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

LiDAR Surveys and Flood Mapping of Maragondon River

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Mapua Institute of Technology

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AAC	Asian Aerospace Corporation
Ab	abutment
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
ASTI	Advanced Science and Technology Institute
AWLS	Automated Water Level Sensor
BA	Bridge Approach
BM	benchmark
CAD	Computer-Aided Design
CN	Curve Number
CSRS	Chief Science Research Specialist
DA	Department of Agriculture
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
MIT	Mapúa Institute of Technology
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
RBCO	River Basin Control Office
RIDF	Rainfall-Intensity-Duration-Frequency
RMSE	Root Mean Square Error
SAR	Synthetic Aperture Radar
SCS	Soil Conservation Service
SRTM	Shuttle Radar Topography Mission
SRS	Science Research Specialist
SSG	Special Service Group
TBC	Thermal Barrier Coatings
UP-TCAGP	University of the Philippines – Training Center for Applied Geodesy and Photogrammetry
UTM	Universal Transverse Mercator
WGS	World Geodetic System

CHAPTER 1: OVERVIEW OF THE PROGRAM AND MARAGONDON RIVER

Enrico C. Paringit, Dr. Eng., Dr. Francis Aldrine Uy, and Engr. Fibor Tan

1.1 Background of the Phil-LiDAR 1 Program

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

The program was also aimed at producing an up-to-date and detailed national elevation dataset suitable for a 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 the 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), available separately.

The implementing partner university for the Phil-LiDAR 1 Program is the Mapúa Institute of Technology (MIT). MIT 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 twenty-six (26) river basins in the Southern Tagalog Region. The university is located in the City of Manilain the National Capital Region (NCR).

1.2 Overview of the Maragondon River Basin

The Maragondon River Basin is located in the Municipality of Maragondon in the province of Cavite. The river basin is one of the six major river basins of Cavite. It is one of the largest, having a total area of 357 square kilometers with an irrigable range of around five percent (5%). According to the Department of Environment and Natural Resources – River Basin Control Office (DENR-RCBO), the Maragondon River Basin has an estimated annual run-off of 542 million cubic meters (MCM), with a drainage area of 339 square kilometers.

The basin's main stem, the Maragondon River, is one of the river systems in the Southern Tagalog Region. It drains the upland municipalities of General Aguinaldo, Magallanes, Alfonso, and Indang. Its main channel intersects with the Municipality of Maragondon, releasing volumes of freshwater into the Manila Bay.

Most of the areas found within the river basin are in the highlands, but most of the urbanized sections are in low-lying surfaces, and are flood-prone.

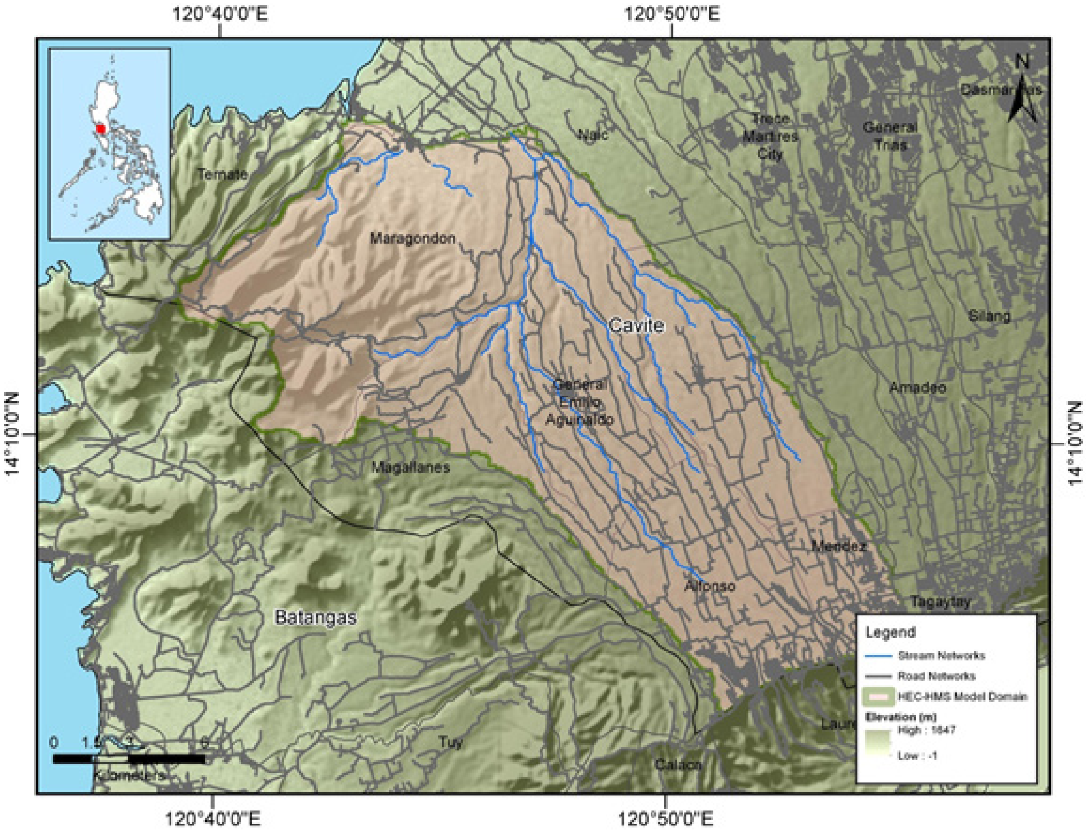

Figure 1. Location map of the Maragondon River Basin (in brown)

The total population of residents within the immediate vicinity of the river which is 37,455, which are distributed in the Municipalities of General Emilio Aguinaldo, Maragondon, and Ternate.
The river remains to be a healthy and conducive habitat for marine life, such as fish, shrimp, and seaweeds. Freshwater fish species include mackerel (including the short-bodied mackerel, or hasa-hasa), nemipteridae, grouper, squid, and tuna. However, fishing in Maragondon River is limited in scope, as much of the fishery resources of the municipality are still untapped..

Settlements in the area face a constant threat of flooding due to heavy and sustained rainfall caused by typhoons in the recent years. These include Typhoon Ondoy in 2009, Typhoon Gorio in 2013, and Typhoon Glenda in 2014. Such flooding events have required all affected families in the province of Cavite to evacuate to safer ground. While evacuation does provide aid to those that have been displaced, it is but a temporary solution.

Generating flood hazard maps through the Phil-LiDAR 1 Program could significantly contribute to identifying flood-prone areas within the river basin. Several technologies have been employed to produce the said flood hazard maps. One is the introduction of Light Detection and Ranging (LiDAR) data, which primarily contains the elevation values used to derive the Digital Elevation Model (DEM). From these elevation values, one can infer the presence and behavior of waterbodies (e.g., rivers, streams, ponds, and lakes) and structures (e.g., roads, bridges, and buildings). In addition to this, important data, such as discharge and rainfall events, gathered through fieldwork were used as inputs to form the hydrological model. The gathered data were utilized to generate hydrographs that were used to create the calibrated model. These generated outputs, along with the LiDAR data, were then applied as input for the generation of the river hydraulic model. The final outputs for these processes were the flood hazard maps for different return periods of the Maragondon River Basin.

The flood hazard map indicates the flood-prone areas within the river basin. Through the accuracy and precision of the LiDAR data, one is able to determine the flood height in a particular point or area. Furthermore, the local government units (LGUs) of the Municipalities of Ternate, Naic, and Maragondon in Cavite were aided on which types of flood mitigation measures can be applied in their respective municipalities, and would be beneficial in the long run. Thus, the flood hazard maps would enable community leaders to make the wisest decisions that could save many lives and properties.

CHAPTER 2: LIDAR DATA ACQUISITION OF THE MARAGONDON 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

To initiate the LiDAR acquisition survey of the Maragondon floodplain, the Data Acquisition Component (DAC) created flight plans within the delineated priority area for the floodplain in the Cavite Province. These missions were planned for nineteen (19) lines that ran for at most four and a half (4.5) hours, including take-off, landing, and turning time. The Pegasus, Gemini, and ALS-80 LiDAR systems were used in the missions (See Annex 1 for the sensor specifications). The flight planning parameters for the LiDAR systems are found in Table 1 to Table 3. Figure 2 illustrates the flight plans for the Maragondon floodplain survey.

Table 1. Flight planning parameters for the Pegasus LiDAR system

Block Name	Flying Height (AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed	Average Turn Time (Minutes)
BLK 18A	1000, 1100	30	50	200	50	130	5
BLK 18B	1000	30	50	200	50	130	5
BLK 18C	1000	30	50	200	50	130	5
BLK 18D	1000	30	50	200	50	130	5
BLK 18S	1200	30	50	200	30	130	5

Table 2. Flight planning parameters for the Gemini LiDAR system

Block Name	Flying Height (AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed	Average Turn Time (Minutes)
BLK 18SG	1000	40, 30	40	100	50	120	5
BLK 18SM	1000	40	40	100	50	120	5

Table 3. Flight planning parameters for the ALS-80 LiDAR system

Block Name	Flying Height (AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed	Average Turn Time (Minutes)
BLK 18AS	1500	30	45	128	42	130	5
BLK 18BS	1500	30	45	128	42	130	5

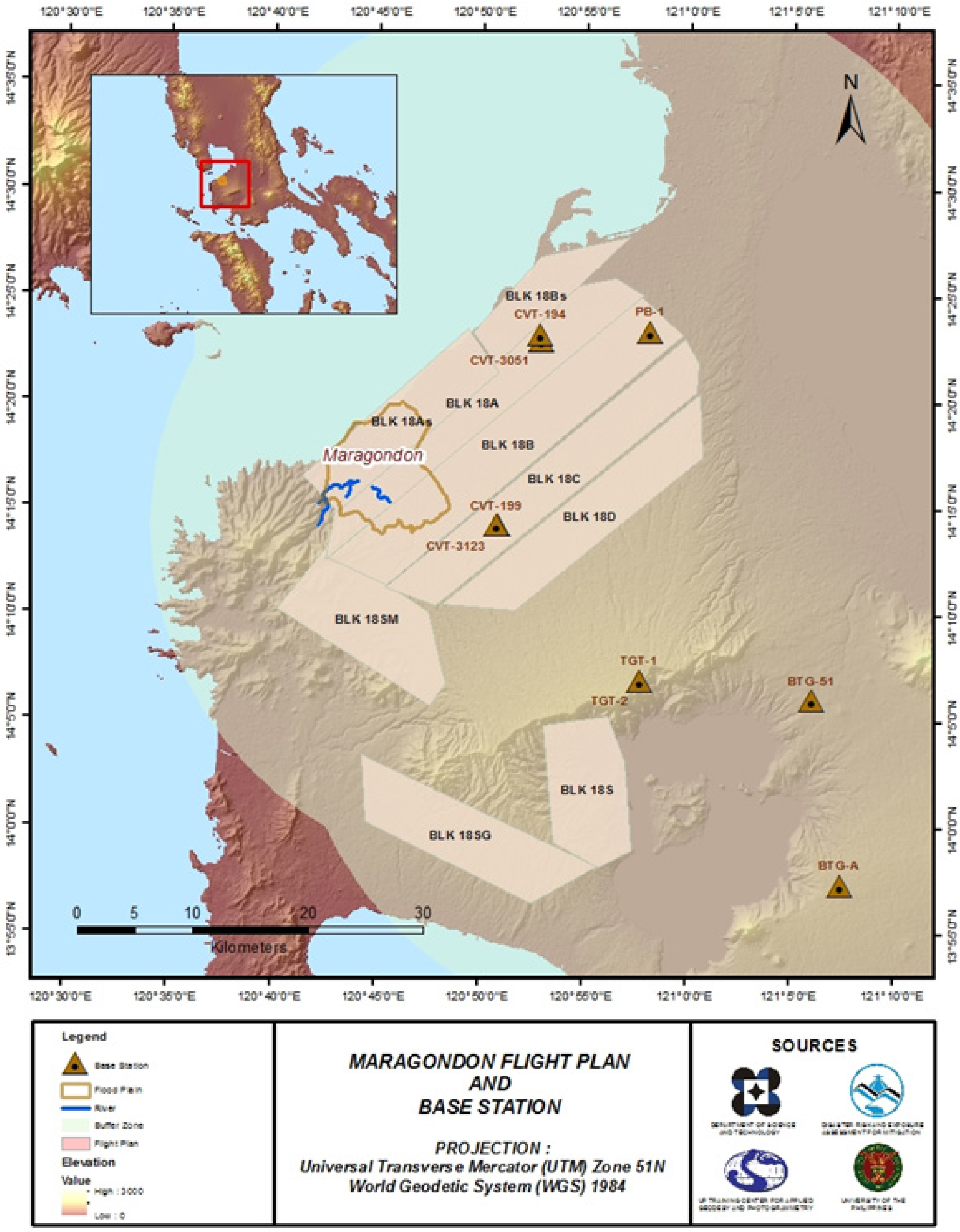
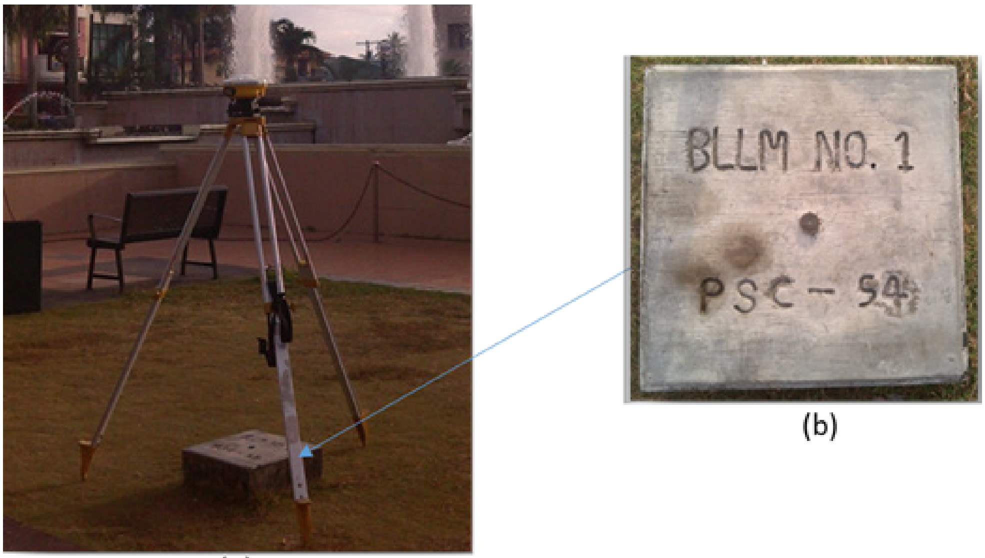


Figure 2. Flight plans and base stations used to cover the Maragondon floodplain survey

2.2 Ground Base Stations

The field team for this undertaking was able to recover five (5) NAMRIA ground control points: (i.) CVT-194, (ii.) CVT-199, and (iii.) BTG-51, which are of second (2nd) order accuracy; and (iv.) CVT-3051 and (v.) CVT-3123, which are reprocessed NAMRIA ground control points of fourth (4th) order accuracy. The project team established four (4) ground control points, BTG-1, TGT-1, TGT-2, and PB-1. The certifications for the NAMRIA reference points are found in Annex 2; while the processing reports for the reprocessed and established control points are found in Annex 3. These were used as the base stations during the flight operations for the entire duration of the survey, held on January 26 – February 3, 2014; on August 18, 2015; on January 7 – 8, 2016; and on May 7, 2016. The base stations were observed using dual frequency GPS receivers, TRIMBLE SPS852, TRIMBLE SPS882, and Topcon GR-5. The flight plans and locations of the base stations used during the aerial LiDAR acquisition in the Maragondon floodplain are shown in Figure 2. The composition of the full project team is given in Annex 4.

Figure 3 to Figure 7 exhibit the recovered NAMRIA reference points within the area. Table 4 to Table 12 provide the details about the NAMRIA control stations and established points. Table 13 lists all of the ground control points occupied during the acquisition, together with the corresponding dates of utilization.



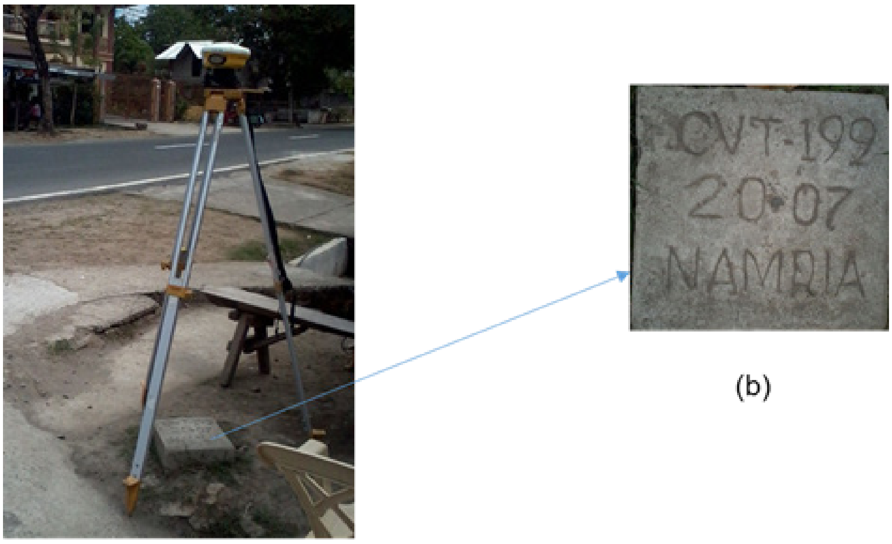
(b)

(a)

Figure 3. (a) GPS set-up over CVT-194 (BLLM NO.1 PSC-94) near the Municipal Hall of General Trias, Cavite; and (b) NAMRIA reference point CVT-194, as recovered by the field team

Table 4. Details of the recovered NAMRIA horizontal control point CVT-194, used as a base station for the LiDAR acquisition

Station Name	CVT-194	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	14° 23’ 15.01186” North 120° 52’ 43.52184” East 18.337 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92	Easting Northing	486924.253 meters 1591045.311 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	14°23 ’9.63386” North 120° 52’ 48.43458” East 62.184 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984	Easting Northing	271265.13 meters 1591537.44 meters



(a) (b)

Figure 4. (a) GPS set-up over CVT-199 found near the covered basketball covered court of Barangay Calumpang Lejos; and (b) NAMRIA reference point CVT-199, as recovered by the field team

Table 5. Details of the recovered NAMRIA horizontal control point CVT-199, used as a base station for the LiDAR acquisition

Station Name	CVT-199	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	14° 14' 16.32329" North 120° 50' 40.63536" East 166.20100 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting Northing	483231.789 meters 1574493.218 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	14° 14' 10.97763" North 120° 50' 45.56096" East 210.38600 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	267428.74 meters 1575012.80 meters

(a)

(b)

Figure 5. (a) GPS set-up over CVT-3051 in a concrete bridge leading to Manggahan, 70 m SE of Jetti Gas Station and about 250 m from General Trias Poblacion; and (b) NAMRIA reference point CVT-3051, as recovered by the field team

Table 6. Details of the recovered NAMRIA horizontal control point CVT-3051, used as a base station for the LiDAR acquisition, with reprocessed coordinates

Station Name	CVT-3051	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	14° 22’ 58.33330” North 120° 52’ 44.06059” East 21.122 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	14° 22’ 52.95639” North 120° 52’ 48.97372” East 64.983 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	7° 52’ 29.01321” N 271276.565 meters 1591024.612 meters

Figure 6. (a) GPS set-up over BTG-51, as recovered inside the vicinity of Mabini Shrine in Barangay Talaga, Tanuan City, Batangas; and (b) NAMRIA reference point BTG-51, as recovered by the field team

Table 7. Details of the established horizontal control point BTG-51, used as a base station for the LiDAR acquisition

Station Name	BTG-51	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	14° 06’ 08.57112” North 121° 05’ 52.31002” East 152.36900 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting Northing	510567.544 meters 1559501.067 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	14° 06’ 03.27790” North 121° 05’ 57.24592” East 197.55100 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	294641.94 meters 1559783.81 meters

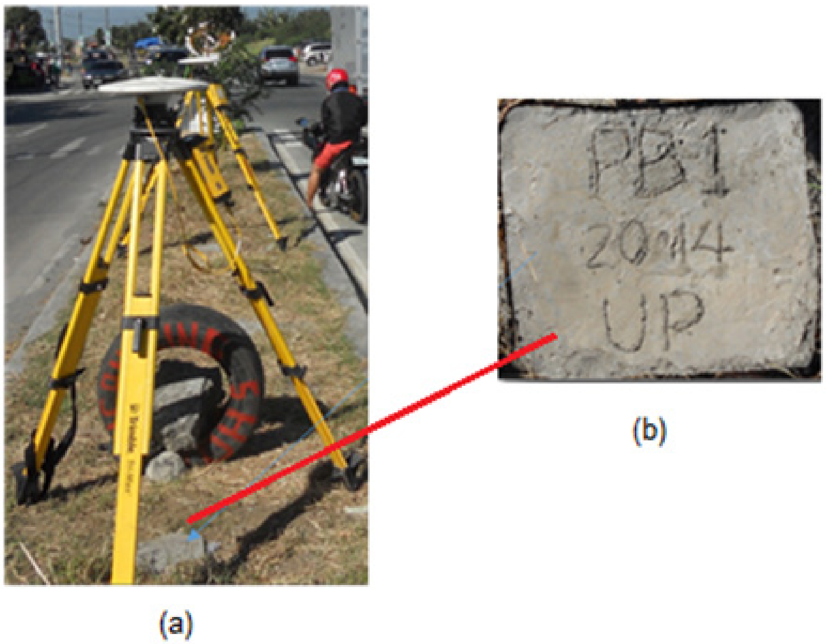


Figure 7. (a) GPS set-up over PB-1, as established in an elevated traffic island in Daang Hari Road, Imus, Cavite; and (b) reference point PB-1, as established by the field team

Table 8. Details of the established horizontal control point PB-1, used as a base station for the LiDAR acquisition

Station Name	PB-1	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	14° 23’ 19.56635” North 120° 58’ 04.29835” East 87.568 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	14° 23’ 19.56635” North 120° 58’ 04.29835“ East 87.568 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	280881.093 meters 1591688.776 meters

Table 9. Details of the recovered NAMRIA horizontal control point CVT-3123, used as a base station for the LiDAR acquisition, with reprocessed coordinates

Station Name	CVT-3123	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	14° 14' 15.59521" North 120° 50' 41.86474" East 167.527 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	14° 14' 10.24962" North 120° 50' 46.79435" East 211.713 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	267465.517 meters 1574990.072 meters

Table 10. Details of the established horizontal control point BTG-A, used as a base station for the LiDAR acquisition

Station Name	BTG-A	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	13° 57' 27.65020" North 121° 07' 18.59698" East 373.826 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 5 PRS 92)	Easting Northing	297103.192 meters 1543753.102 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13° 57' 22.39320" North 121° 07' 23.54499" East 419.466 meters

Table 11. Details of the established horizontal control point TGT-1, used as a base station for the LiDAR acquisition

Station Name	TGT-1	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	14° 07' 00.06528" North 120° 57' 38.31871" East 613.37000 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 5 PRS 92)	Easting Northing	279835.821 meters 1561490.819 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	14° 06' 54.75787" North 120° 57' 43.25375" East 93.60200 meters

Table 12. Details of the established horizontal control point TGT-2, used as a base station for the LiDAR acquisition

Station Name	TGT-2	
Order of Accuracy (vertical)	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	14° 07' 00.17316" North 120° 57' 38.32462" East 613.333 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting Northing	279836.028 meters 1561494.133 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	14° 06' 54.86474" North 120° 57' 43.25967" East 658.140 meters

Table 13. Ground control points used during the LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
26-Jan-14	1031P	1BLK18C026A	PB-1 and CVT-194
28-Jan-14	1039P	1BLK18B028A	PB-1 and CVT-194
29-Jan-14	1043P	1BLK18AS029A	PB-1 and CVT-194
3-Feb-14	1063P	1BLK18D034A	PB-1 and CVT-194
18-Aug-15	3309P	1BLK18AsS230A	CVT-3051
7-Jan-16	3681G	2BLK18SM007A	BTG-51, BTG-A, TGT-1 and TGT-2
8-Jan-16	3687G	2BLK18SGS008B	BTG-51, BTG-A, TGT-1 and TGT-2
7-May-16	10144L	4BLK18ABS128A	CVT-199 and CVT-3123

2.3 Flight Missions

Eight (8) missions were conducted to complete the LiDAR Data Acquisition in Maragondon Floodplain, for a total of twenty-five hours and twenty minutes (25+20) of flying time for RP-C9022 and RP-C9522. All missions were acquired using the Pegasus, Gemini and Leica ALS-80 HP LiDAR systems. Table 14 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 15 presents the actual parameters used during the LiDAR data acquisition.

Table 14. Flight missions for the LiDAR data acquisition in the Maragondon floodplain

Date Surveyed	Flight Number	Flight Plan Area (km2)	Surveyed Area (km2)	Area Surveyed within the Floodplain (km2)	Area Surveyed Outside the Floodplain (km2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
26-Jan-14	1031P	239.06	124.01	NA	124.01	NA	3	17
28-Jan-14	1039P	304.35	196.90	9.54	187.36	NA	3	17
29-Jan-14	1043P	224.69	64.44	24.10	40.34	NA	2	23
3-Feb-14	1063P	108.53	33.70	NA	33.7	346	2	59
18-Aug-15	3309P	224.69	113.87	16.13	97.74	NA	3	16
7-Jan-16	3681G	96.41	129.27	NA	129.27	NA	3	41
8-Jan-16	3687G	197.59	127.71	NA	127.71	NA	2	59
7-May-16	10144L	133.24	53.35	3.13	50.22	195	3	28
TOTAL		1528.56	843.25	52.9	790.35	541	25	20

Table 15. Actual parameters used during the LiDAR data acquisition

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (khz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
1031P	1000	30	50	200	30	130	5
1039P	1000	30	50	200	30	130	5
1043P	1000	30	50	200	30	130	5
1063P	1000	30	50	200	30	130	5
3309P	1100	30	50	200	30	130	5
3681G	850	30	40	100	30	130	5
3687G	1000	40	40	100	50	120	5
10144L	1500	30	45	128	42	130	5

2.4 Survey Coverage

The Maragondon floodplain is located in the province of Cavite, with majority of the floodplain situated within the Municipalities of Maragondon and Naic. The Municipalities of Trece Martires City, Magallanes, General Trias, and Tanza were mostly covered by the survey. The municipalities and cities surveyed, with at least one (1) square kilometer coverage, are enumerated in Table 16. The actual coverage of the LiDAR acquisition for the Maragondon floodplain is presented in Figure 8. See Annex 7 for the flight status reports.

Table 16. List of municipalities and cities surveyed during the Maragondon floodplain LiDAR survey

Province	City/Municipality	Area of Munici-pality/ City (km2)	Total Area Surveyed (km2	Percentage of Area Surveyed
Batangas	Calaca	117.85	47.08	39.95%
	Lemery	82.32	24.68	29.98%
	Tuy	92.55	20.9	22.58%
	Nasugbu	266.83	30.41	11.40%
	Balayan	94.45	8	8.47%
	Agoncillo	39.54	1.34	3.39%
Cavite	Trece Martires City	44.35	44.2	99.66%
	Magallanes	69.07	67.31	97.45%
	General Trias	85.98	75.69	88.03%
	Tanza	71.41	58.6	82.06%
	Dasmariñas	84.01	66.72	79.42%
	Naic	76.11	57.49	75.54%
	General Emilio Aguinaldo	39.39	26.62	67.58%
	Maragondon	147.39	88.33	59.93%
	Rosario	4.89	2.56	52.35%
	Bacoor	47.43	17.81	37.55%
	Imus	56.81	20.79	36.60%
	Indang	88.65	25.56	28.83%
	Noveleta	5.72	1.21	21.15%
	Amadeo	45.9	4.05	8.82%
	Ternate	44.52	1.88	4.22%
	Alfonso	54.64	1.17	2.14%
	Silang	154	1.97	1.28%
Laguna	San Pedro	21.41	2.73	12.75%
Metro Manila	Las Piñas	33.19	4.14	12.47%
	Muntinlupa	38.52	7.91	20.53%
Total		1906.93	709.15	38.62%

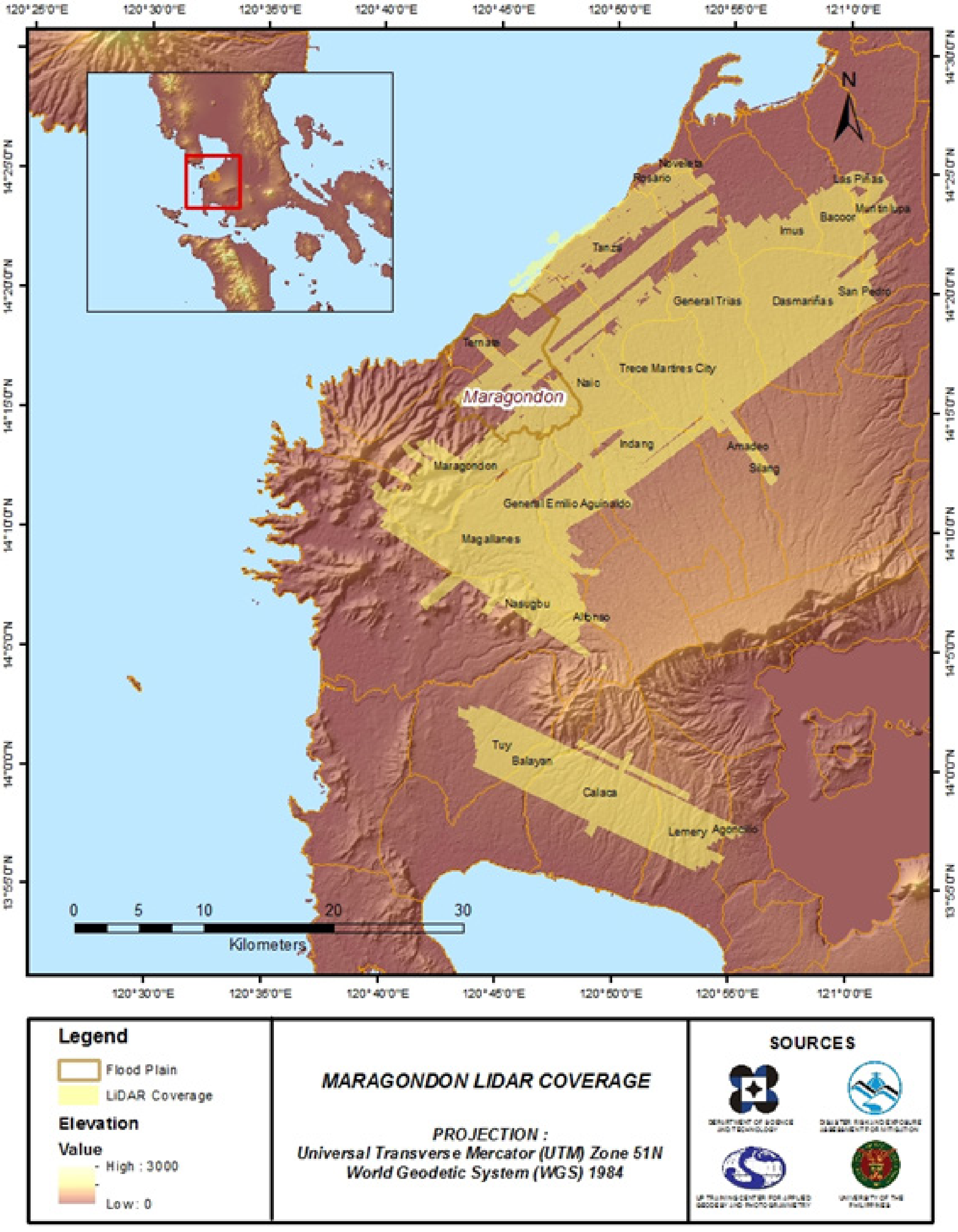


Figure 8. Actual LiDAR survey coverage of the Maragondon floodplain

CHAPTER 3: LIDAR DATA PROCESSING OF THE MARAGONDON FLOODPLAIN

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

3.1 Overview of the LIDAR Data Pre-Processing

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

Using the elevation of points gathered from the field, the LiDAR-derived digital models were calibrated. Portions of the river that were barely penetrated by the LiDAR system were replaced by the actual river geometry, measured from the field by the Data Validation and Bathymetry Component (DVBC). LiDAR acquired temporally were then mosaicked to completely cover the target river systems in the Philippines. Orthorectification of images acquired simultaneously with the LiDAR data was obtained through the help of the georectified point clouds, and the metadata containing the time the image was captured.
These processes are summarized in the diagram in Figure 9.

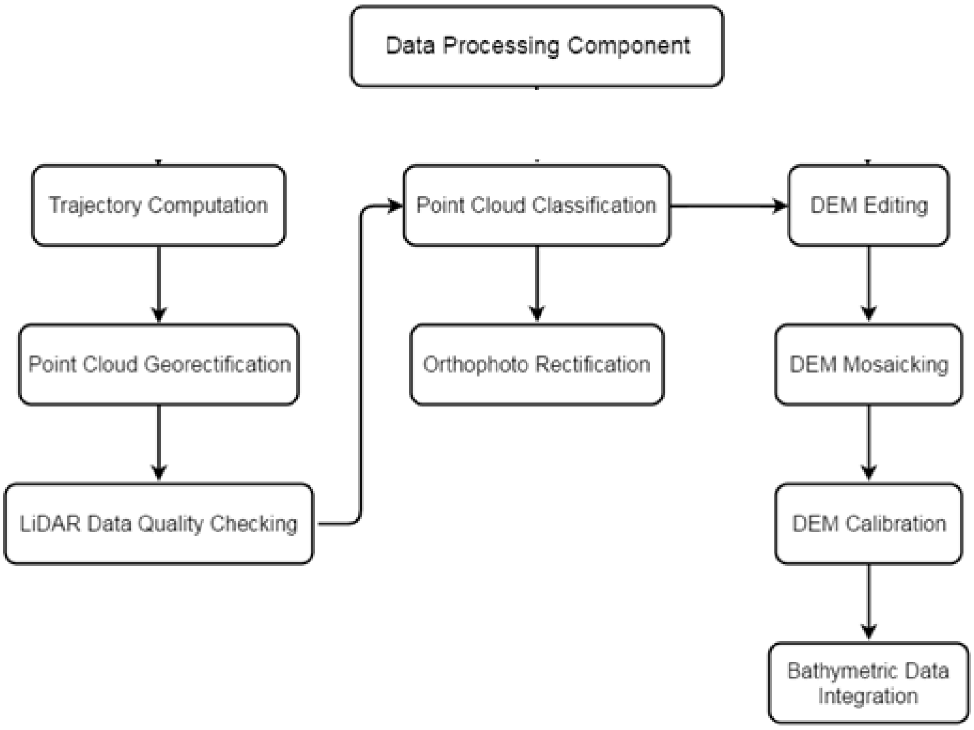

Figure 9. Schematic diagram for the Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

The data transfer sheets for all the LiDAR missions for the Maragondon floodplain can be found in Annex 5. Missions flown over Maragondon, Cavite used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system during the first survey conducted in January 2014, the Gemini system during the second survey in January 2016, and the Leica system during the third survey in June 2016. The DAC transferred a total of 147.03 Gigabytes of Range data, 1.78 Gigabytes of POS data, and 99.84 Megabytes of GPS base station data, and 55.65 Gigabytes of Image data to the data server from May 26, 2014 until January 15, 2016 for the Optech LiDAR systems. On the other hand, a total of 19.46 Gigabytes of RawLaser data, 1,377 Megabytes of GNSSIMU data, 355 Megabytes of base station data, and 89.7 Gigabytes of RCD30 raw image data were transferred on June 20, 2016 for the Leica LiDAR system. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for the Maragondon survey was fully transferred on June 20, 2016, as indicated on the data transfer sheets for the Maragondon floodplain.

3.2 Transmittal of Acquired LiDAR Data

The Smoothed Performance Metrics of the computed trajectory for Flight 3681G, one of the Maragondon flights, which are the North, East, and Down position RMSE values, are illustrated in Figure 10. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which fell on January 3, 2016 at 00:00 hrs. on that week. The y-axis represents the RMSE value for that particular position.

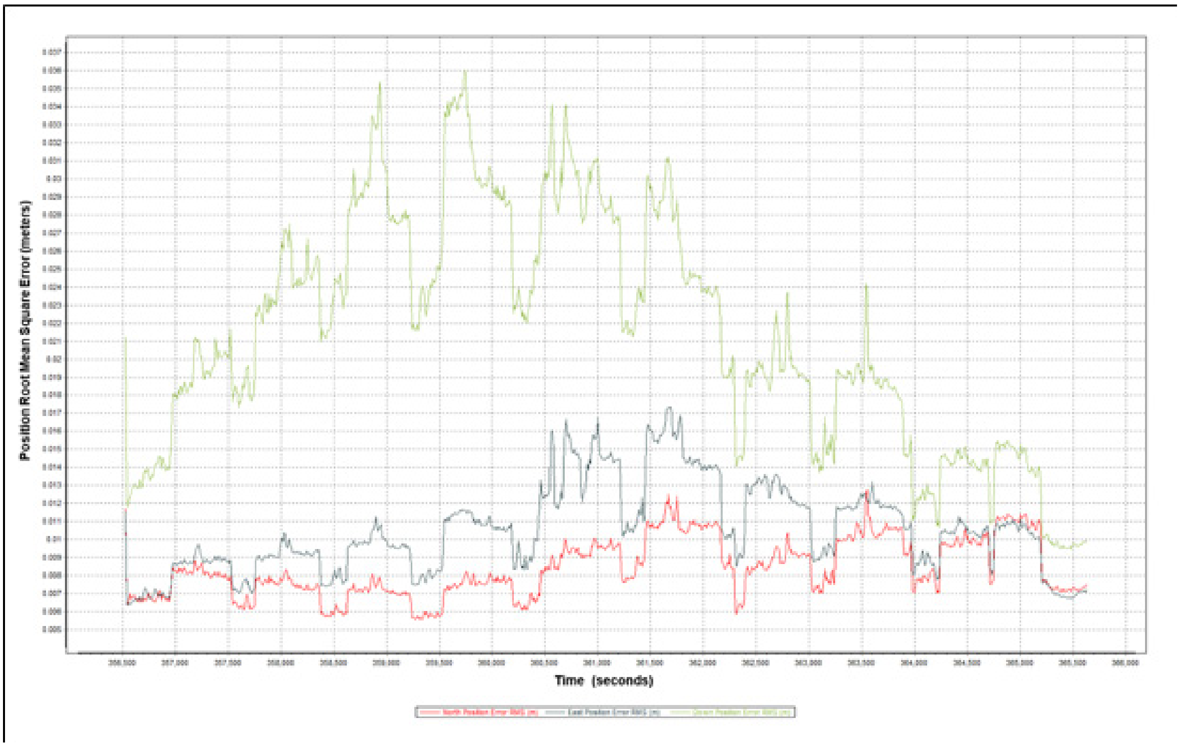

Figure 10. Smoothed Performance Metrics of Maragondon Flight 3681G.

The time of flight was from 356500 seconds to 365500 seconds, which corresponds to the morning of January 7, 2016. The initial spike reflected on the data indicates the time that the aircraft was getting into position to start the acquisition, and the POS system was starting to compute for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE values of the positions. The periodic increase in RMSE values from an otherwise smoothly curving set of RMSE values corresponds to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 10 demonstrates that the North position RMSE peaked at 1.30 centimeters, the East position RMSE peaked at 1. 70 centimeters, and the Down position RMSE peaked at 3.60 centimeters, which are within the prescribed accuracies described in the methodology.

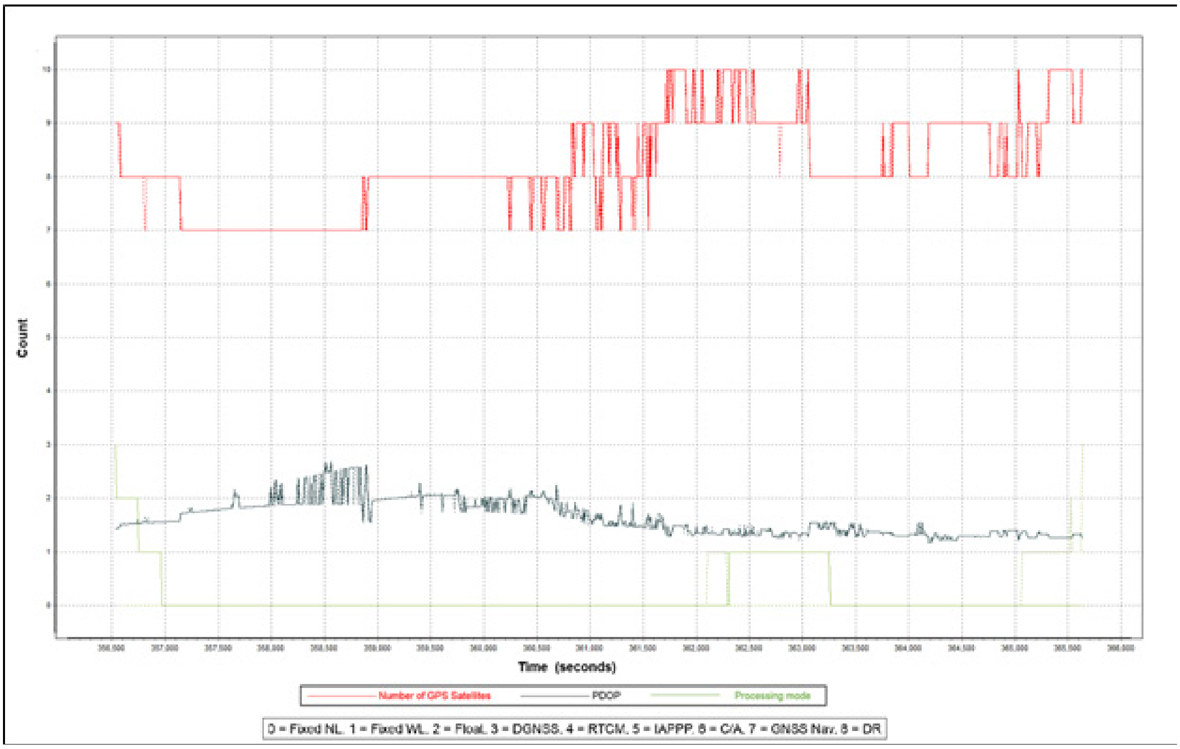

Figure 11. Solution Status Parameters of Maragondon Flight 3681G

The Solution Status parameters of Flight 3681G, one of the Maragondon flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are presented in Figure 11. 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 7 and 10. The PDOP value did not go above the value of 3, which indicates optimal GPS geometry. The processing mode remained at the value of 0 for majority of the survey, with some to 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 satisfied the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Maragondon flights is depicted in Figure 12.

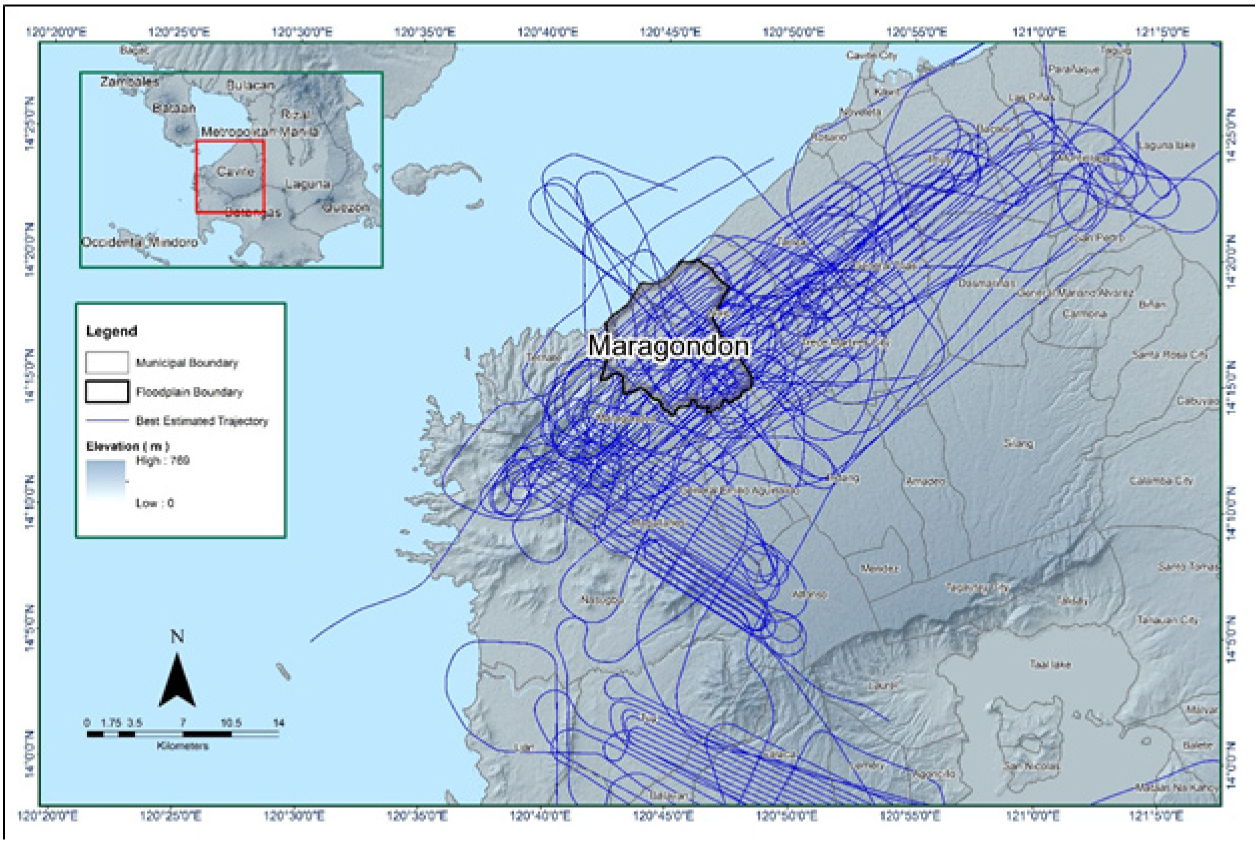

Figure 12. Best Estimated Trajectory for Maragondon Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 91 flight lines, with each flight line containing either one or two channels, since the Gemini system contains one channel while the Pegasus and Leica systems contain two. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Maragondon floodplain are given in Table 17.

Table 17. Self-calibration results for the Maragondon flights

Parameter	Computed Value
Boresight Correction stdev (<0.001degrees)	0.000453
IMU Attitude Correction Roll and Pitch Corrections stdev (<0.001degrees)	0.000946
GPS Position Z-correction stdev (<0.01meters)	0.0019

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

3.5 LiDAR Data Quality Checking

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

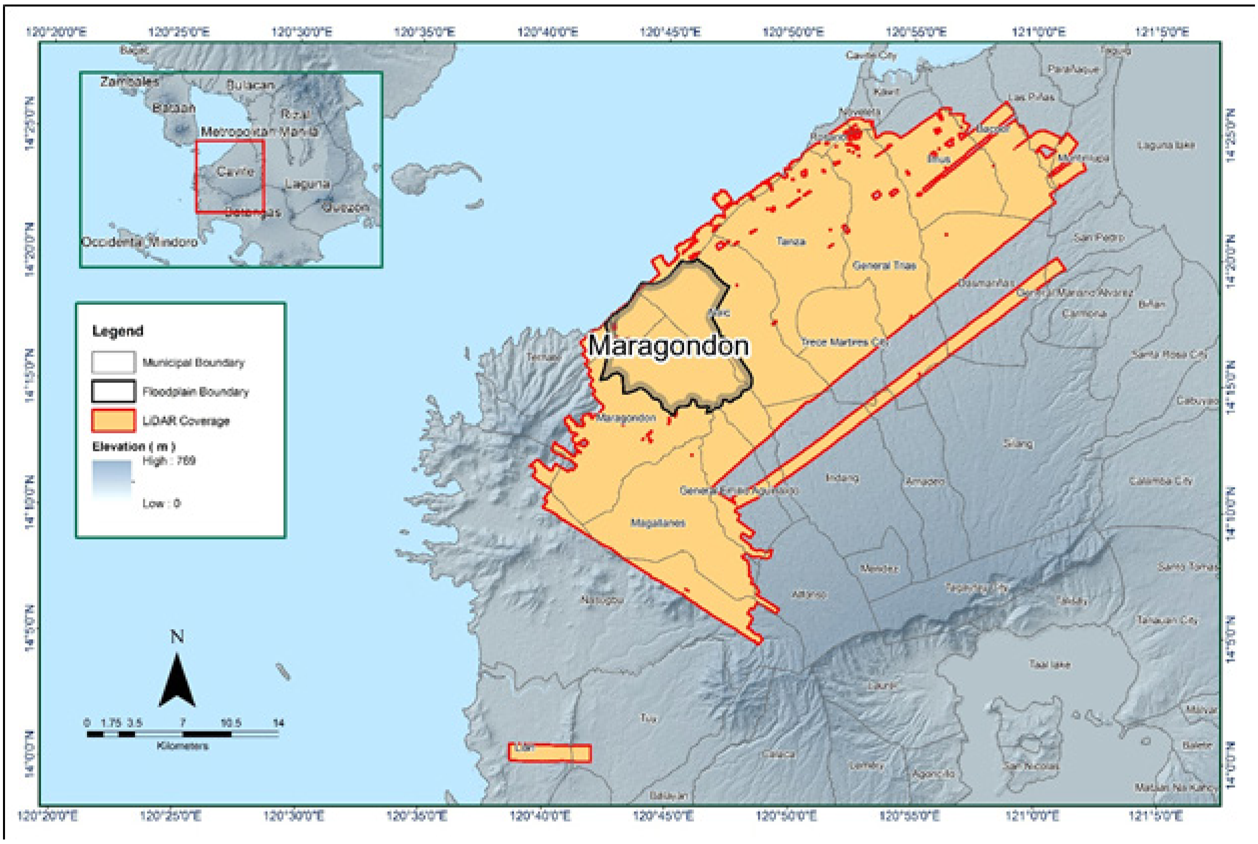

Figure 13. Boundary of the processed LiDAR data over Maragondon Floodplain

The total area covered by the Maragondon missions is 1016.24 sq.km that is comprised of twelve (12) flight acquisitions grouped and merged into nine (9) blocks as shown in Table 18.

Table 18. List of LiDAR blocks for Maragondon Floodplain

LiDAR Blocks	Flight Numbers	Area (sq km)
CALABARZON_Blk18B_supplement	3309P	106.91
CALABARZON_reflights_Blk18A_ supplement	10144L	53.33
CALABARZON_reflights_Blk18A	10136L	229.66
	10142L	
Cavite_Blk18C_additional	1039P	210.76
	1063P	
Cavite_Blk18AB	1031P	127.12
	1035P	
Cavite_Blk18A_supplement	1043P	56.96
Cavite_Blk18ABC_supplement	1137P	82.42
Batangas_Blk18SM	3681G	125.46
Batangas_Blk18SM_supplement	3687G	23.62
TOTAL		1016.24 sq.km.

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 14. Since the Gemini system employs one channel, we would expect an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines. While for the Pegasus and Leica systems which employ two channels, we would expect an average value of 2 (blue) for areas where there is limited overlap and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines.

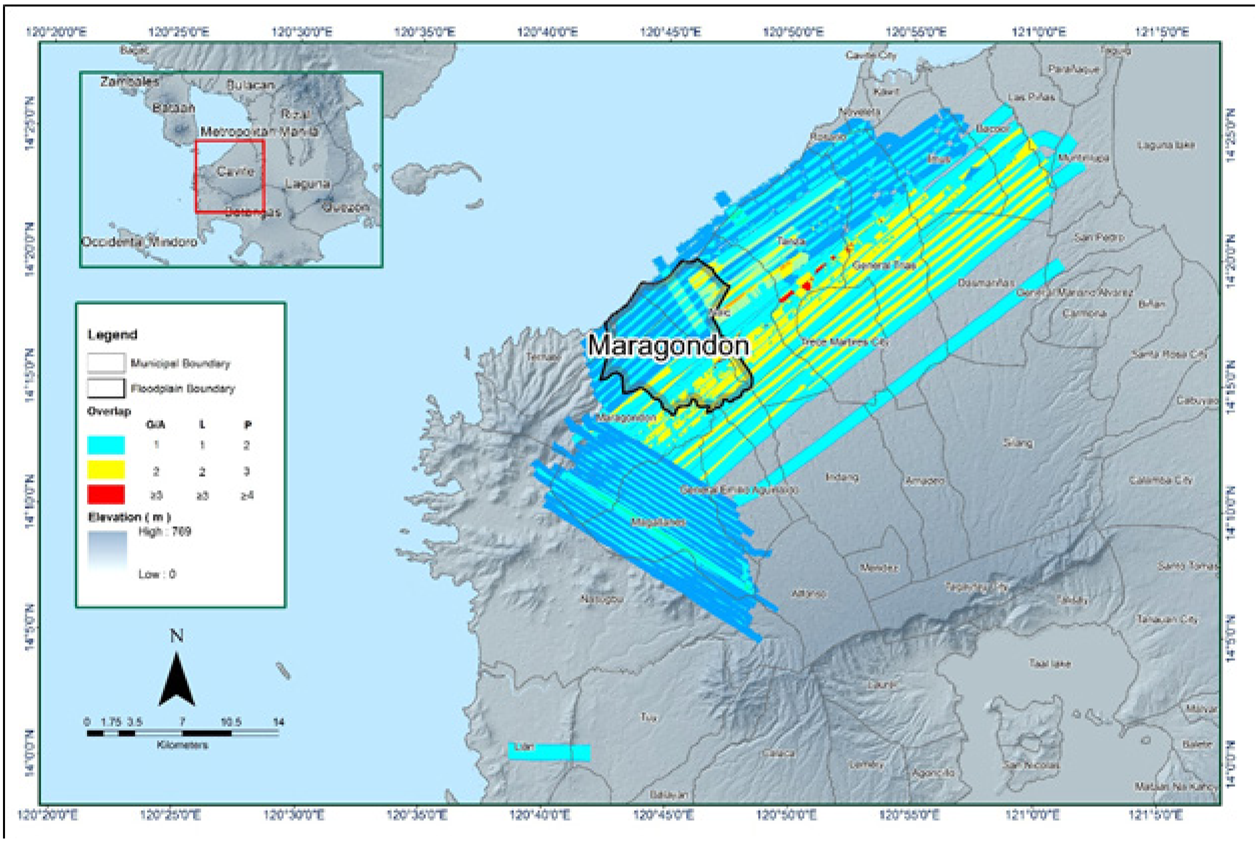

Figure 14. Image of data overlap for Maragondon Floodplain

The overlap statistics per block for the Salug Diut Floodplain can be found in Annex 8. It should be noted that one pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 30.63% and 51.19% respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion, is shown in Figure 15. It was determined that all LiDAR data for Maragondon Floodplain satisfy the point density requirement, and the average density for the entire survey area is 4.30 points per square meter.

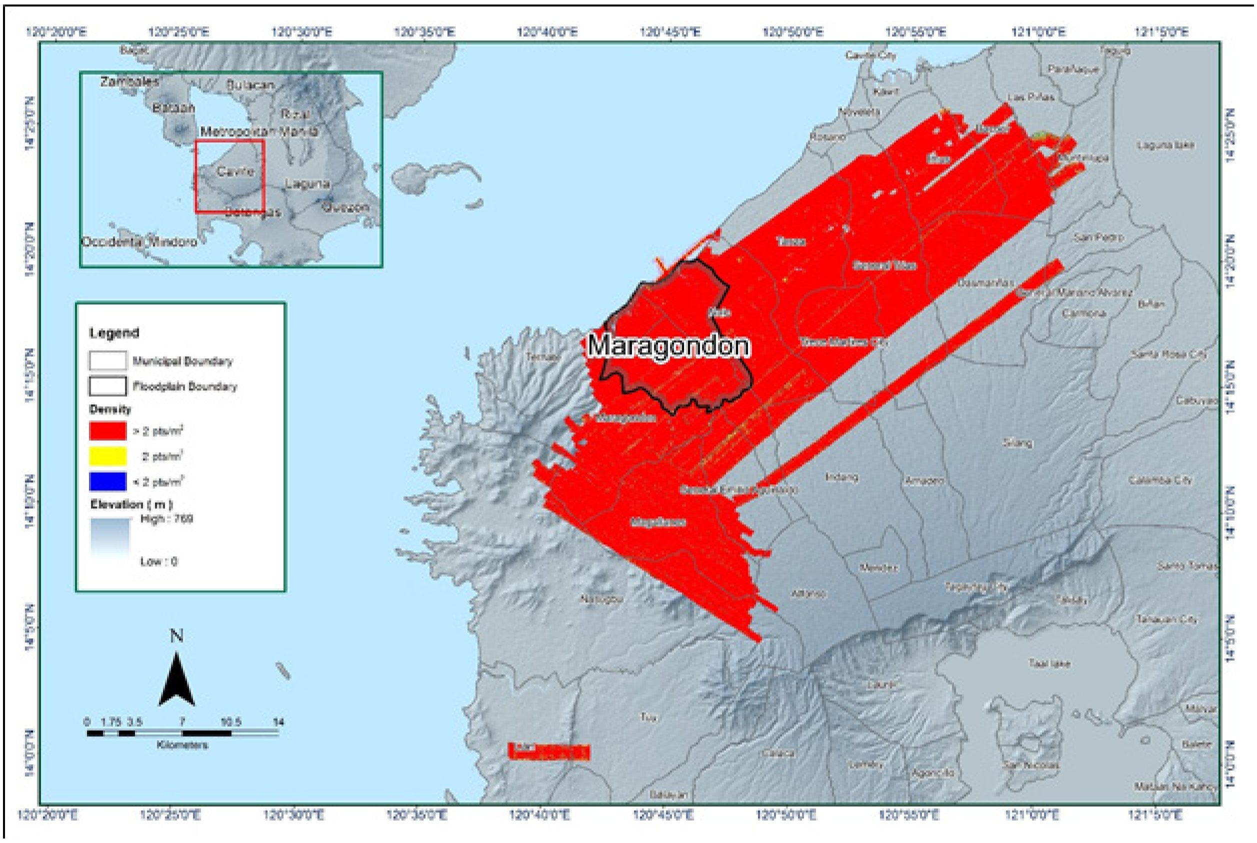

Figure 15. Pulse density map of merged LiDAR data for Maragondon Floodplain

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

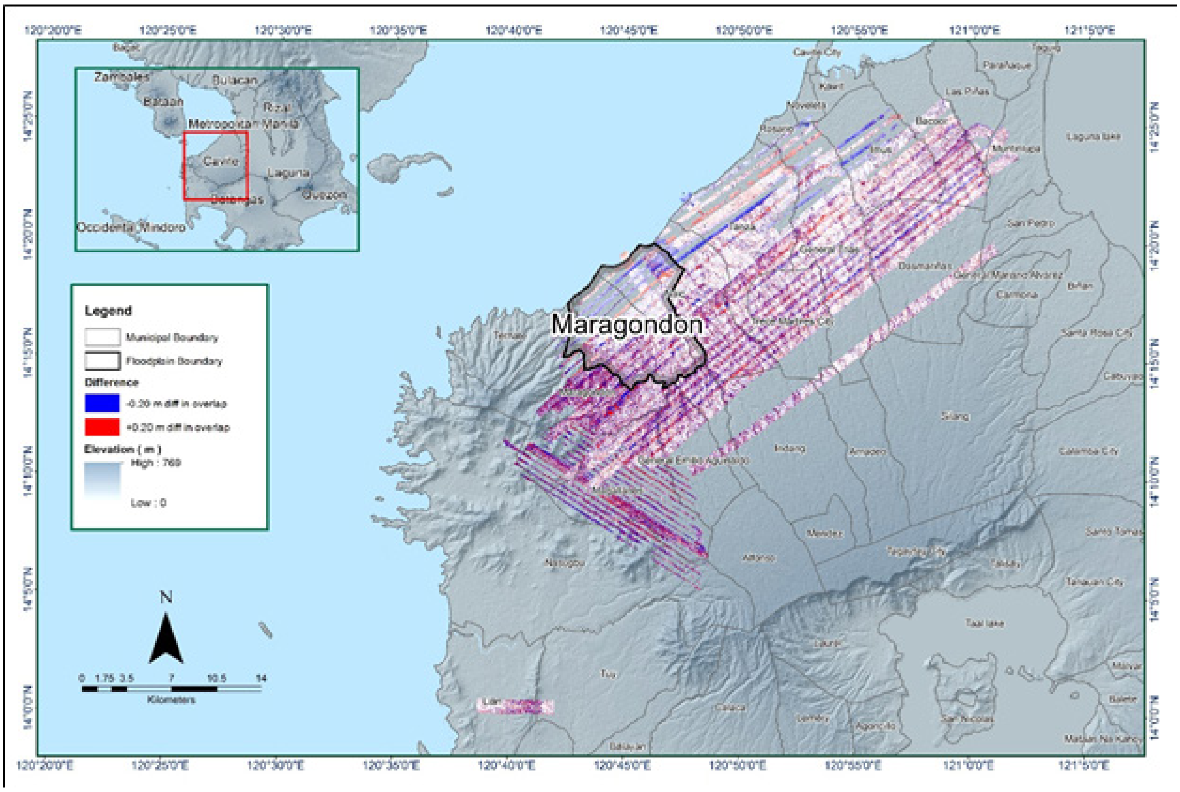

Figure 16. Elevation difference map between flight lines for the Maragondon floodplain

A screen capture of the processed LAS data from Maragondon Flight 3681G loaded in the QT Modeler is displayed in Figure 17. The upper left image shows the elevations of the points from two (2) overlapping flight strips traversed by the profile, illustrated by a dashed yellow line. The x-axis represents the length of the profile. It is evident that there were differences in elevation, but the differences did not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data became satisfactory. No reprocessing was done for this LiDAR dataset.

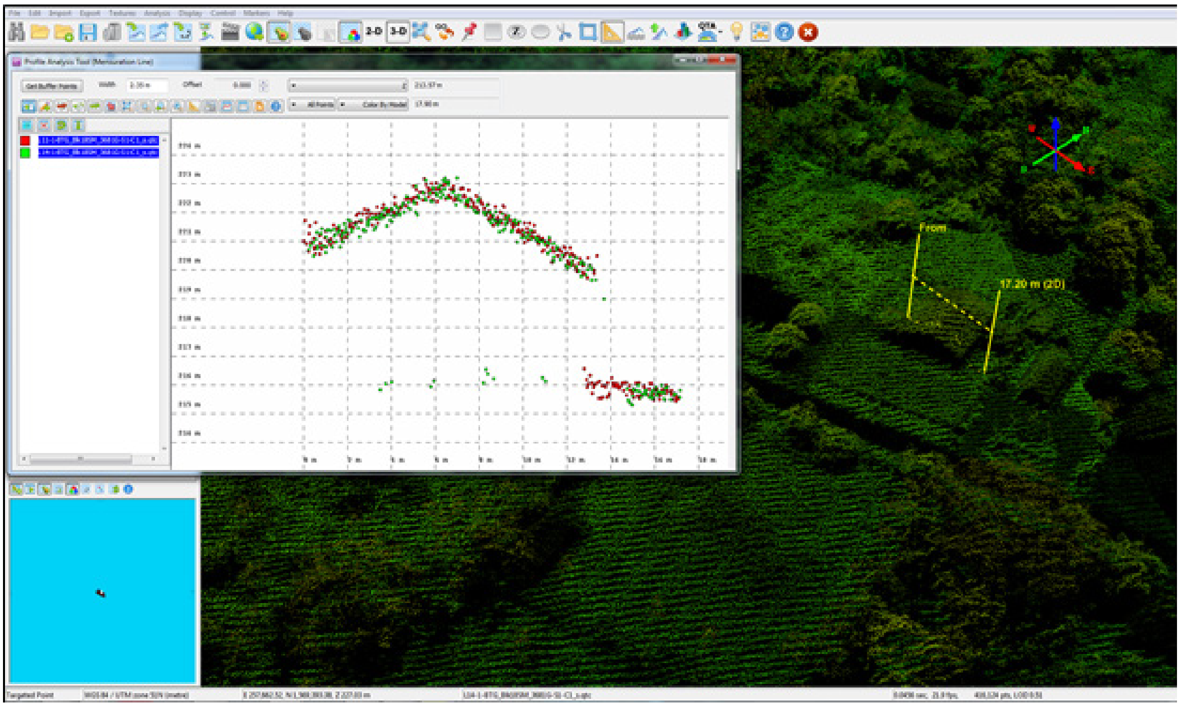

Figure 17. Quality checking for Maragondon Flight 3681G, using the Profile Tool of QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 19. Maragondon classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	989,616,829
Low Vegetation	761,274,010
Medium Vegetation	1,121,573,196
High Vegetation	1,059,999,819
Building	206,519,543

The tile system that TerraScan employed for the LiDAR data, as well as the final classification image for a block in the Maragondon floodplain, are presented in Figure 18. A total of 1,484 1km by 1km tiles were produced. The number of points classified according to the pertinent categories is illustrated in Table 19. The point cloud had a maximum and minimum height of 656.08 meters and 41.14 meters, respectively.

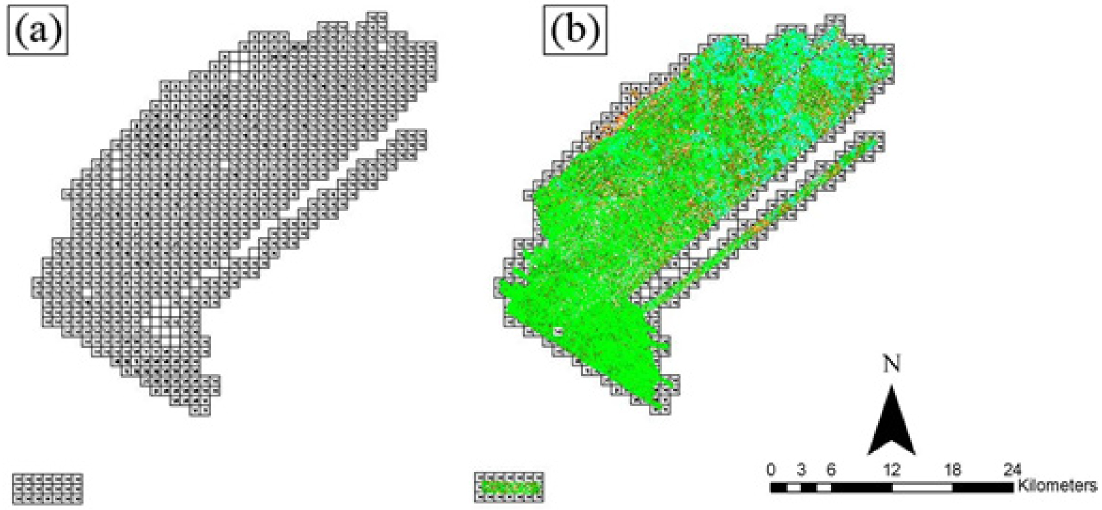

Figure 18. (a) Tiles for Maragondon Floodplain; and (b) classification results in TerraScan

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

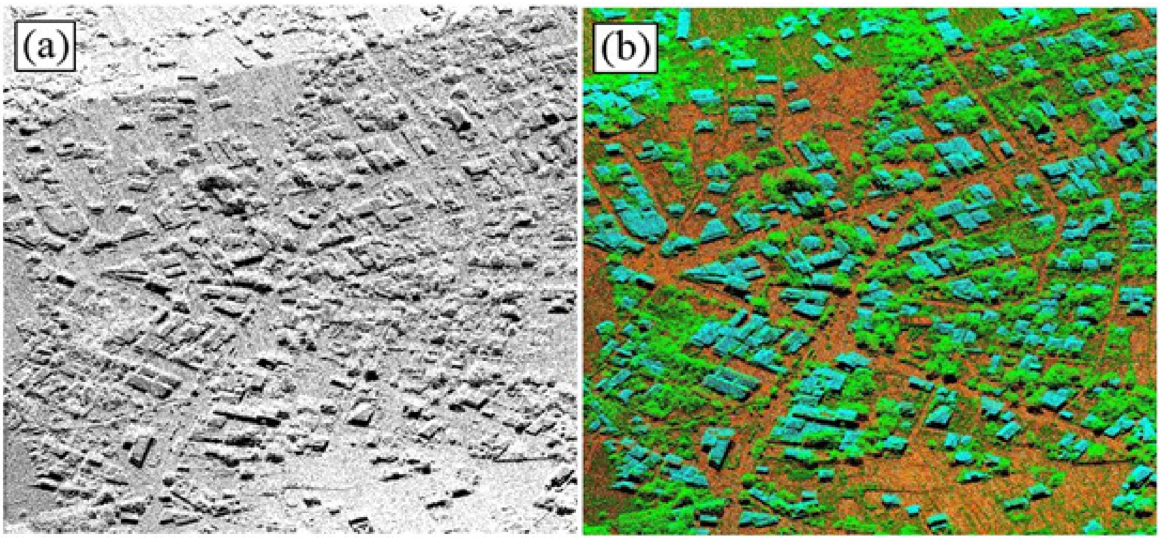

Figure 19. Point cloud (a) before and (b) after classification

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

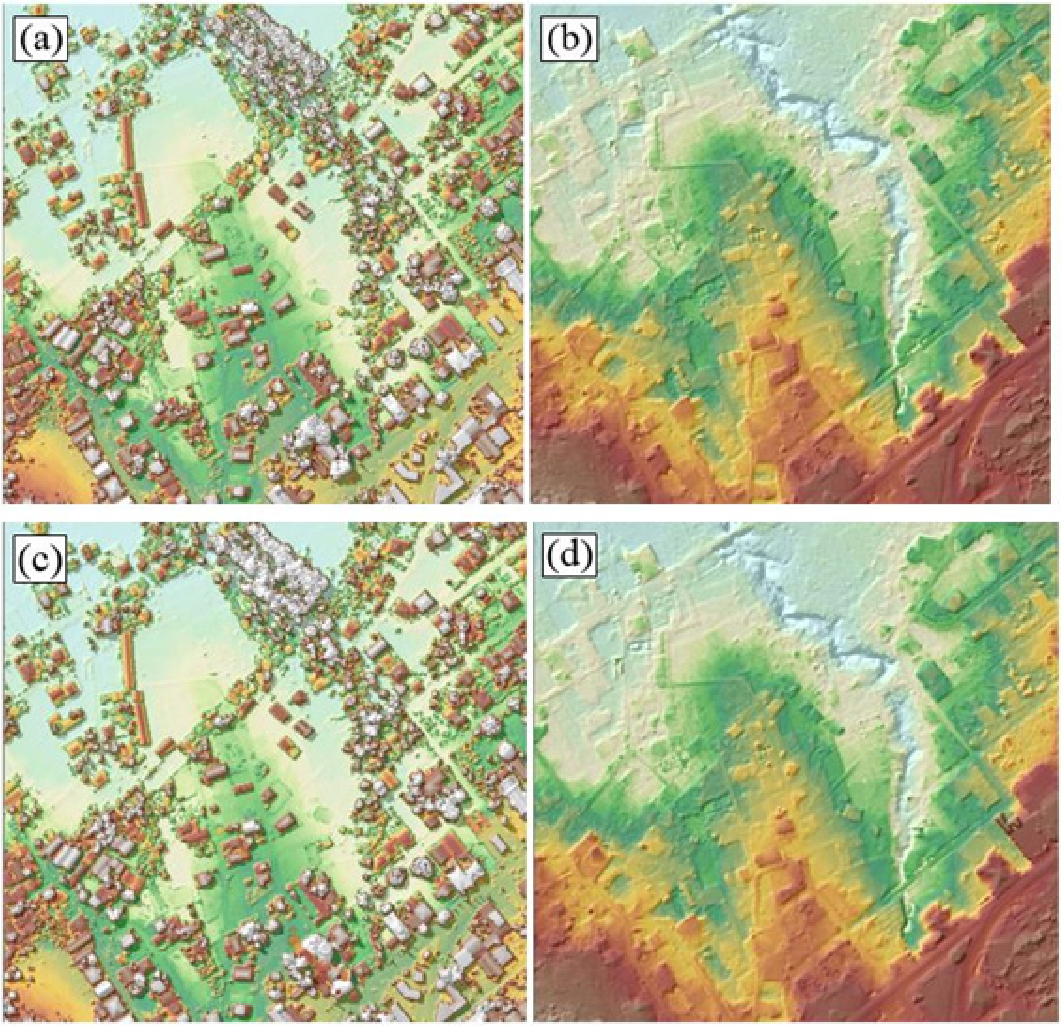

Figure 20. (a) The production of last return DSM and (b) DTM;, (c) first return DSM and (d) secondary DTM in some portion of the Maragondon floodplain

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 510 1km by 1km tiles area covered by the Maragondon floodplain is exhibited in Figure 21. After employing tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Maragondon floodplain survey attained a total of 299.32 square kilometers in orthophotographic coverage, comprised of 1,839 images. Zoomed-in versions of sample orthophotographs, identified by their tile numbers, are provided in Figure 22.

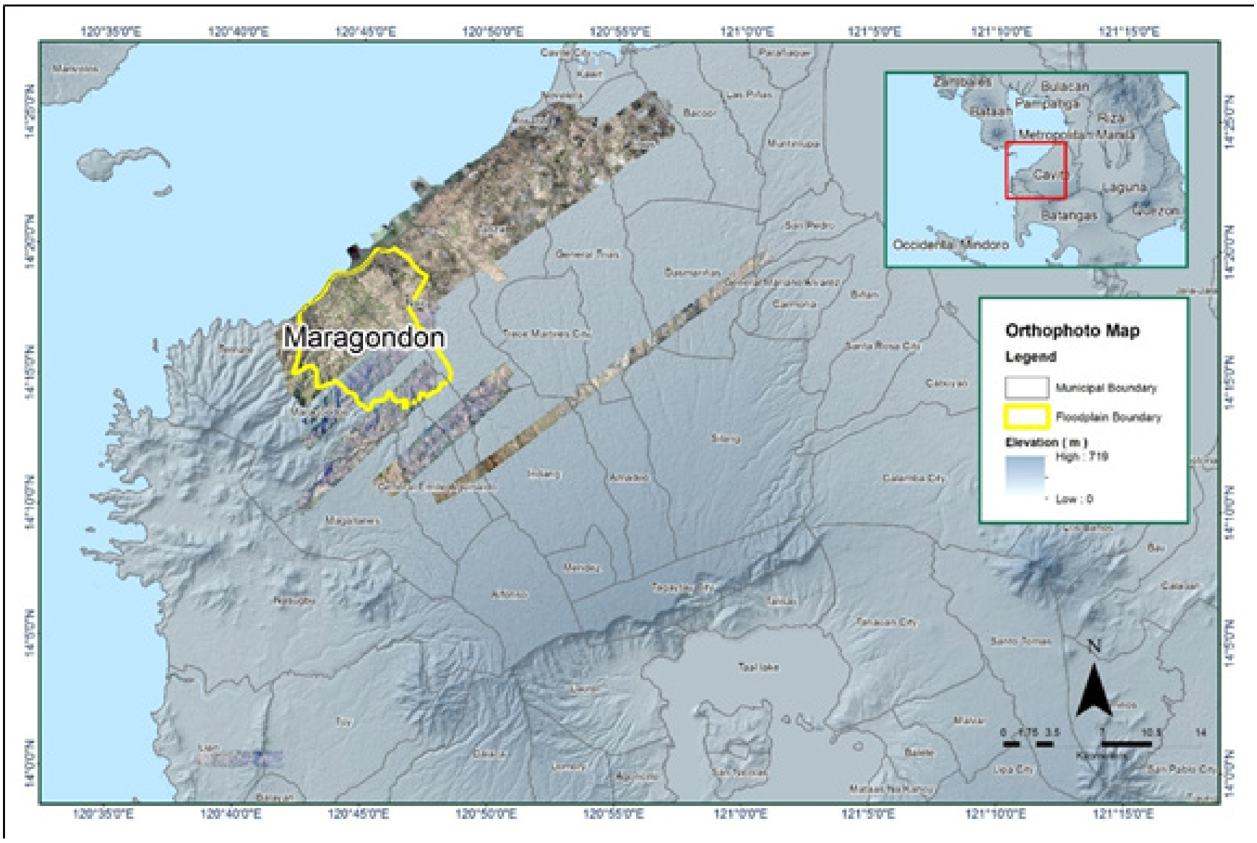

Figure 21. The Maragondon Floodplain, with available orthophotographs

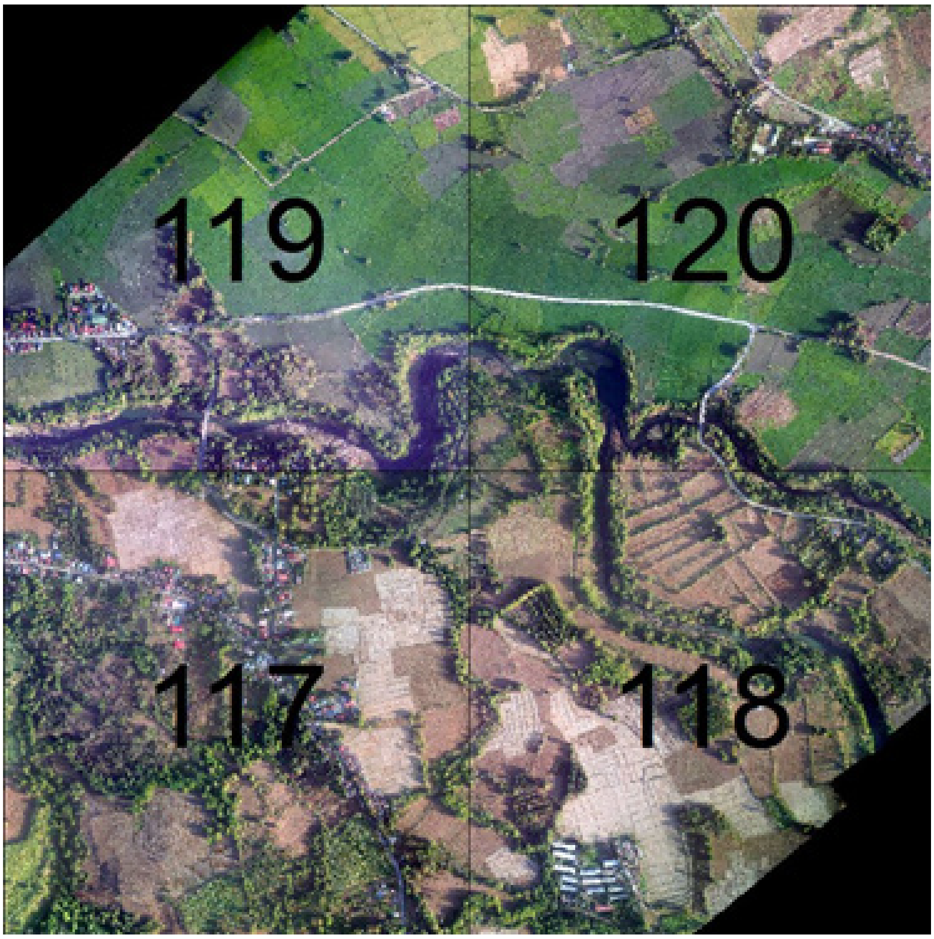

Figure 22. Sample orthophotograph tiles for the Maragondon Floodplain

3.8 DEM Editing and Hydro-Correction

Nine (9) mission blocks were processed for the Maragondon floodplain. These blocks are composed of CALABARZON, Cavite, and Batangas blocks, with a total area of 1016.24 square kilometers. Table 20 specifies the names and corresponding areas of the blocks, in square kilometers.

Table 20. LiDAR blocks with their corresponding areas

LiDAR Blocks	Area (sq km)
CALABARZON_Blk18B_ supplement	106.91
CALABARZON_reflights_Blk18A_ supplement	53.33
CALABARZON_reflights_Blk18A	229.66
Cavite_Blk18C_additional	210.76
Cavite_Blk18AB	127.12
Cavite_Blk18A_supplement	56.96
Cavite_Blk18ABC_supplement	82.42
Batangas_Blk18SM	125.46
Batangas_Blk18SM_supplement	23.62
TOTAL	1016.24 sq.km

Portions of the DTM before and after manual editing are exhibited in Figure 23. The bridge (Figure 23a) was considered to be an obstruction to the flow of water along the river, and had to be removed (Figure 23b) in order to hydrologically correct the river. A ridge (Figure 23c) was misclassified and removed during the classification process, and had to be retrieved to complete the surface (Figure 23d) to allow for the correct flow of water. Another case was a building that was still present in the DTM after classification (Figure 23e), and had to be removed through manual editing (Figure 23f).

