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

# LiDAR Surveys and Flood Mapping of Bongabong River

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

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| | |
|---|---|
| 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 |
| NAMRIA | National Mapping and Resource Information Authority |
| NSTC | Northern Subtropical Convergence |
| PAF | Philippine Air Force |
| PAGASA | Philippine Atmospheric Geophysical and Astronomical Services Administration |
| PDOP | Positional Dilution of Precision |
| PPK | Post-Processed Kinematic [technique] |
| PRF | Pulse Repetition Frequency |
| PTM | Philippine Transverse Mercator |
| QC | Quality Check |
| QT | Quick Terrain [Modeler] |
| RA | Research Associate |
| RIDF | Rainfall-Intensity-Duration-Frequency |
| RMSE | Root Mean Square Error |
| SAR | Synthetic Aperture Radar |
| SCS | Soil Conservation Service |
| SRTM | Shuttle Radar Topography Mission |
| SRS | Science Research Specialist |
| SSG | Special Service Group |
| TBC | Thermal Barrier Coatings |
| UPLB | University of the Philippines Los Baños |
| 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 BONGABONG RIVER

*Enrico C. Paringit, Dr. Eng., Prof. Edwin R. Abucay, and Asst. Prof. Joan Pauline P. Talubo*

## 1.1 Background of the Phil-LIDAR 1 Program

The University of the Philippines Training Center for Applied Geodesy and Photogrammetry (UP-TCAGP) launched a research program in 2014 entitled “Nationwide Hazard Mapping using LiDAR” or Phil-LiDAR 1, supported by the Department of Science and Technology (DOST) 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 methods applied in this report are thoroughly described in a separate publication entitled “FLOOD MAPPING OF RIVERS IN THE PHILIPPINES USING AIRBORNE LIDAR: METHODS” (Paringit, et. Al. 2017).

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 MIMAROPA Region. The university is located in Los Baños in the province of Laguna.

## 1.2 Overview of the Bongabong River Basin

Bongabong River Basin that encompasses the Municipality of Bongabong is located in the Southeastern part of Oriental Mindoro as shown in Figure C-1. The basin has a catchment area of 396 km2 according to DENR River Basin Control Office (DENR-RBCO, 2015). It is recorded to have a total population of 62,271 people based on the 2010 census of National Statistics Office.

Its main stem, Bongabong River, is part of the 45 river systems in Southern Luzon under the PHIL-LiDAR partner HEI, the University of the Philippines Los Baños. The delineated extent of the Bongabong River channel has an estimated length of 22.7 km starting from Brgy. Lasan to the boundary of Bongabong River and Tablas Strait. It is bounded by Brgy. Formon to the North; by Tablas Strait to the East; by Brgy. Lisap to the West; by Brgy. San Vicente to the South. The vicinity along Bongabong River reflects medium to high susceptibility of flooding according to the 2012 Mines and Geosciences Bureau (MGB)'s hazard maps. Recent flooding event occurred last December 9, 2014 caused by Typhoon Ruby which also led families to evacuate from their communities.

Climate Type I and III prevails in MIMAROPA and Laguna 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.

Bongabong River Basin is a 45,000-hectare watershed located in Oriental Mindoro. It covers the barangays of Ligaya, Malisbong, San Agustin and Tuban in Sablayan municipality; Conrazon, Malo, Manihala and Rosacara in Bansud; Anilao, Batangan, Formon, Hagan, Hagupit, Lisap, Luna, Malitbog, Mapang, Masaguisi, Mina de Oro, Morente, San Isidro, San Jose, San Juan, Sigange and Tawas in Bongabong; Macario Adriatico, Manguyang and Mirayan in Gloria; and, Bonbon and San Vicente in Mansalay and Roxas, respectively. The basin area has twelve geological classifications including Basement Complex, Recent, Upper Miocene-Pliocene, Oligocene-Miocene, Cretaceous-Paleogene, Paleocene-Eocene, Oligocene, Jurrasic, Pliocene-Pleistocene and Neogene. Moreover, the river basin is generally characterized by 30-50% slope and elevation of 500-750 meters above mean sea level. Bongabong River Basin is also characterized by six soil types including Maranlig gravelly sandy clay loam, Buguay loamy sand, San Manuel silt/silt Loam, Maranlig loam, San Manuel sandy loam and Cabangan sandy loam. On the other hand, about ten land cover types exists in the area including open forest, annual crop, built-up, grassland, mangrove forest, open/barren, perennial crop, shrubs and wooded grassland.

Bongabong River passes through Ligaya, Malisbong, San Agustin and Tuban in Sablayan; Conrazon, Malo, Manihala and Rosacara in Bansud; Anilao, Batangan, Formon, Hagan, Hagupit, Lisap, Luna, Malitbog, Mapang, Masaguisi, Mina de Oro, Morente, San Isidro, San Jose, San Juan, Sigange and Tawas in Bongabong; Macario Adriatico, Manguyan and Mirayan in Gloria; and, Bonbon and San Vicente in Mansalay and Roxas, respectively. As recorded in the 2010 NSO Census of Population and Housing, among the barangays in Sablayan, Ligaya is the most populated, Conrazon in Bansud, and Lisap in Bongabong.

According to the Mines and Geoscience Bureau, the barangays at high-risk during landslides are in Sablayan, Bansud, Gloria, Mansalay and Roxas; Batangan, Formon, Hagan, Lisap, Malitbog, Masaguisi, San-Juan, Sigange and Tawas in Bongabong. Based on the field surveys conducted by the PHIL-LiDAR 1 validation team, there were eight notable weather disturbance that caused flooding in 1993 (Monang and Manny), 2009 (Ondoy), 2013 (Yolanda), 2015 (Nona), and 2016 (Nina).

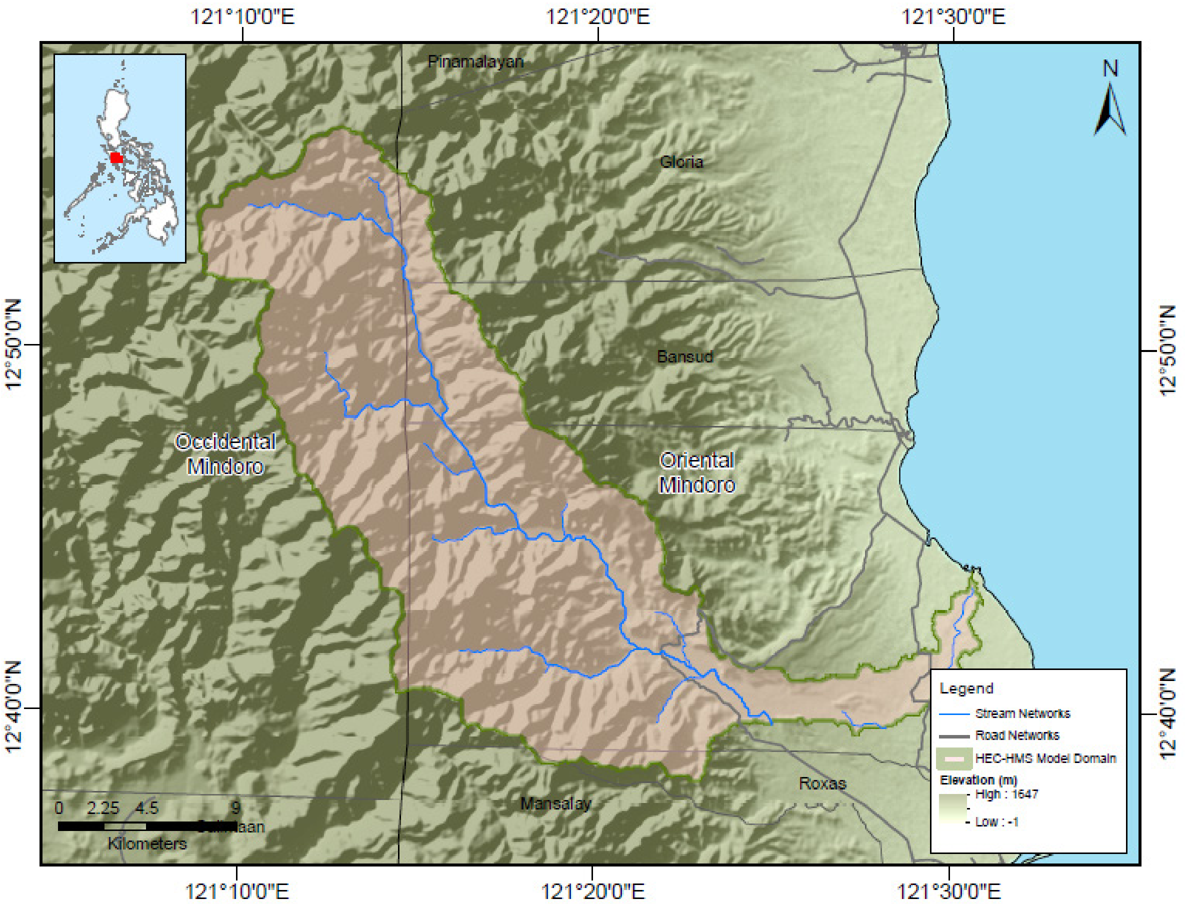


Figure 1. Map of the Bongabong River Basin (in brown)

# CHAPTER 2: LIDAR DATA ACQUISITION OF THE BONGABONG 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 Bongabong Floodplain in Oriental Mindoro. These missions were planned for 21 lines that run for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR system is found in Table 1 and Table 2. Figure 2 shows the flight plan for Bongabong Floodplain.

Table 1. Flight planning parameters for Aquarius LiDAR system.

| Block Name | Flying Height (m AGL) | Overlap (%) | Max. Field of View(θ) | Pulse Rate Frequency (PRF) (kHz) | Scan Frequency (Hz) | Average Speed (kts) | Average Turn Time (Minutes) |
|---|---|---|---|---|---|---|---|
| BLK 28A | 600 | 30 | 36 | 50 | 45 | 130 | 5 |
| BLK 28B | 600 | 30 | 36 | 50 | 45 | 130 | 5 |
| BLK 28D | 600 | 30 | 36 | 50 | 45 | 130 | 5 |
| BLK 28E | 600 | 30 | 36 | 50 | 45 | 130 | 5 |
| BLK 28F | 600 | 30 | 36 | 50 | 45 | 130 | 5 |
| BLK 28G | 600 | 30 | 36 | 50 | 45 | 130 | 5 |
| BLK 28H | 600 | 30 | 36 | 50 | 45 | 130 | 5 |
| BLK 28I | 600 | 30 | 36 | 50 | 45 | 130 | 5 |
| BLK 28J | 1000 | 30 | 36 | 50 | 45 | 130 | 5 |

Table 2. Flight planning parameters for Gemini LiDAR system.

| Block Name | Flying Height (m AGL) | Overlap (%) | Max. Field of View(θ) | Pulse Rate Frequency (PRF) (kHz) | Scan Frequency (Hz) | Average Speed (kts) | Average Turn Time (Minutes) |
|---|---|---|---|---|---|---|---|
| BLK 28E | 1200 | 30 | 30 | 100 | 50 | 130 | 5 |
| BLK 28F | 1200 | 30 | 30 | 100 | 50 | 130 | 5 |
| BLK 28H | 1000 | 30 | 40 | 100 | 50 | 130 | 5 |
| BLK 28I | 1200 | 30 | 30 | 100 | 50 | 130 | 5 |

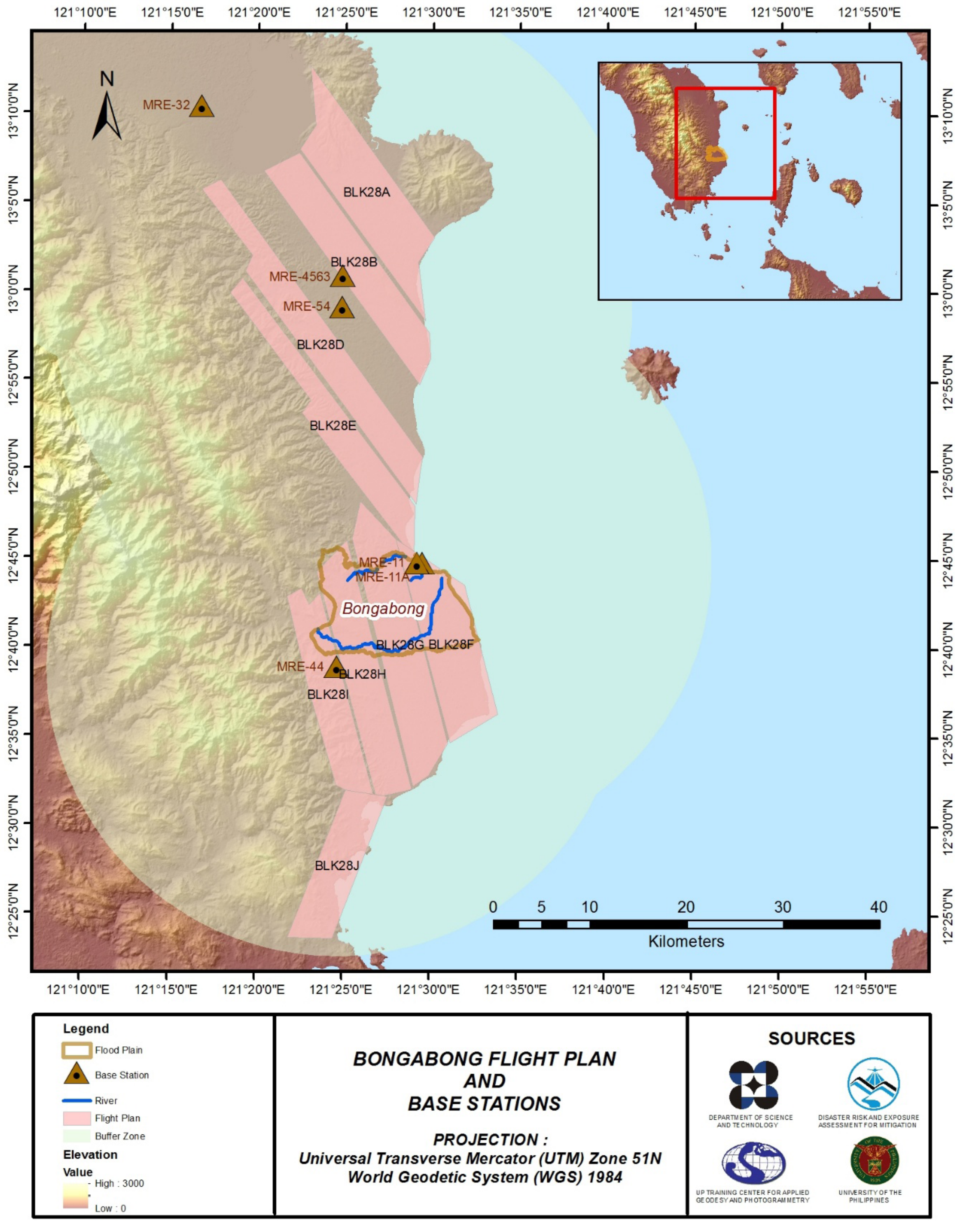
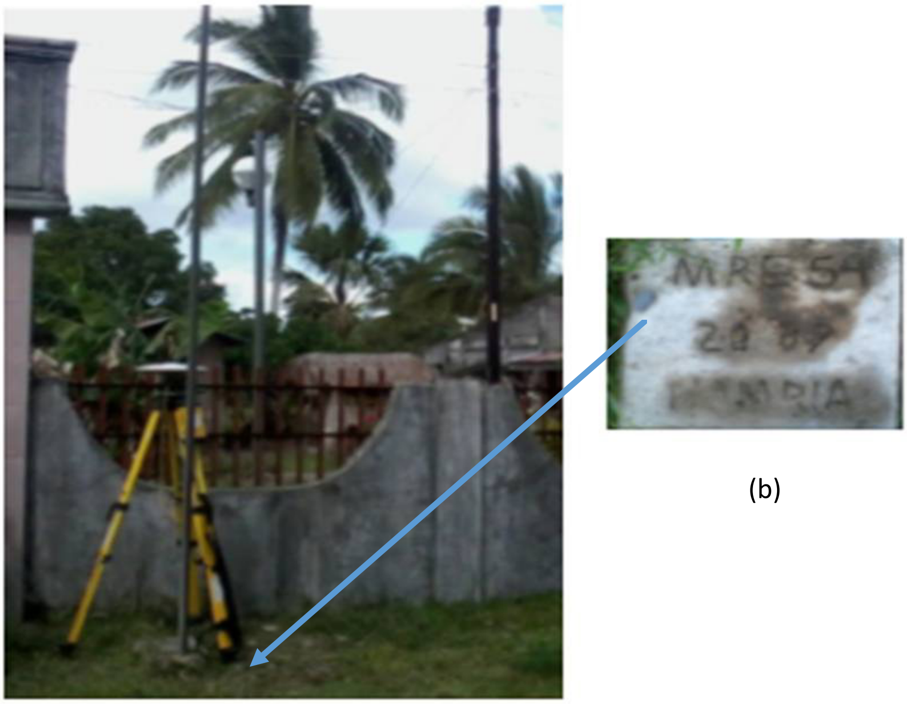



Figure 2. Flight plan and base stations used for Bongabong floodplain.

## 2.2 Ground Base Stations

The project team was able to recover three (3) NAMRIA ground control points: MRE-54, MRE-44, and MRE-32 which are of second (2nd) order accuracy. The project team also re-established ground control points MRE-11 which is of third (3rd) order accuracy, and MRE-4563 which is of fourth (4th) order accuracy. The project team also established one (1) ground control point MRE-11A. The certifications for the NAMRIA reference points are found in Annex 2 the while the baseline processing report for the established ground control point is found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey (February 6 - 15, 2014 and October 23 - 25, 2015). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and SPS 985. Flight plans and location of base stations used during the aerial LiDAR acquisition in Bongabong floodplain are shown in Figure 2.

Figure 3 to Figure 5 show the recovered NAMRIA reference points within the area. In addition, Table 3 to Table 8 show the details about the following NAMRIA control stations and established points while Table 9 shows the list of all ground control points occupied during the acquisition together with the dates the corresponding dates of utilization.



(b)

(a)

Figure 3. GPS set-up over MRE-54 as recovered inside the compound of the barangay hall of Maliangcog, municipality of Pinamalayan, Oriental Mindoro (a) and NAMRIA reference point MRE-54 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point MRE-54 used as base station for the LiDAR acquisition.

| Station Name | MRE-54 | |
|---|---|---|
| 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 | 12°59'12.43671'' North<br>121°24'46.52637'' East<br>42.40800 meters |
| Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92) | Easting<br>Northing | 544797.009 meters<br>1436124.562 meters |
| Geographic Coordinates World Geodetic System 1984 Datum (WGS 84) | Latitude<br>Longitude<br>Ellipsoidal Height | 12°59'7.43505'' North<br>122°41'8.09853'' East<br>91.39500 meters |
| Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N -PRS 1992) | Easting<br>Northing | 327864.09 meters<br>1436121.49 meters |

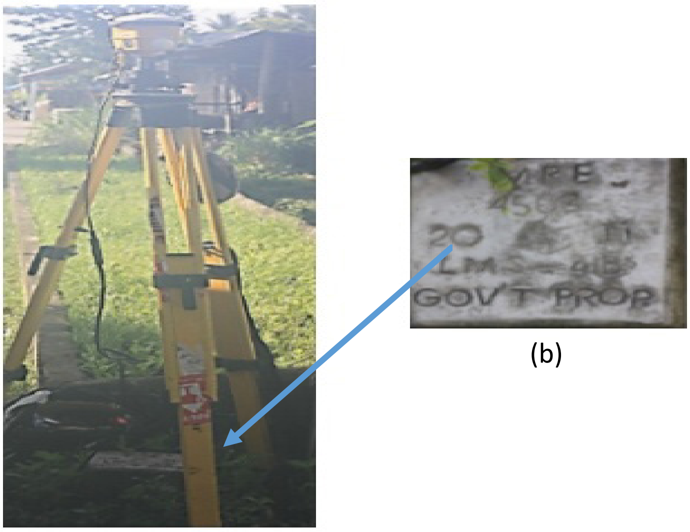
(a)


(b)

Figure 4. GPS set-up over MRE-44 as recovered just outside the compound of the barangay hall of Happy Valley, municipality of Roxas, Oriental Mindoro (a) NAMRIA reference point MRE-44 (b) as recovered by the field team.

Table 4. Details of the recovered NAMRIA horizontal control point MRE-44 used as base station for the LiDAR acquisition.

| Station Name | MRE-44 | |
|---|---|---|
| Order of Accuracy | 2nd | |
| Relative Error (horizontal positioning) | 1 in 50,000 | |
| Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92) | Latitude | 12°38’59.03778’’ North |
| | Longitude | 121°24’32.60444’’ East |
| | Ellipsoidal Height | 87.94200 meters |
| Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92) | Easting | 544436.519 meters |
| | Northing | 1398838.995 meters |
| Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84) | Latitude | 12°38’54.11733’’ North |
| | Longitude | 121°24’37.66392’’ East |
| | Ellipsoidal Height | 137.80400 meters |
| Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992) | Easting | 327214.81 meters |
| | Northing | 1398840.08 meters |




(b)

(a)

Figure 5. GPS set-up over MRE-4563 as recovered, just outside the compound of the barangay hall of Brgy. Pagala-gala, municipality of Pinamalayan, Oriental Mindoro (a) and NAMRIA reference point MRE-4563 (b) as recovered by the field team.

Table 5. Details of the recovered NAMRIA horizontal control point MRE-4563 used as base station for the LiDAR acquisition with reprocessed coordinates.

| Station Name | MRE-4563 | |
|---|---|---|
| Order of Accuracy | 2nd | |
| Relative Error (horizontal positioning) | 1:50,000 | |
| Grid Coordinates, World Geodetic System 1984 Datum (WGS 84) | Latitude | 13°00’53.01692’’ North |
| | Longitude | 121°24’51.45337’’ East |
| | Ellipsoidal Height | 73.715 meters |
| Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992) | Easting | 328034.015 meters |
| | Northing | 1439300.319 meters |

Table 6. Details of the recovered NAMRIA horizontal control point MRE-32 used as base station for the LiDAR acquisition.

| Station Name | MRE-32 | |
|---|---|---|
| Order of Accuracy | 2nd | |
| Relative Error (horizontal positioning) | 1 in 50,000 | |
| Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92) | Latitude | 13°10’28.85064’’ North |
| | Longitude | 121°16’38.44761’’ East |
| | Ellipsoidal Height | 19.49300 meters |
| Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92) | Easting | 530065.679 meters |
| | Northing | 1456889.419 meters |
| Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84) | Latitude | 13°10’23.79251’’ North |
| | Longitude | 121°16’43.46244’’ East |
| | Ellipsoidal Height | 67.64700 meters |
| Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992) | Easting | 313296.85 meters |
| | Northing | 1457002.75 meters |

Table 7. Details of the recovered NAMRIA horizontal control point MRE-11 used as base station for the LiDAR acquisition.

| Station Name | MRE-11 | |
|---|---|---|
| Order of Accuracy | 3rd | |
| Relative Error (horizontal positioning) | 1 in 20,000 | |
| Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92) | Latitude | 12°44’50.41380’’ North |
| | Longitude | 121°29’7.80130’’ East |
| | Ellipsoidal Height | 5.11500 meters |
| Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92) | Easting | 552720.766 meters |
| | Northing | 1409650.153 meters |
| Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84) | Latitude | 12°44’45.47630’’ North |
| | Longitude | 121°29’12.85191’’ East |
| | Ellipsoidal Height | 54.91100 meters |
| Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992) | Easting | 335581.55 meters |
| | Northing | 1409587.05 meters |

Table 8. Details of the established horizontal control point MRE-11A used as base station for the LiDAR acquisition.

| Station Name | MRE-11A | |
|---|---|---|
| Order of Accuracy | 3rd | |
| Relative Error (horizontal positioning) | 1:20,000 | |
| Grid Coordinates, World Geodetic System 1984 Datum (WGS 84) | Latitude | 12°44’45.50783’’ North |
| | Longitude | 121°29’29.79714’’ East |
| | Ellipsoidal Height | 55.558 m |
| Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N -PRS 1992) | Easting | 338880.152 meters |
| | Northing | 1409583.946 meters |

Table 9. Ground control points used during LiDAR data acquisition

| Date Surveyed | Flight Number | Mission Name | Ground Control Points |
|---|---|---|---|
| 6-Feb-14 | 1070A | 3BLK28DSE037A | MRE-54, MRE-4563 |
| 7-Feb-14 | 1072A | 3BLK28F038A | MRE-44 |
| 7-Feb-14 | 1074A | 3BLK28FSG038B | MRE-44 |
| 8-Feb-14 | 1076A | 3BLK28G039A | MRE-44 |
| 8-Feb-14 | 1078A | 3BLK28GSH039B | MRE-44 |
| 11-Feb-14 | 1088A | 3BLK28HS042A | MRE-44 |
| 11-Feb-14 | 1090A | 3BLK28J042B | MRE-44 |
| 12-Feb-14 | 1092A | 3BLK28ABES043A | MRE-54, MRE-4563 |
| 13-Feb-14 | 1098A | 3BLK28JSI044B | MRE-44, MRE-32 |
| 15-Feb-14 | 1104A | 3BLK28JSI046A | MRE-44 |
| 23-Oct-15 | 8302G | 2BLK28ASEHI296A | MRE-54, MRE-11 |
| 24-Oct-15 | 8304G | 2BLK28FHS297A | MRE-54, MRE-11 |
| 25-Oct-15 | 8306G | 2CALIBBLK28FSGS298A | MRE-11, MRE11A |

## 2.3 Flight Missions

Thirteen (13) missions were conducted to complete the LiDAR Data Acquisition in Bongabong floodplain, for a total of fifty hours (50+00) of flying time for RP-C9122 and RP-C9322. All missions were acquired using the Aquarius and Gemini LiDAR systems. Table 10 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 11 presents the actual parameters used during the LiDAR data acquisition.

Table 10. Flight missions for LiDAR data acquisition in Bongabong floodplain.

| Date Surveyed | Flight Number | Flight Plan Area ($km^2$) | Surveyed Area ($km^2$) | Area Surveyed within the Floodplain ($km^2$) | Area Surveyed Outside the Floodplain ($km^2$) | No. of Images (Frames) | Flying Hours | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Hr | Min |
| 6-Feb-14 | 1070A | 204.55 | 134.14 | 0.69 | 133.45 | 1517 | 4 | 29 |
| 7-Feb-14 | 1072A | 100.27 | 106.58 | 42.63 | 63.95 | 1143 | 4 | 23 |
| 7-Feb-14 | 1074A | 218.60 | 53.87 | 17.15 | 36.72 | 538 | 3 | 5 |
| 8-Feb-14 | 1076A | 118.33 | 100.75 | 32.25 | 68.50 | 1041 | 4 | 5 |
| 8-Feb-14 | 1078A | 215.35 | 68.06 | 22.76 | 45.30 | 869 | 3 | 29 |
| 11-Feb-14 | 1088A | 97.02 | 90.59 | 30.09 | 60.5 | 1235 | 4 | 29 |
| 11-Feb-14 | 1090A | 69.40 | 28.77 | NA | 28.77 | 319 | 2 | 47 |
| 12-Feb-14 | 1092A | 308.50 | 99.90 | NA | 99.90 | 1176 | 4 | 5 |
| 13-Feb-14 | 1098A | 103.26 | 76.86 | 5.57 | 71.29 | 909 | 3 | 59 |
| 15-Feb-14 | 1104A | 144.96 | 125.50 | 0.64 | 124.86 | 771 | 4 | 41 |
| 23-Oct-15 | 8302G | 144.96 | 117.20 | 22.21 | 94.99 | 444 | 3 | 37 |
| 24-Oct-15 | 8304G | 259.93 | 110.37 | 31.93 | 78.44 | 368 | 3 | 20 |
| 25-Oct-15 | 8306G | 197.29 | 70.58 | 11.50 | 59.08 | NA | 3 | 31 |
| TOTAL | | 2182.42 | 1183.17 | 217.42 | 965.75 | 10330 | 50 | 00 |

Table 11. Actual parameters used during LiDAR data acquisition

| Flight Number | Flying Height (m AGL) | Overlap (%) | FOV (θ) | PRF (kHz) | Scan Frequency (Hz) | Average Speed (kts) | Average Turn Time (Minutes) |
|---|---|---|---|---|---|---|---|
| 1070A | 600 | 30 | 36 | 50 | 40 | 130 | 5 |
| 1072A | 600 | 30 | 36 | 50 | 50, 40 | 130 | 5 |
| 1074A | 600 | 30 | 36 | 50 | 50 | 130 | 5 |
| 1076A | 600 | 30 | 36 | 50 | 50 | 130 | 5 |
| 1078A | 600, 1000 | 30 | 36, 30, 20 | 50, 70 | 50 | 130 | 5 |
| 1088A | 600 | 30 | 36 | 50 | 50 | 130 | 5 |
| 1090A | 600 | 30 | 36 | 50 | 50 | 130 | 5 |
| 1092A | 600 | 30 | 36 | 50 | 40 | 130 | 5 |
| 1098A | 600 | 30 | 36 | 50 | 40, 50 | 130 | 5 |
| 1104A | 600, 1000 | 30 | 36, 30 | 50, 30, 40 | 50 | 130 | 5 |
| 8302G | 1200, 800 | 30 | 30, 40 | 100 | 50 | 130 | 5 |
| 8304G | 1200, 900 | 35 | 30, 36 | 100 | 50 | 130 | 5 |
| 8306G | 1200, 900 | 35 | 30, 40 | 100 | 50 | 130 | 5 |

## 2.4 Survey Coverage

Bongabong floodplain is located in the province of Oriental Mindoro, with majority of the floodplain situated within the municipality of Bongabong. Municipalities of Bongabong and Roxas are mostly covered by the survey. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 12. The actual coverage of the LiDAR acquisition for Bongabong floodplain is presented in Figure 6.

Table 12. List of municipalities and cities surveyed during Bongabong floodplain LiDAR survey.

| Province | Municipality/ City | Area of Municipality/City ($km^2$) | Total Area Surveyed ($km^2$) | Percentage of Area Surveyed |
|---|---|---|---|---|
| Oriental Mindoro | Roxas | 90.14 | 79.78 | 88% |
| | Bongabong | 493.74 | 270.98 | 55% |
| | Bansud | 197 | 83.33 | 42% |
| | Gloria | 327.28 | 127.86 | 39% |
| | Pola | 127.04 | 38.21 | 30% |
| | Mansalay | 477.24 | 130.61 | 27% |
| | Pinamalayan | 206.87 | 52.8 | 26% |
| | Socorro | 206.05 | 35.25 | 17% |
| | Bulalacao | 365.58 | 40.39 | 11% |
| | Naujan | 431.57 | 3.69 | 1% |
| | Victoria | 216.22 | 1.03 | 0% |
| TOTAL | | 3138.73 | 863.93 | 27.52% |

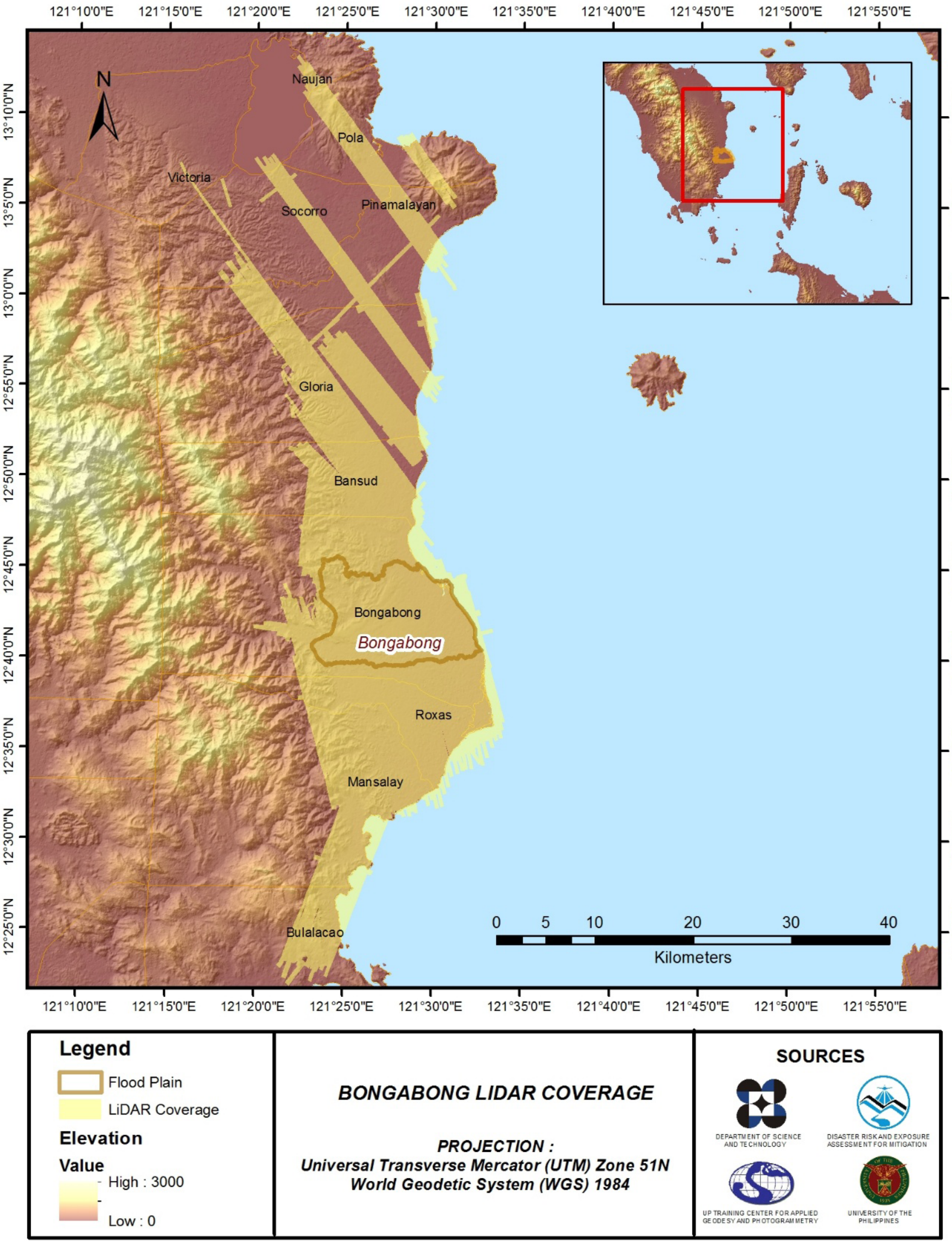



Figure 6. Actual LiDAR survey coverage for Bongabong floodplain.

# CHAPTER 3: LIDAR DATA PROCESSING FOR BONGABONG 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 LiDAR Data Processing for Bongabong Floodplain

### 3.1.1 Overview of the LiDAR Date 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 7.

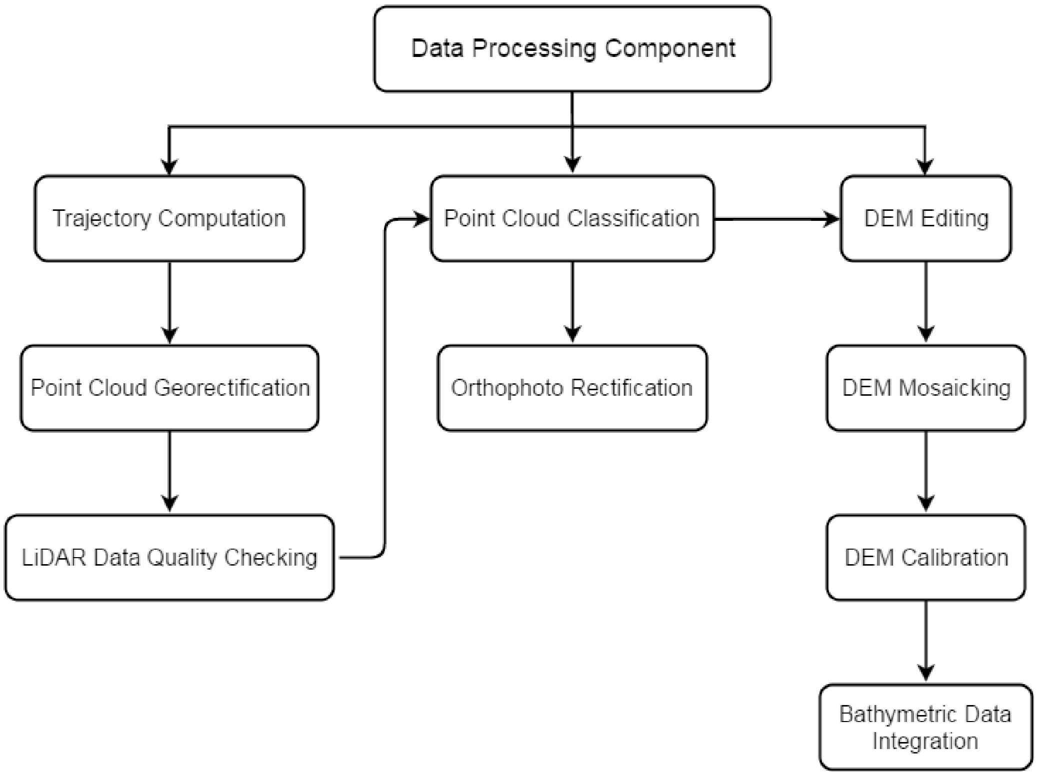


Figure 7. Schematic Diagram for Data Pre-Processing Component

## 3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Bongabong floodplain can be found in Annex 5. Missions flown during the first survey conducted on February 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Aquarius system while missions acquired during the second survey on October 2015 were flown using the Gemini system over Bongabong, Oriental Mindoro. The Data Acquisition Component (DAC) transferred a total of 136.27 Gigabytes of Range data, 2.664 Gigabytes of POS data, 152.95 Megabytes of GPS base station data, and 585.9 Gigabytes of raw image data to the data server on February 21, 2014 for the first survey and November 12, 2015 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Bongabong was fully transferred on November 12, 2015, as indicated on the Annex 5: Data Transfer Sheets for Bongabong floodplain.

## 3.3 Trajectory Computation

The *Smoothed Performance Metrics* of the computed trajectory for flight 1078A, one of the Bongabong flights, which is the North, East, and Down position RMSE values are shown in Figure 8. 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 February 8, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

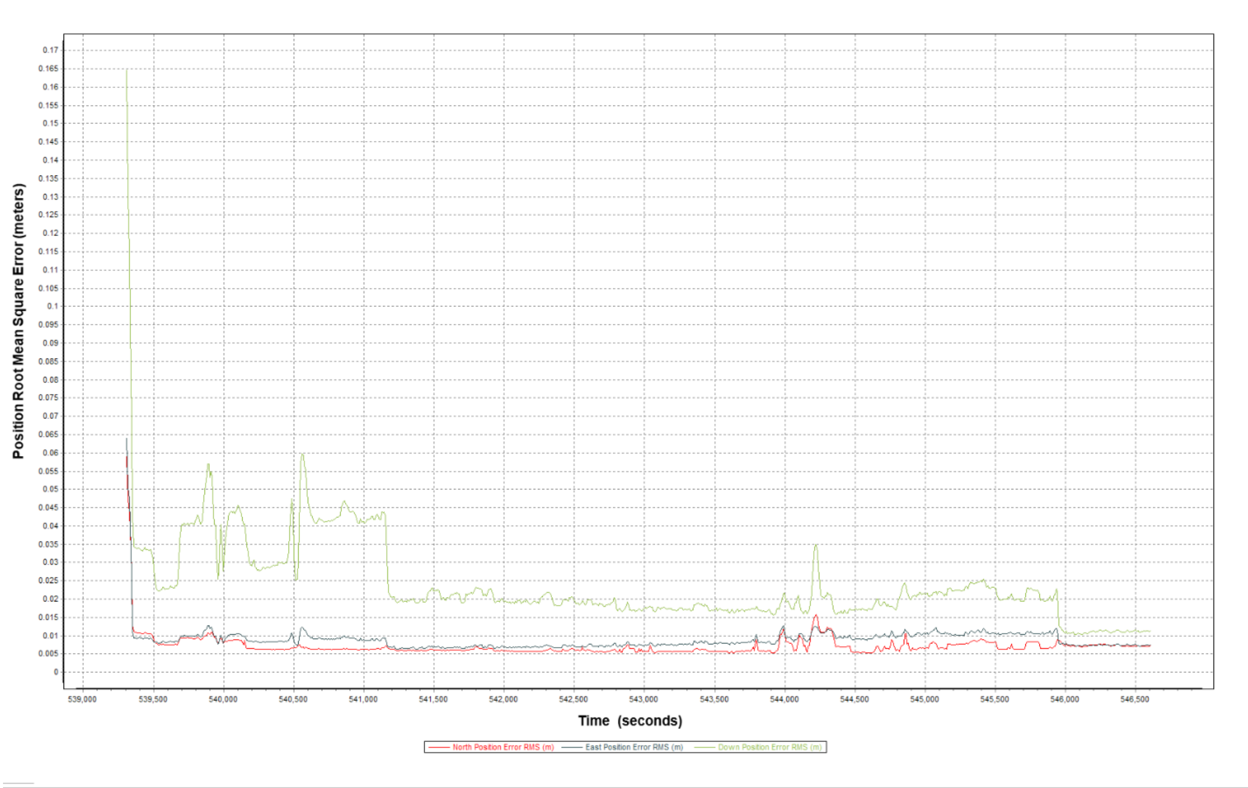


Figure 8. Smoothed Performance Metric Parameters of a Bongabong Flight 1078A.

The time of flight was from 539250 seconds to 546250 seconds, which corresponds to afternoon of February 8, 2014. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 8 shows that the North position RMSE peaks at 1.51 centimeters, the East position RMSE peaks at 1.30 centimeters, and the Down position RMSE peaks at 3.50 centimeters, which are within the prescribed accuracies described in the methodology.

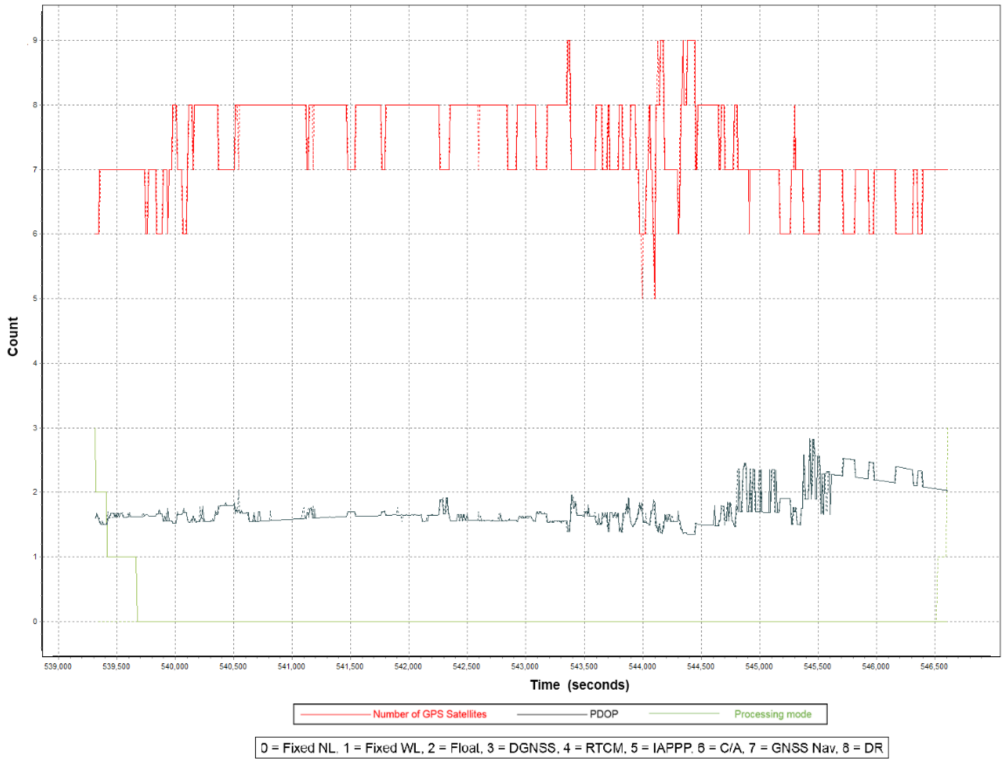


Figure 9. Solution Status Parameters of Bongabong Flight 1078A.

The *Solution Status* parameters of flight 1078A, one of the Bongabong flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 9. 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 Bongabong flights is shown in Figure 10.

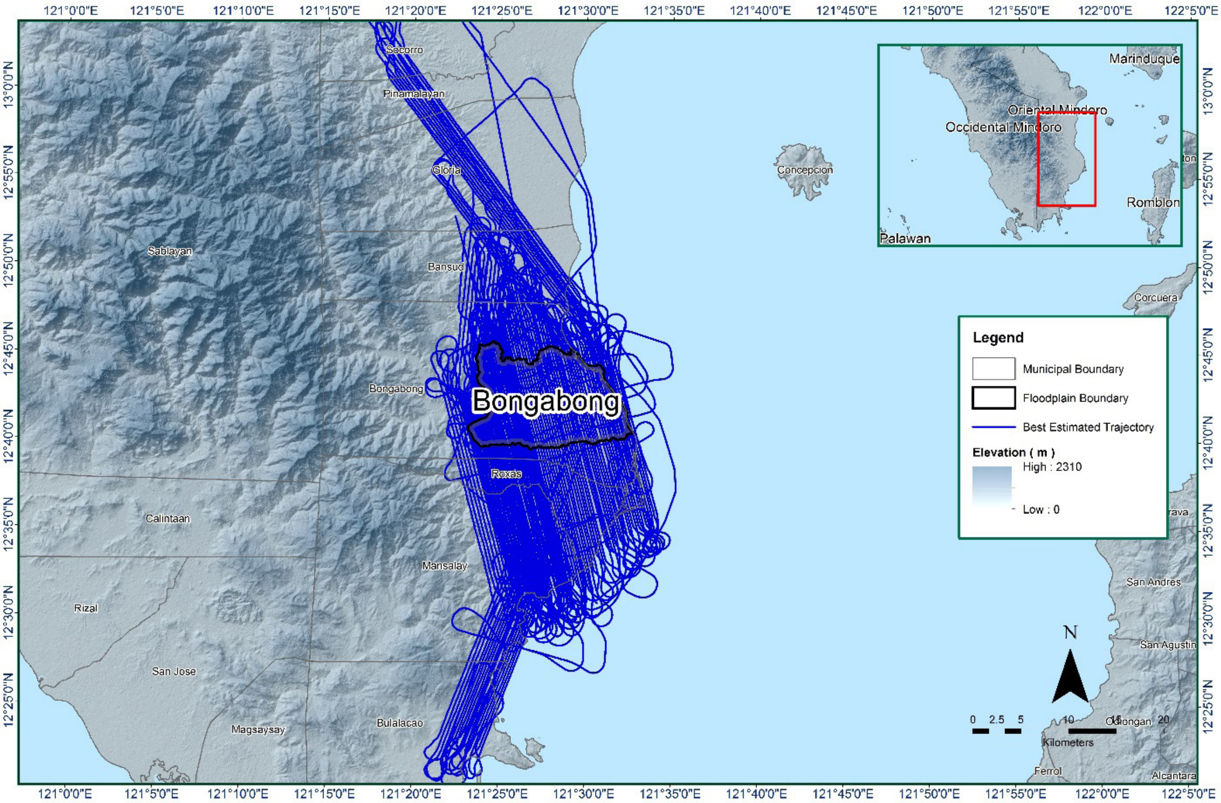


Figure 10. The best estimated trajectory of the LiDAR missions conducted over the Bongabong floodplain.

## 3.4 LiDAR Point Cloud Computation

The produced LAS data contains 153 flight lines, with each flight line containing one channel, since the Gemini and Aquarius systems both contain one channel only. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Bongabong floodplain are given in Table 13.

Table 13. Self-Calibration Results values for Bongabong flights.

| Parameter | Absolute Value | Computed Value |
|---|---|---|
| Boresight Correction stdev | (<0.001degrees) | 0.000220 |
| IMU Attitude Correction Roll and Pitch Corrections stdev | (<0.001degrees) | 0.000962 |
| GPS Position Z-correction stdev | (<0.01meters) | 0.0037 |

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

## 3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Bongabong Floodplain is shown in Figure 11. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

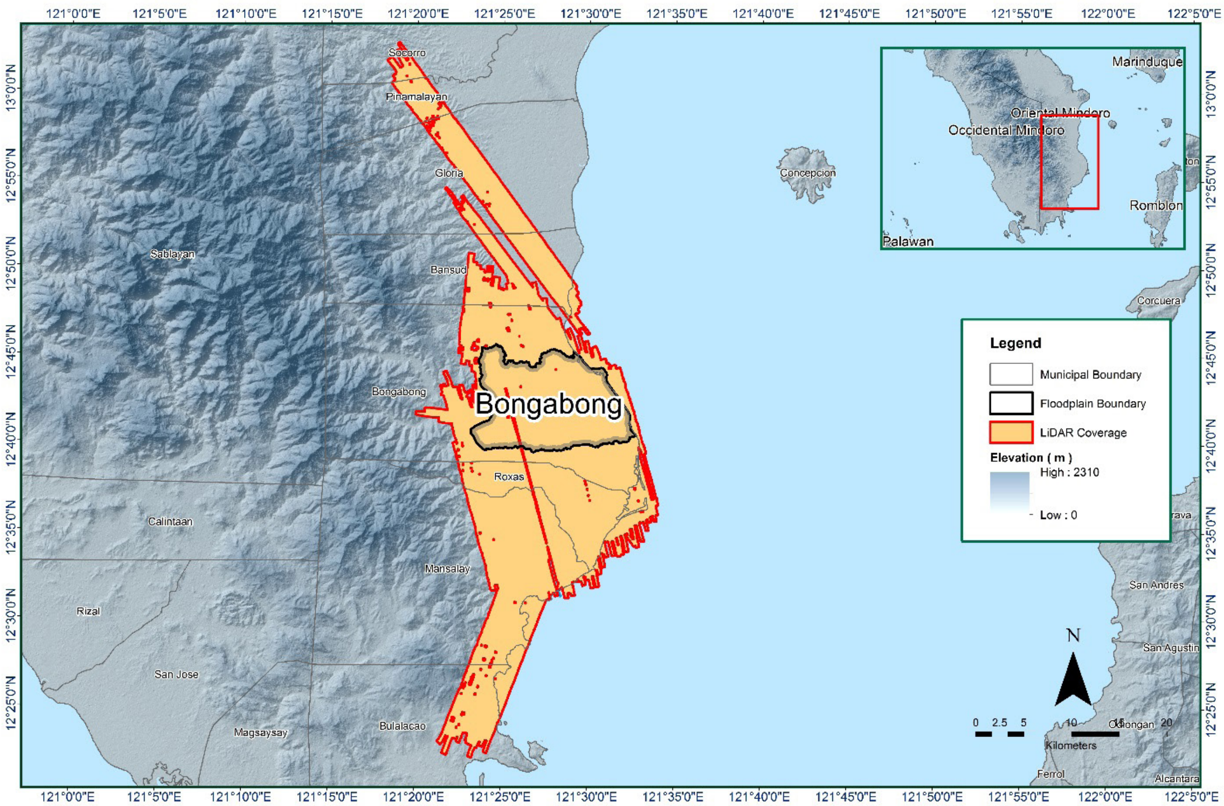


Figure 11. Boundary of the processed LiDAR data over Bongabong Floodplain

The total area covered by the Bongabong missions is 776.62 sq.km that is comprised of twelve (12) flight acquisitions grouped and merged into eleven (11) blocks as shown in Table 14

Table 14. List of LiDAR blocks for Bongabong floodplain.

| LiDAR Blocks | Flight Numbers | Area (sq. km) |
|---|---|---|
| OrientalMindoro_Blk28E | 1070A | 125.84 |
| OrientalMindoro_Blk28F | 1072A | 124.61 |
| | 1074A | |
| OrientalMindoro_Blk28F_additional | 1072A | 12.70 |
| OrientalMindoro_Blk28G | 1076A | 95.35 |
| OrientalMindoro_Blk28G_supplementH | 1078A | 62.40 |
| OrientalMindoro_Blk28H_supplement | 1088A | 84.37 |
| OrientalMindoro_Blk28I | 1098A | 97.92 |
| | 1104A | |
| OrientalMindoro_Blk28J | 1090A | 92.85 |
| | 1098A | |
| | 1104A | |
| OrientalMindoro_reflights_Blk28F | 8302G | 23.25 |
| OrienalMindoro_reflights_Blk28H_supplement | 8304G | 51.60 |
| | 8306G | |
| OrientalMindoro_reflights_Blk28I_additional | 8306G | 5.73 |
| | **TOTAL** | **776.62 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 12. Since the Gemini and Aquarius systems both employ one channel, we would expect an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines.

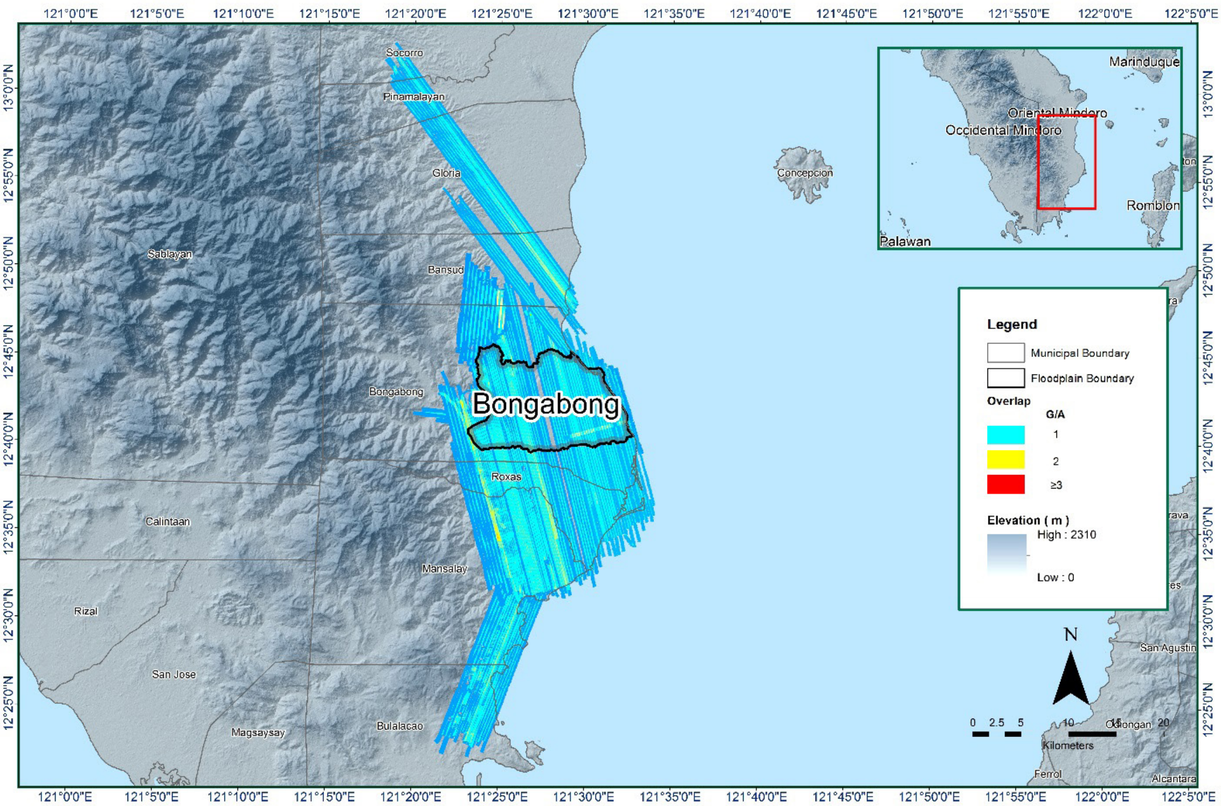


Figure 12. Image of data overlap for Bongabong floodplain.

The overlap statistics per block for the Bongabong 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 33.03% and 66.45% respectively, which passed the 25% requirement.

The density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 13. It was determined that all LiDAR data for Bongabong floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.42 points per square meter.

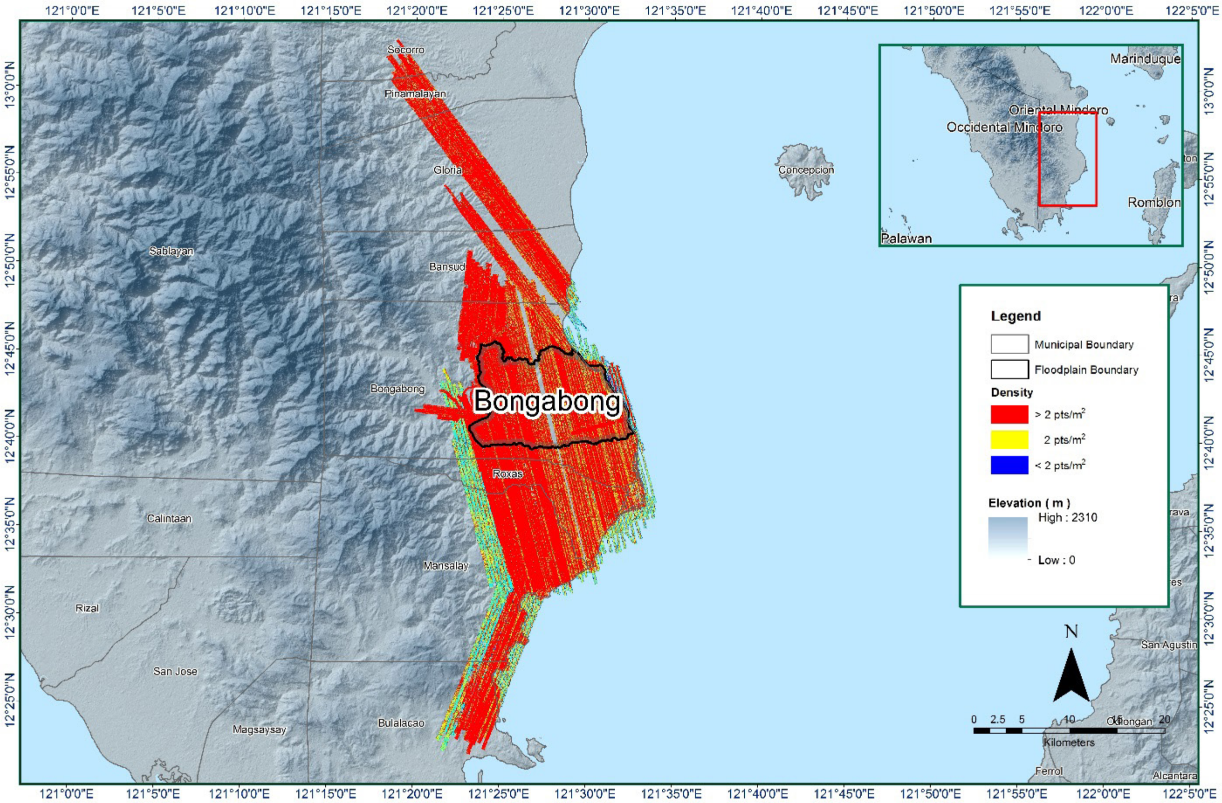


Figure 13. Density map of merged LiDAR data for Bongabong floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 14. 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.

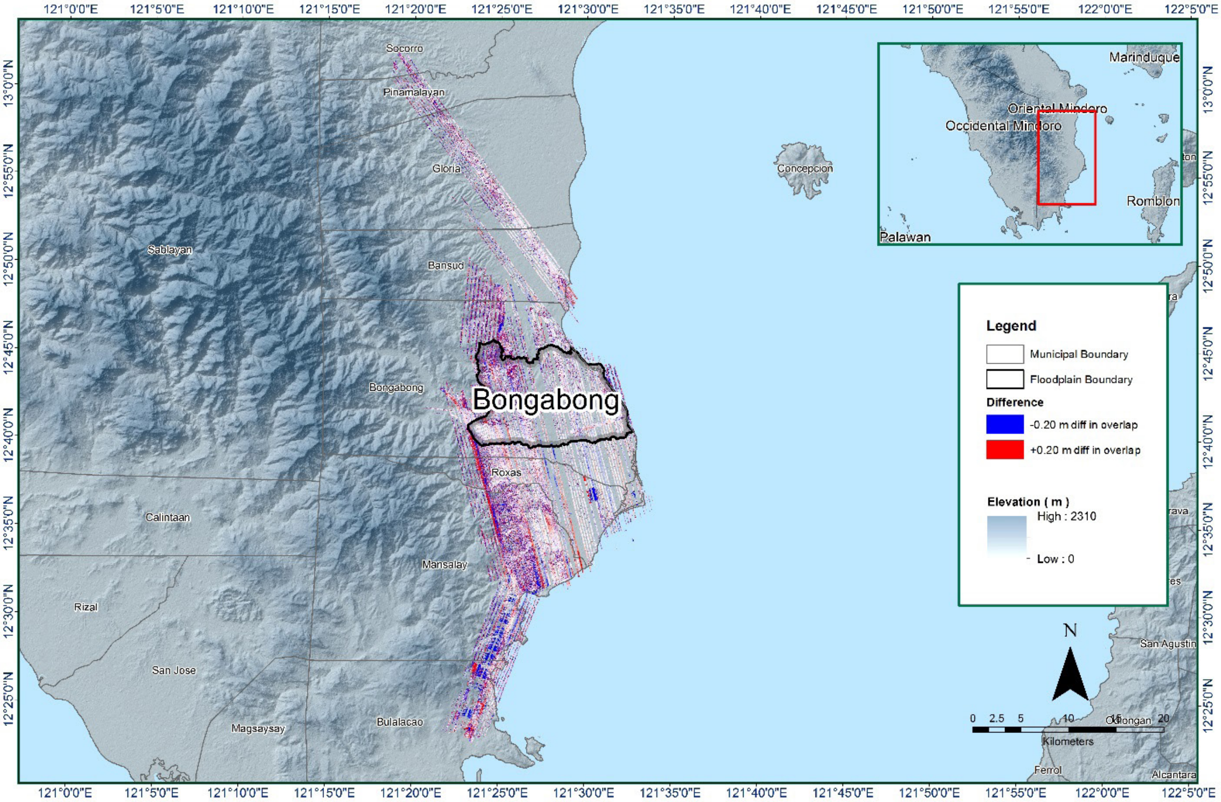


Figure 14. Elevation difference map between flight lines for Bongabong floodplain.

A screen capture of the processed LAS data from a Bongabong flight 1078A loaded in QT Modeler is shown in Figure 15. 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.

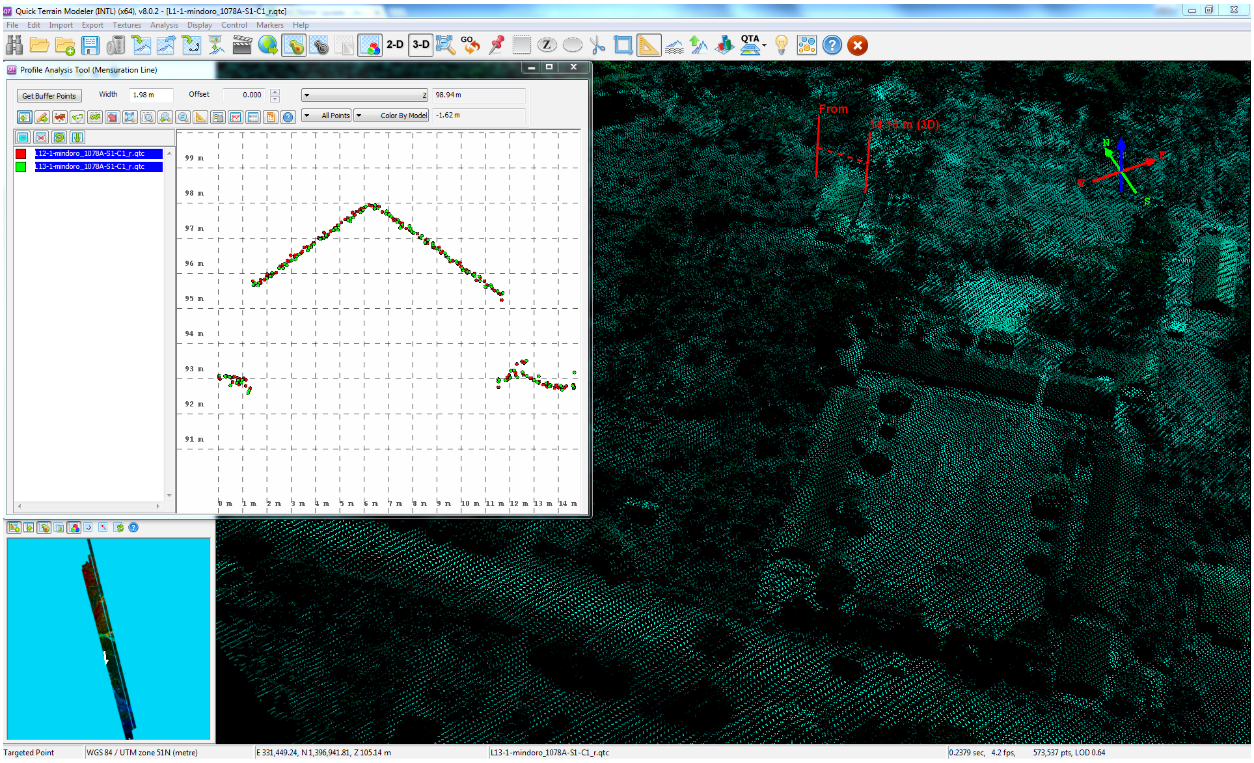

Figure 15. Quality checking for a Bongabong flight 1078A using the Profile Tool of QT Modeler.

## 3.6 LiDAR Point Cloud Classification and Rasterization

Table 15. Bongabong classification results in TerraScan.

| Pertinent Class | Total Number of Points |
|---|---|
| Ground | 505,025,141 |
| Low Vegetation | 562,415,876 |
| Medium Vegetation | 558,547,228 |
| High Vegetation | 593,014,797 |
| Building | 21,576,597 |

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Bongabong floodplain is shown in Figure 16. A total of 1,158 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 15. The point cloud has a maximum and minimum height of 570.88 meters and 31.32 meters respectively.

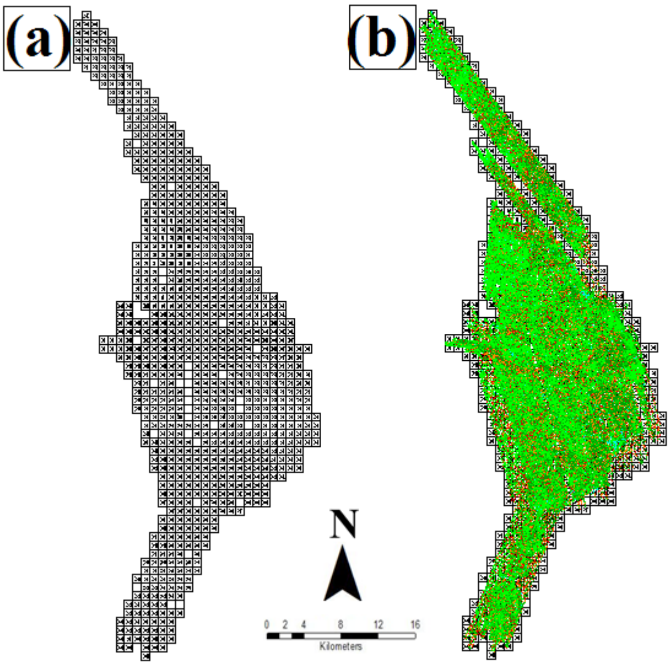


Figure 16. Tiles for Bongabong floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 17. 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.

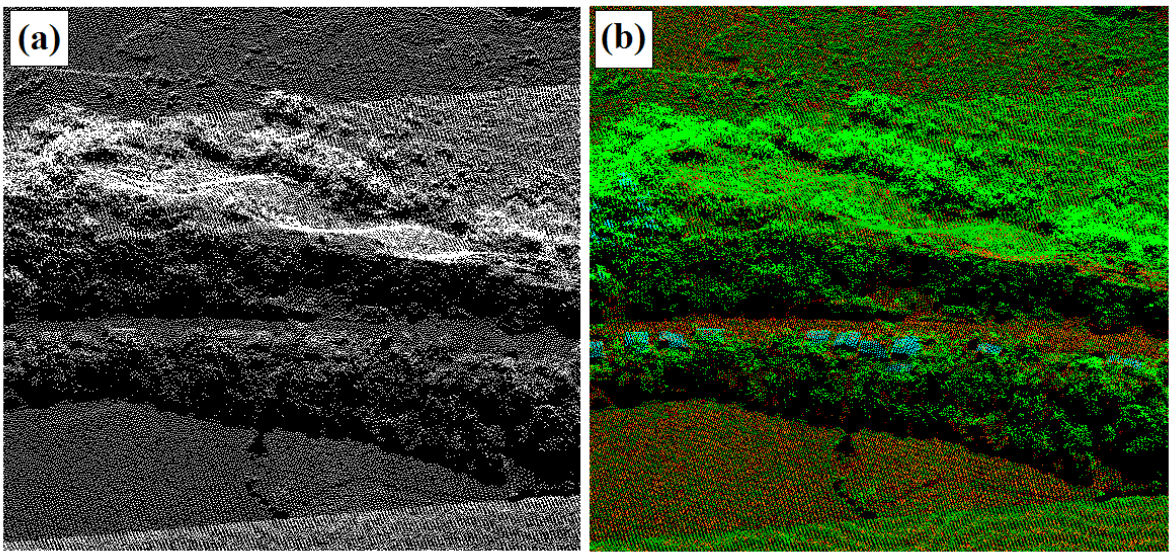


Figure 17. Point cloud before (a) and after (b) classification.

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

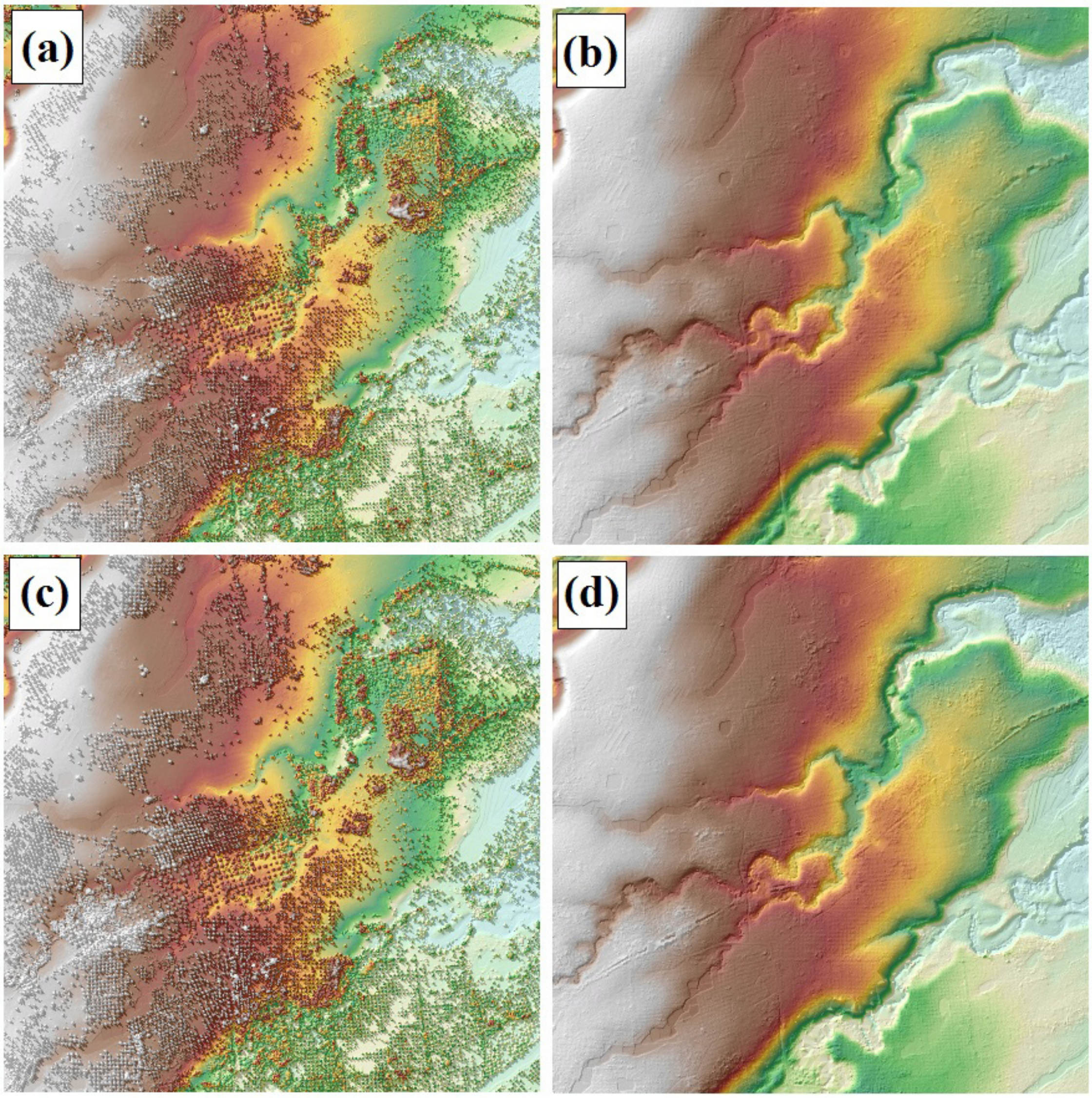


Figure 18. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Bongabong floodplain.

## 3.7 LiDAR Image Processing and Orthophotograph Rectification

The 991 1km by 1km tiles area covered by Bongabong floodplain is shown in Figure 19. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Bongabong floodplain survey attained a total of 609.69 km$^2$ in orthophotogaph coverage, comprised of 6,389 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 20.

