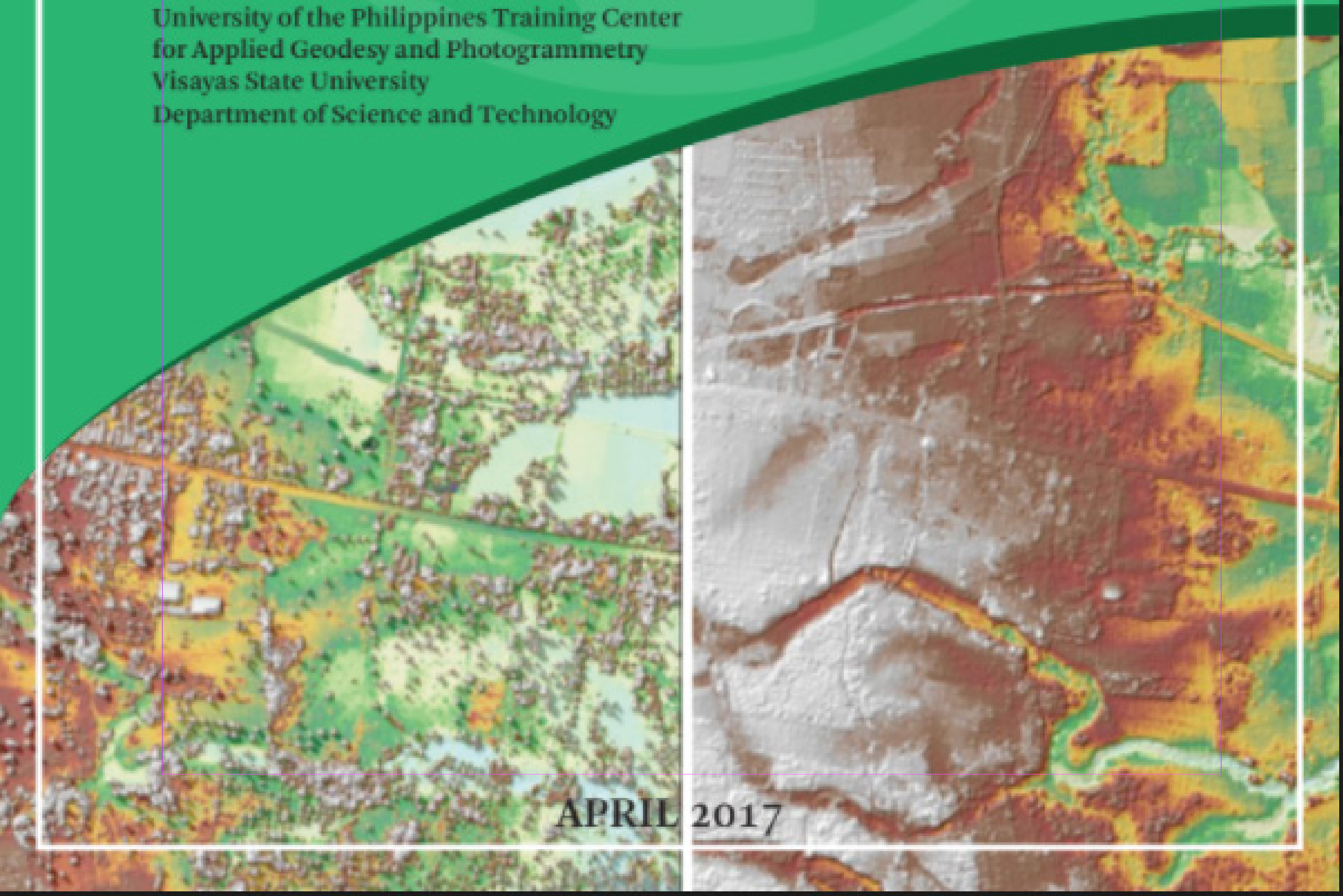
HAZARD MAPPING OF THE PHILIPPINES USING LIDAR (PHIL-LIDAR 1)

LiDAR Surveys and Flood Mapping of Daguitan-Marabong River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
Visayas State University
Department of Science and Technology



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For questions/queries regarding this report, contact:

Engr. Florentino Morales, Jr.
Project Leader, PHIL-LiDAR 1 Program
Visayas State University
Baybay, Leyte, Philippines 6521
ffmorales_jr@yahoo.com

Enrico C. Paringit, Dr. Eng.
Program Leader, PHIL-LiDAR 1 Program
University of the Philippines Diliman
Quezon City, Philippines 1101
E-mail: ecparingit@up.edu.ph

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

CHAPTER 1: OVERVIEW OF THE PROGRAM AND BINAHAAN RIVER

Enrico C. Paringit, Dr. Eng. and Engr. Florentino Morales, Jr.

1.1 Background of the Phil-LiDAR 1 Program

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

The program also aimed to produce an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through DOST. The methods applied in this report are thoroughly described in a separate publication titled 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 Visayas State University. VSU 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 ________ river basins in the ____________________ (LiDAR covered area). The university is located in Baybay City in the province of Leyte.

1.2 Overview of the Daguitan-Marabong River Basin

Daguitan-Marabong River Basin covers a major portion of the Municipalities of Barauen, and Julita. It also covers minor portions of the Municipalitites of Dulag, Mayorga, La Paz, and Macarthur. It has a drainage area of 266 km2 and an estimated 505 million cubic meter (MCM) annual run-off.

Its main stem, Daguitan-Marabong River, is located in the Municipality of Dulag, Leyte. Dulag is a third-class municipality with a total population of 41,757 distributed among 45 barangays.

According to the data gathered from the local government units in Leyte, the Municipality of Dulag has experienced two (2) significant flooding events in 2011. The first one occurred on January 4, 2011. The onslaught of heavy rains that continued for five (5) days inundated an area of 15 ha with flood heights reaching 15 ft and lasting one and a half hours. The second one occurred on March 17, 2011. Heavy rains went on for four (4) days and covered an area of 10 ha. The flood height was recorded at twelve (12) ft. The data from the local government units in Leyte have showed the crucial role of the Daguitan River when it comes to the inundation of the Municipality of Dulag.

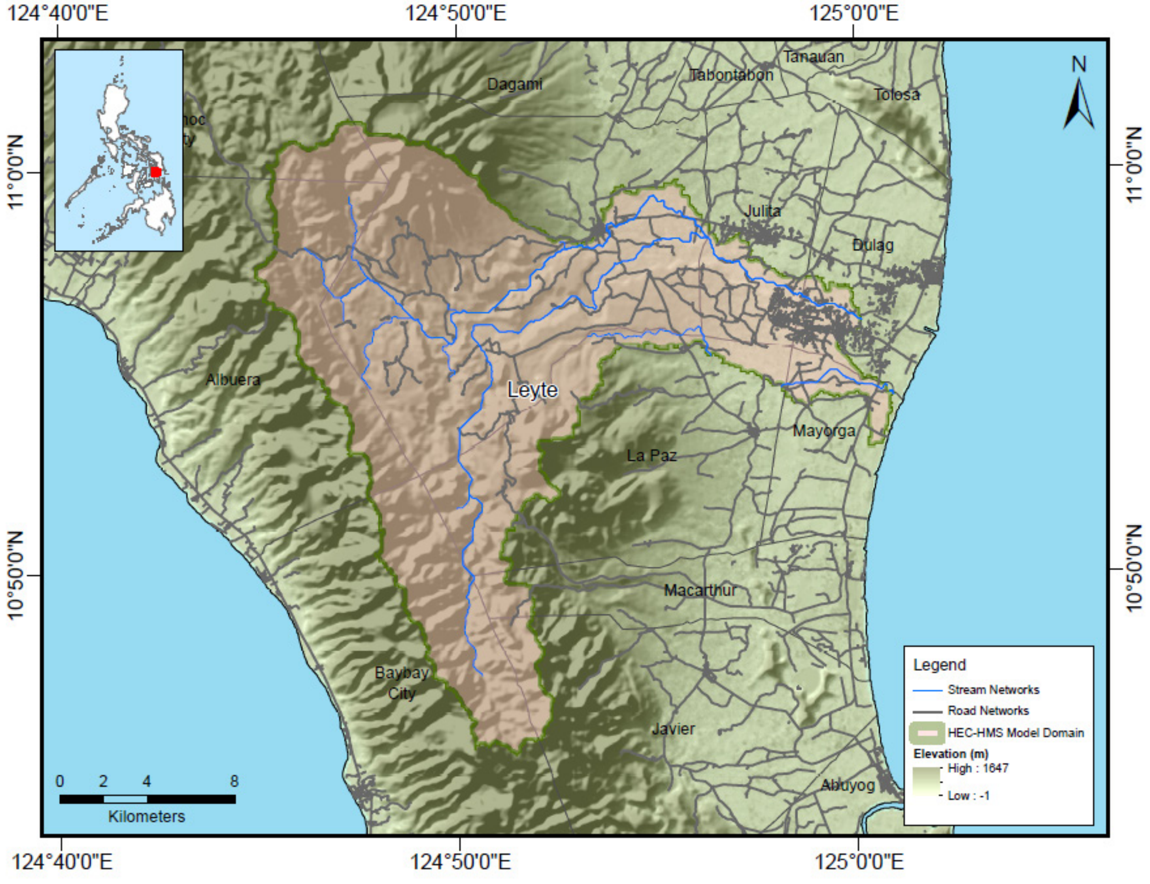


Figure 1. Map of Daguitan-Marabong River Basin (in brown)

CHAPTER 2: LIDAR DATA ACQUISITION OF THE DAGUITAN-MARABONG FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Gracia Acuña, Engr. Gerome Hipolito, Engr. Christopher L. Joaquin, Mr. Jonathan M. Almalvez

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

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Daguitan-Marabong Floodplain in Leyte. Each flight mission had an average of 15 flight lines that run for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR system are found in Table 1 and Table 2. Figure 2 shows the flight plan for Daguitan-Marabong Floodplain.

Table 1. Flight planning parameters for Aquarius LiDAR system

Block Name	Flying Height (m AGL)	Overlap (%)	Field of view (ø)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK34A	600	30	36	70	50	120	5
BLK33B	600	30	36	70	50	120	5
BLK33C	600	30	36	70	50	120	5
BLK33L	600	30	36	70	50	120	5
BLK34M	600	30	36	70	50	120	5

Table 2. Flight planning parameters for Gemini LiDAR system

Block Name	Flying Height (m AGL)	Overlap (%)	Field of view (ø)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK34N	850	30	40	125	50	130	5
BLK34O	1000	30	40	125	50	130	5
BLK34P	1000	30	40	125	50	130	5

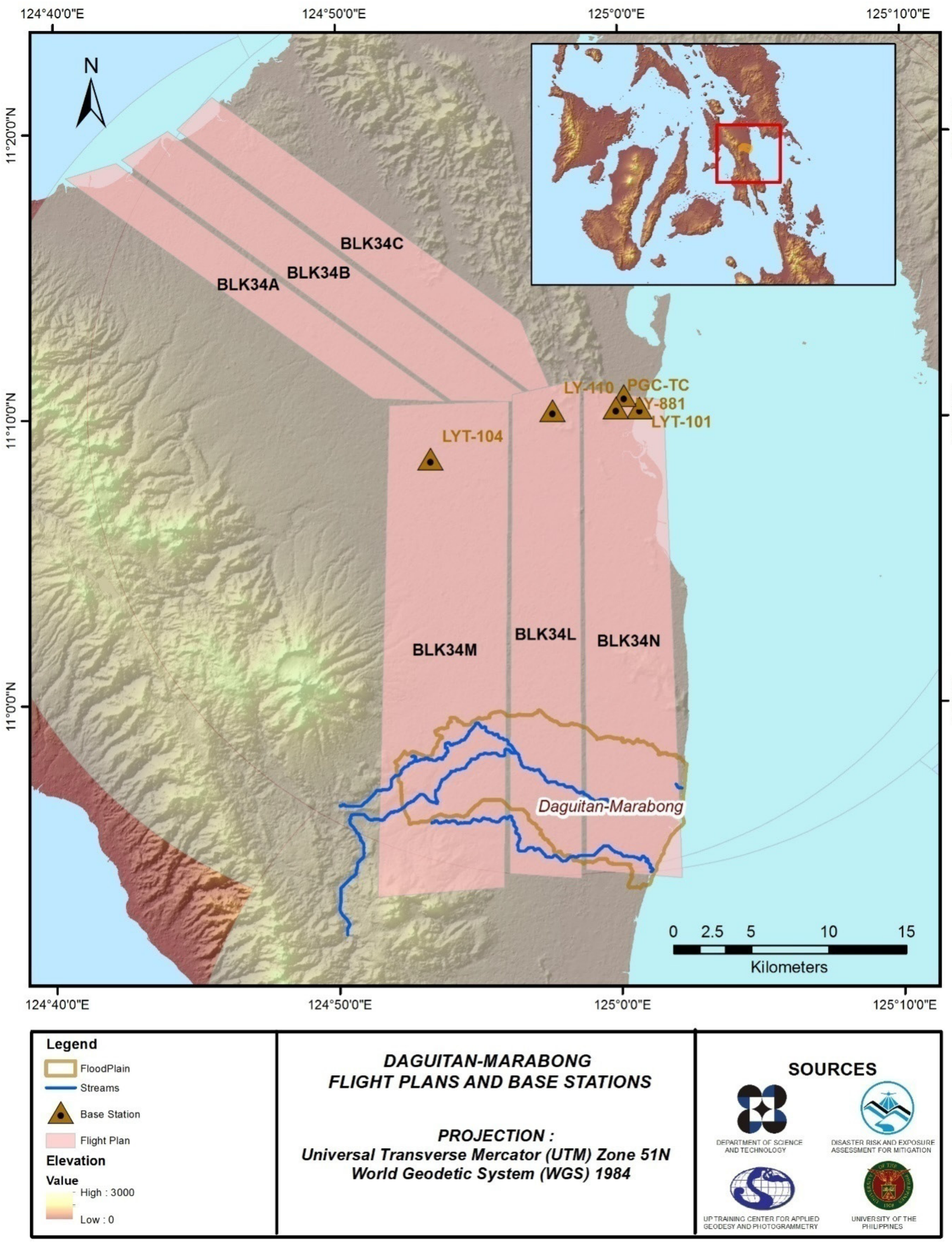
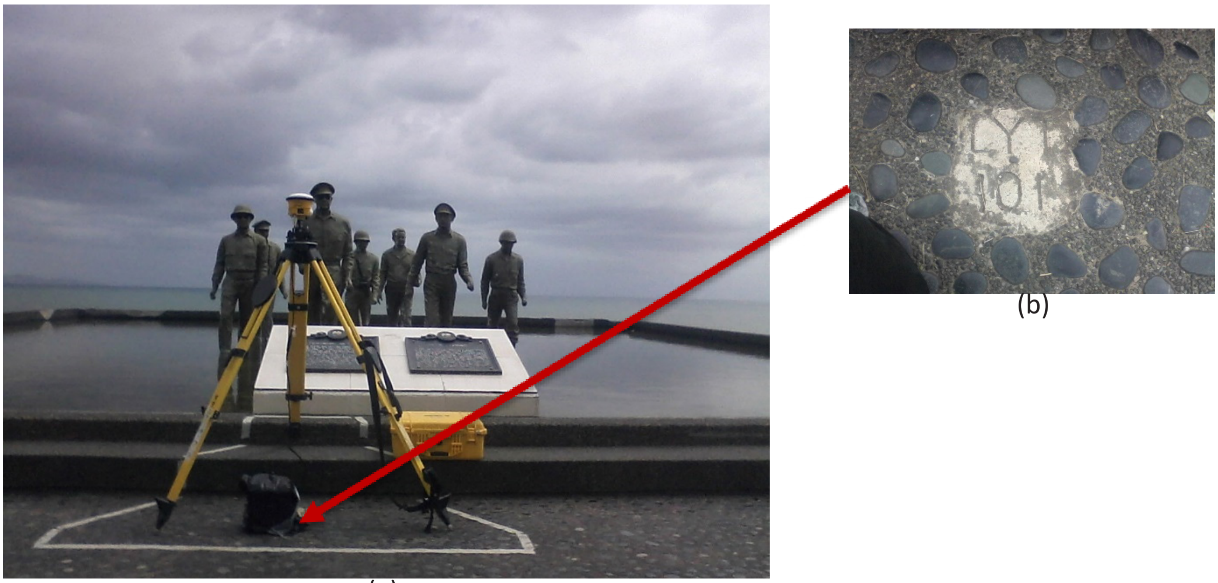


Figure 2. Flight plans for Daguitan-Marabong Floodplain

2.2 Ground Base Stations

The project team was able to recover three (3) NAMRIA horizontal ground control points: LYT- 93, LYT-101 and SMR-53 which are all of second (2nd) order accuracy. The project team also re-established ground control point LYT-104, a NAMRIA reference point of third 3rd order accuracy; the team also established a ground control point named PGC-TC and used it as a base station during aerial survey. Two (2) NAMRIA benchmarks were recovered: LY-110 and LY-881 which are all of first (1st) order accuracy. These benchmarks were used as vertical reference points and were also established as ground control points. The certification for the NAMRIA reference points and benchmarks are found in Annex 2 while the baseline processing reports for the established control points are found in Annex 3. These points were used as base stations during flight operations for the entire duration of the survey (January 26-27, April 20, May 8-9 2014 and January 23, 2016). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and SPS 985. Flight plans and location of base stations used during the aerial LiDAR acquisition in Daguitan-Marabong Floodplain are shown in Figure 2.

Figure 3 to Figure 9 show the recovered NAMRIA reference points within the area. Table 3 to Table 9 show the details about the following NAMRIA control stations and established points, while Table 10shows the list of all ground control points occupied during the acquisition with the corresponding dates of utilization.



(a) (b)

Figure 3. GPS set-up over LYT-101 situated within the premises of MacArthur's Landing Memorial Park, Palo, Leyte (a) and NAMRIA reference points SMR-53 (b) as recovered by field team

Table 3. Details of the recovered NAMRIA horizontal control point PNG-3034 used as base station for the LiDAR Acquisition

Station Name	LYT-101	
Order of Accuracy	2ND	
Relative Error (Horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11° 10’ 23.89707” North 125° 0’ 38.62071” East 6.58600 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	501171.719 meters 1235497.253 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 10’ 19.64869” North 125° 0’ 43.78230” East 69.02100 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	719575.03 meters 1235811.61 meters

(b)

(a)

Figure 4. GPS set-up over LYT-93 recovered within the premises of Abuyog Municipal Hall, Brgy. Sto. Abuyog, Leyte (a) and NAMRIA reference point LYT-93 (b) as recovered by the field team.

Table 4. Details of the recovered NAMRIA horizontal control point LYT-93 used as base station for the LiDAR Acquisition

Station Name	LYT-93	
Order of Accuracy	1ST	
Relative Error (Horizontal positioning)	1 in 100,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 44' 52.03339" North 125° 0' 43.59630"East 2.66000 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	501324.552meters 1188433.982meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 44' 47.89310"North 125° 0' 48.79542"East 66.12300 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	720040.44meters 1188738.73meters

(a)

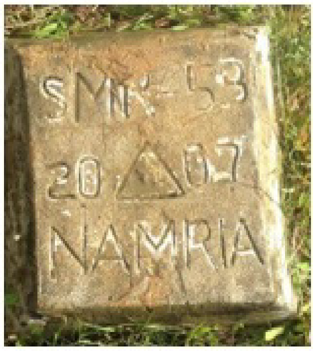
(b)

Figure 5. GPS set-up over SMR-53 as recovered 15 meters west inside the San Isidro Elementary School, and almost near at the school building and flag pole, Brgy. San Isidro, Santa Rita (a) and NAMRIA reference point SMR-53 (b) as recovered by the field team

Table 5. Details of the recovered NAMRIA horizontal control point SMR-53 used as base station for the LiDAR Acquisition

Station Name	**SMR-53**	
Order of Accuracy	**2nd Order**	
Relative Error (Horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11° 30’ 17.85657” North 125° 1’ 29.837339” East 26.13400 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	502722.403 m 1272180.079 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 30’ 13.52495” North 125° 1’ 34.96980” East 87.78700 m
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	720,874.14 m 1,272,513.40 m

(a)



(b)

Figure 6. GPS set-up over LYT-104 as recovered and re-established along rice paddy trail, approximately 90 meters from the centerline, east side of Pastrana-Santa Fe Road, District IV, Pastrana, Leyte (a) and NAMRIA reference point LYT-104 (b) as recovered by the field team

Table 6. Details of the recovered NAMRIA horizontal control point LYT-104 used as base station for the LiDAR Acquisition

Station Name	**LYT-104**	
Order of Accuracy	**2nd order**	
Relative Error (Horizontal positioning)	**1:50000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11° 08' 38.92234" North 124° 53' 13.52786"East 33.659 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 08' 34.67033" North 124° 53' 18.69323" East 95.861 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	718,144.536 meters 1,244,004.859 meters

(b)

(a)

Figure 7. GPS set-up over LY-881 located at the concrete foundation of Governor Center Welcome sign at the junction of the road going to Ormoc, Samar, Tacloban and MacArthur Landing Memorial Park in Brgy. Pawing, Palo, Leyte (a) and NAMRIA reference point LY-881 (b) as recovered by the field team

Table 7. Details of the recovered NAMRIA Benchmark LY-881 used as base station for the LiDAR acquisition

Station Name	LY-881	
Order of Accuracy	**1st Order**	
Relative Error (Horizontal positioning)	**1: 100, 000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11° 10' 50.05" North 125° 00' 05.58"East 5.96 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 10' 45.19178" North 125° 00' 09.85226" East 68.330 m
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	718694.89 m 1236537.244 m

(b)

(a)

Figure 8. GPS set-up over established Ground Control Point by the team on the rooftop of Philippine Coast Guard Tacloban Station, Kuta Kankabato, San Jose, Tacloban City (a) and established reference point PGC-TC as recovered by the field team

Table 8. Details of the established control point PGC-TC

Station Name	PCG-TC	
Order of Accuracy	1: 50,000	
Relative Error (Horizontal positioning)	2nd Order	
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 10' 19.64869" North 124° 59' 53.38556" East 70.882 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	718144.536 m 1244004.859 m

(a)

(b)

Figure 9. GPS set-up over a bridge located about 225 meters of km. post 919, road leading to Ormoc City (a) and NAMRIA reference point LY-110 (b) as recovered by the field team

Table 9. Details of the recovered NAMRIA Benchmark LY-110 used as base station for the LiDAR acquisition

Station Name	SMR-53	
Order of Accuracy	2nd Order	
Relative Error (Horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11° 10' 19.48389" 124° 57' 32.98736" 14.336 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 10' 15.23095" North 124° 57' 38.14961" East 76.647 m
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	713942.863 m 1234538.117 m

Table 10. Ground Control Points used during LiDAR Data Acquisiton

Date Surveyed	Flight Number	Mission Name	Ground Control Points
January 26, 2014	1026A	3BLK33AS34A026A	LYT-101 and PCG-TC
January 27, 2014	1028A	3BLK34ABS33DS027A	LYT-101 and PCG-TC
April 20, 2014	1358A	3BLK34F110A	LY-881 and LYT-101
April 20,2014	1360A	3BLK34FS110B	LY-881 and SMR-53
May 8, 2014	1430A	3BLK34L128A	LY-199 and LYT-93
May 9, 2014	1434A	3BLK34LSM129A	LY-199 and LYT-93
May 9, 2014	1436A	3BLK34MS129B	LY-199 and LYT-93
January 23, 2016	3769G	2BLK34ADEG023A	LY-110 and LYT-104

2.3 Flight Missions

Eight (8) missions were conducted to complete the LiDAR data acquisition in Daguitan-Marabong Floodplain, for a total of 31 hours and 31 minutes of flying time for RP-C9122 and RP-C9322. All missions were acquired using the Aquariusand Gemini LiDAR systems. Table 9 shows the total area of actual coverage and actual flying hours while Table 12 presents the actual parameters used during the LiDAR data acquisition.

Table 11. Flight Missions for LiDAR Data Acquisition in Alaminos Floodplain

Date Surveyed	Flight Number	Flight Plan Area (km^2)	Surveyed Area (km^2)	Area Surveyed within the Floodplain (km^2)	Area Surveyed Outside the Floodplain (km^2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
January 26, 2014	1026A	108.5	102.51	12.11	90.4	NA	2	47
January 27, 2014	1028A	223.12	205.35	49.01	156.34	NA	4	25
April 20, 2014	1358A	134.31	121.29	29.31	91.98	NA	4	11
April 20,2014	1360A	96.04	71.46	14.45	57.01	NA	3	23
May 8, 2014	1430A	122.3	119.43	7.73	111.7	NA	4	5
May 9, 2014	1434A	186.5	125.18	16.45	108.73	NA	4	47
May 9, 2014	1436A	78.83	71.97	6.35	65.62	NA	3	41
January 23, 2016	3769G	190.43	171.75	49.06	122.69	NA	4	12

Table 12. Actual Parameters used during LiDAR Data Acquisition

Date Surveyed	Flight Number	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Scan Frequency (Hz)	Speed of Plane (Kts)
January 26, 2014	1026A	700	30	50	40	120
January 27, 2014	1028A	700	30	50	40	120
April 20, 2014	1358A	700	30	36	50	120
April 20,2014	1360A	700	30	50	40	120
May 8, 2014	1430A	600	30	44	45	120
May 9, 2014	1434A	600	30	36	50	120
May 9, 2014	1436A	600	30	36	50	110
January 23, 2016	3769G	1200	30	34	50	120

2.4 Survey Coverage

Daguitan-Marabong Floodplain is located in the province of Leyte with the majority situated within the municipality of Dulag. Municipalities of Palo, Tanuan and Palosa are mostly covered by the survey. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 13. The actual coverage of the LiDAR acquisition for Daguitan-Marabong Floodplain is presented in Figure 10.

Table 13. List of municipalities and cities Surveyed during Daguitan-Marabong Floodplain LiDAR survey

Province	Municipality/ City	Area of Municipality/City (km^2)	Total Area Surveyed (km^2)	Percentage of Area Surveyed
Leyte	Julita	57.17	57.17	100
	Mayorga	39.45	39.45	100
	Tabontabon	20.46	20.46	100
	Dulag	63.65	63.56	99.85
	Tanauan	62.78	62.57	99.66
	Tolosa	28.17	28.07	99.64
	Palo	65.34	61.66	94.36
	Macarthur	57.86	32.2	55.65
	Santa Fe	57.15	22.24	38.91
	Javier	153.11	57.86	37.78
	Burauen	205.31	64.38	31.35
	La Paz	136.02	38.47	28.28
	Dagami	134.09	34.25	25.54
	Abuyog	256.64	59.36	23.12
	Pastrana	79.17	17.02	21.49
	Alangalang	145.45	1.71	1.17
	Tacloban City	118.46	1.01	0.85
Total		1,680.28	661.44	39.36%

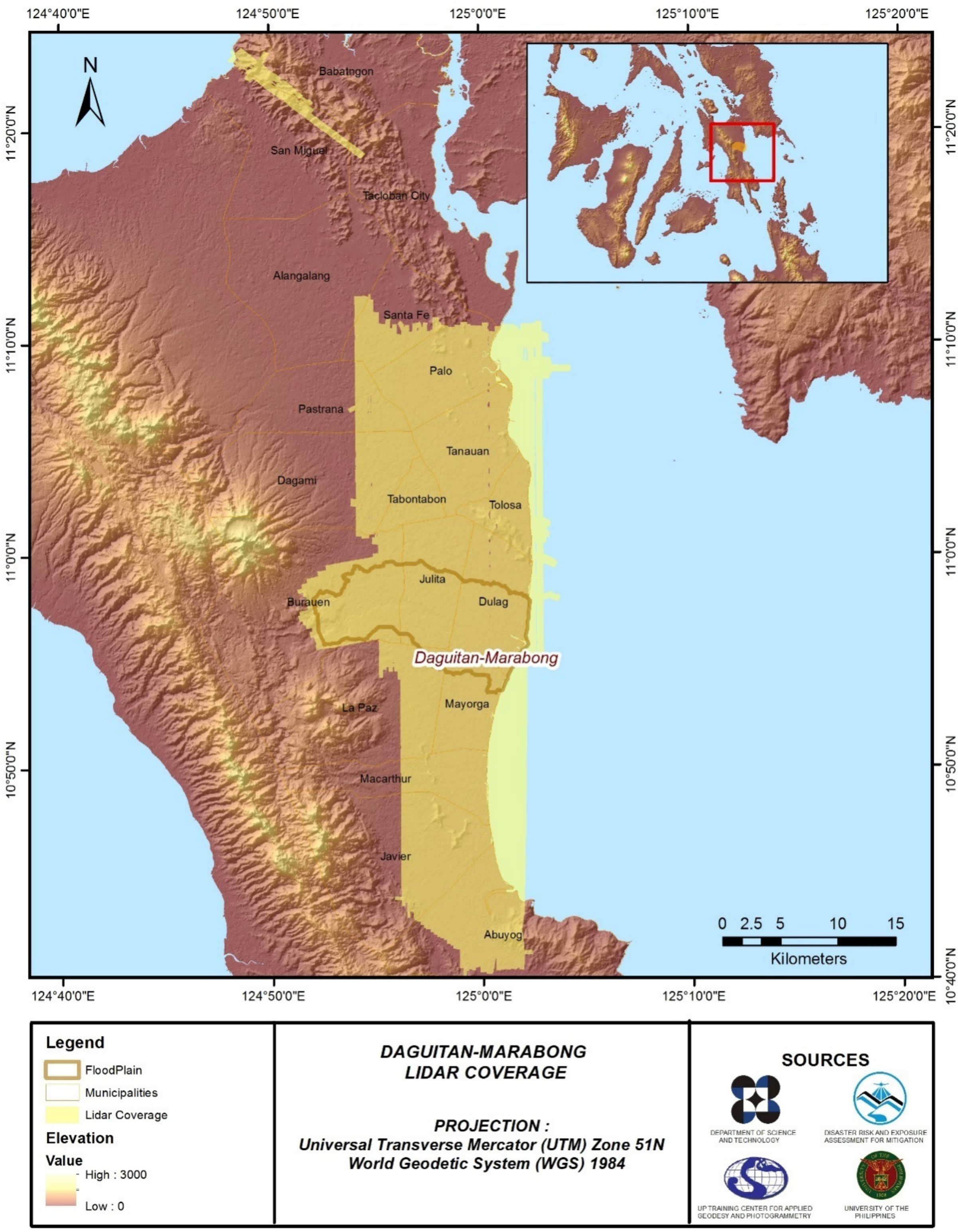


Figure 10. Actual LiDAR survey coverage for Daguitan-Marabong Floodplain

CHAPTER 3: LIDAR DATA PROCESSING FOR DAGUITAN-MARABONG FLOODPLAIN

Engr. Ma. Rosario Concepcion O. Ang, Engr. John Louie D. Fabila, Engr. Sarah Jane D. Samalburo , Engr. Harmond F. Santos , Engr. Gladys Mae Apat , Engr. Jovelle Anjeanette S. Canlas, Alex John B. Escobido, Engr. Monalyne C. Rabino , Nereo Joshua G. Pecson, Areanne Katrice K. Umali

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).

3.1 Overview of the LiDAR Data Pre-Processing

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

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

These processes are summarized in the flowchart shown in Figure 11.

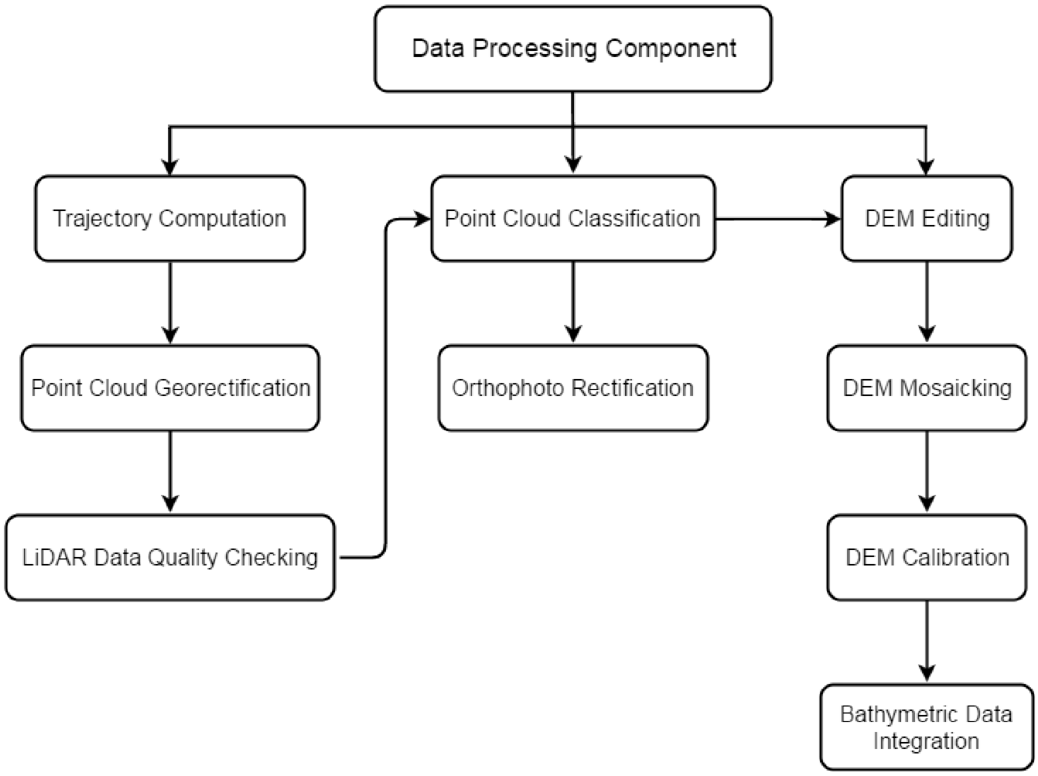


Figure 11. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Daguitan-Marabong Floodplain can be found in Annex 5. Missions flown during the first survey conducted in January 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Aquarius system while missions acquired during the last survey in January 2016 were flown using the Gemini system over Leyte.The Data Acquisition Component (DAC) transferred a total of 118.98 Gigabytes of Range data, 1.83 Gigabytes of POS data, 109.48 Megabytes of GPS base station data, and 522.70 Gigabytes of raw image data to the data server on January 26, 2014 for the first survey and January 23, 2016 for the last survey.The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Daguitan-Marabong was fully transferred on February 12, 2016, as indicated in the Data Transfer Sheets for Daguitan-Marabong Floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 1434A, one of the Daguitan-Marabong flights, which is the North, East, and Down position RMSE values are shown in Figure 12. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on May 09, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

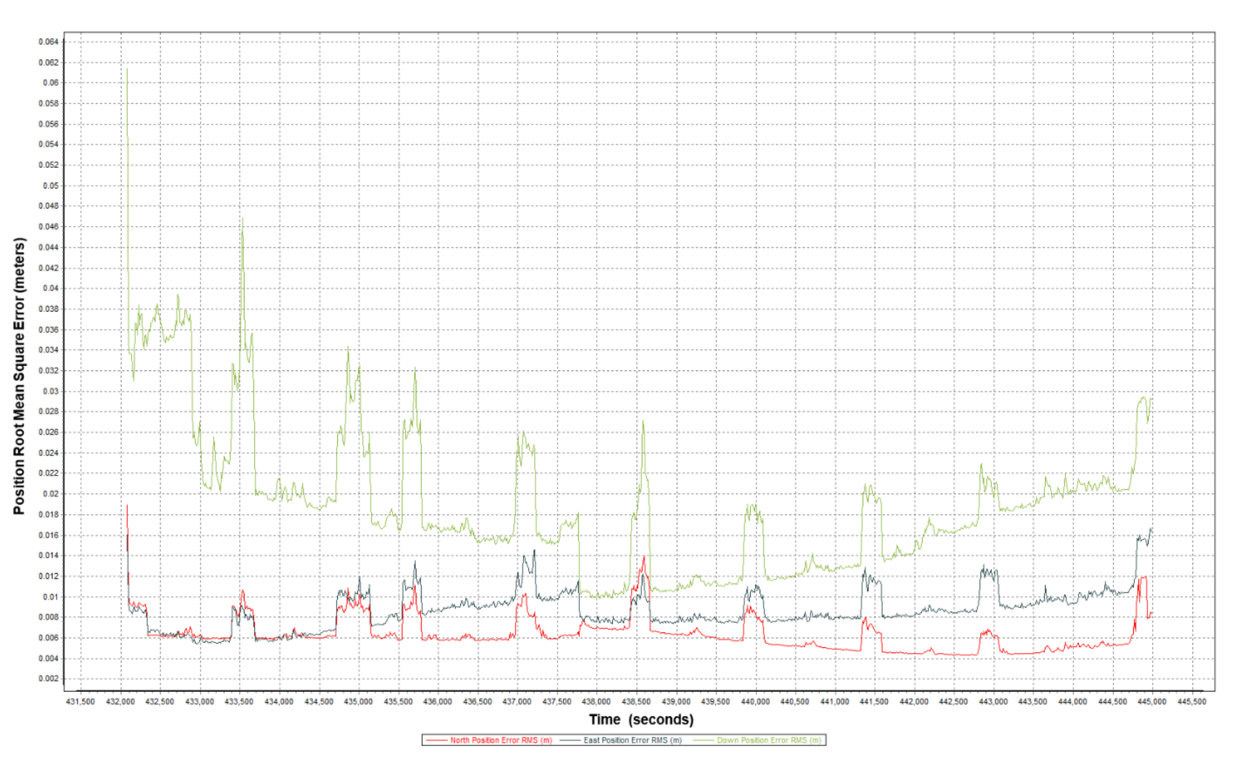


Figure 12. Smoothed Performance Metrics of a Daguitan-Marabong Flight 1434A

The time of flight was from 432000 seconds to 44500 seconds, which corresponds to morning of May 09, 2014. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 12 shows that the North position RMSE peaks at 1.40 centimeters, the East position RMSE peaks at 1. 80 centimeters, and the Down position RMSE peaks at 4.80 centimeters, which are within the prescribed accuracies described in the methodology.

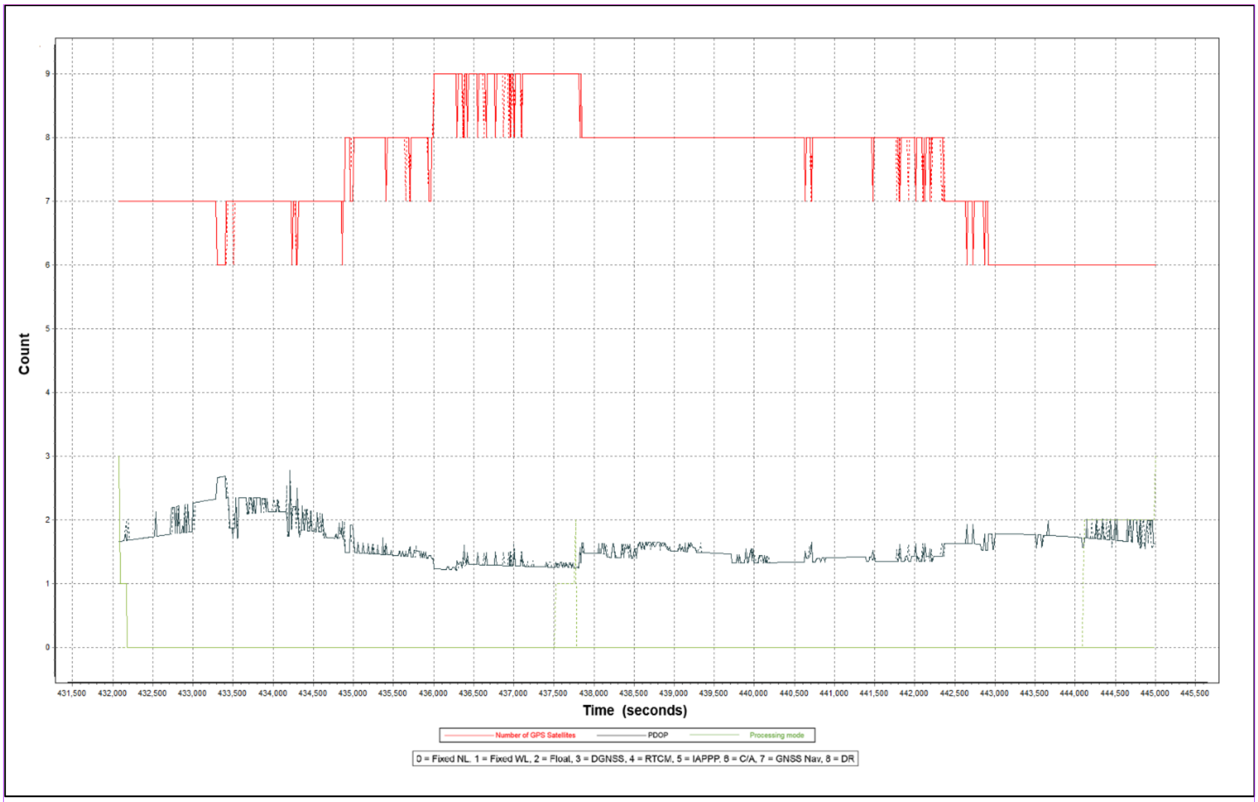


Figure 13. Solution Status Parameters of Daguitan-Marabong Flight 1434A

The Solution Status parameters of flight 1434A, one of the Daguitan-Marabong flights, which indicate the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 13. The graphs indicate that the number of satellites during the acquisition did not go down below 6. Most of the time, the number of satellites tracked was between 6 and 9. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode remained at 0 for majority of the survey with a sudden peak up to 2 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Daguitan-Marabong flights is shown in Figure 14.

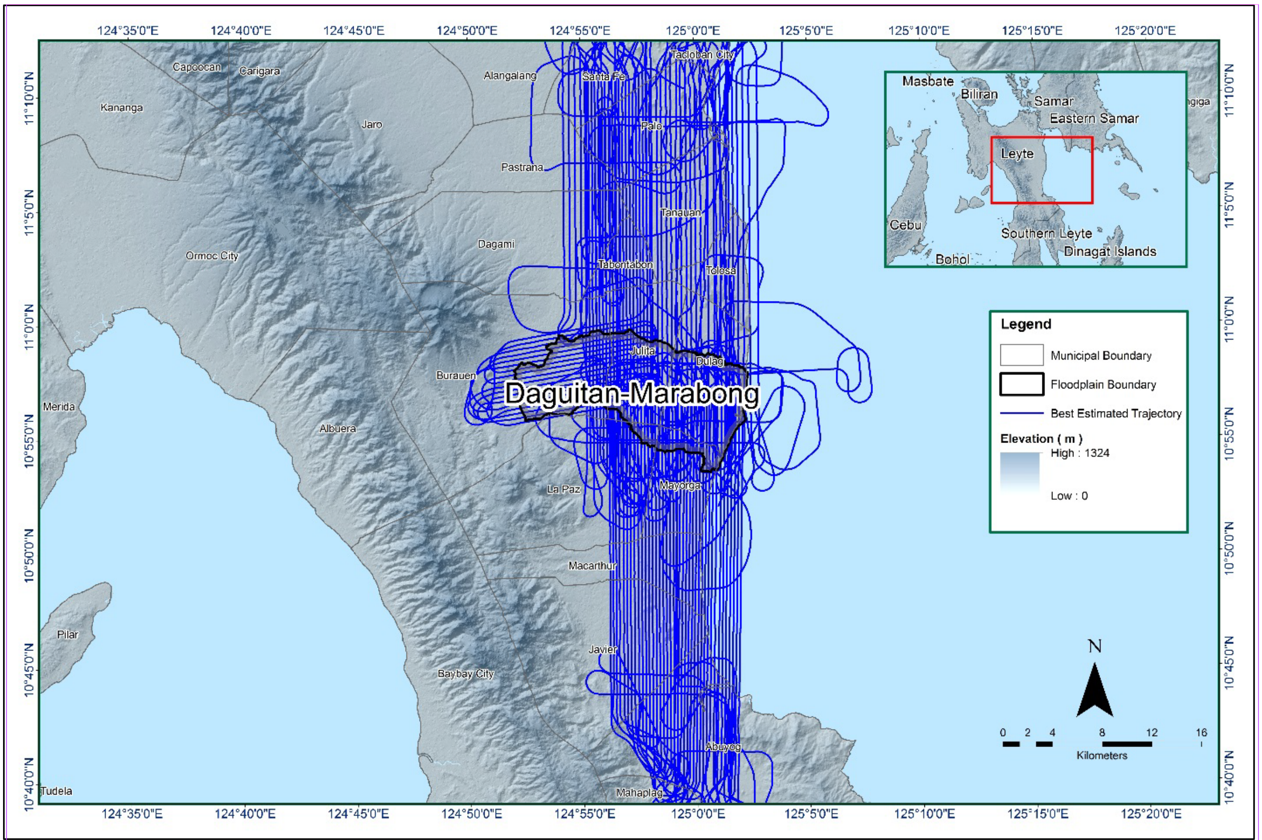


Figure 14. Best estimated trajectory for Daguitan-Marabong Floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 107 flight lines, with each flight line containing one channel, since the Gemini and Aquarius systems both contain one channel only. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Daguitan-Marabong Floodplain are given in Table 14.

Table 14. Self-Calibration Results values for Daguitan-Marabong flights

Parameter	Computed Value
Boresight Correction stdev(<0.001degrees)	0.000471
IMU Attitude Correction Roll and Pitch Corrections stdev(<0.001degrees)	0.000993
GPS Position Z-correction stdev(<0.01meters)	0.0080

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

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data is shown in Figure 15. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

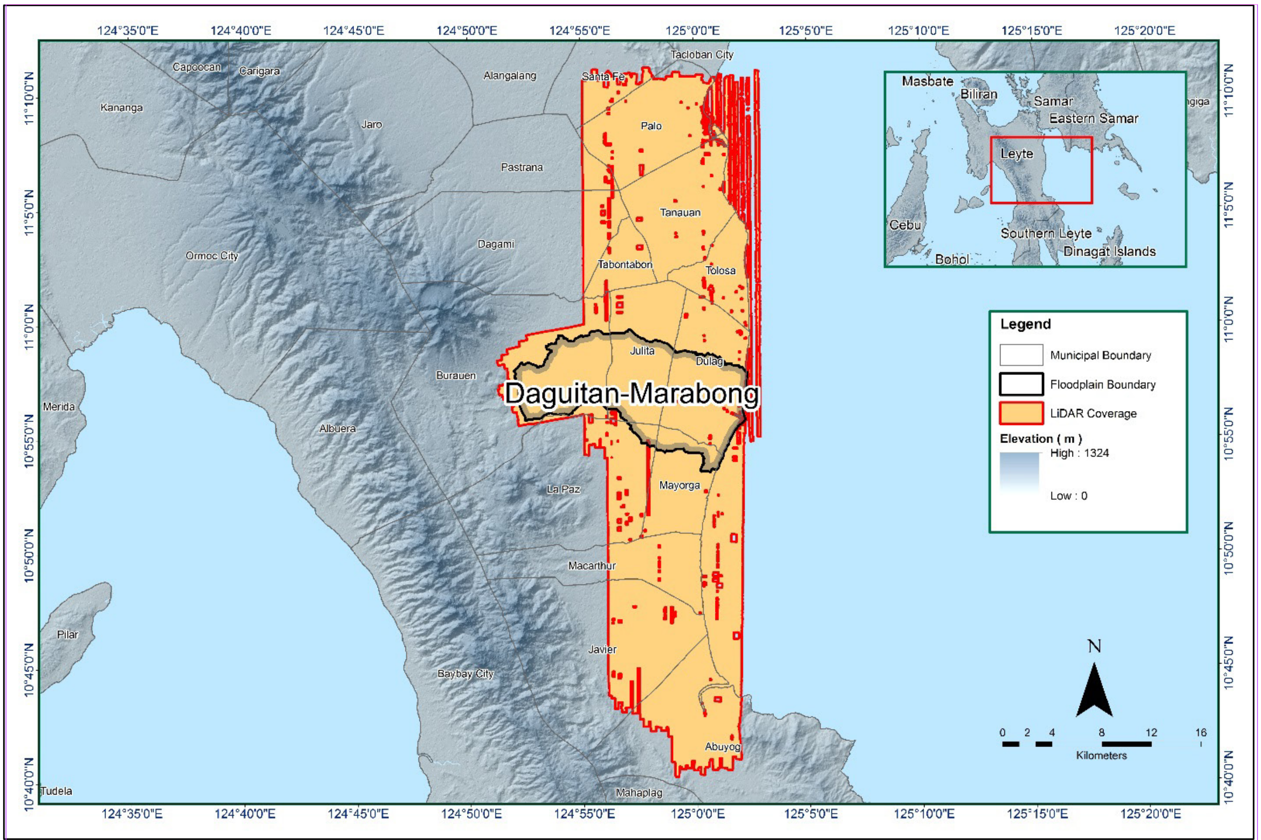


Figure 15. Boundary of the processed LiDAR data on top of a SAR Elevation Data over Daguitan-Marabong Floodplain

The total area covered by the Daguitan-Marabong missions is 761.40 sq.km comprised of eight (8) flight acquisitions grouped and merged into five (5) blocks as shown in Table 15.

Table 15. List of LiDAR blocks for Daguitan-Marabong Floodplain

LiDAR Blocks	Flight Numbers	Area (sq. km)
Samar_Leyte Blk34F	1434A	147.98
	1436A	
Leyte_Blk34C	1430A	140.20
	1434A	
Leyte_Blk34G_supplement	1358A	164.18
	1360A	
Leyte Blk34F_additional	3769A	69.32
Tacloban_1026A	1026G	239.72
	1028G	
TOTAL		**761.40 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 16. Since the Gemini and Aquarius systems both employ one channel, 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 are expected.

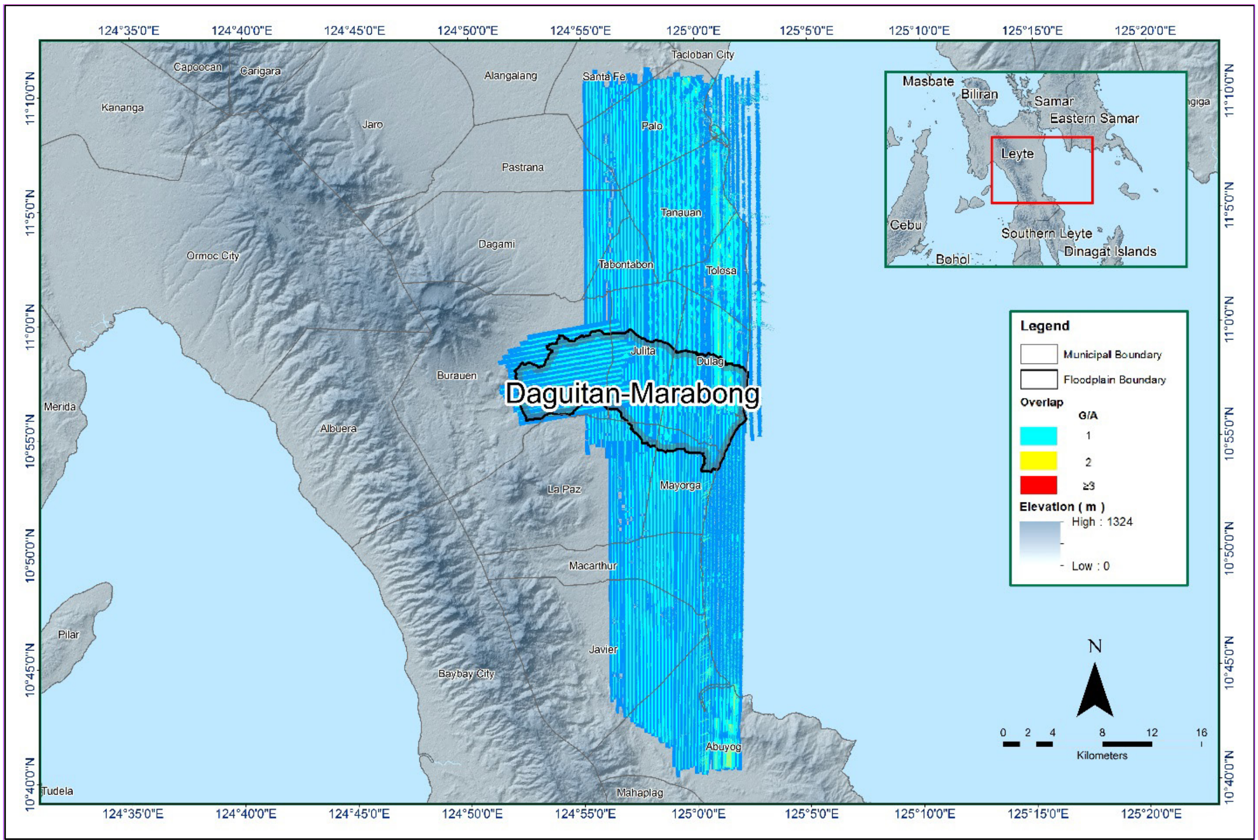


Figure 16. Image of data overlap for Daguitan-Marabong Floodplain

The overlap statistics per block for the Daguitan-Marabong Floodplain can be found in Annex 8. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 31.11% and 43.14% 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 17. It was determined that all LiDAR data for Daguitan-Marabong Floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.27 points per square meter.

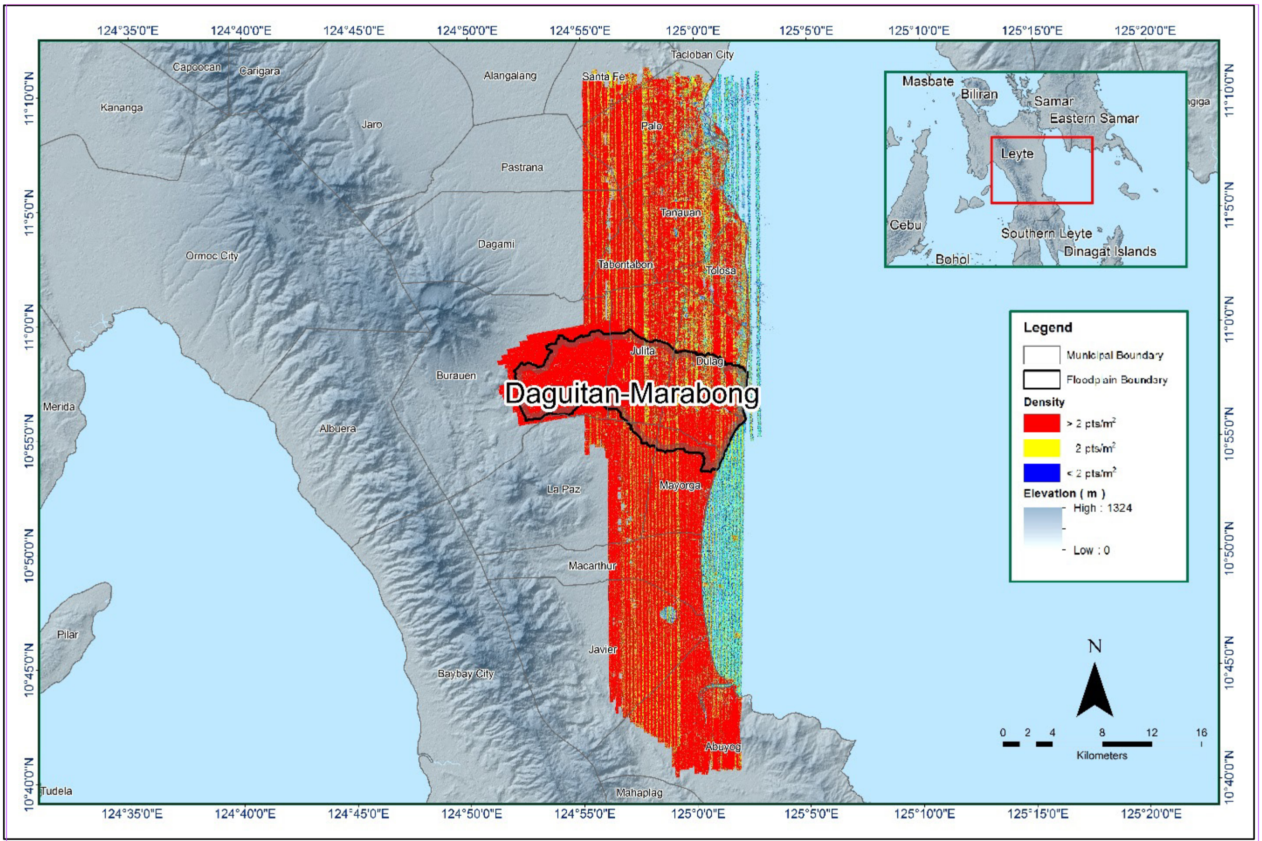


Figure 17. Pulse density map of merged LiDAR data for Daguitan-Marabong Floodplain

The elevation difference between overlaps of adjacent flight lines is shown in Figure 18. 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.

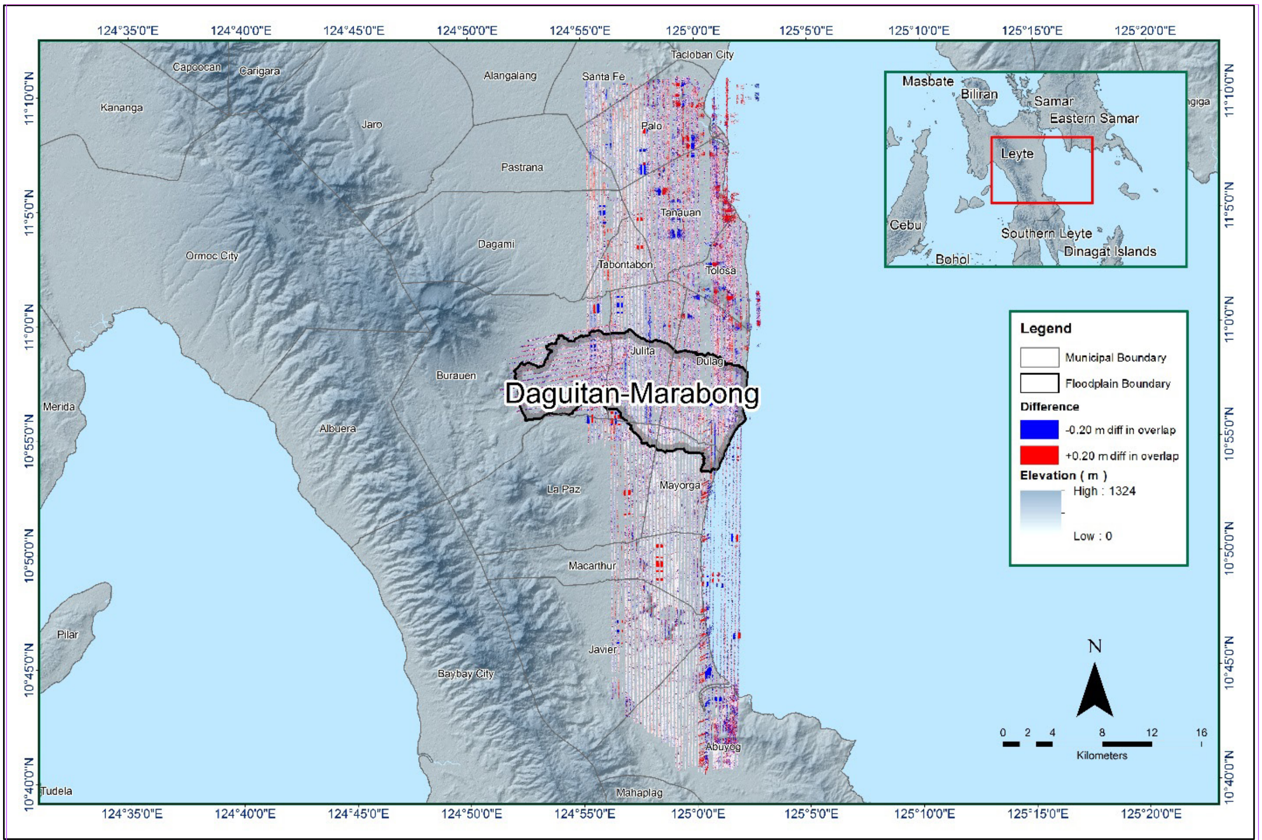


Figure 18. Elevation difference map between flight lines for Daguitan-Marabong Floodplain

A screen capture of the processed LAS data from a Daguitan-Marabong flight 1434A loaded in QT Modeler is shown in Figure 19. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed magenta line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

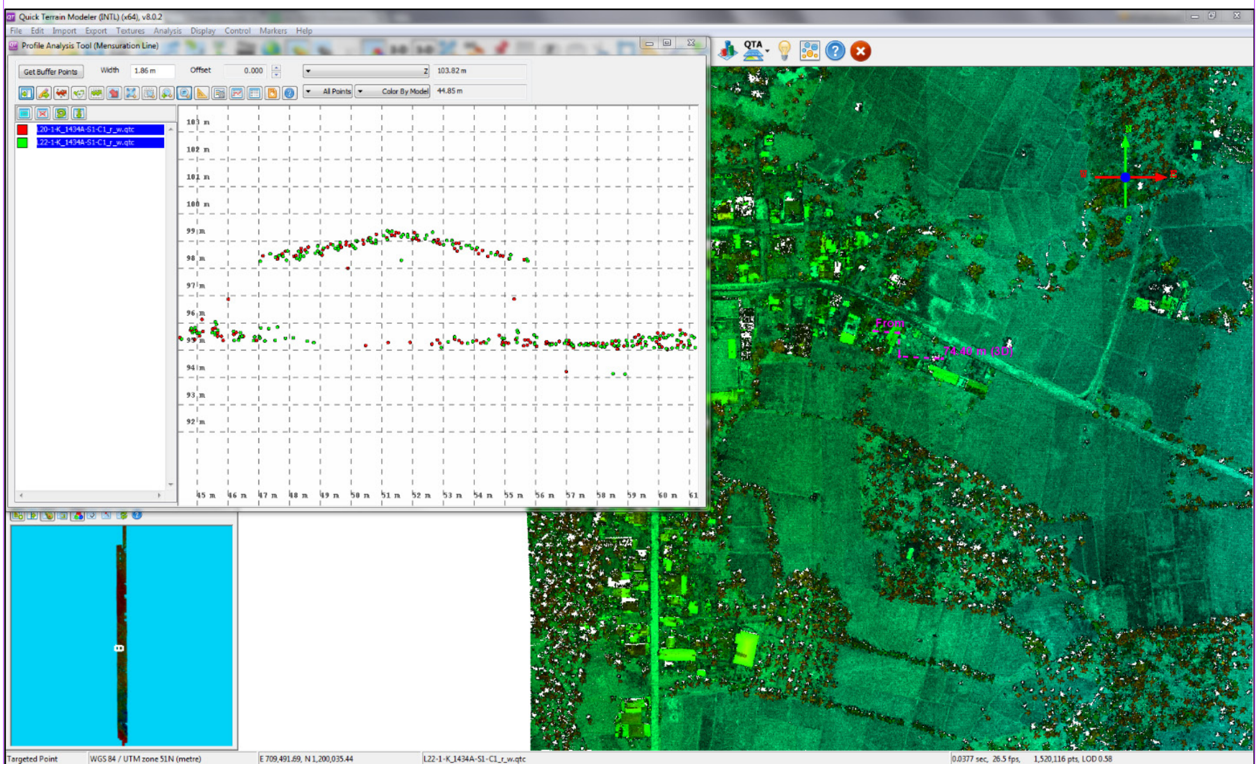


Figure 19. Quality checking for a Daguitan-Marabong flight 1434A using the Profile Tool of QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 16. Daguitan-Marabong classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	455,482,679
Low Vegetation	537,829,245
Medium Vegetation	661,814,183
High Vegetation	235,790,326
Building	9,298,935

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Daguitan-Marabong Floodplain is shown in Figure 20. A total of 1,029 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 16. The point cloud has a maximum and minimum height of 425.31 meters and 42.55 meters respectively.

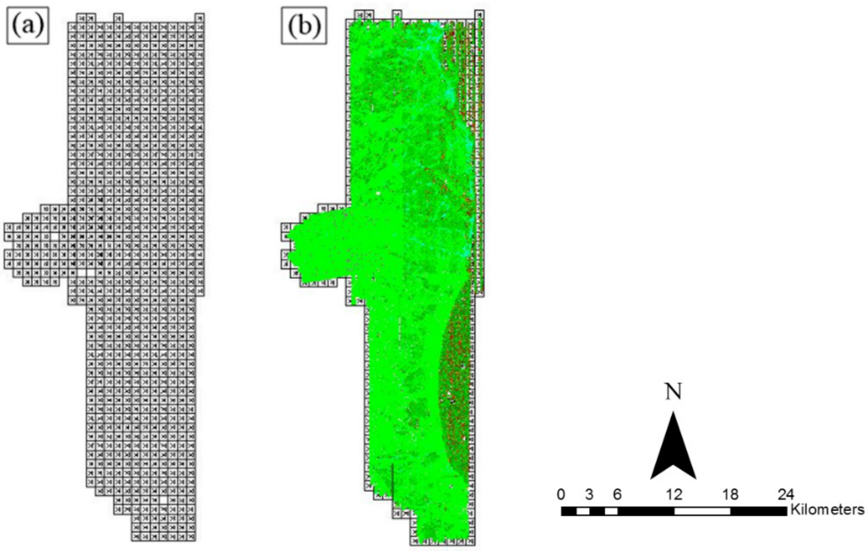


Figure 20. Tiles for Daguitan-Marabong Floodplain (a) and classification results (b) in TerraScan

An isometric view of an area before and after running the classification routines is shown in Figure 21. The ground points are in orange, the vegetation is in different shades of green, and the buildings are in cyan. It can be seen that residential structures adjacent or even below canopy are classified correctly, due to the density of the LiDAR data.

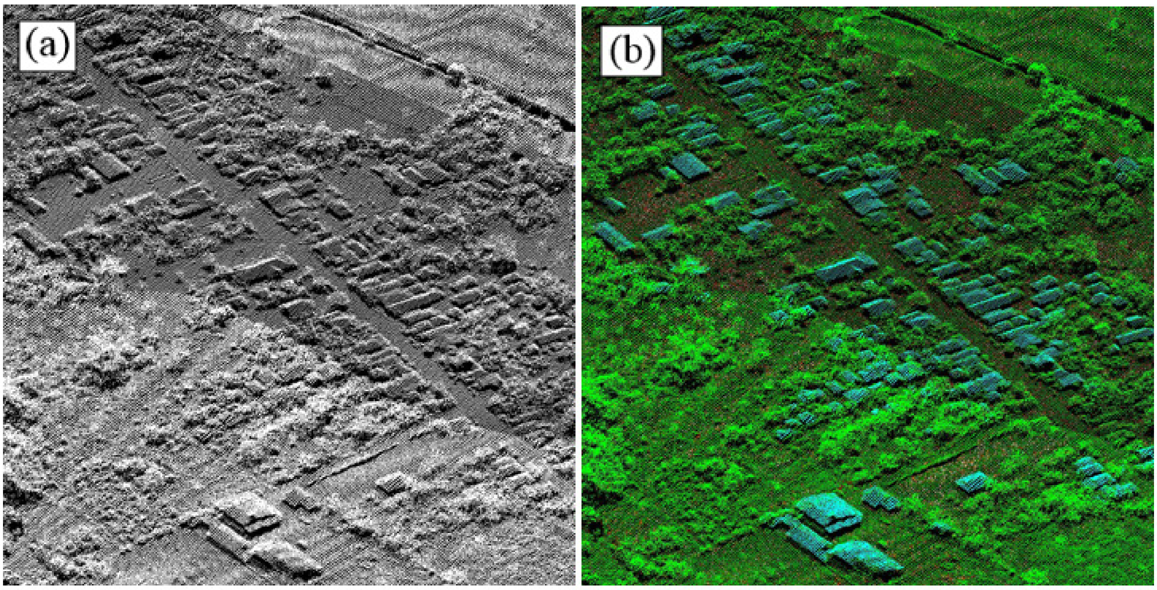


Figure 21. Point cloud before (a) and after (b) classification.

The production of last return (V_ASCII) and the secondary (T_ ASCII) DTM, first (S_ ASCII) and last (D_ ASCII) return DSM of the area in top view display are shown in Figure 22. It shows that DTMs are the representation of the bare earth while on the DSMs, all features are present such as buildings and vegetation.

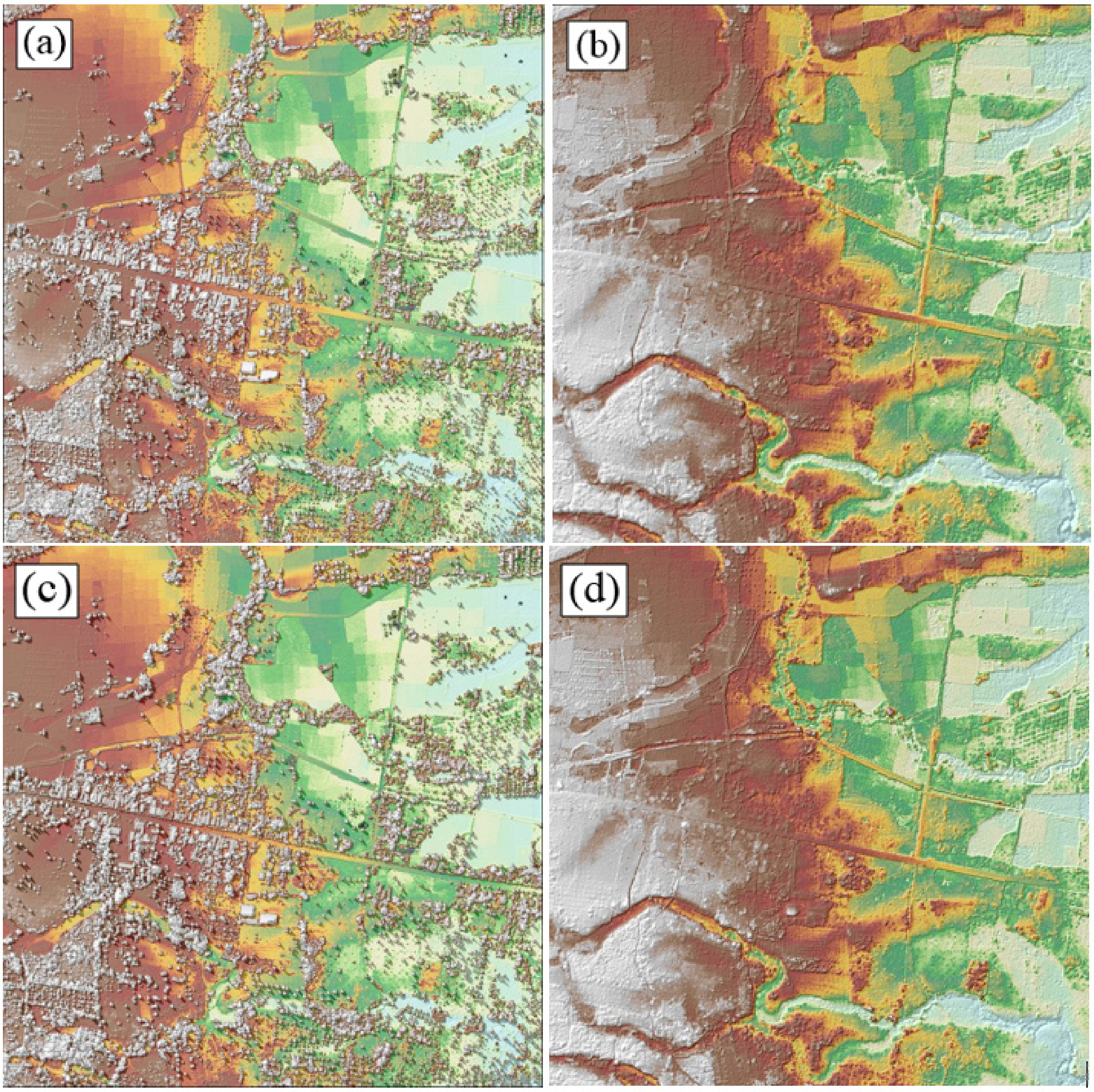


Figure 22. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Daguitan-Marabong Floodplain

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 810 1km by 1km tiles area covered by Daguitan-Marabong Floodplain is shown in Figure 23. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Daguitan-Marabong Floodplain has a total of 602.27 sq.km orthophotogaph coverage comprised of 7,296 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 24.

