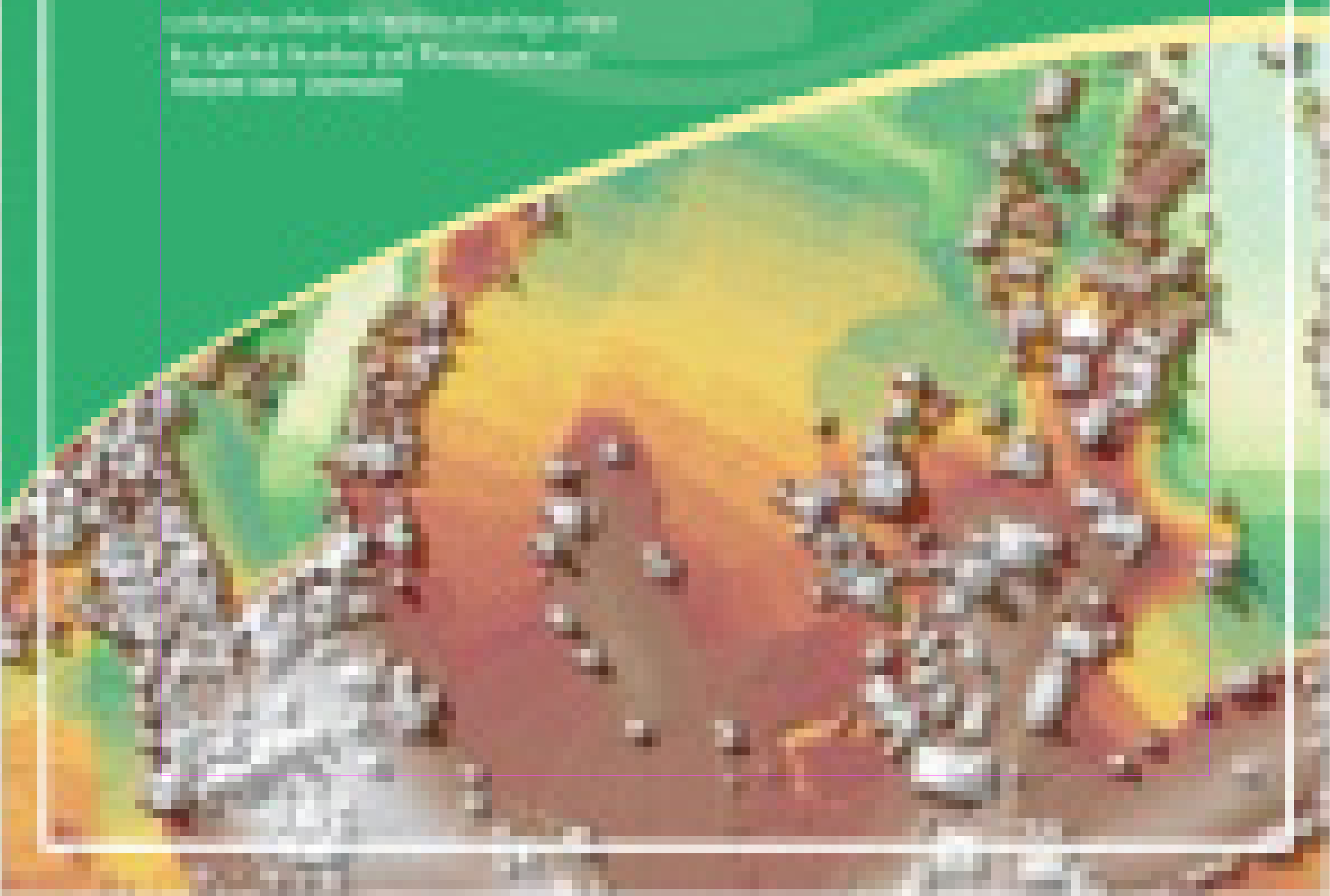
LiDAR Surveys and Flood Mapping of Silaga River



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LIST OF ACRONYMS AND ABBREVIATIONS

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
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
VSU	Visayas State University
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 SILAGA RIVER

Enrico C. Paringit, Dr. Eng., Engr. Florentino F. Morales, Jr., and Engr. Omar P. 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 in 2014, supported by the Department of Science and Technology (DOST) Grant-in-Aid (GiA) Program. The program was primarily aimed at acquiring a national elevation and resource dataset at sufficient resolution to produce information necessary to support the different phases of disaster management. Particularly, it targeted to operationalize the development of flood hazard models that would produce updated and detailed flood hazard maps for the major river systems in the country.

Also, the program was aimed at producing an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through DOST. The methods described in this report are thoroughly described in a separate publication entitled "Flood Mapping of Rivers in the Philippines Using Airborne LiDAR: Methods (Paringit, et. al., 2017) available separately.

The implementing partner university for the Phil-LiDAR 1 Program is the Visayas State University (VSU). VSU is in charge of processing LiDAR data and conducting data validation reconnaissance, cross section, bathymetric survey, validation, river flow measurements, flood height and extent data gathering, flood modeling, and flood map generation for the 28 river basins in the Eastern Visayas Region. The university is located in Baybay City in the province of Leyte.

1.2 Overview of the Silaga River Basin

The Silaga River Basin lies along the municipalities of Pinabacdao, Basey, and Sta. Rita in the province of Samar on the island of the same name. Based on the DENR River Basin Control Office (RBCO), it has a drainage area of 204 km2 bounded by the Samar mountain range on the east side with an estimated 388 million cubic-meter (MCM) annual run-off that drains into the San Juanico Strait between Samar and Leyte islands). Located in the Western part of Sta. Rita is Silaga River, which is part of the 28 river systems in the region of Eastern Visayas.

There are two types of climate predominant in the region under the Corona system of classification: Type II and Type IV; the former characterized by a climate with no dry season but a pronounced maximum rainfall from November to January, while the latter has an even distribution of rainfall all year round and a short period of dry season that can be observed starting February up to May. Samar Island falls under the Type II climate.

In general, the Silaga River Basin has an undulating terrain in the upper section of the basin with a maximum elevation of only 280 meters above sea level. On the other hand, the lower and central sections of the basin have flat to low slope areas, which are very suitable for agriculture. The shape of the basin is nearly circular, which will probably yield a moderate sharp peak of flood discharge than a narrow and long-shaped basin. The basin has a dendritic pattern of river networks, which is a very common pattern in the region. It also has a 4th order stream, so it is considered one of the major river basins in the Eastern Visayas province.

Santa Rita, the locality where the Silaga River is located, is categorized as a 3rd class municipality in the province of Samar. It has a total population of 41,591 people, according to the 2015 National Census (PSA, 2017). A total of 10,734 people are currently residing along the Silaga River, distributed among nine (9) barangays, namely: Tulay, Tominamos, Camayse, Anibongan, Old Manunca, New Manunca, Aslum, Lupig, and La Paz. Since most of these barangays are agricultural areas, the main source of livelihood in the aforesaid communities is farming, particularly growing lowland and upland rice and corn. Fishing, however, is still a primary source of income alongside farming. Dense mangrove areas are also found in the coastline

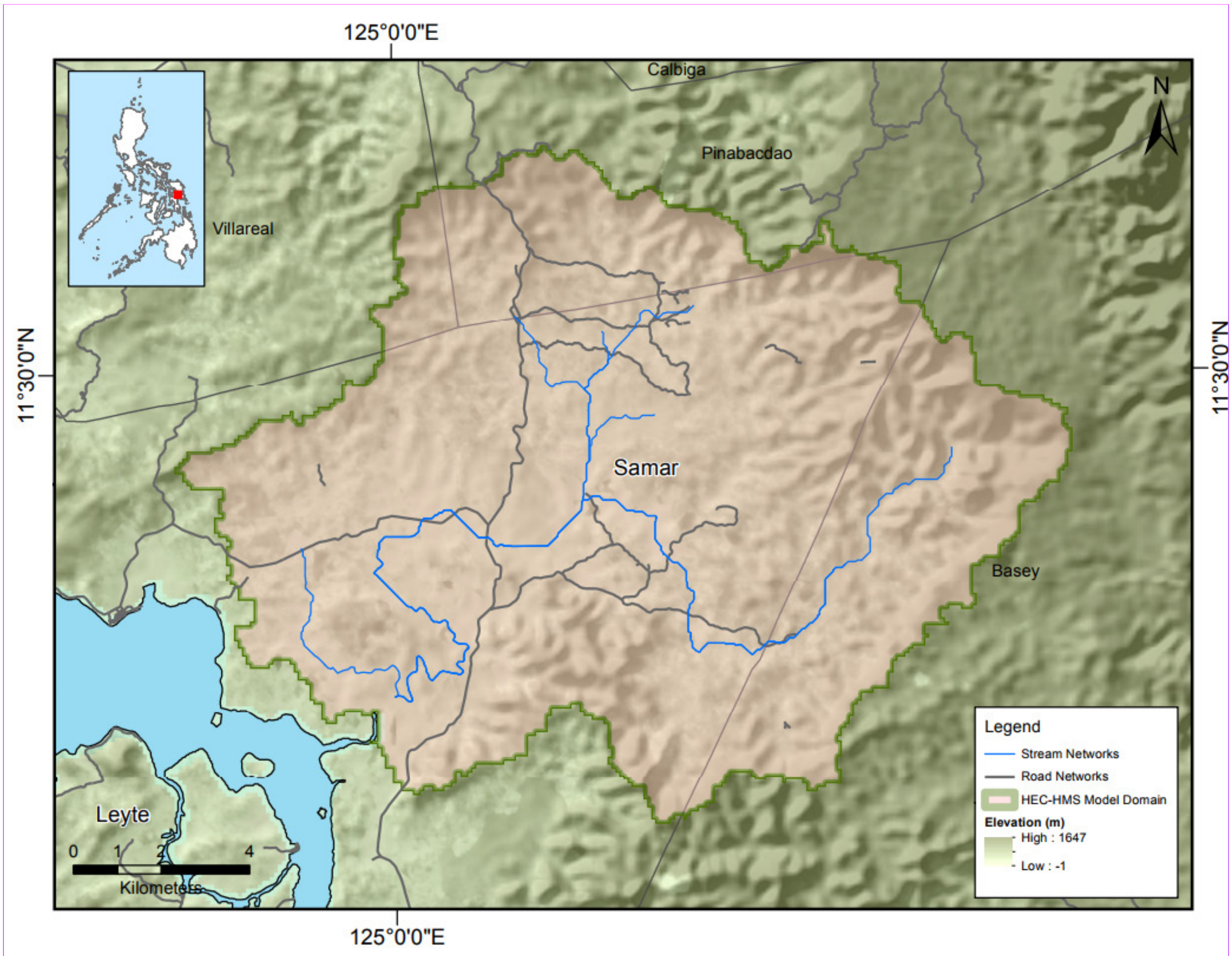


Figure 1. Map of the Silaga River Basin (in brown)