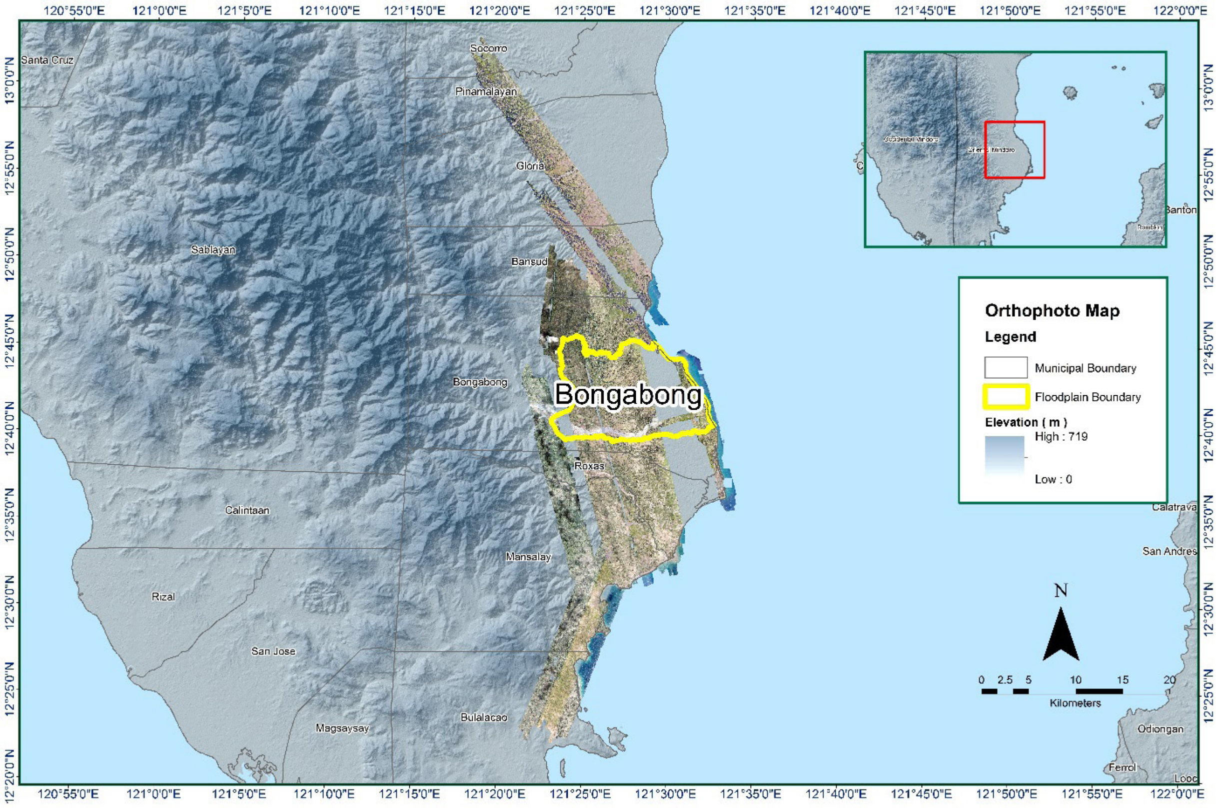


Figure 19. Bongabong floodplain with available orthophotographs.

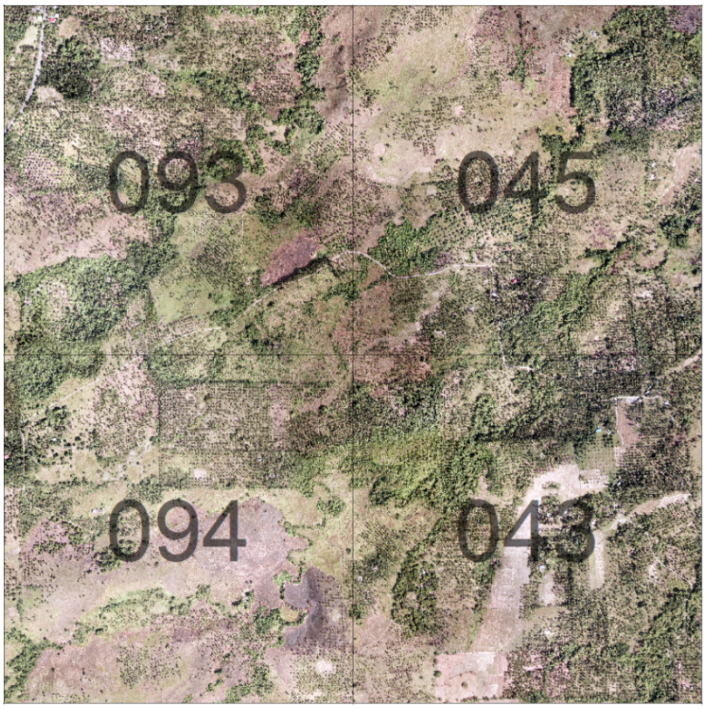


Figure 20. Sample orthophotograph tiles for Bongabong floodplain.

## 3.8 DEM Editing and Hydro-Correction

Eleven (11) mission blocks were processed for Bongabong flood plain. These blocks are composed of Oriental Mindoro and OrientalMindoro_reflights blocks with a total area of 776.62 square kilometers. Table 16 shows the name and corresponding area of each block in square kilometers.

Table 16. LiDAR blocks with its corresponding area.

| LiDAR Blocks | Area (sq.km) |
|---|---|
| OrientalMindoro_Blk28E | 125.84 |
| OrientalMindoro_Blk28F | 124.61 |
| OrientalMindoro_Blk28F_additional | 12.70 |
| OrientalMindoro_Blk28G | 95.35 |
| OrientalMindoro_Blk28G_supplementH | 62.40 |
| OrientalMindoro_Blk28H_supplement | 84.37 |
| OrientalMindoro_Blk28I | 97.92 |
| OrientalMindoro_Blk28J | 94.85 |
| OrientalMindoro_reflights_Blk28F | 23.25 |
| OrienalMindoro_reflights_Blk28H_supplement | 51.60 |
| OrientalMindoro_reflights_Blk28I_additional | 5.73 |
| TOTAL | 776.62 sq.km |

Portions of DTM before and after manual editing are shown in Figure 21. The bridge (Figure 21a) is also considered to be an impedance to the flow of water along the river and has to be removed (Figure 21b) in order to hydrologically correct the river. The river embankment (Figure 21c) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 21d) to allow the correct flow of water. A portion of hill also (Figure 21e) has been misclassified that needs to be retrieved to retain the correct terrain (Figure 21f). Object retrieval uses the secondary DTM (t_layer) to fill in these areas.

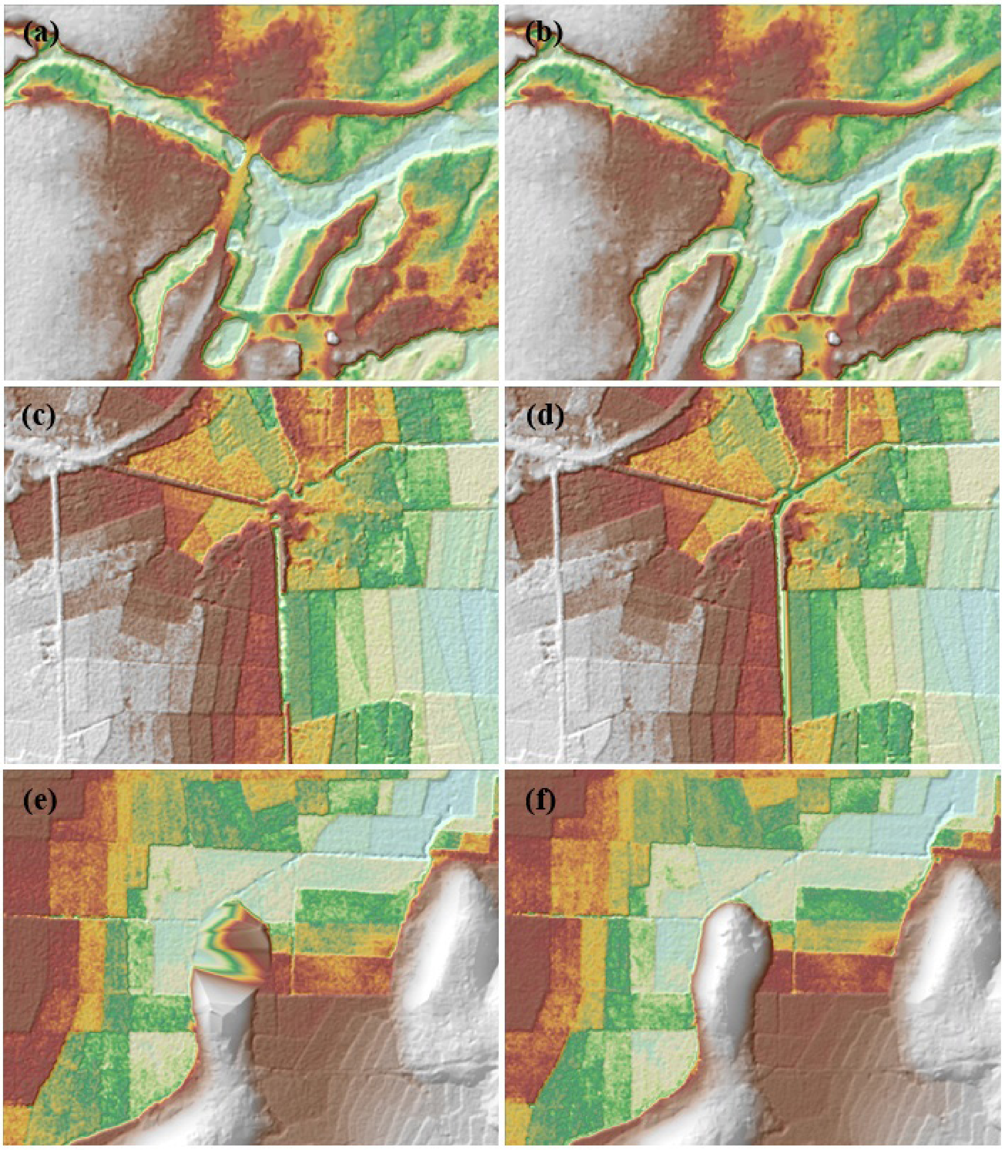


Figure 21. Portions in the DTM of Bongabong floodplain – a bridge before (a) and after (b) manual editing; a river embankment before (c) and after (d) data retrieval; and a misclassified hill before (e) and after (f) manual editing.

## 3.9 Mosaicking of Blocks

OccidentalMindoro_Blk29N was used as the reference block at the start of mosaicking because it was referred to a base station with an acceptable order of accuracy. Table B-5 shows the shift values applied to each LiDAR block during mosaicking.

Table 17. Shift Values of each LiDAR block of Bongabong floodplain

| Mission Blocks | Shift Values (meters) | | |
|---|---|---|---|
| | x | y | z |
| OrientalMindoro_Blk28E | 0.00 | 0.00 | 0.69 |
| OrientalMindoro_Blk28F | 0.00 | 0.00 | 0.84 |
| OrientalMindoro_Blk28F_additional | 0.00 | 0.00 | 0.85 |
| OrientalMindoro_Blk28G | 0.00 | 0.00 | 0.86 |
| OrientalMindoro_Blk28G_supplementH | 0.00 | 0.00 | -0.08 |
| OrientalMindoro_Blk28H_supplement | 0.00 | 0.00 | -0.29 |
| OrientalMindoro_Blk28I | 0.00 | 0.00 | -0.20 |
| OrientalMindoro_Blk28J | 0.00 | 0.00 | 0.00 |
| OrientalMindoro_reflights_Blk28F | 0.00 | 0.00 | 0.01 |
| OrienalMindoro_reflights_Blk28H_supplement | 0.00 | 0.00 | 0.04 |
| OrientalMindoro_reflights_Blk28I_additional | 0.00 | 0.00 | -1.20 |

Mosaicked LiDAR DTM for Bongabong floodplain is shown in Figure 22. It can be seen that the entire Bongabong floodplain is 99.20% covered by LiDAR data.

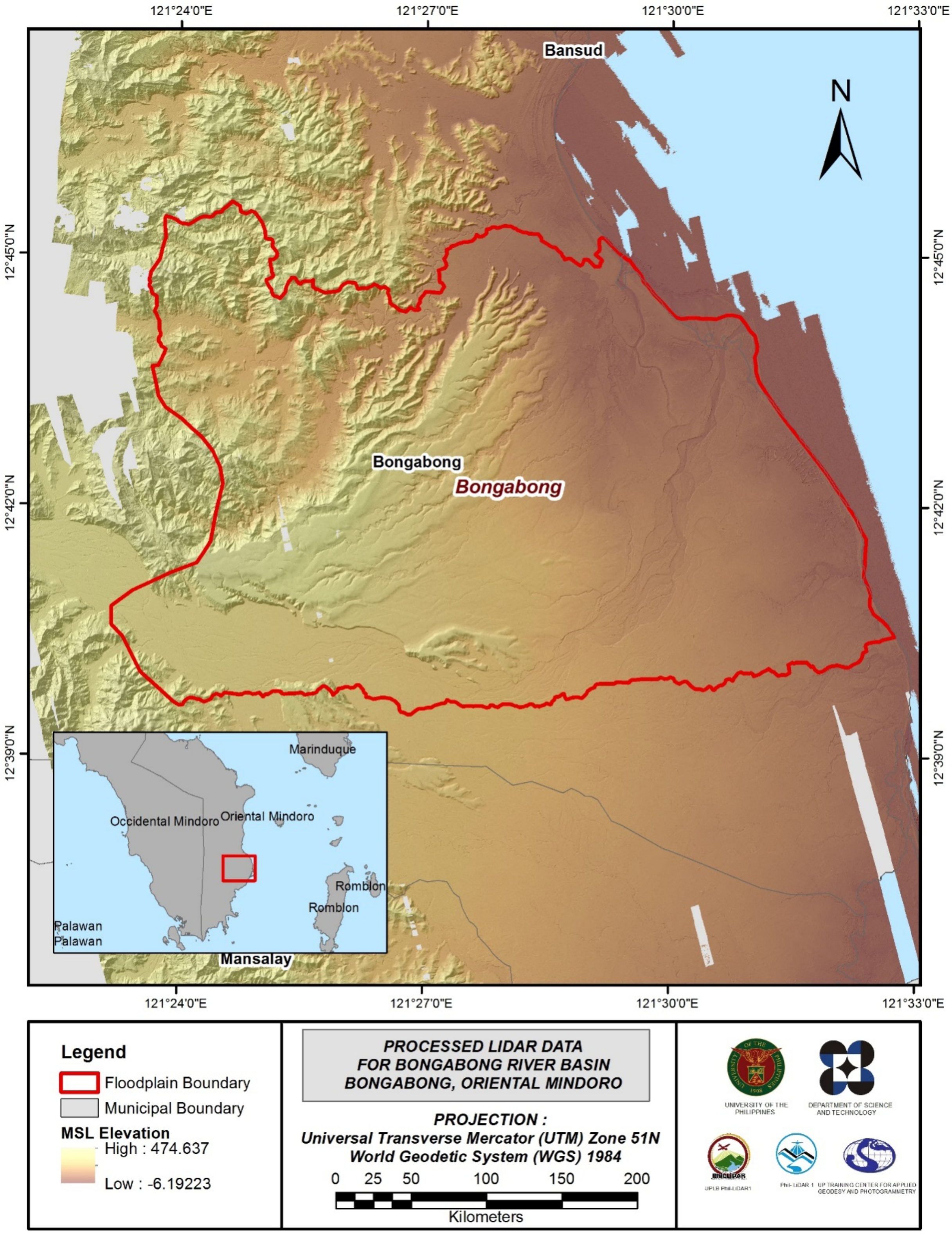


Figure 22. Map of Processed LiDAR Data for Bongabong Flood Plain.

## 3.10 Calibration and Validation of Mosaicked LiDAR DEM

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Bongabong to collect points with which the LiDAR dataset is validated is shown in Figure 23. A total of 19,114 survey points were gathered for all the flood plains within Oriental Mindoro wherein the Bongabong floodplain is located. Random selection of 80% of the survey points, resulting to 15,291 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 24. 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 2.60 meters with a standard deviation of 0.17 meters. Calibration of Bongabong LiDAR data was done by subtracting the height difference value, 2.60 meters, to Bongabong mosaicked LiDAR data. Table 18 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

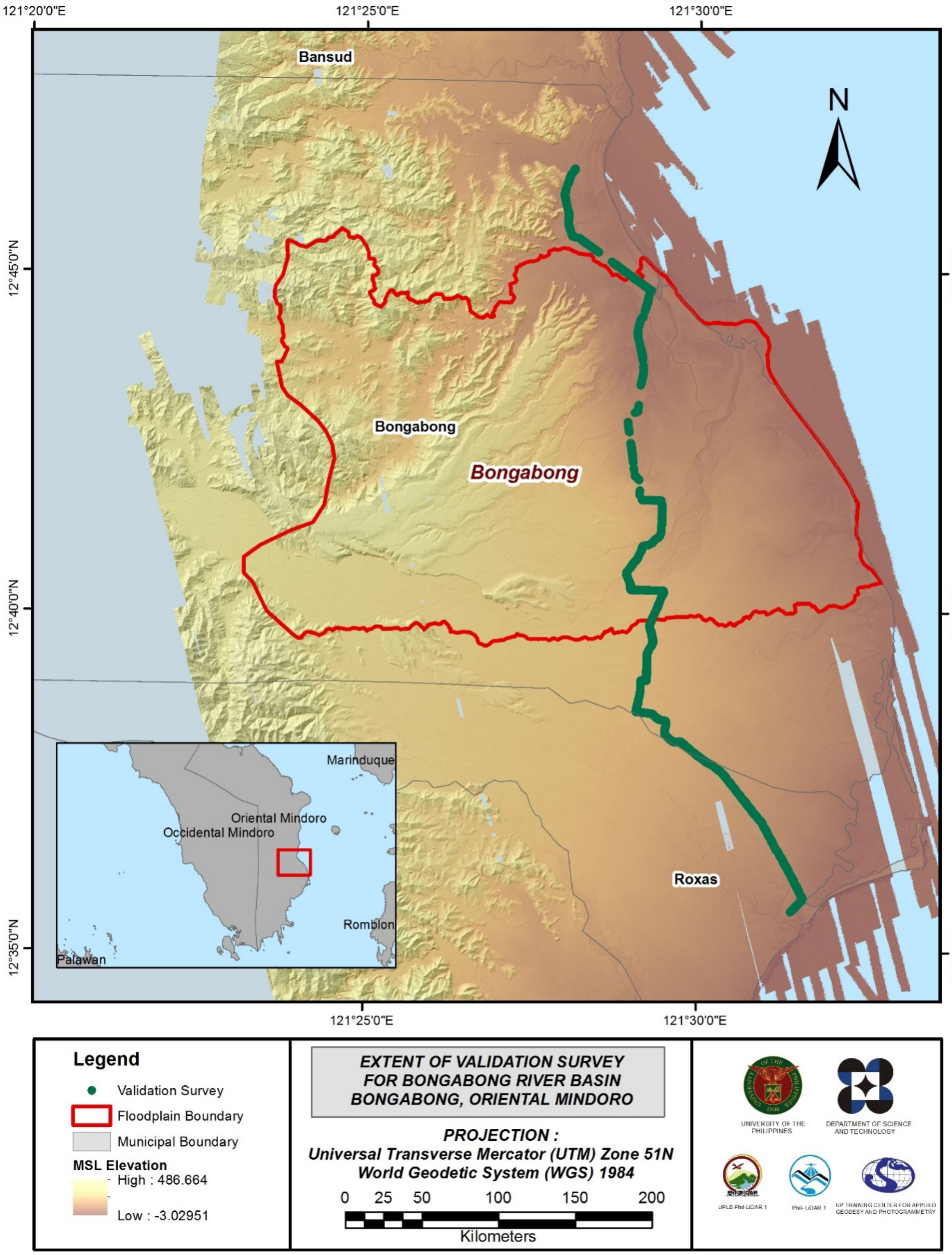


Figure 23. Map of Bongabong Floodplain with validation survey points in green.

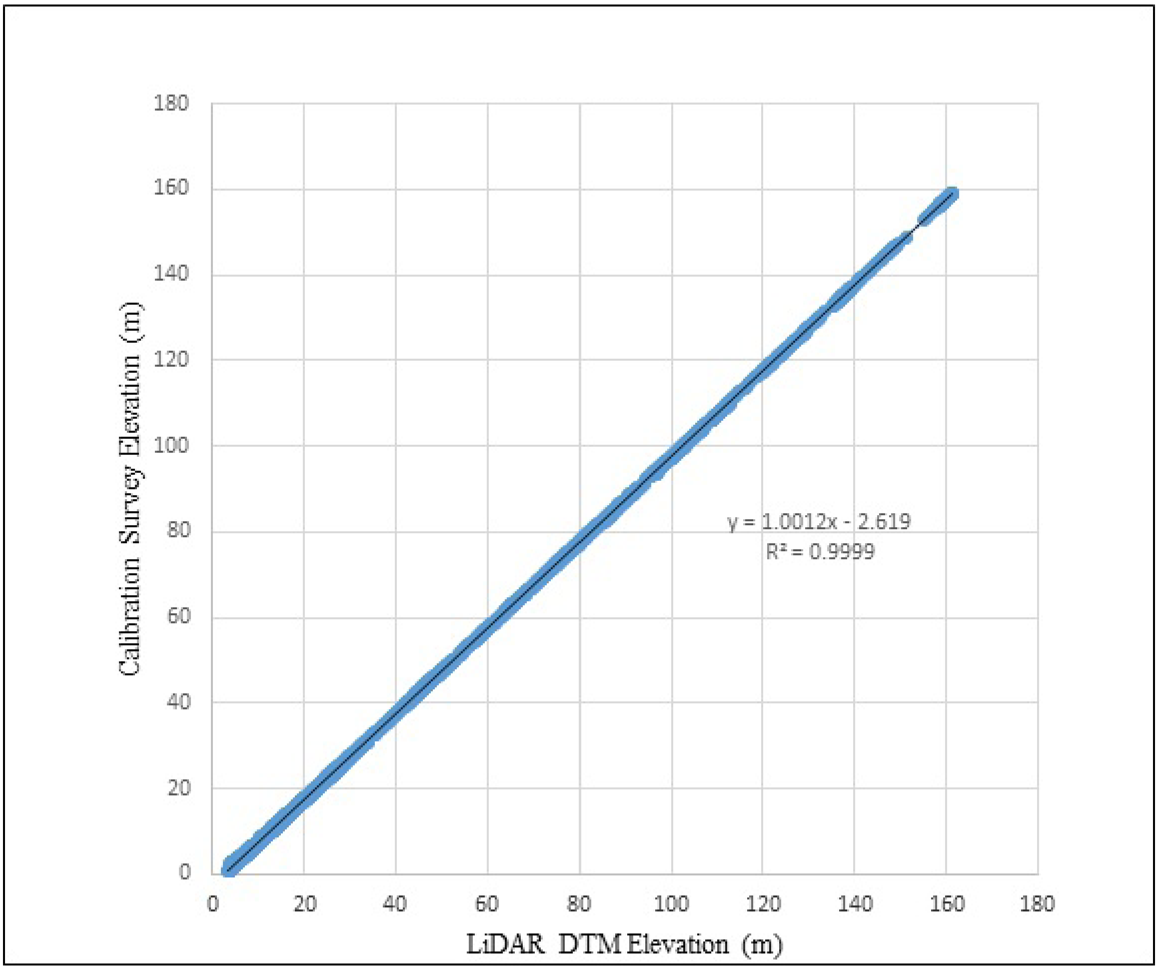


Figure 24. Correlation plot between calibration survey points and LiDAR data.

Table 18. Calibration Statistical Measures.

| Calibration Statistical Measures | Value (meters) |
|---|---|
| Height Difference | 2.60 |
| Standard Deviation | 0.17 |
| Average | -2.59 |
| Minimum | -3.03 |
| Maximum | -1.70 |

The remaining 20% of the total survey points were intersected to the flood plain, resulting to 726 points. These were used for the validation of calibrated Bongabong 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 25. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.09 meters with a standard deviation of 0.09 meters, as shown in Table 19.

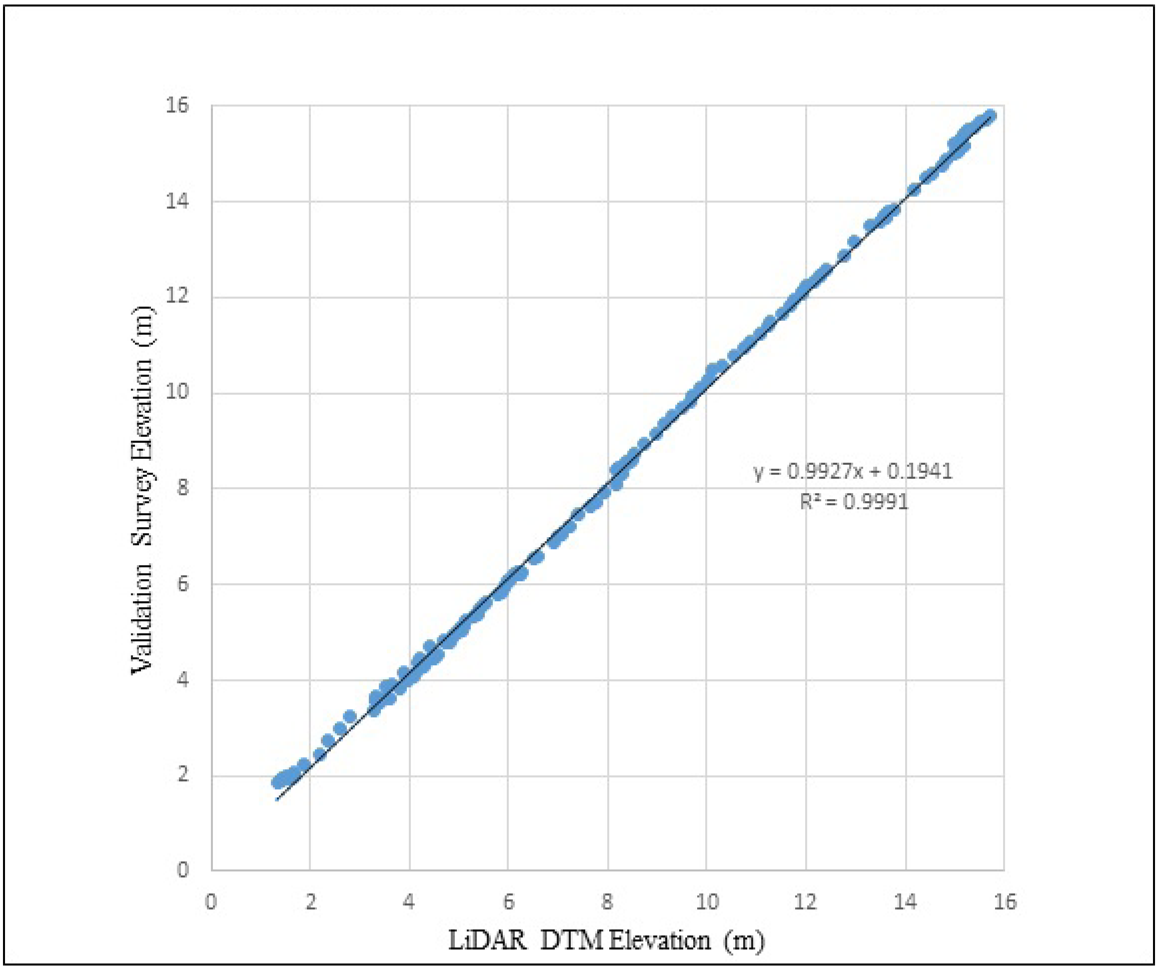


Figure 25. Correlation plot between validation survey points and LiDAR data.

Table 19. Validation Statistical Measures.

| Validation Statistical Measures | Value (meters) |
|---|---|
| RMSE | 0.09 |
| Standard Deviation | 0.09 |
| Average | -0.00 |
| Minimum | -0.35 |
| Maximum | 0.48 |

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

For bathy integration, only centerline data was available for Bongabong with 522 bathymetric survey points. The resulting raster surface produced was done by Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.15 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Bongabong integrated with the processed LiDAR DEM is shown in Figure 26.

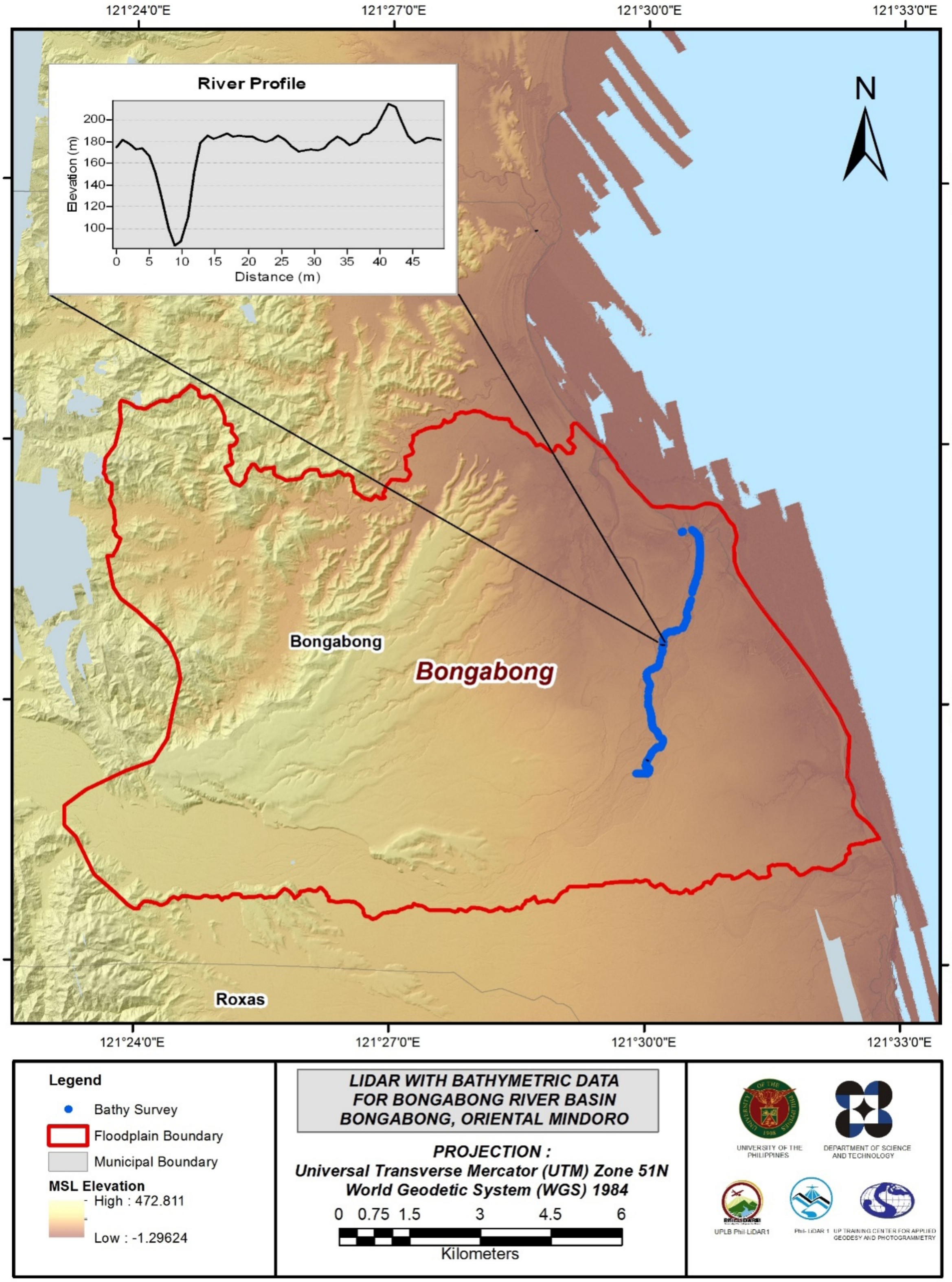


Figure 26. Map of Bongabong Flood Plain with bathymetric survey points shown in blue.

# CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS OF THE BONGABONG 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

The project team conducted a fieldwork in Bongabong River on May 30, 2014 to June 11, 2014. The objectives were to conduct the following activities: courtesy call to the LGU of Bongabong Municipality; static survey for the establishment of control point at the approach of the bridge to be occupied as base station for GNSS surveys; cross-section, and bridge as-built survey of Bongabong Bridge in Brgy. San Isidro, Muicipality of Bongabong; LiDAR ground validation with estimated length of 26.071 km; and manual bathymetric survey of Bongabong River with distance of approximately 9.21 km starting from the Bongabong Bridge to the Barangays of San Isidro, Mina de Oro and Anilao down to the mouth of the Bongabong River at Tablas Strait using Trimble® SPS 882 in GNSS RTK survey technique. The fieldwork activities were assisted by the partner SUC, University of the Philippines Los Baños.

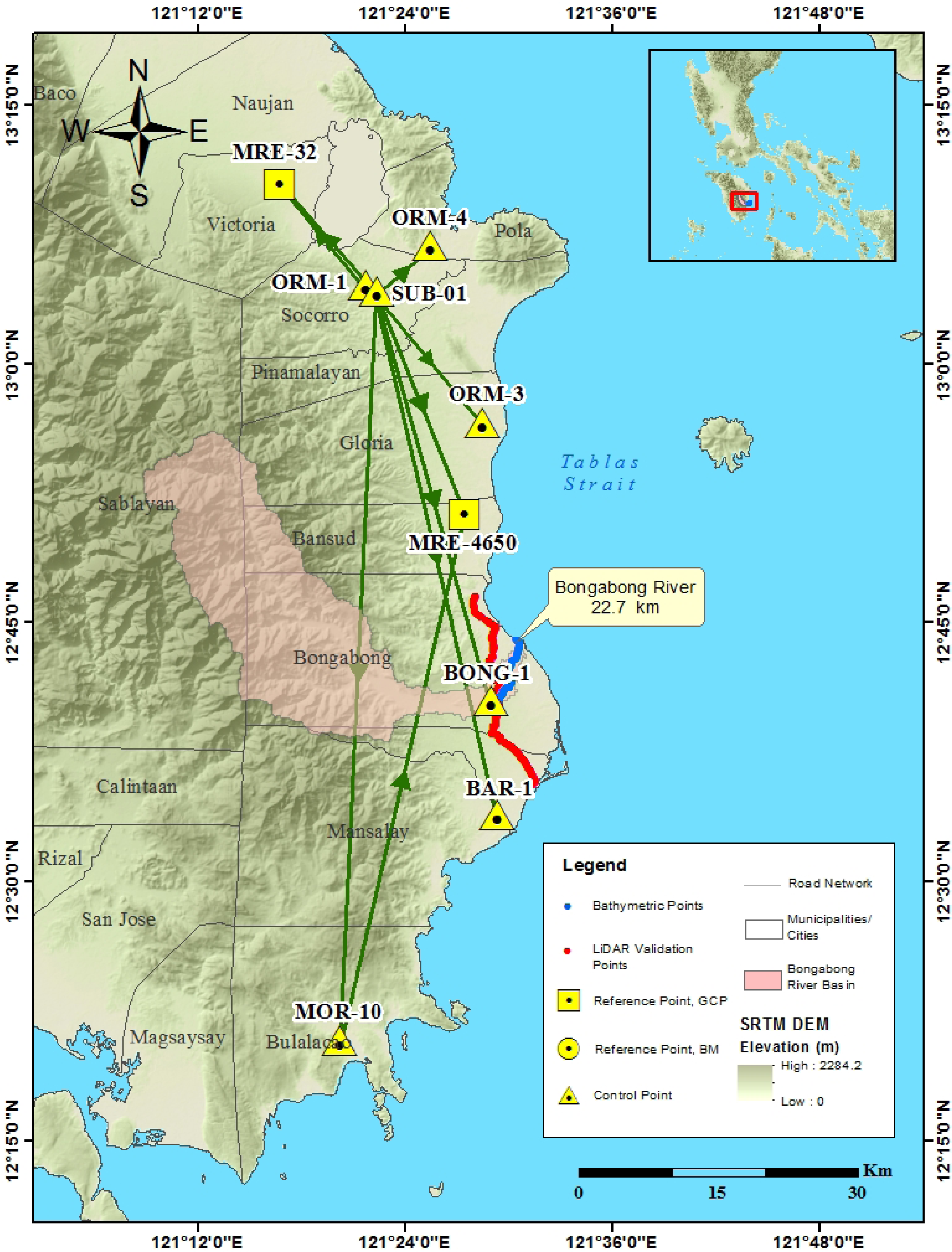



Figure 27. Extent of the bathymetric survey (blue line) in Bongabong River and the LiDAR data validation survey (in red)

## 4.2 Control Survey

A GNSS network was established for previous PHIL-LiDAR fieldwork in Mindoro on February 28 – March 11, 2013 occupying MR-178, a first-order BM located at the approach of Panggalaan Bridge in Brgy. Bucayao, Calapan City, Oriental Mindoro; and MRE-32, a second order GCP in Brgy. Poblacion 1, Mun. of Victoria, Oriental Mindoro.

The GNSS network used for Bongabong River Basin is composed of two (2) loops and four (4) baselines established on May 30 and May 31, 2014 occupying the reference point MRE-32, a second-order GCP fixed from the previous field survey in Mindoro Oriental for Mag Asawang Tubig river.

Seven (7) control points were established namely: BAR-1 located at the approach of Baroc Bridge in Brgy. San Isidro, Municipality of Mansalay; BONG-01 located near Bongabong Bridge in Brgy. San Isidro, Municipality of Luna; MOR-10, located at the approach of Cawacat Bridge in Brgy. Campaasan, Municipality of Bulalacao; ORM-1, located in Subaan Bridge in Barangay Subaan, Municipality of Socorro; ORM-3 located in Balete bridge in Brgy. Balete, Municipality of Gloria; ORM-4 in Pola Bridge, Brgy. Casiligan, Municipality of Pola; and SUB-01, located within the Maramot Residence in Brgy. Subaan, Municipality of Socorro. An LMS-established control point namely MRE-4650, located at Bansud Bridge, Brgy. Pagasa, Municipality of Bansud, Oriental Mindoro was also occupied to use as marker in the survey.

The summary of references and control points and its location is summarized in Table 30 while the GNSS network established is illustrated in Table 24.

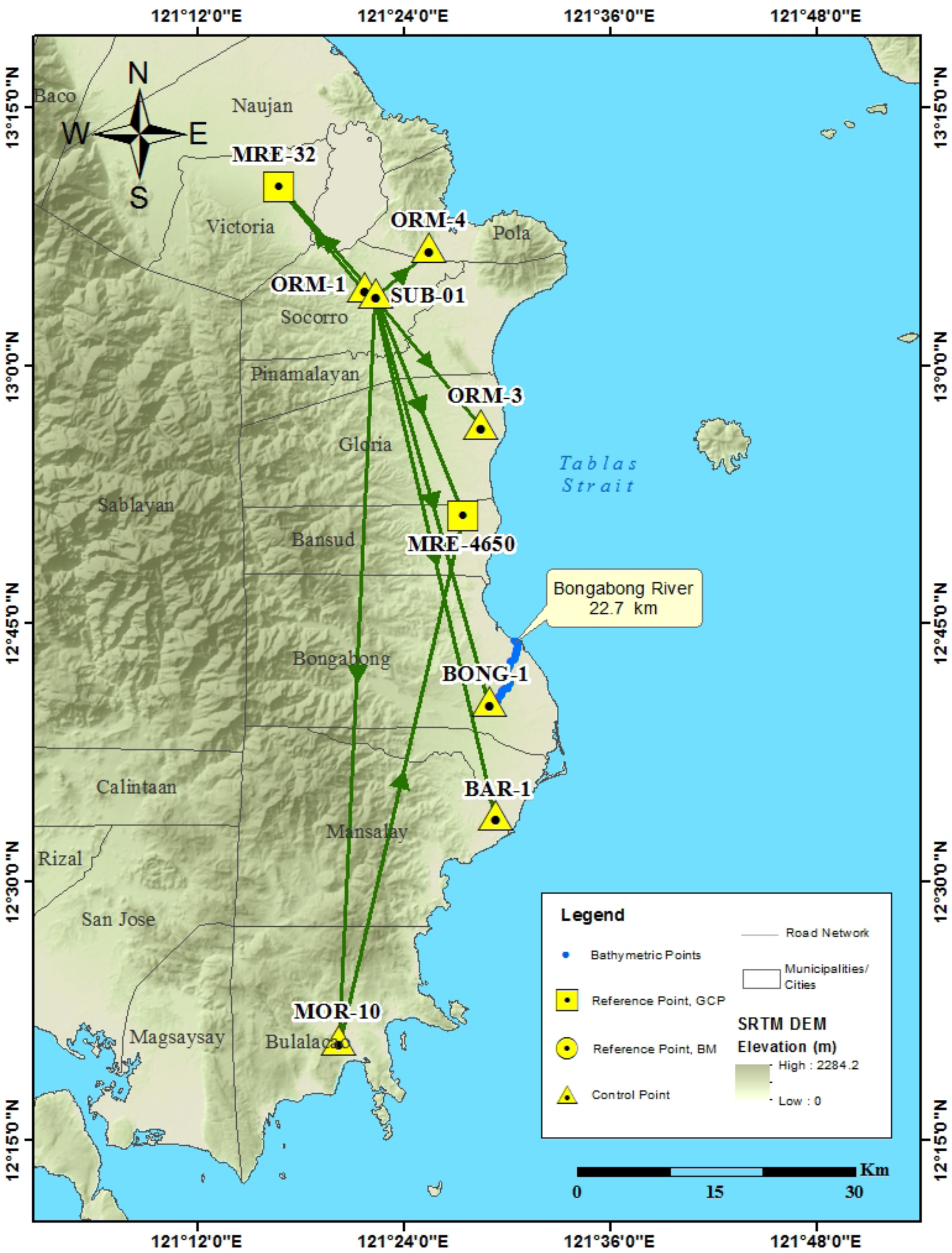



Figure 28 GNSS network of Bongabong River field survey

Table 20. List of Reference and Control Points used in Bongabong River Basin survey (Source: NAMRIA; UP-TCAGP)

| Control Point | Order of Accuracy | Geographic Coordinates (WGS 84) | | | | |
|---|---|---|---|---|---|---|
| | | Latitude | Longitude | Ellipsoid height (Meter) | Elevation in MSL (m) | Date Estab-lished |
| MRE-32 | 2nd order, GCP | 13°10’23.79251” | 121°16’43.46244” | 65.638 | 17.175 | 2007 |
| MRE-4650 | Used as marker | - | | - | - | 2011 |
| BAR-1 | UP Estab-lished | - | - | - | - | 6-1-20014 |
| BONG-01 | UP Estab-lished | - | - | - | - | 6-1-2014 |
| MOR-10 | UP Estab-lished | - | - | - | - | 5-31-2014 |
| ORM-1 | UP Estab-lished | - | - | - | - | 5-30-2014 |
| ORM-3 | UP Estab-lished | - | - | - | - | 5-31-2014 |
| ORM-4 | UP Estab-lished | - | - | - | - | 5-31-2014 |
| SUB-01 | UP Estab-lished | - | - | - | - | 5-31-2014 |

The GNSS set ups made in the location of the reference and control points are exhibited in Figure 29 to Figure 37.


Figure 29. GPS setup of Trimble® SPS 882 at MRE-32, located at the Municipal Park of Victoria, in Brgy. Poblacion 1, Oriental Mindoro

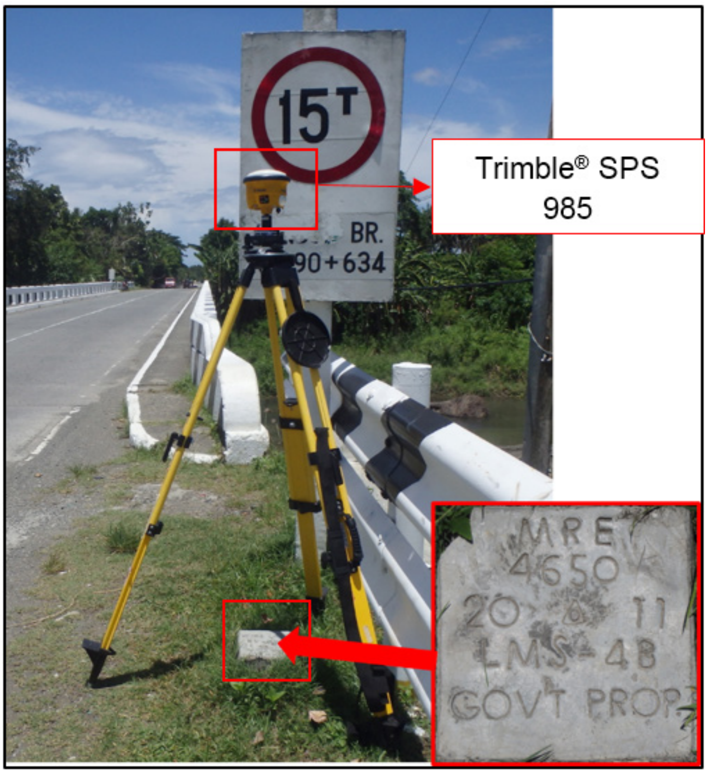



Figure 30. The GPS setup of Trimble® SPS 985 at MRE-4650, an LMS control point located at the approach of Bansud Bridge, in Brgy. Pagasa, Municipality of Bansud, Oriental Mindoro


Figure 31. GPS setup of Trimble® SPS 882 at BAR-1, an established control point located in Baroc Bridge, Brgy. San Isidro, Mansalay, Oriental Mindoro

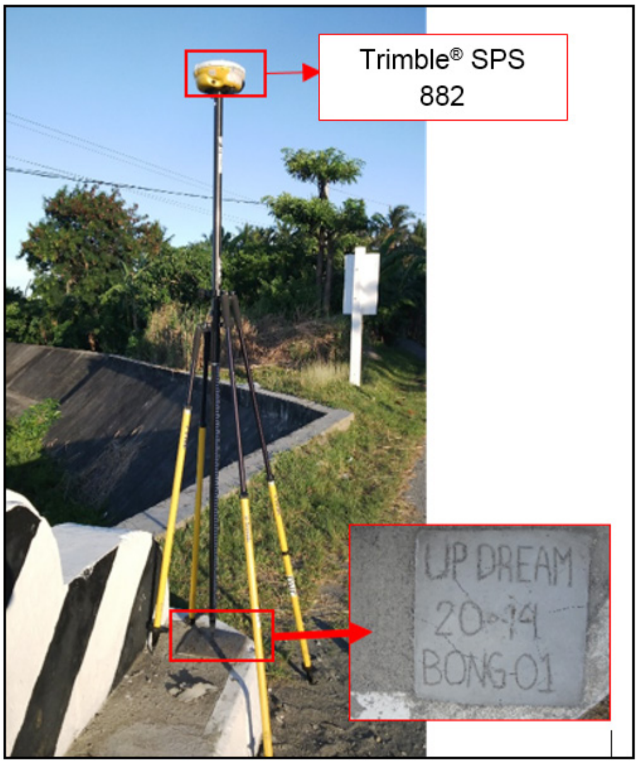



Figure 32. GNSS setup of Trimble® SPS 882 on BONG-01 in Brgy. San Isidro, Municipality of Bongabong, Oriental Mindoro


Figure 33. GPS setup of Trimble® SPS 852 at MOR-10, located in the approach of the Cawacat Bridge, in Bry. Campasaan, Municipality of Bulalacao, Oriental Mindoro


Figure 34. GPS setup of Trimble® SPS 852 at ORM-1, located on Subaan Bridge, Brgy. Subaan, Municipality of Socorro, Oriental Mindoro


Figure 35. Trimble® SPS 985 setup at ORM-3 located at the approach of Balete Bridge, Brgy. Balete, Municipality of Gloria, Oriental Mindoro

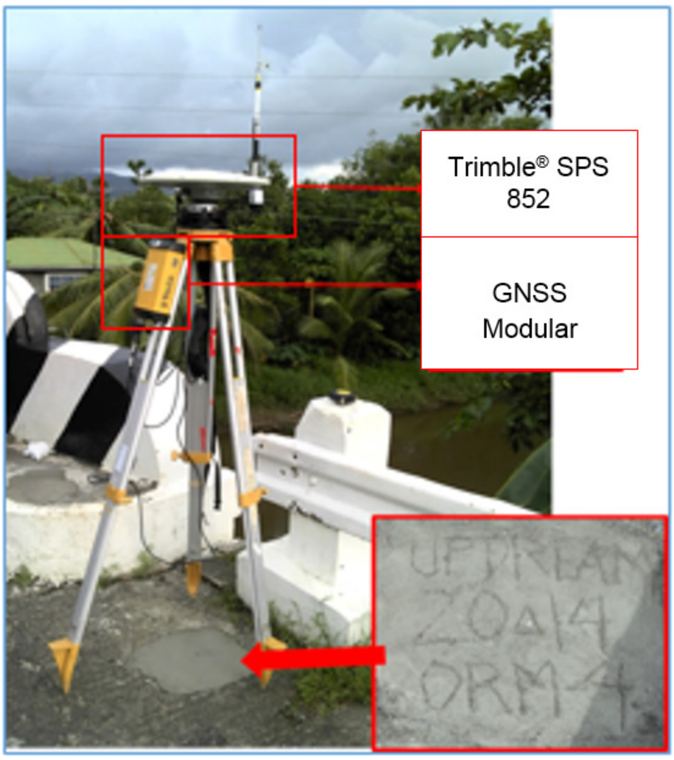



Figure 36. GNSS receiver Trimble® SPS 852 setup at ORM-4, located at the right side of the approach of Pola Bridge in Barangay Casiligan, Municipality of Pola, Oriental Mindoro

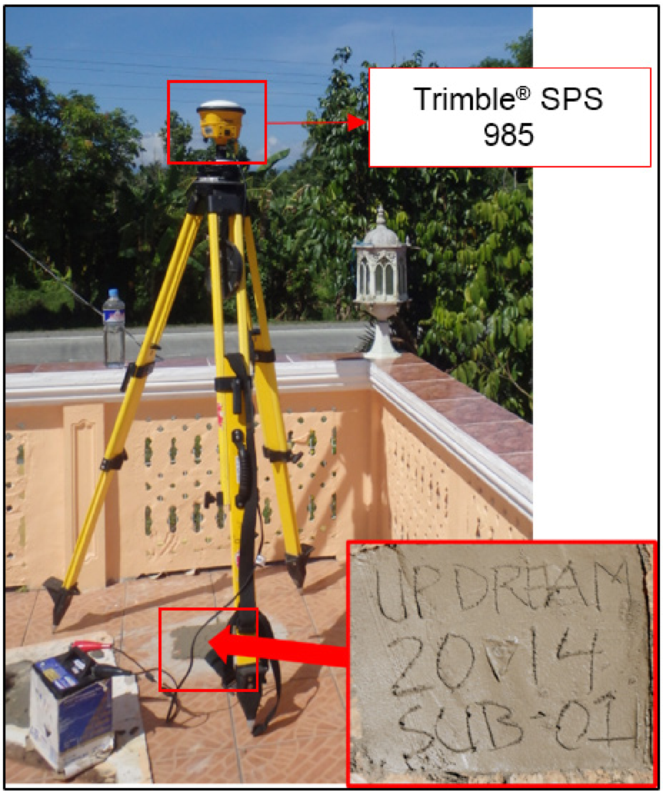



Figure 37. GPS setup of Trimble® SPS 985 at SUB-1, an established control point located at Maramot Residence in Brgy. Subaan, Municipality of Socorro, Oriental Mindoro

## 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 +/-20cm and +/-10cm 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 Bongabong River Basin is summarized in Table 21 which was generated using the TBC software.

Table 21. Baseline Processing Report for Bongabong River Static survey

| Observation | Date of Observation | Solution Type | H. Prec. (Meter) | V. Prec. (Meter) | Geodetic Az. | Ellipsoid Dist. (Meter) | ΔHeight (Meter) |
|---|---|---|---|---|---|---|---|
| ORM-1 --- SUB-01 | 05-30-2014 | Fixed | 0.004 | 0.006 | 301°40’27” | 1466.251 | 4.823 |
| SUB-01 --- MRE-32 | 05-30-2014 | Fixed | 0.010 | 0.031 | 318°11’52” | 15342.18 | -9.283 |
| SUB-01 --- MOR-10 | 05-31-2014 | Fixed | 0.014 | 0.044 | 182°47’52” | 80162.62 | -16.502 |
| SUB-01 --- MRE-4650 | 05-31-2014 | Fixed | 0.006 | 0.038 | 158°49’08” | 25506.78 | -9.971 |
| SUB-01 --- ORM-3 | 5-31-2014 | Fixed | 0.007 | 0.028 | 141°48’05” | 17755.532 | -12.886 |
| SUB-01 --- ORM-4 | 6-1-2014 | Fixed | 0.003 | 0.022 | 48°43’17” | 7475.934 | -19.149 |
| SUB-01 --- BAR-1 | 6-1-2014 | Fixed | 0.024 | 0.107 | 167°15’17” | 57308.832 | -16.370 |
| SUB-01 --- BONG-01 | 6-1-2014 | Fixed | 0.021 | 0.035 | 164°45’51” | 45313.95 | 0.212 |
| ORM-1 --- MRE 32 | 05-30-2014 | Fixed | 0.010 | 0.032 | 319°54’33” | 13942.72 | -14.146 |
| MOR-10 --- MRE 4650 | 05-31-2014 | Fixed | 0.012 | 0.051 | 13°07’21” | 57794.34 | 6.484 |

As shown in Table 21, a total of ten (10) baselines were processed and all of them passed the required accuracy set by the project.

## 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 from:

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

Where:

$x_e$ is the Easting Error,
$y_e$ is the Northing Error, and
$z_e$ is the Elevation Error

The five (5) control points, MRE-32, ORM-1, MOR-10, MRE-4650 and SUB-01 were occupied and observed simultaneously to form a GNSS loop. Coordinates and elevation values of MRE-32 were held fixed during the processing of the control points as presented in Table 22. Through these reference points, the coordinates and elevation of the unknown control points were computed.

Table 22. Control Point Constraints

| Point ID | Type | East σ (Meter) | North σ (Meter) | Height σ (Meter) | Elevation σ (Meter) |
|---|---|---|---|---|---|
| MRE-32 | Grid | Fixed | Fixed | Fixed | Fixed |
| Fixed = 0.000001(Meter) | | | | | |

The list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 23. All fixed control points have no values for grid and elevation errors.

Table 23. Adjusted Grid Coordinates

| Point ID | Easting (Meter) | Easting Error (Meter) | Northing (Meter) | Northing Error (Meter) | Elevation (Meter) | Elevation Error (Meter) | Constraint |
|---|---|---|---|---|---|---|---|
| MOR-10 | 319188.891 | 0.010 | 1365393.240 | 0.010 | 6.868 | 0.052 | |
| MRE-32 | 313449.201 | ? | 1456936.499 | ? | 17.175 | ? | ENe |
| MRE-4650 | 332665.789 | 0.008 | 1421592.819 | 0.006 | 14.627 | 0.049 | |
| ORM-1 | 322358.982 | 0.007 | 1446211.774 | 0.003 | 30.565 | 0.028 | |
| SUB-01 | 323601.847 | 0.007 | 1445433.872 | 0.003 | 25.687 | 0.028 | |

The network is fixed at reference points. The list of adjusted grid coordinates of the network is shown in Table 24. Using the equation  for horizontal and   for the vertical; below is the computation for accuracy that passed the required precision:

a. **MRE-32**
Horizontal accuracy = Fixed
Vertical accuracy = Fixed

b. **MOR-10**
Horizontal accuracy = √ ((1.0) ² + (1.0) ²
= √(1.0 + 1.0)
= 1.1 cm < 20 cm
Vertical accuracy = 1.4 cm< 10 cm

c. **MRE-4650**
Horizontal accuracy = √ ((0.8) ² + (0.6) ²
= √(0.64 + 0.36)
= 1.0 cm < 20 cm
Vertical accuracy = 4.9 cm < 10 cm

d. **ORM-1**

Horizontal accuracy = √ ((0.7) ² + (0.3) ²
= √(0.49 + 0.90)
= 1.2 cm < 20 cm
Vertical accuracy = 2.8 cm < 10 cm

e. **SUB-01**
Horizontal accuracy = √ ((0.7) ² + (0.3) ²
= √(0.49 + 0.90)
= 1.2 cm < 20 cm
Vertical accuracy = 2.8 cm < 10 cm

Following the given formula, the horizontal and vertical accuracy result of the five (5) occupied control points are within the required accuracy of the project.

Table 24. Adjusted Geodetic Coordinates

| Point ID | Latitude | Longitude | Ellipsoidal Height (Meter) | Height Error (Meter) | Constraint |
|---|---|---|---|---|---|
| MOR-10 | N12°20'46.18547" | E121°20'13.54772" | 58.186 | 0.052 | |
| MRE-32 | N13°10'23.79251" | E121°16'43.46244" | 65.368 | ? | ENe |
| MRE-4650 | N12°51'17.70515" | E121°27'28.71020" | 64.693 | 0.049 | |
| ORM-1 | N13°04'36.74731" | E121°21'41.63863" | 79.500 | 0.028 | |
| SUB-01 | N13°04'11.69491" | E121°22'23.06063" | 74.676 | 0.028 | |

Table 25. List of references and control points used in Bongabong River Survey

| Con trol Point | Order | Geographic Coordinates (WGS 84) | | | UTM Zone N51 | | |
|---|---|---|---|---|---|---|---|
| | | Latitude | Longitude | Ellip-soidal Height (m) | Northing (m) | Easting (m) | Eleva-tion in MSL |
| MRE-32 | 2nd Order, GCP | 13°10’23.79251” | 121°16’43.46244” | 65.368 | 1456936.499 | 313449.201 | 17.175 |
| MRE-4650 | Used as Marker | 12°51’17.70515” | 121°27’28.71020” | 64.693 | 1421592.819 | 332665.789 | 14.627 |
| BAR-1 | UP Estab-lished | 12°33’52.65149” | 121°29’21.90040” | 58.344 | 1389460.775 | 335892.131 | 6.953 |
| BONG-01 | UP Estab-lished | 12°40’28.89755” | 121°28’57.71173” | 74.917 | 1401640.553 | 335232.485 | 23.974 |
| MOR-10 | UP Estab-lished | 12°20’46.18547” | 121°20’13.54772” | 58.186 | 1365393.24 | 319188.891 | 6.868 |
| ORM-1 | UP Estab-lished | 13°04’36.74731” | 121°21’41.63863” | 79.5 | 1446211.774 | 322358.982 | 30.565 |
| ORM-3 | UP Estab-lished | 12°56’37.56304” | 121°28’27.33712” | 61.799 | 1431410.893 | 334491.821 | 12.031 |
| ORM-4 | UP Estab-lished | 13°06’52.16736” | 121°25’29.58456” | 55.523 | 1450329.531 | 329251.554 | 6.585 |
| SUB-01 | UP Estab-lished | 13°04’11.69491” | 121°22’23.06063” | 74.676 | 1445433.872 | 323601.847 | 25.687 |

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

GNSS receiver Trimble® SPS 882 in PPK survey technique was utilized to acquire a cross section of the river along the downstream side of Bongabong Bridge in Brgy. San Isidro, Oriental Mindoro. The cross-section survey setup for Bongabong Bridge on October 29, 2014 is shown in Figure 40. Bridge as-built features determination was also performed to get the distance of piers and abutments from the bridge approach. The bridge deck was measured using GNSS receiver Trimble® SPS 882 to get the high cord, and meter tapes to get its low cord elevation. The DVBC established control BONG-01 was used as base station during the conduct of the survey.

Figure 38. Cross-section and bridge as-built survey for Bongabong Bridge, Brgy San Isidro, Oriental Mindoro

The cross-sectional line for the Bongabong Bridge is about 329.24 meters with 26 cross-sectional points. The planimetric location map, the summary of gathered cross-section, and as-built data for Bongabong Bridge are displayed in Figure 39 to Figure 41, respectively.

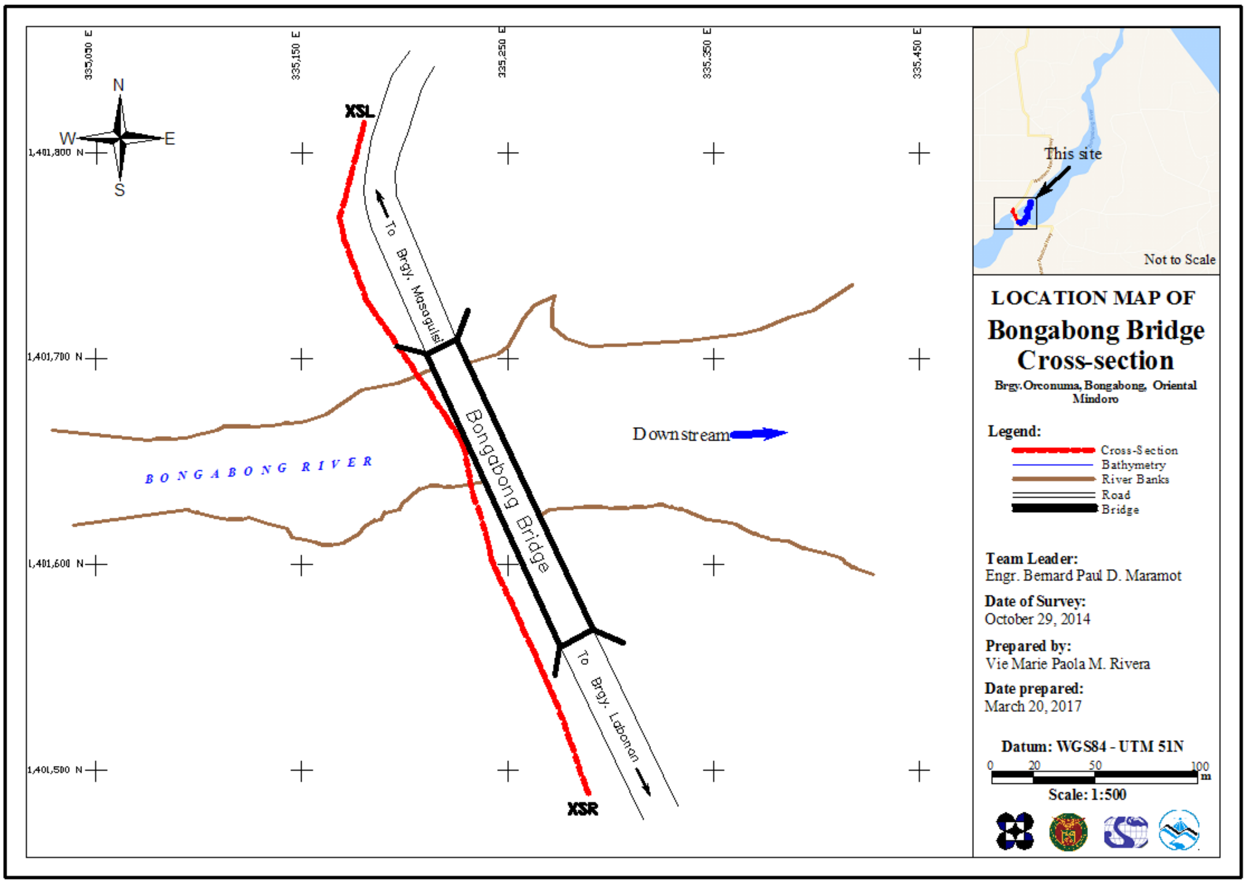


Figure 39. Bongabong bridge cross-section location map

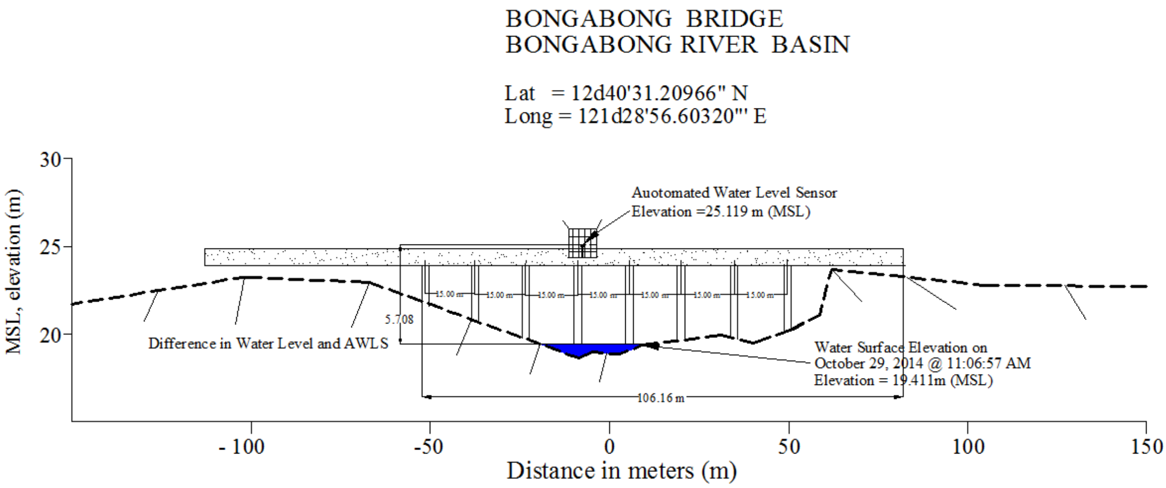


Figure 40. Bongabong Bridge cross-section diagram

**Bridge Data Form**

**Bridge Name:** BONGABONG BRIDGE **Date:** October 29, 2014

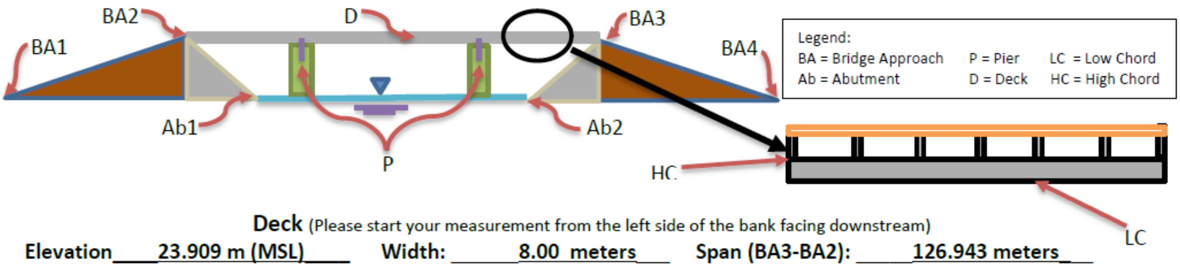
**River Name:** BONGABONG RIVER **Time:** 10:20 am

**Location (Brgy, City, Region):** Brgy.Orconuma , Bongabong Oriental Mindoro

**Survey Team:** DVBC Mindoro Survey Team

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

**Latitude:** 12d40'31.20966" N **Longitude:** 121d28'56.60320" E




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

**Elevation** 23.909 m (MSL) **Width:** 8.00 meters **Span (BA3-BA2):** 126.943 meters

| | Station | High Chord Elevation | Low Chord Elevation |
|---|---|---|---|
| 1 | Pier 1 | 23.952 m | 22.803 m |
| 2 | | | |
| 3 | | | |

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

| | Station(Distance from BA1) | Elevation | | Station(Distance from BA1) | Elevation |
|---|---|---|---|---|---|
| BA1 | 0 | 21.932 | BA3 | 202.419 | 23.971 |
| BA2 | 96.270 | 23.996 | BA4 | 329.366 | 23,261 |

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

| | Station (Distance from BA1) | Elevation |
|---|---|---|
| Ab1 | | |
| Ab2 | 195.449 | 19.765 |

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

**Shape:** Cylindrical **Number of Piers:** 0 **Height of column footing:**

| | Station (Distance from BA1) | Elevation | Pier Width |
|---|---|---|---|
| Pier 1 | 98.642 | 23.939 | |
| Pier 2 | 112.647 | 23.964 | |
| Pier 3 | 127.024 | 23.910 | |
| Pier 4 | 141.354 | 23.940 | |
| Pier 5 | 155.939 | 23.927 | |
| Pier 6 | 170.526 | 23.916 | |
| Pier 7 | 185.242 | 23.933 | |
| Pier 8 | 200.024 | 23.962 | |

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

Figure 41. Bongabong Bridge Data Form

## 4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on June 5, 2014 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted on a range pole which was attached on the roof rack of a vehicle as shown in Figure C-16. It was secured with a cable-tie to ensure that it was horizontally and vertically balanced. The antenna height was measured and recorded to be 1.498m from the ground up to the bottom of notch of the GNSS Rover receiver. The survey was conducted using PPK technique on a continuous topography mode, which started from Brgy. Dangay along Strong Republic Nautical Highway to Brgy. Labasan, Bongabong which gathered 3,671 validation points covering an approximate distance of 26.071 km using the DVBC established control BONG-01 as base station. The gaps in the validation line as shown in Figure 44 were due to some difficulties in acquiring satellite because of the presence of obstruction such as dense canopy cover of trees along the roads.


Figure 42. Trimble SPS®882 setup for validation points acquisition survey of Bongabong River Basin


Figure 43. Validation points acquisition survey along Bongabong River Basin

## 4.7 River Bathymetric Survey

Bathymetric survey for Bongabong River was conducted on May 29, 2014 to June 11, 2014 covering Brgy. San Isidro, Brgy. Mina de Oro and Brgy. Anilao Trimble® SPS 882 in GNSS PPK survey technique as shown in Figure 46. It started at the upstream part of the river in Bongabong Bridge in Brgy. San Isidro, Municipality of Bongabong with coordinates 12°40'28.89771" 121°28'57.71150" traversed the river via foot, and ended at the mouth of the river in Brgy. Anilao, also in Municipality of Bongabog with coordinates 12d43'58.34656" 121°30'24.60034". The UP established control point BONG-01 was used as the GNSS base all throughout the survey.

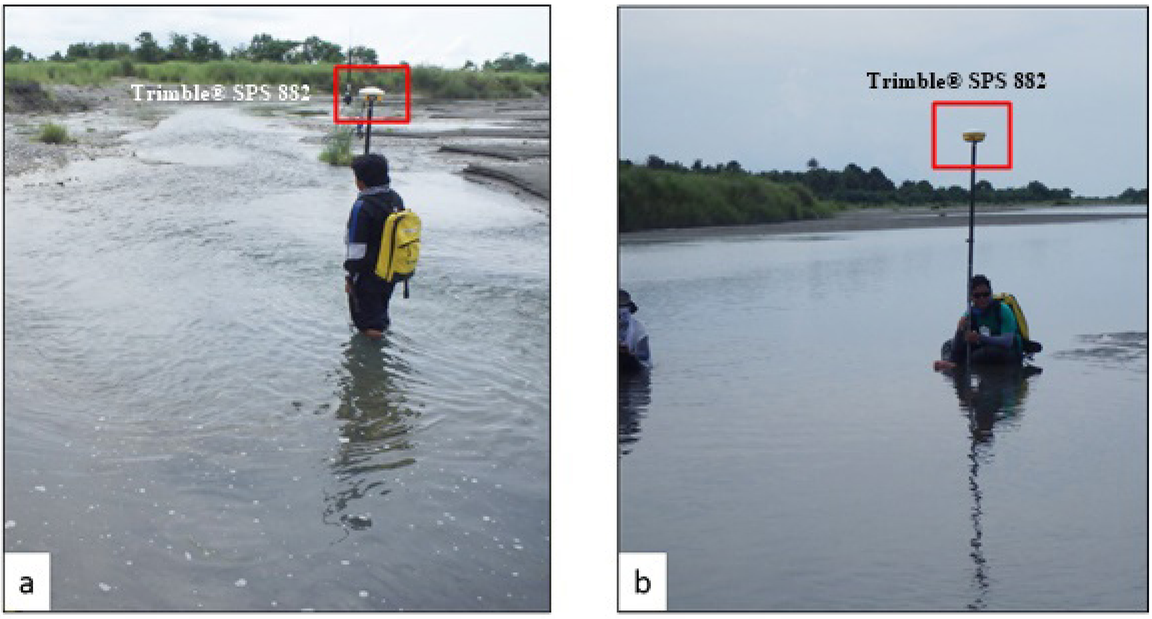



Figure 44. Bathymetric survey in Bongabong River: (a) upstream and (b) downstream

The bathymetric line length surveyed covered an estimated 9.21 km with 533 bathymetric points covering the bridge and passing three barangay boundaries namely Brgy. San Isidro, Brgy. Mina de Oro and Brgy. Anilao down to the boundary of Bongabong River and Tablas Strait as shown in Figure 47. Problems. A CAD drawing was also produced to illustrate the riverbed profile of Bongabong river. As shown in Figure 48, an elevation drop of 21 meters in MSL was observed within the surveyed distance of the river. The highest elevation value observed was 20.589 m in MSL located at the upstream part of the river near the bridge, while the lowest elevation value observed was -0.859 m below MSL located at the downstream part of the river in Brgy. Anilao. Problems were encountered such as the presence of security threats in the upstream region of the river which made it non-traversable thus only a portion of the river delineated was surveyed. About 13.41km of the planned bathy survey in the upstream was not covered.

