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

LiDAR Surveys and Flood Mapping of Das-ay River

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

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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 DAS-AY 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 in 2014 entitled “Nationwide Hazard Mapping using LiDAR” or Phil-LiDAR 1, supported by the Department of Science and Technology (DOST) Grants-in-Aid (GiA) Program. The program was primarily aimed at acquiring a national elevation and resource dataset at sufficient resolution to produce information necessary to support the different phases of disaster management. Particularly, it targeted to operationalize the development of flood hazard models that would produce updated and detailed flood hazard maps for the major river systems in the country.

Also, the program was aimed at producing an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through DOST. The methods applied in this report are thoroughly described in a separate publication entitled “FLOOD MAPPING OF RIVERS IN THE PHILIPPINES USING AIRBORNE LIDAR: METHODS (Paringit, et. al. 2017) available separately.

The implementing partner university for the Phil-LiDAR 1 Program is the Visayas State University (VSU). 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 28 river basins in the Eastern Visayas Region. The university is located in Baybay City in the province of Leyte.

1.2 Overview of the Das-ay River Basin

Das-ay River Basin covers five (5) municipalities in Southern Leyte (8) namely: Hinunangan, Hinundayan, Anahawan, Saint Bernard. According to DENR -River Basin Control Office, it has a drainage area of 103 km2 and an estimated 196 million cubic meter (MCM) annual run-off of (RCBO, 2015).

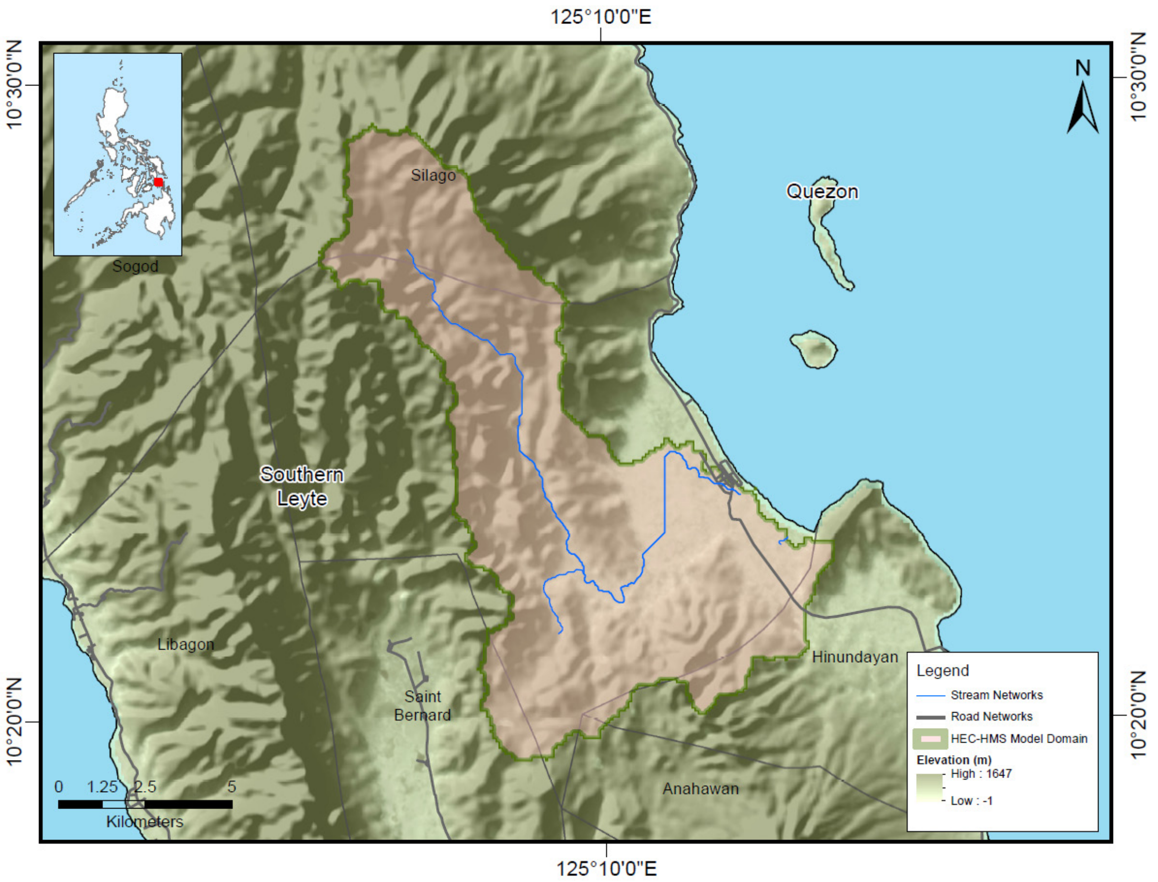

Figure 1. Map of Das-ay River Basin (in brown).

Its main stem, Bisay River, also called by the locals as Das-Ay River, is part of the 28 river systems under the PHIL-LiDAR 1 partner HEI, Visayas State University. According to the 2010 national census of NSO, a total of 7,624 locals are residing in the immediate vicinity of the river which are distributed among the eleven barangays in Municipality of Hinunangan. Farming and fishing are the two major sources of income in the area. Coconut, rice, banana, root crops, fruits and vegetables are the major crops that they produce. According to the Southern Leyte government official website, municipal fishing in Hinunangan contributed 51 percent of the total volume of fish production in Southern Leyte in 2007 (http://www.southernleyte.gov.ph/general-information/179-local-economy, 2015). There are also quarrying firms in the area of the river. The most recent and significant flooding in the area was on November 2013 cause by typhoon Haiyan "Yolanda" (https://newcomfeatsay.wordpress.com/2014/01/29/super-typhoon-yolanda-wrought-great-damages-in-southern-leyte/, 2014).

CHAPTER 2: LIDAR DATA ACQUISITION OF THE DAS-AY FLOODPLAIN

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

2.1 Flight Plans

To initiate the LiDAR acquisition survey of the Das-ay floodplain, the Data Acquisition Component (DAC) created flight plans within the delineated priority area for Das-ay Floodplain in Leyte and Southern Leyte. These flight missions were planned for 21 lines and ran for at most four hours (4) including take-off, landing and turning time using two sensors – the Gemini and Aquarius (see Annex 1 for sensor specifications). The flight planning parameters for the LiDAR system are outlined in Table 1 and Table 2. Figure 2 and Figure 3, on the other hand, show the flight plan for Das-ay floodplain survey.

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)
BLK50A	600	35	36	50	45	120	5
BLK50B	600	35	36	50	45	120	5
BLK50C	500	35	36	50	45	120	5
BLK50D	500	35	36	50	45	120	5
BLK50E	500	35	36	50	45	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)
BLK34aC	1000	30	36	100	50	120	5
BLK34aB	1000	30	36	100	50	120	5
BLK 34B	1000/850	30	36/40	100	50	120	5
BLK 49A	1000/850	30	36/40	100	50	120	5
BLK 49B	1000/850	30	36/40	100	50	120	5
BLK50A	1000	30	36	100	50	120	5
BLK50B	1000/850	30	36/40	100	50	120	5
BLK50C	1000/850	30	36/40	100	50	120	5
BLK50D	850	30	50	50	40	120	5

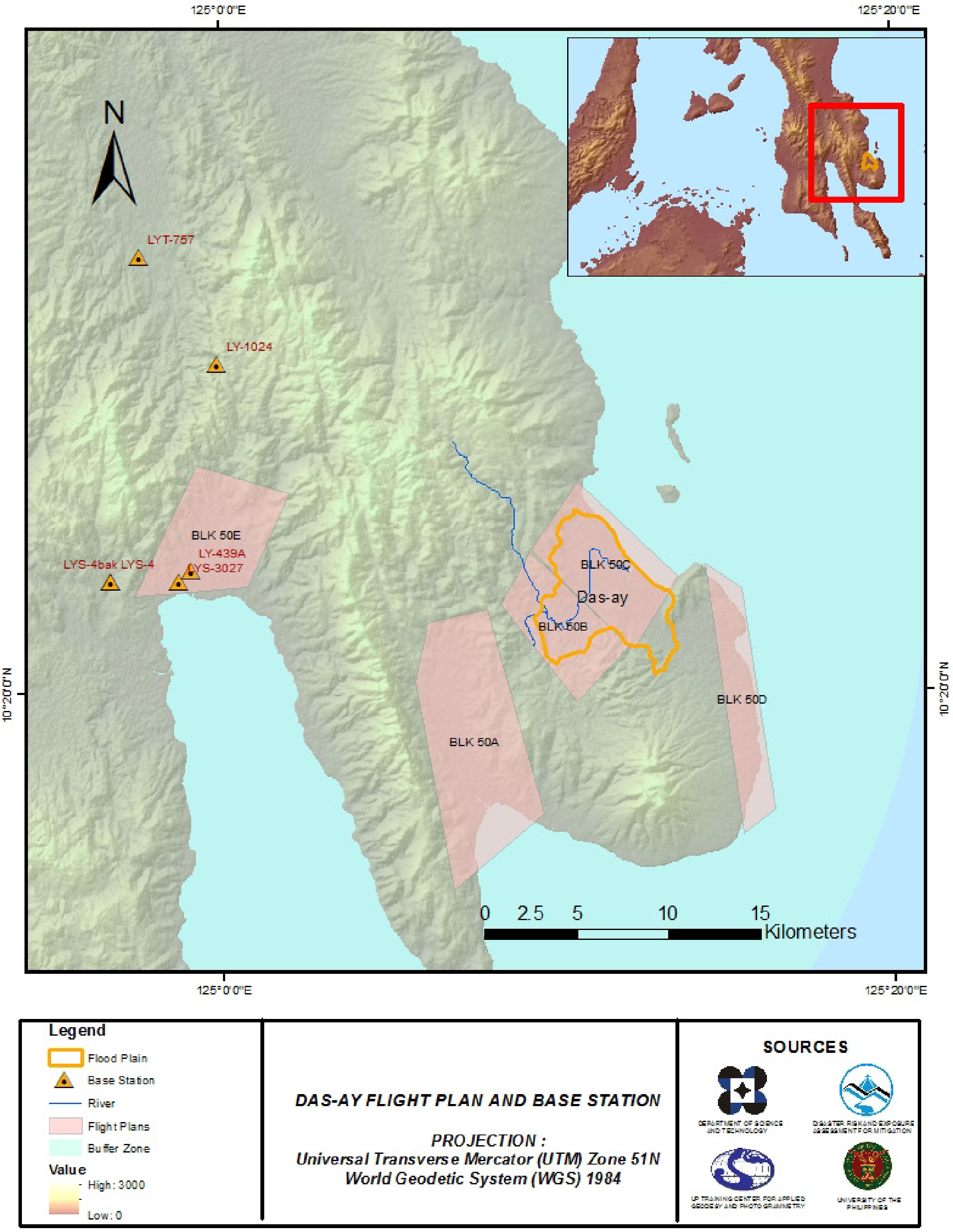


Figure 2. Flight plans and base stations used for Das-ay floodplain using the Aquarius sensor.

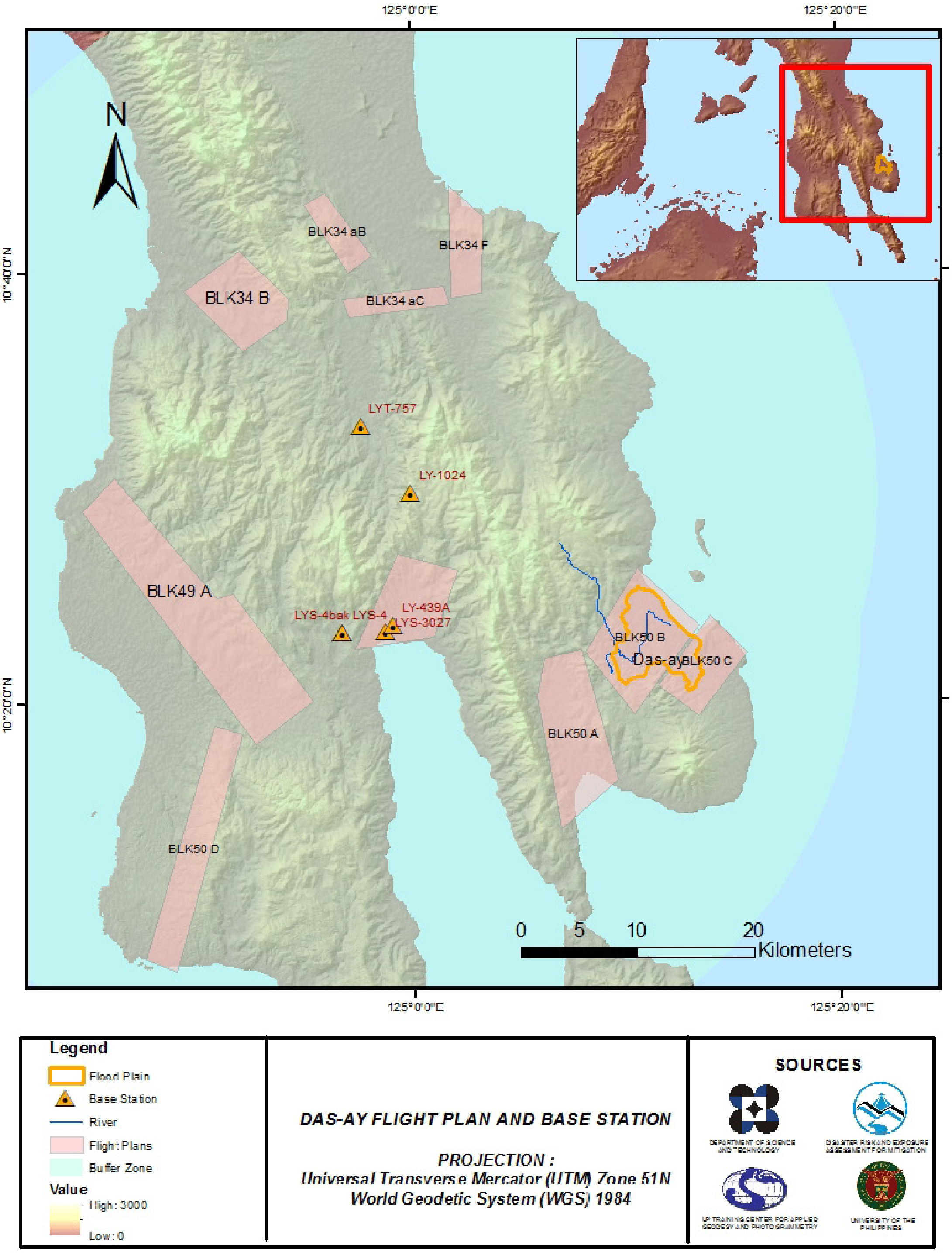


Figure 3. Flight plans and base stations used for Das-ay floodplain using the Gemini sensor.

2.2 Ground Base Stations

The project team was able to recover two (2) NAMRIA ground control points, LYT-757 which is of second (2nd) order accuracy and LYS-4 which is of first (1st) order accuracy. The project team also established two (2) ground control points LYS-4bak and LY-439a, and re-processed one (1) benchmark LY-1024 and one (1) NAMRIA reference point of fourth (4th) order accuracy LYS-3027.

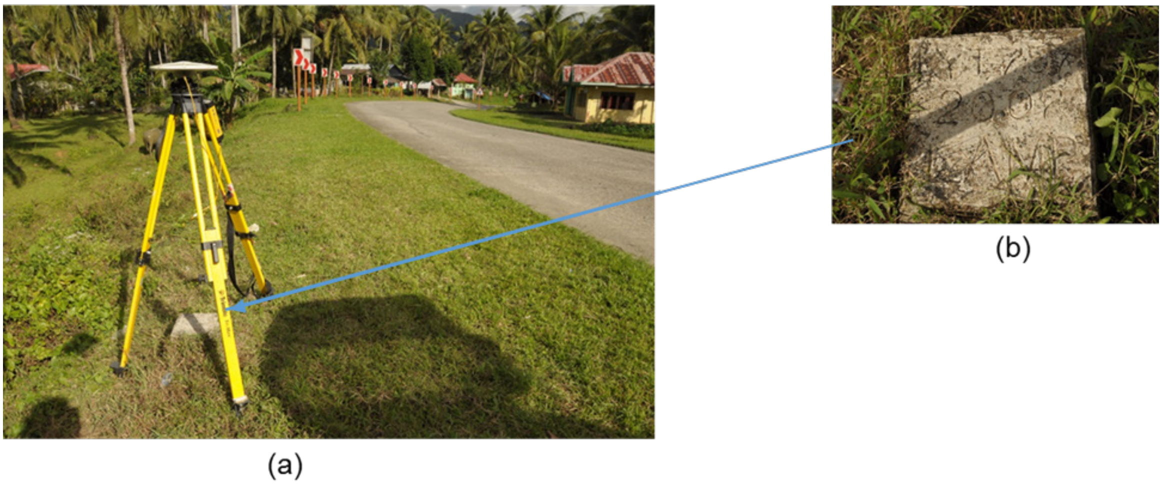
The certification for the NAMRIA reference points and benchmarks are found in Annex 2 while the baseline processing reports for the established control points are found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey from January 21 to February 19, 2015, February 4 to 18, 2016, and April 6 to 20, 2016. Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852, and TRIMBLE SPS 985. Flight plans and location of base stations used during the aerial LiDAR acquisition in Das-ay floodplain are shown in Figure 2 and Figure 3.

The succeeding sections depict the sets of reference points, control stations and established points, and the ground control points for the entire Das-ay Floodplain LiDAR Survey. Figure 4 to Figure 6 show the recovered NAMRIA reference points within the area of the floodplain, while Table 3 to Table 8 show the details about the following NAMRIA control stations and established points occupide during the acquisition together with the corresponding dates of utilization.

Figure 4. GPS set-up over LY-1024 located at the SE end of the sidewalk of Agas-agas Bridge at KM post 1006 + 972.6 and 4 meters from the road centerline (a); and NAMRIA reference point LY-1024 (b) as recovered by the field team.

Table 3. Details of the reprocessed NAMRIA horizontal control point LY-1024 used as base station for the LiDAR acquisition.

Station Name	**LY-1024**	
Order of Accuracy	**2nd order**	
Relative Error (Horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 29' 46.27905" North 124° 59' 49.85591" East 366.202 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 29' 42.20218" North 124° 59' 55.07713" East 430.223 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	718586.237 meters 1160895.197 meters



(b)

(a)

Figure 5. GPS set-up over LYT-757 as recovered on the opposite side of the kilometer post 997 in barangay Mahayahay, Leyte (a); and NAMRIA reference point LYT-757 (b) as recovered by the field team.

Table 4. Details of the recovered NAMRIA horizontal control point LYT-757 used as base station for the LiDAR acquisition.

Station Name	**LYT-757**	
Order of Accuracy	**2nd order**	
Relative Error (Horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 32’ 54.87” North 124° 57’ 31.14” East 99.55 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	495474.491 meters 1166401.318 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 32’ 50.77355” North 124° 57’ 36.36037” East 163.36300 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	714331.34 meters 1166663.62 meters

(a)

(b)

Figure 6. GPS set-up over LYS-3027 inside the campus of Sogod National High School in the Municipality of Sogod, Southern Leyte (a); and NAMRIA reference point LYS-3027 (b) as recovered by the field team.

Table 5. Details of the reprocessed NAMRIA horizontal control point LYS-3027 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	10°23'21.51724'' North 124°58'38.32069'' East 16.531 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10°23'17.46586'' North 124°58'43.55182'' East 78.65700 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	716484.590 meters 1149058.376 meters

Table 6. Details of the recovered NAMRIA horizontal control point LY-439A used as base station for the LiDAR Acquisition.

Station Name	**LY-439**	
Order of Accuracy	**2nd order**	
Relative Error (Horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 23' 39.44046" North 124° 59' 00.17361" East 27.012 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Northing Easting	1574493.218 meters 483231.789 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 23' 35.38833" North 124° 59' 05.40423" East 91.238 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS1992)	Easting Northing	717145.997 meters 1149613.271 meters

Table 7. Details of the recovered NAMRIA horizontal control point LYS-4 used as base station for the LiDAR Acquisition.

Station Name	LYS-4	
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	10°23' 20.19669" North 124° 56' 38.63363" East 15.25600 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Northing Easting	1148746.143 meters 407522.022 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 23' 16.14540" North 124° 56' 43.76469" East 79.47900 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS1992)	Easting Northing	716, 491.34 meters 1,149,017.84 meters

Table 8. Details of the recovered NAMRIA horizontal control point LYS-4bak used as base station for the LiDAR Acquisition.

Station Name	LYS-4bak	
Order of Accuracy	2nd	
Relative Error (Horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 23' 20.14352" North 124° 56' 36.50151" East 15.20700 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Northing Easting	1149016.196 meters 716190.354 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 23' 16.092223" North 124° 56' 43.73267" East 79.430 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS1992)	Easting Northing	716489.354 meters 1149016.196 meters

Table 9. Ground control points used during the LiDAR data acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
February 10, 2016	23773G	2BLK34A041A	LY-1024 and LYT-757
February 9, 2015	7791AC	3BLK50CDE040B	LYS-3027 and LY-439A
May 24, 2014	7768AC	3BLK34O130A	LYS-3027 and LY-439A
February 9, 2015	7790AC	3BLK50B040A	LYS-3027 and LY-439A
April 13, 2016	3933G	2BLK50ABC104A	LYS-4 and LYS-4bak
April 14, 2016	3937G	2BLK50DS105A	LYS-4 and LYS-4bak

2.3 Flight Missions

A total of six (6) missions were conducted to complete the LiDAR data acquisition in Das-ay floodplain, for a total of twenty-three hours and fifty-five (23+55) minutes of flying time for RP-C9322 and RP-C9022 (See Annex 6). All missions were acquired using the Gemini and Aquarius LiDAR systems. As shown below, the total area of actual coverage per mission and the corresponding flying hours are depicted in Table 10, while the actual parameters used during the LiDAR data acquisition are presented in Table 11.

Table 10. Flight missions for LiDAR data acquisition in Das-ay 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 29, 2015	7768AC	64.71	47.92	NA	47.92	0	3	53
February 9, 2015	7790AC	61.06	35.98	27.48	8.5	0	3	47
February 9, 2015	7791AC	95.7	35.98	27.48	8.5	0	3	47
February 10, 2016	23773G	118.15	77.42	16.09	61.33	306	3	23
April 13, 2016	3933G	401.67	324.00	37.738	286.26	0	4	25
April 14, 2016	3937G	401.67	383.85	38.060	345.79	0	4	40
TOTAL		1142.96	905.15	146.85	740.3	306	23	55

Table 11. Actual parameters used during LiDAR data acquisition.

Flight Number	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	PRF (kHz)	Scan Frequency (Hz)	Speed of Plane (Kts)	Average Turn Time (Minutes)
23773G	1000	30	36	100	50	120	5
7791AC	500	35	36	50	45	120	5
7768AC	600	35	36	50	45	120	5
7790AC	600	35	36	50	45	120	5
3933G	1000/850	30	36/40	100	50	120	5
3937G	850	30	50	50	40	120	5

2.4 Survey Coverage

This certain LiDAR acquisition survey covered the Das-ay floodplain (See Annex 7). It is situated within the municipalities of Leyte and Southern Leyte. The municipality of Hinundayan in Southern Leyte is mostly covered during the survey. The list of municipalities and cities surveyed with at least one (1) square kilometer coverage, is shown in Table 12. Figure 7, on the other hand, shows the actual coverage of the LiDAR acquisition for the Das-ay floodplain.

Table 12. List of municipalities and cities surveyed during Das-ay floodplain LiDAR survey.

Province	Municipality/ City	Area of Municipality/City (km²)	Total Area Surveyed (km²)	Percentage of Area Surveyed
Leyte	Bato	57.552	22.526	39.14%
	Hilongos	156.796	58.354	37.222%
	Hindang	106.765	25.174	23.58%
	Matalom	110.125	21.078	19.14%
	Baybay City	404.371	39.176	9.69%
	Inopacan	196.051	16.249	8.29%
Southern Leyte	Hinundayan	53.282	36.852	69.16%
	Hinunangan	136.384	59.750	43.81%
	Saint Bernard	79.682	28.340	35.57%
	Sogod	217.204	40.037	18.43%
	Maasin City	206.856	30.189	14.59%
	Bontoc	89.134	8.711	9.77%
	Anahawan	51.029	3.920	7.68%
Total		1,865.23	390.356	20.93%

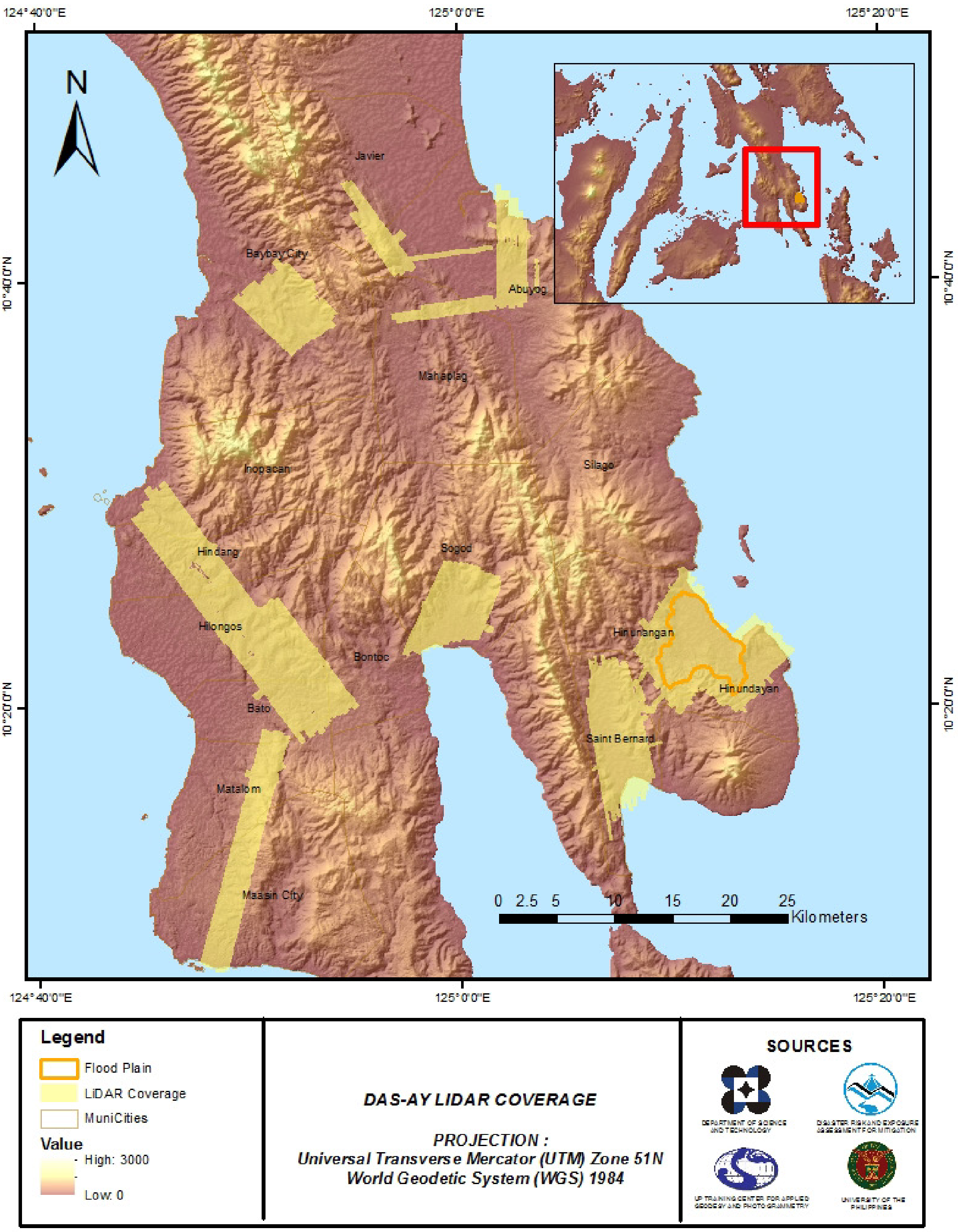


Figure 7. Actual LiDAR survey coverage for Das-ay floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE DAS-AY FLOODPLAIN

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

3.1 Overview of the LiDAR Data Pre-Processing

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

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

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

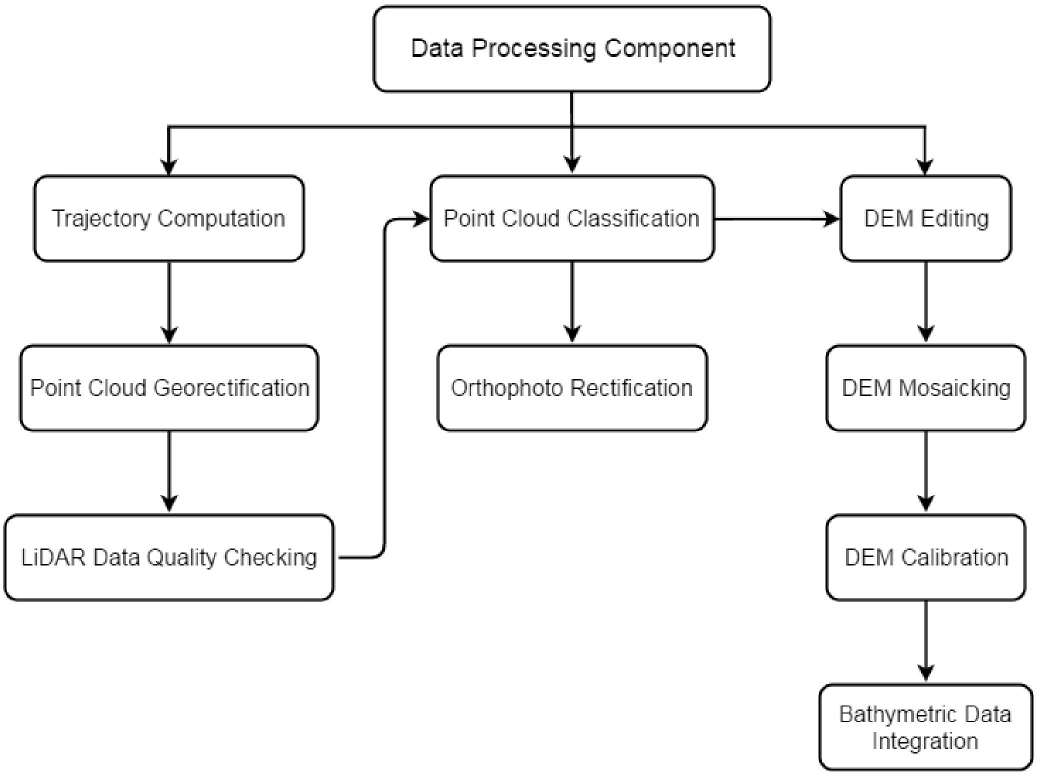


Figure 8. Schematic diagram for the data pre-processing.

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Das-ay floodplain can be found in Annex 5. Missions flown during the first survey conducted on May 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Gemini system while missions acquired during the second survey on February 2015 were flown using the Aquarius and Gemini systems over Hinunangan, Southern Leyte.

The Data Acquisition Component (DAC) transferred a total of 67.29 Gigabytes of Range data, 1.38 Gigabytes of POS data, 17.7 Megabytes of GPS base station data, and 73.5 Gigabytes of raw image data to the data server on May 29, 2014 for the first survey, February 25, 2015 for the second survey, and May 2, 2016 for the third survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Das-ay was fully transferred on May 6, 2016, as indicated on the Data Transfer Sheets for Das-ay floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for flight 7791AC, one of the Das-ay flights, which is the North, East, and Down position RMSE values are shown in Figure 9. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on February 25, 2015 00:00 AM. The y-axis is the RMSE value for that particular position.

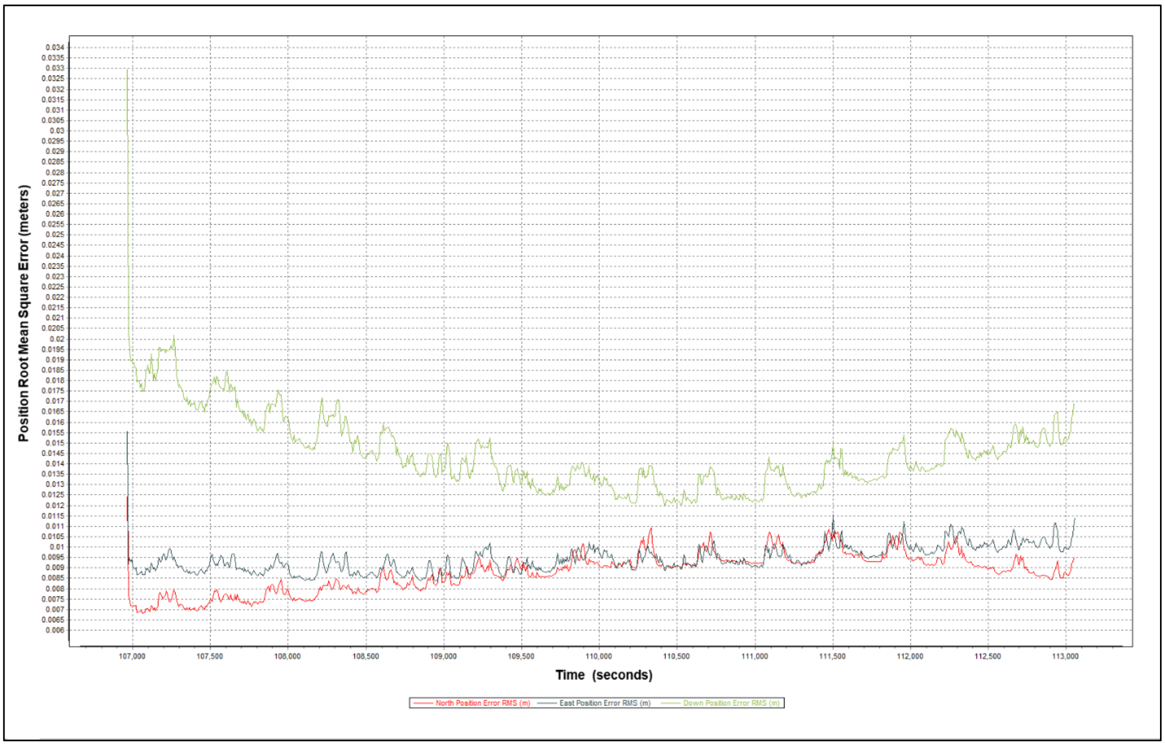


Figure 9. Smoothed Performance Metric Parameters of a Das-ay Flight 7791AC.

The time of flight was from 107,000 seconds to 113,000 seconds, which corresponds to afternoon of February 25, 2015. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft.

Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 9 shows that the North position RMSE peaks at 1.10 centimeters, the East position RMSE peaks at 1.12 centimeters, and the Down position RMSE peaks at 2.00 centimeters, which are within the prescribed accuracies described in the methodology.

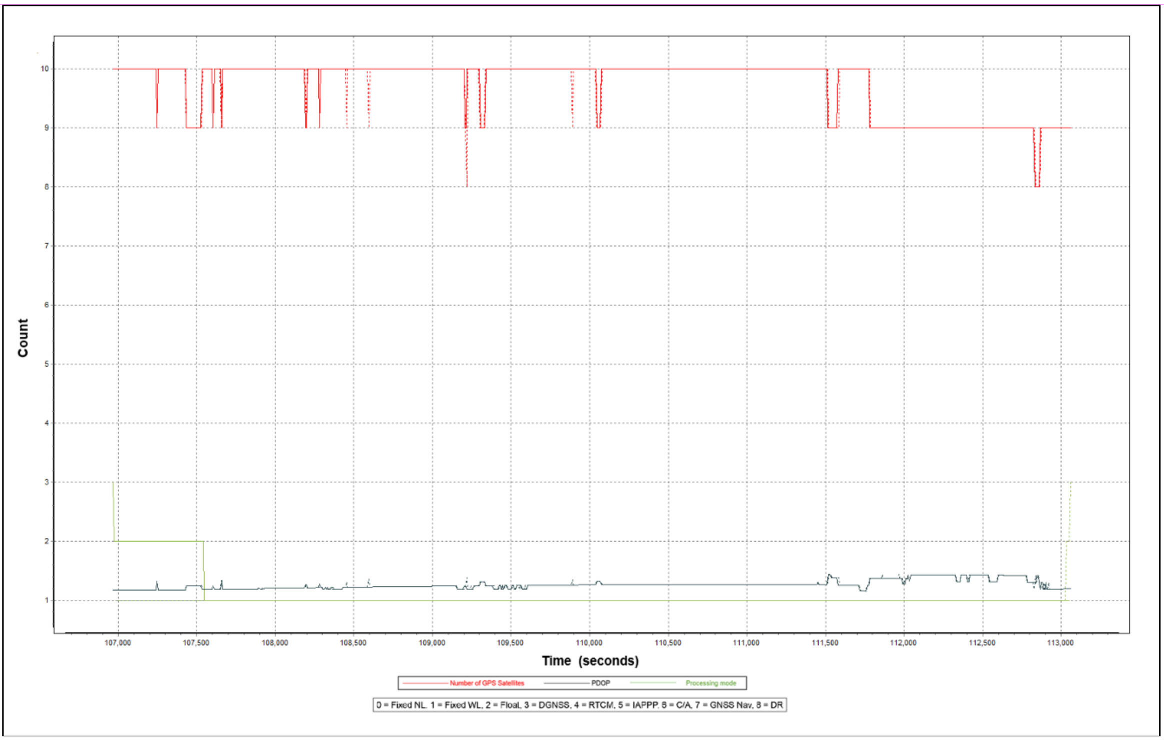


Figure 10. Solution Status Parameters of Das-ay Flight 7791AC.

The Solution Status parameters of flight 7791AC one of the Das-ay flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 10. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Majority of the time, the number of satellites tracked was between 8 and 10. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 2 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Das-ay flights is shown in Figure 11.

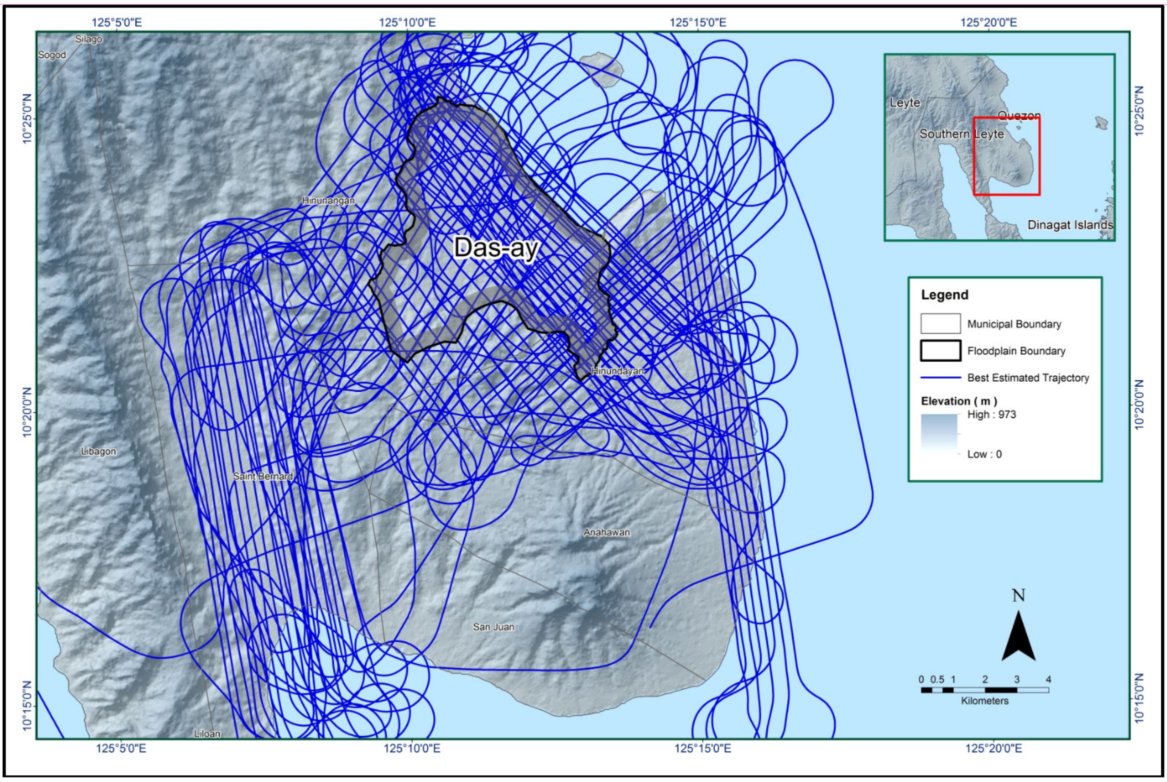


Figure 11. Best Estimated Trajectory of the LiDAR missions conducted over the Das-ay Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS contains 109 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 the Das-ay floodplain are given in Table 13.

Table 13. Self-calibration Results values for Das-ay flights.

Parameter	Acceptable Value	Computed Value
Boresight Correction stdev)	<0.001degrees	0.000384
IMU Attitude Correction Roll and Pitch Corrections stdev)	<0.001degrees	0.000890
GPS Position Z-correction stdev)	<0.01meters	0.0097

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

3.5 LiDAR Data Quality Checking

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

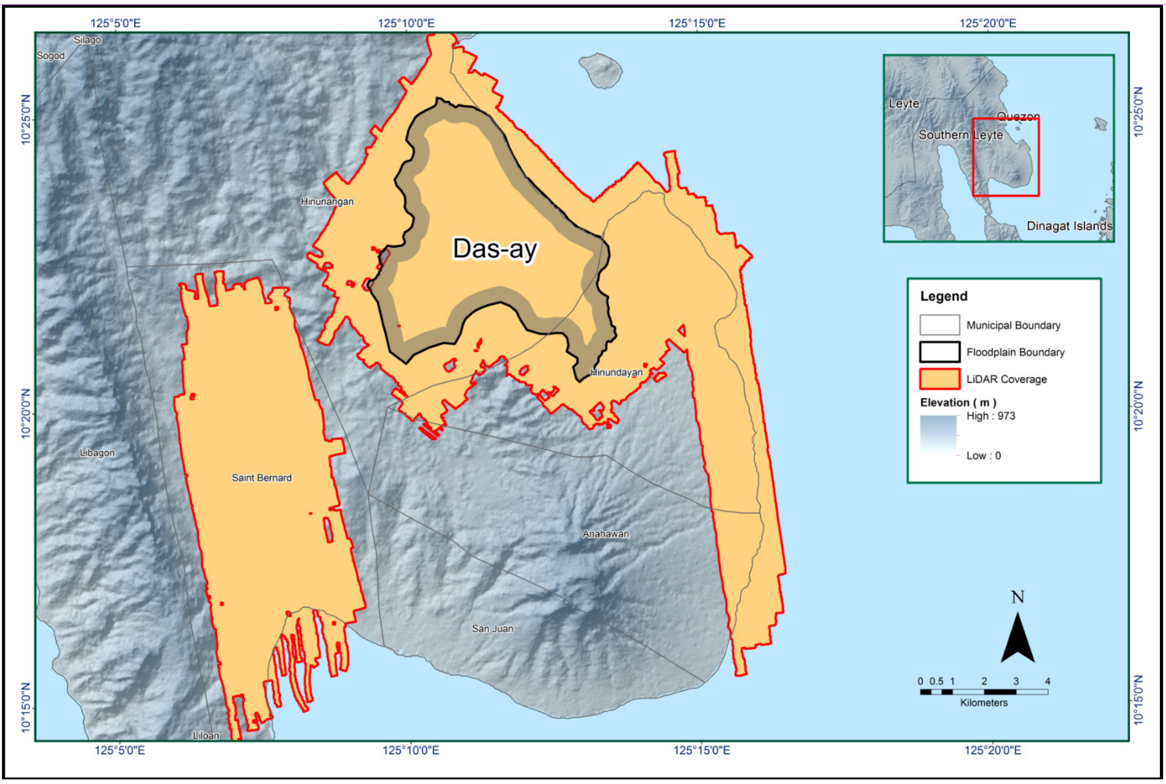


Figure 12. Boundaries of the processed LiDAR data over the Das-ay Floodplain.

The total area covered by the Das-ay missions is 275.91 square kilometers (sq. kms.) that is comprised of seven (7) flight acquisitions grouped and merged into seven (7) blocks as shown in Table 14.

Table 14. List of LiDAR blocks for the Das-ay floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Ormoc_Blk50CDE	7791A	38.44
Ormoc_Blk50A	7268A	44.12
Ormoc_Blk50B	7790A	33.85
Ormoc_South_Blk50B	3933G	25.41
Ormoc_South_Blk50A	3933G	79.15
Ormoc_South_Blk50A_supplement	3937G	35.51
Leyte_Blk50A	23773G	19.43
TOTAL		**275.91 sq.km**

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 13. Since the Gemini and Aquarius systems both employ one channel, we would expect an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines.

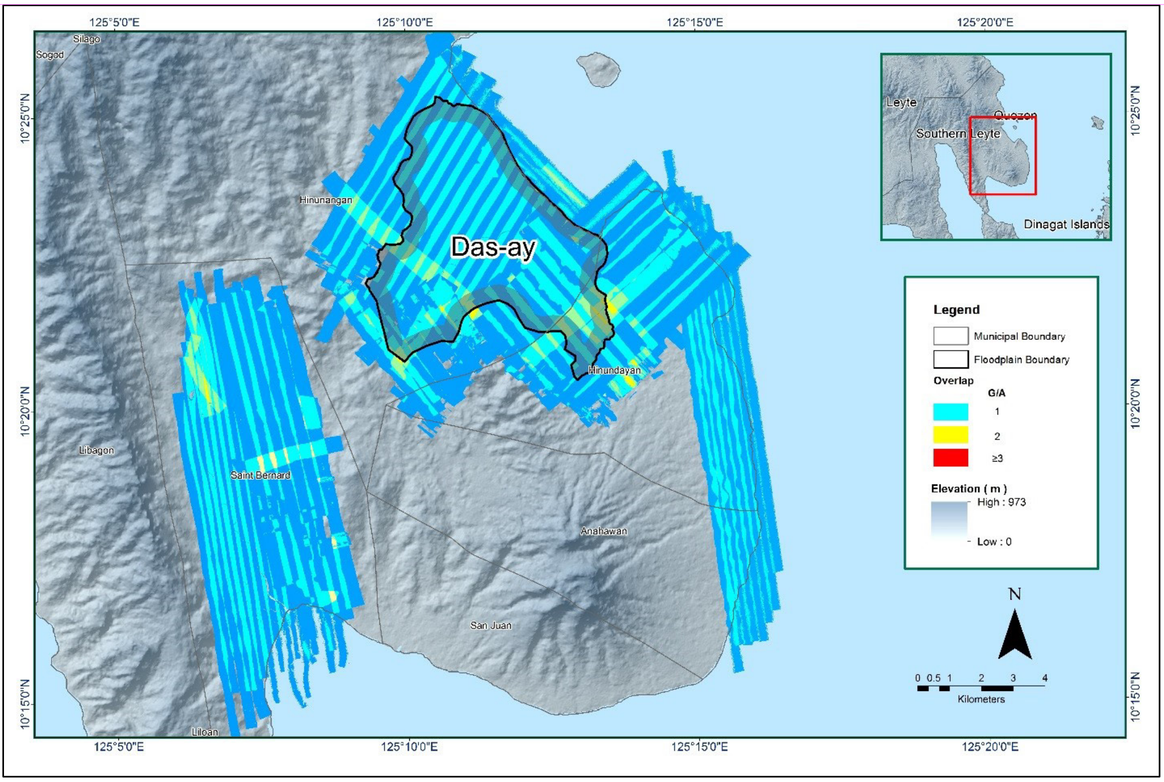


Figure 13. Image of data overlap for Das-ay floodplain.

The overlap statistics per block for the Das-ay floodplain can be found in the Mission Summary Reports (Annex 8). One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 28.42% and 44.34% 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 two (2) points per square meter criterion is shown in Figure 14. It was determined that all LiDAR data for the Das-ay floodplain satisfy the point density requirement, and the average density for the entire survey area is 4.41 points per square meter.

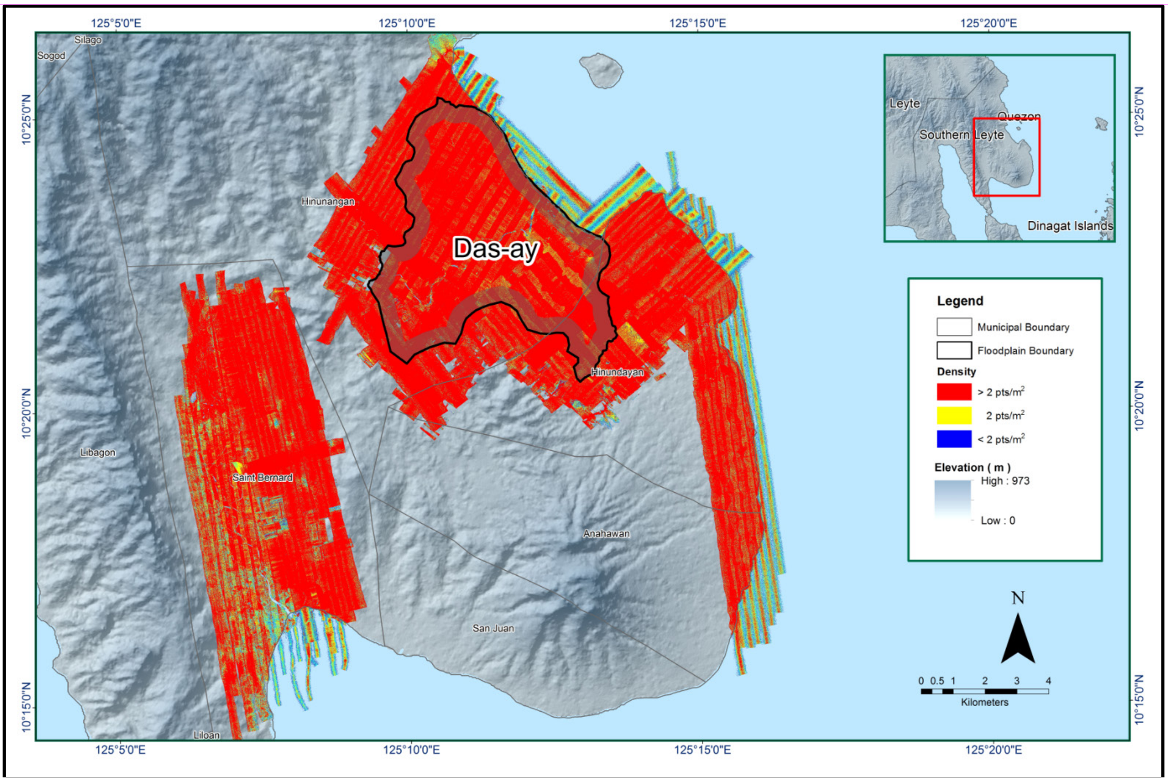


Figure 14. Pulse density map of the merged LiDAR data for Das-ay floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 15. The default color range is from blue to red, where bright blue areas correspond to portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.20m relative to elevations of its adjacent flight line. Bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20m relative to elevations of its adjacent flight line. Areas with bright red or bright blue need to be investigated further using Quick Terrain Modeler software.

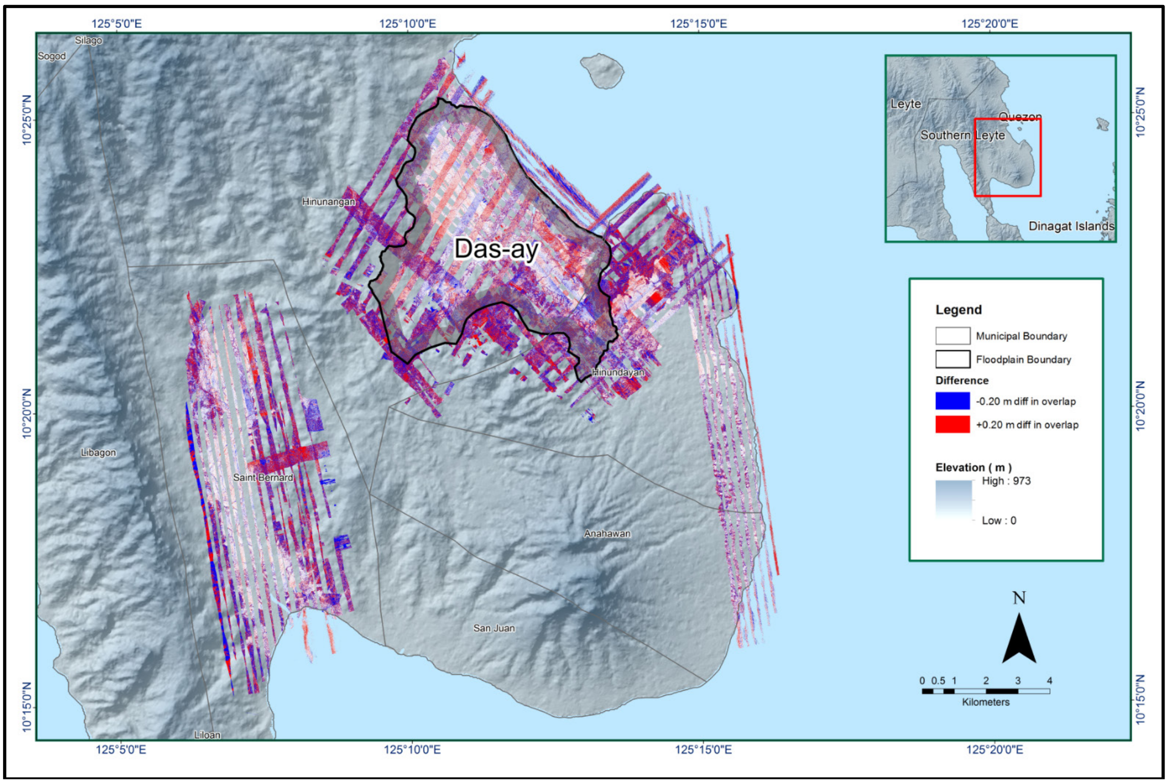
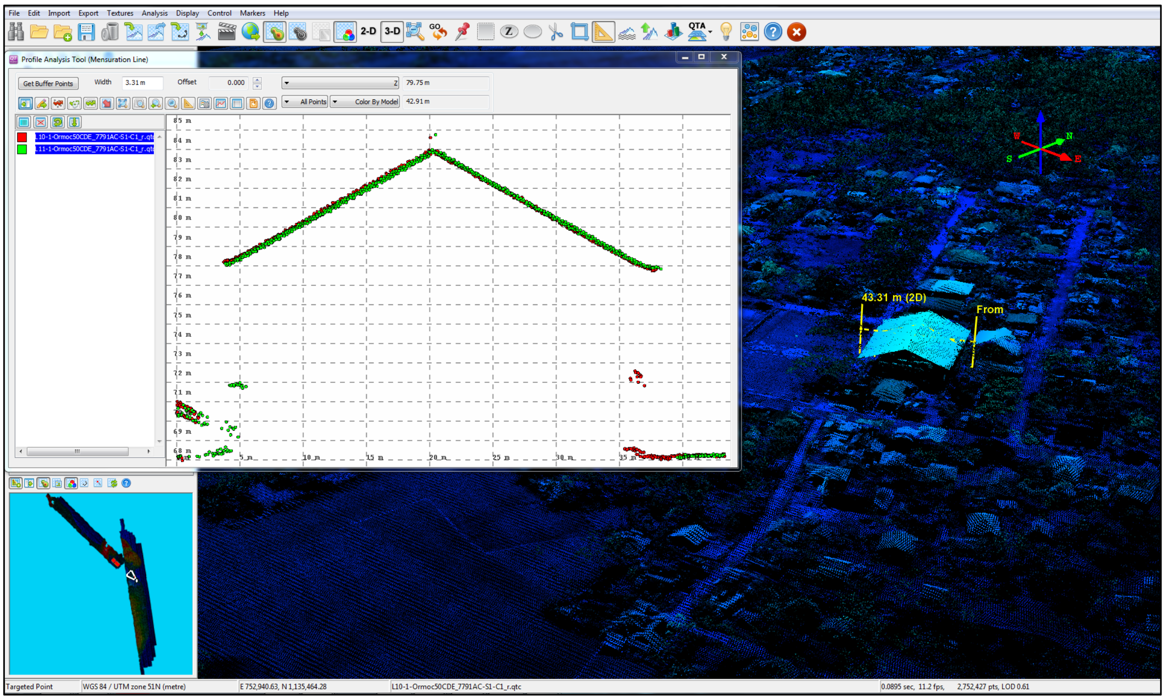


Figure 15. Elevation difference Map between flight lines for the Das-ay Floodplain Survey

A screen capture of the processed LAS data from a Das-ay flight 7791A loaded in QT Modeler is shown in Figure 16. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there 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.



Width 3.31 m
Offset 0.000
Z 79.75 m
42.91 m
L10-1-Ormoc50CDE_7791AC-S1-C1_r.qtc
L11-1-Ormoc50CDE_7791AC-S1-C1_r.qtc
WGS 84 / UTM zone 51N (metre)
E 752,940.63, N 1,135,464.28
L10-1-Ormoc50CDE_7791AC-S1-C1_r.qtc
0.0895 sec, 11.2 fps, 2,752,427 pts, LOD 0.61

Figure 16. Quality checking for aDas-ay flight 7791A using the Profile Tool of QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 15. Das-ay classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	121,658,174
Low Vegetation	125,844,055
Medium Vegetation	262,849,998
High Vegetation	506,911,849
Building	6,831,813

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Das-ay floodplain is shown in Figure 17. A total of 452 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 15. The point cloud has a maximum and minimum height of 727.15 meters and 55.49 meters, respectively.

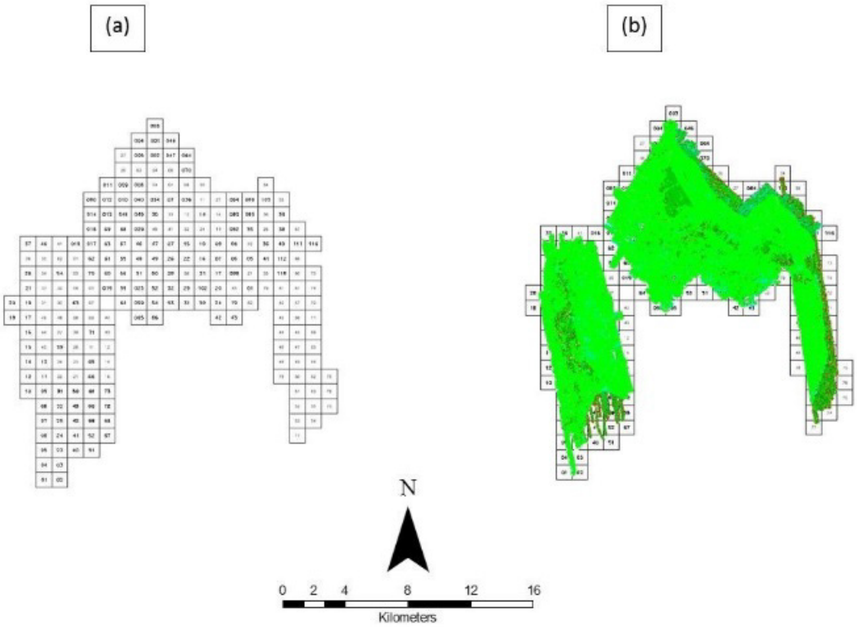


Figure 17. Tiles for Das-ay floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 18. The ground points are in orange, while 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 the canopy are classified correctly, due to the density of the LiDAR data.

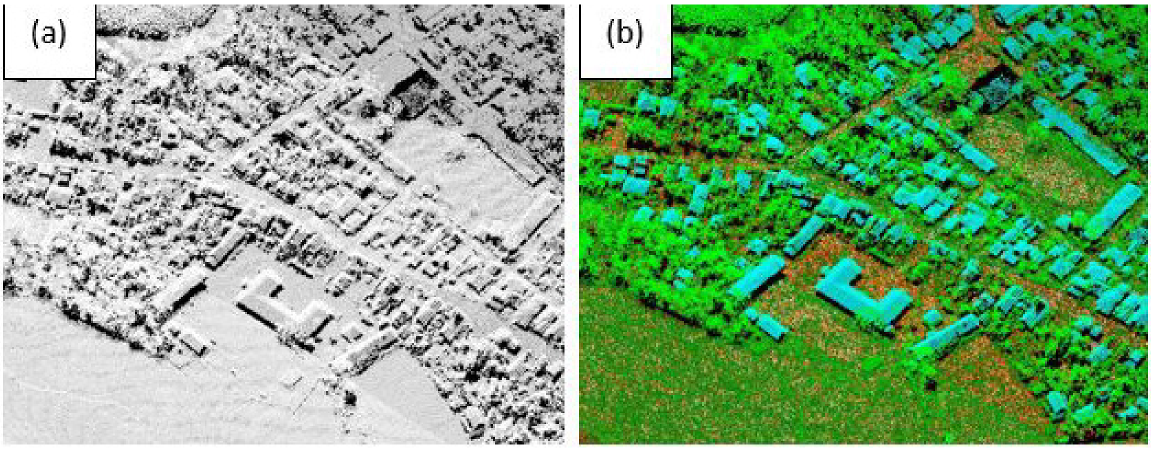


Figure 18. Point cloud before (a) and after (b) classification.

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

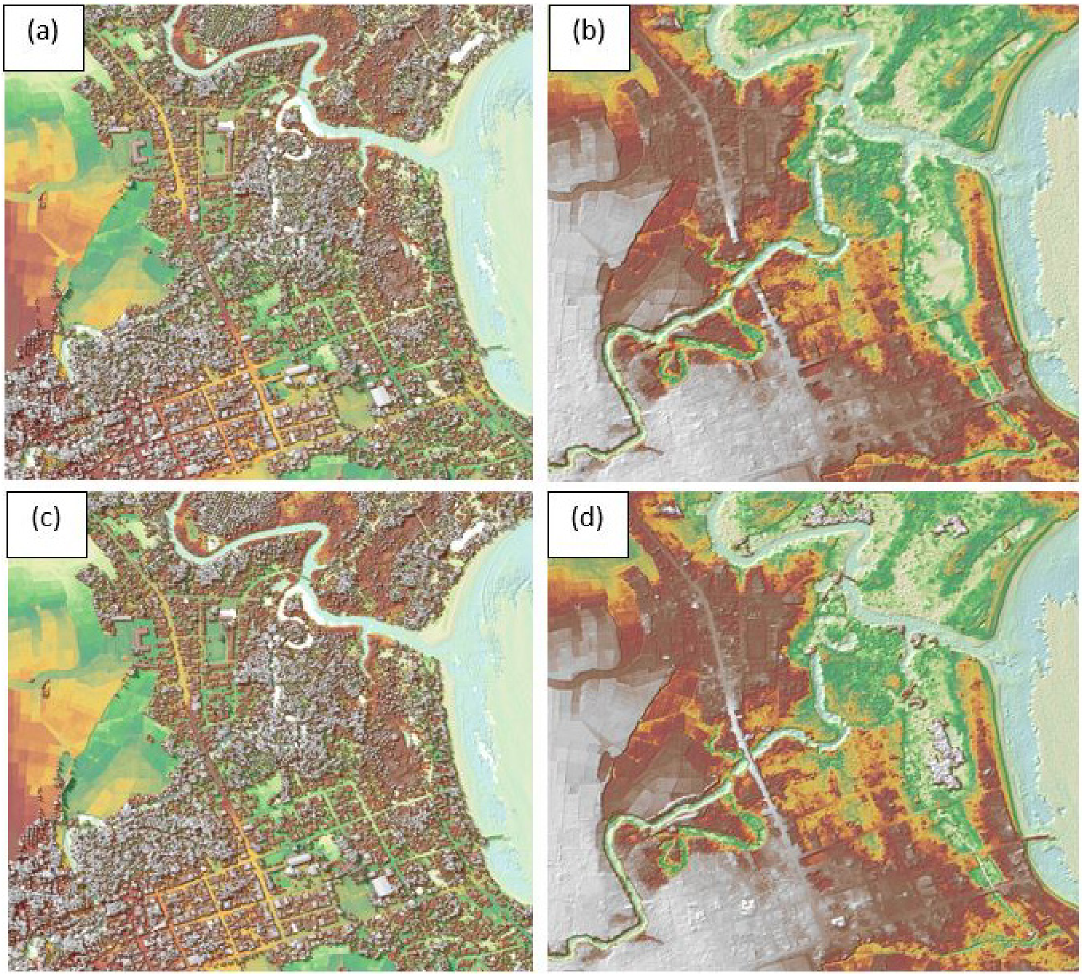


Figure 19. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Das-ay floodplain.

3.7LiDAR Image Processing and Orthophotograph Rectification

The 59 1km by 1km tiles area covered by Das-ay floodplain is shown in Figure 20. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Das-ay floodplain has a total of 19.47 sq.km. in orthophotogaph coverage comprised of 149 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 21.

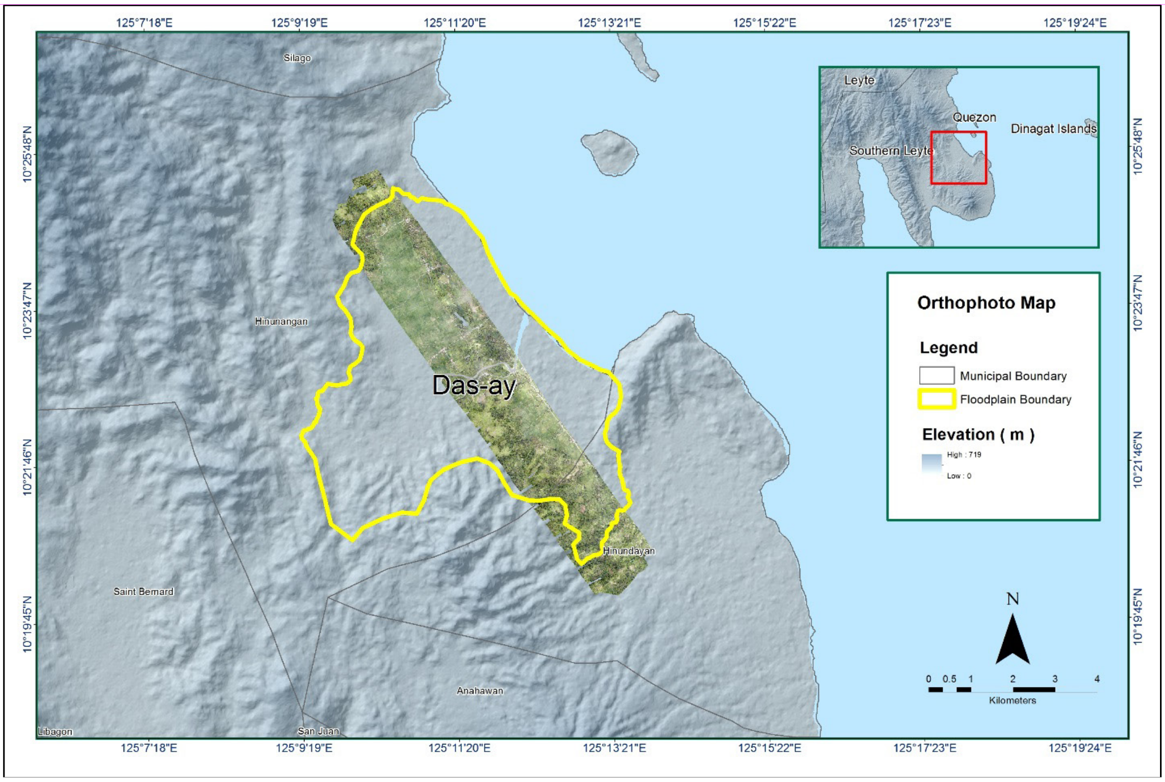


Figure 20. Das-ay Floodplain with the available orthophotographs.

