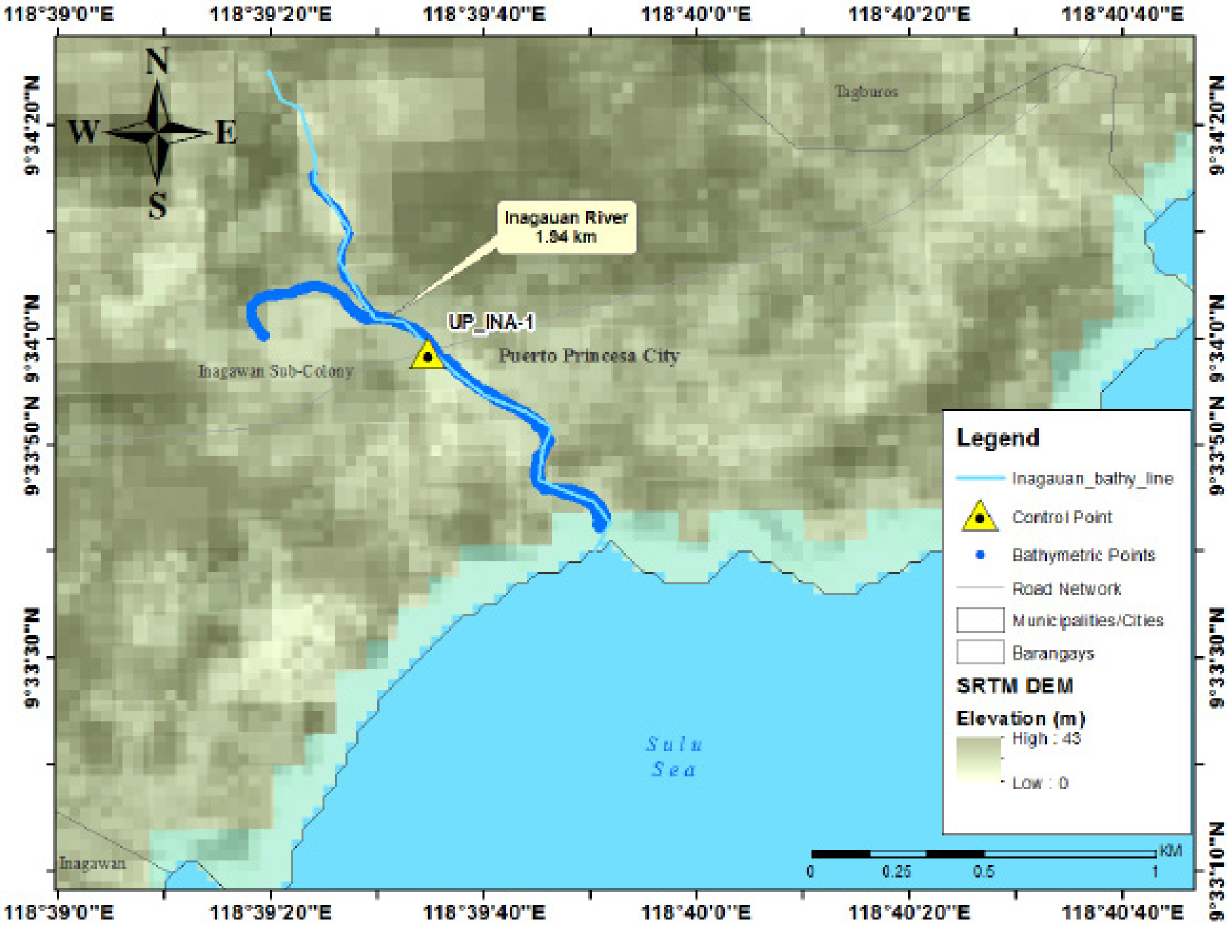



Figure 46. Bathymetric survey of Inagauan River

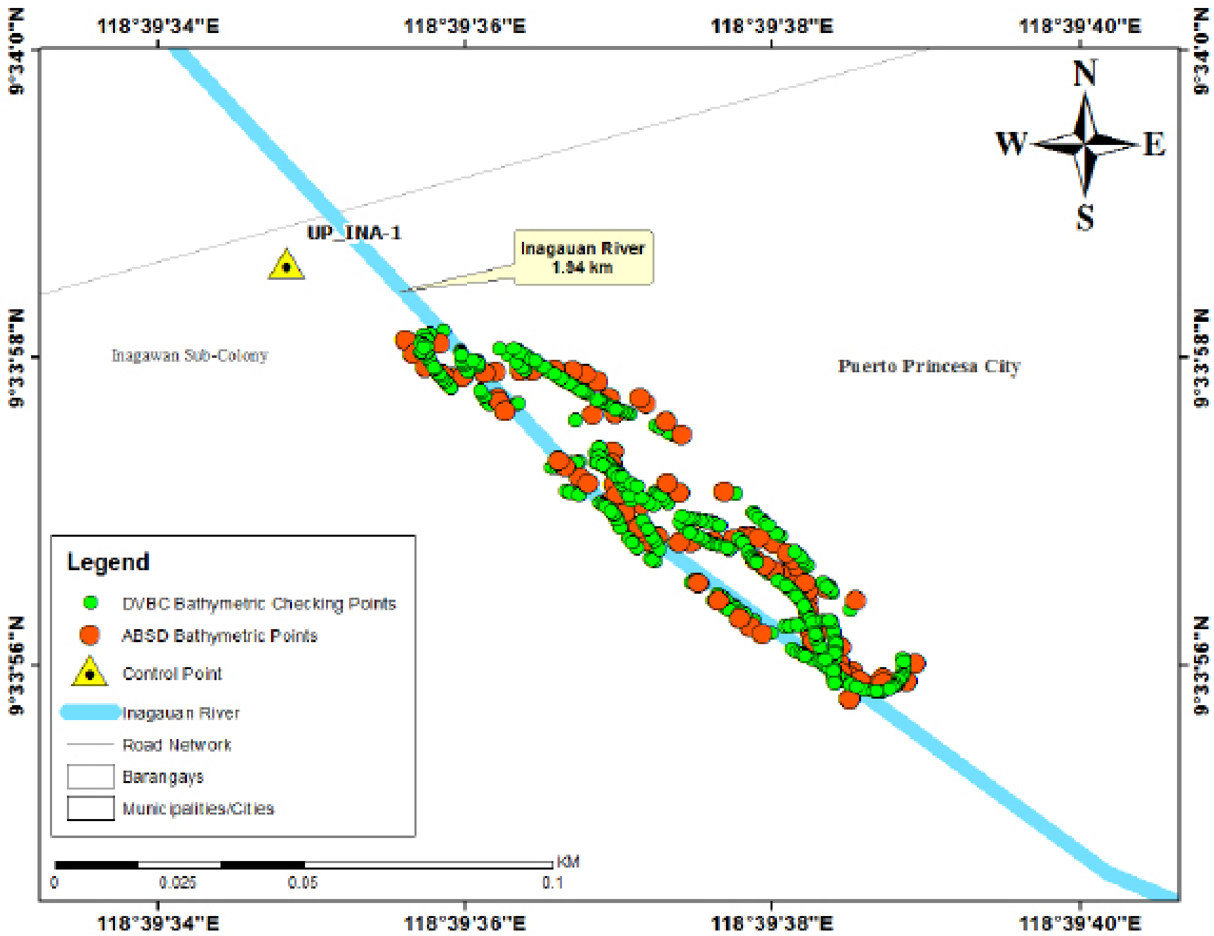



Figure 47. Inagauan centerline riverbed profile (Upstream)

A CAD drawing was also produced to illustrate the riverbed profile of Inagauan River. As shown in Figure 48, the highest and lowest elevation has a 4-m difference. The highest elevation observed was -1.483 m below MSL located in Brgy. Inagawan Sub-Colony, Puerto Princesa City while the lowest was –5.753 m below MSL located in Brgy. Inagawan Sub-Colony, Puerto Princesa City as well.

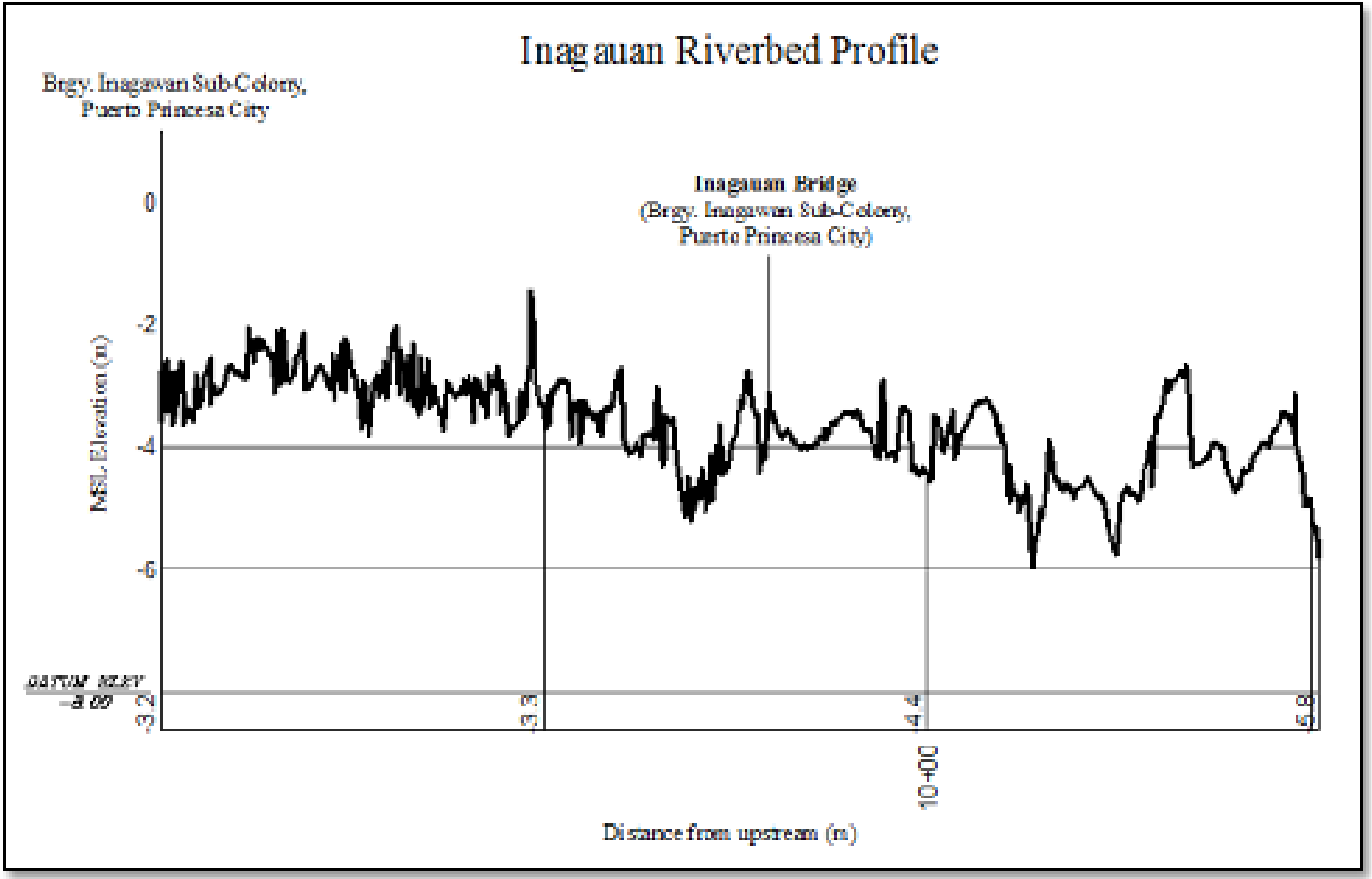



Figure 48. Inagauan centerline riverbed profile (Downstream)

# 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, Khristoffer Quinton, John Alvin B. Reyes, Alfi Lorenz B. Cura, Angelica T. Magpantay, Maria Michaela A. Gonzales Paulo Joshua U. Quilao, Jayson L. Arizapa, and Kevin M. Manalo*

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

## 5.1 Data used

No gathered rainfall data for Inagauan river basin. The HMS model is not calibrated. The values generated HMS model are by default.

## 5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Romblon 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 chosen based on its proximity to the Inagauan watershed. The extreme values for this watershed were computed based on a 48-year record, with the computed extreme values shown in Table 28.

Table 25. RIDF values for Puerto Princesa 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 | 14.8 | 22 | 27.3 | 36.2 | 49.8 | 58.8 | 75.1 | 88 | 104.1 |
| 5 | 21.3 | 31.9 | 39.7 | 52.3 | 73 | 86.9 | 112.8 | 135.4 | 156.4 |
| 10 | 25.6 | 38.5 | 48 | 63 | 88.4 | 105.5 | 137.8 | 166.8 | 191.1 |
| 15 | 28.1 | 42.2 | 52.6 | 69 | 97 | 116 | 151.9 | 184.5 | 210.6 |
| 20 | 29.8 | 44.7 | 55.9 | 73.3 | 103.1 | 123.4 | 161.7 | 196.8 | 224.3 |
| 25 | 31.1 | 46.7 | 58.4 | 76.5 | 107.8 | 129.1 | 169.3 | 206.4 | 234.9 |
| 50 | 35.2 | 52.9 | 66.1 | 86.5 | 122.2 | 146.5 | 192.7 | 235.8 | 267.3 |
| 100 | 39.2 | 59 | 73.7 | 96.4 | 136.5 | 163.8 | 216 | 265 | 299.6 |

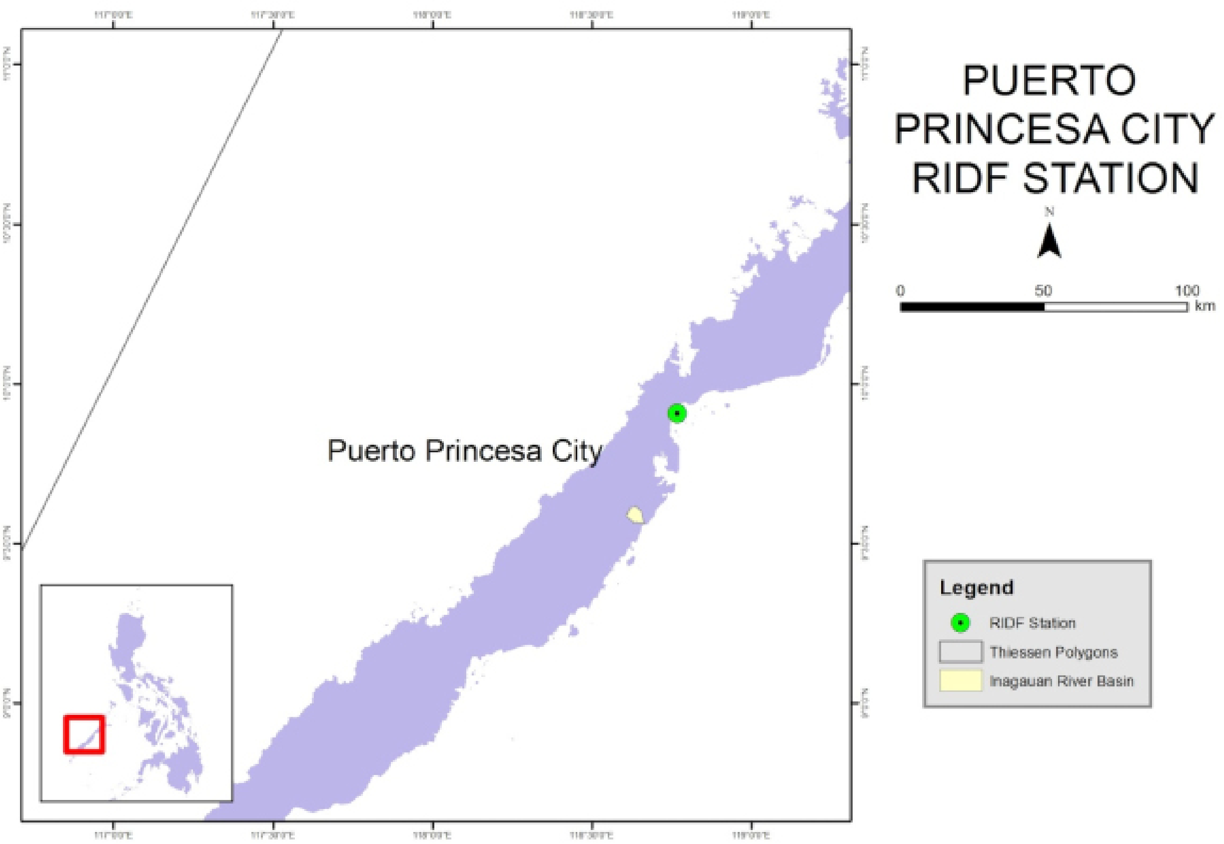



Figure 49. Location of Puerto Princesa RIDF relative to Inagauan River Basin

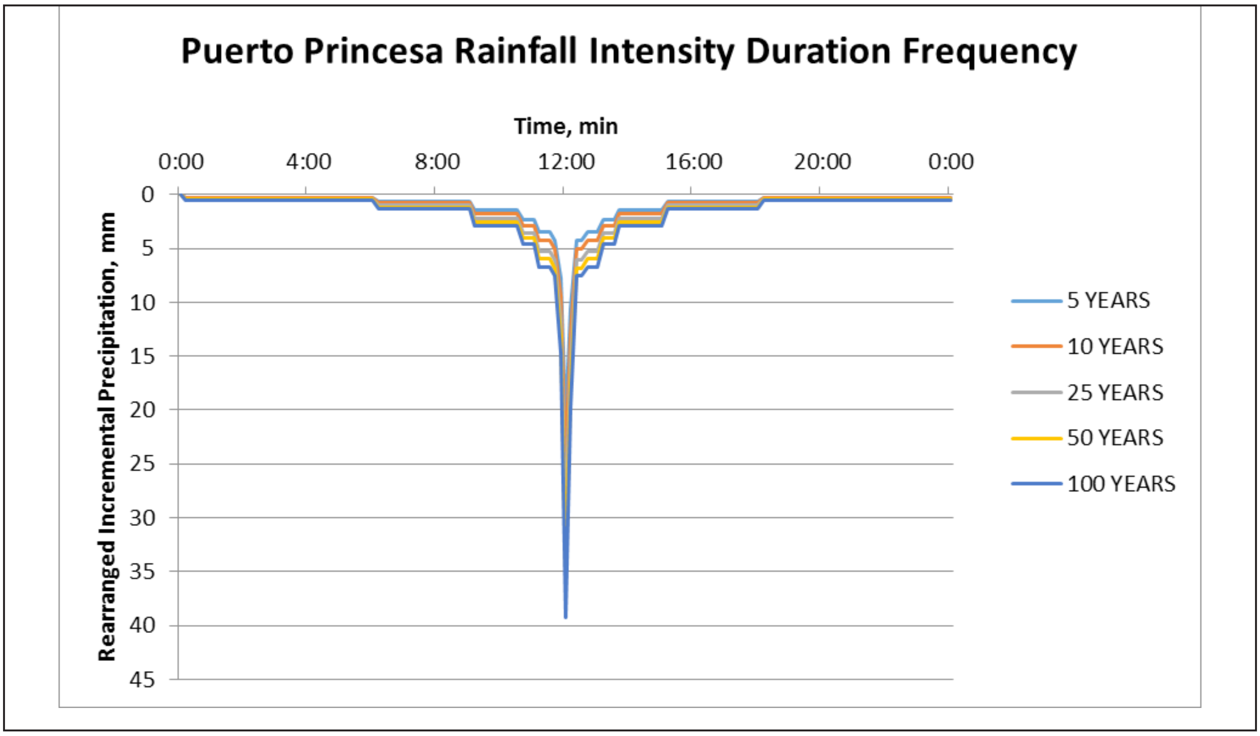



Figure 50. Synthetic storm generated for a 24-hr period rainfall for various return periods.

## 5.3 HMS Model

The soil dataset was generated before 2004 by the Bureau of Soils and Water Management under the Department of Agriculture (DA-BSWM). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Inagauan River Basin are shown in Figure 51 and Figure 52, respectively.

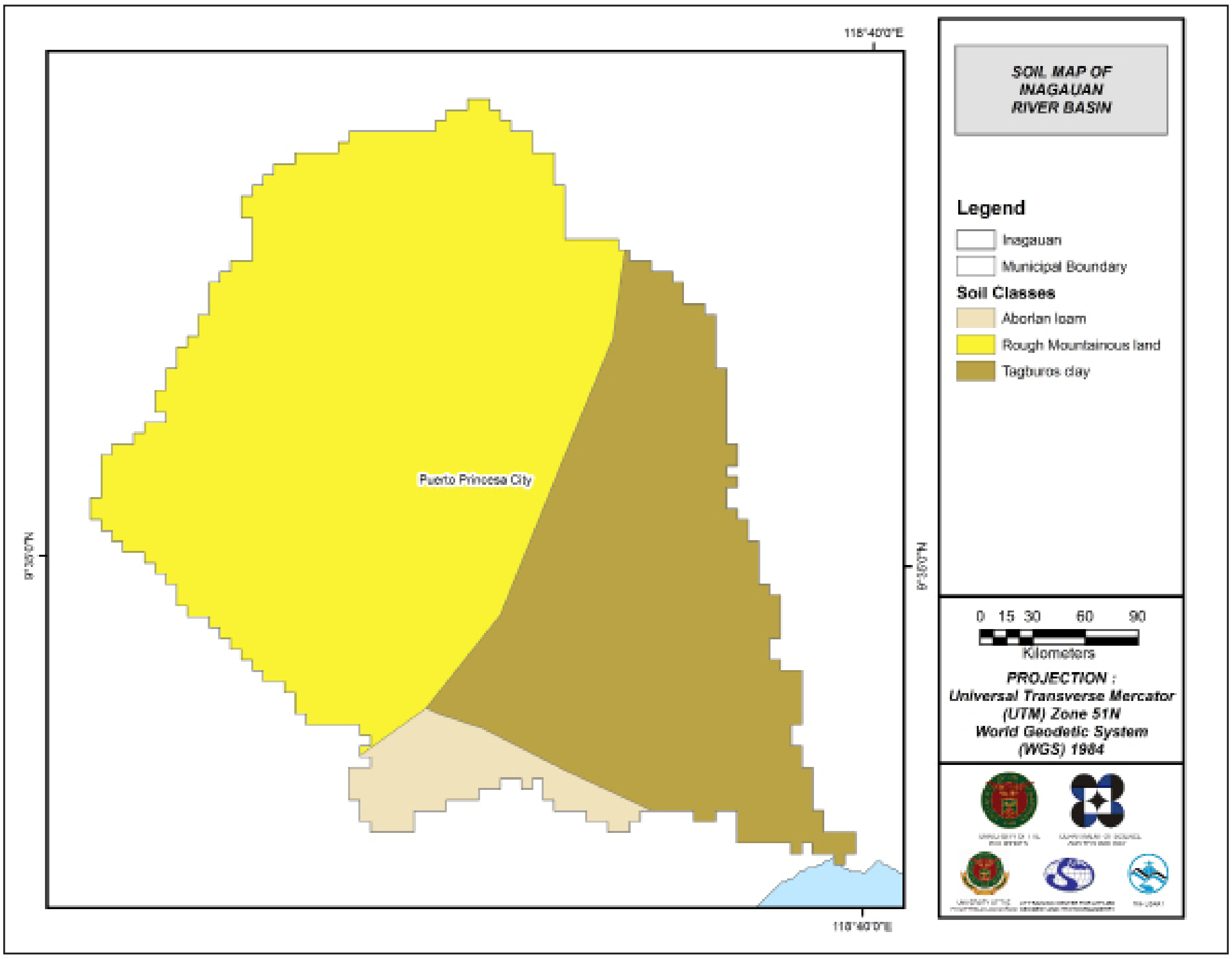



Figure 51. Soil map of Inagauan River Basin used for the estimation of the CN parameter. (Source: DA)

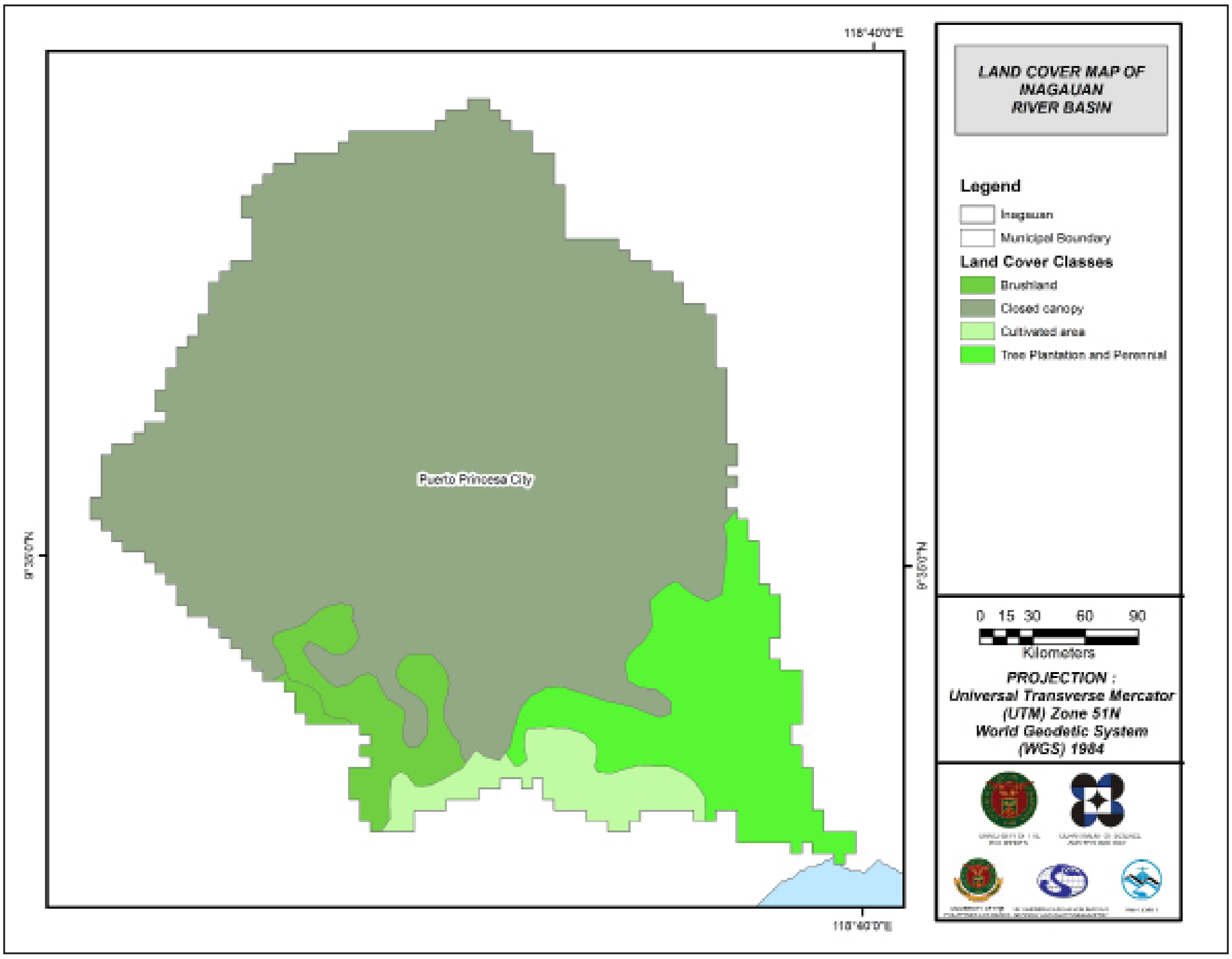



Figure 52. Land cover map of Caramay River Basin used for the estimation of the CN and watershed lag parameters of the rainfall-runoff model. (Source: NAMRIA)

For Inagauan river basin, three (3) soil classes were identified. The river basin area is largely rough mountainous land and Tagburos clay, with a smaller portion of Aborlan loam. Moreover, the four (4) land cover types identified were mostly closed canopy, followed by tree plantation and perennial, cultivated area, and brushland.

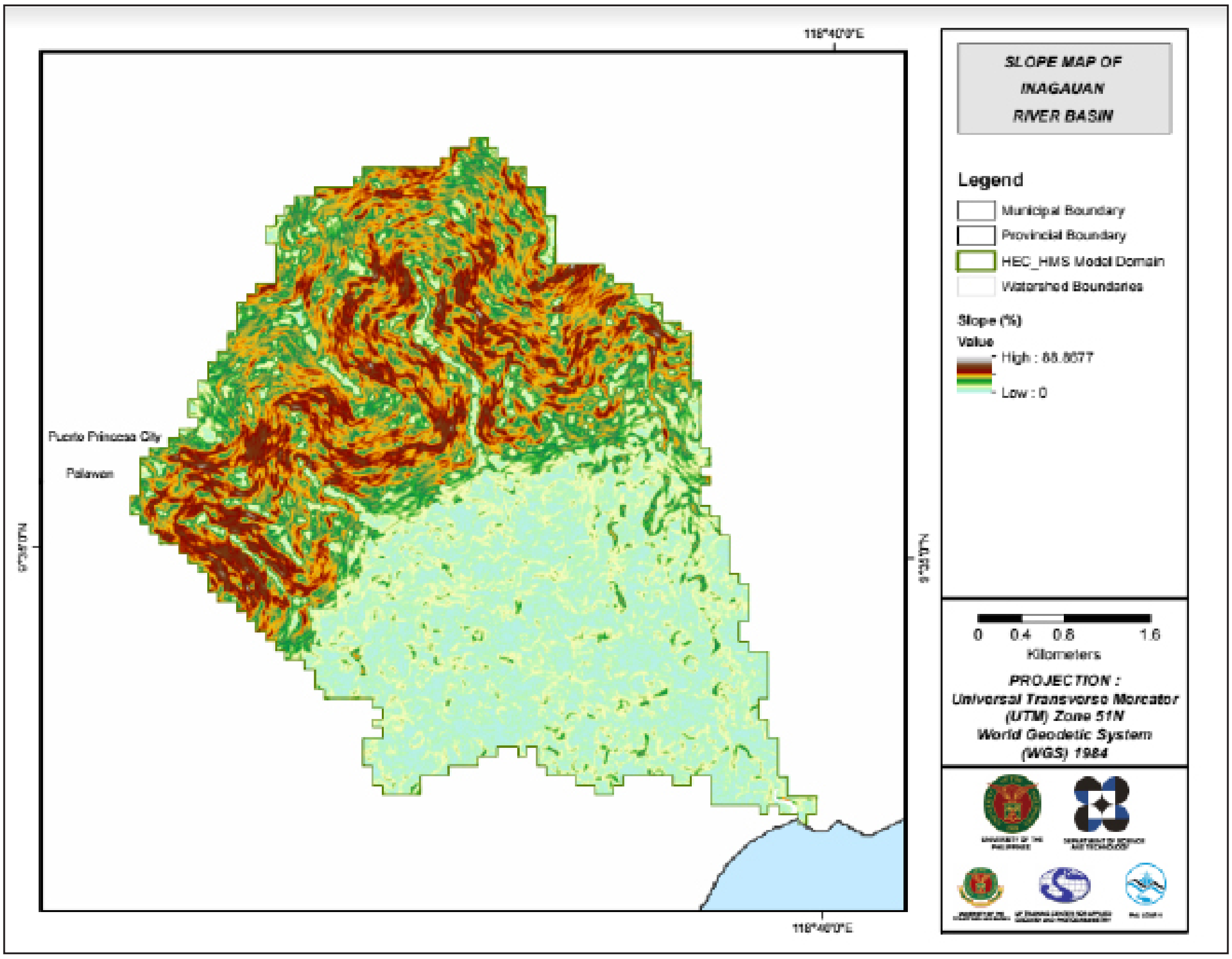



Figure 53. Slope map of Inagauan River Basin

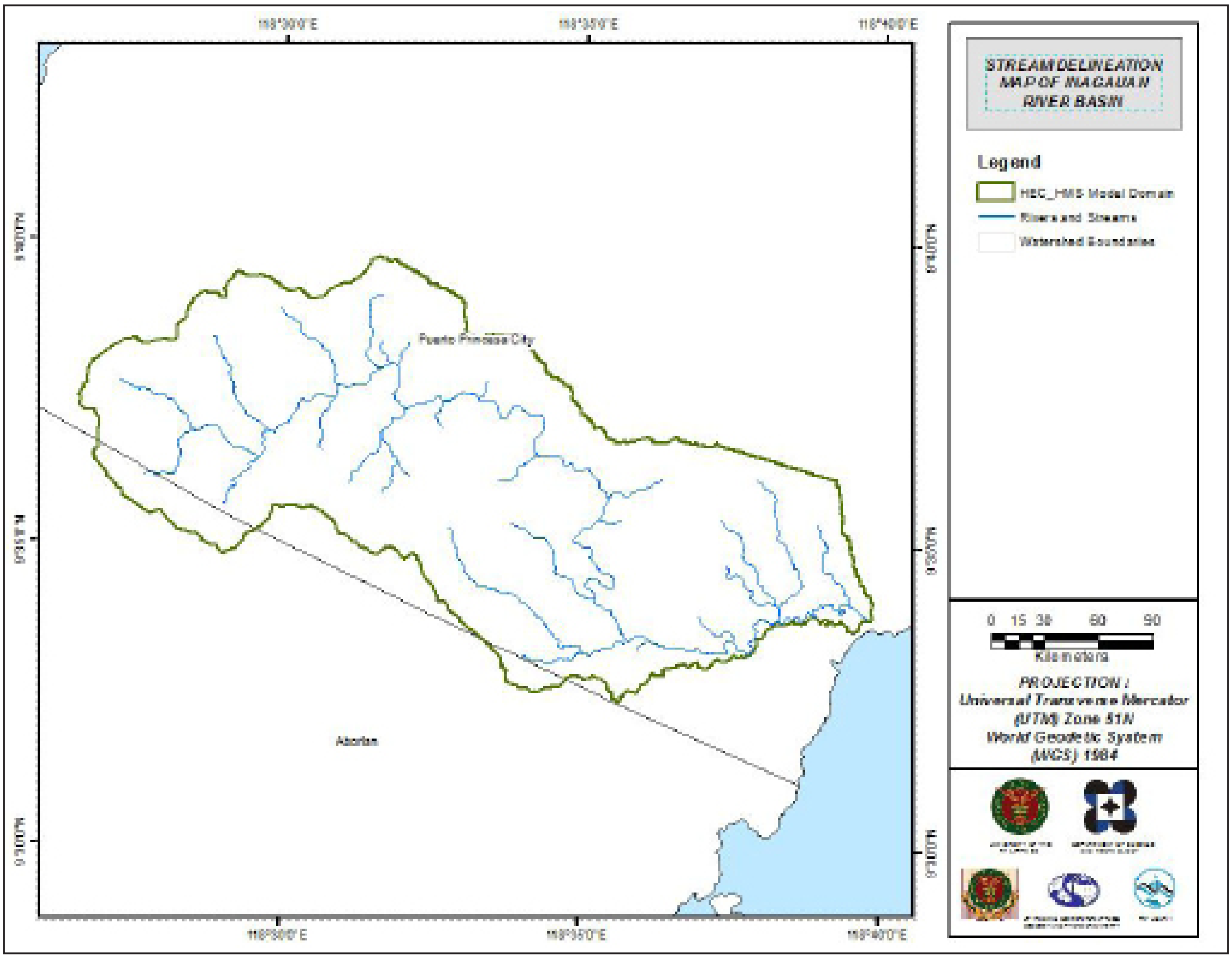



Figure 54. Stream delineation map of Inagauan River Basin

Using SAR-based DEM, the Inagauan basin was delineated and further subdivided into subbasins. The model consists of 54 sub basins, 26 reaches, and 25 junctions. The main outlet is labelled as Inagauan_ outlet. This basin model is illustrated in Figure 55. The basins were identified based on soil and land cover characteristics of the area.

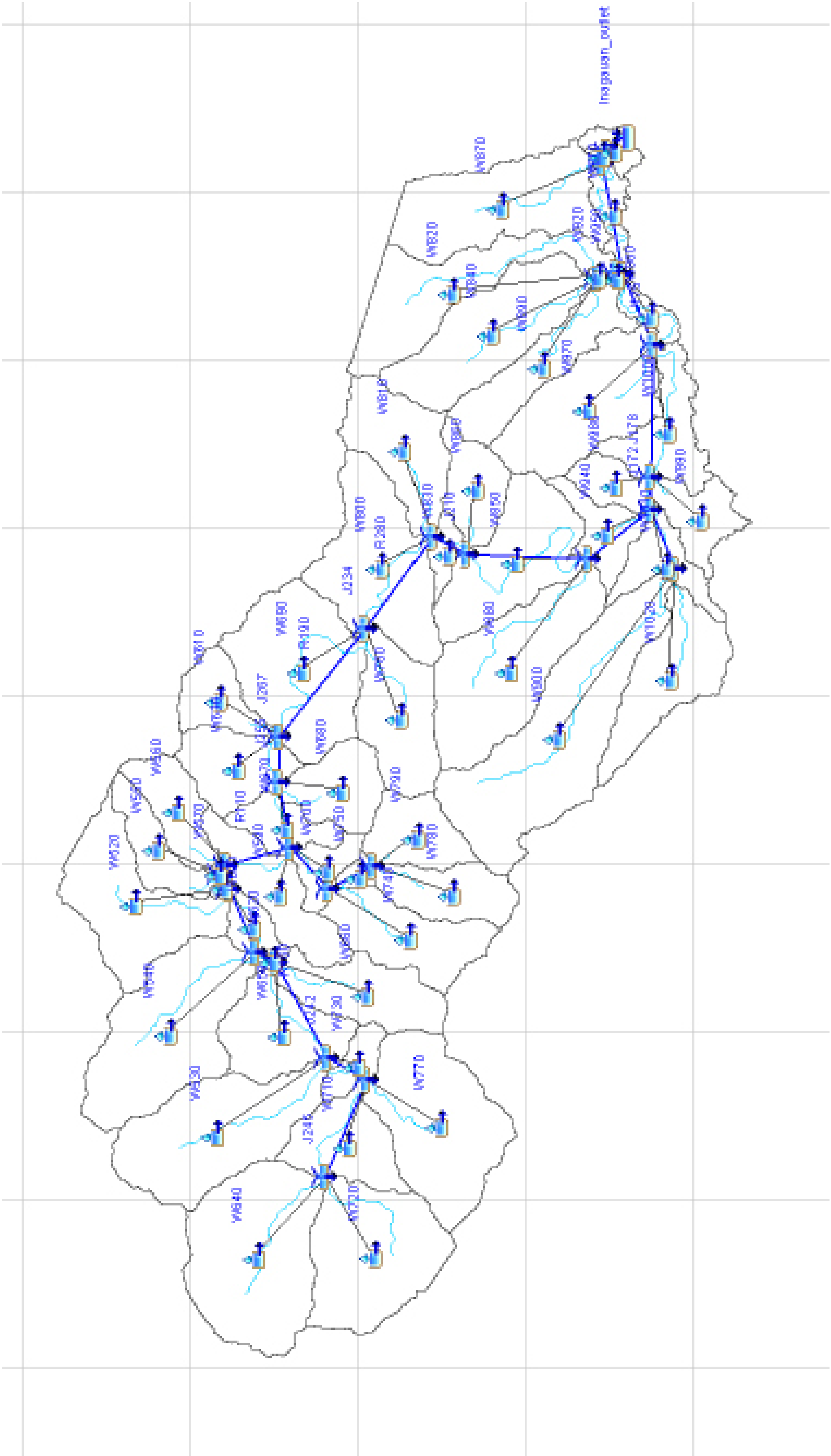



Figure 55. HEC-HMS generated Inagauan River Basin Model.

## 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 56. River cross-section of Inagauan 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 west of the model to the east, following the main channel. As such, boundary elements in those particular regions of the model are assigned as inflow and outflow elements respectively.

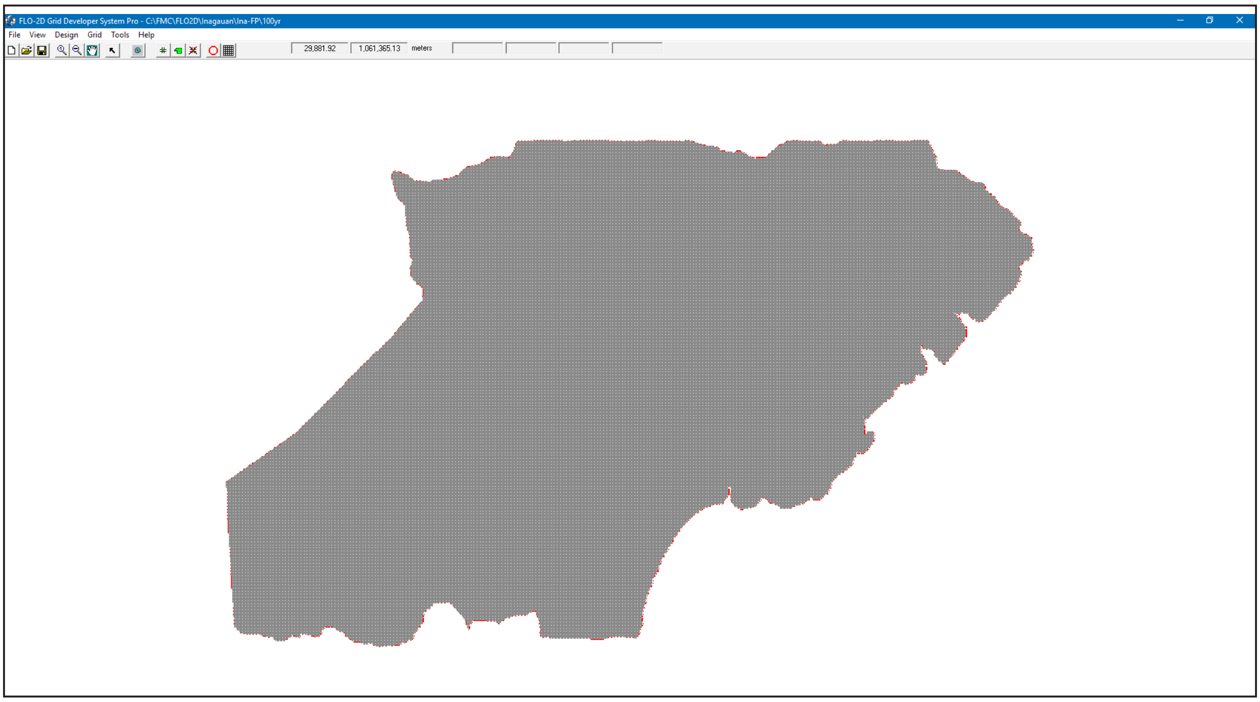



Figure 57. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 34.37207 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 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 38 286 800.00 m2.