The municipality of Sta. Rita, Samar is also one of the most disaster-prone areas in the Philippines, as it was among the most devastated areas when Typhoon Haiyan (Local Code Name: Yolanda) struck on November 8, 2013, which was dubbed the strongest and deadliest typhoon in the country's recorded history. A year after, Sta. Rita, alongside other neighboring localities, was also hit by Typhoon Hagupit (Local Code Name: Ruby) on December 6, 2014. In times of disasters, the San Juanico Bridge serves as the main conduit for aid and relief goods and services to Santa Rita and the rest of Eastern Samar, as it is directly connected to the latter.

CHAPTER 2: LIDAR DATA ACQUISITION OF THE SILAGA FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Acuna, Engr. Gerome Hipolito, Christopher Joaquin and Jasmine Domingo.

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

2.1 Flight Plans

To initiate the LiDAR acquisition survey of the Silaga Floodplain, the Data Acquisition Component (DAC) created flight plans within the delineated priority area for the Silaga Floodplain in Samar. These missions were planned for 14 lines each, which ran for, at most, four and a half (4.5) hours including takeoff, landing, and turning time using two sensors – the Gemini and Aquarius (See Annex 1 for sensor specifications). The flight planning parameters[1] for the LiDAR system are outlined in Table 1. Figure 2, on the other hand, shows the flight plan for the Silaga Floodplain survey.

Table 1. Flight planning parameters for the Aquarius LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of view (ø)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
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

Table 2. Flight planning parameters for the Gemini LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of view (ø)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK33A	850	30	40	125	50	130	5
BLK33B	850	30	40	125	50	130	5
BLK34H	850	30	40	125	50	130	5
BLK34I	850	30	50	125	40	130	5
BLK34J	850	30	50	125	40	130	5
BLK34K	850	30	40	125	50	130	5
BLK34M	850	30	40	125	40	130	5

[1] The explanation of the parameters used are in the volume "LiDAR Surveys and Flood Mapping in the Philippines: Methods."

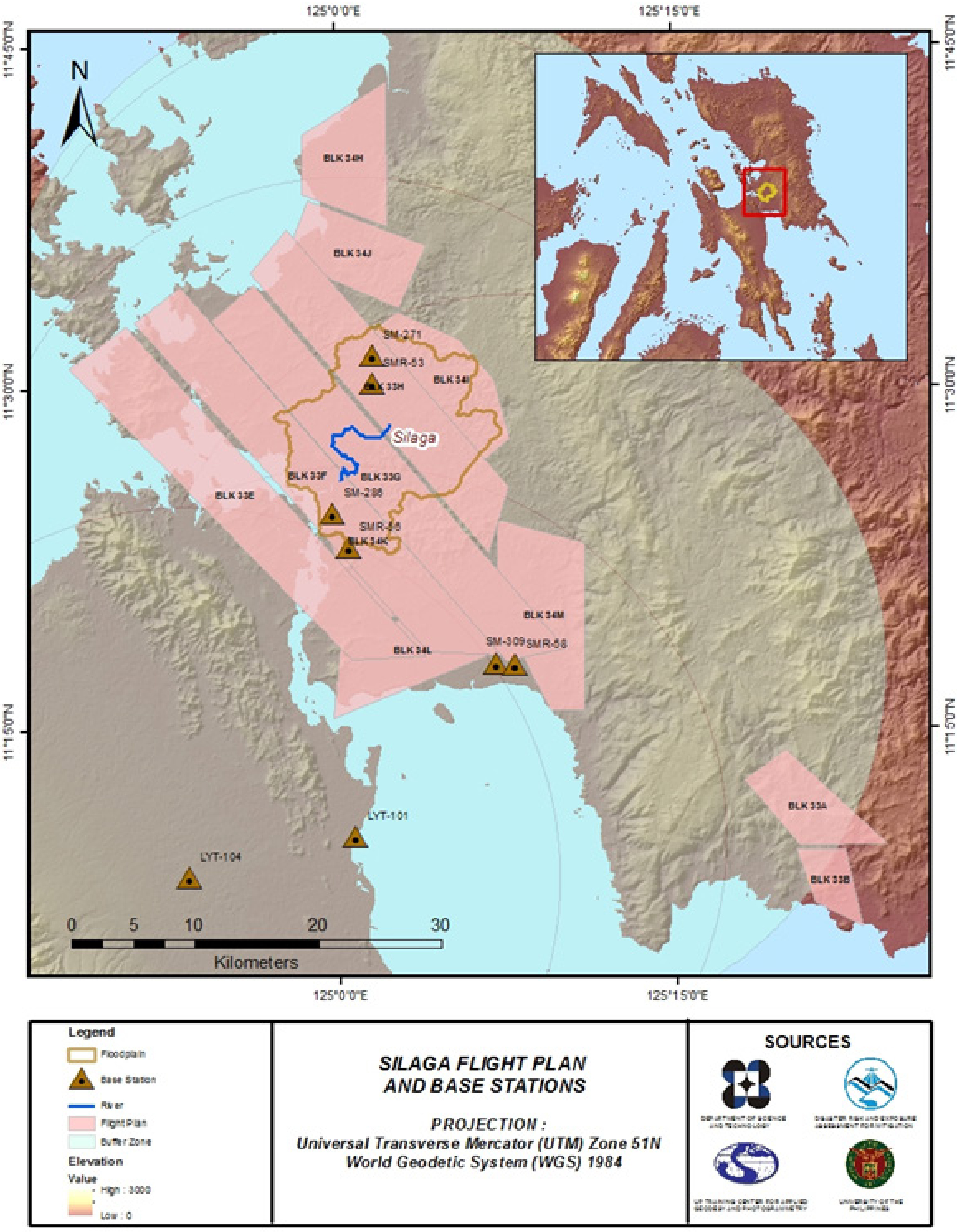


Figure 2. Flight Plan and base stations used for the Silaga Floodplain survey.

2.2 Ground Base Stations

The field team for this undertaking was able to recover four (4) NAMRIA horizontal ground control points, namely: SMR-53, SMR-56, SMR-58, and LYT-101, which are all of second (2nd) order accuracy. The team also reestablished ground control point LYT-104, a NAMRIA reference point of third (3rd) order accuracy. Three (3) NAMRIA benchmarks were also recovered, specifically: SM-286, SM-271, and SM-309, which are all of first (1st) order accuracy. These benchmarks were used as vertical reference points and were also established as ground control points.

The certification for the NAMRIA reference points and benchmarks are found in Annex 2, while the baseline processing reports for the established control points are found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey from May 3-13, 2014 and January 29-February 6, 2016. Dual frequency GPS receivers Trimble SPS 852 and SPS 985 were used to observe the base stations. Figure 2 delineates the flight plans and locations of the base stations used during the aerial LiDAR acquisition of the Silaga Floodplain. The list of team members are found in Annex 4.

The succeeding sections depict the sets of reference points, control stations and established points, and the ground control points for the entire Silaga Floodplain LiDAR Survey. Figure 3 to Figure 9 below depict the recovered NAMRIA reference points within the area of the floodplain, while Table 3 to Table 10 show the details about the following NAMRIA control stations and established points. Table 11, on the other hand, shows the list of all ground control points occupied during the LiDAR acquisition with their corresponding dates of utilization.

(a) (b)

Figure 3. Photo (A) shows the GPS set-up over SMR-53 located near the flagpole of San Isidro Elementary School, Brgy. San Isidro, Santa Rita, Samar; while Photo (B) depicts the close-up view of NAMRIA reference point SMR-53 as recovered by the field team.

Table 3. Description of the recovered NAMRIA horizontal control point SMR-53, which was used as a base station for the LiDAR acquisition.

Station Name	**SMR-53**	
Order of Accuracy	**2nd**	
Relative Error (Horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference 0f 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11o 30’ 17.85657” North 125o 1’ 29.837339” East 26.13400 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	502722.403 meters 1272180.079 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11o 30’ 13.52495” North 125o 1’ 34.96980” East 87.78700 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	720874.14 meters 127513.40 meters

Figure 4. Photo (A) shows the GPS set-up over SMR-56 located inside Cabacungan Elementary School, Brgy. Cabacungan, Sta. Rita, Samar; while Photo (B) presents a close-up view of NAMRIA reference point SMR-56 as recovered by the field team.

Table 4. Details of the recovered NAMRIA horizontal control point SMR-56, which was used as a base station for the LiDAR acquisition.