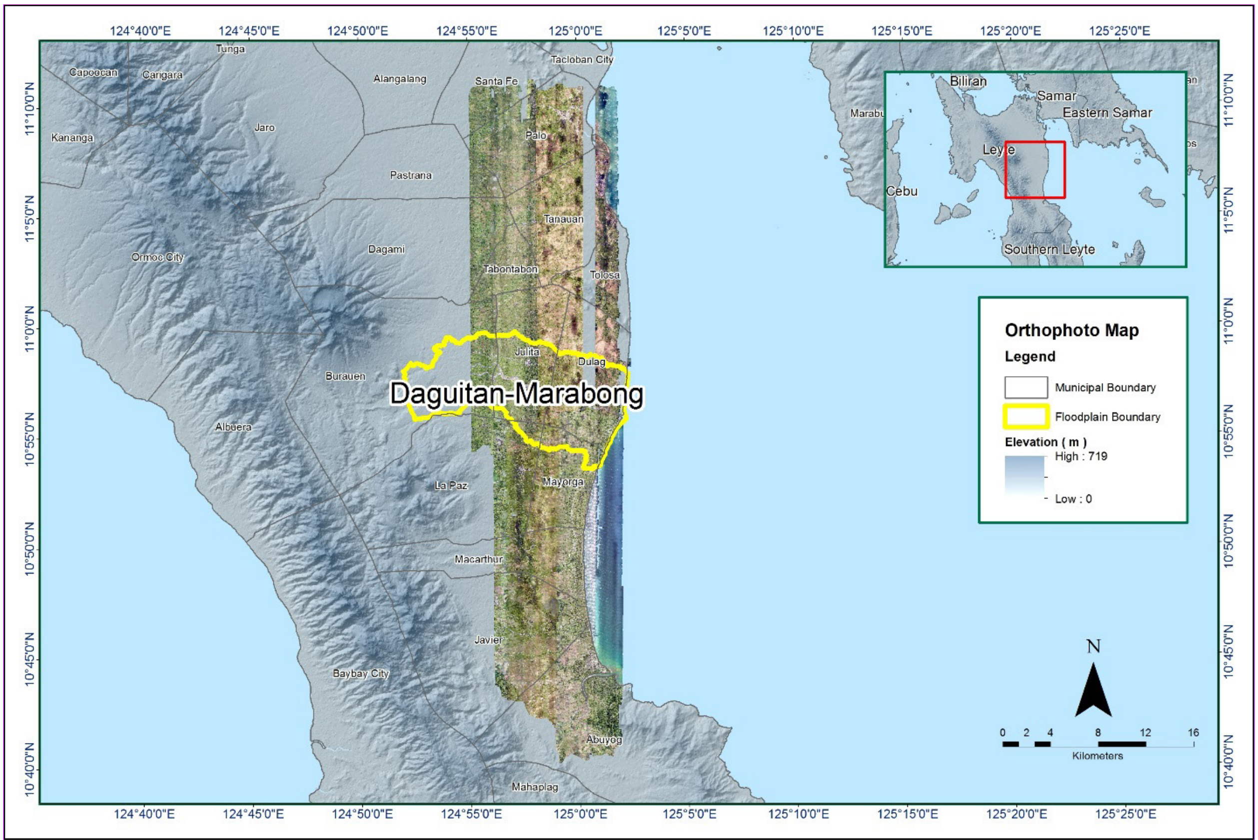


Figure 23. Daguitan-Marabong Floodplain with available orthophotographs

Figure 24. Sample orthophotograph tiles for Daguitan-Marabong Floodplain

3.8 DEM Editing and Hydro-Correction

Five (5) mission blocks were processed for Daguitan-Marabong Floodplain. These blocks are composed of SamarLeyte, Leyte and Tacloban blocks with a total area of 761.40 square kilometers. Table 17 shows the name and corresponding area of each block in square kilometers.

Table 17. LiDAR blocks with its corresponding area

LiDAR Blocks	Area (sq.km)
Tacloban_1026A	239.72
SamarLeyte_Blk34H	147.98
SamarLeyte_Blk34G	140.20
SamarLeyte_Blk34F	164.18
Leyte_Blk34F_additional	69.32
TOTAL	**761.40 sq.km**

Portions of the DTM before and after manual editing are shown in Figure 25. It shows that the river embankment (Figure 25a) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 25b) to allow the correct flow of water. The bridge (Figure 25c) is also considered to be an impedance to the flow of water along the river and has to be removed (Figure 25d) in order to hydrologically correct the river.

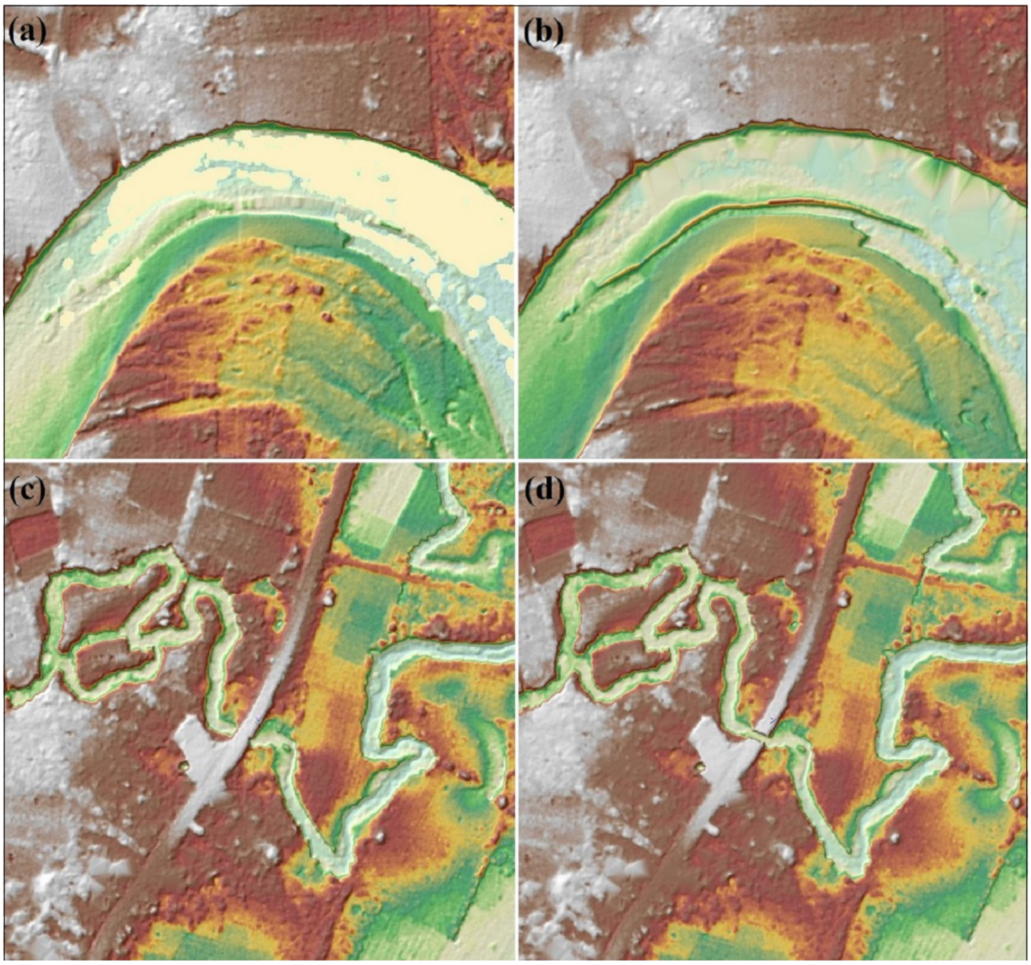


Figure 25. Portions in the DTM of Daguitan-Marabong Floodplain – a river embankment before (a) and after (b) data retrieval and a bridge before (c) and after (d) manual editing

3.9 Mosaicking of Blocks

No assumed reference block was used in mosaicking because the identified reference for shifting was an existing calibrated Tacloban DEM overlapping with the blocks to be mosaicked. Table 18 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Daguitan-Marabong Floodplain is shown in Figure 26. It can be seen that the entire Daguitan-Marabong Floodplain is 99.80% covered by LiDAR data.

Table 18. Shift Values of each LiDAR Block of Daguitan-Marabong Floodplain

Mission Blocks	Shift Values		
	x	y	z
Tacloban_1026A	0.00	0.00	0.00
SamarLeyte_Blk34H	0.00	0.00	-0.52
SamarLeyte_Blk34G	0.00	0.00	-0.54
SamarLeyte_Blk34F	0.00	1.00	-1.01
Leyte_Blk34F_additional	0.00	0.00	-0.89

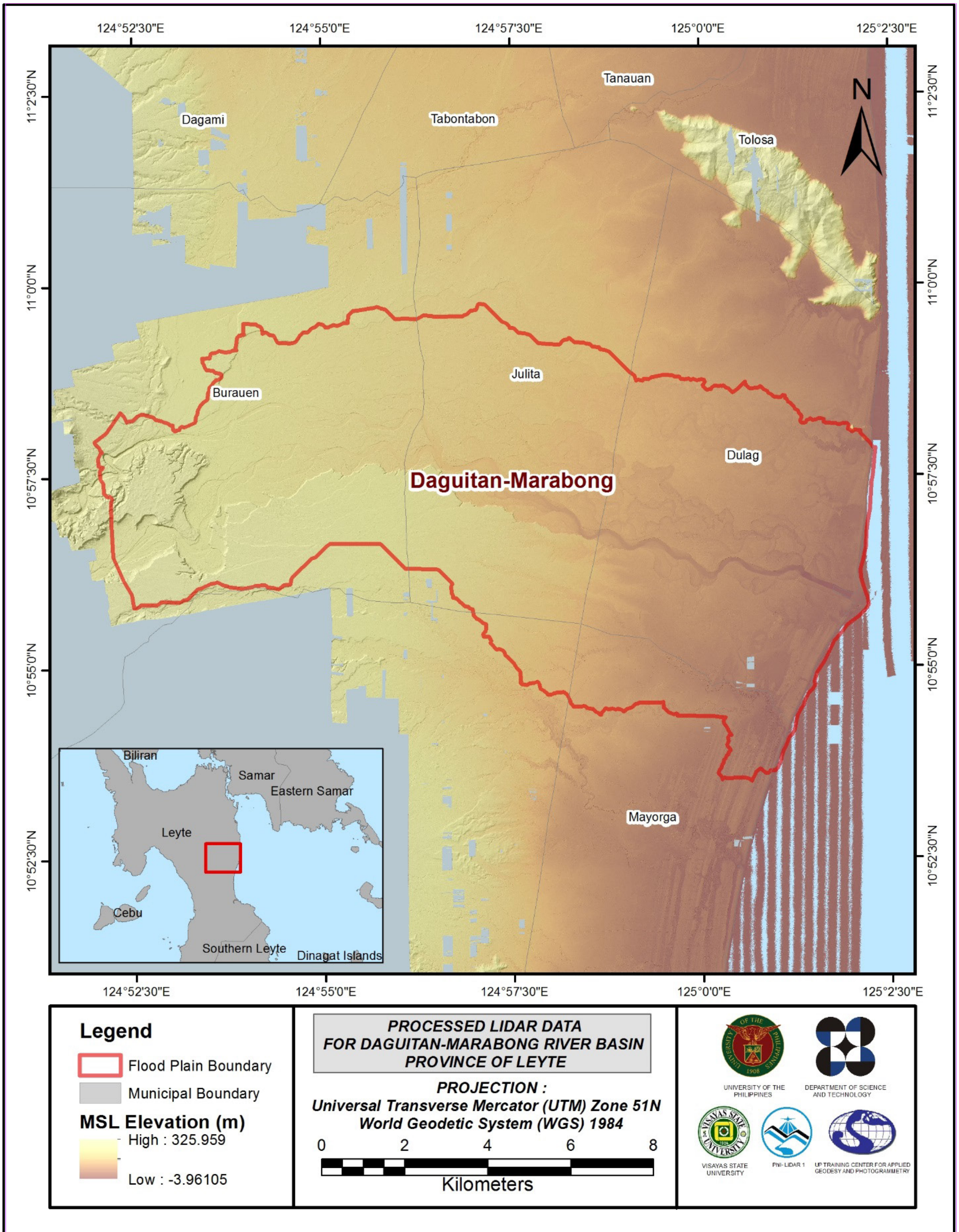


Figure 26. Map of Processed LiDAR Data for Daguitan-Marabong Floodplain

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Daguitan-Marabong to collect points with which the LiDAR dataset was validated is shown in Figure 27. A total of 5,797 survey points were gathered for Daguitan-Marabong Floodplain. However, the point dataset was not used for the calibrationof the LiDAR data for Daguitan-Marabong because during the mosaicking process, each LiDAR block was referred to the calibrated Tacloban DEM. Therefore, the mosaicked DEM of Daguitan-Marabong can already be considered as a calibrated DEM.

A good correlation between the uncalibrated Tacloban LiDAR DTM and ground survey elevation values is shown in Figure 28. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration points is 0.14 meters with a standard deviation of 0.13 meters. Calibration of Tacloban LiDAR data was done by subtracting the height difference value, 0.14 meters, to Tacloban mosaicked LiDAR data. Table 19 shows the statistical values of the compared elevation values between Tacloban LiDAR data and calibration data. These values were also applicable to the Daguitan-Marabong DEM.

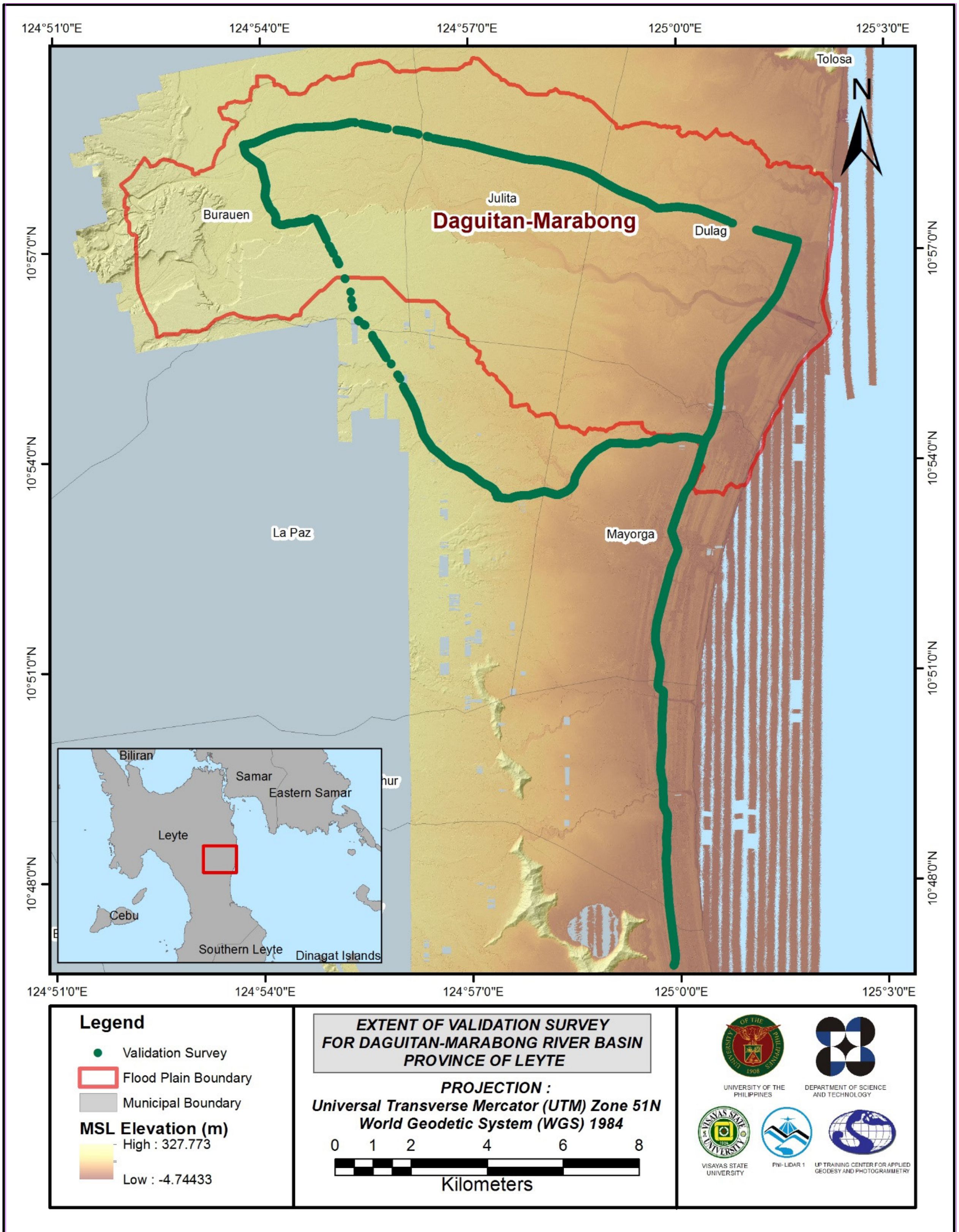


Figure 27. Map of Daguitan-Marabong Floodplain with validation survey points in green

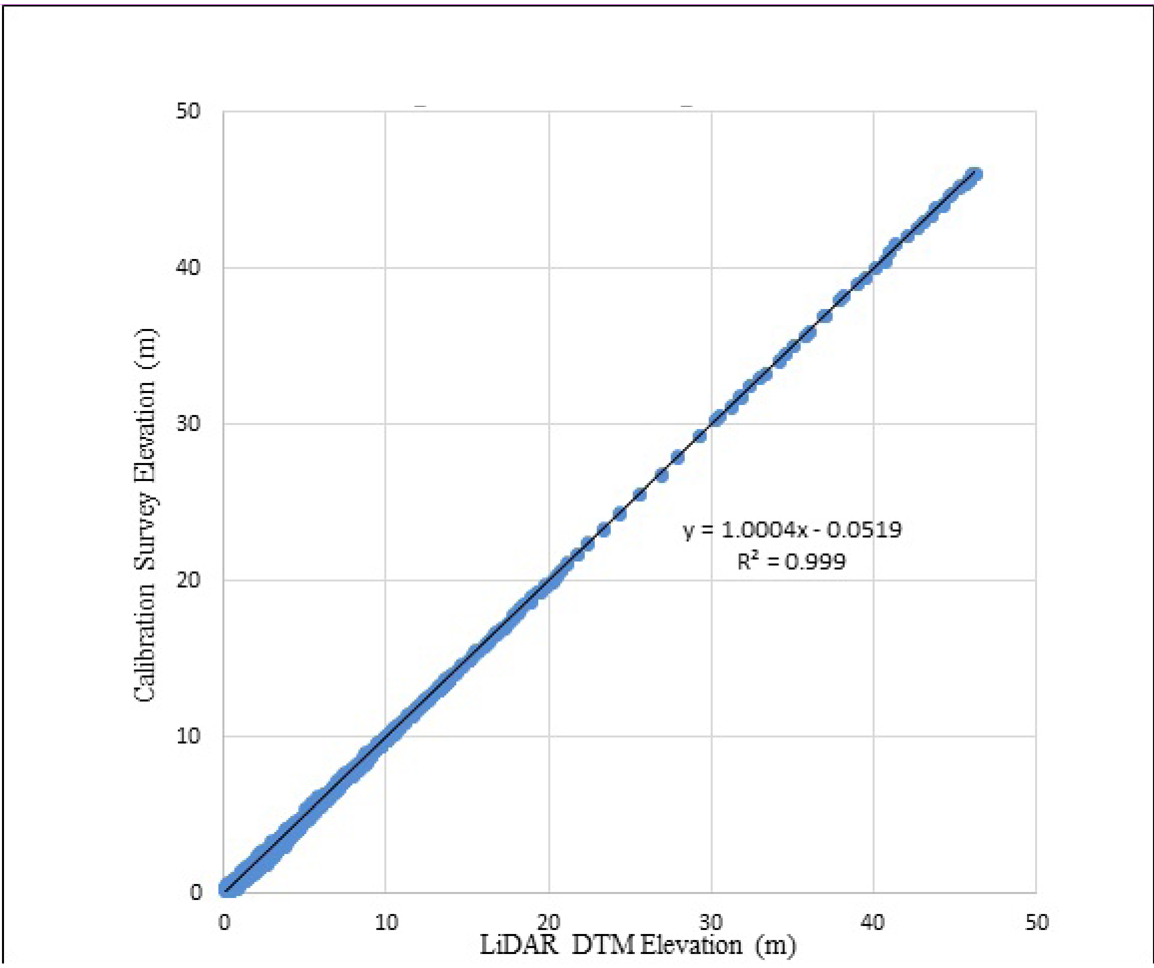


Figure 28. Correlation plot between calibration survey points and LiDAR data

Table 19. Calibration Statistical Measures

Calibration Statistical Measures	Value (meters)
Height Difference	0.14
Standard Deviation	0.13
Average	-0.05
Minimum	-0.65
Maximum	0.50

A total of 3,099 survey points lie within Daguitan-Marabong Floodplain and were used for the validation of the calibrated Daguitan-Marabong 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 29. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.18 meters with a standard deviation of 0.08 meters, as shown in Table 20.

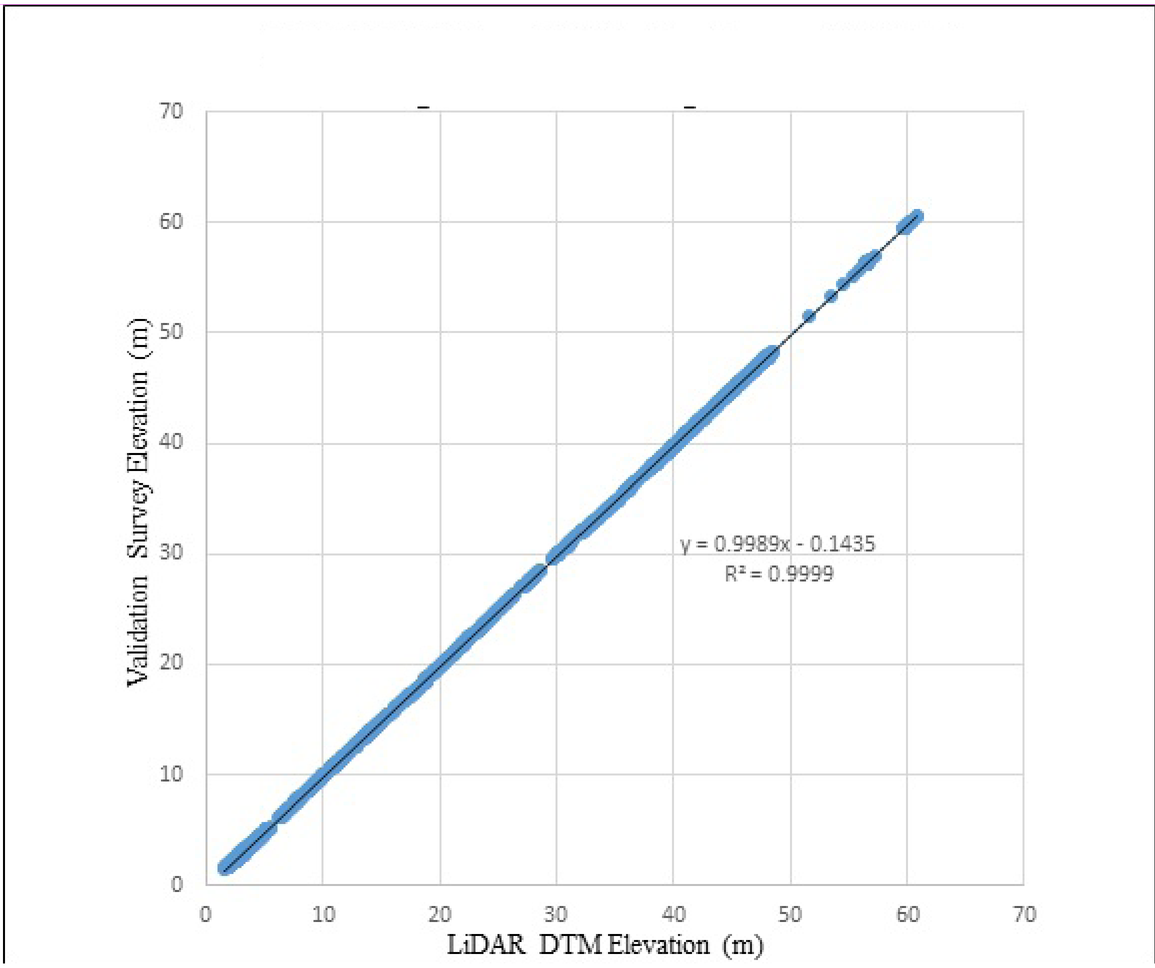


Figure 29. Correlation plot between validation survey points and LiDAR data

Table 20. Validation Statistical Measures

Validation Statistical Measures	Value (meters)
RMSE	0.18
Standard Deviation	0.08
Average	-0.16
Minimum	-0.40
Maximum	0.09

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and cross-section data were available for Daguitan-Marabong with 691 bathymetric survey points. The resulting raster surface produced was done by Kernel Interpolation with Barriers method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.19 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Daguitan-Marabong integrated with the processed LiDAR DEM is shown in Figure 30.

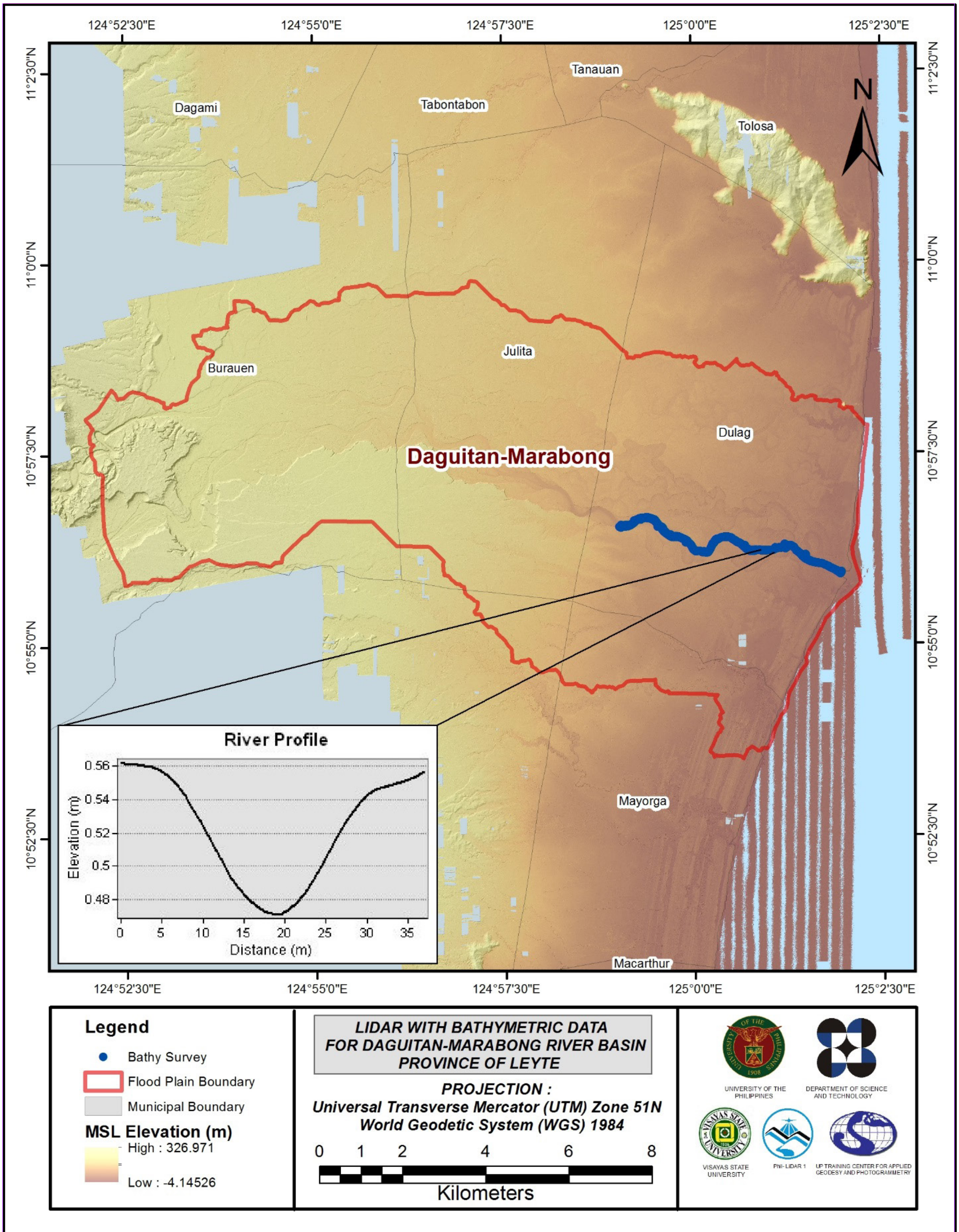


Figure 30. Map of Daguitan-Marabong Floodplain with bathymetric survey points shown in blue

3.12 Feature Extraction

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

3.12.1 Quality Checking of Digitized Features' Boundary

Daguitan-Marabong Floodplain, including its 200 m buffer, has a total area of 134.67 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 1810 building features, are considered for QC. Figure 31 shows the QC blocks for Daguitan-Marabong Floodplain.

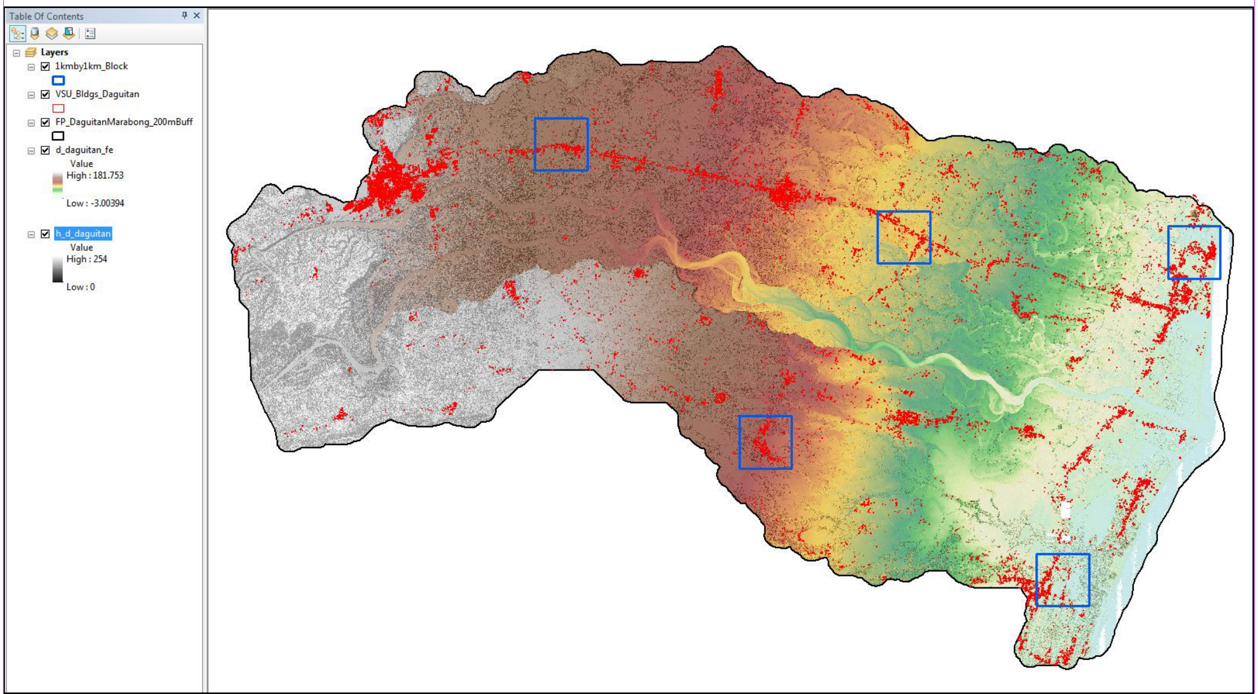


Figure 31. Blocks (in blue) for Daguitan-Marabong building features subjected to QC

Quality checking of Daguitan-Marabong building features resulted in the ratings shown in Table 21.

Table 21. Quality Checking Ratings for Daguitan-Marabong Building Features

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Daguitan-Marabong	99.78	99.78	98.90	PASSED

3.12.2 Height Extraction

Height extraction was done for 18,533 building features in Daguitan-Marabong Floodplain. Of these building features, 236 were filtered out after height extraction, resulting in 18,297 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 6.54 m.

3.12.3 Feature Attribution

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

Table 22 summarizes the number of building features per type. On the other hand, Table 23 indicates the total length of each road type while Table 24 shows the number of water features extracted per type.

Table 22. Building Features Extracted for Daguitan-Marabong Floodplain

Facility Type	No. of Features
Residential	17,234
School	470
Market	21
Agricultural/Agro-Industrial Facilities	42
Medical Institutions	19
Barangay Hall	68
Military Institution	0
Sports Center/Gymnasium/Covered Court	28
Telecommunication Facilities	5
Transport Terminal	2
Warehouse	25
Power Plant/Substation	0
NGO/CSO Offices	19
Police Station	3
Water Supply/Sewerage	5
Religious Institutions	89
Bank	1
Factory	0
Gas Station	11
Fire Station	1
Other Government Offices	64
Other Commercial Establishments	190
Total	**18,297**

Table 23. Total Length of Extracted Roads for Daguitan-Marabong Floodplain

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/ Municipal Road	Provincial Road	National Road	Others	
Daguitan-Marabong	181.79	14.62	35.08	9.48	0.00	**240.96**

Table 24. Number of Extracted Water Bodies for Daguitan-Marabong Floodplain

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Daguitan-Marabong	42	30	0	0	0	72

A total of 140 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 32 shows the Digital Surface Model (DSM) of Daguitan-Marabong Floodplainoverlaid with its ground features.

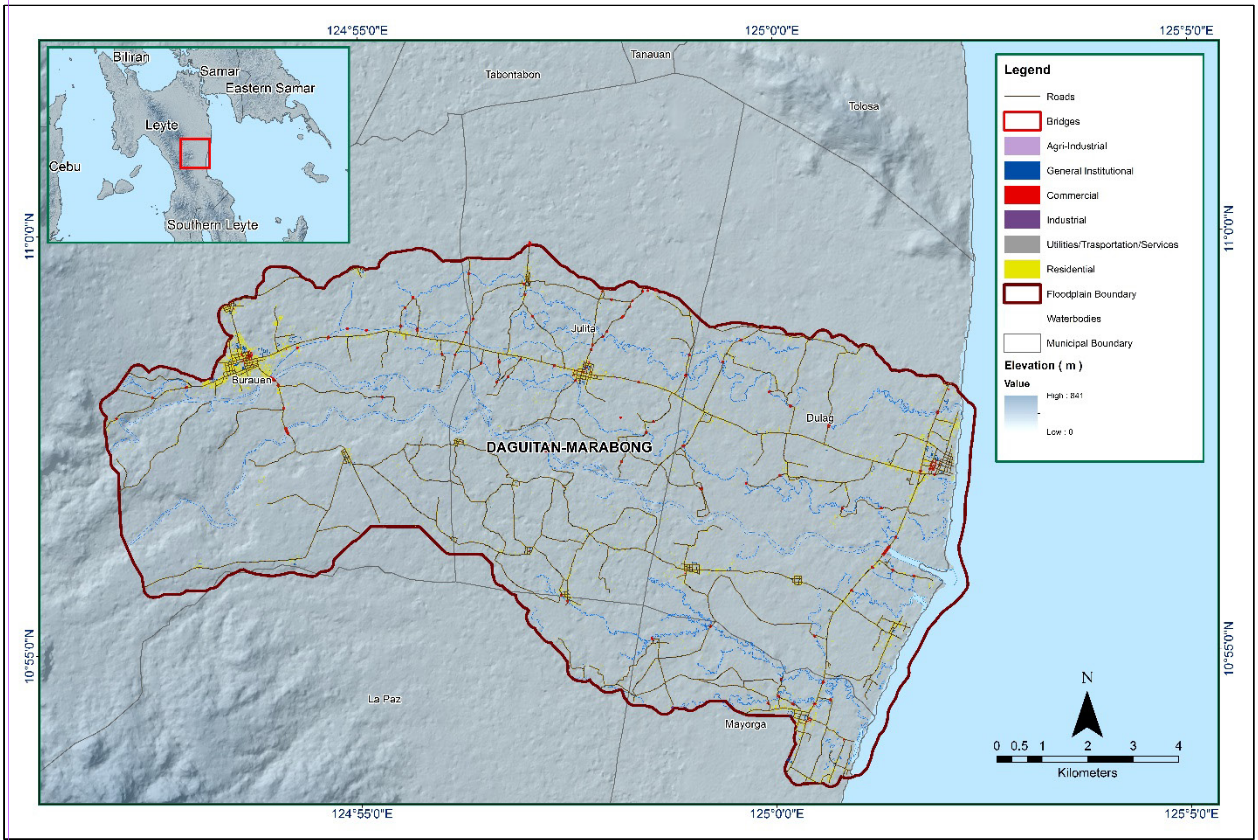


Figure 32. Extracted features for Daguitan-Marabong Floodplain

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS OF THE DAGUITAN-MARABONG FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Joemarie S. Caballero, Ms. Patrizcia Mae. P. dela Cruz, Engr. Kristine Ailene B. Borromeo For. Dona Rina Patricia C. Tajora, Elaine Bennet Salvador, For. Rodel C. Alberto

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).

4.1 Summary of Activities

The DVBC conducted a survey from September 10 to 24, 2015 (Phase 1) for reconnaissance, cross-section and bathymetric and LiDAR validation surveys in Daguitan River from January 6 to 20, 2015. The bathymetric survey started in Brgy. Batug and finished in Brgy. Sabang Daguitan in the Municipality of Dulag. Bathymetric survey was conducted using GNSS PPK survey technique. A Trimble® SPS 882 rover GPS was used as the primary equipment for the survey.

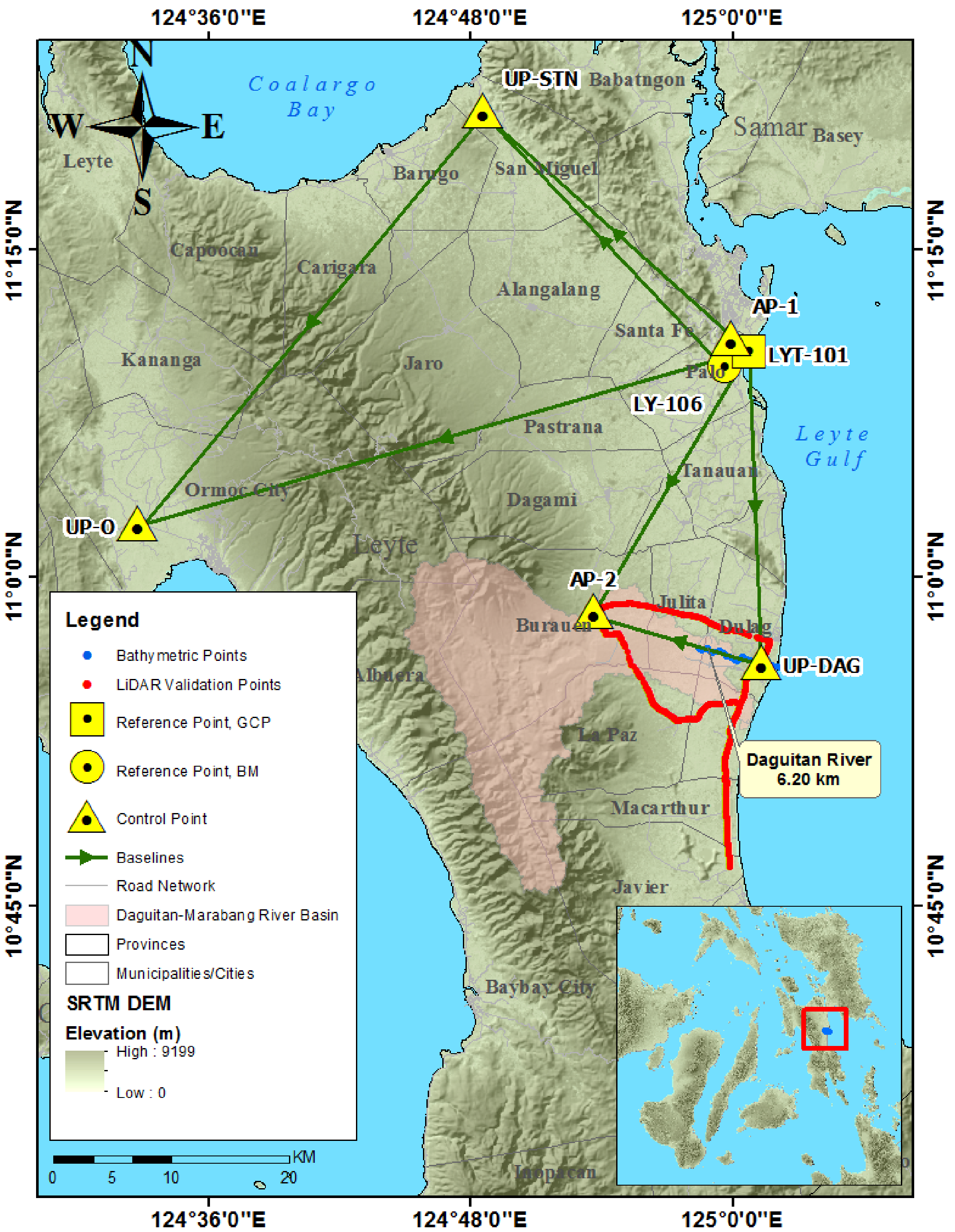


Figure 33. Extent of the bathymetric survey (in blue) in Palo River and the LiDAR data validation survey (in red)

4.2 Control Survey

The GNSS network used for Daguitan River Basin is composed of three (3) loops established on September 18 to 20, 2014 occupying the following reference points: LYT-101, a second-order GCP, in Brgy. Candahog, Municipality of Palo; and LY-106, a second-order GCP, in Brgy. Luntad, Municipality of Palo.

Three (3) control points were established at the approach of bridges namely: UP-DAG at Daguitan Bridge, in Brgy. Fatima, Municipality of Dulag; UP-O at Ormoc Merida Bridge, in Brgy. Liloan, Ormoc City; and UP-STN at Calay-calay Bridge, in Brgy. Caraycaray, Municipality of San Miguel. Two (2) arbitrary points were also observed to complete the network. AP1 and AP2 are located at the corner of Maharlika Highway and an unnamed street going to Campetic Road, in Brgy. Campetik, Municipality of Palo and inside Burauen Church Plaza, Julita Burauen Road corner Burauen – Dagami Road, Brgy. Poblacion VII, Municipality of Burauen, Province of Leyte, respectively.

The summary of reference and control points and its location is summarized in 25 while GNSS network established is illustrated in Figure 34.

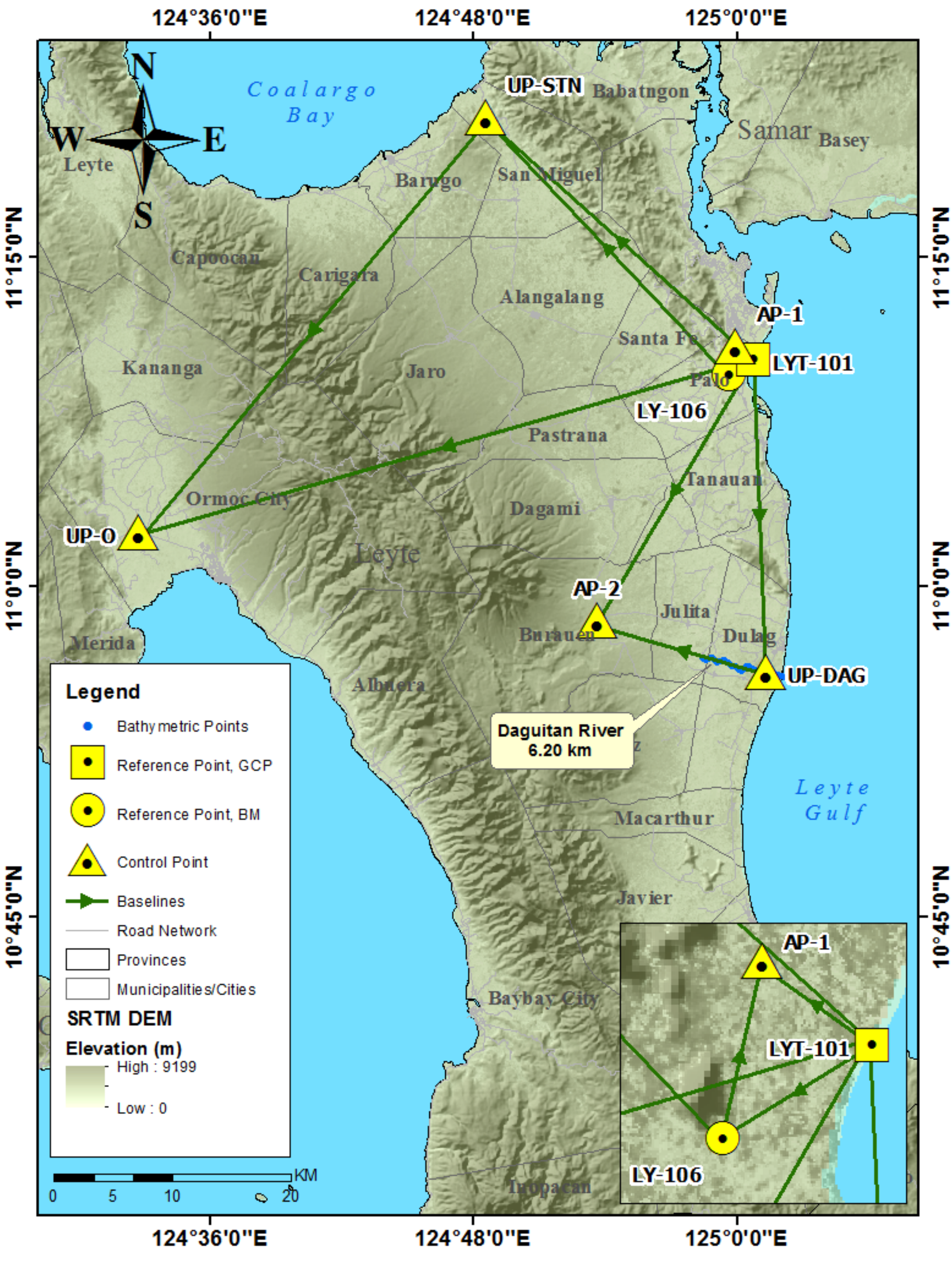


Figure 34. GNSS network for the Daguitan River survey

Table 25.List of references and control points occupied for Daguitan River Survey (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (m)	MSL Elevation (m)	Date established
LYT-101	2nd order, GCP	11°10'19.64869" N	125°00'43.78230" E	69.228	-	09-20-2014
LY-106	1st order, BM	-	-	68.051	4.028	2007
UP-DAG	UP Established	-	-	-	-	09-20-2014
UP-O	UP Established	-	-	-	-	09-19-2014
UP-STN	UP Established	-	-	-	-	09-11-2014
AP1	Arbitrary	-	-	-	-	09-18-2014
AP2	Arbitrary	-	-	-	-	09-20-2014

The GNSS set up made in the location of the reference and control points are shown in Figure 35 to Figure 39.

Figure 35. GNSS base set up, Trimble® SPS 852, at LYT-101, located at the General McArthur Shrine in Brgy. Candahog, Municipality of Palo, Leyte

Figure 36. GNSS base set up, Trimble® SPS 985, at LY-106, located at the approach of Bernard Reed Bridge along Maharlika Highway , Brgy. Luntad, Municipality of Palo, Leyte

Figure 37. GNSS receiver set up, Trimble® SPS 985, at UP DAG, an established control point, located at the bridge approach of the Daguitan Bridge along Maharlika Highway in Brgy. Fatima, Municipality of Dulag, Province of Leyte

Figure 38. GNSS receiver set up, Trimble® SPS 985, at UP-O, an established control point, located at the bridge approach of the Ormoc Merida Bridge along Ormoc-Merida-Isabel-Palompon Road in Brgy. Liloan, City of Ormoc, Province of Leyte.

Figure 39. GNSS base set up, Trimble® SPS 852, at UP-STN, an established control point, located at Pagbanganan Bridge approach in Brgy. Brgy. Poblacion Zone 12, City of Baybay, Leyte

4.3 Baseline Processing

GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement, respectively. In case where one or more baselines did not meet all of these criteria, masking was performed. Masking is done by removing/masking portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. Baseline processing result of control points in Daguitan River Basin is summarized in Table 26 generated by TBC software.

Table 26. Baseline Processing Report for Daguitan River Basin Static Survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)
UP-STN --- UP-O (B2)	09-19-2014	Fixed	0.003	0.013	219°39'13”	45132.753
LY-106 --- AP1 (B4)	09-18-2014	Fixed	0.003	0.012	12°44'49"	2489.516
LY-106 --- UP-STN (B11)	09-18-2014	Fixed	0.005	0.042	317°02'38"	29477.609
LYT-101 --- UP-O (B1)	09-19-2014	Fixed	0.005	0.013	254°12'03"	52970.388
LYT-101 ---AP1 (B6)	09-18-2014	Fixed	0.002	0.003	307°32'43"	1903.266
LYT-101 --- UP-STN (B10)	09-18-2014	Fixed	0.005	0.039	312°31'18"	30045.665
LYT-101 --- UP-STN (B3)	09-18-2014	Fixed	0.003	0.011	312°31'18"	30045.649
LYT-101 --- LY-106 (B7)	09-20-2014	Fixed	0.003	0.016	238°21'43"	2417.850
LYT-101 --- LY-106 (B5)	09-20-2014	Fixed	0.002	0.004	238°21'42"	2417.858
LYT-101 --- UPDAG (B13)	09-20-2014	Fixed	0.004	0.011	177°43'46"	26154.013
LYT-101 --- AP2 (B12)	09-20-2014	Fixed	0.003	0.012	210°46'11"	25458.032
UP-DAG --- AP2 (B14)	09-20-2014	Fixed	0.004	0.014	286°51'16"	14691.113

As shown in Table 26, a total of twelve (12) baselines were processed with reference points LYT-101 and LY-106 held fixed for grid and elevation values, respectively. All of them passed the required accuracy.

4.4 Network Adjustment

After the baseline processing procedure, network adjustment was performed using TBC. Looking at the Adjusted Grid Coordinates (Table 28) of the TBC generated Network Adjustment Report, it is observed that the square root of the sum of the squares of x and y must be less than 20 cm and z less than 10 cm or in equation form:

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

Where:

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

for each control point. See the Network Adjustment Report shown in Table 27 to Table 29 for the complete details.

The seven (7) control points, LYT-101, LY-106, UP-DAG, UP-O, UP-STN, and two (2) arbitrary points were occupied and observed simultaneously to form a GNSS loop. The coordinates of point LYT-101 and elevation value of LY-106 were held fixed during the processing of the control points as presented in Table 27. Through these reference points, the coordinates and elevation of the unknown control points were computed.

Table 27. Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
LYT-101	Local	Fixed	Fixed		
LY-106	Grid				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 28. The fixed control points LYT-101 has no values for grid errors; and LY-106, for elevation error.

Table 28. Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
LYT-101	1235759.250	?	719729.823	?	5.141	0.040	LL
LY-106	1234476.732	0.007	717679.601	0.006	4.028	?	e
UP-DAG	1209628.100	0.013	720942.270	0.009	5.993	0.077	e
UP-O	1220991.402	0.014	668855.819	0.010	8.719	0.076	
UP-STN	1255916.567	0.009	697443.625	0.007	8.835	0.070	
AP1	1236908.994	0.007	718212.616	0.007	4.834	0.051	
AP2	1213793.946	0.012	706851.618	0.010	56.317	0.079	

The network is fixed at reference points LYT-101 with known coordinates and LY-106 with known elevation. With the mentioned equation, $\sqrt{((x_e)^2 + (y_e)^2)} < 20cm$ for horizontal and $|z_e < 10\ cm$ for the vertical; the computation for the accuracy are as follows:

a. LYT-101

horizontal accuracy = Fixed
vertical accuracy = 4.0 cm < 10 cm

b. LY-106

horizontal accuracy = $\sqrt{((1.30)^2 + (0.6)^2)}$
= $\sqrt{(0.49 + 0.36)}$
= 0.92 cm < 20 cm
vertical accuracy = Fixed

c. UP-DAG

horizontal accuracy = $\sqrt{((1.3)^2 + (0.90)^2)}$
= $\sqrt{(1.69 + 0.81)}$
= 1.58 cm < 20 cm
vertical accuracy = 7.70 cm < 10 cm

d.UP-O

horizontal accuracy = $\sqrt{((1.40)^2 + (1.10)^2)}$
= $\sqrt{(1.96 + 1.21)}$
= 1.78 cm < 20 cm
vertical accuracy = 7.60 cm < 10 cm

e. UP-STN

horizontal accuracy	=	$\sqrt{((0.90)^2 + (0.70)^2}$
	=	$\sqrt{(0.81 + 0.49)}$
	=	1.14 cm < 20 cm
vertical accuracy	=	7.0 cm < 10 cm

f. AP1

horizontal accuracy	=	$\sqrt{((0.70)^2 + (0.70)^2}$
	=	$\sqrt{(0.49 + 0.49)}$
	=	0.98 cm < 20 cm
vertical accuracy	=	5.10 cm < 10 cm

g. AP2

horizontal accuracy	=	$\sqrt{((1.20)^2 + (1.0)^2}$
	=	$\sqrt{(1.44 + 1.0)}$
	=	1.56 cm < 20 cm
vertical accuracy	=	7.9 cm < 10 cm

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

Table 29. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
LY-106	N11°09'38.36982"	E124°59'35.93684"	68.051	?	e
UP-DAG	N10°56'09.12671"	E125°01'17.90763"	70.609	0.077	
UP-O	N11°02'28.97646"	E124°32'44.58922"	71.626	0.076	
UP-STN	N11°21'20.28504"	E124°48'33.44650"	71.793	0.070	
AP1	N11°10'57.39411"	E124°59'54.04241"	68.821	0.051	
AP2	N10°58'27.65859"	E124°53'34.80074"	120.385	0.079	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 29. Based on the result of the computation, the equation is satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table 30.

Table 30. Reference and control points used and its location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
LYT-101	2nd Order, GCP	11°10'19.64869"	125°00'43.78230"	69.228	1235759.250	719729.823	5.141
LY-106	1st order, BM	11°09'38.36982"	124°59'35.93684"	68.051	1234476.732	717679.601	4.028
UP-DAG	UP Established	10°56'09.12671"	125°01'17.90763"	70.609	1209628.100	720942.270	5.993
UP-O	UP Established	11°02'28.97646"	124°32'44.58922"	71.626	1220991.402	668855.819	8.719
UP-STN	UP Established	11°21'20.28504"	124°48'33.44650"	71.793	1255916.567	697443.625	8.835
AP1	Arbitrary Point	11°10'57.39411"	124°59'54.04241"	68.821	1236908.994	718212.616	4.834
AP2	Arbitrary Point	10°58'27.65859"	124°53'34.80074"	120.385	1213793.946	706851.618	56.317

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

Cross-section and as-built survey were conducted on September 15, 2014 at the upstream part of Daguitan Bridge in Brgy. Dulag, Daguitan, Leyte using a GNSS receiver Trimble® SPS 882 in PPK survey technique as shown in Figure 40.

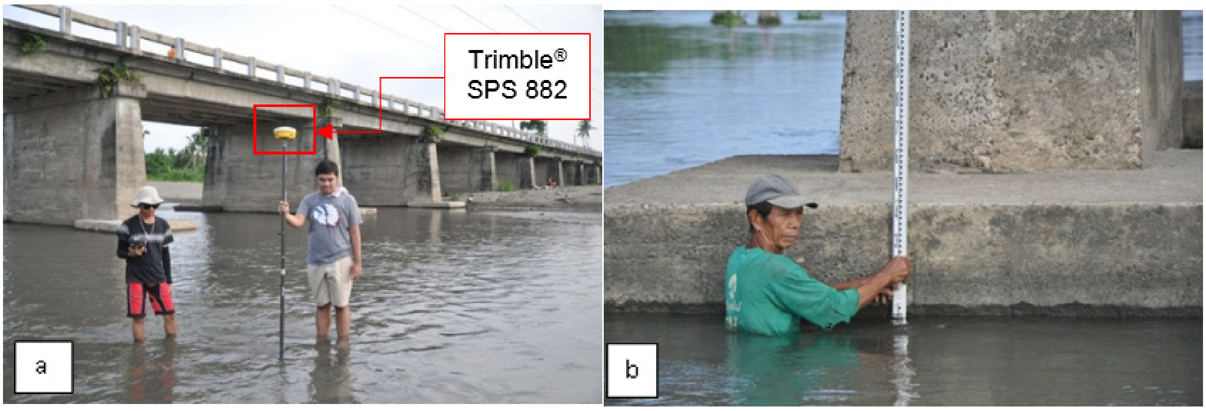


Figure 40. (a) Bridge cross-section and (b) As-Built Surveys at Daguitan Bridge, Dulag, Leyte

The cross-section line length for Daguitan Bridge was about 371.04 m with a total of 32 points gathered using UP-DAG as the GSS base station. Figure 42 to Figure 44 show the summary of gathered cross-section in diagram, location map, and bridge data form, respectively.

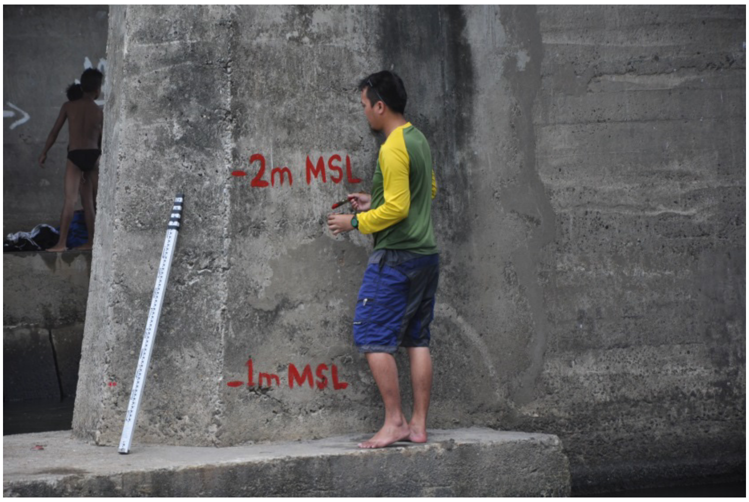


Figure 41. Water level marking of Daguitan Bridge's Pier

Water surface elevation in MSL of Daguitan River, as shown in Figure 40 was determined using Trimble® SPS 882 in PPK mode technique on September 15, 2014 at 3:54 PM with a value of 0.224 m in MSL. This was translated onto marking on one of the bridge's pier using digital level which were used by Visayas State University PHIL-LiDAR 1. The marking served as their reference for flow data gathering and depth gauge deployment for Daguitan River.

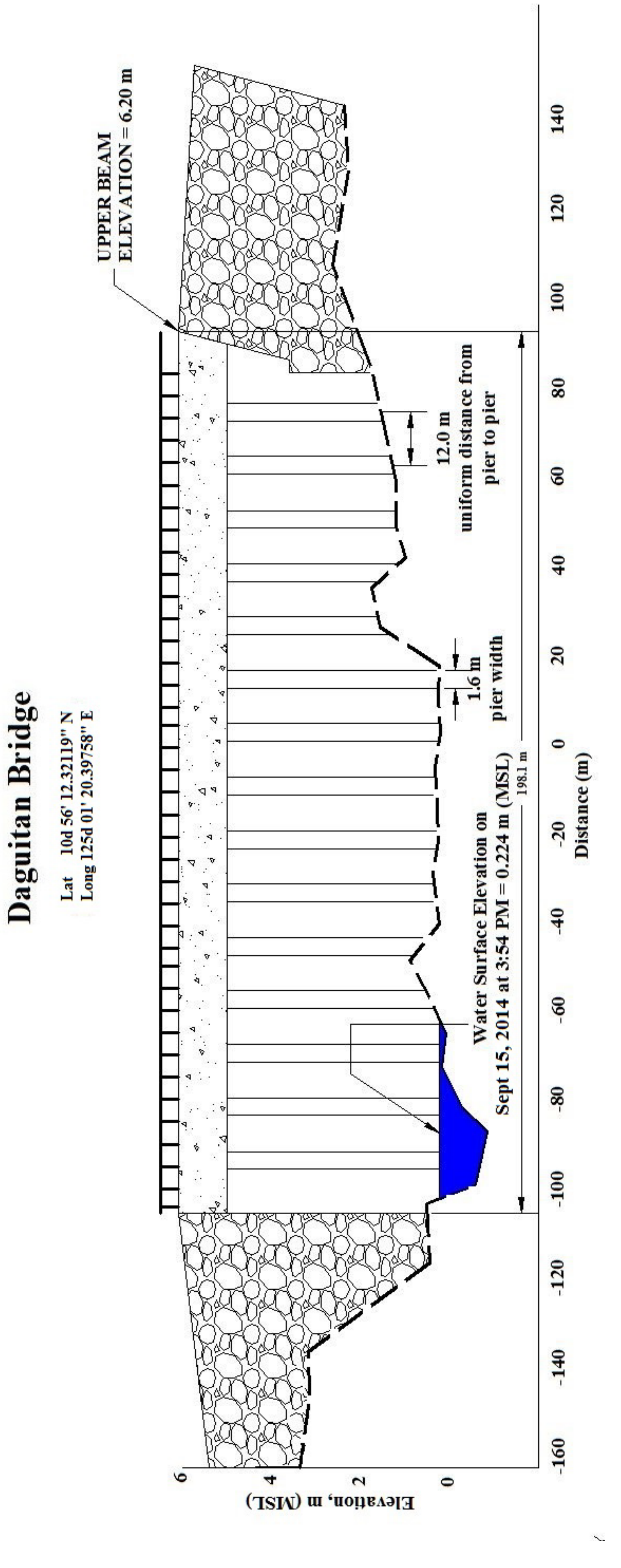


Figure 42. Daguitan Bridge cross-section diagram

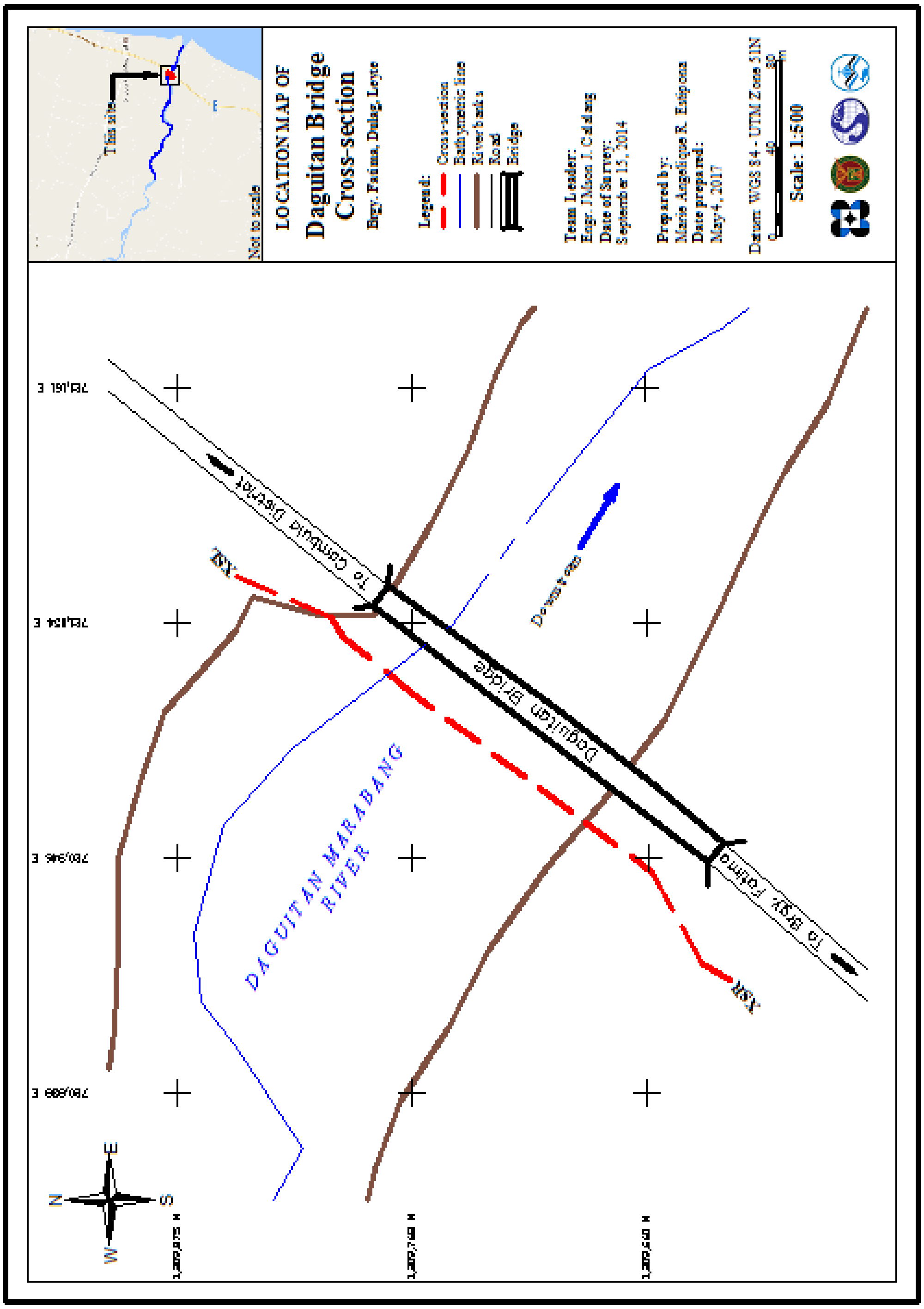


Figure 43. Daguitan bridge cross-section location map

Bridge Data Form

Bridge Name: Daguitan Bridge Date: 9/15/14

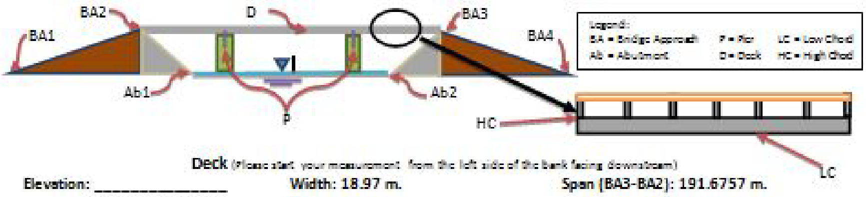
River Name: Daguitan Marabang Time: ______________

Location (Brgy, City, Region): Dulag, Leyte

Survey Team:______________________

Flow condition: low normal high Weather Condition: fair rainy

Latitude: 10d56'13.87923" Longitude: 125d01'21.59622"



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

Elevation: ______________ Width: 18.97 m. Span (BA3-BA2): 191.6757 m.

	Station (Distance from BA2)	High Chord Elevation	Low Chord Elevation
1	137.0996	6.08	4.98
2	160.7226	6.22	5.12
3	184.762	6.23	5.13
4	208.7644	6.19	5.09
5	232.7445	6.20	5.1
6	256.7209	6.21	5.11
7	280.6878	6.18	5.08
8	304.8943	6.18	5.08
9	328.7753	6.08	4.98

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	4.21	BA3	328.7753	6.08
BA2	137.0996	6.08	BA4	466.1009	4.86

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

	Station (Distance from BA1)	Elevation
Ab1	137.8996	2.15
Ab2	327.9684	1.50

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

Shape: ____________________ Number of Piers: 15

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	148.6606	0.1719	1.6
Pier 2	160.7225	0.0999	1.6

Figure 44. Daguitan bridge as-built survey data form

4.6. Validation Points Acquisition Survey

Validation points acquisition survey was conducted on September 20, 2014 using a survey-grade GNSS Rover receiver, Trimble® SPS 882 mounted on a pole which was attached to the side of vehicle as shown in Figure 45. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna height was 2.404 m and measured from the ground up to the bottom of notch of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with UP-DAG occupied as the GNSS base station throughout the conduct of the survey.

The ground validation survey traversed the Municipalities of Macarthur, Javier, Mayorga, Dulag, Julita, Burauen, and La Paz as shown in Figure 46. The total length of the survey is approximately 54.54 km with a total of 5,797 points.