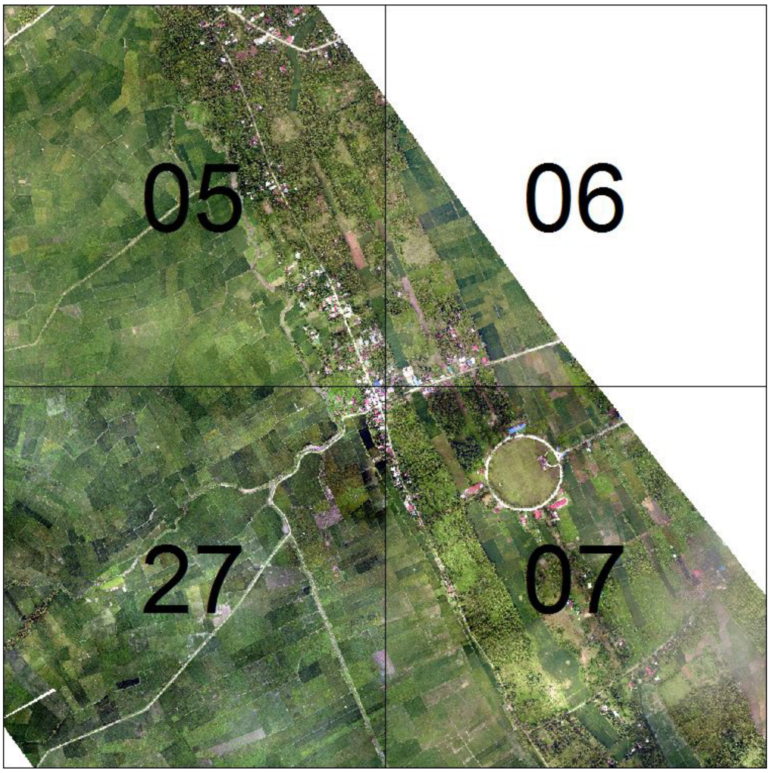


Figure 21. Sample orthophotograph tiles for Silaga Floodplain.

3.8 DEM Editing and Hydro-Correction

Seven (7) mission blocks were processed for Das-ay flood plain. These blocks are composed of Ormoc, Ormoc_South and Leyte blocks with a total area of 275.91 square kilometers. Table 16 shows the name and corresponding area of each block in square kilometers.

Table 16. LiDAR blocks with its corresponding areas.

LiDAR Blocks	Area (sq.km)
Ormoc_Blk50CDE	38.44
Ormoc_Blk50A	44.12
Ormoc_Blk50B	33.85
Ormoc_South_Blk50B	25.41
Ormoc_South_Blk50A	79.15
Ormoc_South_Blk50A_supplement	35.51
Leyte_Blk50A	19.43
TOTAL	**275.91 sq.km**

Figure 22 shows portions of a DTM before and after manual editing. As evident in the figure, the bridge (Figure 22a) has obstructed the flow of water along the river. To correct the river hydrologically, the bridge was removed through manual editing (Figure 22b). The river embankment (Figure 22c) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 22d) to allow the correct flow of water.

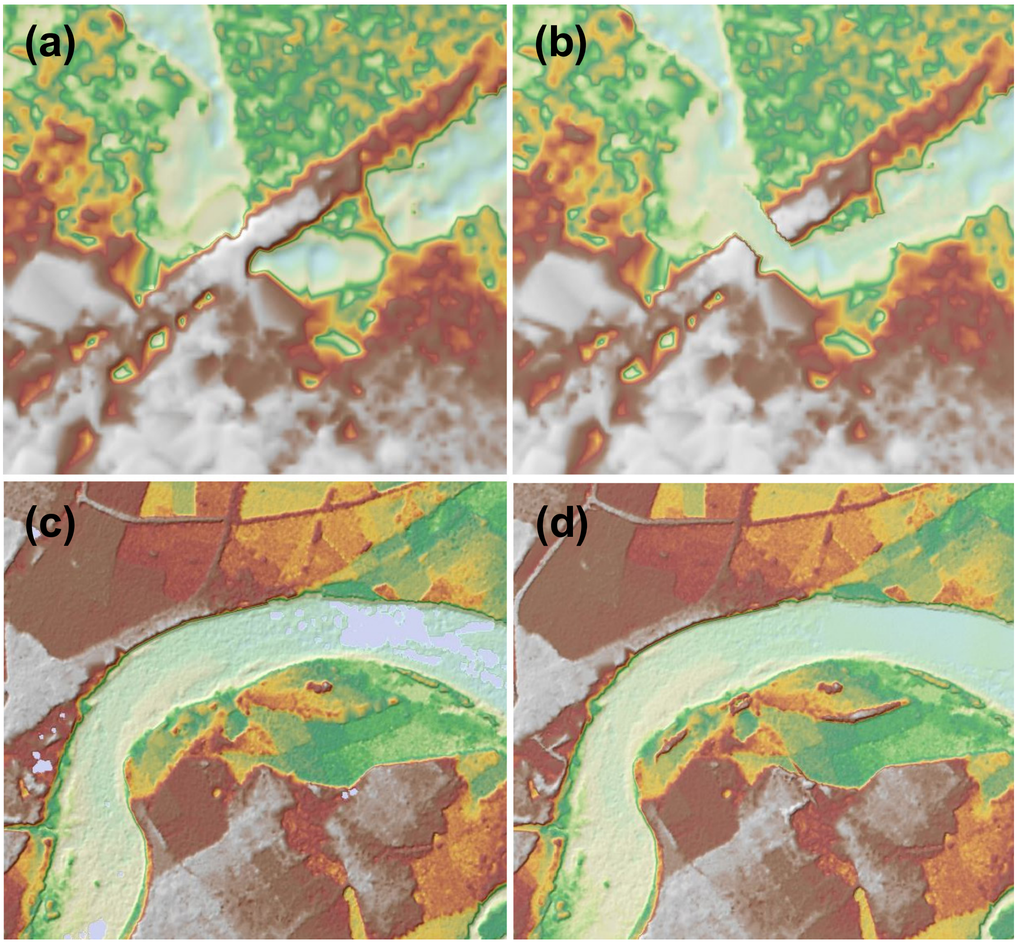


Figure 22. Portions in the DTM of the Das-ay Floodplain – a bridge before (a) and after (b) manual editing; a river embankment before (c) and after (d) data retrieval.

3.9 Mosaicking of Blocks

Ormoc_Blk50B was used as the reference block for Ormoc_Blk50CDE, Leyte_Blk50A, Ormoc_South_Blk50A and Ormoc_South_Blk50A_supplement while Ormoc_Blk50A was used as the reference block for Ormoc_South_Blk50B at the start of mosaicking because these blocks were made available for editing and mosaicking before the other blocks. Table 17 shows the shift values applied to each LiDAR block during mosaicking.

.

Mosaicked LiDAR DTM for Das-ay floodplain is shown in Figure 23. It can be seen that the entire Das-ay floodplain is 99.60% covered by LiDAR data.

Table 17. Shift values of each LiDAR block of Das-ay Floodplain.

Mission Blocks	Shift Values		
	x	y	z
Ormoc_Blk50B	0.00	0.00	0.00
Ormoc_Blk50CDE	0.00	0.00	0.00
Leyte_Blk50A	0.00	0.00	-0.30
Ormoc_South_Blk50A	0.00	0.00	-0.24
Ormoc_South_Blk50A_supplement	0.00	0.00	-0.26
Ormoc_Blk50A	0.00	0.00	0.00
Ormoc_South_Blk50B	0.00	0.00	-0.19

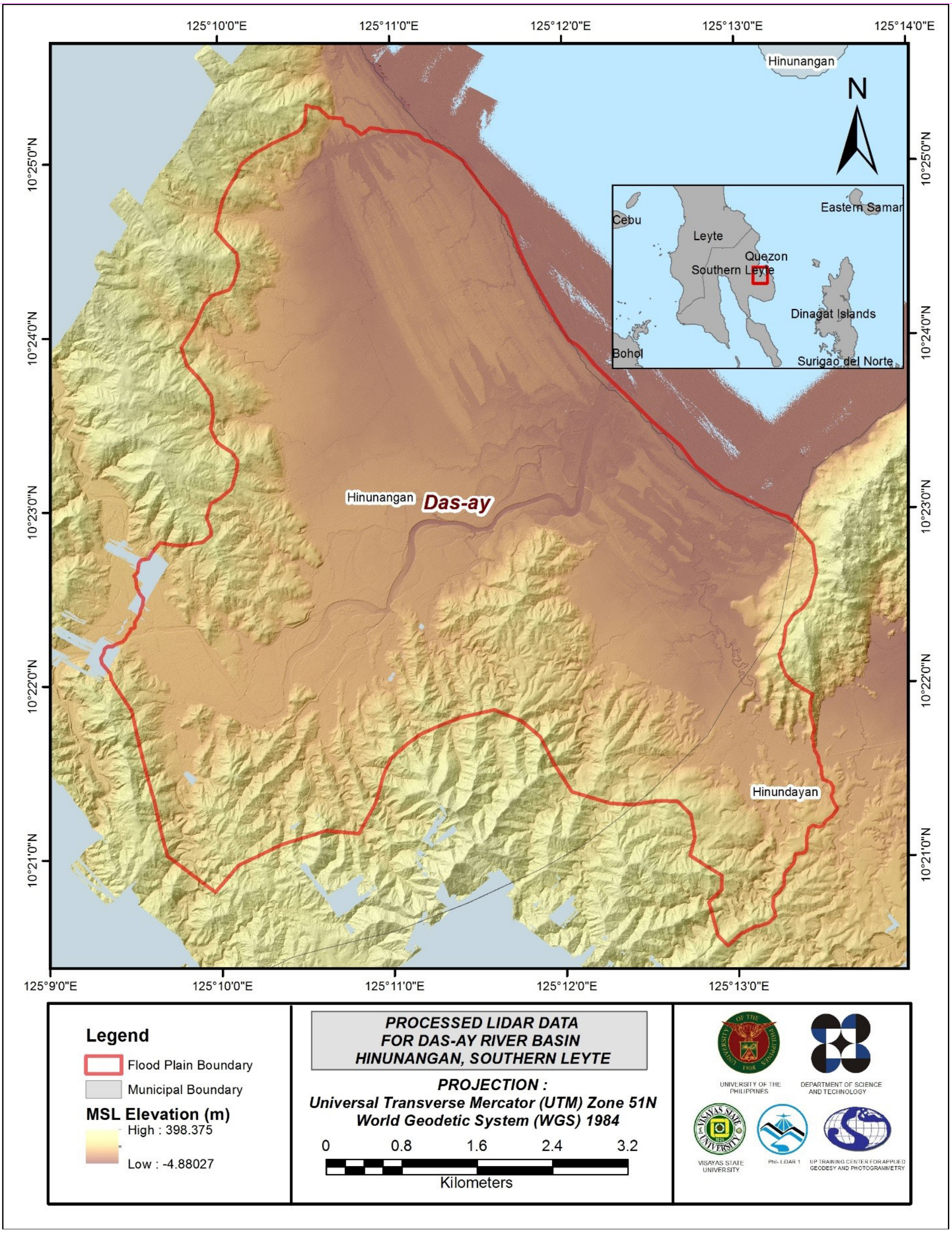


Figure 23. Map of processed LiDAR data for the Das-ay Floodplain.

3.10 Calibration and Validation of Mosaicked LiDAR DEM

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Das-ay to collect points with which the LiDAR dataset is validated is shown in Figure 24, with the validation survey points highlighted in green. A total of 3,863 survey points were gathered within Southern Leyte wherein the Das-ay is located. Random selection of 80% of the survey points, resulting to 3,090 points, was used for calibration.

A good correlation between the uncalibrated Das-ay LiDAR DTM and ground survey elevation values is shown in Figure 25. 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 0.35 meters with a standard deviation of 0.16 meters. Calibration of Das-ay LiDAR data was done by subtracting the height difference value, 2.79 meters, to Das-ay mosaicked LiDAR data. Table 18 shows the statistical values of the compared elevation values between Das-ay LiDAR data and calibration data.

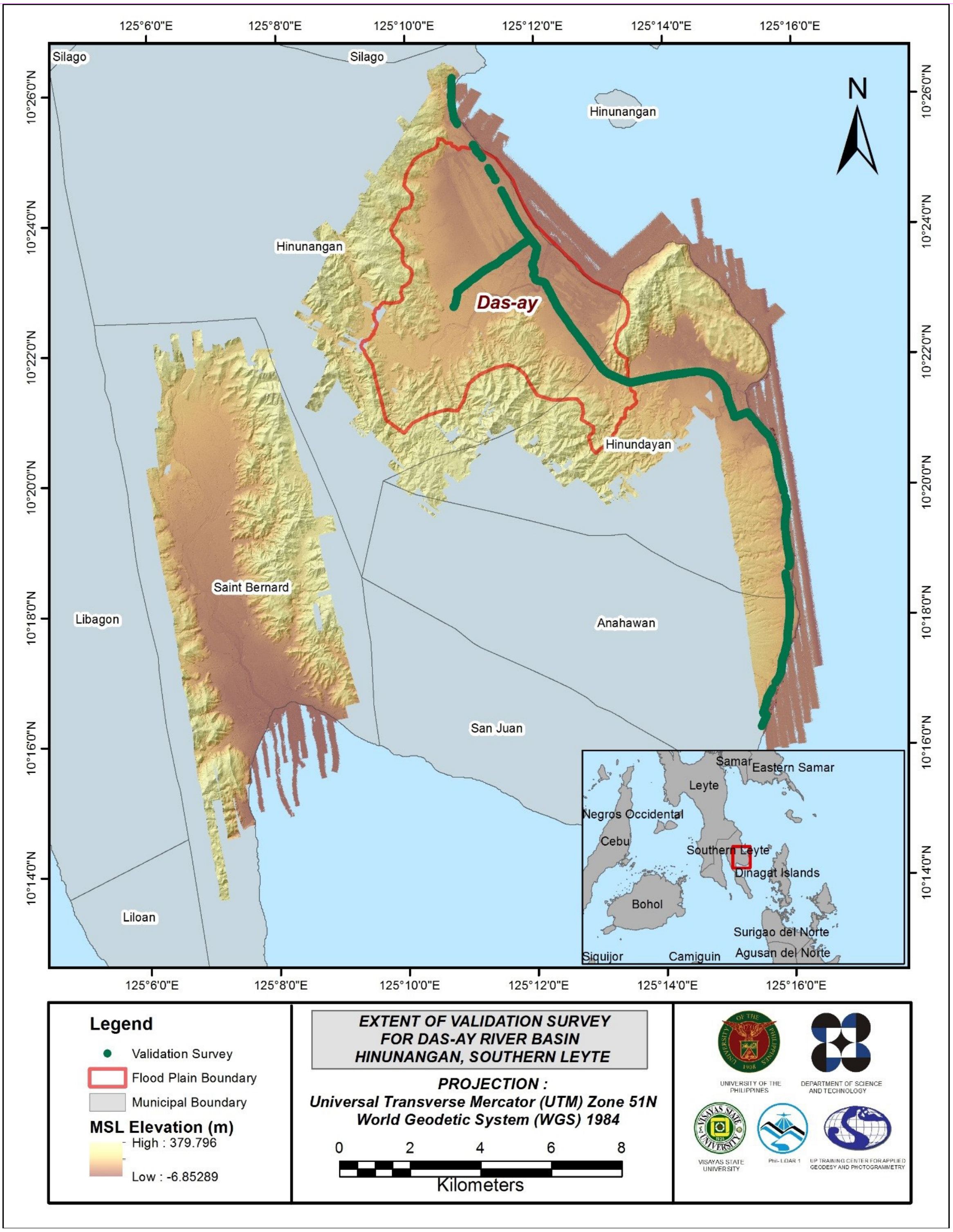


Figure 24. Map of Das-ay Floodplain with validation survey points in green.

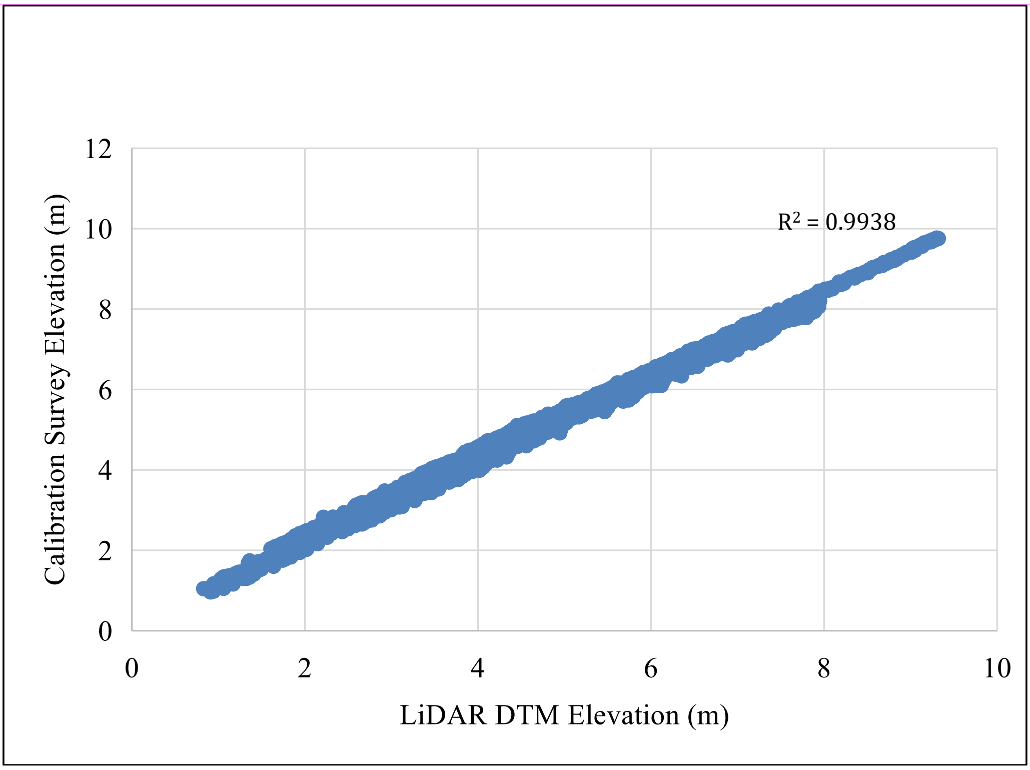


Figure 25. Correlation plot between calibration survey points and LiDAR data.

Table 18. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	0.35
Standard Deviation	0.16
Average	-0.32
Minimum	-0.63
Maximum	0.00

A total of 773 points lie within the Das-ay floodplain and were used for the validation of calibrated Das-ay 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 26. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.16 meters with a standard deviation of 0.16 meters, as shown in Table 19.

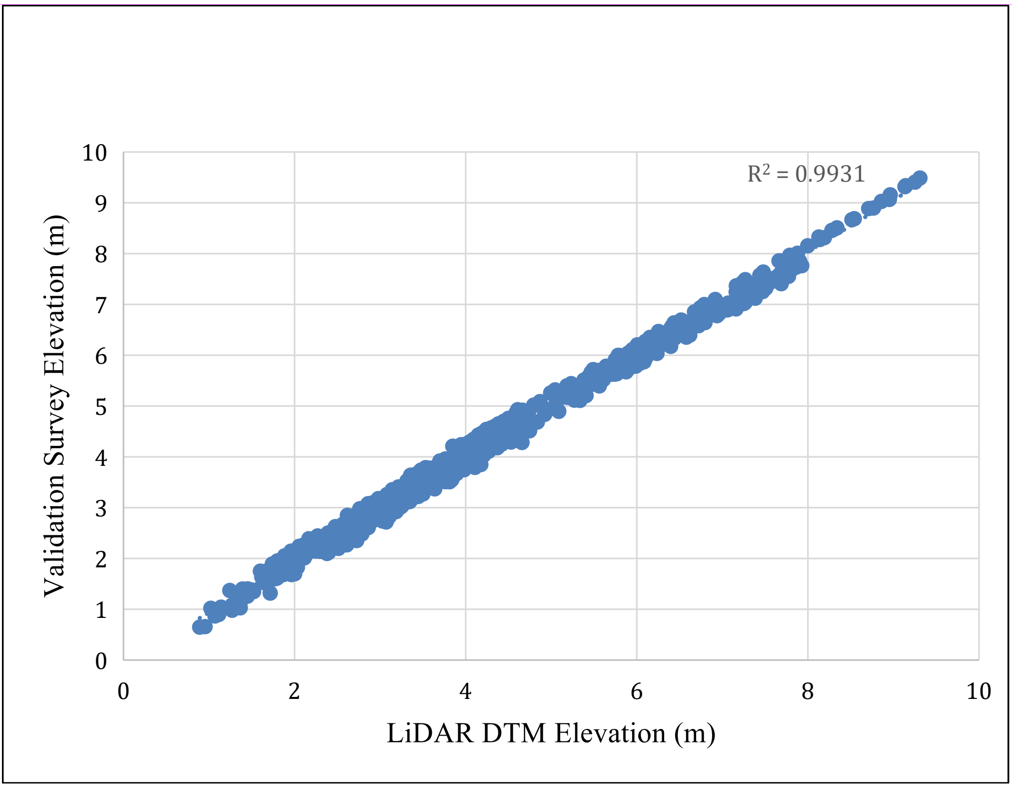


Figure 26. Correlation plot between the validation survey points and the LiDAR data.

Table 19. Validation Statistical Measures

Validation Statistical Measures	Value (meters)
RMSE	0.16
Standard Deviation	0.16
Average	0.016
Minimum	-0.31
Maximum	0.34

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline was available for Das-ay with 6,677 bathymetric survey points. The resulting raster surface produced was done by Inverse Distance Weighted (IDW) interpolation metho. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.30 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Das-ay integrated with the processed LiDAR DEM is shown in Figure 27.

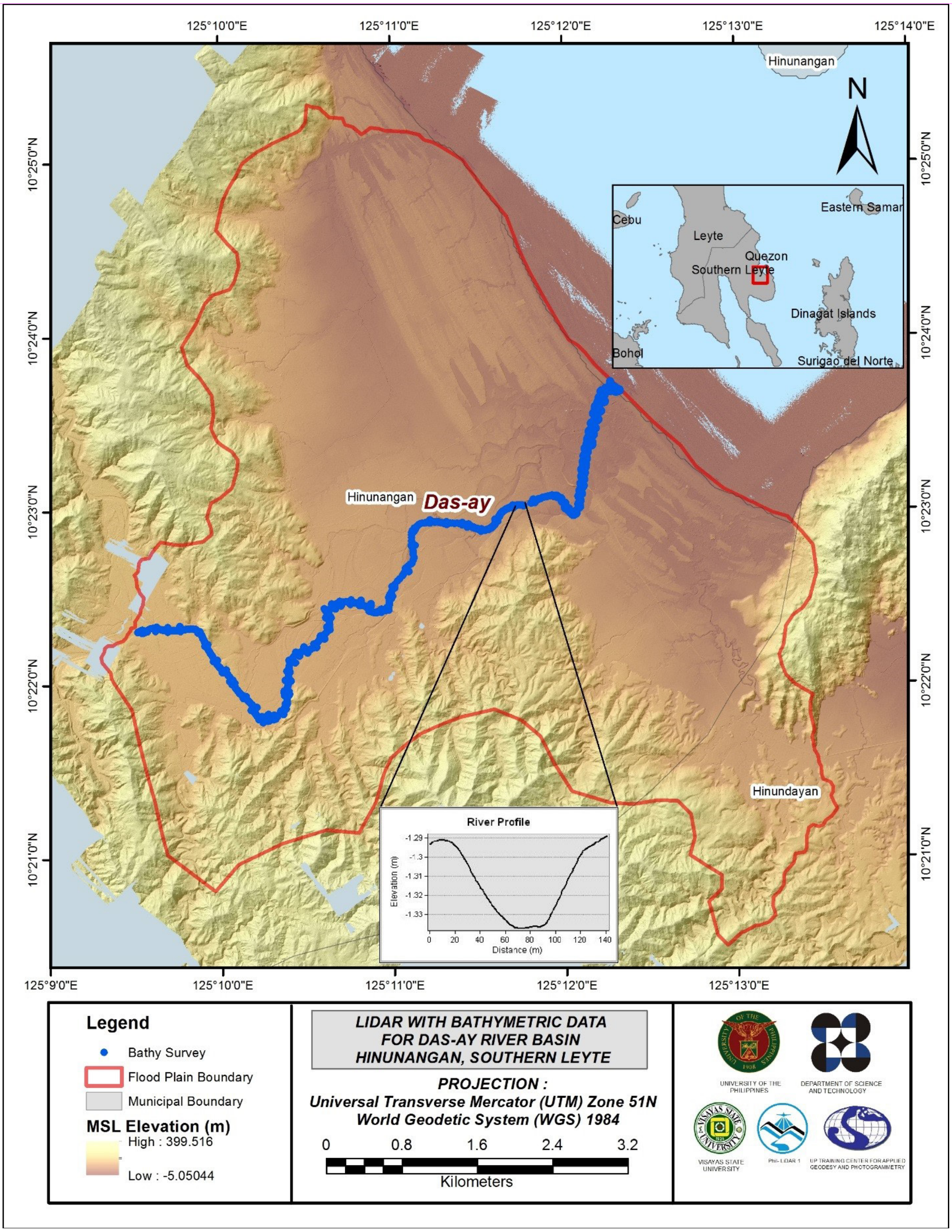


Figure 27. Map of Das-ay floodplain with bathymetric survey points in blue.

3.12 Feature Extraction

The features salient in flood hazard exposure analysis include buildings, road networks, bridges, and water bodies within the floodplain area with a 200-meter buffer zone. Mosaicked LiDAR DEMs with a 1-m resolution were used to delineate footprints of building features, which comprised 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 the routing of disaster response efforts. These features are represented by network of road centerlines.

3.12.1 Quality Checking of Digitized Features' Boundary

Das-ay floodplain, including its 200 m buffer, has a total area of 44.50 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 1,026 building features, are considered for QC. Figure 28 shows the QC blocks for Das-ay floodplain.

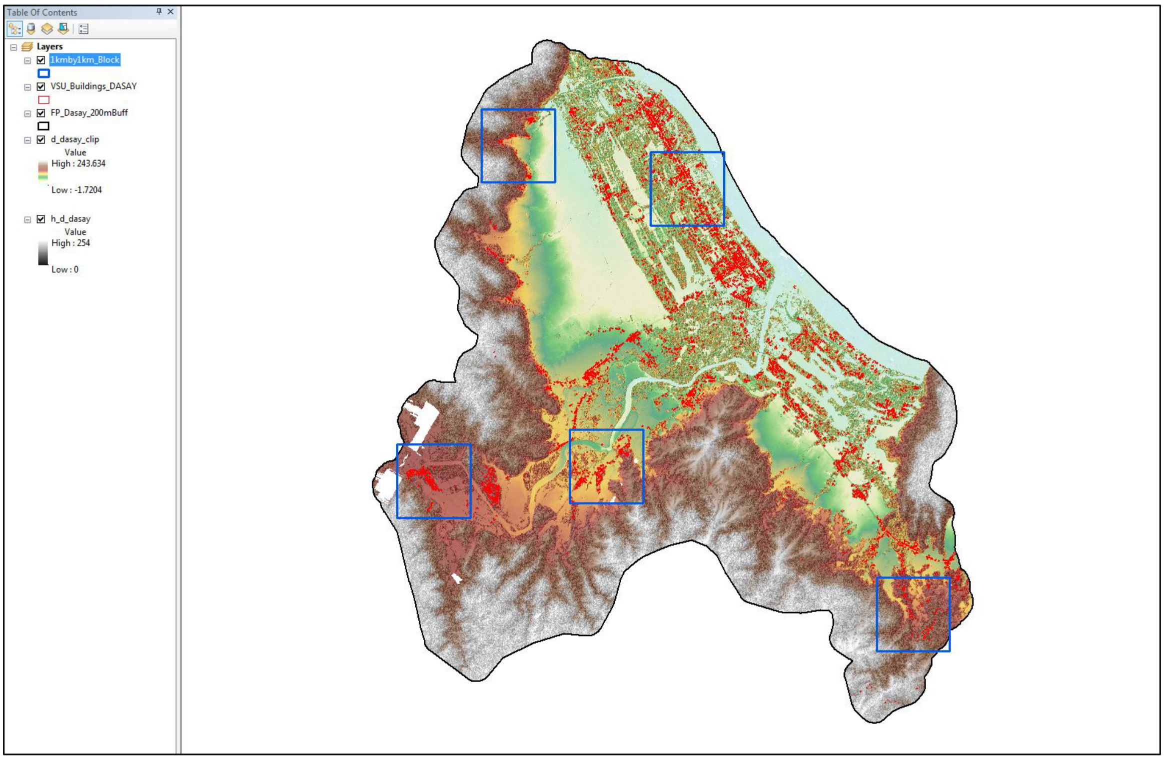


Figure 28. Blocks (in blue) of Das-ay building features that was subjected to QC.

Quality checking of Das-ay building features resulted in the ratings shown in Table 20.

Table 20. Details of the quality checking ratings for the building features extracted for the Das-ay River Basin

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Das-ay	98.37	99.90	97.08	PASSED

3.12.2 Height Extraction

Height extraction was done for 6,168 building features in Das-ay floodplain. Of these building features, none was filtered out after height extraction, resulting to 6,168 buildings with height attributes. The lowest building height is at 2.00 meters, while the highest building is at 8.23 meters.

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. A 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 21 summarizes the number of building features per type. On the other hand, Table 22 shows the total length of each road type, while Table 23 shows the number of water features extracted per type.

Table 21. Building features extracted for Das-ay Floodplain.

Facility Type	No. of Features
Residential	5779
School	139
Market	2
Agricultural/Agro-Industrial Facilities	10
Medical Institutions	8
Barangay Hall	16
Military Institution	0
Sports Center/ Gymnasium/Covered Court	23
Telecommunication Facilities	3
Transport Terminal	3
Warehouse	8
Power Plant/Substation	1
NGO/CSO Offices	2
Police Station	1
Water Supply/Sewerage	3
Religious Institutions	58
Bank	0
Factory	0
Gas Station	3
Fire Station	1
Other Government Offices	11
Other Commercial Establishments	97
Total	**6168**

Table 22. Total length of extracted roads for Das-ay Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/ Municipal Road	Provincial Road	National Road	Others	
Das-ay	63.46	1.82	5.47	8.84	0.00	**79.59**

Table 23. Number of extracted water bodies for Das-ay Floodplain.

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Das-ay	20	0	0	1	0	21

A total of 11 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 29 shows the completed Digital Surface Model (DSM) of the Das-ay floodplain overlaid with its ground features.

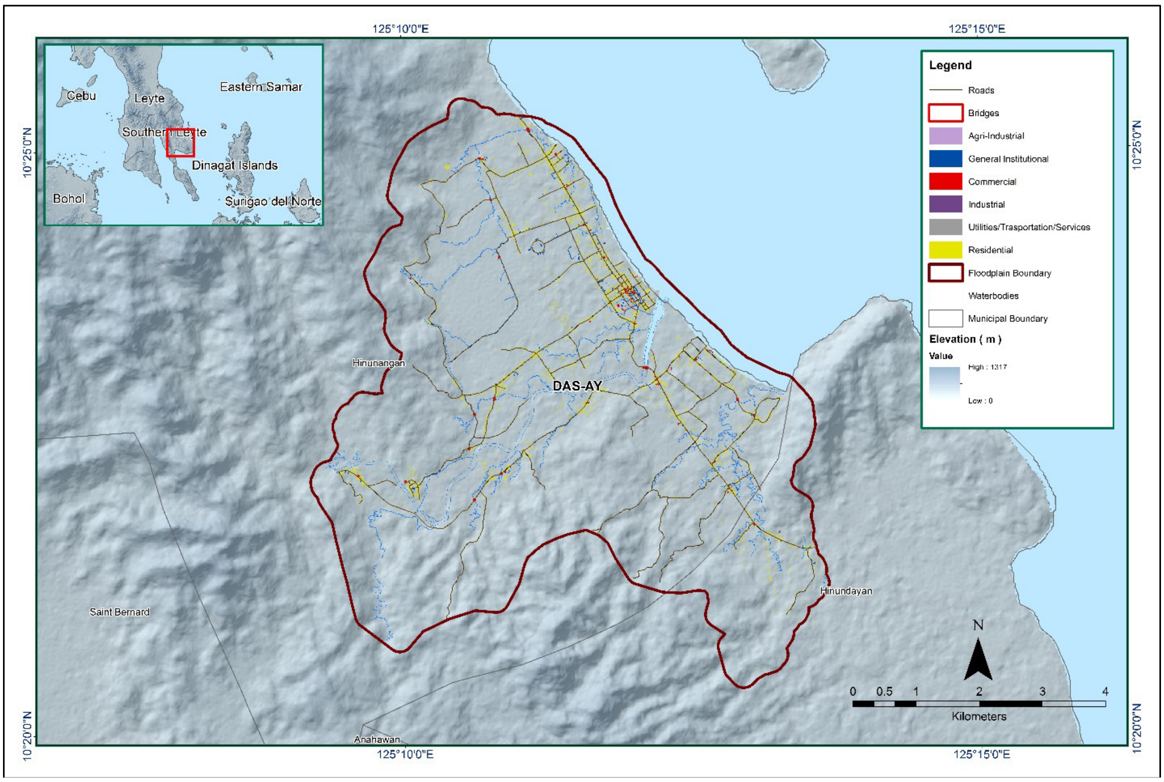


Figure 29. Extracted features of the Das-ay Floodplain.

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS OF THE DAS-AY RIVER BASIN

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

4.1 Summary of Activities

The Data Validation and Bathymetry Component (DVBC) conducted a field survey in Das-ay River on March 9 to 23, 2016. Generally, the scope of work was comprised of (i) initial reconnaissance; (ii) control point survey for the establishment of a control point; (iii) the cross section survey at Brgy. Patong Spillway; (iv) validation points acquisition of about 46 km covering the Das-ay River Basin area; and (v) bathymetric survey from its upstream in Brgy. Nueva Esperanza down to the mouth of the river in Brgy.Labrador, both in Municipality of Hinunangan, with an approximate length of 8.739 km using Ohmex™ single beam echo sounder and Trimble® SPS 882 GNSS PPK survey technique. Figure 30 illustrates the extent of the entire survey in Das-ay River.

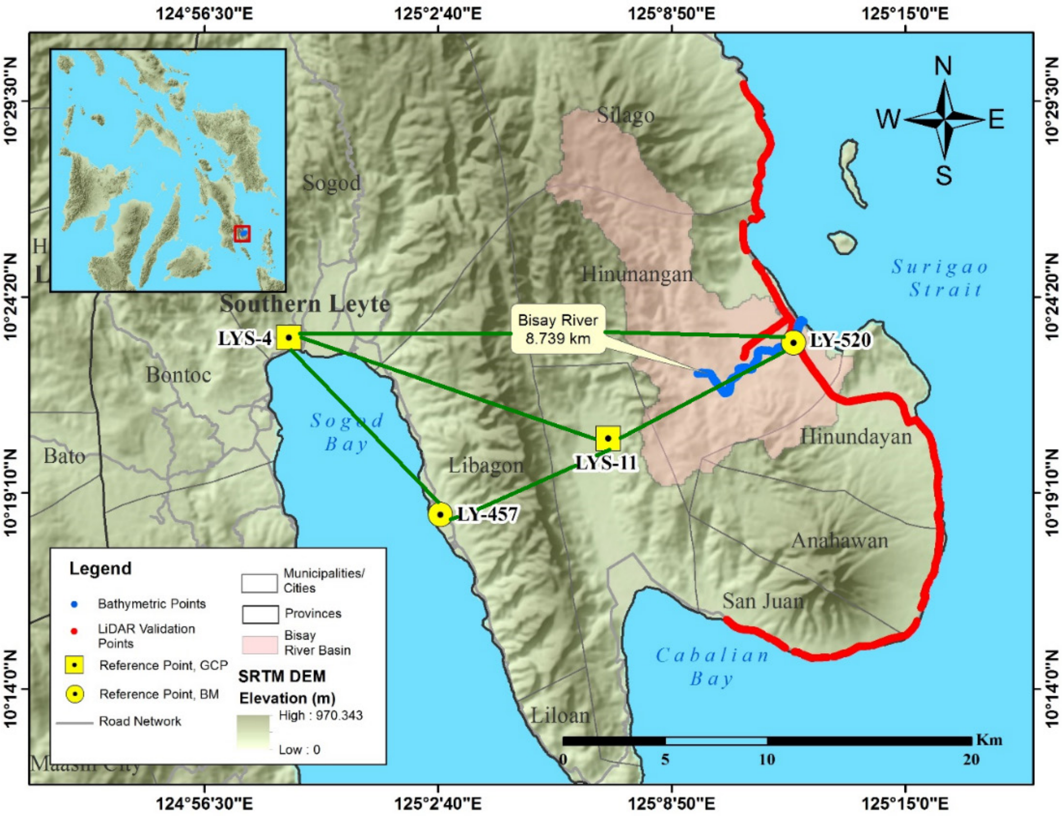

Figure 30. Das-ay River Survey Extent

4.2 Control Survey

The GNSS network utilized for the Das-ay River Basin is composed of two (2) loops and a baseline that was established on April 1, 2016, which occupied the following reference points: LYS-4, a first-order GCP in Brgy. Zone 1 in the Municipality of Sogod; LY-457, a first-order BM in Brgy. Bogasong in the Municipality of Libagon; and LY-520, a first-order BM in Brgy. Labrador in the Municipality of Hinunangan.

A NAMRIA-established control point was also used as marker in this survey: LYS-11 located in Brgy. Cabagawan, Municipality of Saint Bernard. Table 24 depicts the summary of reference and control points utilized, with their corresponding locations, while Figure 31 shows the GNSS network established in the Das-ay River Survey.

Table 24. List of reference and control points used during the survey in Das-ay River (Source: NAMRIA, UP-TCAGP).

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (m)	MSL Elevation (m)	Date established
LYS-4	1st Order, GCP	10°23'16.14540"N	124°58'43.76469"E	79.528	-	2006
LY-457	1st Order, BM	-	-	72.351	7.002	2007
LY-520	1st Order, BM	-	-	72.293	6.181	2008
LYS-11	Used as Marker	-	-	-	-	2007

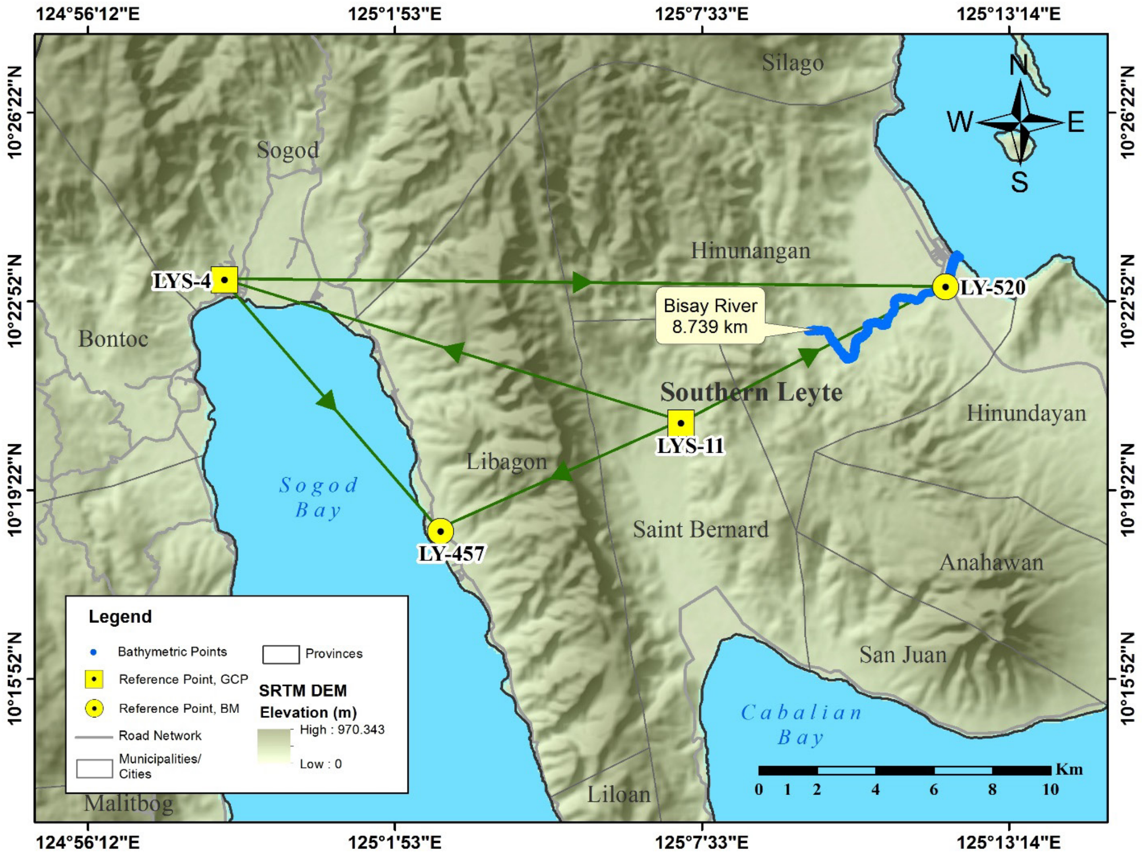

Figure 31. Das-ay River Basin Control Survey Extent.

Figure 32 to Figure 35 depict the setup of the GNSS on recovered reference points and established control points in the Das-ay River.

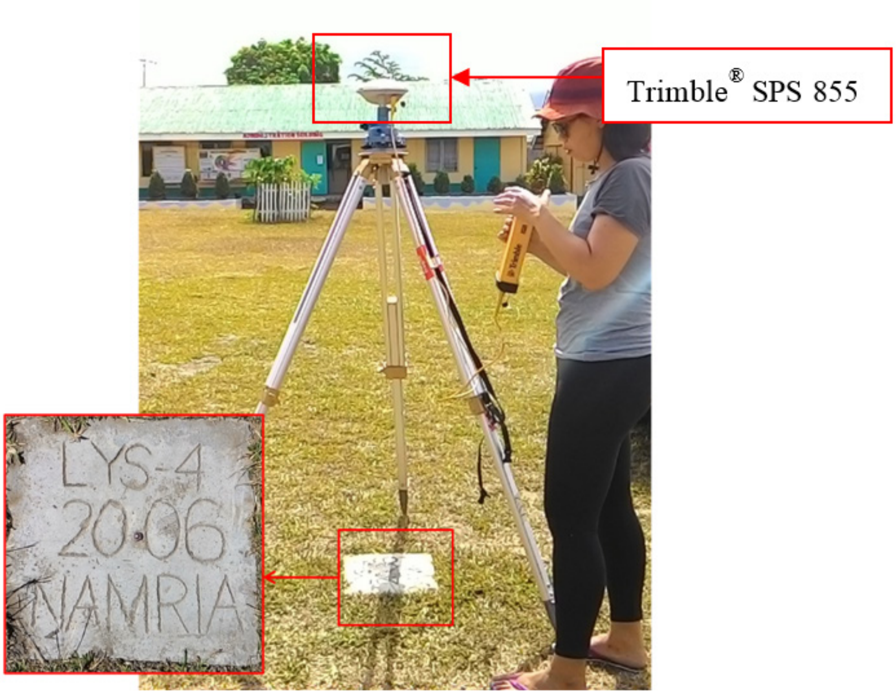

Figure 36. GNSS base set up, Trimble® SPS 985, at LY-106, located at the approach of Bernard Reed Bridge along Maharlika Highway , Brgy. Luntad, Municipality of Palo, Leyte

Figure 33. GNSS base set up, Trimble® SPS 855, at LY-457, located at the approach of Tigbao-cib Bridge 2 in Brgy. Bogasong, Libagon, Southern Leyte.

Figure 34. GNSS base set up, Trimble® SPS 882, at LY-520, located along the approach of Das-Ay Bridge in Brgy. Labrador, Hinunangan, Southern Leyte.

Figure 35. GNSS base set up, Trimble® SPS 852, at LYS-11, located at the St. Bernard Elementary School Grounds, Brgy. Cabagawan, St. Bernard, Southern Leyte.

4.3 Baseline Processing

The GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement respectively. In cases where one or more baselines did not meet all of these criteria, masking was performed. Masking is the removal or covering of portions of the baseline data using the same processing software. The data is then repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, a resurvey is initiated. Table 25 presents the baseline processing results of control points in the Das-ay River Basin, as generated by the TBC software.

Table 25. The Baseline processing report for the Pambujan River GNSS static observation survey.

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)
LYS-4 --- LY-520	04-01-2016	Fixed	0.003	0.021	90°33'33"	24329.003
LYS-11 --- LYS-4	04-01-2016	Fixed	0.002	0.010	287°40'27"	16158.815
LYS-11 --- LY-520	04-01-2016	Fixed	0.007	0.024	62°27'32"	10073.109
LYS-11 --- LY-520	04-01-2016	Fixed	0.003	0.021	62°27'32"	10073.125
LYS-4 --- LY-457	04-01-2016	Fixed	0.004	0.020	319°43'05"	11285.176
LYS-11 --- LY-457	04-01-2016	Fixed	0.004	0.021	65°24'42"	8908.644
LYS-4 --- LY-520	04-01-2016	Fixed	0.007	0.025	90°33'33"	24328.999

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, the network adjustment is performed using the TBC software. Looking at the Adjusted Grid Coordinates table of the TBC-generated Network Adjustment Report, it is observed that the square root of the sum of the squares of x and y must be less than 20 cm and z less than 10 cm for each control point; 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 complete details, see the Network Adjustment Report shown in Table 26 to Table 29.

The four (4) control points, LYS-4, LY-457, LY-520, and LYS-11 were occupied and observed simultaneously to form a GNSS loop. Elevation value of LY-457 and L-520 and coordinates of point LYS-4 were held fixed during the processing of the control points as presented in Table 26. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 26. Constraints applied to the adjustment of the control points.

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
LYS-4	Local	Fixed	Fixed		
LY-457	Grid				Fixed
LY-520	Grid				Fixed
Fixed = 0.000001 (Meter)					

Likewise, 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 27. All fixed control points have no values for grid and elevation errors.

Table 27. Adjusted grid coordinates for the control points used in the Das-ay River flood plain survey.

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
LYS-4	716648.623	?	1148966.313	?	14.299	0.048	LL
LY-457	724001.615	0.012	1140402.435	0.008	7.002	?	e
LY-520	740983.532	0.009	1148880.417	0.007	6.181	?	e
LYS-11	732080.501	0.008	1144162.005	0.006	35.617	0.048	

The results of the computation for accuracy are as follows:

a. LYS-4

horizontal accuracy	=	Fixed
vertical accuracy	=	4.80< 10 cm

b. LY-457

horizontal accuracy = $\sqrt{((1.20)^2 + (0.80)^2}$
= $\sqrt{(1.44 + 0.64)}$
= 1.44 cm < 20 cm
vertical accuracy = Fixed

c. LY-520

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

d. LYS-11

horizontal accuracy = $\sqrt{((0.80)^2 + (0.60)^2}$
= $\sqrt{(0.64+ 0.36)}$
= 1.00 cm < 20 cm
vertical accuracy = 4.8 cm < 10 cm

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

Table 28. Adjusted geodetic coordinates for control points used in the Das-ay River Flood Plain validation.

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
LYS-4	N10°23'16.14540"	E124°58'43.76469	79.528	0.048	LL
LY-457	N10°18'35.97042"	E125°02'43.63239	72.351	?	e
LY-520	N10°23'08.14105"	E125°12'03.52892	72.293	?	e
LYS-11	N10°20'36.58650	E125°07'09.90652	101.468	0.048	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 28. Based on the results of the computation, the accuracy conditions are satisfied; hence, the required accuracy for the program was met. The computed coordinates of the reference and control points utilized in the Das-ay River GNSS Static Survey are seen in Table 29.

Table 29. The reference and control points utilized in the Das-ay River Static Survey, with their corresponding locations (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
LYS-4	1st order, GCP	10°23'16.1454"N	124°58'43.7646"E	79.528	1148966.313	716648.623	14.299
LY-457	1st Order, BM	10°18'35.9704"N	125°02'43.6323"E	72.351	1140402.435	724001.615	7.002
LY-520	1st order, BM	10°23'08.1410"N	125°12'03.5289"E	72.293	1148880.417	740983.532	6.181
LYS-11	Used as Marker	10°20'36.5865"N	125°07'09.9065"E	101.468	1144162.005	732080.501	35.617

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

The bridge cross-section survey was conducted on April 6, 2016 at the upstream side of Patong Spillway in Brgy. Panalaron, Municipality of Hinunangan using GNSS receiver Trimble® SPS 882 in PPK survey technique was utilized for this survey. The area identified by Visayas State University for their flow data gathering is a non-bridge location as shown in Figure 36.

Figure 36. Cross-section survey conducted at Das-ay Bridge.

The length of the cross-sectional line surveyed at Patong Spillway is about 118.798 m. (Figure 38) using the control point LY-520 as the GNSS base station. The location map and cross-section diagram are shown in Figure 37 and Figure 38, respectively.

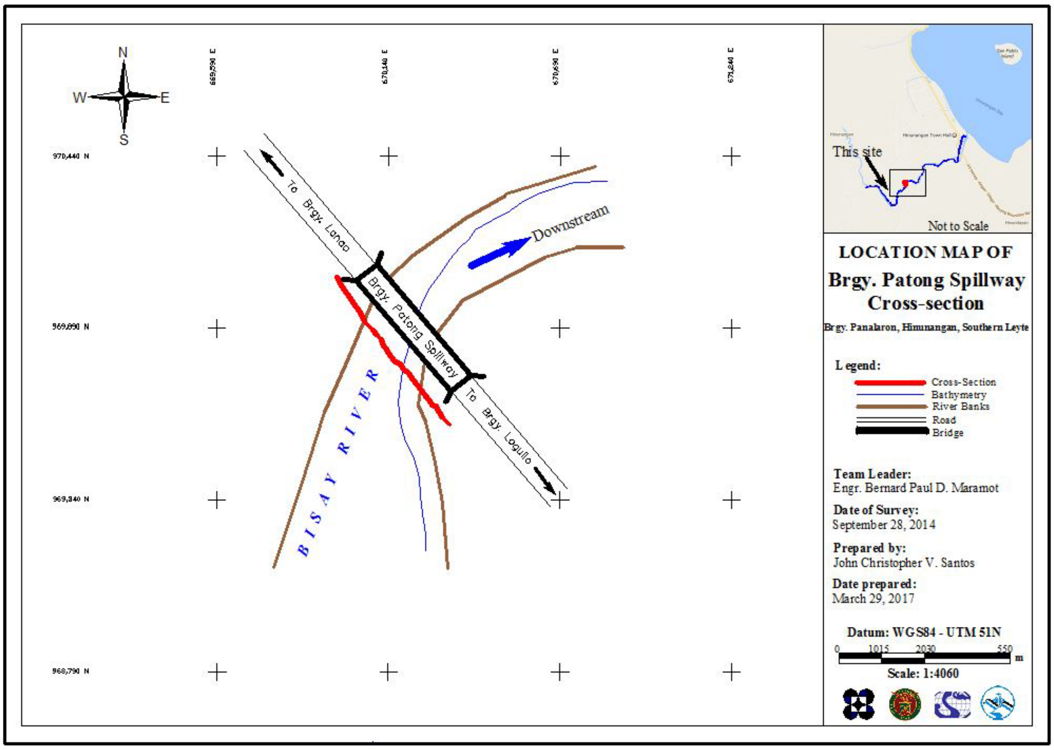

Figure 37. Location map of the Patong Spillway Cross Section.

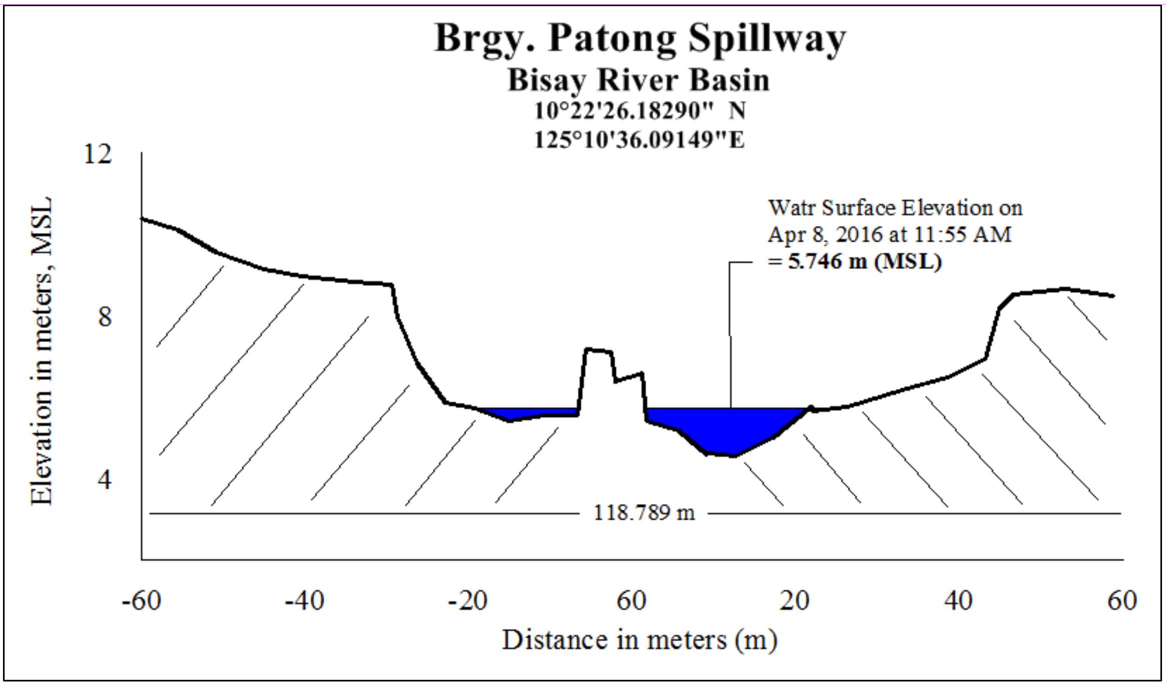

Figure 38. Brgy. Patong Spillway cross-section planimetric map

4.6. Validation Points Acquisition Survey

The validation points acquisition survey was conducted on April 7, 2016 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted in front of a vehicle as shown in Figure 39. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna height was 2.315 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 LY-520 occupied as the GNSS base stations in the conduct of the survey.

Figure 39. GNSS Receiver Trimble® SPS 882 installed on a vehicle for Ground Validation Survey.

The survey started from Brgy. Sap-Ang in the Municipality of Silago, going south towards the municipalities of Hinunangan, Hinundayan, Anahawan and ended in Brgy. Osao, Municipality of San Juan. The survey gathered a total of 6,176 points with approximate length of 46 km using LY-520 as GNSS base stations for the entire extent validation points acquisition survey as illustrated in the map in Figure 40.

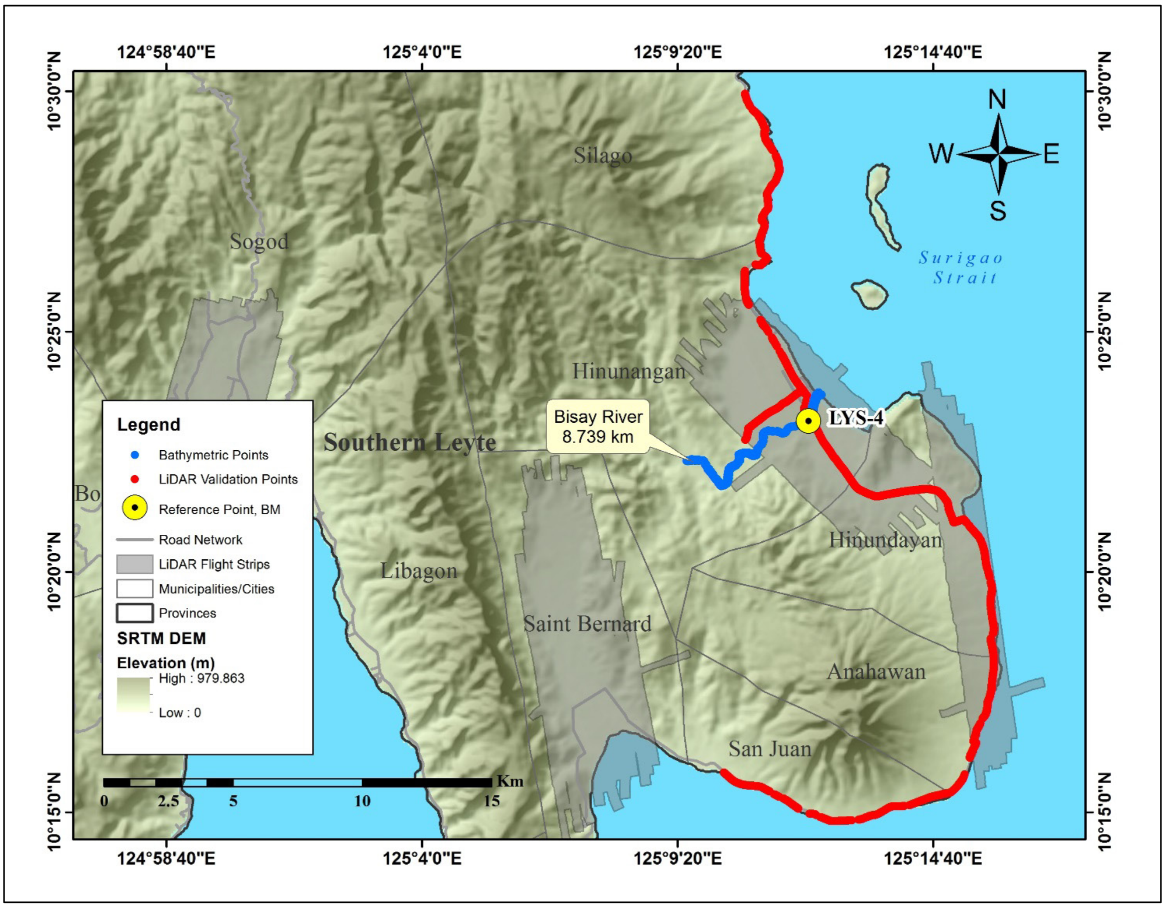

Figure 40. The extent of the LiDAR ground validation survey (in red) for Das-ay River Basin.

4.7 Bathymetric Survey

A bathymetric survey was performed on April 6, 2016 using a Trimble® SPS 882 in GNSS PPK survey technique and Ohmex™ single beam echo sounder, as illustrated in Figure 41. The extent of the survey is from the upstream in Brgy. Sto. Niño 1, Municipality of Hinunangan with coordinates 10°23’04.79205”N, 125°11’55.69112”E, down to the mouth of the river in the same Brgy. Labrador, also in Hinunangan with coordinates 10°23’44.08058”N, 125°12’16.27500”E, as shown in the map in Figure 42.

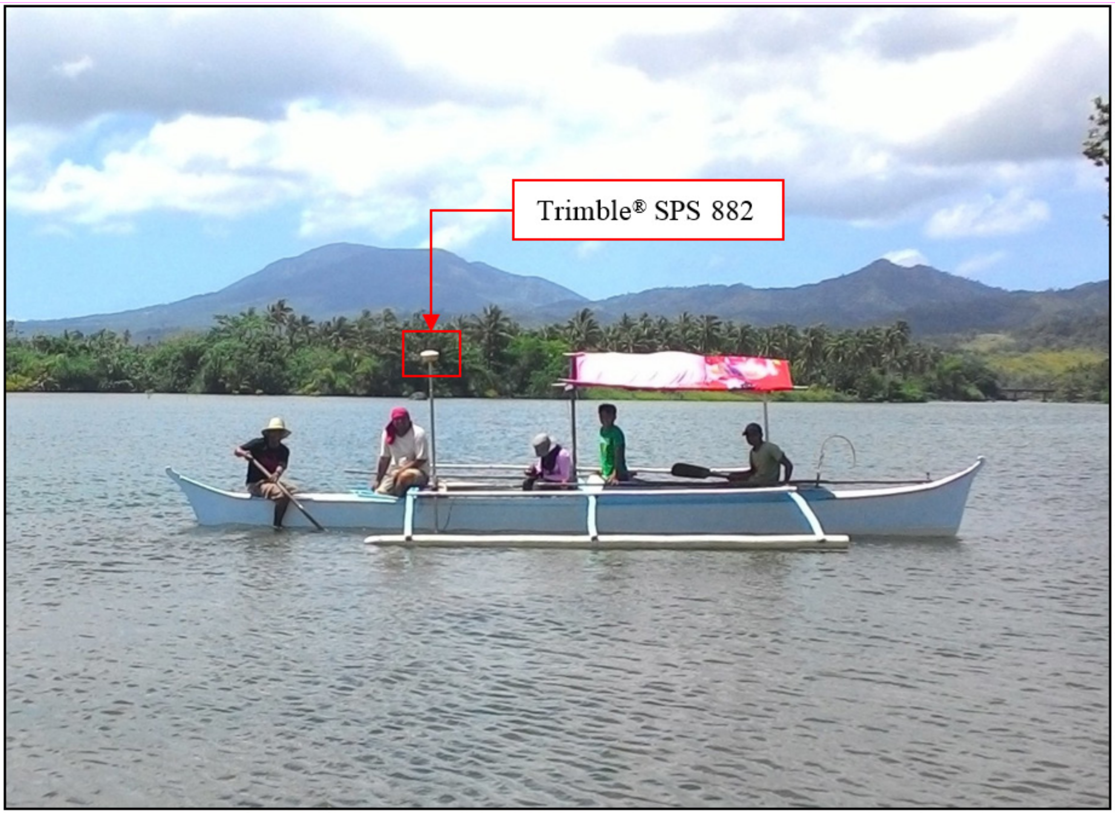

Figure 41. Set up of the bathymetric survey at Das-ay River using Trimble® SPS 882 in GNSS PPK survey technique.

Manual bathymetric survey was done on the same day using a Trimble® SPS 882 GNSS PPK survey technique. The survey began from the upstream portion of the river in Brgy. Nueva Esperanza in Municipality of Hinunangan with coordinates 10°22'18.89746"N, 125°09'31.76757"E; traversed down by foot and ended at the starting point of bathymetric survey using a boat in the same barangay. The control point LY-520, was occupied as the GNSS base station all throughout the surveys.

Overall, the bathymetric survey for Das-ay River gathered a total of 7,324 points covering 8.739 km of the river traversing eleven (11) barangays in Municipality of Hinunangan. To further illustrate this, a CAD drawing of the riverbed profile of the Das-ay River was produced. As seen in Figure 43, the highest and lowest elevation has a 26-m difference. The highest elevation observed was 23.899 m above MSL located at the mid upstream portion of the river in Brgy. Panalaron, while the lowest was -2.0244 m below MSL located at the mid downstream portion of the river in Brgy. Badiangon, both in Municipality of Hinunangan.

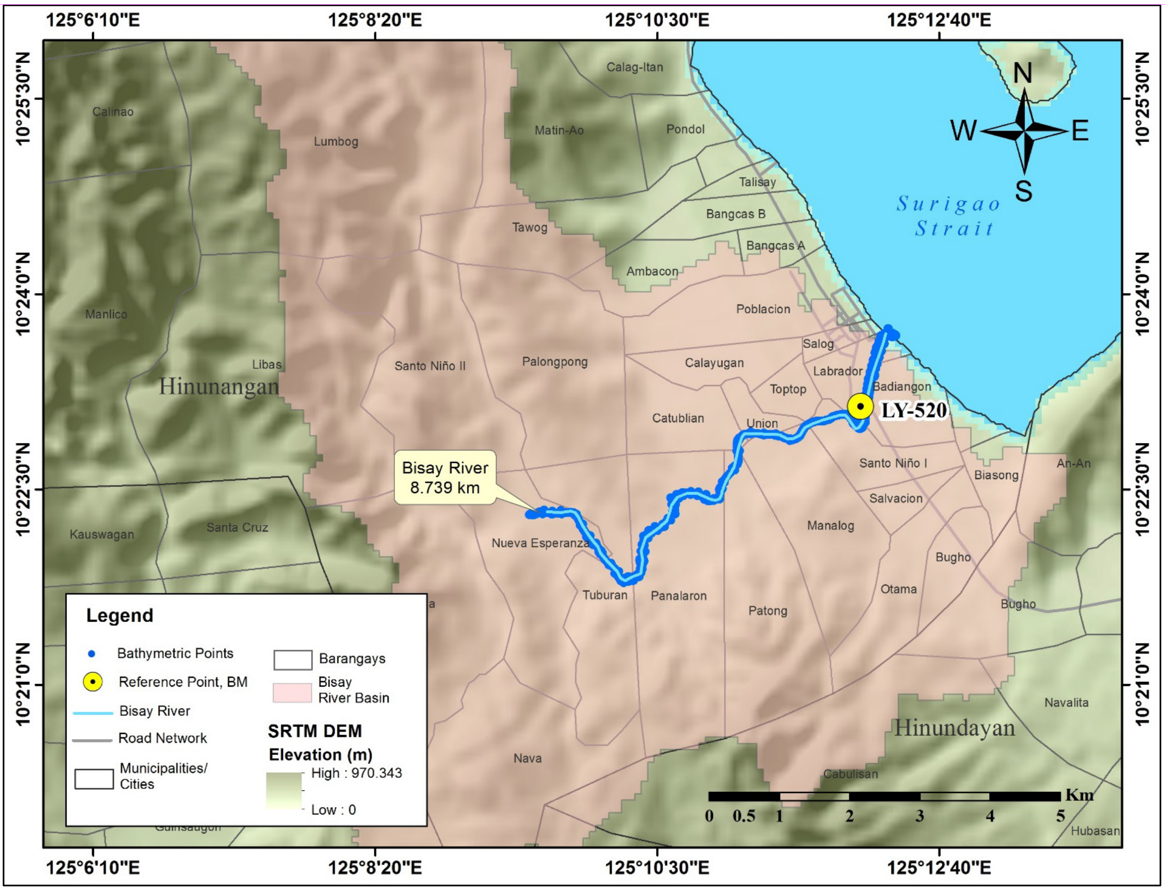

Figure 42. The extent of the Das-ay River Bathymetry Survey.

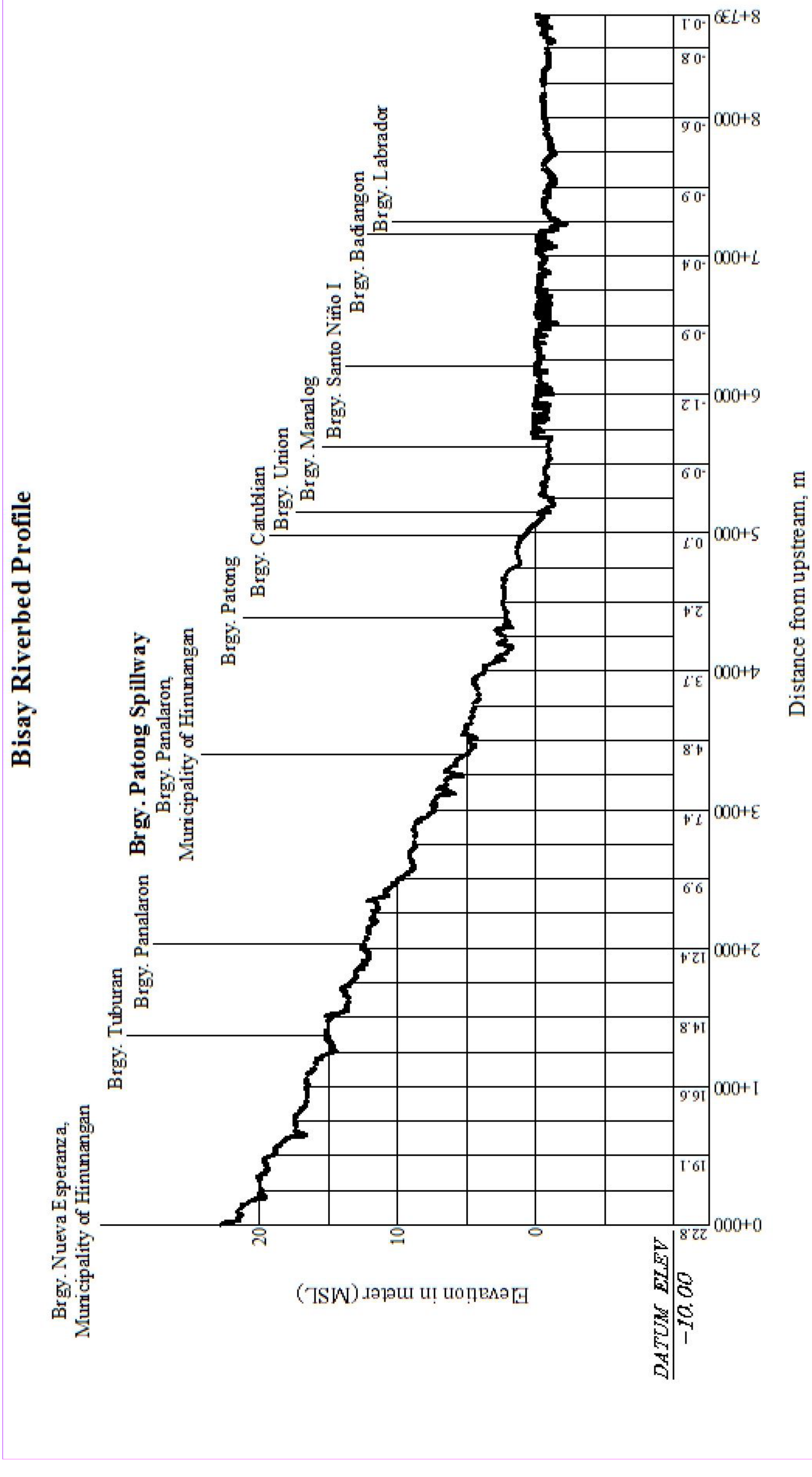

Figure 43. The Das-ay Riverbed Profile.