Station Name	SMR-56	
Order of Accuracy	2nd	
Relative Error (Horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11o 23' 6.52702" North 125o 0' 23.99607" East 11.82200 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	500727.475 meters 1258927.861 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11o 23' 2.22413" North 125o 0' 29.13917" East 73.72700 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	718970.61 meters 1259244.38 meters

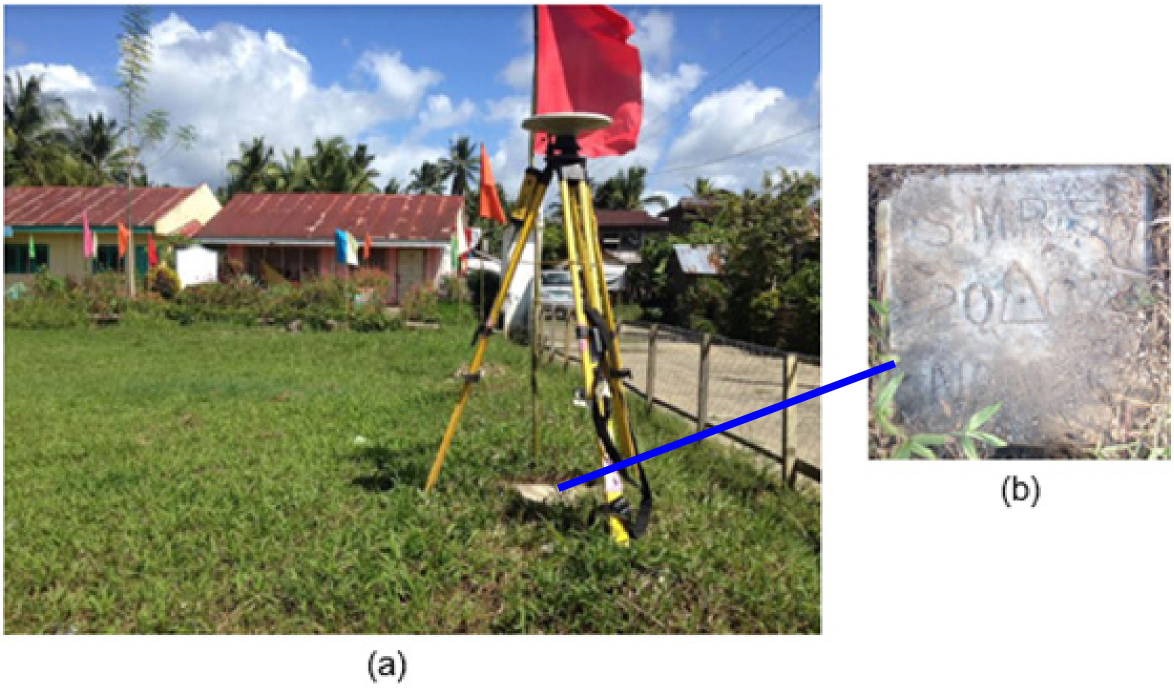
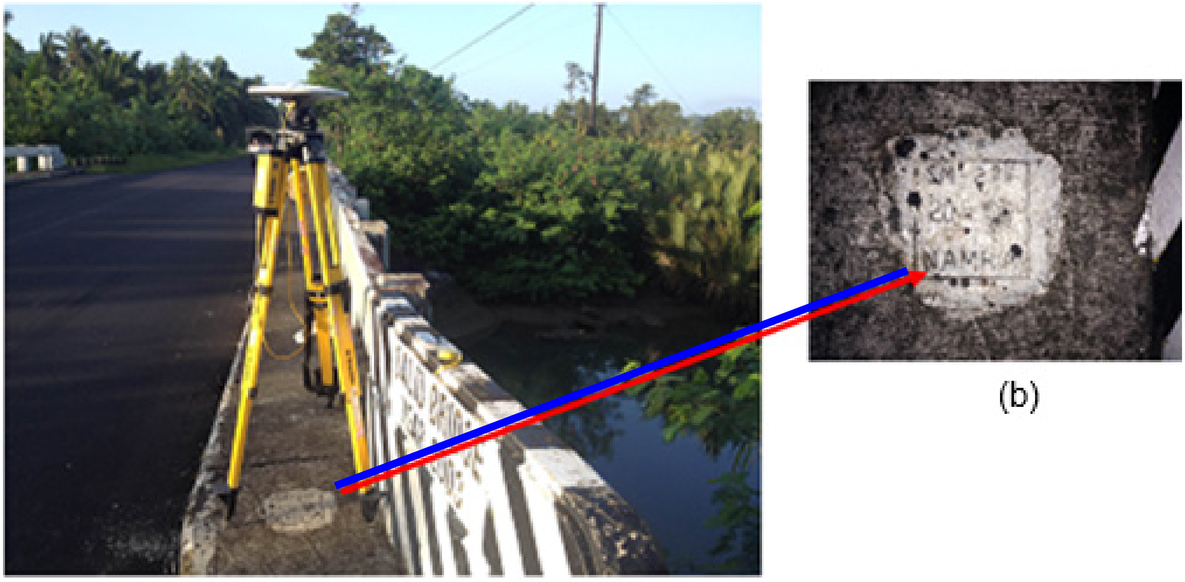


Figure 5. Photo (A) shows the GPS set-up over SMR-58 located inside Serum Elementary School, Brgy. Serum, Basey; while Photo (B) depicts a close-up view of NAMRIA reference point SMR-58 as recovered by the field team.

Table 5. Details of the recovered NAMRIA horizontal control point SMR-58, which was used as a base station for the LiDAR acquisition.

Station Name	SMR-58	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1:50,000**	
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)	Latitude Longitude Ellipsoidal Height	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



(a) (b)

Figure 6. Photo (A) shows the GPS set-up over SM-286 located at Dalid Bridge along the National Highway in Brgy. San Pascual, Sta. Rita, Samar; while Photo (B) offers a close-up view of NAMRIA reference point SM-286 as recovered by the field team.

Table 6. Details of the recovered NAMRIA vertical control point SM-286, which was used as a base station for the LiDAR acquisition with established coordinates.

Station Name	SM-286	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
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
Geographic Coordinates, Philippine Reference of 1992 Datum (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

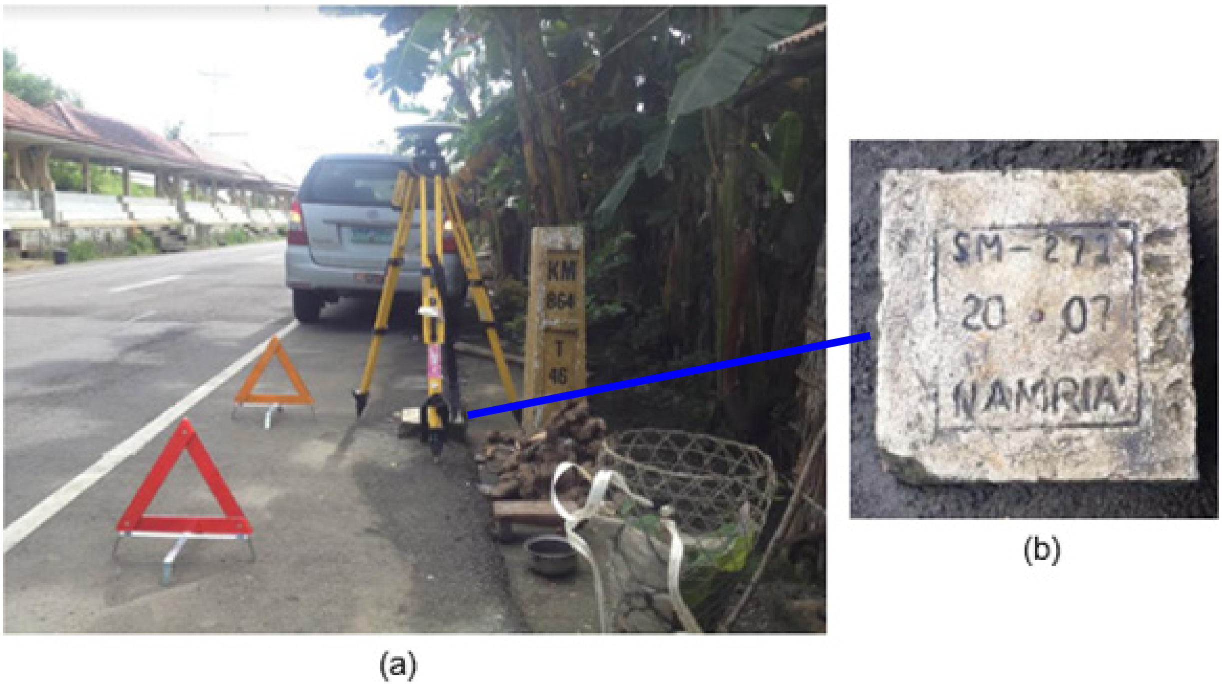


Figure 7. Photo (A) depicts the GPS set-up over SM-271 located beside Kilometer Post 864 along the right side of the National Highway, Bgry. Laygayon, Pinabacdao, Samar; while Photo (B) shows a close-up view of NAMRIA reference point SM-271 as recovered by the field team.

Table 7. Details of the recovered NAMRIA vertical control point SM-271, which was used as a base station for the LiDAR acquisition with established coordinates.