There is a total of 48 222 036.13 m3 of water entering the model. Of this amount, 11 614 261.65 m3 is due to rainfall while 36 607 774.48 m3 is inflow from other areas outside the model. 4 851 129.50 m3 of this water is lost to infiltration and interception, while 5 848 386.93 m3 is stored by the flood plain. The rest, amounting up to 37 522 462.19 m3, is outflow.

## 5.6 HEC-HMS Model Values (Uncalibrated)

Enumerated in Table 26 are the range of values of the parameters in the model.

Table 26. Range of Calibrated Values for Inagauan River

| Hydrologic Element | Calculation Type | Method | Parameter | Range of Calibrated Values |
|---|---|---|---|---|
| Basin | Loss | SCS Curve number | Initial Abstraction (mm) | 3 - 14 |
| | | | Curve Number | 48 - 83 |
| | Transform | Clark Unit Hydrograph | Time of Concentration (hr) | 0.3 - 5 |
| | | | Storage Coefficient (hr) | 0.5 - 9 |

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 3 to 14mm means that there is minimal amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. For this watershed, there is a wide range of values from 48 to 83 depending on the subbasin.

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 0.3 hours to 9 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.

Manning's roughness coefficient from 0.04 to 0.5 is high compared to the the common roughness of Philippine watersheds. This means that the riverbed is relatively rough and water will most likely flow slower. (Brunner, 2010).

## 5.7 River Analysis Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. The sample map of Inagauan River using the HMS base flow is shown on Figure 67 below.

Figure 58. Sample output of Inagauan RAS Model

## 5.9 Flood Hazard and Flow Depth Map

The resulting hazard and flow depth maps for 5-, 25-, and 100-year rain return scenarios of the Inagauan floodplain are shown in Figure 59 to Figure 63. The floodplain, with an area of 38.29 sq. km., covers Puerto Princesa City. Table 27 shows the percentage of area affected by flooding per municipality.

Table 27. Municipalities affected in Inagauan Floodplain

| City / Municipality | Total Area | Area Flooded | % Flooded |
|---|---|---|---|
| Puerto Princesa | 2186.36 | 37.97 | 1.74% |

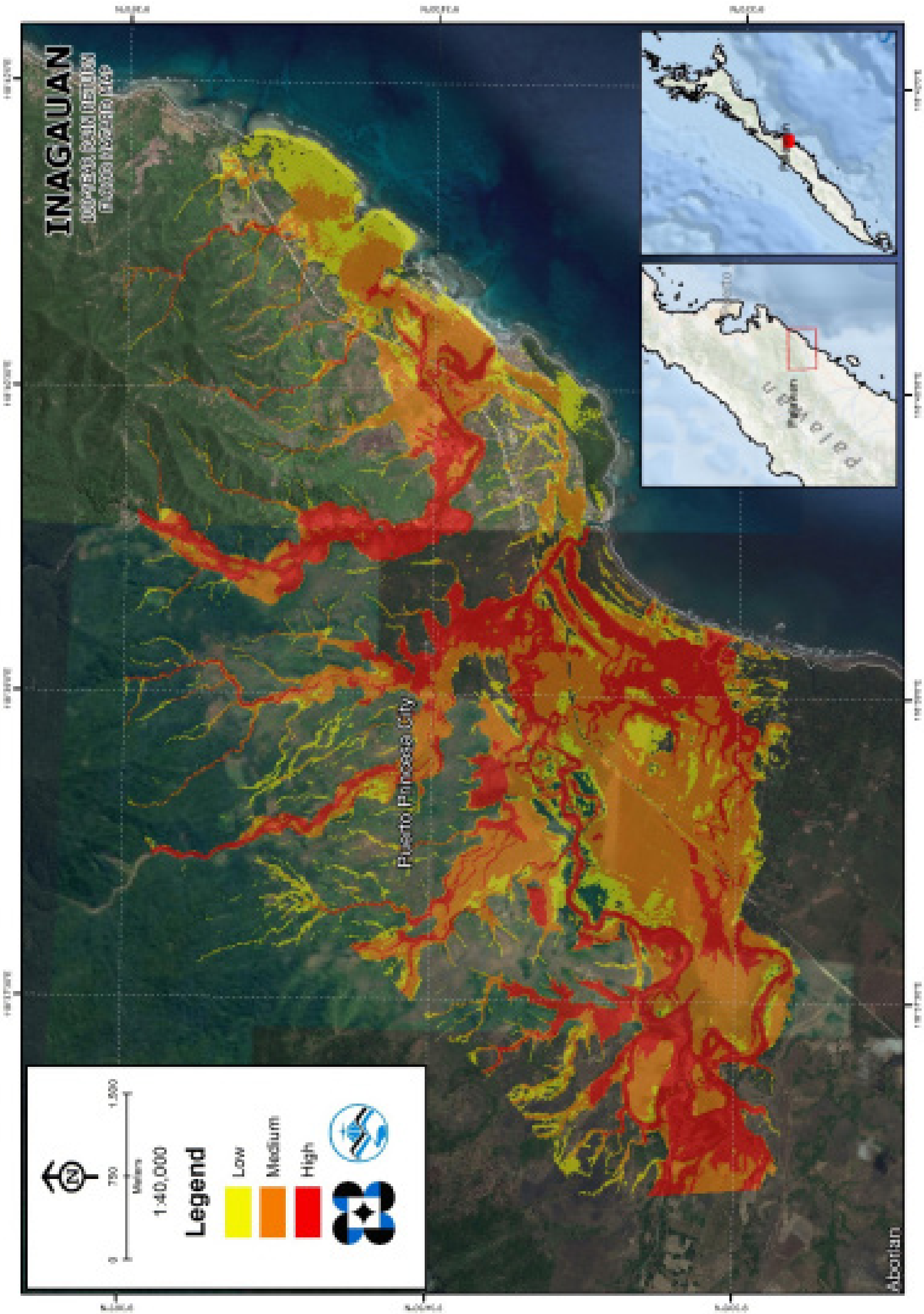



Figure 59. 100-year Flood Hazard Map for Inagauan Floodplain overlaid in Google Earth imagery

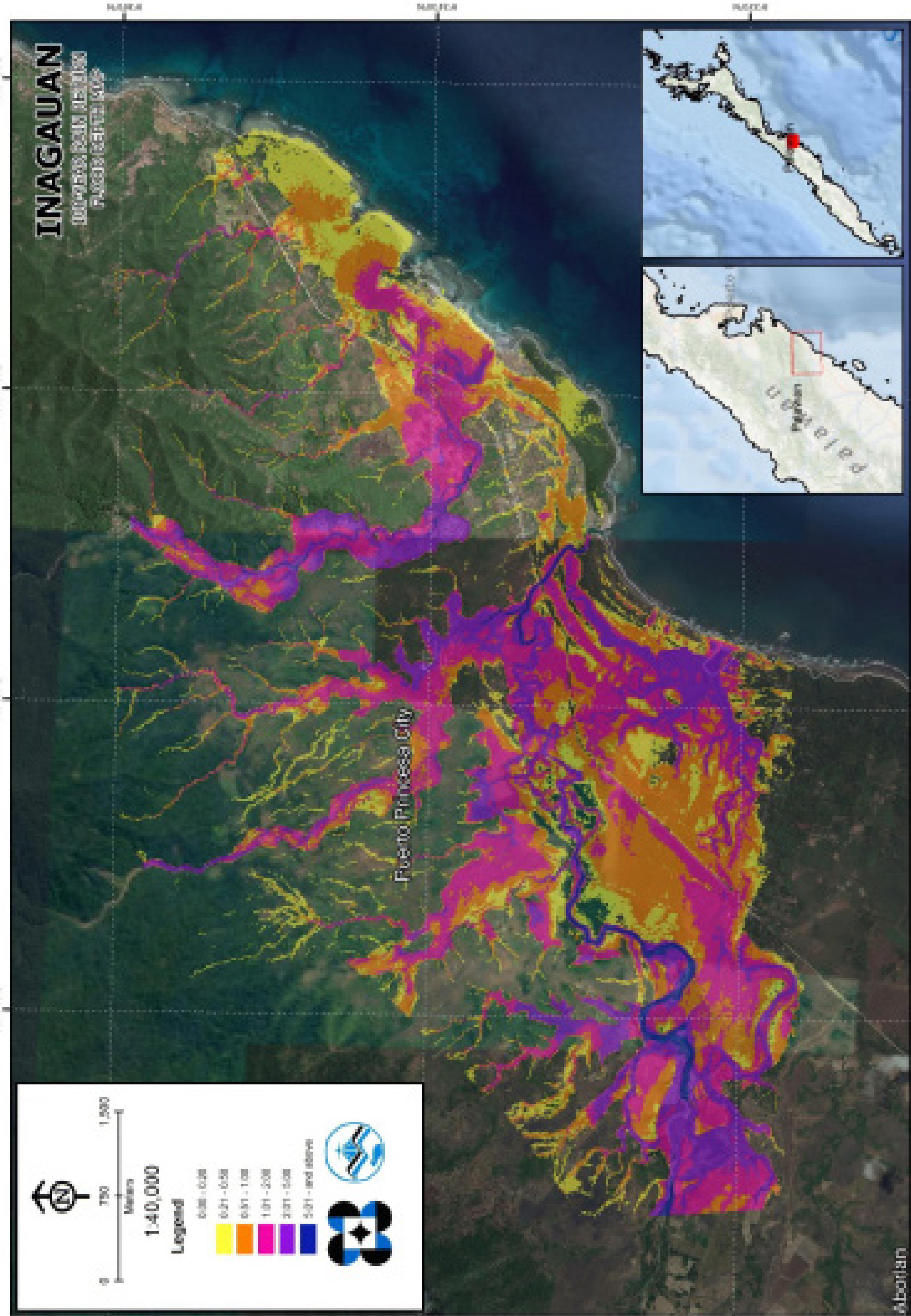



Figure 60. 100-year Flow Depth Map for Inagauan Floodplain overlaid in Google Earth imagery

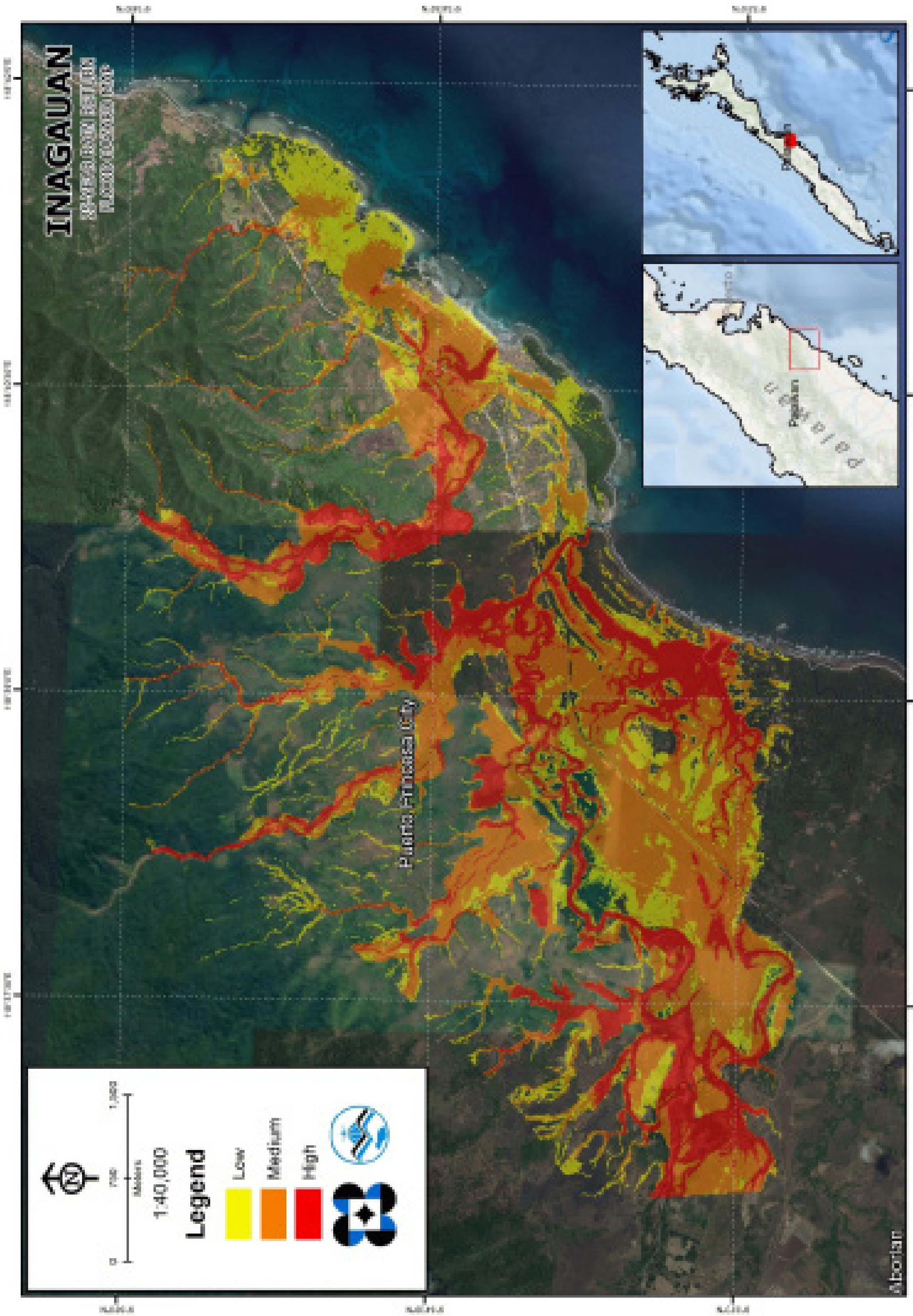



Figure 61. 25-year Flood Hazard Map for Inagauan Floodplain overlaid in Google Earth imagery

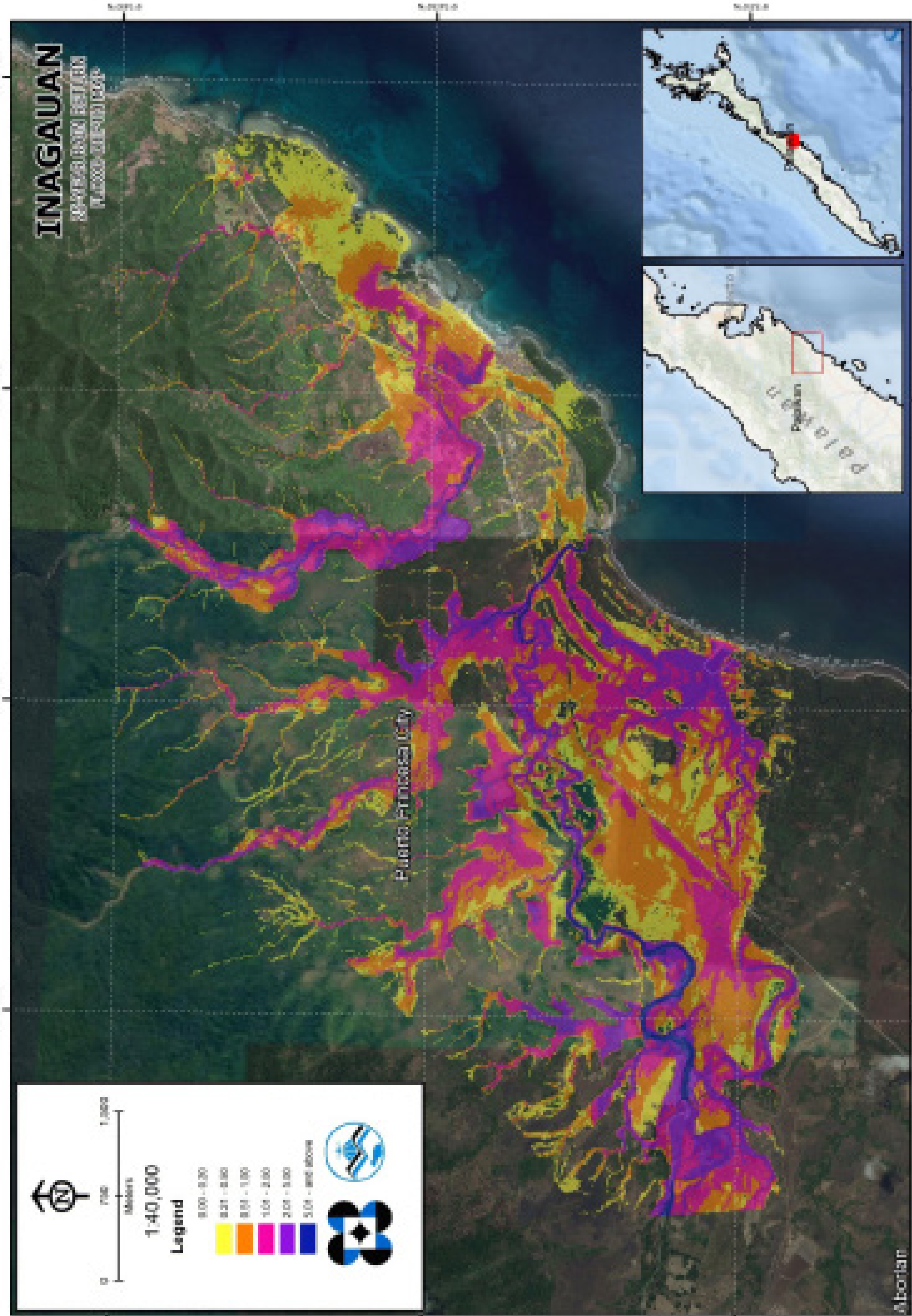



Figure 62. 25-year Flow Depth Map for Inagauan Floodplain overlaid in Google Earth imagery

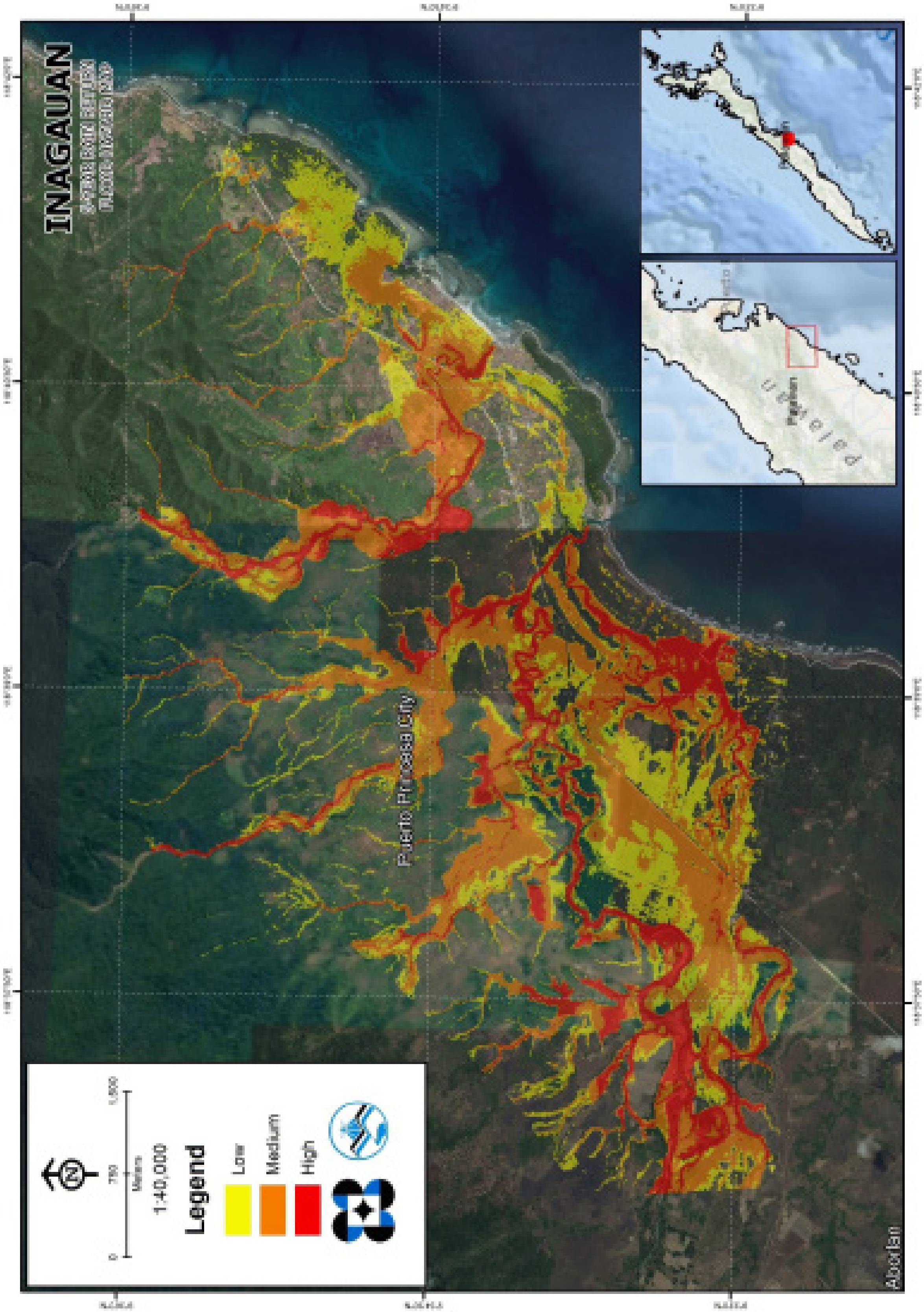



Figure 63. 5-year Flood Hazard Map for Inagauan Floodplain overlaid in Google Earth imagery

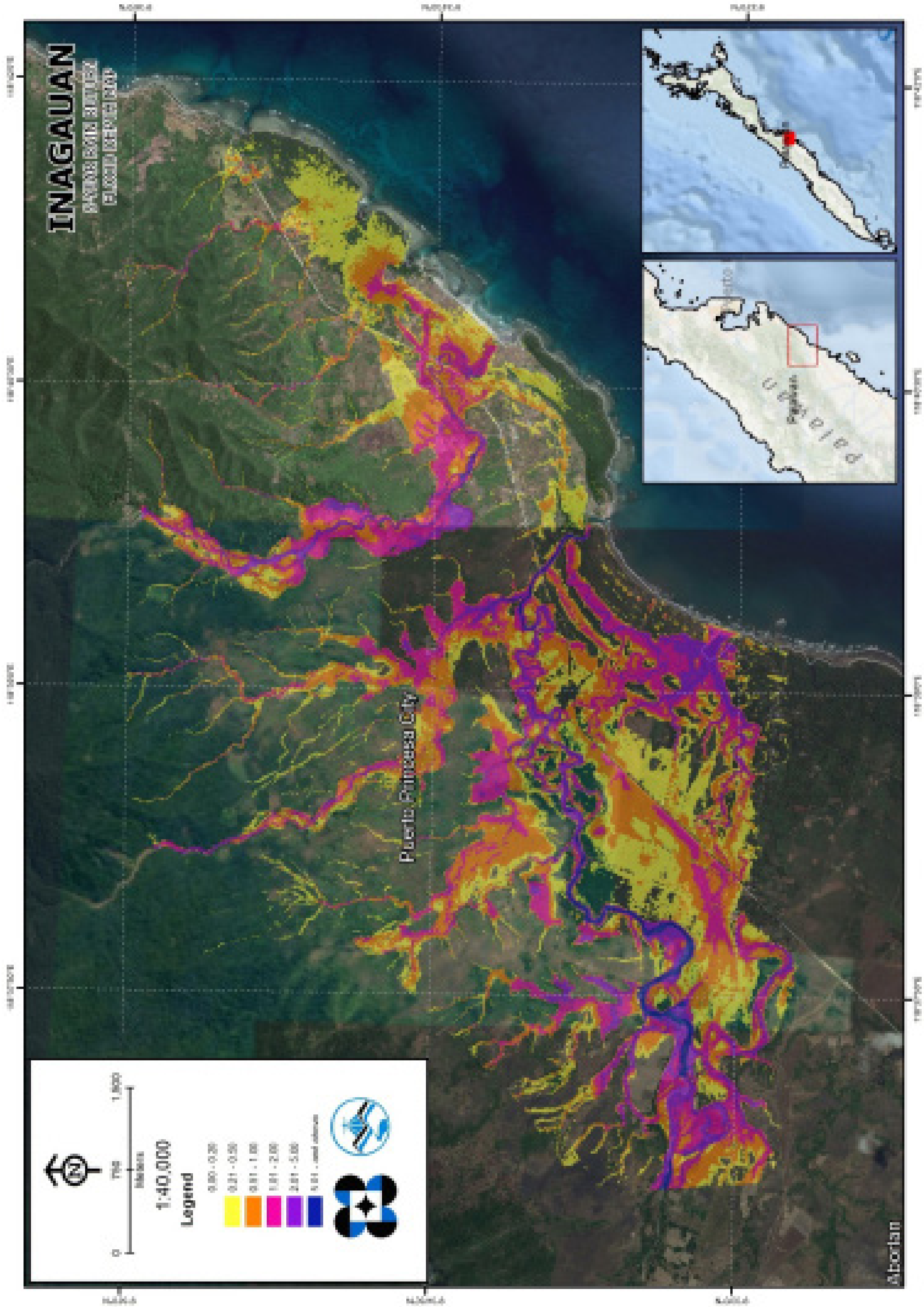



Figure 64. 5-year Flow Depth Map for Inagauan Floodplain overlaid in Google Earth imagery

## 5.9 Inventory of Areas Exposed to Flooding

Affected barangays in Inagauan river basin, grouped by municipality, are listed below. For the said basin, only one city consisting of three (3) barangays is expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 1.08% of the municipality of Puerto Princesa City with an area of 2186.36 sq. km. will experience flood levels of less than 0.20 meters. 0.21% of the area will experience flood levels of 0.21 to 0.50 meters while 0.20%, 0.16%, 0.07%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 28 and shown in Figure 65 are the affected areas in square kilometers by flood depth per barangay.

Table 28. Affected Areas in Puerto Princesa City, Palawan during 5-Year Rainfall Return Period

| Affected area (sq.km.) by flood depth (in m.) | Area of affected barangays in Puerto Princesa City (in sq. km) | | |
|---|---|---|---|
| | Inagawan | Inagawan Sub-Colony | Tagburos |
| 0.03-0.20 | 0.8 | 16.17 | 6.75 |
| 0.21-0.50 | 0.48 | 3.07 | 1.01 |
| 0.51-1.00 | 0.29 | 3.38 | 0.77 |
| 1.01-2.00 | 0.18 | 2.85 | 0.52 |
| 2.01-5.00 | 0.12 | 1.27 | 0.091 |
| > 5.00 | 0 | 0.21 | 0.00081 |

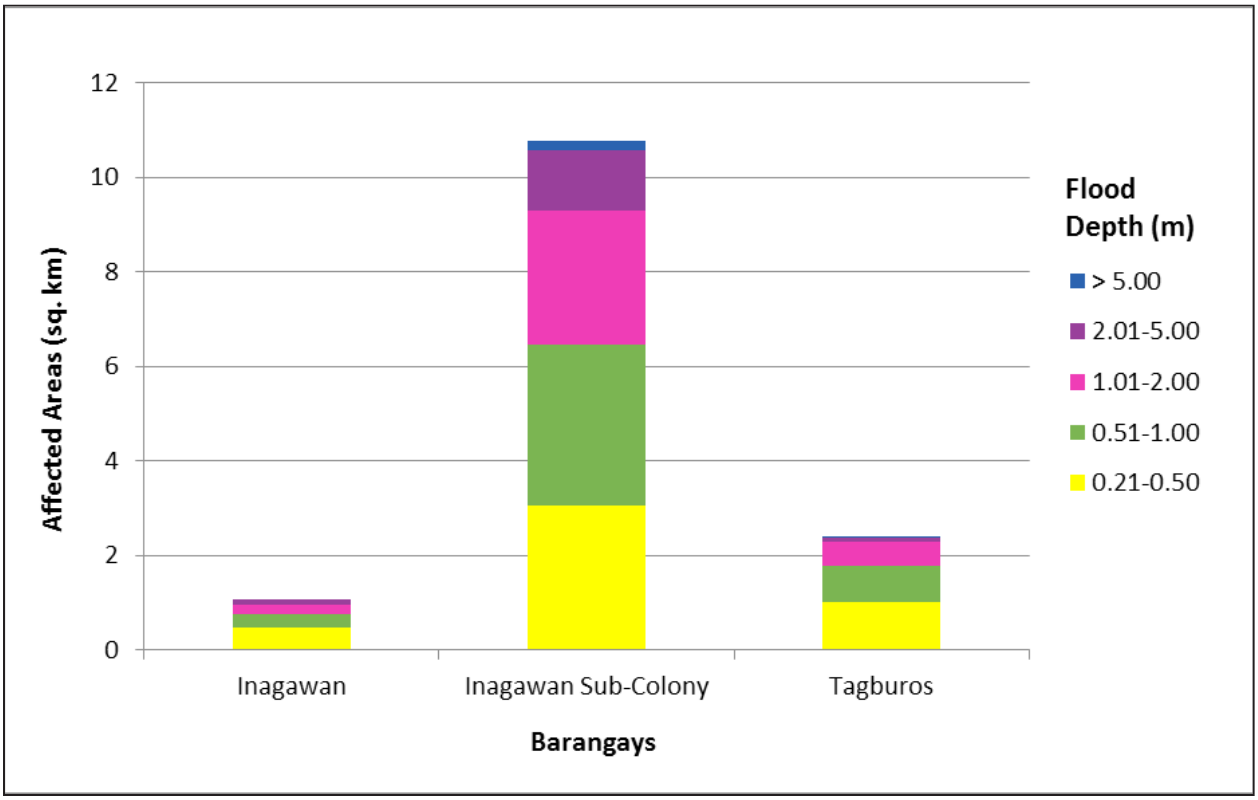



Figure 65. Affected Areas in Puerto Princesa City, Palawan during 5-Year Rainfall Return Period

For the 25-year return period, 0.98% of the municipality of Puerto Princesa City with an area of 2186.36 sq. km. will experience flood levels of less than 0.20 meters. 0.18% of the area will experience flood levels of 0.21 to 0.50 meters while 0.23%, 0.23%, 0.11%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 29 and shown in Figure 66 are the affected areas in square kilometers by flood depth per barangay.

Table 29. Affected Areas in Puerto Princesa City, Palawan during 25-Year Rainfall Return Period

| Affected area (sq.km.) by flood depth (in m.) | Area of affected barangays in Puerto Princesa City (in sq. km) | | |
|---|---|---|---|
| | Inagawan | Inagawan Sub-Colony | Tagburos |
| 0.03-0.20 | 0.53 | 14.54 | 6.34 |
| 0.21-0.50 | 0.38 | 2.53 | 1.01 |
| 0.51-1.00 | 0.53 | 3.66 | 0.84 |
| 1.01-2.00 | 0.27 | 3.95 | 0.8 |
| 2.01-5.00 | 0.16 | 2.02 | 0.15 |
| > 5.00 | 0 | 0.24 | 0.0016 |

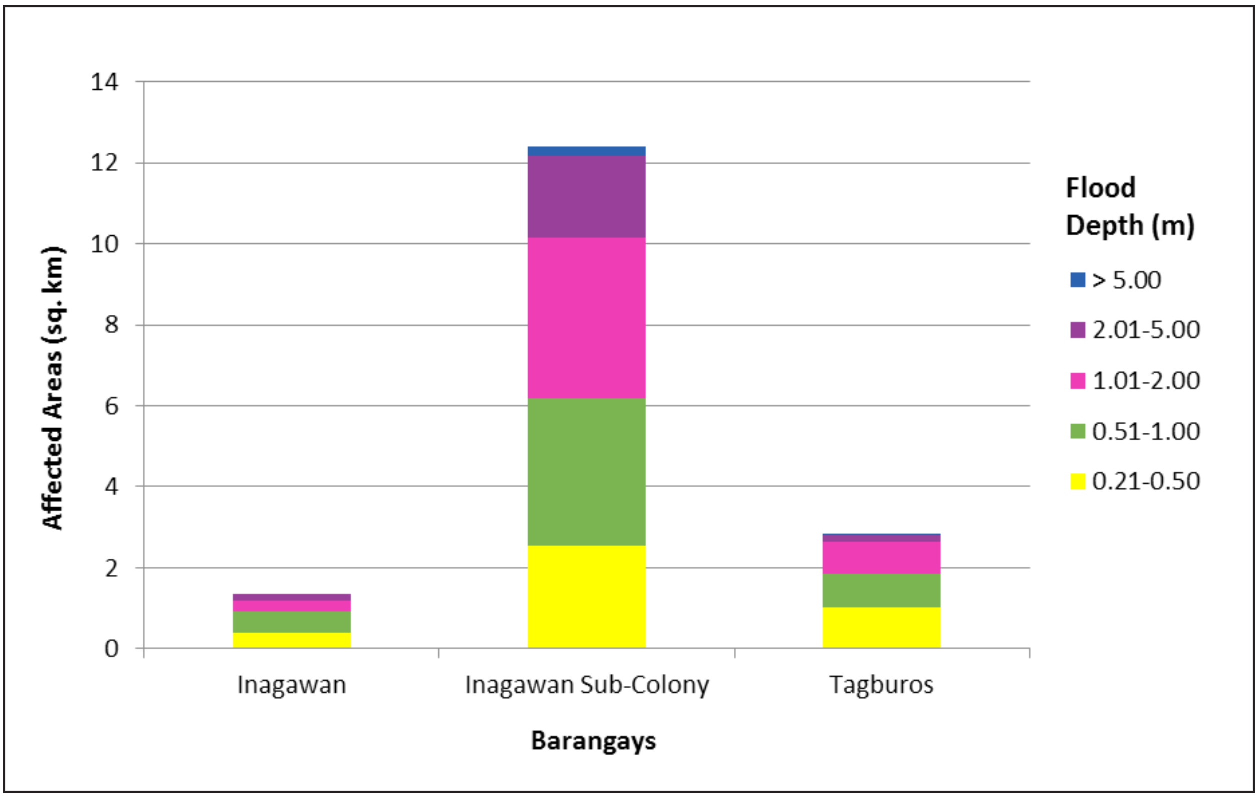



Figure 66. Affected Areas in Puerto Princesa City, Palawan during 25-Year Rainfall Return Period

For the 100-year return period, 0.93% of the municipality of Puerto Princesa City with an area of 2186.36 sq. km. will experience flood levels of less than 0.20 meters. 0.16% of the area will experience flood levels of 0.21 to 0.50 meters while 0.23%, 0.26%, 0.14%, 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,

Table 30. Affected Areas in Puerto Princesa City, Palawan during 100-Year Rainfall Return Period

| Affected area (sq.km.) by flood depth (in m.) | Area of affected barangays in Puerto Princesa City (in sq. km) | | |
|---|---|---|---|
| | Inagawan | Inagawan Sub-Colony | Tagburos |
| 0.03-0.20 | 0.42 | 13.73 | 6.15 |
| 0.21-0.50 | 0.27 | 2.28 | 0.96 |
| 0.51-1.00 | 0.64 | 3.46 | 0.91 |
| 1.01-2.00 | 0.35 | 4.52 | 0.88 |
| 2.01-5.00 | 0.2 | 2.69 | 0.23 |
| > 5.00 | 0 | 0.27 | 0.0034 |

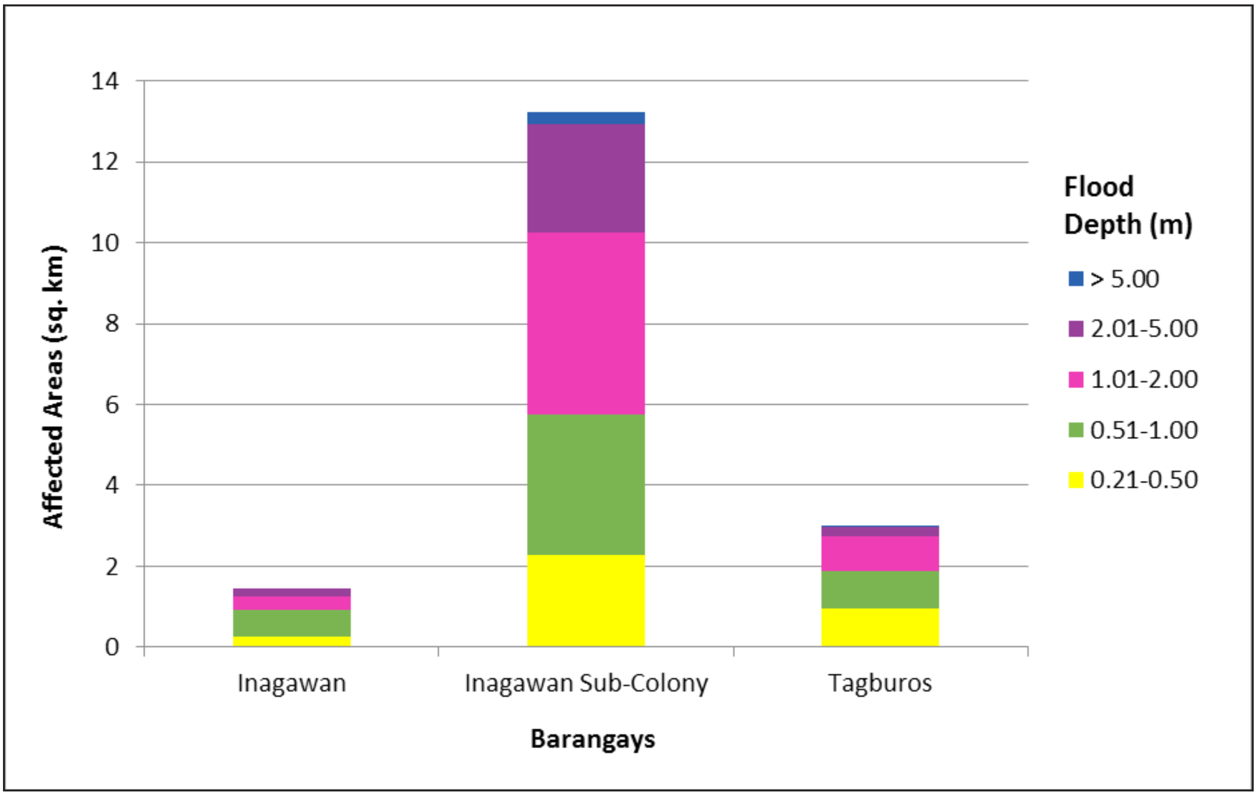



Figure 67. Affected Areas in Puerto Princesa City, Palawan during 100-Year Rainfall Return Period

Among the barangays in the municipality of Puerto Princesa City in Palawan, Inagawan Sub-Colony is projected to have the highest percentage of area that will experience flood levels at 1.23%. Meanwhile, Tagburos posted the second highest percentage of area that may be affected by flood depths at 0.42%.

## 5.10 Flood Validation

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

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

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

After which, the actual data from the field was compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed. The points in the flood map versus its corresponding validation depths are shown in Figure 69.

The flood validation consisted of 86 points randomly selected all over the Inagauan flood plain. Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 0.53m. Table 31 shows a contingency matrix of the comparison.