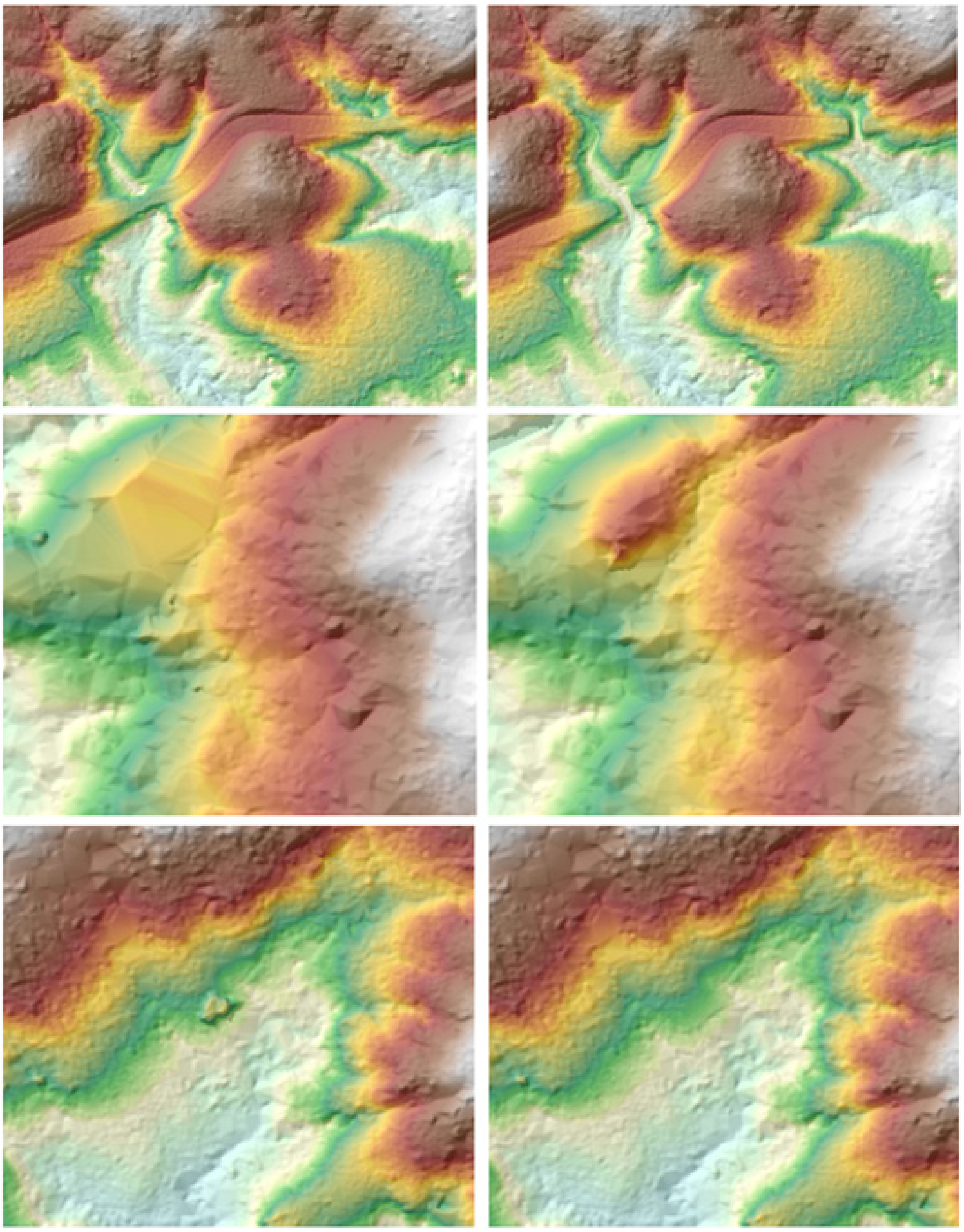

Figure 23. Portions in the DTM of the Maragondon Floodplain – a bridge (a) before and (b) after manual editing; a ridge (c) before and (d) after data retrieval; and a building (e) before and (f) after manual editing

3.9 Mosaicking of Blocks

No assumed reference block was used in mosaicking, because the identified reference for shifting was an existing calibrated CALABARZON DEM overlapping with the blocks to be mosaicked. Table 21 summarizes the shift values applied to each LiDAR block during the mosaicking process.

The mosaicked LiDAR DTM for the Maragondon floodplain is illustrated in Figure 24. It demonstrates that the entire Maragondon floodplain was 100% covered by LiDAR data.

Table 21. Shift values of each LiDAR block of the Maragondon Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
CALABARZON_Blk18B_supplement	-3.10	1.47	-0.13
CALABARZON_reflights_Blk18A_ supplement	34.04	-20.59	1.40
CALABARZON_reflights_Blk18A	0.55	-2.81	1.41
Cavite_Blk18C_additional	-1.81	1.32	-0.50
Cavite_Blk18AB	-1.80	1.13	-0.50
Cavite_Blk18A_supplement	-1.55	1.14	-0.20
Cavite_Blk18ABC_supplement	-15.70	-28.85	0.50
Batangas_Blk18SM	0.00	0.00	0.00
Batangas_Blk18SM_supplement	0.00	0.00	0.00

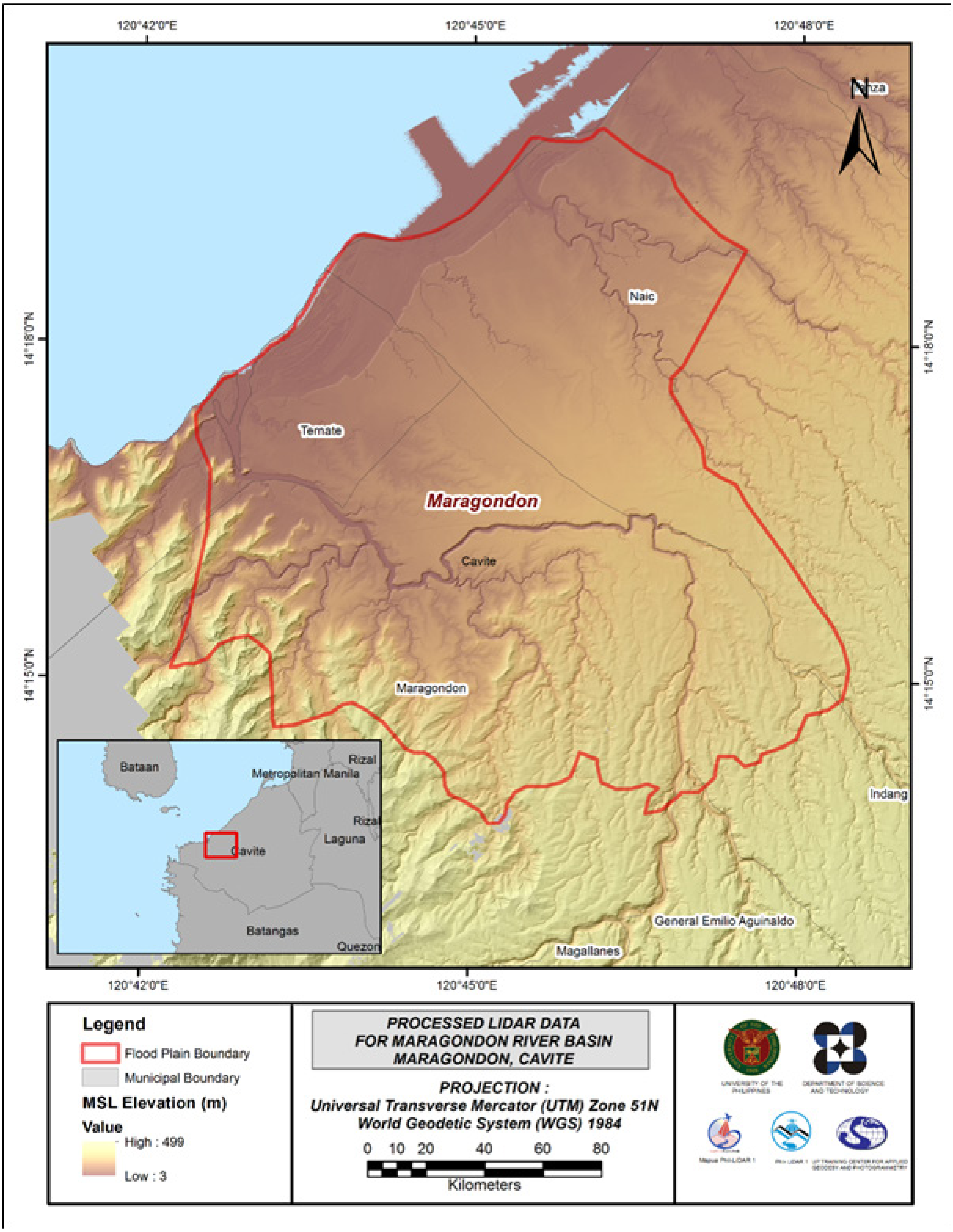

Figure 24. Map of processed LiDAR data for the Maragondon Floodplain

3.10 Calibration and Validation of Mosaicked LiDAR DEM

To undertake the data validation of the mosaicked LiDAR DEMs, the DVBC conducted a validation survey along the Maragondon floodplain. The extent of the validation survey done in Maragondon to collect points with which the LiDAR dataset was validated is presented in Figure 25, with the validation survey points highlighted in green. A total of 1,855 survey points were used for the calibration and validation of the Maragondon LiDAR data.Random selection of 80% of the survey points resulted in 1,484 points, which were used for the calibration.

A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is reflected in Figure 26. Statistical values were computed from the extracted LiDAR values using the selected points, to assess the quality of data and to obtain the values for vertical adjustment. The computed height difference between the LiDAR DTM and the calibration elevation values is 2.94 meters, with a standard deviation of 0.15 meters. Calibration of the Maragondon LiDAR data was performed by subtracting the height difference value, 2.94 meters, from the Maragondon mosaicked LiDAR data. Table 22 specifies the statistical measurements of the compared elevation values between the LiDAR data and the calibration data.

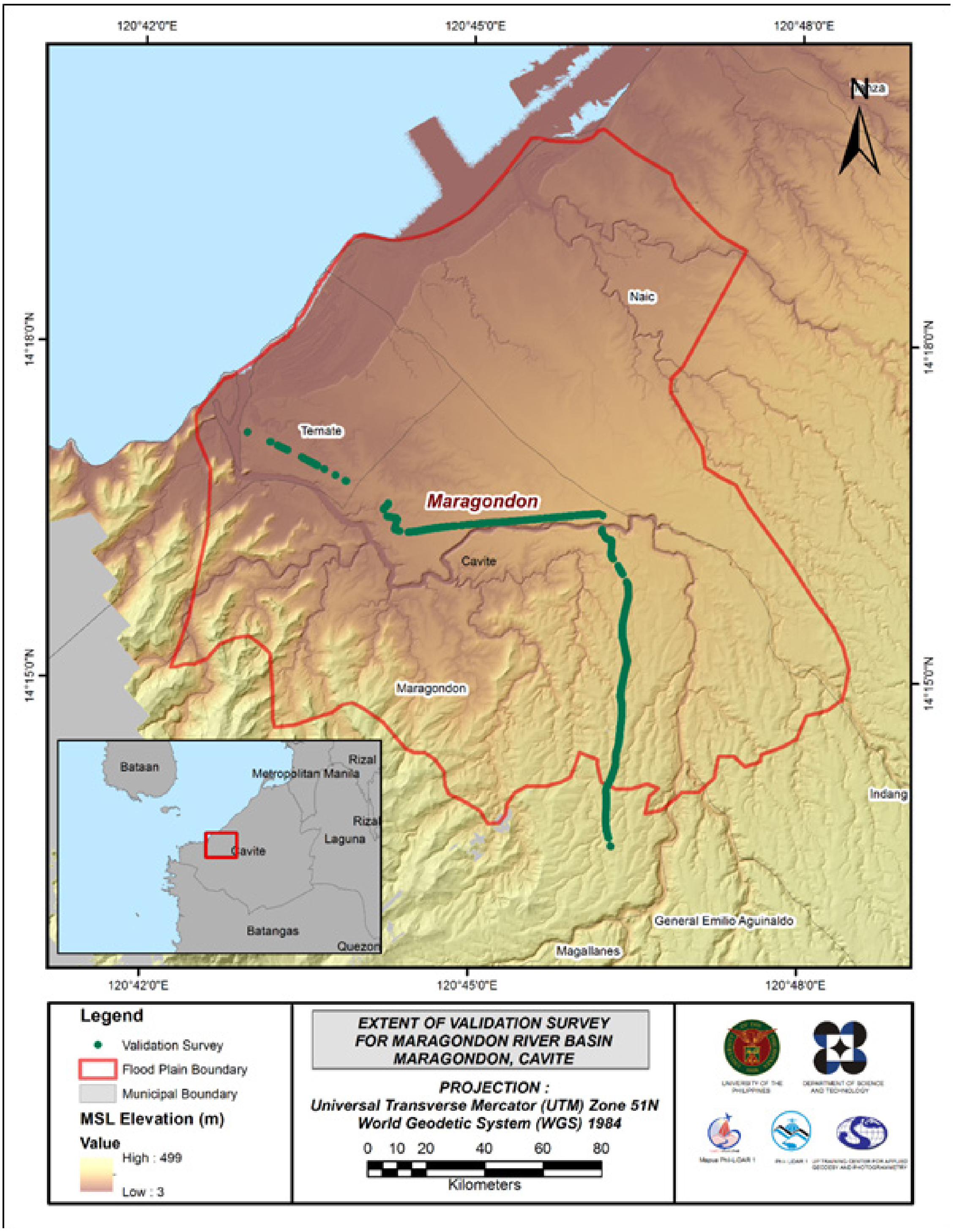

Figure 25. Map of the Maragondon floodplain with the validation survey points in green

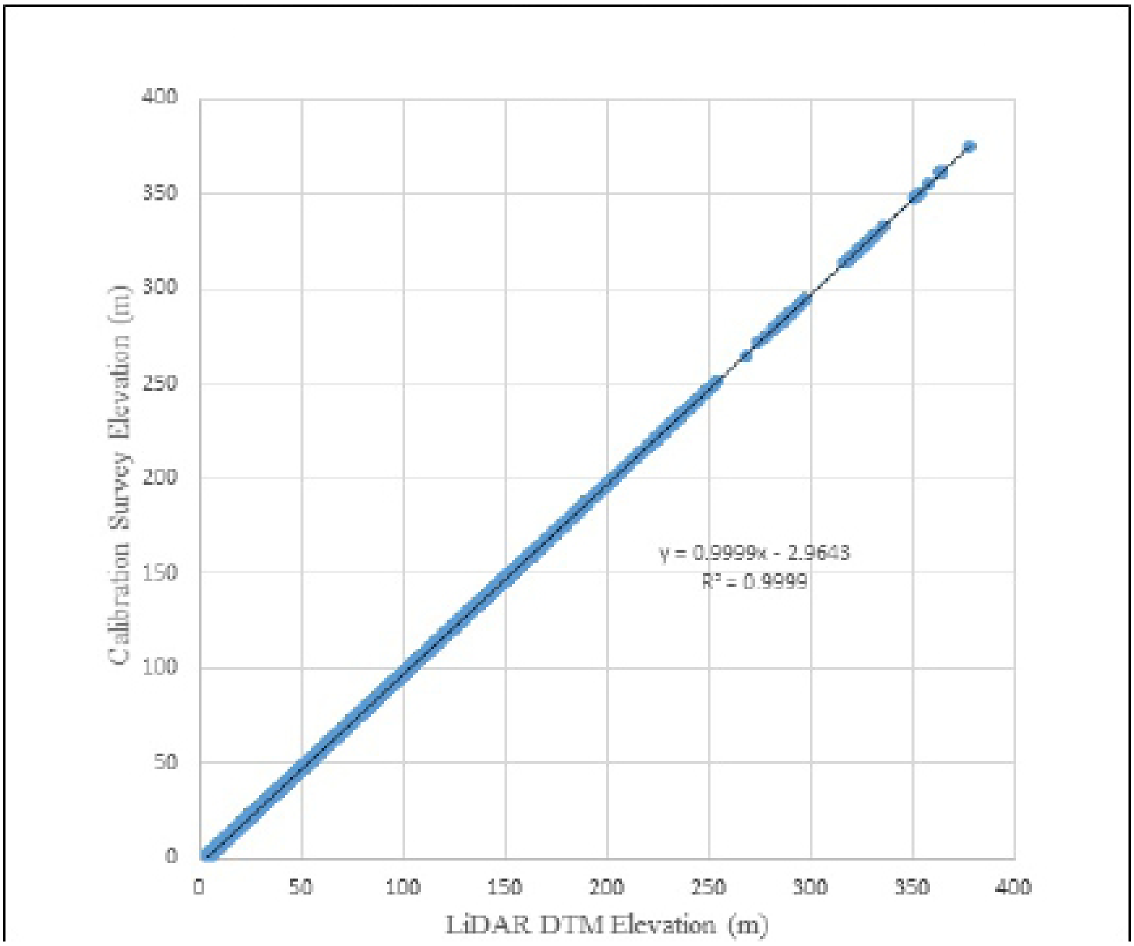

Figure 26. Correlation plot between the validation survey points and the LiDAR data

Table 22. Correlation plot between the calibration survey points and the LiDAR data

Calibration Statistical Measures	Value (meters)
Height Difference	2.97
Standard Deviation	0.20
Average	-2.97
Minimum	-3.48
Maximum	-2.40

The remaining 20% of the total survey points were intersected to the flood plain, resulting to 335 points, were used for the validation of calibrated Maragondon DTM. A good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM, is shown in Figure 27. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.16 meters with a standard deviation of 0.16 meters, as shown in Table 23.

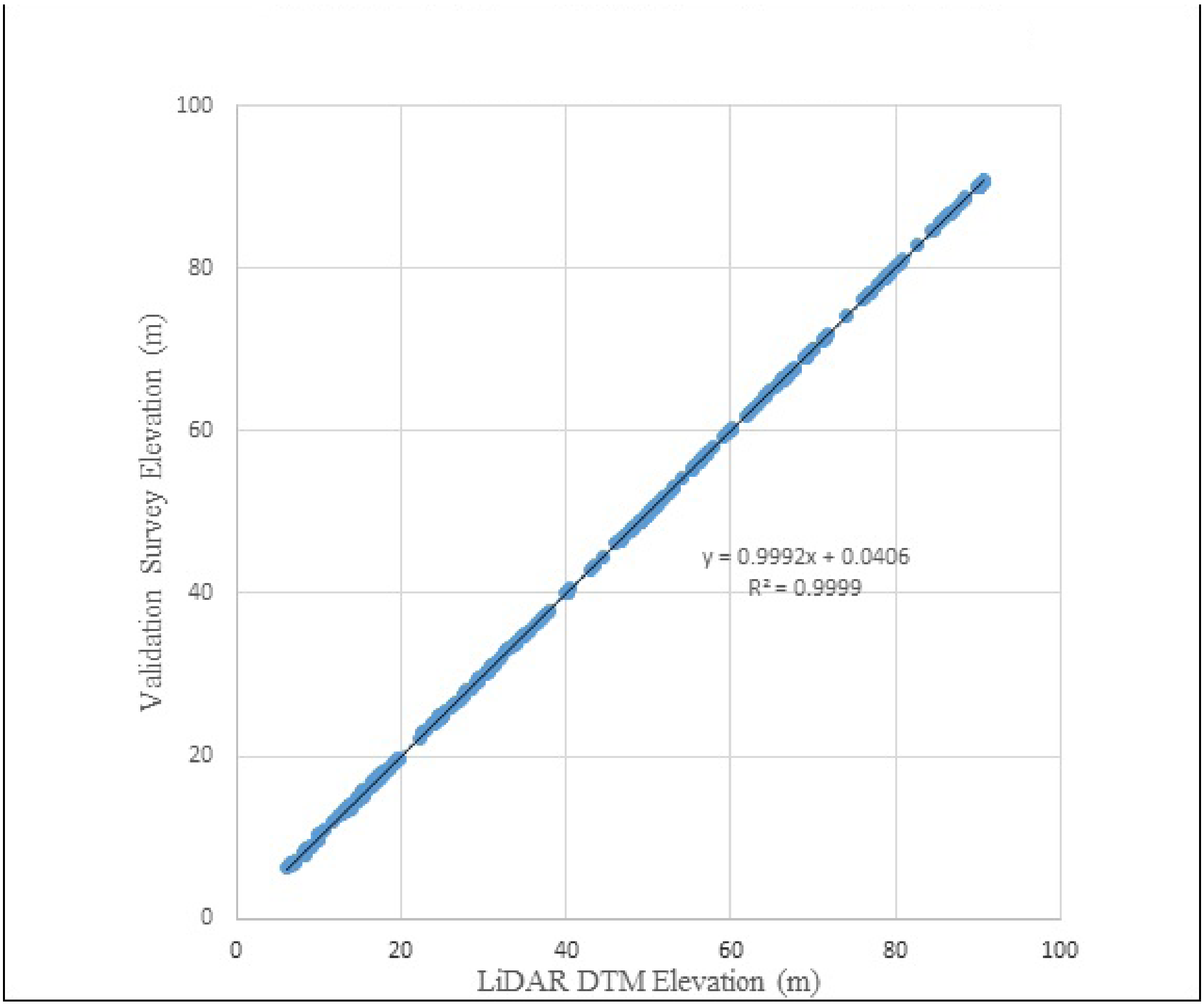

Figure 27. Correlation plot between the validation survey points and the LiDAR data

Table 23. Validation statistical measures

Validation Statistical Measures	Value (meters)
RMSE	0.17
Standard Deviation	0.17
Average	0.01
Minimum	-0.33
Maximum	0.35

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data were available for Maragondon, with 8,928 bathymetric survey points. The resulting raster surface produced was obtained through the Kernel Interpolation with Barriers method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.44 meters. The extent of the bathymetric survey conducted by the DVBC in the Maragondon River, integrated with the processed LiDAR DEM, is illustrated in Figure 28.

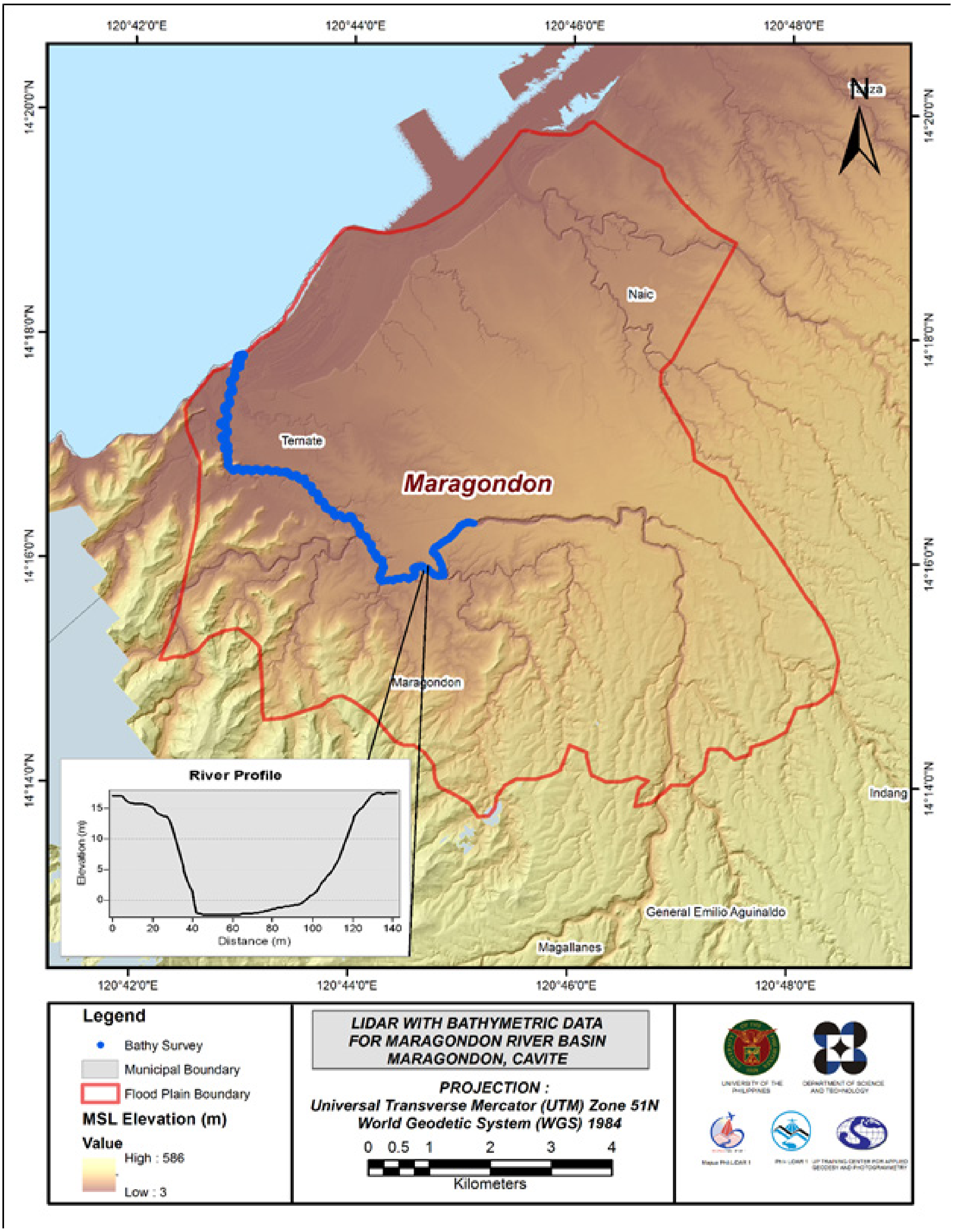

Figure 28. Map of the Maragondon Floodplain, with bathymetric survey points shown in blue

3.12 Feature Extraction

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

3.12.1 Quality Checking of Digitized Features' Boundary

The Maragondon floodplain, including its 200-meter buffer zone, has a total area of 86.65 square kilometers. Of this area, a total of 5.0 square kilometers, corresponding to a total of 2,974 building features, were considered for quality checking (QC). Figure 29 presents the QC blocks for the Maragondon floodplain.

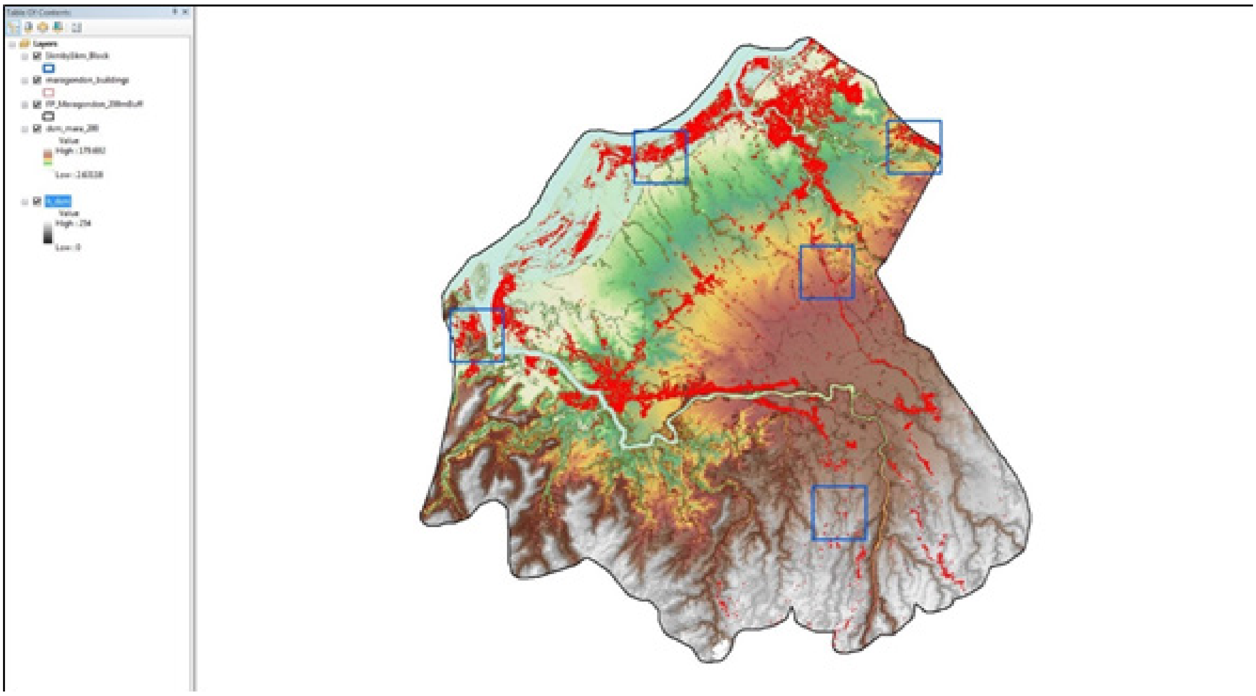

Figure 29. Map of the Maragondon Floodplain, with bathymetric survey points shown in blue

Quality checking of Maragondon building features resulted in the ratings shown in Table 24

Table 24. Quality checking ratings for the Maragondon building features

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Maragondon	99.91	100.00	98.35	PASSED

3.12.2 Height Extraction

Height extraction was done for 24,567 building features in the Maragondon floodplain. Of these building features, 400 were filtered out after height extraction, resulting in 24,167 buildings with height attributes. The lowest building height is at 2.00 meters, while the highest building is at 18.55 meters.

3.12.3 Feature Attribution

The attributes were obtained by field data gathering. GPS devices were used to determine the coordinates of important features. These points were uploaded and overlaid in ArcMap, and were then integrated with the shapefiles.

Table 25 summarizes the number of building features per type. Table 26 indicates the total length of each road type, and Table 27 specifies the number of water features extracted per type.

Table 25. Building features extracted for the Maragondon Floodplain

Facility Type	No. of Features
Residential	23,590
School	319
Market	7
Agricultural/Agro-Industrial Facilities	1
Medical Institutions	29
Barangay Hall	27
Military Institution	0
Sports Center/Gymnasium/Covered Court	10
Telecommunication Facilities	0
Transport Terminal	5
Warehouse	27
Power Plant/Substation	0
NGO/CSO Offices	0
Police Station	1
Water Supply/Sewerage	5
Religious Institutions	40
Bank	10
Factory	0
Gas Station	7
Fire Station	0
Other Government Offices	8
Other Commercial Establishments	71
Total	24,167

Table 26. Total length of extracted roads for the Maragondon Floodplain

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Maragondon	143.25	20.13	40.85	0.00	0.00	204.23

Table 27. Number of extracted water bodies for the Maragondon Floodplain

Floodplain	Water Body Type					Total
	Rivers/ Streams	Lakes/ Ponds	Sea	Dam	Fish Pen	
Maragondon	9	92	1	0	0	102

A total of thirty-six (36) bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

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

Figure 30 represents the Digital Surface Model (DSM) of the Maragondon floodplain, overlaid with its ground features.

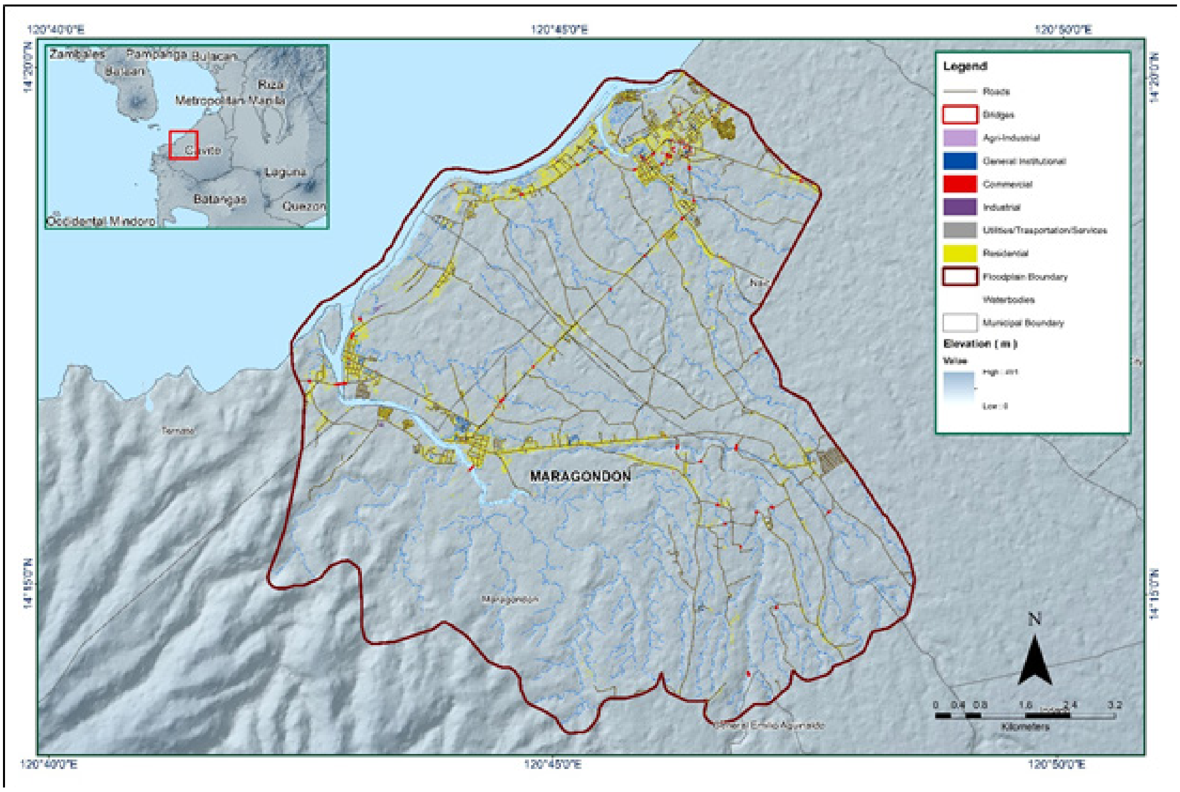

Figure 30. Extracted features for the Maragondon Floodplain

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS OF THE MARAGONDON 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 Data Validation and Bathymetry Component (DVBC) conducted field surveys in the Maragondon River on September 13 - 25, 2015. The scope of work was comprised of: (i.) initial reconnaissance; (ii.) control survey for the establishment of control point at the approach of the Mabacao Bridge, occupied as base station for the GNSS surveys; (iii.) bridge as-built and cross-section surveys of the Mabacao Bridge in Barangay Bucal IV B, Municipality of Maragondon, Cavite; (iv.) validation acquisition survey for LiDAR data covering the Municipality of Maragondon, with an estimated length of 12.30 kilometers; and (v.) bathymetric survey from Barangay Bucal II towards the mouth of the river in Barangay Sapang I, Municipality of Maragondon, Cavite, with an approximate bathymetric length of 7.96 kilometers.

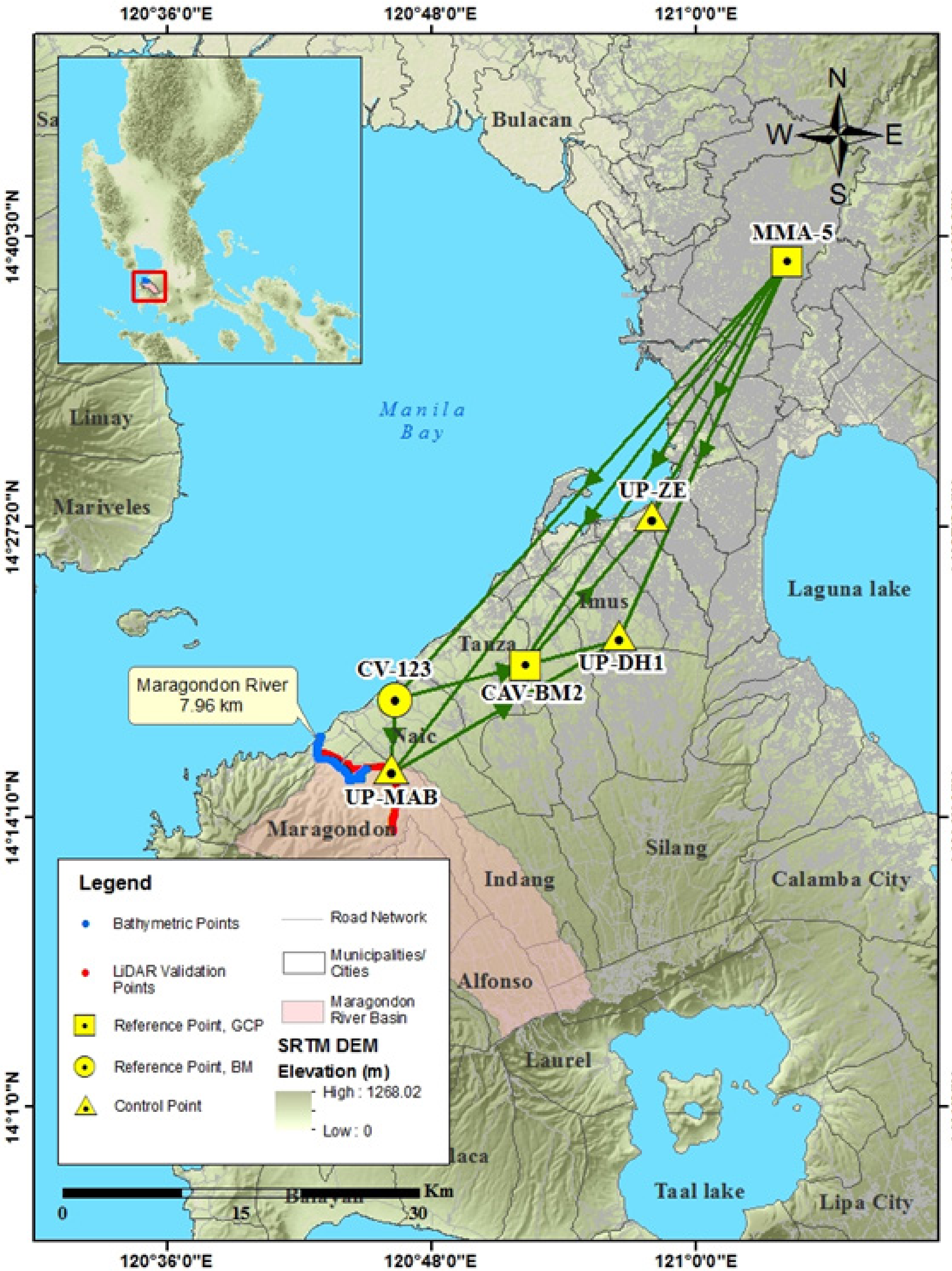


Figure 31. Extent of the bathymetric survey (in blue line) in Maragondon River and the LiDAR data validation survey (in red)

4.2 Control Survey

The GNSS network used for the Imus River Basin is composed of three (3) loops established on September 15, 2015, occupying the following reference points: (i.) MMA-5, a first-order GCP in the University of the Philippines, Diliman, Quezon City; and (ii.) CV-123, a first-order BM, located in front of an Iglesia ni Cristo church in Barangay Amaya, Municipality of Naic, Cavite.

Two (2) control points that were established along the approach of the bridges were also used during the survey, which are: (i.) UP-DH1, located at the Daang Hari Bridge in Barangay Anabu II-A, Municipality of Imus, Cavite; and (ii.) UP-MAB, located at the Mabacao Bridge in Barangay Bucal IV B, Municipality of Maragondon, Cavite.

The summary of the reference and control points and their corresponding locations is given in Table 28; while the established GNSS network is illustrated in Figure 32.

Table 28. List of reference and control points occupied in the Maragondon River survey (Source: NAMRIA and UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoid Height (m)	BM Ortho (m)	Date Established
MMA-5	2nd Order, GCP	14°39'22.97451"	121°04'11.14940"	133.379	-	1956
CV-123	1st Order,	8°04'07.74591"	123°32'17.19275"	101.138	-	2005
BM	-	-	52.071	9.314	2008	7-5-2015
UP-DH1	UP Established	-	-	-	-	Sept. 15, 2015
UP-MAB	UP Established	-	-	-	-	Sept. 17, 2015

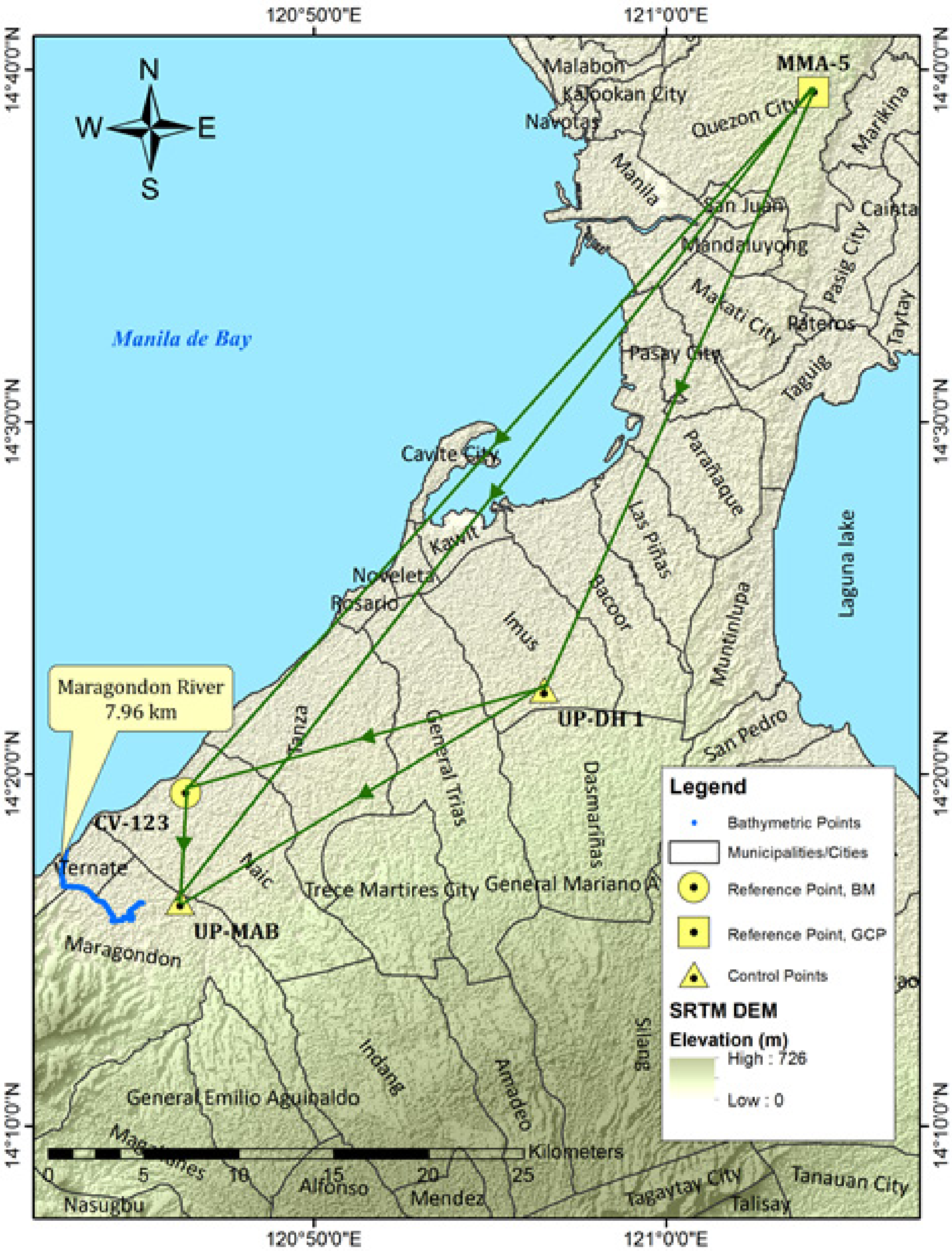


Figure 32. GNSS network covering the Maragondon River survey

The GNSS set-ups established in the locations of the reference and control points are exhibited in Figure 33 to Figure 36..

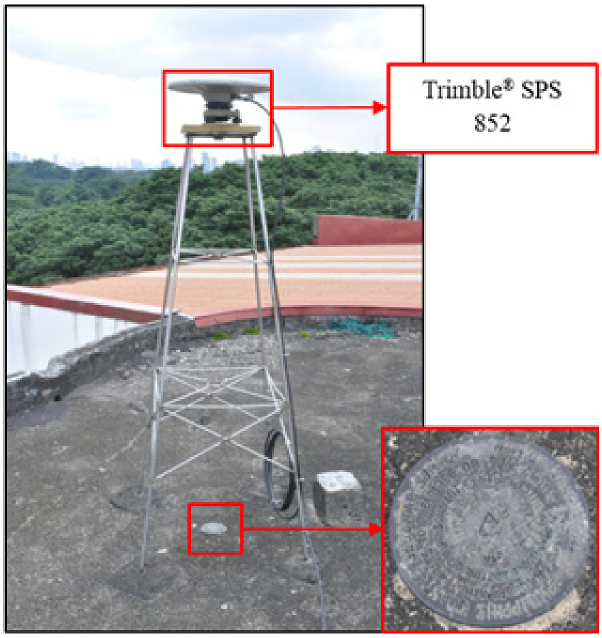


Figure 33. Trimble® SPS 852 set-up at MMA-5, located at the Melchor Hall, University of the Philippines, Diliman, Quezon City

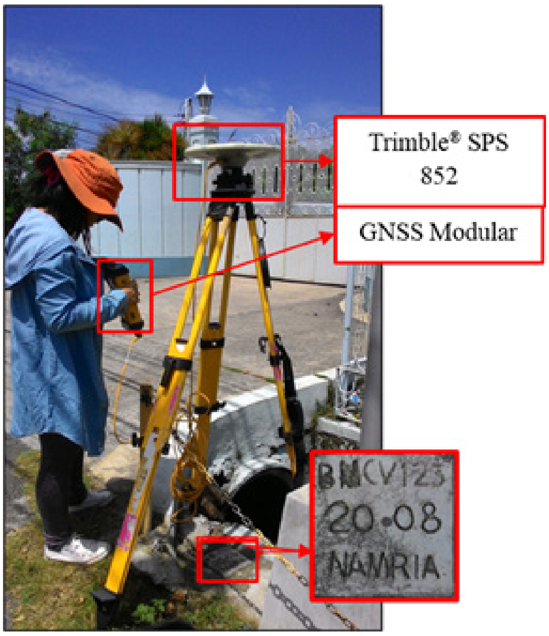


Figure 34. GNSS base set-up of Trimble® SPS 852 at CV-123, located in front of the Iglesia in Cristo chapel in Municipality of Naic, Cavite

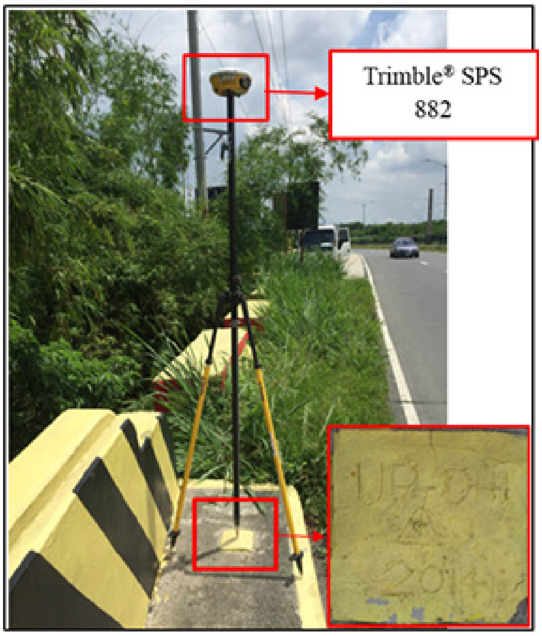


Figure 35. Trimble® SPS 882 set-up at UP-DH1, located in the Daang Hari Bridge, Barangay Anabu II-A, Municipality of Imus, Cavite

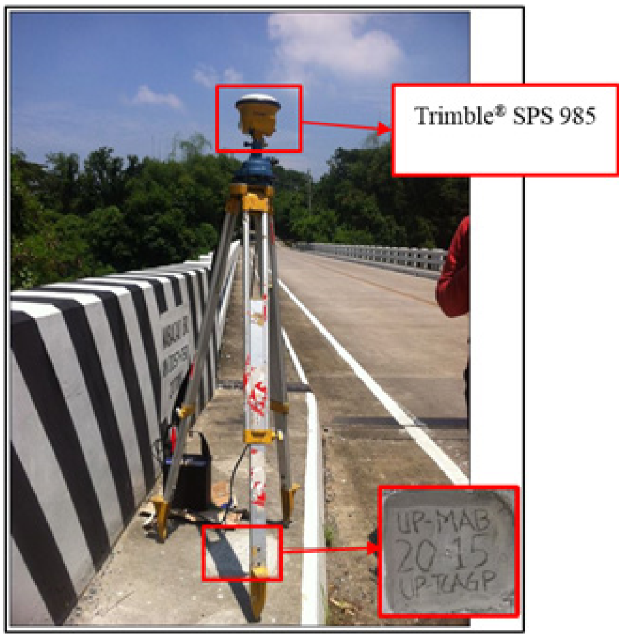


Figure 36. Trimble® SPS 985 set-up at UP-MAB, located at the approach of the Mabacao Bridge, Barangay Bucal IV B, Municipality of Maragondon, Cavite

4.3 Baseline Processing

The GNSS baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions, with horizontal and vertical precisions within the +/-20-centimeter and +/-10-centimeter requirement, respectively. In cases where one or more of the baselines did not meet all of these criteria, masking was performed. Masking is the removal of portions of 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, a re-survey is initiated. The baseline processing results of the control points in the Maragondon River Basin, generated TBC software, are summarized in Table 29..

Table 29. Baseline processing report for the Maragondon River Basin survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
CV-123---UP-MAB	09-15-2015	Fixed	0.005	0.022	182°55'06"	5730.614	19.916
CV-123---UP-MAB	09-15-2015	Fixed	0.005	0.012	182°55'05"	5730.599	19.913
UP-DH1---UP-MAB	09-15-2015	Fixed	0.088	0.108	239°06'21"	21662.35	-9.875
UP-DH1---CV-123	09-15-2015	Fixed	0.006	0.034	253°33'16"	19073.15	-29.7
MMA-5---UP-DH1	09-15-2015	Fixed	0.006	0.014	203°41'56"	34213.76	-51.591
MMA-5---CV-123	09-15-2015	Fixed	0.023	0.021	221°06'52"	48736.51	-81.313
MMA-5---CV-123	09-15-2015	Fixed	0.023	0.025	221°06'52"	48736.48	-81.311

As shown in Table 29, a total of seven (7) baselines were processed, with reference point MMA-5 held fixed for coordinate values, and CV-123 held fixed for elevation values. All of the baselines satisfied the required accuracy set by the Program.

4.4 Network Adjustment

After the baseline processing procedure, network adjustment was performed using TBC. Looking at the adjusted grid coordinates table of the TBC-generated Network Adjustment Report, it is observed that the square root of the sum of the squares of x and y must be less than 20 centimeters, and z less than 10 centimeters, or in equation from:

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

Where:

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

The four (4) control points – MMA-5, CV-123, UP-DH1, and UP-MAB – were occupied and observed simultaneously to form a GNSS loop. The coordinates of MMA-5 and the elevation values of CV-123 were held fixed during the processing of the control points, as presented in Table 30. Through these reference points, the coordinates and elevation values of the unknown control points were computed.

Table 30. Constraints applied to the adjustments of the control points

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
CV-123	Grid				Fixed
MMA-5	Global	Fixed	Fixed	Fixed	
Fixed = 0.000001(Meter)					

The list of adjusted grid coordinates; i.e., Northing, Easting, Elevation, and computed standard errors of the control points in the network, is indicated in Table 31. All fixed control points did not yield values for grid and elevation errors.

Table 31. Adjusted grid coordinates for the control points used in the Maragondon floodplain survey

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
MMA-5	292122.994	?	1621207.085	?	89.331	0.047	LL
CV-123	259759.978	0.023	1584752.533	0.010	9.314	?	e
UP-DH1	278104.989	0.018	1589990.469	0.007	38.572	0.055	
UP-MAB	259413.172	0.025	1579030.620	0.013	29.050	0.040	

With the mentioned equation, √((x]_e)^2+(y_e)^2)<20cm for horizontal accuracy, and z_e<10 cm for vertical accuracy, the computations for accuracy are as follows:

MMA-5
Horizontal Accuracy = Fixed
Vertical Accuracy = 4.7 cm < 10 cm

CV-123
Horizontal Accuracy = $\sqrt{(2.3)^2 + (1.0)^2}$
= 2.51 cm < 20 cm
Vertical Accuracy = Fixed

UP-DH 1
Horizontal Accuracy = $\sqrt{(1.8)^2 + (0.7)^2}$
= √((3.24 + 0.49)
= 1.93 cm < 20 cm
Vertical Accuracy = 5.5 cm < 10 cm

UP-MAB
Horizontal Accuracy = $\sqrt{(2.5)^2 + (1.3)^2}$
= 2.82 cm < 20 cm
Vertical Accuracy = 4.0 cm < 10 cm

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

Table 32. Adjusted geodetic coordinates for control points used in the Maragondon River floodplain validation

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
MMA-5	N14°39'22.97451"	E121°04'11.14940"	133.379	0.047	LL
CV-123	N14°19'27.61225"	E120°46'21.72442"	52.071	?	e
UP-DH1	N14°22'23.52073"	E120°56'32.16087"	81.814	0.055	
UP-MAB	N14°16'21.39512"	E120°46'11.99131"	71.979	0.040	

The corresponding geodetic coordinates of the observed points are within the required accuracy, as reflected in Table 32. Based on the results of the computation, the accuracy conditions are satisfied; hence, the required accuracy for the program was met.

The computed coordinates of the reference and control points utilized in the Maragondon River GNSS Static Survey are indicated in Table 33.

Table 33. Reference and control points used in the Maragondon River Static Survey, with their corresponding locations (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
MMA-5	2nd Order, GCP	14°39'22.97451"	121°04'11.14940"	133.379	1621207.085	292122.994	89.331
CV-123	1st Order,	8°04'07.74591"	123°32'17.19275"	101.138	891944.915	559290.041	32.884
BM	14°19'27.61225"	120°46'21.72442"	52.071	1584752.533	259759.978	9.314	25.387
UP-DH1	UP Established	14°22'23.52073"	120°56'32.16087"	81.814	1589990.469	278104.989	38.572
UP-MAB	UP Established	14°16'21.39512"	120°46'11.99131"	71.979	1579030.620	259413.172	29.050

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

The cross-section and bridge as-built surveys were done simultaneously on September 18, 2015 at the Mabacao Bridge in Barangay Bucal IV B, Municipality of Maragondon, Cavite, using GNSS receiver Trimble® SPS 985 in PPK survey technique at the downstream side of the bridge. The determination of bridge as-built features was performed to obtain the distance of the piers and abutments from the bridge approach, as depicted in Figure 37. The bridge deck was measured to get the high chord and meter tapes, to get its low chord elevation. The control point UP-MAB was used as the base station all throughout the survey.

Figure 37. Cross-section and bridge as-built survey at the downstream side of the Mabacao Bridge

The length of the cross-sectional line for the Mabacao Bridge is about 136.48 meters, with 39 cross-sectional points. The location map, cross-section diagram, and as-built bridge data form for the Mabacao Bridge are presented in Figure 38 to Figure 40.

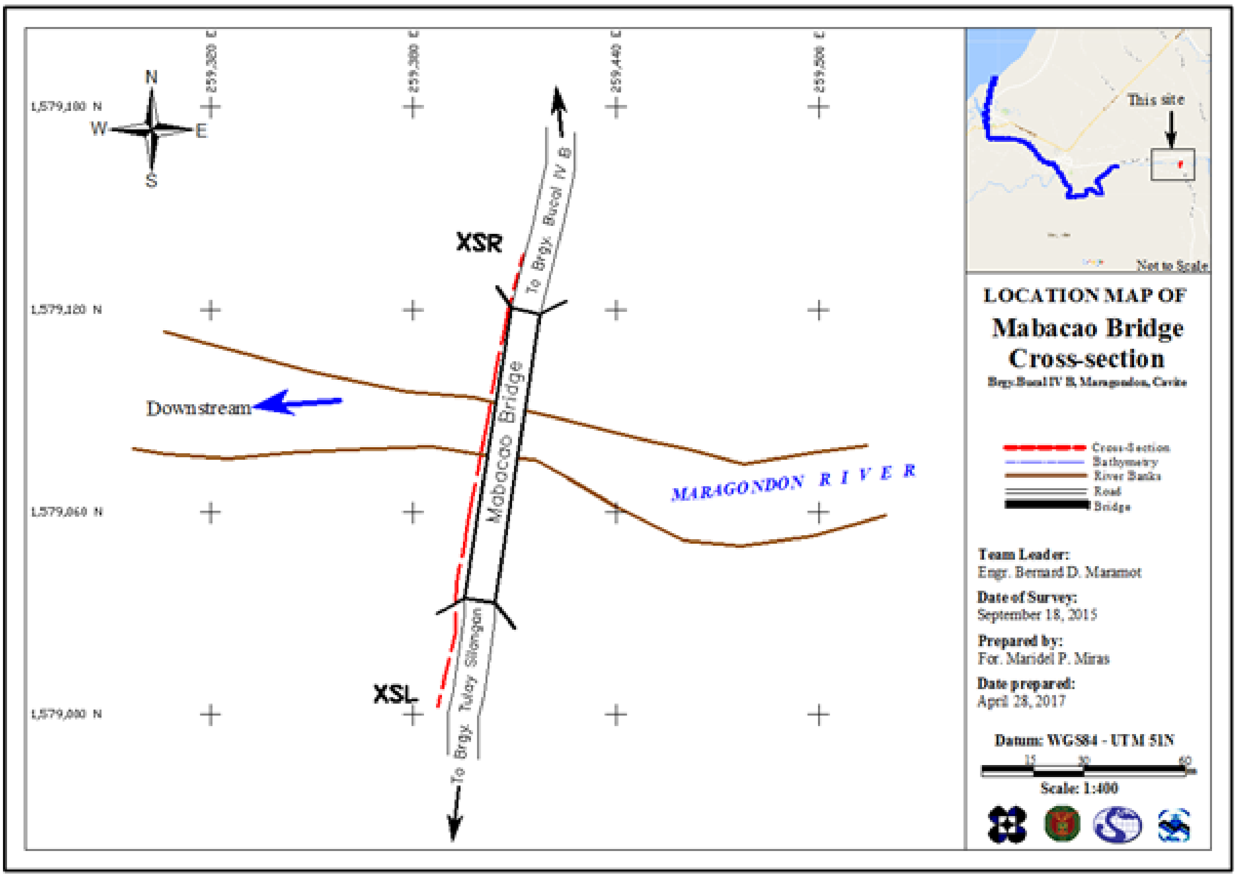


Figure 38. Mabacao Bridge cross-section location map

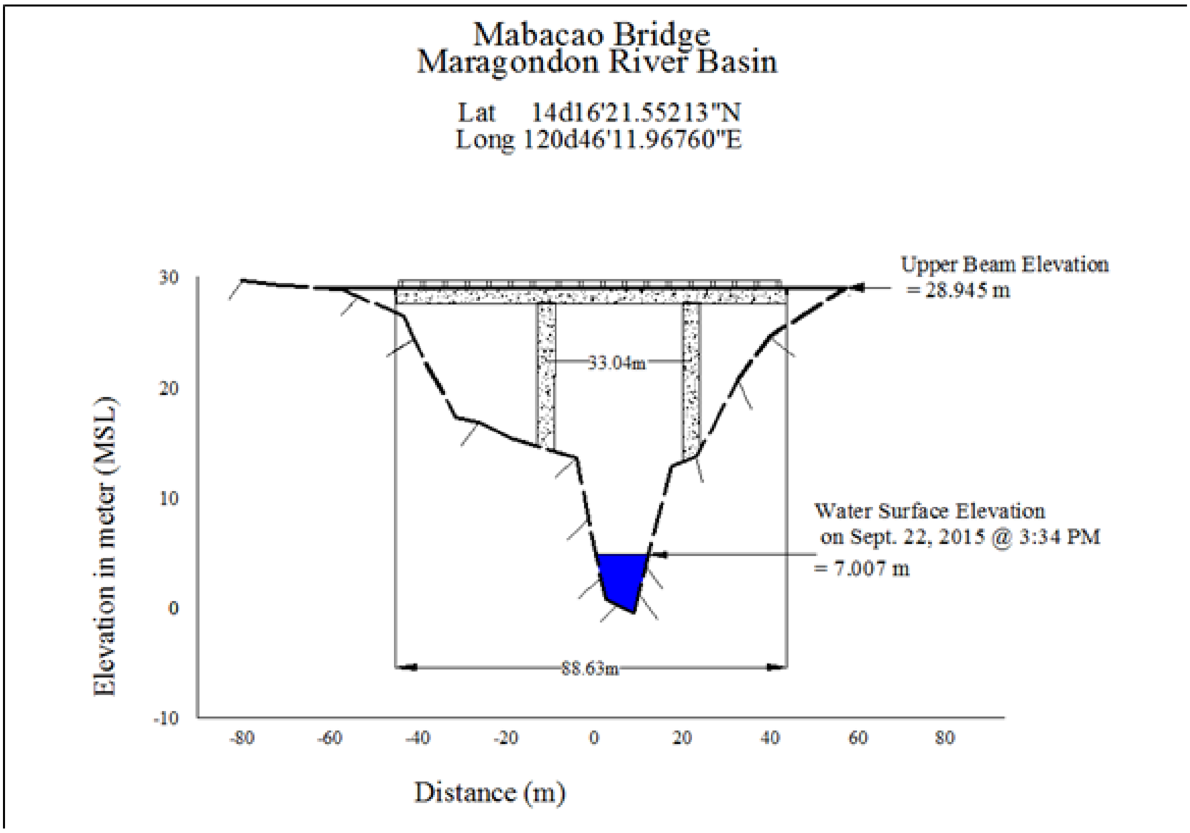


Figure 39. Mabacao Bridge cross-sectional diagram

Bridge Data Form

Bridge Name: Mabacao Bridge **Date:** September 18, 2015

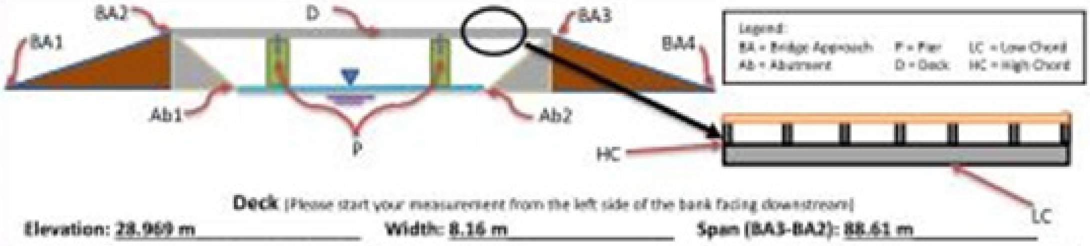
River Name: Imus River **Time:** 2:03 P.M.

Location (Brgy, City, Region): Brgy Bucal IV B, Maragondon, Cavite

Survey Team: Team Bernard

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

Latitude: 14d16'21.55213" N **Longitude:** 120d46'11.96760" E



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

Elevation: 28.969 m **Width:** 8.16 m **Span (BA3-BA2):** 88.61 m

	Station	High Chord Elevation	Low Chord Elevation
1			
2			
3			
4			
5			

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	29.636	BA3	124.307	28.974
BA2	35.694	28.941	BA4	136.574	28.936

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

	Station (Distance from BA1)	Elevation
Ab1		
Ab2		

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

Shape: ____ **Number of Piers:** 2 **Height of column footing:** ____

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	68.965	28.963	
Pier 2	102.01	28.961	
Pier 3			
Pier 4			
Pier 5			
Pier 6			

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

Figure 40. Mabacao Bridge data form

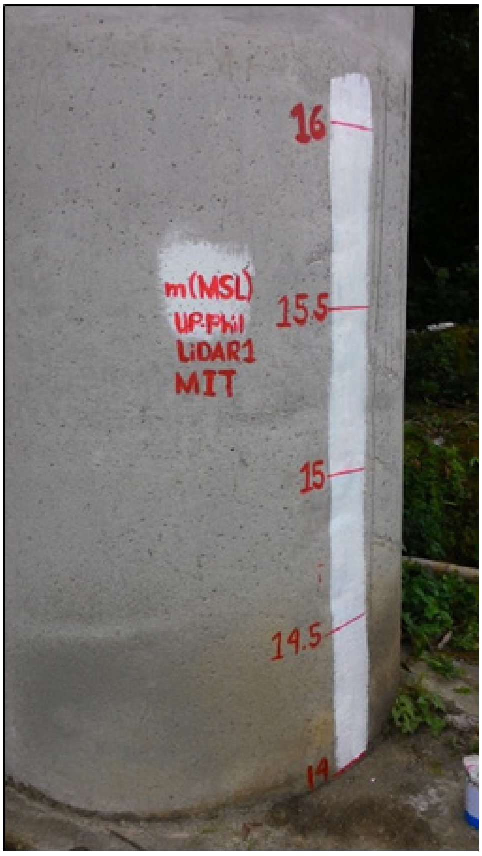


Figure 41. Water level markings on the side of the pier of the Mabacao Bridge

The water surface elevation of the Maragondon River was determined using Trimble® SPS 882 in PPK mode technique on September 22, 2014 at 15:34 hrs., along the banks of the Mabacao Bridge. The water surface elevation was translated into markings on the bridge's pier using a digital level scale (Figure 41). The marked pier served as reference for flow data gathering and depth gauge deployment of the MIT Phil-LiDAR 1 Team.

4.6 Validation Points Acquisition Survey

The validation points acquisition survey was conducted on September 18, 2015 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, utilizing PPK technique on a continuous topo mode. The receiver was mounted on a pole attached in front of a vehicle, as demonstrated in Figure 42. 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 2.36 meters from the ground up to the bottom of the notch of the GNSS Rover receiver. The survey began in the Municipality of Ternate, and traversed the national highway until the Municipality of General Emilio Aguinaldo. Both points are in the province of Cavite.

Figure 42. Validation points acquisition set-up for the Maragondon River Basin

The survey acquired one thousand nine hundred forty-two (1,942) ground validation points with an approximate length of 12.30 kilometers, using UP-MAB as the GNSS base station (Refer to the map in Figure 43).

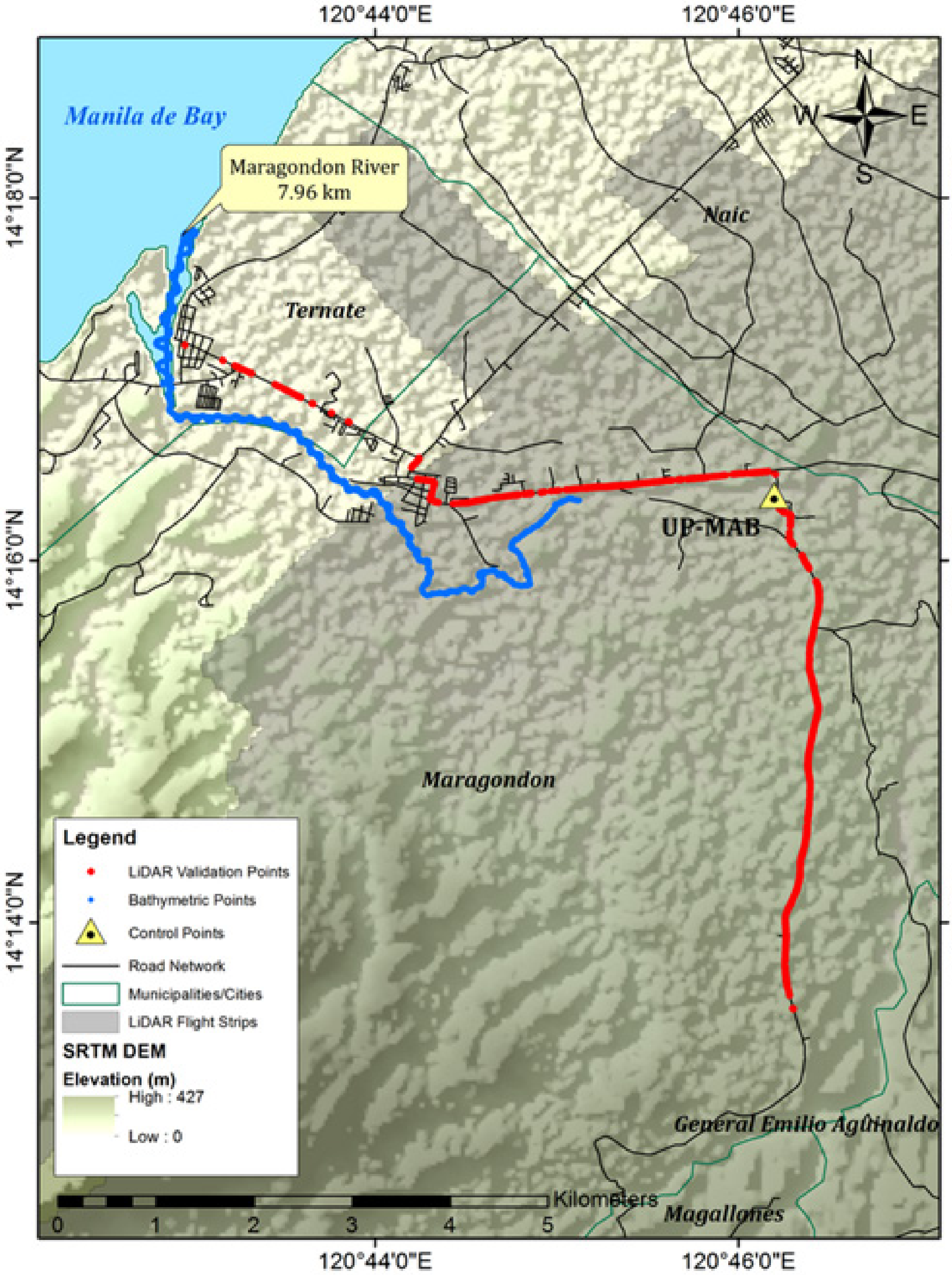


Figure 43. Extent of the LiDAR ground validation survey of Maragondon River basin

4.7 Bathymetric Survey

A bathymetric survey of the Maragondon River was conducted on September 18, 2015, utilizing a GNSS Rover receiver, Trimble® SPS 882, in PPK survey technique mounted on top of a pole with an Ohmex™ single-beam echo sounder (seen in Figure 44). The survey began in the river's upstream portion in Barangay Tulay in the Municipality of Maragondon, with coordinates 14°16'19.76537" 120°45'06.99831"; and ended at the mouth of the river in Barangay San Jose in the Municipality of Ternate, with coordinates 14°17'49.25186" 120°42'59.73346". The control point UP-MAB was used as the base station for the survey.

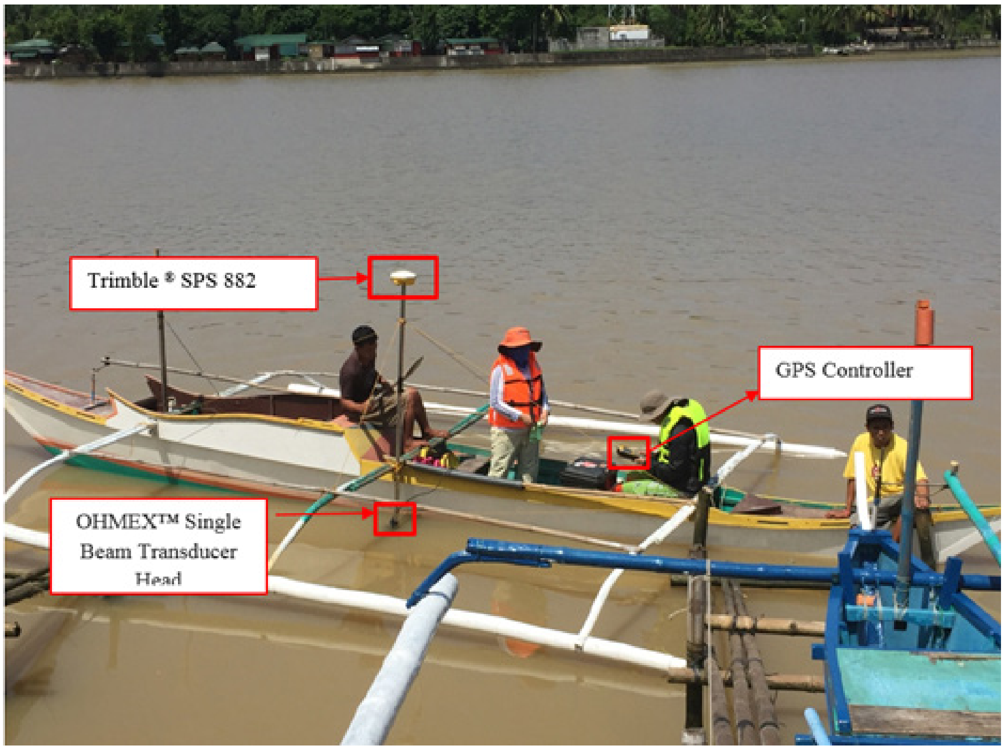


Figure 44. Bathymetric survey in the Maragondon River

The bathymetric survey for the Maragondon River gathered a total of 4,579 bathymetric points, covering an estimated length of 7.96 kilometers, which traversed three (3) barangay boundaries: Barangay Tulay,; the town proper of Maragondon; and Ternate. This is depicted in Figure 45. A CAD drawing was also produced to illustrate the riverbed profile of the Maragondon River, as presented in Figure 46. The profile shows an elevation drop of -6.5 meters in MSL was observed within the entire length. The highest elevation observed was 0.249 meters MSL, located in Barangay Bucal I, Municipality of Maragondon; while the lowest elevation observed was -12.99 meters below MSL, located in Barangay Sapang II, Municipality of Ternate.

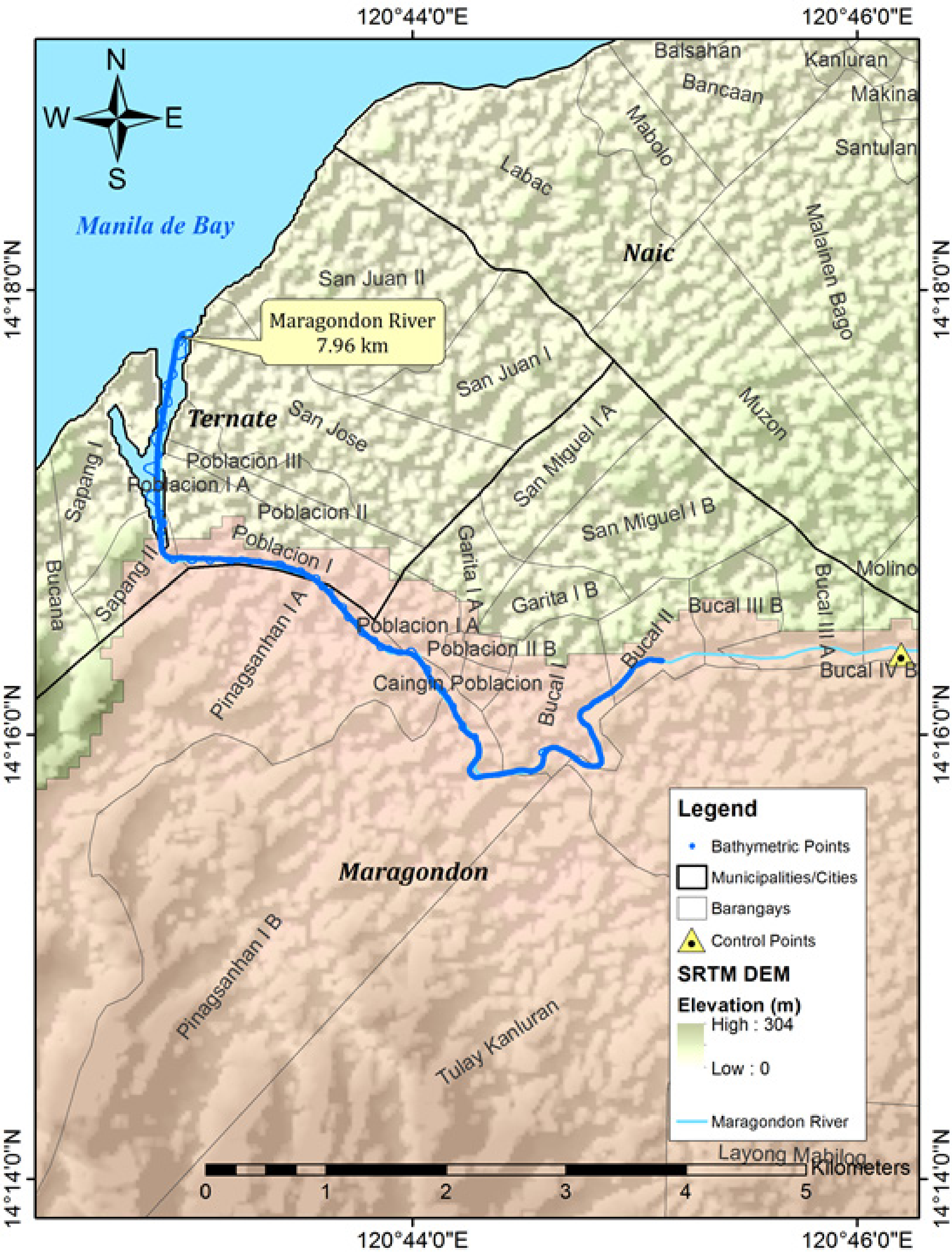


Figure 45. Bathymetric survey coverage of the Salug Diut River

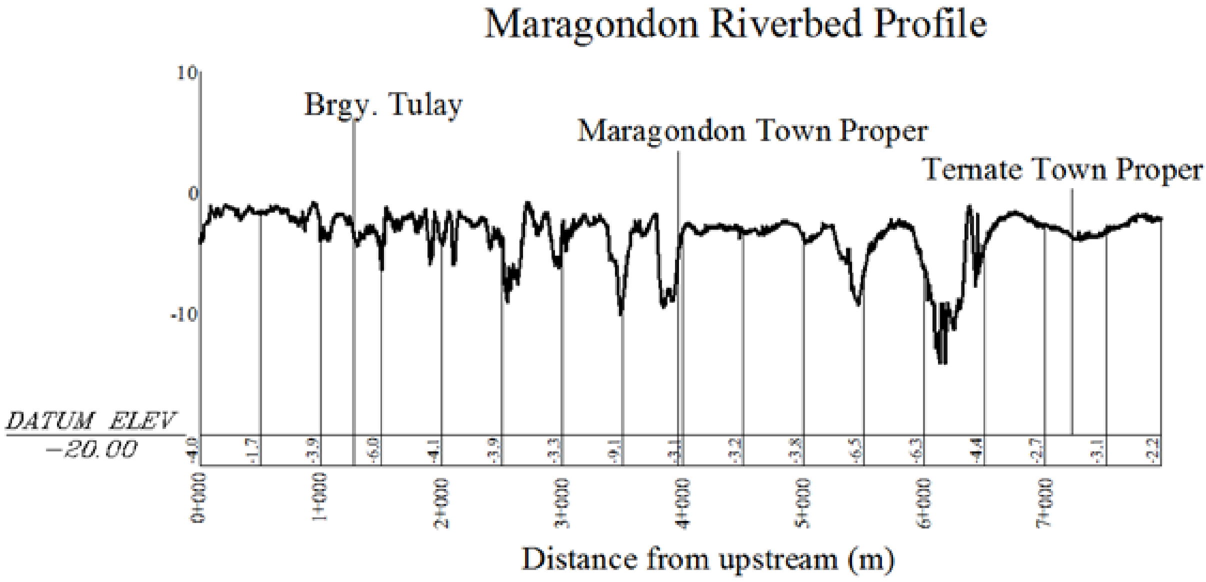


Figure 46. Riverbed profile of the Maragondon River

CHAPTER 5: FLOOD MODELING AND MAPPING

Dr. Alfredo Mahar Lagmay, Christopher Uichanco, Sylvia Sueno, Marc Moises, Hale Ines, Miguel del Rosario, Kenneth Punay, Neil Tingin, and Pauline Racoma

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

Rainfall, water level, and flow in a certain period of time, which are components and data that may affect the hydrologic cycle of the Maragondon River Basin, were monitored, collected, and analyzed.

5.1.2 Precipitation

Precipitation data was taken from three (3) automatic rain gauges (ARGs) installed by the Department of Science and Technology – Advanced Science and Technology Institute (DOST-ASTI). These rain gauges are identified as the: (i.) Cavite State University ARG (14°11'14.48"N, 120°53'0.52"E), located in Indang, Cavite; (ii.) Dayap Itaas ARG (14° 3'19.26"N, 120°51'6.80"E), located in Calaca, Cavite; and (iii.) Naic Campus ARG (14°19'4.90"N, 120°44'38.20"E), located in Naic, Cavite. The location maps of the ARGs are seen in Figure 47.

The precipitation data collection was held on September 13, 2016 at 00:00 hrs. until September 13, 2016 at 23:45 hrs., with a fifteen-minute recording interval.