Figure 45. Set up for Validation Points Acquisition Survey in Daguitan River Basin

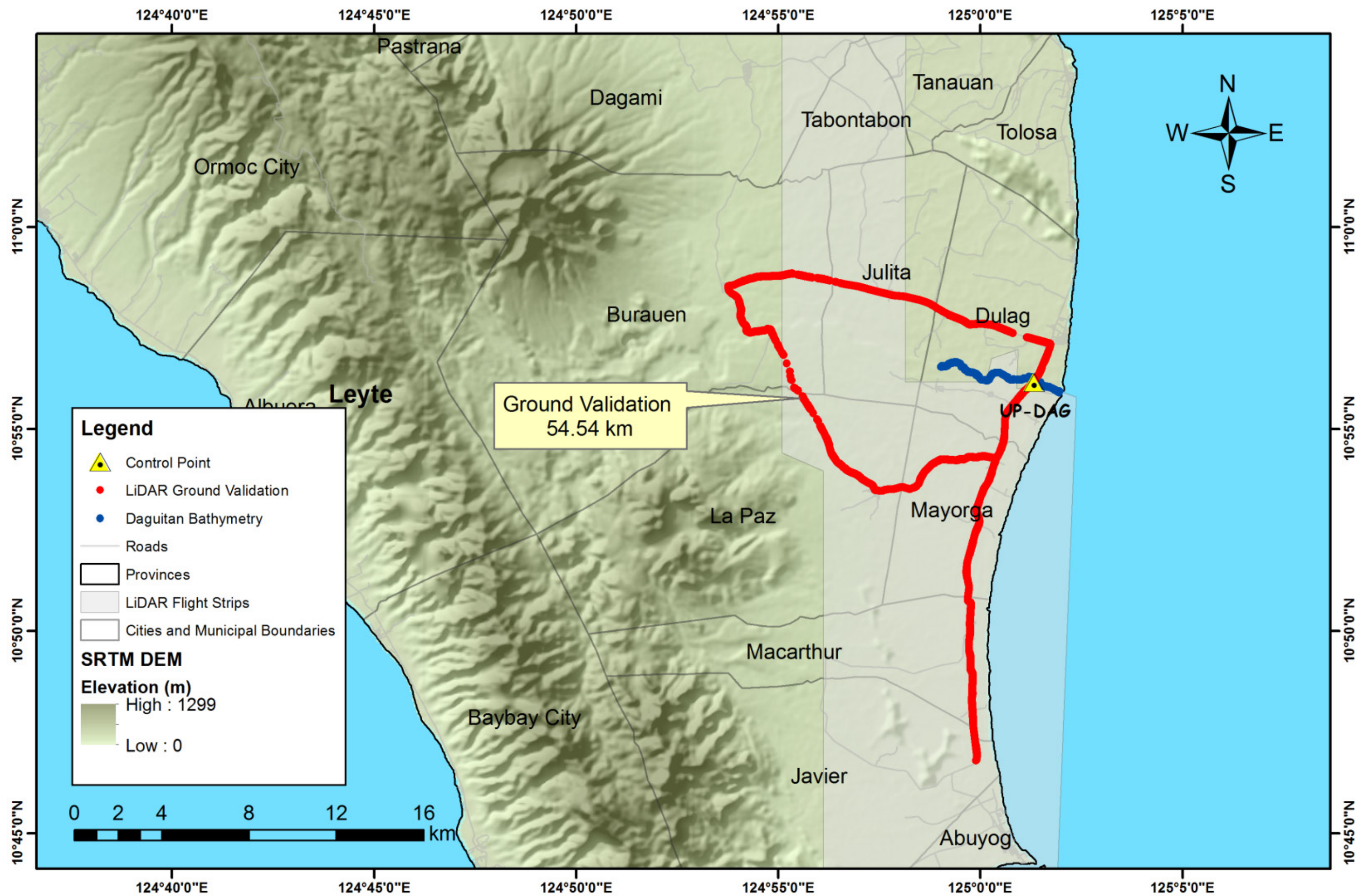


Figure 46. Validation Points Acquisition Survey for Daguitan River Basin

4.7 Bathymetric Survey

Manual bathymetric survey was conducted in Daguitan River on January 12, 2015 using a Trimble® SPS 882 rover in GNSS PPK survey technique as shown in Figure 47. The survey began from the upstream portion of the river in Brgy. Batug down, Municipality of Dulag, Leyte with coordinates 10˚56'32.35312"124˚59'01.39722", down to its mouth in Brgy. Sabang Daguitan, also in Dulag, Leyte with coordinates 10˚55'55.80597" 125˚01'57.00170". The UP established control point UP-DAG was occupied as the base station throughout the survey.

Figure 47. Manual bathymetric survey of Daguitan River

The bathymetry line length is about 6.20 km with a total of 729 points. The processed data were generated into a map using GIS software as shown in Figure 48. A CAD drawing was also produced to illustrate the riverbed profile of Daguitan River. As shown in Figure 49, there is about a 6 m elevation difference between the starting point of the bathymetry profile down to the mouth of the river.

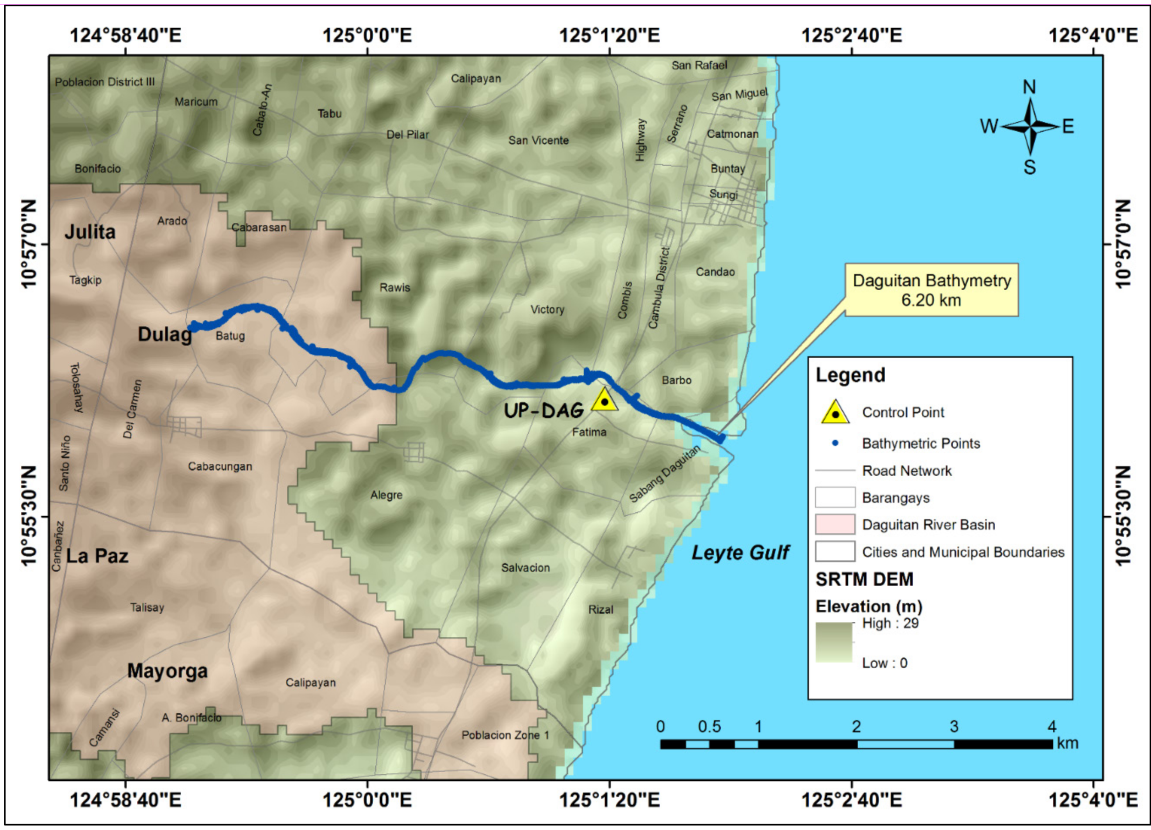


Figure 48. Bathymetric points gathered of Daguitan River

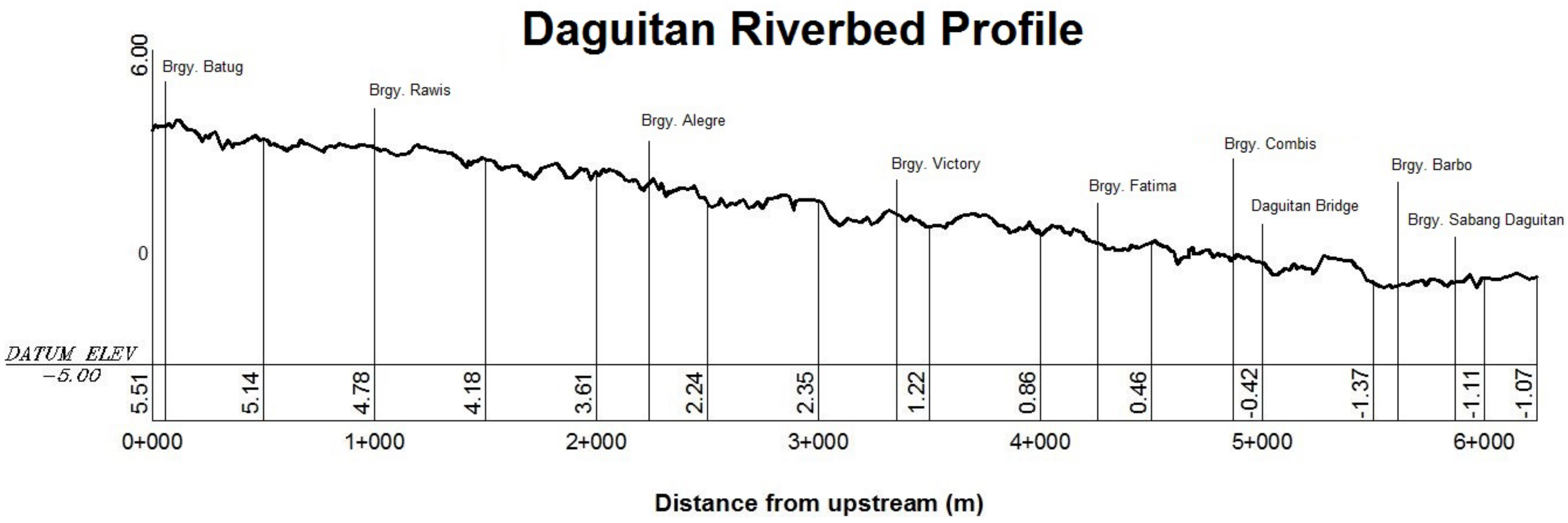


Figure 49. Riverbed profile of Daguitan River

CHAPTER 5: RESULTS AND DISCUSSION FMC

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

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).

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

Precipitation data was taken from the automatic rain gauge (ARG) installed by DOST-PREDICT at District 6, Burauen, Leyte. The location of the rain gauges is seen in Figure 50.
Total rain from NIA Dam rain gauge was 70 mm. It peaked to 5.6 mm on 24 November 2016, 06:45 PM. A summary of the data is seen in Table 30. The lag time between the peak rainfall and discharge is one hour and forty five minutes.

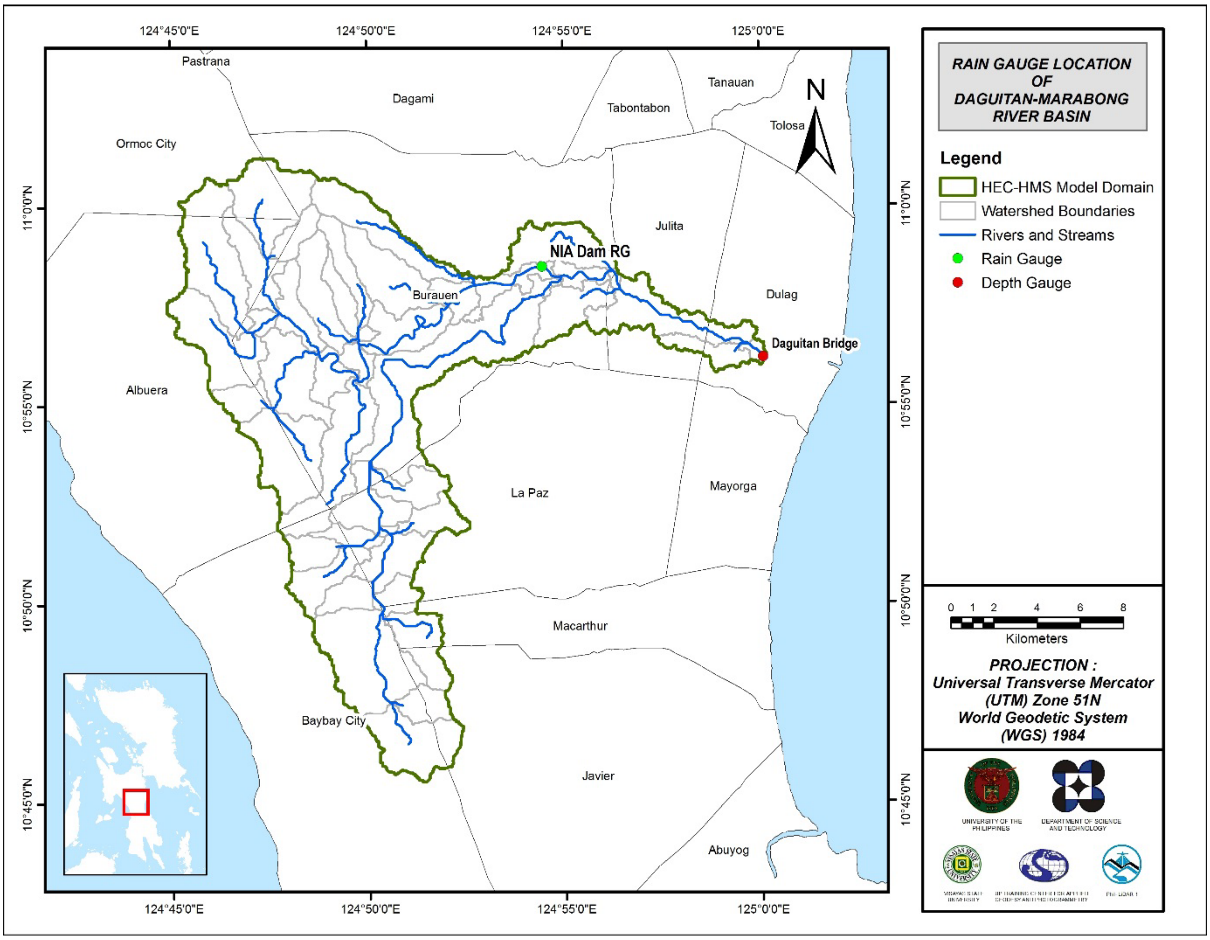


Figure 50. The location map of Daguitan-Marabong HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Daguitan Bridge, Barangay Fatima, Dulag, Leyte. It gives the relationship between the observed water levels at Daguitan Bridge and outflow of the watershed at this location.

For Daguitan Bridge, the rating curve is expressed as $Q = 17.588838e^{2.38340}$ has shown in Figure 52.

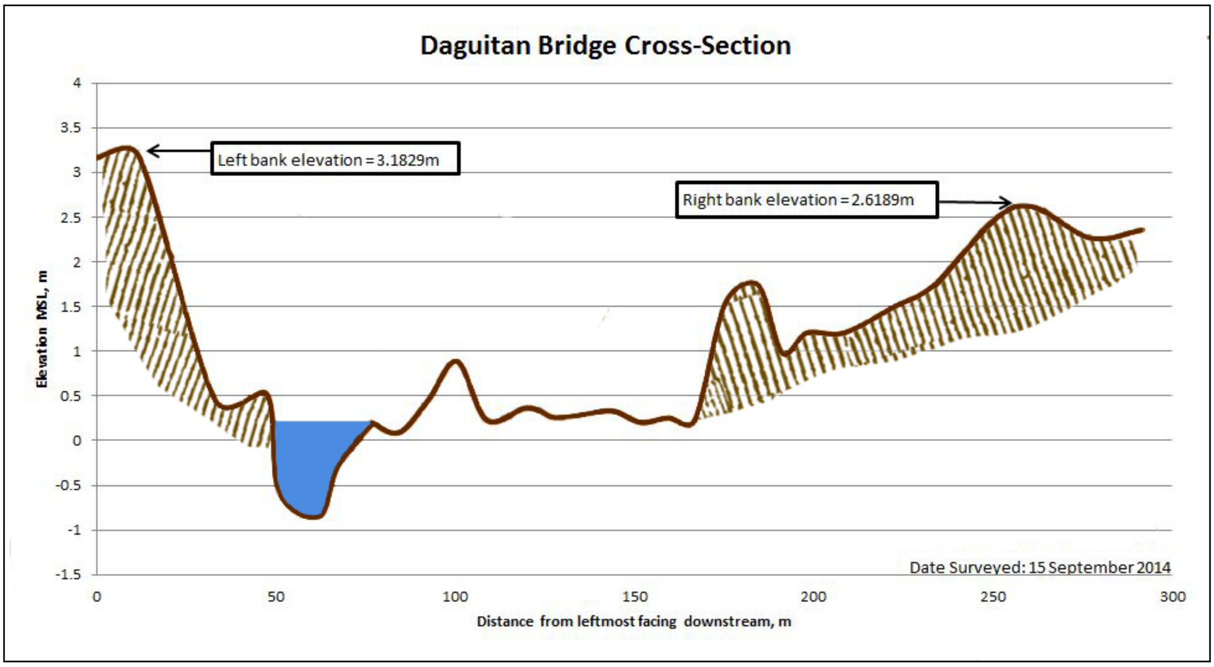


Figure 51. Cross-Section Plot of Daguitan Bridge

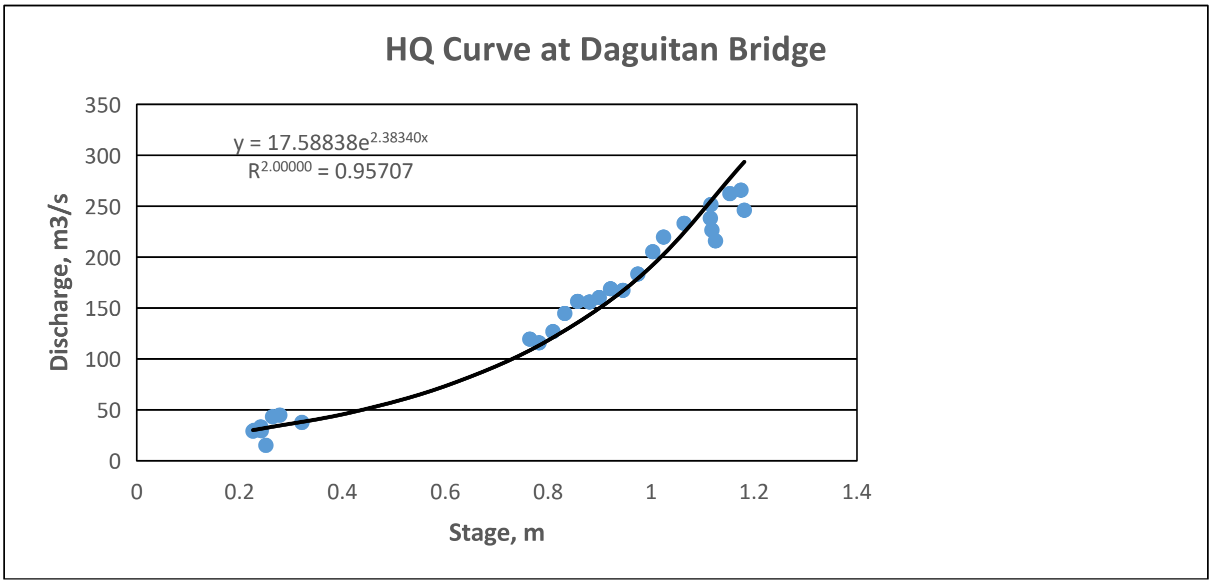


Figure 52. Rating Curve at Daguitan Bridge

This rating curve equation was used to compute the river outflow at Daguitan Bridge for the calibration of the HEC-HMS model shown in Figure 53. Peak discharge is 295.7 cu.m/s at 02:30 AM, November 25, 2016.

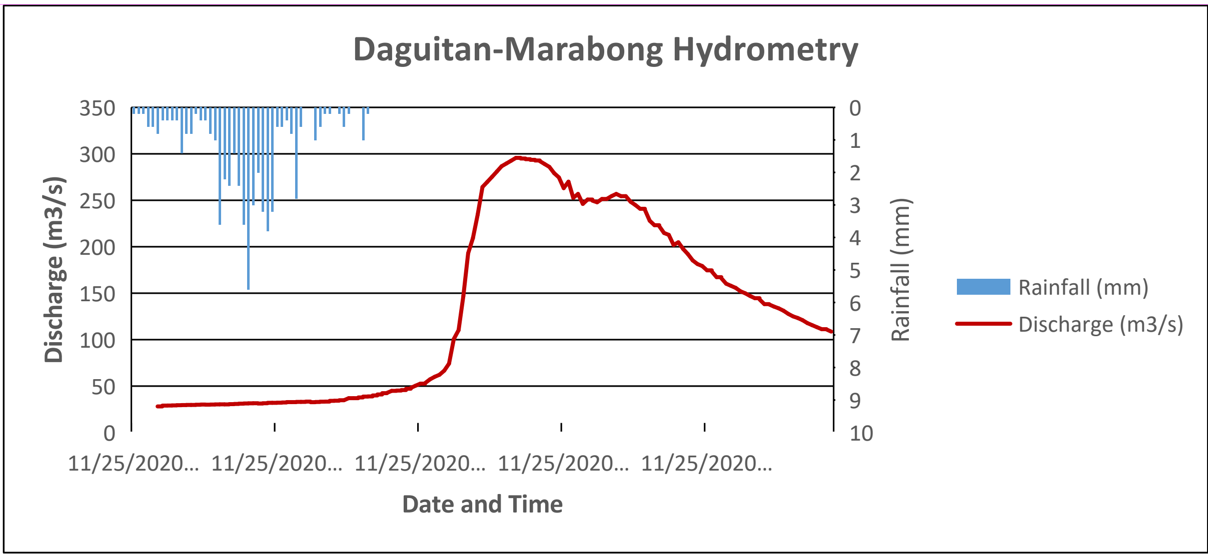


Figure 53. Rainfall and outflow data at Daguitan-Marabong used for modeling

5.2 RIDF Station

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

Table 31. RIDF values for Tacloban Rain Gauge computed by PAGASA

T (yrs)	10 min	20 min	30 min	1 hr	2 hrs	3 hrs	6 hrs	12 hrs	24 hrs
2	17.8	26.9	33.6	42.8	59.7	70.5	87.2	104	120.6
5	24.3	36.7	45.7	57.4	80.7	95.2	117.9	140.6	161.4
10	28.5	43.2	53.7	67.1	94.6	111.5	138.2	164.9	188.4
15	30.9	46.8	58.3	72.5	102.5	120.7	149.6	178.6	203.7
20	32.6	49.4	61.4	76.3	108	127.1	157.7	188.1	214.3
25	33.9	51.4	63.9	79.3	112.2	132.1	163.8	195.5	222.6
50	37.9	57.5	71.4	88.3	125.2	147.4	182.9	218.2	247.9
100	41.8	63.5	78.9	97.3	138.2	162.5	201.8	240.8	273

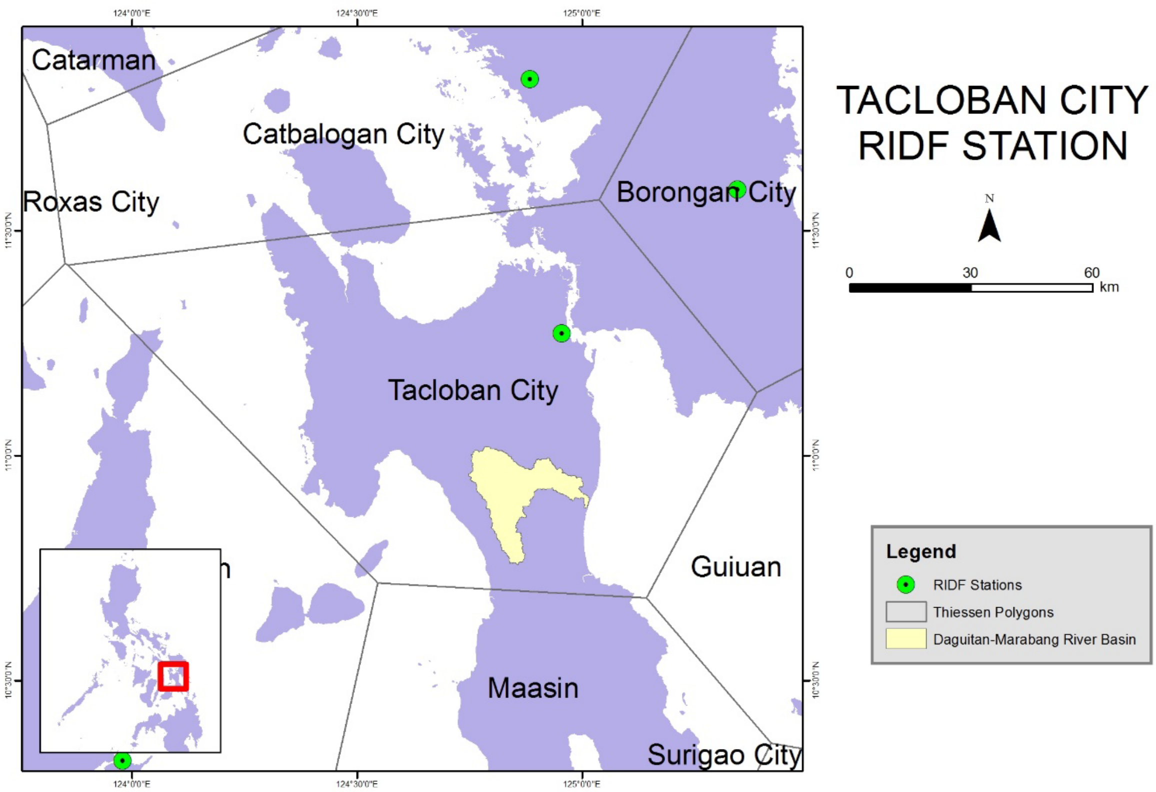


Figure 54. Location of Tacloban RIDF station relative to Daguitan-Marabong River Basin

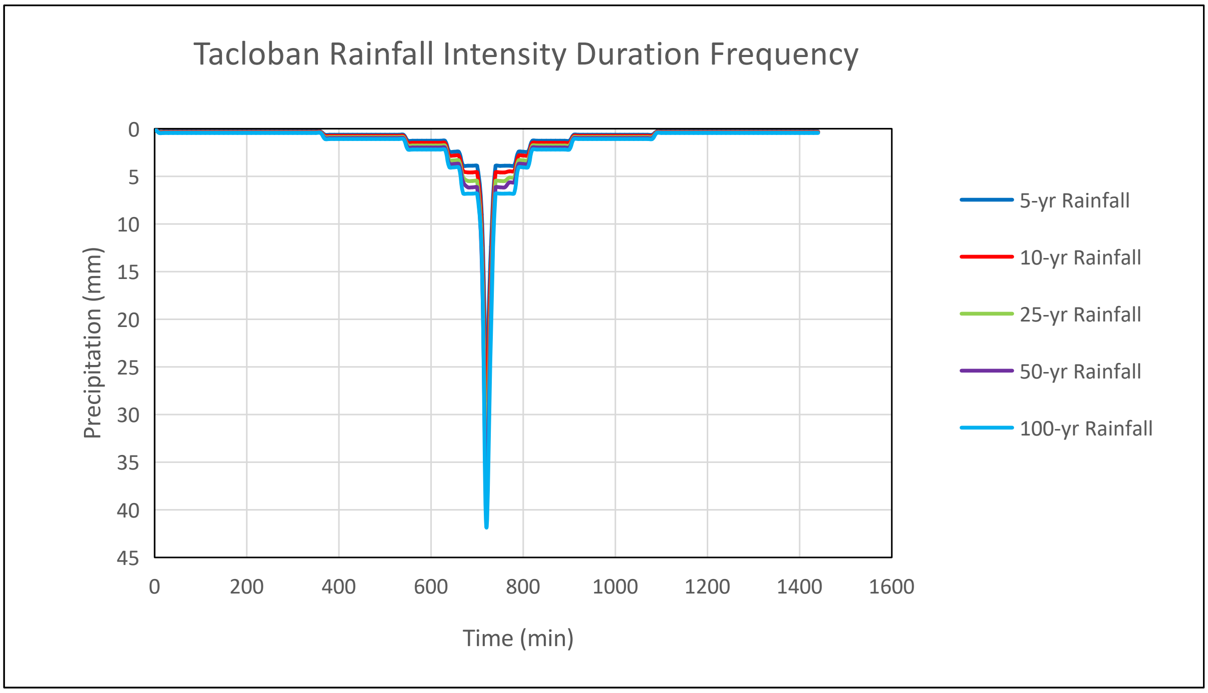


Figure 55. Synthetic storm generated for a 24-hr period rainfall for various return periods

5.3 HMS Model

The soil dataset was taken from and generated by the Bureau of Soils and Water Management (BSWM) under the Department of Agriculture. The land cover shape file is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Daguitan-Marabong River Basin are shown in Figure 56 and Figure 57, respectively.

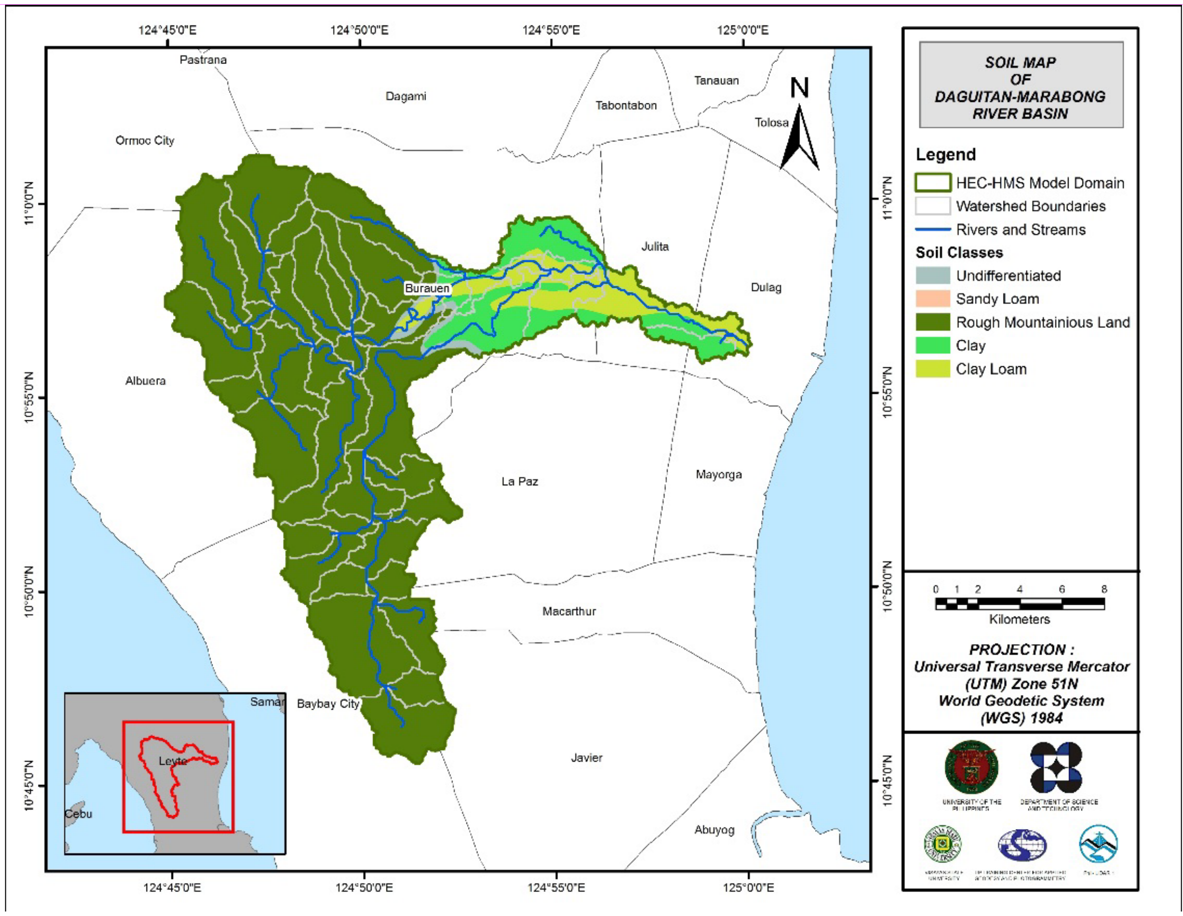


Figure 56. Soil Map of Daguitan-Marabong River Basin

Daguitan-Marabong River Basin is located in Eastern Visayas, at the Eastern portion of Leyte. It traverses through the municipalities of Dulag, Julieta, Burauen, and portions of the municipalities of La Paz, Baybay City, Abuera, and Ormoc City. It covers an area of 271 square kilometers and travels for approximately 35 kilometers from its source to its mouth in Dulag.

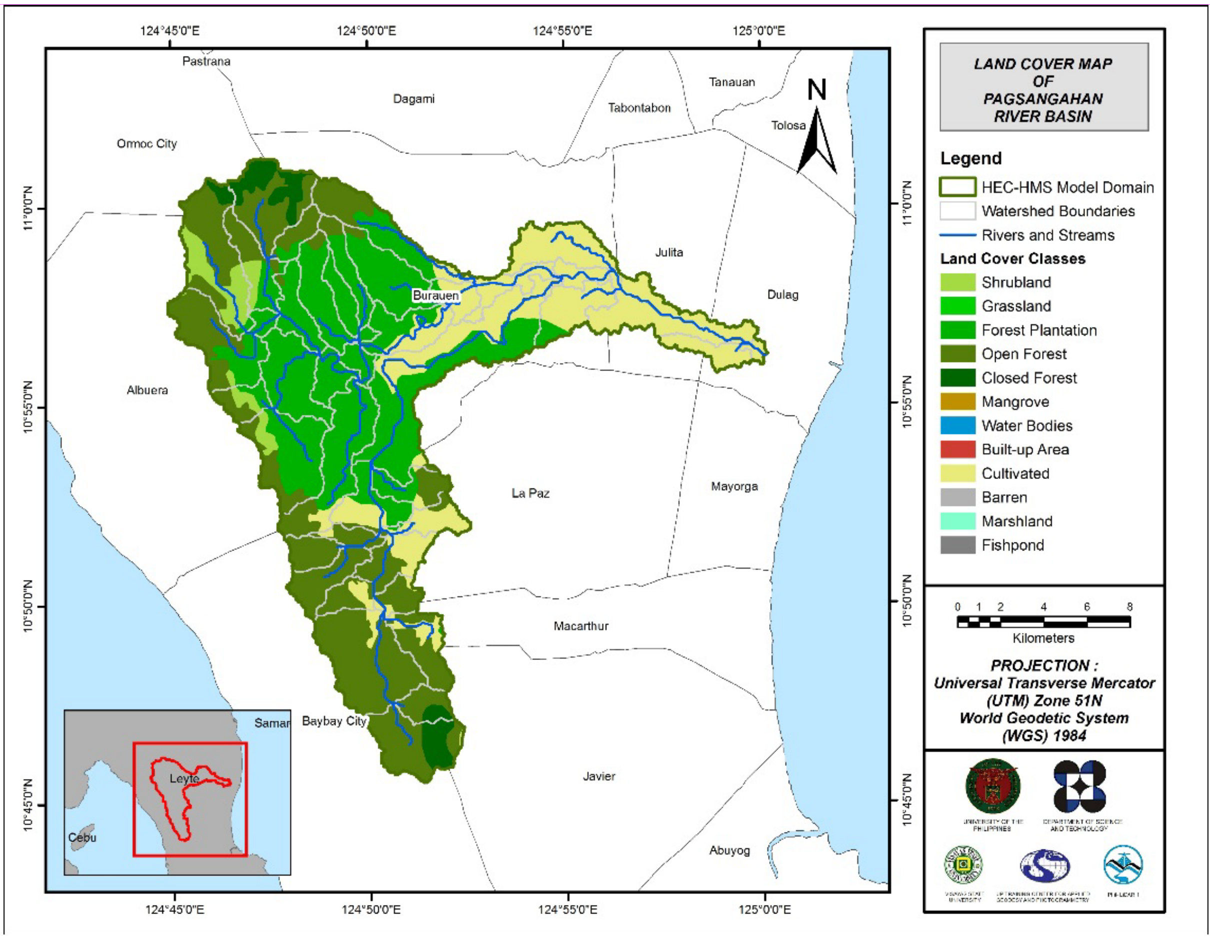


Figure 57. Land Cover Map of Daguitan-Marabong River Basin

For Daguitan-Marabong, the soil class identified were undifferentiated, rough mountainious land, clay, and clay loam. The land cover types identified were shrubland, grassland, forest plantation, open forest, closed forest, and cultivated.

Figure 58. [insert Slope Map]

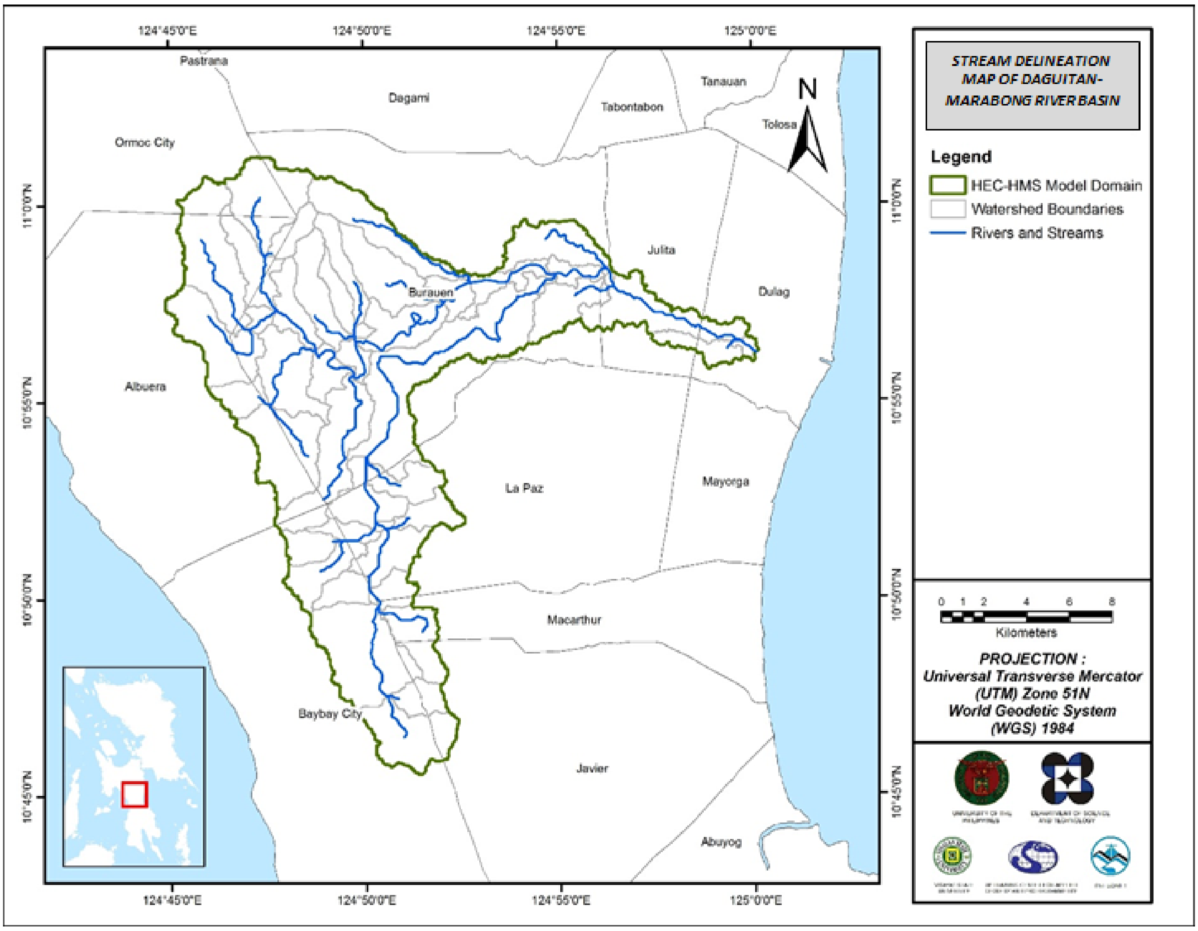


Figure 59. Stream delineation map of Daguitan-Marabong River Basin

Using the SAR-based DEM, the Daguitan-Marabong basin was delineated and further subdivided into subbasins. The model consists of 45 sub basins, 22 reaches, and 22 junctions as shown in Figure 60. The main outlet is at Daguitan Bridge.

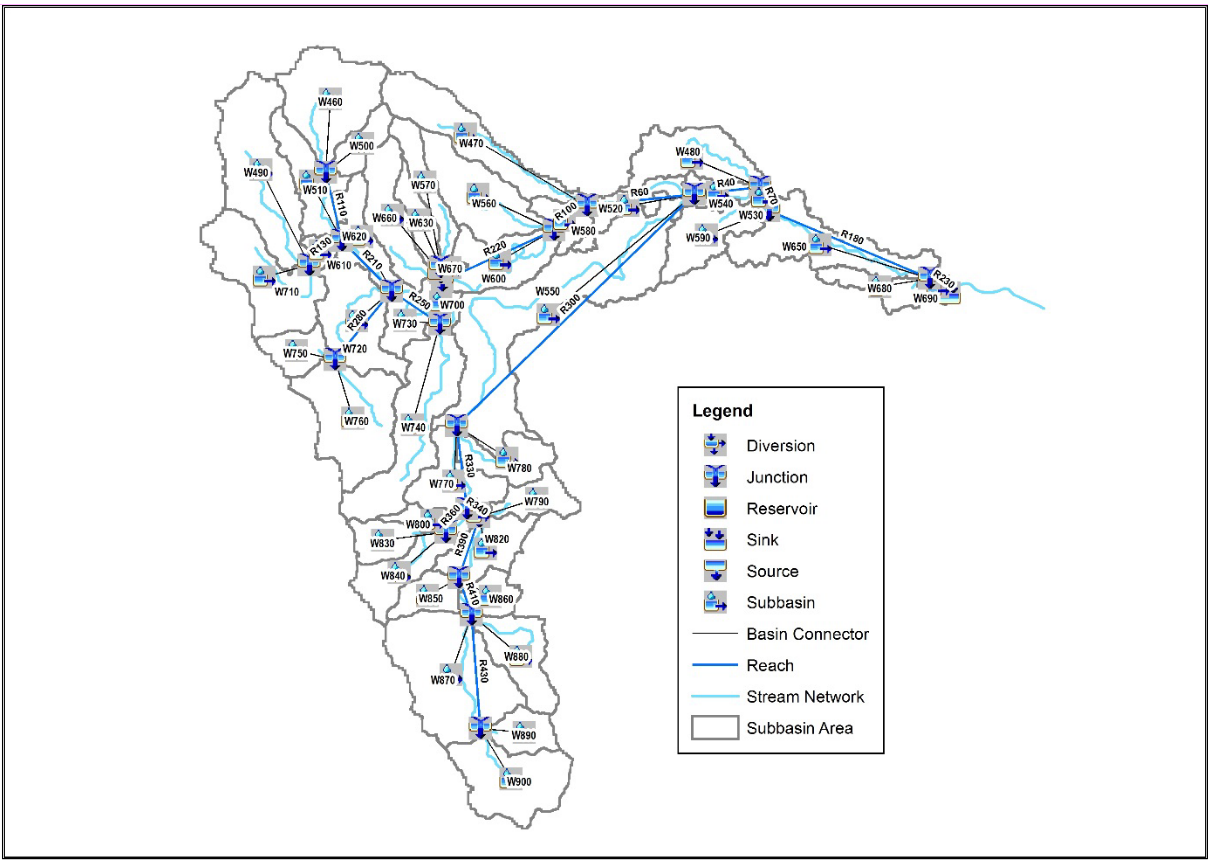


Figure 60. The Daguitan-Marabong river basin model generated using HEC-HMS

5.4 Cross-section Data

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

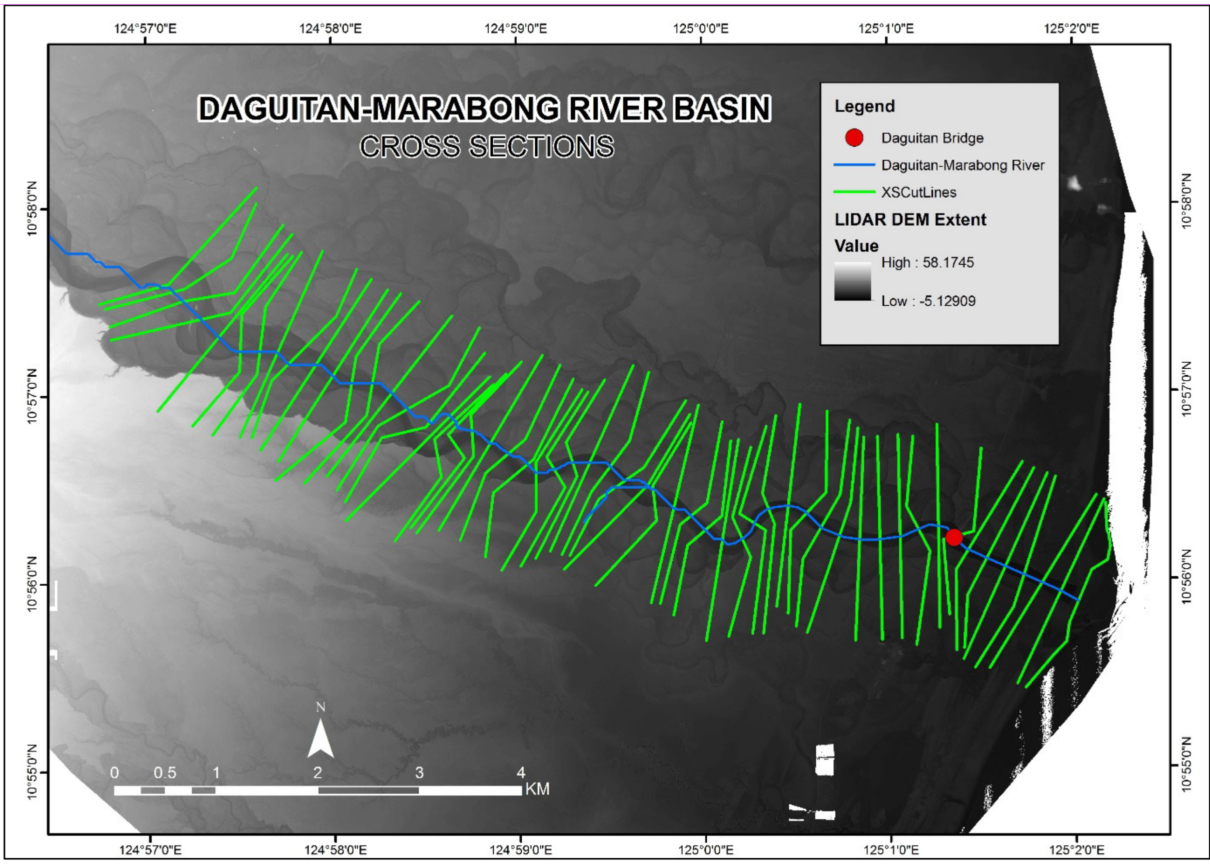


Figure 61. River cross-section of Daguitan-Marabong River generated through Arcmap HEC GeoRAS tool

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 meter by 10 meter in size. Each element was assigned a unique grid element number which served as its identifier, then attributed with the parameters required for modeling such as x-and y-coordinate of centroid, names of adjacent grid elements, Manning coefficient of roughness, infiltration, and elevation value. The elements were arranged spatially to form the model, allowing the software to simulate the flow of water across the grid elements and in eight directions (north, south, east, west, northeast, northwest, southeast, southwest).

Based on the elevation and flow direction, it is seen that the water will generally flow from the 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.

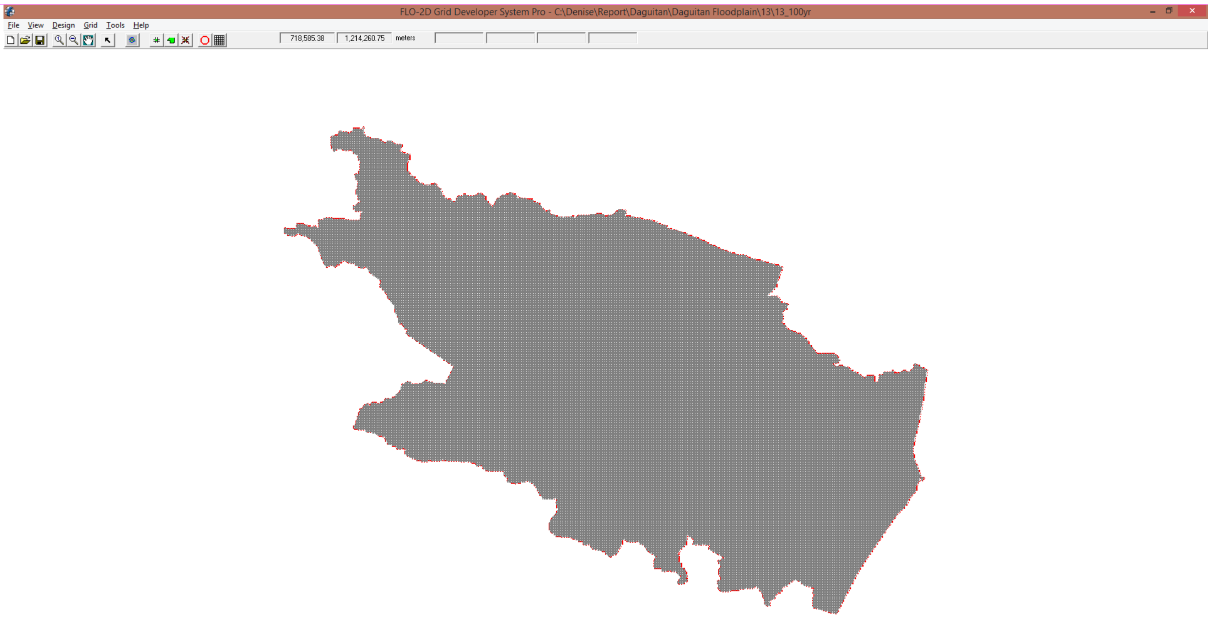


Figure 62. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

5.6 Results of HMS Calibration

After calibrating the Daguitan-Marabong HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 63 shows the comparison between the two discharge data.

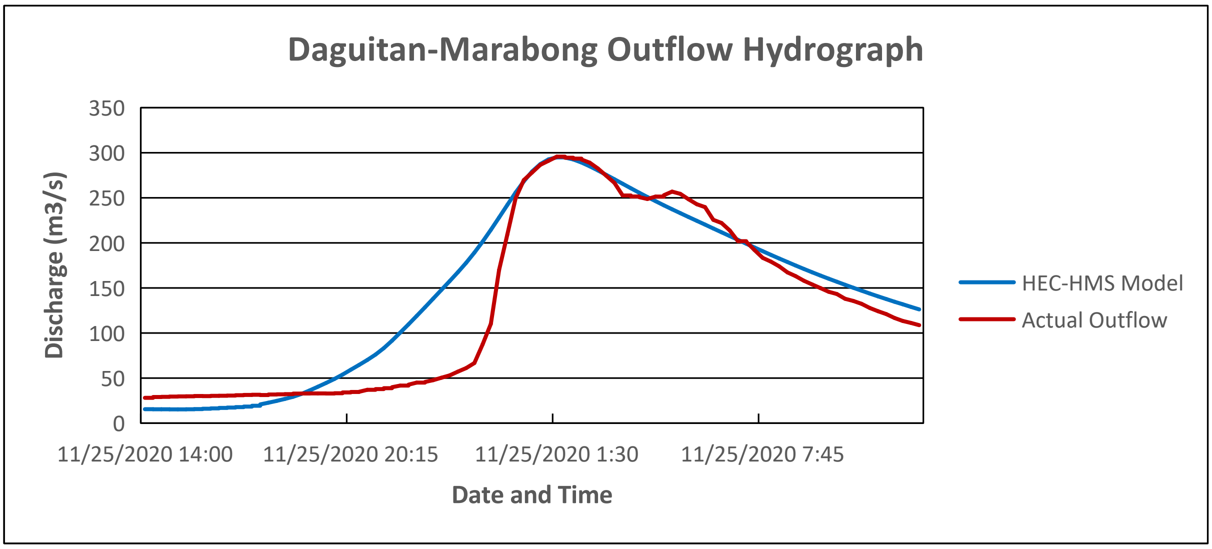


Figure 63. Outflow Hydrograph of Daguitan-Marabong produced by the HEC-HMS model compared with observed outflow

Table 32. [insert renge of calibrated]

Table 33. Summary of the Efficiency Test of Daguitan-Marabong HMS Model

RMSE	30.2
r2	0.87
NSE	0.96
PBIAS	-2.93
RSR	0.21

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 30.2 (m3/s).

The Pearson correlation coefficient (r2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.87.

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 0.96.
A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is -2.93.

The Observation Standard Deviation Ratio, RSR, is an error index. A perfect model attains a value of 0 when the error in the units of the valuable a quantified. The model has an RSR value of 0.21.

5.7 Calculated Outflow hydrographs and Discharge Values for different Rainfall Return Periods

5.7.1 Hydrograph using the Rainfall Runoff Mode

The summary graph (Figure 64) shows the Daguitan-Marabong outflow using the Tacloban RIDF in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the PAG-ASA data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return

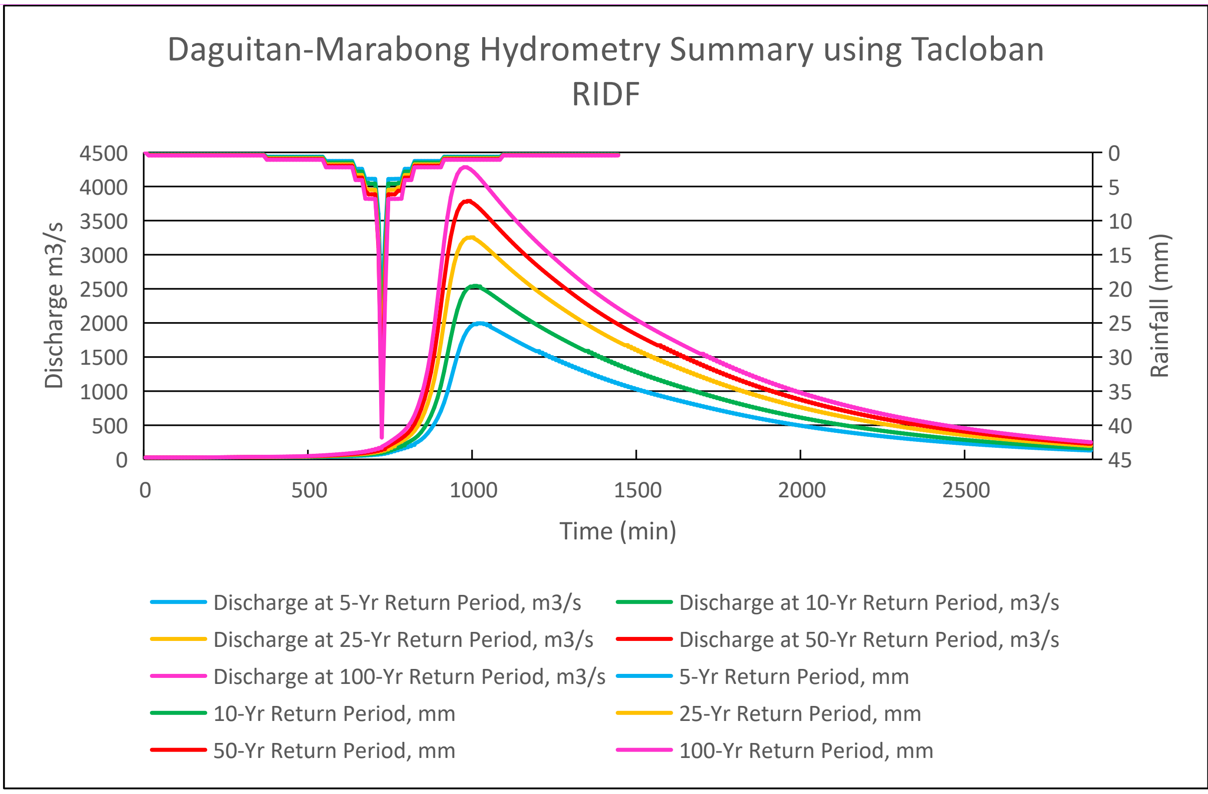


Figure 64. Outflow hydrograph at Daguitan-Marabong Station generated using Tacloban RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Daguitan-Marabong discharge using the Tacloban RIDF in five different return periods is shown in Table 34.

Table 34. Peak values of the Daguitan-Marabong HEC-HMS Model outflow using the Tacloban RIDF

RIDF Period	Total Precipitation (mm)	Peak Rainfall (mm)	Peak Outflow (m^3/s)	Time to Peak
5-Year	161.4	24.3	1993.8	4 hours, 50 minutes
10-Year	188.4	28.5	2543.0	4 hours, 40 minutes
25-Year	222.6	33.9	3254.7	4 hours, 30 minutes
50-Year	247.9	37.9	3788.1	4 hours, 20 minutes
100-Year	273.0	41.8	4282.5	4 hours, 10 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 was used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. For this publication, only a sample output map river was to be shown, since only the VSU-FMC base flow was calibrated. The sample generated map of Daguitan-Marabong River using the calibrated HMS base flow is shown in Figure 65.

Figure 65. Sample output of Daguitan-Marabong RAS Model

5.9 Flood Hazard and Flow Depth

The resulting hazard and flow depth maps for 100-, 25-, and 5-year rain return scenarios of the Daguitan-Marabong Floodplain are shown in Figure 66 to Figure 71. The floodplain, with an area of 53.72 sq. km., covers four municipalities namely Dulag, Julita, La Paz, and Mayorga. Table 35 shows the percentage of area affected by flooding per municipality.

Table 35. Municipalities affected in Daguitan-Marabong Floodplain

Municipality	Total Area	Area Flooded	% Flooded
Dulag	63.65	39.28	6170.93%
Julita	57.17	11.057	1934.10%
La Paz	136.017	1.17	85.94%
Mayorga	39.45	2.031	514.80%