CHAPTER 5: FLOOD MODELING AND MAPPING

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

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

All components and data, such as rainfall, water level, and flow in a certain period of time, which may affect the hydrologic cycle of the Das-ay River Basin were monitored, collected, and analyzed.

5.1.2 Precipitation

Precipitation data was taken from two automatic rain gauge (ARG) installed by Department of Science and Technology – Advanced Science and Technology Institute (DOST-ASTI) and the Visayas State University Phil-Lidar 1 Flood Modeling Component (FMC). The location of the Das-ay ARG is illustrated in Figure 44.

Total rain from Das-ay rain gauge is 101 mm. It peaked to 4.33 mm on 24 November 2016, 16:40. The lag time between the peak rainfall and discharge is 29 hours and 20 minutes.

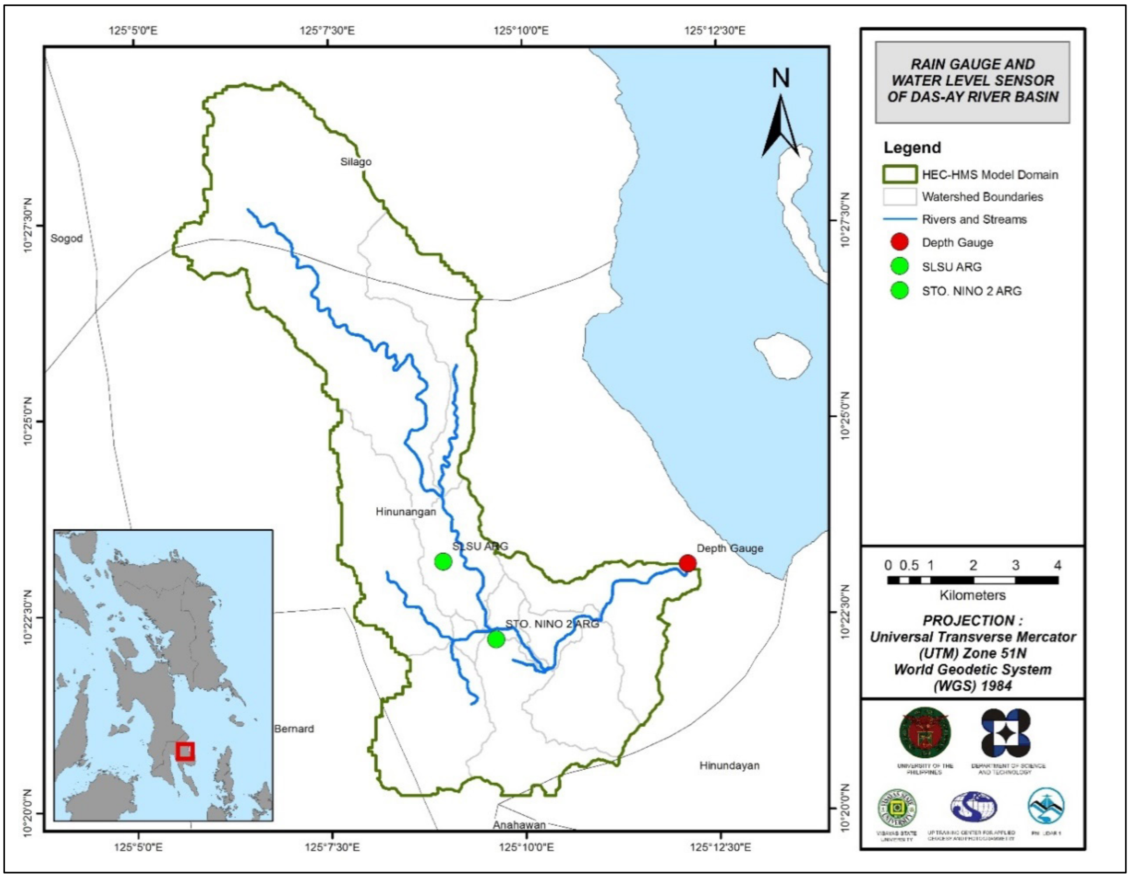

Figure 44. Location Map of the Das-ay HEC-HMS model used for calibration.

5.1.3 Rating Curves and River Outflow

A rating curve was computed using the prevailing cross-section (Figure 45) at Das-ay Bridge, Hinunangan, Southern Leyte (10°23'7.45''N, 125°12'6.18''E) to establish the relationship between the observed water levels (H) from Das-ay Bridge Automated Water Level Sensor (AWLS) HOBO Depth Gauge and the outflow (Q) of the watershed at this location.

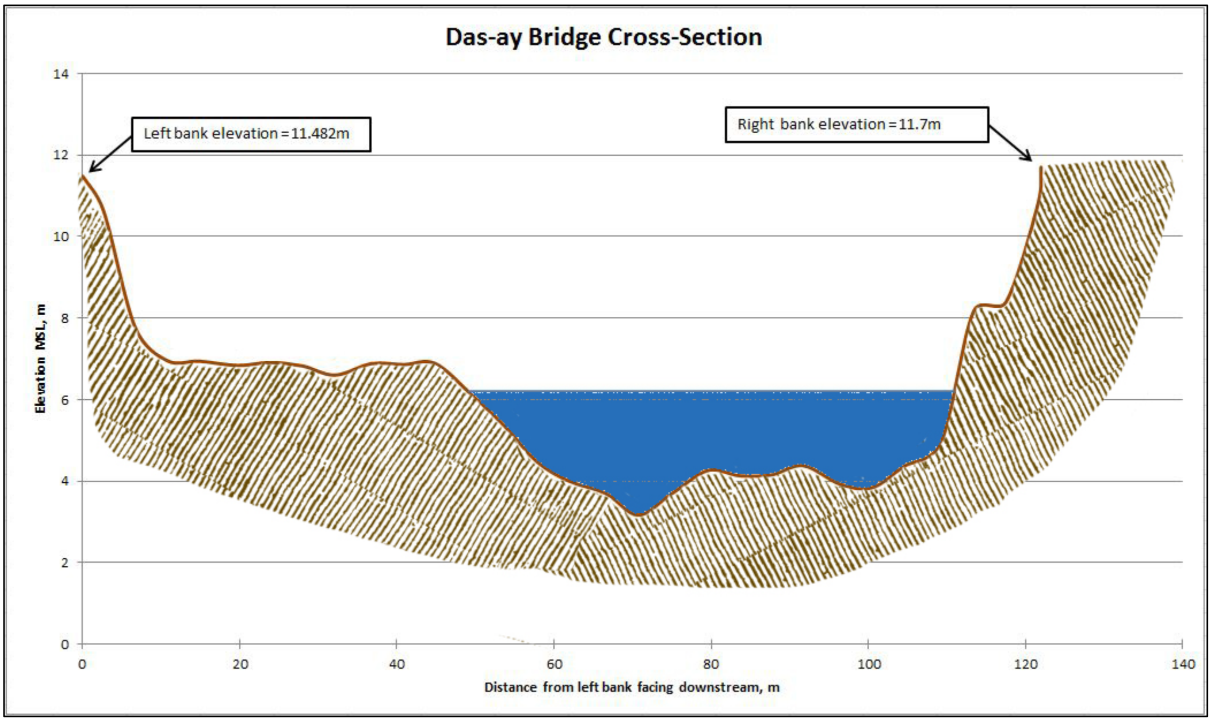

Figure 45. Cross-Section Plot of Das-ay Bridge.

For Das-ay Bridge, the rating curve is expressed as Q = 5E-15e$^{7.2609\,h}$ as shown in Figure 46.

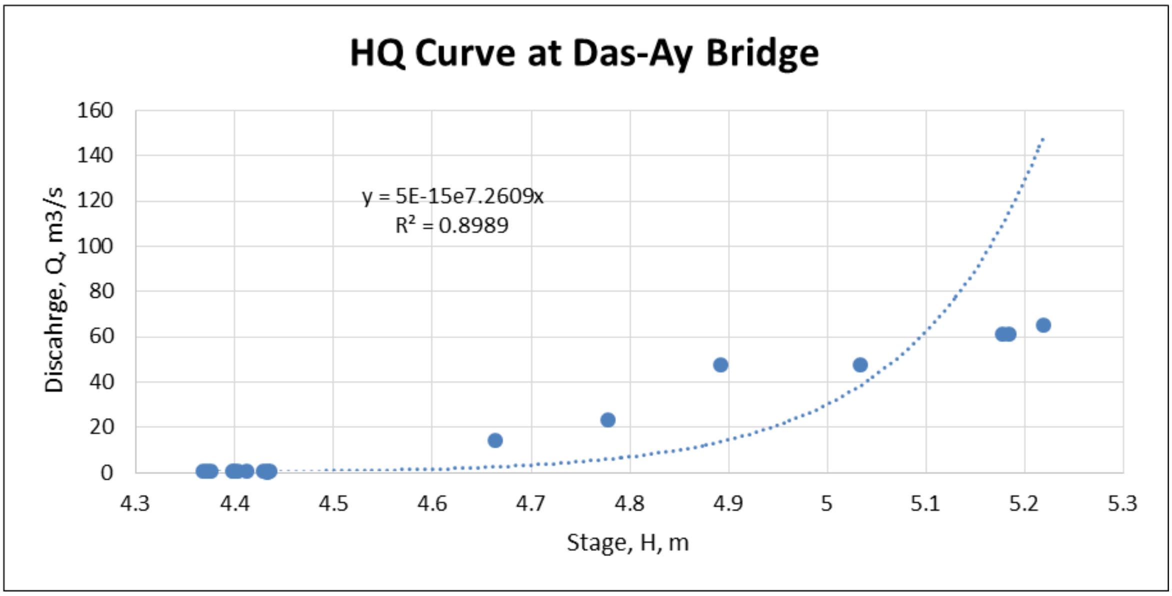

Figure 46. The rating curve at Das-ay Bridge.

This rating curve equation was used to compute the river outflow at Das-ay Bridge for the calibration of the HEC-HMS model shown in Figure 47. The total rainfall from Das-ay rain gauge is 101 mm. It peaked to 4.33 mm on 24 November 2016, 16:40. The lag time between the peak rainfall and discharge is 24 hours and 20 minutes.

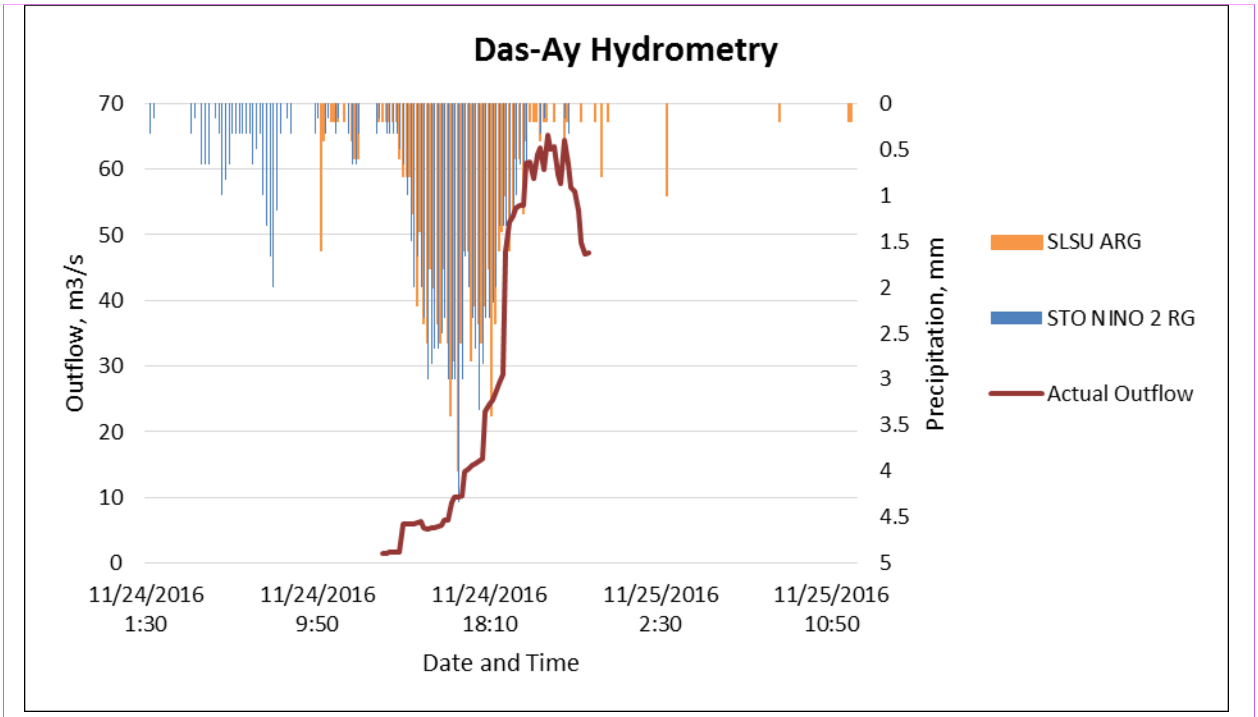

Figure 47. Rainfall and outflow data at Das-ay Bridge, which was used for modeling.

5.2 RIDF Station

PAGASA computed the Rainfall Intensity Duration Frequency (RIDF) values for the Maasin Rain Gauge (Table 30). The RIDF rainfall amount for 24 hours was converted into a synthetic storm by interpolating and re-arranging the values in such a way that certain peak values will be attained at a certain time (Figure 49). This station was selected based on its proximity to the Das-ay watershed. The extreme values for this watershed were computed based on a 16-year record.

Table 30. RIDF values for the Das-ay River Basin based on average RIDF data of Catarman station, as computed by PAGASA.

T (yrs)	10 mins	20 mins	30 mins	1 hr	2 hrs	3 hrs	6 hrs	12 hrs	24 hrs
2	18.5	28.1	35.6	48.1	68	82.1	104.6	124.9	145
5	25.9	38.3	63.8	63.8	90.4	108.8	137.5	165.2	190.8
10	30.8	45	74.2	74.2	105.3	126.5	159.3	191.9	221.2
15	33.5	48.8	80.1	80.1	113.7	136.5	171.5	206.9	238.4
20	35.5	51.5	84.2	84.2	119.6	143.5	180.1	217.5	250.4
25	37	53.6	87.3	87.3	124.1	148.9	186.7	225.6	259.6
50	41.5	59.9	97.1	97.1	138.1	165.5	207.1	250.6	288.1
100	46.1	66.2	106.8	106.8	151.9	181.9	227.4	275.4	316.3

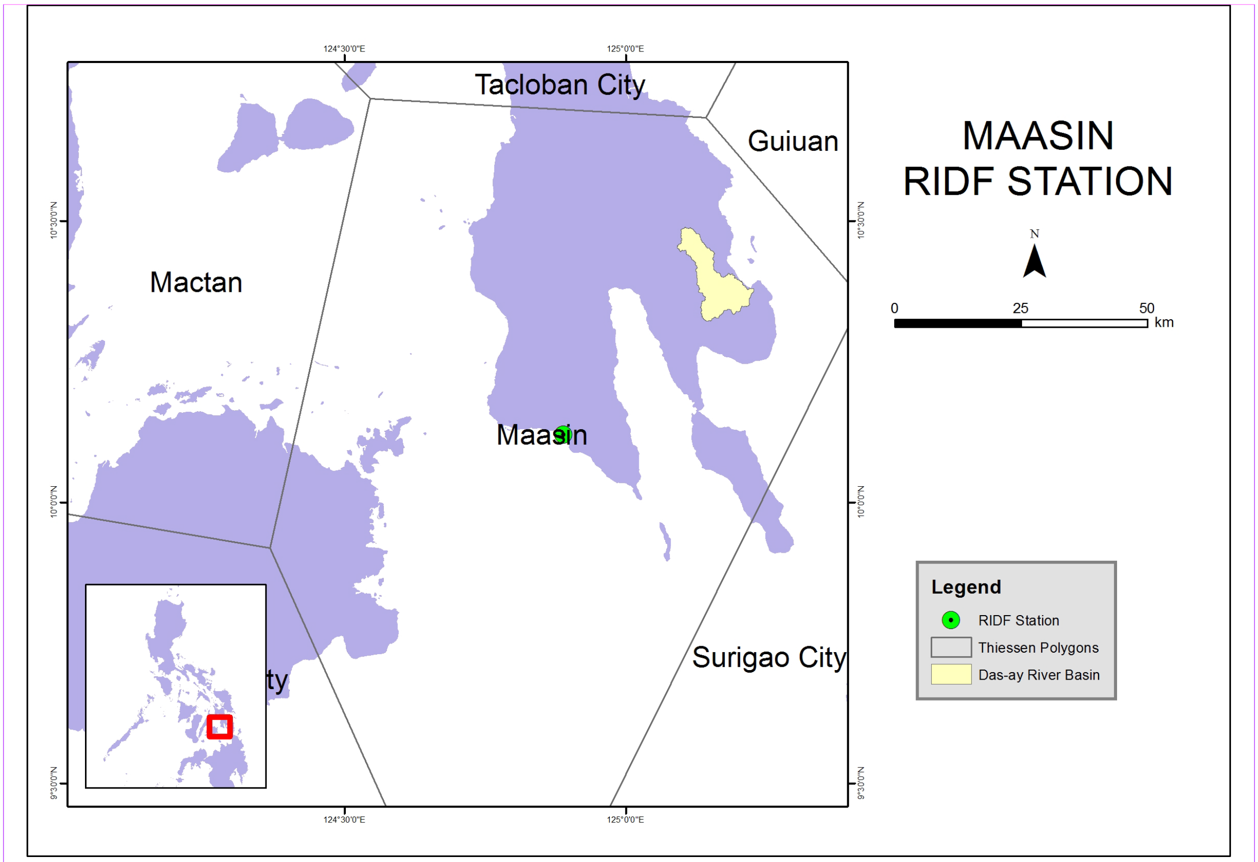

Figure 48. Location of the Maasin RIDF station relative to the Das-ay River Basin.

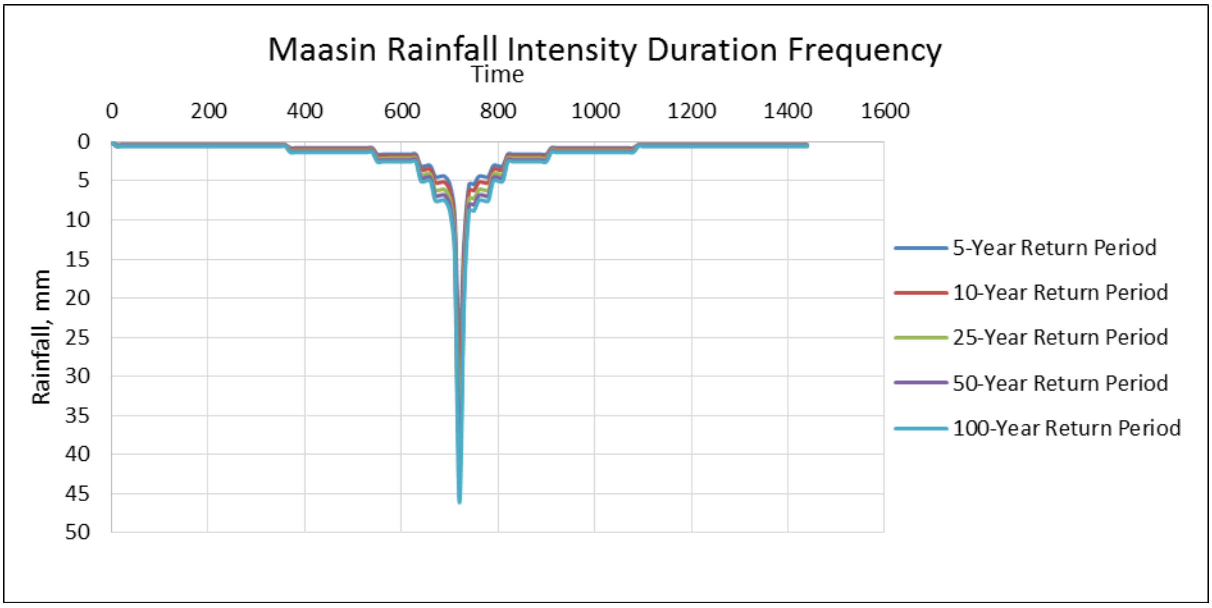

Figure 49. Synthetic storm generated for a 24-hr period rainfall for various return periods.

5.3 HMS Model

The soil dataset was generated before 2004 from the Bureau of Soils under the Department of Environment and Natural Resources Management. The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Das-ay River Basin are shown in Figure 50 and Figure 51, respectively.

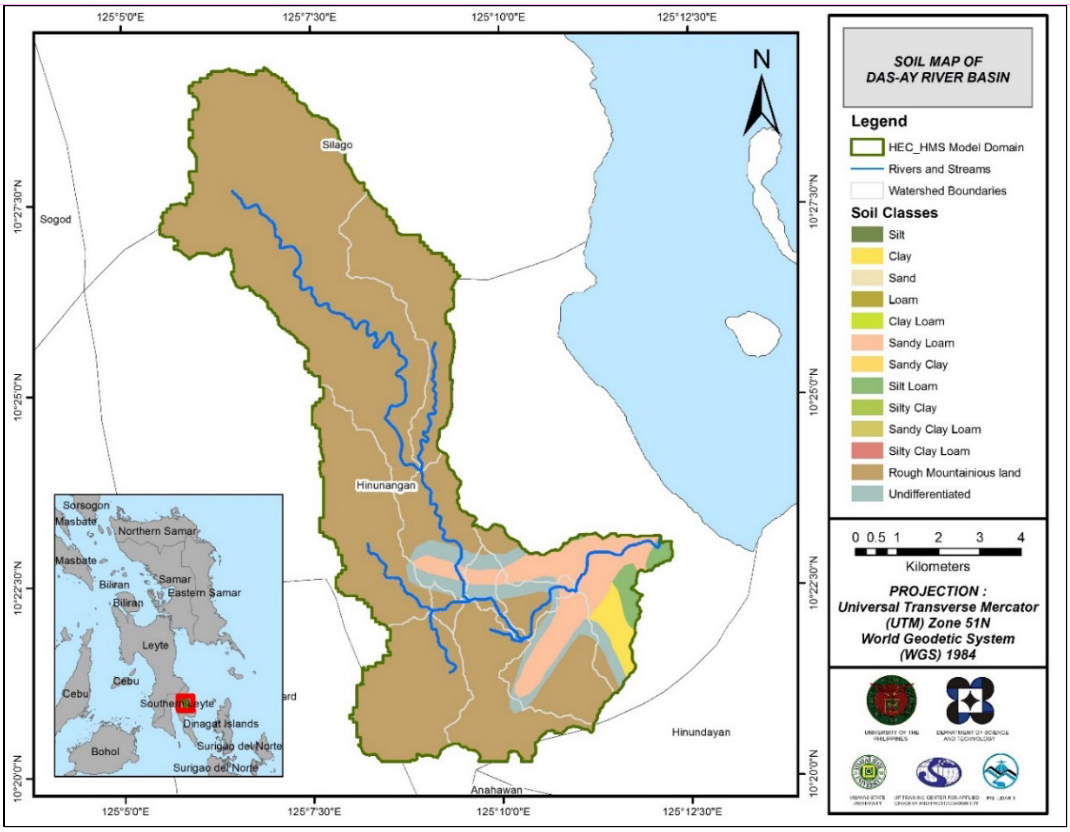

Figure 50. Soil Map of Das-ay River Basin.

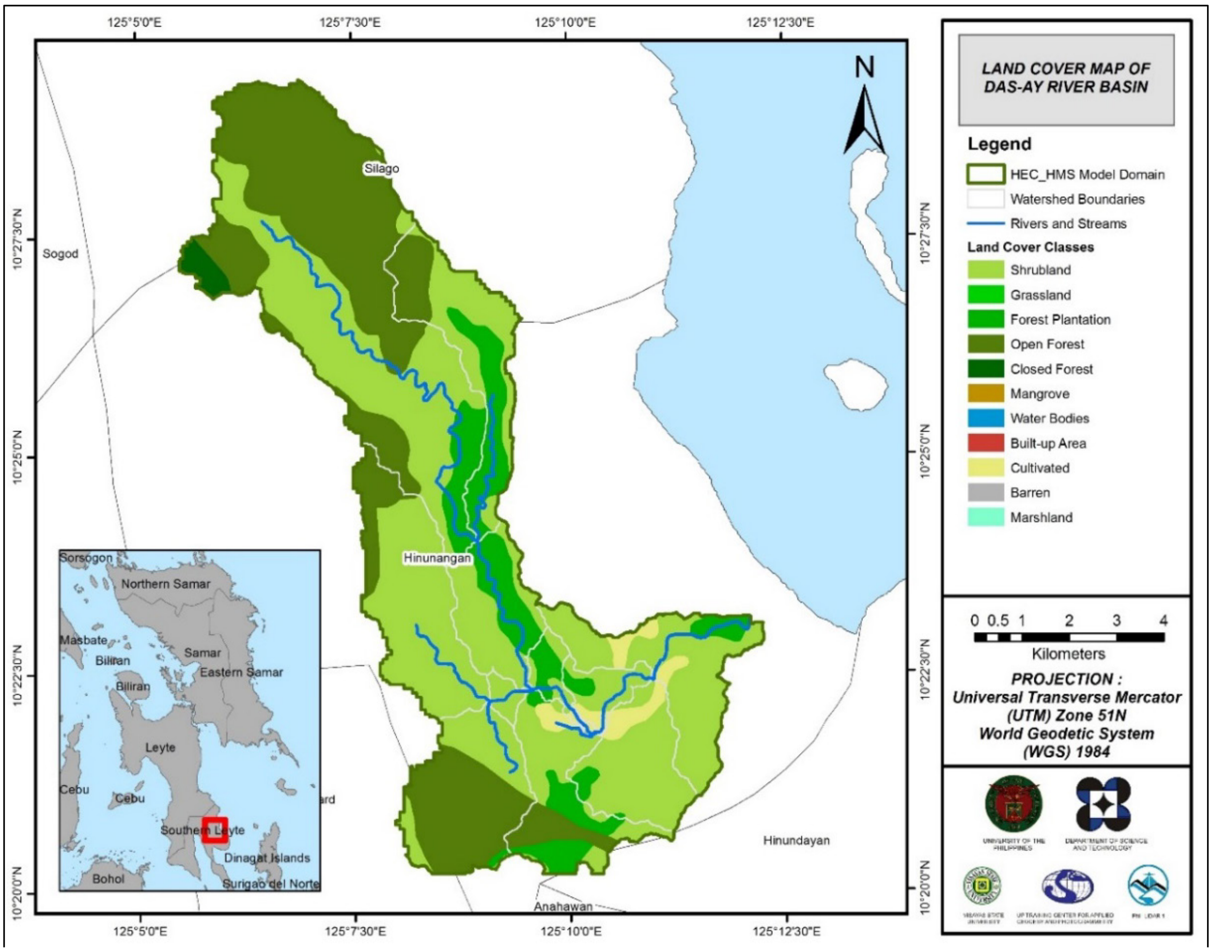

Figure 51. Land Cover Map of Das-ay River Basin.

For Das-ay, five (5) soil classes were identified. These are rough mountainous land, sandy loam, clay, silt loam, and undifferentiated. Moreover, six (6) land cover classes were identified. These are shrubland, grassland, forest plantation, open forest, closed forest, and cultivated area.

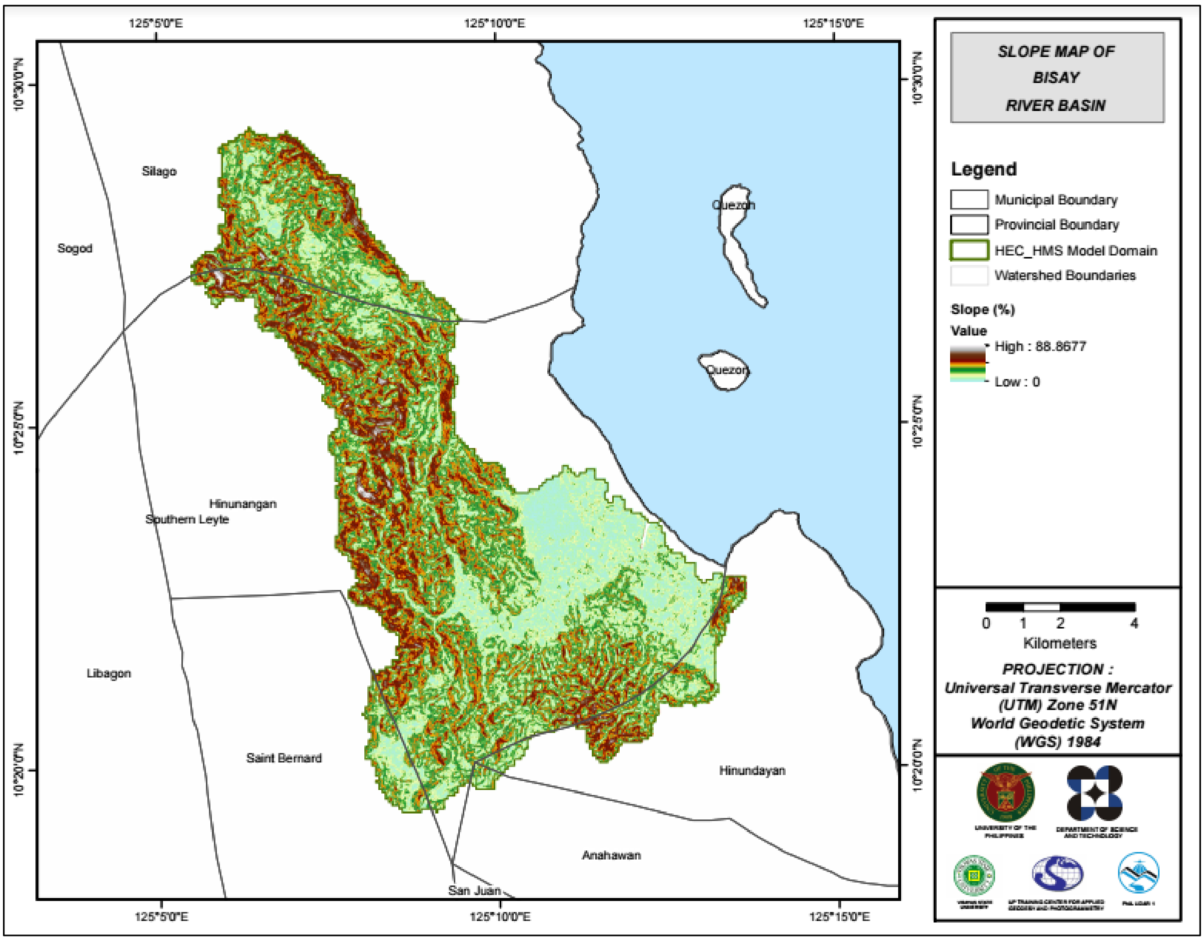

Figure 52. Slope Map of the Das-ay River Basin.

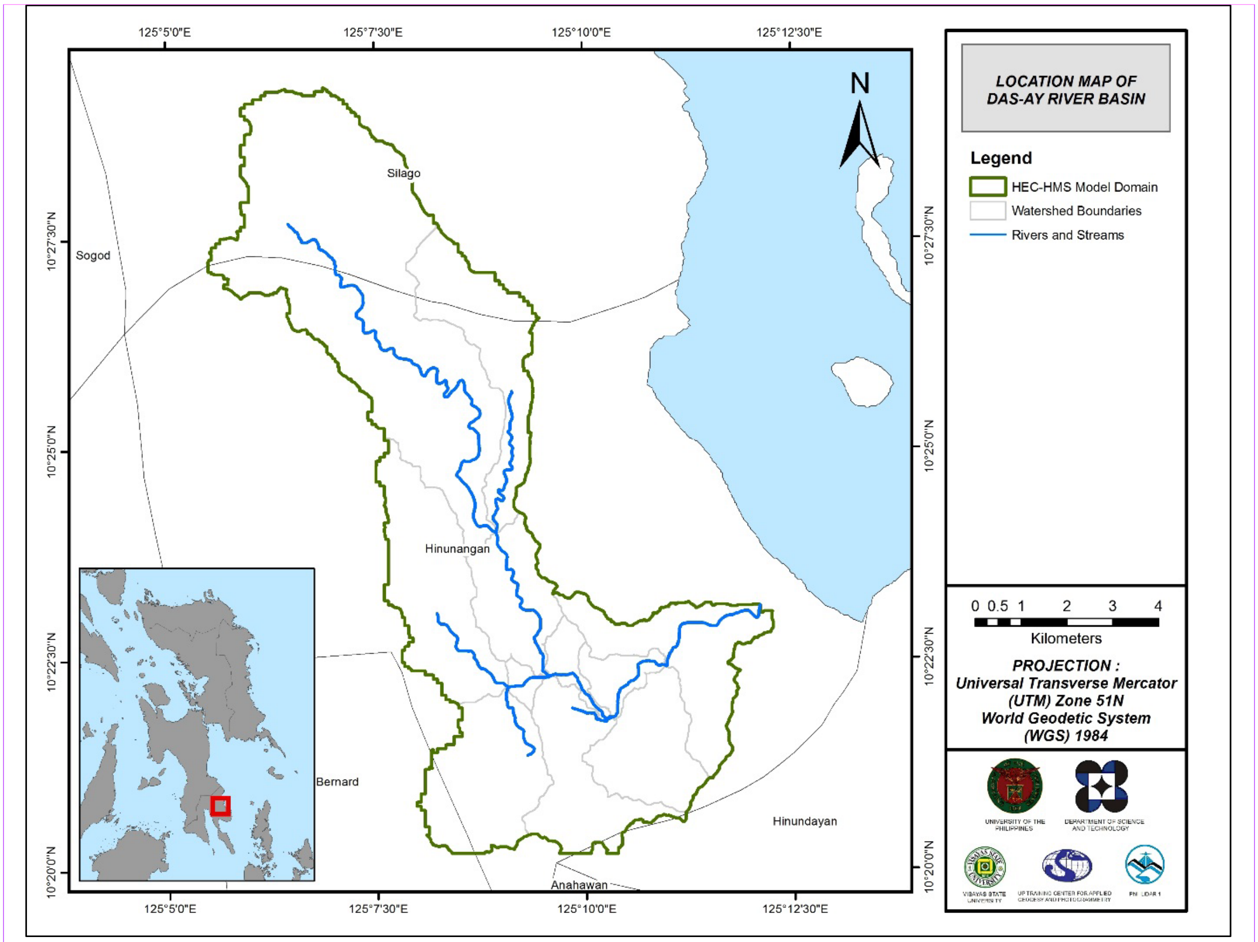

Figure 53. Stream Delineation Map of Das-ay River Basin

Using the SAR-based DEM, the Das-ay basin was delineated and further subdivided into subbasins. The model consists of 11 sub basins, 5 reaches, and 5 junctions as shown in Figure 54 (See Annex 10). The main outlet is at Das-ay Bridge.

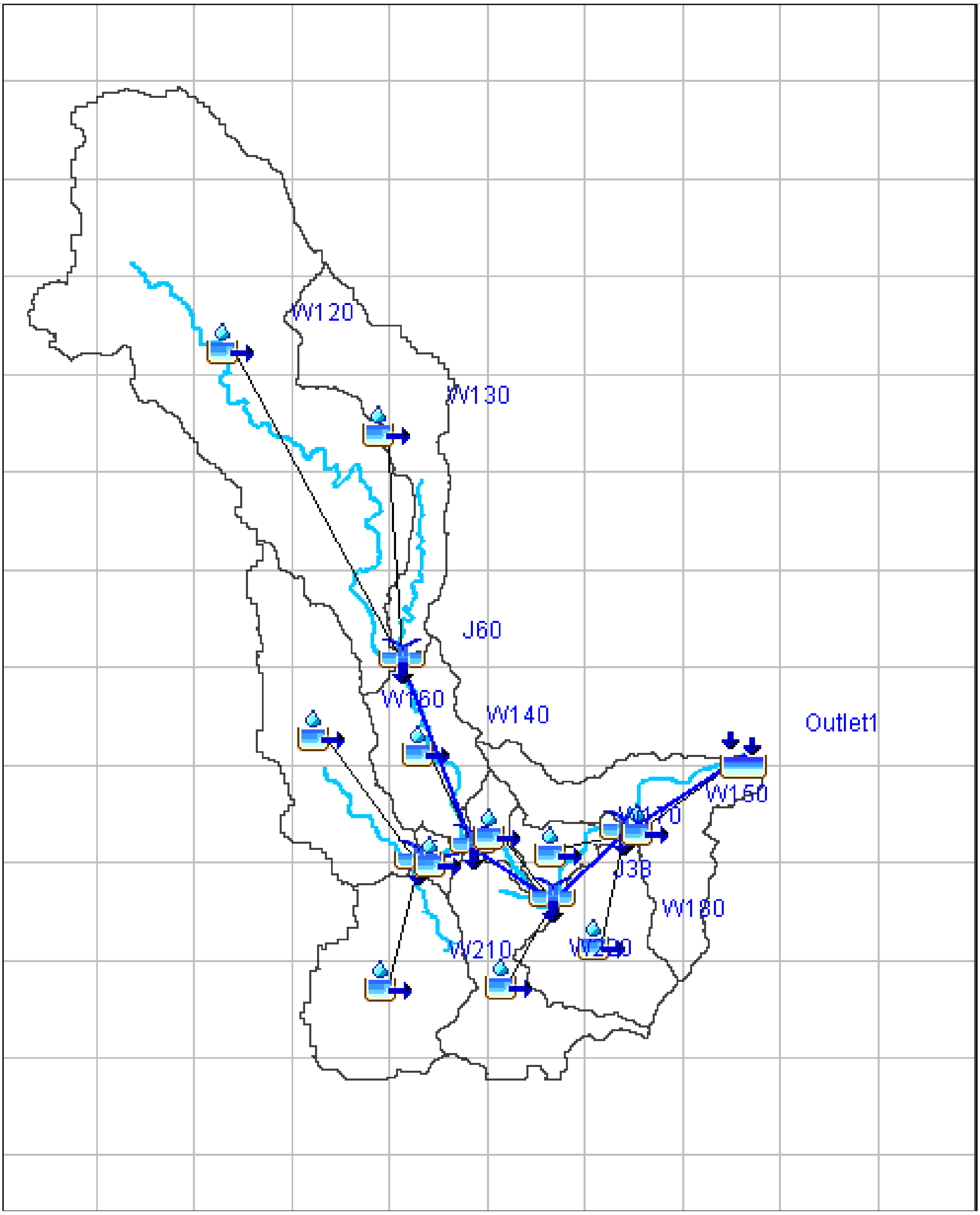

Figure 54. Das-ay river basin model generated in HEC-HMS.

5.4 Cross-section Data

The riverbed cross-sections of the watershed were necessary in the HEC-RAS model setup. The cross-section data for the HEC-RAS model was derived from the LiDAR DEM data, which was defined using the Arc GeoRAS tool and was post-processed in ArcGIS (Figure 55).

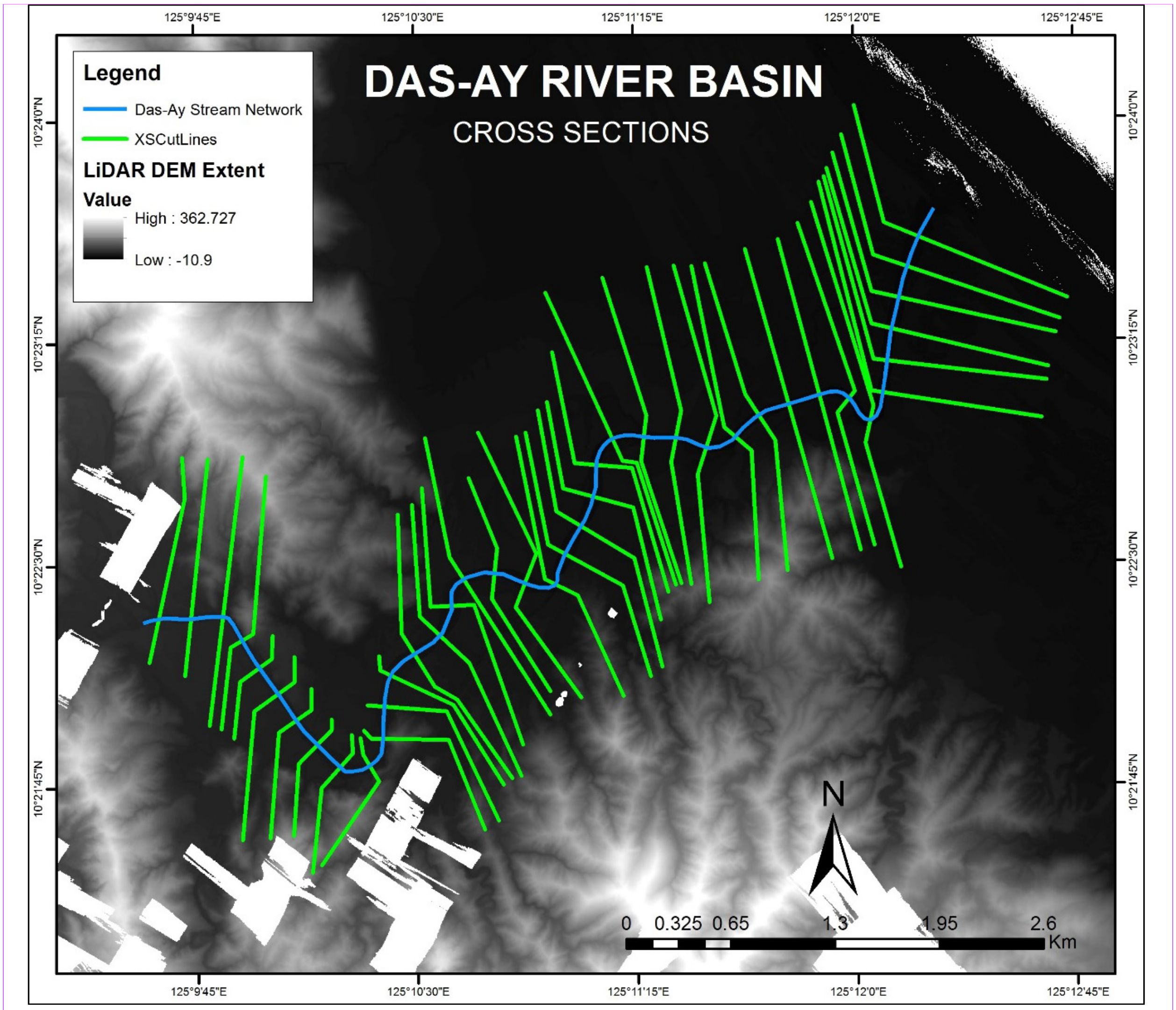

Figure 55. River cross-section of the Das-ay River through the ArcMap HEC GeoRas tool.

5.5 Flo 2D Model

The automated modelling process allows for the creation of a model with boundaries that are almost exactly coincidental with that of the catchment area. As such, they have approximately the same land area and location. The entire area is divided into square grid elements, 10 meter by 10 meter in size. Each element is assigned a unique grid element number which serves as its identifier, then attributed with the parameters required for modelling such as x-and y-coordinate of centroid, names of adjacent grid elements, Manning coefficient of roughness, infiltration, and elevation value. The elements are arranged spatially to form the model, allowing the software to simulate the flow of water across the grid elements and in eight directions (north, south, east, west, northeast, northwest, southeast, southwest).

Based on the elevation and flow direction, it is seen that the water will generally flow from the south of the model to the north, following the main channel. As such, boundary elements in those particular regions of the model are assigned as inflow and outflow elements respectively.

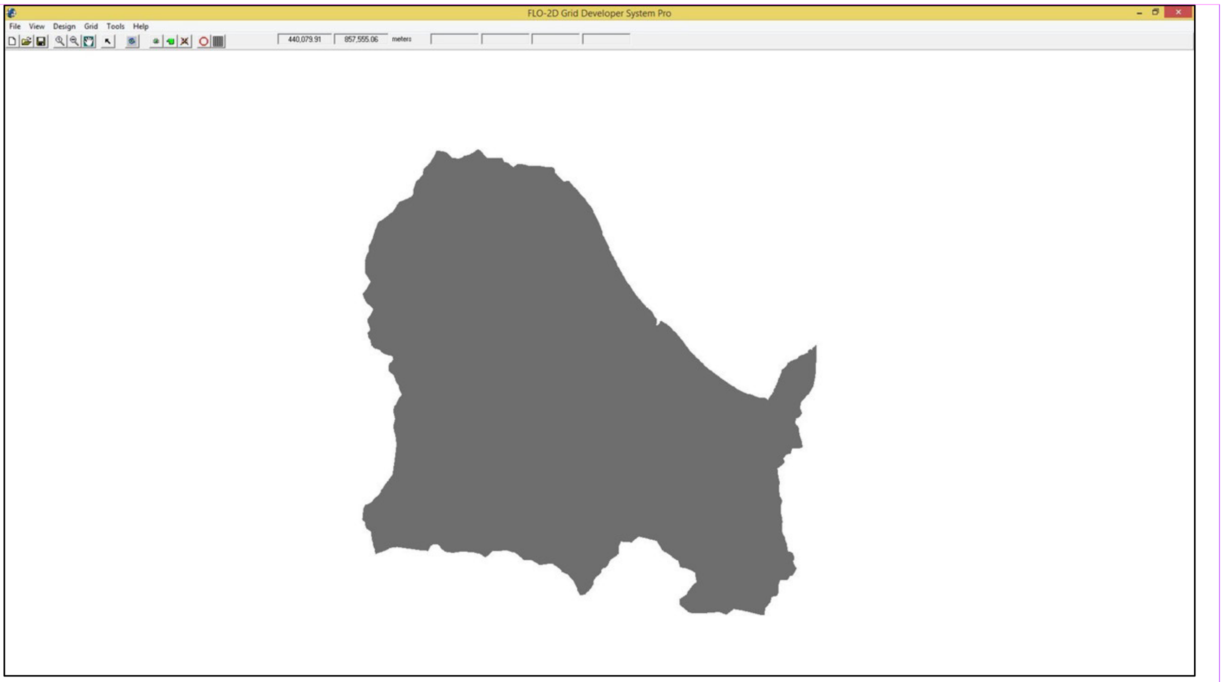

Figure 56. A screenshot of the river sub-catchment with the computational area to be modeled in FLO-2D Grid Developer S[What is GDS?][ok]ystem Pro (FLO-2D GDS Pro).

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 127.14526 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m²/s. The generated hazard maps for Das-ay are in Figures 60, 62, and 64.

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 41490800.00 m². The generated flood depth maps for Das-ay are in Figures 61, 63, and 65.

There is a total of 34740062.88 m³ of water entering the model. Of this amount, 14335239.33 m³ is due to rainfall while 20404823.55 m³ is inflow from other areas outside the model. 5162416.50 m³ of this water is lost to infiltration and interception, while 4814946.55 m³ is stored by the flood plain. The rest, amounting up to 24762649.19 m³, is outflow.

5.6 Results of HMS Calibration

After calibrating the Das-ay HEC-HMS river basin model (See Annex 9), its accuracy was measured against the observed values. Figure 57 shows the comparison between the two discharge data.

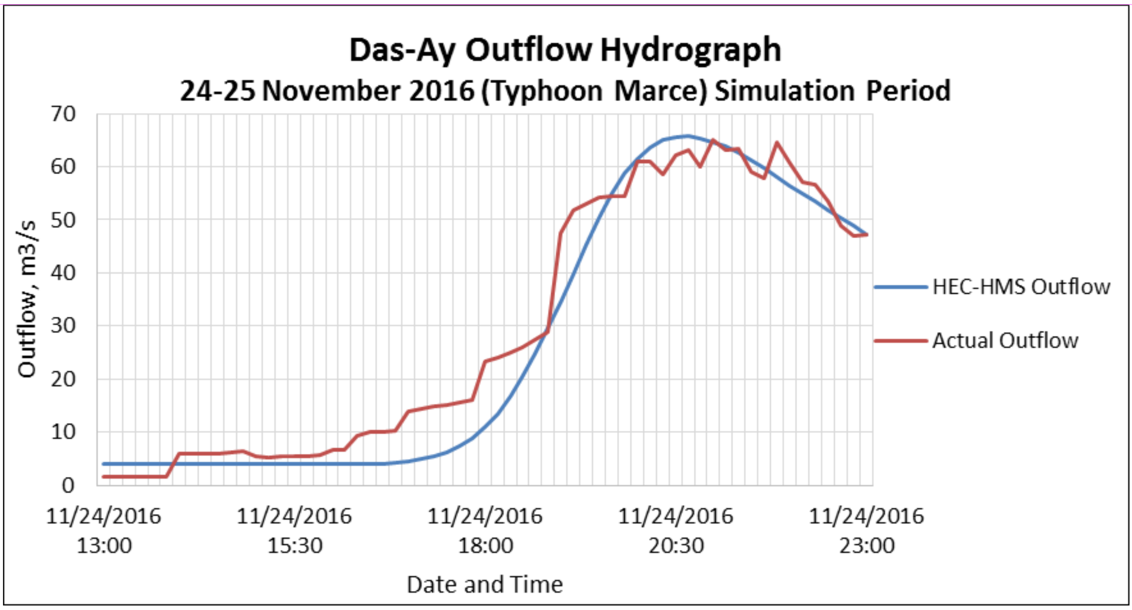

Figure 57. Outflow Hydrograph of Das-ay produced by the HEC-HMS model compared with observed outflow.

Table 31 shows the adjusted ranges of values of the parameters used in calibrating the model.

Table 31. Range of calibrated values for the Das-ay River Basin.

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	28 - 45
			Curve Number	81
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.1 - 1
			Storage Coefficient (hr)	0.7 - 6
	Baseflow	Recession	Recession Constant	1
			Ratio to Peak	0.003 – 0.02
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.04

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 28mm to 45mm means that there is an average to high amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The value of 81 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012).

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.1 hours to 6 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 1 indicates that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.003 to

0.02 indicates a steeper receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.04 corresponds to the common roughness of Das-ay watershed, which is determined to be cultivated with mature field crops (Brunner, 2010).

Table 32. Summary of the Efficiency Test of the Das-ay HMS Model

Accuracy measure	Value
RMSE	2.80
r2	0.8989
NSE	0.99
PBIAS	8.24
RSR	0.10

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 2.80 (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 0.8989.

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 0.99.

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 8.24.

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 0.10.

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 58) shows the Das-ay outflow using the Maasin Rainfall Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAG-ASA) data. The simulation results show increasing outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

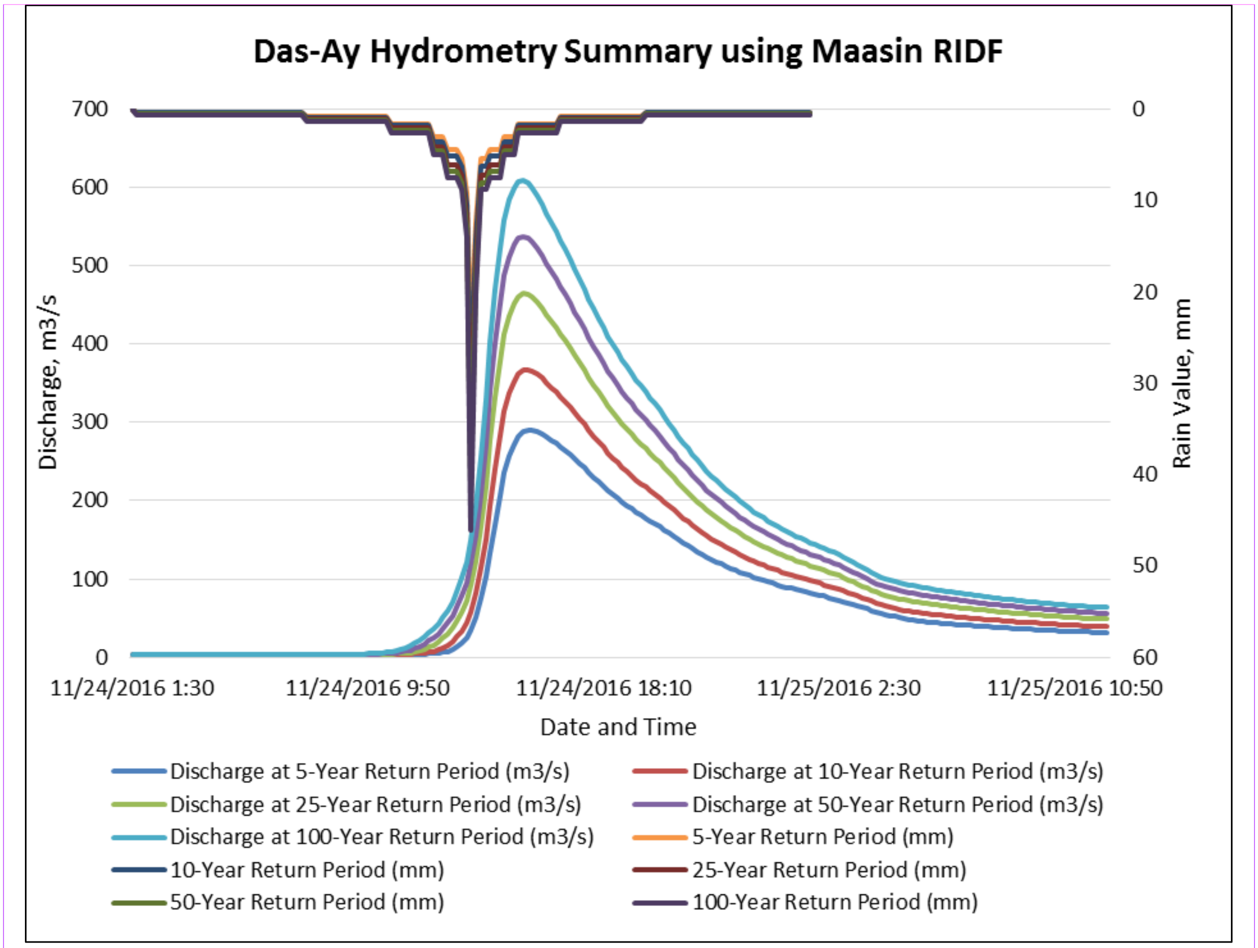

Figure 58. The Outflow hydrograph at the Das-ay Station, generated using the Maasin RIDF simulated in HEC-HMS.

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Das-ay discharge using the Maasin Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 33.

Table 33. The peak values of the Das-ay HEC-HMS Model outflow using the Maasin RIDF.

RIDF Period	Total Precipitation (mm)	Peak Rainfall (mm)	Peak Outflow (m^3/s)	Time to Peak
5-Year	190.8	25.9	290.6	2 hours
10-Year	221.2	30.8	367.1	2 hours
25-Year	259.6	37	464.4	1 hours, 50 minutes
50-Year	288.1	41.5	537.8	1 hours, 50 minutes
100-Year	316.3	46.1	609.8	1 hours, 50 minutes

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. Figure 59 shows a generated sample map of the Das-ay River using the calibrated HMS base flow.

Figure 59. Sample output map of the Das-ay RAS Model.

5.9 Flood Hazard and Flow Depth

The resulting hazard and flow depth maps have a 10m resolution. Figure 60 to Figure 65 show the 5-, 25-, and 100-year rain return scenarios of the Das-ay floodplain. The floodplain, with an area of 56.17 sq. km., covers two municipalites namely Hinunangan and Hinundayan. Table 34 shows the percentage of area affected by flooding per municipality.

Table 34. Municipalities affected in Das-ay floodplain.

Municipality	Total Area	Area Flooded	% Flooded
Hinunangan	136.38	49.52	36%
Hinundayan	53.28	6.58	12%

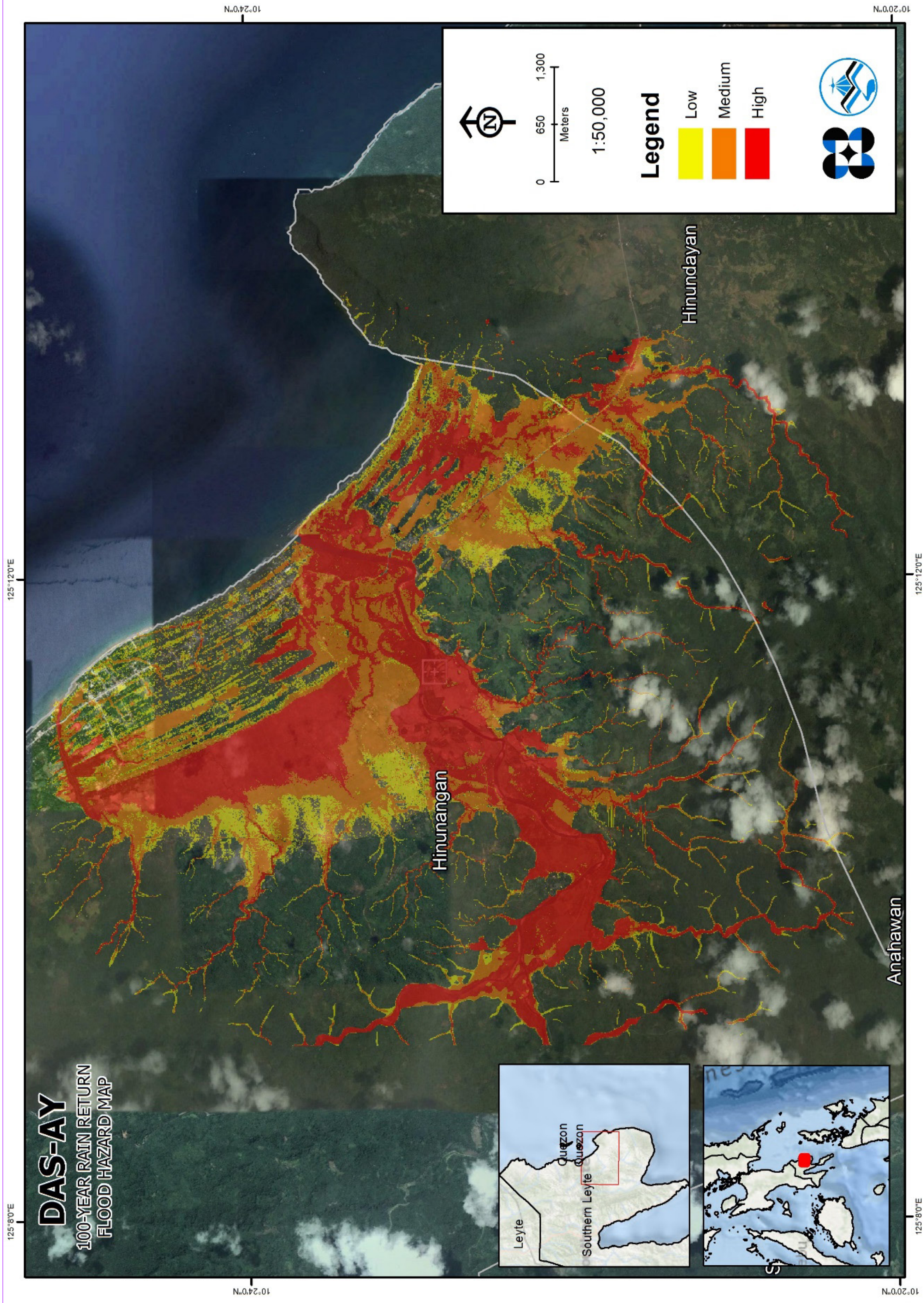

Figure 60. A 100-year Flood Hazard Map for Das-ay Floodplain overlaid on Google Earth imagery.

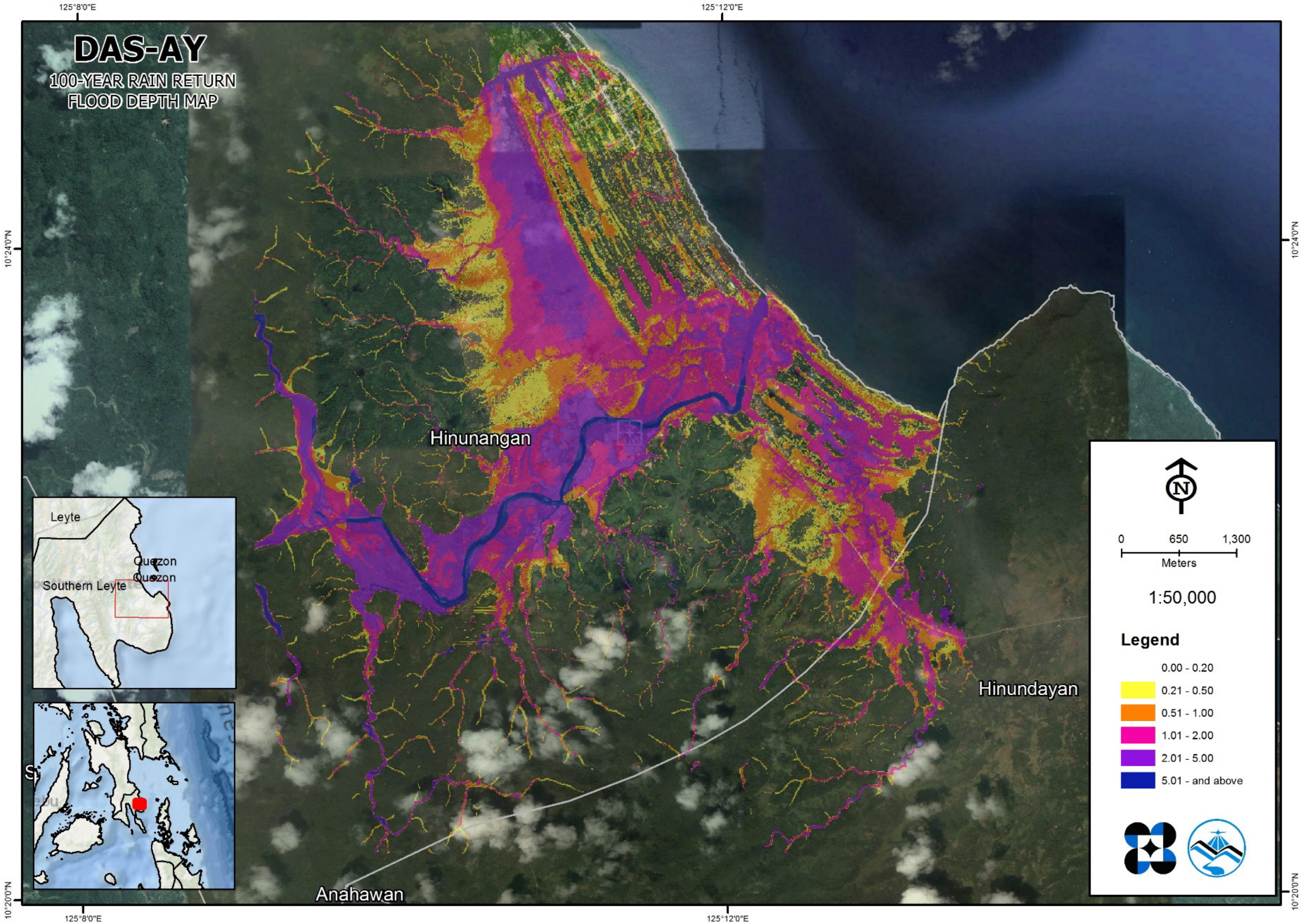

Figure 61. A 100-year Flow Depth Map for Das-ay Floodplain overlaid on Google Earth imagery.

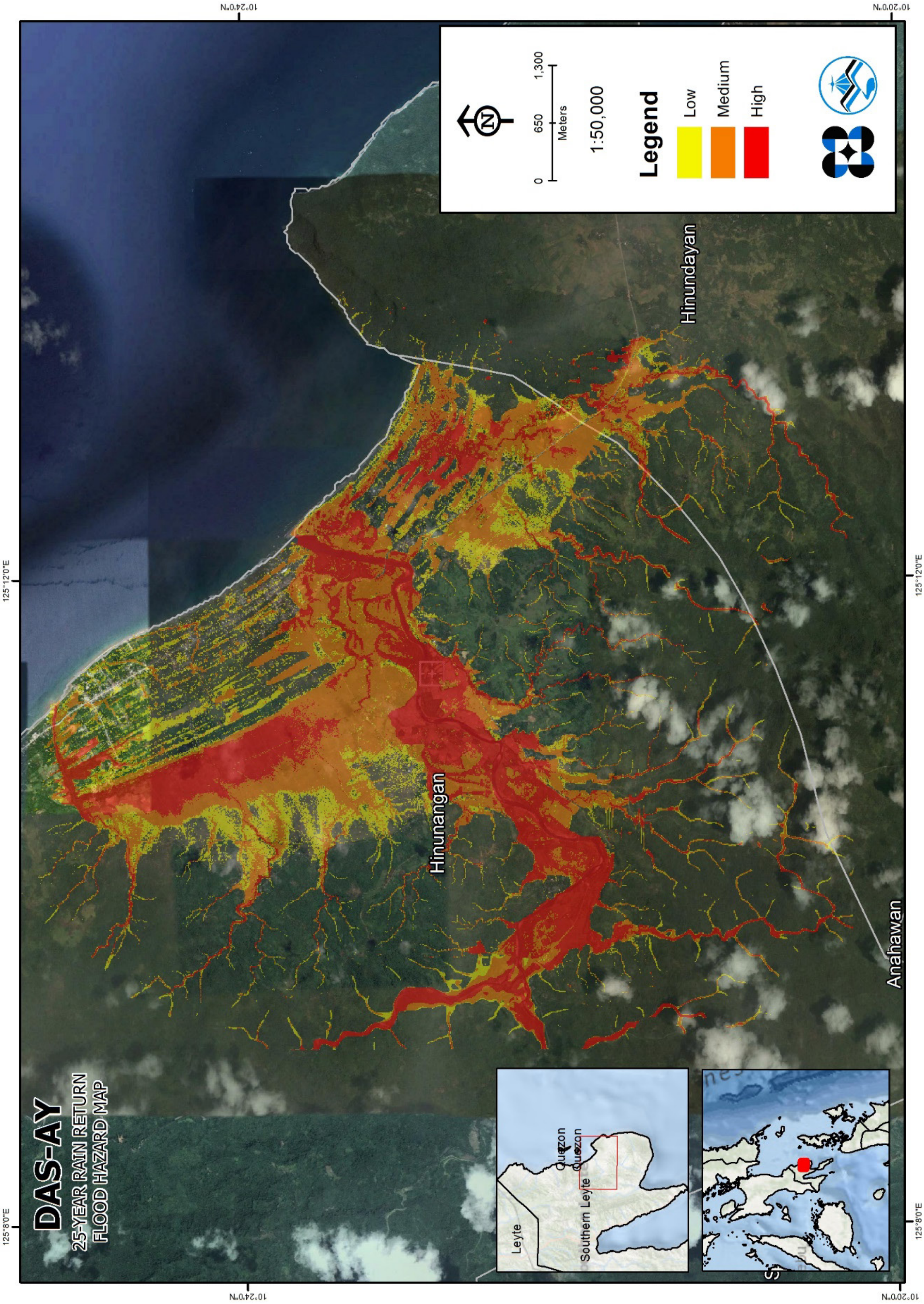

Figure 62. A 25-year Flood Hazard Map for Das-ay Floodplain overlaid on Google Earth imagery.