Station Name	**SM-271**	
Order of Accuracy	**2nd order**	
Relative Error (horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11o 31’ 31.48945” North 125o 01’ 36.88429” East 82.083 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11o 31’ 27.15288” North 125o 01’ 34.96980” East 143.69 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	721071.742 meters 1274777.721 meters

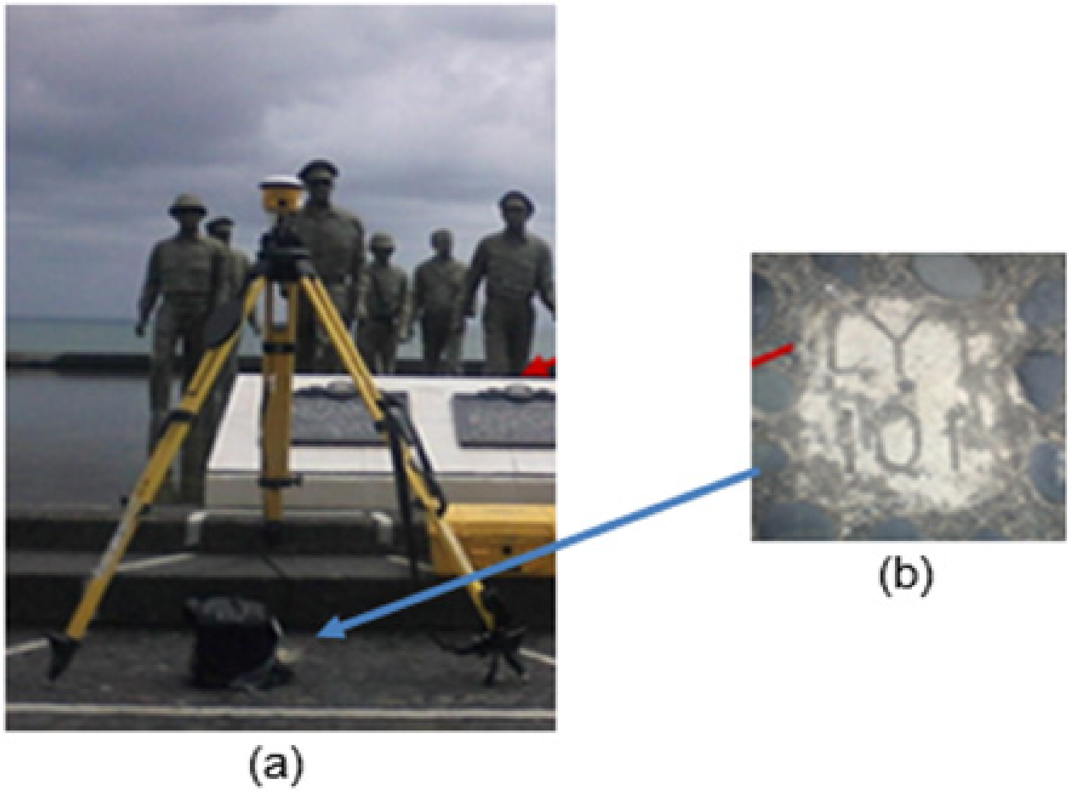


Figure 8. Photo (A) depicts the GPS set-up over LYT-101 located within the premises of MacArthur's Landing Memorial Park, Palo, Leyte; while Photo (B) shows a close-up view of NAMRIA reference point LYT-101 as recovered by the field team.

Table 8. Details of the recovered NAMRIA horizontal control point LYT-101, which was used as a base station for the LiDAR acquisition.

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

(a) (b)

Figure 9. Photo (A) displays the GPS set-up over LYT-104 located and reestablished along a rice paddy trail, approximately 90 meters from the centerline, east side of Pastrana-Santa Fe Road, District IV, Pastrana, Leyte; while Photo (B) shows a close-up view of NAMRIA reference point LYT-104 as recovered by the field team.

Table 9. Details of the recovered and reestablished NAMRIA horizontal control point LYT-104, which was used as a base station for the LiDAR acquisition.

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

Table 10. Details of the recovered NAMRIA vertical control point SM-309, which was used as a base station for the LiDAR acquisition with established coordinates.

Station Name	SM-309	
Order of Accuracy	2nd order	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	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
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	730935.362 meters 1249887.315 meters

Table 11. Ground control points that were used during the LiDAR data acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
May 3, 2014	1410A	AQUATACTF123A	SMR-56 and SM-286
May 4, 2014	1414A	AQUATACTF124A	SMR-56 and LYT-101
May 10, 2014	1438A	3BLK34O130A	SMR-56 and SM-286
May 10, 2014	1440A	3BLK34OSP130B	SMR-56 and SM-286
May 11, 2014	1442A	3BLK34PS131A	SMR-56 and SM-286
May 11, 2014	1444A	3BLK34PSQ131B	SMR-56 and SM-286
May 13, 2014	1450A	3BLK34QS133A	SMR-56 and SM-286
May 13, 2014	1452A	3BLK34QS133B	SMR-56 and SM-286
January 29, 2016	3727G	2BLK34IJ029B	SMR-53 and SM-271
January 30, 2016	3729G	2BLK34HJ030A	SMR-53 and LYT-104
February 5, 2016	3753G	2BLK34K33AB036A	SMR-58 and SM-309
February 6, 2016	3757G	2BLK34K037A	SMR-58 and SM-309

2.3 Flight Missions

A total of twelve (12) flight missions were conducted to complete the LiDAR data acquisition of the Silaga Floodplain, amounting to forty-seven hours and six minutes (47+6) of flying time for aircrafts RP-C9122 and RP-C9022 (See Annex 6). All missions were acquired using the Aquarius and Gemini LiDAR systems. As shown below, the total area of actual area coverage and the corresponding flying hours are depicted in Table 12, while the actual parameters used during the LiDAR data acquisition are presented Table 13.

Table 12. Flight missions for the LiDAR data acquisition of the Silaga Floodplain.

Date Surveyed	Flight Number	Flight Plan Area (km2)	Surveyed Area (km2)	Area Surveyed within the Floodplain (km2)	Area Surveyed Outside the Floodplain (km2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
May 3, 2014	1410A	176.92	128.36	0.18	128.18	772	4	47
May 4, 2014	1414A	176.92	67.14	0.14	67	649	3	11
May 10, 2014	1438A	169.38	157.70	25.29	132.41	1855	4	41
May 10, 2014	1440A	334.03	107.20	34.89	72.31	989	3	11
May 11, 2014	1442A	164.65	150.42	37.30	113.12	1536	4	47
May 11, 2014	1444A	297.68	127.72	52.96	74.76	1290	4	35
May 13, 2014	1450A	133.03	53.06	25.31	27.75	507	2	23
May 13, 2014	1452A	309.95	76.72	12.81	63.91	819	3	53
January 29, 2016	3727G	114.1	149.02	44.48	104.54	NA	4	05
January 30, 2016	3729G	110.62	113.57	31.07	82.5	NA	4	11
February 5, 2016	3753G	148.61	93.64	25.50	68.14	NA	4	17
February 6, 2016	3757G	86.64	77.94	39.88	38.06	NA	3	05
TOTAL	2222.53	1302.49	329.81	972.68	8417	47	06	

Table 13. Actual parameters used during the LiDAR data acquisition of the Silaga Floodplain.

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (khz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
1410A	600	30	36	70	50	120	5
1414A	600	30	36	70	50	120	5
1438A	600	30	36	70	50	120	5
1440A	600	30	36	70	50	120	5
1442A	600	30	36	70	50	120	5
1444A	600	30	36	70	50	120	5
1450A	600	30	36	70	50	120	5
1452A	600	30	36	70	50	120	5
3727G	800	30	50	125	40	130	5
3729G	650	30	40	125	50	130	5
3753G	850	30	40	125	50	130	5
3757G	850	30	40	125	50	130	5

2.4 Survey Coverage

This certain LiDAR acquisition survey covered the Silaga floodplain (See Annex 7). It is located in the province of Samar, majority of which is situated within the municipality of Santa Rita. The survey predominantly covered the municipalities of Villareal, Talalora, Santa Rita, and San Sebastian. Table 14 shows the list of municipalities and cities surveyed with at least one (1) square kilometer coverage; Figure 10, on the other hand, shows the actual coverage of the LiDAR acquisition for the Silaga Floodplain.

Table 14. List of municipalities and cities surveyed of the Silaga Floodplain LiDAR acquisition.

Province	Municipality/ City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Eastern Samar	Balangiga	206.52	46.45	22.49%
Leyte	Lawaan	141.75	5.68	4.01%
Samar	Babatngon	136.57	42.92	31.43%
	Villareal	130.22	127.61	98.00%
	Santa Rita	250.37	243.71	97.34%
	Talalora	26.56	25.73	96.88%
	San Sebastian	15.84	15.17	95.77%
	Pinabacdao	118.38	62.12	52.48%
	Basey	627.97	206.67	32.91%
	Calbiga	216.76	71.98	33.21%
	Daram	109.26	3.18	2.91%
TOTAL		1980.20	851.22	42.99%