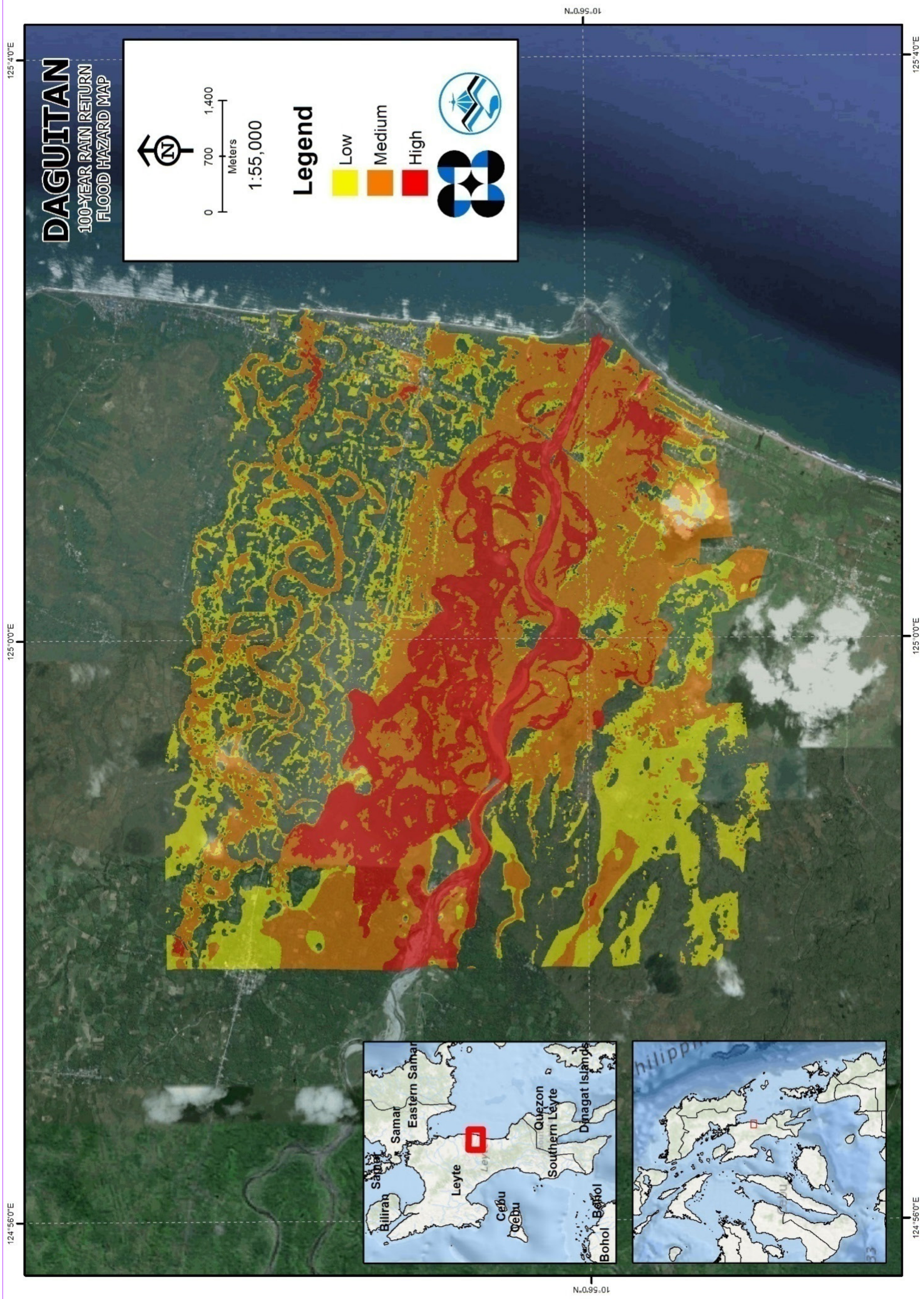


Figure 66. 100-year Flood Hazard Map for Daguitan Floodplain

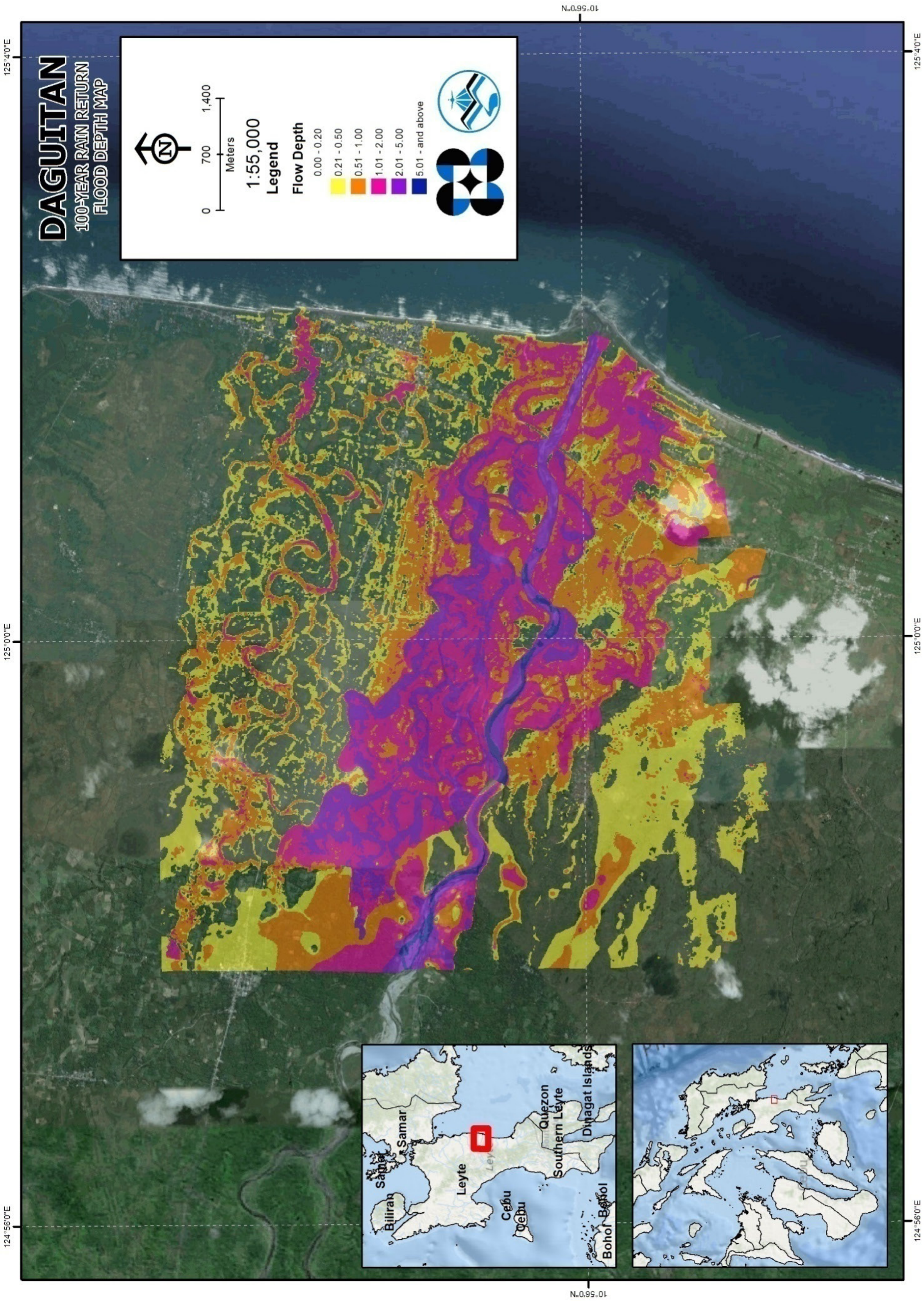


Figure 67. 100-year Flow Depth Map for Daguitan Floodplain

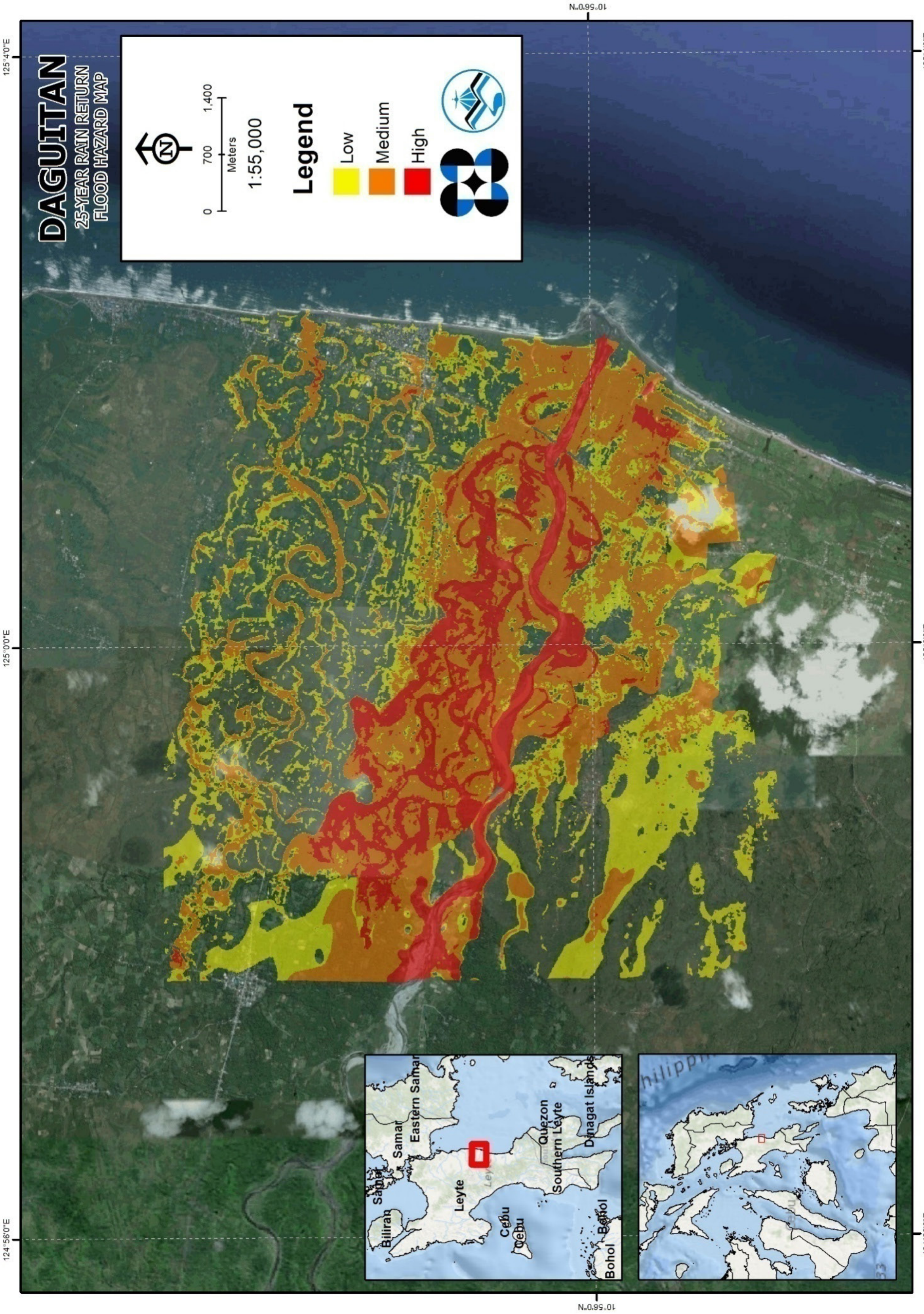


Figure 68. 25-year Flood Hazard Map for Daguitan Floodplain

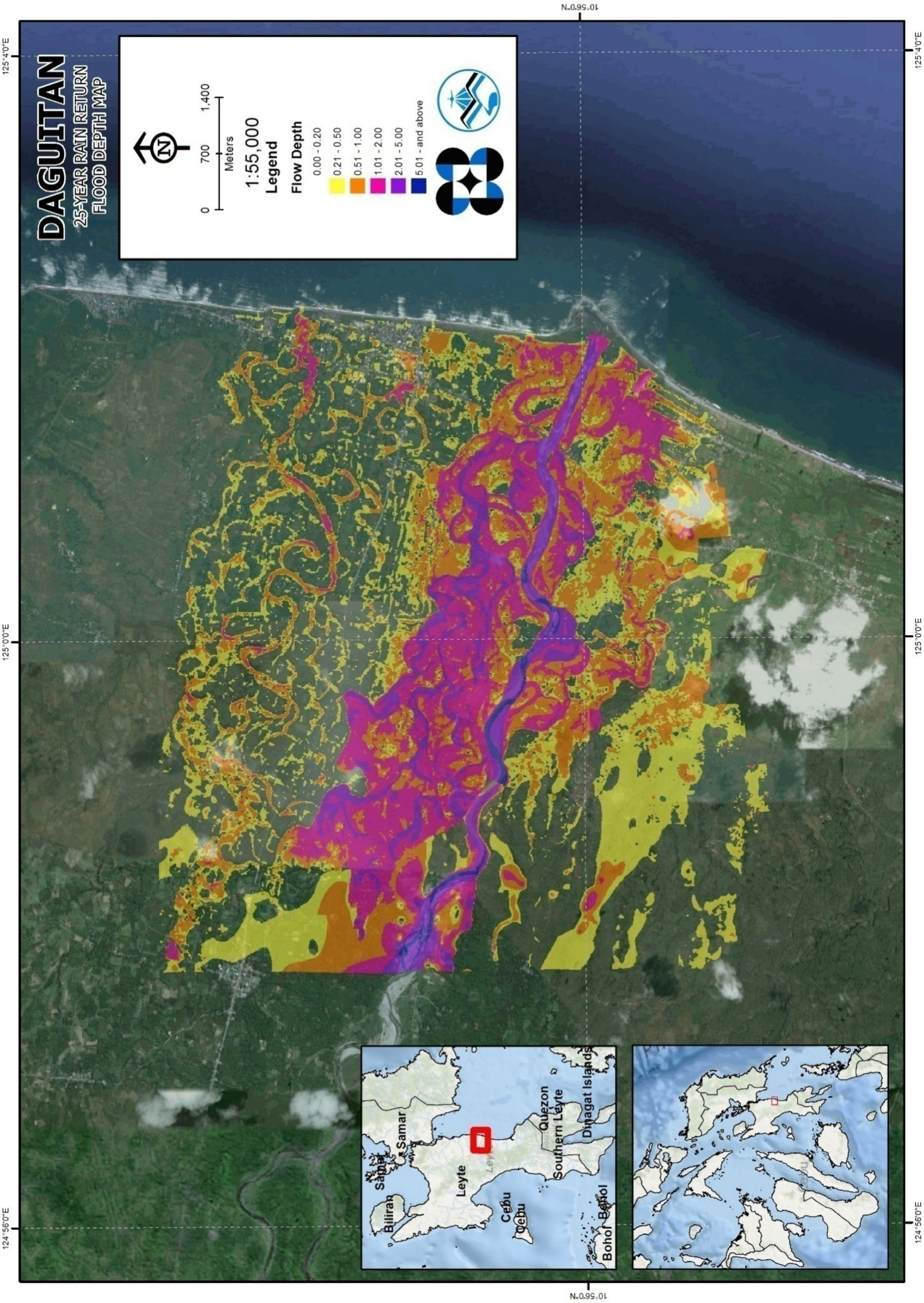


Figure 69. 25-year Flow Depth Map for Daguitan Floodplain

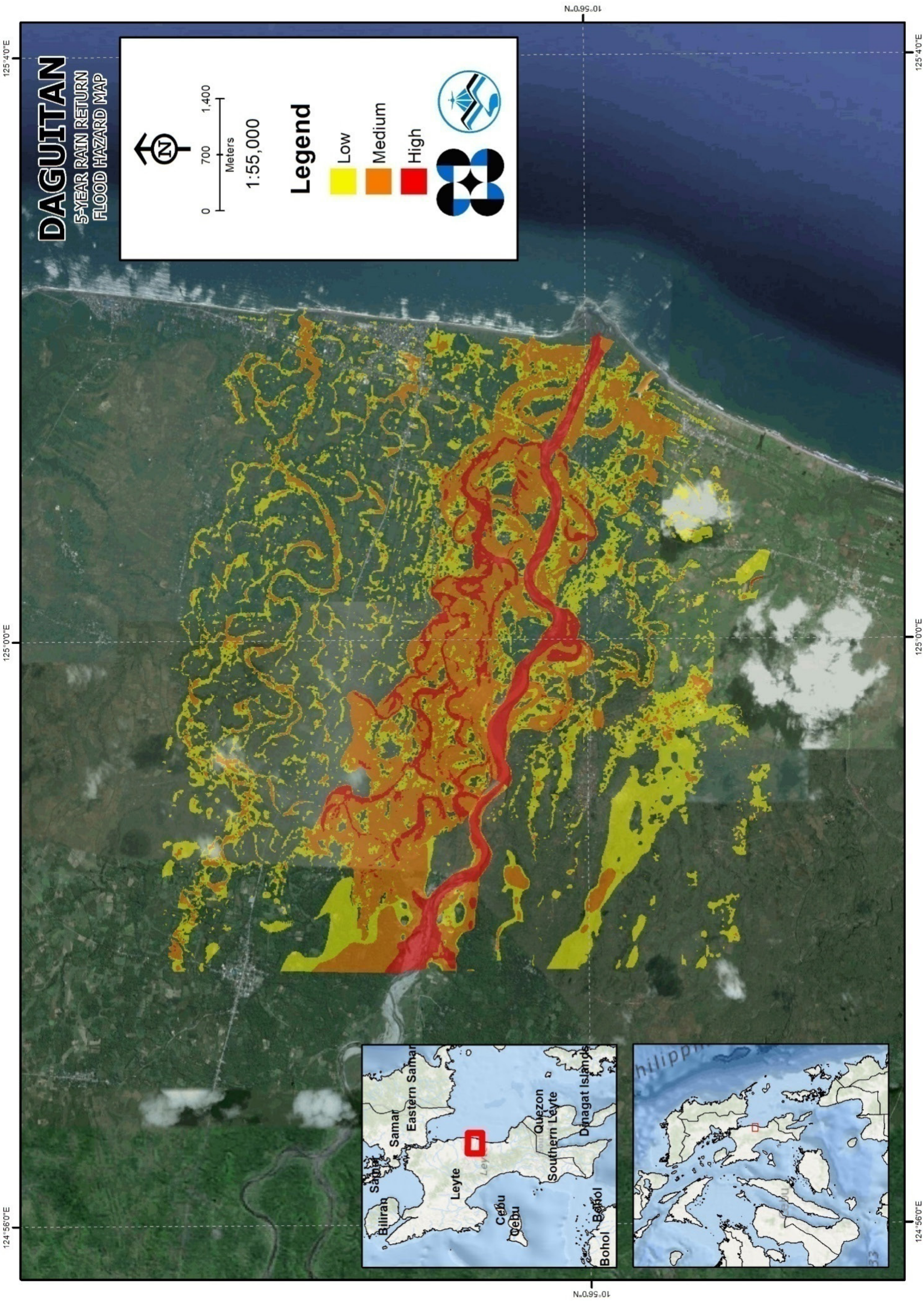


Figure 70. 5-year Flood Hazard Map for Daguitan Floodplain

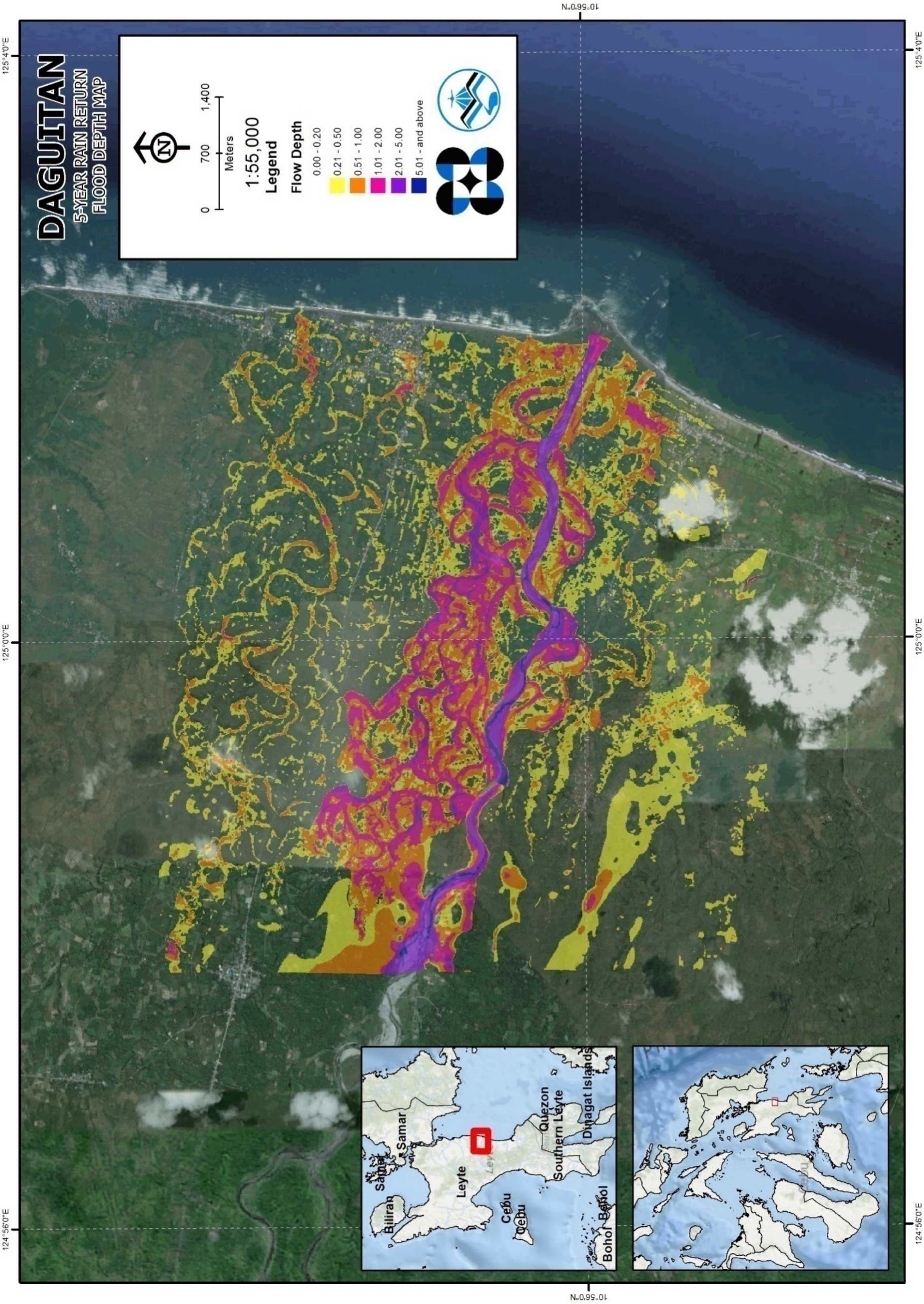


Figure 71. 5-year Flow Depth Map for Daguitan Floodplain

5.10 Inventory of Areas Exposed to Flooding

Listed below are the barangays affected by the Daguitan-Marabong River Basin, grouped accordingly by municipality. For the said basin, four(4) municipalities consisting of 47 barangays are expected to experience flooding when subjected to a 5-year rainfall return period.

For the 5-year return period, 19.95% of the municipality of Dulag with an area of 63.65 sq. km. will experience flood levels of less 0.20 meters while 11.40% of the area will experience flood levels of 0.21 to 0.50 meters; 12.93%, 12.24%, 5.07%, and 0.33% 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. Table 36 depicts the areas affected in Dulag in square kilometers by flood depth per barangay.

Table 36. Affected areas in Dulag, Leyte during a 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Dulag (in sq. km.)							
	Alegre	Arado	Barbo	Batug	Buntay	Cabacungan	Cabarasan	Cabato-An
0.03-0.20	0.84	0.061	0.039	0.062	0.22	0.41	0.0027	0.64
0.21-0.50	0.84	0.021	0.056	0.064	0.078	0.9	0.0089	0.22
0.51-1.00	1.78	0.065	0.24	0.25	0.013	0.35	0.15	0.13
1.01-2.00	0.99	0.55	0.28	0.27	0	0.18	0.72	0.096
2.01-5.00	0.23	0.42	0.033	0.17	0	0.0003	0.39	0.081
> 5.00	0.03	0	0	0.081	0	0	0	0

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Dulag (in sq. km.)							
	Calipayan	Cambula District	Candao	Catmonan	Combis	Del Carmen	Del Pilar	Fatima
0.03-0.20	0.88	0.22	0.52	0.22	0.18	0.85	0.72	0.033
0.21-0.50	0.4	0.12	0.27	0.049	0.065	0.68	0.33	0.091
0.51-1.00	0.18	0.16	0.28	0.017	0.084	0.16	0.21	0.45
1.01-2.00	0.023	0.11	0.04	0	0.15	0.015	0.03	0.49
2.01-5.00	0	0.0067	0	0	0.057	0.03	0	0.17
> 5.00	0	0	0	0	0	0.00036	0	0

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Dulag (in sq. km.)							
	General Roxas	Highway	Magsaysay	Maricum	Market Site	Rawis	Rizal	Sabang Daguitan
0.03-0.20	0.27	0.36	0.29	0.62	0.065	0.12	0.32	0.051
0.21-0.50	0.21	0.079	0.16	0.26	0.021	0.17	0.14	0.028
0.51-1.00	0.2	0.055	0.066	0.18	0.026	0.79	0.14	0.16
1.01-2.00	0.026	0.036	0.0034	0.097	0.03	1.53	0.16	0.43
2.01-5.00	0	7.4E-05	0	0.11	0	0.99	0.014	0.058
> 5.00	0	0	0	0	0	0.096	0	0

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Dulag (in sq. km.)									
	Salvacion	San Agustin	San Antonio	San Miguel	San Rafael	San Vicente	Serrano	Sungi	Tabu	Victory
0.03-0.20	0.23	0.46	0.24	0.14	0.96	1.51	0.15	0.085	0.72	0.21
0.21-0.50	0.26	0.17	0.22	0.033	0.23	0.57	0.042	0.049	0.28	0.14
0.51-1.00	0.64	0.049	0.14	0.049	0.18	0.36	0.019	0.014	0.18	0.46
1.01-2.00	0.38	0.00096	0.0034	0.086	0.046	0.072	0.021	0.0013	0.051	0.87
2.01-5.00	0.0086	0	0	0.0014	0	0	0.0046	0	0.03	0.42
> 5.00	0	0	0	0	0	0	0	0	0	0.0039

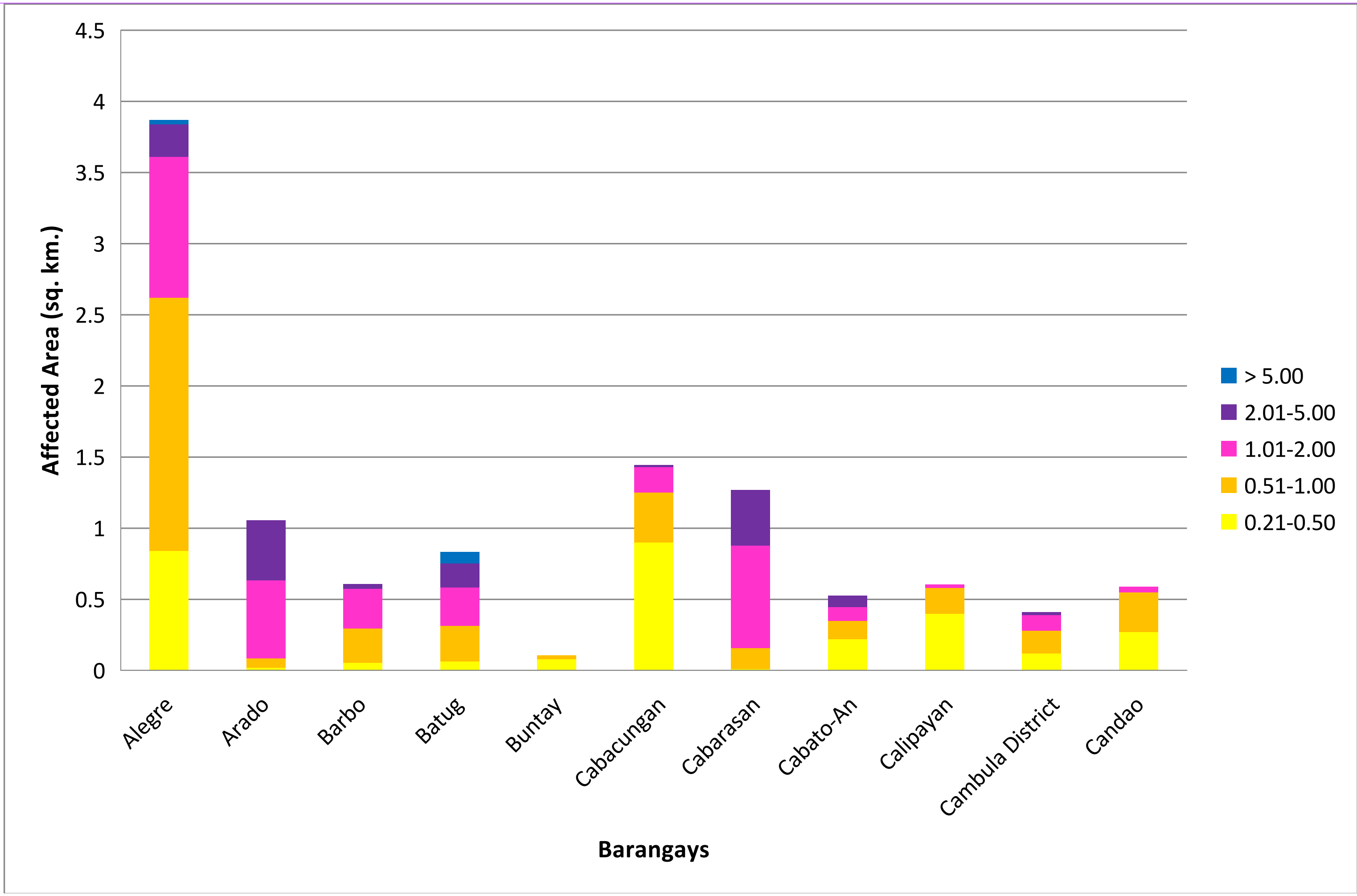


Figure 72. Affected areas in Dulag, Leyte during a 5-Year Rainfall Return Period

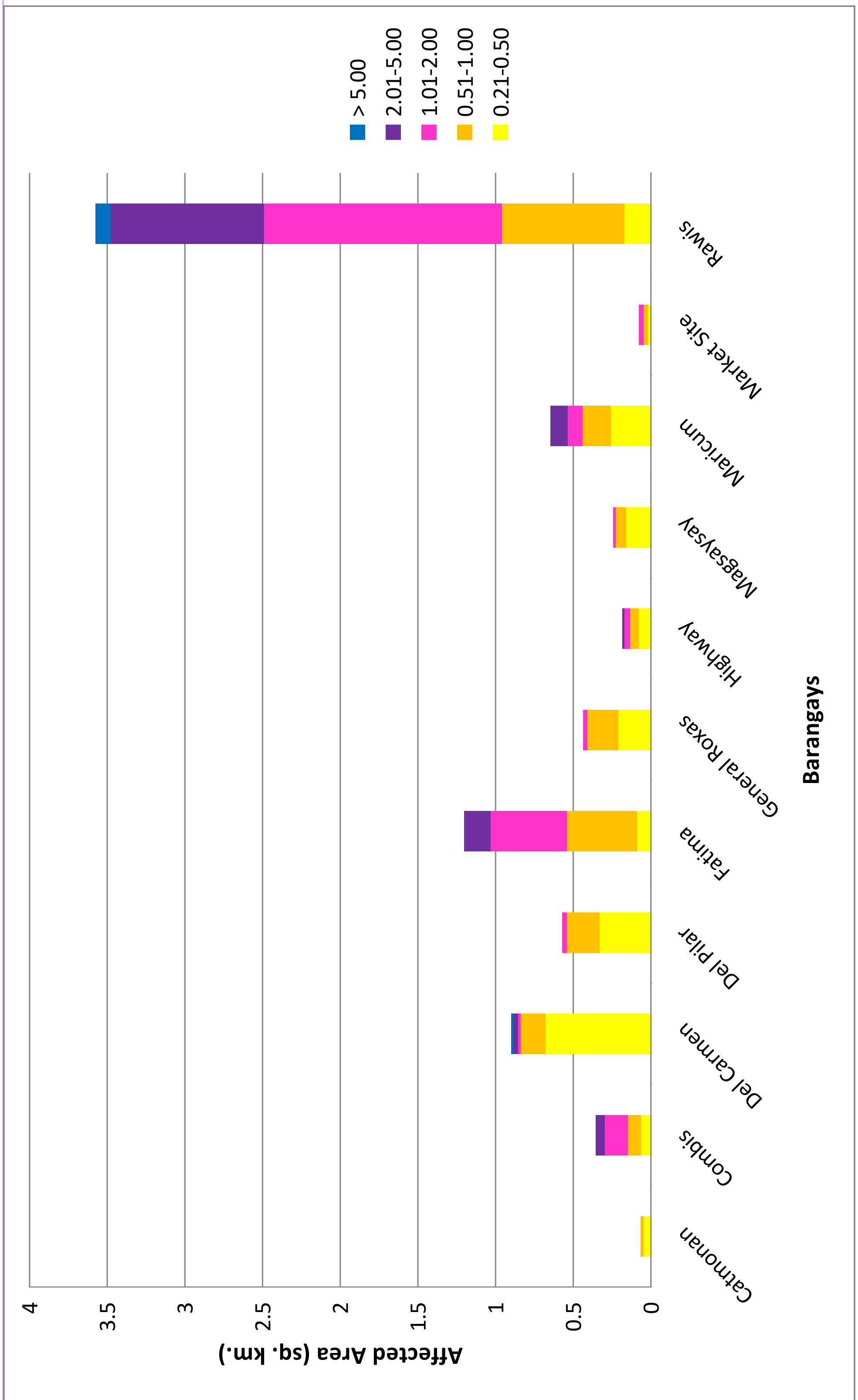


Figure 73. Affected areas in Dulag, Leyte during a 5-Year Rainfall Return Period

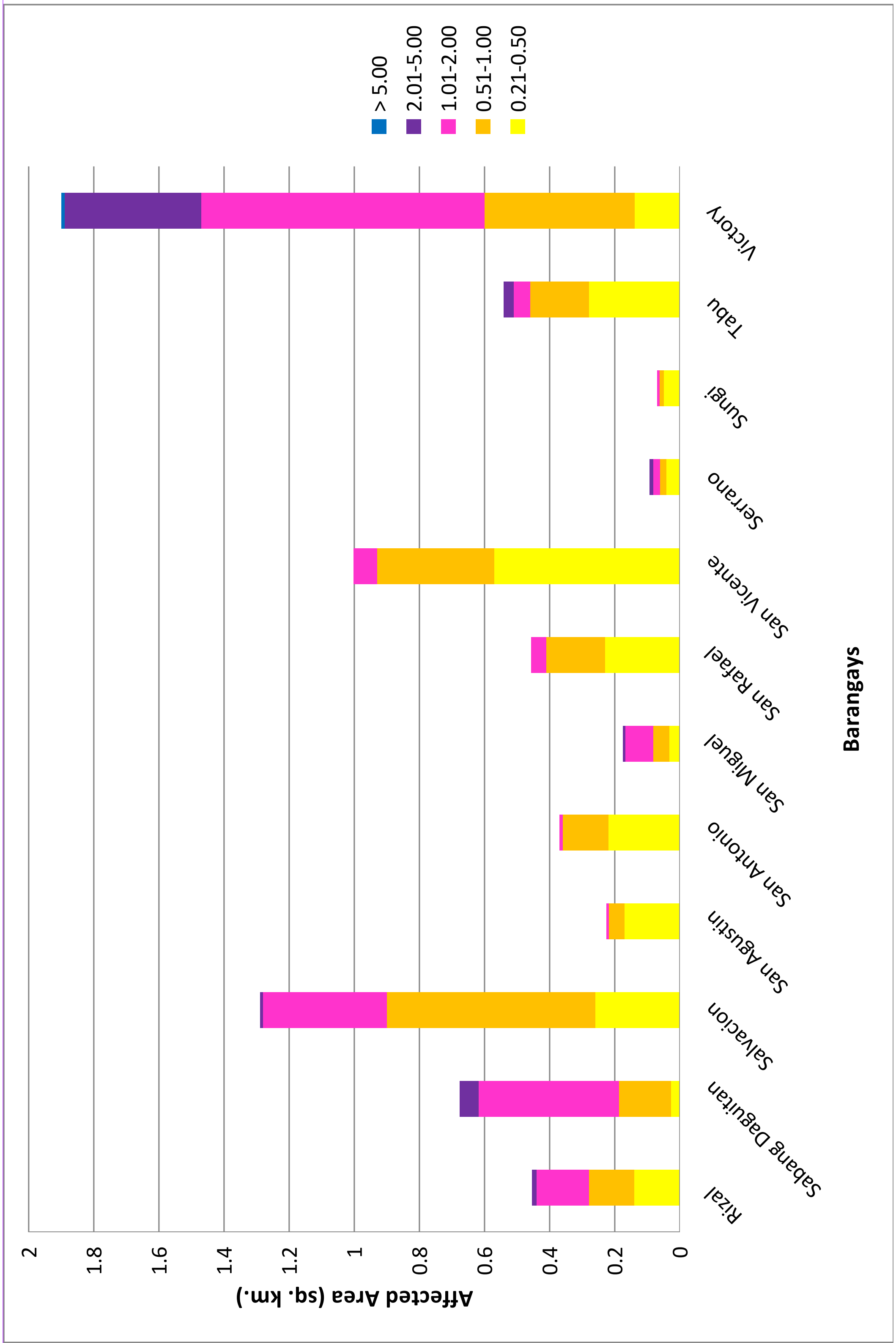


Figure 74. Affected areas in Dulag, Leyte during a 5-Year Rainfall Return Period

For the municipality of Julita, with an area of 57.17 sq. km., 6.57% will experience flood levels of less 0.20 meters. 4.18% of the area will experience flood levels of 0.21 to 0.50 meters while 3.79%, 3.01%, 1.75%, and 0.23% 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. Table 37 depicts the affected areas in square kilometers by flood depth per barangay.

Table 37. Affected areas in Julita, Leyte during a 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Julita (in sq. km.)								
	Bonifacio	Cuya-E	Poblacion District I	Poblacion District II	Poblacion District III	Poblacion District IV	Santo Niño	Tagkip	Tolosahay
0.03-0.20	0.021	0.0031	0.61	0.35	0.52	0.054	0.48	0.74	0.98
0.21-0.50	0.088	0	0.52	0.32	0.22	0.49	0.45	0.18	0.12
0.51-1.00	0.71	0	0.32	0.16	0.16	0.36	0.21	0.2	0.049
1.01-2.00	0.87	0	0.074	0.042	0.29	0	0.048	0.39	0.0082
2.01-5.00	0.51	0	0	0.0023	0.12	0	0	0.37	0
> 5.00	0.0034	0	0	0	0	0	0	0.13	0

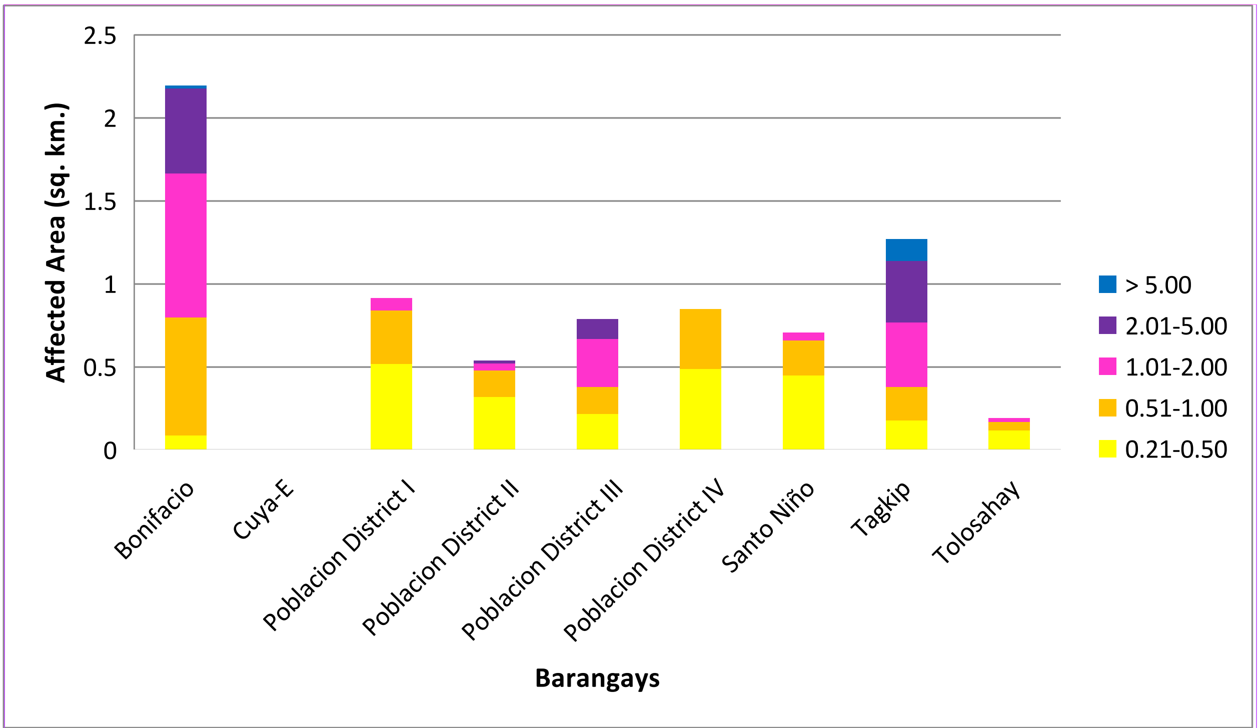


Figure 75. Affected areas in Julita, Leyte during a 5-Year Rainfall

For the municipality of La Paz, with an area of 136.02 sq. km., 0.57% will experience flood levels of less 0.20 meters. 0.28% of the area will experience flood levels of 0.21 to 0.50 meters while 0.006% of the area will experience flood depths of 0.51 to 1 meter, respectively. Table 38 presents the affected areas in square kilometers by flood depth per barangay.

Table 38. Affected areas in La Paz, Leyte during a 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in La Paz (in sq. km.)
	Canbañez
0.03-0.20	0.78
0.21-0.50	0.38
0.51-1.00	0.0086
1.01-2.00	0
2.01-5.00	0
> 5.00	0

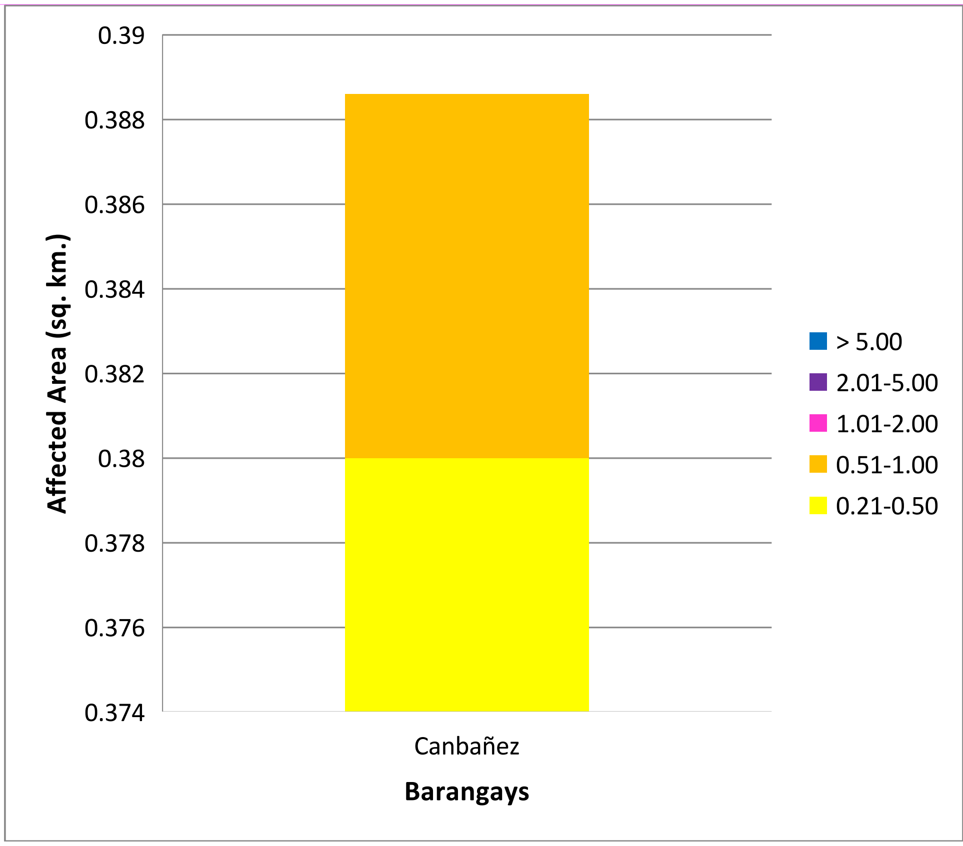


Figure 76. Affected areas in La Paz, Leyte during a 5-Year Rainfall Return Period

For the municipality of Mayorga, with an area of 39.45 sq. km., 4.72% will experience flood levels of less 0.20 meters. 2.98% of the area will experience flood levels of 0.21 to 0.50 meters while 0.63%, and 0.07% of the area will experience flood depths of 0.51 to 1 meter,and 1.01 to 2 meters, respectively. Table 39 depicts the affected areas in square kilometers by flood depth per barangay.

Table 39. Affected areas in Mayorga, Leyte during a 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Mayorga (in sq. km.)		
	A. Bonifacio	Calipayan	Talisay
0.03-0.20	0.014	0.88	0.97
0.21-0.50	0.017	0.4	0.76
0.51-1.00	0.0034	0.18	0.065
1.01-2.00	0.00048	0.023	0.0032
2.01-5.00	0	0	0
> 5.00	0	0	0

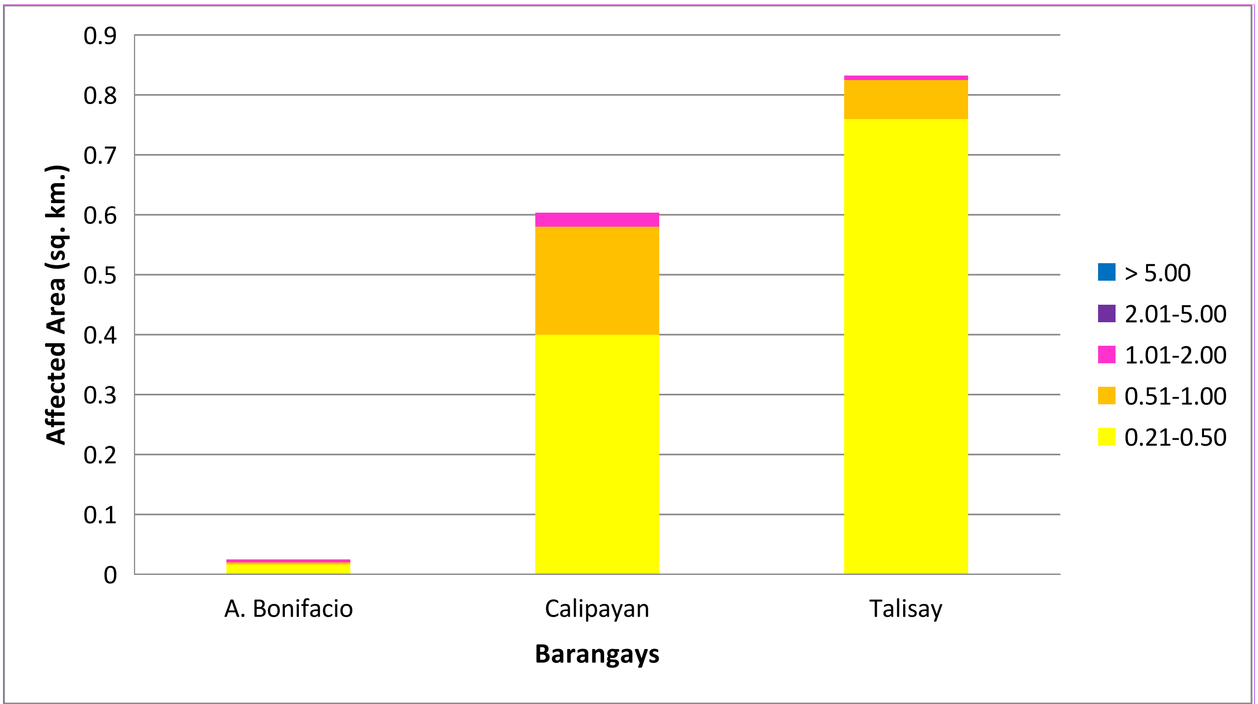


Figure 77. Affected areas in Mayorga, Leyte during a 5-Year Rainfall Return Period

For the 25-year return period, 24.56% of the municipality of Dulag with an area of 63.65 sq. km. will experience flood levels of less 0.20 meters, while 12.66% of the area will experience flood levels of 0.21 to 0.50 meters; 11.63%, 9.37%, 3.44%, and 0.25% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 t0 5 meters, and more than 5 meters respectively. Table 40 depicts the areas affected in Dulag in square kilometers by flood depth per barangay.

Table 40. Affected areas in Dulag, Leyte during a 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Dulag (in sq. km.)							
	Alegre	Arado	Barbo	Batug	Buntay	Cabacungan	Cabarasan	Cabato-An
0.03-0.20	1.29	0.074	0.065	0.11	0.24	0.56	0.018	0.73
0.21-0.50	1.27	0.024	0.08	0.18	0.062	0.92	0.071	0.18
0.51-1.00	1.44	0.18	0.28	0.18	0.0091	0.31	0.32	0.12
1.01-2.00	0.5	0.6	0.19	0.23	0	0.054	0.63	0.13
2.01-5.00	0.18	0.25	0.032	0.12	0	0	0.24	0.014
> 5.00	0.024	0	0	0.076	0	0	0	0

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Dulag (in sq. km.)							
	Calipayan	Cambula District	Candao	Catmonan	Combis	Del Carmen	Del Pilar	Fatima
0.03-0.20	1.02	0.25	0.61	0.23	0.2	0.98	0.89	0.083
0.21-0.50	0.33	0.13	0.28	0.044	0.064	0.65	0.28	0.22
0.51-1.00	0.12	0.15	0.2	0.012	0.1	0.055	0.11	0.48
1.01-2.00	0.0098	0.077	0.021	0	0.12	0.011	0.012	0.3
2.01-5.00	0	0.0022	0	0	0.05	0.031	0	0.15
> 5.00	0	0	0	0	0	0.00028	0	0

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Dulag (in sq. km.)							
	General Roxas	Highway	Magsaysay	Maricum	Market Site	Rawis	Rizal	Sabang Daguitan
0.03-0.20	0.38	0.39	0.36	0.75	0.077	0.28	0.41	0.064
0.21-0.50	0.2	0.072	0.11	0.22	0.017	0.38	0.12	0.043
0.51-1.00	0.11	0.058	0.041	0.12	0.025	0.87	0.12	0.25
1.01-2.00	0.012	0.012	0.0022	0.088	0.022	1.42	0.12	0.34
2.01-5.00	0	0	0	0.074	0	0.69	0.0019	0.022
> 5.00	0	0	0	0	0	0.06	0	0

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Dulag (in sq. km.)									
	Salvacion	San Agustin	San Antonio	San Miguel	San Rafael	San Vicente	Serrano	Sungi	Tabu	Victory
0.03-0.20	0.41	0.51	0.31	0.16	1.04	1.75	0.17	0.1	0.85	0.27
0.21-0.50	0.46	0.13	0.21	0.033	0.21	0.51	0.037	0.038	0.24	0.24
0.51-1.00	0.5	0.031	0.082	0.063	0.15	0.22	0.016	0.0083	0.12	0.55
1.01-2.00	0.15	0	0.0002	0.06	0.013	0.039	0.02	0.00019	0.038	0.74
2.01-5.00	0.0028	0	0	0.0001	0	0	0.0001	0	0.017	0.31
> 5.00	0	0	0	0	0	0	0	0	0	0

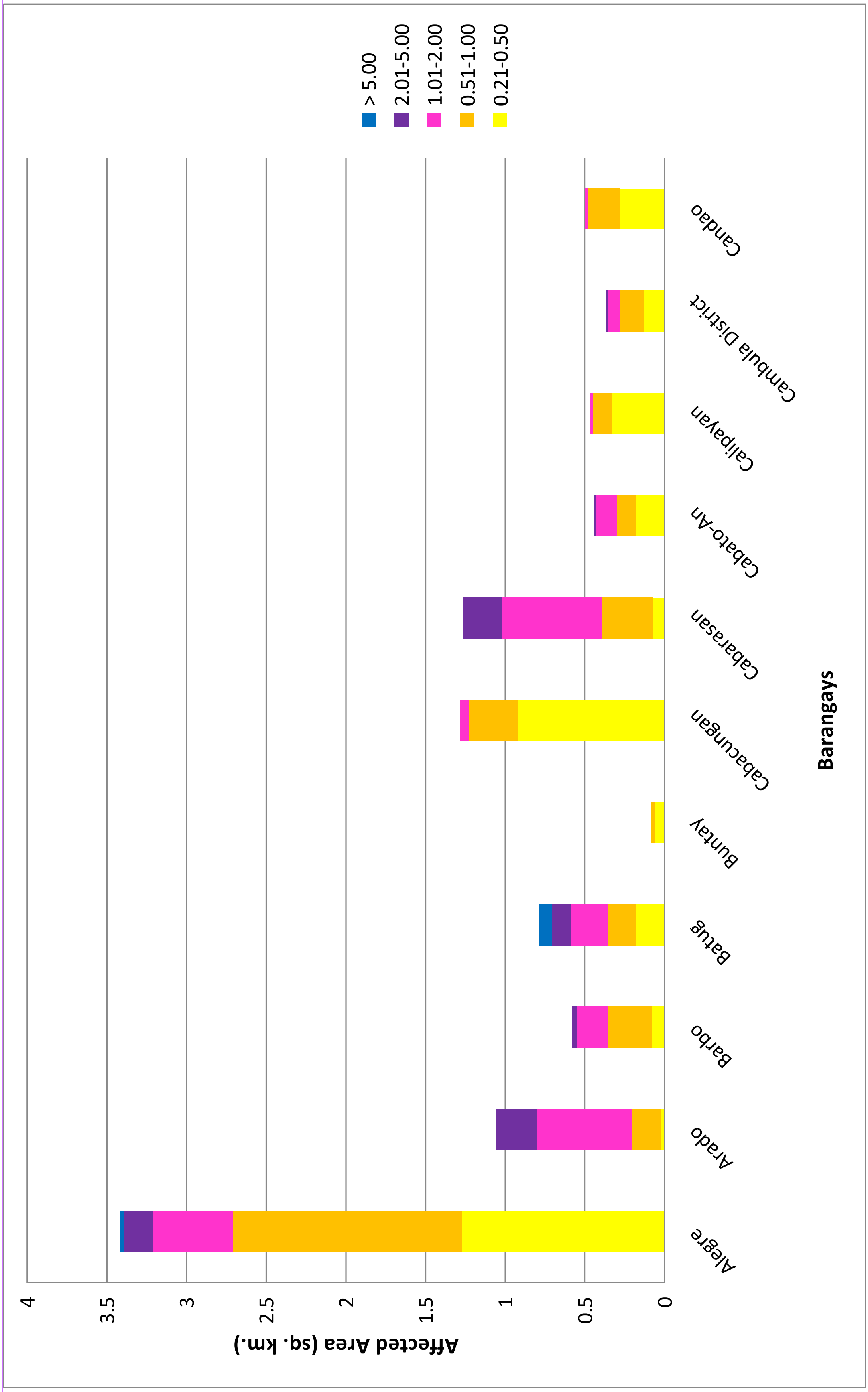


Figure 78. Affected areas in Dulag, Leyte during a 25-Year Rainfall Return Period

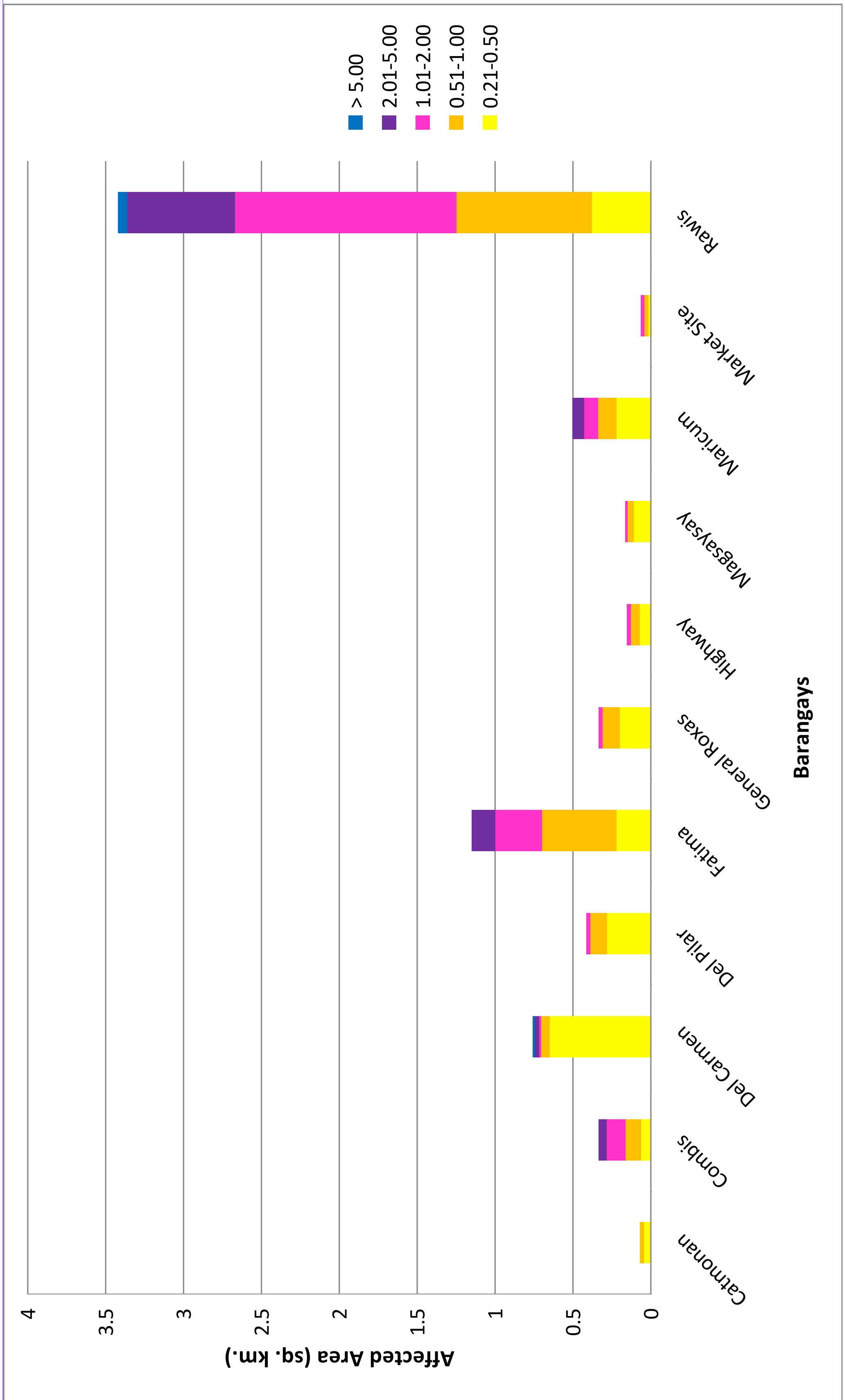


Figure 79. Affected areas in Dulag, Leyte during a 25-Year Rainfall Return Period

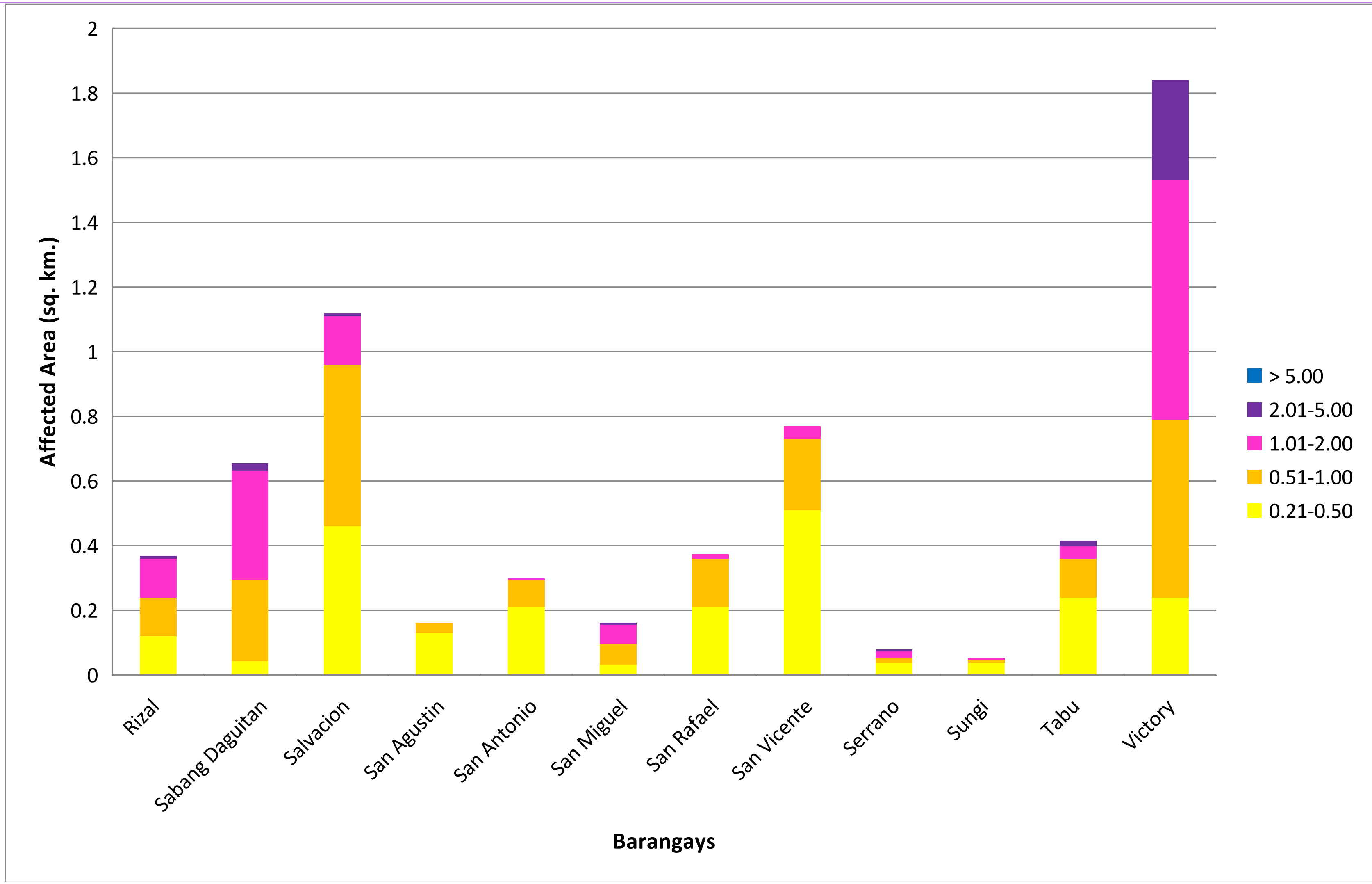


Figure 80. Affected areas in Dulag, Leyte during a 25-Year Rainfall Return Period

For the municipality of Julita, with an area of 57.17 sq. km., 8.31% will experience flood levels of less 0.20 meters. 4.17% of the area will experience flood levels of 0.21 to 0.50 meters while 3.05%, 2.72%, 1.03%, and 0.16% 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. Table 41 shows the affected areas in square kilometers by flood depth per barangay.

Table 41. Affected areas in Julita, Leyte during a 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Julita (in sq. km.)								
	Bonifacio	Cuya-E	Poblacion District I	Poblacion District II	Poblacion District III	Poblacion District IV	Santo Niño	Tagkip	Tolosahay
0.03-0.20	0.046	0.0031	0.81	0.52	0.69	0.27	0.6	0.8	1.01
0.21-0.50	0.22	0	0.46	0.22	0.2	0.61	0.42	0.16	0.095
0.51-1.00	0.83	0	0.23	0.1	0.17	0.027	0.14	0.21	0.039
1.01-2.00	0.9	0	0.011	0.03	0.21	0	0.031	0.37	0.0051
2.01-5.00	0.19	0	0	0.0011	0.027	0	0	0.37	0
> 5.00	0.003	0	0	0	0	0	0	0.09	0

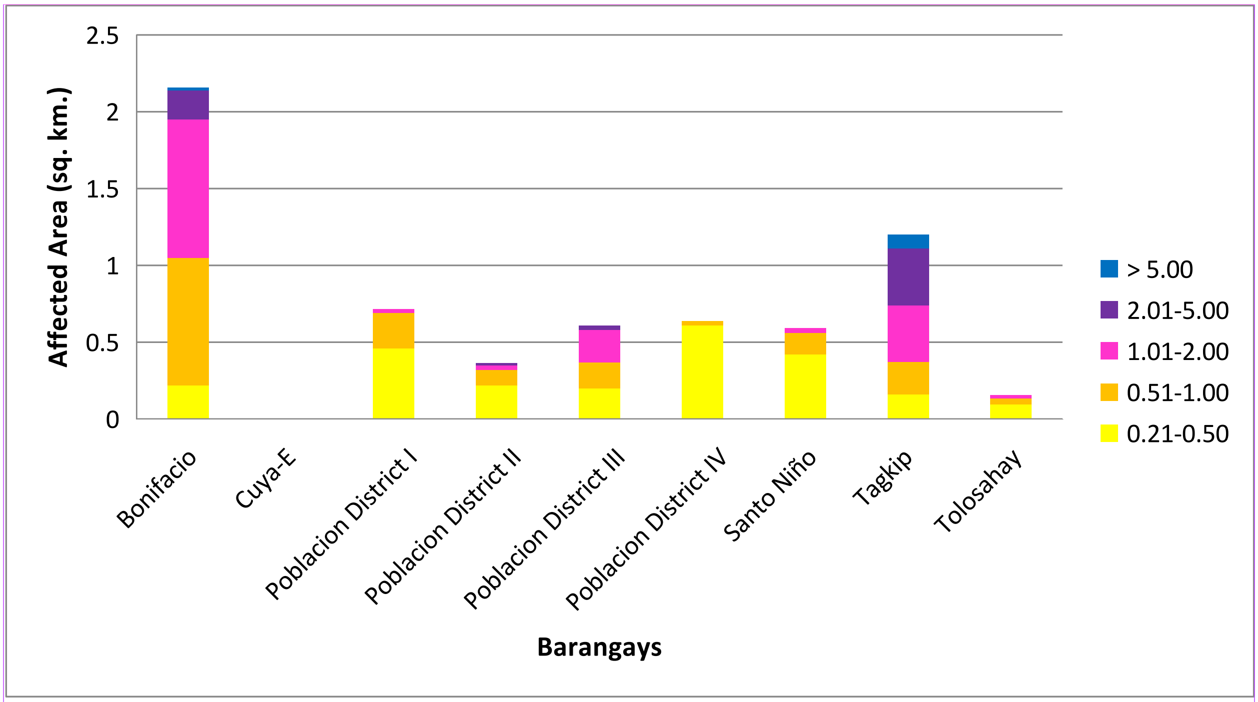


Figure 81. Affected areas in Julita, Leyte during a 25-Year Rainfall Return Period

For the municipality of La Paz, with an area of 136.02 sq. km., 0.68% will experience flood levels of less 0.20 meters. 0.18% of the area will experience flood levels of 0.21 to 0.50 meters while 0.003% of the area will experience flood depths of 0.51 to 1 meter, respectively. Table 42 depicts the affected areas in square kilometers by flood depth per barangay.

Table 42 .Affected areas in La Paz, Leyte during a 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in La Paz (in sq. km.)
	Canbañez
0.03-0.20	0.92
0.21-0.50	0.24
0.51-1.00	0.004
1.01-2.00	0
2.01-5.00	0
> 5.00	0

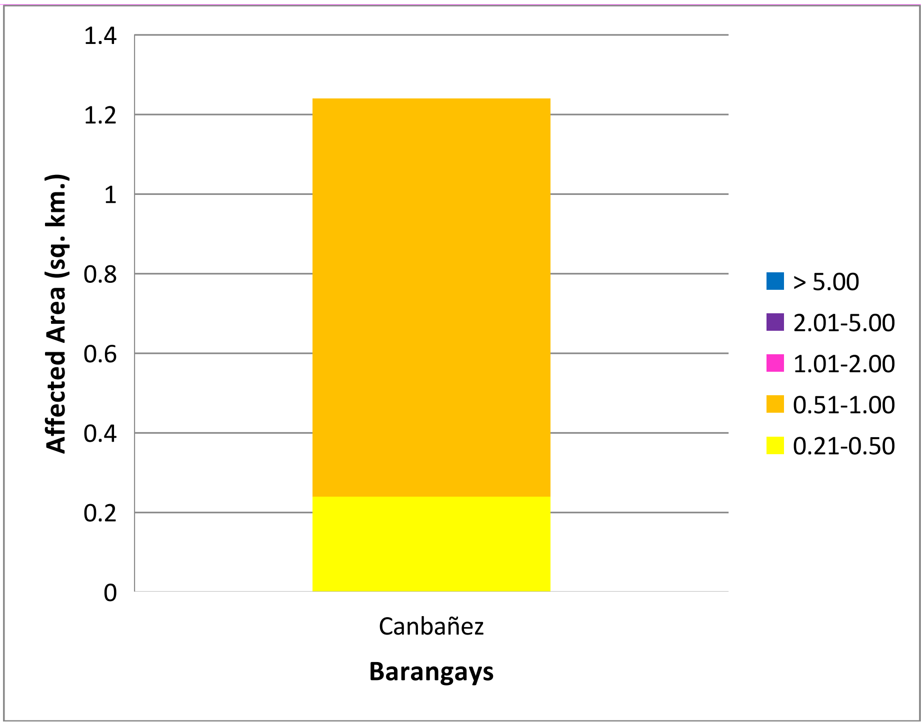


Figure 82. Affected areas in La Paz, Leyte during a 25-Year Rainfall Return Period

For the municipality of Mayorga, with an area of 39.45 sq. km., 5.90% will experience flood levels of less 0.20 meters. 2.07% of the area will experience flood levels of 0.21 to 0.50 meters while 0.40%, and 0.03% of the area will experience flood depths of 0.51 to 1 meter,and 1.01 to 2 meters, respectively. Table 43 depicts the affected areas in square kilometers by flood depth per barangay.

Table 43. Affected areas in Mayorga, Leyte during a 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Mayorga (in sq. km.)		
	A. Bonifacio	Calipayan	Talisay
0.03-0.20	0.017	1.02	1.29
0.21-0.50	0.017	0.33	0.47
0.51-1.00	0.0015	0.12	0.036
1.01-2.00	0.00018	0.0098	0.002
2.01-5.00	0	0	0
> 5.00	0	0	0

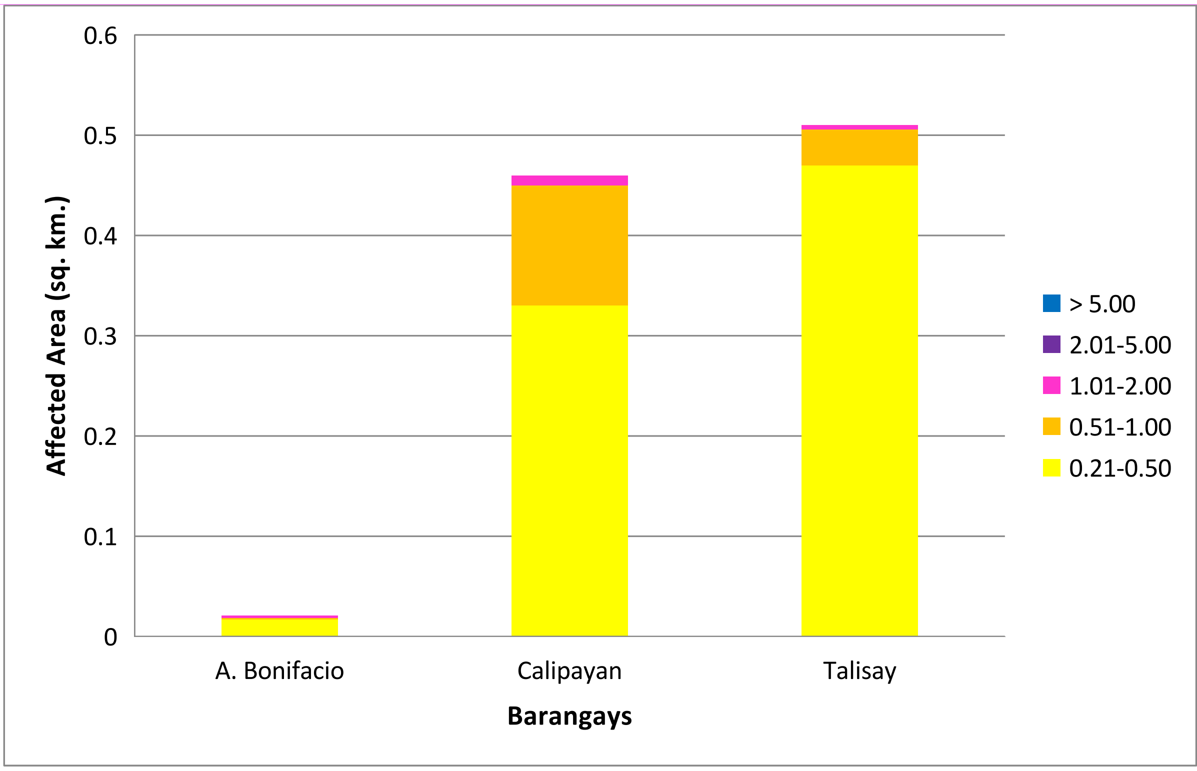


Figure 83. Affected areas in Mayorga, Leyte during a 25-Year Rainfall Return Period

For the 100-year return period, 19.95% of the municipality of Dulag with an area of 63.65 sq. km. will experience flood levels of less 0.20 meters, while 11.40% of the area will experience flood levels of 0.21 to 0.50 meters; 12.93%, 12.24%, 5.07%, and 0.33% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 t0 5 meters, and more than 5 meters respectively. Table 44 depicts the areas affected in Dulag in square kilometers by flood depth per barangay.