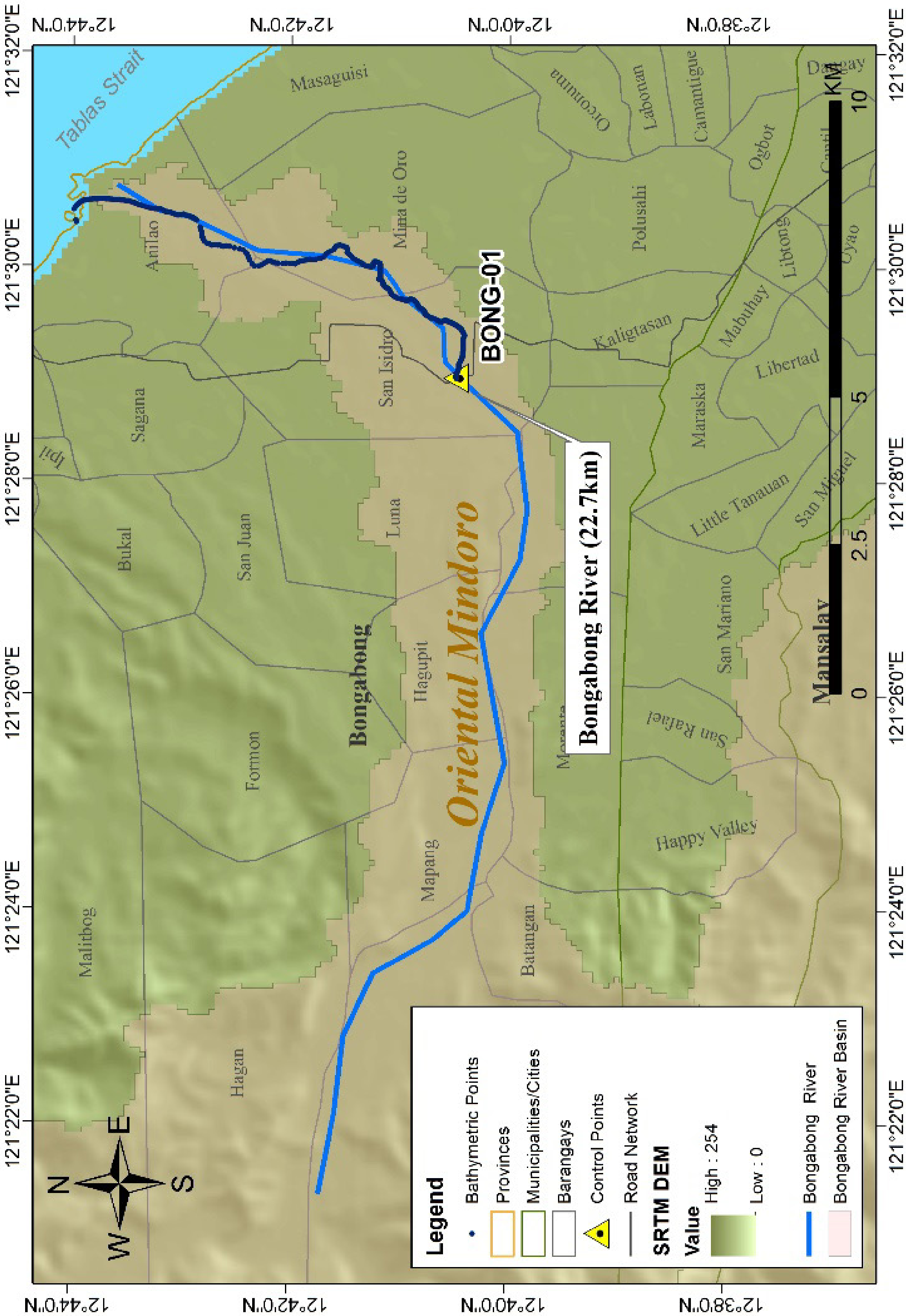



Figure 45. Bathymetric points gathered along Bongabong River

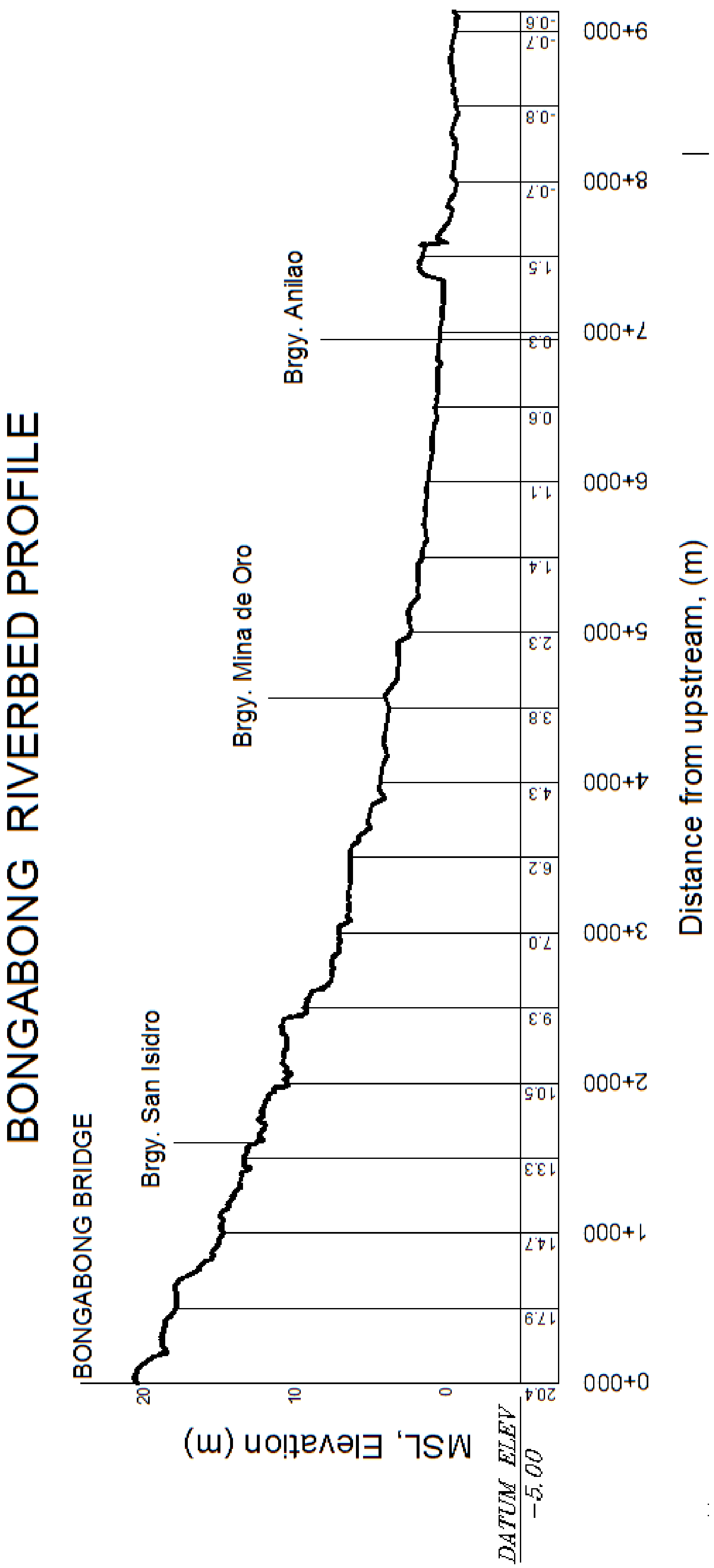



Figure 46. Riverbed profile of Bongabong

# CHAPTER 5: FLOOD MODELING AND MAPPING

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

## 5.1 Data Used for Hydrologic Modeling

### 5.1.1 Hydrometry and Rating Curves

All data that affect the hydrologic cycle of the river basin were monitored, collected, and analyzed. Rainfall, water level, and flow in a certain period of time, which may affect the hydrologic cycle of the Bongabong River Basin were monitored, collected, and analyzed.

### 5.1.2 Precipitation

Precipitation data was taken from two Automatic Rain Gauge (ARG) Stations surrounding the watershed. The location of the rain gauges is seen in Figure 49.

The total precipitation for each rain gauge station are as follows: Brgy. Villa Pag-asa, 34.01 mm and Sta. Maria, 21.2 mm. The corresponding peak rainfall are as follows: Brgy, Villa Pag-asa ARG, 10.8 mm. on March 27, 2017 at 5:00 am and Sta. Maria ARG, 3.556 mm on March 27, 2017 at 4:45 am.

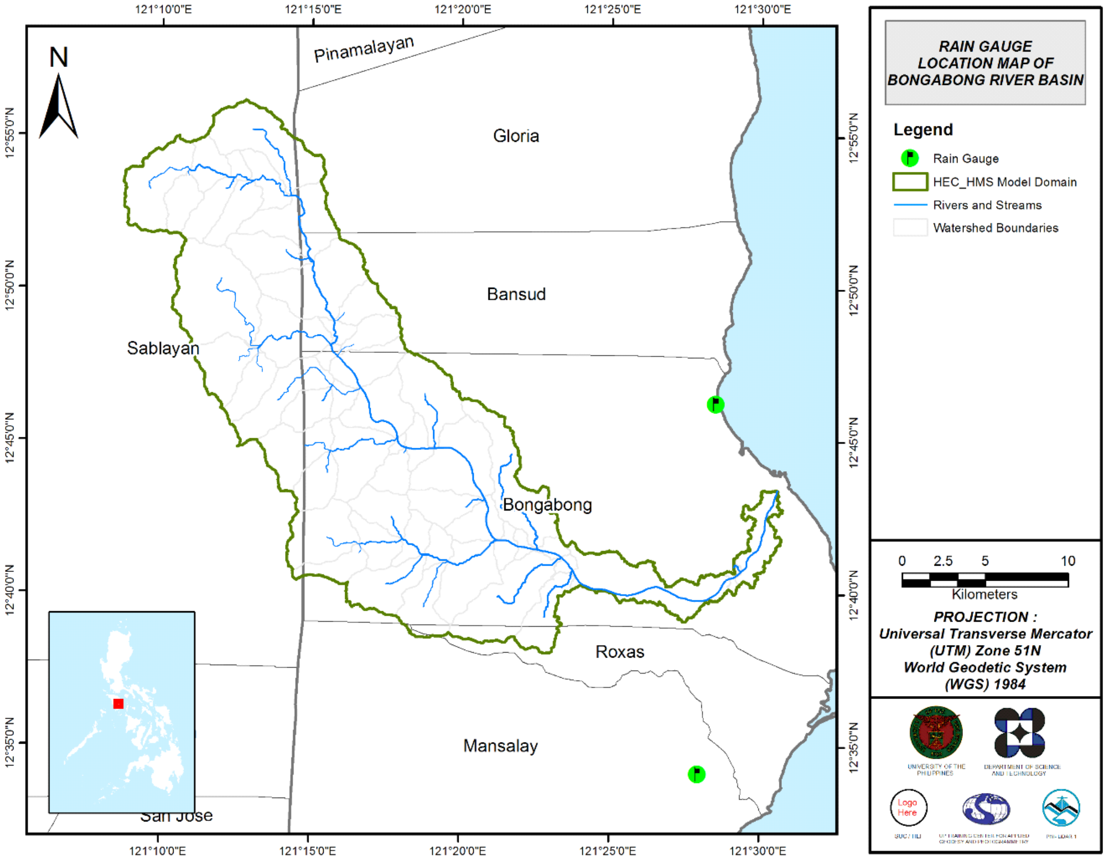


Figure 47. The location map of Bongabong HEC-HMS model used for calibration

### 5.1.3 Rating Curves and River Outflow

A rating curve was developed at Orconuma Bridge, Oriental Mindoro (12.675211° N, 121.482694° E) using Manning's Bankfull Method. It gives the relationship between the observed change in water and the outflow of the watershed at this location.

For Orconuma Bridge, the rating curve is expressed as $Q = 6E\text{-}11e^{1.3038x}$ as shown in Figure 51.

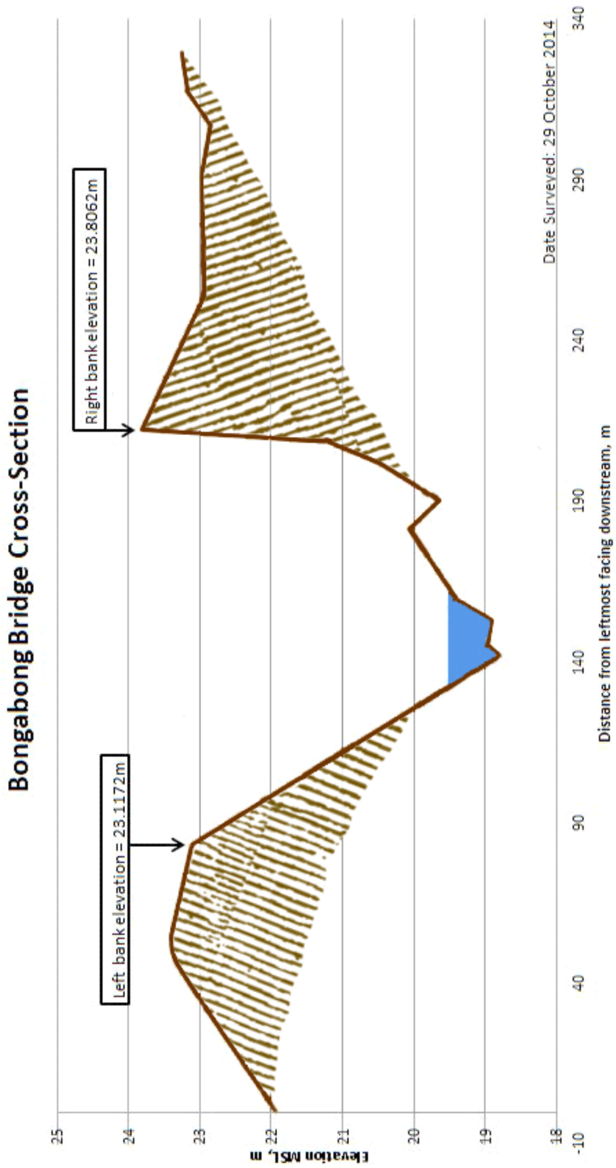


Figure 48. Cross-Section Plot of Orconuma Bridge

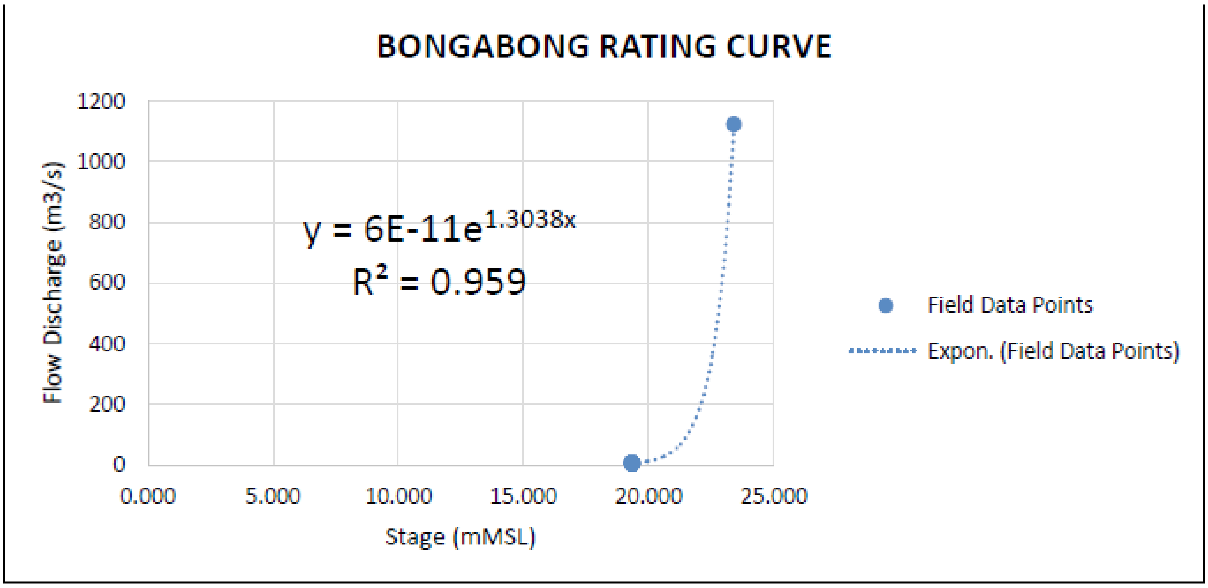


Figure 49. Rating Curve at Bongabong Bridge, Oriental Mindoro

For the calibration of the HEC-HMS model, shown in Figure 52, actual flow discharge during a rainfall event was collected in the Orconuma bridge. Peak discharge is 13.0 cu.m/s on March 27, 2017 at 10:50 am.

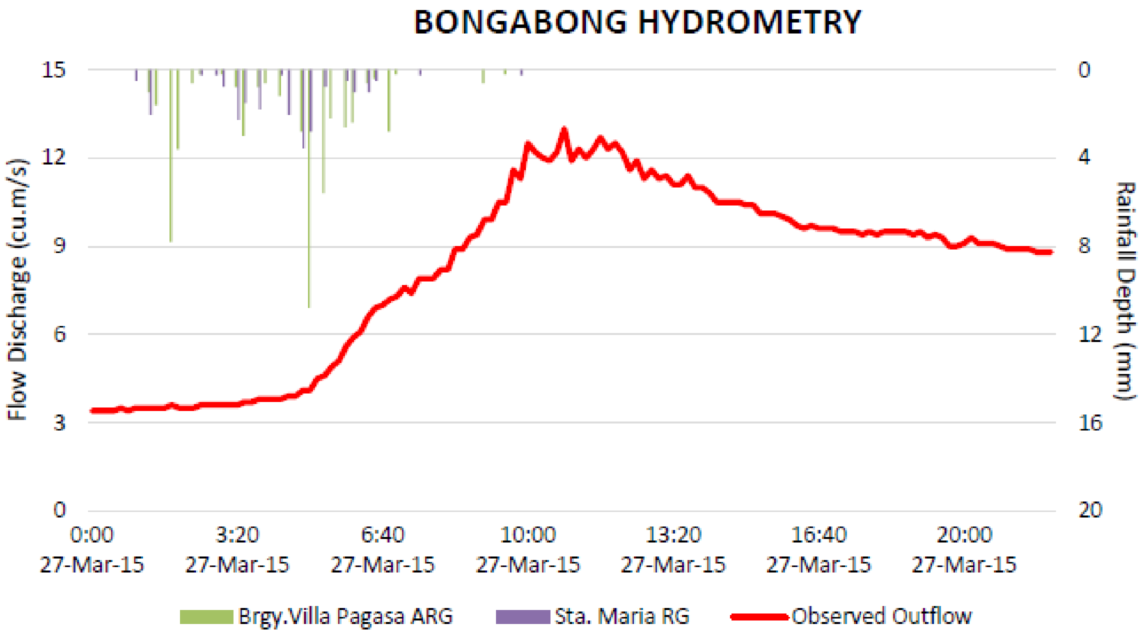


Figure 50. Rainfall and outflow data at Bongabong used for modeling

## 5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the 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 Bongabong watershed. The extreme values for this watershed were computed based on a 48-year record.

Table 26. RIDF values for Romblon 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 | 18.2 | 27 | 33.5 | 44.3 | 59.5 | 70.4 | 89.5 | 107 | 119.8 |
| 5 | 26 | 37.7 | 46.5 | 60.7 | 82.2 | 97.6 | 125.5 | 152.9 | 171.6 |
| 10 | 31.1 | 44.8 | 55 | 71.5 | 97.3 | 115.7 | 149.3 | 183.4 | 205.9 |
| 15 | 34 | 48.8 | 59.9 | 77.7 | 105.8 | 125.8 | 162.8 | 200.5 | 225.2 |
| 20 | 36 | 51.6 | 63.3 | 82 | 111.8 | 133 | 172.2 | 212.6 | 238.8 |
| 25 | 37.6 | 53.8 | 65.9 | 85.3 | 116.4 | 138.4 | 179.4 | 221.8 | 249.2 |
| 50 | 42.4 | 60.4 | 74 | 95.4 | 130.5 | 155.3 | 201.8 | 250.3 | 281.4 |
| 100 | 47.2 | 67 | 81.9 | 105.5 | 144.5 | 172.1 | 223.9 | 278.6 | 313.3 |

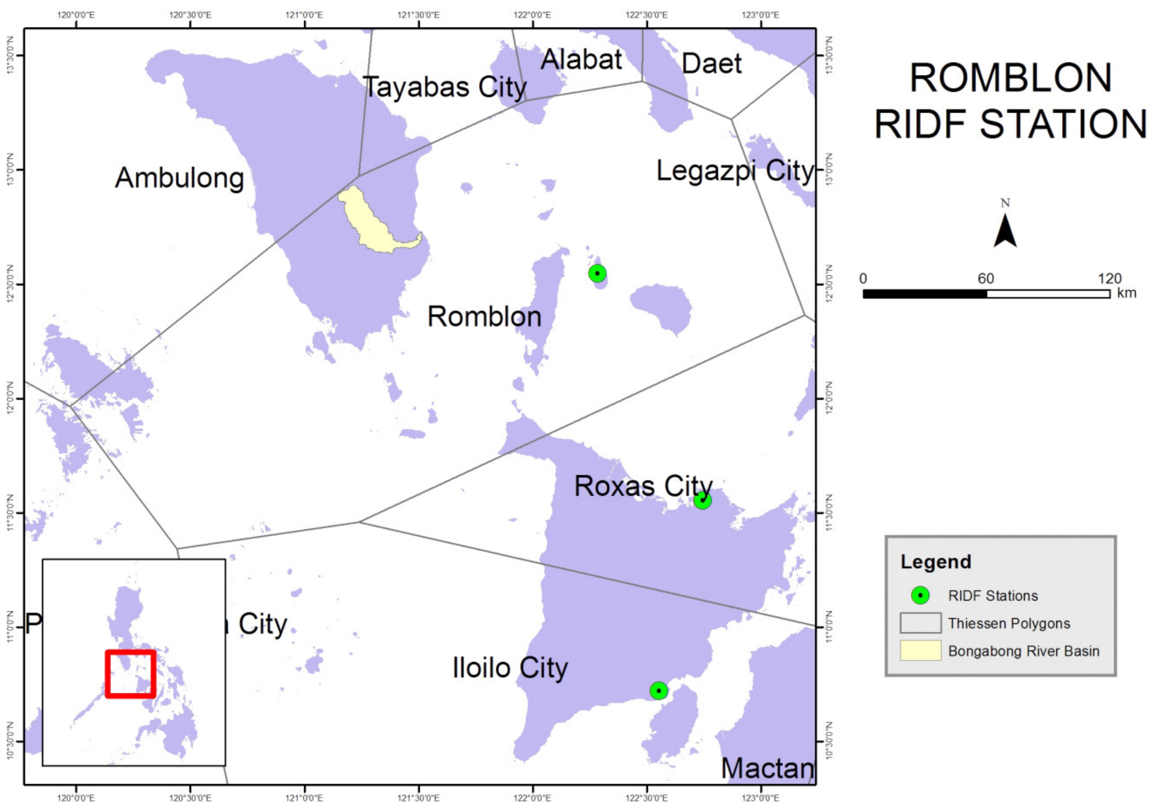


Figure 51. Location of Romblon RIDF relative to Bongabong River Basin

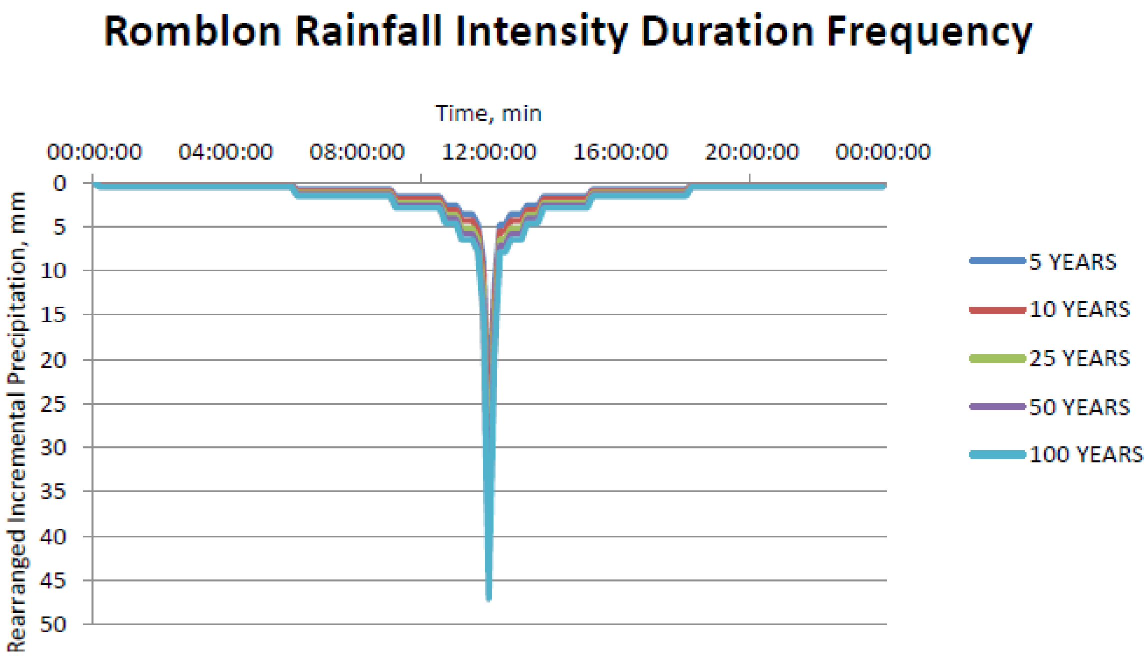


Figure 52. Synthetic Storm Generated For A 24-hr Period Rainfall For Various Return Periods

## 5.3 HMS Model

The soil shape file was taken on 2004 from the Bureau of Soils and Water Management under the Department of Agriculture. The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil map and land cover map can be found in Figures 53 and 54, respectively.

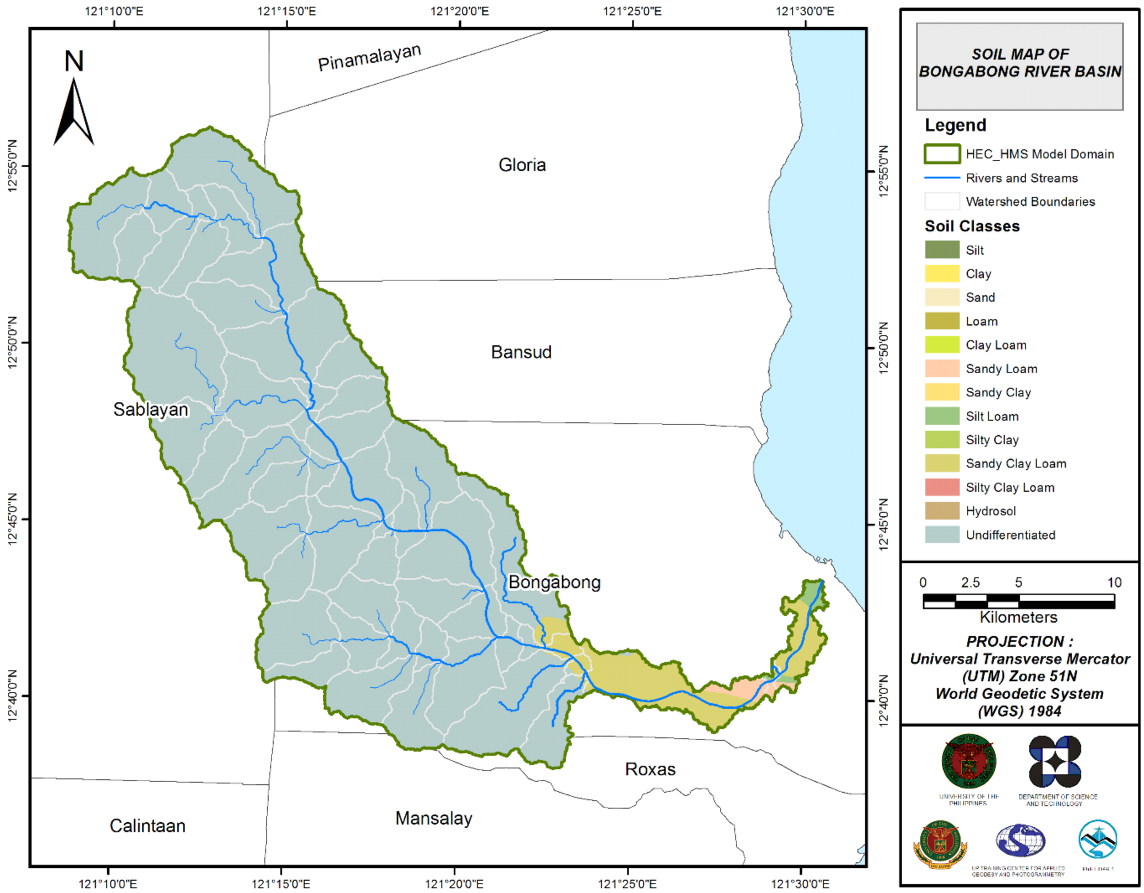


Figure 53. The soil map of the Bongabong River Basin used for the estimation of the CN parameter. (Source of data: Digital soil map of the Philippines published by the Bureau of Soil and Water Management – Department of Agriculture)

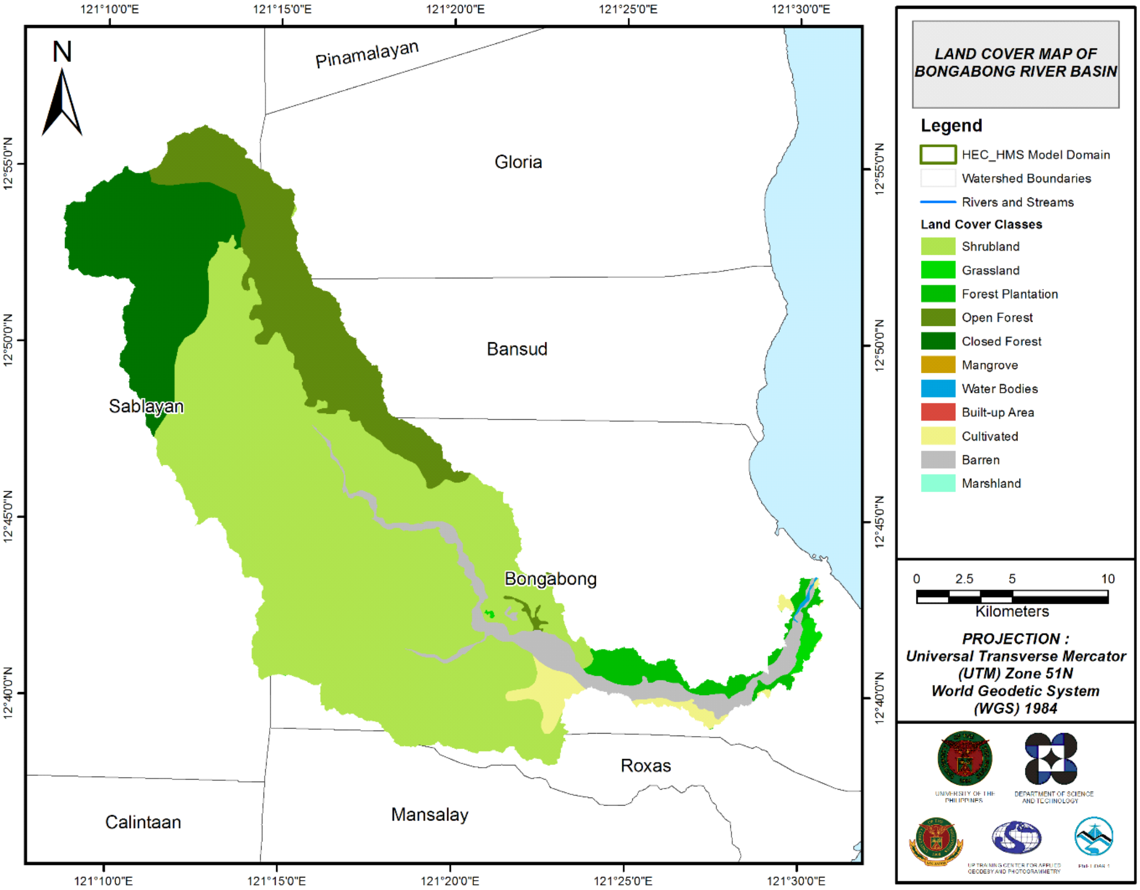


Figure 54. The land cover map of the Bongabong River Basin used for the estimation of the CN and watershed lag parameters of the rainfall-runoff model. (Source of data: Digital soil map of the Philippines published by the Bureau of Soil and Water Management – Dep

For Bongabong, the soil classes identified were silt loam, sandy loam, sandy clay loam, and undifferentiated. The land cover types identified were shrubland, grassland, forest plantation, open forest, closed forest, barren, and cultivated.

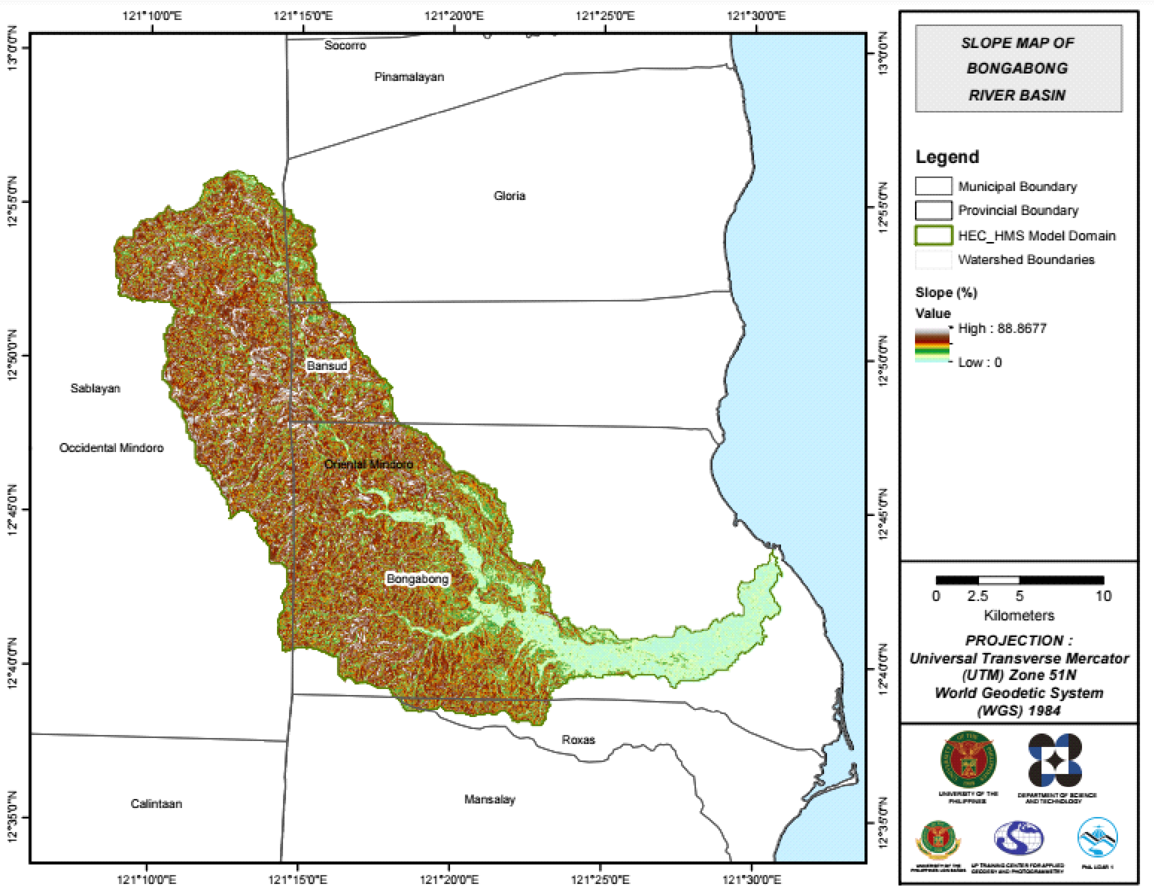


Figure 55. Slope Map of the Bongabong River Basin

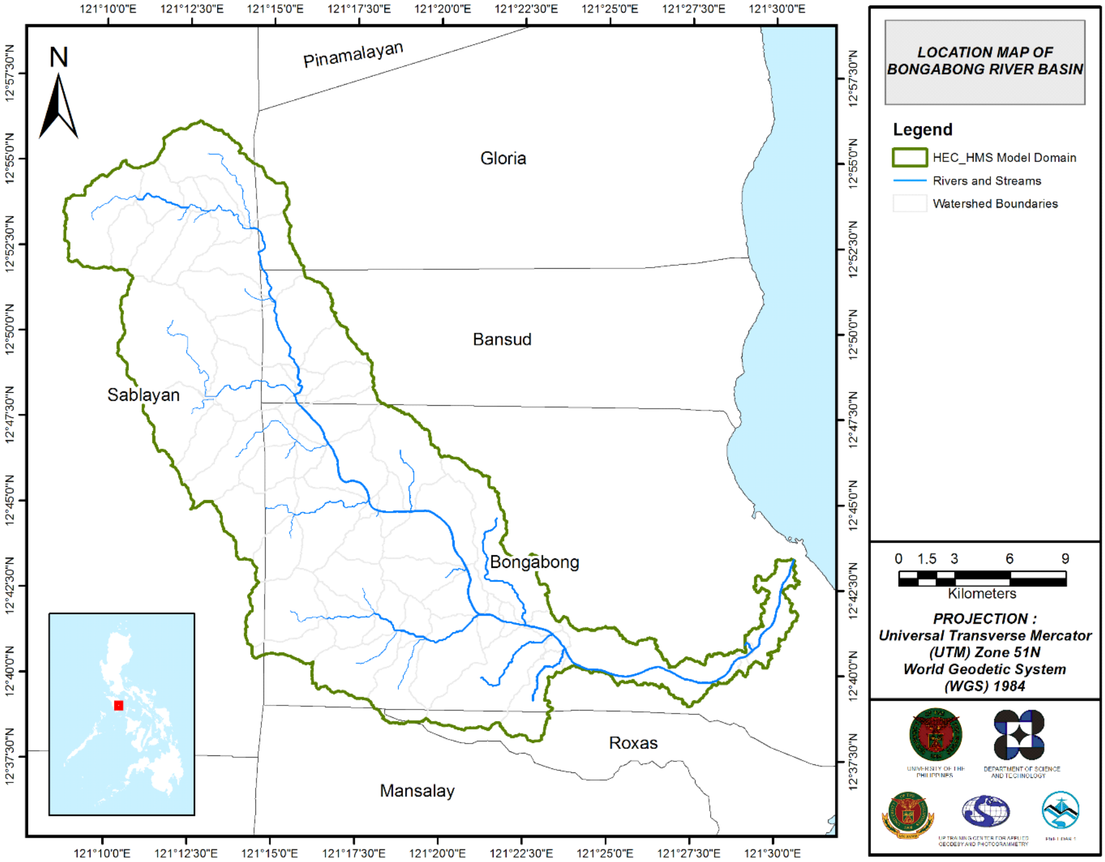


Figure 56. Stream Delineation Map of the Bongabong River Basin

Using SAR-based DEM, the Bongabong basin was delineated and further subdivided into subbasins. The model consists of 55 sub basins, 28 reaches, and 28 junctions as shown in Figure 59. The main outlet is in Orconuma Bridge.

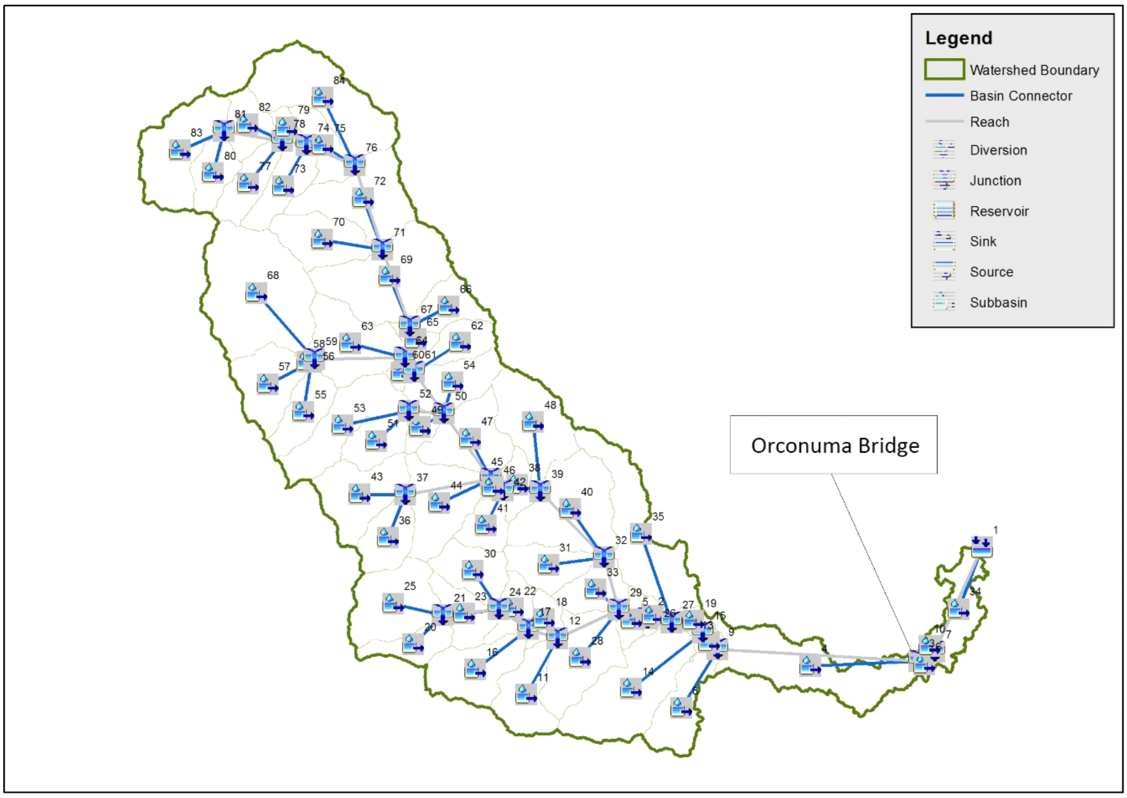


Figure 57. The Bongabong river basin model generated using HEC-HMS

## 5.4 Cross-section Data

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

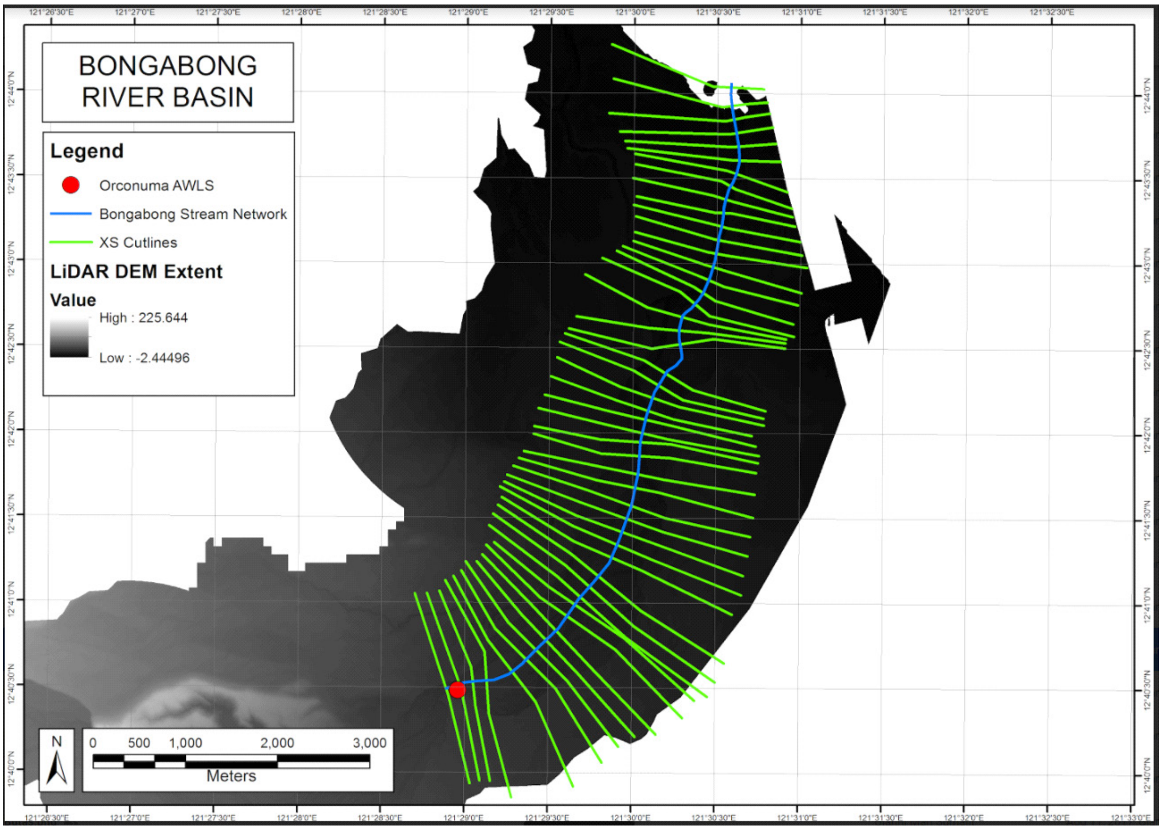


Figure 58. River cross-section of Bongabong River generated through Arcmap HEC GeoRAS tool

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

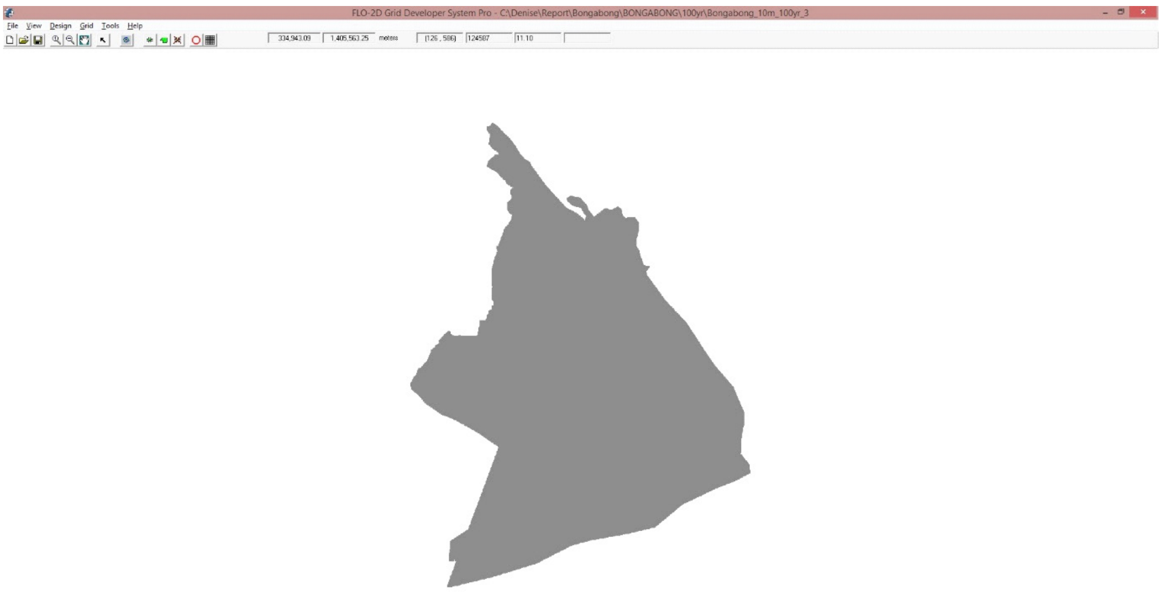


Figure 59. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 34.08411 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 42738700.00 m2.

There is a total of 89570449.32 m3 of water entering the model. Of this amount 13310963.40 m3 is due to rainfall while 76259485.92 m3 is inflow from other areas outside the model. 9047591.00 m3 of this water is lost to infiltration and interception, while 13328470.10 m3 is stored by the flood plain. The rest, amounting up to 67194394.02 m3, is outflow.

## 5.6 Results of HMS Calibration

After calibrating the Bongabong HEC-HMS river basin model, its accuracy was measured against the observed values (see Annex 9: Bongabong Model Basin Parameters). Figure 62 shows the comparison between the two discharge data.

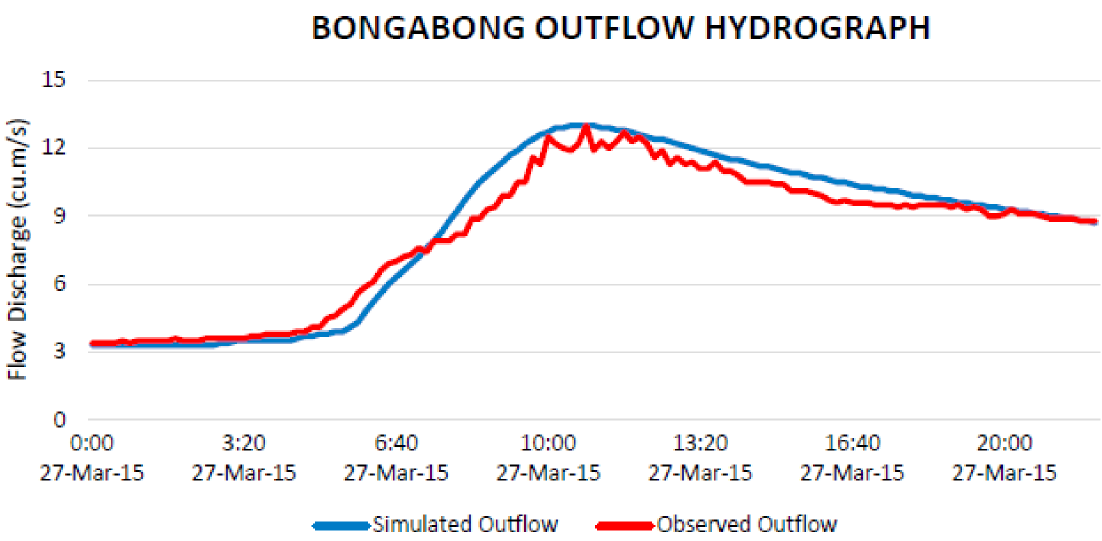


Figure 60. Outflow Hydrograph of Bongabong produced by the HEC-HMS model compared with observed outflow

Enumerated in Table 27 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 27. Range of Calibrated Values for Bongabong

| Hydrologic Element | Calculation Type | Method | Parameter | Range of Calibrated Values |
|---|---|---|---|---|
| Basin | Loss | SCS Curve number | Initial Abstraction (mm) | 2 - 46 |
| | | | Curve Number | 35 - 95 |
| | Transform | Clark Unit Hydrograph | Time of Concentration (hr) | 0.1 - 7 |
| | | | Storage Coefficient (hr) | 2 - 103 |
| | Baseflow | Recession | Recession Constant | 0.2 - 1 |
| | | | Ratio to Peak | 0.2 – 0.5 |
| Reach | Routing | Muskingum-Cunge | Manning’s Coefficient | 0.004 – 0.04 |

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 2mm to 46mm means that there is a minimal to average amount of infiltration or rainfall interception by vegetation per subbasin.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 35 to 95 for curve number is acceptable for Philippine watersheds, however, some of the subbasins corresponds to a lower value than common watersheds. This depends on the soil and land cover of the watershed.

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 0.1 to 103 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.2 indicates that the basin is likely to quickly go back to its original discharge. Ratio to peak of 0.2 to 0.5 indicates a steeper to a relatively average receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.004 to 0.04 means that each river segment reacts differently wherein water flow smoothly or otherwise.

Table 28. Summary of the Efficiency Test of Bongabong HMS Model

| Accuracy Measure | Value |
|---|---|
| Root Mean Square Error (RMSE) | 0.685 |
| Pearson Correlation Coefficient (r2) | 0.991 |
| Nash-Sutcliffe (E) | 0.948 |
| Percent Bias (PBIAS) | -3.391 |
| Observation Standard Deviation Ratio (RSR) | 0.227 |

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 0.685.

The Pearson correlation coefficient (r2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.991.

The Nash-Sutcliffe (E) method was also used to assess the predictive power of the model. Here the optimal value is 1. The model attained an efficiency coefficient of 0.948.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is -3.391.

The Observation Standard Deviation Ratio, RSR, is an error index. A perfect model attains a value of 0 when the error in the units of the valuable a quantified. The model has an RSR value of 0.227.

## 5.7 Calculated outflow hydrographys and discharge values for different rainfall return periods

### 5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph (Figure 63) shows the Bongabong outflow using the Romblon Rainfail Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

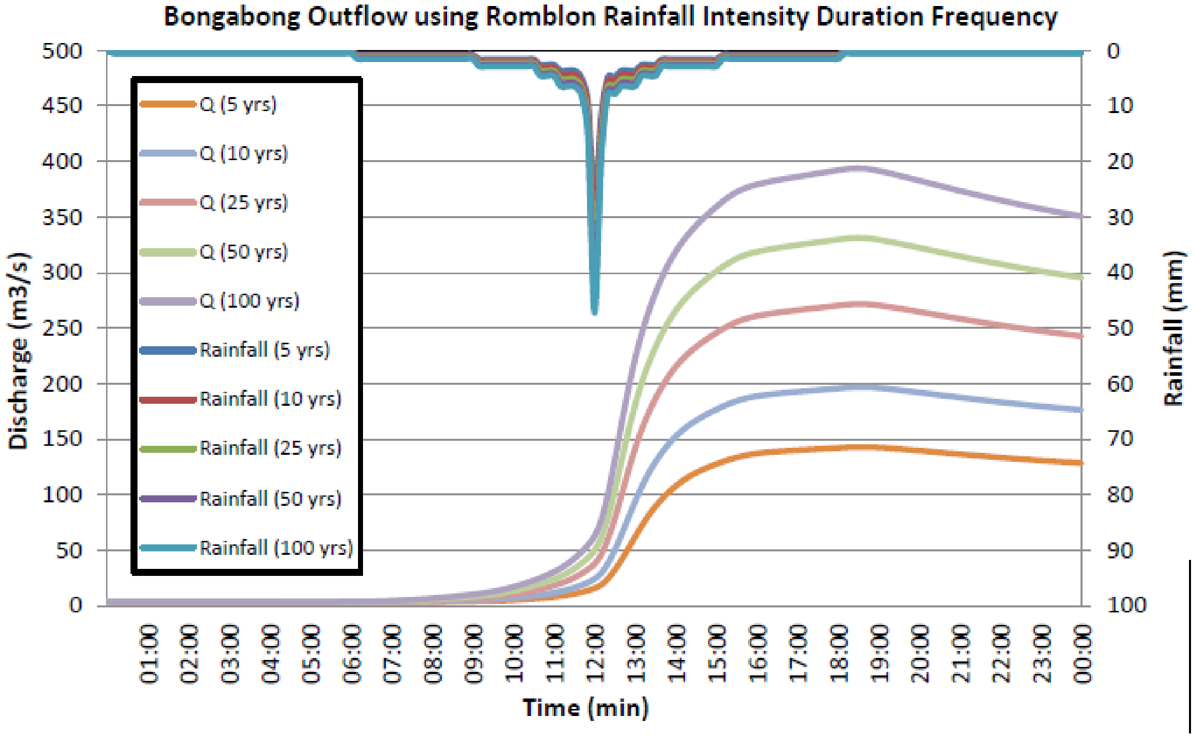


Figure 61. Outflow hydrograph at Bongabong Station generated using Romblon RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow, time to peak and lag time of the Bongabong discharge using the Romblon Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 29.

Table 29. Peak values of the Bongabong HECHMS Model outflow using the Romblon RIDF

| RIDF PERIOD | Total Precipitation (mm) | Peak Rainfall (mm) | Peak Outflow (cu.m/s) | Time to Peak | Lag Time |
|---|---|---|---|---|---|
| 5-yr | 171.60 | 26 | 142.70 | 18 hours 30 minutes | 6 hours 30 minutes |
| 10-yr | 205.90 | 31.1 | 196.70 | | |
| 25-yr | 249.20 | 37.6 | 271.70 | | |
| 50-yr | 281.40 | 42.4 | 331.40 | | |
| 100-yr | 313.30 | 47.2 | 393.80 | | |

The river discharges for the three points in the floodplain where rivers are shown in Figure 64 to Figure 66 and the peak values are summarized in Table 34 to Table 36.

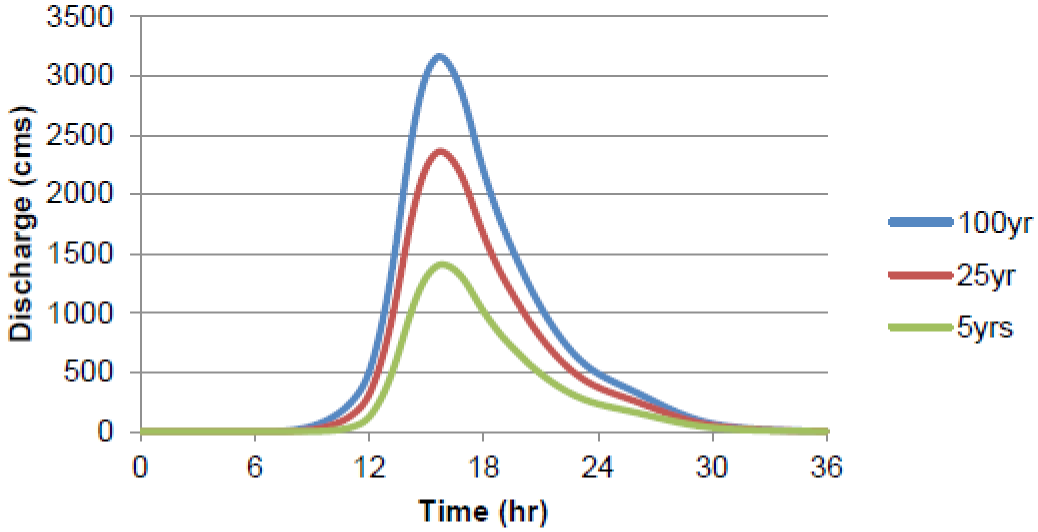


Figure 62. Bongabong river (1) generated discharge using 5-, 25-, and 100-year Romblon rainfall intensity-duration-frequency (RIDF) in HEC-HMS

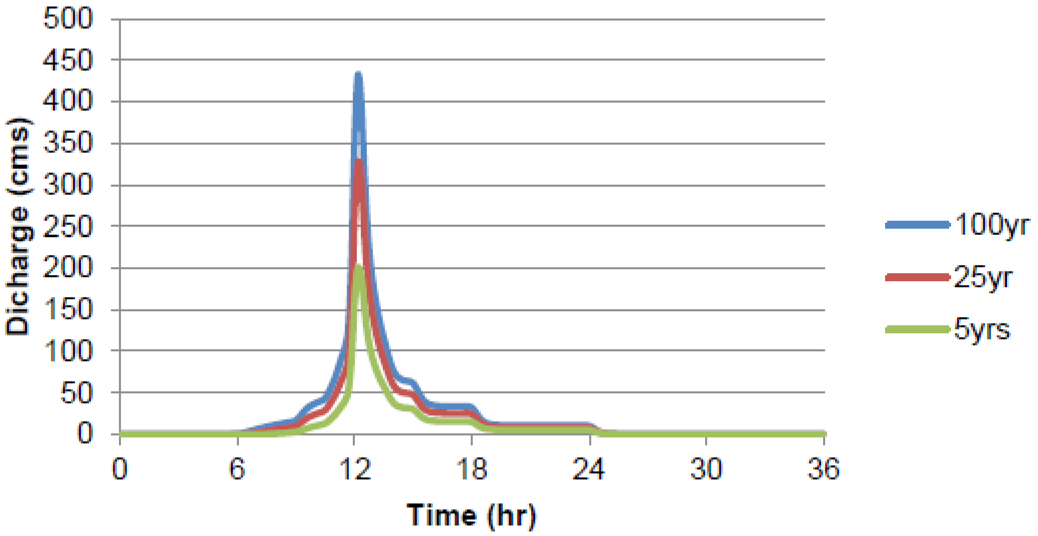


Figure 63. Bongabong river (2) generated discharge using 5-, 25-, and 100-year Romblon rainfall intensity-duration-frequency (RIDF) in HEC-HMS

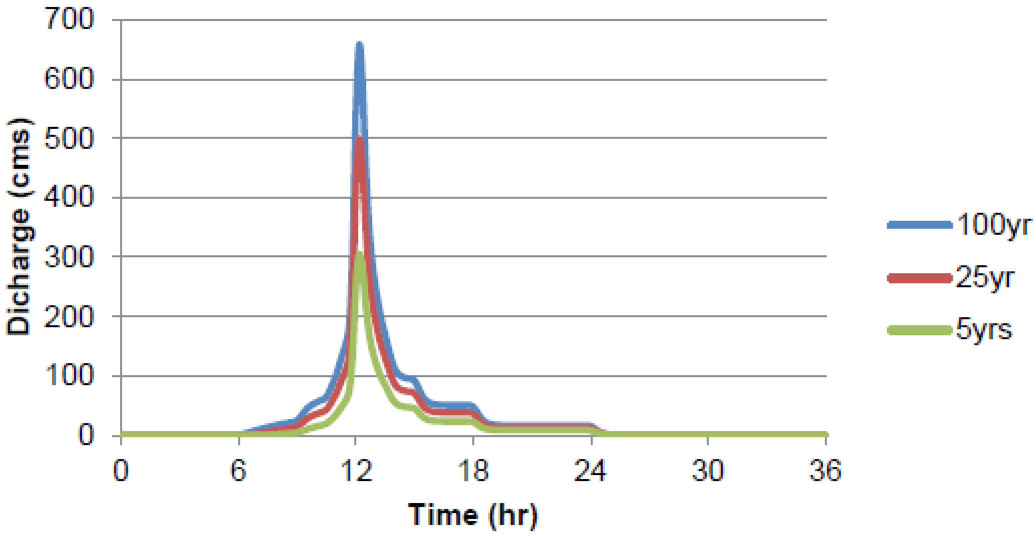


Figure 64. Bongabong river (3) generated discharge using 5-, 25-, and 100-year Romblon rainfall intensity-duration-frequency (RIDF) in HEC-HMS

Table 30. Summary of Bongabong river (1) discharge generated in HEC-HMS

| RIDF Period | Peak discharge (cms) | Time-to-peak |
|---|---|---|
| 100-Year | 3162.6 | 15 hours, 40 minutes |
| 25-Year | 2361.5 | 15 hours, 40 minutes |
| 5-Year | 1410.7 | 15 hours, 50 minutes |

Table 31. Summary of Bongabong river (2) discharge generated in HEC-HMS

| RIDF Period | Peak discharge (cms) | Time-to-peak |
|---|---|---|
| 100-Year | 431.8 | 12 hours, 10 minutes |
| 25-Year | 327.4 | 12 hours, 10 minutes |
| 5-Year | 200.4 | 12 hours, 10 minutes |

Table 32. Summary of Bongabong river (3) discharge generated in HEC-HMS

| RIDF Period | Peak discharge (cms) | Time-to-peak |
|---|---|---|
| 100-Year | 656.8 | 12 hours, 10 minutes |
| 25-Year | 497.5 | 12 hours, 10 minutes |
| 5-Year | 303.9 | 12 hours, 10 minutes |

The comparison of the discharge results using Dr. Horritt's recommended hydrological method against the bankful and specific discharge estimates is shown in Table 33.

Table 33. Validation of river discharge estimates

| Discharge Point | QMED(SCS), cms | QBANKFUL, cms | QMED(SPEC), cms | VALIDATION | |
|---|---|---|---|---|---|
| | | | | Bankful Discharge | Specific Discharge |
| Bongabong (1) | 1241.416 | 2027.884 | 1316.795 | Pass | Pass |
| Bongabong (2) | 176.352 | 168.809 | 159.254 | Pass | Pass |
| Bongabong (3) | 267.432 | 505.510 | 215.543 | Pass | Pass |

All three values from the HEC-HMS river discharge estimates were able to satisfy the conditions for validation using the bankful and specific discharge methods. The calculated values are based on theory but are supported using other discharge computation methods so they were good to use flood modeling. These values will need further investigation for the purpose of validation. It is therefore recommended to obtain actual values of the river discharges for higher-accuracy modeling.

## 5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. The sample map of Bongabong River using the HMS base flow is shown on Figure 65 below.


Figure 65. Bongabong HEC-RAS Output

## 5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps for 5-, 25-, and 100-year rain return scenarios of the Bongabong floodplain are shown in Figure 68 to 73. The floodplain, with an area of 53.89 sq. km., covers one municipality namely Bongabong. Table 34 shows the percentage of area affected by flooding per municipality.

Table 34. Municipalities affected in Bongabong floodplain

| Municipality | Total Area | Area Flooded | % Flooded |
|---|---|---|---|
| Bongabong | 493.741 | 53.48787 | 10.83318 |

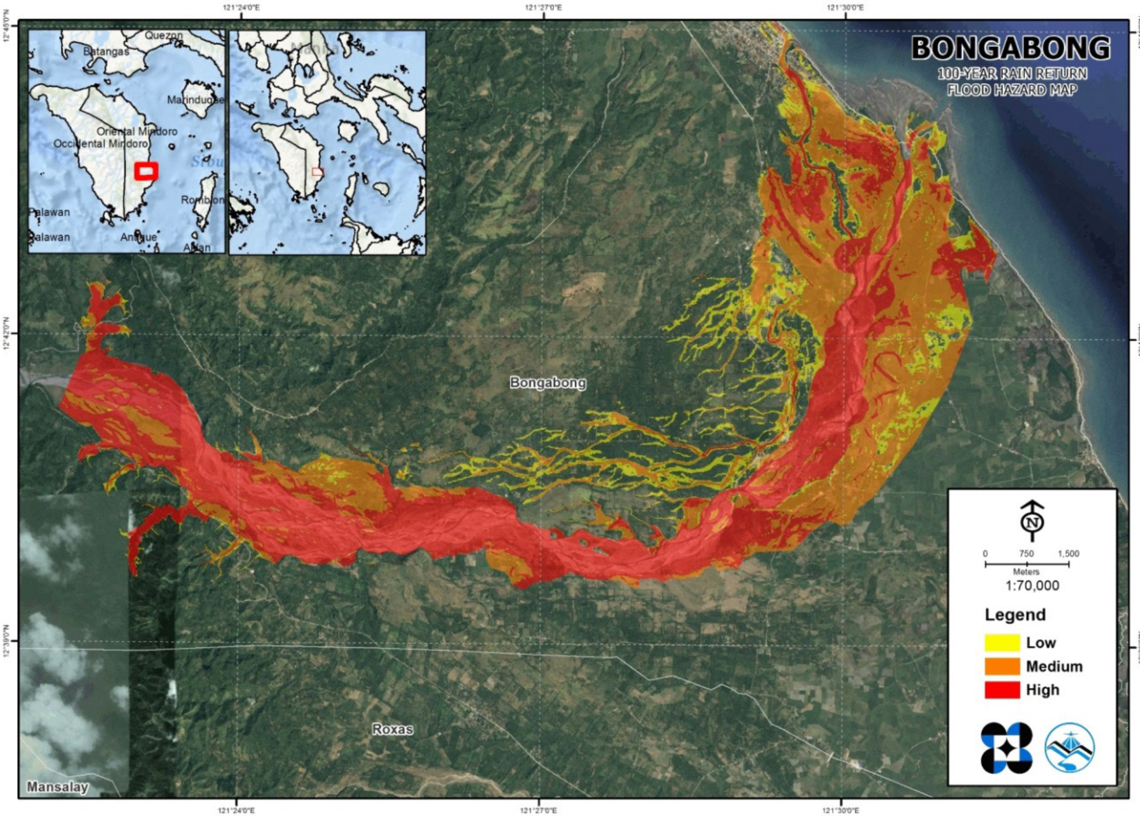


Figure 66. 100-year Flood Hazard Map for Bongabong Floodplain

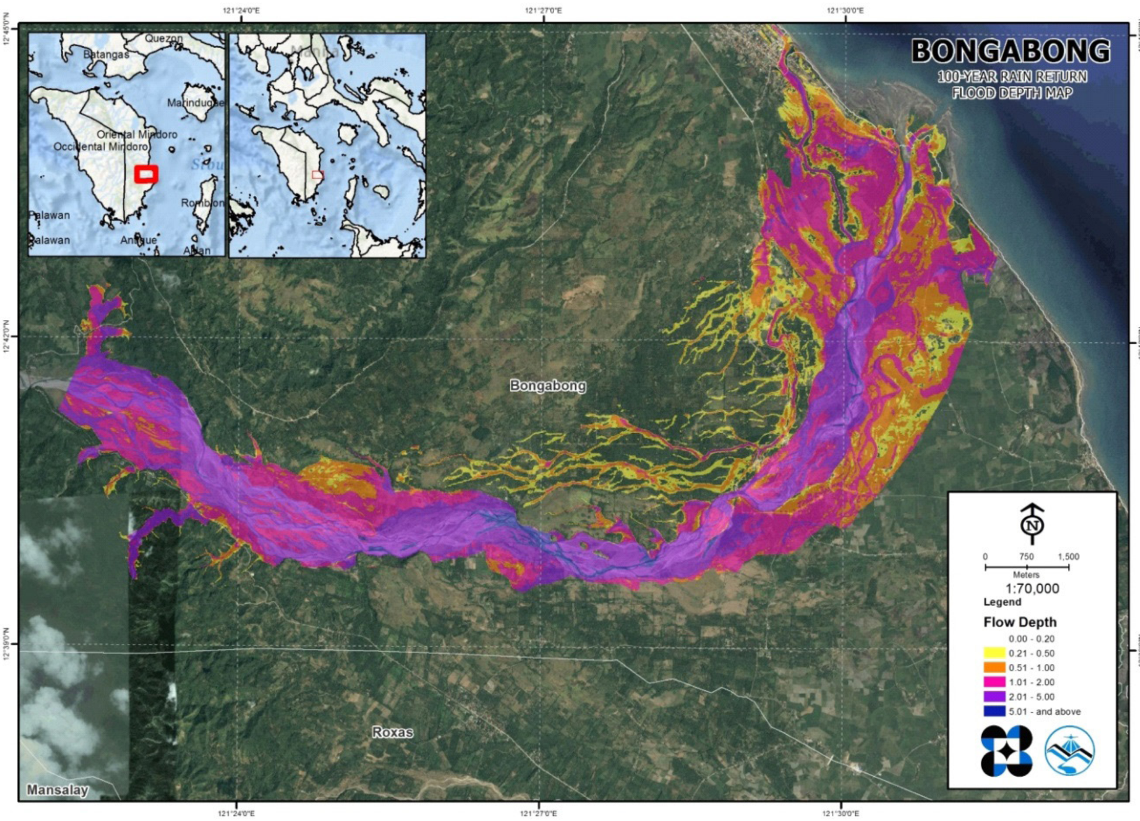


Figure 67. 100-year Flow Depth Map for Bongabong Floodplain

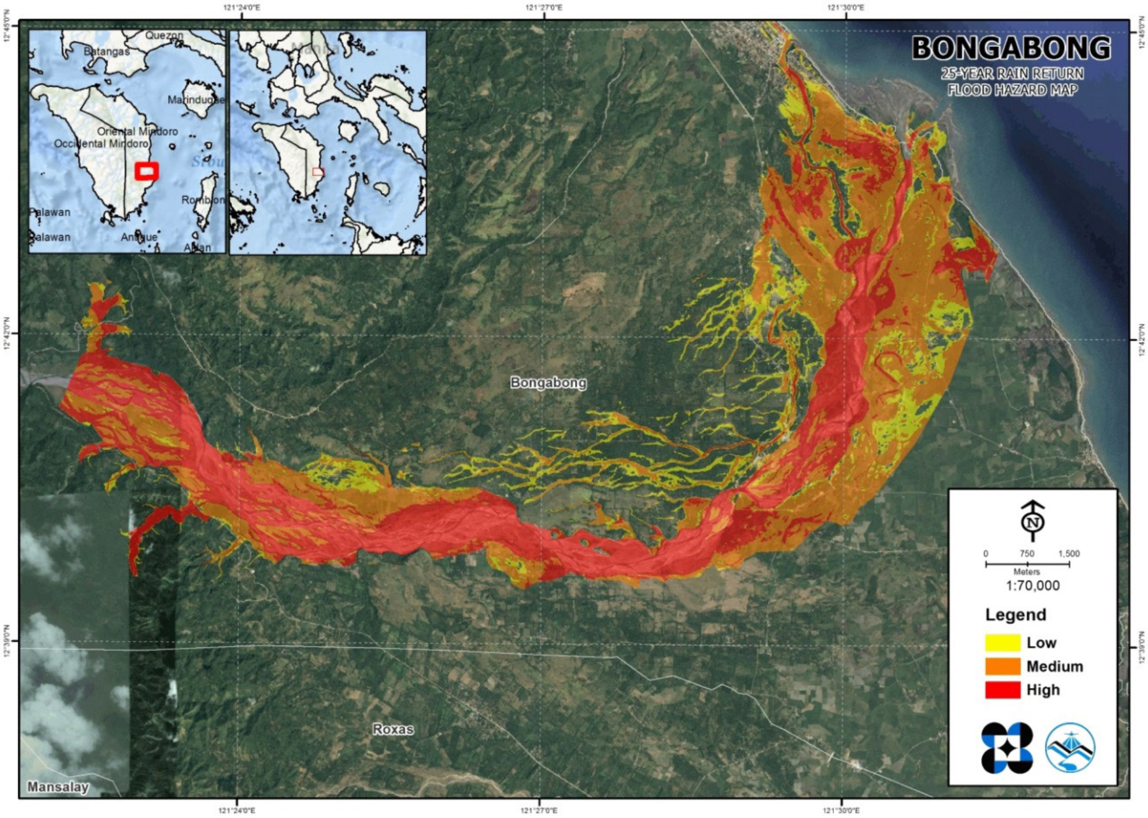


Figure 68. 25-year Flood Hazard Map for Bongabong Floodplain

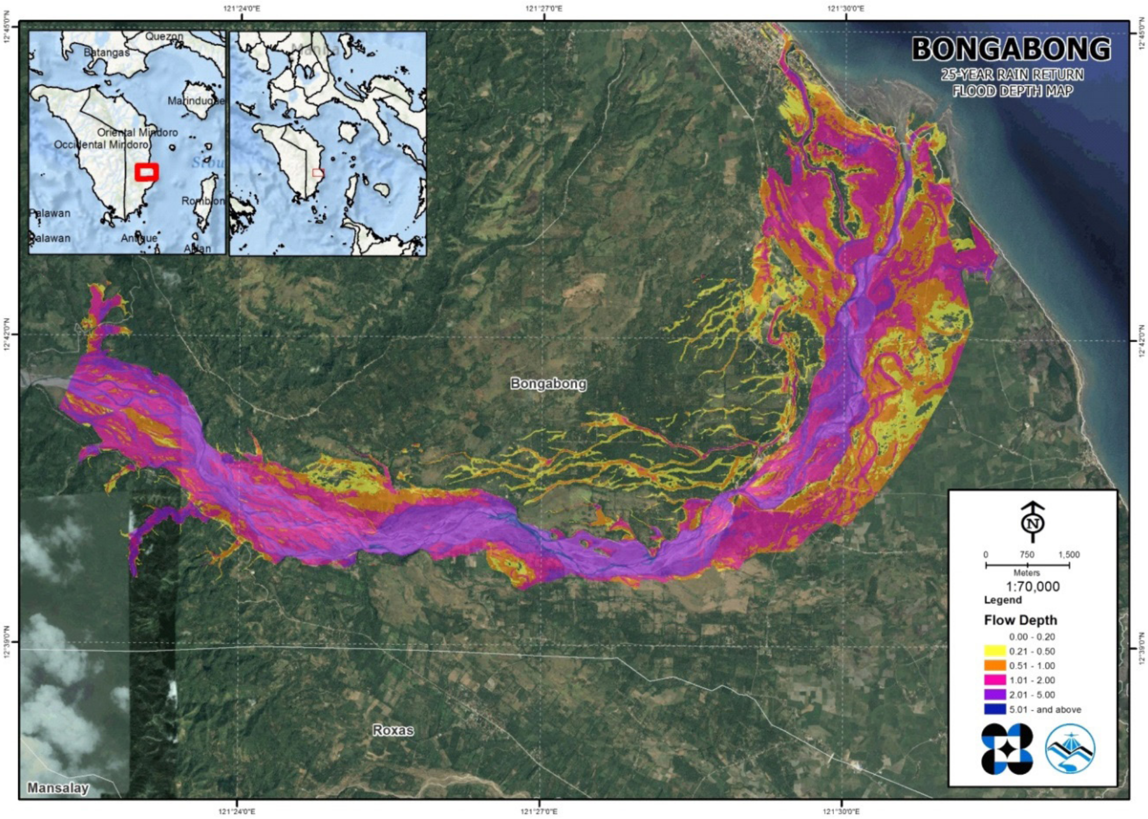


Figure 69. 25-year Flow Depth Map for Bongabong Floodplain

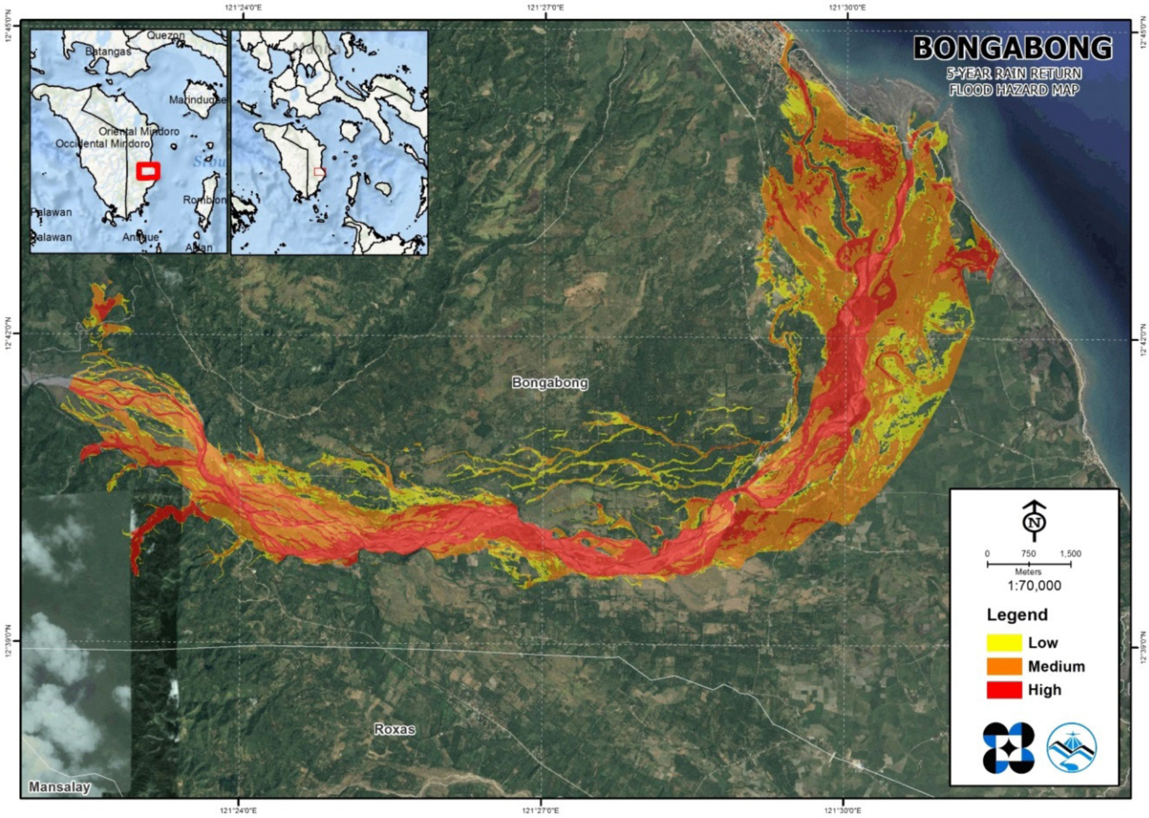


Figure 70. 5-year Flood Hazard Map for Bongabong Floodplain

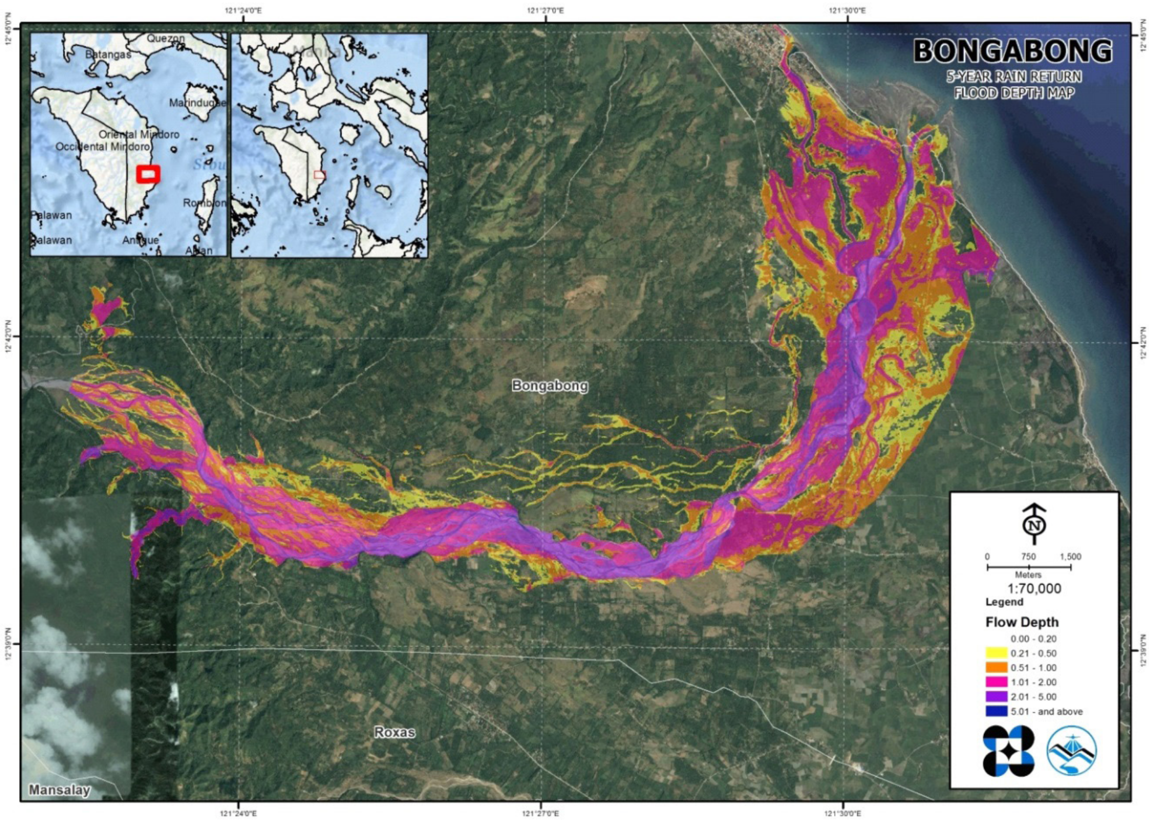


Figure 71. 5-year Flow Depth Map for Bongabong Floodplain

## 5.10 Inventory of Areas Exposed to Flooding of Affected Areas

Affected barangays in Bongabong river basin, grouped by municipality, are listed below. For the said basin, four municipalities consisting of 17 barangays are expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 3.56% of the municipality of Bongabong with an area of 493.74 sq. km. will experience flood levels of less 0.20 meters. 1.40% of the area will experience flood levels of 0.21 to 0.50 meters while 2.16%, 2.48%, 1.22%, 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 Tables 35-36 are the affected areas in square kilometres by flood depth per barangay.