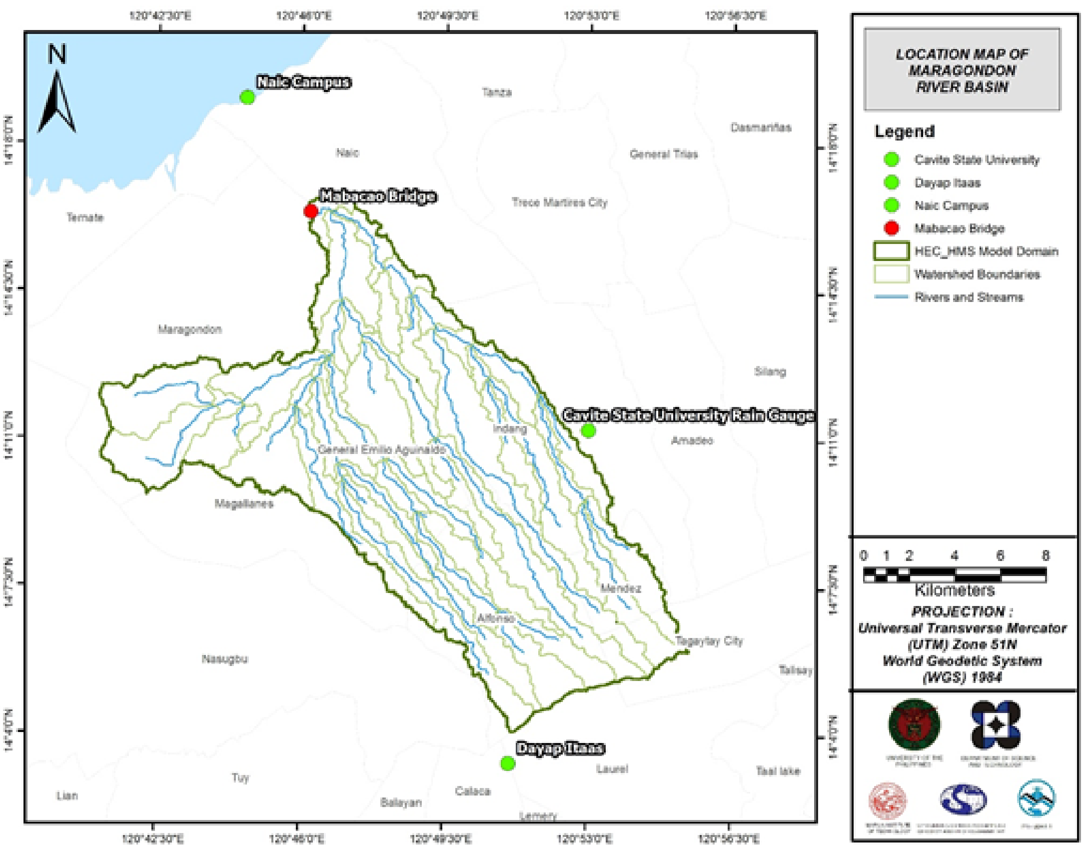


Figure 47. The location map of rain gauges used for the calibration of the Maragondon HEC-HMS Model

For the Cavite State University ARG, total rain for the event was 19.6 millimeters. Peak rain of 9.2 millimeters was recorded on September 13, 2016. The lag time between the peak rainfall and discharge was five (5) hours and forty (40) minutes, as seen in Figure 50.

For the Dayap Itaas ARG, total rain for the event was 10.4 millimeters. Peak rain of 1.8 millimeters was recorded on September 13, 2016. The lag time between the peak rainfall and discharge was eight (8) hours and forty-five (45) minutes, as reflected in Figure 50.

For the Naic Campus ARG, total rain for the event was 1.4 millimeters. Peak rain of 0.8 millimeters was recorded on September 13, 2016. The lag time between the peak rainfall and discharge was six (6) hours and fifty-five (55) minutes, as observed in Figure 50.

5.1.3 Rating Curves and River Outflow

A rating curve was computed using the prevailing cross-section (Figure 48) at the Mabacao Bridge, Maragondon, Cavite (14°16'21.55"N, 120°46'11.97"E). The curve establishes the relationship between the observed water levels (H) from the Mabacao Bridge using the depth gage, and the outflow (Q) of the watershed obtained from the flow meter at this location. It is expressed in the form of the following equation:
Q=anh
where, Q : Discharge (m3/s),
h : Gauge height (reading from the deployed depth gauge at the Mabacao Bridge), and;
a and n: Constants.

For the Mabacao Bridge, the rating curve is expressed as Q = 0.000053e1.403789h, as illustrated in Figure 49.

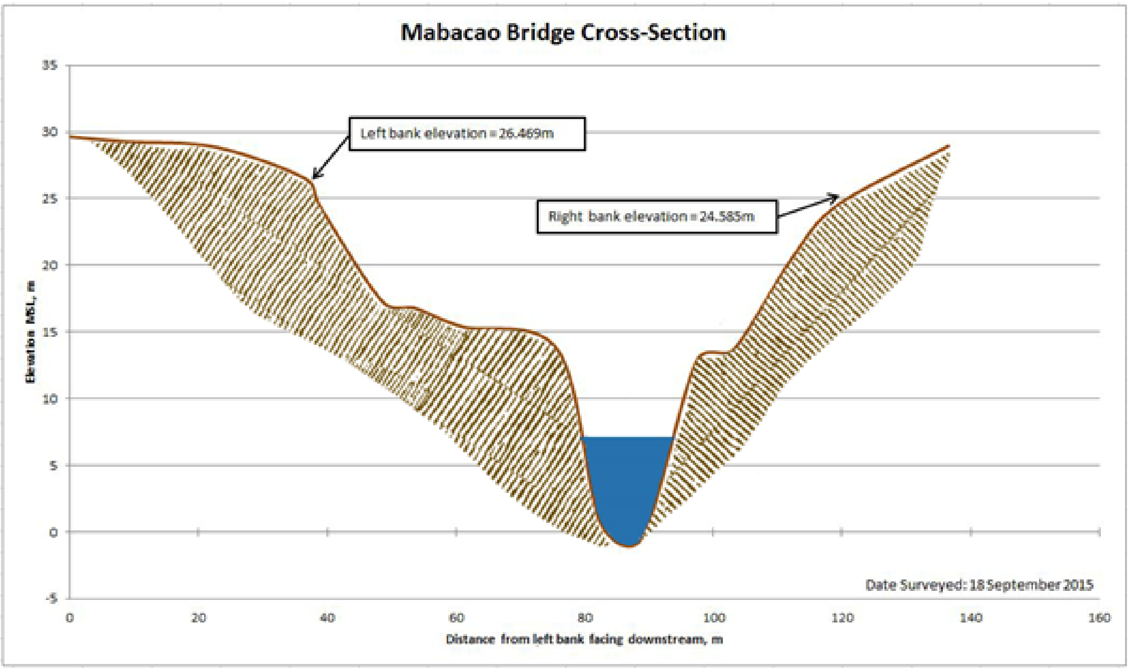


Figure 48. Cross-section plot of the Mabacao Bridge

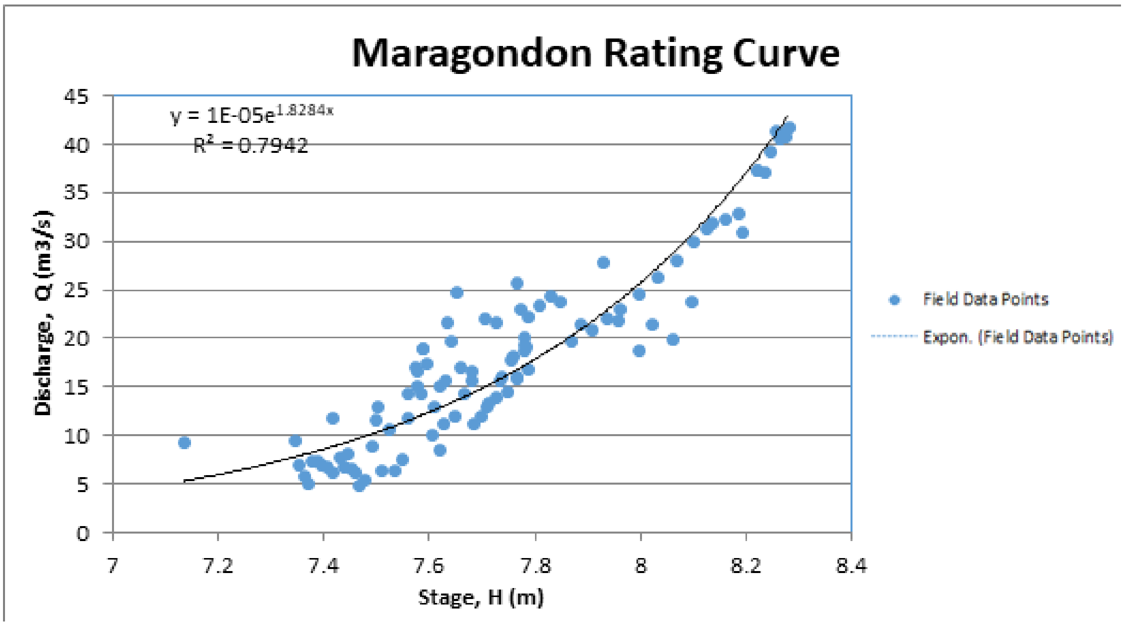


Figure 49. Rating curve at the Mabacao Bridge in Maragondon, Cavite

The rating curve equation was used to compute for the river outflow at the Mabacao Bridge, for the calibration of the HEC-HMS model presented in Figure 50. The peak discharge was at 41.8 cubic meters per second (m3/s) on September 13, 2016 at 13:40 hrs.

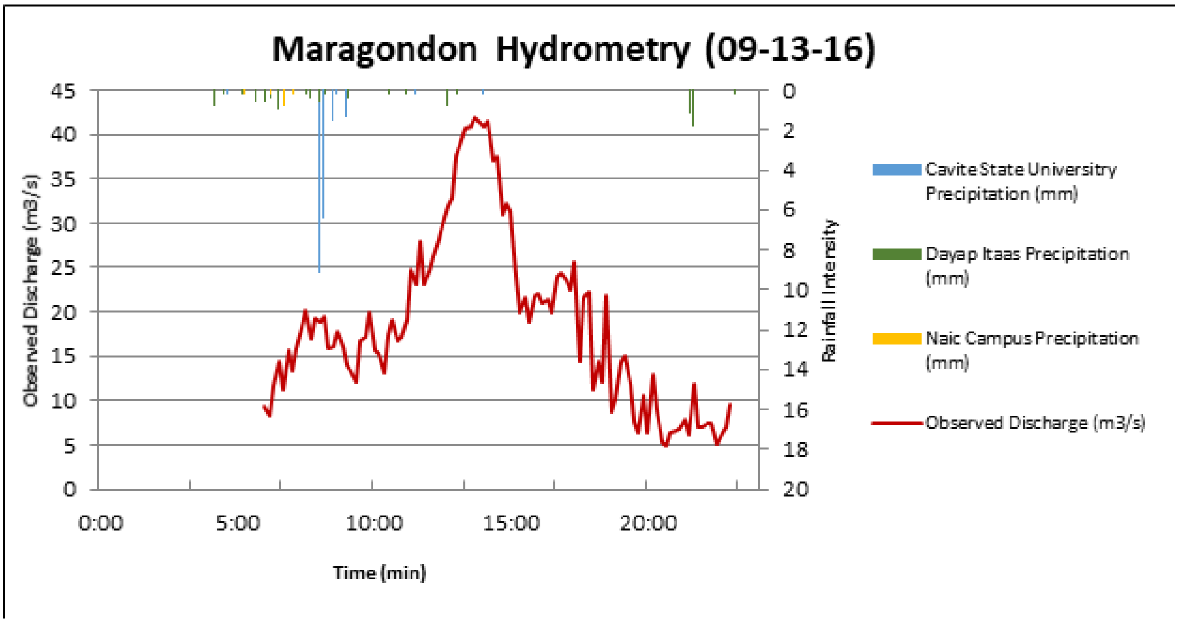


Figure 50. Rainfall and outflow data at the Maragondon, which were used for modeling

5.2 RIDF Station

The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed for the Rainfall Intensity Duration Frequency (RIDF) values for the Sangley Gauge (Table 34). This station was selected based on its proximity to the Maragondon watershed (Figure 51). The RIDF rainfall amount for twenty-four (24) hours was converted into a synthetic storm by interpolating and re-arranging the values such that certain peak values were attained at a certain time. The extreme values for this watershed were computed based on a 54-year record.

Table 34. RIDF values for the Sangley 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	20.3	30	36.6	46.4	63.2	74.6	96.6	119.6	147.9
5	28.3	41.8	50.8	64.6	89.8	106.8	140.3	174	209.4
10	33.6	49.7	60.2	76.7	107.3	128.2	169.2	210	250.1
15	36.6	54.1	65.5	83.5	117.2	140.3	185.6	230.3	273.1
20	38.7	57.2	69.2	88.3	124.2	148.7	197	244.6	289.1
25	40.3	59..6	72.1	91.9	129.5	155.2	205.8	255.5	301.5
50	45.3	66.9	80.9	103.3	146	175.2	233	289.3	339.7
100	50.3	74.2	89.7	114.5	162.3	195.1	259.9	322.8	337.6

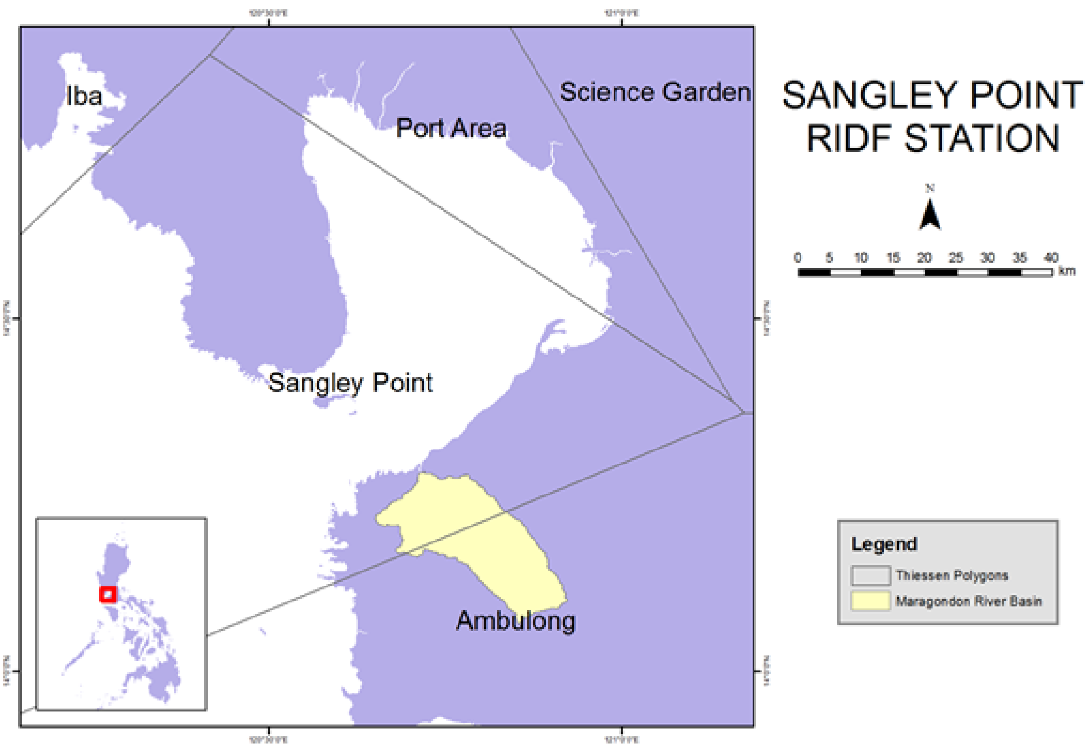


Figure 51. Sangley RIDF location relative to the Maragondon River Basin

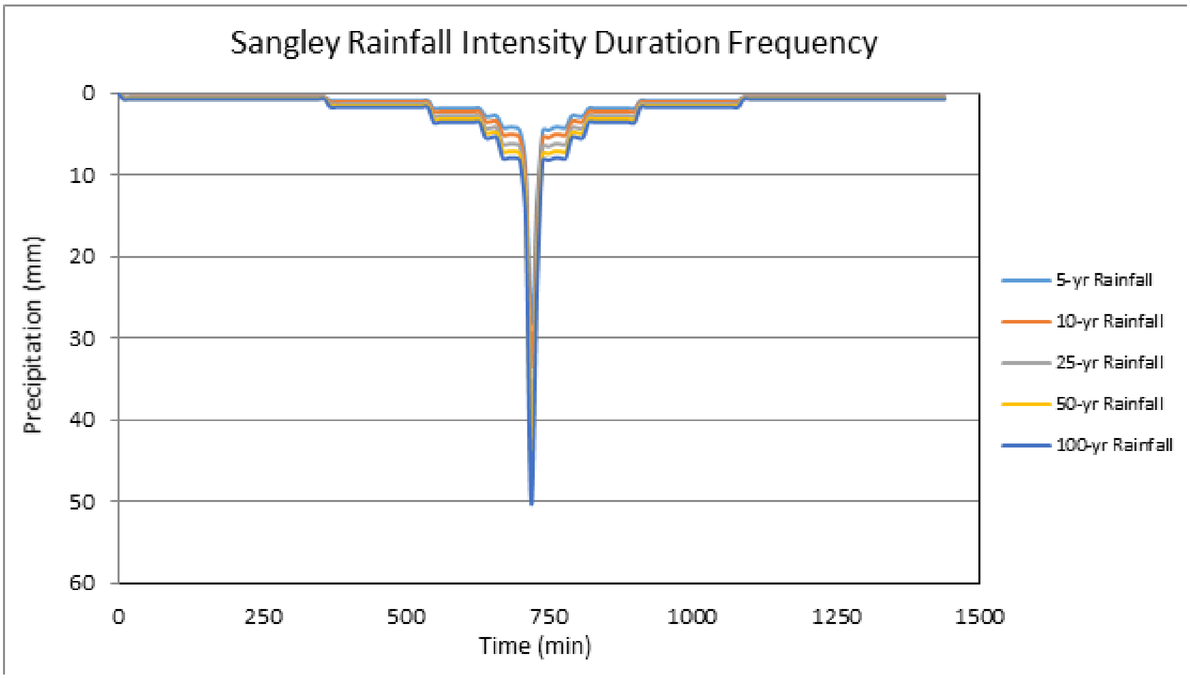


Figure 52. Synthetic storm generated from a 24-hour period rainfall, for various return periods

5.3 HMS Model

The soil shapefile was taken in 2004 from the Bureau of Soils and Water Management (BSWM) under the Department of Agriculture (DA). The land cover dataset is from the National Mapping and Resource Information Authority (NAMRIA). The soil and land cover maps of the Maragondon River Basin are presented in Figures 53 and 54, respectively.

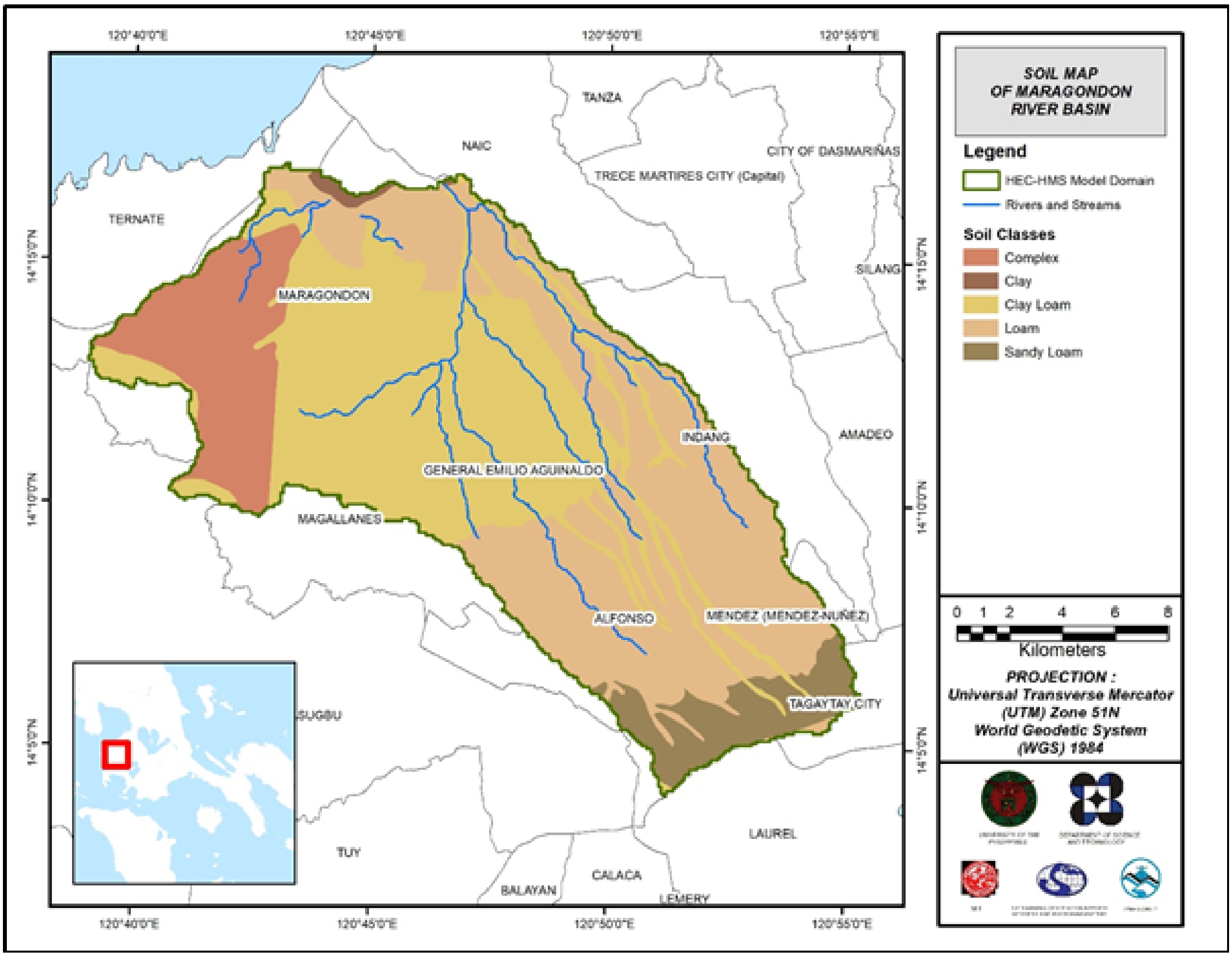


Figure 53. Soil map of the Maragondon River Basin (Source: DA)

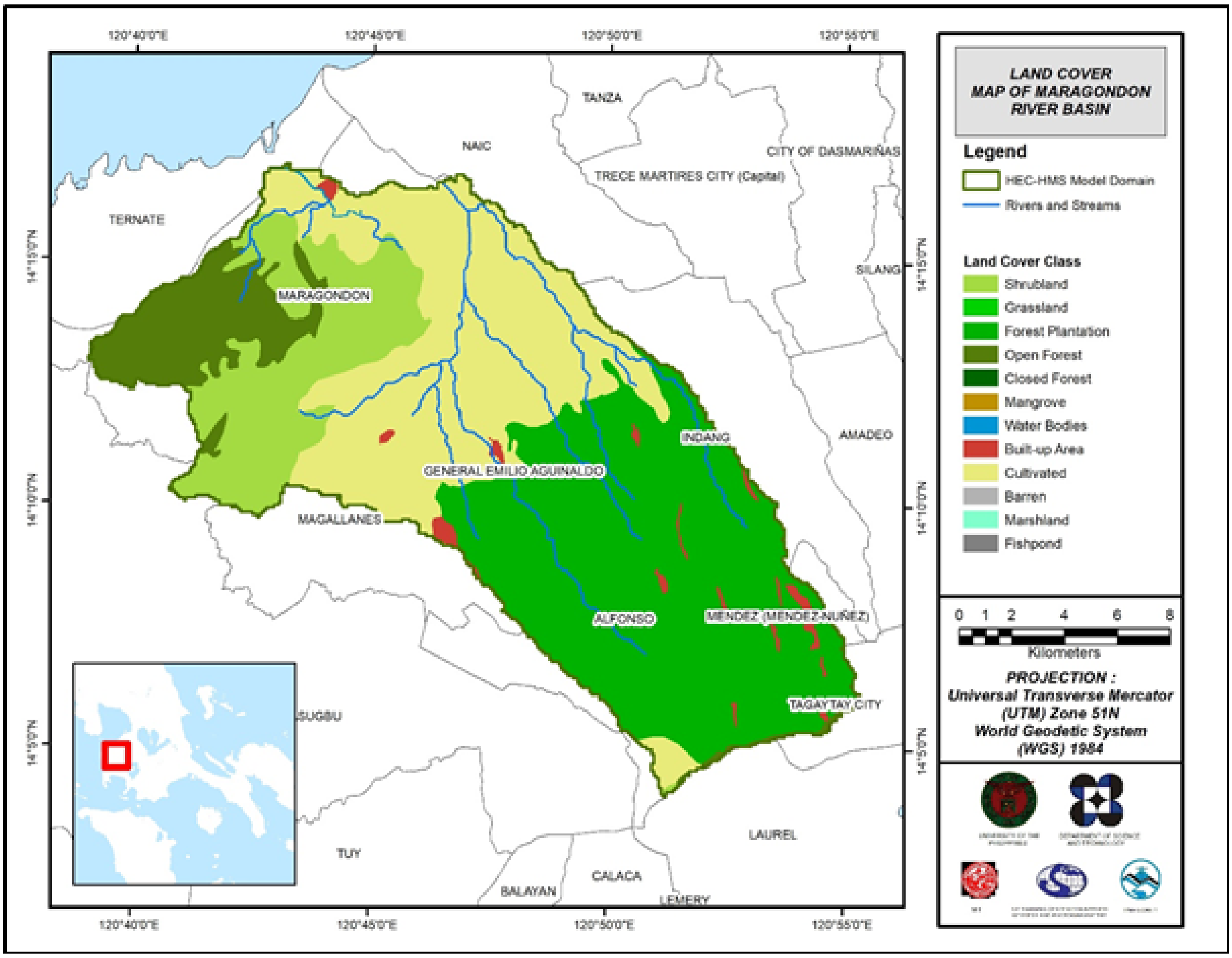


Figure 54. Land cover map of the Maragondon River Basin (Source: NAMRIA)

The soil classes identified in the Maragondon River Basin were clay loam, clay, loam, sandy loam, and complex soil. The land cover types identified were open canopy forests, shrub lands, cultivated and built-up areas, and forest plantations.

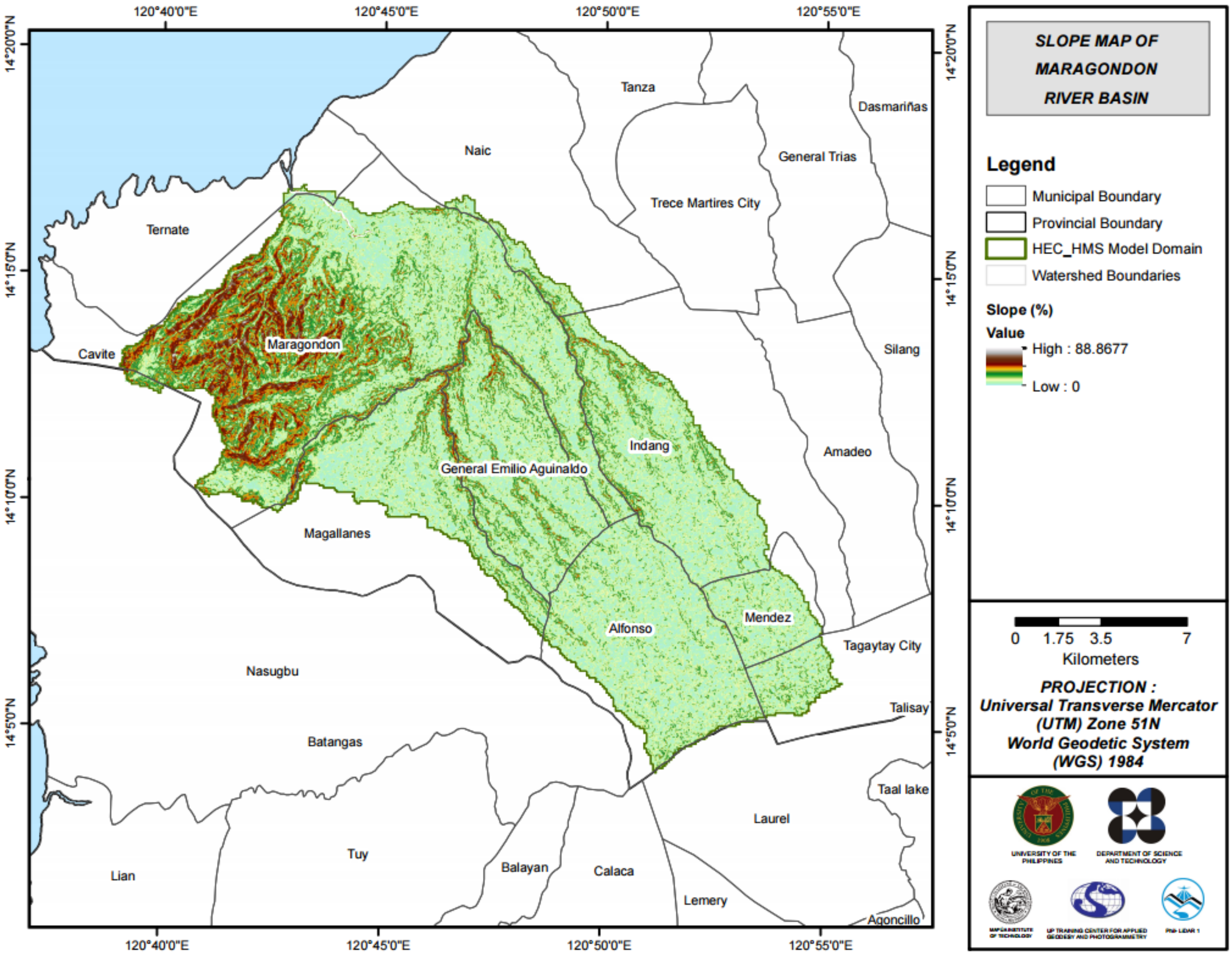


Figure 55. Slope map of the Maragondon River Basin

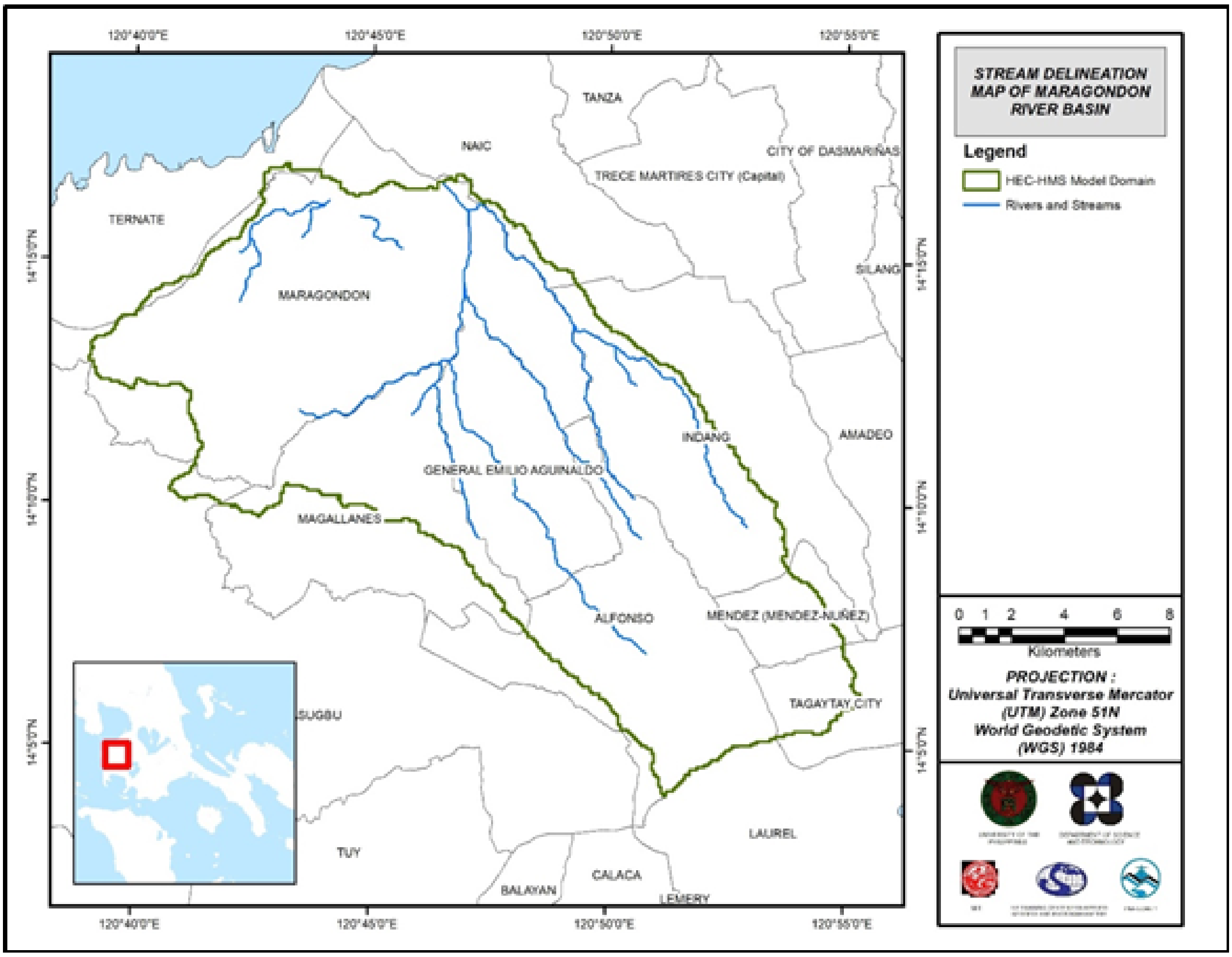


Figure 56. Stream delineation map of the Maragondon River Basin

Using the SAR-based DEM, the Maragondon basin was delineated and further subdivided into sub-basins. The Maragondon basin model consists of forty-five (45) sub-basins, twenty-two (22) reaches, and twenty-seven (27) junctions. The main outlet is at the most northeastern tip of the watershed. The basin model is illustrated in Figure 57. The sub-basins were identified based on soil and land cover characteristics of the area. Precipitation was taken from an installed Rain Gauge near and inside the river basin. Finally, the model was calibrated using the data from actual discharge flow gathered in the Mabacao Bridge. See Annex 10 for the Maragondon Model Reach Parameters.

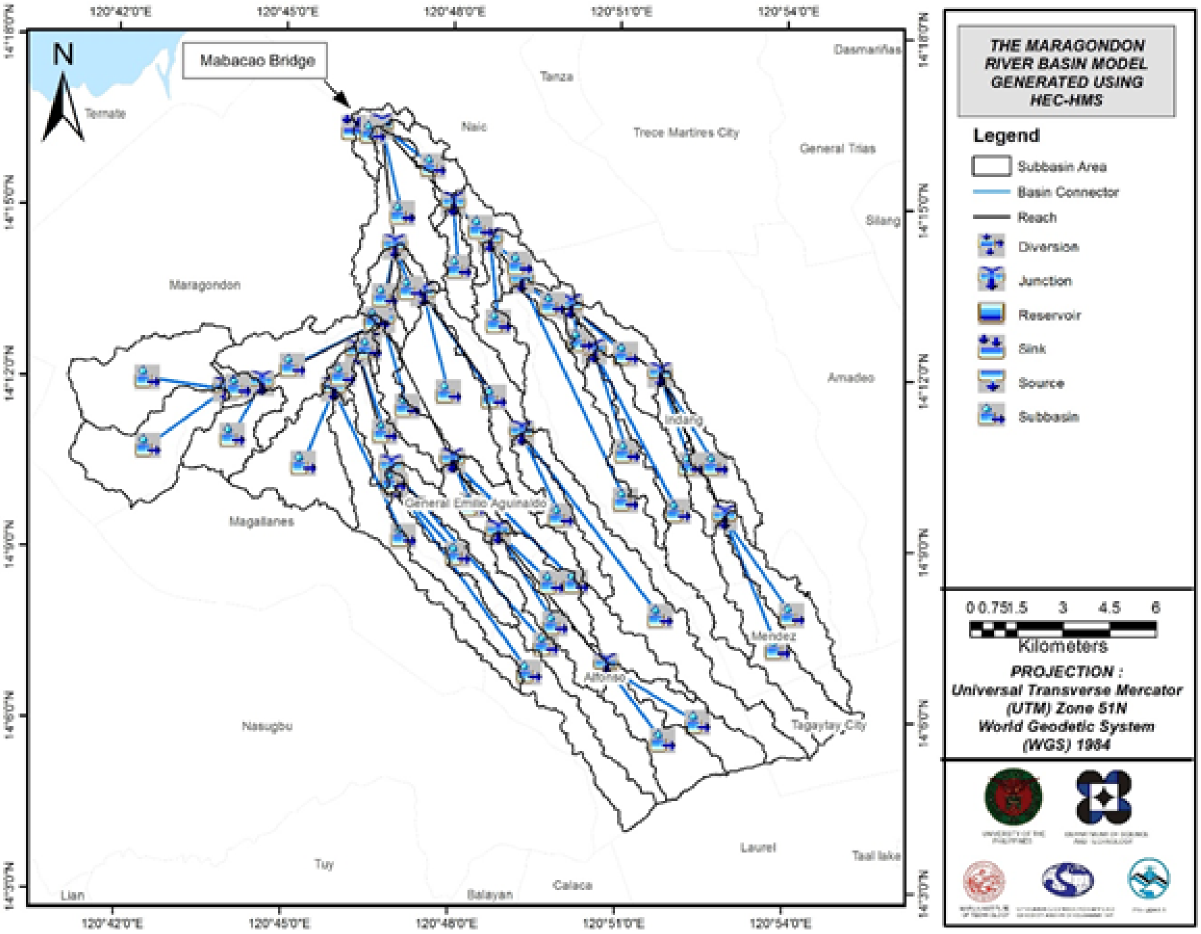


Figure 57. The Maragondon River Basin Model domain, generated by HEC-HMS

5.4 Cross-section Data

Riverbed cross-sections of the watershed were necessary in the HEC-RAS model set-up. 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).

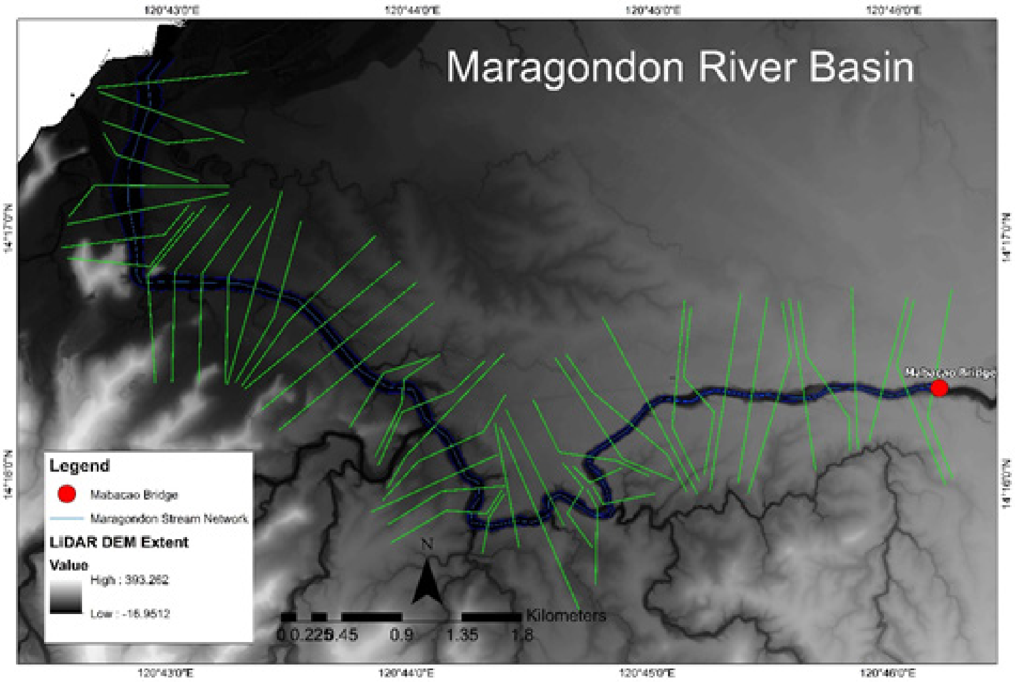


Figure 58. River cross-section of the Maragondon River, generated through the ArcMap HEC GeoRAS tool

5.5 Flo 2D Model

The automated modeling process allowed 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 was divided into square grid elements, 10 meters by 10 meters in size. Each element was assigned a unique grid element number, which served as its identifier. The elements were then attributed with the parameters required for modeling, such as x- and y-coordinates of centroid, names of adjacent grid elements, Manning's coefficient of roughness, infiltration, and elevation values. The elements were arranged spatially to form the model, allowing the software to simulate the flow of water across the grid elements in eight (8) directions (i.e., north, south, east, west, northeast, northwest, southeast, and southwest).

Based on the elevation and flow direction, it was determined that the water will generally flow from the southeast of the model to the northwest, following the main channel. As such, boundary elements in those particular regions of the model were assigned as inflow and outflow elements. respectively.

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

The simulation was then run through the FLO-2D GDS Pro. This particular model had a computer run time of 223.16406 hours. After the simulation, the FLO-2D Mapper Pro was used to transform the simulation results into spatial data that shows the 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 generated the flood hazard map. Most of the default values given by the FLO-2D Mapper Pro were used, except for those in the Low hazard level. For this particular level, the minimum h (maximum depth) was set at 0.2 meters; while the minimum vh (product of maximum velocity (v) and maximum depth (h)) was set at 0 square meters per second (m2/s).

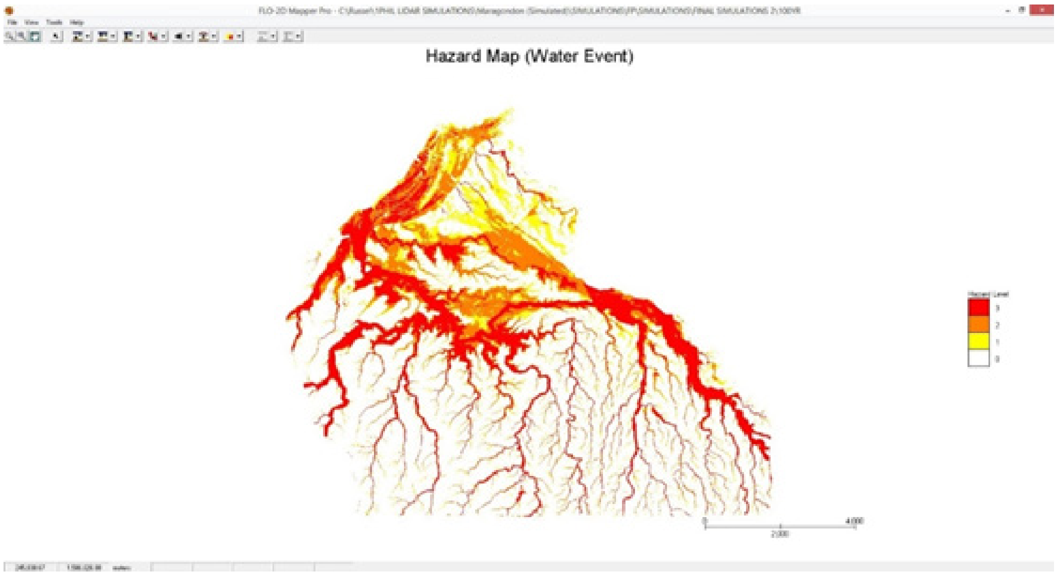


Figure 60. Generated 100-year rain return hazard map from the FLO-2D Mapper

The creation of a flood hazard map from the model also automatically generated a flow depth map, depicting the maximum amount of inundation for every grid element. The legend used by default in the Flo-2D Mapper was not a good representation of the range of flood inundation values; hence, a different legend was used for the layout. In this particular model, the inundated parts covered a maximum land area of 89 049 792.00 square meters (m2).

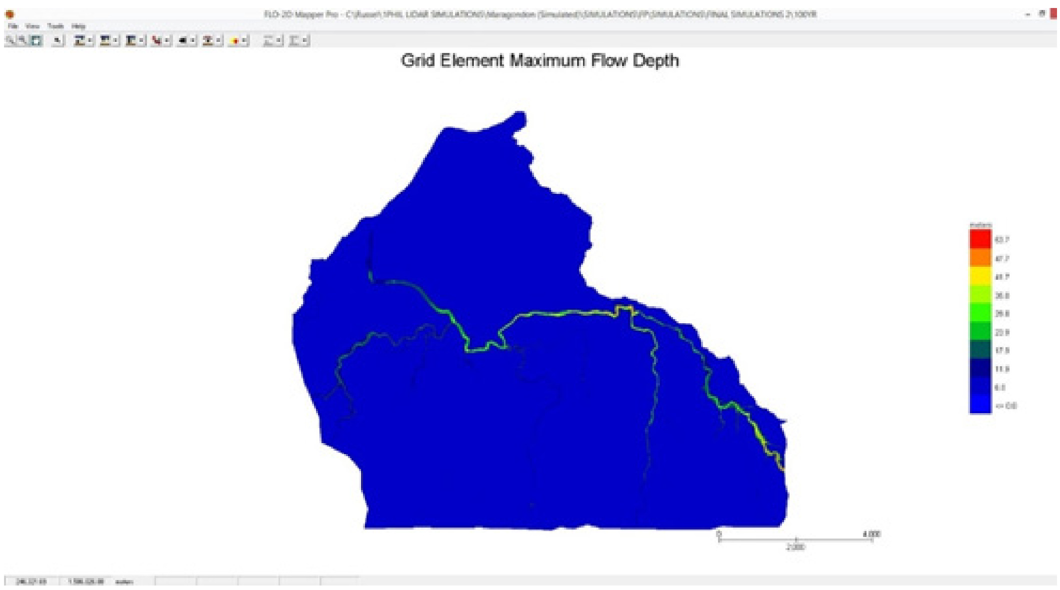


Figure 61. Generated 100-year rain return flow depth map from the FLO-2D Mapper

There was a total of 87 508 115.66 cubic meters (m3) of water that entered the model. Of this amount, 38 981 740.73 m3 was due to rainfall, while 48 526 374.93 m3 was inflow from areas outside the model. 10 309 305.00 m3 of this water was lost to infiltration and interception, while 13 832 479.84 m3 was stored by the floodplain. The rest, amounting to up to 53 957 061.24 m3, was outflow.

5.6 Results of HMS Calibration

After calibrating the Maragondon HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 62 depicts the comparison between the two discharge data. The Maragondon Model Basin Parameters are available in Annex 9.

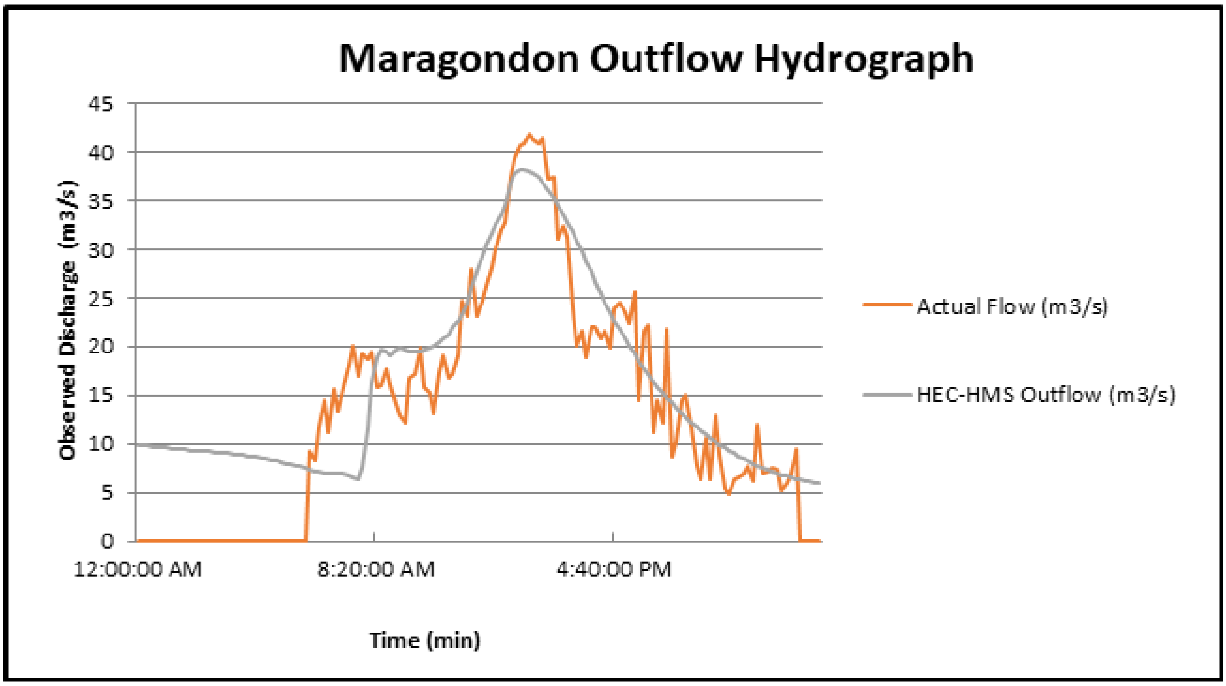


Figure 62. Outflow hydrograph of Maragondon produced by the HEC-HMS model, compared with observed outflow

Enumerated in Table 35 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 35. Range of calibrated values for the Maragondon model

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.019 – 88.82
			Curve Number	35.85 - 99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.017 – 115.39
			Storage Coefficient (hr)	0.017 - 1000
	Baseflow	Recession	Recession Constant	0.00001 – 0.20
			Ratio to Peak	0.0009 - 1
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.0001 - 1

The initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as the initial abstraction decreases. A range of values of 0.019 to 88.82 millimeters signifies a minimal to substantial amount of infiltration or rainfall interception by vegetation.

The curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as the curve number increases. The range of the curve number for the Maragondon watershed’s sub-basins are from 35.85 to 99. The soil classes in the basin were identified as clay loam, clay, loam, sandy loam, and complex soil. The land cover types identified were open canopy forests, shrub lands, cultivated and built-up areas, and forest plantations.

The time of concentration and the storage coefficient are the travel time and the index of temporary storage of runoff in a watershed. The range of calibrated values from 0.017 hours to 1000 hours determines the reaction time of the model, with respect to the rainfall. The peak magnitude of the hydrograph decreases when these parameters are increased.

The recession constant is the rate at which the baseflow recedes between storm events; and the ratio to peak is the ratio of the baseflow discharge to the peak discharge. The recession constant of the model ranges from 0.00001 to 0.20; while values for the ratio to peak are from 0.0009 to 1. The receding limb of the outflow hydrograph is unlikely to quickly revert to its original discharge values.

A Manning's roughness coefficient of 0.0001 to 1 corresponds to the common roughness in the Maragondon watershed's sub-basins.

Table 36. Efficiency Test of the Maragondon HMS Model

Accuracy Measure	Value
RMSE	4.73
r2	0.79
NSE	0.77
PBIAS	-2.005
RSR	0.48

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 4.73.

The Pearson correlation coefficient (r2) assesses the strength of the linear relationship between the observations and the model. A coefficient value close to 1 signifies an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it was measured at 0.79.

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 0.77.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate a bias towards over-prediction. The optimal value is 0. In the model, the PBIAS is -2.005.

The Observation Standard Deviation Ratio (RSR) is an error index. A perfect model attains a value of 0 when the error units of the values are quantified. The model attained an RSR value of 0.48.

5.7 Calculated outflow hydrographs and Discharge values for different rainfall return periods

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph in Figure 63 presents the Maragondon outflow using the Sangley RIDF curves in five (5) different return periods (i.e., 5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series), based on data from the PAGASA. The simulation results reveal a significant increase in outflow magnitude as the rainfall intensity increases, for a range of durations and return periods.

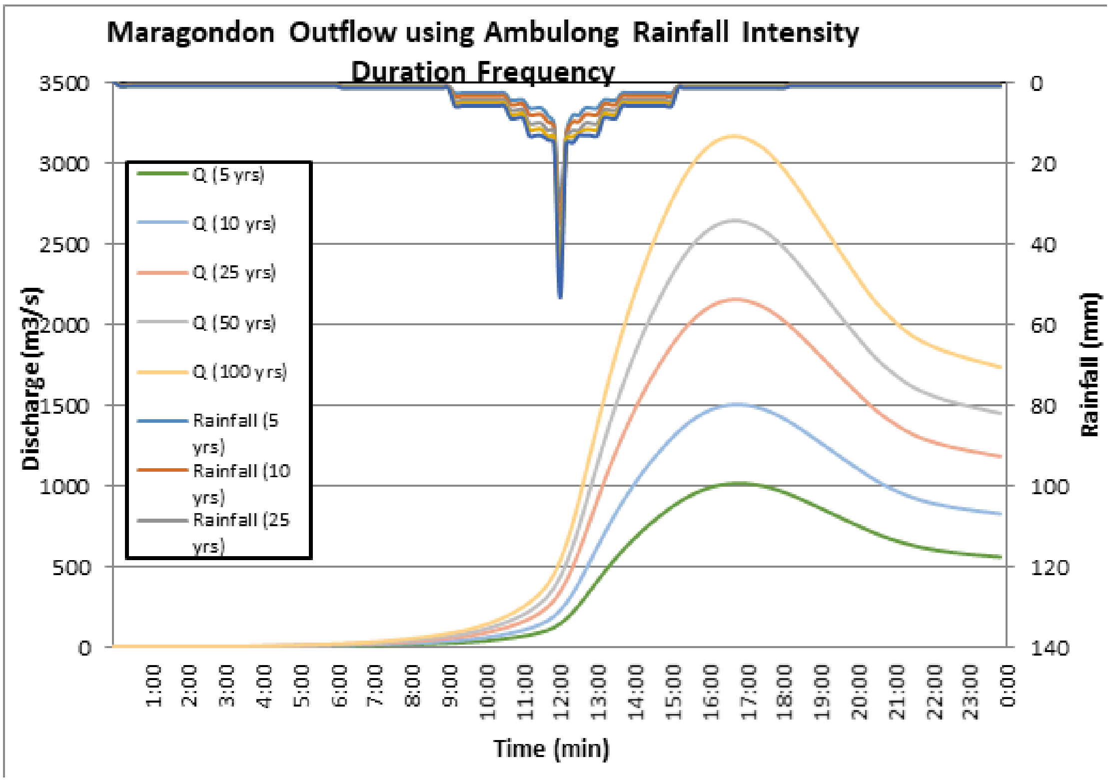


Figure 63. Figure 63. Outflow hydrograph at the Maragondon Station generated using the Sangley RIDF, simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow, and time to peak of the Maragondon River discharge using the Sangley RIDF curves in five (5) different return periods is outlined in Table 37.

Table 37. Peak values of the Maragondon HEC-HMS Model outflow, using the Sangley RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow	Time to Peak
(m 3/s)	Time to Peak	25.9	441.3	15 hours 40 mins
5-Year	279.5	29.6	1015.7	16 hours, 50 minutes
10-Year	334.9	35.4	1505.5	16 hours, 50 minutes
25-Year	404.8	42.6	2152	16 hours, 40 minutes
50-Year	456.7	48	2648.8	16 hours, 40 minutes
100-Year	508.3	53.4	3166.8	16 hours, 40 minutes

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS flood model produced a simulated water level at every cross-section, for every time step, for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining the real-time flood inundation extent of the river, after it has been automated and uploaded on the DREAM website. For this publication, only a sample output map of the river is presented, since only the MIT-Flood Acquisition and Validation Component (MIT-FAVC) base flow was calibrated. The sample generated map of the Maragondon River using the calibrated HMS base flow is displayed in Figure 64.

Figure 64. Sample output map of the Maragondon RAS Model

5.9 Flow Depth and Flood Hazard

The resulting flood hazard and flow depth maps have a 10-meter resolution. Figure 65 to Figure 70 exhibit the 5-year, 25-year, and 100-year rain return scenarios of the Maragondon floodplain.

Table 38. Municipalities affected in Maragondon Floodplain

City / Municipality	Total Area	Area Flooded	% Flooded
General Emilio Aguinaldo	39.39	1.4539	3.69%
Maragondon	147.39	66.019	44.79%
Naic	76.11	10.23	13.45%
Ternate	44.52	11.49	25.81%

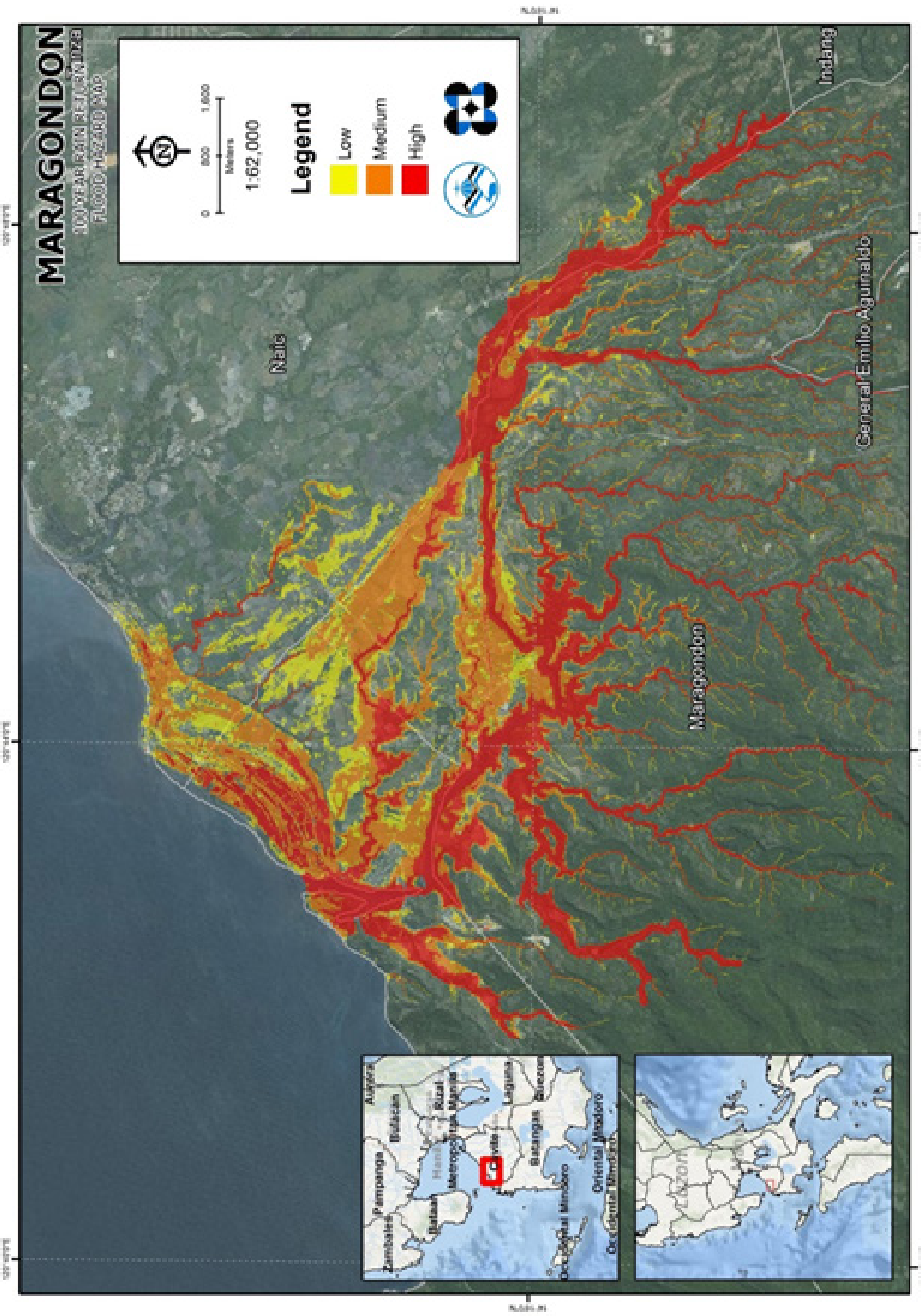


Figure 65. 100-year flood hazard map for the Maragondon floodplain

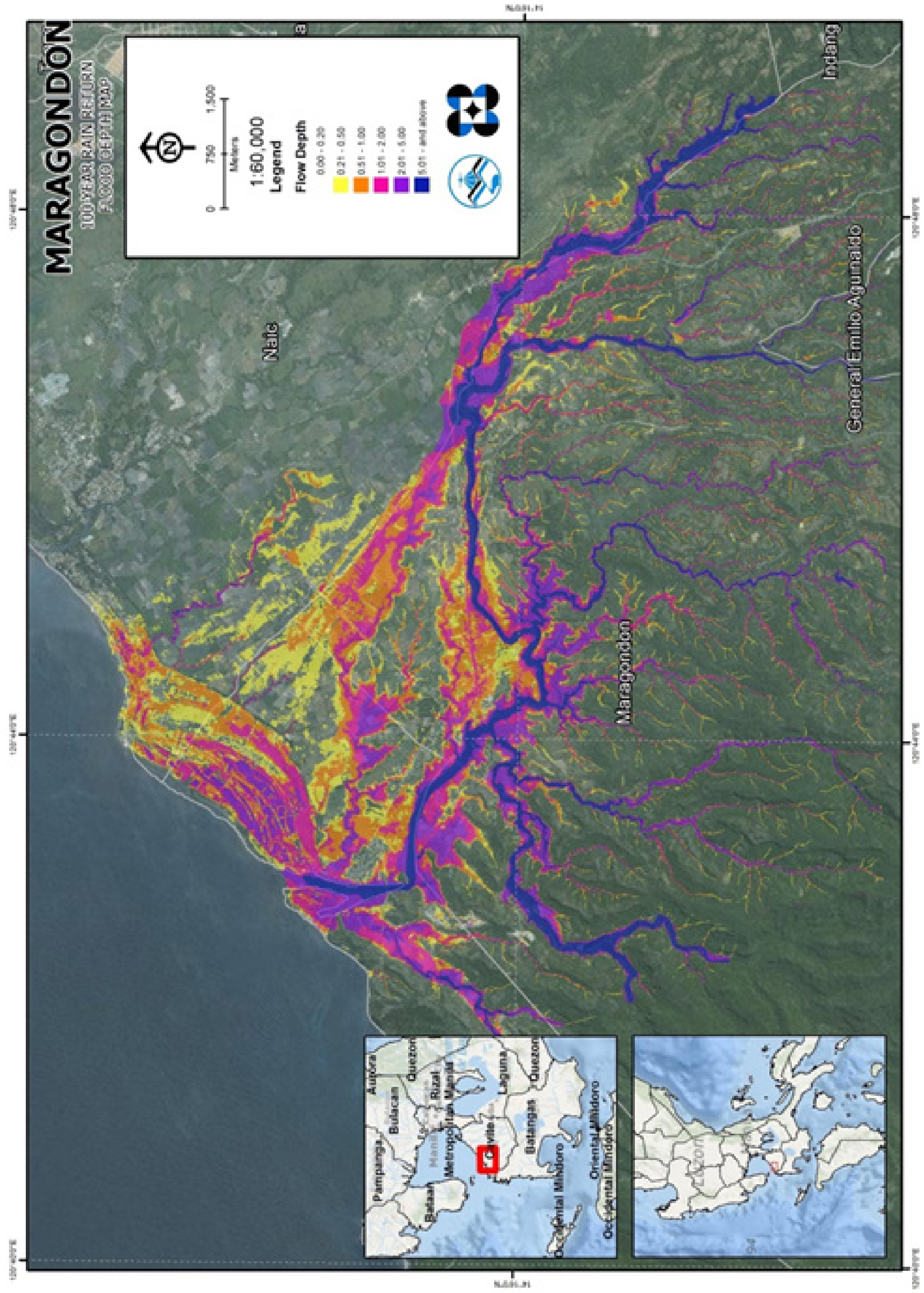


Figure 66. 100-year flow depth map for the Maragondon floodplain

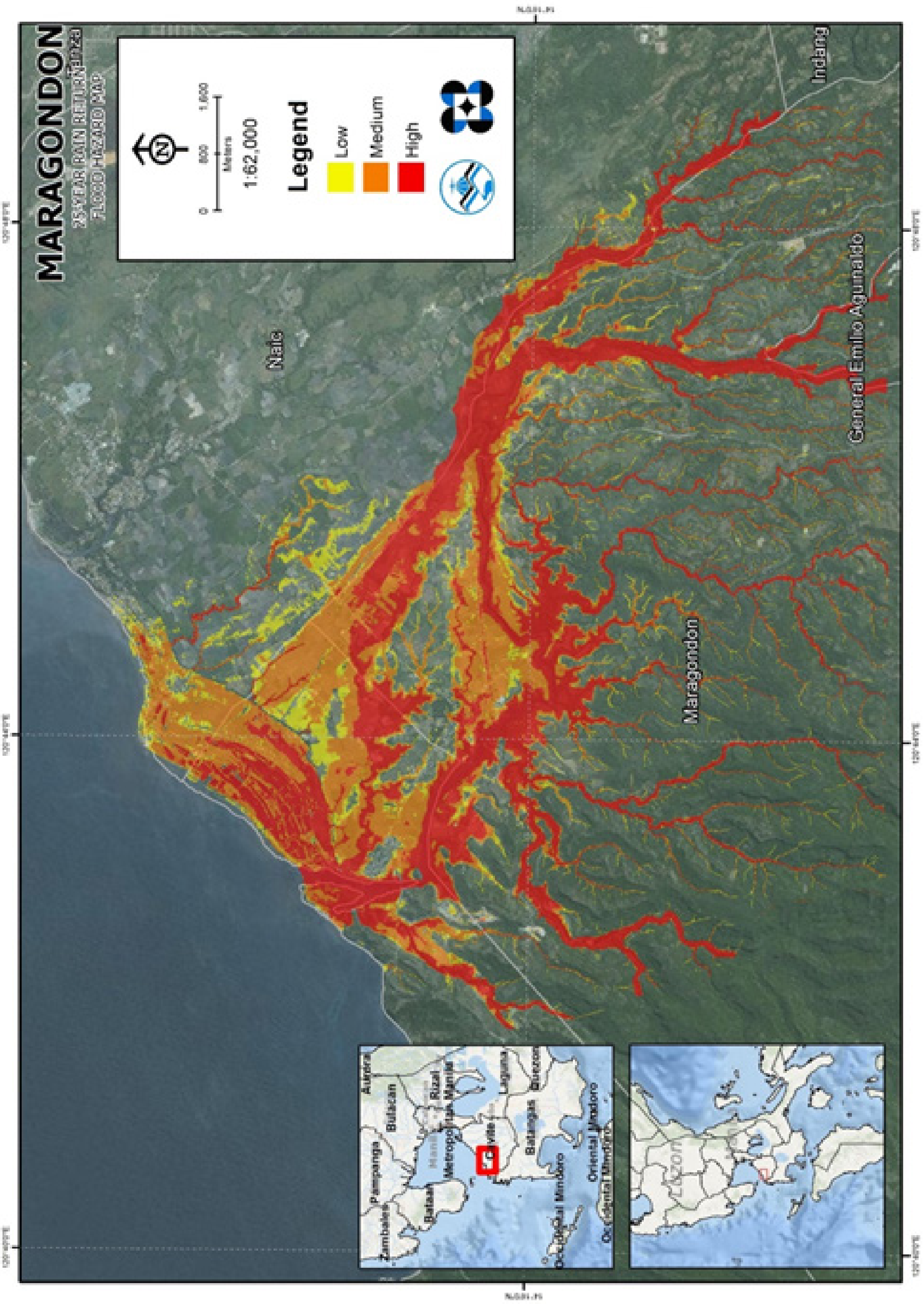


Figure 67. 25-year flood hazard map for the Maragondon floodplain

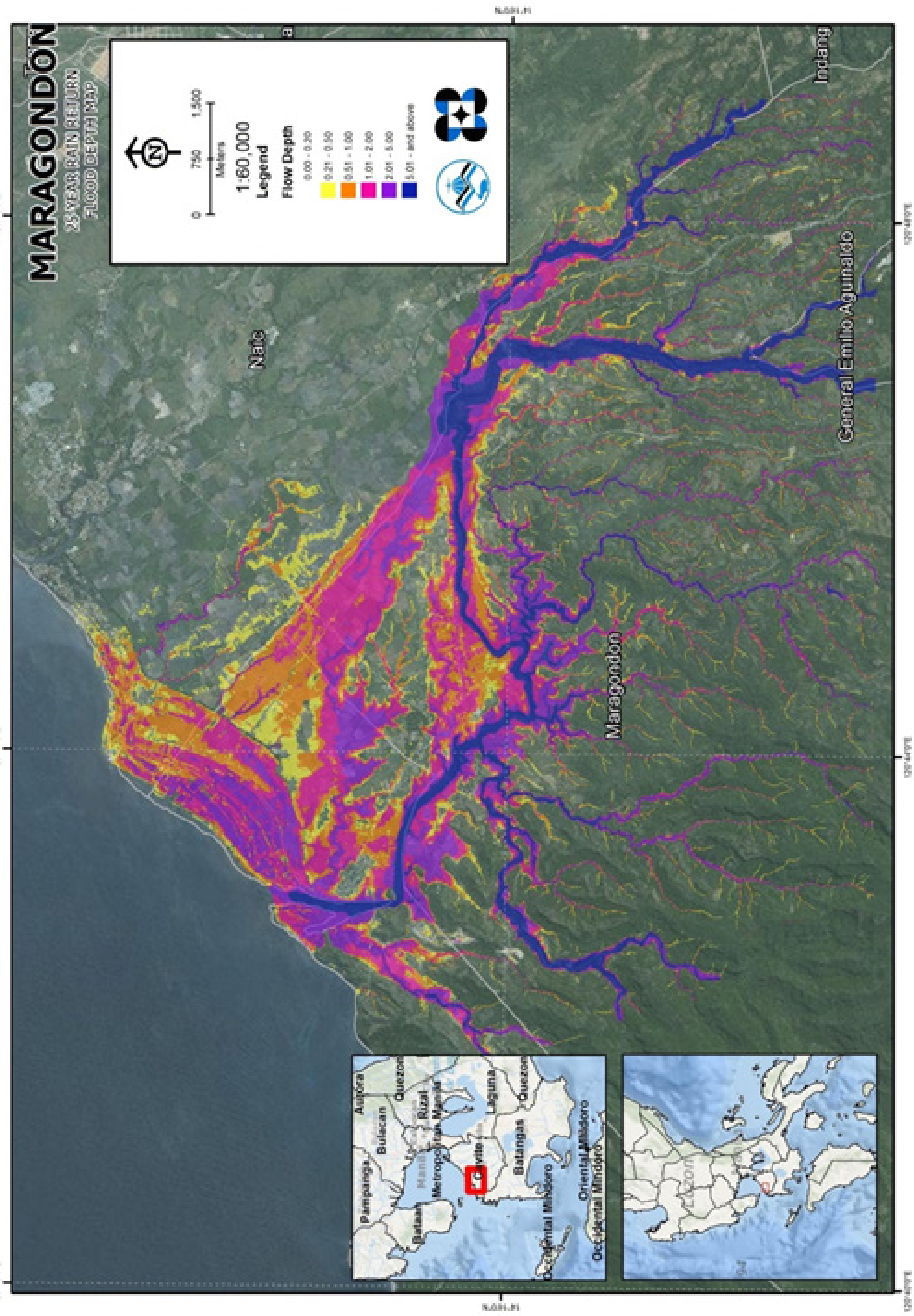


Figure 68. 25-year flow depth map for the Maragondon floodplain

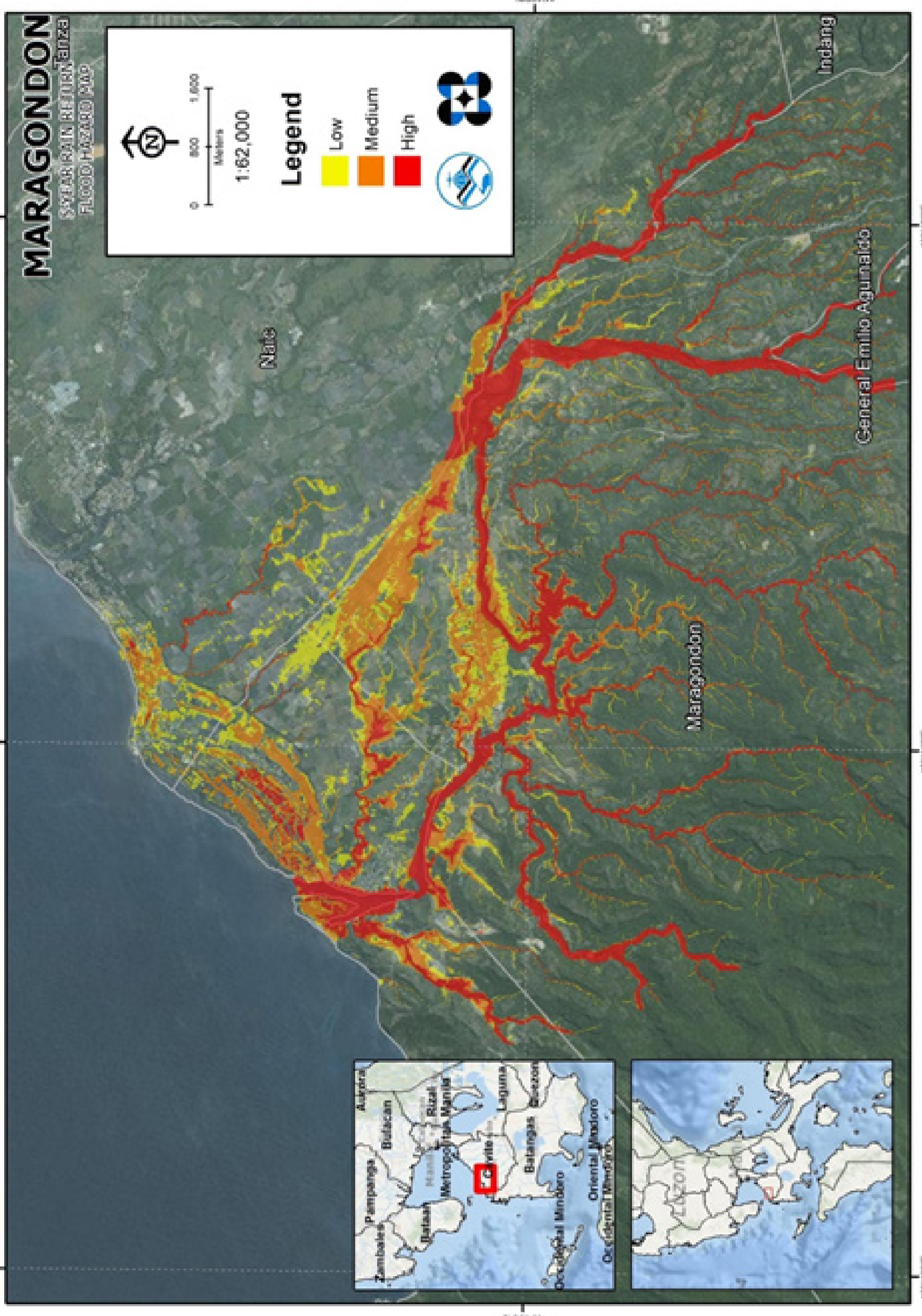


Figure 69. 5-year flood hazard map for the Maragondon floodplain

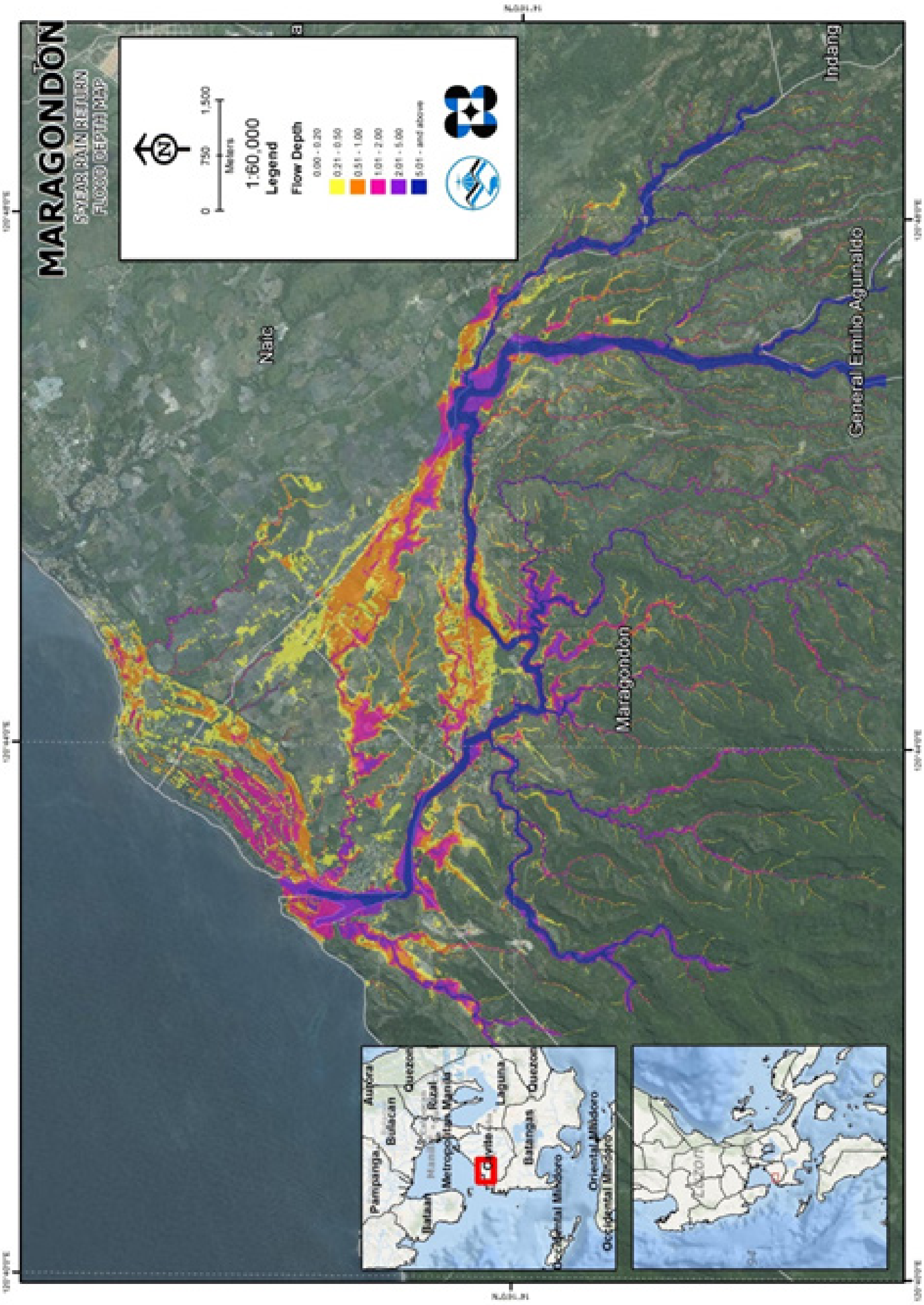


Figure 70. 5-year flow depth map for the Maragondon floodplain

5.10 Inventory of Areas Exposed to Flooding

Listed below are the barangays affected by the Maragondon River Basin, grouped accordingly by municipality. For the said basin, four (4) municipalities consisting of forty-three (43) barangays are expected to experience flooding when subjected to 5-year, 25-year, and 100-year rainfall return periods.

For the 5-year return period, 2.98% of the Municipality of General Emilio Aguinaldo, with an area of 39.39 square kilometers, will experience flood levels of less than 0.20 meters. 0.07% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.05%, 0.06%, 0.10%, and 0.44% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 39 are the affected areas, in square kilometers, by flood depth per barangay.

Table 39. Affected areas in General Emilio Aguinaldo, Cavite during a 5-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in General Emilio Aguinaldo (in sq. km)	
	Batas Dao	Lumipa
0.03-0.20	0.075	1.1
0.21-0.50	0.002	0.025
0.51-1.00	0.0017	0.017
1.01-2.00	0.0017	0.021
2.01-5.00	0.004	0.035
> 5.00	0.012	0.16

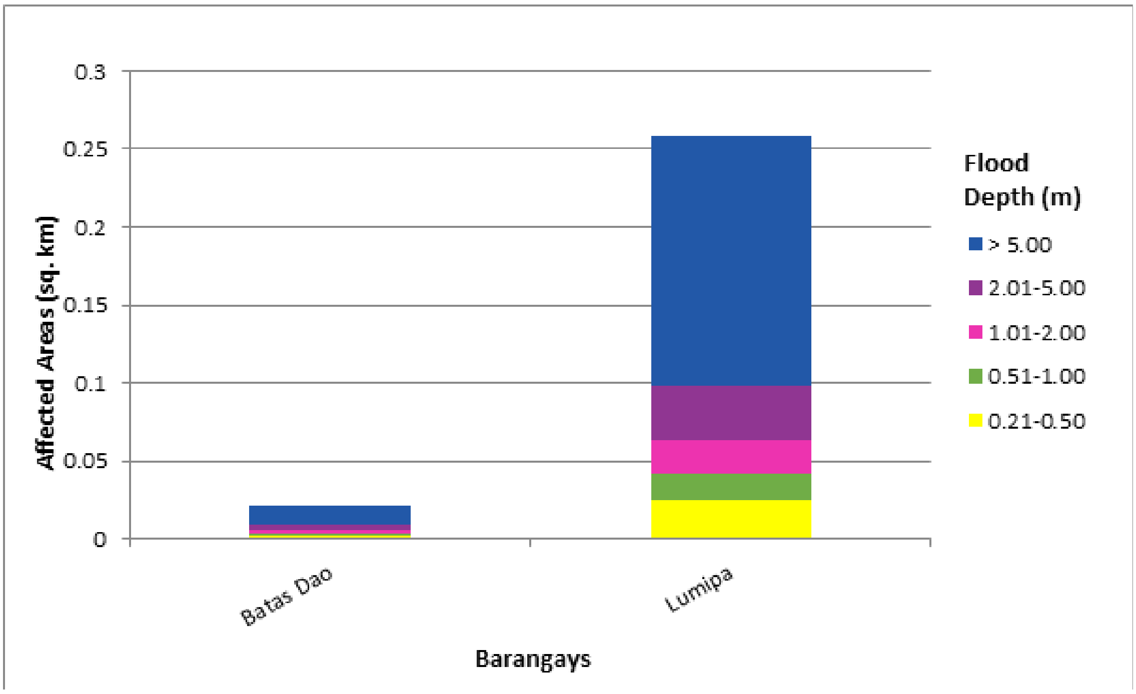


Figure 71. Affected areas in General Emilio Aguinaldo, Cavite during a 5-year rainfall return period

For the 5-year return period, 35.86% of the Municipality of Maragondon, with an area of 147.39 square kilometers, will experience flood levels of less than 0.20 meters. 2.10% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 2.13%, 1.47%, 1.50%, and 1.72% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 40 are the affected areas, in square kilometers, by flood depth per barangay.