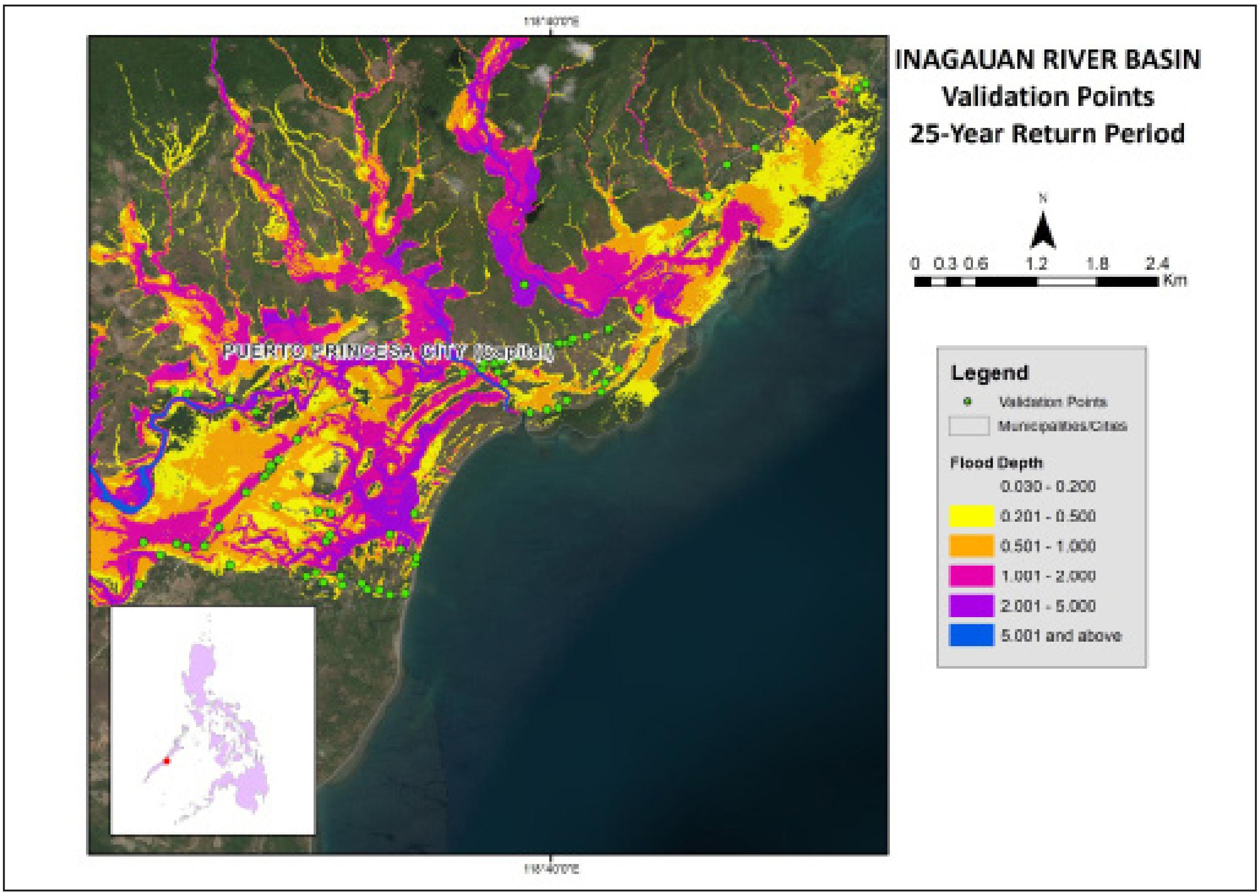



Figure 68. Validation points for 25-year Flood Depth Map of Inagauan Floodplain

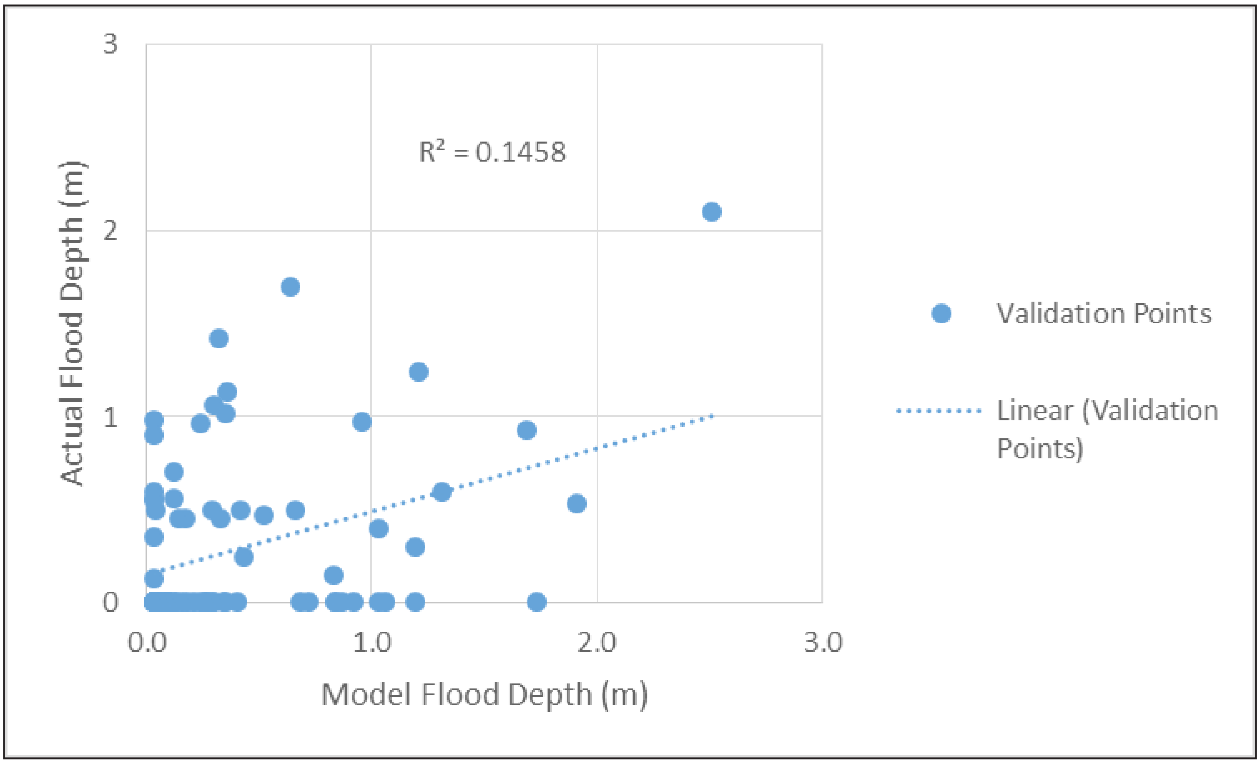



Figure 69. Flood map depth vs. actual flood depth

Table 31. Actual flood vs simulated flood depth at different levels in the Inagauan River Basin.

| Actual Flood Depth (m) | Modeled Flood Depth (m) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0-0.20 | 0.21-0.50 | 0.51-1.00 | 1.01-2.00 | 2.01-5.00 | > 5.00 | Total |
| 0-0.20 | 34 | 10 | 7 | 4 | 0 | 0 | 55 |
| 0.21-0.50 | 4 | 4 | 2 | 2 | 0 | 0 | 12 |
| 0.51-1.00 | 7 | 1 | 1 | 3 | 0 | 0 | 12 |
| 1.01-2.00 | 0 | 4 | 1 | 1 | 0 | 0 | 6 |
| 2.01-5.00 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| > 5.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 45 | 19 | 11 | 10 | 1 | 0 | 86 |

The overall accuracy generated by the flood model is estimated at 47.67% with 41 points correctly matching the actual flood depths. In addition, there were 19 points estimated one level above and below the correct flood depths while there were 20 points and 4 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 4 points were overestimated while a total of 28 points were underestimated in the modelled flood depths of Inagauan. Table 32 depicts the summary of the Accuracy Assessment in the Inagauan River Basin Survey.

Table 32. Summary of Accuracy Assessment in the Inagauan River Basin Survey

| | No. of Points | % |
|---|---|---|
| Correct | 41 | 47.67 |
| Overestimated | 28 | 32.56 |
| Underestimated | 17 | 19.77 |
| Total | 86 | 100.00 |

# REFERENCES

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

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

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

Palawan Council on Sustainable Development (PCSD), 2015, Our Palawan, retrieved from <http://pcsd.gov.ph/OurPalawanJournal/OUR%20PALAWAN.pdf>

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

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

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

www.rappler.com, 2013, Palawan towns in state of calamity, retrieved from <http://www.rappler.com/move-ph/issues/disasters/typhoon-yolanda/43901-palawan-towns-state-calamity>

# Annex 1. Optech Technical Specification of the Sensor

1. AQUARIUS SENSOR

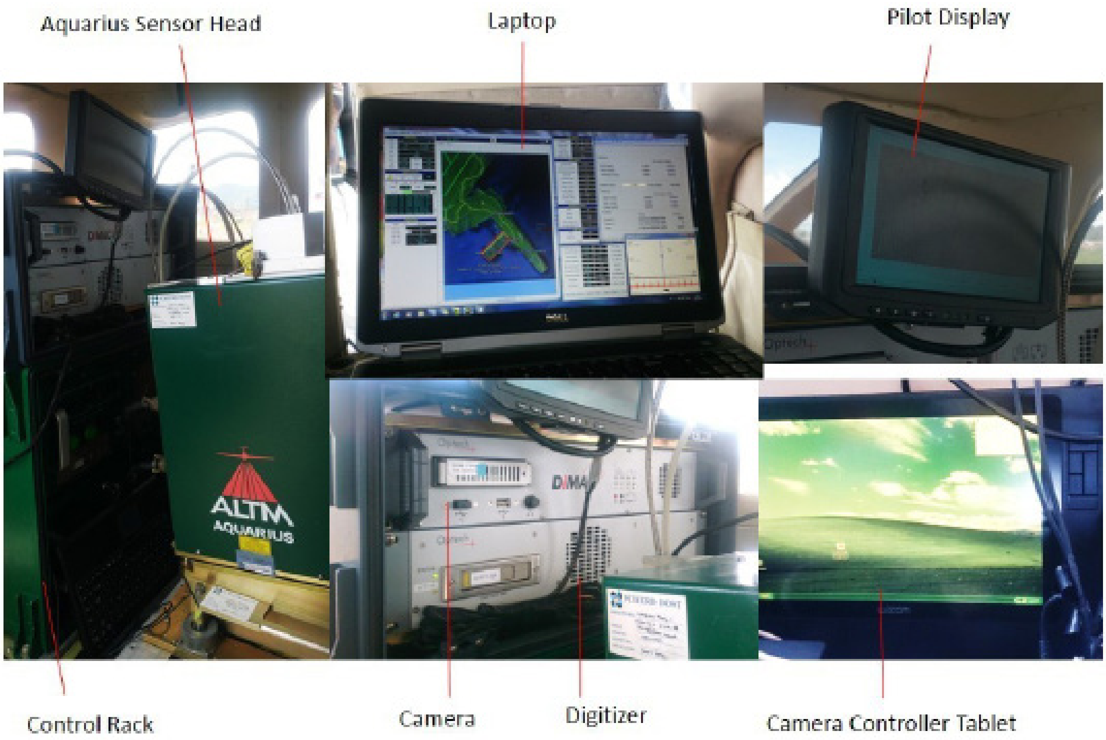


Figure A-1.1 Aquarius Sensor

## 2. PARAMETERS AND SPECIFICATIONS OF THE AQUARIUS SENSOR

Table A-1.1 Parameters and Specifications of the Aquarius Sensor

| Parameter | Specification |
|---|---|
| Operational altitude | 300-600 m AGL |
| Laser pulse repetition rate | 33, 50. 70 kHz |
| Scan rate | 0-70 Hz |
| Scan half-angle | 0 to ± 25 ˚ |
| Laser footprint on water surface | 30-60 cm |
| Depth range | 0 to > 10 m (for k < 0.1/m) |
| Topographic mode | |
| Operational altitude | 300-2500 |
| Range Capture | Up to 4 range measurements, including 1st, 2nd, 3rd, and last returns |
| Intensity capture | 12-bit dynamic measurement range |
| Position and orientation system | POS AVTM 510 (OEM) includes embedded 72-channel GNSS receiver (GPS and GLONASS) |
| Data Storage | Ruggedized removable SSD hard disk (SATA III) |
| Power | 28 V, 900 W, 35 A |
| Image capture | 5 MP interline camera (standard); 60 MP full frame (optional) |
| Full waveform capture | 12-bit Optech IWD-2 Intelligent Waveform Digitizer (optional) |
| Dimensions and weight | Sensor:250 x 430 x 320 mm; 30 kg;<br>Control rack: 591 x 485 x 578 mm; 53 kg |
| Operating temperature | 0-35˚C |
| Relative humidity | 0-95% no-condensing |
| Relative humidity | 0-95% non-condensing |

3. PEGASUS SENSOR

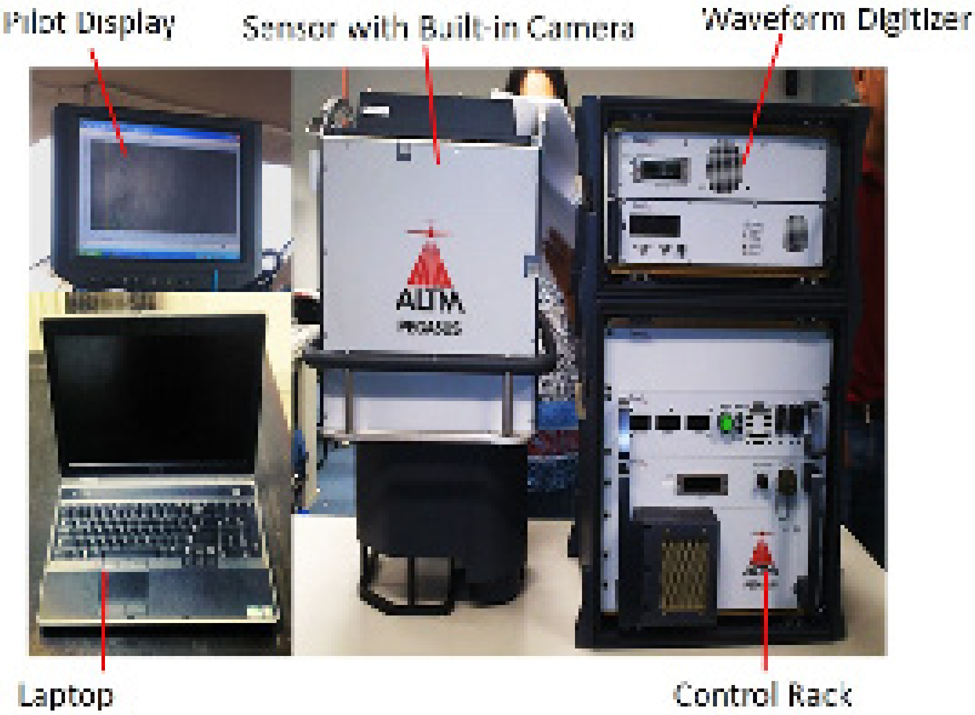


Figure A-1.2 Pegasus Sensor

## 4. PARAMETERS AND SPECIFICATIONS OF THE PEGASUS SENSOR

Table A-1.2 Parameters and Specifications of the Pegasus Sensor

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

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

# Annex 2. NAMRIA Certificates of Reference Points Used

1. MRW-18

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

December 11, 2015

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: OCCIDENTAL MINDORO
Station Name: MRW-18
Order: 2nd

| | | |
|---|---|---|
| Island: LUZON | Barangay: | |
| Municipality: MAGSAYSAY | MSL Elevation: | |
| | *PRS92 Coordinates* | |
| Latitude: 12° 18' 45.39463" | Longitude: 121° 8' 36.92441" | Ellipsoidal Hgt: 21.29500 m. |
| | *WGS84 Coordinates* | |
| Latitude: 12° 18' 40.53383" | Longitude: 121° 8' 42.01469" | Ellipsoidal Hgt: 71.37500 m. |
| | *PTM / PRS92 Coordinates* | |
| Northing: 1361517.851 m. | Easting: 515618.524 m. | Zone: 3 |
| | *UTM / PRS92 Coordinates* | |
| Northing: 1,361,734.74 | Easting: 298,113.89 | Zone: 51 |

Location Description

MRW-18

From Municipality of Magsaysay, located in front of statue of President Ramon Magsaysay, inside the Municipal Compound, about 40 m SE of Municipal Bldg. of Magsaysay. Station is located in Municipality of Magsaysay, Occ. Mindoro. Mark is the head of a 4 in. copper nail flushed in a cement block embedded in the ground with inscriptions, "MRW-18, 2007, NAMRIA".

Requesting Party: UP DREAM
Purpose: Reference
OR Number: 8088861 I
T.N.: 2015-4114

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

991211120151132937

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.1 MRW-18

2. MRW-22

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

March 04, 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: **OCCIDENTAL MINDORO**
Station Name: **MRW-22**
Order: **2nd**

Island: **LUZON**
Municipality: **CALINTAAN**
Barangay: **TANYAG**

***PRS92 Coordinates***

Latitude: **12° 31' 36.76881"** Longitude: **120° 59' 13.46492"** Ellipsoidal Hgt: **35.12700 m.**

***WGS84 Coordinates***

Latitude: **12° 31' 31.84278"** Longitude: **120° 59' 18.53734"** Ellipsoidal Hgt: **84.27100 m.**

***PTM Coordinates***

Northing: **1385214.96 m.** Easting: **498595.125 m.** Zone: **3**

***UTM Coordinates***

Northing: **1,385,663.72** Easting: **281,265.62** Zone: **51**

Location Description

MRW-22

From Abra de Ilog to San Jose, along Nat'l Road, approx. 9 Km. from Calintaan Town Proper, located Lumintao Bridge at Brgy. Tanyag, Sitio Marilao, Calintaan, Occ. Mindoro. Station is located at the N end of the catwalk of Lumintao Bridge. Mark is the head of a 4 in. copper nail flushed in a cement block embedded in the ground with inscriptions, "MRW-22, 2007, NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795470 A**
T.N.: **2014-446**

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

CIP/470/U12/09/814

NAMRIA OFFICES:
Main : Lawton Avenue, Fort Bonifacio, 1634 Taguig City, Philippines Tel. No.: (632) 810-4831 to 41
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Figure A-2.2 MRW-22

3. MRE-56

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

October 28, 2015

**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: **ORIENTAL MINDORO**

Station Name: **MRE-56**

Order: **2nd**

| | | |
|---|---|---|
| Island: **LUZON** | Barangay: | |
| Municipality: **MANSALAY** | MSL Elevation: | |
| | ***PRS92 Coordinates*** | |
| Latitude: **12° 31' 25.76362"** | Longitude: **121° 26' 25.21109"** | Ellipsoidal Hgt: **7.87000 m.** |
| | ***WGS84 Coordinates*** | |
| Latitude: **12° 31' 20.87629"** | Longitude: **121° 26' 30.28143"** | Ellipsoidal Hgt: **58.13600 m.** |
| | ***PTM / PRS92 Coordinates*** | |
| Northing: **1384916.657 m.** | Easting: **547857.861 m.** | Zone: **3** |
| | ***UTM / PRS92 Coordinates*** | |
| Northing: **1,384,892.31** | Easting: **330,530.08** | Zone: **51** |

Location Description

MRE-56

From Calapan City to Bulalacao, along Nat'l Road approx. 4 Km. from Roxas Proper is an intersection of Roxas, Mansalay, Bongabong Road, turn left, approx. 14 Km. travel, right side of Nat'l Road located Mun. Hall of Mansalay, Oriental Mindoro, in front of Mansalay Hospital. Station is located in corner wall of Mun. Park in front of Mun. Hall. Mark is the head of a 4 in. copper nail flushed in a cement block embedded in the ground with inscritions, "MRE-56, 2007, NAMRIA".

Requesting Party: **ENGR. CHRISTOPHER CRUZ**
Purpose: **Reference**
OR Number: **8088472 I**
T.N.: **2015-3523**

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

9 9 1 0 2 8 2 0 1 5 1 3 4 8 1 7

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Figure A-2.3 MRE-56

4. MRW-4203

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

March 25, 2014

**CERTIFICATION**

To whom it may concern:

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

Province: **OCCIDENTAL MINDORO**
Station Name: **MRW-4203**
Order: **3rd**

| | | |
|---|---|---|
| Island: **LUZON** | | Barangay: **MAPAYA** |
| Municipality: **SAN JOSE** | | |
| | ***PRS92 Coordinates*** | |
| Latitude: **12° 21' 24.45294"** | Longitude: **121° 7' 26.92407"** | Ellipsoidal Hgt: **7.40100 m.** |
| | ***WGS84 Coordinates*** | |
| Latitude: **12° 21' 19.57973"** | Longitude: **121° 7' 32.01059"** | Ellipsoidal Hgt: **57.32000 m.** |
| | ***PTM Coordinates*** | |
| Northing: **1366404.003 m.** | Easting: **513501.246 m.** | Zone: **3** |
| | ***UTM Coordinates*** | |
| Northing: **1,366,637.32** | Easting: **296,032.79** | Zone: **51** |

Location Description

MRW-4203

From San Jose Town Proper to Brgy. Mapaya, approx. 7.8 Km. travel to reach brgy. hall. The station is located inside the compound of brgy. plaza, beside the gate post, left side fronting brgy. hall about 40 m NE of brgy. hall, 200 m NW of post Km. post 228, along Nat'l Road, 7 Km. to San Jose. Station is located in Brgy. Mapaya, San Jose, Occ., Mindoro. Mark is the head of a 4 in. copper nail flushed in a cement block embedded in the ground with inscriptions, "MRW-4203, 2007, NAMRIA".

| | |
|---|---|
| Requesting Party: | **UP DREAM** |
| Pupose: | **Reference** |
| OR Number: | **8795829 A** |
| T.N.: | **2014-643** |

**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
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Figure A-2.4 MRW-4203

5. MRW-4205

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

March 04, 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: **OCCIDENTAL MINDORO**
Station Name: **MRW-4205**
Order: **3rd**

| | | |
|---|---|---|
| Island: **LUZON** | | Barangay: **CENTRAL** |
| Municipality: **SAN JOSE** | | |
| | ***PRS92 Coordinates*** | |
| Latitude: **12° 26' 8.33964"** | Longitude: **121° 2' 46.62783"** | Ellipsoidal Hgt: **12.56900 m.** |
| | ***WGS84 Coordinates*** | |
| Latitude: **12° 26' 3.44072"** | Longitude: **121° 2' 51.70789"** | Ellipsoidal Hgt: **62.09500 m.** |
| | ***PTM Coordinates*** | |
| Northing: **1375124 m.** | Easting: **506032.188 m.** | Zone: **3** |
| | ***UTM Coordinates*** | |
| Northing: **1,375,422.19** | Easting: **287,627.78** | Zone: **51** |

Location Description

MRW-4205

From Abra de Ilog to San Jose, along Nat'l Road, approx. 10 Km. travel from San Jose Town Proper, 70 m E of Km. post 247 located Mabuhay Home Based ECCD Center for Health and Nutrition Bldg. located at Brgy. Central, Sitio Mabuhay, San Jose, Occ., Mindoro. Station is located beside fence, 2.0 m SW of Sitio Mabuhay Home Based ECCD Center of Health and Nutrition Post, 40 m NE of Nat'l Road, 70 m E of Km. post 247. Mark is the head of a 4 in. copper nail flushed in a cement block embedded in the ground with inscriptions, "MRW-4205, 2007, NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795470 A**
T.N.: **2014-448**

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

9903042014140315

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CERTIFICATION INTERNATIONAL ISO 9001:2008 CP/4701/12/09/654

Figure A-2.5 MRW-4205

# Annex 3. Baseline Processing Report of Reference Points Used

| Project information | | Coordinate System | |
|---|---|---|---|
| Name: | C:\Users\qwerty\Documents\Business Center - HCE\mrw18-mrw18a.vce | Name: | UTM |
| Size: | 156 KB | Datum: | PRS 92 |
| Modified: | 12/21/2015 2:56:44 PM (UTC:8) | Zone: | 51 North (123E) |
| Time zone: | Taipei Standard Time | Geoid: | EGMPH |
| Reference number: | | Vertical datum: | |
| Description: | | | |

## Baseline Processing Report

### Processing Summary

| Observation | From | To | Solution Type | H. Prec. (Meter) | V. Prec. (Meter) | Geodetic Az. | Ellipsoid Dist. (Meter) | ΔHeight (Meter) |
|---|---|---|---|---|---|---|---|---|
| MRW-18 --- MRW-18a (B1) | MRW-18 | MRW-18a | Fixed | 0.001 | 0.002 | 312°48'54" | 6.566 | 0.551 |

### Acceptance Summary

| Processed | Passed | Flag | Fail |
|---|---|---|---|
| 1 | 1 | 0 | 0 |

### MRW-18 - MRW-18a (6:38:43 AM-10:41:45 AM) (S1)

| | |
|---|---|
| **Baseline observation:** | MRW-18 --- MRW-18a (B1) |
| **Processed:** | 12/21/2015 3:00:47 PM |
| **Solution type:** | Fixed |
| **Frequency used:** | Dual Frequency (L1, L2) |
| **Horizontal precision:** | 0.001 m |
| **Vertical precision:** | 0.002 m |
| **RMS:** | 0.000 m |
| **Maximum PDOP:** | 2.035 |
| **Ephemeris used:** | Broadcast |
| **Antenna model:** | NGS Absolute |
| **Processing start time:** | 12/12/2015 6:38:51 AM (Local: UTC+8hr) |
| **Processing stop time:** | 12/12/2015 10:41:45 AM (Local: UTC+8hr) |
| **Processing duration:** | 04:02:54 |
| **Processing interval:** | 1 second |

1

Figure A-3.1 Baseline Processing Report - A

**Vector Components (Mark to Mark)**

| From: | MRW-18 | | | | |
|---|---|---|---|---|---|
| Grid | | Local | | Global | |
| Easting | 298113.895 m | Latitude | N12°18'45.39463" | Latitude | N12°18'40.53383" |
| Northing | 1361734.745 m | Longitude | E121°08'38.92444" | Longitude | E121°08'42.01469" |
| Elevation | 20.797 m | Height | 21.295 m | Height | 71.375 m |

| To: | MRW-18a | | | | |
|---|---|---|---|---|---|
| Grid | | Local | | Global | |
| Easting | 298109.109 m | Latitude | N12°18'45.53986" | Latitude | N12°18'40.67904" |
| Northing | 1361739.241 m | Longitude | E121°08'38.76504" | Longitude | E121°08'41.85529" |
| Elevation | 21.348 m | Height | 21.845 m | Height | 71.926 m |

| Vector | | | | | |
|---|---|---|---|---|---|
| ΔEasting | -4.786 m | NS Fwd Azimuth | 312°48'54" | ΔX | 4.336 m |
| ΔNorthing | 4.496 m | Ellipsoid Dist. | 6.566 m | ΔY | 2.137 m |
| ΔElevation | 0.551 m | ΔHeight | 0.551 m | ΔZ | 4.477 m |

**Standard Errors**

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

**Aposteriori Covariance Matrix (Meter²)**

| | X | Y | Z |
|---|---|---|---|
| X | 0.0000002319 | | |
| Y | -0.0000003031 | 0.0000009420 | |
| Z | -0.0000000678 | 0.0000001601 | 0.0000001302 |

Figure A-3.2 Baseline Processing Report - B

# Annex 4. The LiDAR Survey Team Composition

Figure A-4.1 LiDAR Survey Team Composition

| Data Acquisition Component Sub -Team | Designation | Name | Agency / Affiliation |
|---|---|---|---|
| PHIL-LIDAR 1 | Program Leader | ENRICO C. PARINGIT, D.ENG | UP-TCAGP |
| Data Acquisition Component Leader | Data Component Project Leader – I | ENGR. CZAR JAKIRI SARMIENTO | UP-TCAGP |
| Survey Supervisor | Chief Science Research Specialist (CSRS) | ENGR. CHRISTOPHER CRUZ | UP-TCAGP |
| | Supervising Science Research Specialist (Supervising SRS) | LOVELY GRACIA ACUÑA | UP-TCAGP |
| | | LOVELYN ASUNCION | UP-TCAGP |

FIELD TEAM

| | | | |
|---|---|---|---|
| LiDAR Operation | Senior Science Research Specialist (SSRS) | PAULINE JOANNE ARCEO | UP-TACGP |
| | Research Associate (RA) | PATRICIA YSABEL ALCANTARA | UP-TCAGP |
| | RA | ENGR. LARAH KRISELLE PARAGAS | UP-TCAGP |
| | RA | ENGR. MILLIE SHANE REYES | UP-TCAGP |
| | RA | GRACE SINADJAN | UP-TCAGP |
| Ground Survey, Data Download and Transfer | RA | ENGR. FRANK NICOLAS ILEJAY | UP-TCAGP |
| | RA | GRACE SINADJAN | UP-TCAGP |
| LiDAR Operation | Airborne Security | SSG. ERIC CACANINDIN | PHILIPPINE AIR FORCE (PAF) |
| | | SSG. BENJAMIN CARBOLLEDO | PAF |
| | Pilot | CAPT. JEFFREY JEREMY ALAAR | ASIAN AEROSPACE CORPORATION (AAC) |
| | | CAPT. JACKSON JAVIER | AAC |
| | | CAPT. SHERWIN ALFONSO III | AAC |
| | | CAPT. JUSTINE JOYA | AAC |

# Annex 5. Data Transfer Sheet For Inagauan Floodplain

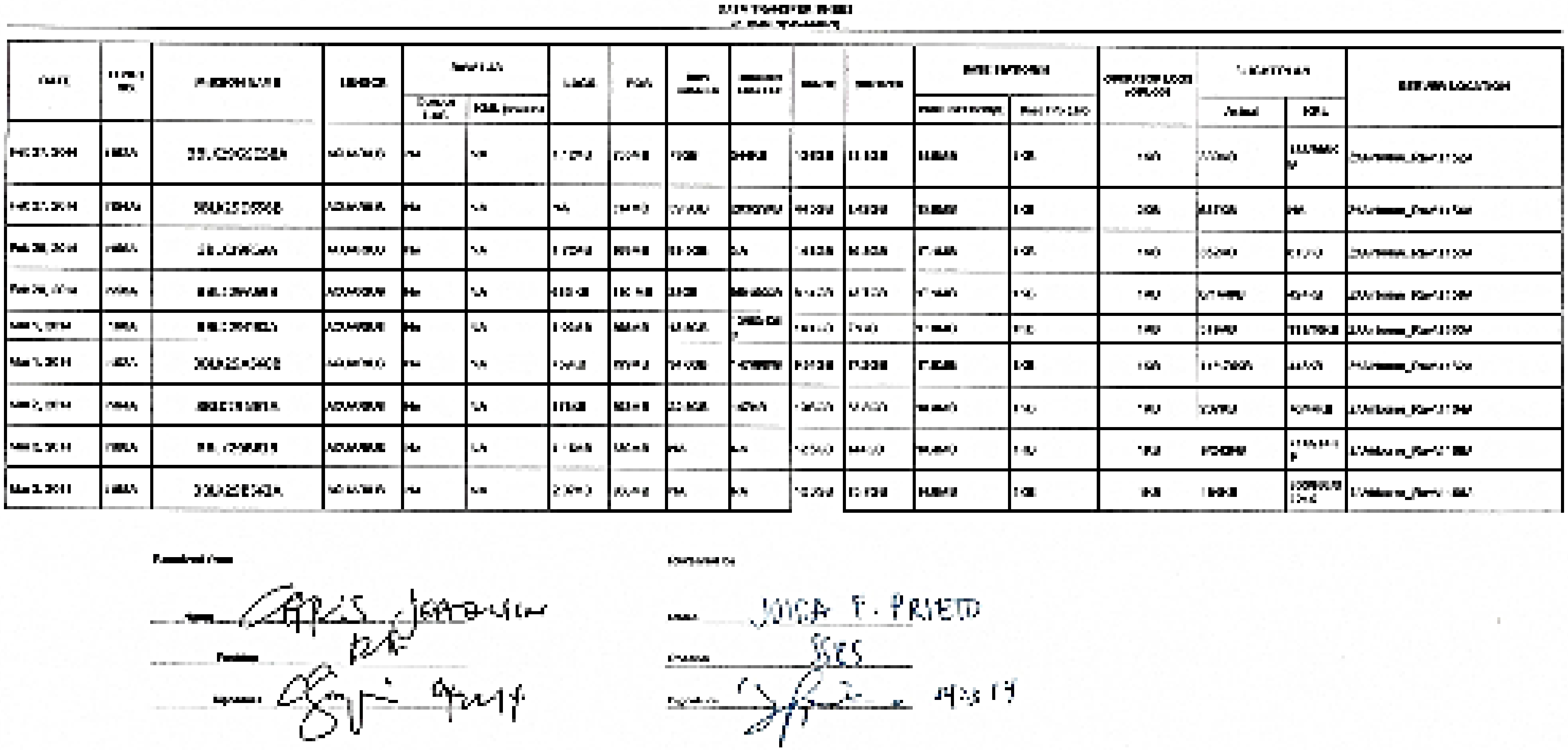


Figure A-5.1 Data Transfer Sheet for Inagauan Floodplain - A

DATA TRANSFER SHEET

Occ. Mindoro 1/13/16

| 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-Dec-15 | 3058P | 1BLK29C340A | pegasus | 732 | 109 | 3.09 | 120 | 8.79 | 74 | 3.66 | na | 10.4 | 1KB | 1KB | 40 | na | Z:\DAC\RAW DATA |
| 6-Dec-15 | 3060P | 1BLK29DE340B | pegasus | 460 | 108 | 3.83 | 115 | 6.06 | 48 | 4.79 | na | 10.4 | 1KB | 1KB | 284/344/50 | na | Z:\DAC\RAW DATA |
| 7-Dec-15 | 3062P | 1BLK29BCS341A | pegasus | 1.40 | 430 | 9.18 | 208 | 26.6 | 192 | 14.4 | na | 7.01 | 1KB | 1KB | 100/96/96 | na | Z:\DAC\RAW DATA |
| 8-Dec-15 | 3066P | 1BLK29ACD342A | pegasus | 960 | 278 | 7.18 | 177 | 57 | 121 | 9.79 | na | 16 | 1KB | 1KB | 146/150 | na | Z:\DAC\RAW DATA |
| 8-Dec-15 | 3068P | 1BLK29GJ342B | pegasus | 6 | 67 | 2.1 | 114 | 4.63 | 37 | 2.77 | na | 16 | 1KB | 1KB | 146/156 | na | Z:\DAC\RAW DATA |
| 9-Dec-15 | 3070P | 1BLK29GH343A | pegasus | 950 | 217 | 5.7 | 140 | 14.3 | na | 5.37 | na | 8.98 | 1KB | 1KB | 148/166 | na | Z:\DAC\RAW DATA |
| 10-Dec-15 | 3074P | 1BLK29KLMO344A | pegasus | 2.09 | 212 | 9.12 | 220 | 30.9 | 224 | 20.7 | na | 14.1 | 1KB | 1KB | 313 | na | Z:\DAC\RAW DATA |
| 10-Dec-15 | 3076P | 1BLK29P344B | pegasus | 258 | 73 | 3.5 | 162 | 4.32 | 34 | 3.2 | na | 14.1 | 1KB | 1KB | 366/316/230/315/146/156 | na | Z:\DAC\RAW DATA |
| 11-Dec-15 | 3078P | 1BLK29NQRS345A | pegasus | 641 | 171 | 5.28 | 167 | 12.9 | 105 | 8.2 | na | 7.02 | 1KB | 1KB | 47/284/344/313/140 | na | Z:\DAC\RAW DATA |
| 12-Dec-15 | 3082P | 1BLK29R346A | pegasus | 992 | 208 | 5.85 | 174 | 13.1 | 96 | 6.33 | na | 7.41 | 1KB | 1KB | 47/140 | na | Z:\DAC\RAW DATA |

Received from

Name C. Joaquin

Position

Signature

Received by

Name AC Bongat

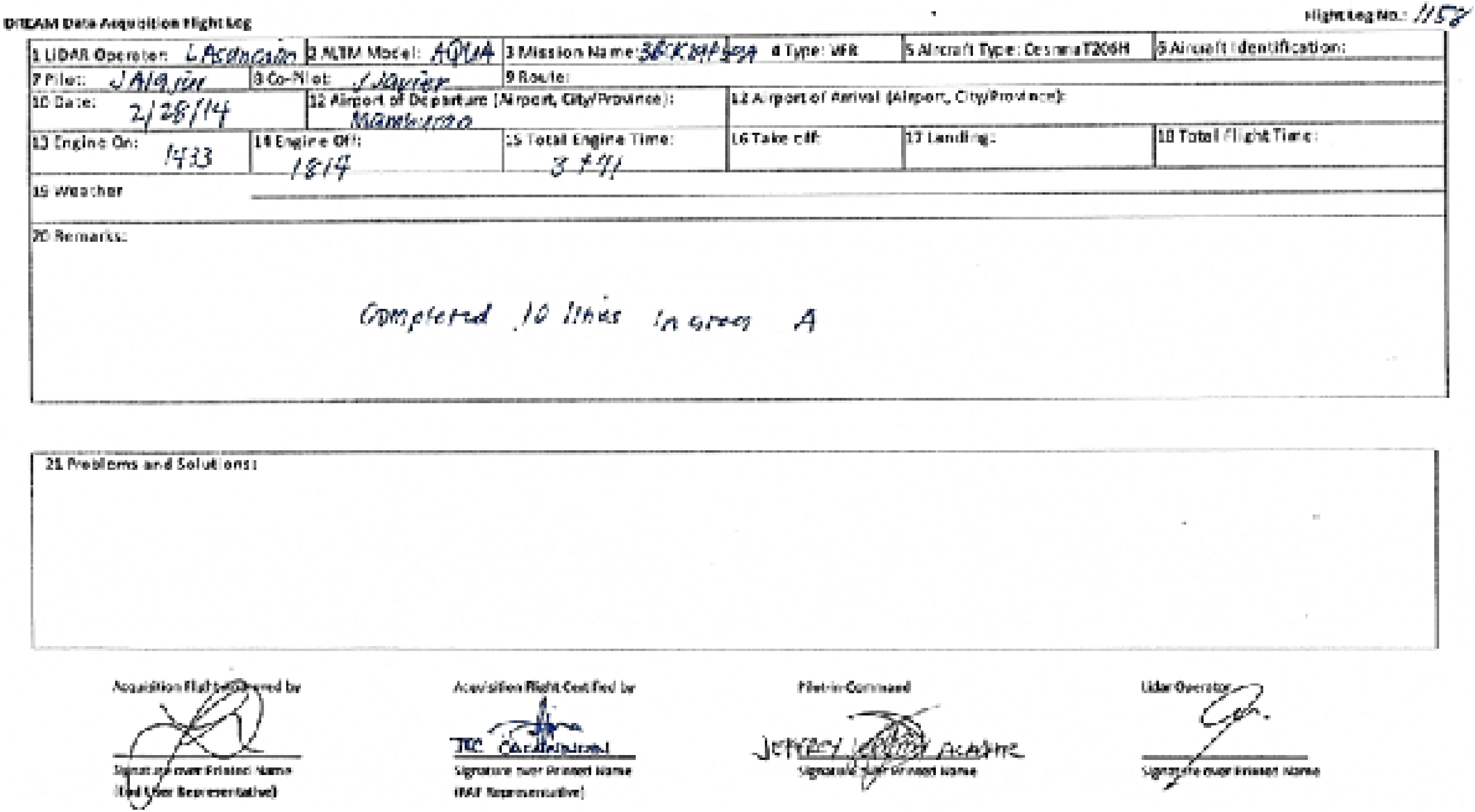
Position SSRS

Signature 1/13/16

Figure A-5.1 Data Transfer Sheet for Inagauan Floodplain - B

# Annex 6. Flight Logs

1. Flight Log for 3BLK29A59B Mission


DREAM Data Acquisition Flight Log

Flight Log No.: 1157

| | | | | | |
|---|---|---|---|---|---|
| 1 LIDAR Operator: L Ascuncion | 2 ALTM Model: AQUA | 3 Mission Name: 3BLK29A59B | 4 Type: VFR | 5 Aircraft Type: Cessna T206H | 6 Aircraft Identification: |
| 7 Pilot: J Alajar | 8 Co-Pilot: J Javier | 9 Route: | | | |
| 10 Date: 2/28/14 | 12 Airport of Departure (Airport, City/Province): Mambucao | | 12 Airport of Arrival (Airport, City/Province): | | |
| 13 Engine On: 1433 | 14 Engine Off: 1814 | 15 Total Engine Time: 3+41 | 16 Take off: | 17 Landing: | 18 Total Flight Time: |
| 19 Weather | | | | | |
| 20 Remarks: Completed 10 lines in area A | | | | | |

21 Problems and Solutions:

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

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

Pilot-in-Command — Jeffrey Alajar — Signature over Printed Name

Lidar Operator — Signature over Printed Name

Figure A-6.1 Flight Log for Mission 3BLK29A59B

2. Flight Log for 3BLK29C60A Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1160

| | | | | | |
|---|---|---|---|---|---|
| 1 LiDAR Operator: J.K Pacaña | 2 ALTM Model: AQUA | 3 Mission Name: 3BLK29C60A | 4 Type: VFR | 5 Aircraft Type: Cessna T206H | 6 Aircraft Identification: |
| 7 Pilot: J. Javier | 8 Co-Pilot: J. Alajar | 9 Route: | | | |
| 10 Date: 3/1/14 | 12 Airport of Departure (Airport, City/Province): Mamburao | | 12 Airport of Arrival (Airport, City/Province): | | |
| 13 Engine On: 822 | 14 Engine Off: 1257 | 15 Total Engine Time: 4+35 | 16 Take off: | 17 Landing: | 18 Total Flight Time: |
| 19 Weather | | | | | |
| 20 Remarks: Mission Completed | | | | | |

21 Problems and Solutions:

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

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

Pilot-in-Command — Signature over Printed Name

Lidar Operator — Signature over Printed Name

Figure A-6.2 Flight Log for Mission 3BLK29C60A

3. Flight Log for 3BLK29AS60B Mission

Flight Log No.: 1162

REAM Data Acquisition Flight Log

| | | | | | |
|---|---|---|---|---|---|
| 1 LiDAR Operator: L Asuncion | 2 ALTM Model: AQUA | 3 Mission Name: 3BLK29AS60B | 4 Type: VFR | 5 Aircraft Type: CesnnaT206H | 6 Aircraft Identification: |
| 7 Pilot: J Javier | 8 Co-Pilot: J Alajar | 9 Route: | | | |
| 10 Date: 3/1/14 | 12 Airport of Departure (Airport, City/Province): Mamburao | | 12 Airport of Arrival (Airport, City/Province): | | |
| 13 Engine On: 1438 | 14 Engine Off: 1819 | 15 Total Engine Time: 3+41 | 16 Take off: | 17 Landing: | 18 Total Flight Time: |
| 19 Weather | | | | | |
| 20 Remarks: Mission completed | | | | | |

21 Problems and Solutions:

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

Figure A-6.3 Flight Log for Mission 3BLK29AS60B

4. Flight Log for 3BLK29N61A Mission

EAM Data Acquisition Flight Log

Flight Log No.: 1164

| | | | | | |
|---|---|---|---|---|---|
| 1 LiDAR Operator: LK Paragas | 2 ALTM Model: AQUA | 3 Mission Name: 3BLK29N61A | 4 Type: VFR | 5 Aircraft Type: CesnnaT206H | 6 Aircraft Identification: |
| 7 Pilot: J Alajar | 8 Co-Pilot: J Javier | 9 Route: | | | |
| 10 Date: 3/2/14 | 12 Airport of Departure (Airport, City/Province): Nambuao | | 12 Airport of Arrival (Airport, City/Province): | | |
| 13 Engine On: 0812 | 14 Engine Off: 1305 | 15 Total Engine Time: 4+53 | 16 Take off: | 17 Landing: | 18 Total Flight Time: |
| 19 Weather | | | | | |
| 20 Remarks: Mission Completed | | | | | |

21 Problems and Solutions:

| | | | |
|---|---|---|---|
| Acquisition Flight Approved by | Acquisition Flight Certified by | Pilot-in-Command | Lidar Operator |
| | TEC CA CANDIDPAS | JEFFREY [illegible] ALAJAR | |
| Signature over Printed Name (End User Representative) | Signature over Printed Name (PAF Representative) | Signature over Printed Name | Signature over Printed Name |