Table 35. Affected Areas in Bongabong, Oriental Mindoro during 5-Year Rainfall Return Period

| BONGABONG BASIN | | Affected Barangays in Bongabong | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Anilao | Aplaya | Batangan | Formon | Hagan | Hagupit | Lisap | Luna |
| Affected Area (sq. km.) | 0.03-0.20 | 0.56 | 0.0025 | 1.01 | 0.015 | 1.14 | 2.61 | 2.12 | 4.44 |
| | 0.21-0.50 | 1.08 | 0.0031 | 0.1 | 0.0001 | 0.25 | 0.5 | 0.54 | 0.6 |
| | 0.51-1.00 | 2.82 | 0.0036 | 0.28 | 0 | 0.22 | 0.16 | 1.01 | 0.28 |
| | 1.01-2.00 | 3.21 | 0.0081 | 0.24 | 0 | 0.18 | 0.49 | 1.59 | 0.14 |
| | 2.01-5.00 | 0.77 | 0.0012 | 0.061 | 0 | 0.0026 | 0.4 | 0.62 | 0.14 |
| | > 5.00 | 0.0072 | 0 | 0 | 0 | 0 | 0.0093 | 0 | 0 |

Table 36. Affected Areas in Bongabong, Oriental Mindoro during 5-Year Rainfall Return Period

| BONGABONG BASIN | | Affected Barangays in Bongabong | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Mapang | Masaguisi | Mina de Oro | Morente | Sagana | San Isidro | San Jose | San Juan |
| Affected Area (sq. km.) | 0.03-0.20 | 1.39 | 0.15 | 0.57 | 0.63 | 0.056 | 2.67 | 0.19 | 0.0091 |
| | 0.21-0.50 | 0.62 | 0.15 | 1.61 | 0.21 | 0.1 | 1.05 | 0.13 | 0.0015 |
| | 0.51-1.00 | 0.95 | 0.28 | 2.18 | 0.27 | 0.093 | 1.94 | 0.19 | 0 |
| | 1.01-2.00 | 1.06 | 0.56 | 1.38 | 0.57 | 0.1 | 2.25 | 0.46 | 0 |
| | 2.01-5.00 | 0.23 | 0.058 | 1.23 | 0.87 | 0.0001 | 0.74 | 0.92 | 0 |
| | > 5.00 | 0 | 0 | 0.022 | 0.0094 | 0 | 0.0064 | 0.0013 | 0 |

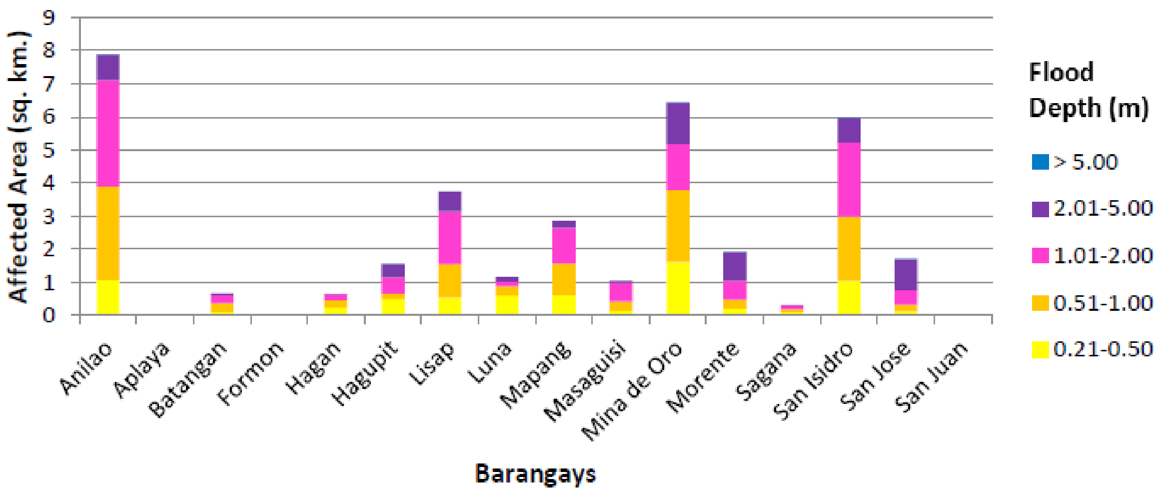


Figure 72. Affected Areas Bongabong, Oriental Mindoro during 5-Year Rainfall Return Period

For the 25-year return period, 3.73% of the municipality of Bongabong with an area of 493.74 sq. km. will experience flood levels of less 0.20 meters. 1.27% of the area will experience flood levels of 0.21 to 0.50 meters while 2.02%, 2.96%, 2.09%, and 0.06% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Tables 37-38 are the affected areas in square kilometres by flood depth per barangay.

Table 37. Affected Areas in Bongabong, Oriental Mindoro during 25-Year Rainfall Return Period

| BONGABONG BASIN | | Affected Barangays in Bongabong | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Anilao | Aplaya | Bagumbayan II | Batangan | Formon | Hagan | Hagupit | Lisap | Luna |
| Affected Area (sq. km.) | 0.03-0.20 | 1.32 | 0.21 | 0.000074 | 0.99 | 0.014 | 0.59 | 2.28 | 1.33 | 4.19 |
| | 0.21-0.50 | 0.98 | 0.044 | 0 | 0.081 | 0.0002 | 0.084 | 0.35 | 0.18 | 0.74 |
| | 0.51-1.00 | 2.58 | 0.0083 | 0 | 0.18 | 0 | 0.16 | 0.32 | 0.57 | 0.46 |
| | 1.01-2.00 | 3.65 | 0.01 | 0 | 0.34 | 0 | 0.57 | 0.27 | 2 | 0.15 |
| | 2.01-5.00 | 0.87 | 0.0012 | 0 | 0.11 | 0 | 0.38 | 0.91 | 1.79 | 0.24 |
| | > 5.00 | 0.0094 | 0 | 0 | 0 | 0 | 0 | 0.055 | 0.0012 | 0.00099 |

Table 38. Affected Areas in Bongabong, Oriental Mindoro during 25-Year Rainfall Return Period

| BONGABONG BASIN | | Affected Barangays in Bongabong | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Mapang | Masaguisi | Mina de Oro | Morente | Sagana | San Isidro | San Jose | San Juan |
| Affected Area (sq. km.) | 0.03-0.20 | 1.39 | 0.15 | 0.57 | 0.63 | 0.056 | 2.67 | 0.19 | 0.0091 |
| | 0.21-0.50 | 0.62 | 0.15 | 1.61 | 0.21 | 0.1 | 1.05 | 0.13 | 0.0015 |
| | 0.51-1.00 | 0.95 | 0.28 | 2.18 | 0.27 | 0.093 | 1.94 | 0.19 | 0 |
| | 1.01-2.00 | 1.06 | 0.56 | 1.38 | 0.57 | 0.1 | 2.25 | 0.46 | 0 |
| | 2.01-5.00 | 0.23 | 0.058 | 1.23 | 0.87 | 0.0001 | 0.74 | 0.92 | 0 |
| | > 5.00 | 0 | 0 | 0.022 | 0.0094 | 0 | 0.0064 | 0.0013 | 0 |

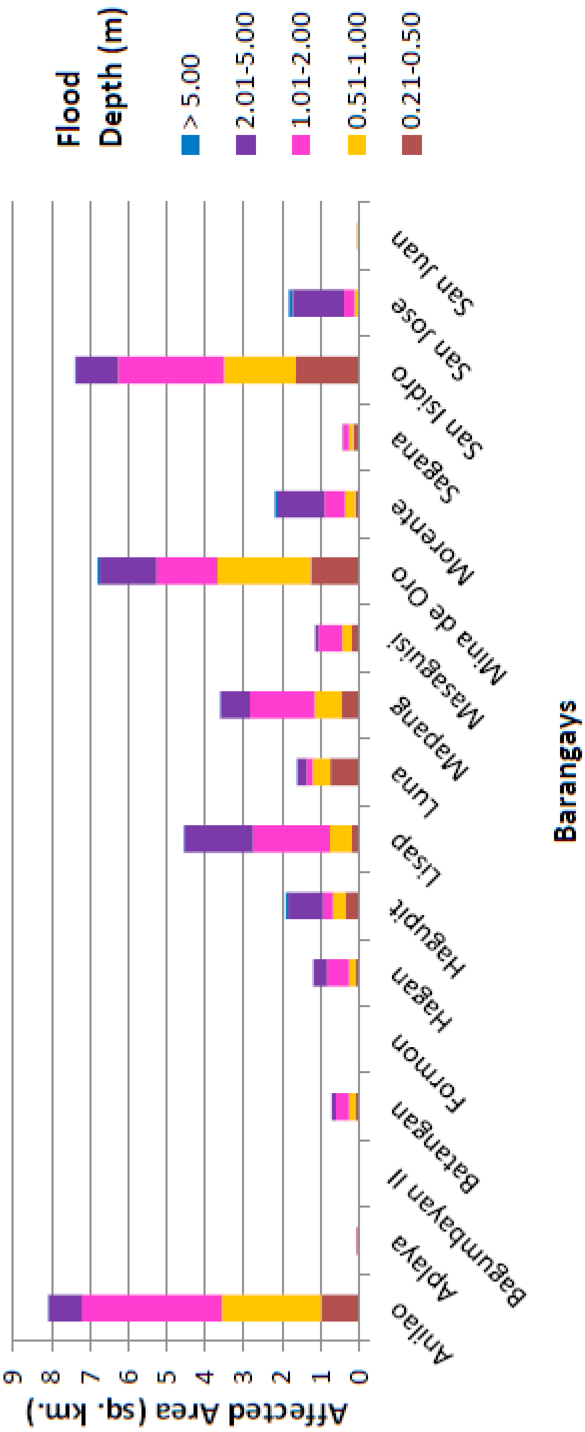


Figure 73. Affected Areas in Bongabong, Oriental Mindoro during 25-Year Rainfall Return Period

For the 100-year return period, 3.38% of the municipality of Bongabong with an area of 493.74 sq. km. will experience flood levels of less 0.20 meters. 1.09% of the area will experience flood levels of 0.21 to 0.50 meters while 1.75%, 3.030%, 2.71%, and 0.15% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Tables 39-40 are the affected areas in square kilometres by flood depth per barangay.

Table 39. Affected Areas in Bongabong, Oriental Mindoro during 100-Year Rainfall Return Period

| BONGABONG BASIN | | Affected Barangays in Bongabong | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Anilao | Aplaya | Bagumbayan II | Batangan | Formon | Hagan | Hagupit | Lisap |
| Affected Area (sq. km.) | 0.03-0.20 | 1.13 | 0.2 | 0.000067 | 0.96 | 0.014 | 0.56 | 2.19 | 1.28 |
| | 0.21-0.50 | 0.85 | 0.054 | 0.000006 | 0.07 | 0.0003 | 0.055 | 0.34 | 0.11 |
| | 0.51-1.00 | 2.32 | 0.0089 | 0 | 0.12 | 0 | 0.085 | 0.18 | 0.27 |
| | 1.01-2.00 | 4.06 | 0.011 | 0 | 0.36 | 0 | 0.4 | 0.37 | 1.6 |
| | 2.01-5.00 | 1.03 | 0.0014 | 0 | 0.19 | 0 | 0.69 | 0.98 | 2.6 |
| | > 5.00 | 0.013 | 0 | 0 | 0 | 0 | 0 | 0.13 | 0.012 |

Table 40. Affected Areas in Bongabong, Oriental Mindoro during 100-Year Rainfall Return Period

| BONGABONG BASIN | | Affected Barangays in Bongabong | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Luna | Mapang | Masaguisi | Mina de Oro | Morente | Sagana | San Isidro | San Jose | San Juan |
| Affected Area (sq. km.) | 0.03-0.20 | 3.97 | 0.48 | 0.039 | 0.14 | 0.35 | 0.31 | 4.74 | 0.047 | 0.28 |
| | 0.21-0.50 | 0.78 | 0.13 | 0.18 | 0.78 | 0.009 | 0.14 | 1.84 | 0.0044 | 0.04 |
| | 0.51-1.00 | 0.53 | 0.62 | 0.22 | 2.48 | 0.1 | 0.12 | 1.57 | 0.039 | 0.0016 |
| | 1.01-2.00 | 0.22 | 1.73 | 0.63 | 1.92 | 0.49 | 0.18 | 2.84 | 0.19 | 0 |
| | 2.01-5.00 | 0.28 | 1.29 | 0.15 | 1.72 | 1.42 | 0.0096 | 1.71 | 1.34 | 0 |
| | > 5.00 | 0.0026 | 0.0091 | 0 | 0.081 | 0.19 | 0 | 0.033 | 0.26 | 0 |

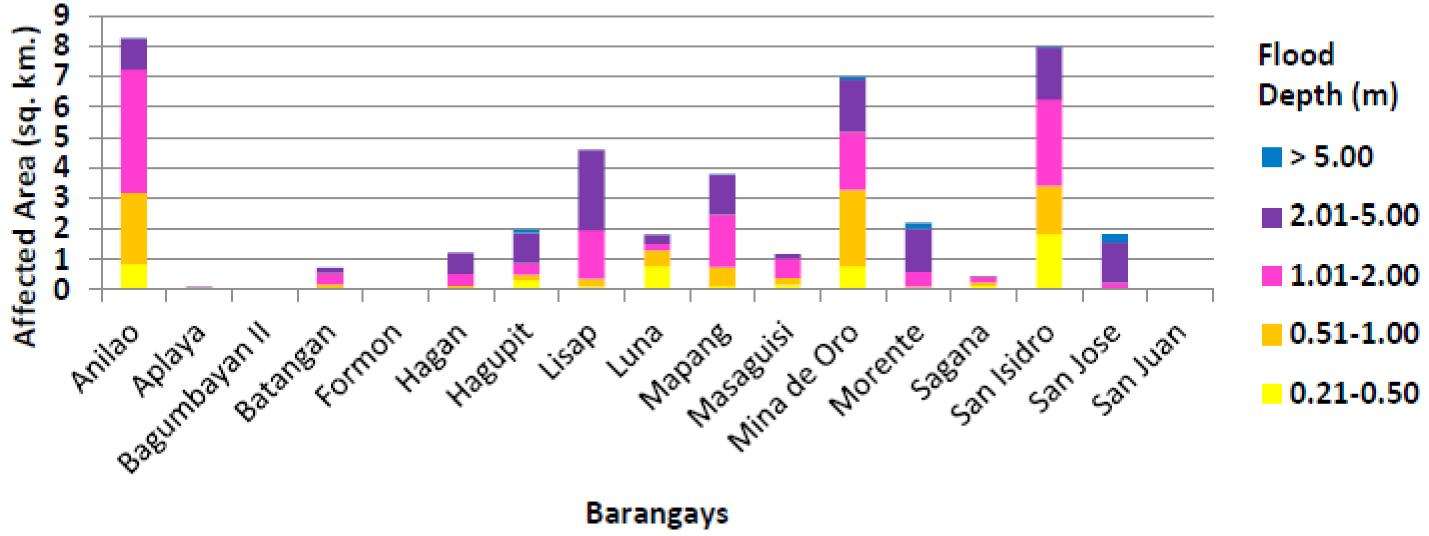


Figure 74. Affected Areas in Bongabong, Oriental Mindoro during 100-Year Rainfall Return Period

Among the barangays in the municipality of Bongabong, San Isidro is projected to have the highest percentage of area that will experience flood levels at 1.75%. Meanwhile, Anilao posted the second highest percentage of area that may be affected by flood depths at 1.71%.

## 5.11 Flood Validation

In order to check and validate the extent of flooding in different river systems, a validation survey work was performed. 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 the help of the local DRRM office in obtaining maps or situation reports about the past flooding events and through interviews of some residents with knowledge of or have had experienced flooding in a particular area.

The actual data from the field were compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed.

The flood validation consists of 77 points randomly selected all over the Bongabong flood plain. It has an RMSE value of 0.60.

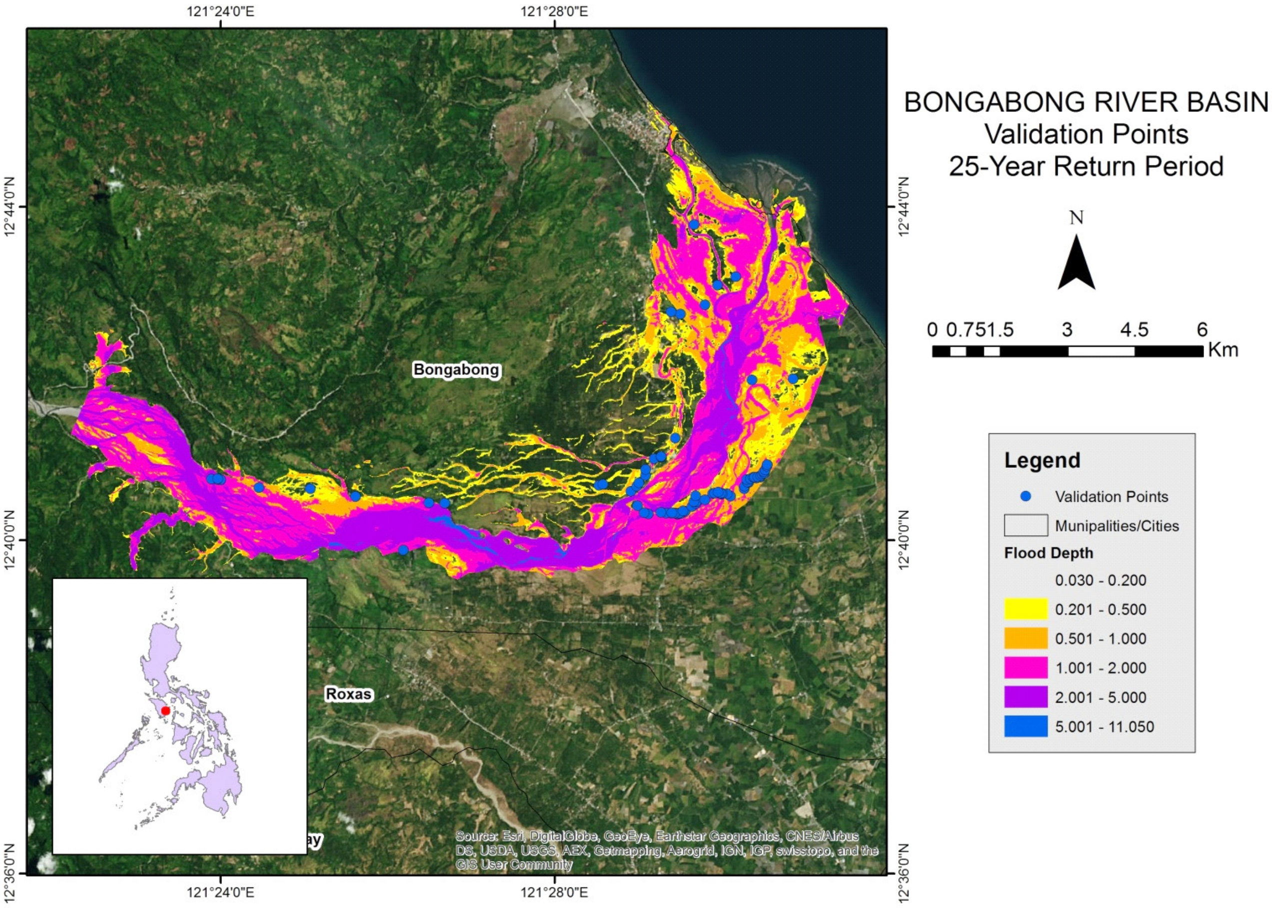


Figure 75. Validation points for 25-year Flood Depth Map of Bongabong Floodplain

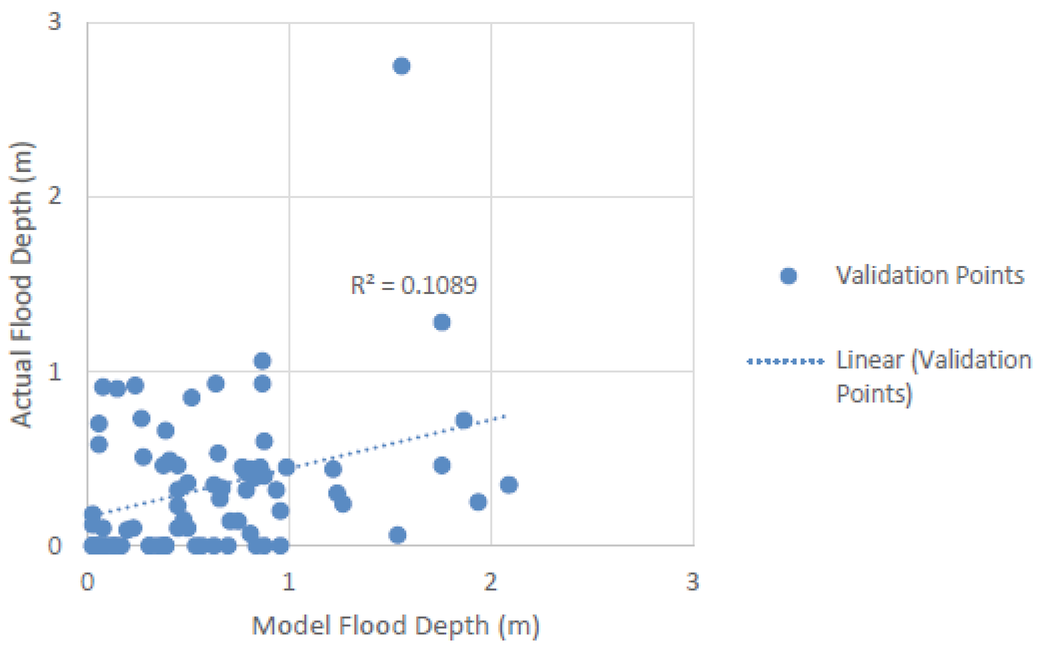


Figure 76. Flood map depth vs actual flood depth

Table 41. Actual Flood Depth vs Simulated Flood Depth in Bongabong

| 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 | 14 | 10 | 11 | 1 | 0 | 0 | 36 |
| 0.21-0.50 | 0 | 6 | 12 | 5 | 1 | 0 | 24 |
| 0.51-1.00 | 4 | 4 | 5 | 1 | 0 | 0 | 14 |
| 1.01-2.00 | 0 | 0 | 1 | 1 | 0 | 0 | 2 |
| 2.01-5.00 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| > 5.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 18 | 20 | 29 | 9 | 1 | 0 | 77 |

The overall accuracy generated by the flood model is estimated at 33.77%, with 26 points correctly matching the actual flood depths. In addition, there were 29 points estimated one level above and below the correct flood depths while there were 20 points estimated two levels above and below the correct flood. A total of 41 points were overestimated while a total of 10 points were underestimated in the modelled flood depths of Bongabong.

Table 42. Summary of Accuracy Assessment in Bongabong

| | No. of Points | % |
|---|---|---|
| Correct | 26 | **33.77** |
| Overestimated | 41 | 53.25 |
| Underestimated | 10 | 12.99 |
| Total | 77 | 100 |

# REFERENCES

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

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

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

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

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

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

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

# ANNEXES

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

1. AQUARIUS SENSOR

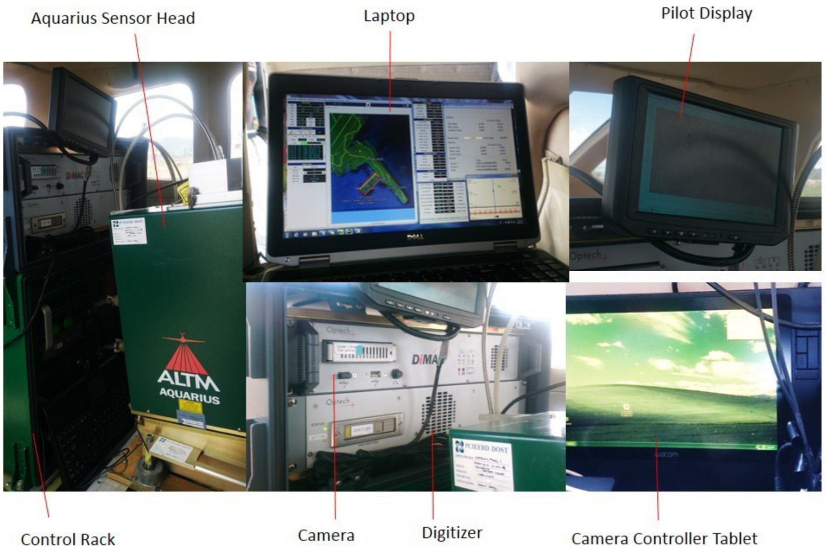


Figure A-1.1. Aquarius Sensor

Table A-1.1. Parameters and Specification of 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 |

2. GEMINI SENSOR


Figure A-1.2. Gemini Sensor

Table A-1.2. Parameters and Specification of Gemini Sensor

| Parameter | Specification |
|---|---|
| Operational envelope (1,2,3,4) | 150-4000 m AGL, nominal |
| Laser wavelength | 1064 nm |
| Horizontal accuracy (2) | 1/5,500 x altitude, (m AGL) |
| Elevation accuracy (2) | <5-35 cm, 1 σ |
| Effective laser repetition rate | Programmable, 33-167 kHz |
| Position and orientation system | POS AV™ AP50 (OEM);<br>220-channel dual frequency GPS/GNSS/Galileo/L-Band receiver |
| Scan width (WOV) | Programmable, 0-50˚ |
| Scan frequency (5) | Programmable, 0-70 Hz (effective) |
| Sensor scan product | 1000 maximum |
| Beam divergence | Dual divergence: 0.25 mrad (1/e) and 0.8 mrad (1/e), nominal |
| Roll compensation | Programmable, ±5˚ (FOV dependent) |
| Range capture | Up to 4 range measurements, including 1st, 2nd, 3rd, and last returns |
| Intensity capture | Up to 4 intensity returns for each pulse, including last (12 bit) |
| Video Camera | Internal video camera (NTSC or PAL) |
| Image capture | Compatible with full Optech camera line (optional) |
| Full waveform capture | 12-bit Optech IWD-2 Intelligent Waveform Digitizer (optional) |
| Data storage | Removable solid state disk SSD (SATA II) |
| Power requirements | 28 V; 900 W;35 A(peak) |
| Dimensions and weight | Sensor: 260 mm (w) x 190 mm (l) x 570 mm (h); 23 kg<br>Control rack: 650 mm (w) x 590 mm (l) x 530 mm (h); 53 kg |
| Operating temperature | -10˚C to +35˚C (with insulating jacket) |

| | |
|---|---|
| Relative humidity | 0-95% no-condensing |

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

1. MRE-54

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

February 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: **ORIENTAL MINDORO**
Station Name: **MRE-54**
Order: **2nd**

Island: **LUZON**
Municipality: **PINAMALAYAN**
Barangay: **MALIANGCOG**

***PRS92 Coordinates***

| | | | | | |
|---|---|---|---|---|---|
| Latitude: | **12° 59' 12.43671"** | Longitude: | **121° 24' 46.52637"** | Ellipsoidal Hgt: | **42.40800 m.** |

***WGS84 Coordinates***

| | | | | | |
|---|---|---|---|---|---|
| Latitude: | **12° 59' 7.43505"** | Longitude: | **121° 24' 51.55668"** | Ellipsoidal Hgt: | **91.39500 m.** |

***PTM Coordinates***

| | | | | | |
|---|---|---|---|---|---|
| Northing: | **1436124.562 m.** | Easting: | **544797.009 m.** | Zone: | **3** |

***UTM Coordinates***

| | | | | | |
|---|---|---|---|---|---|
| Northing: | **1,436,121.49** | Easting: | **327,864.09** | Zone: | **51** |

Location Description

MRE-54

From Calapan City to Roxas, along Nat'l Road, approx. 100 m from Pula Bridge, along Brgy. Sto. Niño, right turn to Brgy. Road leading to Gloria Airport, passing through Brgy. Sto. Niño, Brgy. Sta. Maria, Brgy. Pambigan Malaki, all in Mun. of Pinamalayan. approx. 7.8 Km. from Nat'l Road, 1.1 Km. from Brgy. Chapel, 600 m from Maliangkog Elem. School, left side of road located Brgy. Hall of Maliangkog, Pinamalayan, Oriental Mindoro. Station is located beside of flagpole near gate of brgy. hall. Mark is the head of a 4 in, copper nail flushed in a cement block embedded in the ground with inscriptions, "MRE-54, 2007, NAMRIA".

| | |
|---|---|
| Requesting Party: | **UP-DREAM** |
| Pupose: | **Reference** |
| OR Number: | **8795255 A** |
| T.N.: | **2014-196** |

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

9 9 0 2 0 4 2 0 1 4 1 2 5 8 5 5

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

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

Figure A-2.1. MRE-54

2. MRE-44

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

February 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: **ORIENTAL MINDORO**
Station Name: **MRE-44**
Order: **2nd**

Island: **LUZON**
Municipality: **ROXAS**
Barangay: **HAPPY VALLEY**

| | | |
|---|---|---|
| | *PRS92 Coordinates* | |
| Latitude: **12° 38' 59.03778"** | Longitude: **121° 24' 32.60444"** | Ellipsoidal Hgt: **87.94200 m.** |
| | *WGS84 Coordinates* | |
| Latitude: **12° 38' 54.11733"** | Longitude: **121° 24' 37.66392"** | Ellipsoidal Hgt: **137.80400 m.** |
| | *PTM Coordinates* | |
| Northing: **1398838.995 m.** | Easting: **544436.519 m.** | Zone: **3** |
| | *UTM Coordinates* | |
| Northing: **1,398,840.08** | Easting: **327,214.81** | Zone: **51** |

MRE-44

Location Description

From Calapan City to Bulalacao, approx. 4 Km. from Roxas Town Proper, along Nat'l Road is an intersection going to Roxas Proper, Mansalay, and Bongabong, Oriental Mindoro. Turn right to road leading to Bongabong Town Proper, approx. 6.9 Km., passing through Brgy. San Aquilino, Brgy. Libertad, Brgy. Little Tanauan, and Brgy. San Mariano, all in Mun. of Roxas. Along Brgy. San Rafael, left side of road located Km. post 130 about 50 m after RCBCulvert, turn left to Brgy. Road leading to Sitio Amawan, approx. 800 m passing through San Rafael Elem. School, and GK Village, left side of road located Brgy. Hall of Happy Valley, Roxas, Oriental Mindoro. Station is located beside of streetlight outside wall of brgy. hall. Mark is the head of a 4 in. copper nial flushed in a cement block embedded in the ground with inscriptions, "MRE-44, 2007, NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795255 A**
T.N.: **2014-198**

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

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

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

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

Figure A-2.2. MRE-44

3. MRE-32

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

April 05, 2013

**CERTIFICATION**

To whom it may concern:

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

Province: **ORIENTAL MINDORO**
Station Name: **MRE-32**
Order: **2nd**

Island: **LUZON**
Municipality: **VICTORIA**
Barangay:

| | | |
|---|---|---|
| | *PRS92 Coordinates* | |
| Latitude: **13° 10' 28.85064"** | Longitude: **121° 16' 38.44761"** | Ellipsoidal Hgt: **19.49300 m.** |
| | *WGS84 Coordinates* | |
| Latitude: **13° 10' 23.79251"** | Longitude: **121° 16' 43.46244"** | Ellipsoidal Hgt: **67.64700 m.** |
| | *PTM Coordinates* | |
| Northing: **1456889.419 m.** | Easting: **530065.679 m.** | Zone: **3** |
| | *UTM Coordinates* | |
| Northing: **1,457,002.75** | Easting: **313,296.85** | Zone: **51** |

Location Description

MRE-32

From Calapan City to Roxas, along Nat'l. Road approx. 34 Km. travel to Victoria Town Proper, 10 Km. from intersection of Naujan, left turn to Shell Gasoline Station, approx. 150 m, right side of road located Mun. Hall of Victoria, Oriental Mindoro. Station is located in Mun. Park in front of Former Mayor Statue, along corner of pathwalk. Mark is the head of a 4 in. copper nail flushed in a cement block embedded in the ground with inscriptions, "MRE-32, 2007, NAMRIA".

Requesting Party: **UP-TCAGP**
Pupose: **Reference**
OR Number: **3943485 B**
T.N.: **2013-0270**

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

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

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

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

Figure A-2.3. MRE-32

4. MRE-11

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-11** | |
| | Order: **3rd** | |
| Island: **LUZON** | Barangay: | |
| Municipality: **BONGABONG** | MSL Elevation: | |
| | ***PRS92 Coordinates*** | |
| Latitude: **12° 44' 50.41380"** | Longitude: **121° 29' 7.80130"** | Ellipsoidal Hgt: **5.11500 m.** |
| | ***WGS84 Coordinates*** | |
| Latitude: **12° 44' 45.47630"** | Longitude: **121° 29' 12.85191"** | Ellipsoidal Hgt: **54.91100 m.** |
| | ***PTM / PRS92 Coordinates*** | |
| Northing: **1409650.153 m.** | Easting: **552720.766 m.** | Zone: **3** |
| | ***UTM / PRS92 Coordinates*** | |
| Northing: **1,409,587.05** | Easting: **335,581.55** | Zone: **51** |

Location Description

MRE-11
To reach the station from Calapan town proper, travel SE to S ìalong the nat'l. road for about 120 kms. leading to the town of ìBongabong, passing by the towns of Victoria, Pinamalayan and ìBansud. Station is located inside the school compound of ìMagdalena Umali Suyon Elem. School on the SE corner of the ìfooting of a concrete landmark bearing the school name. It is ìabout 20 m. W of the main gate along Gov. Umali St. Mark is the ìhead of a 4 in. copper nail embedded and centered on a 0.15 m. x ì0.15 m. cement putty, with inscriptions "MRE-11 1997 NAMRIA".

| | |
|---|---|
| Requesting Party: | **ENGR. CHRISTOPHER CRUZ** |
| Purpose: | **Reference** |
| OR Number: | **8088472 I** |
| T.N.: | **2015-3525** |

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

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

NAMRIA OFFICES:
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Branch : 421 Barraca St. San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3494 to 98
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ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

CIP/4701/12/01/814

Figure A-2.4. MRE-11

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

Table A-3.1. Baseline Processing Reports of Control Points used in the LIDAR Survey

**Vector Components (Mark to Mark)**

| From: | MRE-54 | | | | |
|---|---|---|---|---|---|
| Grid | | Local | | Global | |
| Easting | 328016.924 m | Latitude | N12°59'07.43505" | Latitude | N12°59'07.43505" |
| Northing | 1436055.870 m | Longitude | E121°24'51.55668" | Longitude | E121°24'51.55668" |
| Elevation | 41.949 m | Height | 91.395 m | Height | 91.395 m |

| To: | MRE-4563 | | | | |
|---|---|---|---|---|---|
| Grid | | Local | | Global | |
| Easting | 328034.015 m | Latitude | N13°00'53.01692" | Latitude | N13°00'53.01692" |
| Northing | 1439300.319 m | Longitude | E121°24'51.45337" | Longitude | E121°24'51.45337" |
| Elevation | 24.394 m | Height | 73.715 m | Height | 73.715 m |

| Vector | | | | | |
|---|---|---|---|---|---|
| ΔEasting | 17.091 m | NS Fwd Azimuth | 359°56'42" | ΔX | 392.071 m |
| ΔNorthing | 3244.450 m | Ellipsoid Dist. | 3244.605 m | ΔY | -635.982 m |
| ΔElevation | -17.555 m | ΔHeight | -17.680 m | ΔZ | 3157.508 m |

Table A-3.2. MRE-11

| Project information | | Coordinate System | |
|---|---|---|---|
| Name: | | Name: | Default |
| Size: | | Datum: | WGS 1984 |
| Modified: | 10/12/2012 4:40:11 PM (UTC:-6) | Zone: | Default |
| Time zone: | Mountain Standard Time | Geoid: | |
| Reference number: | | Vertical datum: | |
| Description: | | | |

## Baseline Processing Report

### Processing Summary

| Observation | From | To | Solution Type | H. Prec. (Meter) | V. Prec. (Meter) | ΔX (Meter) | ΔY (Meter) | ΔZ (Meter) | Geodetic Az. | Ellipsoid Dist. (Meter) | ΔHeight (Meter) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MRE11 -25 --- MRE11A - 25 (B1) | MRE11 - 25 | MRE11A - 25 | Fixed | 0.001 | 0.002 | 1.673 | 0.540 | 1.035 | 302°48'16" | 2.032 | 0.515 |

### Acceptance Summary

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

1

Table A-3.3. MRE-1125

**MRE11 -25 - MRE11A - 25 (7:49:43 AM-10:53:15 AM) (S1)**

| | |
|---|---|
| **Baseline observation:** | MRE11 -25 --- MRE11A - 25 (B1) |
| **Processed:** | 11/5/2015 4:59:57 PM |
| **Solution type:** | Fixed |
| **Frequency used:** | Dual Frequency (L1, L2) |
| **Horizontal precision:** | 0.001 m |
| **Vertical precision:** | 0.002 m |
| **RMS:** | 0.001 m |
| **Maximum PDOP:** | 3.139 |
| **Ephemeris used:** | Broadcast |
| **Antenna model:** | NGS Absolute |
| **Processing start time:** | 10/25/2015 7:49:43 AM (Local: UTC+8hr) |
| **Processing stop time:** | 10/25/2015 10:53:15 AM (Local: UTC+8hr) |
| **Processing duration:** | 03:03:32 |
| **Processing interval:** | 1 second |

**Vector Components (Mark to Mark)**

| **From:** | MRE11 -25 | | | | |
|---|---|---|---|---|---|
| **Grid** | | **Local** | | **Global** | |
| **Easting** | 0.310 m | **Latitude** | N12°44'45.47200" | **Latitude** | N12°44'45.47200" |
| **Northing** | -4.205 m | **Longitude** | E121°29'12.85377" | **Longitude** | E121°29'12.85377" |
| **Elevation** | 55.043 m | **Height** | 55.043 m | **Height** | 55.043 m |

| **To:** | MRE11A - 25 | | | | |
|---|---|---|---|---|---|
| **Grid** | | **Local** | | **Global** | |
| **Easting** | -1.398 m | **Latitude** | N12°44'45.50783" | **Latitude** | N12°44'45.50783" |
| **Northing** | -3.104 m | **Longitude** | E121°29'12.79714" | **Longitude** | E121°29'12.79714" |
| **Elevation** | 55.558 m | **Height** | 55.558 m | **Height** | 55.558 m |

| **Vector** | | | | | |
|---|---|---|---|---|---|
| **ΔEasting** | -1.708 m | **NS Fwd Azimuth** | 302°48'16" | **ΔX** | 1.321 m |
| **ΔNorthing** | 1.101 m | **Ellipsoid Dist.** | 2.032 m | **ΔY** | 1.114 m |
| **ΔElevation** | 0.515 m | **ΔHeight** | 0.515 m | **ΔZ** | 1.188 m |

| | | |
|---|---|---|
| 11/5/2015 5:01:03 PM | | Business Center - HCE |

2

## Annex 4. The LIDAR Survey Team Composition

Table A-4.1. The LIDAR Survey Team Composition

| Data Acquisition Component Sub -Team | Designation | Name | Agency / Affiliation |
|---|---|---|---|
| PHIL-LIDAR 1 | Program Leader | ENRICO C. PARINGIT, D.ENG | UP-TCAGP |
| Data Acquisition Component Leader | Data Component Project Leader – I | ENGR. CZAR JAKIRI SARMIENTO | UP-TCAGP |
| 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 | PAULINE JOANNE ARCEO | UP-TCAGP |
| | Research Associate (RA) | MARY CATHERINE BALIGUAS | UP-TCAGP |
| | RA | ENGR. MILLIE SHANE REYES | UP-TCAGP |
| | RA | ENGR. IRO NIEL ROXAS | UP-TCAGP |
| Ground Survey, Data Download and Transfer | RA | GRACE SINADJAN | UP-TCAGP |
| | RA | ENGR. GEF SORIANO | UP-TCAGP |
| LiDAR Operation | Airborne Security | SSG. ERIC CACANINDIN | PHILIPPINE AIR FORCE (PAF) |
| | Pilot | CAPT. JEFFREY JEREMY ALAAR | ASIAN AEROSPACE CORPORATION (AAC) |
| | | CAPT. JACKSON JAVIER | AAC |

# Annex 5. Data Transfer Sheet for Bongabong Floodplain

**DATA TRANSFER SHEET**
Feb 18, 2014

| DATE of Operation | FLIGHT NO. | SENSOR | MISSION NAME | RAW LAS (MB) | LOGS (KB) | POS (MB) | RAW IMAGES | MISSION LOG FILE | RANGE (GB) | DIGITIZER (GB) | BASE STATION(S) (MB) | OPERATOR COMMENTS (DPC LOGS) (Bytes) | FLIGHT PLAN (KB) | SERVER LOCATION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2/7/2014 | 1072A | Aquarius | 3BLK28F038A | 703KB | 1.16MB | 256 | 81.4GB | 563KB | 12.5 | 174 | 14.1 | 767 | 13 | \\FREENAS\geostorage3\Airborne_Raw\1072A |
| 2/7/2014 | 1074A | Aquarius | 3BLK28G038B | 134 KB | 968 KB | 174 | 33.7GB | 274KB | 6.4 | 60.9 | 14.1 | 258 | 11 (28F)&12(28G) | \\FREENAS\geostorage3\Airborne_Raw\1074A |
| 2/8/2014 | 1076A | Aquarius | 3BLK28GS039A | 643KB | 1.21MB | 233 | 76.8 | 308KB&218KB | 11.5 | 101 | 14.3 | 357 | 12 | \\FREENAS\geostorage3\Airborne_Raw\1076A |
| 2/5/2014 | 1066A | Aquarius | 3BLK28DS036A | 360KB | 1.38MB | 203 | 73.9 | 311KB | 11.7 | N/A | 14.5 | 414 | 11 | \\FREENAS\geostorage3\Airborne_Raw\1066A |
| 2/6/2014 | 1070A | Aquarius | 3BLK28DSE037A | 932KB | 1.46MB | 270 | 104 | 764KB | 15.9 | 249 | 14.9 | 300 | 12 | \\FREENAS\geostorage3\Airborne_Raw\1070A |
| 2/8/2014 | 1078A | Aquarius | 3BLK28GSH039B | 530KB | 892KB | 197 | 56.8 | 442KB | 9.71 | N/A | 14.3 | 738 | 12 (28G) & 12 (28H) | \\FREENAS\geostorage3\Airborne_Raw\1078A |

**Received from**

Name/Signature Lovely Acuña
Position Supervising SRS
Date 02/19/2014

**Received by**

Name/Signature JOIDA PRIETO
Position SSRS
Date 02/20/2014

**Verified by**

Name/Signature JOIDA PRIETO
Position SSRS
Date 02/20/14

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

DATA TRANSFER SHEET
Feb 21, 2014

| DATE | FLIGHT NO. | MISSION NAME | SENSOR | RAW LAS | | LOGS | POS | RAW IMAGES | MISSION LOG FILE | RANGE | DIGITIZER | BASE STATION(S) | | OPERATOR LOGS (OPLOG) | FLIGHT PLAN | | SERVER LOCATION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Output LAS | KML (swath) | | | | | | | BASE STATION(S) | Base info (.txt) | | Actual | KML | |
| 2/11/2014 | 1088A | 3BLK28HS042A | AQUARIUS | N/A | 781 | 1.23MB | 269 | 80.7GB ~~25.4~~ | 565 | 14 | N/A | 14.7 | 143 | 506 | 6 | 12 | \\FREENAS\geostorage3\Airborne_Raw\1088A |
| 2/11/2014 | 1090A | 3BLK28J042B | AQUARIUS | N/A | 215 | 822KB | 156 | 19.4 | 162 | 4.96 | N/A | 14.7 | 143 | 267 | N/A | N/A | \\FREENAS\geostorage3\Airborne_Raw\1090A |
| 2/12/2014 | 1092A | 3BLK28ABES043A | AQUARIUS | N/A | 1657 | 1.70MB | 242 | 23.7 | 601 | 12.7 | N/A | 15.4 | 123 | 364 | N/A | N/A | \\FREENAS\geostorage3\Airborne_Raw\1092A |
| 2/12/2014 | 1094A | 3BLK28BS043B | AQUARIUS | N/A | 332 | 2.27MB | 128 | 28.4GB ~~22.1~~ | 186 | 6.05 | N/A | 15.4 | 123 | 334 | 8 | N/A | \\FREENAS\geostorage3\Airborne_Raw\1094A |
| 2/13/2014 | 1096A | 3BLK28NAJ044A | AQUARIUS | N/A | 449 | 772KB | 207 | 36.6 | 291 | 7.46 | N/A | 13.3 | 175 | 411 | 6 | N/A | \\FREENAS\geostorage3\Airborne_Raw\1096A |
| 2/13/2014 | 1098A | 3BLK28JSI044B | AQUARIUS | N/A | 582 | 954KB | 235 | 23.9 | 291 | 11 | N/A | 13.3 | 175 | 725 | 4 | N/A | \\FREENAS\geostorage3\Airborne_Raw\1098A |
| 2/15/2014 | 1104A | 3BLK28JSI046A | AQUARIUS | N/A | 787 | 1.08MB | 276 | 56.2 | 288KB&170KB | 10.3 | N/A | 9.85 | 134 | 325 | 4 | N/A | \\FREENAS\geostorage3\Airborne_Raw\1104A |

**Received from**

Name Lovely Acuña
Position Supervising SRS
Signature 02/21/2014

**Received by**

Name JOIDA F. PRIETO
Position SSRS
Signature

**Verified by**

Name JOIDA F. PRIETO
Position SSRS
Signature

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

DATA TRANSFER SHEET
Calapan 11/9/15

| 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 | |
| Oct. 22, 2015 | 8300 | 2BLK28ABC295A | Gemini | na | 400 | 675 | 236 | 28.5 | 214 | 18.2 | 247 | 15.6 | 1KB | 1KB | 24 | na | Z:\DAC\RAW DATA |
| Oct. 22, 2015 | 8301 | 2BLK28CSD295B | Gemini | na | 587 | 947 | 249 | 39.1/10.5 | 307/87 | 22.7 | na | 15.6 | 1KB | 1KB | 22/24 | na | Z:\DAC\RAW DATA |
| Oct. 23, 2015 | 8302 | 2BLK28ASEHI296A | Gemini | na | 343 | 593 | 228 | 28.2 | 223 | 14.5 | na | 11.5 | 1KB | 1KB | 22/24 | na | Z:\DAC\RAW DATA |
| Oct. 24, 2015 | 8304 | 2BLK28FHS297A | Gemini | na | 315 | 519 | 214 | 24.8 | 187 | 14.2 | 221 | 8.92 | 1KB | 1KB | 5/11/24/14/13 | na | Z:\DAC\RAW DATA |
| Oct. 25, 2015 | 8306 | 2CALIBBLK28FSGS298A | Gemini | na | 136 | 366 | 220 | na | na | 10.7 | 4.29 | 8.28 | 1KB | 1KB | 28/27 | na | Z:\DAC\RAW DATA |
| Oct. 26, 2015 | 8308 | 2BLK28J299A | Gemini | na | 312 | 356 | 235 | na | na | 14 | 153 | 8.39 | 1KB | 1KB | 7/5/2 | na | Z:\DAC\RAW DATA |
| Oct. 28, 2015 | 8312 | 2BLK28JKLS301A | Gemini | na | 40 | 292 | 215 | na | na | 11 | 427 | 7.5 | 1KB | 1KB | 7 | 270 | Z:\DAC\RAW DATA |

Received from
Name C. Joaquin
Position RA
Signature

Received by
Name AC Bongat
Position SSRS
Signature 11/12/15

15-20

Figure A-5.3. Transfer Sheet for Bongabong Floodplain - C

## Annex 6. Flight Logs for the Flight Missions

1. Flight Log for Mission 3BLK28DSE037A

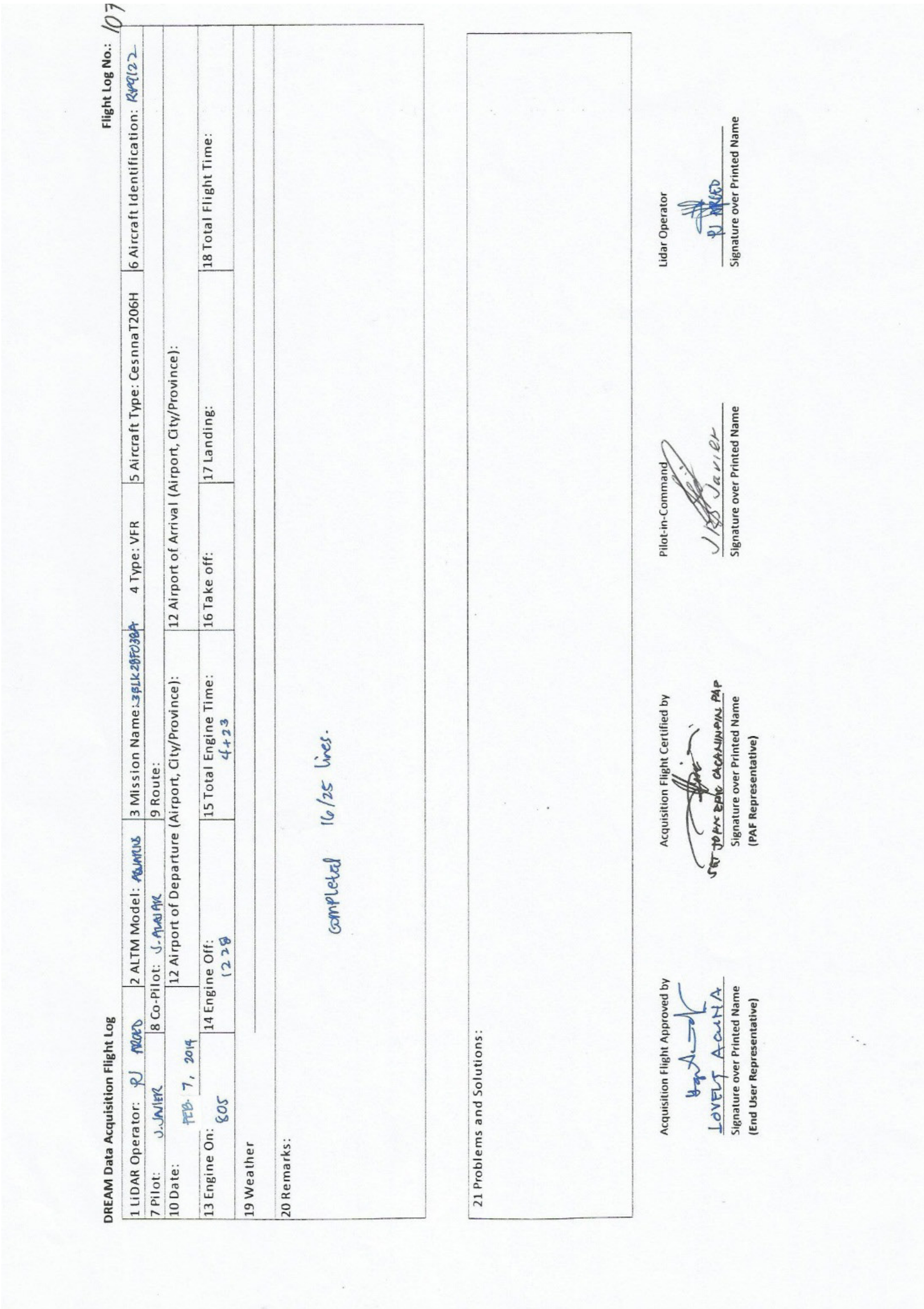
**DREAM Data Acquisition Flight Log** — **Flight Log No.:** 1070

| | | | | | |
|---|---|---|---|---|---|
| 1 LiDAR Operator: I.RO ROXAS | 2 ALTM Model: AQUA | 3 Mission Name: 3BLK28DSE037A | 4 Type: VFR | 5 Aircraft Type: Cesnna T206H | 6 Aircraft Identification: |
| 7 Pilot: J ALAJAR | 8 Co-Pilot: J JAVIER | 9 Route: | | | |
| 10 Date: Feb 6, 14 | 12 Airport of Departure (Airport, City/Province): Collapan | | 12 Airport of Arrival (Airport, City/Province): | | |
| 13 Engine On: 1254 | 14 Engine Off: 1723 | 15 Total Engine Time: 4+29 | 16 Take off: | 17 Landing: | 18 Total Flight Time: |
| 19 Weather | | | | | |
| 20 Remarks: Completed 3BLK 29D | | | | | |
| 21 Problems and Solutions: | | | | | |

| Acquisition Flight Approved by | Acquisition Flight Certified by | Pilot-in-Command | Lidar Operator |
|---|---|---|---|
| LOVELY ACUÑA | SGT JOHN ERIC CAGANDAHAN PAF | J J ALAJAR | I ROXAS |
| Signature over Printed Name (End User Representative) | Signature over Printed Name (PAF Representative) | Signature over Printed Name | Signature over Printed Name |

Figure A-6.1. Flight Log for Mission 3BLK28DSE037A

2. Flight Log for Mission 3BLK28F038A



**DREAM Data Acquisition Flight Log** — **Flight Log No.:** 107

| | | | | | |
|---|---|---|---|---|---|
| 1 LiDAR Operator: RJ ARQED | 2 ALTM Model: AQUARIUS | 3 Mission Name: 3BLK28F038A | 4 Type: VFR | 5 Aircraft Type: CesnnaT206H | 6 Aircraft Identification: RP9122 |
| 7 Pilot: J.JAVIER | 8 Co-Pilot: J. ALAJAR | 9 Route: | | | |
| 10 Date: FEB. 7, 2014 | 12 Airport of Departure (Airport, City/Province): | | 12 Airport of Arrival (Airport, City/Province): | | |
| 13 Engine On: 805 | 14 Engine Off: 1228 | 15 Total Engine Time: 4+23 | 16 Take off: | 17 Landing: | 18 Total Flight Time: |
| 19 Weather | | | | | |
| 20 Remarks: completed 16/25 lines. | | | | | |

21 Problems and Solutions:

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

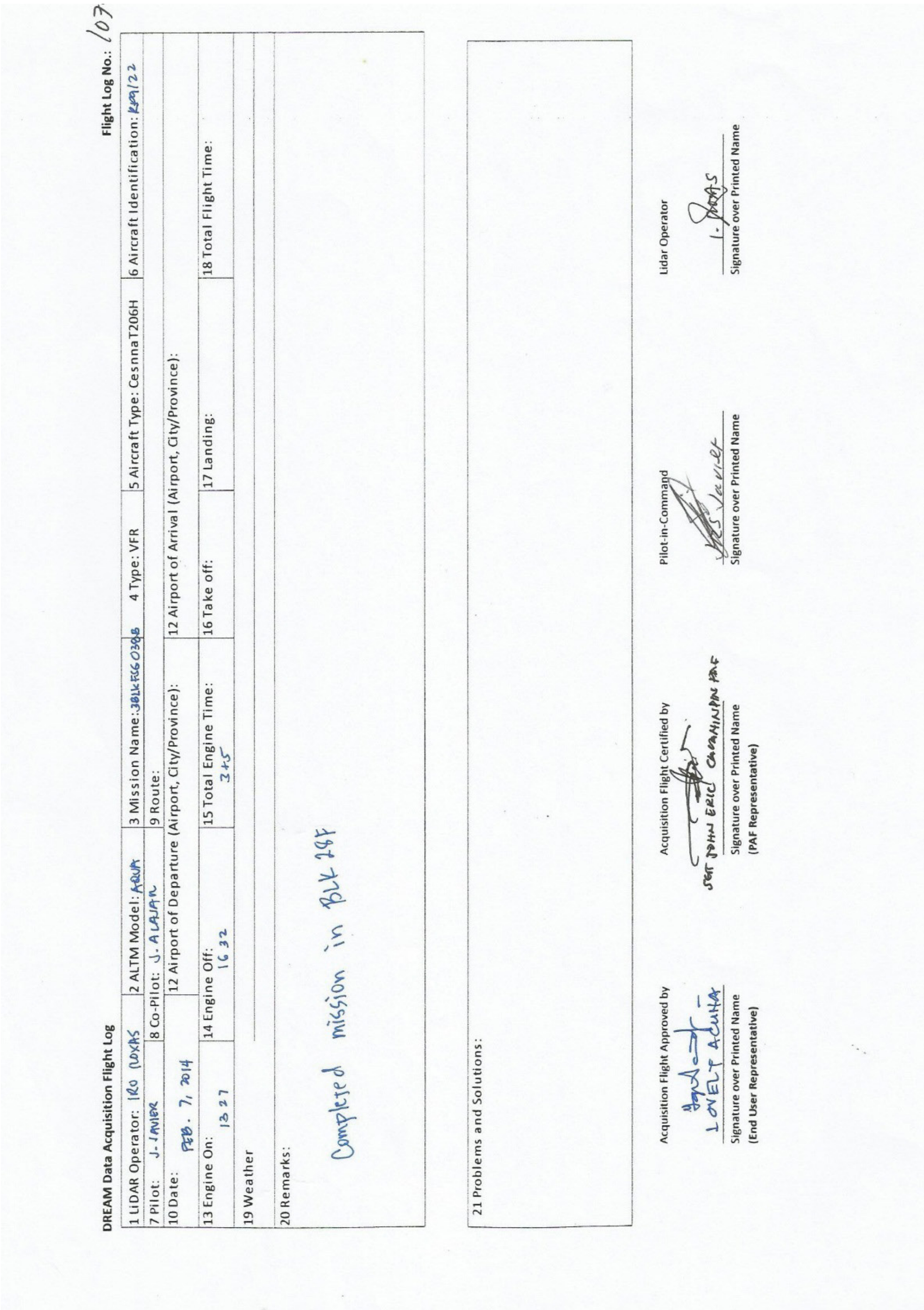
Acquisition Flight Certified by
SSGT JOHN ERIC CACANINDIN PAF
Signature over Printed Name
(PAF Representative)

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

Lidar Operator
RJ ARQED
Signature over Printed Name

Figure A-6.2. Flight Log for Mission 3BLK28F038A

3. Flight Log for Mission 3BLK28FSG038B



DREAM Data Acquisition Flight Log — Flight Log No.: 107

| | | | | | |
|---|---|---|---|---|---|
| 1 LiDAR Operator: IRO ROXAS | 2 ALTM Model: AQUA | 3 Mission Name: 3BLK28SG038B | 4 Type: VFR | 5 Aircraft Type: CesnnaT206H | 6 Aircraft Identification: RP9122 |
| 7 Pilot: J. JAVIER | 8 Co-Pilot: J. ALAJAR | 9 Route: | | | |
| 10 Date: FEB. 7, 2014 | 12 Airport of Departure (Airport, City/Province): | | 12 Airport of Arrival (Airport, City/Province): | | |
| 13 Engine On: 1327 | 14 Engine Off: 1632 | 15 Total Engine Time: 3+5 | 16 Take off: | 17 Landing: | 18 Total Flight Time: |
| 19 Weather | | | | | |

20 Remarks:

Completed mission in BLK 28F

21 Problems and Solutions:

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

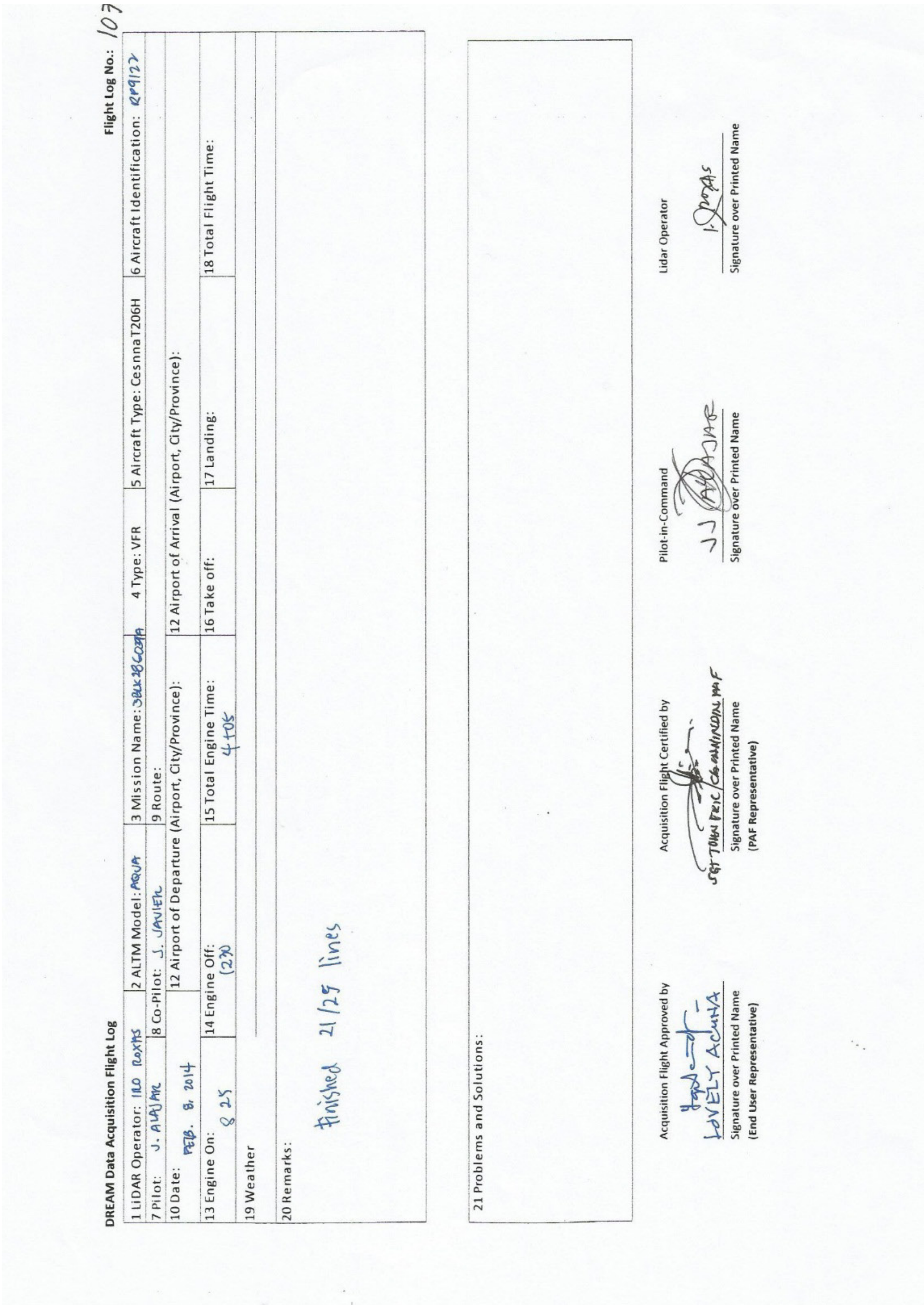
Acquisition Flight Certified by
SGT JOHN ERIC CABAHUNAN PAF
Signature over Printed Name
(PAF Representative)

Pilot-in-Command
J. JAVIER
Signature over Printed Name

Lidar Operator
I. ROXAS
Signature over Printed Name

Figure A-6.3. Flight Log for Mission 3BLK28FSG038B

4. Flight Log for Mission 3BLK28G039A


DREAM Data Acquisition Flight Log

Flight Log No.: 107

| | | | | | |
|---|---|---|---|---|---|
| 1 LiDAR Operator: ILO ROXAS | 2 ALTM Model: AQUA | 3 Mission Name: 3BLK28G039A | 4 Type: VFR | 5 Aircraft Type: Cesnna T206H | 6 Aircraft Identification: RP9122 |
| 7 Pilot: J. ALAJAR | 8 Co-Pilot: J. JAVIER | 9 Route: | | | |
| 10 Date: FEB. 8, 2014 | 12 Airport of Departure (Airport, City/Province): | | 12 Airport of Arrival (Airport, City/Province): | | |
| 13 Engine On: 8 25 | 14 Engine Off: 1230 | 15 Total Engine Time: 4+05 | 16 Take off: | 17 Landing: | 18 Total Flight Time: |
| 19 Weather | | | | | |
| 20 Remarks: finished 21/25 lines | | | | | |

21 Problems and Solutions:

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

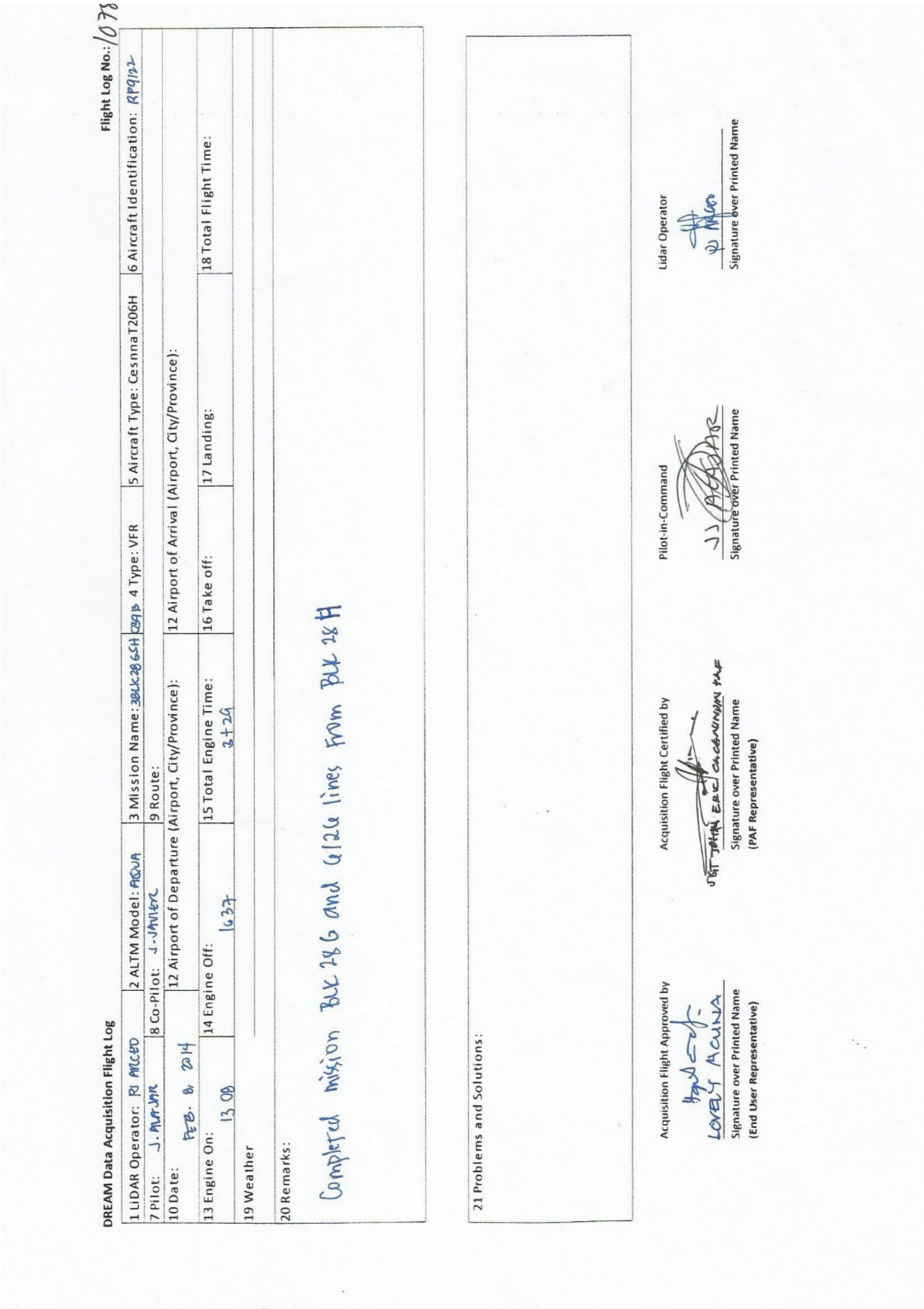
Acquisition Flight Certified by: SGT JOHN ERIC CABANINDING PAF — Signature over Printed Name (PAF Representative)

Pilot-in-Command: J J ALAJAR — Signature over Printed Name

Lidar Operator: I. ROXAS — Signature over Printed Name

Figure A-6.4. Flight Log for Mission 3BLK28G039A

5. Flight Log for Mission 3BLK28GSH039B


DREAM Data Acquisition Flight Log

Flight Log No.: 1078

| | | | | | |
|---|---|---|---|---|---|
| 1 LiDAR Operator: RI Arceo | 2 ALTM Model: AQUA | 3 Mission Name: 3BLK28GSH039B | 4 Type: VFR | 5 Aircraft Type: Cesnna T206H | 6 Aircraft Identification: RP9122 |
| 7 Pilot: J. Alajar | 8 Co-Pilot: J. Javier | 9 Route: | | | |
| 10 Date: Feb. 8, 2014 | 12 Airport of Departure (Airport, City/Province): | | 12 Airport of Arrival (Airport, City/Province): | | |
| 13 Engine On: 1308 | 14 Engine Off: 1637 | 15 Total Engine Time: 3+29 | 16 Take off: | 17 Landing: | 18 Total Flight Time: |
| 19 Weather | | | | | |

20 Remarks:

Completed mission BLK 28G and G126 lines from BLK 28H

21 Problems and Solutions:

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

Acquisition Flight Certified by: SSgt John Eric Cacanindin PAF — Signature over Printed Name (PAF Representative)