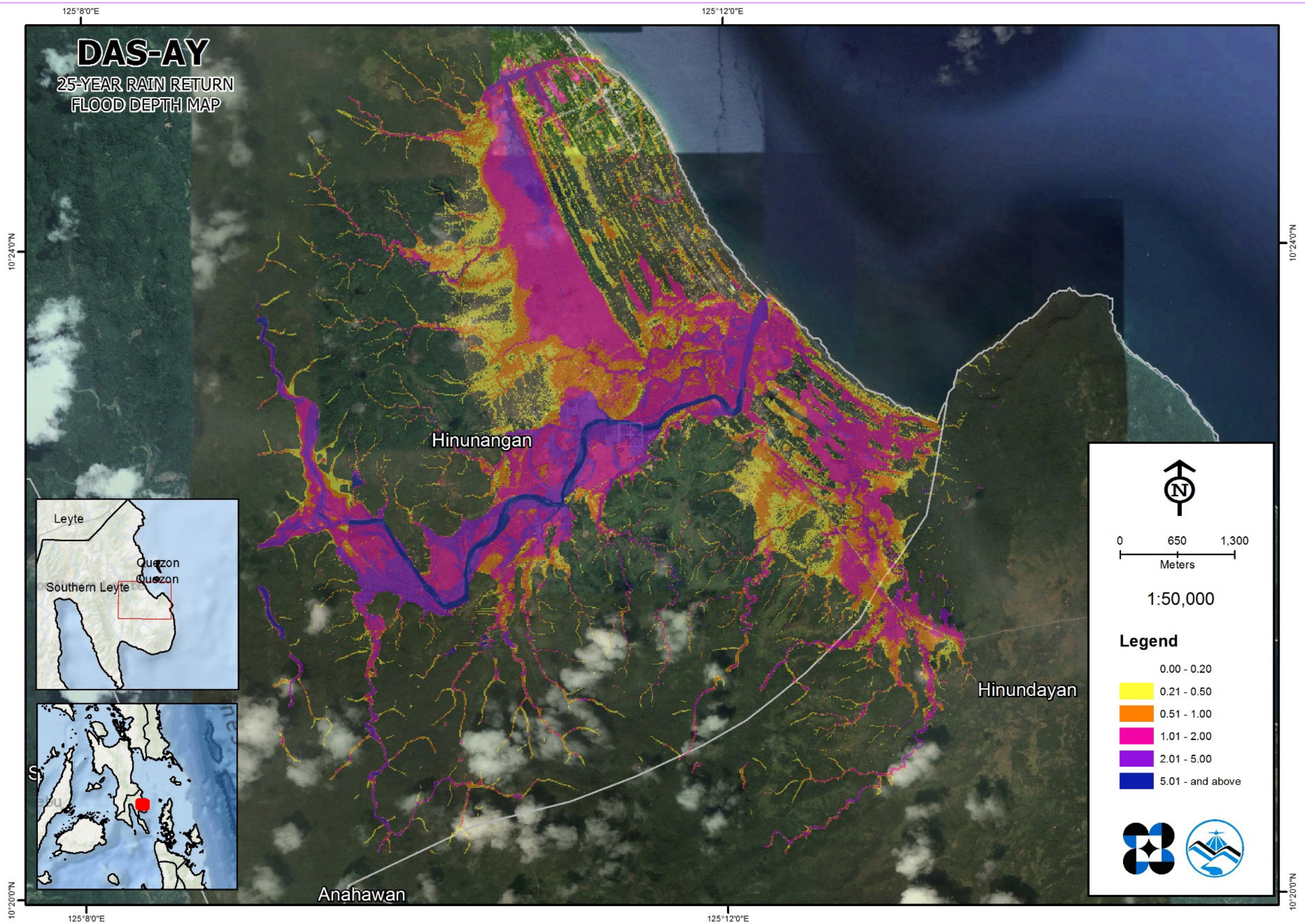

Figure 63. A 25-year Flow Depth Map for Das-ay Floodplain overlaid on Google Earth imagery.

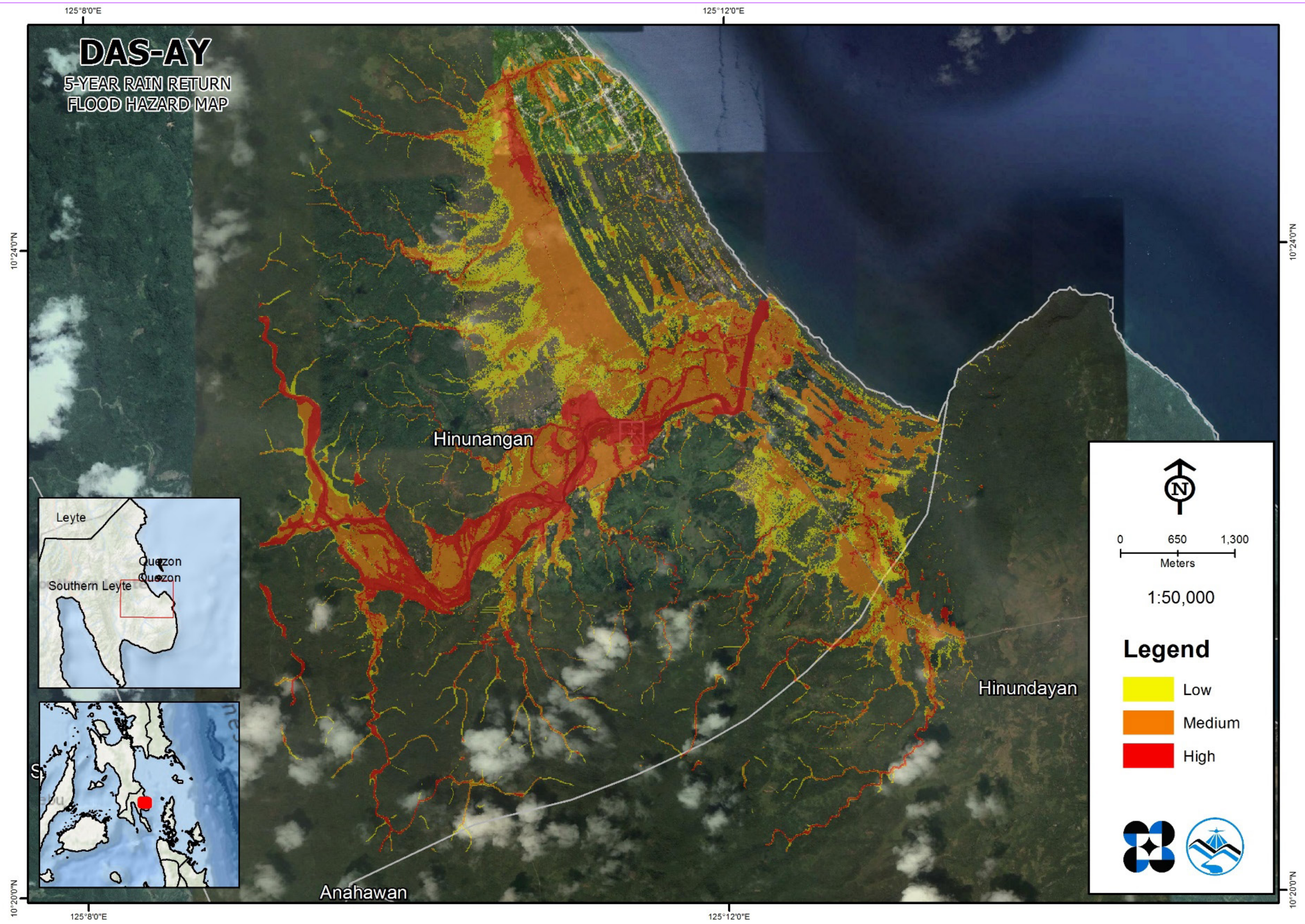

Figure 64. A 5-year Flood Hazard Map for Das-ay Floodplain overlaid on Google Earth imagery.

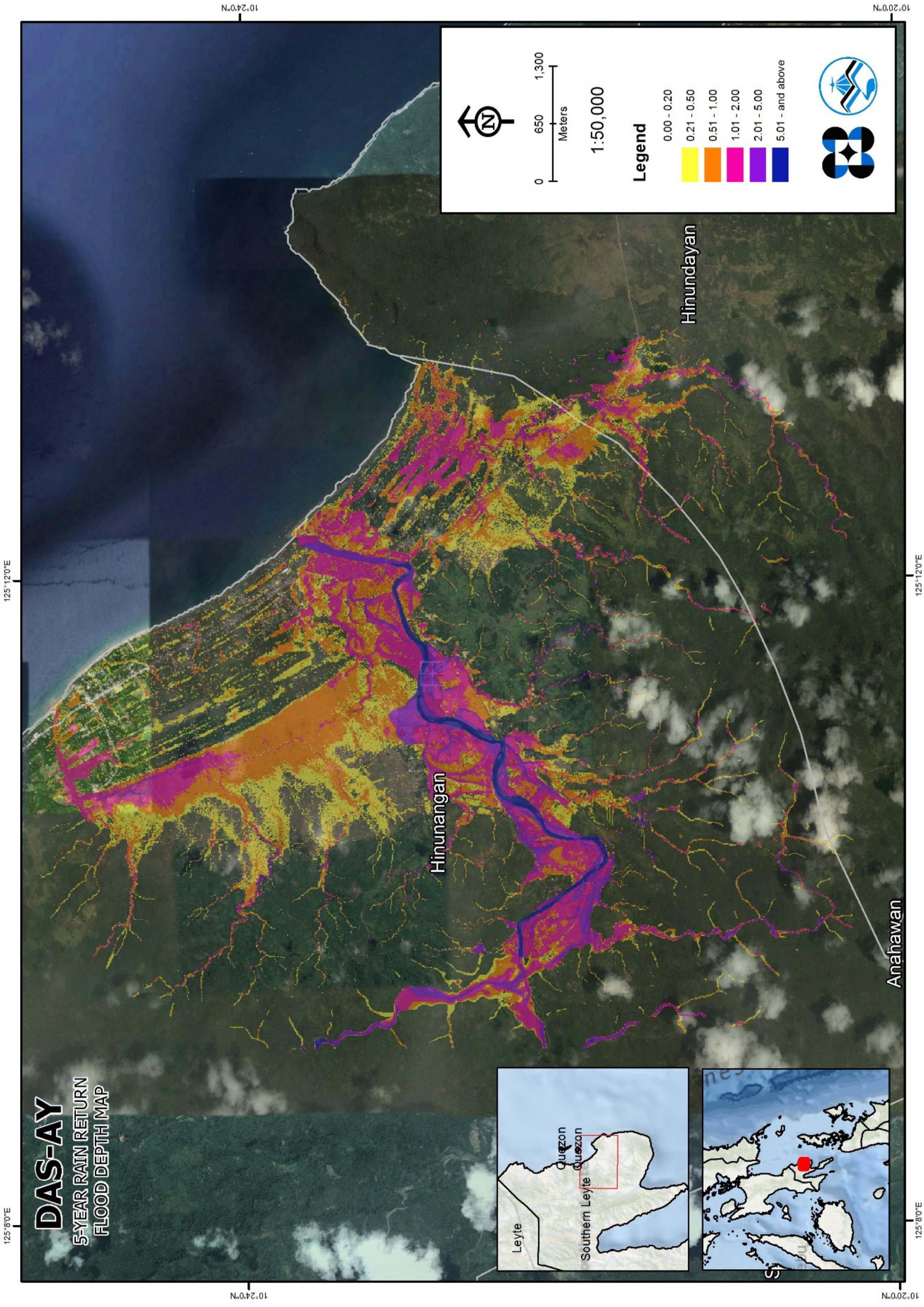

Figure 65. A 5-year Flood Depth Map for Das-ay Floodplain overlaid on Google Earth imagery.

5.10 Inventory of Areas Exposed to Flooding

Listed below are the affected barangays in the Das-ay River Basin, grouped accordingly by municipality. For the said basin, three (3) municipalities are expected to experience flooding when subjected to a 5-year rainfall return period.

For the 5-year return period, 24.57% of the municipality of Hinunangan with an area of 136.38 sq. km. will experience flood levels of less 0.20 meters. 3.23% of the area will experience flood levels of 0.21 to 0.50 meters while 3.77%, 3.29% and 1.47% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and more than 2 meters, respectively. Listed in Table 35 are the affected areas in square kilometers by flood depth per barangay. Annex 12 and Annex 13 show the educational and health institutions exposed to flooding.

Table 35. Affected Areas in Hinunangan, Leyte during 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Areas of Affected Barangays in Hinunangan							
	Ambacon	Badiangon	Bangcas A	Bangcas B	Biasong	Bugho	Calayugan	Canipaan
0.03-0.20	0.931289381	0.537335512	0.538420181	0.626410214	0.462818529	0.401282889	0.265080901	0.178214164
0.21-0.50	0.326506772	0.135695459	0.099543406	0.140713407	0.121123104	0.179814345	0.344272189	0.032997418
0.51-1.00	0.286696524	0.247857439	0.020898624	0.098180745	0.165682811	0.272569464	0.454309746	0.07431032
1.01-2.00	0.156948145	0.299547816	0.006514105	0.165313089	0.095124586	0.106186556	0.02671484	0.096362108
2.01-5.00	0.016111989	0.043447842	0	0.017382119	0.0007	0.023644824	0.000605142	0.000171012
> 5.00	0.0005	0.003375137	0	0	0.0005	0	0	0

Affected Area (sq. km.) by flood depth (in m.)	Areas of Affected Barangays in Hinunangan							
	Catublian	Ilaya	Labrador	Manalog	Matin-Ao	Nava	Nueva Esperanza	Otama
0.03-0.20	1.002230695	0.304327415	0.076067306	2.583257837	1.302953982	1.224671571	2.399284003	1.299403388
0.21-0.50	0.244810115	0.011093362	0.090239507	0.106856677	0.042568306	0.034982789	0.138381103	0.171208916
0.51-1.00	0.112821771	0.008905534	0.263752037	0.143248241	0.026507779	0.023940665	0.240365388	0.119850383
1.01-2.00	0.132369315	0.019315168	0.335141257	0.287853973	0.009187408	0.02484289	0.512516378	0.113233354
2.01-5.00	0.077186524	0.032310315	0.070757781	0.131981396	0.001888219	0.015746566	0.161190879	0.006818687
> 5.00	0.015046278	0.0009	0.005763552	0.040373317	0	0.0005	0.047631535	0

Affected Area (sq. km.) by flood depth (in m.)	Areas of Affected Barangays in Hinunangan							
	Hinunanganngpong	Panalaron	Patong	Poblacion	Pondol	Salog	Salvacion	Santo Niño I
0.03-0.20	4.397034657	3.358215757	3.391963378	1.578116009	0.481266912	0.139058968	0.160535132	0.6064371
0.21-0.50	0.126623209	0.335275572	0.115072496	0.575176718	0.029518276	0.067151271	0.224010296	0.181602933
0.51-1.00	0.075718032	0.494052422	0.116224598	0.663347292	0.031887413	0.073682654	0.118377307	0.204676307
1.01-2.00	0.035669491	0.588075742	0.138404485	0.044966178	0.080995655	0.039403394	0.050345732	0.222754825
2.01-5.00	0.010017913	0.278416661	0.053231818	0.002095269	0.001981991	0.0003	0.001010945	0.029876036
> 5.00	0.000106963	0.132578364	0.044617608	0	0	0	0	0.033574057

Affected Area (sq. km.) by flood depth (in m.)	Areas of Affected Barangays in Hinunangan							
	Santo Niño II	Tahusan	Talisay	Tawog	Toptop	Tuburan	Union	Santo Niño II
0.03-0.20	0.569061077	0.08586917	0.287399507	1.626178544	0.007586247	2.687877504	0.000787876	0.569061077
0.21-0.50	0.035356226	0.07130155	0.08438951	0.179203938	0.032182073	0.114828429	0.019736865	0.035356226
0.51-1.00	0.034860971	0.056833643	0.041259965	0.171792406	0.20812411	0.08669227	0.206782385	0.034860971
1.01-2.00	0.072705468	0.10048007	0.030997729	0.136893126	0.246932229	0.212724687	0.093831542	0.072705468
2.01-5.00	0.123674307	0.004194897	0.003667784	0.078062245	0.048224405	0.274723501	0.076112716	0.123674307
> 5.00	0.023792408	0	0	0	0	0.047313105	0.022344352	0.023792408

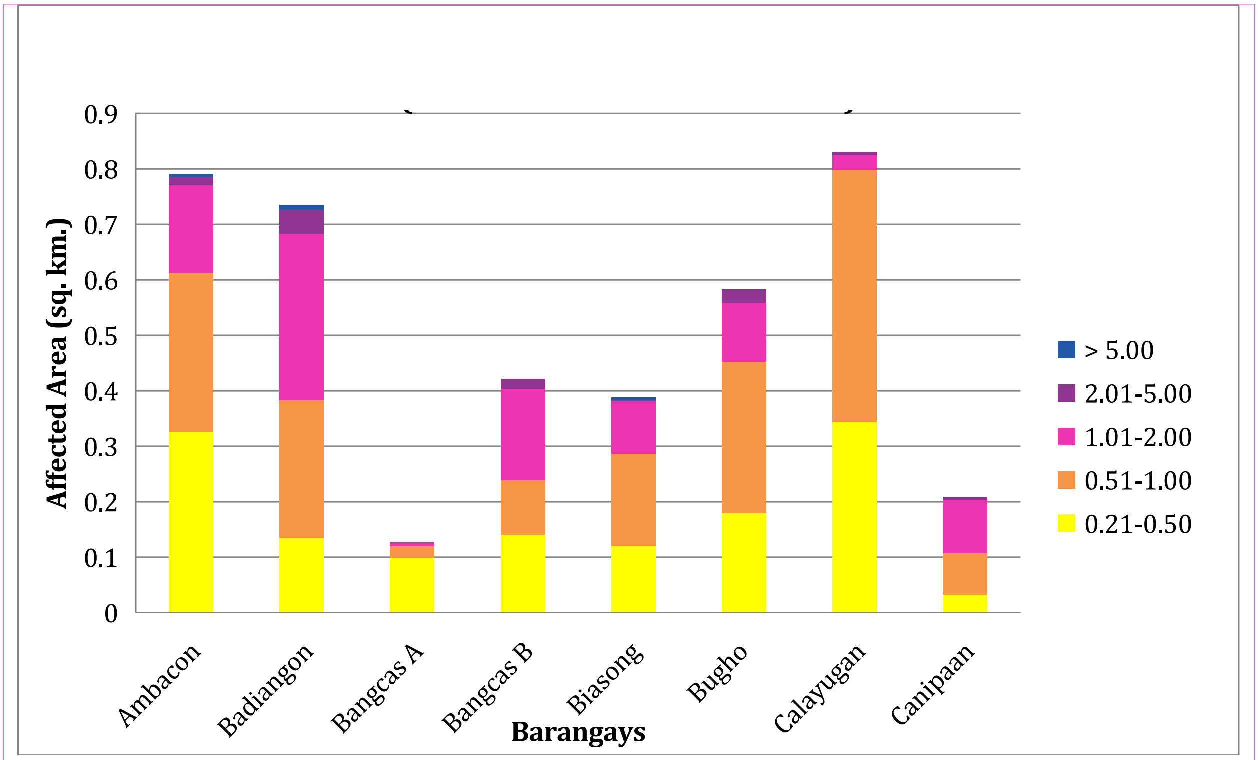

Figure 66. Affected Areas in Hinunangan, Leyte during 5-Year Rainfall Return Period.

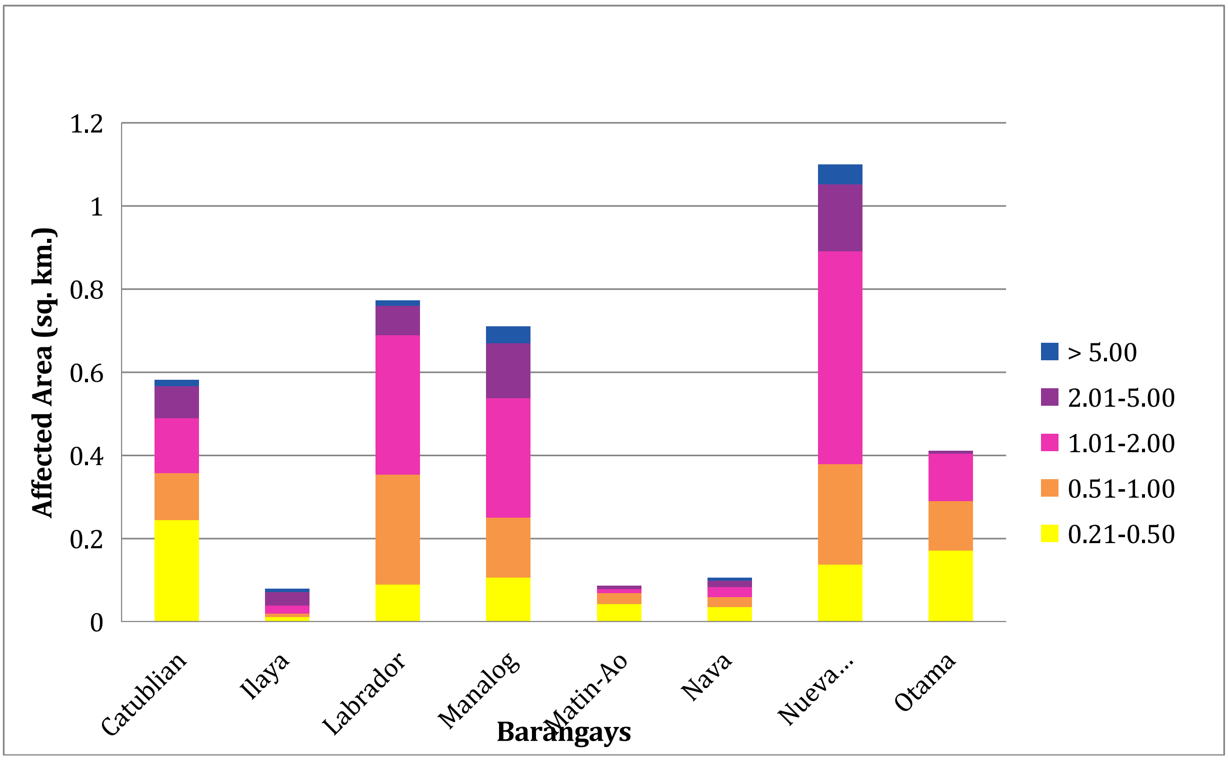

Figure 67. Affected Areas in Hinunangan, Leyte during 5-Year Rainfall Return Period.

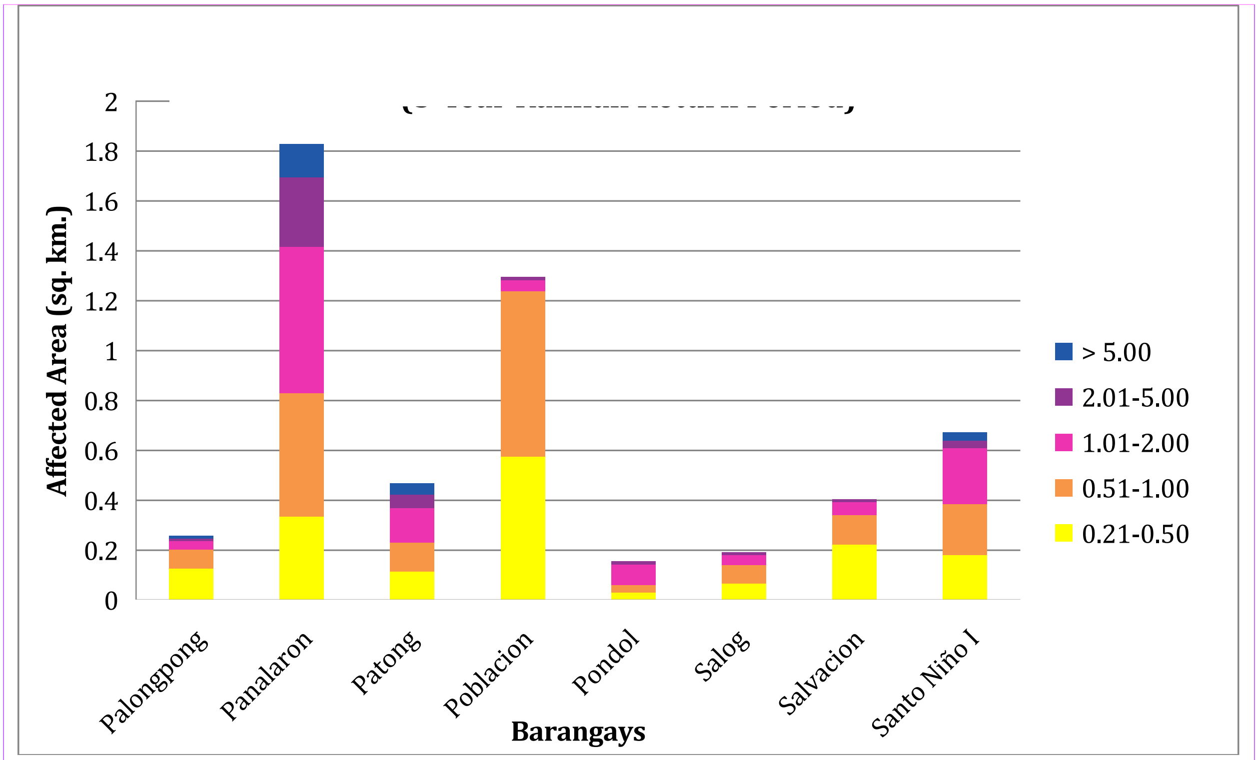

Figure 68. Affected Areas in Hinunangan, Leyte during 5-Year Rainfall Return Period.

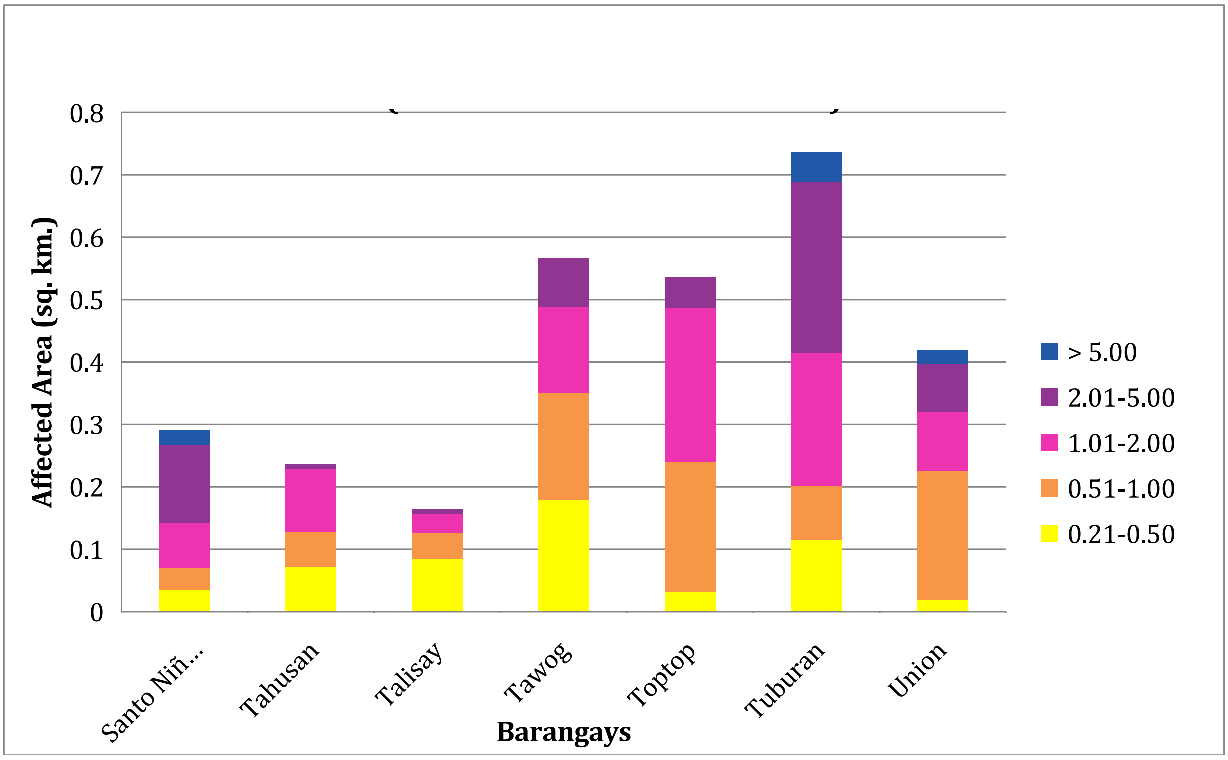

Figure 69. Affected Areas in Hinunangan, Leyte during 5-Year Rainfall Return Period.

For the municipality of Hinundayan, with an area of 53.28 sq. km., 10.47% will experience flood levels of less 0.20 meters. 0.59% of the area will experience flood levels of 0.21 to 0.50 meters while 0.71%, 0.48%, and 0.11% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, respectively. Listed in Table 36 are the affected areas in square kilometers by flood depth per barangay.

Table 36. Affected Areas in Hinundayan, Leyte during 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Areas of Affected Barangays in Hinundayan			
	An-An	Bugho	Cabulisan	Navalita
0.03-0.20	1.114935307	1.476211409	2.6393196	0.345748222
0.21-0.50	0.022621188	0.21403166	0.064727582	0.011693831
0.51-1.00	0.004199999	0.294434351	0.059709074	0.020435573
1.01-2.00	0.0024	0.189192241	0.04483596	0.017993091
2.01-5.00	0.0016	0.03578654	0.011955212	0.009159089
> 5.00	0.0001	0.0016	0.000103896	0.000696104

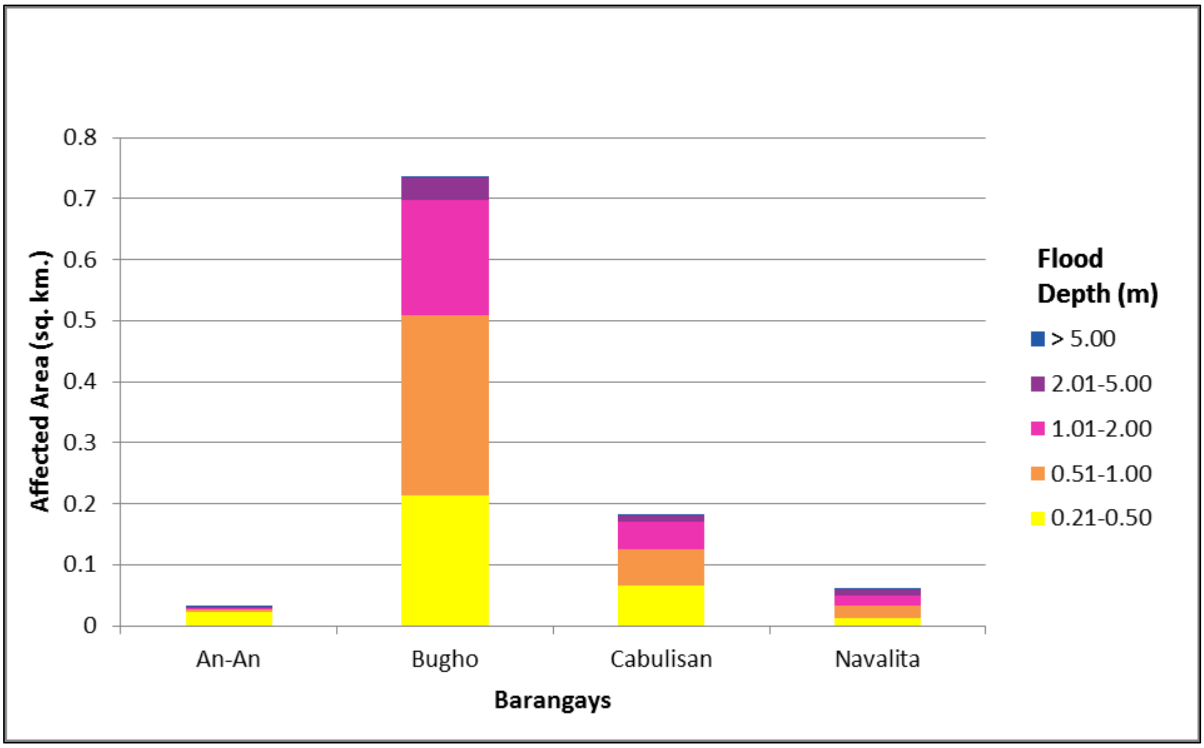

Figure 70. Affected Areas in Hinundayan, Leyte during 5-Year Rainfall Return Period.

For the 25-year return period, 23.19% of the municipality of Hinunangan with an area of 136.38 sq. km. will experience flood levels of less 0.20 meters. 3.02% of the area will experience flood levels of 0.21 to 0.50 meters while 3.03%, 4.83% and 2.26% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and more than 2 meters, respectively. Listed in Table 37 are the affected areas in square kilometers by flood depth per barangay.

Table 37. Affected Areas in Hinunangan, Leyte during 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Areas of Affected Barangays in Hinunangan							
	Ambacon	Badiangon	Bangcas A	Bangcas B	Biasong	Bugho	Calayugan	Canipaan
0.03-0.20	0.718173186	0.38167098	0.478151016	0.48473138	0.390825665	0.338151035	0.119536807	0.143171369
0.21-0.50	0.352467289	0.121438726	0.139801499	0.179298749	0.108552857	0.097670601	0.197461992	0.035334566
0.51-1.00	0.184346459	0.190028332	0.03171358	0.093000942	0.141302171	0.271812158	0.310955501	0.049756816
1.01-2.00	0.344304719	0.484373388	0.01571022	0.14827828	0.197904751	0.240592088	0.461497174	0.124240932
2.01-5.00	0.118061158	0.080779181	0	0.142690224	0.006863586	0.035272196	0.001531344	0.029551339
> 5.00	0.0007	0.008968597	0	0	0.0005	0	0	0

Affected Area (sq. km.) by flood depth (in m.)	Areas of Affected Barangays in Hinunangan							
	Catublian	Ilaya	Labrador	Manalog	Matin-Ao	Nava	Nueva Esperanza	Otama
0.03-0.20	0.799876175	0.28430983	0.019906819	2.518069035	1.286751951	1.203766452	2.314607903	1.172739322
0.21-0.50	0.307652466	0.013499129	0.044354526	0.108693269	0.045456433	0.037988368	0.100807945	0.194095094
0.51-1.00	0.185436894	0.010318485	0.162872336	0.105268697	0.032657759	0.02534621	0.13454842	0.144764384
1.01-2.00	0.127402313	0.01082358	0.42950093	0.262950513	0.014651333	0.027091427	0.472369393	0.161852066
2.01-5.00	0.148550571	0.035686609	0.175365889	0.255916609	0.003388219	0.026092023	0.417380516	0.037263861
> 5.00	0.015546278	0.022214161	0.009720941	0.042873316	0	0.0044	0.060265081	0

Affected Area (sq. km.) by flood depth (in m.)	Areas of Affected Barangays in Hinunangan							
	Hinunanganngpong	Panalaron	Patong	Poblacion	Pondol	Salog	Salvacion	Santo Niño I
0.03-0.20	4.339424667	3.217996026	3.327423674	1.266388058	0.454192292	0.087710198	0.096558202	0.487686587
0.21-0.50	0.145801229	0.19110289	0.106242915	0.492264729	0.032986498	0.028590969	0.18683387	0.197698558
0.51-1.00	0.088733237	0.369347998	0.105634187	0.288643036	0.021676522	0.088357957	0.184627969	0.185827903
1.01-2.00	0.054510708	0.739547573	0.174107934	0.794713501	0.066360122	0.112063574	0.083304375	0.323442228
2.01-5.00	0.016826943	0.501892517	0.100288064	0.021692154	0.050434814	0.002873589	0.002954996	0.039142776
> 5.00	0.000106963	0.132578364	0.044617608	0	0	0	0	0.033574057

Affected Area (sq. km.) by flood depth (in m.)	Areas of Affected Barangays in Hinunangan							
	Santo Niño II	Tahusan	Talisay	Tawog	Toptop	Tuburan	Union	Santo Niño II
0.03-0.20	0.602936656	0.151450663	0.346828504	1.742137777	0.05147006	2.774383992	0.024028489	0.602936656
0.21-0.50	0.037684812	0.044755903	0.055573708	0.192768213	0.114316051	0.096566848	0.117054348	0.037684812
0.51-1.00	0.039282633	0.060532352	0.030229611	0.122652303	0.213936742	0.12821764	0.13118066	0.039282633
1.01-2.00	0.079747858	0.061940413	0.014946596	0.120124963	0.14728984	0.230634912	0.061466143	0.079747858
2.01-5.00	0.090531558	0	0.000136075	0.014147004	0.01603637	0.167270277	0.065921743	0.090531558
> 5.00	0.009266939	0	0	0	0	0.0256958	0.019944352	0.009266939

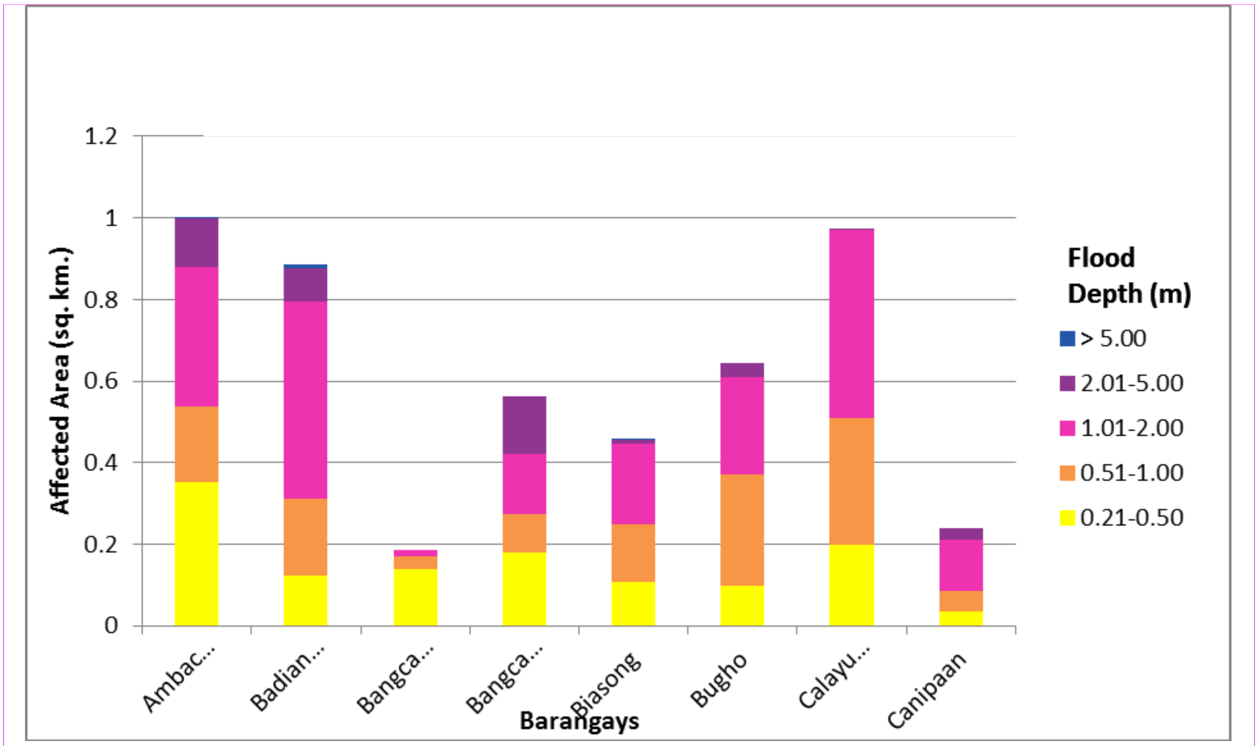

Figure 71. Affected Areas in Hinunangan, Leyte during 25-Year Rainfall Return Period.

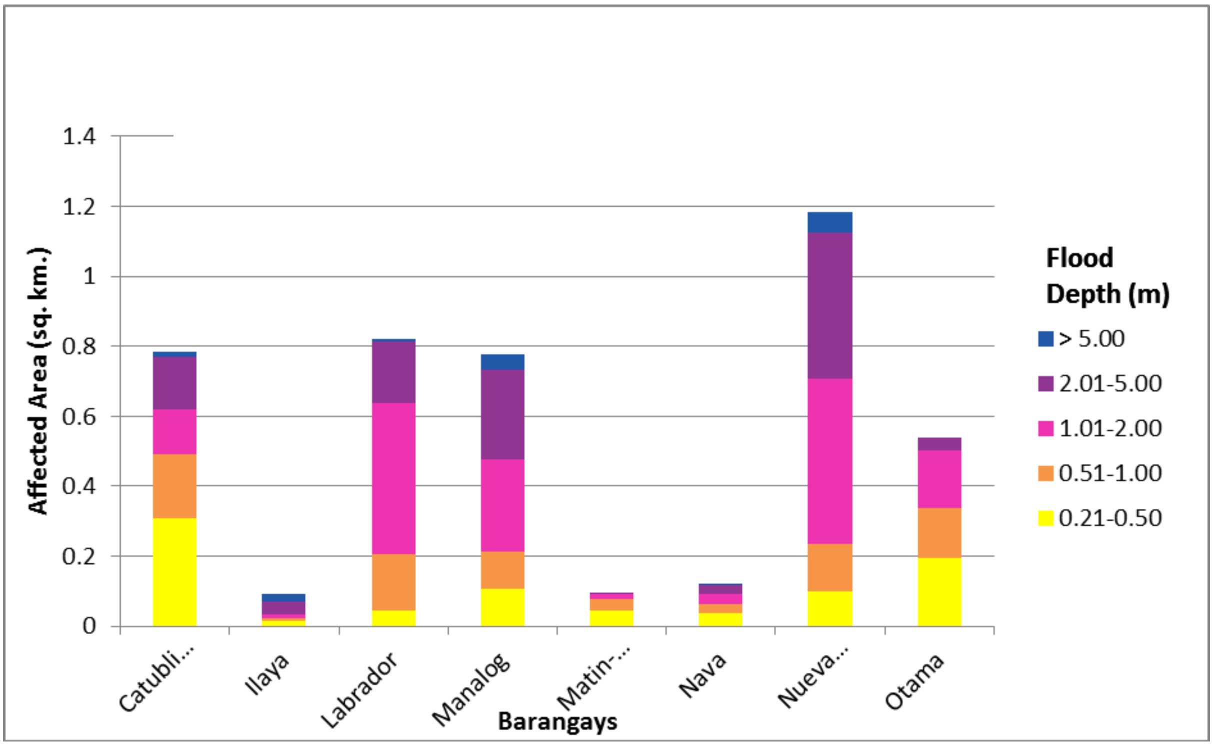

Figure 72. Affected Areas in Hinunangan, Leyte during 25-Year Rainfall Return Period.

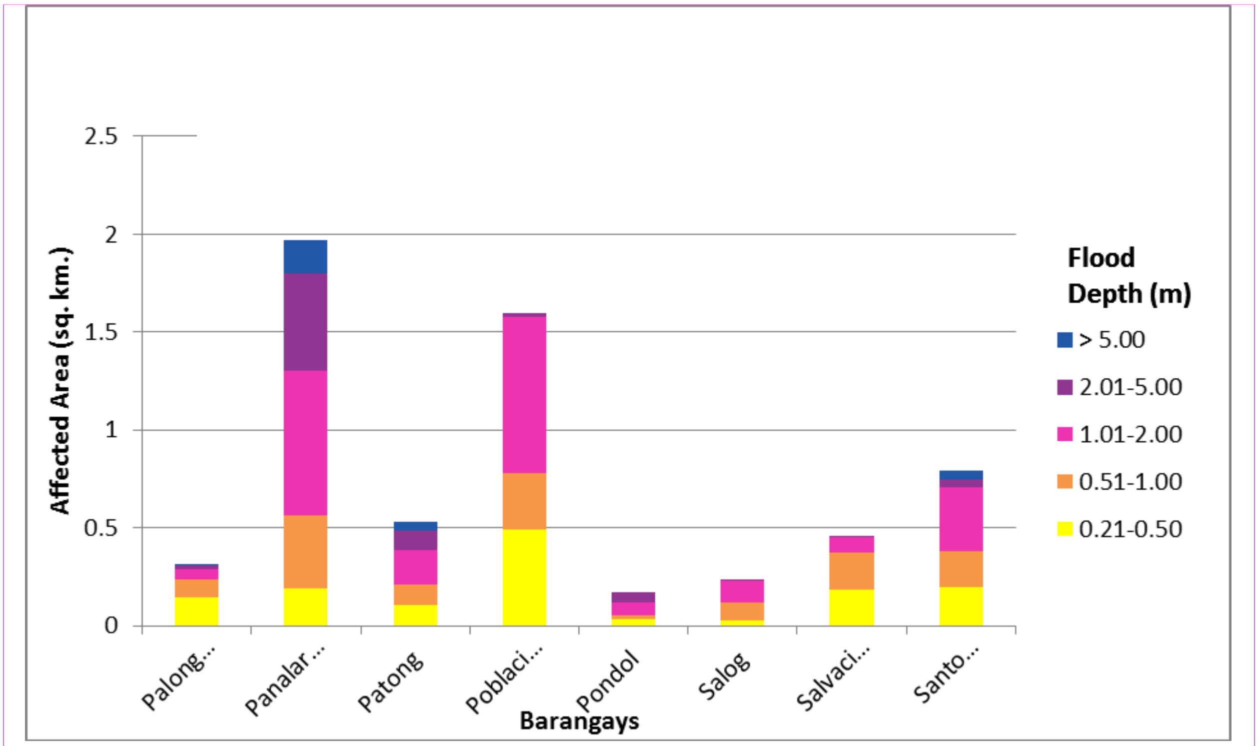

Figure 73. Affected Areas in Hinunangan, Leyte during 25-Year Rainfall Return Period.

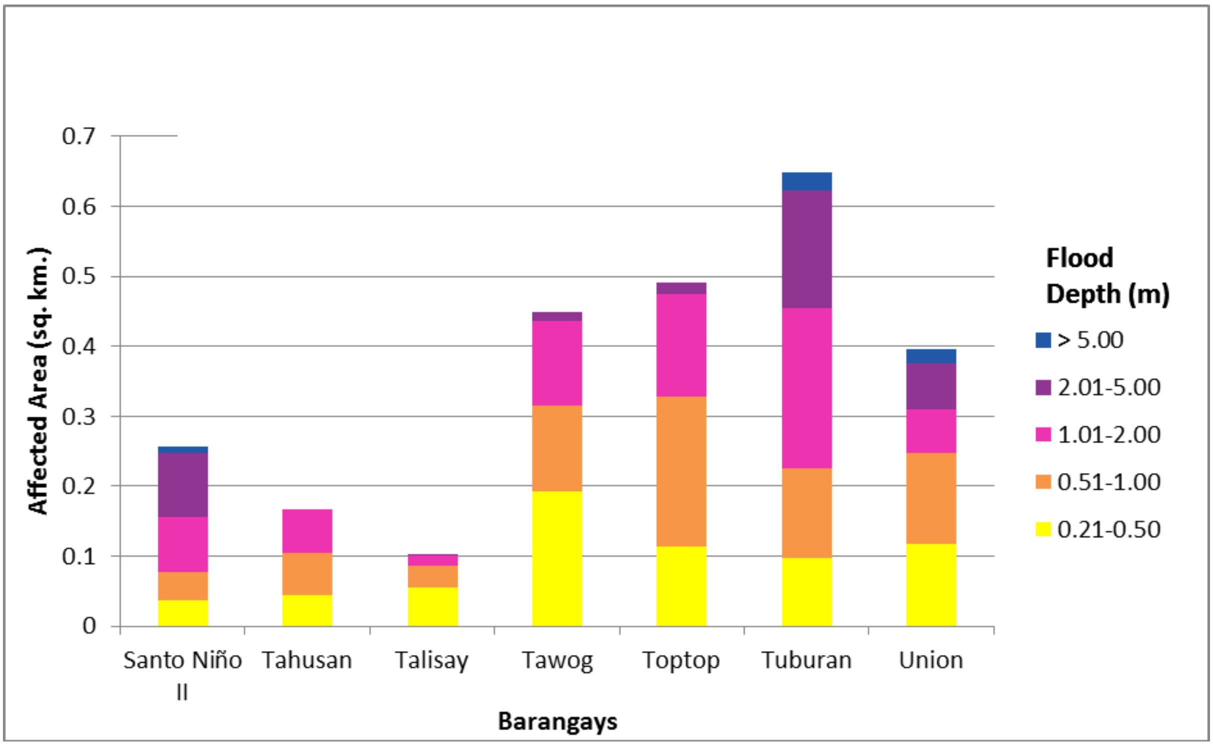

Figure 74. Affected Areas in Hinunangan, Leyte during 25-Year Rainfall Return Period.

For the municipality of Hinundayan, with an area of 53.28 sq. km., 10.17% will experience flood levels of less 0.20 meters. 0.54% of the area will experience flood levels of 0.21 to 0.50 meters while 0.69%, 0.76%, and 0.21% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, respectively. Listed in Table 38 are the affected areas in square kilometers by flood depth per barangay.

Table 38. Affected Areas in Hinundayan, Leyte during 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Areas of Affected Barangays in Hinundayan			
	An-An	Bugho	Cabulisan	Navalita
0.03-0.20	1.10024754	1.37612784	2.601647503	0.338194025
0.21-0.50	0.032808956	0.169096455	0.07481721	0.009685616
0.51-1.00	0.007299999	0.28502007	0.055340342	0.020395912
1.01-2.00	0.0027	0.315789675	0.063279318	0.022714189
2.01-5.00	0.0025	0.062522161	0.026444032	0.013359089
> 5.00	0.0003	0.003	0.000103896	0.001296104

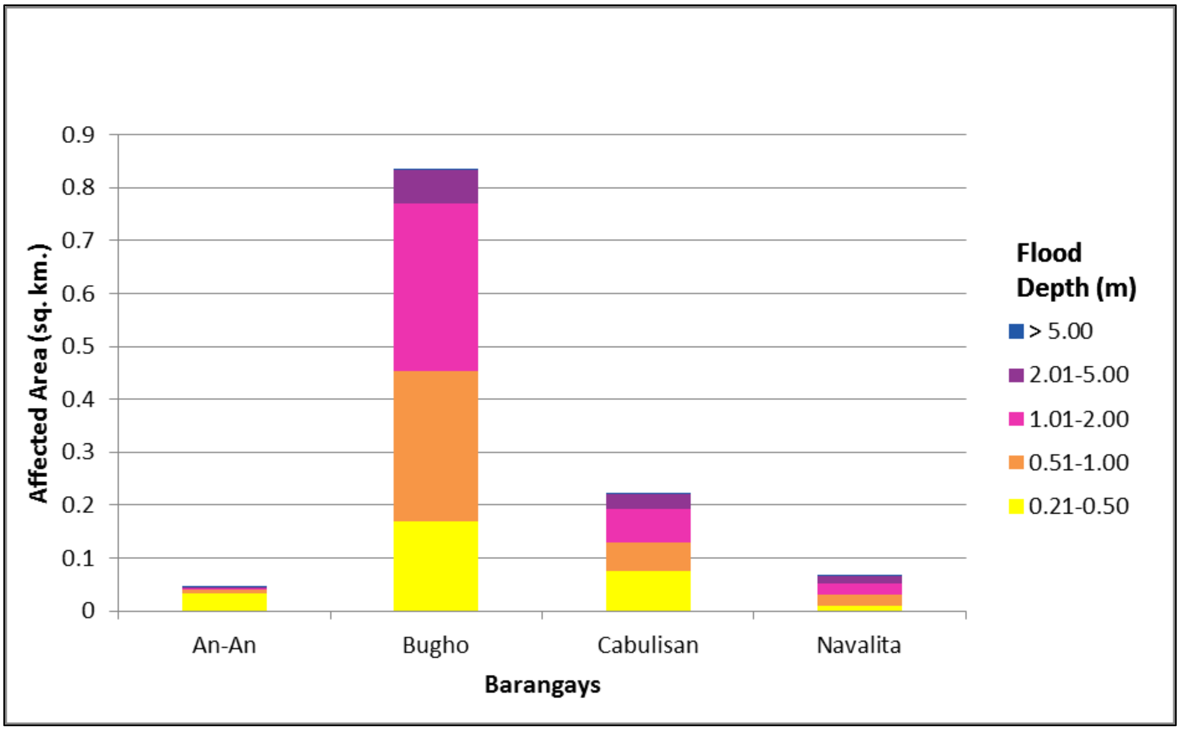

Figure 75. Affected Areas in Hinundayan, Leyte during 25-Year Rainfall Return Period.

For the 100-year return period, 21.64% of the municipality of Hinunangan with an area of 136.38 sq. km. will experience flood levels of less 0.20 meters. 2.78% of the area will experience flood levels of 0.21 to 0.50 meters while 3.05%, 4.71% and 4.15% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and more than 2 meters, respectively. Listed in Table 39 are the affected areas in square kilometers by flood depth per barangay.

Table 39. Affected Areas in Hinunangan, Leyte during 100-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Areas of Affected Barangays in Hinunangan							
	Ambacon	Badiangon	Bangcas A	Bangcas B	Biasong	Bugho	Calayugan	Canipaan
0.03-0.20	0.579334654	0.31859179	0.401087882	0.358137487	0.331681838	0.312649945	0.064382944	0.100483755
0.21-0.50	0.338104737	0.100692019	0.155830408	0.160196862	0.107520356	0.077352754	0.106466471	0.051126207
0.51-1.00	0.267966841	0.188857614	0.088683028	0.156597294	0.14980548	0.200679575	0.192337719	0.050830132
1.01-2.00	0.229551153	0.463642846	0.019674998	0.152107642	0.228008167	0.348779542	0.578018076	0.090239183
2.01-5.00	0.302134461	0.180626836	0.0001	0.220960289	0.028333188	0.044036263	0.149777608	0.089375744
> 5.00	0.000960965	0.0148481	0	0	0.0006	0	0	0

Affected Area (sq. km.) by flood depth (in m.)	Areas of Affected Barangays in Hinunangan							
	Catublian	Ilaya	Labrador	Manalog	Matin-Ao	Nava	Nueva Esperanza	Otama
0.03-0.20	0.567149315	0.274069274	0.008390365	2.486534757	1.277821086	1.191216781	2.273482791	1.10907066
0.21-0.50	0.389747687	0.012755778	0.017689244	0.103735047	0.04552439	0.037935675	0.094261724	0.198810313
0.51-1.00	0.309464602	0.009959271	0.099817174	0.107496575	0.035151197	0.028636901	0.094718213	0.149990637
1.01-2.00	0.114439873	0.012905409	0.424221416	0.223503569	0.019787692	0.026271589	0.352938892	0.180782317
2.01-5.00	0.187921639	0.037180317	0.279461805	0.327928177	0.004921329	0.03322204	0.615992607	0.072060802
> 5.00	0.015741582	0.029981746	0.012141438	0.044573316	0	0.007401494	0.067876055	0.0001

Affected Area (sq. km.) by flood depth (in m.)	Areas of Affected Barangays in Hinunangan							
	Hinunangganngpong	Panalaron	Patong	Poblacion	Pondol	Salog	Salvacion	Santo Niño I
0.03-0.20	4.299849737	3.154841607	3.291133327	1.05858716	0.433639829	0.067134252	0.073087853	0.429687303
0.21-0.50	0.159645184	0.164778049	0.1059246	0.512635819	0.035009019	0.022586419	0.155599682	0.190515579
0.51-1.00	0.096116422	0.261870686	0.111347187	0.336822662	0.027029578	0.043990611	0.219732254	0.199214181
1.01-2.00	0.06706815	0.684981816	0.154828193	0.444713034	0.046024095	0.149580684	0.087139437	0.309735297
2.01-5.00	0.022447834	0.741714847	0.149663468	0.510942802	0.083947726	0.03630432	0.018720185	0.101145691
> 5.00	0.001142938	0.178127514	0.047317608	0	0	0	0	0.048623208

Affected Area (sq. km.) by flood depth (in m.)	Areas of Affected Barangays in Hinunangan							
	Santo Niño II	Tahusan	Talisay	Tawog	Toptop	Tuburan	Union	Santo Niño II
0.03-0.20	0.542088119	0.051278404	0.235221485	1.577374174	0.00184166	2.641163861	1E-04	0.542088119
0.21-0.50	0.027997354	0.075753621	0.096398785	0.132507905	0.010000942	0.101691095	0.004387498	0.027997354
0.51-1.00	0.032825543	0.072016119	0.058197047	0.215226509	0.119686892	0.104193115	0.132424597	0.032825543
1.01-2.00	0.056634348	0.105962602	0.039583006	0.139678625	0.34105957	0.163261808	0.170263209	0.056634348
2.01-5.00	0.154082054	0.013668586	0.018314172	0.127543045	0.07046	0.352356462	0.089171384	0.154082054
> 5.00	0.045823038	0	0	0	0	0.062002131	0.023249048	0.045823038

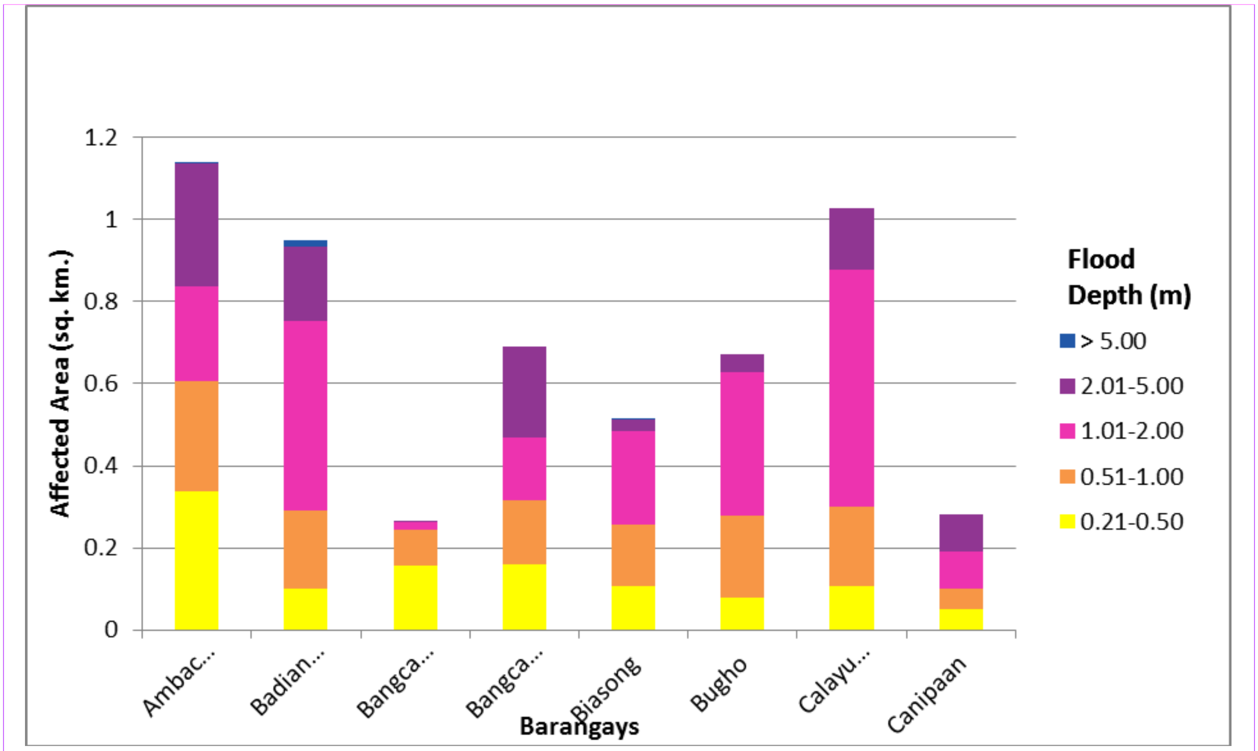

Figure 76. Affected Areas in Hinunangan, Leyte during 100-Year Rainfall Return Period.

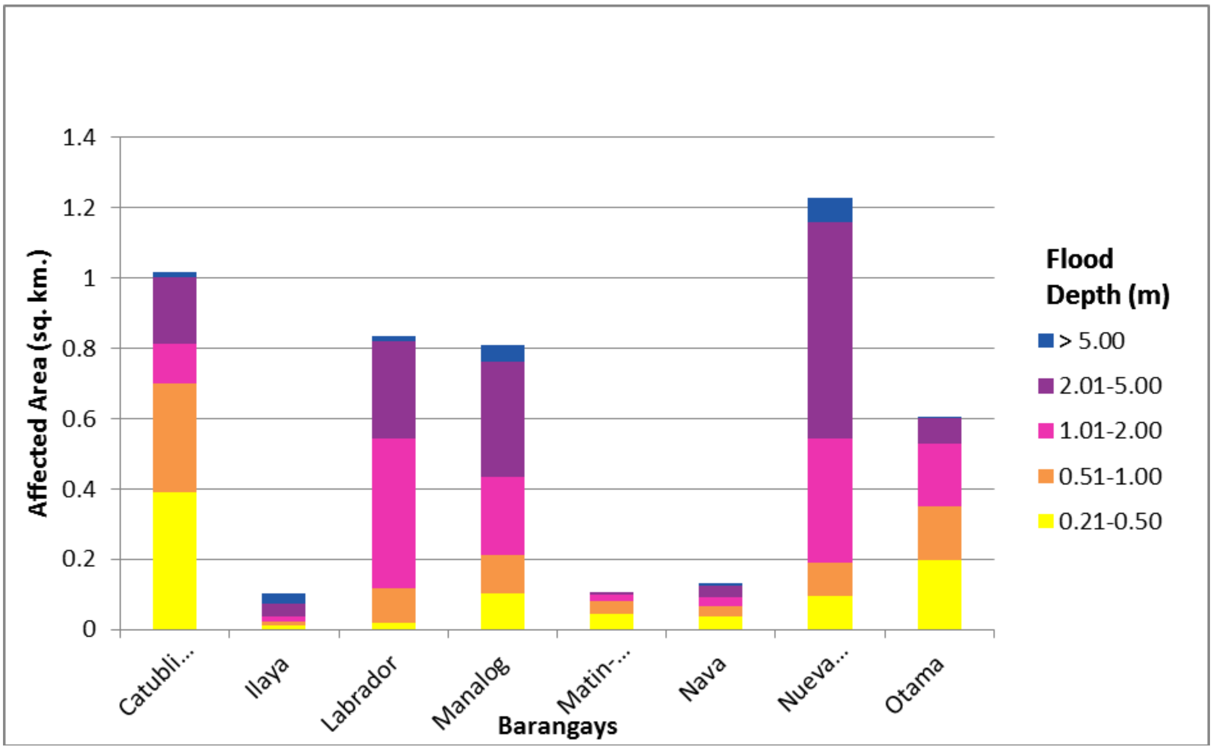

Figure 77. Affected Areas in Hinunangan, Leyte during 100-Year Rainfall Return Period.

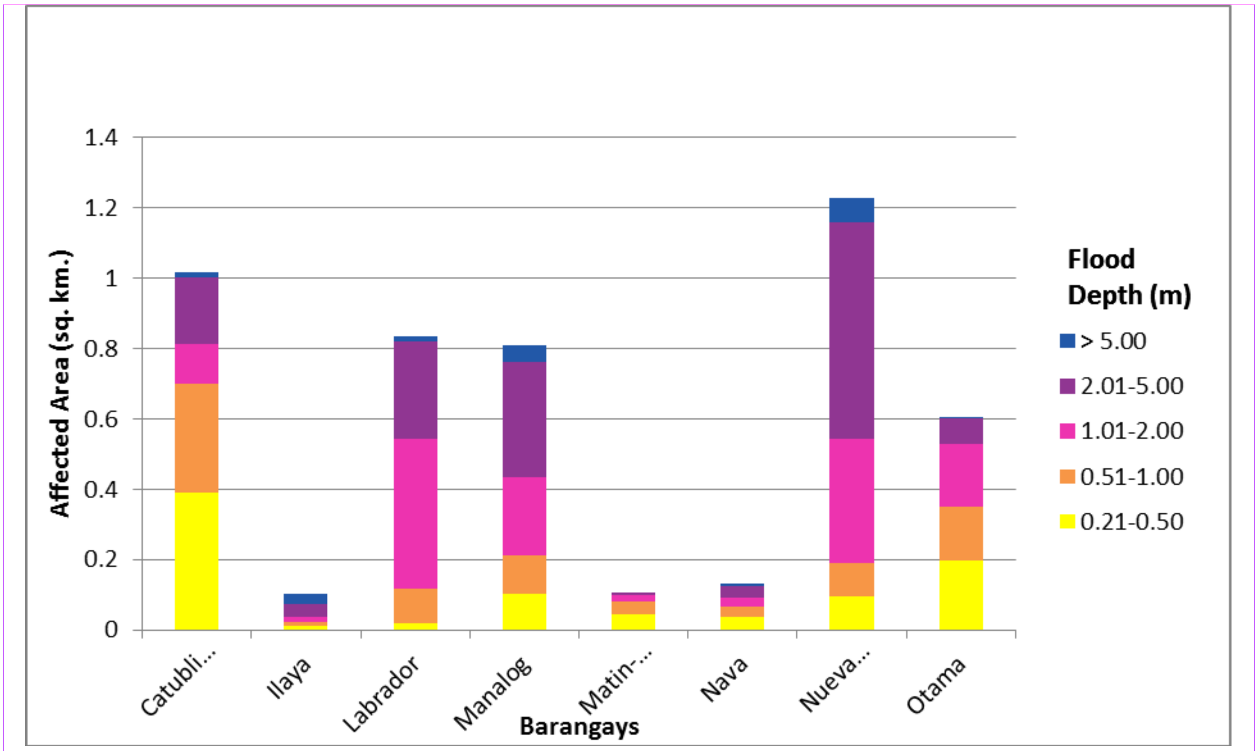

Figure 78. Affected Areas in Hinunangan, Leyte during 100-Year Rainfall Return Period.

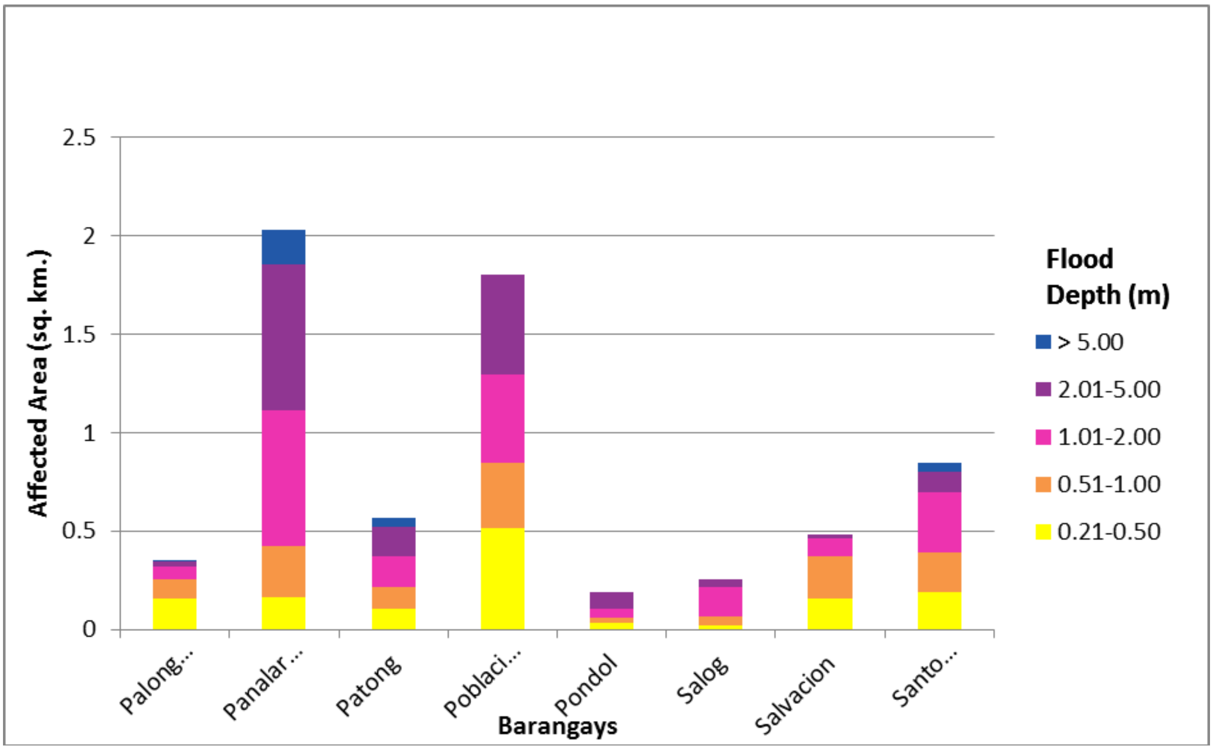

Figure 79. Affected Areas in Hinunangan, Leyte during 100-Year Rainfall Return Period.

For the municipality of Hinundayan, with an area of 57.14 sq. km., 11.91% will experience flood levels of less 0.20 meters. 0.51% of the area will experience flood levels of 0.21 to 0.50 meters while 0.94%, 2.04%, and 2.67% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, respectively. Listed in Table 40 are the affected areas in square kilometers by flood depth per barangay.