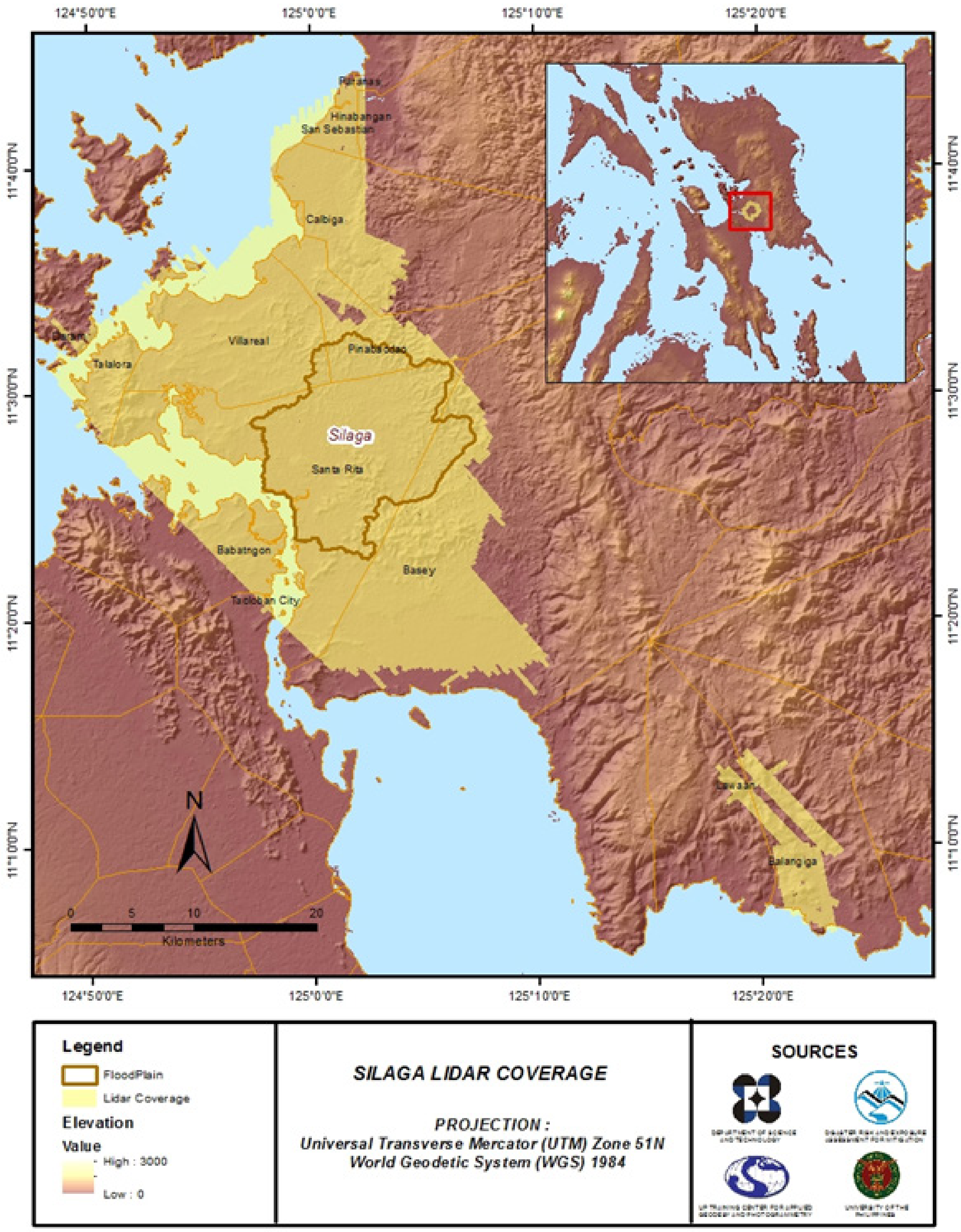


Figure 10. Actual LiDAR survey coverage of the Silaga Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE SILAGA 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 11.

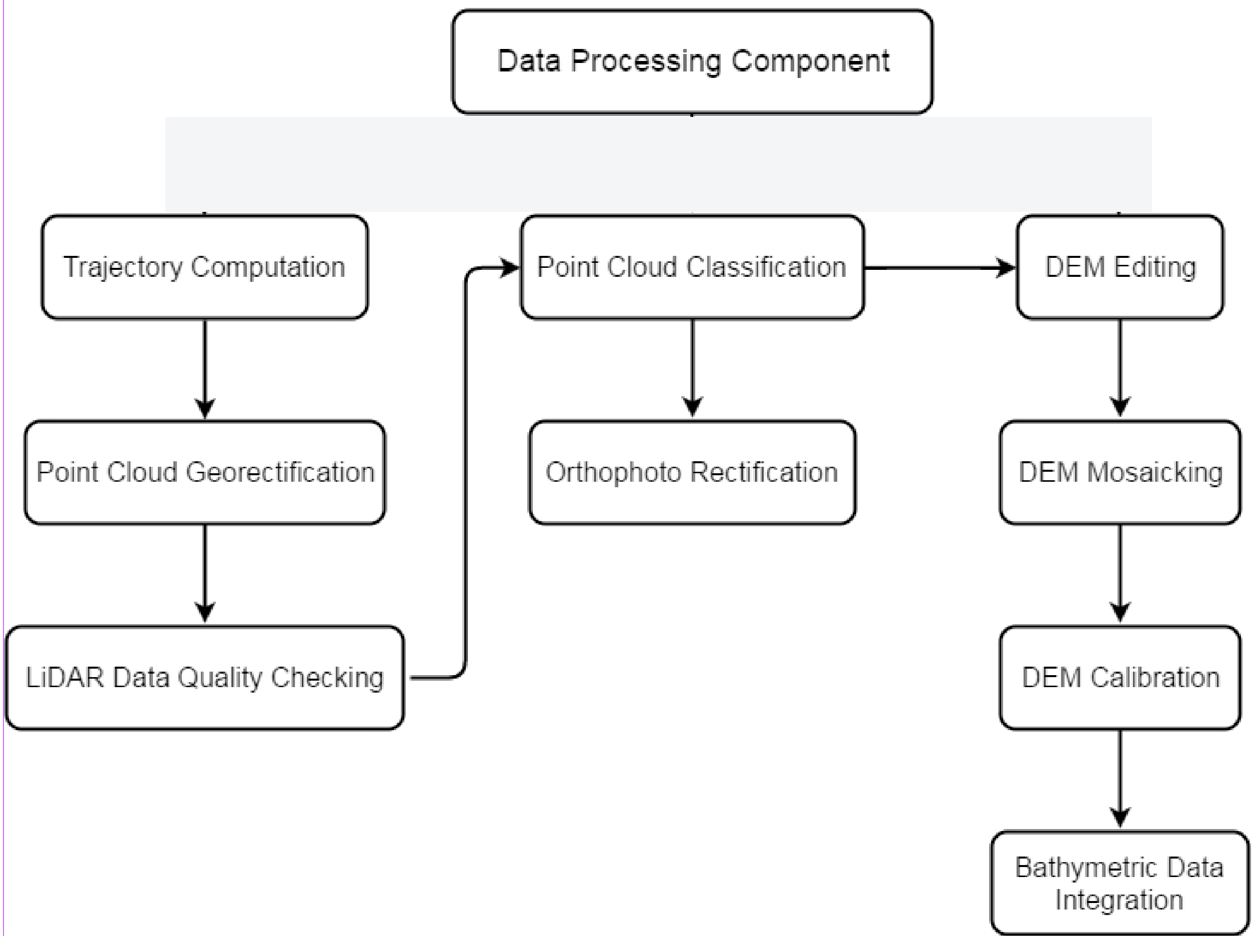

Figure 11. Schematic diagram for Data Pre-Processing Component.

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Silaga floodplain can be found in Annex 5. Missions flown during the first survey conducted on May 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Aquarius system while missions acquired during the second survey on February 2016 were flown using the Gemini system over Sta. Rita, Samar.

The Data Acquisition Component (DAC) transferred a total of 168.57 Gigabytes of Range data, 2.43 Gigabytes of POS data, 82.168 Megabytes of GPS base station data, and 442.2 Gigabytes of raw image data to the data server on June 4, 2014 for the first survey and February 6, 2016 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Silaga was fully transferred on February 26, 2016, as indicated on the Data Transfer Sheets for Silaga floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 1444A, one of the Silaga flights, which is the North, East, and Down position RMSE values are shown in Figure 12. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on May 11, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

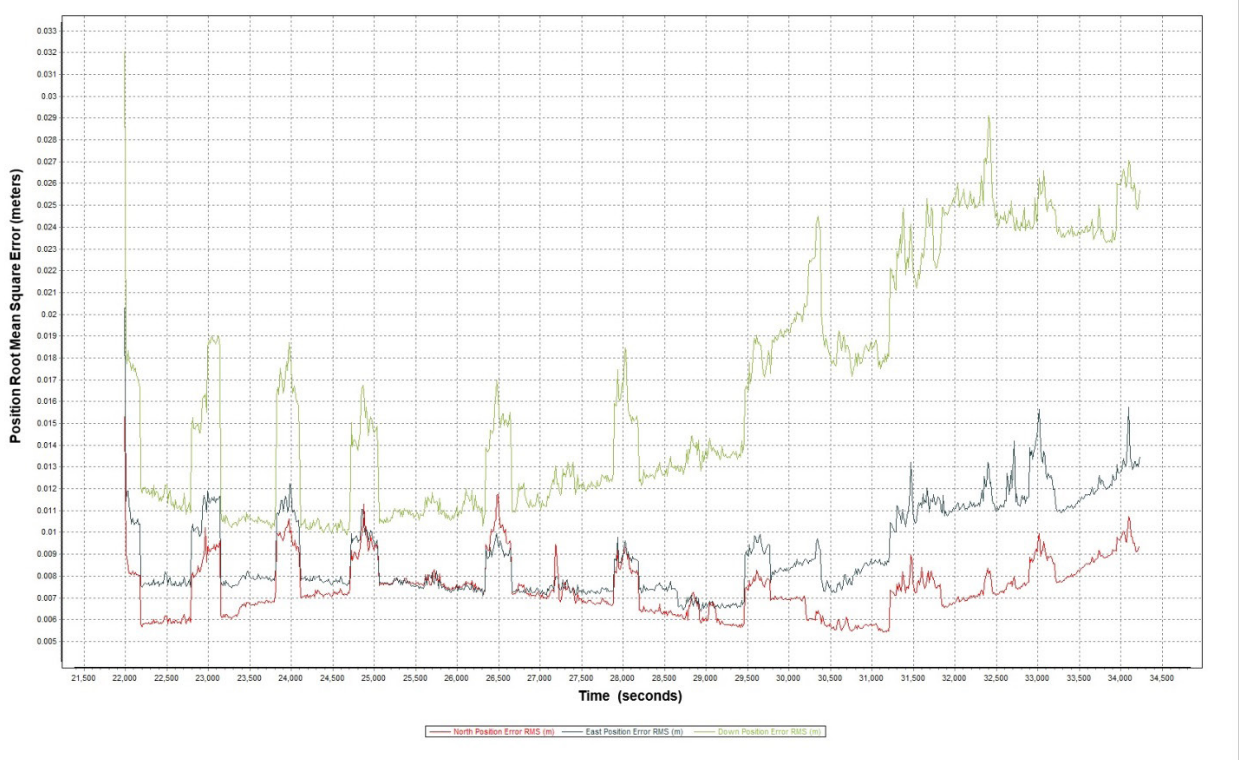

Figure 12. Smoothed Performance Metrics of Silaga Flight 1444A.