Pilot-in-Command: J. Alajar — Signature over Printed Name

Lidar Operator: RI Arceo — Signature over Printed Name

Figure A-6.5. Flight Log for Mission 3BLK28GSH039B

6. Flight Log for Mission 3BLK28HS042A

**DREAM Data Acquisition Flight Log** — Flight Log No.: 108

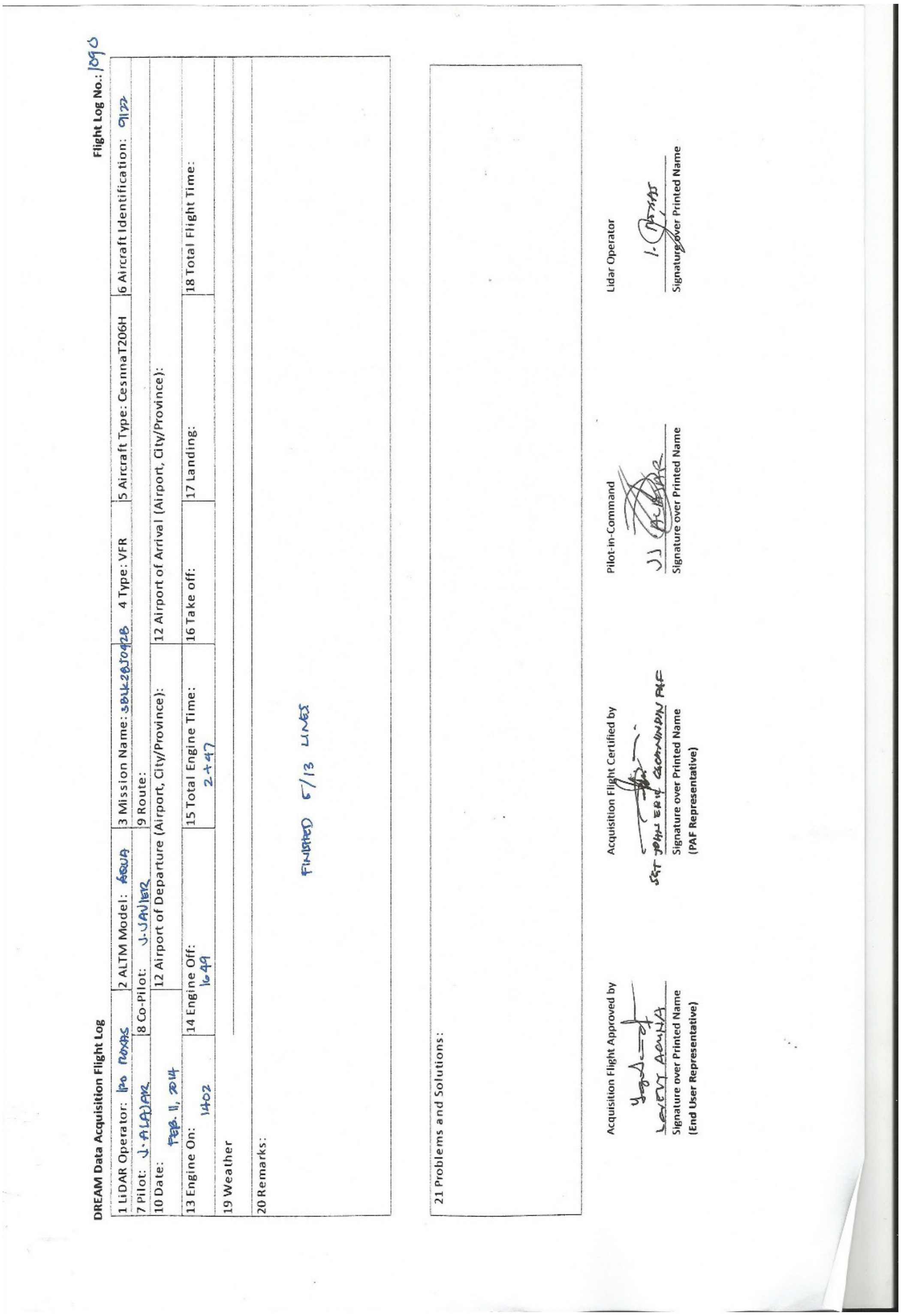
| | | | | | |
|---|---|---|---|---|---|
| 1 LiDAR Operator: PJ ARCEO | 2 ALTM Model: AQUA | 3 Mission Name: 3BLK28HS042A | 4 Type: VFR | 5 Aircraft Type: CesnnaT206H | 6 Aircraft Identification: RP9122 |
| 7 Pilot: J. ALAJAR | 8 Co-Pilot: J. JAVIER | 9 Route: | | | |
| 10 Date: FEB. 11, 2014 | 12 Airport of Departure (Airport, City/Province): | | 12 Airport of Arrival (Airport, City/Province): | | |
| 13 Engine On: 851 | 14 Engine Off: 1320 | 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 | Acquisition Flight Certified by | Pilot-in-Command | Lidar Operator |
|---|---|---|---|
| LOVELY ACUNA | SGT JOHN EEL CABANIHAN PAF | J. ALAJAR | LOVELY ACUNA |
| Signature over Printed Name (End User Representative) | Signature over Printed Name (PAF Representative) | Signature over Printed Name | Signature over Printed Name |

Figure A-6.6. Flight Log for Mission 3BLK28HS042A

7. Flight Log for Mission 3BLK28J042B



DREAM Data Acquisition Flight Log

Flight Log No.: 1090

| | | | | | |
|---|---|---|---|---|---|
| 1 LiDAR Operator: I. ROXAS | 2 ALTM Model: AQUA | 3 Mission Name: 3BLK28J042B | 4 Type: VFR | 5 Aircraft Type: CesnnaT206H | 6 Aircraft Identification: 9122 |
| 7 Pilot: J. ALAJAR | 8 Co-Pilot: J. JAVIER | 9 Route: | | | |
| 10 Date: FEB. 11, 2014 | 12 Airport of Departure (Airport, City/Province): | | 12 Airport of Arrival (Airport, City/Province): | | |
| 13 Engine On: 1402 | 14 Engine Off: 1649 | 15 Total Engine Time: 2+47 | 16 Take off: | 17 Landing: | 18 Total Flight Time: |
| 19 Weather | | | | | |
| 20 Remarks: FINISHED 5/13 LINES | | | | | |

21 Problems and Solutions:

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

Acquisition Flight Certified by
SGT JOHN ERIC [illegible] PAF
Signature over Printed Name
(PAF Representative)

Pilot-in-Command
JJ ALAJAR
Signature over Printed Name

Lidar Operator
I. ROXAS
Signature over Printed Name

Figure A-6.7. Flight Log for Mission 3BLK28J042B

8. Flight Log for Mission 3BLK28ABES043A

**DREAM Data Acquisition Flight Log** — **Flight Log No.:** 1092

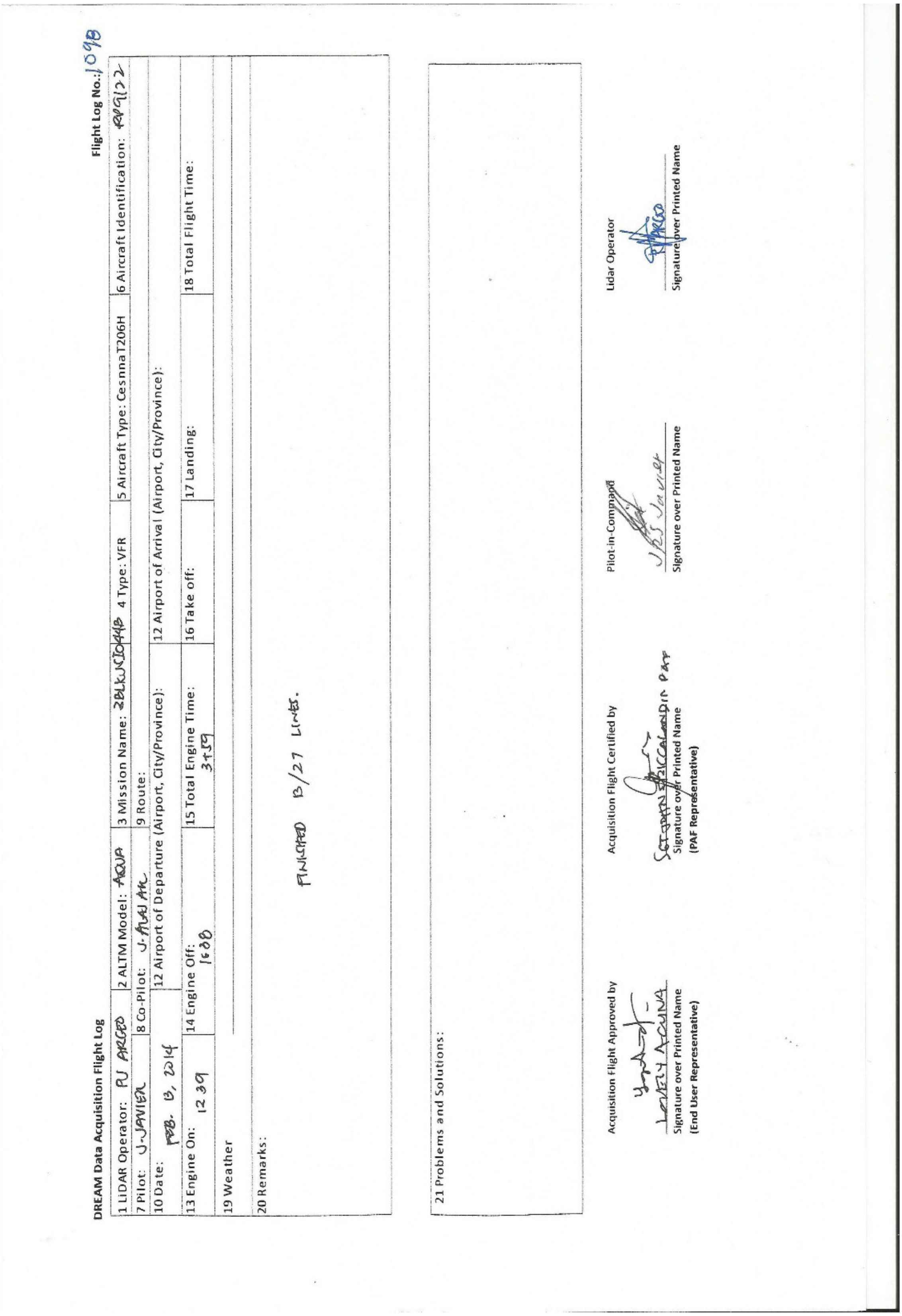
| | | | | | |
|---|---|---|---|---|---|
| 1 LiDAR Operator: I. ROXAS | 2 ALTM Model: AQUA | 3 Mission Name: 3BLKABES043A | 4 Type: VFR | 5 Aircraft Type: CesnnaT206H | 6 Aircraft Identification: RP9122 |
| 7 Pilot: J. JAVIER | 8 Co-Pilot: J. ALAJAR | 9 Route: | | | |
| 10 Date: FEB. 12, 2014 | 12 Airport of Departure (Airport, City/Province): | | 12 Airport of Arrival (Airport, City/Province): | | |
| 13 Engine On: 908 | 14 Engine Off: 1313 | 15 Total Engine Time: 4+05 | 16 Take off: | 17 Landing: | 18 Total Flight Time: |
| 19 Weather | | | | | |
| 20 Remarks: completed lines in Areas A & E. | | | | | |

21 Problems and Solutions:

| Acquisition Flight Approved by | Acquisition Flight Certified by | Pilot-in-Command | Lidar Operator |
|---|---|---|---|
| LOVELY ACUNA | SGT JOHN ERIC DACANANDIN PAF | J. JAVIER | I. ROXAS |
| Signature over Printed Name (End User Representative) | Signature over Printed Name (PAF Representative) | Signature over Printed Name | Signature over Printed Name |

Figure A-6.8. Flight Log for Mission 3BLK28ABES043A

9. Flight Log for Mission 3BLK28JSI044B



DREAM Data Acquisition Flight Log

Flight Log No.: 1098

| | | | | | |
|---|---|---|---|---|---|
| 1 LiDAR Operator: PJ ARCEO | 2 ALTM Model: AQUA | 3 Mission Name: 3BLK28JSI044B | 4 Type: VFR | 5 Aircraft Type: Cesnna T206H | 6 Aircraft Identification: RP9122 |
| 7 Pilot: J. JAVIER | 8 Co-Pilot: J. ALAJAR | 9 Route: | | | |
| 10 Date: FEB. 13, 2014 | 12 Airport of Departure (Airport, City/Province): | | 12 Airport of Arrival (Airport, City/Province): | | |
| 13 Engine On: 1239 | 14 Engine Off: 1638 | 15 Total Engine Time: 3+59 | 16 Take off: | 17 Landing: | 18 Total Flight Time: |
| 19 Weather | | | | | |

20 Remarks:

FINISHED 13/27 LINES.

21 Problems and Solutions:

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

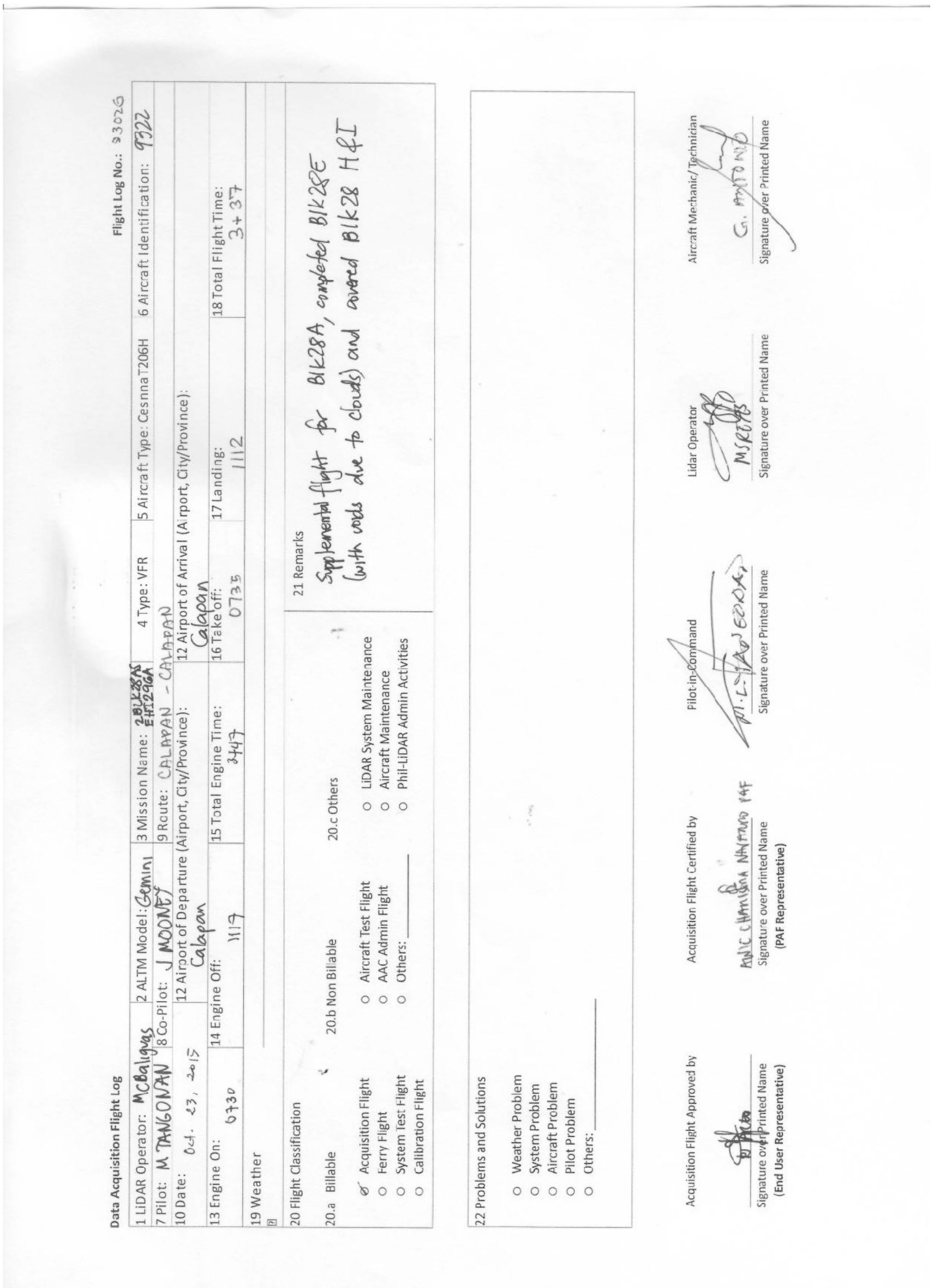
Acquisition Flight Certified by: SGT JOHN ... PAF, Signature over Printed Name (PAF Representative)

Pilot-in-Command: J. JAVIER, Signature over Printed Name

Lidar Operator: PJ ARCEO, Signature over Printed Name

Figure A-6.9. Flight Log for Mission 3BLK28JSI044B

## 10. Flight Log for Mission 3BLK28JSI046A



**Data Acquisition Flight Log** Flight Log No.: 93026

| | | | | | |
|---|---|---|---|---|---|
| 1 LiDAR Operator: MCBaliguas | 2 ALTM Model: Gemini | 3 Mission Name: 2BLK28AS EHI296A | 4 Type: VFR | 5 Aircraft Type: CesnnaT206H | 6 Aircraft Identification: 9322 |
| 7 Pilot: M TANGONAN | 8 Co-Pilot: J MOONEY | 9 Route: CALAPAN - CALAPAN | | | |
| 10 Date: Oct. 23, 2015 | 12 Airport of Departure (Airport, City/Province): Calapan | | 12 Airport of Arrival (Airport, City/Province): Calapan | | |
| 13 Engine On: 0730 | 14 Engine Off: 1119 | 15 Total Engine Time: 3+47 | 16 Take off: 0735 | 17 Landing: 1112 | 18 Total Flight Time: 3+37 |
| 19 Weather | | | | | |

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

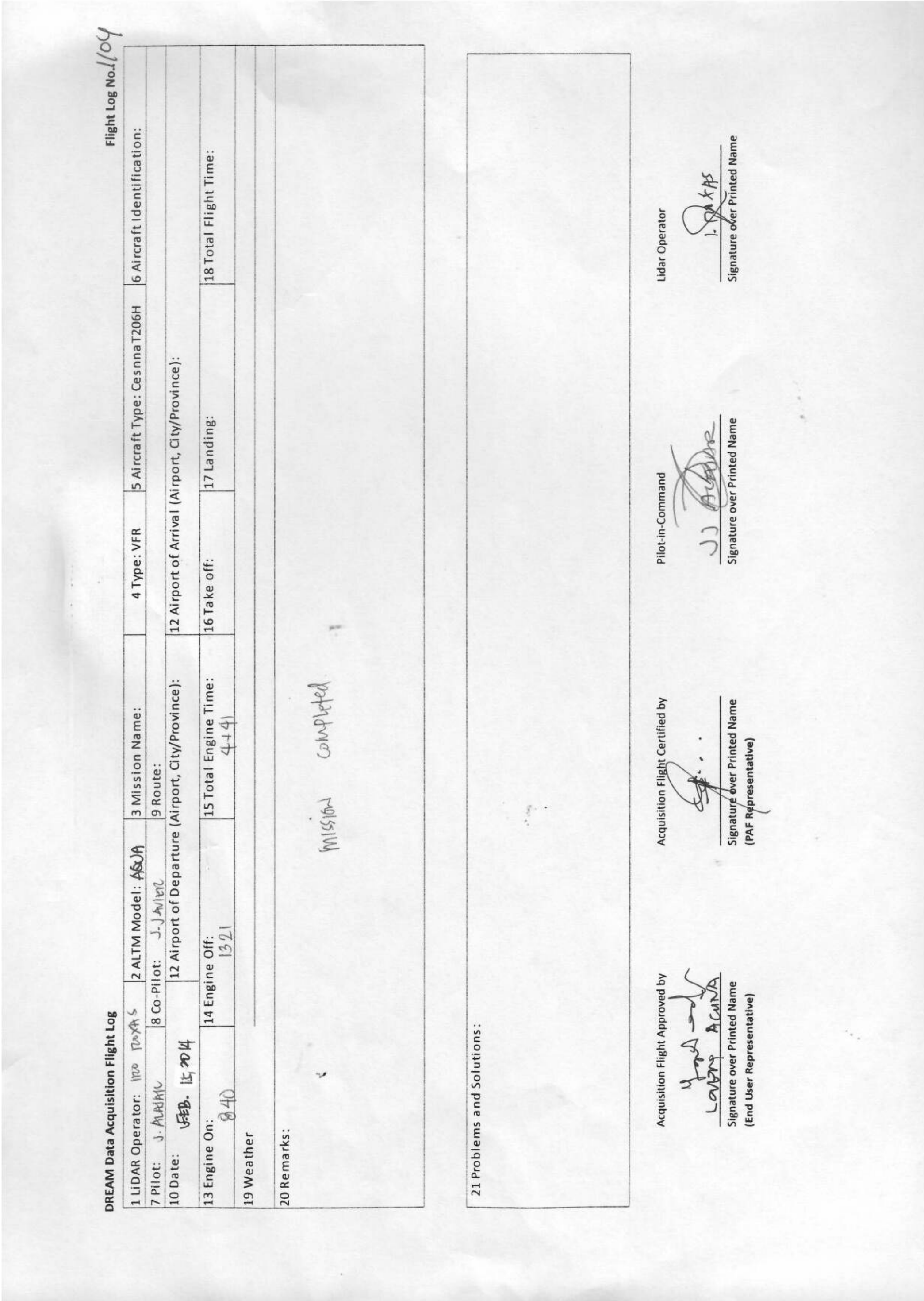
Supplemental flight for BLK28A, completed BLK28E (with voids due to clouds) and covered BLK28 H&I

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 |
|---|---|---|---|---|
| | ANIC CHANIDNA NAVARRO PAF | M.L. TANGONAN | MSREYES | G. ANTONIO |
| 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-6.10. Flight Log for Mission 3BLK28JSI046A

11. Flight Log for Mission 2BLK28ASEHI296A



**DREAM Data Acquisition Flight Log** — Flight Log No.: 1109

| | | | | | |
|---|---|---|---|---|---|
| 1 LiDAR Operator: I. ROXAS | 2 ALTM Model: AQUA | 3 Mission Name: | 4 Type: VFR | 5 Aircraft Type: Cesnna T206H | 6 Aircraft Identification: |
| 7 Pilot: J. ALBRIO | 8 Co-Pilot: J. JAVIER | 9 Route: | | | |
| 10 Date: FEB. 15, 2014 | 12 Airport of Departure (Airport, City/Province): | | 12 Airport of Arrival (Airport, City/Province): | | |
| 13 Engine On: 840 | 14 Engine Off: 1321 | 15 Total Engine Time: 441 | 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)

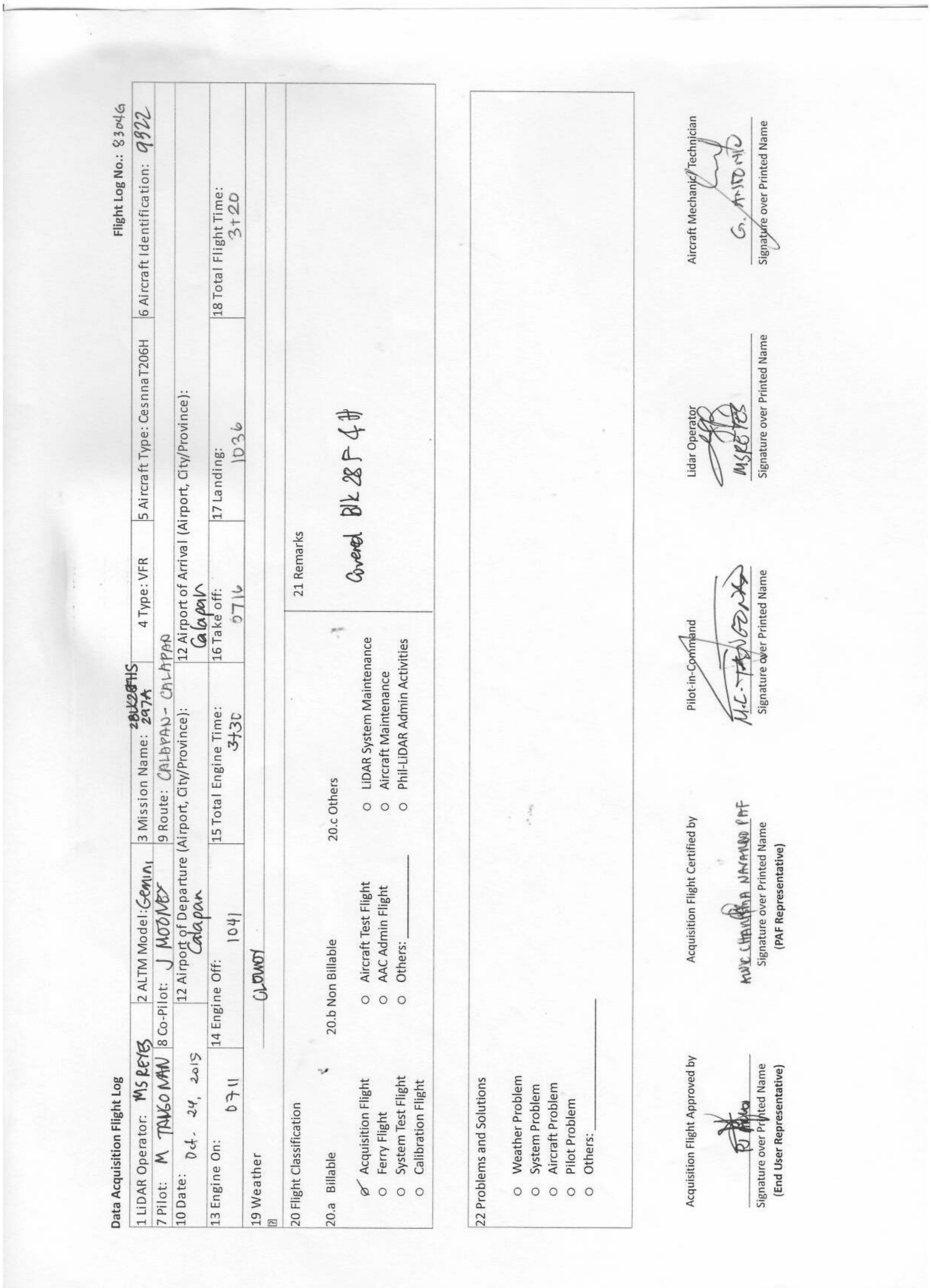
Acquisition Flight Certified by — Signature over Printed Name (PAF Representative)

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

Lidar Operator — I. ROXAS — Signature over Printed Name

Figure A-6.11. Flight Log for Mission 2BLK28ASEHI296A

12. Flight Log for Mission 2BLK28FHS297A



**Data Acquisition Flight Log** — **Flight Log No.:** 83046

| | | | | | |
|---|---|---|---|---|---|
| 1 LiDAR Operator: MS REYES | 2 ALTM Model: Gemini | 3 Mission Name: 2BLK28FHS297A | 4 Type: VFR | 5 Aircraft Type: CesnnaT206H | 6 Aircraft Identification: 9322 |
| 7 Pilot: M TANGONAN | 8 Co-Pilot: J MOJONES | 9 Route: CALAPAN - CALAPAN | | | |
| 10 Date: Oct. 24, 2015 | 12 Airport of Departure (Airport, City/Province): Calapan | | 12 Airport of Arrival (Airport, City/Province): Calapan | | |
| 13 Engine On: 0711 | 14 Engine Off: 1041 | 15 Total Engine Time: 3+30 | 16 Take off: 0716 | 17 Landing: 1036 | 18 Total Flight Time: 3+20 |
| 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

Covered BLK 28F 47

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)

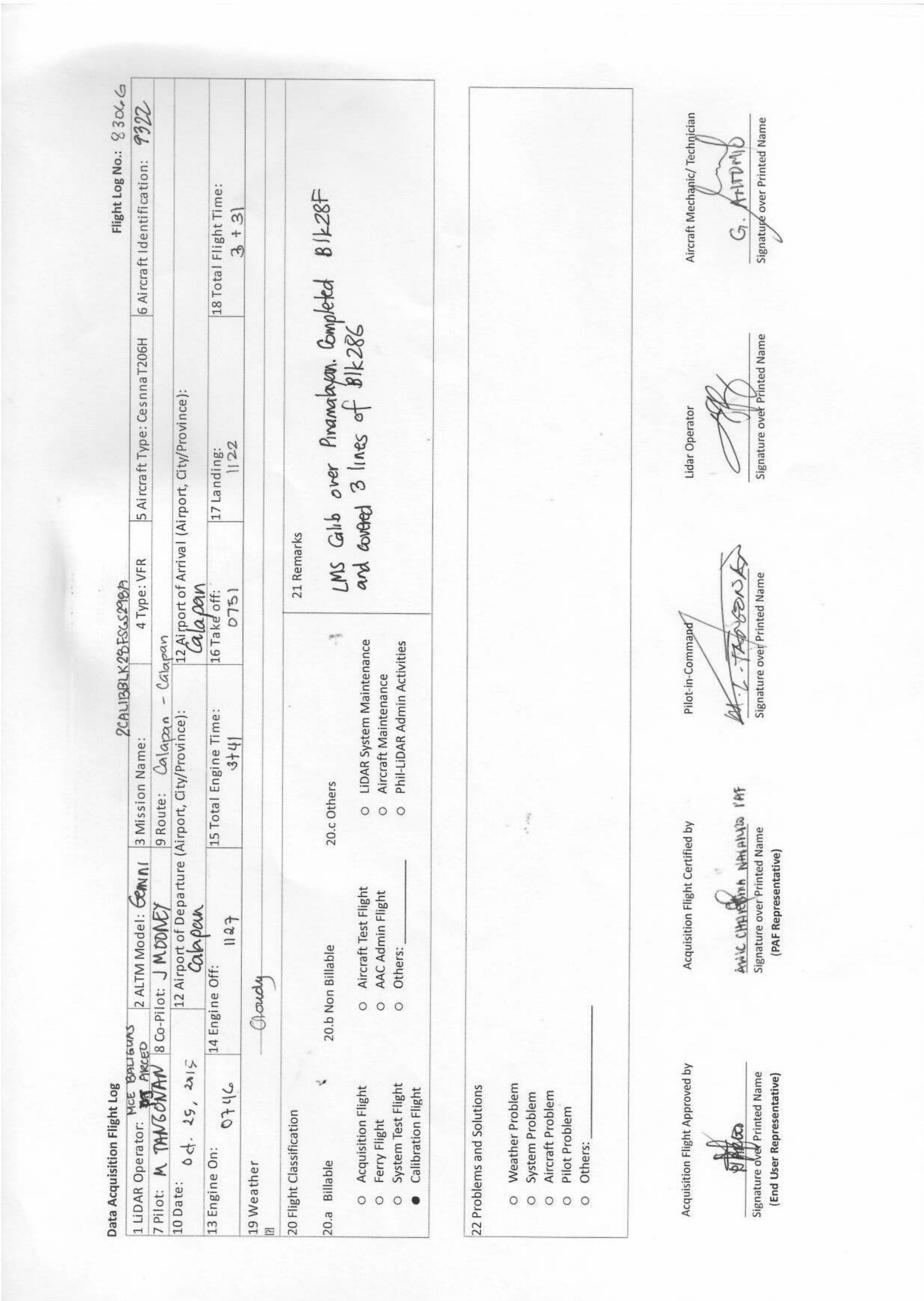
Pilot-in-Command — M.C. TANGONAN — Signature over Printed Name

Lidar Operator — MS REYES — Signature over Printed Name

Aircraft Mechanic/ Technician — G. ANTONIO — Signature over Printed Name

Figure A-6.12. Flight Log for Mission 2BLK28FHS297A

13. Flight Log for Mission 2CALIBBLK28FSGS298A



Flight Log No.: 8306G

Data Acquisition Flight Log

| | | | | | |
|---|---|---|---|---|---|
| 1 LiDAR Operator: MCE BALIGUAS ~~PJ~~ ARCEO | 2 ALTM Model: Gemini | 3 Mission Name: 2CALIBBLK28FSGS298A | 4 Type: VFR | 5 Aircraft Type: Cesnna T206H | 6 Aircraft Identification: 9322 |
| 7 Pilot: M TANGONAN | 8 Co-Pilot: J MOONEY | 9 Route: Calapan - Calapan | | | |
| 10 Date: oct. 25, 2015 | 12 Airport of Departure (Airport, City/Province): Calapan | | 12 Airport of Arrival (Airport, City/Province): Calapan | | |
| 13 Engine On: 0746 | 14 Engine Off: 1127 | 15 Total Engine Time: 3+41 | 16 Take off: 0751 | 17 Landing: 1122 | 18 Total Flight Time: 3+31 |
| 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

LMS Calib over Pinamalayan. Completed BlK28F and covered 3 lines of BlK28G

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: A1C [illegible] PAF — Signature over Printed Name (PAF Representative)

Pilot-in-Command: M. L. TANGONAN — Signature over Printed Name

Lidar Operator: Signature over Printed Name

Aircraft Mechanic/ Technician: G. ALFONSO — Signature over Printed Name

Figure A-6.13. Flight Log for Mission 2CALIBBLK28FSGS298A

# Annex 7. Flight Status Reports

BONGABONG FLOODPLAIN
February 2-15, 2014; October 23-25, 2015

Table A-7.1. Flight Status Report

| FLIGHT NO. | AREA | MISSION | OPERATOR | DATE FLOWN | REMARKS |
|---|---|---|---|---|---|
| 1070A | BLOCK 28D & 28E | 3BLK28DSE037A | IRO ROXAS | FEB 6, 2014 | Finished Block 28D and some lines of Block 28E |
| 1072A | BLOCK 28F | 3BLK28F038A | PAULINE ARCEO | FEB 7, 2014 | Mission Complete |
| 1074A | BLOCK 28F, 28G | 3BLK28G038B | IRO ROXAS | FEB 7, 2014 | Mission Complete |
| 1076A | BLOCK 28G | 3BLK28GS039A | IRO ROXAS | FEB 8, 2014 | Mission Complete |
| 1078A | BLOCK 28G & BLOCK 28H | 3BLK28GSH039B | PAULINE ARCEO | FEB 8, 2014 | Mission Complete |
| 1088A | BLK 28H | 3BLK28HS042A | IRO ROXAS | FEB 11, 2014 | Mission Complete |
| 1090A | BLK 28J | 3BLK28J042B | PAU ARCEO | FEB 11, 2014 | Mission Complete |
| 1092A | BLK 28A,B,E | 3BLK28ABES043A | IRO ROXAS | FEB 12, 2014 | Mission Complete |
| 1098A | BLK28J,I | 3BLK28JSI044B | PAU ARCEO | FEB 13, 2014 | Mission Complete |
| 1104A | BLK28J,I | 3BLK28JSI046A | IRO ROXAS | FEB 15, 2014 | Mission Complete |
| 8302G | BLK28E,H,I | 2BLK28ASEHI296A | CATH BALIGUAS | OCT 23, 2014 | Supplemental flight for BLK 28A, completed BLK28E and covered BLK 28 H&I |
| 8304G | BLK28FH | 2BLK28FHS297A | CATH BALIGUAS, SHANE REYES | OCT 24, 2014 | Covered BLK 28 F&H |
| 8306G | BLK28F | 2CALIBBLK28FSGS298A | PAU ARCEO, CATH BALIGUAS | OCT 25, 2014 | LMS Calib over Pinamalayan; completed BLK 28F and covered BLK 28G |

| | | |
|---|---|---|
| FLIGHT LOG NO. | 1070A | Scan Freq: 45 kHz |
| AREA: | BLOCK 28D & BLOCK 28E | Scan Angle: 18 deg |
| MISSION NAME: | 3BLK28DSE037A | Alt: 600 m |

SURVEY COVERAGE:

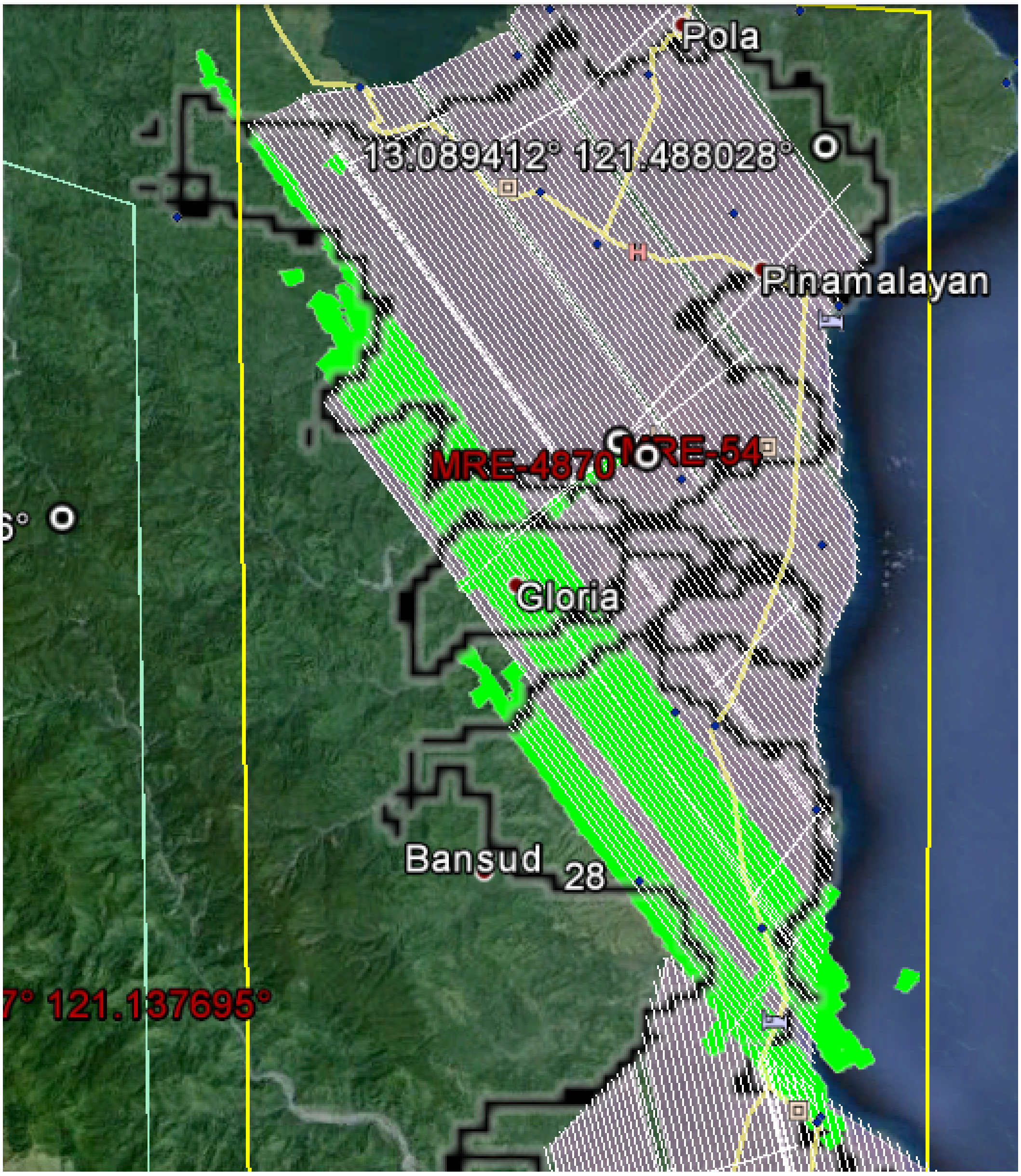



Figure A-7.1. 1070A

| | | |
|---|---|---|
| FLIGHT LOG NO. | 1072A | Scan Freq: 45 kHz |
| AREA: | BLOCK 28F | Scan Angle: 18 deg |
| MISSION NAME: | 3BLK28F038A | Alt: 600 m |

SURVEY COVERAGE:

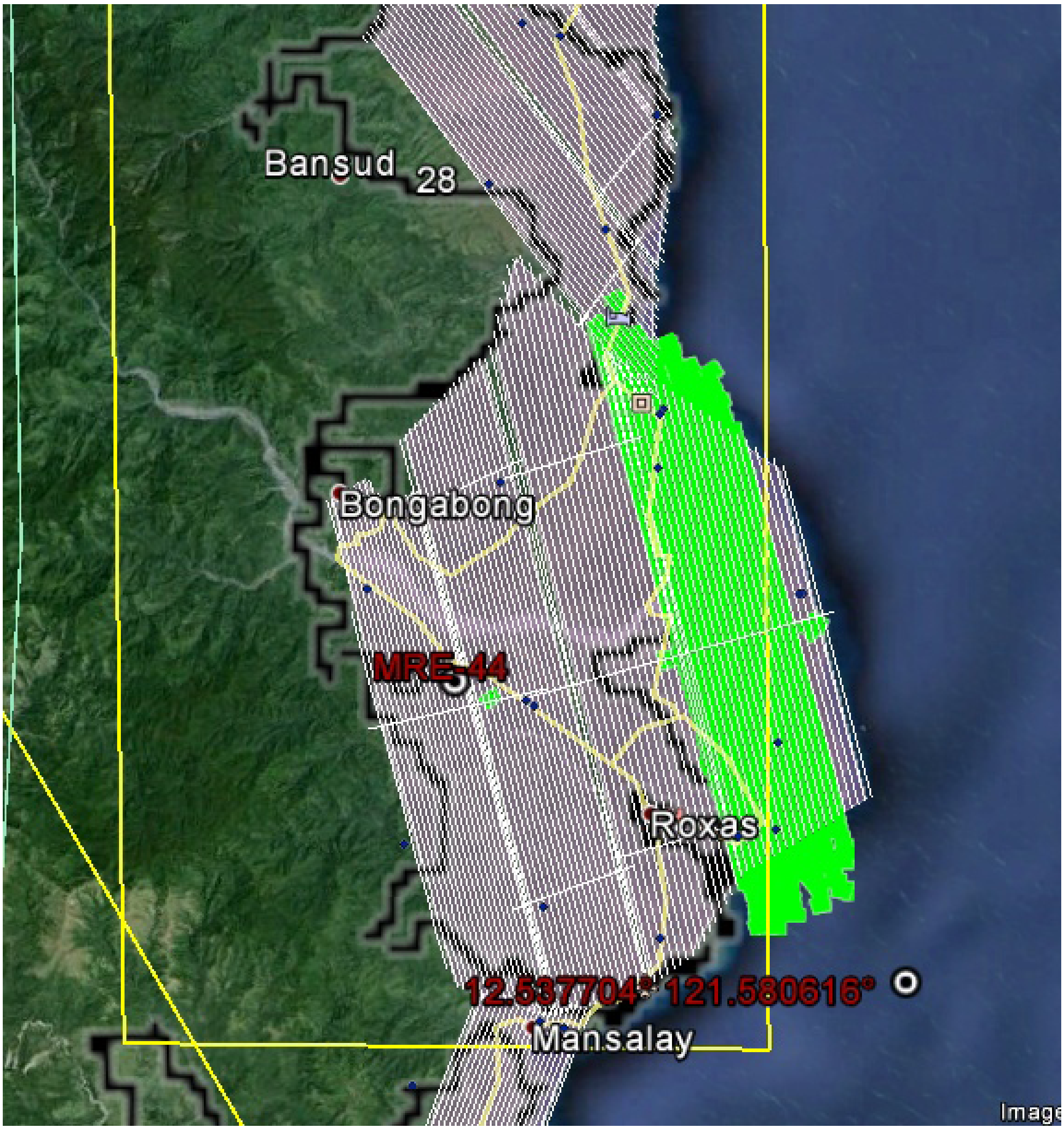



Figure A-7.2. 1072A

| | | |
|---|---|---|
| FLIGHT LOG NO. | 1074A | Scan Freq: 45 kHz |
| AREA: | BLOCK 28F & BLOCK28G | Scan Angle: 18 deg |
| MISSION NAME: | 3BLK28FSG038B | Alt: 600 m |

SURVEY COVERAGE:

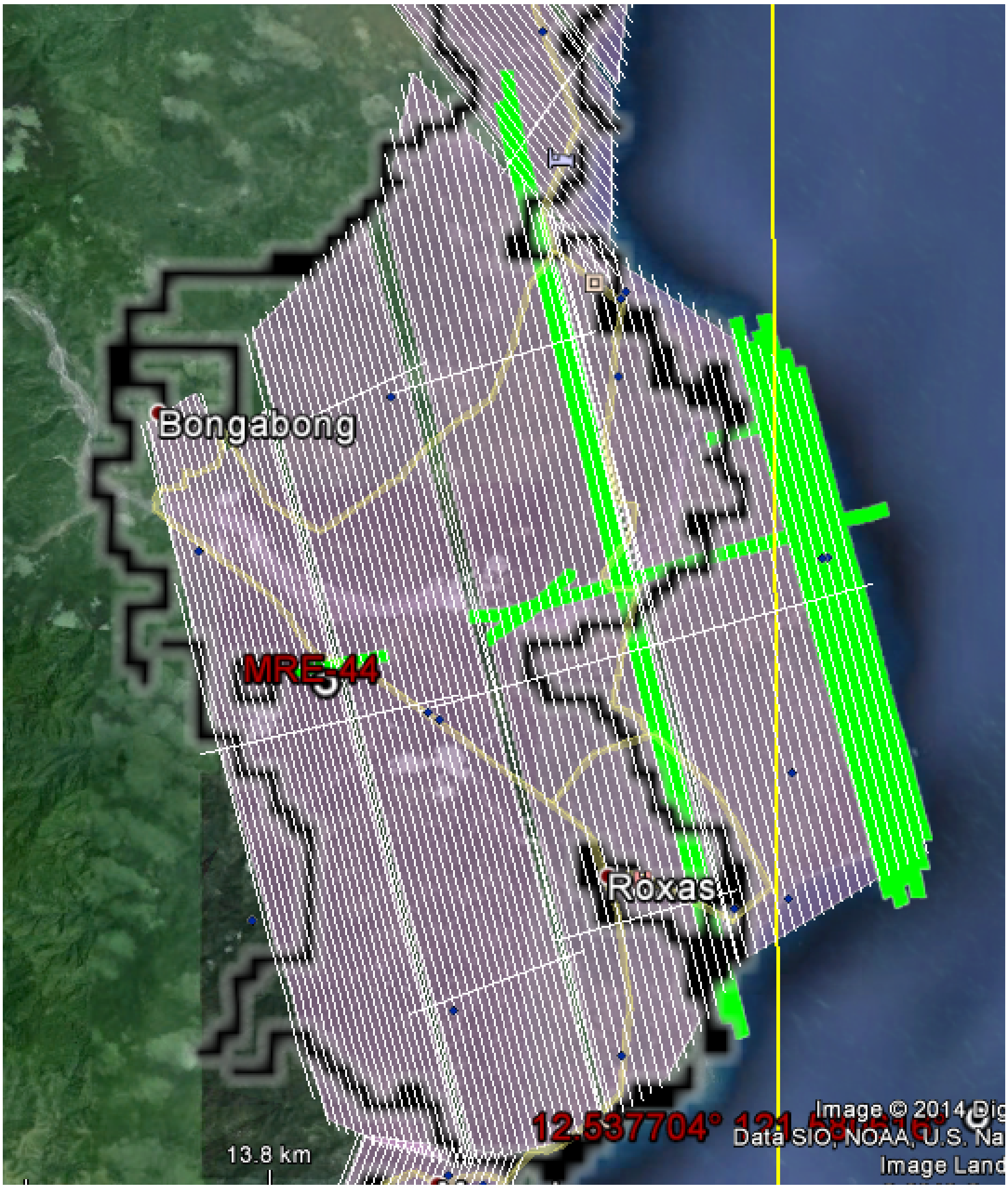



Figure A-7.3. 1074A

| | | |
|---|---|---|
| FLIGHT LOG NO. | 1076A | Scan Freq: 45 kHz |
| AREA: | BLOCK 28G | Scan Angle:18deg |
| MISSION NAME: | 3BLK28G039A | Alt: 600 m |

SURVEY COVERAGE:

Figure A-7.4. 1076A

FLIGHT LOG NO. 1078A
AREA: BLOCK 28G, 28H
MISSION NAME: 3BLK28GSH039B

Scan Freq: 45 kHz
Scan Angle: 18 deg
Alt: 600 m

SURVEY COVERAGE:

Figure A-7.5. 1078A

| | | |
|---|---|---|
| FLIGHT LOG NO. | 1088A | Scan Freq: 45 kHz |
| AREA: | BLOCK 28H | Scan Angle: 18 deg |
| MISSION NAME: | 3BLK28HS042A | Alt: 600 m |

SURVEY COVERAGE:

Figure A-7.6. 1088A

| | | |
|---|---|---|
| FLIGHT LOG NO. | 1090A | Scan Freq: 45 kHz |
| AREA: | BLOCK 28J | Scan Angle: 18 deg |
| MISSION NAME: | 3BLK28HS042B | Alt: 600 m |

SURVEY COVERAGE:

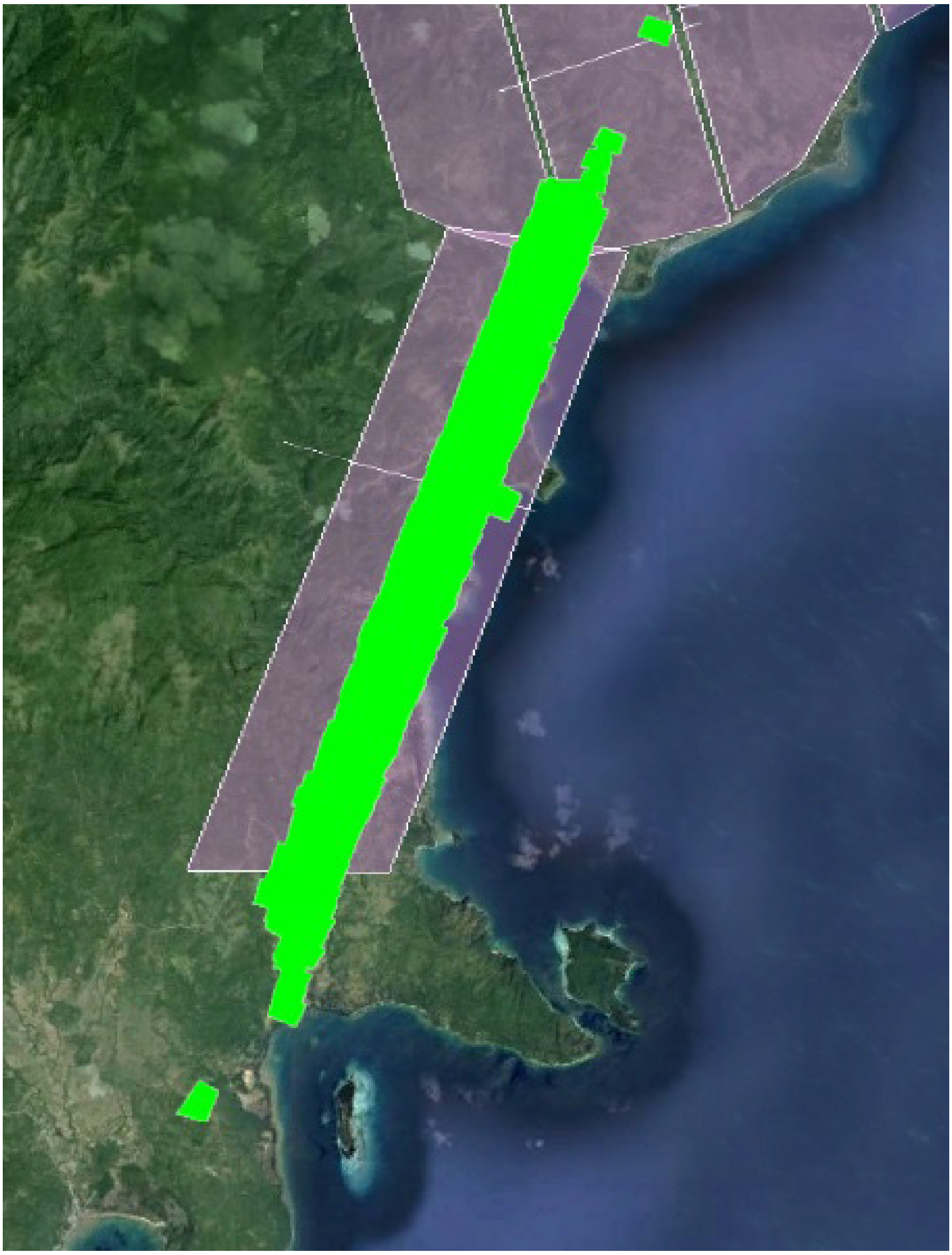


Figure A-7.7. 1090A

| | | |
|---|---|---|
| FLIGHT LOG NO. | 1092A | Scan Freq: 45 kHz |
| AREA: | BLOCK 28A, B, E | Scan Angle: 18 deg |
| MISSION NAME: | 3BLK28ABES43A | Alt: 600 m |

SURVEY COVERAGE:

Figure A-7.8. 1092A

FLIGHT LOG NO. 1098A
AREA: BLOCK 28JI
MISSION NAME: 3BLK28JSI044B

Scan Freq: 45 kHz
Scan Angle: 18 deg
Alt: 600 m

SURVEY COVERAGE:

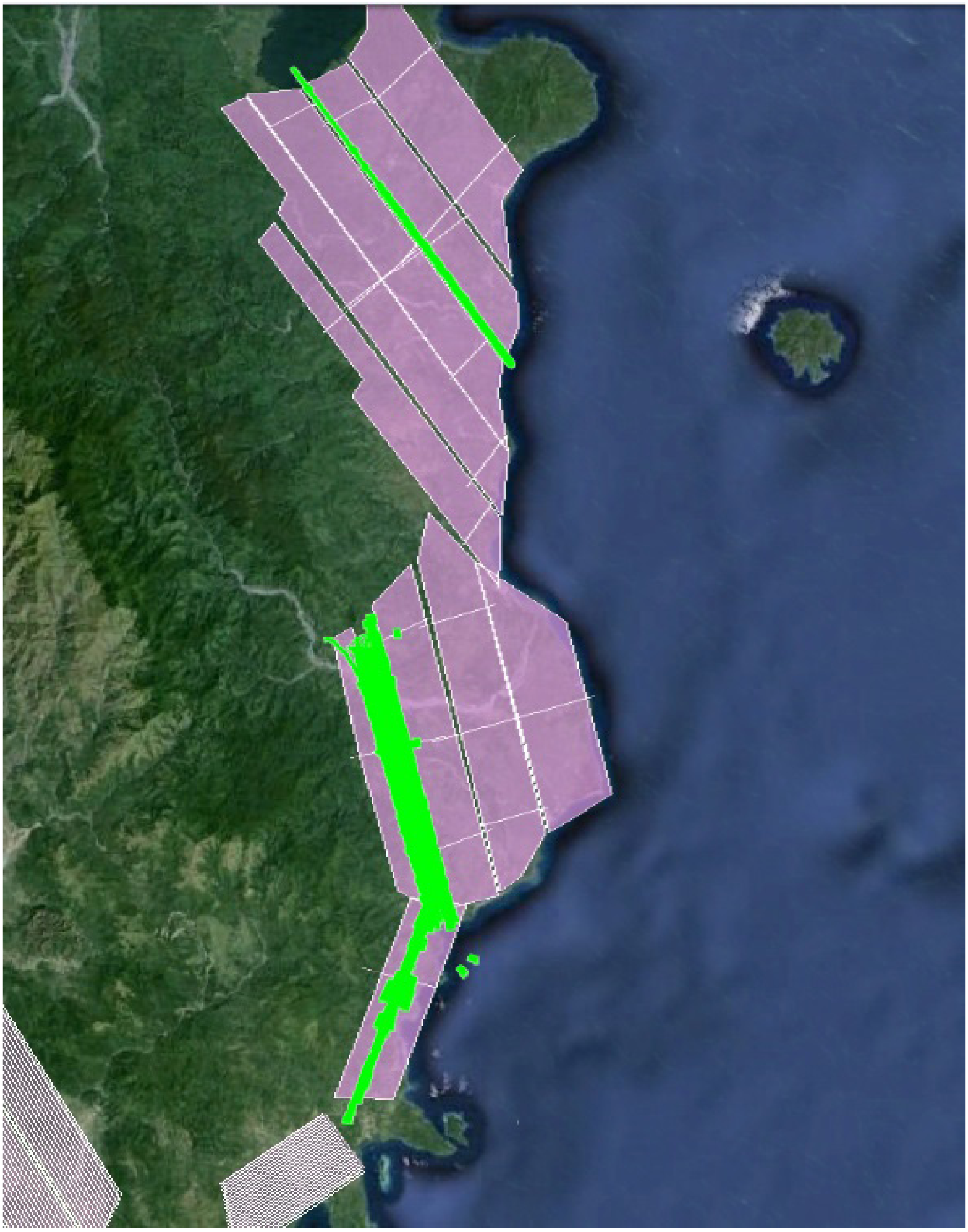


Figure A-7.9. 1098A

| | | |
|---|---|---|
| FLIGHT LOG NO. | 1104A | Scan Freq: 45 kHz |
| AREA: | BLOCK 28JI | Scan Angle: 18 deg |
| MISSION NAME: | 3BLK28JSI046A | Alt: 1000 m |

SURVEY COVERAGE:

Figure A-7.10. 1104A

| | | |
|---|---|---|
| FLIGHT LOG NO. | 8302G | Scan Freq: 50 kHz |
| AREA: | BLOCK 28A, 28E, 28H & 28I | Scan Angle: 15 deg |
| MISSION NAME: | 2BLK28ASEHI296A | Alt: 1200 m |

SURVEY COVERAGE:

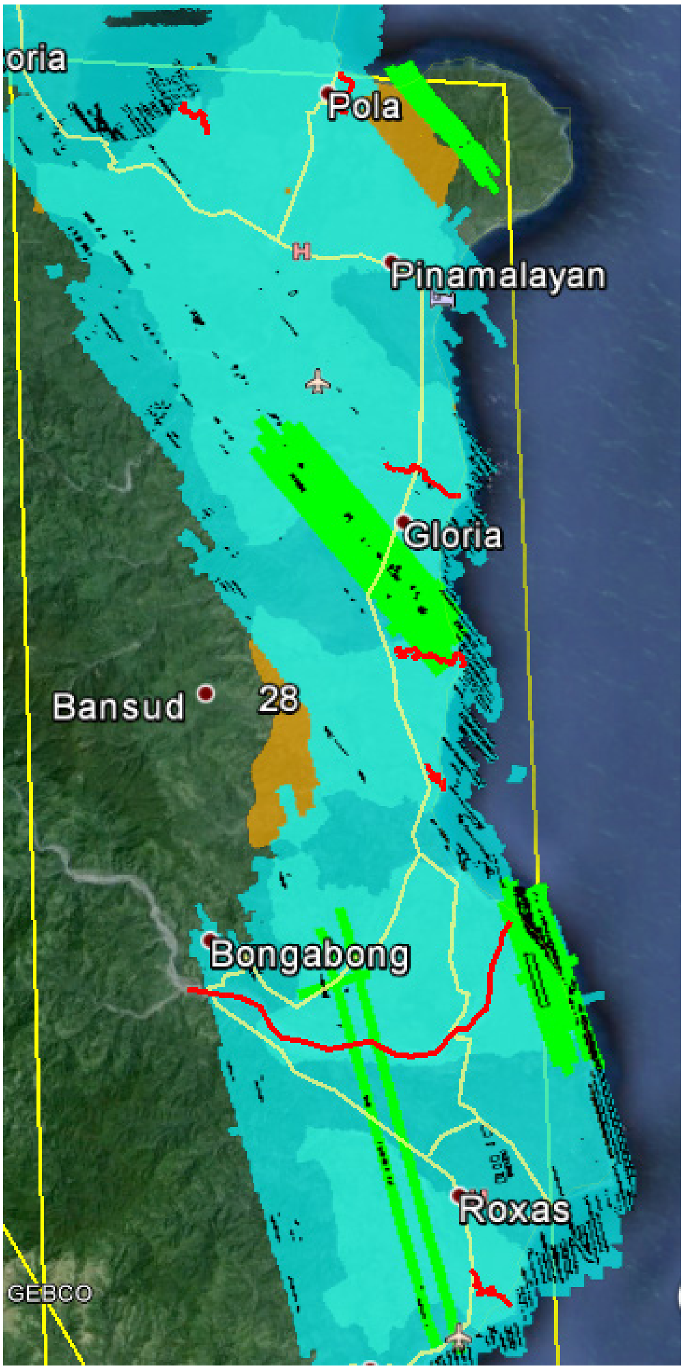



Figure A-7.11. 8302G

| | | |
|---|---|---|
| FLIGHT LOG NO. | 8304G | Scan Freq: 50 kHz |
| AREA: | BLOCK 28F & 28H | Scan Angle: 15 deg |
| MISSION NAME: | 2BLK28FHS297A | Alt: 1200 m |

SURVEY COVERAGE:

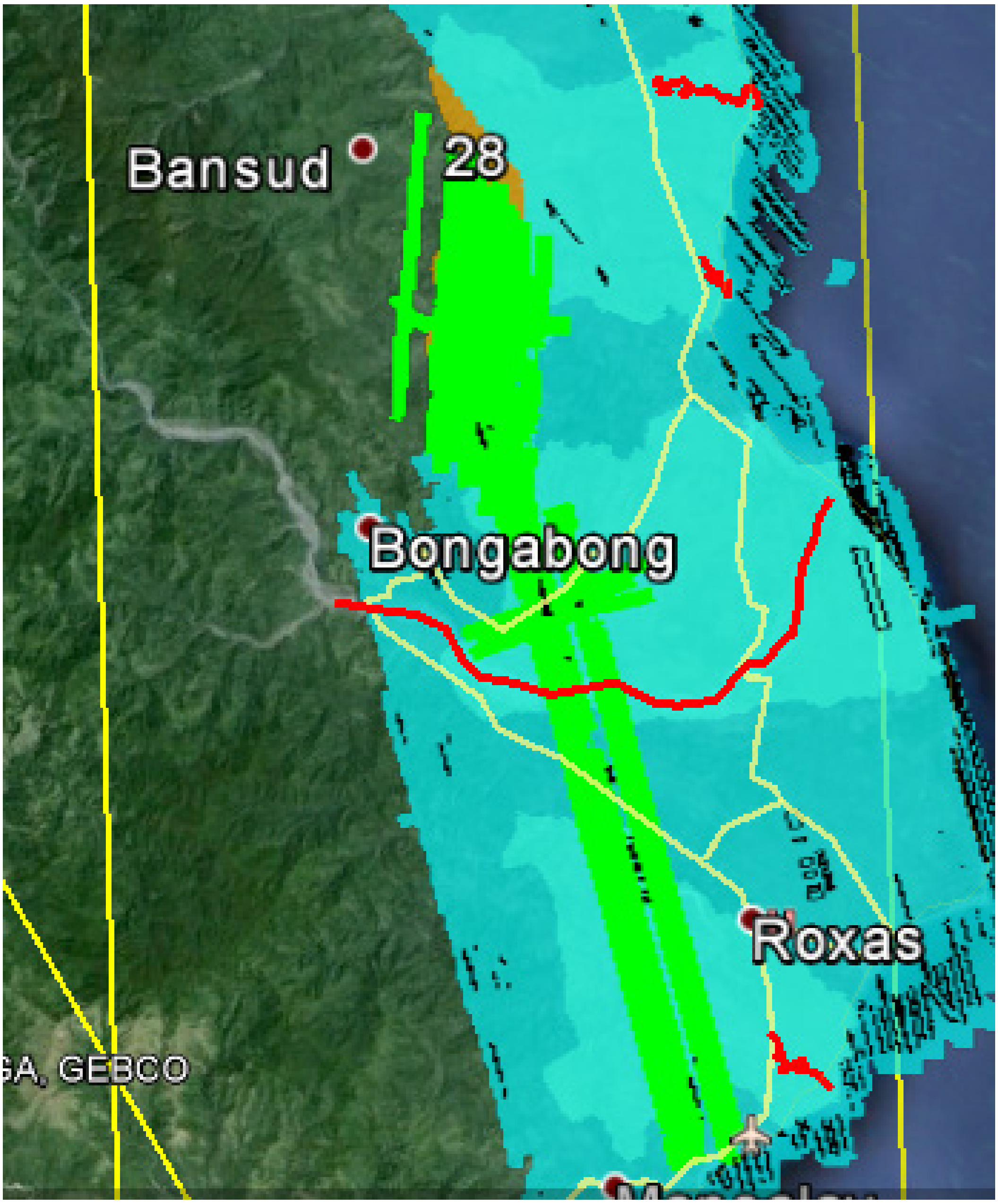



Figure A-7.12. 8304G

| | | |
|---|---|---|
| FLIGHT LOG NO. | 8306G | Scan Freq: 50 kHz |
| AREA: | BLOCK 28F & 28G | Scan Angle: 20deg |
| MISSION NAME: | 2CALIBBLK28FSGS298A | Alt: 1000 m |

SURVEY COVERAGE:

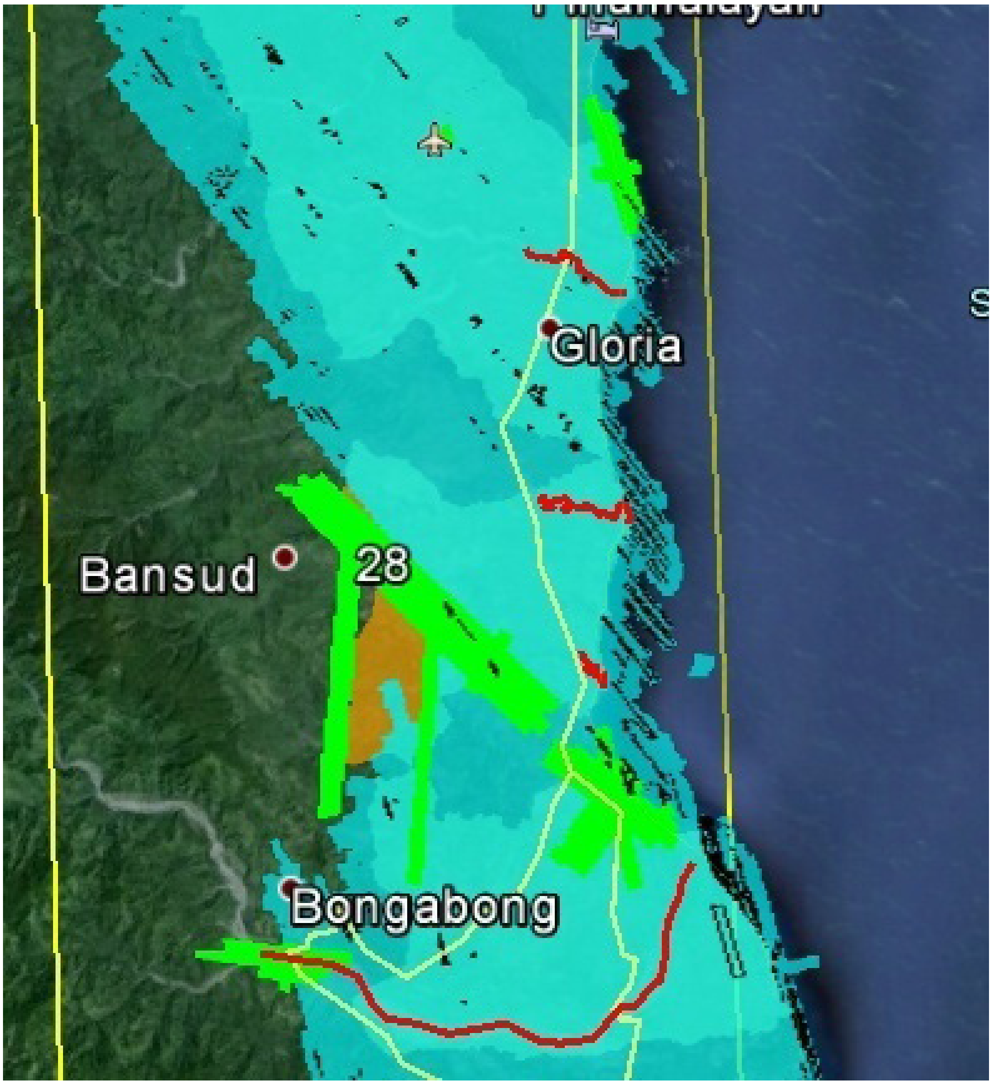



Figure A-7.13. 8306G

## Annex 8: Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Blk28E

| Flight Area | Oriental Mindoro |
|---|---|
| Mission Name | Blk28E |
| Inclusive Flights | 1070A |
| Range data size | 15.9 GB |
| Base data size | 14.9 MB |
| POS | 270 MB |
| Image | 104 GB |
| Transfer date | February 20, 2014 |
| | |
| Solution Status | |
| Number of Satellites (>6) | No |
| PDOP (<3) | No |
| Baseline Length (<30km) | No |
| Processing Mode (<=1) | Yes |
| | |
| Smoothed Performance Metrics(in cm) | |
| RMSE for North Position (<4.0 cm) | 1.7 |
| RMSE for East Position (<4.0 cm) | 1.9 |
| RMSE for Down Position (<8.0 cm) | 3.8 |
| | |
| Boresight correction stdev (<0.001deg) | 0.000346 |
| IMU attitude correction stdev (<0.001deg) | 0.0001166 |
| GPS position stdev (<0.01m) | 0.0087 |
| | |
| Minimum % overlap (>25) | 38.34% |
| Ave point cloud density per sq.m. (>2.0) | 3.35 |
| Elevation difference between strips (<0.20m) | Yes |
| | |
| Number of 1km x 1km blocks | 202 |
| Maximum Height | 388.91 m |
| Minimum Height | 48.91 m |
| | |
| Classification (# of points) | |
| Ground | 81,447,001 |
| Low vegetation | 92,938,121 |
| Medium vegetation | 85,912,374 |
| High vegetation | 92,936,807 |
| Building | 3,360,220 |
| Orthophoto | Yes |
| Processed by | Engr. Carlyn Ann Ibanez, Engr. Charmaine Cruz, Engr. Elainne Lopez, Engr. John Dill Macapagal |

