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

LiDAR Surveys and Flood Mapping of Basey River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
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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
UPC	University of the Philippines Cebu
UP-TCAGP	University of the Philippines – Training Center for Applied Geodesy and Photogrammetry
UTM	Universal Transverse Mercator
WGS	World Geodetic System

CHAPTER 1: OVERVIEW OF THE PROGRAM AND BASEY RIVER

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

1.1 Background of the Phil-LiDAR 1 Program

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

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

The implementing partner university for the Phil-LiDAR 1 Program is the 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 in the province of Leyte.

1.2 Overview of the Basey River Basin

Basey River Basin covers a portion of the Municipality of Basey in the province of Samar. Based on DENR River Basin Control Office (RBCO), it has a drainage area of 250 km2 and an estimated 475 million cubic meter (MCM) annual run-off (River Basin Control Office, 2017).

Basey River is located in the southwestern part of the province of Samar and it is part of the thirty 28 river systems in the province of Samar and Leyte. It is one of the major rivers in the province that is utilized for irrigation and transportation way by the populace that lives in the interior barangays of the municipality. According to the 2015 National Census, there is a total of 9,294 people living near the river, distributed among nine (9) barangays, namely: Guirang, Loog, Burgos, Pelit, San Fernando (Nouvelas Oriental), Nouvelas Occidental, Binongtu-an, Sugponon and Iba (Philippine Statistics Authority, 2016). The Municipality of Basey, Samar is among the areas hit by Typhoon Haiyan (Yolanda) on November 8, 2013 and by Typhoon Hagupit (Ruby) on December 6, 2014 (Amadore, 2013).

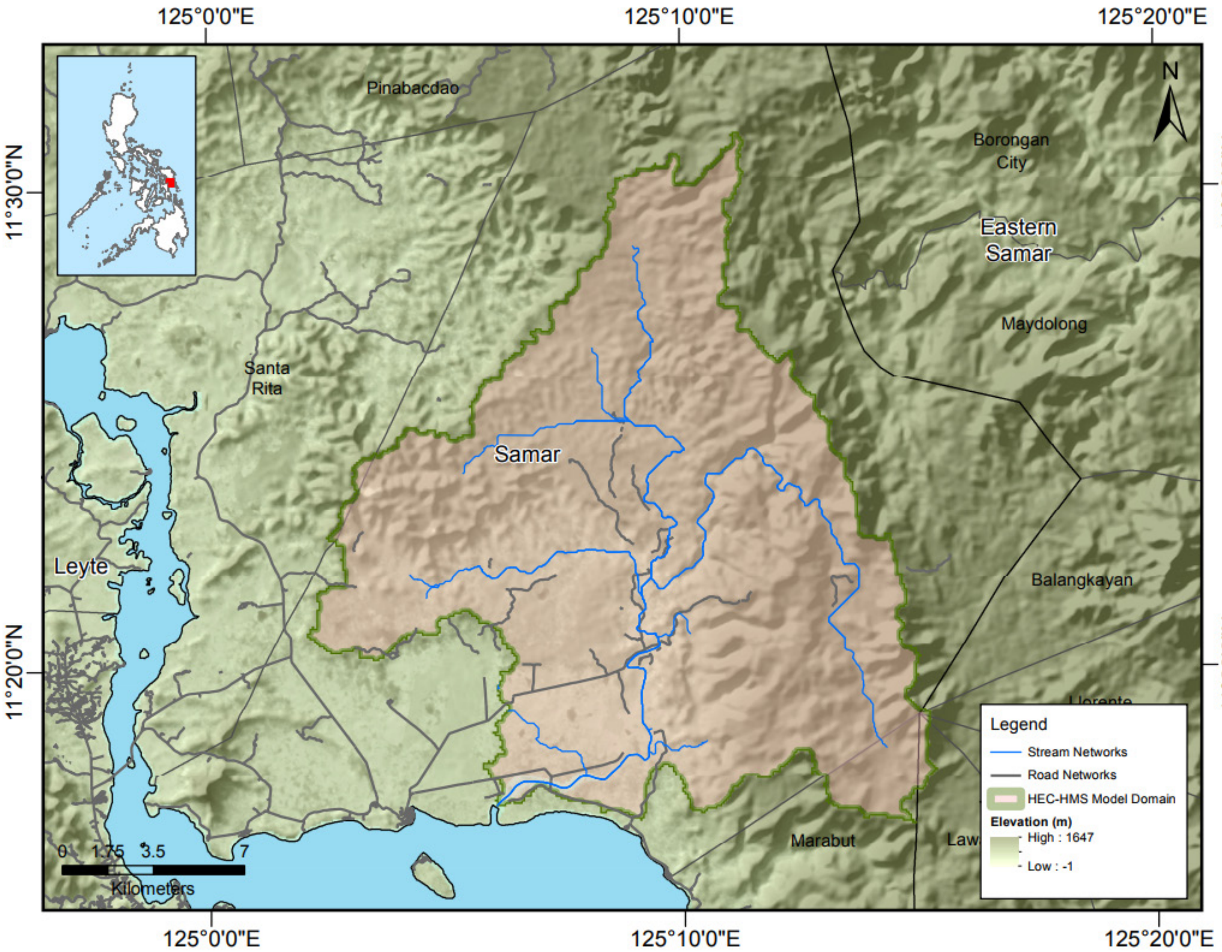

Figure 1. Map of the Basey River Basin

CHAPTER 2: LIDAR DATA ACQUISITION OF THE BASEY FLOODPLAIN

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

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Basey floodplain in Samar. These missions were planned for 16 lines that run for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the Aquarius LiDAR system is found in Table 1, while the flight planning parameters for the Gemini LiDAR system is found in Table 2. Figure 2 shows the flight plan for Basey floodplain using Aquarius LiDAR system, and Figure 3 shows the flight plan for Basey floodplain using Gemini LiDAR system.

Table 1. Flight planning parameters for Aquarius LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency	Average Speed (kts)	Average Turn Time (Minutes)
BLK33B	600	30	36	70	50	120	5
BLK33C	600	30	36	70	50	120	5
BLK33E	600	30	36	70	50	120	5
BLK33F	600	30	36	70	50	120	5
BLK33G	600	30	36	70	50	120	5
BLK33H	600	30	36	70	50	120	5
BLK34AX	600	30	36	70	50	120	5

Table 2. Flight planning parameters for Gemini LiDAR system

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency	Average Speed (kts)	Average Turn Time (Minutes)
BLK34K	900/1200	30	40	125	50	130	5
BLK34L	900/1100	30	40	125	50	130	5

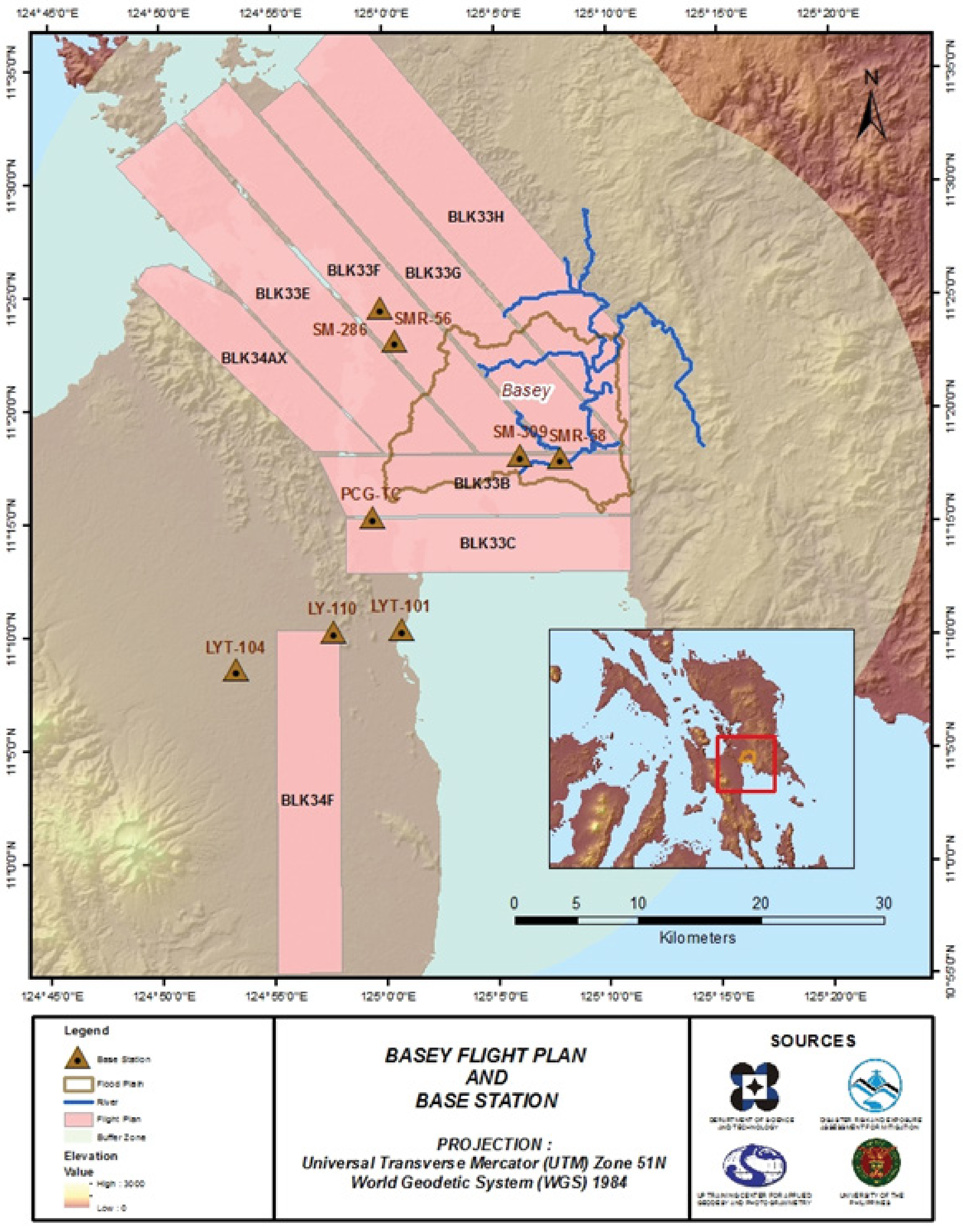

Figure 2. Flight plan and base stations used for Basey Floodplain using Aquarius LiDAR system.

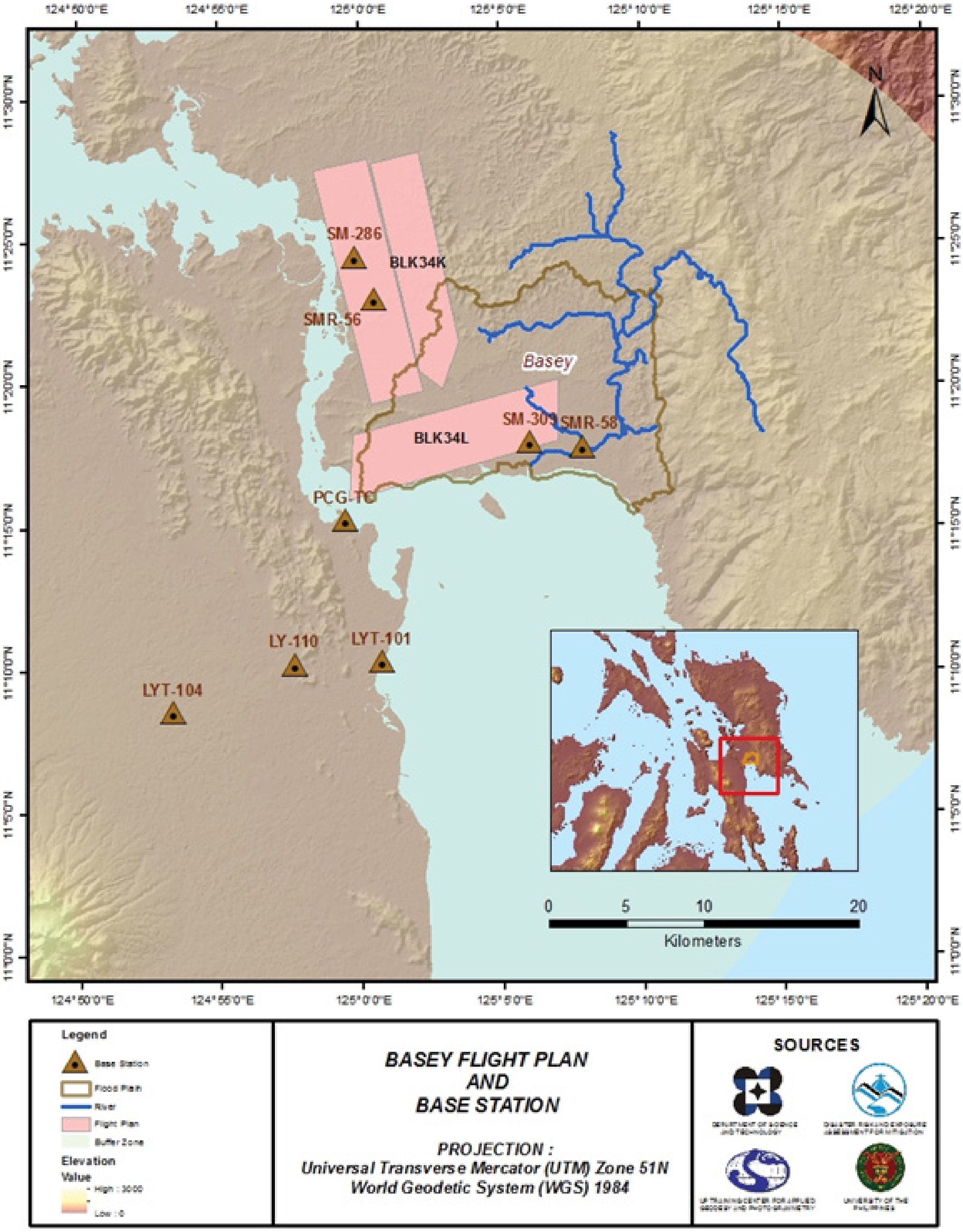

Figure 3. Flight plan and base stations used to cover Basey Floodplain using Gemini LiDAR system.

2.2 Ground Base Station

The project team was able to recover four (4) NAMRIA ground control points: LYT-101, LYT-104, SMR-56 and SMR-58 which are of second (2nd) order accuracy. Three (3) NAMRIA benchmarks were also recovered: LY-110, SM-286 and SM-309 which are of first (1st) order accuracy. These benchmarks were used as vertical reference points and were also established as ground control points. The certifications for the NAMRIA reference points and benchmarks are found in Annex 2 while the baseline processing reports for the established control points is found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey (May 5-4, 10-11 and 13, 2014, February 7 and 13, 2015, and January 23, 31 and February 6, 2016). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852, SPS 882 and SPS 985. Flight plans and location of base stations used during the aerial LiDAR acquisition in Basey floodplain are shown in Figure 2 and Figure 3.

Figure 4 to Figure 10 show the recovered NAMRIA control station within the area, in addition Table 3 to Table 10 show the details about the following NAMRIA control stations and established points, Table 11 shows the list of all ground control points occupied during the acquisition together with the dates they are utilized during the survey.

Figure 4. GPS set-up over LYT-101 within the premises of MacArthur's Landing Memorial Park, Palo, Leyte (a) and NAMRIA reference point LYT-101 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point LYT-101 used as base station for the LiDAR acquisition.

Station Name	**LYT-101**	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11° 10’ 23.89707’’ 125° 0’ 38.62071’’ 6.58600 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	501,171.719 meters 1,235,497.253 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 10’ 19.64869’’ North 125° 0’ 43.78230’’ East 69.02100 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	719,575.03 meters 1,235,811.61 meters

(a) (b)

Figure 5. GPS set-up over LYT-104 located and re-established along rice paddy trail, approximately 90 meters from the centerline, east side of Pastrana-Santa Fe Road, District IV, Pastrana, Leyte (a) and NAMRIA reference point LYT-104 (b) as recovered by the field team

Table 4. Details of the recovered and re-established NAMRIA horizontal control point LYT-104 used as base station for the LiDAR acquisition.

Station Name	**LYT-104**	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11°08’38.92234” North 124o 53’ 13.52786” East 33.659 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11°08’34.67033” North 124o 53’ 18.69323” East 95.861 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	706089.510m 1232496.838

Figure 6. GPS set-up over SMR-56 at Cabacungan Elementary School in Barangay Cabacungan, Sta. Rita, Samar (a) and NAMRIA reference point SMR-56 (b) as recovered by the field team.

Table 5. Details of the recovered NAMRIA horizontal control point SMR-56 used as base station for the LiDAR acquisition.

Station Name	LYT-101	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11° 23' 6.52702" 125° 0' 23.99607" 11.82200 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	500,727.475 meters 1,258,927.861 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 23' 2.22413" North 125° 0' 29.13917" East 73.72700 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	718,970.61 meters 1,259,244.38 meters

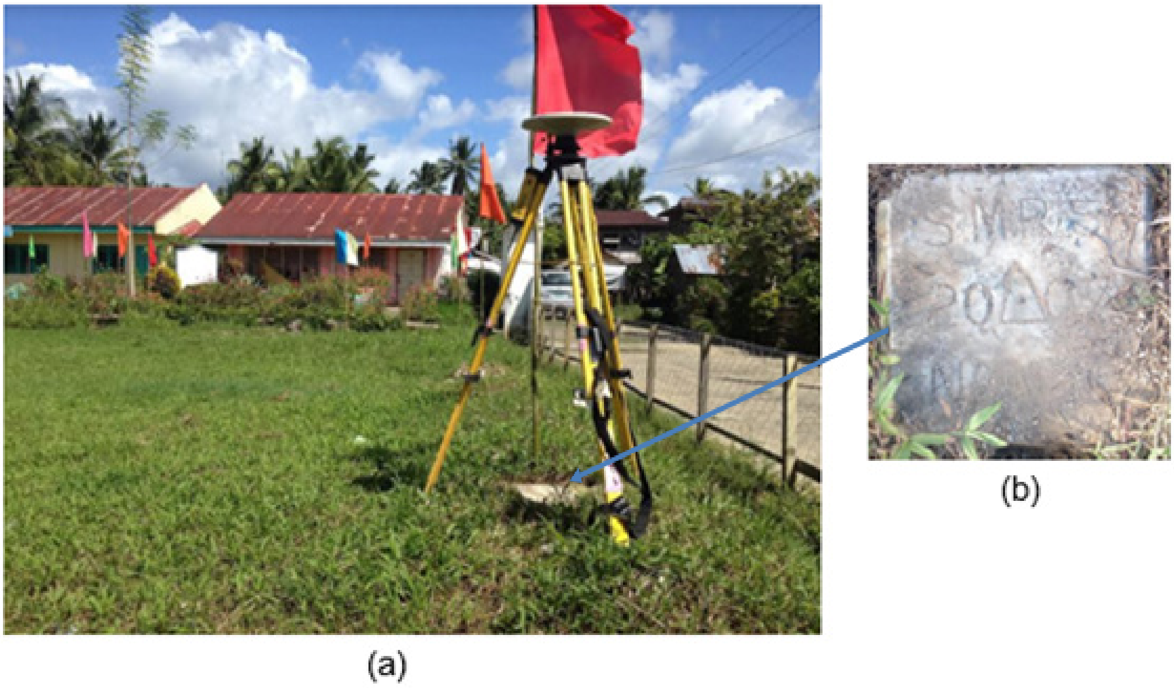

Figure 7. GPS set-up over SMR-58 located inside Serum Elementary School, Brgy. Serum, Basey (a) and NAMRIA reference point SMR-58 (b) as recovered by the field team.

Table 6. Details of the recovered NAMRIA horizontal control point SMR-58 used as base station for the LiDAR acquisition.

Station Name	**LYT-101**	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11o 17’ 55.05617” North 125o 7’ 51.16145” East 6.30062 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	514288.239 meters 1249361.531 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11o 17’ 50.78580” North 125o 7’ 56.31100” East 68.72300 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	732600.57 meters 1249768.75 meters

Figure 8. GPS set-up over LY-110 located along Palo-Pastrana Road, Pastrana, Leyte (a) and NAMRIA reference point LY-110 (b) as recovered by the field team.

Table 7. Details of the recovered NAMRIA vertical control point LY-110 used as base station for the LiDAR acquisition with established coordinates.

Station Name	**LY-110**	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11o 10’ 19.48389” North 124o 57’ 32.98736” East 14.336 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11o 10’ 15.23095” North 124o 57’ 38.14961” East 76.647 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	713,942.863 meters 1,235,638.117 meters

Figure 9. GPS set-up over SM-286 located at Dalid bridge along national highway in Brgy. San Pascual, Sta. Rita, Samar (a) and NAMRIA reference point SM-286 (a) as recovered by the field team.

Table 8. Details of the recovered NAMRIA vertical control point SM-286 used as base station for the LiDAR acquisition with established coordinates.

Station Name	**SM-286**	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11o 24’ 35.73” North 124o 59’ 44.05” East 5.47 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	499516.558 meters 1261668.44 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11o 24’ 30.81671” North 124o 59’ 48.35250” East 67.268 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	717869.251 meters 1261905.903 meters

Figure 10. GPS set-up over SM-309 located at Dalid bridge along national highway in Brgy. San Pascual, Sta. Rita, Samar (a) and NAMRIA reference point SM-309 (a) as recovered by the field team.

Table 9. Details of the recovered NAMRIA vertical control point SM-309 used as base station for the LiDAR acquisition with established coordinates.

Station Name	SM-309	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11o 17' 59.30748" North 125o 06' 56.29744" East 9.743 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11o 17' 55.03553" North 125o 07' 01.44700" East 72.125 meters

Table 10. Details of the established vertical control point PCG-TC used as base station for the LiDAR acquisition with established coordinates.

Station Name	PCG-TC	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11o 14' 48.29466" North 124o 59' 53.38556" East 70.882 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	718,144.536 meters 1,244,004.859 meters

Table 11. Ground control points used during LiDAR data acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
January 25, 2014	1022A	3BLK33BSC025B	LYT-101 and PCG-TC
May 3, 2014	1410A	AQUATACTF123A	SMR-58 and SM-286
May 4, 2014	1414A	AQUATACTF124A	LYT-101 and SMR-56
May 10, 2014	1438A	3BLK34O130A	SMR-56 and SM-286
May 10, 2014	1440A	3BLK34OSP130B	SMR-56 and SM-286
May 11, 2014	1442A	3BLK33GS131A	SMR-56 and SM-286
May 11, 2014	1444A	3BLK33GSH131B	SMR-56 and SM-286
May 13, 2014	1450A	3BLK33HS133A	SMR-56 and SM-286
May 13, 2014	1452A	3BLK33HSES133B	SMR-56 and SM-286
February 7, 2015	7786AC	3BLK34A038A	SMR-56 and SM-286
February 13, 2015	7798AC	3BLK34AV44A	SMR-56 and SM-286
January 23, 2016	3769G/3703G	2BLK34ADEG023A	LYT-104 and LY-110
January 31, 2016	3733G	2BLK33ABLK34L031A	SMR-58 and SM-309
February 5, 2016	3753G	2BLK34K33AB036A	SMR-58 and SM-309
February 6, 2016	3757G	2BLK34K037A	SMR-58 and SM-309

2.3 Flight Missions

Fifteen (15) missions were conducted to complete the LiDAR Data Acquisition in Basey Floodplain, for a total of fifty-six hours and fifty-three minutes (56+53) of flying time for RP-C9122 and RP-C9022. The missions were acquired using the Aquarius and Gemini LiDAR systems. Table 12 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 13 shows the actual parameters used during the LiDAR data acquisition.

Table 12. Flight missions for LiDAR data acquisition in Basey Floodplain.

Date Surveyed	Flight Number	Flight Plan Area (km2)	Surveyed Area (km2)	Area Surveyed within the Floodplain (km2)	Area Surveyed outside the Floodplain (km2)	No. of Images (Frames)	Flying Hour	
							Hr	Min
January 25, 2014	1022A	221.76	181.39	59.30	122.09	1302	4	11
May 3, 2014	1410A	196.15	128.42	17.14	111.28	772	4	47
May 4, 2014	1414A	196.15	68.14	5.91	62.23	649	3	11
May 10, 2014	1438A	169.29	157.72	32.18	125.54	1855	4	41
May 10, 2014	1440A	335.45	316.16	59.92	256.24	989	3	11
May 11, 2014	1442A	166.16	150.41	47.33	103.08	1536	4	47
May 11, 2014	1444A	400.01	123.22	14.46	108.76	1290	4	35
May 13, 2014	1450A	233.85	53.06	0.62	52.44	507	2	23
May 13, 2014	1452A	430.00	76.69	NA	76.69	819	3	53
February 7, 2015	7786AC	90.76	92.34	1.65	90.69	NA	4	23
February 13, 2015	7798AC	90.76	60.82	0.57	60.25	NA	3	11
January 23, 2016	3703G/ 3769G	101.63	167.12	NA	167.12	NA	3	29
January 31, 2016	3733G	54.18	248.73	166.37	82.36	NA	2	59
February 5, 2016	3753G	96.91	93.62	10.36	83.26	NA	4	17
February 6, 2016	3757G	96.91	77.95	12.83	65.12	NA	2	55
TOTAL		2879.97	1995.75	428.64	1567.15	9719	56	53

Table 13. Actual parameters used during LiDAR data acquisition.

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes
1022A	700	40	50	70	40	130	5
1410A	700	40	36	50	50	130	5
1414A	700	40	36	50	50	130	5
1438A	600	40	44	50	45	130	5
1440A	600	40	44	50	45	130	5
1442A	700	40	36	50	50	130	5
1444A	700	40	36	50	50	130	5
1450A	700	40	36	50	50	130	5
1452A	700	40	36	50	50	130	5
7786AC	600	40	36	50	45	130	5
7798AC	700	40	36	50	45	130	5
3703G/ 3769G	1200	30	34	100	50	130	5
3733G	900	30	40	100	50	130	5
3753G	900	30	40	100	50	130	5
3757G	1100	30	36	100	50	130	5

2.4 Survey Coverage

Basey floodplain is located in the province of Samar with majority of the floodplain situated within the municipality of Basey. The list of city and municipalities surveyed, with at least one (1) square kilometer coverage, is shown in Table 14. The actual coverage of the LiDAR acquisition for Basey floodplain is presented in Figure 11.

Table 14. List of municipalities and cities surveyed during Basey floodplain LiDAR survey

Province	Municipality/City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Eastern Samar	Balangiga	206.52	66.09	32.00%
	Lawaan	141.75	11.32	7.99%
Leyte	Abuyog	256.64	17.33	6.75%
	Alangalang	145.45	1.71	1.18%
	Babatngon	136.57	95.34	69.81%
	Burauen	205.31	59.9	29.18%
	Dagami	134.08	31.43	23.44%
	Dulag	63.65	4.85	7.62%
	Julita	57.17	11.71	20.48%
	Palo	65.34	9.94	15.21%
	Pastrana	79.17	15.51	19.59%
	San Miguel	103.86	12.27	11.81%
	Santa Fe	57.15	12.42	21.73%
	Tabontabon	20.46	7.1	34.70%
	Tacloban City	118.46	39.28	33.16%
Samar	Basey	627.97	291.2	46.37%
	Daram	109.26	3.16	2.89%
	Marabut	148.82	8.77	5.89%
	Pinabacdao	118.38	20.04	16.93%
	Santa Rita	250.37	230.79	92.18%
	Talalora	26.56	25.73	96.88%
	Villareal	130.22	126.08	96.82%
Total		3203.16	1101.97	34.40%

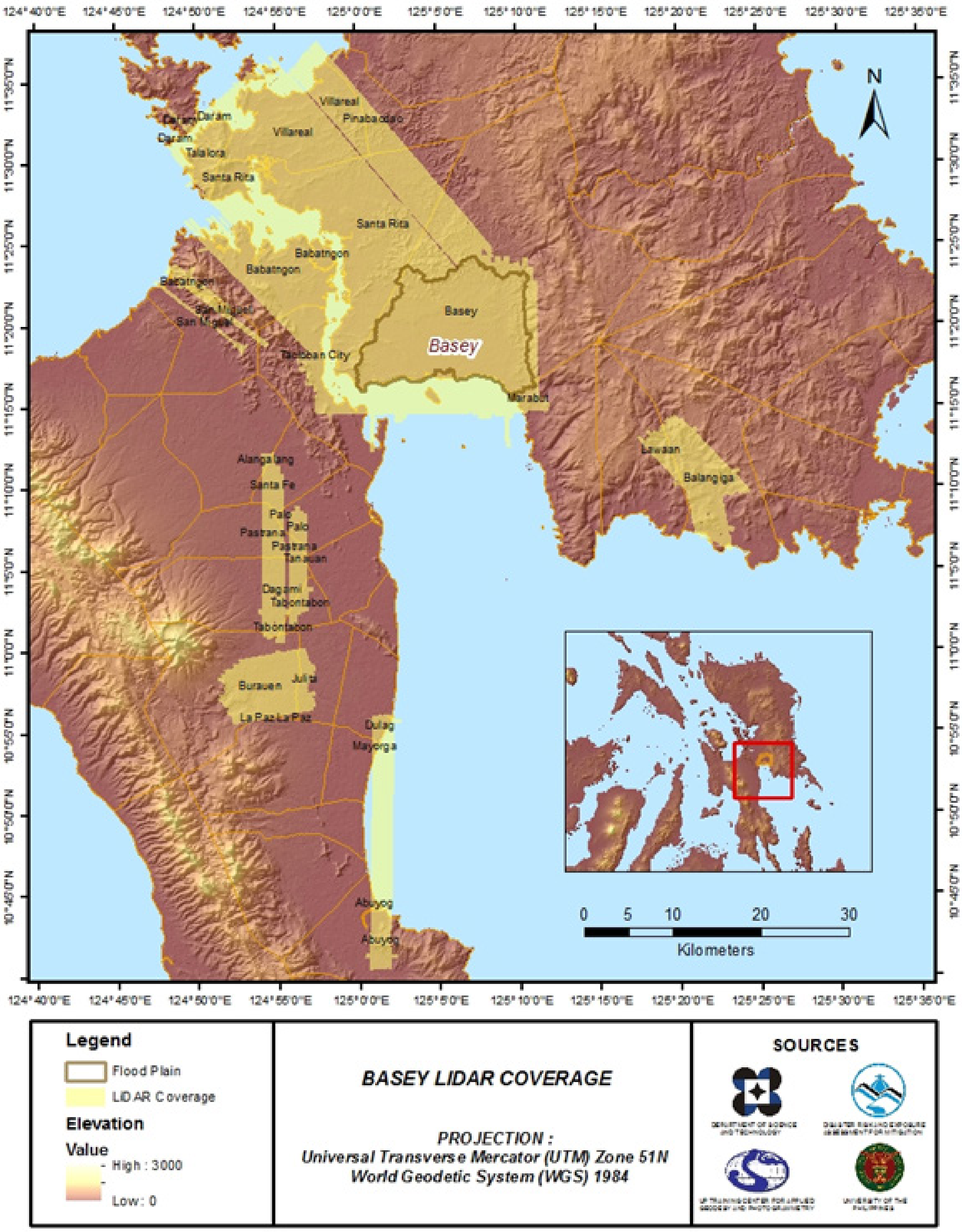

Figure 11. Actual LiDAR survey coverage for Basey Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE BASEY FLOODPLAIN

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

3.1 Overview of the LiDAR Data Pre-Processing

The data transmitted by the 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 12.

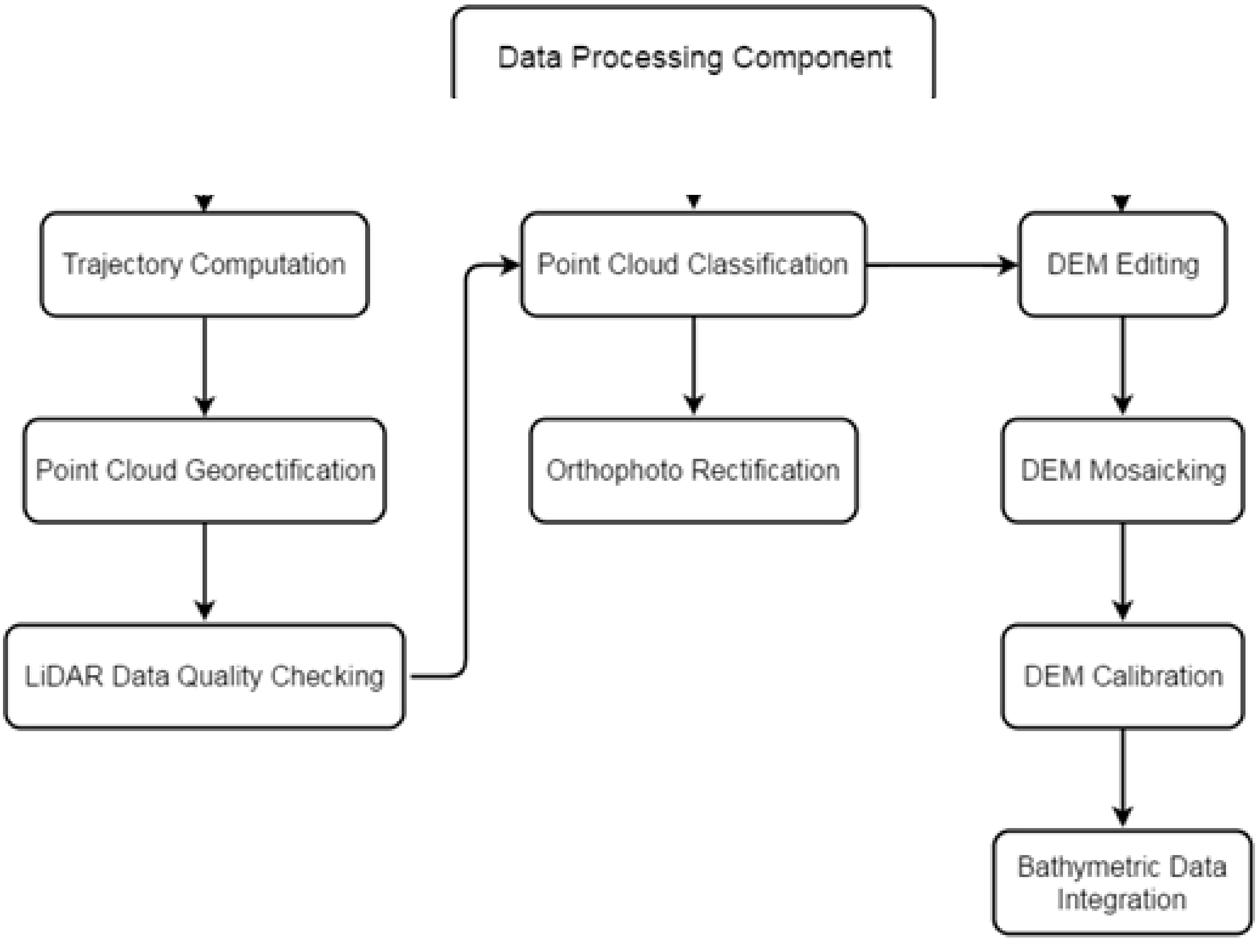

Figure 12. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Basey floodplain can be found in Annex 5. Data Transfer Sheets. Missions flown during the first survey conducted on January 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Aquarius system while missions acquired during the second survey on January 2016 were flown using the Gemini system over Basey, Samar. The Data Acquisition Component (DAC) transferred a total of 223.36 Gigabytes of Range data, 3.54 Gigabytes of POS data, 189.05 Megabytes of GPS base station data, and 625.5 Gigabytes of raw image data to the data server on May 28, 2014 for the first survey and February 26, 2016 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Basey was fully transferred on

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 1442A, one of the Basey flights, which is the North, East, and Down position RMSE values are shown in Figure 13. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on May 11, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

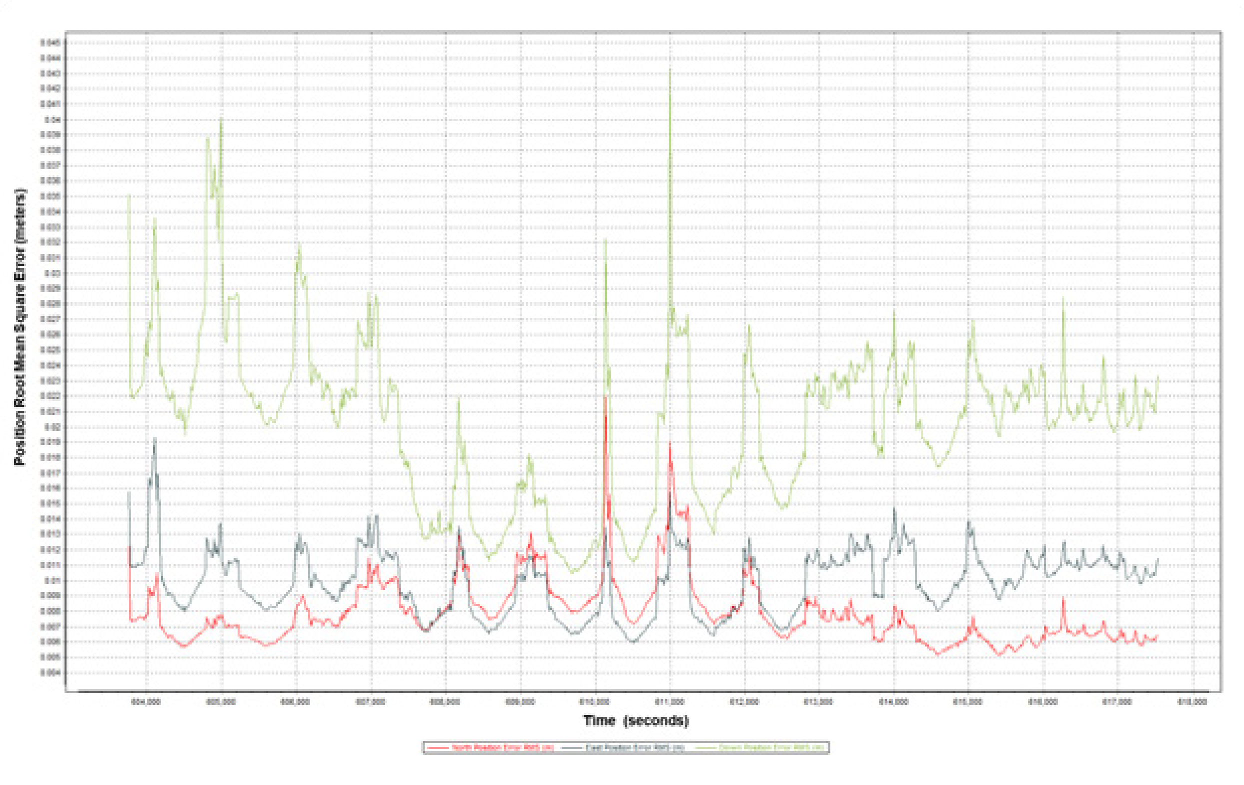

Figure 13. Smoothed Performance Metrics of a Basey Flight 1442A.

The time of flight was from 604,000 seconds to 618,000 seconds, which corresponds to afternoon of May 11, 2014. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 13 shows that the North position RMSE peaks at 2.20 centimeters, the East position RMSE peaks at 1.60 centimeters, and the Down position RMSE peaks at 4.30 centimeters, which are within the prescribed accuracies described in the methodology.

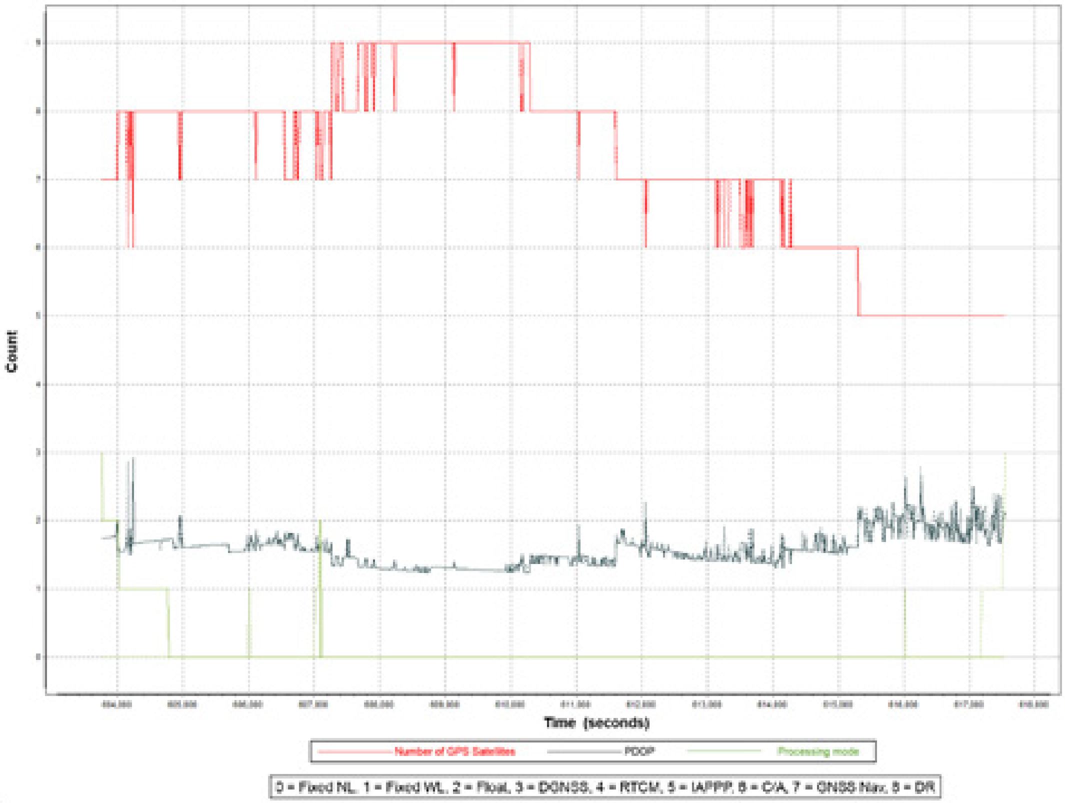

Figure 14. Solution Status Parameters of Basey Flight 1442A.

The Solution Status parameters of flight 1442A, one of the Basey flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 14. The graphs indicate that the number of satellites during the acquisition did not go down to 5. Majority of the time, the number of satellites tracked was between 5 and 9. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 1 and 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 Basey flights is shown in Figure 15.

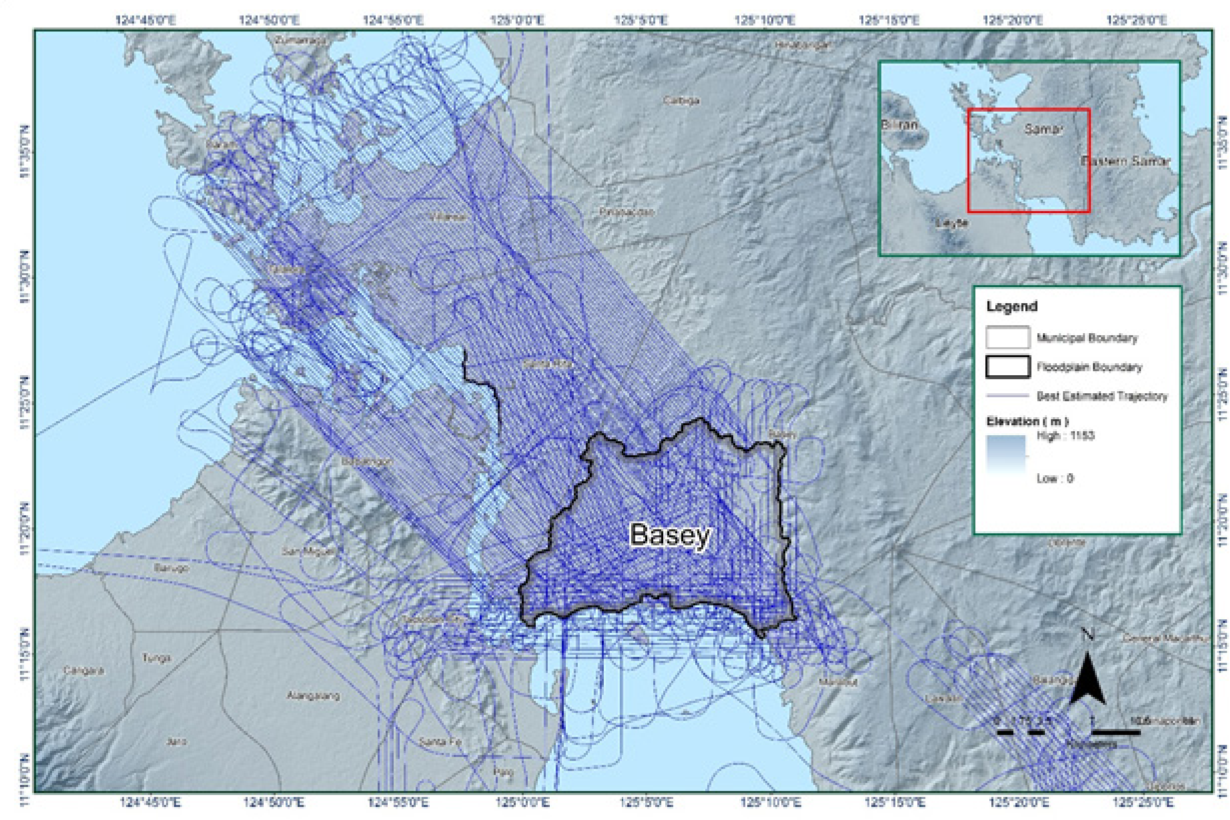

Figure 15. Best Estimated Trajectory for Basey Floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 217 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 Basey floodplain are given in Table 15

Table 15. Self-Calibration Results values for Basey flights.

Parameter	Acceptable Value	Computed Value
Boresight Correction stdev	(<0.001degrees)	0.000310
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.000915
GPS Position Z-correction stdev	(<0.01meters)	0.0027

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

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Basey Floodplain is shown in Figure 16. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

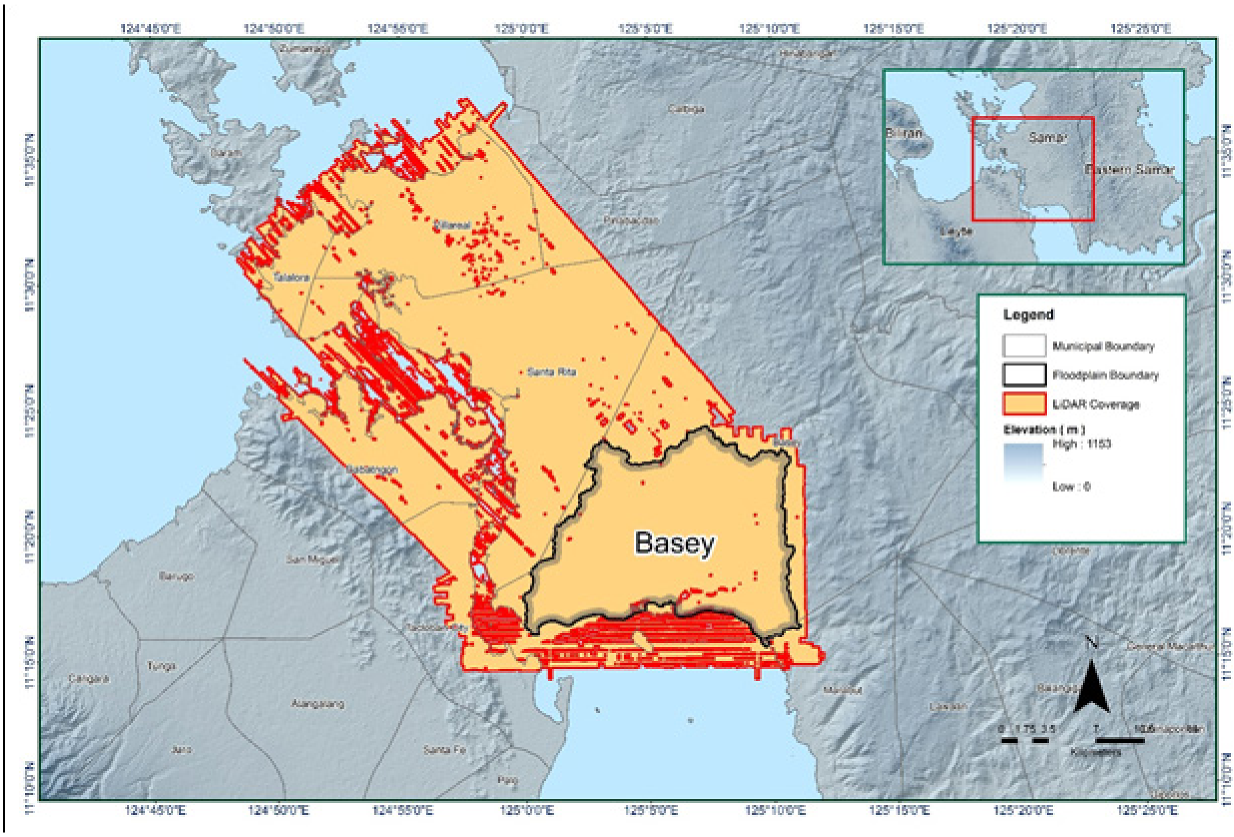

Figure 16. Boundary of the processed LiDAR data over Basey Floodplain

The total area covered by the Basey missions is 1388.42 sq.km that is comprised of sixteen (16) flight acquisitions grouped and merged into twelve (12) blocks as shown in Table 16.

Table 13. Shift values of each LiDAR Block of Basey Floodplain

LiDAR Blocks	Flight Numbers	Area (sq. km.)
Samar_Leyte_Blk33H	1444A	183.22
	1450A	
	1452A	
Samar_Leyte_Blk33G	1440A	222.63
	1442A	
Samar_Leyte_Blk33F	1438A	225.06
	1440A	
Samar_Leyte_Blk33E_additional	1410A	98.82
Samar_Leyte_Blk33E	1414A	93.33
	1452A	
Leyte_Blk33F	3753G	103.33
	3757G	
Leyte_Blk33E	3731G	84.72
	3733G	
Leyte_Blk33E_additional	3769G	8.32
Leyte_Blk33G	3731G	126.91
Ormoc_Blk34AX_additional	7798AC	5.78
Ormoc_Blk34AX	7786AC	93.56
	7798AC	
Tacloban_1022A	1022A	142.74
TOTAL		**1388.42**

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 17. 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.

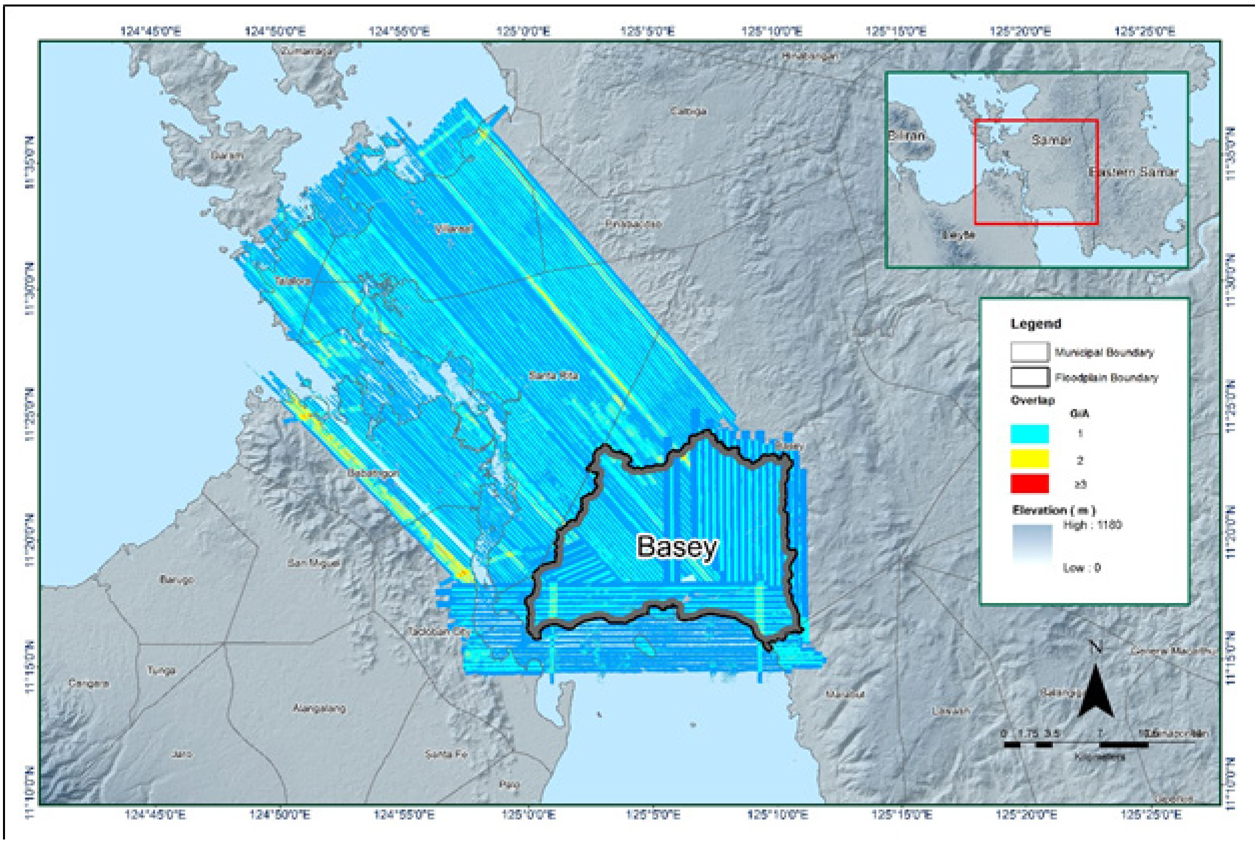

Figure 17. Image of data overlap for Basey Floodplain.

The overlap statistics per block for the Basey floodplain can be found in Annex 8. Mission Summary Reports. It should be noted that one pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 25.09% and 46.76% respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 18. It was determined that all LiDAR data for Basey floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.08 points per square meter.

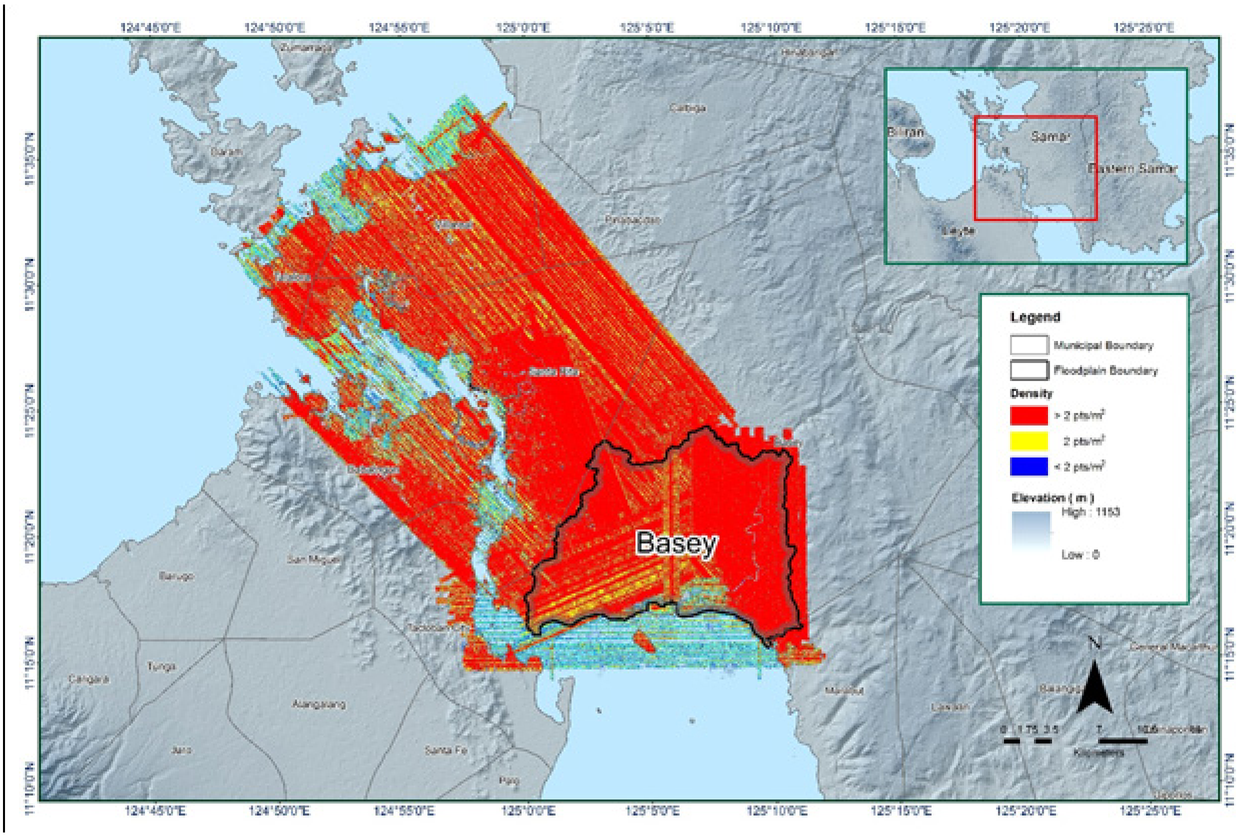

Figure 18. Pulse density map of merged LiDAR data for Basey Floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 19. 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.

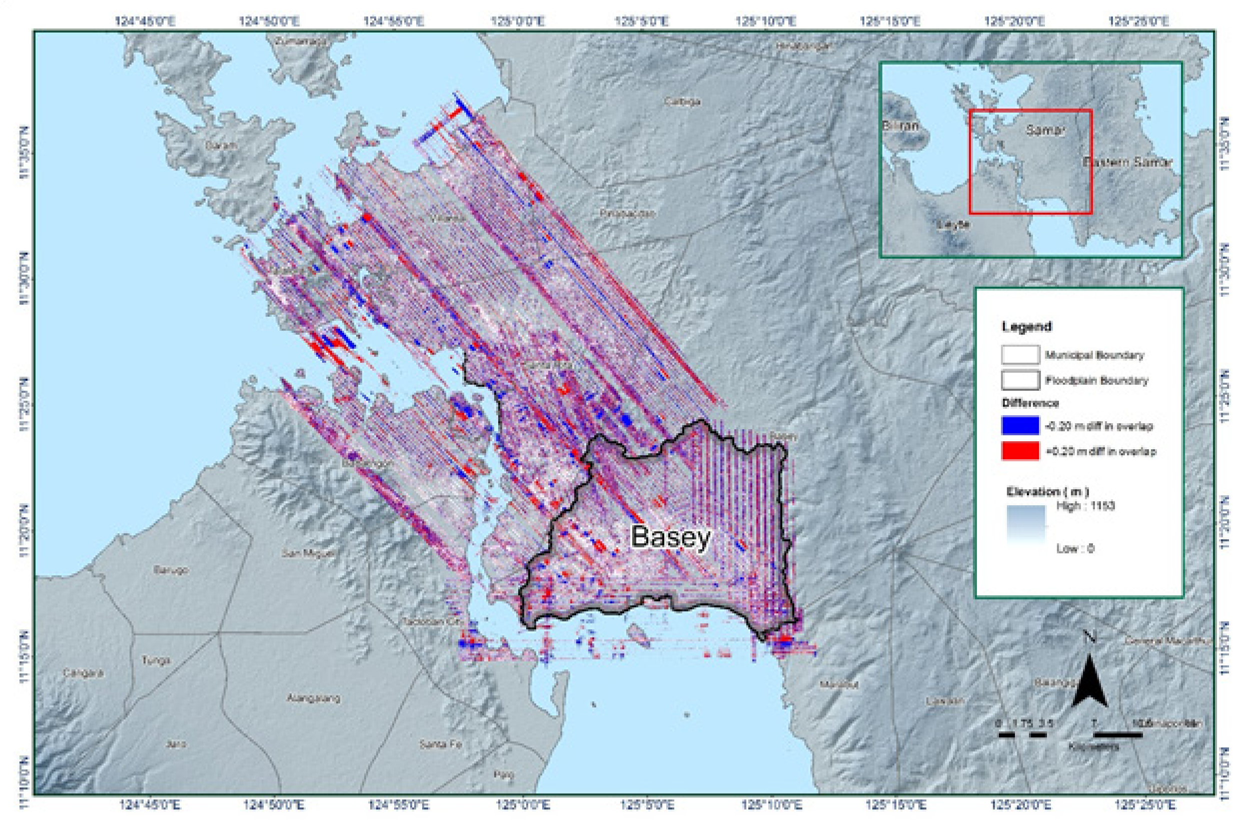

Figure 19. Elevation difference map between flight lines for Basey Floodplain.

A screen capture of the processed LAS data from a Basey flight 1442A loaded in QT Modeler is shown in Figure 20. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed yellow line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

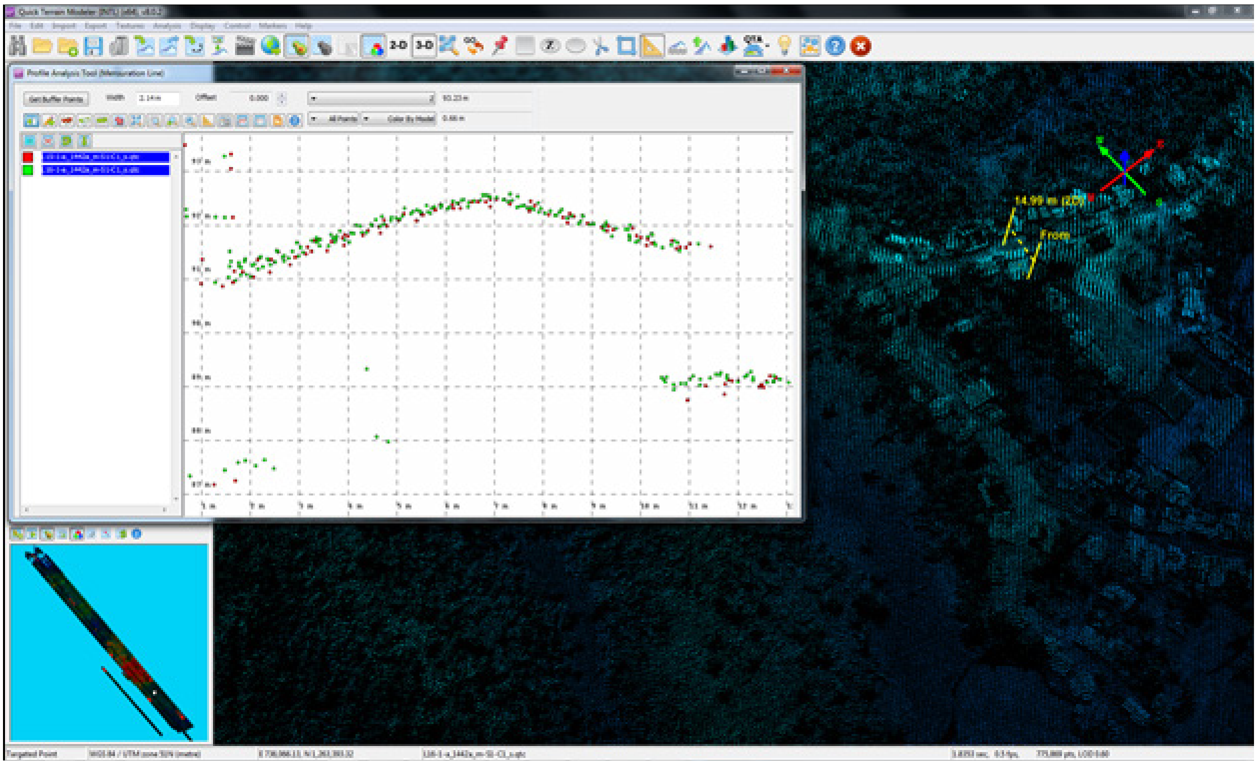

Figure 20. Quality checking for a Basey flight 1442A using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 17. Basey classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	706,274,194
Low Vegetation	490,619,269
Medium Vegetation	1,679,694,257
High Vegetation	1,334,876,725
Building	22,528,349

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Basey floodplain is shown in Figure 21. A total of 2,120 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 17. The point cloud has a maximum and minimum height of 878.23 meters and 25.54 meters.

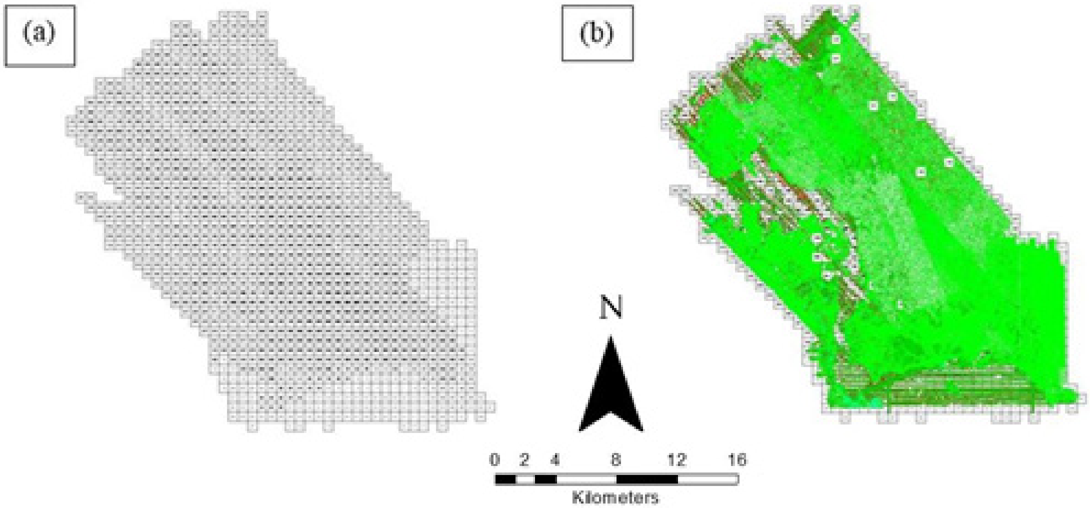

Figure 21. Tiles for Basey Floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 22. The ground points are in orange, the vegetation is in different shades of green, and the buildings are in cyan. It can be seen that residential structures adjacent or even below canopy are classified correctly, due to the density of the LiDAR data.

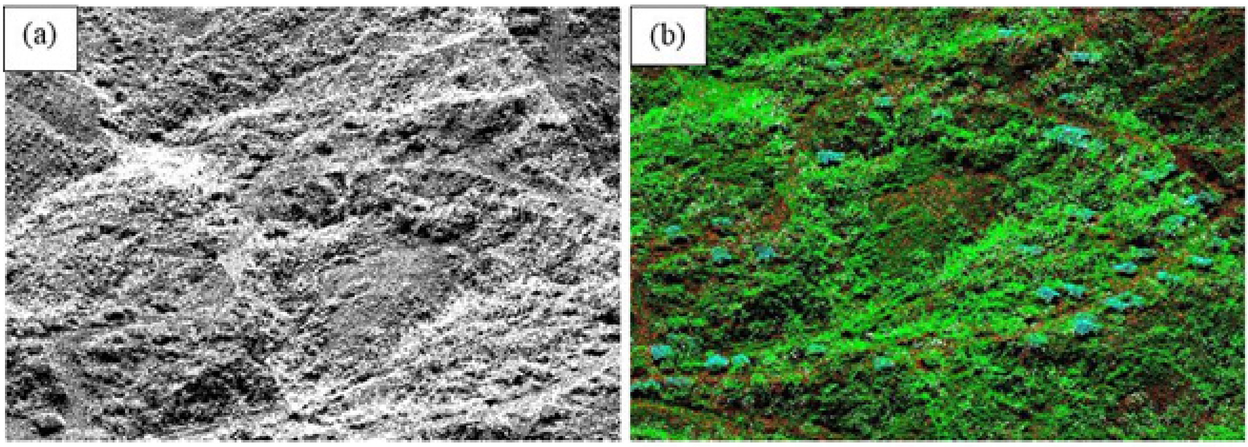

Figure 22. Point cloud before (a) and after (b) classification.

The production of last return (V_ASCII) and the secondary (T_ ASCII) DTM, first (S_ ASCII) and last (D_ ASCII) return DSM of the area in top view display are shown in Figure 23. It shows that DTMs are the representation of the bare earth while on the DSMs, all features are present such as buildings and vegetation.

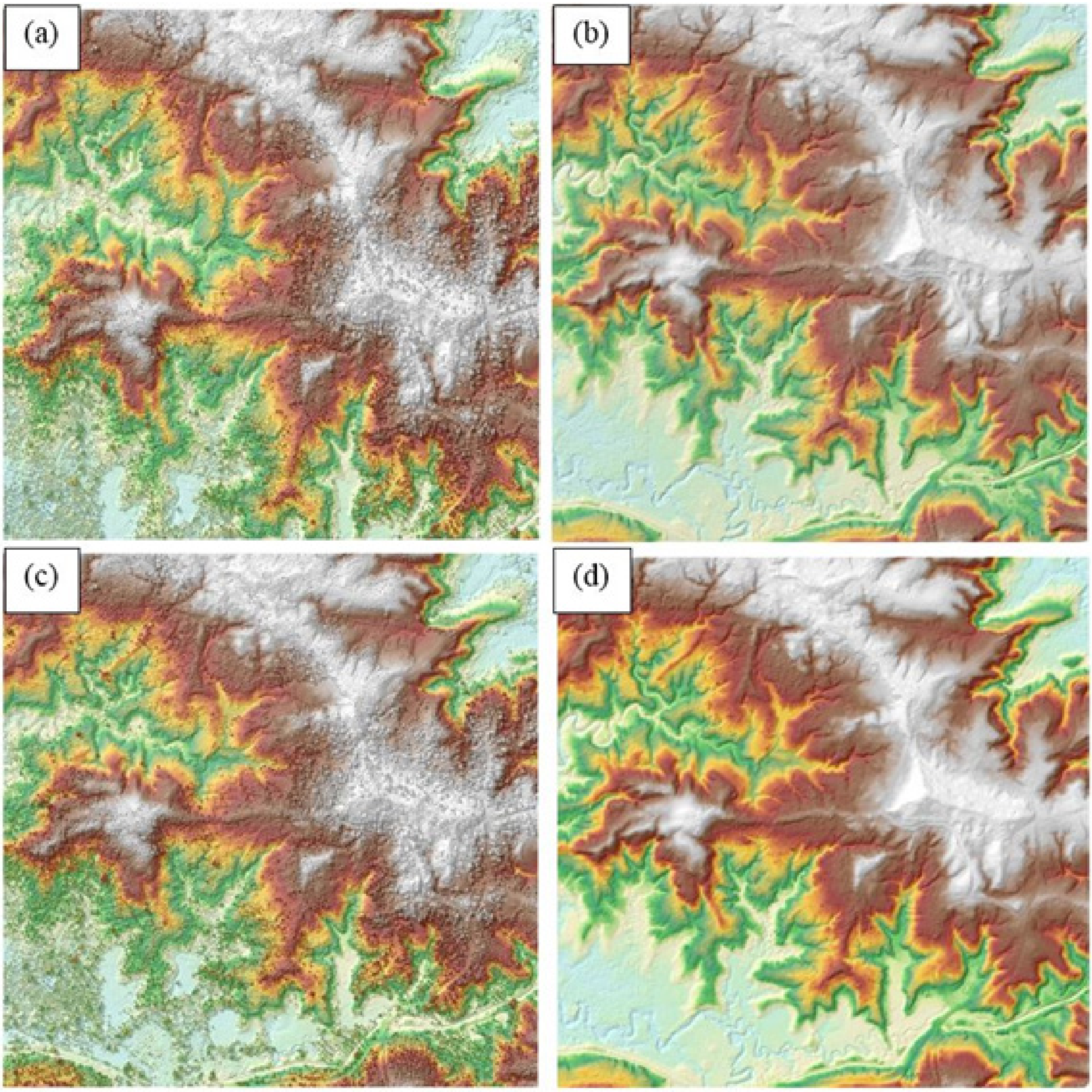

Figure 23. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Basey Floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 2,096 1km by 1km tiles area covered by Basey floodplain is shown in Figure 24. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Basey floodplain has a total of 774.01 sq.km orthophotogaph coverage comprised of 9,549 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 25.

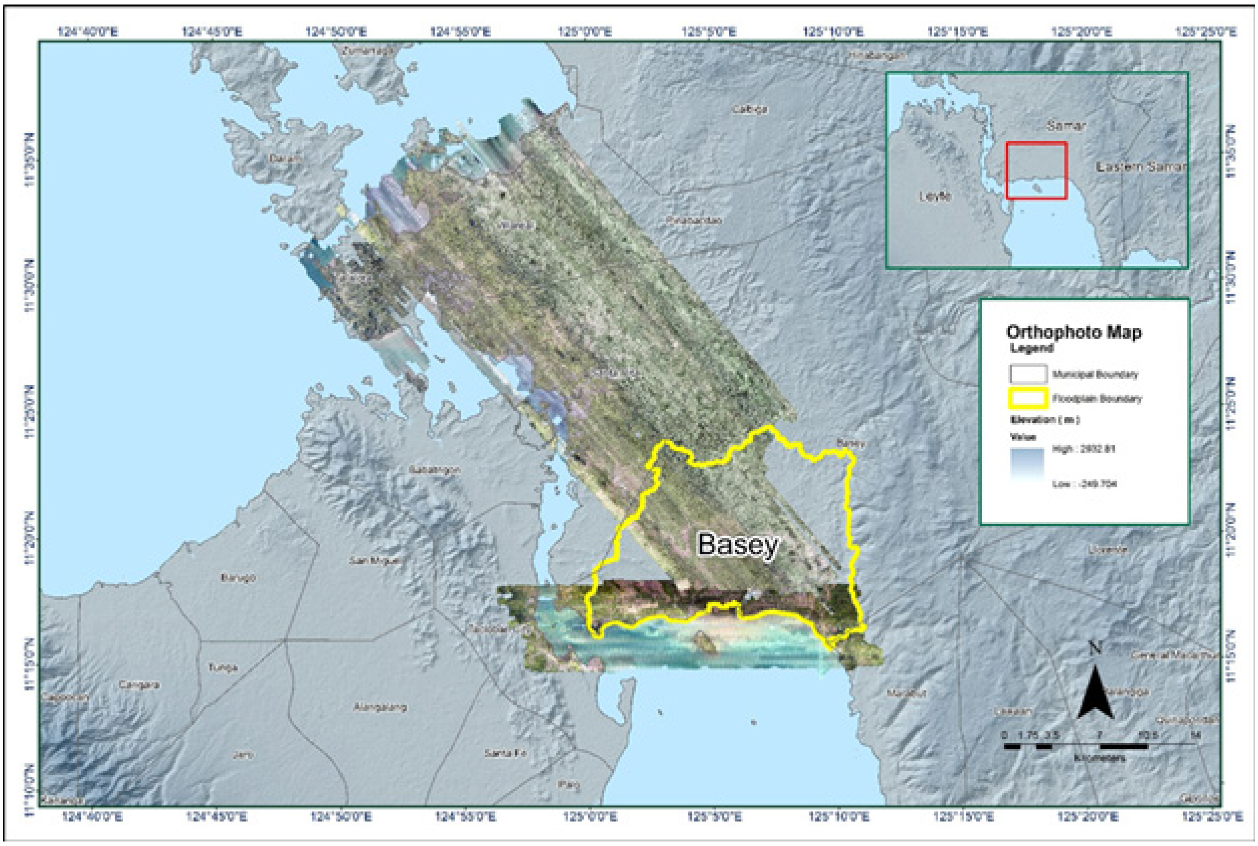

Figure 24. Basey floodplain with available orthophotographs.

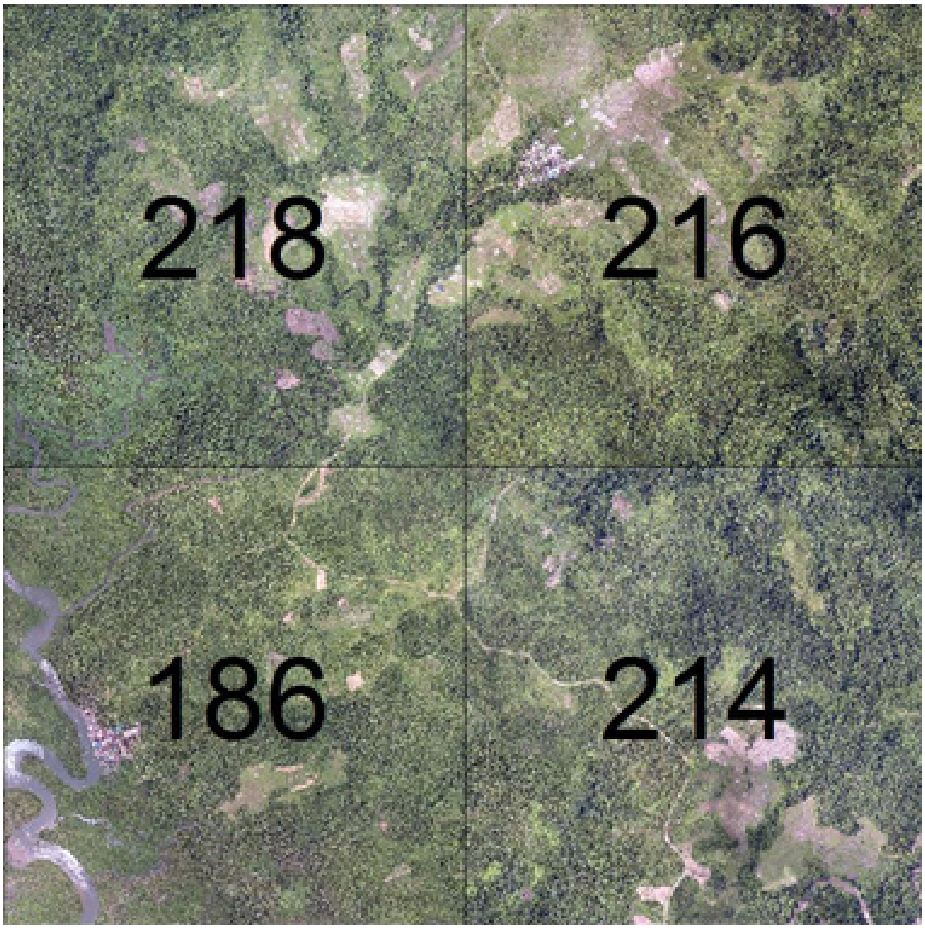

Figure 25. Sample orthophotograph tiles for Basey floodplain.

3.8 DEM Editing and Hydro-Correction

Twelve (12) mission blocks were processed for Basey flood plain. These blocks are composed of the Tacloban DEM, SamarLeyte and Leyte blocks with a total area of 1388.42 square kilometers. Table 18 shows the name and corresponding area of each block in square kilometers.

Table 18. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq.km)
Samar_Leyte_Blk33H	183.22
Samar_Leyte_Blk33G	222.63
Samar_Leyte_Blk33F	225.06
Samar_Leyte_Blk33E_additional	98.82
Samar_Leyte_Blk33E	93.33
Leyte_Blk33F	103.33
Leyte_Blk33E	84.72
Leyte_Blk33E_additional	8.32
Leyte_Blk33G	126.91
Ormoc_Blk34AX_additional	5.78
Ormoc_Blk34AX	93.56
Tacloban_1022A	142.74
TOTAL	1388.42

Portions of DTM before and after manual editing are shown in Figure 26. The bridge and other misclassified objects on the river (Figure 26a) are considered to be impedances to the flow of water and has to be removed (Figure 26b) in order to hydrologically correct the river. Areas with no data on the river (Figure 26c) and other locations in the flood plain (Figure 26d) has to be removed through manual editing.

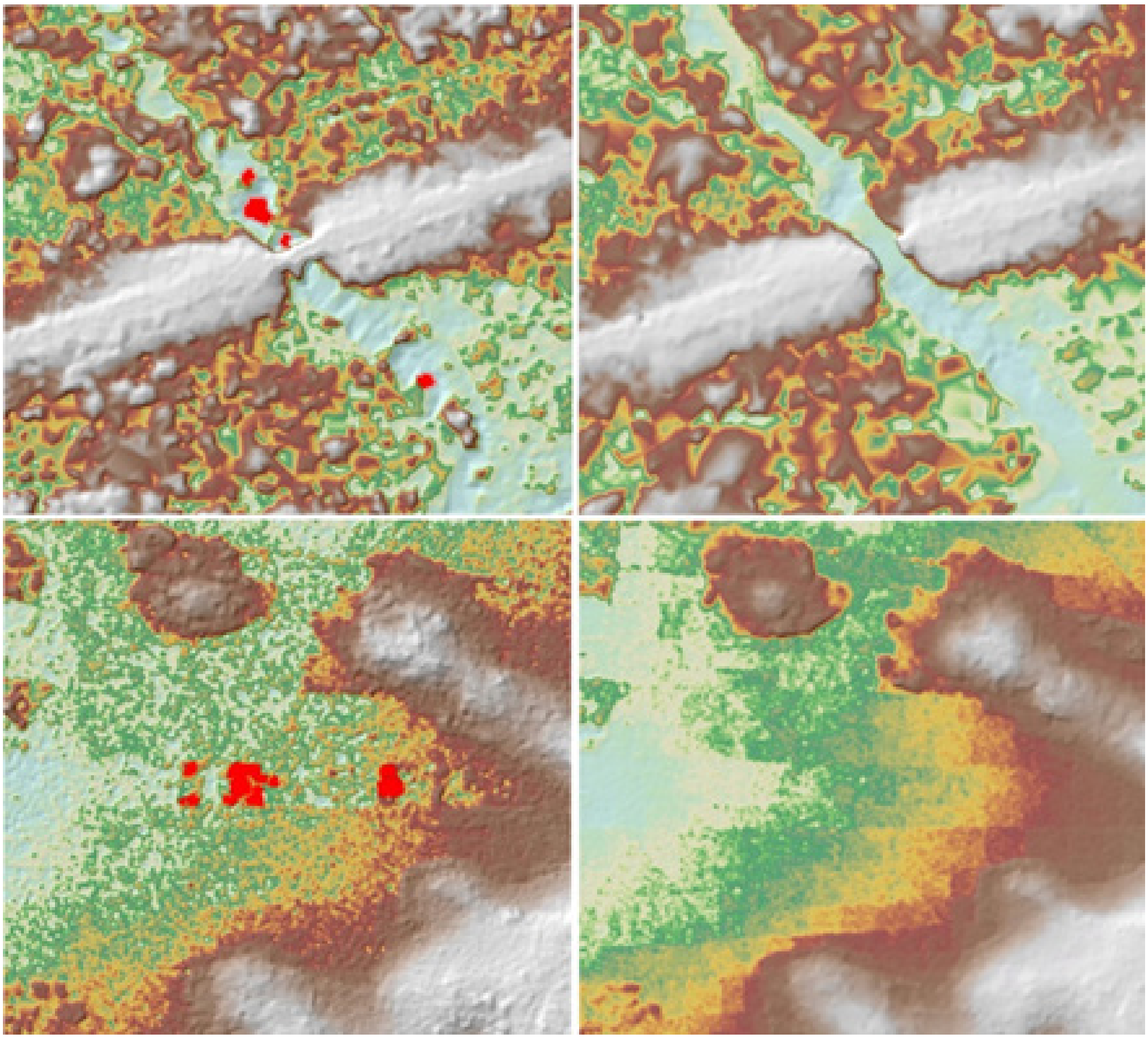

Figure 26. Portions in the DTM of Basey floodplain – a bridge and other obstructions on the river before (a) and after (b) manual editing; a flat area near the river before (c) and after (d) manual editing.

3.9 Mosaicking of Blocks

No assumed reference block was used in mosaicking because the identified reference for shifting was an existing calibrated Tacloban DEM overlapping with the blocks to be mosaicked. Table 19 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Basey floodplain is shown in Figure 27. It can be seen that the entire Basey floodplain is 100% covered by LiDAR data.

Table 19. Shift Values of each LiDAR Block of Basey floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Tacloban_1022A	0.00	0.00	0.00
Ormoc_Blk34AX	0.00	0.00	-0.33
Ormoc_Blk34AX_additional	0.00	0.00	-0.33
SamarLeyte_Blk33F	0.00	0.00	-0.62
SamarLeyte_Blk33G	0.00	0.00	-0.62
SamarLeyte_Blk33H	1.00	0.00	-0.62
SamarLeyte_Blk33E_additional	0.00	0.00	-0.36
SamarLeyte_Blk33E	0.00	0.00	-0.54
Leyte_Blk33E_additional	1.00	0.00	-4.64
Leyte_Blk33G	0.00	0.00	-1.12
Leyte_Blk33E	5.00	0.00	-4.49
Leyte_Blk33F	-1.00	1.00	-4.56

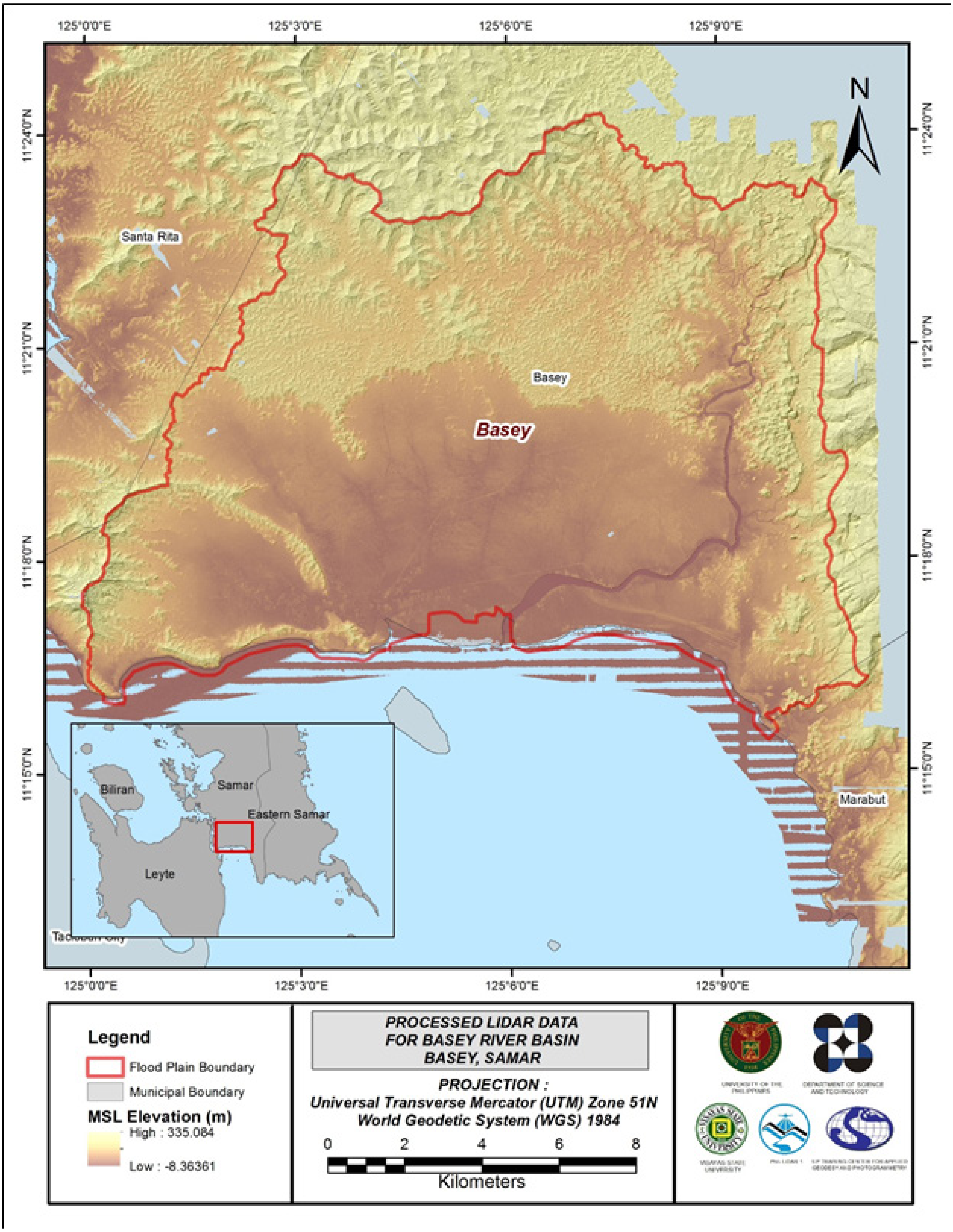

Figure 27. Map of Processed LiDAR Data for Basey Floodplain.

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Basey to collect points with which the LiDAR dataset is validated is shown in Figure 28. A total of 28,096 survey points were gathered for all the floodplains within Eastern and Western Samar wherein the Basey is located. However, the point dataset was not used for the calibration of the LiDAR data for Basey because during the mosaicking process, each LiDAR block was referred to the calibrated Tacloban DEM. Therefore, the mosaicked DEM of Basey can already be considered as a calibrated DEM.

A good correlation between the uncalibrated Tacloban LiDAR DTM and ground survey elevation values is shown in Figure 29. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration points is 0.14 meters with a standard deviation of 0.13 meters. Calibration of Tacloban LiDAR data was done by subtracting the height difference value, 0.14 meters, to Tacloban mosaicked LiDAR data. Table 20 shows the statistical values of the compared elevation values between Tacloban LiDAR data and calibration data. These values were also applicable to the Basey DEM.

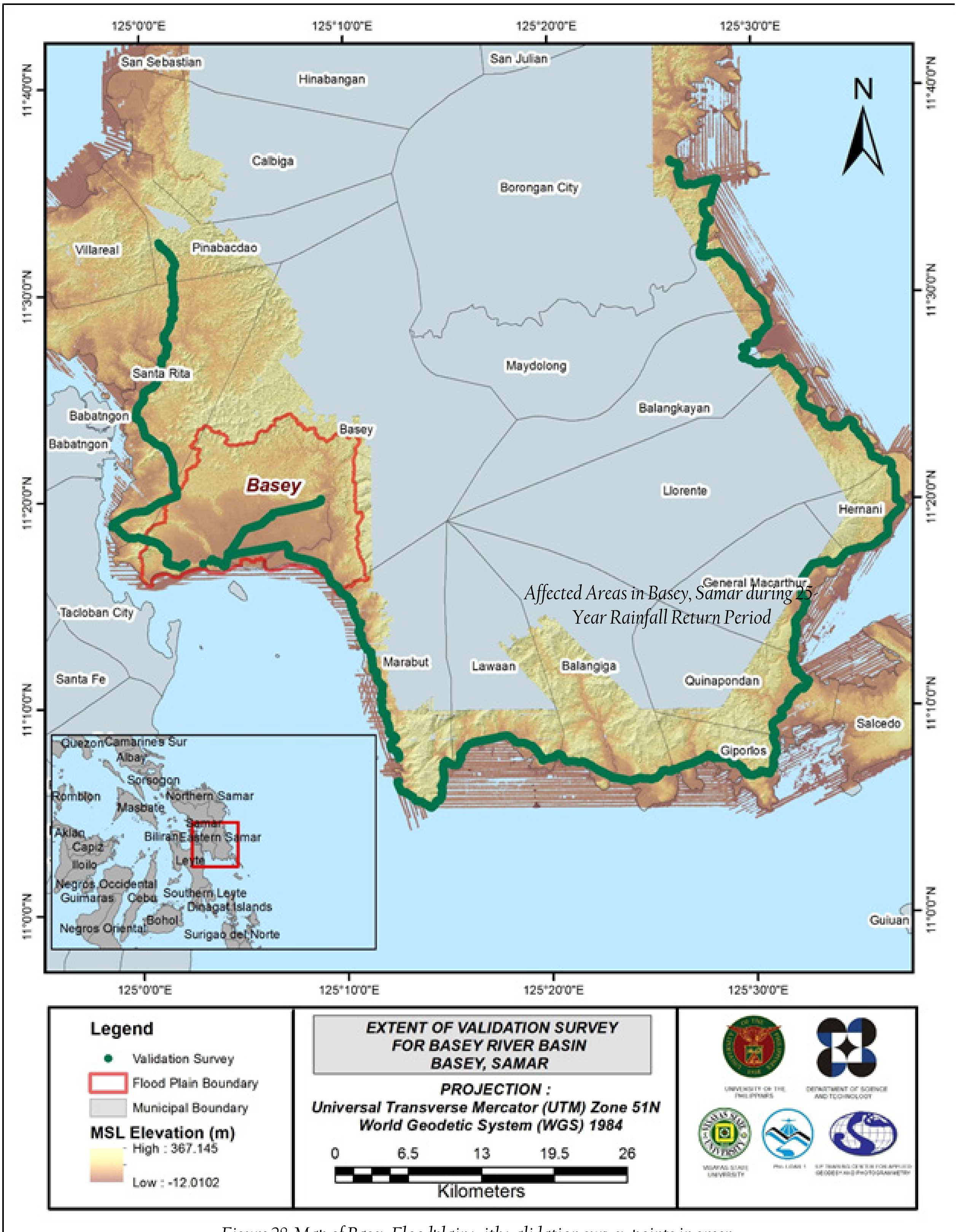

Figure 28. Map of Basey Floodplain with validation survey points in green.

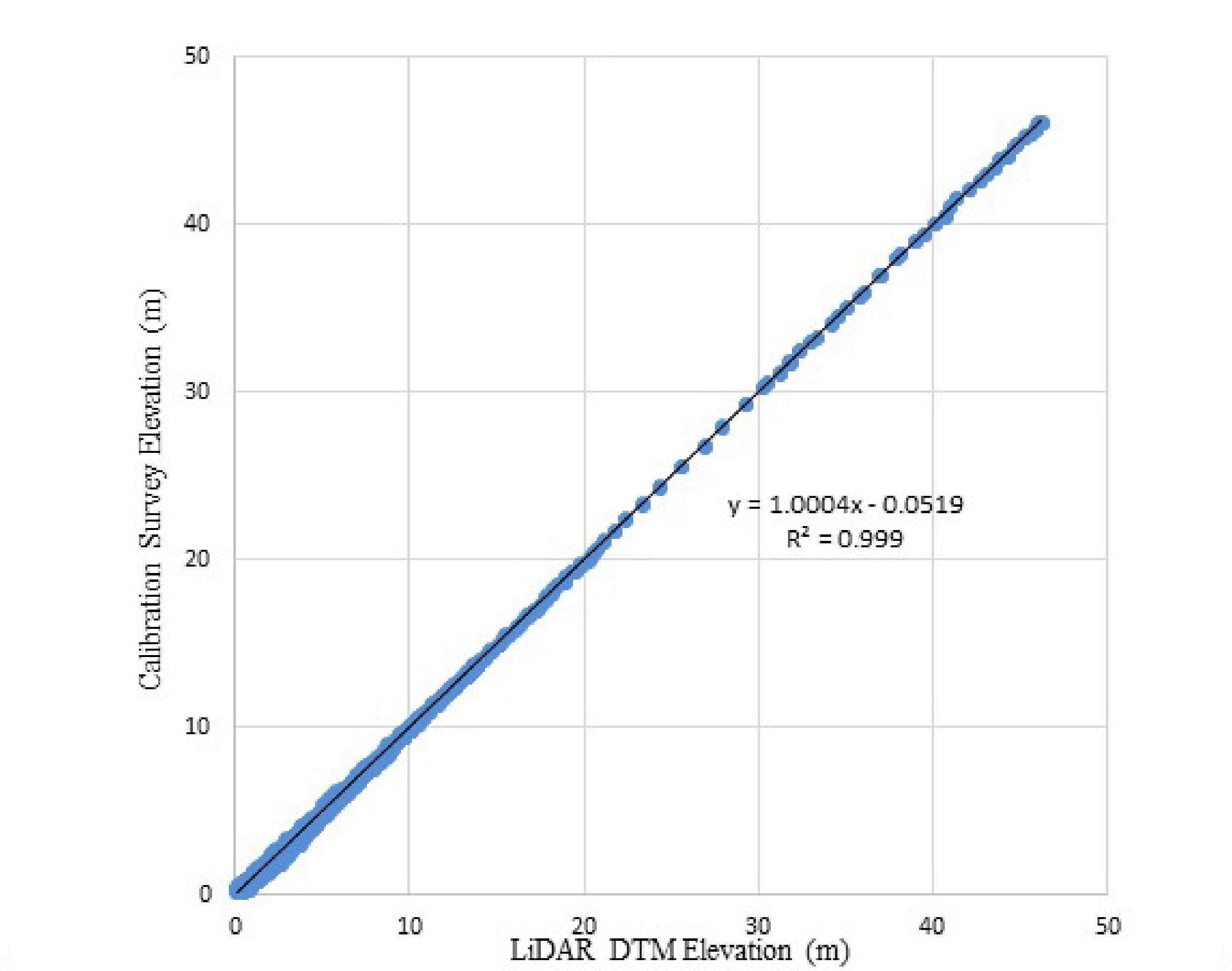

Figure 29. Correlation plot between calibration survey points and LiDAR data

Table 20. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	1.28
Standard Deviation	0.19
Average	1.27
Minimum	0.89
Maximum	1.64

A total of 4,323 survey points lie within the Basey flood plain and were used for the validation of the calibrated Basey 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 30. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.17 meters with a standard deviation of 0.16 meters, as shown in Table 21.