Table 40. Affected areas in Maragondon, Cavite during a 5-year rainfall return period

Affected Area (sq km.) by flood depth (in m.)	Area of affected barangays in Maragondon (in sq. km)										
	Bucal I	Bucal II	Bucal III A	Bucal III B	Bucal IV A	Bucal IV B	Caingin Poblacion	Garita I A	Garita I B	Layong Mabilog	Mabato	Pantihan I
0.03-0.20	0.32	0.15	0.28	0.35	0.000055	0.078	0.053	0.34	0.31	4	0.22	1.72
0.21-0.50	0.25	0.11	0.071	0.06	0	0.024	0.024	0.059	0.063	0.097	0.0078	0.17
0.51-1.00	0.24	0.16	0.15	0.039	0.0012	0.055	0.024	0.052	0.072	0.085	0.0049	0.097
1.01-2.00	0.064	0.065	0.15	0.026	0.0071	0.055	0.0044	0.024	0.026	0.1	0.0039	0.1
2.01-5.00	0.032	0.018	0.043	0.0064	0.041	0.015	0.00044	0.00048	0.0022	0.13	0.0035	0.18
> 5.00	0.13	0.071	0.1	0.018	0.091	0.059	0	0	0	0.019	0.027	0.33

Affected Area (sq km.) by flood depth (in m.)	Area of affected barangays in Maragondon (in sq. km)										
	Pantihan II			Poblacion I A	Poblacion I B	Poblacion II A	Poblacion II B	San Miguel I A	San Miguel I B	Talipusngo	Tulay	Tulay Silangan
0.03-0.20	8.14	5.24	6.88	0.23	0.0018	0.0013	0.0089	0.5	0.61	0.46	12.85	10.11
0.21-0.50	0.22	0.31	0.24	0.038	0.0033	0.0081	0.023	0.26	0.21	0.014	0.34	0.49
0.51-1.00	0.17	0.23	0.17	0.029	0.0076	0.027	0.014	0.21	0.64	0.0085	0.26	0.39
1.01-2.00	0.17	0.25	0.21	0.035	0.016	0.011	0.009	0.051	0.1	0.011	0.3	0.38
2.01-5.00	0.2	0.38	0.28	0.02	0.0012	0	0	0.0051	0.0035	0.015	0.27	0.56
> 5.00	0.2	0.5	0.24	0.018	0	0	0	0	0	0.00091	0.035	0.69

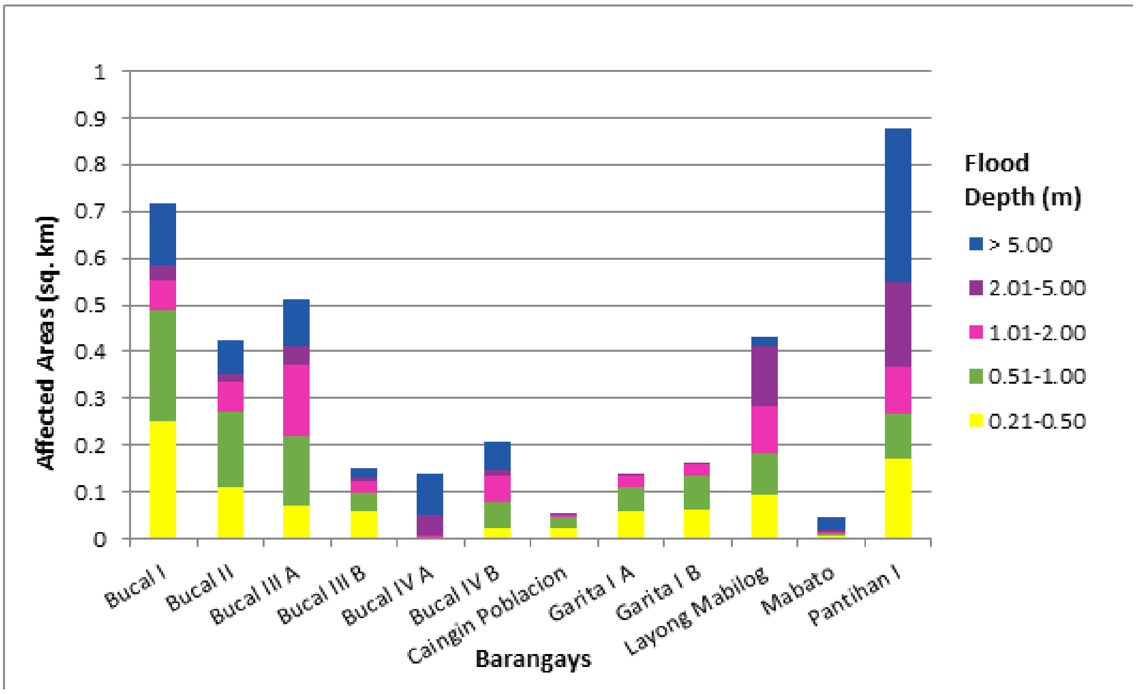


Figure 72. Areas affected by flooding in Maragondon, Cavite for a 5-year return period rainfall event

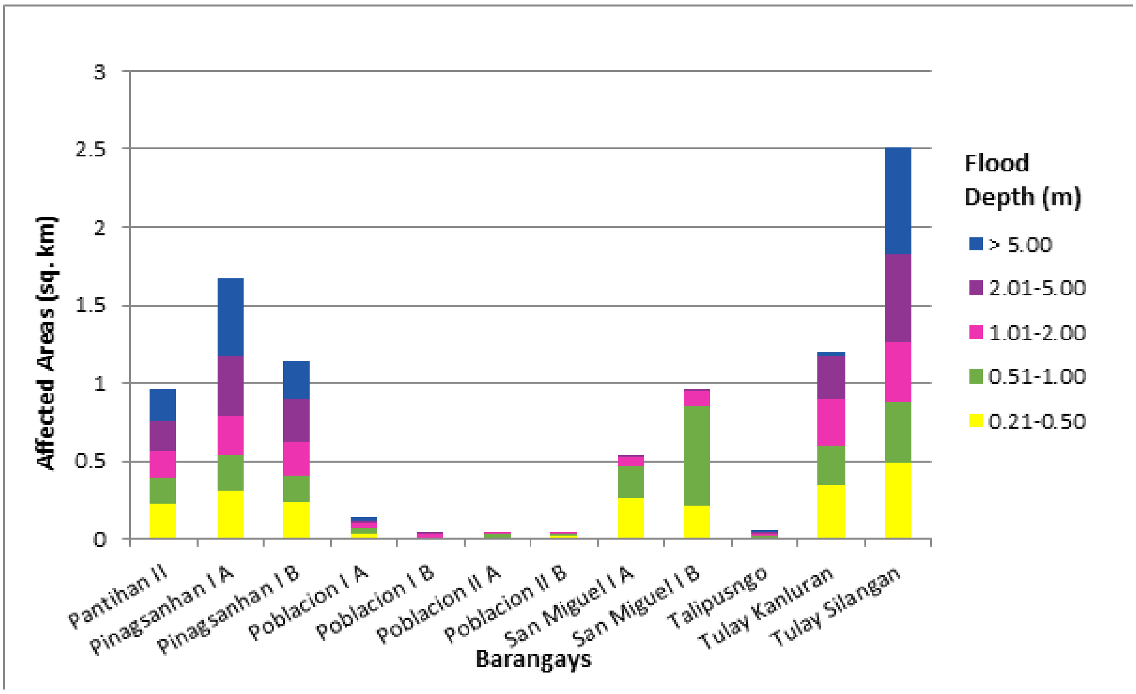


Figure 73. Areas affected by flooding in Maragondon, Cavite for a 5-year return period rainfall event

For the Municipality of Naic, with an area of 130.22 square kilometers, 3.05% will experience flood levels of less than 0.20 meters. 0.10% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.14%, 0.11%, and 0.003% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, respectively. Illustrated in Table 41 are the affected areas, in square kilometers, by flood depth per barangay.

Table 41. Affected areas in Maragondon, Cavite during a 5-year rainfall return period

Affected Area (sq km.) by flood depth (in m.)	Area of affected barangays in Maragondon (in sq. km)						
	Bancaan	Labac	Mabolo	Malainen Bago	Malainen Luma	Molino	Muzon
0.03-0.20	0.11	2.22	0.42	0.4	1.9	0.042	2.35
0.21-0.50	0.014	0.5	0.046	0.055	0.12	0.044	0.38
0.51-1.00	0.00026	0.27	0.017	0.018	0.091	0.11	0.1
1.01-2.00	0	0.088	0.0023	0.0046	0.098	0.083	0.019
2.01-5.00	0	0.042	0	0	0.12	0.052	0.017
> 5.00	0	0.0006	0	0	0.42	0.058	0

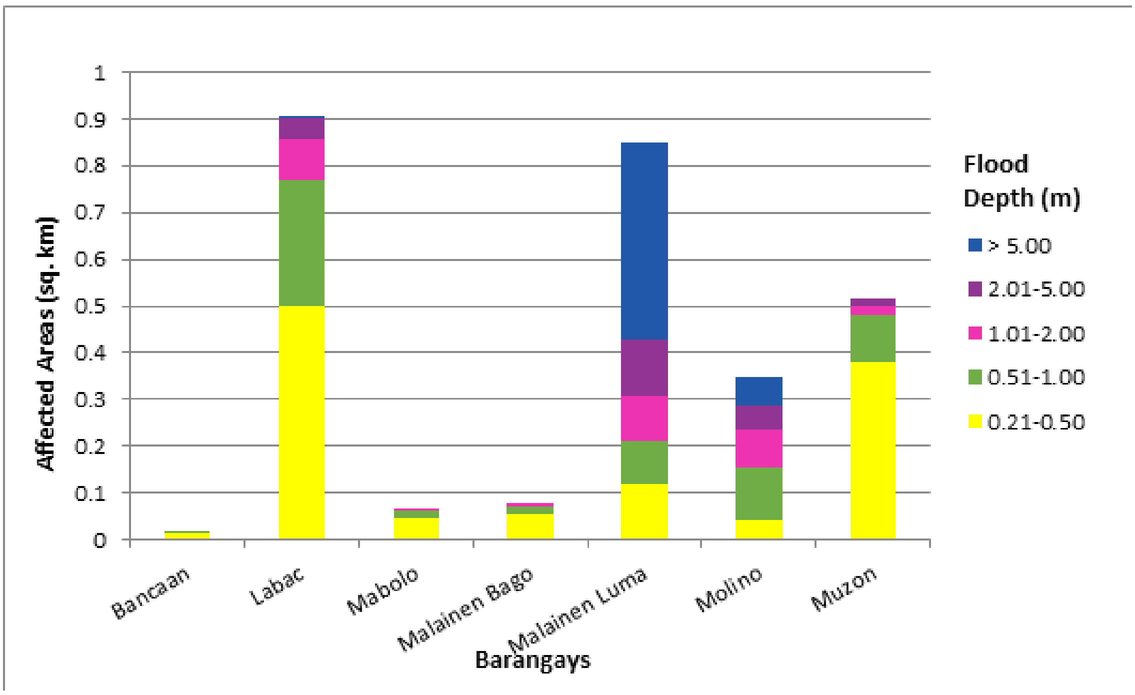


Figure 74. Affected areas in Naic, Cavite during a 5-year rainfall return period

For the 5-year return period, 15.99% of the Municipality of Ternate, with an area of 44.52 square kilometers, will experience flood levels of less than 0.20 meters. 2.82% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 2.37%, 2.99%, 1.25%, and 0.38% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 42 are the affected areas, in square kilometers, by flood depth per barangay.

Table 42. Affected areas in Ternate, Cavite by flood level for a 5-year rainfall return period

Affected Area (sq km.) by flood depth (in m.)	Area of affected barangays in Ternate (in sq. km)									
	Bucana	Poblacion I	Poblacion I A	Poblacion II	Poblacion III	San Jose	San Juan I	San Juan II	Sapang I	Sapang II
0.03-0.20	1.67	0.62	0.079	0.33	0.16	1.13	1.22	1.25	0.33	0.33
0.21-0.50	0.096	0.092	0.003	0.043	0.034	0.27	0.24	0.37	0.078	0.029
0.51-1.00	0.12	0.032	0.0016	0.038	0.033	0.33	0.011	0.33	0.13	0.031
1.01-2.00	0.098	0.032	0.0036	0.02	0.065	0.41	0.012	0.44	0.22	0.03
2.01-5.00	0.15	0.052	0.0038	0.0075	0.054	0.081	0.014	0.0026	0.16	0.033
> 5.00	0.025	0.11	0.0033	0.0013	0.00041	0	0	0	0.003	0.026

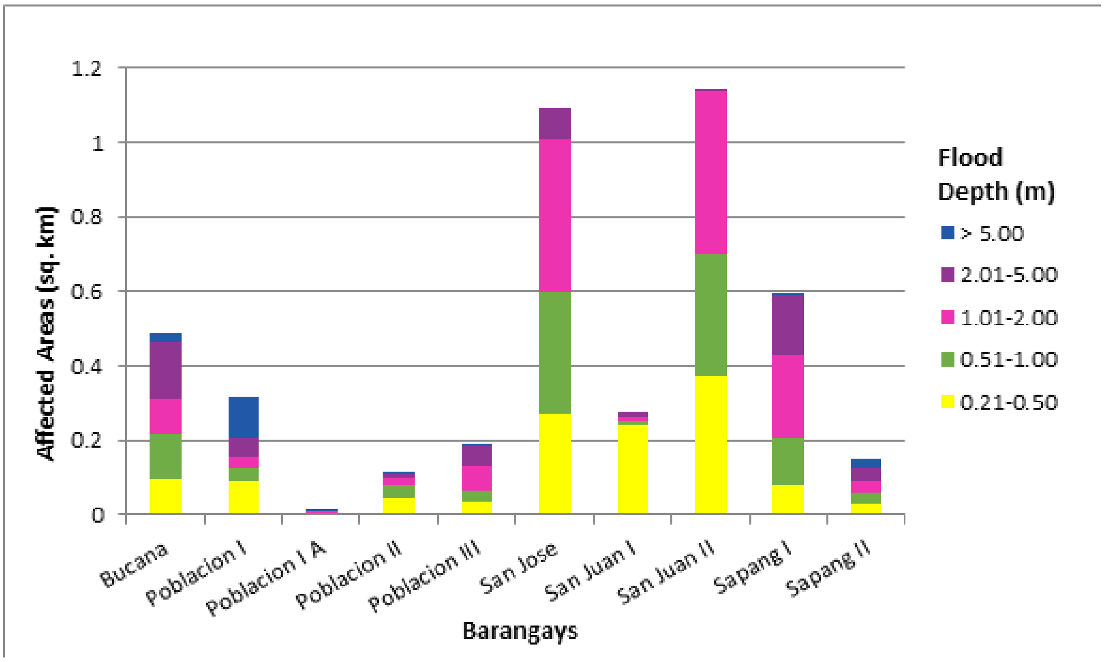


Figure 75. Affected areas in Ternate, Cavite during a 5-year rainfall return period

For the 25-year return period, 2.74% of the Municipality of General Emilio Aguinaldo, with an area of 39.39 square kilometers, will experience flood levels of less than 0.20 meters. 0.07% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.06%, 0.08%, 0.15%, and 0.61% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 43 are the affected areas, in square kilometers, by flood depth per barangay.

Table 43. Affected areas in General Emilio Aguinaldo, Cavite during a 25-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in General Emilio Aguinaldo (in sq. km)	
	Batas Dao	Lumipa
0.03-0.20	0.068	1.01
0.21-0.50	0.0026	0.025
0.51-1.00	0.0018	0.021
1.01-2.00	0.0017	0.028
2.01-5.00	0.0043	0.054
> 5.00	0.019	0.22

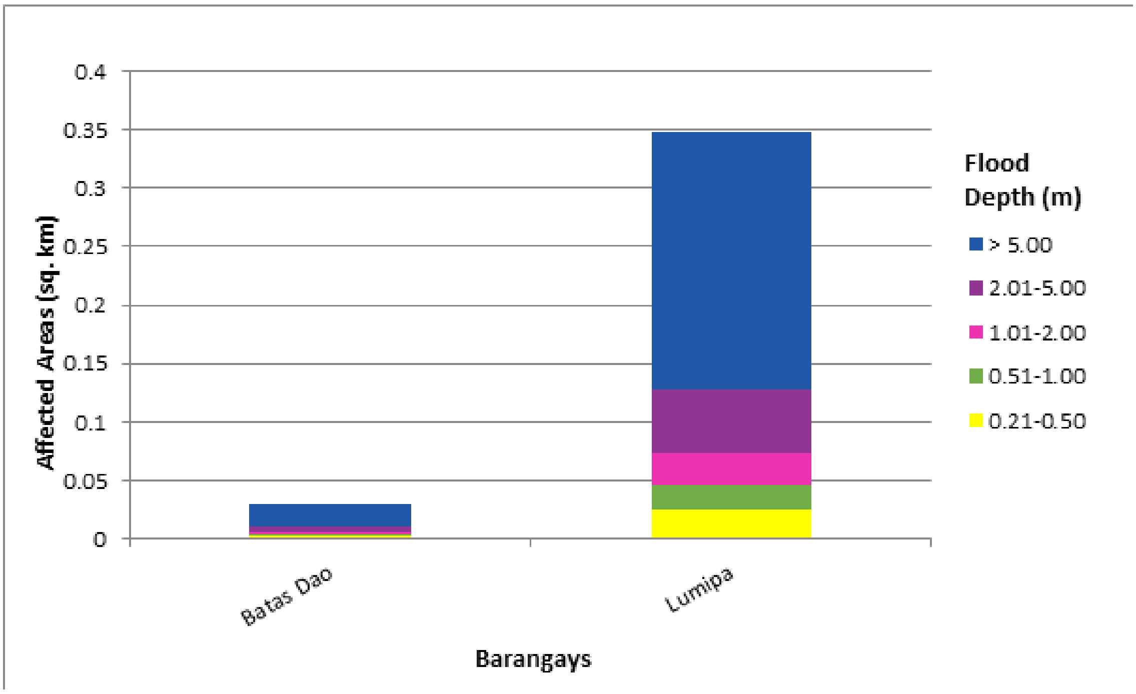


Figure 76. Affected areas in General Emilio Aguinaldo, Cavite during a 25-year rainfall return period

For the 25-year return period, 32.17% of the Municipality of Maragondon, with an area of 147.39 square kilometers, will experience flood levels of less than 0.20 meters. 1.58% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 2.06%, 3.48%, 3.05%, and 2.45% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 44 are the affected areas, in square kilometers, by flood depth per barangay.

Table 44. Affected areas in Maragondon, Cavite during a 5-year rainfall return period

Affected Area (sq km.) by flood depth (in m.)	Area of affected barangays in Maragondon (in sq. km)											
	Bucal I	Bucal II	Bucal III A	Bucal III B	Bucal IV A	Bucal IV B	Caingin Poblacion	Garita I A	Garita I B	Layong Mabilog	Mabato	Pantihan I
0.03-0.20	0.031	0.062	0.047	0.24	0	0	0.023	0.27	0.24	3.93	0.21	1.24
0.21-0.50	0.079	0.026	0.053	0.056	0	0.0013	0.01	0.028	0.046	0.11	0.0076	0.13
0.51-1.00	0.33	0.15	0.098	0.057	0	0.026	0.031	0.034	0.067	0.088	0.0072	0.16
1.01-2.00	0.38	0.22	0.24	0.084	0	0.091	0.034	0.085	0.11	0.11	0.0045	0.3
2.01-5.00	0.079	0.037	0.25	0.042	0.026	0.1	0.0088	0.067	0.014	0.17	0.0039	0.28
> 5.00	0.14	0.073	0.11	0.019	0.12	0.065	0.000041	0	0	0.042	0.032	0.49

Affected Area (sq km.) by flood depth (in m.)	Area of affected barangays in Maragondon (in sq. km)											
	Pantihan II			Poblacion I A	Poblacion I B	Poblacion II A	Poblacion II B	San Miguel I A	San Miguel I B	Talipusngo	Tulay	Tulay Silangan
0.03-0.20	7.86	4.46	6.31	0.11	0.00007	0.0003	0.0001	0.2	0.45	0.45	12.51	8.77
0.21-0.50	0.24	0.21	0.22	0.026	0.00014	0.0002	0.0022	0.067	0.063	0.016	0.38	0.56
0.51-1.00	0.19	0.2	0.21	0.058	0.0035	0.0083	0.027	0.25	0.11	0.011	0.27	0.65
1.01-2.00	0.21	0.49	0.35	0.092	0.016	0.036	0.022	0.42	0.8	0.011	0.33	0.7
			0.6									

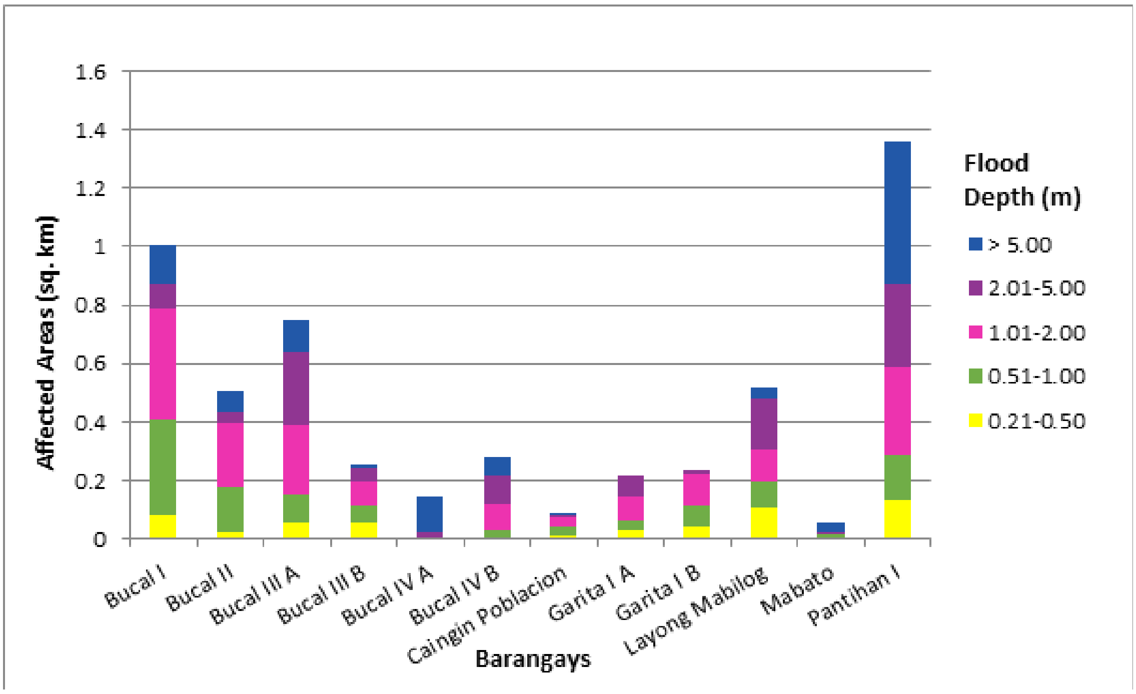


Figure 77. Affected areas in Maragondon, Cavite during a 25-year rainfall return period

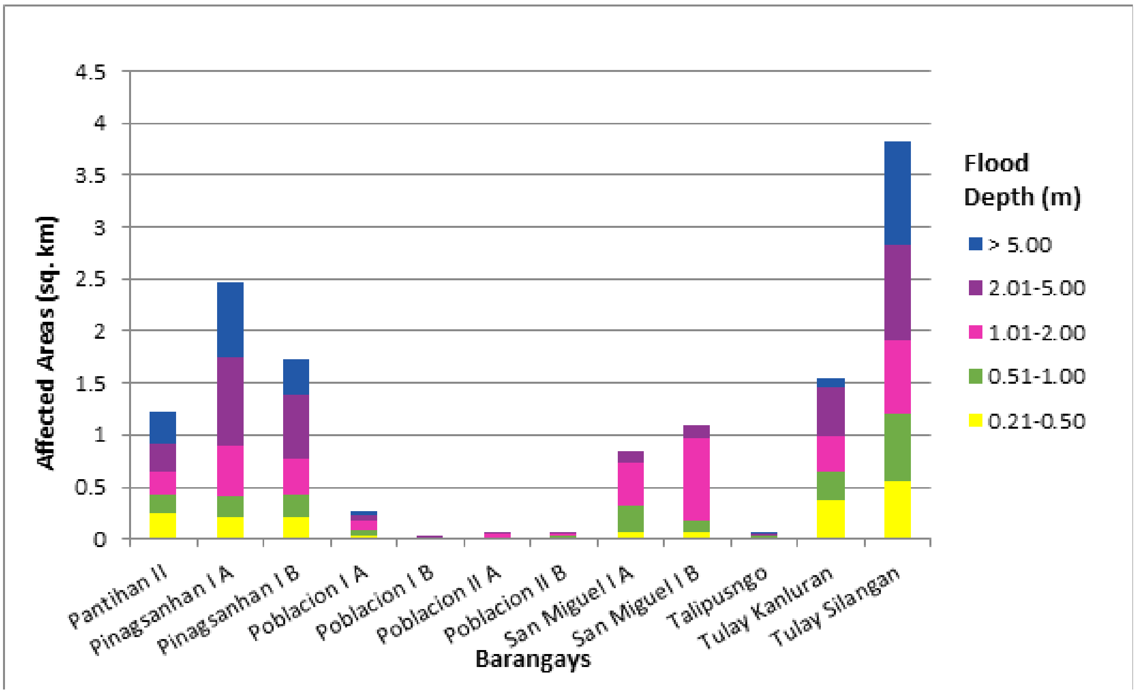


Figure 78. Affected areas in Maragondon, Cavite during a 25-year rainfall return period

For the 25-year return period, 7.45% of the Municipality of Naic, with an area of 76.11 square kilometers, will experience flood levels of less than 0.20 meters. 1.71% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 1.59%, 1.20%, 0.65%, and 0.82% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 45 are the affected areas, in square kilometers, by flood depth per barangay.

Table 45. Affected areas in General Emilio Aguinaldo, Cavite during a 25-year rainfall return period

Affected Area (sq km.) by flood depth (in m.)	Area of affected barangays in Naic (in sq. km)						
	Bancaan	Labac	Mabolo	Malainen Bago	Malainen Luma	Muzon	Molino
0.03-0.20	0.1	1.43	0.38	0.37	1.56	1.83	0
0.21-0.50	0.02	0.47	0.072	0.067	0.12	0.55	0.0004
0.51-1.00	0.00076	0.78	0.029	0.029	0.1	0.26	0.0093
1.01-2.00	0	0.37	0.0039	0.0096	0.19	0.2	0.14
2.01-5.00	0	0.086	0	0	0.21	0.03	0.17
> 5.00	0	0.0037	0	0	0.55	0.001	0.073

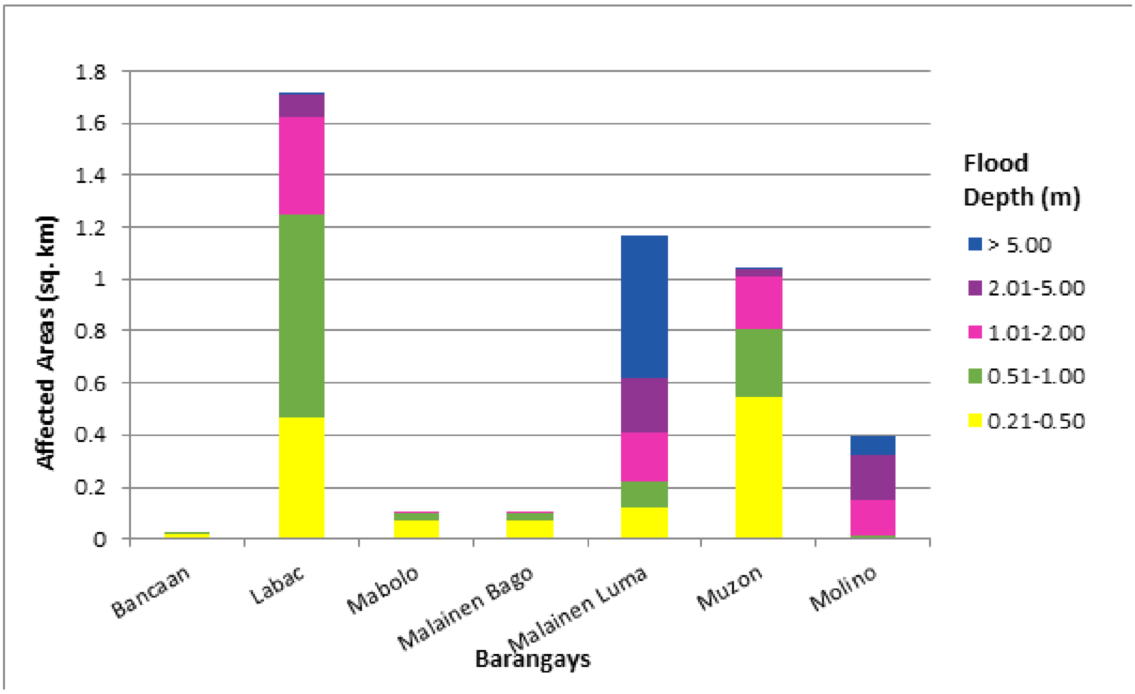


Figure 79. Affected areas in Naic, Cavite during a 25-year rainfall return period

For the 25-year return period, 6.86% of the Municipality of Ternate, with an area of 44.52 square kilometers, will experience flood levels of less than 0.20 meters. 2.29% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 4.90%, 6.31%, 4.95%, and 0.50% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 46 are the affected areas, in square kilometers, by flood depth per barangay.

Table 46. Affected areas in Ternate, Cavite during a 25-year rainfall return period

Affected Area (sq km.) by flood depth (in m.)	Area of affected barangays in Ternate (in sq. km)									
	Bucana	Poblacion I	Poblacion I A	Poblacion II	Poblacion III	San Jose	San Juan I	San Juan II	Sapang I	Sapang II
0.03-0.20	1.56	0.2	0.071	0.18	0.032	0.15	0.15	0.18	0.23	0.3
0.21-0.50	0.082	0.065	0.0064	0.051	0.02	0.14	0.35	0.24	0.04	0.026
0.51-1.00	0.11	0.22	0.0029	0.079	0.053	0.32	0.81	0.47	0.089	0.028
1.01-2.00	0.18	0.22	0.0039	0.094	0.12	0.87	0.15	0.9	0.24	0.032
2.01-5.00	0.18	0.11	0.0069	0.035	0.12	0.73	0.03	0.61	0.32	0.063

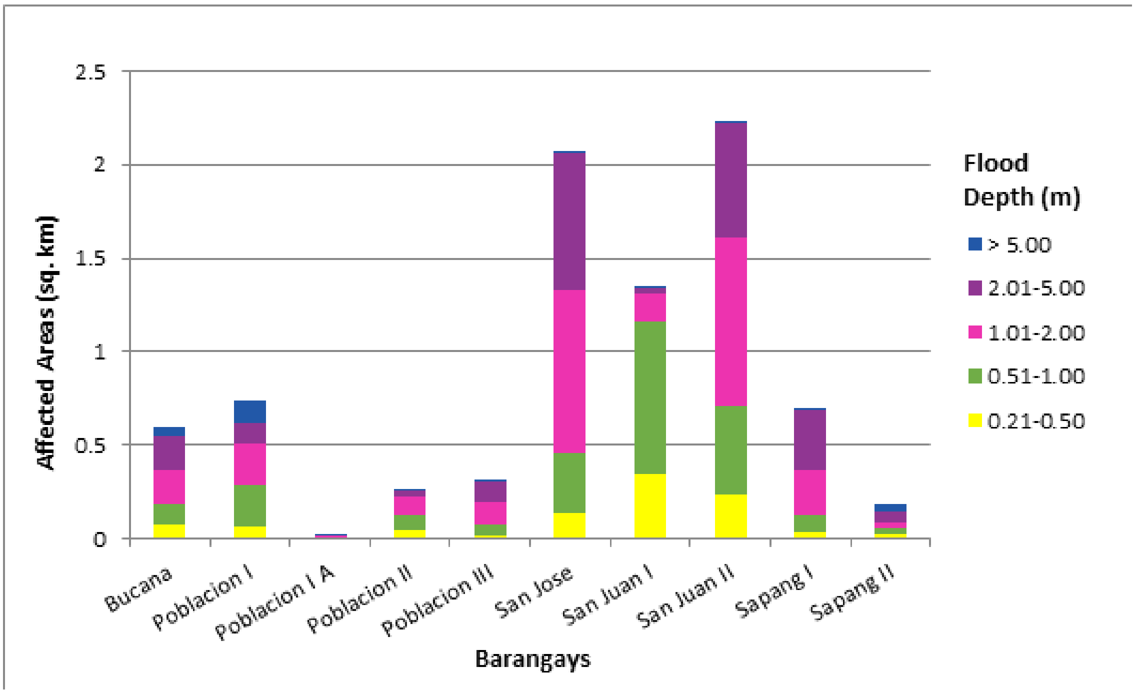


Figure 80. Affected areas in Ternate, Cavite during a 25-year rainfall return period

For the 100-year return period, 3.34% of the Municipality of General Emilio Aguinaldo, with an area of 39.39 square kilometers, will experience flood levels of less than 0.20 meters. 0.08% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.06%, 0.06%, 0.09%, 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 Table 47 are the affected areas, in square kilometers, by flood depth per barangay.

Table 47. Affected areas in General Emilio Aguinaldo, Cavite during a 100-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in General Emilio Aguinaldo (in sq. km)	
	Batas Dao	Lumipa
0.03-0.20	0.086	1.23
0.21-0.50	0.0024	0.03
0.51-1.00	0.0017	0.022
1.01-2.00	0.0024	0.021
2.01-5.00	0.0031	0.032
> 5.00	0.0013	0.022

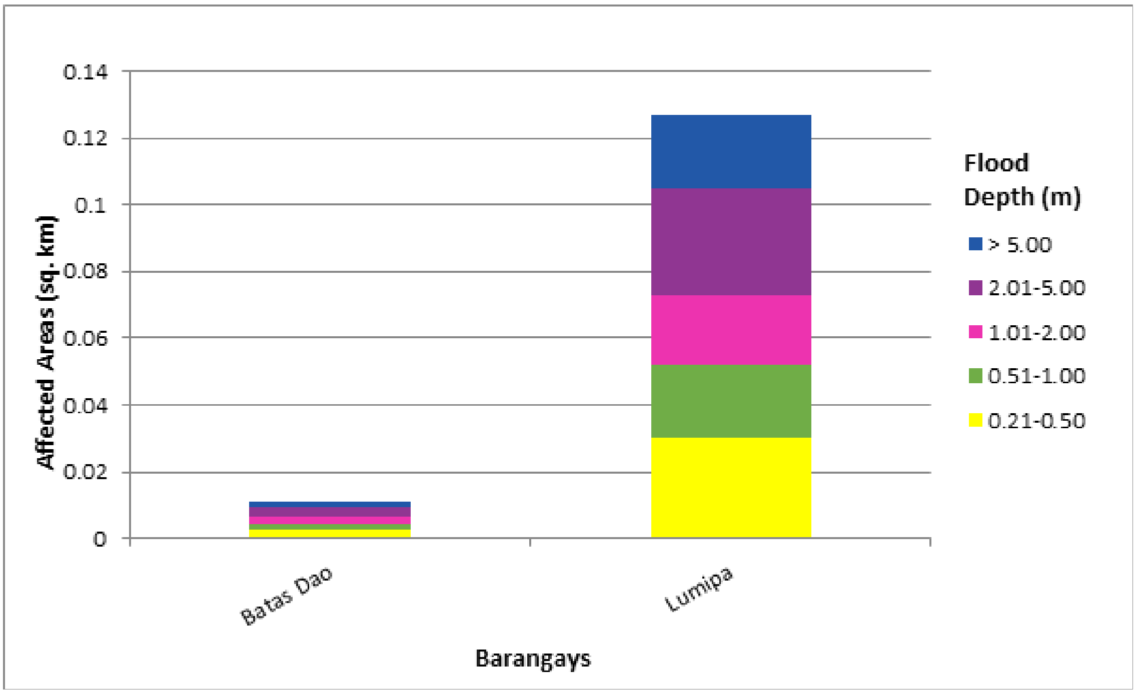


Figure 81. Affected areas in General Emilio Aguinaldo, Cavite during a 100-year rainfall return period

For the 100-year return period, 32.93% of the Municipality of Maragondon, with an area of 147.39 square kilometers, will experience flood levels of less than 0.20 meters. 2.00% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 2.52%, 2.61%, 2.69%, and 2.05% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 48 are the affected areas, in square kilometers, by flood depth per barangay.

Table 48. Affected areas in Maragondon, Cavite during a 5-year rainfall return period

Affected Area (sq km.) by flood depth (in m.)	Area of affected barangays in Maragondon (in sq. km)											
	Bucal I	Bucal II	Bucal III A	Bucal III B	Bucal IV A	Bucal IV B	Caingin Poblacion	Garita I A	Garita I B	Layong Mabilog	Mabato	Pantihan I
0.03-0.20	0.066	0.088	0.2	0.3	0	0.043	0.033	0.3	0.27	3.87	0.24	1.34
0.21-0.50	0.17	0.085	0.062	0.068	3.5E-07	0.031	0.011	0.042	0.046	0.12	0.0071	0.15
0.51-1.00	0.41	0.17	0.13	0.063	0.000055	0.041	0.042	0.061	0.091	0.097	0.0073	0.19
1.01-2.00	0.2	0.12	0.22	0.038	0.0032	0.069	0.013	0.066	0.057	0.11	0.0039	0.26
2.01-5.00	0.058	0.022	0.082	0.013	0.038	0.043	0.0068	0.011	0.007	0.18	0.0039	0.42
> 5.00	0.14	0.072	0.11	0.018	0.099	0.06	0.000041	0	0	0.069	0.0041	0.25

Affected Area (sq km.) by flood depth (in m.)	Area of affected barangays in Maragondon (in sq. km)											
	Pantihan II			Poblacion I A	Poblacion I B	Poblacion II A	Poblacion II B	San Miguel I A	San Miguel I B	Talipusngo	Tulay	Tulay Silangan
0.03-0.20	7.77	4.34	6.21	0.13	0.00021	0.0004	0.0017	0.33	0.52	0.44	12.41	9.63
0.21-0.50	0.26	0.21	0.23	0.043	0.0015	0.0013	0.0087	0.21	0.11	0.016	0.42	0.64
0.51-1.00	0.21	0.23	0.24	0.049	0.0064	0.018	0.029	0.31	0.53	0.014	0.28	0.5
1.01-2.00	0.23	0.49	0.35	0.081	0.017	0.027	0.015	0.16	0.39	0.011	0.36	0.55
2.01-5.00	0.33	0.81	0.63	0.04	0.0048	0.00031	4.5E-08	0.015	0.0097	0.02	0.48	0.74
> 5.00	0.29	0.84	0.37	0.024	0	0	0	0	0	0.0038	0.11	0.56

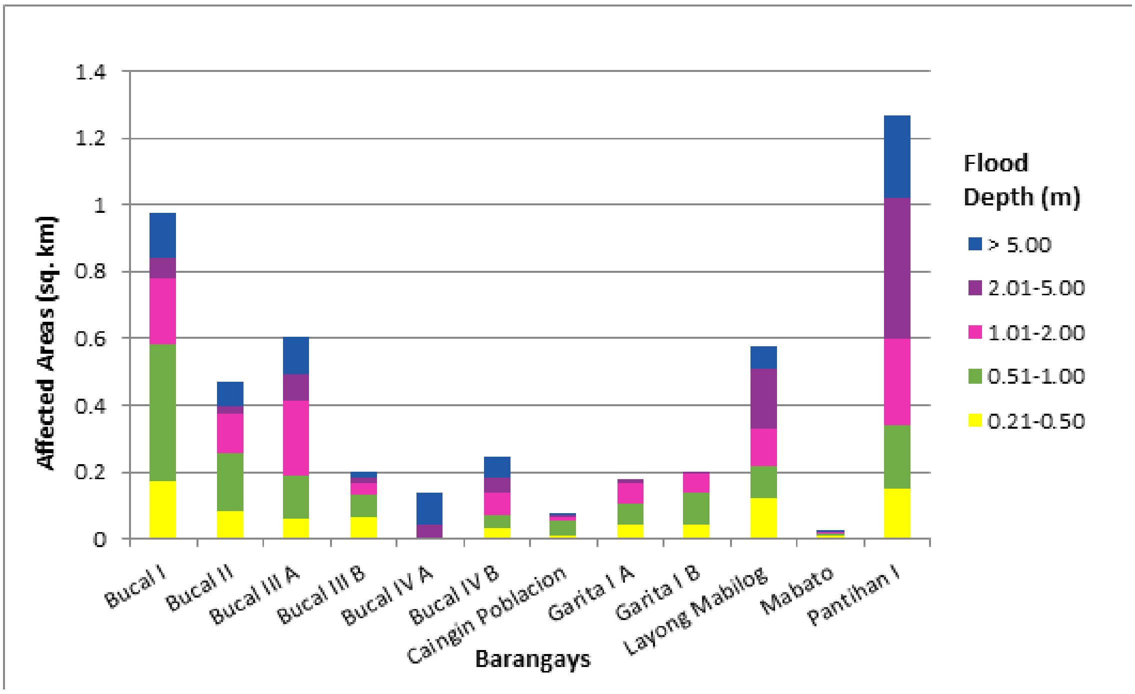


Figure 82. Affected areas in Maragondon, Cavite during a 100-year rainfall return period

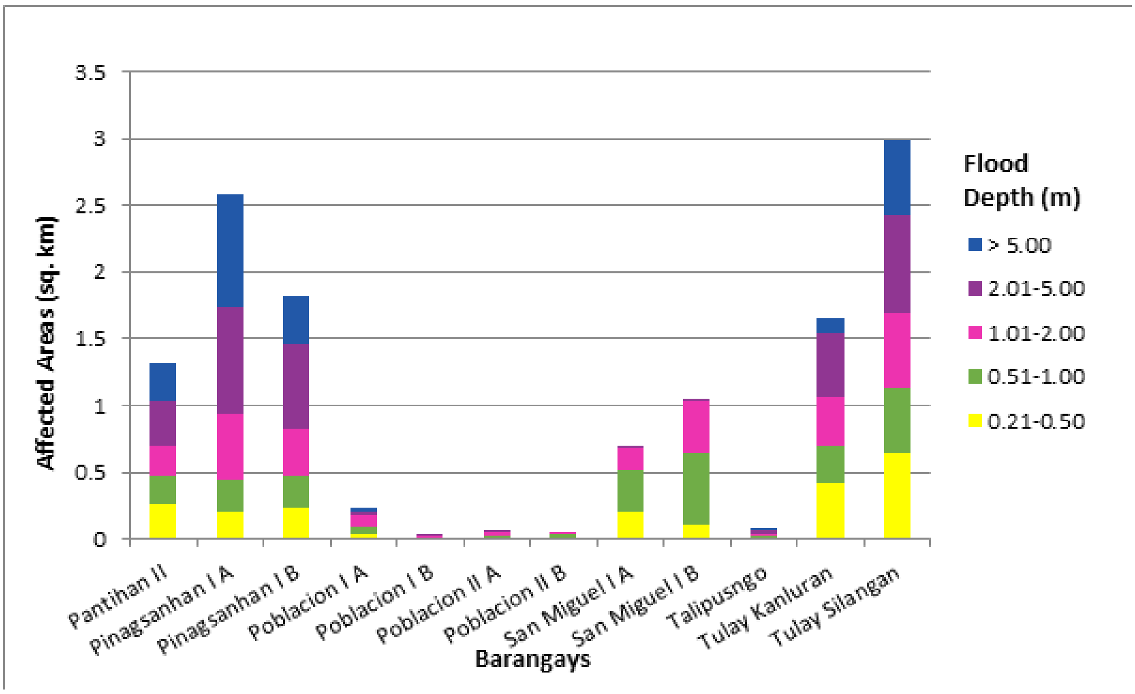


Figure 83. Affected areas in Maragondon, Cavite during a 100-year rainfall return period

For the 100-year return period, 7.33% of the Municipality of Naic, with an area of 76.11 square kilometers, will experience flood levels of less than 0.20 meters. 2.32% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 1.34%, 0.82%, 0.69%, and 0.94% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 49 are the affected areas, in square kilometers, by flood depth per barangay.

Table 49. Affected areas in Naic, Cavite during a 100-year rainfall return period

Affected Area (sq km.) by flood depth (in m.)	Area of affected barangays in Naic (in sq. km)						
	Bancaan	Labac	Mabolo	Malainen Bago	Malainen Luma	Molino	Muzon
0.03-0.20	0.096	1.51	0.36	0.35	1.41	0.0052	1.85
0.21-0.50	0.027	0.74	0.084	0.079	0.12	0.0069	0.71
0.51-1.00	0.0011	0.6	0.039	0.036	0.093	0.033	0.22
1.01-2.00	0.000058	0.19	0.0062	0.014	0.17	0.18	0.061
2.01-5.00	0	0.082	0	0	0.31	0.11	0.026
> 5.00	0	0.0082	0	0	0.64	0.064	0.0021

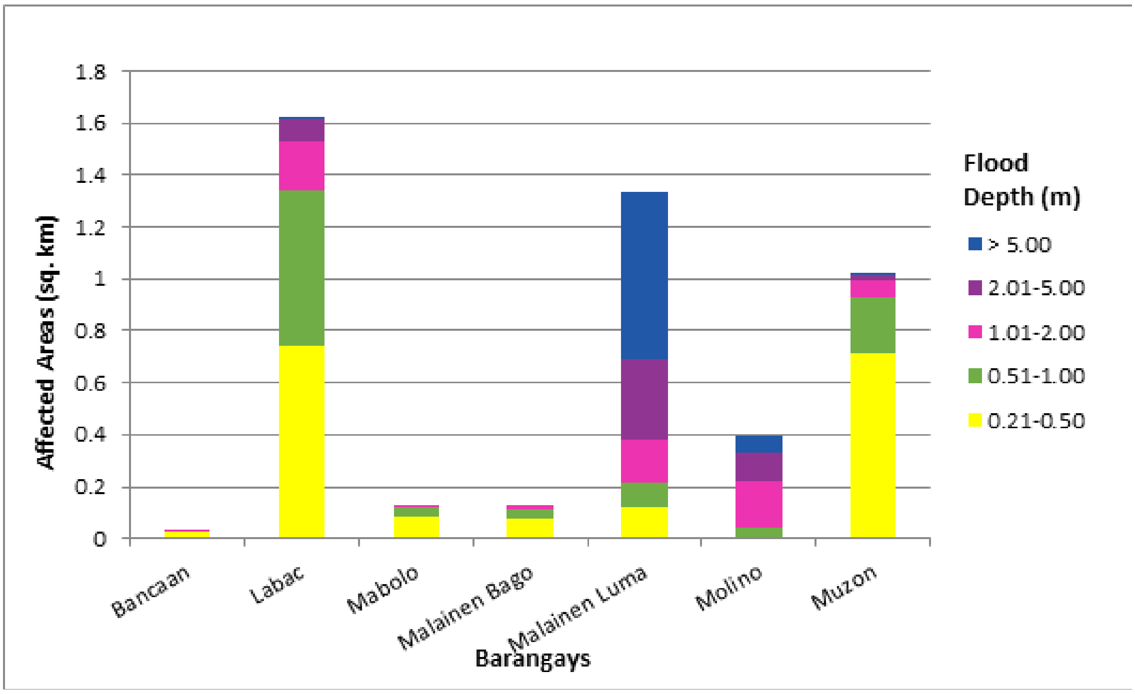


Figure 84. Affected areas in Maragondon, Cavite during a 100-year rainfall return period

For the 100-year return period, 9.71% of the Municipality of Ternate, with an area of 44.52 square kilometers, will experience flood levels of less than 0.20 meters. 3.76% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 3.93%, 4.41%, 3.49%, and 0.50% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 50 are the affected areas, in square kilometers, by flood depth per barangay.

Table 50. Affected areas in Ternate, Cavite during a 100-Year rainfall return period

Affected Area (sq km.) by flood depth (in m.)	Area of affected barangays in Ternate (in sq. km)									
	Bucana	Poblacion I	Poblacion I A	Poblacion II	Poblacion III	San Jose	San Juan I	San Juan II	Sapang I	Sapang II
0.03-0.20	1.51	0.23	0.074	0.2	0.06	0.42	0.78	0.54	0.22	0.29
0.21-0.50	0.081	0.11	0.005	0.07	0.036	0.37	0.59	0.34	0.041	0.033
0.51-1.00	0.095	0.23	0.0024	0.09	0.084	0.48	0.089	0.57	0.086	0.024
1.01-2.00	0.2	0.15	0.0036	0.063	0.066	0.58	0.017	0.59	0.25	0.042
2.01-5.00	0.2	0.097	0.0061	0.016	0.1	0.37	0.021	0.37	0.31	0.063
> 5.00	0.069	0.11	0.0033	0.0016	0.00085	0.0002	0.0001	0	0.007	0.032

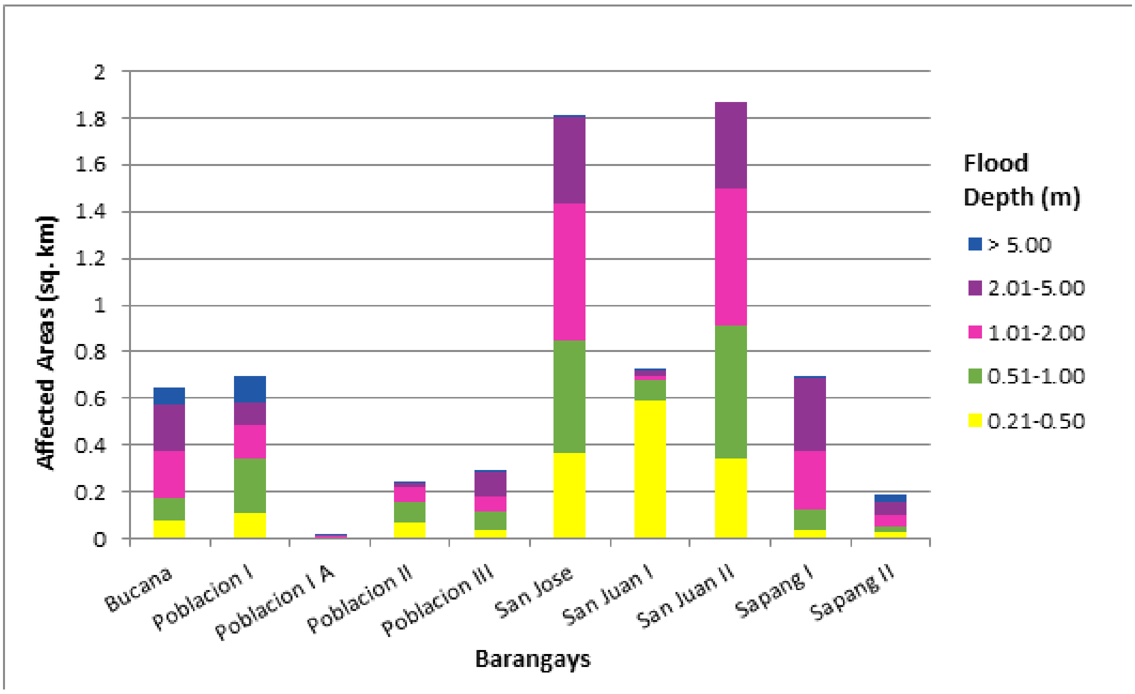


Figure 85. Affected areas in Ternate, Cavite during a 100-year rainfall return period

The generated flood hazard maps for the Maragondon floodplain were also used to assess the vulnerability of the educational and medical institutions in the floodplain. Using the flood depth units of PAGASA for the hazard maps – "Low", "Medium", and "High" – the affected institutions were given an individual assessment for each flood hazard scenario (i.e., 5-year, 25-year, and 100-year). Annex 12 and Annex 13 present the educational and health institutions exposed to flooding, respectively.

Table 51. Areas covered by each warning level, with respect to the rainfall scenarios

Warning Level	Area Covered in sq. km.		
	5-year	25-year	100-year
Low	5.67	4.76	6.52
Medium	7.067	11.56	10.27
High	8.47	16.25	13.30
TOTAL	21.207	32.57	30.09

Of the twenty-eight (28) identified educational institutions in the Maragondon floodplain, four (4) were discovered to be exposed to Low-level flooding during a 5-year scenario, while another four (4) were found to be exposed to Medium-level flooding. In the same scenario, Dinglas Elementary School in the Municipality of Ternate was assessed to be exposed to High-level flooding.

In the 25-year scenario, three (3) schools were found to be exposed to Low-level flooding, eight (8) to Medium-level flooding, and three (3) to High-level flooding. For the 100-year scenario, four (4) schools were discovered to be exposed to Low-level flooding. Six (6) schools were assessed to be exposed to Medium-level flooding and two (2) schools were discovered to be exposed to High-level flooding in the same scenario.

Seven (7) medical institutions were identified in the Maragondon floodplain. One (1) each was assessed to be exposed to Low-level and Medium-level flooding in the 5-year scenario.

For the 25-year scenario, one (1) institution each was found to be exposed to Low-level flooding, another one (1) to Medium-level, and another one (1) to High-level flooding. In the 100-year scenario, two (2) institutions were discovered to be exposed to Medium-level flooding.

5.11 Flood Validation

In order to check and validate the extent of flooding in different river systems, there is a need to perform validation survey work. For this purpose, field personnel gathered secondary data regarding flood occurrences in the respective areas within the major river systems in the Philippines.

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

The validation personnel then went to the specified points identified in a river basin to gather data regarding the actual flood levels in each location. Data gathering was conducted through assistance from a local DRRM office to obtain maps or situation reports about the past flooding events, or through interviews with some residents with knowledge or experience of flooding in a particular area.

After which, the actual data from the field were compared with the simulated data to assess the accuracy of the flood depth maps produced, and to improve on the results of the flood map. The points in the flood map versus the corresponding validation depths are illustrated in Figure 84.

The flood validation consists of one hundred and ninety-four (194), points randomly selected all over the Maragondon floodplain (Figure 83). Comparing the points with the flood depth map of the nearest storm event, the map attained an RMSE value of 1.26 meters. Table 52 presents a contingency matrix of the comparison. The validation points are found in Annex 11.

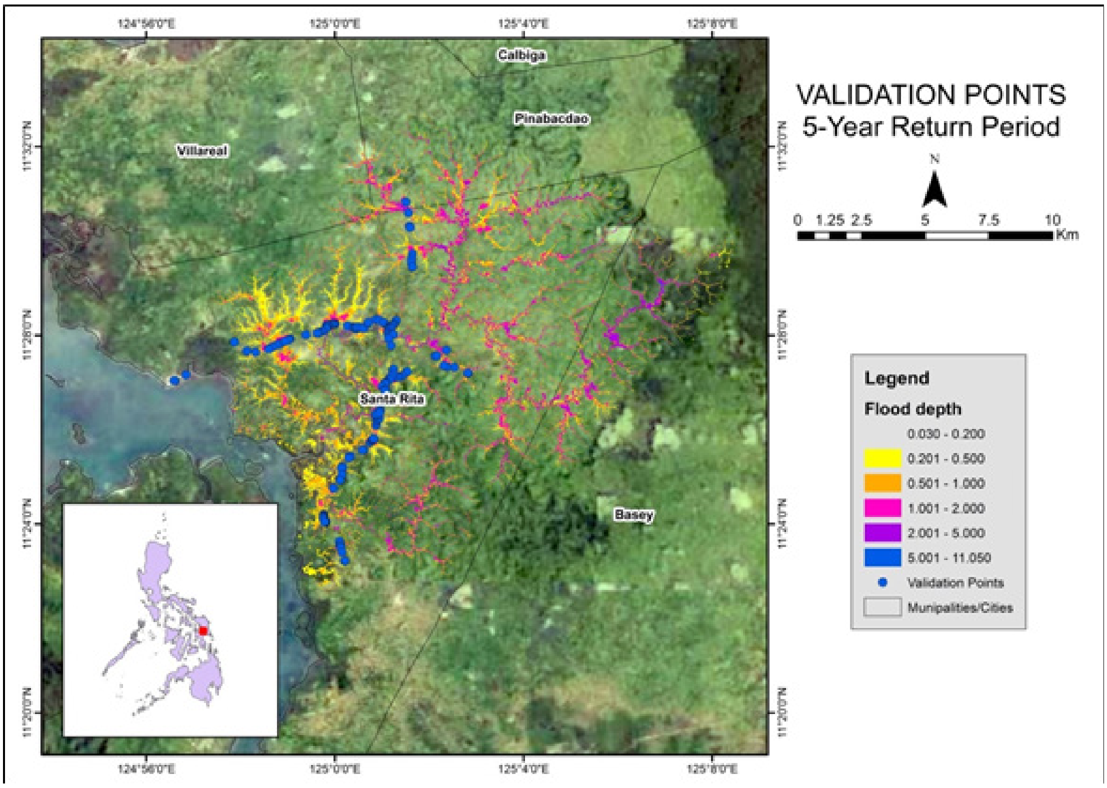


Figure 86. Validation points for the 5-year flood depth map of the Maragondon floodplain

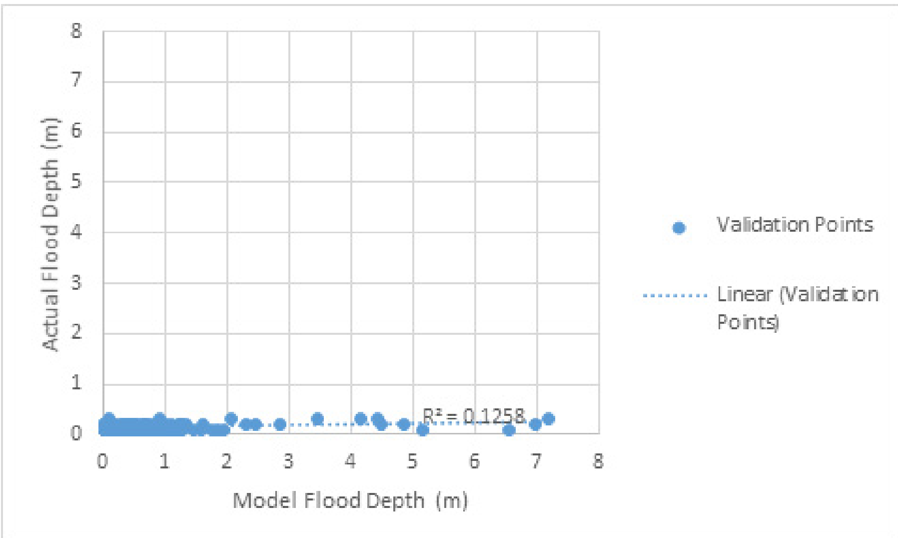


Figure 87. Flood map depth vs. actual flood depth

Table 52. Actual flood depth vs. simulated flood depth in Maragondon

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	94	32	33	20	5	3	187
0.21-0.50	0-0.20	0	1	0	4	1	7
0.51-1.00	0	0	0	0	0	0	0
1.01-2.00	0	0	0	0	0	0	0
2.01-5.00	0	0	0	0	0	0	0
> 5.00	0	0	0	0	0	0	0
Total	95	32	34	20	9	4	194

The overall accuracy generated by the flood model is estimated at 48.45%, with ninety-four (94) points correctly matching the actual flood depths. In addition, there were thirty-four (34) points estimated one (1) level above and below the correct flood depths. Meanwhile, there were thirty-three (33) points and thirty-three (33) points estimated two (2) levels above and below, and three (3) or more levels above and below the correct flood levels, respectively. A total of four (4) points were overestimated, while a total of one (1) point was underestimated in the modeled flood depths of Maragondon.

Table 53. Summary of Accuracy Assessment in the Maragondon River Basin

	No. of Points	**%**
Correct	94	48.45
Overestimated	99	51.03
Underestimated	1	0.52
Total	194	100.00

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 Maragondon Floodplain Survey

Table A-1.1. Technical specifications of the Pegasus sensor

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

Table A-1.2. Technical specifications of the Gemini sensor

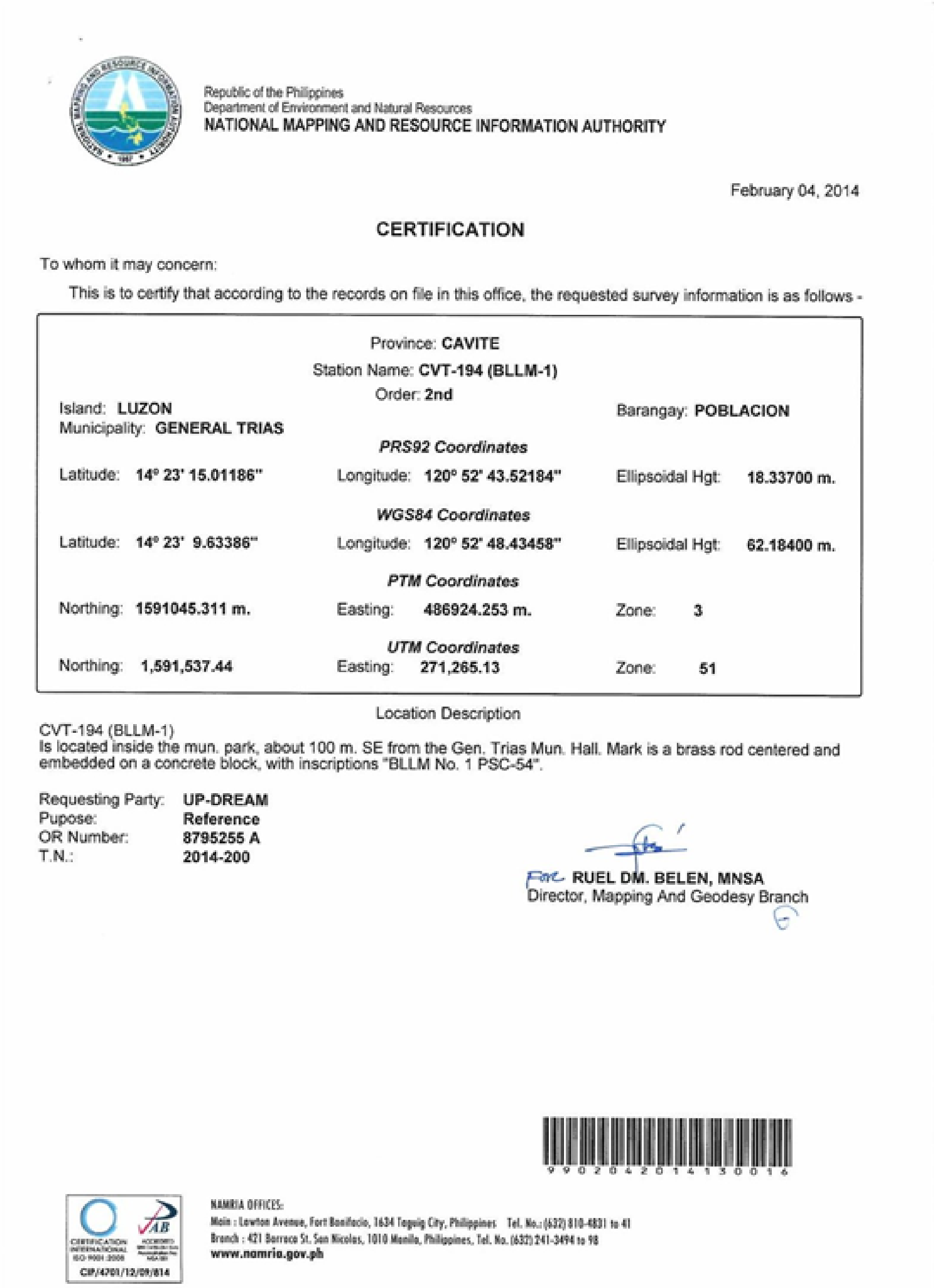
Parameter	Specification
Operational envelope (1,2,3,4)	150-4000 m AGL, nominal
Laser wavelength	1064 nm
Horizontal accuracy (2)	1/5,500 x altitude, (m AGL)
Elevation accuracy (2)	<5-35 cm, 1 σ
Effective laser repetition rate	Programmable, 33-167 kHz
Position and orientation system	POS AV™ AP50 (OEM);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

Table A-1.3. Technical specifications of the Leica Geosystems ALS80-HP sensor

Parameter	Specification
Operational altitude	100 to 3500 m max AGL
Maximum measurement rate	1000 kHz
Maximum scan rate	200 Hz for sine; 158 for triangle;120 for raster
Field of view (degrees, full angle, user-adjustable)	0 to 72
Roll Stabilization (automatic adaptive, degrees)	72 – active FOV
Number of returns	unlimited
Number of intensity measurements	3(first, second and third)
Data Storage	ALS80: removable SSD hard disk (800GB each volume)
Power Consumption	922 W @ 22.0-30.3 VDC
Dimensions and weight	Scanner:37 W x 68 L x 26 H cm; 47 kg;
Control Electronics: 45 W x 47 D x 25 H cm; 33 kg	Dual divergence: 0.25 mrad (1/e) and 0.8 mrad (1/e), nominal
Operating temperature	0-40˚C

Annex 2. NAMRIA Certification of Reference Points used in the LiDAR Survey

1. CVT-194



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: **CAVITE**
Station Name: **CVT-194 (BLLM-1)**
Order: **2nd**

Island: **LUZON**
Municipality: **GENERAL TRIAS**
Barangay: **POBLACION**

		PRS92 Coordinates			
Latitude:	14° 23' 15.01186"	Longitude:	120° 52' 43.52184"	Ellipsoidal Hgt:	18.33700 m.
		WGS84 Coordinates			
Latitude:	14° 23' 9.63386"	Longitude:	120° 52' 48.43458"	Ellipsoidal Hgt:	62.18400 m.
		PTM Coordinates			
Northing:	1591045.311 m.	Easting:	486924.253 m.	Zone:	3
		UTM Coordinates			
Northing:	1,591,537.44	Easting:	271,265.13	Zone:	51

Location Description

CVT-194 (BLLM-1)
Is located inside the mun. park, about 100 m. SE from the Gen. Trias Mun. Hall. Mark is a brass rod centered and embedded on a concrete block, with inscriptions "BLLM No. 1 PSC-54".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795255 A**
T.N.: **2014-200**

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

9902042014130016

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

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

Figure A-2.1. CVT-194

2. CVT-199

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

February 26, 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: **CAVITE**
Station Name: **CVT-199**
Order: **2nd**

Island: **LUZON**
Municipality: **INDANG**
Barangay: **CALUMPANG LEJOS**

PRS92 Coordinates

Latitude: **14° 14' 16.32329"**	Longitude: **120° 50' 40.63536"**	Ellipsoidal Hgt: **166.20100 m.**

WGS84 Coordinates

Latitude: **14° 14' 10.97763"**	Longitude: **120° 50' 45.56096"**	Ellipsoidal Hgt: **210.38600 m.**

PTM Coordinates

Northing: **1574493.218 m.**	Easting: **483231.789 m.**	Zone: **3**

UTM Coordinates

Northing: **1,575,012.80**	Easting: **267,428.74**	Zone: **51**

Location Description

CVT-199
To reach Brgy. Calumpang Lejos, take the nat'l. road from Indang Town Proper towards Naic for about 5 km. Station is located approx. 15 m. NW of the chapel, about 8 m. N of the basketball covered court. Mark is the head of a 4 in. copper nail centered and embedded on a 30 cm. x 30 cm. x 10 cm. concrete block, with inscriptions "CVT-199 2007 NAMRIA".

Requesting Party: **UP DREAM**
Pupose: **Reference**
OR Number: **8795440 A**
T.N.: **2014-391**

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

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

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

Figure A-2.2. CVT-199

3. BTG-51

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

January 05, 2016

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: **BATANGAS**		
	Station Name: **BTG-51**		
	Order: **2nd**		
Island: **LUZON**	Barangay: **TALAGA**		
Municipality: **TANAUAN**	MSL Elevation:		
	PRS92 Coordinates		
Latitude: **14° 6' 8.57112"**	Longitude: **121° 5' 52.31002"**	Ellipsoidal Hgt:	**152.36900 m.**
	WGS84 Coordinates		
Latitude: **14° 6' 3.27790"**	Longitude: **121° 5' 57.24592"**	Ellipsoidal Hgt:	**197.55100 m.**
	PTM / PRS92 Coordinates		
Northing: **1559501.067 m.**	Easting: **510567.544 m.**	Zone:	**3**
	UTM / PRS92 Coordinates		
Northing: **1,559,783.81**	Easting: **294,641.94**	Zone:	**51**

Location Description

BTG-51
From Star Expressway Exit, Tanauan City, turn right to Talisay and continue traveling W until reaching the Y-road. Station is located inside the Mabini Shrine, approx. 100 m. from the right side of the road. It is situated approx. 2 m. S of the flagpole, about 15 m. N from the gate of the said shrine. Mark is the head of a 4 in. copper nail centered and embedded on a 30 cm. x 30 cm. concrete block flushed on the ground, with inscriptions "BTG-51 2007 NAMRIA".