The time of flight was from 22000 seconds to 34500 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 B-2 shows that the North position RMSE peaks at 1.20 centimeters, the East position RMSE peaks at 1. 60 centimeters, and the Down position RMSE peaks at 2.90 centimeters, which are within the prescribed accuracies described in the methodology.

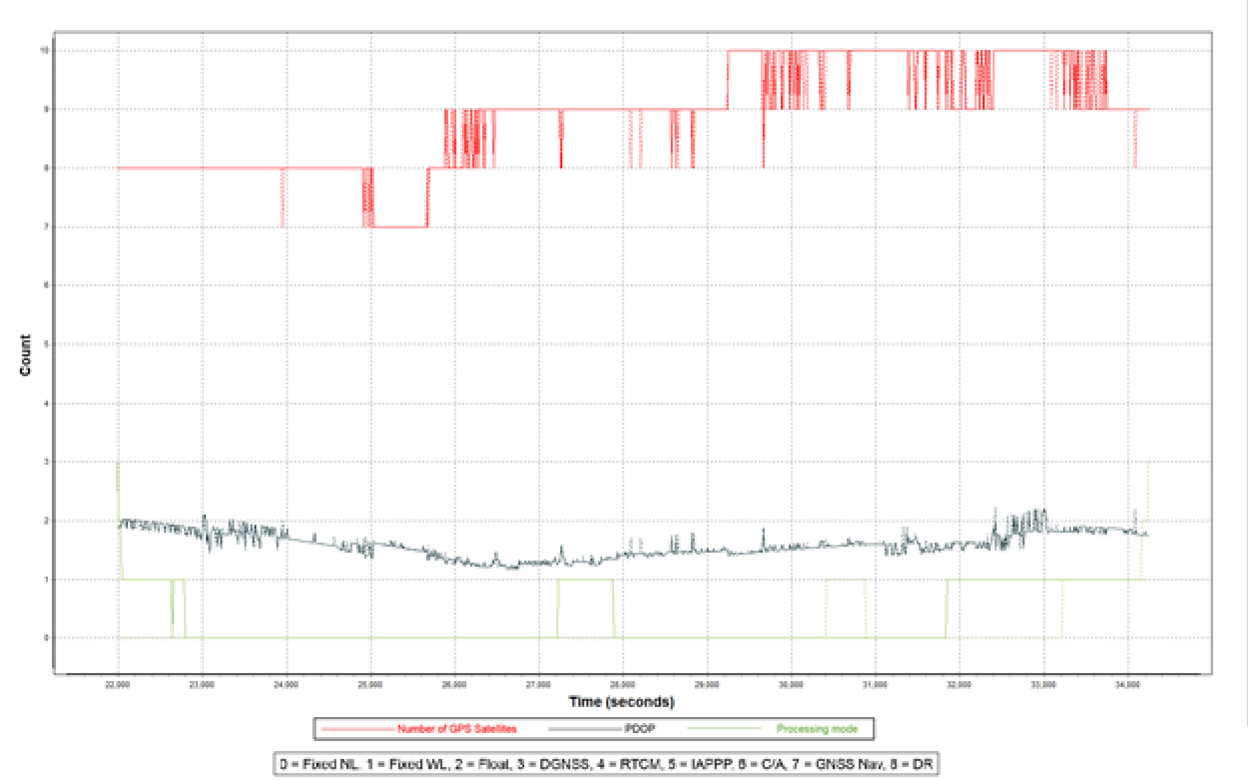

Figure 13. Solution Status Parameters of Silaga Flight 1444A.

The Solution Status parameters of flight 1444A, one of the Silaga flights, which indicate the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 13. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Most of the time, the number of satellites tracked was between 6 and 10. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode remained at 0 for majority of the survey with some peaks up to 1 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Silaga flights is shown in Figure 14.

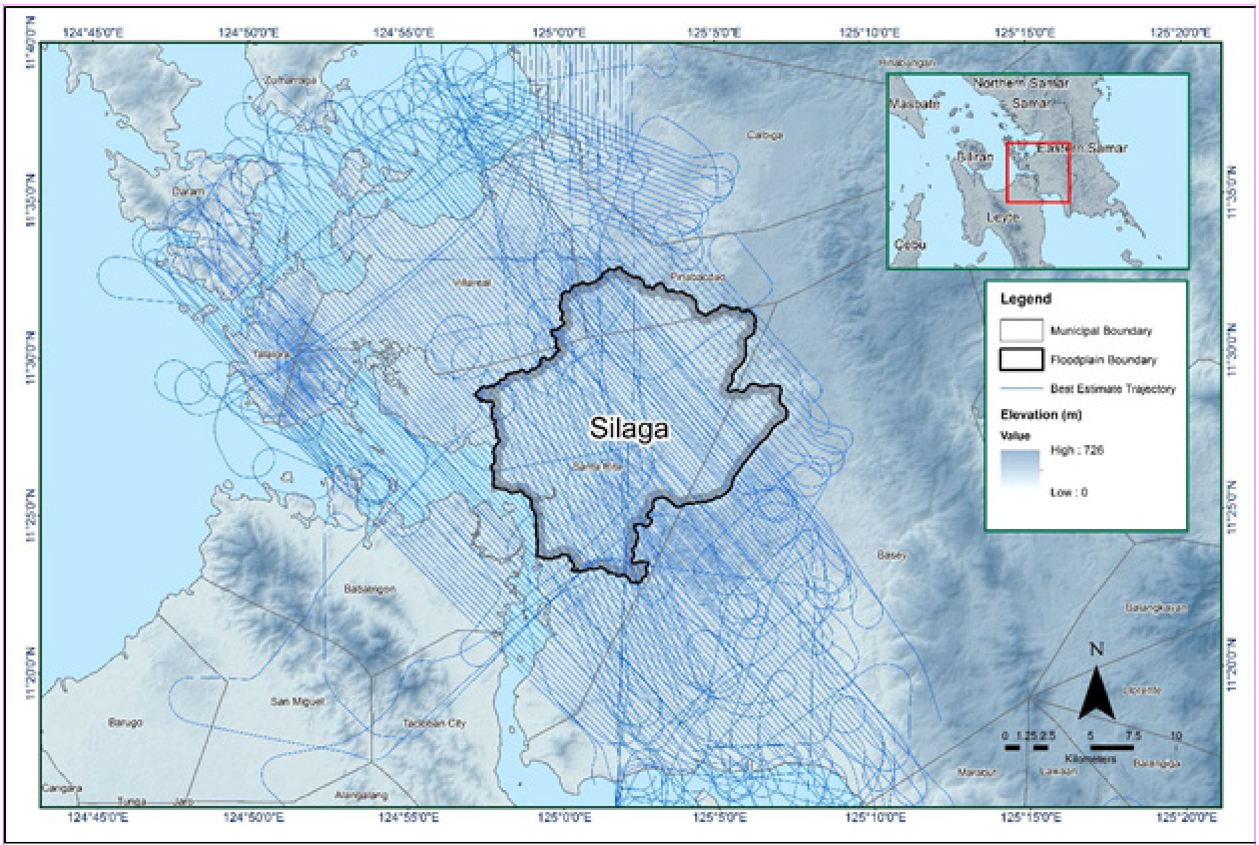

Figure 14. Best Estimated Trajectory of the LiDAR missions conducted over the Silaga Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 164 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 Silaga floodplain are given in Table 15.

Table 15. Self-calibration Results values for Silaga flights.

Parameter	Acceptable Value	Value
Boresight Correction stdev)	<0.001degrees	0.000498
IMU Attitude Correction Roll and Pitch Correction stdev)	<0.001degrees	0.000997
GPS Position Z-correction stdev)	<0.01meters	0.0088