Table 44. Affected areas in Dulag, Leyte during a 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Dulag (in sq. km.)							
	Alegre	Arado	Barbo	Batug	Buntay	Cabacungan	Cabarasan	Cabato-An
0.03-0.20	0.84	0.061	0.039	0.062	0.22	0.41	0.0027	0.64
0.21-0.50	0.84	0.021	0.056	0.064	0.078	0.9	0.0089	0.22
0.51-1.00	1.78	0.065	0.24	0.25	0.013	0.35	0.15	0.13
1.01-2.00	0.99	0.55	0.28	0.27	0	0.18	0.72	0.096
2.01-5.00	0.23	0.42	0.033	0.17	0	0.0003	0.39	0.081
> 5.00	0.03	0	0	0.081	0	0	0	0

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Dulag (in sq. km.)							
	Calipayan	Cambula District	Candao	Catmonan	Combis	Del Carmen	Del Pilar	Fatima
0.03-0.20	0.88	0.22	0.52	0.22	0.18	0.85	0.72	0.033
0.21-0.50	0.4	0.12	0.27	0.049	0.065	0.68	0.33	0.091
0.51-1.00	0.18	0.16	0.28	0.017	0.084	0.16	0.21	0.45
1.01-2.00	0.023	0.11	0.04	0	0.15	0.015	0.03	0.49
2.01-5.00	0	0.0067	0	0	0.057	0.03	0	0.17
> 5.00	0	0	0	0	0	0.00036	0	0

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Dulag (in sq. km.)							
	General Roxas	Highway	Magsaysay	Maricum	Market Site	Rawis	Rizal	Sabang Daguitan
0.03-0.20	0.27	0.36	0.29	0.62	0.065	0.12	0.32	0.051
0.21-0.50	0.21	0.079	0.16	0.26	0.021	0.17	0.14	0.028
0.51-1.00	0.2	0.055	0.066	0.18	0.026	0.79	0.14	0.16
1.01-2.00	0.026	0.036	0.0034	0.097	0.03	1.53	0.16	0.43
2.01-5.00	0	7.4E-05	0	0.11	0	0.99	0.014	0.058
> 5.00	0	0	0	0	0	0.096	0	0

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Dulag (in sq. km.)									
	Salvacion	San Agustin	San Antonio	San Miguel	San Rafael	San Vicente	Serrano	Sungi	Tabu	Victory
0.03-0.20	0.23	0.46	0.24	0.14	0.96	1.51	0.15	0.085	0.72	0.21
0.21-0.50	0.26	0.17	0.22	0.033	0.23	0.57	0.042	0.049	0.28	0.14
0.51-1.00	0.64	0.049	0.14	0.049	0.18	0.36	0.019	0.014	0.18	0.46
1.01-2.00	0.38	0.00096	0.0034	0.086	0.046	0.072	0.021	0.0013	0.051	0.87
2.01-5.00	0.0086	0	0	0.0014	0	0	0.0046	0	0.03	0.42
> 5.00	0	0	0	0	0	0	0	0	0	0.0039

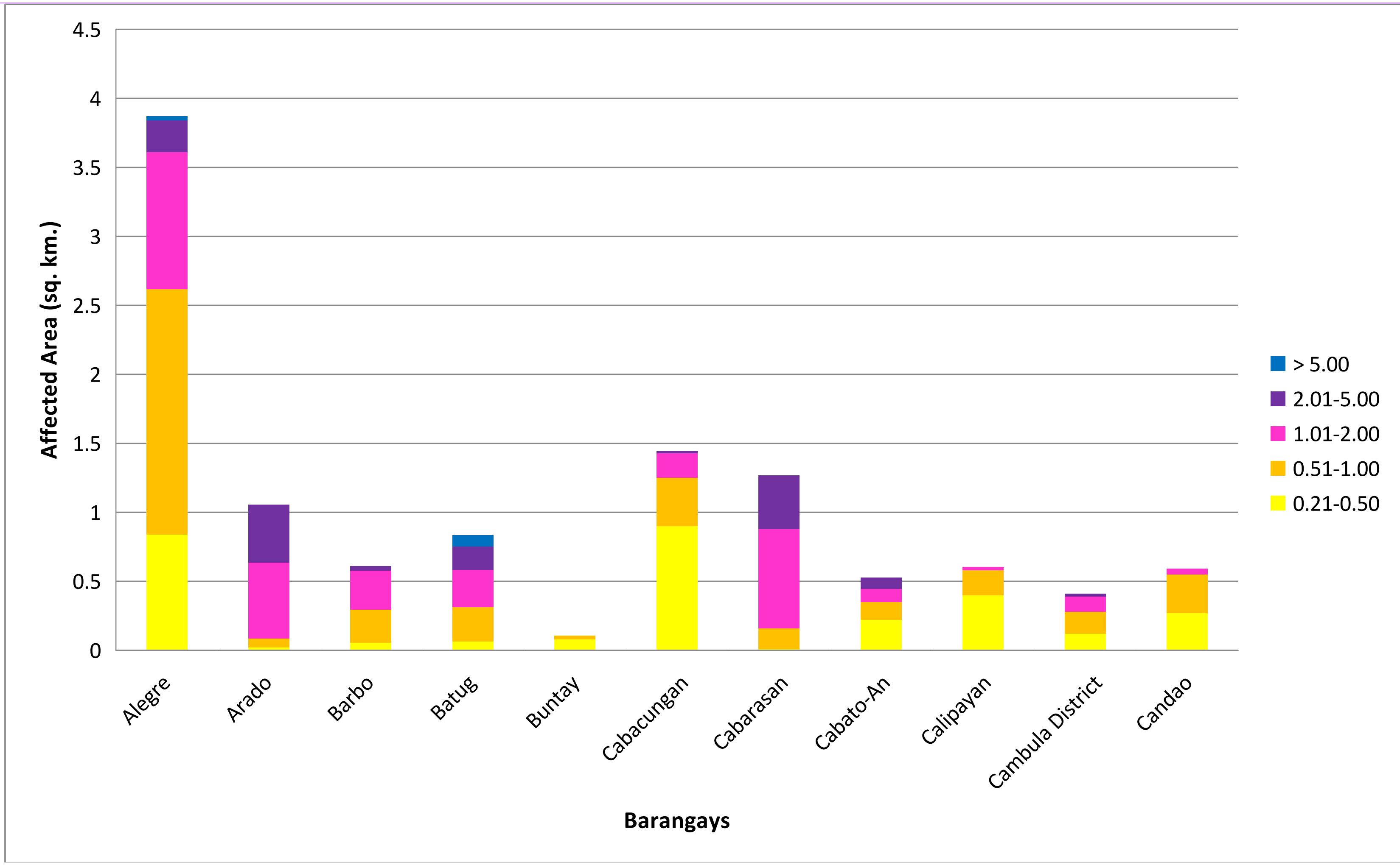


Figure 84. Affected areas in Dulag, Leyte during a 100-Year Rainfall Return Period

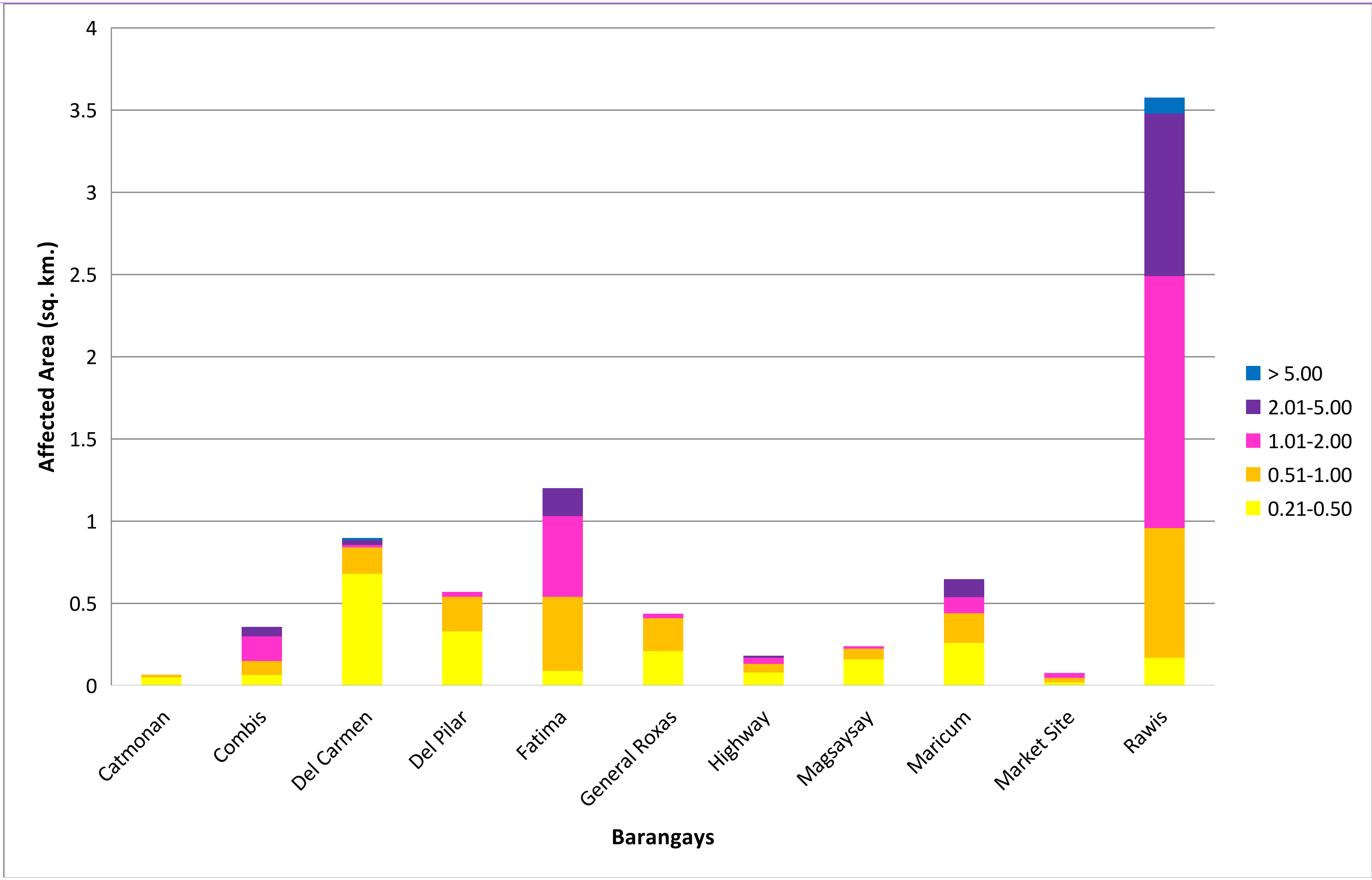


Figure 85. Affected areas in Dulag, Leyte during a 100-Year Rainfall Return Period

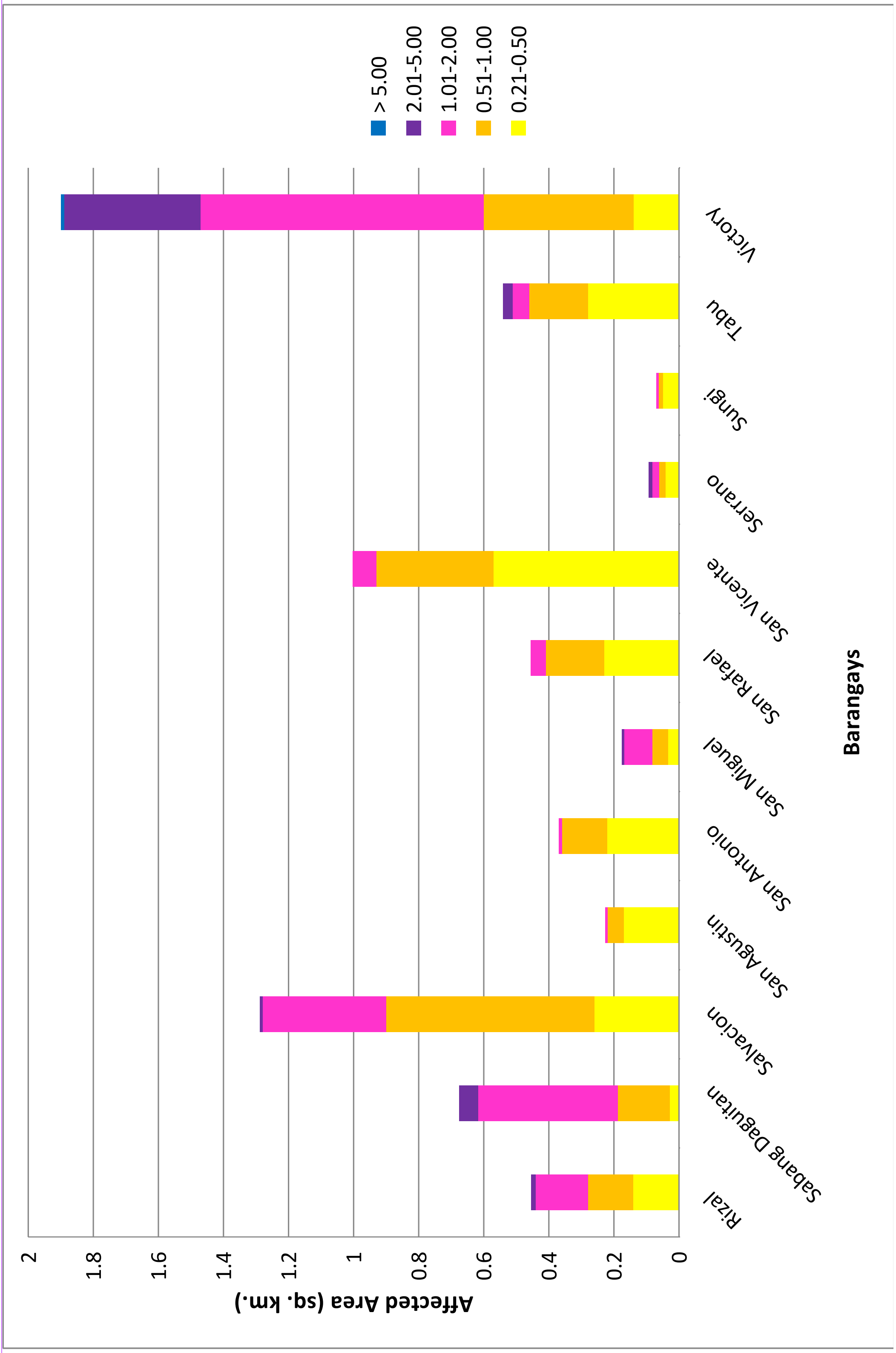


Figure 86. Affected areas in Dulag, Leyte during a 100-Year Rainfall Return Period

For the municipality of Julita, with an area of 57.17 sq. km., 8.31% will experience flood levels of less 0.20 meters. 4.17% of the area will experience flood levels of 0.21 to 0.50 meters while 3.05%, 2.72%, 1.03%, and 0.16% 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. Table 41 shows the affected areas in square kilometers by flood depth per barangay.

Table 45.Affected areas in Julita, Leyte during a 100-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Julita (in sq. km.)								
	Bonifacio	Cuya-E	Poblacion District I	Poblacion District II	Poblacion District III	Poblacion District IV	Santo Niño	Tagkip	Tolosahay
0.03-0.20	0.021	0.0031	0.61	0.35	0.52	0.054	0.48	0.74	0.98
0.21-0.50	0.088	0	0.52	0.32	0.22	0.49	0.45	0.18	0.12
0.51-1.00	0.71	0	0.32	0.16	0.16	0.36	0.21	0.2	0.049
1.01-2.00	0.87	0	0.074	0.042	0.29	0	0.048	0.39	0.0082
2.01-5.00	0.51	0	0	0.0023	0.12	0	0	0.37	0
> 5.00	0.0034	0	0	0	0	0	0	0.13	0

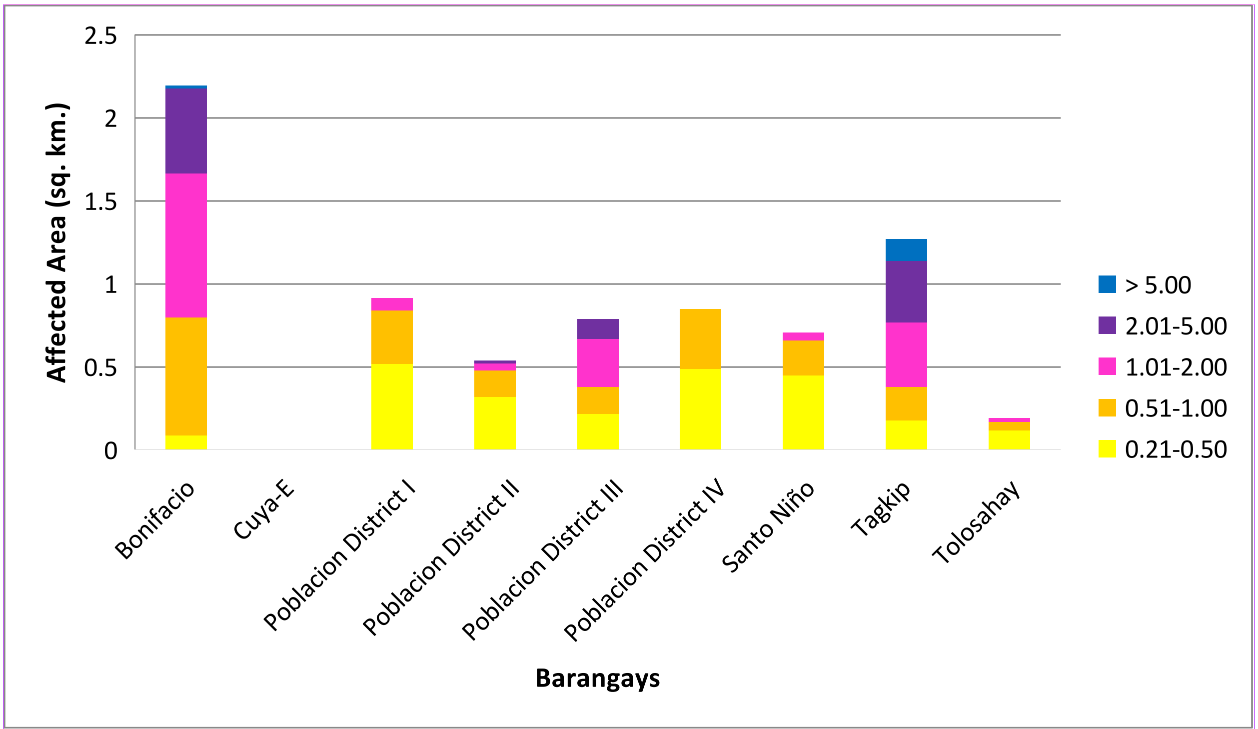


Figure 87. Affected areas in Julita, Leyte during a 100-Year Rainfall Return Period

For the municipality of La Paz, with an area of 136.02 sq. km., 0.57% will experience flood levels of less 0.20 meters. 0.28% of the area will experience flood levels of 0.21 to 0.50 meters while 0.006% of the area will experience flood depths of 0.51 to 1 meter, respectively. Table 46 lists the affected areas in square kilometers by flood depth per barangay.

Table 46. Affected areas in La Paz, Leyte during a 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in La Paz (in sq. km.)
	Canbañez
0.03-0.20	0.78
0.21-0.50	0.38
0.51-1.00	0.0086
1.01-2.00	0
2.01-5.00	0
> 5.00	0

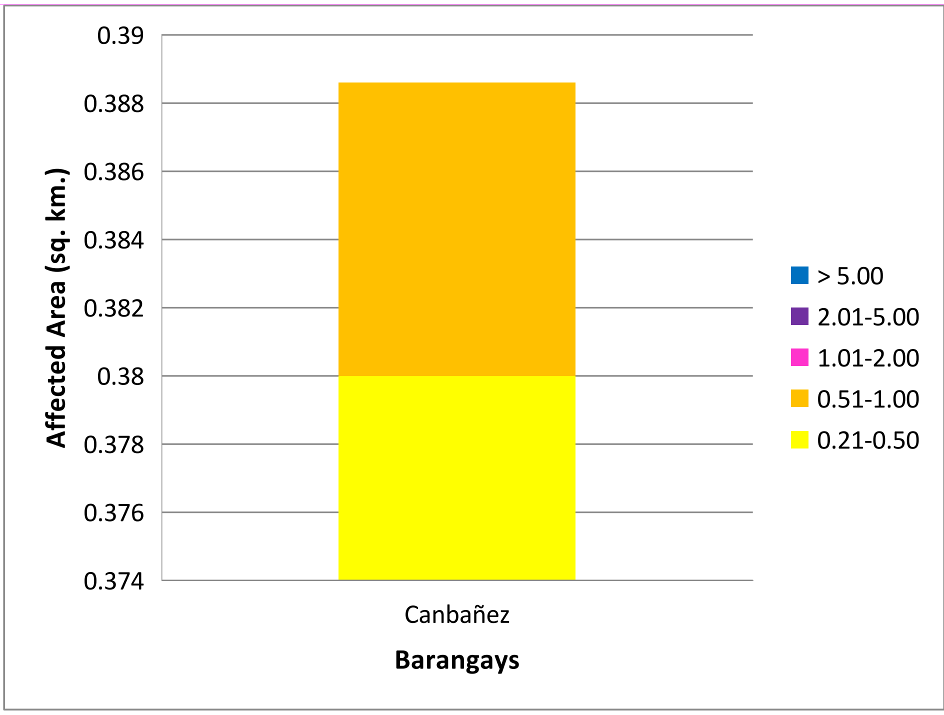


Figure 88. Affected areas in La Paz, Leyte during a 100-Year Rainfall Return Period

For the municipality of Mayorga, with an area of 39.45 sq. km., 4.72% will experience flood levels of less 0.20 meters. 2.98% of the area will experience flood levels of 0.21 to 0.50 meters while 0.63%, and 0.07% of the area will experience flood depths of 0.51 to 1 meter,and 1.01 to 2 meters, respectively. Table 47 shows the affected areas in square kilometers by flood depth per barangay.

Table 43. Affected areas in Mayorga, Leyte during a 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Mayorga (in sq. km.)		
	A. Bonifacio	Calipayan	Talisay
0.03-0.20	0.014	0.88	0.97
0.21-0.50	0.017	0.4	0.76
0.51-1.00	0.0034	0.18	0.065
1.01-2.00	0.00048	0.023	0.0032
2.01-5.00	0	0	0
> 5.00	0	0	0

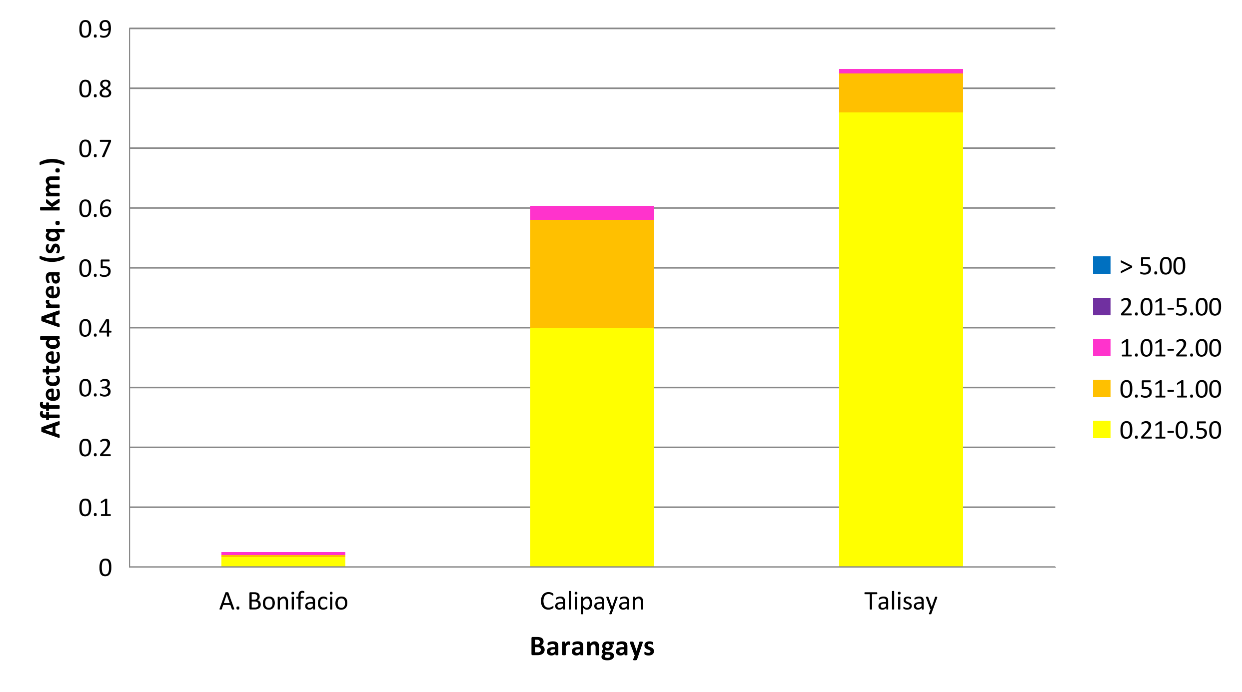


Figure 89. Affected areas in Mayorga, Leyte during a 100-Year Rainfall Return Period

Among the barangays in the municipality of Dulag, Alegre is projected to have the highest percentage of area that will experience flood levels of at 7.40%. On the other hand, Rawis posted the percentage of area that may be affected by flood depths of at 5.81%.

Among the barangays in the municipality of Julita, Bonifacio is projected to have the highest percentage of area that will experience flood levels of at 3.85%. On the other hand, Tagkip posted the percentage of area that may be affected by flood depths of at 3.52%.

Among the barangays in the municipality of La Paz, Canbañezis projected to have the highest percentage of area that will experience flood levels of at 0.86%.

Among the barangays in the municipality of Mayorga, Talisayis projected to have the highest percentage of area that will experience flood levels of at 4.56%. On the other hand, Calipayan posted the percentage of area that may be affected by flood depths of at 3.76%.

Moreover, the generated flood hazard maps for the Daguitan-Marabong Floodplain were used to assess the vulnerability of the educational and medical institutions in the floodplain. Using the flood depth units of PAG-ASA for hazard maps - “Low”, “Medium”, and “High” - the affected institutions were given their individual assessment for each Flood Hazard Scenario (5 yr, 25 yr, and 100 yr).

Table 48. Area covered by each warning level with respect to the rainfall scenario

Warning Level	Area Covered in sq. km		
	5 year	25 year	100 year
Low	10.46	11.57	11.18
Medium	9.29	14.14	16.59
High	3.00	5.97	8.38

Of the 53 identified educational institutions in Daguitan-Marabong Floodplain, 11 schools were assessed to be exposed to the low level flooding during a 5-year scenario while 6 schools were assessed to be exposed to medium level flooding. In the 25-year scenario, 11 schools were assessed to be exposed to the low level flooding while 8 schools were assessed to be exposed to medium level flooding and 2 schools were assessed to be exposed to high level flooding in the same scenario. For the 100 year scenario, 21 schools were assessed for low level flooding and 6 schools for Medium level flooding. In the same scenario, 4 schools were assessed to be exposed to high level flooding. See Annex 12 for a detailed enumeration of schools inside Daguitan-Marabong Floodplain.

Of the 6 identified health institutions in Daguitan-Marabong Floodplain, 2 were assessed to be exposed to the Low level flooding during a 5-year scenario. In the 25-year scenario, 3 were assessed to be exposed to the low level flooding. For the 100-year scenario, 3 schools were assessed for low level flooding and 2 for medium level flooding. In the same scenario. See Annex 13 for a detailed enumeration of medical insitutions inside Daguitan-Marabong Floodplain.

5.11 Flood Validation

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

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

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

After which, the actual data from the field were compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed.
The flood validation consists of 239 points randomly selected all over the Daguitan-Marabong Floodplain. It has an RMSE value of 0.68. The validation points are found in Annex 11.

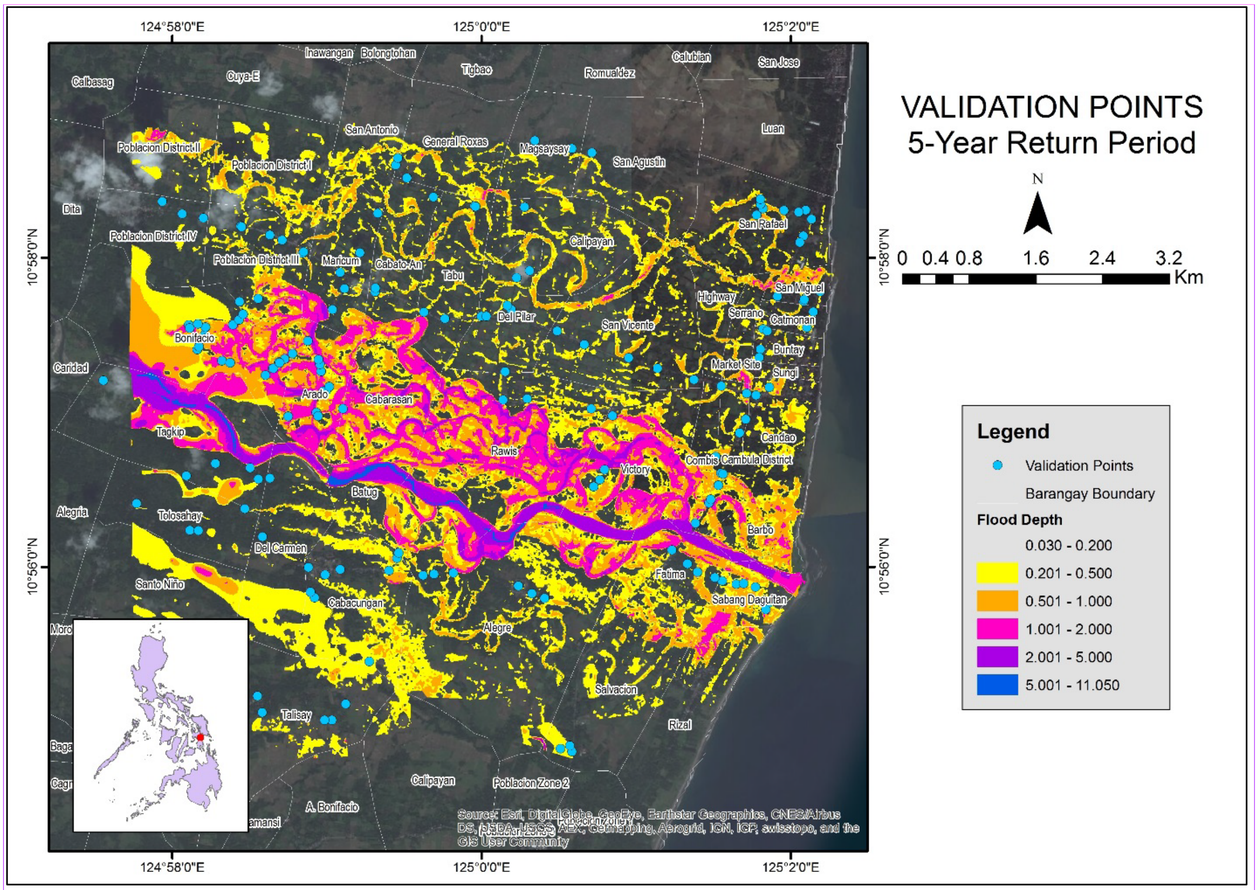


Figure 90. Validation points for 5-year Flood Depth Map of Daguitan-Marabong Floodplain

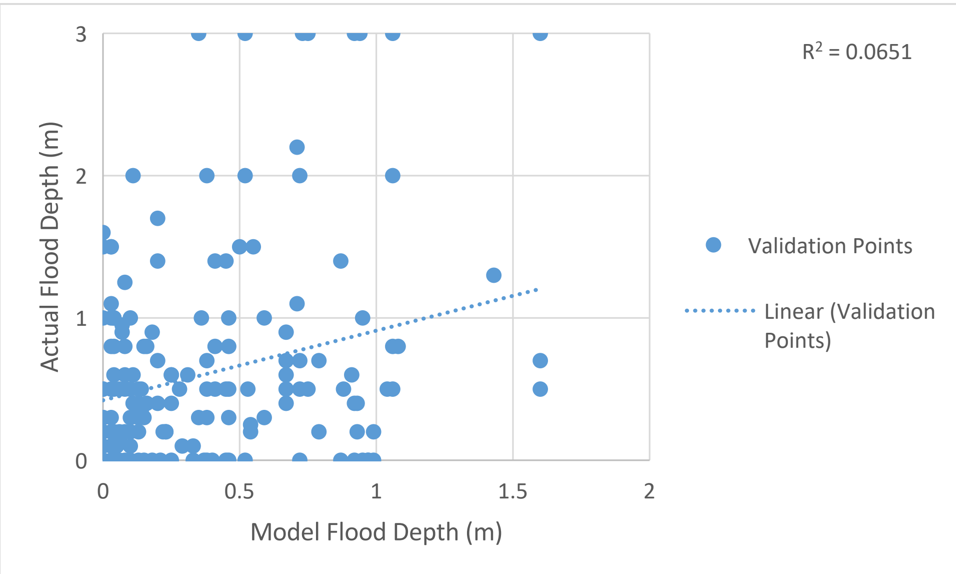


Figure 91. Flood map depth vs actual flood depth

Table 49. Actual Flood Depth vs Simulated Flood Depth in Daguitan-Marabong

MAINIT-TUBAY BASIN		Modeled Flood Depth (m)						
		0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	>5.00	Total
Actual Flood Depth (m)	0-0.20	51	19	17	0	0	0	87
	0.21-0.50	46	13	11	3	0	0	73
	0.51-1.00	32	9	8	3	0	0	52
	1.01-2.00	7	4	5	2	0	0	18
	2.01-5.00	0	1	6	2	0	0	9
	>5.00	0	0	0	0	0	0	0
	Total	136	46	47	10	0	0	239

The overall accuracy generated by the flood model is estimated at 30.96% with 74 points correctly matching the actual flood depths. In addition, there were 86 points estimated one level above and below the correct flood depths while there were 62 points and 8 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 4 points were overestimated while a total of 112 points were underestimated in the modeled flood depths of Daguitan-Marabong.

Table 50. Summary of Accuracy Assessment in Daguitan-Marabong

	No. of Points	%
Correct	74	**30.96**
Overestimated	53	**22.18**
Underestimated	112	**46.86**
Total	239	**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.

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 Daguitan-Marabong Floodplain Survey

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

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
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
Operating temperature	-10˚C to +35˚C (with insulating jacket)
Relative humidity	0-95% no-condensing

Annex 2. NAMRIA certification of reference points used in the LiDAR survey

1. LYT-101

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

January 20, 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: **LEYTE**
Station Name: **LYT-101**
Order: **2nd**

Island: **VISAYAS**
Municipality: **PALO**
Barangay:

	PRS92 Coordinates	
Latitude: **11° 10' 23.89707"**	Longitude: **125° 0' 38.62071"**	Ellipsoidal Hgt: **6.58600 m.**
	WGS84 Coordinates	
Latitude: **11° 10' 19.64869"**	Longitude: **125° 0' 43.78230"**	Ellipsoidal Hgt: **69.02100 m.**
	PTM Coordinates	
Northing: **1235497.253 m.**	Easting: **501171.719 m.**	Zone: **5**
	UTM Coordinates	
Northing: **1,235,811.61**	Easting: **719,575.03**	Zone: **51**

Location Description

LYT-101
Station is located in the province of Leyte, municipality of Palo. From Tacloban City travel SE to McArthur Park. The point is located infront of Gen. Douglas McArthur Shrine and is approximately 10 m away and adjacent to center of lower step. Station mark is a concrete nail on center of a 20 x 20 cm. cement putty on the concrete ground.

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795097 A**
T.N.: **2014-94**

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

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

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

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

2. LYT-93

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

April 23, 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: **LEYTE**
Station Name: **LYT-93**
Order: **1st**

Island: **VISAYAS**
Municipality: **ABUYOG**
Barangay: **SANTO NIÑO (POB.)**

PRS92 Coordinates

Latitude: **10° 44' 52.03339"**	Longitude: **125° 0' 43.59630"**	Ellipsoidal Hgt: **2.66000 m.**

WGS84 Coordinates

Latitude: **10° 44' 47.89310"**	Longitude: **125° 0' 48.79542"**	Ellipsoidal Hgt: **66.12300 m.**

PTM Coordinates

Northing: **1188433.982 m.**	Easting: **501324.552 m.**	Zone: **5**

UTM Coordinates

Northing: **1,188,738.73**	Easting: **720,040.44**	Zone: **51**

Location Description

LYT-93
From Tacloban City travel 60kms S until you reach Abuyog Municipal Hall. From the gate near the post office walk 100m SE until you reach the office of the Municipal Engineer. Station is about 35m S of the S corner of the Municipal Engineer's building. Mark is the head of a 4" copper nail centered on a 0.30m x 0.30m x 1.00m concrete monument protruding 0.10m above the ground with inscription "LYT-93 2006 NAMRIA."

Requesting Party: **Engr. Christopher Cruz/ UP-DREAM**
Pupose: **Reference**
OR Number: **8796021 A**
T.N.: **2014-915**

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

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

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

3. SMR-53

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

April 23, 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: **SAMAR (WESTERN SAMAR)**
Station Name: **SMR-53**
Order: **2nd**

Island: **VISAYAS**
Municipality: **SANTA RITA**
Barangay: **SAN ISIDRO**

PRS92 Coordinates

Latitude: **11° 30' 17.85657"**	Longitude: **125° 1' 29.83739"**	Ellipsoidal Hgt: **26.13400 m.**

WGS84 Coordinates

Latitude: **11° 30' 13.52495"**	Longitude: **125° 1' 34.96980"**	Ellipsoidal Hgt: **87.78700 m.**

PTM Coordinates

Northing: **1272180.079 m.**	Easting: **502722.403 m.**	Zone: **5**

UTM Coordinates

Northing: **1,272,513.40**	Easting: **720,874.14**	Zone: **51**

Location Description

SMR-53
From Tacloban City Proper, travel about 45 km. north going to Brgy. San.Isidro. The NAMRIA monument was located about 15 m. west inside the San Isidro Elementary School, and almost near at the school building and flag pole about 5 m. north. Mark is the head of a 4" copper nail flushed in a cement block embedded in the ground with inscriptions "SMR-53; 2007; NAMRIA."

Requesting Party: **Engr. Christopher Cruz/ UP-DREAM**
Pupose: **Reference**
OR Number: **8796021 A**
T.N.: **2014-920**

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

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

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

CIP/4701/12/09/814

4. LY-110

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

January 27, 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: **LEYTE**
Station Name: **LY-110**

Island: **Visayas**	Municipality: **PALO**	Barangay: **LIBERTAD**
Elevation: **12.9339 +/- 0.03 m.**	Order: **1st Order**	Datum: **Mean Sea Level**
Latitude:	Longitude:	

Location Description

LY-110
Is in the Province of Leyte, Municipality of Palo, Brgy. Libertad. it is about 225m West of km post 919, 4.15 North of Centerline of the road leading to Ormoc, at the Northwest end of a 42.0m long bridge. A 24 minutes drive from Tacloban City going to South to Ormoc on a bridge located about 225 meters of km post 919. Mark is a 4" copper nail, drilled on hole on top of concrete footwalk at the top of culvert headwall and cemented flush with inscription "LY-110 2007 NAMRIA".

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8089687 I**
T.N.: **2016-0240**

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

9 9 0 1 2 7 2 0 1 6 1 5 1 2 0 1

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

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Figure A-2.4. LYT-741

5. LY-881

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

April 23, 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: **LEYTE**
Station Name: **LY-881**

Island: **Visayas**	Municipality: **PALO**	Barangay: **PAWING**
Elevation: **4.6195 m.**	Order: **1st Order**	Datum: **Mean Sea Level**

Location Description

BM-LY-881 is in the Province of Leyte, Municipality of Palo, Brgy. Pawing along the Tacloban-Ormoc National Highway. The station is located at the concrete foundation of Governor Center Welcome sign at the junction of the road going to Ormoc, Samar, Tacloban and Mac Arthur Landing Memorial Park.

Mark is the head of a 4 in. copper nail set flush on a 15 cm. x 15 cm. cementt putty with inscriptions "LY-881, 2008, NAMRIA".
Re-computed March 2014

Requesting Party: **Engr. Christopher Cruz/ UP-DREAM**
Pupose: **Reference**
OR Number: **8796021 A**
T.N.: **2014-923**

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

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

CIP/4701/12/09/814

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

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

1. LYT-104

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
LYT 104 --- LY 110 (B1)	LYT 104	LY 110	Fixed	0.004	0.013	68°33'52"	8457.064	-19.323
LY 110 --- LYT 104 (B2)	LYT 104	LY 110	Fixed	0.004	0.015	68°33'52"	8457.047	-19.343

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

Vector Components (Mark to Mark)

From:	LYT 104				
Grid		Local		Global	
Easting	706089.510 m	Latitude	N11°08'38.92234"	Latitude	N11°08'34.67033"
Northing	1232496.838 m	Longitude	E124°53'13.52786"	Longitude	E124°53'18.69323"
Elevation	32.311 m	Height	33.659 m	Height	95.861 m

To:	LY 110				
Grid		Local		Global	
Easting	713942.863 m	Latitude	N11°10'19.48389"	Latitude	N11°10'15.23095"
Northing	1235638.117 m	Longitude	E124°57'32.98736"	Longitude	E124°57'38.14961"
Elevation	12.819 m	Height	14.336 m	Height	76.647 m

Vector					
ΔEasting	7853.353 m	NS Fwd Azimuth	68°33'52"	ΔX	-6101.546 m
ΔNorthing	3141.279 m	Ellipsoid Dist.	8457.064 m	ΔY	-5012.598 m
ΔElevation	-19.492 m	ΔHeight	-19.323 m	ΔZ	3027.816 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.004 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.002 m	σ ΔY	0.005 m
σ ΔElevation	0.007 m	σ ΔHeight	0.007 m	σ ΔZ	0.002 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000143938		
Y	-0.0000177190	0.0000287509	
Z	-0.0000052060	0.0000075812	0.0000037601

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	0.006 m
σ ΔElevation	0.007 m	σ ΔHeight	0.007 m	σ ΔZ	0.002 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000183425		
Y	-0.0000236542	0.0000368797	
Z	-0.0000062060	0.0000094836	0.0000037530

2. LY-110

Vector Components (Mark to Mark)

From:	LYT 104				
Grid		Local		Global	
Easting	706089.510 m	Latitude	N11°08'38.92234"	Latitude	N11°08'34.67033"
Northing	1232496.838 m	Longitude	E124°53'13.52786"	Longitude	E124°53'18.69323"
Elevation	32.311 m	Height	33.659 m	Height	95.861 m

To:	LY 110				
Grid		Local		Global	
Easting	713942.863 m	Latitude	N11°10'19.48389"	Latitude	N11°10'15.23095"
Northing	1235638.117 m	Longitude	E124°57'32.98736"	Longitude	E124°57'38.14961"
Elevation	12.819 m	Height	14.336 m	Height	76.647 m

Vector					
ΔEasting	7853.353 m	NS Fwd Azimuth	68°33'52"	ΔX	-6101.546 m
ΔNorthing	3141.279 m	Ellipsoid Dist.	8457.064 m	ΔY	-5012.598 m
ΔElevation	-19.492 m	ΔHeight	-19.323 m	ΔZ	3027.816 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.004 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.002 m	σ ΔY	0.005 m
σ ΔElevation	0.007 m	σ ΔHeight	0.007 m	σ ΔZ	0.002 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000143938		
Y	-0.0000177190	0.0000287509	
Z	-0.0000052060	0.0000075812	0.0000037601

Annex 4. The Survey Team

Date 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
	Data Component Project Leader – I	ENGR. LOUIE P. 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	Senior Science Research Specialist (SSRS)	JULIE PEARL MARS	UP-TCAGP
	Senior Science Research Specialist (SSRS) 2016/ RA (2014)	PAULINE JOANNE ARCEO	UP-TCAGP
	Research Associate (RA)	ENGR. IRO NIEL ROXAS	UP-TCAGP
	RA	FAITH JOY SABLE	UP-TCAGP
	RA	JONATHAN ALMALVEZ	UP-TCAGP
	RA	ENGR. DAN ALDOVINO	UP-TCAGP
Ground Survey, Data download and transfer	RA	JERIEL PAUL ALAMBAN, GEOL.	UP-TCAGP
LiDAR Operation	Airborne Security	SSG RANDY SISON	PHILIPPINE AIR FORCE (PAF)
		SSG RAYMUND DOMINE	PAF
	Pilot	CAPT. ALBERT PAUL LIM	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. RANDY LAGCO	AAC
		CAPT. JACKSON JAVIER	AAC
		CAPT. NIEL AGAWIN	AAC

Annex 5. Data Transfer Sheet for Daguitan-Marabong Floodplain

DATA TRANSFER SHEET

Feb 3, 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	1016A	3BLK33A024A	AQUARIUS	N/A	56.5KB	699KB	159MB	41.2GB	N/A	9.96GB	50.6GB	14.4MB	245B	649B	6.83KB	504KB	X:\Airborne_Raw\1016A
Jan 24, 2014	1018A	3BLK33A024B	AQUARIUS	N/A	56.5KB	1.41MB	81MB	N/A	N/A	2.63GB	12.6GB	14.4MB	245B	278B	4.21KB	345KB	X:\Airborne_Raw\1018A
Jan 25, 2014	1020A	3BLK33B025A	AQUARIUS	N/A	119KB	1.85MB	237MB	67.7GB	N/A	15.1GB	75GB	20.7MB	245B	530B	4.2KB	1.21KB	X:\Airborne_Raw\1020A
Jan 25, 2014	1022A	3BLK33B025B	AQUARIUS	N/A	819KB	1.28MB	242MB	75.3GB	N/A	18.9GB	57.2GB	20.7MB	245B	1.25KB	4.2KB	819KB	X:\Airborne_Raw\1022A
Jan 26, 2014	1024A	3BLK33AS34A026A	AQUARIUS	N/A	652KB	1.36MB	247MB	55.2GB	N/A	16.3GB	48.1GB	20MB	245B	488B	6.72KB	652KB	X:\Airborne_Raw\1024A

Received from

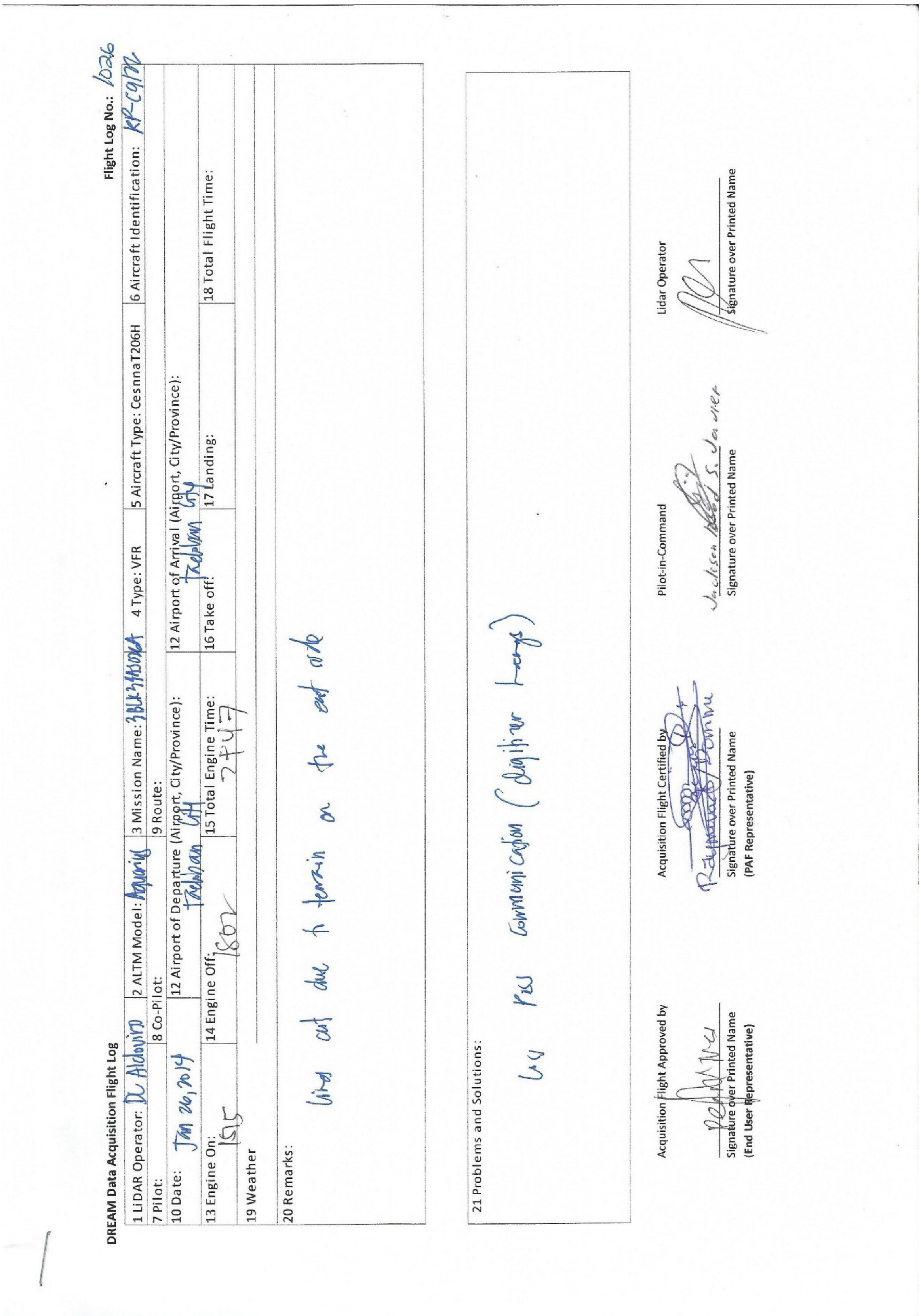
Name: Larah Paragas
Position: RA
Signature: [signature]

Received by

Name: JOIDA PRIETO 02/03/2014
Position: SRS
Signature: [signature]

Annex 6. Flight logs for the Flight Missions

1. Flight Log for 1026A Mission



DREAM Data Acquisition Flight Log

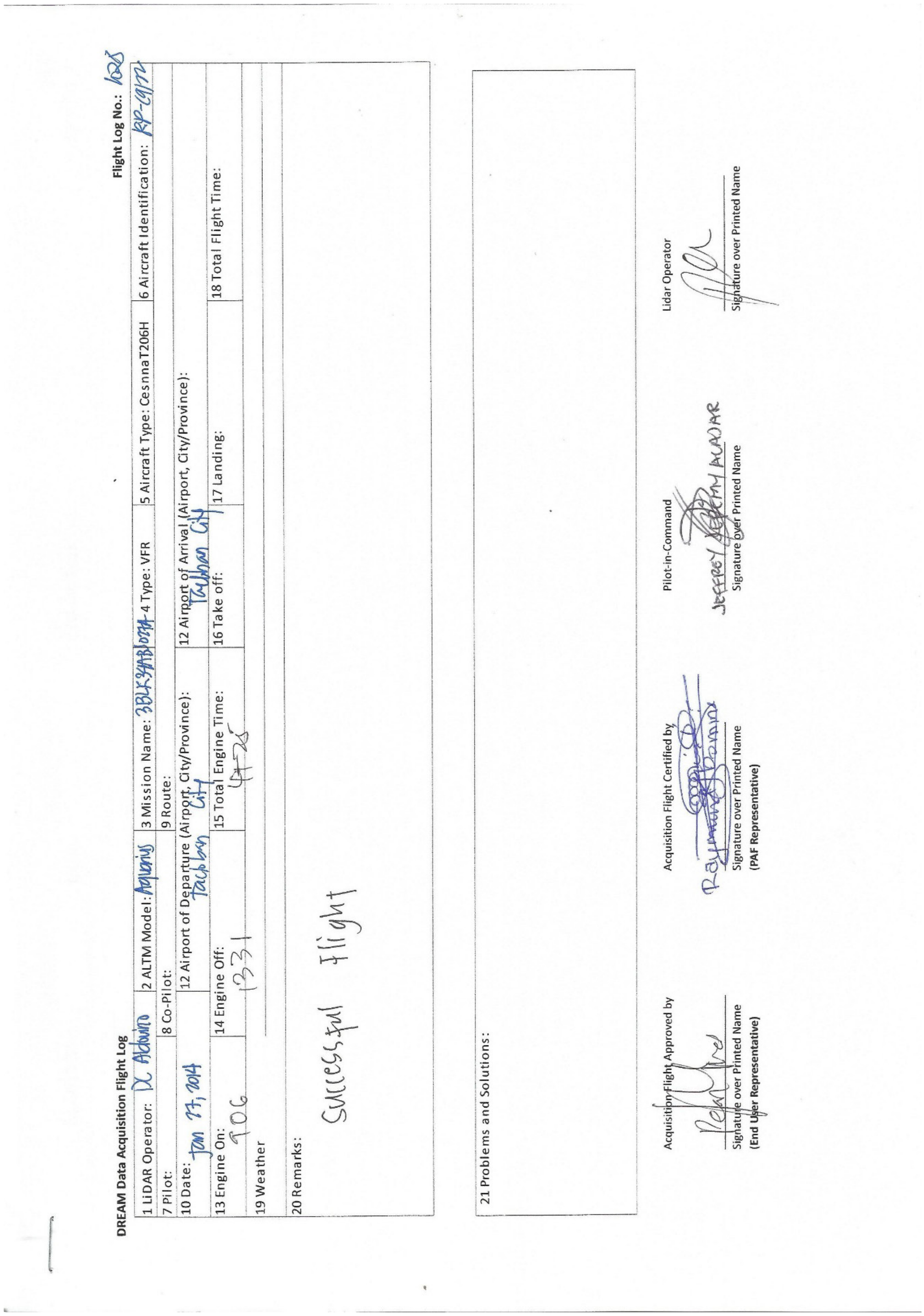
Flight Log No.: 1026

1 LiDAR Operator: DL Aldovino	2 ALTM Model: Aquarius	3 Mission Name: 3BLK34AS026A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9122
7 Pilot:	8 Co-Pilot:	9 Route:			
10 Date: Jan 26, 2014	12 Airport of Departure (Airport, City/Province): Tacloban City		12 Airport of Arrival (Airport, City/Province): Tacloban City		
13 Engine On: 1515	14 Engine Off: 1802	15 Total Engine Time: 2+47	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: line cut due to terrain on the east side					

21 Problems and Solutions: Lost PCS communication (digitizer hangs)

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)	Jackson S. Javier Signature over Printed Name	Signature over Printed Name

2.Flight Log for 1028A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1028

1 LiDAR Operator: JC Alduino	2 ALTM Model: Aquarius	3 Mission Name: 3BLK34AB027A 4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9122
7 Pilot:	8 Co-Pilot:	9 Route:		
10 Date: Jan 27, 2014	12 Airport of Departure (Airport, City/Province): Tacloban City	12 Airport of Arrival (Airport, City/Province): Tacloban City		
13 Engine On: 906	14 Engine Off: 1331	15 Total Engine Time: 4+25	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather				
20 Remarks: Successful Flight				

21 Problems and Solutions:

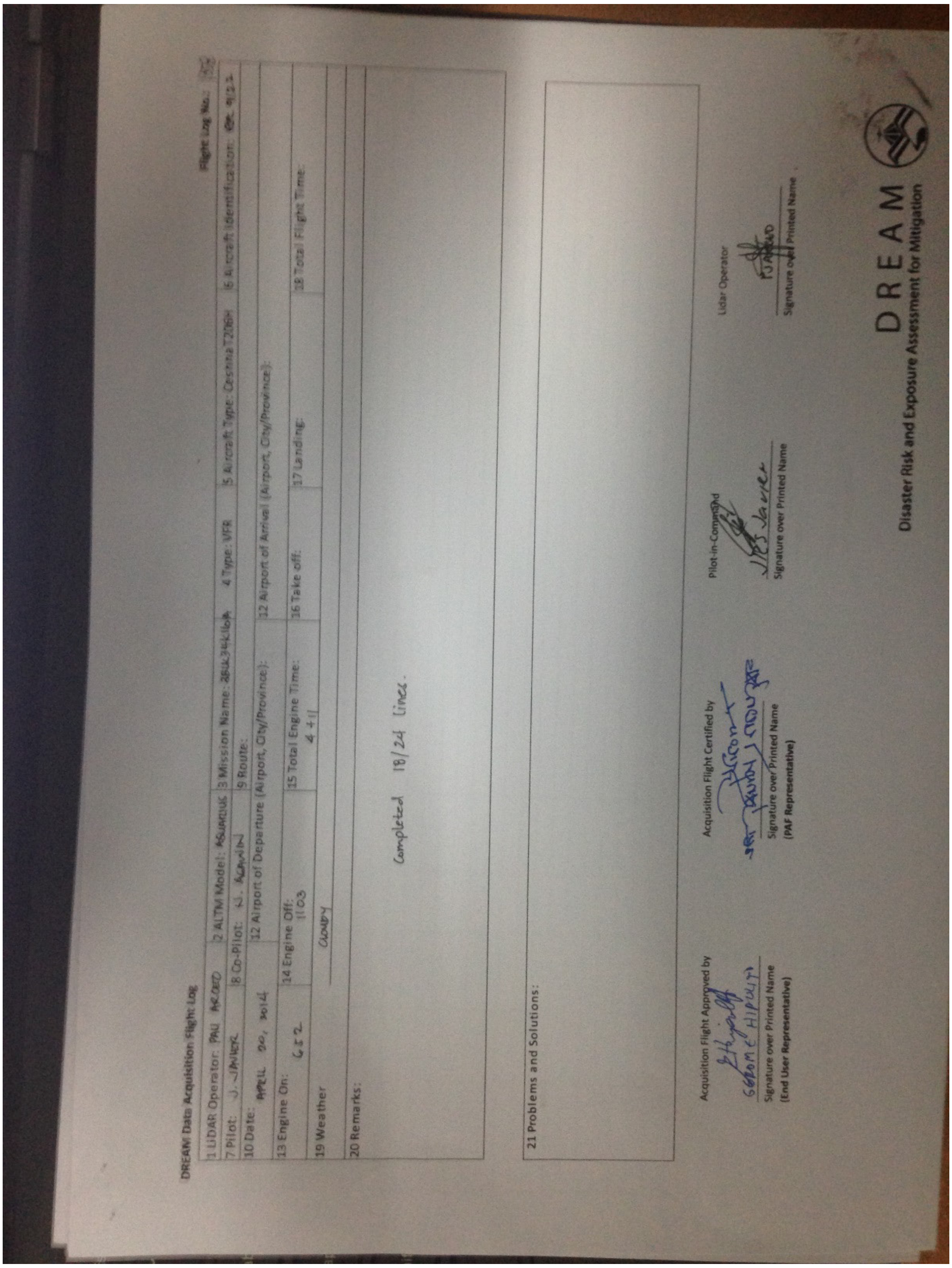
Acquisition Flight Approved by
Signature over Printed Name
(End User Representative)

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

Pilot-in-Command
JEFFREY JEREMY ALAJAR
Signature over Printed Name

Lidar Operator
Signature over Printed Name

3. Flight Log for 1358A Mission



DREAM Data Acquisition Flight Log

Flight Log No.:

1 LiDAR Operator: PAU ARCEO	2 ALTM Model: AQUARIUS	3 Mission Name: [illegible]	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RP-C9122
7 Pilot: J. JAVIER	8 Co-Pilot: W. RONALDO	9 Route:			
10 Date: APRIL 20, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 652	14 Engine Off: 1103	15 Total Engine Time: 4+11	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: CLOUDY					

20 Remarks:

Completed 18/24 lines.

21 Problems and Solutions:

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

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

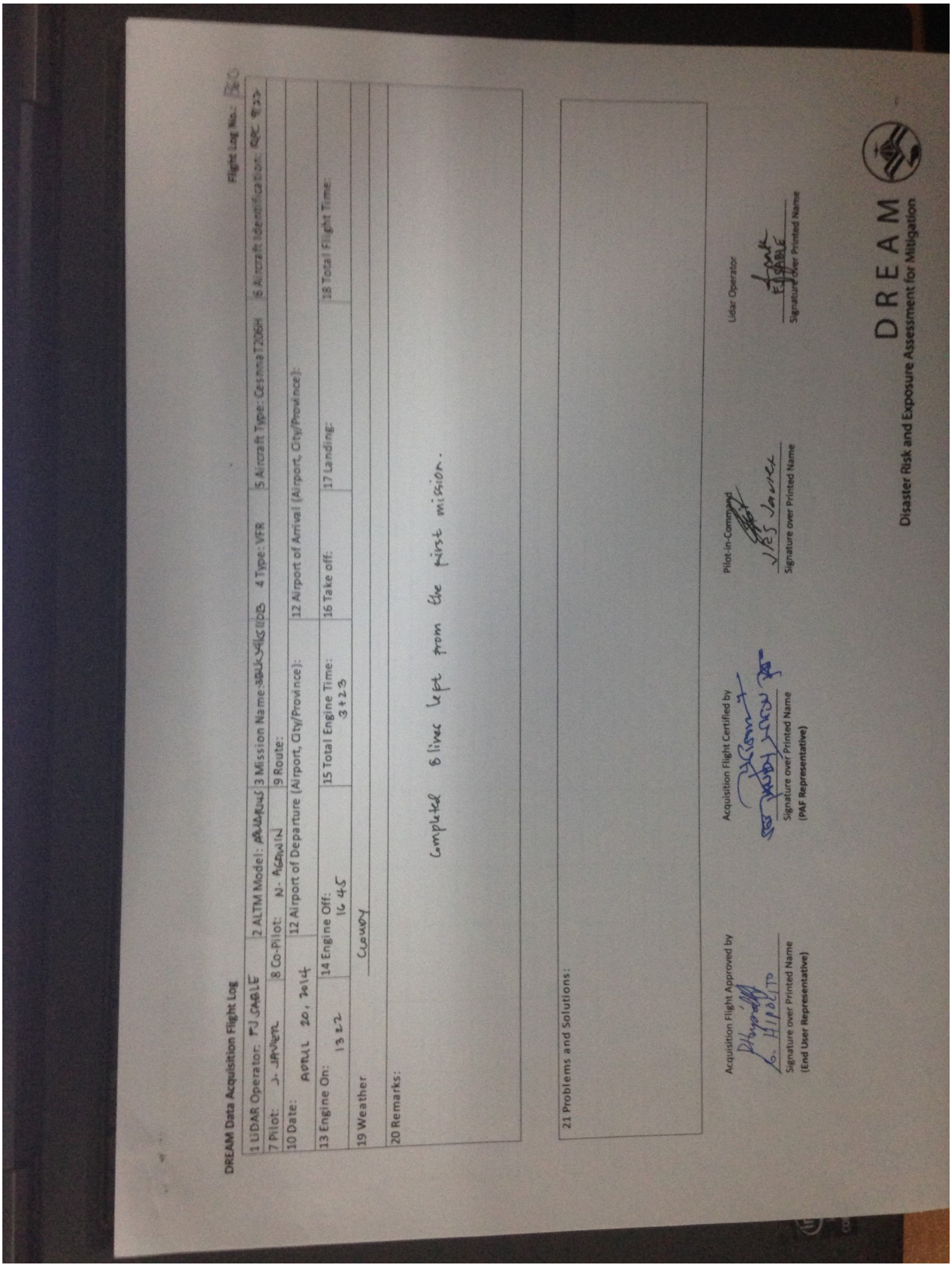
Pilot-in-Command — J. Javier — Signature over Printed Name

Lidar Operator — PJ Arceo — Signature over Printed Name

DREAM Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.3. Flight Log for Mission 3781G

4. Flight Log for 1360A Mission



DREAM Data Acquisition Flight Log

Flight Log No.:

1 LiDAR Operator: FJ SABLE	2 ALTM Model: AQUARIUS	3 Mission Name: [illegible]	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RPC [illegible]
7 Pilot: J. JAVIER	8 Co-Pilot: N. AGAWIN	9 Route:			
10 Date: APRIL 20, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1322	14 Engine Off: 1645	15 Total Engine Time: 3+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	CLOUDY				

20 Remarks:

Completed 8 lines left from the first mission.

21 Problems and Solutions:

Acquisition Flight Approved by
G. HIPOLITO
Signature over Printed Name
(End User Representative)

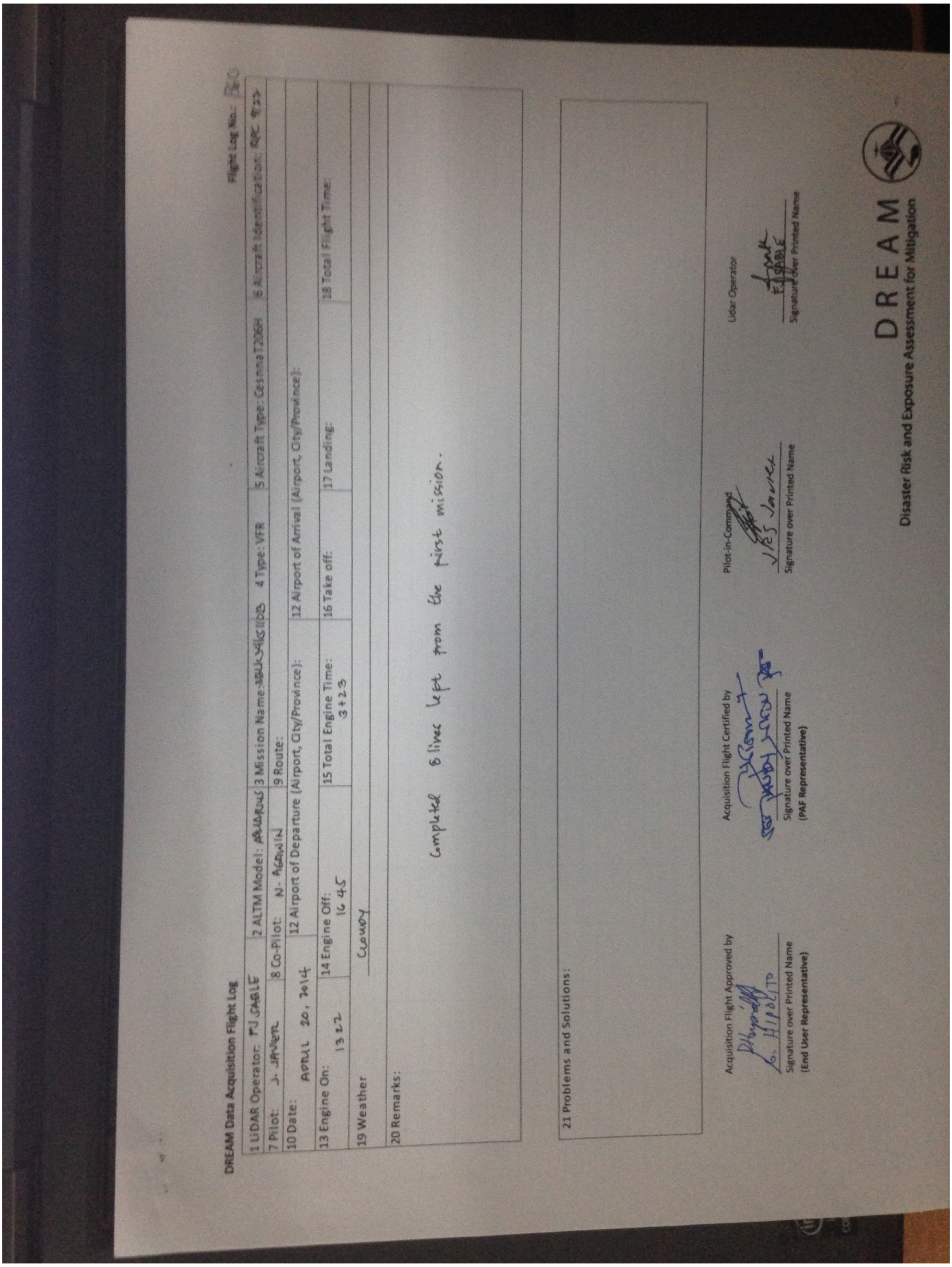
Acquisition Flight Certified by
Signature over Printed Name
(PAF Representative)

Pilot-in-Command
JRS Javier
Signature over Printed Name

Lidar Operator
FJ SABLE
Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

5. Flight Log for 1430A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: [illegible]

1 LiDAR Operator: FJ SABLE	2 ALTM Model: AQUARIUS	3 Mission Name: 3BLK49KS110B	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RPC 9122
7 Pilot: J. JAVIER	8 Co-Pilot: N. AGAWIN	9 Route:			
10 Date: APRIL 20, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1322	14 Engine Off: 1645	15 Total Engine Time: 3+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	Cloudy				

20 Remarks:

Completed 6 lines left from the first mission.

21 Problems and Solutions:

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

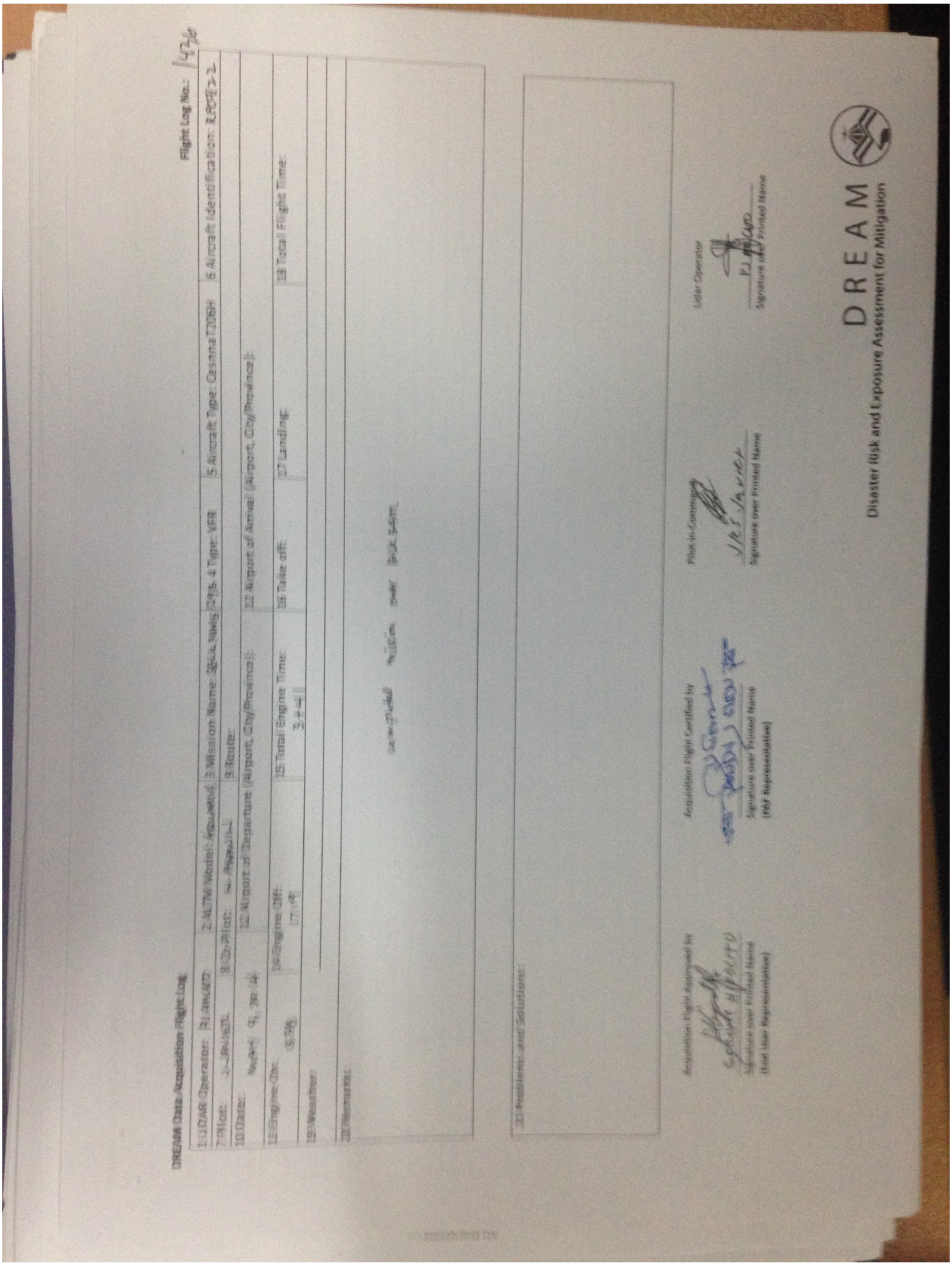
Acquisition Flight Certified by
Signature over Printed Name
(PAF Representative)

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

Lidar Operator
FJ SABLE
Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

6. Flight Log for 1436A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1436

1 LIDAR Operator: [illegible]	2 ALTM Model: [illegible]	3 Mission Name: [illegible]	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: [illegible]
7 Pilot: [illegible]	8 Co-Pilot: [illegible]	9 Route:			
10 Date: [illegible]	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: [illegible]	14 Engine Off: [illegible]	15 Total Engine Time: [illegible]	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: completed mission over [illegible]					
21 Problems and Solutions:					

Acquisition Flight Approved by: [illegible] — Signature over Printed Name (End User Representative)

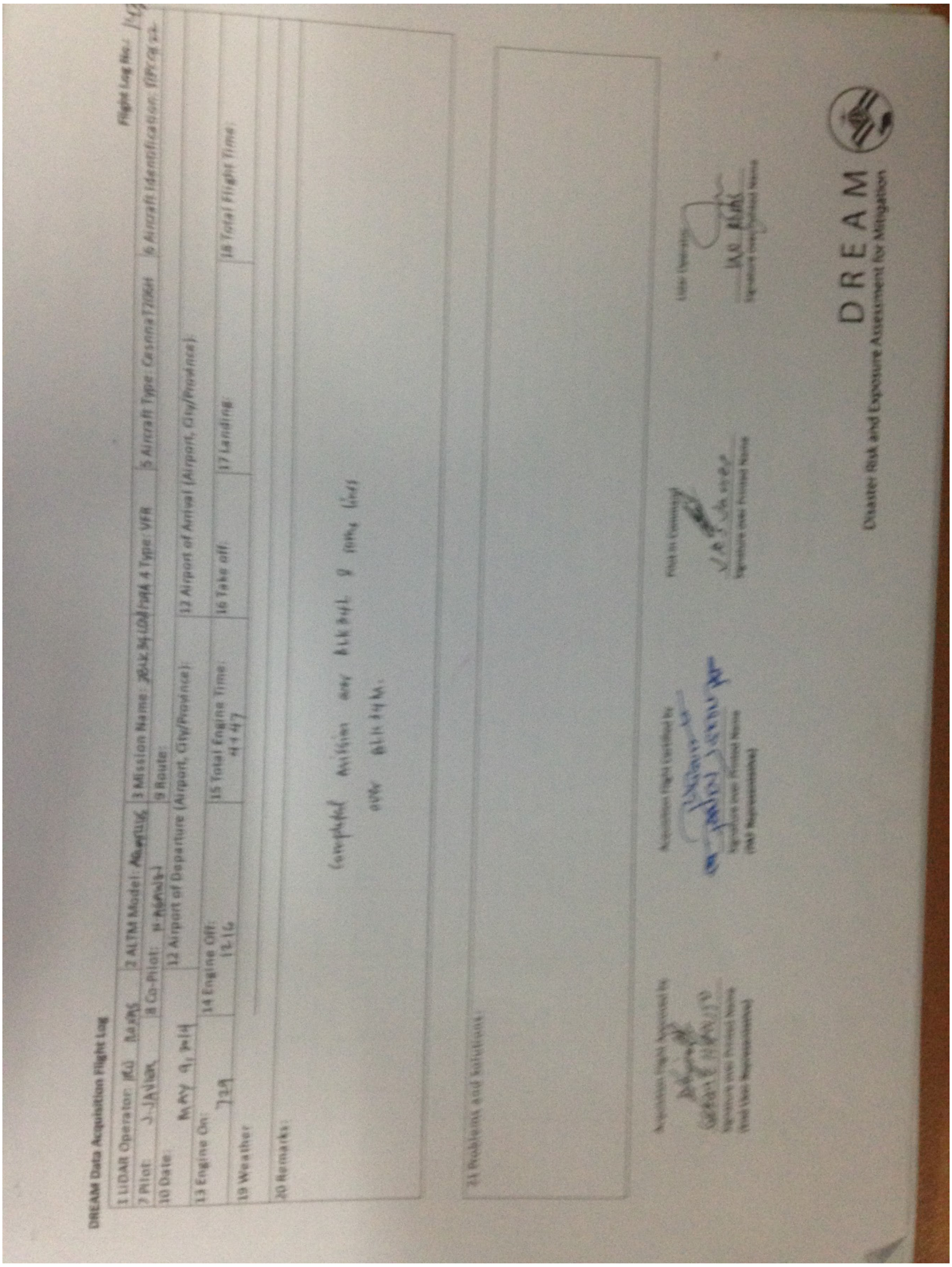
Acquisition Flight Certified by: [illegible] — Signature over Printed Name (PAF Representative)

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

Lidar Operator: [illegible] — Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

7. Flight Log for 1434A Mission


DREAM Data Acquisition Flight Log

Flight Log No.:

1 LiDAR Operator:	2 ALTM Model:	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification:
7 Pilot: J. Javier	8 Co-Pilot:	9 Route:			
10 Date: May 9, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 729	14 Engine Off: 1216	15 Total Engine Time: 4+47	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

DREAM

Disaster Risk and Exposure Assessment for Mitigation

Annex 7. Flight Status Reports

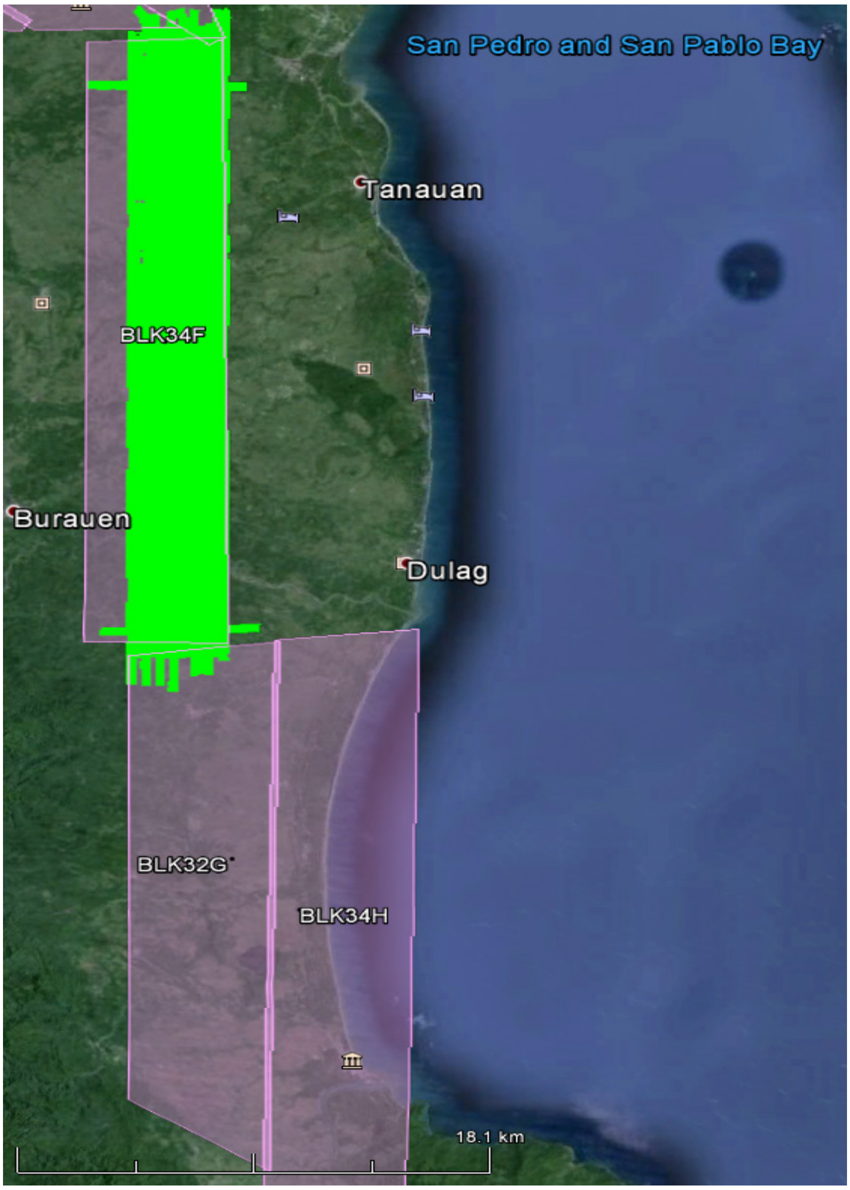
SAMAR AND LEYTE
January 26-27, April 20, May8-9, 2014; January 23, 2016

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1026A*	BLK34A	3BLK34AS026A	DC ALDOVINO	26 JAN 14	Completed 8 flight lines over BLK34A.
1028A*	BLK34A	3BLK 34ABS027A	DC ALDOVINO	27 JAN 14	Completed remaining flight lines over BLK34A.
1358A	BLK34F	3BLK34F110A	PJ ARCEO	20 APR 14	Completed 18/ 24 lines over BLK34F.
1360A	BLK34F	3BLK34FS110B	FJ SABLE	20 APR 14	Completed mission 8 lines left from the morning flight.
1430A	BLK34G	3BLK34G128A	PJ ARCEO	08 MAY 14	Completed 18/22 lines over BLK34G.
1434A	BLK33G BLK33H	3BLK34GSH129A	IN ROXAS	09 MAY 14	Completed mission over BLK33G and few lines in BLK33H.
1436A	BLK34H	3BLK34HS129B	PJ ARCEO	09 MAY 14	Completed mission over BLK34H.
3769G	BLK34D	2BLK34ADEG023A	J ALMALVEZ	23 JAN 16	Completed BLK34A, BLK34D and BLK 34E. Surveyed 6 lines at BLK34G.