Requesting Party: **DOST-PCIEERD**
Purpose: **Reference**
OR Number: **8089513 I**
T.N.: **2016-0018**

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

9 9 0 1 0 5 2 0 1 6 1 5 0 5 1 0

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.3. BTG-51

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

1. CVT-3051

Vector Components (Mark to Mark)

From:	CVT-199				
Grid		Local		Global	
Easting	267428.741 m	Latitude	N14°14'16.32329"	Latitude	N14°14'10.97763"
Northing	1575012.795 m	Longitude	E120°50'40.63536"	Longitude	E120°50'45.56096"
Elevation	167.120 m	Height	166.201 m	Height	210.386 m

To:	CVT-3051				
Grid		Local		Global	
Easting	271276.565 m	Latitude	N14°22'58.33330"	Latitude	N14°22'52.95639"
Northing	1591024.612 m	Longitude	E120°52'44.06059"	Longitude	E120°52'48.97372"
Elevation	22.137 m	Height	21.122 m	Height	64.983 m

Vector					
ΔEasting	3847.824 m	NS Fwd Azimuth	12°58'47"	ΔX	-1068.623 m
ΔNorthing	16011.817 m	Ellipsoid Dist.	16463.417 m	ΔY	-5421.802 m
ΔElevation	-144.982 m	ΔHeight	-145.079 m	ΔZ	15509.176 m

Standard Errors

Vector errors:					
σ ΔEasting	0.029 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.036 m
σ ΔNorthing	0.020 m	σ Ellipsoid Dist.	0.019 m	σ ΔY	0.058 m
σ ΔElevation	0.065 m	σ ΔHeight	0.065 m	σ ΔZ	0.029 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0012710639		
Y	-0.0011111494	0.0033830758	
Z	-0.0004897536	0.0012701754	0.0008644866

2

Figure A.3.1. CVT-3051

CVT-3123

Vector Components (Mark to Mark)

From:	CVT-199				
Grid		Local		Global	
Easting	267428.741 m	Latitude	N14°14'16.32329"	Latitude	N14°14'10.97763"
Northing	1575012.795 m	Longitude	E120°50'40.63536"	Longitude	E120°50'45.56096"
Elevation	167.120 m	Height	166.201 m	Height	210.386 m

To:	CVT-3123				
Grid		Local		Global	
Easting	267465.517 m	Latitude	N14°14'15.59521"	Latitude	N14°14'10.24962"
Northing	1574990.072 m	Longitude	E120°50'41.86874"	Longitude	E120°50'46.79435"
Elevation	168.445 m	Height	167.527 m	Height	211.713 m

Vector					
ΔEasting	36.776 m	NS Fwd Azimuth	121°10'48"	ΔX	-35.227 m
ΔNorthing	-22.723 m	Ellipsoid Dist.	43.218 m	ΔY	-13.131 m
ΔElevation	1.325 m	ΔHeight	1.326 m	ΔZ	-21.362 m

Standard Errors

Vector errors:					
σ ΔEasting	0.000 m	σ NS fwd Azimuth	0°00'01"	σ ΔX	0.000 m
σ ΔNorthing	0.000 m	σ Ellipsoid Dist.	0.000 m	σ ΔY	0.001 m
σ ΔElevation	0.001 m	σ ΔHeight	0.001 m	σ ΔZ	0.000 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000001903		
Y	-0.0000001733	0.0000004088	
Z	-0.0000000653	0.0000001166	0.0000001007

2

Figure A-3.2. CVT-3123

PB-1

Vector Components (Mark to Mark)

From:	CVT-194				
Grid		Local		Global	
Easting	271413.844 m	Latitude	N14°23'09.63386"	Latitude	N14°23'09.63386"
Northing	1591468.703 m	Longitude	E120°52'48.43458"	Longitude	E120°52'48.43458"
Elevation	19.356 m	Height	62.184 m	Height	62.184 m

To:	PB-1				
Grid		Local		Global	
Easting	280881.093 m	Latitude	N14°23'19.56635"	Latitude	N14°23'19.56635"
Northing	1591688.776 m	Longitude	E120°58'04.29835"	Longitude	E120°58'04.29835"
Elevation	44.199 m	Height	87.568 m	Height	87.568 m

Vector					
ΔEasting	9467.249 m	NS Fwd Azimuth	88°08'29"	ΔX	-8091.412 m
ΔNorthing	220.073 m	Ellipsoid Dist.	9467.724 m	ΔY	-4906.972 m
ΔElevation	24.843 m	ΔHeight	25.384 m	ΔZ	302.003 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.004 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.007 m
σ ΔElevation	0.009 m	σ ΔHeight	0.009 m	σ ΔZ	0.003 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000191800		
Y	-0.0000293093	0.0000523957	
Z	-0.0000093650	0.0000161874	0.0000064708

2

Figure A-3.3. PB-1

BTG-A

BTG-51 - BTG-A (10:17:13 AM-4:00:13 PM) (S1)

Baseline observation:	BTG-51 --- BTG-A (B1)
Processed:	1/6/2016 4:11:57 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.003 m
Vertical precision:	0.013 m
RMS:	0.003 m
Maximum PDOP:	1.859
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	12/21/2015 10:17:33 AM (Local: UTC+8hr)
Processing stop time:	12/21/2015 4:00:13 PM (Local: UTC+8hr)
Processing duration:	05:42:40
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	BTG-51				
Grid		**Local**		**Global**	
Easting	294641.947 m	**Latitude**	N14°06'08.57113"	**Latitude**	N14°06'03.27790"
Northing	1559783.810 m	**Longitude**	E121°05'52.31001"	**Longitude**	E121°05'57.24592"
Elevation	152.867 m	**Height**	152.369 m	**Height**	197.551 m

To:	BTG-A				
Grid		**Local**		**Global**	
Easting	297103.192 m	**Latitude**	N13°57'27.65020"	**Latitude**	N13°57'22.39320"
Northing	1543753.102 m	**Longitude**	E121°07'18.59698"	**Longitude**	E121°07'23.54499"
Elevation	374.449 m	**Height**	373.826 m	**Height**	419.468 m

Vector					
ΔEasting	2461.246 m	**NS Fwd Azimuth**	170°48'36"	**ΔX**	-4333.540 m
ΔNorthing	-16030.708 m	**Ellipsoid Dist.**	16216.677 m	**ΔY**	2168.834 m
ΔElevation	221.582 m	**ΔHeight**	221.457 m	**ΔZ**	-15477.964 m

2

Figure A-3.4. BTG-A

TGT-1

TGT-1 - BTG-A (8:02:03 AM-12:33:59 PM) (S4)

Baseline observation:	TGT-1 --- BTG-A (B4)
Processed:	1/6/2016 4:19:10 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.008 m
Vertical precision:	0.017 m
RMS:	0.021 m
Maximum PDOP:	2.798
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	12/22/2015 8:02:03 AM (Local: UTC+8hr)
Processing stop time:	12/22/2015 12:33:59 PM (Local: UTC+8hr)
Processing duration:	04:31:56
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	BTG-A				
Grid		Local		Global	
Easting	297103.192 m	Latitude	N13°57'27.65020"	Latitude	N13°57'22.39320"
Northing	1543753.102 m	Longitude	E121°07'18.59698"	Longitude	E121°07'23.54499"
Elevation	374.473 m	Height	373.850 m	Height	419.492 m

To:	TGT-1				
Grid		Local		Global	
Easting	279835.803 m	Latitude	N14°07'00.06415"	Latitude	N14°06'54.75674"
Northing	1561490.784 m	Longitude	E120°57'38.31809"	Longitude	E120°57'43.25314"
Elevation	614.013 m	Height	613.234 m	Height	658.040 m

Vector					
ΔEasting	-17267.390 m	NS Fwd Azimuth	315°18'50"	ΔX	16999.982 m
ΔNorthing	17737.682 m	Ellipsoid Dist.	24750.750 m	ΔY	5522.228 m
ΔElevation	239.540 m	ΔHeight	239.384 m	ΔZ	17124.706 m

Figure A-3.5. TGT-1

TGT-2

Vector Components (Mark to Mark)

From:	BTG-51				
Grid		Local		Global	
Easting	294641.947 m	Latitude	N14°06'08.57113"	Latitude	N14°06'03.27790"
Northing	1559783.810 m	Longitude	E121°05'52.31001"	Longitude	E121°05'57.24592"
Elevation	152.867 m	Height	152.369 m	Height	197.551 m

To:	TGT-2				
Grid		Local		Global	
Easting	279836.028 m	Latitude	N14°07'00.17316"	Latitude	N14°06'54.86574"
Northing	1561494.133 m	Longitude	E120°57'38.32462"	Longitude	E120°57'43.25967"
Elevation	614.112 m	Height	613.333 m	Height	658.140 m

Vector					
ΔEasting	-14805.919 m	NS Fwd Azimuth	276°07'32"	ΔX	12666.633 m
ΔNorthing	1710.323 m	Ellipsoid Dist.	14901.989 m	ΔY	7690.363 m
ΔElevation	461.245 m	ΔHeight	460.964 m	ΔZ	1650.022 m

Standard Errors

Vector errors:					
σ ΔEasting	0.003 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.005 m
σ ΔNorthing	0.002 m	σ Ellipsoid Dist.	0.003 m	σ ΔY	0.007 m
σ ΔElevation	0.009 m	σ ΔHeight	0.009 m	σ ΔZ	0.003 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000291618		
Y	-0.0000296204	0.0000467722	
Z	-0.0000126383	0.0000148753	0.0000083643

Figure A-3.6. TGT-2

Annex 4. The LiDAR Survey Team Composition

Table A-4.1. LiDAR Survey Team Composition

Data Acquisition Component Sub -Team	Designation	Name	Agency / Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
		ENGR. LOUIE BALICANTA	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, Data Download and Transfer	Senior Science Research Specialist (SSRS)	PAULINE JOANNE ARCEO	UP-TCAGP
		JASMINE ALVIAR	UP-TCAGP
		AUBREY MATIRA	UP-TCAGP
		JULIE PEARL MARS	UP.TCAGP
	Research Associate (RA)	ENGR. IRO NIEL ROXAS	UP-TCAGP
		ENGR. LARAH KRISELLE PARAGAS	UP-TCAGP
		JONALYN GONZALES	UP-TCAGP
		ENGR. RENAN PUNTO	UP-TCAGP
		KRISTINE JOY ANDAYA	UP-TCAGP
Ground Survey	Research Associate (RA)	JONALYN GONZALES	UP-TCAGP
		ENGR. RENAN PUNTO	UP-TCAGP
		ENGR. RENAN PUNTO	UP-TCAGP

LiDAR Operation	Airborne Security	SSG. RAYMUND DOMINE	PHILIPPINE AIR FORCE (PAF)
		TSG. BENJIE CARBOLLEDO	PAF
		SSG. PRADYUMNA DAS RAMIREZ	PAF
		TSG. LEE JAY PUNZALAN	PAF
		SSG. RICHARD TEDD MONTILLA	PAF
	Pilot	CAPT. RAUL SAMAR II	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. MARK TANGONAN	AAC
		CAPT. NEIL ACHILLES AGAWIN	AAC
		CAPT. JUSTIN JOYA	AAC
		CAPT. RANDY LAGCO	AAC
		CAPT. ALBERT LIM	AAC
		CAPT. FRANCO PEPITO	AAC

Annex 5. Data Transfer Sheets for the Maragondon Floodplain Flights

DATA TRANSFER SHEET
Apr 4, 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	
Jan 24, 2014	1023P	1BLK18B024A	PEGASUS	968MB	1.01MB	4.74MB	52.6MB	11.8GB	111KB	9.28GB	39.8GB	8.04MB	109B	245B	33.3KB	N/A	Z:\Airborne_Raw\1023P
Jan 25, 2014	1027P	1BLK18A025A	PEGASUS	1.51GB	1.62MB	5.69MB	194MB	7.11GB	83.9KB	14.3GB	N/A	6.71MB	112B	718B	105KB	N/A	Z:\Airborne_Raw\1027P
Jan 26, 2014	1031P	1BLK18C026A	PEGASUS	1.52GB	1.63MB	5.60MB	185MB	N/A	N/A	14.7GB	N/A	8.03MB	110B	62B	40.6KB	N/A	Z:\Airborne_Raw\1031P
Jan 29, 2014	1043P	1BLK18AS029A	PEGASUS	594MB	687KB	3.52MB	125MB	N/A	N/A	6.13GB	N/A	6.78MB	141B	352B	33.3KB	N/A	Z:\Airborne_Raw\1043P
Jan 31, 2014	1051P	1BLK18E031A	PEGASUS	1.28GB	1.60MB	5.47MB	189MB	14.4GB	154KB	13.3GB	N/A	2.28MB	217B	504B	78.5KB	N/A	Z:\Airborne_Raw\1051P
Feb 2, 2014	1059P	1BLK18F033A	PEGASUS	1.04GB	1.13MB	5.61MB	167MB	11.7GB	118KB	10.1GB	N/A	3MB	201B	421B	133KB	N/A	Z:\Airborne_Raw\1059P
Feb 3, 2014	1063P	1BLK18D034A	PEGASUS	1.18GB	853KB	5.17MB	144MB	19.2GB	174KB	18.5GB	N/A	5.95MB	191B	321B	29.3KB	N/A	Z:\Airborne_Raw\1063P
Feb 4, 2014	1067P	1BLK18H035A	PEGASUS	921MB	1.39MB	4.99MB	167MB	11.6GB	111KB	11.5GB	N/A	5.03MB	138B	383B	63.3KB	N/A	Z:\Airborne_Raw\1067P
Feb 5, 2014	1071P	1BLK18I036A	PEGASUS	1.62GB	1.81MB	4.91MB	157MB	16GB	157KB	15.4GB	N/A	2.50MN	193B	411B	95.2KB	N/A	Z:\Airborne_Raw\1071P
Feb 7, 2014	1079P	1BLKEFS038A	PEGASUS	451MB	603MB	3.17MB	132MB	4.97GB	55.8KB	5.51GB	N/A	3.01MB	194B	479B	69.9KB	N/A	Z:\Airborne_Raw\1079P
Feb 8, 2014	1083P	1BLK18J39A	PEGASUS	1.47GB	1.92MB	5.56MB	198MB	22.6GB	187KB	16.5GB	N/A	12.4MB	180B	604B	62.6KB	N/A	Z:\Airborne_Raw\1083P
Feb 9, 2014	1087P	1BLK18K40A	PEGASUS	1.28GB	1.77MB	5.19MB	188MB	16GB	139KB	14.8GB	N/A	10.7MB	186B	429B	32.8KB	N/A	Z:\Airborne_Raw\1087P
Feb 10, 2014	1091P	1BLK18W41A	PEGASUS	2.17GB	2.40MB	6.22MB	171MB	32.7GB	256KB	20.2GB	N/A	10.1MB	188B	426B	66.1KB	N/A	Z:\Airborne_Raw\1091P
Feb 11, 2014	1095P	1BLK18U42A	PEGASUS	1.16GB	1.58MB	7.92MB	235MB	96.9MB	1.61KB	14.9GB	N/A	11.4MB	205B	287B	76.7KB	N/A	Z:\Airborne_Raw\1095P
Feb 12, 2014	1099P	1BLK18US43A	PEGASUS	1.70GB	2.39MB	7.46MB	234MB	N/A	739B	20.7GB	N/A	11.4MB	205B	543B	95.2KB	N/A	Z:\Airborne_Raw\1099P
Feb 13, 2014	1103P	1BLK18VWS44A	PEGASUS	2.12GB	2.38MB	6.86MB	221MB	N/A	N/A	19.8GB	N/A	16.6MB	305B	429B	191KB	N/A	Z:\Airborne_Raw\1103P
Feb 13,2014	1105P	1BLK18T44B	PEGASUS	2.33GB	2.67MB	6.85MB	219MB	N/A	N/A	22.2GB	N/A	16.6MB	305B	394B	161KB	N/A	Z:\Airborne_Raw\1105P
Feb 14,2014	1107P	1BLK18QRS45A	PEGASUS	799MB	1.54MB	7.08MB	215MB	15.7GB	149KB	10.2GB	N/A	12MB	217B	N/A	N/A	N/A	Z:\Airborne_Raw\1107P
Feb 14,2014	1109P	1BLK18US45B	PEGASUS	N/A	1.87MB	5.61MB	183MB	N/A	N/A	15.9GB	N/A	12MB	217B	310B	195KB	N/A	Z:\Airborne_Raw\1109P

Figure A-5.1. Data Transfer Sheet for Maragondon Floodplain – A

DATA TRANSFER SHEET
Calabarzon 9/10/15

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	
17-Aug	3307P	1BLK18JS229B	Pegasus	972	756	6.66	171	na	na	9.59	na	18.4	1KB	1KB	1/42	na	Z:\DAC\RAW DATA
18-Aug	3309P	1BLK18AsS230A	Pegasus	1.17	757	7.65	202	na	na	11.9	na	19.4	1KB	1KB	88	na	Z:\DAC\RAW DATA
3-Sep	3373P	1BLK18OS246A	Pegasus	1.81	2.06	9.59	212	na	na	18.2	na	7.67	1KB	1KB	1	na	Z:\DAC\RAW DATA
4-Sep	3377P	1BLK18JS247A	Pegasus	1.29	777	8.1	196	na	na	13.4	na	6.43	1KB	1KB	61.6	na	Z:\DAC\RAW DATA
5-Sep	3381P	1BLK18OS248A	Pegasus	2.12	1.54	10.3	256	na	na	20.6	na	9.05	1KB	1KB	59/59	na	Z:\DAC\RAW DATA

Received from

Name C. JOAQUIN
Position RA
Signature

Received by

Name AC Bongat 9/11/15
Position SSRS
Signature

Figure A-5.1. Data Transfer Sheet for Maragondon Floodplain – A

DATA TRANSFER SHEET
Batangas 1/13/16

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
21-Dec 1	3000P	1BLK18SB355A	pegasus	736	656	3.8	107	11.1	85	7.11	na	11.1	1KB	1KB	100	na	Z:\DAC\RAW DATA
6-Jan 6	3677G	2BLK18SK006A	GEMINI	NA	322	699	157	NA	NA	38.7	na	27.2	0KB	1KB	11	na	Z:\DAC\RAW DATA
6-Jan 7	3679G	2BLK18SDG006B	GEMINI	NA	60	401	131	NA	NA	12.8	na	27.2	0KB	1KB	5/3	na	Z:\DAC\RAW DATA
7-Jan 8	3681G	2BLK18SM007A	GEMINI	NA	226	0	209	NA	NA	24	na	18.5	0KB	1KB	NA	na	Z:\DAC\RAW DATA
8-Jan 9	3685G	2BLK18SF008A	GEMINI	NA	99	786	185	NA	NA	24.4	na	20.9	0KB	1KB	4/2	na	Z:\DAC\RAW DATA
8-Jan 10	3687G	2BLK18SGS008B	GEMINI	NA	214	0	172	NA	NA	17.2	na	20.9	0KB	1KB	4/20	na	Z:\DAC\RAW DATA
9-Jan 11	3689G	2BLK18SV009A	GEMINI	NA	201	1.54	219	NA	NA	16.3	na	12.9	0KB	1KB	23	na	Z:\DAC\RAW DATA
9-Jan 12	3691G	2BLK18SVV009B	GEMINI	NA	12.8	440	124	NA	NA	6.93	na	12.9	0KB	1KB	10	na	Z:\DAC\RAW DATA

Received from
Name C. Joson W
Position
Signature

Received by
Name KBongat
Position SRS
Signature KBongat 1/15/16

Figure A-5.3. Data Transfer Sheet for Maragondon Floodplain – C

DATA TRANSFER SHEET
CALABARZON 6/72016

DATE	FLIGHT NO.	MISSION NAME	SENSOR	KML (swath)	GnssImu	LogFiles	TestData	RawLaser	RawTDC	RawWFD	WebCam	RCD30 RAW IMAGES	BASE STATION(S)		SERVER LOCATION
													BASE STATION(S)	Base Info (.txt)	
3-May-16	10136L	4BLK18B124A	ALS 80	51	463	136	41.7	6.59/3.92	4.64/2.98	NA	275/182	43.4	103	1KB	Z:\DAC\RAW DATA
6-May-16	10142L	4BLK18AB127A	ALS 80	195	506	151	40.4	9.28	6.39	NA	359	33.4	97	1KB	Z:\DAC\RAW DATA
7-May-16	10144L	4BLKABS128A	ALS 80	88	408	115	95.6	3.59	2.3	NA	152	12.9	155	1KB	Z:\DAC\RAW DATA

Received from

Name RENAN PUNTO
Position RA
Signature

Received by

Name AC Bongat
Position SSRS
Signature ACBongat 6/20/16

Figure A-5.4. Data Transfer Sheet for Maragondon Floodplain – D

Annex 6. Flight Logs for the Flight Missions

1. Flight Log for 1BLK18C026A Mission

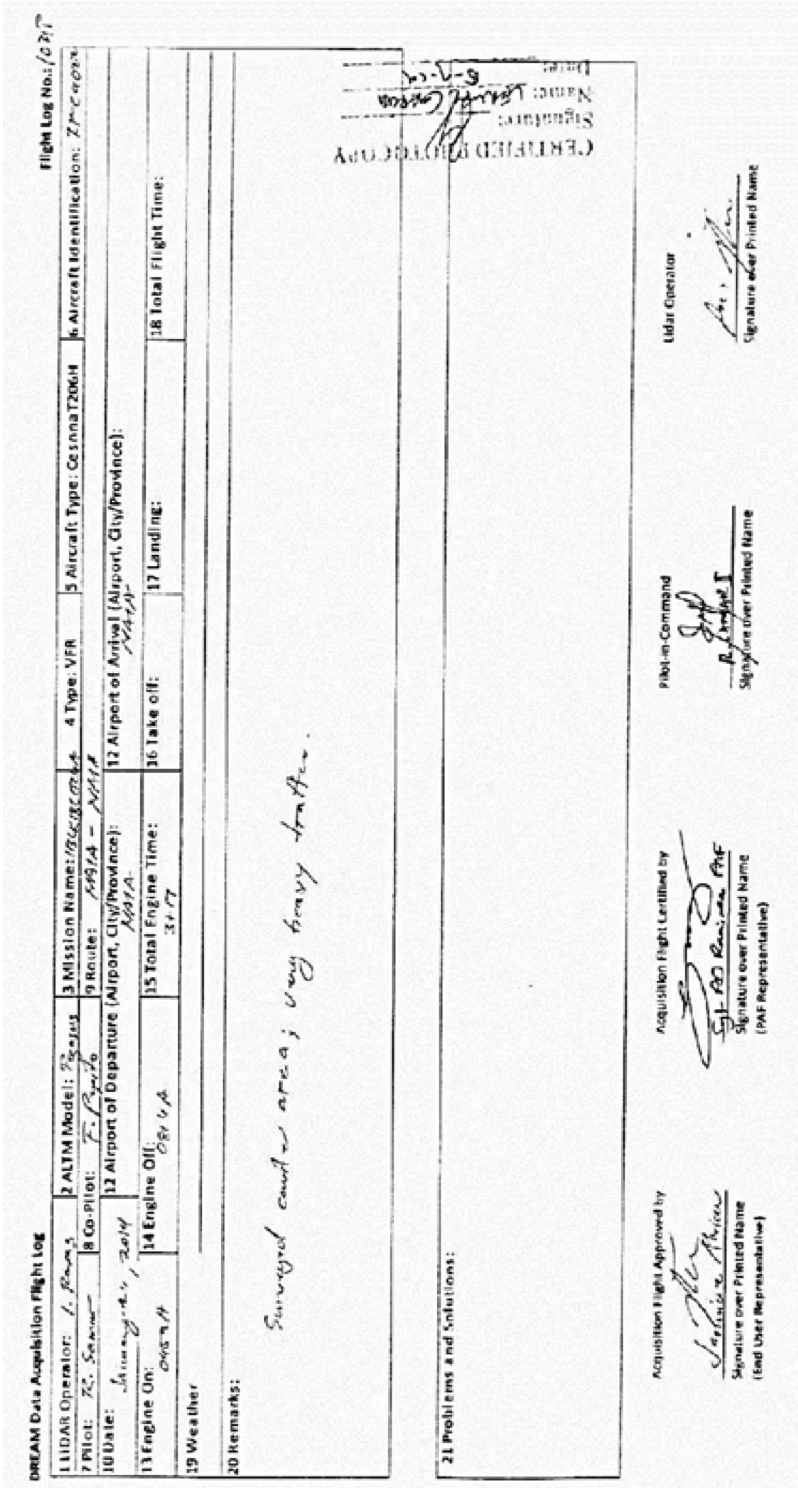
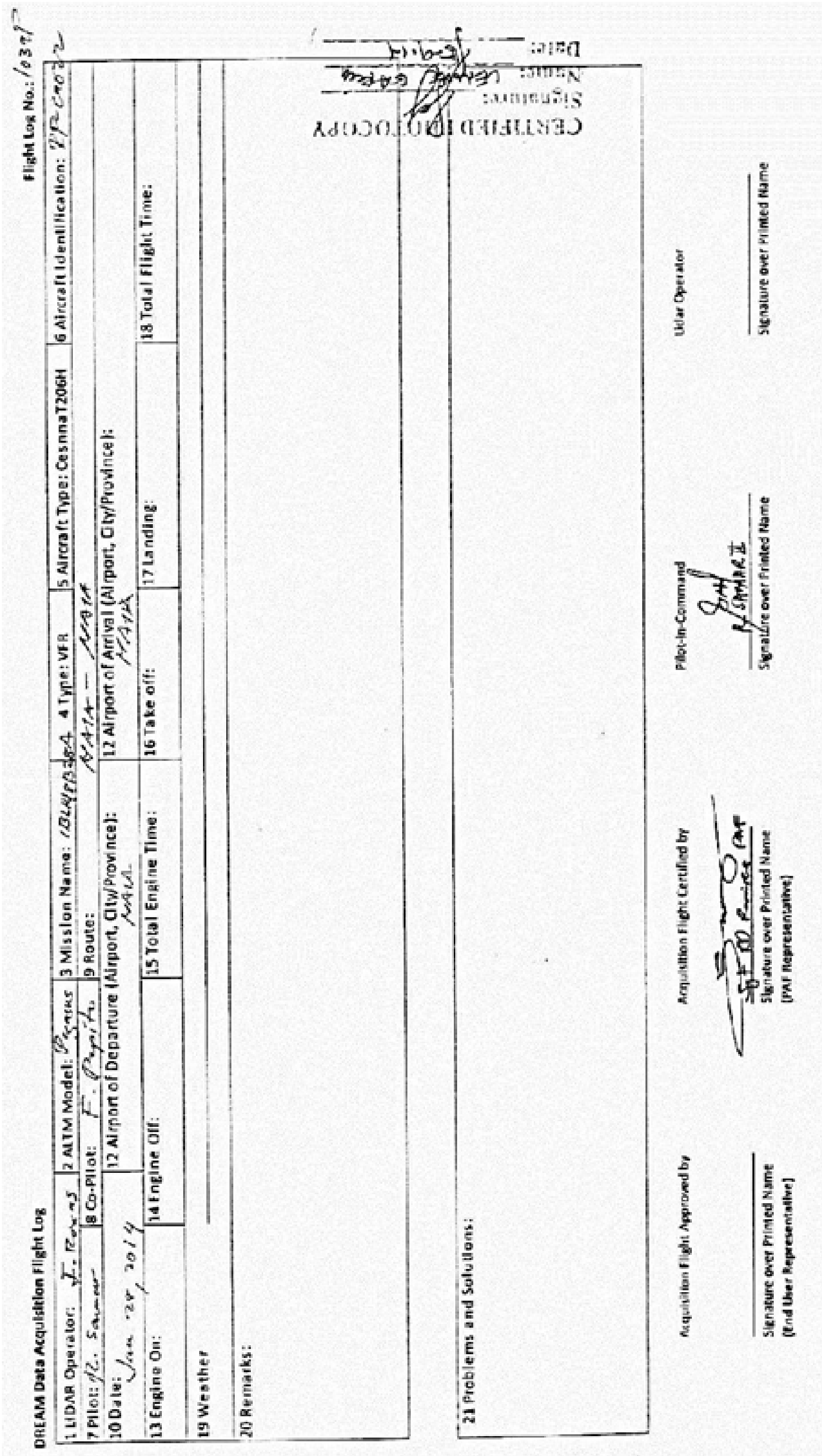


Figure A-6.1. Flight Log for Mission 1BLK18C026A

2. Flight Log for 1BLK18B028A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1039?

1 LIDAR Operator: J. Reyes	2 ALTM Model: Pegasus	3 Mission Name: 1BLK18B28A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9022
7 Pilot: R. Samson	8 Co-Pilot: F. Pagao	9 Route: MAIA – MAIA			
10 Date: Jan 28, 2014	12 Airport of Departure (Airport, City/Province): MAIA		12 Airport of Arrival (Airport, City/Province): MAIA		
13 Engine On:	14 Engine Off:	15 Total Engine Time:	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks:					
21 Problems and Solutions:					

Acquisition Flight Approved by

Signature over Printed Name
(End User Representative)

Acquisition Flight Certified by

Signature over Printed Name
(PAF Representative)

Pilot-in-Command

Signature over Printed Name

Lidar Operator

Signature over Printed Name

CERTIFIED PHOTOCOPY

Signature:
Name:
Date:

Figure A-6.2. Flight Log for Mission 1BLK18B028A

3. Flight Log for 1BLK18AS029A Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1043P

1 LIDAR Operator: P. Arceo	2 ALTM Model: Pegasus	3 Mission Name: 1BLK18AS029A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: E. Samar	8 Co-Pilot: N. Aguarin	9 Route: NAIA - NAIA			
10 Date: Jan 29, 2014	12 Airport of Departure (Airport, City/Province): NAIA		12 Airport of Arrival (Airport, City/Province): NAIA		
13 Engine On: 0519H	14 Engine Off: 0742H	15 Total Engine Time: 2+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Data acquired at 1600m AGL

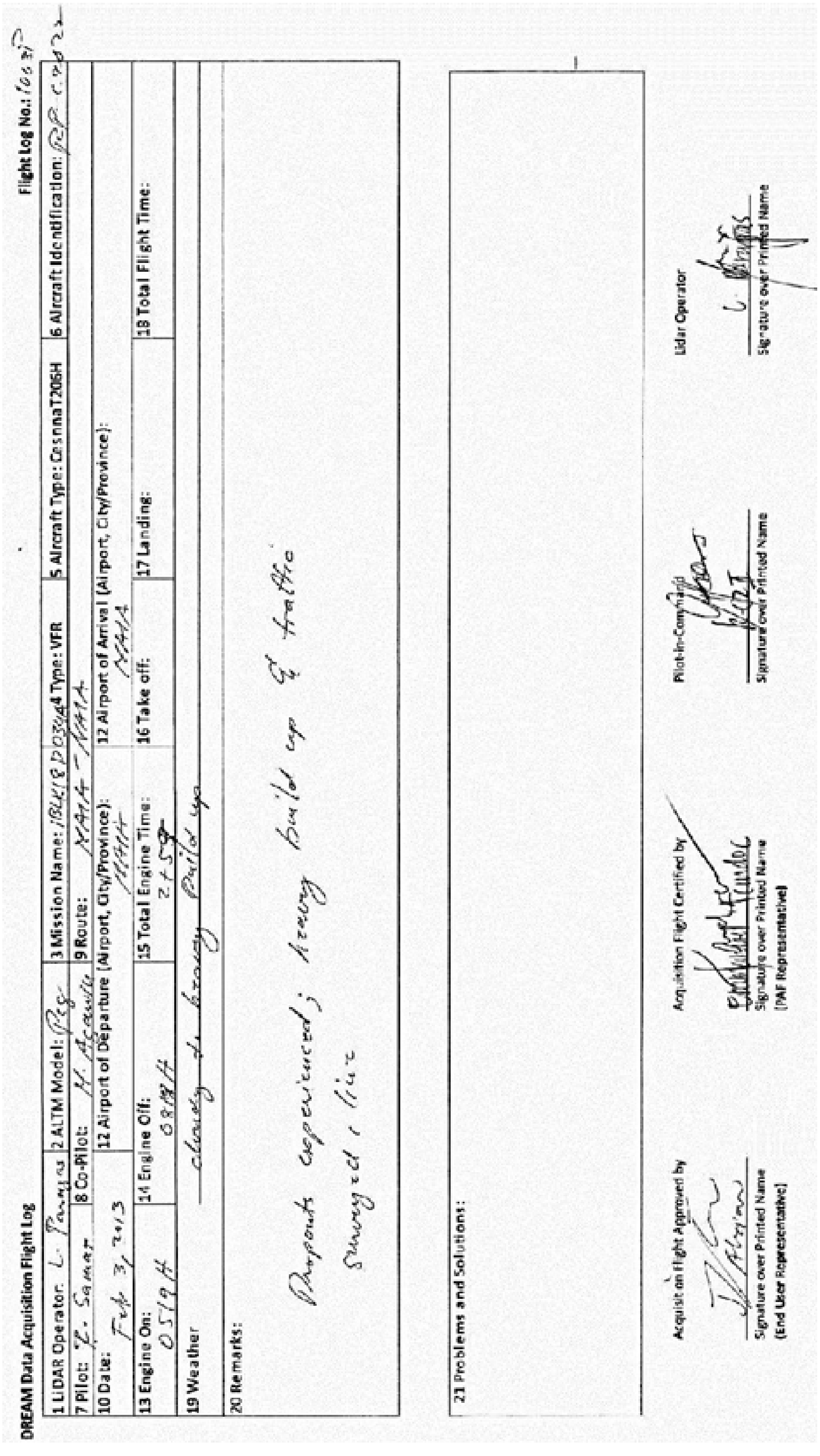
21 Problems and Solutions:

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

CERTIFIED TRUE COPY
Signature:
Name:
Date:

Figure A-6.3. Flight Log for Mission 1BLK18AS029A

4. Flight Log for 1BLK18D034A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 10037

1 LiDAR Operator: L. Paragas	2 ALTM Model: Peg	3 Mission Name: 1BLK18D034A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9022
7 Pilot: E. Samar	8 Co-Pilot: H. Agawin	9 Route: NAIA - NAIA			
10 Date: Feb 3, 2013	12 Airport of Departure (Airport, City/Province): NAIA		12 Airport of Arrival (Airport, City/Province): NAIA		
13 Engine On: 0519H	14 Engine Off: 0818H	15 Total Engine Time: 2+59	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	cloudy to heavy build up				

20 Remarks:

Dropouts experienced; heavy build up & traffic
surveyed 1 line

21 Problems and Solutions:

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

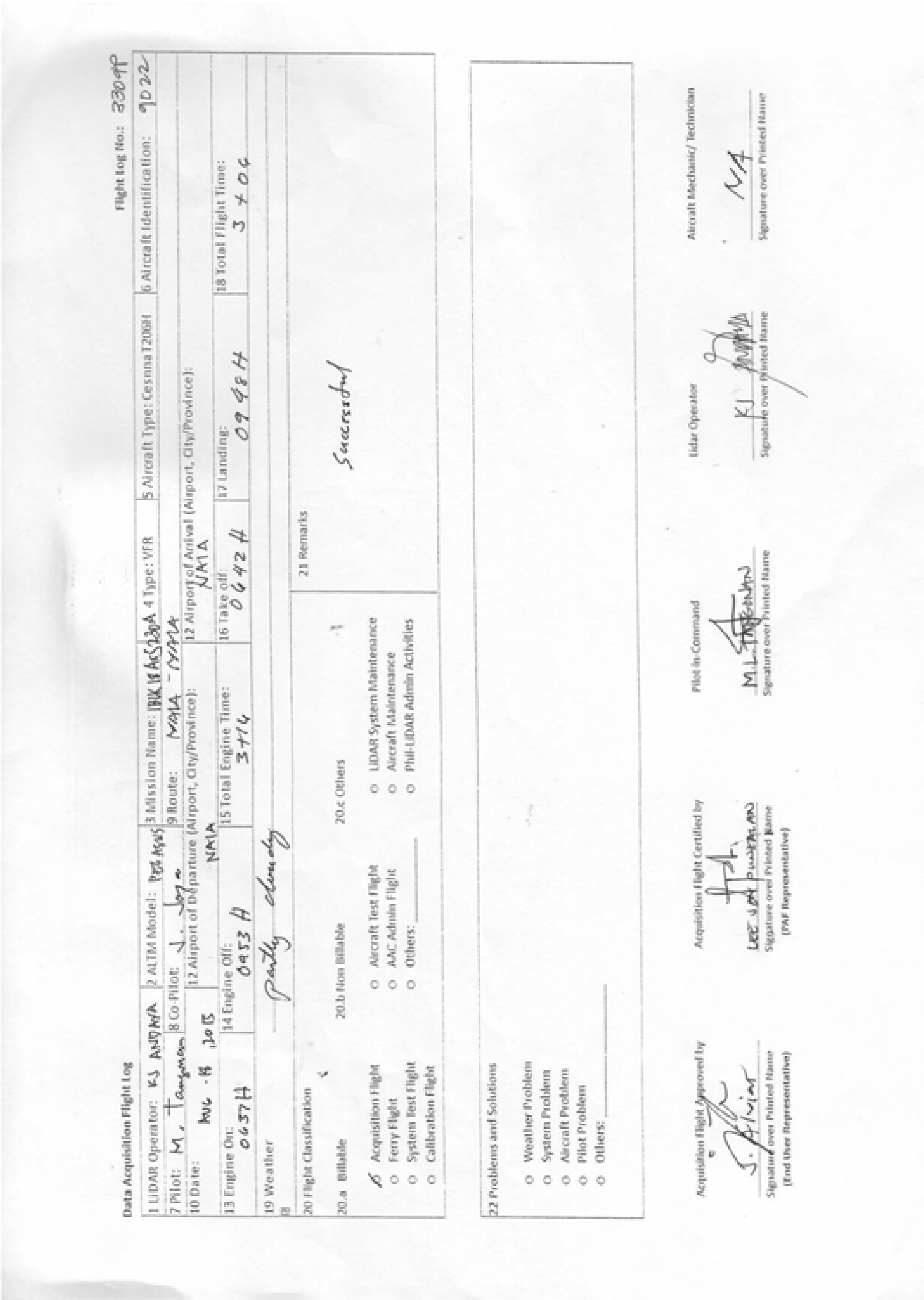
Acquisition Flight Certified by — Signature over Printed Name (PAF Representative)

Pilot-in-Command — Signature over Printed Name

Lidar Operator — L. Paragas — Signature over Printed Name

Figure A-6.4. Flight Log for Mission 1BLK18D034A

5. Flight Log for 1BLK18AsS230A Mission



Data Acquisition Flight Log

Flight Log No.: 3309P

1 LiDAR Operator: KJ ANDAYA	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK18AsS230A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: M. Tangonan	8 Co-Pilot: J. Joya	9 Route: NAIA - NAIA			
10 Date: AUG. 18, 2015	12 Airport of Departure (Airport, City/Province): NAIA		12 Airport of Arrival (Airport, City/Province): NAIA		
13 Engine On: 0637H	14 Engine Off: 0953 H	15 Total Engine Time: 3+16	16 Take off: 0642 H	17 Landing: 0948 H	18 Total Flight Time: 3 + 06
19 Weather: partly cloudy					

20 Flight Classification

20.a Billable
- ø Acquisition Flight
- o Ferry Flight
- o System Test Flight
- o Calibration Flight

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

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

21 Remarks

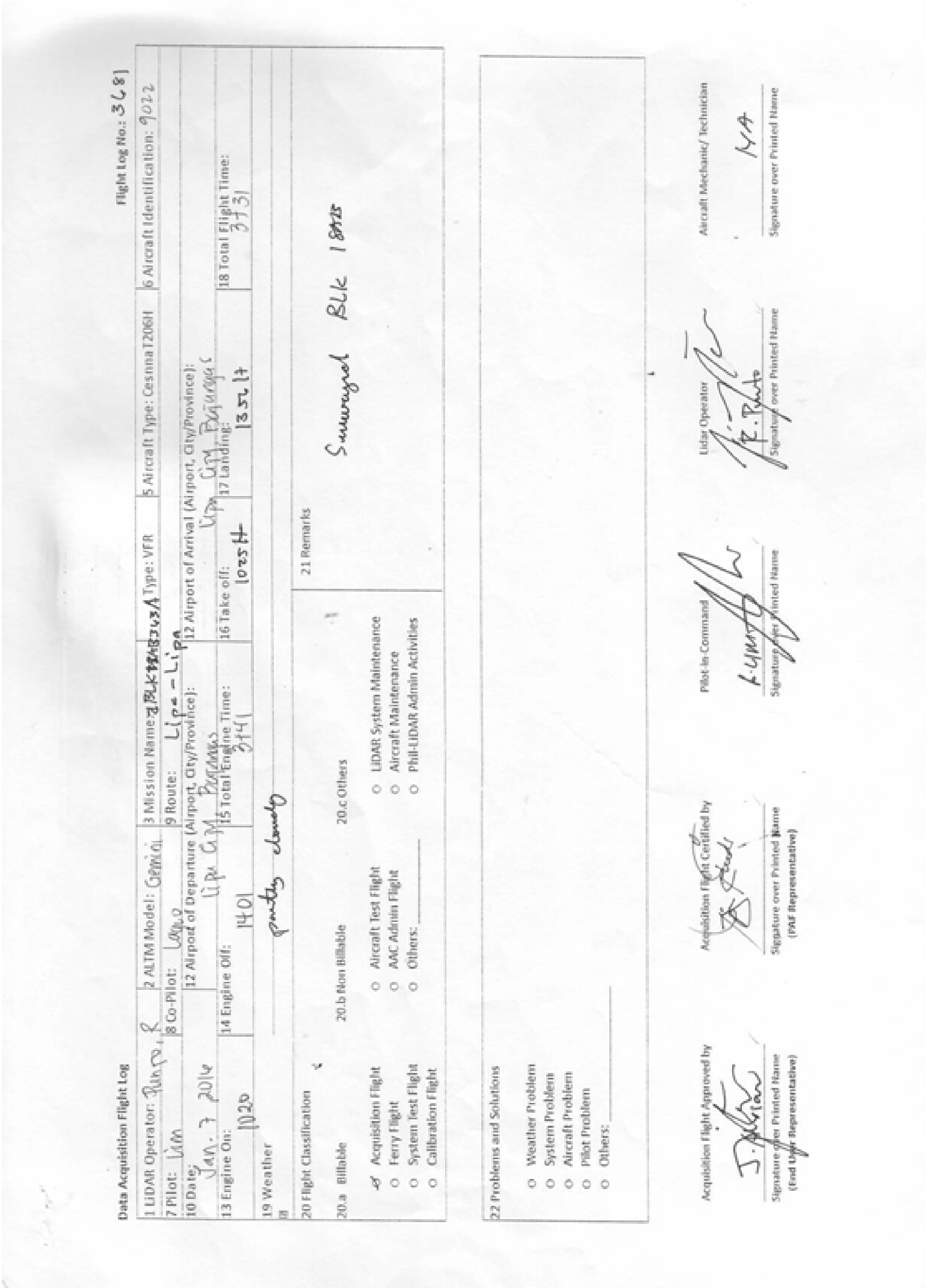
Successful

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator	Aircraft Mechanic/ Technician
J. Alviar	LEE JAY PUNZALAN	M.L. TANGONAN	KJ ANDAYA	NA
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-6.5. Flight Log for Mission 1BLK18AsS230A

6. Flight Log for 2BLK18SM007A Mission



Data Acquisition Flight Log

Flight Log No.: 3681

1 LiDAR Operator: Punto, R	2 ALTM Model: Gemini	3 Mission Name: [illegible]	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: Lim	8 Co-Pilot: Lagno	9 Route: Lipa - Lipa			
10 Date: Jan. 7 2016	12 Airport of Departure (Airport, City/Province): Lipa City, Batangas		12 Airport of Arrival (Airport, City/Province): Lipa City, Batangas		
13 Engine On: 1020	14 Engine Off: 1401	15 Total Engine Time: 3+41	16 Take off: 1025H	17 Landing: 1356H	18 Total Flight Time: 3+31
19 Weather: partly cloudy					

20 Flight Classification

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

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

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

21 Remarks

Surveyed BLK 18A2S

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
J. Alviar	[illegible]	L. Lim	R. Punto	NA
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-6.6. Flight Log for Mission 2BLK18SM007A

7. Flight Log for 2BLK18SGS008B Mission

Data Acquisition Flight Log — Flight Log No.: 3687

1 LiDAR Operator: R. Punto	2 ALTM Model: Gemini	3 Mission Name: 2BLK18SG008B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: Lim	8 Co-Pilot: Lagco	9 Route: Lipa - Lipa			
10 Date: Jan. 6, 2016	12 Airport of Departure (Airport, City/Province): Lipa	12 Airport of Arrival (Airport, City/Province): Lipa			
13 Engine On: 1432	14 Engine Off: 1742	15 Total Engine Time: 3+10	16 Take off: 1437H	17 Landing: 1737H	18 Total Flight Time: 3+00
19 Weather: cloudy					

20 Flight Classification

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

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

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

21 Remarks

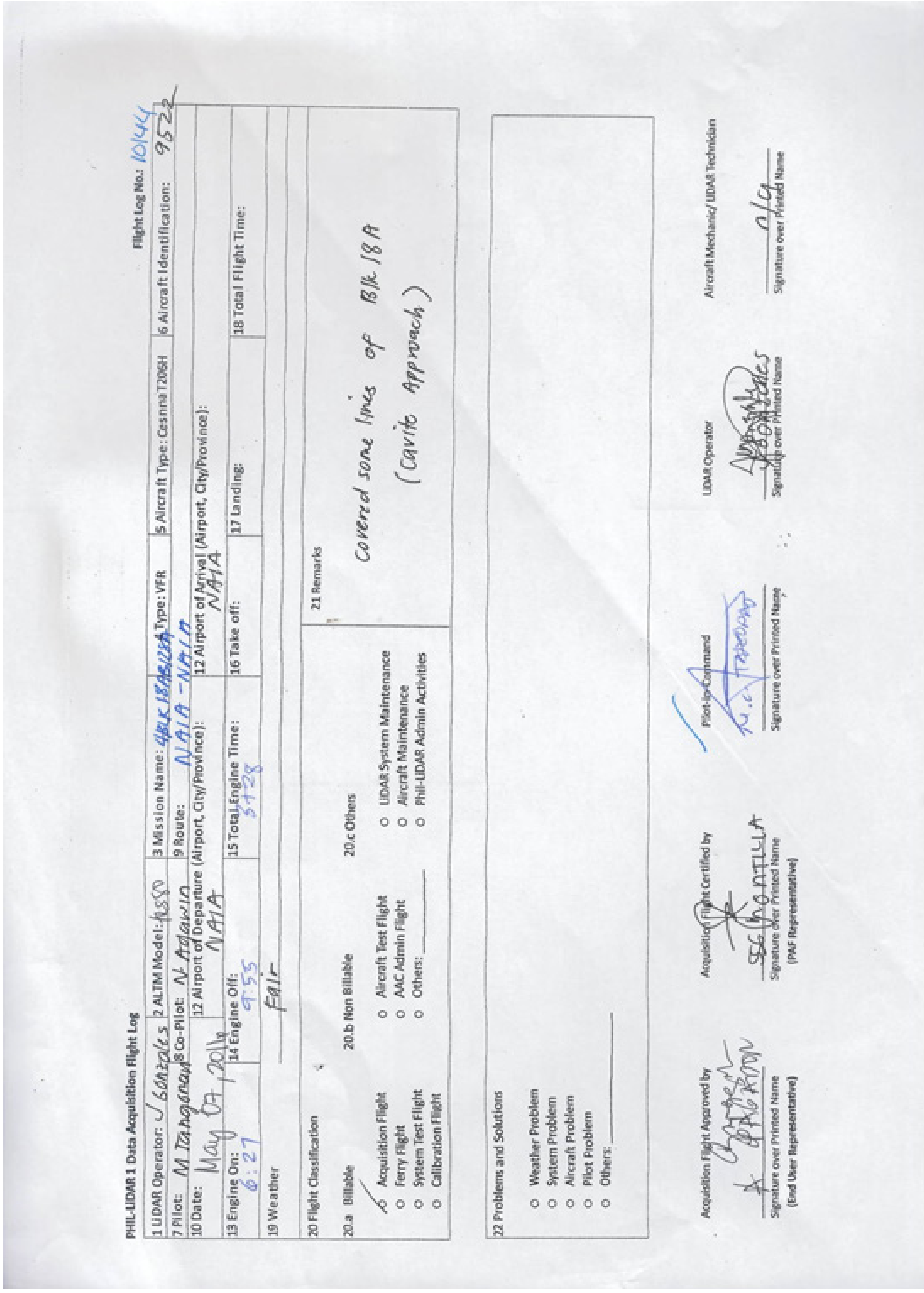
Surveyed BLK 18S6

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
Prof. Mays		A. Lim	R. Punto	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-6.7. Flight Log for Mission 2BLK18SGS008B

8. Flight Log for 4BLK18ABS128A Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 10144

1 LiDAR Operator: J Gonzales	2 ALTM Model: AQ	3 Mission Name: 4BLK18ABS128A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9522
7 Pilot: M Tangonan	8 Co-Pilot: N Adawin	9 Route: NAIA-NAIA			
10 Date: May 07, 2016	12 Airport of Departure (Airport, City/Province): NAIA		12 Airport of Arrival (Airport, City/Province): NAIA		
13 Engine On: 6:27	14 Engine Off: 9:55	15 Total Engine Time: 3+28	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Fair					

20 Flight Classification

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

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

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

21 Remarks

Covered some lines of BLK 18A (Cavite Approach)

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: SSG Mantilla, Signature over Printed Name (PAF Representative)

Pilot-in-Command: Signature over Printed Name

LiDAR Operator: J Gonzales, Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician: n/a, Signature over Printed Name

Figure A-6.8. Flight Log for Mission 4BLK18ABS128A

Annex 7. Flight Status Reports

MARAGONDON FLOODPLAIN
(January 26 - February 3, 2014; August 18, 2015; January 7-8 & May 7, 2016)

Table A-7.1. Flight Status Report

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1031P	BLK 18CD	1BLK18C026A	I. Roxas	26-Jan-14	Acquired data at 1000m, broken lines and irregular survey pattern due to very heavy traffic and tower restrictions
1039P	BLK 18BC	1BLK18B028A	I. Roxas	28-Jan-14	Data acquired at 1000m AGL
1043P	BLK 18AS	1BLK18AS029A	P. Arceo	29-Jan-14	Data acquired at 1000m AGL
1063P	BLK 18D	1BLK18D034A	L. Paragas	3-Feb-14	Dropouts experienced; heavy build up and traffic; surveyed 1 line
3309P	BLK 18AsS	1BLK18AsS230A	K. Andaya	18-Aug-15	Voids due to low cloud ceiling; Laser off due to Clouds; Experienced POSAV error; Without Digitizer and Camera
3681G	BLK 18SM	2BLK18SM007A	R. Punto	7-Jan-16	Surveyed BLK 18SM
3687G	BLK 18SG, SM	2BLK18SGS008B	R. Punto	8-Jan-16	Surveyed BLK 18SG and gaps in BLK 18SM
10144L	BLK 18AB	4BLK18ABS128A	J. Gonzales	7-May-16	Cover some lines of BLK 18AB

SWATH PER FLIGHT MISSION

FLIGHT LOG NO. 1031P
AREA: BLOCK 18CD
MISSION NAME: 1BLK18C026A

Scan Freq: 50 Hz
Scan Angle: 25 deg
PRF: 200

SURVEY COVERAGE:

LAS/SWATH

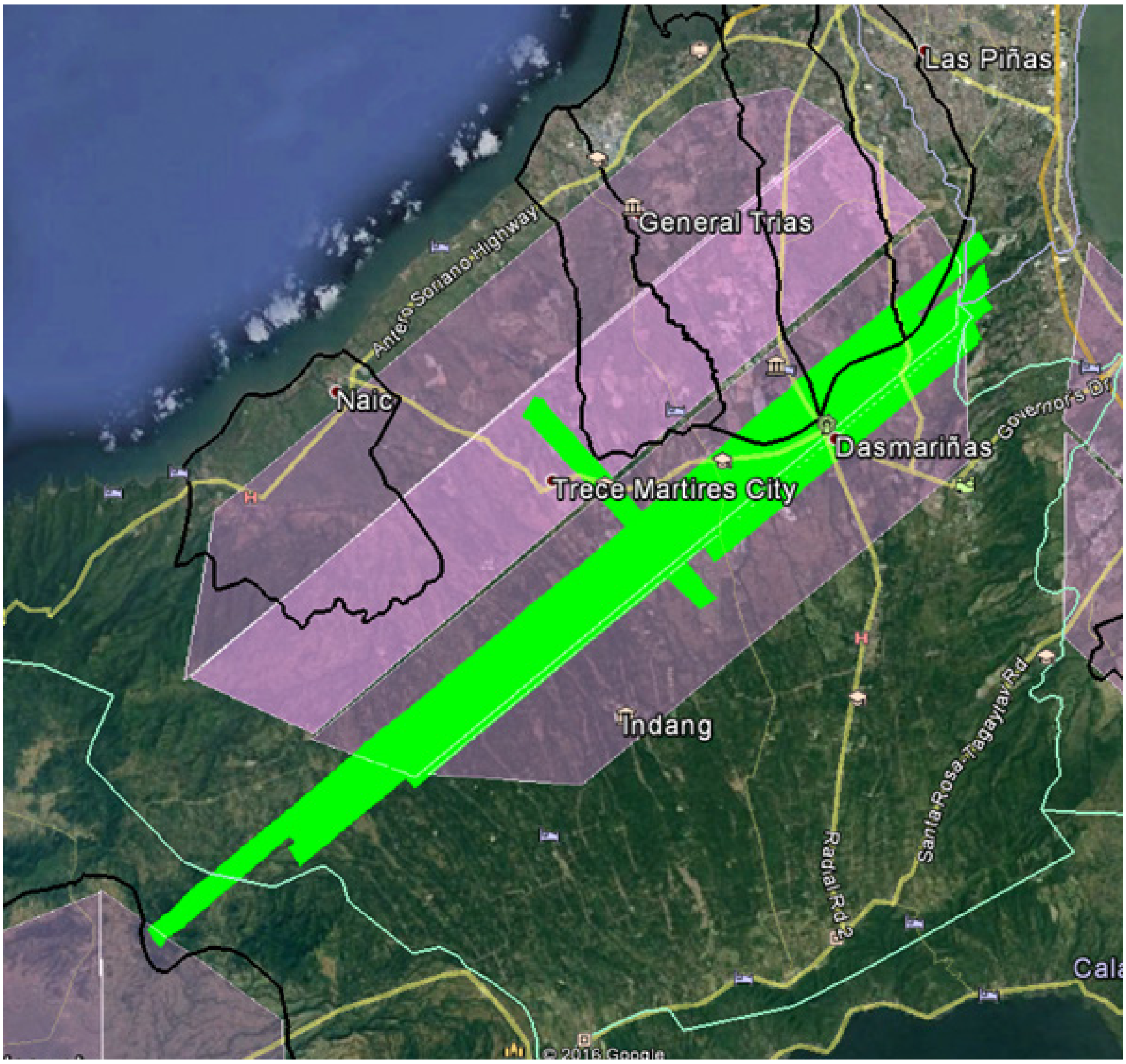


Figure A-7.1. Swath for Flight No. 1031P

FLIGHT LOG NO. 1039P
AREA: BLOCK 18BC
MISSION NAME: 1BLK18B028A

Scan Freq: 50 Hz
Scan Angle: 25 deg
PRF: 200

SURVEY COVERAGE:

LAS/SWATH

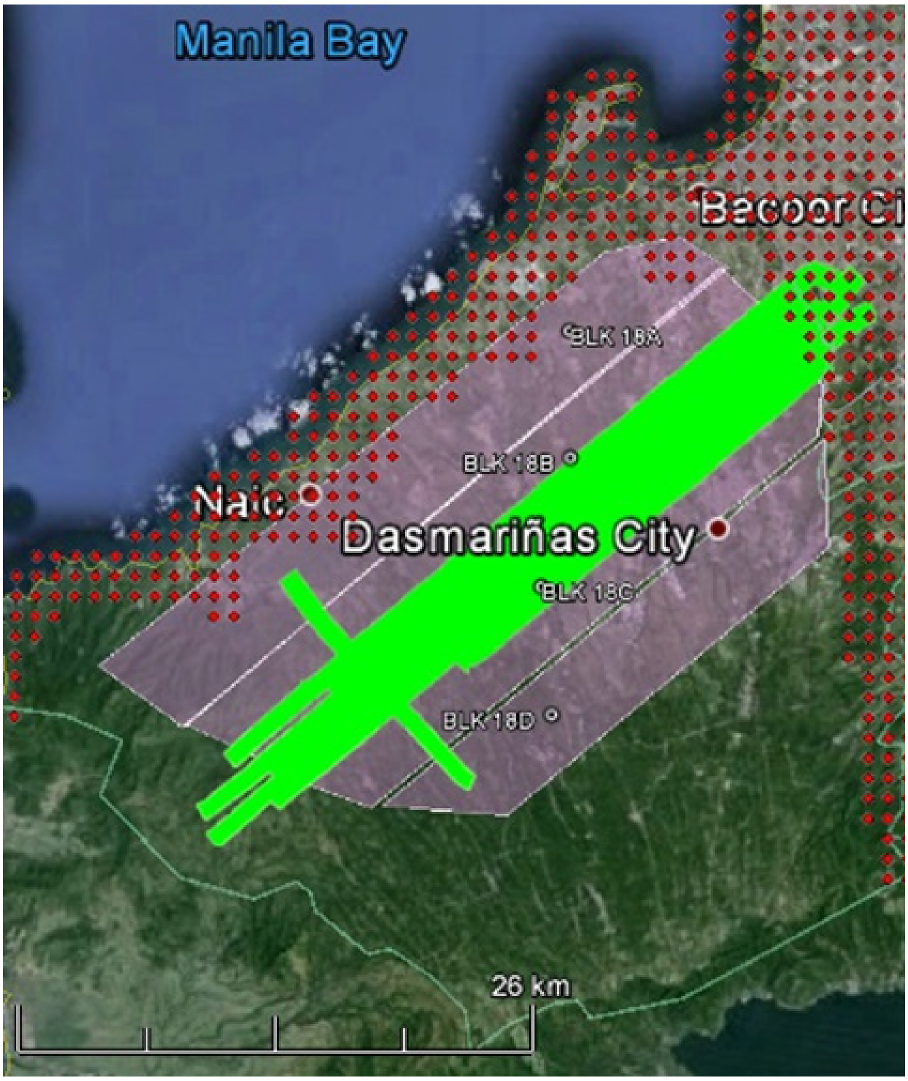


Figure A-7.2. Swath for Flight No. 1039P

FLIGHT LOG NO. 1043P
AREA: BLOCK 18AS
MISSION NAME: 1BLK18AS029A

Scan Freq: 50 Hz
Scan Angle: 25 deg
PRF: 200

SURVEY COVERAGE:

LAS/SWATH

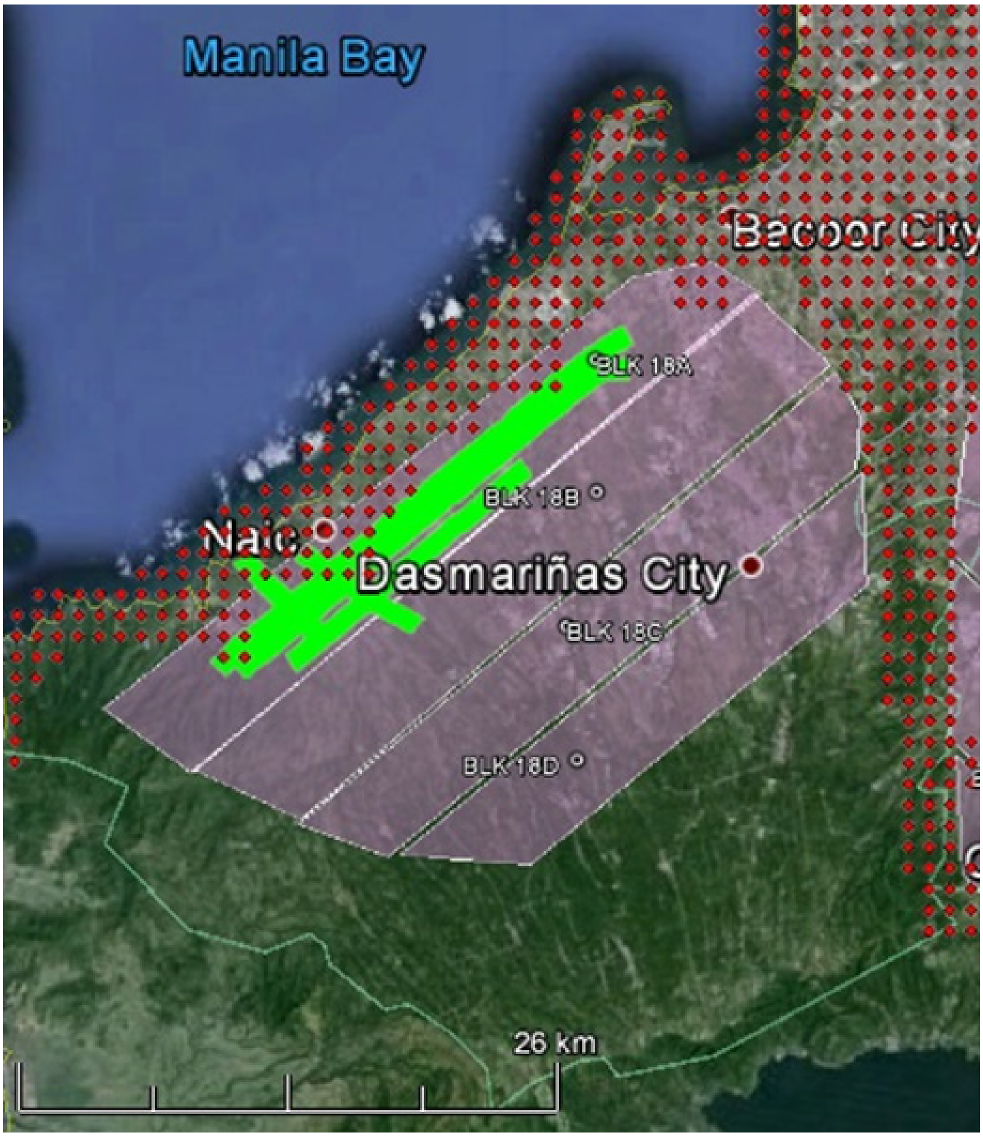


Figure A-7.3. Swath for Flight No. 1043P

FLIGHT LOG NO. 1063P
AREA: BLOCK 18D
MISSION NAME: 1BLK18D034A

Scan Freq: 50 Hz
Scan Angle: 25 deg
PRF: 200

SURVEY COVERAGE:

LAS/SWATH

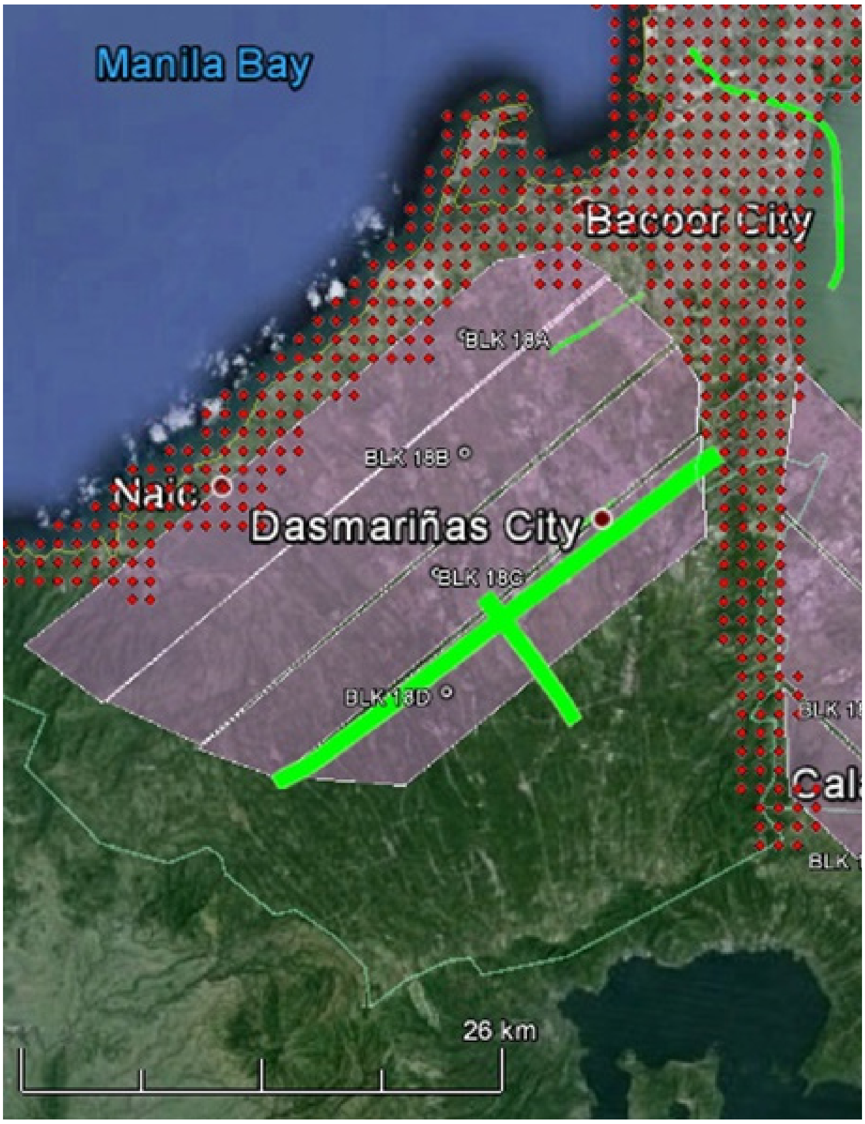


Figure A-7.4. Swath for Flight No. 1063P

FLIGHT LOG NO. 3309P
AREA: BLOCK 18AsS
MISSION NAME: 1BLK18AsS230A

Scan Freq: 30 Hz
Scan Angle: 25 deg
PRF: 200

SURVEY COVERAGE:

LAS/SWATH

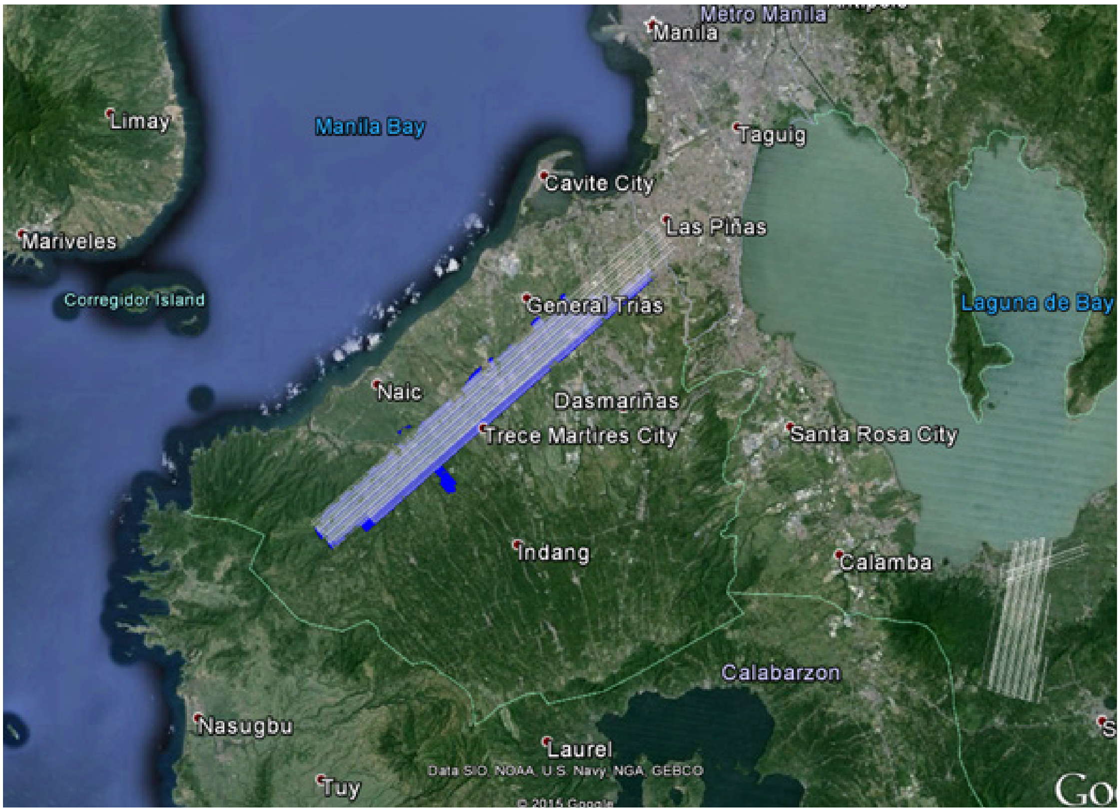


Figure A-7.5. Swath for Flight No. 3309P

FLIGHT LOG NO. 3681G
AREA: BLOCK 18SM
MISSION NAME: 2BLK18SM007A

Scan Freq: 50 Hz
Scan Angle: 20 deg
PRF: 142

SURVEY COVERAGE:

LAS/SWATH

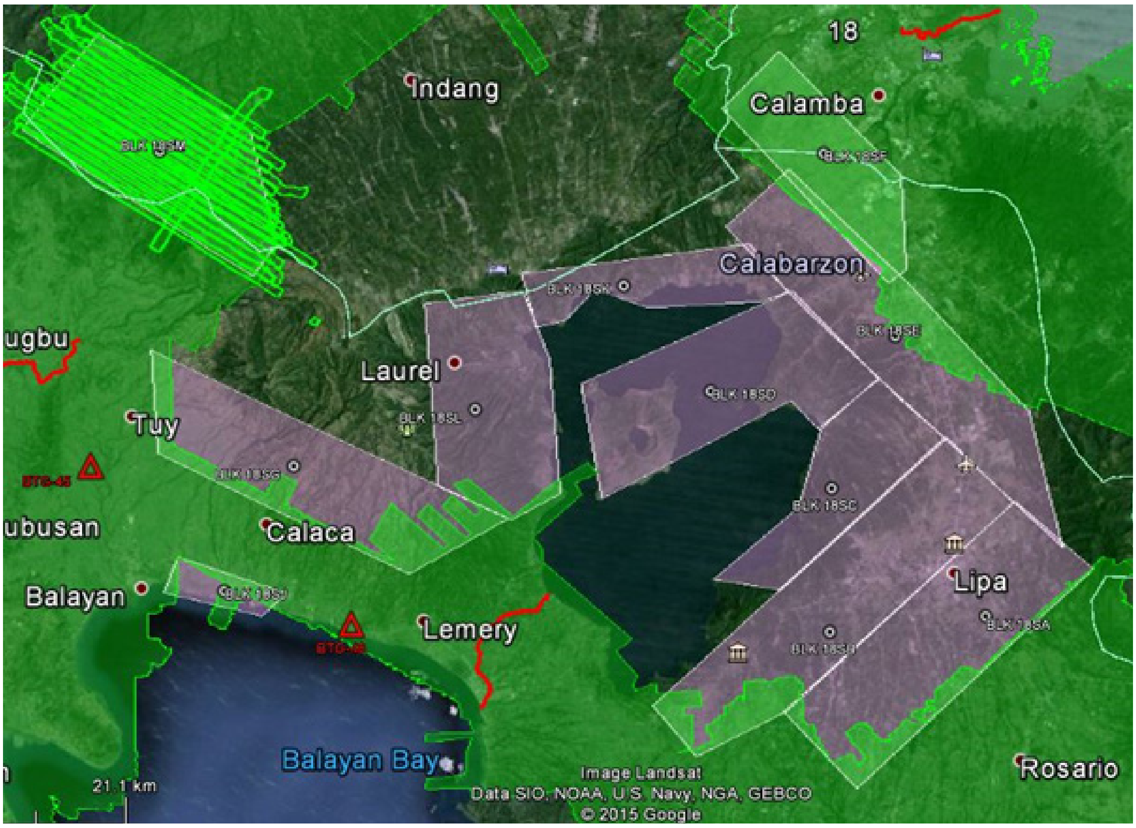


Figure A-7.6. Swath for Flight No. 3681G

FLIGHT LOG NO. 3687G
AREA: BLOCK 18SG, SM
MISSION NAME: 2BLK18SGS008B

Scan Freq: 40 Hz
Scan Angle: 25 deg
PRF: 100

SURVEY COVERAGE:

LAS/SWATH

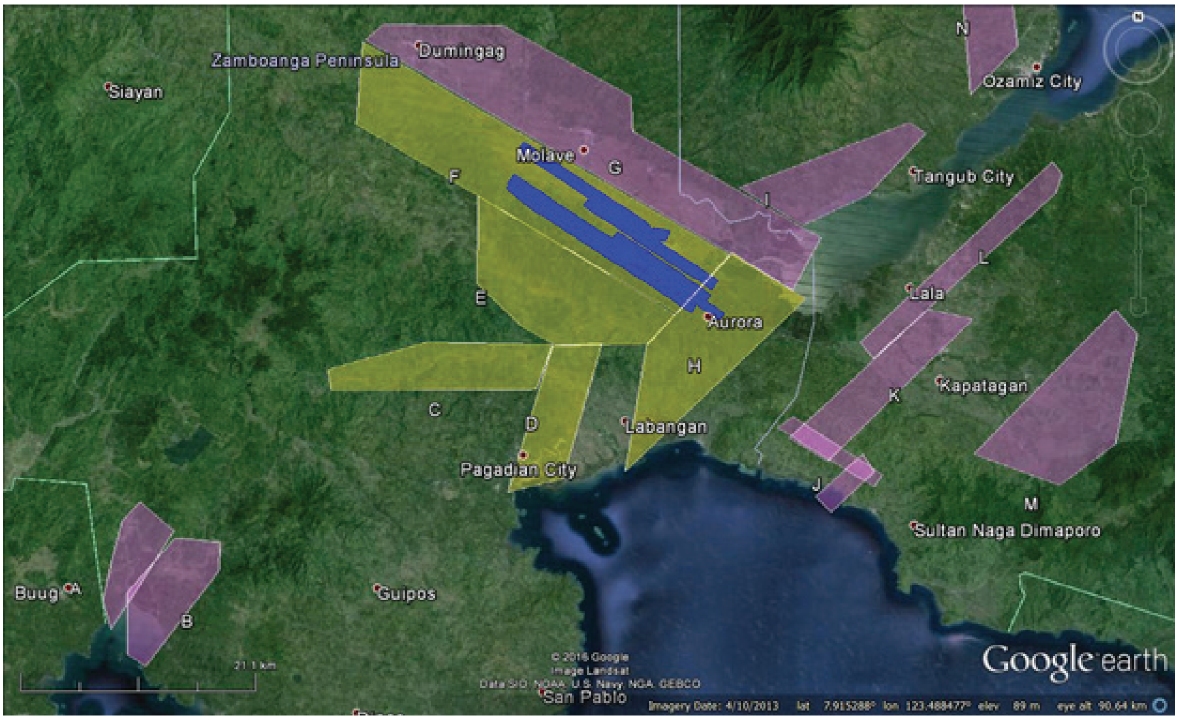


Figure A-7.7. Swath for Flight No. 3687G

FLIGHT LOG NO. 10144L
AREA: BLOCK 18AB
MISSION NAME: 4BLK18ABS128A

Scan Freq: 40 Hz
Scan Angle: 45 deg
Alt: 900 m

SURVEY COVERAGE:

LAS/SWATH

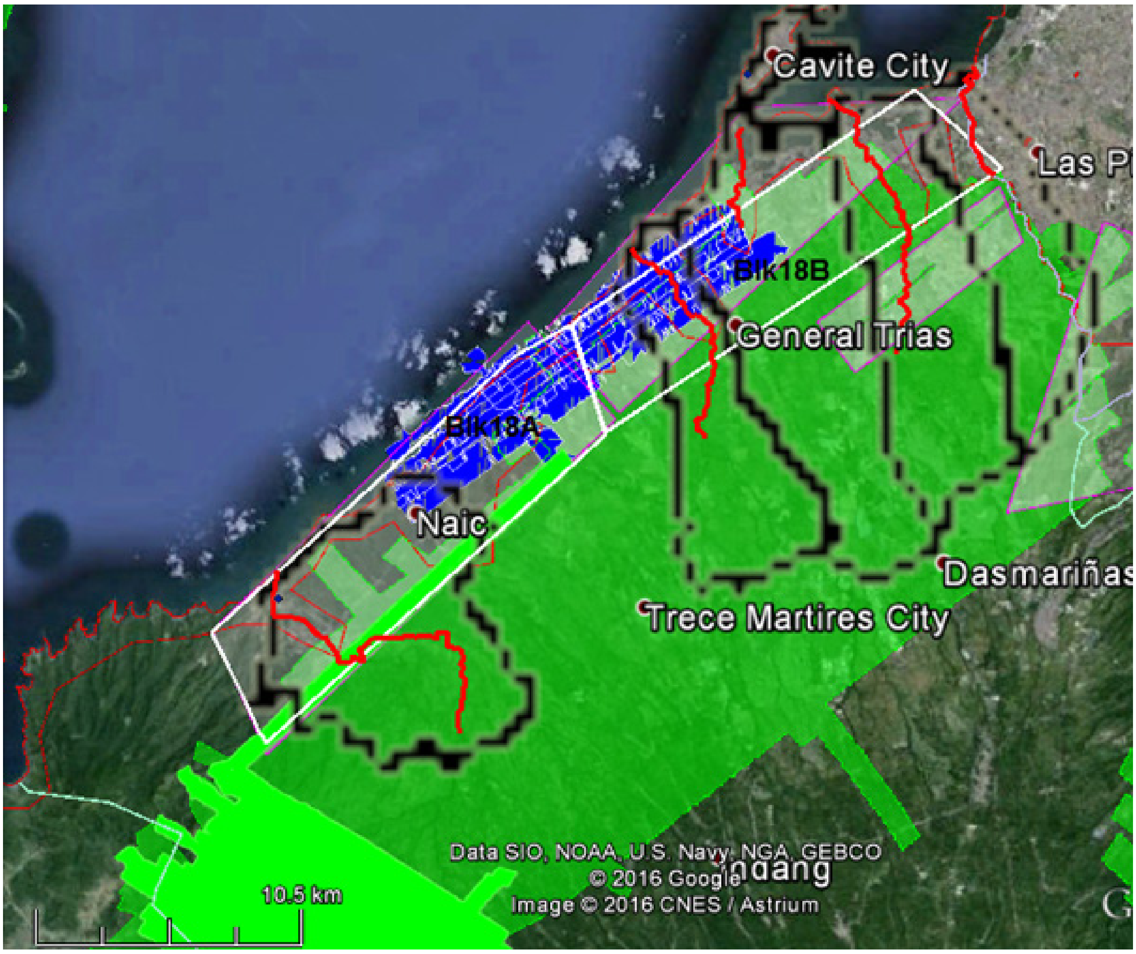


Figure A-7.8. Swath for Flight No. 10144L

Annex 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Blk18B_supplement

Flight Area	CALABARZON
Mission Name	Blk18B_supplement
Inclusive Flights	3309P
Range data size	11.9GB
POS	202 MB
Image	N/A
Transfer date	09/11/2015
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)	2.3
RMSE for East Position (<4.0 cm)	2.9
RMSE for Down Position (<8.0 cm)	2.9
Boresight correction stdev (<0.001deg)	0.000273
IMU attitude correction stdev (<0.001deg)	0.000737
GPS position stdev (<0.01m)	0.0103
Minimum % overlap (>25)	43.55%
Ave point cloud density per sq.m. (>2.0)	2.82
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	171
Maximum Height	426.11 m
Minimum Height	57.0 m
Classification (# of points)	
Ground	95,328,099
Low vegetation	65,505,303
Medium vegetation	120,204,321
High vegetation	132,825,937
Building	23,238,819
Orthophoto	No
Processed by	Engr. Analyn Naldo, Aljon Rei Araneta, Jovy Ann Narisma

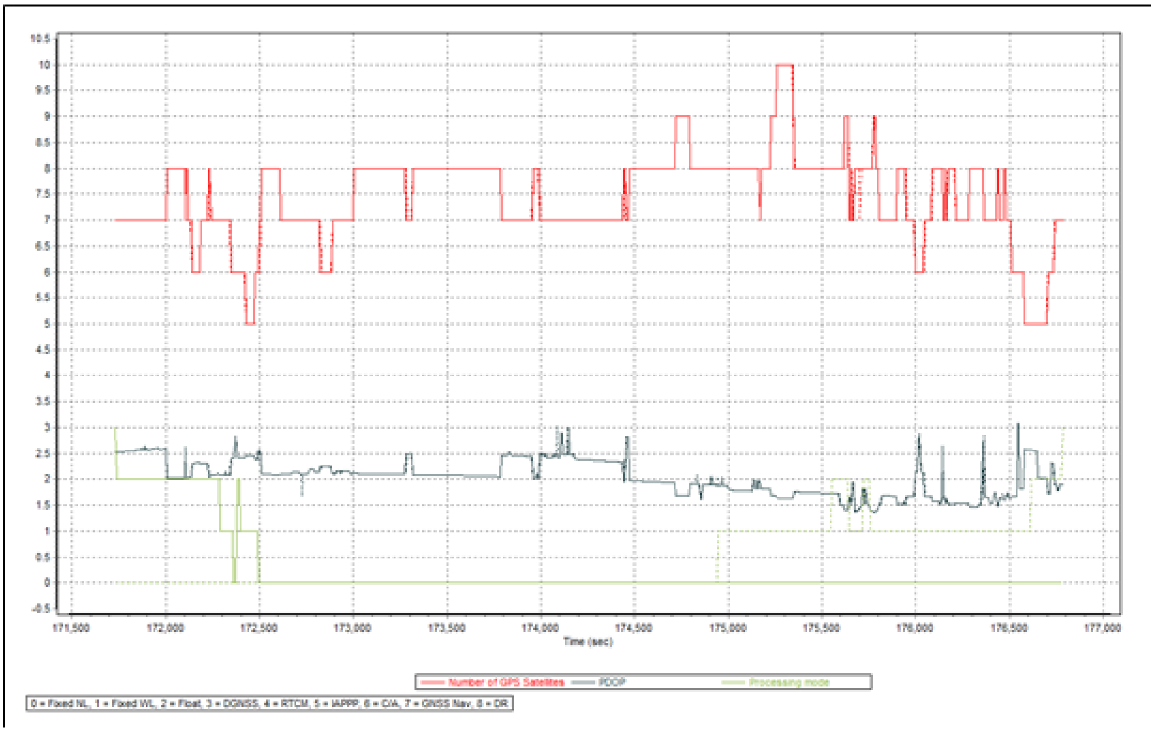


Figure A-8.1. Solution Status

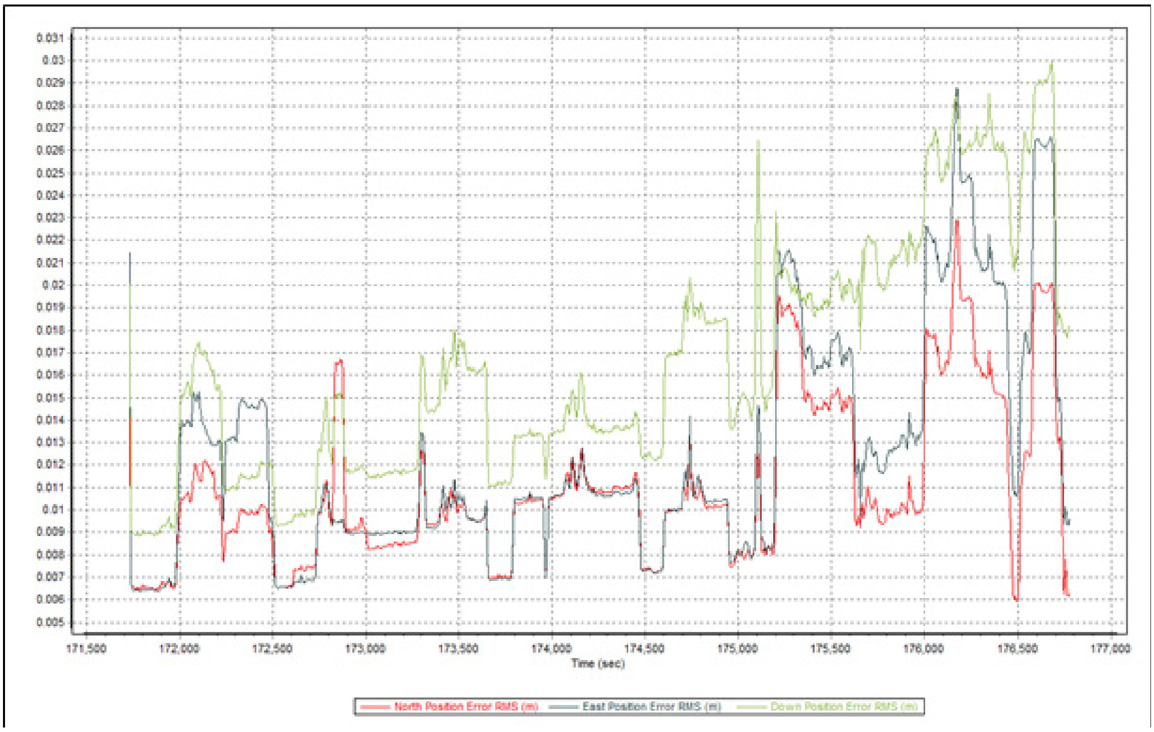


Figure A-8.2. Smoothed Performance Metrics Parameters

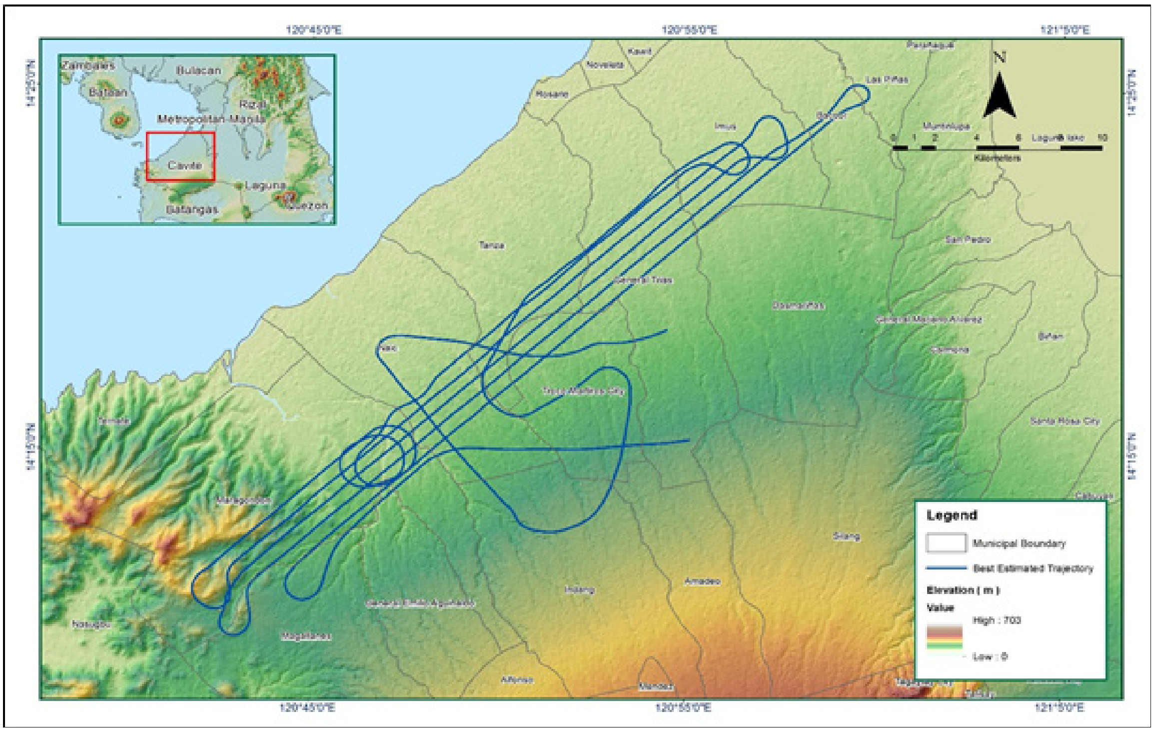


Figure A-8.3. Best Estimated Trajectory

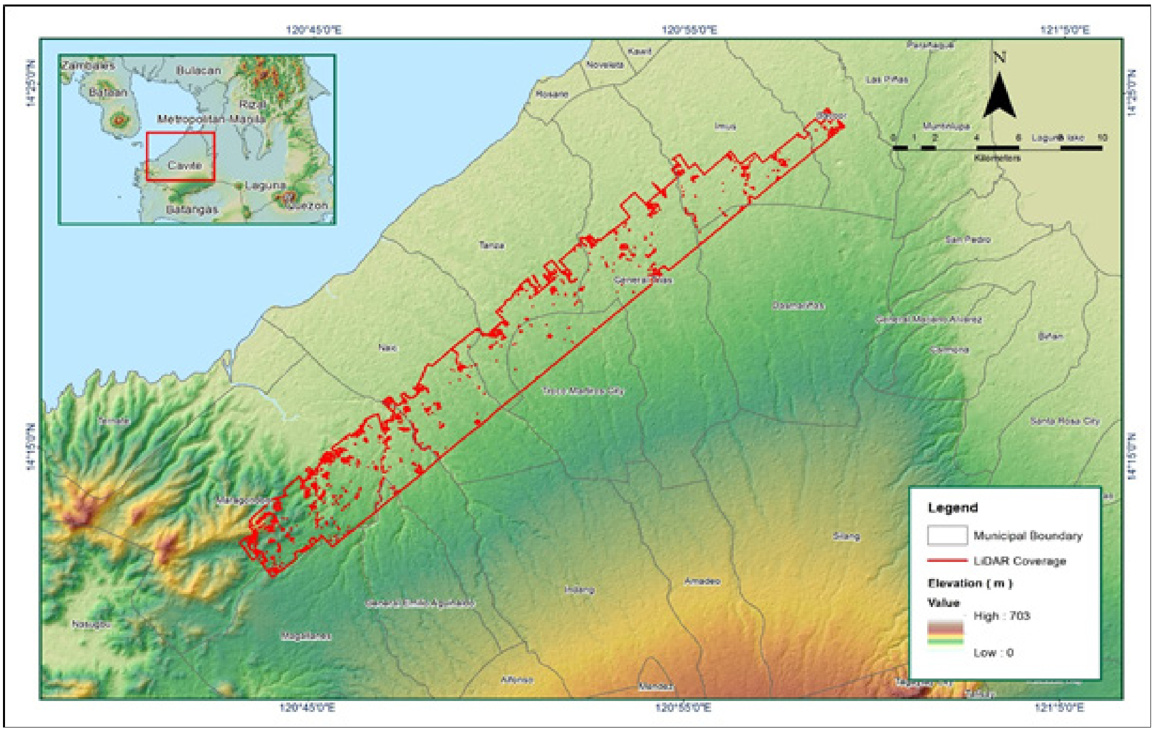


Figure A-8.4. Coverage of LiDAR data

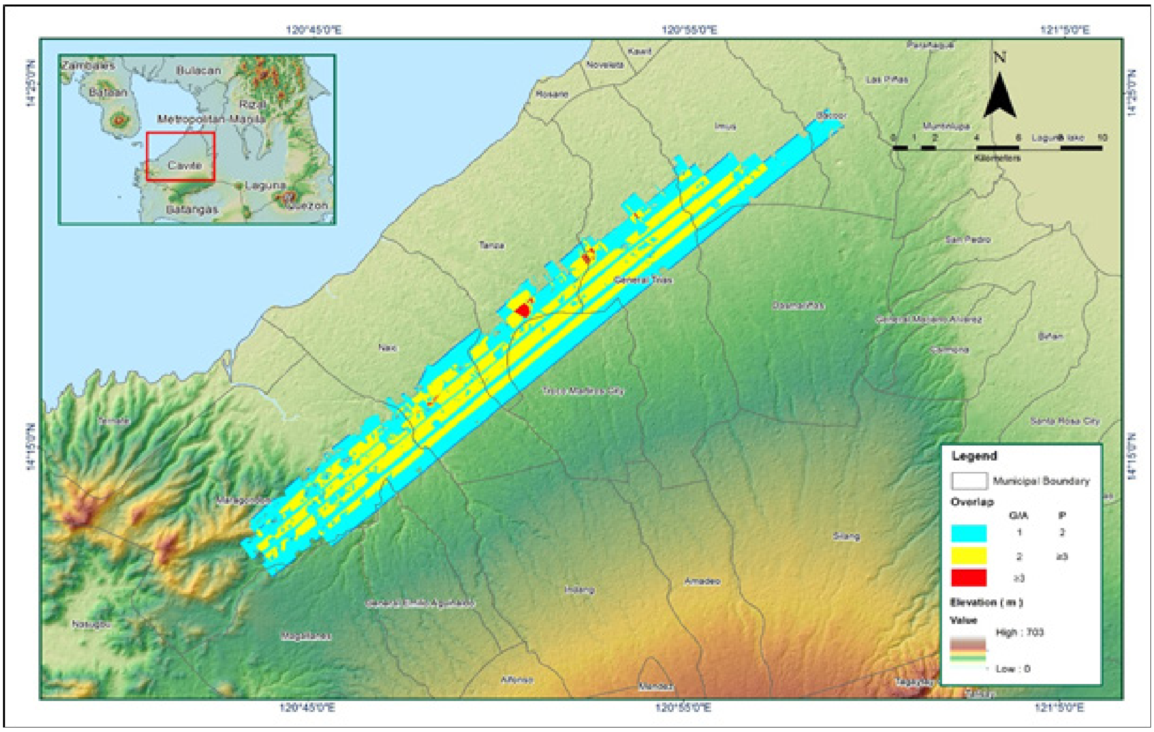


Figure A-8.5. Image of data overlap

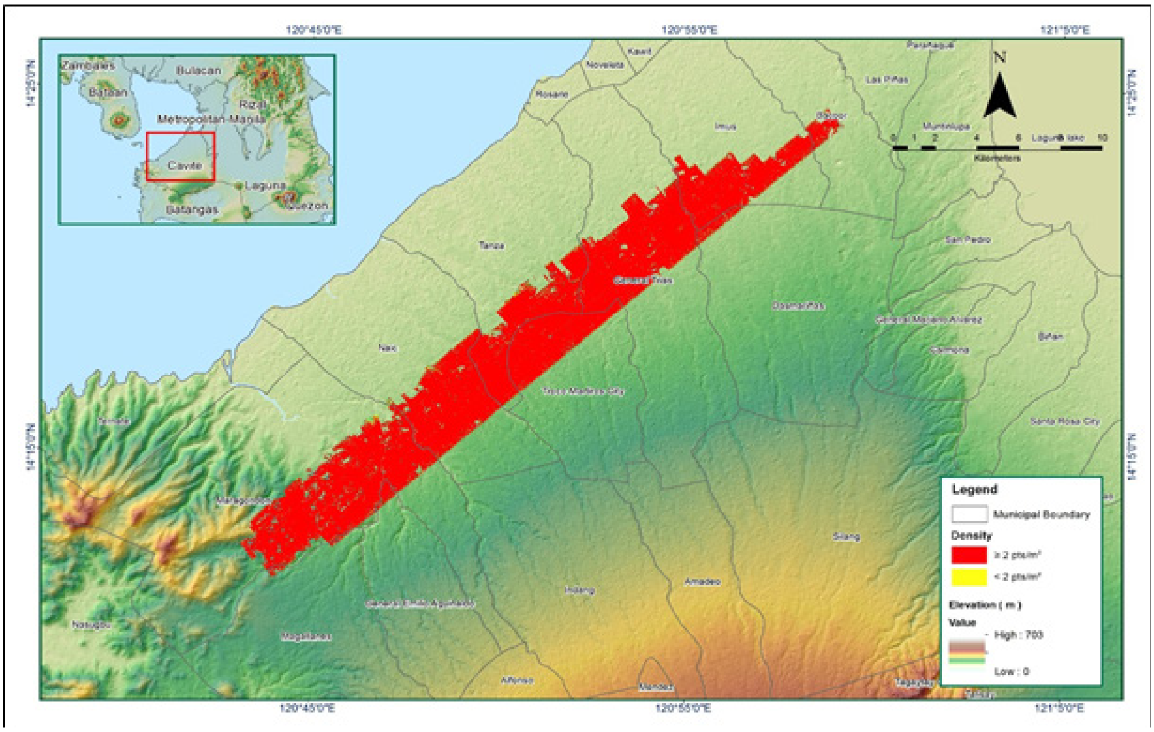


Figure A-8.6. Density map of merged LiDAR data

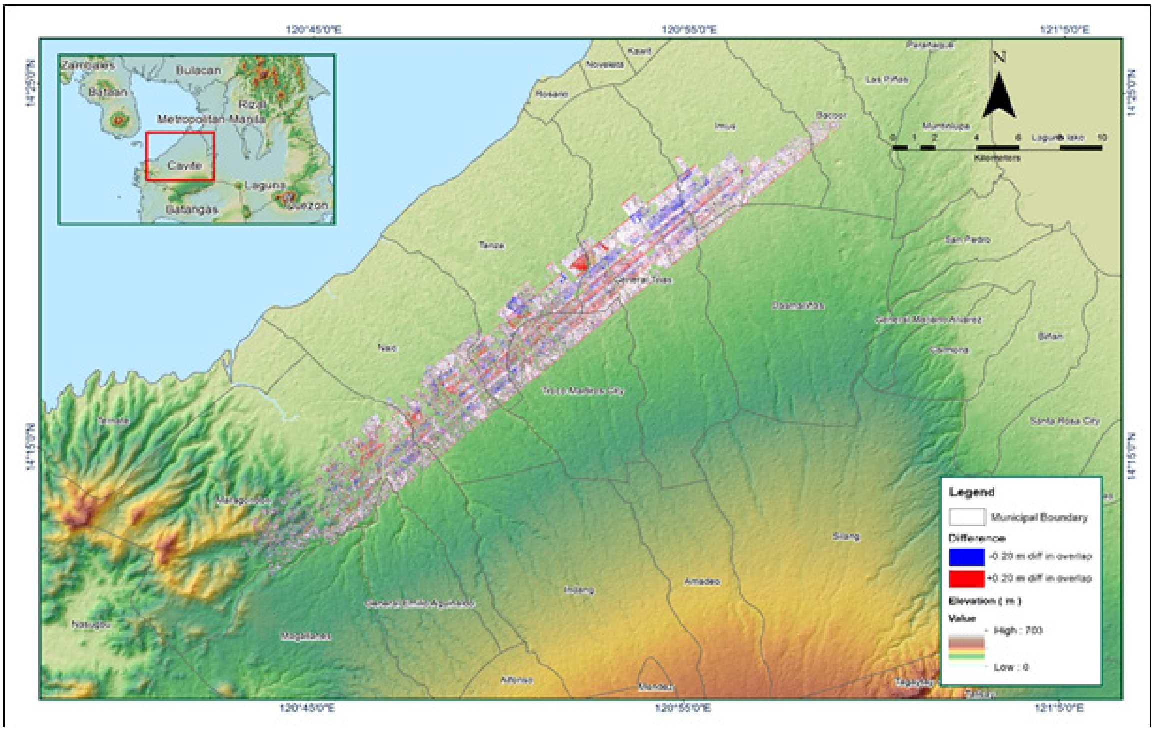


Figure A-8.7. Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Blk18A

Flight Area	CALABARZON Reflights
Mission Name	Blk18A
Inclusive Flights	10136L, 10142L
RawLaser	19.79 GB
GnssImu	969 MB
Image	76.8 GB
Transfer date	6/20/2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Combined Separation (-0.1 up to 0.1)	Yes
Estimated Position Accuracy (in cm)	
Estimated Standard Deviation for North Position (<4.0 cm)	0.65
Estimated Standard Deviation for East Position (<4.0 cm)	0.80
Estimated Standard Deviation for Height Position (<8.0 cm)	1.80
Minimum % overlap (>25)	47.33%
Ave point cloud density per sq.m. (>2.0)	3.22
Elevation difference between strips (<0.20 m)	
Number of 1km x 1km blocks	215
Maximum Height	354.74 m
Minimum Height	44.59 m
Classification (# of points)	
Ground	258,626,866
Low vegetation	250,593,109
Medium vegetation	204,765,100
High vegetation	216,443,750
Building	62,593,079
Orthophoto	Yes
Processed by	Engr. Regis Guhiting, Engr. Melanie Hingpit, Kathryn Claudyn Zarate
Orthophoto	No
Processed by	Engr. Analyn Naldo, Aljon Rei Araneta, Jovy Ann Narisma