Table 40. Affected Areas in Hinundayan, Leyte during 100-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Areas of Affected Barangays in Hinundayan			
	An-An	Bugho	Cabulisan	Navalita
0.03-0.20	1.10024754	1.37612784	2.601647503	0.338194025
0.21-0.50	0.032808956	0.169096455	0.07481721	0.009685616
0.51-1.00	0.007299999	0.28502007	0.055340342	0.020395912
1.01-2.00	0.0027	0.315789675	0.063279318	0.022714189
2.01-5.00	0.0025	0.062522161	0.026444032	0.013359089
> 5.00	0.0003	0.003	0.000103896	0.001296104

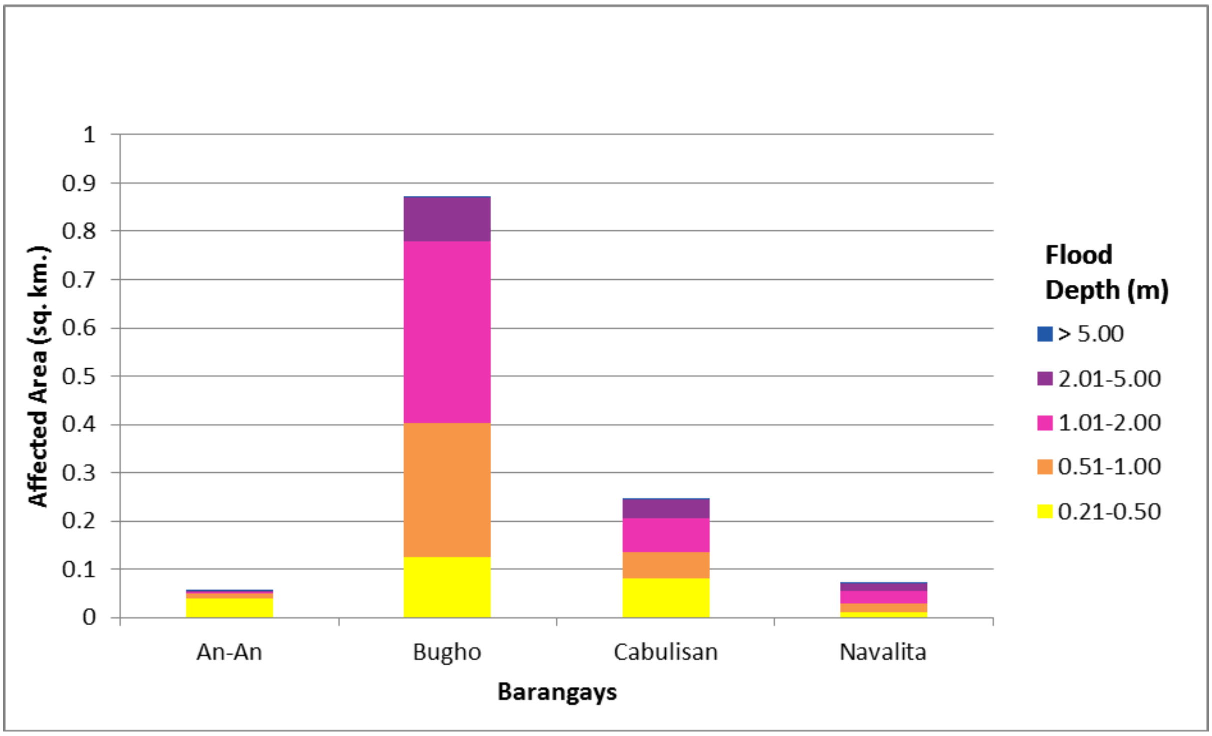

Figure 80. Affected Areas in Hinundayan, Leyte during 100-Year Rainfall Return Period.

Among the barangays in the municipality of Hinunangan, Panalaron is projected to have the highest percentage of area that will experience flood levels at 3.80%. Meanwhile, Palongpong posted the second highest percentage of area that may be affected by flood depths at 3.41%.

Among the barangays in the municipality of Hinundayan, Cabulisan and Navalita are projected to have the highest percentage of area that will experience flood levels at 5.3%. Meanwhile, Bugho posted the second highest percentage of area that may be affected by flood depths at 4.15%.

Moreover, the generated flood hazard maps for the Das-ay 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 41. Area covered by each warning level with respect to the rainfall scenarios

Warning Level	Area Covered in sq. km		
	5 year	25 year	100 year
Low	4.86	4.30	4.03
Medium	8.46	8.32	7.84
High	3.50	7.11	9.59

Of the 32 identified Education Institutions in Das-ay Flood plain, 6 schools were assessed to be exposed to the Low level flooding during a 5 year scenario while 4 were assessed to be exposed to Medium level flooding in the same scenario. In the 25 year scenario, 8 schools were assessed to be exposed to the Low level flooding while 6 schools were assessed to be exposed to Medium level flooding. For the 100 year scenario, 10 schools were assessed for Low level flooding and 7 schools for Medium level flooding. In the same scenario, 1 school namely Brgy. Sato Niño I Daycare Center, was assessed to be exposed to High level flooding.

Of the 6 identified Medical Institutions in Das-ay Flood plain, 2 were assessed to be exposed to the Low and Medium level flooding during a 5 year scenario. In the 25 year scenario, 3 were assessed to be exposed to the Medium level flooding while 1 was assessed to be exposed to High level flooding. For the 100 year scenario, 2 schools were assessed for Medium and High level flooding.

5.11 Flood Validation

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

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

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

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 the results of the flood map. The points in the flood map versus its corresponding validation depths are shown in Figure 81 and Figure 82.

The flood validation consists of 209 points randomly selected all over the Das-ay flood plain. The points were grouped depending on the RIDF return period of the event. Comparing it with the flood depth of the nearest storm event, the map has an RMSE value of 0.52m. The validation points are found in Annex 11.

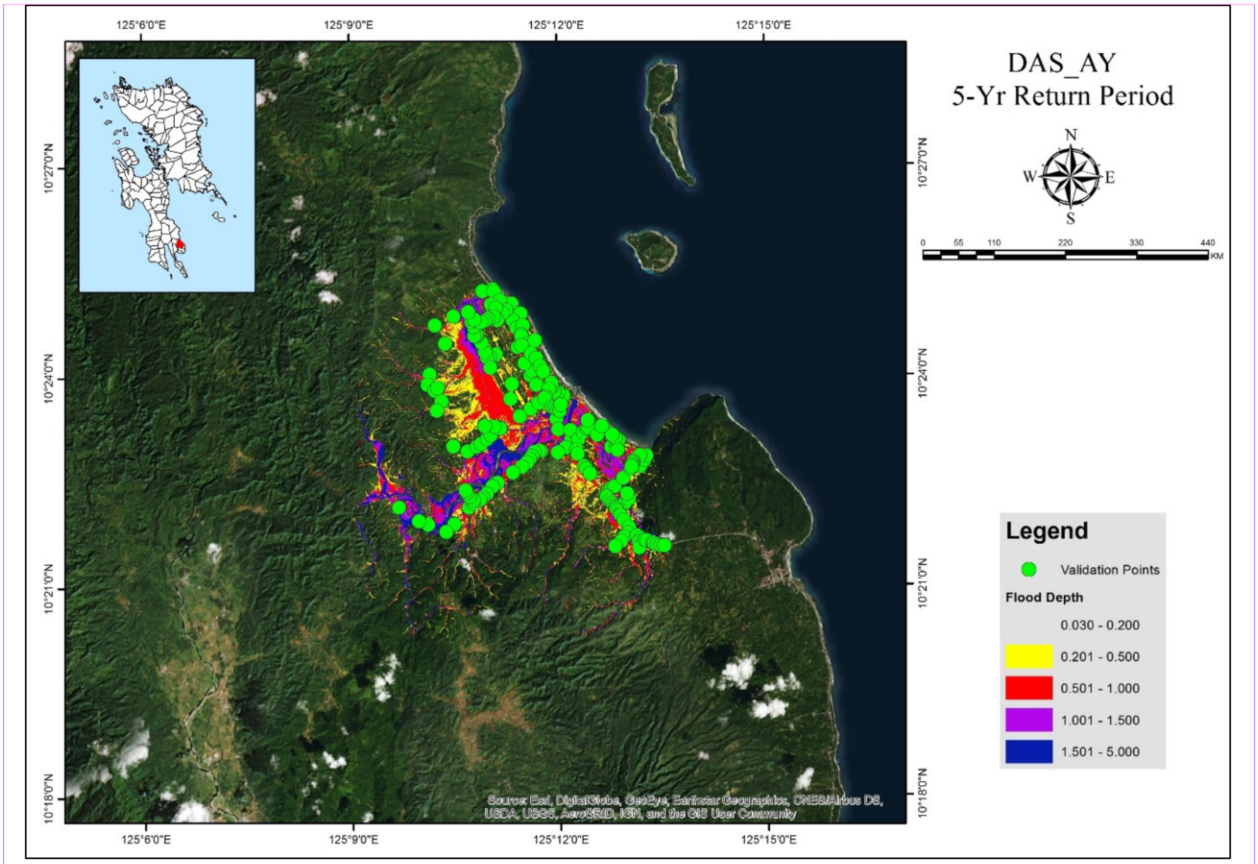

Figure 81. Validation Points for a 5-year Flood Depth Map of the Das-ay Floodplain.

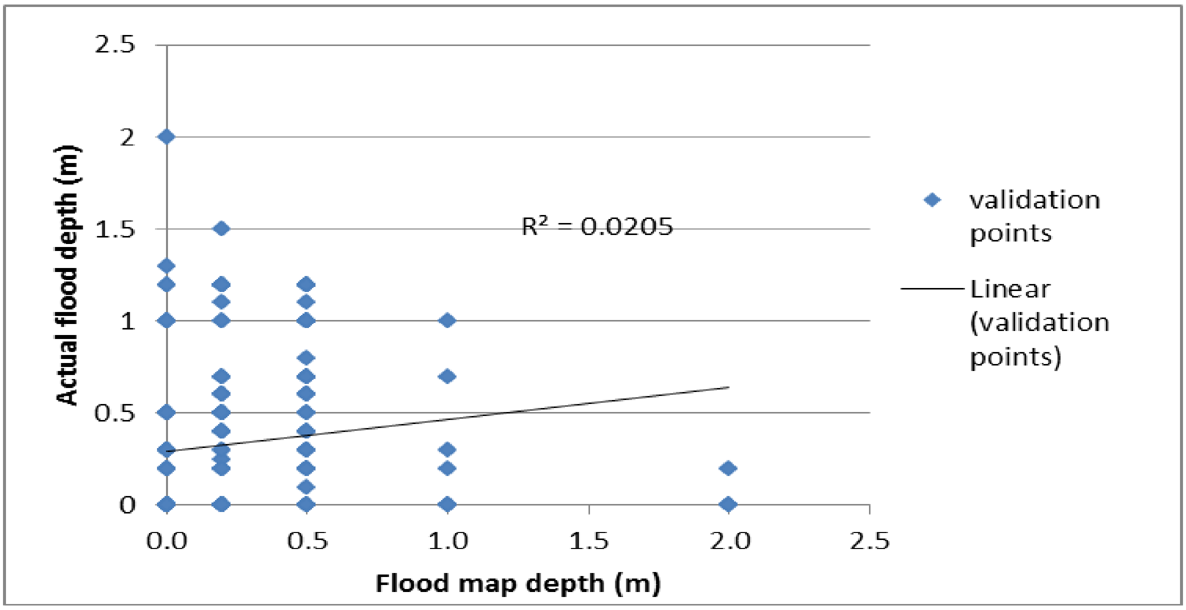

Figure 82. Validation points for 5-year Flood Depth Map of Das-ay Floodplain

Table 42. Actual Flood Depth versus Simulated Flood Depth at different levels in the Das-ay River Basin.

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**	96	16	3	3	0	0	118
	0.21-0.50	23	10	2	0	0	0	35
	0.51-1.00	14	14	1	0	0	0	29
	1.01-2.00	12	8	1	1	0	0	22
	2.01-5.00	3	1	1	0	0	0	5
	>5.00	0	0	0	0	0	0	0
	Total	148	49	8	4	0	0	209

On the whole, the overall accuracy generated by the 5-yr flood model is estimated at 51.67%, with 108 points correctly matching the actual flood depths. In addition, there were 56 points estimated one level above and below the correct flood depths while there were 26 points and 19 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 24 points were overestimated while a total of 77 points were underestimated in the modelled flood depths of Das-ay. Table 43 depicts the summary of the Accuracy Assessment in the Das-ay River Basin Flood Depth Map.

Table 43. Summary of the Accuracy Assessment in the Das-ay River Basin Survey.

	No. of Points	%
Correct	108	**51.67**
Overestimated	24	**11.48**
Underestimated	77	**36.84**
Total	209	**100**

REFERENCES

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

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

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

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

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

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

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

ANNEXES

Annex 1. Technical Specifications of the LIDAR Sensors used in the Das-ay Floodplain Survey

1. AQUARIUS SENSOR

Figure A-1.1 Aquarius Sensor

Table A-1.1 Parameters and Specifications of Aquarius Sensor

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

2. GEMINI SENSOR

Figure A-1.2. Gemini Sensor

Table A-1.2 Parameters and Specifications of Gemini Sensor

Parameter	Specification
Operational envelope (1,2,3,4)	150-4000 m AGL, nominal
Laser wavelength	1064 nm
Horizontal accuracy (2)	1/5,500 x altitude, (m AGL)
Elevation accuracy (2)	<5-35 cm, 1 σ
Effective laser repetition rate	Programmable, 33-167 kHz
Position and orientation system	POS AV™ AP50 (OEM); 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-757

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: **LYT-757**
Order: **2nd**

Island: **VISAYAS**
Municipality: **MAHAPLAG**
Barangay: **MAHAYAHAY**
MSL Elevation:

PRS92 Coordinates

Latitude: **10° 32' 54.86740"**
Longitude: **124° 57' 31.14319"**
Ellipsoidal Hgt: **99.55943 m.**

WGS84 Coordinates

Latitude: **10° 32' 50.77355"**
Longitude: **124° 57' 36.36037"**
Ellipsoidal Hgt: **163.36300 m.**

PTM / PRS92 Coordinates

Northing: **1166401.318 m.**
Easting: **495474.491 m.**
Zone: **5**

UTM / PRS92 Coordinates

Northing: **1,166,663.62**
Easting: **714,331.34**
Zone: **51**

Location Description

LYT-757
About 7.0 km. from poblacion mahaplag taking the national road to southern leyte, there is a restaurant named "Dragonfly restaurant" located at the right side of the highway and on the left isde is the junction going to the proper of brgy. mahayahay. The LYT-757 is located on the left side, 30 meters before you reach the junction. LYT-757 is almost on the opposite side of the kilometer post # 997. 30x30x100 cm. cocnrete monument having 40 cm height above the ground with 5 inches concrete nail as center and is marked with "LYT-757, 2007, LAMP".

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8089687 I**
T.N.: **2016-0239**

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

G

9901272016151125

CP/0701/12/09/816

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.1. LYT-757

2. LYS-4

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

April 14, 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: **SOUTHERN LEYTE**
Station Name: **LYS-4**
Order: **1st**

Island: **VISAYAS**	Barangay: **POBLACION**		
Municipality: **SOGOD**	MSL Elevation:		

PRS92 Coordinates

Latitude:	**10° 23' 20.19669"**	Longitude:	**124° 58' 38.53353"**	Ellipsoidal Hgt:	**15.25600 m.**

WGS84 Coordinates

Latitude:	**10° 23' 16.14540"**	Longitude:	**124° 58' 43.76469"**	Ellipsoidal Hgt:	**79.47900 m.**

PTM / PRS92 Coordinates

Northing:	**1148746.143 m.**	Easting:	**497522.022 m.**	Zone:	**5**

UTM / PRS92 Coordinates

Northing:	**1,149,017.84**	Easting:	**716,491.34**	Zone:	**51**

Location Description

LYS-4
From Tacloban City, travel 220 km. S until you reach Sogod Nat'l. High School (SNHS), adjacent to Sogod Elem. School. Station is located at the middle of the open ground of SNHS, NW of the NW corner of the basketball court at a distance of about 15 m. All reference marks (RM) are heads of a 2 in. copper nail, centered on a 0.15 m. x 0.15 m. x 0.2 m. concrete monument, flush with the ground surface and inscribed with the RM nos. and arrow pointing to the station. Station mark is the head of a 4 in. copper nail centered on a 0.3 m. x 0.3 m. x 1 m. concrete monument leveled on the ground, with inscriptions "LYS-4 2006 NAMRIA."

Requesting Party:	**UP DREAM**
Purpose:	**Reference**
OR Number:	**8084228 I**
T.N.:	**2016-0918**

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

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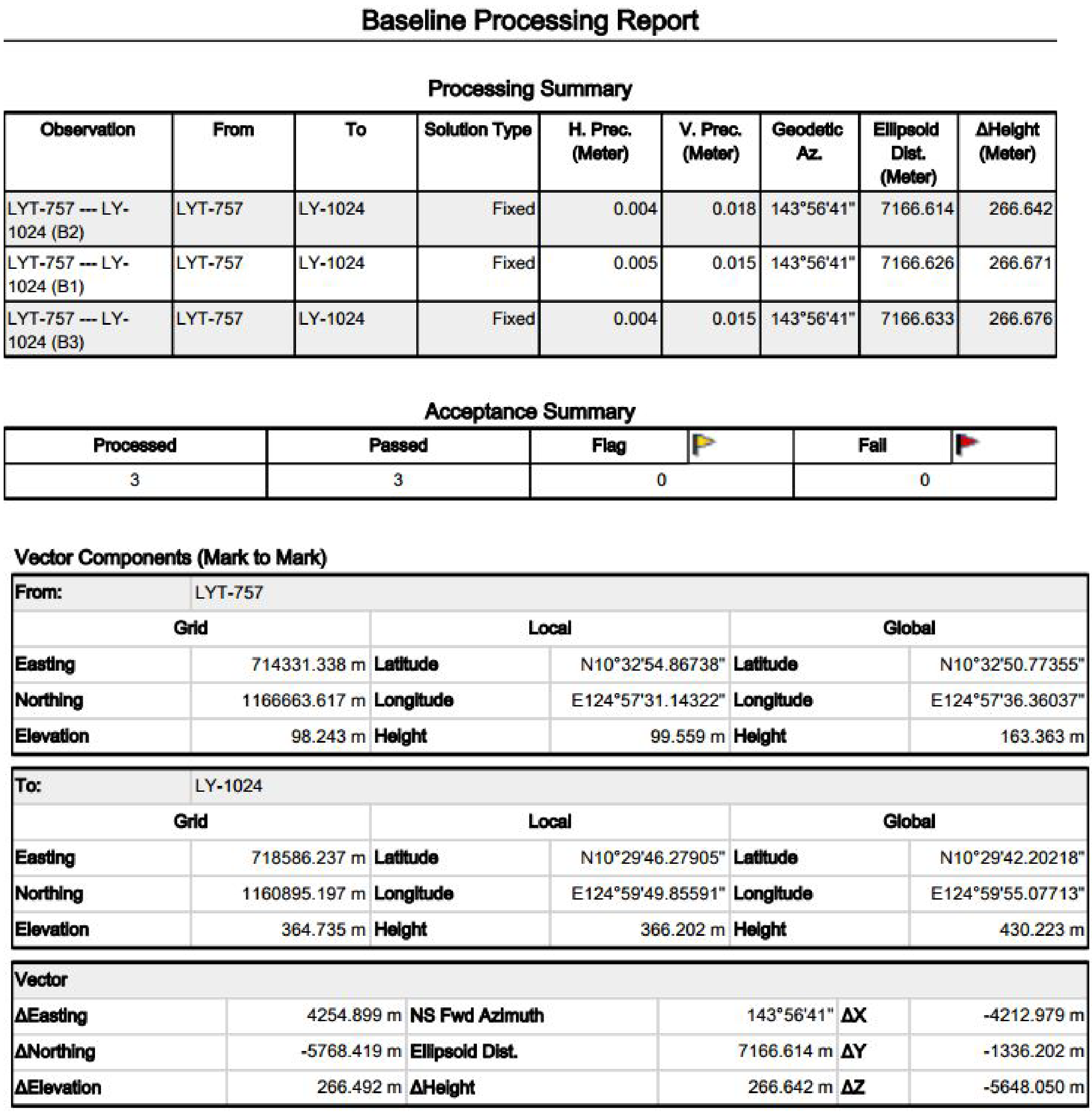
Figure A-2.2 LYS-4

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

1. LY-1024



Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
LYT-757 --- LY-1024 (B2)	LYT-757	LY-1024	Fixed	0.004	0.018	143°56'41"	7166.614	266.642
LYT-757 --- LY-1024 (B1)	LYT-757	LY-1024	Fixed	0.005	0.015	143°56'41"	7166.626	266.671
LYT-757 --- LY-1024 (B3)	LYT-757	LY-1024	Fixed	0.004	0.015	143°56'41"	7166.633	266.676

Acceptance Summary

Processed	Passed	Flag ⚑	Fail ⚑
3	3	0	0

Vector Components (Mark to Mark)

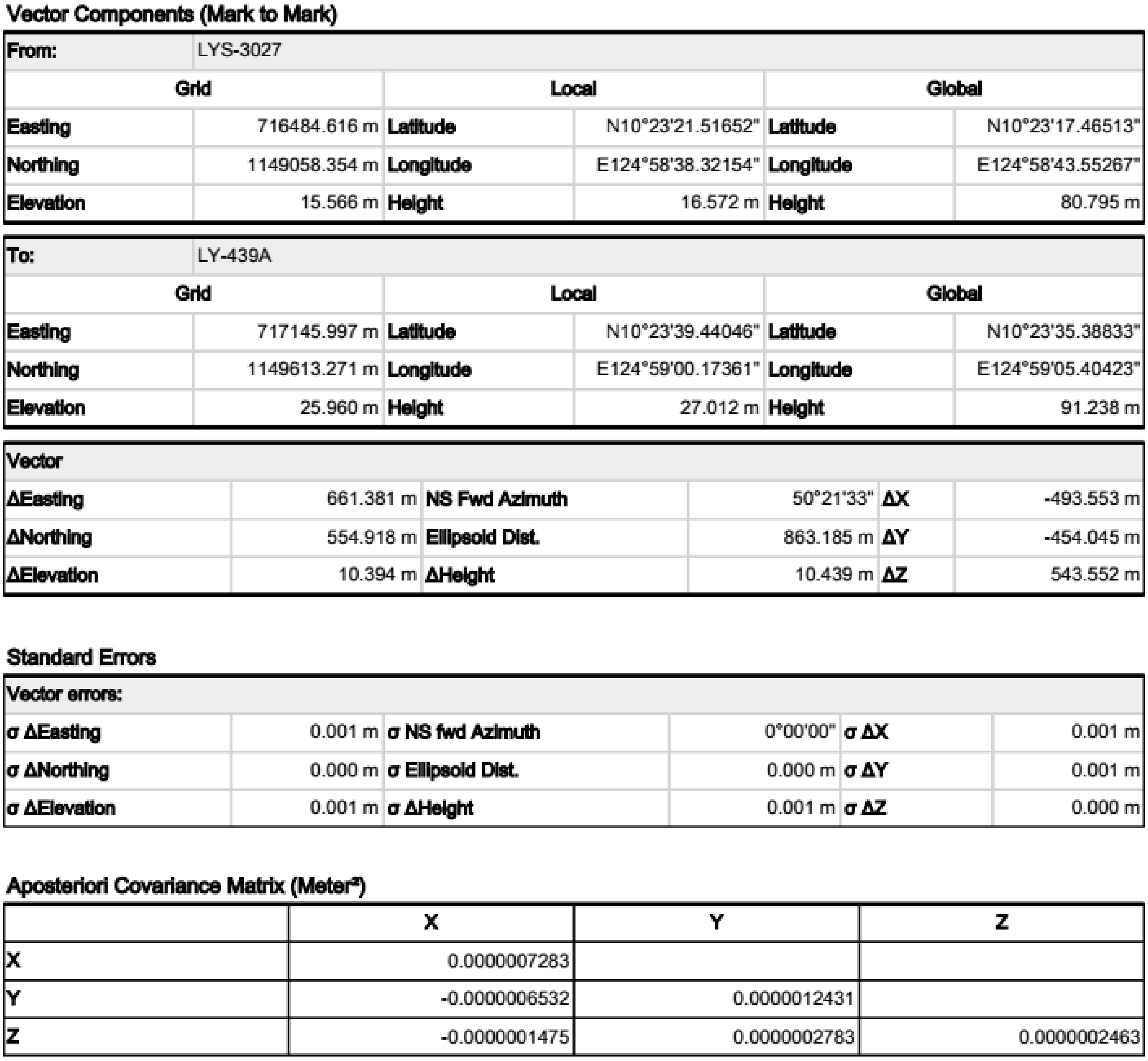
From:	LYT-757				
Grid		**Local**		**Global**	
Easting	714331.338 m	**Latitude**	N10°32'54.86738"	**Latitude**	N10°32'50.77355"
Northing	1166663.617 m	**Longitude**	E124°57'31.14322"	**Longitude**	E124°57'36.36037"
Elevation	98.243 m	**Height**	99.559 m	**Height**	163.363 m

To:	LY-1024				
Grid		**Local**		**Global**	
Easting	718586.237 m	**Latitude**	N10°29'46.27905"	**Latitude**	N10°29'42.20218"
Northing	1160895.197 m	**Longitude**	E124°59'49.85591"	**Longitude**	E124°59'55.07713"
Elevation	364.735 m	**Height**	366.202 m	**Height**	430.223 m

Vector					
ΔEasting	4254.899 m	**NS Fwd Azimuth**	143°56'41"	**ΔX**	-4212.979 m
ΔNorthing	-5768.419 m	**Ellipsoid Dist.**	7166.614 m	**ΔY**	-1336.202 m
ΔElevation	266.492 m	**ΔHeight**	266.642 m	**ΔZ**	-5648.050 m

2. BM-439A

Table A-3.2. BM-439A



Vector Components (Mark to Mark)

From:	LYS-3027				
Grid		**Local**		**Global**	
Easting	716484.616 m	**Latitude**	N10°23'21.51652"	**Latitude**	N10°23'17.46513"
Northing	1149058.354 m	**Longitude**	E124°58'38.32154"	**Longitude**	E124°58'43.55267"
Elevation	15.566 m	**Height**	16.572 m	**Height**	80.795 m

To:	LY-439A				
Grid		**Local**		**Global**	
Easting	717145.997 m	**Latitude**	N10°23'39.44046"	**Latitude**	N10°23'35.38833"
Northing	1149613.271 m	**Longitude**	E124°59'00.17361"	**Longitude**	E124°59'05.40423"
Elevation	25.960 m	**Height**	27.012 m	**Height**	91.238 m

Vector					
ΔEasting	661.381 m	**NS Fwd Azimuth**	50°21'33"	**ΔX**	-493.553 m
ΔNorthing	554.918 m	**Ellipsoid Dist.**	863.185 m	**ΔY**	-454.045 m
ΔElevation	10.394 m	**ΔHeight**	10.439 m	**ΔZ**	543.552 m

Standard Errors

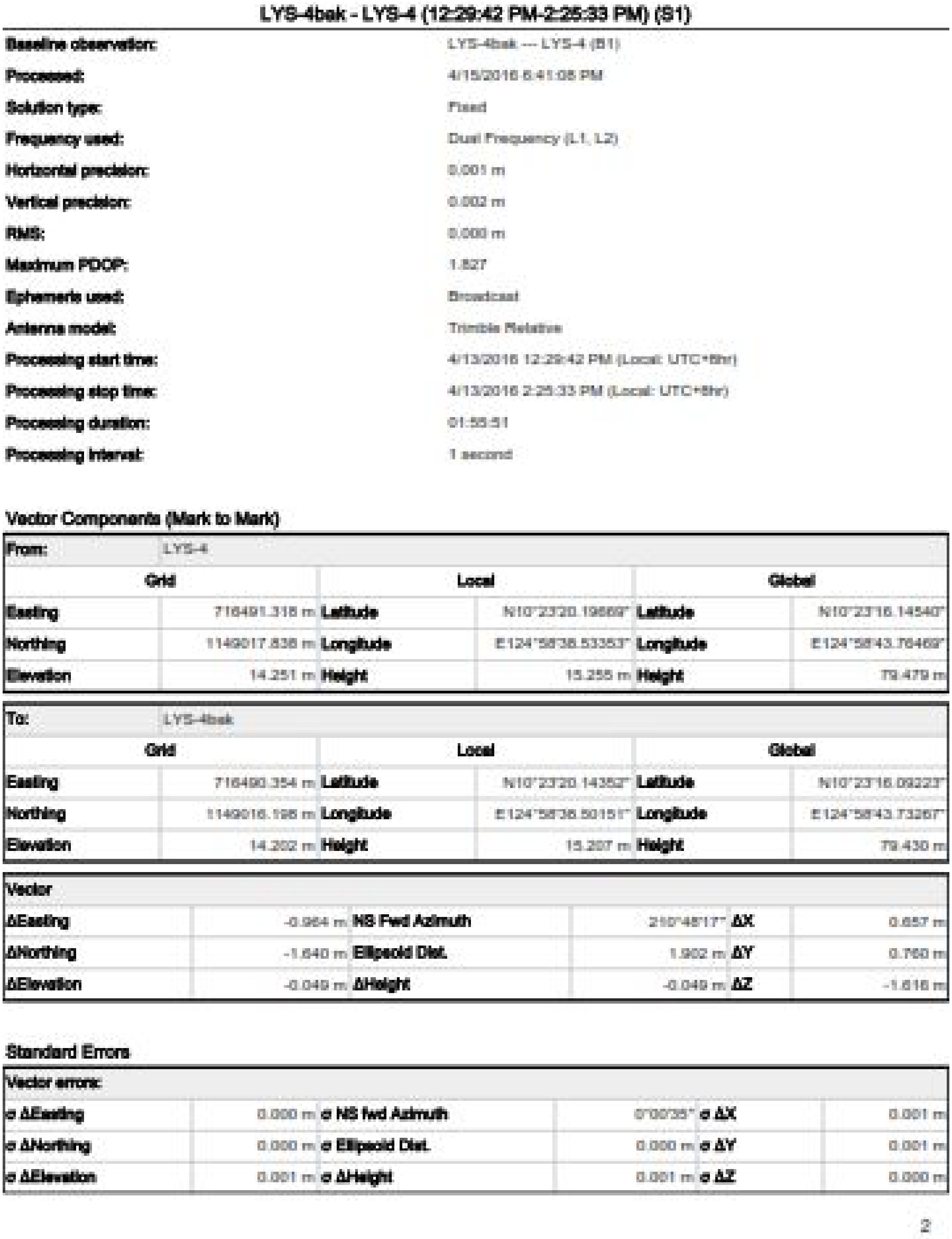
Vector errors:					
σ ΔEasting	0.001 m	**σ NS fwd Azimuth**	0°00'00"	**σ ΔX**	0.001 m
σ ΔNorthing	0.000 m	**σ Ellipsoid Dist.**	0.000 m	**σ ΔY**	0.001 m
σ ΔElevation	0.001 m	**σ ΔHeight**	0.001 m	**σ ΔZ**	0.000 m

Aposteriori Covariance Matrix (Meter²)

	X	**Y**	**Z**
X	0.0000007283		
Y	-0.0000006532	0.0000012431	
Z	-0.0000001475	0.0000002783	0.0000002463

3. LYS-4BAK

Table A-3.3. LYS-4BAK



LYS-4bak - LYS-4 (12:29:42 PM-2:25:33 PM) (S1)

Baseline observation:	LYS-4bak --- LYS-4 (B1)
Processed:	4/15/2016 6:41:08 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.001 m
Vertical precision:	0.002 m
RMS:	0.000 m
Maximum PDOP:	1.827
Ephemeris used:	Broadcast
Antenna model:	Trimble Relative
Processing start time:	4/13/2016 12:29:42 PM (Local: UTC+8hr)
Processing stop time:	4/13/2016 2:25:33 PM (Local: UTC+8hr)
Processing duration:	01:55:51
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	LYS-4				
Grid		**Local**		**Global**	
Easting	716491.318 m	**Latitude**	N10°23'20.19669"	**Latitude**	N10°23'16.14540"
Northing	1149017.838 m	**Longitude**	E124°58'38.53353"	**Longitude**	E124°58'43.76469"
Elevation	14.251 m	**Height**	15.255 m	**Height**	79.479 m

To:	LYS-4bak				
Grid		**Local**		**Global**	
Easting	716490.354 m	**Latitude**	N10°23'20.14352"	**Latitude**	N10°23'16.09223"
Northing	1149016.198 m	**Longitude**	E124°58'38.50151"	**Longitude**	E124°58'43.73267"
Elevation	14.202 m	**Height**	15.207 m	**Height**	79.430 m

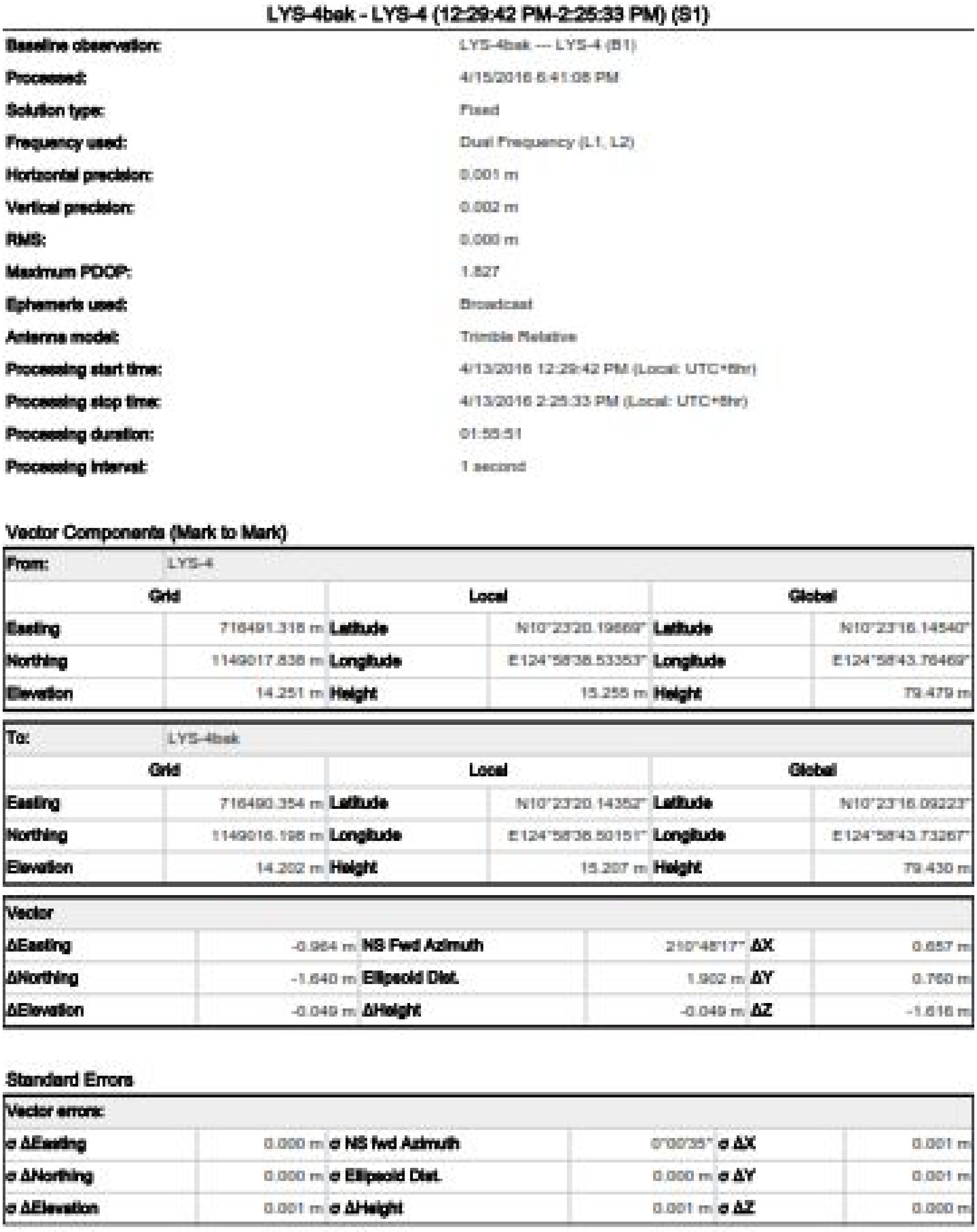
Vector					
ΔEasting	-0.964 m	**NS Fwd Azimuth**	210°48'17"	**ΔX**	0.657 m
ΔNorthing	-1.640 m	**Ellipsoid Dist.**	1.902 m	**ΔY**	0.760 m
ΔElevation	-0.049 m	**ΔHeight**	-0.049 m	**ΔZ**	-1.616 m

Standard Errors

Vector errors:					
σ ΔEasting	0.000 m	**σ NS fwd Azimuth**	0°00'35"	**σ ΔX**	0.001 m
σ ΔNorthing	0.000 m	**σ Ellipsoid Dist.**	0.000 m	**σ ΔY**	0.001 m
σ ΔElevation	0.001 m	**σ ΔHeight**	0.001 m	**σ ΔZ**	0.000 m

4. LSY-3027

Table A-3.4. LYS-3027



LYS-4bak - LYS-4 (12:29:42 PM-2:25:33 PM) (S1)

Baseline observation:	LYS-4bak --- LYS-4 (B1)
Processed:	4/15/2016 6:41:08 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.001 m
Vertical precision:	0.002 m
RMS:	0.000 m
Maximum PDOP:	1.827
Ephemeris used:	Broadcast
Antenna model:	Trimble Relative
Processing start time:	4/13/2016 12:29:42 PM (Local: UTC+8hr)
Processing stop time:	4/13/2016 2:25:33 PM (Local: UTC+8hr)
Processing duration:	01:55:51
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	LYS-4				
Grid		**Local**		**Global**	
Easting	716491.318 m	**Latitude**	N10°23'20.19669"	**Latitude**	N10°23'16.14540"
Northing	1149017.838 m	**Longitude**	E124°58'38.53353"	**Longitude**	E124°58'43.76469"
Elevation	14.251 m	**Height**	15.255 m	**Height**	79.479 m

To:	LYS-4bak				
Grid		**Local**		**Global**	
Easting	716490.354 m	**Latitude**	N10°23'20.14352"	**Latitude**	N10°23'16.09223"
Northing	1149016.198 m	**Longitude**	E124°58'38.50151"	**Longitude**	E124°58'43.73267"
Elevation	14.202 m	**Height**	15.207 m	**Height**	79.430 m

Vector					
ΔEasting	-0.964 m	**NS Fwd Azimuth**	210°48'17"	**ΔX**	0.657 m
ΔNorthing	-1.640 m	**Ellipsoid Dist.**	1.902 m	**ΔY**	0.760 m
ΔElevation	-0.049 m	**ΔHeight**	-0.049 m	**ΔZ**	-1.616 m

Standard Errors

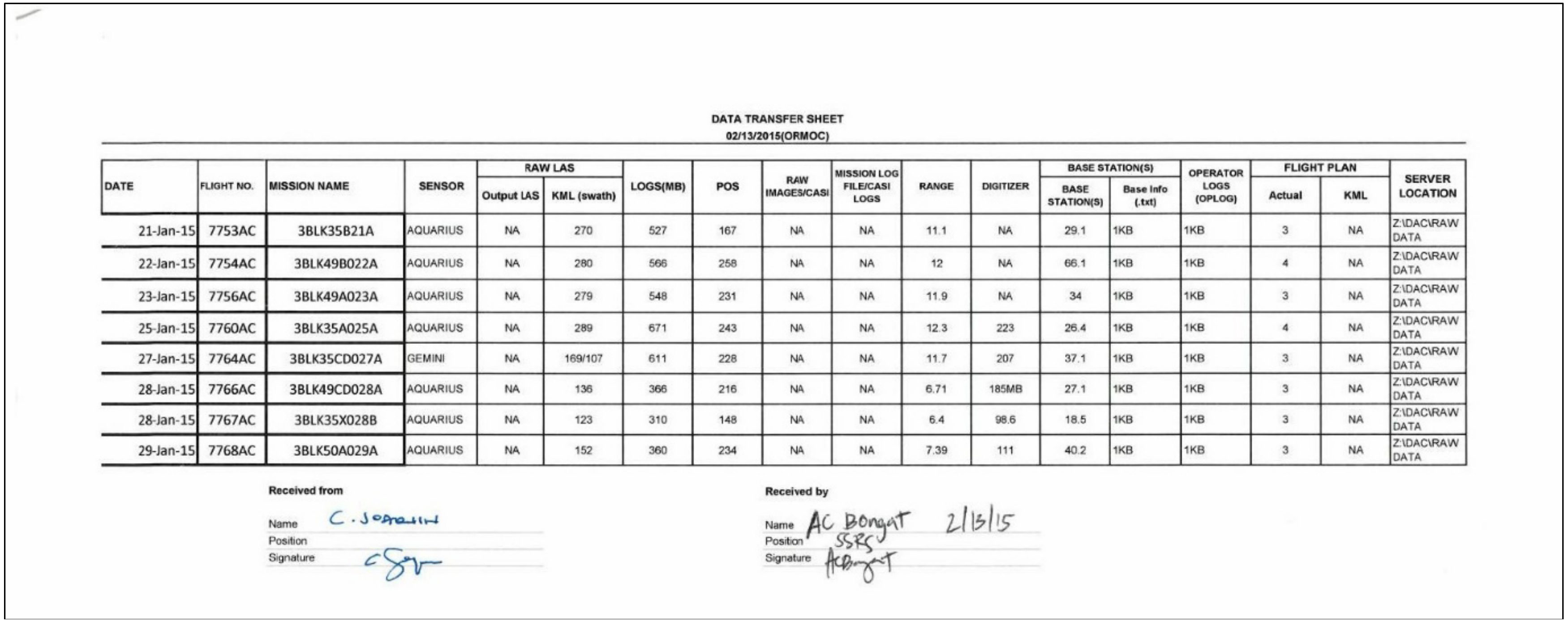
Vector errors:					
σ ΔEasting	0.000 m	**σ NS fwd Azimuth**	0°00'35"	**σ ΔX**	0.001 m
σ ΔNorthing	0.000 m	**σ Ellipsoid Dist.**	0.000 m	**σ ΔY**	0.001 m
σ ΔElevation	0.001 m	**σ ΔHeight**	0.001 m	**σ ΔZ**	0.000 m

Annex 4. The LiDAR Survey Team Composition

Table A-4.1. The LiDAR Survey Team Composition

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	
		LOVELYN ASUNCION	
LiDAR Operation	Senior Science Research Specialist (SSRS)	JULIE PEARL MARS	UP-TCAGP
		JASMINE ALVIAR	
		PAULINE JOANNE ARCEO	
	Research Associate (RA)	ENGR. LARAH KRISELLE PARAGAS	UP-TCAGP
		ENGR. GRACE SINADJAN	
		ENGR. KENNETH QUISADO	
		KRISTINE JOY ANDAYA	
		JONATHAN ALMALVEZ	
		JERIEL PAUL ALAMBAN, GEOL.	
Ground Survey	RA	JERIEL PAUL ALAMBAN	UP-TCAGP
		ENGR. FRANK NICOLAS ILEJAY	
		ENGR. IRO NIEL ROXAS	
LiDAR Operation	Airborne Security	SSG RANDY SISON	PHILIPPINE AIR FORCE (PAF)
		SSG RAYMUND DOMINE	
	Pilot	CAPT. ALBERT PAUL LIM	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. RANDY LAGCO	
		CAPT. JACKSON JAVIER	
		CAPT. NIEL AGAWIN	
		CAPT. NEIL ACHILLES AGAWIN	
		CAPT. FERDINAND DE OCAMPO	
		CAPT. JEROME MOONEY	
		CAPT. ANTON RETSE DAYO	

Annex 5. Data Transfer Sheet for Das-ay Floodplain



DATA TRANSFER SHEET
02/13/2015(ORMOC)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
21-Jan-15	7753AC	3BLK35B21A	AQUARIUS	NA	270	527	167	NA	NA	11.1	NA	29.1	1KB	1KB	3	NA	Z:\DAC\RAW DATA
22-Jan-15	7754AC	3BLK49B022A	AQUARIUS	NA	280	566	258	NA	NA	12	NA	66.1	1KB	1KB	4	NA	Z:\DAC\RAW DATA
23-Jan-15	7756AC	3BLK49A023A	AQUARIUS	NA	279	548	231	NA	NA	11.9	NA	34	1KB	1KB	3	NA	Z:\DAC\RAW DATA
25-Jan-15	7760AC	3BLK35A025A	AQUARIUS	NA	289	671	243	NA	NA	12.3	223	26.4	1KB	1KB	4	NA	Z:\DAC\RAW DATA
27-Jan-15	7764AC	3BLK35CD027A	GEMINI	NA	169/107	611	228	NA	NA	11.7	207	37.1	1KB	1KB	3	NA	Z:\DAC\RAW DATA
28-Jan-15	7766AC	3BLK49CD028A	AQUARIUS	NA	136	366	216	NA	NA	6.71	185MB	27.1	1KB	1KB	3	NA	Z:\DAC\RAW DATA
28-Jan-15	7767AC	3BLK35X028B	AQUARIUS	NA	123	310	148	NA	NA	6.4	98.6	18.5	1KB	1KB	3	NA	Z:\DAC\RAW DATA
29-Jan-15	7768AC	3BLK50A029A	AQUARIUS	NA	152	360	234	NA	NA	7.39	111	40.2	1KB	1KB	3	NA	Z:\DAC\RAW DATA

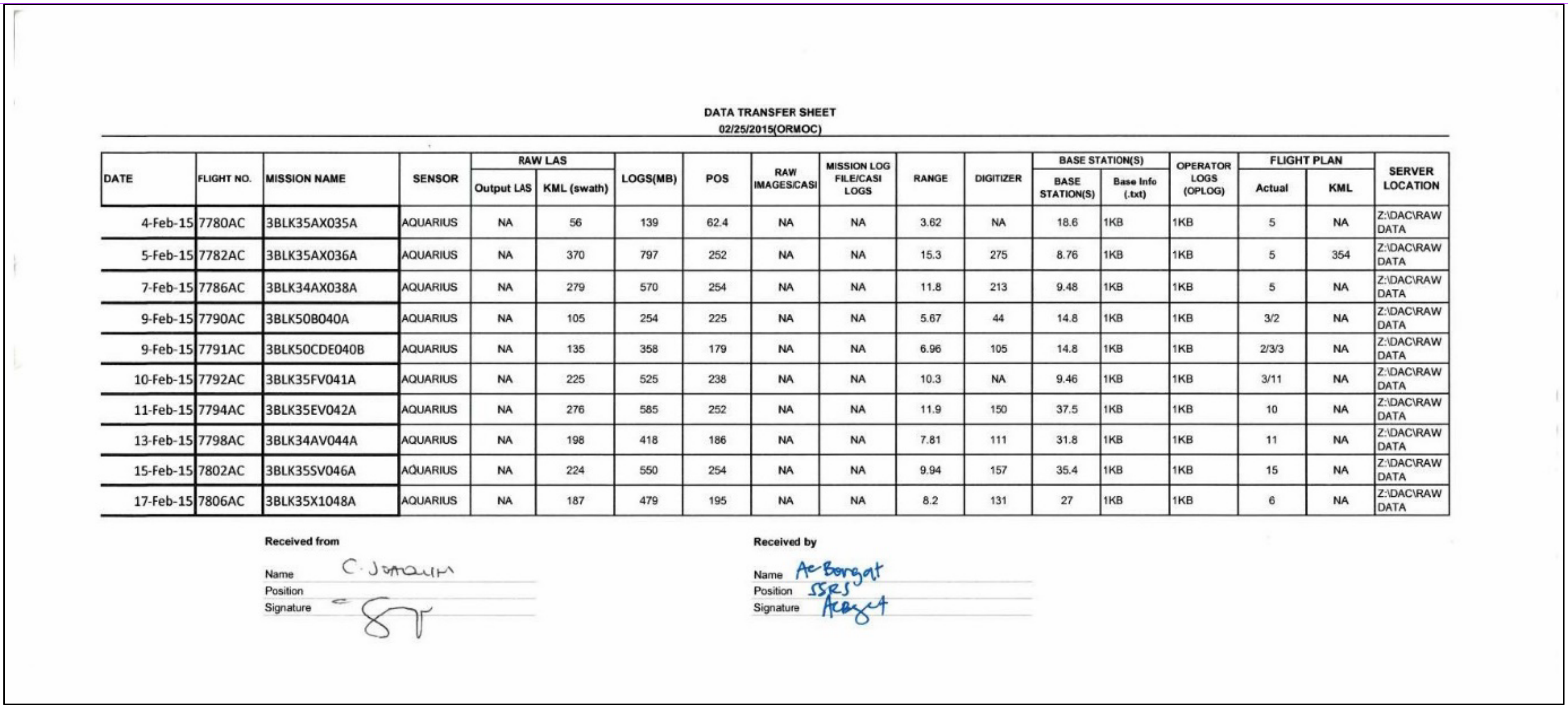
Received from

Name C. Joaquin
Position
Signature

Received by

Name AC Bongat 2/13/15
Position SSRS
Signature ACBongat

Figure A-5.1. Transfer Sheet for Das-ay Floodplain - A



DATA TRANSFER SHEET
02/25/2015(ORMOC)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
4-Feb-15	7780AC	3BLK35AX035A	AQUARIUS	NA	56	139	62.4	NA	NA	3.62	NA	18.6	1KB	1KB	5	NA	Z:\DAC\RAW DATA
5-Feb-15	7782AC	3BLK35AX036A	AQUARIUS	NA	370	797	252	NA	NA	15.3	275	8.76	1KB	1KB	5	354	Z:\DAC\RAW DATA
7-Feb-15	7786AC	3BLK34AX038A	AQUARIUS	NA	279	570	254	NA	NA	11.8	213	9.48	1KB	1KB	5	NA	Z:\DAC\RAW DATA
9-Feb-15	7790AC	3BLK50B040A	AQUARIUS	NA	105	254	225	NA	NA	5.67	44	14.8	1KB	1KB	3/2	NA	Z:\DAC\RAW DATA
9-Feb-15	7791AC	3BLK50CDE040B	AQUARIUS	NA	135	358	179	NA	NA	6.96	105	14.8	1KB	1KB	2/3/3	NA	Z:\DAC\RAW DATA
10-Feb-15	7792AC	3BLK35FV041A	AQUARIUS	NA	225	525	238	NA	NA	10.3	NA	9.46	1KB	1KB	3/11	NA	Z:\DAC\RAW DATA
11-Feb-15	7794AC	3BLK35EV042A	AQUARIUS	NA	276	585	252	NA	NA	11.9	150	37.5	1KB	1KB	10	NA	Z:\DAC\RAW DATA
13-Feb-15	7798AC	3BLK34AV044A	AQUARIUS	NA	198	418	186	NA	NA	7.81	111	31.8	1KB	1KB	11	NA	Z:\DAC\RAW DATA
15-Feb-15	7802AC	3BLK35SV046A	AQUARIUS	NA	224	550	254	NA	NA	9.94	157	35.4	1KB	1KB	15	NA	Z:\DAC\RAW DATA
17-Feb-15	7806AC	3BLK35X1048A	AQUARIUS	NA	187	479	195	NA	NA	8.2	131	27	1KB	1KB	6	NA	Z:\DAC\RAW DATA

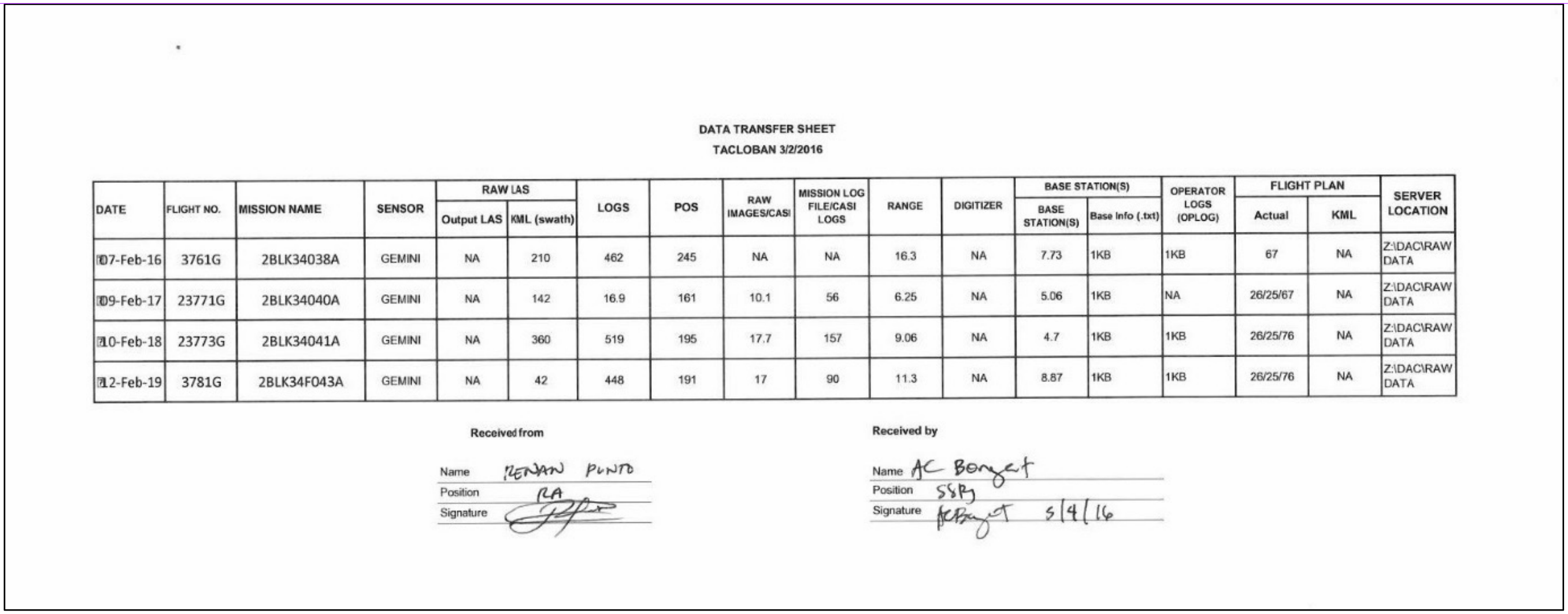
Received from

Name C. Joaquin
Position
Signature

Received by

Name Ac Bongat
Position SSRS
Signature

Figure A-5.2. Transfer Sheet for Das-ay Floodplain - B



DATA TRANSFER SHEET
TACLOBAN 3/2/2016

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
07-Feb-16	3761G	2BLK34038A	GEMINI	NA	210	462	245	NA	NA	16.3	NA	7.73	1KB	1KB	67	NA	Z:\DAC\RAW DATA
09-Feb-17	23771G	2BLK34040A	GEMINI	NA	142	16.9	161	10.1	56	6.25	NA	5.06	1KB	NA	26/25/67	NA	Z:\DAC\RAW DATA
10-Feb-18	23773G	2BLK34041A	GEMINI	NA	360	519	195	17.7	157	9.06	NA	4.7	1KB	1KB	26/25/76	NA	Z:\DAC\RAW DATA
12-Feb-19	3781G	2BLK34F043A	GEMINI	NA	42	448	191	17	90	11.3	NA	8.87	1KB	1KB	26/25/76	NA	Z:\DAC\RAW DATA

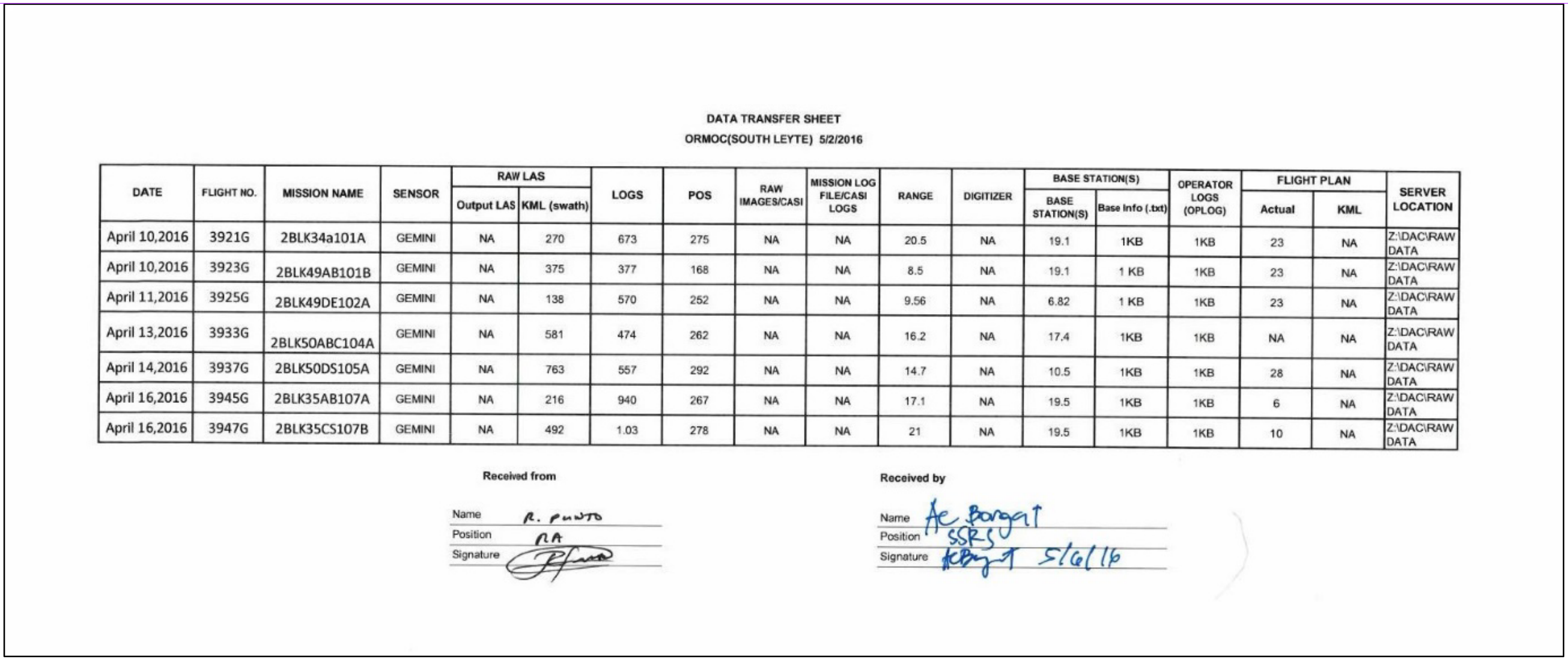
Received from

Name RENAN PUNTO
Position RA
Signature

Received by

Name AC Bongat
Position SSRS
Signature 5/4/16

Figure A-5.3. Transfer Sheet for Das-ay Floodplain - C



DATA TRANSFER SHEET
ORMOC(SOUTH LEYTE) 5/2/2016

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
April 10,2016	3921G	2BLK34a101A	GEMINI	NA	270	673	275	NA	NA	20.5	NA	19.1	1KB	1KB	23	NA	Z:\DAC\RAW DATA
April 10,2016	3923G	2BLK49AB101B	GEMINI	NA	375	377	168	NA	NA	8.5	NA	19.1	1 KB	1KB	23	NA	Z:\DAC\RAW DATA
April 11,2016	3925G	2BLK49DE102A	GEMINI	NA	138	570	252	NA	NA	9.56	NA	6.82	1 KB	1KB	23	NA	Z:\DAC\RAW DATA
April 13,2016	3933G	2BLK50ABC104A	GEMINI	NA	581	474	262	NA	NA	16.2	NA	17.4	1KB	1KB	NA	NA	Z:\DAC\RAW DATA
April 14,2016	3937G	2BLK50DS105A	GEMINI	NA	763	557	292	NA	NA	14.7	NA	10.5	1KB	1KB	28	NA	Z:\DAC\RAW DATA
April 16,2016	3945G	2BLK35AB107A	GEMINI	NA	216	940	267	NA	NA	17.1	NA	19.5	1KB	1KB	6	NA	Z:\DAC\RAW DATA
April 16,2016	3947G	2BLK35CS107B	GEMINI	NA	492	1.03	278	NA	NA	21	NA	19.5	1KB	1KB	10	NA	Z:\DAC\RAW DATA

Received from

Name R. PUNTO
Position RA
Signature

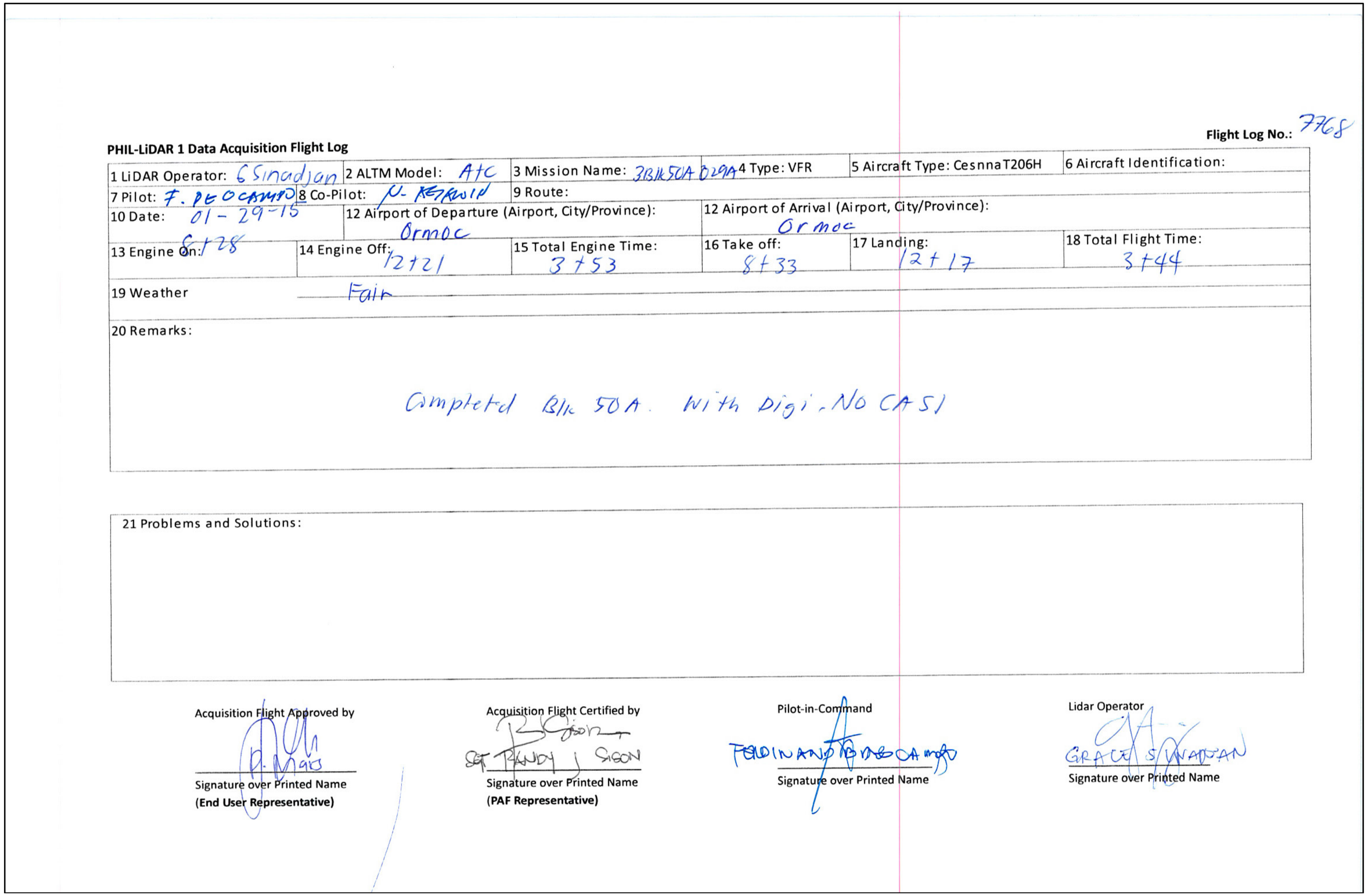
Received by

Name Ac Borgat
Position SSRS
Signature 5/6/16

Figure A-5.4. Transfer Sheet for Das-ay Floodplain - D

Annex 6. Flight logs for the flight missions

1. Flight Log for 7768AC Mission



Flight Log No.: 7768

PHIL-LiDAR 1 Data Acquisition Flight Log

1 LiDAR Operator: G Sinadjan
2 ALTM Model: ATC
3 Mission Name: 3BLK50A029A
4 Type: VFR
5 Aircraft Type: CesnnaT206H
6 Aircraft Identification:
7 Pilot: F. DE OCAMPO
8 Co-Pilot: N. KERWIN
9 Route:
10 Date: 01-29-15
12 Airport of Departure (Airport, City/Province): Ormoc
12 Airport of Arrival (Airport, City/Province): Ormoc
13 Engine On: 8+28
14 Engine Off: 12+21
15 Total Engine Time: 3+53
16 Take off: 8+33
17 Landing: 12+17
18 Total Flight Time: 3+44
19 Weather: Fair
20 Remarks:

Completed Blk 50A. With Digi. No CASI

21 Problems and Solutions:

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

Acquisition Flight Certified by
SGT RANDY J SIGON
Signature over Printed Name
(PAF Representative)

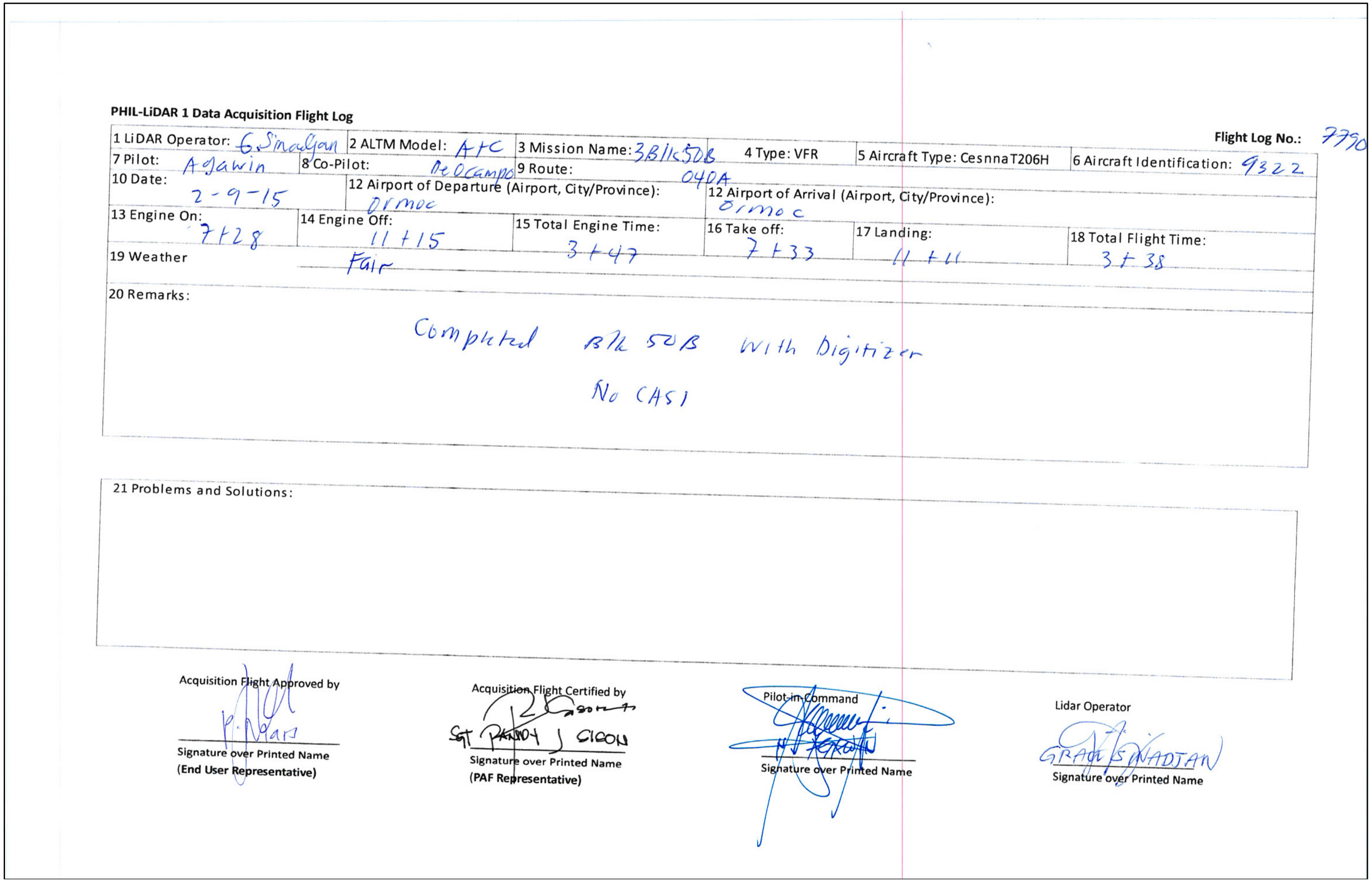
Pilot-in-Command
FERDINAND DE OCAMPO
Signature over Printed Name