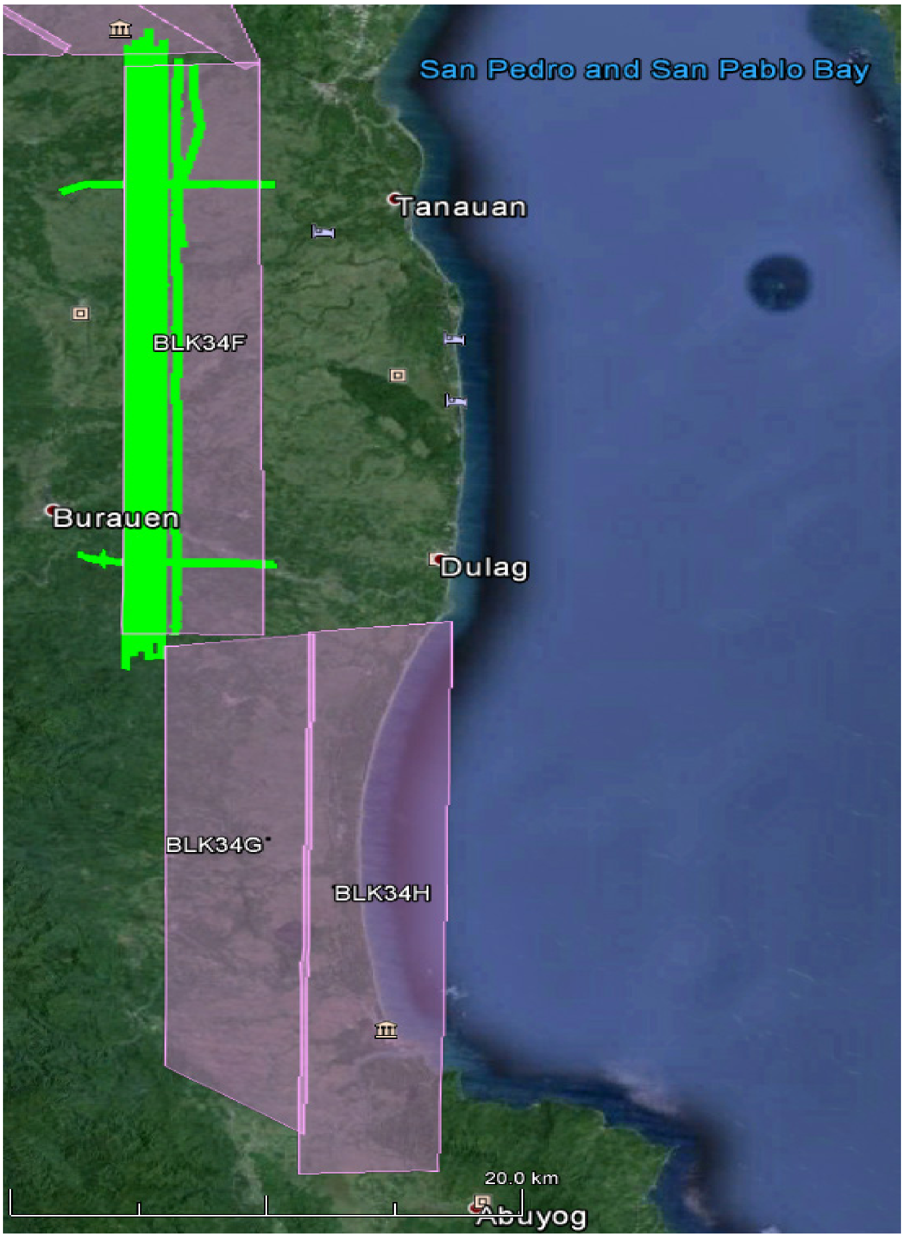
*not yet for transfer

LAS/SWATH BOUNDARIES PER MISSION FLIGHT

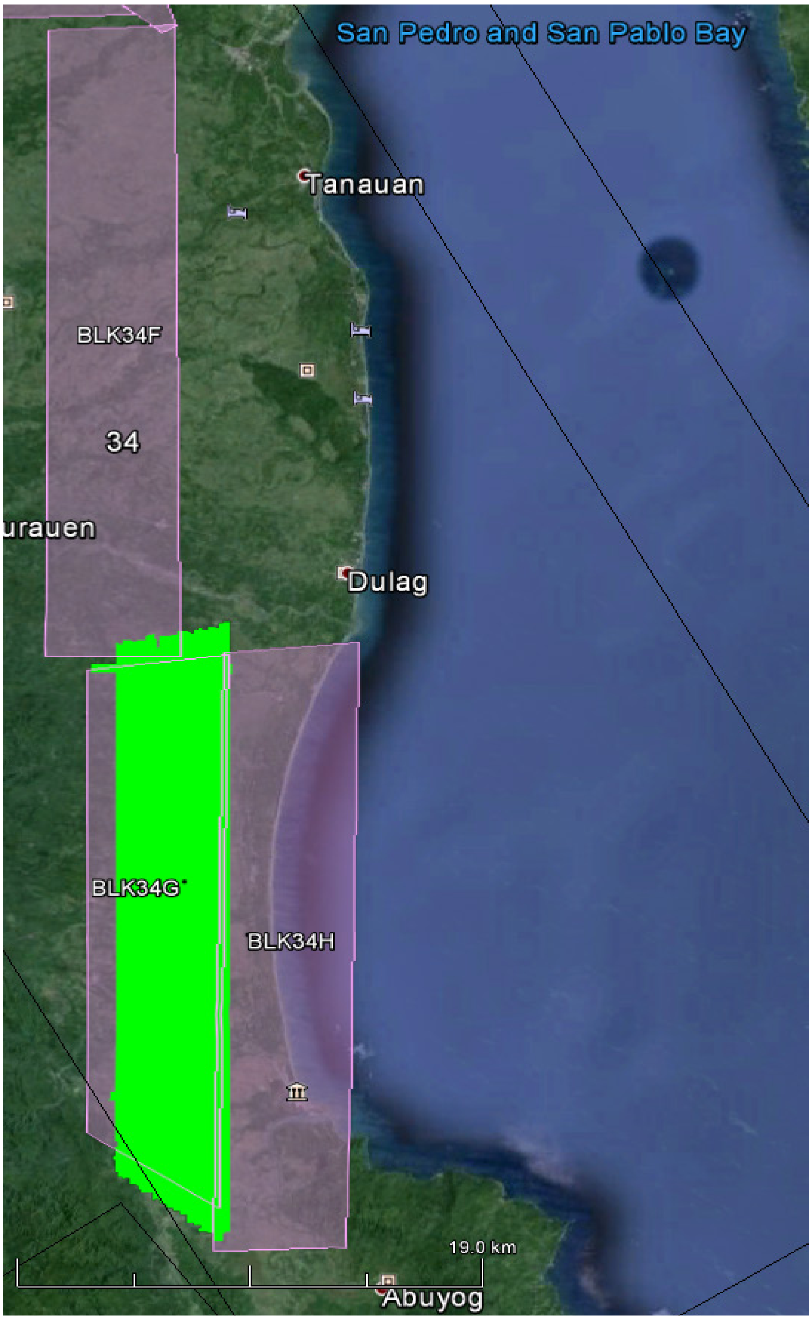
Flight No. :	1358A		
Area:	BLK34F		
Mission Name:	3BLK34F110A		
Total Area:	122.03 sq km		
Altitude:	600m		
PRF:	50 kHz	SCF:	50 Hz
Lidar FOV:	18 deg	Sidelap:	30%



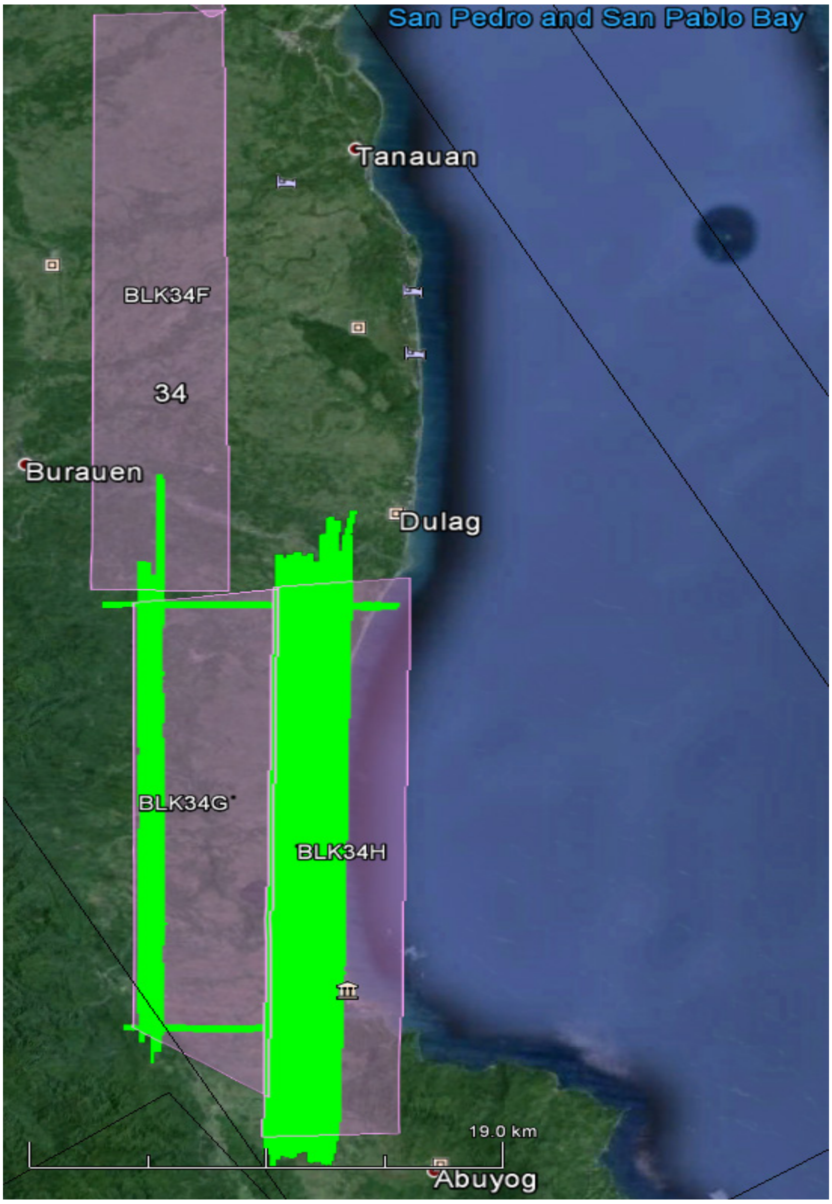
Flight No. :	1360A		
Area:	BLK34K		
Mission Name:	3BLK34K110B		
Total Area:	74.498 sq km		
Altitude:	600m		
PRF:	50 kHz	SCF:	50 Hz
Lidar FOV:	18 deg	Sidelap:	30%



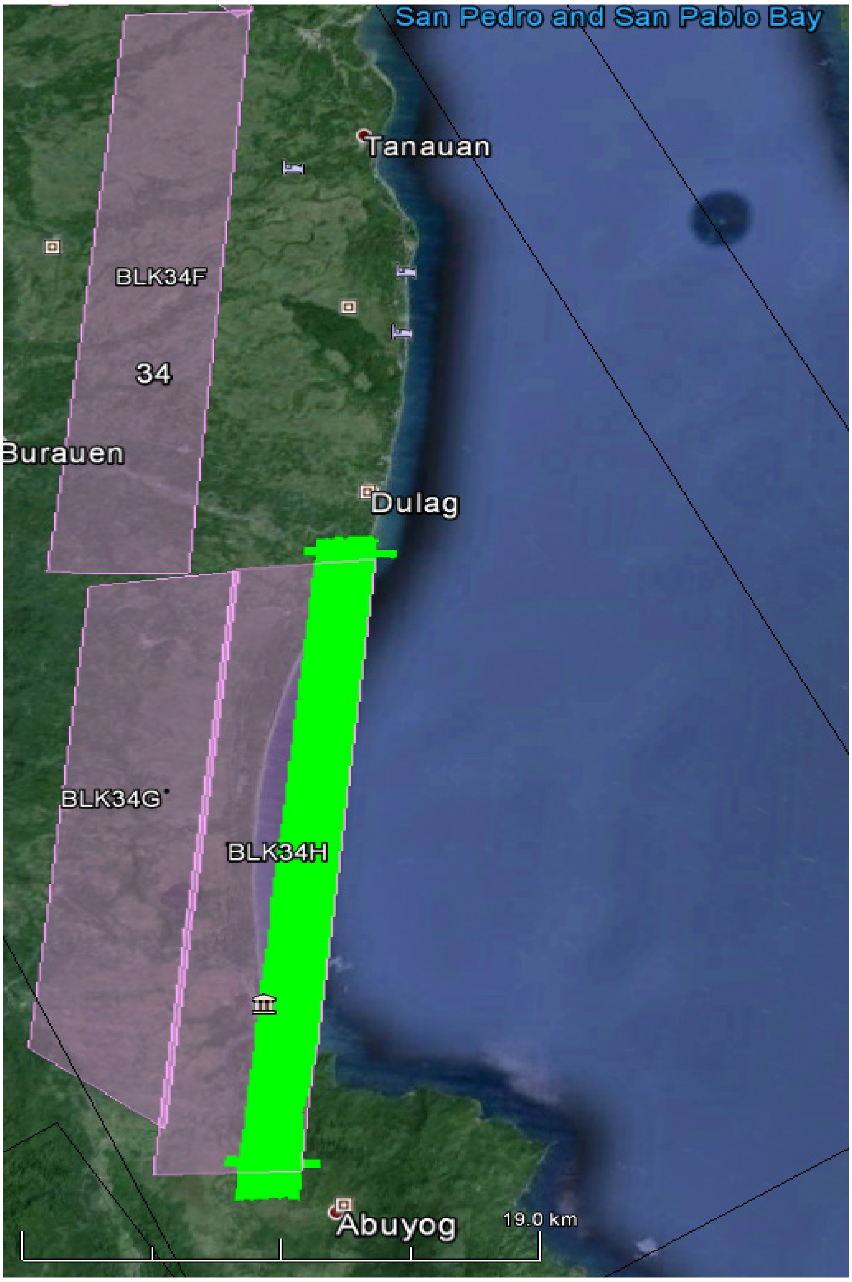
Flight No. :	1430A		
Area:	BLK34G		
Mission Name:	3BLK34G128A		
Total Area:	120.49 sq. km.		
Altitude:	500m		
PRF:	50 kHz	SCF:	50 Hz
Lidar FOV:	18 deg	Sidelap:	30%



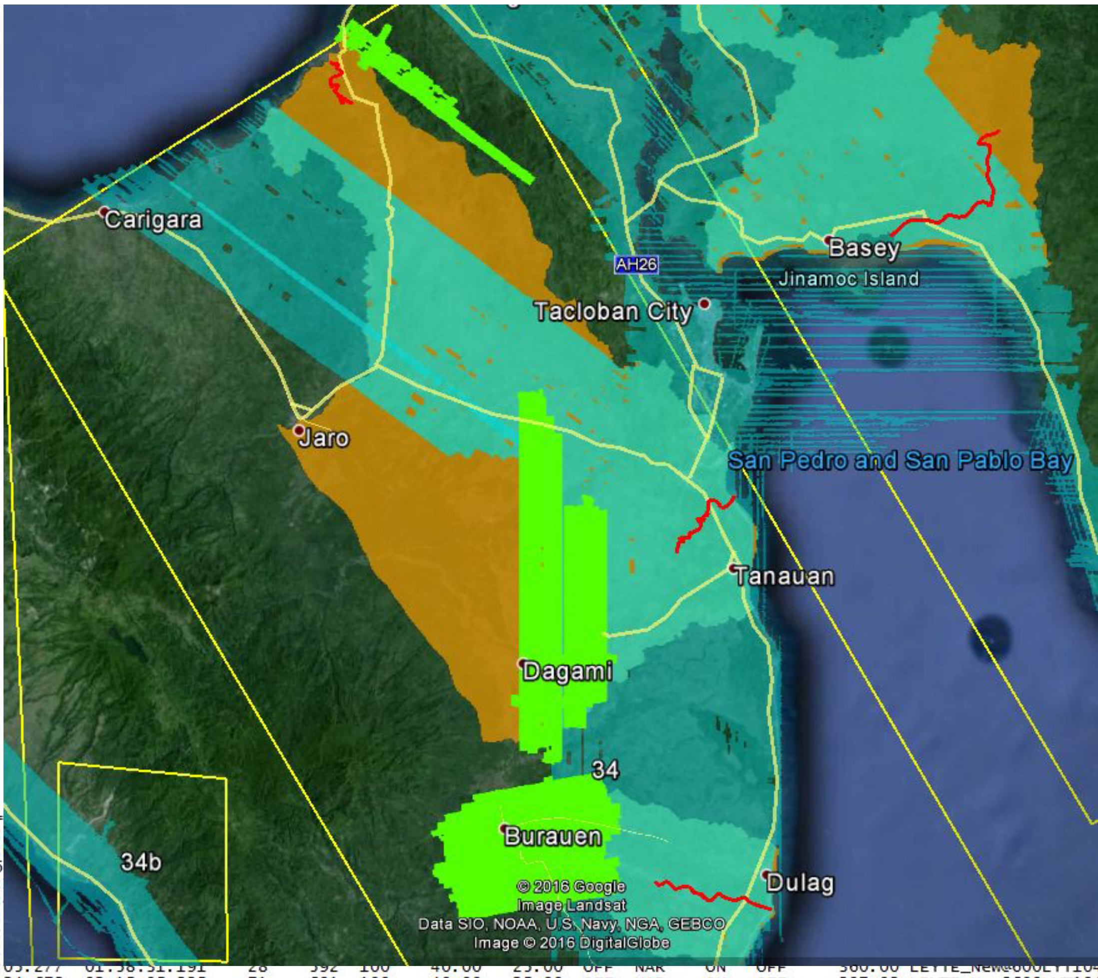
Flight No. :	1434A		
Area:	BLK34G & BLK34H		
Mission Name:	3BLK34GSH129A		
Total Area:	125.909 sq km		
Altitude:	500m		
PRF:	50 kHz	SCF:	50 Hz
Lidar FOV:	18 deg	Sidelap:	30%



Flight No. :	1436A		
Area:	BLK34H		
Total area:	71.953 sq km		
Mission Name:	3BLK34HS129B		
Altitude:	500m		
PRF:	50 kHz	SCF:	50 Hz
Lidar FOV:	18 deg	Sidelap:	30%



FLIGHT NO.: 3769
AREA: Leyte
MISSION NAME: 2BLK34ADEG023A
ALT: 1100 m & 600m SCAN FREQ: 50 SCAN ANGLE: 17
SURVEYED AREA: 167.25km²



00:33:												04.pln
00:39:												04.pln
00:46												04.pln
00:56:												04.pln
01:03:												04.pln
01:13:												04.pln
01:25:												.pln
01:37:												.pln
01:57:												.pln
02:07:24.673	02:15:05.335	71	691	100	40.00	25.00	OFF	NAR	ON	OFF	307.03	LEYTE_New@600LYT104.pln
02:17:23.449	02:25:59.311	67	686	100	40.00	25.00	OFF	NAR	ON	OFF	127.03	LEYTE_New@600LYT104.pln
02:31:41.644	02:34:33.843	70	654	100	40.00	25.00	OFF	NAR	ON	OFF	307.03	LEYTE_New@600LYT104.pln
02:31:41.644	02:35:58.793	70	685	100	40.00	25.00	OFF	NAR	ON	OFF	307.03	LEYTE_New@600LYT104.pln
02:39:50.507	02:47:20.039	70	672	100	40.00	25.00	OFF	NAR	ON	OFF	307.03	LEYTE_New@600LYT104.pln
02:49:39.738	02:57:59.426	68	661	100	40.00	25.00	OFF	NAR	ON	OFF	127.03	LEYTE_New@600LYT104.pln
03:00:26.88	03:08:07.342	69	659	100	40.00	25.00	OFF	NAR	ON	OFF	307.03	LEYTE_New@600LYT104.pln
03:00:26.88	03:08:19.227	69	663	100	40.00	25.00	OFF	NAR	ON	OFF	307.03	LEYTE_New@600LYT104.pln
03:10:15.317	03:18:12.774	72	675	100	40.00	25.00	OFF	NAR	ON	OFF	127.03	LEYTE_New@600LYT104.pln
03:20:49.349	03:28:01.001	73	678	100	40.00	25.00	OFF	NAR	ON	OFF	307.03	LEYTE_New@600LYT104.pln
03:30:11.401	03:37:48.178	74	659	100	40.00	25.00	OFF	NAR	ON	OFF	127.03	LEYTE_New@600LYT104.pln
03:40:37.743	03:47:28.916	75	640	100	40.00	25.00	OFF	NAR	ON	OFF	307.03	LEYTE_New@600LYT104.pln
03:49:24.55	03:56:58.098	76	658	100	40.00	25.00	OFF	NAR	ON	OFF	127.03	LEYTE_New@600LYT104.pln

Flight No. :	1026A
Area:	BLK34A AND BLK 34B
Mission Name:	3BLK34AS026B
Parameters:	Alt: 600m; Scan Fz: 40; Scan ange: 25; Overlap: 40

Flight No. :	1028A
Area:	BLK34A AND BLK34B
Mission Name:	3BLK 34ABS027A
Parameters:	Alt: 600m; Scan Fz: 40; Scan ange: 25; Overlap: 40%

Annex 8. Mission Summary Reports

Flight Area	Samar-Leyte
Mission Name	Blk34H
Inclusive Flights	1434A, 1436A
Range data size	25.12 GB
Base data size	505 MB
POS data size	34 MB
Image	169.3 GB
Transfer date	May 28, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics(in cm)	
RMSE for North Position (<4.0 cm)	1.4
RMSE for East Position (<4.0 cm)	1.7
RMSE for Down Position (<8.0 cm)	4.7
Boresight correction stdev (<0.001deg)	0.000471
IMU attitude correction stdev (<0.001deg)	0.002510
GPS position stdev (<0.01m)	0.0080
Minimum % overlap (>25)	32.26%
Ave point cloud density per sq.m. (>2.0)	2.83
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	215
Maximum Height	425.31 m
Minimum Height	51.73 m
Classification (# of points)	
Ground	95,490,667
Low vegetation	112,453,327
Medium vegetation	107,624,730
High vegetation	55,639,375
Building	2,285,212
Orthophoto	Yes
Processed by	Engr. Kenneth Solidum, Engr. Harmond Santos, Engr. Gladys Mae Apat

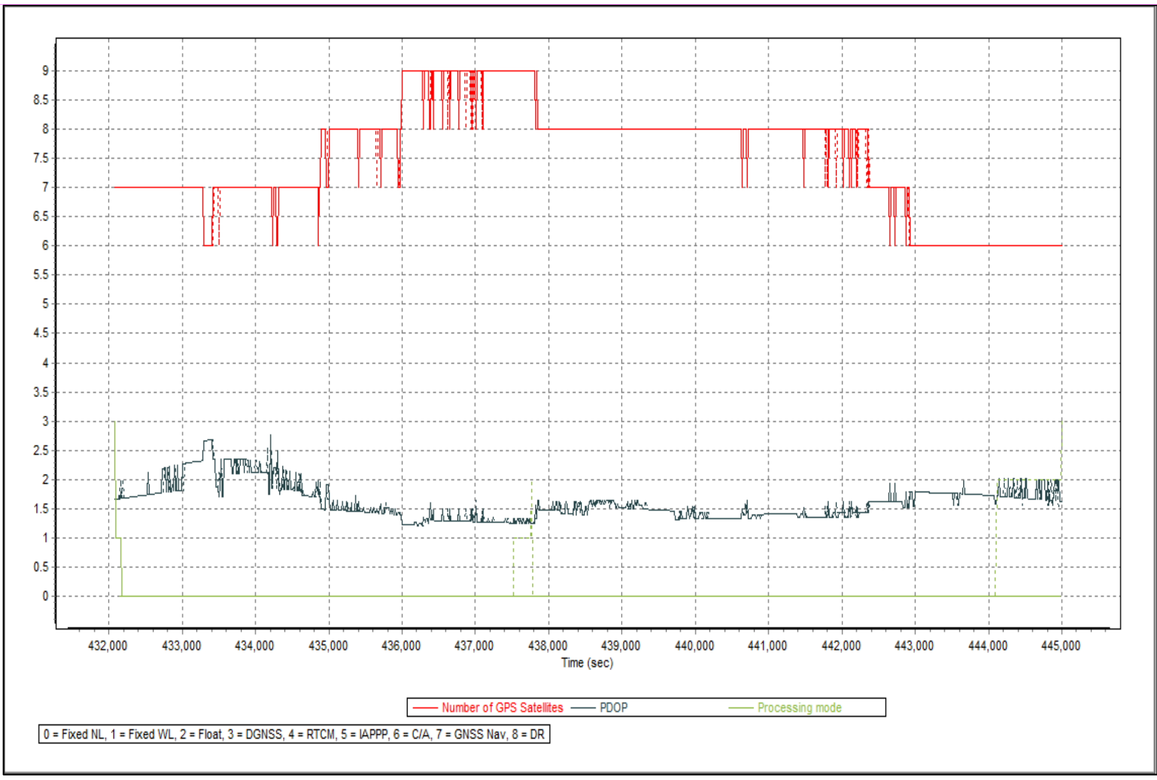


Figure A-7.1 Solution Status

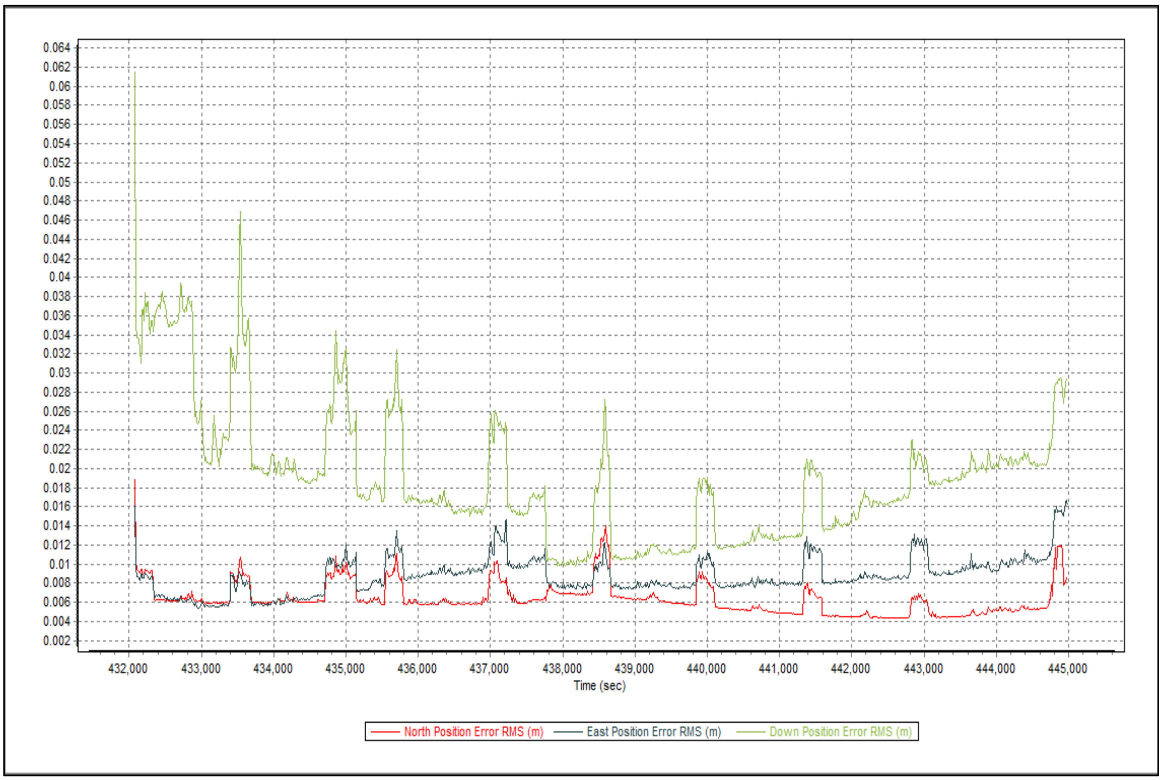


Figure A-7.2 S moothed Performance Metrics Parameters

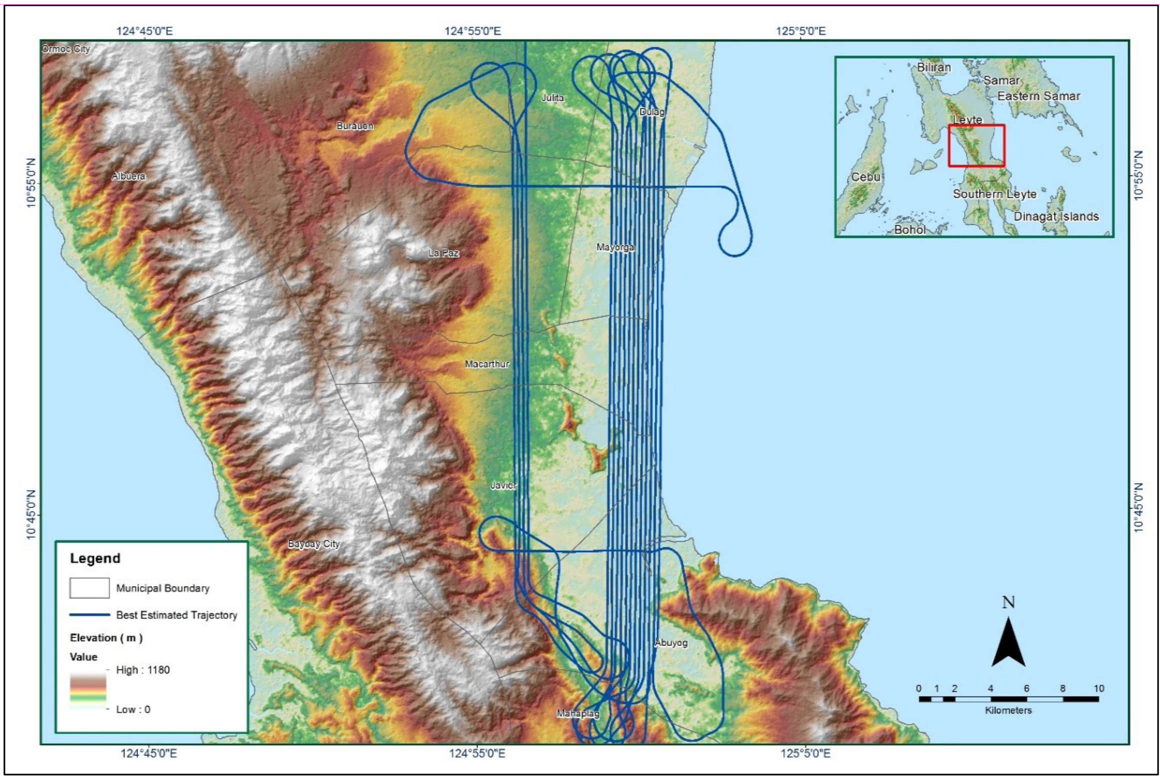


Figure A-7.3. Best Estimated Trajectory

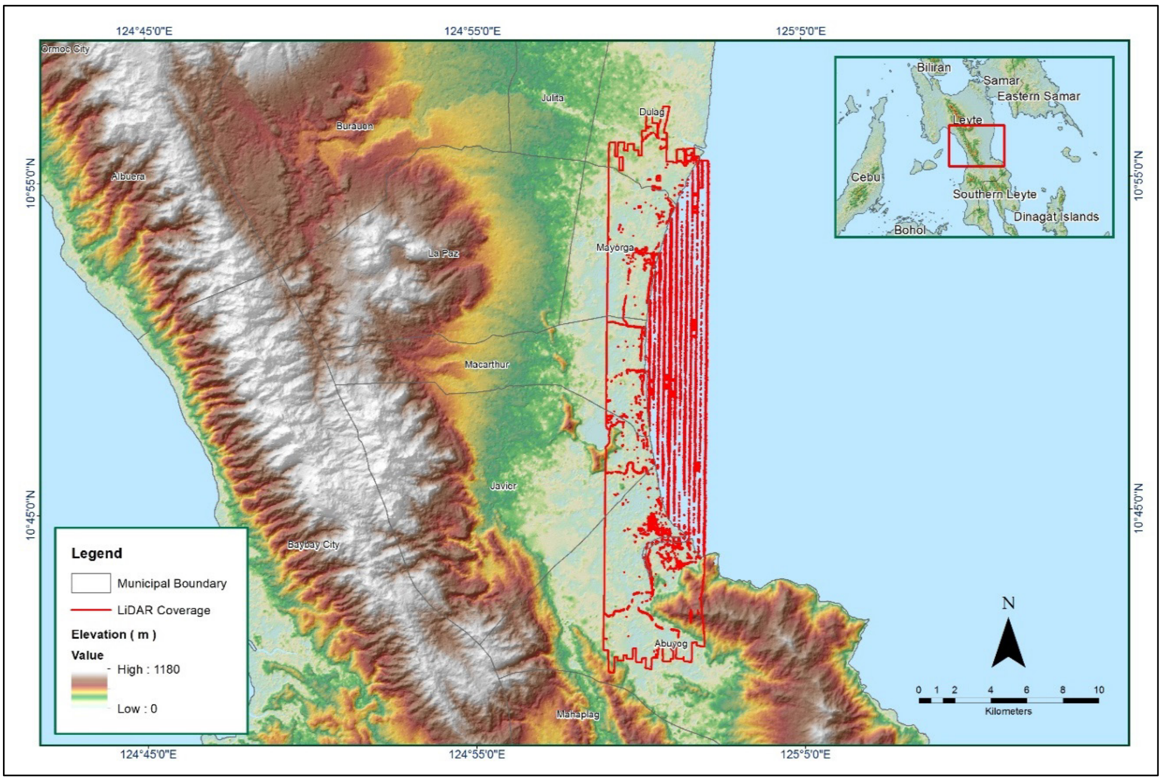


Figure A-7.4 Coverage of LiDAR data

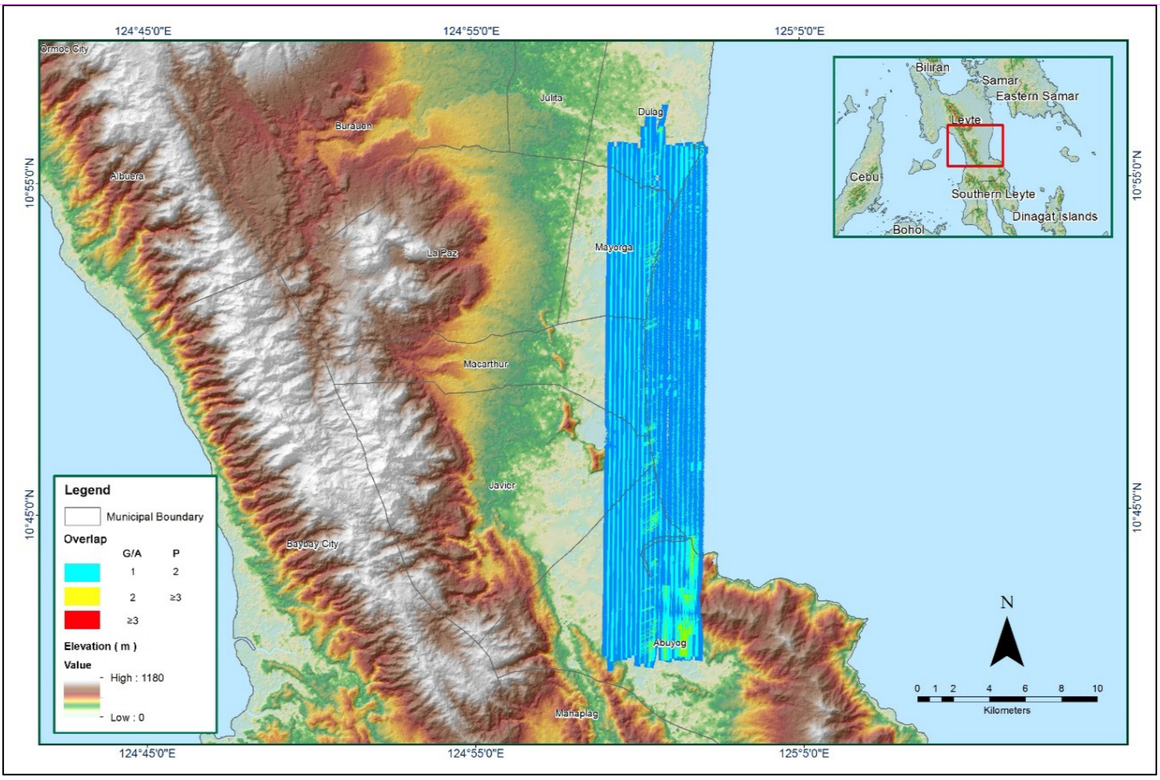


Figure A-7.5 Figure 1.1.5. Image of data overlap

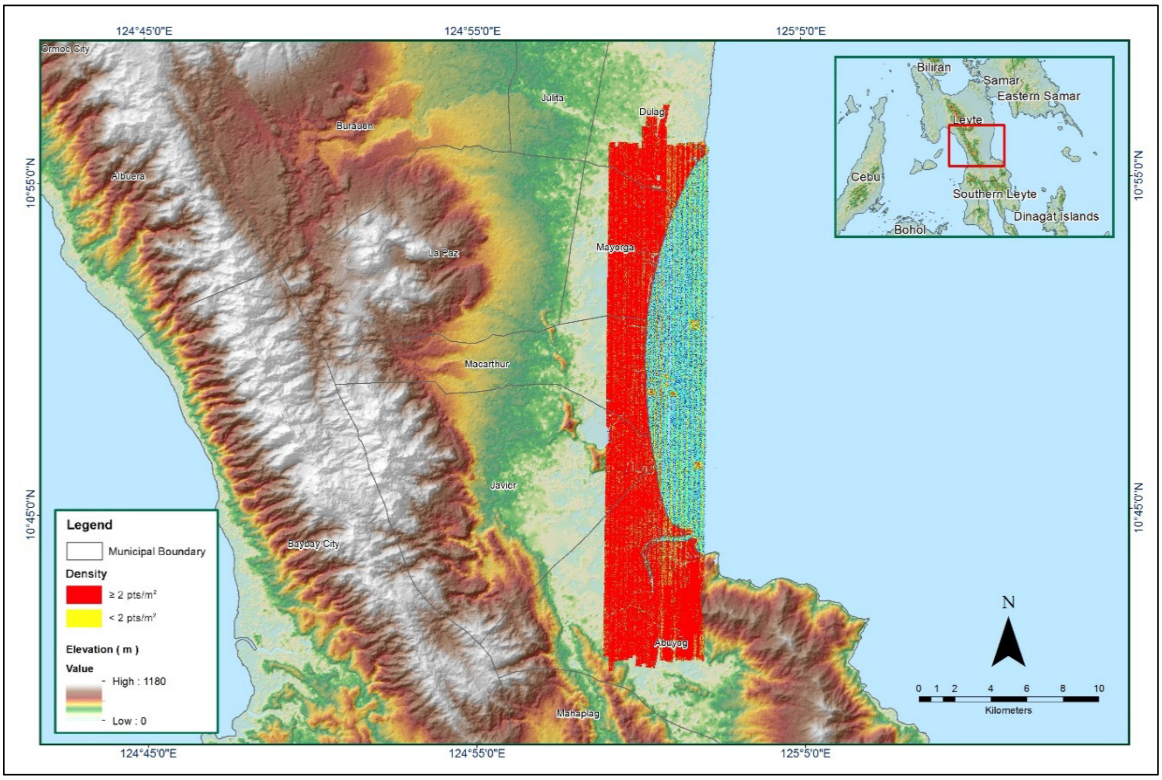


Figure A-7.6 Density map of merged LiDAR data

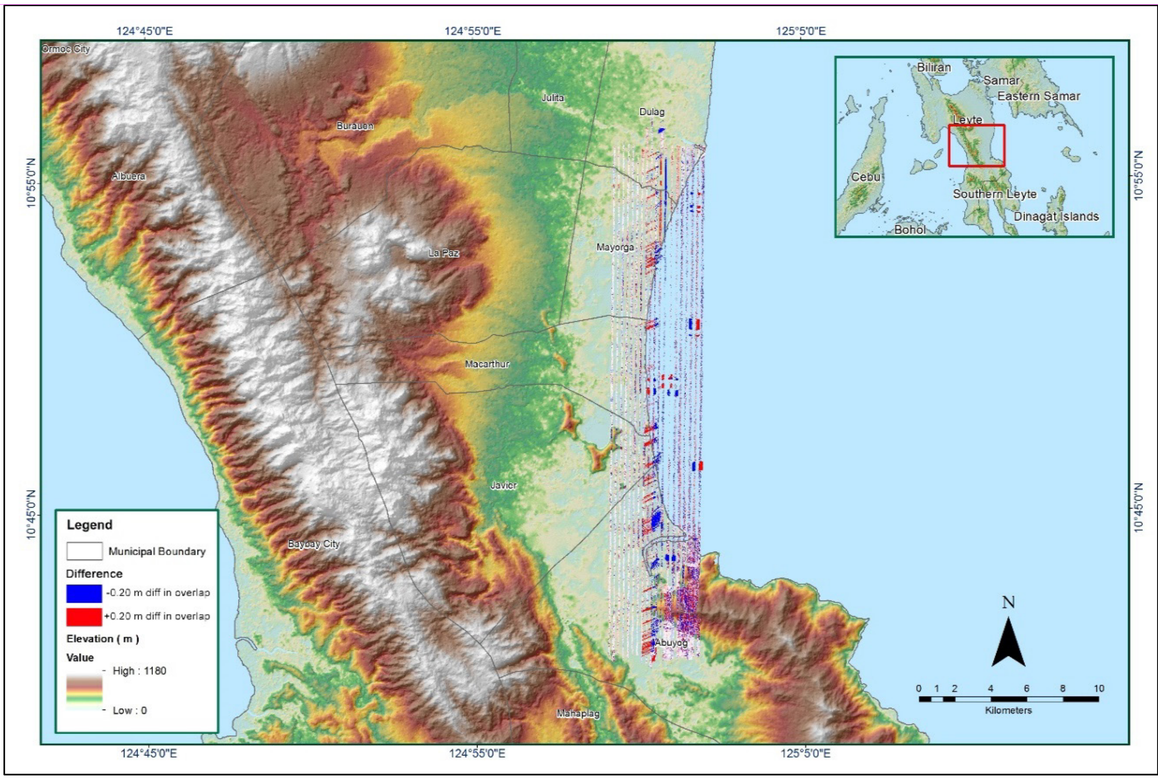


Figure A-7.7 Elevation difference between flight lines

Flight Area	Samar-Leyte
Mission Name	Blk34H
Inclusive Flights	1434A, 1436A
Range data size	25.12 GB
Base data size	505 MB
POS	34 MB
Image	169.3 GB
Transfer date	May 28, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.4
RMSE for East Position (<4.0 cm)	1.7
RMSE for Down Position (<8.0 cm)	4.7
Boresight correction stdev (<0.001deg)	0.000471
IMU attitude correction stdev (<0.001deg)	0.002510
GPS position stdev (<0.01m)	0.0080
Minimum % overlap (>25)	32.26%
Ave point cloud density per sq.m. (>2.0)	2.83
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	215
Maximum Height	425.31 m
Minimum Height	51.73 m
Classification (# of points)	
Ground	95,490,667
Low vegetation	112,453,327
Medium vegetation	107,624,730
High vegetation	55,639,375
Building	2,285,212
Orthophoto	Yes
Processed by	Engr. Kenneth Solidum, Engr. Harmond Santos, Engr. Gladys Mae Apat

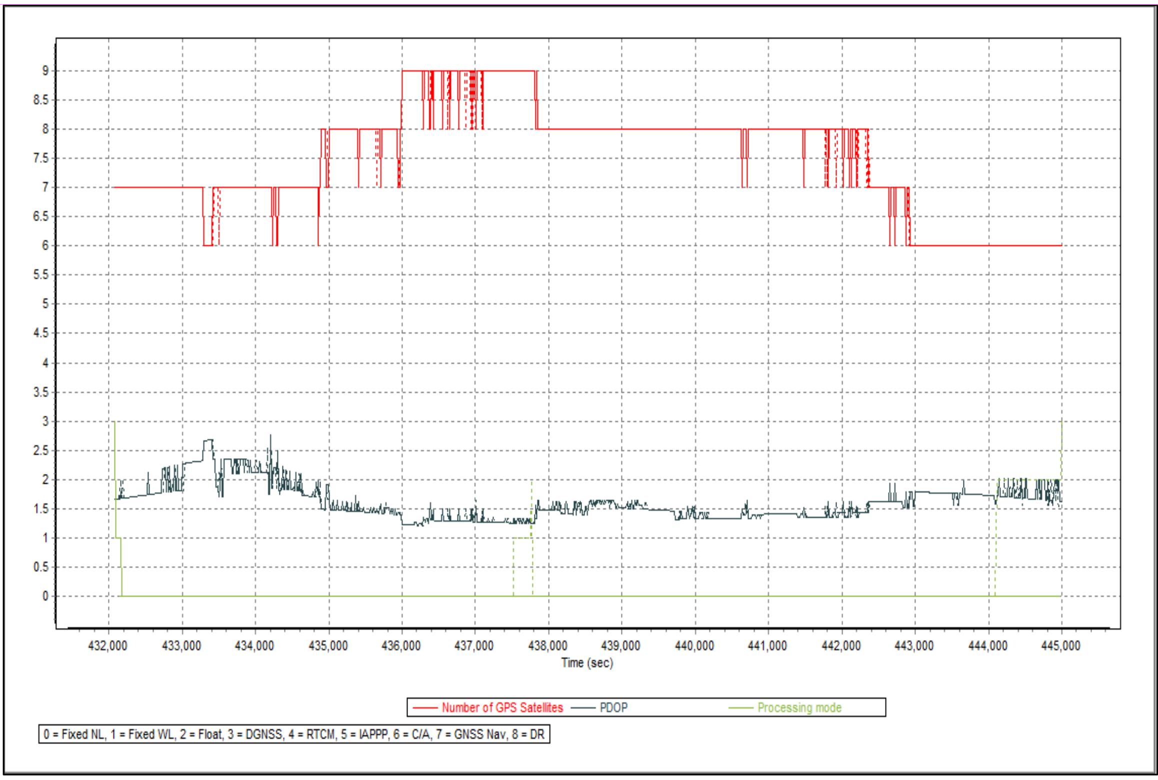


Figure A-8.1 Solution Status

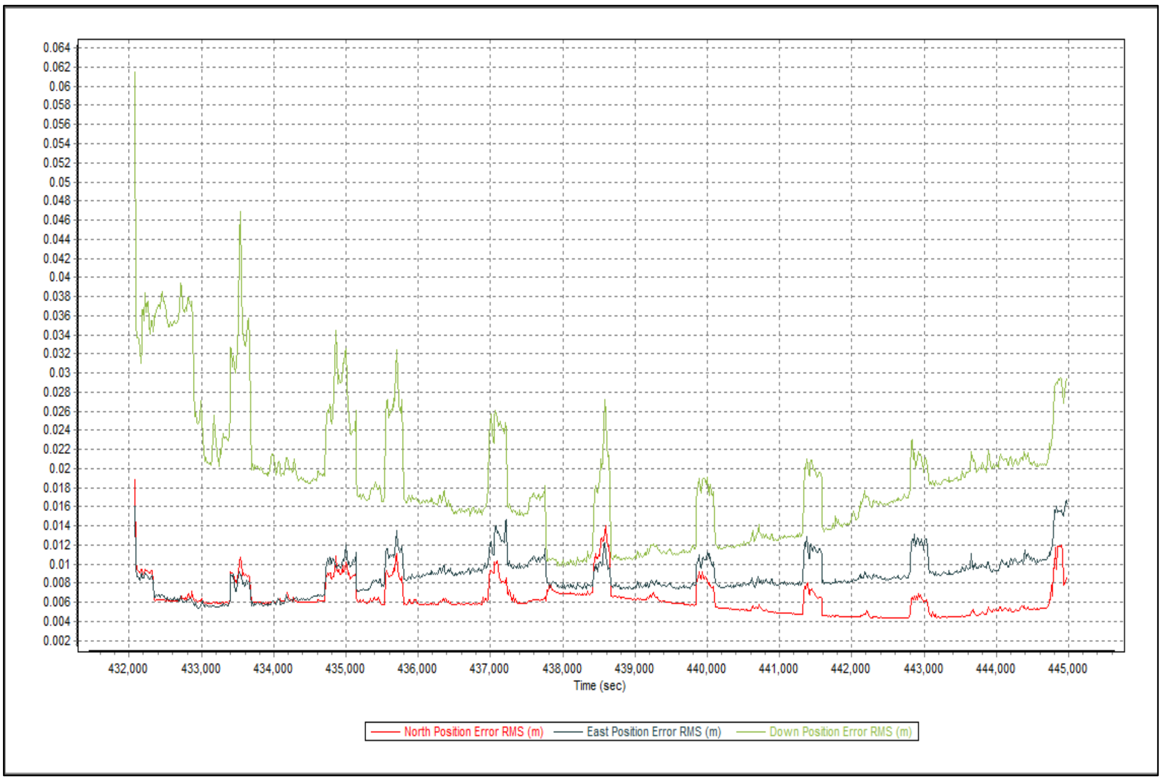


Figure A-8.2Smoothed Performance Metrics Parameters

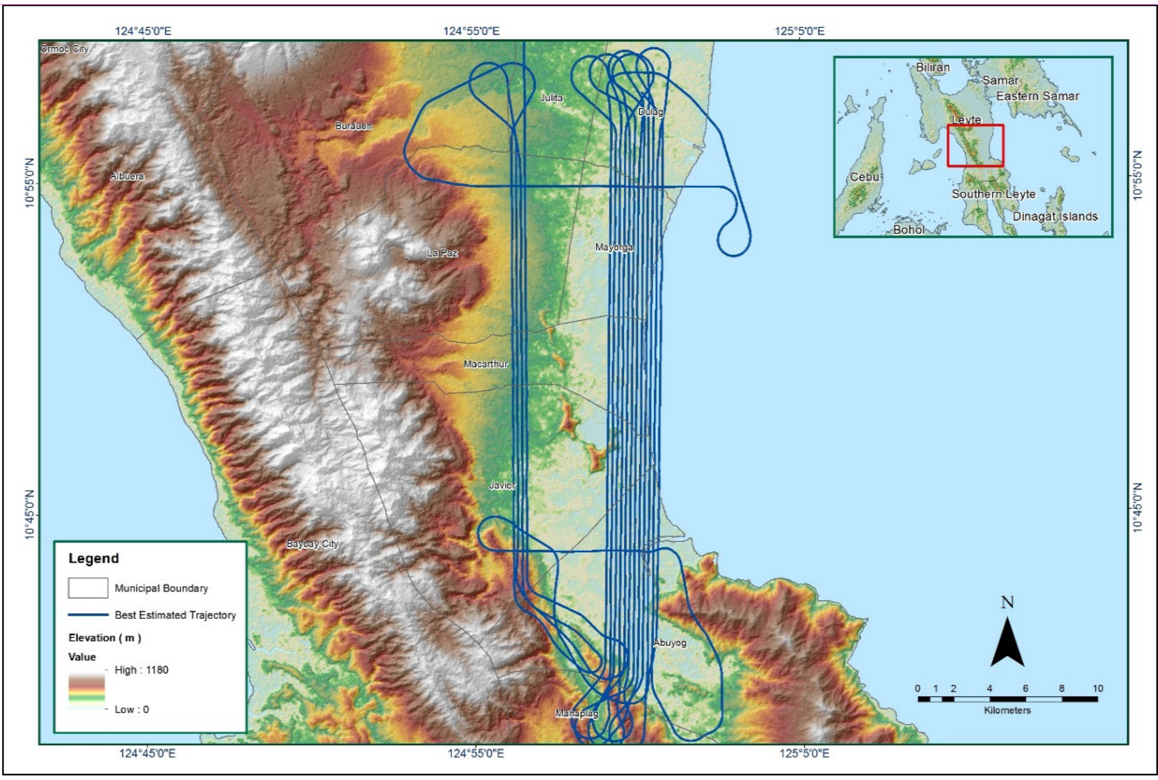


Figure A-8.3Best Estimated Trajectory

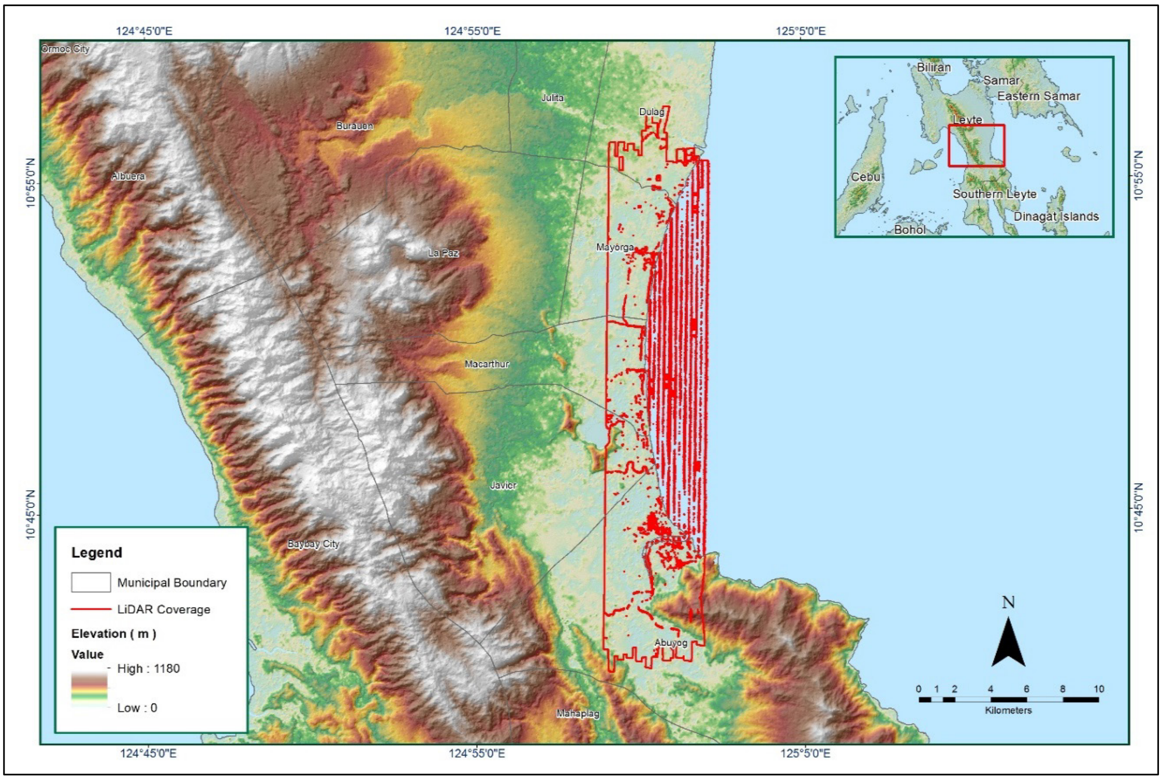


Figure A-8.4Coverage of LiDAR data

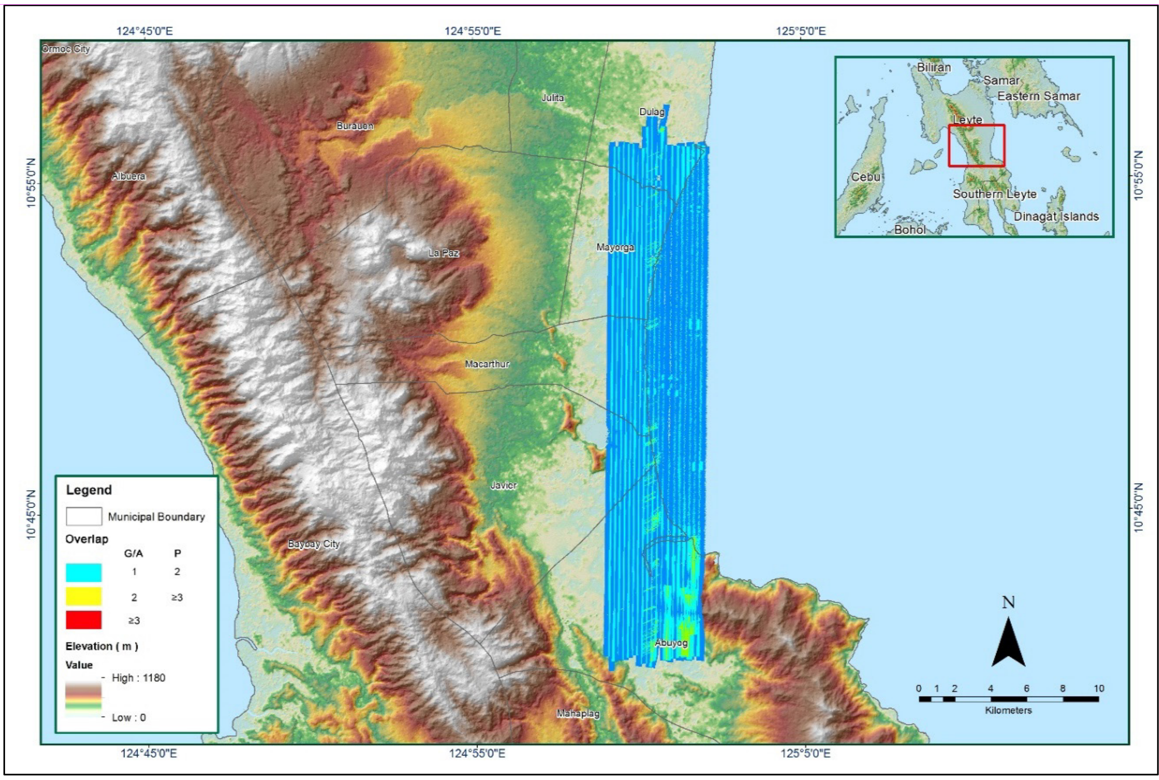


Figure A-8.5 Image of data overlap

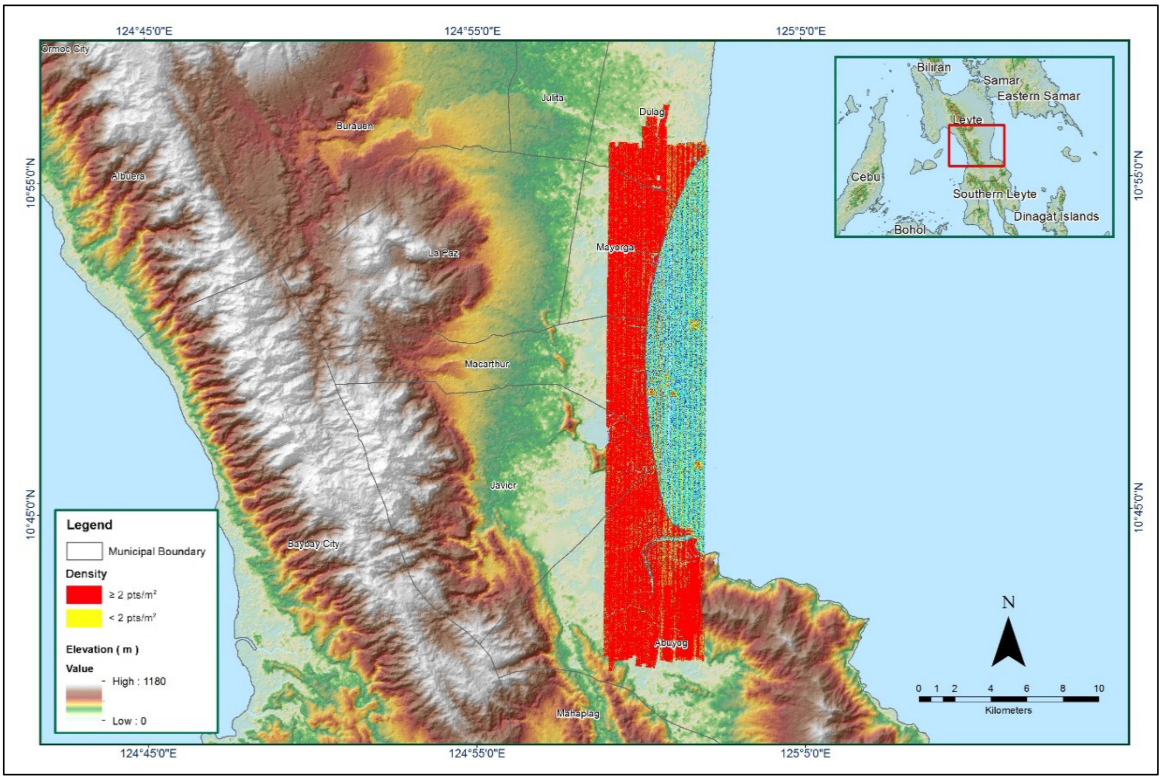


Figure A-8.6 Density map of merged LiDAR data

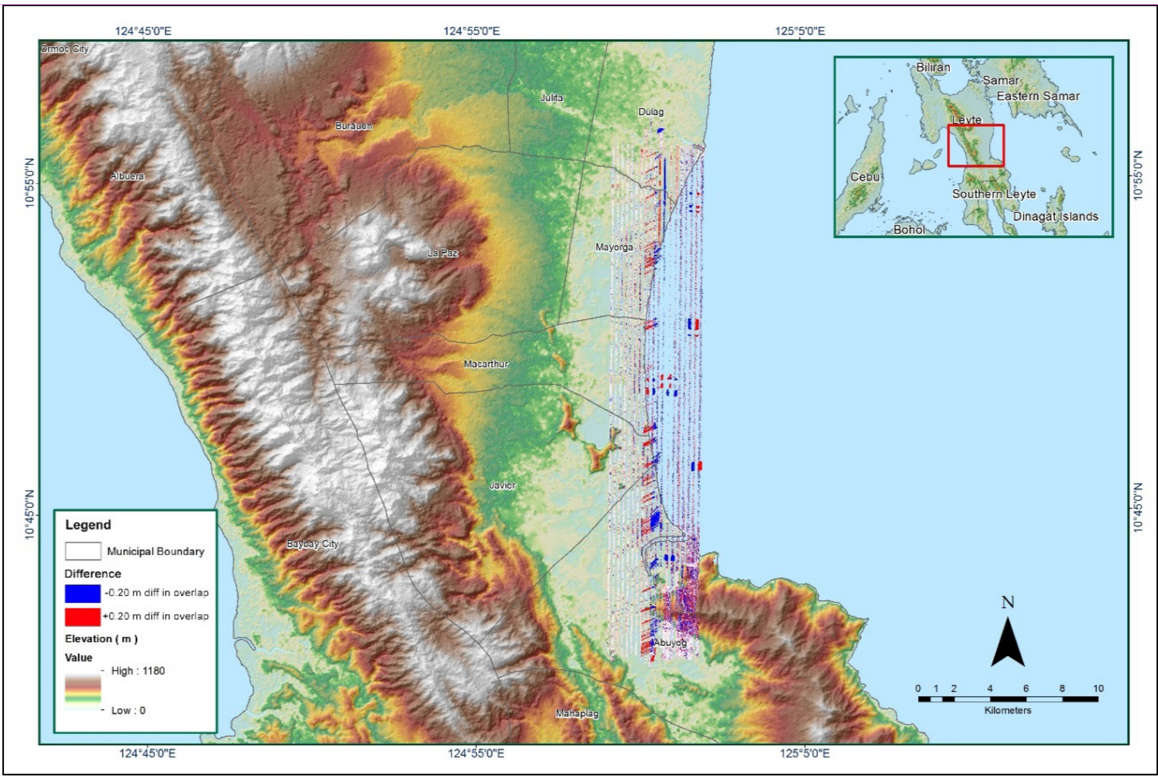


Figure A-8.7 Elevation difference between flight lines

Flight Area	Samar-Leyte
Mission Name	Blk34G
Inclusive Flights	1430A, 1434A
Range data size	29.4 GB
Base data size	528 MB
POS	24.9 MB
Image	210.8 GB
Transfer date	May 28, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.2
RMSE for East Position (<4.0 cm)	1.4
RMSE for Down Position (<8.0 cm)	3.1
Boresight correction stdev (<0.001deg)	0.000492
IMU attitude correction stdev (<0.001deg)	0.001939
GPS position stdev (<0.01m)	0.0085
Minimum % overlap (>25)	42.02%
Ave point cloud density per sq.m. (>2.0)	3.20
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	186
Maximum Height	292.03 m
Minimum Height	63.56 m
Classification (# of points)	
Ground	113,885,129
Low vegetation	135,911,604
Medium vegetation	106,013,368
High vegetation	43,429,000
Building	1,436,140
Orthophoto	Yes
Processed by	Engr. Kenneth Solidum, Engr. Chelou Prado, Engr. Gladys Mae Apat