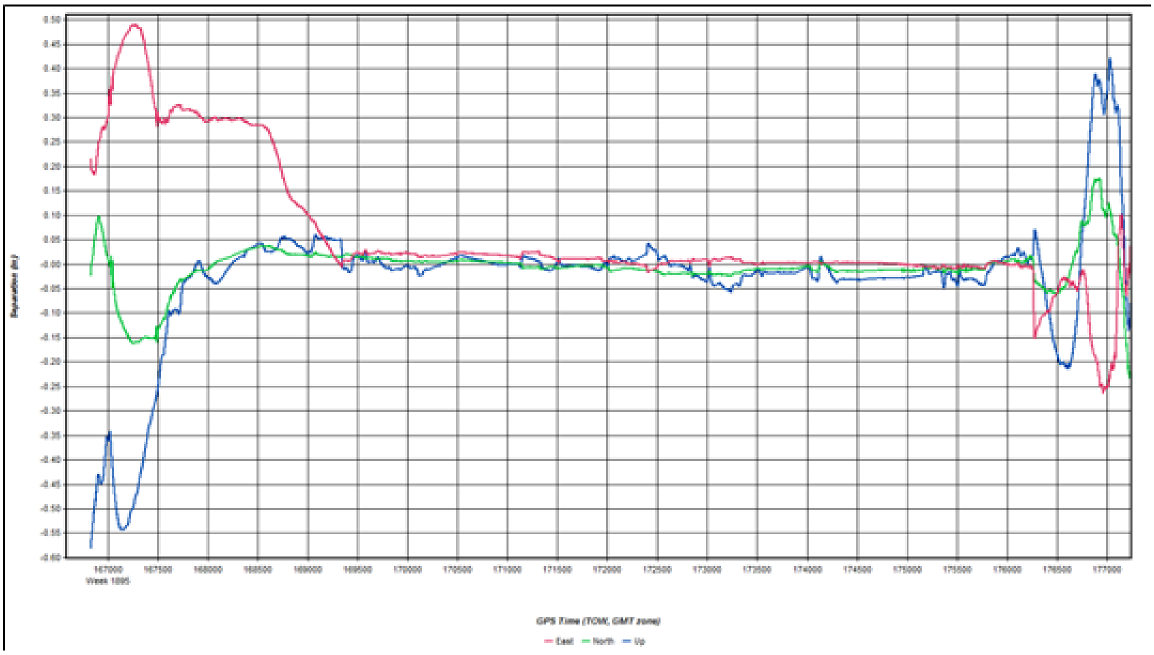


Figure A-8.8. Combined Separation

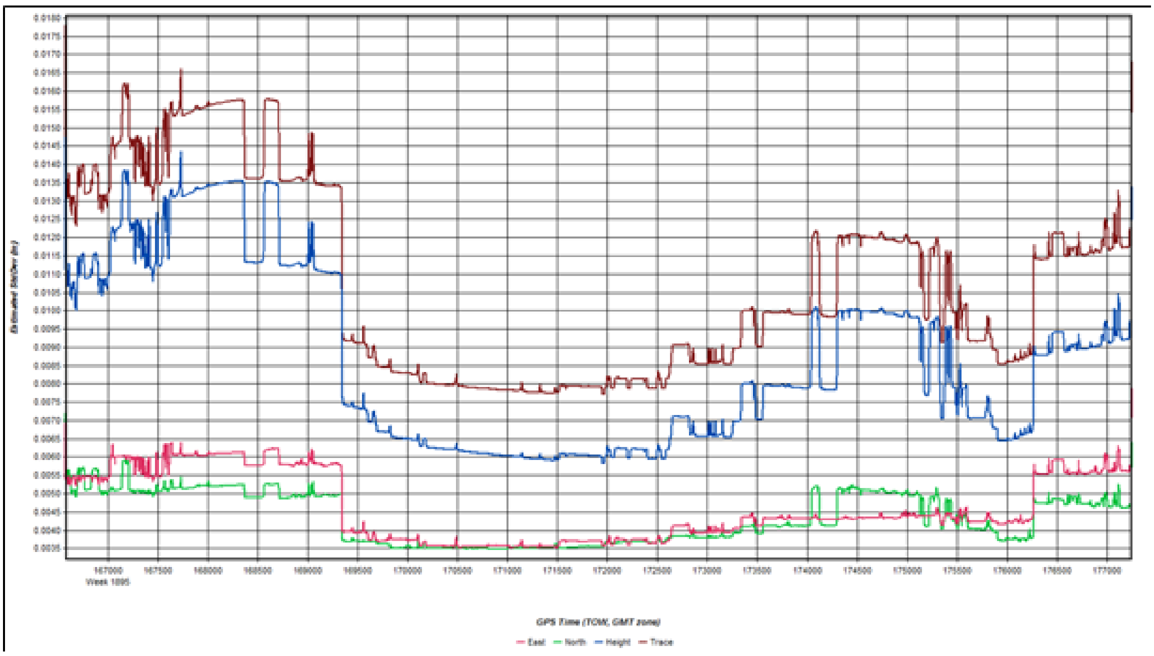


Figure A-8.9. Estimated Position of Accuracy

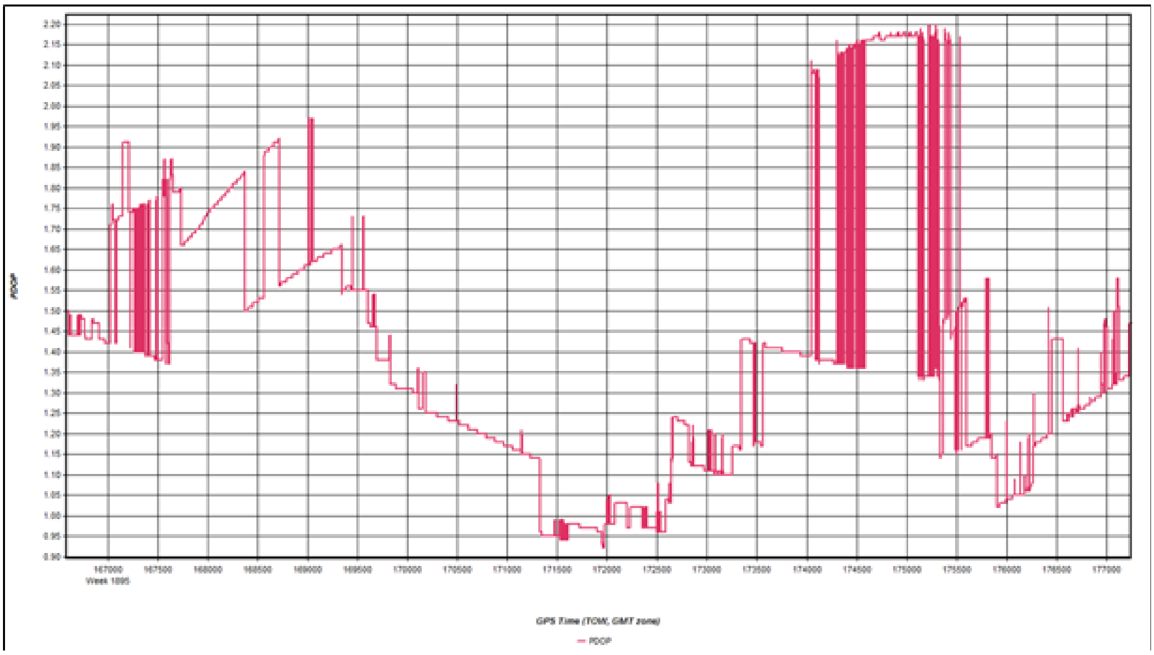


Figure A-8.10. PDOP

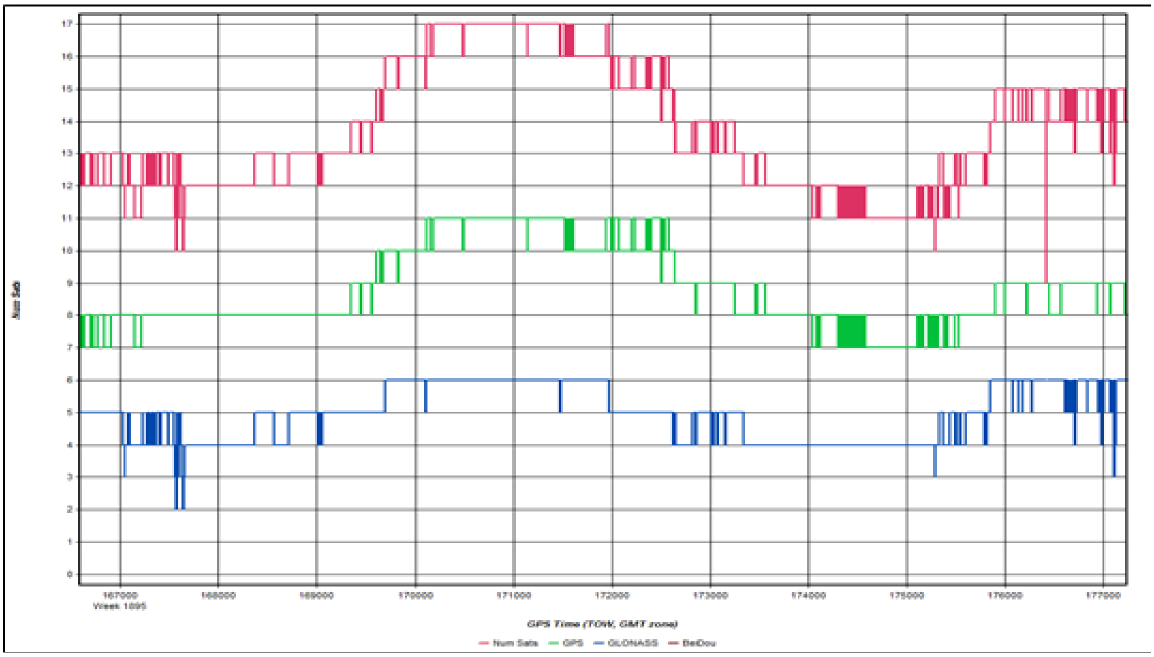


Figure A-8.11. Number of Satellites

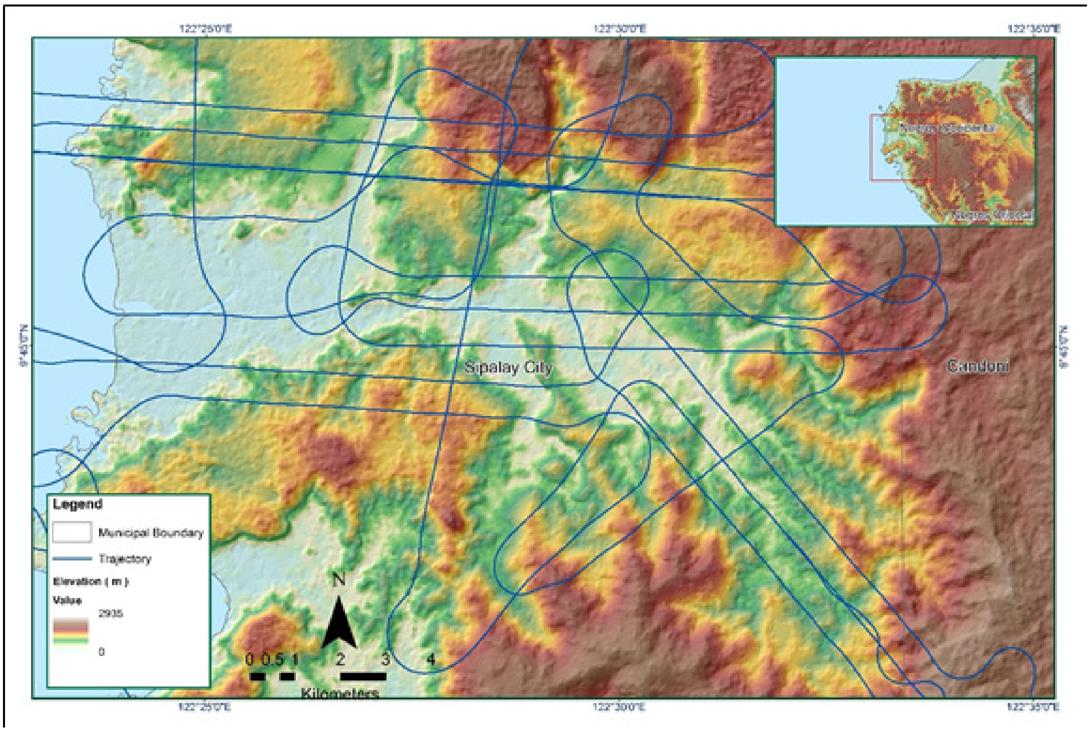


Figure A-8.12. Best Estimated Trajectory

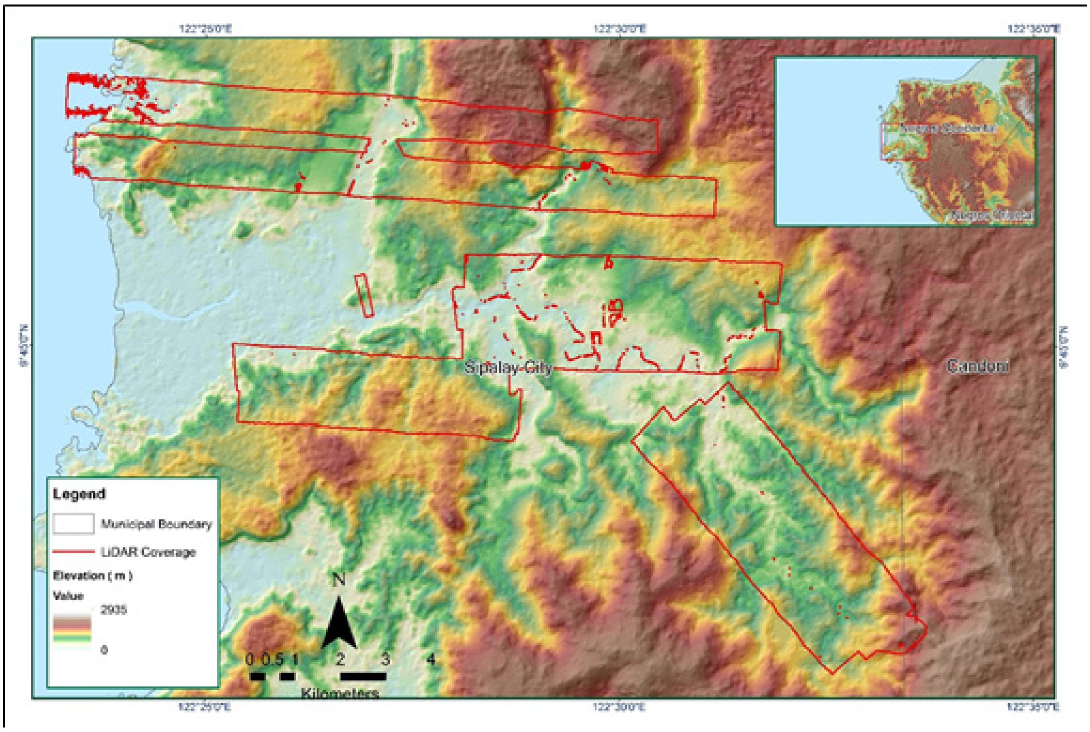


Figure A-8.13. Coverage of LiDAR data

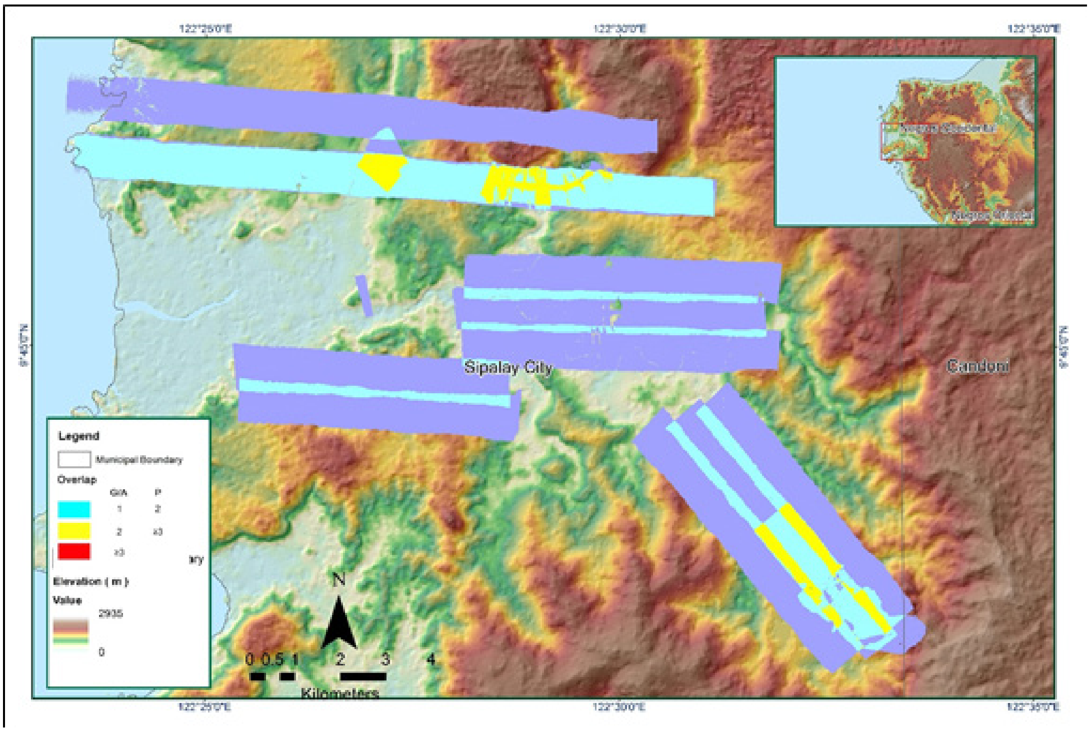


Figure A-8.14. Image of data overlap

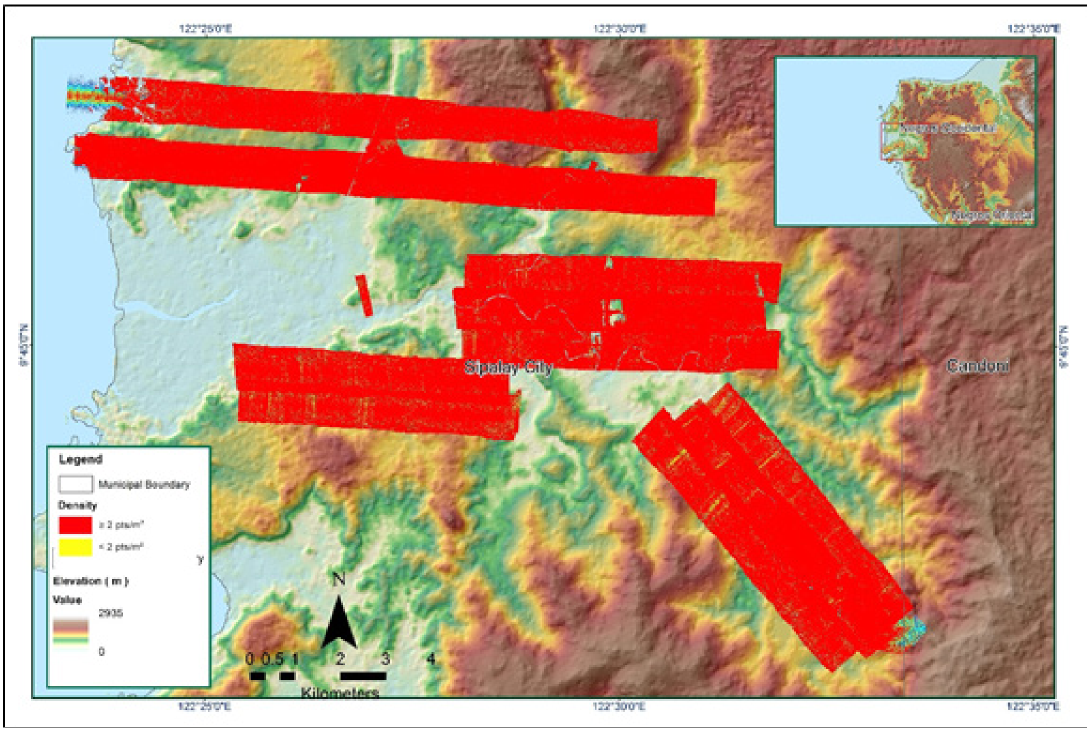


Figure A-8.15, Density map of merged LiDAR data

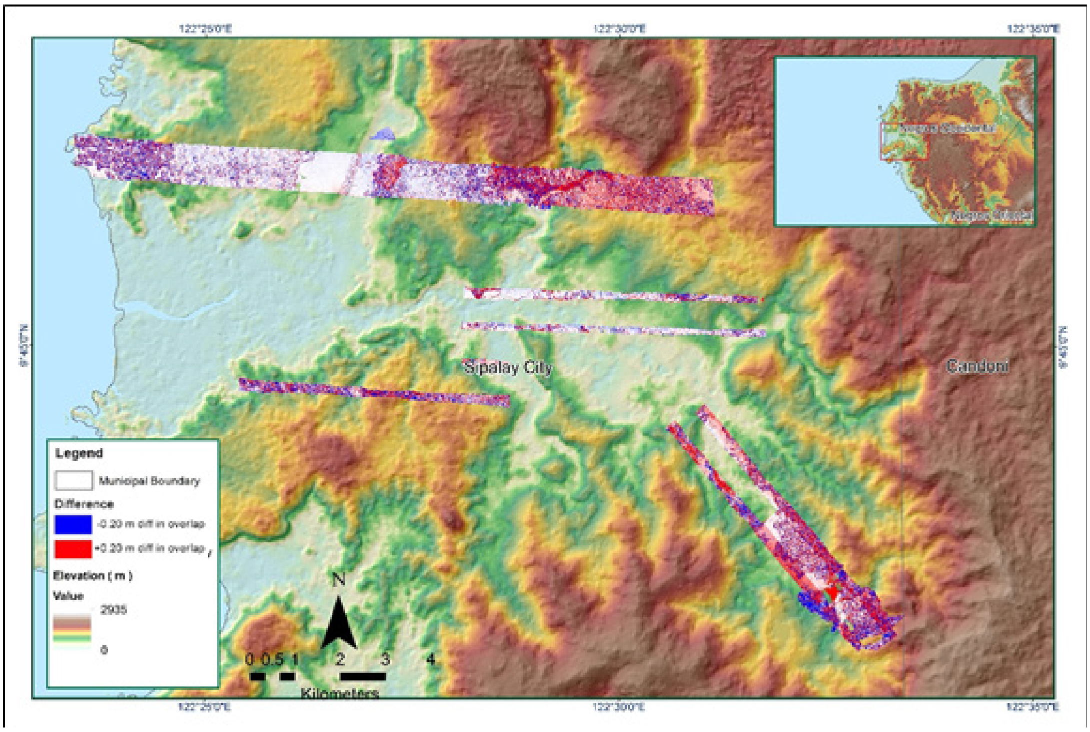


Figure A-8.16. Elevation difference between flight lines

Table A-8.3. Mission Summary Report for Mission Blk18A_supplement

Flight Area	CALABARZON Reflights
Mission Name	Blk18A_supplement
Inclusive Flights	10144L
RawLaser	3.59
GnssImu	408 MB
Image	12.9 GB
Transfer date	6/20/2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Combined Separation (-0.1 up to 0.1)	Yes
Estimated Position Accuracy (in cm)	
Estimated Standard Deviation for North Position (<4.0 cm)	0.55
Estimated Standard Deviation for East Position (<4.0 cm)	0.45
Estimated Standard Deviation for Height Position (<8.0 cm)	1.00
Minimum % overlap (>25)	43.07
Ave point cloud density per sq.m. (>2.0)	4.60
Elevation difference between strips (<0.20 m)	
Number of 1km x 1km blocks	92
Maximum Height	106.83 m
Minimum Height	41.14 m
Classification (# of points)	
Ground	65,752,105
Low vegetation	34,201,252
Medium vegetation	22,488,691
High vegetation	24,727,914
Building	20,212,718
Orthophoto	Yes
Processed by	Engr. Regis Guhiting, Engr. Melanie Hingpit, Engr. Gladys Mae Apat

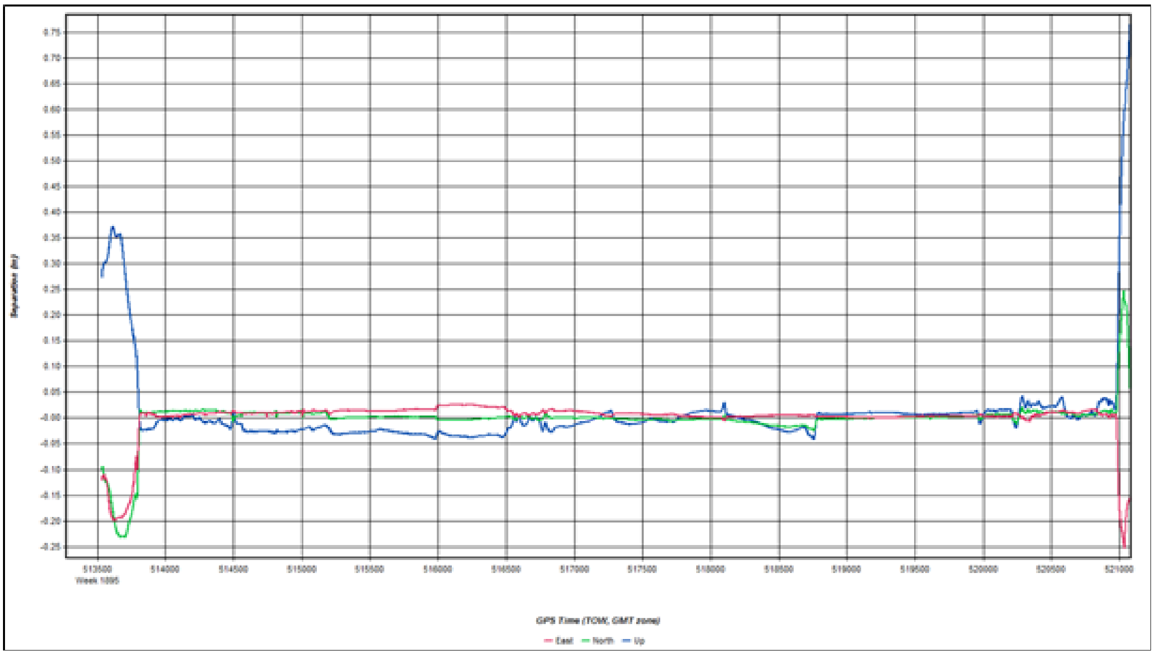


Figure A-8.17, Combined Separation

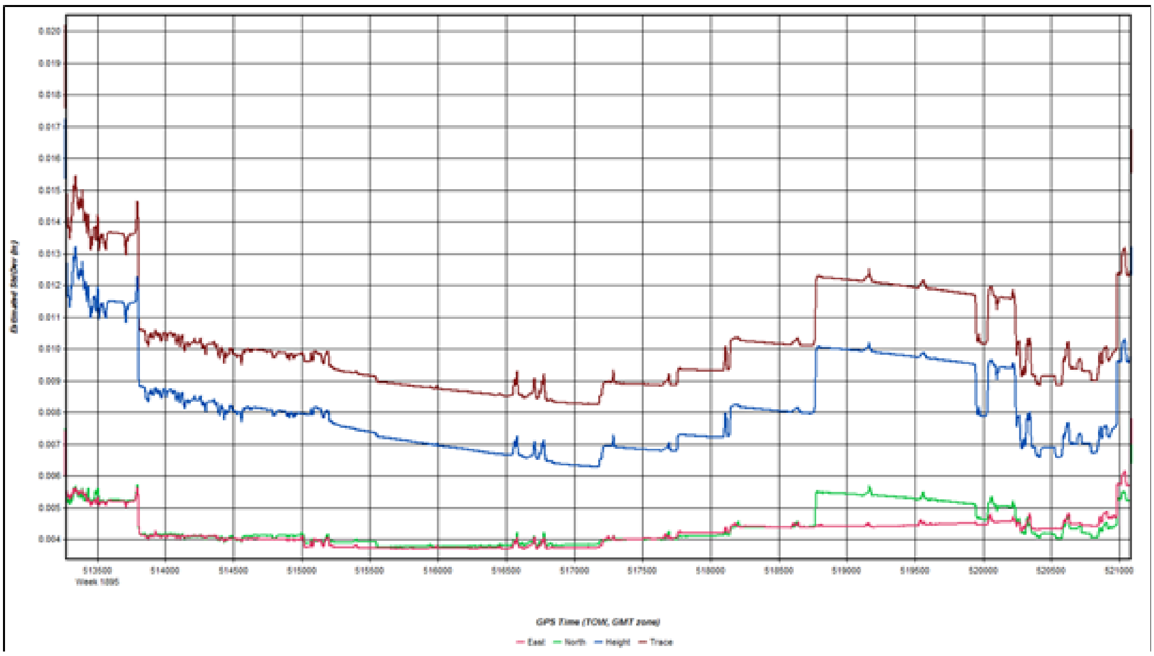


Figure A-8.18. Estimated Position of Accuracy

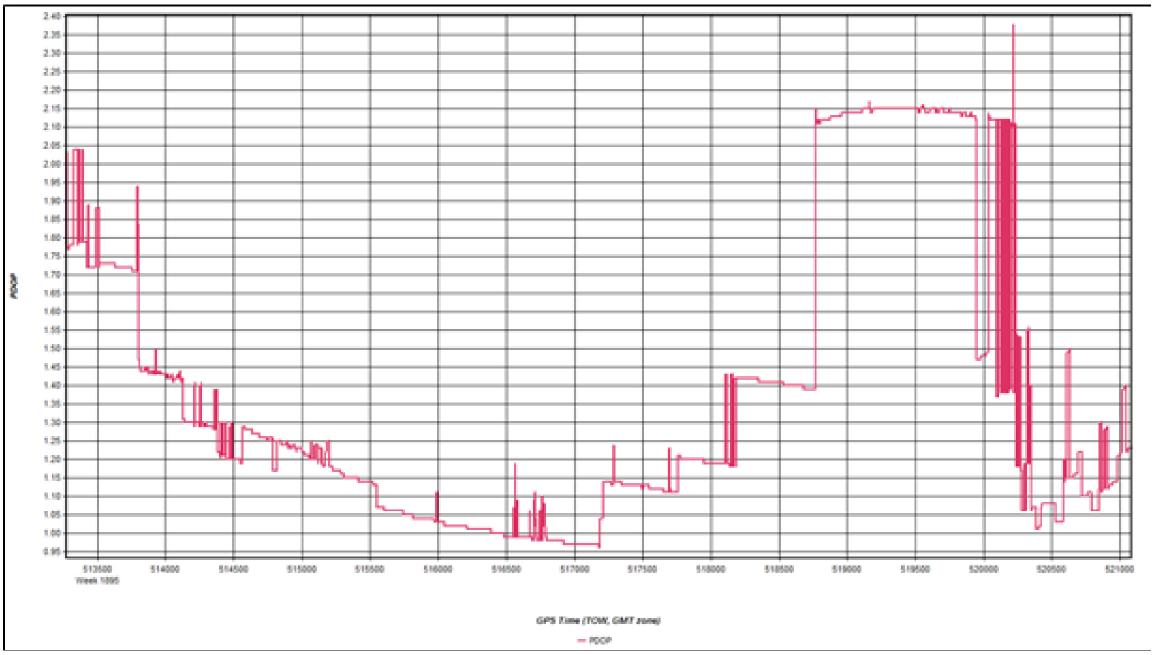


Figure A-8.19. PDOP

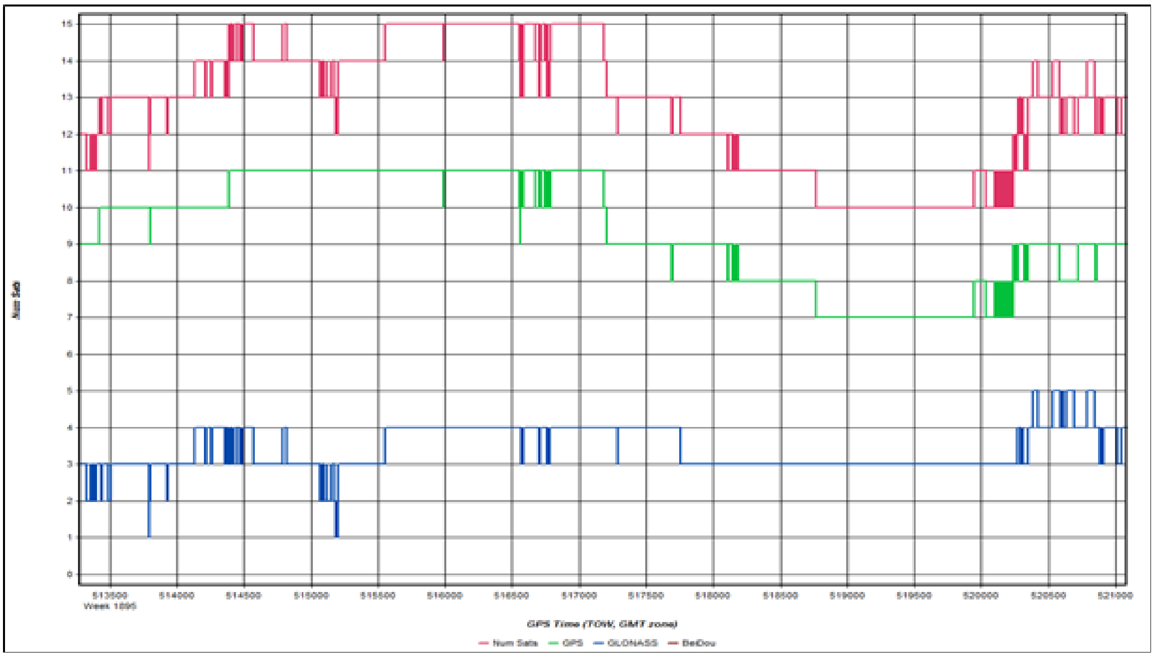


Figure A-8.20. Number of Satellites

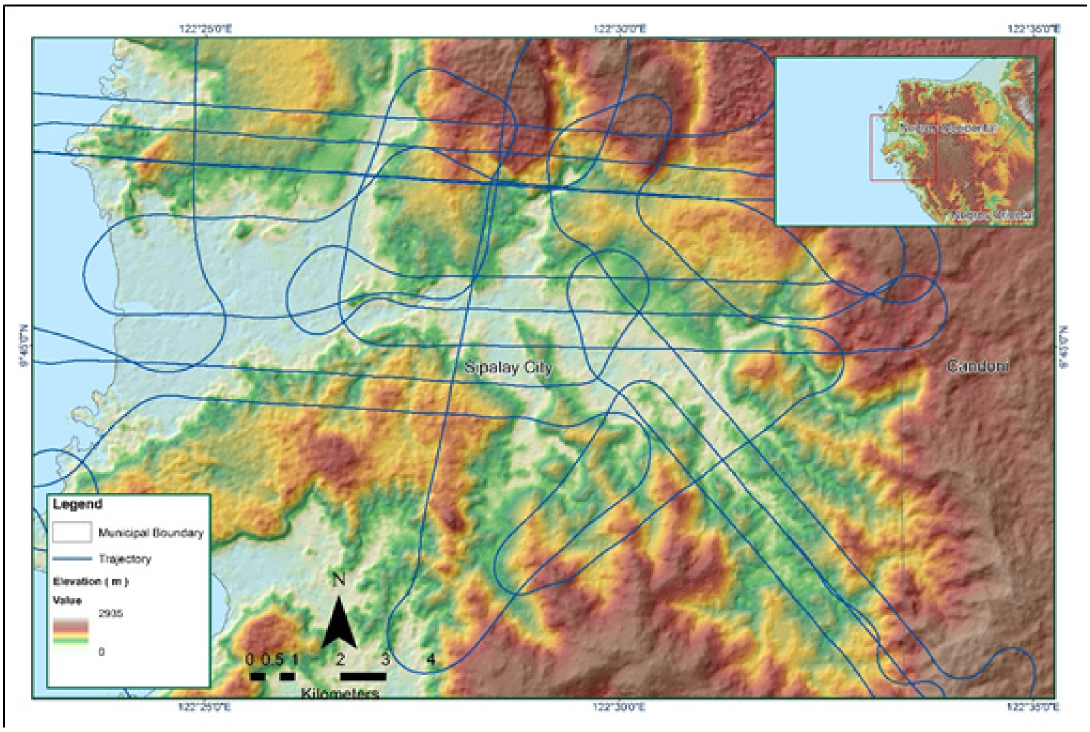


Figure A-8.21. Best Estimated Trajectory

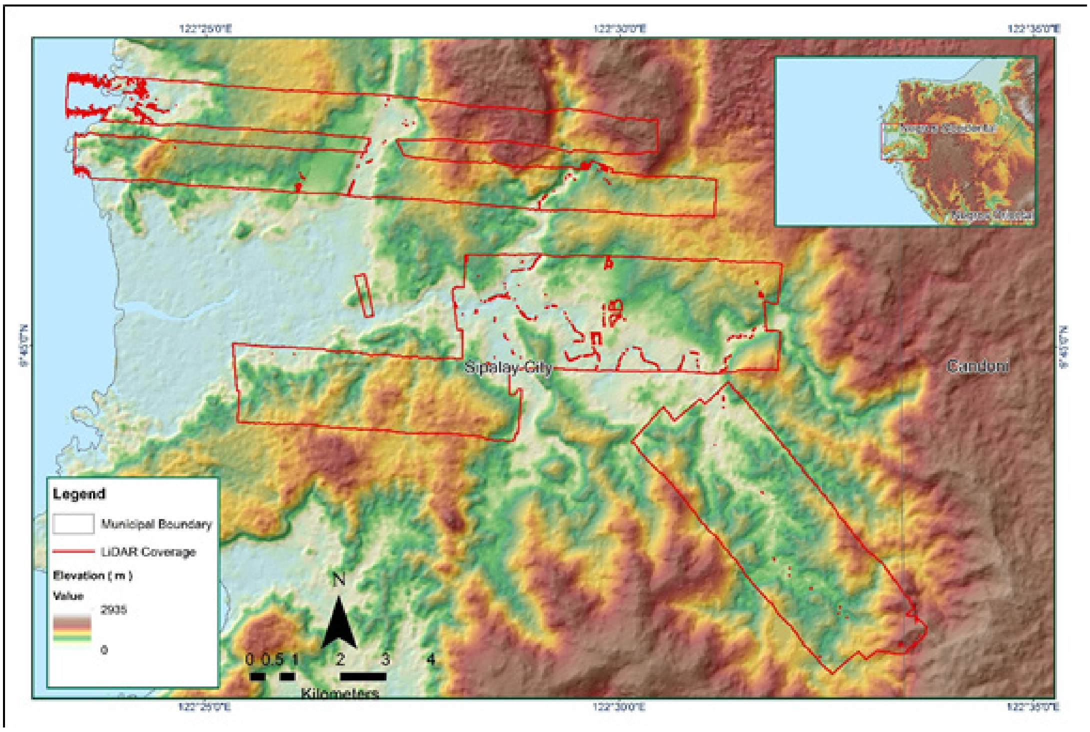


Figure A-8.22. Coverage of LiDAR data

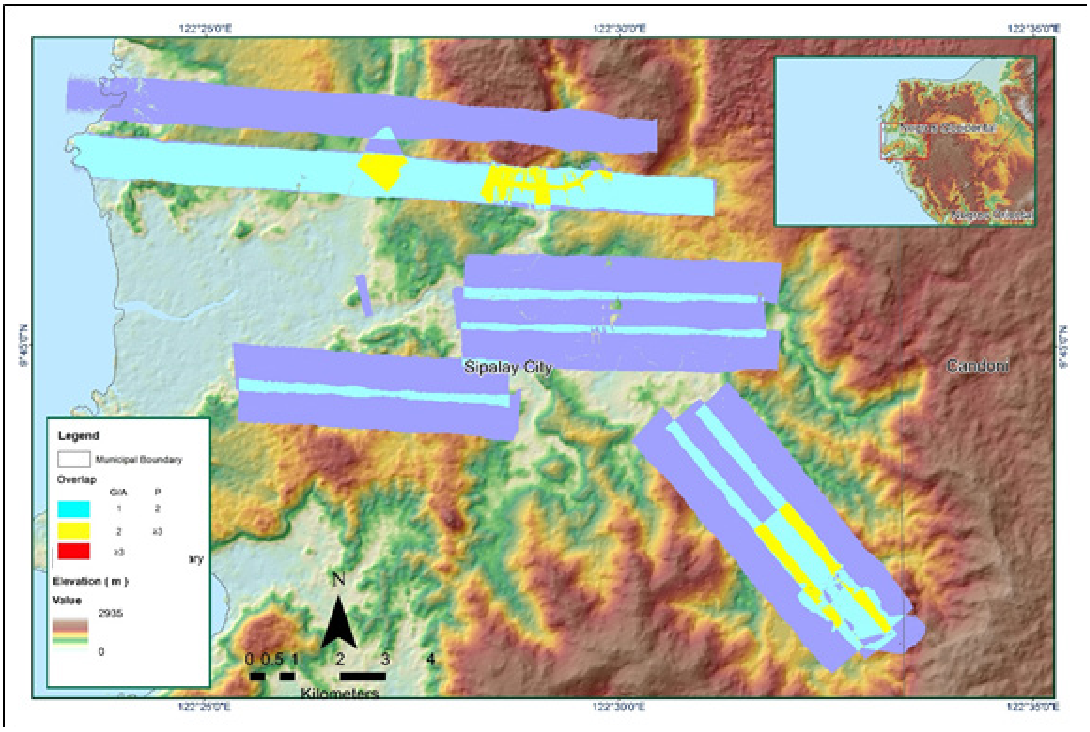


Figure A-8.23. Image of data overlap

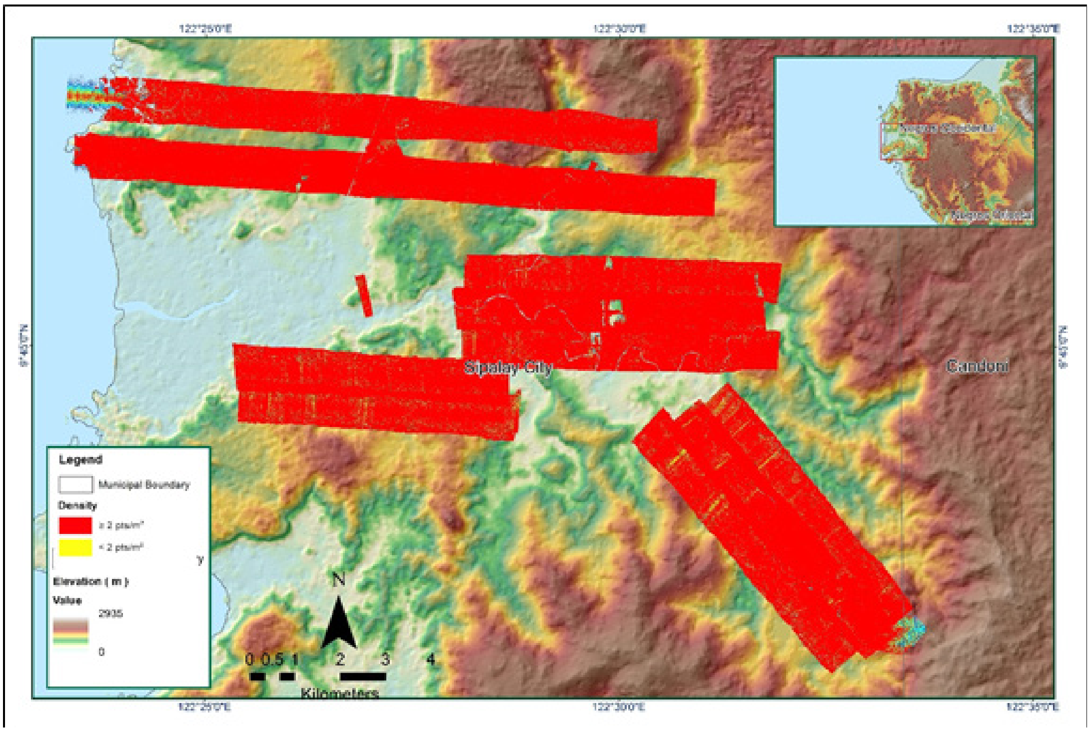


Figure A-8.24. Density map of merged LiDAR data

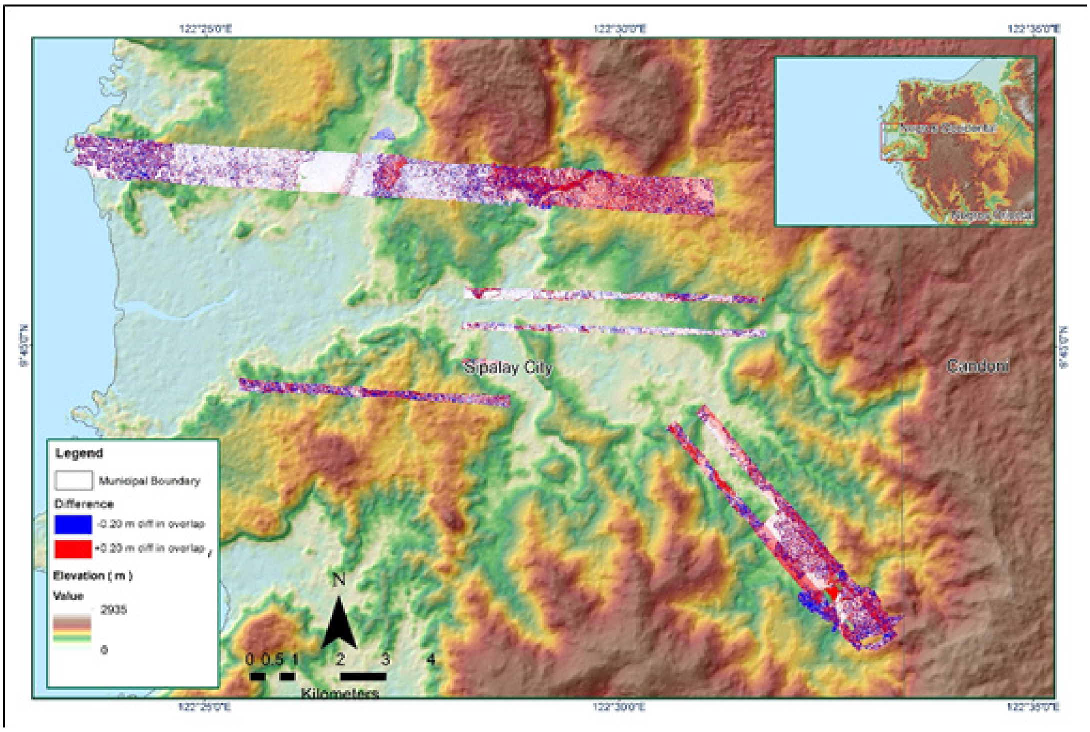


Figure A-8.25, Elevation difference between flight lines

Table A-8.4. Mission Summary Report for Mission Blk18AB

Flight Area	CALABARZON
Mission Name	Blk18AB
Inclusive Flights	1031P, 1027P
Range data size	29.0 GB
POS	379 MB
Image	7.11 GB
Transfer date	04/23/2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.8
RMSE for East Position (<4.0 cm)	2.0
RMSE for Down Position (<8.0 cm)	3.2
Boresight correction stdev (<0.001deg)	0.000453
IMU attitude correction stdev (<0.001deg)	0.005473
GPS position stdev (<0.01m)	0.0019
Minimum % overlap (>25)	28.57%
Ave point cloud density per sq.m. (>2.0)	3.24
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	204
Maximum Height	45.76 m
Minimum Height	603.46 m
Classification (# of points)	
Ground	175,046,421
Low vegetation	131,824,752
Medium vegetation	148,659,196
High vegetation	95,993,464
Building	30,587,801
Orthophoto	No
Processed by	Engr. Angel Carlo Bongat, Celina Rosete, Engr. Gladys Mae Apat

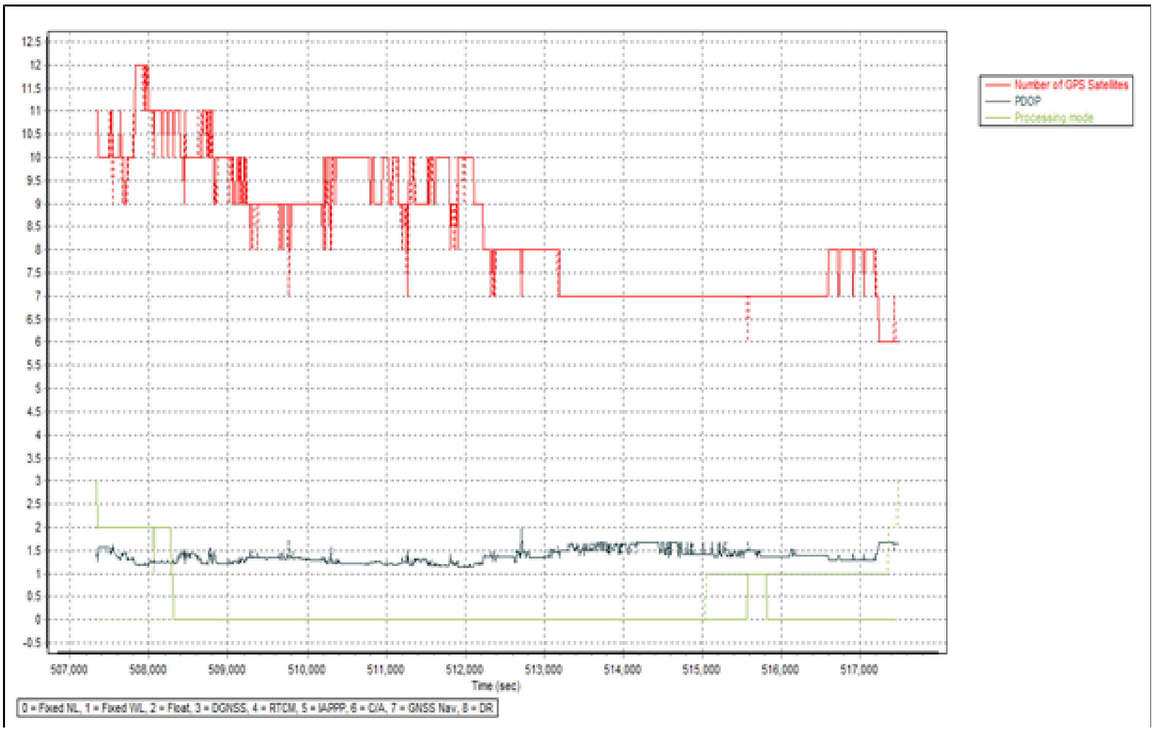


Figure A-8.26. Solution Status

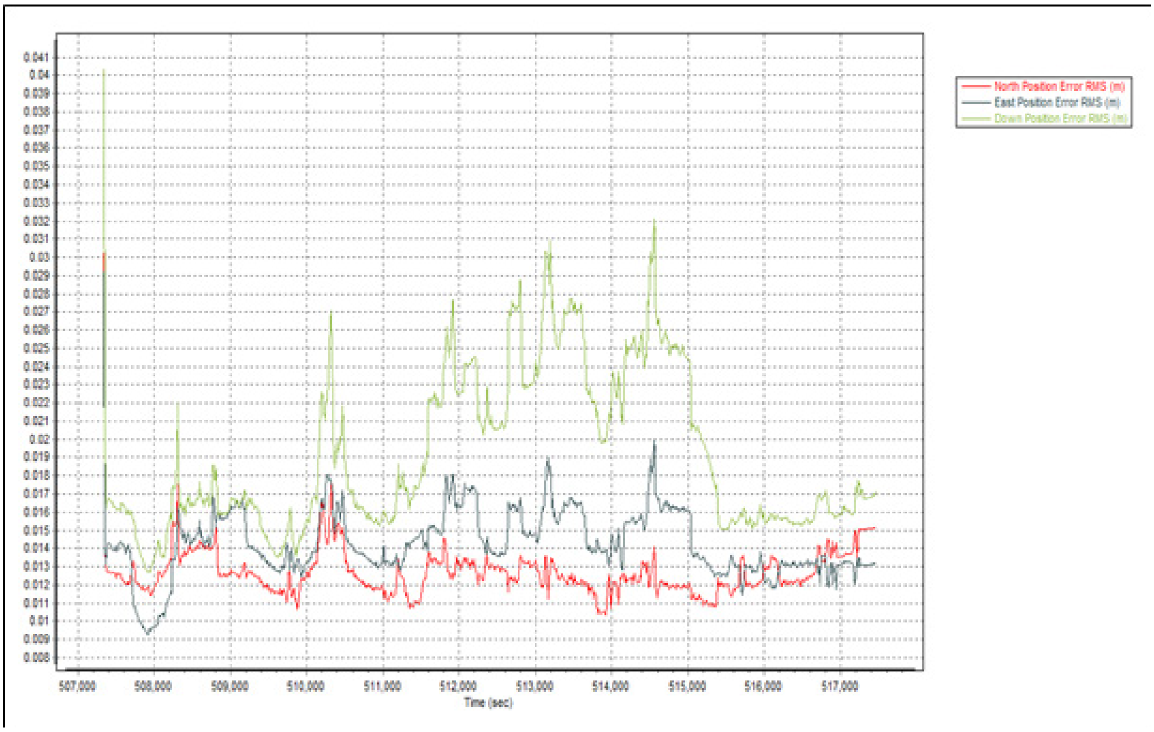


Figure A-8.27. Smoothed Performance Metrics Parameters

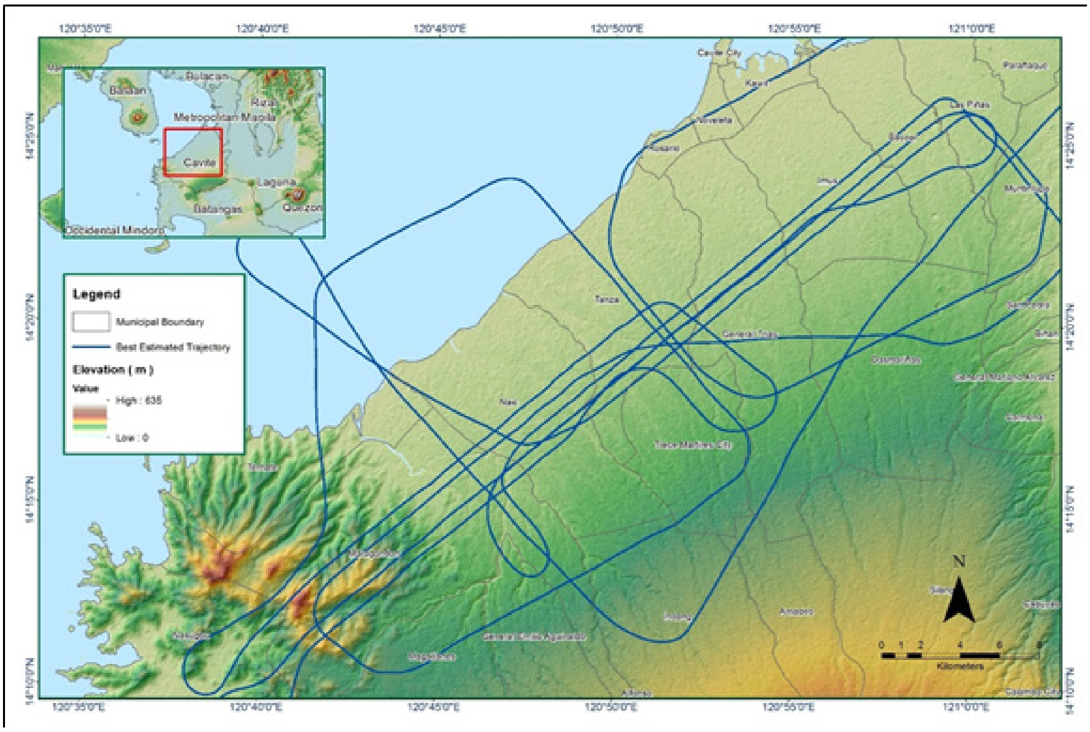


Figure A-8.28. Best Estimated Trajectory

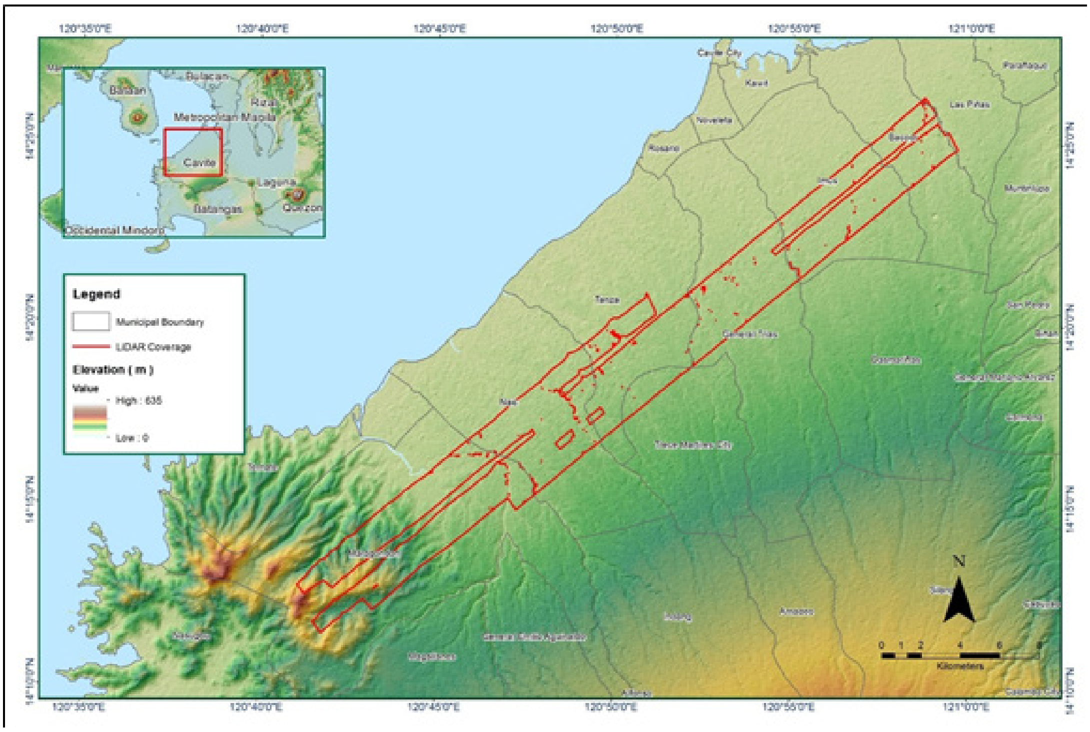


Figure A-8.29. Coverage of LiDAR data

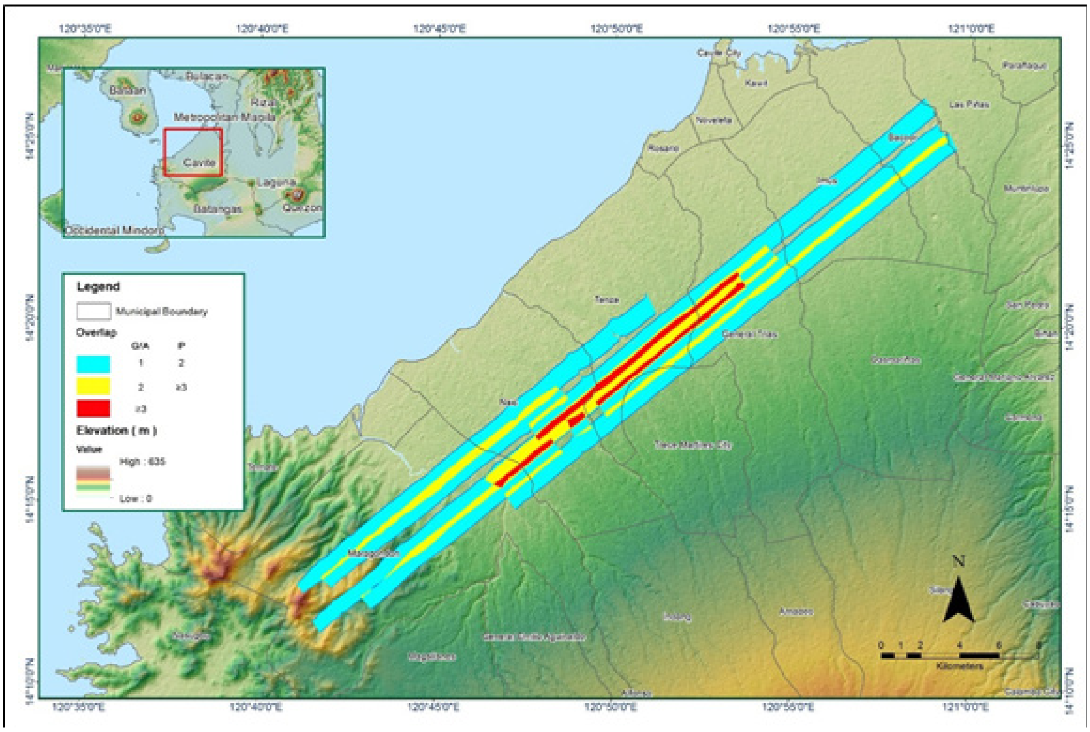


Figure A-8.30. Image of data overlap

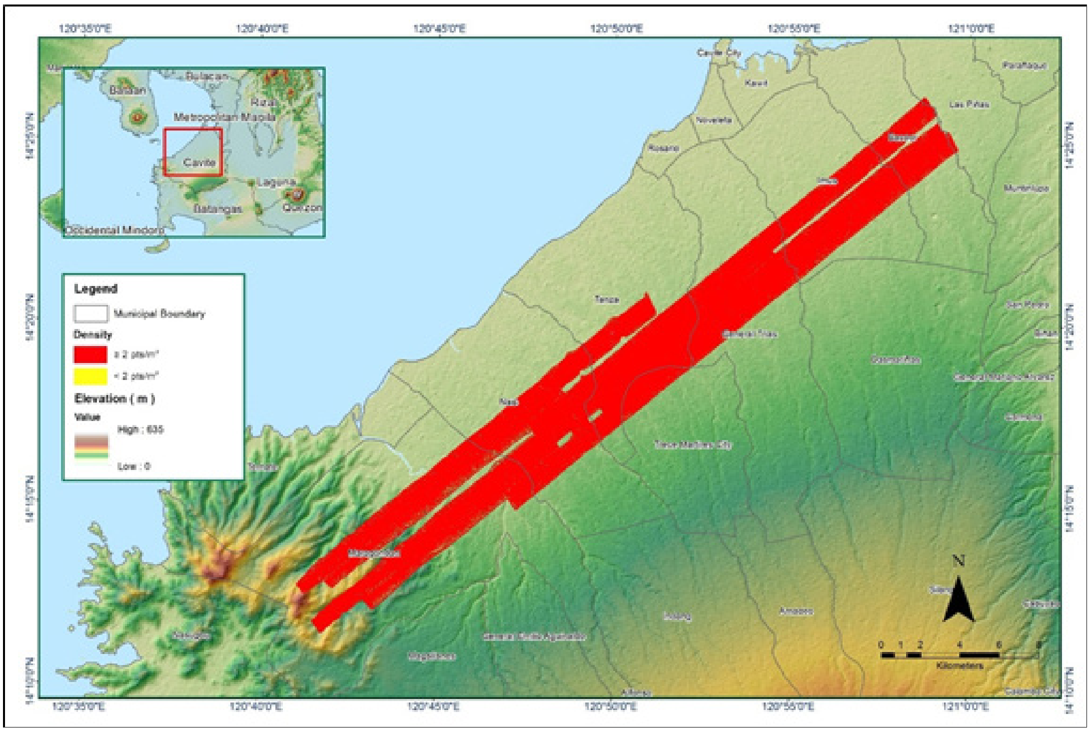


Figure A-8.31. Density map of merged LiDAR data

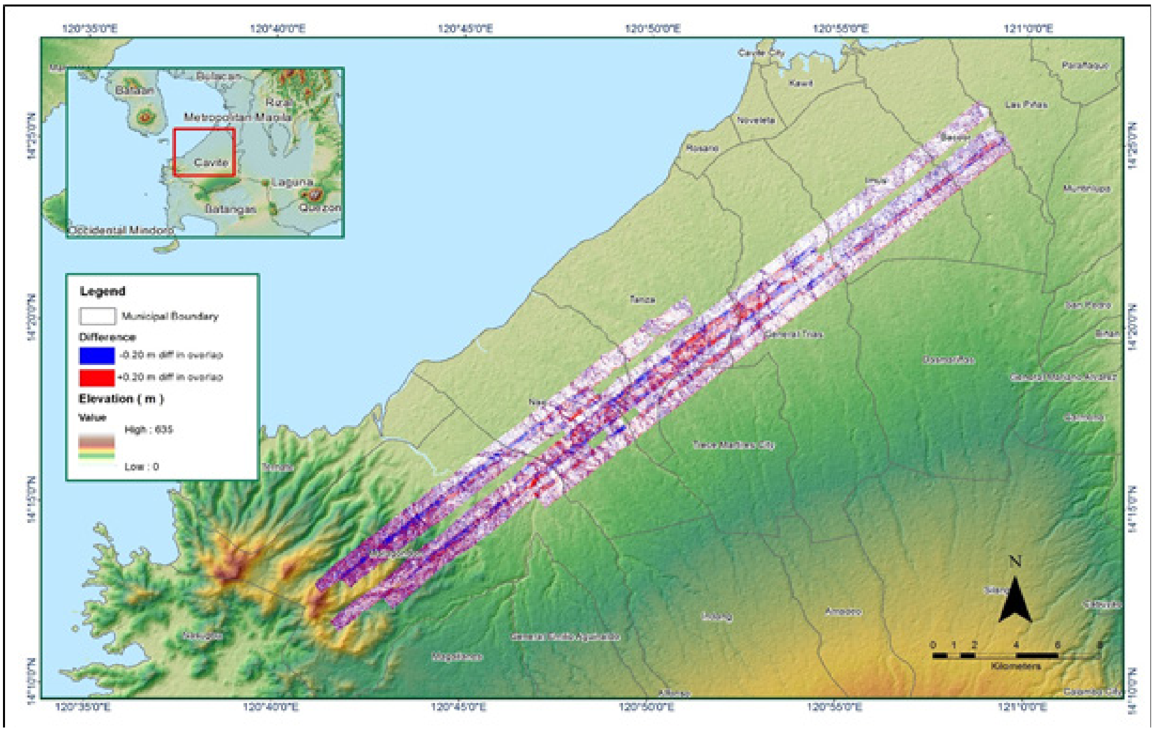


Figure A-8.32. Elevation difference between flight lines

Table A-8.5. Mission Summary Report for Mission Blk18A_supplement

Flight Area	CALABARZON
Mission Name	Blk18A_supplement
Inclusive Flights	1043P
Range data size	6.13 GB
POS	125 MB
Image	N/A
Transfer date	04/23/2014
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)	1.1
RMSE for East Position (<4.0 cm)	1.6
RMSE for Down Position (<8.0 cm)	2.6
Boresight correction stdev (<0.001deg)	0.000829
IMU attitude correction stdev (<0.001deg)	0.001021
GPS position stdev (<0.01m)	0.0013
Minimum % overlap (>25)	11.00%
Ave point cloud density per sq.m. (>2.0)	2.31
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	103
Maximum Height	157.83 m
Minimum Height	45.2 m
Classification (# of points)	
Ground	76,835,956
Low vegetation	48,258,042
Medium vegetation	42,822,105
High vegetation	19,332,576
Building	7,920,574
Orthophoto	No
Processed by	Engr. Angelo Carlo Bongat, Engr. Christy Lubiano, Engr. Gladys Mae Apat