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

3.5 LiDAR Data Quality Checking

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

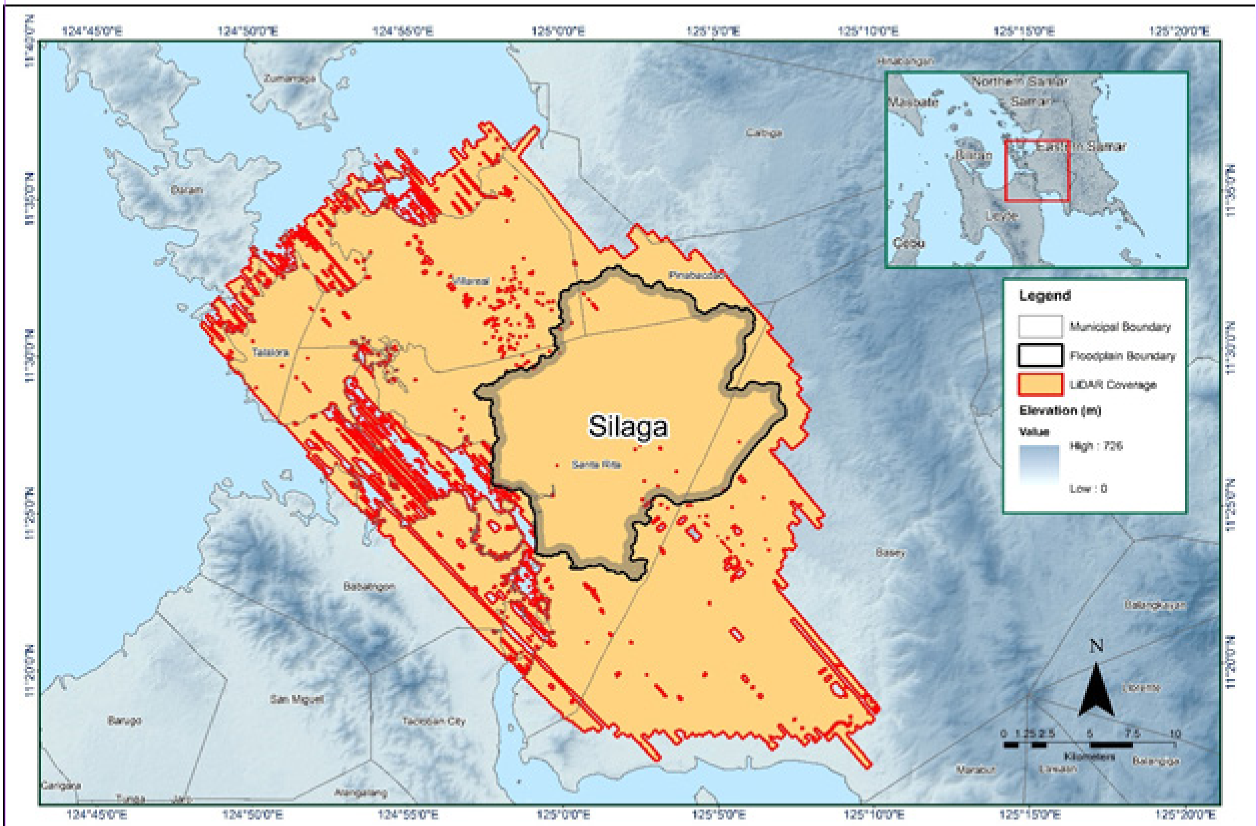

Figure 15. Boundaries of the processed LiDAR data on top of a SAR Elevation Data over Silaga Floodplain.

The total area covered by the Silaga missions is 1070.01 sq.km that is comprised of twelve (12) flight acquisitions grouped and merged into eight (8) blocks as shown in Table 16.

Table 16. List of LiDAR blocks for Silaga floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Samar_Leyte_Blk33E	1414A	161.35
	1452A	
Samar_Leyte_Blk33E_additional	1410A	92.55
Samar_Leyte_Blk33F	1438A	227.31
	1440A	
Sama_Leyte_Blk33G	1440A	217.86
Samar_Leyte_Blk33H	1444A	174.97
	1450A	
	1452A	
Leyte_Blk33F	3753G	88.74
	3757G	
Leyte_Blk33H	3727G	78.99
Leyte_Blk33H_additional	3729G	28.24
TOTAL		1070.01 sq.km

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 16. Since the Gemini and Aquarius systems both employ one channel, 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.

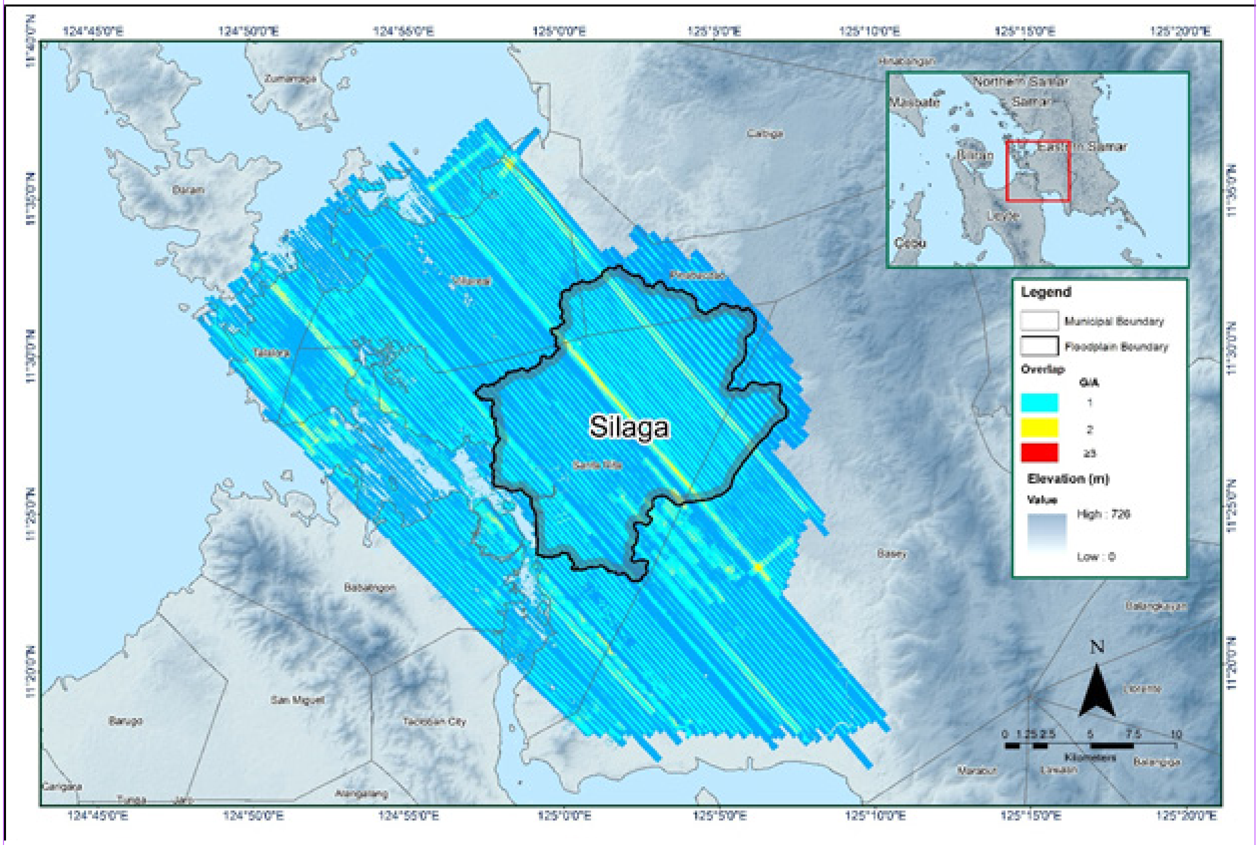

Figure 16. Image of data overlap for Silaga floodplain.

The overlap statistics per block for the Silaga floodplain can be found in Annex 8. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 26.89% 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 17. It was determined that all LiDAR data for Silaga floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.72 points per square meter.

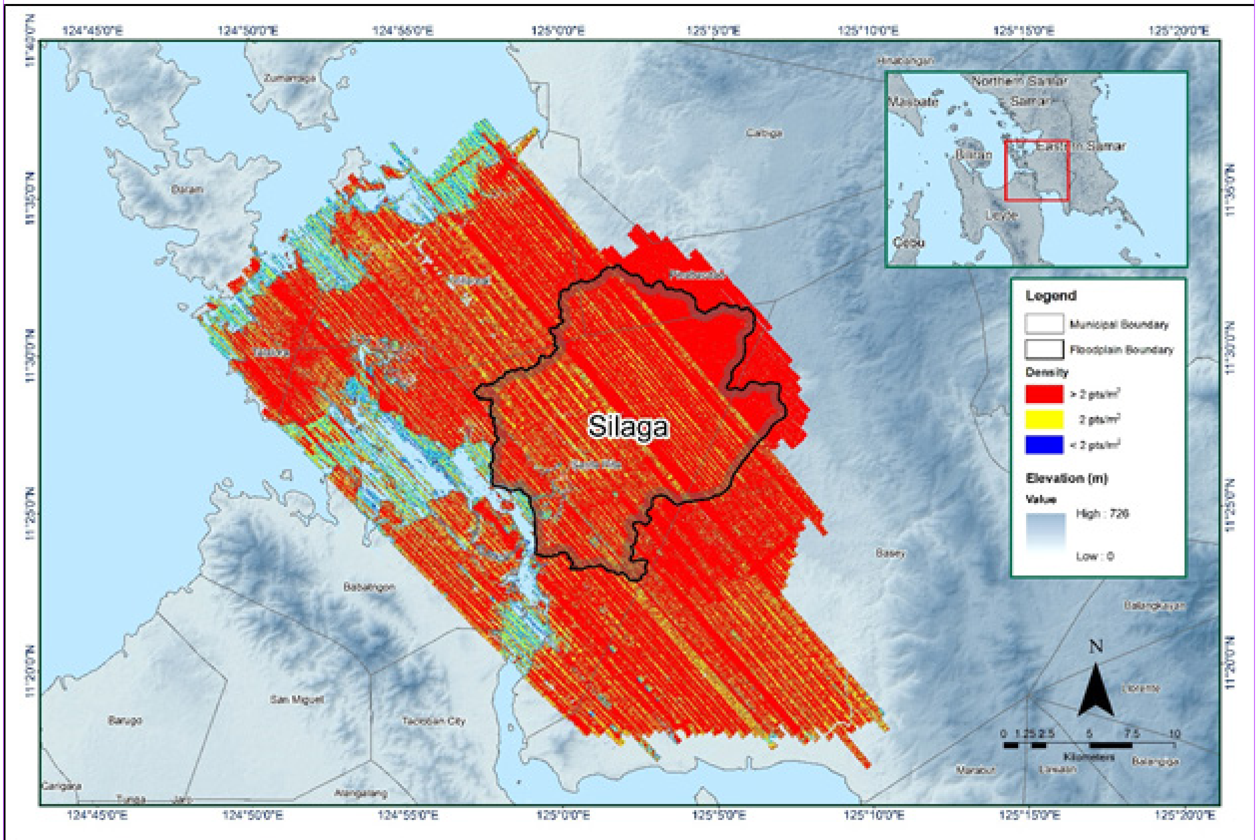

Figure 17. Pulse density map of merged LiDAR data for Silaga floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 18. The default color range is from blue to red, where bright blue areas correspond to portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.20m relative to elevations of its adjacent flight line. Bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20m relative to elevations of its adjacent flight line. Areas with bright red or bright blue need to be investigated further using Quick Terrain Modeler software.