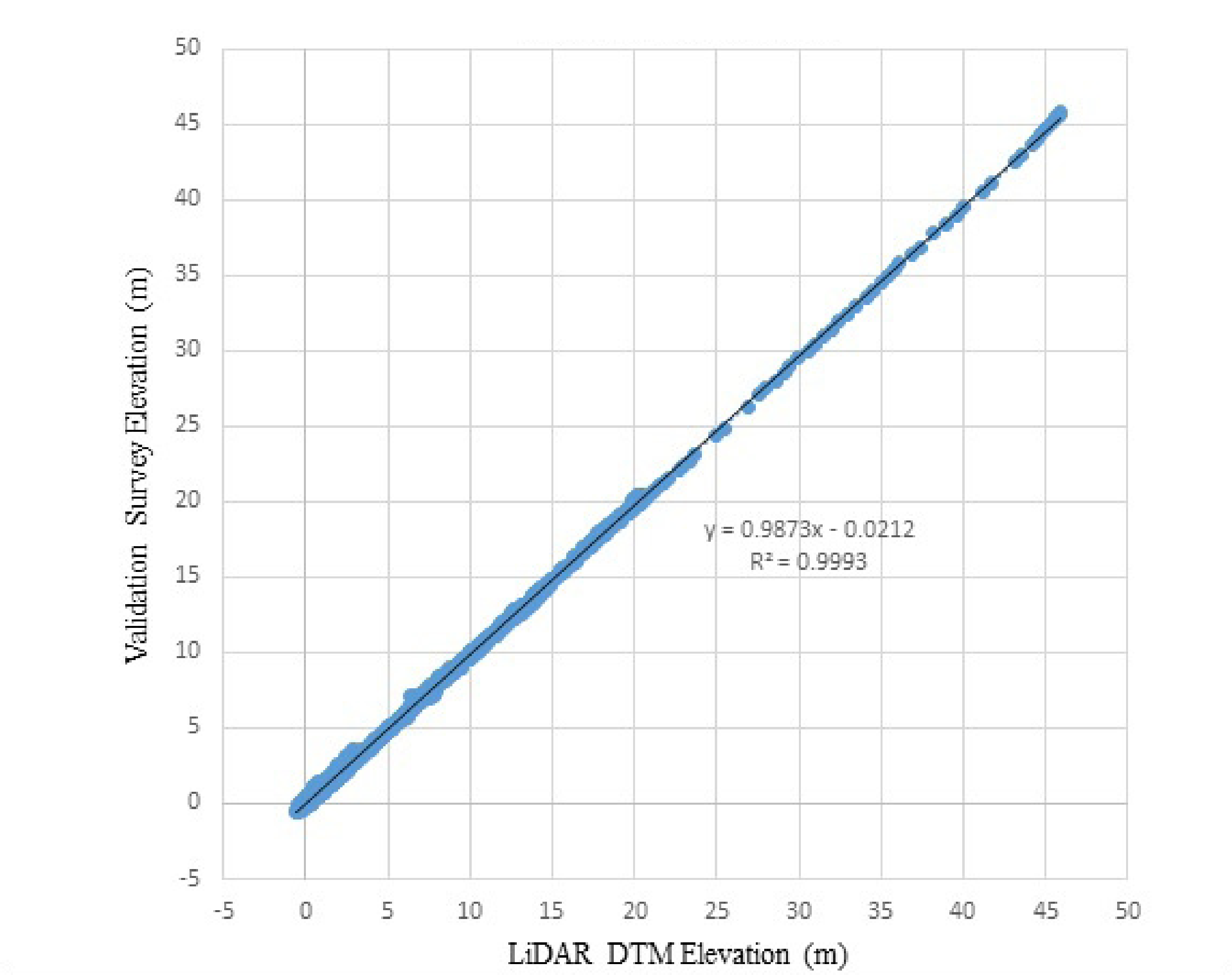

Figure 30. Correlation plot between validation survey points and LiDAR data.

Validation Statistical Measures	Value (meters)
RMSE	0.17
Standard Deviation	0.16
Average	-0.07
Minimum	-0.63
Maximum	0.76

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data was available for Basey with 866 bathymetric survey points. The resulting raster surface produced was done by Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.0067 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Basey integrated with the processed LiDAR DEM is shown in Figure 31.

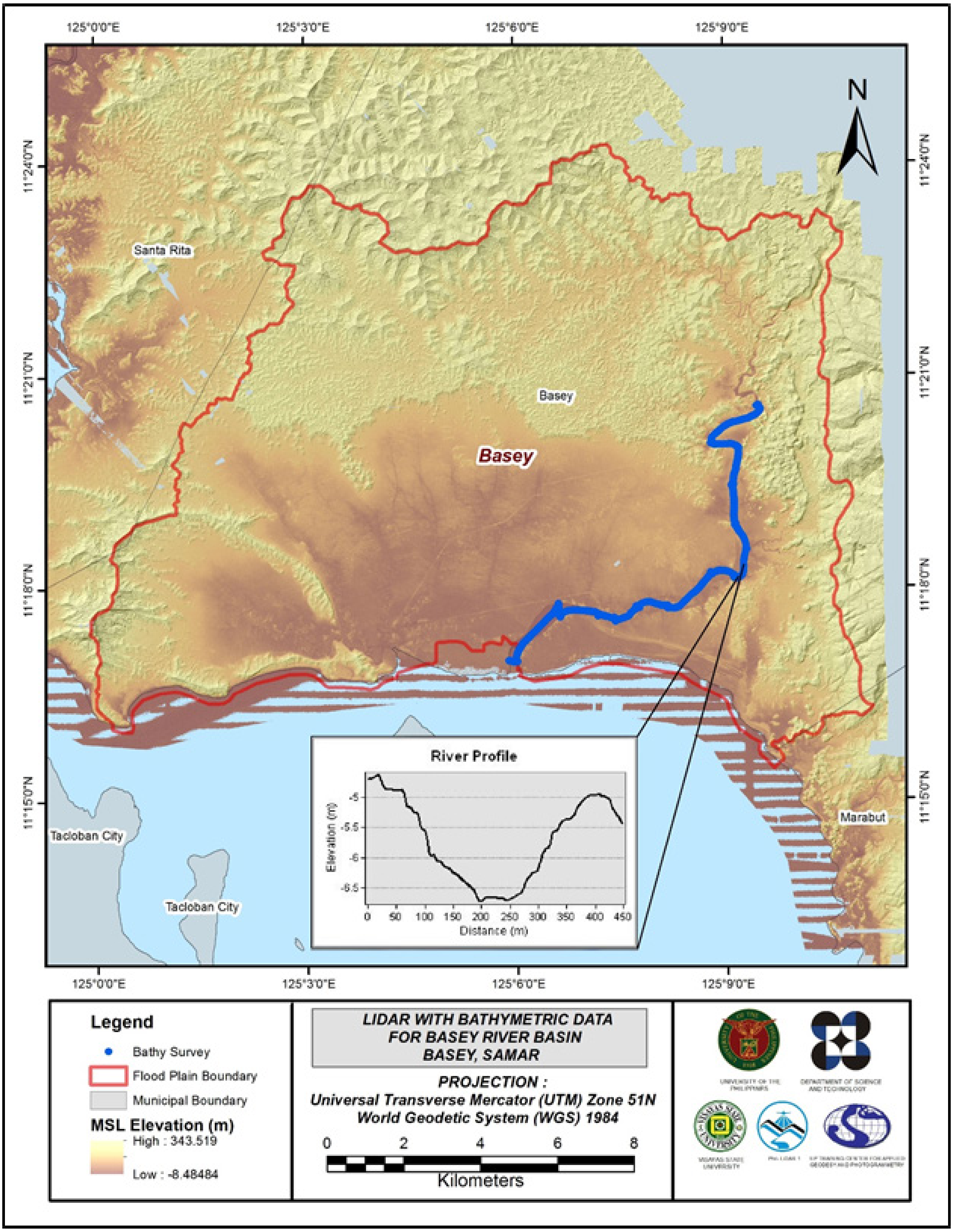

Figure 31. Map of Basey Flood Plain with bathymetric survey points shown in blue.

3.12 Feature Extraction

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

3.12.1 Quality Checking (QC) of Digitized Features' Boundary

Basey floodplain, including its 200 m buffer, has a total area of 226.04 sq km. For this area, a total of 7.0 sq km, corresponding to a total of 1892 building features, are considered for QC. Figure 32 shows the QC blocks for Basey floodplain.

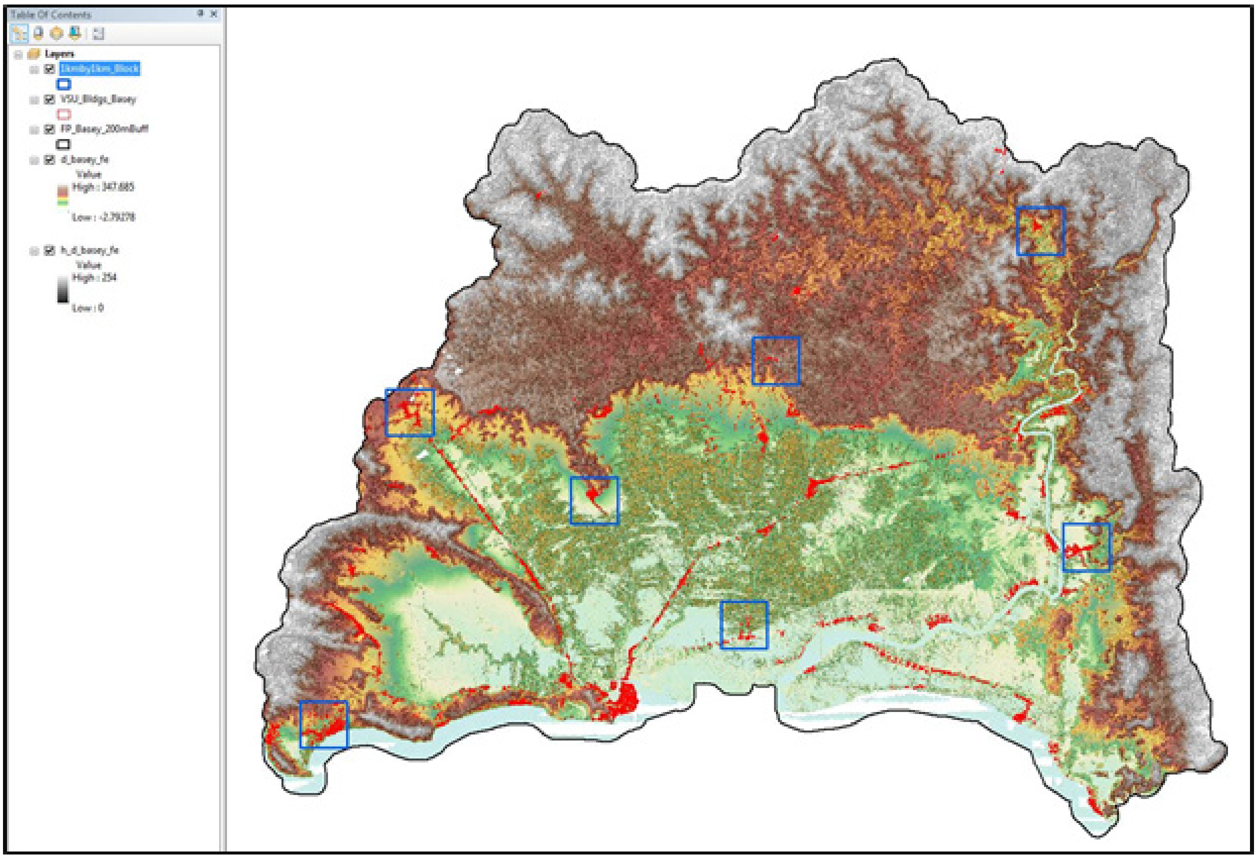

Figure 32. QC blocks for Basey building features.

Quality checking of Basey building features resulted in the ratings shown in Table 22.

Table 22. Quality Checking Ratings for Basey Building Features.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Basey	99.50	100	99.19	PASSED

3.12.2 Height Extraction

Height extraction was done for 11630 building features in Basey floodplain. Of these building features, 884 was filtered out after height extraction, resulting to 10746 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 9.87m.

3.12.3 Feature Attribution

The digitized features were marked and coded in the field using handheld GPS receivers. The attributes of non-residential buildings were first identified; all other buildings were then coded as residential. An nDSM was generated using the LiDAR DEMs to extract the heights of the buildings. A minimum height of 2 meters was used to filter out the terrain features that were digitized as buildings. Buildings that were not yet constructed during the time of LiDAR acquisition were noted as new buildings in the attribute table.3.12.1 Quality Checking of Digitized Features' Boundary

Table 23 summarizes the number of building features per type. On the other hand, Table 24 shows the total length of each road type, while Table 25 shows the number of water features extracted per type.

Table 23. Building Features Extracted for Basey Floodplain.

Facility Type	No. of Features
Residential	10348
School	220
Market	1
Agricultural/Agro-Industrial Facilities	12
Medical Institutions	9
Barangay Hall	24
Military Institution	2
Sports Center/Gymnasium/Covered Court	13
Telecommunication Facilities	1
Transport Terminal	0
Warehouse	7
Power Plant/Substation	0
NGO/CSO Offices	5
Police Station	1
Water Supply/Sewerage	0
Religious Institutions	29
Bank	1
Factory	0
Gas Station	1
Fire Station	1
Other Government Offices	20
Other Commercial Establishments	51
Total	10746

Table 24. Total Length of Extracted Roads for Basey Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/ Municipal Road	Provincial Road	National Road	Others	
Basey	79.58	16.56	20.62	25.93	0.00	142.69

Table 25. Number of Extracted Water Bodies for Basey Floodplain.

Floodplain	Water Body Type					Total
	Rivers/ Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Basey	18	0	0	0	0	18

A total of 27 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 33 shows the Digital Surface Model (DSM) of Basey floodplain overlaid with its ground features.

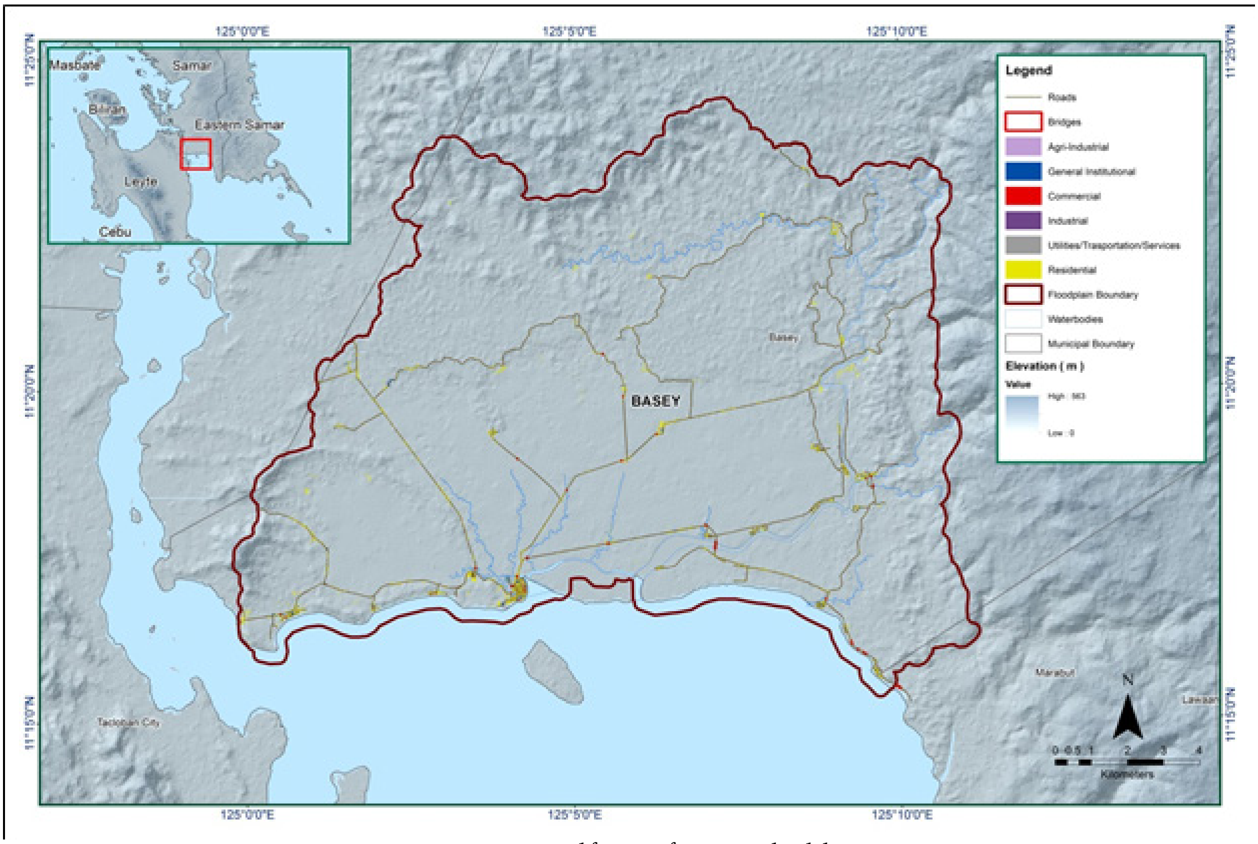

Figure 33. Extracted features for Basey Floodplain.

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS OF THE BASEY RIVER BASIN

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

4.1 Summary of Activities

The Data Validation and Bathymetry Component (DVBC) conducted a survey in Basey River from September 10 to 24, 2014 (Samar Phase 1) and from December 4 to18, 2014 (Samar Phase 2). The scope of work covered reconnaissance; control point survey for the establishment of a control point; cross-section, bridge as-built and water level marking in MSL of Basey Bridge for Samar Phase 1 and bathymetric survey of the Basey River from Brgy. Guirang down to Brgy. Iba (mouth of the river) with an estimated length of 13.70 km for bathymetric survey for Samar Phase 2 using PPK GNSS Survey technique.

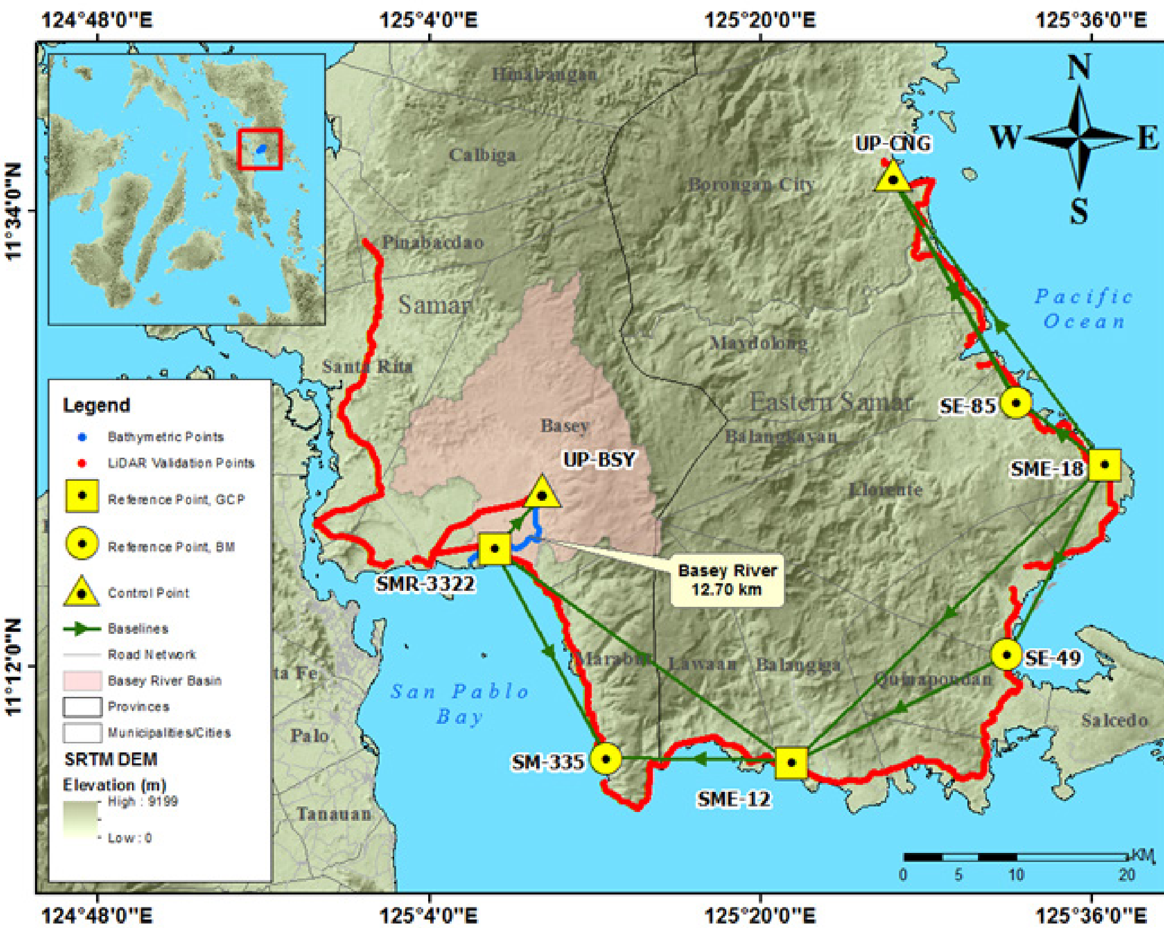


Figure 34. Basey River Survey Extent

4.2 Control Survey

The GNSS network used for Basey River Basin is composed of three (3) loops and a baseline established on September 12, 13, 17 and 19, 2014 occupying the following reference points: SME-18, a second-order GCP in Brgy. Canciledes, Municipality of Hernani; and SE-85, a first-order BM in Brgy. Barangay 11 Poblacion, Municipality of Llorente; both in Eastern Samar.

Two control points were established along the approach of bridges namely: UP-CNG at Can-Obing Bridge in Brgy. Can-Abong, Borongan City, East Samar; and UP-BSY at Basey Bridge, in Brgy. Guirang, Municipality of Basey, Samar. NAMRIA established control points: SME-12 in Brgy. San Miguel, Municipality of Balangiga; SE-49 in Brgy. Aguinaldo, Municipality of General Macarthur, both in Easter Samar; and SMR-3322 in Brgy. Binongtu-an, Municipality of Basey; and SM-335 in Pinalanga, Municipality of Marabut, both in Samar; were also used as marker during the survey.

The summary of reference and control points and its location is summarized in Table 26 while the GNSS network established is illustrated in Figure 35.

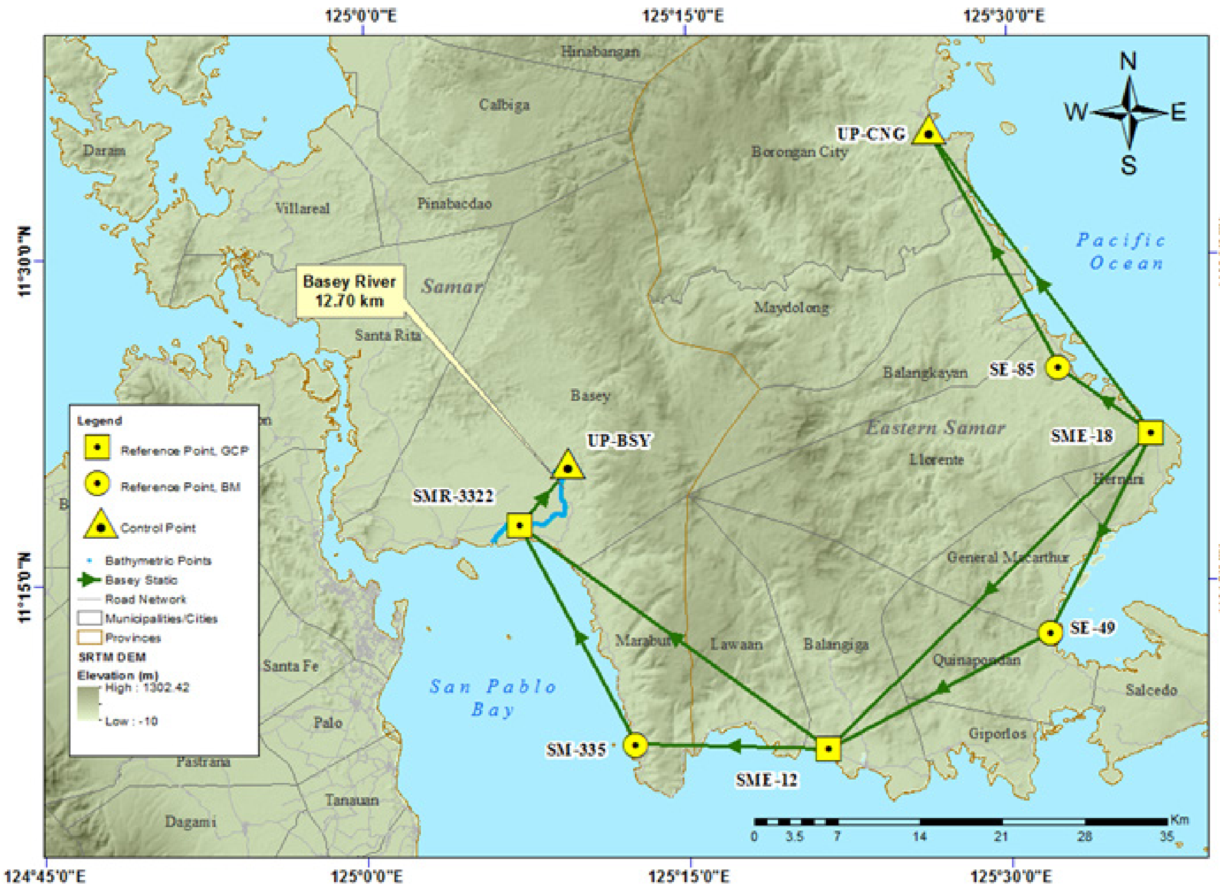


Figure 35. Static Network for Basey River Survey

Table 26. List of References and Control Points used in Basey River survey (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (m)	Elevation in MSL (m)	Date Established
SME-18	2nd Order GCP	11°21'43.08127"°	125°36'37.41862"	78.217	17.66	Sep 12, 2014
SE-85	1st Order BM	11°24'45.65441"	125°32'20.98934"	67.52	6.31	Sep 12, 2014
SME-12	Used as Marker	11°07'19.15395"	125°21'29.28283"	67.212	2.721	Sep 13, 2014
SMR-3322	Used as Marker	11°17'40.55190"	125°07'10.82309"	70.666	6.636	Sep 17, 016
SE-49	Used as Marker	11°12'34.48802"	125°31'52.42238"	66.981	3.779	Sep 13, 2014
SM-33S	Used as Marker	11°07'33.79721"	125°12'32.14831"	68.705	3.951	Sep 17, 2014
UP-CNG	UP Established	11°35'44.92939"	125°26'23.62776"	67.094	6.035	Sep 12, 2014
UP-BSY	UP Established	11°27'57.66166"	125°01'08.84182"	73.078	9.958	Sep 19, 2014

The GNSS set-ups on recovered reference points and established control points in Balangiga River are shown in Figure 36 to Figure 42.

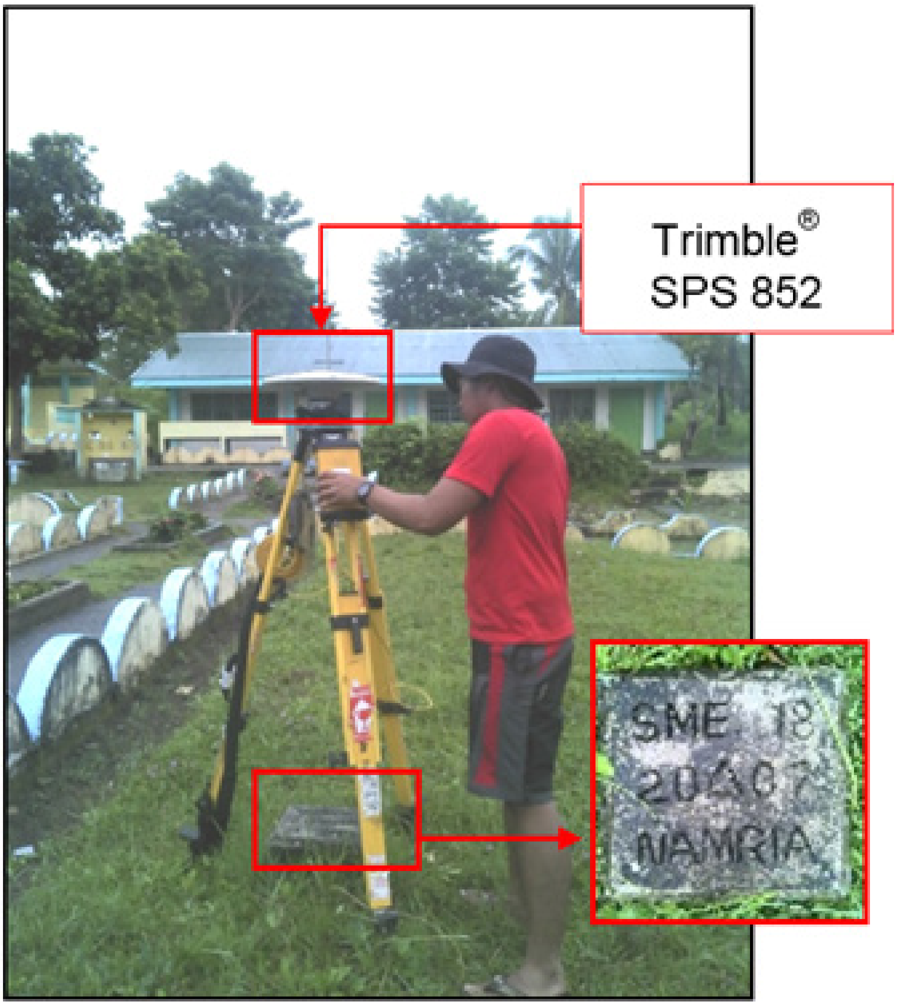


Figure 36. GNSS base receiver setup, Trimble® SPS 852 at SME-18, located inside San Jose Elem. School, Brgy. Cancildes, Municipality of Hernani, Eastern Samar

Figure 37. GNSS receiver, Trimble® SPS 882, at SE-85, located at the approach of Llorente Bridge in Bry. 11, Mun. of Llorente, Eastern Samar

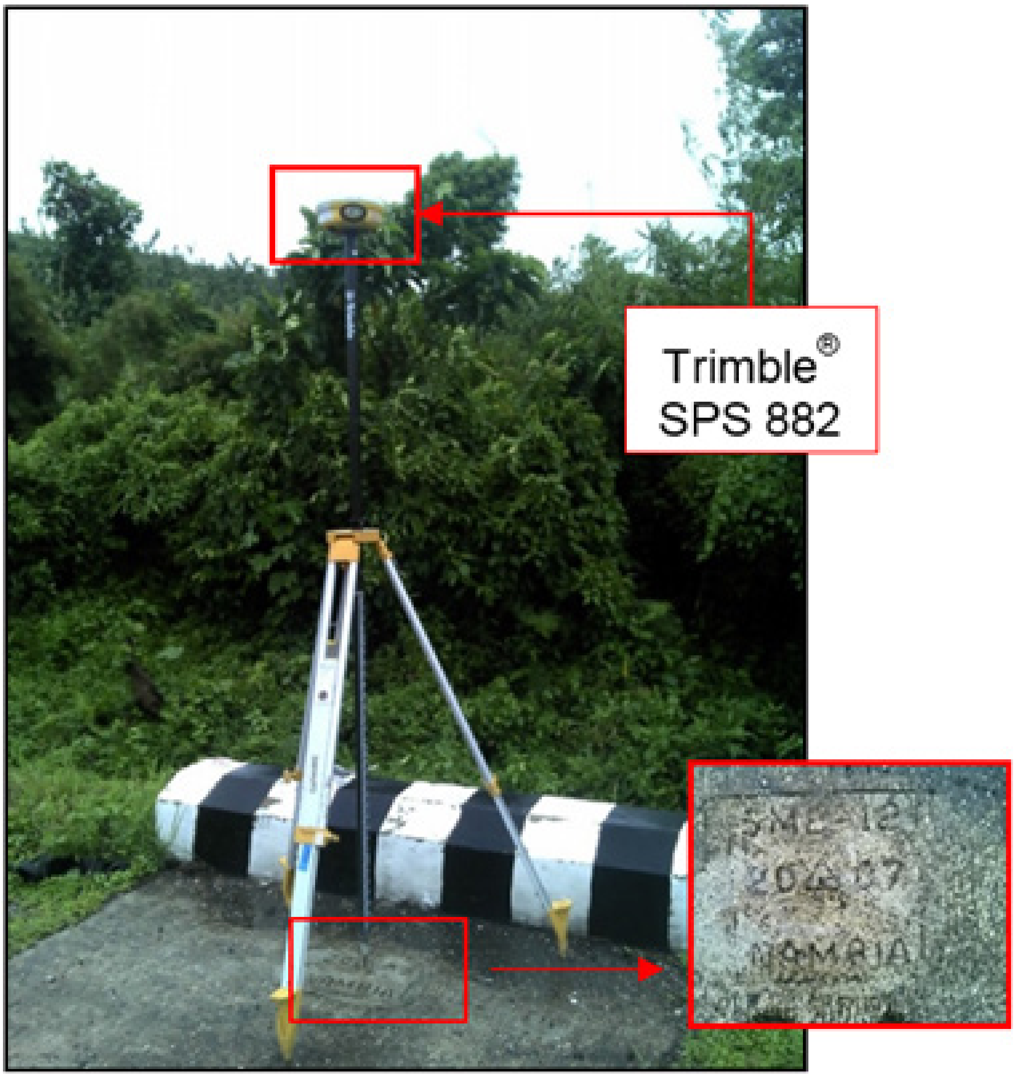


Figure 38. GNSS receiver occupation, Trimble® SPS 882, at SME-12 in Brgy. San Miguel, Mun. of Balangiga, Eastern Samar

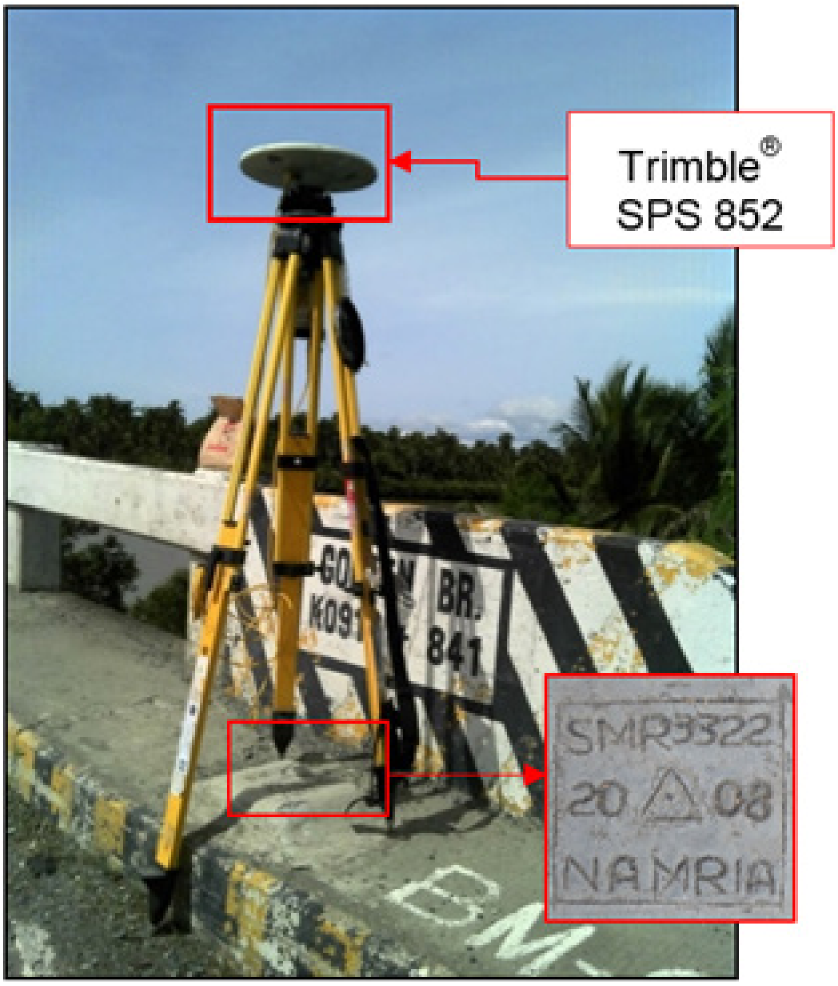


Figure 39. GNSS base occupation, Trimble® SPS 852, at SMR-3322, located at the approach of Golden Bridge in Brgy. Binongtu-an, Mun. of Basey, Samar

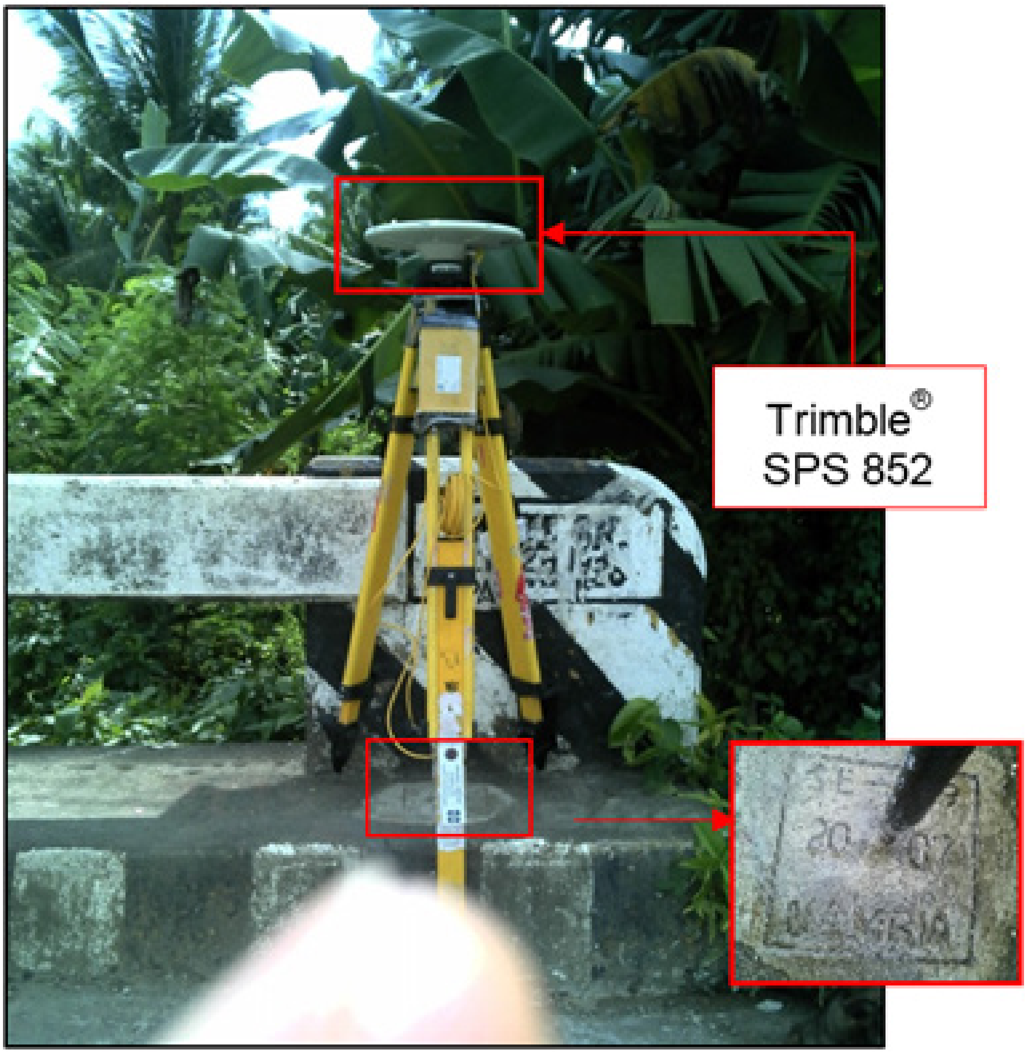


Figure 40. GNSS base occupation, Trimble® SPS 852, at SE-49, in Brgy. Aguinaldo, Mun. of General Macarthur, Eastern Samar

Figure 41. GNSS base occupation, Trimble® SPS 882, at SM-335, in Brgy. Pinalanga, Mun. of Maravut, Samar

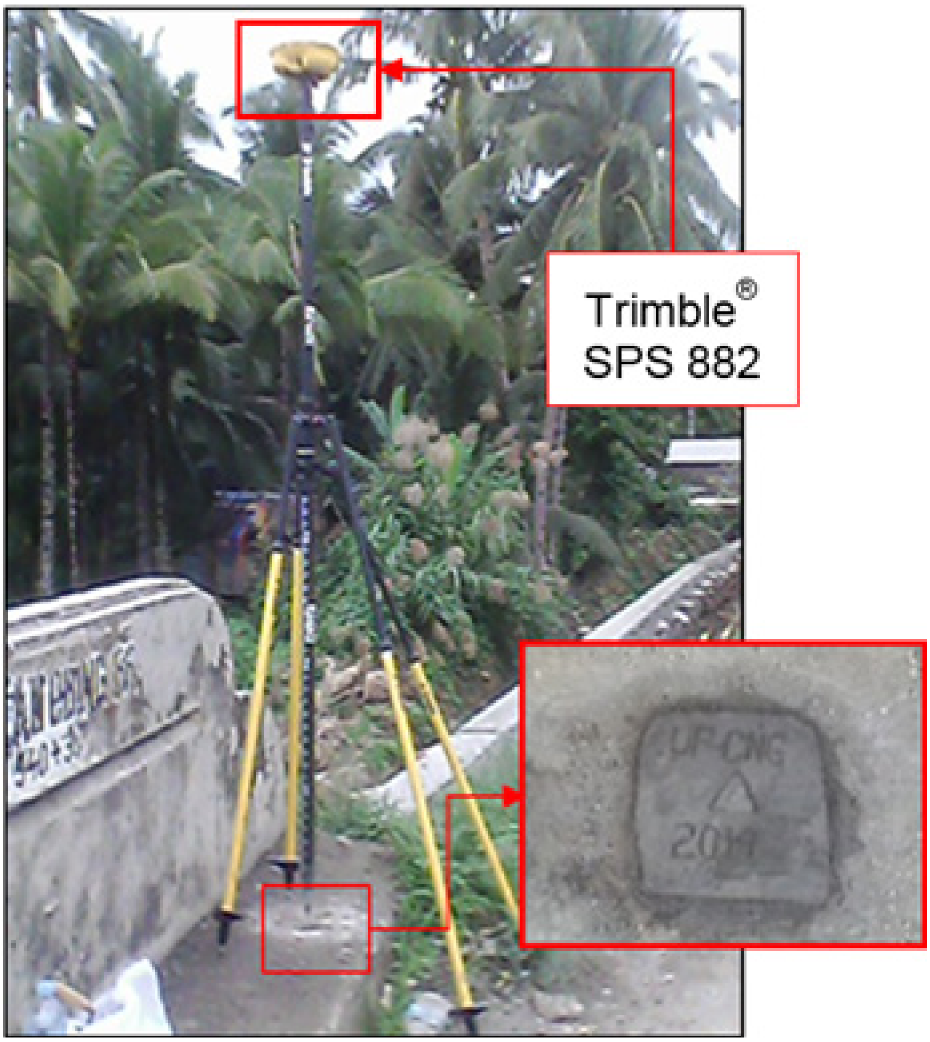


Figure 42. GNSS receiver occupation, Trimble® SPS 882, at UP-CNG, located at the approach of Can-Obing Bridge in Brgy. Can-Abong, Borongan City, Eastern Samar

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 is performed. Masking is done by removing/masking portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. Baseline processing result of control points in Basey River Basin is summarized in Table 27, generated by TBC software.

Table 27. Baseline Processing Report for Basey River static survey

Observation	Date of Observation	Solution Type	Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter	ΔHeight (Meter)
SME-18 --- SE-85	09-12-14	Fixed	0.004	0.015	305°49’17-	9586.978	-10.699
SME-18 --- SE-85	09-12-14	Fixed	0.005	0.033	305°49’17-	9586.977	-10.719
SME-18 --- UP-CNG	09-12-14	Fixed	0.003	0.013	324°17’44-	31862.046	-11.107
SME-18 --- SE-49	09-13-14	Fixed	0.003	0.016	207°09’17-	18943.356	-11.212
UP-CNG --- SE-85	09-12-14	Fixed	0.005	0.041	331°52’51-	22970.859	-0.416
SE-85 --- UP-CNG	09-12-14	Fixed	0.007	0.019	331°52’51-	22970.857	-0.437
SE-49 --- SME-12	09-13-14	Fixed	0.004	0.019	242°52’57-	21244.542	0.227
SME-12 --- SM-33S	09-17-14	Fixed	0.004	0.017	271°35’44-	16305.472	1.501
SME-12 --- SM-33S	09-17-14	Fixed	0.019	0.033	271°35’44-	16305.477	1.450
SME-12 --- SMR-3322	09-17-14	Fixed	0.003	0.014	306°16’15-	32291.859	3.461
SME-18 --- SME-12	09-13-14	Fixed	0.004	0.018	226°05’03-	38255.209	-11.019
SMR-3322 --- UP-BSY	09-19-14	Fixed	0.003	0.012	38°27’35-	6709.313	1.891
SMR-332 --- SM-33S	09-17-14	Fixed	0.004	0.014	152°23’19-	21038.056	-1.964
SMR-3322 --- SM-33S	09-17-14	Fixed	0.006	0.038	152°23’20-	21038.062	-1.978

As shown in Table 27 a total of fourteen (14) baselines were processed with coordinates of SME-18 and elevation value of reference point SE-85 held fixed. All of them passed the required accuracy.

4.4 Network Adjustment

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

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

Where:

x^e is the Easting Error,
y^e is the Northing Error, and
z^e is the Elevation Error

for each control point. See the Network Adjustment Report shown in Table 28 to Table 31 for complete details.

The eight (8) control points, SME-18, SE-85, SME-12, SMR-3322, SE-49, SM-335, UP-CNG and UP-BSY were occupied and observed simultaneously to form a GNSS loop. Coordinates of SME-18 and elevation values SE-85 were held fixed during the processing of the control points as presented in Table 28. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 28. Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
SE-85	Grid				Fixed
SME-18	Local	Fixed	Fixed		
Fixed = 0.000001 (Meter)					

The list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 29. All fixed control points have no values for grid and elevation errors.

Table 29. Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
SE-49	776407.626	0.007	1240340.446	0.005	3.779	0.050	
SE-85	777079.164	0.006	1262825.941	0.004	6.310	?	e
SM-335	741264.593	0.010	1230815.204	0.007	3.951	0.061	
SME-12	757572.894	0.007	1230490.556	0.005	2.721	0.051	
SME-18	784907.431	?	1257282.043	?	17.660	0.032	LL
SMR-3322	731377.313	0.009	1249392.087	0.007	6.636	0.060	
UP-CNG	766068.484	0.005	1282999.389	0.004	6.035	0.036	

With the mentioned equation, $\sqrt{((x\_e)^2+(y\_e)^2)}<20cm$ for horizontal and $z^e<10$ cm for the vertical; the computation for the accuracy are as follows:

a. SME-18
horizontal accuracy = Fixed
vertical accuracy = $3.2 < 10$ cm

b. SE-85
horizontal accuracy = $\sqrt{((0.6)^2 + (0.4)^2}$
= $\sqrt{(0.36 + 0.16)}$
= $0.72 < 20$ cm
vertical accuracy = Fixed

c. SME-12
horizontal accuracy = $\sqrt{((0.7)^2 + (0.5)^2}$
= $\sqrt{(0.49 + 0.25)}$
= $0.86 < 20$ cm
vertical accuracy = $5.1 < 10$ cm

d. SMR-3322
horizontal accuracy = $\sqrt{((0.9)^2 + (0.7)^2}$
= $\sqrt{(0.81 + 0.49)}$
= $1.14 < 20$ cm
vertical accuracy = $6.0 < 10$ cm

e. SE-49
horizontal accuracy = $\sqrt{((0.7)^2 + (0.5)^2}$
= $\sqrt{(0.49 + 0.25)}$
= $0.86 < 20$ cm
vertical accuracy = $5.0 < 10$ cm

f. SM-335
horizontal accuracy = $\sqrt{((1.0)^2 + (0.7)^2}$
= $\sqrt{(1.0 + 0.49)}$
= $1.22 < 20$ cm
vertical accuracy = $6.1 < 10$ cm

g. UP-CNG
horizontal accuracy = $\sqrt{((0.5)^2 + (0.4)^2}$
= $\sqrt{(0.25 + 0.16)}$
= $0.65 < 20$ cm
vertical accuracy = $3.6 < 10$ cm

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

Table 30. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
SE-49	N11°12'34.48802"	E125°31'52.42238	66.981	0.050	
SE-85	N11°24'45.65441"	E125°32'20.98934	67.520	?	e
SM-335	N11°07'33.79721"	E125°12'32.14831	68.705	0.061	
SME-12	N11°07'19.15395"	E125°21'29.28283	67.212	0.051	
SME-18	N11°21'43.08127"	E125°36'37.41862	78.217	0.032	LL
SMR-3322	N11°17'40.55190"	E125°07'10.82309	70.666	0.060	
UP-CNG	N11°35'44.92939"	E125°26'23.62776	67.094	0.036	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 30. Based on the result of the computation, the equation is satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table 31.

Table 31. Reference and control points used and its location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
SME-18	2nd Order, GCP	11°21'43.08127"	125°36'37.41862"	78.217	1257282.043	784907.431	17.66
SE-85	1st Order, BM	11°24'45.65441"	125°32'20.98934"	67.52	1262825.941	777079.164	6.31
SME-12	Used as Marker	11°07'19.15395"	125°21'29.28283"	67.212	1230490.556	757572.894	2.721
SMR-3322	Used as Marker	11°17'40.55190"	125°07'10.82309"	70.666	1249392.087	731377.313	6.636
SE-49	Used as Marker	11°12'34.48802"	125°31'52.42238"	66.981	1240340.446	776407.626	3.779
SM-335	Used as Marker	11°07'33.79721"	125°12'32.14831"	68.705	1230815.204	741264.593	3.951
UP-CNG	UP Established	11°35'44.92939"	125°26'23.62776"	67.094	1282999.389	766068.484	6.035
UP-BSY	UP Established	11°20'31.52354"	125°09'28.44378"	72.554	1254677.422	735513.124	8.581

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

Cross-section and as-built survey were conducted on September 18, 2014 at the upstream side of Basey Bridge in Brgy. Guirang, Municipality of Basey, Samar as shown in Figure 43. Trimble® SPS 882 GNSS PPK survey technique was used as shown in Figure 44.

Figure 43. Basey Bridge taken facing upstream

Figure 44. Cross-section Survey at the left side of Basey Bridge in Brgy. Guirang, Basey, Samar

The cross-section line of Basey Bridge is 196.81 m with a total of twenty-two (22) points gathered using the control point UP-BSY as the GNSS base station. The location map, cross-section diagram, and the bridge data form are shown in Figure 45 to Figure 47, respectively.

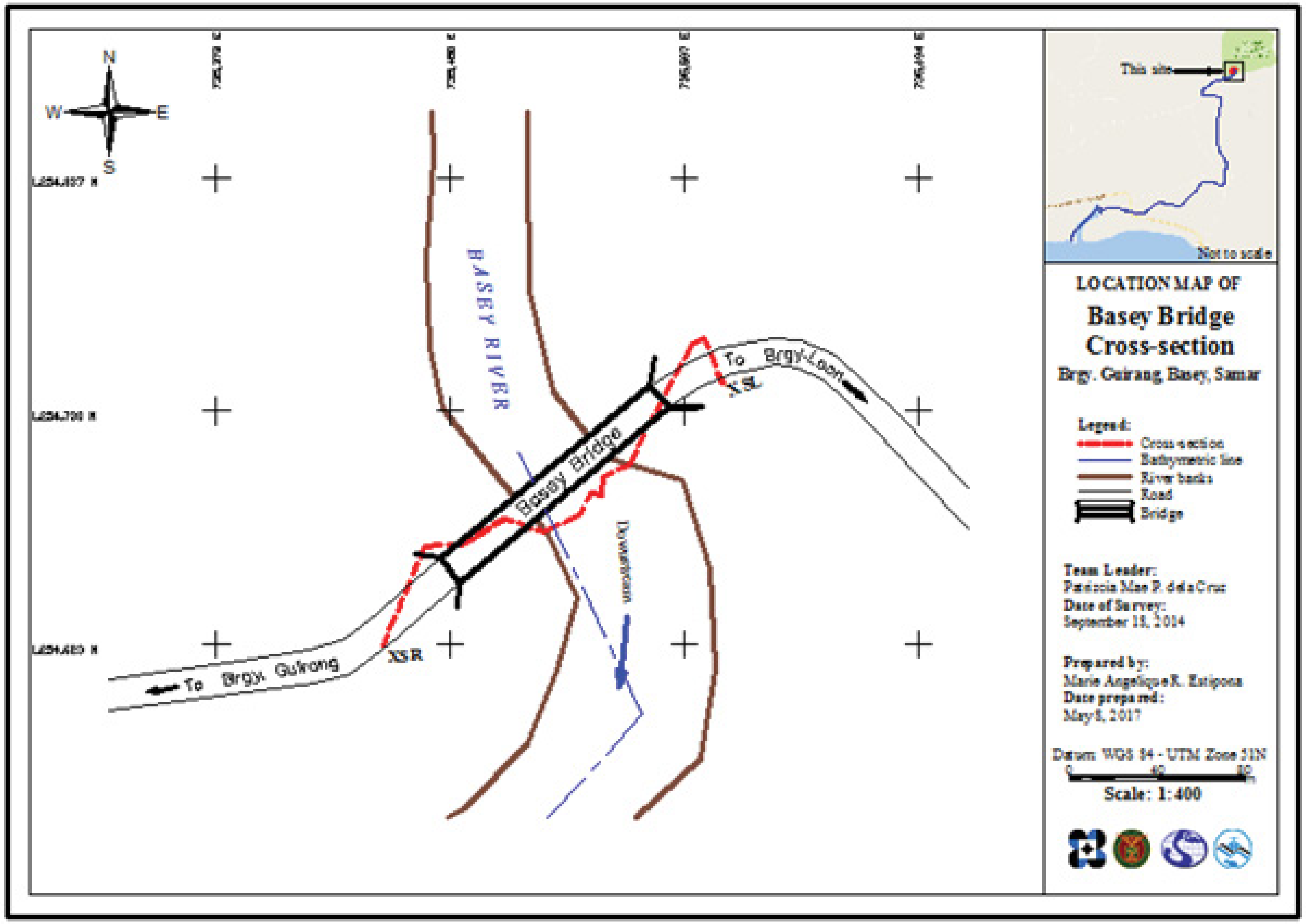


Figure 46. Location map of Basey Bridge cross-section

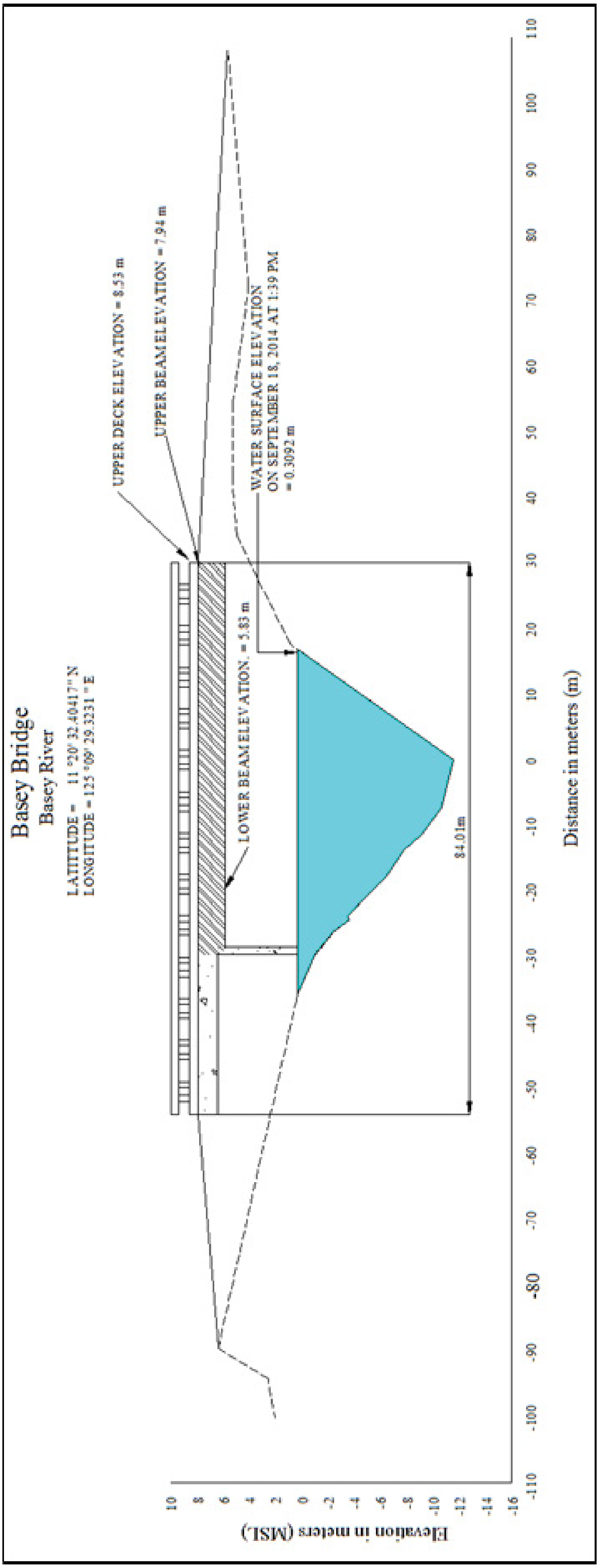


Figure 45. Basey Bridge Cross-section diagram

Bridge Data Form

Bridge Name: BASEY BRIDGE Date: September 18, 2014

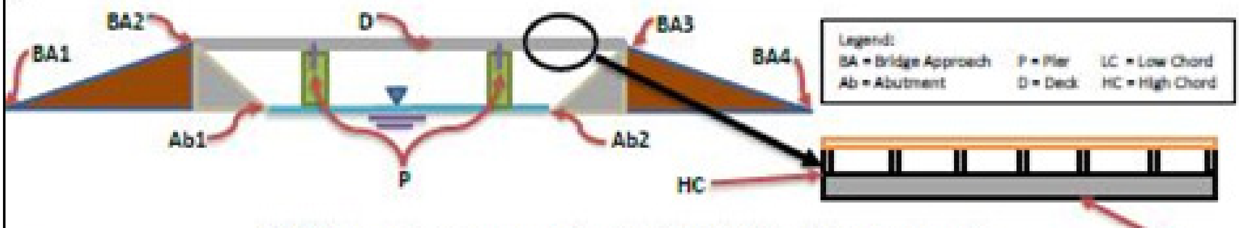
River Name: BASEY RIVER BASIN Time: 11:53 AM

Location (Brgy, City, Region): Barangay Guirang Basey Western Samar

Survey Team: Patricia Dela Cruz Team –Data Validation and Bathymetry Component

Flow condition: low normal high Weather Condition: fair rainy

Latitude: 11 – 20 – 32.40417 " N. Longitude: 125 – 09 – 29.32310 " E.



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

Elevation 7.94 M. Width: 9.41 M. Span (BA3-BA2): 84.01 M.

	Station	High Chord Elevation	Low Chord Elevation
1	PIER 1	8.5332 M.	5.8332 M.
2			
3			
4			
5			

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	6.3822 M.	BA3	118.129 M.	8.2442 M.
BA2	34.640 M.	7.6542 M.	BA4	196.808 M.	5.6472 M.

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

	Station (Distance from BA1)	Elevation
Ab1	51.008 M.	2.7162 M.
Ab2	106.512 M.	0.9072 M.

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

Shape: Oblong Number of Piers: 1 Height of column footing: N/A

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	66.213 M.		5.50 M
Pier 2			
Pier 3			
Pier 4			
Pier 5			
Pier 6			

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

Figure 47. Basey Bridge as Built Data

The water level elevation acquired on September 18, 2014 at 1:39:22 PM Samar Phase 1 in Basey Bridge is 0.3092 m (MSL). The initial water level marking was done on the same day, as shown in Figure 48.

These markings were recovered and converted into MSL on December 10, 2014 during the Samar Phase 2 survey to serve as reference for flow data gathering and depth gauge deployment of Visayas State University.

Figure 48. Finished Water Level Markings at Basey Bridge, Brgy. Guirang, Basey, Samar

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on September 14, 15, 17, 18, 19 and 20 using a survey grade GNSS rover receiver, Trimble® SPS 882 mounted on a pole which was attached in front of the vehicle as shown in Figure 49. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced.

Figure 49. Validation points acquisition survey set-up along Balangiga River Basin

The survey started from Brgy. Purok D1, Borongan City, going south thorugh National high-way traversing Borongan City; nine (9) Municipalities of Eastern Samar, namely: Maydolong, Balangkayan, Llorente, Hernani, General Macarthur, Quinapondan, Giporlos, Balangiga and Lawaan; and four (4) Municipalities of Samar namely: Marabut, Basey, Santa Rita, and ended in Brgy. Laygayon, Municipality of Pinabacdao, Samar. A total of 30,114 points were gathered with approximate length of 296.68 km using UP-CNG, SE-49, SM-33S, SMR-3322, and SE-85 as GNSS base stations for the entire extent validation points acquisition survey as illustrated in the map in Figure 50.

Figure 50. Validation points acquisition survey along Samar and Eastern Samar

4.7 Bathymetric Survey

Manual bathymetric survey was performed all throughout the survey because of the malfunctioning echo sounder. The team rented a boat for the bathymetric survey since the rigid boat of PCG Tacloban was not available for the survey.

The survey began in Brgy. Guirang down to the mouth of the river in Brgy. Iba. The team used a boat and positioned the range pole with an installed Trimble® SPS 882 on the gunwale of the boat as shown in Figure 51. A portable depth sounder was used to measure the depth of the water as shown in Figure 52. Bamboo poles and paddles were used to fix the position of the boat while encoding and entering the readings. The team also deployed a stadia rod every 100 m to check if the portable depth sounder is accurate and functioning properly.

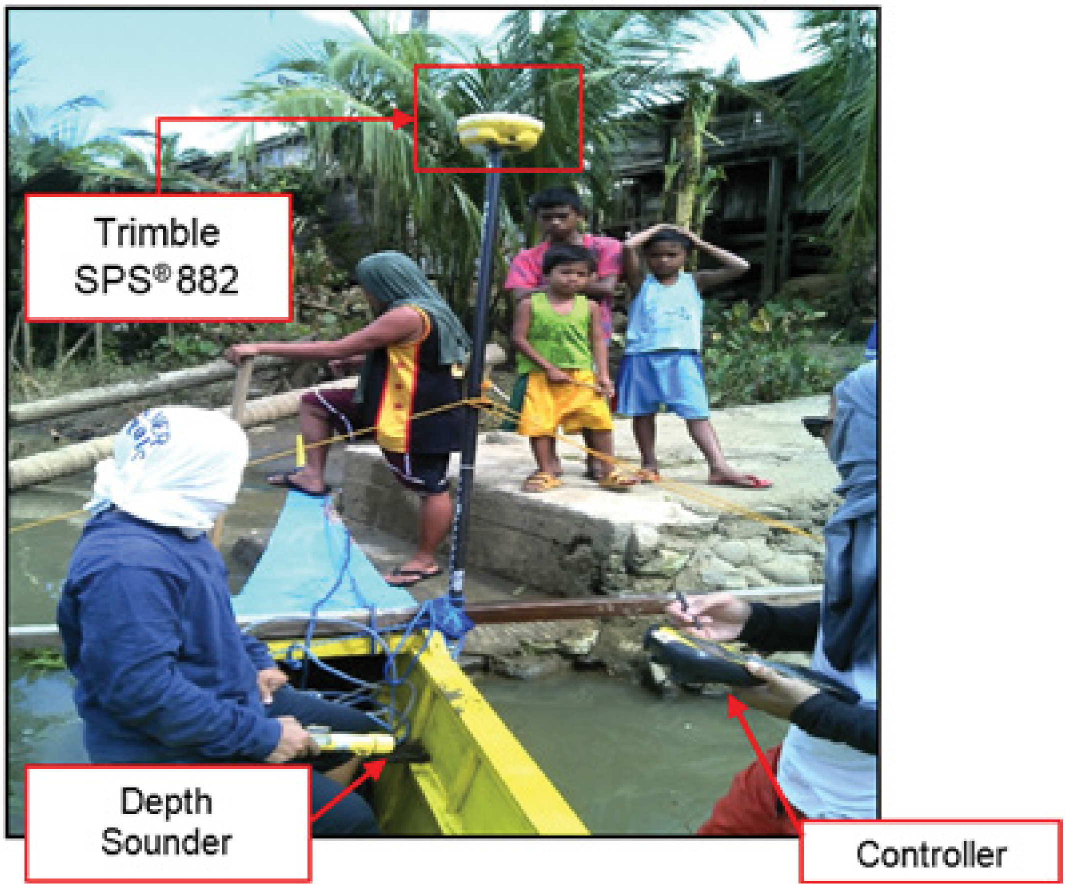


Figure 51. Setting up- Manual Bathymetry in Basey River

Figure 52. A) Actual Execution of Bathymetric Survey in Basey River, (B) depth checking using portable depth sounder and stadia rod

Bathymetric survey started in Brgy. Guirang down to the mouth of the river in Brgy. Iba. The control point SMR-3322 was occupied as a base station throughout the bathymetric survey. The bathymetry length is about 13.7 km, with a total points of 682. Canopy cover along Brgy. Guirang prohibited GPS signals to penetrate; thus, resulting in float data. The processed data were generated into a map using a GIS software as shown in Figure 53.

Figure 53. Basey River Bathymetry in Basey Samar

A CAD drawing was also produced to illustrate the Basey riverbed profile as shown in Figure 54. The profile exhibits irregular depth in its riverbed terrain. The upstream Basey River along the bridge where cross-section was conducted on the previous field work has the deepest elevation, probably because of the unfinished construction of the pier footing. The difference in elevation of the deepest elevation in the upstream, along the bridge, to the mouth of the river is approximately 15 m.

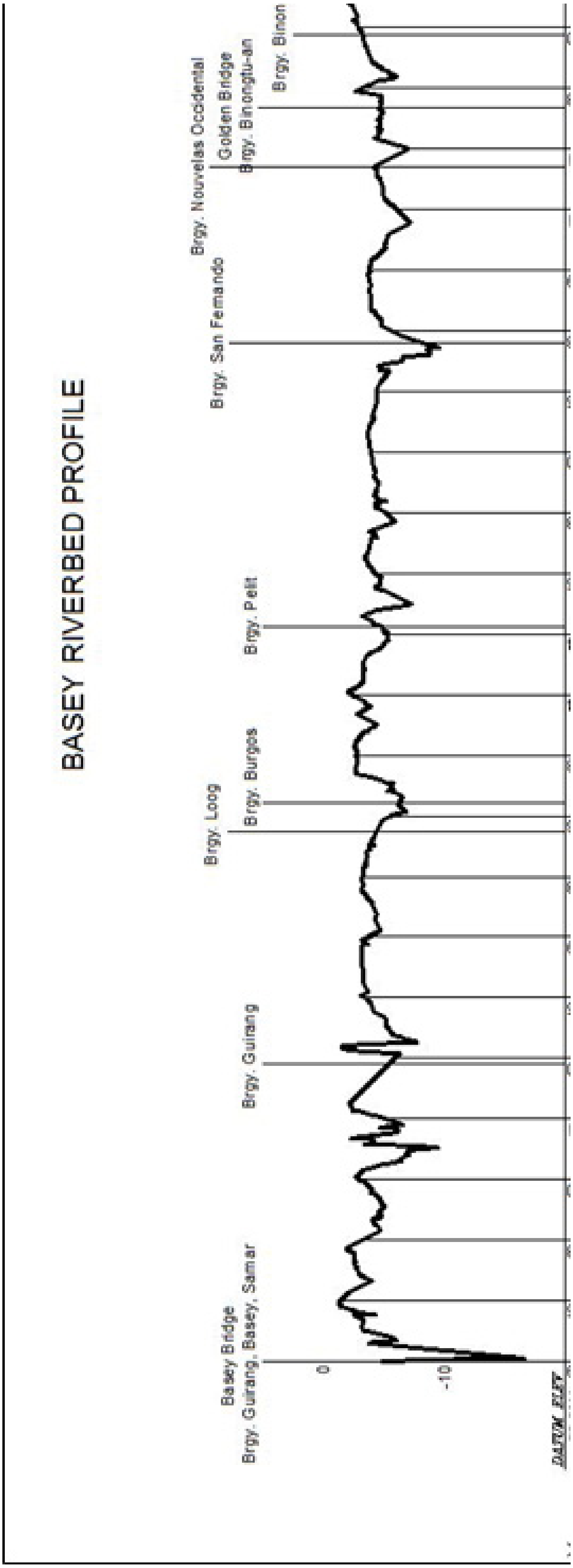


Figure 54. Basey River Bed Profile

CHAPTER 5: FLOOD MODELING AND MAPPING

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

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

Precipitation data was taken from three automatic rain gauges (ARGs) installed by the Department of Science and Technology – Advanced Science and Technology Institute (DOST-ASTI). The location of the rain gauge is seen in Figure 55.

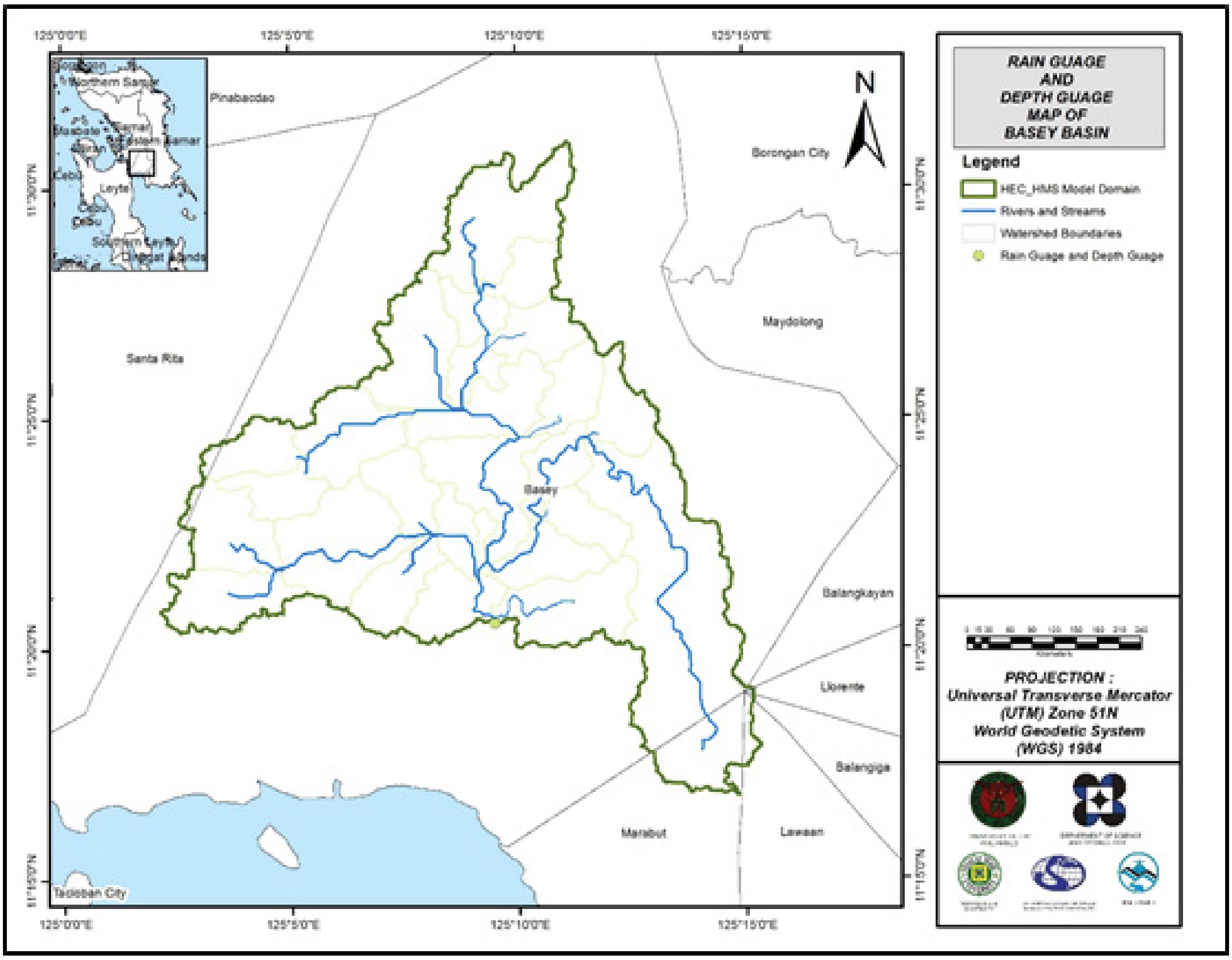


Figure 55. The location map of Basey HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Sohoton Bridge, Basey, Samar (11°20'32.48"N, 125° 9'29.09"E). It gives the relationship between the observed water levels at Sohoton Bridge and outflow of the watershed at this location.

For Sohoton Bridge, the rating curve is expressed as Q = 115.77e.3.097h as shown in Figure 57.

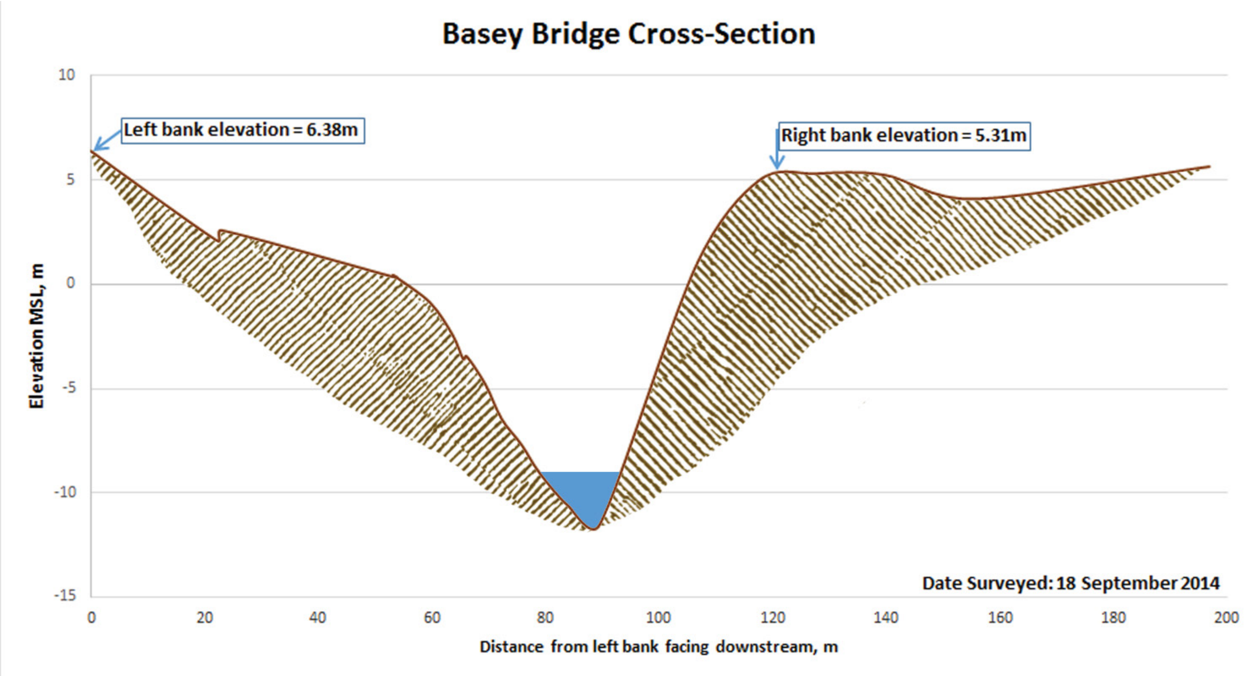


Figure 56. Cross-Section Plot of Sohoton Bridge

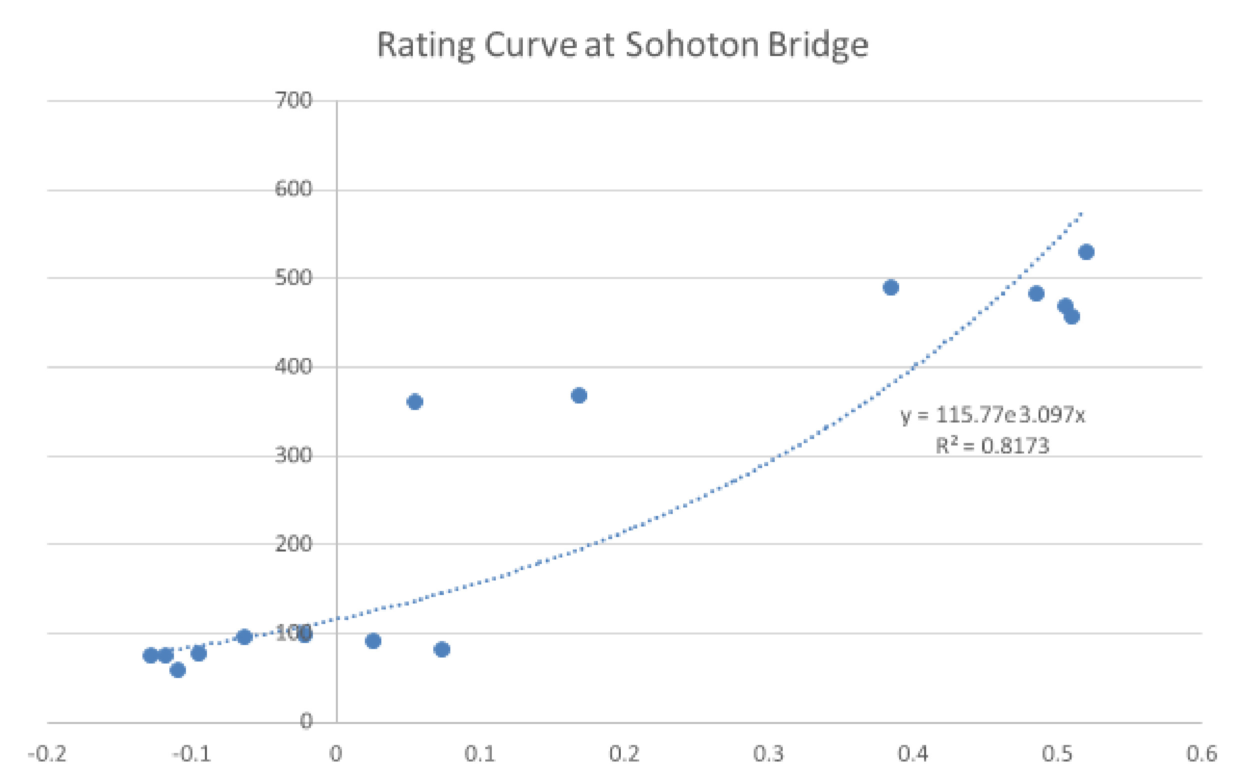


Figure 57. Rating Curve at Sohoton Bridge, Basey, Samar

This rating curve equation was used to compute the river outflow at Sohoton Bridge for the calibration of the HEC-HMS model. Total rain from Basey rain gauge is 220 mm. It peaked to 11 mm on 16 January 2017, 2:00. The lag time between the peak rainfall and discharge is 14 hours and 40 minutes.

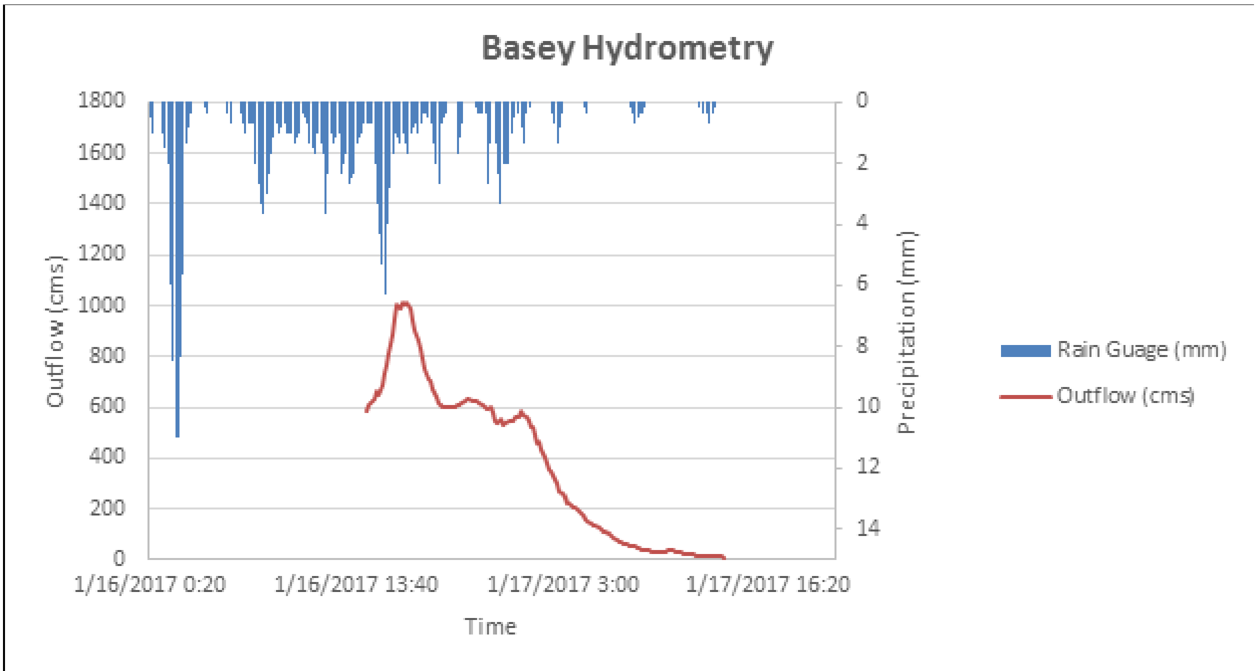


Figure 58. Rainfall and outflow data at Basey used for modeling

5.2 RIDF Station

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

Table 32. RIDF values for Tacloban Rain Gauge computed by PAGASA

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

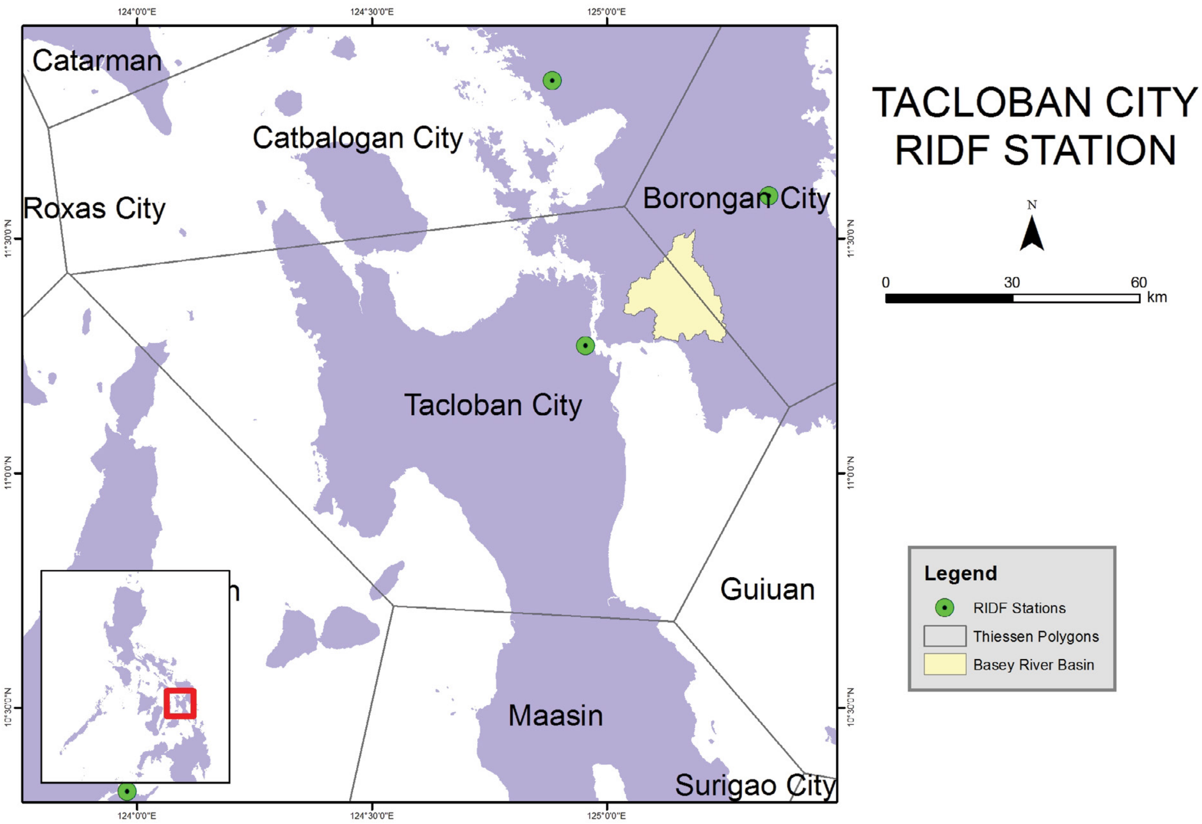


Figure 59. Location of Tacloban RIDF Station relative to Basey River Basin

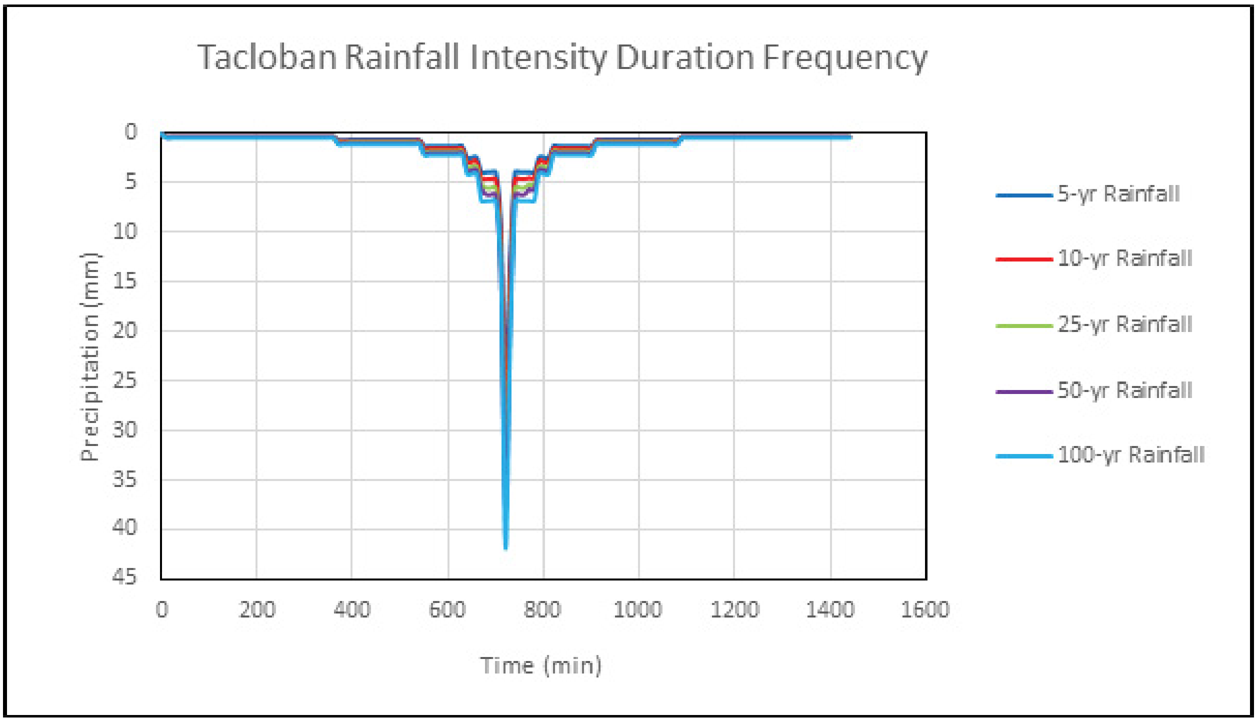


Figure 60. Synthetic storm generated for a 24-hr period rainfall for various return periods

5.3 HMS Model

The soil dataset was generated before 2004 by the Bureau of Soils; this is under the Department of Agriculture. The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Basey River Basin are shown in Figures 61 and 62, respectively.

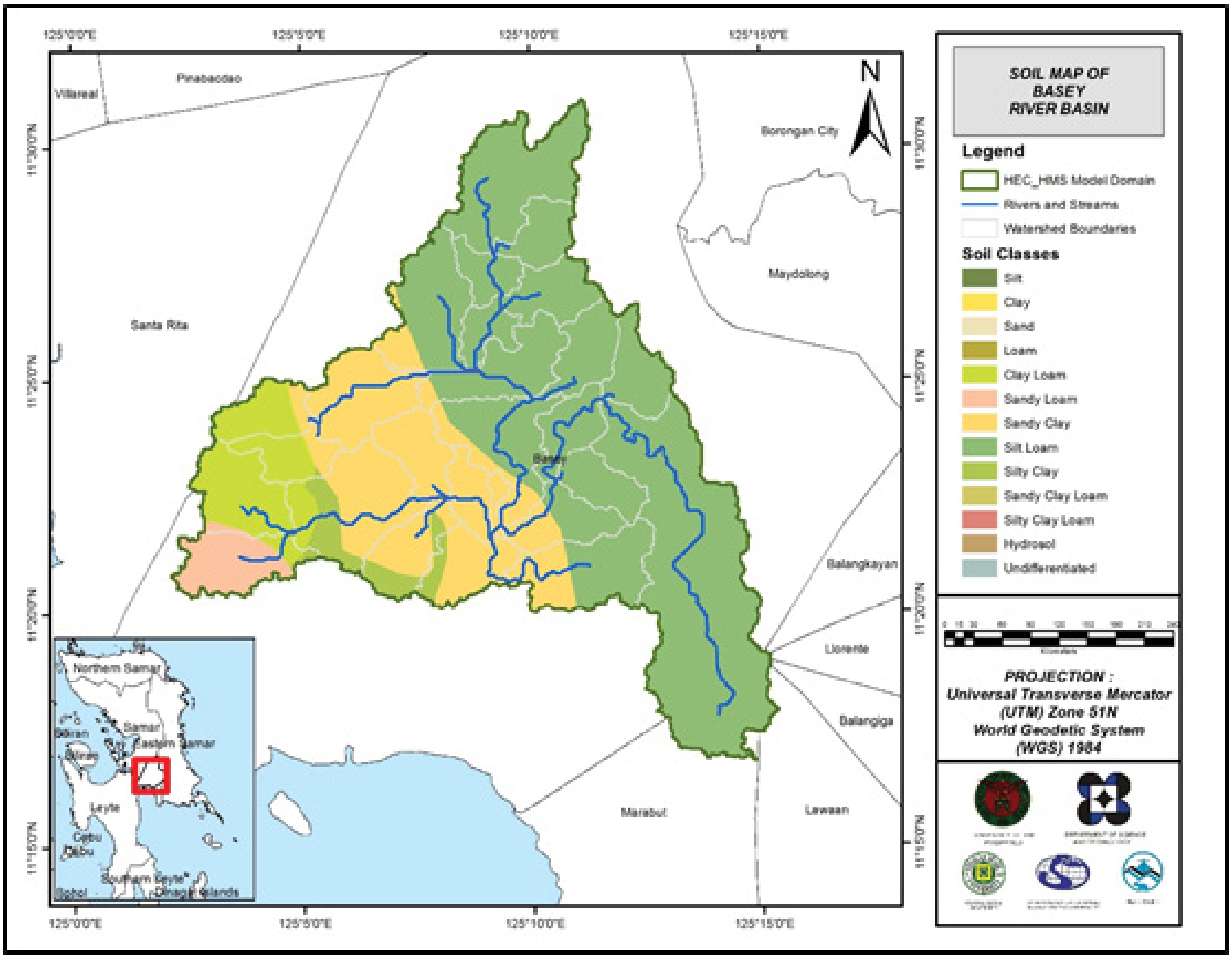


Figure 61. Soil Map of Basey River Basin

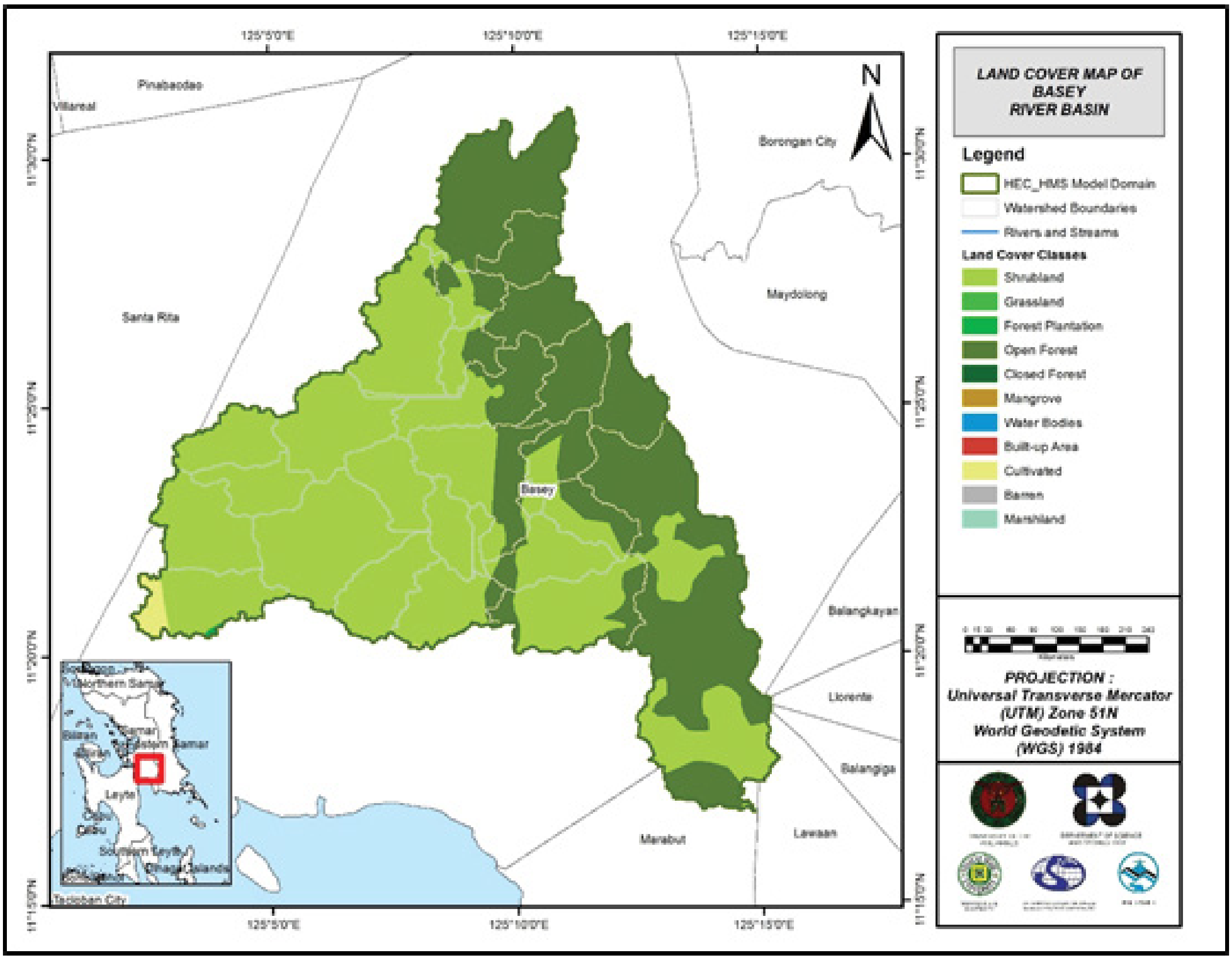


Figure 62. Land Cover Map of Basey River Basin

For Basey, the soil classes identified were silt loam, sandy clay, silty clay, clay loam, and sandy loam. The land cover types identified were shrubland, open forest, and cultivated.