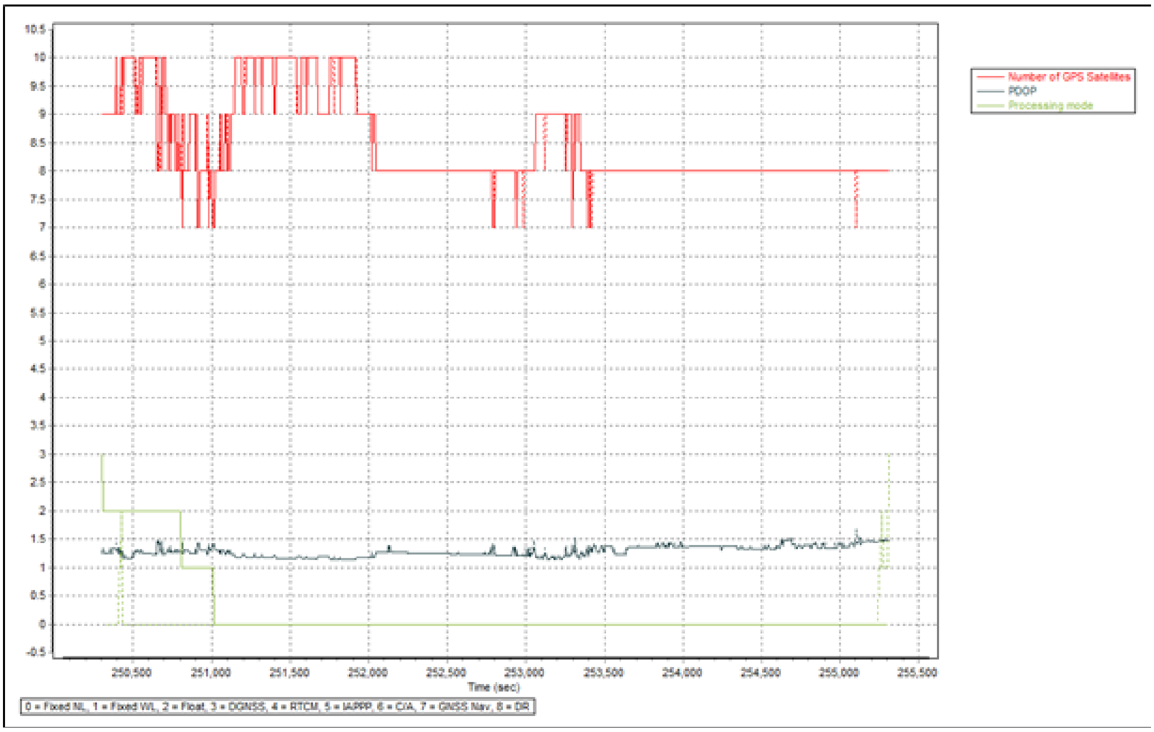


Figure A-8.33. Solution Status

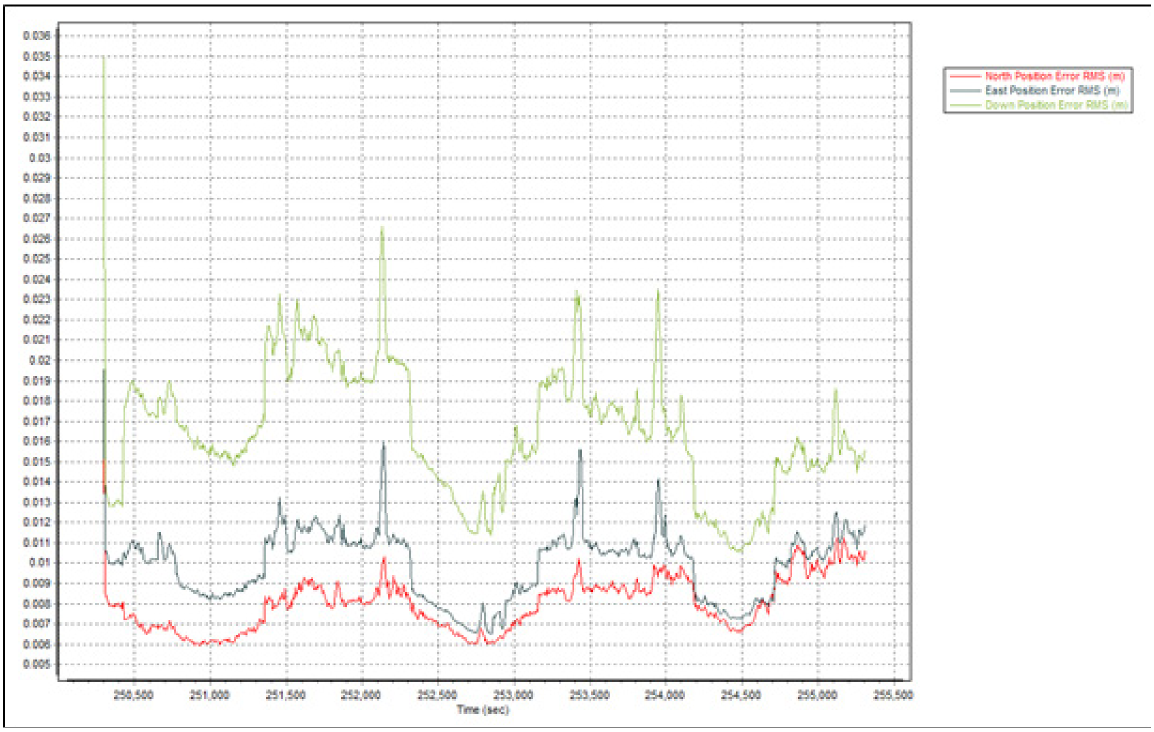


Figure A-8.34. Smoothed Performance Metrics Parameters

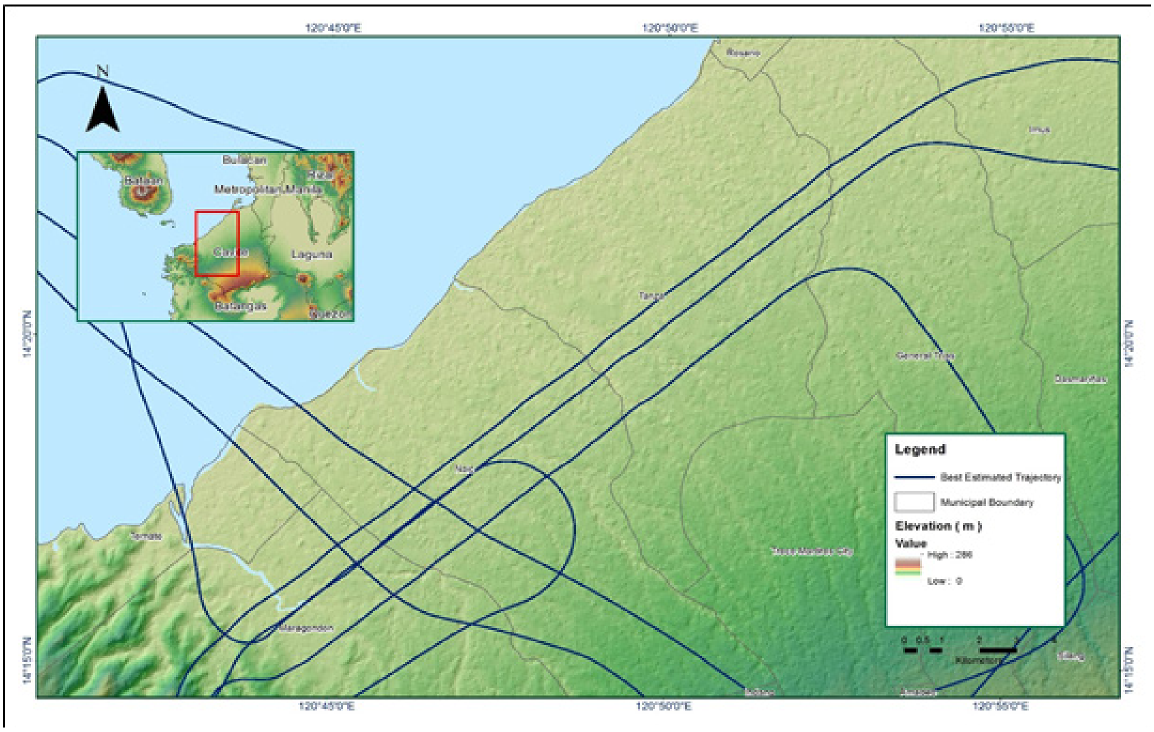


Figure A-8.35. Best Estimated Trajectory

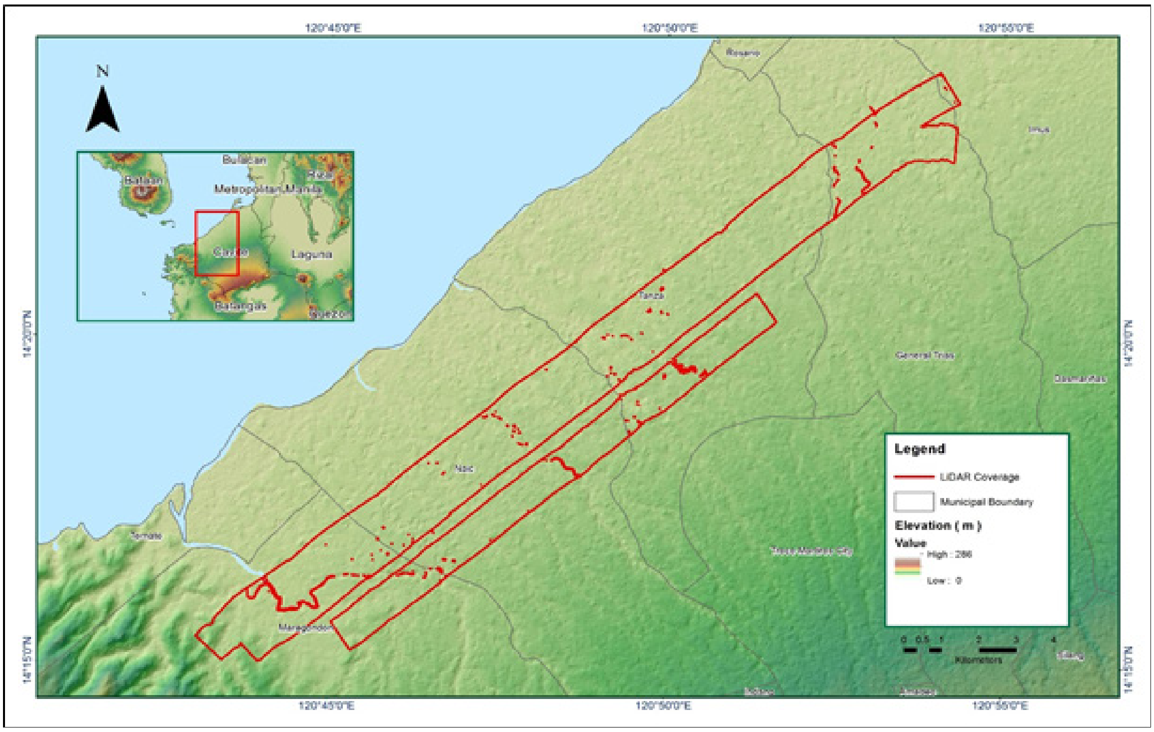


Figure A-8.36. Coverage of LiDAR data

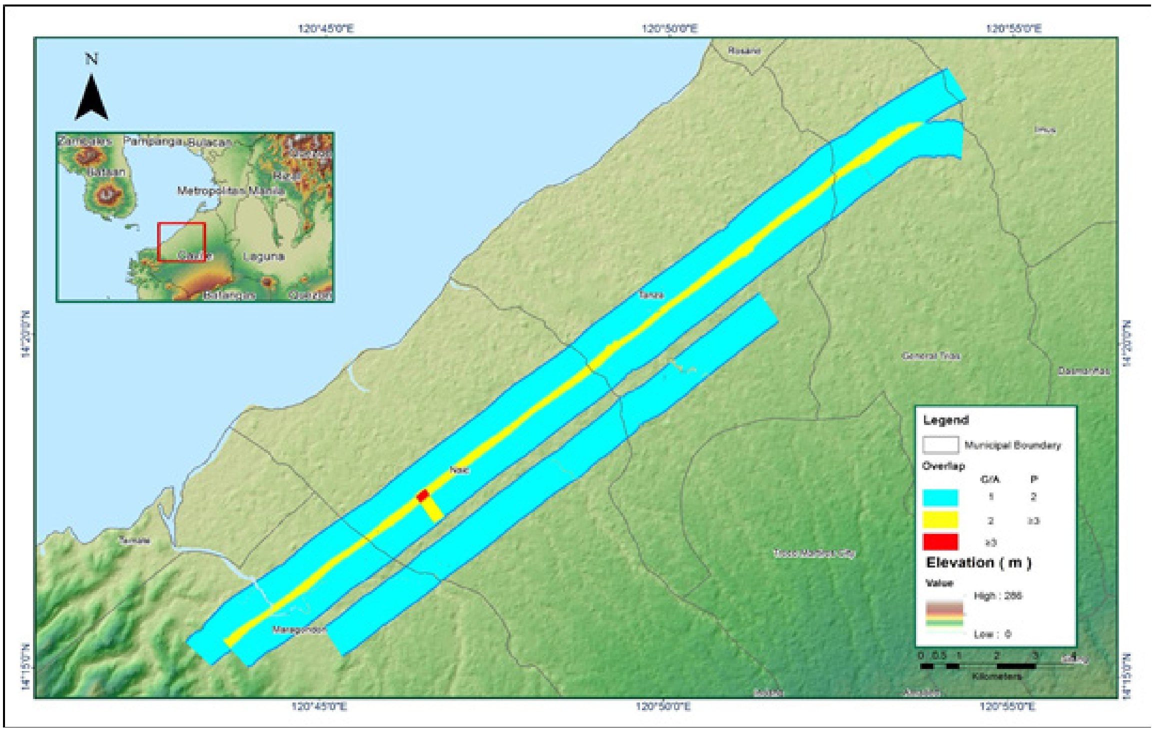


Figure A-8.37. Image of data overlap

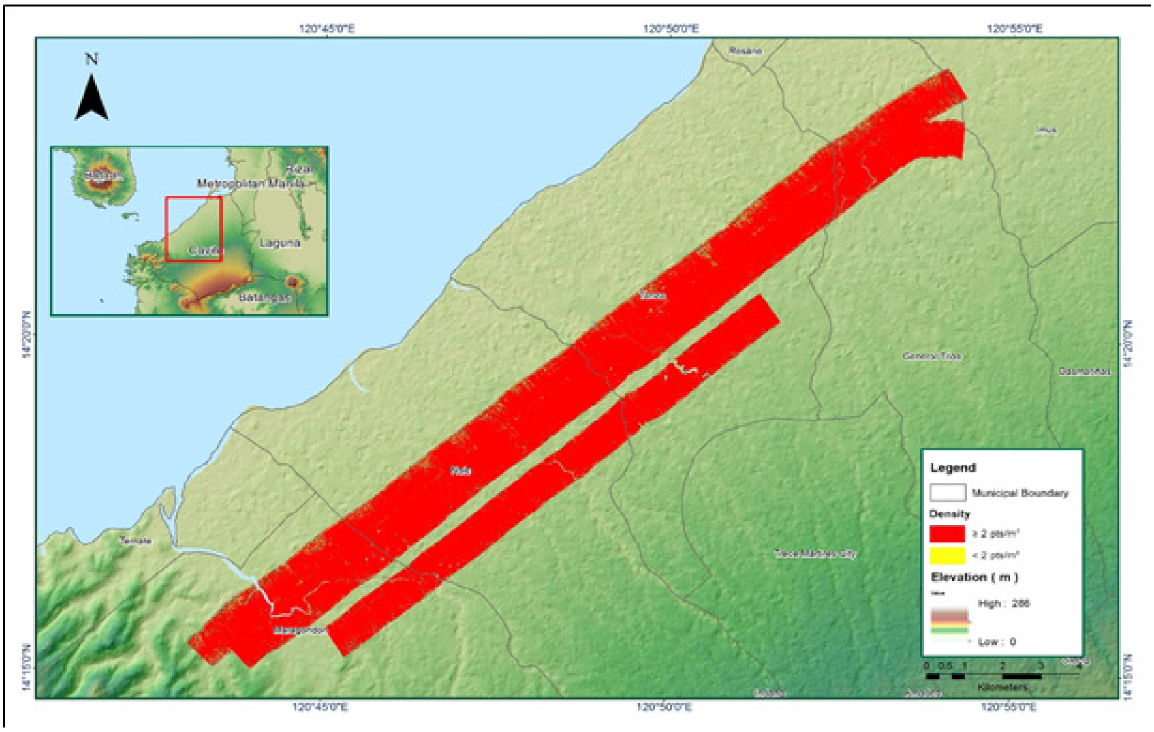


Figure A-8.38. Density map of merged LiDAR data

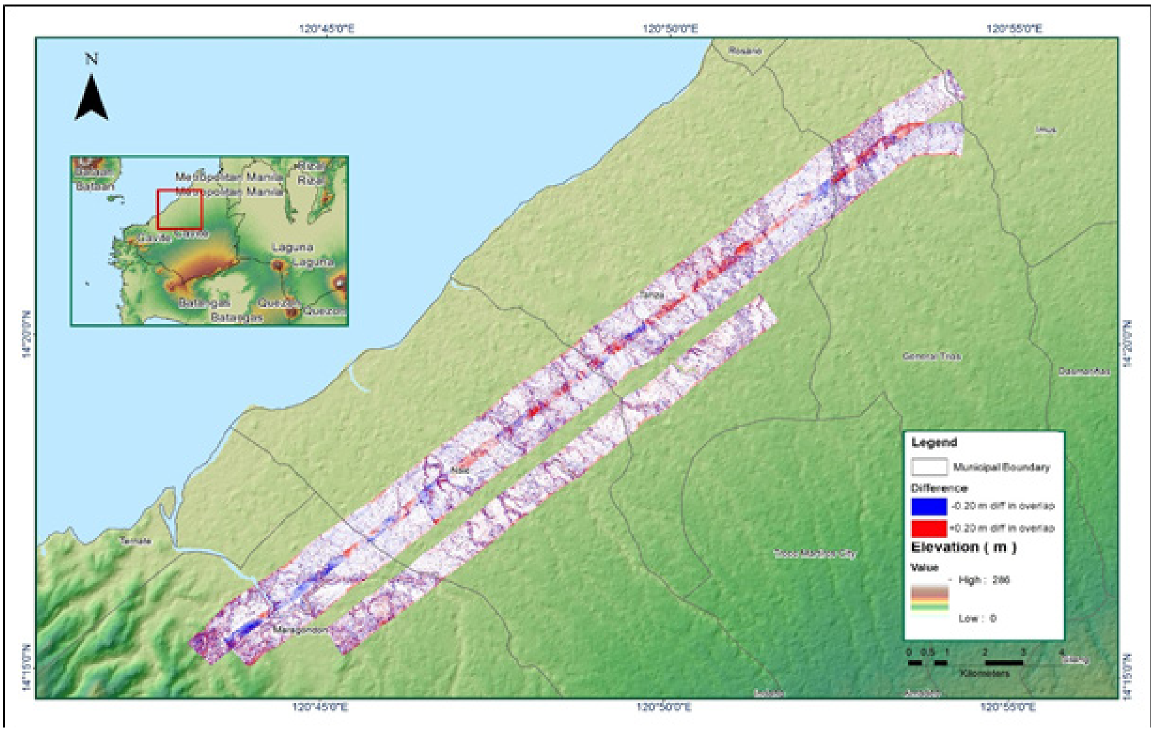


Figure A-8.39. Elevation difference between flight lines

Table A-8.6. Mission Summary Report for Mission Blk18ABCs

Flight Area	CALABARZON
Mission Name	Blk18ABCs
Inclusive Flights	1139P (formerly 1137P)
Range data size	21.0 GB
POS	238 MB
Image	29.3 GB
Transfer date	04/23/2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.0
RMSE for East Position (<4.0 cm)	1.3
RMSE for Down Position (<8.0 cm)	5.0
Boresight correction stdev (<0.001deg)	0.000588
IMU attitude correction stdev (<0.001deg)	0.003259
GPS position stdev (<0.01m)	0.0030
Minimum % overlap (>25)	11.42%
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	160
Maximum Height	482.90 m
Minimum Height	49.73 m
Classification (# of points)	
Ground	72,017,950
Low vegetation	44,436,126
Medium vegetation	60,715,396
High vegetation	66,209,597
Building	1,876,735
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Chelou Prado, Engr. Gladys Mae Apat

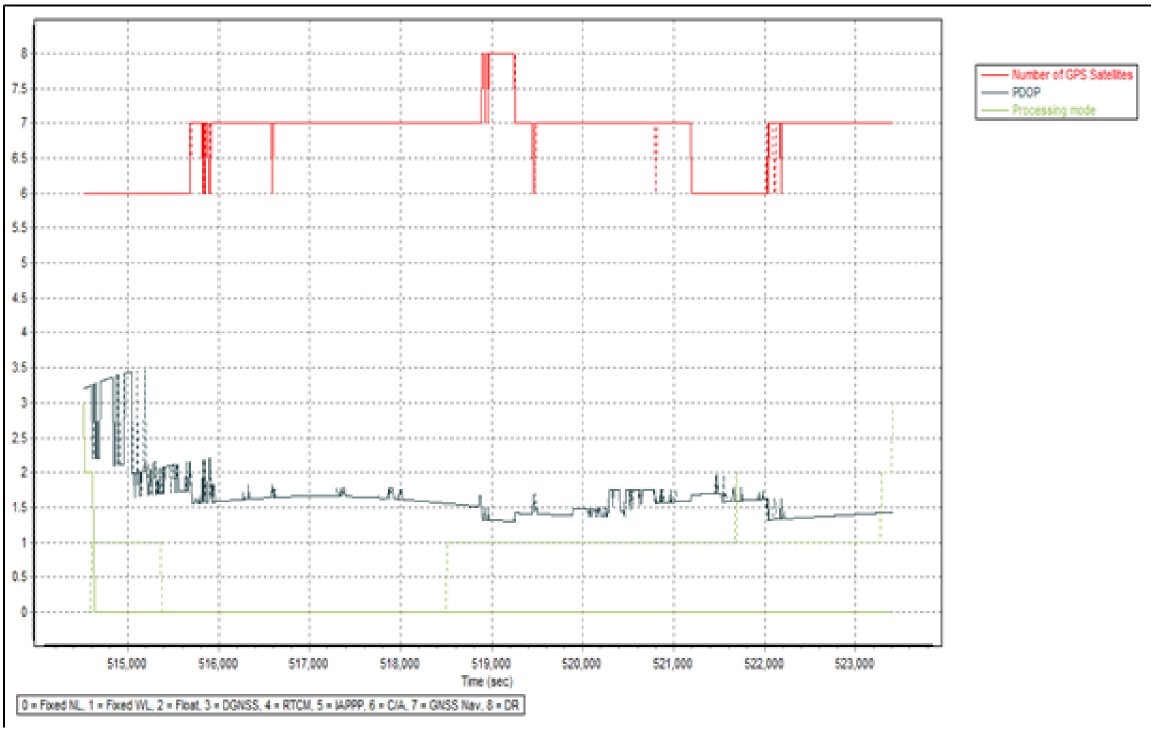


Figure A-8.40. Solution Status

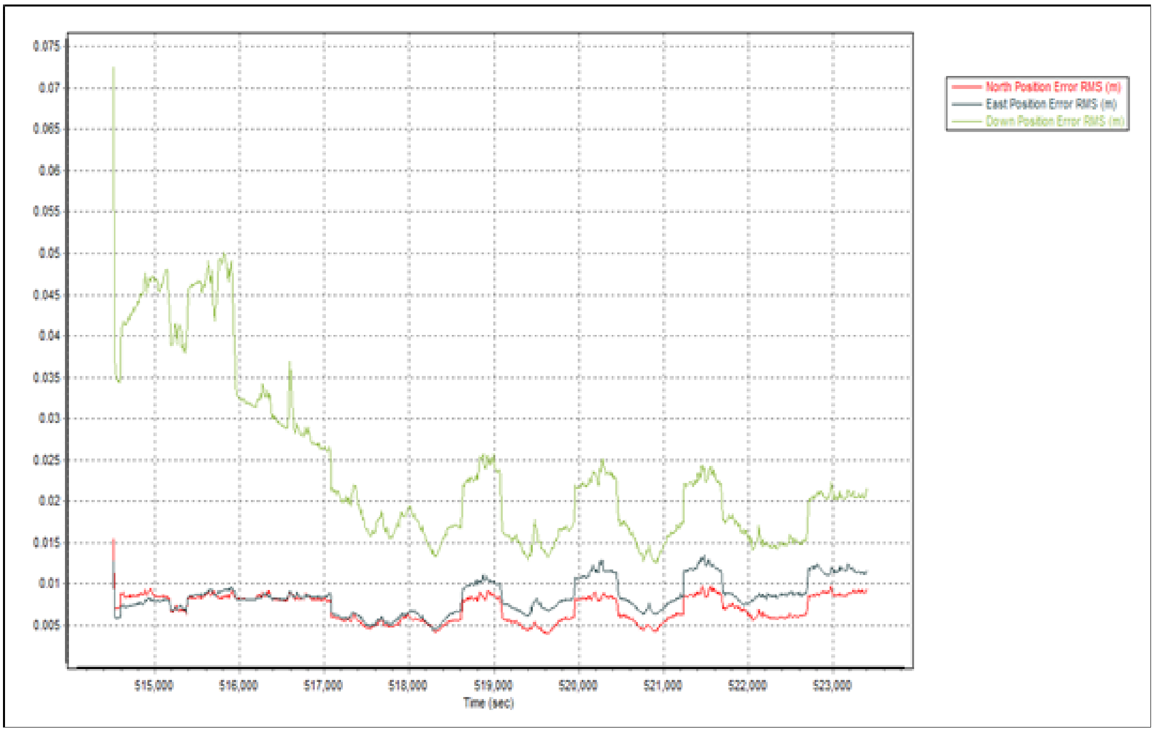


Figure A-8.41. Smoothed Performance Metrics Parameters

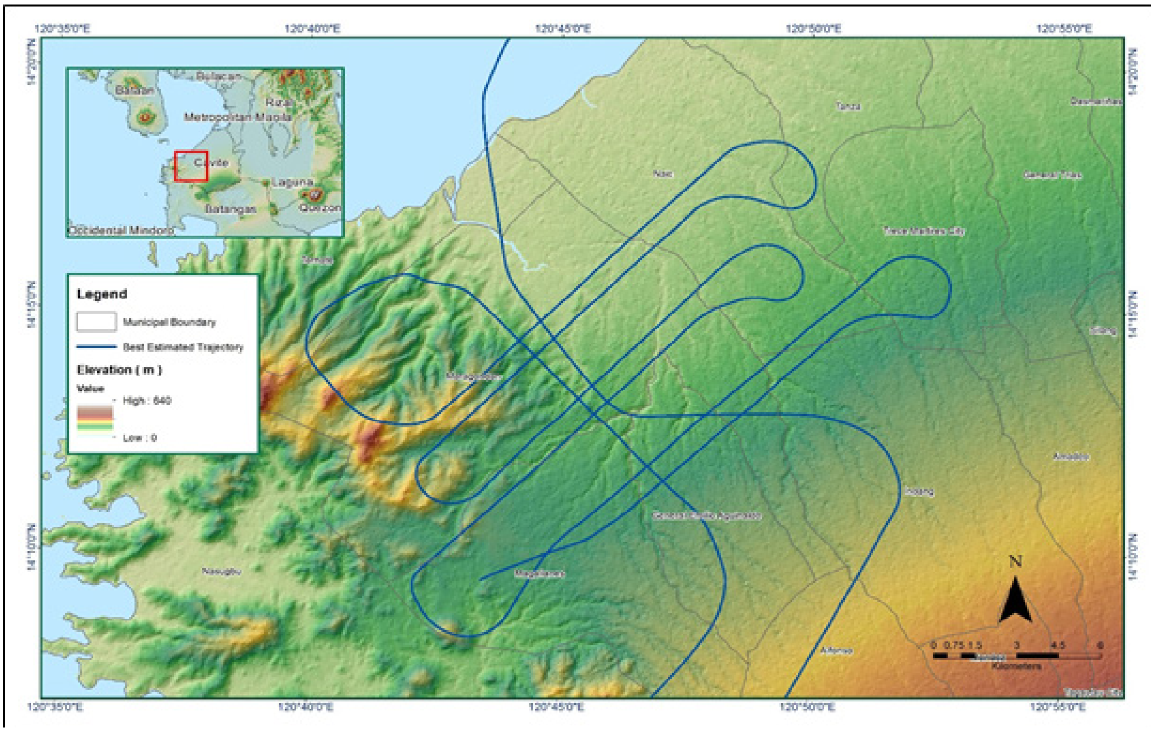


Figure A-8.42. Best Estimated Trajectory

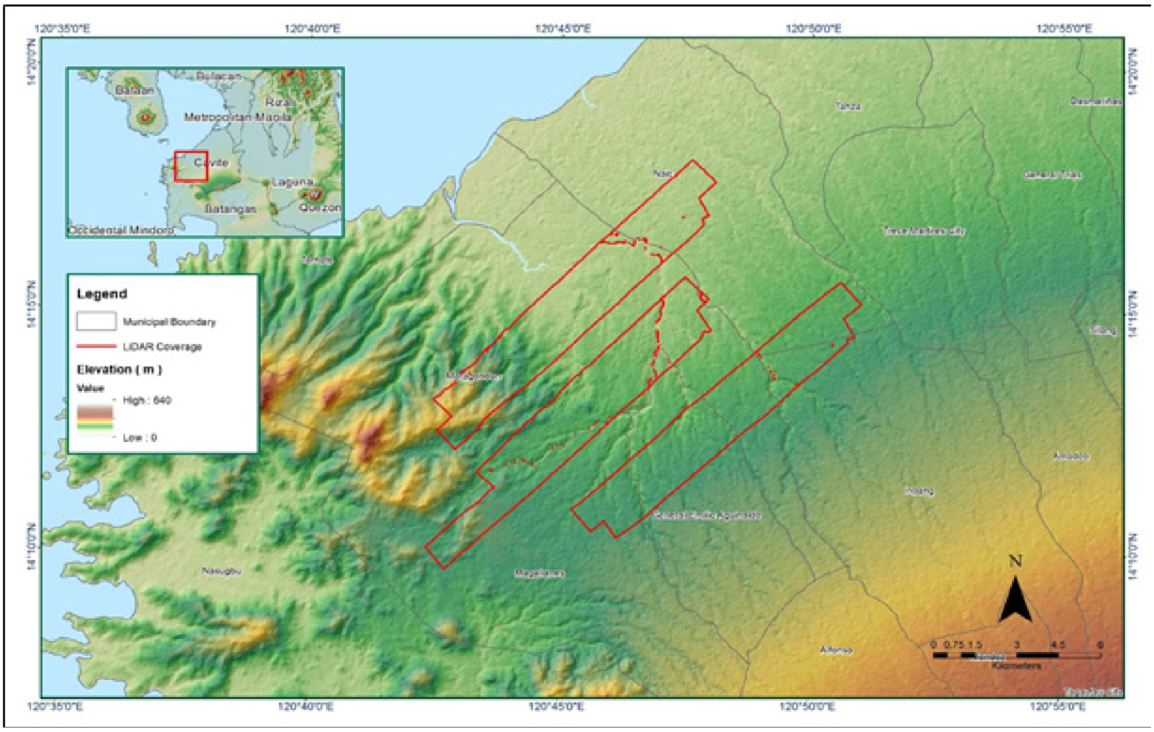


Figure A-8.43. Coverage of LiDAR data

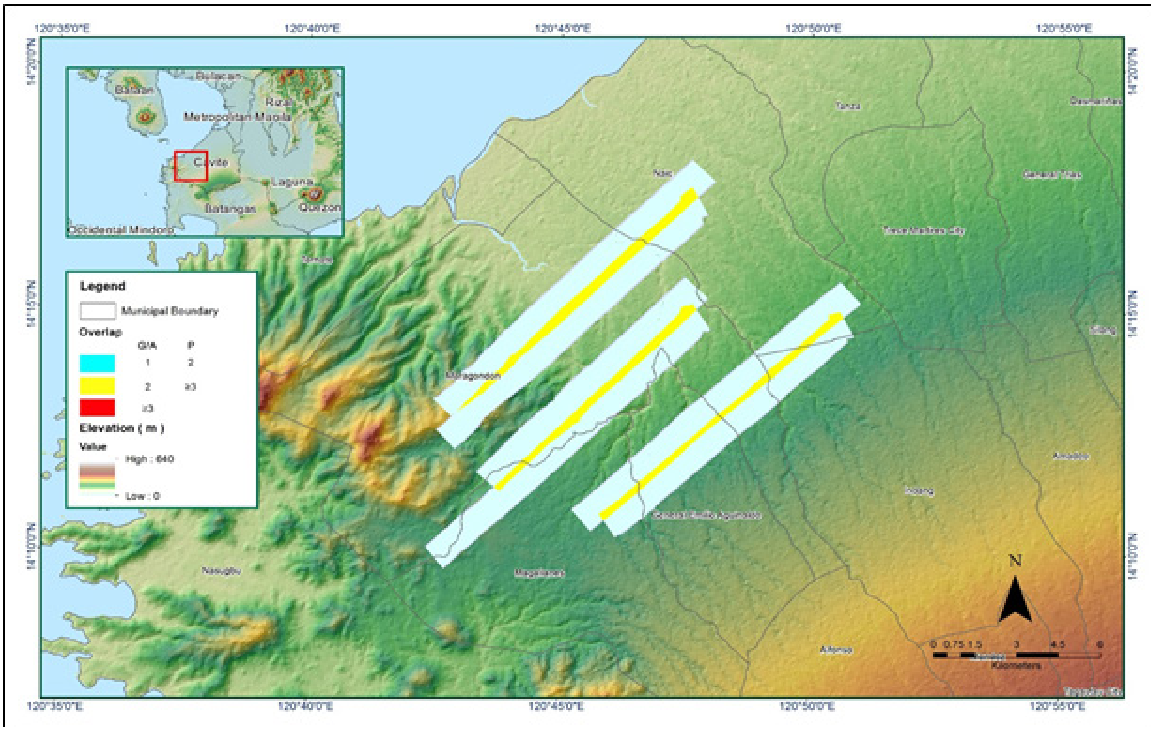


Figure A-8.44. Image of data overlap

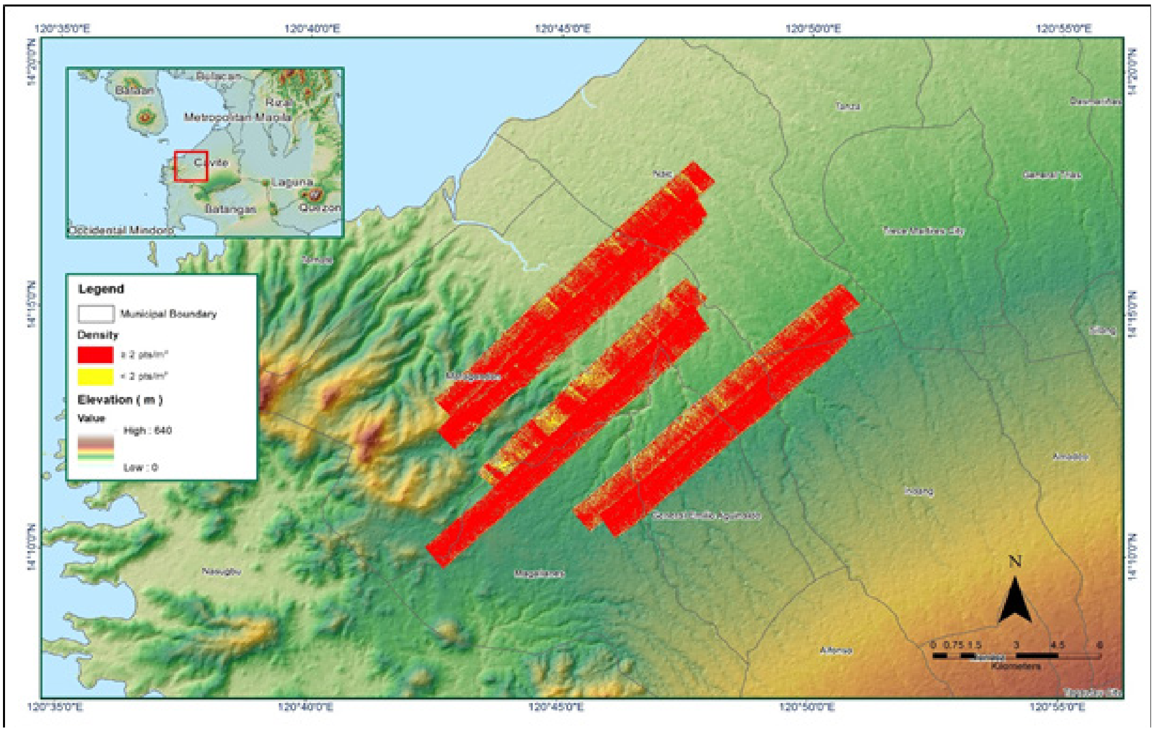


Figure A-8.45. Density map of merged LiDAR data

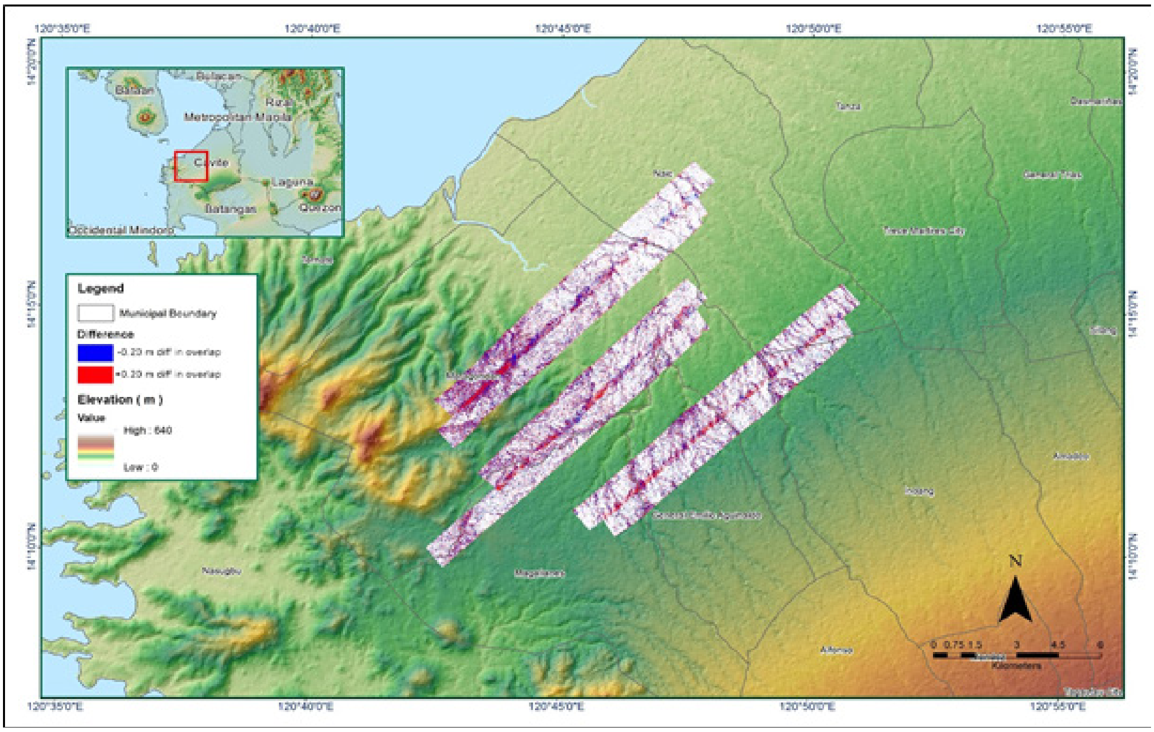


Figure A-8.46. Elevation difference between flight lines

Table A-8.7. Mission Summary Report for Mission Blk18C_additional

Flight Area	CALABARZON
Mission Name	Blk18C_additional
Inclusive Flights	1031P; 1063P
Range data size	33.2 GB
POS	329 MB
Image	19.2 GB
Transfer date	04/23/2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.5
RMSE for East Position (<4.0 cm)	1.9
RMSE for Down Position (<8.0 cm)	3.2
Boresight correction stdev (<0.001deg)	0.000508
IMU attitude correction stdev (<0.001deg)	0.001492
GPS position stdev (<0.01m)	0.0092
Minimum % overlap (>25)	29.92%
Ave point cloud density per sq.m. (>2.0)	2.78
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	327
Maximum Height	460.70 m
Minimum Height	60.39 m
Classification (# of points)	
Ground	187,497,140
Low vegetation	163,676,822
Medium vegetation	212,619,439
High vegetation	144,490,617
Building	59,922,956
Orthophoto	Yes
Processed by	Engr. Kenneth Solidum , Engr. Merven Matthew Natino, Marie Joyce Ilagan

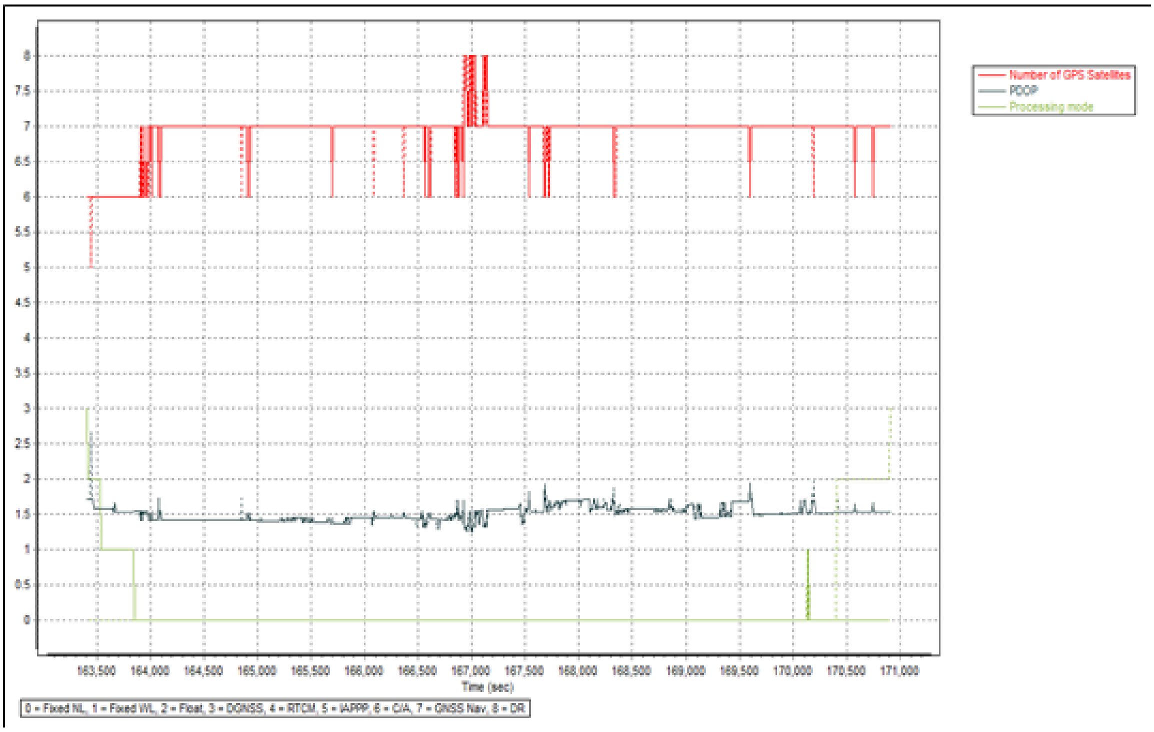


Figure A-8.47. Solution Status

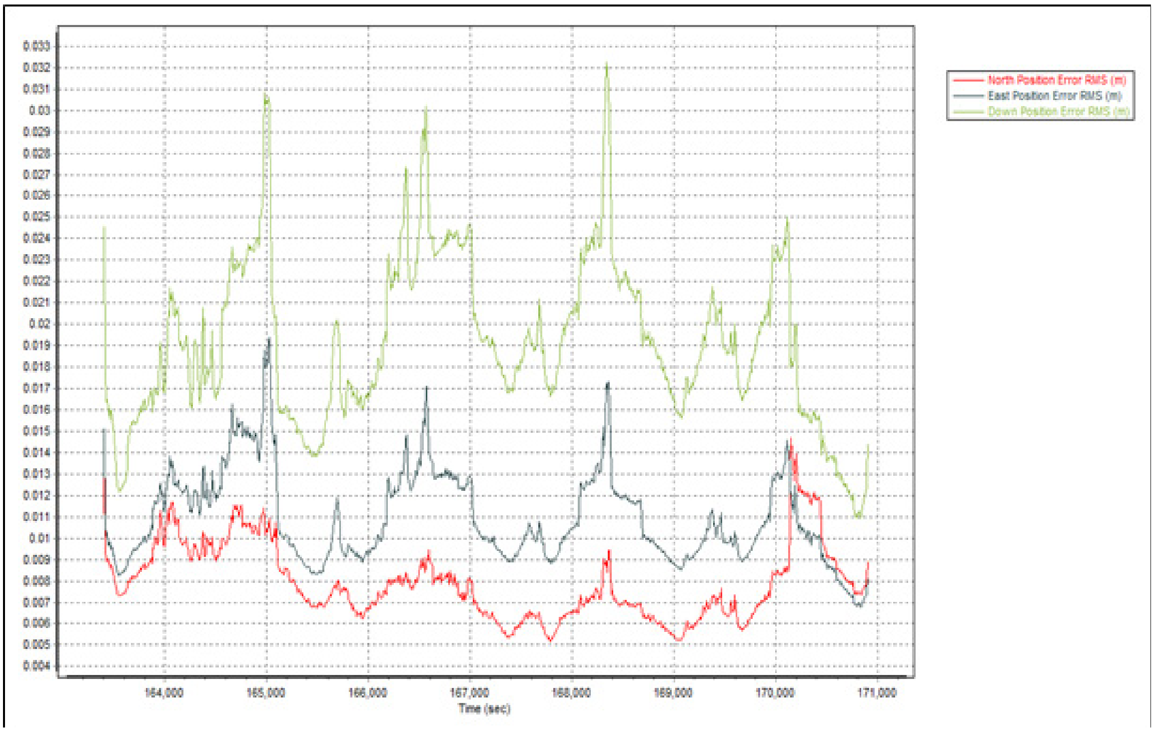


Figure A-8.48. Smoothed Performance Metrics Parameters

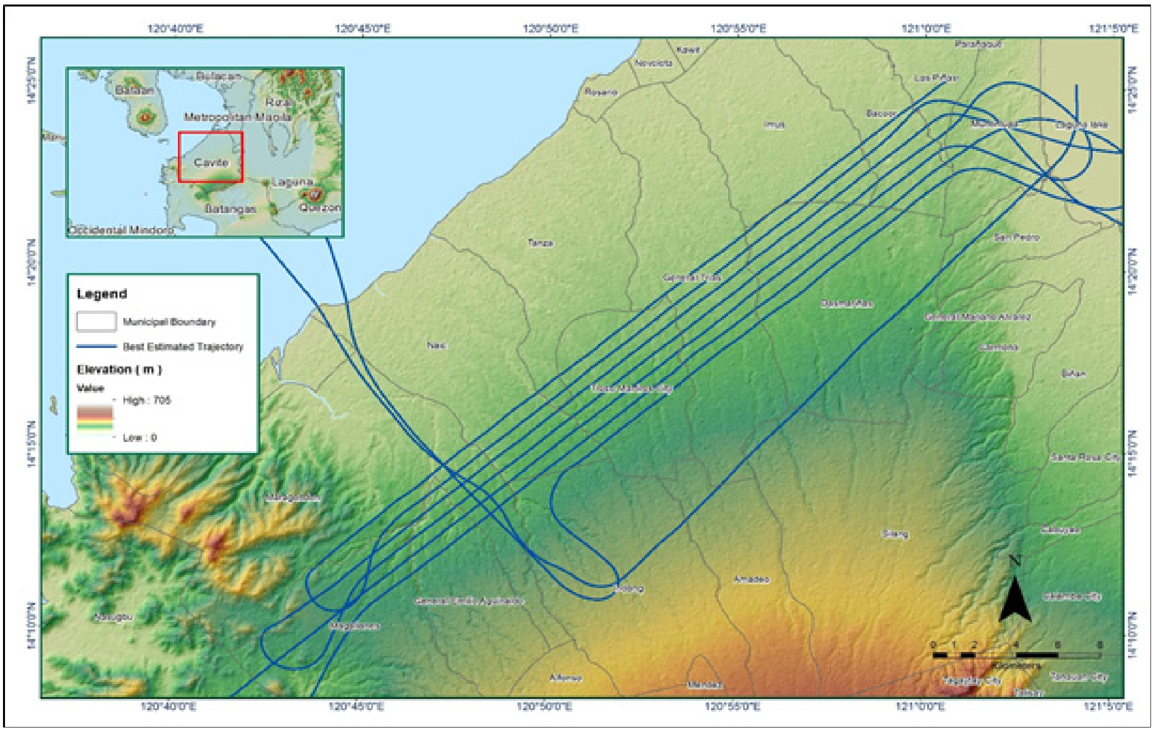


Figure A-8.49. Best Estimated Trajectory

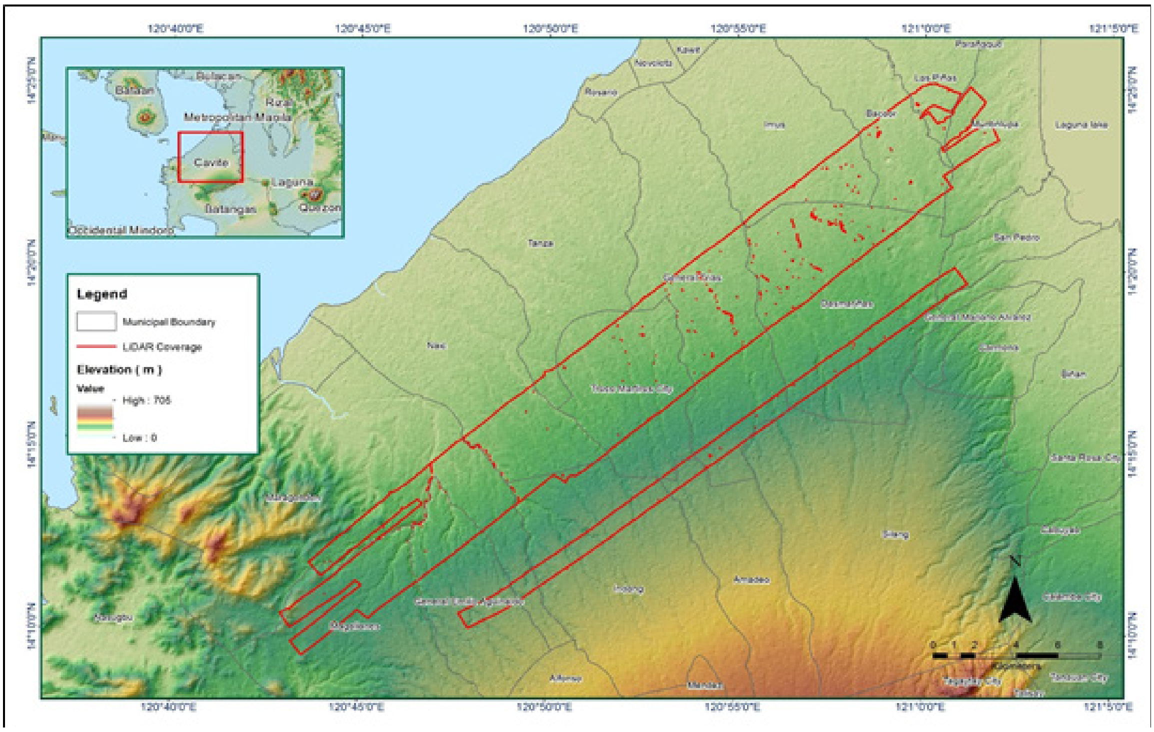


Figure A-8.50. Coverage of LiDAR data

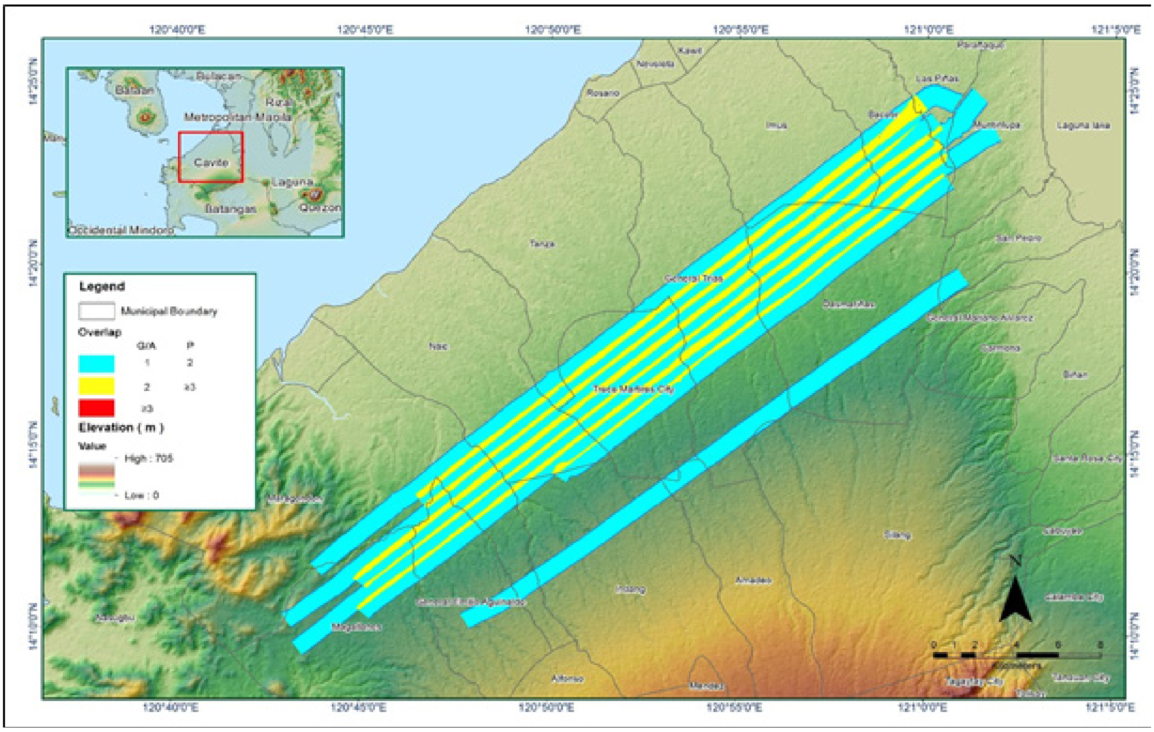


Figure A-8.51. Image of data overlap

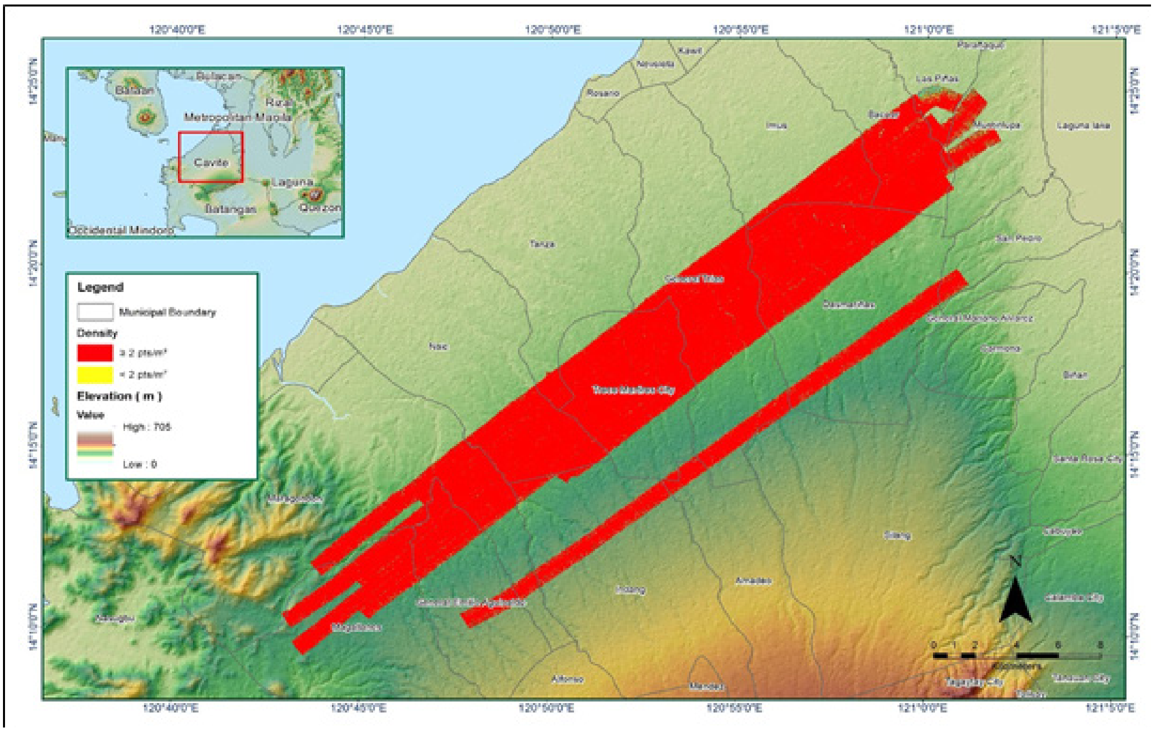


Figure A-8.52. Density map of merged LiDAR data

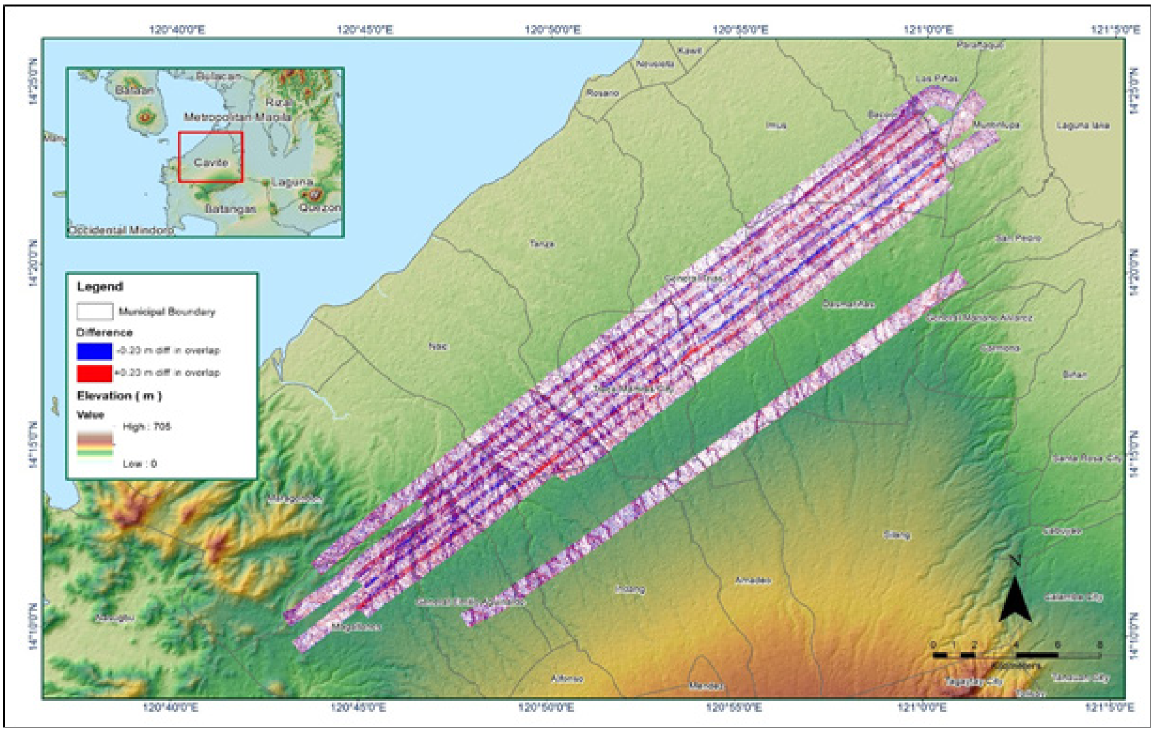


Figure A-8.53. Elevation difference between flight lines

Table A-8.8. Mission Summary Report for Mission Blk18_SM

Flight Area	Batangas 2
Mission Name	Blk18_SM
Inclusive Flights	3681G
Range data size	24 GB
POS	209 MB
Image	NA
Transfer date	January 15, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.279
RMSE for East Position (<4.0 cm)	1.734
RMSE for Down Position (<8.0 cm)	3.603
Boresight correction stdev (<0.001deg)	NA
IMU attitude correction stdev (<0.001deg)	NA
GPS position stdev (<0.01m)	NA
Minimum % overlap (>25)	30.63
Ave point cloud density per sq.m. (>2.0)	5.07
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	170
Maximum Height	656.08 m
Minimum Height	70.15 m
Classification (# of points)	
Ground	49,291,133
Low vegetation	19,348,045
Medium vegetation	270,144,911
High vegetation	305,271,638
Building	135,885
Orthophoto	No
Processed by	Engr. Abigail Joy Ching, Engr. Edgardo Gubatnga Jr., Engr. Elainne Lopez

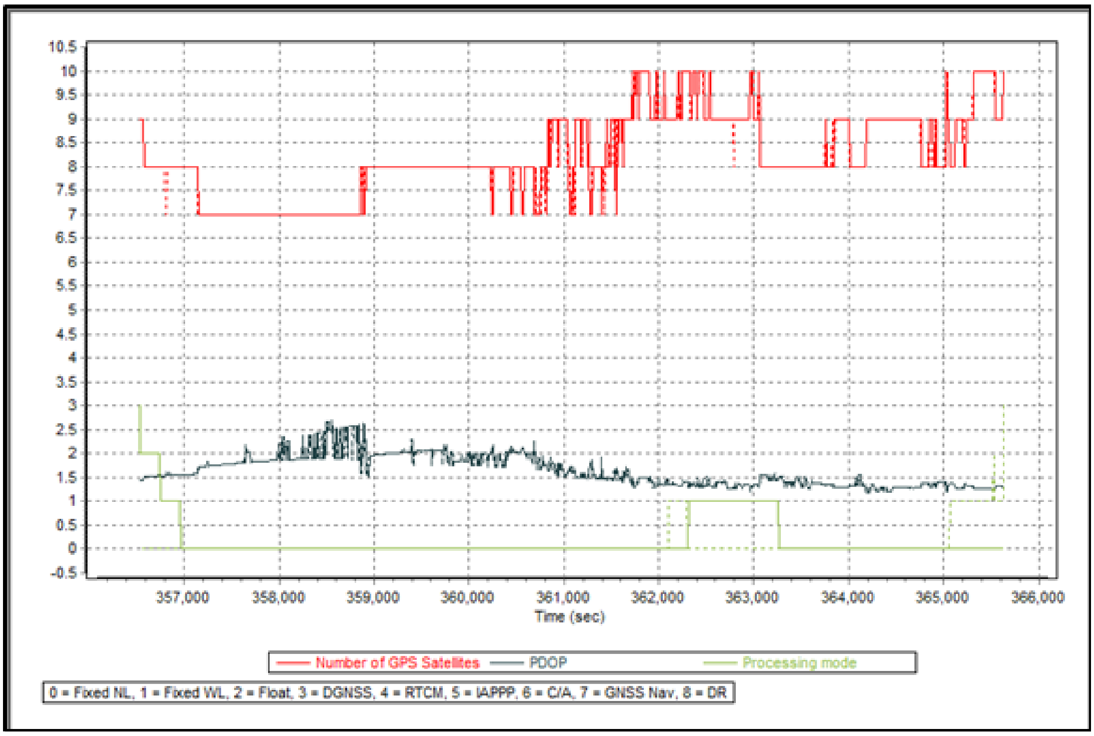


Figure A-8.54. Solution Status

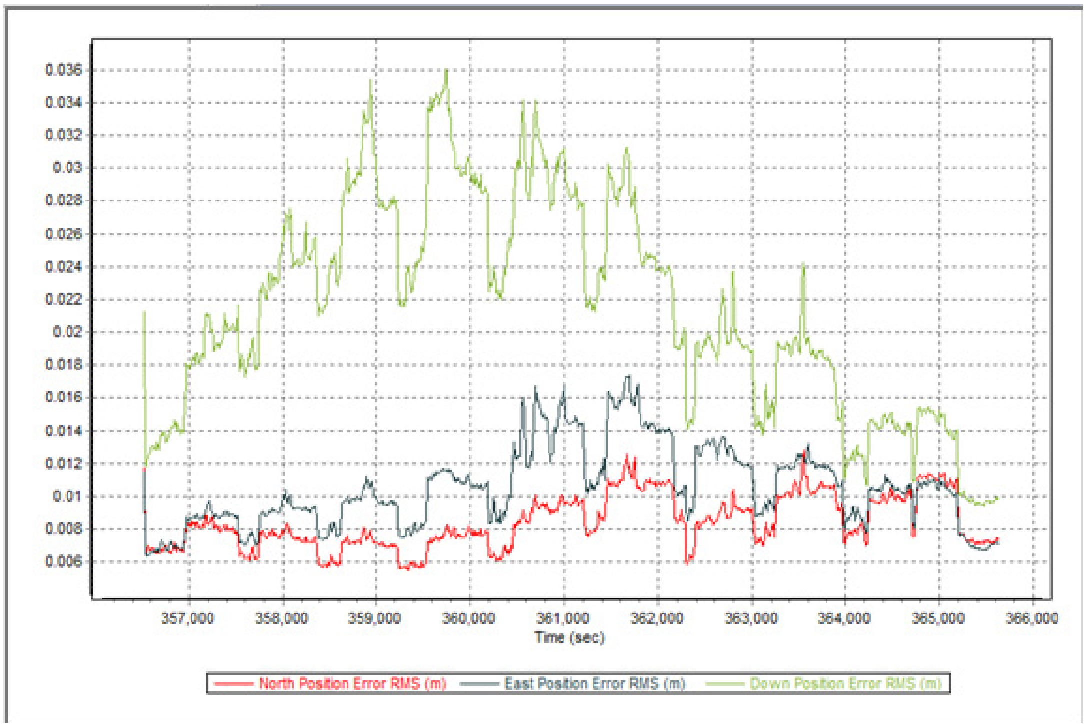


Figure A-8.55. Smoothed Performance Metric Parameters

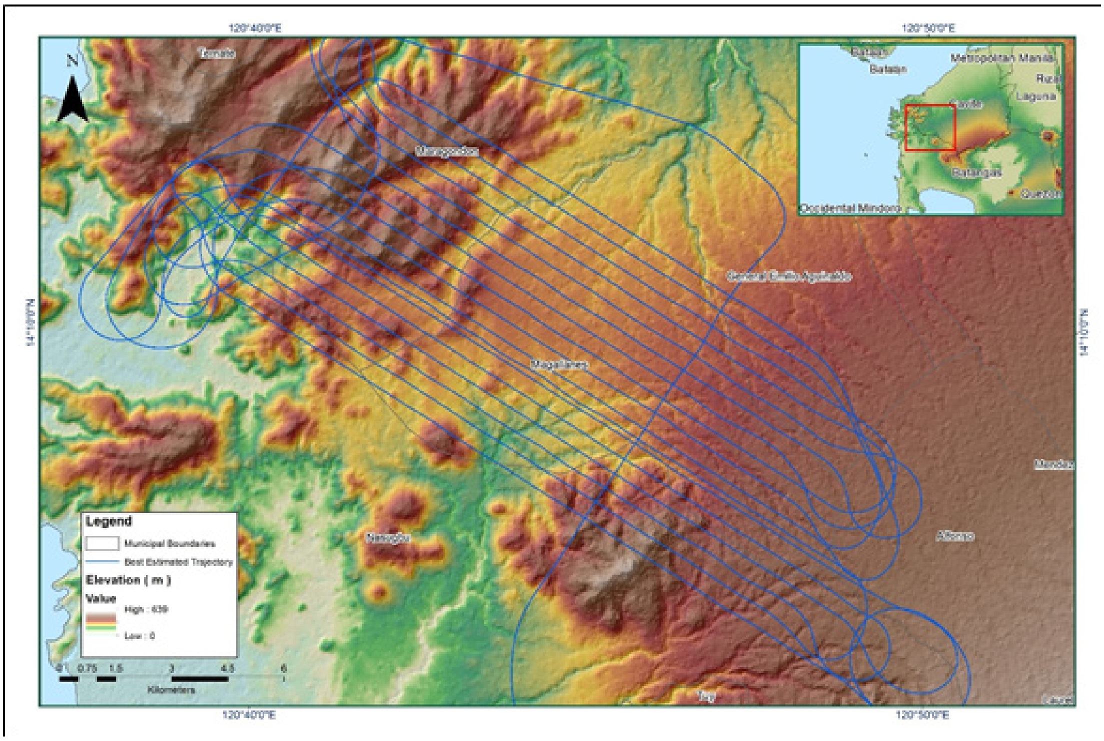


Figure A-8.56. Best Estimate Trajectory

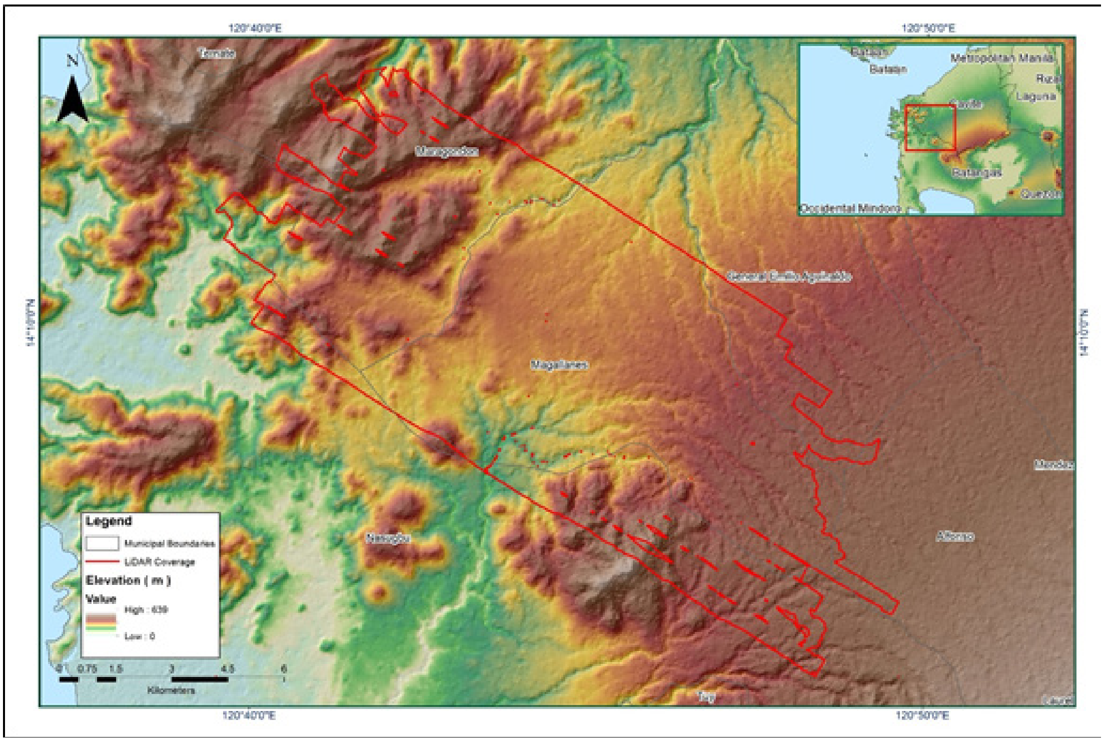


Figure A-8.57. Coverage of LiDAR data

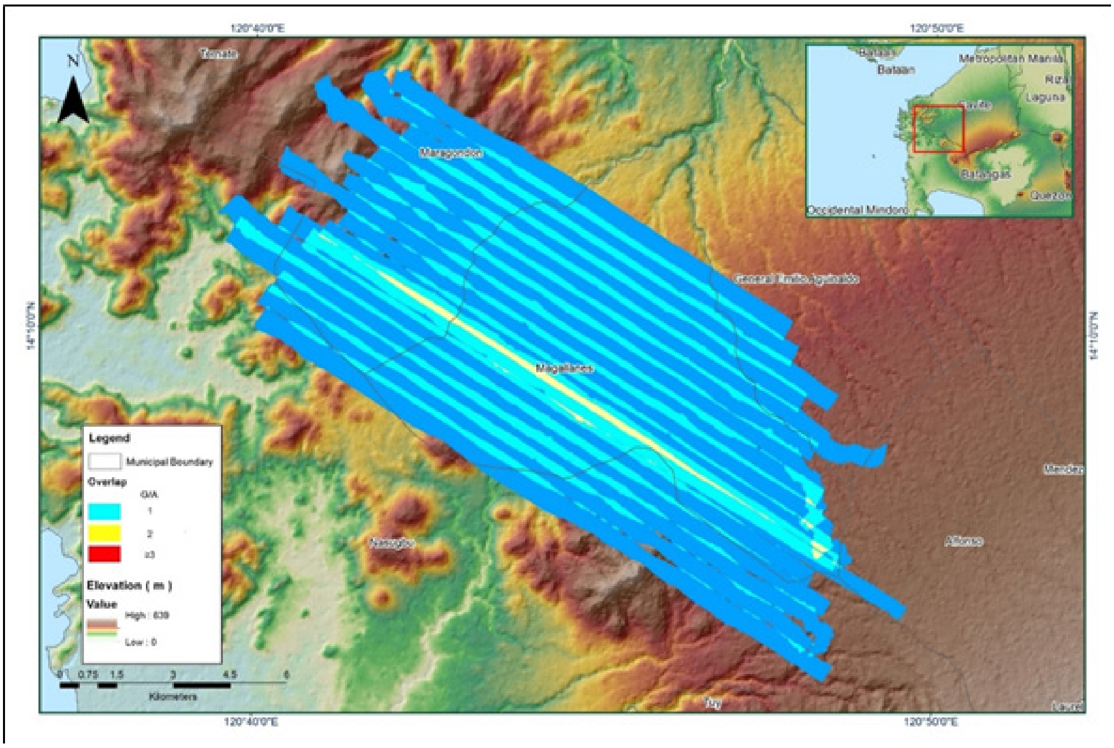


Figure A-8.58 Image of data overlap

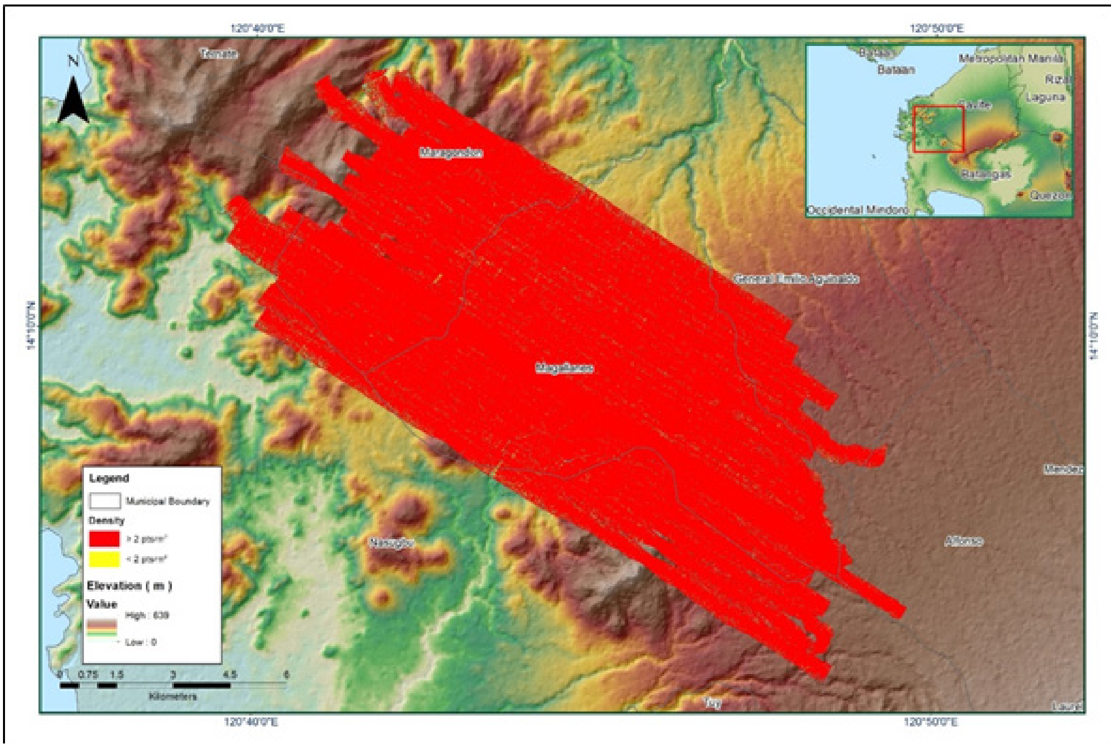


Figure A-8.59. Density Map of merged LiDAR data

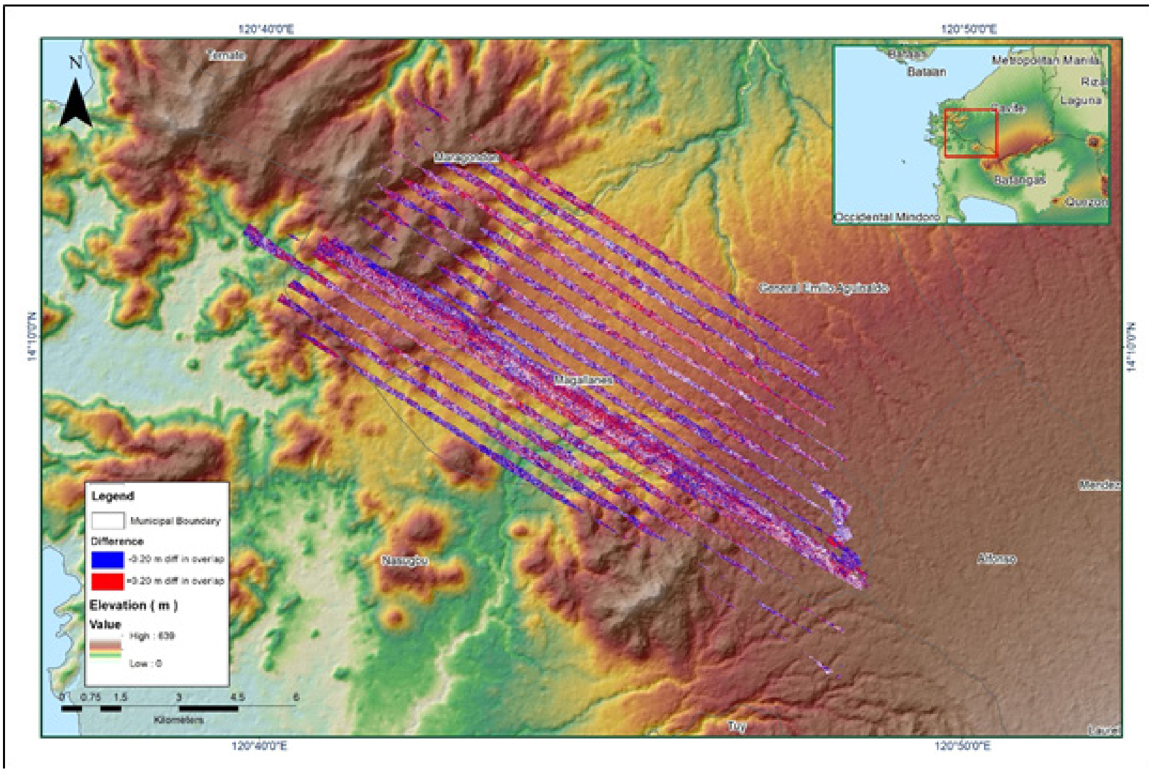


Figure A-8.60. Elevation Difference Between flight lines

Table A-8.9. Mission Summary Report for Mission Blk18_SM_supplement

Flight Area	Batangas 2
Mission Name	Blk18_SM_supplement
Inclusive Flights	3687G
Range data size	17.20 GB
POS	172 MB
Image	NA
Transfer date	January 15, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.271
RMSE for East Position (<4.0 cm)	1.572
RMSE for Down Position (<8.0 cm)	3.414
Boresight correction stdev (<0.001deg)	NA
IMU attitude correction stdev (<0.001deg)	NA
GPS position stdev (<0.01m)	NA
Minimum % overlap (>25)	4.99
Ave point cloud density per sq.m. (>2.0)	15.59
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	42
Maximum Height	637.8 m
Minimum Height	131.2 m
Classification (# of points)	
Ground	9,221,159
Low vegetation	3,430,559
Medium vegetation	39,154,037
High vegetation	54,704,326
Building	30,976
Orthophoto	No
Processed by	Engr. Kenneth Solidum, Engr. Edgardo Gubatnga Jr., Engr. Krisha Marie Bautista