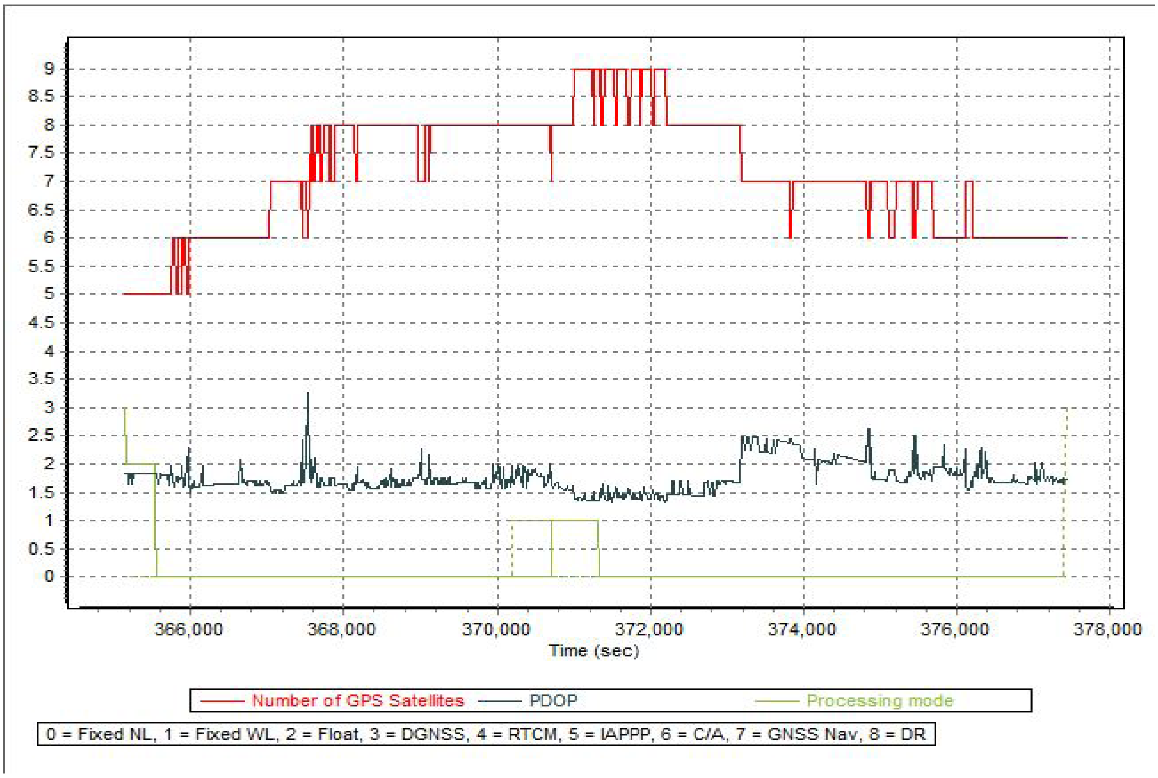



Figure A-8.1. Solution Status

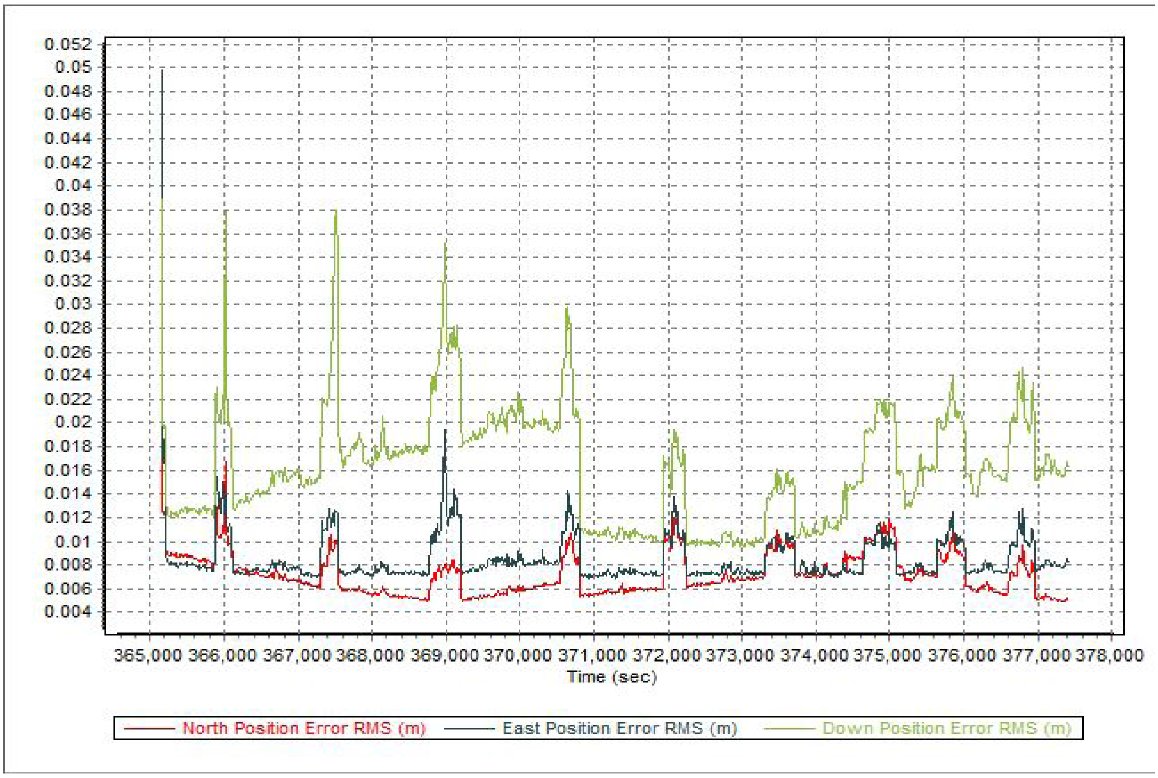



Figure A-8.2. Smoothed Performance Metrics Parameters

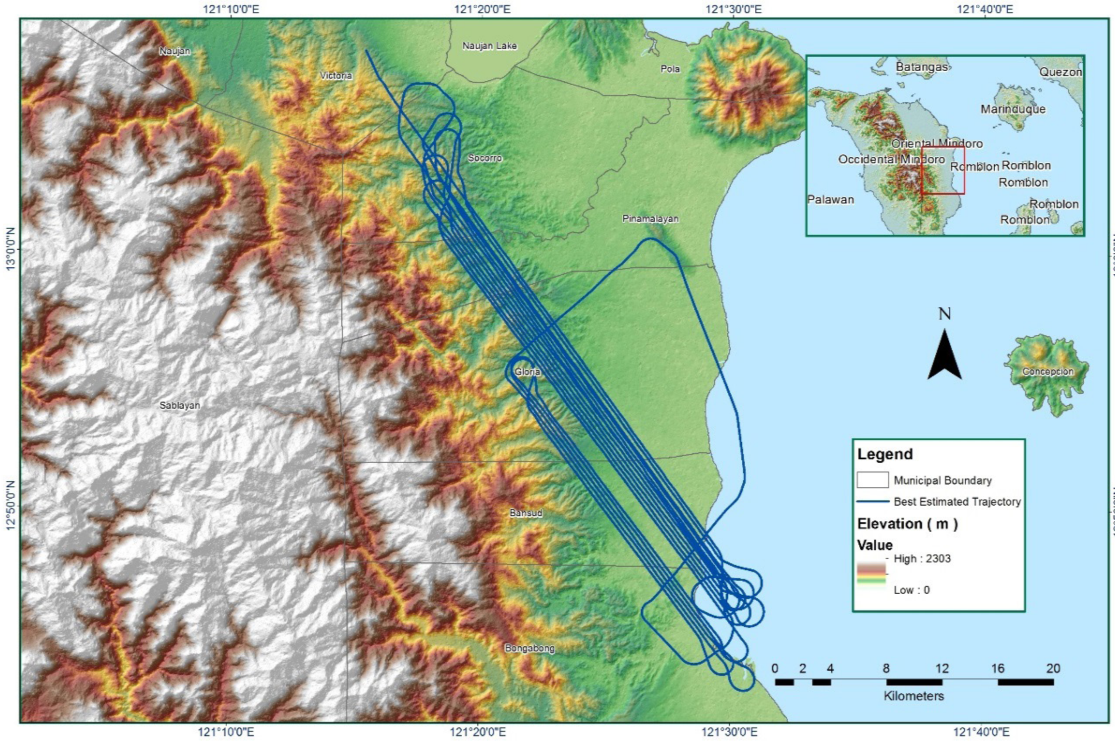



Figure A-8.3. Best Estimated Trajectory

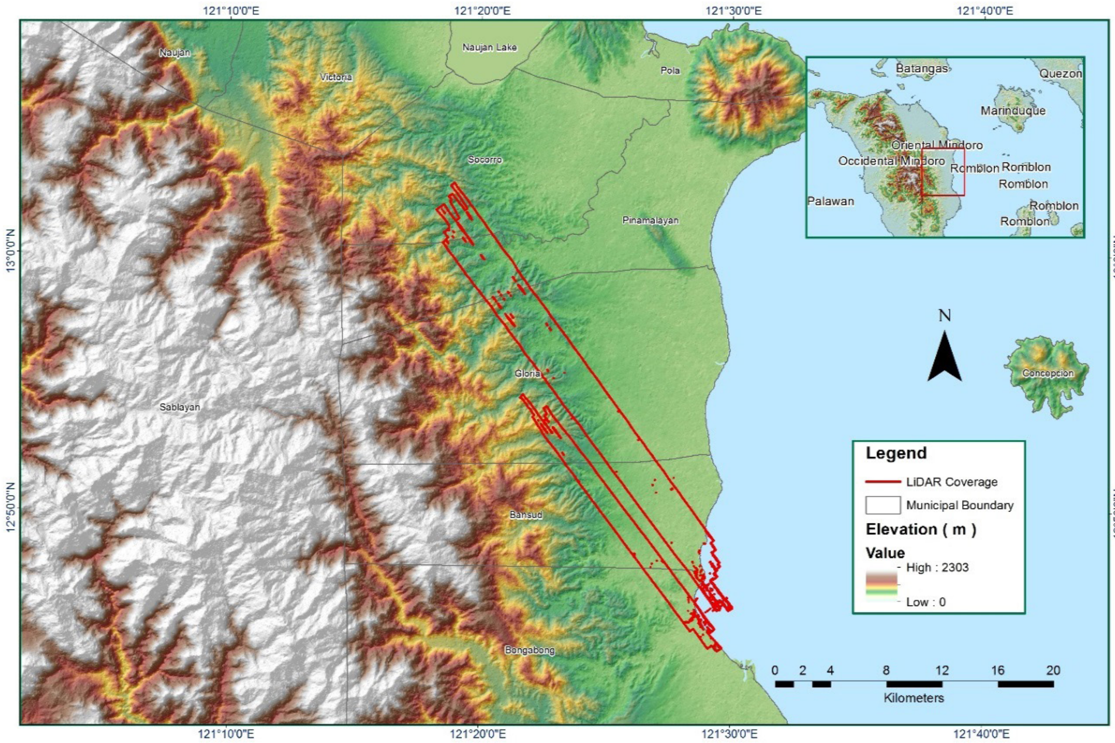



Figure A-8.4. Coverage of LiDAR data

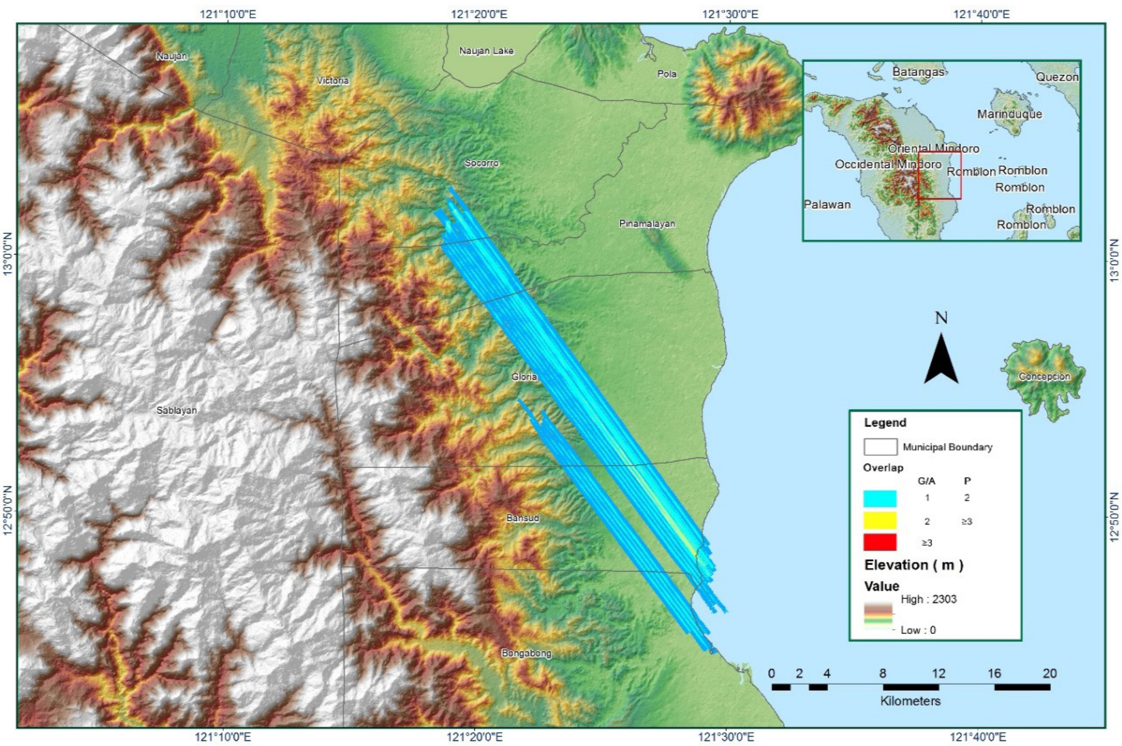



Figure A-8.5. Image of data overlap

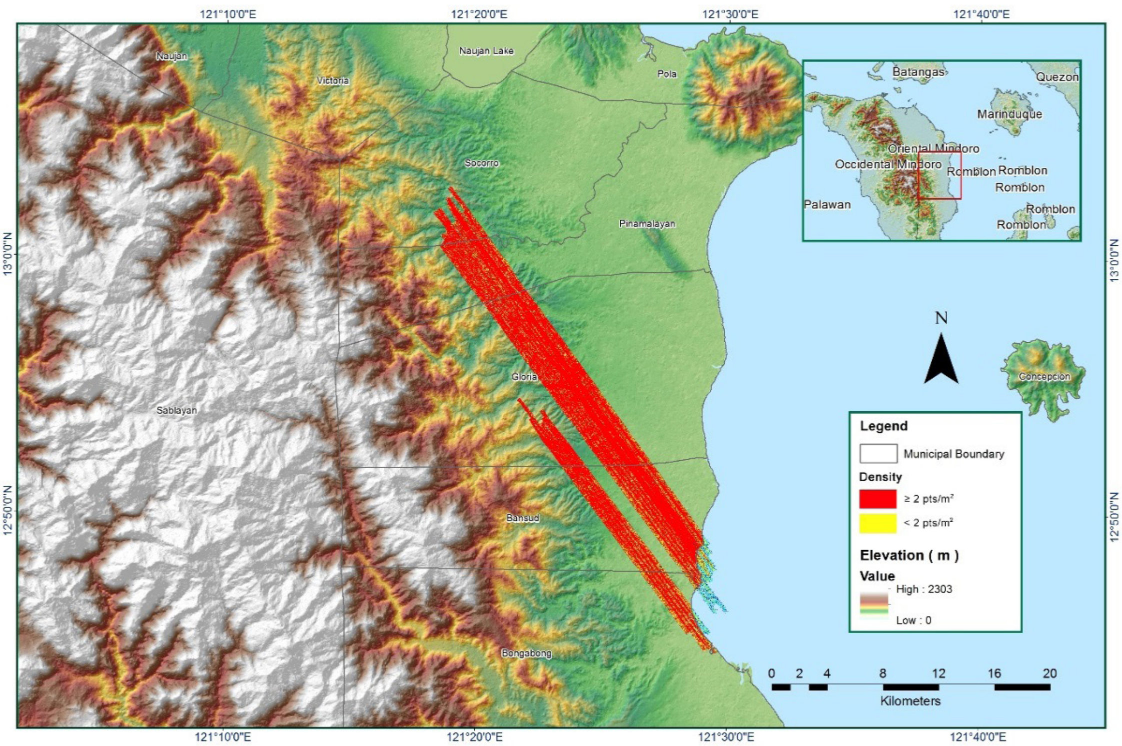



Figure A-8.6. Density map of merged LiDAR data

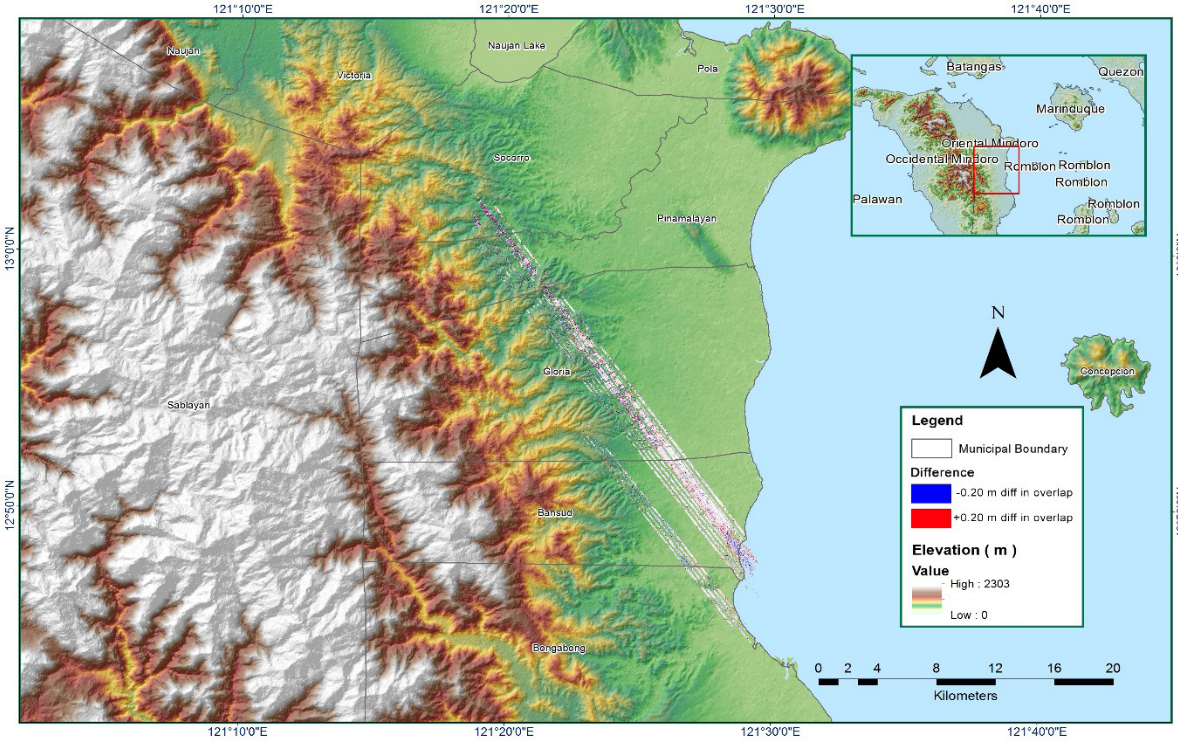



Figure A-8.7. Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Blk28F

| Flight Area | Oriental Mindoro |
|---|---|
| Mission Name | Blk28F |
| Inclusive Flights | 1072A |
| Range data size | 12.5 GB |
| Base data size | 14.1 MB |
| POS | 256 MB |
| Image | 81.4 GB |
| Transfer date | February 20, 2014 |
| | |
| Solution Status | |
| Number of Satellites (>6) | Yes |
| PDOP (<3) | No |
| Baseline Length (<30km) | Yes |
| Processing Mode (<=1) | Yes |
| | |
| Smoothed Performance Metrics (in cm) | |
| RMSE for North Position (<4.0 cm) | 1.4 |
| RMSE for East Position (<4.0 cm) | 1.5 |
| RMSE for Down Position (<8.0 cm) | 3.8 |
| | |
| Boresight correction stdev (<0.001deg) | 0.000425 |
| IMU attitude correction stdev (<0.001deg) | 0.009525 |
| GPS position stdev (<0.01m) | 0.0318 |
| | |
| Minimum % overlap (>25) | 42.58% |
| Ave point cloud density per sq.m. (>2.0) | 2.86 |
| Elevation difference between strips (<0.20 m) | Yes |
| | |
| Number of 1km x 1km blocks | 190 |
| Maximum Height | 146.32 m |
| Minimum Height | 31.32 m |
| | |
| Classification (# of points) | |
| Ground | 83,396,476 |
| Low vegetation | 114,178,225 |
| Medium vegetation | 59,793,586 |
| High vegetation | 34,546,932 |
| Building | 3,692,979 |
| | |
| Orthophoto | Yes |
| Processed by | Engr. Carlyn Ann Ibanez, Engr. Antonio Chua Jr, Engr. Elainne Lopez |


Figure A-8.8. Solution Status

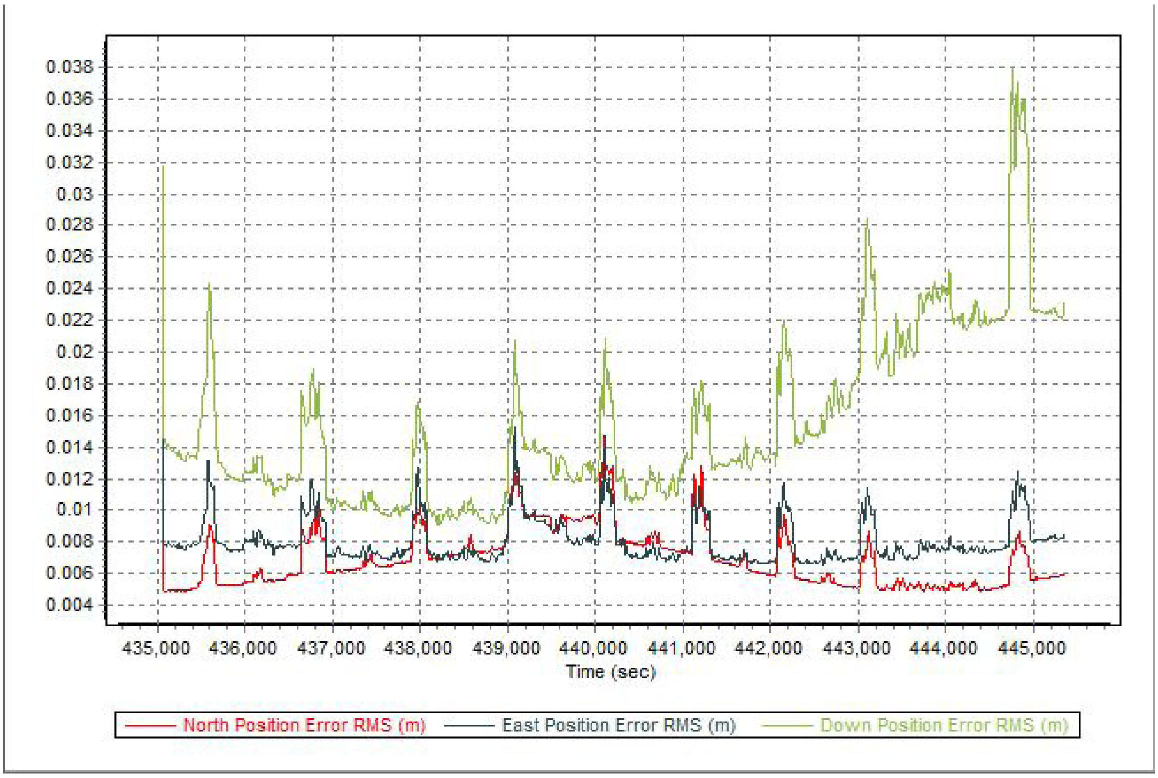



Figure A-8.9. Smoothed Performance Metrics Parameters

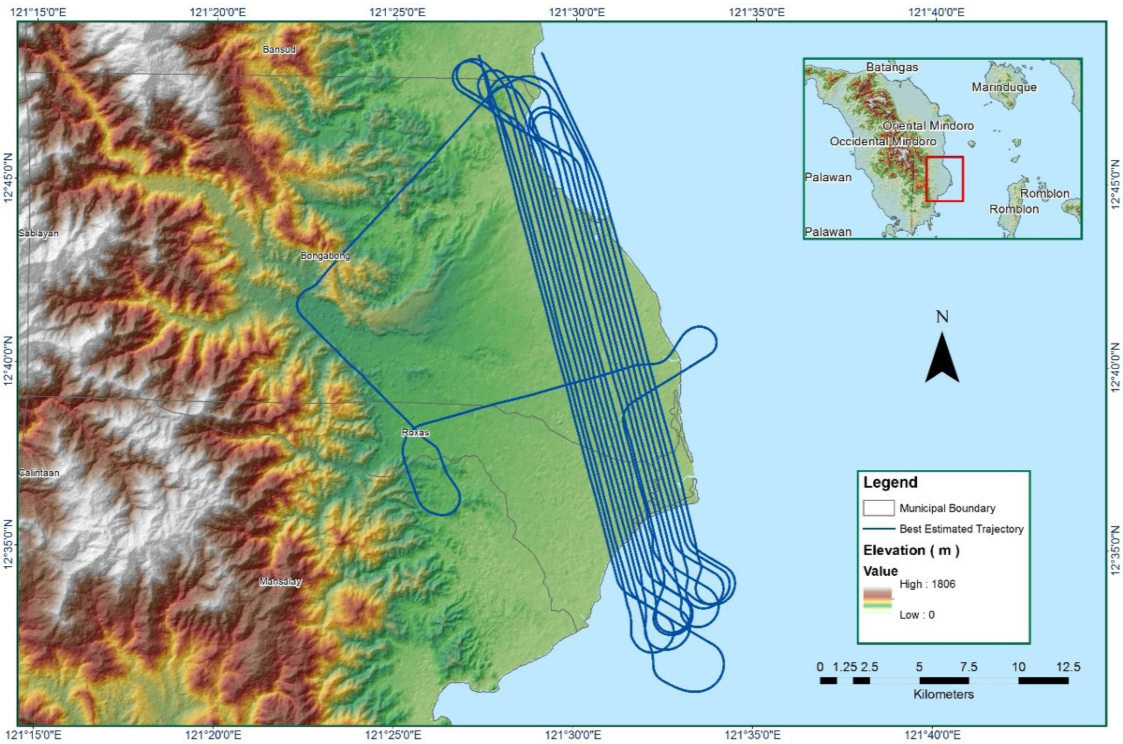



Figure A-8.10. Best Estimated Trajectory

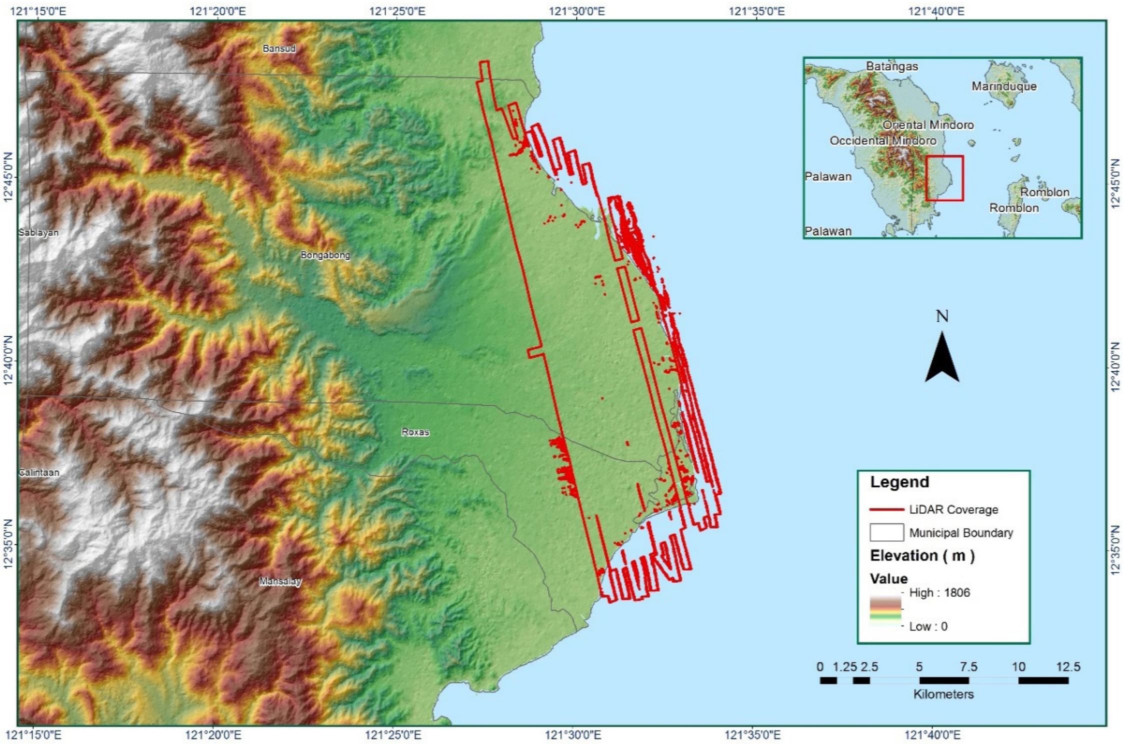



Figure A-8.11. Coverage of LiDAR data

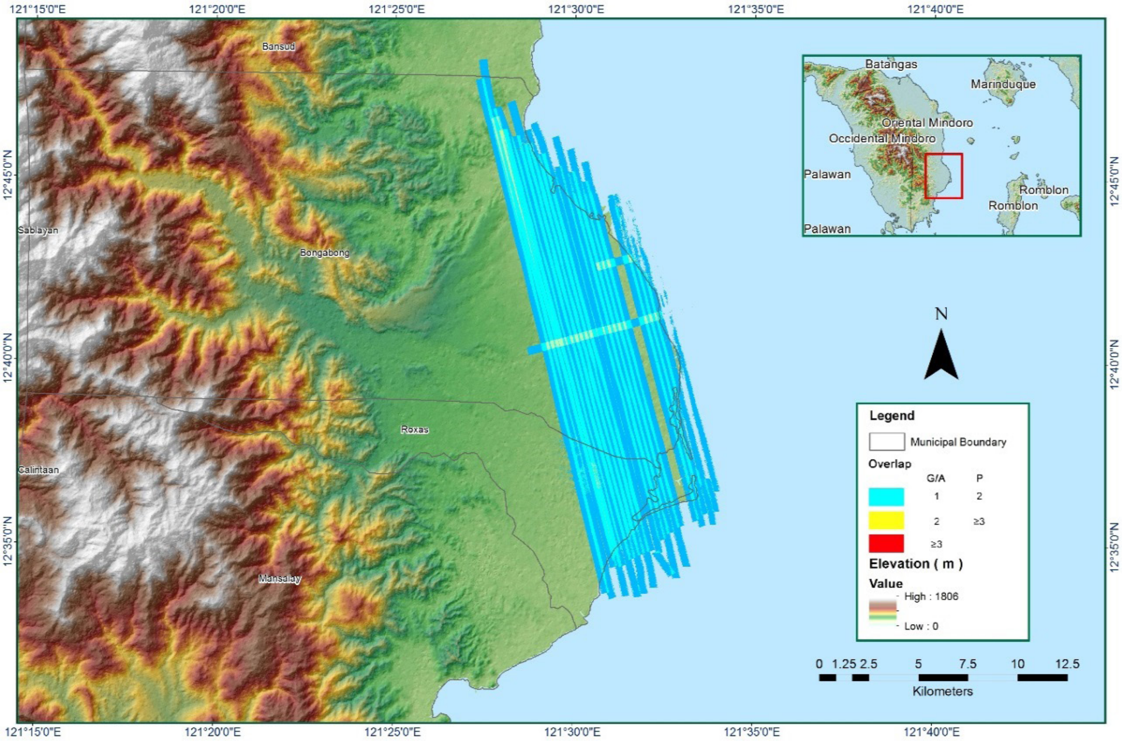



Figure A-8.12. Image of data overlap

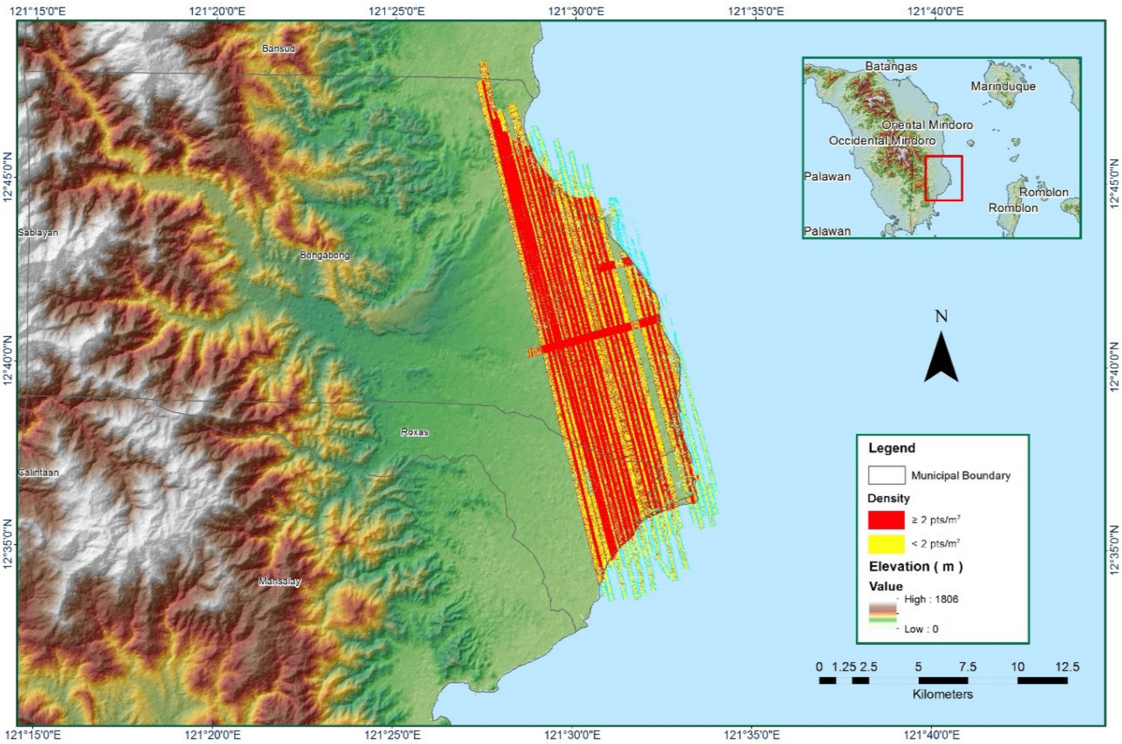



Figure A-8.13. Density of merged LiDAR data

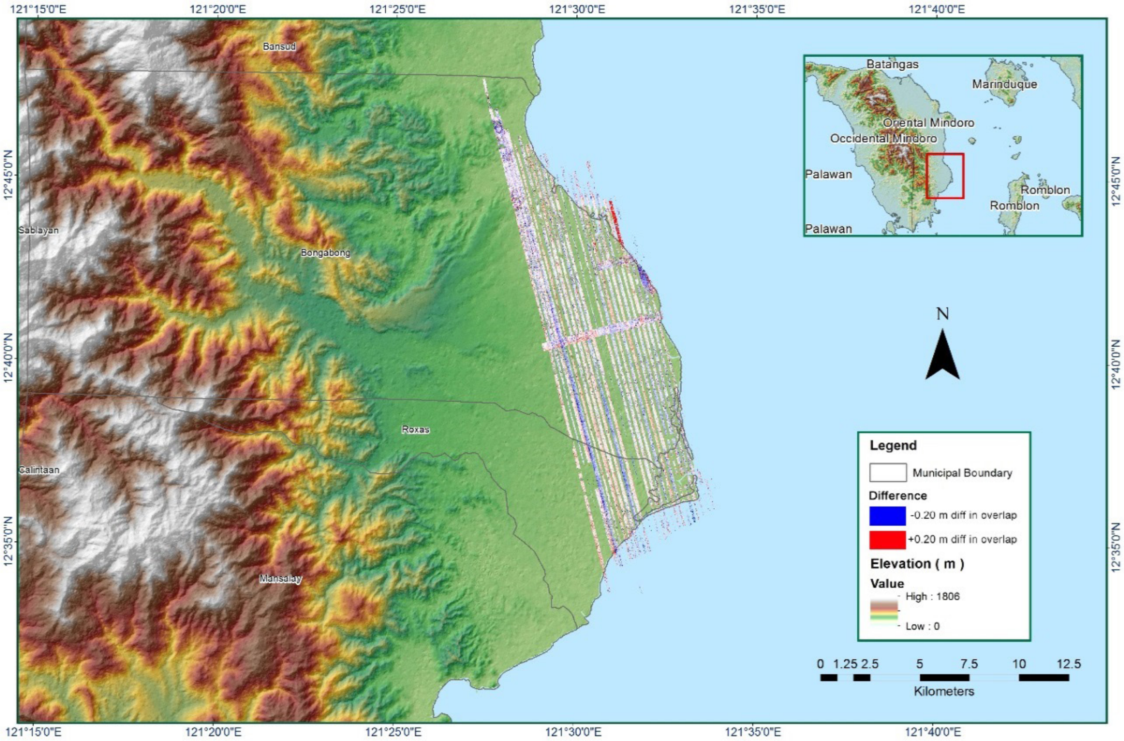



Figure A-8.14. Elevation difference between flight lines

Table A-8.3. Mission Summary Report for Mission Blk28G

| Flight Area | Oriental Mindoro |
|---|---|
| Mission Name | Blk28G |
| Inclusive Flights | 1076A |
| Range data size | 11.5 GB |
| Base data size | 14.3 MB |
| POS | 233 MB |
| Image | 76.8 GB |
| Transfer date | February 20, 2014 |
| | |
| Solution Status | |
| Number of Satellites (>6) | No |
| PDOP (<3) | No |
| Baseline Length (<30km) | Yes |
| Processing Mode (<=1) | No |
| | |
| Smoothed Performance Metrics (in cm) | |
| RMSE for North Position (<4.0 cm) | 4.8 |
| RMSE for East Position (<4.0 cm) | 3.5 |
| RMSE for Down Position (<8.0 cm) | 8.6 |
| | |
| Boresight correction stdev (<0.001deg) | 0.000407 |
| IMU attitude correction stdev (<0.001deg) | 0.001355 |
| GPS position stdev (<0.01m) | 0.0097 |
| | |
| Minimum % overlap (>25) | 33.27% |
| Ave point cloud density per sq.m. (>2.0) | 2.89 |
| Elevation difference between strips (<0.20 m) | Yes |
| | |
| Number of 1km x 1km blocks | 141 |
| Maximum Height | 216.76 m |
| Minimum Height | 35.08 m |
| | |
| Classification (# of points) | |
| Ground | 67,283,967 |
| Low vegetation | 77,300,272 |
| Medium vegetation | 51,202,535 |
| High vegetation | 45,765,772 |
| Building | 1,511,333 |
| | |
| Orthophoto | Yes |
| Processed by | Engr. Kenneth Solidum, Engr. Christy Lubiano, Engr. John Dill Macapagal |

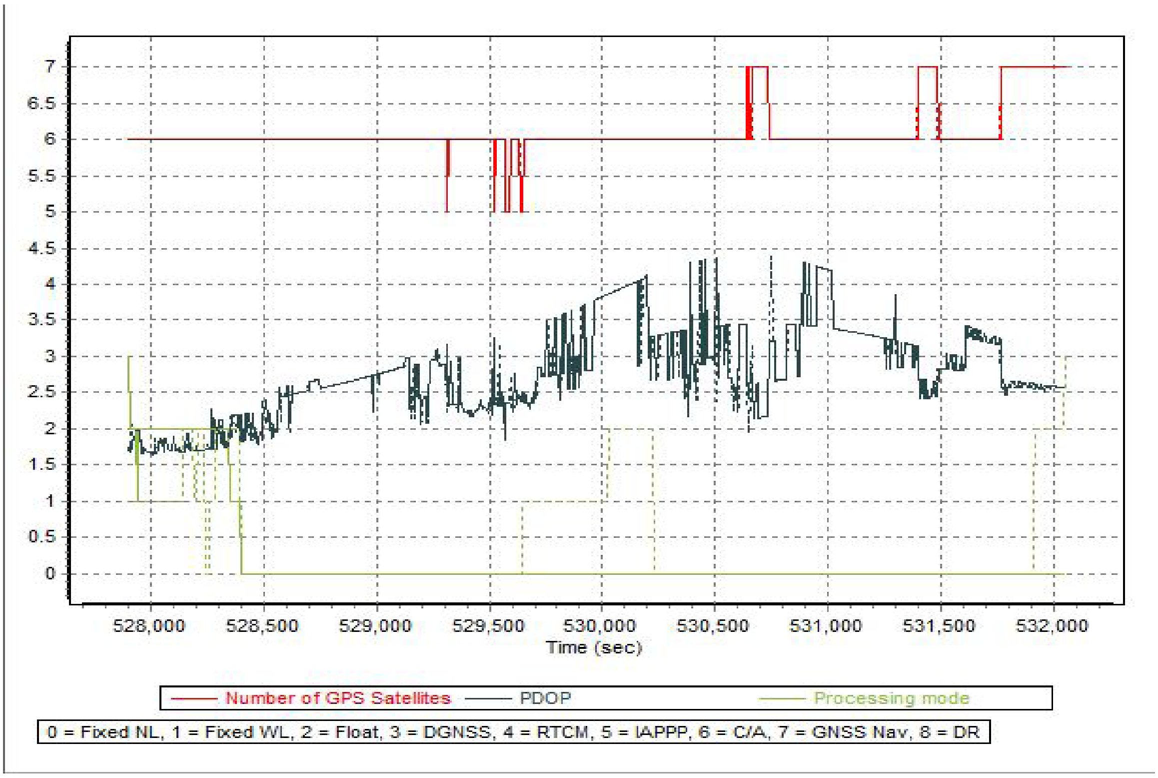



Figure A-8.15. Solution Status

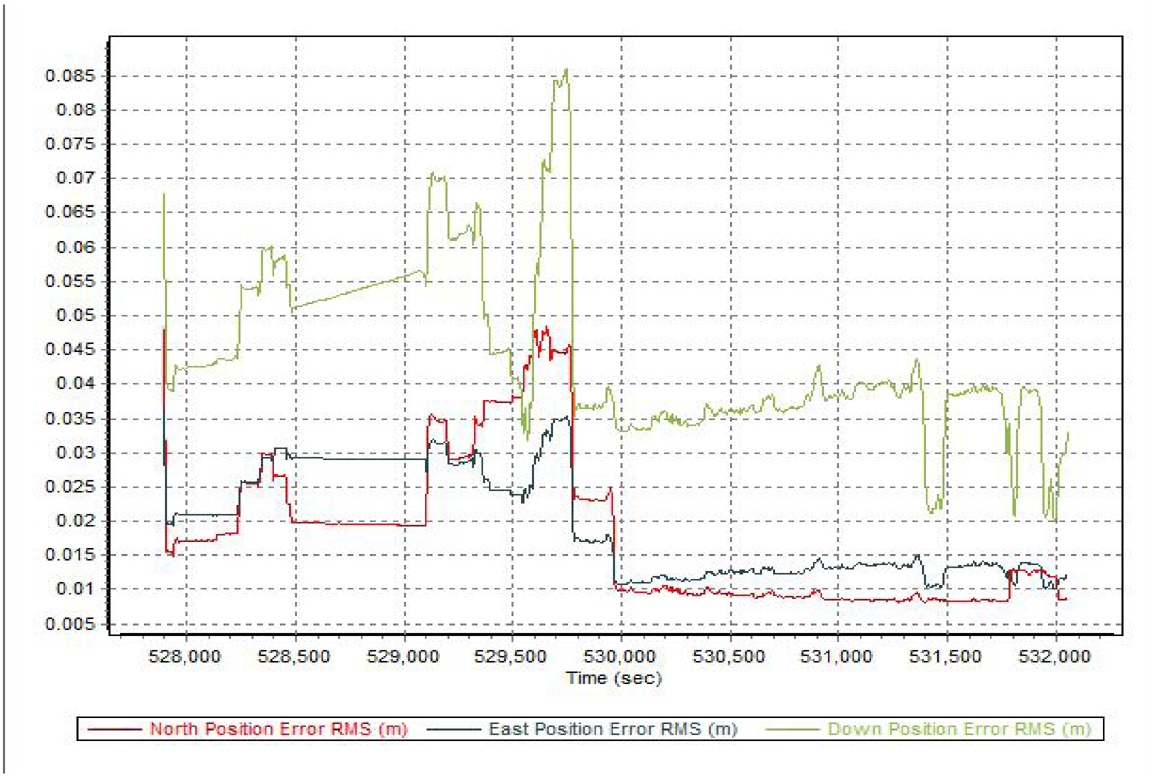



Figure A-8.16. Smoothed Performance Metrics Parameters

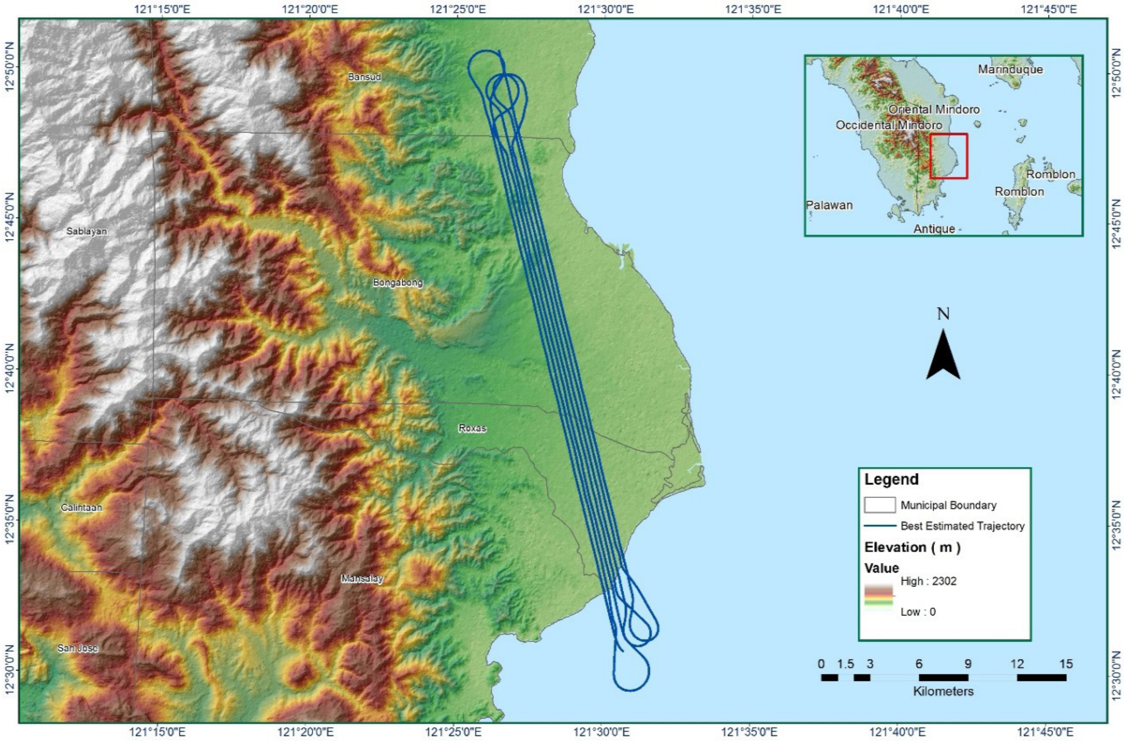



Figure A-8.17. Best Estimated Trajectory

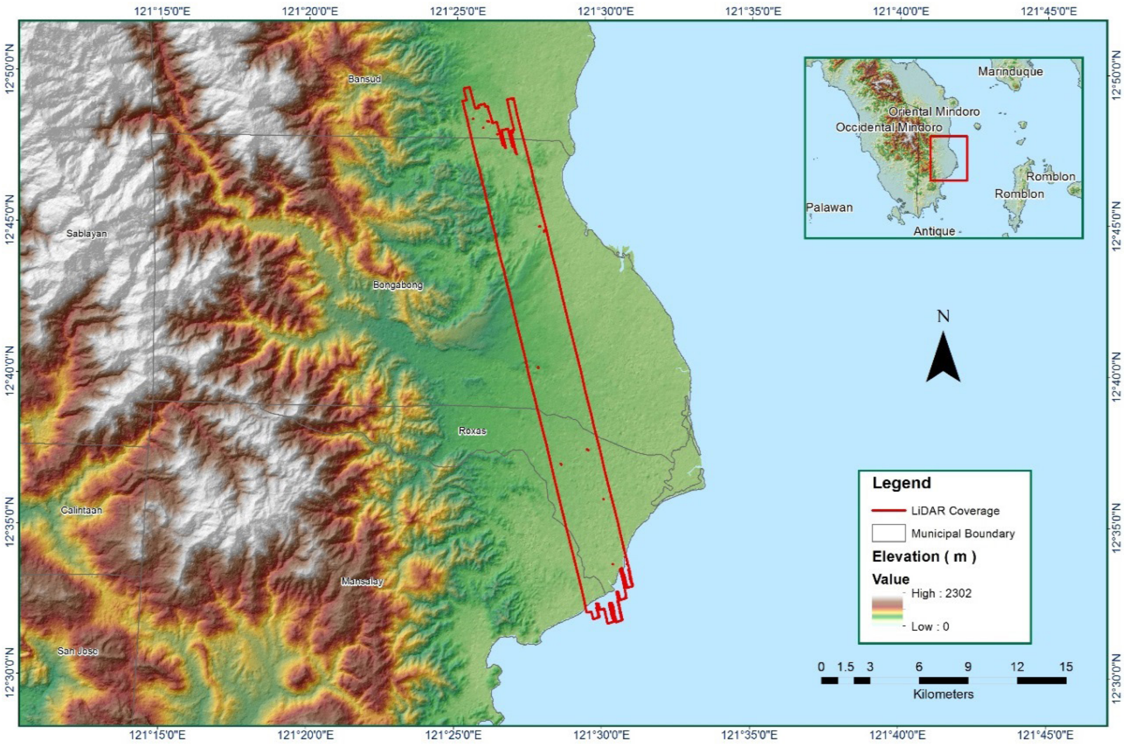



Figure A-8.18. Coverage of LiDAR data

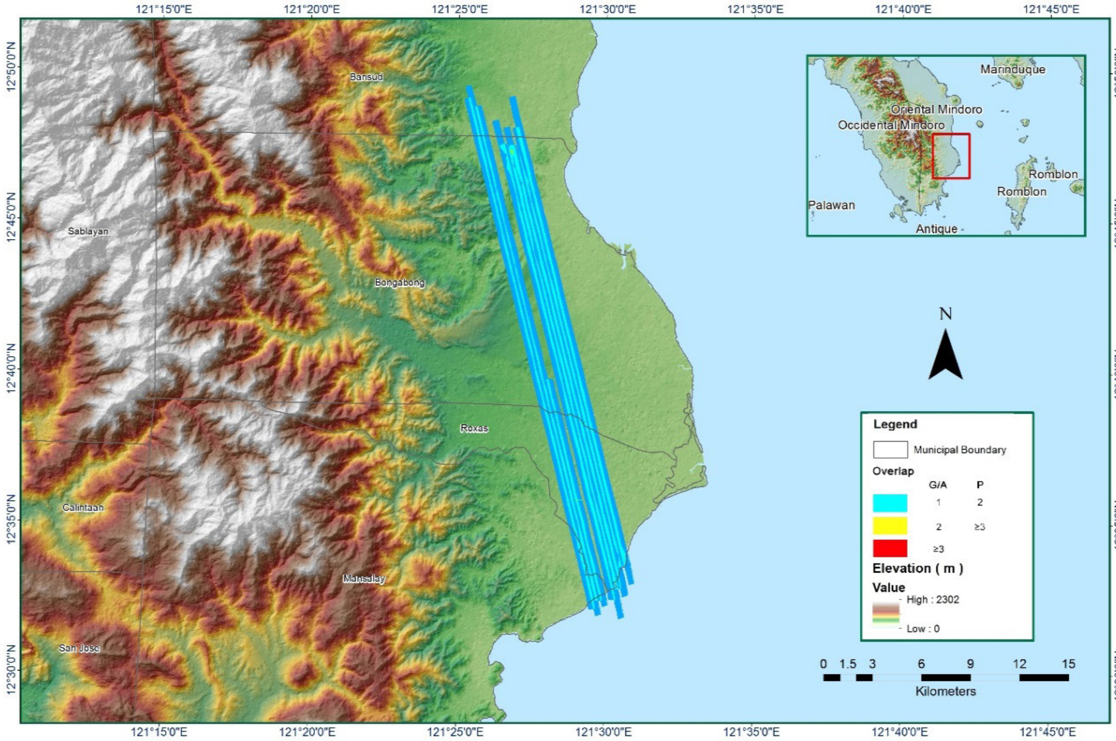



Figure A-8.19. Image of data overlap

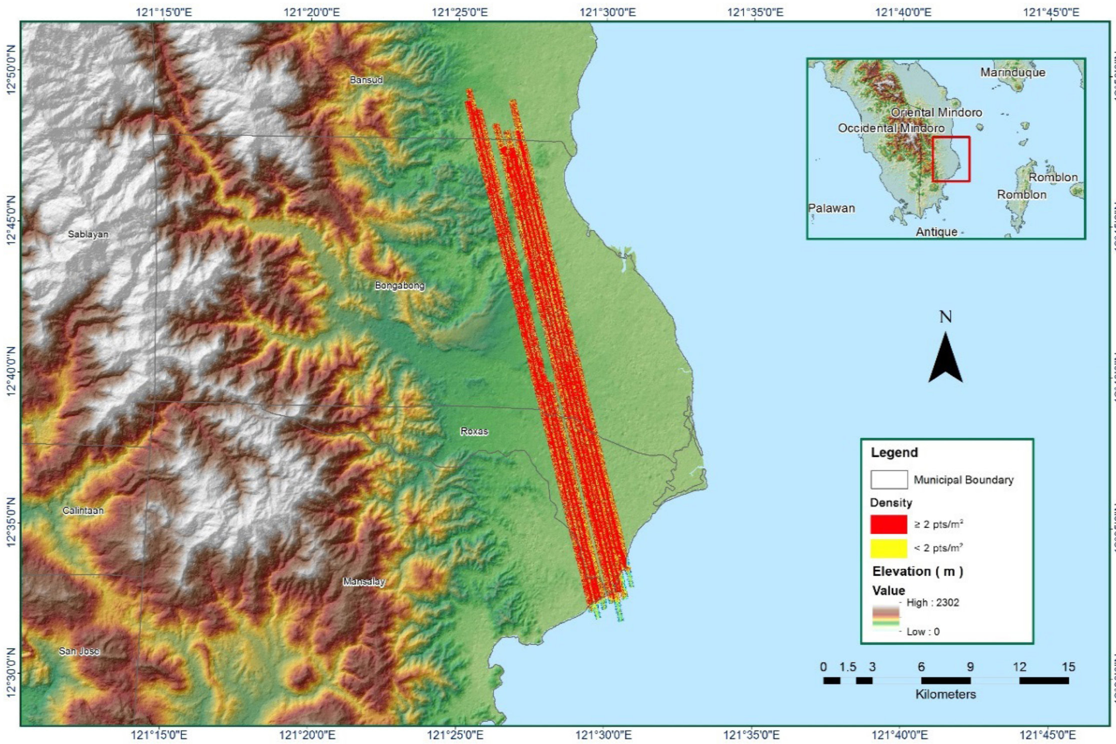



Figure A-8.20. Density of merged LiDAR data

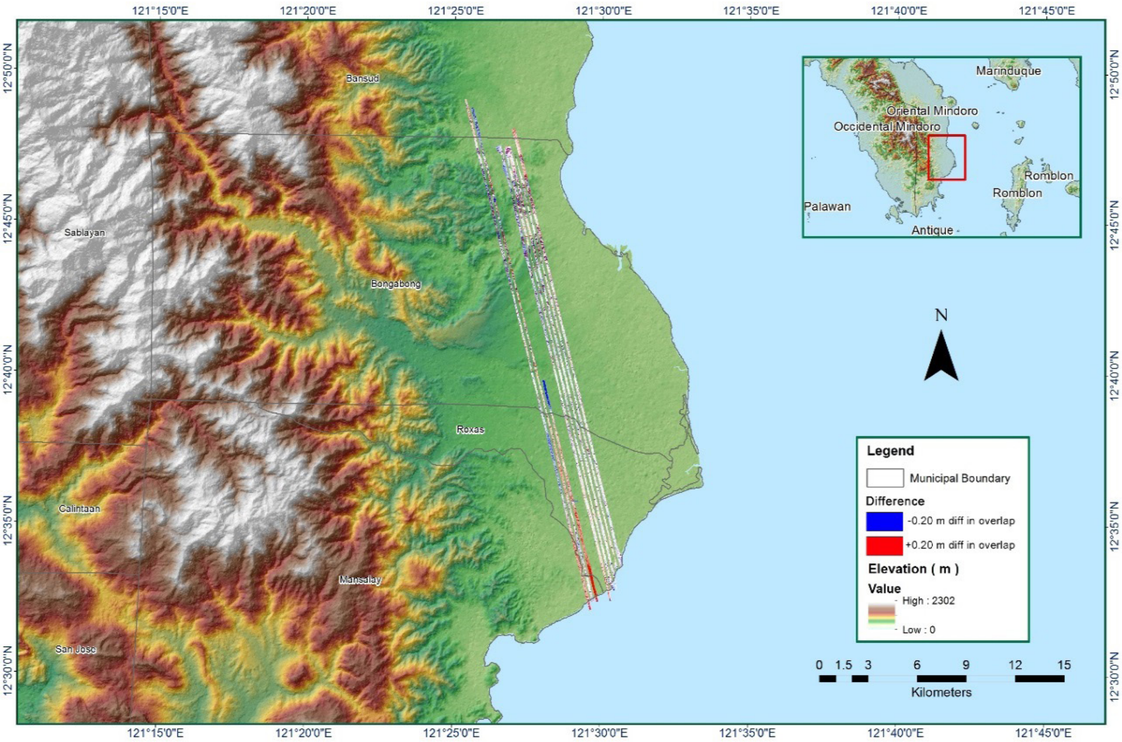



Figure A-8.21. Elevation difference between flight lines

Table A-8.4. Mission Summary Report for Mission Blk28f_Additional

| Flight Area | Oriental Mindoro |
|---|---|
| Mission Name | Blk28F_additional |
| Inclusive Flights | 1074A, 1072A |
| Range data size | 18.9 GB |
| Base data size | 28.2 MB |
| POS | 430 MB |
| Image | 115.1 GB |
| Transfer date | February 20,2014 |
| | |
| Solution Status | |
| Number of Satellites (>6) | Yes |
| PDOP (<3) | Yes |
| Baseline Length (<30km) | Yes |
| Processing Mode (<=1) | No |
| | |
| Smoothed Performance Metrics (in cm) | |
| RMSE for North Position (<4.0 cm) | 1.3 |
| RMSE for East Position (<4.0 cm) | 1.2 |
| RMSE for Down Position (<8.0 cm) | 6.5 |
| | |
| Boresight correction stdev (<0.001deg) | 0.000425 |
| IMU attitude correction stdev (<0.001deg) | 0.009525 |
| GPS position stdev (<0.01m) | 0.0111 |
| | |
| Minimum % overlap (>25) | 15.62% |
| Ave point cloud density per sq.m. (>2.0) | 2.28 |
| Elevation difference between strips (<0.20 m) | Yes |
| | |
| Number of 1km x 1km blocks | 41 |
| Maximum Height | 90.78 m |
| Minimum Height | 47.32 m |
| | |
| Classification (# of points) | |
| Ground | 7,224,934 |
| Low vegetation | 8,421,215 |
| Medium vegetation | 4,311,749 |
| High vegetation | 3,208,204 |
| Building | 105,376 |
| | |
| Orthophoto | No |
| Processed by | Engr. Carlyn Ann Ibanez, Engr. Edgardo Gubatanga Jr., Engr. Gladys Mae Apat |

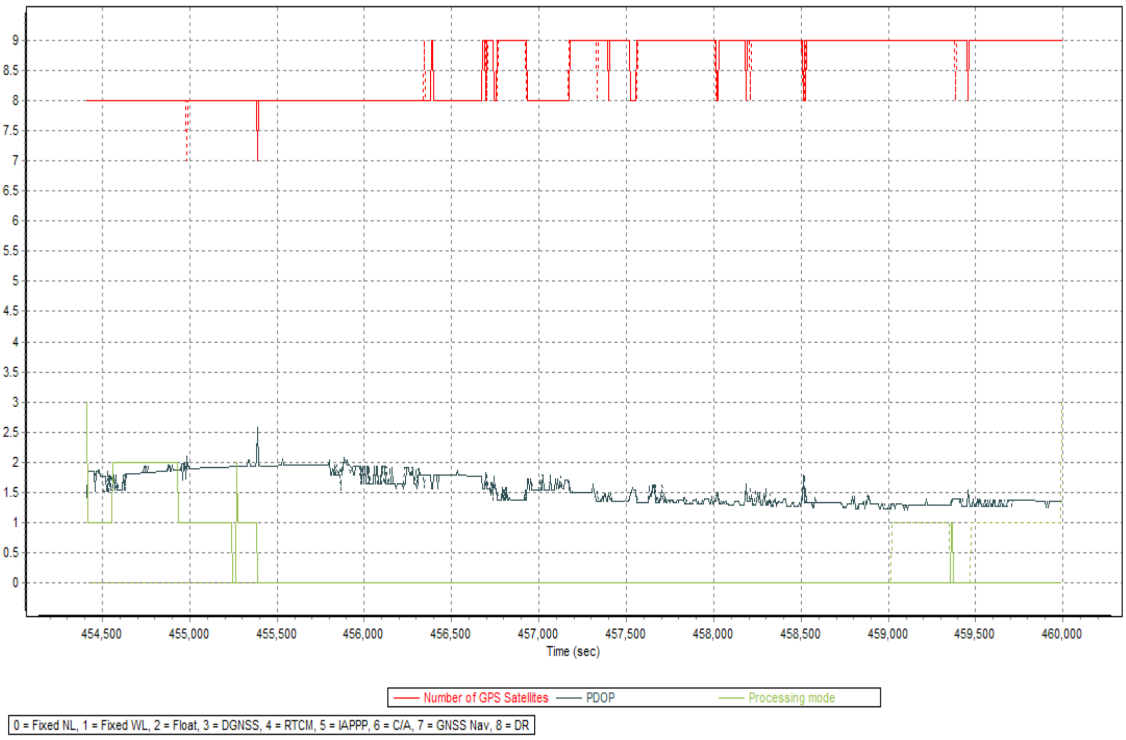



*Figure A-8.22. Solution Status*

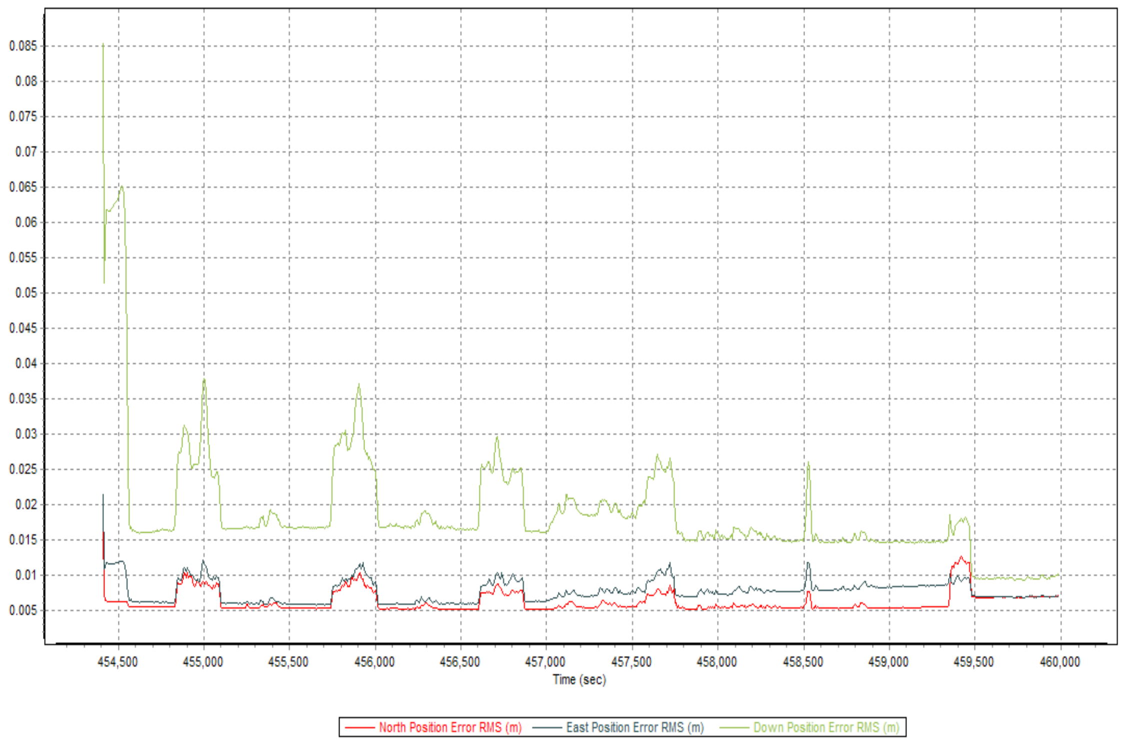



Figure A-8.23. Smoothed Performance Metric Parameters

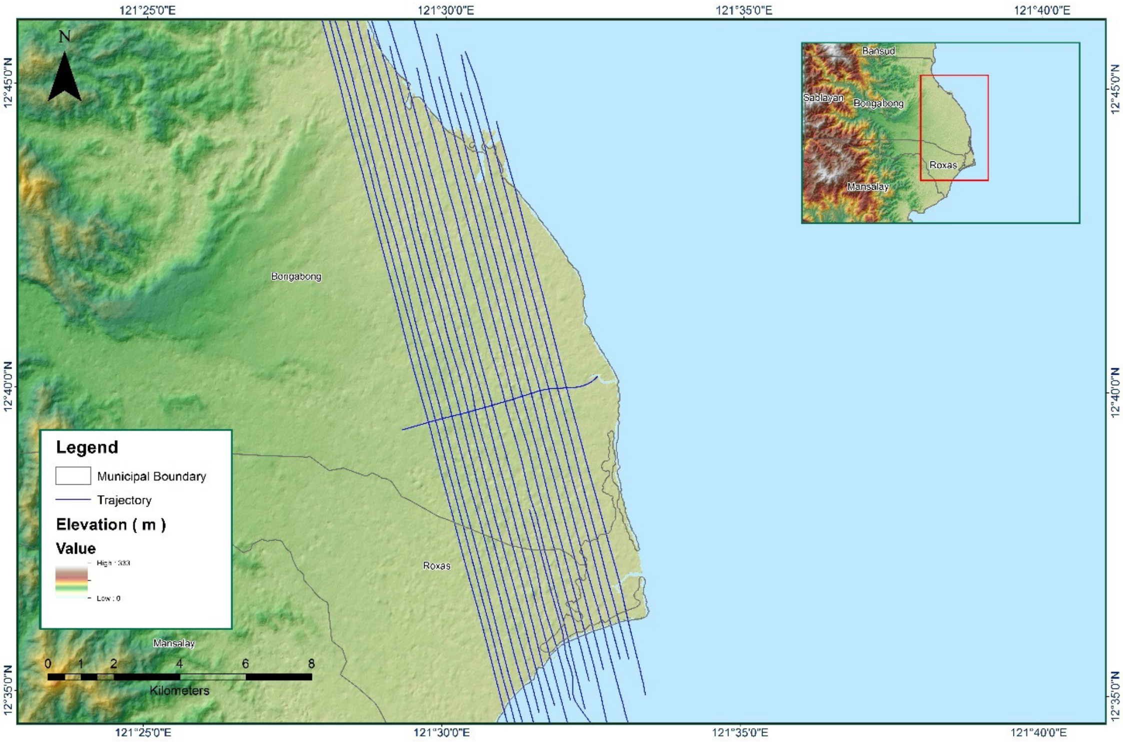



*Figure A-8.24.* Best Estimated Trajectory

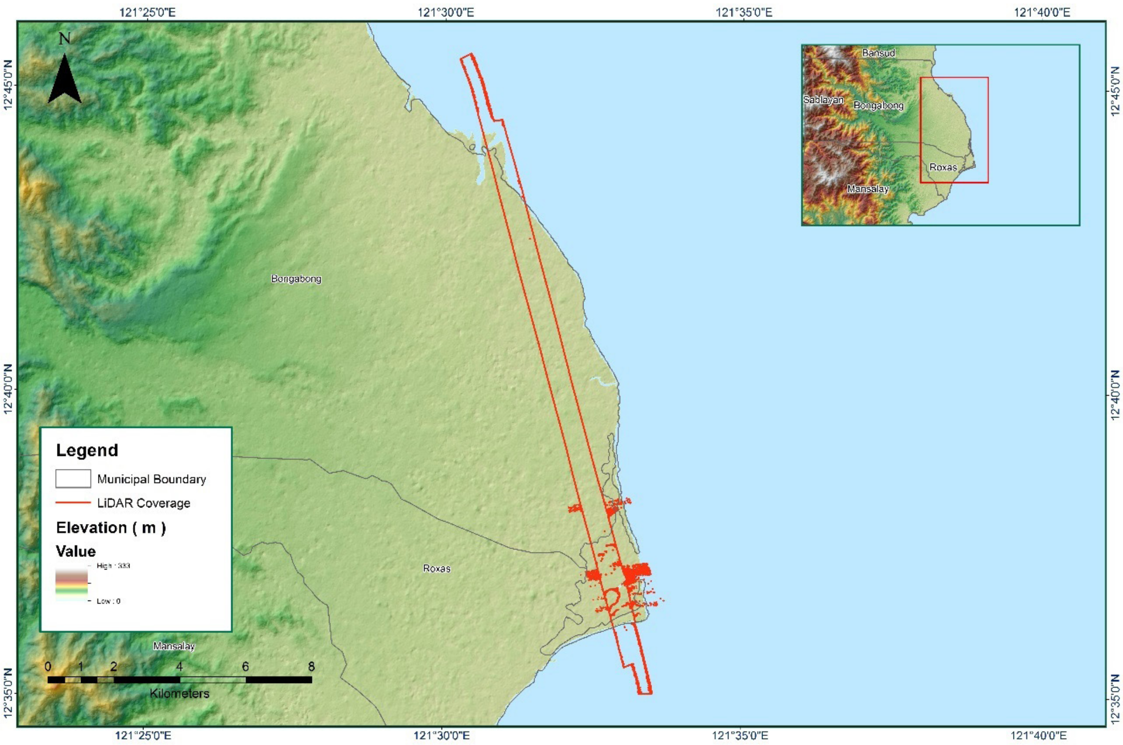



*Figure A-8.25.* ***Coverage of LiDAR data***

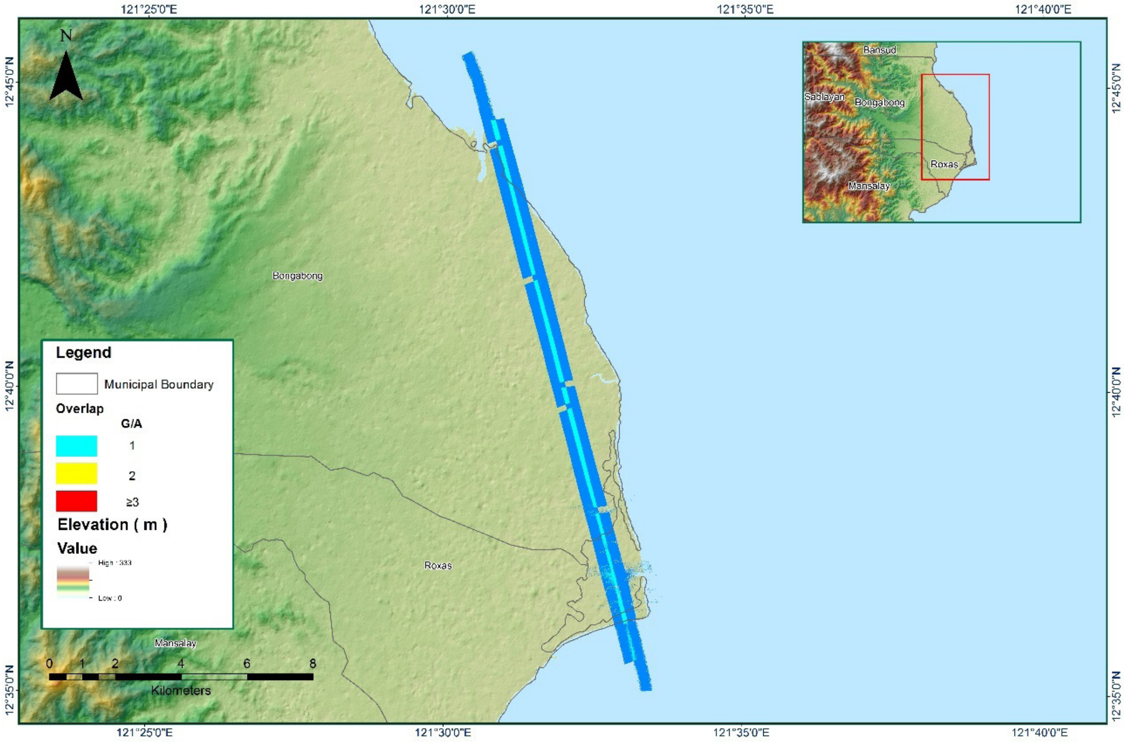



*Figure A-8.26.* ***Image of data overlap***

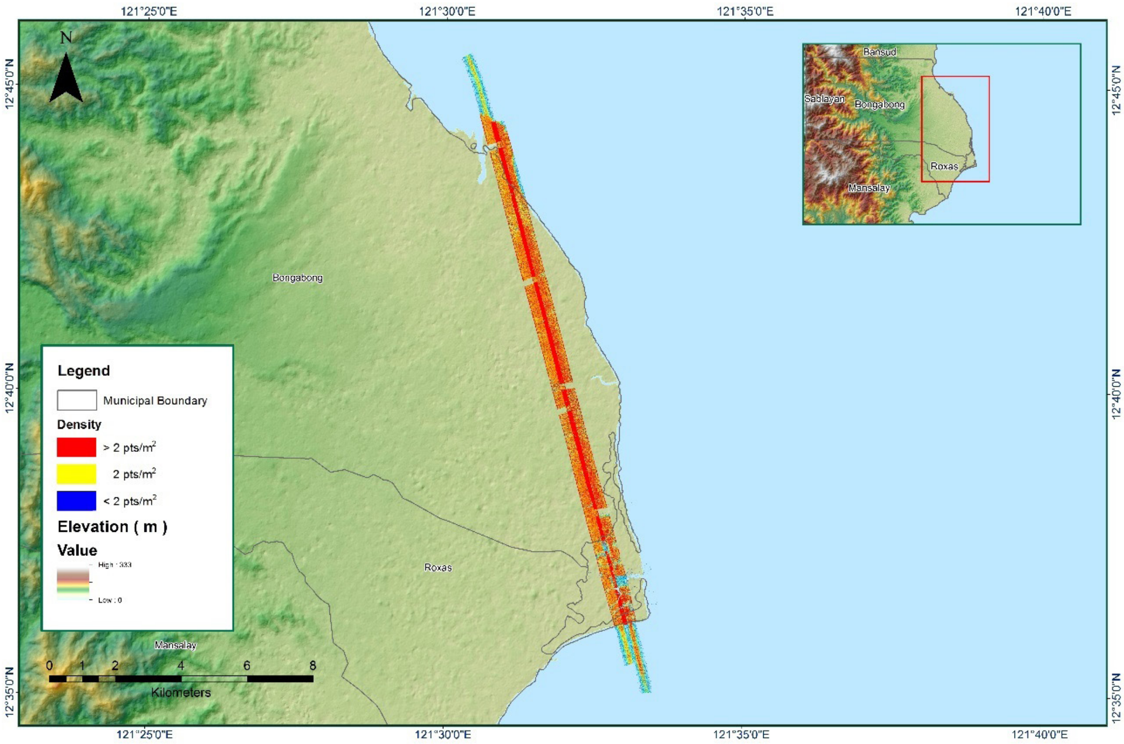



*Figure A-8.27.* ***Density Map of merged LiDAR data***

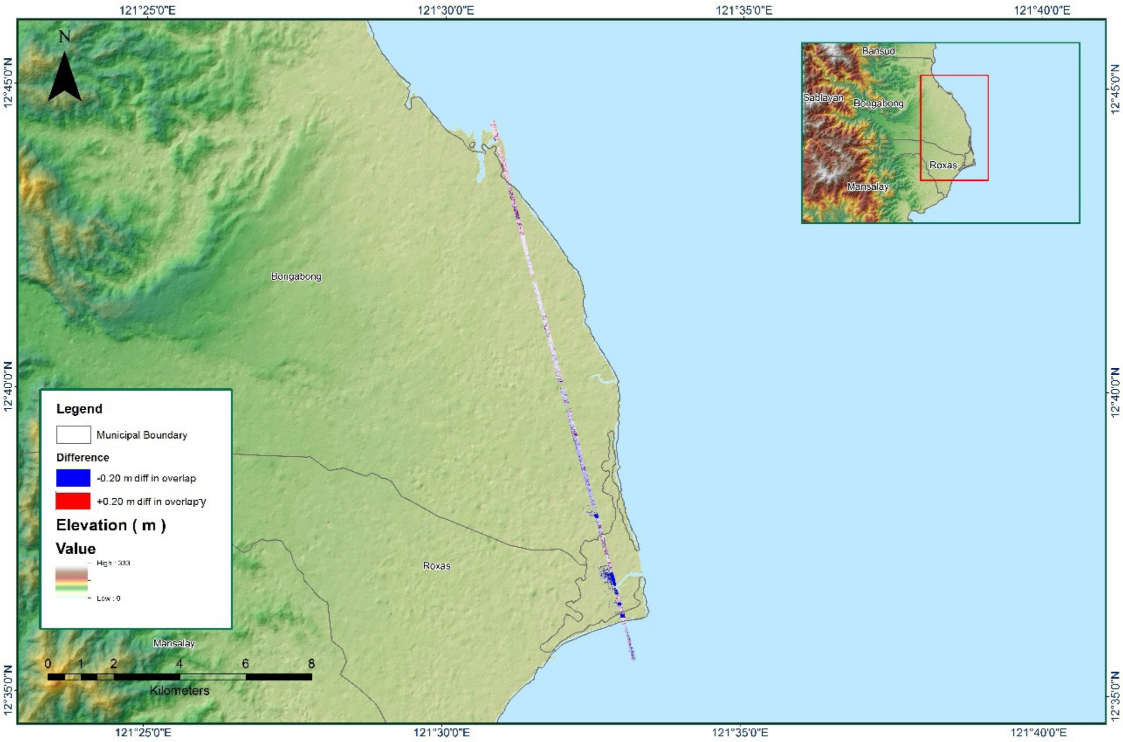



*Figure A-8.28.* ***Elevation Difference Between flight lines***

Table A-8.5. Mission Summary Report for Mission Blk28GsH

| Flight Area | Oriental Mindoro |
|---|---|
| Mission Name | Blk28GsH |
| Inclusive Flights | 1078A |
| Range data size | 9.71 GB |
| Base data size | 14.3 MB |
| POS | 197 MB |
| Image | 56.8 GB |
| Transfer date | February 20, 2014 |
| | |
| Solution Status | |
| Number of Satellites (>6) | No |
| PDOP (<3) | Yes |
| Baseline Length (<30km) | Yes |
| Processing Mode (<=1) | Yes |
| | |
| Smoothed Performance Metrics (in cm) | |
| RMSE for North Position (<4.0 cm) | 1.6 |
| RMSE for East Position (<4.0 cm) | 1.2 |
| RMSE for Down Position (<8.0 cm) | 6.0 |
| | |
| Boresight correction stdev (<0.001deg) | 0.000552 |
| IMU attitude correction stdev (<0.001deg) | 0.004258 |
| GPS position stdev (<0.01m) | 0.0143 |
| | |
| Minimum % overlap (>25) | 58.5% |
| Ave point cloud density per sq.m. (>2.0) | 4.00 |
| Elevation difference between strips (<0.20 m) | Yes |
| | |
| Number of 1km x 1km blocks | 107 |
| Maximum Height | 288.11 m |
| Minimum Height | 48.43 m |
| | |
| Classification (# of points) | |
| Ground | 46,444,727 |
| Low vegetation | 58,505,631 |
| Medium vegetation | 50,918,523 |
| High vegetation | 49,004,112 |
| Building | 1,332,080 |
| Orthophoto | Yes |
| Processed by | Engr. Jennifer Saguran, Celina Rosete, Engr. Elainne Lopez |