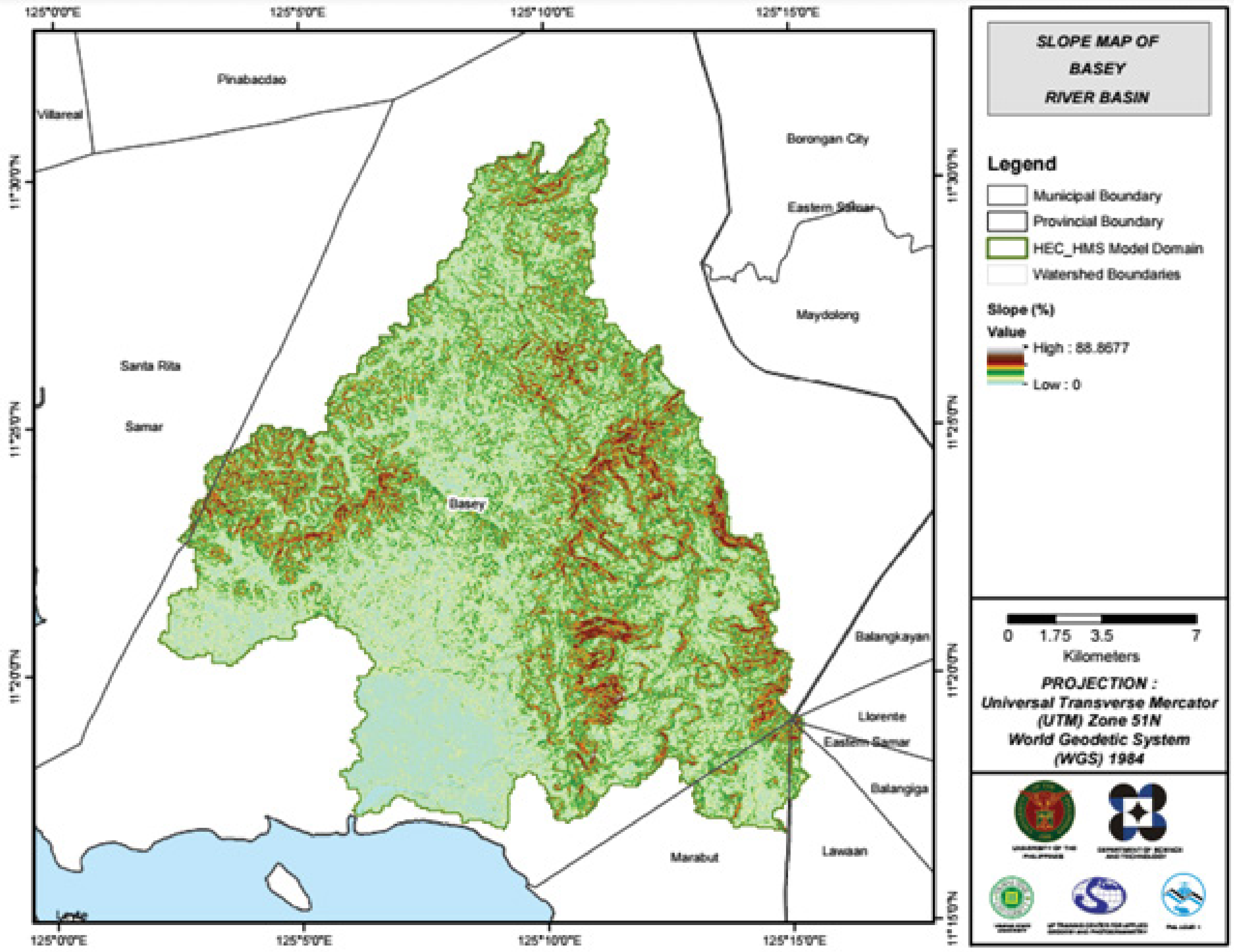


Figure 63. Slope Map of the Basey River Basin

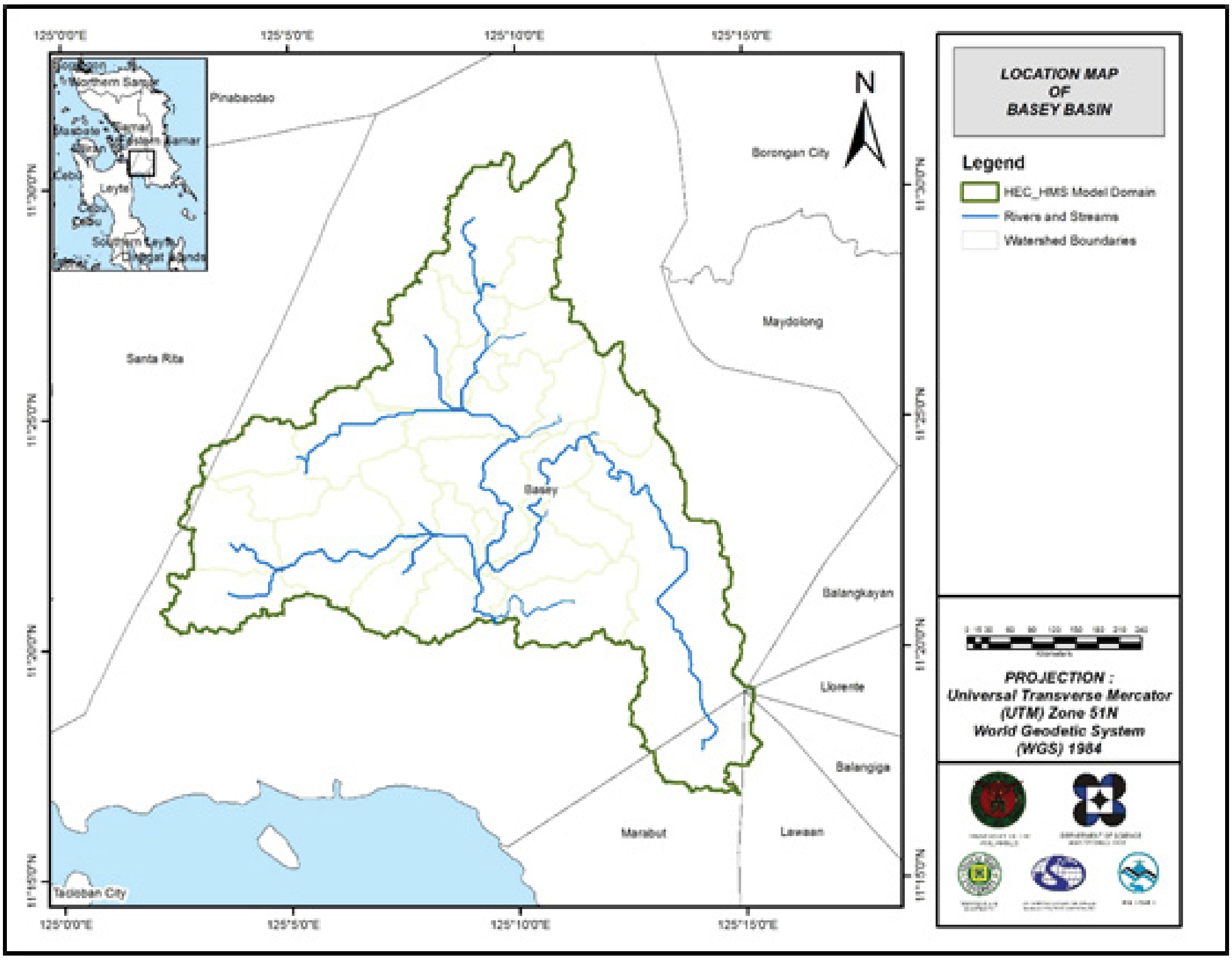


Figure 64. Stream Delineation Map of the Basey River Basin

Using the SAR-based DEM, the Basey basin was delineated and further subdivided into subbasins. The model consists of 29 sub basins, 14 reaches, and 14 junctions. The main outlet is Sohoton Bridge. This basin model is illustrated in Figure 65.

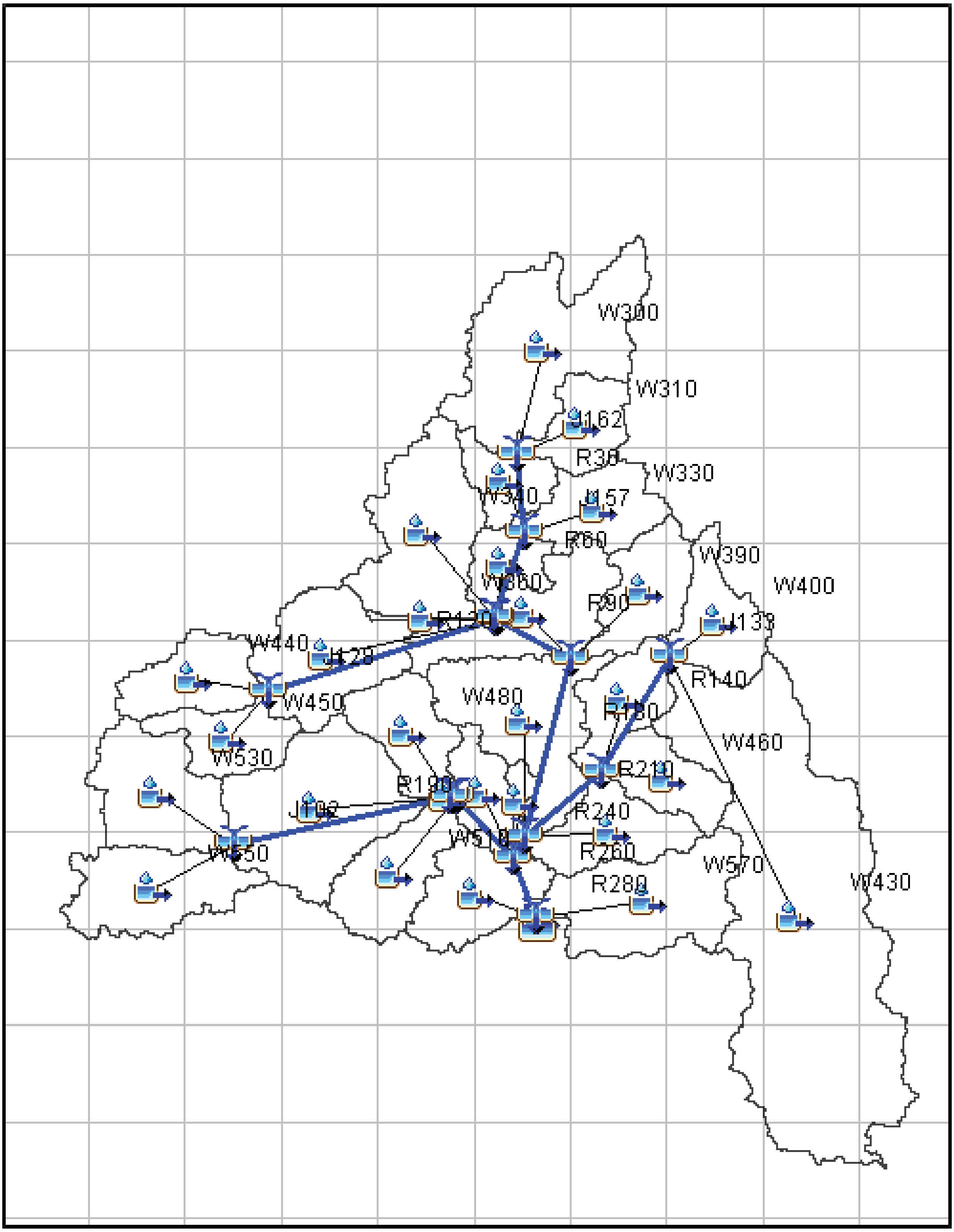


Figure 65. The Basey river basin model generated using HEC-HMS

5.4 Cross-section Data

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

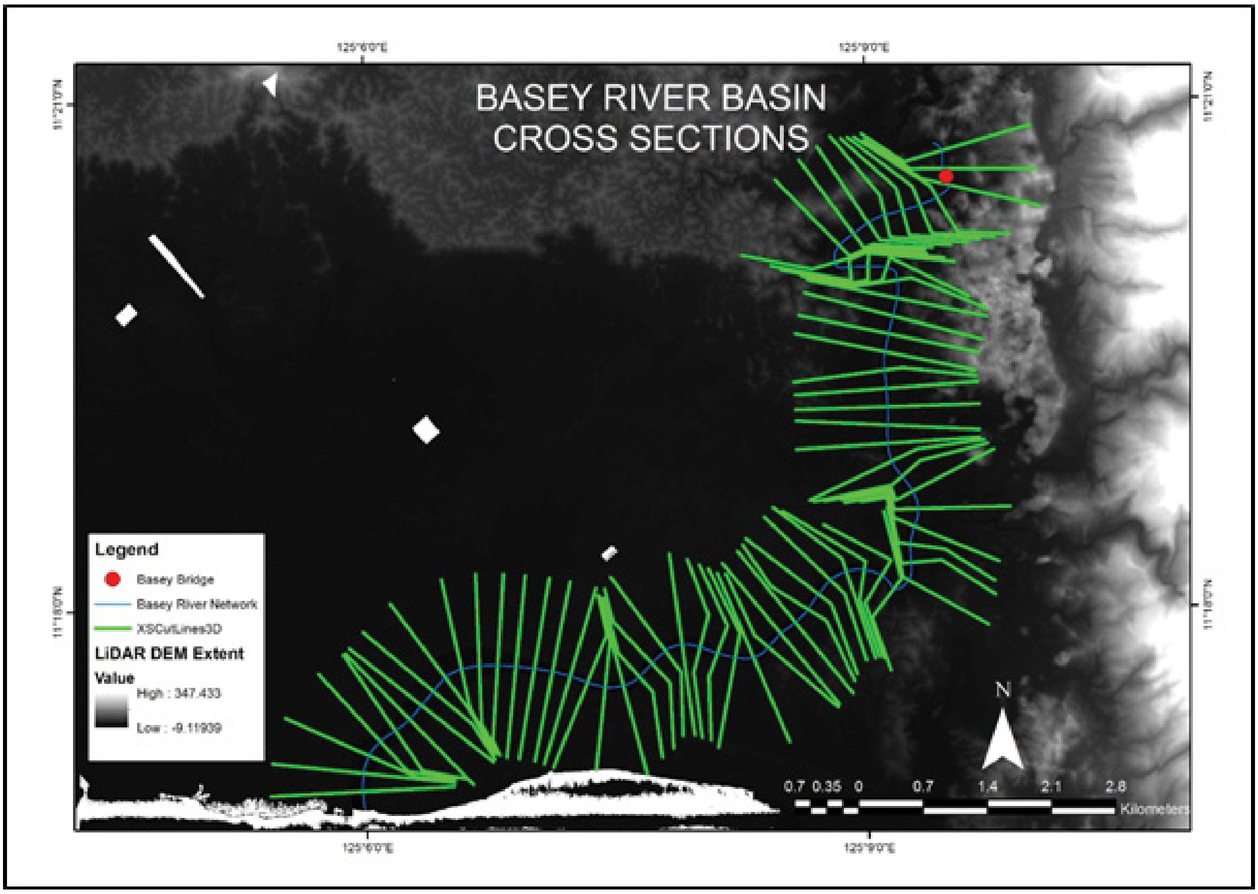


Figure 66. River cross-section of Basey River generated through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

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

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

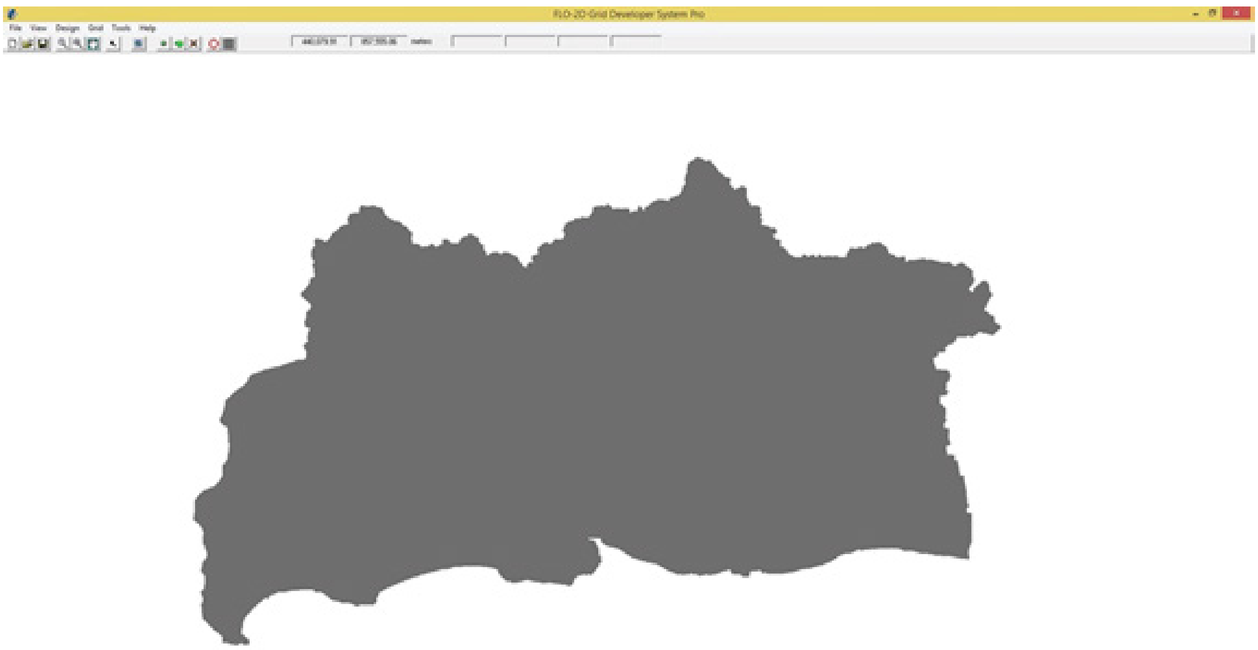


Figure 67. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 38.60889 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 Basey are in Figures 71, 73, and 75.

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 76,944,672.00 m2. The generated flood depth maps for Basey are in Figures 72, 74, and 76.

There is a total of 29,005,764.16 m3 of water entering the model. Of this amount, 29,005,764.16 m3 is due to rainfall while there is no inflow from other areas because it is an independent model. 10,958,439.00 m3 of this water is lost to infiltration and interception, while 14,445,841.09 m3 is stored by the flood plain. The rest, amounting up to 3,601,497.80 m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Basey HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 68 shows the comparison between the two discharge data.

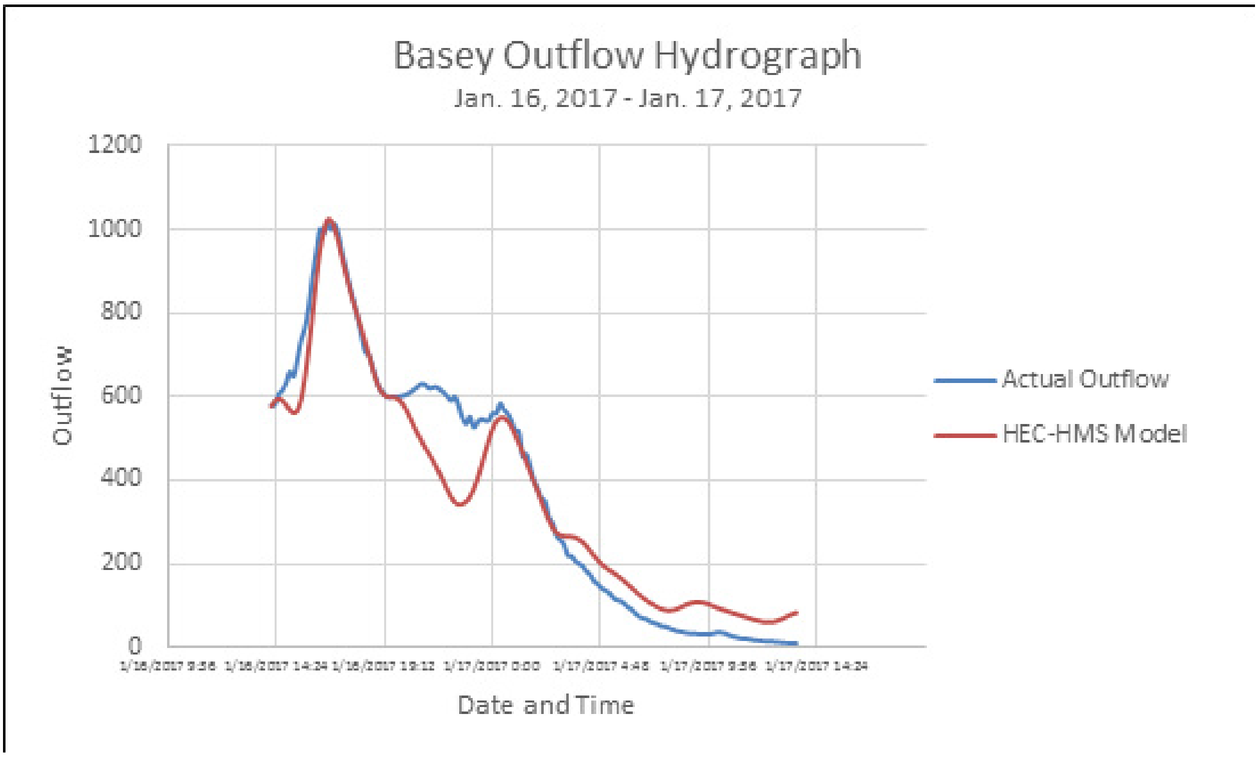


Figure 68. Outflow Hydrograph of Basey produced by the HEC-HMS model compared with observed outflow

Enumerated in Table 33 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 33. Range of Calibrated Values for Basey

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	40 - 151
			Curve Number	99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.1 - 7
			Storage Coefficient (hr)	0.02 - 1
	Baseflow	Recession	Recession Constant	0.9
			Ratio to Peak	0.01
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 40mm to 151mm means that there is a high amount of infiltration or rainfall interception by vegetation per subbasin.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The value of 99 for curve number is the highest possible value for this parameter.

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 0.02 to 7 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.9 indicates that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.01 indicates a steeper receding limb of the outflow hydrograph.

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

Table 34. Summary of the Efficiency Test of Basey HMS Model

RMSE	58.4
r2	0.82
NSE	0.94
PBIAS	0.27
RSR	0.24

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 58.4 (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 0.82.

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 0.94.

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 0.27.

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 0.24.

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

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph (Figure 69) shows the Basey outflow using the Tacloban 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 reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

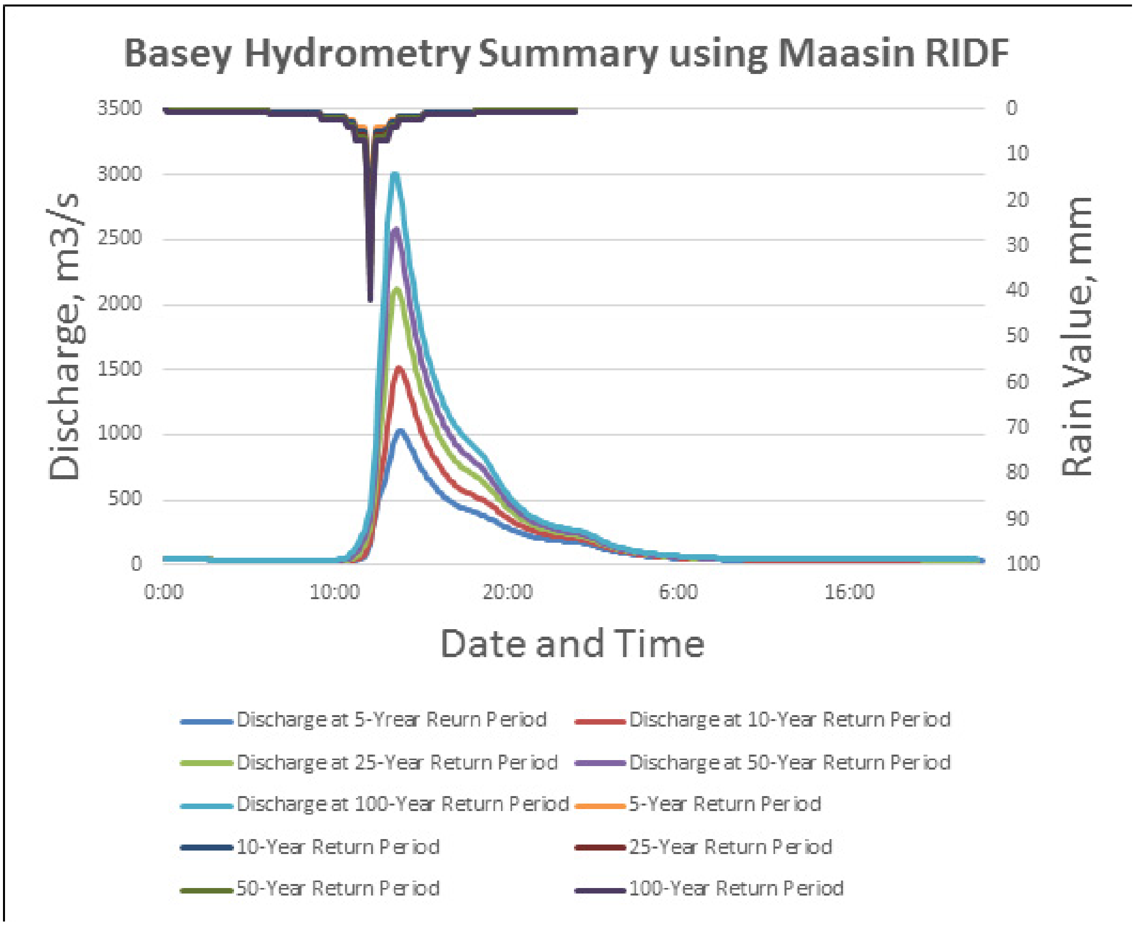


Figure 69. Outflow hydrograph at Basey Station generated using Tacloban RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Basey discharge using the Tacloban Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 35.

Table 35. Peak values of the Basey HEC-HMS Model outflow using the Tacloban RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	161.4	24.3	1028.7	1 hour, 40 minutes
10-Year	188.4	28.5	1514.0	1 hour, 40 minutes
25-Year	222.6	33.9	2129.6	1 hour, 30 minutes
50-Year	247.9	37.9	2579.1	1 hour, 30 minutes
100-Year	273.0	41.80	2999.8	1 hour, 30 minutes

5.8 River Analysis Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. For this publication, only a sample output map river was to be shown, since only the DVC base flow was calibrated. The sample generated map of Maayon River using the calibrated HMS base flow is shown in Figure 70.

Figure 70. Sample output of Basey RAS Model

5.9 Flood Hazard and Flow Depth Map

The resulting hazard and flow depth maps have a 10m resolution. Figure 71 to Figure 76 shows the 5-, 25-, and 100-year rain return scenarios of the Basey floodplain.

The floodplain, with an area of 141.92 sq. km., covers two municipalities namely Basey and Santa Rita. Table 36 shows the percentage of area affected by flooding per municipality.

Table 36. Municipalities affected in Basey floodplain

City / Municipality	Total Area	Area Flooded	% Flooded
Basey	627.97	140.21	22%
Santa Rita	250.37	1.59	1%

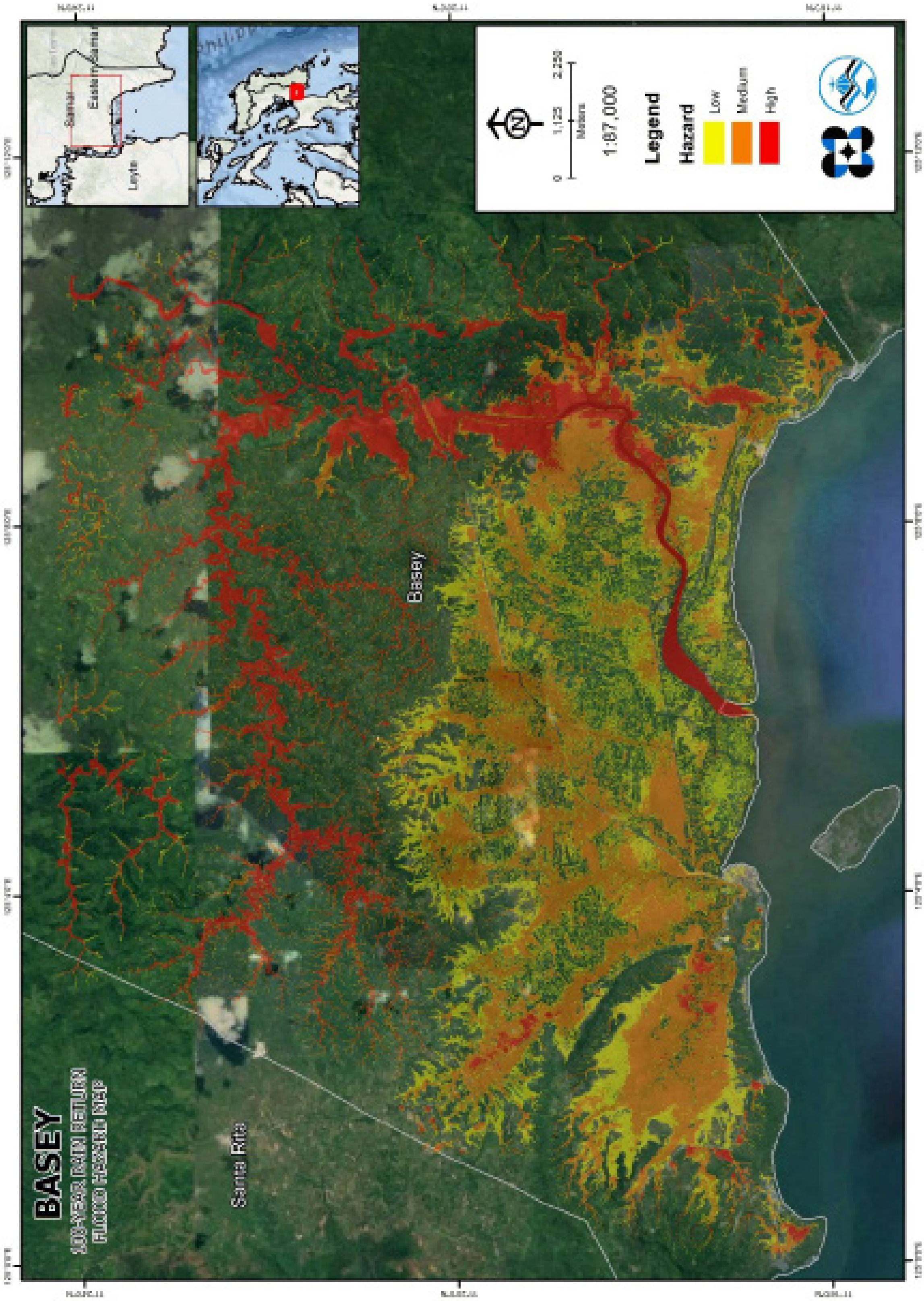


Figure 71. 100-year Flood Hazard Map for Basey Floodplain overlaid on Google Earth imagery

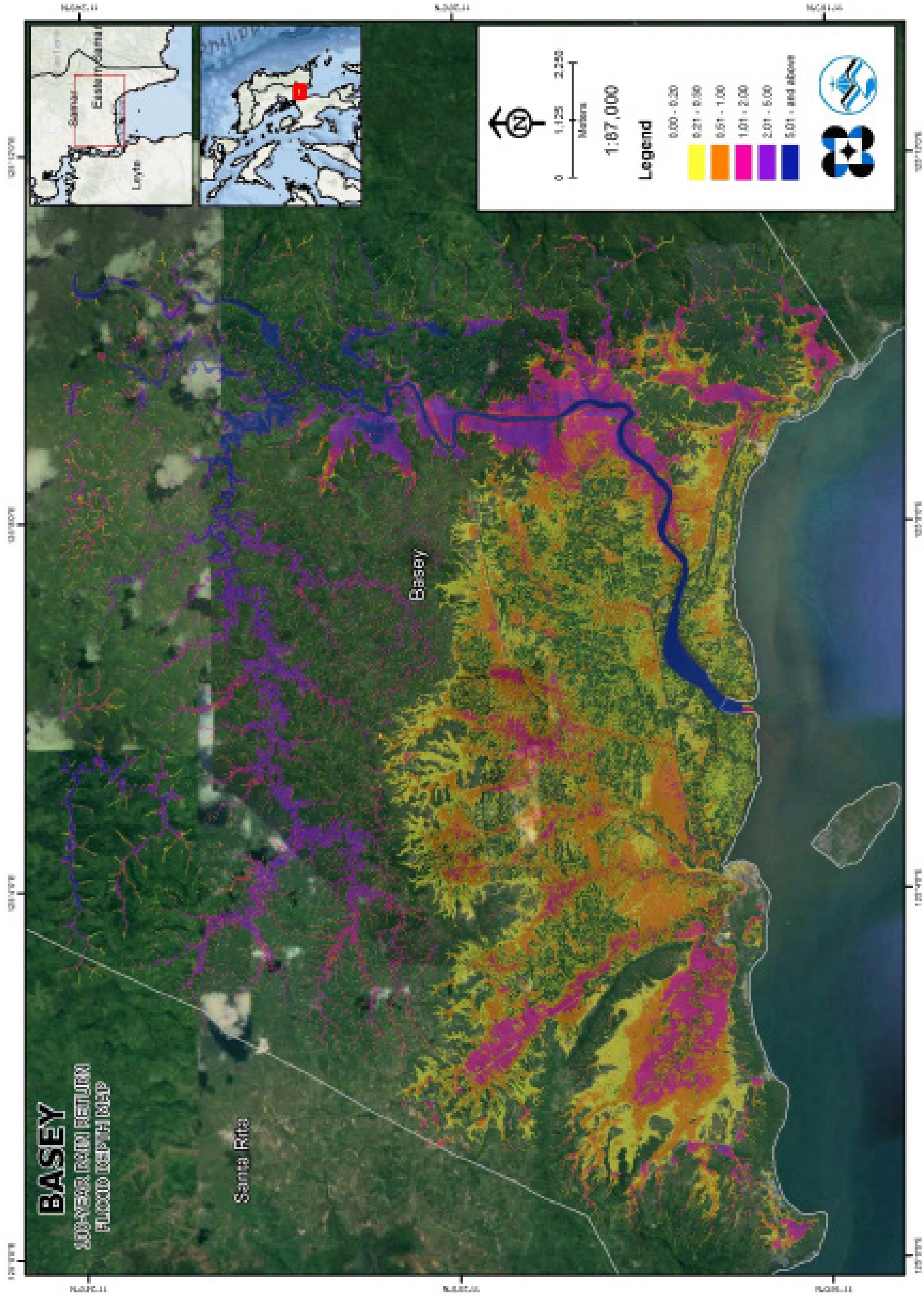


Figure 72. 100-year Flow Depth Map for Basey Floodplain overlaid on Google Earth imagery

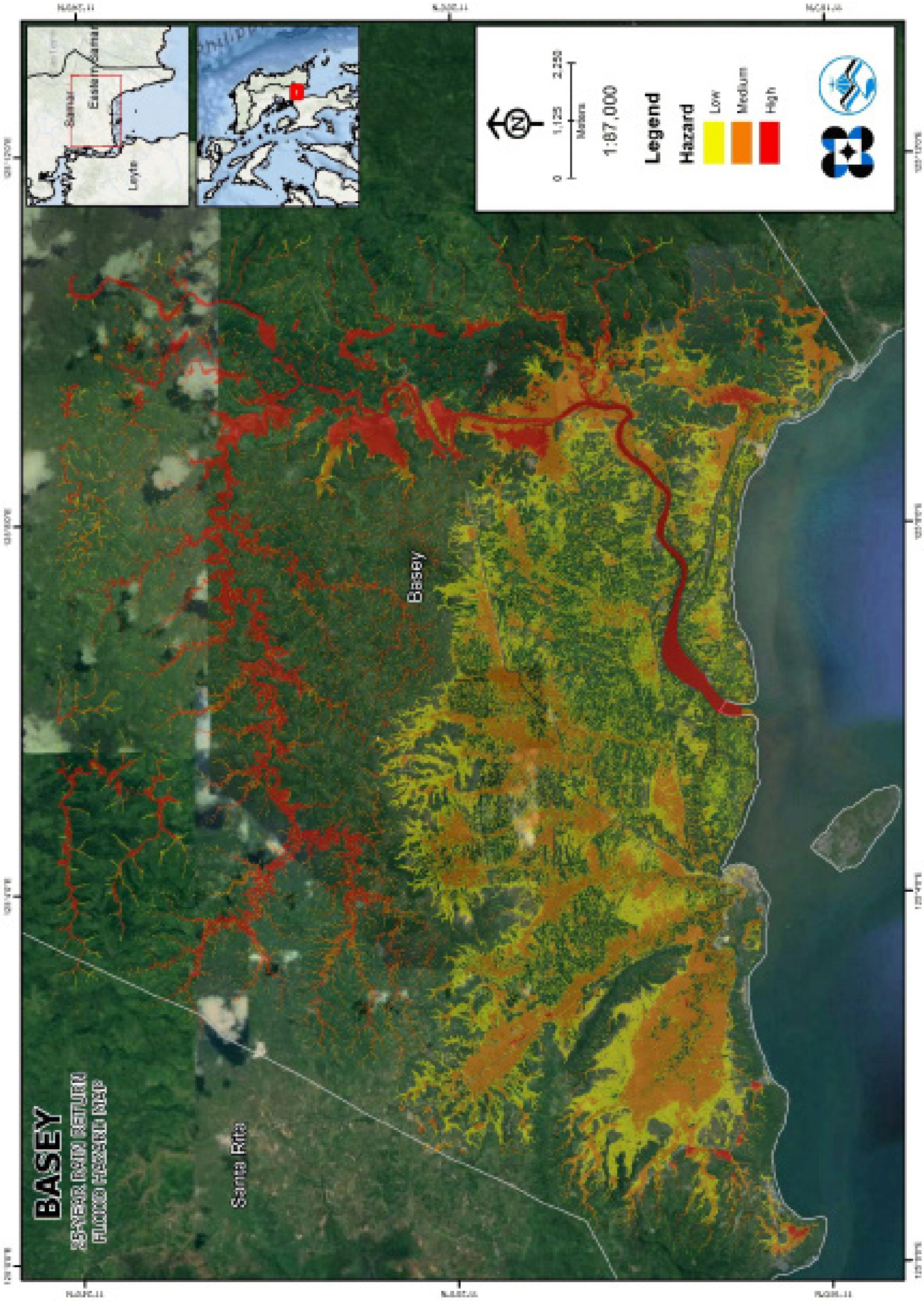


Figure 73. 25-year Flood Hazard Map for Basey Floodplain overlaid on Google Earth imagery

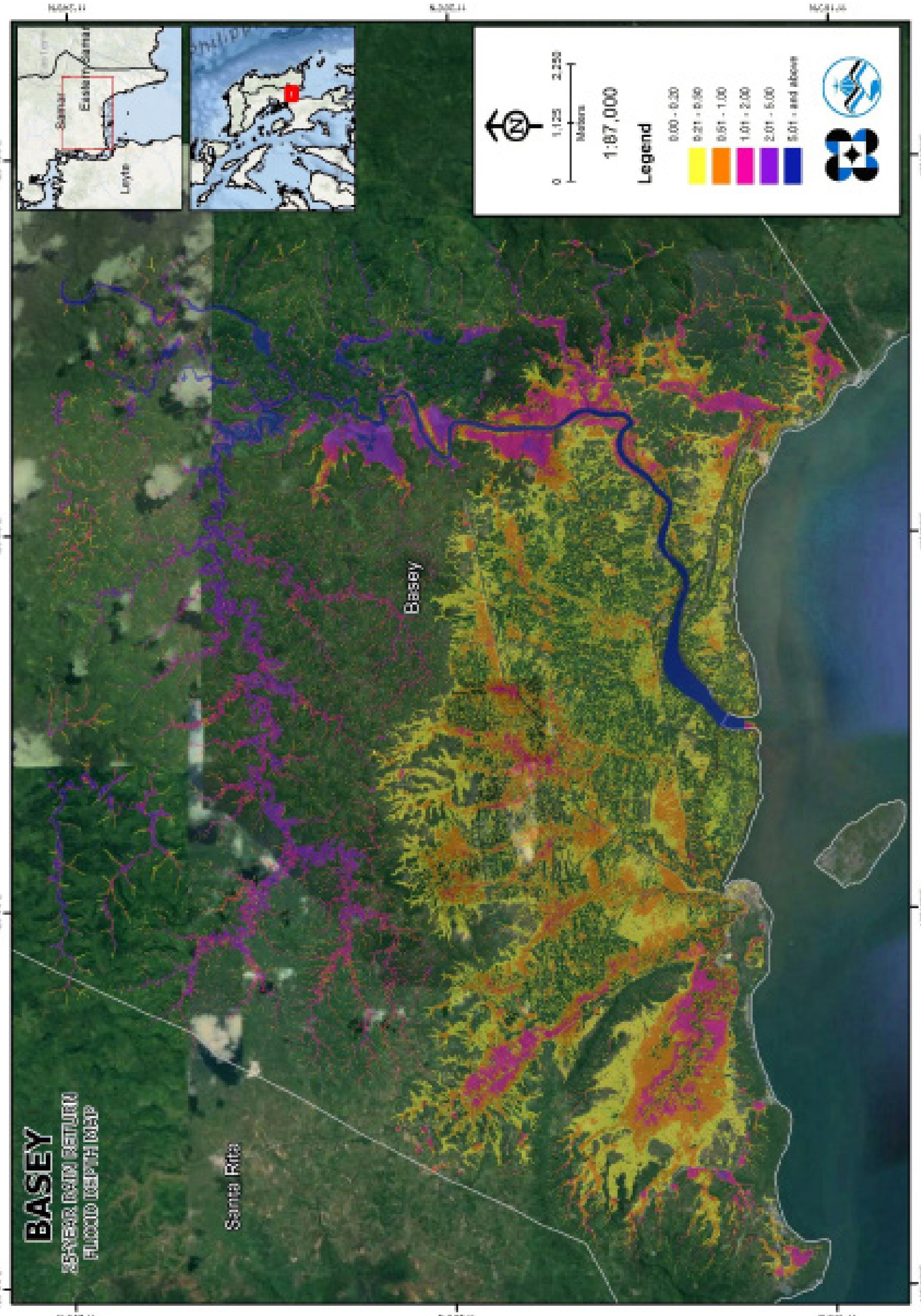


Figure 74. 25-year Flow Depth Map for Basey Floodplain overlaid on Google Earth imagery

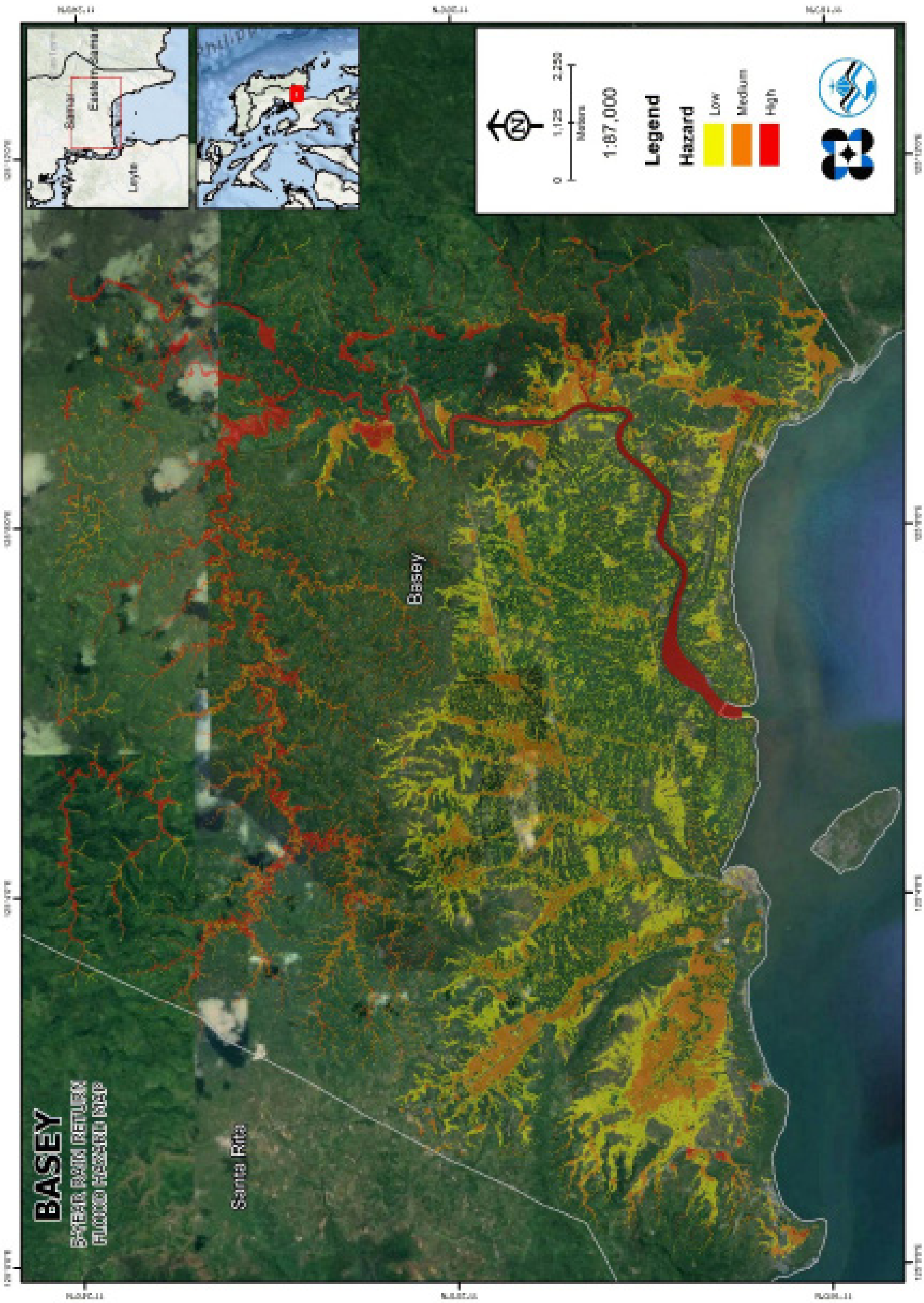


Figure 75. 5-year Flood Hazard Map for Basey Floodplain overlaid on Google Earth imagery

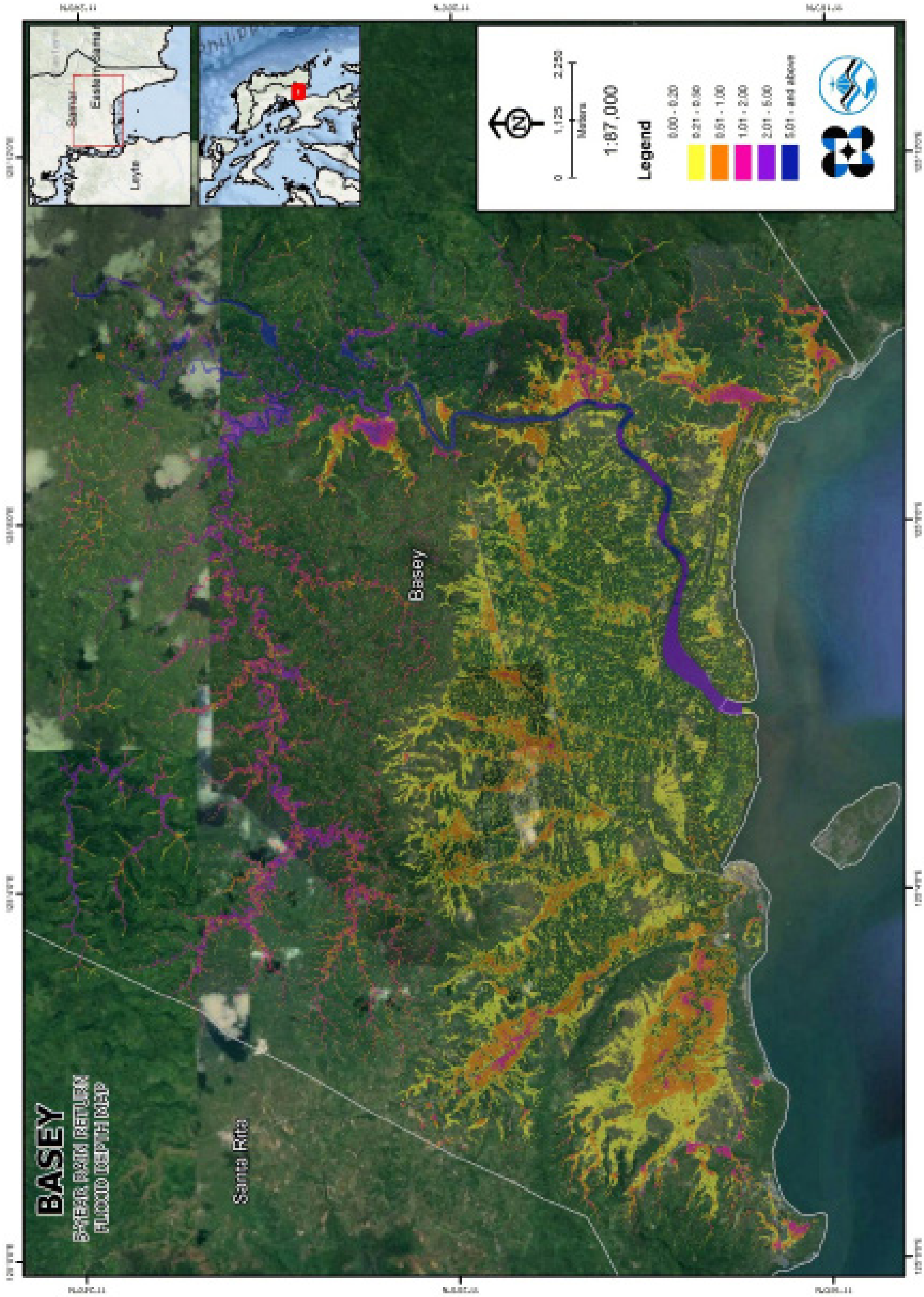


Figure 76. 5-year Flow Depth Map for Basey Floodplain overlaid on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Basey river basin, grouped by municipality, are listed below. For the said basin, three municipalities consisting of 56 barangays are expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 28.52379% of the municipality of Basey with an area of 627.97 sq. km. will experience flood levels of less 0.20 meters. 4.886182% of the area will experience flood levels of 0.21 to 0.50 meters while 2.529466%, 1.230202%, 0.745903%, and 0.260162% 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 kilometres by flood depth per barangay.

Table 37. Affected Areas in Basey, Samar during 5-Year Rainfall Return Period

Affected Areas (in sq.m.) by flood depth (in m.)	Affected Barangays in Basey, Samar									
	Amandayehan	Anglit	Bacubac	Balante	Baloog	Basiao	Baybay	Binongtu-an	Buenavista	Bulao
0.03-0.20	0.79	1.14	0.62	3.18	3.87	2.67	0.28	0.89	6.46	9.95
0.21-0.50	0.14	0.42	0.16	1.2	0.18	0.32	0.067	0.32	2.86	0.28
0.51-1.00	0.13	0.048	0.37	0.38	0.14	0.46	0.0063	0.015	0.82	0.32
1.01-2.00	0.074	0.00031	0.064	0.021	0.17	0.16	0.0001	0.0029	0.043	0.42
2.01-5.00	0.0037	0	0	0.0004	0.024	0.019	0	0.13	0.0082	0.25
> 5.00	0	0	0	0	0	0.0008	0	0.0073	0	0.012

Affected Areas (in sq.m.) by flood depth (in m.)	Affected Barangays in Basey, Samar									
	Amandayehan	Anglit	Bacubac	Balante	Baloog	Basiao	Baybay	Binongtuan	Buenavista	Bulao
0.03-0.20	0.79	1.14	0.62	3.18	3.87	2.67	0.28	0.89	6.46	9.95
0.21-0.50	0.14	0.42	0.16	1.2	0.18	0.32	0.067	0.32	2.86	0.28
0.51-1.00	0.13	0.048	0.37	0.38	0.14	0.46	0.0063	0.015	0.82	0.32
1.01-2.00	0.074	0.00031	0.064	0.021	0.17	0.16	0.0001	0.0029	0.043	0.42
2.01-5.00	0.0037	0	0	0.0004	0.024	0.019	0	0.13	0.0082	0.25
> 5.00	0	0	0	0	0	0.0008	0	0.0073	0	0.012

Affected Areas (in sq.m.) by flood depth (in m.)	Affected Barangays in Basey, Samar									
	Burgos	Buscada	Cambayan	Can-Abay	Cancaiyas	Canmanila	Catadman	Cogon	Del Pilar	Dolongan
0.03-0.20	1.35	0.45	1.15	0.68	4.86	0.83	4.75	12.61	1.66	4.33
0.21-0.50	0.41	0.16	0.071	0.12	0.1	0.16	0.41	1.63	0.71	1.23
0.51-1.00	0.17	0.044	0.043	0.06	0.091	0.15	0.3	0.7	0.15	1.02
1.01-2.00	0.0043	0.0024	0.023	0.065	0.13	0.02	0.26	0.78	0.0003	0.21
2.01-5.00	0.0016	0	0.0024	0.0024	0.26	0.0001	0.034	0.38	0	0.0032
> 5.00	0.017	0	0	0	0.021	0	0.0004	0.0088	0	0

Affected Areas (in sq.m.) by flood depth (in m.)	Affected Barangays in Basey, Samar									
	Guintigui-An	Guirang	Iba	Inuntan	Lawa-An	Loog	Loyo	Mabini	Magallanes	Manlilinab
0.03-0.20	0.82	14.9	5.08	3.42	0.17	8.09	0.5	0.016	1.21	14.01
0.21-0.50	0.54	0.7	2.26	0.22	0.1	0.51	0.043	0.0001	0.63	0.42
0.51-1.00	0.22	0.7	0.28	0.22	0.014	0.41	0.027	0.0002	0.13	0.45
1.01-2.00	0.0057	0.75	0.0033	0.12	0.00019	0.18	0.0069	0.0009	0.0034	0.61
2.01-5.00	0.0016	0.85	0	0.039	0	0.21	0	0.0025	0	0.93
> 5.00	0	0.66	0	0.0011	0	0.21	0	0.0019	0	0.44

Affected Areas (in sq.m.) by flood depth (in m.)	Affected Barangays in Basey, Samar									
	May-It	Mercado	Mongabong	New San Agustin	Nouvelas Occidental	Old San Agustin	Palaypay	Panugmonon	Pelit	Roxas
0.03-0.20	3.01	0.14	2.31	2.61	1.33	16.67	0.14	1.26	4.59	2.6
0.21-0.50	1.24	0.036	0.54	1.33	0.45	2.94	0.061	0.48	0.54	1.15
0.51-1.00	0.72	0.019	0.23	0.86	0.035	1.45	0.012	0.039	0.61	1.11
1.01-2.00	0.11	0.00075	0.039	0.06	0.0022	1.18	0.00065	0.0008	0.39	0.11
2.01-5.00	0.0092	0	0.0027	0	0.12	0.46	0	0	0.24	0.001
> 5.00	0.0001	0	0.0001	0	0.039	0.016	0	0	0.066	0

Affected Areas (in sq.m.) by flood depth (in m.)	Affected Barangays in Basey, Samar									
	San Antonio	San Fernando	Sawa	Serum	Sugca	Sugponon	Sulod	Tinaogan	Tingib	Villa Aurora
0.03-0.20	1.12	6.68	2.48	1.81	1.63	1.7	0.24	0.27	1.91	15.84
0.21-0.50	0.21	1.51	0.75	0.62	0.54	0.59	0.06	0.0034	0.67	0.59
0.51-1.00	0.12	0.82	0.47	0.048	0.022	0.18	0.02	0.0013	0.47	0.82
1.01-2.00	0.037	0.26	0.2	0.0003	0.0006	0.087	0.00015	0.0007	0.045	1.09
2.01-5.00	0.00036	0.18	0.044	0	0	0.0079	0	0.0001	0	0.46
> 5.00	0	0.13	0	0	0	0	0	0	0	0.01

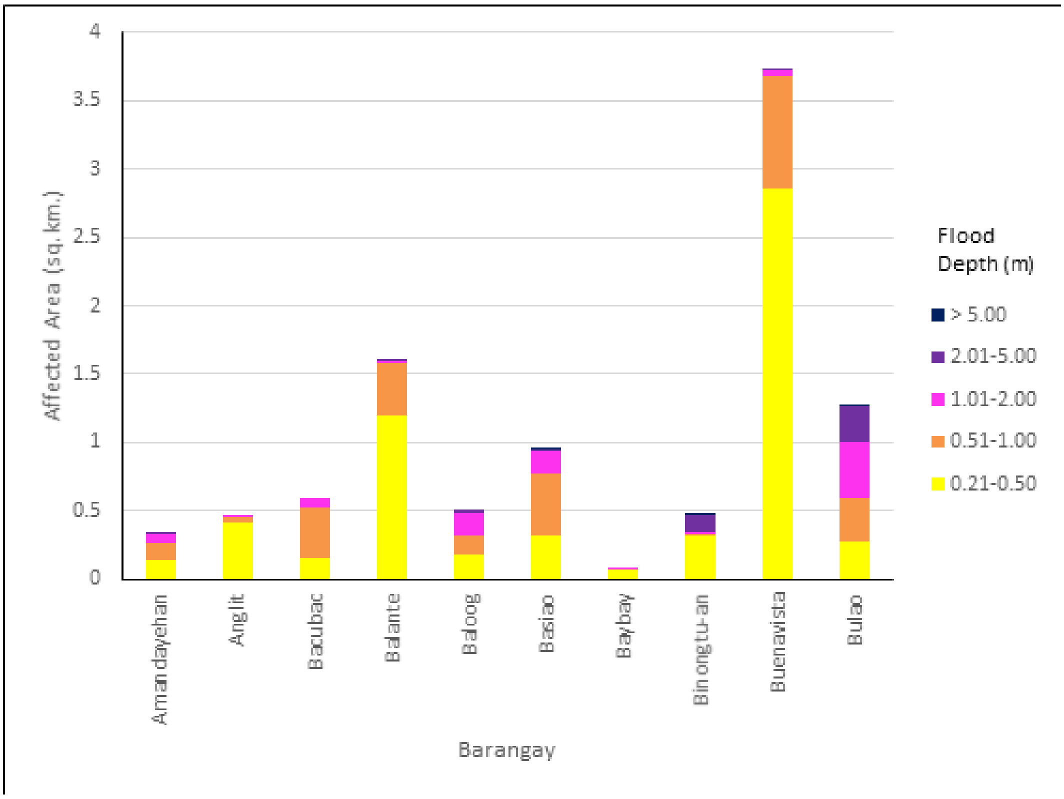


Figure 77. Affected Areas in Basey, Samar during 5-Year Rainfall Return Period

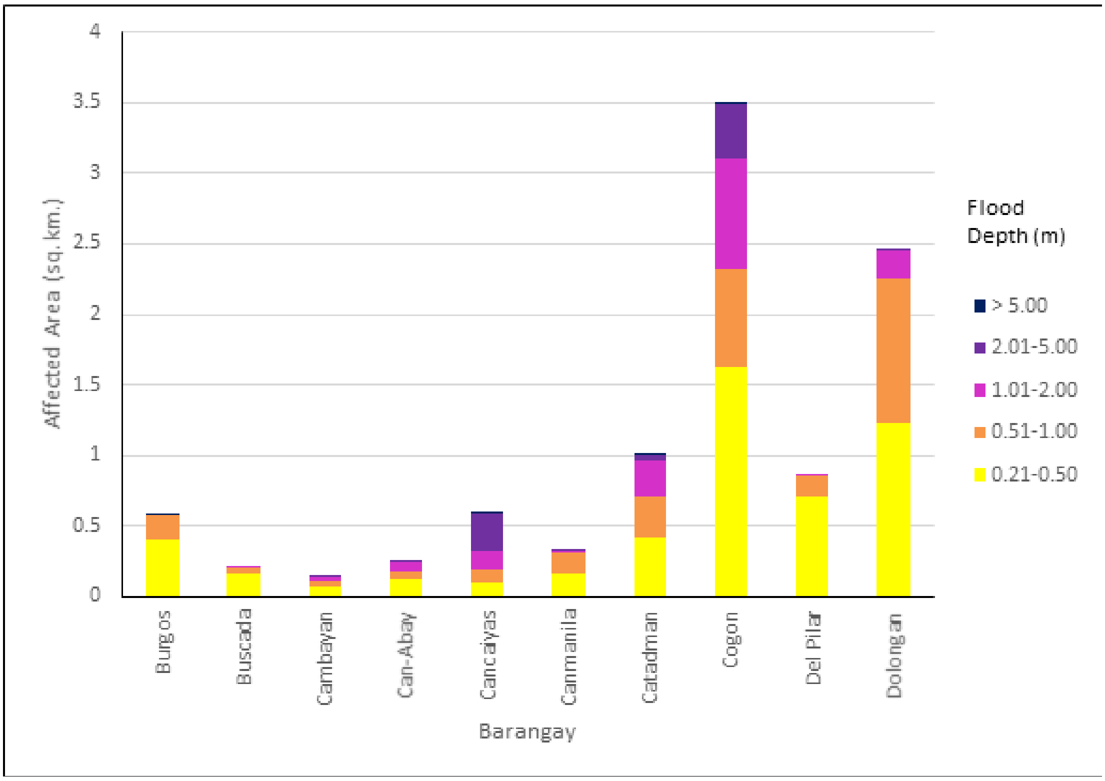


Figure 78. Affected Areas in Basey, Samar during 5-Year Rainfall Return Period

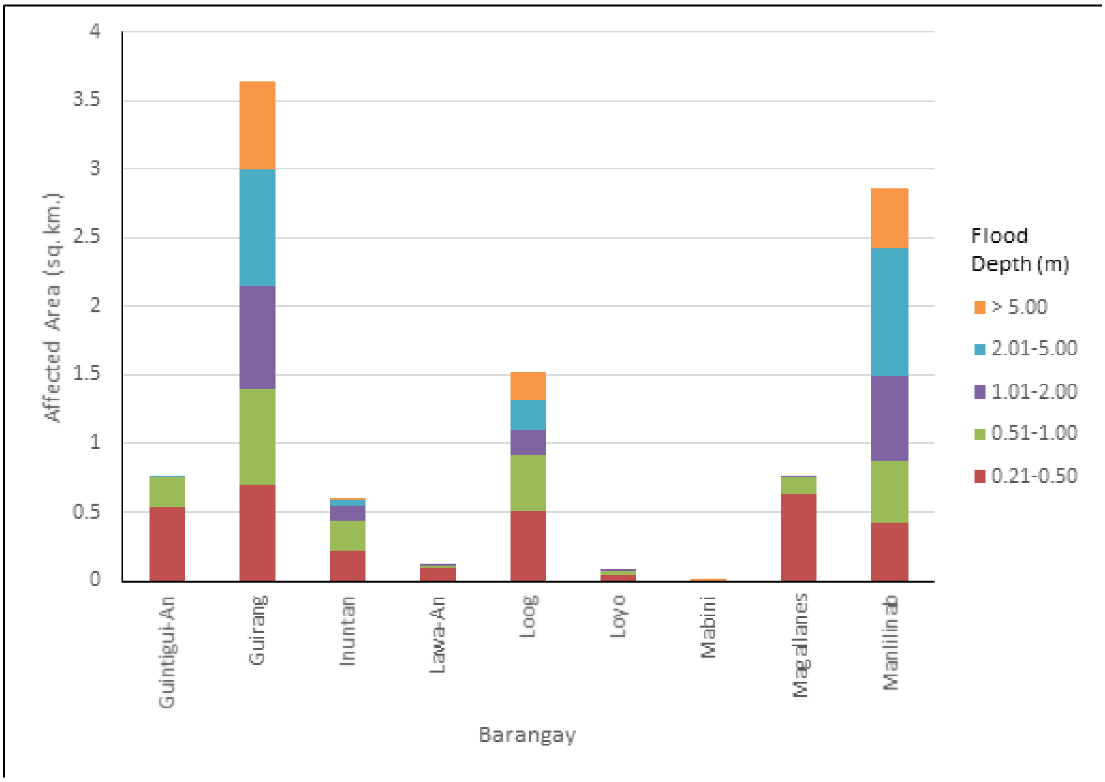


Figure 79. Affected Areas in Basey, Samar during 5-Year Rainfall Return Period

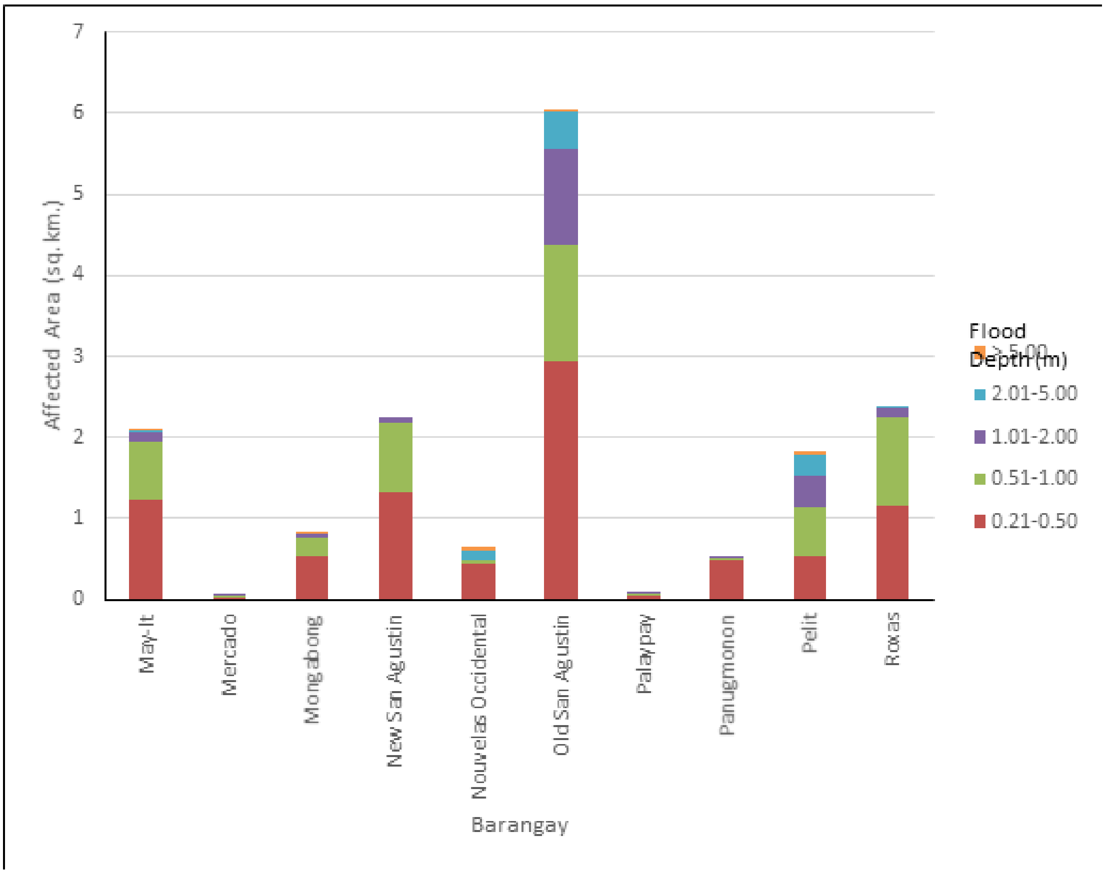


Figure 80. Affected Areas in Basey, Samar during 5-Year Rainfall Return Period

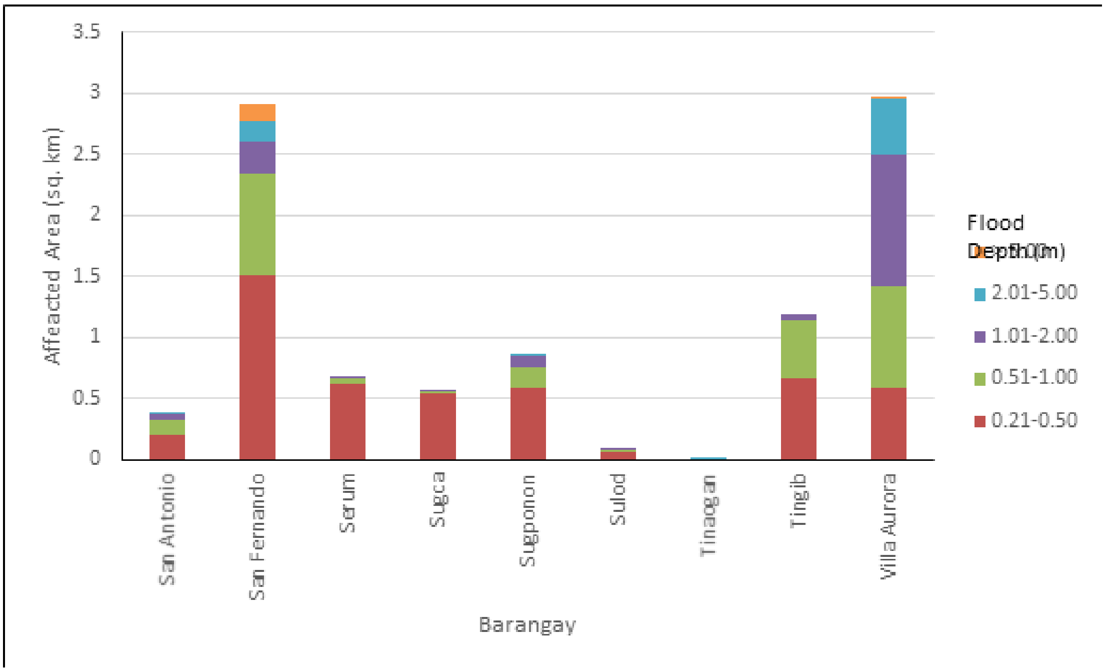


Figure 81. Affected Areas in Basey, Samar during 5-Year Rainfall Return Period

For the municipality of Santa Rita, with an area of 250.371sq. km., 0.554291% will experience flood levels of less 0.20 meters. 0.012747% of the area will experience flood levels of 0.21 to 0.50 meters while 0.008513%, 0.005991%, and 0.002179% 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 kilometres by flood depth per barangay.

Table 38. Affected Areas in Santa Rita, Samar during 5-Year Rainfall Return Period

Affected Areas (in sq.m.) by flood depth (in m.)	Area of affected barangays in Santa Rita (in sq. km.)				
	Bagolibas	Cabacungan	Caticugan	Pagsulhogon	San Pedro
0.03-0.20	0.18	0.67	0.013	0.38	0.14
0.21-0.50	0.0033	0.019	0.0011	0.0069	0.0015
0.51-1.00	0.0043	0.0089	0.0017	0.0056	0.0009
1.01-2.00	0.001	0.0081	0.0015	0.0035	0.001
2.01-5.00	0	0.00088	0	0.0046	0
> 5.00	0	0	0	0	0

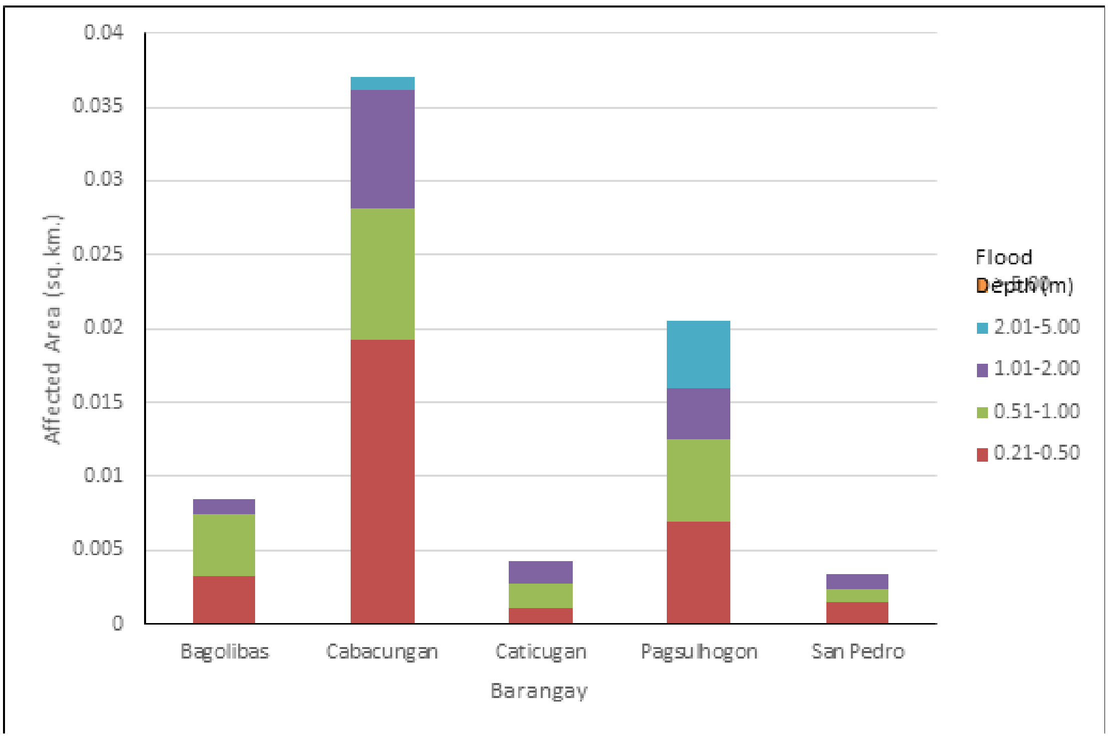


Figure 82. Affected Areas in Santa Rita, Samar during 5-Year Rainfall Return Period

For the 25-year return period, 25.49069% of the municipality of Basey with an area of 627.97 sq. km. will experience flood levels of less 0.20 meters. 5.234104% of the area will experience flood levels of 0.21 to 0.50 meters while 3.594518%, 2.099354%, 1.240996%, and 0.5189% 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 kilometres by flood depth per barangay.

Table 39. Affected Areas in Basey, Samar during 25-Year Rainfall Return Period

Affected Areas (in sq.m.) by flood depth (in m.)	Affected Barangays in Basey									
	Amandayehan	Anglit	Bacubac	Balante	Baloog	Basiao	Baybay	Binongtu-an	Buenavista	Bulao
0.03-0.20	0.72	0.88	0.51	2.65	3.76	2.55	0.25	0.71	4.55	9.77
0.21-0.50	0.14	0.57	0.12	1.31	0.21	0.26	0.089	0.45	3.23	0.29
0.51-1.00	0.15	0.16	0.27	0.71	0.14	0.39	0.012	0.069	2.22	0.28
1.01-2.00	0.12	0.00096	0.32	0.12	0.2	0.39	0.0002	0.002	0.18	0.47
2.01-5.00	0.012	0.000068	0	0.0018	0.059	0.033	0	0.073	0.016	0.38
> 5.00	0	0	0	0	0	0.001	0	0.068	0	0.031

Affected Areas (in sq.m.) by flood depth (in m.)	Affected Barangays in Basey									
	Burgos	Buscada	Cambayan	Can-Abay	Cancaiyas	Canmanila	Catadman	Cogon	Del Pilar	Dolongan
0.03-0.20	0.27	1.12	0.59	4.73	0.73	4.49	11.74	1.31	3.77	3.773204
0.21-0.50	0.23	0.076	0.17	0.11	0.15	0.43	1.89	0.81	1.32	1.321199
0.51-1.00	0.15	0.056	0.076	0.091	0.19	0.37	0.9	0.39	0.98	0.981249
1.01-2.00	0.015	0.031	0.065	0.13	0.094	0.36	0.72	0.0064	0.71	0.708023
2.01-5.00	0	0.0043	0.026	0.29	0.0011	0.096	0.83	0	0.006	0.006
> 5.00	0	0	0	0.11	0	0.0011	0.024	0	0	0

Affected Areas (in sq.m.) by flood depth (in m.)	Affected Barangays in Basey									
	May-It	Mercado	Mongabong	New San Agustin	Nouvelas Occidental	Old San Agustin	Palaypay	Panugmonon	Pelit	Roxas
0.03-0.20	2.72	0.12	2.14	1.82	1.07	15.02	0.097	1	4.13	2.08
0.21-0.50	1.04	0.043	0.56	1.38	0.6	3.09	0.05	0.63	0.36	1.04
0.51-1.00	0.99	0.029	0.35	1.35	0.13	2	0.058	0.15	0.63	1.26
1.01-2.00	0.32	0.0018	0.067	0.31	0.0026	1.27	0.0071	0.0038	0.9	0.59
2.01-5.00	0.016	0	0.0042	0.0002	0.0087	1.26	0	0	0.25	0.002
> 5.00	0.0001	0	0.0001	0	0.16	0.078	0	0	0.16	0

Affected Areas (in sq.m.) by flood depth (in m.)	Affected Barangays in Basey									
	Guintigui-An	Guirang	Iba	Inuntan	Lawa-An	Loog	Loyo	Mabini	Magallanes	Manlilinab
0.03-0.20	0.56	13.74	3.74	3.29	0.1	7.45	0.48	0.013	0.9	13.49
0.21-0.50	0.66	0.58	2.57	0.16	0.055	0.38	0.053	0.001	0.77	0.43
0.51-1.00	0.29	0.56	1.29	0.2	0.12	0.46	0.036	0.00016	0.3	0.42
1.01-2.00	0.07	0.83	0.03	0.25	0.0067	0.75	0.013	0.00034	0.011	0.58
2.01-5.00	0.0019	1.73	0	0.12	0	0.3	0.0001	0.0015	0	1.06
> 5.00	0	1.12	0	0.002	0	0.28	0	0.0053	0	0.89

Affected Areas (in sq.m.) by flood depth (in m.)	Affected Barangays in Basey									
	San Antonio	San Fernando	Sawa	Serum	Sugca	Sugponon	Sulod	Tinaogan	Tingib	Villa Aurora
0.03-0.20	1.06	5.56	2.1	1.51	1.31	1.28	0.19	0.27	1.57	15.42
0.21-0.50	0.19	1.65	0.81	0.83	0.79	0.68	0.072	0.0036	0.64	0.57
0.51-1.00	0.16	1.29	0.6	0.13	0.091	0.33	0.055	0.0023	0.7	0.67
1.01-2.00	0.075	0.74	0.27	0.0003	0.002	0.24	0.0034	0.0006	0.18	1.26
2.01-5.00	0.0015	0.085	0.17	0	0	0.041	0	0.0002	0.0014	0.83
> 5.00	0	0.26	0.0001	0	0	0	0	0	0	0.057

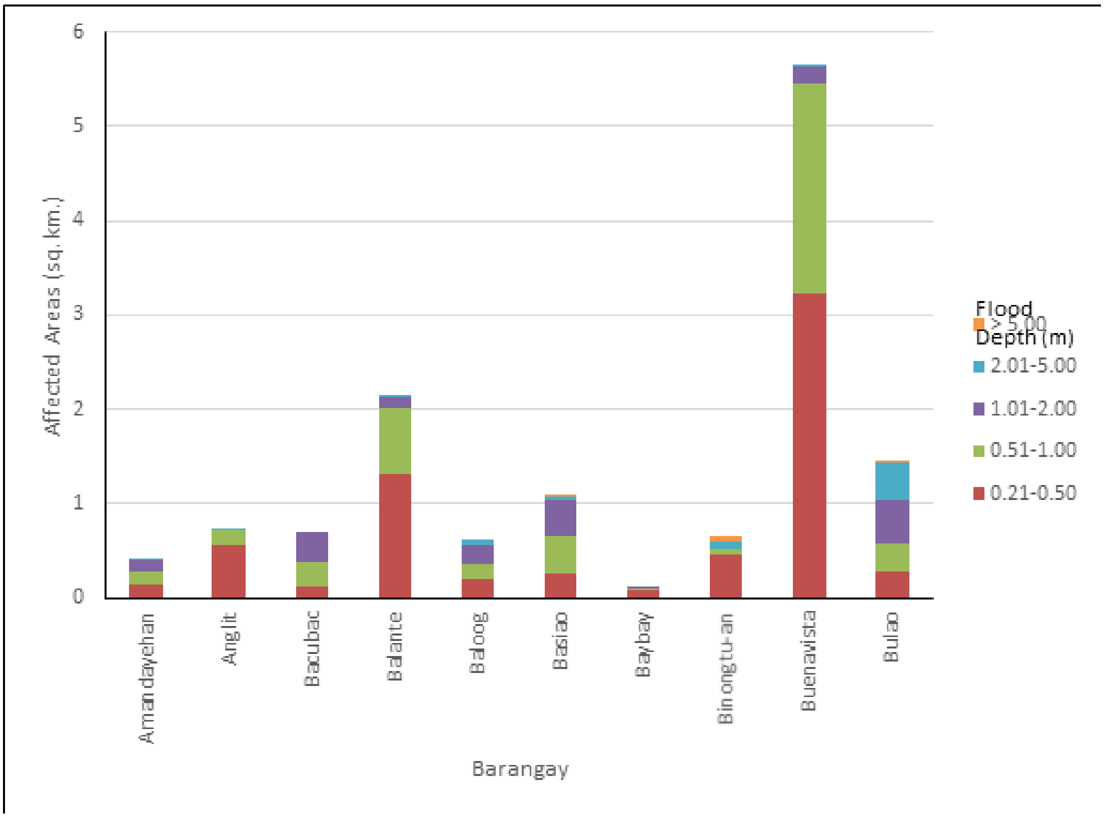


Figure 83. Affected Areas in Basey, Samar during 25-Year Rainfall Return Period

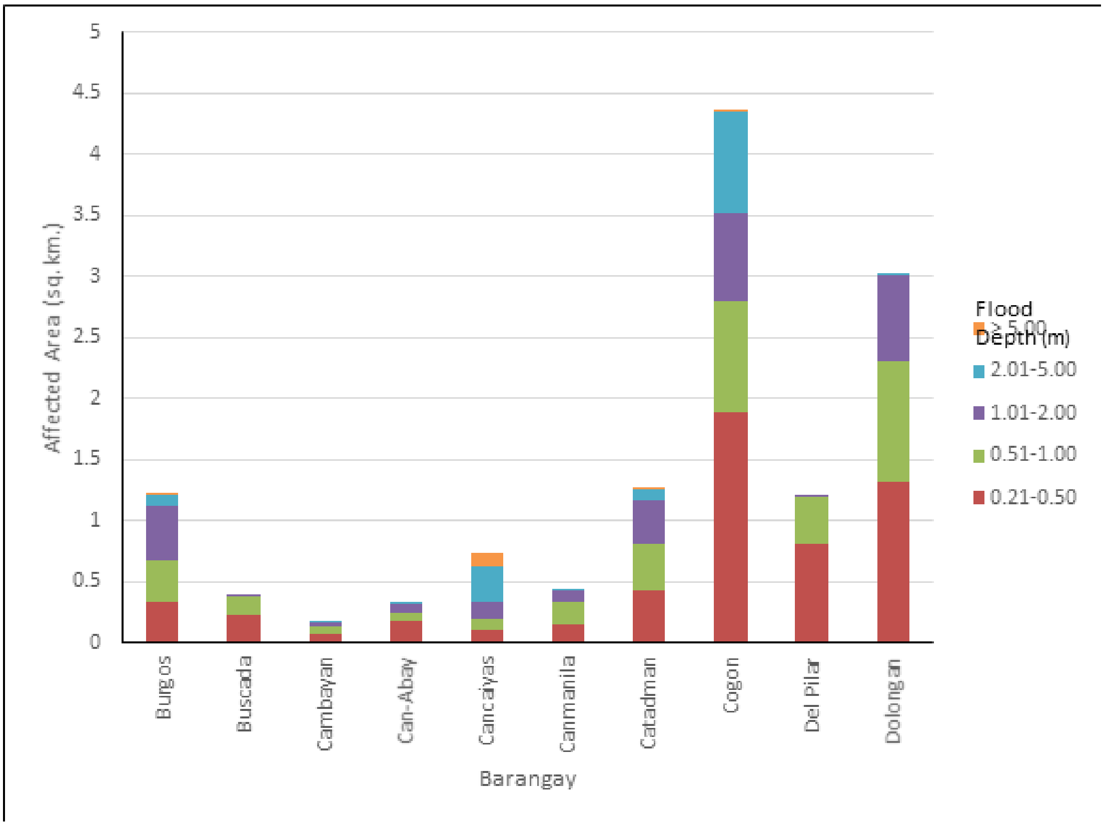


Figure 84. Affected Areas in Basey, Samar during 25-Year Rainfall Return Period

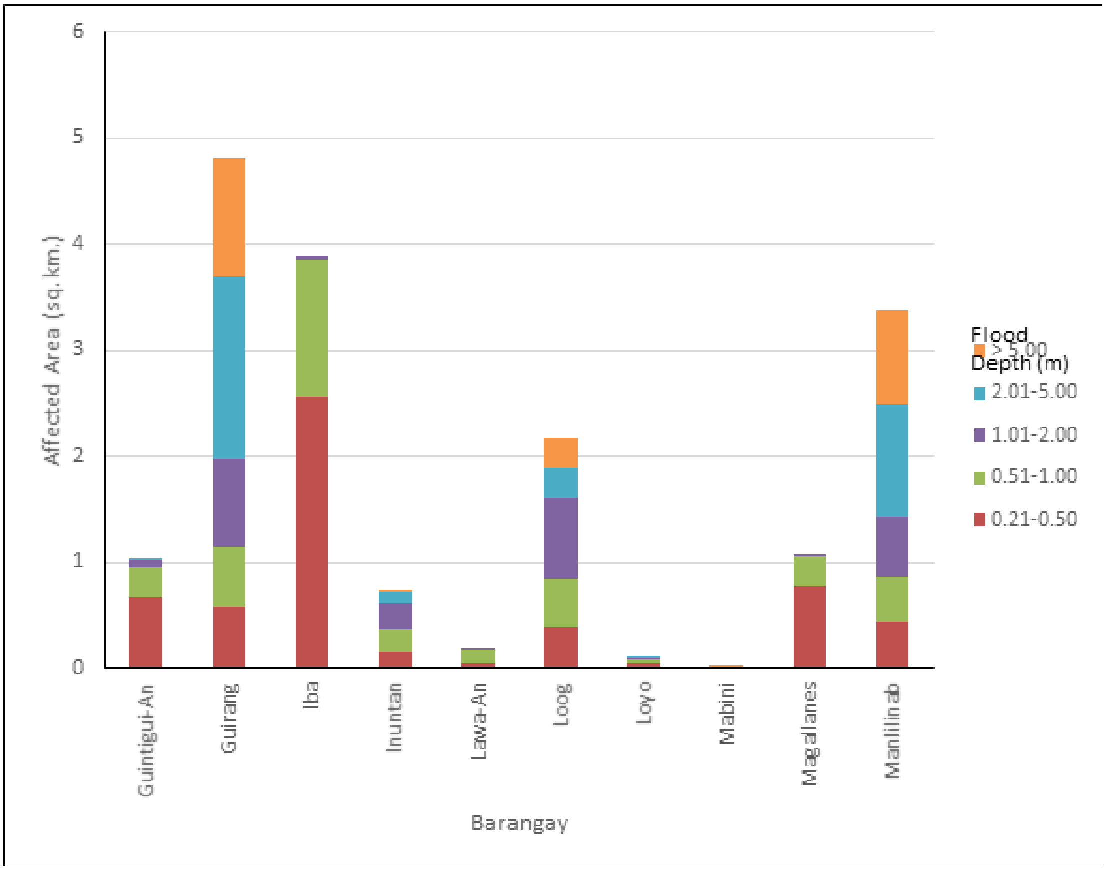


Figure 85. Affected Areas in Basey, Samar during 25-Year Rainfall Return Period

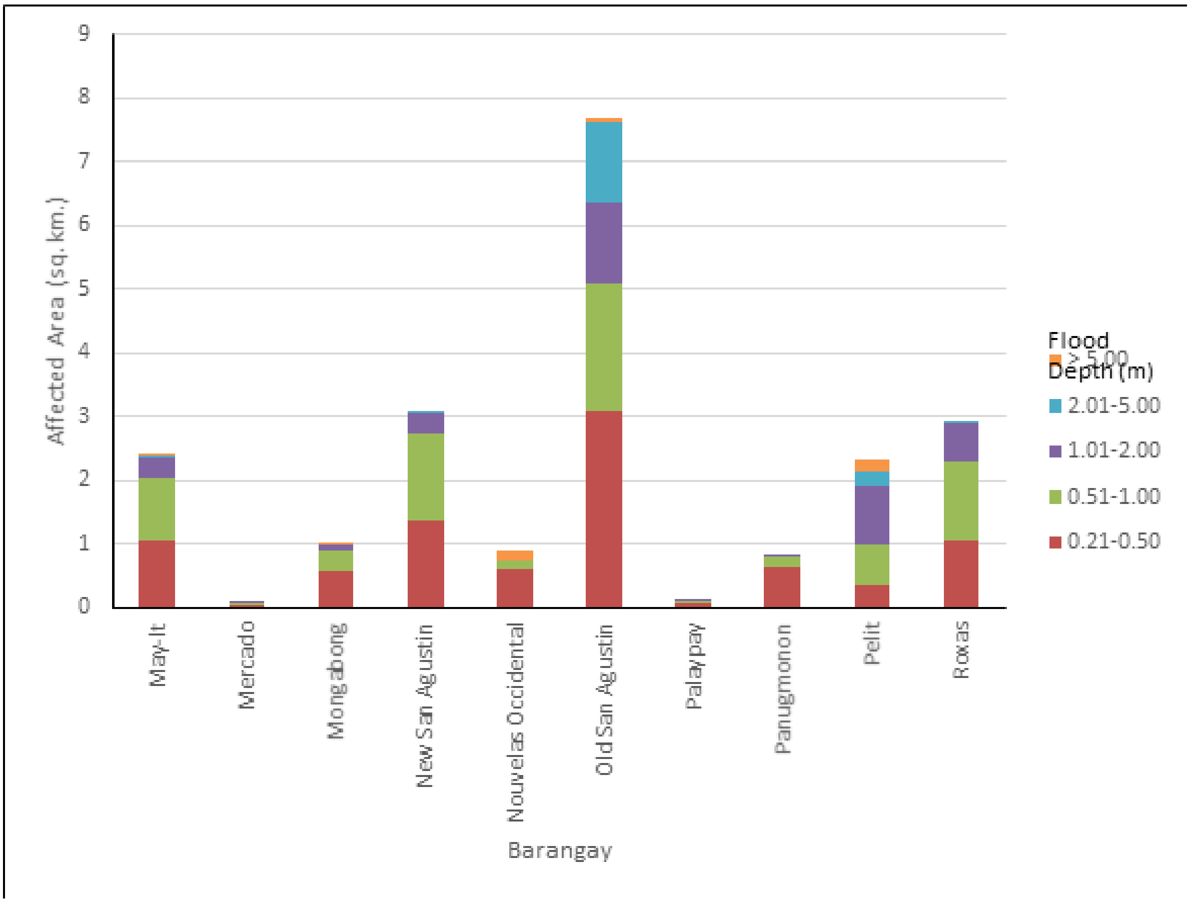


Figure 86. Affected Areas in Basey, Samar during 25-Year Rainfall Return Period

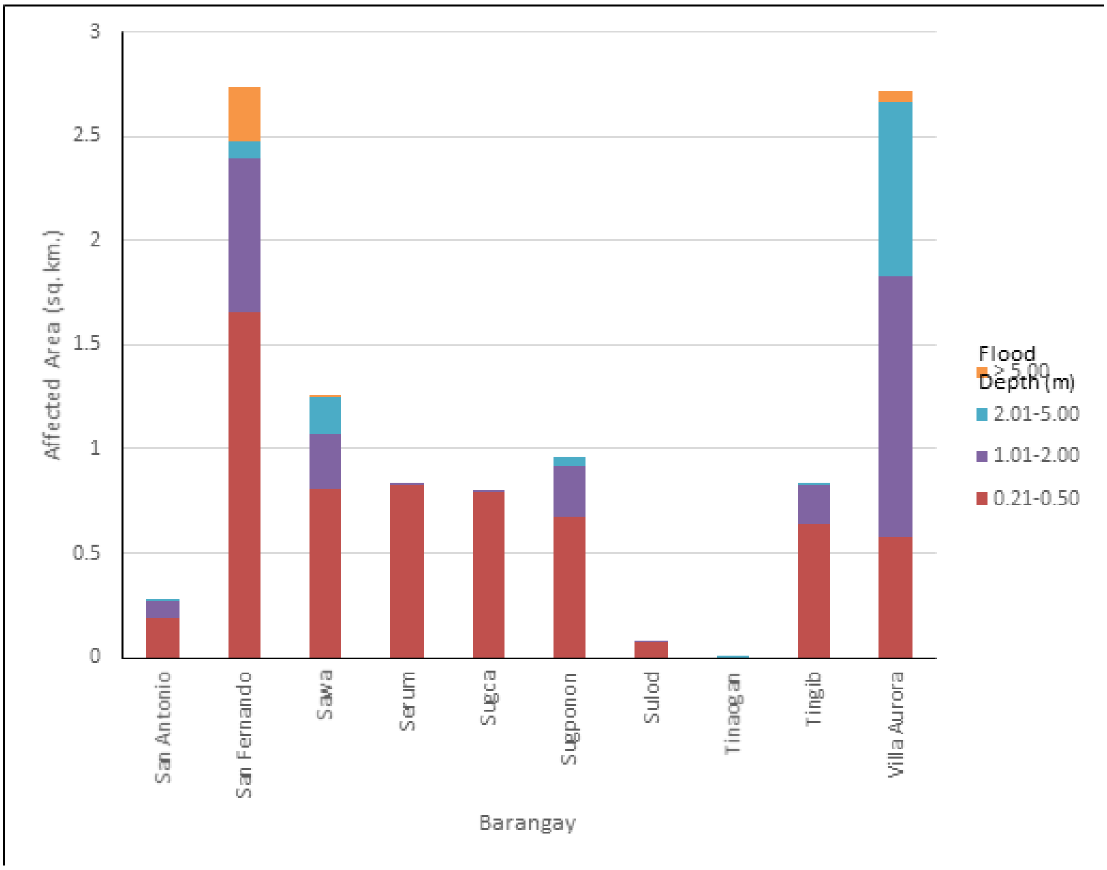


Figure 87. Affected Areas in Basey, Samar during 25-Year Rainfall Return Period

For the municipality of Santa Rita, with an area of 250.371 sq. km., 0.19% will experience flood levels of less 0.20 meters. 0.005%of the area will experience flood levels of 0.21 to 0.50 meters while 0.003%, 0.004%, and 0.002% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, respectively.