Lidar Operator
GRACE S SINADJAN
Signature over Printed Name

Figure A-6.1. Flight Log for Mission 7768AC

2.Flight Log for 1028A Mission

2. Flight Log for 7790AC Mission



PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 7790

1 LiDAR Operator: G.Sinadjan | 2 ALTM Model: A+C | 3 Mission Name: 3Blk50B | 4 Type: VFR | 5 Aircraft Type: CesnnaT206H | 6 Aircraft Identification: 9322

7 Pilot: Agawin | 8 Co-Pilot: De Ocampo | 9 Route: 040A

10 Date: 2-9-15 | 12 Airport of Departure (Airport, City/Province): Ormoc | 12 Airport of Arrival (Airport, City/Province): Ormoc

13 Engine On: 7+28 | 14 Engine Off: 11+15 | 15 Total Engine Time: 3+47 | 16 Take off: 7+33 | 17 Landing: 11+11 | 18 Total Flight Time: 3+38

19 Weather: Fair

20 Remarks:

Completed Blk 50B with Digitizer

No CASI

21 Problems and Solutions:

Acquisition Flight Approved by

P. Naars

Signature over Printed Name
(End User Representative)

Acquisition Flight Certified by

SGT RANDY J SICON

Signature over Printed Name
(PAF Representative)

Pilot-in-Command

Signature over Printed Name

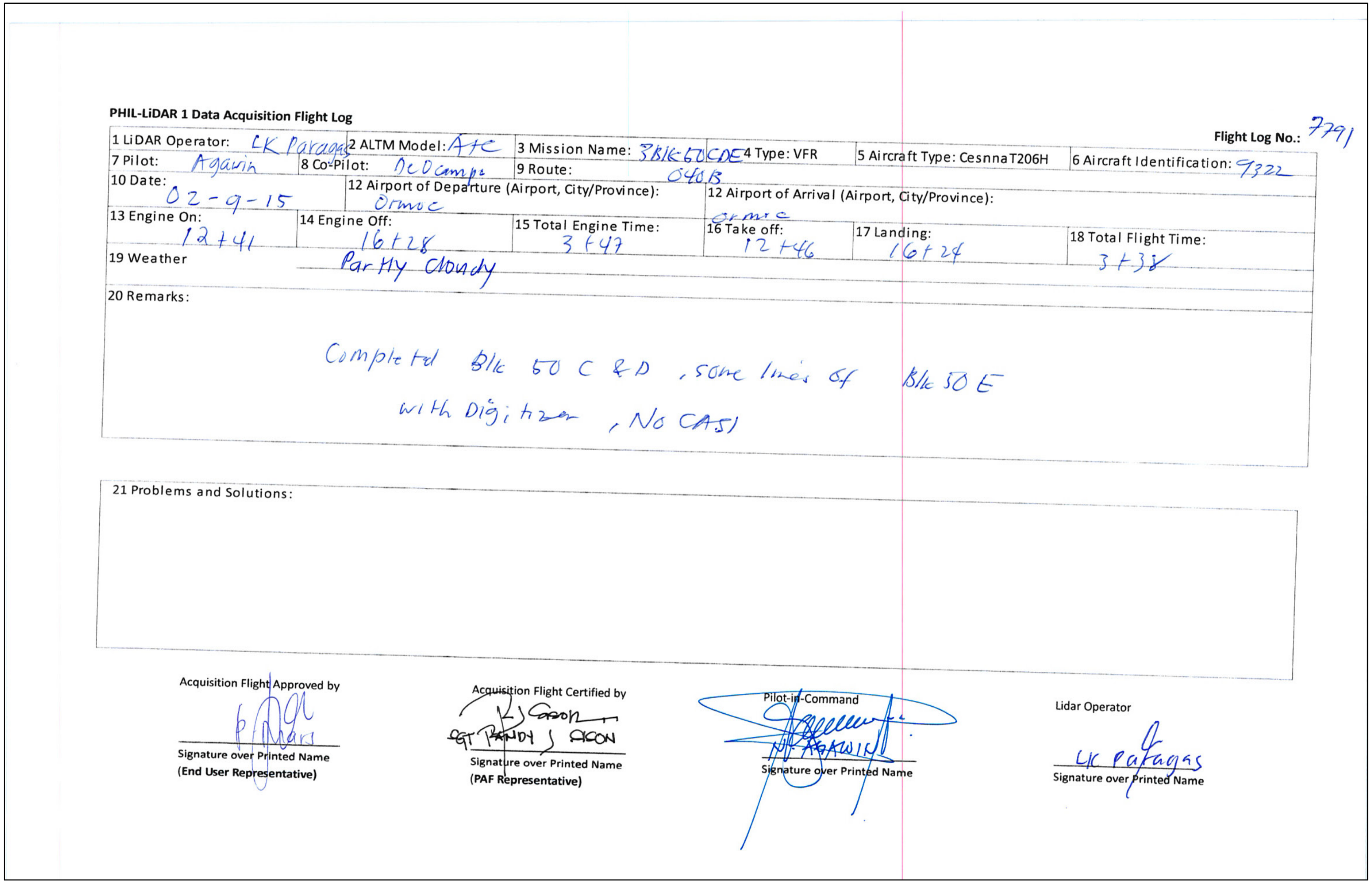
Lidar Operator

GRACE SINADJAN

Signature over Printed Name

Figure A-6.2. Flight Log for Mission 7790AC

3. Flight Log for 7791AC Mission



PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 7791

1 LiDAR Operator: LK Paragas
2 ALTM Model: Aqc
3 Mission Name: 3Blk50CDE
4 Type: VFR
5 Aircraft Type: CesnnaT206H
6 Aircraft Identification: 9322
7 Pilot: Agawin
8 Co-Pilot: DeOcampo
9 Route: 040B
10 Date: 02-9-15
12 Airport of Departure (Airport, City/Province): Ormoc
12 Airport of Arrival (Airport, City/Province): Ormoc
13 Engine On: 12+41
14 Engine Off: 16+28
15 Total Engine Time: 3+47
16 Take off: 12+46
17 Landing: 16+24
18 Total Flight Time: 3+38
19 Weather: Partly Cloudy
20 Remarks:

Completed Blk 50 C & D, some lines of Blk 50 E with Digitizer, No CASI

21 Problems and Solutions:

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

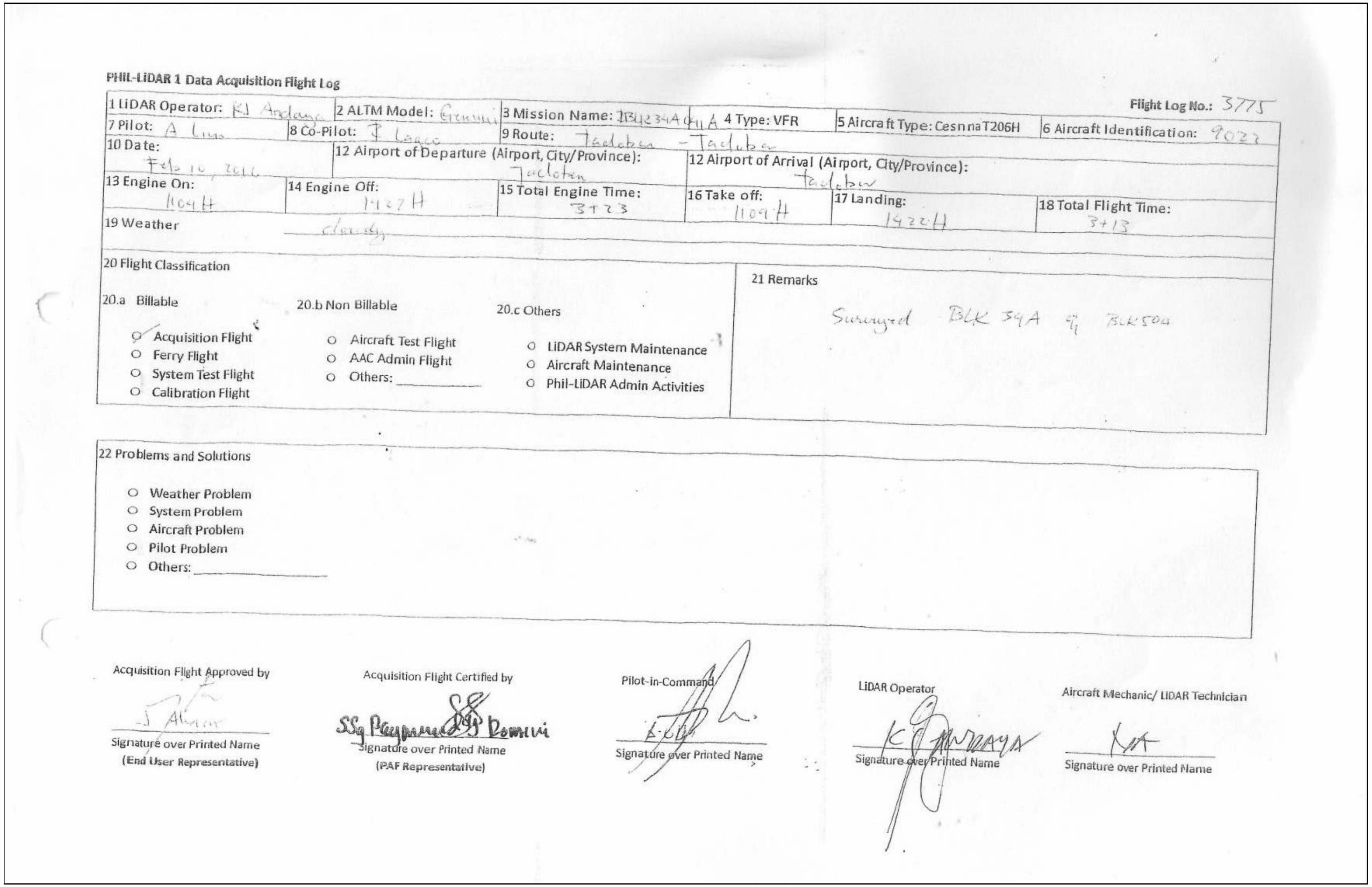
Acquisition Flight Certified by
SGT RANDY J SICON
Signature over Printed Name
(PAF Representative)

Pilot-in-Command
N. AGAWIN
Signature over Printed Name

Lidar Operator
LK Paragas
Signature over Printed Name

Figure A-6.3. Flight Log for Mission 7791AC

4. Flight Log for 23773G Mission



PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 3775

1 LiDAR Operator: KJ Andaya	2 ALTM Model: Gemini	3 Mission Name: 1BLK34A041A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: A Lim	8 Co-Pilot: J Lacco	9 Route: Tacloban - Tacloban			
10 Date: Feb 10, 2016	12 Airport of Departure (Airport, City/Province): Tacloban		12 Airport of Arrival (Airport, City/Province): Tacloban		
13 Engine On: 1104H	14 Engine Off: 1427H	15 Total Engine Time: 3+23	16 Take off: 1109H	17 Landing: 1422H	18 Total Flight Time: 3+13
19 Weather: cloudy					

20 Flight Classification

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

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

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

21 Remarks

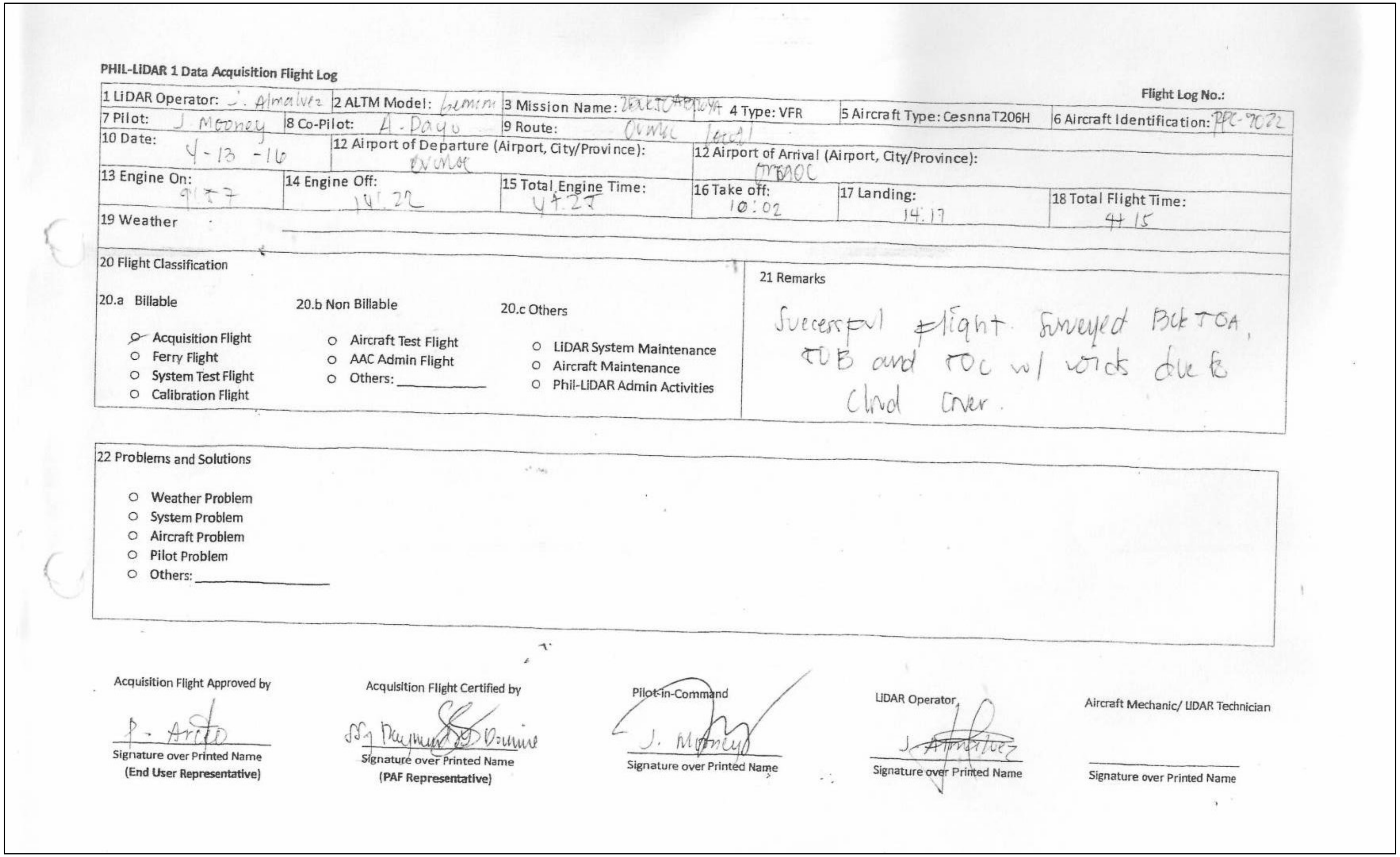
Surveyed BLK 34A & BLK50A

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Technician
J Alviar				
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.4. Flight Log for Mission 23773G

5. Flight Log for 3933G Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.:

1 LiDAR Operator: J. Almalvez
2 ALTM Model: Gemini
3 Mission Name: 2BLK30ABC104A
4 Type: VFR
5 Aircraft Type: CesnnaT206H
6 Aircraft Identification: RPC-9022
7 Pilot: J. Mooney
8 Co-Pilot: A. Dayo
9 Route: Ormoc local
10 Date: 4-13-16
12 Airport of Departure (Airport, City/Province): Ormoc
12 Airport of Arrival (Airport, City/Province): Ormoc
13 Engine On: 9:57
14 Engine Off: 14:22
15 Total Engine Time: 4+25
16 Take off: 10:02
17 Landing: 14:17
18 Total Flight Time: 4+15
19 Weather

20 Flight Classification

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

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

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

21 Remarks

Successful flight. Surveyed BLK 30A, 30B and 30C w/ voids due to cloud cover.

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

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

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

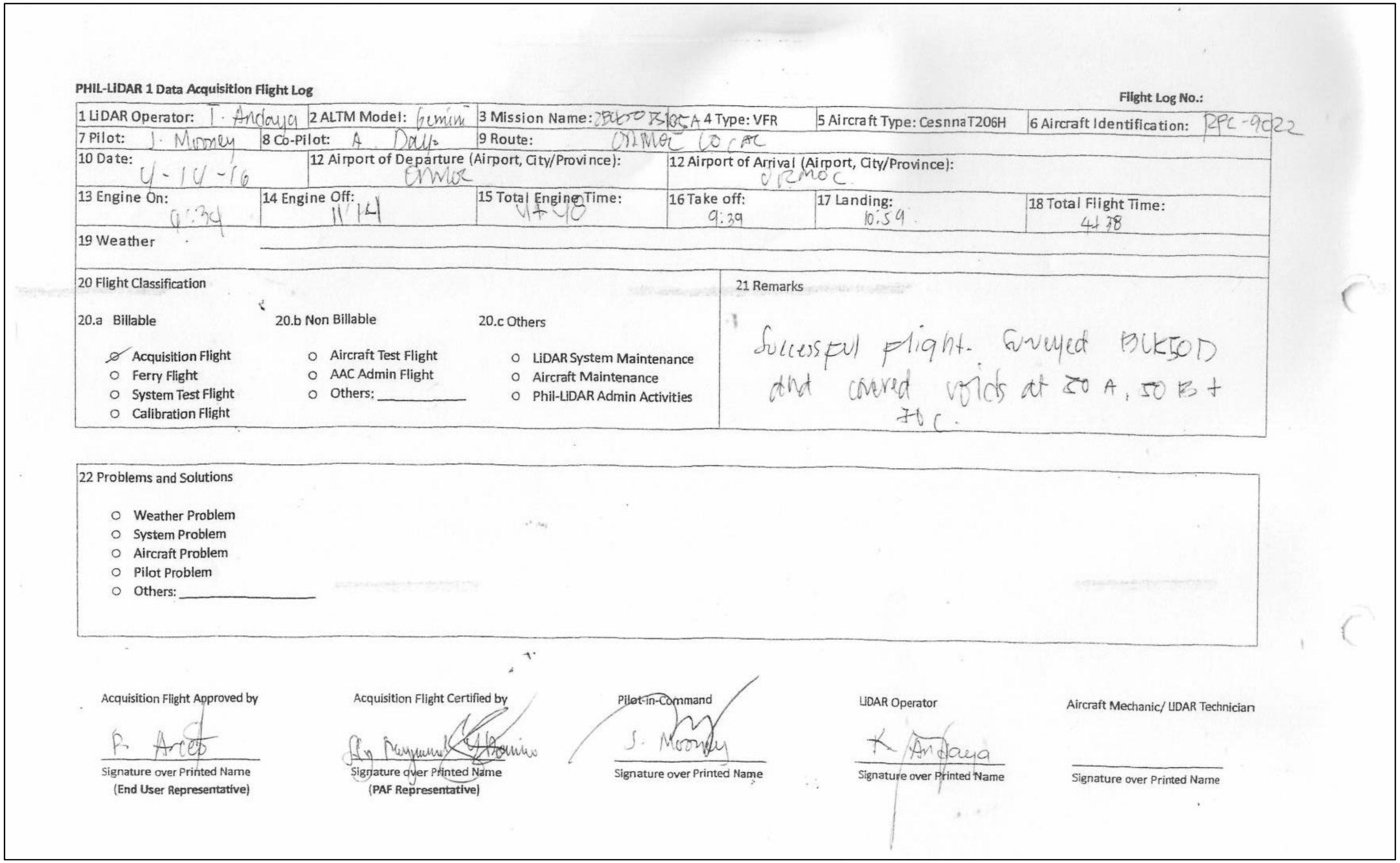
Pilot-in-Command
J. Mooney
Signature over Printed Name

LiDAR Operator
J. Almalvez
Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician
Signature over Printed Name

Figure A-6.5. Flight Log for Mission 3933G

6. Flight Log for 3937G Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.:

1 LiDAR Operator: I. Andaya
2 ALTM Model: Gemini
3 Mission Name: 2BLK50B105A
4 Type: VFR
5 Aircraft Type: CesnnaT206H
6 Aircraft Identification: RPC-9022
7 Pilot: J. Mooney
8 Co-Pilot: A. Dalo
9 Route: ORMOC LOCAL
10 Date: 4-14-16
12 Airport of Departure (Airport, City/Province): Ormoc
12 Airport of Arrival (Airport, City/Province): ORMOC
13 Engine On: 9:34
14 Engine Off: 11:14
15 Total Engine Time: 1+40
16 Take off: 9:39
17 Landing: 10:59
18 Total Flight Time: 1+20
19 Weather

20 Flight Classification

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

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

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

21 Remarks

Successful flight. Surveyed BLK50D and covered voids at 50A, 50B + 50C.

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

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

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

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

LiDAR Operator
I. Andaya
Signature over Printed Name

Aircraft Mechanic/ LIDAR Technician
Signature over Printed Name

Figure A-6.6. Flight Log for Mission 3937G

Annex 7. Flight Status Reports

Leyte and Southern Leyte
January 29-February 10, 2015, February 10, 2016 and April 13-14, 2016

Table A-7.1. Flight Status Report

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
7768AC	BLK50A	3BLK50A029A	G SINADJAN	29 JAN 15	Completed Blk50A with digitizer. No CASI
7790AC	BLK50B	3BLK50B040A	G SINADJAN	9 FEB 15	Completed Blk50B with digitizer. No CASI
7791AC	BLK50CDE	3BLK50CDE040B	LK PARAGAS	9 FEB 15	Completed Blk50C and D, some lines of Blk50E with digitizer. No CASI
23773G	BLK 34aC, 34aB CADACAN FP BLK 50A DAS-AY FP	2BLK34041A	KJ ANDAYA	10 FEB 16	SURVEYED CADACAN AND DAS-AY FPs 105.19 SQ.KM
3933G	ORMOC	2BLK50ABC104A	J. ALMALVEZ	13 APR 16	SURVEYED BLK 50A, 50B AND 50C WITH VOIDS DUE TO CLOUD COVER
3937G	ORMOC	2BLK50DS105A	K.ANDAYA	14 APR 16	SURVEYED VLOCK 50D AND COVERED VOIDS AT 50A, 50B AND 50C

SWATH PER FLIGHT MISSION

Flight No. : 7768
Area: BLK 50A
Mission Name: 3BLK50A029A
Altitude: 600
Scan Frequency: 45
Scan Angle: 18
Overlap: 35%
Area covered: 47.465sq.km.

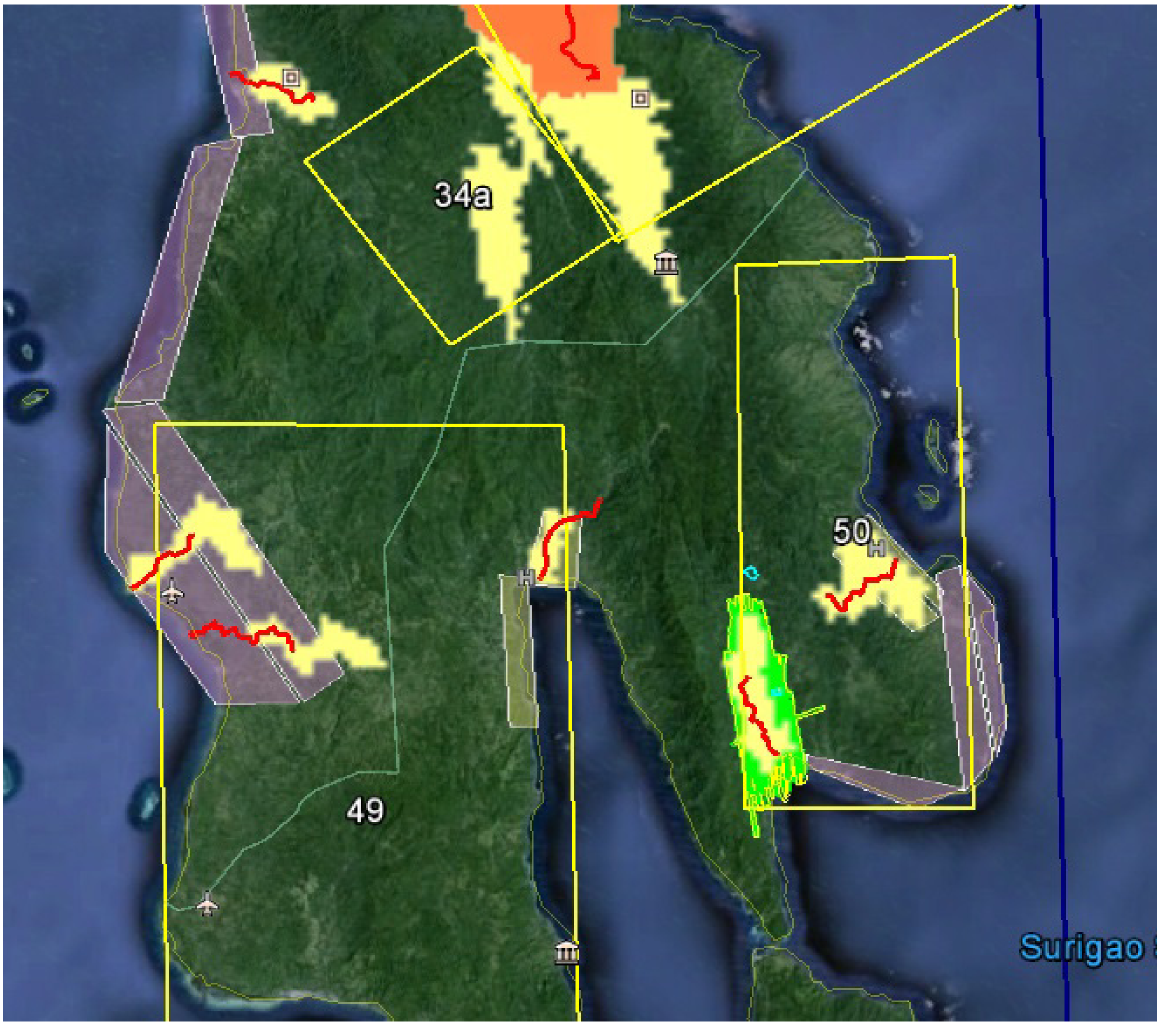


Figure A-7.1. Swath for Flight No. 7768

Flight No. :	7790
Area:	BLK34AX
Mission Name:	3BLK50B040A
Altitude:	600
Scan Frequency:	45
Scan Angle:	18
Overlap:	35%
Area covered:	28.099 sq.km.

Figure A-7.2. Swath for Flight No. 7790

Flight No. :	7791
Area:	BLK50CDE
Mission name:	3BLK50CDE040B
Altitude:	500
Scan Frequency:	45
Scan Angle:	18
Overlap:	35%
Area covered:	37.483 sq.km.

Figure A-7.3. Swath for Flight No. 7791

Flight No. :	23773G
Area:	BLK 34F – Cadacan 2 and Das-ay FPs
Mission Name:	2BLK34041A
Scan Frequency:	50
Scan Angle:	18
PRF:	100 kHz

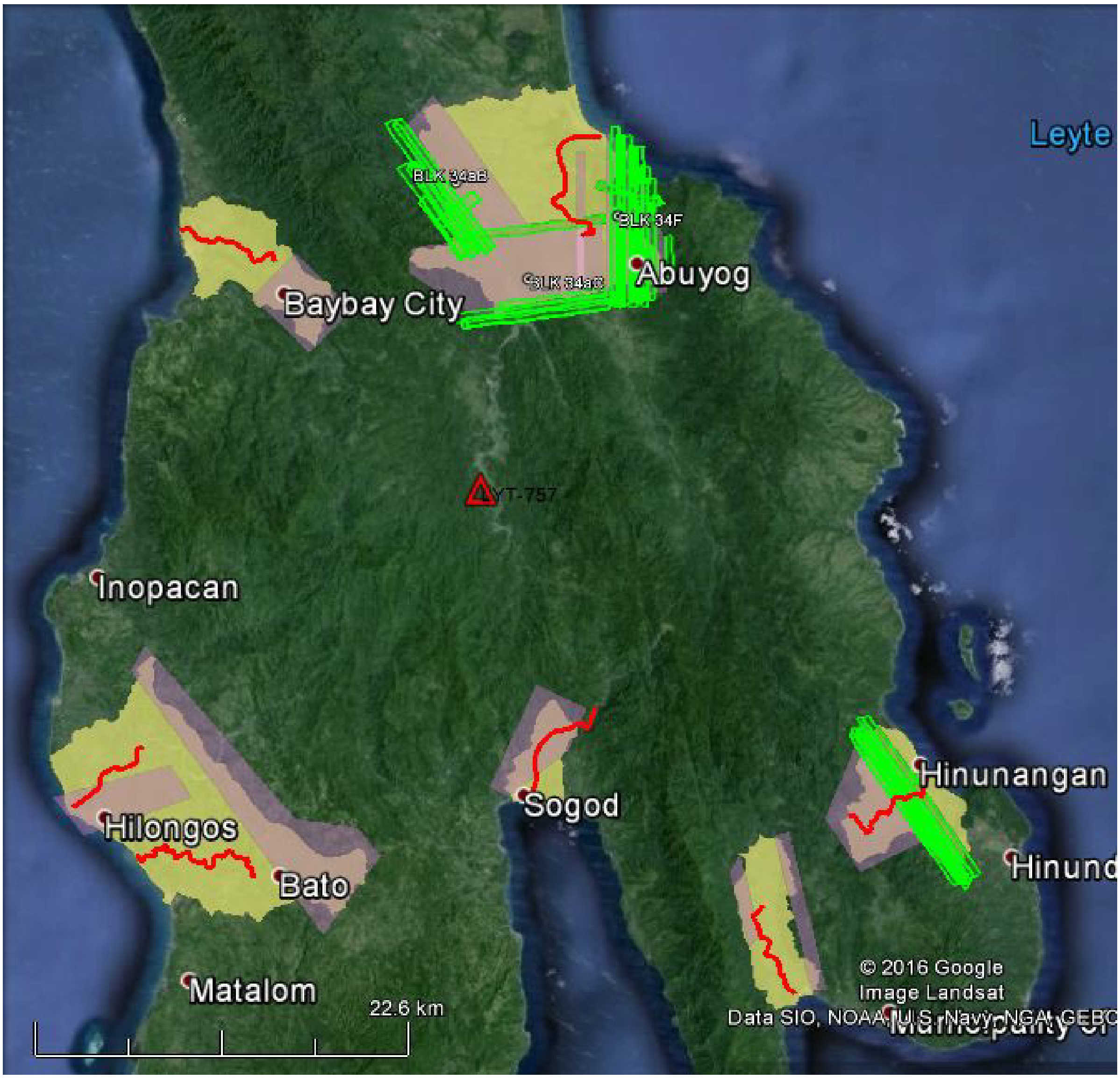


Figure A-7.4. Swath for Flight No. 23773G

Flight No. :	3393
Area:	Ormoc
Mission Name:	2BLK50ABC104A
Altitude:	1000m
Scan Frequency:	50
Scan Angle:	18
Area Surveyed:	22 sq km

Figure A-7.5. Swath for Flight No. 3393

Flight No. :	3937
Area:	Ormoc
Mission Name:	2BLK50DS105A
Altitude:	850
Scan Frequency:	40
Scan Angle:	25
Area Surveyed:	92.6 sq km

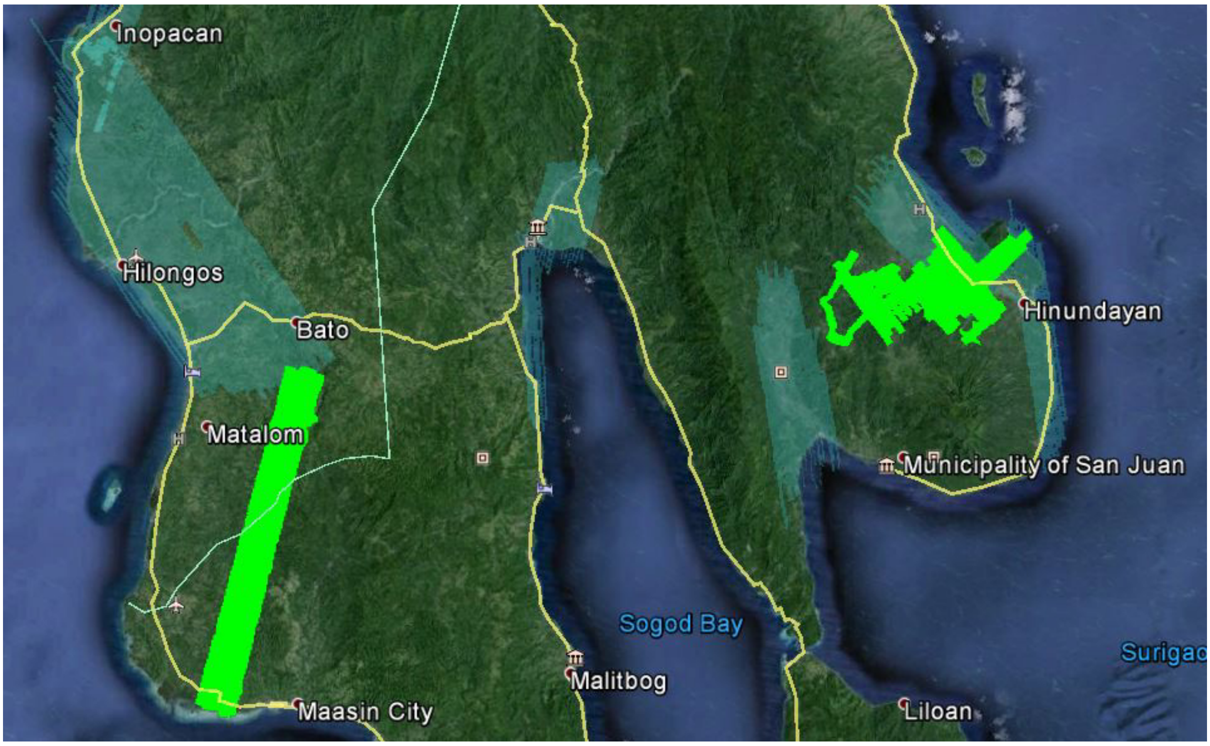


Figure A-7.6. Swath for Flight No. 3937

Annex 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Blk50CDE

Flight Area	Ormoc
Mission Name	Blk50CDE
Inclusive Flights	7791AC
Range data size	6.96 GB
Base data size	14.8 MB
POS data size	179 MB
Image	0 GB
Transfer date	March 9 2015
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)	1.09
RMSE for East Position (<4.0 cm)	1.16
RMSE for Down Position (<8.0 cm)	1.84
Boresight correction stdev (<0.001deg)	0.000384
IMU attitude correction stdev (<0.001deg)	0.004268
GPS position stdev (<0.01m)	0.0327
Minimum % overlap (>25)	39.54
Ave point cloud density per sq.m. (>2.0)	2.98
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	79
Maximum Height	388.29 m
Minimum Height	55.49 m
Classification (# of points)	
Ground	17,574,964
Low vegetation	18,615,933
Medium vegetation	21,916,367
High vegetation	40,772,611
Building	1,986,454
Orthophoto	No
Processed by	Engr. Jommer Medina, Aljon Rie Araneta, Engr. Krisha Marie Bautista

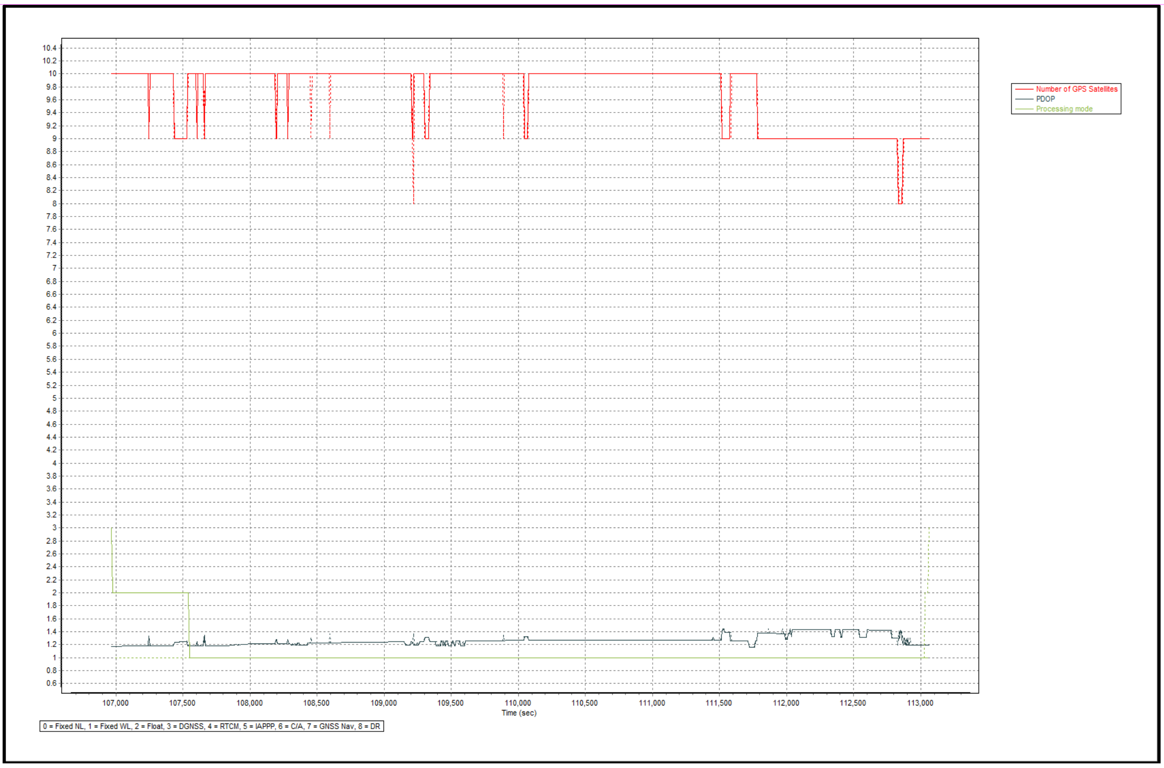


Figure A-8.1 Solution Status

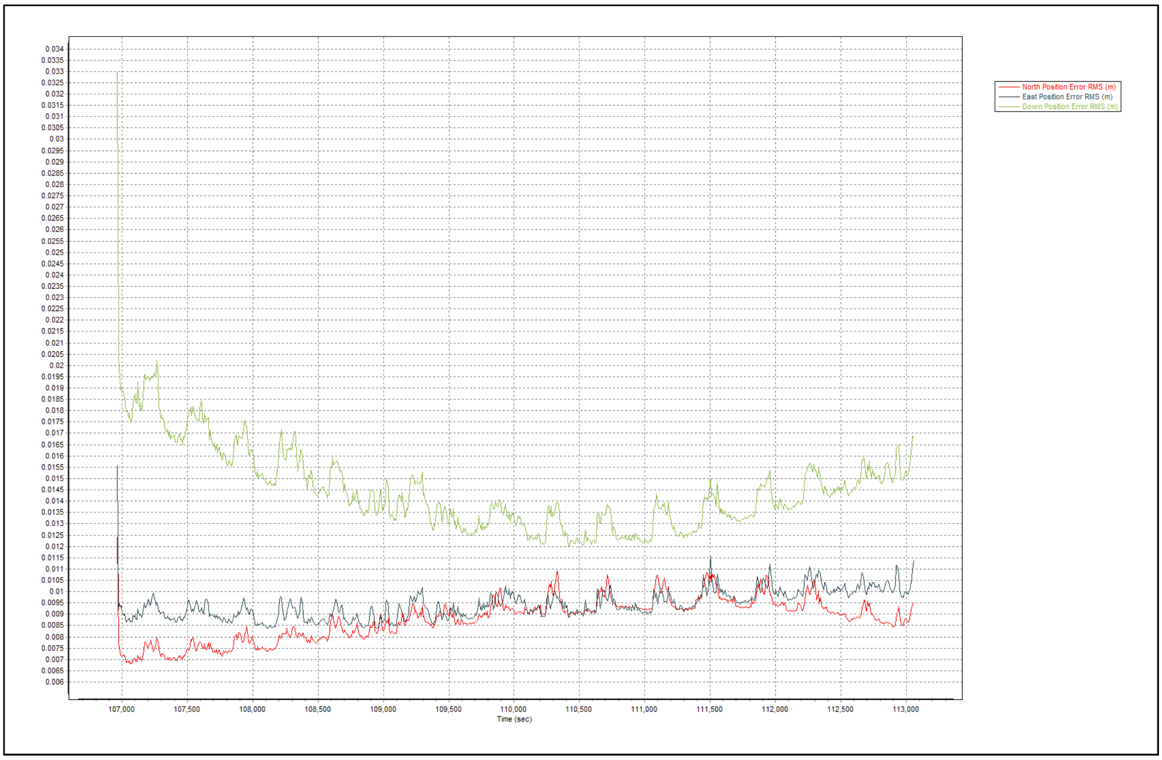


Figure A-8.2 Smoothed Performance Metric Parameters

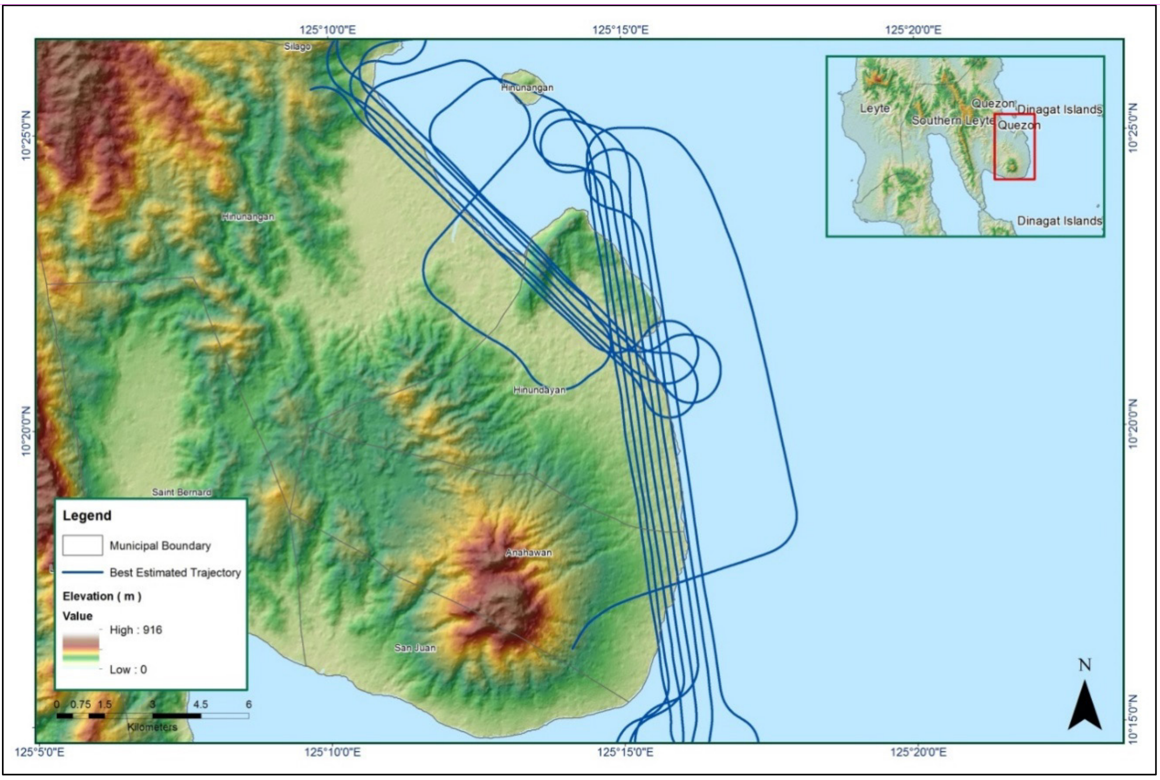


Figure A-8.3 Best Estimated Trajectory

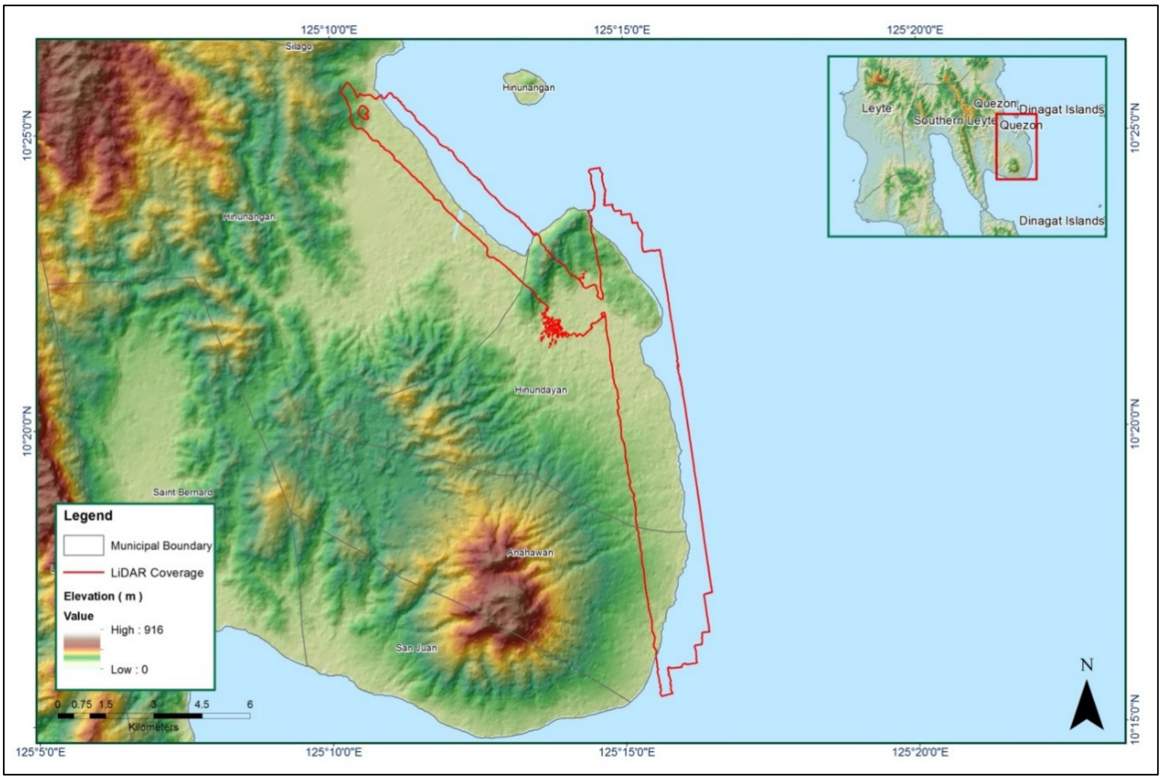


Figure A-8.4 Coverage of LiDAR data

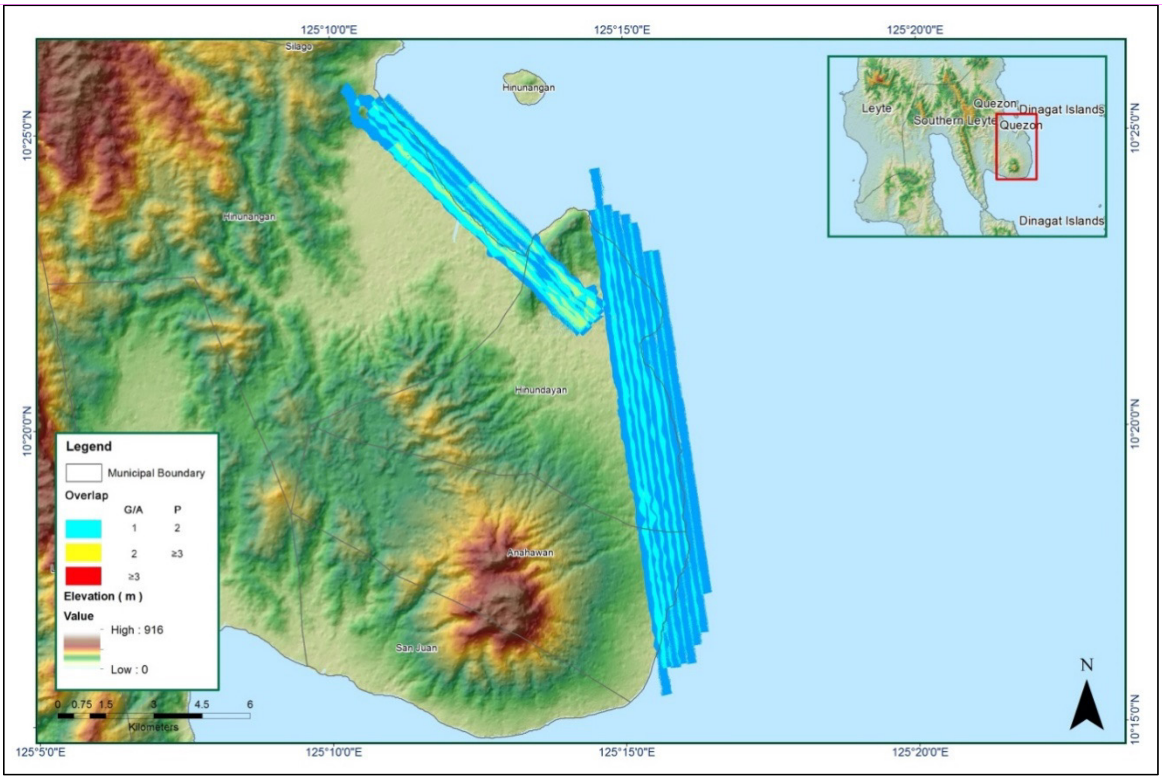


Figure A-8.5 Image of data overlap

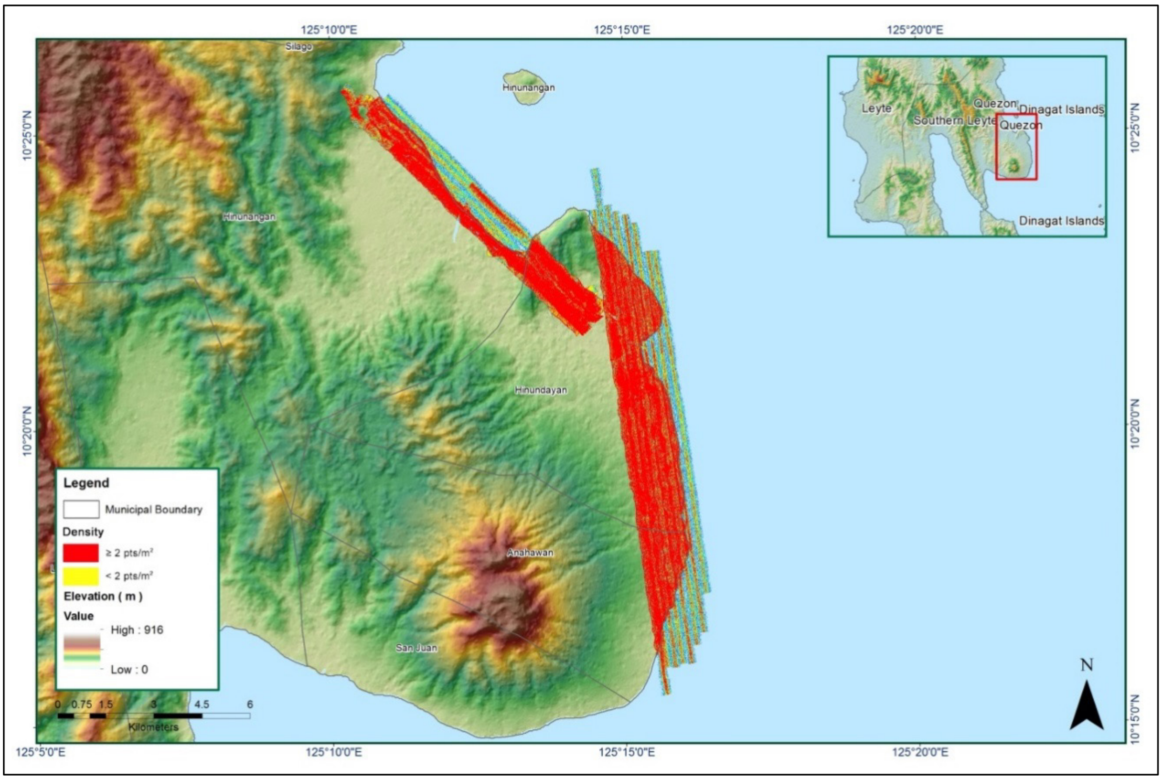


Figure A-8.6 Density map of merged LiDAR data

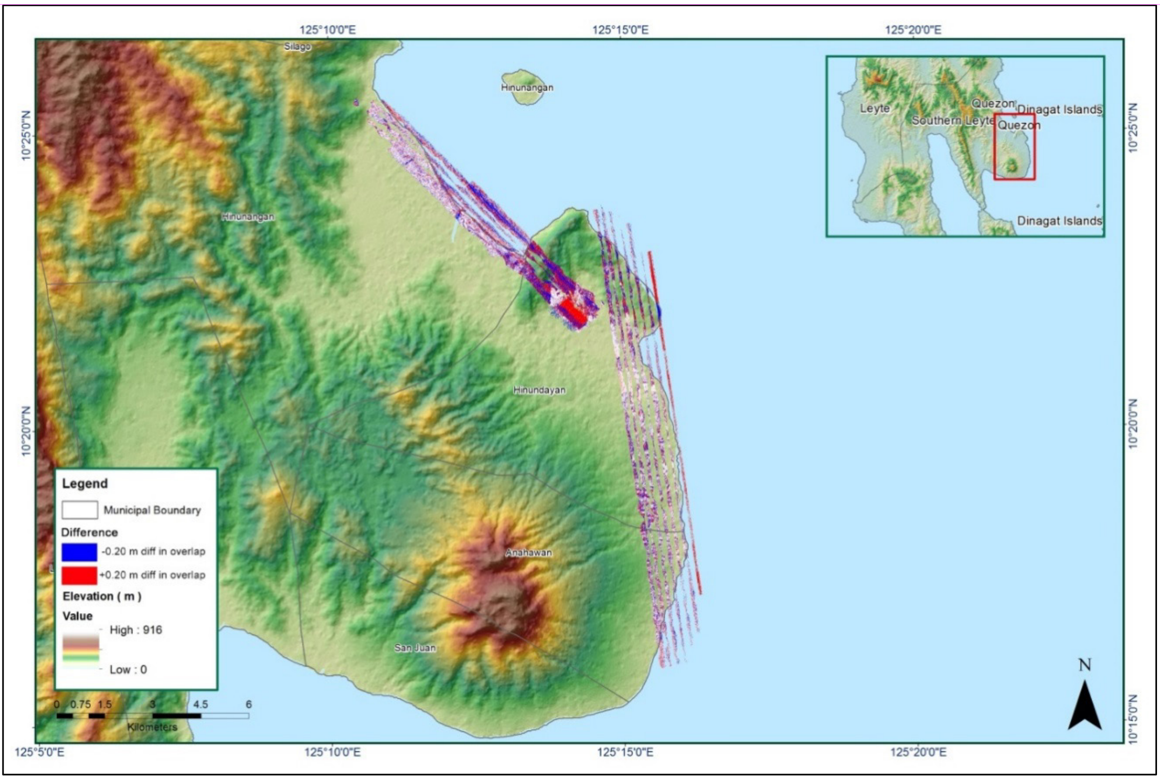


Figure A-8.7 Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Blk50A

Flight Area	Ormoc
Mission Name	Blk50A
Inclusive Flights	7768AC
Range data size	14.7 GB
Base data size	40.2 MB
POS	223 MB
Image	0 GB
Transfer date	March 9 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.08
RMSE for East Position (<4.0 cm)	2.06
RMSE for Down Position (<8.0 cm)	2.33
Boresight correction stdev (<0.001deg)	0.000342
IMU attitude correction stdev (<0.001deg)	0.002225
GPS position stdev (<0.01m)	0.0084
Minimum % overlap (>25)	34.73
Ave point cloud density per sq.m. (>2.0)	2.68
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	73
Maximum Height	406.80 m
Minimum Height	62.16 m
Classification (# of points)	
Ground	17,712,630
Low vegetation	20,911,484
Medium vegetation	26,276,877
High vegetation	42,992,937
Building	854,245
Orthophoto	No
Processed by	Engr. Analyn Naldo, Engr. Velina Angela Bemida, Engr. Jeffrey Delica

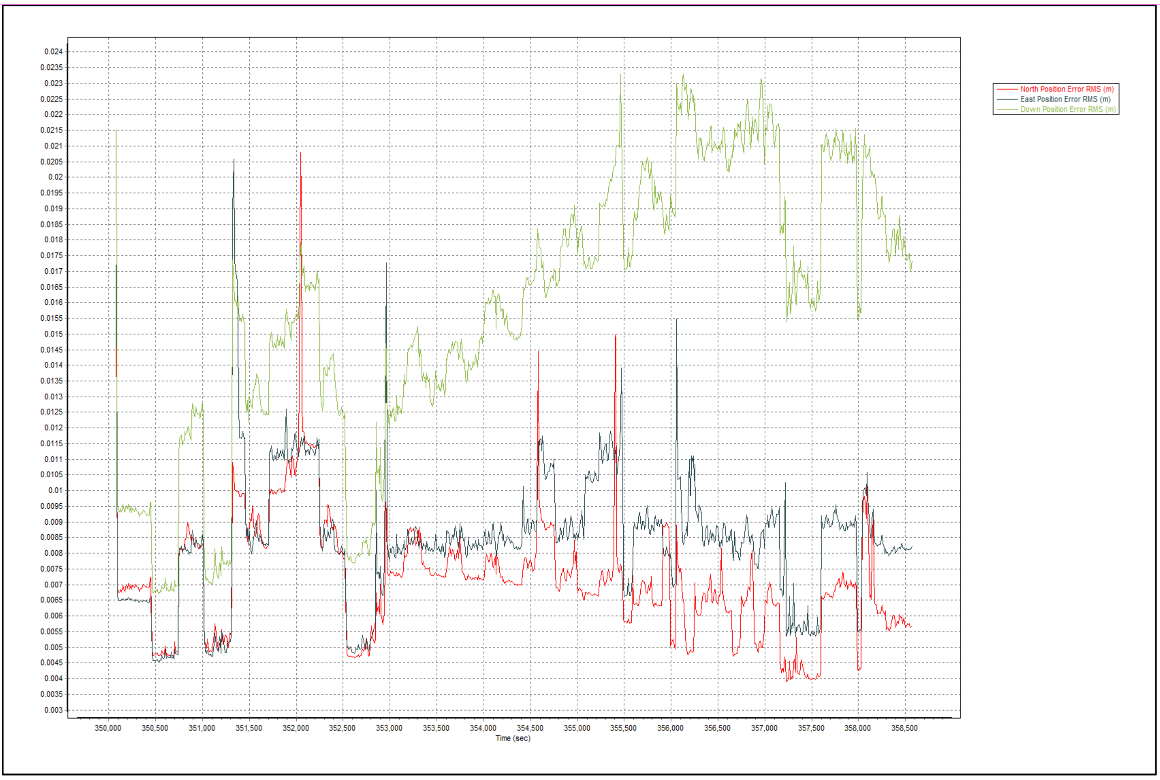


Figure A-8.8 Solution Status

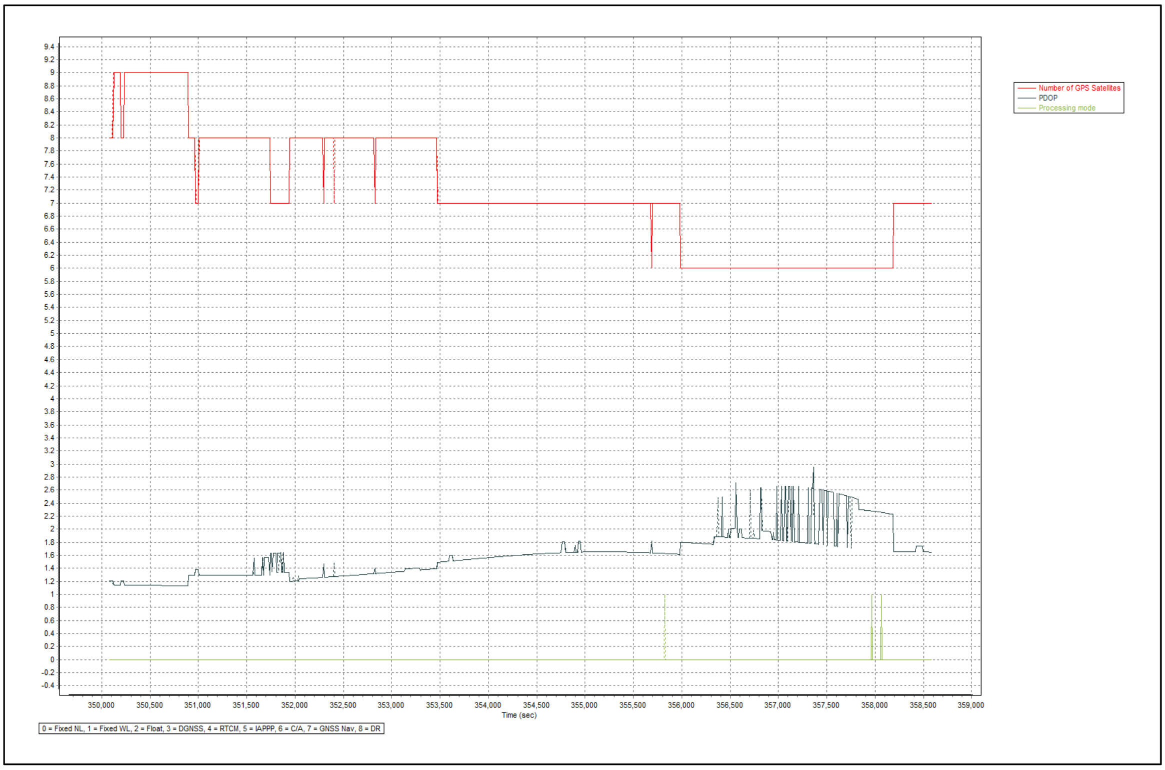


Figure A-8.9 Smoothed Performance Metric Parameters

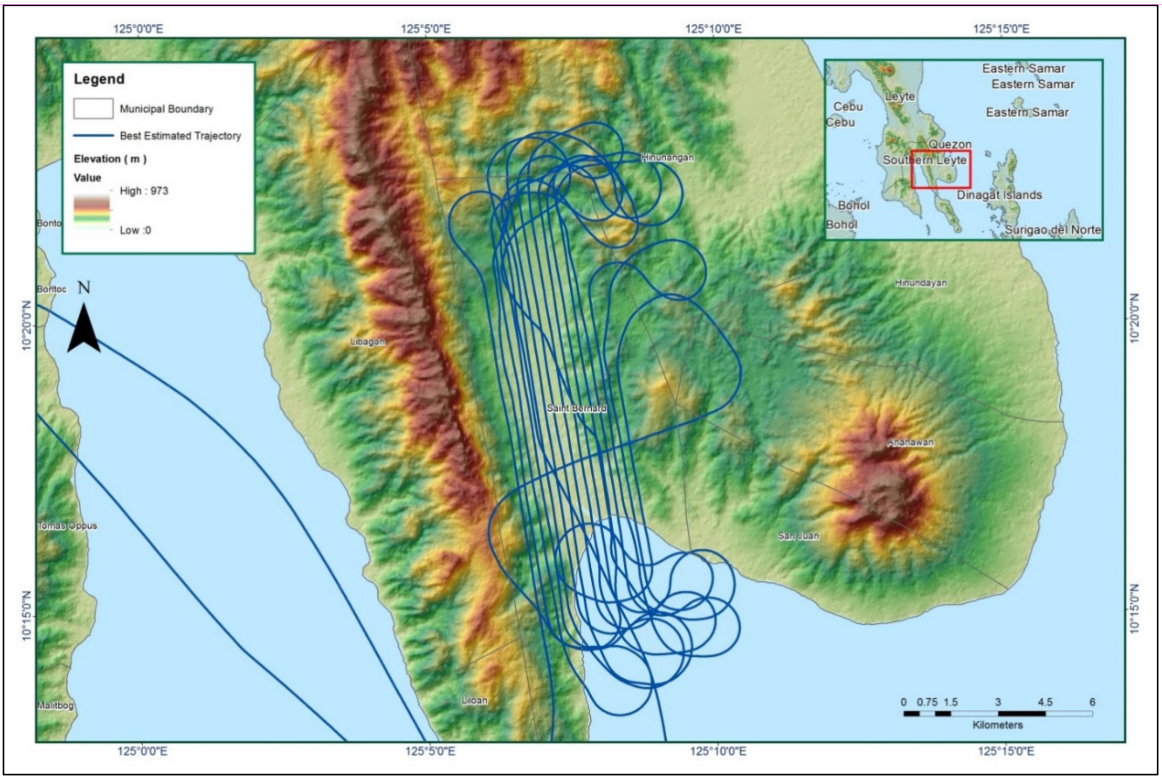


Figure A-8.10 Best Estimated Trajectory

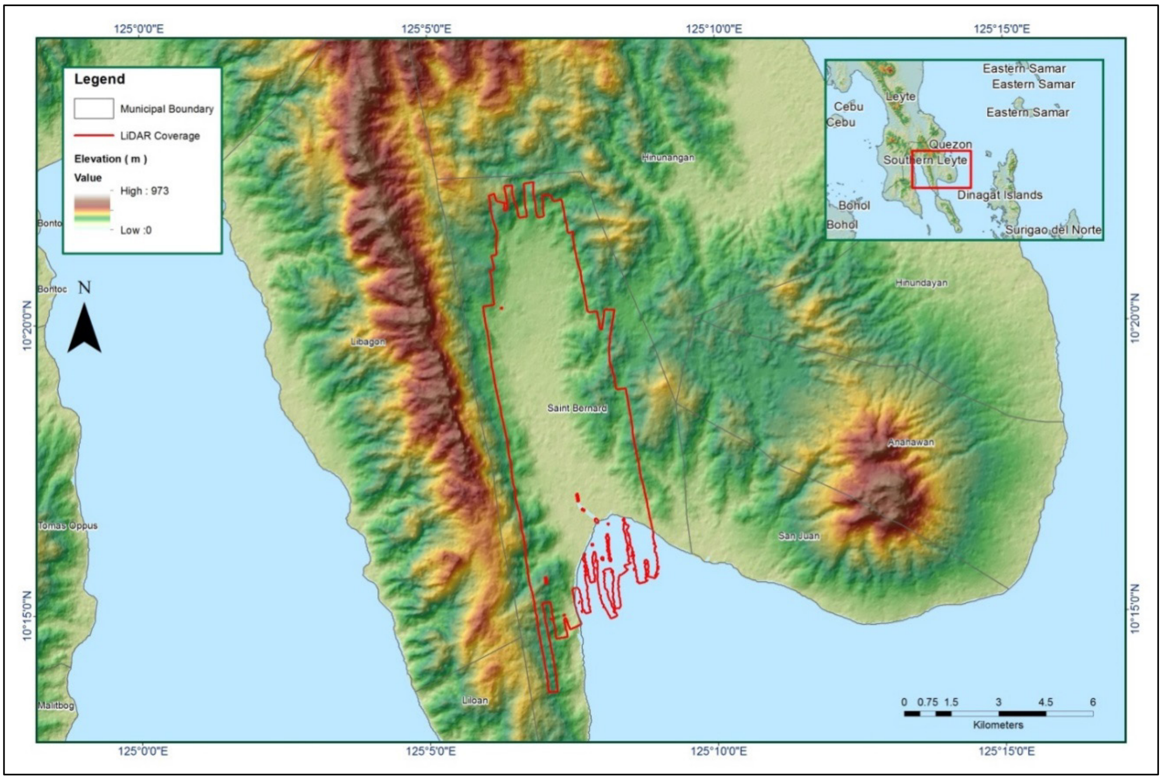


Figure A-8.11 Coverage of LiDAR data

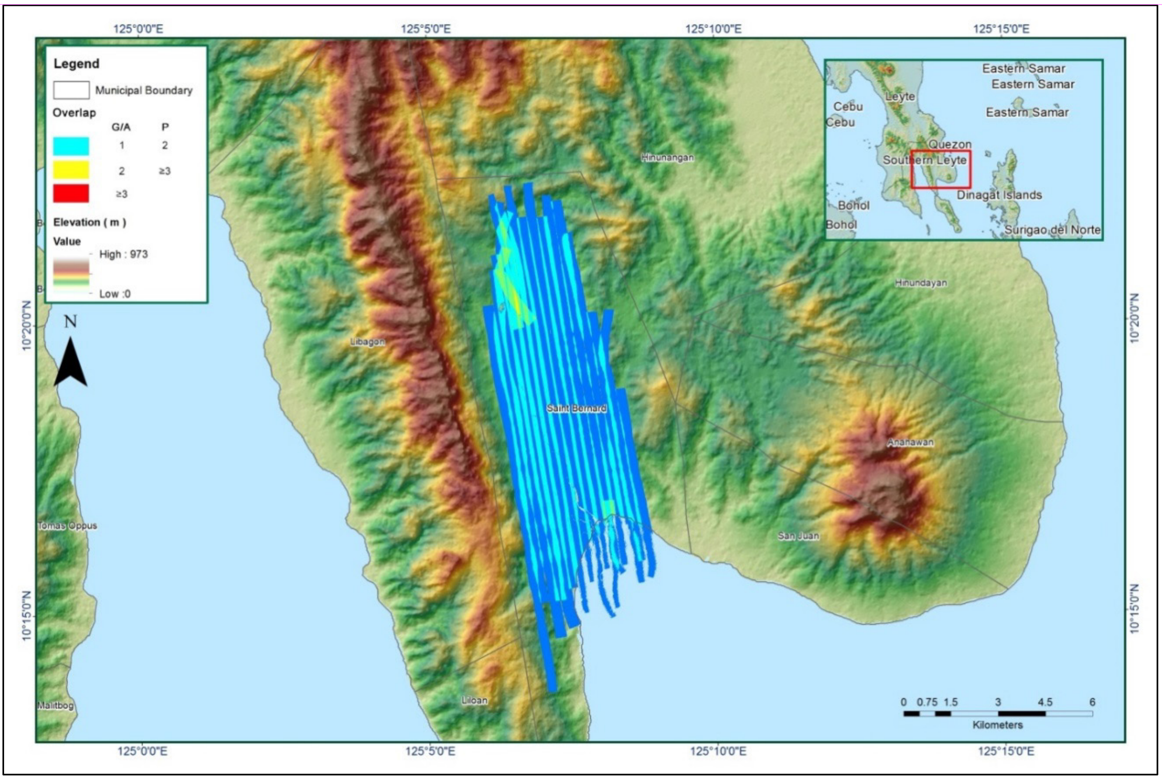


Figure A-8.12 Image of data overlap

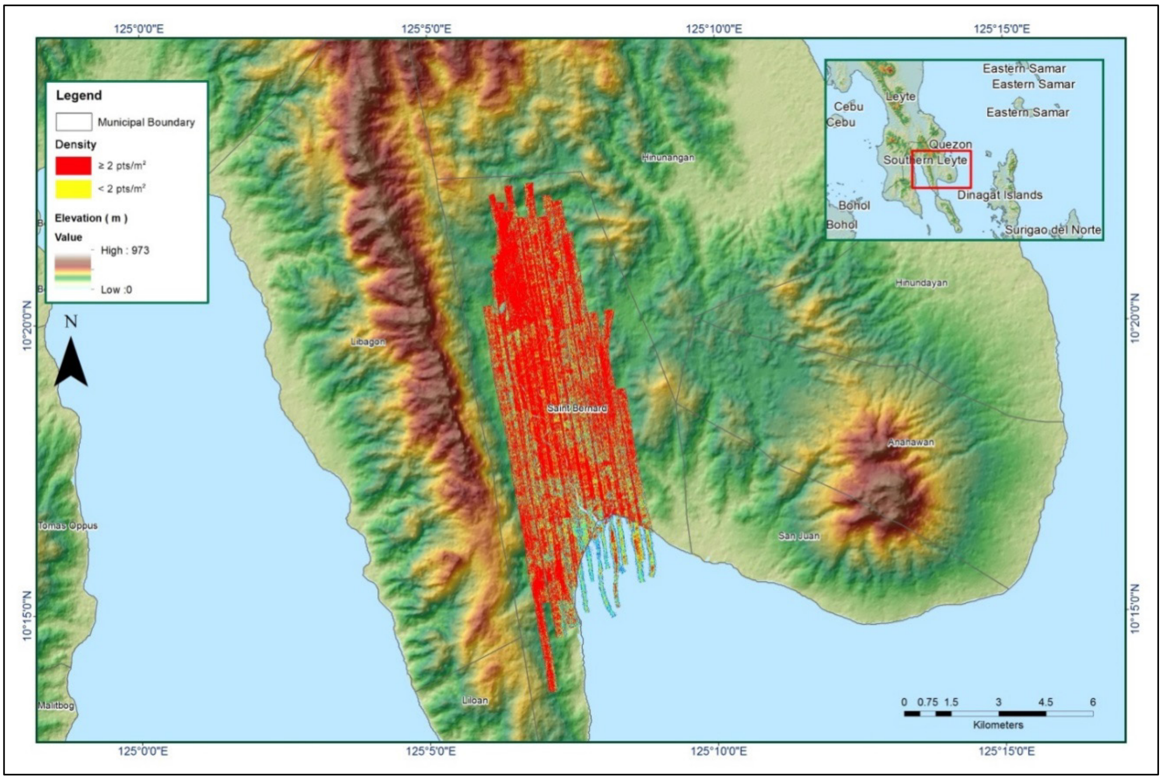


Figure A-8.13 Density map of merged LiDAR data

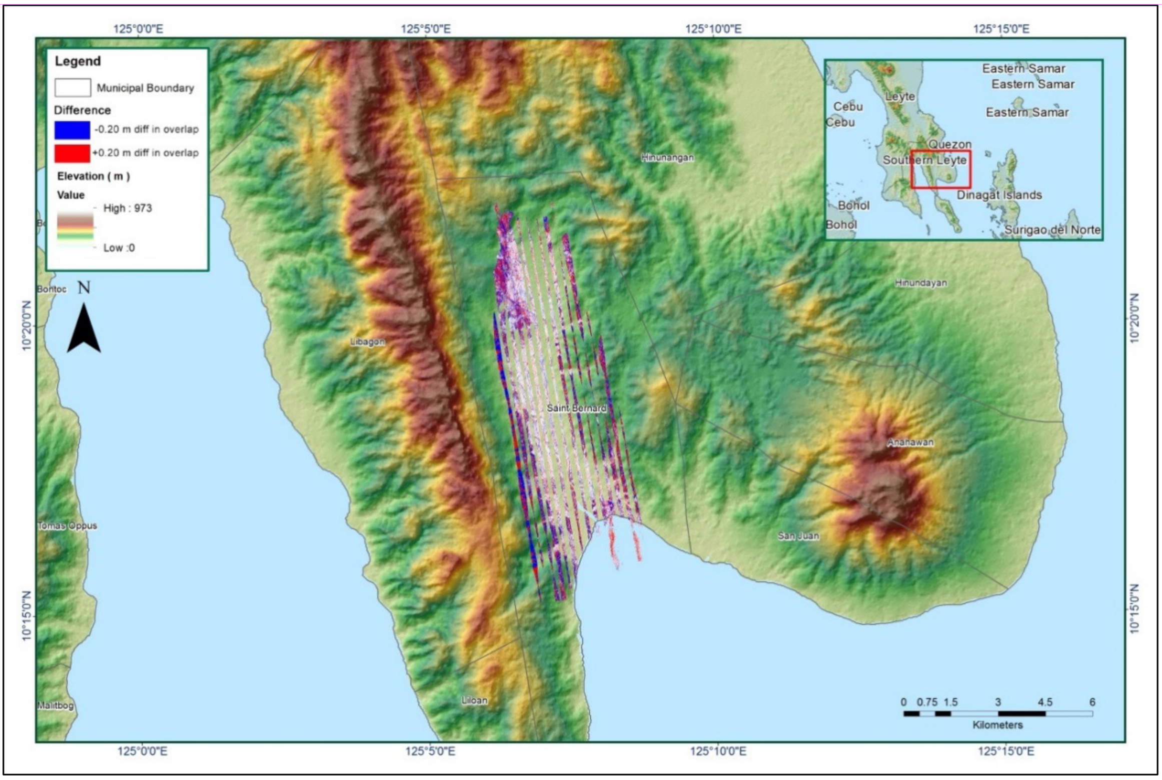


Figure A-8.14 Elevation difference between flight lines

Table A-8.3. Mission Summary Report for Mission Blk50B

Flight Area	Ormoc
Mission Name	Blk50B
Inclusive Flights	7790AC
Range data size	5.67 GB
Base data size	14.8 MB
POS	225 MB
Image	0 GB
Transfer date	March 9 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.12
RMSE for East Position (<4.0 cm)	1.08
RMSE for Down Position (<8.0 cm)	2.55
Boresight correction stdev (<0.001deg)	0.000368
IMU attitude correction stdev (<0.001deg)	0.000981
GPS position stdev (<0.01m)	0.0113
Minimum % overlap (>25)	33.37
Ave point cloud density per sq.m. (>2.0)	2.88
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	62
Maximum Height	368.94 m
Minimum Height	62.60 m
Classification (# of points)	
Ground	19,739,740
Low vegetation	23,293,344
Medium vegetation	18,774,718
High vegetation	25,687,408
Building	1,048,527
Orthophoto	No
Processed by	Engr. Jennifer Saguran, Engr. Chelou Prado, Kathryn Claudyn Zarate