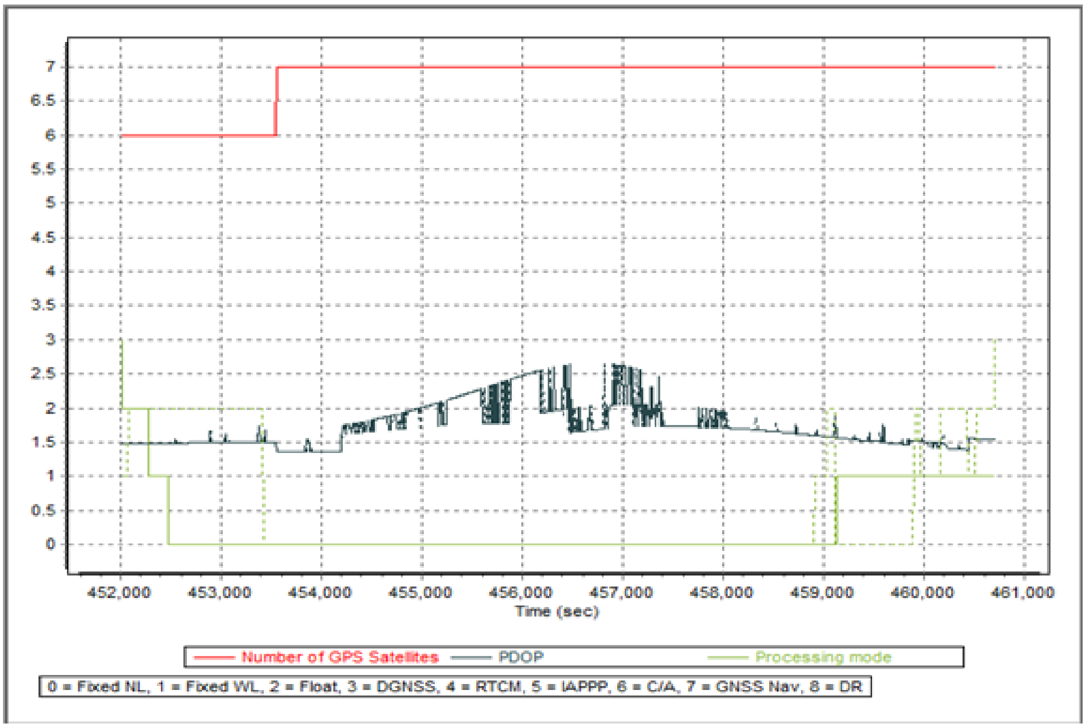


Figure A-8.61. Solution Status

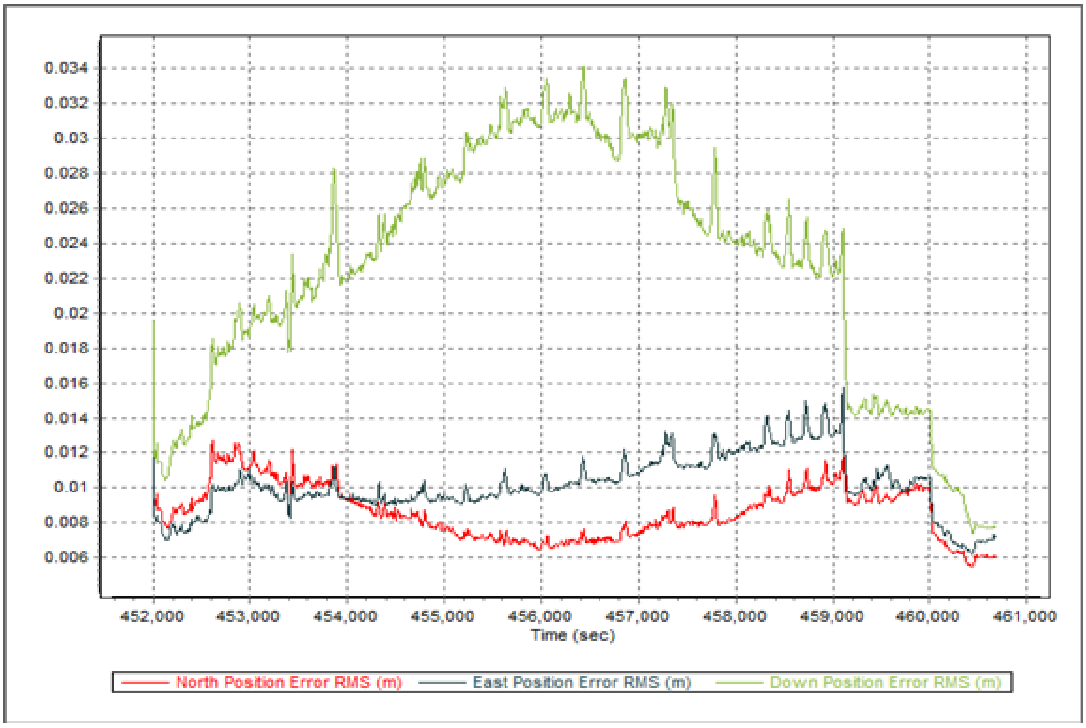


Figure A-8.62. Smoothed Performance Metric Parameters

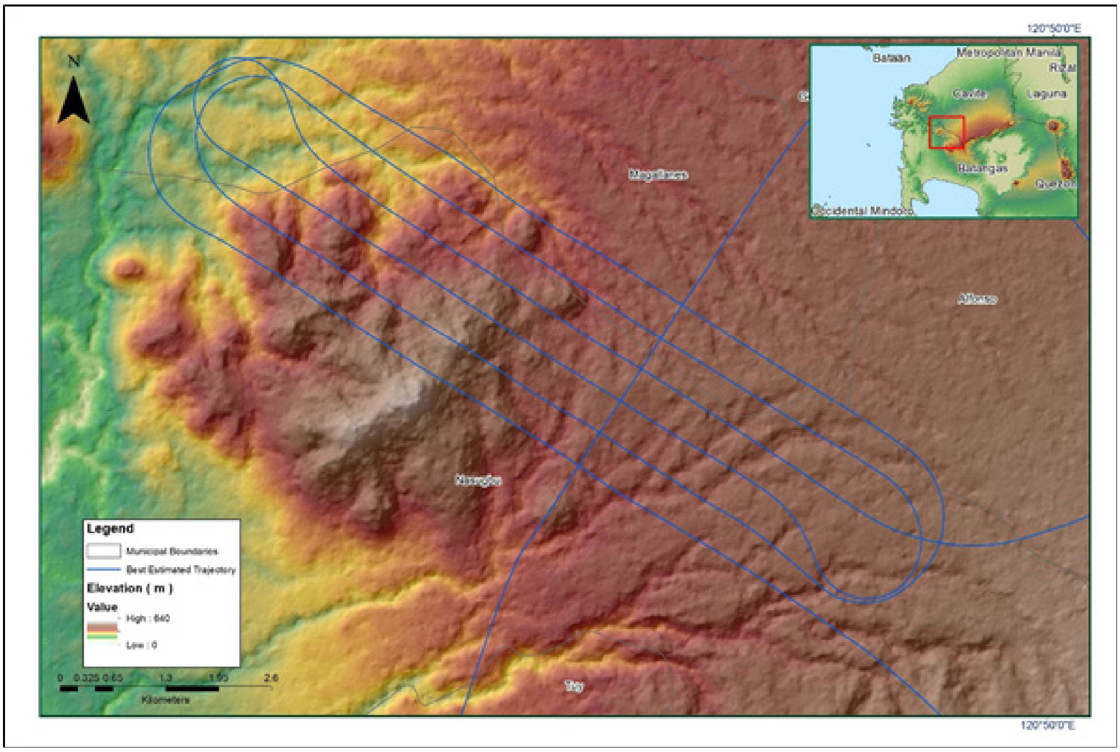


Figure A-8.63. Best Estimate Trajectory

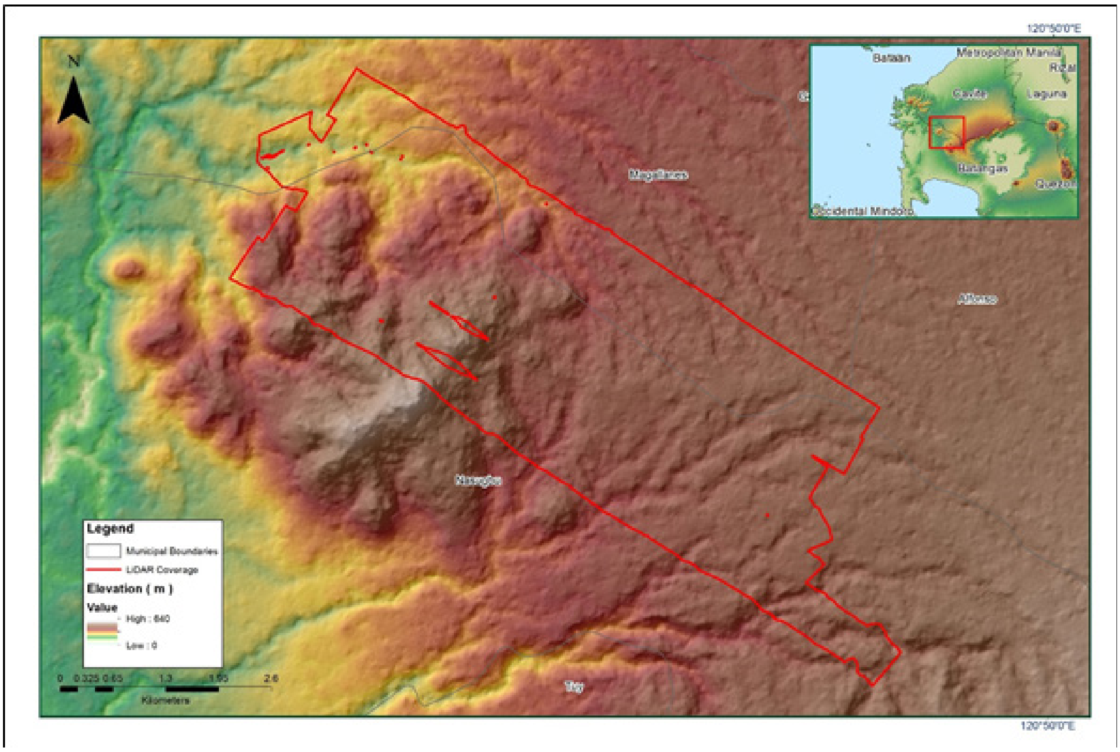


Figure A-8.64. Coverage of LiDAR data

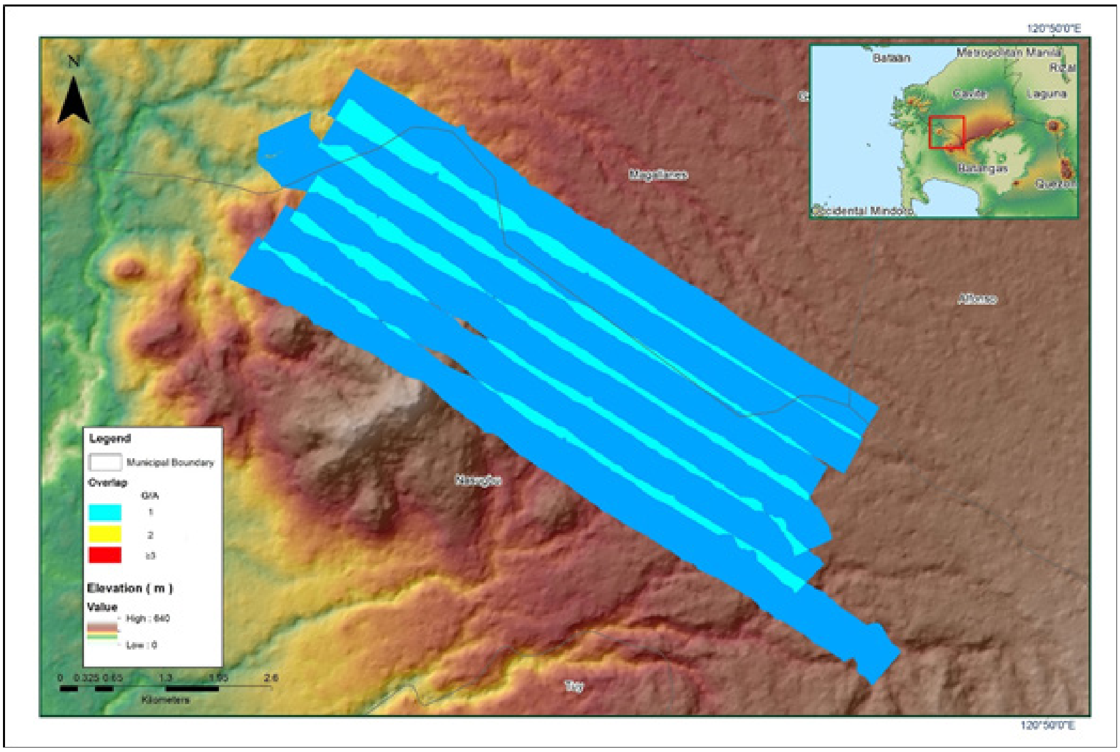


Figure A-8.65 Image of data overlap

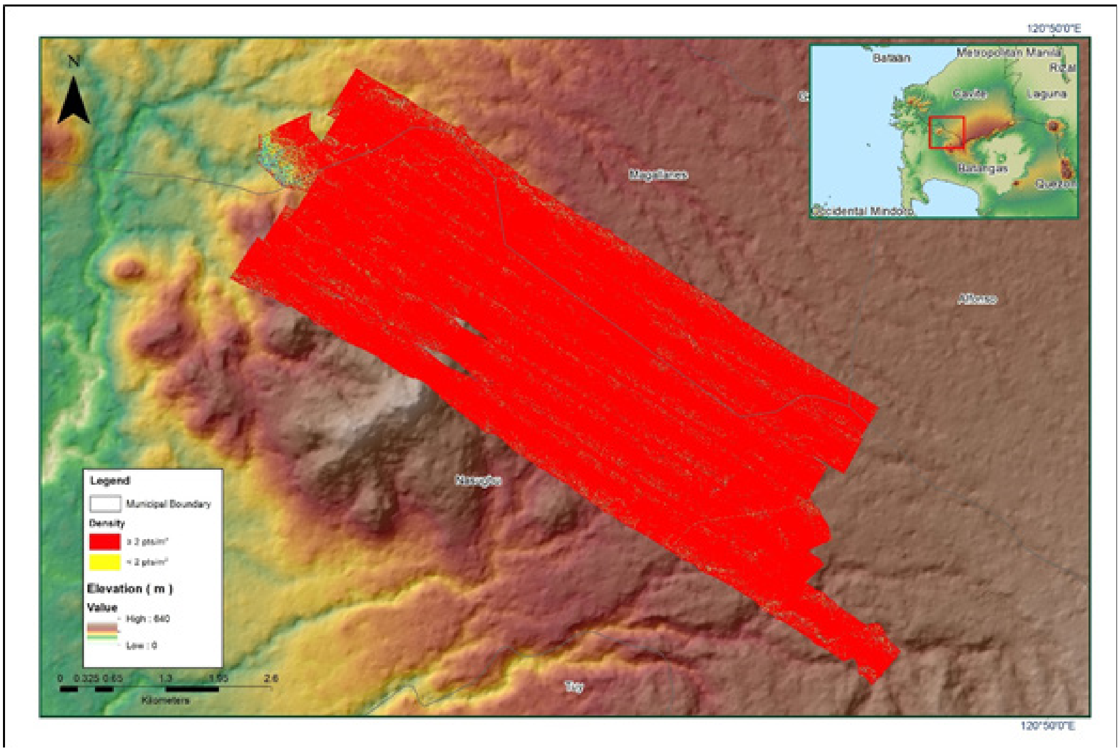


Figure A-8.66. Density Map of merged LiDAR data

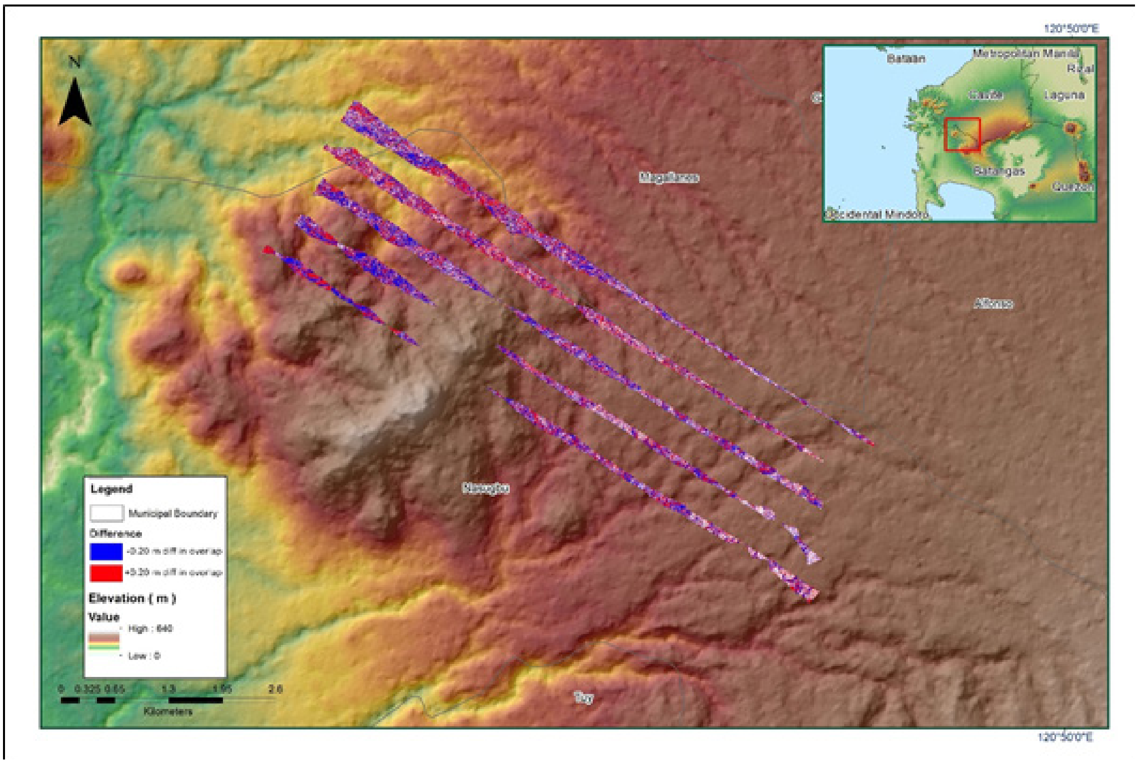


Figure A-8.67. Elevation Difference Between flight lines

Annex 9. Maragondon Model Basin Parameters

Table A-9.1. Maragondon Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W460	6.2778	84.993	30	0.14571	3.9615	Discharge	0.077525	0.070784	Ratio to Peak	0.5
W470	5.5134	87.095	30	0.16608	2.5788	Discharge	0.356034	0.044109	Ratio to Peak	0.33333
W480	6.4078	84.646	30	115.39	69.03	Discharge	0.119599	0.070618	Ratio to Peak	0.5
W490	5.9304	85.935	30	0.14562	4.114	Discharge	0.110055	0.021752	Ratio to Peak	0.5
W500	4.3602	90.47	30	0.16634	2.7607	Discharge	0.110216	0.046987	Ratio to Peak	0.48636
W510	1.1902	99	30	0.1651	1.6458	Discharge	0.144488	0.010857	Ratio to Peak	0.041257
W520	1.4534	99	30	0.1651	3.3599	Discharge	0.095986	0.044182	Ratio to Peak	0.76832
W530	3.3899	94.34	30	1.1605	0.28212	Discharge	0.103228	0.10742	Ratio to Peak	0.28073
W540	10.016	94.328	30	20.781	9.5605	Discharge	0.085684	0.070188	Ratio to Peak	0.5
W550	1.3185	99	30	7.6175	2.5304	Discharge	0.870387	0.19993	Ratio to Peak	0.087466
W560	3.526	99	30	9.8884	3.2596	Discharge	0.069153	0.040003	Ratio to Peak	0.12688
W570	6.9395	99	30	0.14157	10.422	Discharge	0.398769	0.08291	Ratio to Peak	0.08612
W580	4.2149	99	30	6.3417	2.9295	Discharge	0.247968	0.050109	Ratio to Peak	0.14368
W590	14.976	99	30	0.016667	16.094	Discharge	0.173158	0.11821	Ratio to Peak	0.035756
W600	7.3847	94.34	30	18.754	0.69689	Discharge	0.003192	0.01513	Ratio to Peak	0.35534
W610	88.824	38.694	30	0.82861	4.6052	Discharge	0.164424	0.013129	Ratio to Peak	0.5
W620	67.778	45.68	30	17.37	39.923	Discharge	0.340998	0.053527	Ratio to Peak	0.5
W630	13.092	65.178	30	0.016667	0.016667	Discharge	0.024586	0.011143	Ratio to Peak	1
W640	21.655	99	30	0.14387	0.0805	Discharge	0.044177	0.077172	Ratio to Peak	0.043774
W650	64	93.177	30	16.778	69.409	Discharge	0.177377	0.01307	Ratio to Peak	0.5
W660	0.019479	99	30	4.3479	2.9208	Discharge	0.410991	0.026825	Ratio to Peak	0.057039

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W670	8.0787	94.34	30	2.7409	0.95545	Discharge	0.044793	0.003885	Ratio to Peak	0.15535
W680	42.782	39.752	30	68.374	1000	Discharge	0.190214	0.003947	Ratio to Peak	1
W690	16.17	42.389	30	26.261	1000	Discharge	0.434217	1.00E-05	Ratio to Peak	0.4379
W700	19.459	48.535	30	0.12079	1000	Discharge	0.16714	0.009201	Ratio to Peak	0.10884
W710	12.596	48.533	30	0.016667	701.55	Discharge	0.124651	0.010439	Ratio to Peak	0.995
W720	73.83	40.642	30	8.8808	263.51	Discharge	0.048696	0.00036	Ratio to Peak	0.5
W730	62.4	39.773	30	17.73	1000	Discharge	0.189043	0.00023	Ratio to Peak	0.0009
W740	18.127	60.716	30	11.919	1000	Discharge	0.394002	1.00E-05	Ratio to Peak	1
W750	28.093	35.847	30	15.88	460.35	Discharge	0.354018	0.006617	Ratio to Peak	0.50477
W760	52.076	66	30	12.702	113.55	Discharge	0.331212	0.009957	Ratio to Peak	0.35
W770	37.641	38.482	30	0.3506	12.199	Discharge	0.559965	0.010982	Ratio to Peak	0.5
W780	73.444	60.728	30	11.667	1000	Discharge	0.09168	0.020208	Ratio to Peak	1
W790	87.63	99	30	0.32288	54.914	Discharge	0.168787	0.005707	Ratio to Peak	0.5
W800	14.473	52.917	30	17.75	370.15	Discharge	0.011827	3.87E-05	Ratio to Peak	1
W810	82.1	57.577	30	11.512	272.98	Discharge	0.43827	3.87E-05	Ratio to Peak	0.4975
W820	72.765	99	30	10.044	504.24	Discharge	0.31752	0.02018	Ratio to Peak	0.5
W830	64.136	55.906	30	9.1191	405.25	Discharge	0.143651	2.69E-05	Ratio to Peak	0.80365
W840	20.43	52.782	30	5.2801	675.44	Discharge	0.272076	5.80E-05	Ratio to Peak	1
W850	49.528	66.679	30	8.0715	660.1	Discharge	0.320922	8.82E-05	Ratio to Peak	0.34034
W860	77.869	45.237	30	11.677	1000	Discharge	0.149295	0.005004	Ratio to Peak	0.48973
W870	71.887	87.412	30	0.016667	5.3835	Discharge	0.168121	0.001025	Ratio to Peak	0.4925
W880	52.744	58.356	30	12.286	894.32	Discharge	0.375669	3.85E-05	Ratio to Peak	0.37115
W890	23.538	59.639	30	34.572	28.078	Discharge	0.203055	6.74E-05	Ratio to Peak	0.5
W900	23.538	55.016	30	21.719	14.404	Discharge	0.240744	0.00013	Ratio to Peak	0.5

Annex 10. Maragondon Model Reach Parameters

Table A-10.1. Maragondon Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R10	Automatic Fixed Interval	1262.8	0.007392	0.0001	Trapezoid	25	1
R100	Automatic Fixed Interval	2837.2	0.010118	0.73433	Trapezoid	25	1
R110	Automatic Fixed Interval	285.56	0.001871	0.381	Trapezoid	25	1
R120	Automatic Fixed Interval	1839.9	0.022739	1	Trapezoid	25	1
R130	Automatic Fixed Interval	1237.8	0.009004	0.021586	Trapezoid	25	1
R150	Automatic Fixed Interval	4367.3	0.024366	0.34576	Trapezoid	25	1
R160	Automatic Fixed Interval	4737	0.009779	0.034311	Trapezoid	25	1
R180	Automatic Fixed Interval	1371.2	0.008544	0.049309	Trapezoid	25	1
R190	Automatic Fixed Interval	1672.4	0.024307	0.0001	Trapezoid	25	1
R20	Automatic Fixed Interval	4393	0.00845	0.0001	Trapezoid	25	1
R210	Automatic Fixed Interval	6266.7	0.022173	0.21192	Trapezoid	25	1
R250	Automatic Fixed Interval	6256.1	0.022017	0.014182	Trapezoid	25	1
R260	Automatic Fixed Interval	4410.2	0.024523	0.050381	Trapezoid	25	1
R280	Automatic Fixed Interval	691.13	0.017038	0.011489	Trapezoid	25	1
R300	Automatic Fixed Interval	6043.4	0.023692	0.036113	Trapezoid	25	1
R320	Automatic Fixed Interval	3309.5	0.021454	0.0001	Trapezoid	25	1
R390	Automatic Fixed Interval	6530.4	0.026128	0.0001	Trapezoid	25	1
R40	Automatic Fixed Interval	2146.2	0.008427	0.0001	Trapezoid	25	1
R50	Automatic Fixed Interval	4779.5	0.003551	0.0001	Trapezoid	25	1
R60	Automatic Fixed Interval	1952.1	0.017179	0.0001	Trapezoid	25	1
R80	Automatic Fixed Interval	2157.2	0.017555	0.0001	Trapezoid	25	1
R90	Automatic Fixed Interval	2068.9	0.018237	0.0001	Trapezoid	25	1

Annex 11. Maragondon Field Validation Points

Table A-11.1. Maragondon Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
1	13.763473	121.406469	0.05	0	-0.05	Glenda/ July 15,2014	5-Year
2	13.76442	121.408607	0.03	0	-0.03	Glenda/ July 15,2014	5-Year
3	13.767886	121.415832	0.03	0	-0.03	Glenda/ July 15,2014	5-Year
4	13.773522	121.268546	0.04	0	-0.04	Glenda/ July 15,2014	5-Year
5	13.774356	121.268245	0.04	0	-0.04	Glenda/ July 15,2014	5-Year
6	13.776135	121.267035	0.03	0	-0.03	Glenda/ July 15,2014	5-Year
8	13.777296	121.266353	0.34	0	-0.34	Glenda/ July 15,2014	5-Year
9	13.777385	121.39892	0.05	0	-0.05	Glenda/ July 15,2014	5-Year
10	13.777946	121.4339	0.36	0	-0.36	Glenda/ July 15,2014	5-Year
11	13.779356	121.42807	0.03	0	-0.03	Glenda/ July 15,2014	5-Year
13	13.780541	121.414407	0.03	0	-0.03	Glenda/ July 15,2014	5-Year
14	13.780708	121.412881	0.43	0	-0.43	Glenda/ July 15,2014	5-Year
15	13.780729	121.41535	0.42	0	-0.42	Glenda/ July 15,2014	5-Year
16	13.781809	121.423296	0.59	0	-0.59	Glenda/ July 15,2014	5-Year
17	13.781906	121.421345	0.04	0	-0.04	Glenda/ July 15,2014	5-Year
18	13.78228	121.404208	0.03	0	-0.03	Glenda/ July 15,2014	5-Year
19	13.782563	121.404374	0.03	0	-0.03	Glenda/ July 15,2014	5-Year
20	13.782844	121.406204	0.61	0	-0.61	Glenda/ July 15,2014	5-Year
21	13.783084	121.267005	0.72	0	-0.72	Glenda/ July 15,2014	5-Year
22	13.783536	121.410163	0.03	0	-0.03	Glenda/ July 15,2014	5-Year
24	13.788092	121.436544	1.86	0	-1.86	Glenda/ July 15,2014	5-Year
25	13.788712	121.28659	0.06	0	-0.06	Glenda/ July 15,2014	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
26	13.788721	121.286634	0.07	3	2.93	Glenda/ July 15,2014	5-Year
27	13.789492	121.286496	0.83	0	-0.83	Glenda/ July 15,2014	5-Year
28	13.789608	121.274983	0.32	0	-0.32	Glenda/ July 15,2014	5-Year
29	13.789969	121.406005	0.99	0	-0.99	Glenda/ July 15,2014	5-Year
30	13.790194	121.421433	0.14	0	-0.14	Glenda/ July 15,2014	5-Year
31	13.790899	121.411754	0.08	0	-0.08	Glenda/ July 15,2014	5-Year
32	13.791126	121.2861	0.03	0	-0.03	Glenda/ July 15,2014	5-Year
33	13.791256	121.414656	0.18	0	-0.18	Glenda/ July 15,2014	5-Year
34	13.791315	121.421527	0.03	0	-0.03	Glenda/ July 15,2014	5-Year
35	13.791897	121.419066	0.03	0	-0.03	Glenda/ July 15,2014	5-Year
37	13.792479	121.426609	0.03	0	-0.03	Glenda/ July 15,2014	5-Year
38	13.792797	121.2635	0.03	0	-0.03	Glenda/ July 15,2014	5-Year
39	13.797134	121.313464	0.03	0	-0.03	Glenda/ July 15,2014	5-Year
40	13.798602	121.404948	0.56	0	-0.56	Glenda/ July 15,2014	5-Year
41	13.800846	121.374928	0.05	0	-0.05	Glenda/ July 15,2014	5-Year
42	13.801886	121.372138	0.03	0	-0.03	Glenda/ July 15,2014	5-Year
43	13.801898	121.368845	0.03	0	-0.03	Glenda/ July 15,2014	5-Year
44	13.802871	121.371352	0.03	0	-0.03	Glenda/ July 15,2014	5-Year
45	13.803242	121.418152	0.67	0	-0.67	Glenda/ July 15,2014	5-Year
46	13.803456	121.380941	0.77	0	-0.77	Glenda/ July 15,2014	5-Year
48	13.80568	121.318987	0.03	0	-0.03	Glenda/ July 15,2014	5-Year
49	13.807909	121.316893	0.27	0	-0.27	Glenda/ July 15,2014	5-Year
50	13.808068	121.408145	0.49	0	-0.49	Glenda/ July 15,2014	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
51	13.808536	121.404371	0.07	0	-0.07	Glenda/ July 15,2014	5-Year
52	13.808741	121.391333	0.22	0	-0.22	Glenda/ July 15,2014	5-Year
53	13.808798	121.38988	0.28	0	-0.28	Glenda/ July 15,2014	5-Year
54	13.809279	121.398013	0.18	0	-0.18	Glenda/ July 15,2014	5-Year
55	13.809518	121.403707	0.95	0	-0.95	Glenda/ July 15,2014	5-Year
56	13.810019	121.394161	0.91	0	-0.91	Glenda/ July 15,2014	5-Year
57	13.810352	121.399493	0.03	0	-0.03	Glenda/ July 15,2014	5-Year
58	13.810508	121.403035	0.05	0	-0.05	Glenda/ July 15,2014	5-Year
59	13.811375	121.401641	0.03	0	-0.03	Glenda/ July 15,2014	5-Year
60	13.812705	121.43678	0.14	0	-0.14	Glenda/ July 15,2014	5-Year
61	13.815378	121.351167	0.03	0	-0.03	Glenda/ July 15,2014	5-Year
62	13.816349	121.322503	0.03	0	-0.03	Glenda/ July 15,2014	5-Year
63	13.819648	121.26578	0.04	0	-0.04	Glenda/ July 15,2014	5-Year
64	13.820267	121.396755	0.13	0	-0.13	Glenda/ July 15,2014	5-Year
65	13.820376	121.325865	4.97	0	-4.97	Glenda/ July 15,2014	5-Year
66	13.821065	121.397132	0.08	0	-0.08	Glenda/ July 15,2014	5-Year
67	13.822799	121.282438	0.04	0	-0.04	Glenda/ July 15,2014	5-Year
68	13.823059	121.434992	0.05	0	-0.05	Glenda/ July 15,2014	5-Year
69	13.823666	121.39106	0.64	0	-0.64	Glenda/ July 15,2014	5-Year
70	13.824464	121.261658	0.03	0	-0.03	Glenda/ July 15,2014	5-Year
71	13.824918	121.390763	0.92	0	-0.92	Glenda/ July 15,2014	5-Year
72	13.824954	121.40305	1.22	0	-1.22	Glenda/ July 15,2014	5-Year
73	13.825198	121.287914	0.4	0	-0.4	Glenda/ July 15,2014	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
74	13.825536	121.402769	1.14	0	-1.14	Glenda/ July 15,2014	5-Year
75	13.82556	121.247744	0.59	0	-0.59	Glenda/ July 15,2014	5-Year
76	13.82577	121.404373	0.11	0	-0.11	Glenda/ July 15,2014	5-Year
77	13.825799	121.405123	0.95	0	-0.95	Glenda/ July 15,2014	5-Year
78	13.825984	121.433254	0.03	0	-0.03	Glenda/ July 15,2014	5-Year
79	13.826074	121.407243	0.12	0	-0.12	Glenda/ July 15,2014	5-Year
80	13.826404	121.384006	0.26	0	-0.26	Glenda/ July 15,2014	5-Year
81	13.826746	121.397004	0.21	0	-0.21	Glenda/ July 15,2014	5-Year
82	13.826752	121.410305	0.06	0	-0.06	Glenda/ July 15,2014	5-Year
83	13.826808	121.291709	0.03	0	-0.03	Glenda/ July 15,2014	5-Year
84	13.826932	121.2588	0.03	0	-0.03	Glenda/ July 15,2014	5-Year
85	13.827501	121.378474	0.07	0	-0.07	Glenda/ July 15,2014	5-Year
86	13.827536	121.331049	0.94	0	-0.94	Glenda/ July 15,2014	5-Year
87	13.827886	121.375372	0.03	0	-0.03	Glenda/ July 15,2014	5-Year
88	13.828183	121.34181	0.87	0	-0.87	Glenda/ July 15,2014	5-Year
89	13.828325	121.347015	0.03	0	-0.03	Glenda/ July 15,2014	5-Year
90	13.828858	121.368961	0.62	0	-0.62	Glenda/ July 15,2014	5-Year
91	13.828983	121.389415	0.44	0	-0.44	Glenda/ July 15,2014	5-Year
93	13.829226	121.357916	0.03	0	-0.03	Glenda/ July 15,2014	5-Year
94	13.829689	121.255488	0.03	0	-0.03	Glenda/ July 15,2014	5-Year
96	13.829989	121.392949	0.08	0	-0.08	Glenda/ July 15,2014	5-Year
97	13.829996	121.42326	0.45	0	-0.45	Glenda/ July 15,2014	5-Year
98	13.830542	121.393118	0.03	0	-0.03	Glenda/ July 15,2014	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
99	13.83056	121.299246	0.05	0	-0.05	Glenda/ July 15,2014	5-Year
100	13.830562	121.295557	0.25	0	-0.25	Glenda/ July 15,2014	5-Year
101	13.830643	121.395026	0.07	0	-0.07	Glenda/ July 15,2014	5-Year
102	13.830823	121.426295	0.12	0	-0.12	Glenda/ July 15,2014	5-Year
103	13.830851	121.407767	0.33	1	0.67	Glenda/ July 15,2014	5-Year
104	13.831255	121.395895	0.8	0	-0.8	Glenda/ July 15,2014	5-Year
105	13.831875	121.429835	0.07	0	-0.07	Glenda/ July 15,2014	5-Year
106	13.832032	121.252872	0.03	0	-0.03	Glenda/ July 15,2014	5-Year
107	13.832137	121.393325	0.76	0	-0.76	Glenda/ July 15,2014	5-Year
108	13.832534	121.303686	0.25	0	-0.25	Glenda/ July 15,2014	5-Year
109	13.832713	121.408845	0.08	0	-0.08	Glenda/ July 15,2014	5-Year
110	13.83288	121.255161	0.51	0	-0.51	Glenda/ July 15,2014	5-Year
111	13.83298	121.406201	0.27	0	-0.27	Glenda/ July 15,2014	5-Year
112	13.833132	121.24761	0.35	0	-0.35	Glenda/ July 15,2014	5-Year
113	13.833402	121.30719	1.25	0	-1.25	Glenda/ July 15,2014	5-Year
114	13.833567	121.251177	0.21	0	-0.21	Glenda/ July 15,2014	5-Year
115	13.833631	121.395111	0.1	1	0.9	Glenda/ July 15,2014	5-Year
116	13.83373	121.395055	0.72	0	-0.72	Glenda/ July 15,2014	5-Year
117	13.833752	121.25755	0.44	0	-0.44	Glenda/ July 15,2014	5-Year
118	13.833815	121.408537	1.66	0	-1.66	Glenda/ July 15,2014	5-Year
119	13.834228	121.395024	0.17	0	-0.17	Glenda/ July 15,2014	5-Year
120	13.834364	121.409053	0.07	0	-0.07	Glenda/ July 15,2014	5-Year
121	13.834702	121.312528	0.04	0	-0.04	Glenda/ July 15,2014	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
122	13.836385	121.318751	0.03	0	-0.03	Glenda/ July 15,2014	5-Year
123	13.837374	121.367964	0.04	0	-0.04	Glenda/ July 15,2014	5-Year
124	13.838545	121.268957	0.04	0	-0.04	Glenda/ July 15,2014	5-Year
125	13.838648	121.367963	0.05	0	-0.05	Glenda/ July 15,2014	5-Year
126	13.83968	121.269056	0.09	0	-0.09	Glenda/ July 15,2014	5-Year
127	13.839876	121.243696	0.03	0	-0.03	Glenda/ July 15,2014	5-Year
129	13.842062	121.280149	0.07	0	-0.07	Glenda/ July 15,2014	5-Year
130	13.843159	121.240186	0.09	0	-0.09	Glenda/ July 15,2014	5-Year
131	13.843598	121.288974	0.08	0	-0.08	Glenda/ July 15,2014	5-Year
132	13.843646	121.287238	0.09	0	-0.09	Glenda/ July 15,2014	5-Year
133	13.84415	121.293874	0.13	0	-0.13	Glenda/ July 15,2014	5-Year
134	13.844668	121.237951	0.14	0	-0.14	Glenda/ July 15,2014	5-Year
135	13.844756	121.301878	0.27	0	-0.27	Glenda/ July 15,2014	5-Year
136	13.84739	121.319178	0.12	0	-0.12	Glenda/ July 15,2014	5-Year
137	13.84915	121.324253	0.46	0	-0.46	Glenda/ July 15,2014	5-Year
138	13.850171	121.327511	0.21	0	-0.21	Glenda/ July 15,2014	5-Year
139	13.850296	121.328347	0.08	0	-0.08	Glenda/ July 15,2014	5-Year
140	13.85041	121.329213	0.11	0	-0.11	Glenda/ July 15,2014	5-Year
141	13.850534	121.330049	0.3	0	-0.3	Glenda/ July 15,2014	5-Year
142	13.850746	121.331239	1.64	0	-1.64	Glenda/ July 15,2014	5-Year
143	13.850948	121.332186	0.37	0	-0.37	Glenda/ July 15,2014	5-Year
144	13.859363	121.344453	0.04	0	-0.04	Glenda/ July 15,2014	5-Year
145	13.862602	121.349711	0.08	0	-0.08	Glenda/ July 15,2014	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
146	13.863389	121.344665	0.1	0	-0.1	Glenda/ July 15,2014	5-Year
147	13.863452	121.342849	0.08	0	-0.08	Glenda/ July 15,2014	5-Year
148	13.863484	121.343481	0.26	0	-0.26	Glenda/ July 15,2014	5-Year
149	13.863486	121.344376	0.09	1	0.91	Glenda/ July 15,2014	5-Year
150	13.863512	121.344019	0.03	0	-0.03	Glenda/ July 15,2014	5-Year
151	13.863874	121.30641	0.03	0	-0.03	Glenda/ July 15,2014	5-Year
152	13.863908	121.306013	0.5	0	-0.5	Glenda/ July 15,2014	5-Year
153	13.867728	121.334571	0.94	0	-0.94	Glenda/ July 15,2014	5-Year
154	13.867941	121.300511	0.79	0	-0.79	Glenda/ July 15,2014	5-Year
155	13.872914	121.321437	0.97	0	-0.97	Glenda/ July 15,2014	5-Year
156	13.873803	121.323622	0.96	0	-0.96	Glenda/ July 15,2014	5-Year
157	13.874754	121.300344	1.1	0	-1.1	Glenda/ July 15,2014	5-Year
158	13.825815	121.404328	0.81	0	-0.81	Glenda/ July 15,2014	5-Year
159	13.826106	121.404209	1.26	0	-1.26	Glenda/ July 15,2014	5-Year
160	13.8248	121.407747	0.04	0	-0.04	Glenda/ July 15,2014	5-Year
161	13.836449	121.417739	0.95	0	-0.95	Glenda/ July 15,2014	5-Year
162	13.826351	121.409359	0.03	0	-0.03	Glenda/ July 15,2014	5-Year
163	13.826006	121.407203	0.47	0	-0.47	Glenda/ July 15,2014	5-Year
164	13.828785	121.418982	0.35	1	0.65	Glenda/ July 15,2014	5-Year
165	13.829643	121.422446	0.03	1	0.97	Glenda/ July 15,2014	5-Year
166	13.825991	121.405586	0.35	0	-0.35	Glenda/ July 15,2014	5-Year
167	13.831198	121.423943	0.89	2	1.11	Glenda/ July 15,2014	5-Year
168	13.830737	121.423872	0.73	2	1.27	Glenda/ July 15,2014	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
169	13.812816	121.42659	0.63	1	0.37	Glenda/ July 15,2014	5-Year
170	13.839846	121.398472	0.56	1	0.44	Glenda/ July 15,2014	5-Year
171	13.840853	121.396846	0.3	1	0.7	Glenda/ July 15,2014	5-Year
172	13.842973	121.396991	0.42	1	0.58	Glenda/ July 15,2014	5-Year
173	13.827065	121.412168	0.1	1	0.9	Glenda/ July 15,2014	5-Year
174	13.834507	121.405136	1.01	1	-0.01	Glenda/ July 15,2014	5-Year
175	13.836459	121.403731	0.03	1	0.97	Glenda/ July 15,2014	5-Year
176	13.837587	121.403096	1.21	1	-0.21	Glenda/ July 15,2014	5-Year
177	13.839071	121.402289	0.45	1	0.55	Glenda/ July 15,2014	5-Year
178	13.839503	121.400533	0.03	1	0.97	Glenda/ July 15,2014	5-Year
179	13.821787	121.414009	0.03	0	-0.03	Glenda/ July 15,2014	5-Year
180	13.816727	121.414746	3.04	0	-3.04	Glenda/ July 15,2014	5-Year
181	13.825832	121.411563	0.03	0	-0.03	Glenda/ July 15,2014	5-Year
182	13.812572	121.421986	0.09	1	0.91	Glenda/ July 15,2014	5-Year
183	13.813411	121.420719	0.63	1	0.37	Glenda/ July 15,2014	5-Year
184	13.812566	121.424879	1.55	2	0.45	Glenda/ July 15,2014	5-Year
185	13.814001	121.419459	0.64	4	3.36	Glenda/ July 15,2014	5-Year
186	13.813939	121.417506	0.66	5	4.34	Glenda/ July 15,2014	5-Year
187	13.834381	121.423303	3.57	0	-3.57	Glenda/ July 15,2014	5-Year
188	13.825815	121.404328	1	0.5	-0.5	Glenda/ July 15,2014	5-Year
189	13.826106	121.404209	1.26	0.5	-0.76	Glenda/ July 15,2014	5-Year
190	13.8248	121.407747	1.18	0.5	-0.68	Glenda/ July 15,2014	5-Year
191	13.828049	121.416082	1.22	0.5	-0.72	Glenda/ July 15,2014	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
192	13.836449	121.417739	0.66	0.5	-0.16	Glenda/ July 15,2014	5-Year
193	13.826351	121.409359	0.95	1.5	0.55	Glenda/ July 15,2014	5-Year
194	13.826006	121.407203	0.96	1.5	0.54	Glenda/ July 15,2014	5-Year
195	13.828785	121.418982	1.65	1	-0.65	Glenda/ July 15,2014	5-Year
196	13.829643	121.422446	0.7	1	0.3	Glenda/ July 15,2014	5-Year
197	13.825991	121.405586	1.14	0	-1.14	Glenda/ July 15,2014	5-Year
198	13.831198	121.423943	0.05	2	1.95	Glenda/ July 15,2014	5-Year
199	13.827497	121.413906	0.79	0.5	-0.29	Glenda/ July 15,2014	5-Year
200	13.812816	121.42659	0.21	1	0.79	Glenda/ July 15,2014	5-Year
201	13.839846	121.398472	0.42	1	0.58	Glenda/ July 15,2014	5-Year
202	13.840853	121.396846	0.37	1	0.63	Glenda/ July 15,2014	5-Year
203	13.842973	121.396991	0.03	1	0.97	Glenda/ July 15,2014	5-Year
204	13.845156	121.396346	0.04	1	0.96	Glenda/ July 15,2014	5-Year
205	13.827065	121.412168	1.74	1	-0.74	Glenda/ July 15,2014	5-Year
206	13.834507	121.405136	0.38	1	0.62	Glenda/ July 15,2014	5-Year
207	13.836459	121.403731	0.42	1	0.58	Glenda/ July 15,2014	5-Year
208	13.837587	121.403096	0.39	1	0.61	Glenda/ July 15,2014	5-Year
209	13.839071	121.402289	0.12	1	0.88	Glenda/ July 15,2014	5-Year
210	13.839503	121.400533	0.3	1	0.7	Glenda/ July 15,2014	5-Year
211	13.83387	121.40571	0.51	1	0.49	Glenda/ July 15,2014	5-Year
212	13.821787	121.414009	0.29	0.3	0.01	Glenda/ July 15,2014	5-Year
213	13.816727	121.414746	0.05	0.2	0.15	Glenda/ July 15,2014	5-Year
214	13.825832	121.411563	0.59	0.3	-0.29	Glenda/ July 15,2014	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
215	13.812572	121.421986	1.02	1	-0.02	Glenda/ July 15,2014	5-Year
216	13.812688	121.423875	0.03	1	0.97	Glenda/ July 15,2014	5-Year
217	13.813411	121.420719	0.45	1	0.55	Glenda/ July 15,2014	5-Year
218	13.812587	121.425503	0.03	2	1.97	Glenda/ July 15,2014	5-Year
219	13.813939	121.417506	0.16	5	4.84	Glenda/ July 15,2014	5-Year
220	13.833646	121.423517	0.03	1.5	1.47	Glenda/ July 15,2014	5-Year
221	13.834381	121.423303	0.11	1.5	1.39	Glenda/ July 15,2014	5-Year
222	13.835921	121.423301	0.03	1.5	1.47	Glenda/ July 15,2014	5-Year
223	13.836003	121.422207	0.63	1.5	0.87	Glenda/ July 15,2014	5-Year
224	13.836052	121.419889	1.55	1.5	-0.05	Glenda/ July 15,2014	5-Year
225	13.836018	121.418524	0.64	1.5	0.86	Glenda/ July 15,2014	5-Year
226	13.832928	121.423813	3.16	1.5	-1.66	Glenda/ July 15,2014	5-Year
227	13.832025	121.42382	0.03	1	0.97	Glenda/ July 15,2014	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
1	120.7369	14.27419	0.63	0.1	-0.53	Milenyo/Sept. 28, 2006	5-Year
2	120.7363	14.27426	0.63	0.1	-0.53	Milenyo/Sept. 28, 2006	5-Year
3	120.7364	14.27296	0.8	0.1	-0.7	Milenyo/Sept. 28, 2006	5-Year
4	120.735	14.27119	10.13	0.1	-10.03	Milenyo/Sept. 28, 2006	5-Year
5	120.735	14.27128	5.15	0.1	-5.0500001	Milenyo/Sept. 28, 2006	5-Year
6	120.7351	14.27129	1.04	0.1	-0.94	Milenyo/Sept. 28, 2006	5-Year
7	120.7351	14.27129	1.27	0.1	-1.17	Milenyo/Sept. 28, 2006	5-Year
8	120.735	14.27129	1.78	0.1	-1.68	Milenyo/Sept. 28, 2006	5-Year
9	120.7351	14.2713	0.85	0.1	-0.75	Milenyo/Sept. 28, 2006	5-Year
10	120.7351	14.2713	1.13	0.1	-1.03	Milenyo/Sept. 28, 2006	5-Year
11	120.7375	14.27252	1.24	0.1	-1.14	Milenyo/Sept. 28, 2006	5-Year
12	120.7363	14.27429	0.66	0.1	-0.56	Milenyo/Sept. 28, 2006	5-Year
13	120.7386	14.27214	0.97	0.1	-0.87	Milenyo/Sept. 28, 2006	5-Year
14	120.7443	14.27236	0.89	0.1	-0.79	Milenyo/Sept. 28, 2006	5-Year
15	120.7468	14.27269	0.62	0.1	-0.52	Milenyo/Sept. 28, 2006	5-Year
16	120.7481	14.27282	0.35	0.1	-0.25	Milenyo/Sept. 28, 2006	5-Year
17	120.7496	14.27299	0.03	0.1	0.07	Milenyo/Sept. 28, 2006	5-Year
18	120.752	14.2732	0.4	0.1	-0.3	Milenyo/Sept. 28, 2006	5-Year
19	120.753	14.2733	0.21	0.1	-0.11	Milenyo/Sept. 28, 2006	5-Year
20	120.7539	14.27338	0.03	0.1	0.07	Milenyo/Sept. 28, 2006	5-Year
21	120.7553	14.27345	0.03	0.1	0.07	Milenyo/Sept. 28, 2006	5-Year
22	120.758	14.27371	0.07	0.1	0.03	Milenyo/Sept. 28, 2006	5-Year
23	120.7341	14.27362	0.15	0.1	-0.05	Milenyo/Sept. 28, 2006	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
24	120.7604	14.27397	0.03	0.1	0.07	Milenyo/Sept. 28, 2006	5-Year
25	120.7635	14.27425	0.17	0.1	-0.07	Milenyo/Sept. 28, 2006	5-Year
26	120.7658	14.27448	0.05	0.1	0.05	Milenyo/Sept. 28, 2006	5-Year
27	120.7669	14.27459	0.03	0.1	0.07	Milenyo/Sept. 28, 2006	5-Year
28	120.7686	14.27473	0.03	0.1	0.07	Milenyo/Sept. 28, 2006	5-Year
29	120.7714	14.27008	0.05	0.1	0.05	Milenyo/Sept. 28, 2006	5-Year
30	120.7714	14.26912	0.06	0.1	0.04	Milenyo/Sept. 28, 2006	5-Year
31	120.7711	14.26866	0.03	0.1	0.07	Milenyo/Sept. 28, 2006	5-Year
32	120.7697	14.2696	0.06	0.1	0.04	Milenyo/Sept. 28, 2006	5-Year
33	120.7687	14.26981	0.08	0.1	0.02	Milenyo/Sept. 28, 2006	5-Year
34	120.7338	14.27362	0.08	0.1	0.02	Milenyo/Sept. 28, 2006	5-Year
35	120.7677	14.27006	18.98	0.1	-18.88	Milenyo/Sept. 28, 2006	5-Year
36	120.7663	14.27028	0.97	0.1	-0.87	Milenyo/Sept. 28, 2006	5-Year
37	120.7641	14.27085	0.03	0.1	0.07	Milenyo/Sept. 28, 2006	5-Year
38	120.7636	14.27105	0.03	0.1	0.07	Milenyo/Sept. 28, 2006	5-Year
39	120.7625	14.27143	0.03	0.1	0.07	Milenyo/Sept. 28, 2006	5-Year
40	120.7614	14.27174	0.03	0.1	0.07	Milenyo/Sept. 28, 2006	5-Year
41	120.7586	14.27229	0.12	0.1	-0.02	Milenyo/Sept. 28, 2006	5-Year
42	120.7376	14.27408	1.11	0.1	-1.01	Milenyo/Sept. 28, 2006	5-Year
43	120.7336	14.27365	1.17	0.1	-1.07	Milenyo/Sept. 28, 2006	5-Year
44	120.7333	14.27368	0.12	0.1	-0.02	Milenyo/Sept. 28, 2006	5-Year
45	120.733	14.27366	0.09	0.1	0.01	Milenyo/Sept. 28, 2006	5-Year
46	120.7328	14.27367	0.17	0.1	-0.07	Milenyo/Sept. 28, 2006	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
47	120.7347	14.27388	0.43	0.1	-0.33	Milenyo/Sept. 28, 2006	5-Year
48	120.7425	14.27212	0.85	0.1	-0.75	Milenyo/Sept. 28, 2006	5-Year
49	120.7711	14.26866	0.08	0.1	0.02	Milenyo/Sept. 28, 2006	5-Year
50	120.7478	14.27285	0.03	0.1	0.07	Milenyo/Sept. 28, 2006	5-Year
51	120.7348	14.27387	0.03	0.1	0.07	Milenyo/Sept. 28, 2006	5-Year
52	120.7348	14.27385	0.23	0.1	-0.13	Milenyo/Sept. 28, 2006	5-Year
53	120.7349	14.27384	0.06	0.1	0.04	Milenyo/Sept. 28, 2006	5-Year
54	120.7349	14.27384	0.03	0.1	0.07	Milenyo/Sept. 28, 2006	5-Year
55	120.7349	14.27385	0.07	0.1	0.03	Milenyo/Sept. 28, 2006	5-Year
56	120.7352	14.27384	0.03	0.1	0.07	Milenyo/Sept. 28, 2006	5-Year
57	120.7367	14.27519	0.14	0.1	-0.04	Milenyo/Sept. 28, 2006	5-Year
58	120.7372	14.2761	0.04	0.1	0.06	Milenyo/Sept. 28, 2006	5-Year
59	120.7356	14.27697	0.03	0.1	0.07	Milenyo/Sept. 28, 2006	5-Year
60	120.7692	14.26971	0.03	0.1	0.07	Milenyo/Sept. 28, 2006	5-Year
61	120.73	14.27984	0.03	0.1	0.07	Milenyo/Sept. 28, 2006	5-Year
62	120.7294	14.28016	0.03	0.1	0.07	Milenyo/Sept. 28, 2006	5-Year
63	120.7243	14.28272	0.14	0.1	-0.04	Milenyo/Sept. 28, 2006	5-Year
64	120.7215	14.28406	0.03	0.1	0.07	Milenyo/Sept. 28, 2006	5-Year
65	120.7202	14.28398	0.03	0.1	0.07	Milenyo/Sept. 28, 2006	5-Year
66	120.7179	14.28325	0.42	0.1	-0.32	Milenyo/Sept. 28, 2006	5-Year
67	120.7131	14.28266	0.32	0.1	-0.22	Milenyo/Sept. 28, 2006	5-Year
68	120.7127	14.2827	0.1	0.1	0	Milenyo/Sept. 28, 2006	5-Year
69	120.7109	14.28319	0.61	0.1	-0.51	Milenyo/Sept. 28, 2006	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
70	120.7313	14.30074	0.43	0.1	-0.33	Milenyo/Sept. 28, 2006	5-Year
71	120.7662	14.2703	12.25	0.1	-12.15	Milenyo/Sept. 28, 2006	5-Year
72	120.7322	14.30252	0.82	0.1	-0.72	Milenyo/Sept. 28, 2006	5-Year
73	120.7328	14.30372	1.04	0.1	-0.94	Milenyo/Sept. 28, 2006	5-Year
74	120.7353	14.31177	1.11	0.1	-1.01	Milenyo/Sept. 28, 2006	5-Year
75	120.7371	14.31317	0.03	0.1	0.07	Milenyo/Sept. 28, 2006	5-Year
76	120.7373	14.31244	0.03	0.1	0.07	Milenyo/Sept. 28, 2006	5-Year
77	120.7404	14.31301	0.49	0.1	-0.39	Milenyo/Sept. 28, 2006	5-Year
78	120.7418	14.31283	0.03	0.1	0.07	Milenyo/Sept. 28, 2006	5-Year
79	120.7431	14.3132	0.03	0.1	0.07	Milenyo/Sept. 28, 2006	5-Year
80	120.7521	14.31791	0.03	0.1	0.07	Milenyo/Sept. 28, 2006	5-Year
81	120.7543	14.32184	0.47	0.1	-0.37	Milenyo/Sept. 28, 2006	5-Year
82	120.7606	14.27195	0.11	0.1	-0.01	Milenyo/Sept. 28, 2006	5-Year
83	120.756	14.32376	0.19	0.1	-0.09	Milenyo/Sept. 28, 2006	5-Year
84	120.757	14.32046	0.49	0.1	-0.39	Milenyo/Sept. 28, 2006	5-Year
85	120.7591	14.31867	0.55	0.1	-0.45	Milenyo/Sept. 28, 2006	5-Year
86	120.7597	14.31848	0.46	0.1	-0.36	Milenyo/Sept. 28, 2006	5-Year
87	120.7633	14.31788	0.04	0.1	0.06	Milenyo/Sept. 28, 2006	5-Year
88	120.7635	14.31695	0.11	0.1	-0.01	Milenyo/Sept. 28, 2006	5-Year
89	120.764	14.31695	0.58	0.1	-0.48	Milenyo/Sept. 28, 2006	5-Year
90	120.765	14.3176	0.67	0.1	-0.57	Milenyo/Sept. 28, 2006	5-Year
91	120.7645	14.31841	0.69	0.1	-0.59	Milenyo/Sept. 28, 2006	5-Year
92	120.7641	14.31907	0.03	0.1	0.07	Milenyo/Sept. 28, 2006	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
93	120.7542	14.27346	1.57	0.1	-1.4700001	Milenyo/Sept. 28, 2006	5-Year
94	120.7643	14.31933	1.45	0.1	-1.35	Milenyo/Sept. 28, 2006	5-Year
95	120.7658	14.32075	0.21	0.1	-0.11	Milenyo/Sept. 28, 2006	5-Year
96	120.765	14.32166	0.74	0.1	-0.64	Milenyo/Sept. 28, 2006	5-Year
97	120.763	14.32237	0.28	0.1	-0.18	Milenyo/Sept. 28, 2006	5-Year
98	120.7621	14.32182	0.07	0.1	0.03	Milenyo/Sept. 28, 2006	5-Year
99	120.7615	14.32156	0.27	0.1	-0.17	Milenyo/Sept. 28, 2006	5-Year
100	120.7605	14.32126	0.59	0.1	-0.49	Milenyo/Sept. 28, 2006	5-Year
101	120.7598	14.32323	0.03	0.1	0.07	Milenyo/Sept. 28, 2006	5-Year
102	120.7644	14.31932	0.12	0.1	-0.02	Milenyo/Sept. 28, 2006	5-Year
103	120.7649	14.31865	25.87	0.1	-25.770001	Milenyo/Sept. 28, 2006	5-Year
104	120.7449	14.27251	0.03	0.1	0.07	Milenyo/Sept. 28, 2006	5-Year
105	120.7664	14.31706	0.23	0.1	-0.13	Milenyo/Sept. 28, 2006	5-Year
106	120.7673	14.31683	0.27	0.1	-0.17	Milenyo/Sept. 28, 2006	5-Year
107	120.7685	14.31591	0.08	0.1	0.02	Milenyo/Sept. 28, 2006	5-Year
108	120.7709	14.31426	0.49	0.1	-0.39	Milenyo/Sept. 28, 2006	5-Year
109	120.7724	14.31294	0.19	0.1	-0.09	Milenyo/Sept. 28, 2006	5-Year
110	120.7723	14.31152	0.49	0.1	-0.39	Milenyo/Sept. 28, 2006	5-Year
111	120.7719	14.31114	0.56	0.1	-0.46	Milenyo/Sept. 28, 2006	5-Year
112	120.7682	14.31551	0.1	0.1	0	Milenyo/Sept. 28, 2006	5-Year
113	120.7706	14.31064	26.45	0.1	-26.350001	Milenyo/Sept. 28, 2006	5-Year
114	120.7705	14.30986	0.03	0.1	0.07	Milenyo/Sept. 28, 2006	5-Year
115	120.7386	14.27293	0.49	0.1	-0.39	Milenyo/Sept. 28, 2006	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
116	120.767	14.30662	0.03	0.1	0.07	Milenyo/Sept. 28, 2006	5-Year
117	120.7655	14.3051	0.4	0.1	-0.3	Milenyo/Sept. 28, 2006	5-Year
118	120.7649	14.30438	0.03	0.1	0.07	Milenyo/Sept. 28, 2006	5-Year
119	120.7629	14.30233	0.38	0.1	-0.28	Milenyo/Sept. 28, 2006	5-Year
120	120.7608	14.30035	0.98	0.1	-0.88	Milenyo/Sept. 28, 2006	5-Year
121	120.7594	14.29899	0.48	0.1	-0.38	Milenyo/Sept. 28, 2006	5-Year
122	120.7589	14.29854	0.03	0.1	0.07	Milenyo/Sept. 28, 2006	5-Year
123	120.7561	14.29577	0.03	0.1	0.07	Milenyo/Sept. 28, 2006	5-Year
124	120.7545	14.29421	0.11	0.1	-0.01	Milenyo/Sept. 28, 2006	5-Year
125	120.7532	14.2929	6.55	0.1	-6.4500002	Milenyo/Sept. 28, 2006	5-Year
126	120.7388	14.27379	0.03	0.1	0.07	Milenyo/Sept. 28, 2006	5-Year
127	120.7518	14.29154	1.19	0.1	-1.0900001	Milenyo/Sept. 28, 2006	5-Year
128	120.751	14.29068	0.2	0.1	-0.1	Milenyo/Sept. 28, 2006	5-Year
129	120.7499	14.28954	0.03	0.1	0.07	Milenyo/Sept. 28, 2006	5-Year
130	120.7481	14.28772	1.86	0.1	-1.76	Milenyo/Sept. 28, 2006	5-Year
131	120.7464	14.28603	1.94	0.1	-1.8400001	Milenyo/Sept. 28, 2006	5-Year
132	120.7436	14.28314	0.04	0.1	0.06	Milenyo/Sept. 28, 2006	5-Year
133	120.7421	14.28154	0.03	0.1	0.07	Milenyo/Sept. 28, 2006	5-Year
134	120.7414	14.28075	0.03	0.1	0.07	Milenyo/Sept. 28, 2006	5-Year
135	120.7369	14.27549	0.03	0.1	0.07	Milenyo/Sept. 28, 2006	5-Year
136	120.7366	14.27509	0.58	0.1	-0.48	Milenyo/Sept. 28, 2006	5-Year
137	120.7714	14.26984	0.31	0.1	-0.21	Milenyo/Sept. 28, 2006	5-Year
138	120.7157	14.28997	0.03	0.2	0.17	Milenyo/Sept. 28, 2006	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
139	120.716	14.29012	0.03	0.2	0.17	Milenyo/Sept. 28, 2006	5-Year
140	120.7163	14.29084	0.35	0.2	-0.15	Milenyo/Sept. 28, 2006	5-Year
141	120.7171	14.29165	0.03	0.2	0.17	Milenyo/Sept. 28, 2006	5-Year
142	120.7177	14.29205	0.14	0.2	0.06	Milenyo/Sept. 28, 2006	5-Year
143	120.7192	14.29304	26.56	0.2	-26.36	Milenyo/Sept. 28, 2006	5-Year
144	120.7204	14.29364	0.52	0.2	-0.32	Milenyo/Sept. 28, 2006	5-Year
145	120.7227	14.29428	0.51	0.2	-0.31	Milenyo/Sept. 28, 2006	5-Year
146	120.7335	14.30607	0.23	0.2	-0.03	Milenyo/Sept. 28, 2006	5-Year
147	120.7342	14.30783	2.45	0.2	-2.25	Milenyo/Sept. 28, 2006	5-Year
148	120.7599	14.27204	1	0.2	-0.8	Milenyo/Sept. 28, 2006	5-Year
149	120.7361	14.31253	1.28	0.2	-1.08	Milenyo/Sept. 28, 2006	5-Year
150	120.7356	14.31374	0.03	0.2	0.17	Milenyo/Sept. 28, 2006	5-Year
151	120.7351	14.31387	0.76	0.2	-0.56	Milenyo/Sept. 28, 2006	5-Year
152	120.7343	14.31377	0.04	0.2	0.16	Milenyo/Sept. 28, 2006	5-Year
153	120.7379	14.31242	0.3	0.2	-0.1	Milenyo/Sept. 28, 2006	5-Year
154	120.7382	14.31235	0.57	0.2	-0.37	Milenyo/Sept. 28, 2006	5-Year
155	120.7438	14.31396	0.04	0.2	0.16	Milenyo/Sept. 28, 2006	5-Year
156	120.7427	14.31444	0.03	0.2	0.17	Milenyo/Sept. 28, 2006	5-Year
157	120.7466	14.31433	0.03	0.2	0.17	Milenyo/Sept. 28, 2006	5-Year
158	120.7491	14.31561	0.03	0.2	0.17	Milenyo/Sept. 28, 2006	5-Year
159	120.7587	14.27229	0.06	0.2	0.14	Milenyo/Sept. 28, 2006	5-Year
160	120.7516	14.31752	0.05	0.2	0.15	Milenyo/Sept. 28, 2006	5-Year
161	120.7522	14.31951	0.72	0.2	-0.52	Milenyo/Sept. 28, 2006	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
162	120.7522	14.31964	0.65	0.2	-0.45	Milenyo/Sept. 28, 2006	5-Year
163	120.7533	14.32084	0.68	0.2	-0.48	Milenyo/Sept. 28, 2006	5-Year
164	120.7546	14.32229	0.68	0.2	-0.48	Milenyo/Sept. 28, 2006	5-Year
165	120.7554	14.32306	1.33	0.2	-1.13	Milenyo/Sept. 28, 2006	5-Year
166	120.7548	14.32219	0.03	0.2	0.17	Milenyo/Sept. 28, 2006	5-Year
167	120.756	14.32134	0.34	0.2	-0.14	Milenyo/Sept. 28, 2006	5-Year
168	120.7626	14.31985	13.53	0.2	-13.33	Milenyo/Sept. 28, 2006	5-Year
169	120.7642	14.32295	19.6	0.2	-19.4	Milenyo/Sept. 28, 2006	5-Year
170	120.7348	14.27386	22.36	0.2	-22.160001	Milenyo/Sept. 28, 2006	5-Year
171	120.7637	14.32285	25.91	0.2	-25.71	Milenyo/Sept. 28, 2006	5-Year
172	120.7613	14.32156	0.03	0.2	0.17	Milenyo/Sept. 28, 2006	5-Year
173	120.7597	14.32255	0.03	0.2	0.17	Milenyo/Sept. 28, 2006	5-Year
174	120.759	14.32365	2.31	0.2	-2.1099999	Milenyo/Sept. 28, 2006	5-Year
175	120.7647	14.31961	0.43	0.2	-0.23	Milenyo/Sept. 28, 2006	5-Year
176	120.769	14.31558	8.79	0.2	-8.59	Milenyo/Sept. 28, 2006	5-Year
177	120.7694	14.31525	1.62	0.2	-1.42	Milenyo/Sept. 28, 2006	5-Year
178	120.7699	14.31491	0.98	0.2	-0.78	Milenyo/Sept. 28, 2006	5-Year
179	120.769	14.31375	0.86	0.2	-0.66	Milenyo/Sept. 28, 2006	5-Year
180	120.7686	14.31471	0.66	0.2	-0.46	Milenyo/Sept. 28, 2006	5-Year
181	120.7538	14.27347	0.43	0.2	-0.23	Milenyo/Sept. 28, 2006	5-Year
182	120.7693	14.30774	0.03	0.2	0.17	Milenyo/Sept. 28, 2006	5-Year
183	120.7686	14.30702	1.22	0.2	-1.02	Milenyo/Sept. 28, 2006	5-Year
184	120.7683	14.30693	10.84	0.2	-10.64	Milenyo/Sept. 28, 2006	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
185	120.7534	14.29294	0.3	0.2	-0.1	Milenyo/Sept. 28, 2006	5-Year
186	120.7462	14.2859	4.5	0.2	-4.3	Milenyo/Sept. 28, 2006	5-Year
187	120.7452	14.28481	23.47	0.2	-23.269999	Milenyo/Sept. 28, 2006	5-Year
188	120.7413	14.28064	22.77	0.2	-22.570001	Milenyo/Sept. 28, 2006	5-Year
189	120.7414	14.28042	4.86	0.2	-4.6600001	Milenyo/Sept. 28, 2006	5-Year
190	120.7406	14.2799	0.43	0.2	-0.23	Milenyo/Sept. 28, 2006	5-Year
191	120.7381	14.27665	0.14	0.2	0.06	Milenyo/Sept. 28, 2006	5-Year
192	120.7268	14.2815	6.98	0.2	-6.78	Milenyo/Sept. 28, 2006	5-Year
193	120.7375	14.2761	0.03	0.2	0.17	Milenyo/Sept. 28, 2006	5-Year
194	120.735	14.27127	0.07	0.2	0.13	Milenyo/Sept. 28, 2006	5-Year
195	120.7352	14.27144	0.03	0.2	0.17	Milenyo/Sept. 28, 2006	5-Year
196	120.739	14.27198	0.17	0.2	0.03	Milenyo/Sept. 28, 2006	5-Year
197	120.7415	14.27032	0.03	0.2	0.17	Milenyo/Sept. 28, 2006	5-Year
198	120.7218	14.28391	2.86	0.2	-2.6599999	Milenyo/Sept. 28, 2006	5-Year
199	120.7153	14.28795	1.26	0.2	-1.06	Milenyo/Sept. 28, 2006	5-Year
200	120.7154	14.28853	1.11	0.2	-0.91	Milenyo/Sept. 28, 2006	5-Year
201	120.7714	14.26907	0.03	0.2	0.17	Milenyo/Sept. 28, 2006	5-Year
202	120.7156	14.28716	7.2	0.3	-6.8999998	Milenyo/Sept. 28, 2006	5-Year
203	120.7157	14.28773	0.93	0.3	-0.63	Milenyo/Sept. 28, 2006	5-Year
204	120.7162	14.29054	0.09	0.3	0.21	Milenyo/Sept. 28, 2006	5-Year
205	120.7243	14.29459	15.1	0.3	-14.8	Milenyo/Sept. 28, 2006	5-Year
206	120.7258	14.29533	11.66	0.3	-11.36	Milenyo/Sept. 28, 2006	5-Year
207	120.7285	14.29725	4.44	0.3	-4.1400001	Milenyo/Sept. 28, 2006	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
208	120.7299	14.29881	2.07	0.3	-1.7699999	Milenyo/Sept. 28, 2006	5-Year
209	120.7372	14.31247	4.16	0.3	-3.8599998	Milenyo/Sept. 28, 2006	5-Year
210	120.7344	14.31383	26.09	0.3	-25.79	Milenyo/Sept. 28, 2006	5-Year
211	120.7337	14.31359	3.45	0.3	-3.15	Milenyo/Sept. 28, 2006	5-Year
212	120.7578	14.27271	28.16	0.3	-27.86	Milenyo/Sept. 28, 2006	5-Year
213	120.7436	14.31452	30.64	0.3	-30.339999	Milenyo/Sept. 28, 2006	5-Year
214	8.099861	123.486919	0.03	1.22	-1.190	Typhoon Karen / Oct. 11-12, 2016	5 - Year
215	8.099806	123.486844	0.33	1.60	-1.270	Typhoon Karen / Oct. 11-12, 2016	5 - Year
216	8.099750	123.486842	0.33	2.04	-1.710	Typhoon Karen / Oct. 11-12, 2016	5 - Year
217	8.099861	123.486694	1.28	1.68	-0.403	Typhoon Karen / Oct. 11-12, 2016	5 - Year
218	8.099353	123.487424	4.06	0.80	3.255	Typhoon Karen / Oct. 11-12, 2016	5 - Year
219	8.099448	123.487384	3.62	1.50	2.118	Typhoon Karen / Oct. 11-12, 2016	5 - Year
220	8.099453	123.487412	3.62	1.10	2.518	Typhoon Karen / Oct. 11-12, 2016	5 - Year
221	8.099542	123.487217	3.56	1.10	2.461	Typhoon Karen / Oct. 11-12, 2016	5 - Year
223	8.099687	123.486988	0.03	0.90	-0.870	Typhoon Karen / Oct. 11-12, 2016	5 - Year
224	8.099728	123.486928	0.03	1.50	-1.470	Typhoon Karen / Oct. 11-12, 2016	5 - Year
225	8.099870	123.487040	0.03	0.90	-0.870	Typhoon Karen / Oct. 11-12, 2016	5 - Year
226	8.099840	123.486966	0.03	1.30	-1.270	Typhoon Karen / Oct. 11-12, 2016	5 - Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
227	8.098133	123.488564	0.03	1.50	-1.470	Typhoon Karen / Oct. 11-12, 2016	5 - Year
228	8.098039	123.488739	1.08	1.20	-0.121	Typhoon Karen / Oct. 11-12, 2016	5 - Year
229	8.097956	123.488869	1.04	1.50	-0.459	Typhoon Karen / Oct. 11-12, 2016	5 - Year
230	8.097944	123.488944	0.93	1.63	-0.696	Typhoon Karen / Oct. 11-12, 2016	5 - Year
231	8.098058	123.489000	2.14	2.40	-0.261	Typhoon Karen / Oct. 11-12, 2016	5 - Year
232	8.097997	123.489122	0.86	1.65	-0.795	Typhoon Karen / Oct. 11-12, 2016	5 - Year
233	8.098039	123.489089	2.14	1.65	0.489	Typhoon Karen / Oct. 11-12, 2016	5 - Year
234	8.097958	123.489081	0.96	1.30	-0.344	Typhoon Karen / Oct. 11-12, 2016	5 - Year
235	8.096736	123.489542	0.03	0.70	-0.670	Typhoon Karen / Oct. 11-12, 2016	5 - Year
236	8.097371	123.490484	0.76	1.30	-0.539	Typhoon Karen / Oct. 11-12, 2016	5 - Year
237	8.097325	123.490372	0.68	1.30	-0.619	Typhoon Karen / Oct. 11-12, 2016	5 - Year
238	8.097377	123.490333	0.50	0.70	-0.204	Typhoon Karen / Oct. 11-12, 2016	5 - Year
239	8.097378	123.490308	0.50	0.70	-0.204	Typhoon Karen / Oct. 11-12, 2016	5 - Year
240	8.097326	123.490102	0.58	1.30	-0.716	Typhoon Karen / Oct. 11-12, 2016	5 - Year
241	8.097561	123.490301	3.58	0.70	2.878	Typhoon Karen / Oct. 11-12, 2016	5 - Year
242	8.097579	123.490269	2.58	1.10	1.478	Typhoon Karen / Oct. 11-12, 2016	5 - Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
243	8.097508	123.490070	0.66	0.90	-0.243	Typhoon Karen / Oct. 11-12, 2016	5 - Year
244	8.097489	123.489924	0.66	1.40	-0.736	Typhoon Karen / Oct. 11-12, 2016	5 - Year
245	8.097392	123.489899	0.64	1.40	-0.757	Typhoon Karen / Oct. 11-12, 2016	5 - Year
246	8.097341	123.489796	0.77	1.40	-0.633	Typhoon Karen / Oct. 11-12, 2016	5 - Year
247	8.097651	123.489727	0.99	1.30	-0.314	Typhoon Karen / Oct. 11-12, 2016	5 - Year
248	8.097632	123.489534	0.03	0.80	-0.770	Typhoon Karen / Oct. 11-12, 2016	5 - Year
249	8.096610	123.489453	0.03	0.80	-0.770	Typhoon Karen / Oct. 11-12, 2016	5 - Year
250	8.096831	123.489499	0.03	0.30	-0.270	Typhoon Karen / Oct. 11-12, 2016	5 - Year
251	8.096539	123.489409	0.03	0.60	-0.570	Typhoon Karen / Oct. 11-12, 2016	5 - Year
252	8.103566	123.479711	0.84	0.90	-0.060	Typhoon Karen / Oct. 11-12, 2016	5 - Year
253	8.103549	123.479909	0.89	0.90	-0.009	Typhoon Karen / Oct. 11-12, 2016	5 - Year
254	8.103729	123.479728	1.10	0.90	0.196	Typhoon Karen / Oct. 11-12, 2016	5 - Year
255	8.103749	123.479630	0.91	0.90	0.011	Typhoon Karen / Oct. 11-12, 2016	5 - Year
256	8.103662	123.479301	0.78	1.20	-0.422	Typhoon Karen / Oct. 11-12, 2016	5 - Year
257	8.103878	123.479739	0.98	0.90	0.080	Typhoon Karen / Oct. 11-12, 2016	5 - Year
258	8.103818	123.479866	1.08	0.90	0.179	Typhoon Karen / Oct. 11-12, 2016	5 - Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
259	8.103875	123.479899	1.08	0.90	0.179	Typhoon Karen / Oct. 11-12, 2016	5 - Year
260	8.103909	123.479916	1.06	0.90	0.163	Typhoon Karen / Oct. 11-12, 2016	5 - Year
261	8.104121	123.479691	0.85	0.60	0.253	Typhoon Karen / Oct. 11-12, 2016	5 - Year
262	8.104682	123.480358	0.03	0.80	-0.770	Typhoon Karen / Oct. 11-12, 2016	5 - Year
263	8.104468	123.479763	0.03	0.70	-0.670	Typhoon Karen / Oct. 11-12, 2016	5 - Year
264	8.104418	123.479746	0.79	0.00	0.792	Typhoon Karen / Oct. 11-12, 2016	5 - Year
265	8.104374	123.479994	1.23	0.90	0.325	Typhoon Karen / Oct. 11-12, 2016	5 - Year
266	8.104267	123.479316	0.03	0.70	-0.670	Typhoon Karen / Oct. 11-12, 2016	5 - Year
267	8.104036	123.478968	0.23	0.60	-0.371	Typhoon Karen / Oct. 11-12, 2016	5 - Year
268	8.083775	123.493153	0.03	0.51	-0.480	Typhoon Karen / Oct. 11-12, 2016	5 - Year
269	8.084022	123.493028	0.54	0.54	0.004	Typhoon Karen / Oct. 11-12, 2016	5 - Year
270	8.084803	123.492919	0.75	0.63	0.120	Typhoon Karen / Oct. 11-12, 2016	5 - Year
271	8.084922	123.492928	0.43	0.55	-0.120	Typhoon Karen / Oct. 11-12, 2016	5 - Year
272	8.085028	123.493011	0.68	0.52	0.164	Typhoon Karen / Oct. 11-12, 2016	5 - Year
273	8.085450	123.492972	0.49	0.62	-0.133	Typhoon Karen / Oct. 11-12, 2016	5 - Year
274	8.085569	123.492897	0.55	0.63	-0.081	Typhoon Karen / Oct. 11-12, 2016	5 - Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
275	8.085767	123.492828	0.66	0.86	-0.204	Typhoon Karen / Oct. 11-12, 2016	5 - Year
276	8.085931	123.492814	0.59	0.63	-0.040	Typhoon Karen / Oct. 11-12, 2016	5 - Year
277	8.086186	123.492828	0.25	0.11	0.140	Typhoon Karen / Oct. 11-12, 2016	5 - Year
278	8.086144	123.492847	0.29	0.44	-0.150	Typhoon Karen / Oct. 11-12, 2016	5 - Year
279	8.085250	123.493014	0.50	0.58	-0.080	Typhoon Karen / Oct. 11-12, 2016	5 - Year
280	8.085222	123.493094	0.36	0.18	0.180	Typhoon Karen / Oct. 11-12, 2016	5 - Year
281	8.084403	123.492764	0.64	0.27	0.371	Typhoon Karen / Oct. 11-12, 2016	5 - Year
282	8.084136	123.492894	0.81	0.68	0.125	Typhoon Karen / Oct. 11-12, 2016	5 - Year
283	8.083808	123.493597	0.03	0.30	-0.270	Typhoon Karen / Oct. 11-12, 2016	5 - Year
284	8.083814	123.493658	0.04	0.32	-0.280	Typhoon Karen / Oct. 11-12, 2016	5 - Year
285	8.083458	123.493442	0.18	0.29	-0.110	Typhoon Karen / Oct. 11-12, 2016	5 - Year
286	8.083339	123.493167	0.43	0.40	0.030	Typhoon Karen / Oct. 11-12, 2016	5 - Year
287	8.077311	123.497917	0.03	0.40	-0.370	Typhoon Karen / Oct. 11-12, 2016	5 - Year
288	8.077286	123.497489	0.19	0.73	-0.540	Typhoon Karen / Oct. 11-12, 2016	5 - Year
289	8.077531	123.497514	0.03	0.60	-0.570	Typhoon Karen / Oct. 11-12, 2016	5 - Year
290	8.076869	123.497806	0.06	0.53	-0.470	Typhoon Karen / Oct. 11-12, 2016	5 - Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
291	8.076586	123.497933	0.03	0.30	-0.270	Typhoon Karen / Oct. 11-12, 2016	5 - Year
292	8.076256	123.500333	0.05	0.60	-0.550	Typhoon Karen / Oct. 11-12, 2016	5 - Year
293	8.076756	123.456125	0.85	0.90	-0.055	Typhoon Karen / Oct. 11-12, 2016	5 - Year
294	8.076925	123.456061	0.85	0.80	0.054	Typhoon Karen / Oct. 11-12, 2016	5 - Year
295	8.076947	123.456175	0.95	0.72	0.226	Typhoon Karen / Oct. 11-12, 2016	5 - Year
296	8.077119	123.456072	0.86	0.65	0.214	Typhoon Karen / Oct. 11-12, 2016	5 - Year
297	8.077514	123.455778	0.95	1.00	-0.049	Typhoon Karen / Oct. 11-12, 2016	5 - Year
298	8.077503	123.455697	1.00	1.16	-0.165	Typhoon Karen / Oct. 11-12, 2016	5 - Year
299	8.077244	123.456322	0.97	0.83	0.137	Typhoon Karen / Oct. 11-12, 2016	5 - Year
300	8.077456	123.456297	1.05	0.93	0.123	Typhoon Karen / Oct. 11-12, 2016	5 - Year
301	8.070881	123.455803	1.16	1.19	-0.029	Typhoon Karen / Oct. 11-12, 2016	5 - Year
302	8.070861	123.455608	1.05	0.88	0.173	Typhoon Karen / Oct. 11-12, 2016	5 - Year
303	8.070892	123.455489	0.92	0.82	0.095	Typhoon Karen / Oct. 11-12, 2016	5 - Year
304	8.065136	123.464408	0.98	0.90	0.082	Typhoon Karen / Oct. 11-12, 2016	5 - Year
305	8.065053	123.464714	0.78	1.05	-0.270	Typhoon Karen / Oct. 11-12, 2016	5 - Year
306	8.065269	123.464775	0.95	1.04	-0.090	Typhoon Karen / Oct. 11-12, 2016	5 - Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
307	8.065239	123.464839	0.86	0.50	0.360	Typhoon Karen / Oct. 11-12, 2016	5 - Year
308	8.065303	123.465222	1.12	0.70	0.421	Typhoon Karen / Oct. 11-12, 2016	5 - Year
309	8.065428	123.465917	1.26	0.63	0.628	Typhoon Karen / Oct. 11-12, 2016	5 - Year
310	8.064633	123.466439	1.07	0.63	0.444	Typhoon Karen / Oct. 11-12, 2016	5 - Year
311	8.066272	123.462761	0.53	0.90	-0.373	Typhoon Karen / Oct. 11-12, 2016	5 - Year
312	8.066319	123.462867	0.85	0.45	0.402	Typhoon Karen / Oct. 11-12, 2016	5 - Year
313	8.065822	123.462653	1.16	0.60	0.556	Typhoon Karen / Oct. 11-12, 2016	5 - Year
314	8.065639	123.462433	1.02	0.70	0.323	Typhoon Karen / Oct. 11-12, 2016	5 - Year
315	8.065733	123.462011	0.78	0.52	0.261	Typhoon Karen / Oct. 11-12, 2016	5 - Year
316	8.066064	123.460836	0.76	0.63	0.131	Typhoon Karen / Oct. 11-12, 2016	5 - Year

Annex 12. Educational Institutions Affected by Flooding in Maragondon Floodplain

Table A-12.1. Educational Institutions Affected by Flooding in the Maragondon Floodplain – Maragondon, Cavite

Cavite				
Maragondon				
Building	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Bucal 2 Elementary School	Bucal II	None	Medium	Low
Bucal National High School	Bucal II	Low	Medium	Medium
Day Care Center	Pantihan I	None	None	None
Palayungan Elementary School	Pantihan I	None	None	None
Pantihan II Elementary School	Pantihan II	None	None	None
Pinagsanhan Elementary School	Pinagsanhan I A	None	None	None
Cavite Science High School	Poblacion I A	None	None	None
FEAPITSAT College of Maragondon	Poblacion I A	Medium	High	High
Maragondon Elementary School	Poblacion I A	None	None	None
Maragondon National High School	Poblacion I A	Low	Medium	Low
Maragondon Parochial School	Poblacion I A	None	None	None
Polytechnic University of the Philippines	Poblacion I A	Medium	High	Medium
Bucal National High School	Poblacion II A	Medium	Medium	Medium
Muzon Elementary School	San Miguel I A	Low	Medium	Medium
San Miguel Elementary School	San Miguel I A	None	Low	None
JLG Training Center	Tulay Silangan	None	None	None
Tulay Elementary School	Tulay Silangan	None	None	None

Table A-12.2. Educational Institutions Affected by Flooding in the Maragondon Floodplain – Naic, Cavite

Cavite				
Naic				
Building	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Naic Coastal High School	Labac	Medium	Medium	Medium
The Valley Cathedral Academy	Labac	Low	Medium	Medium

Table A-12.3. Educational Institutions Affected by Flooding in the Maragondon Floodplain – Ternate, Cavite

Cavite				
Ternate				
Building	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Cavite West Point College	Poblacion I	None	Low	None
Parang Elementary School	Poblacion I	None	Low	Low
Ternate National High School	Poblacion I	None	None	None
Parang Elementary School	Poblacion I A	None	None	None
Ternate Central Elementary School	Poblacion I A	None	None	None
Ternate National High School	Poblacion I A	None	None	None
Ternate Central Elementary School	Poblacion II	None	None	None
Dinglas Elementary School	Poblacion III	High	High	High
The Valley Cathedral Academy	San Juan II	None	Medium	Low

Annex 13. Medical Institutions Affected by Flooding in Maragondon Floodplain

Table A-13.1. Medical Institutions Affected by Flooding in the Maragondon Floodplain

Cavite				
Maragondon				
Building	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
San Lucas Clinic	Bucal III A	None	Medium	None
Baldobino Medical Clinic	Garita I A	None	None	None
Baldovino Medical Family Clinic	Garita I A	None	None	None
Health Center	Pinagsanhan I A	Low	Low	Medium
Cavite Municipal Hospital	Poblacion I A	None	None	None
Maragondon Health Center	Poblacion I A	Medium	High	Medium
J. A. Manalo Medical Laboratory	San Miguel I A	None	None	None