Table 40. Affected Areas in Santa Rita, Samar during 25-Year Rainfall Return Period

Affected Areas (in sq.m.) by flood depth (in m.)	Affected Barangays in Santa Rita, Samar				
	Bagolibas	Cabacungan	Caticugan	Pagsulhogon	San Pedro
0.03-0.20	0.18	0.66	0.011	0.38	0.14
0.21-0.50	0.0023	0.02	0.0019	0.0099	0.0016
0.51-1.00	0.0055	0.012	0.0021	0.0055	0.0007
1.01-2.00	0.0016	0.0071	0.0024	0.0048	0.0009
2.01-5.00	0	0.0038	0.0003	0.005	0.0005
> 5.00	0	0	0	0.0001	0

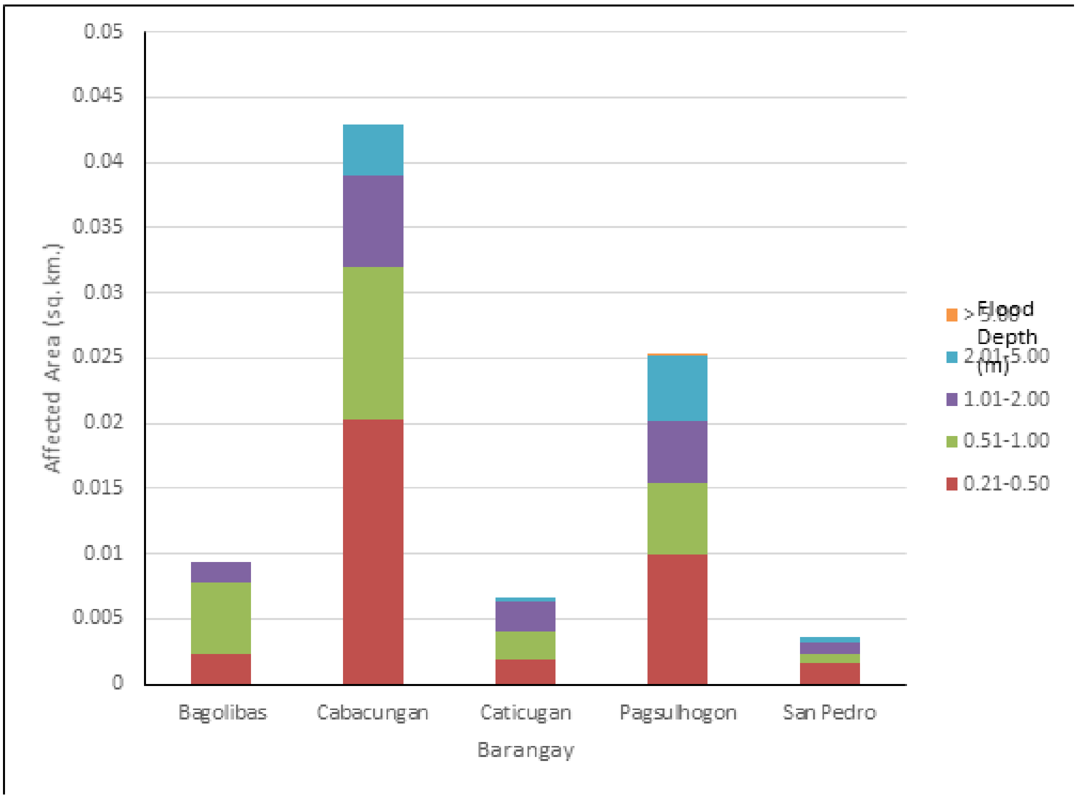


Figure 88. Affected Areas in Santa Rita, Samar during 25-Year Rainfall Return Period

For the 100-year return period, 23.75% of the municipality of Basey with an area of 627.97 sq. km. will experience flood levels of less 0.20 meters. 4.80% of the area will experience flood levels of 0.21 to 0.50 meters while 4.46%, 2.72%, 1.76%, and 0.68% 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 41 are the affected areas in square kilometres by flood depth per barangay.

Table 41. Affected Areas in Basey, Samar during 100-Year Rainfall Return Period

Affected Areas (in sq.m.) by flood depth (in m.)	Affected Barangays in Basey, Samar									
	Amandayehan	Anglit	Bacubac	Balante	Baloog	Basiao	Baybay	Binongtu-an	Buenavista	Bulao
0.03-0.20	0.68	0.74	0.45	2.28	3.7	2.47	0.23	0.6	3.74	9.64
0.21-0.50	0.13	0.57	0.093	1.29	0.23	0.25	0.1	0.49	2.64	0.3
0.51-1.00	0.16	0.29	0.21	0.98	0.15	0.32	0.018	0.13	3.33	0.27
1.01-2.00	0.12	0.0028	0.46	0.23	0.21	0.54	0.0003	0.002	0.46	0.46
2.01-5.00	0.029	0.00011	0	0.0036	0.095	0.043	0	0.066	0.023	0.5
> 5.00	0	0	0	0	0	0.0015	0	0.077	0	0.047

Affected Areas (in sq.m.) by flood depth (in m.)	Affected Barangays in Basey, Samar									
	Burgos	Buscada	Cambayan	Can-Abay	Cancaiyas	Canmanila	Catadman	Cogon	Del Pilar	Dolongan
0.03-0.20	0.5	0.19	1.1	0.5	4.65	0.68	4.35	11.28	0.99	3.48
0.21-0.50	0.056	0.17	0.078	0.22	0.12	0.14	0.44	1.88	0.64	1.31
0.51-1.00	0.27	0.27	0.064	0.1	0.09	0.19	0.41	1.16	0.73	1.01
1.01-2.00	0.66	0.033	0.035	0.064	0.12	0.16	0.38	0.61	0.17	0.98
2.01-5.00	0.44	0	0.0069	0.037	0.31	0.0028	0.16	1.13	0	0.0096
> 5.00	0.018	0	0	0	0.18	0	0.0023	0.047	0	0

Affected Areas (in sq.m.) by flood depth (in m.)	Affected Barangays in Basey, Samar									
	Guintigui-An	Guirang	Iba	Inuntan	Lawa-An	Loog	Loyo	Mabini	Magallanes	Manlilinab
0.03-0.20	0.48	13.33	2.87	3.23	0.079	7.21	0.46	0.013	0.72	13.15
0.21-0.50	0.59	0.56	2.43	0.13	0.044	0.26	0.061	0.0012	0.8	0.46
0.51-1.00	0.35	0.5	2.14	0.18	0.13	0.24	0.043	0.00011	0.44	0.42
1.01-2.00	0.15	0.78	0.19	0.25	0.036	0.77	0.017	0.000094	0.021	0.61
2.01-5.00	0.0024	1.92	0	0.22	0	0.8	0.0003	0.0013	0	1.02
> 5.00	0	1.46	0	0.011	0	0.34	0	0.0059	0	1.21

Affected Areas (in sq.m.) by flood depth (in m.)	Affected Barangays in Basey, Samar									
	May-It	Mercado		New San Agustin	Nouvelas Occidental	Old San Agustin	Palaypay	Panugmonon	Pelit	Roxas
0.03-0.20	2.61	0.11	2.05	1.4	0.56	14.04	0.069	0.5	3.95	1.86
0.21-0.50	0.81	0.05	0.51	1.26	0.53	3.01	0.031	0.3	0.29	0.87
0.51-1.00	1.12	0.033	0.46	1.61	0.56	2.53	0.097	0.62	0.43	1.21
1.01-2.00	0.53	0.0062	0.089	0.6	0.15	1.2	0.016	0.36	1.04	1.03
2.01-5.00	0.023	0	0.0058	0.0005	0.0065	1.76	0	0.0017	0.56	0.0027
> 5.00	0.0001	0	0.0001	0	0.16	0.19	0	0	0.17	0

Affected Areas (in sq.m.) by flood depth (in m.)	Affected Barangays in Basey, Samar									
	San Antonio	San Fernando	Sawa	Serum	Sugca	Sugponon	Sulod	Tinaogan	Tingib	Villa Aurora
0.03-0.20	1.03	4.88	1.88	1.25	1.08	1.13	0.16	0.27	1.41	15.15
0.21-0.50	0.17	1.35	0.8	0.9	0.89	0.68	0.063	0.0045	0.56	0.58
0.51-1.00	0.19	1.53	0.69	0.3	0.22	0.39	0.083	0.0024	0.73	0.62
1.01-2.00	0.095	1.29	0.26	0.019	0.0051	0.23	0.014	0.0009	0.4	1.19
2.01-5.00	0.0034	0.28	0.31	0	0	0.14	0	0.0002	0.0056	1.17
> 5.00	0	0.27	0.0019	0	0	0	0	0	0	0.096

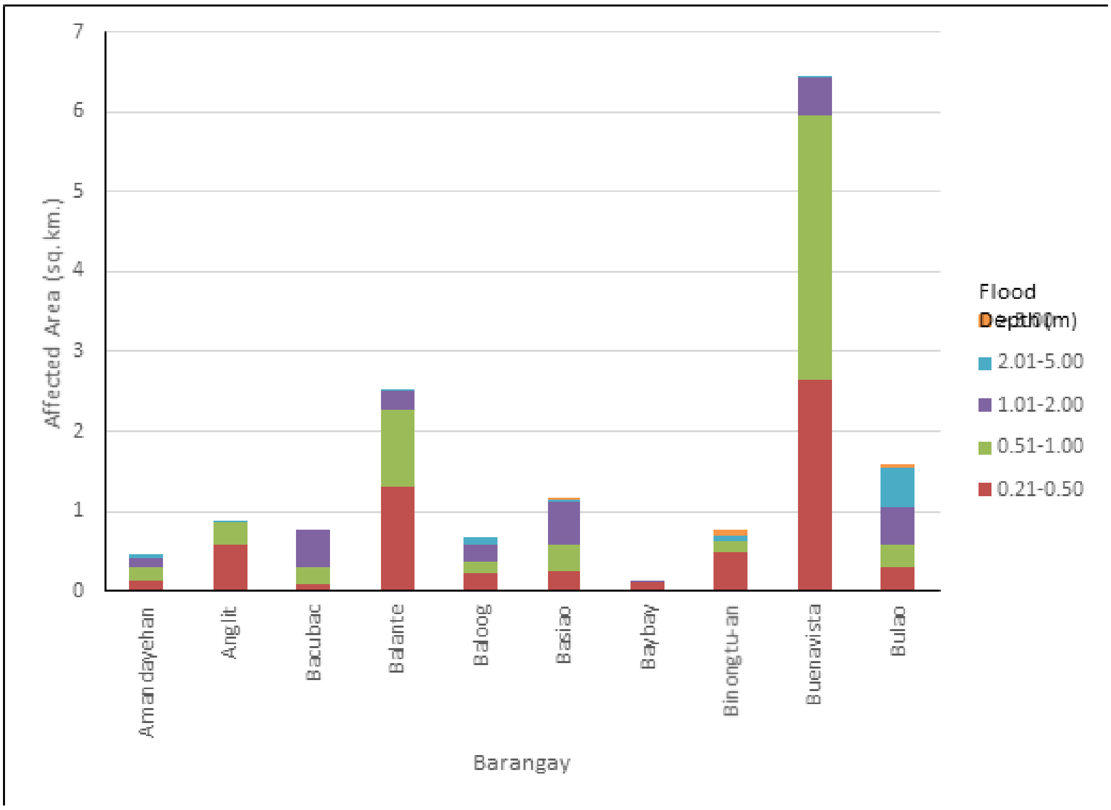


Figure 89. Affected Areas in Basey, Samar during 100-Year Rainfall Return Period

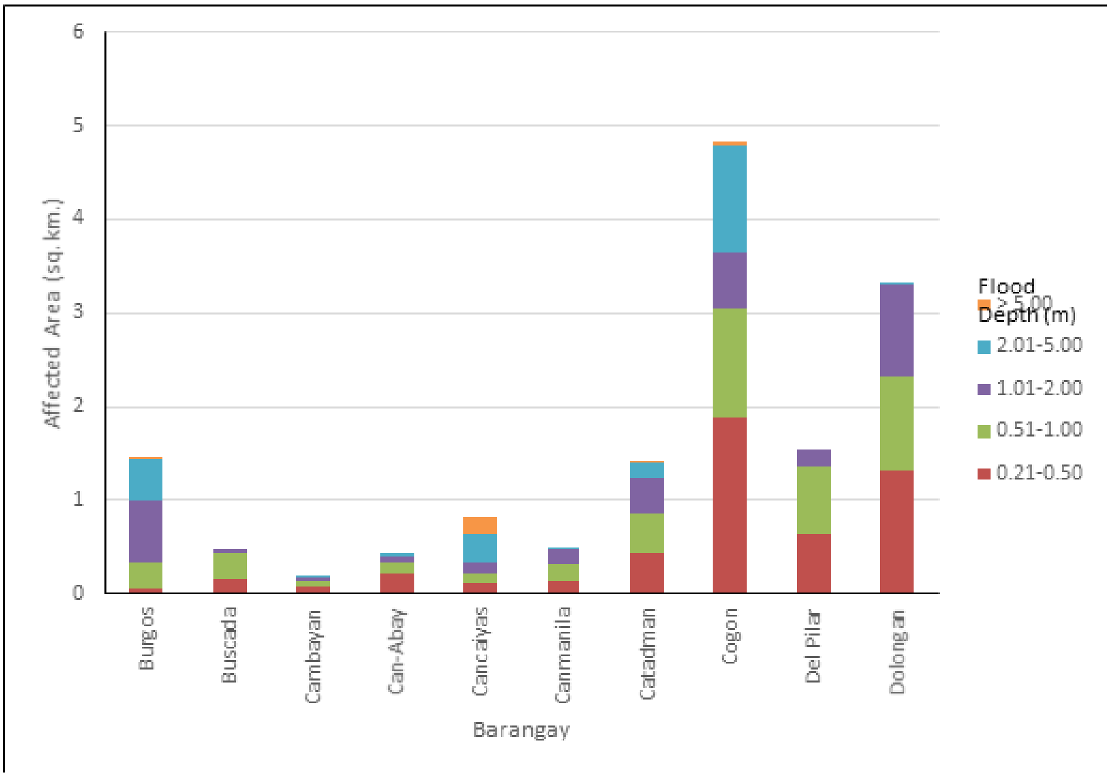


Figure 90. Affected Areas in Basey, Samar during 100-Year Rainfall Return Period

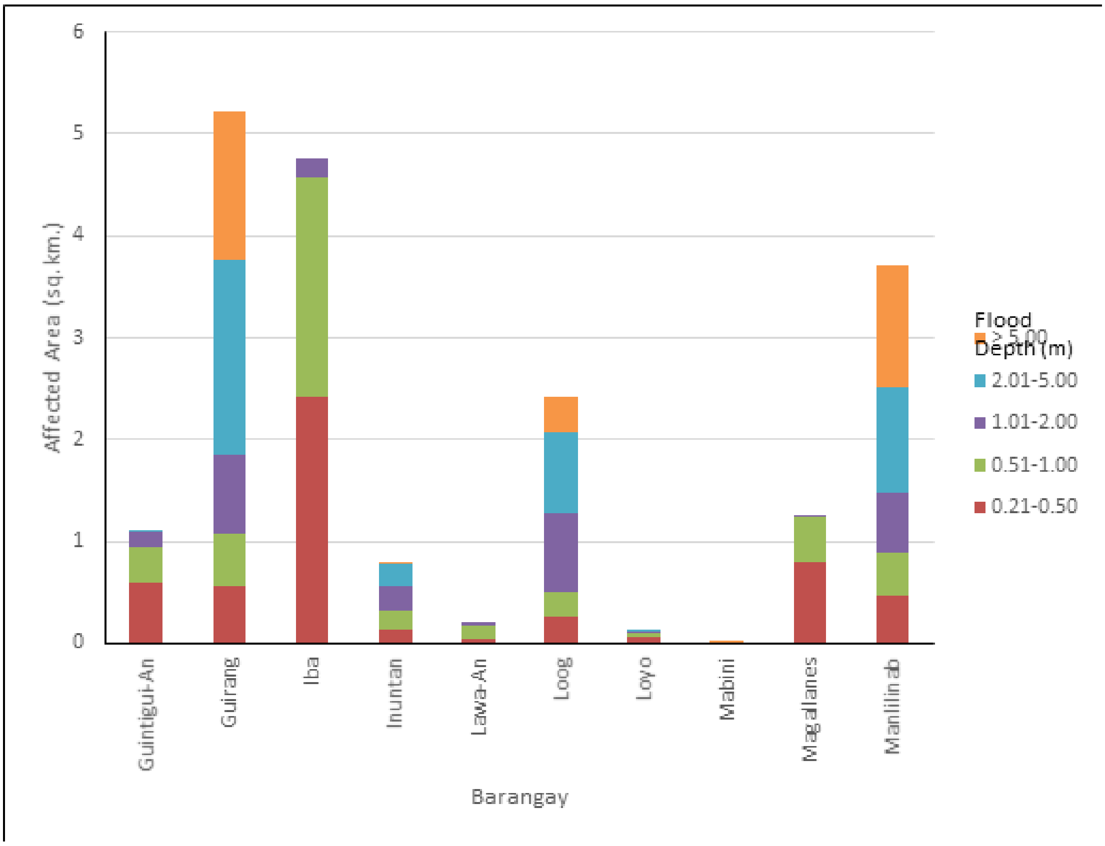


Figure 91. Affected Areas in Basey, Samar during 100-Year Rainfall Return Period

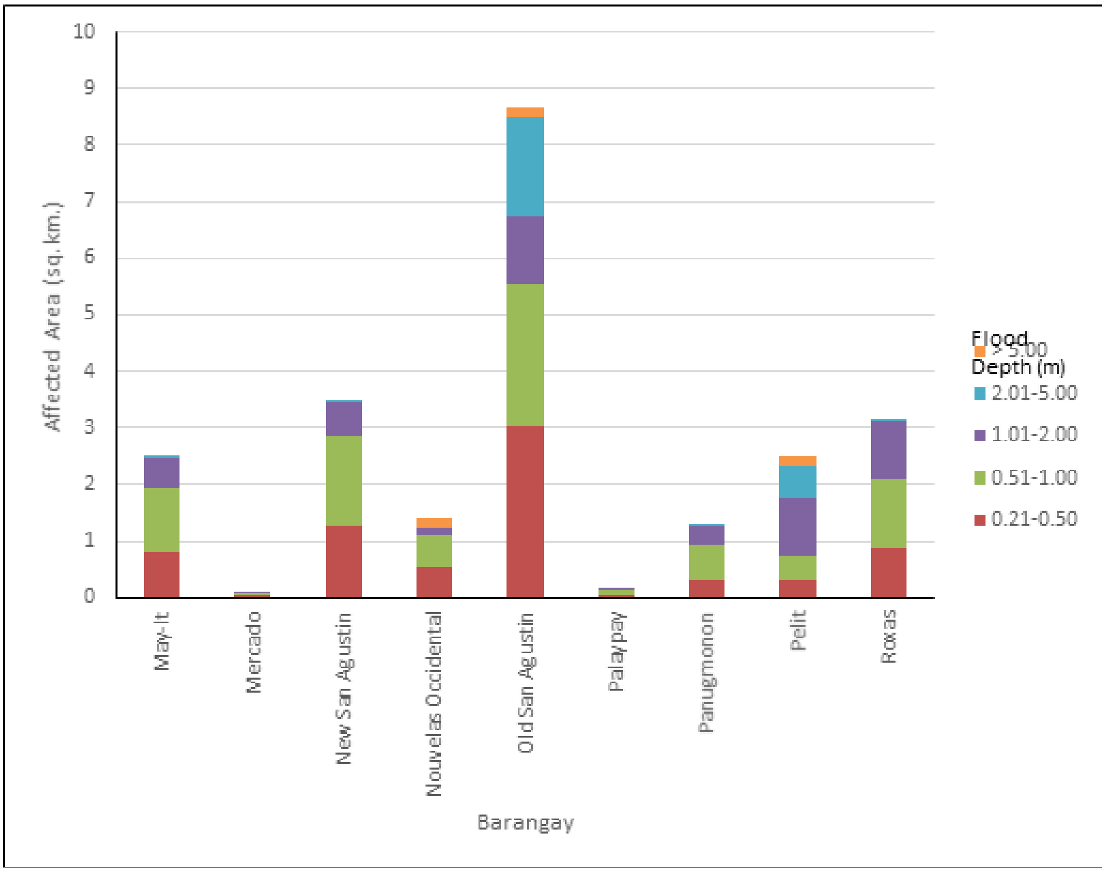


Figure 92. Affected Areas in Basey, Samar during 100-Year Rainfall Return Period

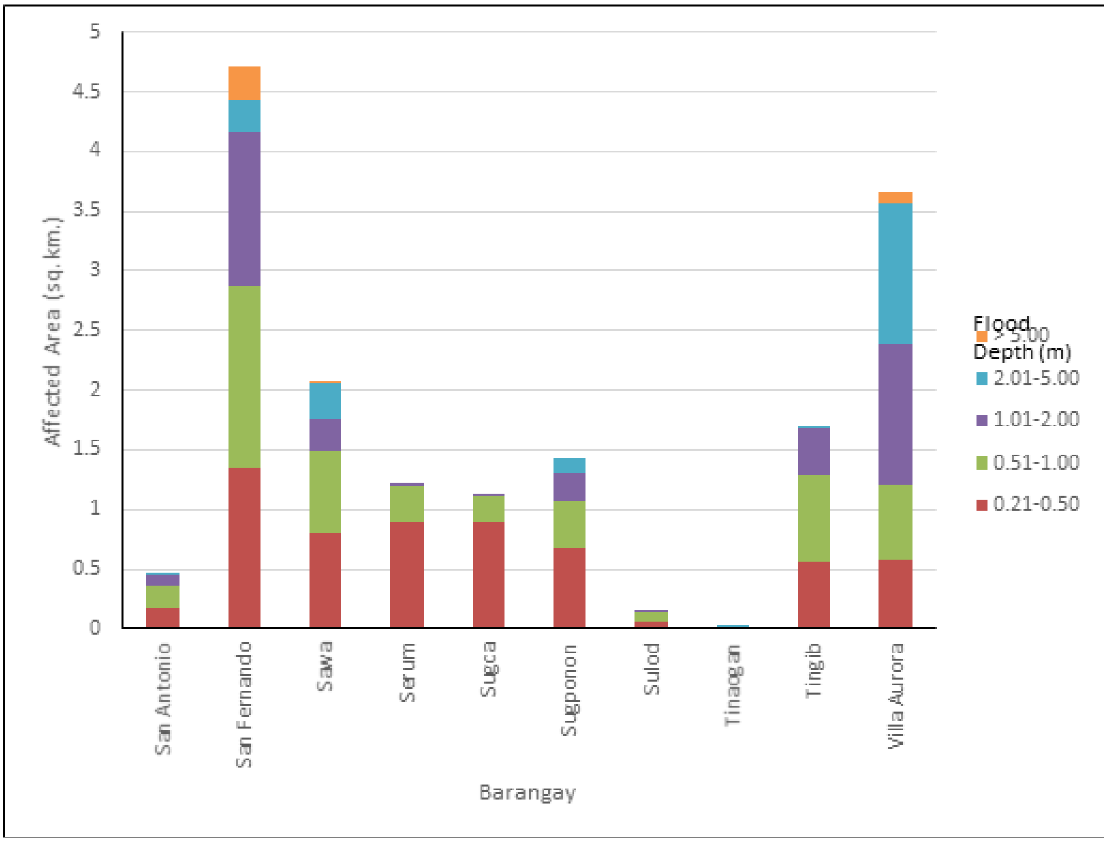


Figure 93. Affected Areas in Basey, Samar during 100-Year Rainfall Return Period

For the municipality of Santa Rita, with an area of 250.371 sq. km., 0.545% will experience flood levels of less 0.20 meters. 0.015% of the area will experience flood levels of 0.21 to 0.50 meters while 0.011%, 0.007%, and 0.005% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, respectively. Listed in Table 42 are the affected areas in square kilometres by flood depth per barangay.

Table 42. Affected Areas in Santa Rita, Samar during 100-Year Rainfall Return Period

Affected Areas (in sq.m.) by flood depth (in m.)	Affected Barangays in Santa Rita, Samar				
	Bagolibas	Cabacungan	Caticugan	Pagsulhogon	San Pedro
0.03-0.20	0.18	0.66	0.0092	0.38	0.14
0.21-0.50	0.0025	0.021	0.0014	0.011	0.0024
0.51-1.00	0.0051	0.013	0.0031	0.0062	0.0007
1.01-2.00	0.0022	0.0069	0.003	0.005	0.0007
2.01-5.00	0.0002	0.0061	0.0007	0.0055	0.0007
> 5.00	0	0	0	0.0002	0.0001

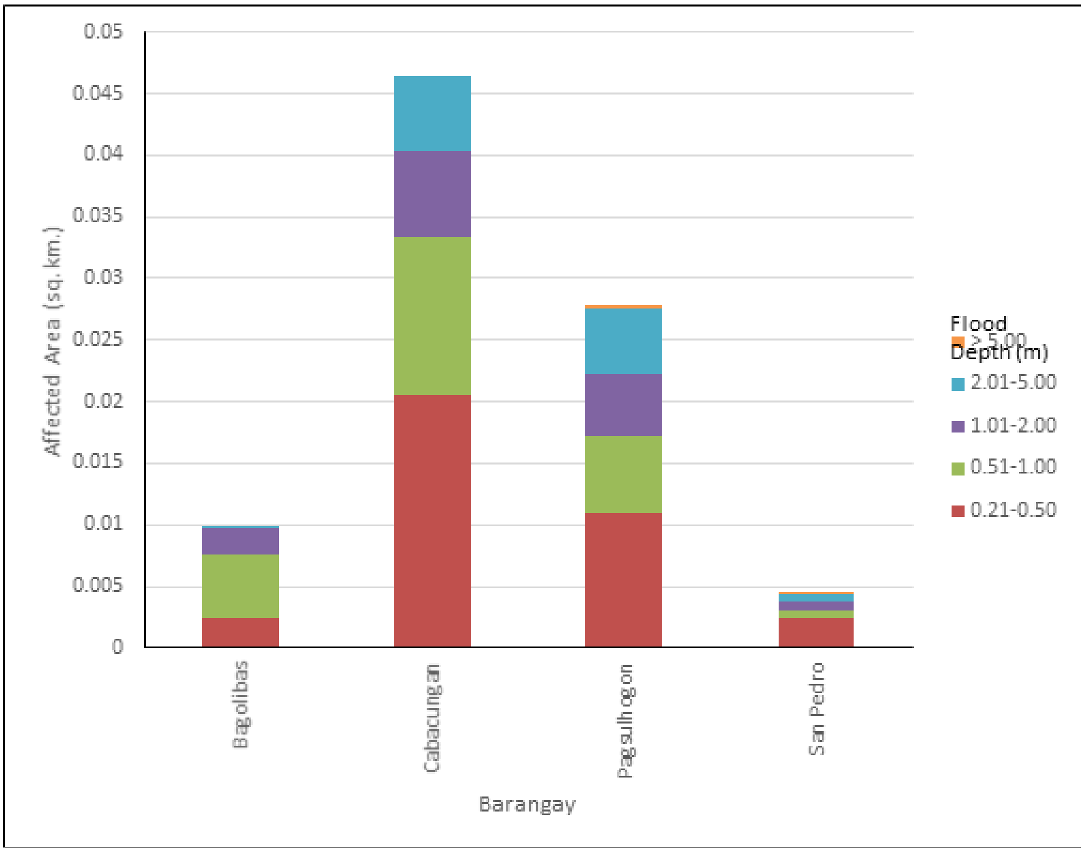


Figure 94. Affected Areas in Santa Rita, Samar during 100-Year Rainfall Return Period

Among the barangays in the municipality of Basey, Villa Aurora is projected to have the highest percentage of area that will experience flood levels at 2.996%. Meanwhile, Manlilinab posted the second highest percentage of area that may be affected by flood depths at 2.686%.

Among the barangays in the municipality of Marabut, San Roque is projected to have the highest percentage of area that will experience flood levels at 0.20%.

Among the barangays in the municipality of Santa Rita, Cabacungan is projected to have the highest percentage of area that will experience flood levels at 0.281%. Meanwhile, Pagsulhogon posted the second highest percentage of area that may be affected by flood depths of at 0.162%.

Moreover, the generated flood hazard maps for the Basey 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 43. Area covered by each warning level with respect to the rainfall scenario

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	31.7	33.33	30.35
Medium	21.31	32.16	40.08
High	9.32	15.74	21.50
TOTAL	**62.33**	**81.23**	**91.93**

Of the 23 identified Education Institutions in Basey Floodplain, 4 schools were assessed to be exposed to the Low level flooding during a 5 year scenario while 2 schools were assessed to be exposed to Medium level flooding. In the 25-year scenario, 8 schools were assessed to be exposed to the Low level flooding while 5 schools were assessed to be exposed to Medium level flooding. For the 100-year scenario, 6 schools were assessed for Low level flooding and 8 schools for Medium level flooding. In the same scenario, 2 schools were assessed to be exposed to High level flooding. See Annex 12 for a detailed enumeration of schools inside Basey floodplain.

For the Medical Institution identified in Basey Floodplain namely New San Agustin Health Center, it was assessed to be exposed to the Low level flooding during a 25 year scenario and to be exposed to the Medium level flooding during a 100 year scenario.

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 are identified for validation.

The validation personnel went to the specified points identified in a river basin and gathered data regarding the actual flood level in each location. Data gathering 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.

After which, the actual data from the field will be compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed.

The flood validation consists of 397 points randomly selected all over the Basey floodplain. The points were grouped depending on the RIDF return period of the event.

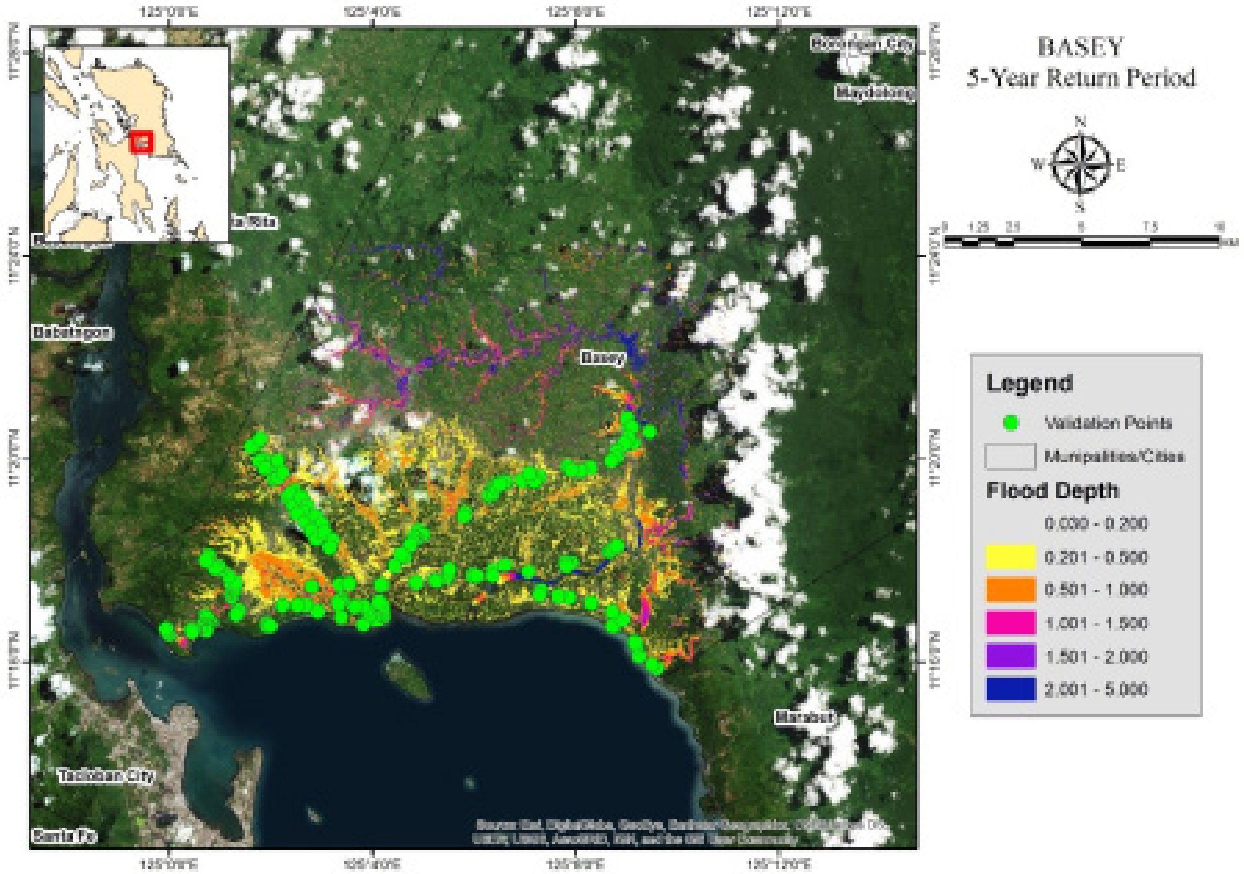


Figure 95. Validation points for 5-year Flood Depth Map of Basey Floodplain

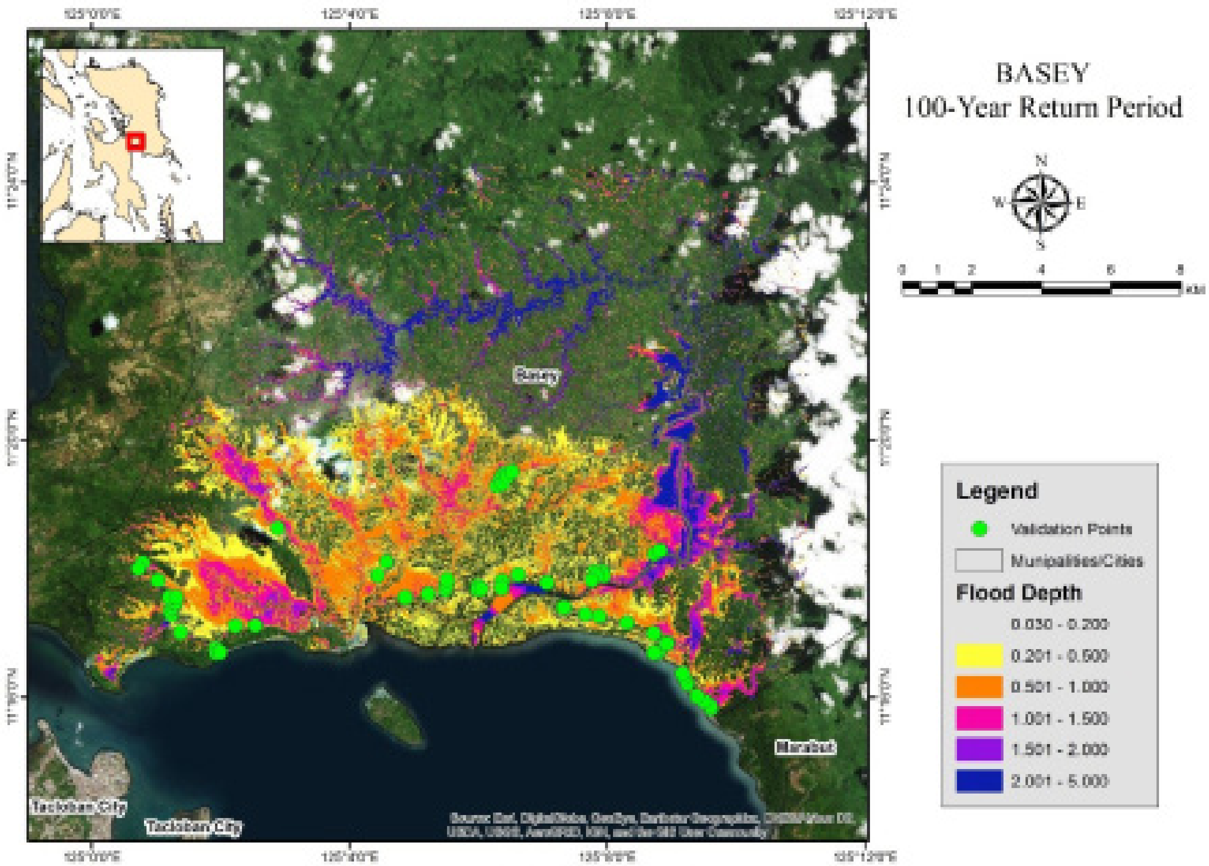


Figure 96. Validation points for 100-year Flood Depth Map of Basey Floodplain

The RMSE value for each flood depth map is listed in the table below:

Table 44. RMSE values for each return period of flood depth map

Return Period	RMSE
5-year	0.94
100-year	3.25

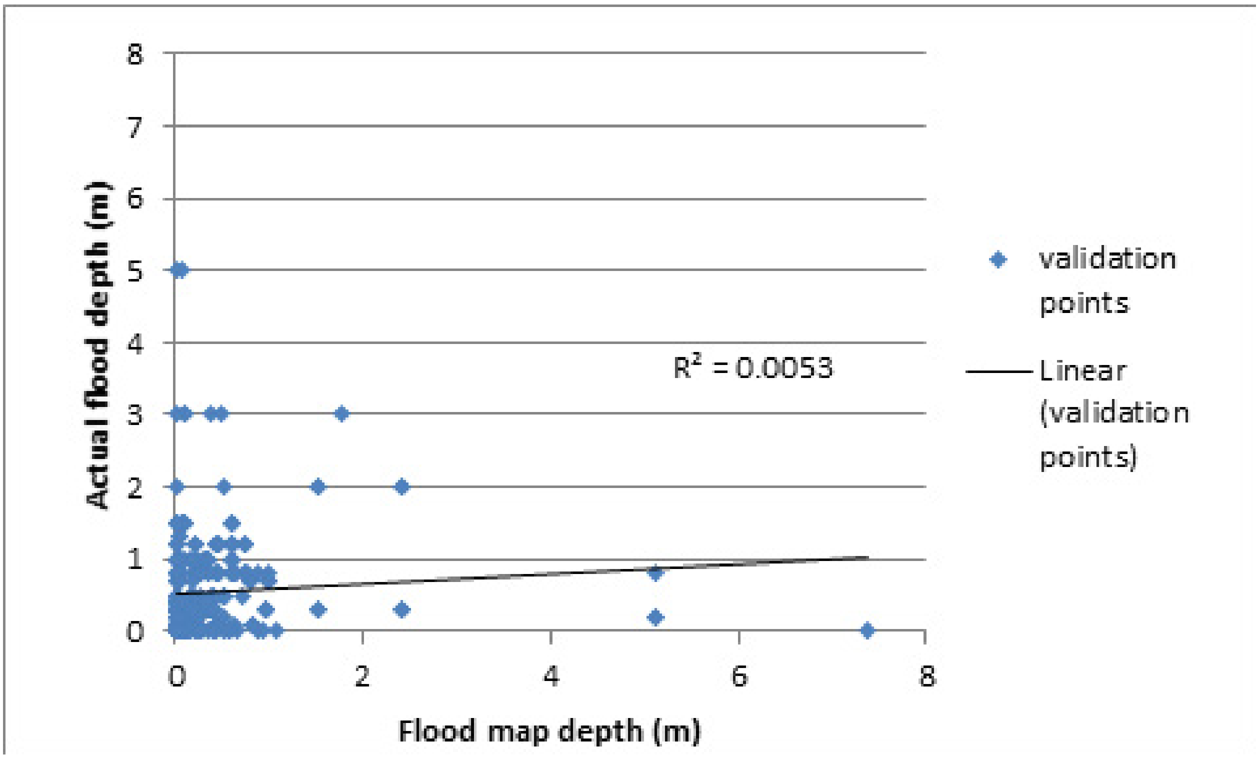


Figure 97. Flood map depth vs actual flood depth for 5-year return period

Table 45. Actual Flood Depth vs Simulated Flood Depth in Basey for 5-year return period

Actual Flood Depth (m)	Modeled Flood Depth (m)						
	0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
0.03-0.20	77	17	11	1	0	3	109
0.21-0.50	61	35	7	2	2	0	107
0.51-1.00	27	21	26	0	0	1	75
1.01-2.00	15	6	10	2	2	0	35
2.01-5.00	5	2	0	1	0	0	8
> 5.00	0	0	0	0	0	0	0
Total	185	81	54	6	4	4	334

The overall accuracy generated by the flood model is estimated at 41.92%, with 140 points correctly matching the actual flood depths. In addition, there were 119 points estimated one level above and below the correct flood depths while there were 46 points and 29 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 46 points were overestimated while a total of 148 points were underestimated in the modelled flood depths of Basey.

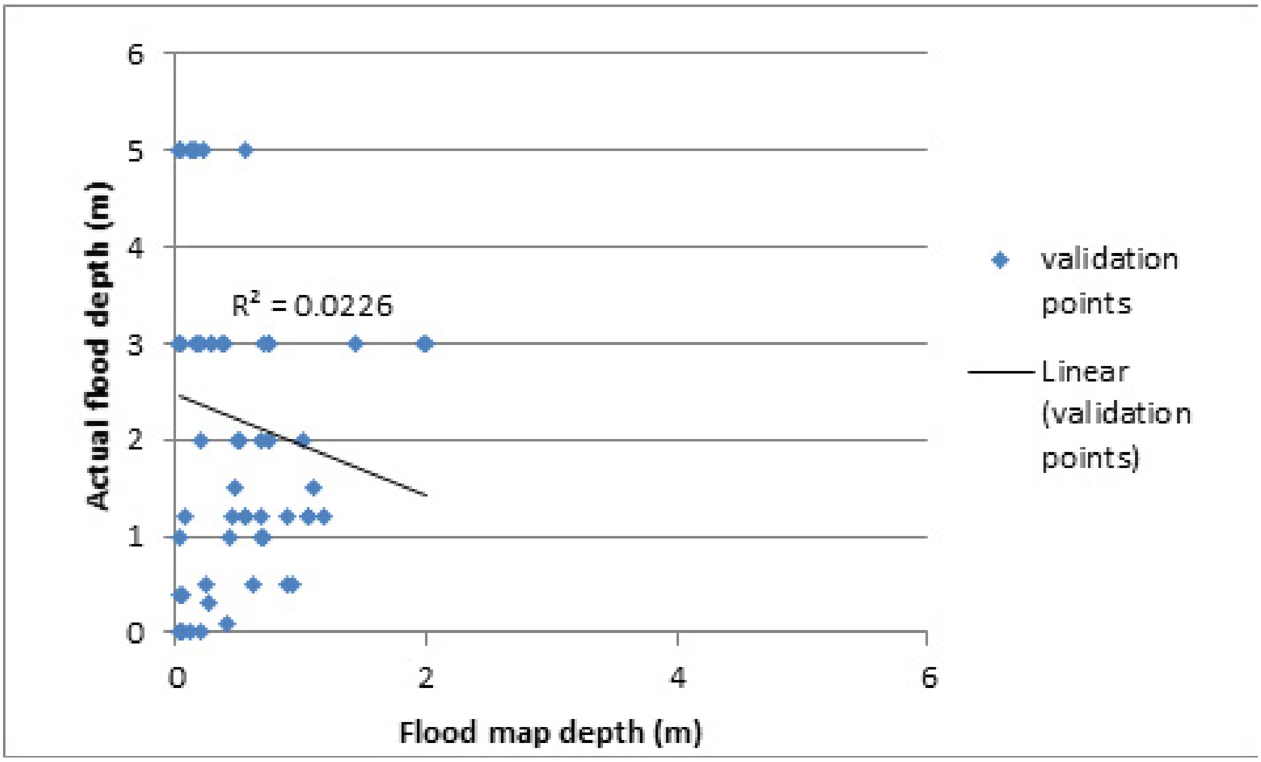


Figure 98. Flood map depth vs actual flood depth for 100-year return period

Table 46. Actual Flood Depth vs Simulated Flood Depth in Basey for 100-year return period

Actual Flood Depth (m)	Modeled Flood Depth (m)						
	0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
0.03-0.20	4	2	0	0	0	0	6
0.21-0.50	2	2	3	0	0	0	7
0.51-1.00	1	1	2	0	0	0	4
1.01-2.00	2	3	7	5	0	0	17
2.01-5.00	17	5	4	3	0	0	29
> 5.00	0	0	0	0	0	0	0
Total	26	13	16	8	0	0	63

The overall accuracy generated by the flood model is estimated at 20.63%, with 13 points correctly matching the actual flood depths. In addition, there were 18 points estimated one level above and below the correct flood depths while there were 8 points and 24 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 5 points were overestimated while a total of 45 points were underestimated in the modelled flood depths of Basey.

Table 47. Summary of Accuracy Assessment in Basey River Basin Survey

	No. of Points	%
Correct	140	41.92
Overestimated	46	13.77
Underestimated	148	44.31
Total	334	100

REFERENCES

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ANNEXES

Annex 1. OPTECH Technical Specification

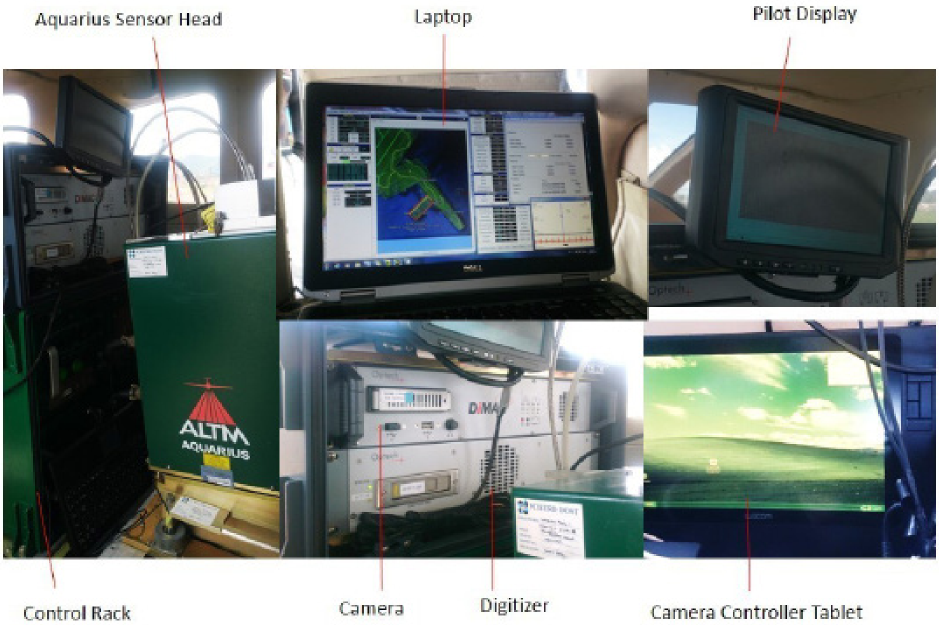

Figure A-1.1 Aquarius Sensor

Table A-1.1 Parameters and Specifications of the Aquarius Sensor

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

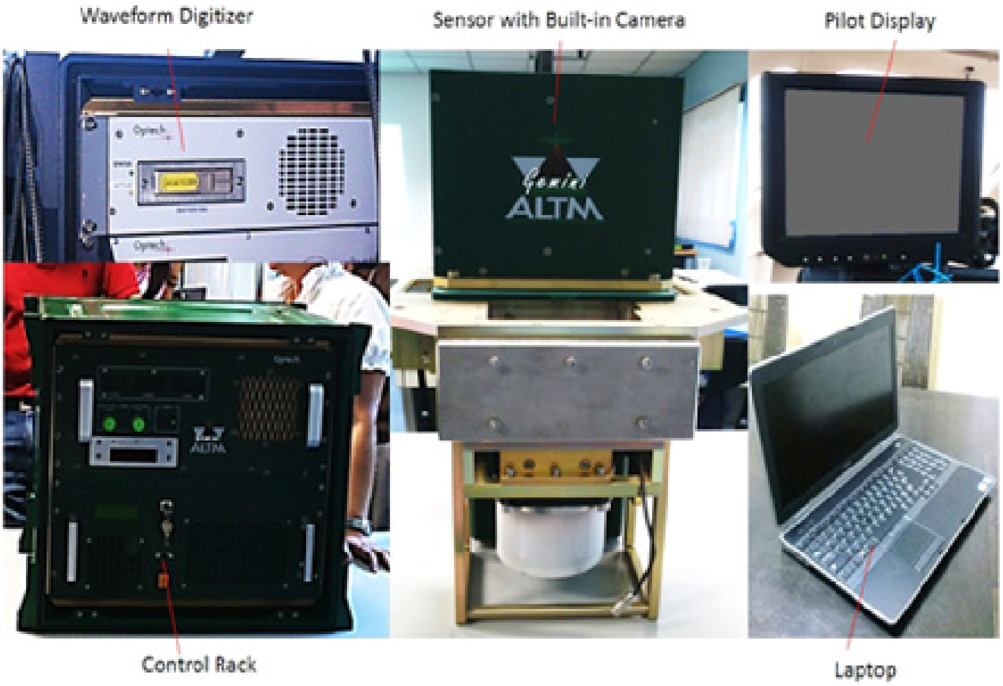

Figure A-1.2 Gemini Sensor

Table A-1.2 Parameters and Specifications of the Gemini Sensor

Parameter	Specification
Operational envelope (1,2,3,4)	150-4000 m AGL, nominal
Laser wavelength	1064 nm
Horizontal accuracy (2)	1/5,500 x altitude, (m AGL)
Elevation accuracy (2)	<5-35 cm, 1 σ
Effective laser repetition rate	Programmable, 33-167 kHz
Position and orientation system	POS AV™ AP50 (OEM); 220-channel dual frequency GPS/GNSS/Galileo/L-Band receiver
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 Certificates of Reference Points Used

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

April 23, 2014

CERTIFICATION

To whom it may concern:

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

Province: **SAMAR (WESTERN SAMAR)**
Station Name: **SMR-56**
Order: **2nd**

Island: **VISAYAS**		Barangay: **CABACUNGAN**
Municipality: **SANTA RITA**		
	PRS92 Coordinates	
Latitude: **11° 23' 6.52702"**	Longitude: **125° 0' 23.99607"**	Ellipsoidal Hgt: **11.82200 m.**
	WGS84 Coordinates	
Latitude: **11° 23' 2.22413"**	Longitude: **125° 0' 29.13917"**	Ellipsoidal Hgt: **73.72700 m.**
	PTM Coordinates	
Northing: **1258927.861 m.**	Easting: **500727.475 m.**	Zone: **5**
	UTM Coordinates	
Northing: **1,259,244.38**	Easting: **718,970.61**	Zone: **51**

Location Description

SMR-56
From Tacloban City, travel about 15 km. north going to Brgy. Cabacungan. Before reaching the of Sta. Rita town proper Western Samar. The monument was established at the Brgy. Cabacungan Elementary School, at the side of the road, 20 m. east fronting school's entrance gate, 50 m. northeast from Waiting Shed about , and 3 m. east along the side the of pathway. Mark is the head of a 4" copper nail flushed in a 30X30 cm. cement block embedded in the ground protruding about 20 cm., with inscriptions "SMR-56; 2007; NAMRIA."

Requesting Party:	**Engr. Christopher Cruz/ UP-DREAM**
Pupose:	**Reference**
OR Number:	**8796021 A**
T.N.:	**2014-919**

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

NAMRIA OFFICES:
www.namria.gov.ph
ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure 2.1 LYT-101

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

April 23, 2014

CERTIFICATION

To whom it may concern:

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

	Province: **SAMAR (WESTERN SAMAR)**	
	Station Name: **SMR-56**	
	Order: **2nd**	
Island: **VISAYAS** Municipality: **SANTA RITA**		Barangay: **CABACUNGAN**
	PRS92 Coordinates	
Latitude: **11° 23' 6.52702"**	Longitude: **125° 0' 23.99607"**	Ellipsoidal Hgt: **11.82200 m.**
	WGS84 Coordinates	
Latitude: **11° 23' 2.22413"**	Longitude: **125° 0' 29.13917"**	Ellipsoidal Hgt: **73.72700 m.**
	PTM Coordinates	
Northing: **1258927.861 m.**	Easting: **500727.475 m.**	Zone: **5**
	UTM Coordinates	
Northing: **1,259,244.38**	Easting: **718,970.61**	Zone: **51**

Location Description

SMR-56
From Tacloban City, travel about 15 km. north going to Brgy. Cabacungan. Before reaching the of Sta. Rita town proper Western Samar. The monument was established at the Brgy. Cabacungan Elementary School, at the side of the road, 20 m. east fronting school's entrance gate, 50 m. northeast from Waiting Shed about , and 3 m. east along the side the of pathway. Mark is the head of a 4" copper nail flushed in a 30X30 cm. cement block embedded in the ground protruding about 20 cm., with inscriptions "SMR-56; 2007; NAMRIA."

Requesting Party: **Engr. Christopher Cruz/ UP-DREAM**
Pupose: **Reference**
OR Number: **8796021 A**
T.N.: **2014-919**

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

Figure 2.2 SMR-56

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

February 10, 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: **SAMAR (WESTERN SAMAR)**	
	Station Name: **SMR-58**	
	Order: **2nd**	
Island: **VISAYAS**	Barangay: **SERUM**	
Municipality: **BASEY**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **11° 17' 55.05617"**	Longitude: **125° 7' 51.16145"**	Ellipsoidal Hgt: **6.30062 m.**
	WGS84 Coordinates	
Latitude: **11° 17' 50.78580"**	Longitude: **125° 7' 56.31100"**	Ellipsoidal Hgt: **68.72300 m.**
	PTM / PRS92 Coordinates	
Northing: **1249361.531 m.**	Easting: **614288.239 m.**	Zone: **5**
	UTM / PRS92 Coordinates	
Northing: **1,249,768.75**	Easting: **732,600.57**	Zone: **51**

Location Description

SMR-58
From Basey proper, travel about 20 km. north going to Brgy. Serum. From National Road, travel another 1 km. north going to Brgy. Serum. The NAMRIA was established inside the Serum Elementary School, 10 m. east from the school gate, and 15 m. north from the school building. The School site was near the River about 30 m. north. Mark is the head of a 4" copper nail flushed in a 30X30 cm. cement block embedded in the ground protruding about 20 cm., with inscriptions "SMR-58; 2007; NAMRIA."

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8089774 I**
T.N.: **2016-0327**

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

NAMRIA OFFICES:

www.namria.gov.ph

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure 2.3 SMR-58

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

January 27, 2016

CERTIFICATION

To whom it may concern:

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

Province: **LEYTE**
Station Name: **LY-110**

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

Location Description

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

Requesting Party:	**UP DREAM**
Purpose:	**Reference**
OR Number:	**8089607 I**
T.N.:	**2016-0240**

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure 2.4 LY-110

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

June 06, 2014

CERTIFICATION

To whom it may concern:

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

Province: **SAMAR (WESTERN SAMAR)**
Station Name: **SM-286**

Island: **VISAYAS**	Municipality: **SANTA RITA**	Barangay: **SAN PASCUAL**
Elevation: **3.3970 m.**	Order: **1st Order**	Datum:

Location Description

SM-286 is in the Province of Western Samar, town of Sta. Rita, Brgy. San Pascual. It is located at Dalib bridge, positioned at the SE part of the bridge, 4m from the centerline of the national highway. Station mark is the head of 4" copper nail on a drilled hole set flush on a 0.10m x 0.10cement putty inscribed "SM-286, 2007, NAMRIA."

Requesting Party:	**UP-TCAGP**
Pupose:	**Reference**
OR Number:	**8796290 A**
T.N.:	**2014-1291**

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure 2.5 SM-286

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

February 10, 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: **SAMAR (WESTERN SAMAR)**
Station Name: **SM-309**

Island: **VISAYAS**	Municipality: **BASEY**	Barangay: **ANGLIT**
Elevation: **4.1232 +/- 0.06 m.**	Accuracy Class at 95% C.L: **6 CM**	Datum: **Mean Sea Level**
Latitude:	Longitude:	

Location Description

SM-309 is in the Province of Western Samar, town of Basey, Brgy. Anglit. It is located at Anglit bridge at the SE part, 4.00m from the centerline of the national highway. Station mark is the head of 4" copper nail on a drilled hole set flush on a 0.10m x 0.10cement putty inscribed "SM-309, 2007, NAMRIA."

Requesting Party:	**UP DREAM**
Purpose:	**Reference**
OR Number:	**8089774 I**
T.N.:	**2016-0326**

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

NAMRIA OFFICES:
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ISO 9001:2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure 2.6 SM-309

Annex 3. Baseline Processing Report of Reference Point Used

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
SMR-53 --- LYT-104 (B1)	SMR-53	LYT-104	Fixed	0.008	0.017	200°40'31"	42653.401	7.525
SMR-53 --- LYT-104 (B2)	SMR-53	LYT-104	Fixed	0.004	0.016	200°40'31"	42653.384	7.601

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

Vector Components (Mark to Mark)

From:	SMR-53				
Grid		Local		Global	
Easting	720874.133 m	Latitude	N11°30'17.85656"	Latitude	N11°30'13.52495"
Northing	1272513.396 m	Longitude	E125°01'29.83738"	Longitude	E125°01'34.96980"
Elevation	24.750 m	Height	26.134 m	Height	87.787 m

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

Vector					
ΔEasting	-14784.623 m	NS Fwd Azimuth	200°40'31"	ΔX	7839.600 m
ΔNorthing	-40016.558 m	Ellipsoid Dist.	42653.401 m	ΔY	15051.644 m
ΔElevation	7.561 m	ΔHeight	7.525 m	ΔZ	-39131.928 m

Standard Errors

Vector errors:					
σ ΔEasting	0.003 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.006 m
σ ΔNorthing	0.002 m	σ Ellipsoid Dist.	0.002 m	σ ΔY	0.007 m
σ ΔElevation	0.009 m	σ ΔHeight	0.009 m	σ ΔZ	0.002 m

Figure 3.1 LYT-104

Processing Summary

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

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

Vector Components (Mark to Mark)

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

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

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

Standard Errors

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

Figure 3.2 LYT-110

Baseline Processing Report

Processing Summary

Observation	From	To	Occupation Start Time	Occupation Stop Time	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	ΔX (Meter)	ΔY (Meter)	ΔZ (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	Δ Height (Meter)	Satellite Available
SM-286 --- SMR-56 (B1)	SMR-56	SM-286	5/11/2014 6:44:03 AM	5/11/2014 1:54:43 PM	Fixed	0.003	0.009	1325.026	263.512	2667.292	335°34'25"	2989.904	-6.335	GPS: 14 GLONASS: 13 Galileo: 0 QZSS: 0

Acceptance Summary

Processed	Passed	Flag	Fail
1	1	0	0

Vector Components (Mark to Mark)

From:	SMR-56				
Grid		Local		Global	
Easting	718970.608 m	Latitude	N11°23'06.52702"	Latitude	N11°23'02.22413"
Northing	1259244.377 m	Longitude	E125°00'23.99607"	Longitude	E125°00'29.13917"
Elevation	10.345 m	Height	11.822 m	Height	73.727 m

To:	SM-286				
Grid		Local		Global	
Easting	717715.152 m	Latitude	N11°24'35.12705"	Latitude	N11°24'30.81697"
Northing	1261958.553 m	Longitude	E124°59'43.21146"	Longitude	E124°59'48.35252"
Elevation	4.047 m	Height	5.488 m	Height	67.304 m

Vector					
ΔEasting	-1255.456 m	NS Fwd Azimuth	335°34'25"	ΔX	1325.020 m
ΔNorthing	2714.176 m	Ellipsoid Dist.	2989.904 m	ΔY	263.518 m
ΔElevation	-6.298 m	ΔHeight	-6.335 m	ΔZ	2667.293 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.003 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.004 m
σ ΔElevation	0.005 m	σ ΔHeight	0.005 m	σ ΔZ	0.001 m

Figure 3.3 SM-286

Figure A 3.4 SM-309

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
SMR-58 --- SM-309 (B1)	SMR-58	SM-309	Fixed	0.002	0.003	274°29'25"	1668.981	3.442

Acceptance Summary

Processed	Passed	Flag	Fail
1	1	0	0

Vector Components (Mark to Mark)

From:	SMR-58				
Grid		Local		Global	
Easting	732600.570 m	Latitude	N11°17'56.05616"	Latitude	N11°17'50.78580"
Northing	1249768.751 m	Longitude	E125°07'51.16148"	Longitude	E125°07'56.31100"
Elevation	4.664 m	Height	6.301 m	Height	68.723 m

To:	SM-309				
Grid		Local		Global	
Easting	730935.362 m	Latitude	N11°17'59.30748"	Latitude	N11°17'55.03553"
Northing	1249887.315 m	Longitude	E125°06'56.29744"	Longitude	E125°07'01.44700"
Elevation	8.117 m	Height	9.743 m	Height	72.125 m

Vector					
ΔEasting	-1665.207 m	NS Fwd Azimuth	274°29'25"	ΔX	1373.678 m
ΔNorthing	118.564 m	Ellipsoid Dist.	1668.981 m	ΔY	939.122 m
ΔElevation	3.453 m	ΔHeight	3.442 m	ΔZ	128.718 m

Standard Errors

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

Figure 3.4 SM-309

Annex 4. The Survey Team

Table 4.1 LiDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
Survey Supervisor	Supervising Science Research Specialist (Supervising SRS)	ENGR. LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Supervising SRS	LOVELY GRACIA ACUÑA	UP-TCAGP
LiDAR Operation	Senior Science Research Specialist (SSRS)	JULIE PEARL MARS	UP-TCAGP
LiDAR Operation	Senior Science Research Specialist (SSRS)	ENGR. GEROME HIPOLITO	UP-TCAGP
LiDAR Operation	Senior Science Research Specialist (SSRS)	PAULINE JOANNE ARCEO	UP-TCAGP
LiDAR Operation	Research Associate (RA)	ENGR. DAN CHRISTOFFER ALDOVINO	UP-TCAGP
LiDAR Operation	Research Associate (RA)	FAITH JOY SABLE	UP-TCAGP
LiDAR Operation	Research Associate (RA)	MARY CATHERINE ELIZABETH BALIGUAS	UP-TCAGP
LiDAR Operation	Research Associate (RA)	ENGR. IRO NIEL ROXAS	UP-TCAGP
LiDAR Operation	Research Associate (RA)	ENGR. LARAH KRISELLE PARAGAS	UP-TCAGP
LiDAR Operation	Research Associate (RA)	GRACE SINADJAN	UP-TCAGP
LiDAR Operation	Research Associate (RA)	JONATHAN ALMALVEZ	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	JERIEL PAUL ALAMBAN, GEOL.	UP-TCAGP
LiDAR Operation	Airborne Security	SSG. RAYMUND DOMINE	PHILIPPINE AIR FORCE (PAF)
LiDAR Operation	Airborne Security	SSG. RANDY SISON	PAF
LiDAR Operation	Pilot	CAPT. JACKSON JAVIER	ASIAN AEROSPACE CORPORATION (AAC)
LiDAR Operation	Pilot	CAPT. NEIL ACHILLES AGAWIN	AAC
LiDAR Operation	Pilot	CAPT. ALBERT PAUL LIM	AAC
LiDAR Operation	Pilot	CAPT. RANDY LAGCO	AAC

Annex 5. Data Transfer Sheet for Basey Floodplain

DATA TRANSFER SHEET
Feb 3, 2014

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES	MISSION LOG FILE	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
Jan 24, 2014	1016A	3BLK33A024A	AQUARIUS	N/A	56.5KB	899KB	159MB	41.2GB	N/A	9.96GB	50.6GB	14.4MB	245B	646B	8.83KB	534KB	X:\Airborne_Raw\1016A
Jan 24, 2014	1018A	3BLK33A024B	AQUARIUS	N/A	68.5KB	1.41MB	81MB	N/A	N/A	2.83GB	12.9GB	14.4MB	245B	278B	4.21KB	345KB	X:\Airborne_Raw\1018A
Jan 25, 2014	1020A	3BLK33B025A	AQUARIUS	N/A	119KB	1.85MB	237MB	67.7GB	N/A	15.1GB	75GB	20.7MB	245B	636B	4.2KB	1.21KB	X:\Airborne_Raw\1020A
Jan 25, 2014	1022A	3BLK33B025B	AQUARIUS	N/A	819KB	1.28MB	242MB	75.3GB	N/A	18.5GB	57.2GB	20.7MB	245B	1.25KB	4.2KB	819KB	X:\Airborne_Raw\1022A
Jan 26, 2014	1024A	3BLK33AS34A026A	AQUARIUS	N/A	652KB	1.36MB	247MB	55.2GB	N/A	16.3GB	48.1GB	20MB	245B	466B	6.72KB	652KB	X:\Airborne_Raw\1024A

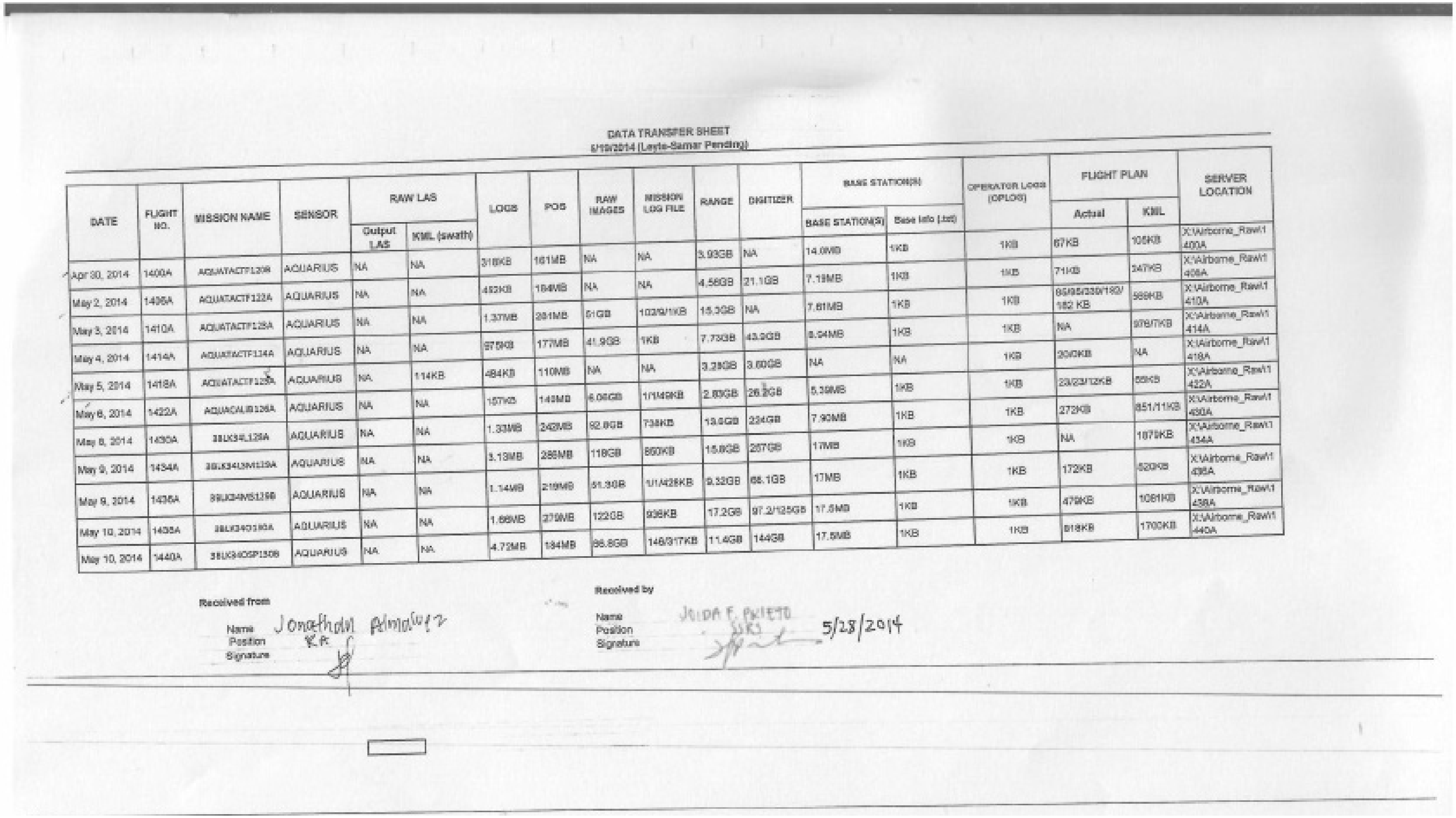
Received from

Name Larah Tareugas
Position AA
Signature

Received by

Name JOIDA PRIETO 02/03/2014
Position SSRS
Signature

Figure 5.1 Data Transfer Sheet for Basey Floodplain - A



DATA TRANSFER SHEET
5/19/2014 (Leyte-Samar Pending)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES	MISSION LOG FILE	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
Apr 30, 2014	1400A	AQUATACTF120B	AQUARIUS	NA	NA	318KB	161MB	NA	NA	3.93GB	NA	14.0MB	1KB	1KB	67KB	105KB	X:\Airborne_Raw\1400A
May 2, 2014	1406A	AQUATACTF122A	AQUARIUS	NA	NA	492KB	164MB	NA	NA	4.56GB	21.1GB	7.19MB	1KB	1KB	71KB	347KB	X:\Airborne_Raw\1406A
May 3, 2014	1410A	AQUATACTF125A	AQUARIUS	NA	NA	1.37MB	281MB	51GB	103/9/1KB	15.3GB	NA	7.61MB	1KB	1KB	85/95/339/182/182 KB	569KB	X:\Airborne_Raw\1410A
May 4, 2014	1414A	AQUATACTF124A	AQUARIUS	NA	NA	975KB	177MB	41.9GB	1KB	7.73GB	43.9GB	8.04MB	1KB	1KB	NA	978/7KB	X:\Airborne_Raw\1414A
May 5, 2014	1418A	AQUATACTF125A	AQUARIUS	NA	114KB	484KB	110MB	NA	NA	3.28GB	3.60GB	NA	NA	1KB	20/0KB	NA	X:\Airborne_Raw\1418A
May 6, 2014	1422A	AQUACALIB126A	AQUARIUS	NA	NA	157KB	140MB	6.06GB	1/1/149KB	2.80GB	26.2GB	5.39MB	1KB	1KB	23/23/12KB	55KB	X:\Airborne_Raw\1422A
May 8, 2014	1430A	3BLK34L128A	AQUARIUS	NA	NA	1.33MB	242MB	92.6GB	738KB	13.6GB	224GB	7.90MB	1KB	1KB	272KB	851/11KB	X:\Airborne_Raw\1430A
May 9, 2014	1434A	3BLK34L3M129A	AQUARIUS	NA	NA	3.13MB	286MB	118GB	860KB	15.8GB	287GB	17MB	1KB	1KB	NA	1879KB	X:\Airborne_Raw\1434A
May 9, 2014	1436A	3BLK34MS129B	AQUARIUS	NA	NA	1.14MB	219MB	51.30B	1/1/426KB	9.32GB	66.1GB	17MB	1KB	1KB	172KB	520KB	X:\Airborne_Raw\1436A
May 10, 2014	1438A	3BLK34O130A	AQUARIUS	NA	NA	1.66MB	279MB	122GB	936KB	17.2GB	97.2/125GB	17.5MB	1KB	1KB	479KB	1081KB	X:\Airborne_Raw\1438A
May 10, 2014	1440A	3BLK34OSP130B	AQUARIUS	NA	NA	4.72MB	184MB	86.8GB	146/317KB	11.4GB	144GB	17.5MB	1KB	1KB	918KB	1700KB	X:\Airborne_Raw\1440A

Received from

Name Jonathan Almalvez
Position RA
Signature

Received by

Name JOIDA F. PRIETO
Position SRS
Signature 5/28/2014

Figure 5.2 Data Transfer Sheet for Basey Floodplain - B

DATA TRANSFER SHEET
5/22/2014 (Leyte Ongoing)

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	
4/20/2014	1358A	3BLK34F110A	AQUARIUS	NA	NA	1.17MB	243MB	63.3/10.7GB	3/510/87KB	14.1GB	NA	12.1MB	1KB	1KB	5KB	773/13KB	Z:\Airborne_Raw\1358A
4/20/2014	1360A	3BLK34FS110B	AQUARIUS	NA	NA	7.75MB	174MB	41.1GB	206KB	8.36GB	NA	11.3MB	1KB	1KB	6KB	849/13KB	Z:\Airborne_Raw\1360A
4/22/2014	1366A	3BLK34E117A	AQUARIUS	NA	NA	1.37MB	257MB	95.5GB	415/1/203KB	14.9GB	NA	9.53MB	1KB	1KB	5KB	899/10KB	Z:\Airborne_Raw\1366P
5/11/2014	1442A	3BLK33GS131A	AQUARIUS	NA	NA	5.86MB	270MB	109GB	59/697KB	16.6GB	NA	14.3MB	1KB	1KB	NA	2652KB	Z:\Airborne_Raw\1442A
5/11/2014	1444A	3BLK33GSH131B	AQUARIUS	NA	NA	3.82MB	254MB	79.3GB	1/1/515/1/139KB	15.2GB	229GB	14.3MB	1KB	1KB	50KB	2613/750 KB	Z:\Airborne_Raw\1444A
5/13/2014	1450A	3BLK33HS133A	AQUARIUS	NA	NA	906KB	132MB	34.1GB	357KB	5.07GB	87.0GB	10.5MB	1KB	1KB	5KB	1019KB	Z:\Airborne_Raw\1450A
5/13/2014	1452A	3BLK33HSES133B	AQUARIUS	NA	NA	2.33MB	233MB	47.1GB	1/415KB	9.57GB	86.9GB	11.2MB	1KB	1KB	6/10KB	512KB	Z:\Airborne_Raw\1452A
5/14/2014	1454A	3BLK34D134A	AQUARIUS	NA	NA	1.88MB	268MB	15.7/71.5GB	23/102/517KB	14.6GB	206GB	8.41MB	1KB	1KB	5/2KB	1522KB	Z:\Airborne_Raw\1454A
5/14/2014	1456A	3BLK34C134B	AQUARIUS	NA	NA	0.96MB	212MB	66.6GB	278/226KB	11.8GB	58.6GB	7.92MB	1KB	1KB	5KB	641KB	Z:\Airborne_Raw\1456P
5/15/2014	1460A	3BLK35CD135B	AQUARIUS	NA	NA	1.24MB	273MB	74.9GB	622KB	14.7GB	235GB	11.4MB	1KB	1KB	5/5KB	476/307KB	Z:\Airborne_Raw\1460A
5/16/2014	1462A	3BLK35DSE136A	AQUARIUS	NA	NA	1.29MB	275MB	91.2GB	669KB	15.3GB	NA	11.6MB	1KB	1KB	5/4KB	842KB	Z:\Airborne_Raw\1462A
5/16/2014	1464A	3BLK35ES136B	AQUARIUS	NA	NA	1.28MB	281MB	76.9GB	637KB	14.0GB	NA	11.4MB	1KB	1KB	4KB	786KB	Z:\Airborne_Raw\1464A

Received from

Name Dan Alemino
Position Research Associate
Signature

Received by

Name JOIDA F. PRIETO
Position SSRS
Signature
5/28/2014

Figure 5.3 Data Transfer Sheet for Basey Floodplain - C

DATA TRANSFER SHEET
03/30/2015(DPM/DC)

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	58	139	62.4	NA	NA	3.82	NA	18.0	1KB	1KB	5	NA	Z:\DAC\RAW DATA
5-Feb-15	7782AC	3BLK35AX036A	AQUARIUS	NA	370	797	262	NA	NA	15.3	376	8.70	1KB	1KB	8	384	Z:\DAC\RAW DATA
7-Feb-15	7786AC	3BLK34AX038A	AQUARIUS	NA	379	878	254	NA	NA	11.8	213	8.40	1KB	1KB	5	NA	Z:\DAC\RAW DATA
9-Feb-15	7790AC	3BLK35DB040A	AQUARIUS	NA	109	254	226	NA	NA	5.67	44	14.8	1KB	1KB	3/2	NA	Z:\DAC\RAW DATA
9-Feb-15	7791AC	3BLK50CD6E040B	AQUARIUS	NA	155	358	178	NA	NA	6.98	105	14.8	1KB	1KB	3/93	NA	Z:\DAC\RAW DATA
10-Feb-15	7792AC	3BLK35FV041A	AQUARIUS	NA	223	609	238	NA	NA	18.3	NA	9.48	1KB	1KB	3/11	NA	Z:\DAC\RAW DATA
11-Feb-15	7794AC	3BLK35EV042A	AQUARIUS	NA	278	585	202	NA	NA	11.9	150	37.9	1KB	1KB	10	NA	Z:\DAC\RAW DATA
13-Feb-15	7798AC	3BLK34AV044A	AQUARIUS	NA	168	418	185	NA	NA	7.81	111	31.5	1KB	1KB	11	NA	Z:\DAC\RAW DATA
15-Feb-15	7802AC	3BLK35SV046A	AQUARIUS	NA	224	530	264	NA	NA	9.84	157	38.4	1KB	1KB	15	NA	Z:\DAC\RAW DATA
17-Feb-15	7806AC	3BLK35X048A	AQUARIUS	NA	187	479	185	NA	NA	8.2	191	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 5.4 Data Transfer Sheet for Basey Floodplain - D

DATA TRANSFER SHEET
Leyte 2/11/16

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
22-Jan	3765G	2BLK34AD022A	gemini	NA	93	690	255	na	na	25.2	na	4.38	1KB	1KB	23/57/22/58/21/58/21/21	na	Z:\DAC\RAW DATA
22-Jan-16	3767G	2BLK34AG022B	gemini	NA	76	490	204	na	na	19.1	na	3.4	1KB	1KB	57/11	na	Z:\DAC\RAW DATA
23-Jan-16	3769G	2BLK34ADEG023A	gemini	NA	82	670	260	na	na	23.8	na	9.58	1KB	1KB	na	na	Z:\DAC\RAW DATA
23-Jan-16	3771G	2BLK34BCG023B	gemini	NA	77	526	212	na	na	20.3	na	9.2	1KB	1KB	57/22	na	Z:\DAC\RAW DATA
24-Jan-16	3773G	2BLK34CG024A	gemini	NA	63	582	248	na	na	16.8	na	4.74	1KB	1KB	27/26/58	na	Z:\DAC\RAW DATA

Received from

Name C. JOAQUIN
Position
Signature

Received by

Name AC Bongat 2/12/16
Position SSRA
Signature

Figure 5.5 Data Transfer Sheet for Basey Floodplain - E

DATA TRANSFER SHEET
Tacloban,Leyte 2/23/16

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
29-Jan	3727G	2BLK34U029B	GEMINI	NA	322	691	243	NA	NA	22.8	NA	4.2	1KB	1KB	206	NA	Z:\DAC\RAW DATA
30-Jan	3729G	2BLK34HJ030A	GEMINI	NA	562	0.97	243	NA	NA	20.3	NA	608	1KB	1KB	208	NA	Z:\DAC\RAW DATA
30-Jan	3731G	2BLK34LM030B	GEMINI	NA	39	NA	208	NA	NA	24.2	NA	3.19	1KB	1KB	206/209/194	NA	Z:\DAC\RAW DATA
31-Jan	3733G	2BLK33ABLK34L031A	GEMINI	NA	646	1.03	172	NA	NA	11.4	NA	3.84	1KB	1KB	238/250/253	NA	Z:\DAC\RAW DATA
5-Feb	3753G	2BLK34K33AB036A	GEMINI	NA	853	712	227	NA	NA	16.2	NA	4.1	1KB	1KB	250/431/293	NA	Z:\DAC\RAW DATA
6-Feb	3757G	2BLK34K037A	GEMINI	NA	772	483	177	NA	NA	10.2	NA	4.51	1KB	1KB	378	NA	Z:\DAC\RAW DATA

Received from

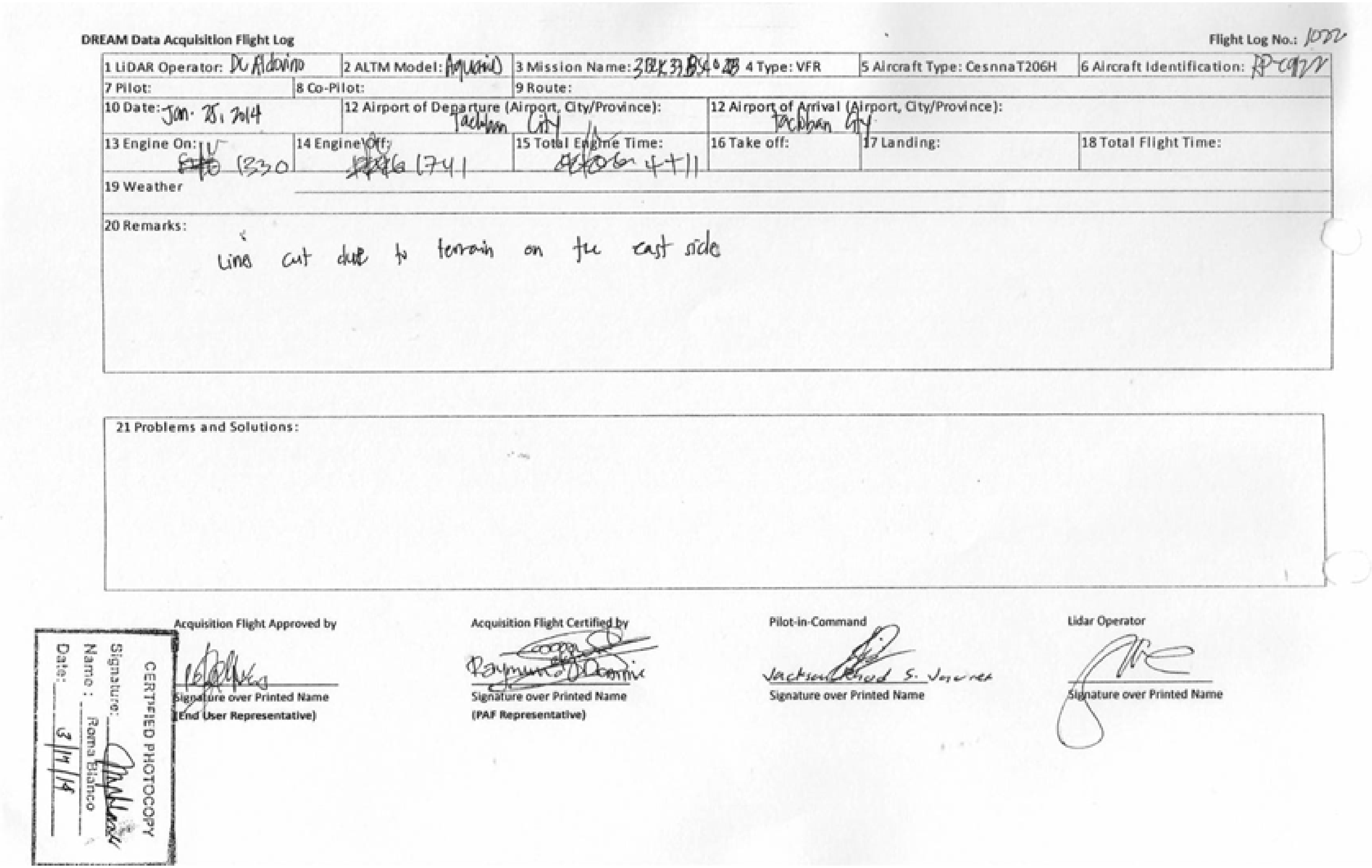
Name KEDPAN P unSTD
Position
Signature

Received by

Name JC Bongat
Position SSRP
Signature 2/26/16

Figure 5.6 Data Transfer Sheet for Basey Floodplain - F

Annex 6. Flight Logs



DREAM Data Acquisition Flight Log

Flight Log No.: 1022

1 LiDAR Operator: [illegible]	2 ALTM Model: Aquarius	3 Mission Name: [illegible]	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9122
7 Pilot:	8 Co-Pilot:	9 Route:			
10 Date: Jan. 25, 2014	12 Airport of Departure (Airport, City/Province): Tacloban City		12 Airport of Arrival (Airport, City/Province): Tacloban City		
13 Engine On: 1330	14 Engine Off: 1741	15 Total Engine Time: 4+11	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Line cut due to terrain on the east side

21 Problems and Solutions:

Acquisition Flight Approved by

Signature over Printed Name
(End User Representative)

Acquisition Flight Certified by

Raymund [illegible]

Signature over Printed Name
(PAF Representative)

Pilot-in-Command

Jackson [illegible] S. Jonrec

Signature over Printed Name

Lidar Operator

Signature over Printed Name

CERTIFIED PHOTOCOPY
Signature:
Name: Roma Blanco
Date: 3/17/14

Figure 6.1 Flight Log for Mission 1022A

DREAM Data Acquisition Flight Log

[illegible]

Flight Log No.: 1410

1 LiDAR Operator: Iro Roxas	2 ALTM Model: Aqua	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RPC-9122
7 Pilot: J. Javier	8 Co-Pilot: N. Agawin	9 Route:			
10 Date: May 3, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 911	14 Engine Off: 1358	15 Total Engine Time: 4+47	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: completed test flight for Aquarius over survey area of BLK 34 N (15 lines completed)					

21 Problems and Solutions:

CERTIFIED PHOTOCOPY

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
G. Hipolito	[illegible]	J. Javier	Iro Roxas
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure 6.2 Flight Log for Mission 1410A

DREAM Data Acquisition Flight Log

Flight Log No.: 1414

1 LiDAR Operator: RJ ARCEO	2 ALTM Model: AQUA	3 Mission Name: AQUARIUS 1414A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RPC9122
7 Pilot: J. JAVIER	8 Co-Pilot: N. AGAWIN	9 Route:			
10 Date: MAY 4, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1058	14 Engine Off: 1409	15 Total Engine Time: 3+11	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Completed test flight for aquarius over survey area BLLC34N (9 lines)

21 Problems and Solutions:

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

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

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

Lidar Operator — RJ ARCEO — Signature over Printed Name

CERTIFIED PHOTOCOPY

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure 6.3 Flight Log for Mission 1414A

DREAM Data Acquisition Flight Log

Flight Log No.: 1434

1 LiDAR Operator: RJ Amoro	2 ALTM Model: Aquarius	3 Mission Name: 3BLK340130A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RPC 9122
7 Pilot: J. Javier	8 Co-Pilot: N. Agawin	9 Route:			
10 Date: May 10, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 729	14 Engine Off: 1210	15 Total Engine Time: 4+41	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

completed 18 lines over BLK340.

21 Problems and Solutions:

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

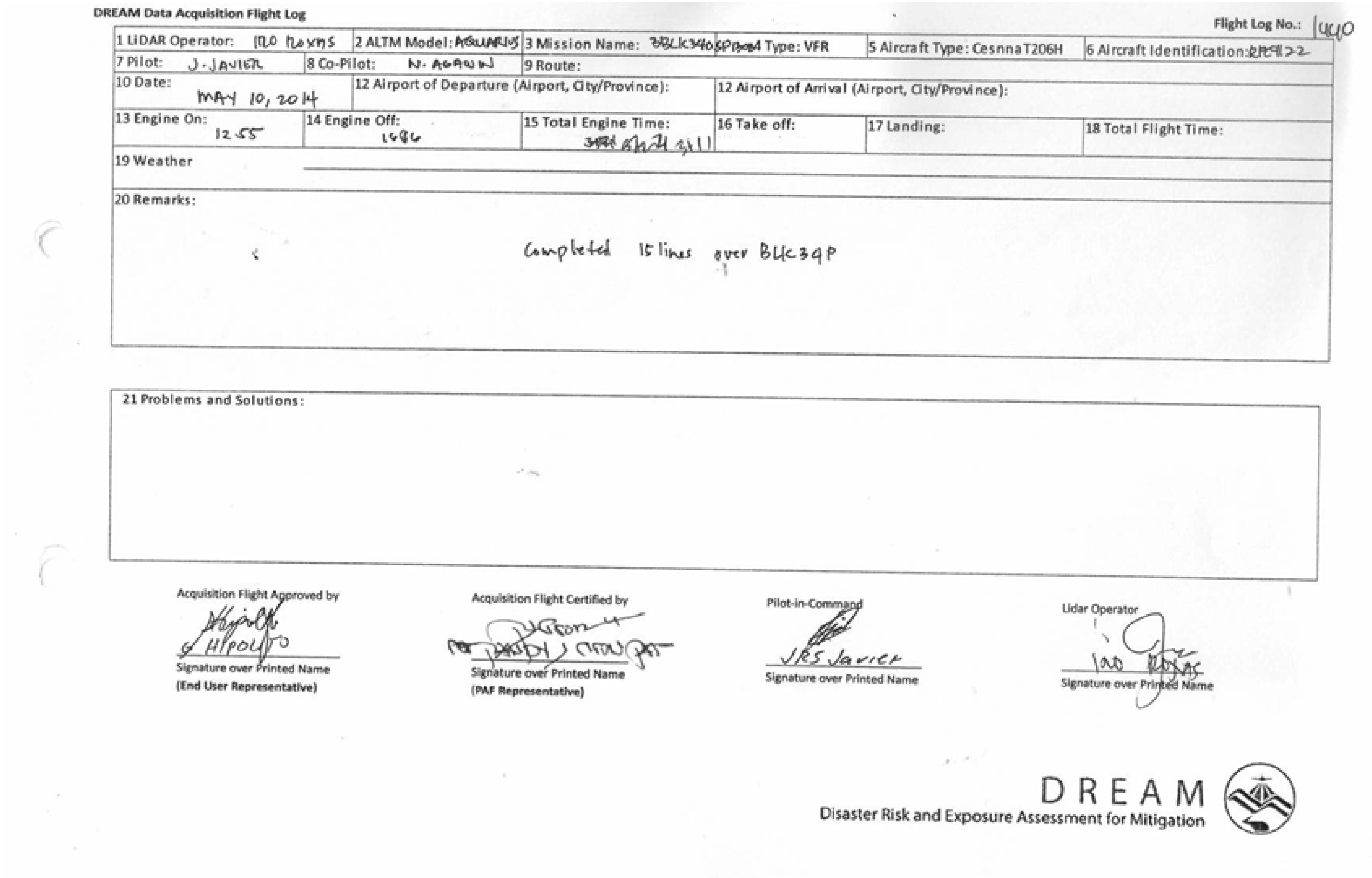
Acquisition Flight Certified by
[illegible]
Signature over Printed Name
(PAF Representative)

Pilot-in-Command
JRS Javier
Signature over Printed Name

Lidar Operator
RJ Amoro
Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure 6.4 Flight Log for Mission 1438A



DREAM Data Acquisition Flight Log

Flight Log No.: 1440

1 LiDAR Operator: IRO ROXAS	2 ALTM Model: AQUARIUS	3 Mission Name: 3BLK34OSP130A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9122
7 Pilot: J. JAVIER	8 Co-Pilot: N. AGAWIN	9 Route:			
10 Date: MAY 10, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 12:55	14 Engine Off: 1646	15 Total Engine Time: [illegible]	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Completed 15 lines over BLK34P					

21 Problems and Solutions:

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

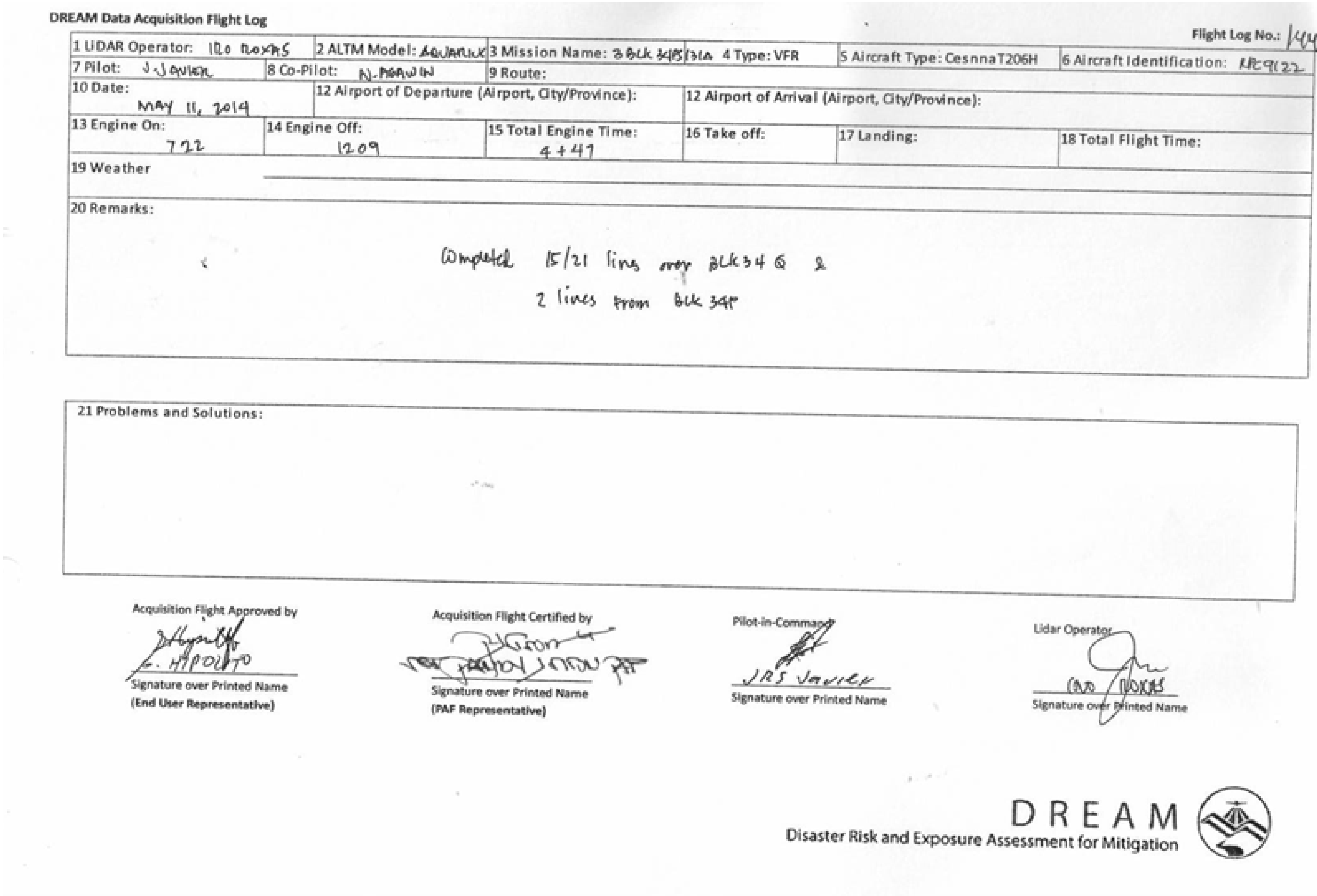
Acquisition Flight Certified by
Signature over Printed Name
(PAF Representative)

Pilot-in-Command
JRS Javier
Signature over Printed Name

Lidar Operator
Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure 6.5 Flight Log for Mission 1440A


DREAM Data Acquisition Flight Log

Flight Log No.: 1442

1 LiDAR Operator: I.Ro Roxas	2 ALTM Model: AQUARIUS	3 Mission Name: 3BLK34B/34A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RPC9122
7 Pilot: J. Javier	8 Co-Pilot: N. Anawin	9 Route:			
10 Date: MAY 11, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 722	14 Engine Off: 1209	15 Total Engine Time: 4+47	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Completed 15/21 lines over BLK34Q &
2 lines from BLK34P

21 Problems and Solutions:

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

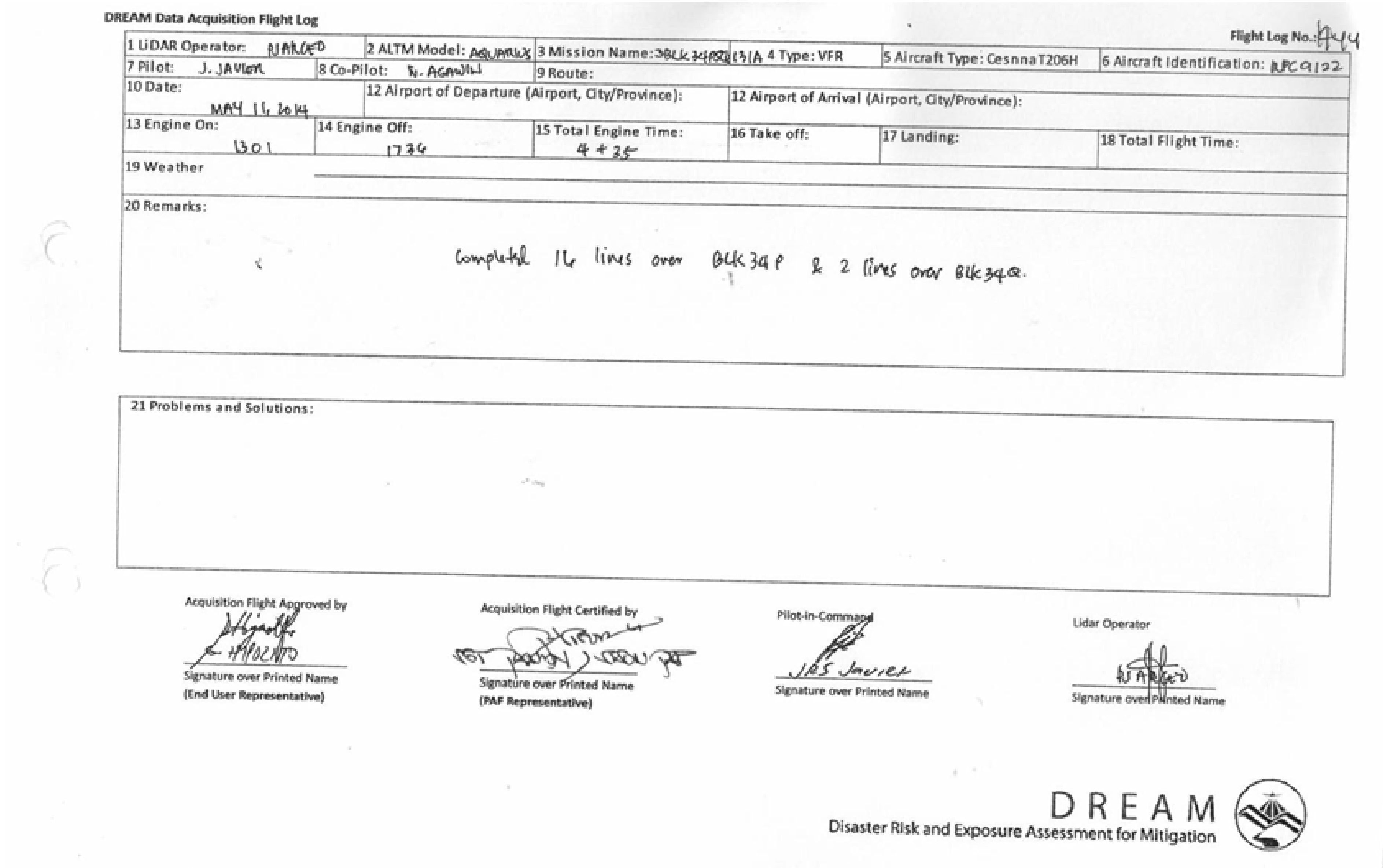
Acquisition Flight Certified by
Signature over Printed Name
(PAF Representative)

Pilot-in-Command
JRS Javier
Signature over Printed Name

Lidar Operator
Ivo Roxas
Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure 6.6 Flight Log for Mission 1442A



DREAM Data Acquisition Flight Log

Flight Log No.: 1444

1 LiDAR Operator: RJ ARCED	2 ALTM Model: AQUARIUS	3 Mission Name: 3BLK34PQ131A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RPC9122
7 Pilot: J. JAVIER	8 Co-Pilot: R. AGAWIN	9 Route:			
10 Date: MAY 11, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1301	14 Engine Off: 1736	15 Total Engine Time: 4+35	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Completed 16 lines over BLK34P & 2 lines over BLK34Q.