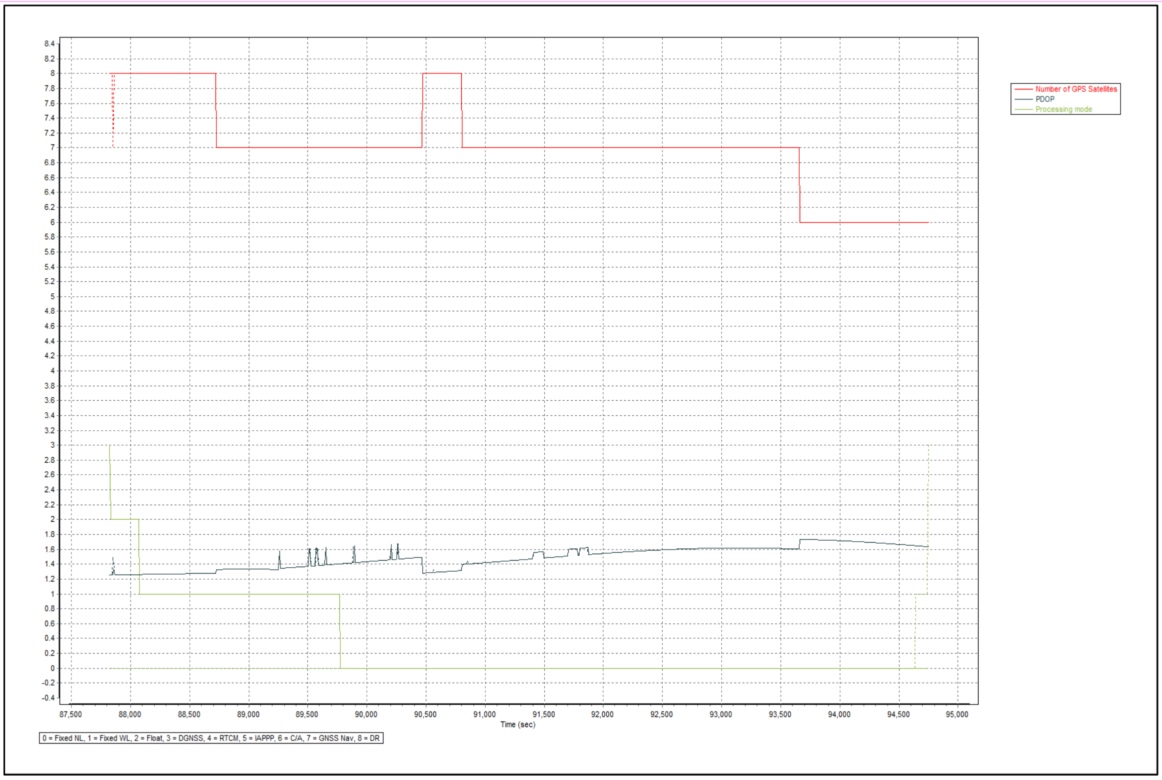


Figure A-8.15 Solution Status

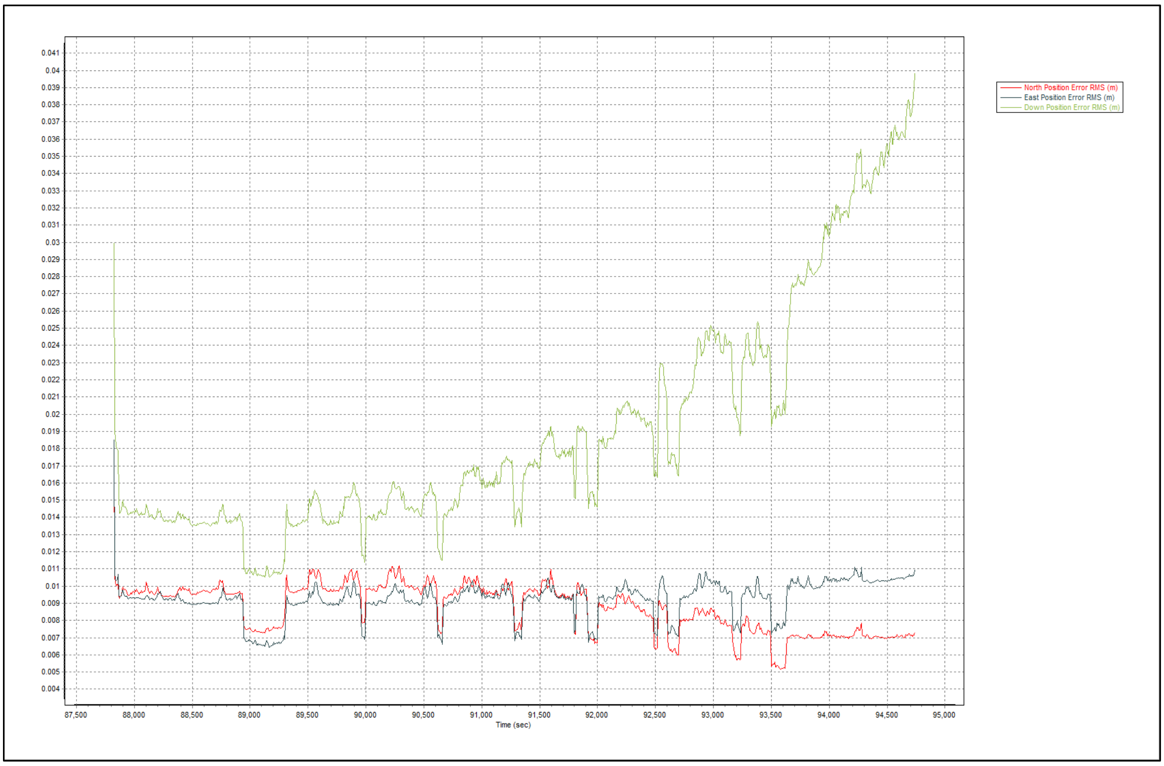


Figure A-8.16 Smoothed Performance Metric Parameters

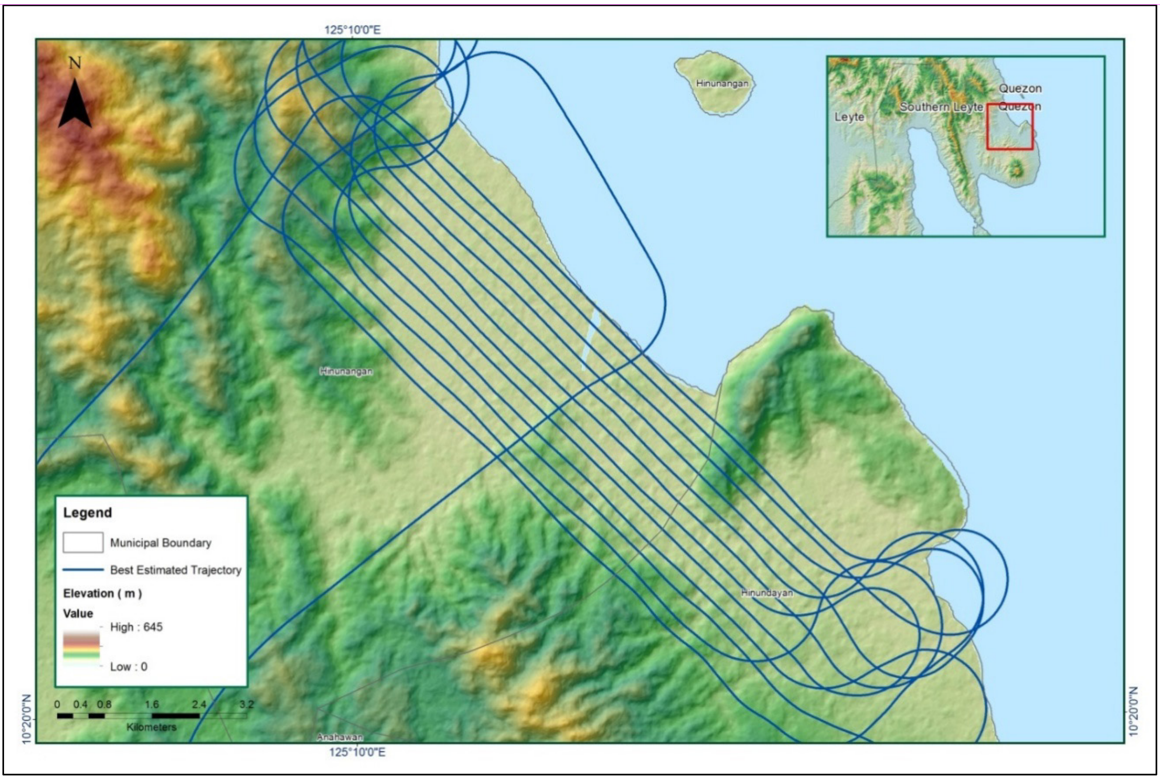


Figure A-8.17 Best Estimated Trajectory

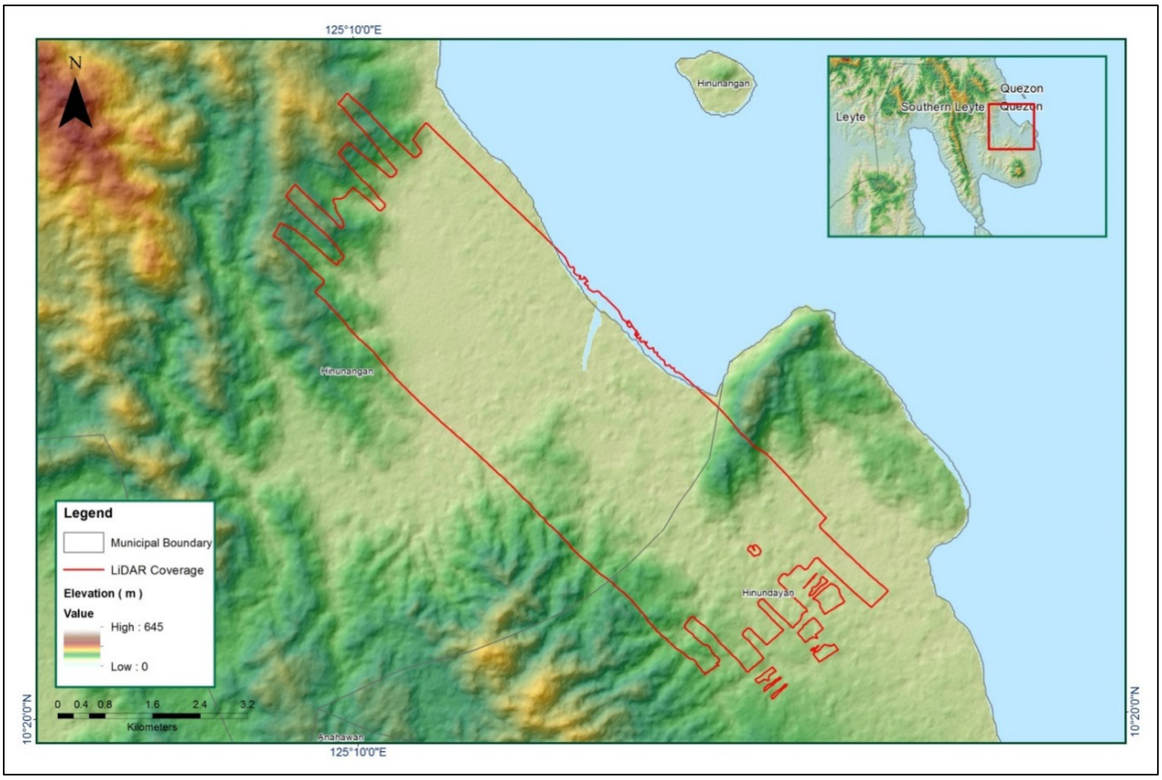


Figure A-8.18 Coverage of LiDAR data

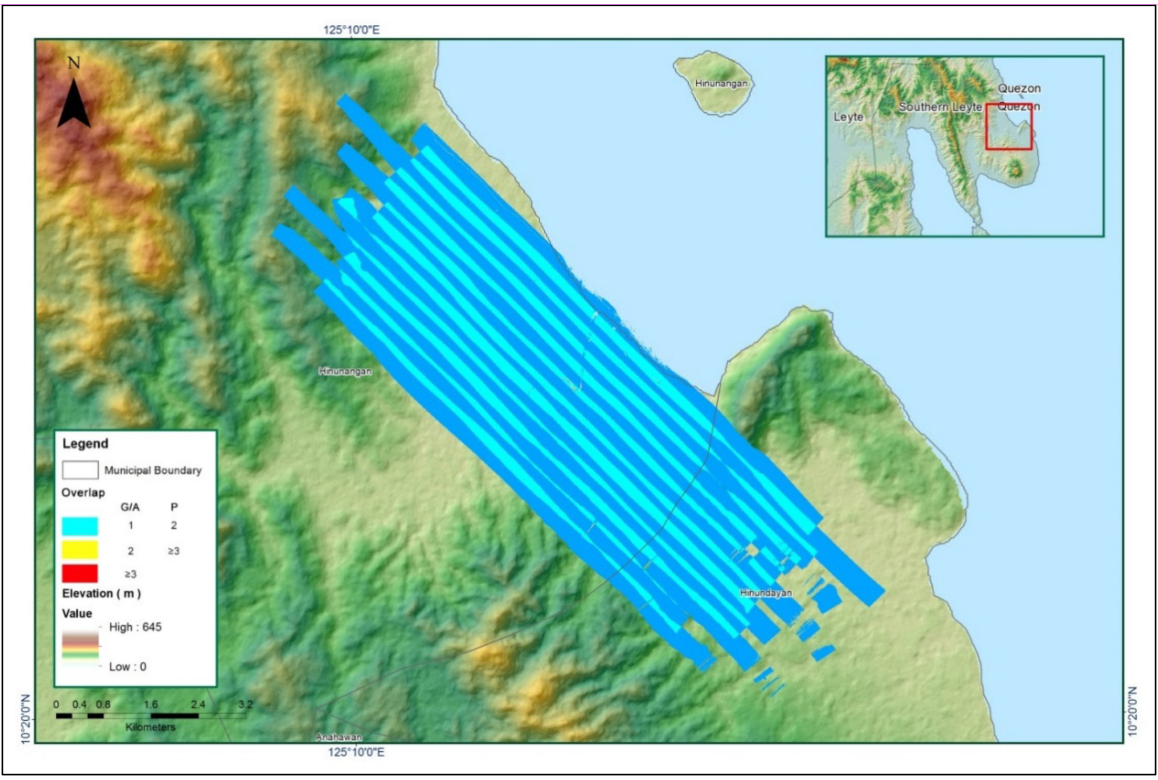


Figure A-8.19 Image of data overlap

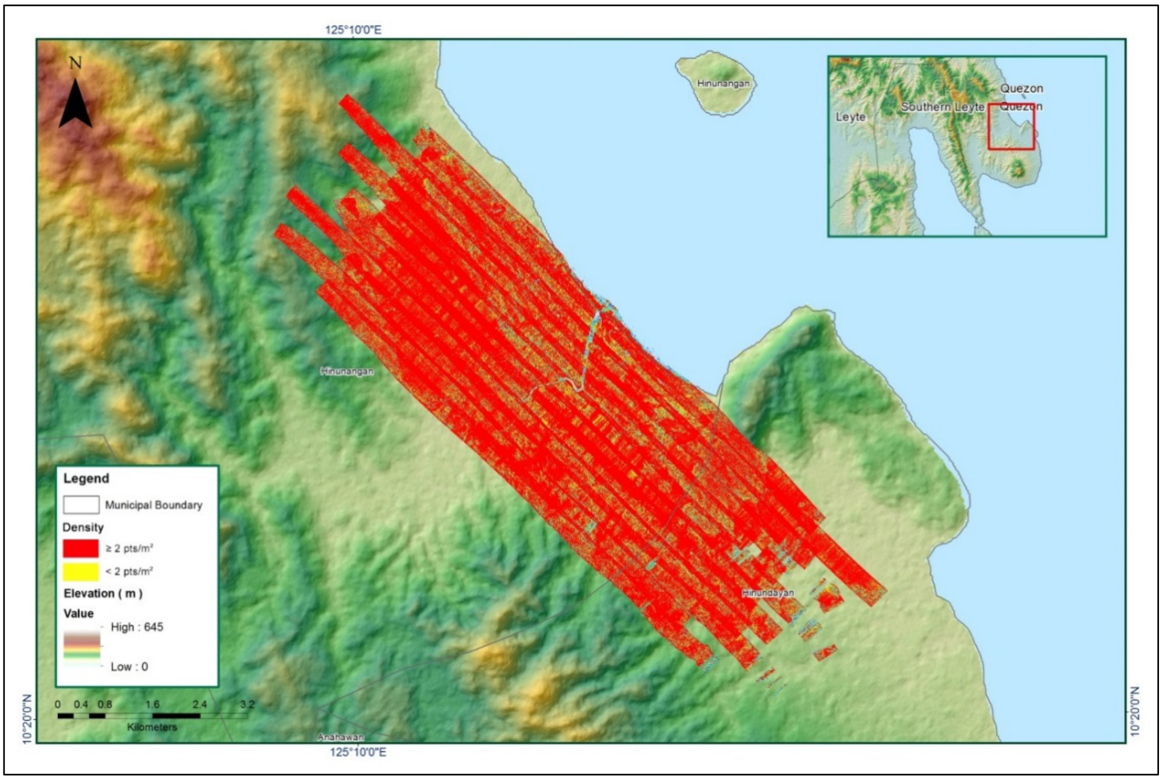


Figure A-8.20 Density map of merged LiDAR data

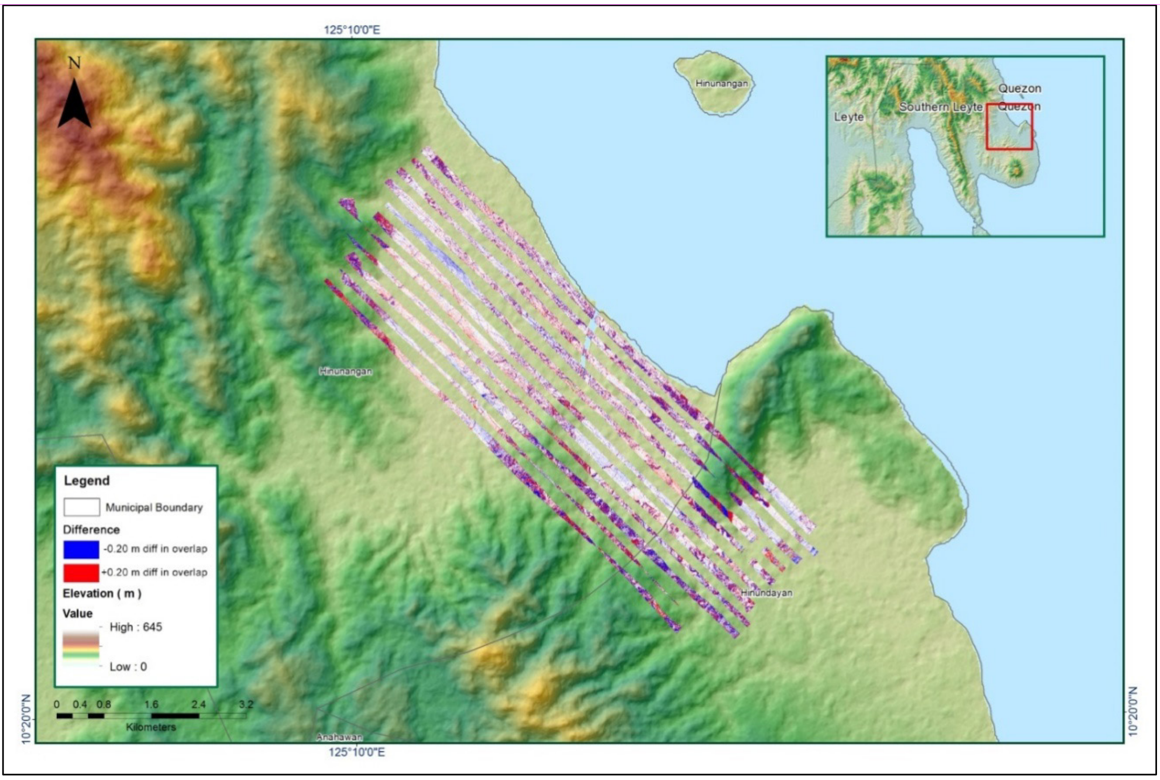


Figure A-8.21 Elevation difference between flight lines

Table A-8.4. Mission Summary Report for Mission Blk50B

Flight Area	Ormoc South
Mission Name	Blk50B
Inclusive Flights	3933G
Range data size	16.2 GB
Base data size	17.4 MB
POS	262 MB
Image	NA
Transfer date	May 6, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.62
RMSE for East Position (<4.0 cm)	1.51
RMSE for Down Position (<8.0 cm)	6.30
Boresight correction stdev (<0.001deg)	NA
IMU attitude correction stdev (<0.001deg)	NA
GPS position stdev (<0.01m)	NA
Minimum % overlap (>25)	28.05
Ave point cloud density per sq.m. (>2.0)	4.99
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	48
Maximum Height	481.72 m
Minimum Height	64.96 m
Classification (# of points)	
Ground	7,677,377
Low vegetation	6,145,895
Medium vegetation	27,186,958
High vegetation	71,682,323
Building	531,696
Orthophoto	No
Processed by	Engr. Don Matthew Banatin, Engr. Melanie Hingpit, Jovy Narisma

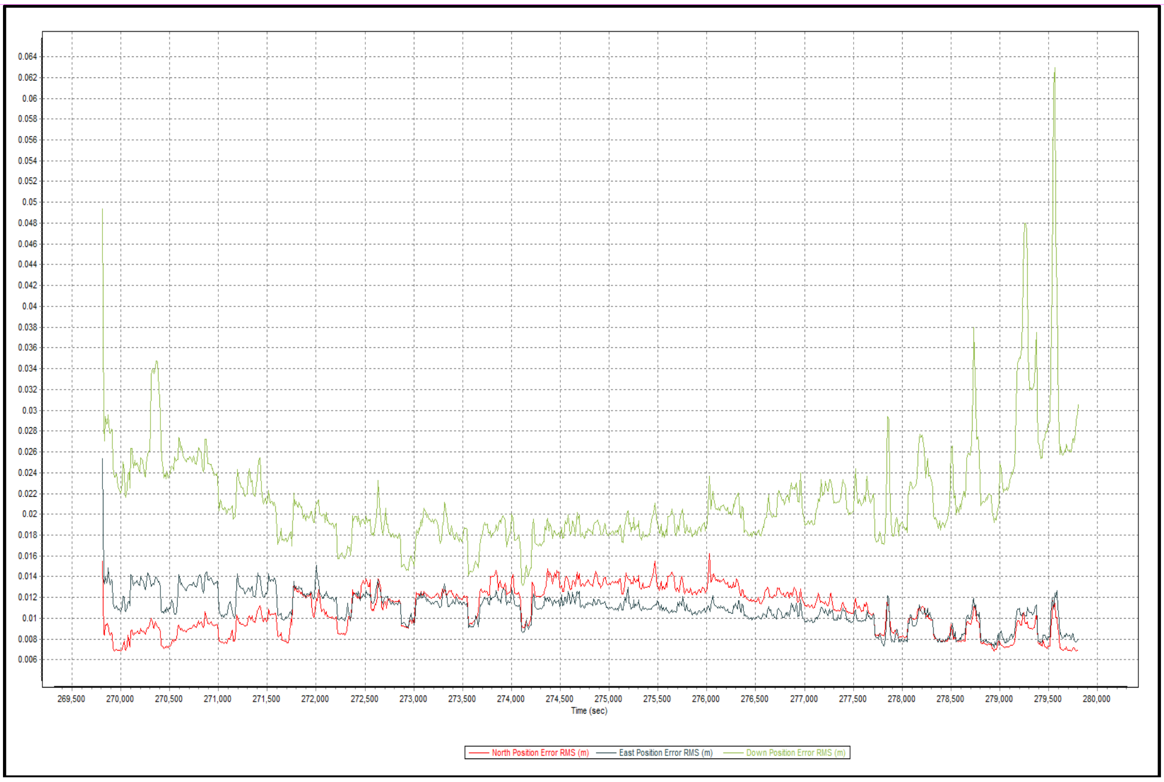


Figure A-8.22 Solution Status

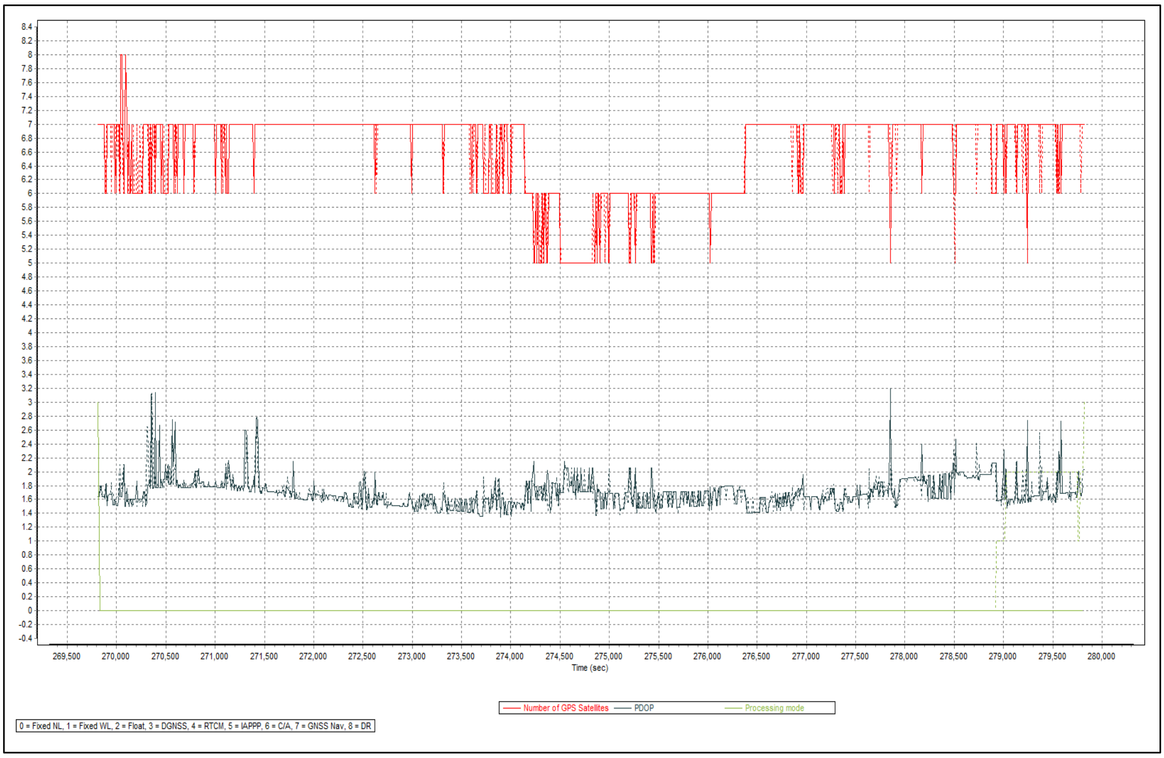


Figure A-8.23 Smoothed Performance Metric Parameters

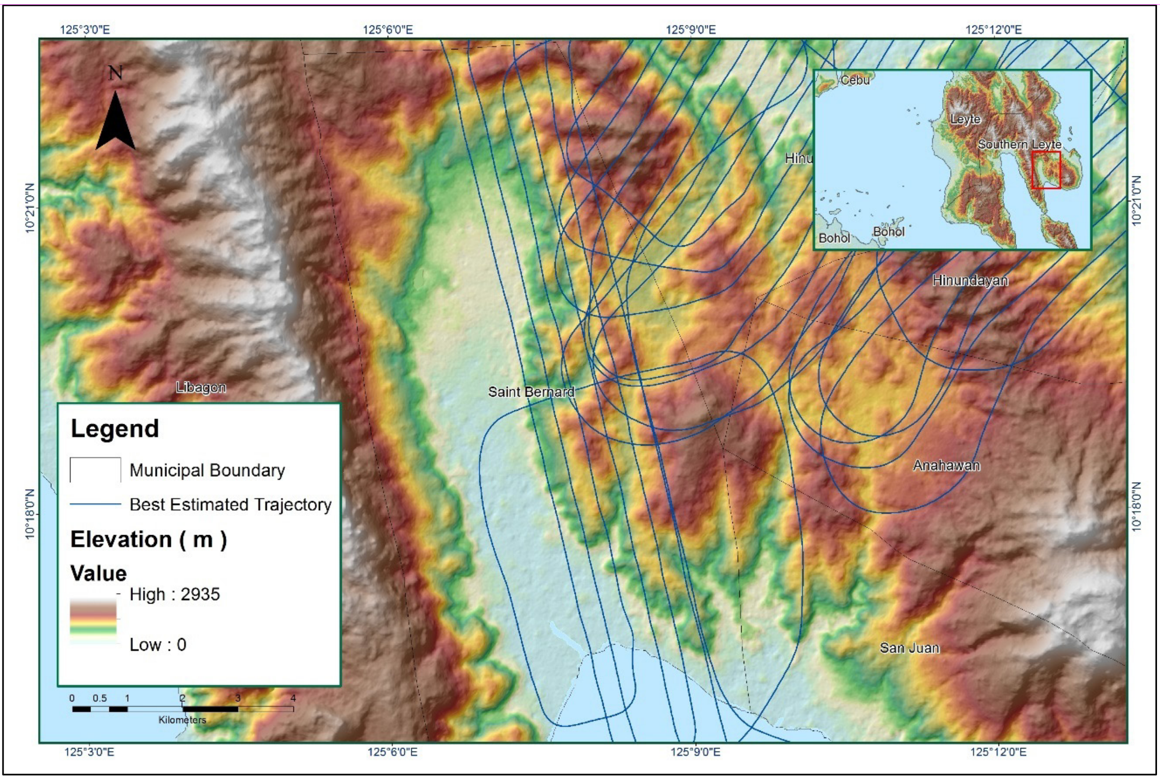


Figure A-8.24 Best Estimated Trajectory

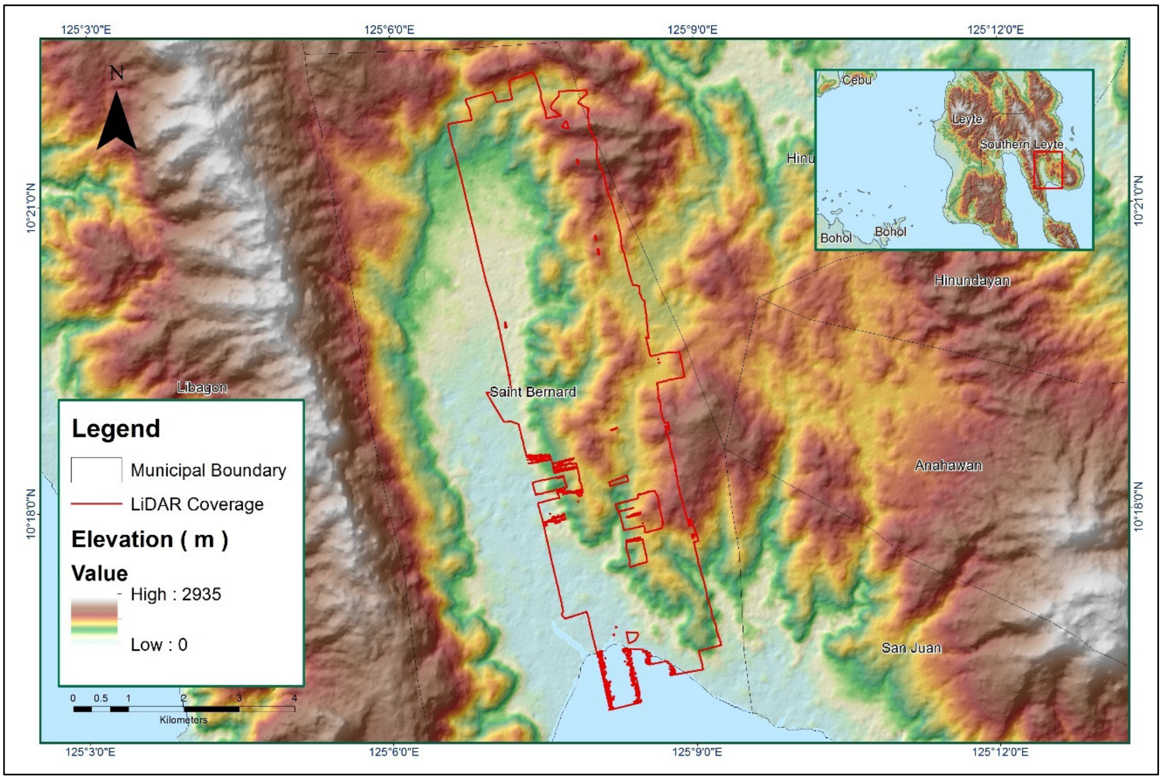


Figure A-8.25 Coverage of LiDAR data

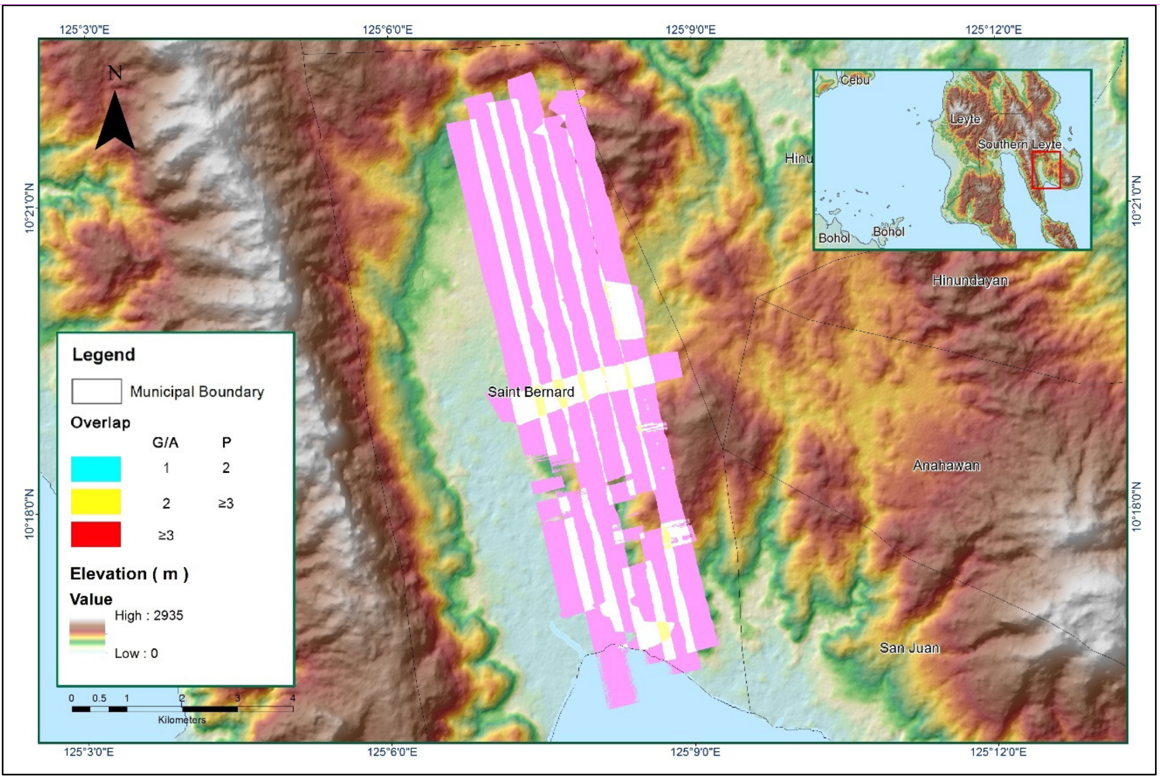


Figure A-8.26 Image of data overlap

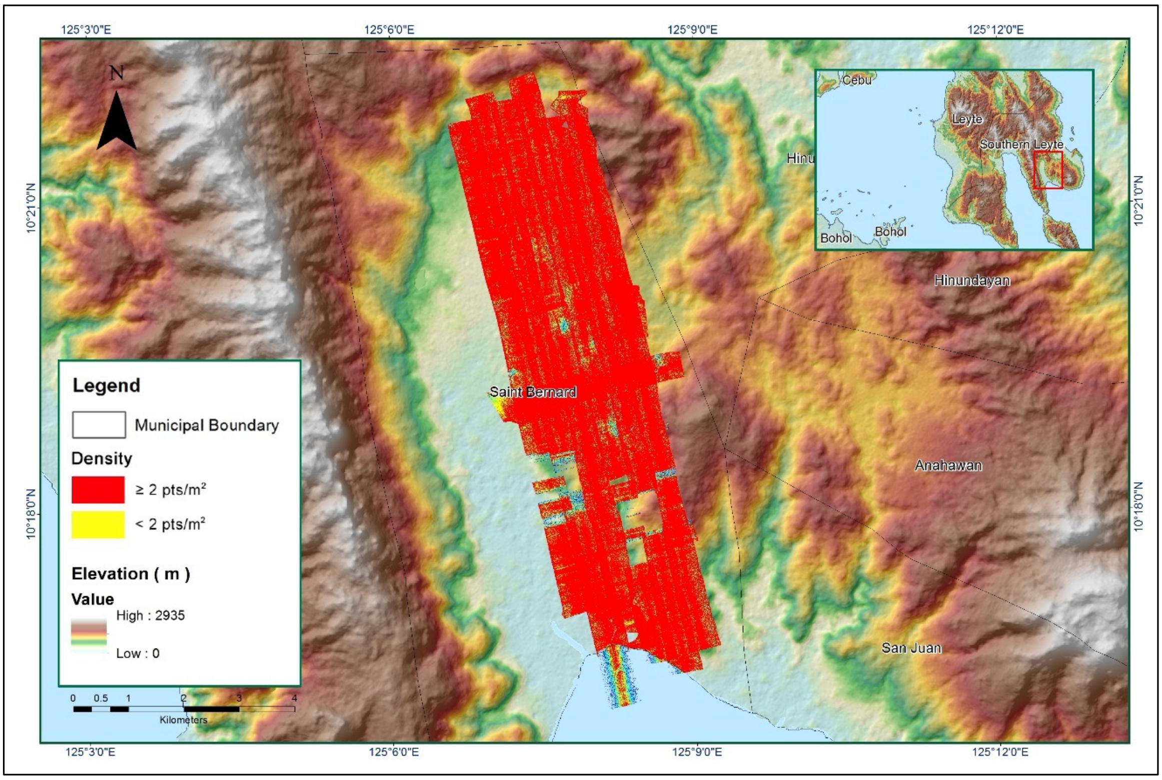


Figure A-8.27 Density map of merged LiDAR data

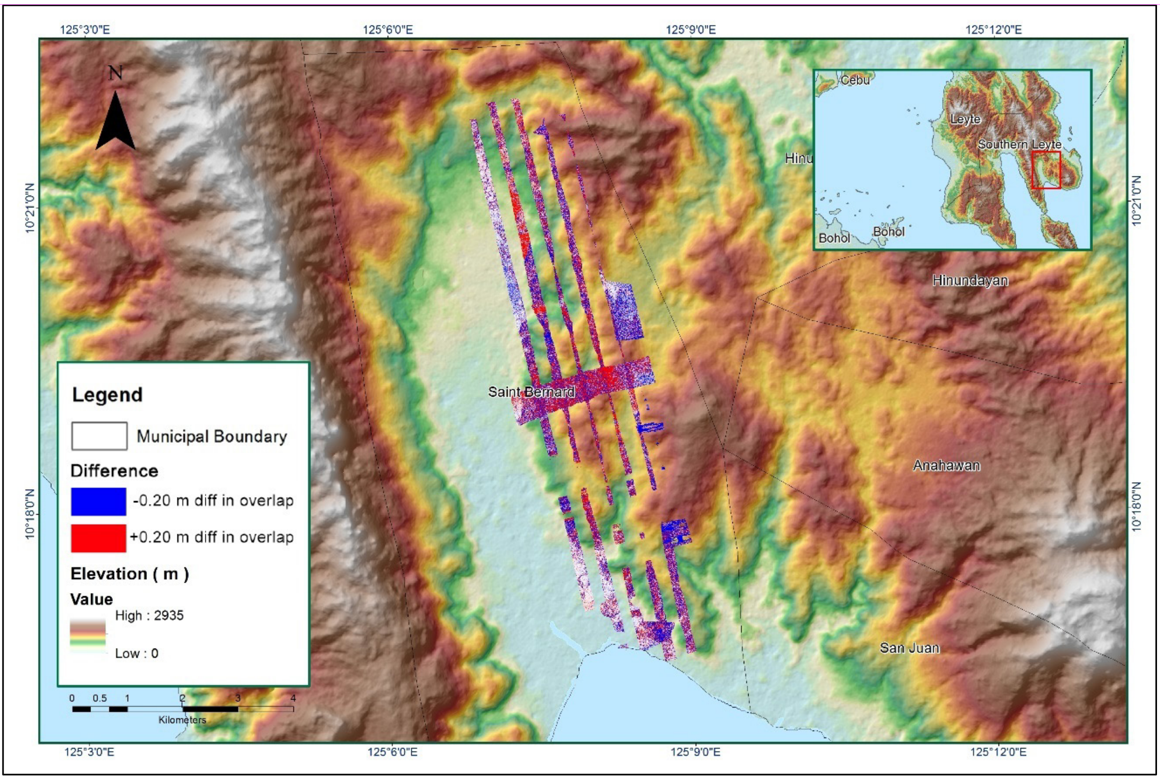


Figure A-8.28 Elevation difference between flight lines

Table A-8.5. Mission Summary Report for Mission Blk50A

Flight Area	Ormoc South
Mission Name	Blk50A
Inclusive Flights	3933G
Range data size	16.2 GB
Base data size	17.4 MB
POS	262MB
Image	NA
Transfer date	May 6, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.62
RMSE for East Position (<4.0 cm)	1.51
RMSE for Down Position (<8.0 cm)	6.30
Boresight correction stdev (<0.001deg)	NA
IMU attitude correction stdev (<0.001deg)	NA
GPS position stdev (<0.01m)	NA
Minimum % overlap (>25)	39.82
Ave point cloud density per sq.m. (>2.0)	4.68
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	120
Maximum Height	465.92 m
Minimum Height	64.31 m
Classification (# of points)	
Ground	33,306,040
Low vegetation	24,860,972
Medium vegetation	88,168,723
High vegetation	170,549,283
Building	710,545
Orthophoto	No
Processed by	Engr. Don Matthew Banatin, Aljon Rie Araneta, Engr. Vincent Louise Azucena

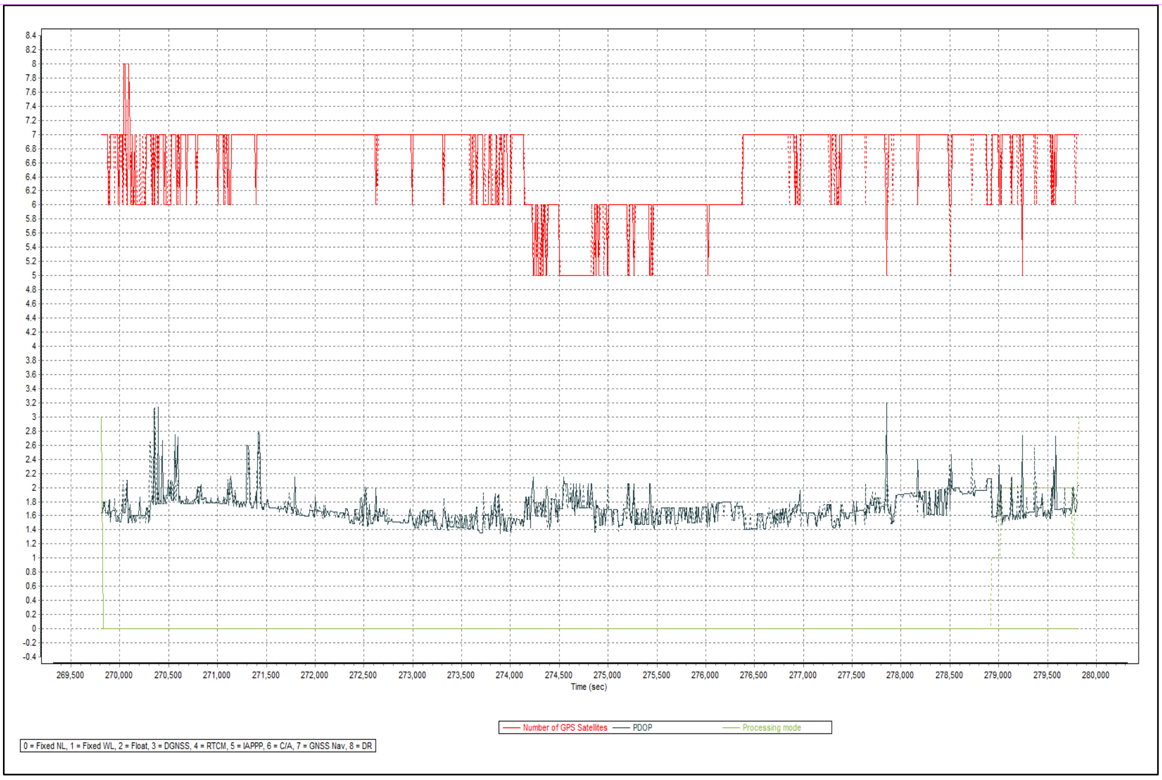


Figure A-8.29 Solution Status

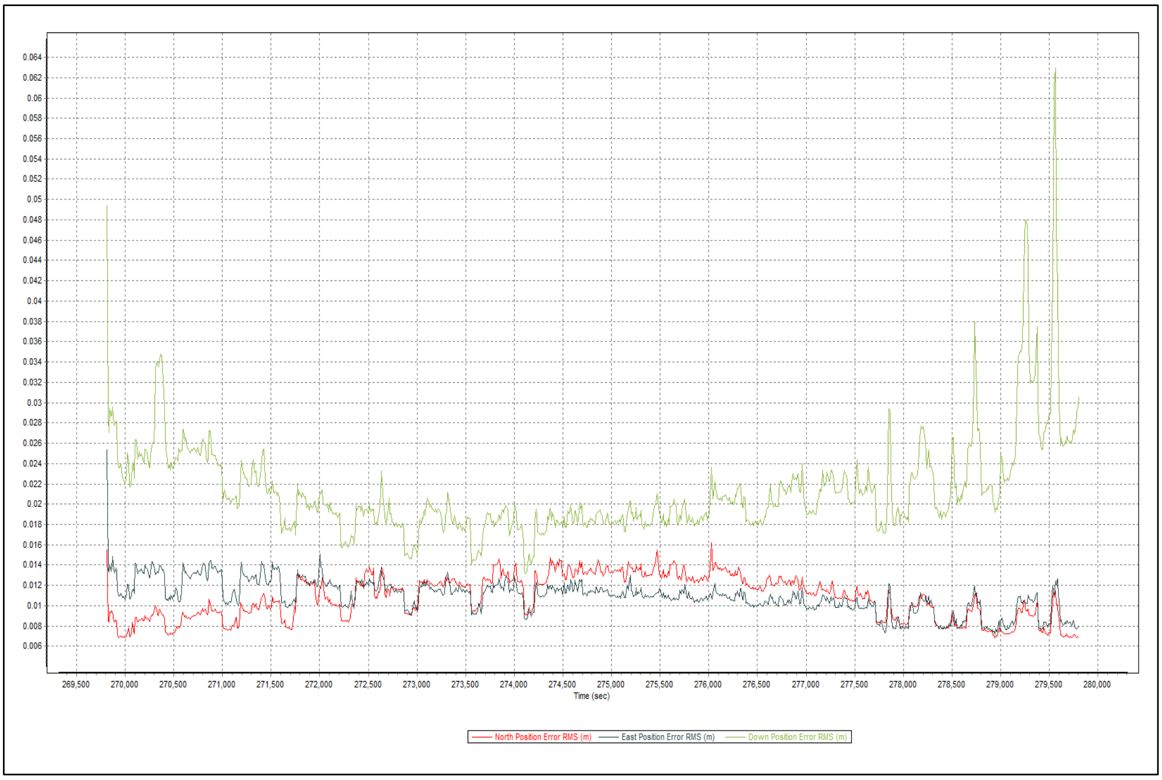


Figure A-8.30 Smoothed Performance Metric Parameters

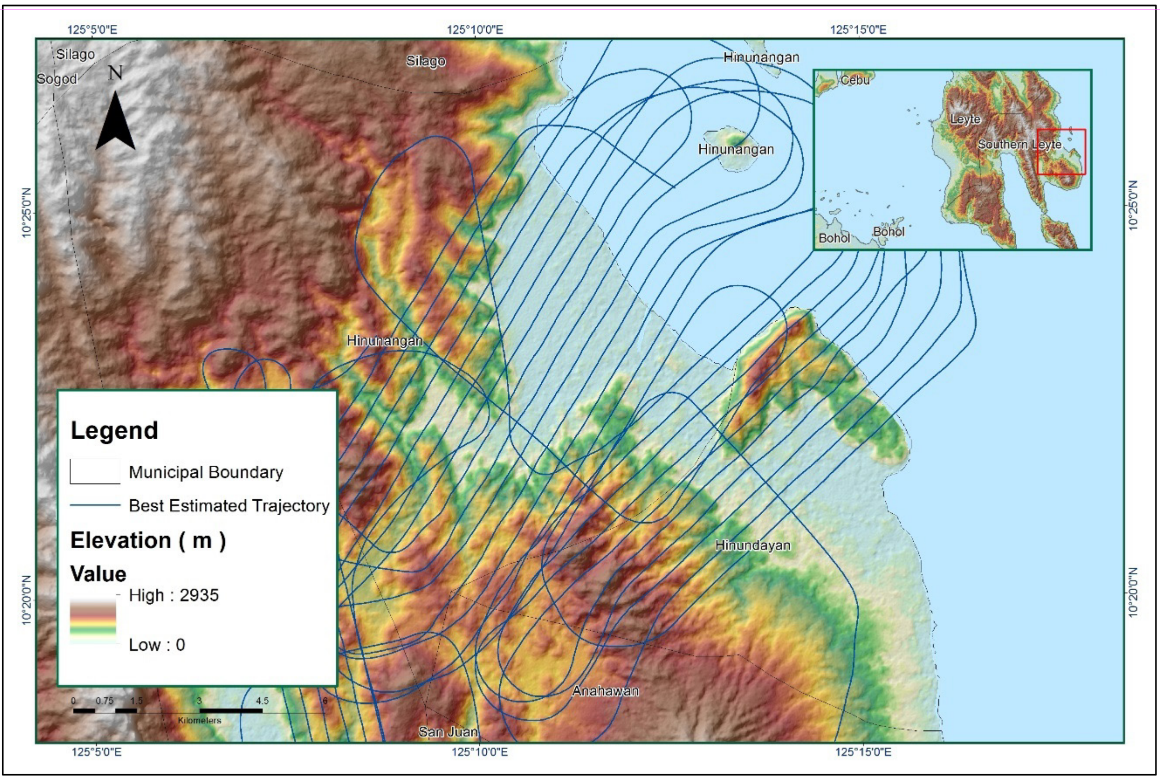


Figure A-8.31 Best Estimated Trajectory

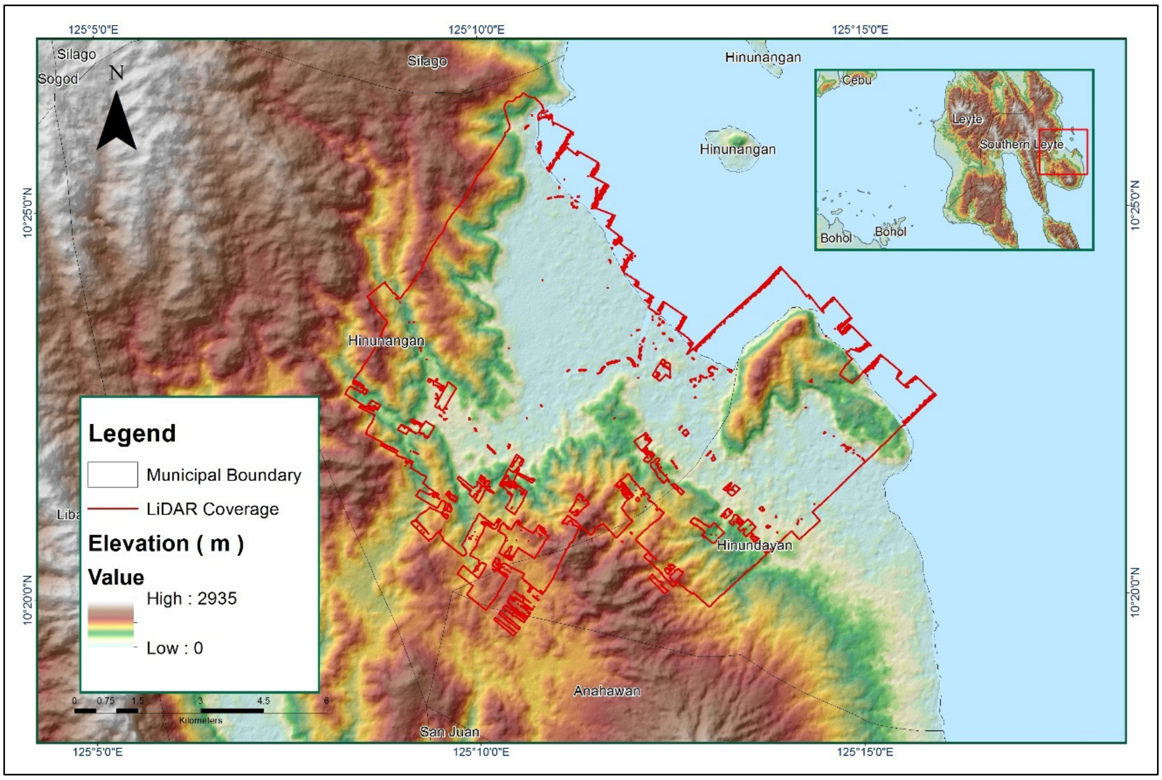


Figure A-8.32 Coverage of LiDAR data

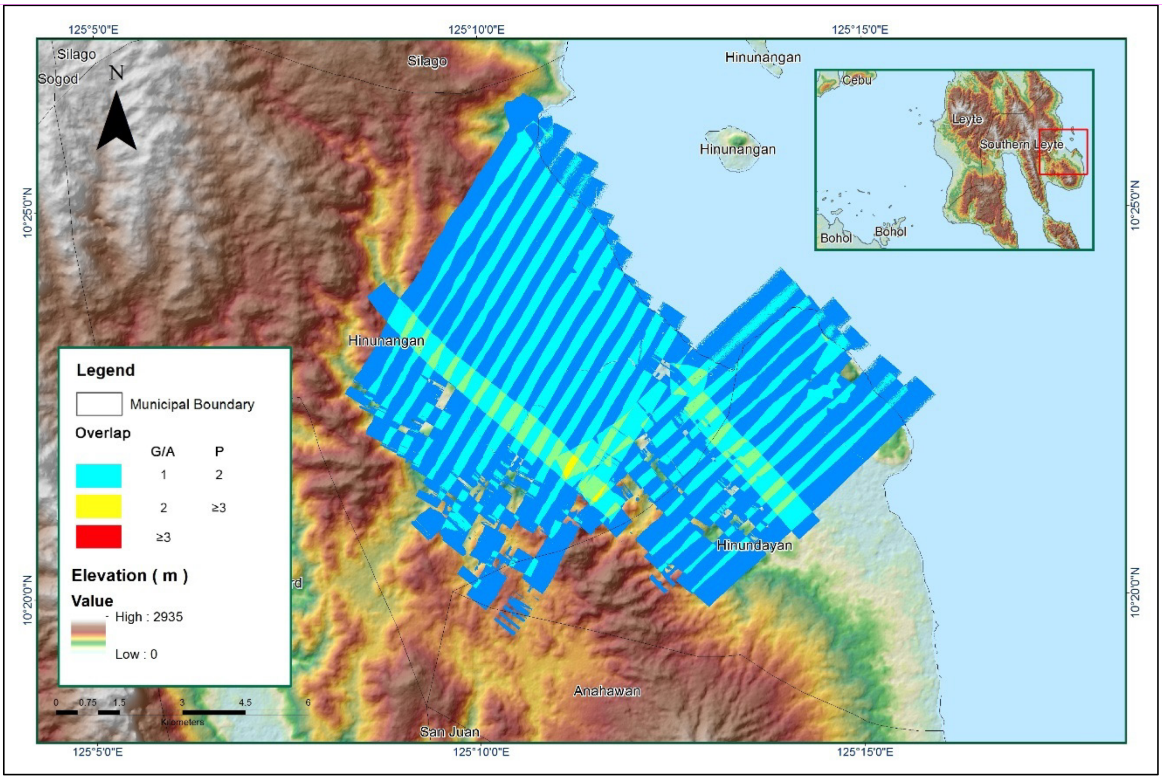


Figure A-8.33 Image of data overlap

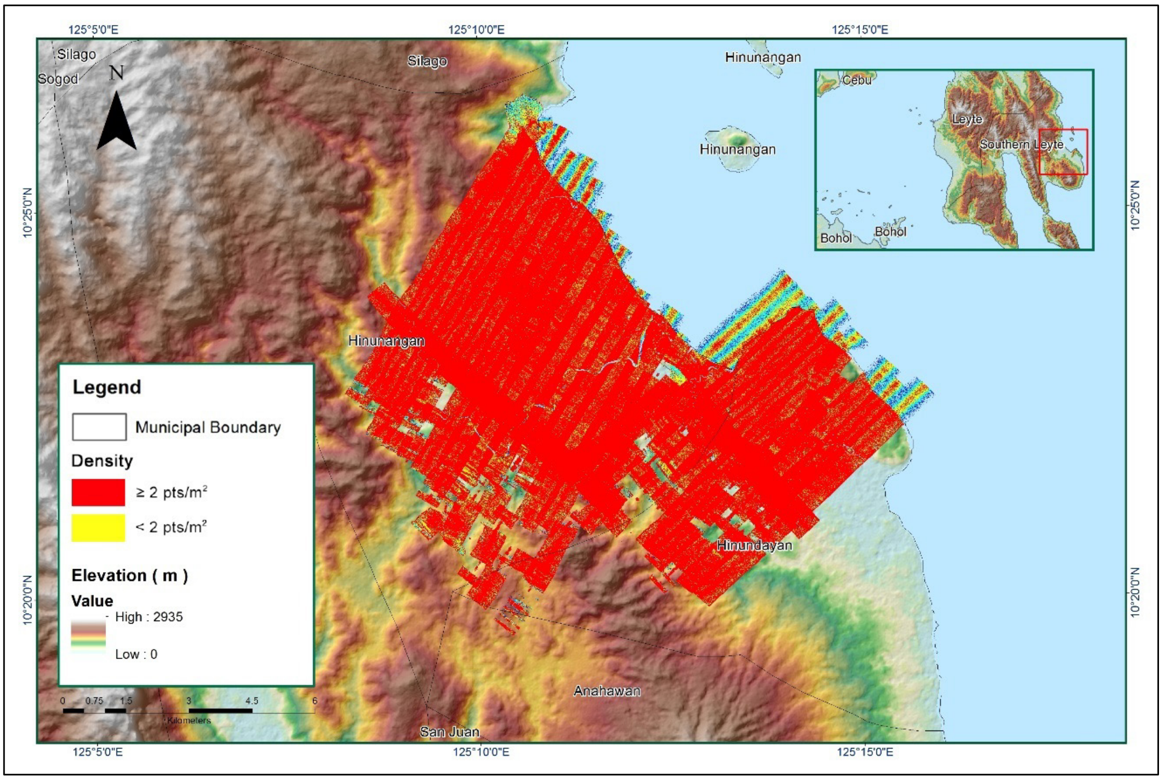


Figure A-8.34 Density map of merged LiDAR data

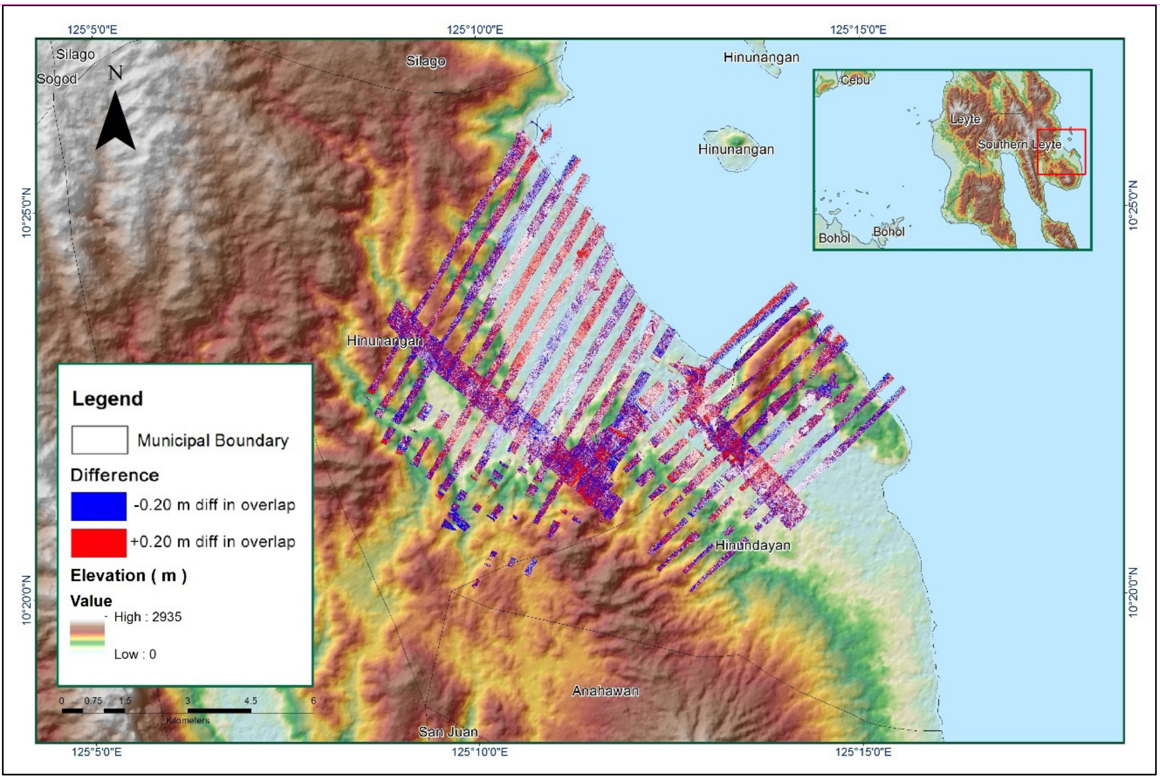


Figure A-8.35 Elevation difference between flight lines

Table A-8.6. Mission Summary Report for Mission Blk50A_supplement

Flight Area	Ormoc South
Mission Name	Blk50A_supplement
Inclusive Flights	3937G
Range data size	14.7 GB
Base data size	10.5 MB
POS	292 MB
Image	NA
Transfer date	May 6, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.16
RMSE for East Position (<4.0 cm)	1.67
RMSE for Down Position (<8.0 cm)	3.44
Boresight correction stdev (<0.001deg)	NA
IMU attitude correction stdev (<0.001deg)	NA
GPS position stdev (<0.01m)	NA
Minimum % overlap (>25)	44.34
Ave point cloud density per sq.m. (>2.0)	5.85
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	70
Maximum Height	727.15 m
Minimum Height	64.83 m
Classification (# of points)	
Ground	10,620,264
Low vegetation	10,416,379
Medium vegetation	39,315,009
High vegetation	105,254,391
Building	482,518
Orthophoto	No
Processed by	Engr. Don Matthew Banatin, Engr. Ma Joanne Balaga, Engr. Melissa Fernandez