Figure A-6.4 Flight Log for Mission 3BLK29N61A

5. Flight Log for 3BLK29B61B Mission

**DREAM Data Acquisition Flight Log**

Flight Log No.: 1166

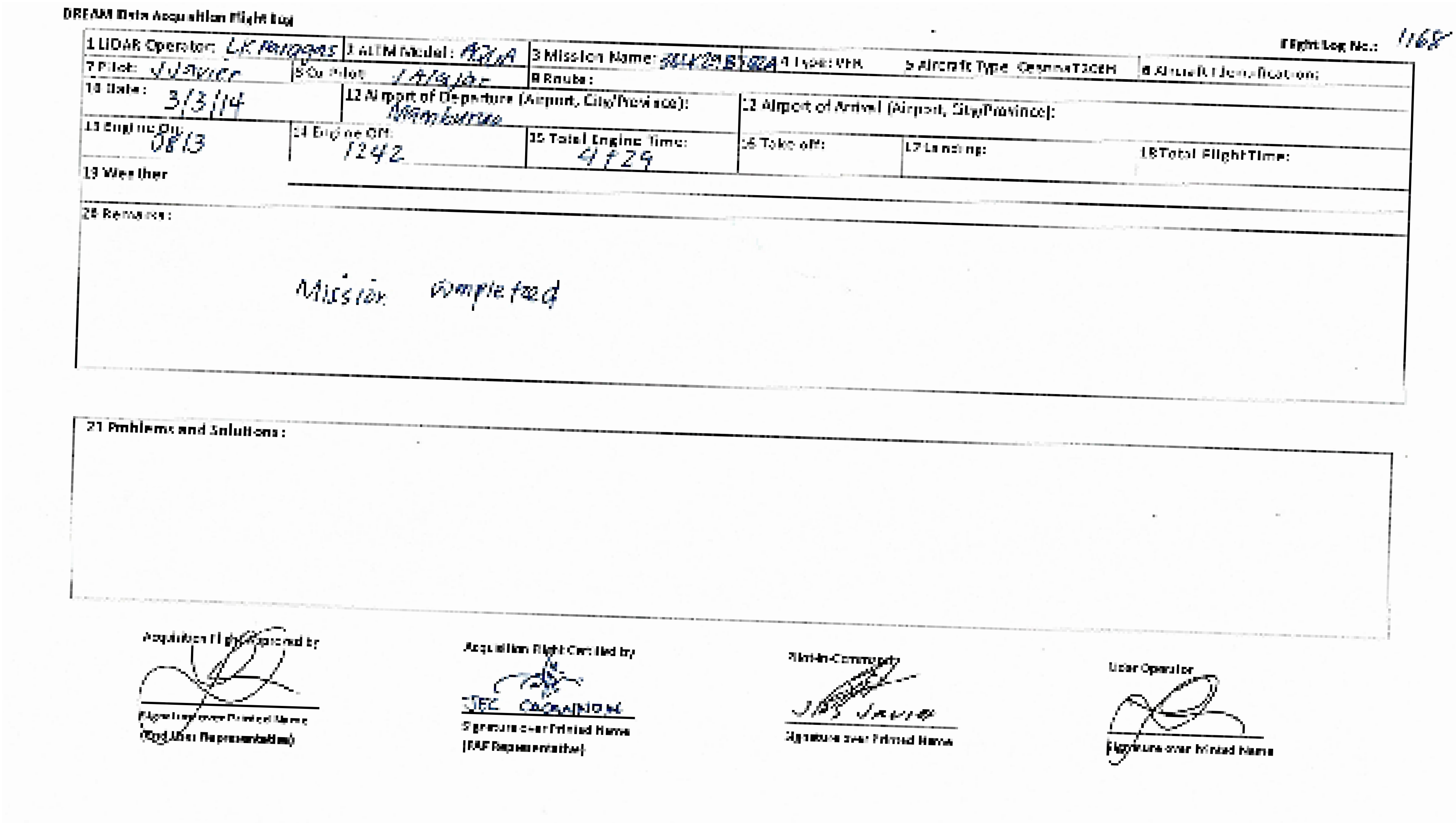
| | | | | | |
|---|---|---|---|---|---|
| 1 LiDAR Operator: LAsungon | 2 ALTM Model: AQUA | 3 Mission Name: 3BLK29B61B | 4 Type: VFR | 5 Aircraft Type: CesnnaT206H | 6 Aircraft Identification: |
| 7 Pilot: J Alajar | 8 Co-Pilot: J Javier | 9 Route: | | | |
| 10 Date: 3/2/14 | 12 Airport of Departure (Airport, City/Province): Mamburao | | 12 Airport of Arrival (Airport, City/Province): | | |
| 13 Engine On: 1423 | 14 Engine Off: 1822 | 15 Total Engine Time: 3+59 | 16 Take off: | 17 Landing: | 18 Total Flight Time: |
| 19 Weather | | | | | |
| 20 Remarks: Completed lines in Area B | | | | | |

21 Problems and Solutions:

| Acquisition Flight Approved by | Acquisition Flight Certified by | Pilot-in-Command | Lidar Operator |
|---|---|---|---|
| Signature over Printed Name (End User Representative) | TEC CAGUINDON<br>Signature over Printed Name (PAF Representative) | JEFFREY [illegible] ALAJAR<br>Signature over Printed Name | Signature over Printed Name |

Figure A-6.5 Flight Log for Mission 3BLK29B61B

6. Flight Log for 3BLK29BS62A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1168

| | | | | | |
|---|---|---|---|---|---|
| 1 LiDAR Operator: LK Paragas | 2 ALTM Model: AQUA | 3 Mission Name: 3BLK29BS62A | 4 Type: VFR | 5 Aircraft Type: CessnaT206H | 6 Aircraft Identification: |
| 7 Pilot: J. Javier | 8 Co-Pilot: J. Alajar | 9 Route: | | | |
| 10 Date: 3/3/14 | 12 Airport of Departure (Airport, City/Province): Mambucal | | 12 Airport of Arrival (Airport, City/Province): | | |
| 13 Engine On: 0813 | 14 Engine Off: 1242 | 15 Total Engine Time: 4+29 | 16 Take off: | 17 Landing: | 18 Total Flight Time: |
| 19 Weather | | | | | |

20 Remarks:

Mission completed

21 Problems and Solutions:

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

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

Pilot-in-Command — J. Javier — Signature over Printed Name

LiDAR Operator — Signature over Printed Name

Figure A-6.6 Flight Log for Mission 3BLK29BS62A

7. Flight Log for 1BLK29NQRS345A Mission

DREAM Program's Data Acquisition Flight Log

Flight Log No.: 2958

| | | | | | |
|---|---|---|---|---|---|
| 1 LIDAR Operator: RJ ARCEO | 2 ALTM Model: PEGASUS | 3 Mission Name: 1BLK 29NQRS345A | 4 Type: VFR | 5 Aircraft Type: CesnnaT206H | 6 Aircraft Identification: 9122 |
| 7 Pilot: CS ALFONSO | 8 Co-Pilot: J JOYA | 9 Route: Mamburao Rizal and Magsaysay | | | |
| 10 Date: DEC 11, 2015 | 12 Airport of Departure (Airport, City/Province): MAMBURAO | | 12 Airport of Arrival (Airport, City/Province): MAMBURAO | | |
| 13 Engine On: 0813 | 14 Engine Off: 1100 | 15 Total Engine Time: 2+47 | 16 Take off: 0818 | 17 Landing: 1055 | 18 Total Flight Time: 2+37 |
| 19 Weather: Cloudy | | | | | |

20 Flight Classification

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

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

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

21 Remarks

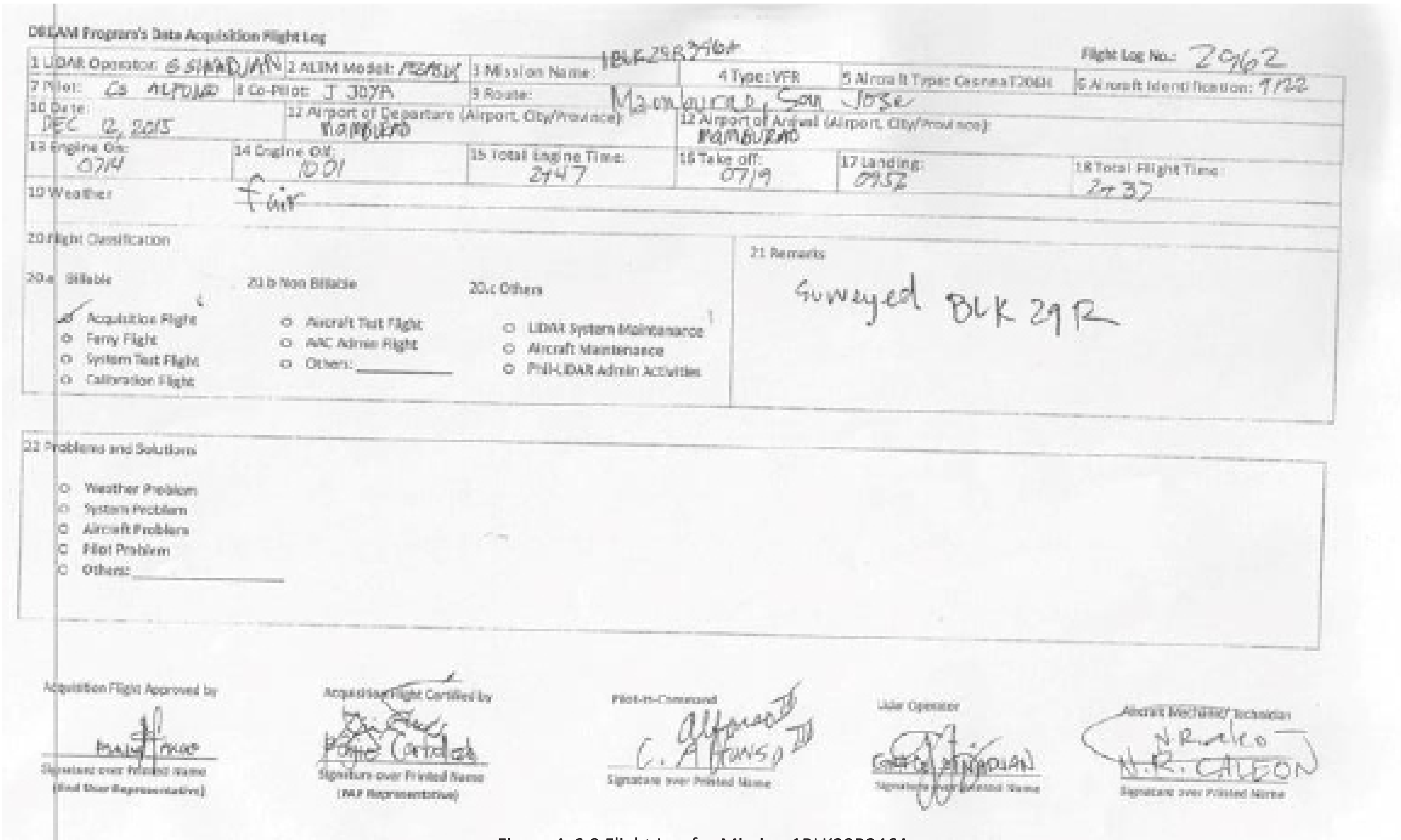
Surveyed BLK 29 N, Q, R & S.

22 Problems and Solutions
- ○ Weather Problem
- ○ System Problem
- ○ Aircraft Problem
- ○ Pilot Problem
- ○ Others: ____________

| Acquisition Flight Approved by | Acquisition Flight Certified by | Pilot-in-Command | Lidar Operator | Aircraft Mechanic/ Technician |
|---|---|---|---|---|
| [signature] | [signature] | C. ALFONSO III | [signature] | N.R. CAJEON |
| Signature over Printed Name (End User Representative) | Signature over Printed Name (PAF Representative) | Signature over Printed Name | Signature over Printed Name | Signature over Printed Name |

Figure A-6.7 Flight Log for Mission 1BLK29NQRS345A

8. Flight Log for 1BLK29R346A Mission



DREAM Program's Data Acquisition Flight Log

Flight Log No.: 2962

| | | | | | |
|---|---|---|---|---|---|
| 1 LiDAR Operator: G SINADJAN | 2 ALTM Model: PEGASUS | 3 Mission Name: 1BLK29R346A | 4 Type: VFR | 5 Aircraft Type: Cessna T206H | 6 Aircraft Identification: 9122 |
| 7 Pilot: CS ALFONSO | 8 Co-Pilot: J JOYA | 9 Route: Mamburao, San Jose | | | |
| 10 Date: DEC 12, 2015 | 12 Airport of Departure (Airport, City/Province): Mamburao | | 12 Airport of Arrival (Airport, City/Province): Mamburao | | |
| 13 Engine On: 0714 | 14 Engine Off: 1001 | 15 Total Engine Time: 2+47 | 16 Take off: 0719 | 17 Landing: 0952 | 18 Total Flight Time: 2+37 |
| 19 Weather: Fair | | | | | |

20 Flight Classification

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

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

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

21 Remarks: Surveyed BLK 29R

22 Problems and Solutions
- ○ Weather Problem
- ○ System Problem
- ○ Aircraft Problem
- ○ Pilot Problem
- ○ Others: ____

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

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

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

Lidar Operator: Signature over Printed Name

Aircraft Mechanic/ Technician: N. R. Caleon, Signature over Printed Name

Figure A-6.8 Flight Log for Mission 1BLK29R346A

# Annex 7. Flight Status

FLIGHT STATUS REPORT
Inagauan FLOODPLAIN
February 28-March 3, 2014; December 11-12, 2015

Table A-7.1 Flight Status Report

| FLIGHT NO. | AREA | MISSION | OPERATOR | DATE FLOWN | REMARKS |
|---|---|---|---|---|---|
| 1158A | BLK29A | 3BLK29A59B | L. ASUNCION | 28-Feb-14 | Covered 10 lines. |
| 1160A | BLK29C | 3BLK29C60A | L. PARAGAS | 01-Mar-14 | Mission completed. |
| 1162A | BLK29A & 29D | 3BLK29AS+DV60B | L. ASUNCION | 01-Mar-14 | Mission completed. Continuation of BLK29A and covered voids in BLK29D. |
| 1164A | BLK29N & 29B | 3BLK29N+B61A | L. PARAGAS | 02-Mar-14 | Mission completed. Covered lines 10 and 11 of BLK29B. |
| 1166A | BLK29B | 3BLK29B61B | L. ASUNCION | 02-Mar-14 | Covered gap in line 10 from the morning flight. |
| 1168A | BLK29B, 29A, 29D, 29C & 29K | 3BLK29BS+ AB+DB+CV+ KV62B | L. PARAGAS | 03-Mar-14 | Mission completed. |
| 3078P | BLK 29N, 29Q, 29R & 29S. | 1BLK29NQRS345A | P. ARCEO | 11-Dec-15 | Surveyed BLK 29N, Q, R & S. |
| 3082P | BLK 29R | 1BLK29R346A | G. SINADJAN | 12-Dec-15 | Surveyed BLK29R. |

LAS/SWATH BOUNDARIES PER MISSION FLIGHT

| | | | |
|---|---|---|---|
| FLIGHT LOG NO. | 1158A | | |
| AREA: | BLK29A | | |
| MISSION NAME: | 3BLK29A59B | | |
| PARAMETERS: | Alt: 550 | Scan Freq: 40 kHz | Scan Angle: 18 deg |

SURVEY COVERAGE:


Figure A-7.1 Swath for Flight No. 1158A

FLIGHT LOG NO. 1160A
AREA: BLK29C
MISSION NAME: 3BLK29C60A
PARAMETERS: Alt: 650 Scan Freq: 40 kHz Scan Angle: 18 deg

SURVEY COVERAGE:

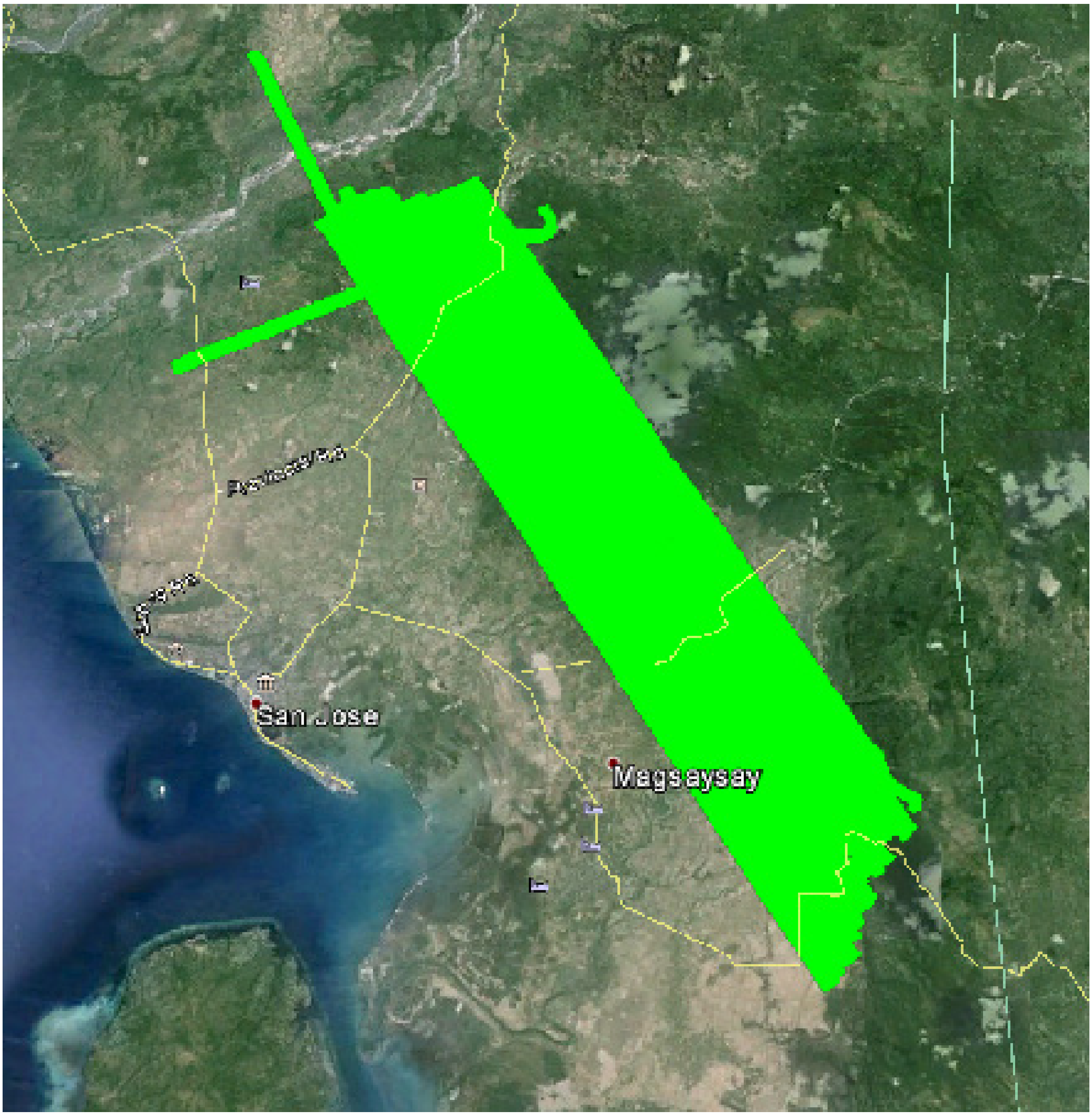



Figure A-7.2 Swath for Flight No. 1160A

FLIGHT LOG NO. 1162A
AREA: BLK29A AND BLK29D
MISSION NAME: 3BLK29AS+DV60B
PARAMETERS: Alt: 600 Scan Freq: 40 kHz Scan Angle: 18 deg

SURVEY COVERAGE:


Figure A-7.3 Swath for Flight No. 1162A

| | | | |
|---|---|---|---|
| FLIGHT LOG NO. | 1164A | | |
| AREA: | BLK29N AND BLK29B | | |
| MISSION NAME: | 3BLK29N+B61A | | |
| PARAMETERS: | Alt: 600 | Scan Freq: 40 kHz | Scan Angle: 18 deg |

SURVEY COVERAGE:


Figure A-7.4 Swath for Flight No. 1164A

FLIGHT LOG NO. 1166A
AREA: BLK29B
MISSION NAME: 3BLK29B61B
PARAMETERS: Alt: 600 Scan Freq: 40 kHz Scan Angle: 18 deg

SURVEY COVERAGE:


Figure A-7.5 Swath for Flight No. 1166A

FLIGHT LOG NO. 1168A
AREA: BLK29B, BLK29A, BLK29D, BLK29C AND BLK29K
MISSION NAME: 3BLK29BS+AB+DB+CV+KV62B
PARAMETERS: Alt: 550 Scan Freq: 40 kHz Scan Angle: 18 deg

SURVEY COVERAGE:

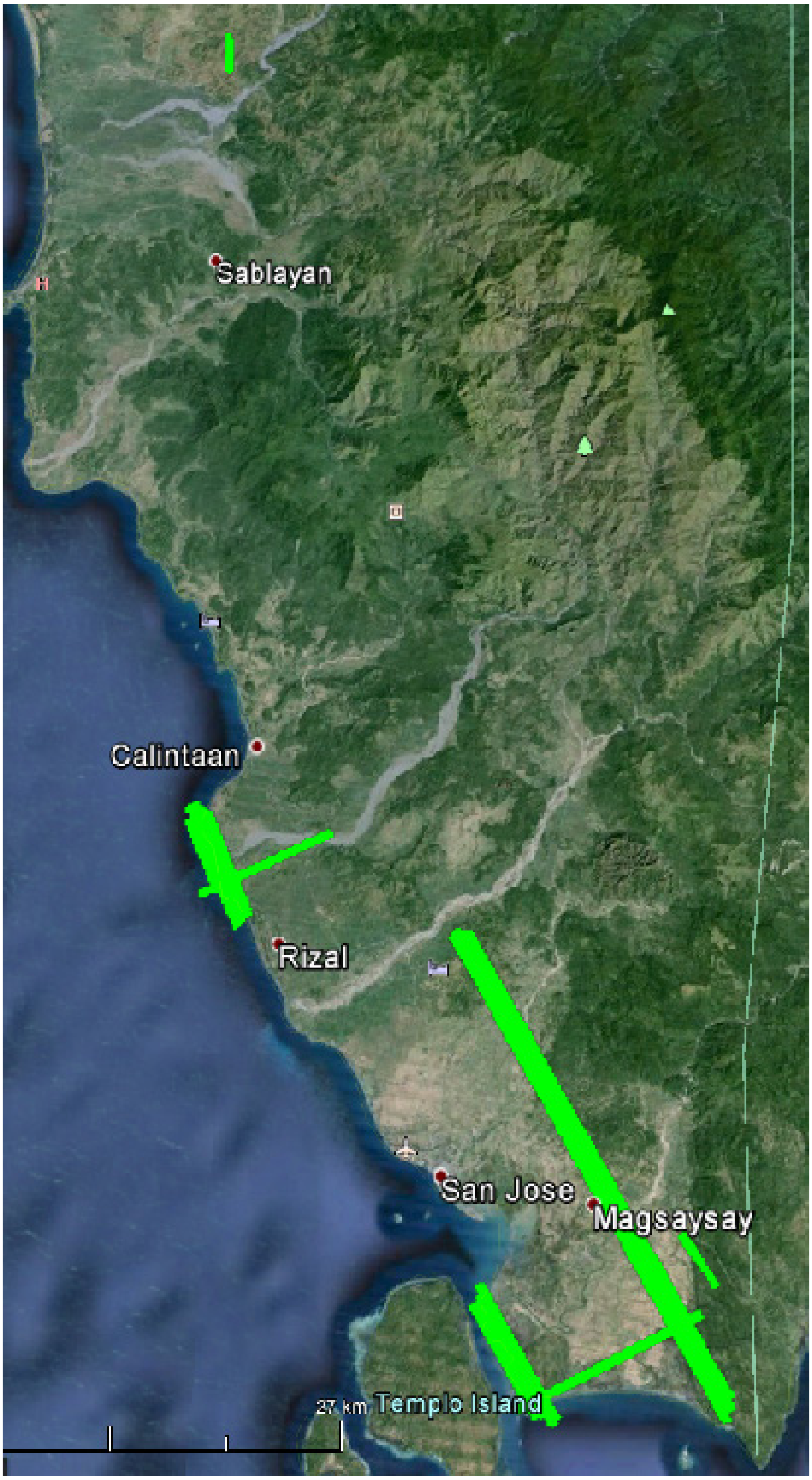



Figure A-7.6 Swath for Flight No. 1168A

| | |
|---|---|
| FLIGHT NO.: | 3078P |
| AREA: | BLK29N, BLK29Q, BLK29R & BLK29S |
| MISSION NAME: | 1BLK29NQRS345A |
| PARAMETERS: | Alt: 850 m Scan Freq: 32 Scan Angle: 25 |

SURVEY COVERAGE:

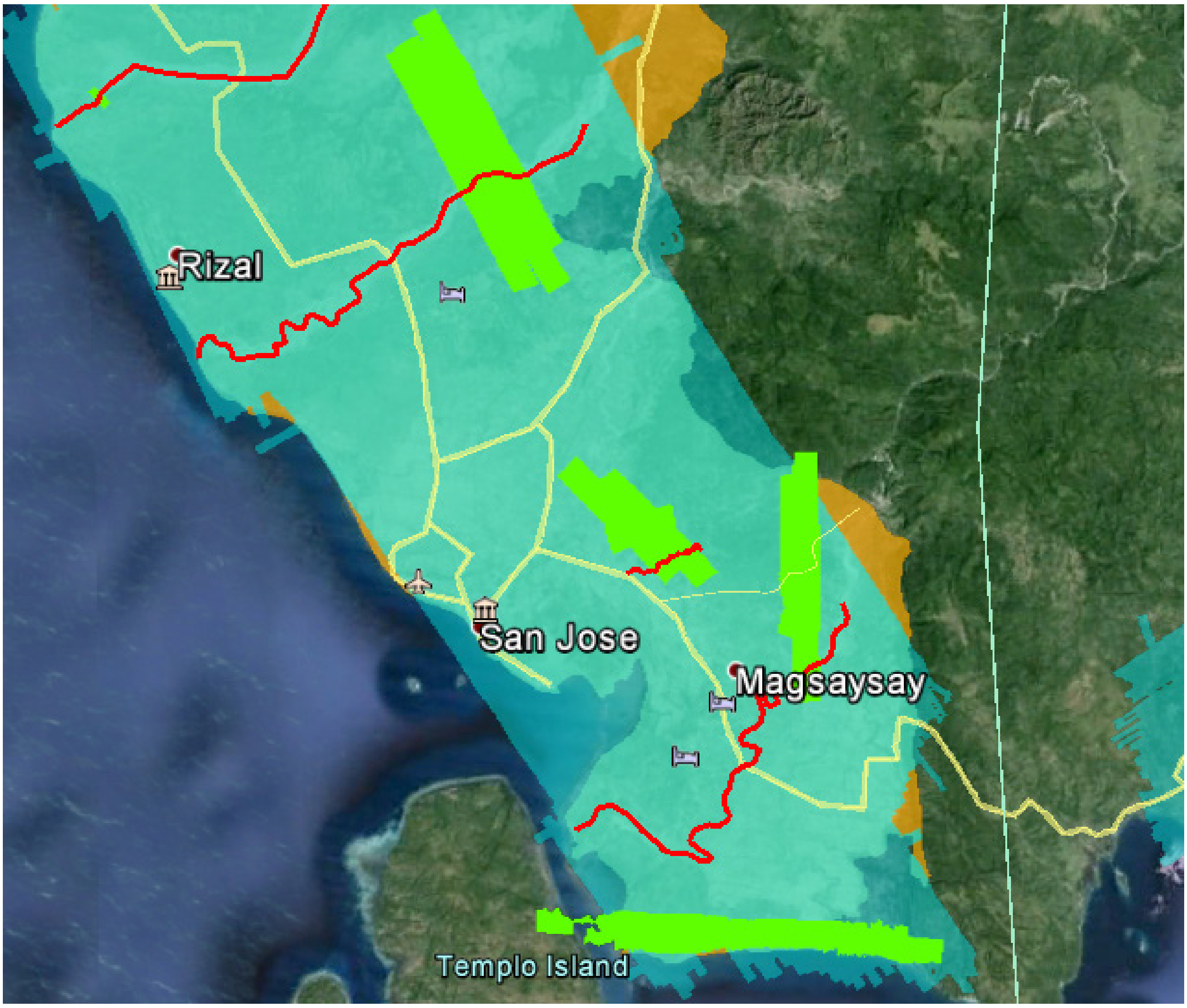



Figure A-7.7 Swath for Flight No. 3078P

FLIGHT NO.: 3082P
AREA: BLK29R
MISSION NAME: 1BLK29R346A
PARAMETERS: Alt: 1100 m Scan Freq: 30 Scan Angle: 25

SURVEY COVERAGE:


Figure A-7.8 Swath for Flight No. 3082P

# Annex 8. Mission Summary Reports

Table A-8.1 Mission Summary Report for Blk 29A

| Flight Area | Davao Oriental |
|---|---|
| Mission Name | Blk29A |
| Inclusive Flights | 1158A. 1162A, 1168A |
| Range data size | 29.98 GB |
| POS | 677 MB |
| Image | 72.6 GB |
| Transfer date | 04/23/2014 |
| | |
| Solution Status | |
| Number of Satellites (>6) | No |
| PDOP (<3) | Yes |
| Baseline Length (<30km) | Yes |
| Processing Mode (<=1) | No |
| | |
| Smoothed Performance Metrics (in cm) | |
| RMSE for North Position (<4.0 cm) | 1.2 |
| RMSE for East Position (<4.0 cm) | 2.1 |
| RMSE for Down Position (<8.0 cm) | 4.4 |
| | |
| Boresight correction stdev (<0.001deg) | 0.000443 |
| IMU attitude correction stdev (<0.001deg) | 0.002081 |
| GPS position stdev (<0.01m) | 0.0294 |
| | |
| Minimum % overlap (>25) | 43.28% |
| Ave point cloud density per sq.m. (>2.0) | 2.76 |
| Elevation difference between strips (<0.20 m) | Yes |
| | |
| Number of 1km x 1km blocks | 194 |
| Maximum Height | 165.41 m |
| Minimum Height | 43.10 m |
| | |
| Classification (# of points) | |
| Ground | 104,722,532 |
| Low vegetation | 130,224,088 |
| Medium vegetation | 60,206,940 |
| High vegetation | 16,625,237 |
| Building | 4,886,963 |
| | |
| Orthophoto | Yes |
| Processed by | Engr. Carlyn Ann Ibañez, Engr. Harmond Santos, Engr. Gladys Mae Apat |