21 Problems and Solutions:

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

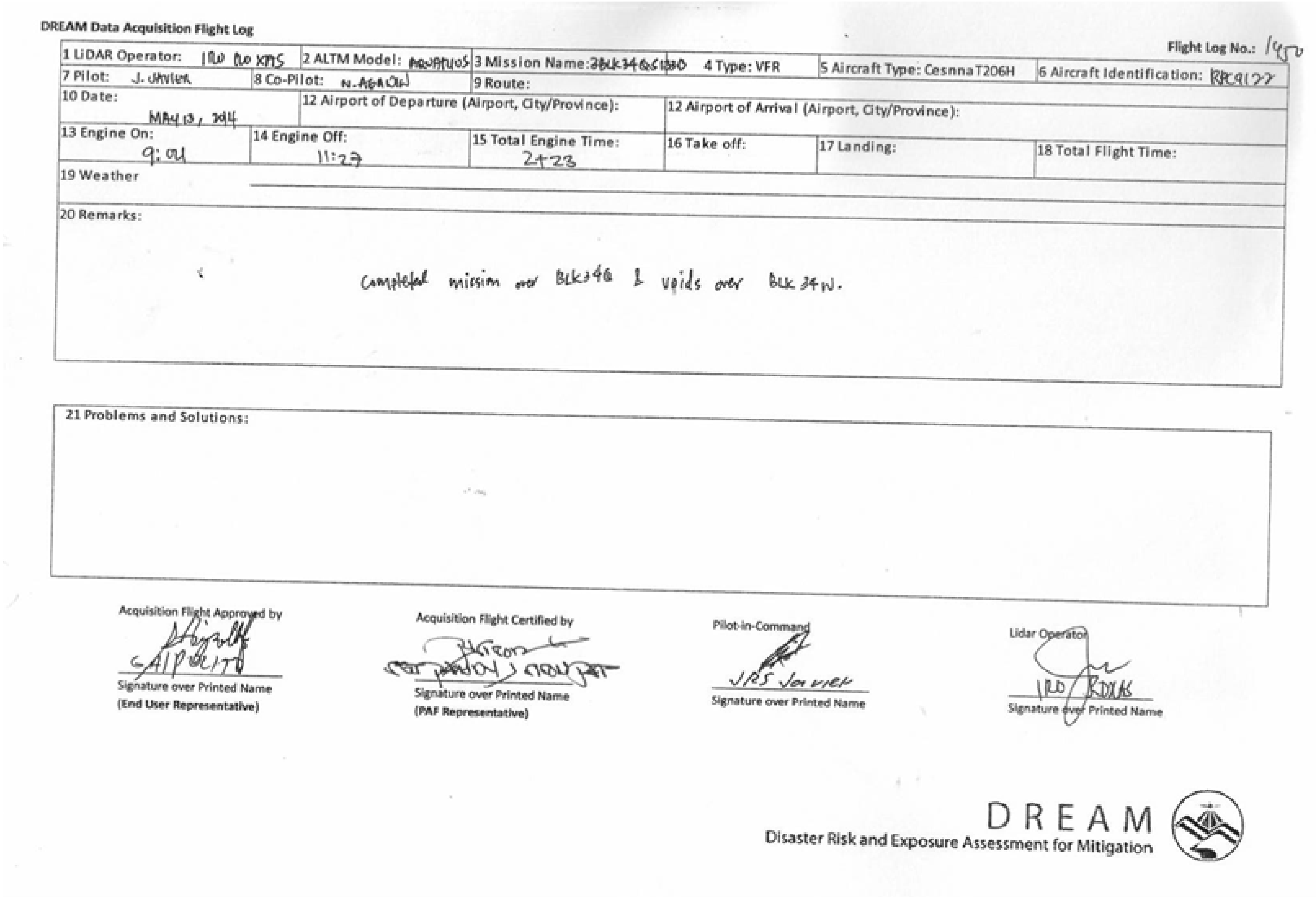
Acquisition Flight Certified by
Signature over Printed Name
(PAF Representative)

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

Lidar Operator
RJ ARCED
Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure 6.7 Flight Log for Mission 1444A



DREAM Data Acquisition Flight Log

Flight Log No.: 1450

1 LiDAR Operator: I.RO. PLOXMOS	2 ALTM Model: AQUARIUS	3 Mission Name: 3BLK34GS130	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RPC9122
7 Pilot: J. JAVIER	8 Co-Pilot: N. ADAOH	9 Route:			
10 Date: MAY 13, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 9:04	14 Engine Off: 11:27	15 Total Engine Time: 2+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Completed mission over BLK34G & voids over BLK 34W.

21 Problems and Solutions:

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

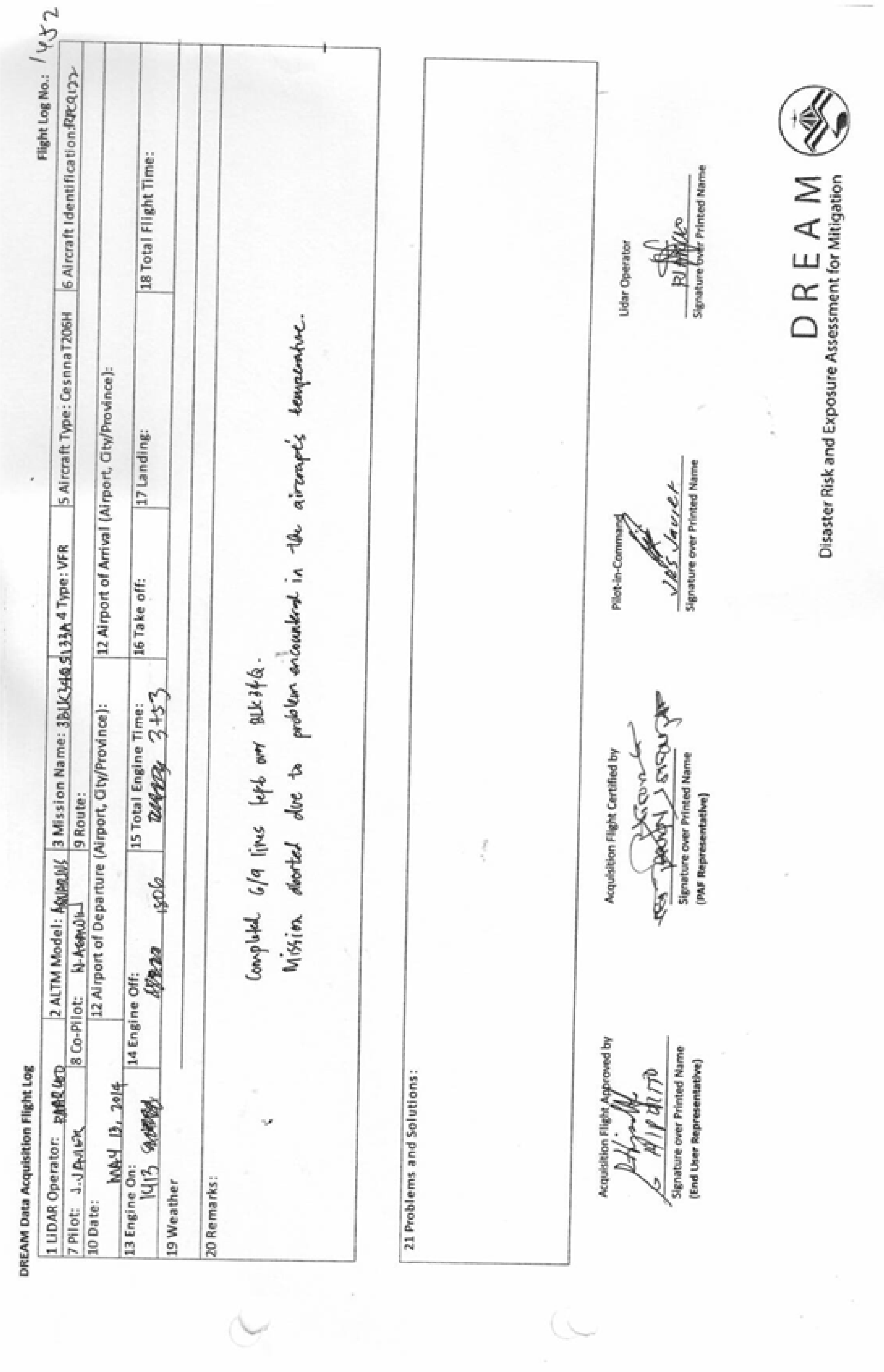
Acquisition Flight Certified by
Signature over Printed Name
(PAF Representative)

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

Lidar Operator
I.RO ROXAS
Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure 6.8 Flight Log for Mission 1450A



DREAM Data Acquisition Flight Log

Flight Log No.: 1452

1 LIDAR Operator: B.MABUED	2 ALTM Model: AQUARIUS	3 Mission Name: 3BLK34GS133A	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RPC9122
7 Pilot: J.JAVIER	8 Co-Pilot: N.AGAWIN	9 Route:			
10 Date: MAY 13, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1413	14 Engine Off: 1506	15 Total Engine Time: 0+53	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Completed 6/9 lines left over BLK34G.

Mission aborted due to problem encountered in the aircraft's temperature.

21 Problems and Solutions:

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

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

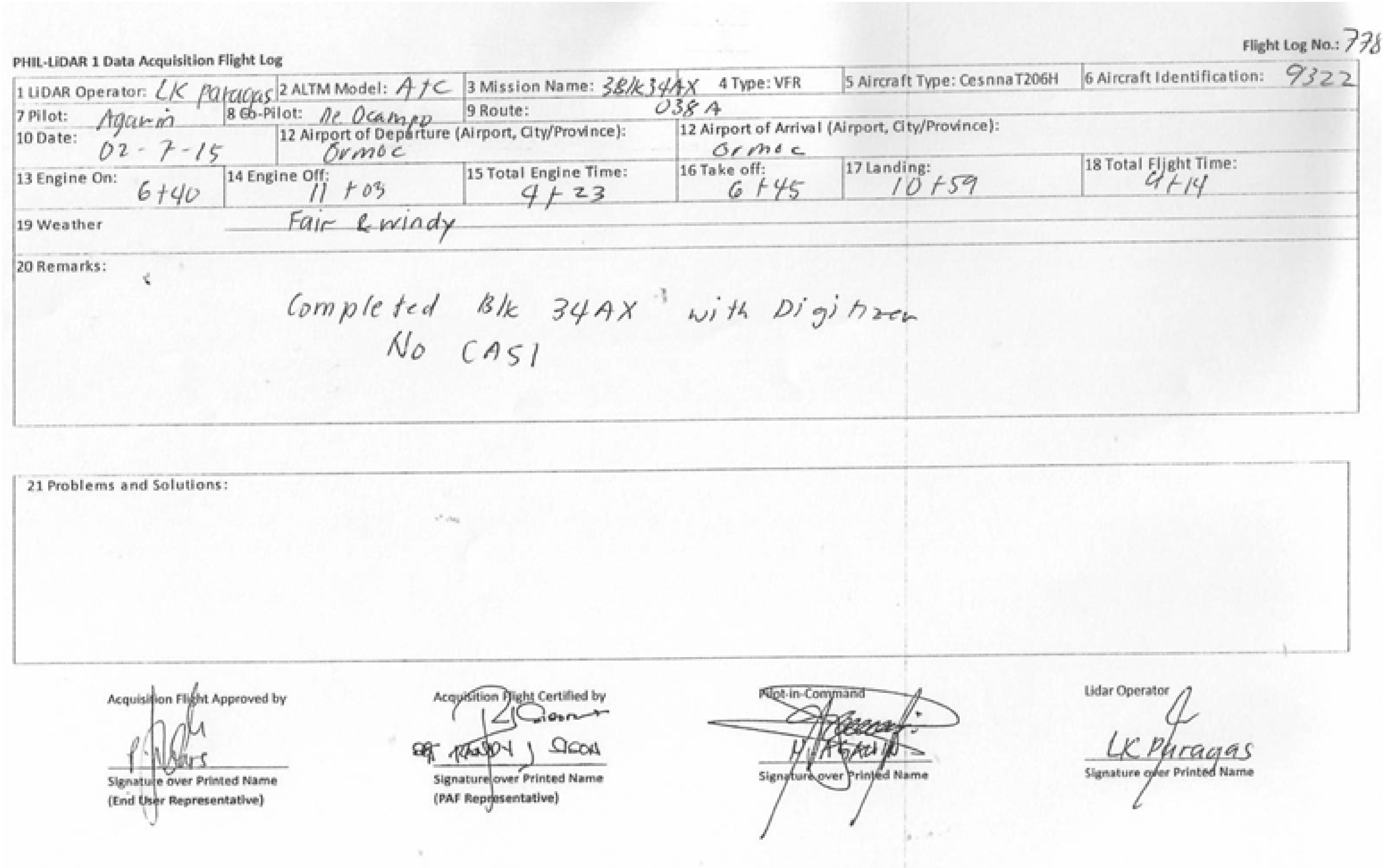
Pilot-in-Command — J.B.S. Javier — Signature over Printed Name

Lidar Operator — B. Mabued — Signature over Printed Name

DREAM

Disaster Risk and Exposure Assessment for Mitigation

Figure 6.9 Flight Log for Mission 1452A



Flight Log No.: 778

PHIL-LiDAR 1 Data Acquisition Flight Log

1 LiDAR Operator: LK Paragas	2 ALTM Model: AJC	3 Mission Name: 3Blk34AX	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9322
7 Pilot: Agarin	8 Co-Pilot: Ne Ocampo	9 Route: 038A			
10 Date: 02-7-15	12 Airport of Departure (Airport, City/Province): Ormoc		12 Airport of Arrival (Airport, City/Province): Ormoc		
13 Engine On: 6+40	14 Engine Off: 11+03	15 Total Engine Time: 4+23	16 Take off: 6+45	17 Landing: 10+59	18 Total Flight Time: 4+14
19 Weather	Fair & windy				

20 Remarks:

Completed Blk 34AX with Digitizer
No CASI

21 Problems and Solutions:

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

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

Pilot-in-Command
Signature over Printed Name

Lidar Operator
LK Paragas
Signature over Printed Name

Figure 6.10 Flight Log for Mission 7786AC

Flight Log No.: 7798

PHIL-LiDAR 1 Data Acquisition Flight Log

1 LiDAR Operator: G. Sinadjan	2 ALTM Model: A+C	3 Mission Name: 3BLK34AVD044A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification:
7 Pilot: N. Acawin	8 Co-Pilot: F. De Ocampo	9 Route:			
10 Date: 02-13-15	12 Airport of Departure (Airport, City/Province): Ormoc		12 Airport of Arrival (Airport, City/Province): Ormoc		
13 Engine On: 6+34	14 Engine Off: 9+45	15 Total Engine Time: 3+11	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Cloudy					

20 Remarks:

Successful flight. No CASI.

21 Problems and Solutions:

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

Acquisition Flight Certified by
Sgt. Randy J. Sison
Signature over Printed Name
(PAF Representative)

Pilot-in-Command
[illegible] B. Ocampo
Signature over Printed Name

Lidar Operator
M. [illegible]
Signature over Printed Name

Figure 6.11 Flight Log for Mission 7798AC

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3703

1 LIDAR Operator: L. Siradjan	2 ALTM Model: GEMINI	3 Mission Name: [illegible]	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RPC 9022
7 Pilot: [illegible] Lim	8 Co-Pilot: Randy [illegible]	9 Route: Tacloban Local			
10 Date: 1-23-16	12 Airport of Departure (Airport, City/Province): Tacloban		12 Airport of Arrival (Airport, City/Province): Tacloban		
13 Engine On: 14:15	14 Engine Off: 17:44	15 Total Engine Time: 3+29	16 Take off: 14:20	17 Landing: 17:39	18 Total Flight Time: 3+19
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

Successful flight.

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
Paulino [illegible] Arceo	SSg Raymund [illegible] Domin PAF	[illegible] Lim	L. Siradjan	N/A
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 6.12 Flight Log for Mission 3703G/3769G

PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 7333

1 LiDAR Operator: J. Almalvez	2 ALTM Model: Gemini	3 Mission Name: 2BLK33A031A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RPC-9022
7 Pilot: A. Lim	8 Co-Pilot: R. Lagco	9 Route:			
10 Date: 1-31-16	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 13:52	14 Engine Off: 16:51	15 Total Engine Time: 2+59	16 Take off: 13:57	17 Landing: 16:46	18 Total Flight Time: 2+49
19 Weather: windy					

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

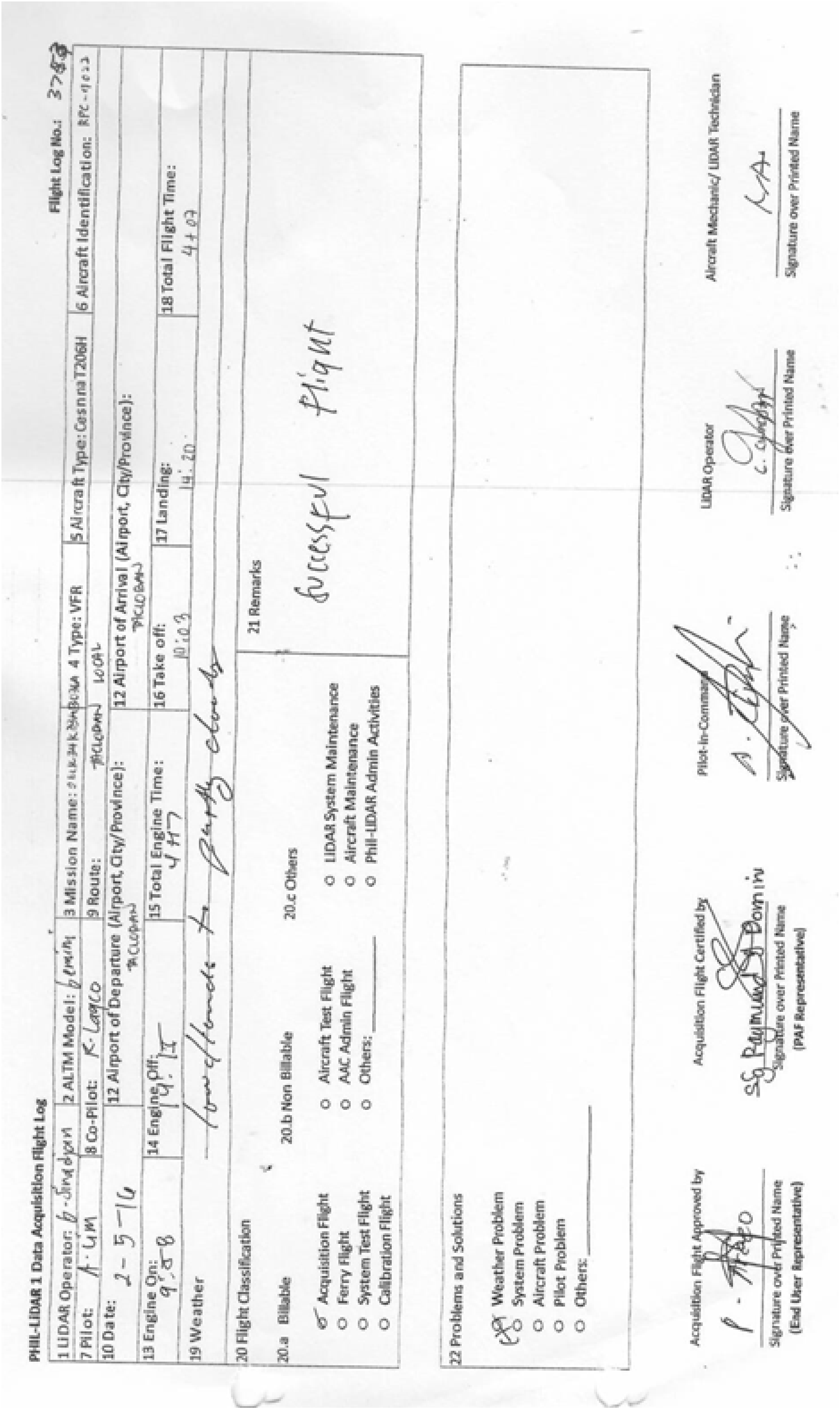
Completed a few lines over Blk 33A only. Aborted flight due to strong winds.

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
P. Arceo	S. Raymund Y. Domingo	A. Lim	J. Almalvez	
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 6.13 Flight Log for Mission 3733G


PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3753G

1 LIDAR Operator: G. Sinadjan	2 ALTM Model: Gemini	3 Mission Name: [illegible]	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RPC-9022
7 Pilot: A. Lim	8 Co-Pilot: R. Lagco	9 Route: Tacloban Local			
10 Date: 2-5-16	12 Airport of Departure (Airport, City/Province): Tacloban	12 Airport of Arrival (Airport, City/Province): Tacloban			
13 Engine On: 9:58	14 Engine Off: 14:[illegible]	15 Total Engine Time: 4H27	16 Take off: 10:03	17 Landing: 14:20	18 Total Flight Time: 4+07
19 Weather: fair to partly cloudy					

20 Flight Classification

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

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

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

21 Remarks

Successful flight

22 Problems and Solutions
- ✓ Weather Problem
- System Problem
- Aircraft Problem
- Pilot Problem
- Others: ______

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

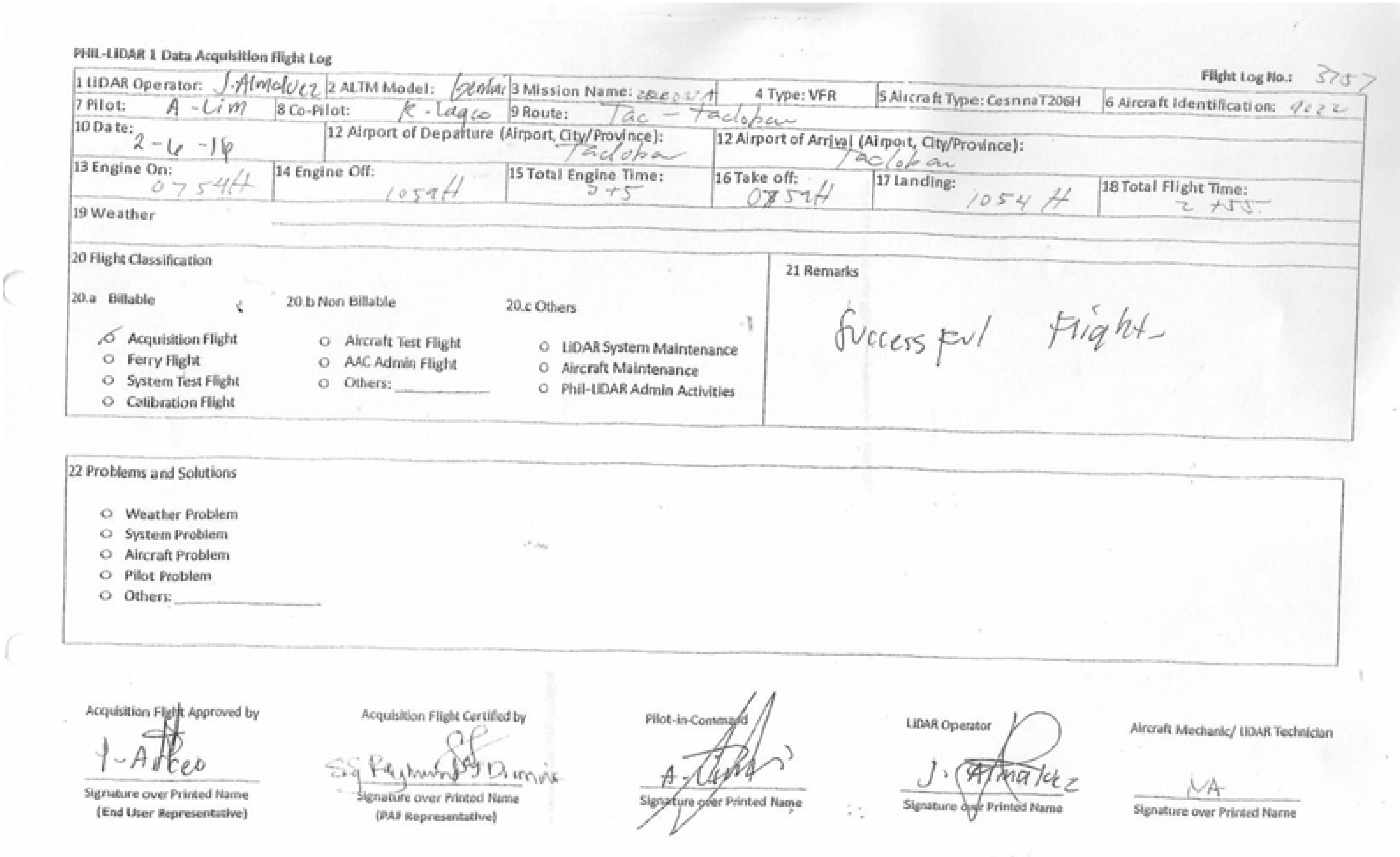
Acquisition Flight Certified by: SG Peyumad S. Domin... Signature over Printed Name (PAF Representative)

Pilot-in-Command: A. Lim — Signature over Printed Name

LIDAR Operator: G. Sinadjan — Signature over Printed Name

Aircraft Mechanic/ LIDAR Technician: Signature over Printed Name

Figure 6.14 Flight Log for Mission 3753G


PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3757

1 LiDAR Operator: J. Almalvez	2 ALTM Model: Gemini	3 Mission Name: 2BLED057A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: A - Lim	8 Co-Pilot: R - Lagco	9 Route: Tac - Tacloban			
10 Date: 2-6-16	12 Airport of Departure (Airport, City/Province): Tacloban		12 Airport of Arrival (Airport, City/Province): Tacloban		
13 Engine On: 0754H	14 Engine Off: 1059H	15 Total Engine Time: 3+5	16 Take off: 0759H	17 Landing: 1054 H	18 Total Flight Time: 2+55
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

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. Alfeo	SSg Raymund Dumi	A. Lim	J. Almalvez	NA
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure 6.15 Flight Log for Mission 3757G

Annex 7. Flight Status Report

SAMAR
(May 5-4, 10-11 and 13, 2014; February 7 and 13, 2015; and January 23, 31 and February 6, 2016)

Table 4.1 LiDAR Survey Team Composition

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1022A	BLK33B, BLK33C	3BLK33BSC025B	D.C. Aldovino	January 25, 2014	Lines cut due to terrain on the east side.
1410A	BLK33E	3BLK33E124A	I. Roxas	May 3, 2014	Completed test flight for Aquarius over survey area BLK33E.
1414A	BLK33E	3BLK33E124A	P.J. Arceo	May 4, 2014	Completed test flight for Aquarius over survey area BLK33E.
1438A	BLK33F	3BLK33F130A	P.J. Arceo	May,10 2014	Completed 18 lines over BLK34F.
1440A	BLK33F, BLK33G	3BLK33FSG130B	I. Roxas	May 10, 2014	Completed 15 lines over BLK33G.
1442A	BLK33G	3BLK33GS131A	I. Roxas	May 11, 2014	Completed 15/21 lines over BLK33G.
1444A	BLK33G, BLK33H	3BLK33GSH131B	P.J. Arceo	May 11, 2014	Completed 16 lines over BLK33H and 2 lines over BLK33G.
1450A	BLK33H	3BLK33HS133A	P.J. Arceo	May 13, 2014	Completed 6 out of 9 lines left over BLK34H, need to abort due to problem encountered in the aircraft temperature.
1452A	BLK33H, BLK33E	3BLK33HSES133B	I. Roxas	May 13, 2014	Completed mission over BLK34H and some voids over BLK33E.
7786AC	BLK34AX	3BLK34AX038A	L.K. Paragas	February 7, 2015	Completed Blk34AX with digitizer; No CASI.
7798AC	BLK34AX+VOIDS	3BLK34AV044A	G. Sinadjan	February 13, 2015	Completed Blk34A and some voids with digitizer; No CASI.

3703G/ 3769G	BLK34D, BLK34F	2BLK34ADEG023A	J. Almalvez	January 23, 2016	Completed BLK34A, BLK34D and BLK 34E; Surveyed 6 lines at BLK34G.
3733G	BLK34L	2BLK33ABLK34L031A	J. Almalvez	January 31, 2016	Completed BLK34L and surveyed 7 lines at BLK33A.
3753G	BLK34K	2BLK34K33AB036A	G. Sinadjan	February 5, 2016	Surveyed BLK34K and completed BLK33A & 33B.
3757G	BLK34K	2BLK34K037A	J. Almalvez	February 6, 2016	Completed BLK34K.

LAS BOUNDARIES PER FLIGHT

Flight No. : 1022A
Area: BLK33B, BLK33C
Mission Name: 3BLK33BSC025B
Parameters: Altitude: 600; Scan Frequency: 40Hz;
Scan Angle: 25deg; Overlap: 40%

LAS

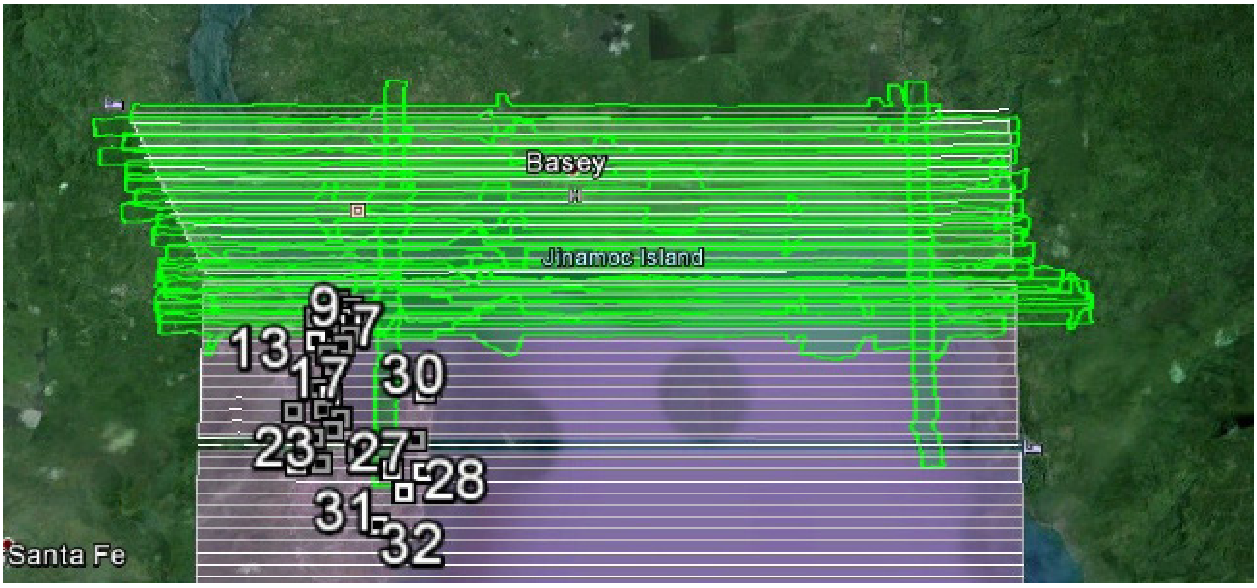


Figure A-7.1 Swath for Flight No. 1022A

Flight No. :	1410A			
Area:	BLK33E			
Mission Name:	AQUATACTF123A			
Parameters:	Altitude:	600;	Scan Frequency:	50Hz;
	Scan Angle:	18deg;	Overlap:	30%

LAS

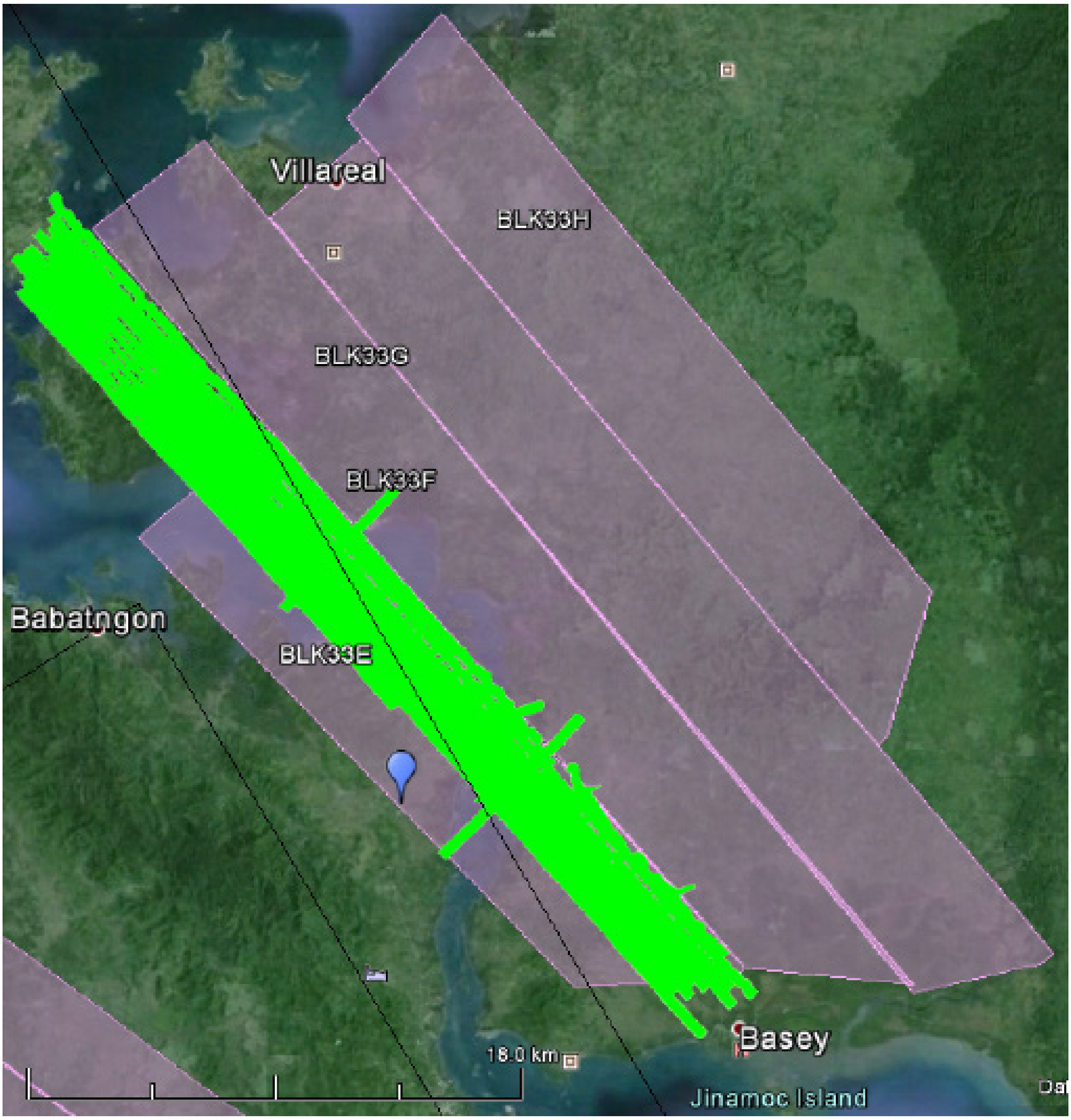


Figure A-7.2 Swath for Flight No.1410

Flight No. :	1414A		
Area:	BLK33E		
Mission Name:	AQUATACTF124A		
Parameters:	Altitude: 600;	Scan Frequency:	50Hz;
	Scan Angle: 18deg;	Overlap:	30%

LAS

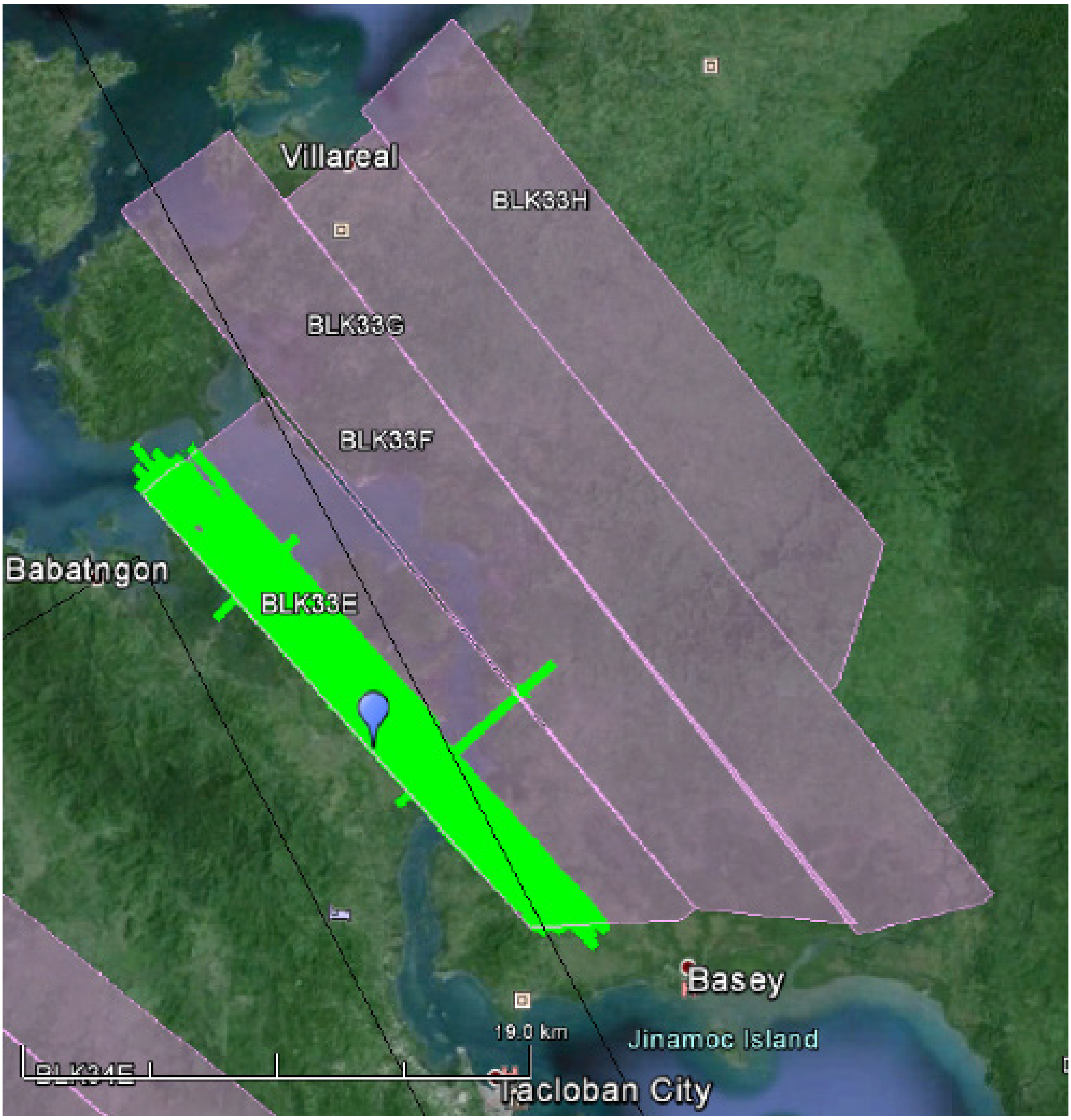


Figure A-7.3 Swath for Flight No. 1414A

Flight No. :	1438A			
Area:	BLK33F			
Mission Name:	3BLK33E124A			
Parameters:	Altitude:	600;	Scan Frequency:	50Hz;
	Scan Angle:	18deg;	Overlap:	30%

LAS

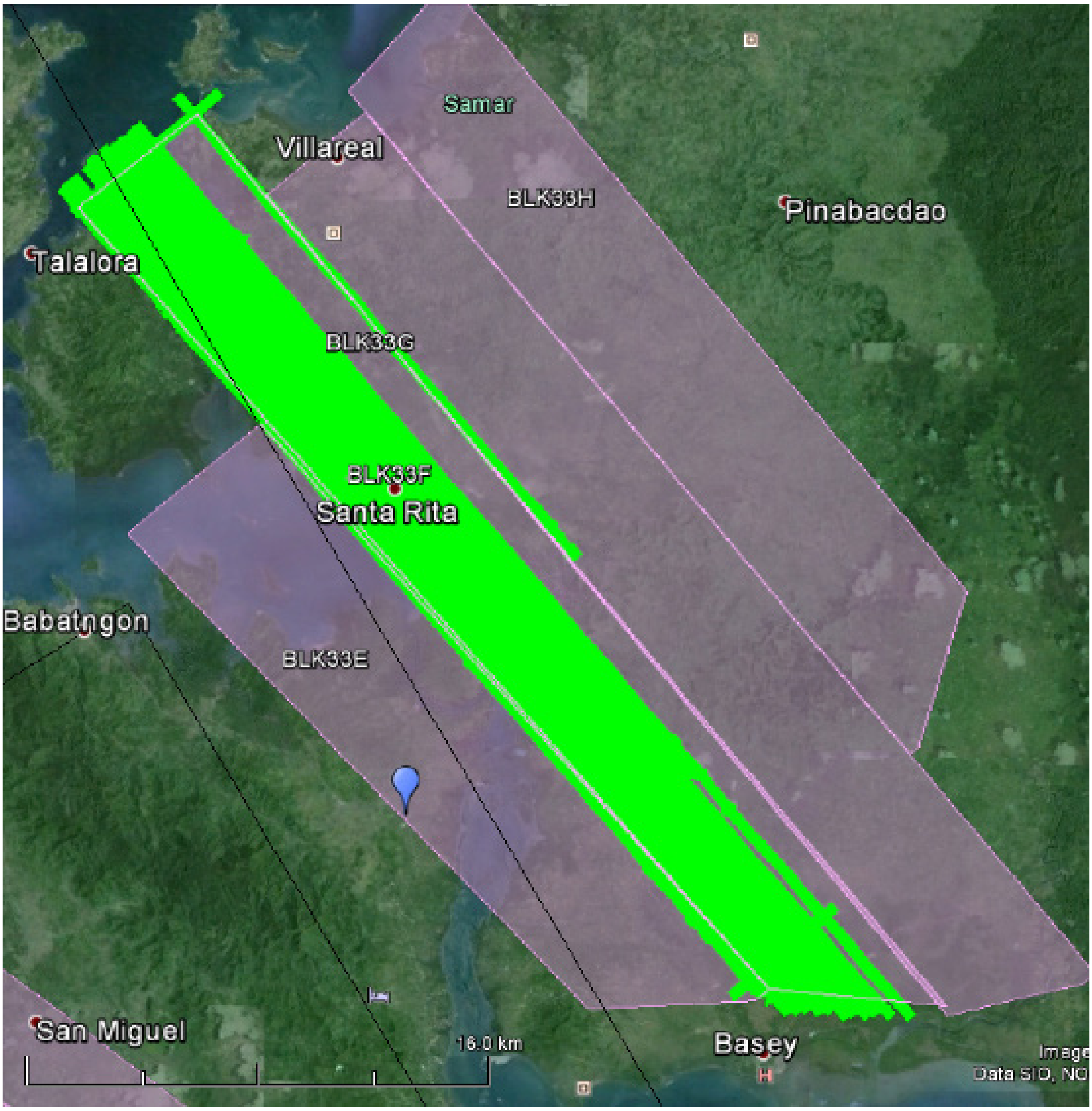


Figure A 7.4 Swath for Flight No. 1438A

Flight No. :	1438A			
Area:	BLK33F			
Mission Name:	3BLK33F130A			
Parameters:	Altitude:	600;	Scan Frequency:	50Hz;
	Scan Angle:	18deg;	Overlap:	30%

LAS

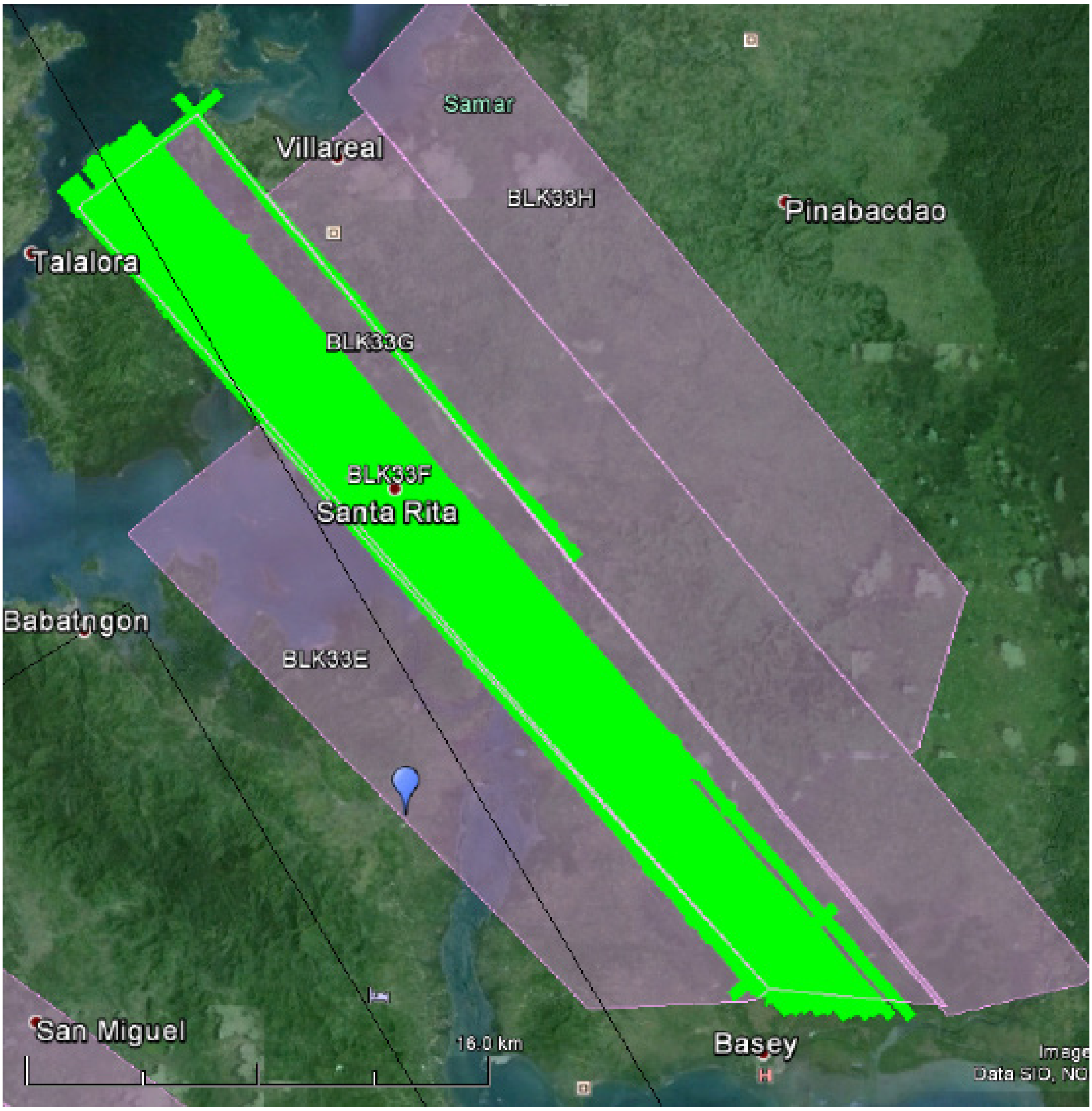


Figure A-7.5 Swath for Flight No. 1438A

Flight No. :	1440A			
Area:	BLK33F, BLK33G			
Mission Name:	3BLK33FSG130B			
Parameters:	Altitude:	600;	Scan Frequency:	50Hz;
	Scan Angle:	18deg;	Overlap:	30%

LAS

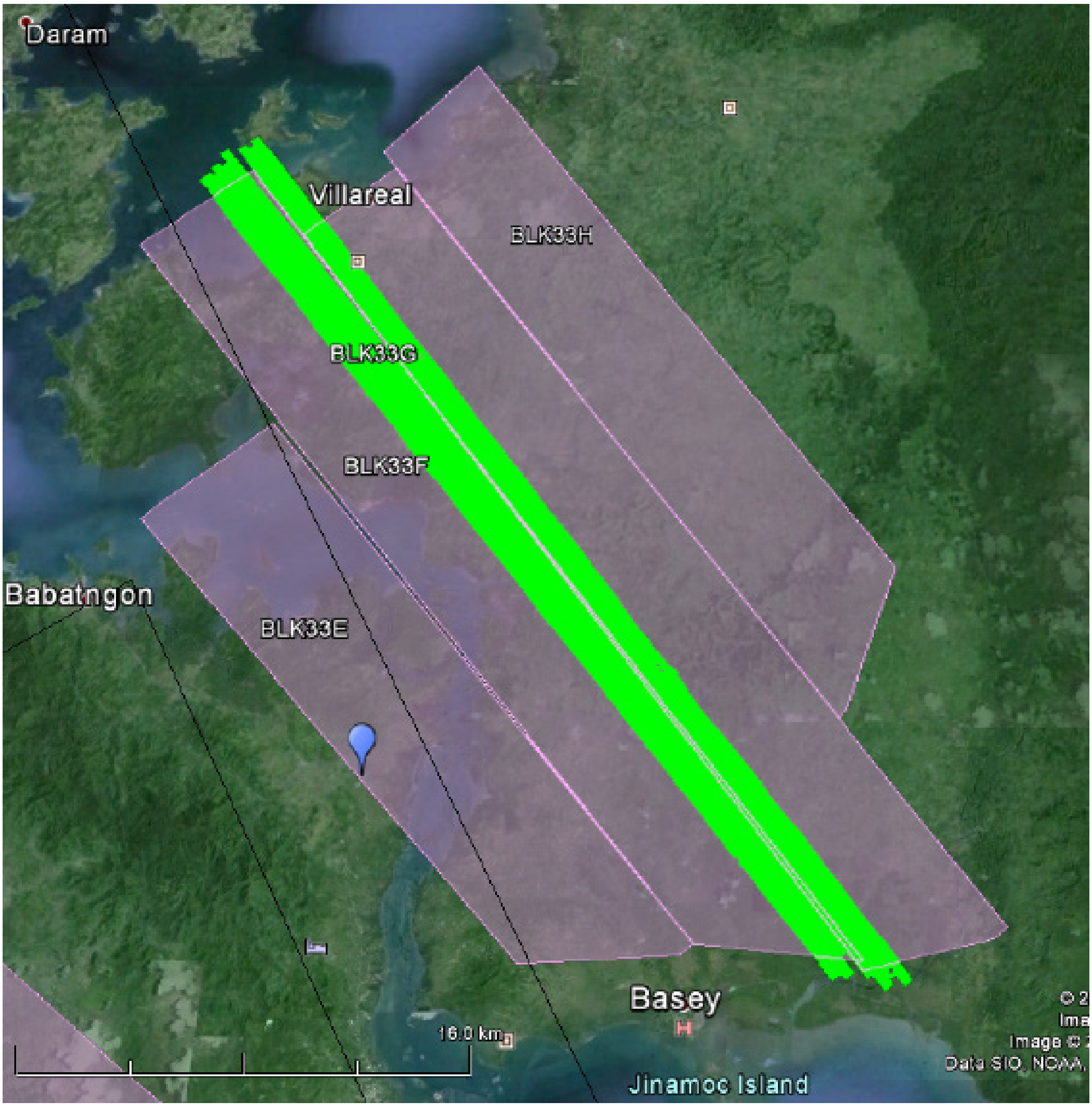


Figure A-7.6 Swath for Flight No. 1440A

Flight No. :	1442A			
Area:	BLK33G			
Mission Name:	3BLK33GS131A			
Parameters:	Altitude: 600;		Scan Frequency:	50Hz;
	Scan Angle: 18deg;		Overlap:	30%

LAS

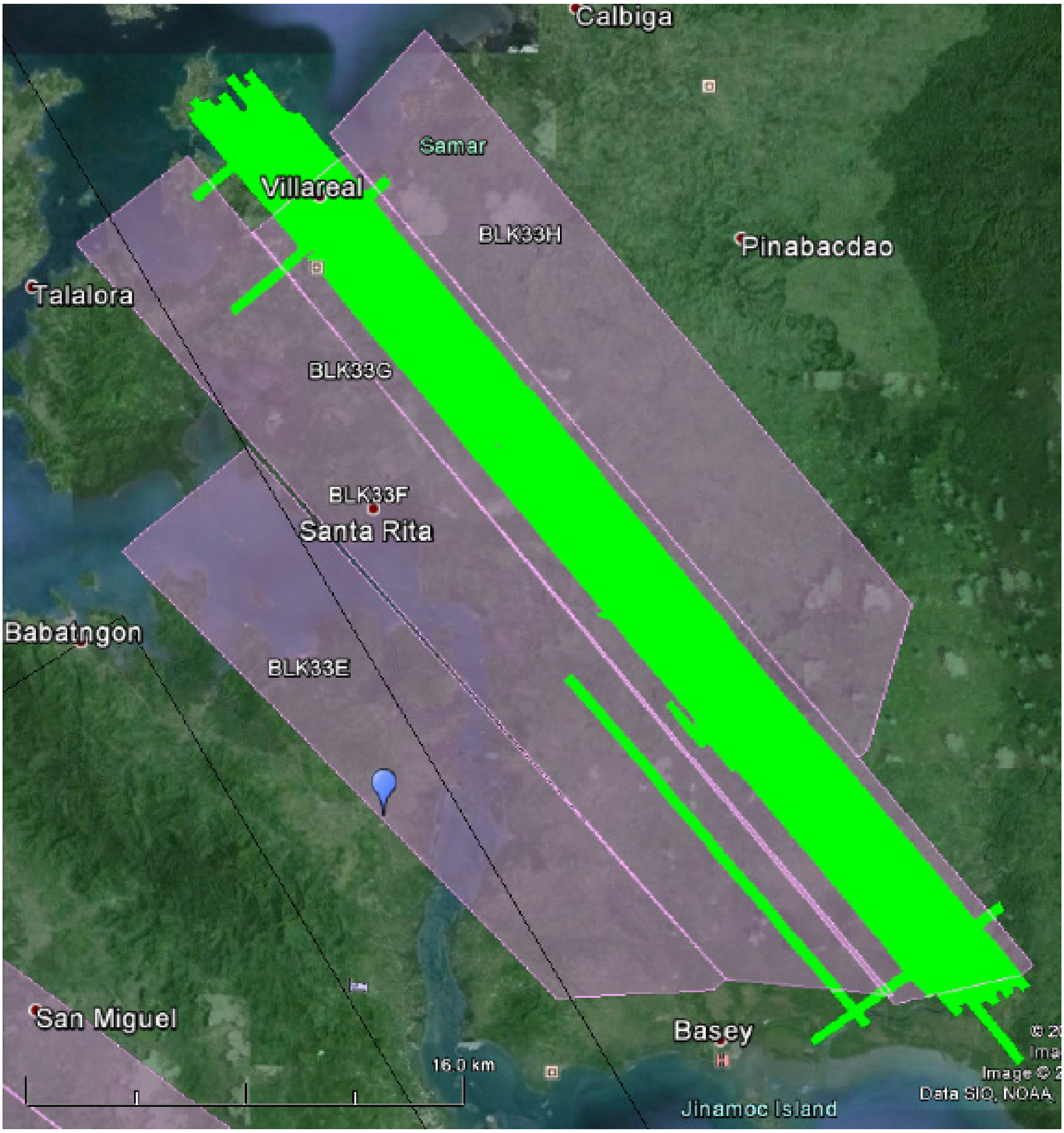


Figure A-7.7 Swath for Flight No. 1442A

Flight No. :	1444A			
Area:	BLK34G, BLK34H			
Mission Name:	3BLK33GSH131B			
Parameters:	Altitude:	600;	Scan Frequency:	50Hz;
	Scan Angle:	18deg;	Overlap:	30%

LAS

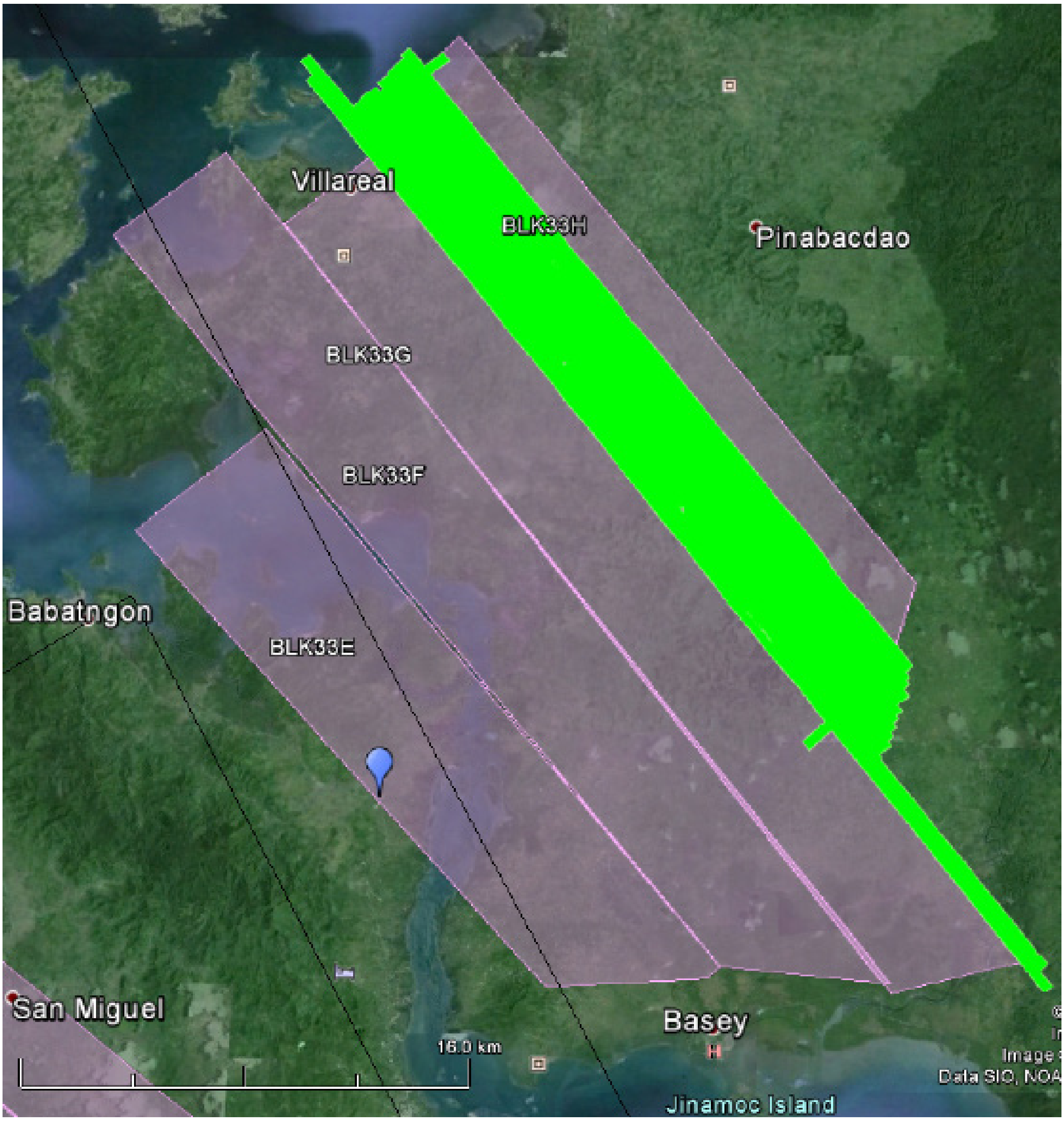


Figure A-7.8 Swath for Flight No. 1444A

Flight No. :	1450A			
Area:	BLK33H			
Mission Name:	3BLK33HS133A			
Parameters:	Altitude: 600;		Scan Frequency:	50Hz;
	Scan Angle: 18deg;		Overlap:	30%

LAS

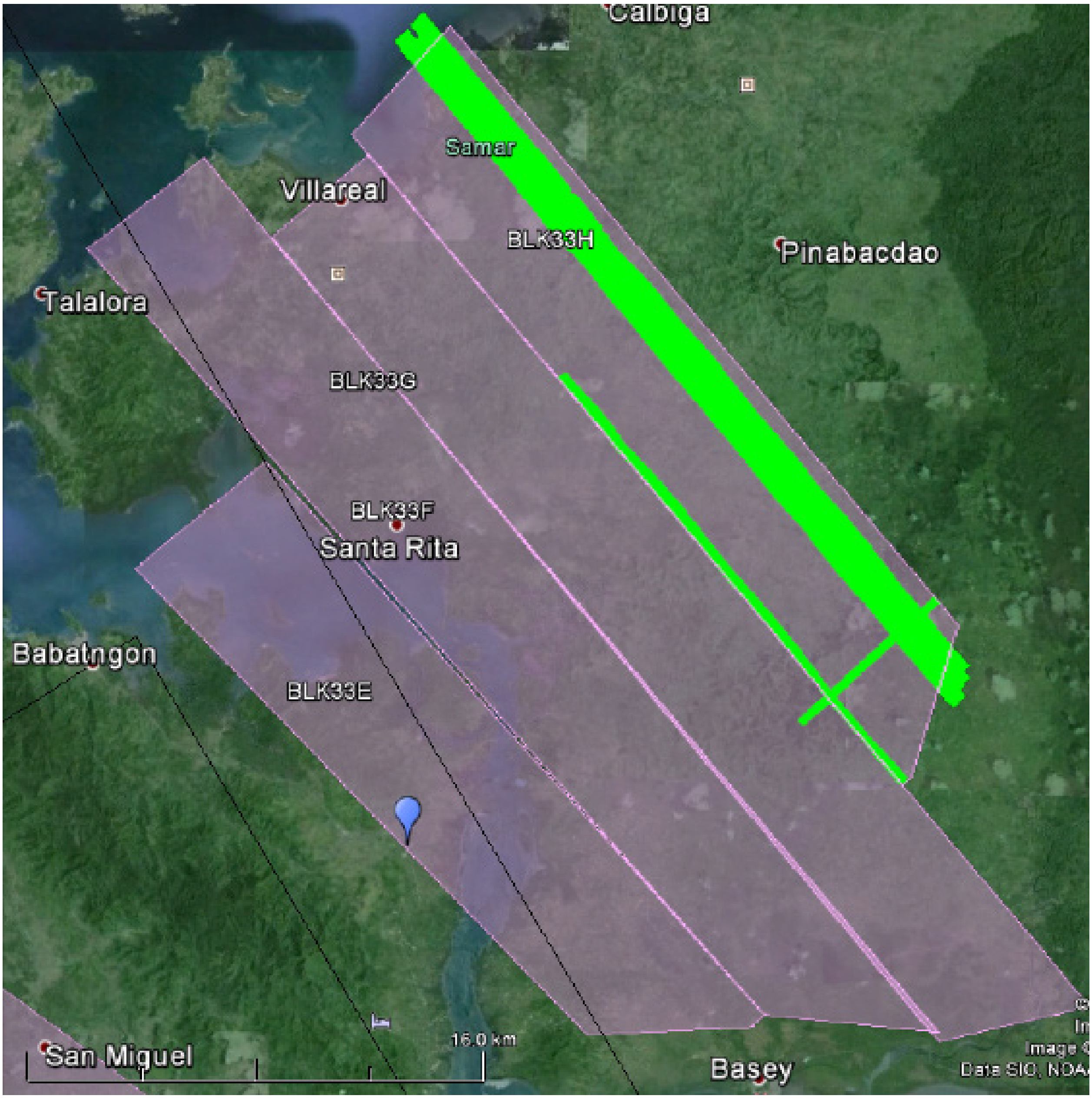


Figure A-7.9 Swath for Flight No. 1450A

Flight No. :	1452A			
Area:	BLK33H, BLK33E			
Mission Name:	3BLK33HSES133B			
Parameters:	Altitude:	600;	Scan Frequency:	50Hz;
	Scan Angle:	18deg;	Overlap:	30%

LAS

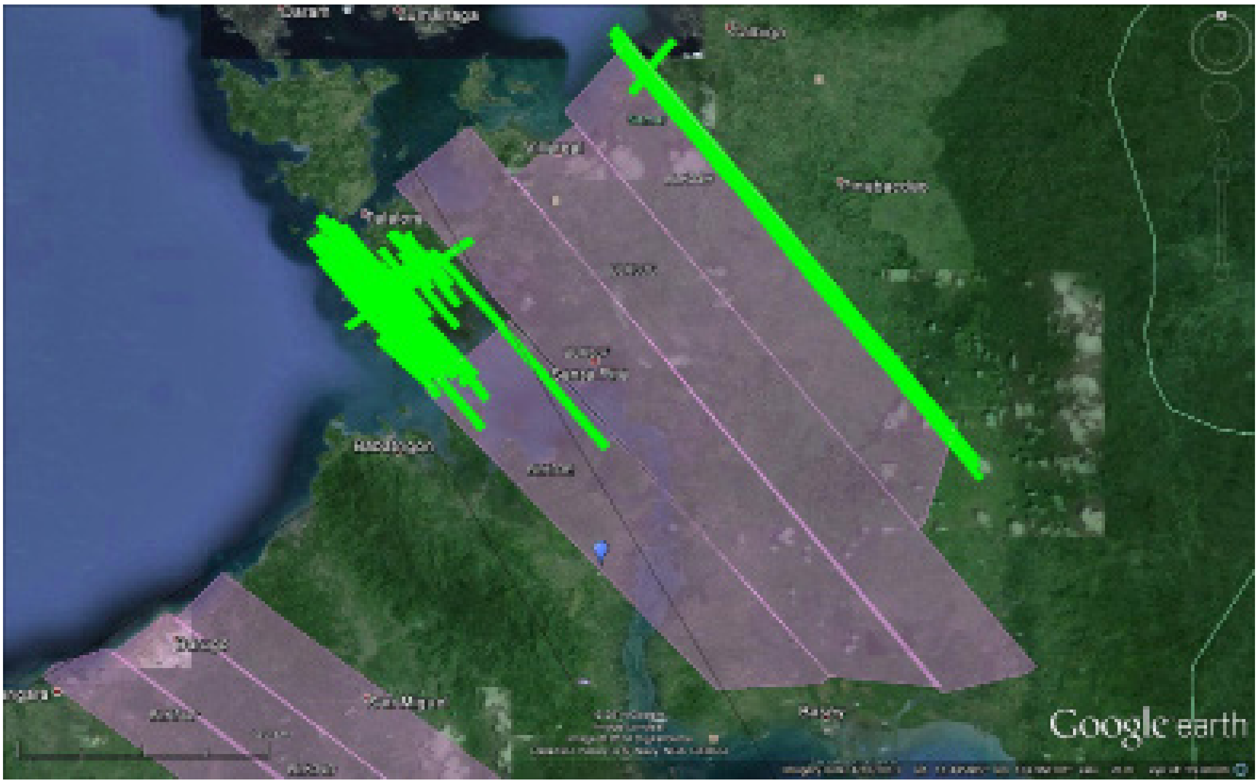


Figure A-7.10 Swath for Flight No. 1452A

Flight No. :	7786AC			
Area:	BLK34AX			
Mission Name:	3BLK34AX038A			
Parameters:	Altitude:	600;	Scan Frequency:	45Hz;
	Scan Angle:	18deg;	Overlap:	35%

LAS

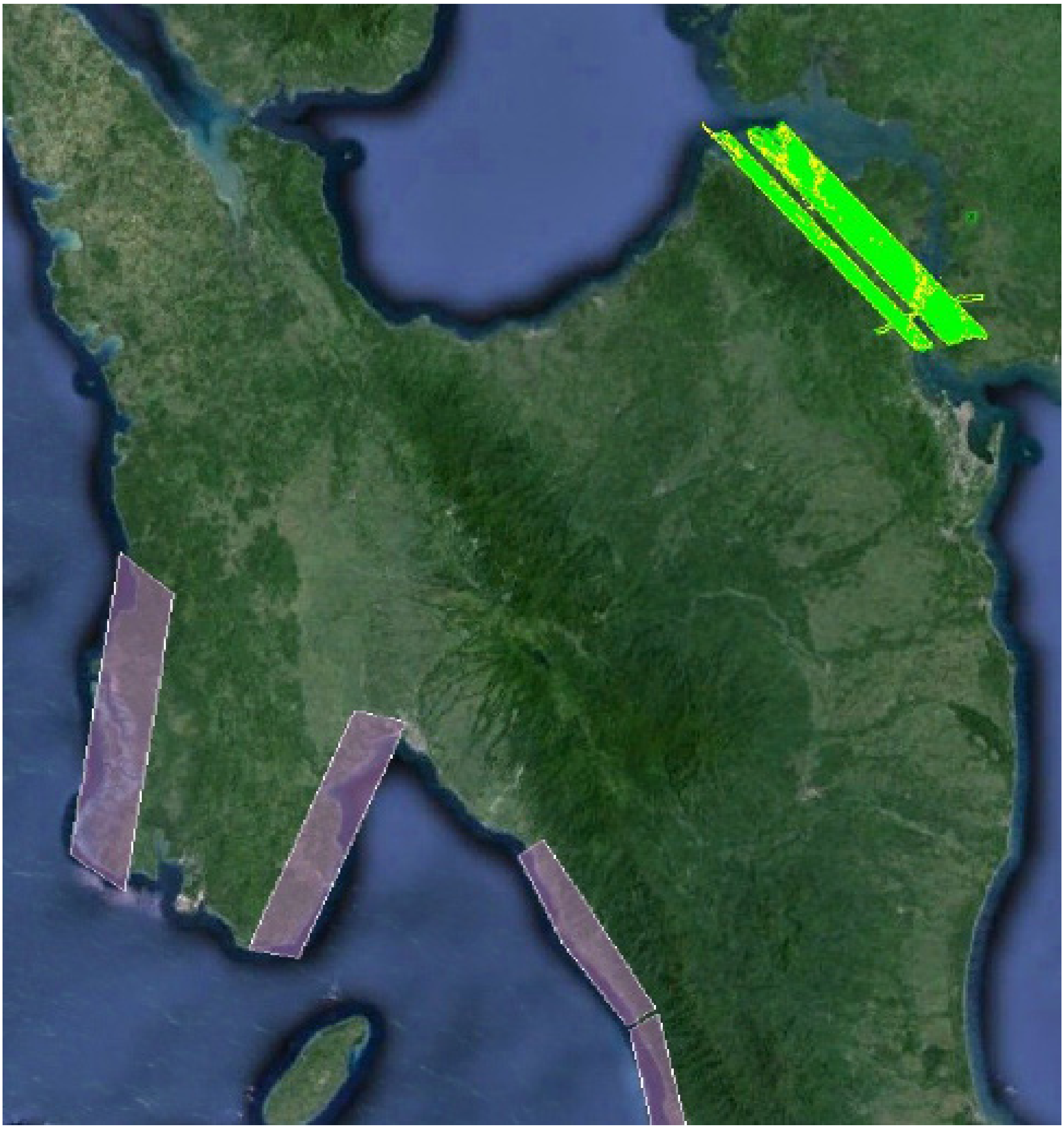


Figure A-7.11 Swath for Flight No. 7786AC

Flight No. :	7798AC			
Area:	BLK34AX+VOIDS			
Mission Name:	3BLK34AX044A			
Parameters:	Altitude:	600;	Scan Frequency:	45Hz;
	Scan Angle:	18deg;	Overlap:	35%

LAS

Figure A-7.12 Swath for Flight No. 7798AC

Flight No. :	3703G/3769G			
Area:	BLK34D, BLK34E			
Mission Name:	2BLK34ADEG023A			
Parameters:	Altitude: 1200;		Scan Frequency:	50Hz;
	Scan Angle: 17deg;		Overlap:	30%

LAS

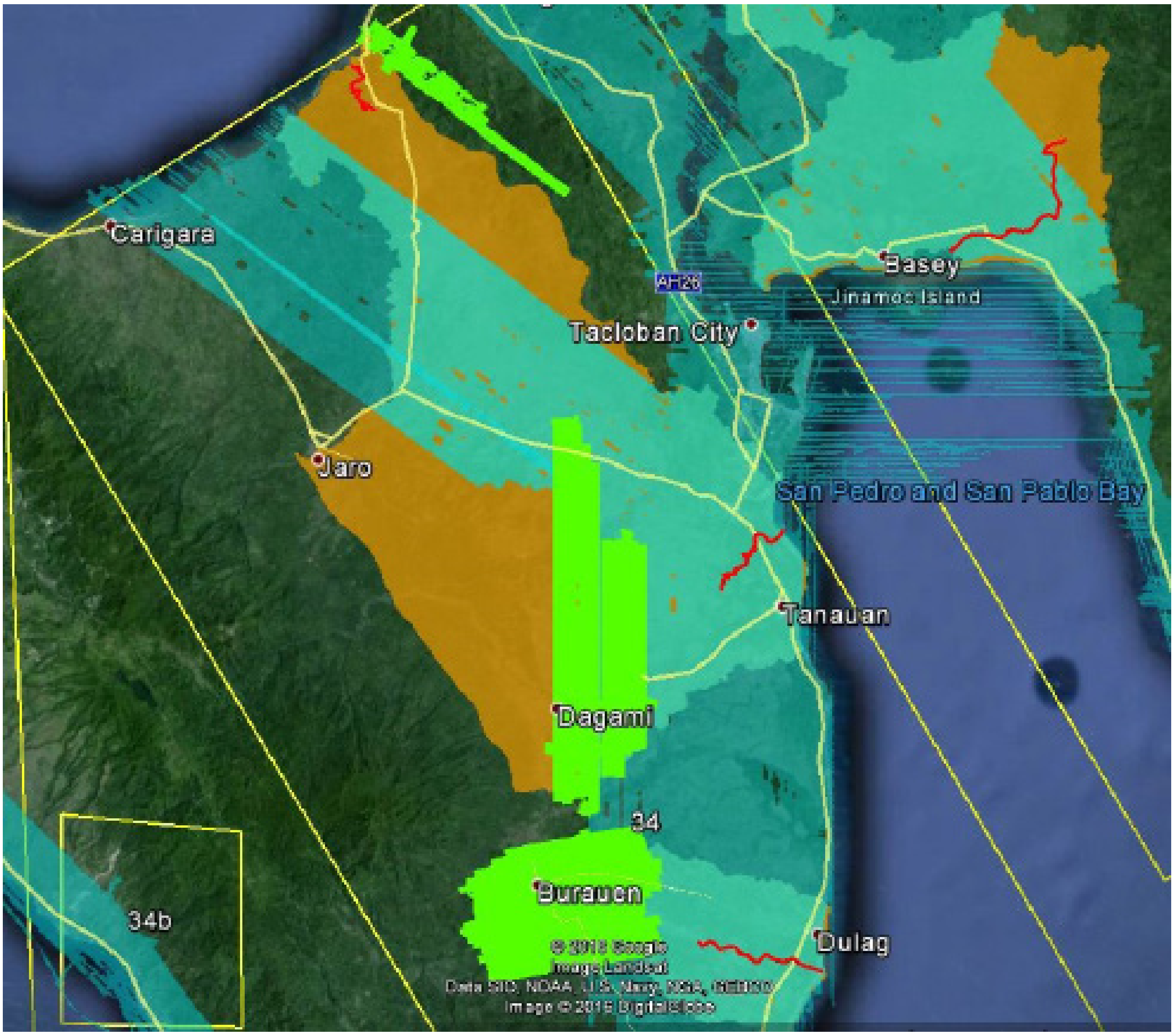


Figure A-7.13 Swath for Flight No. 3703G/3769G

Flight No. :	3733G			
Area:	BLK34L			
Mission Name:	2BLK33ABLK34L031A			
Parameters:	Altitude:	850;	Scan Frequency:	50Hz;
	Scan Angle:	20deg;	Overlap:	35%

LAS

Figure A-7.14 Swath for Flight No. 3733G

Flight No. :	3753G			
Area:	BLK34K			
Mission Name:	2BLK34K33AB036A			
Parameters:	Altitude:	850;	Scan Frequency:	50Hz;
	Scan Angle:	20deg;	Overlap:	35%

LAS

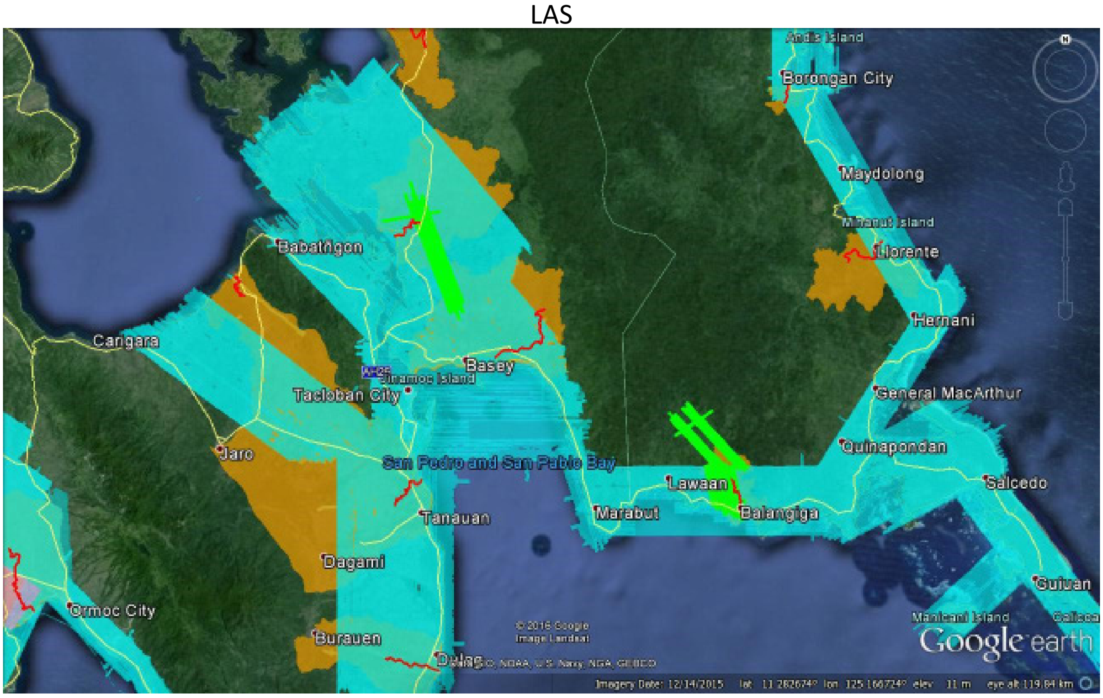


Figure A-7.15 Swath for Flight No. 3753G

Flight No. :	3757G			
Area:	BLK34K			
Mission Name:	2BLK34K037A			
Parameters:	Altitude:	850;	Scan Frequency:	50Hz;
	Scan Angle:	20deg;	Overlap:	35%

LAS

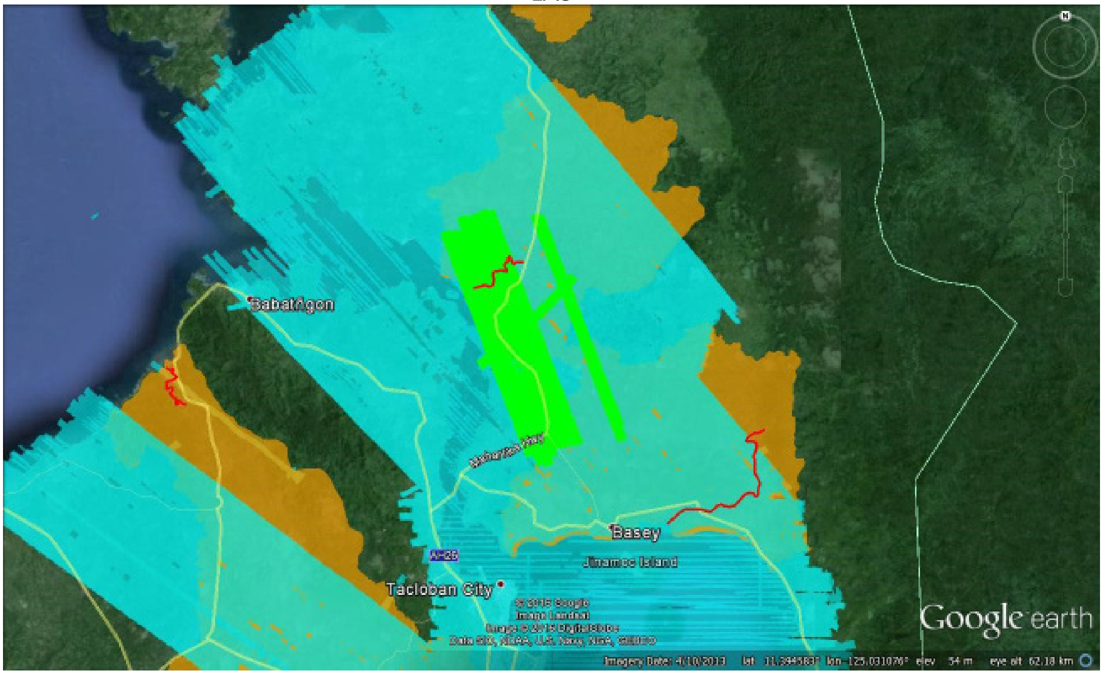


Figure A 7.16 Swath for Flight No. 3757G

Annex 8. Mission Summary Report

Table A-8.1 Mission Summary Report for Blk33H

Flight Area	Samar-Leyte
Mission Name	Blk33H
Inclusive Flights	1444A, 1450A, 1452A
Range data size	30.84 GB
POS data size	619 MB
Base data size	36 MB
Image	160.5 GB
Transfer date	May 28, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.8
RMSE for East Position (<4.0 cm)	1.6
RMSE for Down Position (<8.0 cm)	2.9
Boresight correction stdev (<0.001deg)	0.000310
IMU attitude correction stdev (<0.001deg)	0.000915
GPS position stdev (<0.01m)	0.0030
Minimum % overlap (>25)	46.76%
Ave point cloud density per sq.m. (>2.0)	3.36
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	261
Maximum Height	328.04 m
Minimum Height	56.94 m
Classification (# of points)	
Ground	120,058,822
Low vegetation	54,325,156
Medium vegetation	230,234,006
High vegetation	163,298,807
Building	1,762,420
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Aljon Rie Araneta, Engr. Gladys Mae Apat