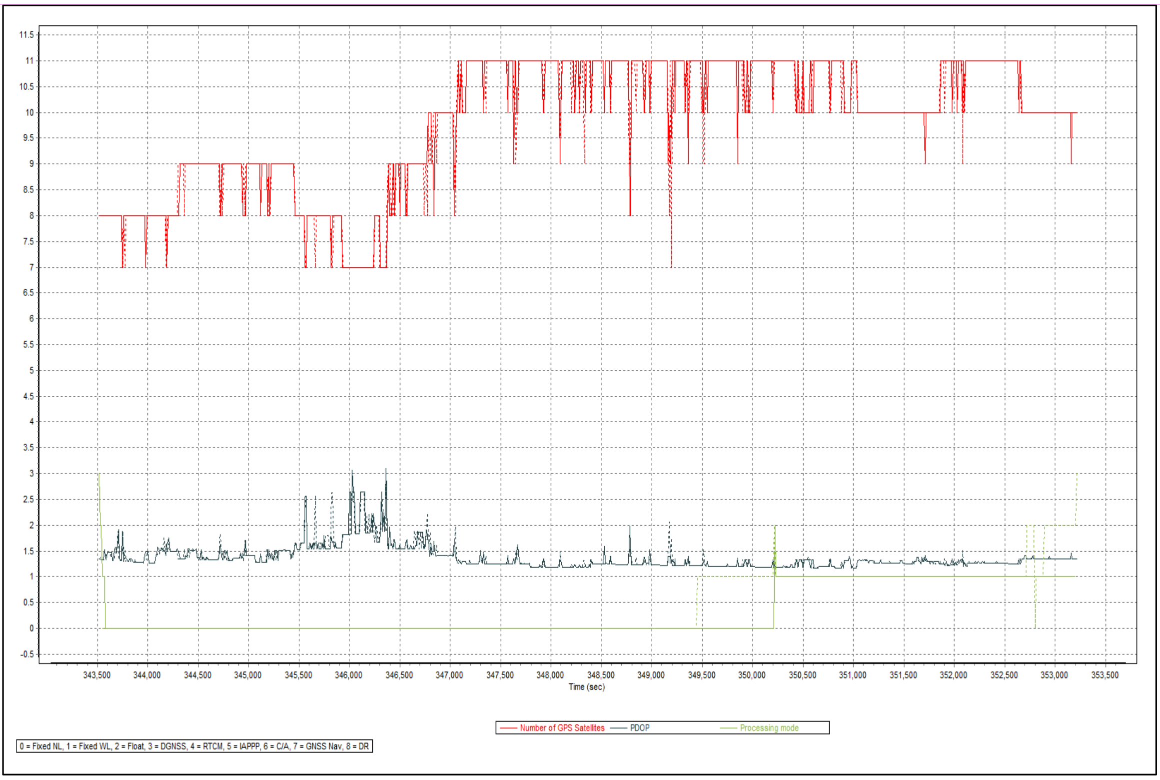


Figure A-8.36 Solution Status

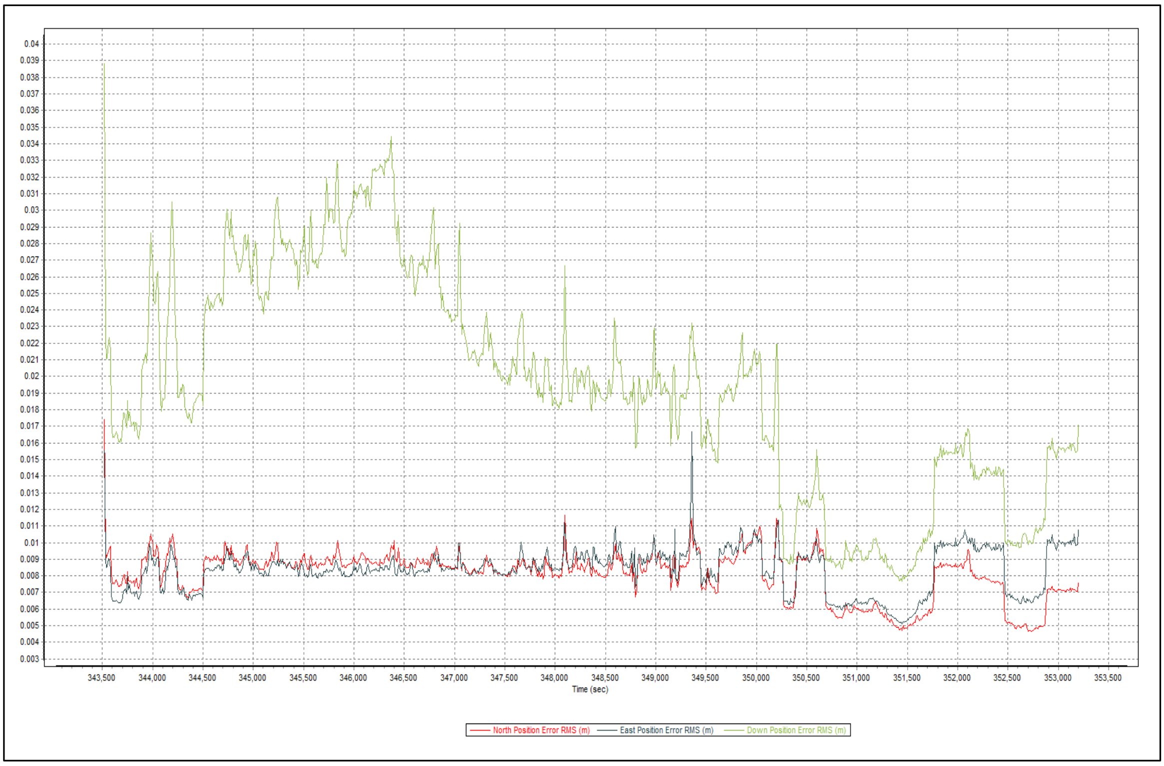


Figure A-8.37 Smoothed Performance Metric Parameters

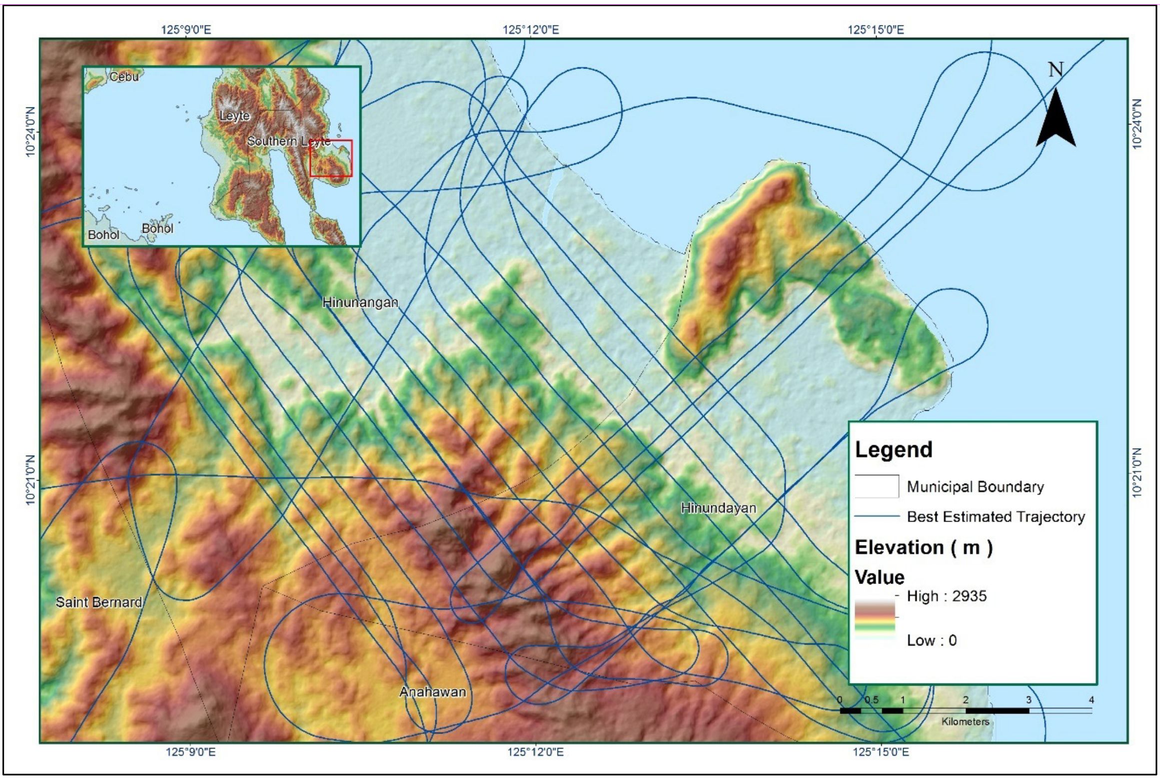


Figure A-8.38 Best Estimated Trajectory

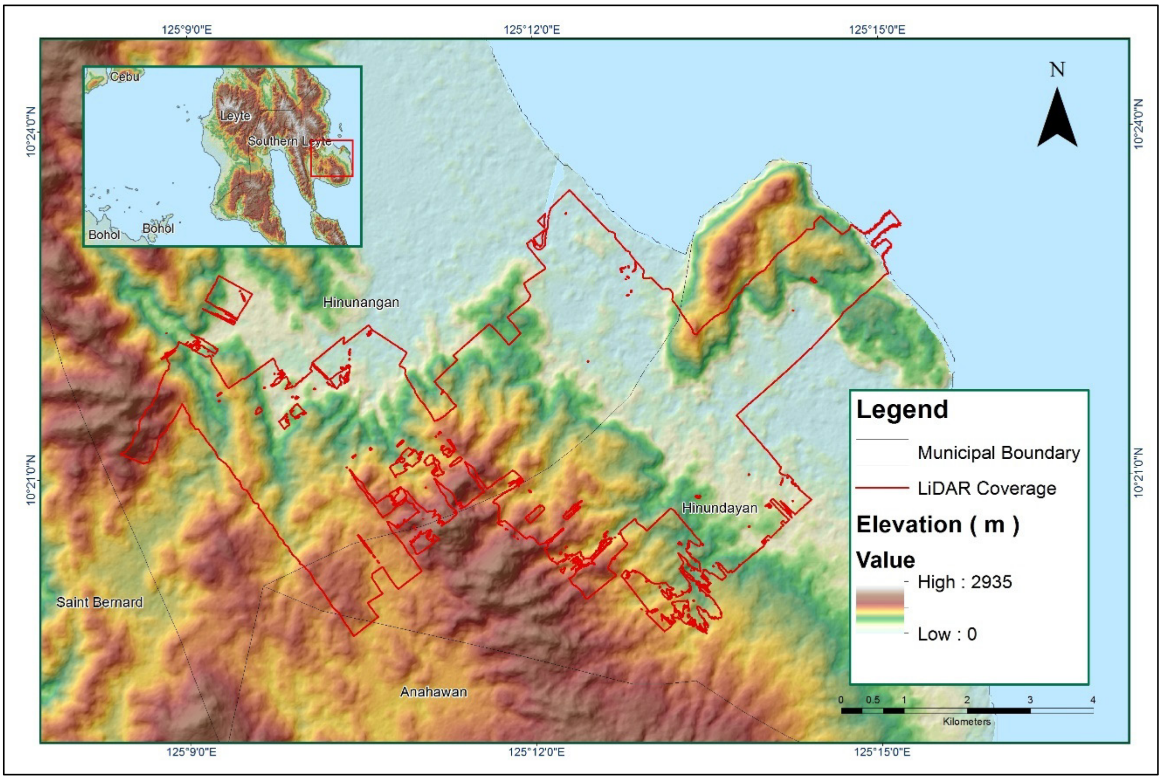


Figure A-8.39 Coverage of LiDAR data

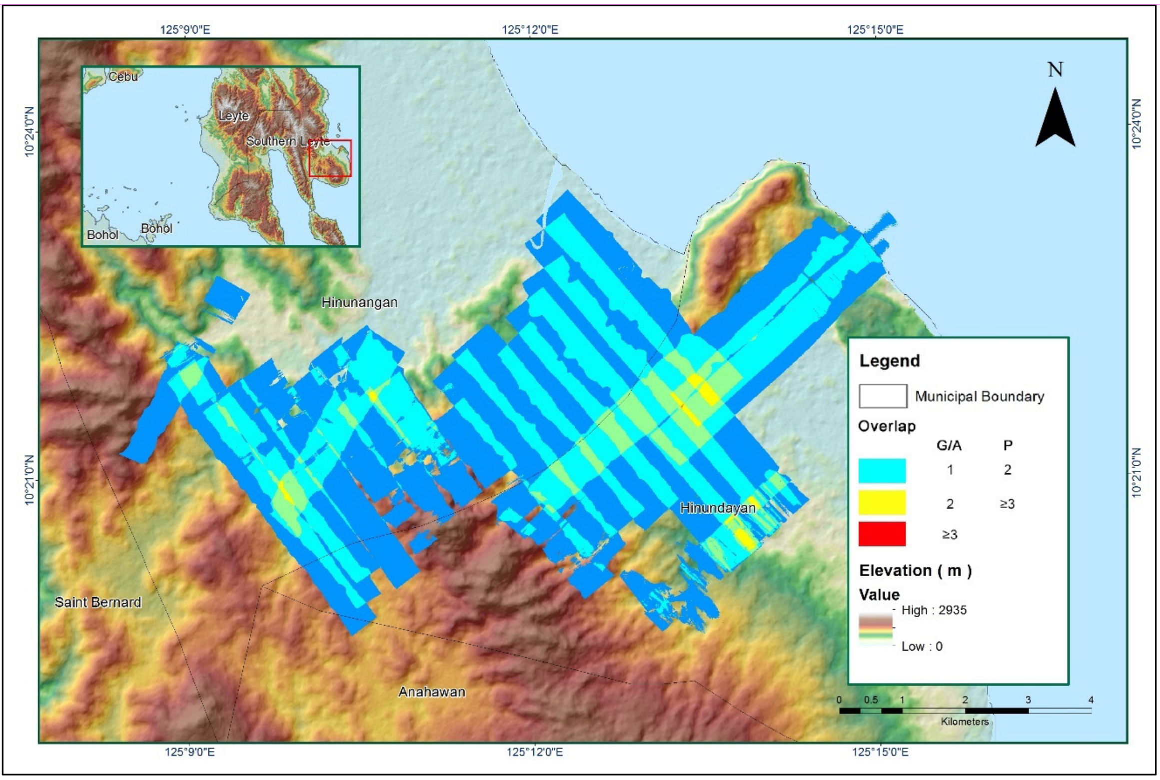


Figure A-8.40 Image of data overlap

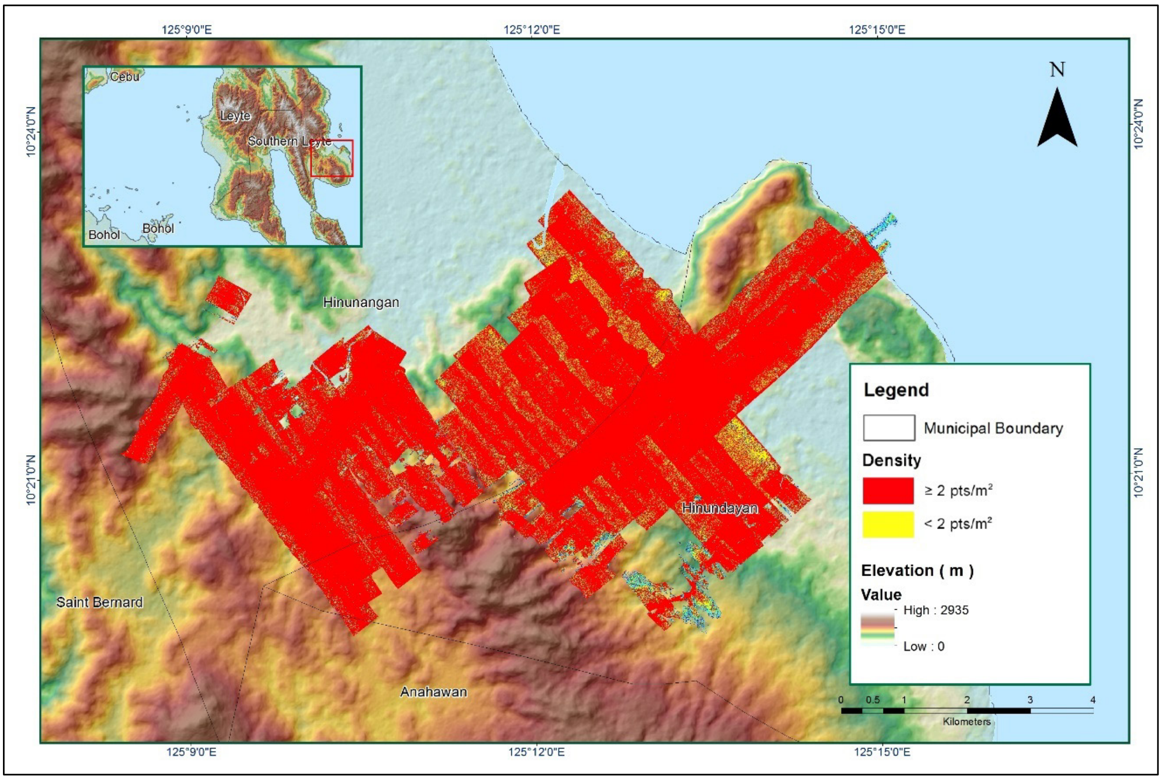


Figure A-8.41 Density map of merged LiDAR data

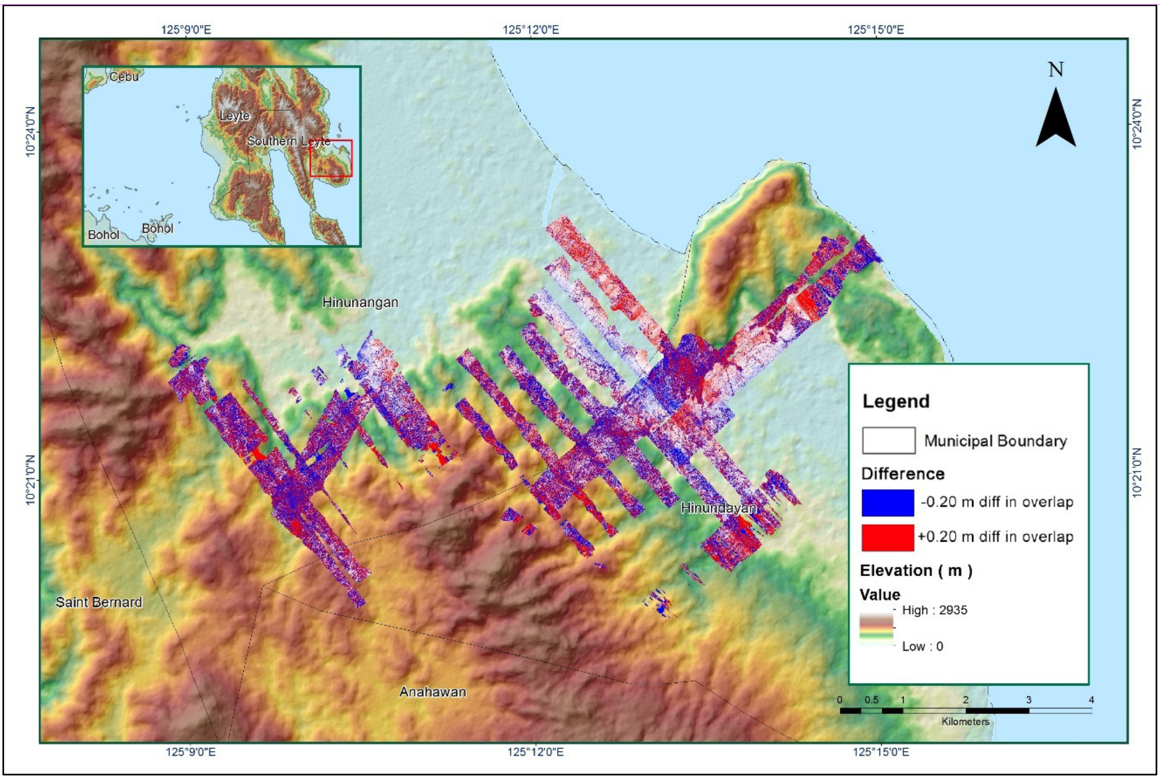


Figure A-8.42 Elevation difference between flight lines

Table A-8.7. Mission Summary Report for Mission Blk50A

Flight Area	Leyte
Mission Name	Blk50A
Inclusive Flights	23773G
Range data size	9.06
Base data size	4.7 MB
POS	195MB
Image	NA
Transfer date	March 4, 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)	1.3
RMSE for East Position (<4.0 cm)	1.2
RMSE for Down Position (<8.0 cm)	2.1
Boresight correction stdev (<0.001deg)	0.001068
IMU attitude correction stdev (<0.001deg)	0.001004
GPS position stdev (<0.01m)	0.0089
Minimum % overlap (>25)	28.42
Ave point cloud density per sq.m. (>2.0)	6.82
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	40
Maximum Height	332.17 m
Minimum Height	64.84 m
Classification (# of points)	
Ground	15,027,159
Low vegetation	21,600,048
Medium vegetation	41,211,346
High vegetation	49,972,896
Building	1,217,828
Orthophoto	Yes
Processed by	Engr. Analyn Naldo, Engr. Ma Joanne Balaga, Engr. Krisha Marie Bautista

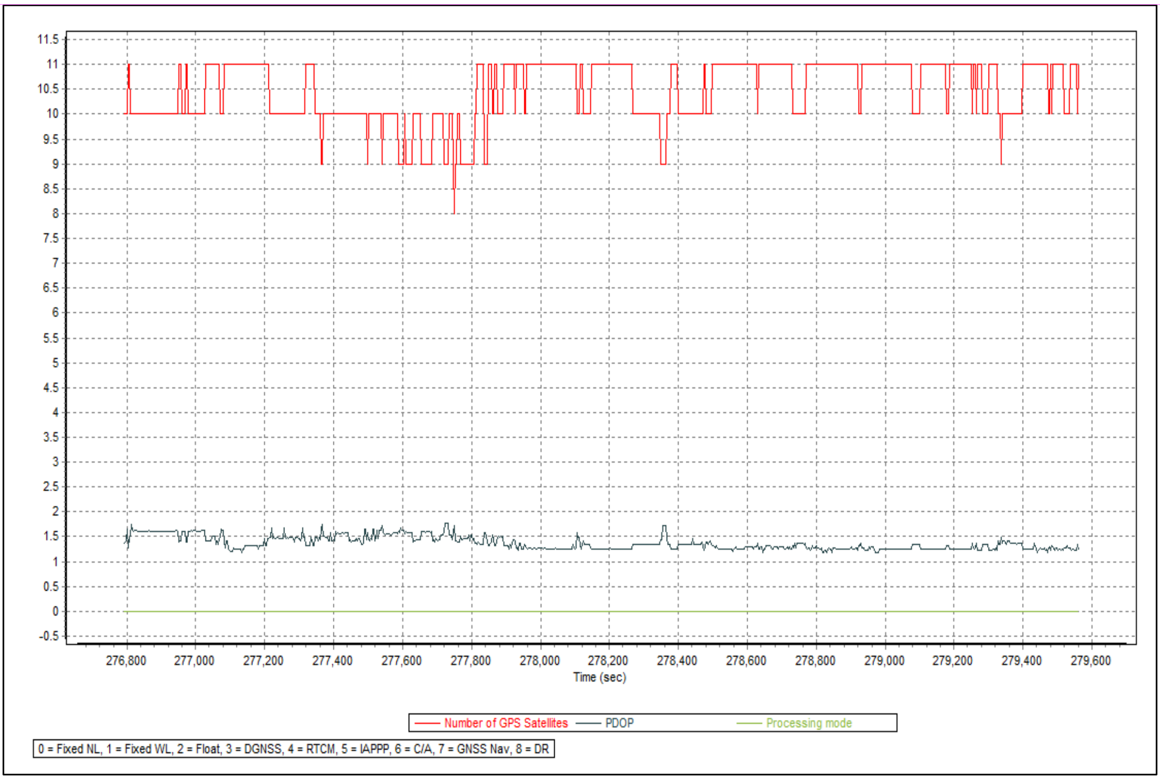


Figure A-8.43 Solution Status

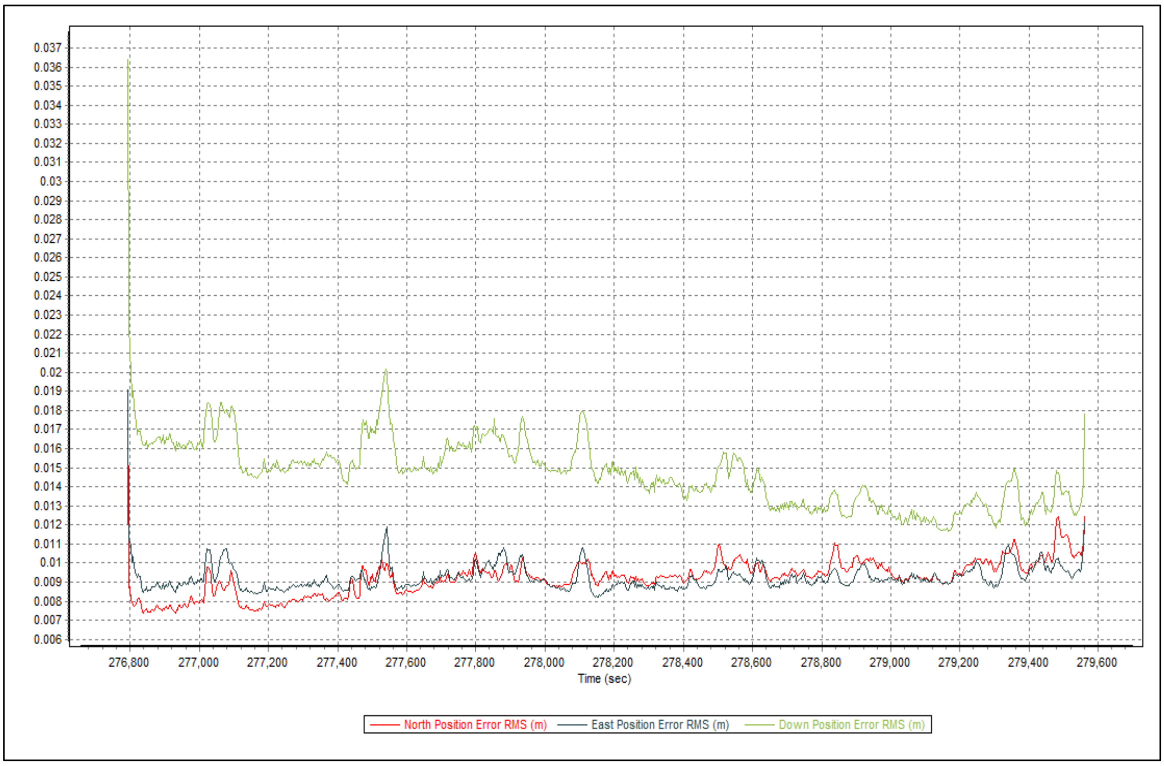


Figure A-8.44 Smoothed Performance Metric Parameters

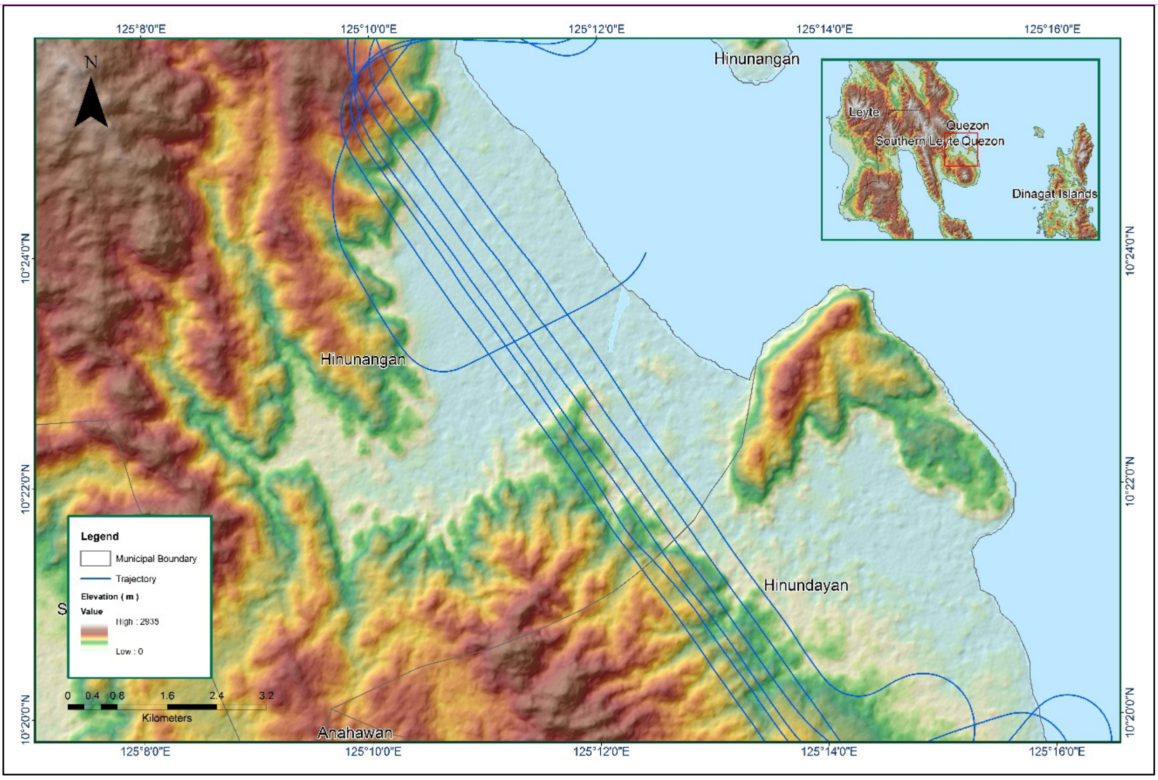


Figure A-8.45 Best Estimated Trajectory

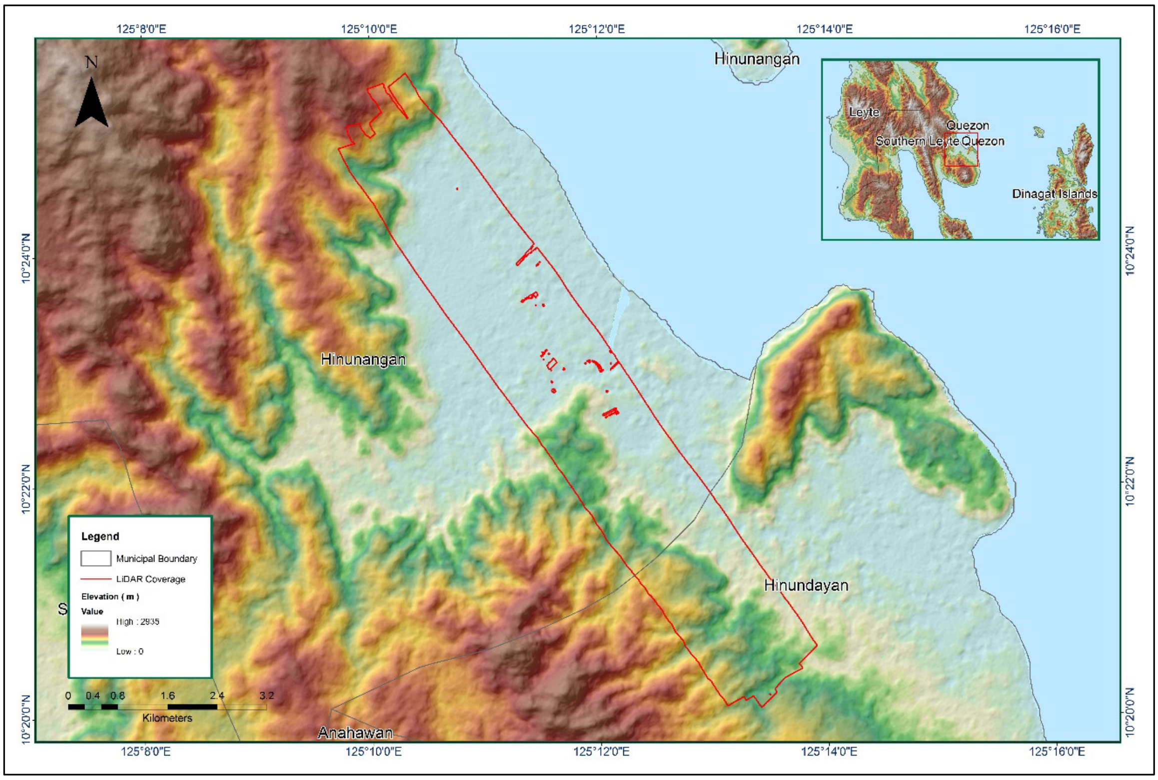


Figure A-8.46 Coverage of LiDAR data

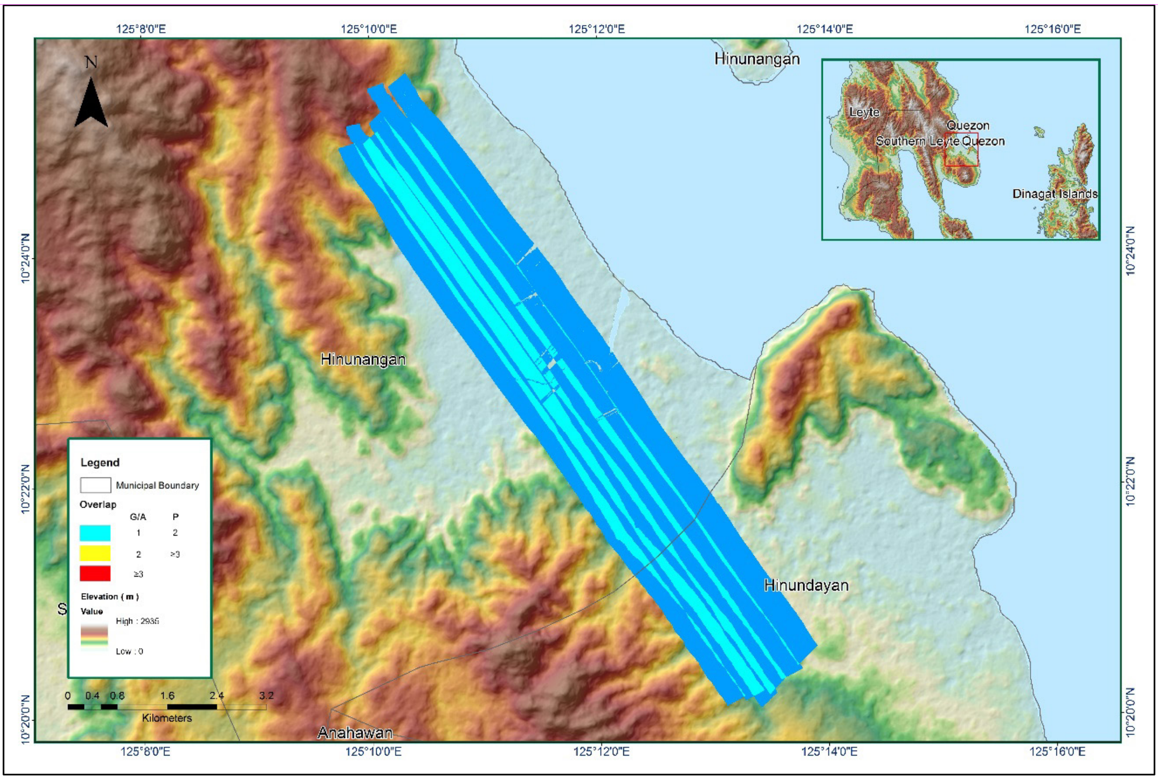


Figure A-8.47 Image of data overlap

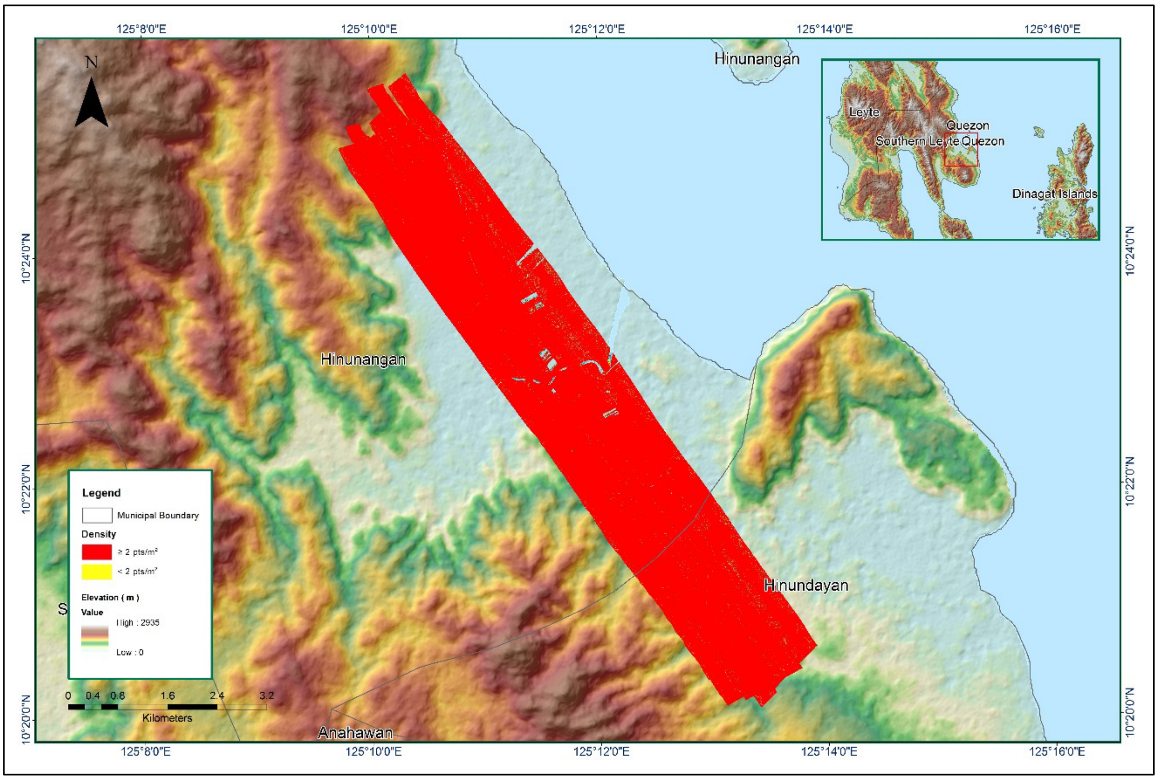


Figure A-8.48 Density map of merged LiDAR data

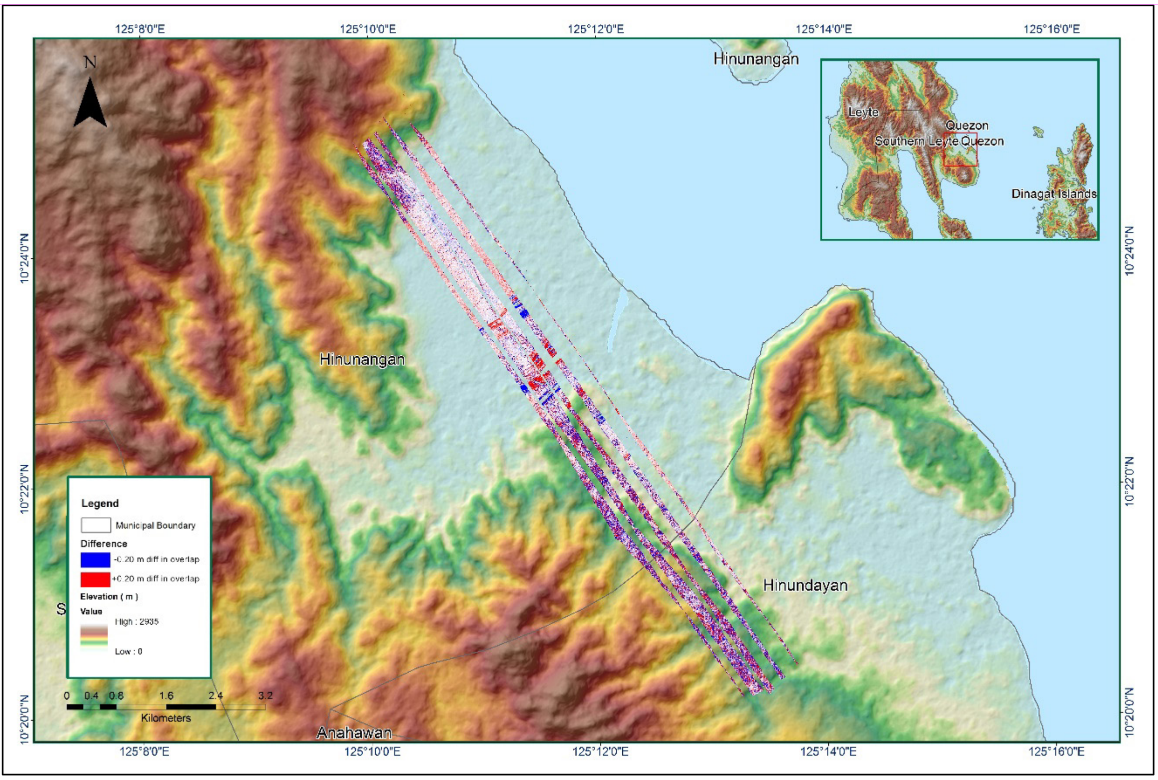


Figure A-8.49 Elevation difference between flight lines

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Annex 9. Das-ay 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
W220	28.8053	81	0	0.6024	3.2771	Discharge	0.364	1	Ratio to Peak	0.1
W210	30.903	81	0	0.66261	3.6046	Discharge	0.364	1	Ratio to Peak	0.1
W200	41.2748	81	0	0.137976	0.7506	Discharge	0.364	1	Ratio to Peak	0.1
W190	36.2423	81	0	0.35958	1.9561	Discharge	0.364	1	Ratio to Peak	0.1
W180	45.1478	81	0	0.38184	2.07725	Discharge	0.364	1	Ratio to Peak	0.1
W170	34.1947	81	0	0.35106	1.90975	Discharge	0.364	1	Ratio to Peak	0.1
W160	35.7623	81	0	0.634725	3.45295	Discharge	0.364	1	Ratio to Peak	0.1
W150	35.8815	81	0	0.626715	3.40935	Discharge	0.364	1	Ratio to Peak	0.1
W140	32.9555	81	0	0.41553	2.2605	Discharge	0.364	1	Ratio to Peak	0.1
W130	28.2105	81	0	0.591135	3.2158	Discharge	0.364	1	Ratio to Peak	0.1
W120	30.63	81	0	1.17219	6.3765	Discharge	0.364	1	Ratio to Peak	0.1

Annex 10. Das-ay Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R30	Automatic Fixed Interval	3292	0.01977	0.035	Trapezoid	43.1	1
R50	Automatic Fixed Interval	4237	0.010896	0.035	Trapezoid	23.9	1
R70	Automatic Fixed Interval	1044	0.00633	0.035	Trapezoid	18.3	1
R80	Automatic Fixed Interval	2292	0.003796	0.035	Trapezoid	42.8	1
R90	Automatic Fixed Interval	2110	0.004842	0.035	Trapezoid	42.6	1

Annex 11. Das-ay Field Validation Points

Table A-11.1. Das-ay Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date of Occurrence	Rain Return / Scenario
	Lat	Long						
1	10.39462284	125.1997534	0	0.20	0.20			5Yr
2	10.39508695	125.19971	0	0.20	0.20			5Yr
3	10.39530379	125.2011823	0	0.00	0.00			5Yr
4	10.39612438	125.1998576	0	0.00	0.00			5Yr
5	10.39623971	125.1989882	0	0.00	0.00			5Yr
6	10.39750295	125.1984569	0	0.00	0.00			5Yr
7	10.39835857	125.198329	1	0.20	-0.80			5Yr
8	10.39689853	125.1976867	0	0.00	0.00			5Yr
9	10.39503071	125.1969538	0	0.00	0.00			5Yr
10	10.39471211	125.1966582	0	0.00	0.00			5Yr
11	10.39263926	125.1983996	0	0.50	0.50			5Yr
12	10.39235839	125.1990643	0.5	0.20	-0.30	Heavy Rain	December	5Yr
13	10.39204859	125.199734	0.5	0.20	-0.30	Heavy Rain	December	5Yr
14	10.39179688	125.2003464	1.2	0.20	-1.00	Amy	1897	5Yr
15	10.39313363	125.2005512	0.7	0.50	-0.20	Heavy Rain	December	5Yr
16	10.42078226	125.1843106	0.5	0.00	-0.50	Heavy Rain	December	5Yr
17	10.42027121	125.1818234	0.5	0.00	-0.50	Ruping	1990	5Yr
18	10.42026962	125.1845681	0	0.00	0.00			5Yr
19	10.41806937	125.186069	0	0.20	0.20			5Yr
20	10.41574758	125.1875396	0	0.00	0.00			5Yr
21	10.41512003	125.1866497	0	0.00	0.00			5Yr
22	10.41599066	125.1842775	0	0.20	0.20			5Yr
23	10.41706765	125.1838638	0	0.00	0.00			5Yr
24	10.41625058	125.1850171	0	0.00	0.00			5Yr
26	10.41417154	125.1845465	0	0.00	0.00			5Yr
27	10.4136366	125.1831281	0	0.00	0.00			5Yr
28	10.41321742	125.1823548	0	0.00	0.00			5Yr
29	10.41288332	125.1814367	0	0.00	0.00			5Yr
30	10.41355899	125.1797996	0	0.00	0.00			5Yr
31	10.41527225	125.1783171	0	0.00	0.00			5Yr
31	10.41429668	125.1748039	0.2	2.00	1.80	Heavy Rain	December	5Yr
32	10.41213314	125.1703539	0	0.00	0.00			5Yr
33	10.40782417	125.172802	0	0.00	0.00			5Yr
34	10.40049721	125.1690294	0	0.00	0.00			5Yr
35	10.39805682	125.1684997	0	0.00	0.00			5Yr

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date of Occurrence	Rain Return / Scenario
	Lat	Long						
36	10.39662469	125.1702097	0.2	0.00	-0.20	Heavy Rain	December	5Yr
37	10.39729482	125.1709163	0	0.00	0.00			5Yr
38	10.39410735	125.171853	0.3	0.00	-0.30	Heavy Rain	December	5Yr
39	10.39192077	125.1706912	0.4	0.50	0.10	Heavy Rain	December	5Yr
40	10.38342026	125.1746314	0	0.00	0.00			5Yr
41	10.38333368	125.1745843	0	0.00	0.00			5Yr
42	10.38213163	125.1780554	2	0.00	-2.00	Amy	8-Dec-51	5Yr
43	10.38321465	125.180301	0	0.00	0.00			5Yr
44	10.3838619	125.1812565	0	0.00	0.00			5Yr
45	10.3851378	125.1827391	0	0.20	0.20			5Yr
46	10.38597682	125.1837206	0.1	0.50	0.40	Heavy Rain	December	5Yr
46	10.38597682	125.1837206	0.3	0.50	0.20	Heavy Rain	December	5Yr
47	10.38760853	125.1859468	0	0.50	0.50			5Yr
48	10.38804984	125.1844292	0.2	0.20	0.00	Heavy Rain	December	5Yr
48	10.38804984	125.1844292	0.5	0.20	-0.30	Heavy Rain	December	5Yr
49	10.38814615	125.1821931	0.2	0.20	0.00	Heavy Rain	December	5Yr
50	10.39041982	125.1906318	0	0.20	0.20			5Yr
51	10.39221246	125.1933358	0.8	0.50	-0.30	Heavy Rain	December	5Yr
52	10.39362623	125.1953373	0	0.50	0.50			5Yr
53	10.39454187	125.1884702	0	0.00	0.00			5Yr
54	10.39811826	125.1887759	0	0.00	0.00			5Yr
55	10.40017803	125.1932631	0	0.00	0.00			5Yr
56	10.39797795	125.1946507	0	0.00	0.00			5Yr
57	10.4012717	125.1935864	0	0.00	0.00			5Yr
58	10.40301799	125.1918759	0	0.00	0.00			5Yr
59	10.40689202	125.1902447	0	0.00	0.00			5Yr
60	10.40523366	125.1849438	0	0.00	0.00			5Yr
61	10.40474374	125.1835159	0	0.00	0.00			5Yr
62	10.40452028	125.1828156	0	0.00	0.00			5Yr
63	10.40206052	125.1836454	0	0.00	0.00			5Yr
64	10.40582542	125.1822947	0	0.00	0.00			5Yr
65	10.40797454	125.1815251	0.5	0.00	-0.50	Heavy Rain	December	5Yr
66	10.40969082	125.1804414	0.3	0.50	0.20	Heavy Rain	December	5Yr

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date of Occurrence	Rain Return / Scenario
	Lat	Long						
67	10.40991973	125.1803541	0.3	0.20	-0.10	Heavy Rain	December	5Yr
68	10.40966836	125.1798344	0.4	0.20	-0.20	Heavy Rain	December	5Yr
69	10.41178135	125.179712	0.2	0.20	0.00	Heavy Rain	December	5Yr
70	10.41298633	125.1790568	0.4	0.20	-0.20	Heavy Rain	December	5Yr
71	10.41368103	125.1791715	0	0.00	0.00			5Yr
72	10.41724803	125.188858	0	0.00	0.00			5Yr
73	10.41511609	125.1895789	0	0.00	0.00			5Yr
74	10.41487696	125.1909817	0	0.20	0.20			5Yr
75	10.41337978	125.1890496	0	0.00	0.00			5Yr
76	10.41142881	125.190021	0	0.00	0.00			5Yr
77	10.41200146	125.1915226	0	0.20	0.20			5Yr
78	10.40989635	125.1909962	0	0.00	0.00			5Yr
79	10.40950131	125.1912141	0	0.20	0.20			5Yr
80	10.40777623	125.1928353	0	0.00	0.00			5Yr
81	10.40847125	125.1944344	0	0.00	0.00			5Yr
82	10.40727809	125.1911969	0.2	0.00	-0.20	Heavy Rain	December	5Yr
83	10.40533382	125.1934636	0	0.00	0.00			5Yr
84	10.40426195	125.1947243	0.25	0.20	-0.05	Heavy Rain	December	5Yr
85	10.40228399	125.1957163	0.3	0.00	-0.30	Heavy Rain	December	5Yr
86	10.40111504	125.1963476	0.2	0.00	-0.20	Heavy Rain	December	5Yr
87	10.38979436	125.199454	0.6	0.50	-0.10	Heavy Rain	December	5Yr
87	10.38979436	125.199454	0.6	0.20	-0.40	Heavy Rain	December	5Yr
88	10.38728633	125.1998481	0.5	0.00	-0.50	Heavy Rain	December	5Yr
89	10.38483622	125.2029912	0.6	0.50	-0.10	Heavy Rain	December	5Yr
90	10.38707326	125.20289	0.5	0.00	-0.50	Heavy Rain	December	5Yr
91	10.384914	125.204736	0	0.00	0.00			5Yr
92	10.38657454	125.2059055	0	0.00	0.00			5Yr
93	10.38747534	125.2067355	0	0.50	0.50			5Yr
94	10.38772169	125.2071909	0.2	0.00	-0.20	Heavy Rain	December	5Yr
95	10.38945984	125.2070042	0	0.20	0.20			5Yr
96	10.38588136	125.209301	0	0.00	0.00			5Yr

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date of Occurrence	Rain Return / Scenario
	Lat	Long						
97	10.38299656	125.2126629	0	0.00	0.00			5Yr
98	10.38338665	125.2139256	0	0.00	0.00			5Yr
99	10.38392577	125.2144246	1.2	0.50	-0.70	Bising	March 1982	5Yr
99	10.38392577	125.2144246	1.2	0.50	-0.70	Ruping	1990	5Yr
100	10.38475449	125.2144079	0.3	0.00	-0.30	Heavy Rain	December	5Yr
101	10.38525347	125.2136766	0.3	0.00	-0.30	Heavy Rain	December	5Yr
102	10.38598655	125.212869	0	0.00	0.00			5Yr
103	10.38804523	125.2103342	0	0.20	0.20			5Yr
104	10.38225962	125.2141518	0	0.00	0.00			5Yr
105	10.38290955	125.2016275	0	0.20	0.20			5Yr
106	10.38184253	125.1997926	0	0.00	0.00			5Yr
107	10.38217328	125.1957463	0	0.00	0.00			5Yr
108	10.38224931	125.1952571	0	0.50	0.50			5Yr
109	10.38193021	125.1940298	0	0.50	0.50			5Yr
110	10.38091575	125.1934412	0	0.00	0.00			5Yr
111	10.3801861	125.1929992	0	0.00	0.00			5Yr
112	10.37937901	125.1922846	0	0.00	0.00			5Yr
113	10.37845063	125.1910451	0.3	0.50	0.20	Heavy Rain	December	5Yr
113	10.37845063	125.1910451	0.2	0.50	0.30	Heavy Rain	December	5Yr
114	10.37702529	125.1888739	1	0.50	-0.50	Heavy Rain	December	5Yr
115	10.37461708	125.1852659	0	0.20	0.20			5Yr
116	10.3737597	125.1839702	0	0.00	0.00			5Yr
117	10.37203453	125.1826005	0.3	1.00	0.70	Heavy Rain	December	5Yr
118	10.37114597	125.181559	0	0.00	0.00			5Yr
119	10.3706309	125.180932	0	2.00	2.00			5Yr
120	10.36878596	125.1782745	0	2.00	2.00			5Yr
121	10.36480405	125.1747248	0	0.00	0.00			5Yr
122	10.36475896	125.1684556	0	1.00	1.00			5Yr
123	10.36563286	125.166165	1	1.00	0.00	Bising	March 1982	5Yr
124	10.36886442	125.1614174	0.7	0.20	-0.50	Amy	8-Dec-51	5Yr
125	10.36300949	125.1728048	0	0.00	0.00			5Yr
126	10.36985055	125.1793028	0	0.20	0.20			5Yr
127	10.37054541	125.1793331	0.2	1.00	0.80	Heavy Rain	December	5Yr
128	10.37144068	125.1784973	0.2	0.50	0.30	Heavy Rain	December	5Yr

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date of Occurrence	Rain Return / Scenario
	Lat	Long						
129	10.37230393	125.1779014	0.2	0.50	0.30	Heavy Rain	December	5Yr
130	10.37288295	125.1774712	0	1.00	1.00			5Yr
131	10.38244201	125.204299	0.2	0.20	0.00	Heavy Rain	December	5Yr
132	10.38146074	125.204543	1	0.20	-0.80	Heavy Rain	December	5Yr
132	10.38146074	125.204543	0.5	0.20	-0.30	Heavy Rain	December	5Yr
133	10.3784627	125.2060872	0.7	0.20	-0.50	Heavy Rain	December	5Yr
134	10.37781495	125.2066125	0.6	0.20	-0.40	Heavy Rain	December	5Yr
135	10.37663997	125.2075241	1.1	0.20	-0.90	Heavy Rain	December	5Yr
136	10.37167512	125.2114236	0	0.00	0.00			5Yr
137	10.3724709	125.2118527	0	0.00	0.00			5Yr
138	10.37319576	125.2125796	0	0.00	0.00			5Yr
139	10.37364319	125.2134388	0.5	0.20	-0.30	Heavy Rain	December	5Yr
139	10.37364319	125.2134388	0.5	0.20	-0.30	Heavy Rain	December	5Yr
140	10.37560933	125.215494	0.6	0.20	-0.40	2010		5Yr
140	10.37560933	125.215494	1.5	0.20	-1.30	Bising	March 1982	5Yr
141	10.37780271	125.2172967	1.3	0.00	-1.30	Bising	March 1982	5Yr
142	10.37842666	125.2196258	0	0.20	0.20			5Yr
143	10.37889998	125.2198333	0	0.00	0.00			5Yr
144	10.37990866	125.2206709	0.4	0.50	0.10	Heavy Rain	December	5Yr
145	10.38091298	125.221073	1	0.00	-1.00	Amy	8-Dec-51	5Yr
145	10.38091298	125.221073	1	0.00	-1.00	Bising	March 1982	5Yr
145	10.38091298	125.221073	1.2	0.00	-1.20	Ruping	1990	5Yr
146	10.38100862	125.2195082	1	0.00	-1.00	Amy	8-Dec-51	5Yr
146	10.38100862	125.2195082	1	0.00	-1.00	Bising	March 1982	5Yr
146	10.38100862	125.2195082	1.2	0.00	-1.20	Ruping	1990	5Yr
147	10.37963063	125.2178399	1	0.50	-0.50	Amy	8-Dec-51	5Yr
147	10.37963063	125.2178399	1	0.50	-0.50	Bising	March 1982	5Yr
147	10.37963063	125.2178399	1.2	0.50	-0.70	Ruping	1990	5Yr

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date of Occurrence	Rain Return / Scenario
	Lat	Long						
148	10.37919855	125.217734	0	0.00	0.00			5Yr
149	10.37864744	125.2175603	0.5	0.00	-0.50	Bising	March 1982	5Yr
149	10.37864744	125.2175603	0.3	0.00	-0.30	Ruping	1990	5Yr
150	10.37829699	125.2174668	0.4	0.50	0.10	Bising	March 1982	5Yr
150	10.37829699	125.2174668	0.4	0.50	0.10	Ruping	1990	5Yr
151	10.37132082	125.2113184	0.7	0.50	-0.20	Bising	March 1982	5Yr
152	10.37108738	125.2115093	0.7	0.50	-0.20	Bising	March 1982	5Yr
153	10.37024399	125.2121778	0.6	0.50	-0.10	Bising	March 1982	5Yr
153	10.37024399	125.2121778	1	0.50	-0.50	Bising	March 1982	5Yr
154	10.36958576	125.2127161	0.6	0.20	-0.40	Heavy Rain	December	5Yr
155	10.36903021	125.2131357	1.2	0.20	-1.00			5Yr
155	10.36903021	125.2131357	0	0.20	0.20			5Yr
156	10.3685226	125.213575		0.50	0.50			5Yr
157	10.36902317	125.2149315	1.2	0.50	-0.70	Bising	March 1982	5Yr
157	10.36902317	125.2149315	1.2	0.50	-0.70	Ruping	1990	5Yr
158	10.36970948	125.2158935	1.2	0.20	-1.00	Bising	March 1982	5Yr
158	10.36970948	125.2158935	1.2	0.20	-1.00	Ruping	1990	5Yr
159	10.37063073	125.2167477	1.2	0.20	-1.00	Bising	March 1982	5Yr
159	10.37063073	125.2167477	1.2	0.20	-1.00	Ruping	1990	5Yr
160	10.37192423	125.2163374	0	0.20	0.20			5Yr
161	10.36827458	125.2137065	0.7	1.00	0.30	Bising	March 1982	5Yr
161	10.36827458	125.2137065	1.1	0.50	-0.60	Ruping	1990	5Yr
162	10.3678238	125.2140495	1	0.50	-0.50	Ruping	1990	5Yr
162	10.3678238	125.2140495	0.7	0.50	-0.20	Bising	March 1982	5Yr
163	10.36708787	125.2145763	1	0.50	-0.50	Ruping	1990	5Yr
163	10.36708787	125.2145763	0.5	0.50	0.00	Bising	March 1982	5Yr
164	10.36661538	125.2148718	1	0.50	-0.50	Ruping	1990	5Yr
164	10.36661538	125.2148718	0.6	0.50	-0.10	Bising	March 1982	5Yr
165	10.3655881	125.2155758	1	0.50	-0.50	Ruping	1990	5Yr
165	10.3655881	125.2155758	0.7	0.50	-0.20	Bising	March 1982	5Yr

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date of Occurrence	Rain Return / Scenario
	Lat	Long						
166	10.36383142	125.2168061	0.5	0.50	0.00	Heavy Rain	December	5Yr
167	10.36252661	125.2165649	0.3	0.20	-0.10	Heavy Rain	December	5Yr
168	10.36157082	125.2156432	0.5	0.20	-0.30	Bising	March 1982	5Yr
169	10.36063791	125.2148673	0	1.00	1.00			5Yr
170	10.35935665	125.2134821	0	2.00	2.00			5Yr
171	10.36191381	125.2187495	1.2	0.50	-0.70	Bising	March 1982	5Yr
172	10.36130461	125.2196899	1.2	0.20	-1.00	Bising	March 1982	5Yr
173	10.36021211	125.2191097	0	0.00	0.00			5Yr
174	10.35904141	125.219274	0	0.00	0.00			5Yr
175	10.36092432	125.2205786	0.4	0.20	-0.20	Heavy Rain	December	5Yr
176	10.36072416	125.2210574	0.4	0.20	-0.20	Heavy Rain	December	5Yr
177	10.36012486	125.2224882	0.2	0.50	0.30	Heavy Rain	December	5Yr
178	10.36020457	125.2224738	0.2	0.50	0.30	Heavy Rain	December	5Yr
178	10.36020457	125.2224738	0.3	0.50	0.20	Bising	March 1982	5Yr
179	10.36001422	125.2228367	0	0.20	0.20			5Yr
180	10.3597522	125.2235744	0	0.50	0.50			5Yr
181	10.35947191	125.2244233	0	1.00	1.00			5Yr
182	10.35946285	125.2252862	0	0.00	0.00			5Yr

Annex 12. Educational Institutions affected by flooding in Das-ay Flood Plain

Table A-12.1. Educational Institutions in Das-ay, Southern Leyte affected by flooding in Das-ay Flood Plain

SOUTHERN LEYTE				
HINUNANGAN				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Ambacon Elementary School	Ambacon	Low	Low	Medium
Matinaw Elementary School	Ambacon			
Southern Leyte State University	Ambacon			
Tahusan Elementary School	Badiangon	Low	Low	Low
Southern Leyte State University	Bangcas A	Low	Medium	Medium
Canipaan Elementary School	Bangcas B	Low	Low	Low
Biasong Elementary School	Biasong	Medium	Medium	Medium
Otama Elementary School	Bugho	Medium	Medium	Medium
Catublian Elementary School	Catublian	Medium	Medium	Medium
Nueva Esperanza Elementary School	Nueva Esperanza			
Sto. Niño II Elementary Schoo	Nueva Esperanza			
Sto. Niño II Elementary School	Nueva Esperanza			
Brgy. Palongpong Daycare Center	Palongpong			
Palongpong Elementary School	Palongpong			
Patong Elementary School	Panalaron			
Hinunangan East Central School	Poblacion	Low	Low	Low
Hinunangan National High School	Poblacion			
Hinunangan West Central School	Poblacion			Low
Holy Rosary Academy	Poblacion			
Southern Leyte State University	Poblacion	Low	Low	Low
Hinunangan East Central School	Salog			
Holy Rosary Academy	Salog			
Holy Rosary Academy Elementary/ Pre-Elementary School	Salog			Low
Holy Rosary Academy Senior High School	Salog			Low
Brgy. Sto. Niño I Daycare Center	Santo Niño I	Medium	Medium	High
Canipaan Elementary School	Talisay		Low	Low
Canipaan Elementary School Principal's Office	Talisay			Low
Canipaan National High School	Talisay		Low	Low

National Academy of Christian Ambassador	Tawog		Medium	Medium
Tawog Elementary School	Tawog		Low	Medium
Nueva Esperanza Elementary School	Tuburan			
Bugho Elementary School	Bugho			

Annex 13. Medical Institutions affected by flooding in Das-ay Flood Plain

Table A-13.1. Medical Institutions in Hinunangan, Southern Leyte affected by flooding in Das-ay Flood Plain

SOUTHERN LEYTE				
HINUNANGAN				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Brgy. Sto. Niño II Health Center	Nueva Esperanza	Low	Medium	Medium
Brgy. Patong Health Center and Tanod Outpost	Panalaron	Low	Medium	High
Hinunangan Community Hospital	Poblacion			
Zenon T. Lagumbay Memorial Hospital	Poblacion			
Rural Health Unit	Salog	Medium	High	High
Brgy. Sto. Niño I Health Center	Santo Niño I	Medium	Medium	Medium