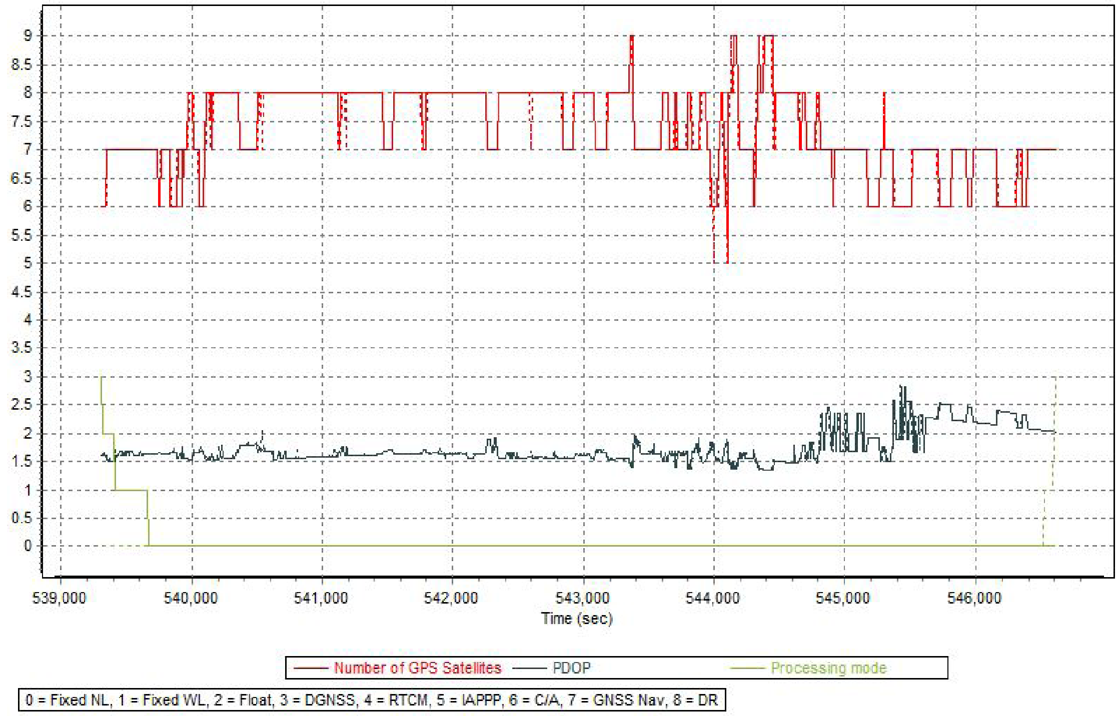



*Figure A-8.29.* Solution Status

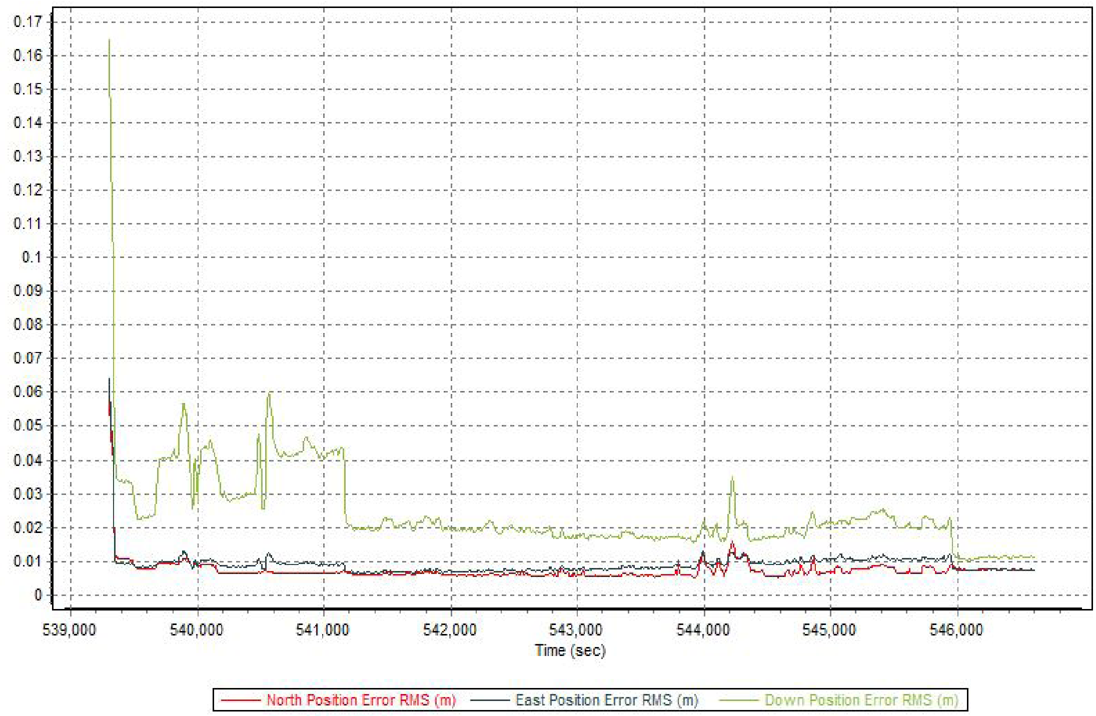



*Figure A-8.30.* Smoothed Performance Metrics Parameters

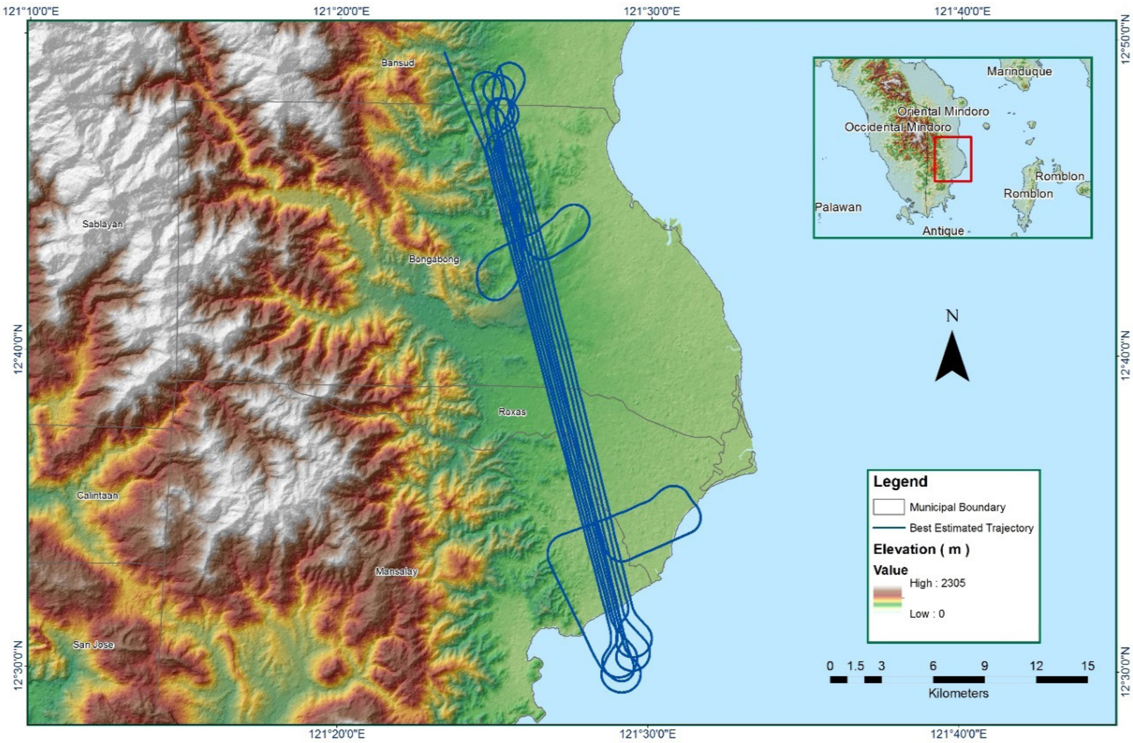



*Figure A-8.31.* Best Estimated Trajectory

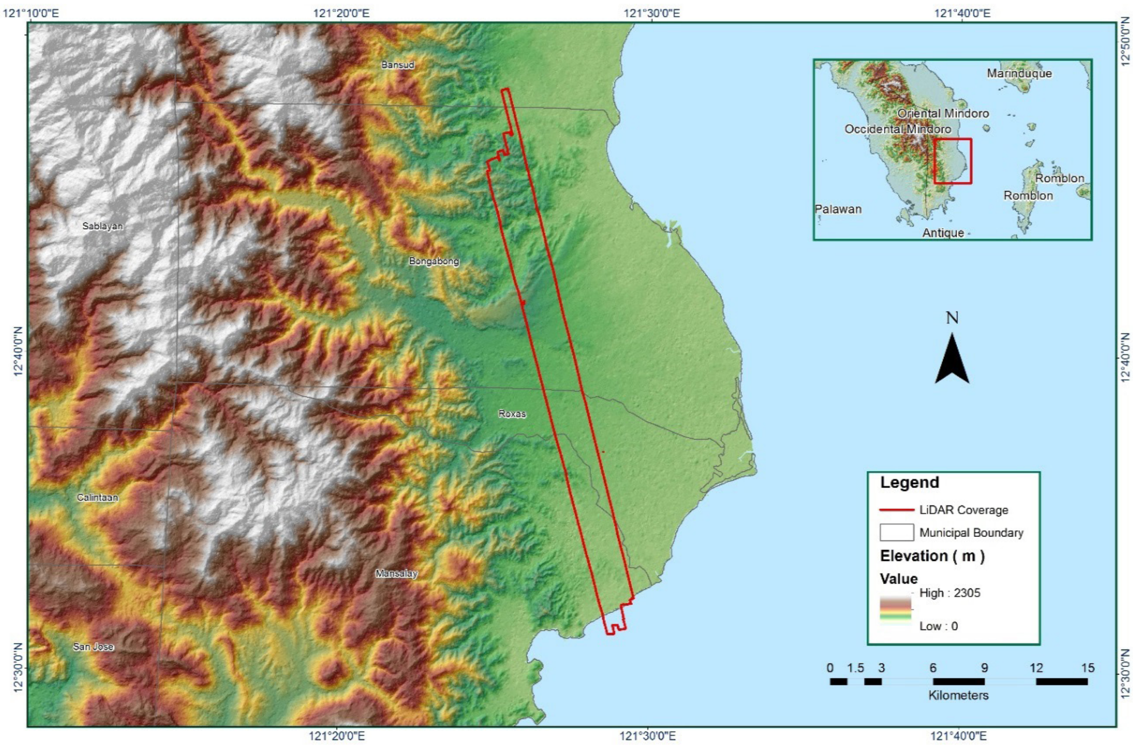



*Figure A-8.32.* Coverage of LiDAR data

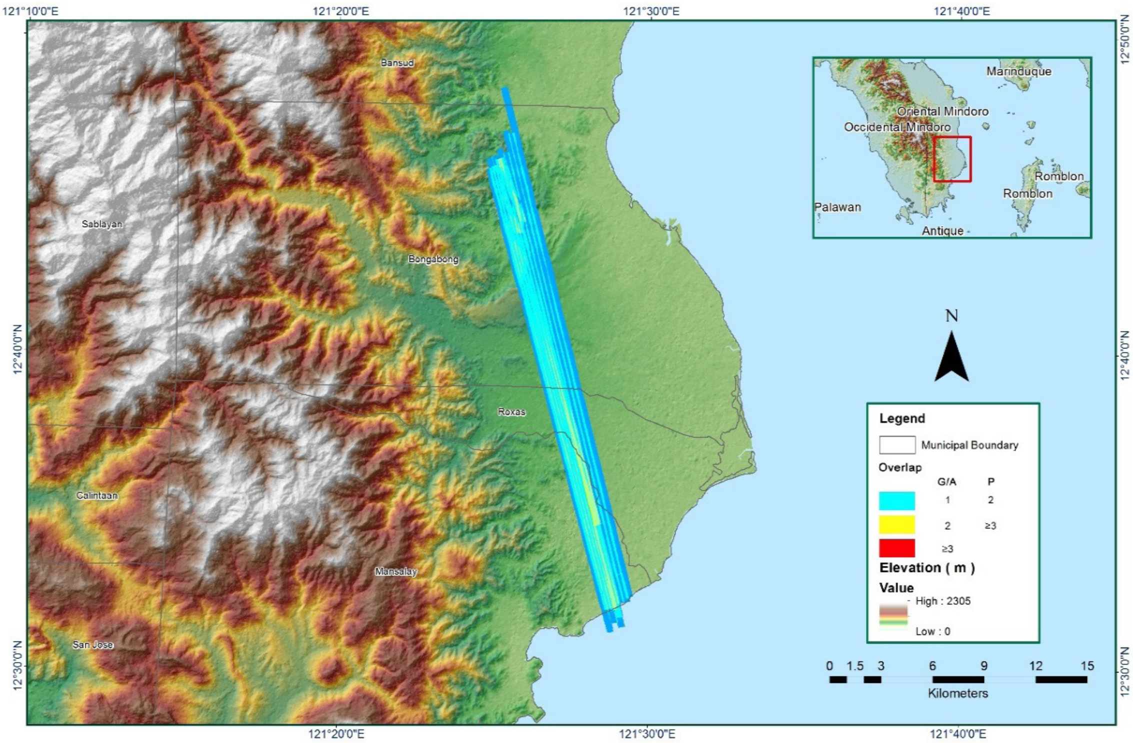



*Figure A-8.33.* Image of data overlap

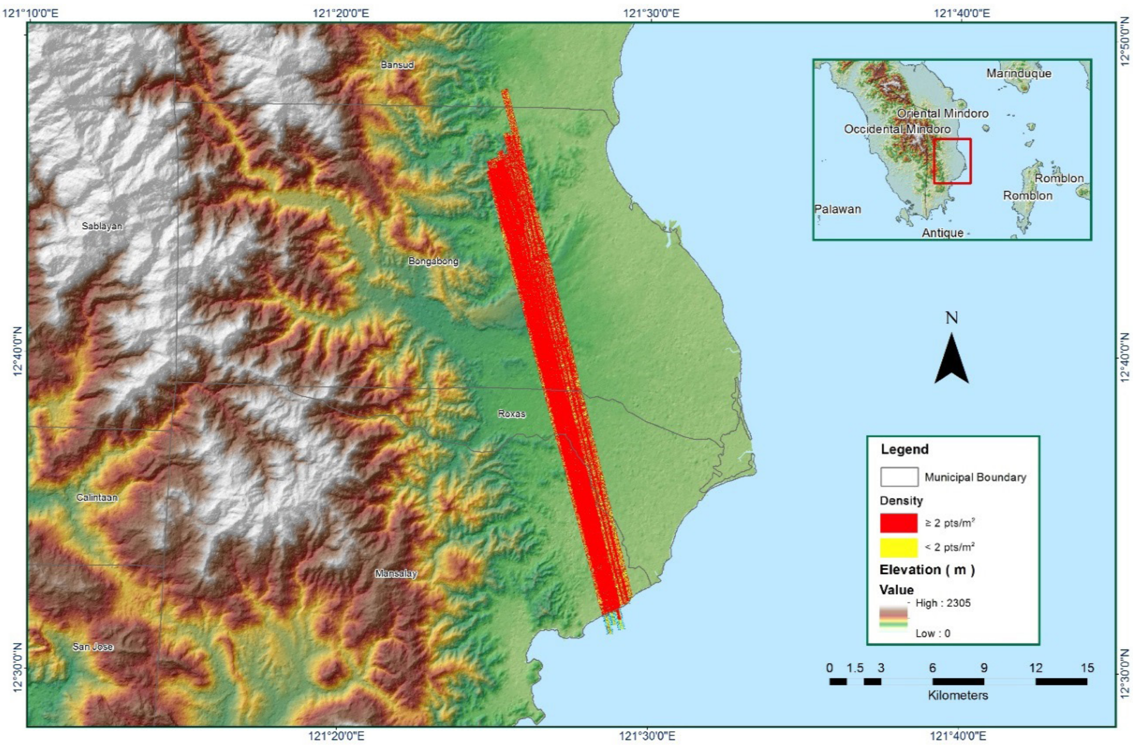



*Figure A-8.34.* Density of merged LiDAR data

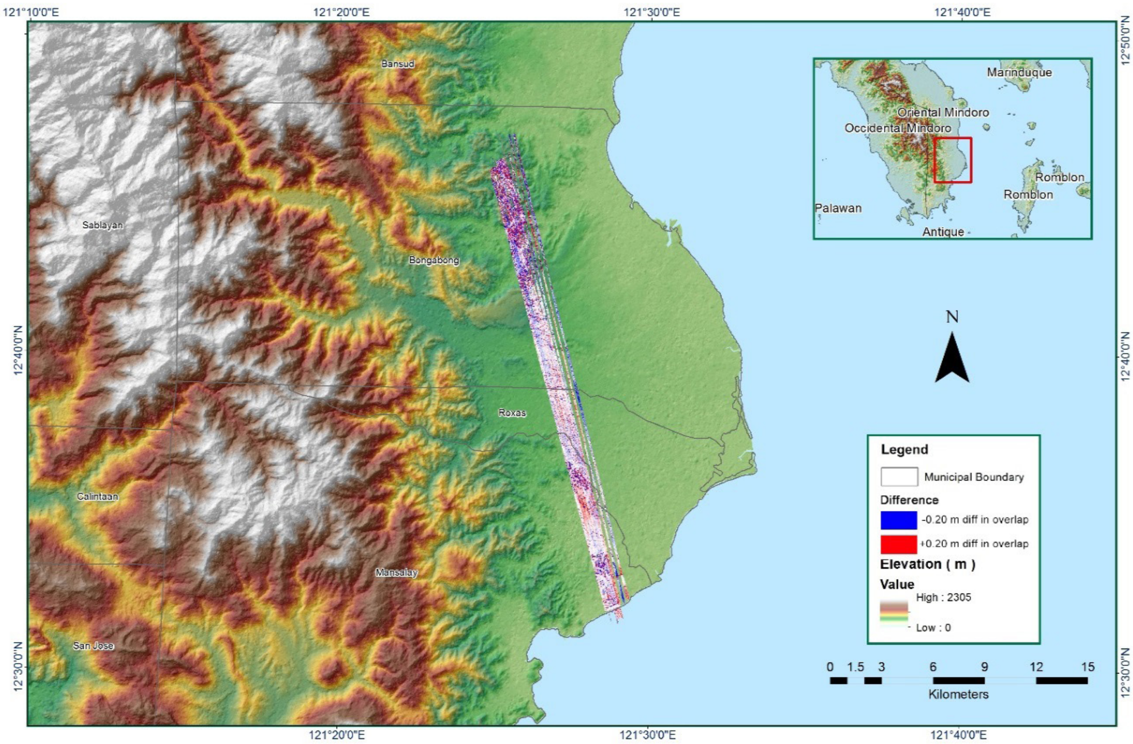



*Figure A-8.35.* Elevation difference between flight lines

Table A-8.6.Mission Summary Report for Mission Blk28Hs

| Flight Area | Oriental Mindoro |
|---|---|
| Mission Name | Blk28Hs |
| Inclusive Flights | 1088A |
| Range data size | 14 GB |
| Base data size | 14.7 MB |
| POS | 269 MB |
| Image | 80.7 GB |
| Transfer date | February 21, 2014 |
| | |
| Solution Status | |
| Number of Satellites (>6) | Yes |
| PDOP (<3) | Yes |
| Baseline Length (<30km) | Yes |
| Processing Mode (<=1) | No |
| | |
| Smoothed Performance Metrics (in cm) | |
| RMSE for North Position (<4.0 cm) | 1.6 |
| RMSE for East Position (<4.0 cm) | 1.8 |
| RMSE for Down Position (<8.0 cm) | 5.3 |
| | |
| Boresight correction stdev (<0.001deg) | 0.000304 |
| IMU attitude correction stdev (<0.001deg) | 0.000768 |
| GPS position stdev (<0.01m) | 0.0088 |
| | |
| Minimum % overlap (>25) | 66.45% |
| Ave point cloud density per sq.m. (>2.0) | 4.35 |
| Elevation difference between strips (<0.20 m) | Yes |
| | |
| Number of 1km x 1km blocks | 128 |
| Maximum Height | 418.58 m |
| Minimum Height | 42.03 m |
| | |
| Classification (# of points) | |
| Ground | 67,410,264 |
| Low vegetation | 78,245,475 |
| Medium vegetation | 73,011,298 |
| High vegetation | 74,100,895 |
| Building | 2,106,955 |
| | |
| Orthophoto | Yes |
| Processed by | Engr. Jennifer Saguran, Eleyn Pama, Marie Joyce Ilagan |

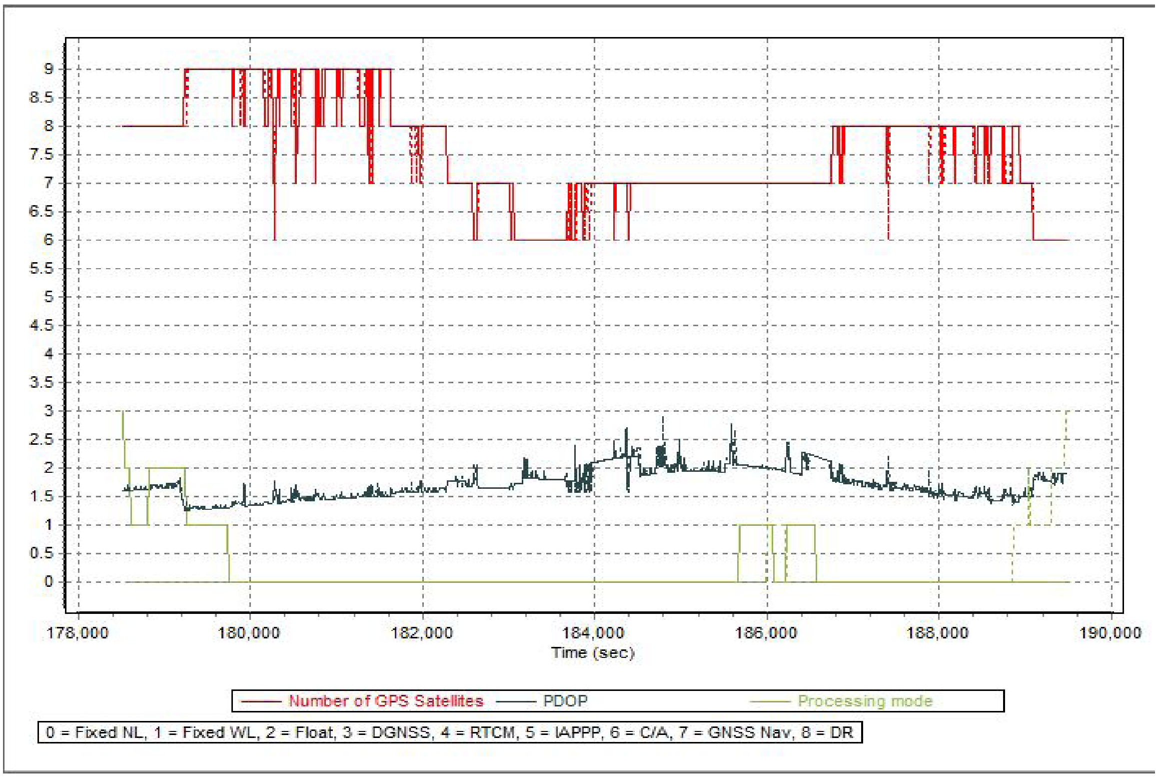



*Figure A-8.36.* Solution Status

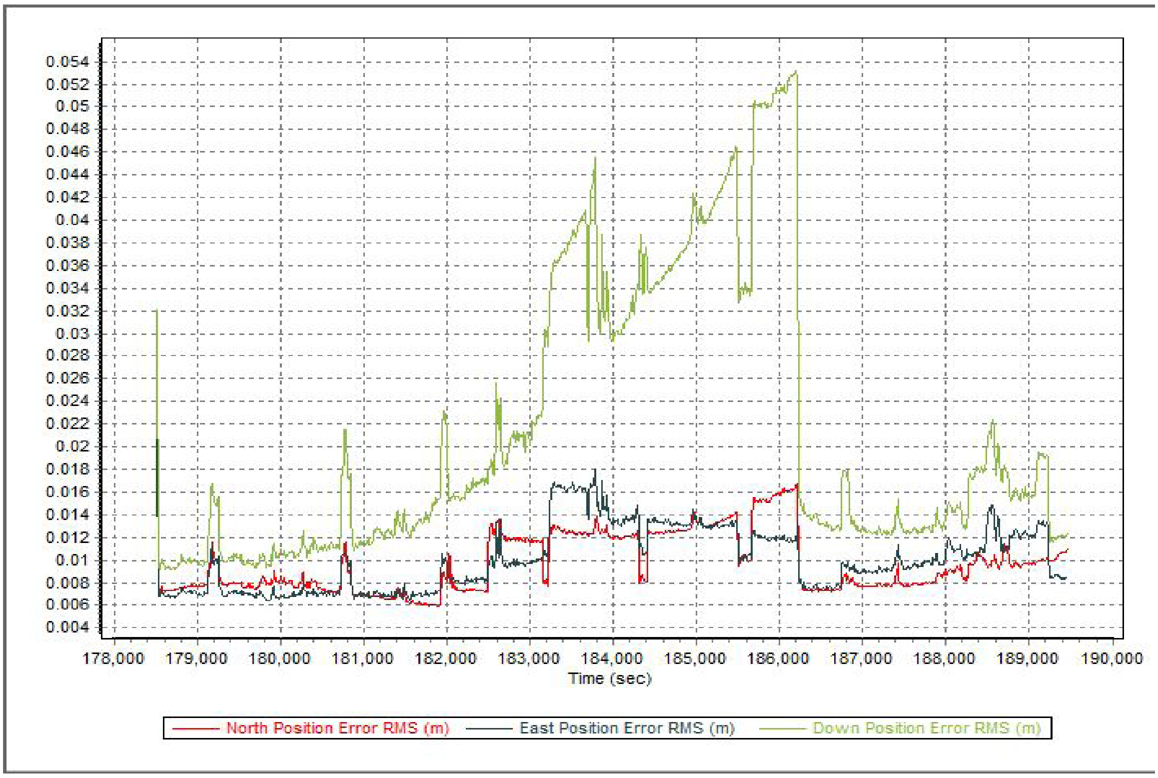



*Figure A-8.37.* Smoothed Performance Metrics Parameters

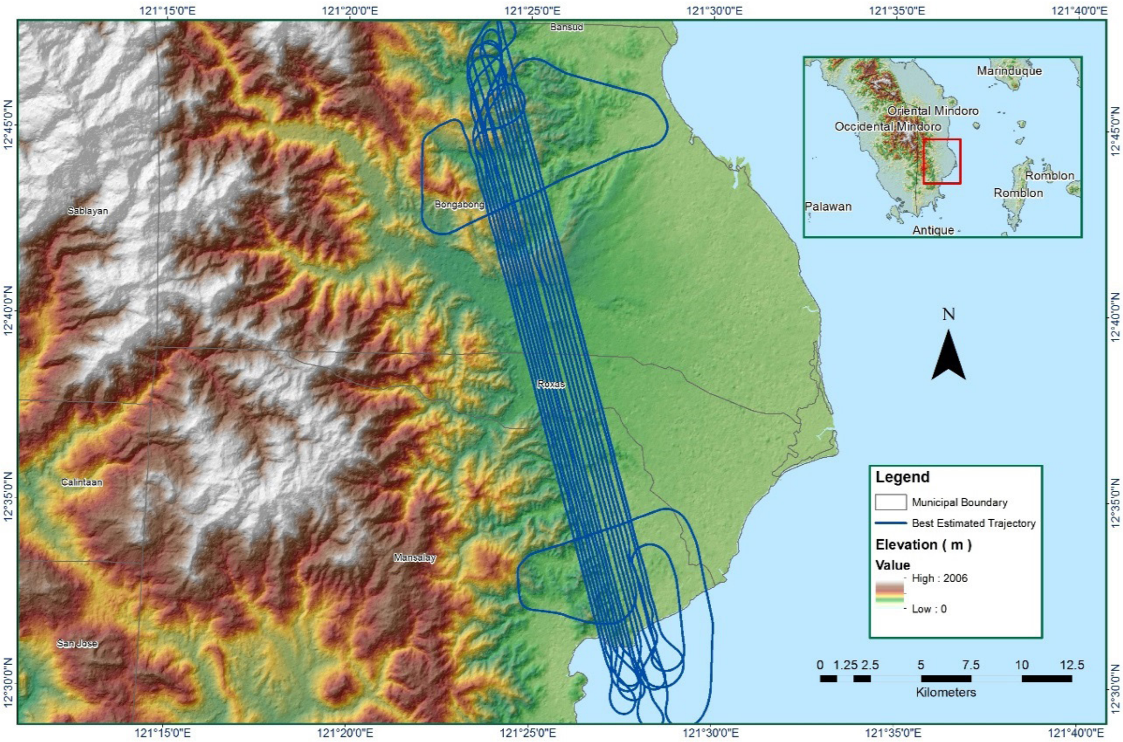



*Figure A-8.38.* Best Estimated Trajectory

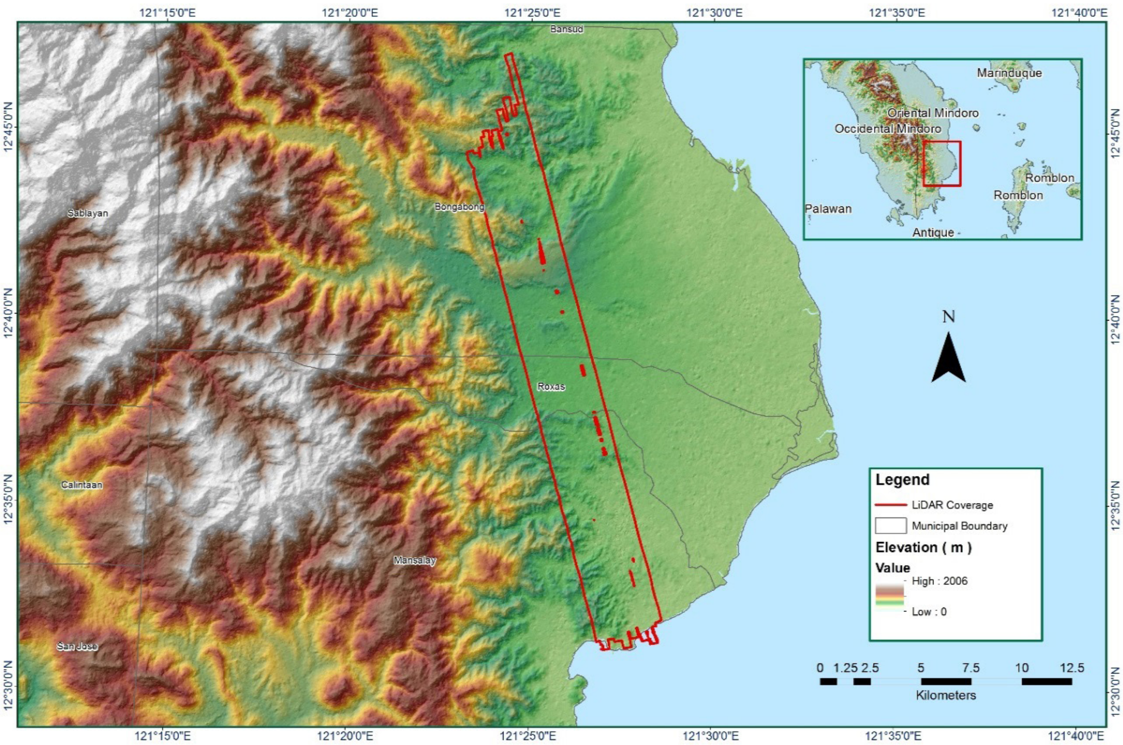



*Figure A-8.39.* Coverage of LiDAR data

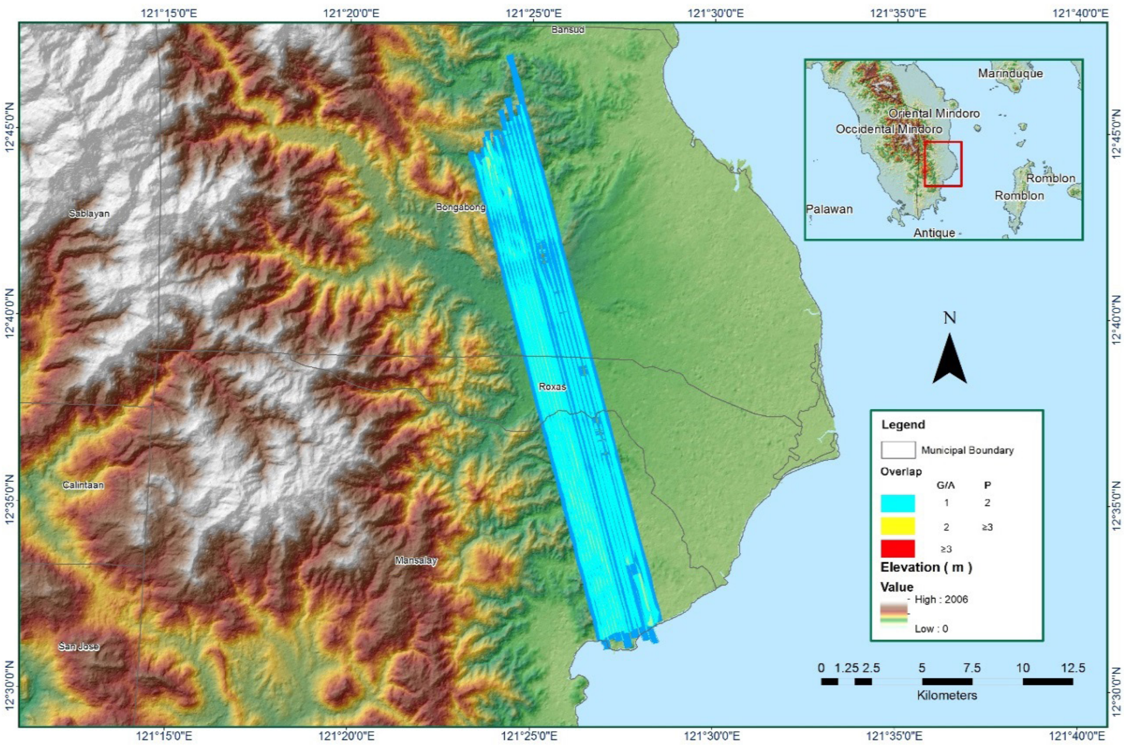



*Figure A-8.40.* Image of data overlap

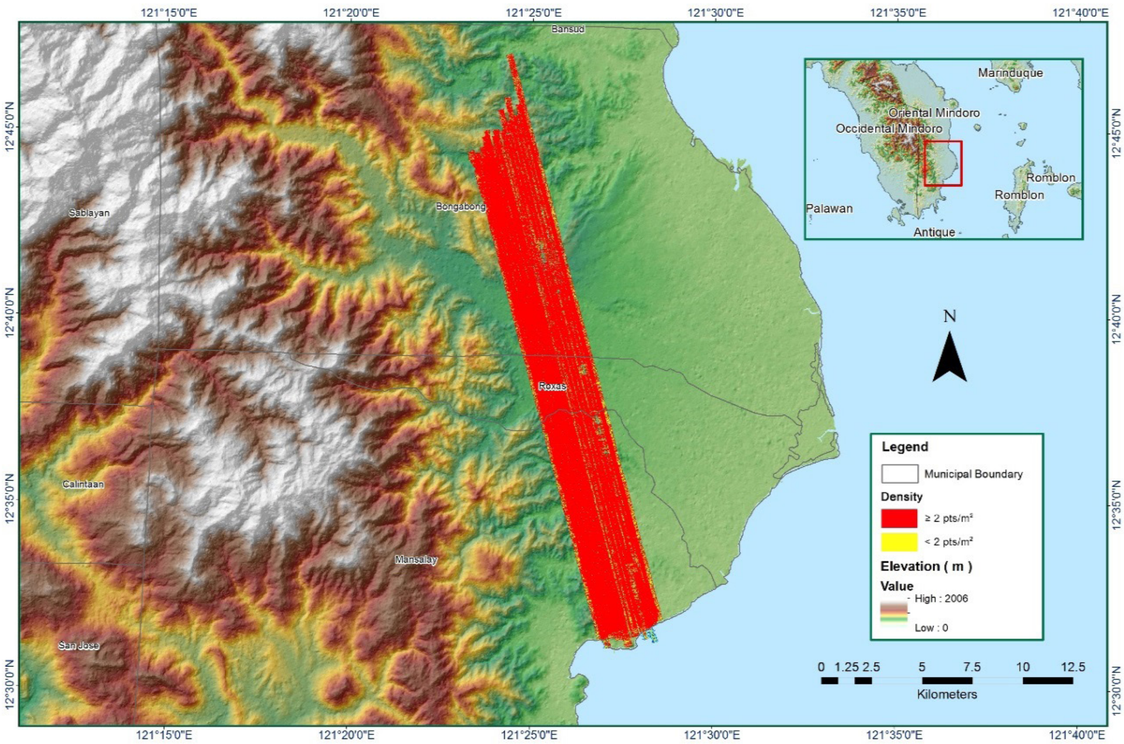



*Figure A-8.41.* Density of merged LiDAR data

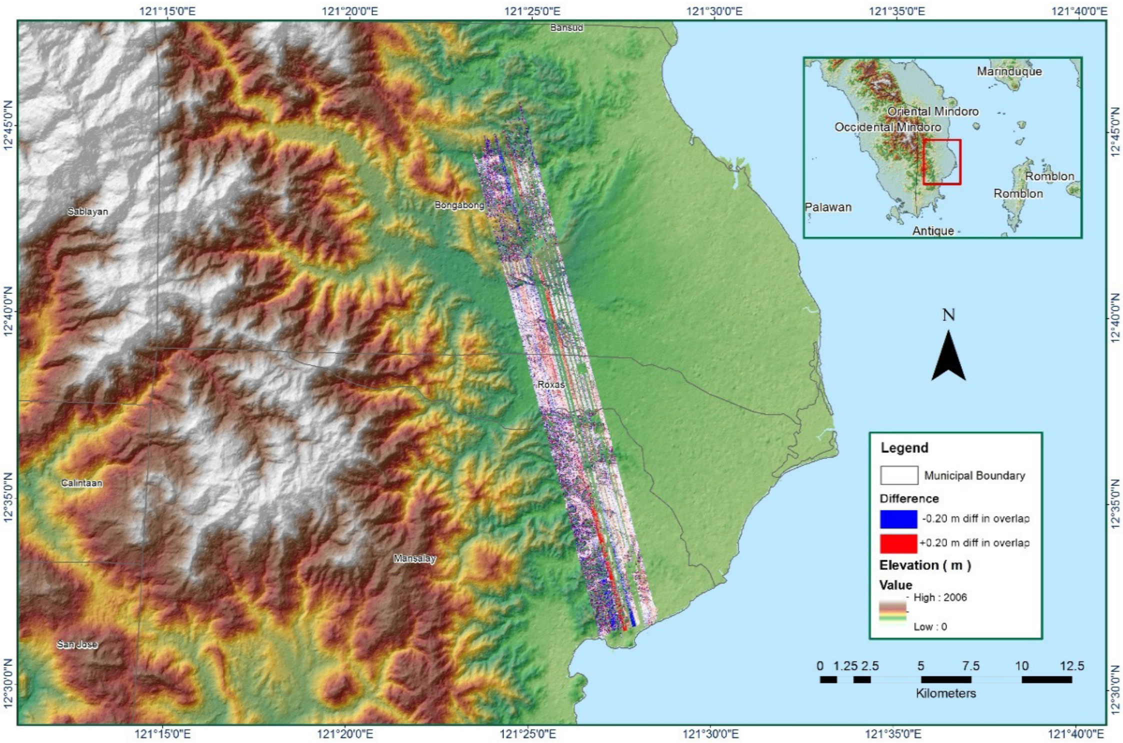



*Figure A-8.42.* Elevation difference between flight lines

Table A-8.7. Mission Summary Report for Mission Blk28IJ

| Flight Area | Oriental Mindoro |
|---|---|
| Mission Name | Blk28IJ |
| Inclusive Flights | 1104A |
| Range data size | 10.3 GB |
| Base data size | 9.85 MB |
| POS | 276 MB |
| Image | 56.2 GB |
| Transfer date | February 21, 2014 |
| | |
| Solution Status | |
| Number of Satellites (>6) | No |
| PDOP (<3) | No |
| Baseline Length (<30km) | No |
| Processing Mode (<=1) | No |
| | |
| Smoothed Performance Metrics (in cm) | |
| RMSE for North Position (<4.0 cm) | 3.4 |
| RMSE for East Position (<4.0 cm) | 3.9 |
| RMSE for Down Position (<8.0 cm) | 1.1 |
| | |
| Boresight correction stdev (<0.001deg) | 0.000220 |
| IMU attitude correction stdev (<0.001deg) | 0.001457 |
| GPS position stdev (<0.01m) | 0.0037 |
| | |
| Minimum % overlap (>25) | 47.15% |
| Ave point cloud density per sq.m. (>2.0) | 3.29 |
| Elevation difference between strips (<0.20 m) | Yes |
| | |
| Number of 1km x 1km blocks | 254 |
| Maximum Height | 570.88 m |
| Minimum Height | 37.28 m |
| | |
| Classification (# of points) | |
| Ground | 110,601,059 |
| Low vegetation | 99,664,631 |
| Medium vegetation | 142,219,461 |
| High vegetation | 131,163,224 |
| Building | 4,203,923 |
| | |
| Orthophoto | Yes |
| Processed by | Engr. Angelo Carlo Bongat, Engr. Christy Lubiano, Engr. Elaine Lopez |

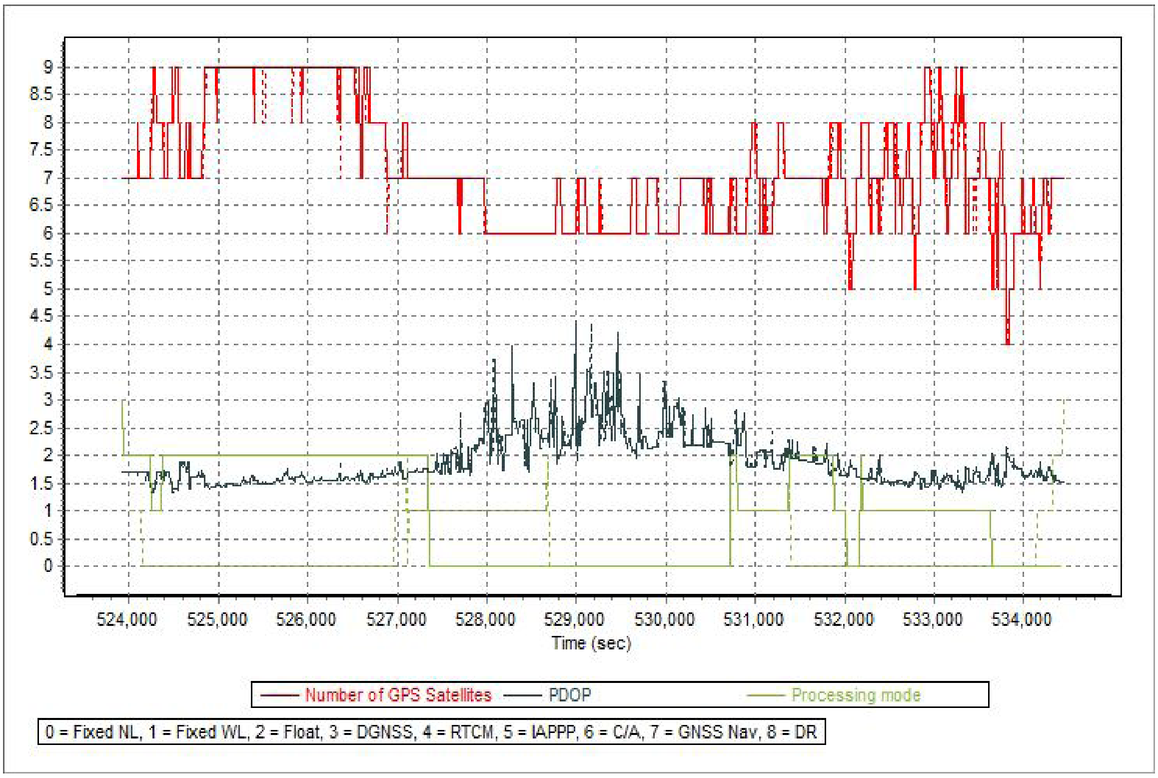



*Figure A-8.43*. Solution Status

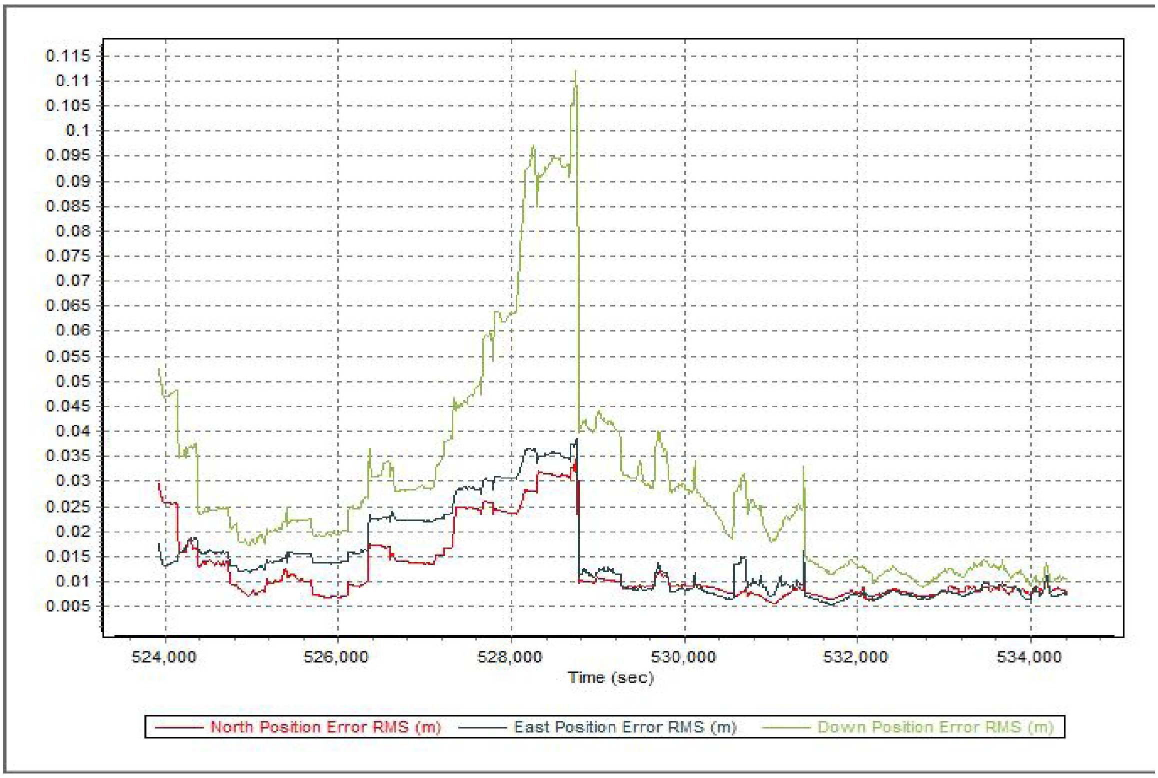



*Figure A-8.44.* Smoothed Performance Metrics Parameters

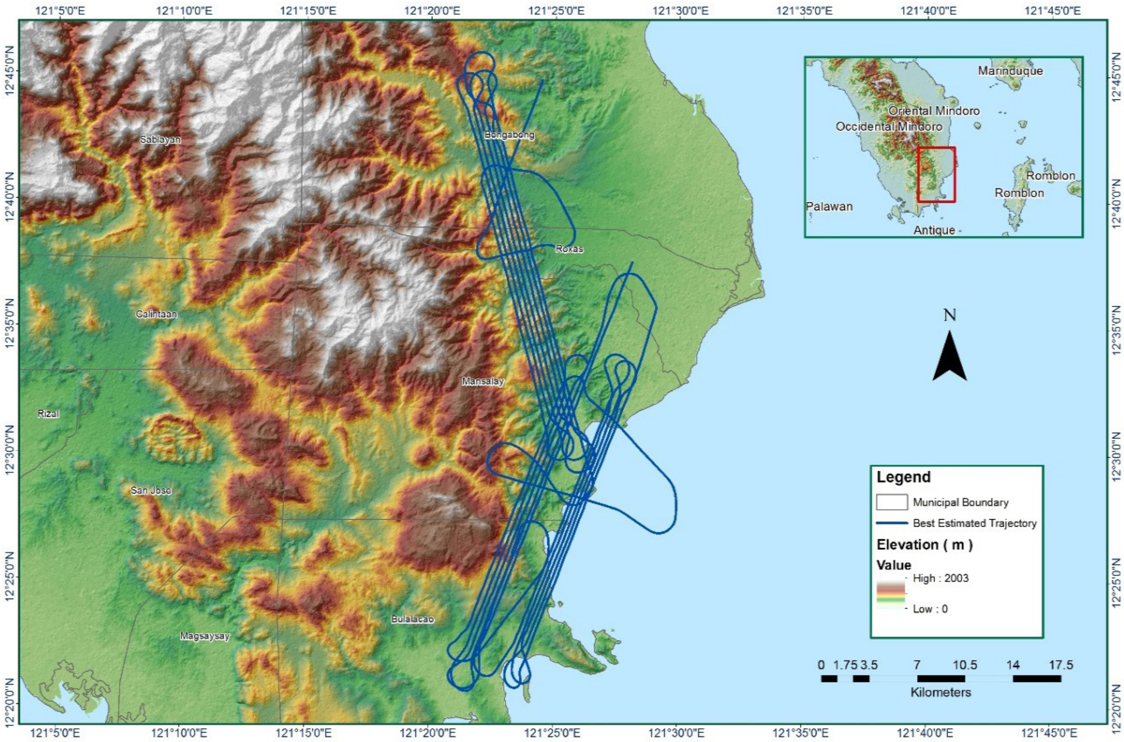



*Figure A-8.45.* Best Estimated Trajectory

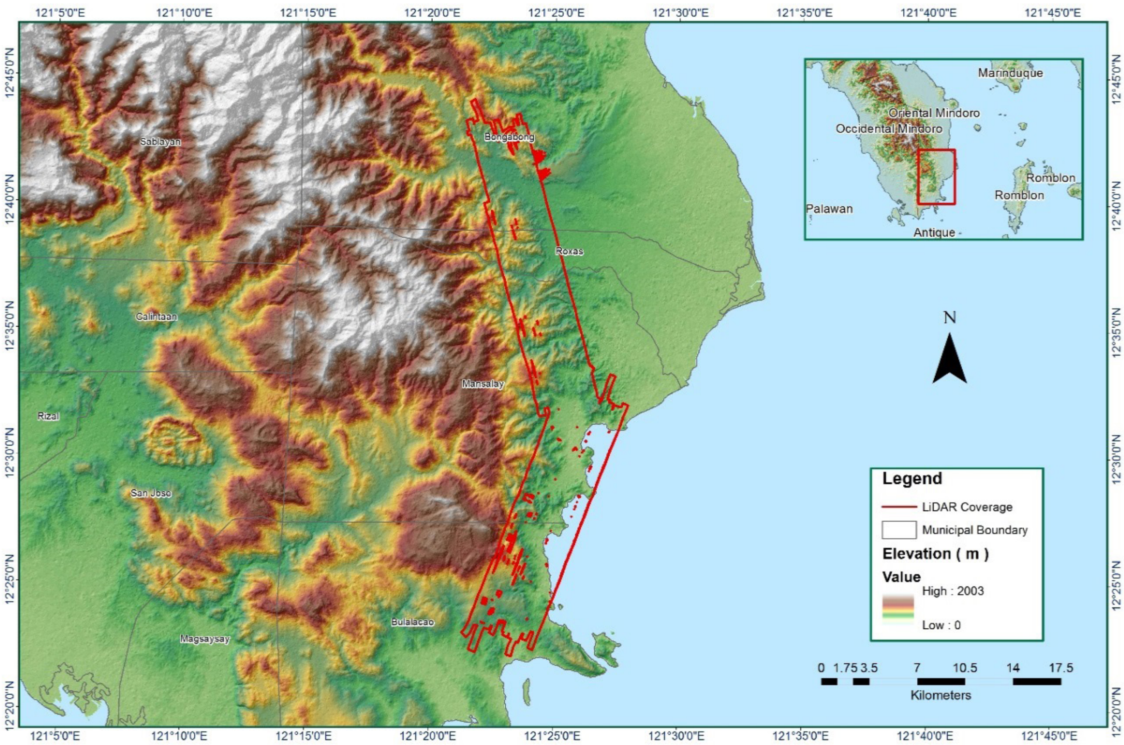



*Figure A-8.46.* Coverage of LiDAR data

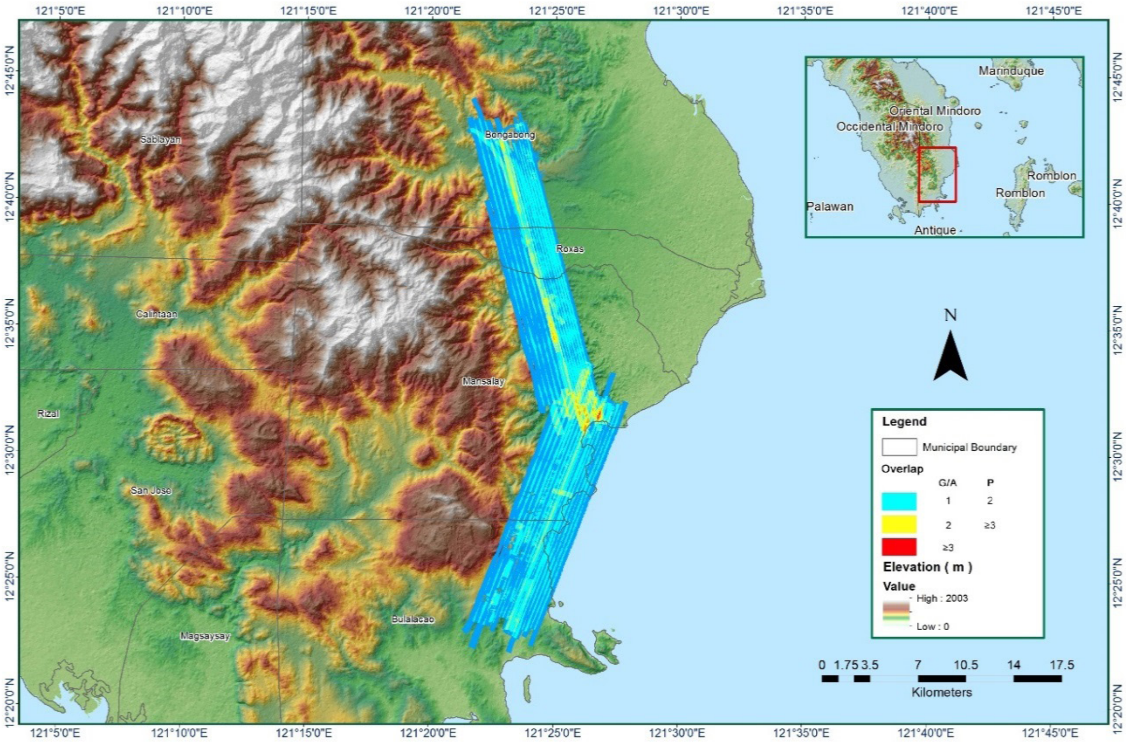



*Figure A-8.47.* Image of data overlap

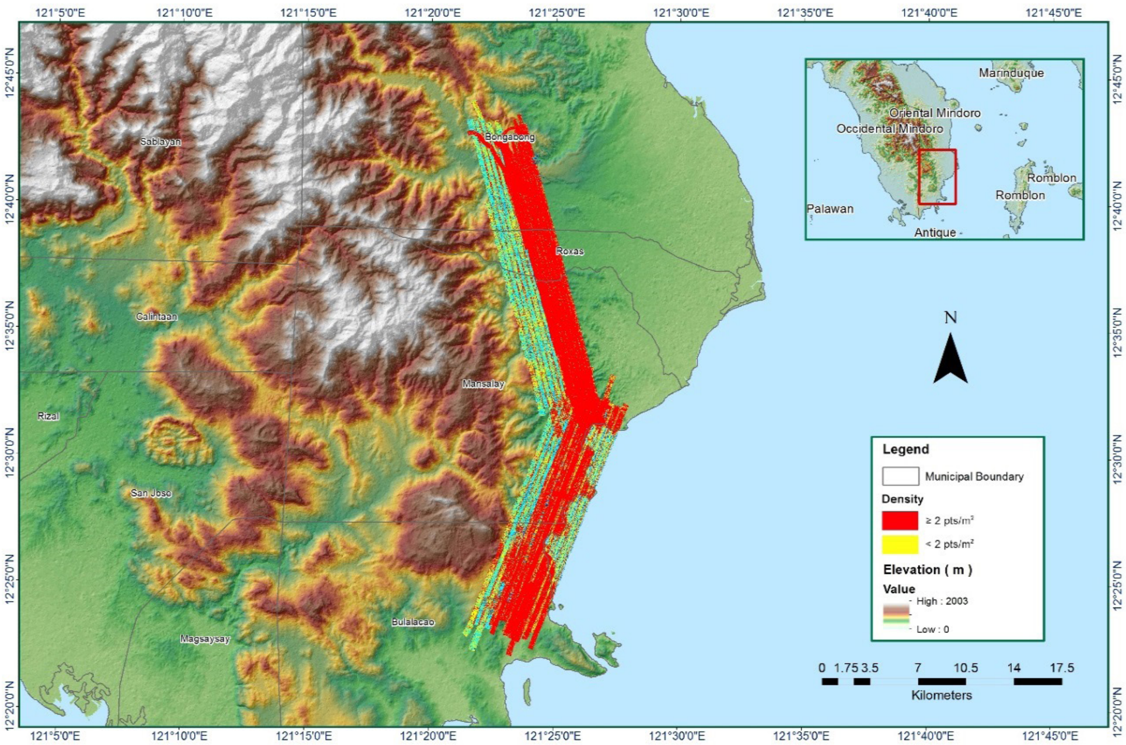



*Figure A-8.48.* Density of merged LiDAR data

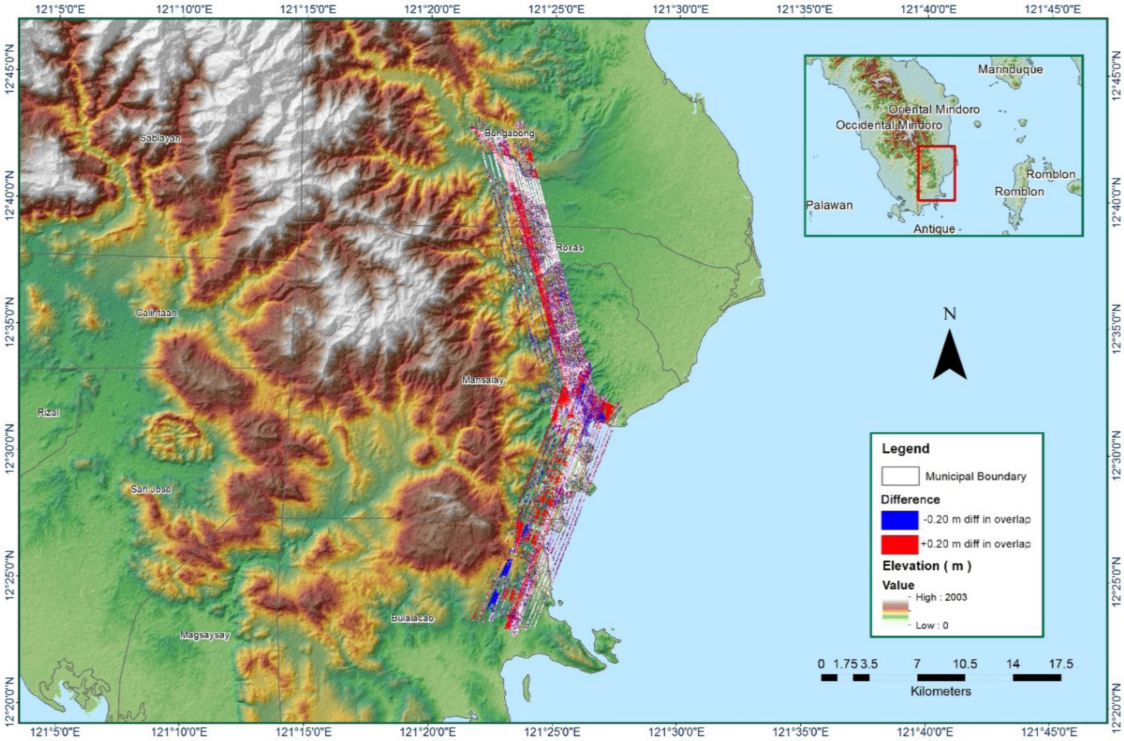



*Figure A-8.49.* Elevation difference between flight lines

Table A-8.8. Mission Summary Report for Mission Blk28F

| Flight Area | Oriental Mindoro Reflights |
|---|---|
| Mission Name | Blk28F |
| Inclusive Flights | 8302G |
| Range data size | 14.5 GB |
| Base data size | 11.5 MB |
| POS | 228 MB |
| Image | 28.2 GB |
| Transfer date | November 12, 2015 |
| | |
| Solution Status | |
| Number of Satellites (>6) | Yes |
| PDOP (<3) | Yes |
| Baseline Length (<30km) | Yes |
| Processing Mode (<=1) | Yes |
| | |
| Smoothed Performance Metrics (in cm) | |
| RMSE for North Position (<4.0 cm) | 0.934 |
| RMSE for East Position (<4.0 cm) | 1.04 |
| RMSE for Down Position (<8.0 cm) | 1.47 |
| | |
| Boresight correction stdev (<0.001deg) | 0.000889 |
| IMU attitude correction stdev (<0.001deg) | 0.000102 |
| GPS position stdev (<0.01m) | 0.0109 |
| | |
| Minimum % overlap (>25) | 33.03 |
| Ave point cloud density per sq.m. (>2.0) | 3.19 |
| Elevation difference between strips (<0.20 m) | Yes |
| | |
| Number of 1km x 1km blocks | 43 |
| Maximum Height | 94.12 m |
| Minimum Height | 51.59 m |
| | |
| Classification (# of points) | |
| Ground | 10,986,543 |
| Low vegetation | 16,821,408 |
| Medium vegetation | 25,819,248 |
| High vegetation | 14,191,912 |
| Building | 289,175 |
| | |
| Orthophoto | Yes |
| Processed by | Engr. Kenneth Solidum, Engr. Anotonio Chua Jr, Marie Denise Bueno |

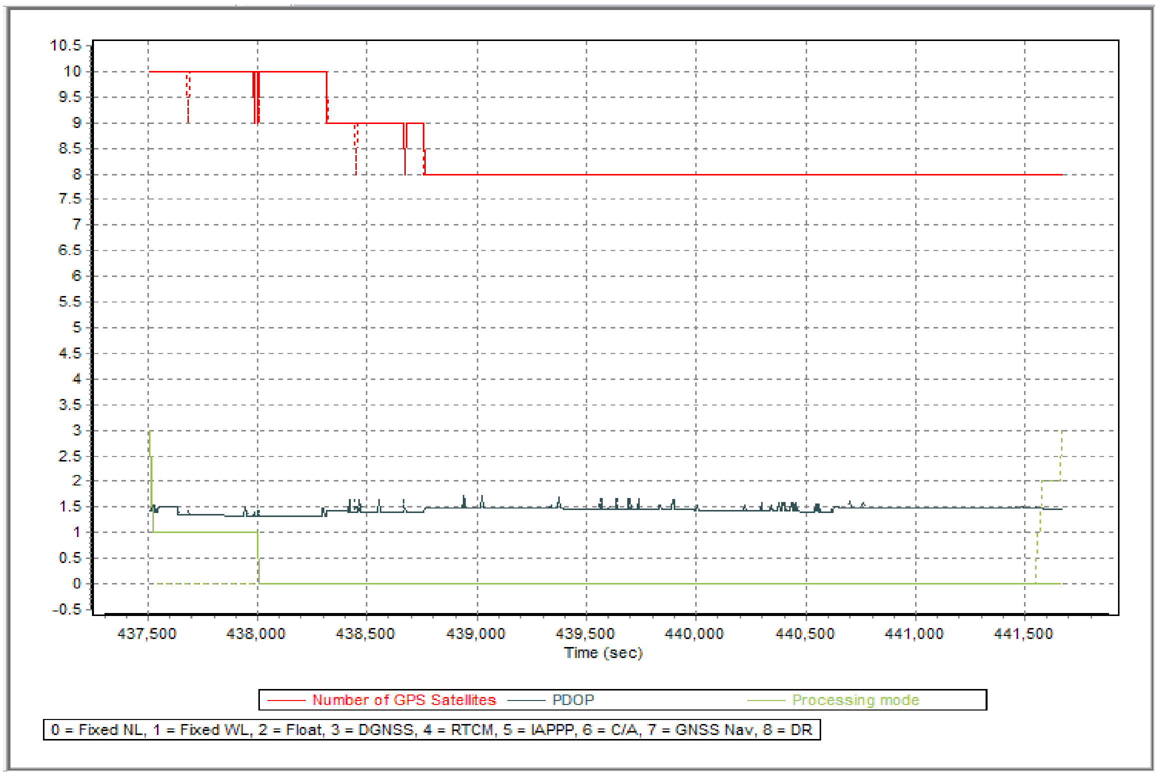



*Figure A-8.50*. Solution Status

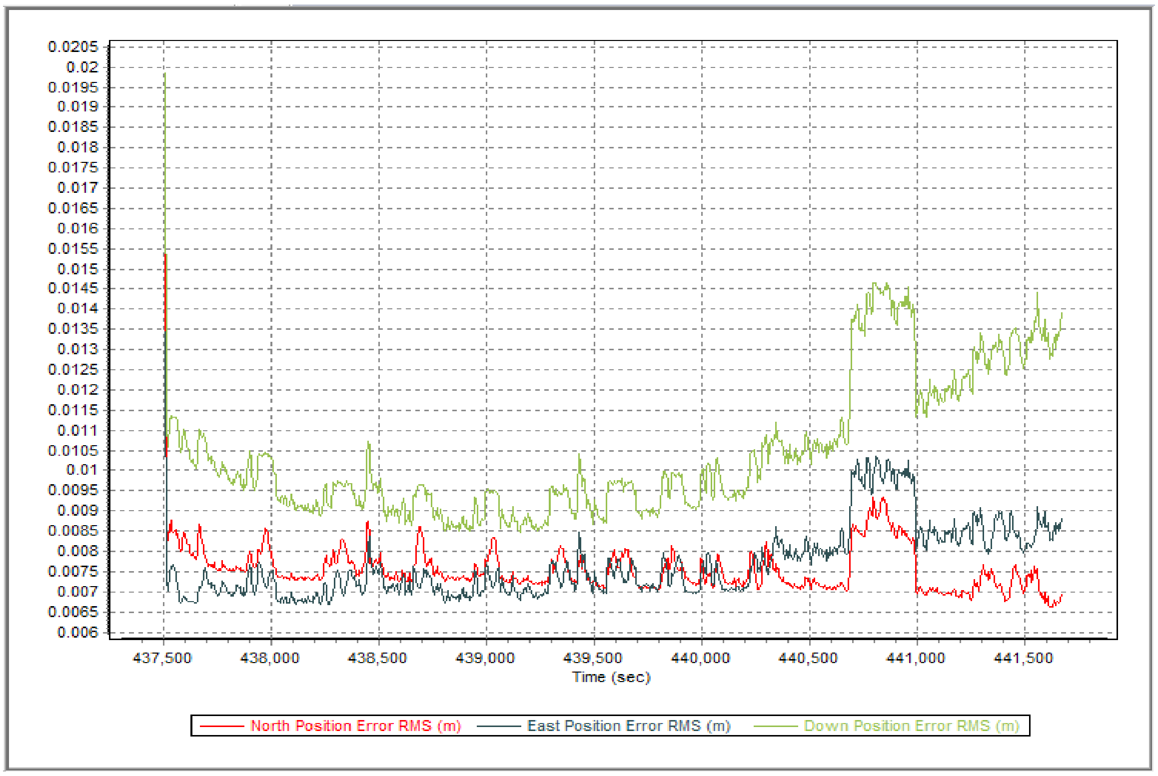



*Figure A-8.51.* Smoothed Performance Metric Parameters

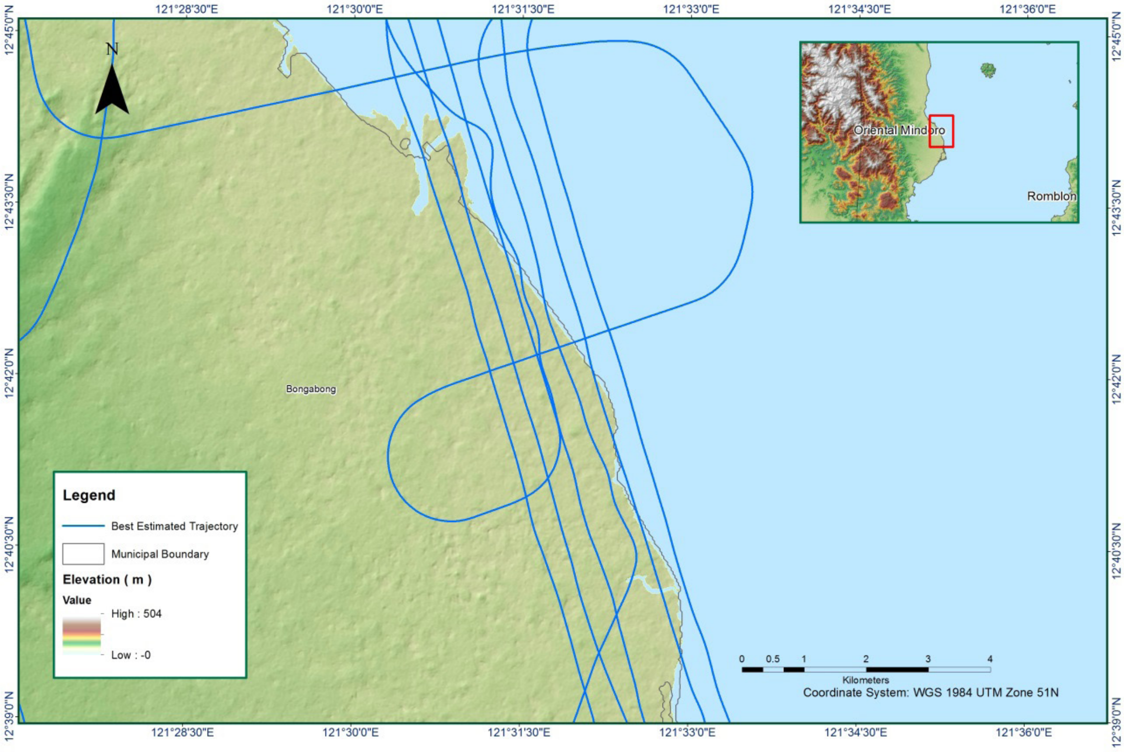



*Figure A-8.52.* Best Estimate Trajectory

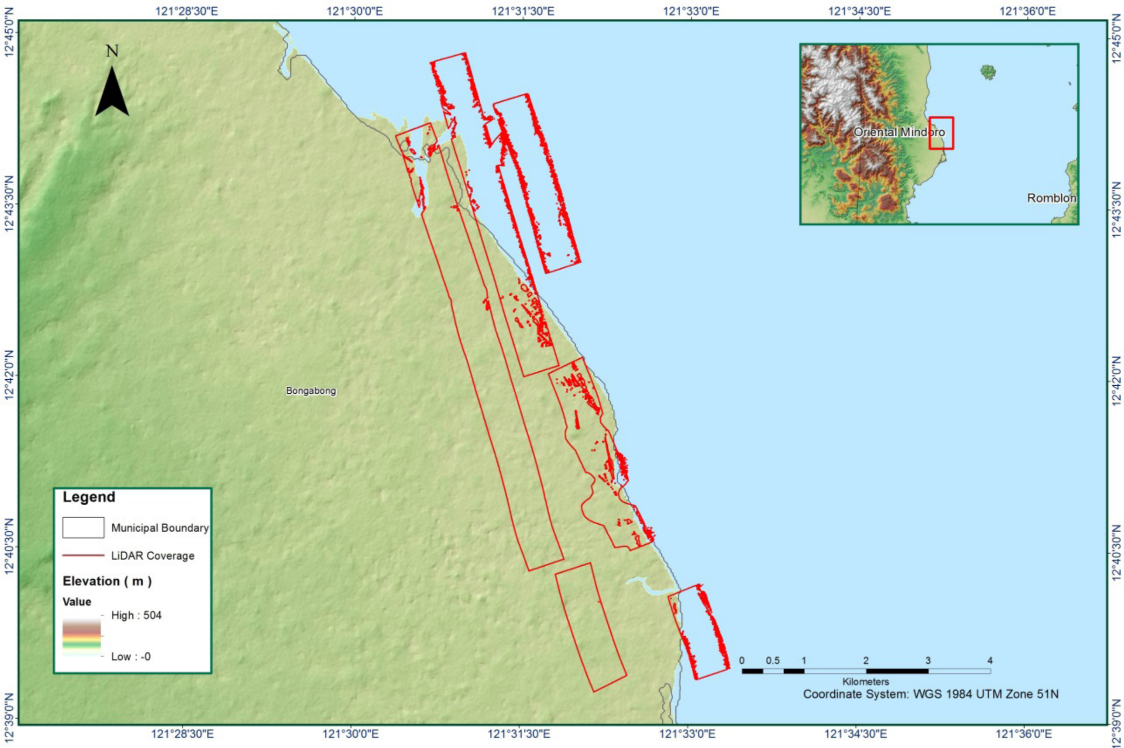



*Figure A-8.53.* Coverage of LiDAR data

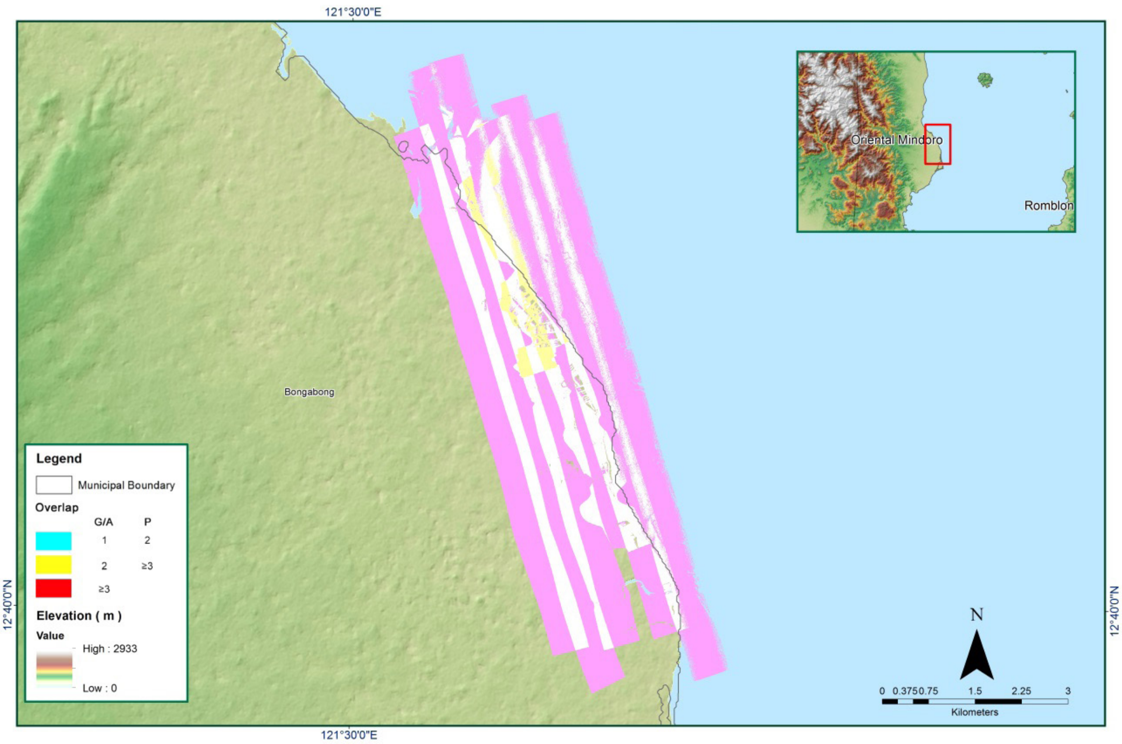



*Figure A-8.54.* Image of data overlap

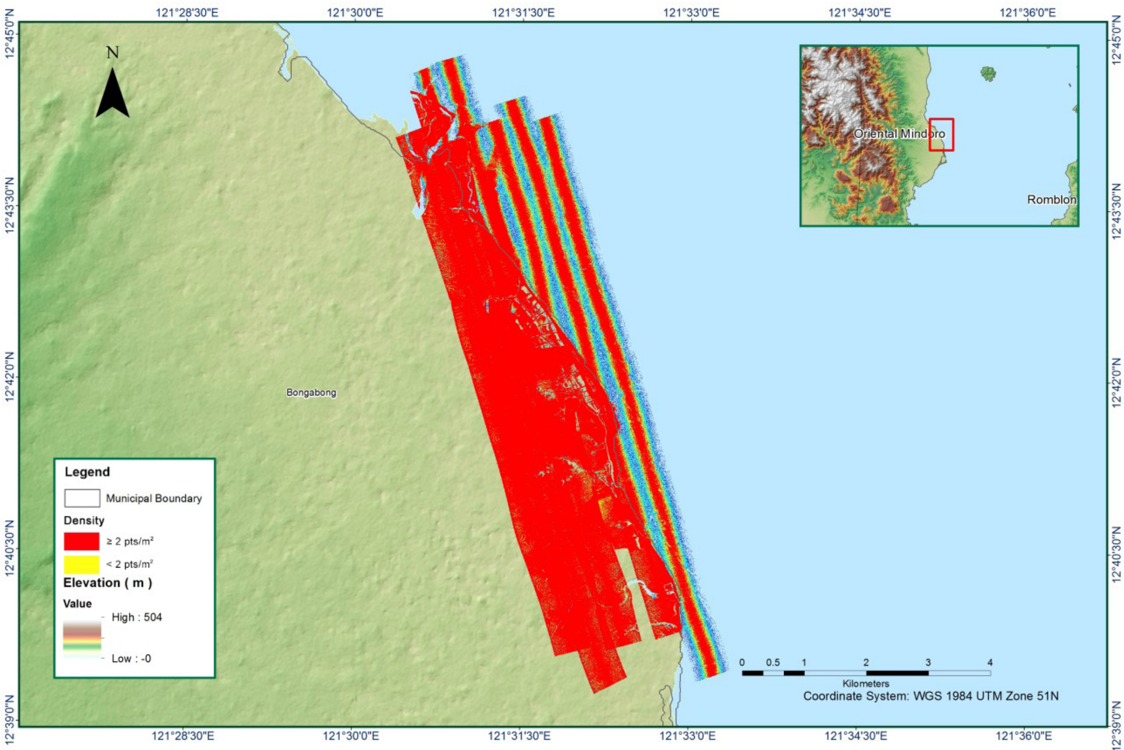



*Figure A-8.55.* Density Map of merged LiDAR data

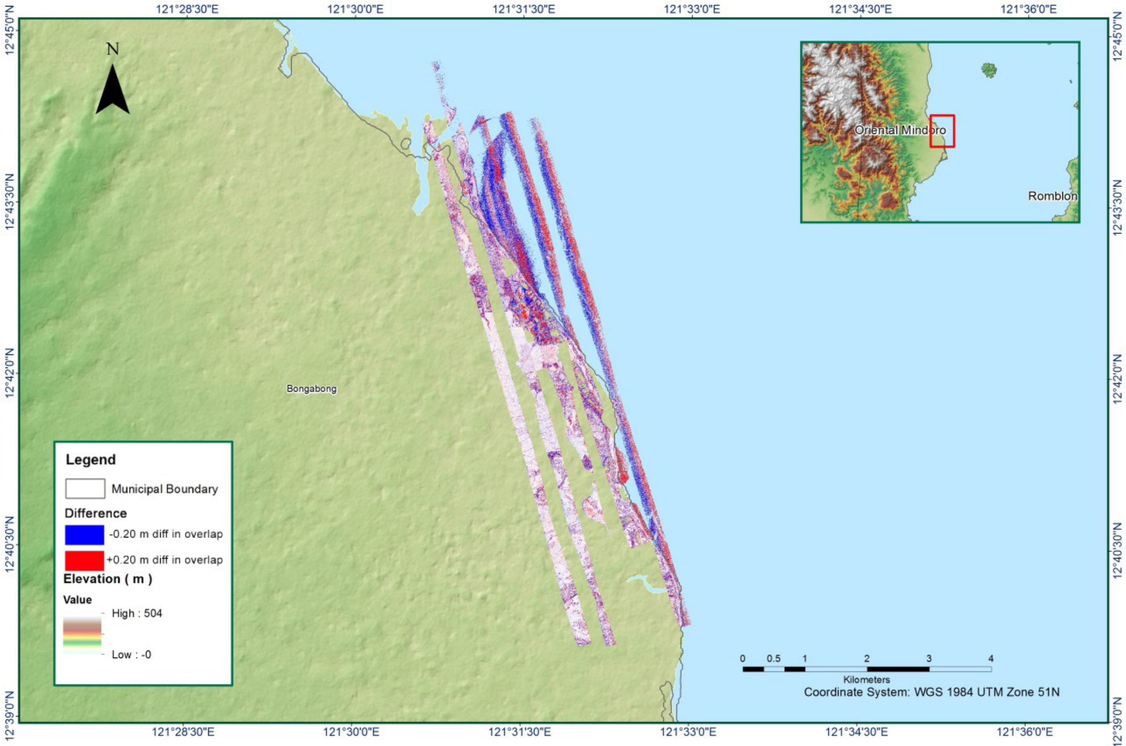



*Figure A-8.56.* Elevation Difference Between flight lines

Table A-8.9. Mission Summary Report for Mission Blk28H_supplement

| Flight Area | Oriental Mindoro Reflights |
|---|---|
| Mission Name | Blk28H_supplement |
| Inclusive Flights | 8304G, 8306G |
| Range data size | 24.9 GB |
| Base data size | 17.2 MB |
| POS | 434 MB |
| Image | 24.8 GB |
| Transfer date | November 12, 2015 |
| | |
| Solution Status | |
| Number of Satellites (>6) | Yes |
| PDOP (<3) | Yes |
| Baseline Length (<30km) | No |
| Processing Mode (<=1) | No |
| | |
| Smoothed Performance Metrics (in cm) | |
| RMSE for North Position (<4.0 cm) | 1.33 |
| RMSE for East Position (<4.0 cm) | 1.40 |
| RMSE for Down Position (<8.0 cm) | 3.05 |
| | |
| Boresight correction stdev (<0.001deg) | 0.000292 |
| IMU attitude correction stdev (<0.001deg) | 0.000461 |
| GPS position stdev (<0.01m) | 0.0016 |
| | |
| Minimum % overlap (>25) | 38.13 |
| Ave point cloud density per sq.m. (>2.0) | 4.70 |
| Elevation difference between strips (<0.20 m) | Yes |
| | |
| Number of 1km x 1km blocks | 78 |
| Maximum Height | 374.61 m |
| Minimum Height | 41.25 m |
| | |
| Classification (# of points) | |
| Ground | 33,733,252 |
| Low vegetation | 20,442,478 |
| Medium vegetation | 63,131502 |
| High vegetation | 145,339525 |
| Building | 5,009,201 |
| | |
| Orthophoto | Yes |
| Processed by | Engr. Abigail Joy Ching, Engr. Melanie Hingpit, Maria Tamsyn Malabanan |