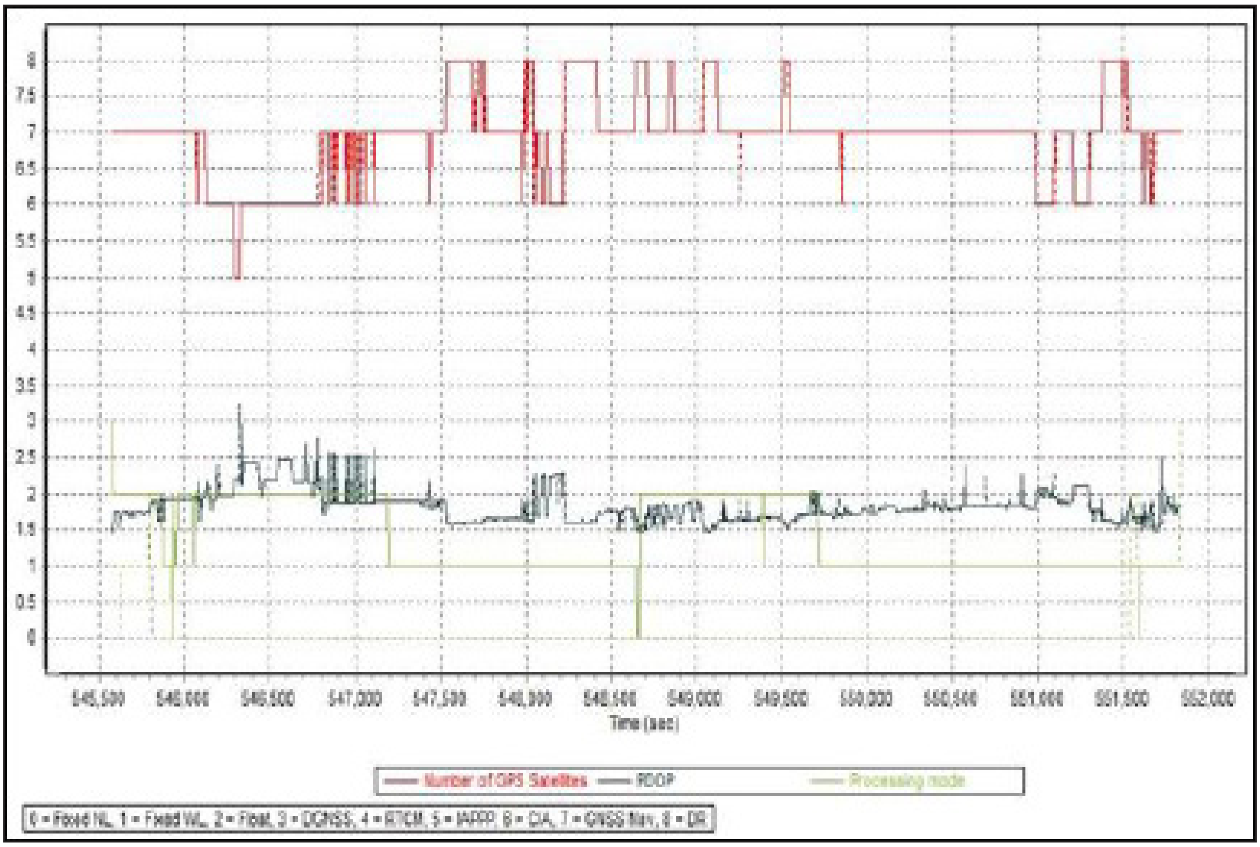



Figure A-8.1. Solution Status

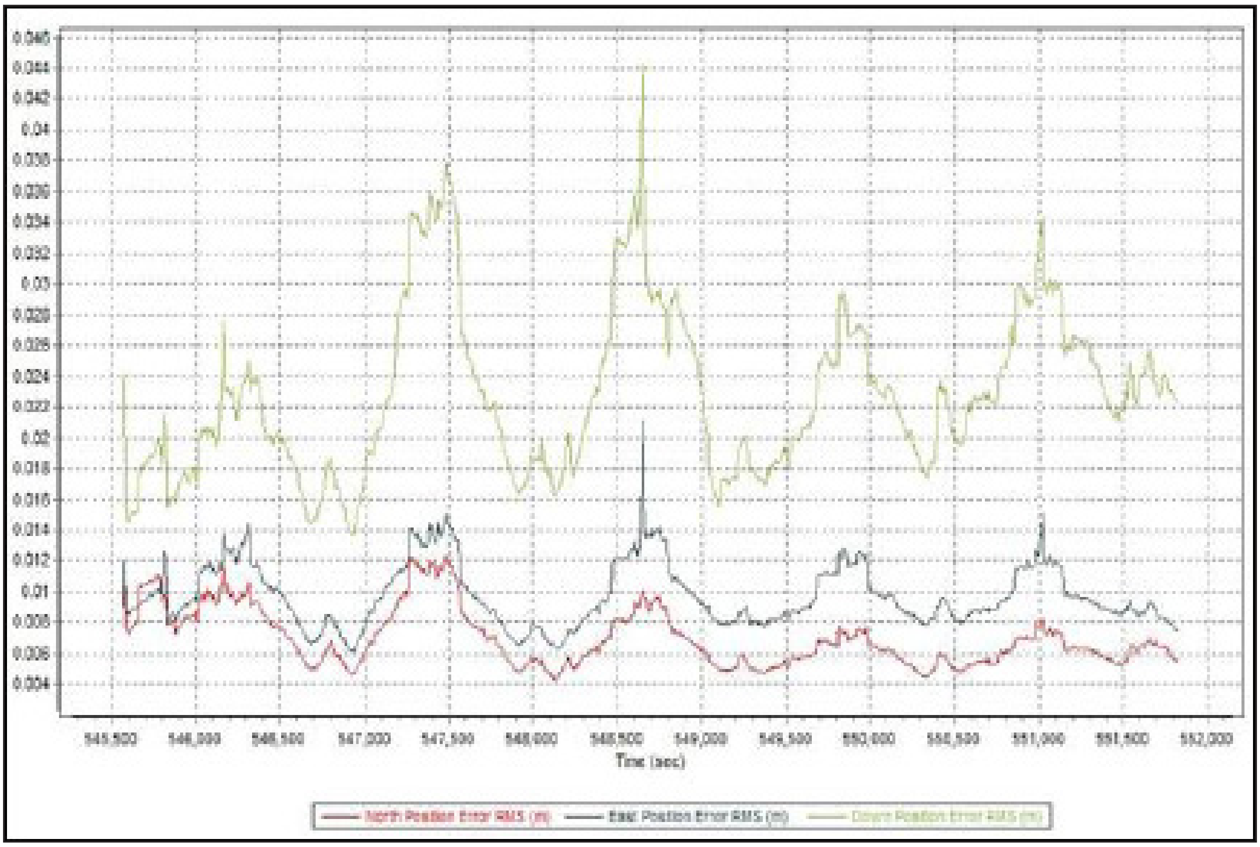



Figure A-8.2. Smoothed Performance Metric Parameters

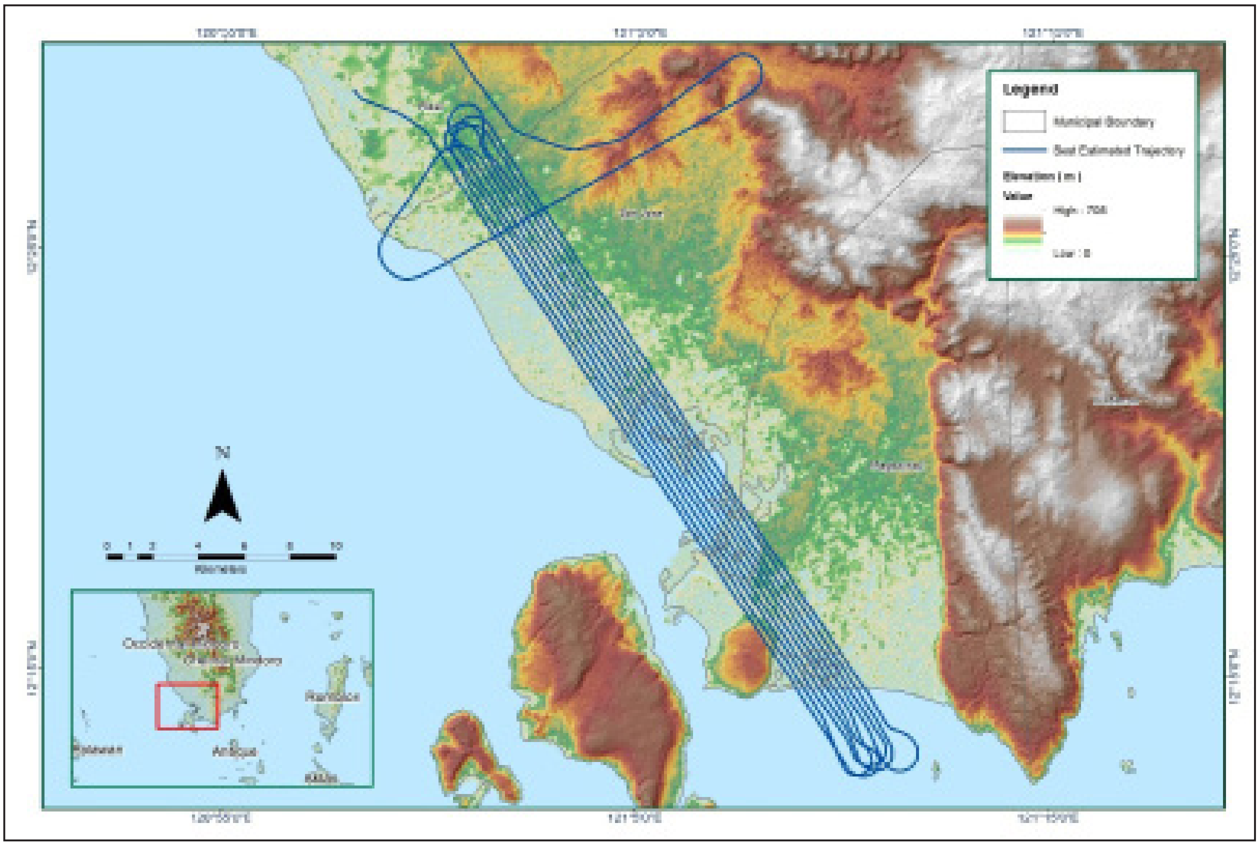



Figure A-8.3. Best Estimated Trajectory

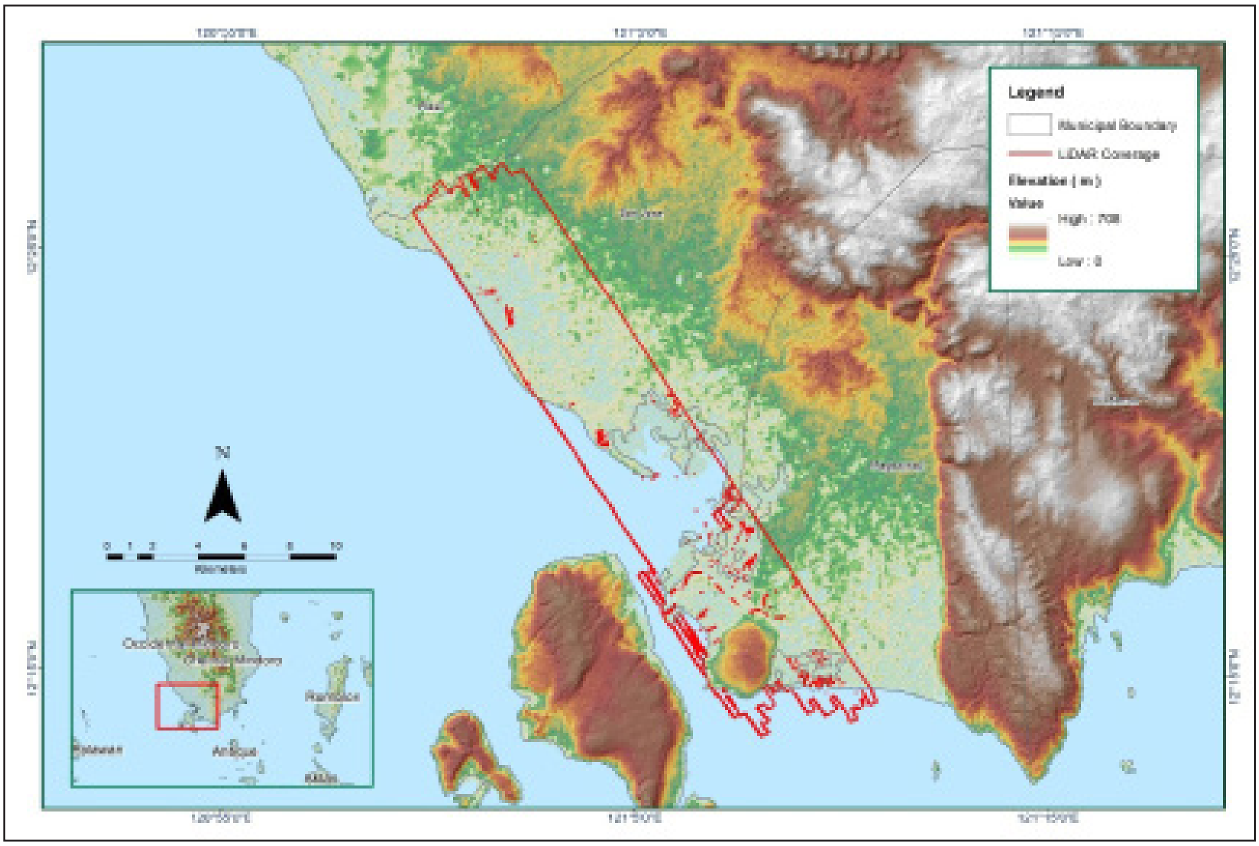



Figure A-8.4. Coverage of LiDAR data

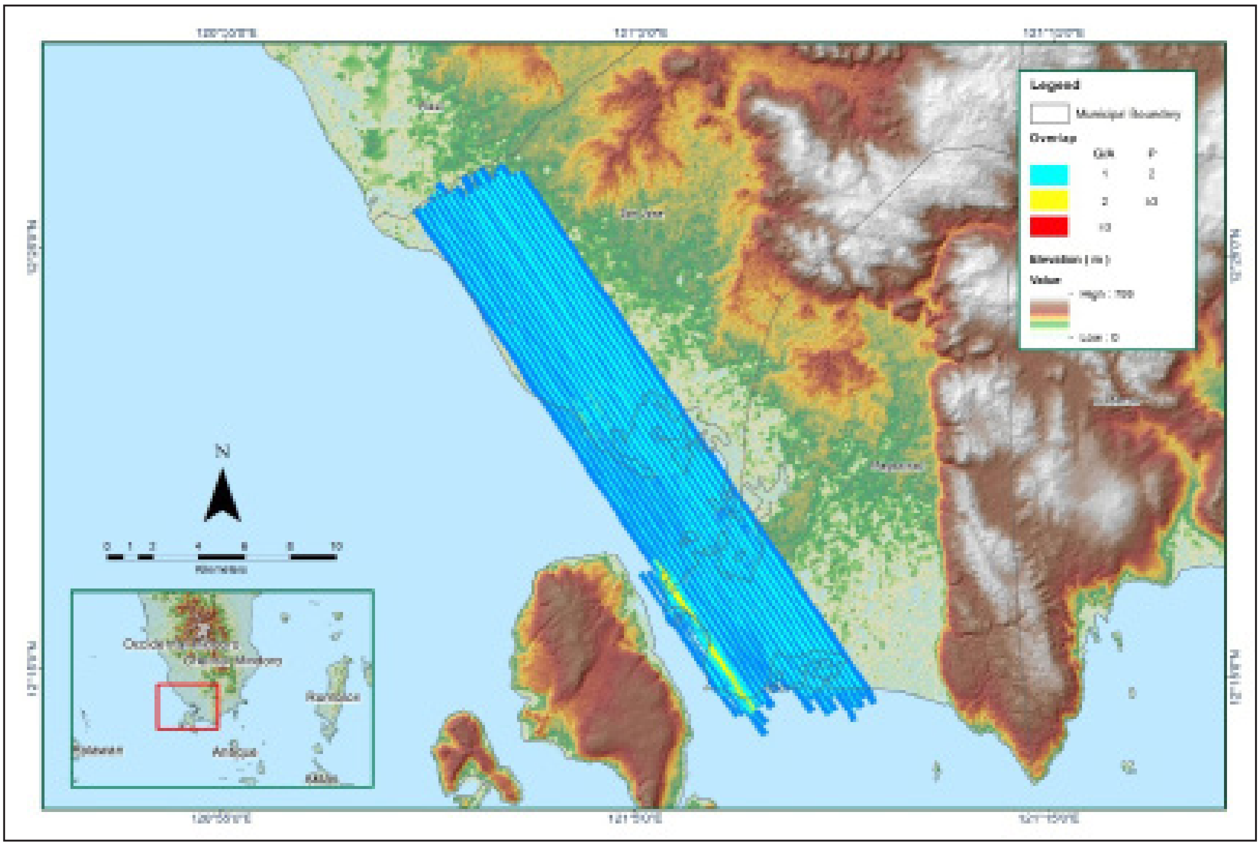



Figure A-8.5. Image of data overlap

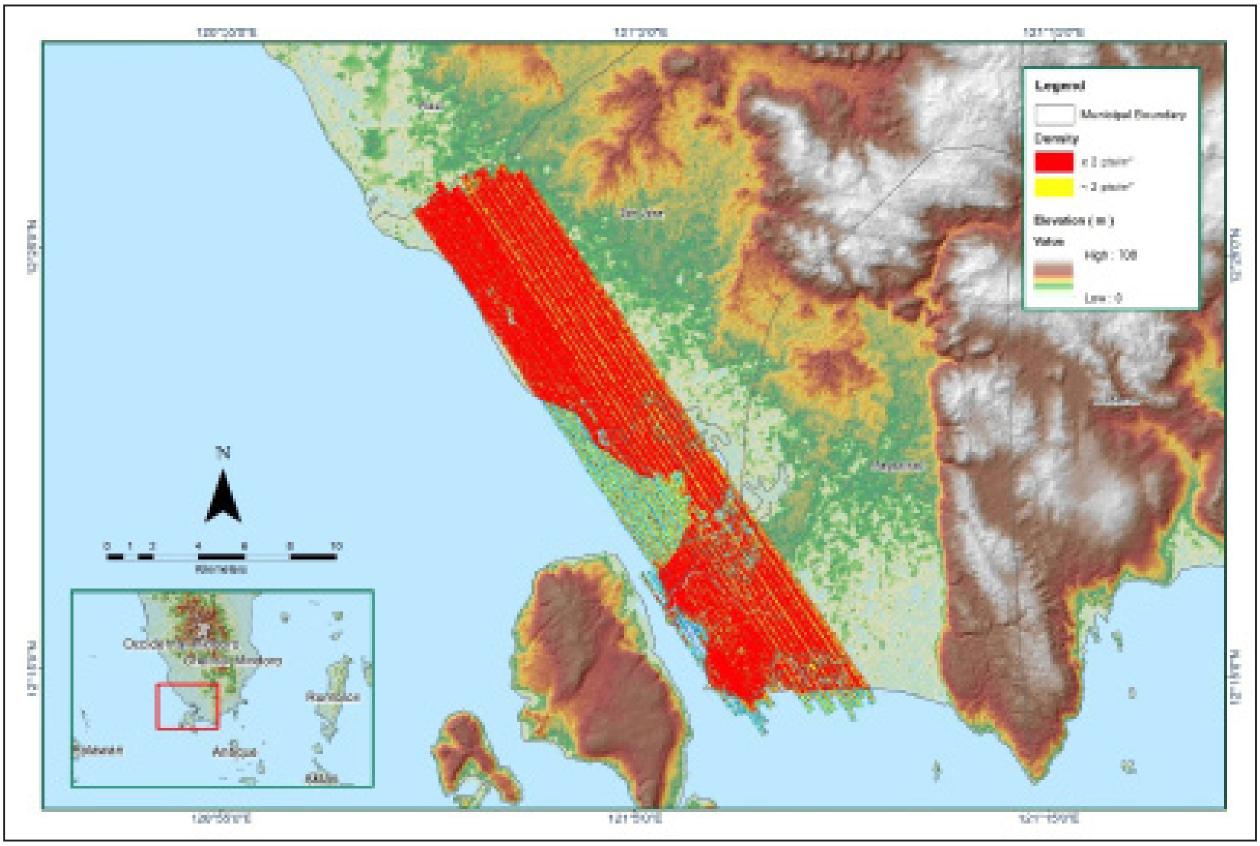



Figure A-8.6. Density map of merged LiDAR data

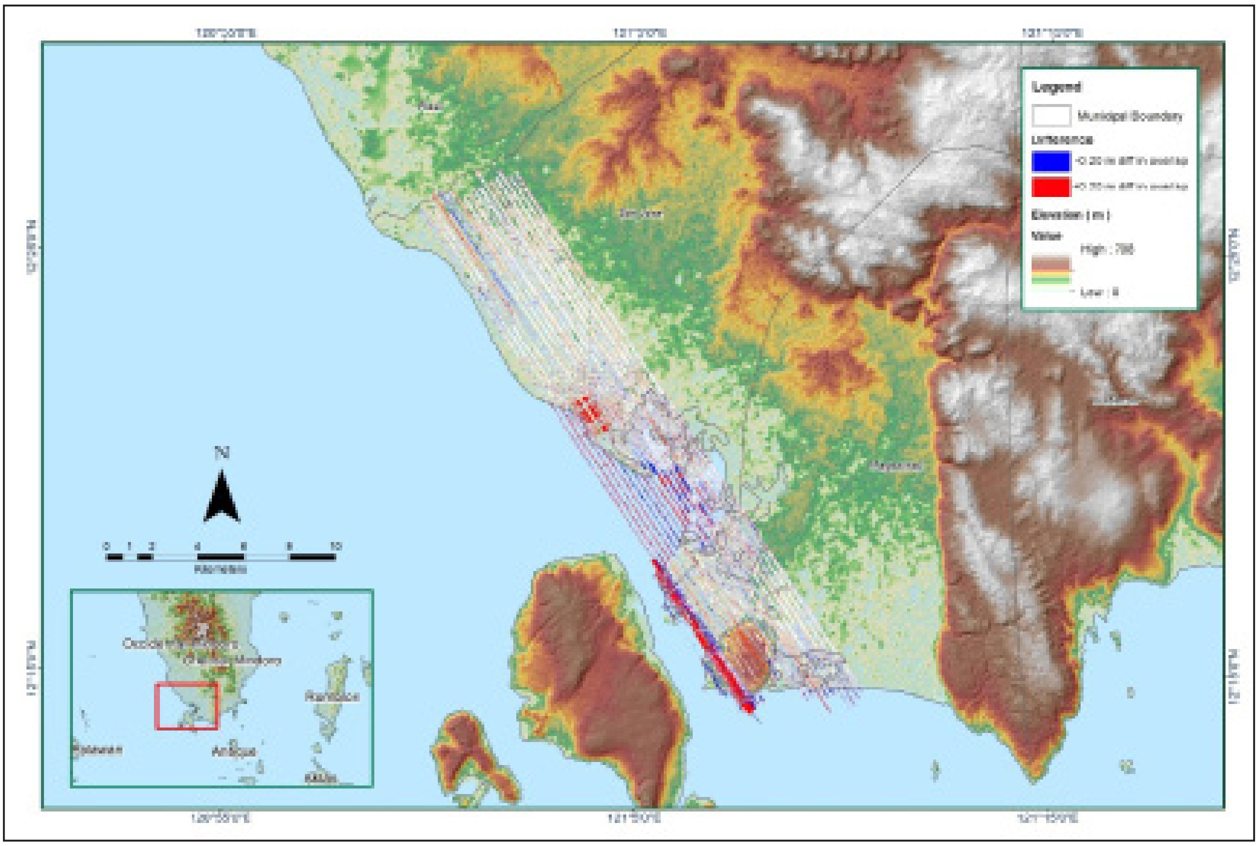



Figure A-8.7. Elevation difference between flight lines

Table A-8.2 Mission Summary Report for Blk 29B

| Flight Area | Davao Oriental |
|---|---|
| Mission Name | Blk29B |
| Inclusive Flights | 1164A. 1166A, 1168A |
| Range data size | 38.4 GB |
| POS | 791 MB |
| Image | 22.5 GB |
| Transfer date | 04/23/2014 |
| | |
| Solution Status | |
| Number of Satellites (>6) | Yes |
| PDOP (<3) | Yes |
| Baseline Length (<30km) | No |
| Processing Mode (<=1) | Yes |
| | |
| Smoothed Performance Metrics (in cm) | |
| RMSE for North Position (<4.0 cm) | 1.3 |
| RMSE for East Position (<4.0 cm) | 1.6 |
| RMSE for Down Position (<8.0 cm) | 3.8 |
| | |
| Boresight correction stdev (<0.001deg) | 0.000629 |
| IMU attitude correction stdev (<0.001deg) | 0.002510 |
| GPS position stdev (<0.01m) | 0.0158 |
| | |
| Minimum % overlap (>25) | 43.01% |
| Ave point cloud density per sq.m. (>2.0) | 3.09 |
| Elevation difference between strips (<0.20 m) | Yes |
| | |
| Number of 1km x 1km blocks | 197 |
| Maximum Height | 258.38 m |
| Minimum Height | 46.77 m |
| | |
| Classification (# of points) | |
| Ground | 115,311,089 |
| Low vegetation | 138,979,099 |
| Medium vegetation | 95,318,939 |
| High vegetation | 30,819,969 |
| Building | 2,104,153 |
| | |
| Orthophoto | Yes |
| Processed by | Ma. Victoria Rejuso, Engr. Harmond Santos, Engr. John Dill Macapagal |

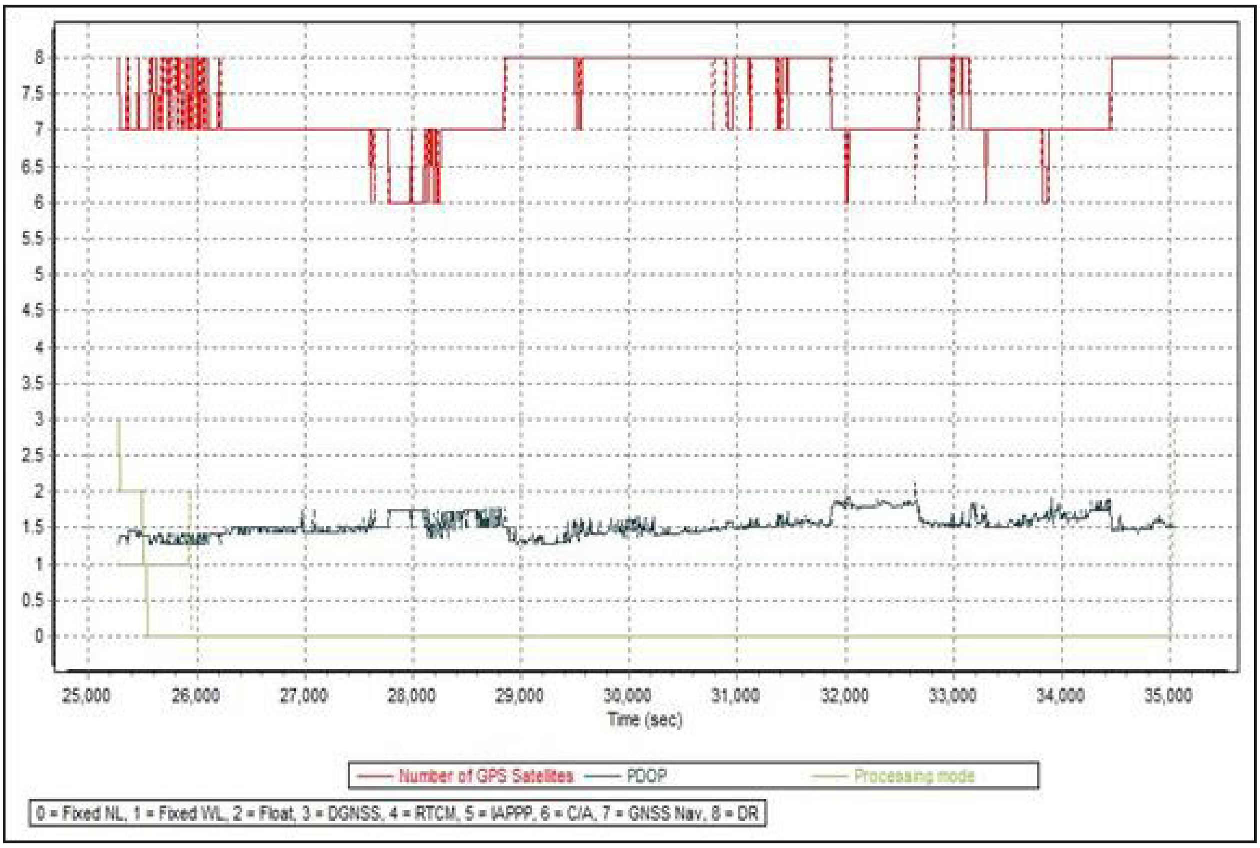



Figure A-8.8. Solution Status

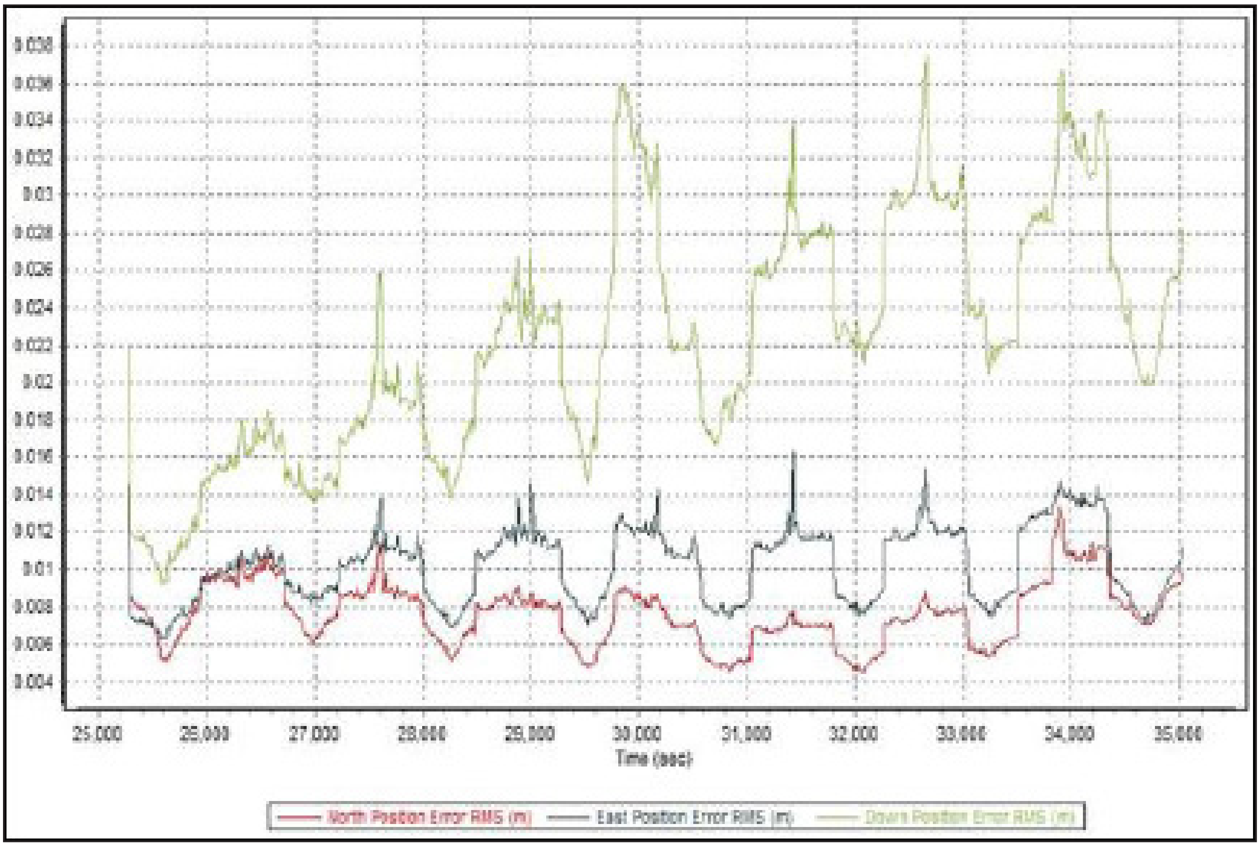



Figure A-8.9. Smoothed Performance Metric Parameters

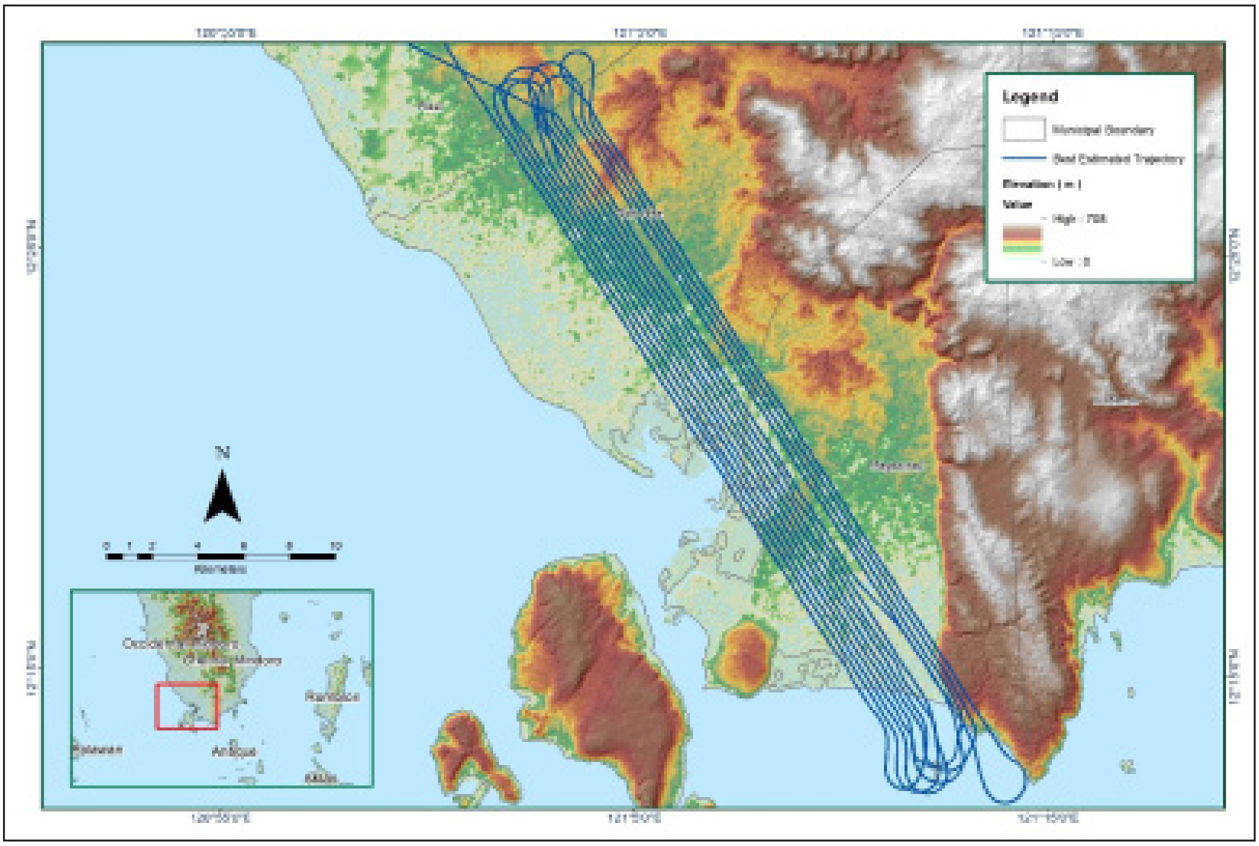



Figure A-8.10. Best Estimated Trajectory

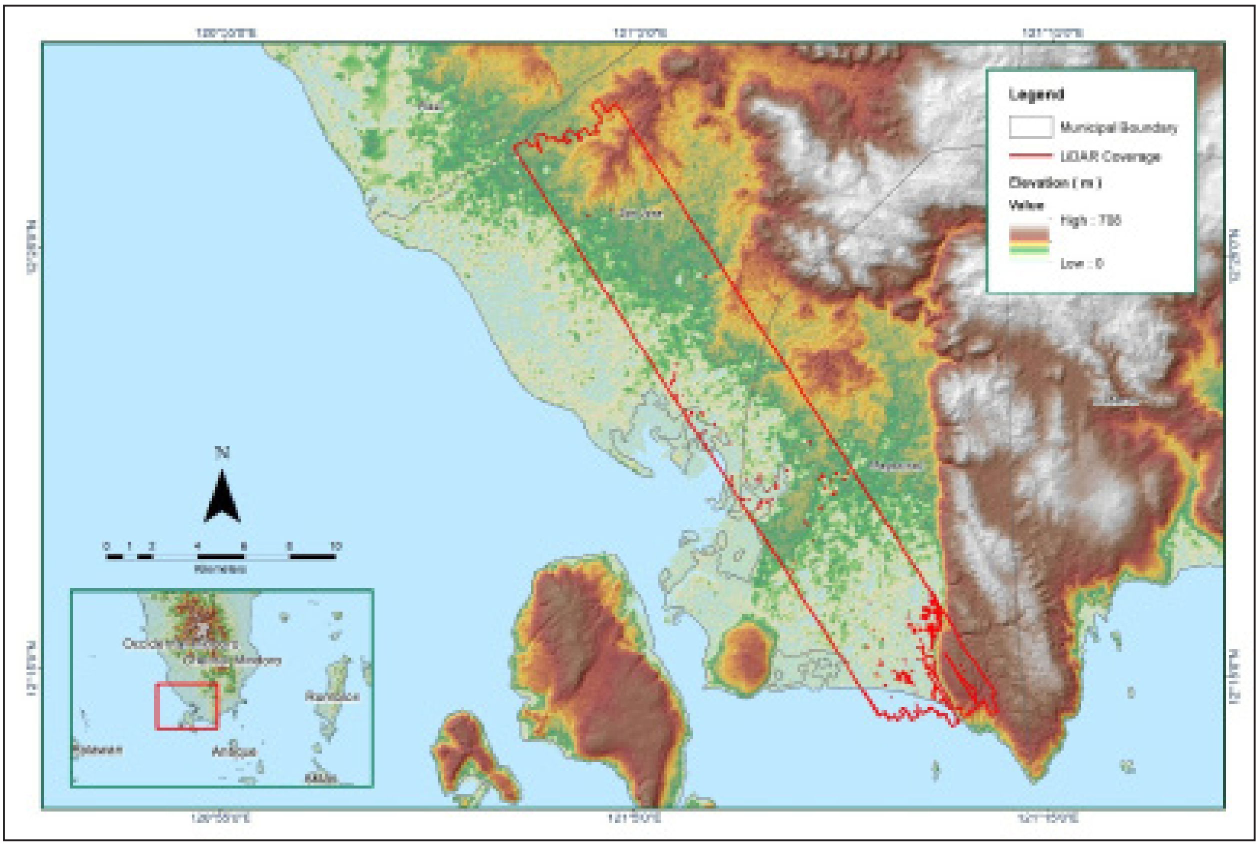



Figure A-8.11. Coverage of LiDAR data

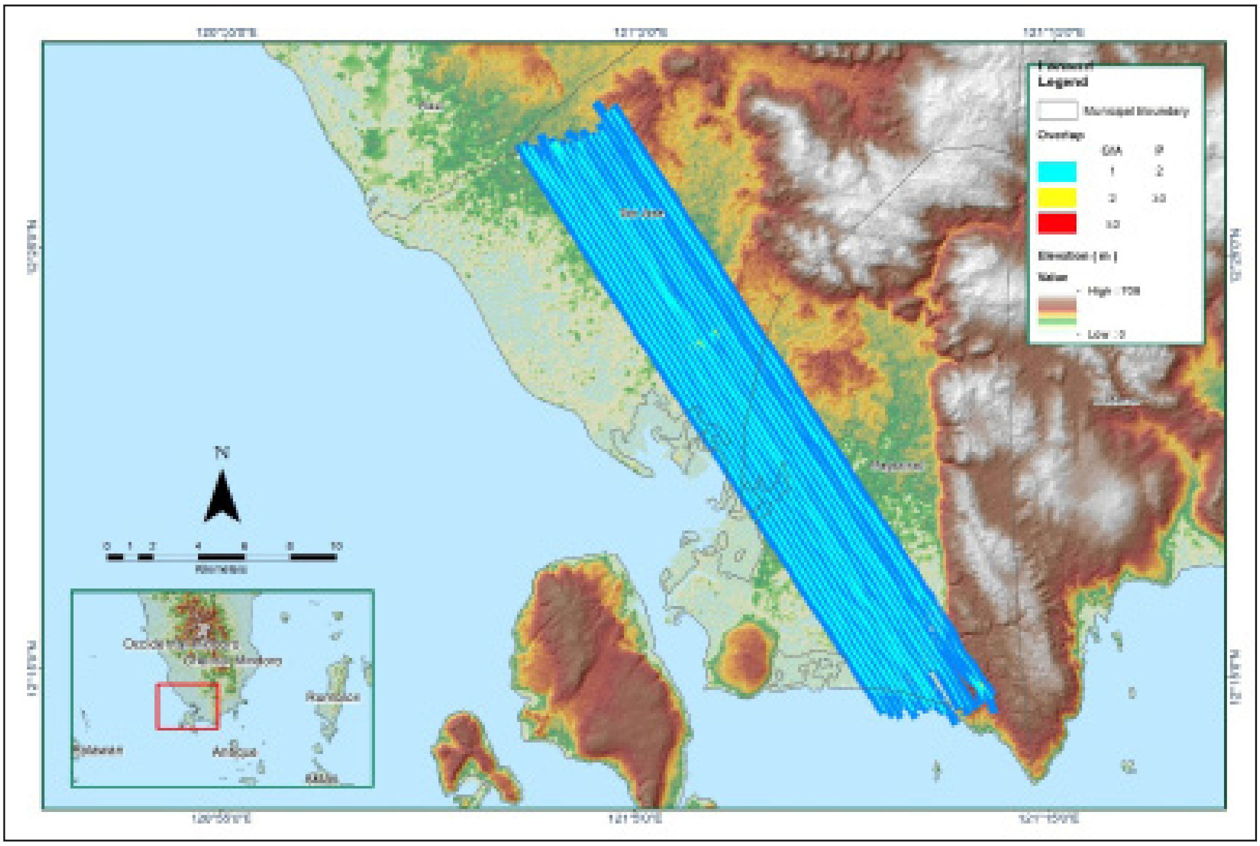



Figure A-8.12. Image of data overlap

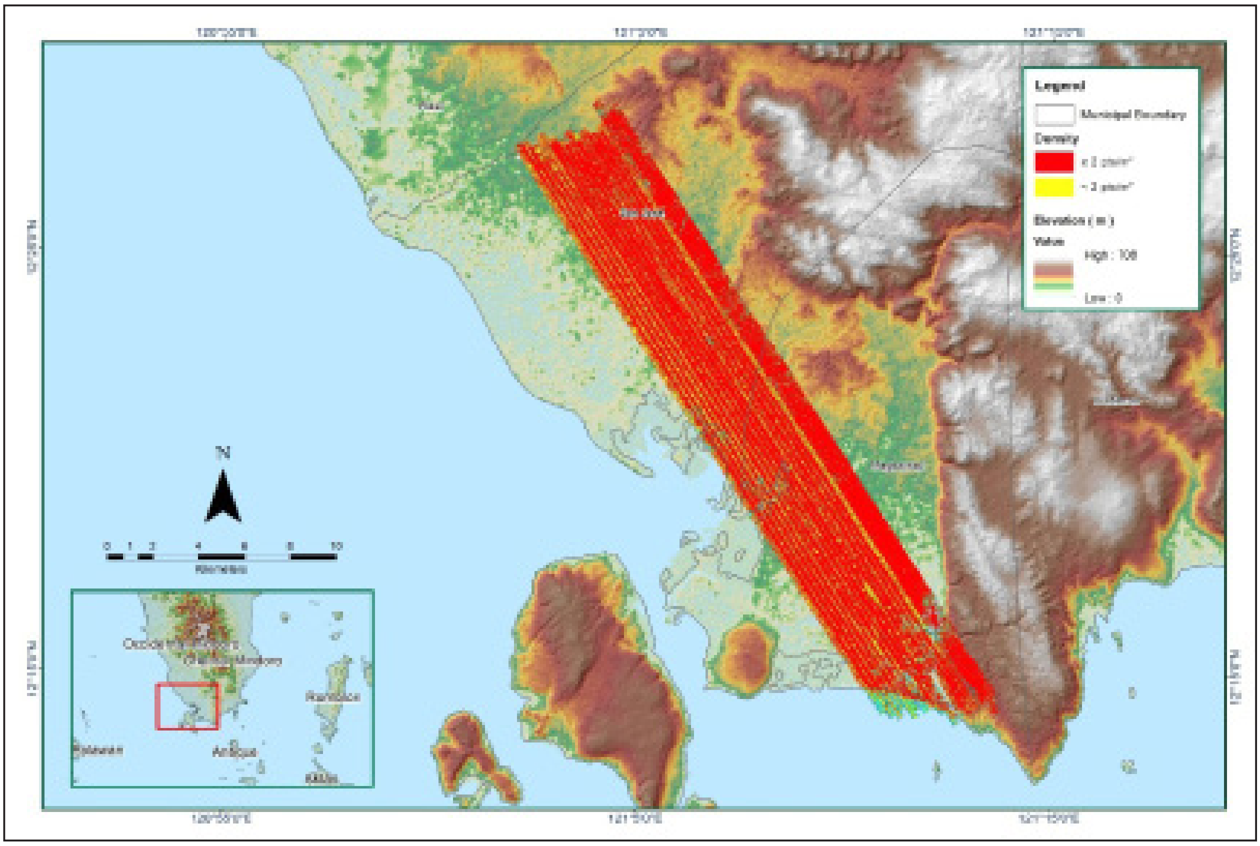



Figure A-8.13. Density map of merged LiDAR data

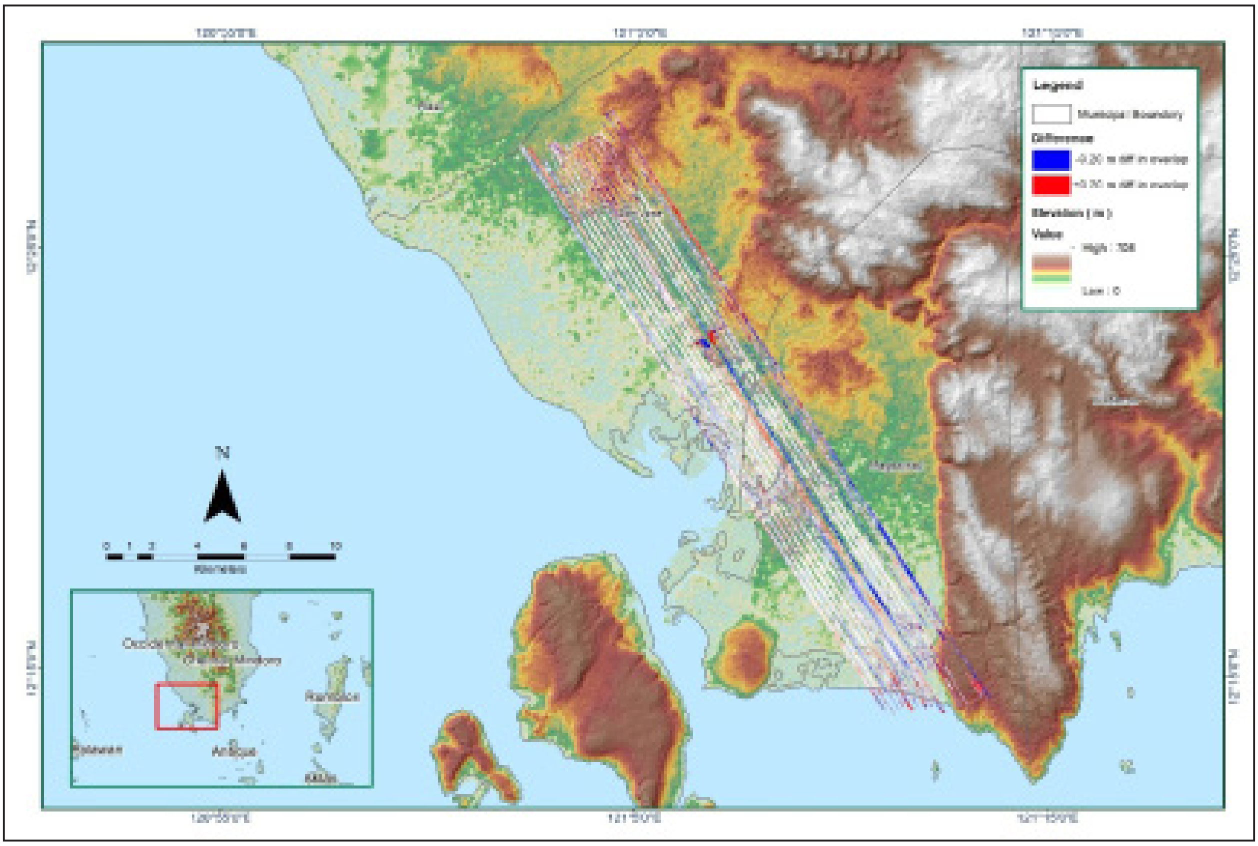


Figure A-8.14. Elevation difference between flight lines

Table A-8.3 Mission Summary Report for Blk 29C

| Flight Area | Davao Oriental |
|---|---|
| Mission Name | Blk29C |
| Inclusive Flights | 1160A |
| Range data size | 14.1 GB |
| POS | 268 MB |
| Image | 13.5 GB |
| Transfer date | 04/23/2014 |
| | |
| Solution Status | |
| Number of Satellites (>6) | No |
| PDOP (<3) | No |
| Baseline Length (<30km) | Yes |
| Processing Mode (<=1) | Yes |
| | |
| Smoothed Performance Metrics (in cm) | |
| RMSE for North Position (<4.0 cm) | 4.8 |
| RMSE for East Position (<4.0 cm) | 2.2 |
| RMSE for Down Position (<8.0 cm) | 5.1 |
| | |
| Boresight correction stdev (<0.001deg) | 0.000373 |
| IMU attitude correction stdev (<0.001deg) | 0.001768 |
| GPS position stdev (<0.01m) | 0.0032 |
| | |
| Minimum % overlap (>25) | 44.16% |
| Ave point cloud density per sq.m. (>2.0) | 3.59 |
| Elevation difference between strips (<0.20 m) | Yes |
| | |
| Number of 1km x 1km blocks | 143 |
| Maximum Height | 481.99 m |
| Minimum Height | 51.54 m |
| | |
| Classification (# of points) | |
| Ground | 109,156,938 |
| Low vegetation | 80,757,959 |
| Medium vegetation | 73,247,510 |
| High vegetation | 71,877,948 |
| Building | 1,281,773 |
| | |
| Orthophoto | Yes |
| Processed by | Engr. Irish Cortez, Engr. Harmond Santos, Ailyn Biñas |