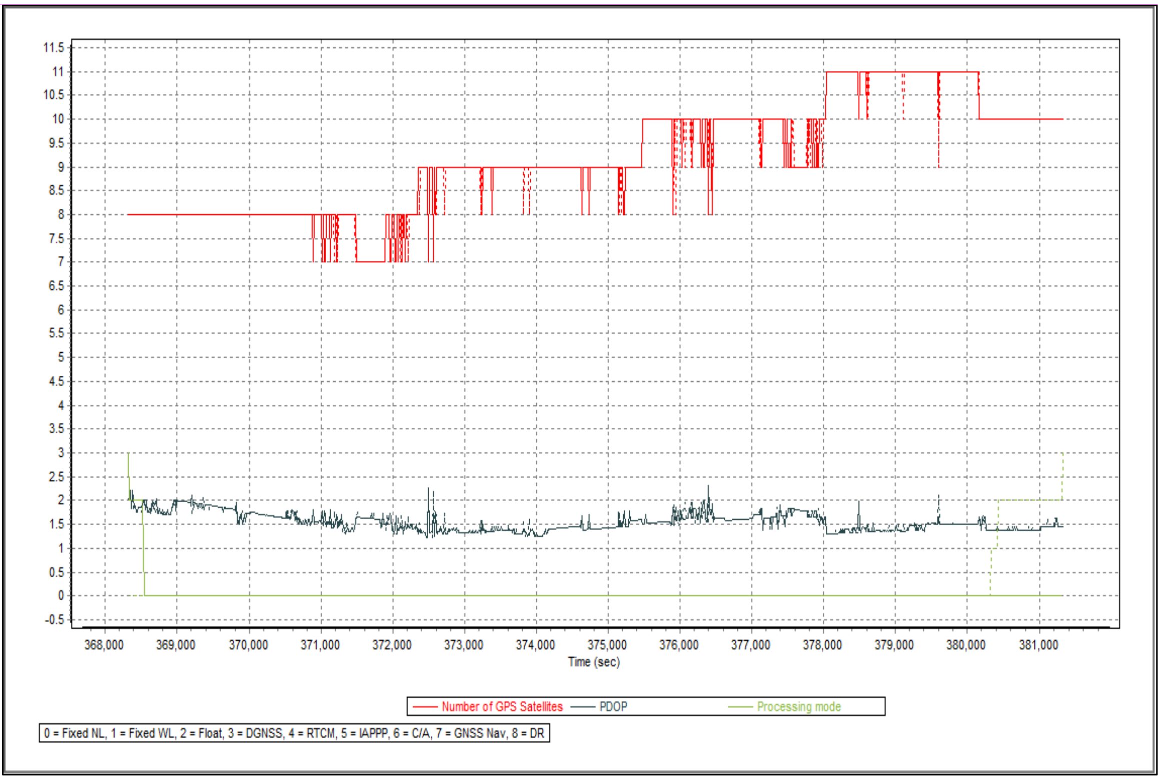


Figure A-8.8 Solution Status

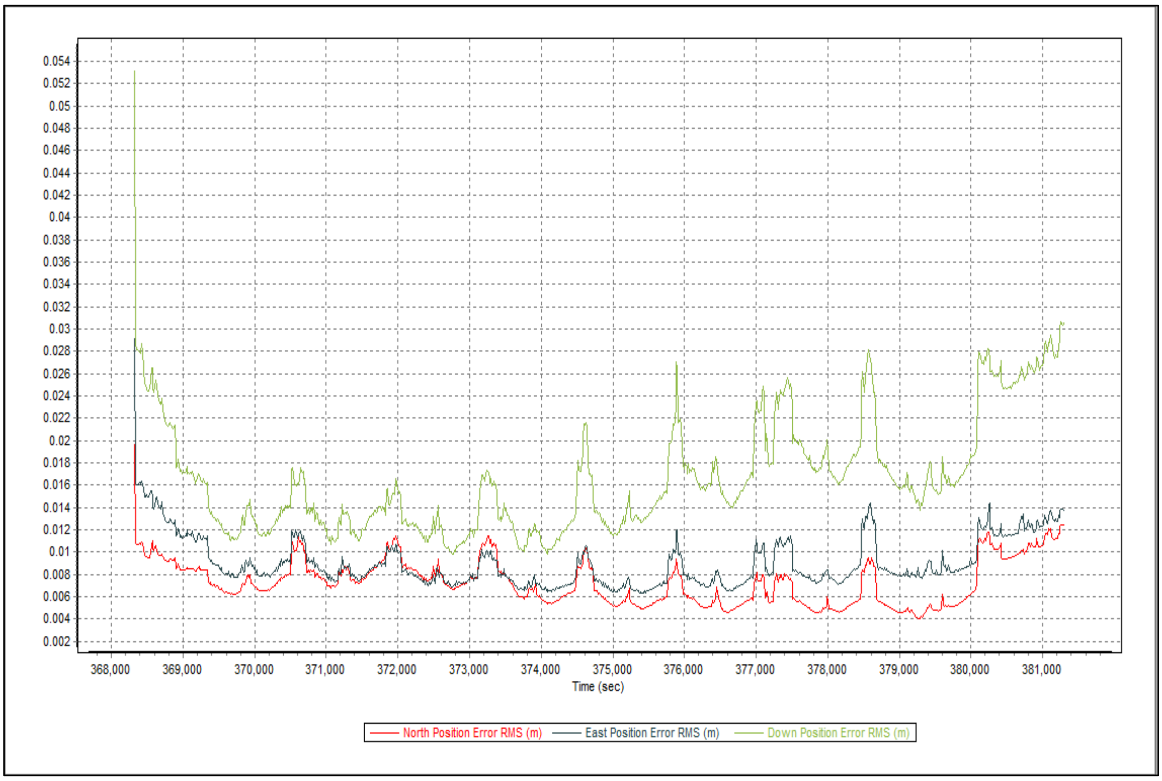


Figure A-8.9 Smoothed Performance Metrics Parameters

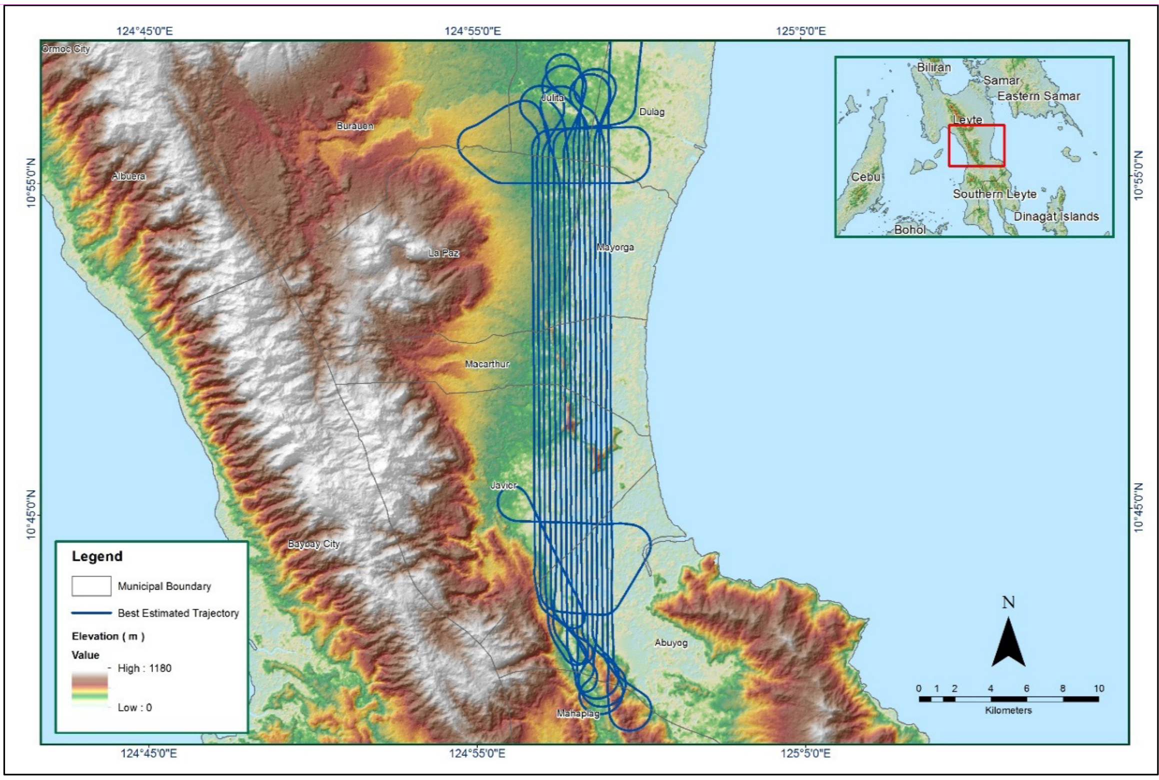


Figure A-8.10. Best Estimated Trajectory

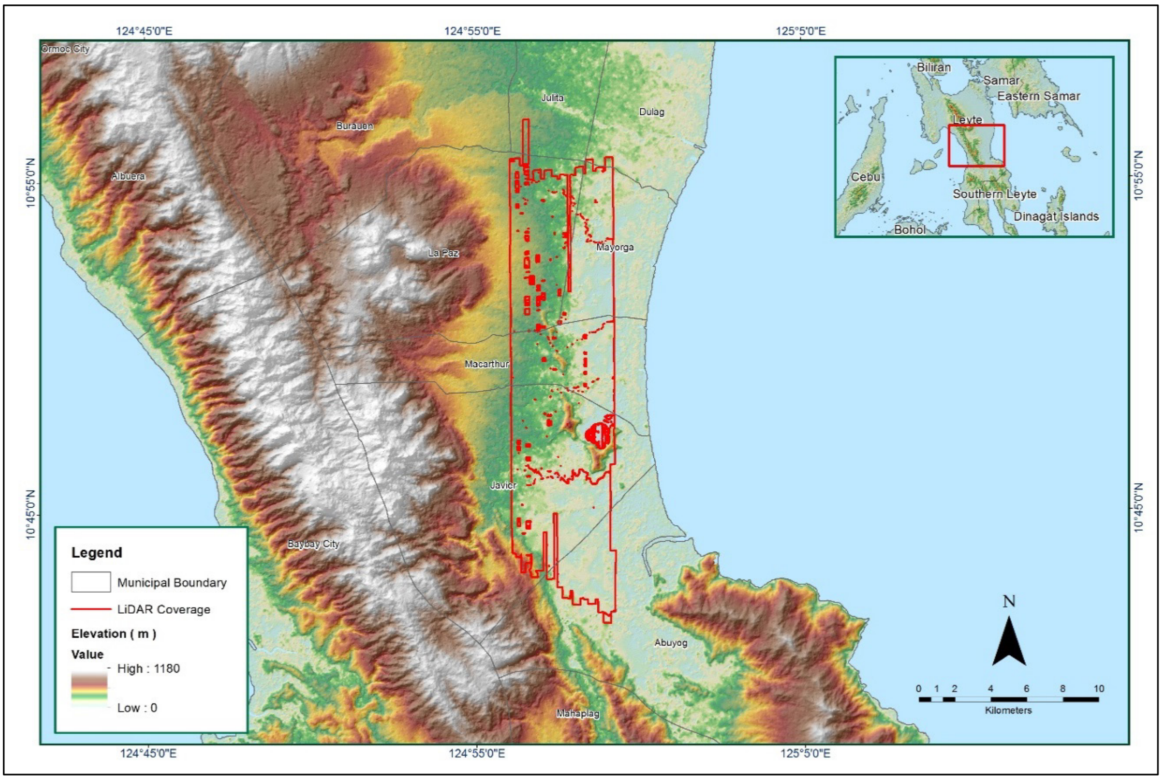


Figure A-8.11 Coverage of LiDAR data

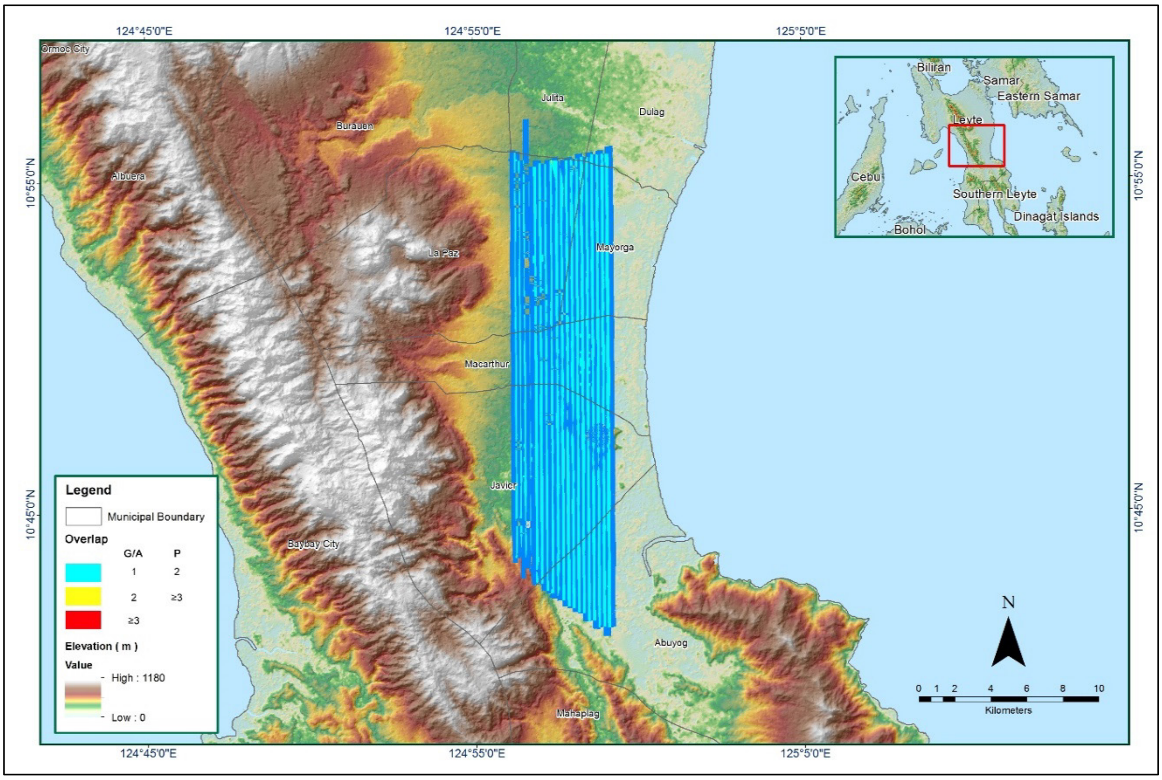


Figure A-8.12 Image of data overlap

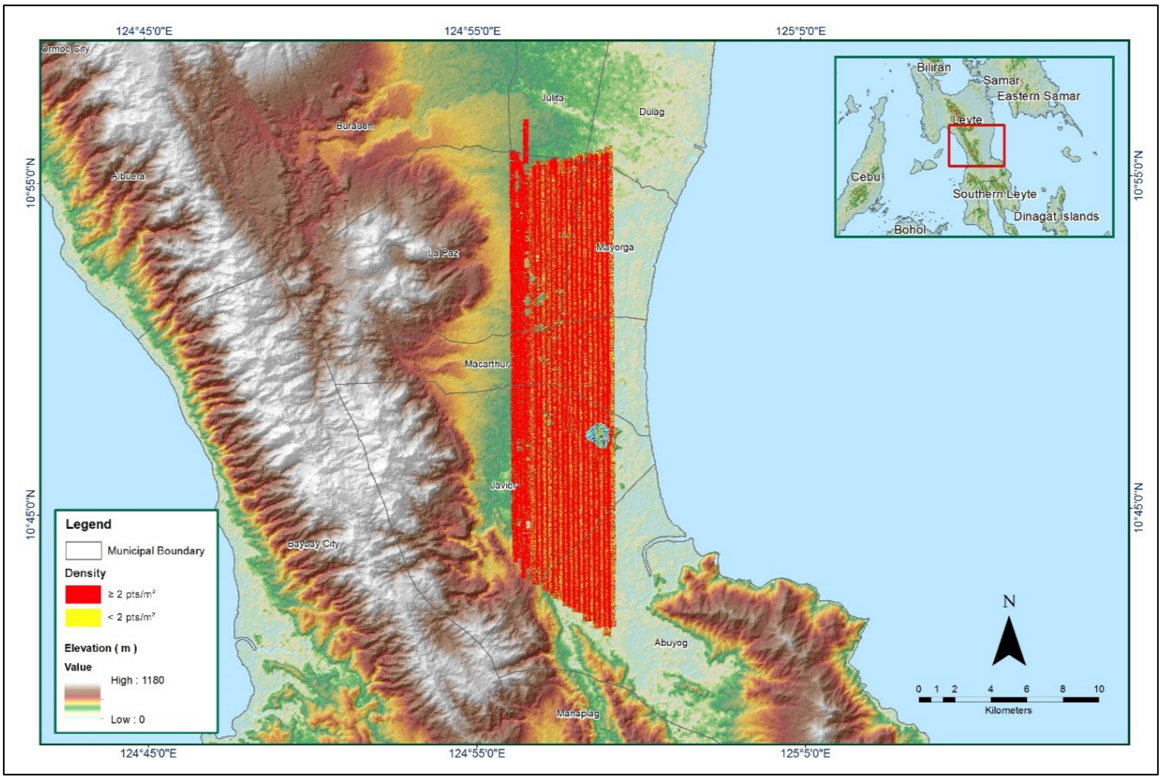


Figure A-8.13 Density map of merged LiDAR data

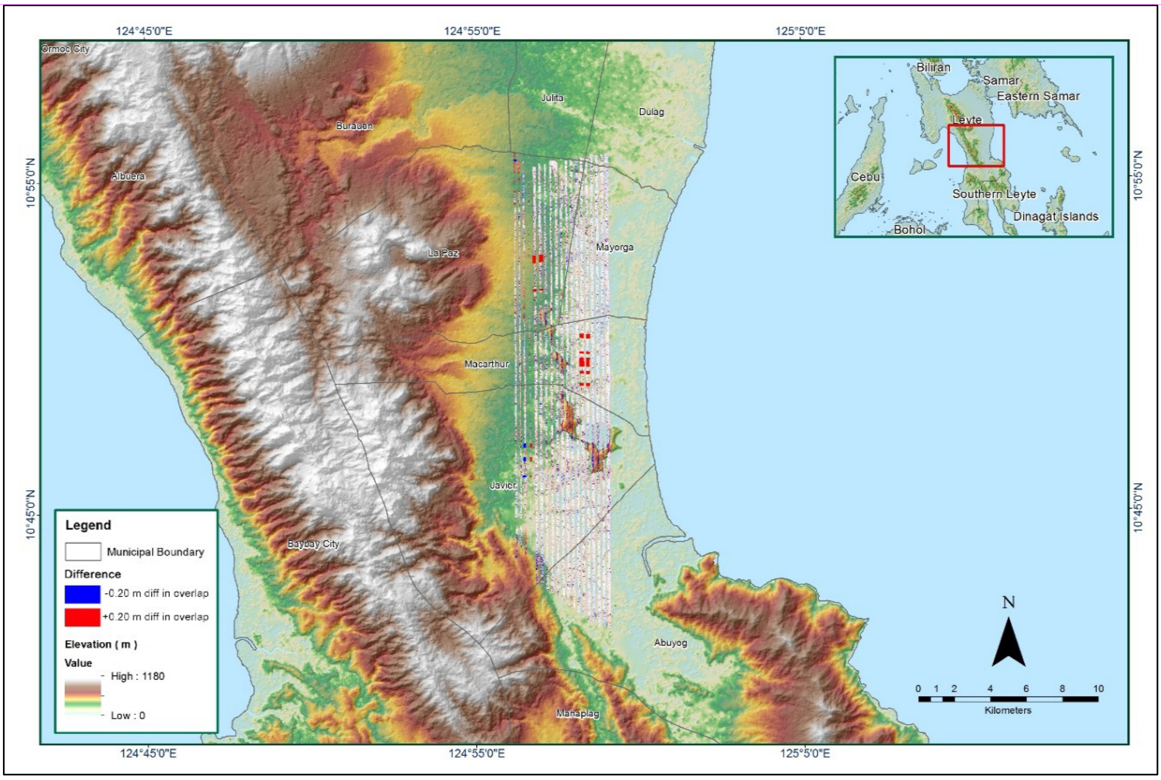


Figure A-8.14 Elevation difference between flight lines

Flight Area	Samar-Leyte
Mission Name	Blk34F
Inclusive Flights	1358A, 1360A
Range data size	22.36 GB
Base data size	417 MB
POS	23.4 MB
Image	115.1 GB
Transfer date	May 28, 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)	2.9
RMSE for East Position (<4.0 cm)	3.5
RMSE for Down Position (<8.0 cm)	5.5
Boresight correction stdev (<0.001deg)	0.000685
IMU attitude correction stdev (<0.001deg)	0.002555
GPS position stdev (<0.01m)	0.0083
Minimum % overlap (>25)	43.14%
Ave point cloud density per sq.m. (>2.0)	3.13
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	221
Maximum Height	268.28 m
Minimum Height	66.43 m
Classification (# of points)	
Ground	127,167,999
Low vegetation	167,959,671
Medium vegetation	145,772,139
High vegetation	22,065,261
Building	1,152,046
Orthophoto	Yes
Processed by	Engr. Analyn Naldo, Engr. Chelou Prado, Jovy Narisma, Engr. Angelo

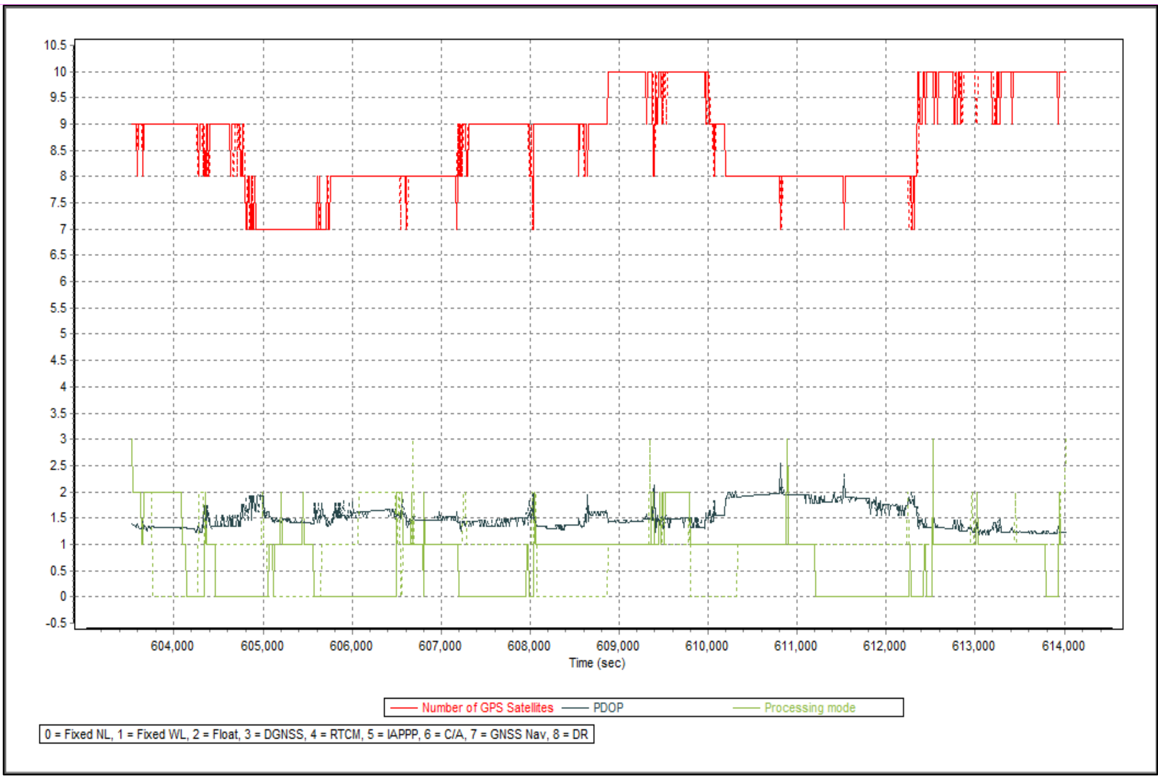


Figure A-8.15 Solution Status

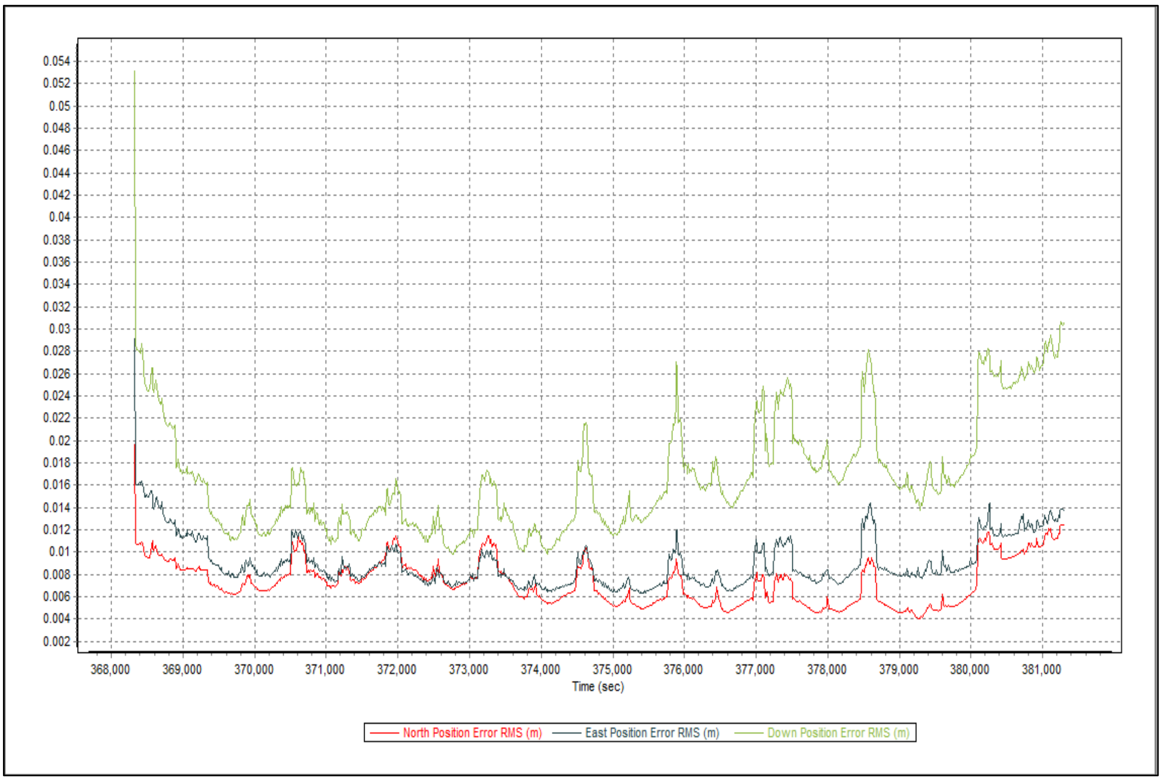


Figure A-8.9 Smoothed Performance Metrics Parameters

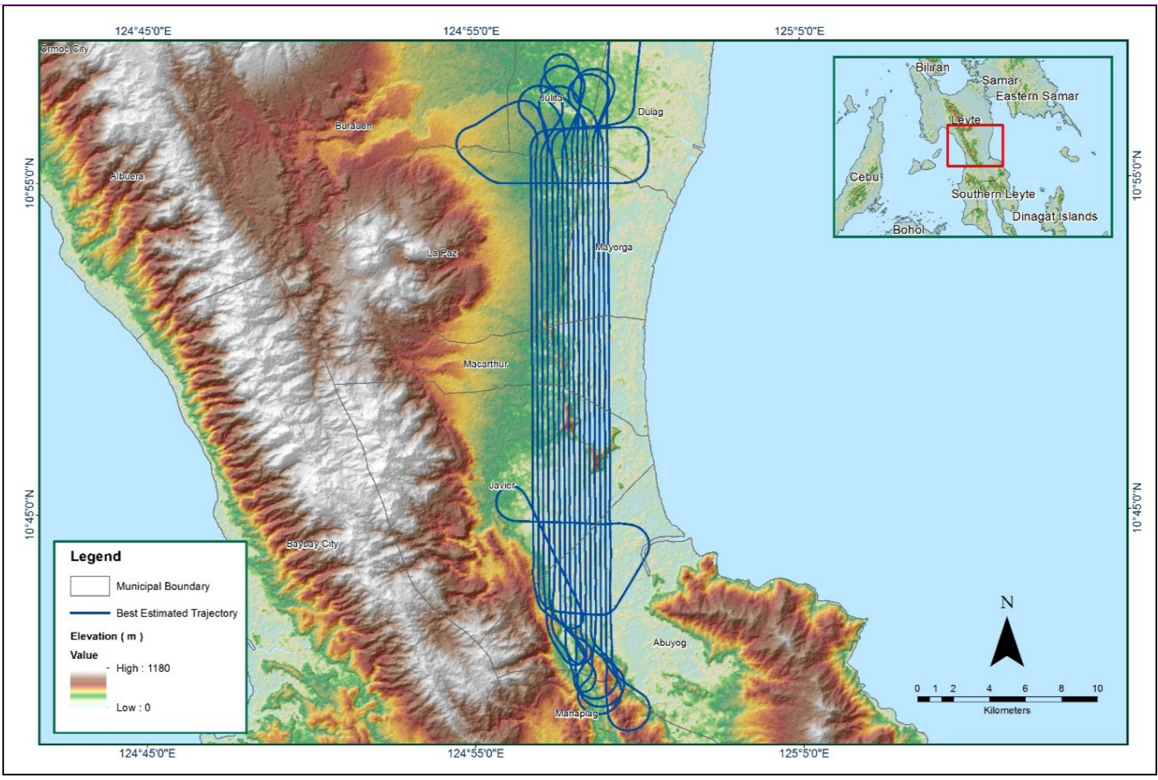


Figure A-8.10. Best Estimated Trajectory

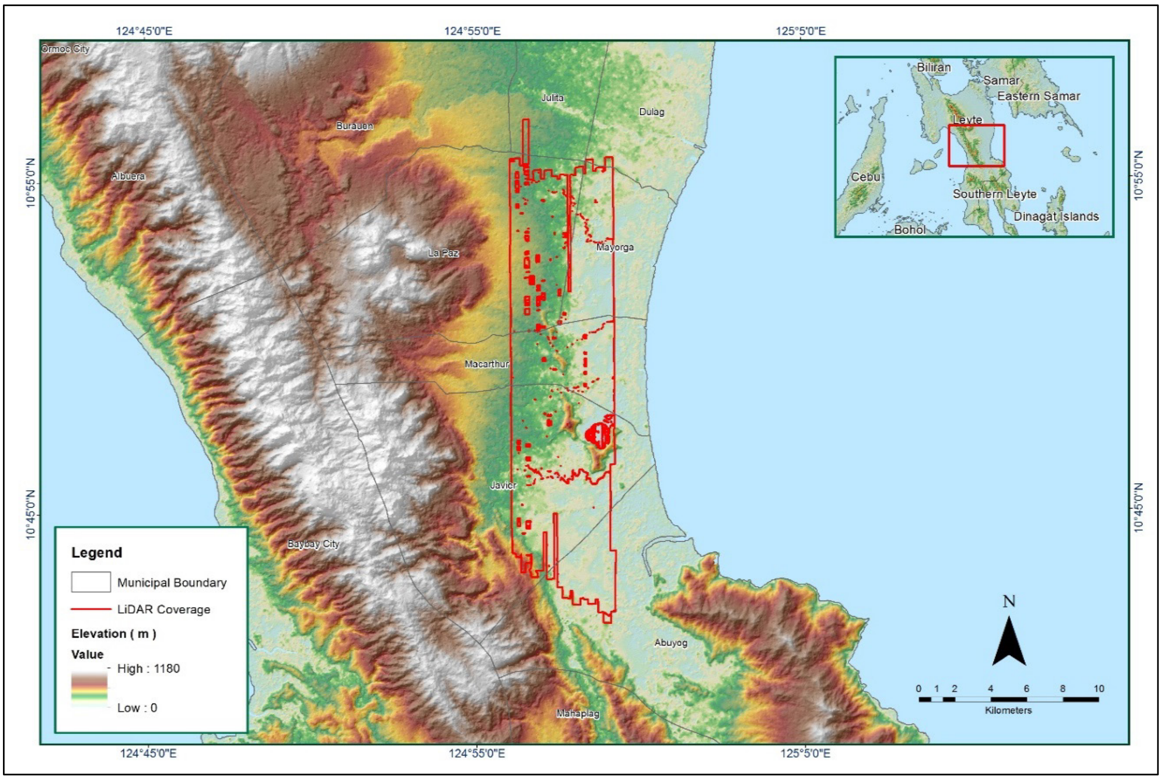


Figure A-8.11 Coverage of LiDAR data

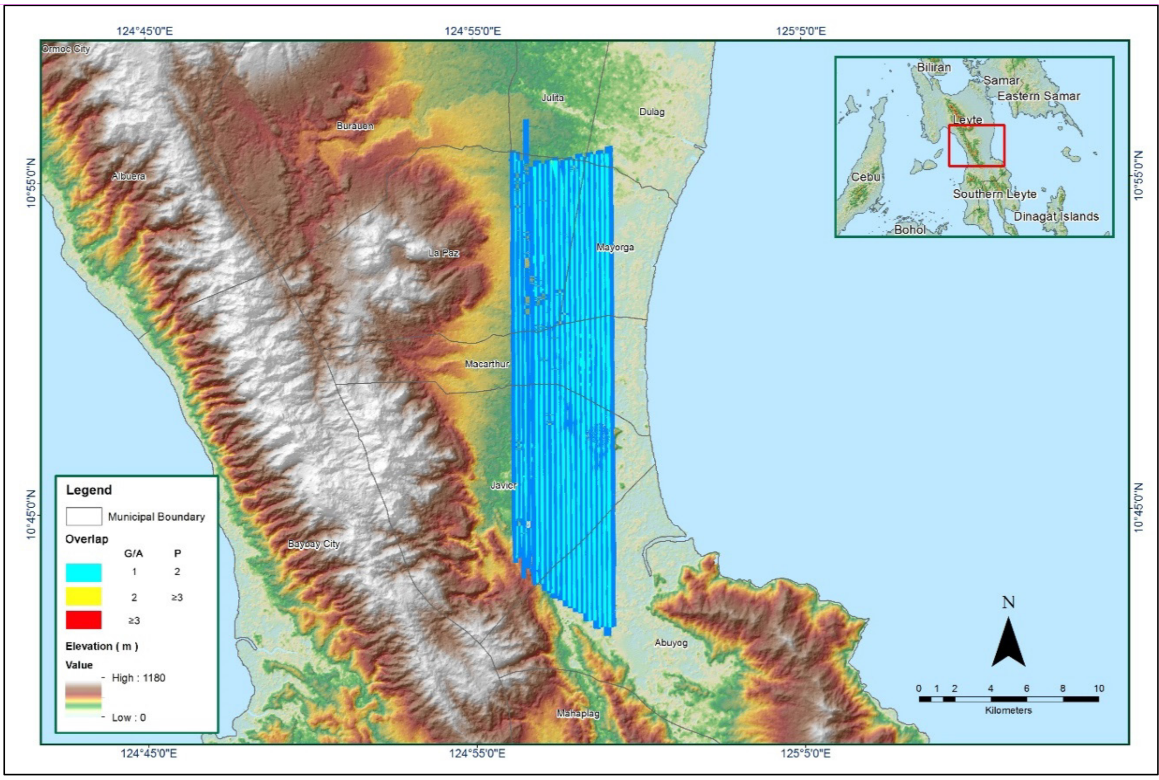


Figure A-8.12 Image of data overlap

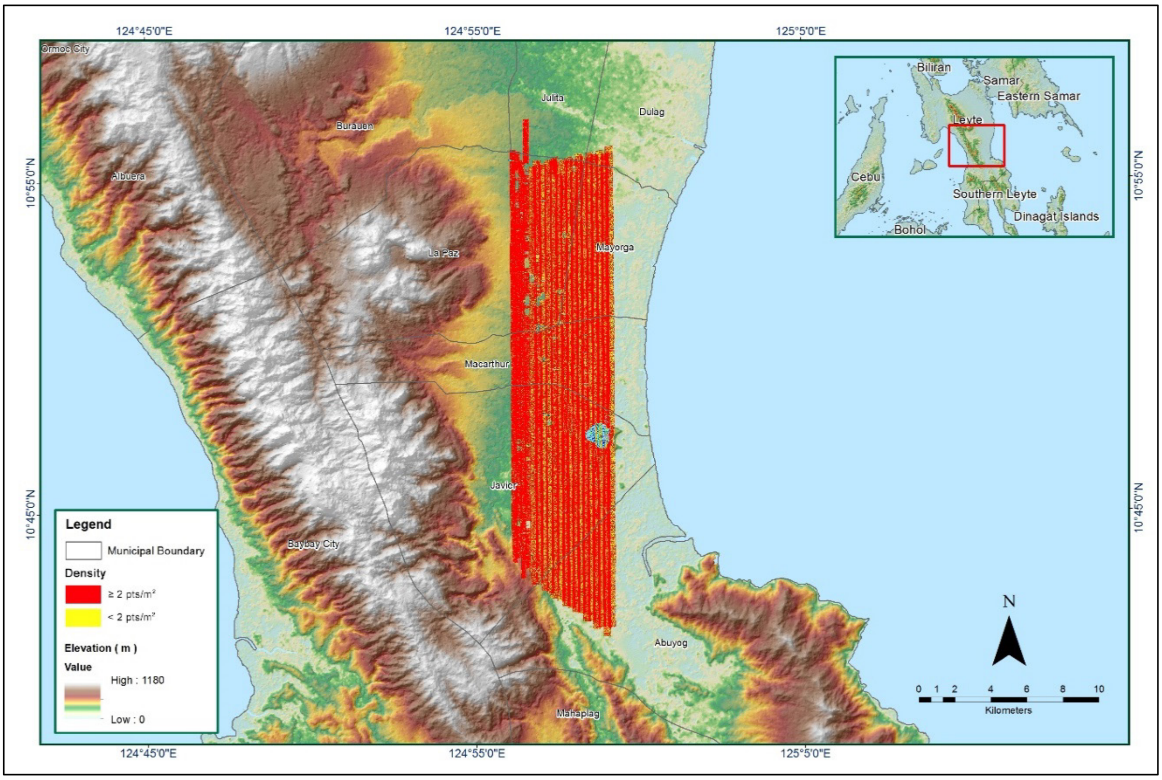


Figure A-8.13 Density map of merged LiDAR data

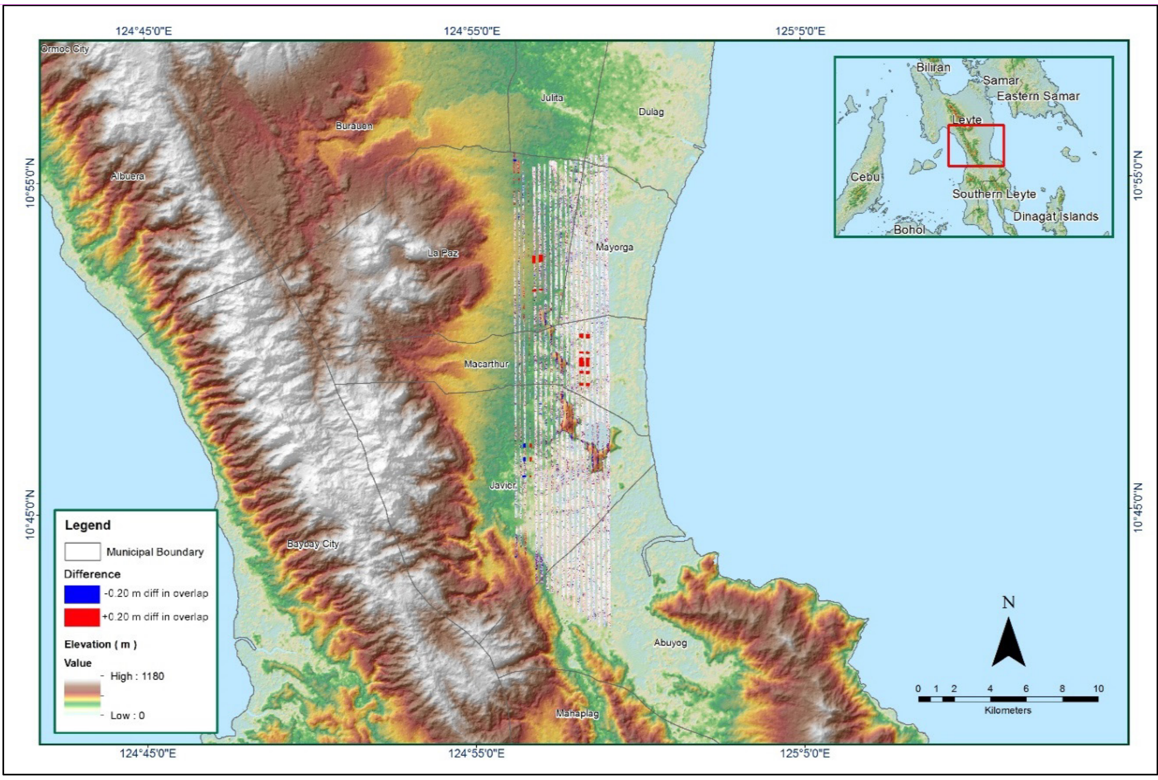


Figure A-8.14 Elevation difference between flight lines

Flight Area	Samar-Leyte
Mission Name	Blk34F
Inclusive Flights	1358A, 1360A
Range data size	22.36 GB
Base data size	417 MB
POS	23.4 MB
Image	115.1 GB
Transfer date	May 28, 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)	2.9
RMSE for East Position (<4.0 cm)	3.5
RMSE for Down Position (<8.0 cm)	5.5
Boresight correction stdev (<0.001deg)	0.000685
IMU attitude correction stdev (<0.001deg)	0.002555
GPS position stdev (<0.01m)	0.0083
Minimum % overlap (>25)	43.14%
Ave point cloud density per sq.m. (>2.0)	3.13
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	221
Maximum Height	268.28 m
Minimum Height	66.43 m
Classification (# of points)	
Ground	127,167,999
Low vegetation	167,959,671
Medium vegetation	145,772,139
High vegetation	22,065,261
Building	1,152,046
Orthophoto	Yes
Processed by	Engr. Analyn Naldo, Engr. Chelou Prado, Jovy Narisma, Engr. Angelo

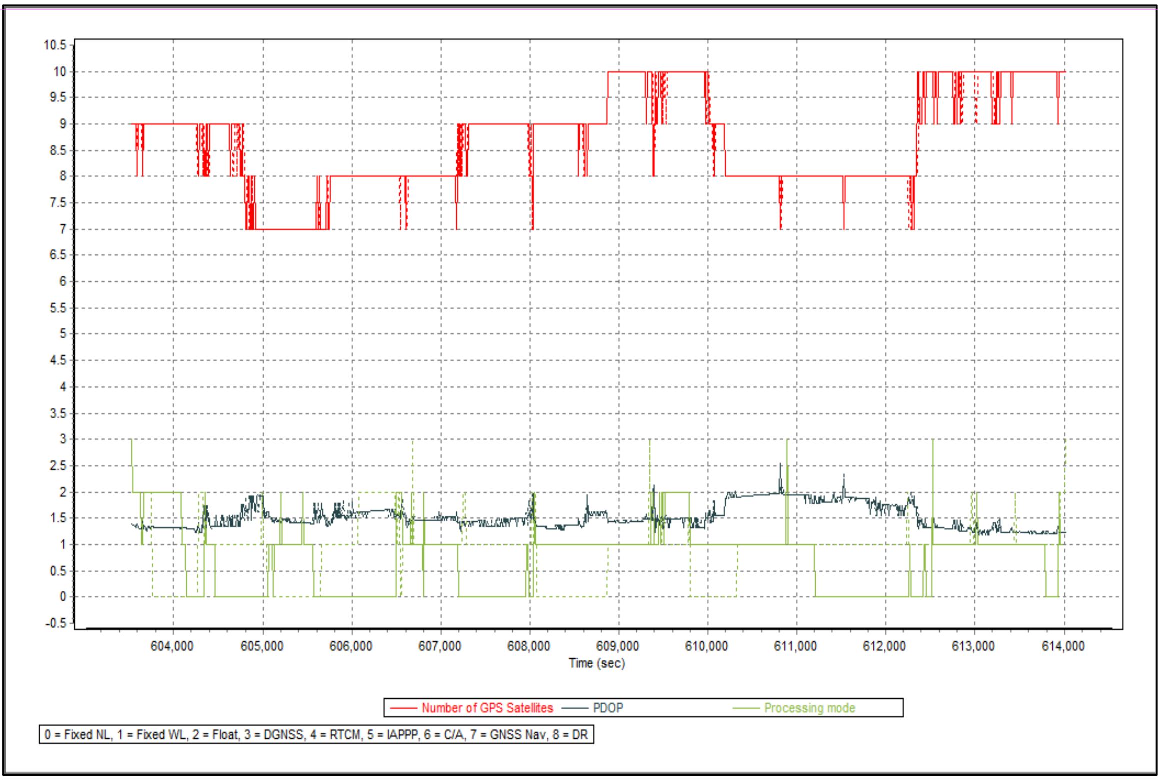


Figure A-8.15 Solution Status

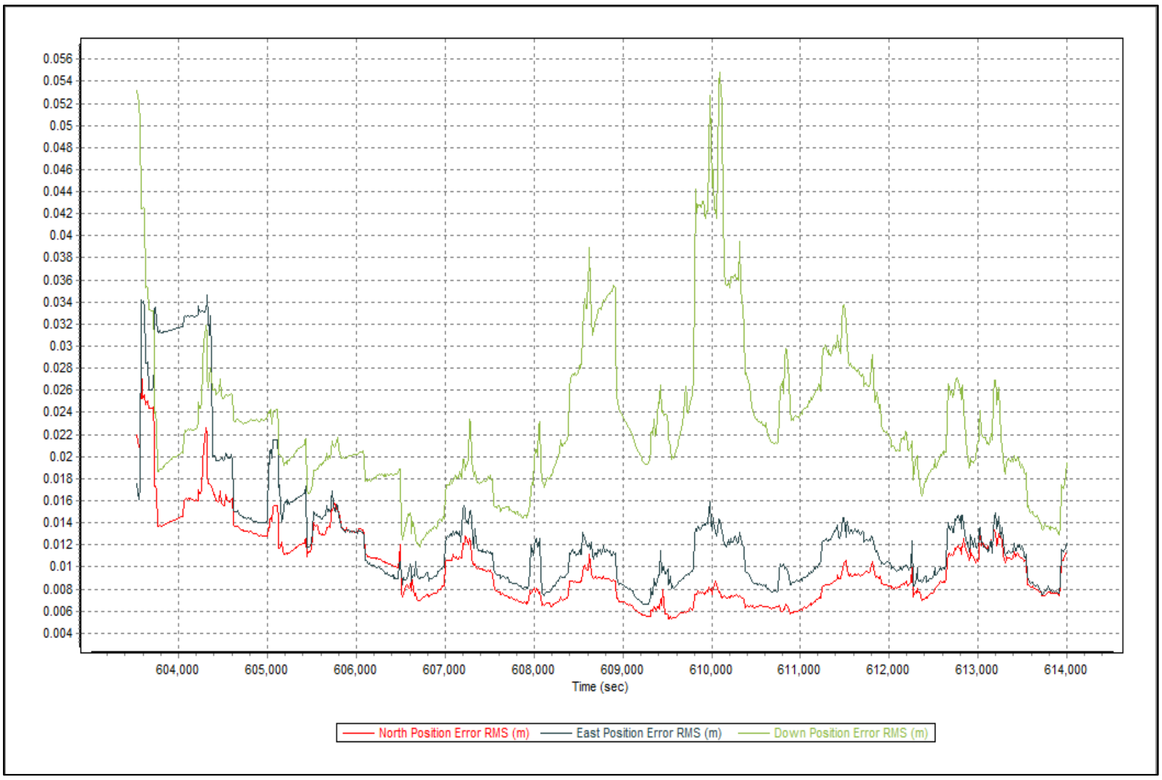


Figure A-8.16 Smoothed Performance Metrics Parameters

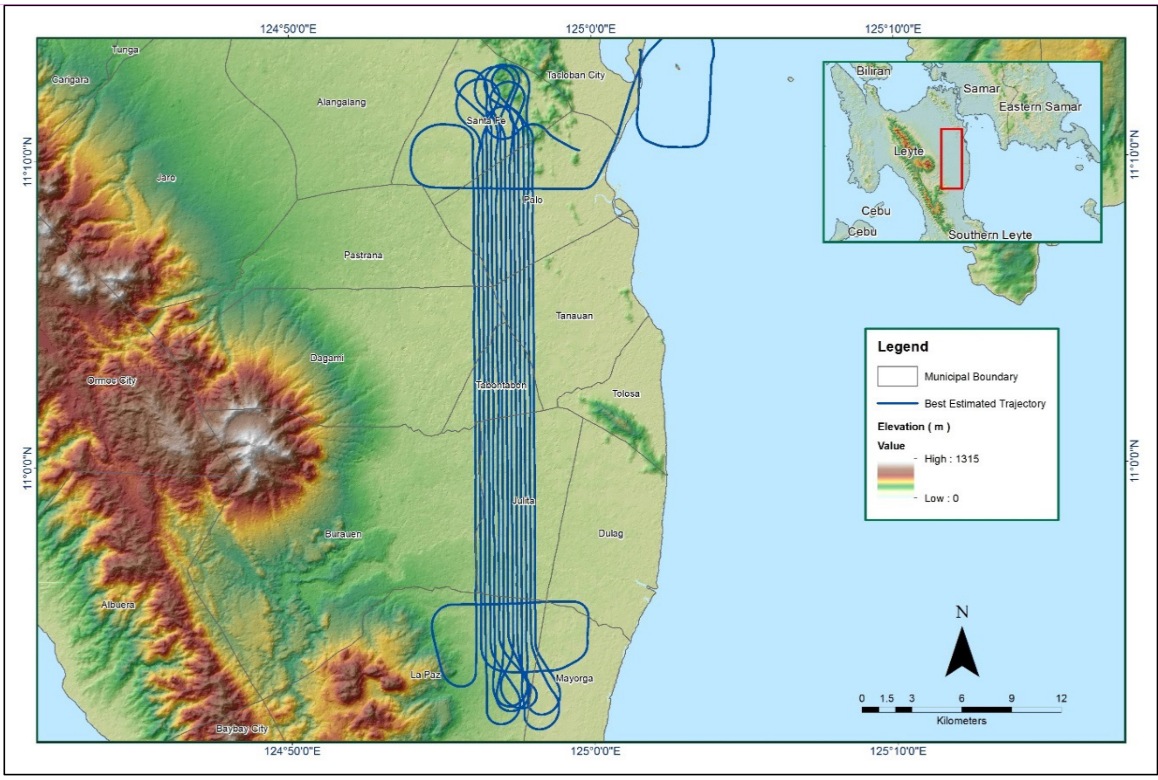


Figure A-8.17 Best Estimated Trajectory

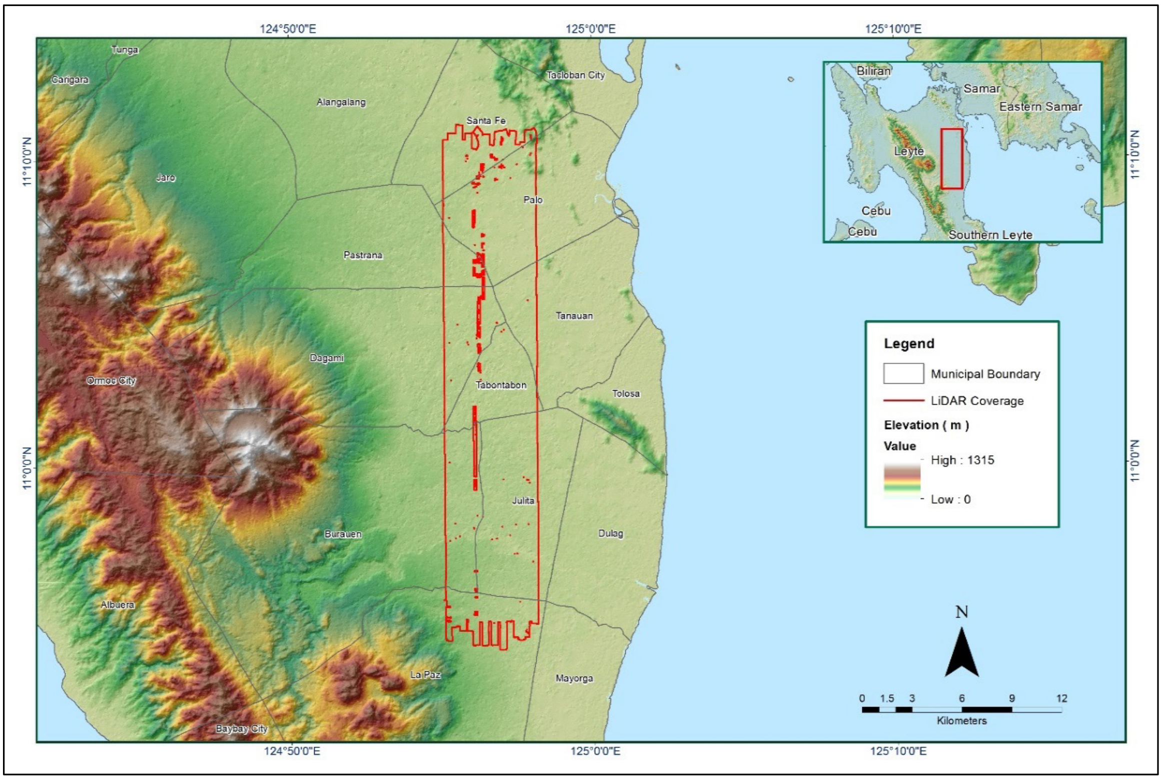


Figure A-8.18 Coverage of LiDAR data

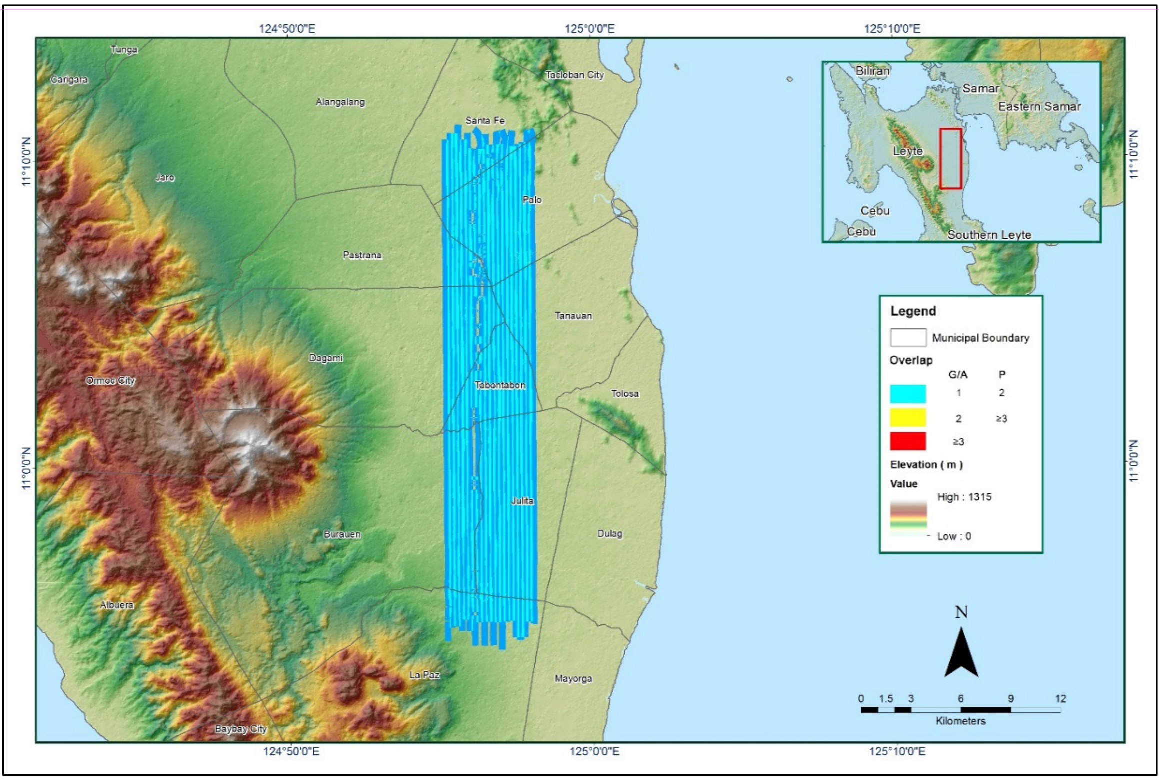


Figure A-8.19 Image of data overlap

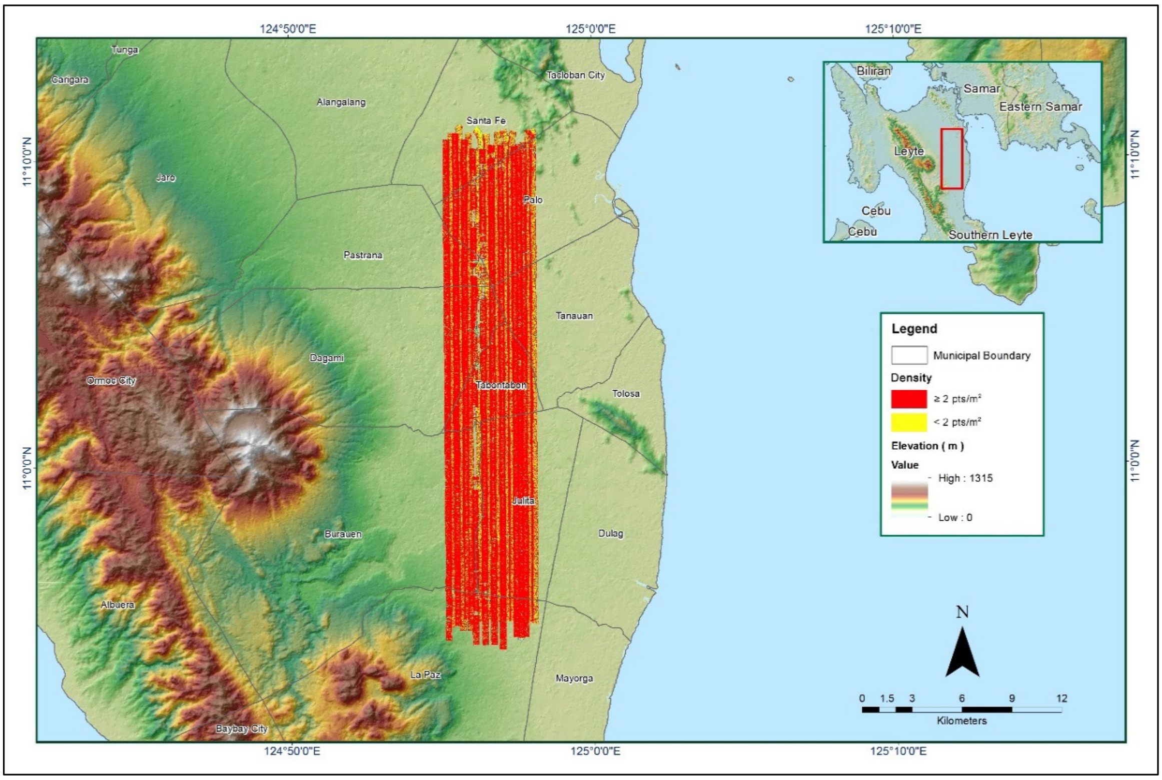


Figure A-8.20 Density map of merged LiDAR data

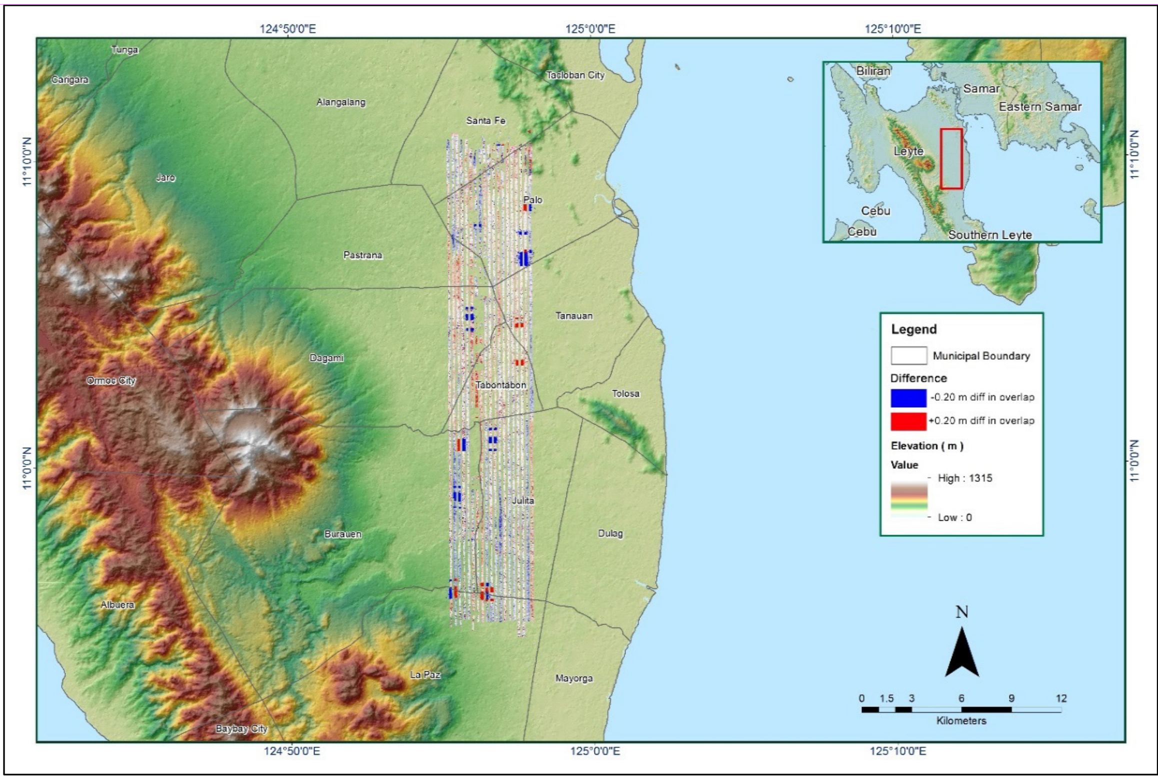


Figure A-8.21 Elevation difference between flight lines

Flight Area	Leyte
Mission Name	34F_Additional
Inclusive Flights	3769G
Range data size	23.8
Base data size	260
POS	9.58
Image	n/a
Transfer date	February 12, 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)	1.1
RMSE for East Position (<4.0 cm)	1.2
RMSE for Down Position (<8.0 cm)	3.3
Boresight correction stdev (<0.001deg)	0.000767
IMU attitude correction stdev (<0.001deg)	0.004064
GPS position stdev (<0.01m)	0.0063
Minimum % overlap (>25)	31.11
Ave point cloud density per sq.m. (>2.0)	4.85
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	93
Maximum Height	415.68 m
Minimum Height	63.54 m
Classification (# of points)	
Ground	35,181,518
Low vegetation	42,803,820
Medium vegetation	136,496,439
High vegetation	111,171,628
Building	2,703,347
Orthophoto	None
Processed by	Engr. Kenneth Solidum, Engr. Chelou Prado, Engr. Krisha Marie Bautista