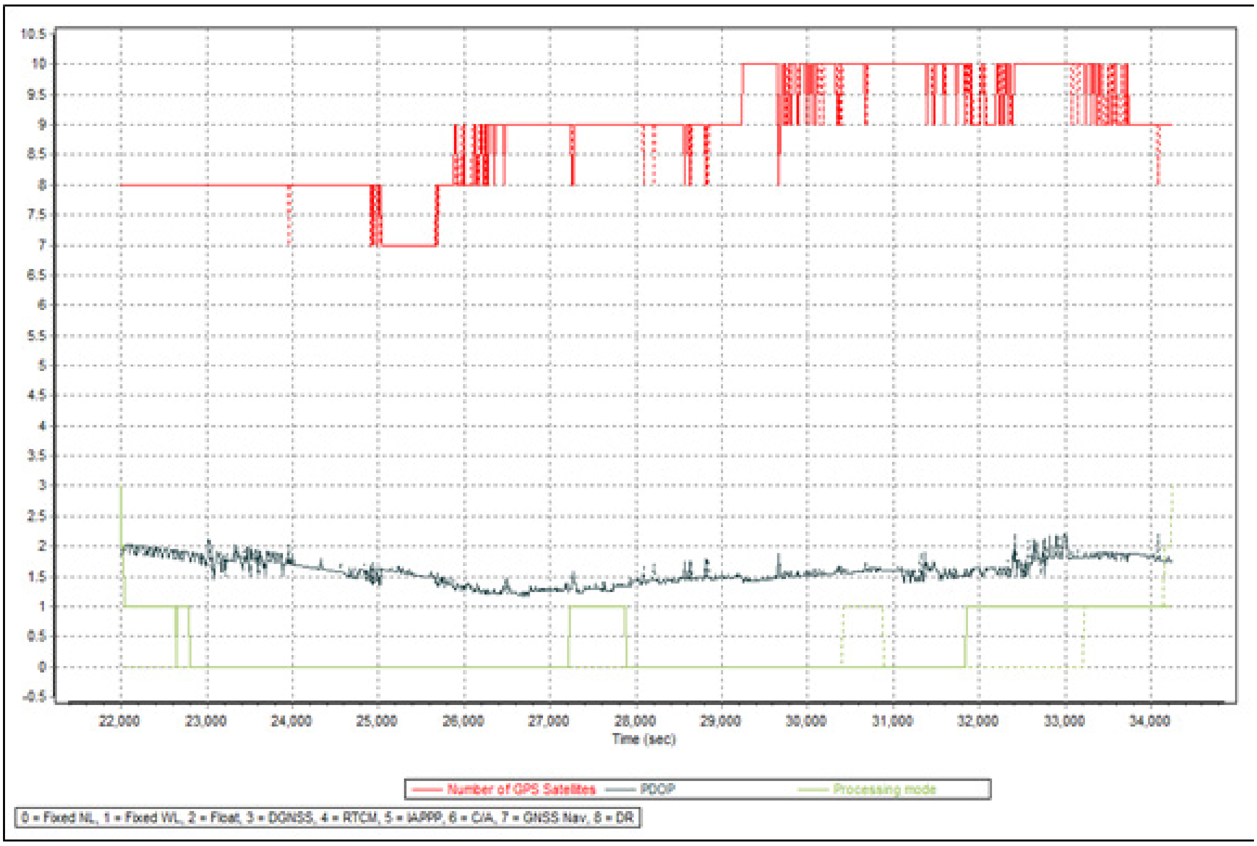


Figure A 8.1. Solution Status

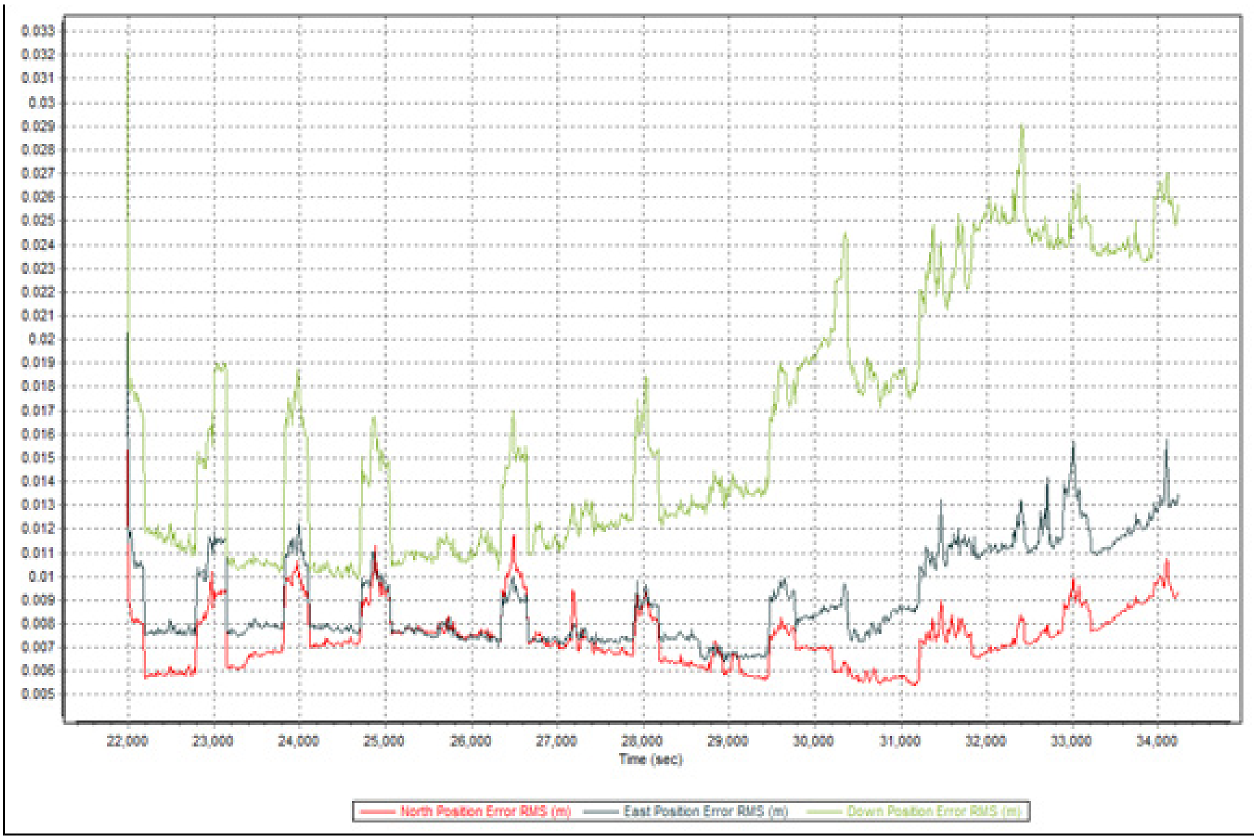


Figure A 8.2 Smoothed Performance Metrics Parameters

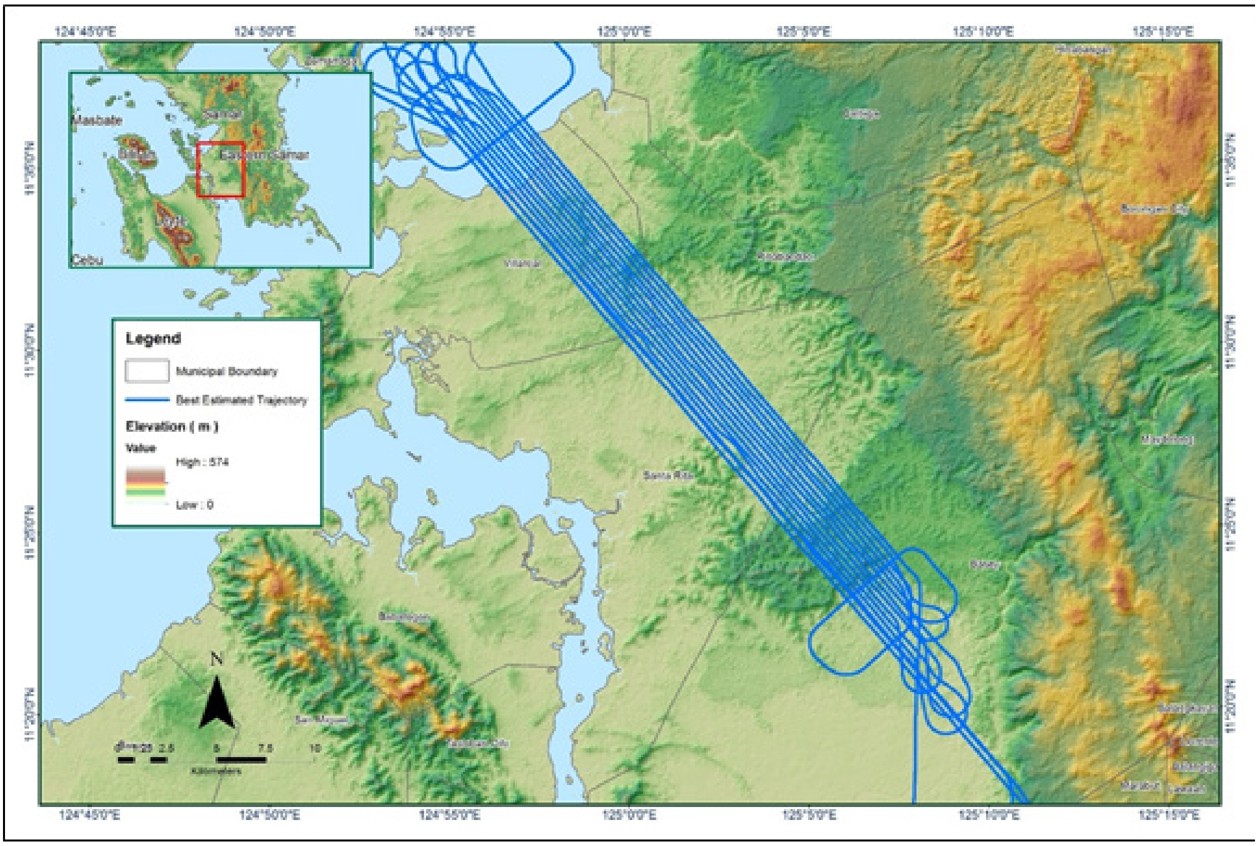


Figure A 8.3 Best Estimated Trajectory

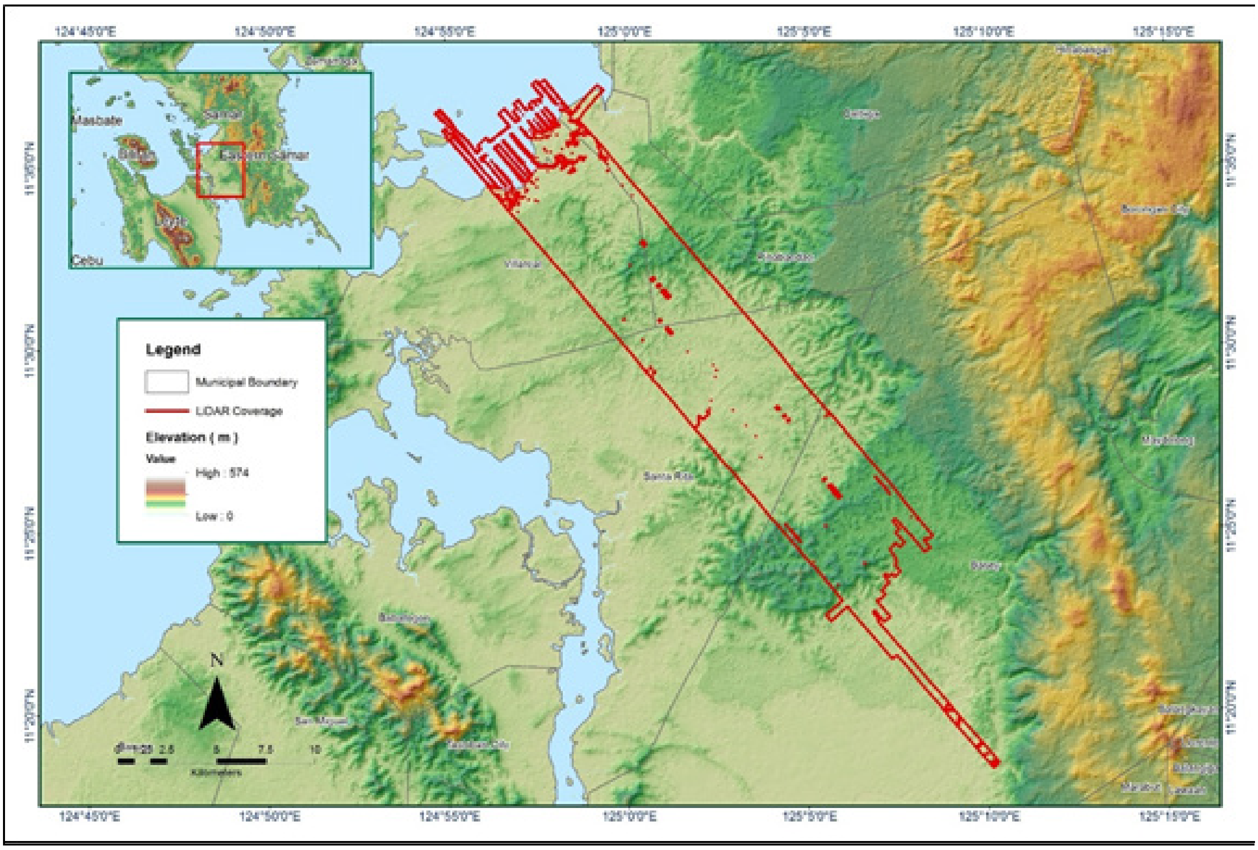


Figure A 8.4 Coverage of LiDAR data

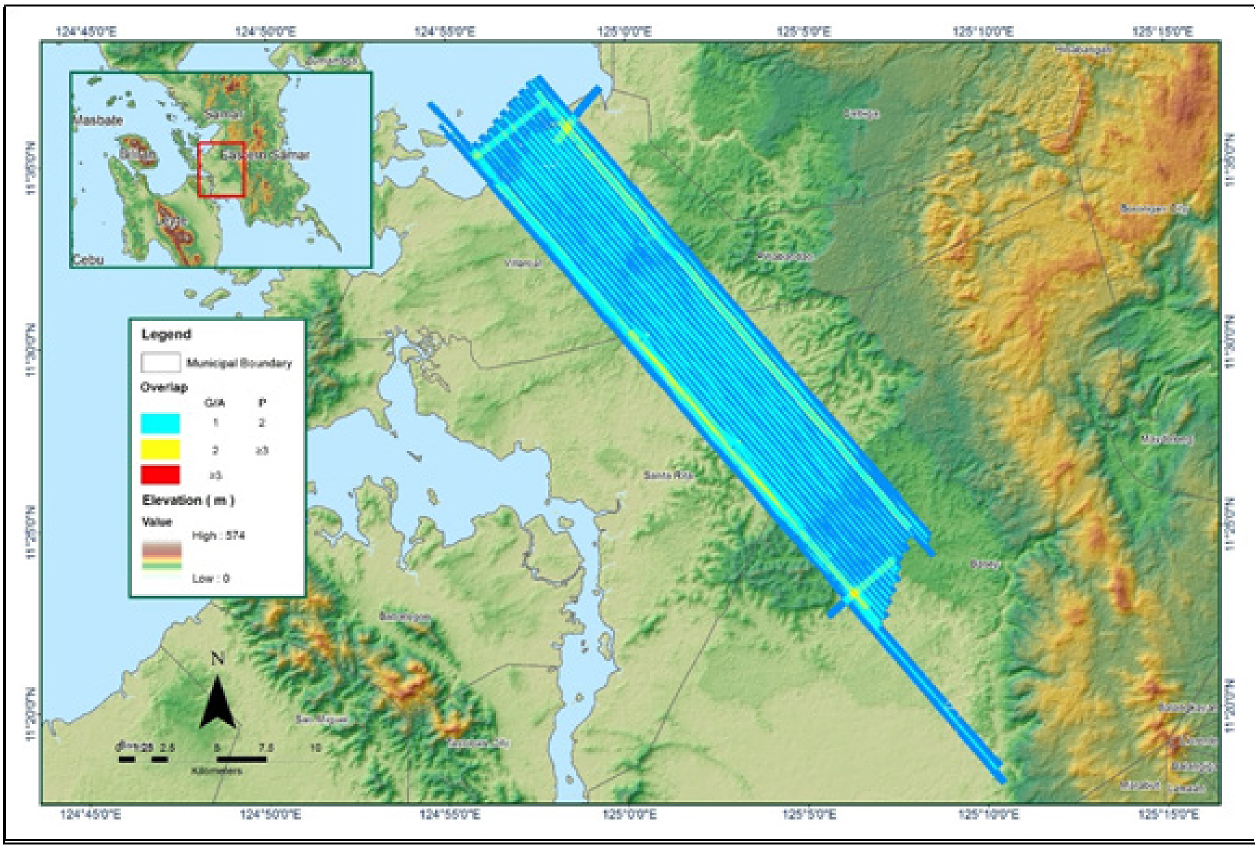


Figure A 8.5 Image of Data Overlap

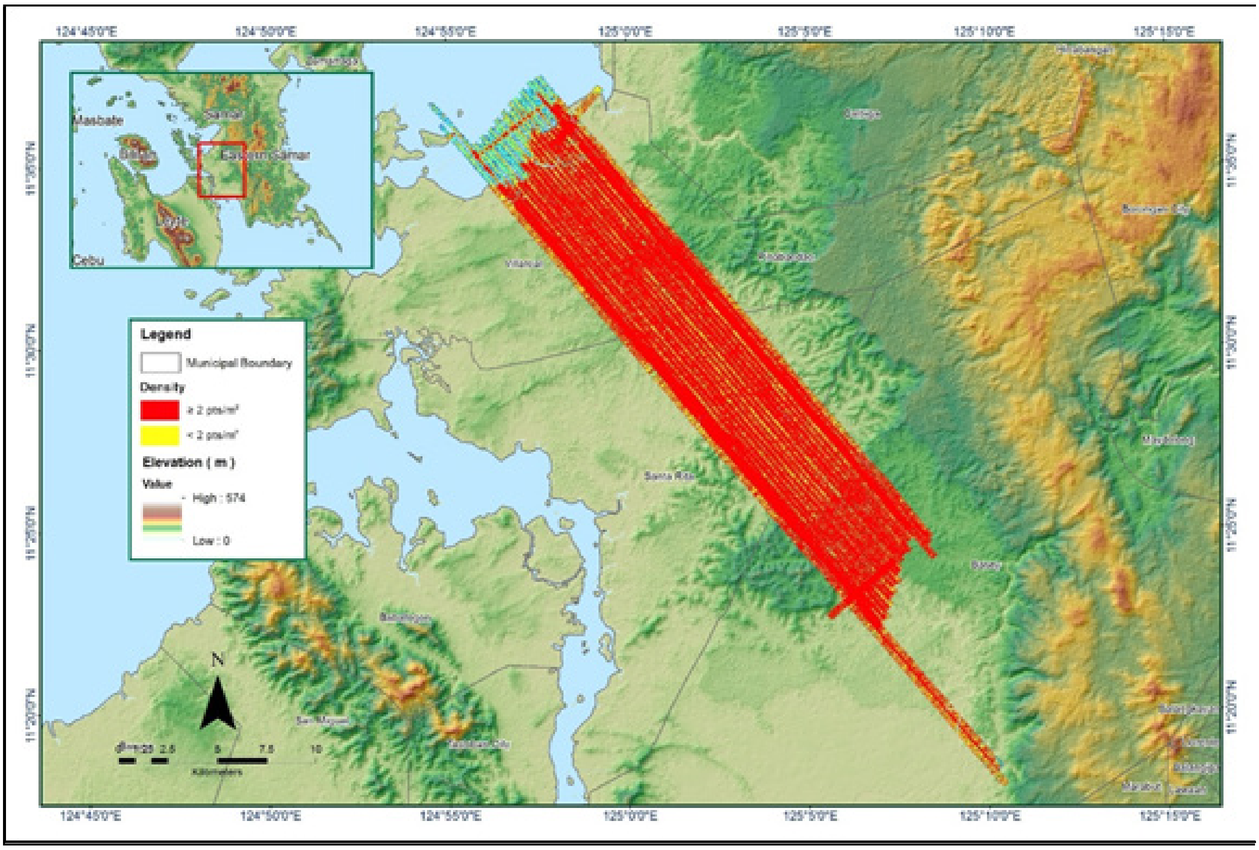


Figure A 8.6 Density map of merged LiDAR data

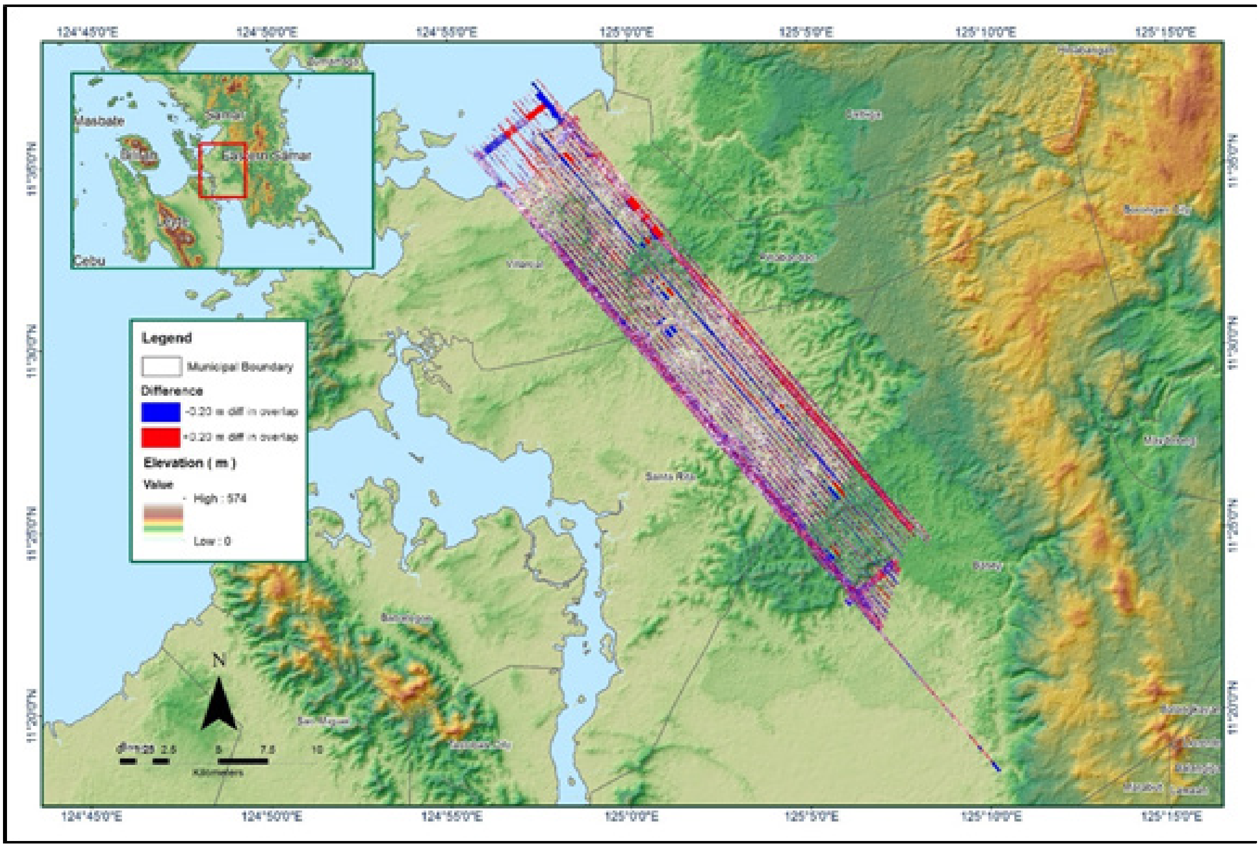


Figure A 8.7 Elevation difference between flight lines

Table A-8.2 Mission Summary Report for Blk33G

Flight Area	Samar-Leyte
Mission Name	Blk33G
Inclusive Flights	1440A, 1442A
Range data size	28 GB
POS data size	459 MB
Base data size	31.8 MB
Image	174.8 GB
Transfer date	May 28, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.2
RMSE for East Position (<4.0 cm)	1.9
RMSE for Down Position (<8.0 cm)	4.3
Boresight correction stdev (<0.001deg)	0.000322186
IMU attitude correction stdev (<0.001deg)	0.0609276
GPS position stdev (<0.01m)	0.034031
Minimum % overlap (>25)	32.09%
Ave point cloud density per sq.m. (>2.0)	3.01
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	312
Maximum Height	365.67 m
Minimum Height	58.80 m
Classification (# of points)	
Ground	77,148,752
Low vegetation	65,926,334
Medium vegetation	201,996,077
High vegetation	198,312,411
Building	3,402,990
Orthophoto	Yes
Processed by	Engr. Carlyn Ann Ibañez, Engr. Antonio Chua, Jr., Ailyn Biñas

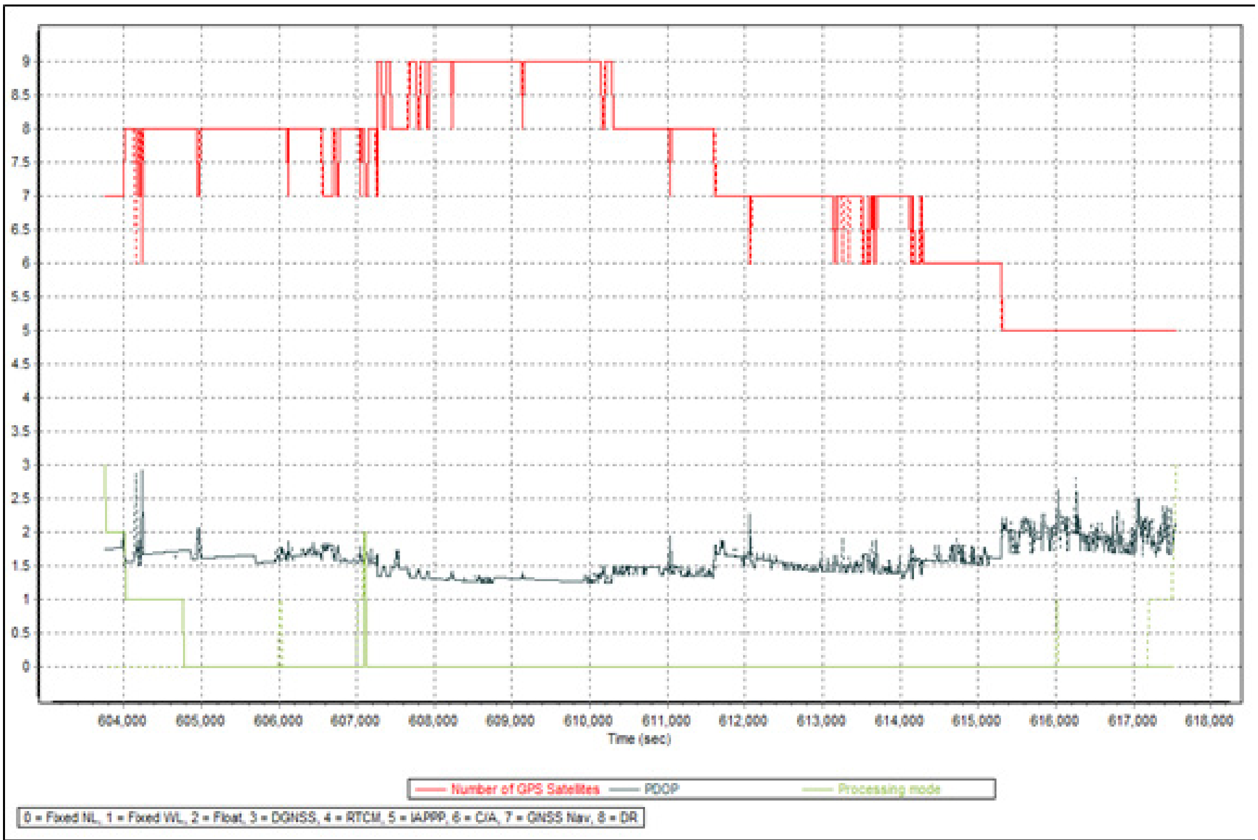


Figure A 8.8 Solution Status

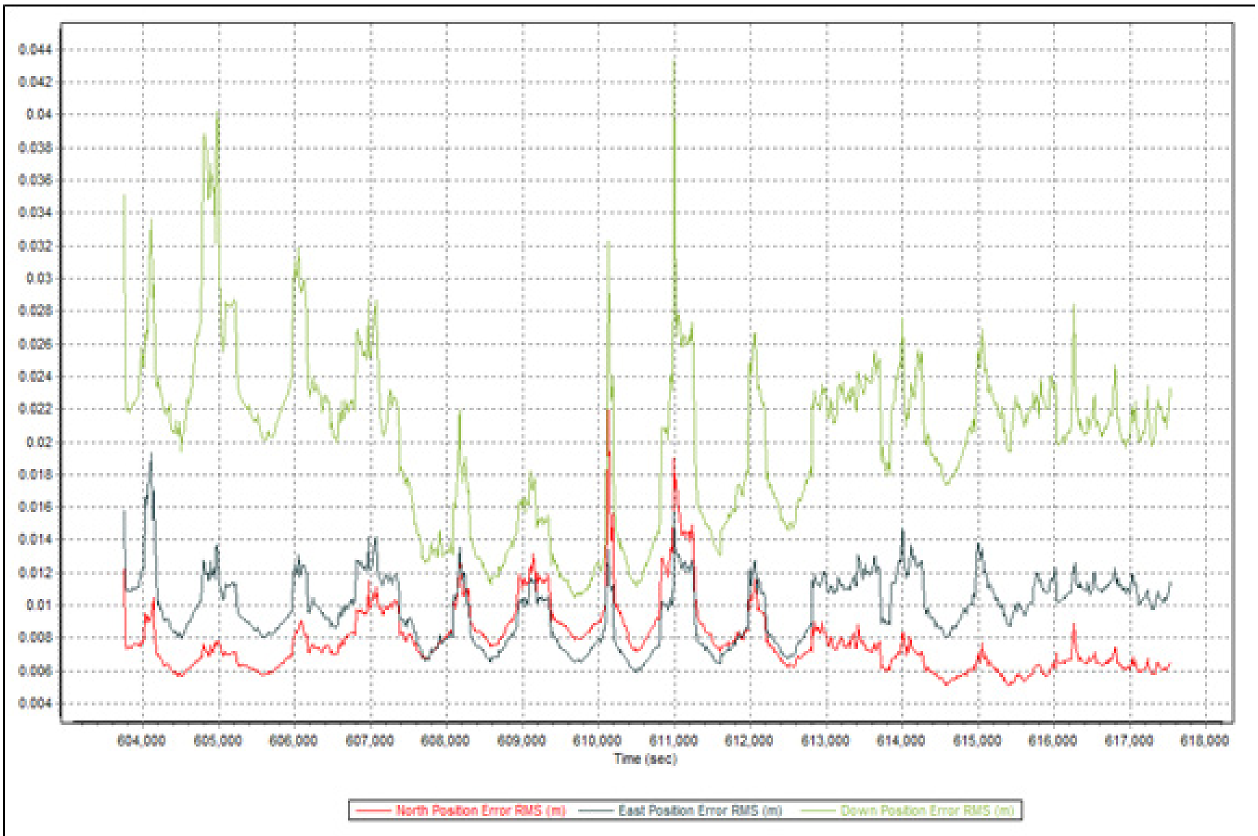


Figure A 8.9 Smoothed Performance Metrics Parameters

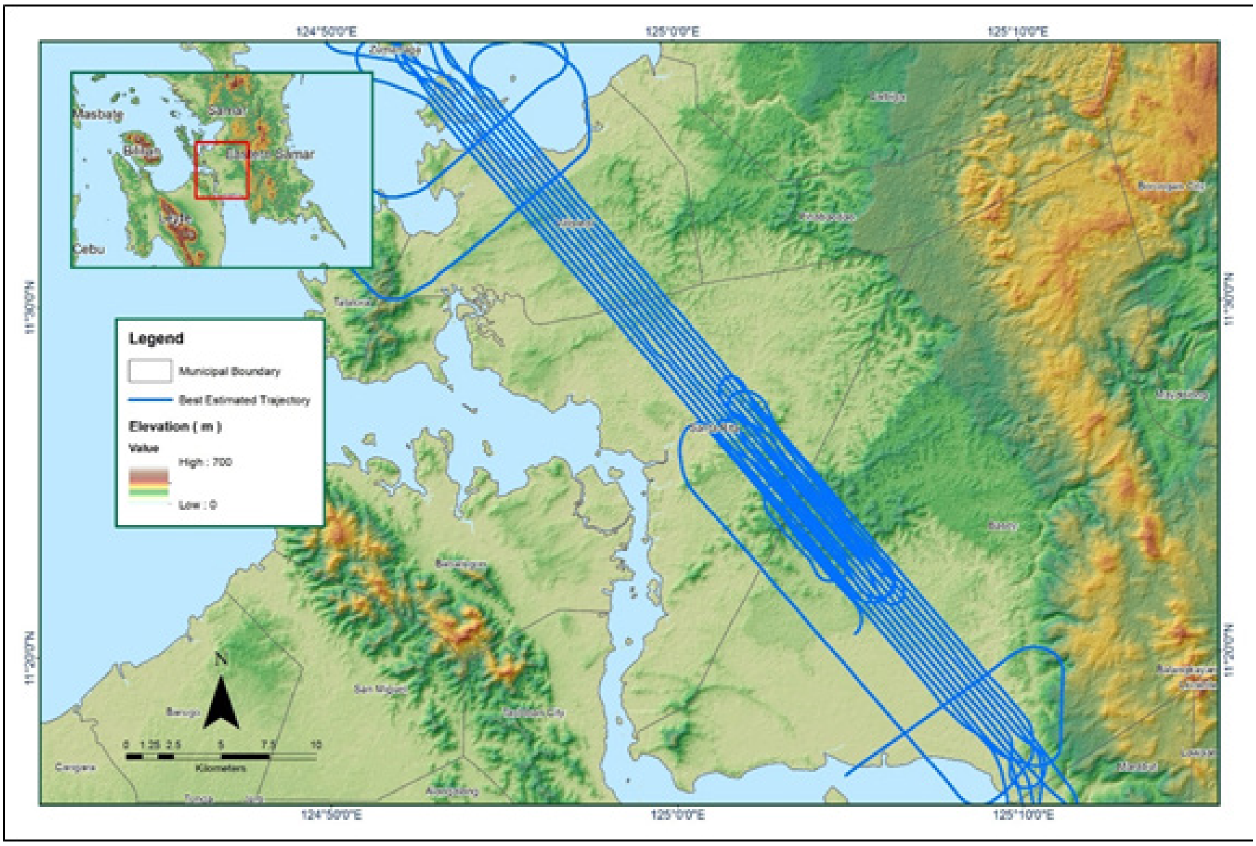


Figure A 8.10 Best Estimated Trajectory

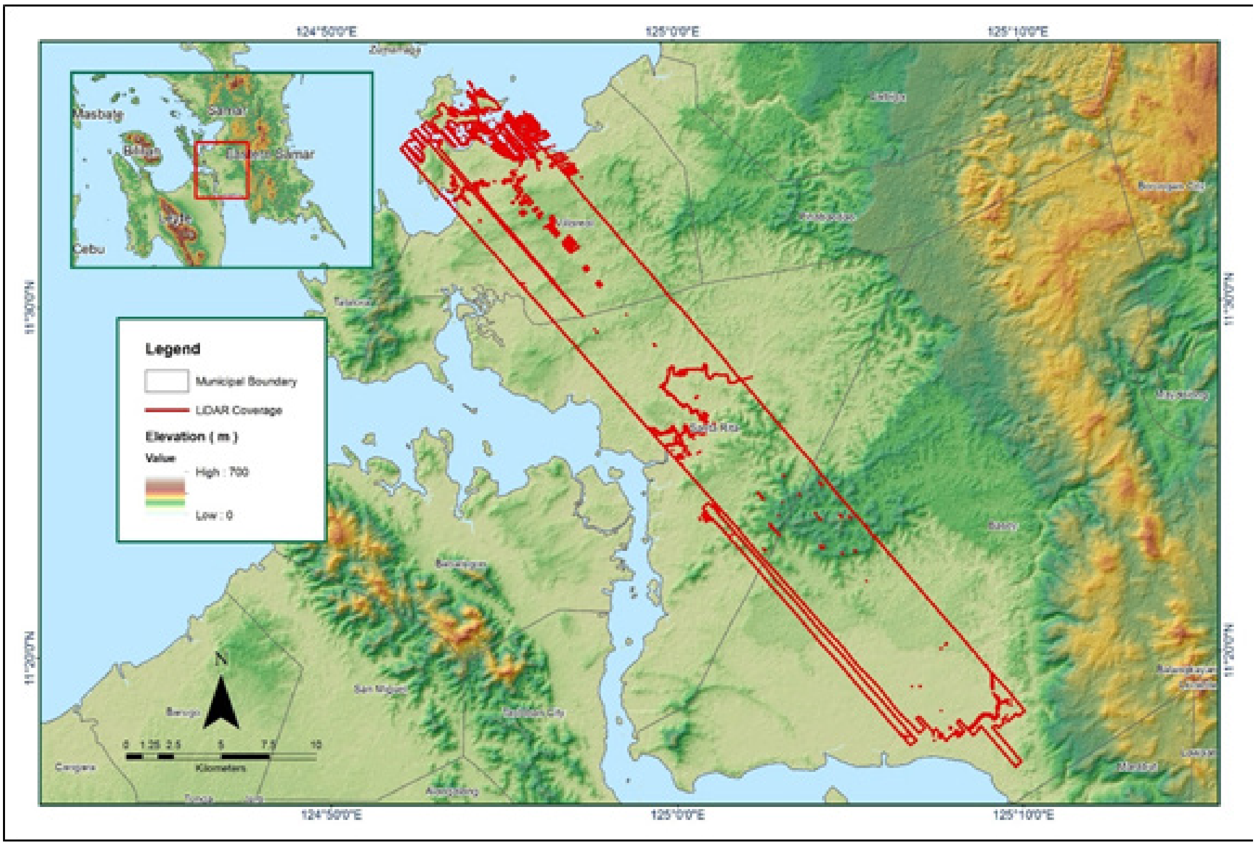


Figure A 8.11 Coverage of LiDAR data

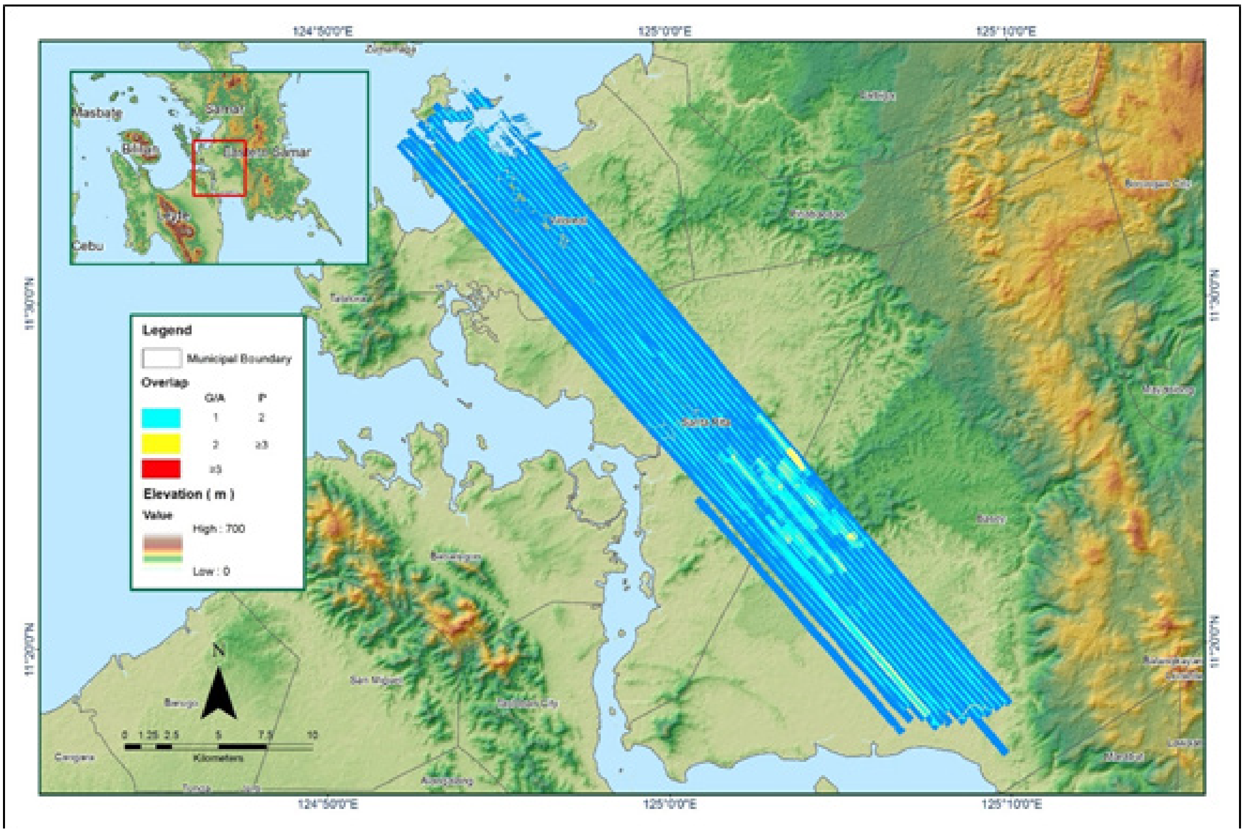


Figure A 8.12 Image of data overlap

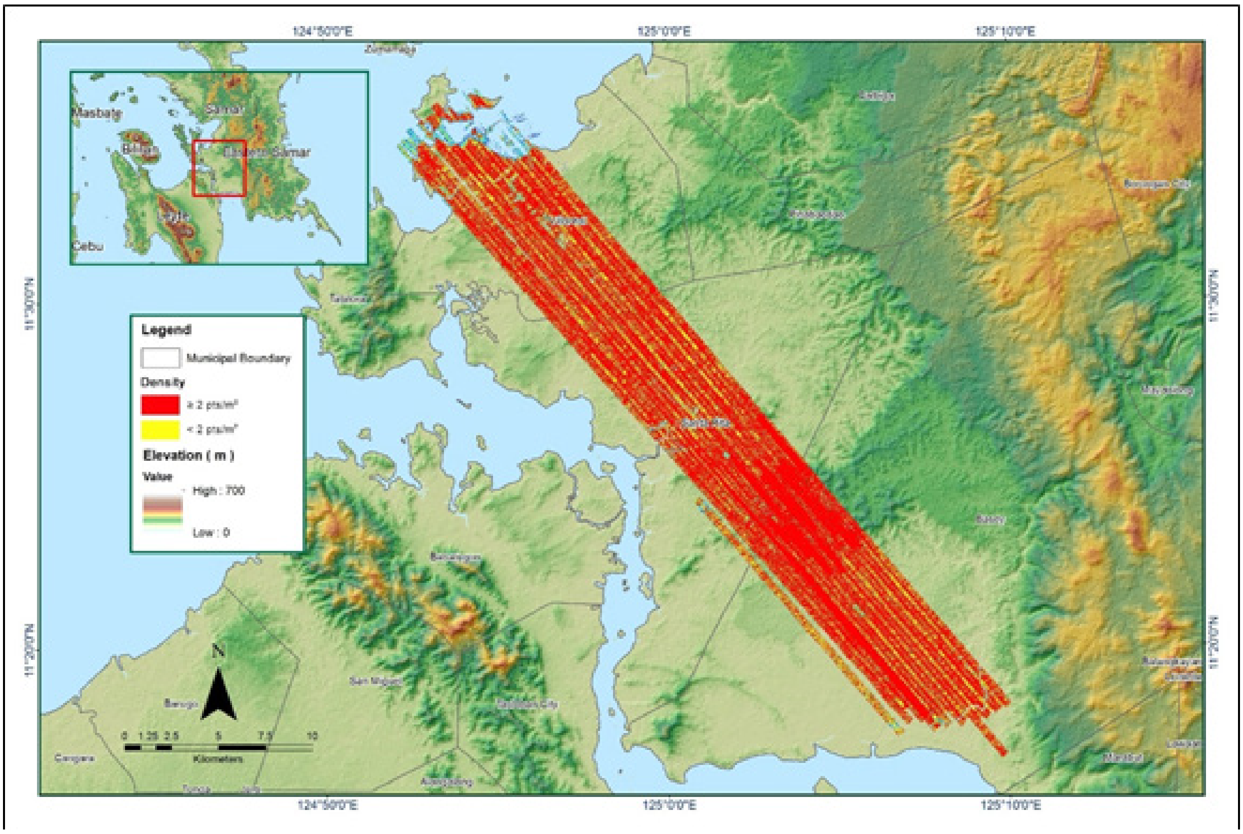


Figure A 8.13 Density map of merged LiDAR data

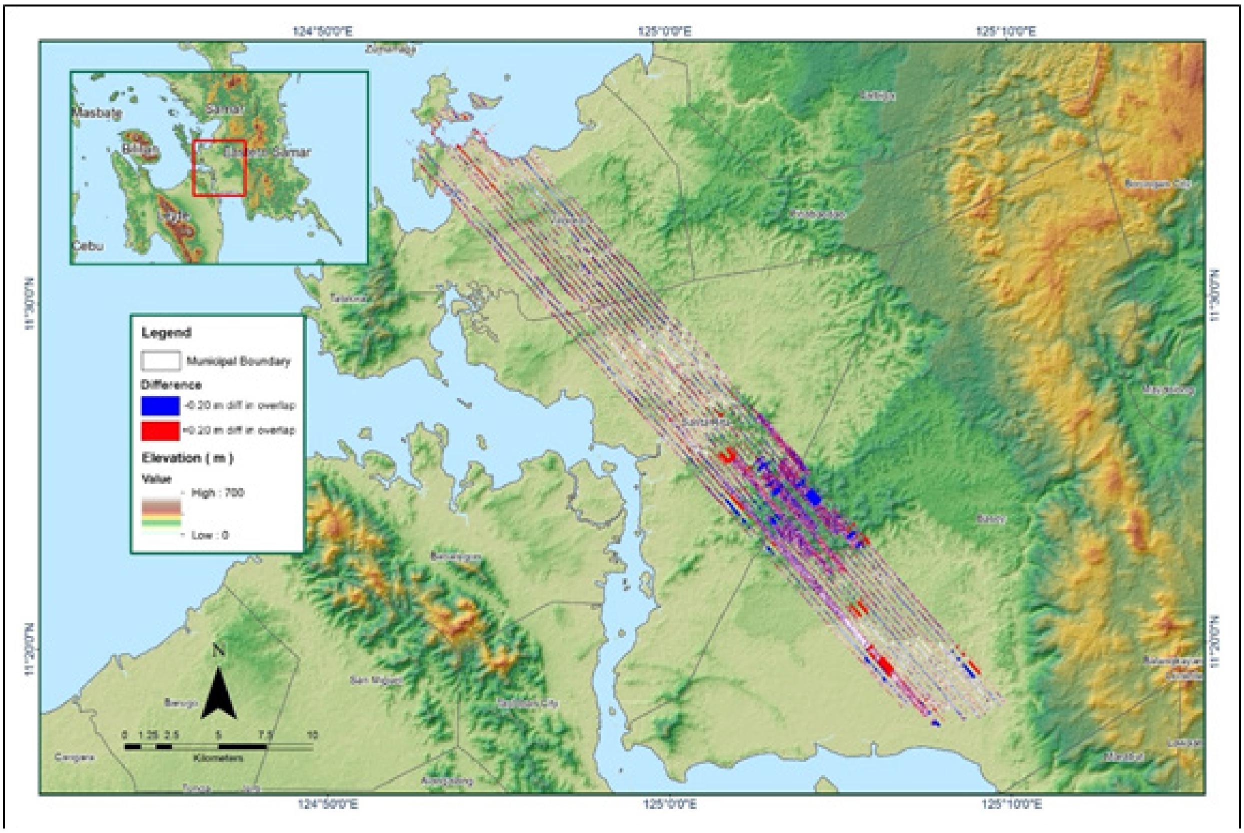


Figure A 8.14 Elevation difference between flight lines

Table A-8.3 Mission Summary Report for Blk33F

Flight Area	Samar-Leyte
Mission Name	Blk33F
Inclusive Flights	1438A, 1440A
Range data size	28.6 GB
POS data size	463 MB
Base data size	35 MB
Image	188.8 GB
Transfer date	May 28, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.3
RMSE for East Position (<4.0 cm)	2.1
RMSE for Down Position (<8.0 cm)	5.3
Boresight correction stdev (<0.001deg)	0.000408
IMU attitude correction stdev (<0.001deg)	0.000997
GPS position stdev (<0.01m)	0.0088
Minimum % overlap (>25)	44.22%
Ave point cloud density per sq.m. (>2.0)	3.01
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	315
Maximum Height	304.65 m
Minimum Height	52.08 m
Classification (# of points)	
Ground	91,416,640
Low vegetation	73,231,907
Medium vegetation	216,370,969
High vegetation	167,159,477
Building	1,402,580
Orthophoto	Yes
Processed by	Engr. Carlyn Ann Ibañez, Engr. Melanie Hingpit, Engr. Gladys Mae Apat

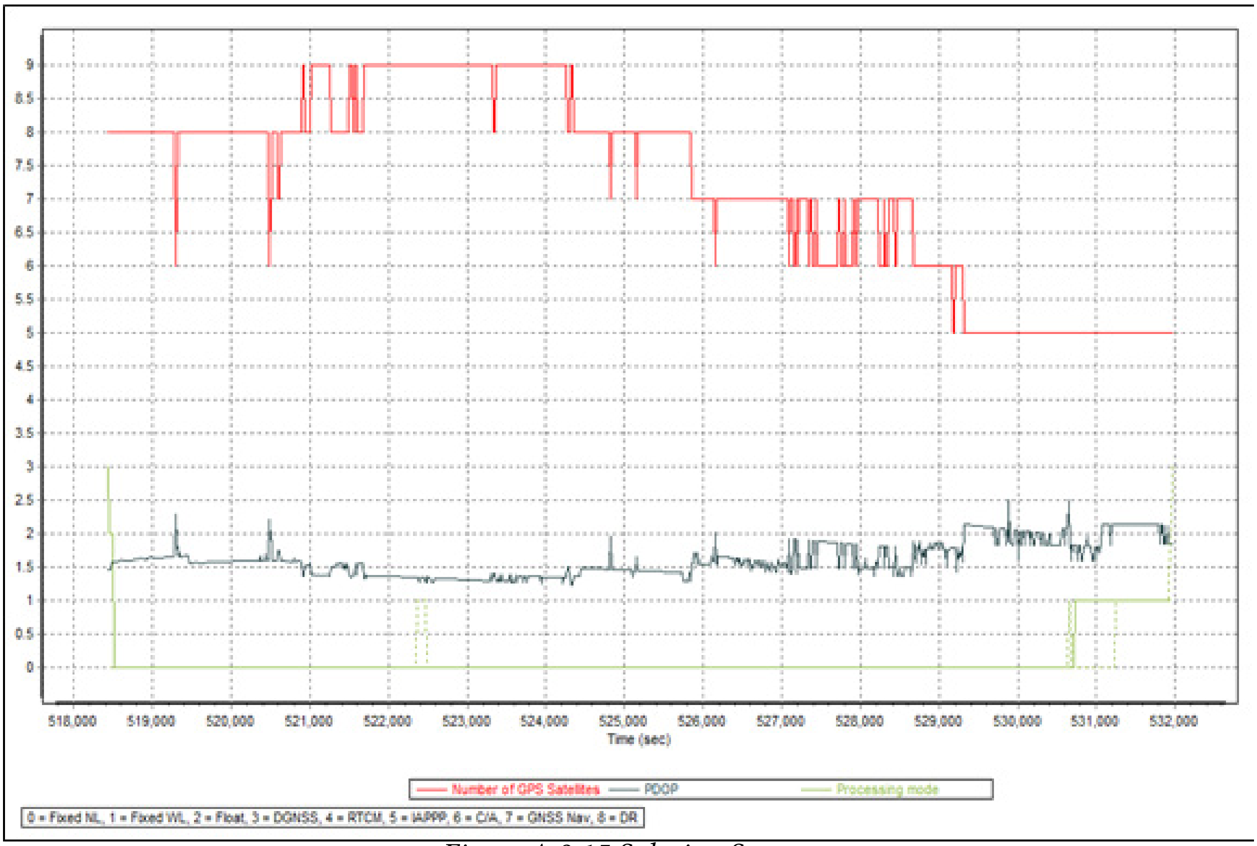


Figure A 8.15 Solution Statust

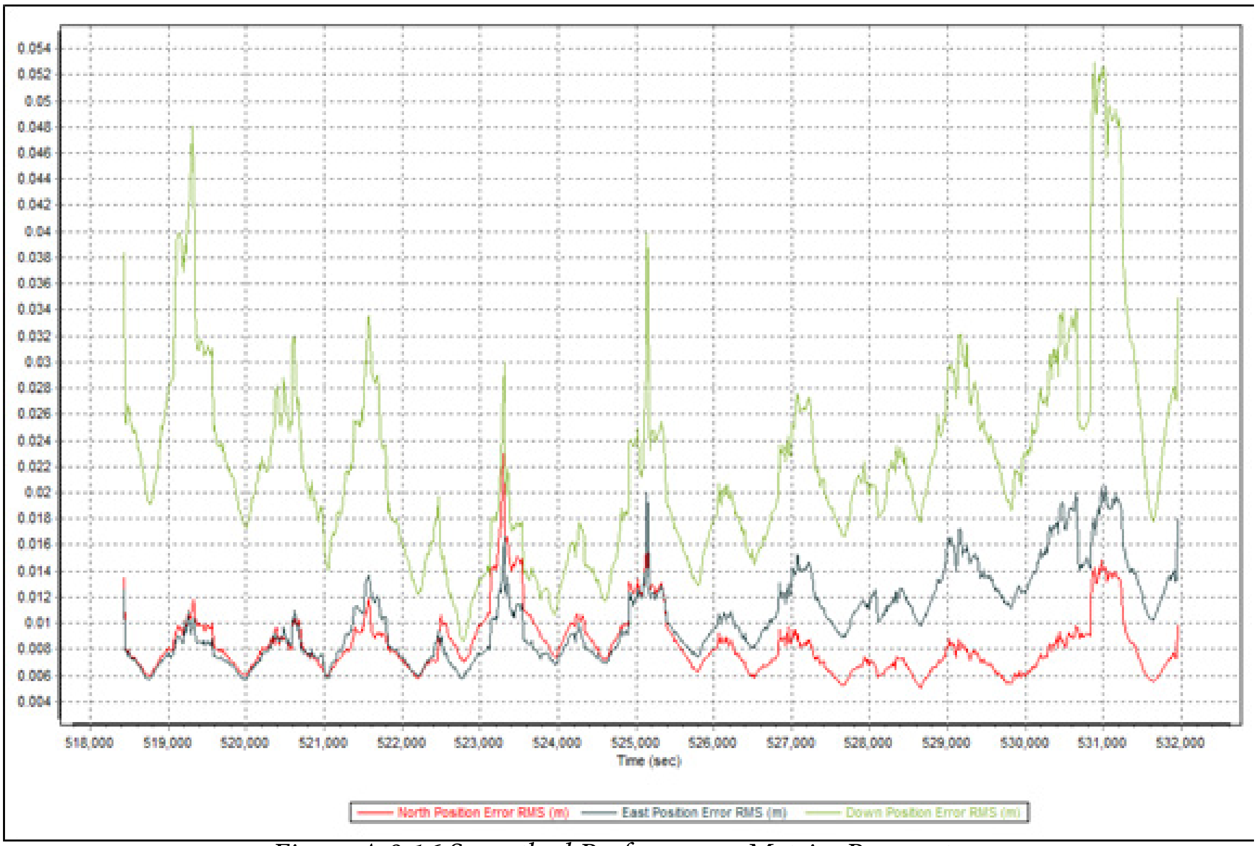


Figure A 8.16 Smoothed Performance Metrics Parameters

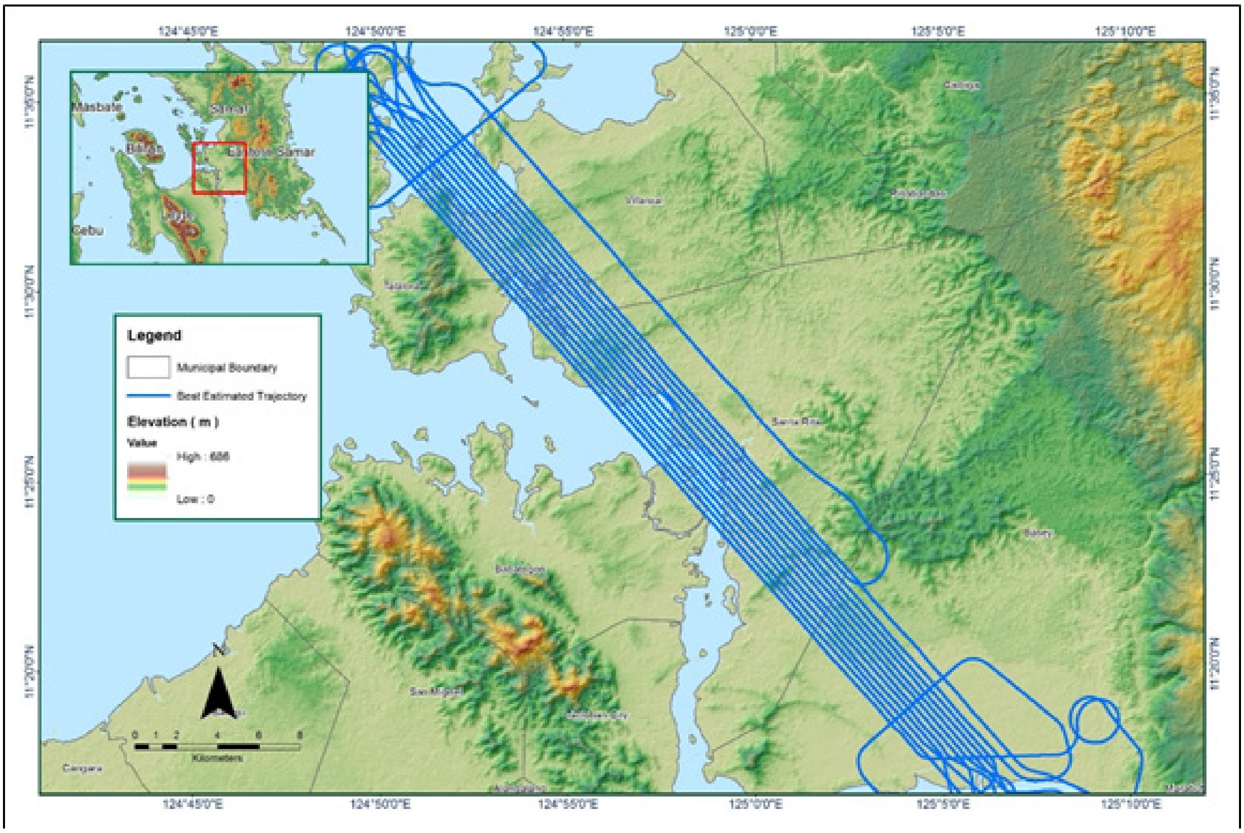


Figure A 8.17 Best Estimated Trajectory

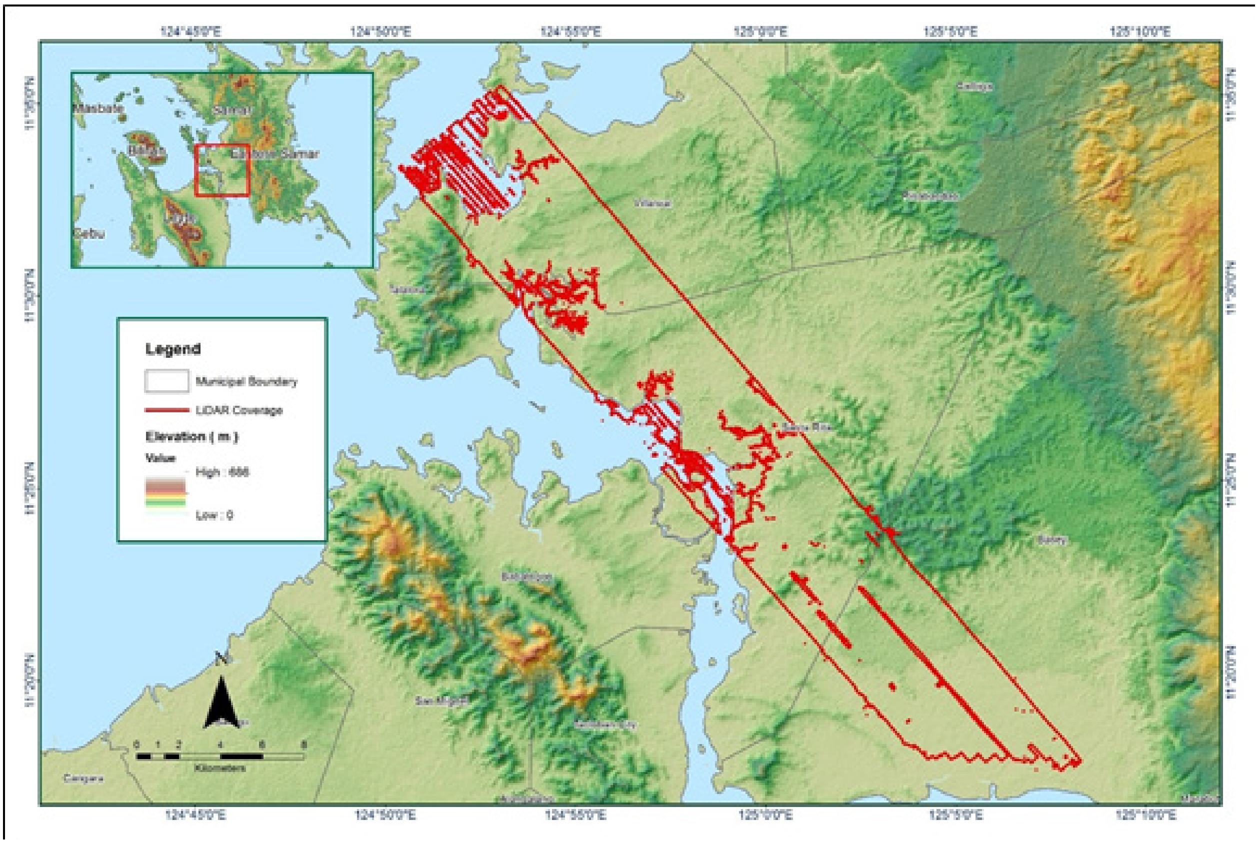


Figure A 8.18 Coverage of LiDAR data

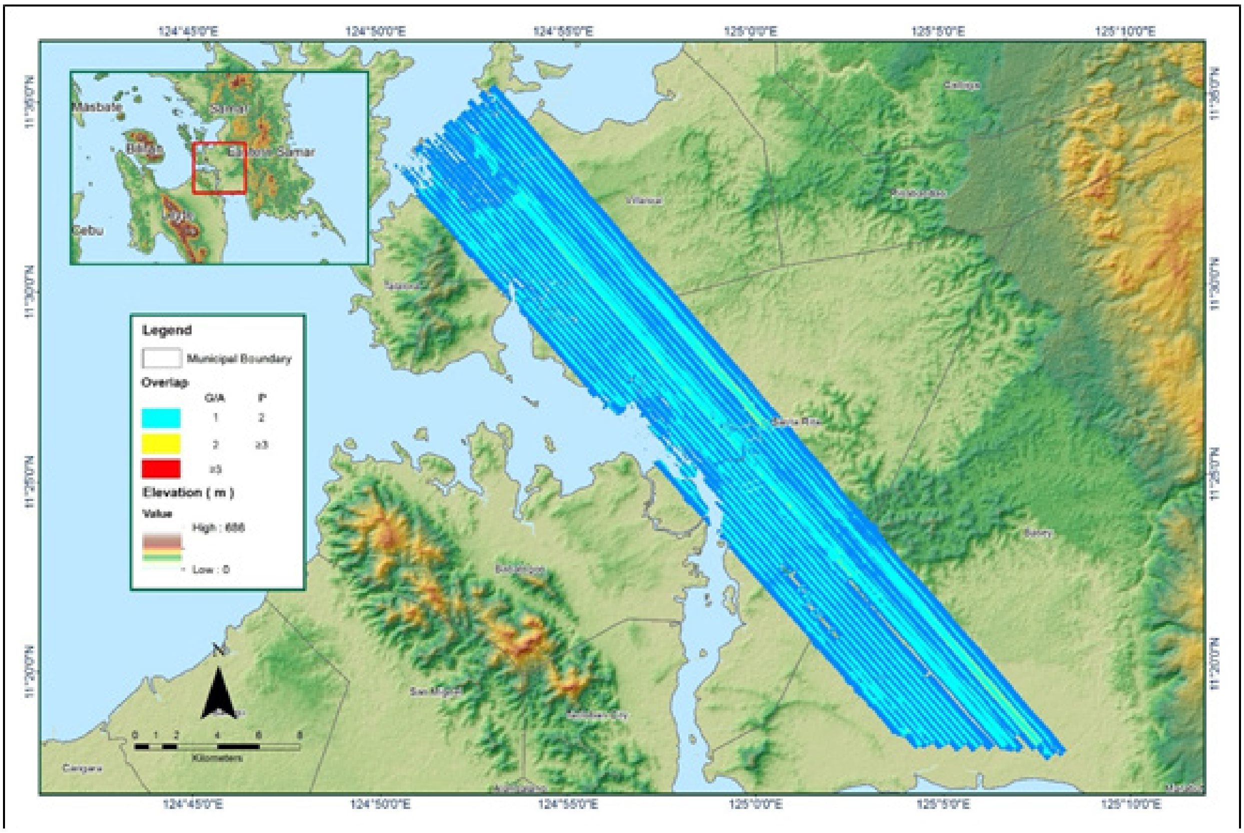


Figure A 8.19 Image of data overlap

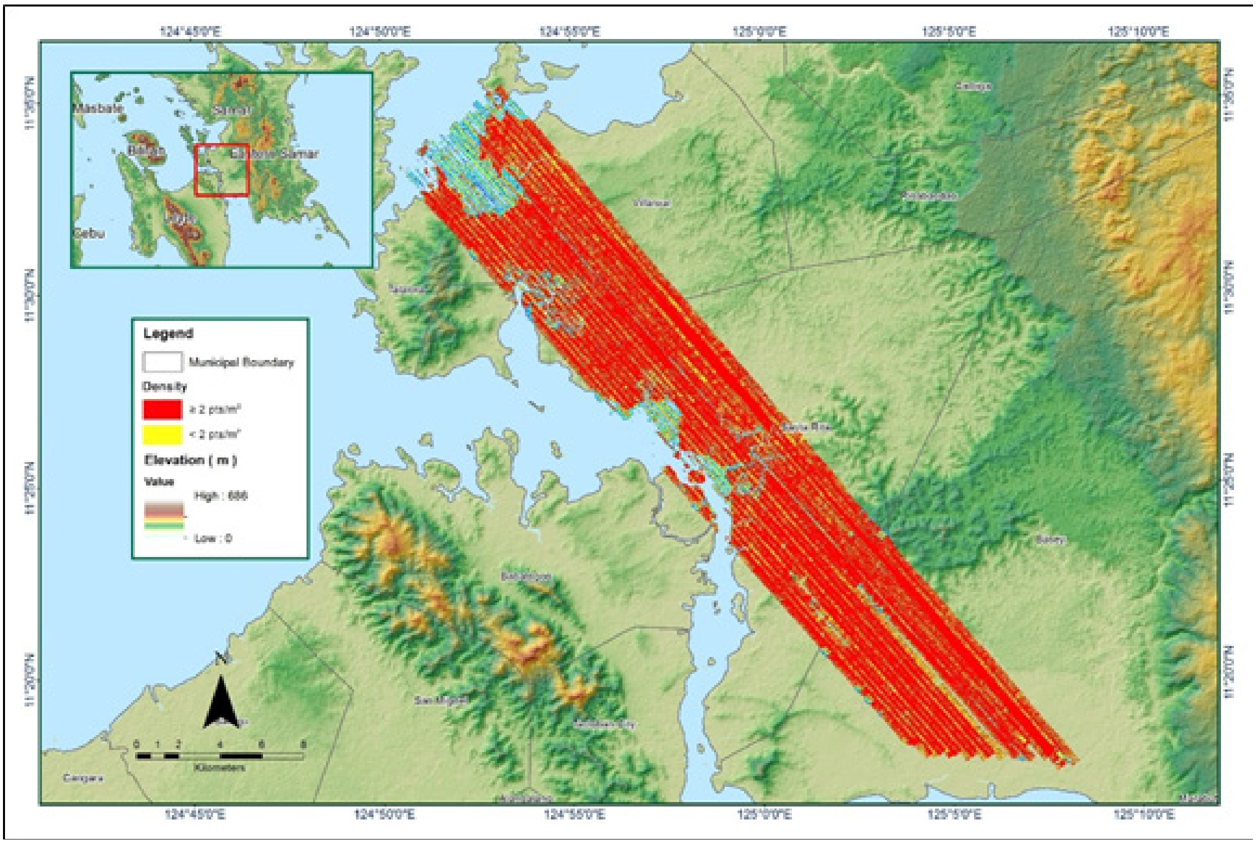


Figure A 8.20 Density map of merged LiDAR data

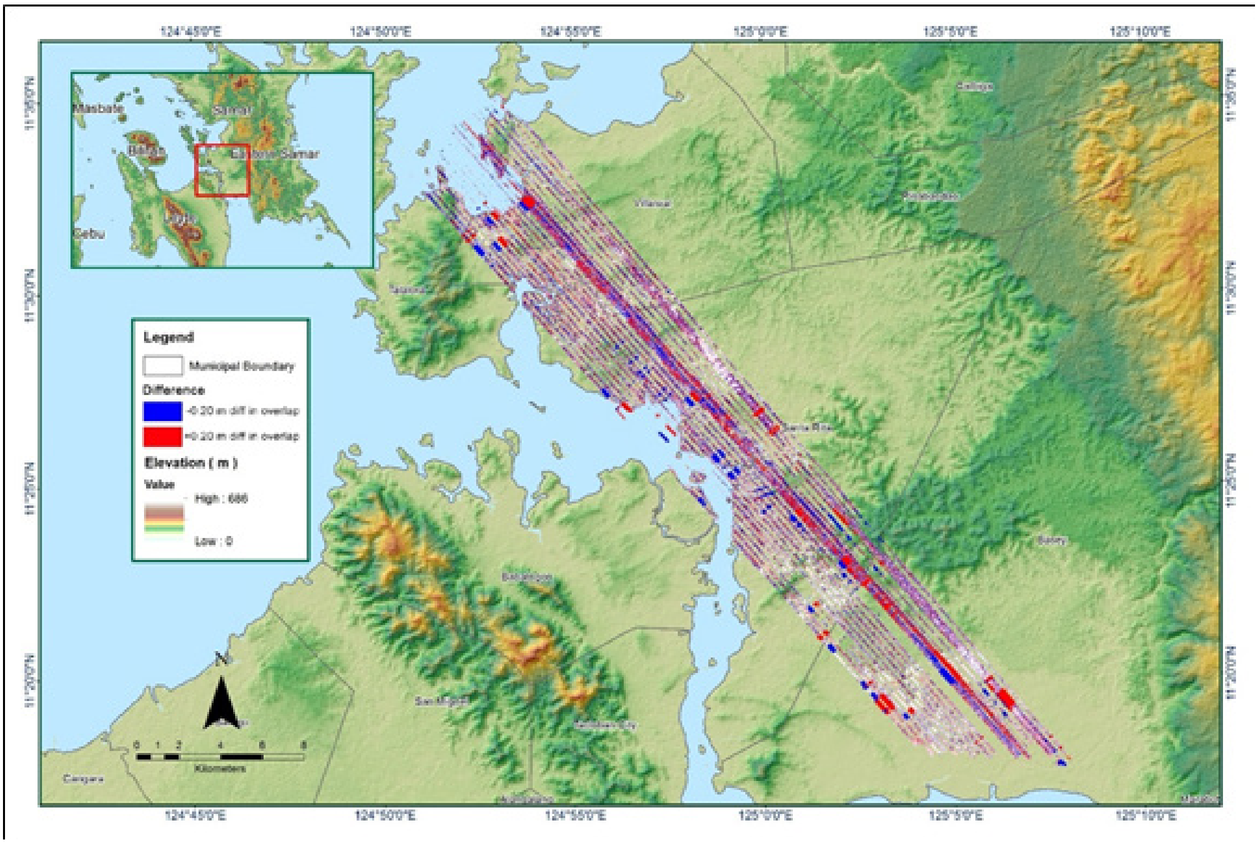


Figure A 8.21 Elevation difference between flight lines

Table A-8.4 Mission Summary Report for Blk33E_additional

Flight Area	Samar-Leyte
Mission Name	Blk33E_addtional
Inclusive Flights	1410A
Range data size	15.3 GB
POS data size	281 MB
Base data size	7.61 MB
Image	51 GB
Transfer date	May 28, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.9
RMSE for East Position (<4.0 cm)	2.3
RMSE for Down Position (<8.0 cm)	3.7
Boresight correction stdev (<0.001deg)	0.000358
IMU attitude correction stdev (<0.001deg)	0.000887
GPS position stdev (<0.01m)	0.0028
Minimum % overlap (>25)	39.41%
Ave point cloud density per sq.m. (>2.0)	2.82
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	179
Maximum Height	419.70 m
Minimum Height	58.53 m
Classification (# of points)	
Ground	28,982,321
Low vegetation	28,320,279
Medium vegetation	56,819,196
High vegetation	65,588,086
Building	872,621
Orthophoto	No
Processed by	Victoria Rejuso, Engr. Melanie Hingpit, Engr. Gladys Mae Apat

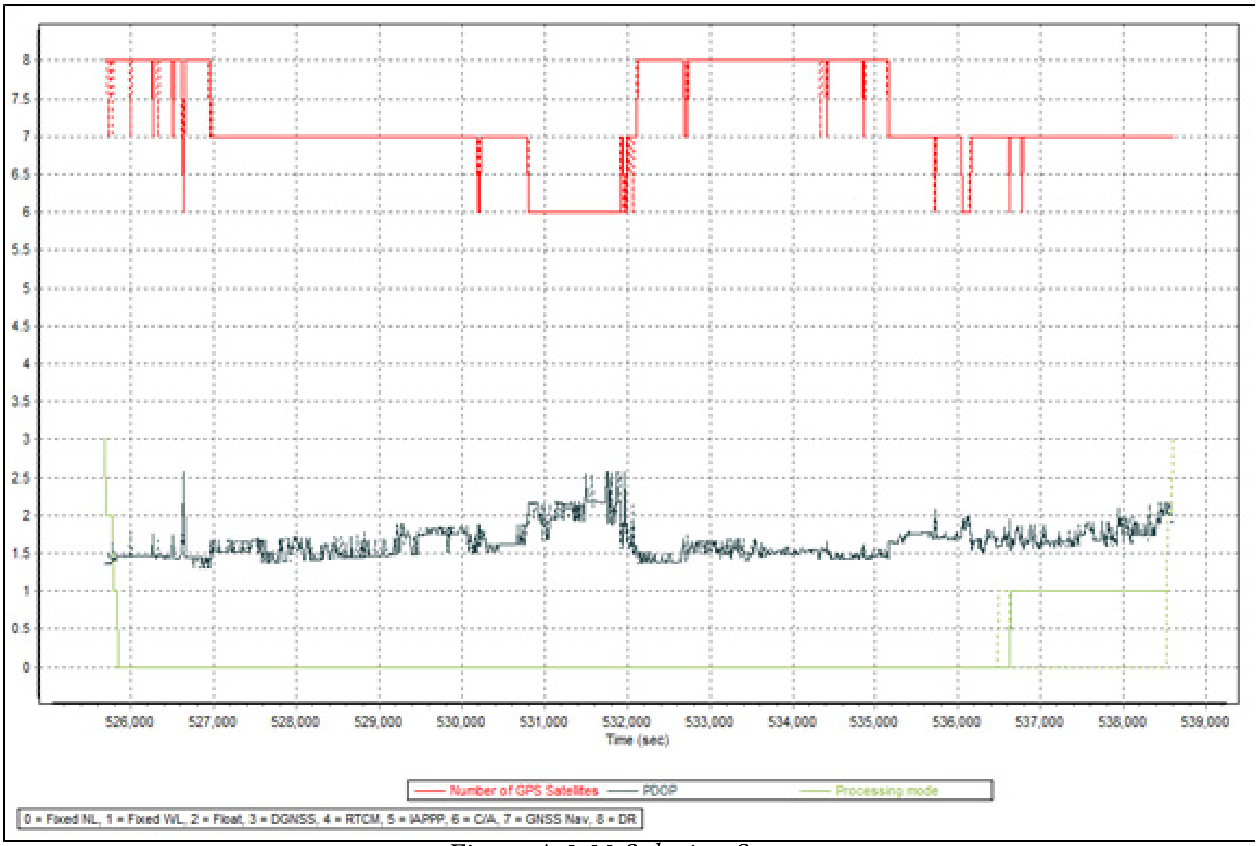


Figure A 8.22 Solution Status

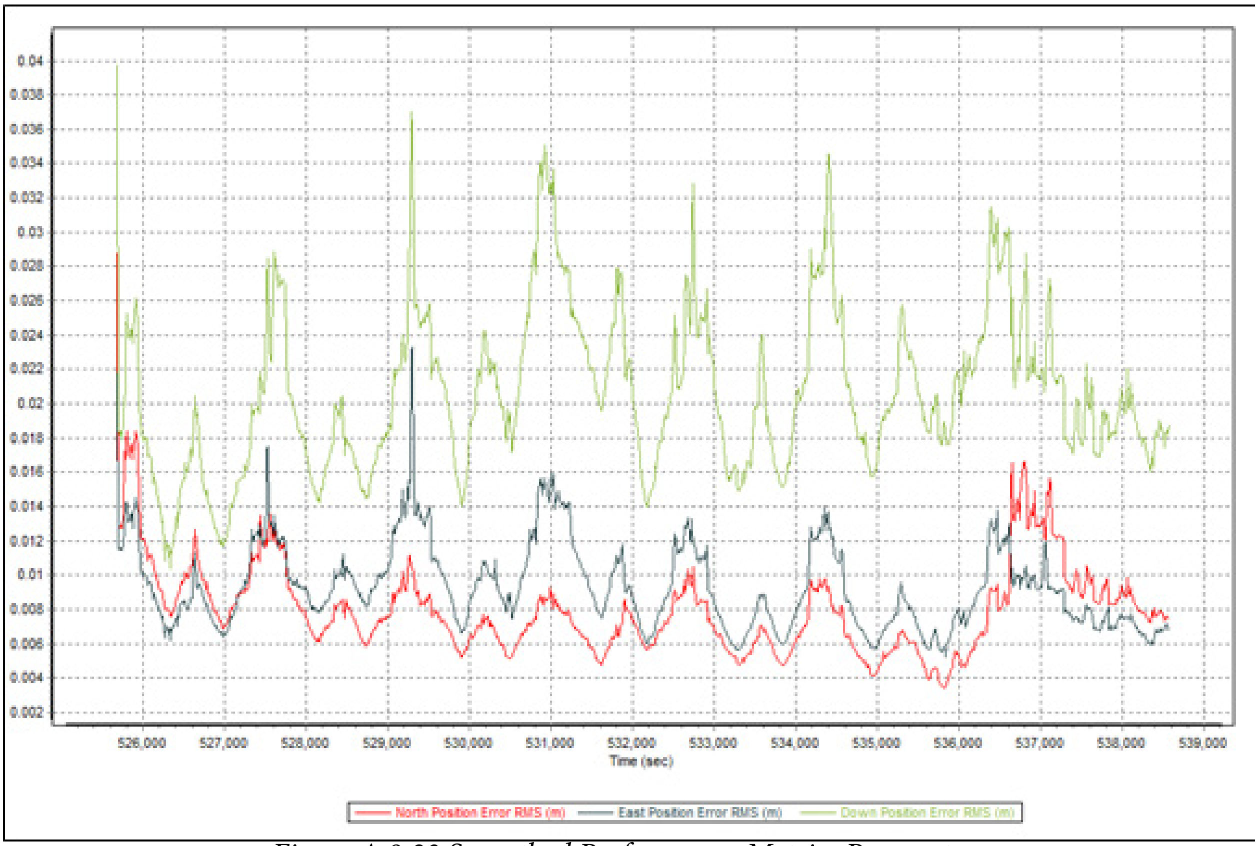


Figure A 8.23 Smoothed Performance Metrics Parameters

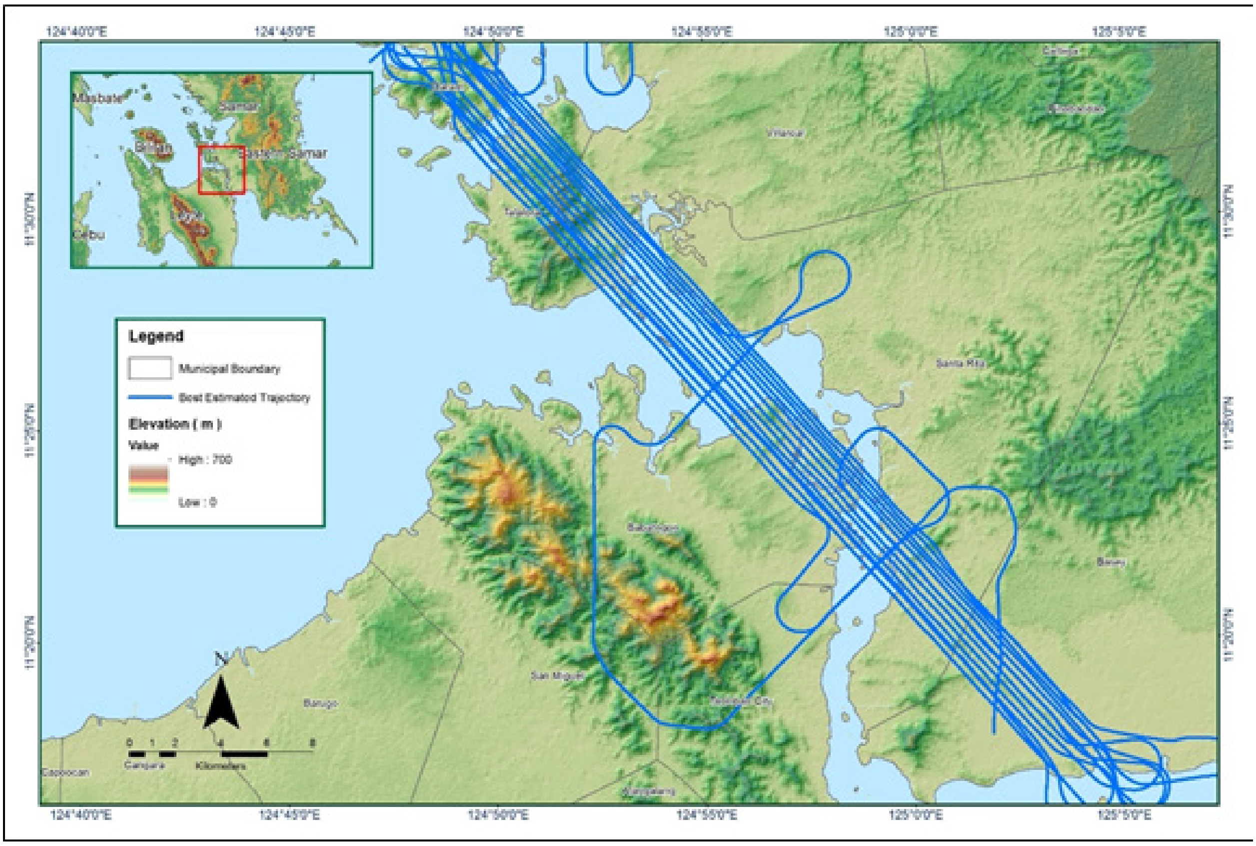


Figure A 8.24 Best Estimated Trajectory

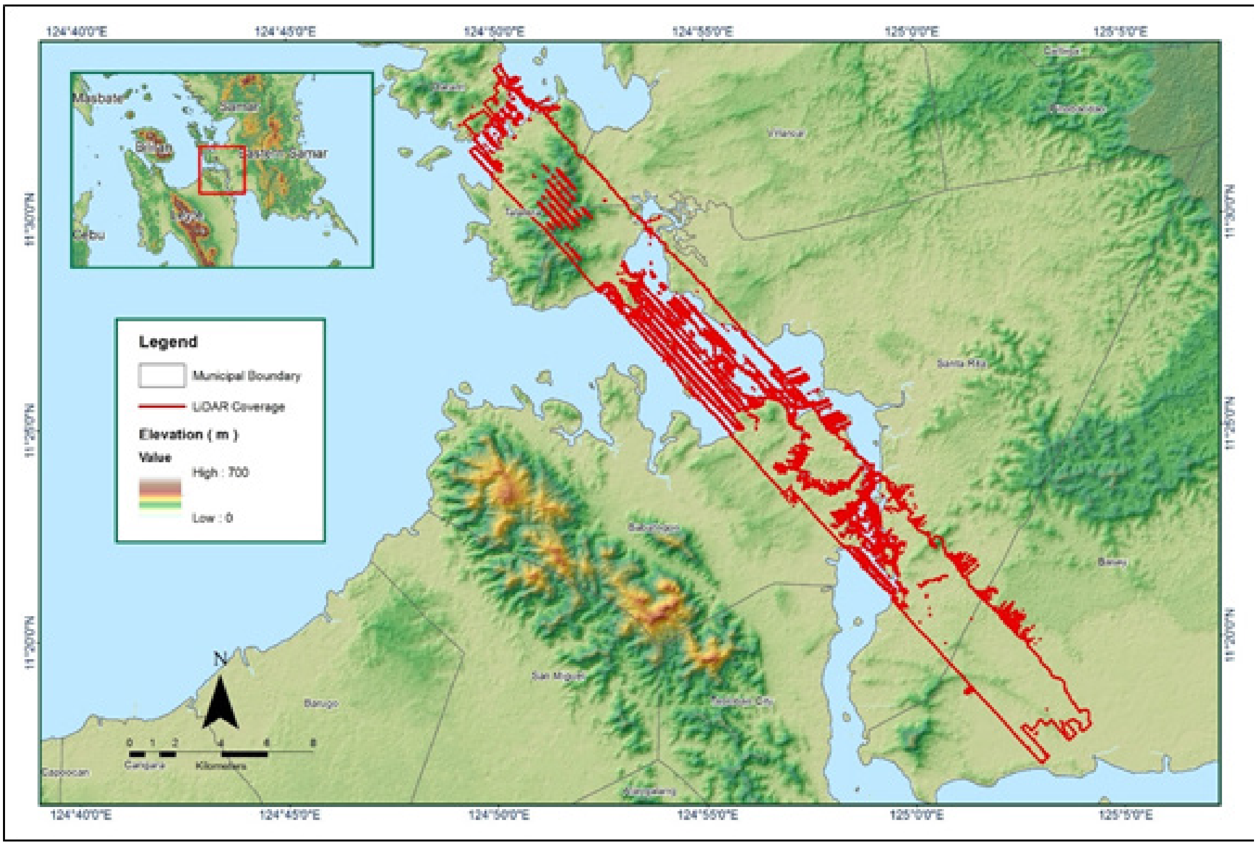


Figure A 8.25 Coverage of LiDAR data

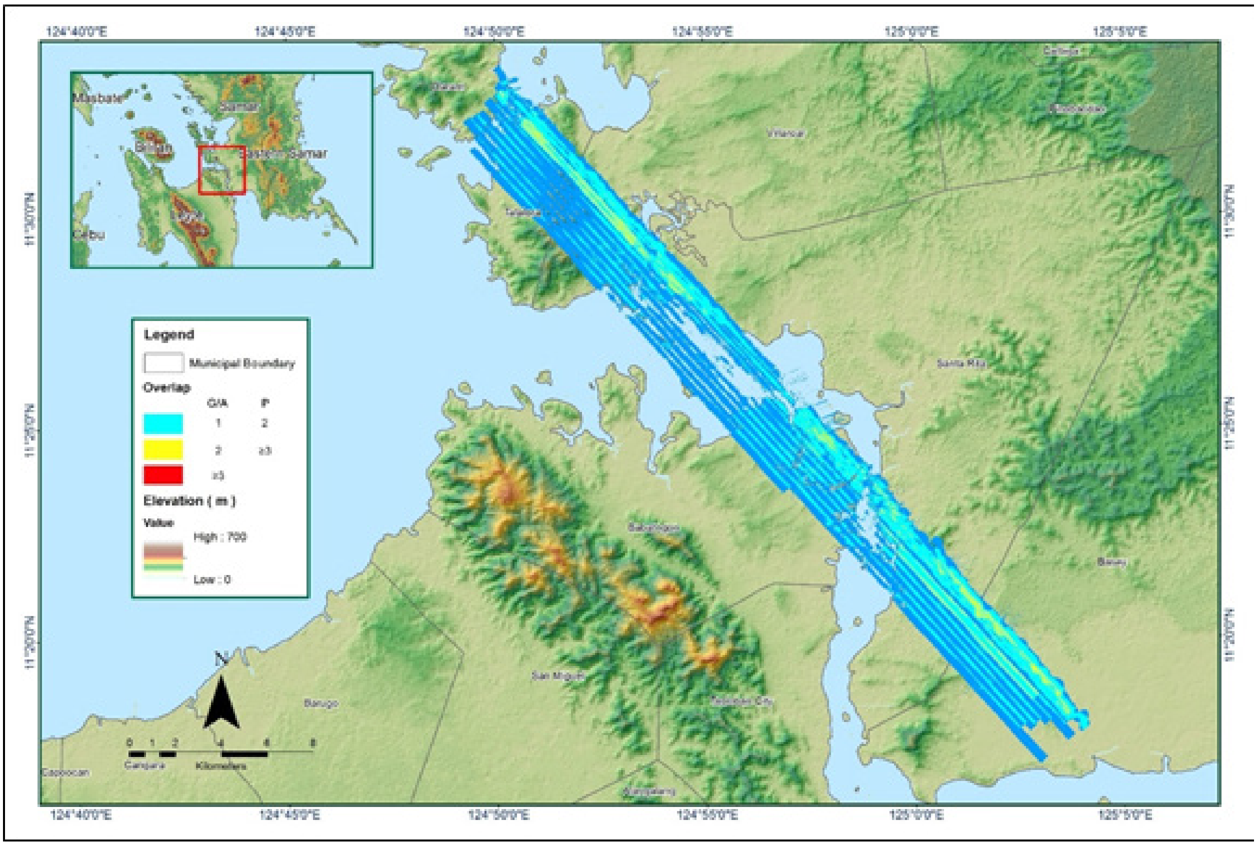


Figure A 8.26 Image of data overlap

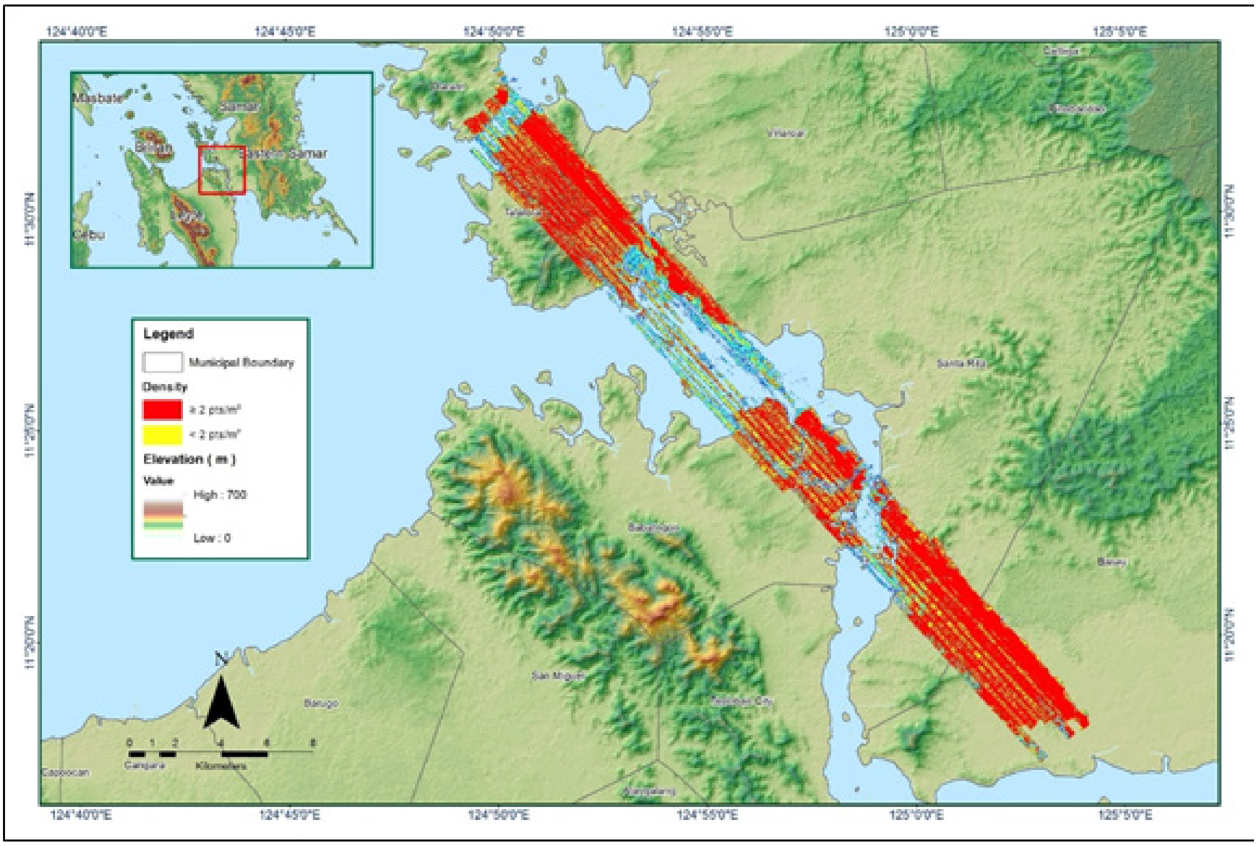


Figure A 8.27 Density map of merged LiDAR data

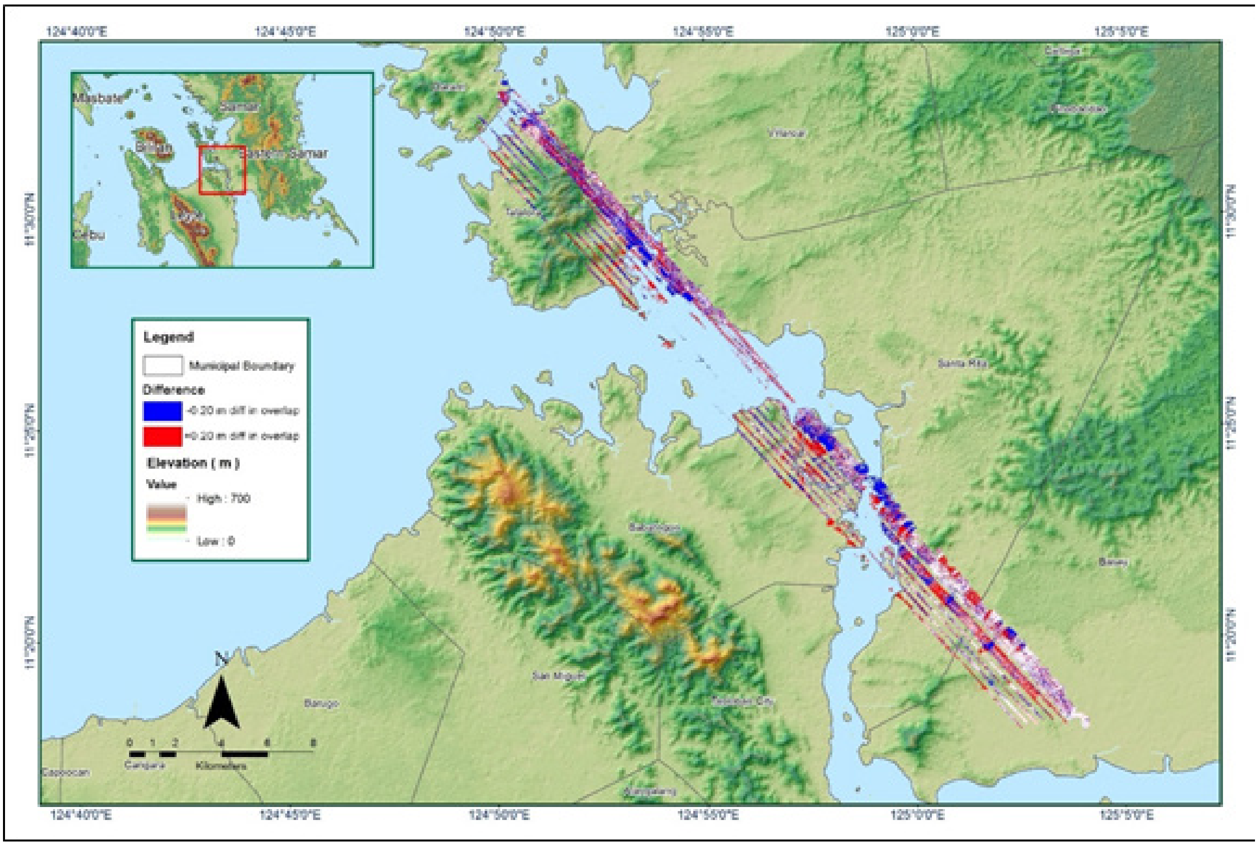


Figure A 8.28 Elevation difference between flight lines

Table A-8.5 Mission Summary Report for Blk33E

Flight Area	Samar-Leyte
Mission Name	Blk33E
Inclusive Flights	1452A
Range data size	9.57 GB
POS data size	233 MB
Base data size	11.2 MB
Image	47.1 GB
Transfer date	May 28, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.58
RMSE for East Position (<4.0 cm)	2.28
RMSE for Down Position (<8.0 cm)	3.9
Boresight correction stdev (<0.001deg)	0.000498
IMU attitude correction stdev (<0.001deg)	0.000909
GPS position stdev (<0.01m)	0.0025
Minimum % overlap (>25)	33.85%
Ave point cloud density per sq.m. (>2.0)	2.63
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	190
Maximum Height	419.67 m
Minimum Height	56.02 m
Classification (# of points)	
Ground	31,505,889
Low vegetation	25,749,491
Medium vegetation	53,225,191
High vegetation	64,445,794
Building	866,018
Orthophoto	Yes
Processed by	Victoria Rejuso, Engr. Melanie Hingpit, Engr. Ma. Ailyn Olanda