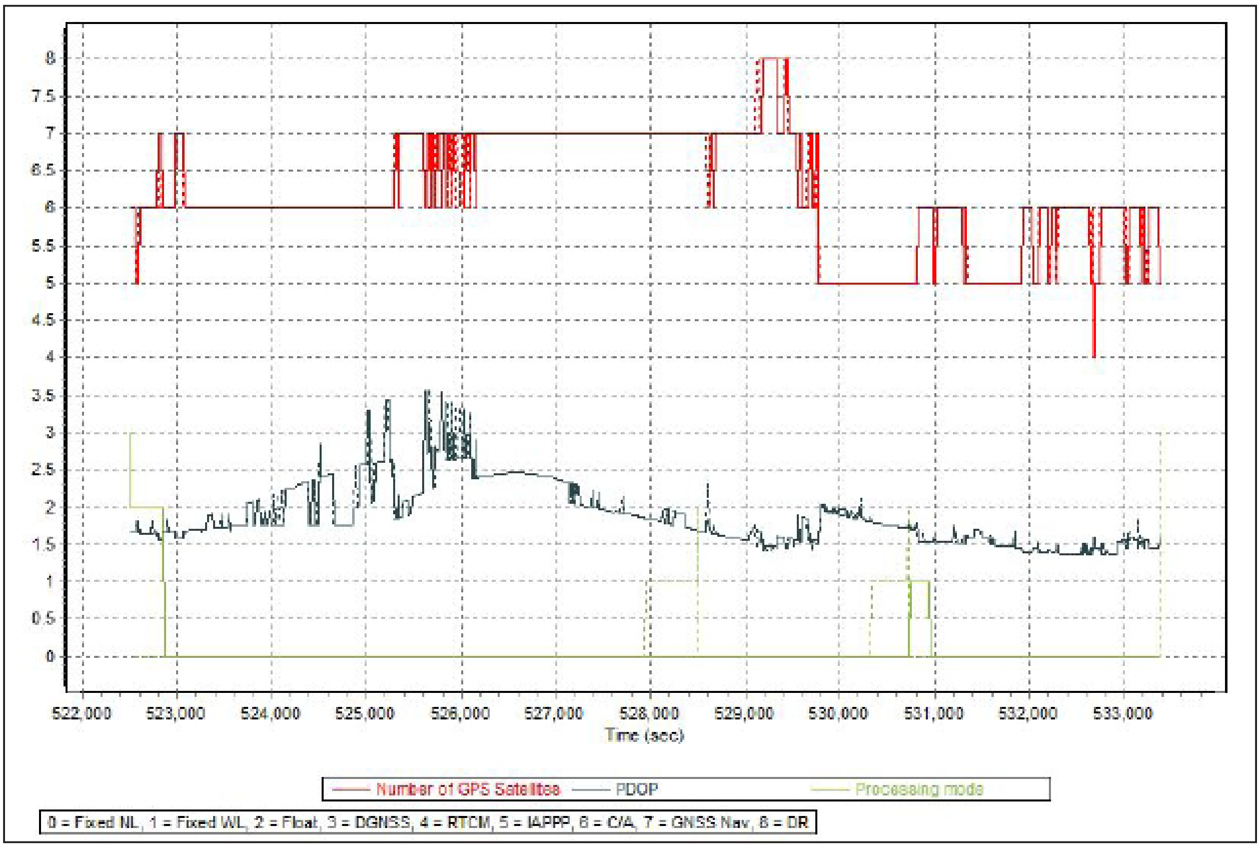



Figure A-8.15. Solution Status

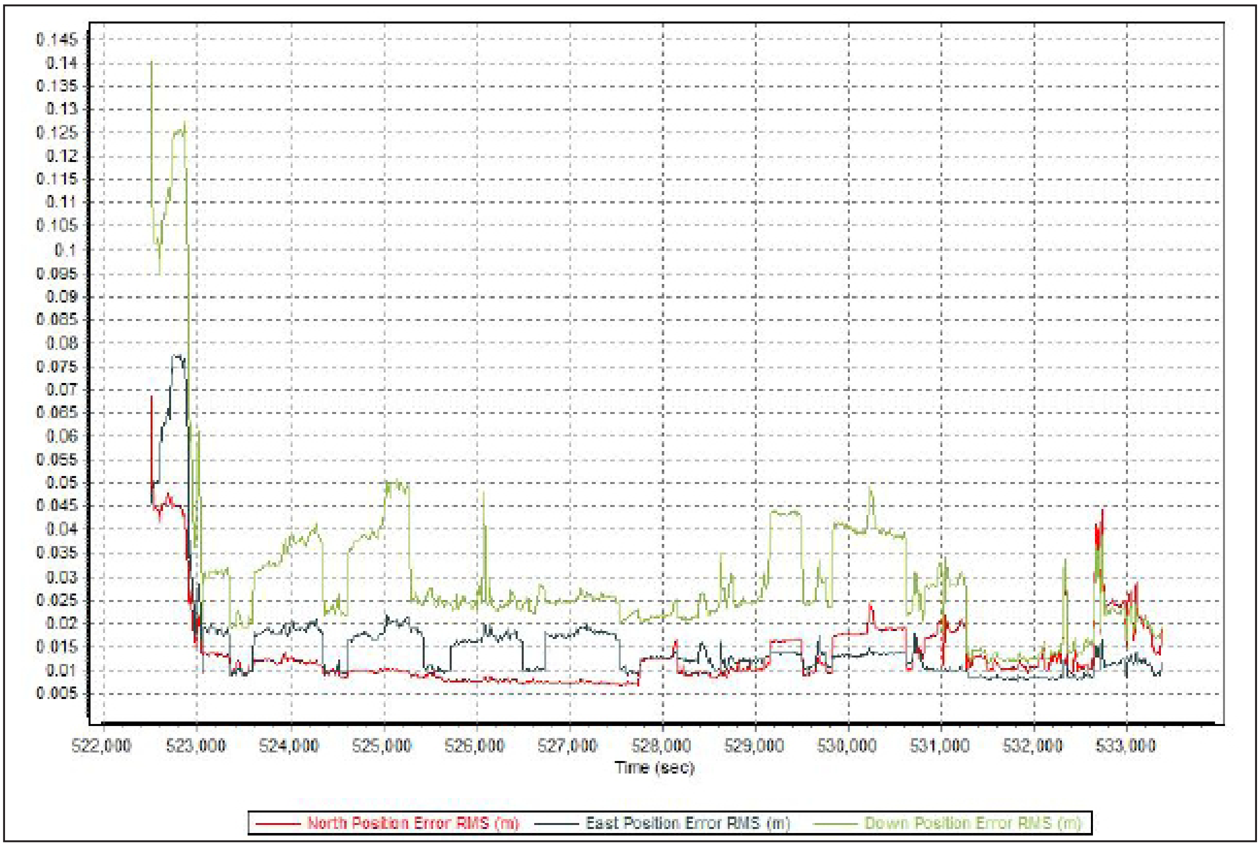



Figure A-8.16. Smoothed Performance Metric Parameters

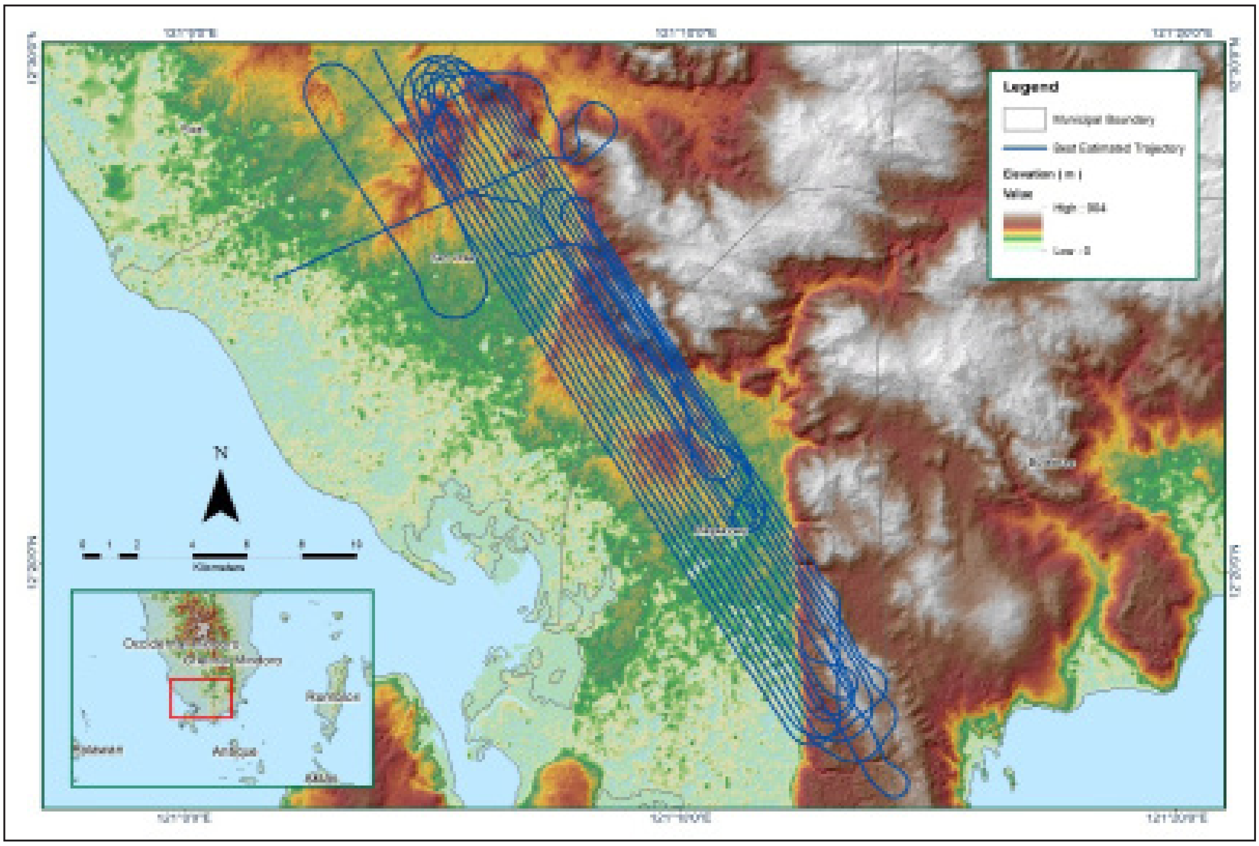



Figure A-8.17. Best Estimated Trajectory

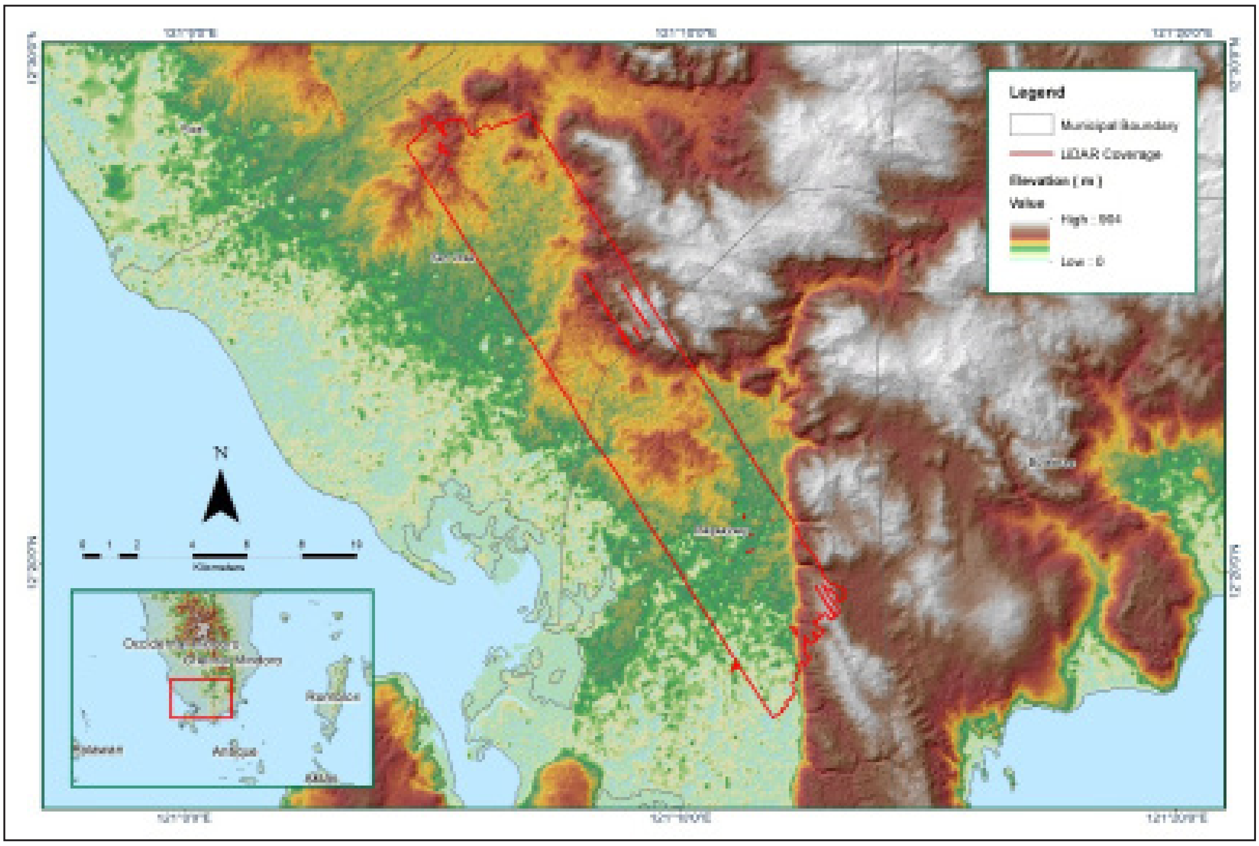



Figure A-8.18. Coverage of LiDAR data

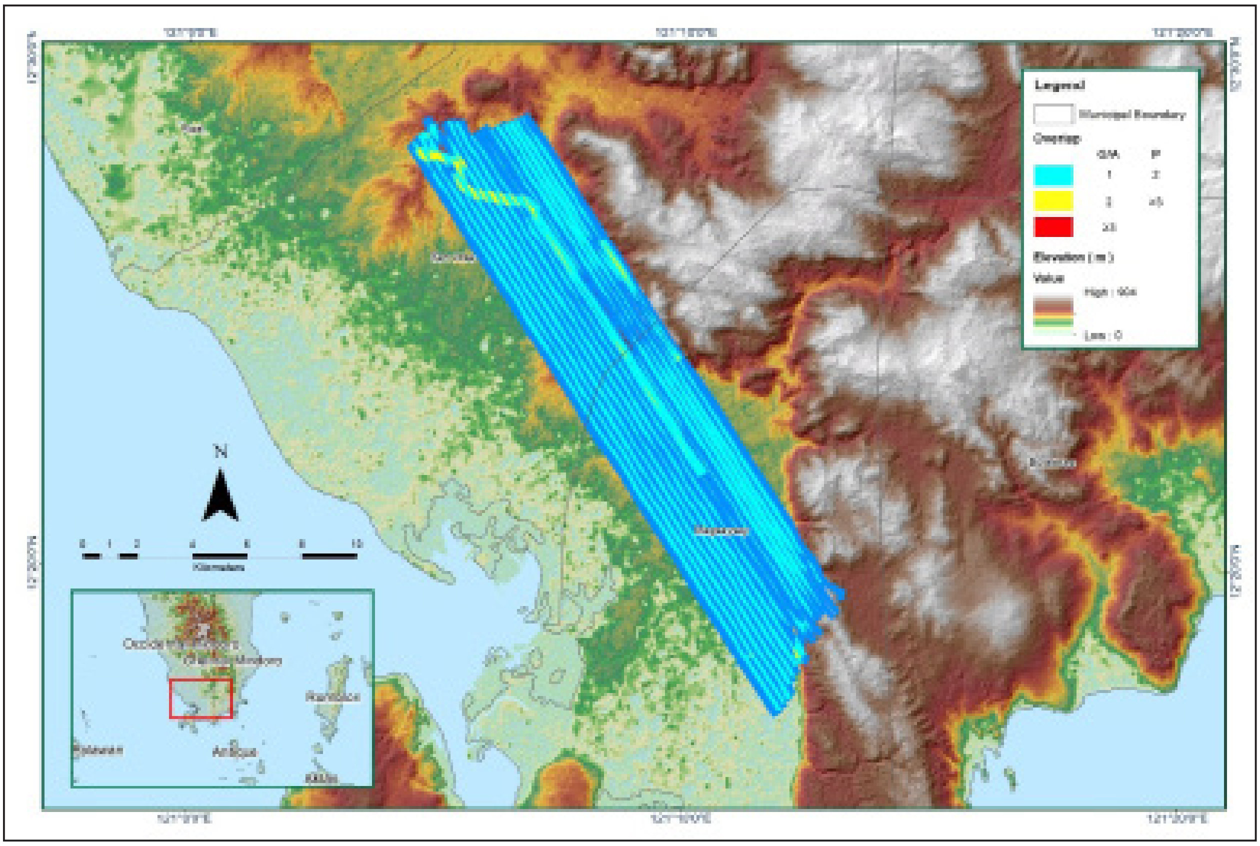



Figure A-8.19. Image of data overlap

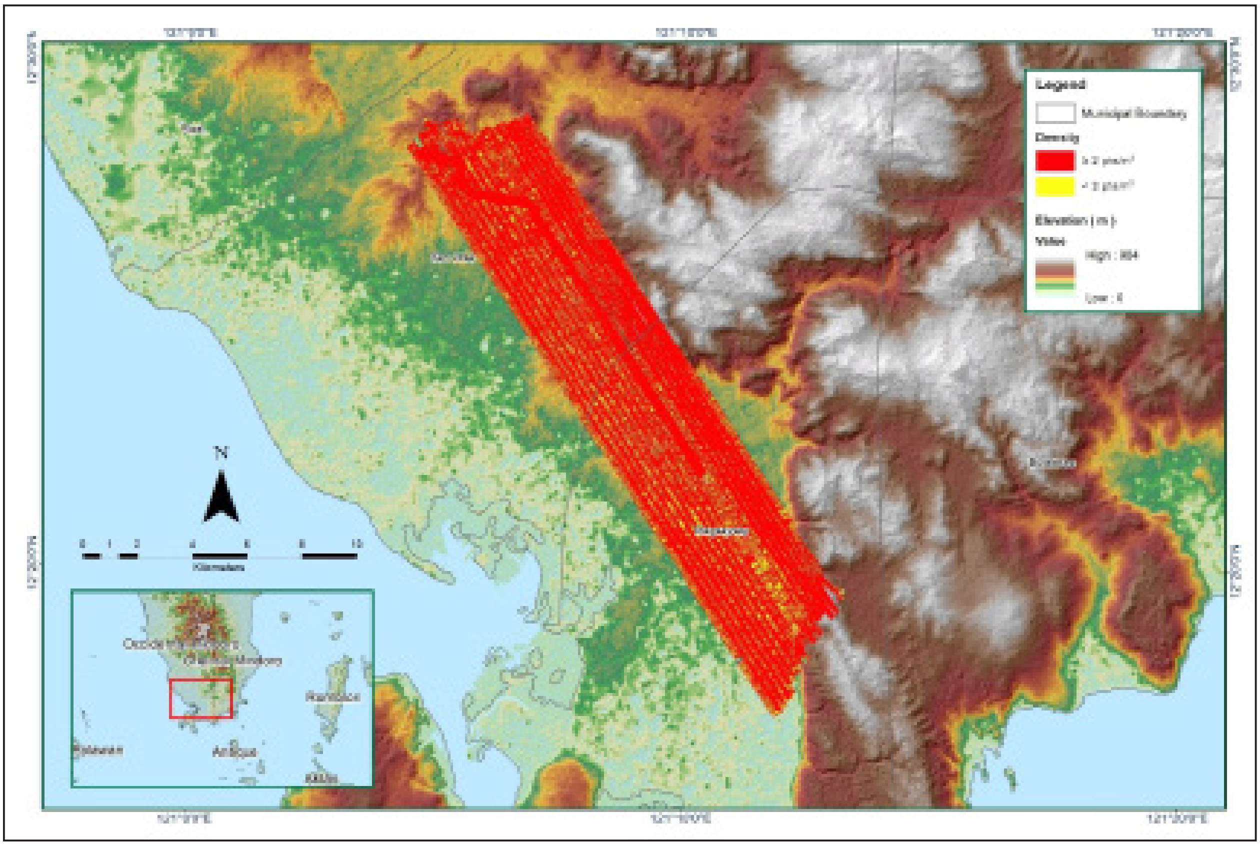



Figure A-8.20. Density map of merged LiDAR data

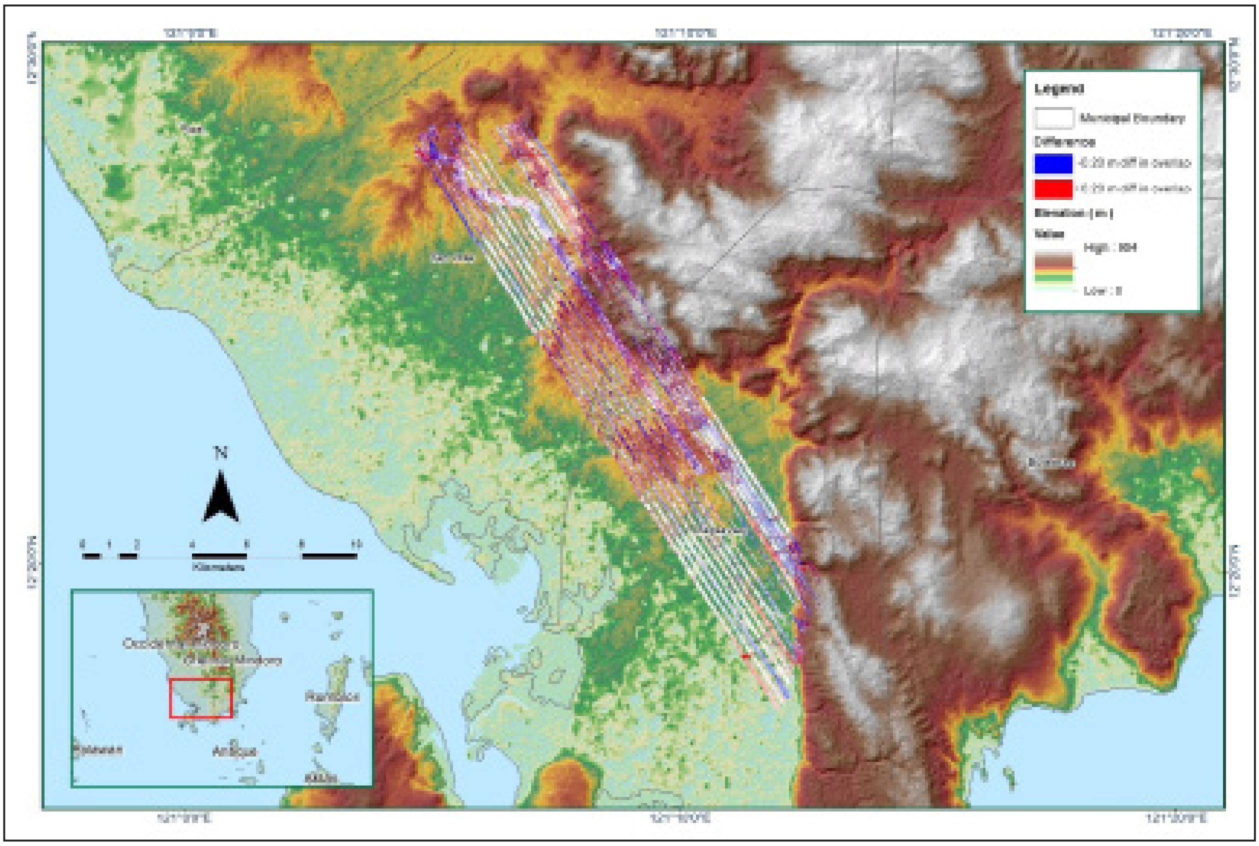



Figure A-8.21. Elevation difference between flight lines

Table A-8.4 Mission Summary Report for Blk 29A_additional

| Flight Area | Davao Oriental |
|---|---|
| Mission Name | Blk29A_additional |
| Inclusive Flights | 3078P |
| Range data size | 6.2GB |
| POS | 167MB |
| Image | 12.9MB |
| Transfer date | January 15, 2016 |
| | |
| Solution Status | |
| Number of Satellites (>6) | Yes |
| PDOP (<3) | Yes |
| Baseline Length (<30km) | No |
| Processing Mode (<=1) | No |
| | |
| Smoothed Performance Metrics (in cm) | |
| RMSE for North Position (<4.0 cm) | 1.01 |
| RMSE for East Position (<4.0 cm) | 1.16 |
| RMSE for Down Position (<8.0 cm) | 4.25 |
| | |
| Boresight correction stdev (<0.001deg) | 0.359804 |
| IMU attitude correction stdev (<0.001deg) | 0.083211 |
| GPS position stdev (<0.01m) | 0.0024 |
| | |
| Minimum % overlap (>25) | |
| Ave point cloud density per sq.m. (>2.0) | |
| Elevation difference between strips (<0.20 m) | Yes |
| | |
| Number of 1km x 1km blocks | 40 |
| Maximum Height | 231.12 m |
| Minimum Height | 50.50 m |
| | |
| Classification (# of points) | |
| Ground | 15,453,565 |
| Low vegetation | 10,246,556 |
| Medium vegetation | 13,004,794 |
| High vegetation | 17,341,456 |
| Building | 271,742 |
| | |
| Orthophoto | Yes |
| Processed by | Engr. Abigail Ching, Engr. Harmond Santos, Engr. Melissa Fernandez |

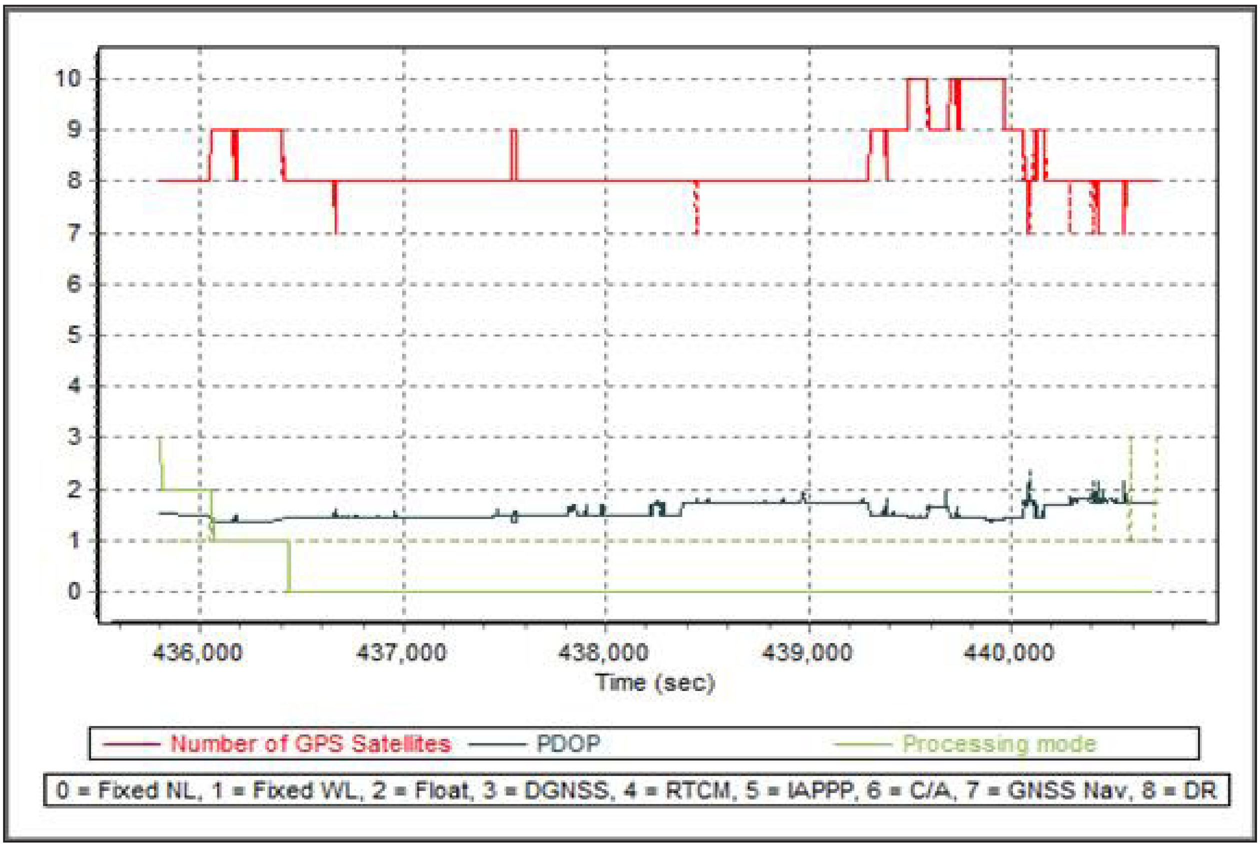



Figure A-8.22. Solution Status

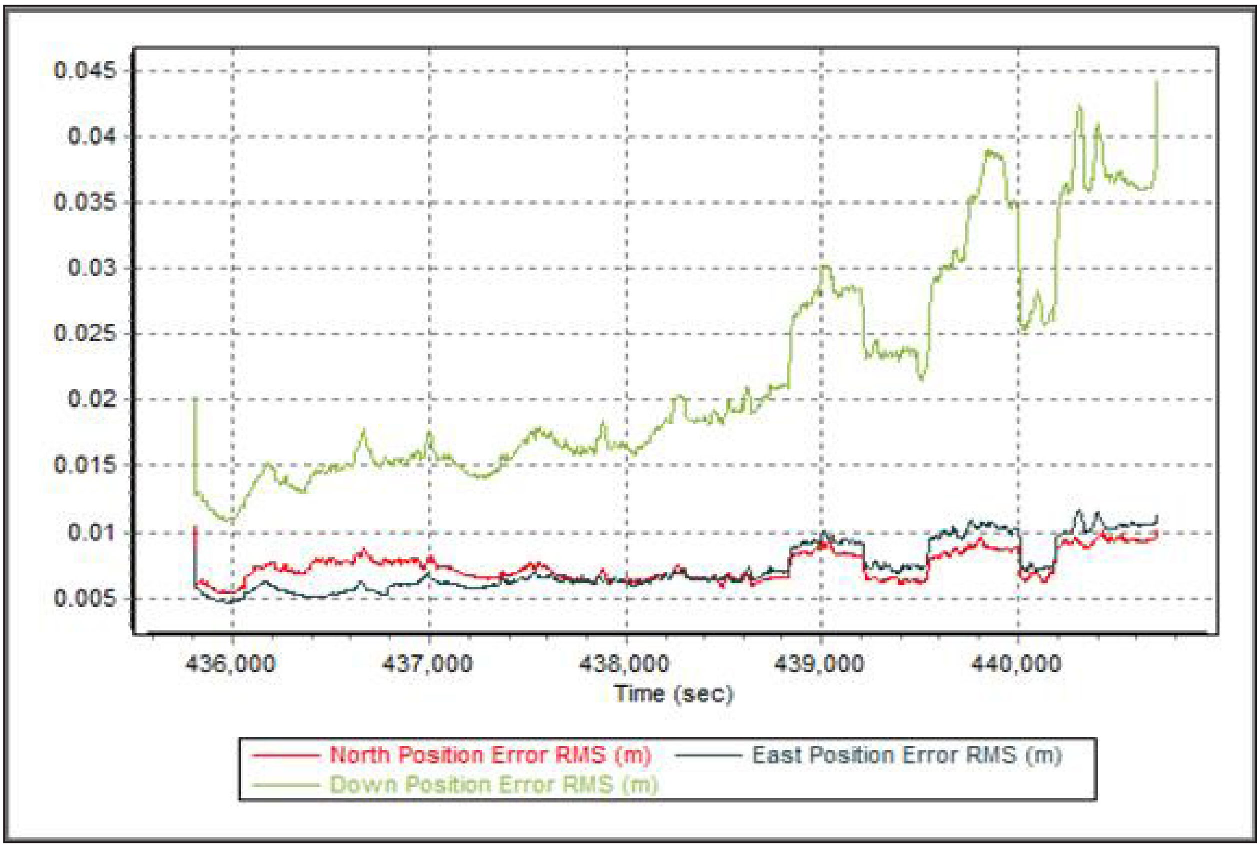



Figure A-8.23. Smoothed Performance Metric Parameters

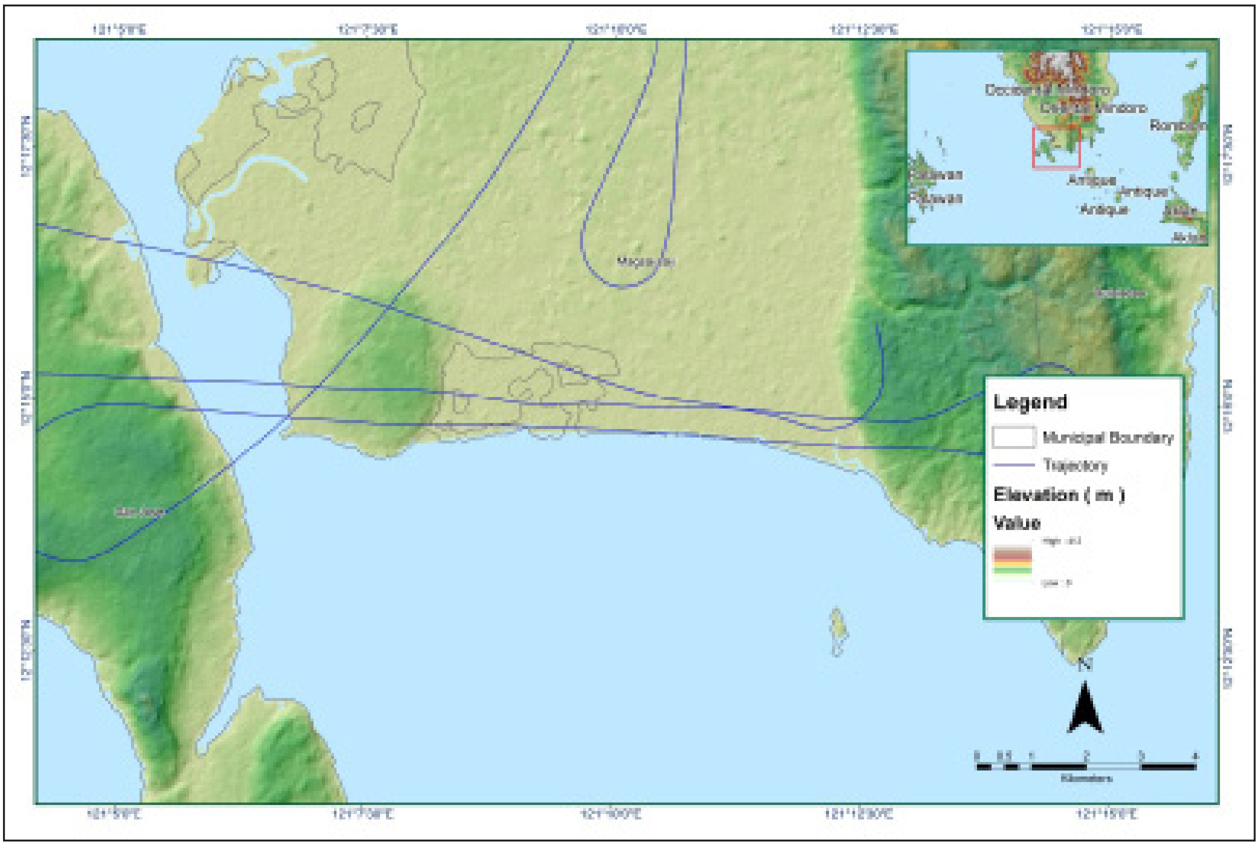



Figure A-8.24. Best Estimated Trajectory

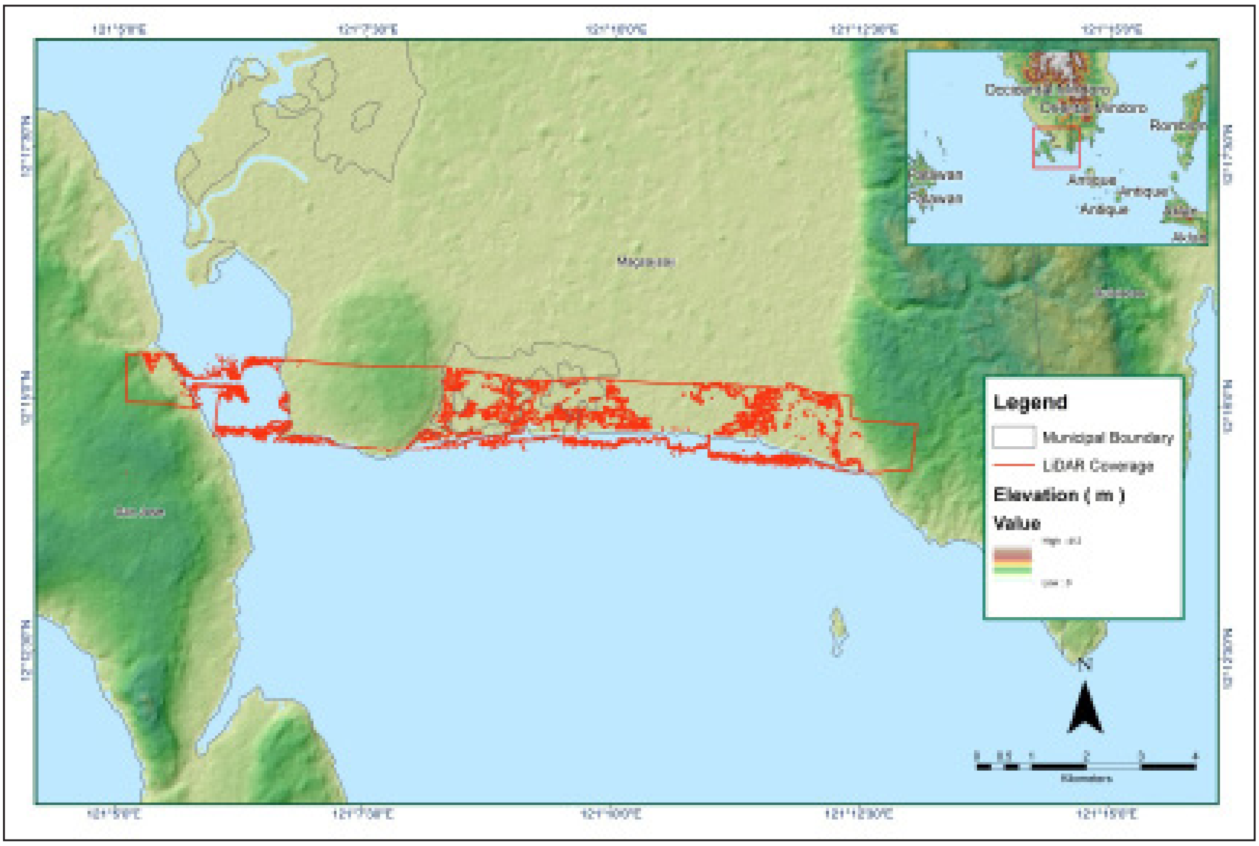



Figure A-8.25. Coverage of LiDAR data

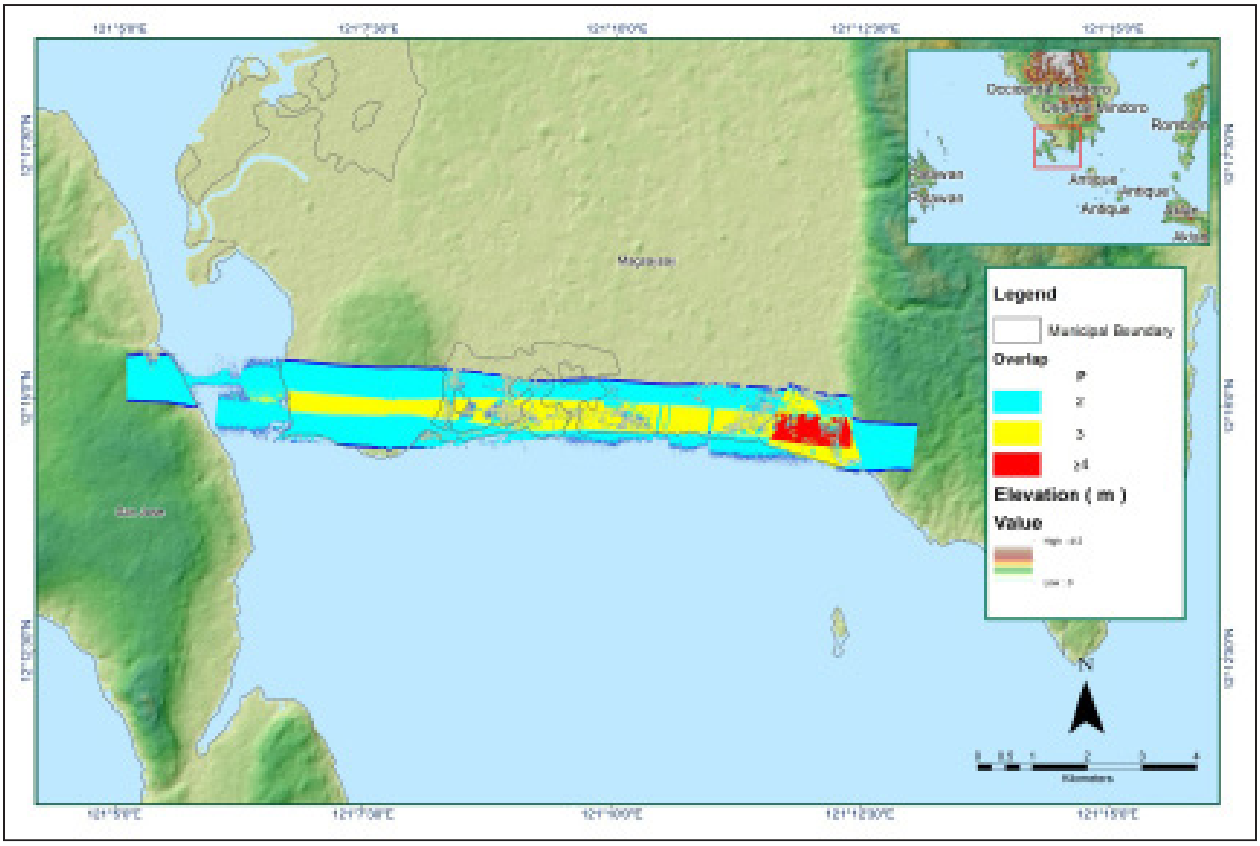



Figure A-8.26. Image of data overlap

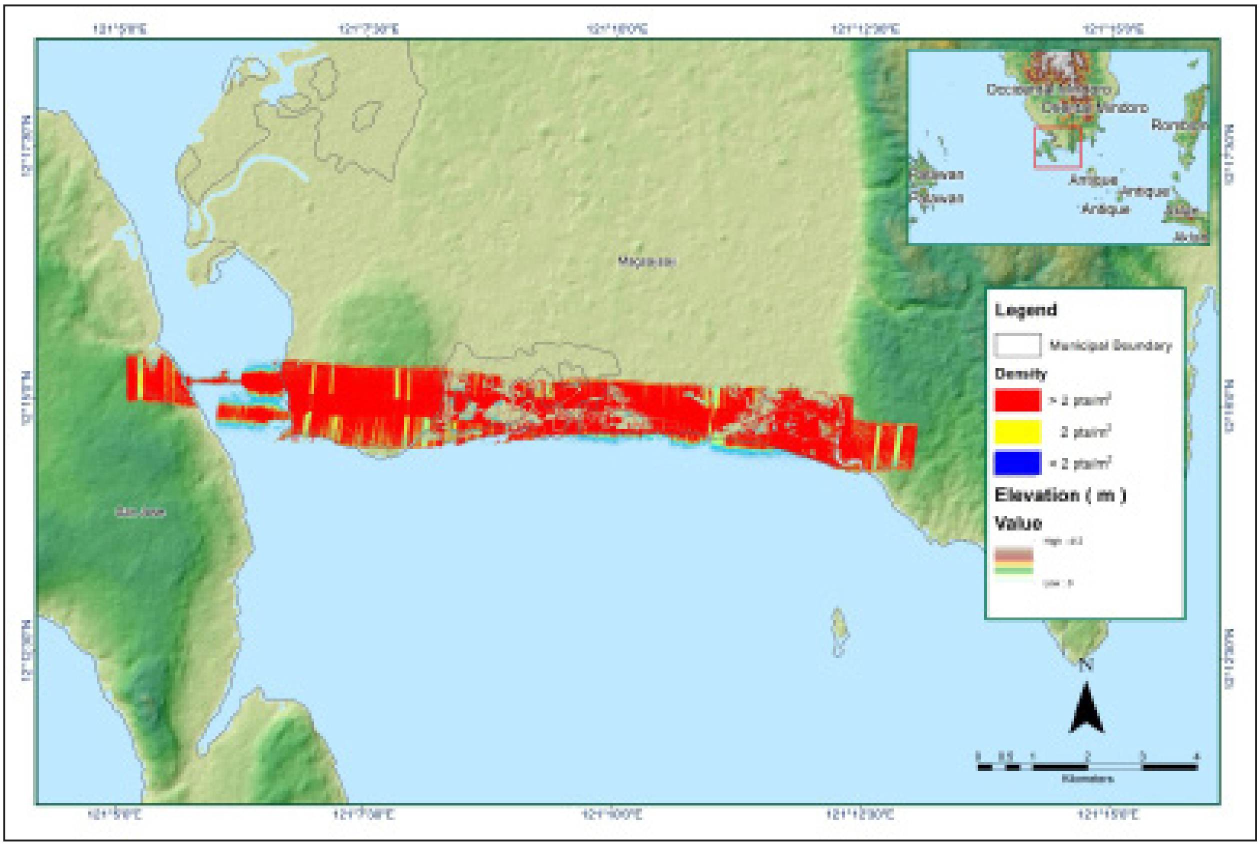



Figure A-8.27. Density map of merged LiDAR data

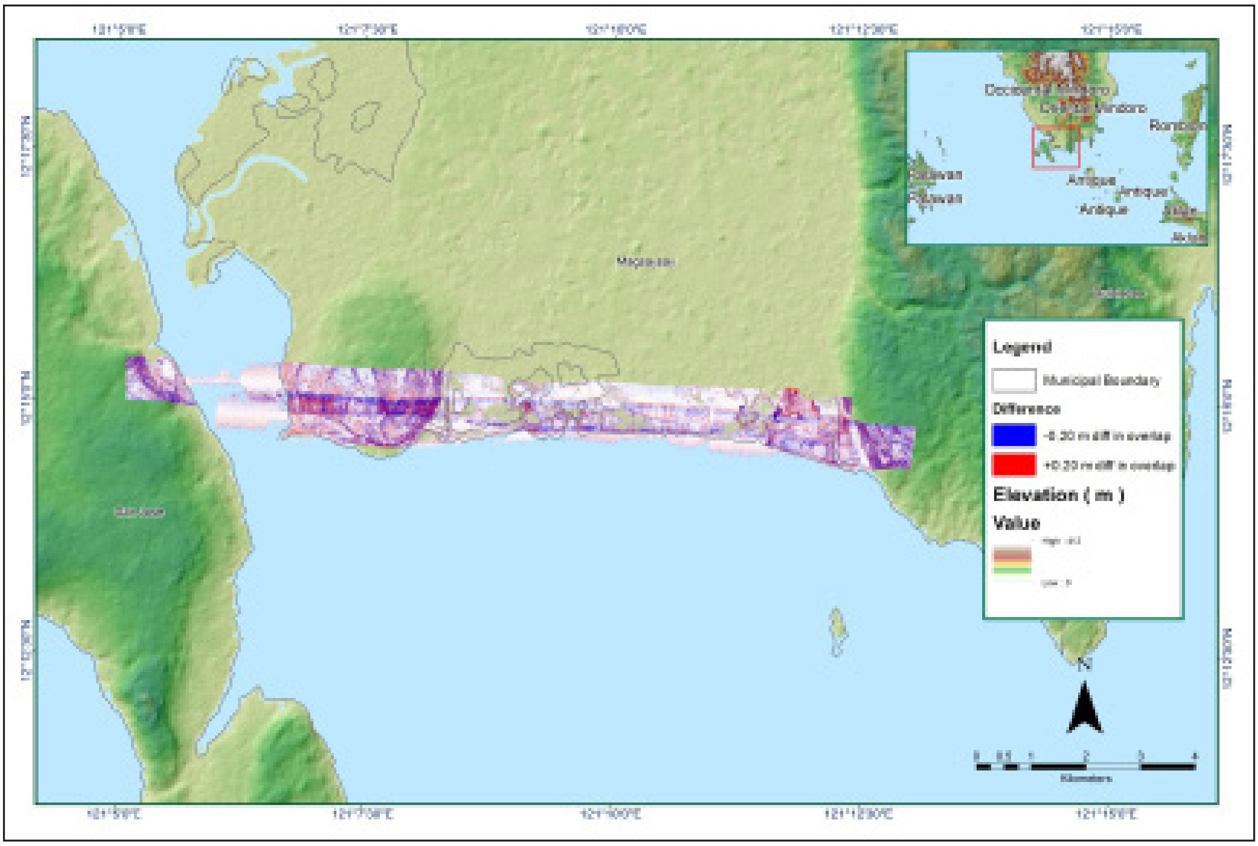



Figure A-8.28. Elevation difference between flight lines

Table A-8.5 Mission Summary Report for Blk 29B_additional

| Flight Area | Davao Oriental |
|---|---|
| Mission Name | Blk29B_additional |
| Inclusive Flights | 3078P |
| Range data size | 6.2GB |
| Base data size | 7.02MB |
| POS | 167MB |
| Image | 12.9MB |
| Transfer date | January 15, 2016 |
| | |
| Solution Status | |
| Number of Satellites (>6) | Yes |
| PDOP (<3) | Yes |
| Baseline Length (<30km) | No |
| Processing Mode (<=1) | No |
| | |
| Smoothed Performance Metrics (in cm) | |
| RMSE for North Position (<4.0 cm) | 1.01 |
| RMSE for East Position (<4.0 cm) | 1.16 |
| RMSE for Down Position (<8.0 cm) | 4.25 |
| | |
| Boresight correction stdev (<0.001deg) | 0.359804 |
| IMU attitude correction stdev (<0.001deg) | 0.083211 |
| GPS position stdev (<0.01m) | 0.0024 |
| | |
| Minimum % overlap (>25) | 17.73% |
| Ave point cloud density per sq.m. (>2.0) | 1.81 |
| Elevation difference between strips (<0.20 m) | Yes |
| | |
| Number of 1km x 1km blocks | 18 |
| Maximum Height | 322.24 m |
| Minimum Height | 53.37 m |
| | |
| Classification (# of points) | |
| Ground | 13,137,914 |
| Low vegetation | 6,256,653 |
| Medium vegetation | 4,588,390 |
| High vegetation | 8,091,371 |
| Building | 187,119 |
| | |
| Orthophoto | Yes |
| Processed by | Engr. Abigail Ching, Engr. Harmond Santos, Engr. Melissa Fernandez |