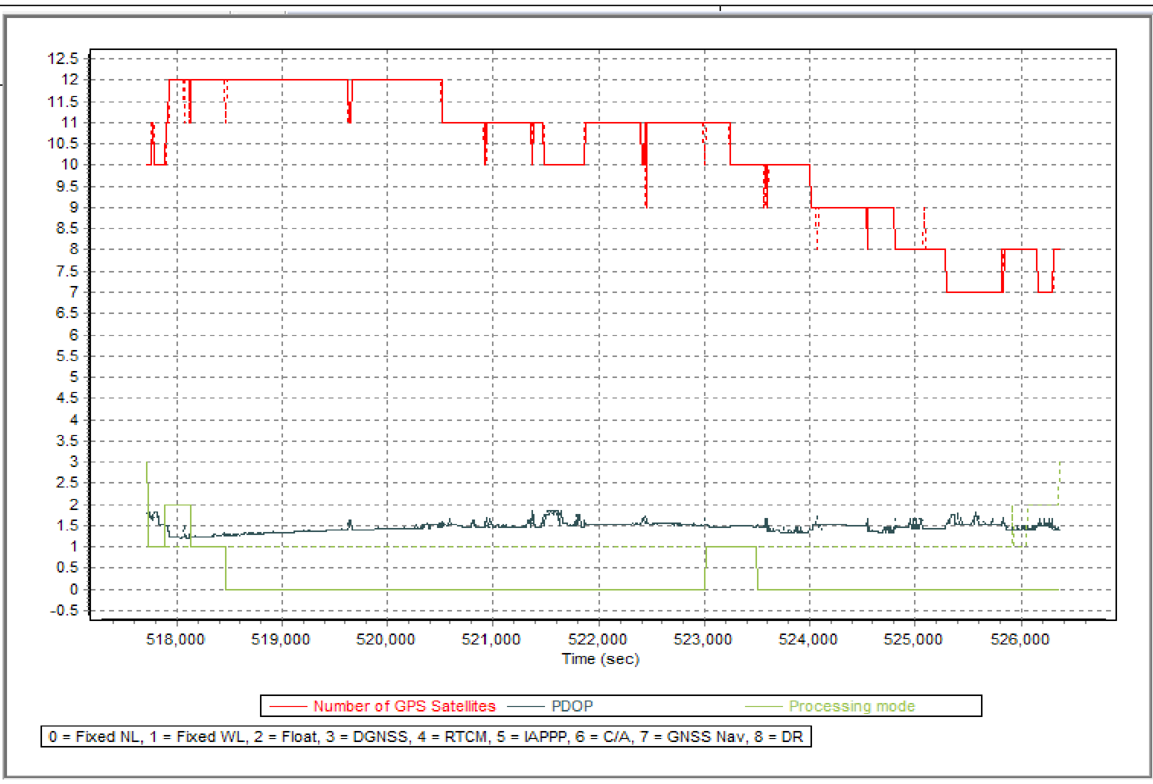



*Figure A-8.57.* Solution Status

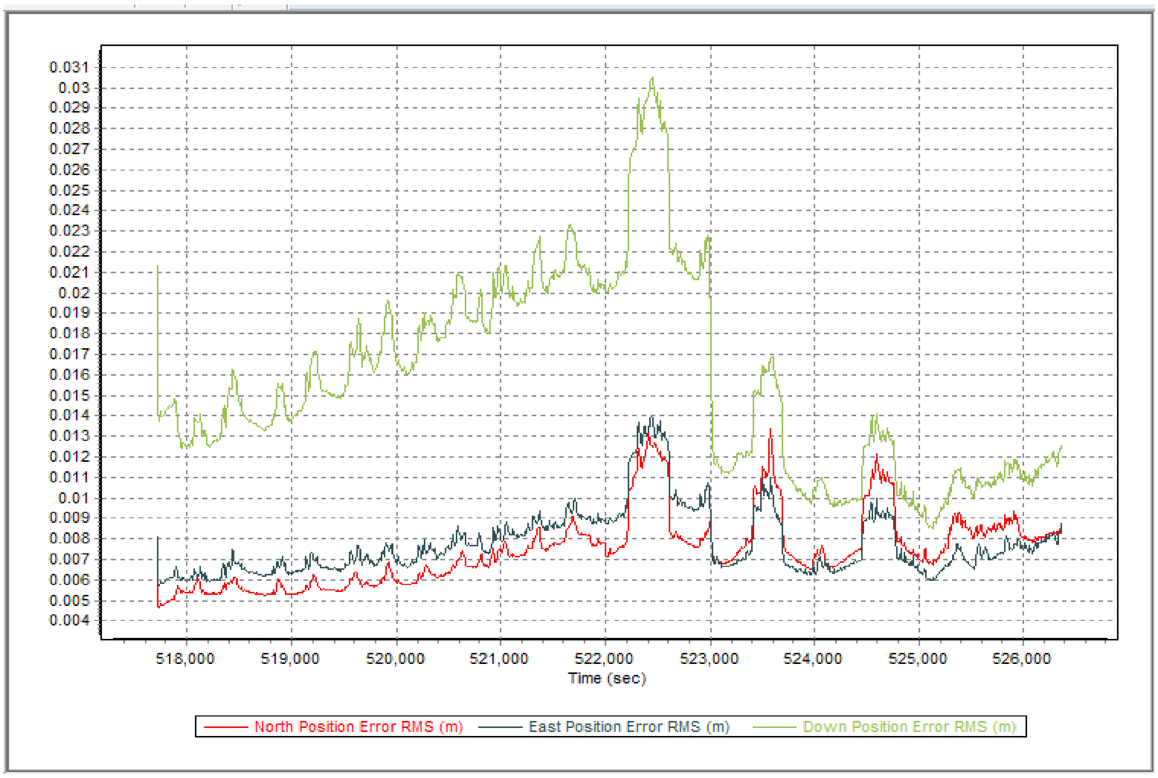



*Figure A-8.58.* Smoothed Performance Metric Parameters

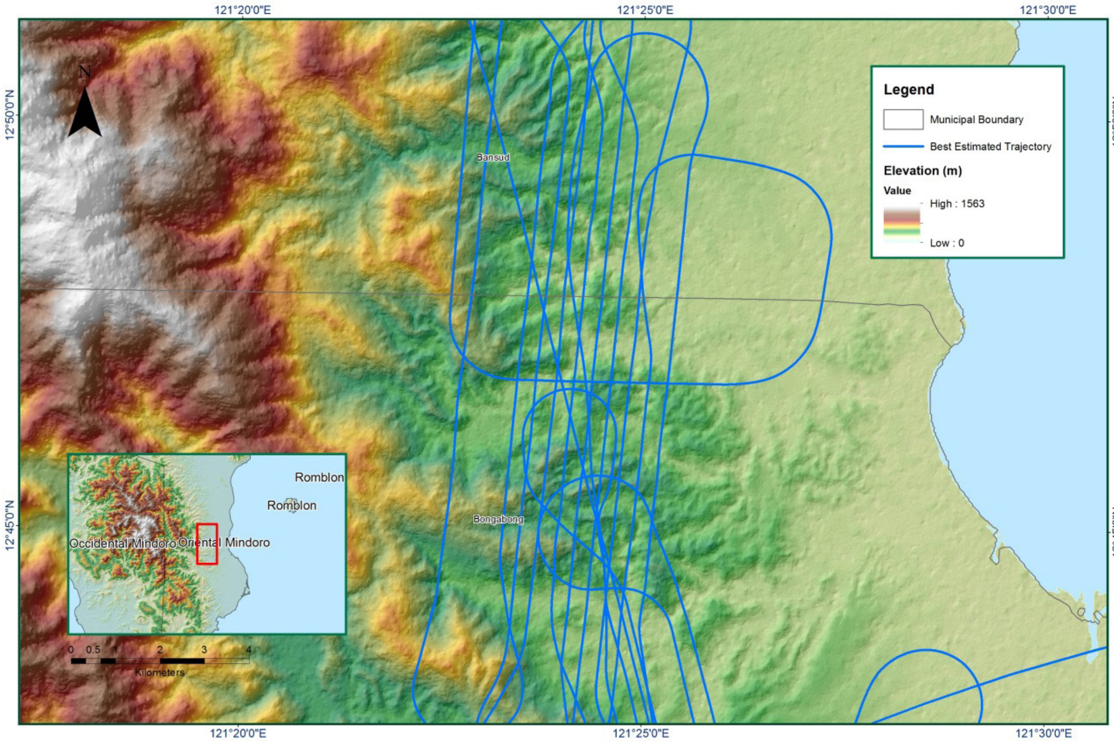



*Figure A-8.59.* Best Estimate Trajectory

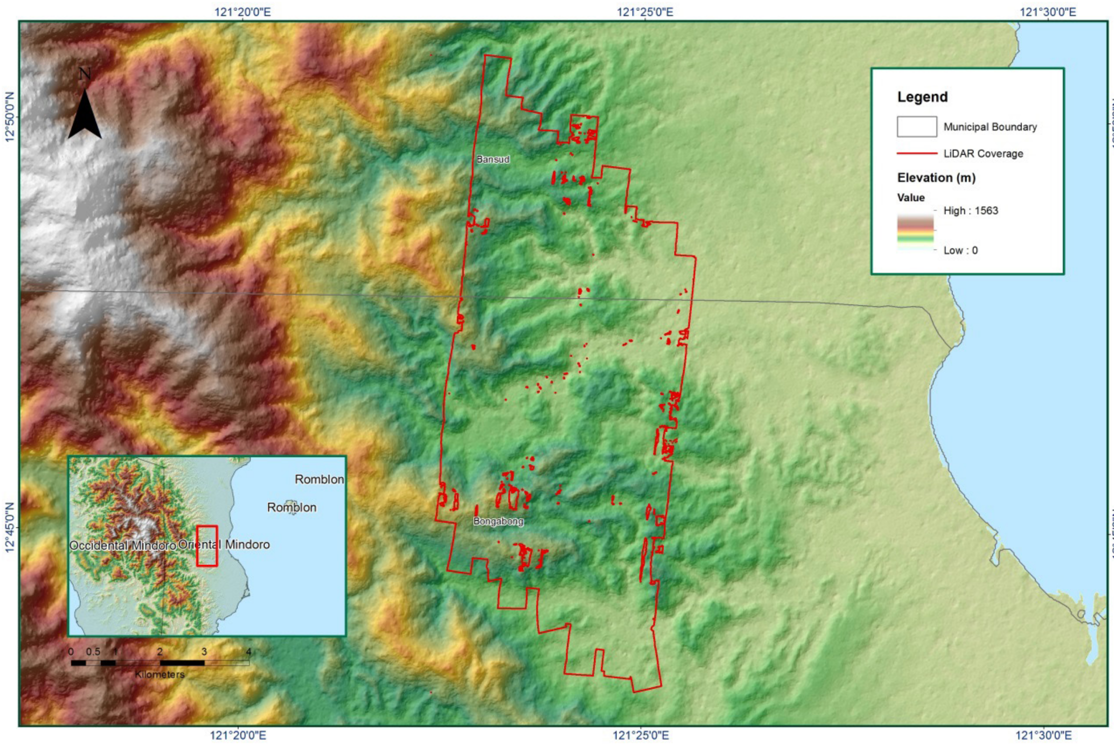



*Figure A-8.60.* Coverage of LiDAR data

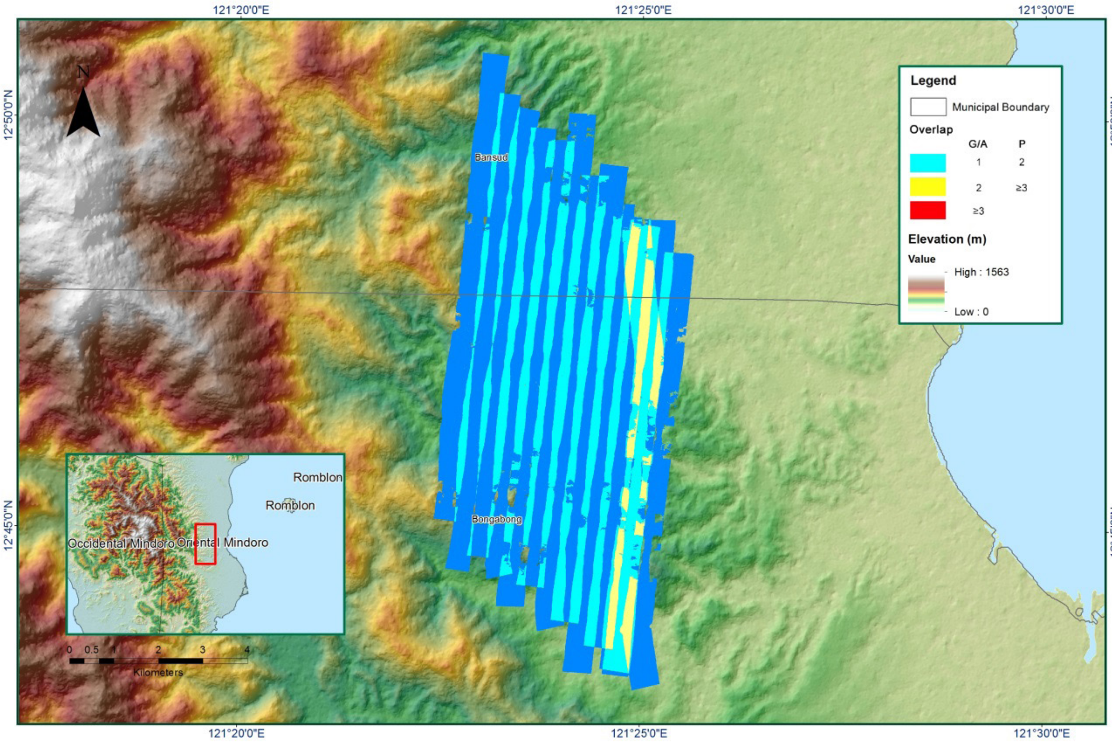



*Figure A-8.61.* Image of data overlap

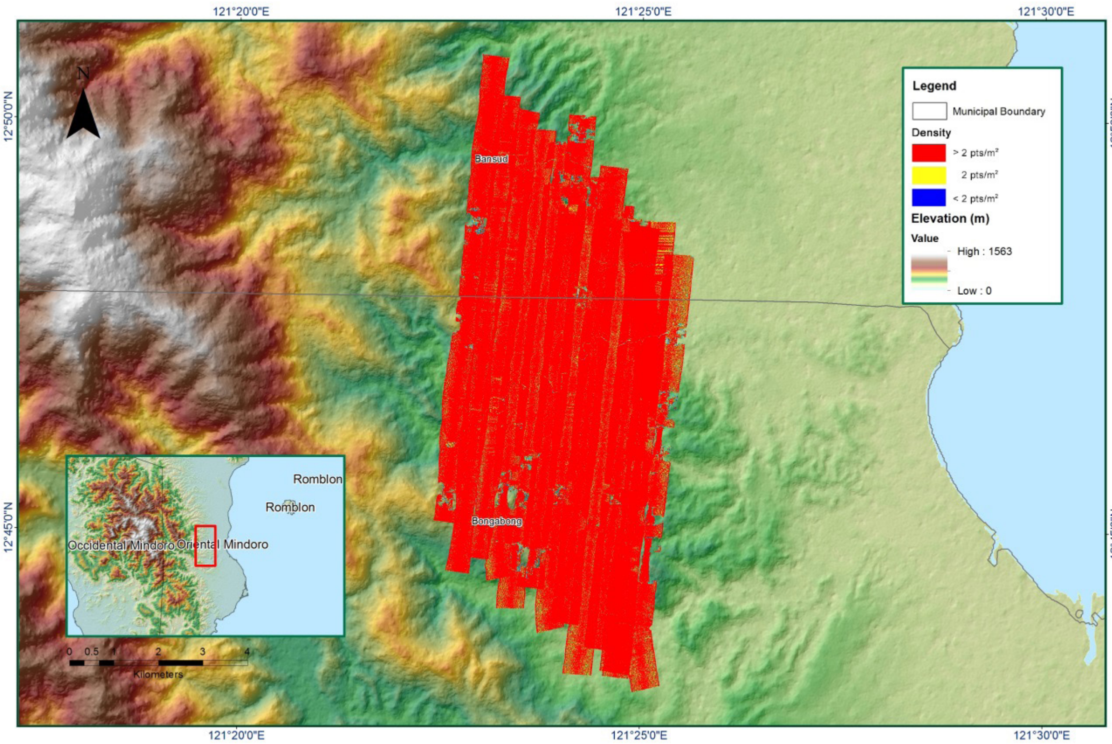



*Figure A-8.62.* Density Map of merged LiDAR data

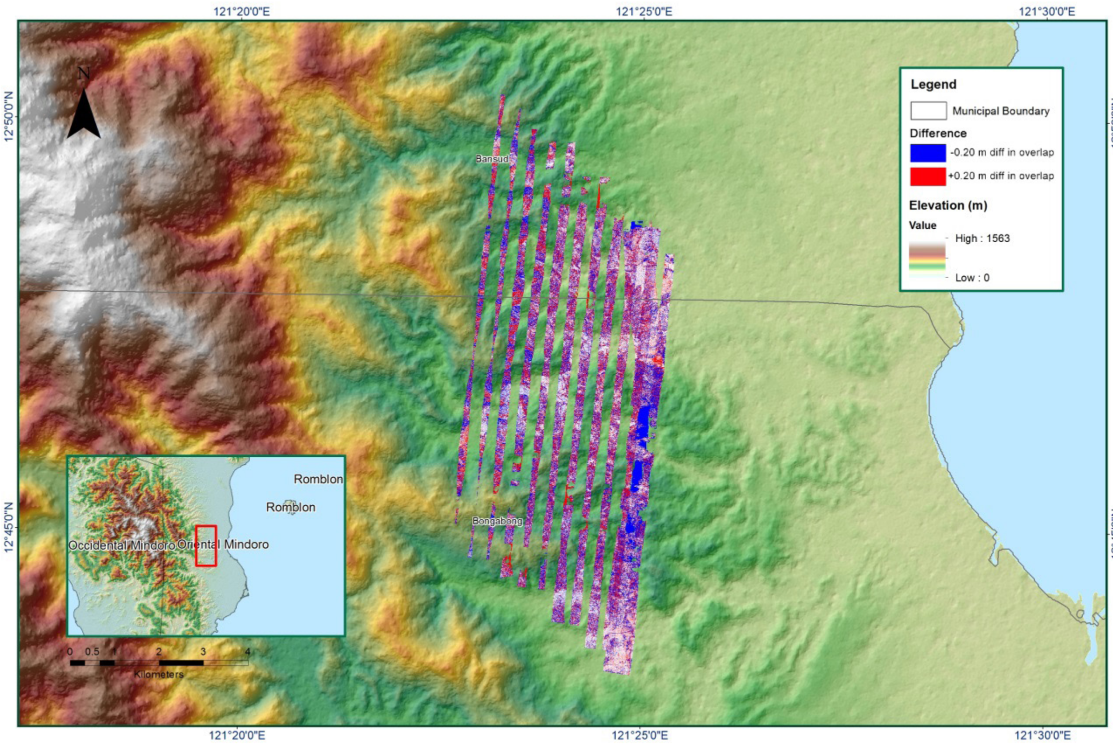



*Figure A-8.63.* Elevation Difference Between flight lines

Table A-8.10. Mission Summary Report for Mission BLk28I_additional

| Flight Area | Oriental Mindoro Reflights |
|---|---|
| Mission Name | Blk28I_additional |
| Inclusive Flights | 8306G |
| Range data size | 10.7 GB |
| Base data size | 8.28 MB |
| POS | 220 MB |
| Image | NA |
| Transfer date | November 12, 2015 |
| | |
| Solution Status | |
| Number of Satellites (>6) | Yes |
| PDOP (<3) | Yes |
| Baseline Length (<30km) | Yes |
| Processing Mode (<=1) | Yes |
| | |
| Smoothed Performance Metrics (in cm) | |
| RMSE for North Position (<4.0 cm) | 0.915 |
| RMSE for East Position (<4.0 cm) | 0.984 |
| RMSE for Down Position (<8.0 cm) | 1.65 |
| | |
| Boresight correction stdev (<0.001deg) | 0.002500 |
| IMU attitude correction stdev (<0.001deg) | 0.000957 |
| GPS position stdev (<0.01m) | 0.0023 |
| | |
| Minimum % overlap (>25) | 11.76 |
| Ave point cloud density per sq.m. (>2.0) | 3.77 |
| Elevation difference between strips (<0.20 m) | Yes |
| | |
| Number of 1km x 1km blocks | 15 |
| Maximum Height | 515.09 m |
| Minimum Height | 159.61 m |
| | |
| Classification (# of points) | |
| Ground | 3,721,852 |
| Low vegetation | 4,319,635 |
| Medium vegetation | 6,538,701 |
| High vegetation | 5,965,618 |
| Building | 70,731 |
| | |
| Orthophoto | No |
| Processed by | Engr. Abigail Joy Ching, Engr. Melanie Hingpit, Engr. Krisha Marie Bautista |

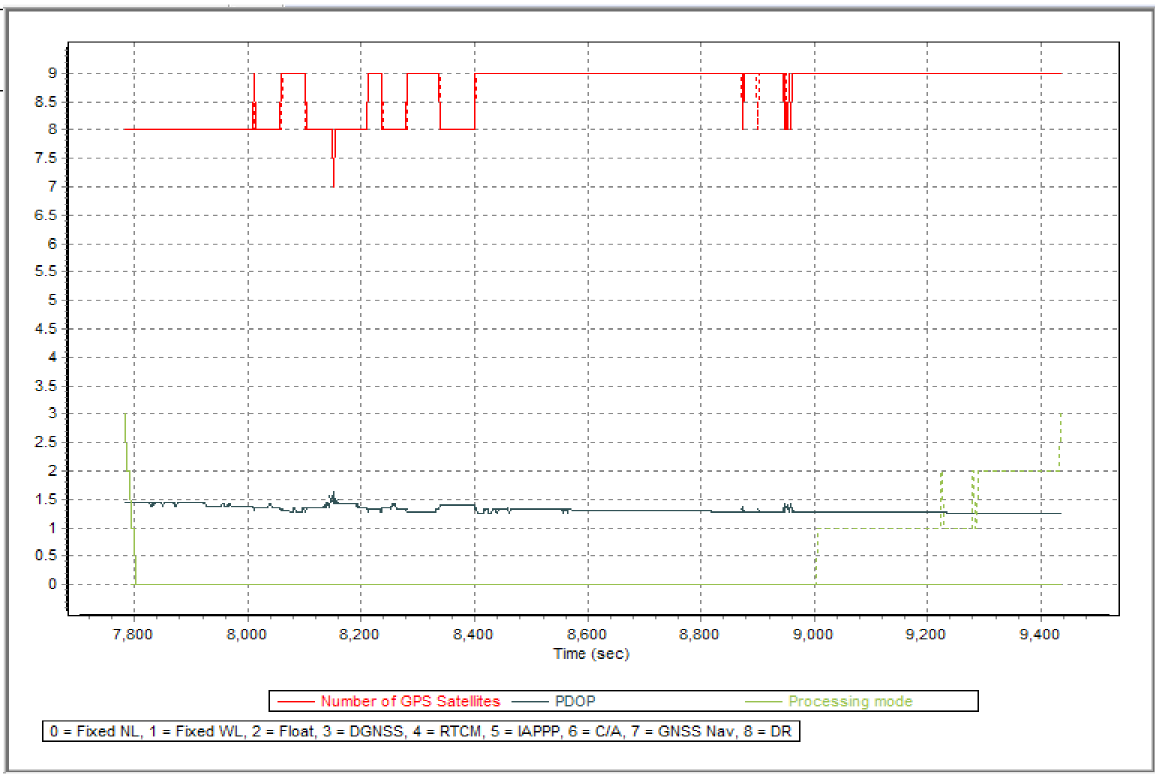



*Figure A-8.64*. Solution Status

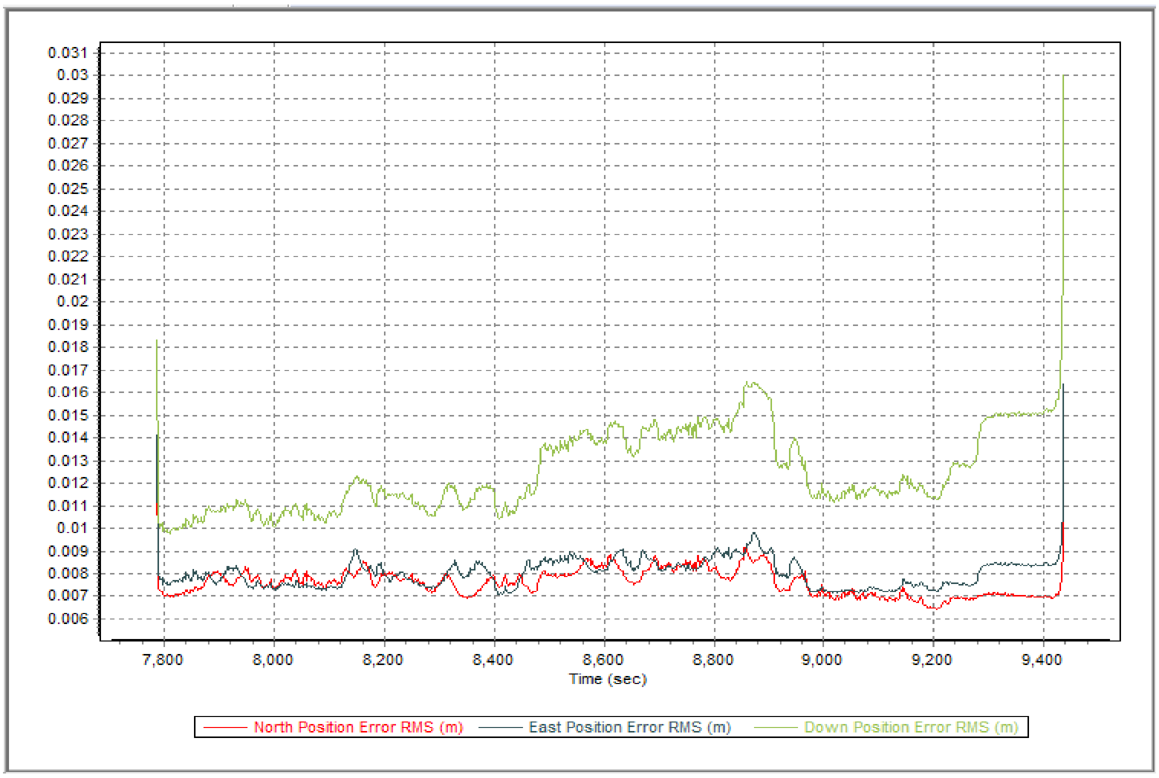



*Figure A-8.65.* Smoothed Performance Metric Parameters

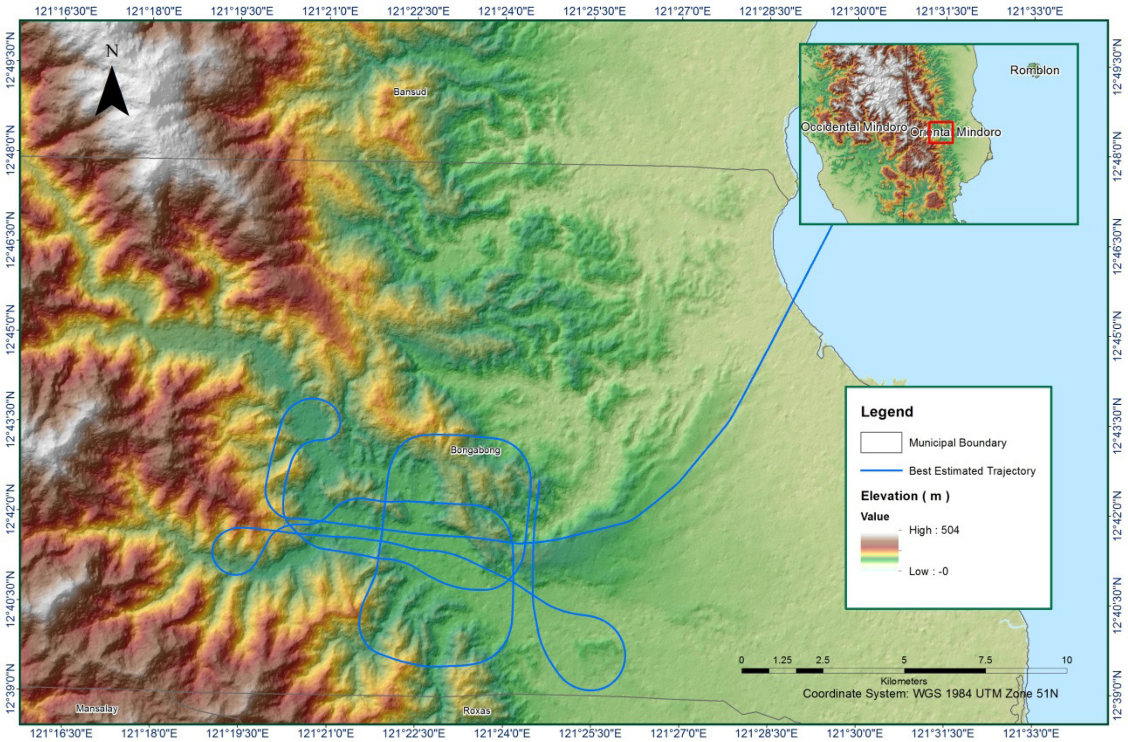



*Figure A-8.66.* Best Estimate Trajectory

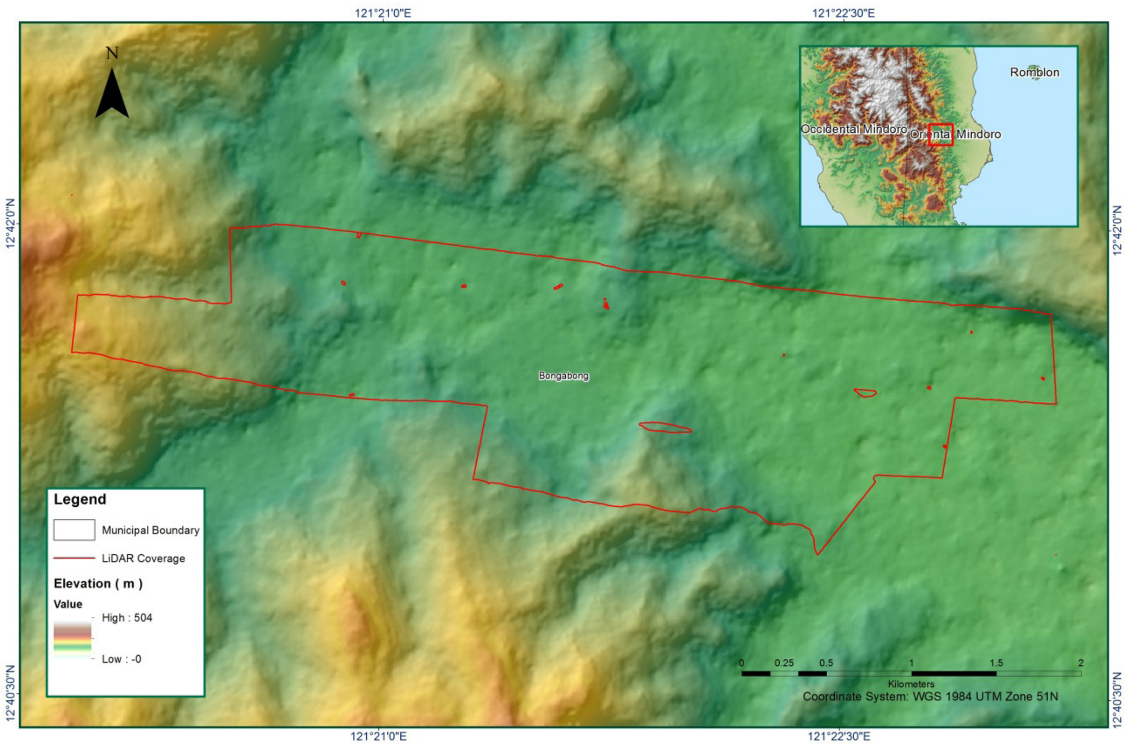



*Figure A-8.67*. Coverage of LiDAR data

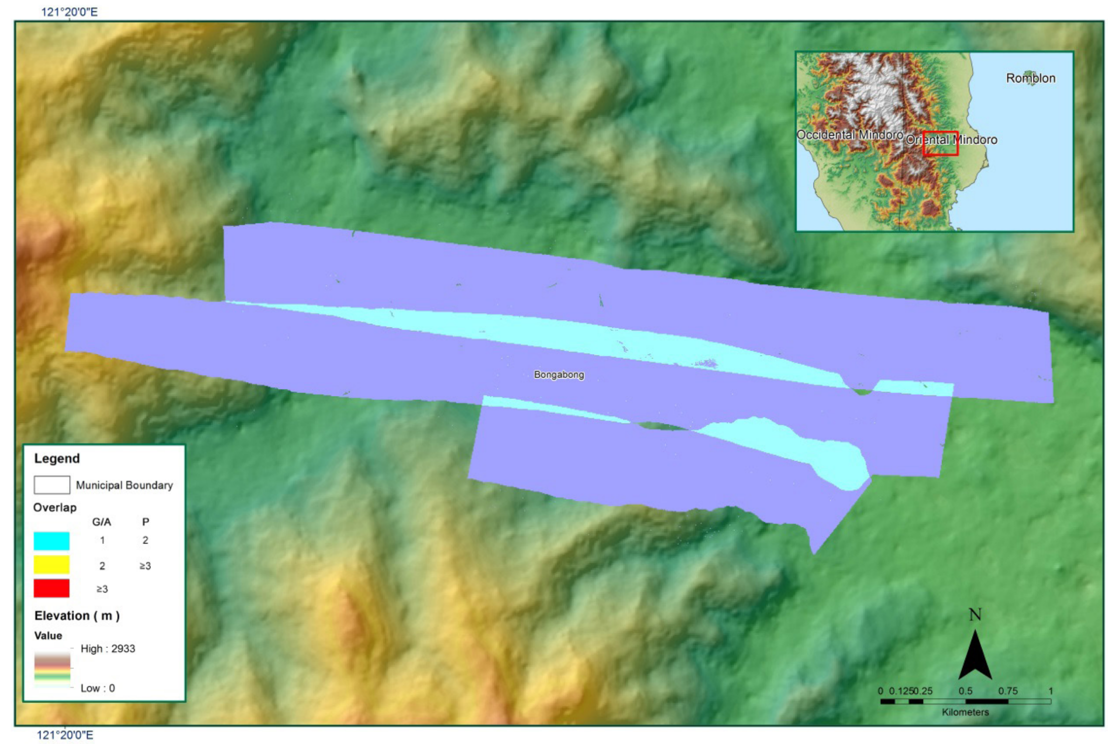



*Figure A-8.68.* Image of data overlap

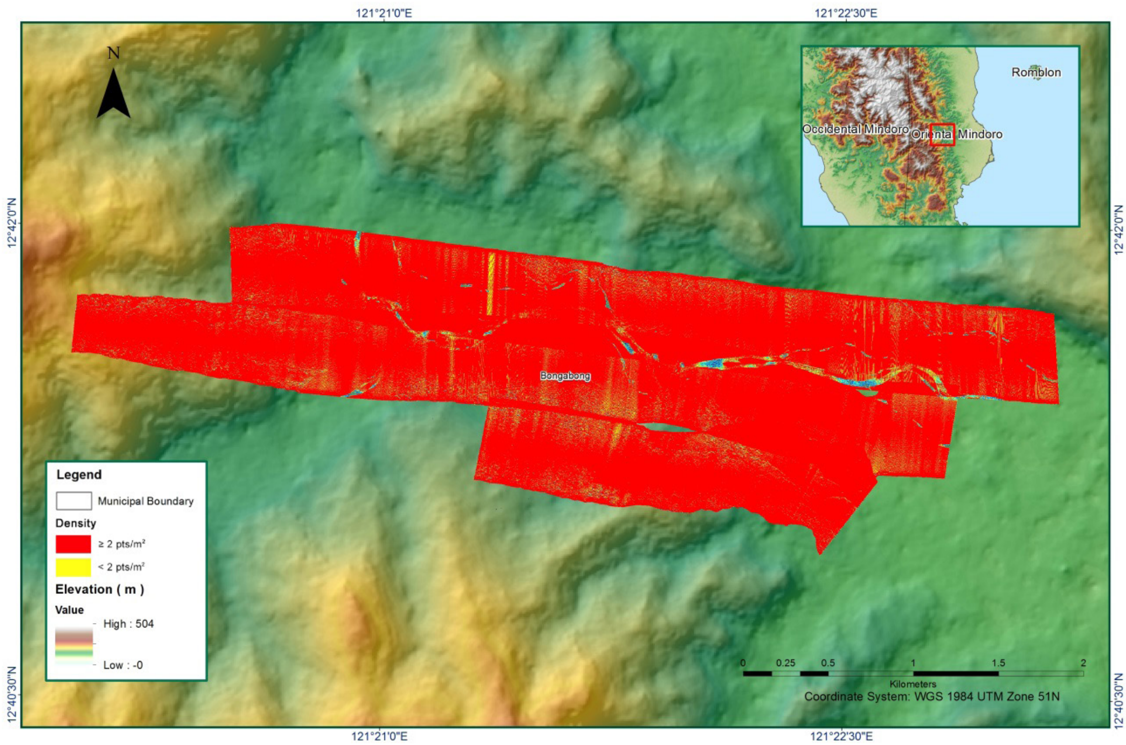



*Figure A-8.69.* Density Map of merged LiDAR data

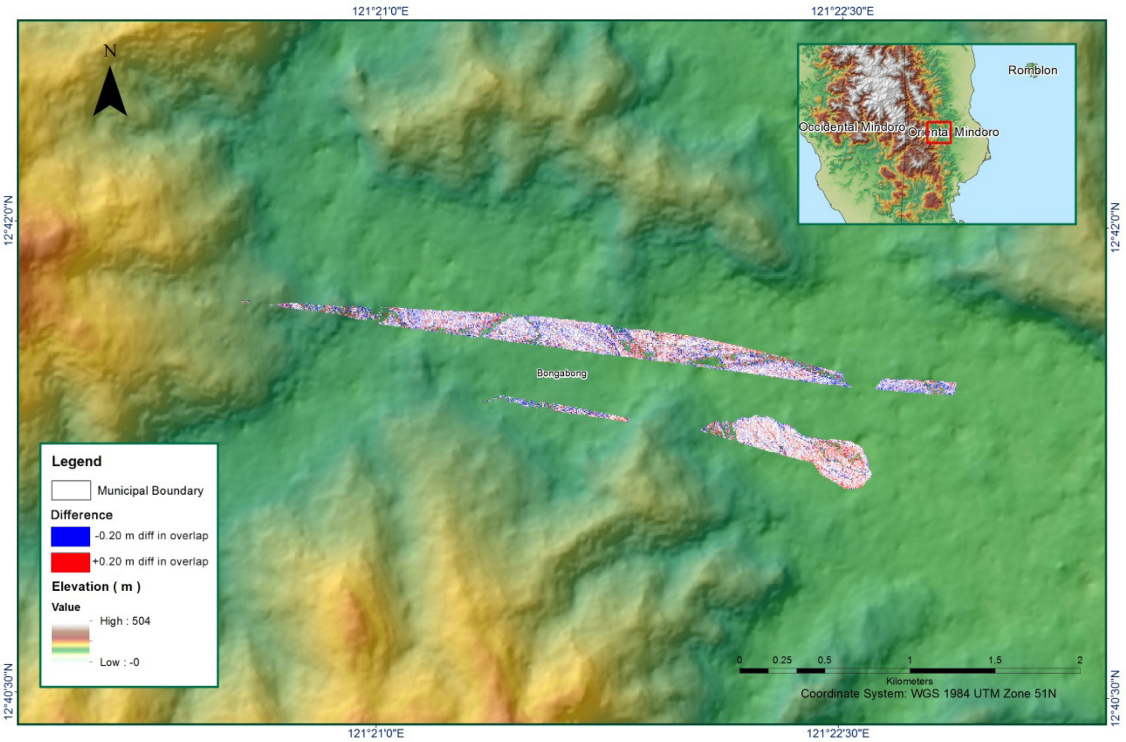



*Figure A-8.70.* Elevation Difference Between flight lines

## Annex 9. Bongabong Model Basin Parameters

Table A-9.1. **Bongabong Model Basin Parameters**

| Subbasin | SCS CURVE NUMBER LOSS | | | CLARK UNIT HYDROGRAPH TRANSFORM | | RECESSION BASEFLOW | | |
|---|---|---|---|---|---|---|---|---|
| | Initial Abstraction (MM) | Curve Number | Imperviousness (%) | Time of Concentration (HR) | Storage Coefficient (HR) | Initial Discharge (CU.M/S) | Recession Constant | Ratio to Peak |
| W1000 | 20.8270 | 38.0420 | 0.0 | 0.2718 | 32.5670 | 0.0788 | 0.2904 | 0.5000 |
| W1010 | 11.0690 | 40.4630 | 0.0 | 0.6389 | 49.9870 | 0.1409 | 0.4269 | 0.5000 |
| W1020 | 4.8898 | 94.7290 | 0.0 | 0.3294 | 11.9930 | 0.0090 | 0.1975 | 0.4706 |
| W1030 | 13.8490 | 37.8140 | 0.0 | 0.4076 | 31.7820 | 0.0647 | 0.6667 | 0.5000 |
| W1040 | 4.1096 | 75.5520 | 0.0 | 1.2752 | 2.0812 | 0.0018 | 0.6403 | 0.5000 |
| W1050 | 7.8157 | 48.0050 | 0.0 | 0.7422 | 58.9710 | 0.0634 | 0.4269 | 0.5000 |
| W1080 | 7.8707 | 48.2490 | 0.0 | 0.1845 | 9.7256 | 0.0104 | 0.1975 | 0.4706 |
| W1090 | 9.3095 | 47.8600 | 0.0 | 0.6589 | 10.7660 | 0.0206 | 0.2904 | 0.4802 |
| W1130 | 8.7328 | 59.2550 | 0.0 | 2.9207 | 4.7666 | 0.0050 | 1.0000 | 0.5000 |
| W1140 | 4.0751 | 58.8560 | 0.0 | 2.7156 | 64.2780 | 0.1493 | 0.4269 | 0.5000 |
| W540 | 8.6179 | 38.4480 | 0.0 | 2.5209 | 58.0160 | 0.1400 | 0.2904 | 0.5000 |
| W550 | 15.6740 | 35.2980 | 0.0 | 1.8549 | 96.7650 | 0.1073 | 0.1975 | 0.5000 |
| W560 | 15.1450 | 43.5530 | 0.0 | 1.2776 | 28.9850 | 0.0414 | 0.1975 | 0.5000 |
| W570 | 10.4770 | 40.4730 | 0.0 | 0.7814 | 17.9650 | 0.0414 | 0.1975 | 0.5000 |
| W580 | 10.3480 | 43.0640 | 0.0 | 0.7557 | 17.6430 | 0.0138 | 0.4445 | 0.4802 |
| W590 | 10.4860 | 40.5600 | 0.0 | 0.5853 | 29.4680 | 0.0465 | 0.2904 | 0.5000 |
| W600 | 15.4670 | 39.4790 | 0.0 | 0.6506 | 22.6190 | 0.0426 | 0.2904 | 0.5000 |
| W610 | 10.4510 | 42.7060 | 0.0 | 0.8836 | 30.3390 | 0.0503 | 0.2904 | 0.5000 |
| W620 | 9.6078 | 44.3740 | 0.0 | 0.7780 | 40.7660 | 0.1071 | 0.4269 | 0.5000 |
| W630 | 12.1480 | 39.8330 | 0.0 | 0.3177 | 37.1280 | 0.0693 | 0.2904 | 0.5000 |
| W640 | 10.3490 | 42.9410 | 0.0 | 0.3871 | 43.8700 | 0.1419 | 0.4269 | 0.5000 |
| W650 | 11.2410 | 38.7190 | 0.0 | 2.8203 | 43.2950 | 0.1991 | 0.6667 | 0.5000 |
| W660 | 8.5385 | 47.2270 | 0.0 | 0.2185 | 24.7710 | 0.0425 | 0.4269 | 0.5000 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| W670 | 15.9280 | 42.3390 | 0.0 | 0.1405 | 16.4120 | 0.0157 | 0.4269 | 0.4900 |
| W680 | 13.9210 | 38.8080 | 0.0 | 0.6628 | 78.6020 | 0.0956 | 0.2904 | 0.5000 |
| W690 | 13.3260 | 46.5470 | 0.0 | 0.5163 | 40.0010 | 0.0395 | 0.4269 | 0.5000 |
| W700 | 20.6240 | 39.0240 | 0.0 | 0.1689 | 5.9620 | 0.0105 | 0.2904 | 0.2178 |
| W710 | 31.0040 | 37.9080 | 0.0 | 0.1720 | 5.8104 | 0.0015 | 0.1975 | 0.4706 |
| W720 | 13.0190 | 39.3330 | 0.0 | 0.2749 | 31.3070 | 0.0730 | 0.4269 | 0.5000 |
| W730 | 20.7940 | 38.8080 | 0.0 | 1.5850 | 16.6640 | 0.0515 | 0.4269 | 0.5000 |
| W740 | 11.7280 | 41.4620 | 0.0 | 0.5379 | 8.8322 | 0.0651 | 0.4269 | 0.4802 |
| W750 | 20.8290 | 38.8080 | 0.0 | 0.7495 | 40.7430 | 0.0911 | 0.4269 | 0.5000 |
| W760 | 13.9500 | 38.8080 | 0.0 | 0.3925 | 20.4700 | 0.0439 | 0.4269 | 0.5000 |
| W770 | 20.8340 | 38.8130 | 0.0 | 0.1965 | 6.7676 | 0.0194 | 0.4377 | 0.4802 |
| W780 | 10.5360 | 44.0600 | 0.0 | 0.5478 | 19.7820 | 0.0976 | 0.4269 | 0.5000 |
| W790 | 12.5520 | 40.6510 | 0.0 | 0.4027 | 32.1290 | 0.0827 | 0.4269 | 0.5000 |
| W800 | 23.8790 | 44.3530 | 0.0 | 0.1984 | 6.9972 | 0.0060 | 0.2977 | 0.4706 |
| W810 | 13.9550 | 38.8080 | 0.0 | 0.4645 | 54.0230 | 0.0910 | 1.0000 | 0.5000 |
| W820 | 20.7940 | 38.8080 | 0.0 | 0.6699 | 23.7680 | 0.0865 | 0.6402 | 0.5000 |
| W830 | 45.9510 | 38.8250 | 0.0 | 0.6092 | 21.0860 | 0.0358 | 0.4330 | 0.5000 |
| W840 | 11.6120 | 42.0260 | 0.0 | 0.8282 | 43.2890 | 0.1279 | 0.4355 | 0.5000 |
| W850 | 17.0230 | 42.1740 | 0.0 | 0.1937 | 10.2080 | 0.0281 | 0.4467 | 0.4802 |
| W860 | 31.0890 | 38.8080 | 0.0 | 0.2936 | 51.1810 | 0.0511 | 0.4355 | 0.5000 |
| W870 | 11.8630 | 47.8340 | 0.0 | 1.5643 | 81.9520 | 0.1349 | 0.4371 | 0.5000 |
| W880 | 3.7729 | 77.0970 | 0.0 | 6.8191 | 11.1290 | 0.0645 | 1.0000 | 0.5000 |
| W890 | 6.5294 | 51.7420 | 0.0 | 0.1765 | 8.9785 | 0.0475 | 0.4466 | 0.4802 |
| W900 | 20.6990 | 38.7110 | 0.0 | 0.5917 | 31.4870 | 0.0510 | 0.4355 | 0.5000 |
| W910 | 13.9520 | 38.8080 | 0.0 | 0.2915 | 23.2590 | 0.0550 | 0.4355 | 0.5000 |
| W920 | 12.7880 | 39.0800 | 0.0 | 0.4804 | 37.3990 | 0.0942 | 0.6534 | 0.5000 |
| W940 | 20.7980 | 38.8090 | 0.0 | 0.8897 | 102.8900 | 0.0978 | 0.4355 | 0.5000 |
| W950 | 13.9230 | 38.8080 | 0.0 | 0.2091 | 36.7880 | 0.0461 | 0.4408 | 0.5000 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| W960 | 20.8240 | 38.8080 | 0.0 | 0.2928 | 22.8640 | 0.0325 | 0.5111 | 0.5000 |
| W970 | 20.7730 | 38.8080 | 0.0 | 0.5349 | 27.9260 | 0.0381 | 0.4355 | 0.5000 |
| W980 | 2.4278 | 93.7230 | 0.0 | 0.1543 | 5.1259 | 0.0136 | 0.2904 | 0.3137 |
| W990 | 20.0290 | 38.8130 | 0.0 | 0.3329 | 39.4750 | 0.0243 | 0.4464 | 0.5000 |

# Annex 10. Bongabong Model Reach Parameters

Table A-10.1. **Bongabong Model Reach Parameters**

| REACH | MUSKINGUM CUNGE CHANNEL ROUTING | | | | | | |
|---|---|---|---|---|---|---|---|
| | Time Step Method | Length (M) | Slope(M/M) | Manning's n | Shape | Width (M) | Side Slope (xH:1V) |
| R110 | Automatic Fixed Interval | 4322.7 | 0.0212813 | 0.0036 | Trapezoid | 40 | 1 |
| R1110 | Automatic Fixed Interval | 1516.4 | 0.0012211 | 0.0036 | Trapezoid | 40 | 1 |
| R1160 | Automatic Fixed Interval | 11548 | 0.0051693 | 0.0036 | Trapezoid | 40 | 1 |
| R130 | Automatic Fixed Interval | 2011.7 | 0.0141579 | 0.0036 | Trapezoid | 40 | 1 |
| R150 | Automatic Fixed Interval | 5949.3 | 0.0467878 | 0.0036 | Trapezoid | 40 | 1 |
| R160 | Automatic Fixed Interval | 197.99 | 0.0467878 | 0.0036 | Trapezoid | 40 | 1 |
| R170 | Automatic Fixed Interval | 855.69 | 0.0224227 | 0.0036 | Trapezoid | 40 | 1 |
| R20 | Automatic Fixed Interval | 3307.4 | 0.0246047 | 0.0036 | Trapezoid | 40 | 1 |
| R210 | Automatic Fixed Interval | 2527.5 | 0.0147726 | 0.0036 | Trapezoid | 40 | 1 |
| R220 | Automatic Fixed Interval | 2085.2 | 0.0783992 | 0.0036 | Trapezoid | 40 | 1 |
| R250 | Automatic Fixed Interval | 4570.3 | 0.0083194 | 0.0036 | Trapezoid | 40 | 1 |
| R260 | Automatic Fixed Interval | 893.26 | 0.0173780 | 0.0036 | Trapezoid | 40 | 1 |
| R280 | Automatic Fixed Interval | 1814.6 | 0.0112009 | 0.0036 | Trapezoid | 40 | 1 |
| R30 | Automatic Fixed Interval | 1463.3 | 0.0472860 | 0.0036 | Trapezoid | 40 | 1 |
| R300 | Automatic Fixed Interval | 5095.5 | 0.0431915 | 0.0036 | Trapezoid | 40 | 1 |
| R330 | Automatic Fixed Interval | 5109.4 | 0.0098821 | 0.0036 | Trapezoid | 40 | 1 |
| R360 | Automatic Fixed Interval | 2886.9 | 0.0099558 | 0.0036 | Trapezoid | 40 | 1 |
| R370 | Automatic Fixed Interval | 3052.8 | 0.0542404 | 0.0036 | Trapezoid | 40 | 1 |
| R390 | Automatic Fixed Interval | 1204.6 | 0.0170020 | 0.0036 | Trapezoid | 40 | 1 |
| R420 | Automatic Fixed Interval | 2005.1 | 0.0228250 | 0.0036 | Trapezoid | 40 | 1 |
| R430 | Automatic Fixed Interval | 1668.8 | 0.0073842 | 0.0036 | Trapezoid | 40 | 1 |
| R440 | Automatic Fixed Interval | 1602.3 | 0.0116300 | 0.0036 | Trapezoid | 40 | 1 |
| R450 | Automatic Fixed Interval | 3750.0 | 0.0179127 | 0.0036 | Trapezoid | 40 | 1 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| R460 | Automatic Fixed Interval | 1079.2 | 0.0125382 | 0.0036 | Trapezoid | 40 | 1 |
| R480 | Automatic Fixed Interval | 5902.4 | 0.0039049 | 0.04 | Trapezoid | 40 | 1 |
| R500 | Automatic Fixed Interval | 903.97 | .00063754 | 0.04 | Trapezoid | 40 | 1 |
| R80 | Automatic Fixed Interval | 3513.6 | 0.0418013 | 0.0036 | Trapezoid | 40 | 1 |
| R90 | Automatic Fixed Interval | 5222.9 | 0.0227292 | 0.0036 | Trapezoid | 40 | 1 |

## Annex 11. Bongabong Field Validation Points

Table A-11.1. Bongabong Field Validation Points

| Point Number | Validation Coordinates | | Model Var (m) | Validation Points (m) | Error | Event/Date | Rain Return/ Scenario |
|---|---|---|---|---|---|---|---|
| | Latitude | Longitude | | | | | |
| 1 | 12.6647230 | 121.4365200 | 1.76 | 1.28 | -0.48 | Unding / November 2004 | 25-Year |
| 2 | 12.6718520 | 121.4912420 | 0.52 | 0.85 | 0.33 | Yolanda / November 2013 | 25-Year |
| 3 | 12.6719820 | 121.4912230 | 0.31 | 0.00 | -0.31 | | 25-Year |
| 4 | 12.6719540 | 121.4854140 | 1.24 | 0.30 | -0.94 | Yolanda / November 2013 | 25-Year |
| 5 | 12.6720320 | 121.4919380 | 0.71 | 0.14 | -0.57 | Typhoon / 1993 | 25-Year |
| 6 | 12.6720700 | 121.4907940 | 0.84 | 0.00 | -0.84 | | 25-Year |
| 7 | 12.6720770 | 121.4900020 | 0.57 | 0.00 | -0.57 | | 25-Year |
| 8 | 12.6721180 | 121.4916210 | 0.63 | 0.35 | -0.28 | Typhoon / 1993 | 25-Year |
| 9 | 12.6721160 | 121.4889630 | 0.64 | 0.93 | 0.29 | Yolanda / November 2013 | 25-Year |
| 10 | 12.6721340 | 121.4906600 | 0.81 | 0.07 | -0.74 | Yolanda / November 2013 | 25-Year |
| 11 | 12.6721370 | 121.4901710 | 0.70 | 0.00 | -0.70 | | 25-Year |
| 12 | 12.6721610 | 121.4845950 | 1.54 | 0.06 | -1.48 | Yolanda / November 2013 | 25-Year |
| 13 | 12.6722750 | 121.4879060 | 1.56 | 2.75 | 1.19 | Yolanda / November 2013 | 25-Year |
| 14 | 12.6724850 | 121.4927440 | 0.94 | 0.32 | -0.62 | Nona / December 2015 | 25-Year |
| 15 | 12.6725600 | 121.4923920 | 0.88 | 0.00 | -0.88 | | 25-Year |
| 16 | 12.6733940 | 121.4941660 | 0.75 | 0.14 | -0.61 | Nona / December 2015 | 25-Year |
| 17 | 12.6735950 | 121.4832580 | 0.87 | 1.06 | 0.19 | Unding / November 2004 | 25-Year |
| 18 | 12.6740510 | 121.4949530 | 0.79 | 0.42 | -0.37 | Nona / December 2015 | 25-Year |
| 19 | 12.6743770 | 121.4950530 | 0.99 | 0.45 | -0.54 | Unding / November 2004 | 25-Year |
| 20 | 12.6740910 | 121.4447680 | 0.03 | 0.12 | 0.09 | Ondoy / Sept. 26, 2009 | 25-Year |
| 21 | 12.6744200 | 121.4945260 | 0.87 | 0.93 | 0.06 | Typhoon / 1993 | 25-Year |
| 22 | 12.6741950 | 121.4416010 | 2.09 | 0.35 | -1.74 | Yolanda / Nov. 8, 2013 | 25-Year |
| 23 | 12.6747590 | 121.4967190 | 0.96 | 0.00 | -0.96 | | 25-Year |
| 24 | 12.6754680 | 121.5018180 | 0.54 | 0.00 | -0.54 | | 25-Year |
| 25 | 12.6755880 | 121.4948850 | 0.45 | 0.46 | 0.01 | | 25-Year |
| 26 | 12.6758390 | 121.5000150 | 0.96 | 0.20 | -0.76 | | 25-Year |
| 27 | 12.6754440 | 121.4269380 | 0.06 | 0.58 | 0.52 | Yolanda / Nov. 8, 2013 | 25-Year |
| 28 | 12.6759760 | 121.5011580 | 0.88 | 0.60 | -0.28 | Typhoon / 1993 | 25-Year |
| 29 | 12.6760020 | 121.5002490 | 0.79 | 0.32 | -0.47 | Typhoon / 1993 | 25-Year |
| 30 | 12.6760150 | 121.4983240 | 0.63 | 0.00 | -0.63 | | 25-Year |
| 31 | 12.6761080 | 121.4998890 | 0.88 | 0.40 | -0.48 | Typhoon / 1993 | 25-Year |
| 32 | 12.6761220 | 121.4986470 | 0.67 | 0.33 | -0.34 | Typhoon / 1993 | 25-Year |
| 33 | 12.6763160 | 121.4994160 | 0.86 | 0.45 | -0.41 | Typhoon / 1993 | 25-Year |
| 34 | 12.6764510 | 121.4819120 | 0.15 | 0.90 | 0.75 | Yolanda / Nov. 8, 2013 | 25-Year |
| 35 | 12.6769890 | 121.5045470 | 0.50 | 0.10 | -0.40 | Nona / December 2015 | 25-Year |
| 36 | 12.6769740 | 121.4179700 | 0.13 | 0.00 | -0.13 | Ondoy / Sept. 26, 2009 | 25-Year |
| 37 | 12.6775290 | 121.5046890 | 0.77 | 0.45 | -0.32 | Typhoon / 1993 | 25-Year |
| 38 | 12.6774850 | 121.4831270 | 0.39 | 0.66 | 0.27 | Yolanda / Nov. 8, 2013 | 25-Year |
| 39 | 12.6771940 | 121.4076820 | 1.22 | 0.44 | -0.78 | Atang | 25-Year |
| 40 | 12.6776420 | 121.4756070 | 0.06 | 0.00 | -0.06 | Caloy / May, 2006 | 25-Year |
| 41 | 12.6779020 | 121.4764070 | 0.10 | 0.00 | -0.10 | Yolanda / Nov. 8, 2013 | 25-Year |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 42 | 12.6782440 | 121.5054870 | 0.45 | 0.23 | -0.22 | | 25-Year |
| 43 | 12.6781450 | 121.4835310 | 0.48 | 0.15 | -0.33 | Yolanda / Nov. 8, 2013 | 25-Year |
| 44 | 12.6783440 | 121.5052520 | 0.83 | 0.39 | -0.44 | Trining | 25-Year |
| 45 | 12.6788570 | 121.5050920 | 0.50 | 0.36 | -0.14 | Unding / November 2004 | 25-Year |
| 46 | 12.6790020 | 121.5058610 | 0.45 | 0.32 | -0.13 | Yolanda / November 2013 | 25-Year |
| 47 | 12.6791530 | 121.5070160 | 0.14 | 0.00 | -0.14 | | 25-Year |
| 48 | 12.6792470 | 121.5064560 | 0.31 | 0.00 | -0.31 | | 25-Year |
| 49 | 12.6792640 | 121.5077710 | 0.20 | 0.09 | -0.11 | Yolanda / November 2013 | 25-Year |
| 50 | 12.6792850 | 121.5066720 | 0.28 | 0.51 | 0.23 | Typhoon / 1993 | 25-Year |
| 51 | 12.6793120 | 121.5072860 | 0.08 | 0.00 | -0.08 | | 25-Year |
| 52 | 12.6787430 | 121.4000210 | 1.87 | 0.72 | -1.15 | Yolanda / Nov. 8, 2013 | 25-Year |
| 53 | 12.6788100 | 121.3993420 | 1.76 | 0.46 | -1.3 | Yolanda / Nov. 8, 2013 | 25-Year |
| 54 | 12.6788910 | 121.3982170 | 1.27 | 0.24 | -1.03 | Caloy / May 2006 | 25-Year |
| 55 | 12.6795740 | 121.5078890 | 0.05 | 0.00 | -0.05 | | 25-Year |
| 56 | 12.6789510 | 121.3994080 | 1.94 | 0.25 | -1.69 | Yolanda / Nov. 8, 2013 | 25-Year |
| 57 | 12.6796450 | 121.4848690 | 0.65 | 0.53 | -0.12 | Yolanda / Nov. 8, 2013 | 25-Year |
| 58 | 12.6798840 | 121.5081870 | 0.38 | 0.46 | 0.08 | Typhoon / 1993 | 25-Year |
| 59 | 12.6800610 | 121.5085600 | 0.27 | 0.73 | 0.46 | | 25-Year |
| 60 | 12.6803600 | 121.5085010 | 0.17 | 0.00 | -0.17 | | 25-Year |
| 61 | 12.6807840 | 121.5087710 | 0.35 | 0.00 | -0.35 | | 25-Year |
| 62 | 12.6808330 | 121.4849140 | 0.24 | 0.92 | 0.68 | 2011 | 25-Year |
| 63 | 12.6814860 | 121.5091280 | 0.38 | 0.00 | -0.38 | | 25-Year |
| 64 | 12.6818190 | 121.5091720 | 0.39 | 0.00 | -0.39 | | 25-Year |
| 65 | 12.6818190 | 121.5091690 | 0.39 | 0.00 | -0.39 | | 25-Year |
| 66 | 12.6829510 | 121.4865980 | 0.03 | 0.00 | -0.03 | Yolanda / Nov. 8, 2013 | 25-Year |
| 67 | 12.6833400 | 121.4880370 | 0.03 | 0.00 | -0.03 | Yolanda / Nov. 8, 2013 | 25-Year |
| 68 | 12.6833970 | 121.4880170 | 0.03 | 0.18 | 0.15 | Yolanda / Nov. 8, 2013 | 25-Year |
| 69 | 12.6871100 | 121.4908210 | 0.08 | 0.91 | 0.83 | Yolanda / Nov. 8, 2013 | 25-Year |
| 70 | 12.6987340 | 121.5061520 | 0.45 | 0.10 | -0.35 | Yolanda / Nov. 2013 | 25-Year |
| 71 | 12.6989290 | 121.5143660 | 0.08 | 0.10 | 0.02 | Nona / Dec. 2015 | 25-Year |
| 72 | 12.7118880 | 121.4918700 | 0.41 | 0.49 | 0.08 | Nina / Dec. 2016 | 25-Year |
| 73 | 12.7123250 | 121.4900200 | 0.06 | 0.70 | 0.64 | Marce / Nov. 2016 | 25-Year |
| 74 | 12.7137530 | 121.4967300 | 0.23 | 0.10 | -0.13 | Yolanda / Nov. 2013 | 25-Year |
| 75 | 12.7176570 | 121.4992470 | 0.03 | 0.00 | -0.03 | Marce / Nov. 2016 | 25-Year |
| 76 | 12.7193890 | 121.5028470 | 0.66 | 0.27 | -0.39 | Yolanda / Nov. 2013 | 25-Year |
| 77 | 12.7298130 | 121.4945600 | 0.81 | 0.44 | -0.37 | Yolanda / Nov. 2013 | 25-Year |

# Annex 12. Phil-LiDAR 1 UPLB Team Composition

**Project Leader**
Asst. Prof. Edwin R. Abucay (CHE, UPLB)

**Project Staffs/Study Leaders**
Asst. Prof. Efraim D. Roxas (CHE, UPLB)
Asst. Prof. Joan Pauline P. Talubo (CHE, UPLB)
Ms. Sandra Samantela (CHE, UPLB)
Dr. Cristino L. Tiburan (CFNR, UPLB)
Engr. Ariel U. Glorioso (CEAT, UPLB)
Ms. Miyah D. Queliste (CAS, UPLB)
Mr. Dante Gideon K. Vergara (SESAM, UPLB)

**Sr. Science Research Specialists**
Gillian Katherine L. Inciong
For. John Alvin B. Reyes

**Research Associates**
Alfi Lorenz B. Cura
Angelica T. Magpantay
Gemmalyn E. Magnaye
Jayson L. Arizapa
Kevin M. Manalo
Leendel Jane D. Punzalan
Maria Michaela A. Gonzales
Paulo Joshua U. Quilao
Sarah Joy A. Acepcion
Raphael P. Gonzales

**Computer Programmers**
Ivan Marc H. Escamos
Allen Roy C. Roberto

**Information Systems Analyst**
Jan Martin C. Magcale

**Project Assistants**
Daisili Ann V. Pelegrina
Athena Mercado
Kaye Anne A. Matre
Randy P. Porciocula