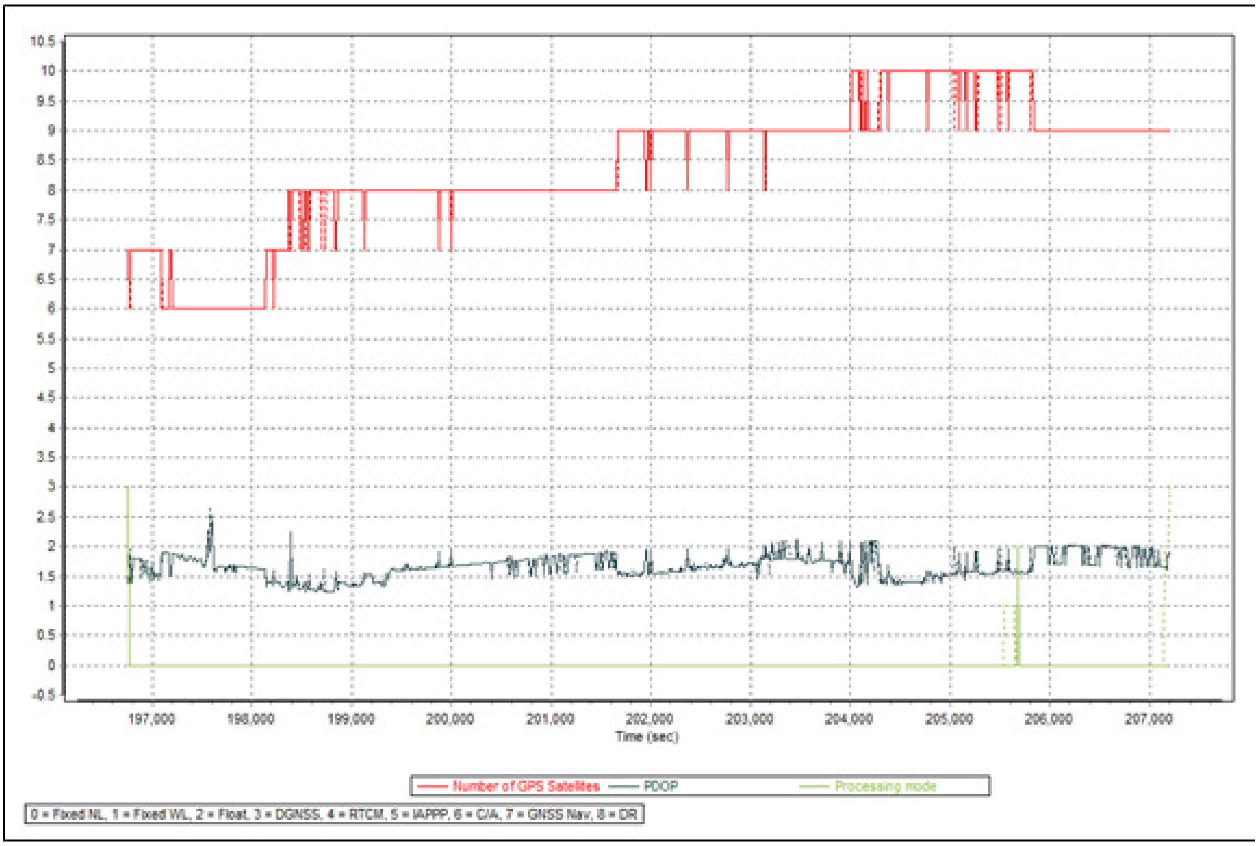


Figure A 8.29 Solution Statust

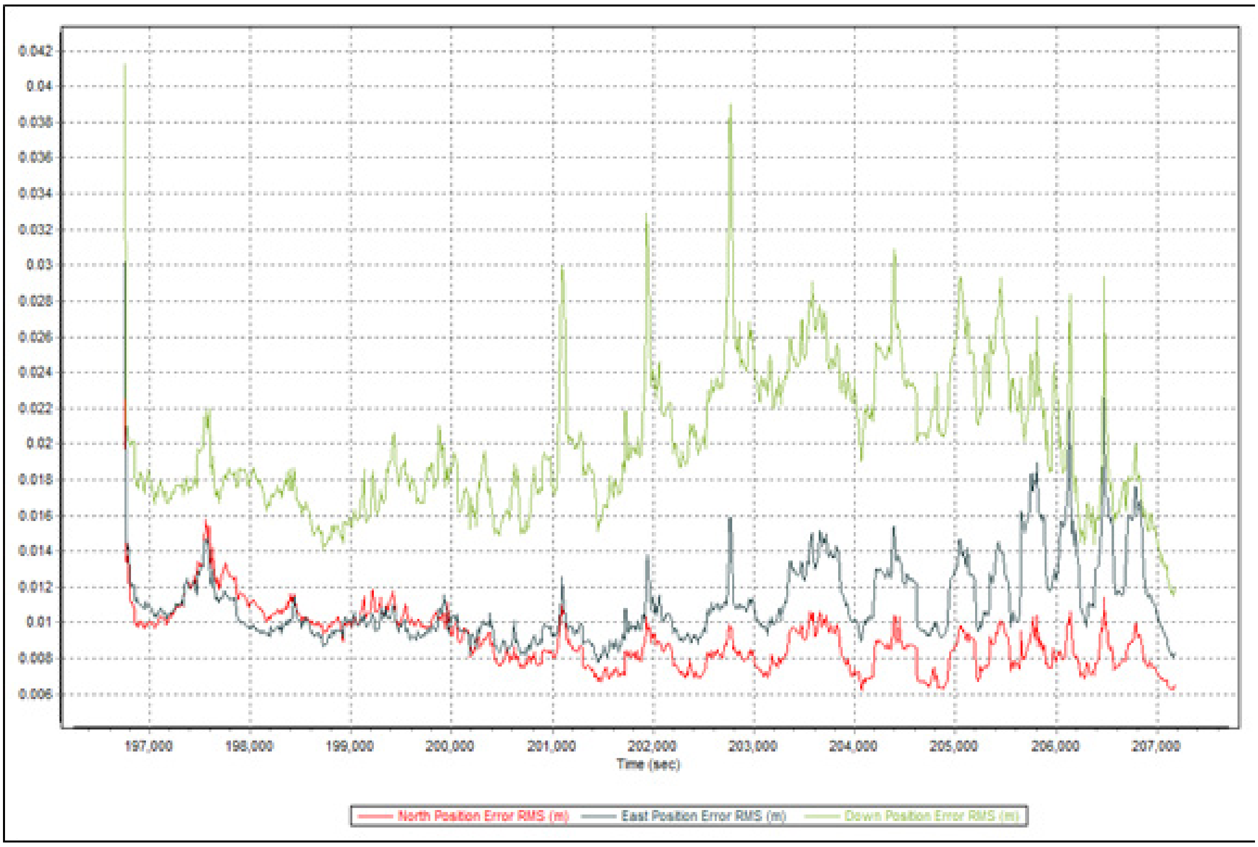


Figure A 8.30 Smoothed Performance Metrics Parameters

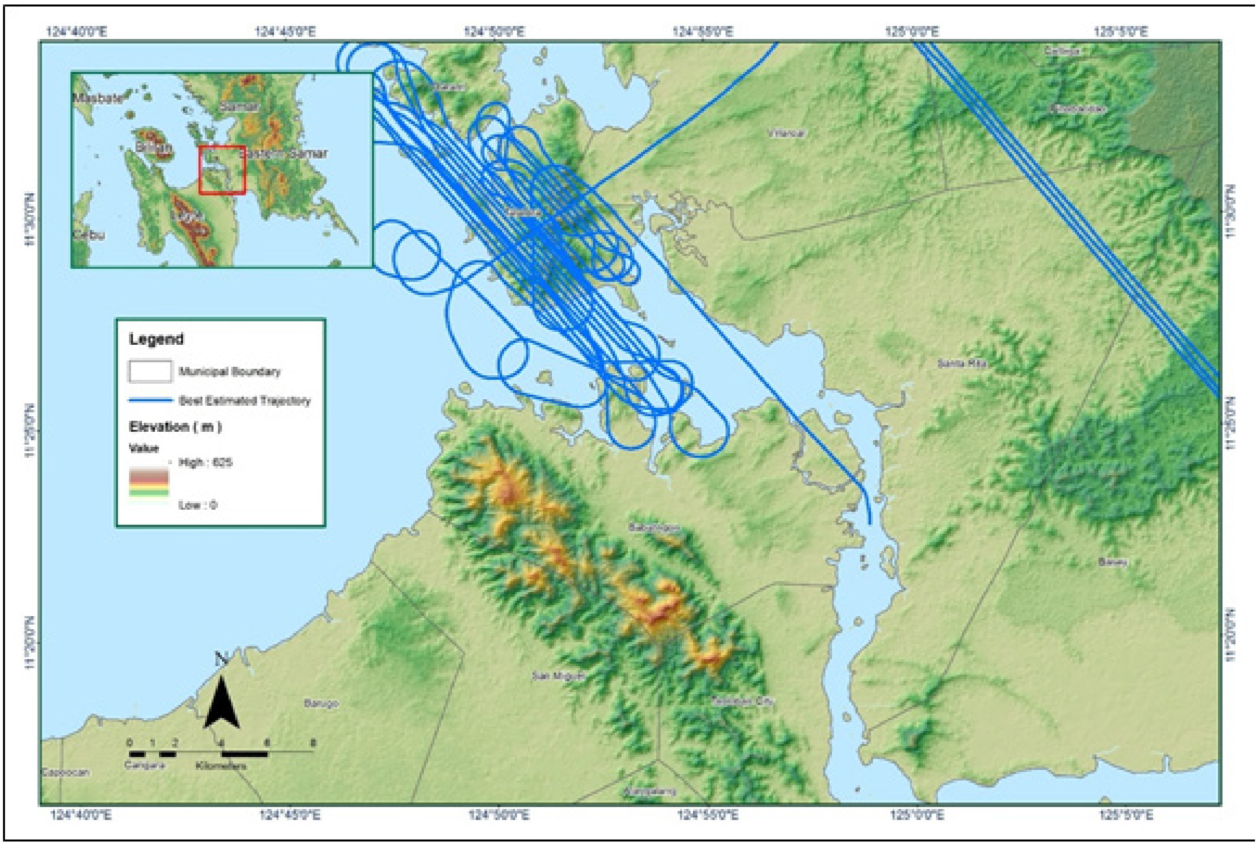


Figure A 8.31 Best Estimated Trajectory

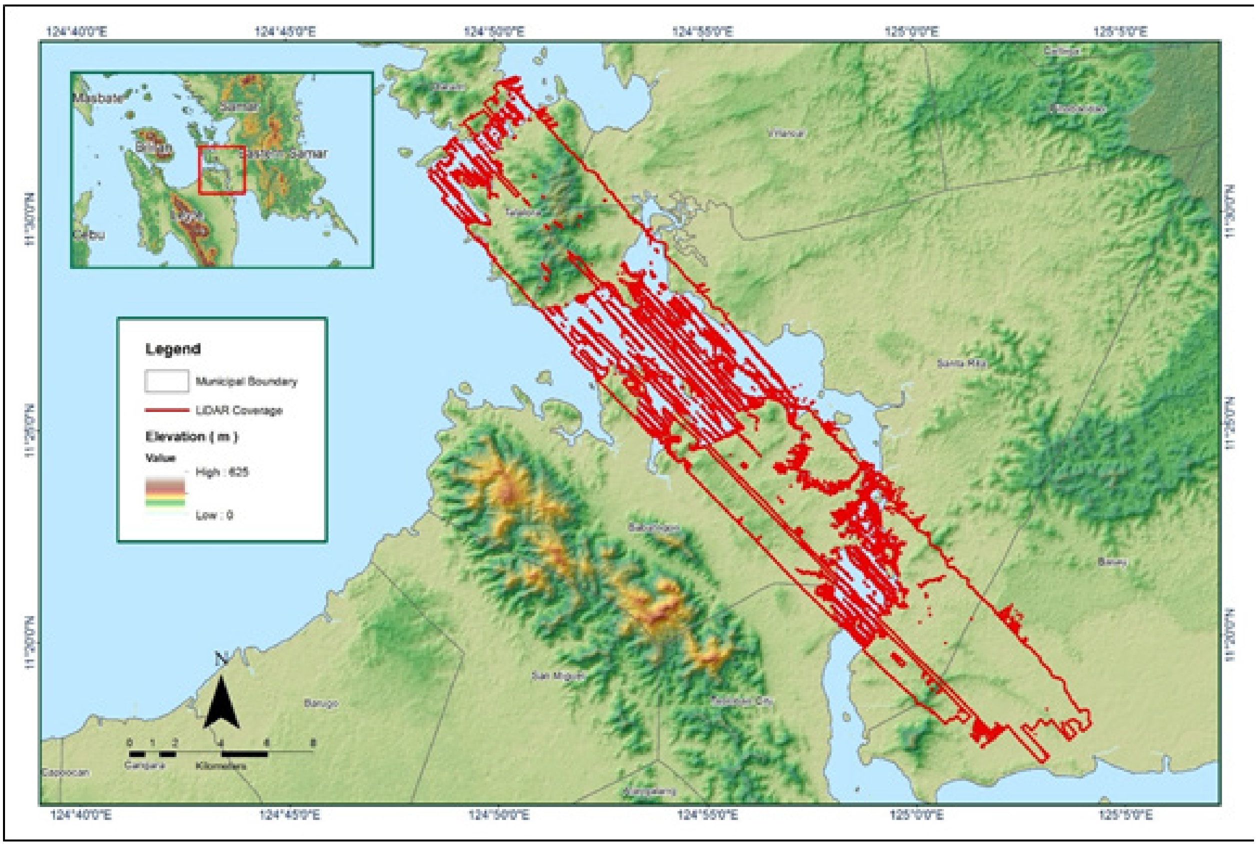


Figure A 8.32 Coverage of LiDAR data

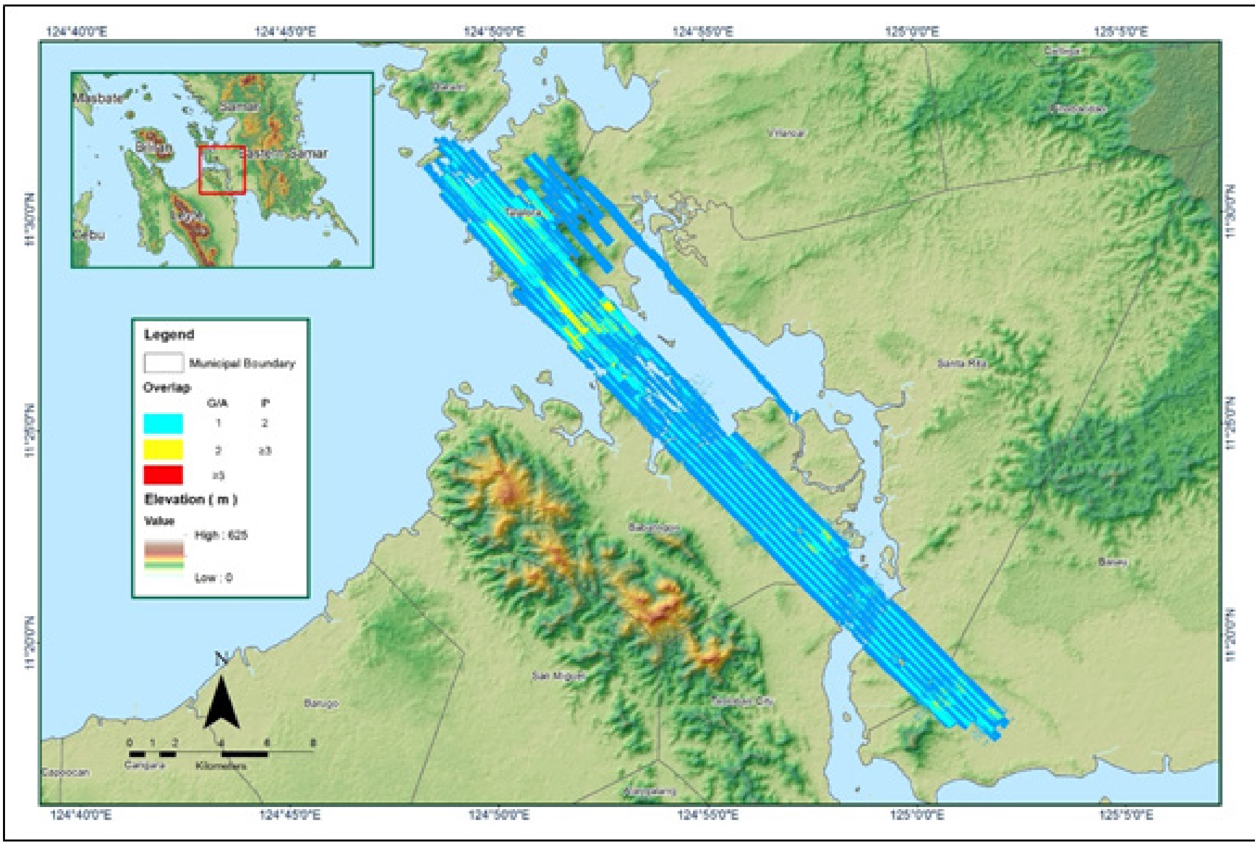


Figure A 8.33 Image of data overlap

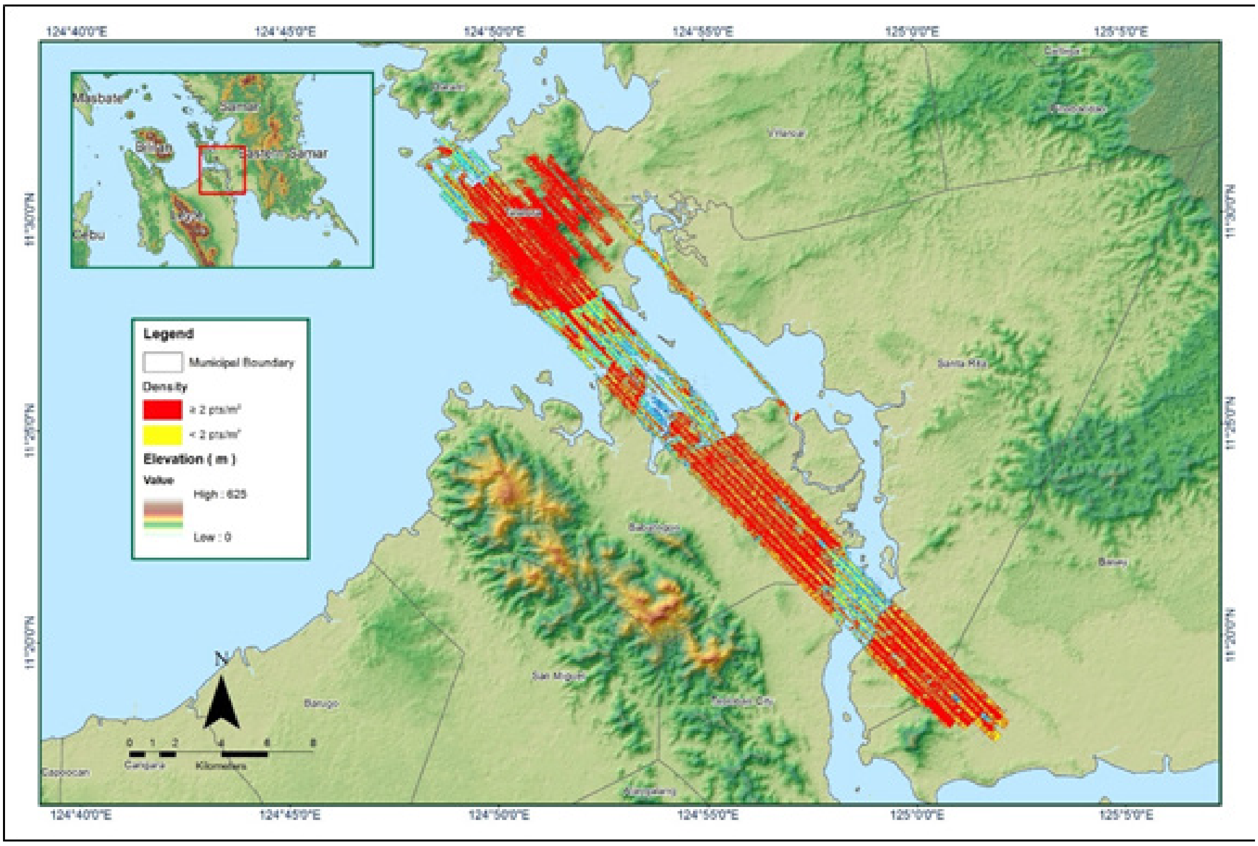


Figure A 8.34 Density map of merged LiDAR data

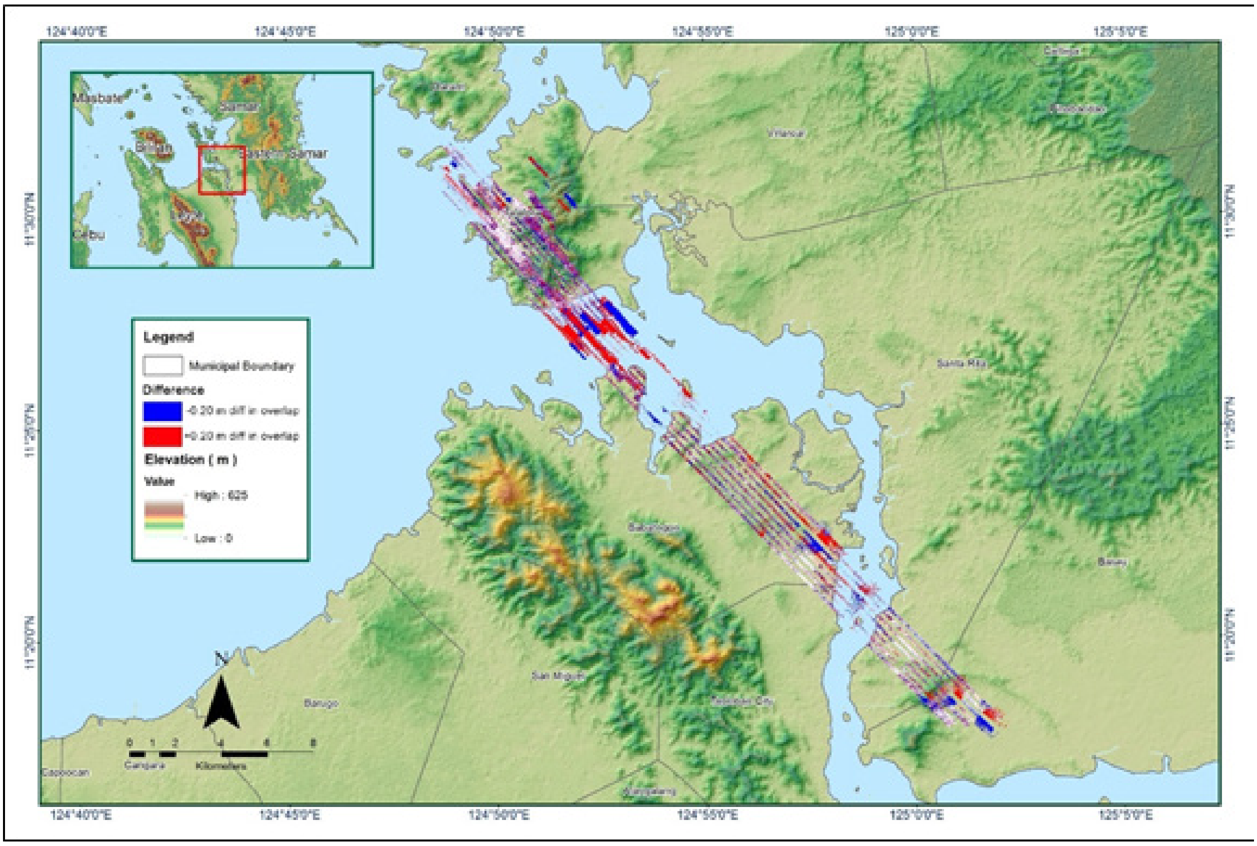


Figure A 8.35 Elevation difference between flight lines

Table A-8.6 Mission Summary Report for Blk33F

Flight Area	Samar-Leyte
Mission Name	33F
Inclusive Flights	3781G, 23773G
Range data size	20.36
POS data size	386
Base data size	13.57
Image	n/a
Transfer date	March 04, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.0
RMSE for East Position (<4.0 cm)	1.4
RMSE for Down Position (<8.0 cm)	3.1
Boresight correction stdev (<0.001deg)	0.001088
IMU attitude correction stdev (<0.001deg)	0.002573
GPS position stdev (<0.01m)	0.0113
Minimum % overlap (>25)	41.49
Ave point cloud density per sq.m. (>2.0)	4.86
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	142
Maximum Height	315.78 m
Minimum Height	25.54 m
Classification (# of points)	
Ground	25,232,203
Low vegetation	25,048,022
Medium vegetation	132,149,471
High vegetation	162,406,497
Building	2,147,712
Orthophoto	no
Processed by	Engr. Don Matthew Banatin, Engr. Melanie Hingpit, Engr. Monalyne Rabino

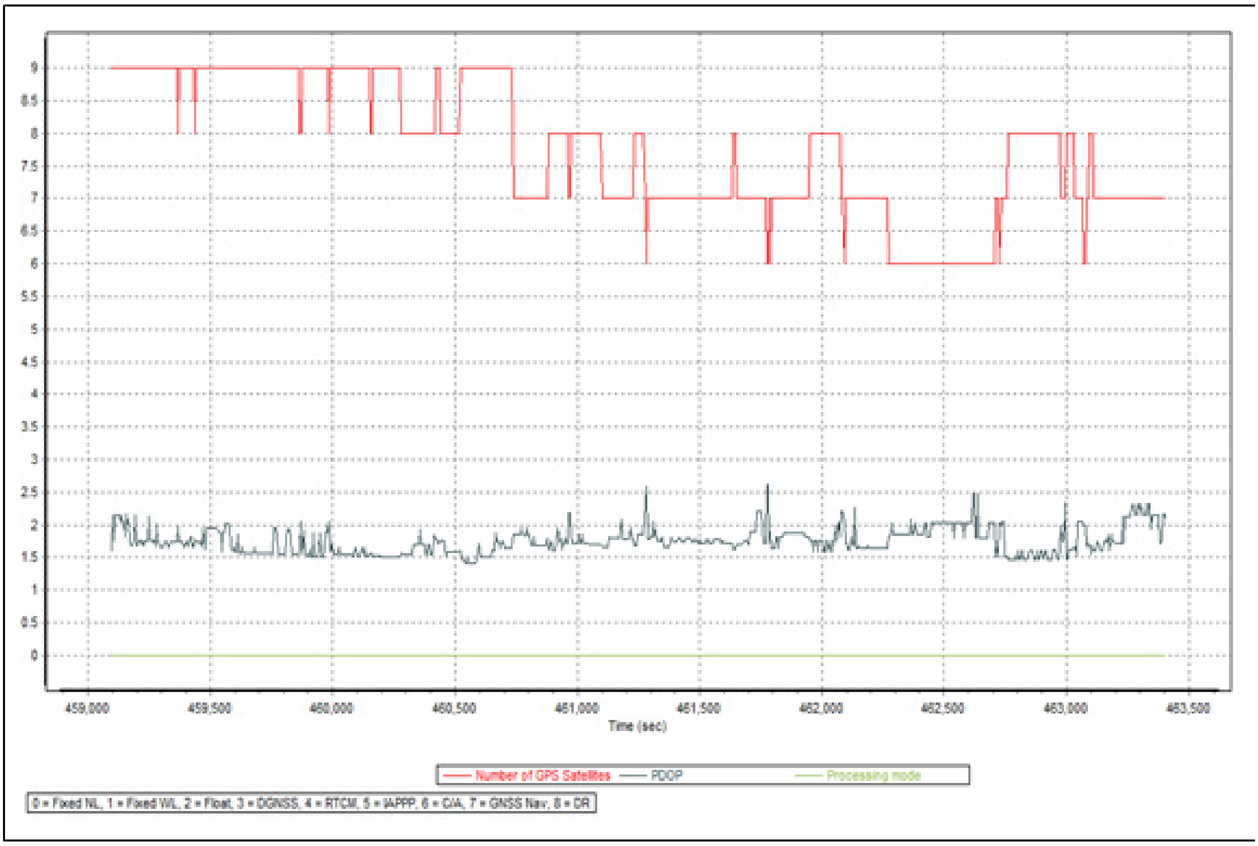


Figure A 8.36. Solution Status

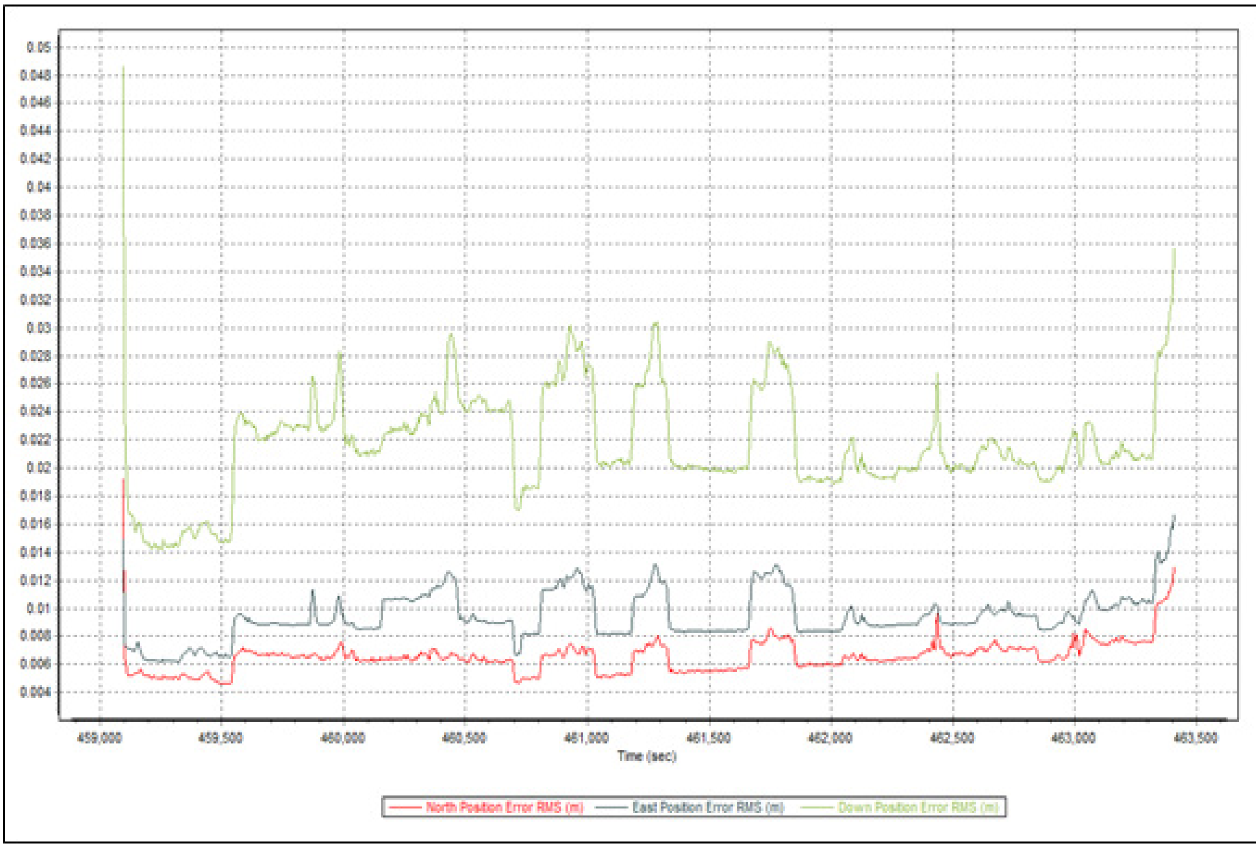


Figure A 8.37 Smoothed Performance Metric Parameters

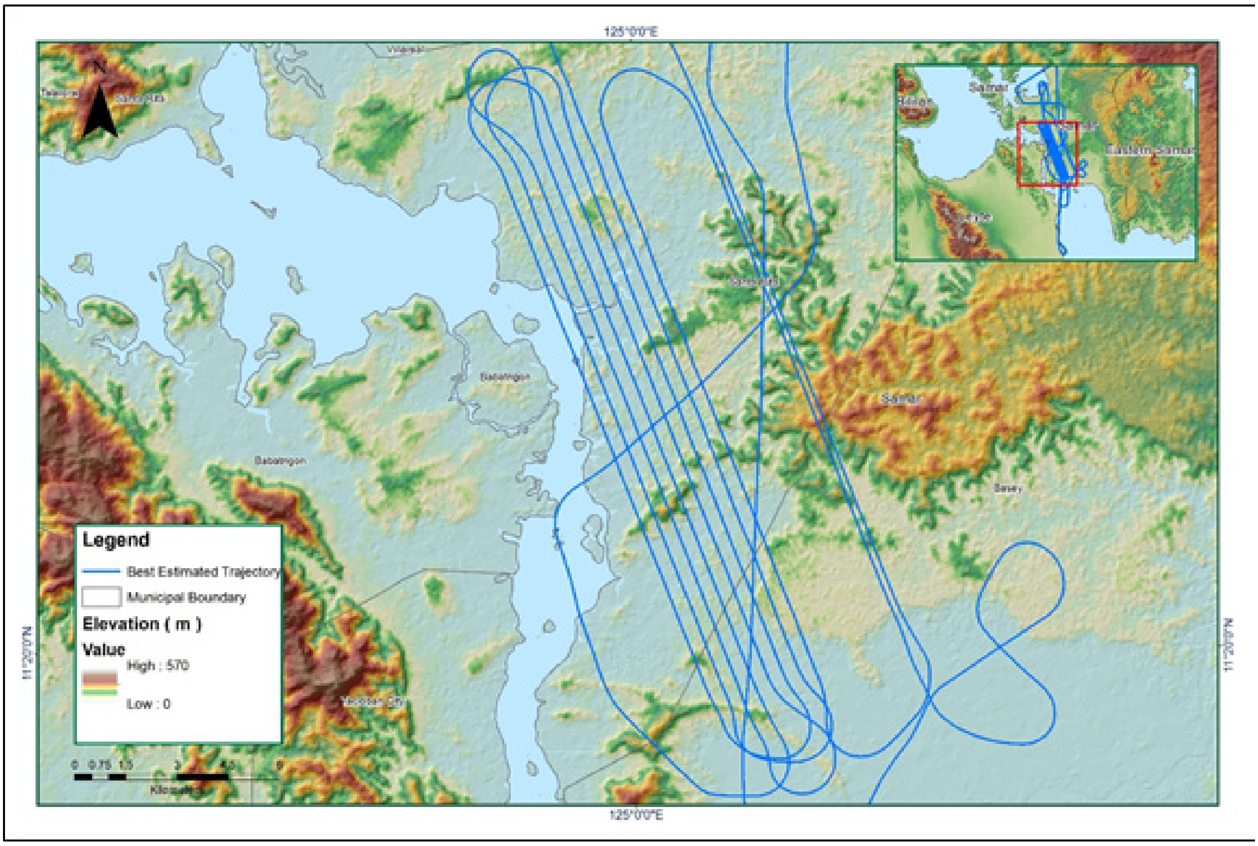


Figure A 8.38 Best Estimated Trajectoryt

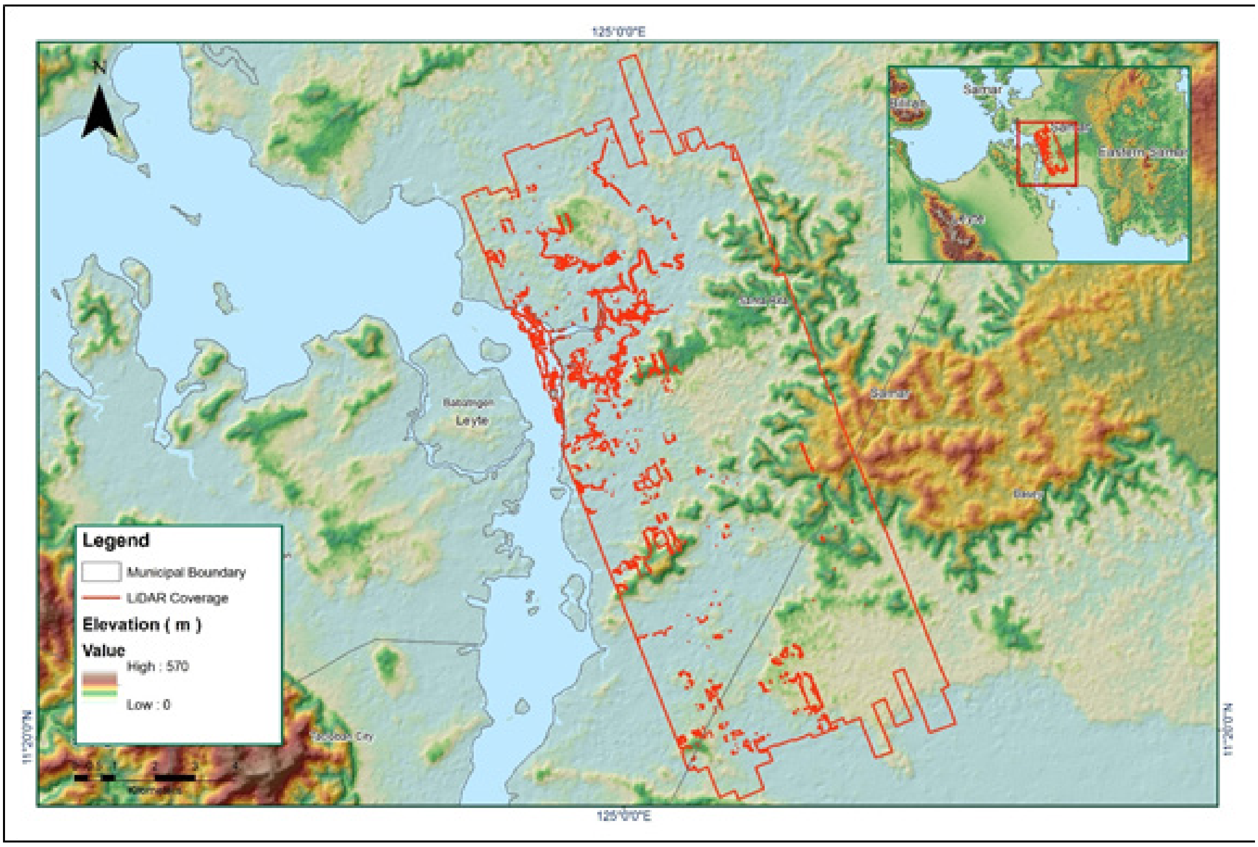


Figure A 8.39 Coverage of LiDAR Data

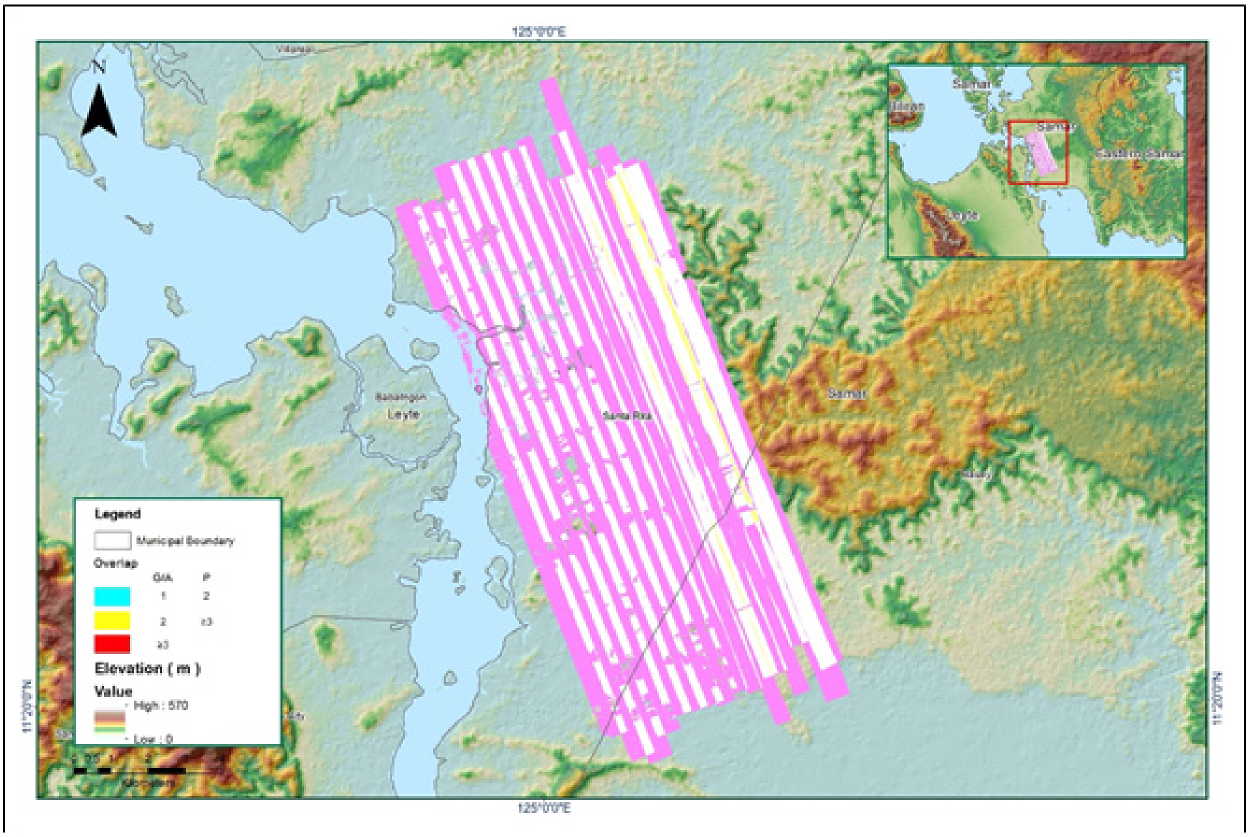


Figure A 8.40 Image of data overlap

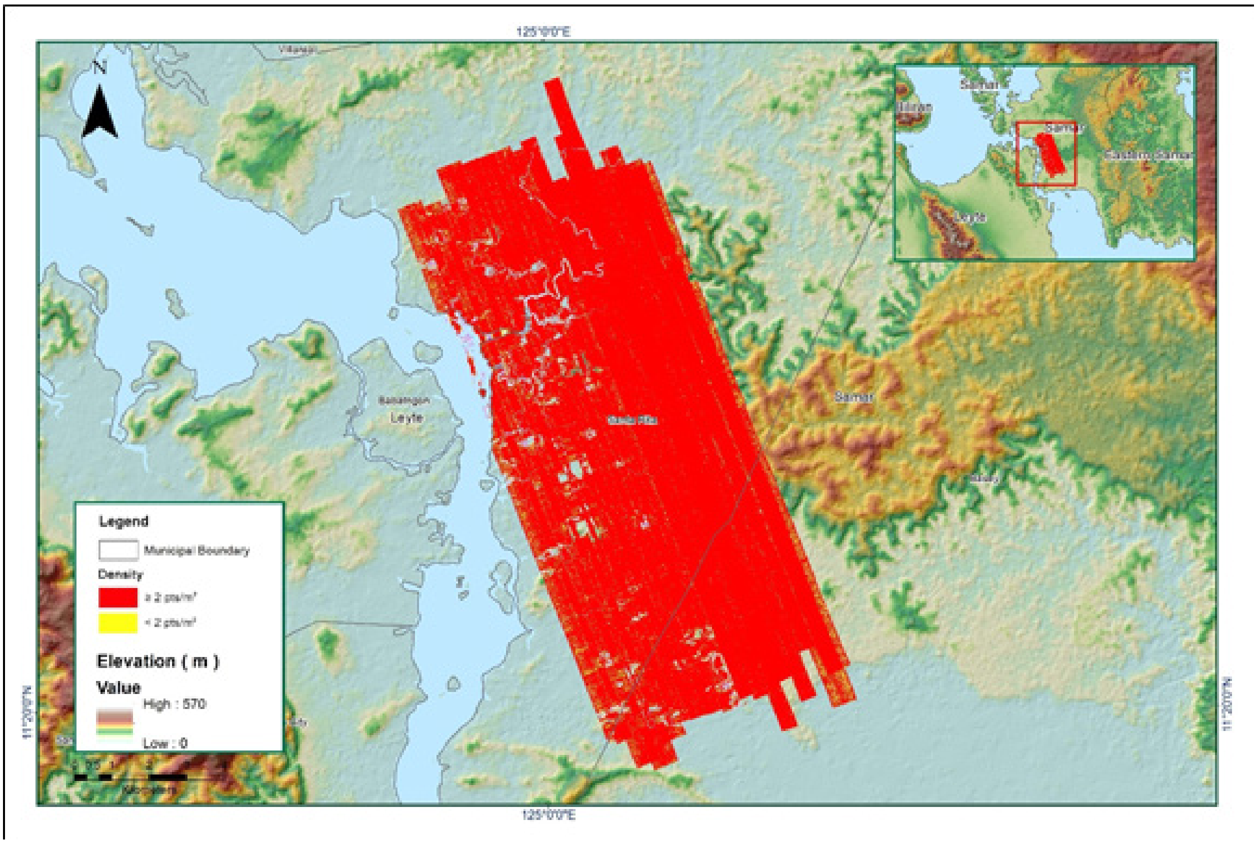


Figure A 8.41 Density map of merged LiDAR data

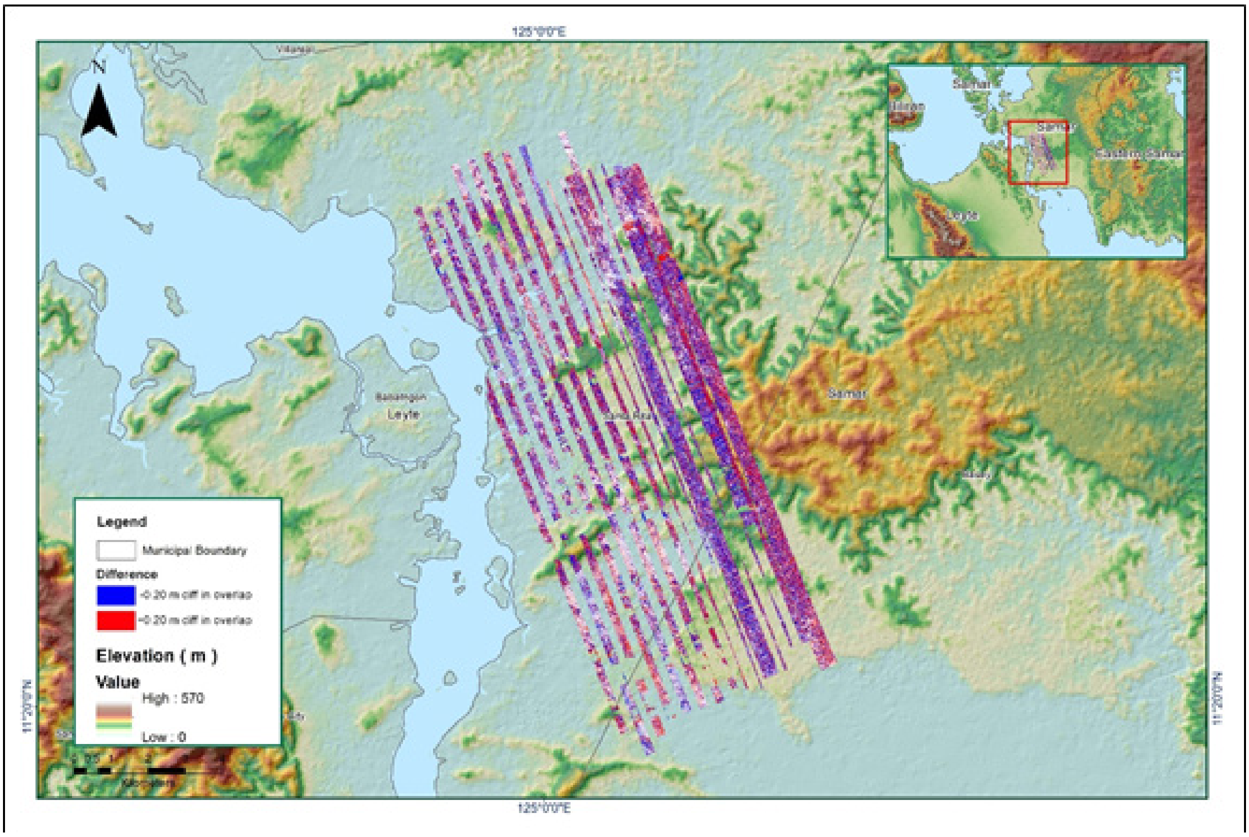


Figure A 8.42 Elevation difference between flight lines

Table A-8.7 Mission Summary Report for Blk33E

Flight Area	Samar-Leyte
Mission Name	33E
Inclusive Flights	3731G, 3733G
Range data size	41
POS data size	456
Base data size	7.93
Image	n/a
Transfer date	February 26, 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)	1.6
RMSE for East Position (<4.0 cm)	1.7
RMSE for Down Position (<8.0 cm)	3.1
Boresight correction stdev (<0.001deg)	0.001467
IMU attitude correction stdev (<0.001deg)	0.015072
GPS position stdev (<0.01m)	0.0030
Minimum % overlap (>25)	25.09
Ave point cloud density per sq.m. (>2.0)	3.27
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	120
Maximum Height	424.91 m
Minimum Height	65.68 m
Classification (# of points)	
Ground	39,315,973
Low vegetation	28,880,555
Medium vegetation	99,951,686
High vegetation	100,500,330
Building	422,184
Orthophoto	No
Processed by	Engr. Abigail Joy Ching, Engr. Velina Angela Bemida, Maria Tamsyn Malabanan

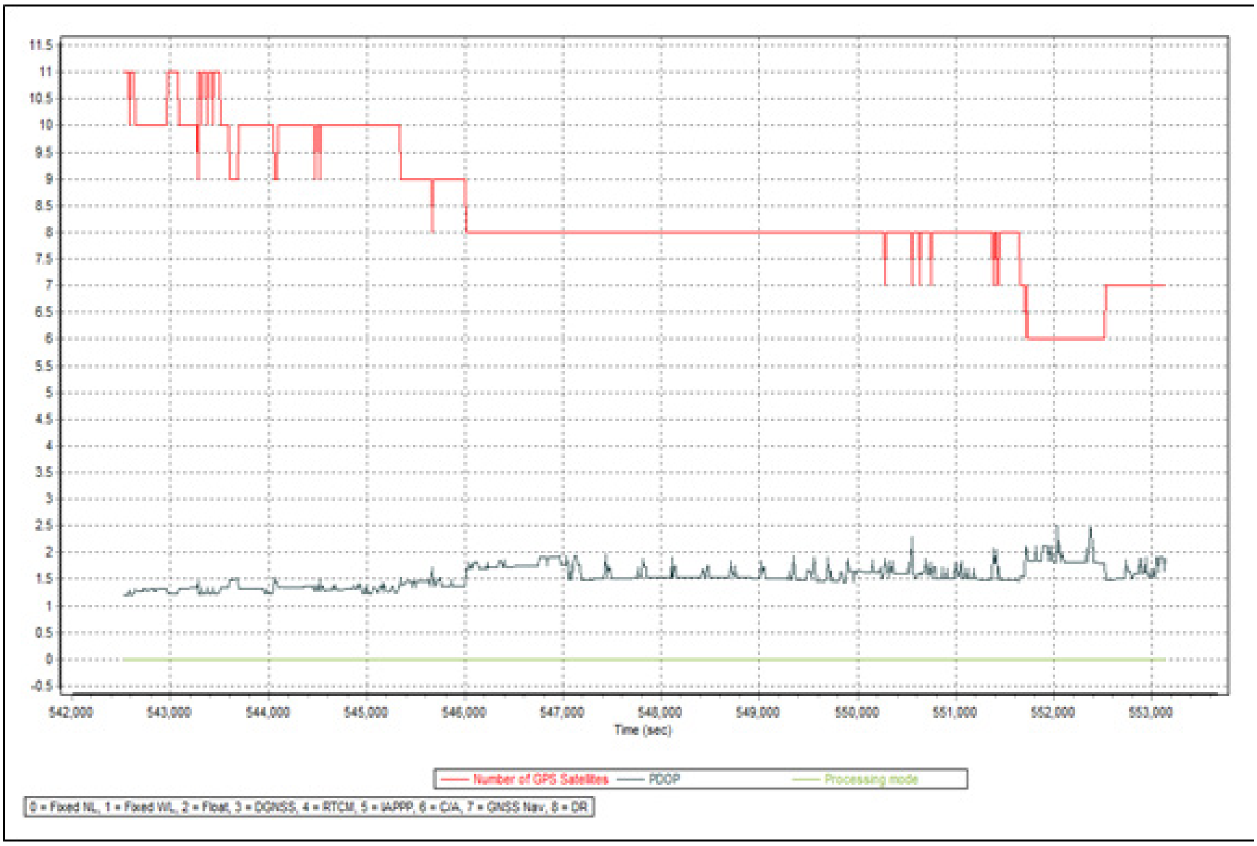


Figure A 8.43 Solution Status

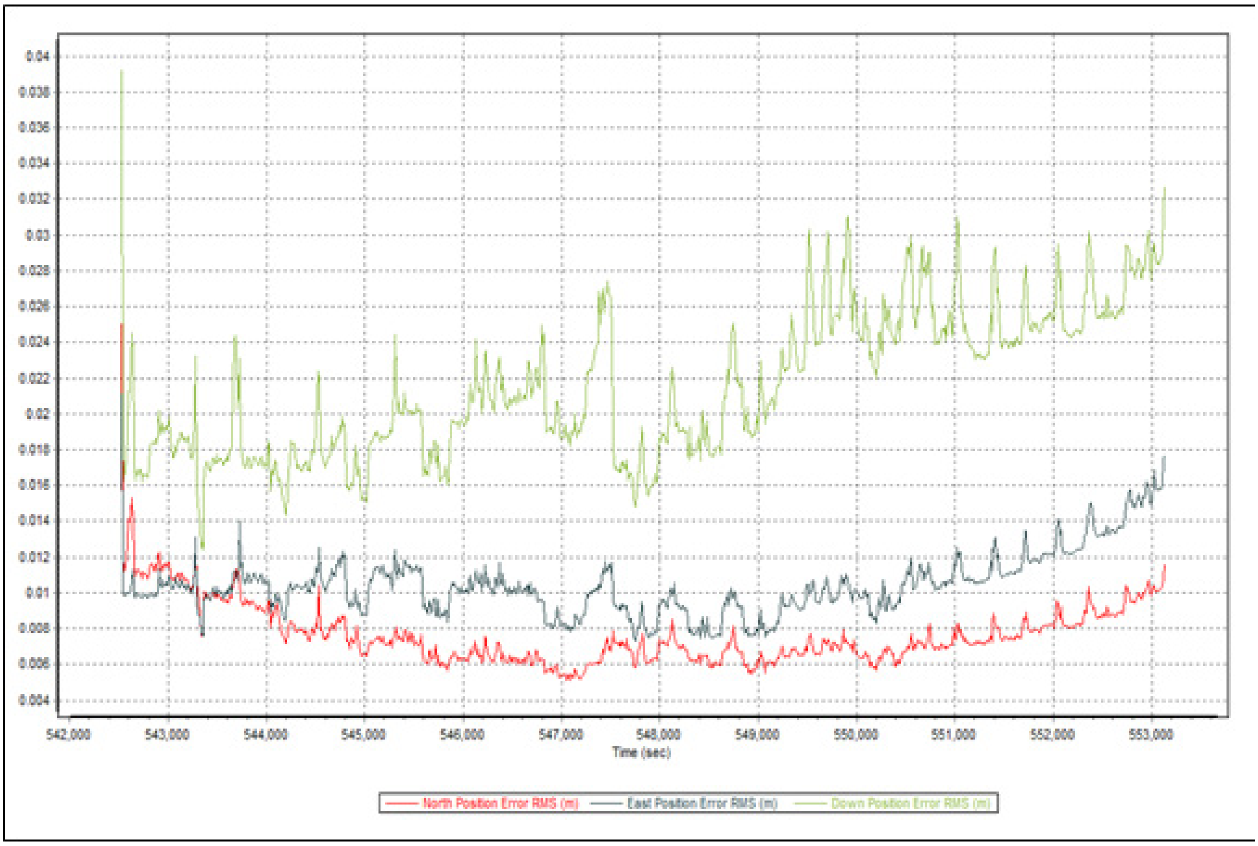


Figure A 8.44 Smoothed Performance Metric Parameters

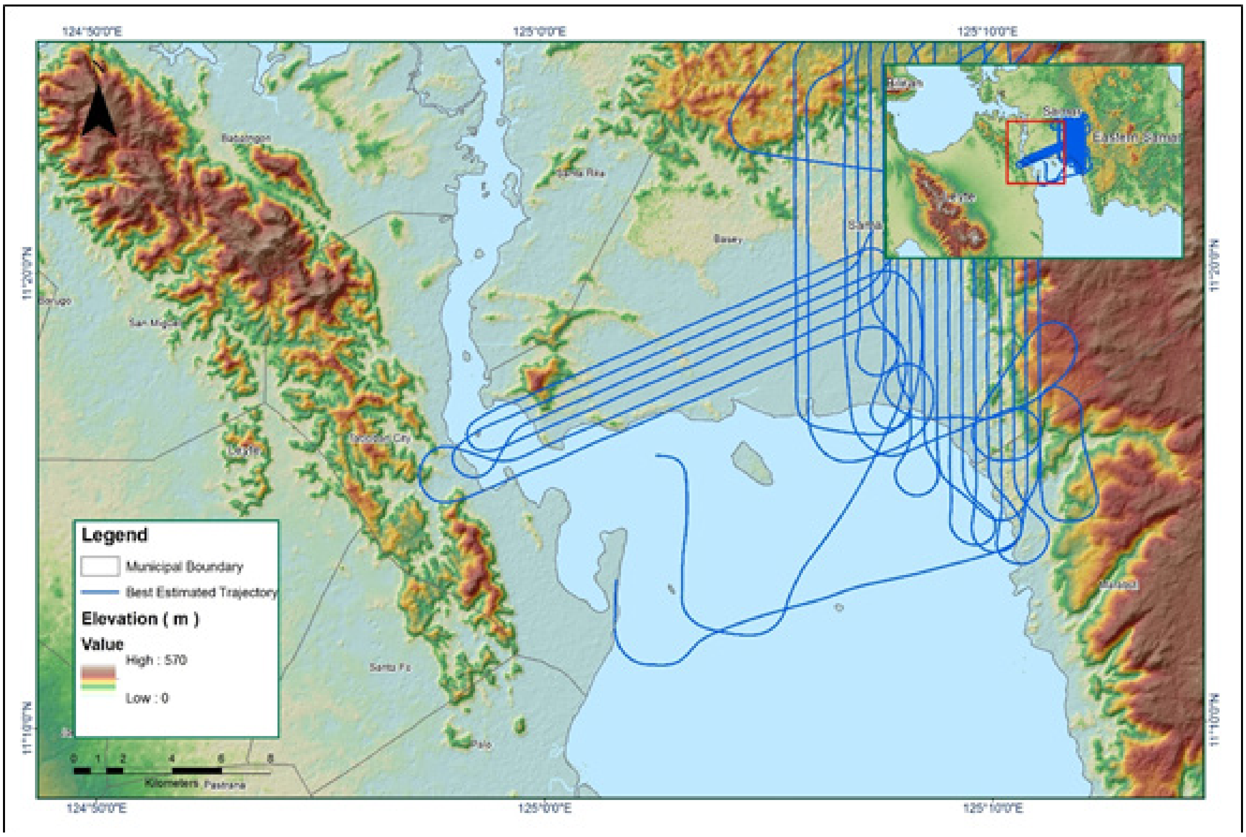


Figure A 8.45 Best Estimated Trajectory

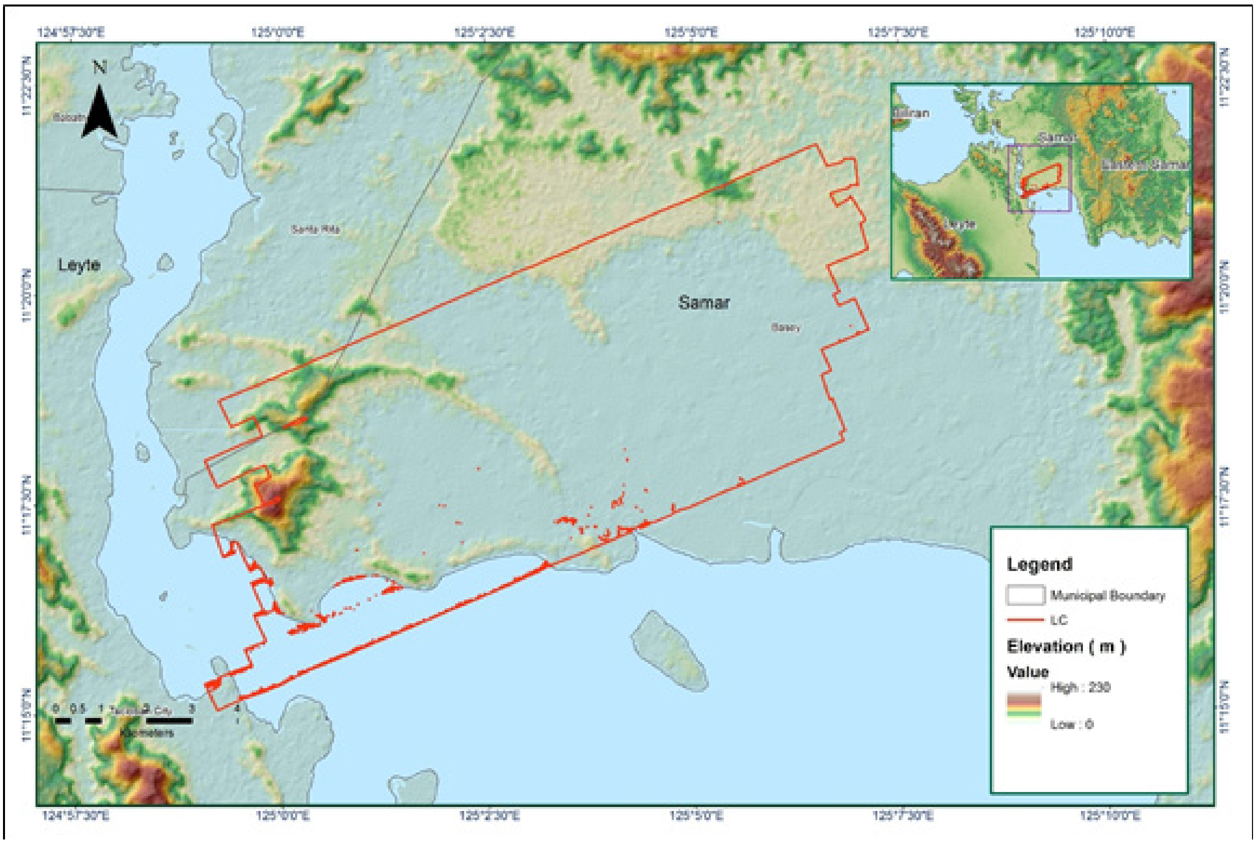


Figure A 8.46 Coverage of LiDAR Data

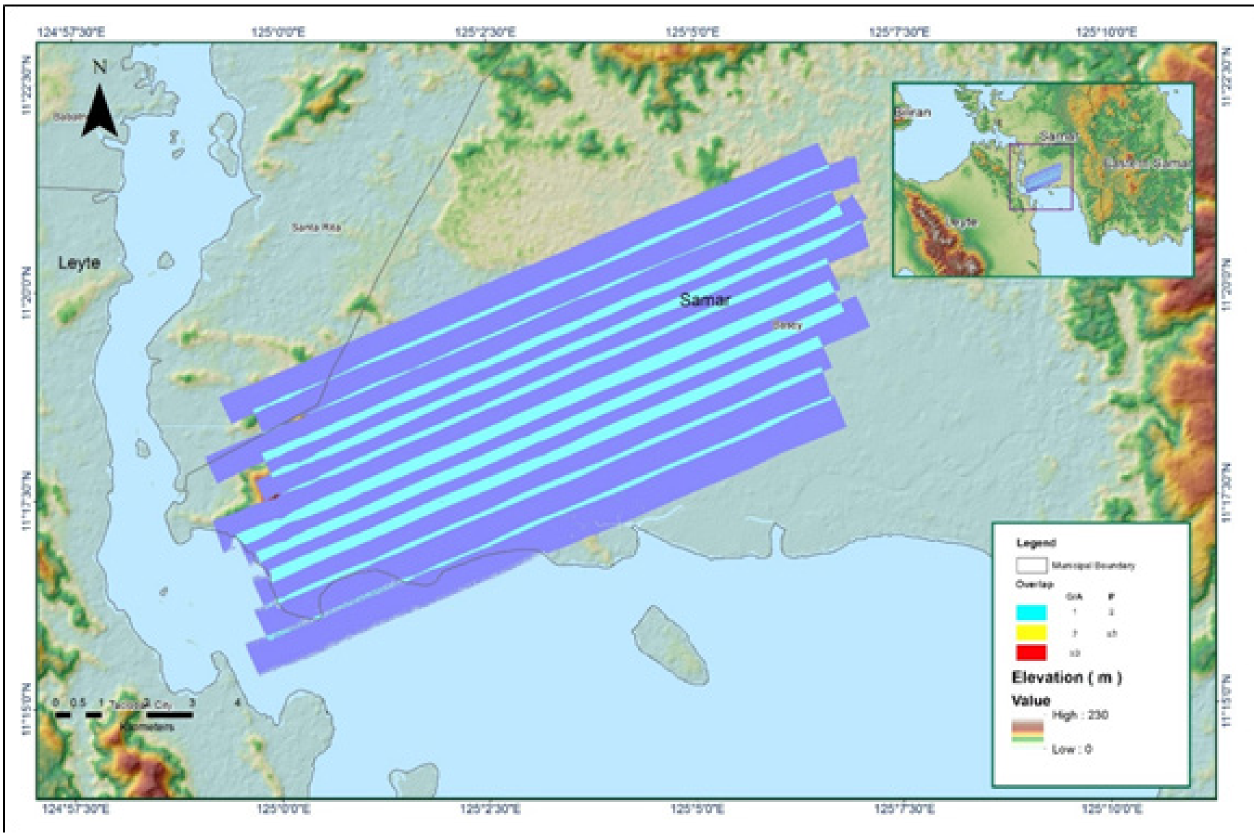


Figure A 8.47 Image of data overlap

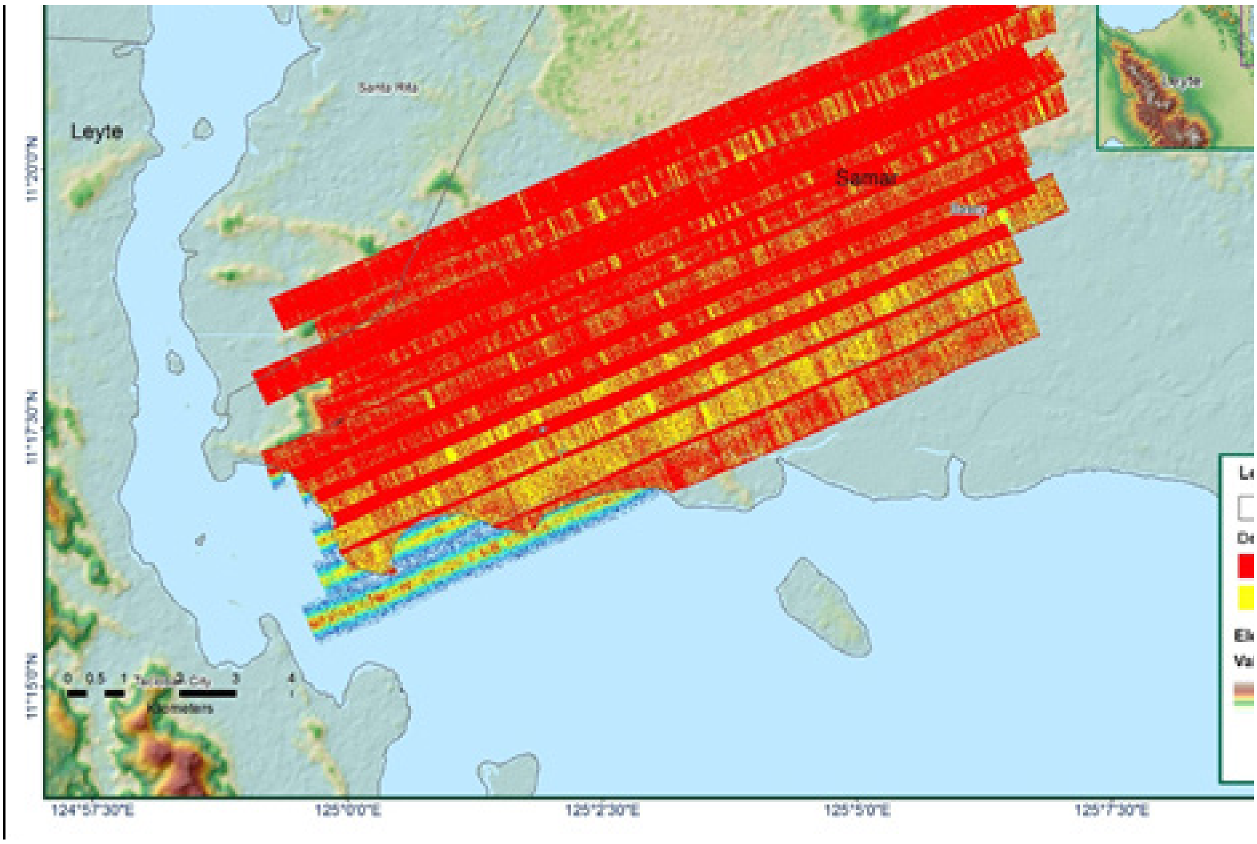


Figure A 8.48 Density map of merged LiDAR data

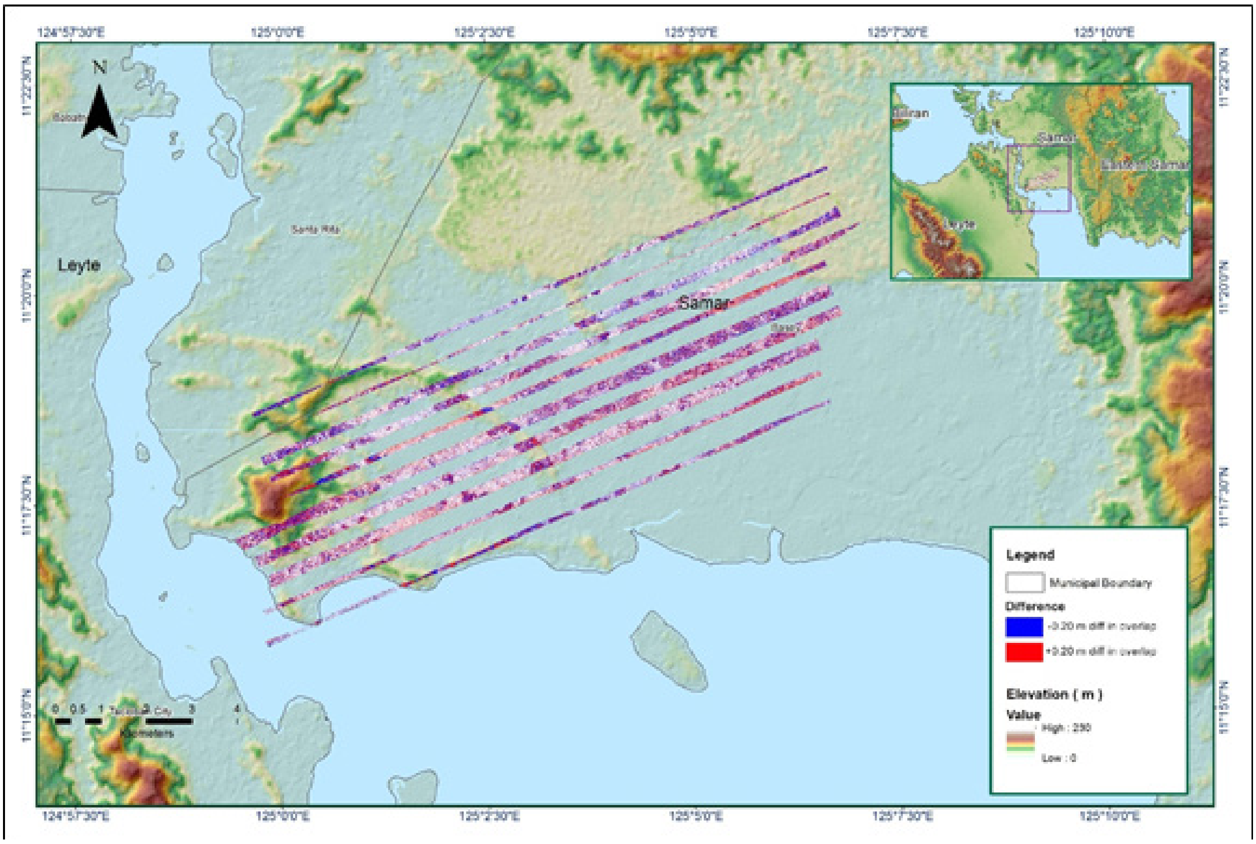


Figure A 8.49 Elevation difference between flight lines

Table A-8.8 Mission Summary Report for Blk33E_additional

Flight Area	Samar-Leyte
Mission Name	33E_Additional
Inclusive Flights	3731G, 3733G
Range data size	41
POS data size	456
Base data size	7.93
Image	n/a
Transfer date	February 26, 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)	1.6
RMSE for East Position (<4.0 cm)	1.7
RMSE for Down Position (<8.0 cm)	3.1
Boresight correction stdev (<0.001deg)	0.001467
IMU attitude correction stdev (<0.001deg)	0.015072
GPS position stdev (<0.01m)	0.0030
Minimum % overlap (>25)	N/A
Ave point cloud density per sq.m. (>2.0)	2.66
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	31
Maximum Height	162.61 m
Minimum Height	66.12 m
Classification (# of points)	
Ground	2,493,277
Low vegetation	1,964,480
Medium vegetation	9,685,599
High vegetation	6,040,442
Building	183,120
Orthophoto	No
Processed by	Engr. Abigail Joy Ching, Aljon Rie Araneta, Jovy Narisma

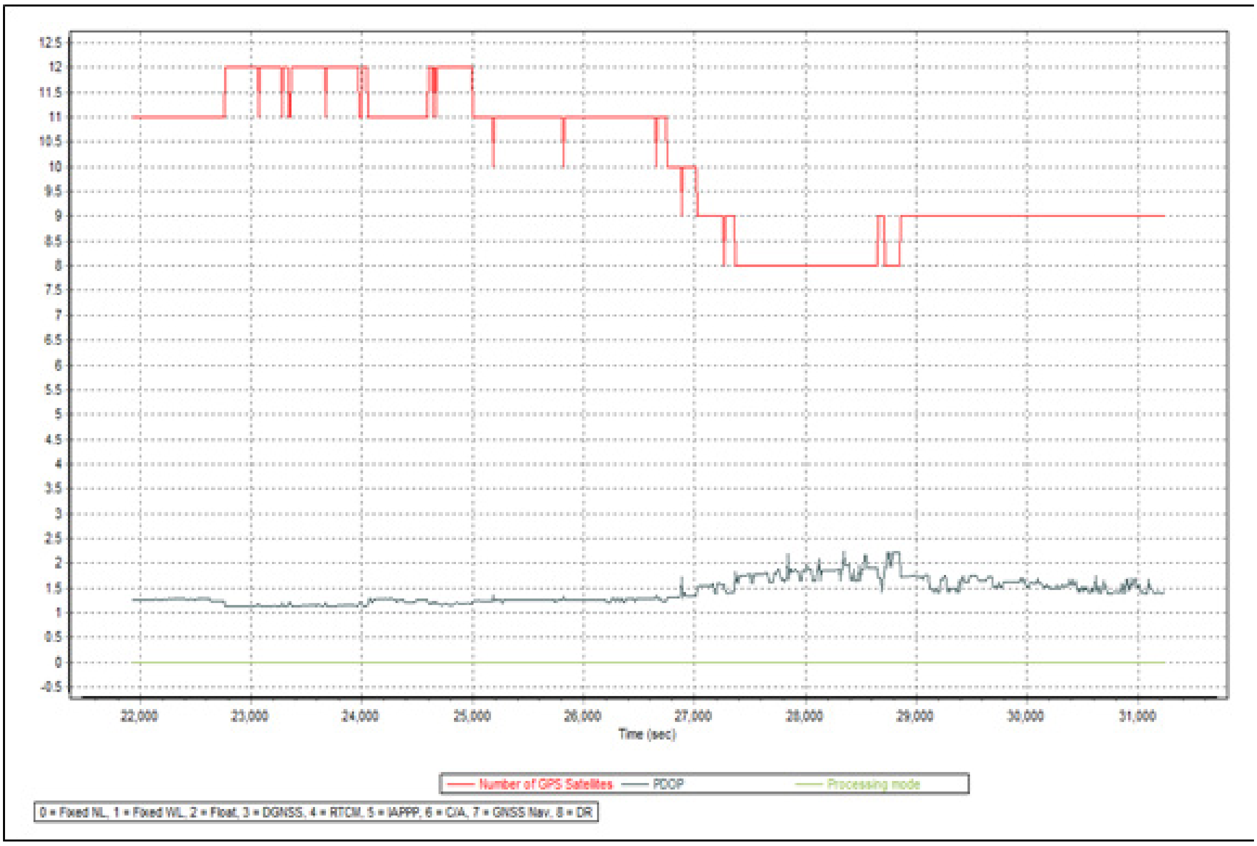


Figure A 8.50 Solution Status

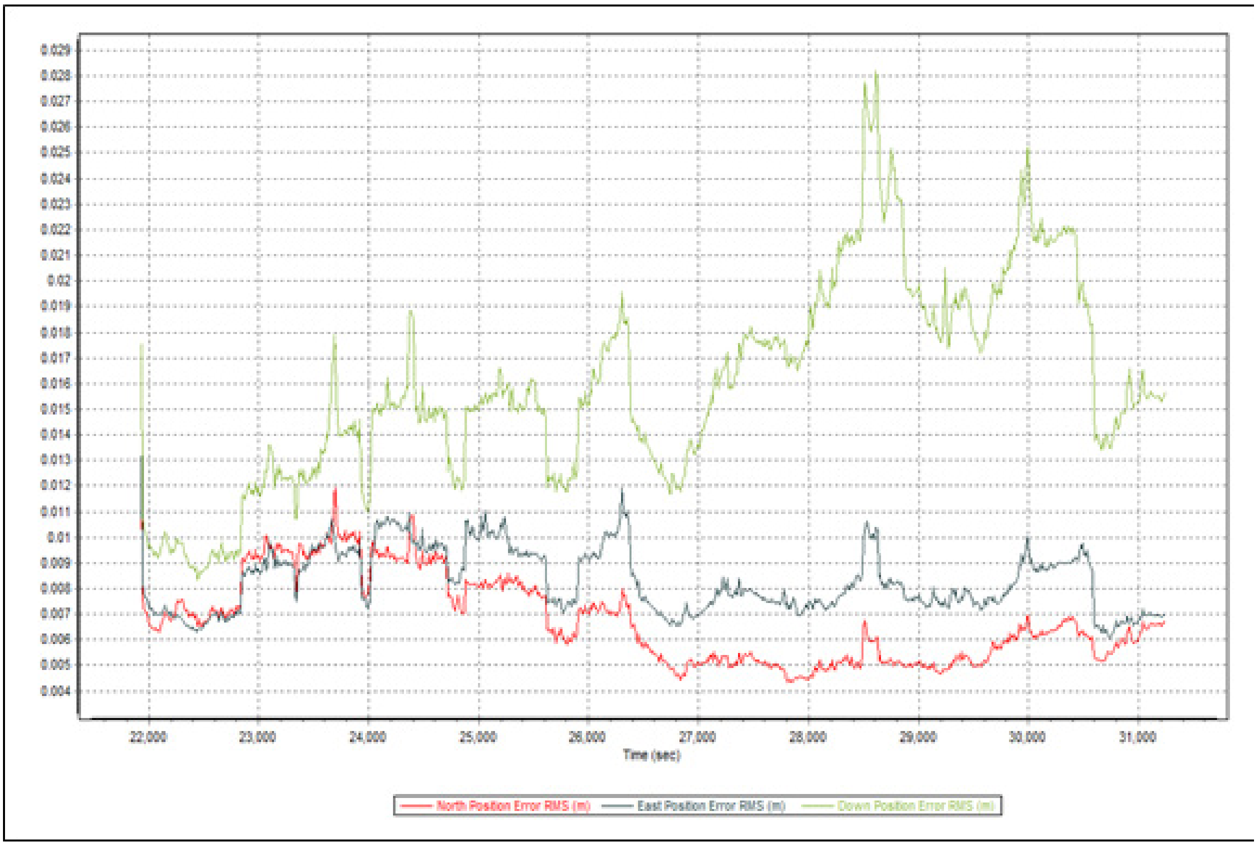


Figure A 8.51 Smoothed Performance Metric Parameters

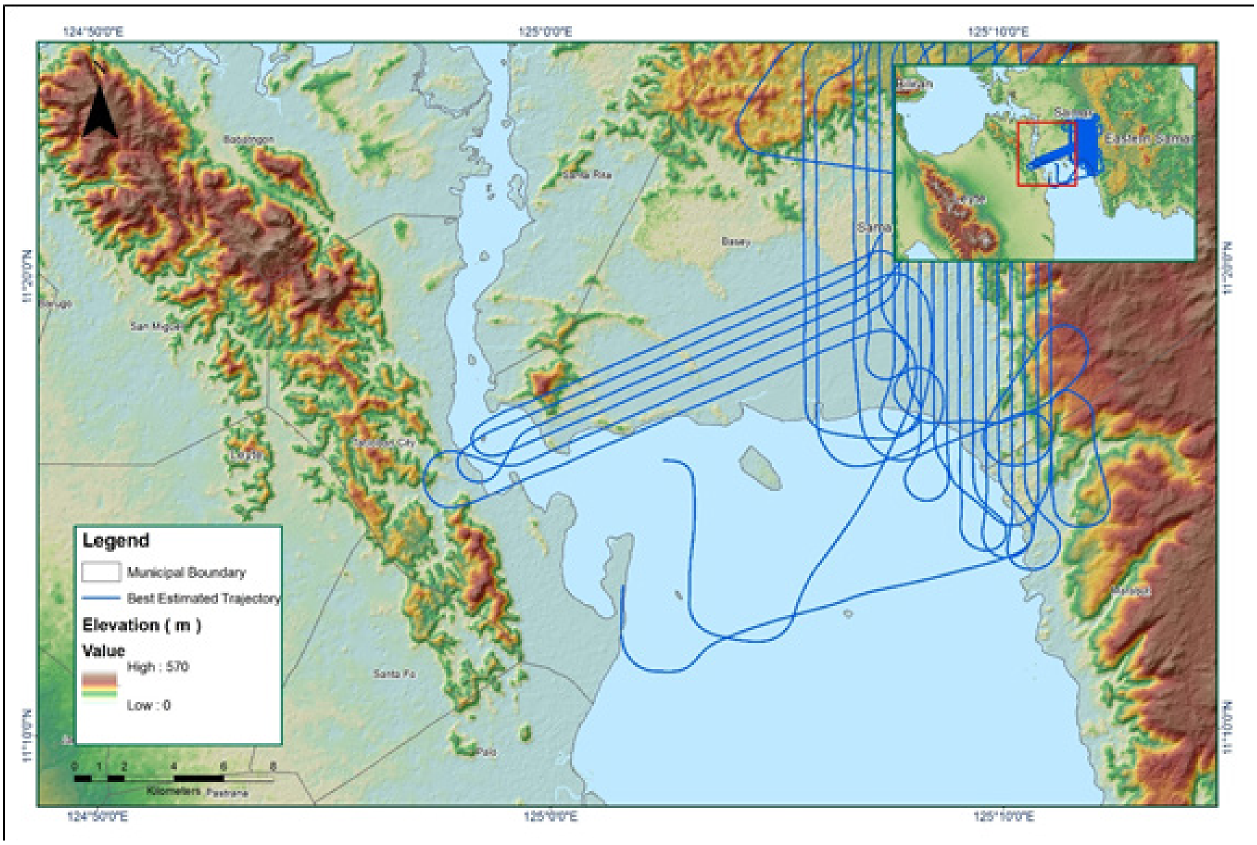


Figure A 8.52 Best Estimated Trajectory

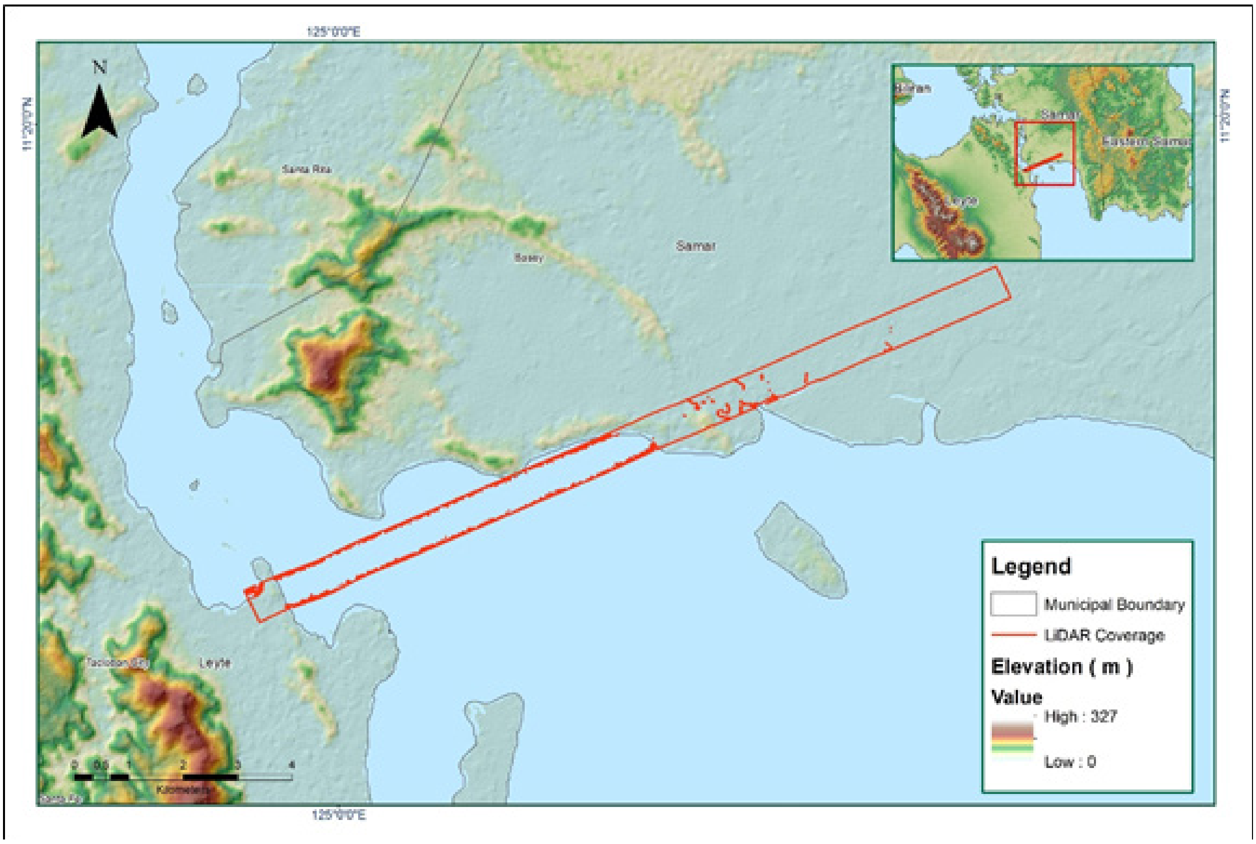


Figure A 8.53 Coverage of LiDAR Data

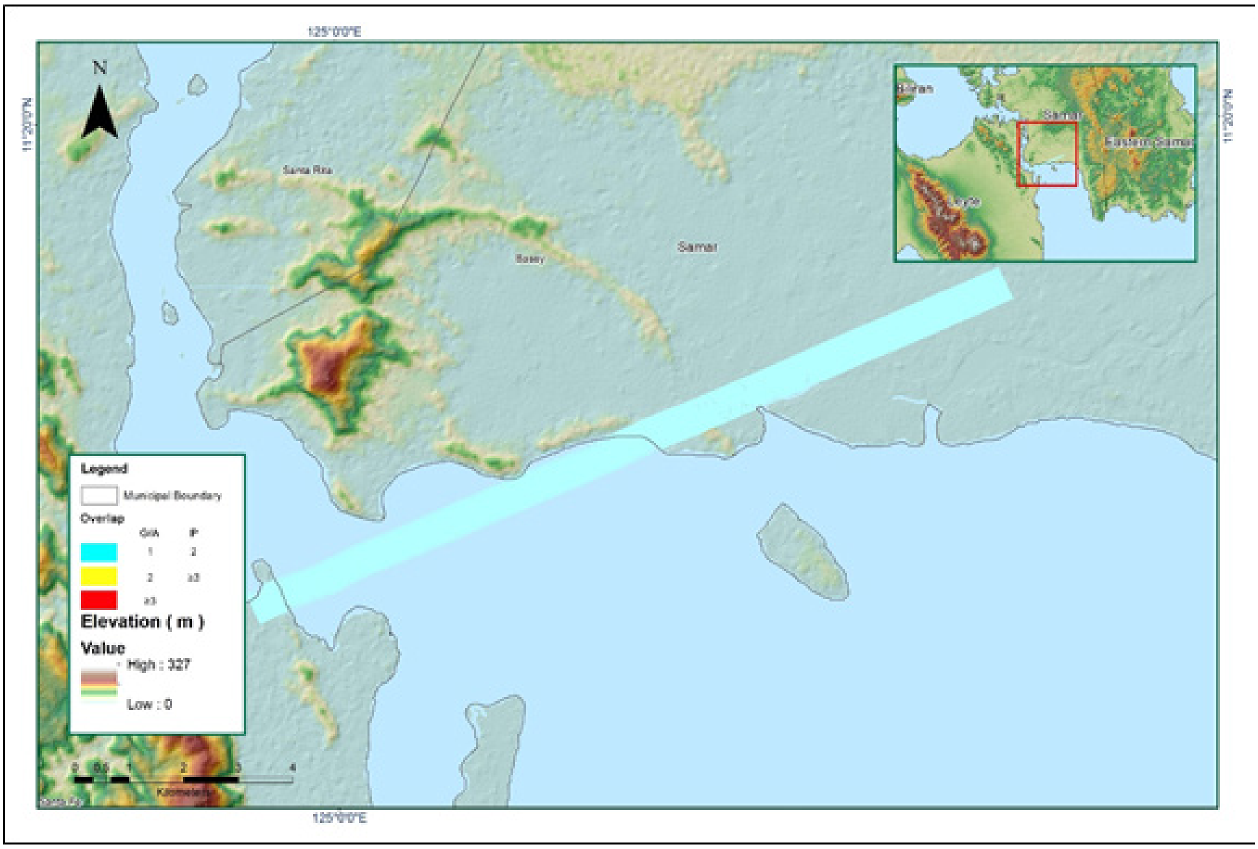


Figure A 8.54 Image of data overlap

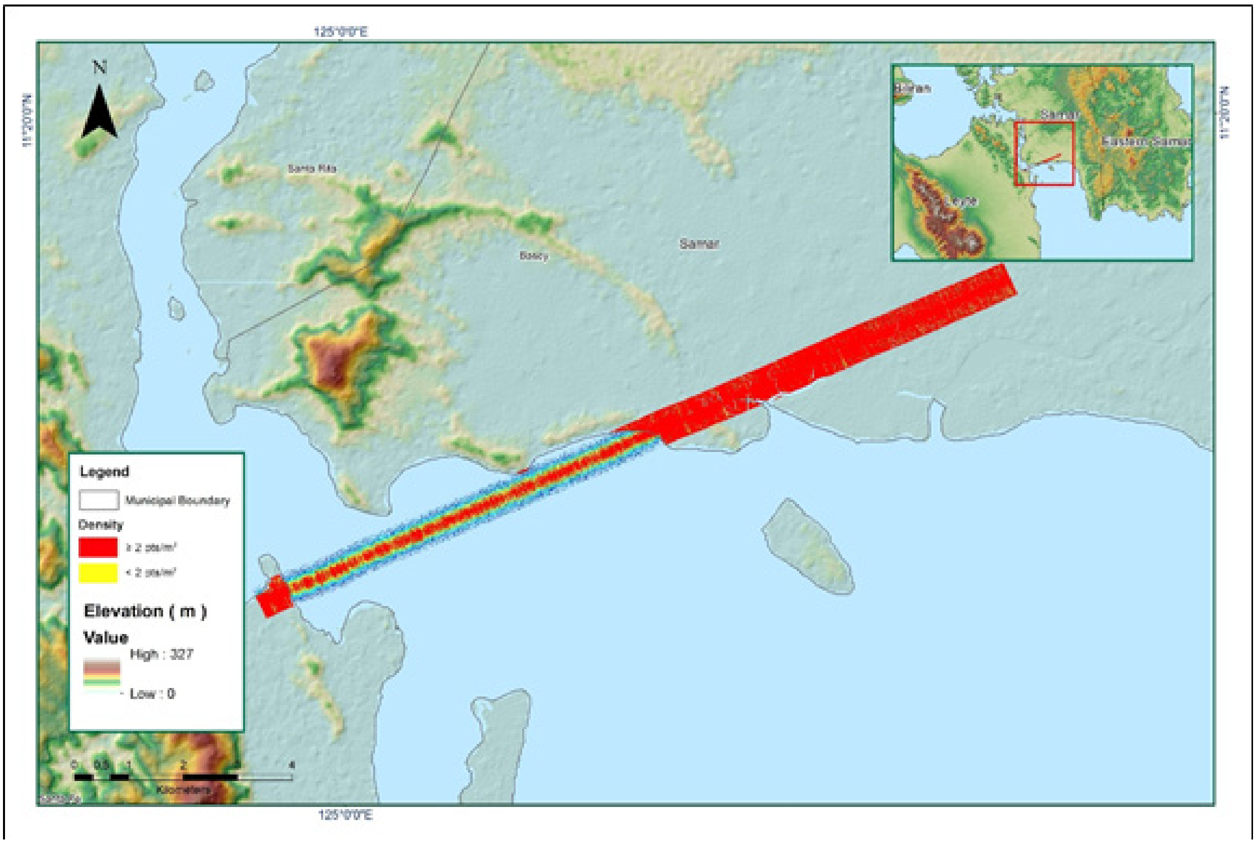


Figure A 8.55 Density map of merged LiDAR data

Table A-8.9 Mission Summary Report for Blk33G

Flight Area	Samar-Leyte
Mission Name	33G
Inclusive Flights	3731G
Range data size	24.2
POS data size	208
Base data size	3.19
Image	n/a
Transfer date	February 26, 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)	1.5
RMSE for Down Position (<8.0 cm)	3.2
Boresight correction stdev (<0.001deg)	0.056859
IMU attitude correction stdev (<0.001deg)	0.014534
GPS position stdev (<0.01m)	0.0028
Minimum % overlap (>25)	33.88
Ave point cloud density per sq.m. (>2.0)	4.58
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	163
Maximum Height	878.23 m
Minimum Height	60.91 m
Classification (# of points)	
Ground	31,482,852
Low vegetation	14,484,247
Medium vegetation	240,244,360
High vegetation	329,944,677
Building	458,985
Orthophoto	No
Processed by	Engr. Abigail Joy Ching, Ma. Joanne Balaga, Marie Denise Bueno