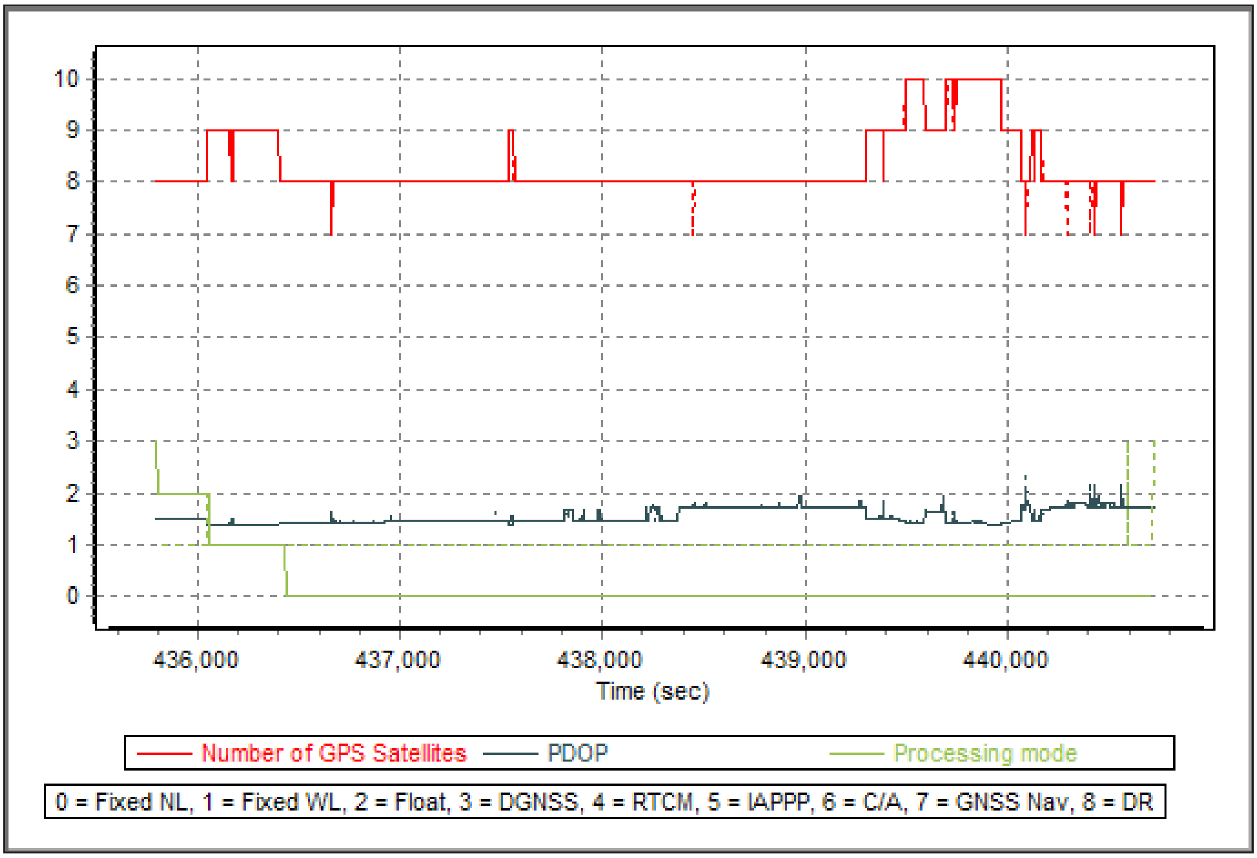



Figure A-8.29. Solution Status

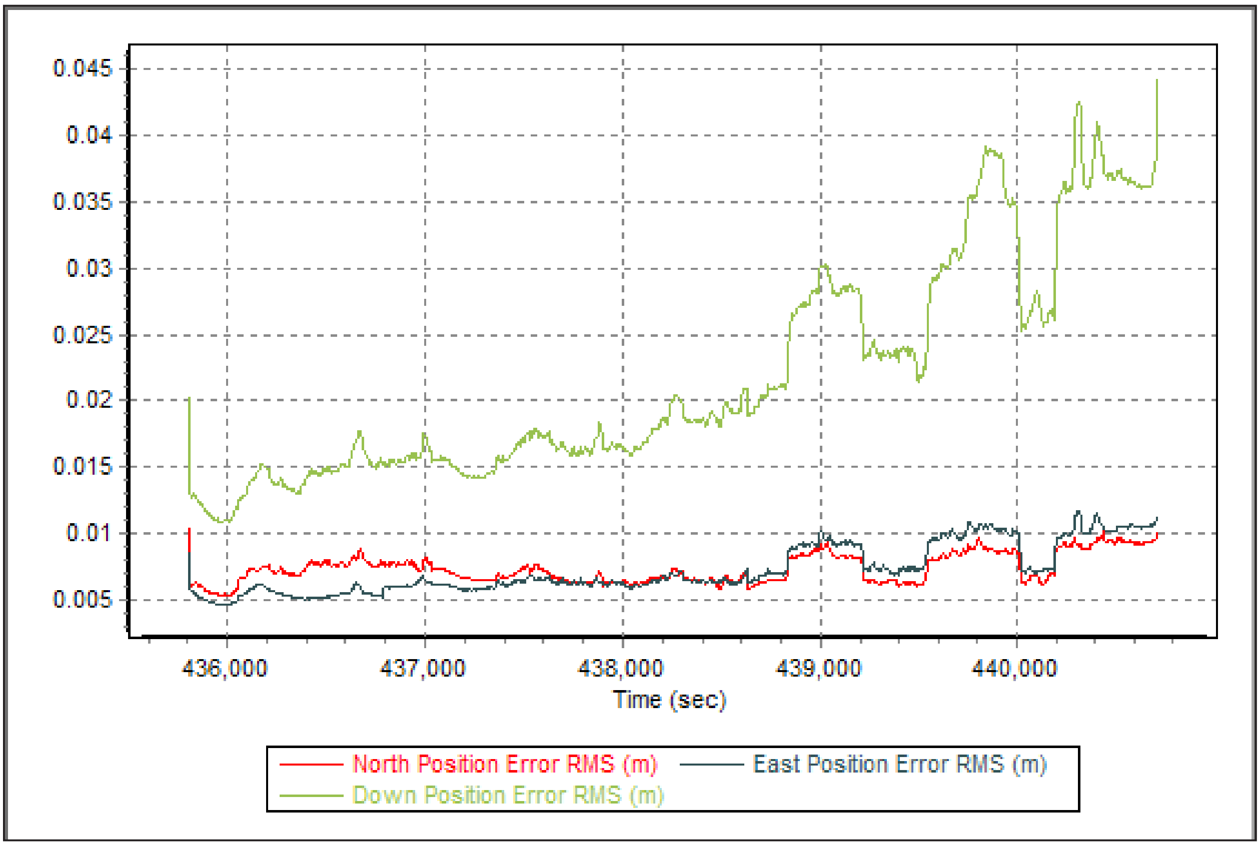



Figure A-8.30. Smoothed Performance Metric Parameters

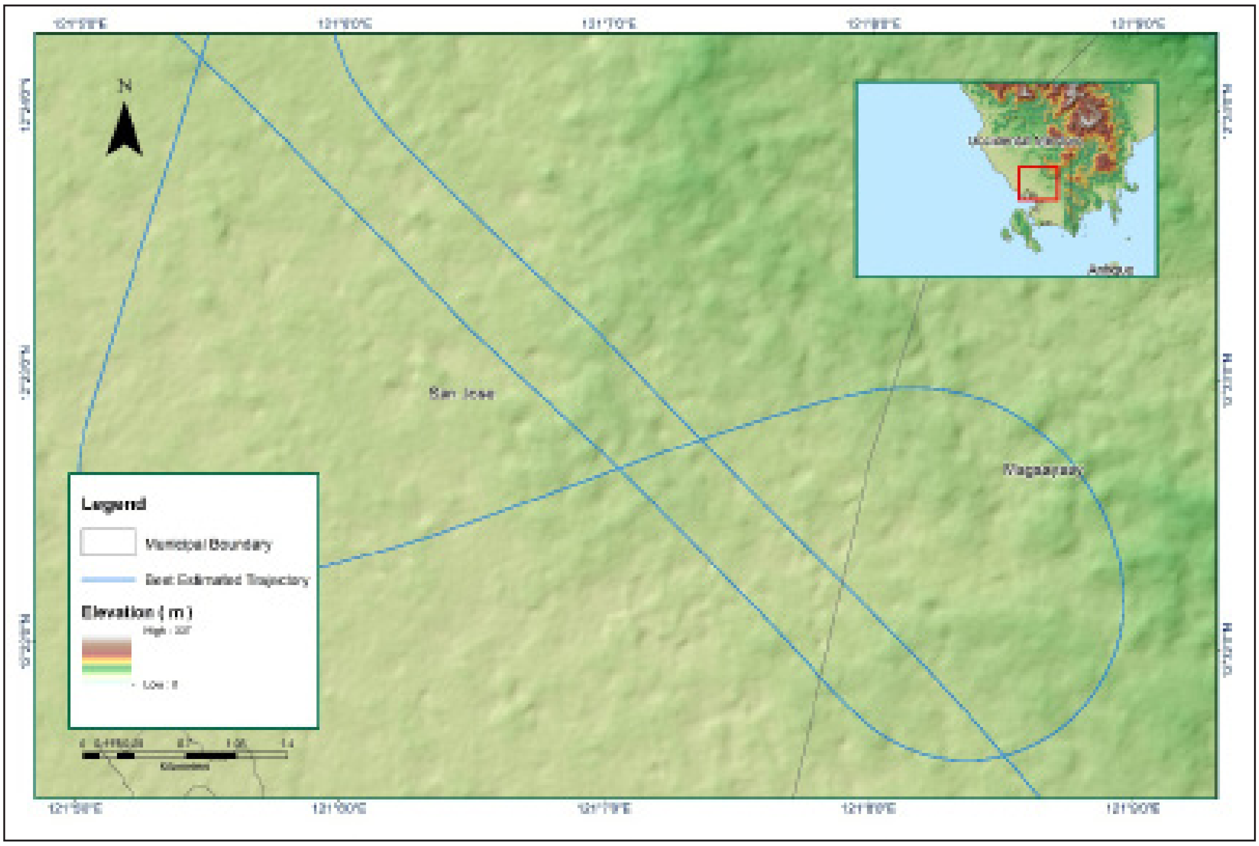



Figure A-8.31. Best Estimated Trajectory

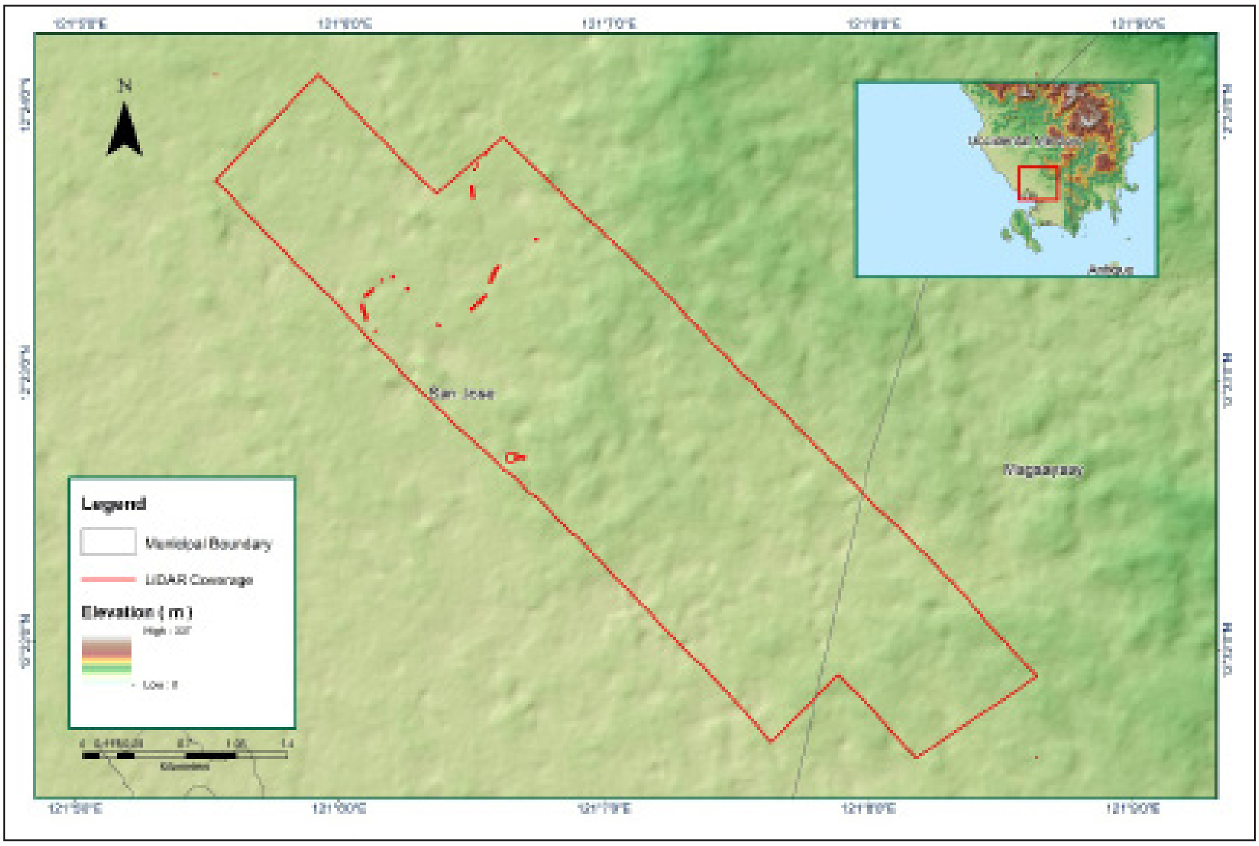



Figure A-8.32. Coverage of LiDAR data

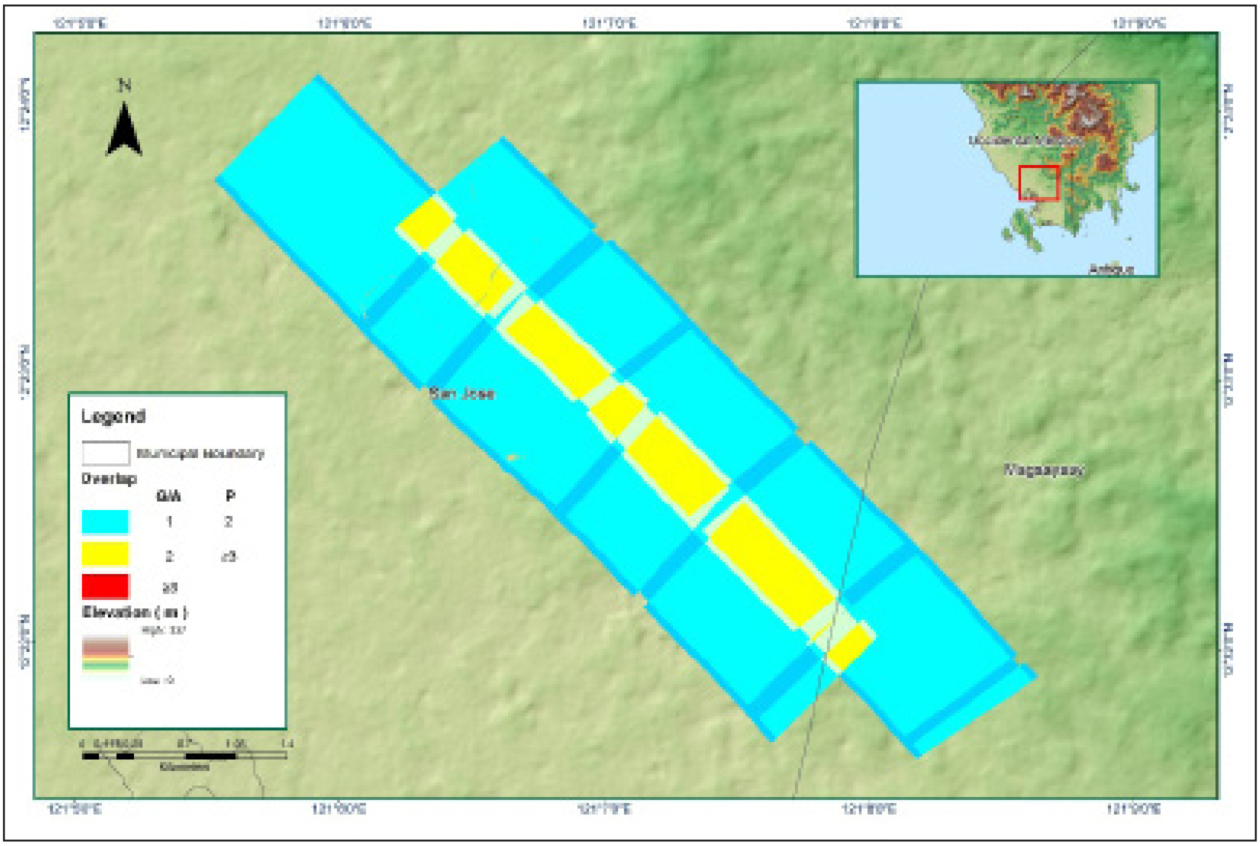



Figure A-8.33. Image of data overlap

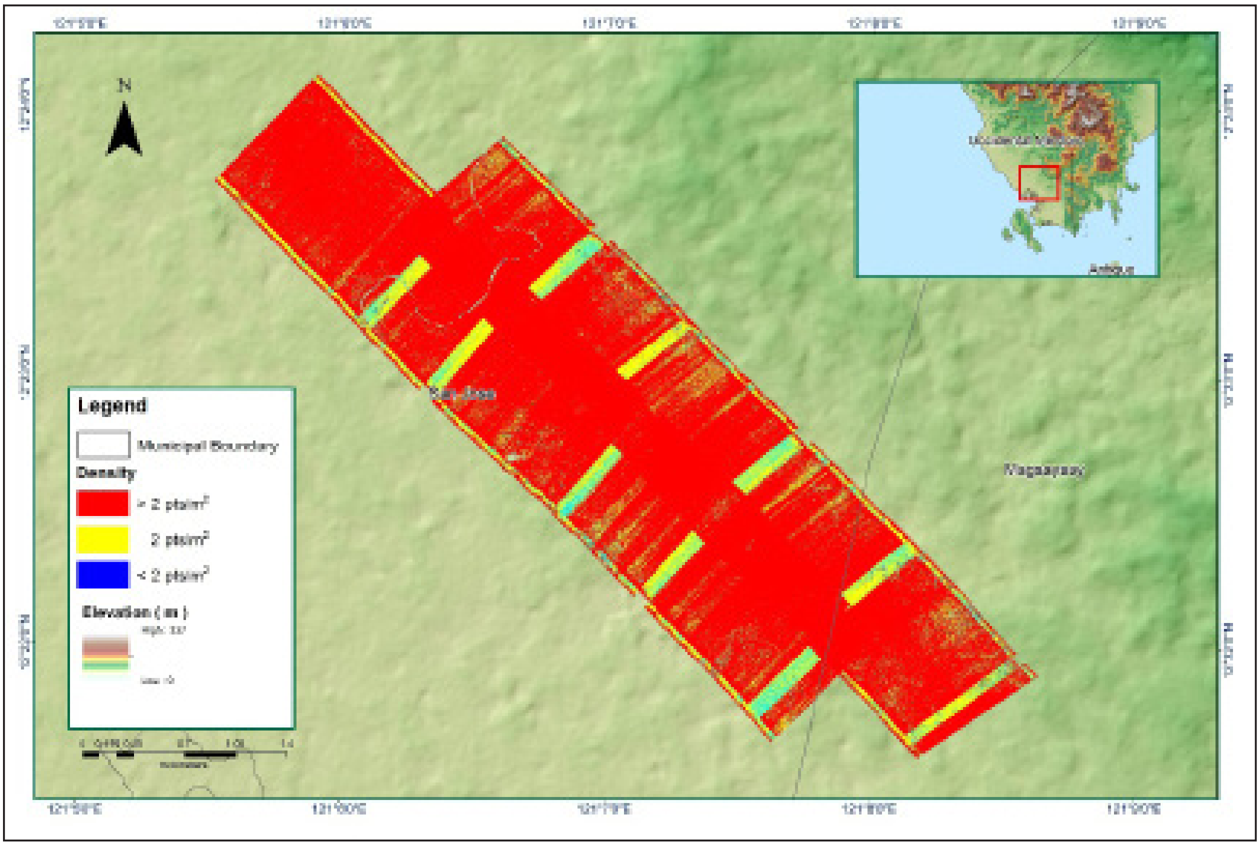



Figure A-8.34. Density map of merged LiDAR data

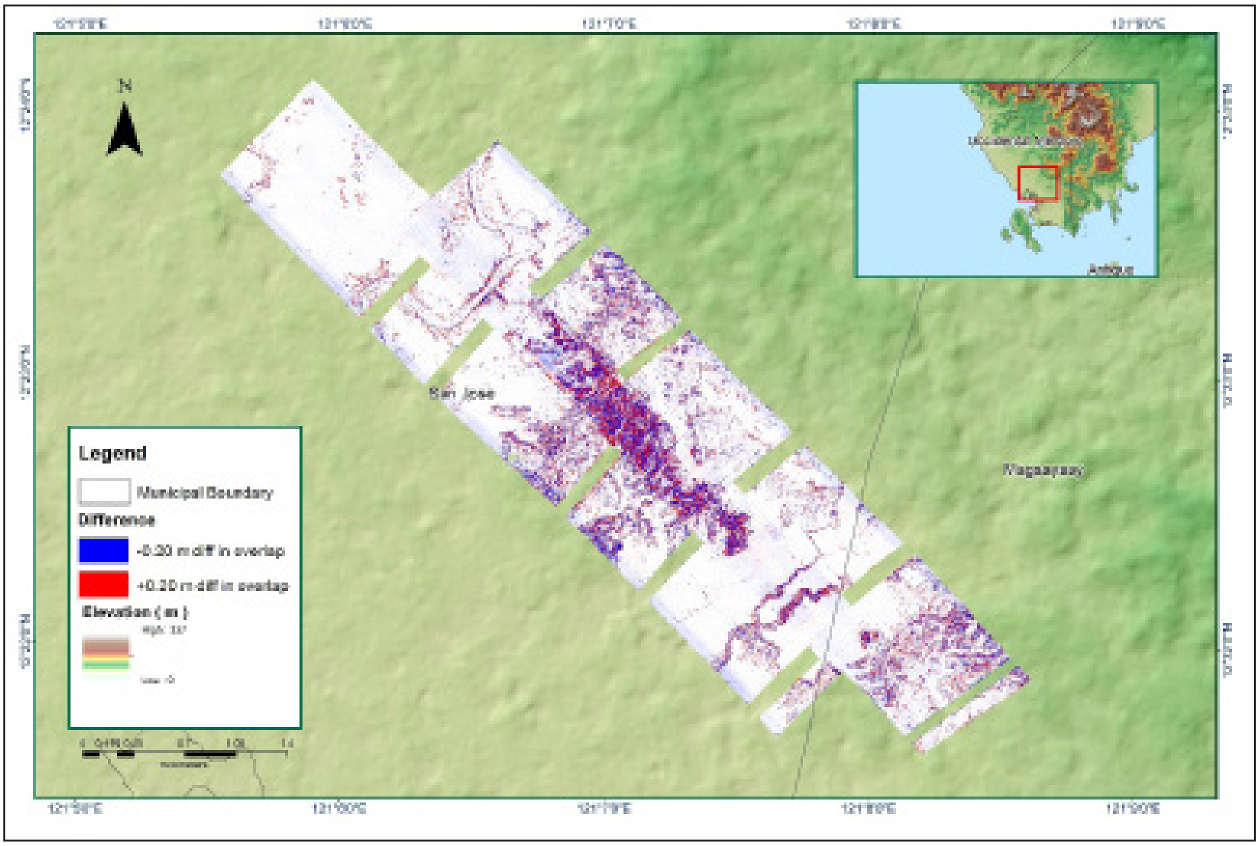



Figure A-8.35. Elevation difference between flight lines

Table A-8.6 Mission Summary Report for Blk 29C_additional

| Flight Area | Davao Oriental |
|---|---|
| Mission Name | Blk29C_additional |
| Inclusive Flights | 3078P, 3082P |
| Range data size | 15.42GB |
| POS | 341MB |
| Image | 26MB |
| Transfer date | January 15, 2016 |
| | |
| 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) | 0.79 |
| RMSE for East Position (<4.0 cm) | 0.78 |
| RMSE for Down Position (<8.0 cm) | 1.67 |
| | |
| Boresight correction stdev (<0.001deg) | 0.359804 |
| IMU attitude correction stdev (<0.001deg) | 0.083211 |
| GPS position stdev (<0.01m) | 0.0024 |
| | |
| Minimum % overlap (>25) | 40.31 |
| Ave point cloud density per sq.m. (>2.0) | 2.10 |
| Elevation difference between strips (<0.20 m) | Yes |
| | |
| Number of 1km x 1km blocks | 108 |
| Maximum Height | 521.55 m |
| Minimum Height | 51.07 m |
| | |
| Classification (# of points) | |
| Ground | 132,379,761 |
| Low vegetation | 125,752,184 |
| Medium vegetation | 199,077,351 |
| High vegetation | 599,574,573 |
| Building | 15,255,571 |
| | |
| Orthophoto | Yes |
| Processed by | Engr. Abigail Ching, Engr. Harmond Santos, Kathryn Claudyn Zarate |