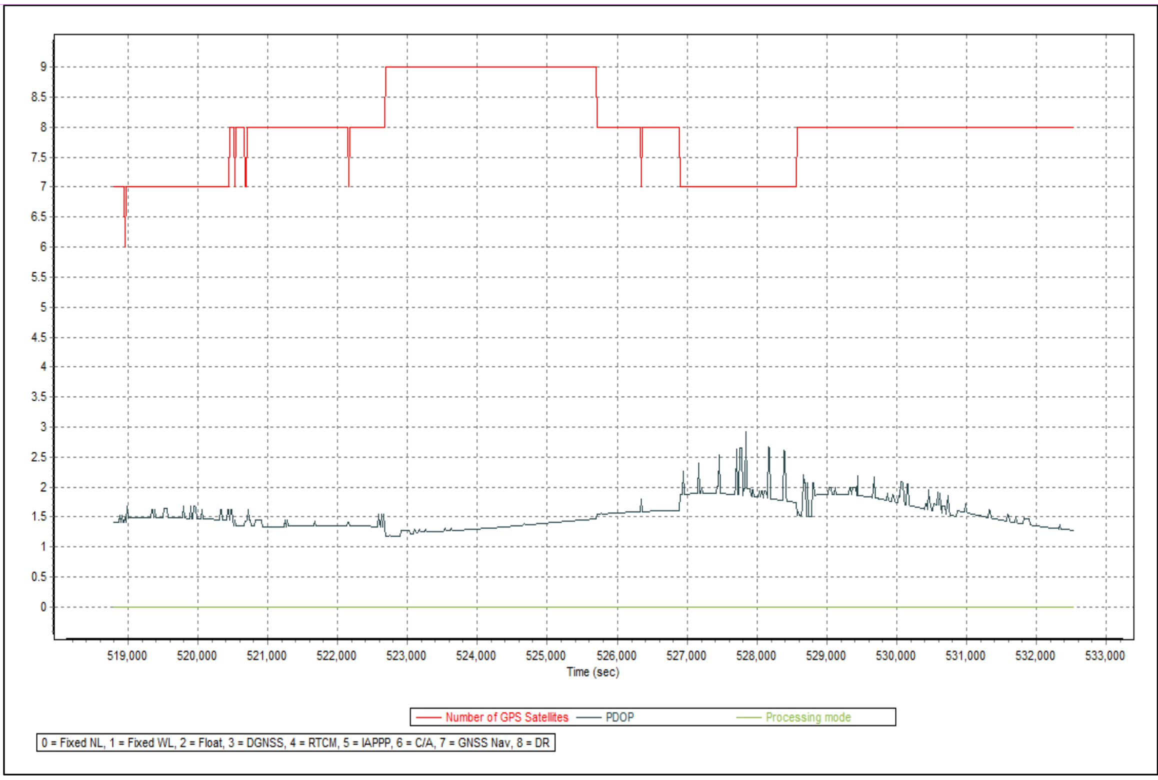


Figure A-8.22 Solution Status

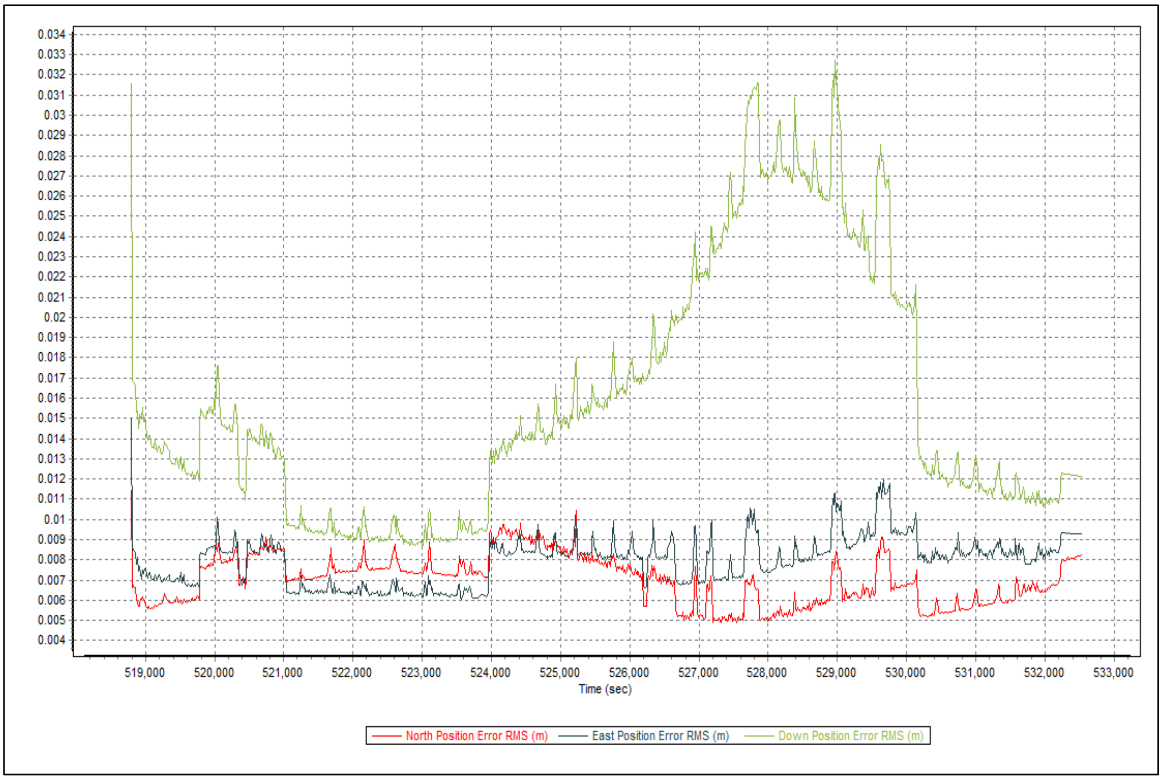


Figure A-8.23 Smoothed Performance Metric Parameters

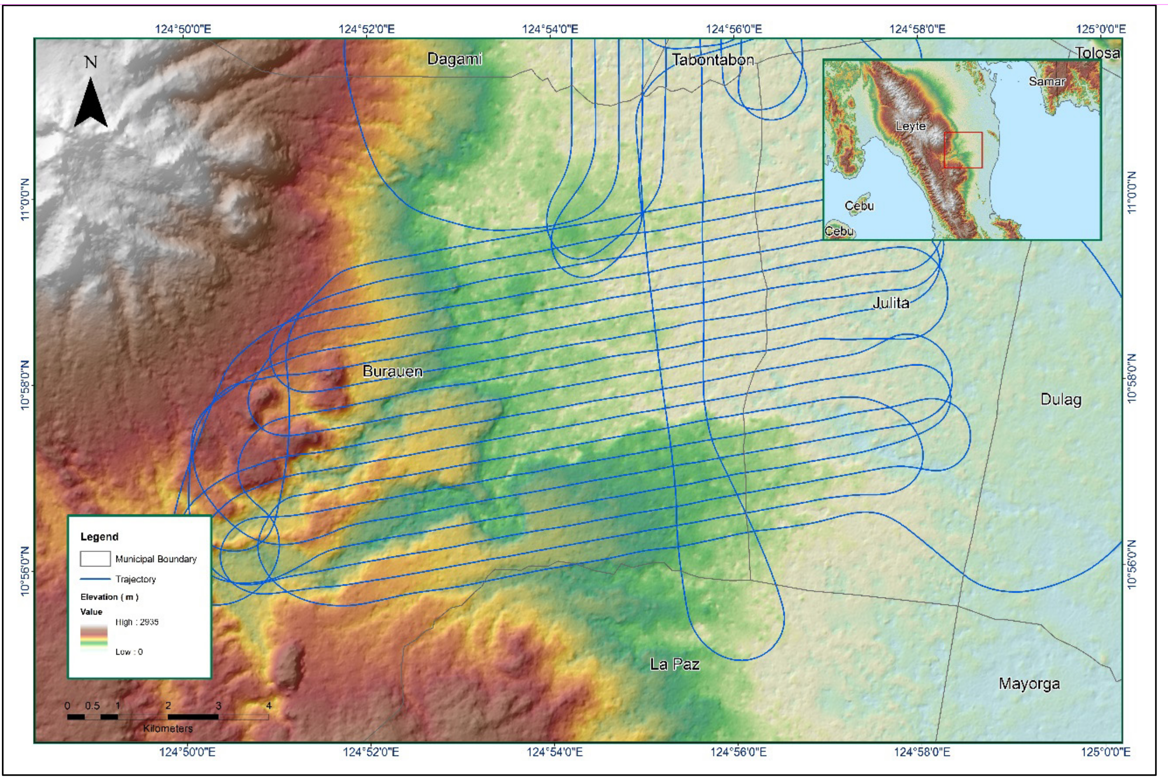


Figure A-8.24 Best Estimated Trajectory

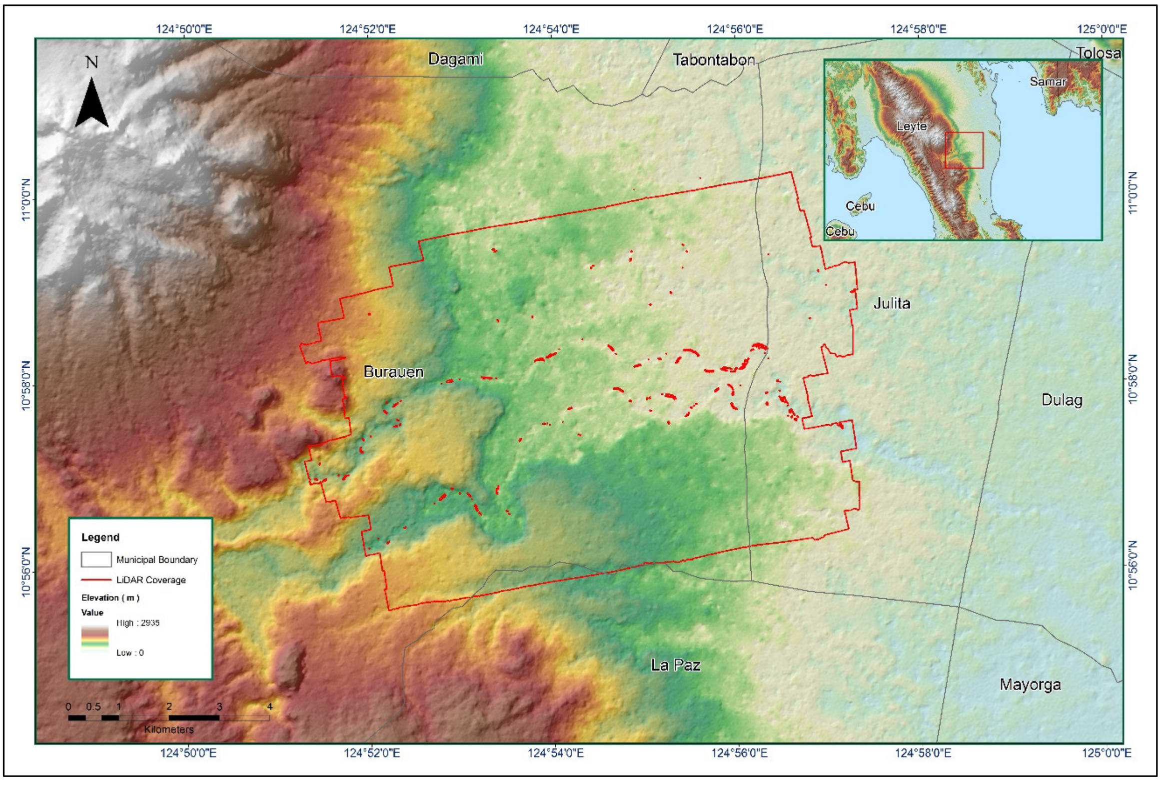


Figure A-8.25 Coverage of LiDAR Data

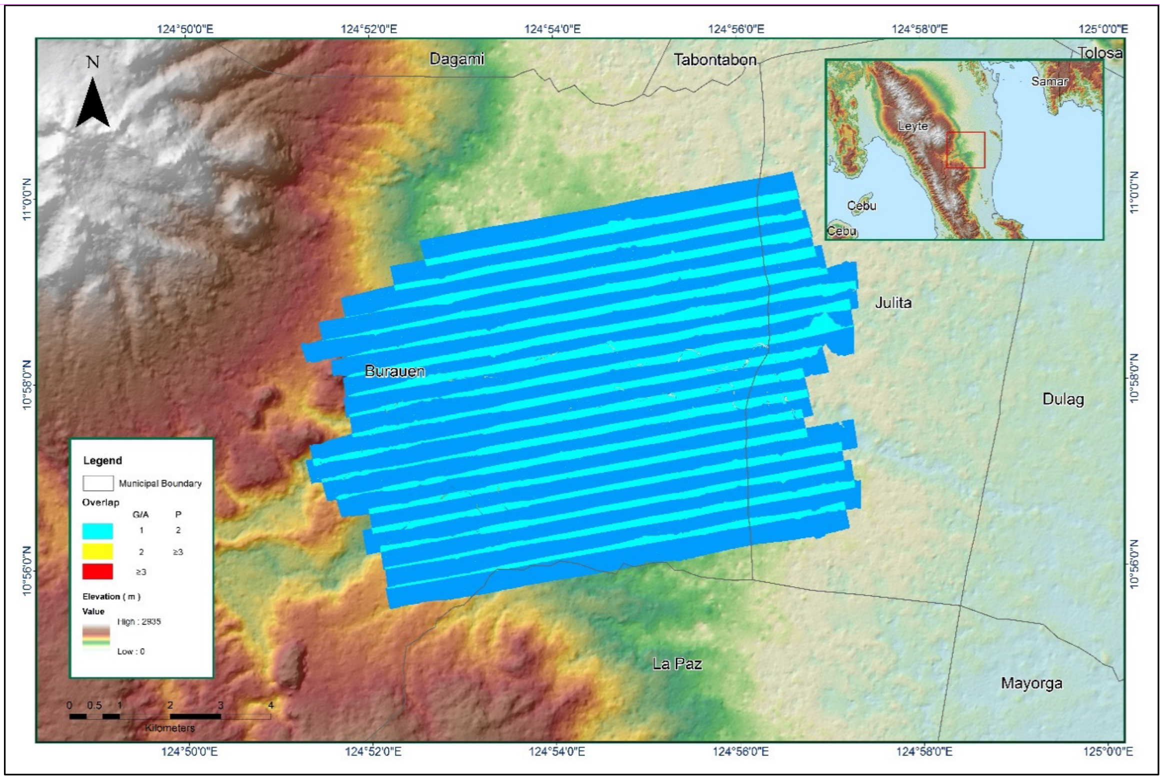


Figure A-8.26 Image of data overlap

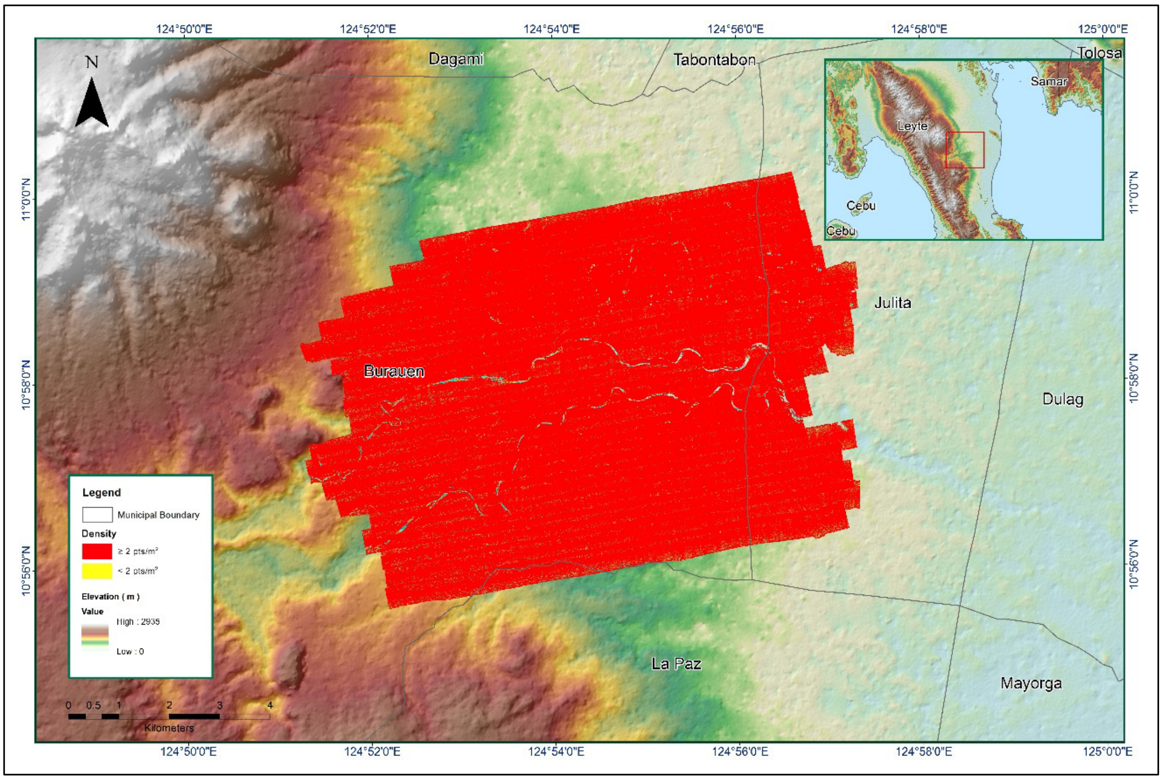


Figure A-8.27 Density map of merged LiDAR data

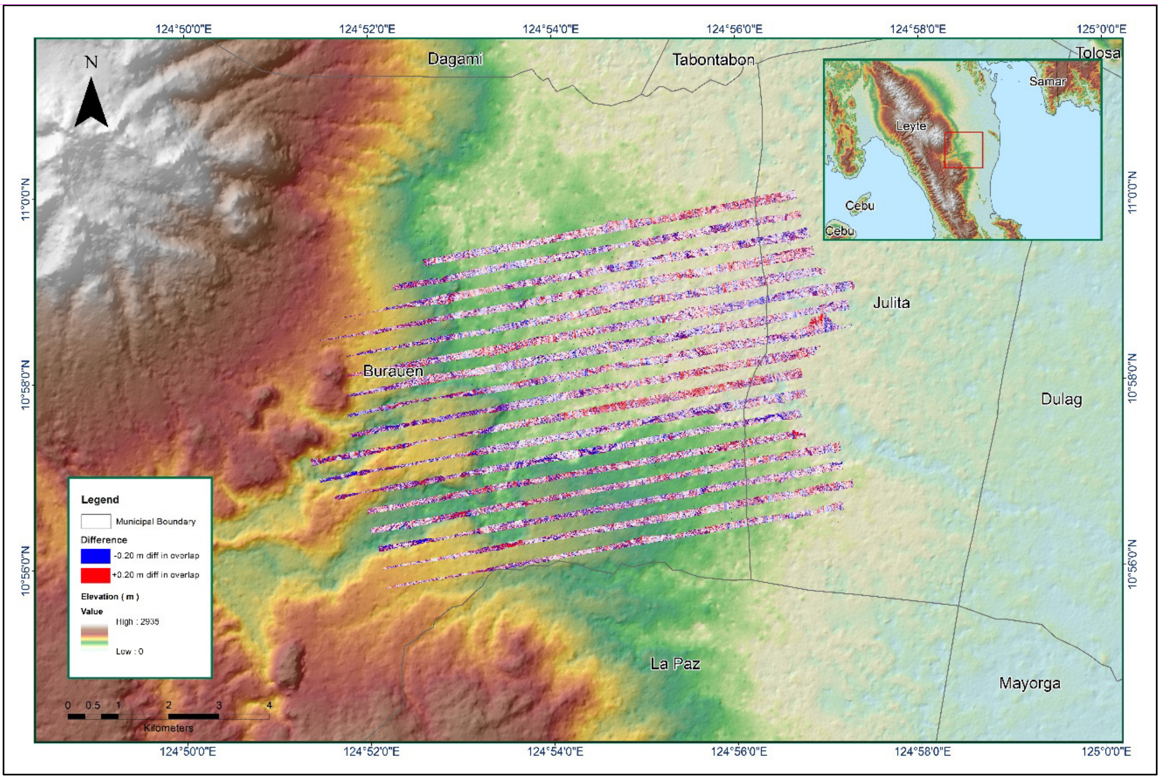


Figure A-8.28 Elevation difference between flight lines

Flight Area	Tacloban
Mission Name	1026A
Inclusive Flights	1026A
Range data size	11.6 GB
Base data size	137 MB
POS	20 MB
Image	55.2 GB
Transfer date	February 3, 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)	1.6
RMSE for East Position (<4.0 cm)	1.8
RMSE for Down Position (<8.0 cm)	3.1
Boresight correction stdev (<0.001deg)	0.000559
IMU attitude correction stdev (<0.001deg)	0.007980
GPS position stdev (<0.01m)	0.0379
Minimum % overlap (>25)	42.17%
Ave point cloud density per sq.m. (>2.0)	2.33
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	314
Maximum Height	386.42 m
Minimum Height	42.55 m
Classification (# of points)	
Ground	83,757,366
Low vegetation	78,700,823
Medium vegetation	165,907,507
High vegetation	4,928,508
Building	1,722,190
Orthophoto	Yes
Processed by	Engr. Angelo Carlo Bongat,Engr. Jennifer Saguran,Engr. Christy Lubiano, Ryan James Nicholai Dizon

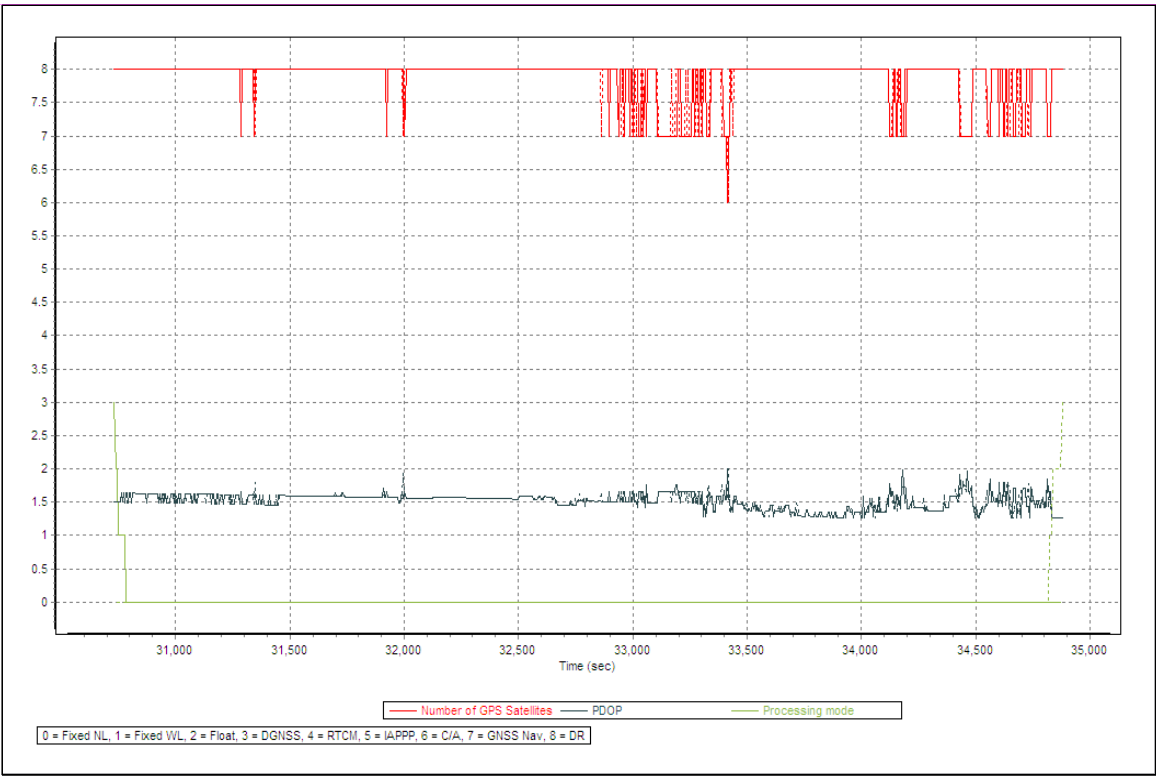


Figure A-8.29 Solution Status

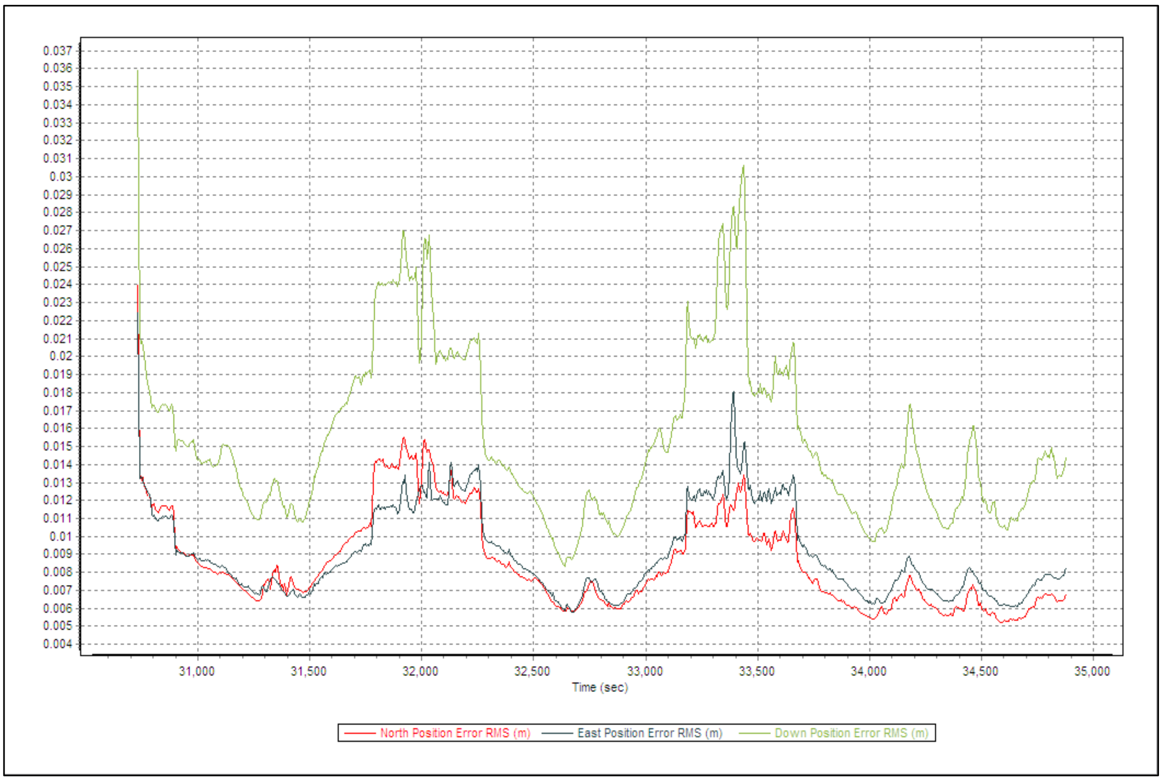


Figure A-8.30 Smoothed Performance Metrics Parameters

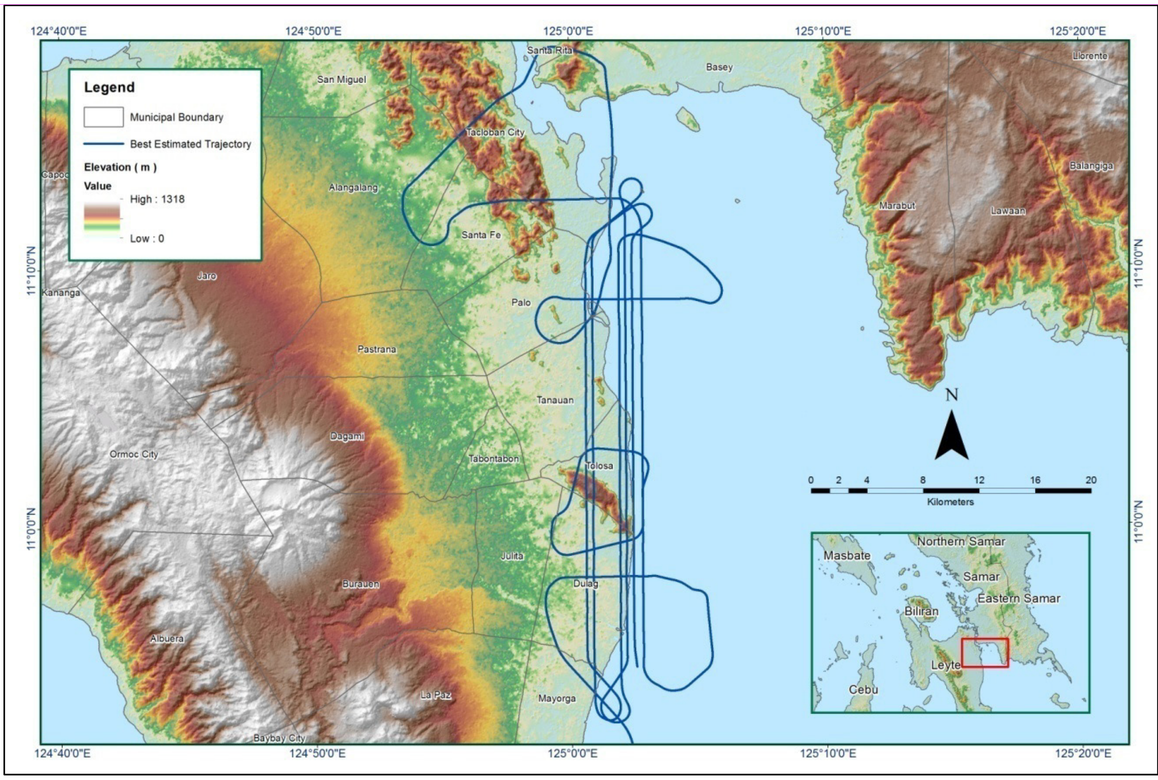


Figure A-8.31 Best Estimated Trajectory

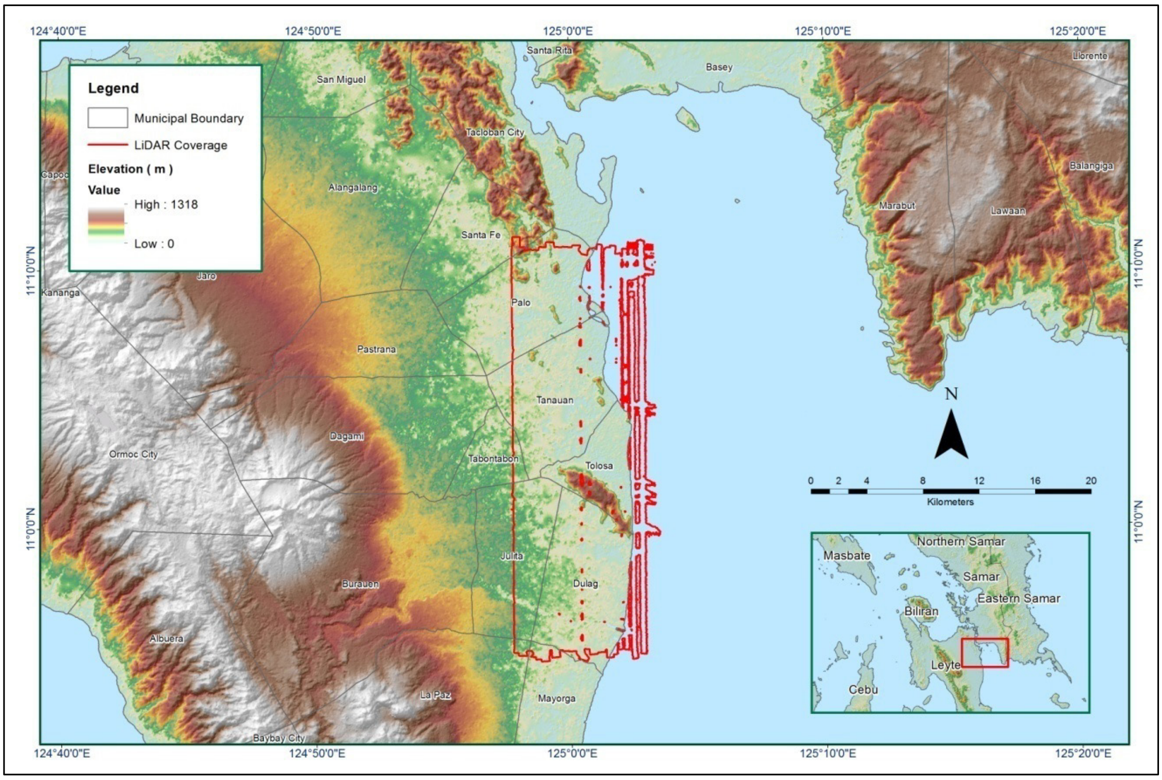


Figure A-8.32 Coverage of LiDAR data

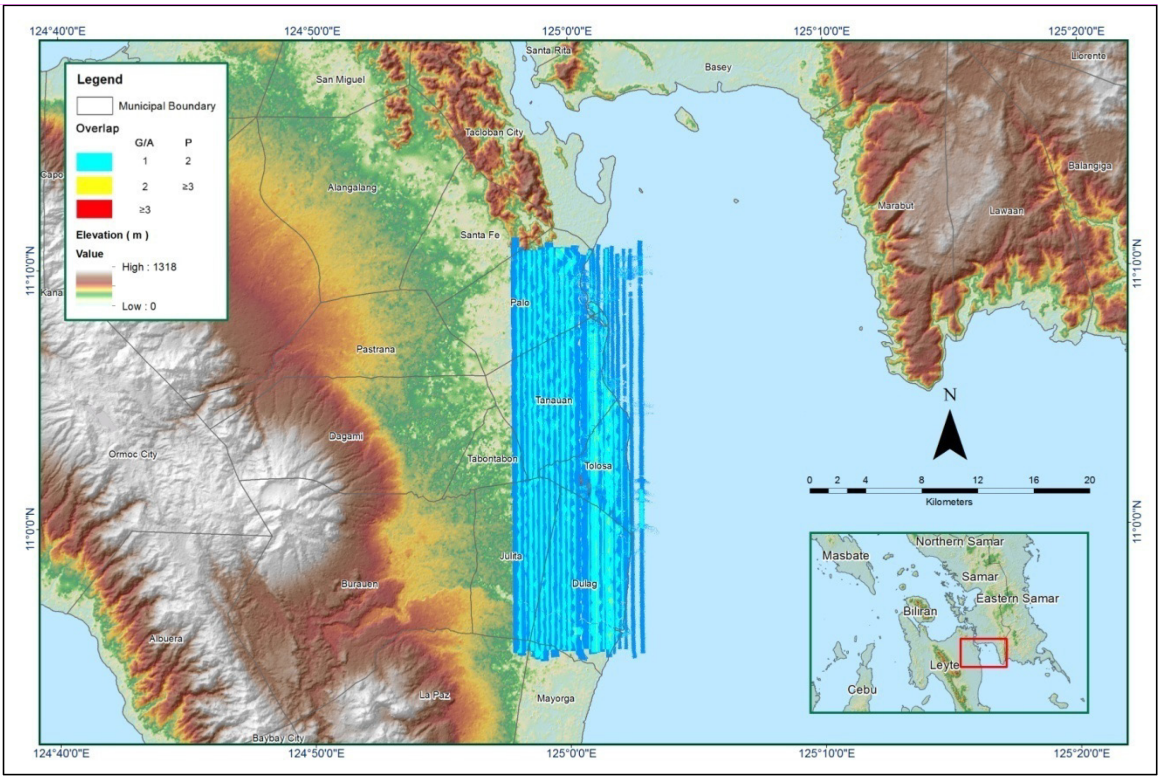


Figure A-8.32 Image of data overlap

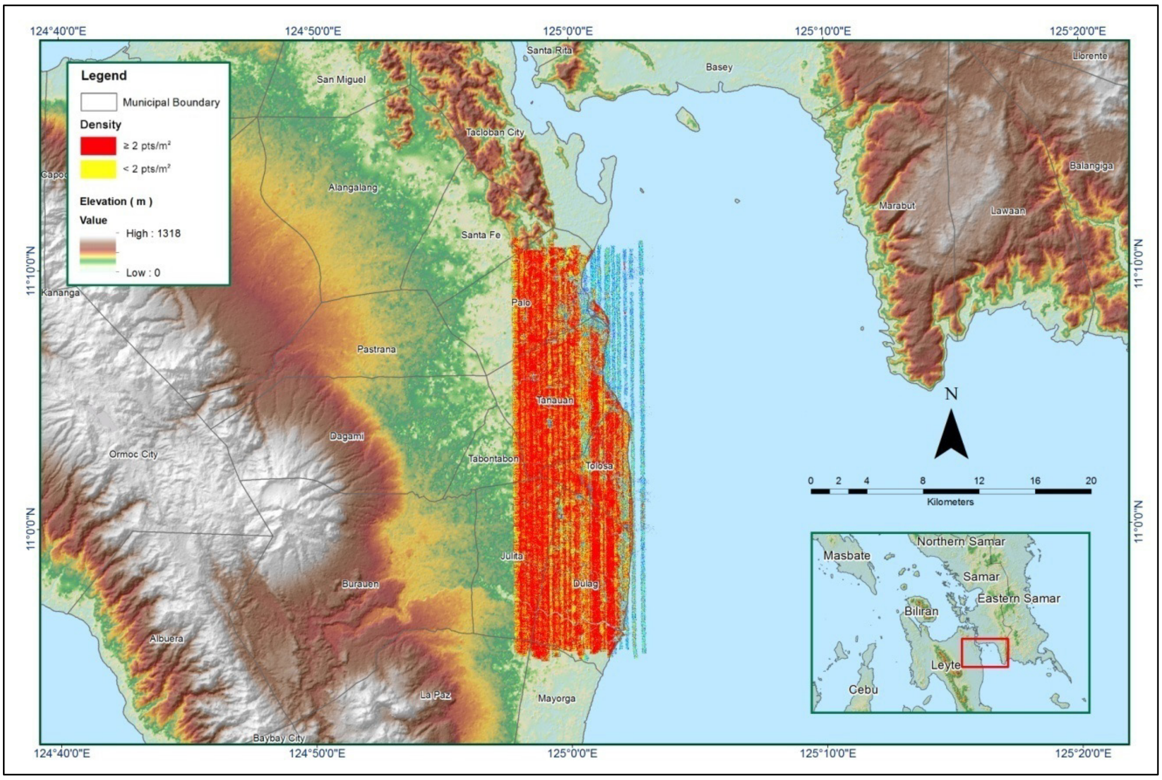


Figure A-8.33 Density map of merged LiDAR data

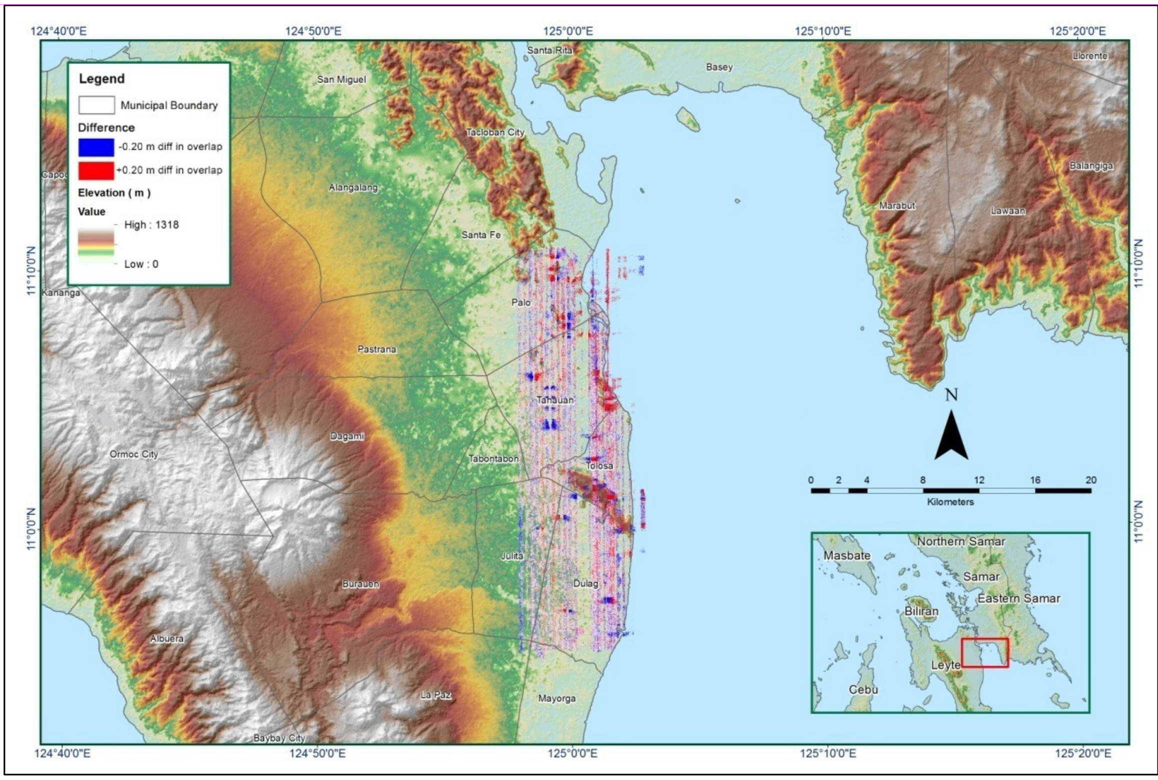


Figure A-8.34 Elevation difference between flight lines

Annex 9. Daguitan-Marabong 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	29.858	65.84	0	1.4708	0.29094	Discharge	1.126	0.1	Ratio to Peak	1
W470	20.459	74.53	0	2.0860	0.41265	Discharge	1.009	0.1	Ratio to Peak	1
W480	1.2208	95.00	0	3.5548	0.70321	Discharge	0.810	0.1	Ratio to Peak	1
W490	32.960	63.40	0	2.8025	0.55439	Discharge	1.470	0.1	Ratio to Peak	1
W500	26.111	69.05	0	0.8422	0.16661	Discharge	0.301	0.1	Ratio to Peak	1
W510	29.137	66.43	0	1.8348	0.36296	Discharge	0.619	0.1	Ratio to Peak	1
W520	1.0897	95.00	0	1.7869	0.35347	Discharge	0.392	0.1	Ratio to Peak	1
W530	1.0897	95.00	0	0.5635	0.11148	Discharge	0.041	0.1	Ratio to Peak	1
W540	1.0897	95.00	0	1.9583	0.38739	Discharge	0.220	0.1	Ratio to Peak	1
W550	9.4260	88.18	0	4.3937	0.86915	Discharge	2.770	0.1	Ratio to Peak	1
W560	19.325	75.73	0	1.6242	0.32130	Discharge	0.956	0.1	Ratio to Peak	1
W570	21.064	73.90	0	1.4342	0.28371	Discharge	0.423	0.1	Ratio to Peak	1
W580	3.9431	95.00	0	0.8581	0.16975	Discharge	0.287	0.1	Ratio to Peak	1
W590	1.5969	95.00	0	2.2604	0.44714	Discharge	0.643	0.1	Ratio to Peak	1
W600	13.191	82.99	0	2.3263	0.46018	Discharge	0.708	0.1	Ratio to Peak	1
W610	23.131	71.83	0	0.8264	0.16349	Discharge	0.133	0.1	Ratio to Peak	1
W620	19.512	75.53	0	1.5658	0.30974	Discharge	0.491	0.1	Ratio to Peak	1
W630	19.201	75.86	0	1.0496	0.20762	Discharge	0.300	0.1	Ratio to Peak	1
W640	19.172	75.90	0	0.1092	0.02161	Discharge	0.002	0.1	Ratio to Peak	1
W650	1.0897	95.00	0	3.7381	0.73946	Discharge	1.115	0.1	Ratio to Peak	1
W660	19.970	75.04	0	1.5402	0.30469	Discharge	0.718	0.1	Ratio to Peak	1
W670	19.172	75.90	0	0.6537	0.12933	Discharge	0.053	0.1	Ratio to Peak	1

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
W680	1.0897	95.00	0	2.2726	0.44957	Discharge	0.342	0.1	Ratio to Peak	1
W690	1.0897	95.00	0	1.0331	0.20436	Discharge	0.078	0.1	Ratio to Peak	1
W700	19.172	75.90	0	1.0758	0.21281	Discharge	0.205	0.1	Ratio to Peak	1
W710	24.728	70.31	0	1.9787	0.39142	Discharge	1.135	0.1	Ratio to Peak	1
W720	19.172	75.90	0	2.0513	0.40579	Discharge	0.930	0.1	Ratio to Peak	1
W730	19.172	75.90	0	2.1416	0.42365	Discharge	0.353	0.1	Ratio to Peak	1
W740	20.144	74.86	0	2.4531	0.48527	Discharge	1.349	0.1	Ratio to Peak	1
W750	27.737	67.62	0	0.9432	0.18660	Discharge	0.336	0.1	Ratio to Peak	1
W760	23.276	71.69	0	1.6914	0.33459	Discharge	1.264	0.1	Ratio to Peak	1
W770	14.532	81.29	0	1.1474	0.22697	Discharge	0.641	0.1	Ratio to Peak	1
W780	20.430	74.56	0	1.1041	0.21841	Discharge	0.468	0.1	Ratio to Peak	1
W790	13.345	82.79	0	0.9223	0.18245	Discharge	0.367	0.1	Ratio to Peak	1
W800	21.191	73.77	0	1.0818	0.21401	Discharge	0.228	0.1	Ratio to Peak	1
W810	12.448	83.97	0	0.2827	0.05593	Discharge	0.034	0.1	Ratio to Peak	1
W820	17.695	77.53	0	1.0370	0.20514	Discharge	0.595	0.1	Ratio to Peak	1
W830	25.584	69.52	0	1.0235	0.20247	Discharge	0.337	0.1	Ratio to Peak	1
W840	26.170	69.00	0	1.2187	0.24109	Discharge	0.535	0.1	Ratio to Peak	1
W850	21.558	73.39	0	0.7717	0.15266	Discharge	0.325	0.1	Ratio to Peak	1
W860	22.718	72.24	0	1.1313	0.22379	Discharge	0.301	0.1	Ratio to Peak	1
W870	25.142	69.93	0	1.4192	0.28074	Discharge	1.689	0.1	Ratio to Peak	1
W880	20.884	74.08	0	1.5286	0.30238	Discharge	0.642	0.1	Ratio to Peak	1
W890	27.041	68.22	0	0.8828	0.17464	Discharge	0.340	0.1	Ratio to Peak	1
W900	28.008	67.39	0	1.4542	0.28767	Discharge	1.024	0.1	Ratio to Peak	1

Annex 10. Daguitan-Marabong Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R100	Automatic Fixed Interval	2643.9	0.0058	0.03	Trapezoid	27.68	70
R110	Automatic Fixed Interval	3228.4	0.0392	0.03	Trapezoid	15.90	70
R130	Automatic Fixed Interval	1635.5	0.0267	0.03	Trapezoid	5.000	70
R160	Automatic Fixed Interval	224.14	0.0084	0.03	Trapezoid	50.20	70
R180	Automatic Fixed Interval	7221.2	0.0013	0.03	Trapezoid	15.92	70
R190	Automatic Fixed Interval	352.13	0.0841	0.03	Trapezoid	15.00	70
R210	Automatic Fixed Interval	3076.8	0.0117	0.03	Trapezoid	61.79	70
R220	Automatic Fixed Interval	7639.9	0.0059	0.03	Trapezoid	50.89	70
R230	Automatic Fixed Interval	942.46	0.0049	0.03	Trapezoid	10.57	70
R250	Automatic Fixed Interval	3859.4	0.0076	0.03	Trapezoid	32.60	70
R260	Automatic Fixed Interval	2711.4	0.0049	0.03	Trapezoid	42.98	70
R280	Automatic Fixed Interval	4655.2	0.0199	0.03	Trapezoid	46.31	70
R300	Automatic Fixed Interval	17936	0.0085	0.03	Trapezoid	33.60	70
R330	Automatic Fixed Interval	3471.1	0.0161	0.03	Trapezoid	30.00	70
R340	Automatic Fixed Interval	574.26	0.0326	0.03	Trapezoid	10.00	70
R360	Automatic Fixed Interval	1326.1	0.0449	0.03	Trapezoid	12.02	70
R390	Automatic Fixed Interval	2699.1	0.0220	0.03	Trapezoid	7.840	70
R40	Automatic Fixed Interval	3062.9	0.0008	0.03	Trapezoid	48.76	70
R410	Automatic Fixed Interval	1616.1	0.0049	0.03	Trapezoid	4.360	70
R430	Automatic Fixed Interval	5022.4	0.0339	0.03	Trapezoid	3.000	70
R60	Automatic Fixed Interval	4780.2	0.0057	0.03	Trapezoid	36.69	70
R70	Automatic Fixed Interval	1010.8	0.0126	0.03	Trapezoid	5.000	70

Annex 11. Daguitan - Marabong Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date of Occurrence	Rain Return / Scenario
	Lat	Long						
17	10.9544	124.9827	1.60	0.7	0.9	Yolanda	November 08, 2013	5Yr
18	10.9544	124.9827	1.60	3.0	-1.4	Uring	November 05, 1991	5Yr
19	10.9544	124.9827	1.60	0.5	1.1	Ruby	December 06, 2014	5Yr
20	10.9547	124.9775	1.43	1.3	0.13	Ruby	December 06, 2014	5Yr
21	10.9523	124.9830	1.08	0.8	0.28	Ruby	December 06, 2014	5Yr
22	10.9547	124.9776	1.06	3.0	-1.94	Uring	November 05, 1991	5Yr
23	10.9547	124.9776	1.06	0.5	0.56	Ruby	December 06, 2014	5Yr
24	10.9500	124.9822	1.06	0.8	0.26	Ruby	December 06, 2014	5Yr
25	10.9500	124.9822	1.06	2.0	-0.94	Uring	November 05, 1991	5Yr
26	10.9584	124.9702	1.04	0.5	0.54	Ruby	December 06, 2014	5Yr
27	10.9594	124.9732	0.99	0.2	0.79	Seniang	December 29, 2014	5Yr
28	10.9594	124.9732	0.99	0.0	0.99	Ruby	December 06, 2014	5Yr
29	10.9552	124.9826	0.97	0.0	0.97	Ruby	December 06, 2014	5Yr
30	10.9552	124.9826	0.97	0.0	0.97	Uring	November 05, 1991	5Yr
31	10.9557	124.9824	0.95	0.0	0.95	Yolanda	November 08, 2013	5Yr
32	10.9557	124.9824	0.95	0.0	0.95	Ruby	December 06, 2014	5Yr
33	10.9557	124.9824	0.95	1.0	-0.05	Uring	November 05, 1991	5Yr
34	10.9563	124.9796	0.94	3.0	-2.06	Uring	November 05, 1991	5Yr
35	10.9563	124.9796	0.94	0.2	0.74	Ruby	December 06, 2014	5Yr
36	10.9496	124.9791	0.93	0.4	0.53	Yolanda	November 08, 2013	5Yr
37	10.9496	124.9791	0.93	0.2	0.73	Ruby	December 06, 2014	5Yr
38	10.9577	124.9813	0.92	3.0	-2.08	Uring	November 05, 1991	5Yr

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date of Occurrence	Rain Return / Scenario
	Lat	Long						
39	10.9577	124.9813	0.92	0.4	0.52	Ruby	December 06, 2014	5Yr
40	10.9577	124.9813	0.92	0.0	0.92	Seniang	December 29, 2014	5Yr
41	10.9438	125.0133	0.91	0.6	0.31	Seniang	December 29, 2014	5Yr
42	10.9428	125.0128	0.88	0.5	0.38	Yolan-da	November 08, 2013	5Yr
43	10.9428	125.0128	0.88	0.5	0.38	Se-niang	December 29, 2014	5Yr
44	10.9557	124.9788	0.87	1.4	-0.53	Uring	November 05, 1991	5Yr
45	10.9557	124.9788	0.87	0.0	0.87	Ruby	December 06, 2014	5Yr
46	10.9496	125.0141	0.79	0.7	0.09	Se-niang	December 29, 2014	5Yr
47	10.9496	125.0141	0.79	0.2	0.59	Yolan-da	November 08, 2013	5Yr
48	10.9580	124.9703	0.75	0.5	0.25	Ruby	December 06, 2014	5Yr
49	10.9580	124.9703	0.75	3.0	-2.25	uring	November 05, 1991	5Yr
50	10.9540	124.9767	0.73	3.0	-2.27	Uring	November 05, 1991	5Yr
51	10.9403	125.0245	0.72	2.0	-1.28	Yolan-da	November 08, 2013	5Yr
52	10.9403	125.0245	0.72	0.7	0.02	Se-niang	December 29, 2014	5Yr
53	10.9403	125.0245	0.72	0.5	0.22	Ruby	December 06, 2014	5Yr
54	10.9556	124.9720	0.72	0.0	0.72	Ruby	December 06, 2014	5Yr
55	10.9556	124.9720	0.72	0.0	0.72	Yolan-da	November 08, 2013	5Yr
56	10.9434	125.0258	0.71	2.2	-1.49	Yolan-da	November 08, 2013	5Yr
57	10.9434	125.0258	0.71	1.1	-0.39	Se-niang	December 29, 2014	5Yr
58	10.9422	125.0256	0.67	0.9	-0.23	Se-niang	December 29, 2014	5Yr
59	10.9422	125.0256	0.67	0.7	-0.03	Ruby	December 06, 2014	5Yr
60	10.9422	125.0256	0.67	0.5	0.17	Yolan-da	November 08, 2013	5Yr
61	10.9433	125.0261	0.67	0.4	0.27	Se-niang	December 29, 2014	5Yr

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date of Occurrence	Rain Return / Scenario
	Lat	Long						
62	10.9527	125.0310	0.67	0.6	0.07	Se-niang	December 29, 2014	5Yr
63	10.9294	125.0309	0.59	1.0	-0.41	Se-niang	December 29, 2014	5Yr
64	10.9554	124.9781	0.59	0.3	0.29	Ruby	December 06, 2014	5Yr
65	10.9620	125.0347	0.55	1.5	-0.95	Se-niang	December 29, 2014	5Yr
66	10.9328	125.0233	0.54	0.2	0.34	Ruby	December 06, 2014	5Yr
67	10.9315	125.0275	0.54	0.3	0.29	Ruby	December 06, 2014	5Yr
68	10.9553	124.9729	0.53	0.0	0.53	Ruby	December 06, 2014	5Yr
69	10.9553	124.9729	0.53	0.5	0.03	uring	November 05, 1991	5Yr
70	10.9592	124.9702	0.52	3.0	-2.48	uring	November 05, 1991	5Yr
71	10.9592	124.9702	0.52	0.0	0.52	Ruby	December 06, 2014	5Yr
72	10.9592	124.9702	0.52	0.0	0.52	Se-niang	December 29, 2014	5Yr
73	10.9504	124.9850	0.52	2.0	-1.48	Uring	November 05, 1991	5Yr
74	10.9448	125.0249	0.50	1.5	-1	Ruby	December 06, 2014	5Yr
75	10.9515	125.0049	0.47	0.0	0.47	Ruby	December 06, 2014	5Yr
76	10.9567	124.9694	0.46	1.0	-0.54	Ruby	December 06, 2014	5Yr
77	10.9567	124.9694	0.46	0.5	-0.04	Se-niang	December 29, 2014	5Yr
78	10.9567	124.9694	0.46	0.3	0.16		Jan-Feb 2016	5Yr
79	10.9571	124.9696	0.46	0.0	0.46	Yolan-da	November 08, 2013	5Yr
80	10.9571	124.9696	0.46	0.0	0.46	Ruby	December 06, 2014	5Yr
81	10.9571	124.9696	0.46	0.8	-0.34	Uring	November 05, 1991	5Yr
82	10.9720	125.0304	0.46	0.5	-0.04	Se-niang	December 29, 2014	5Yr
83	10.9380	125.0231	0.45	0.5	-0.05	Se-niang	December 29, 2014	5Yr
84	10.9496	124.9824	0.45	0.0	0.45	Yolan-da	November 08, 2013	5Yr

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date of Occurrence	Rain Return / Scenario
	Lat	Long						
85	10.9496	124.9824	0.45	0.0	0.45	Ruby	December 06, 2014	5Yr
86	10.9496	124.9824	0.45	1.4	-0.95	Uring	November 05, 1991	5Yr
87	10.9524	124.9833	0.41	1.4	-0.99	Uring	November 05, 1991	5Yr
88	10.9524	124.9833	0.41	0.0	0.41	Ruby	December 06, 2014	5Yr
89	10.9721	125.0046	0.41	0.8	-0.39	Yolan-da	November 08, 2013	5Yr
90	10.9721	125.0046	0.41	0.8	-0.39	Ruby	December 06, 2014	5Yr
91	10.9420	125.0121	0.41	0.5	-0.09	Se-niang	December 29, 2014	5Yr
92	10.9420	125.0121	0.41	0.5	-0.09	Ruby	December 06, 2014	5Yr
93	10.9420	125.0121	0.41	0.5	-0.09	Yolan-da	November 08, 2013	5Yr
94	10.9316	125.0283	0.40	0.0	0.4	Ruby	December 06, 2014	5Yr
95	10.9528	124.9836	0.38	0.0	0.38	Ruby	December 06, 2014	5Yr
96	10.9528	124.9836	0.38	2.0	-1.62	Uring	November 05, 1991	5Yr
97	10.9406	125.0247	0.38	0.7	-0.32	Yolan-da	November 08, 2013	5Yr
98	10.9406	125.0247	0.38	0.5	-0.12	Se-niang	December 29, 2014	5Yr
99	10.9406	125.0247	0.38	0.3	0.08	Ruby	December 06, 2014	5Yr
100	10.9513	125.0023	0.37	0.0	0.37	Ruby	December 06, 2014	5Yr
101	10.9528	125.0259	0.36	1.0	-0.64	Se-niang	December 29, 2014	5Yr
102	10.9553	124.9782	0.35	3.0	-2.65	Uring	November 05, 1991	5Yr
103	10.9553	124.9782	0.35	0.3	0.05	Habag-at	Jan-Feb 2016	5Yr
104	10.9288	125.0307	0.33	0.0	0.33	Ruby	December 06, 2014	5Yr
105	10.9352	125.0205	0.33	0.1	0.23	Ruby	December 06, 2014	5Yr
106	10.9231	124.9879	0.31	0.6	-0.29	Ruby	December 06, 2014	5Yr
107	10.9504	125.0119	0.29	0.1	0.19	Yolan-da	November 08, 2013	5Yr

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date of Occurrence	Rain Return / Scenario
	Lat	Long						
108	10.9622	125.0348	0.28	0.5	-0.22	Se-niang	December 29, 2014	5Yr
109	10.9590	125.0304	0.26	0.4	-0.14	Se-niang	December 29, 2014	5Yr
110	10.9630	124.9885	0.25	0.6	-0.35	Ruby	December 06, 2014	5Yr
111	10.9630	124.9885	0.25	0.6	-0.35	Se-niang	December 29, 2014	5Yr
112	10.9134	125.0098	0.25	0.4	-0.15	Ruby	December 06, 2014	5Yr
113	10.9138	125.0085	0.25	0.0	0.25	Ruby	December 06, 2014	5Yr
114	10.9595	124.9694	0.23	0.2	0.03	Ruby	December 06, 2014	5Yr
115	10.9595	124.9694	0.23	0.2	0.03	Se-niang	December 29, 2014	5Yr
116	10.9300	124.9820	0.22	0.2	0.02	Ruby	December 06, 2014	5Yr
117	10.9141	125.0095	0.22	0.0	0.22	Ruby	December 06, 2014	5Yr
118	10.9594	124.9684	0.21	0.0	0.21	Ruby	December 06, 2014	5Yr
119	10.9594	124.9684	0.21	0.0	0.21	Rain	Jan-Feb 2016	5Yr
120	10.9313	125.0040	0.20	1.4	-1.2	Ruby	December 06, 2014	5Yr
121	10.9343	124.9909	0.20	0.4	-0.2	Se-niang	December 29, 2014	5Yr
122	10.9329	124.9900	0.20	0.7	-0.5	Ruby	December 06, 2014	5Yr
123	10.9306	124.9816	0.20	1.7	-1.5	Ruby	December 06, 2014	5Yr
124	10.9645	125.0038	0.18	0.9	-0.72	Se-niang	December 29, 2014	5Yr
125	10.9318	125.0260	0.18	0.0	0.18	Ruby	December 06, 2014	5Yr
126	10.9300	125.0068	0.16	0.0	0.16	Ruby	December 06, 2014	5Yr
127	10.9727	124.9656	0.16	0.4	-0.24	Ruby	December 06, 2014	5Yr
128	10.9727	124.9656	0.16	0.4	-0.24	Se-niang	December 29, 2014	5Yr
129	10.9622	124.9759	0.16	0.3	-0.14	Ruby	December 06, 2014	5Yr
130	10.9622	124.9759	0.16	0.3	-0.14	Se-niang	December 29, 2014	5Yr

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date of Occurrence	Rain Return / Scenario
	Lat	Long						
131	10.9622	124.9759	0.16	0.8	-0.64	Yolan-da	November 08, 2013	5Yr
132	10.9715	124.9888	0.16	0.0	0.16	Yolan-da	November 08, 2013	5Yr
133	10.9715	124.9888	0.16	0.0	0.16	Ruby	December 06, 2014	5Yr
134	10.9732	124.9948	0.15	0.8	-0.65	Ruby	December 06, 2014	5Yr
135	10.9732	124.9948	0.15	0.8	-0.65	Se-niang	December 29, 2014	5Yr
136	10.9732	124.9948	0.15	0.3	-0.15	Rain	Jan-Feb 2016	5Yr
137	10.9428	124.9759	0.15	0.0	0.15	Ruby	December 06, 2014	5Yr
138	10.9690	125.0347	0.14	0.5	-0.36	Ruby	December 06, 2014	5Yr
139	10.9591	125.0351	0.14	0.4	-0.21	Se-niang	December 29, 2014	5Yr
140	10.9591	125.0351	0.14	0.2	-0.06	Ruby	December 06, 2014	5Yr
141	10.9714	124.9677	0.14	0.3	-0.16	Rain	Jan-Feb 2016	5Yr
142	10.9177	124.9763	0.13	0.5	-0.37	Ruby	December 06, 2014	5Yr
143	10.9710	124.9700	0.13	0.0	0.13	Ruby	December 06, 2014	5Yr
144	10.9710	124.9700	0.13	0.0	0.13	Se-niang	December 29, 2014	5Yr
145	10.9611	124.9840	0.13	0.4	-0.27	Ruby	December 06, 2014	5Yr
146	10.9686	124.9785	0.13	0.2	-0.07	Rain	Jan-Feb 2016	5Yr
147	10.9686	124.9785	0.13	0.4	-0.27	Ruby	December 06, 2014	5Yr
148	10.9686	124.9785	0.13	0.3	-0.17	Se-niang	December 29, 2014	5Yr
149	10.9686	124.9785	0.13	0.4	-0.27	Yolan-da	November 08, 2013	5Yr
150	10.9349	124.9911	0.12	0.0	0.12	Ruby	December 06, 2014	5Yr
151	10.9325	124.9831	0.11	0.3	-0.19	Ruby	December 06, 2014	5Yr
152	10.9591	124.9685	0.11	0.2	-0.09	Rain	Jan-Feb 2016	5Yr
153	10.9591	124.9685	0.11	0.4	-0.29	Ruby	December 06, 2014	5Yr

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date of Occurrence	Rain Return / Scenario
	Lat	Long						
154	10.9591	124.9685	0.11	0.4	-0.29	Se-niang	December 29, 2014	5Yr
155	10.9766	124.9908	0.11	0.4	-0.29	Ruby	December 06, 2014	5Yr
156	10.9766	124.9908	0.11	0.6	-0.49	Yolan-da	November 08, 2013	5Yr
157	10.9766	124.9908	0.11	0.3	-0.19	Rain	Jan-Feb 2016	5Yr
158	10.9766	124.9908	0.11	2.0	-1.89	Uring	November 05, 1991	5Yr
159	10.9724	125.0301	0.10	1.0	-0.9	Yolan-da	November 08, 2013	5Yr
160	10.9724	125.0301	0.10	0.5	-0.4	Ruby	December 06, 2014	5Yr
161	10.9724	125.0301	0.10	0.1	0	Se-niang	December 29, 2014	5Yr
162	10.9608	125.0358	0.10	0.3	-0.2	Ruby	December 06, 2014	5Yr
163	10.9774	124.9910	0.10	0.5	-0.4	Se-niang	December 29, 2014	5Yr
164	10.9774	124.9910	0.10	0.5	-0.4	Ruby	December 06, 2014	5Yr
165	10.9774	124.9910	0.10	0.5	-0.4	Rain	Jan-Feb 2016	5Yr
166	10.9603	125.0000	0.10	0.2	-0.1	Ruby	December 06, 2014	5Yr
167	10.9603	125.0000	0.10	0.2	-0.1	Se-niang	December 29, 2014	5Yr
168	10.9326	124.9949	0.10	0.0	0.1	Ruby	December 06, 2014	5Yr
169	10.9333	124.9813	0.10	0.1	0	Ruby	December 06, 2014	5Yr
170	10.9429	124.9772	0.10	0.5	-0.4	Ruby	December 06, 2014	5Yr
171	10.9600	124.9739	0.09	0.8	-0.71	Se-niang	December 29, 2014	5Yr
172	10.9730	125.0301	0.09	0.2	-0.11	Ruby	December 06, 2014	5Yr
173	10.9730	125.0301	0.09	0.5	-0.41	Se-niang	December 29, 2014	5Yr
174	10.9544	125.0026	0.09	0.0	0.09	Ruby	December 06, 2014	5Yr
175	10.9331	124.9848	0.09	0.8	-0.71	Ruby	December 06, 2014	5Yr
176	10.9312	125.0295	0.08	0.8	-0.72	Se-niang	December 29, 2014	5Yr

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date of Occurrence	Rain Return / Scenario
	Lat	Long						
177	10.9186	124.9854	0.08	0.6	-0.52	Ruby	December 06, 2014	5Yr
178	10.9168	124.9839	0.08	1.3	-1.17	Ruby	December 06, 2014	5Yr
179	10.9194	124.9758	0.08	0.6	-0.52	Ruby	December 06, 2014	5Yr
180	10.9601	124.9961	0.08	0.5	-0.42	Yolan-da	November 08, 2013	5Yr
181	10.9601	124.9961	0.08	0.5	-0.42	Ruby	December 06, 2014	5Yr
182	10.9601	124.9961	0.08	0.5	-0.42	Rain	Jan-Feb 2016	5Yr
183	10.9611	125.0032	0.08	0.0	0.08	Ruby	December 06, 2014	5Yr
184	10.9587	125.0082	0.08	0.2	-0.12	Se-niang	December 29, 2014	5Yr
185	10.9535	125.0229	0.08	0.0	0.08	Ruby	December 06, 2014	5Yr
186	10.9366	124.9764	0.07	1.0	-0.88	Ruby	December 06, 2014	5Yr
187	10.9168	124.9831	0.07	0.9	-0.83	Ruby	December 06, 2014	5Yr
188	10.9322	125.0252	0.06	0.2	-0.09	Ruby	December 06, 2014	5Yr
189	10.9402	124.9628	0.06	0.0	0.06	Ruby	December 06, 2014	5Yr
190	10.9615	125.0028	0.06	0.2	-0.14	Se-niang	December 29, 2014	5Yr
191	10.9568	125.0301	0.06	0.5	-0.44	Se-niang	December 29, 2014	5Yr
192	10.9633	124.9852	0.05	0.0	0.05	Ruby	December 06, 2014	5Yr
193	10.9633	124.9852	0.05	0.0	0.05	Yolan-da	November 08, 2013	5Yr
194	10.9625	125.0319	0.05	0.1	-0.05	Se-niang	December 29, 2014	5Yr
195	10.9305	125.0054	0.05	0.0	0.05	Ruby	December 06, 2014	5Yr
196	10.9327	124.9970	0.04	0.6	-0.56	Ruby	December 06, 2014	5Yr
197	10.9396	124.9745	0.04	0.0	0.04	Ruby	December 06, 2014	5Yr
198	10.9440	124.9751	0.04	0.0	0.04	Ruby	December 06, 2014	5Yr
199	10.9432	124.9682	0.04	1.0	-0.96	Ruby	December 06, 2014	5Yr

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date of Occurrence	Rain Return / Scenario
	Lat	Long						
200	10.9373	124.9685	0.04	0.5	-0.46	Ruby	December 06, 2014	5Yr
201	10.9373	124.9695	0.04	0.0	0.04	Ruby	December 06, 2014	5Yr
202	10.9452	125.0253	0.04	1.0	-0.96	Se-niang	December 29, 2014	5Yr
203	10.9452	125.0253	0.04	1.0	-0.96	Se-niang	December 29, 2014	5Yr
204	10.9701	124.9741	0.04	0.2	-0.16	Ruby	December 06, 2014	5Yr
205	10.9691	124.9772	0.04	0.5	-0.46	Ruby	December 06, 2014	5Yr
206	10.9691	124.9772	0.04	0.6	-0.56	Se-niang	December 29, 2014	5Yr
207	10.9691	124.9772	0.04	0.8	-0.76	Yolan-da	November 08, 2013	5Yr
208	10.9691	124.9772	0.04	0.2	-0.16	Rain	Jan-Feb 2016	5Yr
209	10.9608	124.9938	0.04	0.0	0.04	Ruby	December 06, 2014	5Yr
210	10.9337	125.0222	0.03	0.0	0.03	Ruby	December 06, 2014	5Yr
211	10.9324	124.9937	0.03	1.1	-1.07	Ruby	December 06, 2014	5Yr
212	10.9445	124.9713	0.03	1.0	-0.97	Ruby	December 06, 2014	5Yr
213	10.9683	125.0343	0.03	0.0	0.03	Ruby	December 06, 2014	5Yr
214	10.9708	125.0356	0.03	1.5	-1.47	Yolan-da	November 08, 2013	5Yr
215	10.9718	125.0326	0.03	0.1	-0.07	Ruby	December 06, 2014	5Yr
216	10.9712	125.0297	0.03	0.5	-0.47	Se-niang	December 29, 2014	5Yr
217	10.9712	125.0297	0.03	0.5	-0.47	Yolan-da	November 08, 2013	5Yr
218	10.9653	125.0052	0.03	0.5	-0.47	Se-niang	December 29, 2014	5Yr
219	10.9603	125.0005	0.03	0.5	-0.47	Se-niang	December 29, 2014	5Yr
220	10.9573	125.0111	0.03	0.3	-0.27	Se-niang	December 29, 2014	5Yr
221	10.9573	125.0111	0.03	0.2	-0.17	Ruby	December 06, 2014	5Yr
222	10.9559	125.0159	0.03	0.0	0.03	Ruby	December 06, 2014	5Yr

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date of Occurrence	Rain Return / Scenario
	Lat	Long						
223	10.9547	125.0190	0.03	0.0	0.03	Ruby	December 06, 2014	5Yr
224	10.9478	125.0278	0.03	1.0	-0.97	Se-niang	December 29, 2014	5Yr
225	10.9478	125.0278	0.03	1.0	-0.97	Ruby	December 06, 2014	5Yr
226	10.9493	125.0285	0.03	0.2	-0.17	Yolan-da	November 08, 2013	5Yr
227	10.9520	125.0286	0.03	1.0	-0.97	Se-niang	December 29, 2014	5Yr
228	10.9520	125.0286	0.03	0.5	-0.47	Ruby	December 06, 2014	5Yr
229	10.9518	125.0296	0.03	0.0	0.03	Ruby	December 06, 2014	5Yr
230	10.9559	125.0300	0.03	0.0	0.03	Yolan-da	November 08, 2013	5Yr
231	10.9588	125.0308	0.03	0.5	-0.47	Yolan-da	November 08, 2013	5Yr
232	10.9630	125.0365	0.03	1.5	-1.47	Uring	November 05, 1991	5Yr
233	10.9701	124.9741	0.03	0.5	-0.47	Rain	Jan-Feb 2016	5Yr
234	10.9701	124.9741	0.03	0.5	-0.47	Rain	Jan-Feb 2016	5Yr
235	10.9701	124.9741	0.03	0.8	-0.77	Ruby	December 06, 2014	5Yr
236	10.9700	124.9741	0.03	0.5	-0.47	Rain	Jan-Feb 2016	5Yr
237	10.9700	124.9741	0.03	0.8	-0.77	Ruby	December 06, 2014	5Yr
238	10.9619	124.9739	0.03	0.0	0.03	Se-niang	December 29, 2014	5Yr
239	10.9606	124.9743	0.03	0.8	-0.77	Rain	Jan-Feb 2016	5Yr
240	10.9606	124.9743	0.03	1.0	-0.97	Ruby	December 06, 2014	5Yr
241	10.9606	124.9743	0.03	1.0	-0.97	Yolan-da	November 08, 2013	5Yr
242	10.9672	124.9869	0.03	0.0	0.03	Yolan-da	November 08, 2013	5Yr
243	10.9672	124.9869	0.03	0.0	0.03	Ruby	December 06, 2014	5Yr
244	10.9753	124.9920	0.03	0.8	-0.77	Rain	Jan-Feb 2016	5Yr
245	10.9753	124.9920	0.03	0.2	-0.17	Ruby	December 06, 2014	5Yr

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date of Occurrence	Rain Return / Scenario
	Lat	Long						
246	10.9723	124.9993	0.03	0.0	0.03	Ruby	December 06, 2014	5Yr
247	10.9723	124.9993	0.03	0.5	-0.47	Se-niang	December 29, 2014	5Yr
248	10.9722	124.9994	0.03	0.5	-0.47	Ruby	December 06, 2014	5Yr
249	10.9722	124.9994	0.03	0.8	-0.77	Se-niang	December 29, 2014	5Yr
250	10.9634	124.9886	0.03	0.0	0.03	Ruby	December 06, 2014	5Yr
251	10.9651	124.9848	0.03	0	0.03	Ruby	December 06, 2014	5Yr
252	10.9671	124.9807	0.03	0.5	-0.47	Ruby	December 06, 2014	5Yr
253	10.9671	124.9807	0.03	0.5	-0.47	Rain	Jan-Feb 2016	5Yr
254	10.9673	124.98084	0.03	0	0.03	Ruby	December 06, 2014	5Yr
255	10.9716	125.0342	0	1	-1	Yolan-da	November 08, 2013	5Yr

Annex 12. Educational Institutions affected by flooding in Daguitan- Marabong Floodplain

LEYTE				
DULAG				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Alegre Elementary School	Alegre		Low	Low
Brgy. Alegre Day Care Center	Alegre			Low
Salvacion Elementary School	Alegre			Low
Cabarasan eEementary School	Arado	Medium	High	High
Day Care Center	Arado			Low
BRGY. CATMONAN DAY CARE CENTER	Buntay	Low	Low	Low
DULAG CENTRAL SCHOOL	Buntay	Low	Low	Low
Dulag National High School	Buntay	Low	Low	Low
DULAG SPEED CENTER	Buntay			Low
RALPHS LEARNING CENTER	Buntay			
Cabacungan Elementary School	Cabacungan			
Cabangcungan National High School	Cabacungan	Low	Medium	Medium
Calipayan Elementary School	Calipayan			
BARBO ELEMENTARY SCHOOL	Cambula District	Low	Low	Low
Day Care Center	Cambula District			Low
DULAG CHILD DEVELOPMENT CENTER INC.	Cambula District			
BRGY. CAMBULA DAY CARE CENTER	Candao			
NUESTRA SEÑORA DEL REFUGIO PAROCHIAL SCHOOL INC.	Candao			
San Miguel Elementary School	Catmonan	Low	Low	Low
Calipayan Elementary School	Del Pilar			Low
Day Care Center	Del Pilar			
Brgy. Day Care Center	Fatima		Low	Low
Fatima Elementary School	Fatima			
Day Care Center	General Roxas			
MAGSAYSAY ELEMENTARY SCHOOL	Magsaysay			
Cabato-an Elementary School	Maricum			
Tabu Elementary School	Maricum			Low
Rawis Elementary School	Rawis			Low
Rizal Elementary School	Rizal			

Rizal National High School	Rizal			
Brgy. Day Care Center	Sabang Daguitan		Medium	Medium
Sabang Elementary School	Sabang Daguitan	Medium	Medium	High
GEN. ROXAS ELEMENTARY SCHOOL	San Antonio			Low
Day Care Center	San Vicente	Medium	Medium	Medium
Eastern Visayas State University Dulag Campus	San Vicente			
FRANCISCO DUMAGUIT MEMORIAL ELEMENTARY SCHOOL	San Vicente			
San Vicente Elementary School	San Vicente	Low	Low	Low
DULAG CENTRAL SCHOOL	Sungi		Low	Low
Dulag National High School	Sungi	Low	Low	Low
M.H. DEL PILAR ELEMENTARY SCHOOL	Tabu			
Day Care Center	Victory	Low	Medium	Medium
Eastern Visayas State University Dulag Campus	Victory			
Victory Elementary School	Victory	Medium	Medium	Medium

LEYTE				
JULITA				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
ARADO PRIMARY SCHOOL	Bonifacio	Medium	Medium	High
Day Care Center	Bonifacio	Medium	High	High
Cabato-an Elementary School	Poblacion District III	Low	Low	Low
MARICUM PRIMARY SCHOOL	Poblacion District III	Low	Medium	Medium
JULITA NATIONAL HIGH SCHOOL	Poblacion District IV			Low
Batug Elementary School	Tagkip			
Day Care Center	Tagkip			
Day Care Center	Tolosahay			
Del Carmen Primary School	Tolosahay			
Tolosahay Elementary School	Tolosahay			

LEYTE				
MAYORGA				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Talisay Elementary School	Talisay			

Annex 13. Health Institutions affected by flooding in Daguitan Floodplain

LEYTE				
DULAG				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Ruqayyah's Birthing Clinic	Cabacungan			
HEALTH CARE CENTER	Cambula District	Low	Low	Low
HEALTH CENTER	Maricum			Low
Brgy. Health Center	Rizal		Low	Medium
BRGY. CAMBIS HEALTH CENTER	San Vicente	Low	Low	Medium
PRIVATE CLINIC DR. MANTE	Sungi			Low