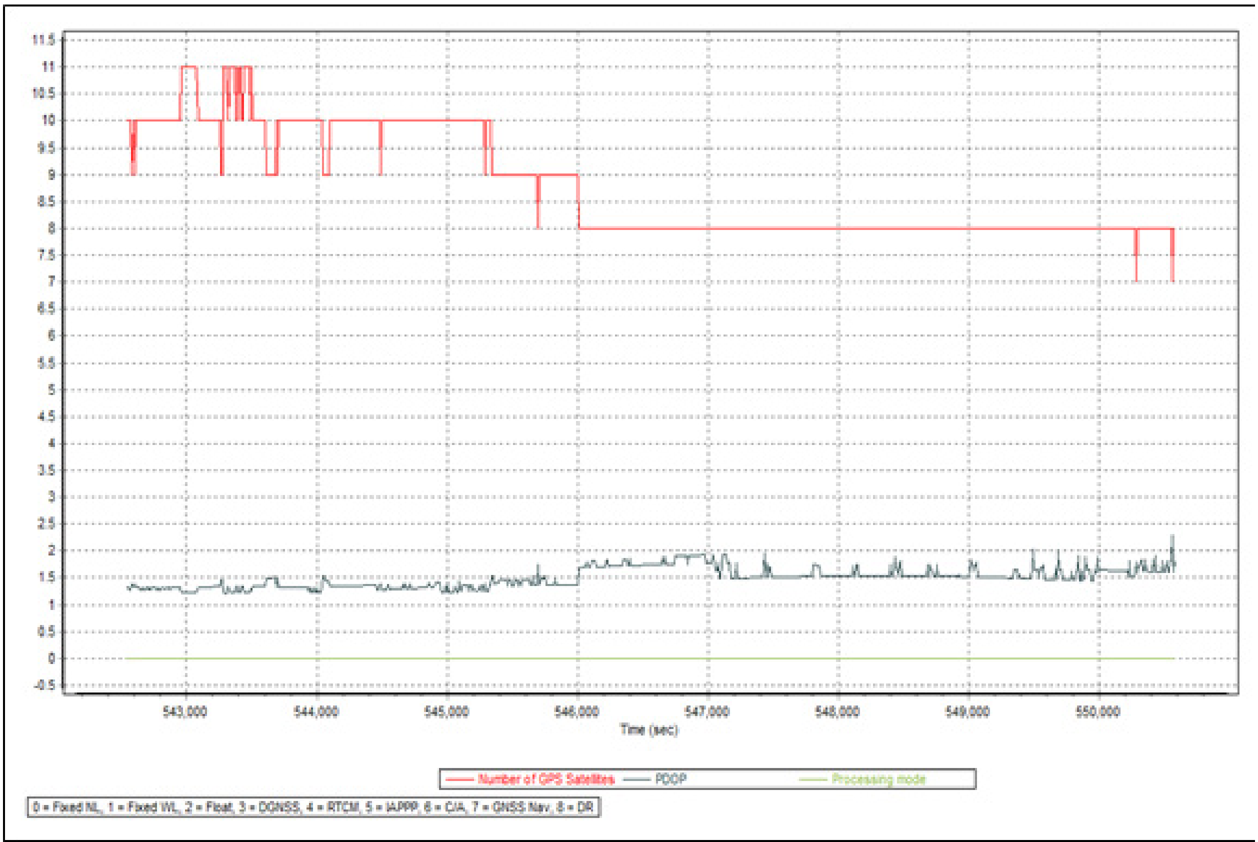


Figure A 8.55 Solution Statust

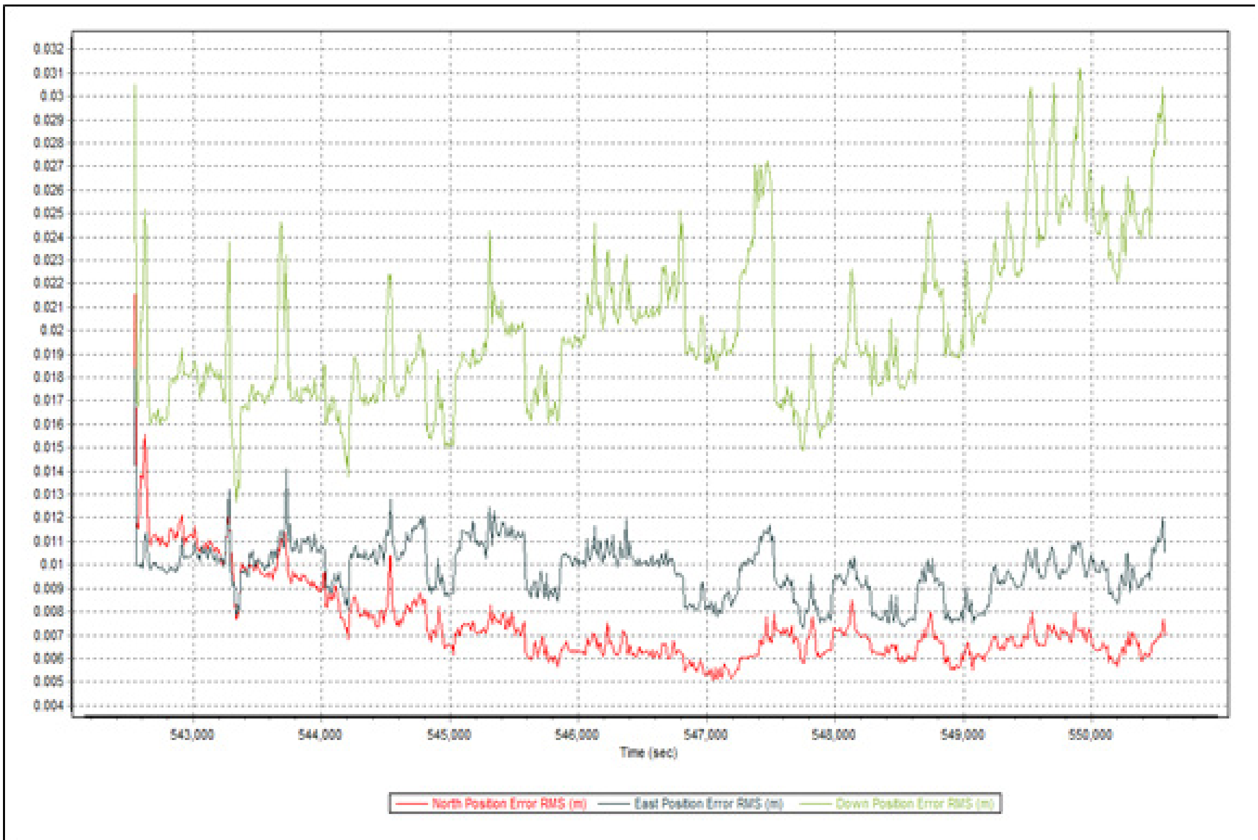


Figure A 8.56 Smoothed Performance Metric Parameters

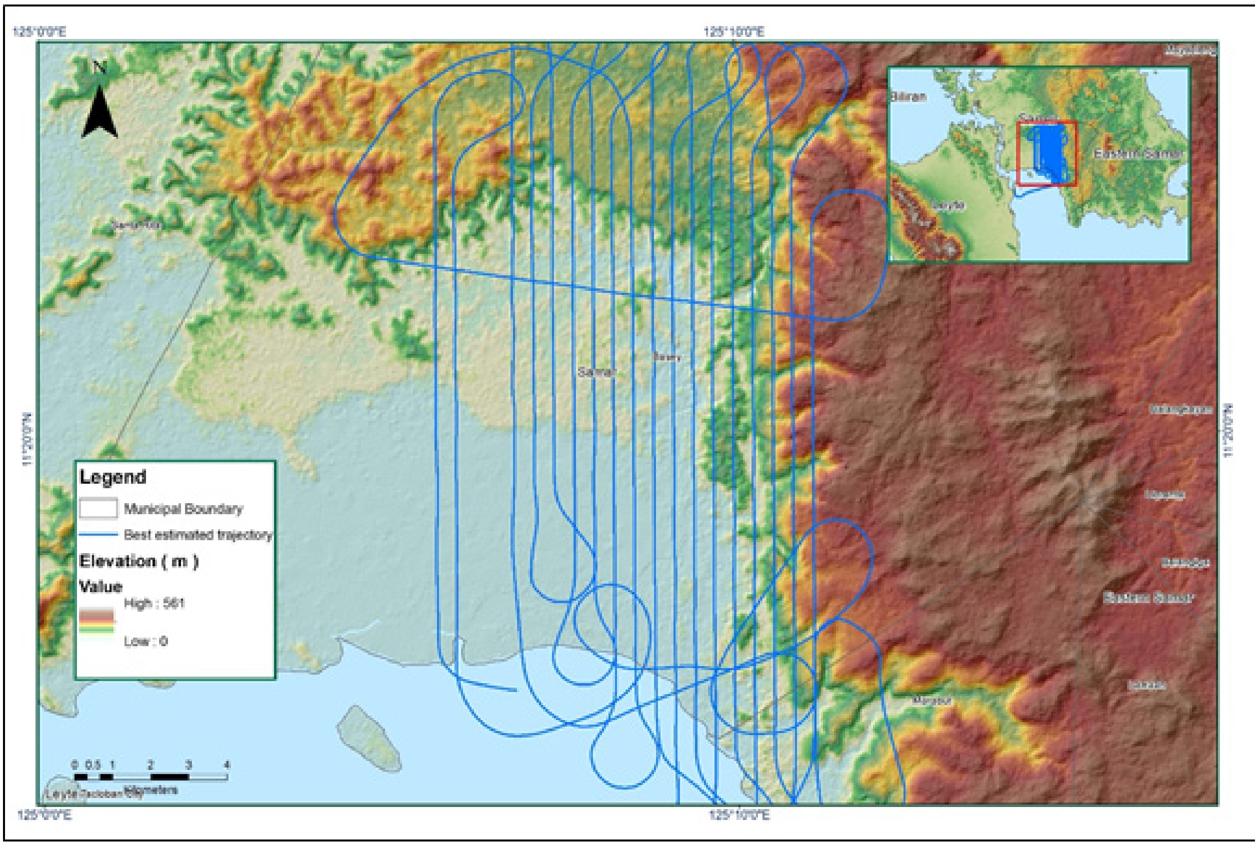


Figure A 8.57 Best Estimated Trajectory

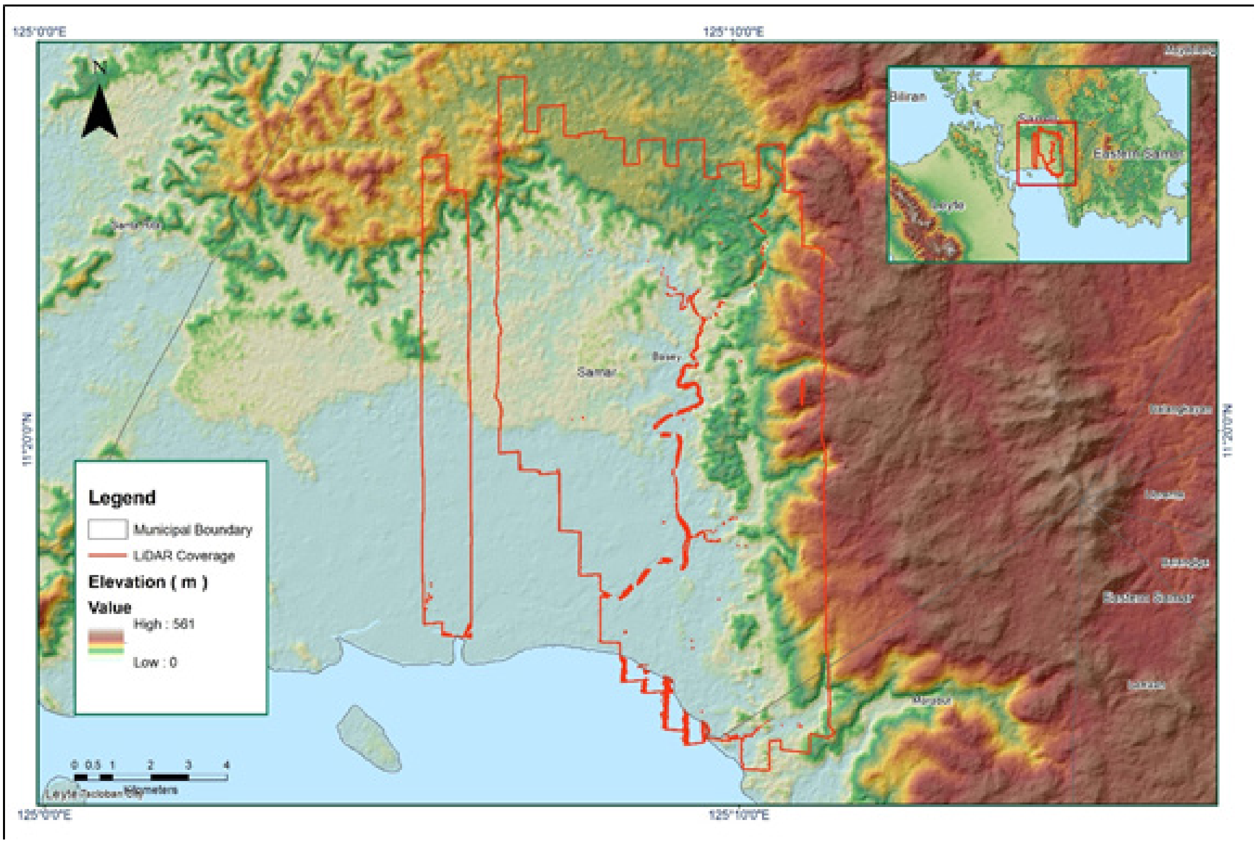


Figure A 8.58 Coverage of LiDAR Data

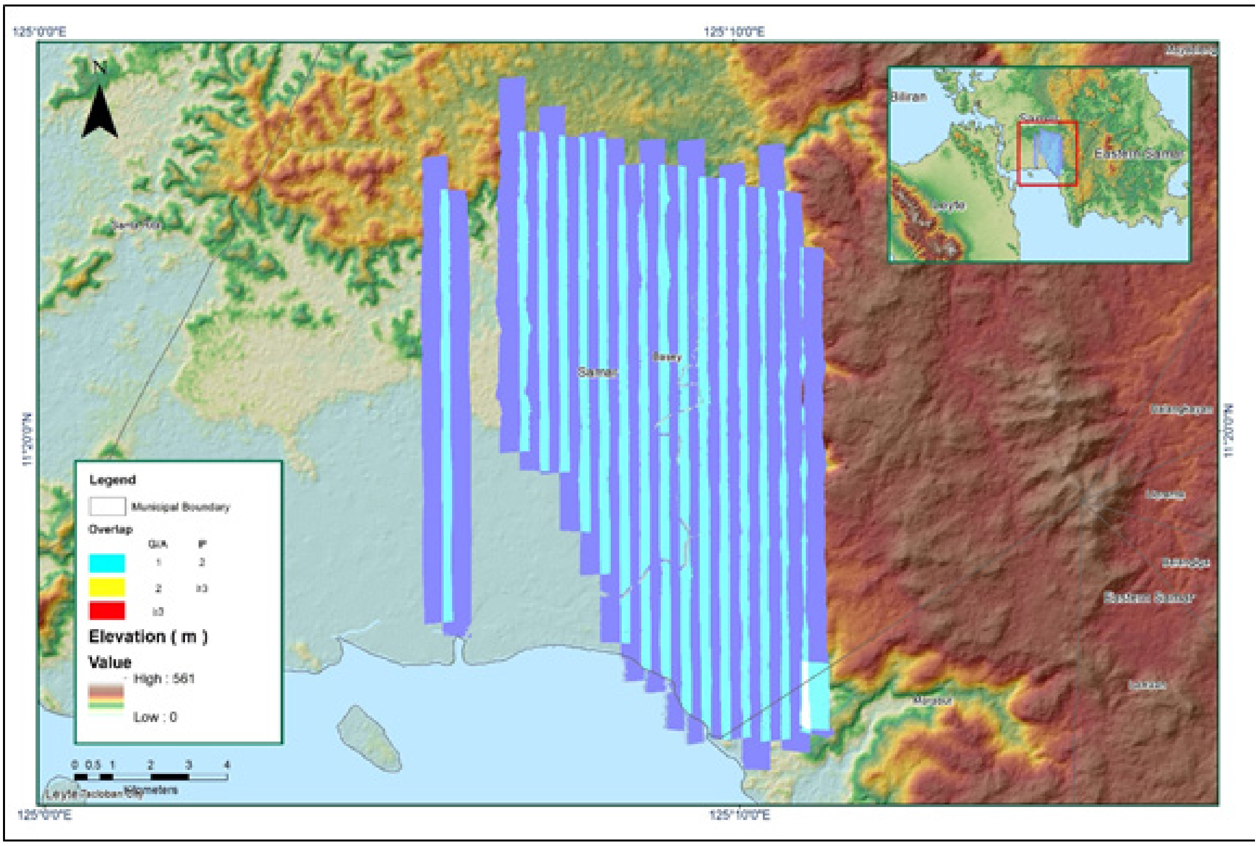


Figure A 8.59 Image of data overlap

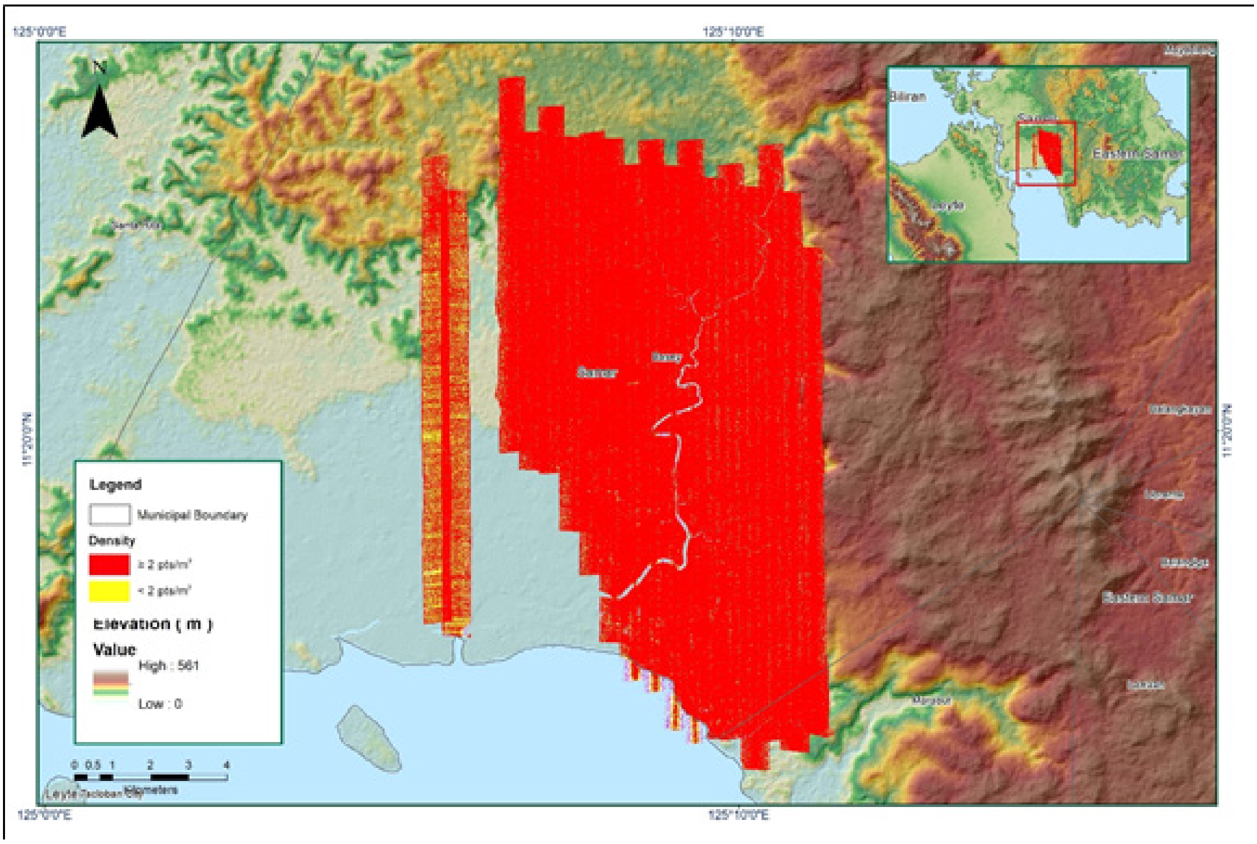


Figure A 8.60 Density map of merged LiDAR data

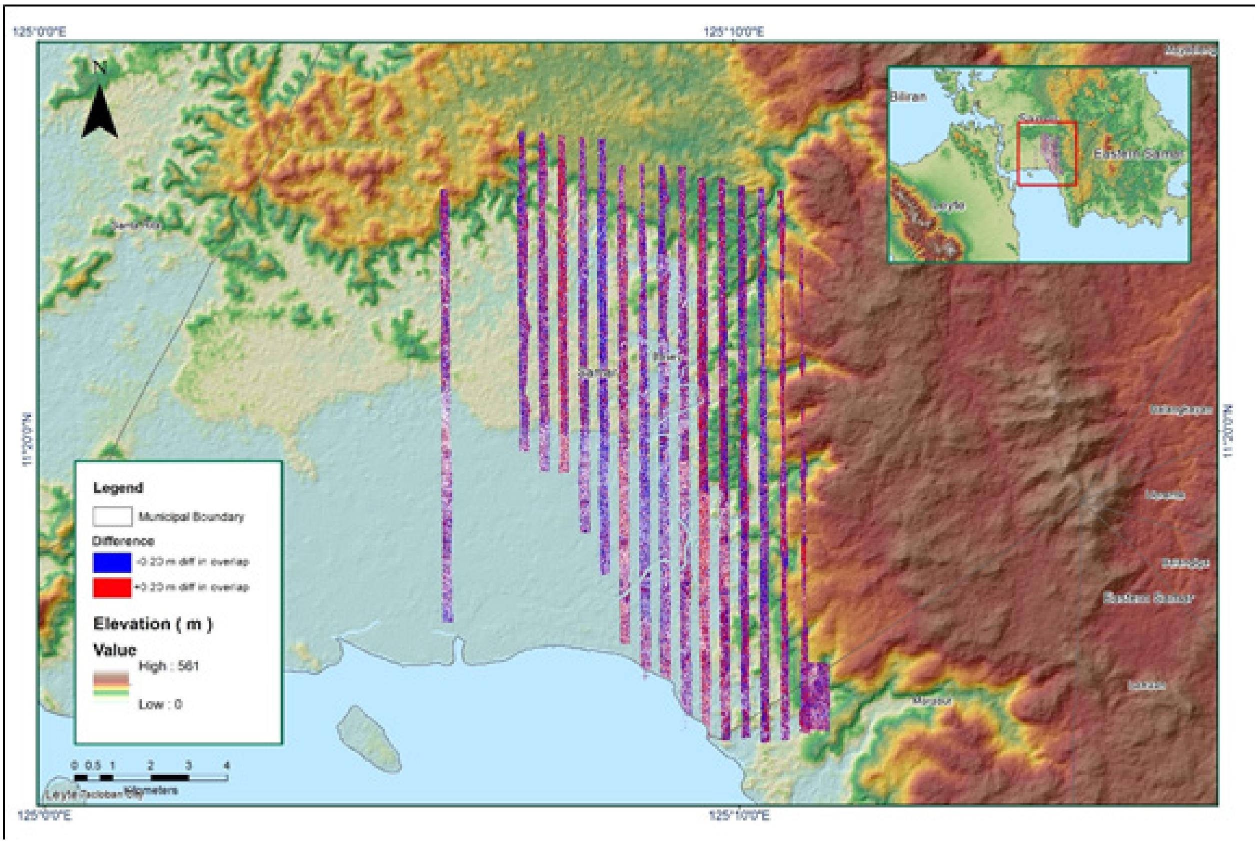


Figure A 8.61 Elevation difference between flight lines

Table A-8.10 Mission Summary Report for Blk34AX

Flight Area	Samar-Leyte
Mission Name	Blk34AX
Inclusive Flights	7786AC, 7798AC
Range data size	19.6 GB
POS	440 MB
Base data size	41.28 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)	1.35
RMSE for East Position (<4.0 cm)	1.32
RMSE for Down Position (<8.0 cm)	2.56
Boresight correction stdev (<0.001deg)	0.000269
IMU attitude correction stdev (<0.001deg)	0.000970
GPS position stdev (<0.01m)	0.0010
Minimum % overlap (>25)	43.46
Ave point cloud density per sq.m. (>2.0)	3.17
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	165
Maximum Height	486.81 m
Minimum Height	58.38 m
Classification (# of points)	
Ground	51,480,658
Low vegetation	54,126,552
Medium vegetation	96,821,393
High vegetation	72,112,485
Building	1,892,628
Orthophoto	No
Processed by	Engr. Sheila-Maye Santillan, Engr. Harmond Santos, Engr. Krisha Marie Bautista

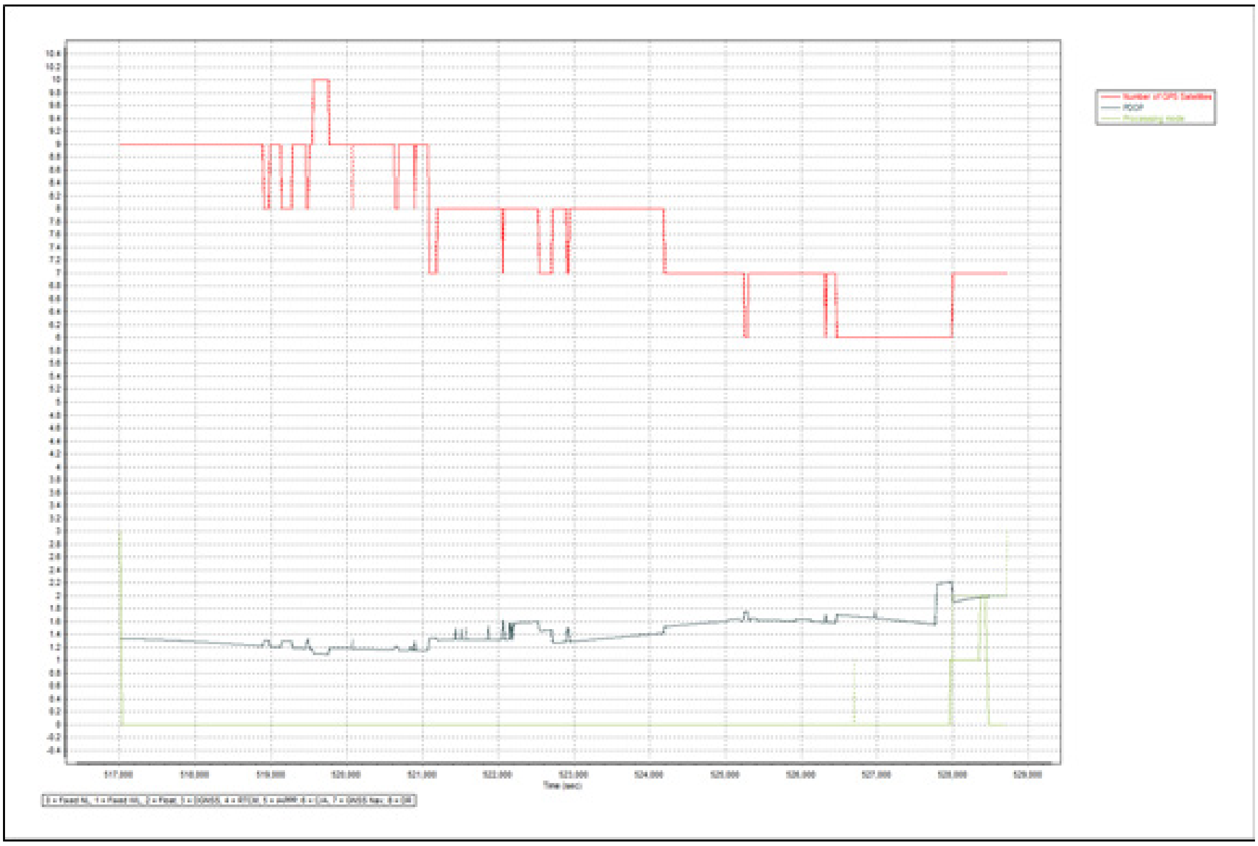


Figure A 8.62Solution Status

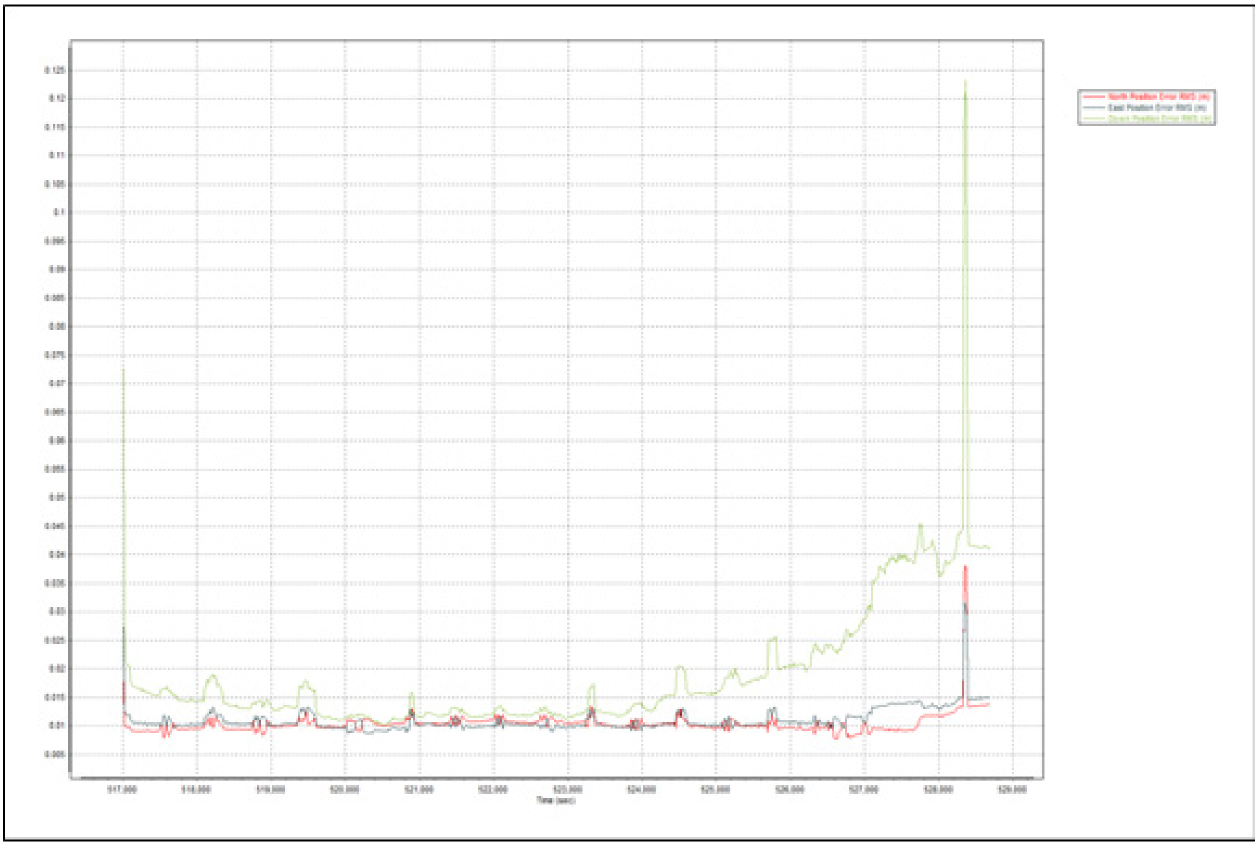


Figure A 8.63 Smoothed Performance Metric Parameters

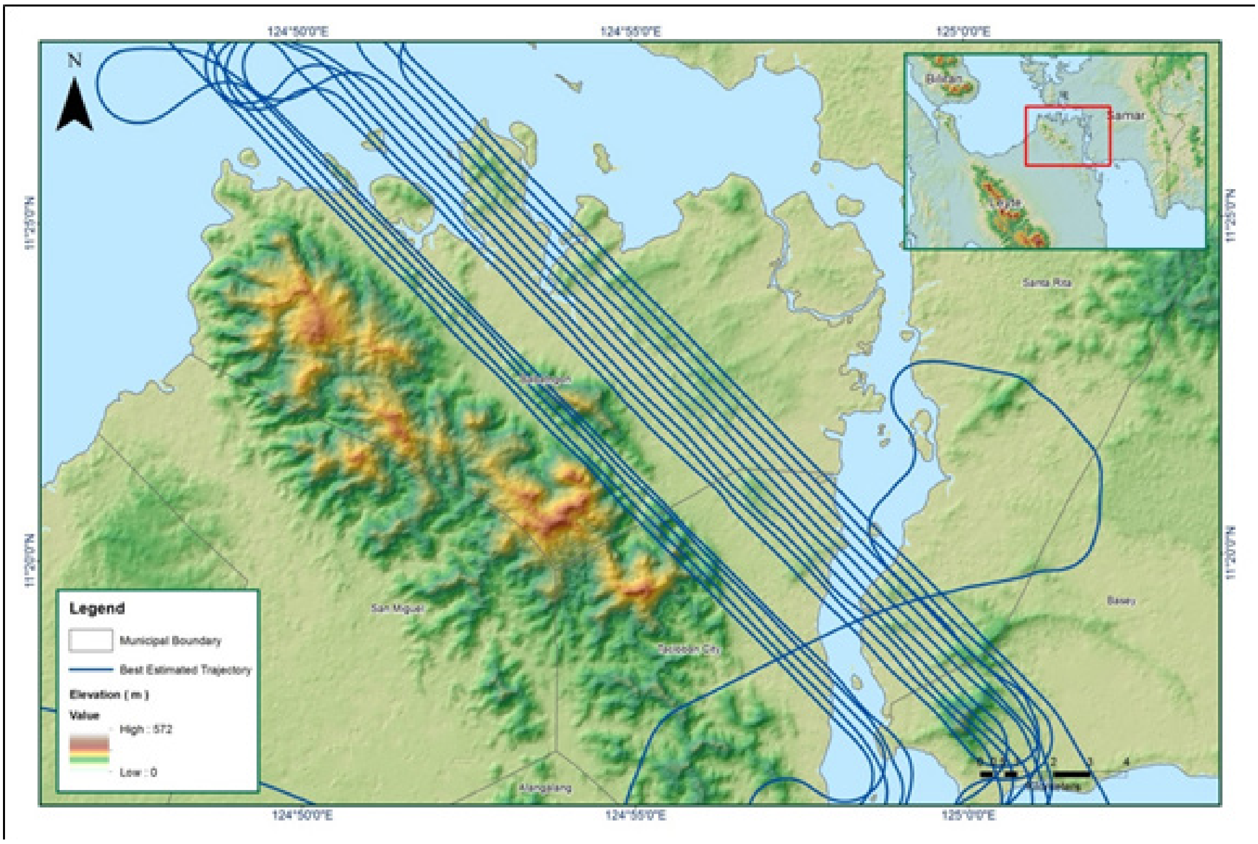


Figure A 8.64 Best Estimated Trajectory

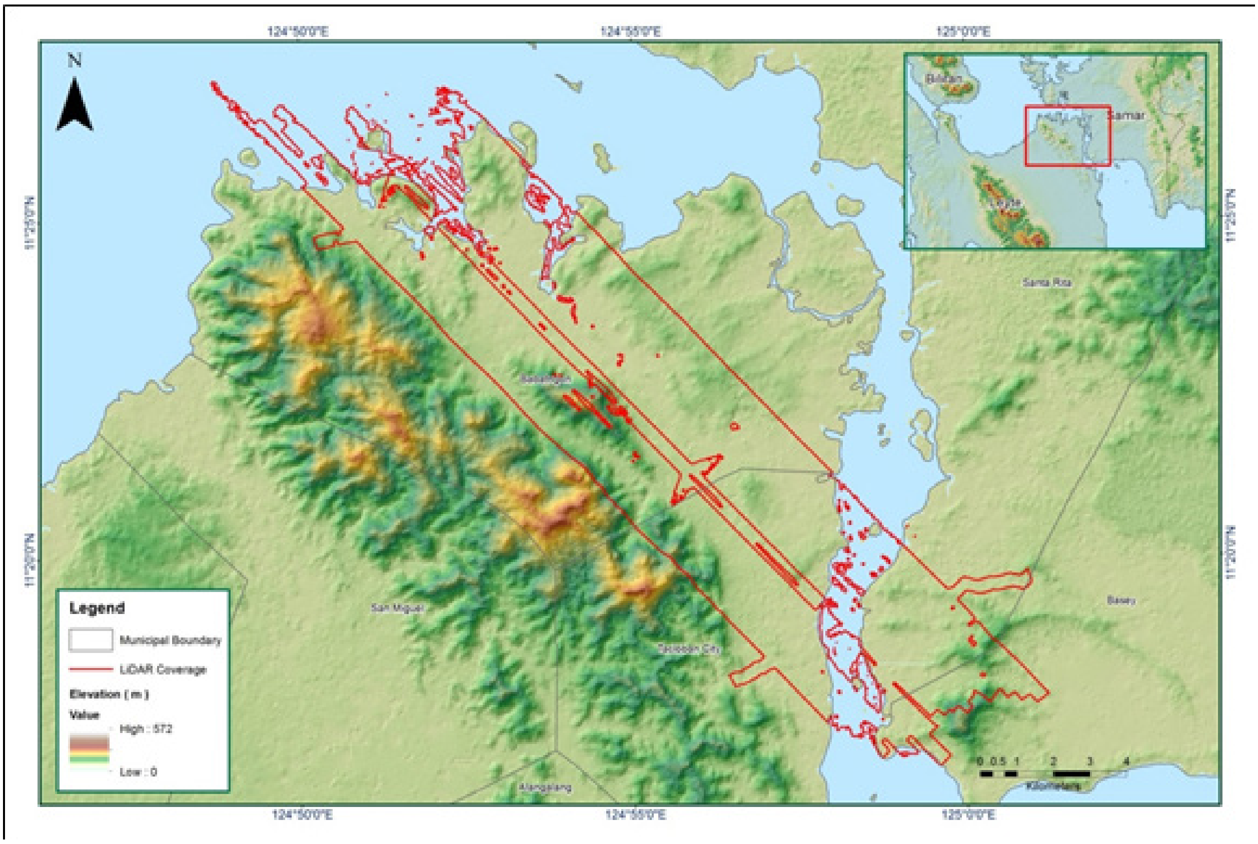


Figure A 8.65 Coverage of LiDAR data

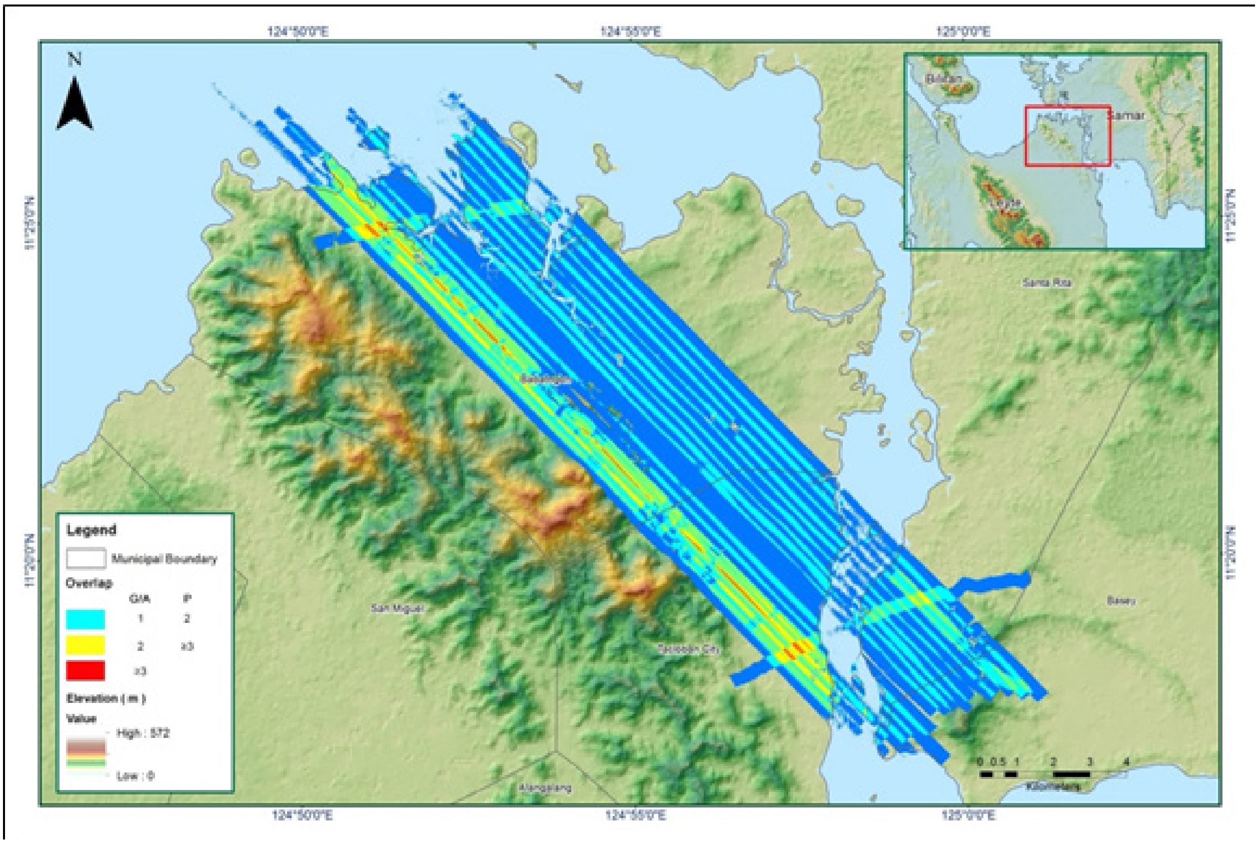


Figure A 8.66 Image of data overlap

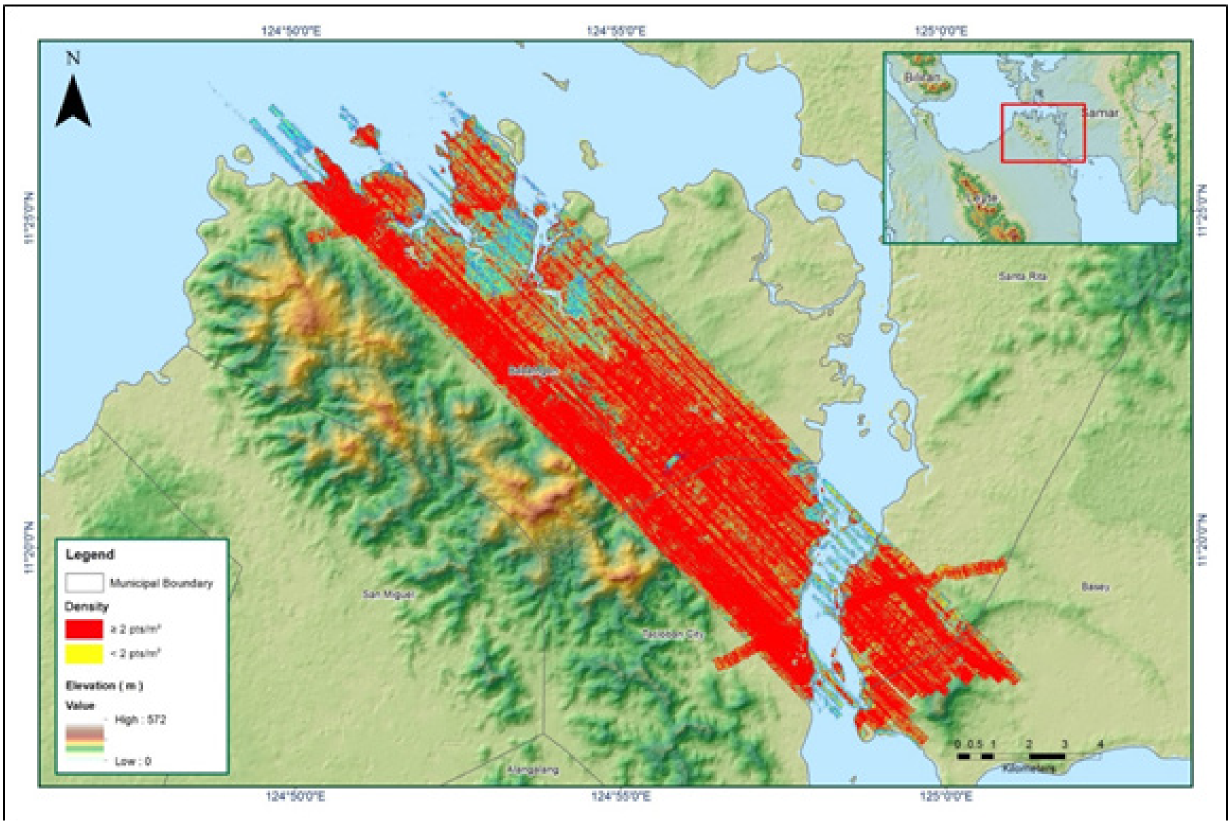


Figure A 8.67 Density map of merged LiDAR data

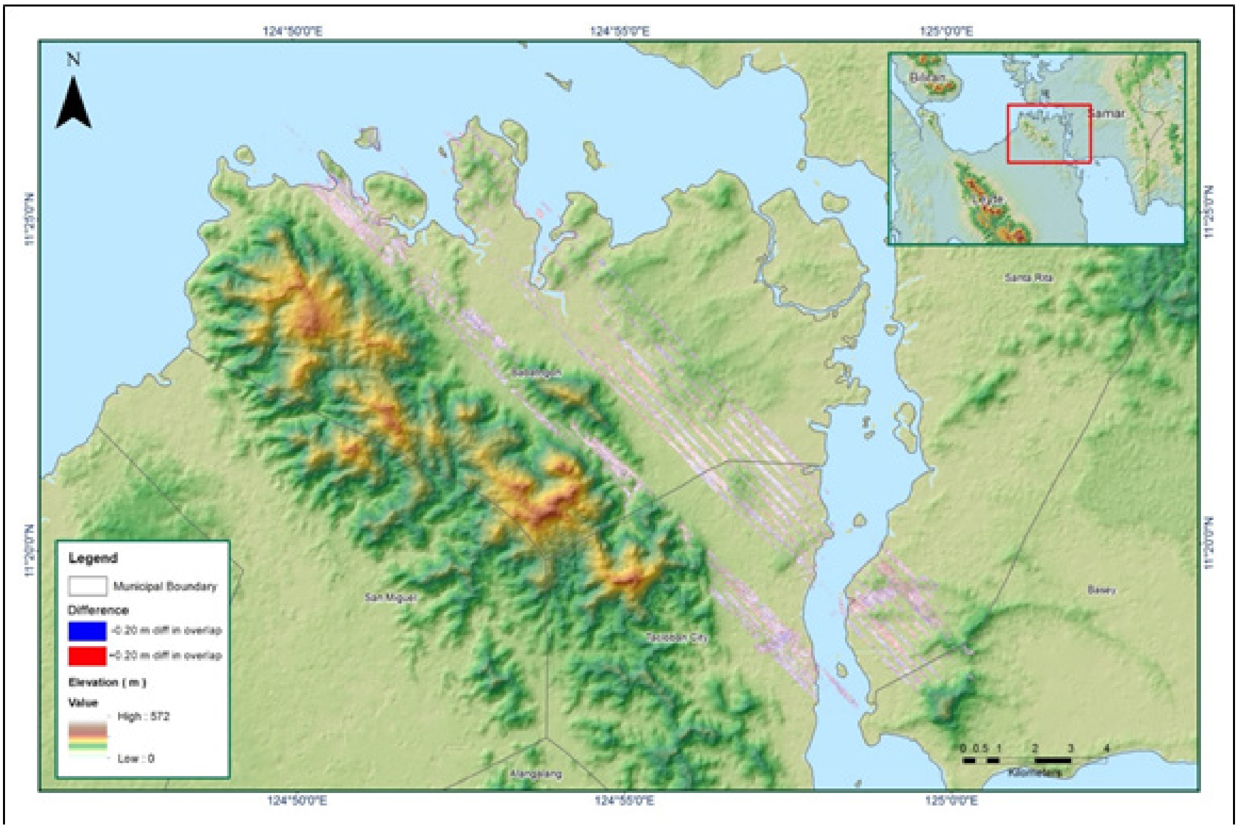


Figure A 8.68 Elevation difference between flight lines

Flight Area	Samar-Leyte
Mission Name	Blk34AX_additional
Inclusive Flights	7798AC
Range data size	7.81 GB
POS data size	186 MB
Base data size	31.8 MB
Image	N/A
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)	1.75
RMSE for East Position (<4.0 cm)	1.75
RMSE for Down Position (<8.0 cm)	1.83
Boresight correction stdev (<0.001deg)	0.000564
IMU attitude correction stdev (<0.001deg)	0.000970
GPS position stdev (<0.01m)	0.0022
Minimum % overlap (>25)	N/A
Ave point cloud density per sq.m. (>2.0)	1.89
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	24
Maximum Height	272.69 m.
Minimum Height	0.0 m.
Classification (# of points)	
Ground	2,417,317
Low vegetation	1,752,643
Medium vegetation	2,609,904
High vegetation	1,582,659
Building	36,220
Orthophoto	No
Processed by	Engr. Abigail Joy Ching, Engr. Harmond Santos, Krisha

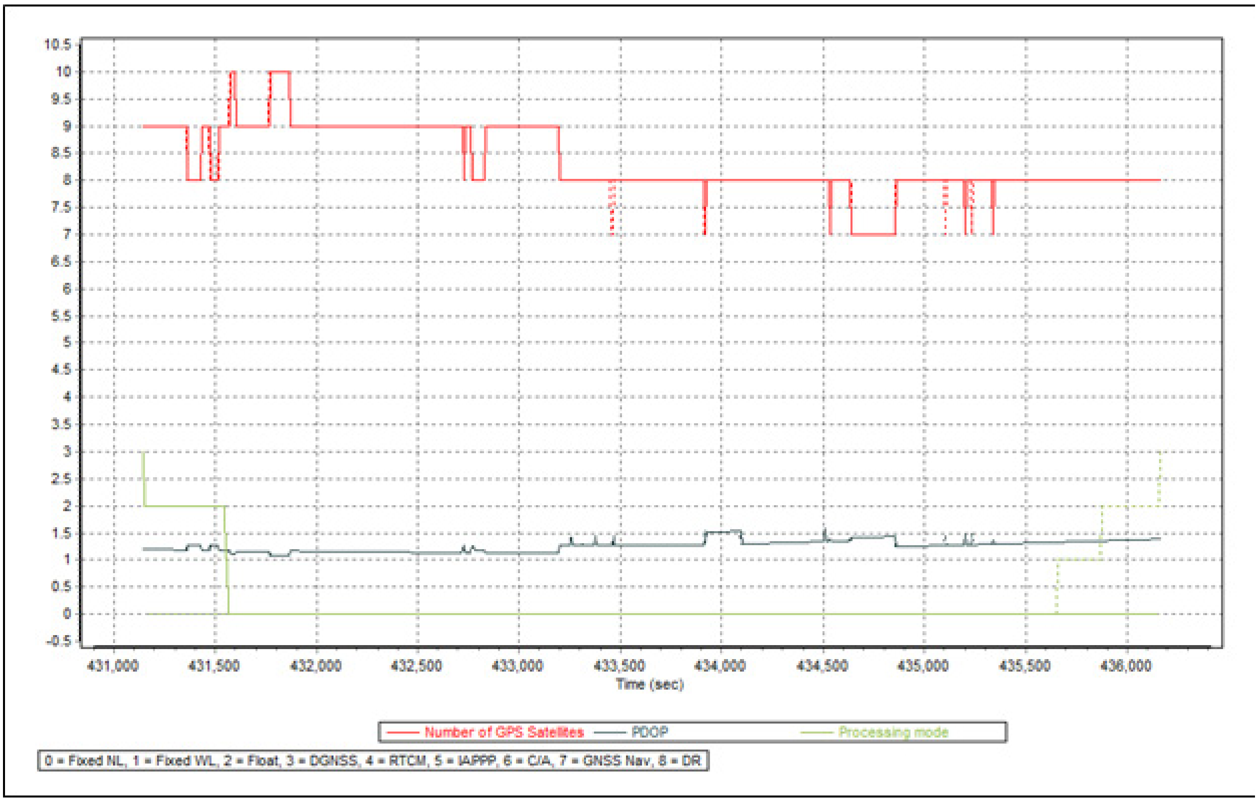


Figure A 8.69 Solution Status

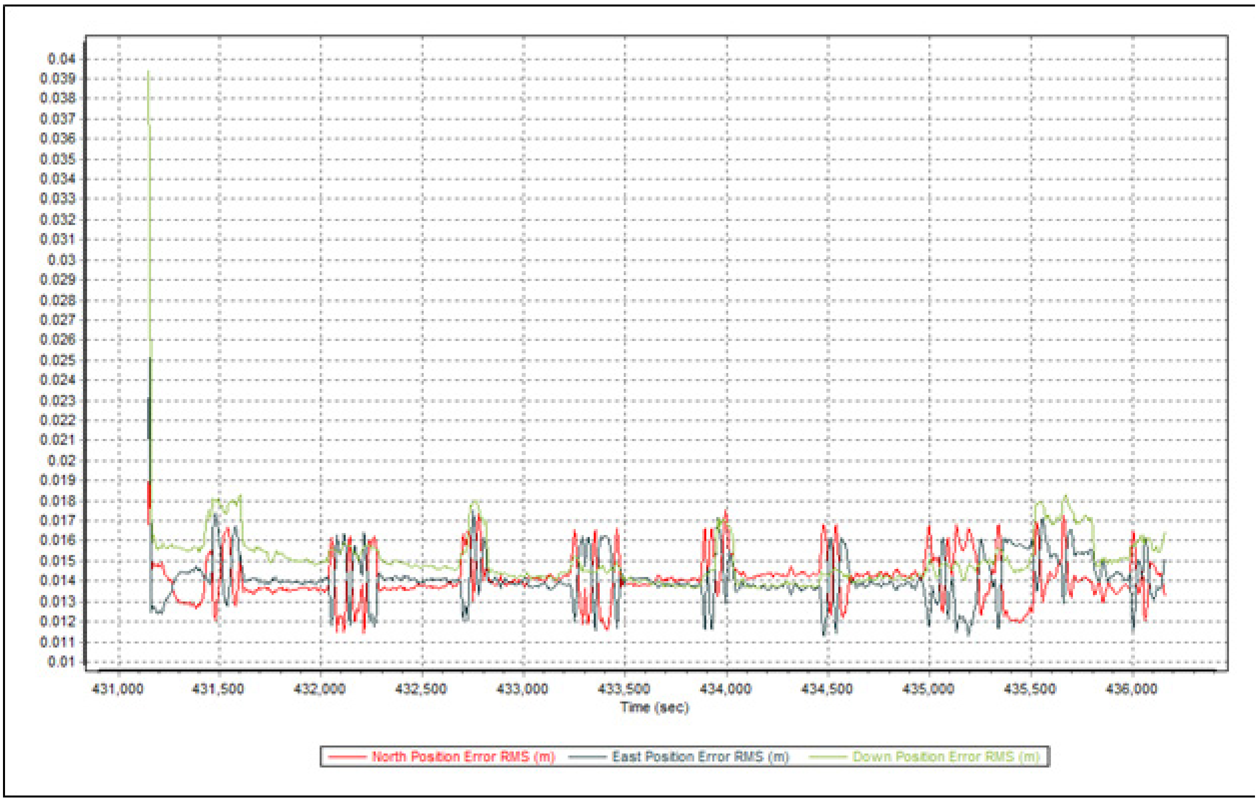


Figure A 8.70 Smoothed Performance Metric Parameters

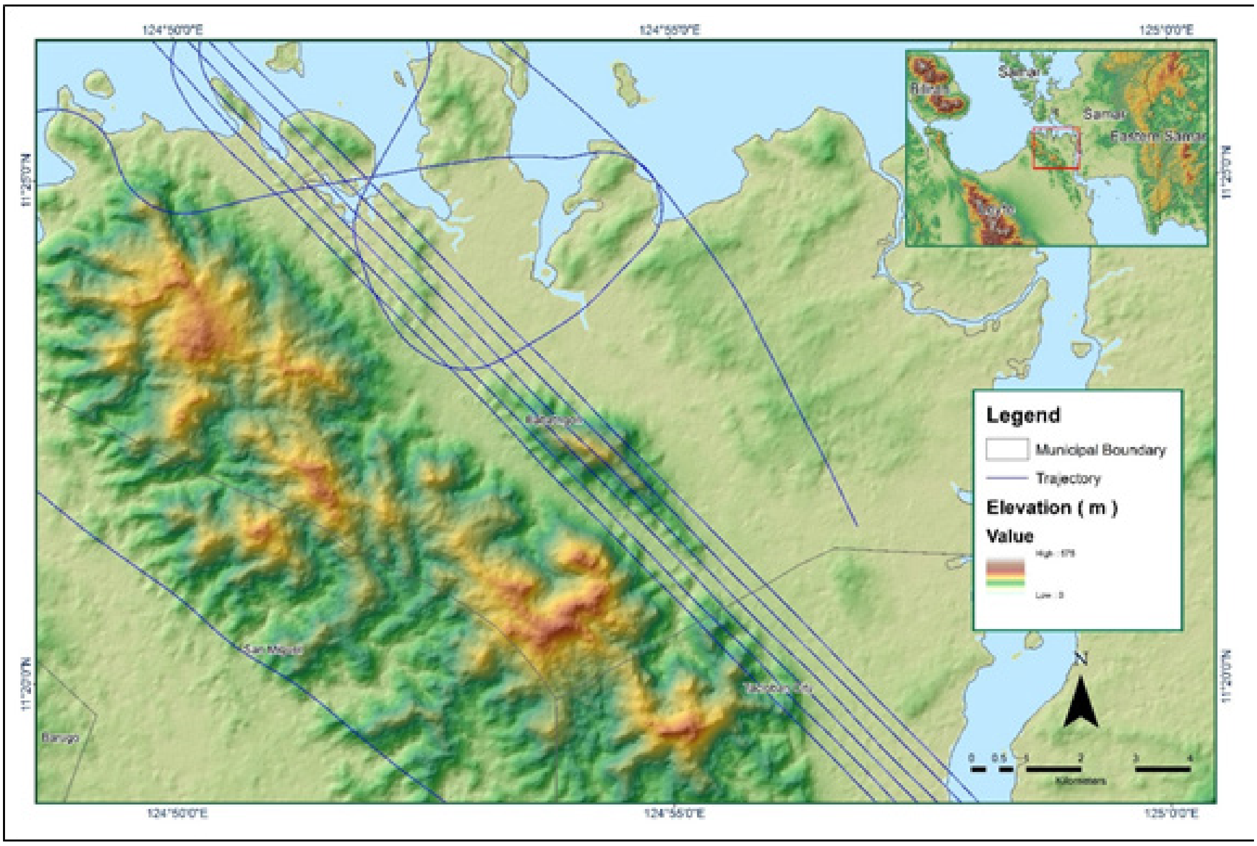


Figure A 8.71 Best Estimated Trajectory

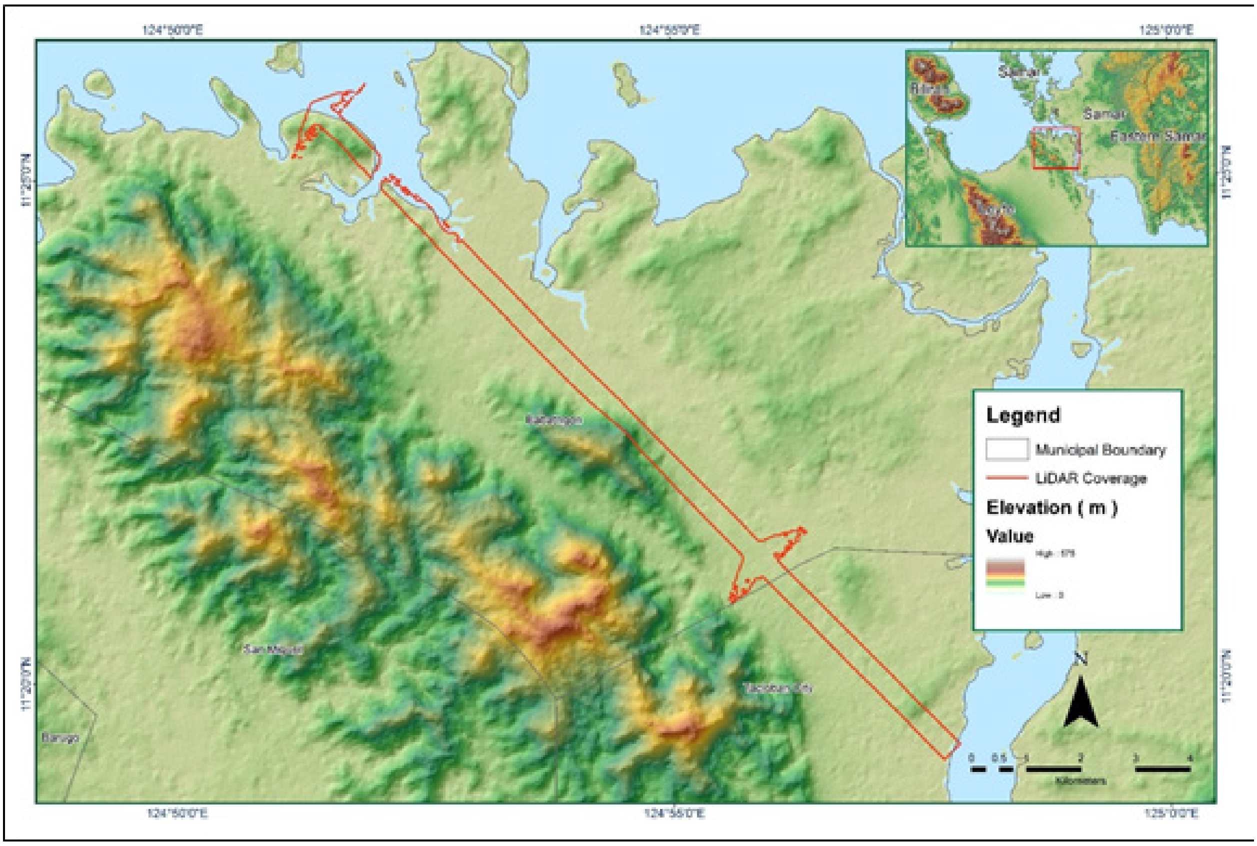


Figure A 8.72Coverage of LiDAR data

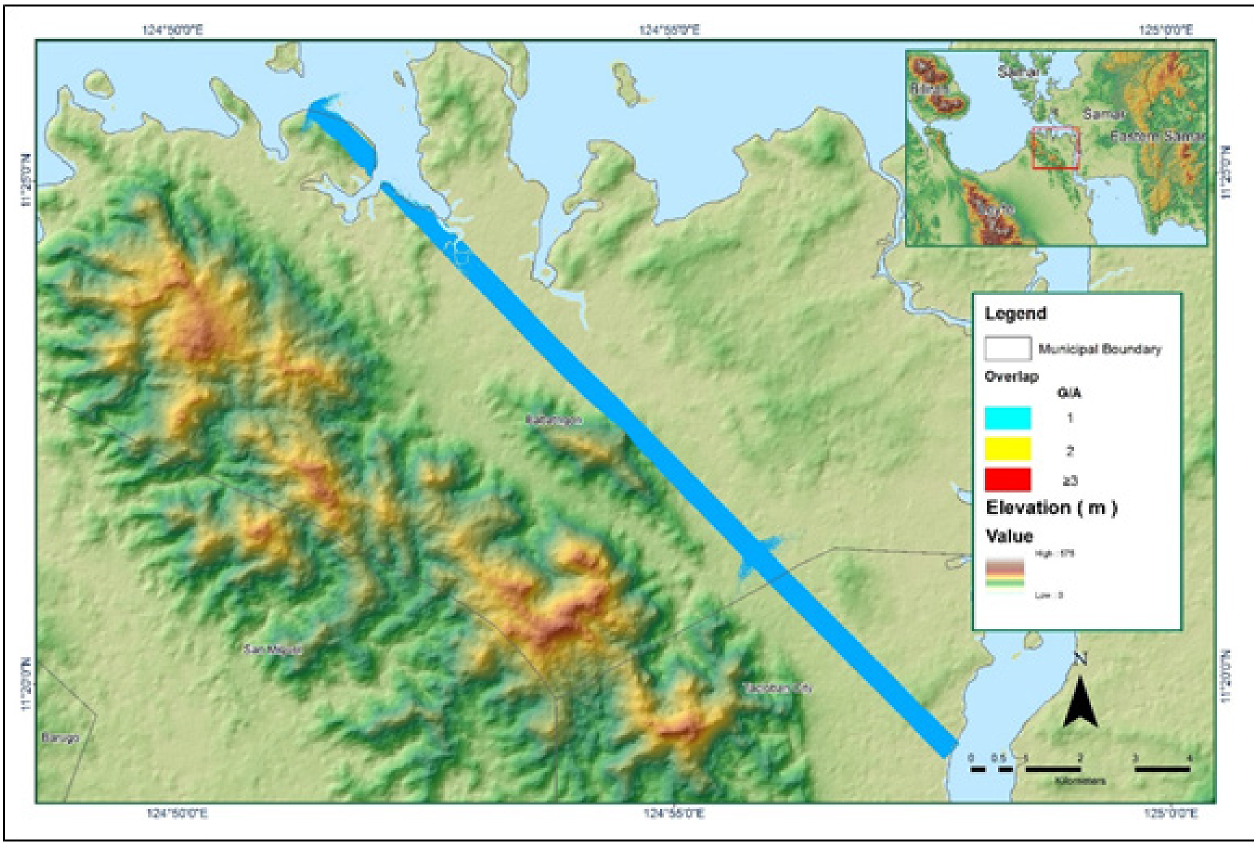


Figure A 8.73 Image of data overlap

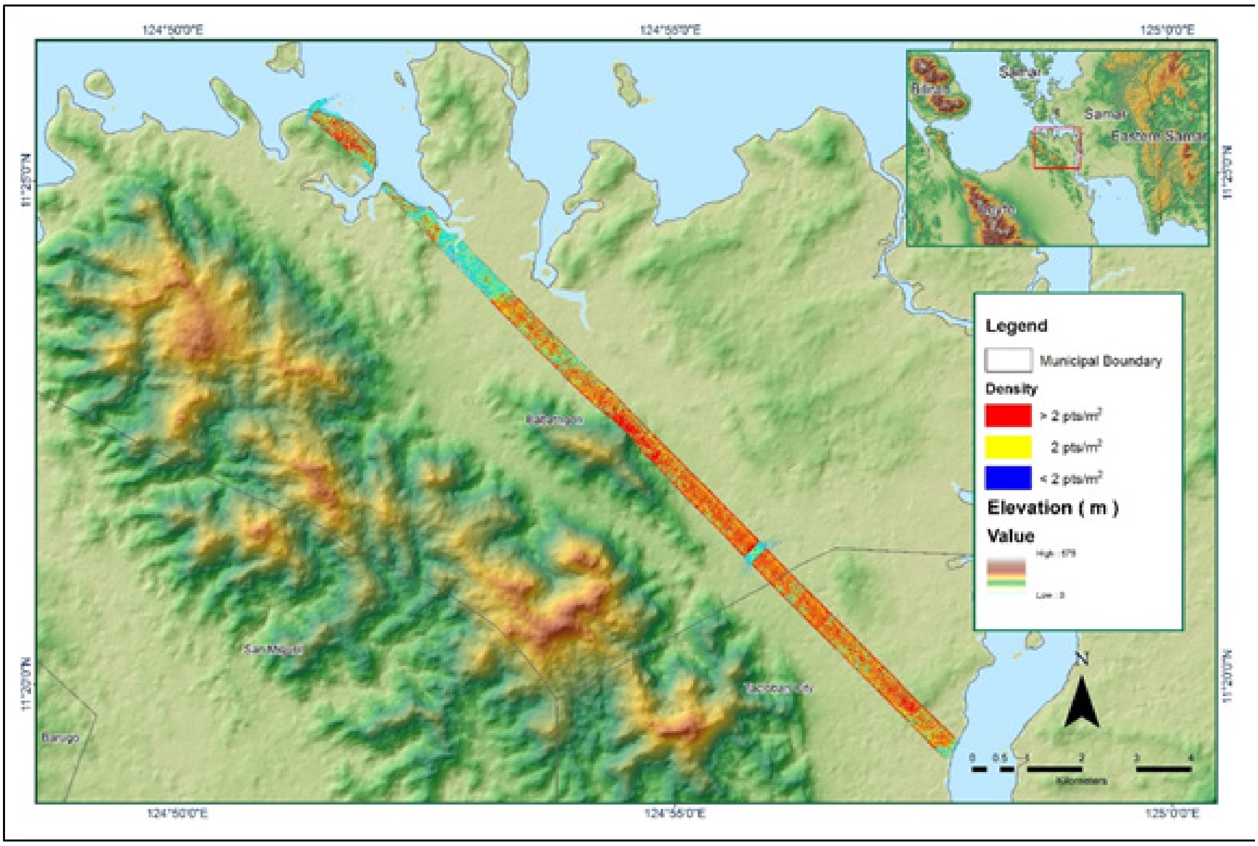


Figure A 8.74 Density map of merged LiDAR data

Flight Area	Samar-Leyte
Mission Name	1022A
Inclusive Flights	1022A
Range data size	18.9 GB
POS	242 MB
Image	75.3 GB
Transfer date	February 3, 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)	3.1
RMSE for East Position (<4.0 cm)	1.7
RMSE for Down Position (<8.0 cm)	5.0
Boresight correction stdev (<0.001deg)	0.018287
IMU attitude correction stdev (<0.001deg)	0.088089
GPS position stdev (<0.01m)	0.018843
Minimum % overlap (>25)	27.88%
Ave point cloud density per sq.m. (>2.0)	1.60
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	218
Maximum Height	420.48 m
Minimum Height	56.96 m
Classification (# of points)	
Ground	204,739,490
Low vegetation	116,809,603
Medium vegetation	339,586,405
High vegetation	57,374,755
Building	9,080,871
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Melanie Hingpit, Engr. Gladys Mae Apat

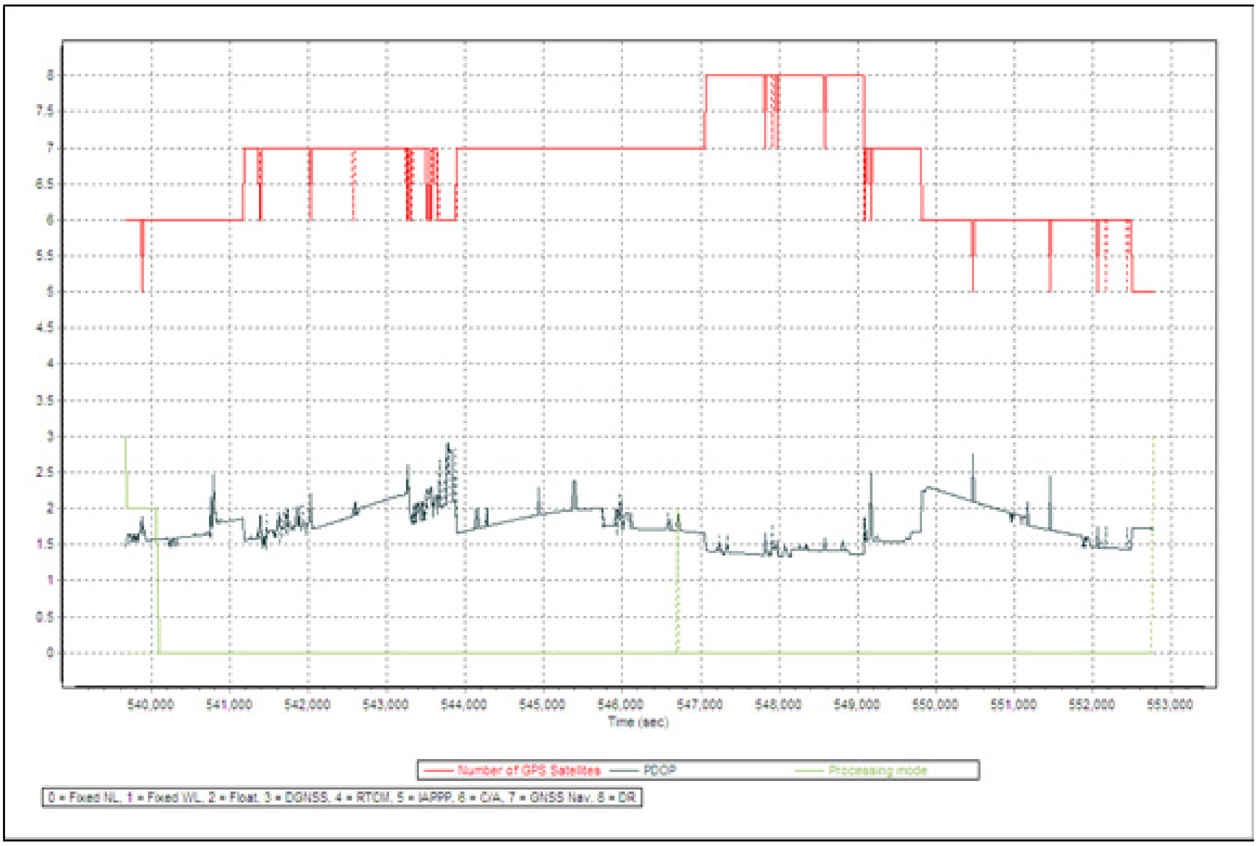


Figure A 8.75 Solution Status

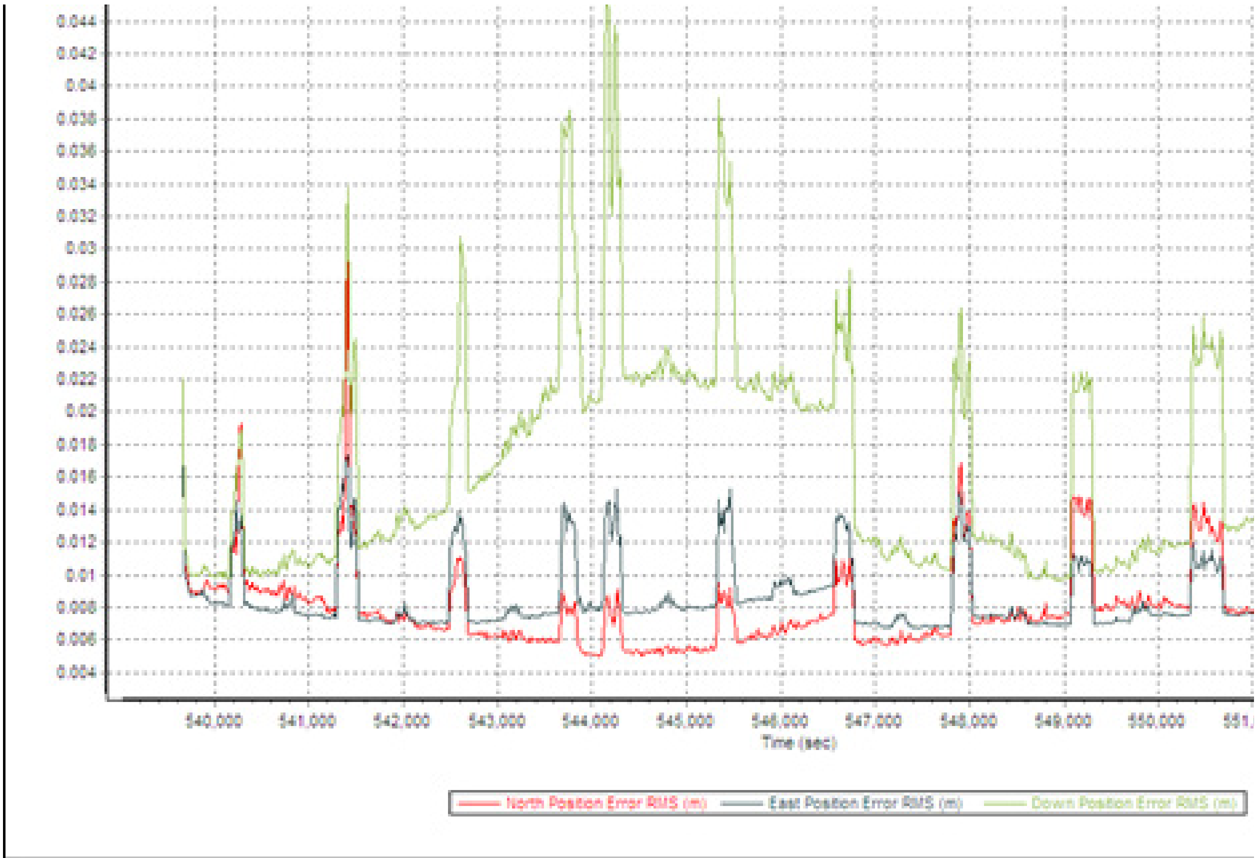


Figure A 8.76 Smoothed Performance Metrics Parameters

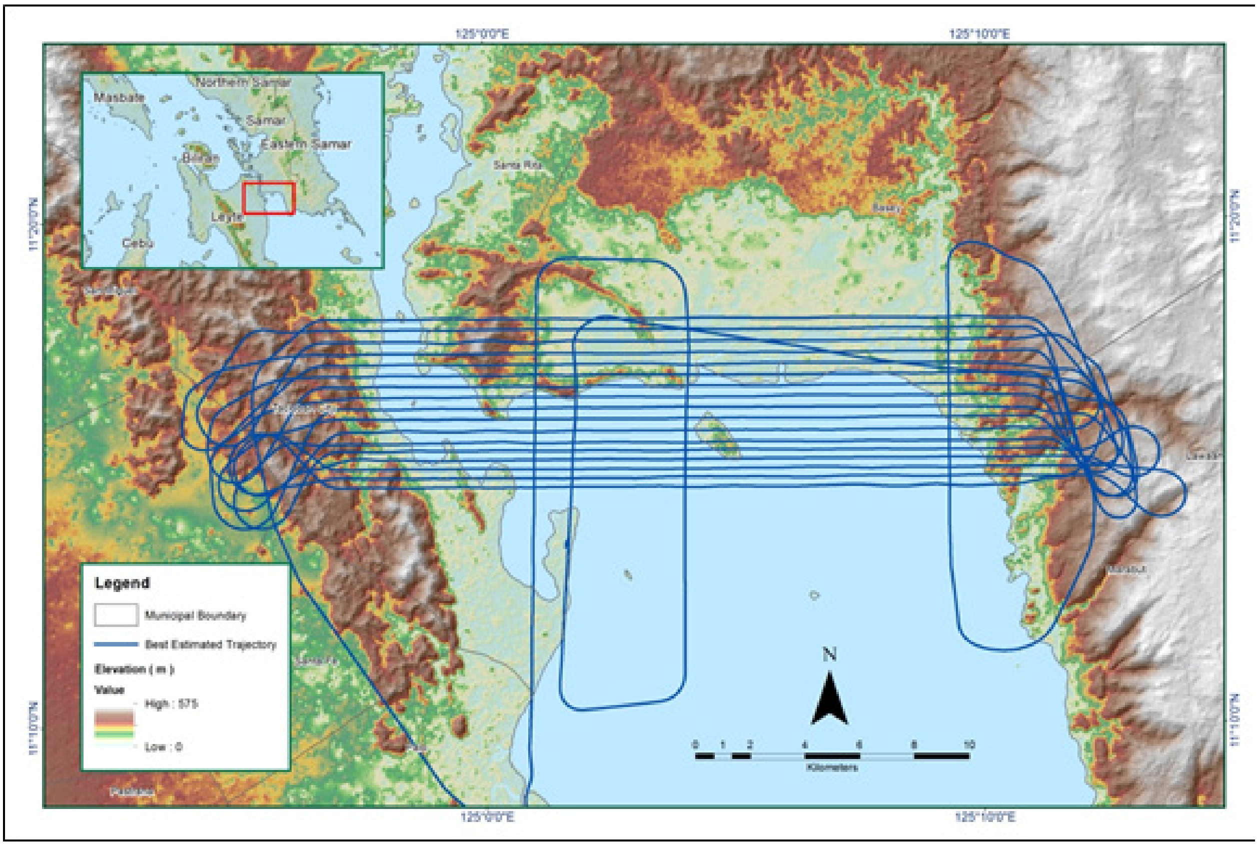


Figure A 8.77 Best Estimated Trajectory

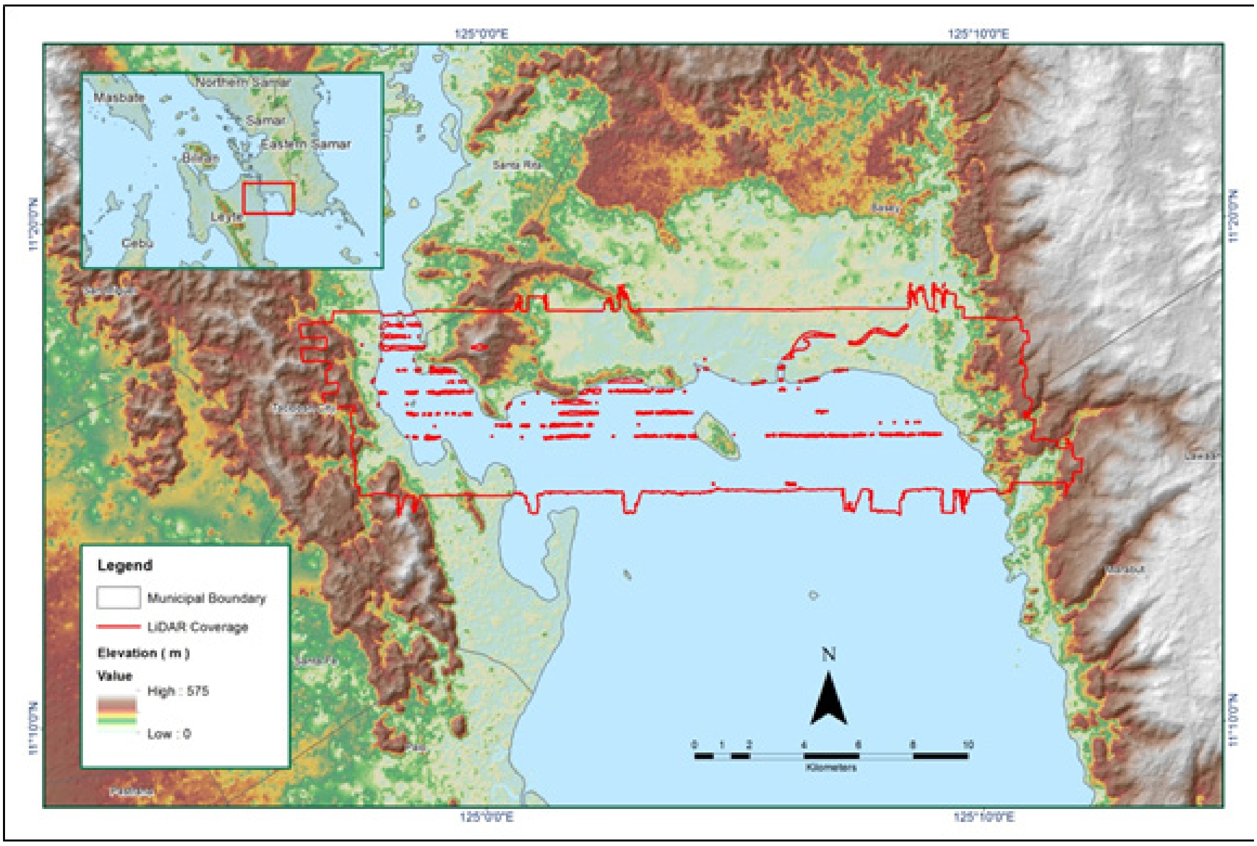


Figure A 8.78 Coverage of LiDAR data

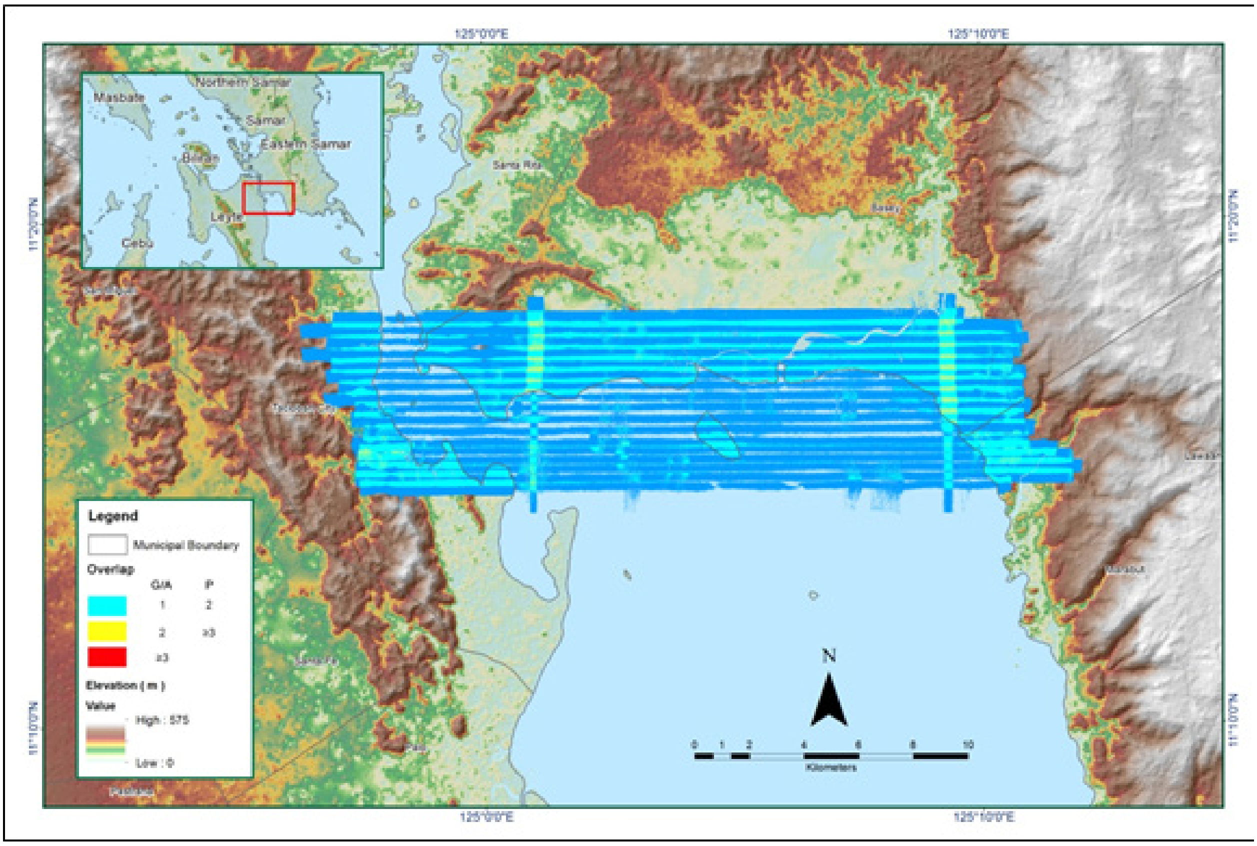


Figure A 8.79 Image of data overlap

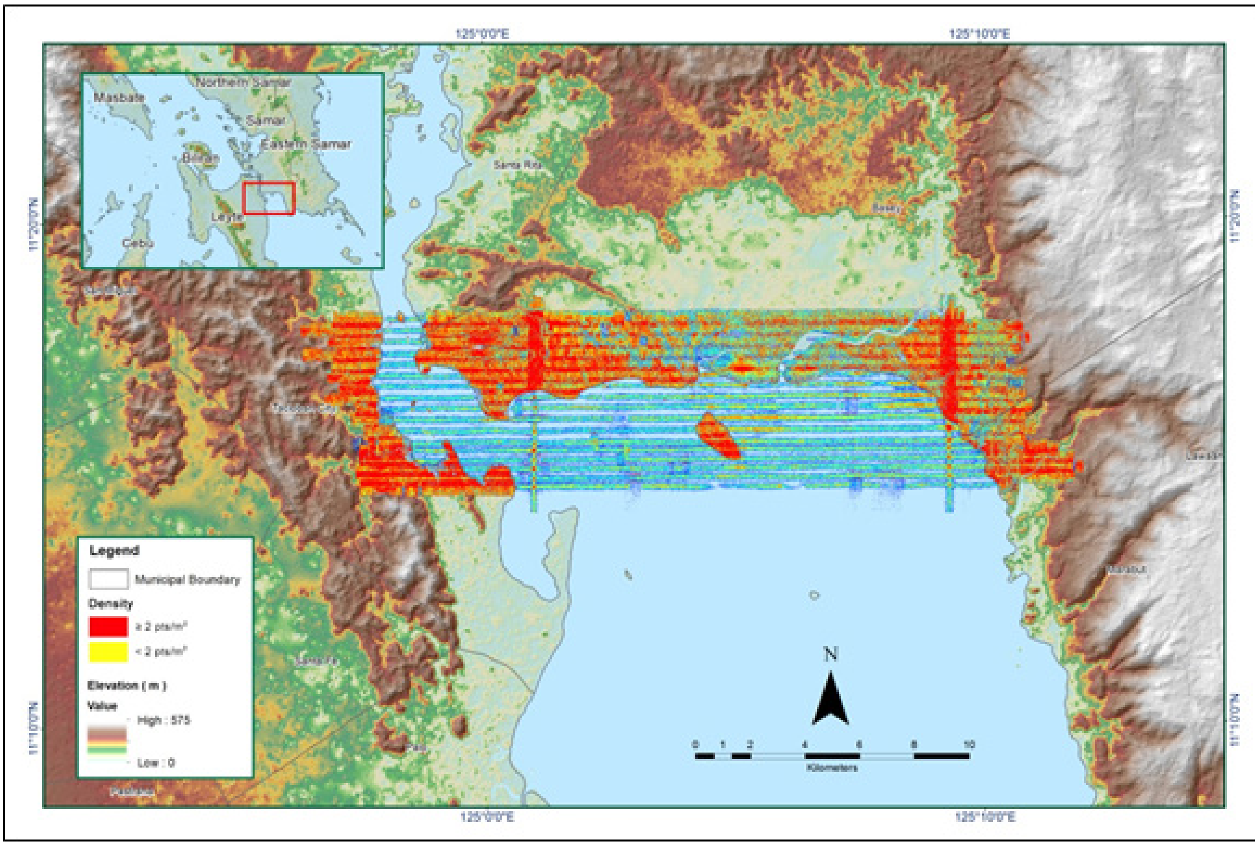


Figure A 8.80 Density map of merged LiDAR data

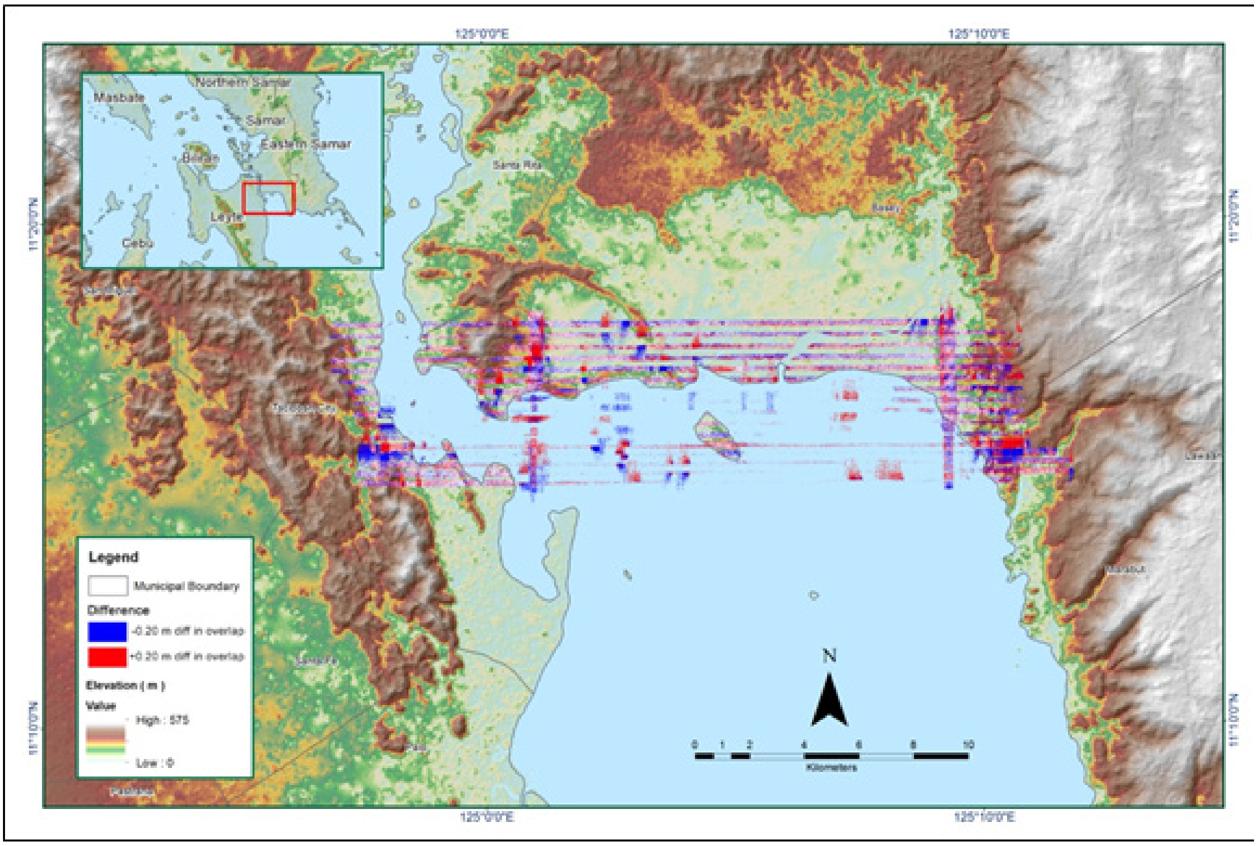


Figure A 8.81 Elevation difference between flight lines

Annex 9. Basey 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
W580	39.7265	99	0	0.10376	0.01881	1.4018	0.9	Ratio to Peak	0.01	0.25
W570	89.3169	99	0	2.0847	0.378	1.4018	0.9	Ratio to Peak	0.01	0.25
W560	46.5764	99	0	1.8347	0.3327	1.4018	0.9	Ratio to Peak	0.01	0.25
W550	151.213	99	0	5.168	0.937	1.4018	0.9	Ratio to Peak	0.01	0.25
W540	46.9726	99	0	0.6978	0.1265	1.4018	0.9	Ratio to Peak	0.01	0.25
W530	51.6607	99	0	1.391	0.2522	1.4018	0.9	Ratio to Peak	0.01	0.25
W520	46.9726	99	0	1.1295	0.2048	1.4018	0.9	Ratio to Peak	0.01	0.25
W510	46.9726	99	0	2.8529	0.517	1.4018	0.9	Ratio to Peak	0.01	0.25
W500	46.9726	99	0	0.5799	0.1052	1.4018	0.9	Ratio to Peak	0.01	0.25
W490	46.9726	99	0	1.6538	0.2999	1.4018	0.9	Ratio to Peak	0.01	0.25
W480	46.9726	99	0	0.9163	0.1662	1.4018	0.9	Ratio to Peak	0.01	0.25
W470	88.8318	99	0	1.4043	0.2546	1.4018	0.9	Ratio to Peak	0.01	0.25
W460	108.71	99	0	1.1627	0.2108	1.4018	0.9	Ratio to Peak	0.01	0.25
W450	46.9726	99	0	1.4008	0.254	1.4018	0.9	Ratio to Peak	0.01	0.25
W440	46.9726	99	0	1.3713	0.2487	1.4018	0.9	Ratio to Peak	0.01	0.25
W430	97.2889	99	0	6.597	1.196	1.4018	0.9	Ratio to Peak	0.01	0.25
W420	89.3691	99	0	3.2796	0.595	1.4018	0.9	Ratio to Peak	0.01	0.25
W410	99.2902	99	0	1.6926	0.3069	1.4018	0.9	Ratio to Peak	0.01	0.25
W400	84.6667	99	0	1.032	0.1871	1.4018	0.9	Ratio to Peak	0.01	0.25
W390	84.6667	99	0	2.5212	0.5658	1.4018	0.9	Ratio to Peak	0.01	0.25
W1460	0.0048898	51.820218	0.0	0.8054	0.65720	Discharge	0.20700	0.19	Ratio to Peak	0.25
W1450	0.0033612	61.204077	0.0	0.64588	0.52704	Discharge	0.25607	0.19	Ratio to Peak	0.25

Annex 10. Basey 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	2661.1	0.0197065	0.04	Trapezoid	6.345	0.1
R60	Automatic Fixed Interval	3036.1	0.0162086	0.04	Trapezoid	4.50625	0.1
R70	Automatic Fixed Interval	113.14	0.0756556	0.04	Trapezoid	7.4525	0.1
R90	Automatic Fixed Interval	2624.2	0.000655691	0.04	Trapezoid	9.92	0.1
R120	Automatic Fixed Interval	7678.9	0.0032939	0.04	Trapezoid	6.975	0.1
R140	Automatic Fixed Interval	6104.1	0.0082528	0.04	Trapezoid	22.49625	0.1
R170	Automatic Fixed Interval	168.28	9.92E-05	0.04	Trapezoid	7.19125	0.1
R180	Automatic Fixed Interval	7733.6	0.0114894	0.04	Trapezoid	17.235	0.1
R190	Automatic Fixed Interval	7362.5	0.000869694	0.04	Trapezoid	5.27375	0.1
R210	Automatic Fixed Interval	3958.6	0.0101424	0.04	Trapezoid	12.63625	0.1
R230	Automatic Fixed Interval	3022.7	9.92E-05	0.04	Trapezoid	10.33875	0.1
R240	Automatic Fixed Interval	752.55	0.0082966	0.04	Trapezoid	12.60125	0.1
R260	Automatic Fixed Interval	2469.7	0.0053036	0.04	Trapezoid	61.94625	0.1
R280	Automatic Fixed Interval	243.99	9.92E-05	0.04	Trapezoid	57.1575	0.1

Annex 11. Basey Field Validation

Point Number	Latitude	Longitude	Validation Points (m)	Model Var (m)	Error	Event	Date of Occurence	Rain Return/ Scenario
1	11.26460874	125.1600624	0.3	0.220	-0.08	Nov. 19-20		5Yr
2	11.26460874	125.1600624	0	0.220	0.22	Ruby	December 06, 2014	5Yr
3	11.26567114	125.1584962	0	0.030	0.03	Ruby	December 06, 2014	5Yr
4	11.26848755	125.1542203	0	0.030	0.03			5Yr
5	11.27174576	125.1533064	0.4	0.040	-0.36	Ruby	December 06, 2014	5Yr
6	11.27174576	125.1533064	0.2	0.040	-0.16	Heavy Rain		5Yr
7	11.27288855	125.152725	0.3	0.280	-0.02	Ruby	December 06, 2014	5Yr
8	11.27288855	125.152725	0.3	0.280	-0.02	Senyang	December 28, 2014	5Yr
9	11.27288855	125.152725	0.3	0.280	-0.02	Dec. 2015		5Yr
10	11.27860249	125.1467403	5	0.030	-4.97	Ruby	December 06, 2014	5Yr
11	11.27813193	125.1462274	5	0.080	-4.92	Ruby	December 06, 2014	5Yr
12	11.27813193	125.1462274	0.4	0.080	-0.32	Senyang	December 28, 2014	5Yr
13	11.27813193	125.1462274	1	0.080	-0.92	Undang		5Yr

Point Number	Latitude	Longitude	Validation Points (m)	Model Var (m)	Error	Event	Date of Occurence	Rain Return/ Scenario
14	11.2781906	125.1455251	0	0.030	0.03	Ruby	December 06, 2014	5Yr
15	11.2781906	125.1455251	0.1	0.030	-0.07	Heavy Rain		5Yr
16	11.28061918	125.1487922	0.2	0.220	0.02	Heavy Rain		5Yr
17	11.28061918	125.1487922	0.5	0.220	-0.28	Ruby	December 06, 2014	5Yr
18	11.28311548	125.1454892		0.150	0.15	Ruby	December 06, 2014	5Yr
19	11.28591679	125.1383577	0	0.030	0.03	Ruby	December 06, 2014	5Yr
20	11.28767733	125.1313067	0.1	0.030	-0.07	Ruby	December 06, 2014	5Yr
21	11.28767733	125.1313067	0	0.030	0.03	Senyang	December 28, 2014	5Yr
22	11.28818703	125.1277848	0	0.030	0.03	Ruby	December 06, 2014	5Yr
23	11.28818703	125.1277848	0.1	0.030	-0.07	Heavy Rain		5Yr
24	11.28996626	125.1220953	0	0.030	0.03	Ruby	December 06, 2014	5Yr
25	11.28856086	125.1215032	0.4	0.030	-0.37	Heavy Rain		5Yr
26	11.30282284	125.1446257	0	0.030	0.03	Heavy Rain		5Yr
27	11.30282284	125.1446257	0.4	0.030	-0.37	Ruby	December 06, 2014	5Yr
28	11.30282284	125.1446257	0.4	0.030	-0.37	Senyang	December 28, 2014	5Yr
29	11.30388575	125.1457168	1.3	0.040	-1.26	Ruby	December 06, 2014	5Yr

Point Number	Latitude	Longitude	Validation Points (m)	Model Var (m)	Error	Event	Date of Occurence	Rain Return/ Scenario
30	11.30388575	125.1457168	1.3	0.040	-1.26	Senyang	December 28, 2014	5Yr
31	11.30388575	125.1457168	0	0.040	0.04	Ruping		5Yr
32	11.30464573	125.1469968	1	0.040	-0.96	Ruby	December 06, 2014	5Yr
33	11.30464573	125.1469968	0	0.040	0.04	Senyang	December 28, 2014	5Yr
34	11.30464573	125.1469968	1	0.040	-0.96	Ruping		5Yr
35	11.30464573	125.1469968	1	0.040	-0.96	Ondoy		5Yr
36	11.30464573	125.1469968	1	0.040	-0.96	Heavy Rain		5Yr
37	11.29918308	125.132101	0.5	0.260	-0.24	Ruby	December 06, 2014	5Yr
38	11.29911594	125.1300947	0.3	0.370	0.07	Ruby	December 06, 2014	5Yr
39	11.29911594	125.1300947	3	0.370	-2.63	Undang		5Yr
40	11.29792982	125.1305735	0.3	0.120	-0.18	Ruby	December 06, 2014	5Yr
41	11.29624506	125.1178368	1.5	0.080	-1.42	Undang		5Yr
42	11.29624506	125.1178368	0	0.080	0.08	Ruby	December 06, 2014	5Yr
43	11.29249684	125.0811016	1	0.090	-0.91	Undang		5Yr

Annex 12. Educational Institutions Affected in Basey Floodplain

Table A-12.1. Educational Institutions in Basey, Samar affected by flooding in Basey Floodplain

SAMAR				
BASEY				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
ANGLIT ELEMENTARY SCHOOL	Anglit	Low	Medium	Medium
SAMAR STATE UNIVERSITY	Balante			
VALERIANO C. YANCHA MEMORIAL AGRICULTURE	Balante			
SAMAR STATE UNIVERSITY	Baloog			
VALERIANO C. YANCHA MEMORIAL AGRICULTURE	Baloog			
BALUD ELEMENTARY SCHOOL	Binongtu-an		Low	Low
DAY CARE CENTER	Binongtu-an		Low	Low
BRGY. DAY CARE CENTER	Buenavista	Low	Low	Low
BUENAVISTA ELEMENTARY SCHOOL	Buenavista			
BURGOS INTEGRATED SCHOOL	Burgos		Low	Medium
COGON ELEMENTARY SCHOOL	Cogon			
VALERIANO C. YANCHA MEMORIAL AGRICULTURE	Dolongan			
DAY CARE CENTER	Iba		Low	Low
IBA ELEMENTARY SCHOOL	Iba	Low	Low	Medium
SAWA ELEMENTARY SCHOOL	Iba	Low	Low	Medium
MAGALLANES ELEMENTARY SCHOOL	Magallanes			Low
NEW SAN AGUSTIN ELEMENTARY SCHOOL	New San Agustin	Medium	Medium	Medium
BALUD ELEMENTARY SCHOOL	Nouvelas Occidental			Low
SERUM ELEMENTARY SCHOOL	Nouvelas Occidental		Low	Medium
OLD SAN AGUSTIN ELEMENTARY SCHOOL	Old San Agustin	Medium	Medium	Medium
PANUGMONON ELEMENTARY SCHOOL	Panugmonon		Medium	High
PANUGMONON ELEMENTARY SCHOOL	San Fernando		Medium	High
SERUM ELEMENTARY SCHOOL	Serum			Medium

Annex 13. Medical Institutions Affected in Basey Floodplain

Table A-13.1. Medical Institutions in Dipolog City, Zamboanga del Norte affected by flooding in Dipolog Floodplain

ZAMBOANGA DEL NORTE				
DIPOLOG CITY				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
NEW SAN AGUSTING HEALTH CENTER	New San Agustin		Low	Medium