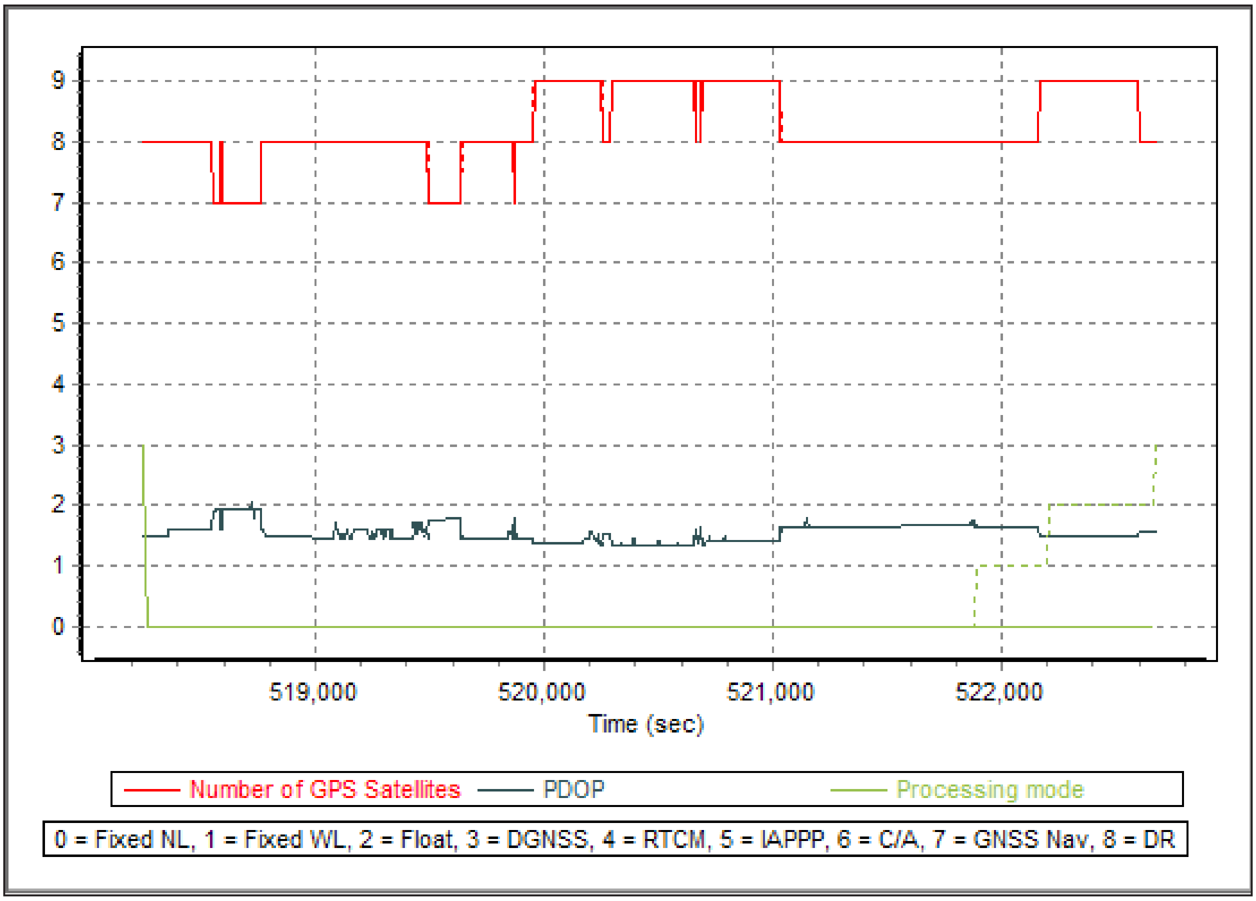



Figure A-8.36. Solution Status

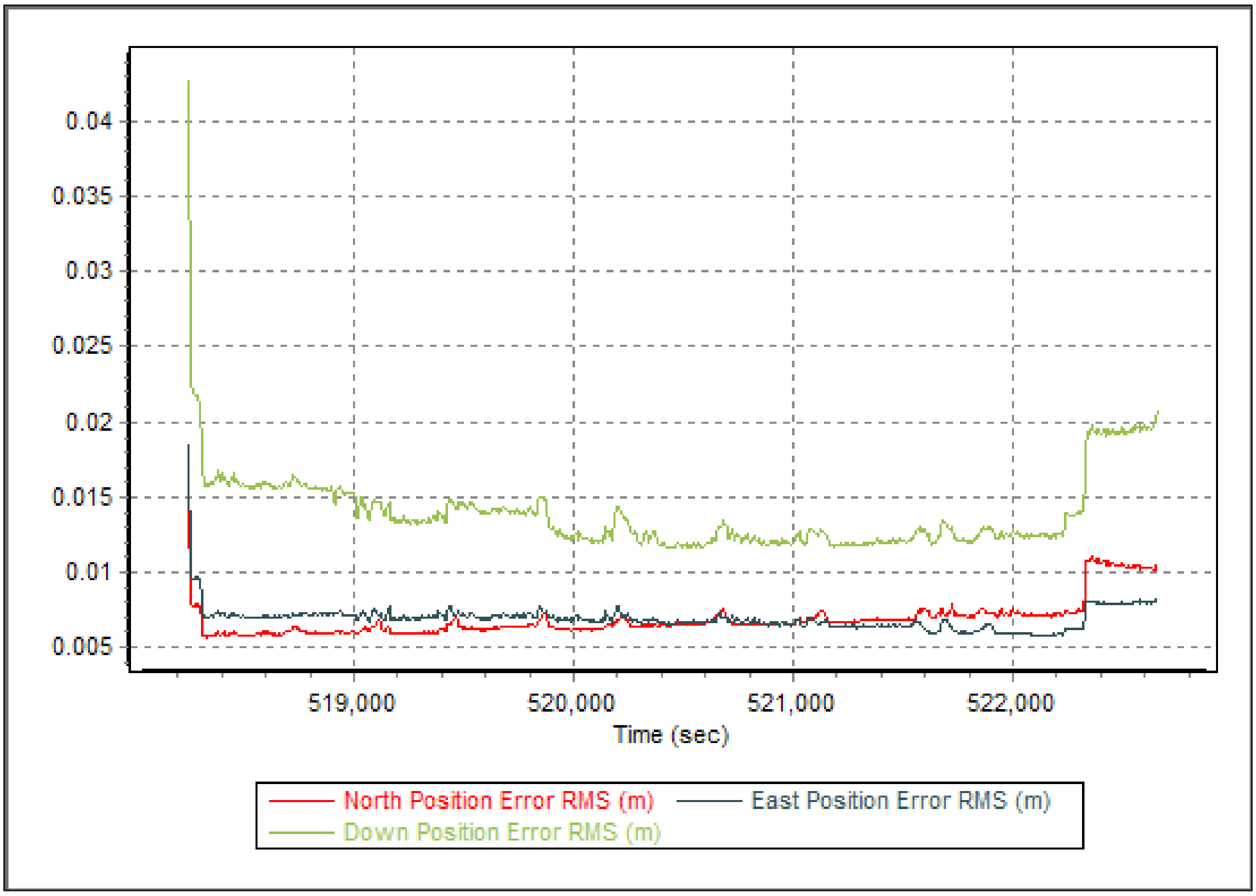



Figure A-8.37. Smoothed Performance Metric Parameters

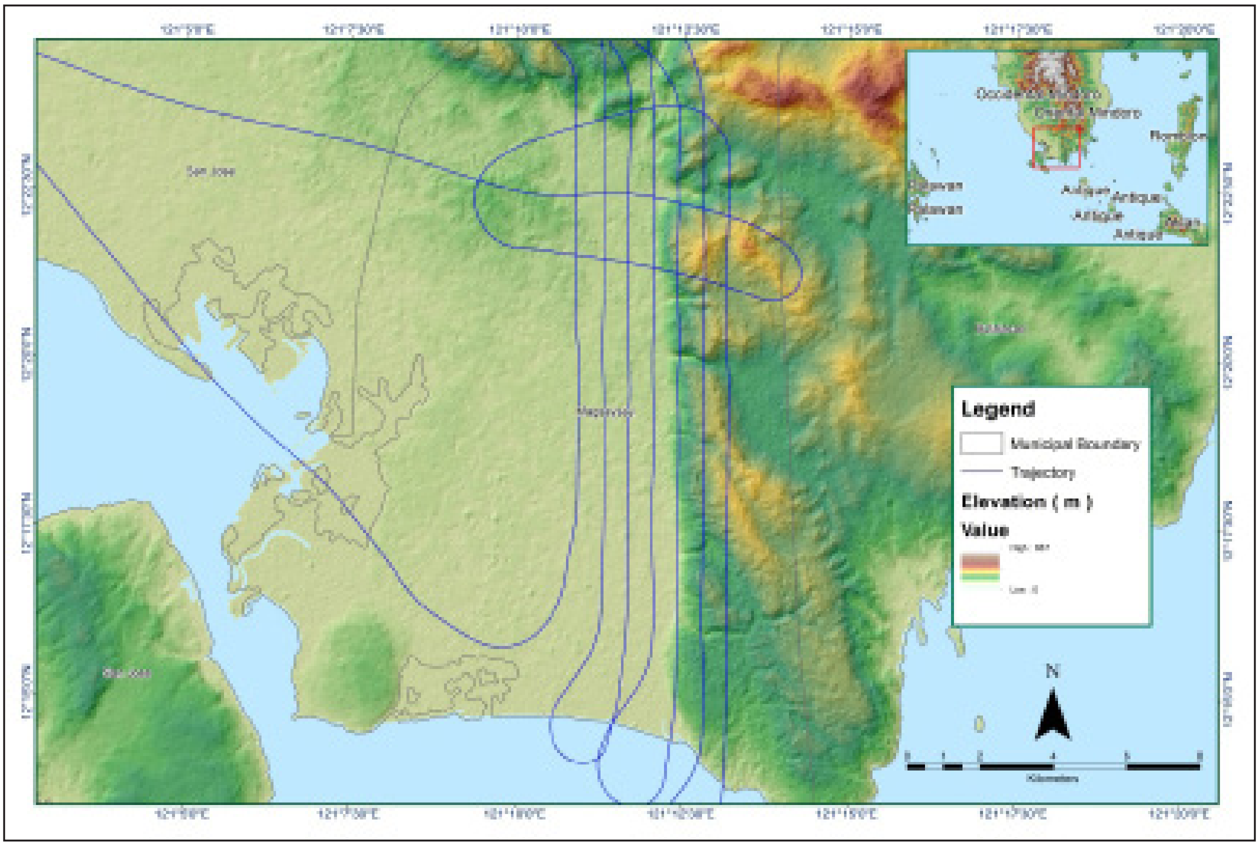



Figure A-8.38. Best Estimated Trajectory

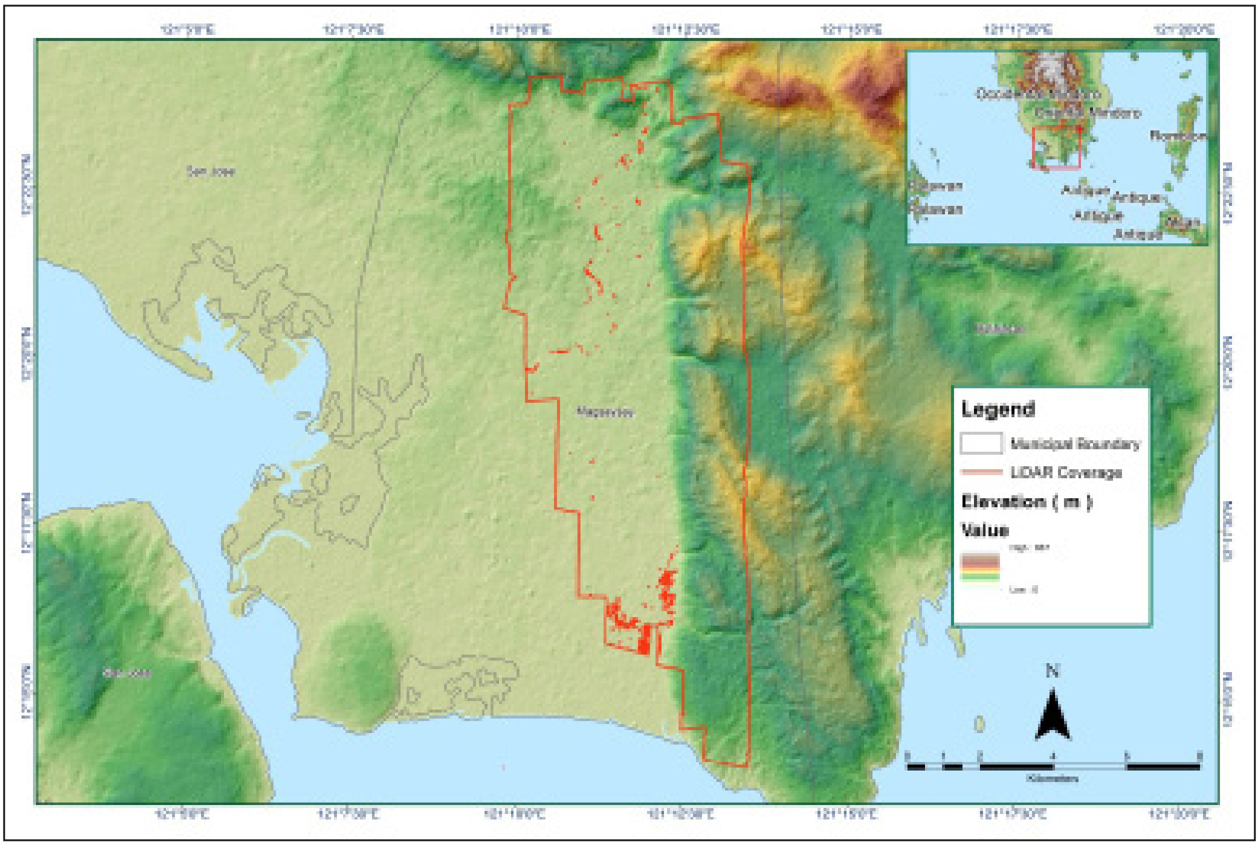



Figure A-8.39. Coverage of LiDAR data

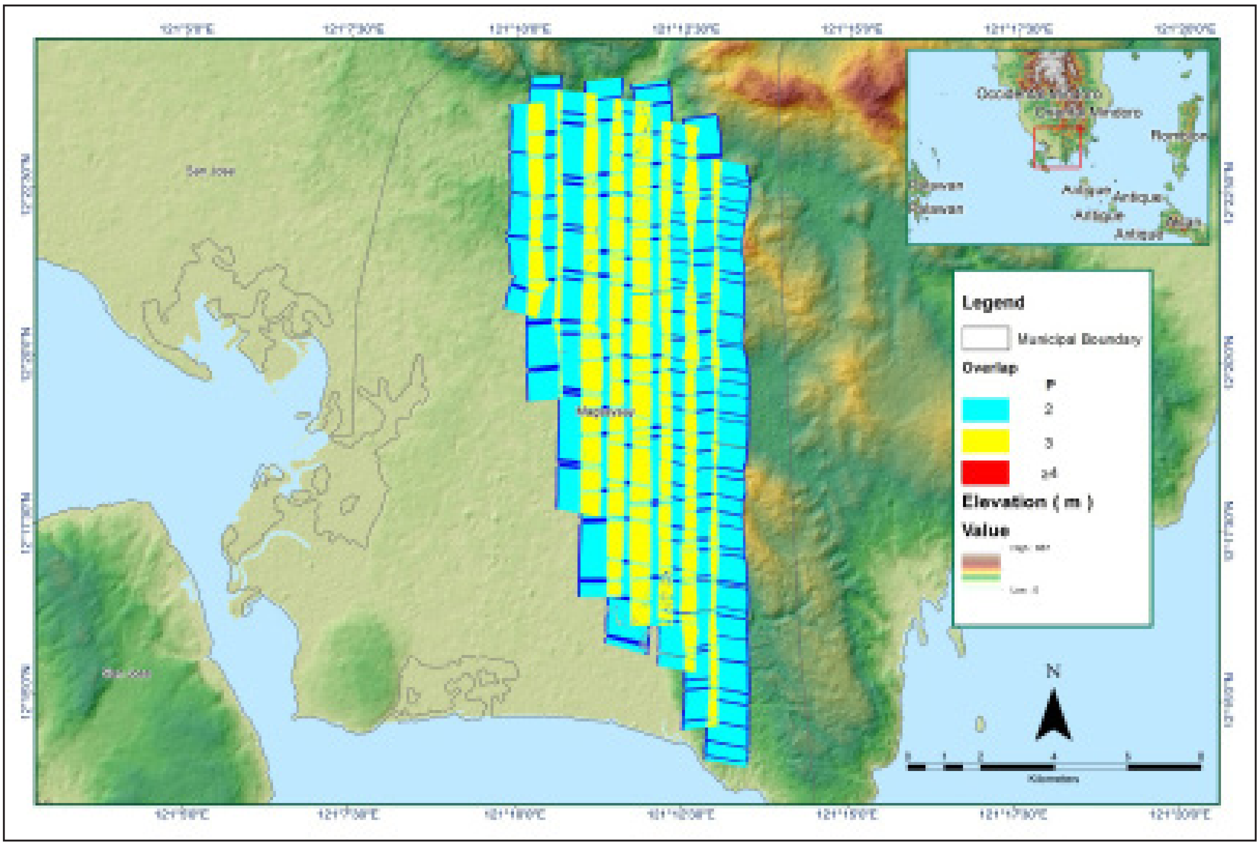



Figure A-8.40. Image of data overlap

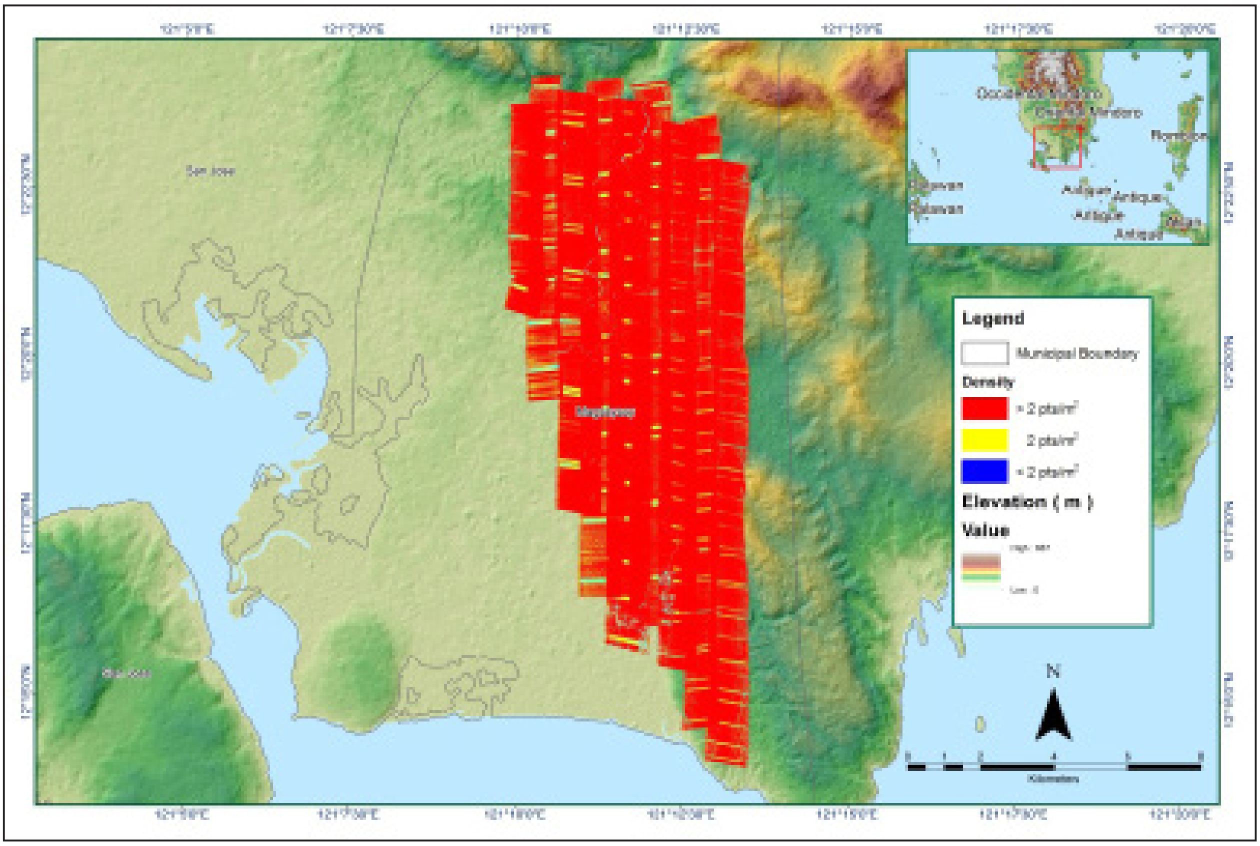



Figure A-8.41. Density map of merged LiDAR data

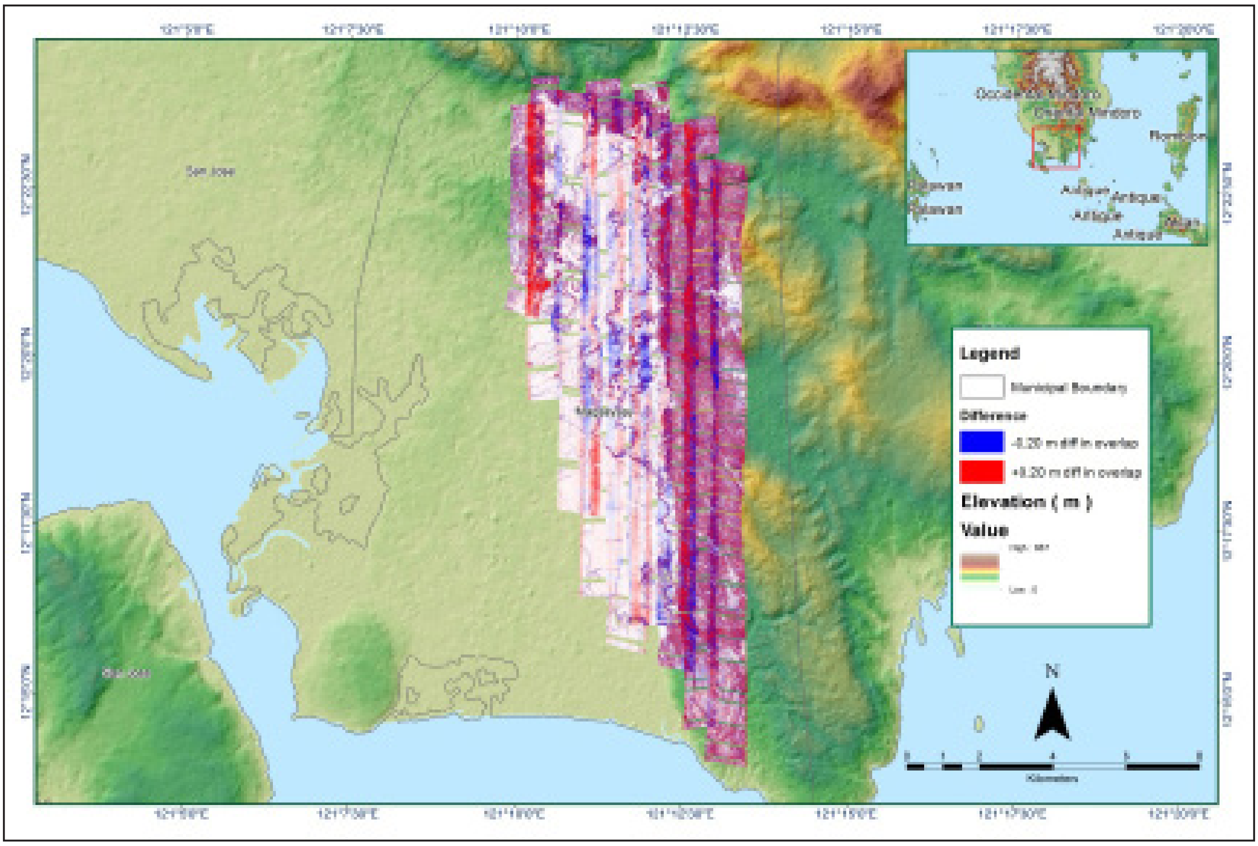



Figure A-8.42. Elevation difference between flight lines

# Annex 9. Inagauan Model Basin Parameters

Table A-9.1 Inagauan Model Basin Parameters

| Sub-basin | SCS Curve Number Loss | | | Clark Unit Hydrograph Transform | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial Abstraction (mm) | Curve Number | Impervious (%) | Time of Concentration (HR) | Storage Coefficient (HR) | Initial Discharge (M3/S) | Recession Constant | Ratio to Peak |
| W1000 | 0.1458 | 68.331 | 0.0 | 0.1253 | 60.304 | 0.27230 | 1 | 0.5000 |
| W1010 | 0.1294 | 68.331 | 0.0 | 0.11321 | 80.099 | 0.10504 | 1 | 0.5000 |
| W1040 | 20.272 | 61.1743 | 0.0 | 1.6278 | 39.849 | 0.31144 | 1 | 0.5000 |
| W1050 | 0.1964 | 99 | 0.0 | 0.54572 | 345.89 | 0.29530 | 1 | 0.5 |
| W520 | 0.5432 | 92.532 | 0.0 | 0.42315 | 60.121 | 0.23650 | 1 | 0.5 |
| W530 | 1.2222 | 92.532 | 0.0 | 0.92922 | 88.414 | 0.34808 | 1 | 0.5 |
| W540 | 0.472 | 99 | 0.0 | 0.65115 | 138.48 | 0.68559 | 1 | 0.5 |
| W550 | 0.5432 | 92.532 | 0.0 | 3.1593 | 89.84 | 0.44300 | 1 | 0.5 |
| W560 | 0.5432 | 94.421 | 0.0 | 1.3939 | 102.05 | 0.35383 | 1 | 0.5 |
| W570 | 0.816 | 96.885 | 0.0 | 2.8 | 174.69 | 0.75110 | 1 | 0.5 |
| W580 | 0.5432 | 92.532 | 0.0 | 1.8204 | 116.46 | 0.28501 | 1 | 0.5 |
| W590 | 0.5432 | 93.802 | 0.0 | 2.9157 | 124.93 | 0.54392 | 1 | 0.5 |
| W600 | 1.2086 | 96.965 | 0.0 | 0.64102 | 92.767 | 0.36002 | 1 | 0.5 |
| W610 | 0.5352 | 97.234 | 0.0 | 2.2193 | 141.25 | 0.72187 | 1 | 0.5 |
| W620 | 0.5076 | 95.826 | 0.0 | 1.3338 | 127.79 | 0.78438 | 1 | 0.5 |
| W630 | 0.5432 | 97.208 | 0.0 | 0.80972 | 76.951 | 0.22689 | 1 | 0.5 |
| W640 | 2.334 | 68.331 | 0.0 | 1.4139 | 138.78 | 0.61288 | 1 | 0.5 |
| W650 | 0.5432 | 62.946 | 0.0 | 0.17336 | 37.838 | 0.0169690 | 1 | 0.5 |
| W660 | 0.5432 | 62.946 | 0.0 | 0.64138 | 94.004 | 0.10105 | 1 | 0.5 |
| W670 | 0.7986 | 92.532 | 0.0 | 0.094735 | 22.522 | .000663181 | 1 | 0.4802 |
| W680 | 0.5432 | 92.532 | 0.0 | 0.86797 | 84.578 | 0.43717 | 1 | 0.5 |
| W690 | 0.5432 | 99 | 0.0 | 0.68016 | 97.427 | 0.26251 | 1 | 0.5 |

| Sub-basin | SCS Curve Number Loss | | | Clark Unit Hydrograph Transform | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial Abstraction (mm) | Curve Number | Impervious (%) | Time of Concentration (HR) | Storage Coefficient (HR) | Initial Discharge (M3/S) | Recession Constant | Ratio to Peak |
| W700 | 0.4816 | 99 | 0.0 | 1.0836 | 155.19 | 0.62682 | 1 | 0.5 |
| W710 | 0.3454 | 99 | 0.0 | 0.21805 | 45.486 | 0.18063 | 1 | 0.5 |
| W720 | 0.4316 | 99 | 0.0 | 0.38721 | 84.853 | 0.35507 | 1 | 0.5 |
| W730 | 1.2222 | 94.809 | 0.0 | 2.1907 | 139.43 | 0.65987 | 1 | 0.5 |
| W740 | 0.5106 | 64.992 | 0.0 | 0.24921 | 79.963 | 0.21583 | 1 | 0.5 |
| W750 | 0.5432 | 62.946 | 0.0 | 0.42364 | 62.246 | 0.0578862 | 1 | 0.5 |
| W760 | 0.3502 | 99 | 0.0 | 0.63613 | 90.826 | 0.17837 | 1 | 0.5 |
| W770 | 0.3946 | 99 | 0.0 | 0.37577 | 120.98 | 0.58995 | 1 | 0.5 |
| W780 | 0.5432 | 99 | 0.0 | 0.09213 | 66.172 | 0.0154847 | 1 | 0.5 |
| W790 | 0.5368 | 99 | 0.0 | 1.9798 | 189.93 | 0.55494 | 1 | 0.5 |
| W800 | 1.1276 | 65.607 | 0.0 | 0.70668 | 102.24 | 0.26565 | 1 | 0.5 |
| W810 | 0.5602 | 91.079 | 0.0 | 1.1138 | 159.5 | 0.95204 | 1 | 0.5 |
| W820 | 1.2222 | 62.946 | 0.0 | 0.4252 | 93.245 | 0.30553 | 1 | 0.5 |
| W830 | 1.1412 | 65.211 | 0.0 | 0.34601 | 75.888 | 0.25639 | 1 | 0.5 |
| W840 | 2.75 | 42.821 | 0.0 | 0.2935 | 95.942 | 0.0912979 | 1 | 0.5 |
| W850 | 0.4842 | 99 | 0.0 | 0.71624 | 69.124 | 0.36562 | 1 | 0.5 |
| W860 | 1.1498 | 67.648 | 0.0 | 0.10129 | 74.201 | 0.28254 | 1 | 0.5 |
| W870 | 0.7656 | 88.905 | 0.0 | 0.3824 | 125.18 | 0.52965 | 1 | 0.5 |
| W880 | 0.5432 | 99 | 0.0 | 0.54271 | 116.51 | 0.25141 | 1 | 0.5 |
| W890 | 0.7986 | 99 | 0.0 | 2.5252 | 105.07 | 0.27817 | 1 | 0.5 |
| W900 | 0.9754 | 99 | 0.0 | 0.22251 | 158.37 | 0.79070 | 1 | 0.5 |
| W910 | 0.403 | 99 | 0.0 | 0.14794 | 47.649 | 0.32253 | 1 | 0.5 |
| W920 | 0.2732 | 99 | 0.0 | 0.07321 | 15.632 | 0.24728 | 1 | 0.2222 |
| W930 | 0.3444 | 99 | 0.0 | 0.25243 | 287.16 | 0.19742 | 1 | 0.5 |
| W940 | 0.5432 | 99 | 0.0 | 0.14816 | 163.49 | 0.37988 | 1 | 0.5 |

| Sub-basin | SCS Curve Number Loss | | | Clark Unit Hydrograph Transform | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial Abstraction (mm) | Curve Number | Impervious (%) | Time of Concentration (HR) | Storage Coefficient (HR) | Initial Discharge (M3/S) | Recession Constant | Ratio to Peak |
| W950 | 0.4394 | 99 | 0.0 | 0.15159 | 32.425 | 0.0517649 | 1 | 0.4917 |
| W960 | 0.3936 | 99 | 0.0 | 0.14121 | 100.67 | 0.48522 | 1 | 0.5 |
| W970 | 0.6004 | 99 | 0.0 | 0.11528 | 24.538 | 0.37268 | 1 | 0.3333 |
| W980 | 0.8932 | 99 | 0.0 | 2.1041 | 456.64 | 1.2000 | 1 | 0.5 |

# Annex 10. Inagauan Model Reach Parameters

Table A-10.1 Inagauan Model Reach Parameters

| Reach Number | Muskingum Cunge Channel Routing | | | | | | |
|---|---|---|---|---|---|---|---|
| | Time Step Method | Length (m) | Slope | Manning's n | Shape | Width | Side Slope |
| R1060 | Automatic Fixed Interval | 8193.6 | 0.0046050 | 0.0669292 | Trapezoid | 40 | 1 |
| R130 | Automatic Fixed Interval | 56.569 | 0.0141509 | 0.5452 | Trapezoid | 40 | 1 |
| R140 | Automatic Fixed Interval | 1393.3 | 0.0067208 | 0.36539 | Trapezoid | 40 | 1 |
| R150 | Automatic Fixed Interval | 5701.9 | 0.0133876 | 0.54531 | Trapezoid | 40 | 1 |
| R160 | Automatic Fixed Interval | 3543.3 | 0.0141264 | 0.2448 | Trapezoid | 40 | 1 |
| R190 | Automatic Fixed Interval | 2426.2 | 0.0077829 | 0.35627 | Trapezoid | 40 | 1 |
| R220 | Automatic Fixed Interval | 3349.1 | 0.0091600 | 0.16238 | Trapezoid | 40 | 1 |
| R230 | Automatic Fixed Interval | 2646.3 | 0.0061734 | 0.24238 | Trapezoid | 40 | 1 |
| R240 | Automatic Fixed Interval | 2658.4 | 0.0065554 | 0.15835 | Trapezoid | 40 | 1 |
| R250 | Automatic Fixed Interval | 1400.5 | 0.0110834 | 0.16076 | Trapezoid | 40 | 1 |
| R260 | Automatic Fixed Interval | 118.28 | 0.0273725 | 0.15836 | Trapezoid | 40 | 1 |
| R280 | Automatic Fixed Interval | 2263.1 | 0.0027761 | 0.23221 | Trapezoid | 40 | 1 |
| R310 | Automatic Fixed Interval | 3547.5 | 0.0048115 | 0.23274 | Trapezoid | 40 | 1 |
| R320 | Automatic Fixed Interval | 1758.5 | 0.0086590 | 0.10772 | Trapezoid | 40 | 1 |

| Reach Number | Muskingum Cunge Channel Routing | | | | | | |
|---|---|---|---|---|---|---|---|
| | Time Step Method | Length (m) | Slope | Manning's n | Shape | Width | Side Slope |
| R330 | Automatic Fixed Interval | 5530.8 | 0.0156066 | 0.16029 | Trapezoid | 40 | 1 |
| R350 | Automatic Fixed Interval | 3248.8 | 0.0051373 | 0.23636 | Trapezoid | 40 | 1 |
| R410 | Automatic Fixed Interval | 1738.2 | 0.0017449 | 0.10244 | Trapezoid | 40 | 1 |
| R420 | Automatic Fixed Interval | 7732.6 | 0.0042001 | 0.15442 | Trapezoid | 40 | 1 |
| R440 | Automatic Fixed Interval | 905.69 | 0.0042001 | 0.10453 | Trapezoid | 40 | 1 |
| R450 | Automatic Fixed Interval | 4671.6 | 0.0305024 | 0.0696889 | Trapezoid | 40 | 1 |
| R460 | Automatic Fixed Interval | 4474.2 | 0.0016455 | 0.0696889 | Trapezoid | 40 | 1 |
| R500 | Automatic Fixed Interval | 1767.8 | 0.0046050 | 0.0696889 | Trapezoid | 40 | 1 |
| R510 | Automatic Fixed Interval | 9161.4 | 0.0046050 | 0.04 | Trapezoid | 40 | 1 |
| R70 | Automatic Fixed Interval | 4911.4 | 0.0201613 | 0.54495 | Trapezoid | 40 | 1 |
| R80 | Automatic Fixed Interval | 7061.7 | 0.0330236 | 0.36499 | Trapezoid | 40 | 1 |
| R90 | Automatic Fixed Interval | 683.55 | 0.0141509 | 0.54533 | Trapezoid | 40 | 1 |

# Annex 11. Inagauan Field Validation Data

Table A-11.1 Inagauan Field Validation Data

| Point Number | Validation Coordinates | | Model Var (m) | Validation Points (m) | Error | Event/Date | Rain Return / Scenario |
|---|---|---|---|---|---|---|---|
| | Lat | Long | | | | | |
| 1 | 12.2677593 | 121.139577 | 0.052 | 0.00 | -0.05 | | 25-Year |
| 2 | 12.26808239 | 121.1359749 | 0.096 | 0.00 | -0.10 | | 25-Year |
| 3 | 12.26811462 | 121.1353353 | 0.042 | 0.00 | -0.04 | | 25-Year |
| 4 | 12.26817205 | 121.1348946 | 0.056 | 0.00 | -0.06 | | 25-Year |
| 5 | 12.2683501 | 121.1396667 | 0.178 | 0.00 | -0.18 | | 25-Year |
| 6 | 12.26855913 | 121.139096 | 0.067 | 0.00 | -0.07 | | 25-Year |
| 7 | 12.26867158 | 121.1358332 | 0.056 | 0.00 | -0.06 | | 25-Year |
| 8 | 12.2687375 | 121.1369316 | 0.097 | 0.00 | -0.10 | | 25-Year |
| 9 | 12.26890997 | 121.1370532 | 0.06 | 0.00 | -0.06 | | 25-Year |
| 10 | 12.26898759 | 121.136709 | 0.072 | 0.00 | -0.07 | | 25-Year |
| 11 | 12.26906449 | 121.1348371 | 0.078 | 0.00 | -0.08 | | 25-Year |
| 12 | 12.26918658 | 121.1388668 | 0.119 | 0.00 | -0.12 | | 25-Year |
| 13 | 12.26918873 | 121.1377438 | 0.138 | 0.00 | -0.14 | | 25-Year |
| 14 | 12.26942876 | 121.1364042 | 0.162 | 0.00 | -0.16 | | 25-Year |
| 15 | 12.26947415 | 121.1384567 | 0.247 | 0.00 | -0.25 | | 25-Year |
| 16 | 12.26948678 | 121.1375942 | 0.278 | 0.00 | -0.28 | | 25-Year |
| 17 | 12.26983985 | 121.1342523 | 0.202 | 0.00 | -0.20 | | 25-Year |
| 18 | 12.26990337 | 121.1332585 | 0.074 | 0.00 | -0.07 | | 25-Year |
| 19 | 12.27053581 | 121.1343376 | 0.293 | 0.00 | -0.29 | | 25-Year |
| 20 | 12.27085968 | 121.1369329 | 0.081 | 0.30 | 0.22 | | 25-Year |
| 21 | 12.27101084 | 121.1333797 | 0.036 | 0.00 | -0.04 | Ruby / Dec. 2014 | 25-Year |
| 22 | 12.27107064 | 121.1403548 | 0.035 | 0.60 | 0.57 | | 25-Year |
| 23 | 12.27104627 | 121.1365413 | 0.268 | 0.60 | 0.33 | Ruby / Dec. 2014 | 25-Year |
| 24 | 12.27130712 | 121.1420051 | 0.056 | 0.60 | 0.54 | Ruby / Dec. 2014 | 25-Year |
| 25 | 12.27148638 | 121.1399971 | 0.067 | 0.90 | 0.83 | Ruby / Dec. 2014 | 25-Year |
| 26 | 12.27155569 | 121.140664 | 0.032 | 0.60 | 0.57 | Ruby / Dec. 2014 | 25-Year |
| 27 | 12.27181344 | 121.1391873 | 0.03 | 0.60 | 0.57 | Ruby / Dec. 2014 | 25-Year |
| 28 | 12.27181687 | 121.1327829 | 0.061 | 0.00 | -0.06 | Ruby / Dec. 2014 | 25-Year |
| 29 | 12.27199171 | 121.1365596 | 0.094 | 0.60 | 0.51 | | 25-Year |
| 30 | 12.27237603 | 121.1318774 | 0.077 | 0.00 | -0.08 | Ruby / Dec. 2014 | 25-Year |
| 31 | 12.27389698 | 121.1320439 | 0.03 | 0.50 | 0.47 | | 25-Year |
| 32 | 12.27420119 | 121.1246051 | 0.216 | 1.00 | 0.78 | Ruby / Dec. 2014 | 25-Year |

| Point Number | Validation Coordinates | | Model Var (m) | Validation Points (m) | Error | Event/Date | Rain Return / Scenario |
|---|---|---|---|---|---|---|---|
| | Lat | Long | | | | | |
| 33 | 12.280456 | 121.140142 | 0.03 | 0.40 | 0.37 | Ruby / Dec. 2014 | 25-Year |
| 34 | 12.280598 | 121.140319 | 0.03 | 0.35 | 0.32 | Ondoy / Sept. 2009 | 25-Year |
| 35 | 12.2815 | 121.1406 | 0.199 | 0.24 | 0.04 | Yolanda / Nov. 2013 | 25-Year |
| 36 | 12.2824 | 121.141125 | 0.03 | 0.42 | 0.39 | Glenda / July, 2014 | 25-Year |
| 37 | 12.2826 | 121.1413 | 0.031 | 0.77 | 0.74 | Nona / Dec. 2015 | 25-Year |
| 38 | 12.28291 | 121.14136 | 0.268 | 0.50 | 0.23 | Yolanda / Nov. 2013 | 25-Year |
| 39 | 12.283027 | 121.142358 | 0.03 | 0.30 | 0.27 | Yolanda / Nov. 2013 | 25-Year |
| 40 | 12.28324598 | 121.1163547 | 0.03 | 0.30 | 0.27 | Yolanda / Nov. 2013 | 25-Year |
| 41 | 12.28343378 | 121.1168896 | 0.03 | 0.00 | -0.03 | Ruby / Dec. 2014 | 25-Year |
| 42 | 12.28369153 | 121.1183253 | 0.03 | 0.00 | -0.03 | | 25-Year |
| 43 | 12.28385491 | 121.1165601 | 0.03 | 0.30 | 0.27 | | 25-Year |
| 44 | 12.283971 | 121.115485 | 0.037 | 0.30 | 0.26 | Ruby / Dec. 2014 | 25-Year |
| 45 | 12.28404456 | 121.1149475 | 0.03 | 0.00 | -0.03 | Ruby / Dec. 2014 | 25-Year |
| 46 | 12.2841044 | 121.1177292 | 0.056 | 0.30 | 0.244 | | 25-Year |
| 47 | 12.28436415 | 121.1161775 | 0.03 | 0.60 | 0.57 | Ruby / Dec. 2014 | 25-Year |
| 48 | 12.28454404 | 121.1174499 | 0.034 | 0.00 | -0.034 | Ruby / Dec. 2014 | 25-Year |
| 49 | 12.28454459 | 121.1145975 | 0.075 | 0.00 | -0.075 | | 25-Year |
| 50 | 12.28473556 | 121.1142957 | 0.054 | 0.00 | -0.054 | | 25-Year |
| 51 | 12.28501068 | 121.1148755 | 0.038 | 0.00 | -0.038 | | 25-Year |
| 52 | 12.28521985 | 121.1413016 | 0.03 | 0.90 | 0.87 | | 25-Year |
| 53 | 12.2852526 | 121.1149556 | 0.044 | 0.00 | -0.044 | Frank / June, 2008 | 25-Year |
| 54 | 12.28541714 | 121.1146135 | 0.03 | 0.60 | 0.57 | | 25-Year |
| 55 | 12.28570751 | 121.1145189 | 0.049 | 0.70 | 0.651 | Ruby / Dec. 2014 | 25-Year |
| 56 | 12.28584209 | 121.1142662 | 0.031 | 1.00 | 0.969 | Ruby / Dec. 2014 | 25-Year |
| 57 | 12.28588312 | 121.1161351 | 0.048 | 0.30 | 0.252 | Ruby / Dec. 2014 | 25-Year |
| 58 | 12.28590879 | 121.1146586 | 0.03 | 0.90 | 0.87 | Ruby / Dec. 2014 | 25-Year |
| 59 | 12.28605087 | 121.1137754 | 0.054 | 1.00 | 0.946 | Ruby / Dec. 2014 | 25-Year |

| Point Number | Validation Coordinates | | Model Var (m) | Validation Points (m) | Error | Event/Date | Rain Return / Scenario |
|---|---|---|---|---|---|---|---|
| | Lat | Long | | | | | |
| 60 | 12.28619179 | 121.1143164 | 0.037 | 1.00 | 0.963 | Ruby / Dec. 2014 | 25-Year |
| 61 | 12.286413 | 121.113646 | 0.03 | 0.70 | 0.67 | Ruby / Dec. 2014 | 25-Year |
| 62 | 12.28662187 | 121.1137243 | 0.03 | 1.00 | 0.97 | Yolanda / Nov. 2013 | 25-Year |
| 63 | 12.28713632 | 121.14006 | 0.03 | 0.00 | -0.03 | Ruby / Dec. 2014 | 25-Year |
| 64 | 12.28713758 | 121.1152344 | 0.03 | 0.00 | -0.03 | | 25-Year |
| 65 | 12.2874 | 121.1118 | 0.03 | 0.40 | 0.37 | | 25-Year |
| 66 | 12.287451 | 121.106806 | 0.123 | 1.30 | 1.177 | Yolanda / Nov. 2013 | 25-Year |
| 67 | 12.287451 | 121.106806 | 0.123 | 0.56 | 0.437 | Yolanda / Nov. 2013 | 25-Year |
| 68 | 12.287712 | 121.110859 | 0.033 | 0.10 | 0.067 | Ruby / Dec. 2014 | 25-Year |
| 69 | 12.2877 | 121.1076 | 0.149 | 0.77 | 0.621 | Ruby / Dec. 2014 | 25-Year |
| 70 | 12.288088 | 121.107628 | 0.343 | 1.00 | 0.657 | Glenda / July, 2014 | 25-Year |
| 71 | 12.288137 | 121.109273 | 0.259 | 0.85 | 0.591 | Ruby / Dec. 2014 | 25-Year |
| 72 | 12.2881785 | 121.1140012 | 0.03 | 0.00 | -0.03 | Aug. 2015 | 25-Year |
| 73 | 12.288228 | 121.108309 | 0.363 | 0.95 | 0.587 | | 25-Year |
| 74 | 12.28826257 | 121.1078895 | 0.286 | 1.30 | 1.014 | Yolanda / Nov. 2013 | 25-Year |
| 75 | 12.28846631 | 121.1084624 | 0.296 | 1.30 | 1.004 | Ruby / Dec. 2014 | 25-Year |
| 76 | 12.288522 | 121.1095252 | 0.111 | 1.30 | 1.189 | Ruby / Dec. 2014 | 25-Year |
| 77 | 12.2888 | 121.1101 | 0.03 | 0.7 | 0.67 | Ruby / Dec. 2014 | 25-Year |
| 78 | 12.29604087 | 121.1485593 | 1.32 | 0.9 | -0.42 | Undang / 1984 | 25-Year |
| 79 | 12.29769703 | 121.1368933 | 0.03 | 0 | -0.03 | Mario / Sept. 2014 | 25-Year |
| 80 | 12.29790457 | 121.1465242 | 0.03 | 0 | -0.03 | | 25-Year |
| 81 | 12.30016443 | 121.1466252 | 0.031 | 0 | -0.031 | | 25-Year |
| 82 | 12.30080732 | 121.1466362 | 0.03 | 0 | -0.03 | | 25-Year |
| 83 | 12.30216259 | 121.1493133 | 0.037 | 0 | -0.037 | | 25-Year |
| 84 | 12.30300969 | 121.151692 | 0.858 | 0.9 | 0.042 | | 25-Year |
| 85 | 12.30471438 | 121.1514492 | 0.03 | 0 | -0.03 | Mario / Sept. 2014 | 25-Year |
| 86 | 12.30694932 | 121.1511363 | 0.03 | 0 | -0.03 | | 25-Year |
| 87 | 12.30704819 | 121.138254 | 0.03 | 0 | -0.03 | | 25-Year |
| 88 | 12.30837591 | 121.1497059 | 0.03 | 0 | -0.03 | | 25-Year |

| Point Number | Validation Coordinates | | Model Var (m) | Validation Points (m) | Error | Event/Date | Rain Return / Scenario |
|---|---|---|---|---|---|---|---|
| | Lat | Long | | | | | |
| 89 | 12.30836425 | 121.1429956 | 0.03 | 0 | -0.03 | | 25-Year |
| 90 | 12.3083822 | 121.1356902 | 0.03 | 0 | -0.03 | | 25-Year |
| 91 | 12.30873982 | 121.1426897 | 0.036 | 0 | -0.036 | | 25-Year |
| 92 | 12.30887093 | 121.1437328 | 0.031 | 0 | -0.031 | | 25-Year |
| 93 | 12.30920466 | 121.1340459 | 0.03 | 0 | -0.03 | | 25-Year |
| 94 | 12.30931966 | 121.1494876 | 0.031 | 0 | -0.031 | | 25-Year |
| 95 | 12.30972792 | 121.1433471 | 0.031 | 0 | -0.031 | | 25-Year |
| 96 | 12.30992565 | 121.147753 | 0.055 | 0 | -0.055 | | 25-Year |
| 97 | 12.31063205 | 121.1464339 | 0.03 | 0 | -0.03 | | 25-Year |
| 98 | 12.31175295 | 121.144631 | 0.03 | 0 | -0.03 | | 25-Year |
| 99 | 12.31194925 | 121.1460993 | 0.03 | 0 | -0.03 | | 25-Year |
| 100 | 12.31682036 | 121.1464441 | 0.03 | 0 | -0.03 | | 25-Year |
| 101 | 12.31818137 | 121.1463399 | 0.03 | 0 | -0.03 | | 25-Year |
| 102 | 12.31878966 | 121.1488838 | 0.03 | 0 | -0.03 | | 25-Year |
| 103 | 12.31892575 | 121.1478403 | 0.03 | 0 | -0.03 | | 25-Year |
| 104 | 12.31937536 | 121.1462643 | 0.03 | 0 | -0.03 | | 25-Year |
| 105 | 12.31981115 | 121.1493826 | 0.03 | 0 | -0.03 | | 25-Year |
| 106 | 12.3212637 | 121.1460699 | 0.031 | 0 | -0.031 | | 25-Year |
| 107 | 12.32141748 | 121.1501692 | 0.03 | 0 | -0.03 | | 25-Year |
| 108 | 12.3231649 | 121.1455786 | 0.03 | 0 | -0.03 | | 25-Year |
| 109 | 12.32450852 | 121.1466509 | 0.03 | 0 | -0.03 | | 25-Year |
| 110 | 12.32641608 | 121.1455303 | 0.031 | 0 | -0.031 | | 25-Year |
| 111 | 12.32794347 | 121.1446483 | 0.03 | 0 | -0.03 | | 25-Year |
| 112 | 12.33484516 | 121.1403739 | 0.631 | 0 | -0.631 | | 25-Year |
| 113 | 12.33541404 | 121.1384496 | 0.03 | 0 | -0.03 | | 25-Year |
| 114 | 12.33617703 | 121.1377899 | 0.066 | 0 | -0.066 | | 25-Year |
| 115 | 12.337552 | 121.17735 | 2.251 | 0.6 | -1.651 | | 25-Year |
| 116 | 12.3375274 | 121.137022 | 0.03 | 0 | -0.03 | Yolanda / Nov. 2013 | 25-Year |
| 117 | 12.337885 | 121.17717 | 1.372 | 0.5 | -0.872 | | 25-Year |
| 118 | 12.3382249 | 121.1352883 | 0.03 | 0 | -0.03 | Undang / 1984 | 25-Year |
| 119 | 12.33915982 | 121.1346933 | 0.078 | 0 | -0.078 | | 25-Year |
| 120 | 12.339481 | 121.17681 | 0.03 | 0 | -0.03 | | 25-Year |
| 121 | 12.33981626 | 121.1342148 | 0.03 | 0 | -0.03 | | 25-Year |
| 122 | 12.34130204 | 121.1338624 | 0.035 | 0 | -0.035 | | 25-Year |
| 123 | 12.34160143 | 121.155423 | 0.03 | 0 | -0.03 | | 25-Year |
| 124 | 12.342589 | 121.133367 | 0.036 | 0 | -0.036 | | 25-Year |
| 125 | 12.343543 | 121.17839 | 0.03 | 0 | -0.03 | | 25-Year |
| 126 | 12.34345954 | 121.133481 | 0.146 | 0 | -0.146 | | 25-Year |
| 127 | 12.344377 | 121.1331039 | 0.03 | 0 | -0.03 | | 25-Year |
| 128 | 12.34475837 | 121.1326007 | 0.089 | 0 | -0.089 | | 25-Year |

| Point Number | Validation Coordinates | | Model Var (m) | Validation Points (m) | Error | Event/Date | Rain Return / Scenario |
|---|---|---|---|---|---|---|---|
| | Lat | Long | | | | | |
| 129 | 12.34692781 | 121.133061 | 0.288 | 0 | -0.288 | | 25-Year |
| 130 | 12.34747038 | 121.1319442 | 0.607 | 0 | -0.607 | | 25-Year |
| 131 | 12.34827659 | 121.1310979 | 0.467 | 0 | -0.467 | | 25-Year |
| 132 | 12.35144908 | 121.1298895 | 0.052 | 0 | -0.052 | | 25-Year |
| 133 | 12.3522015 | 121.1301683 | 0.284 | 0 | -0.284 | | 25-Year |
| 134 | 12.35250501 | 121.1270408 | 0.03 | 0 | -0.03 | | 25-Year |
| 135 | 12.35412972 | 121.1264919 | 0.031 | 0 | -0.031 | | 25-Year |
| 136 | 12.35536653 | 121.1252275 | 0.03 | 0 | -0.03 | | 25-Year |

# Annex 12. Phil-LiDAR 1 UPLB Team Composition

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