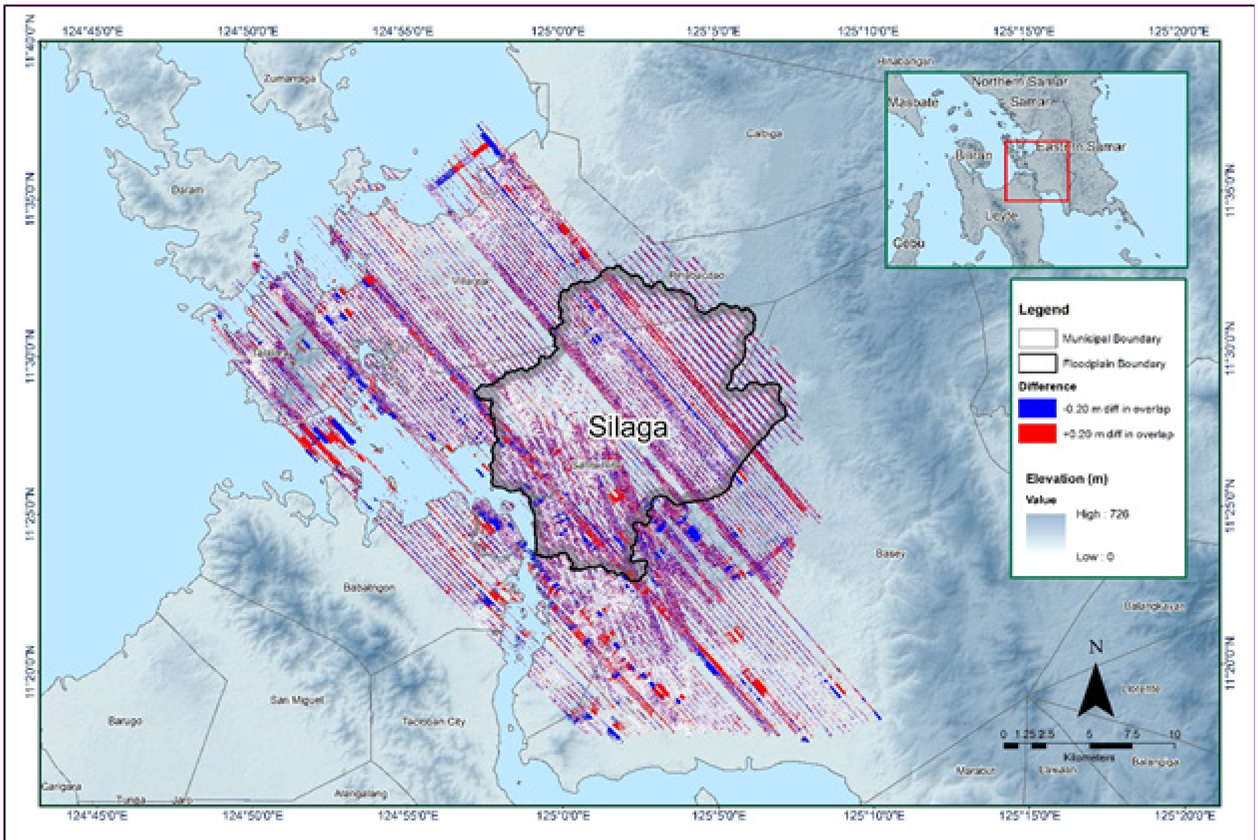

Figure 18. Elevation Difference Map between flight lines for Silaga Floodplain Survey.

A screen capture of the processed LAS data from a Silaga flight 1444A loaded in QT Modeler is shown in Figure 19. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

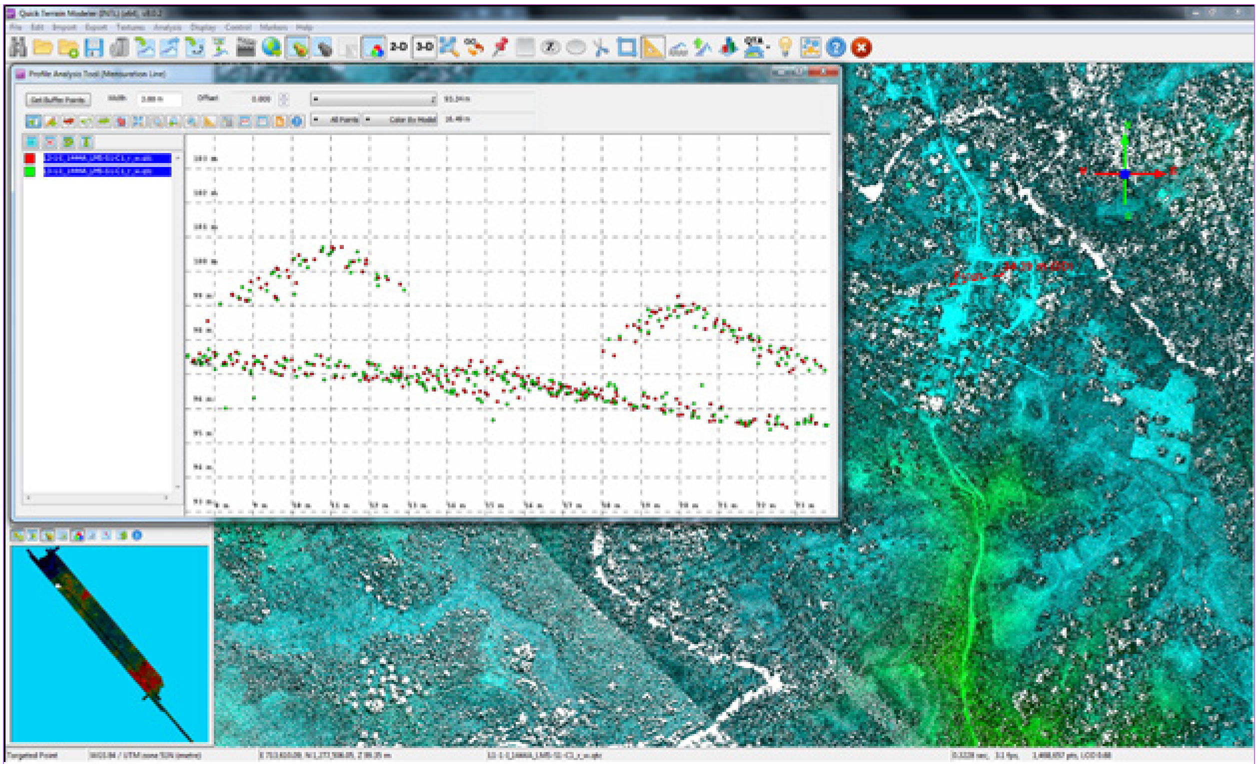

Figure 19. Quality checking for Silaga flight 14444A using the Profile Tool of QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 17. Silaga classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	416,539,503
Low Vegetation	295,000,845
Medium Vegetation	1,112,145,741
High Vegetation	1,134,827,163
Building	22,191,351

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Silaga floodplain is shown in Figure 20. A total of 1,566 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 419.70 meters and 52.08 meters respectively.

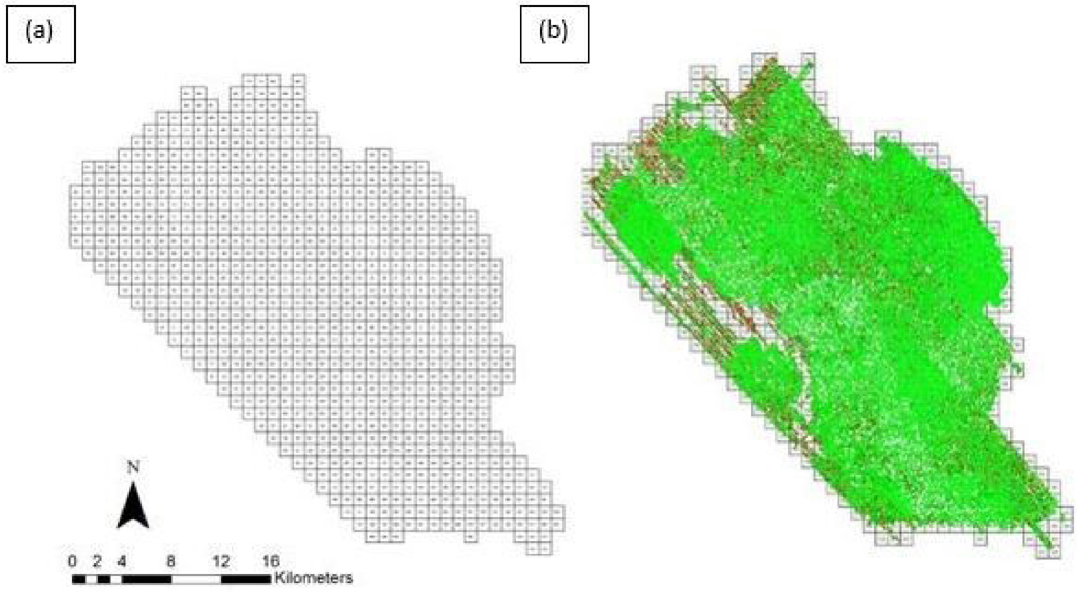

Figure 20. Tiles for Silaga floodplain (a) and classification results (b) in TerraScan.

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

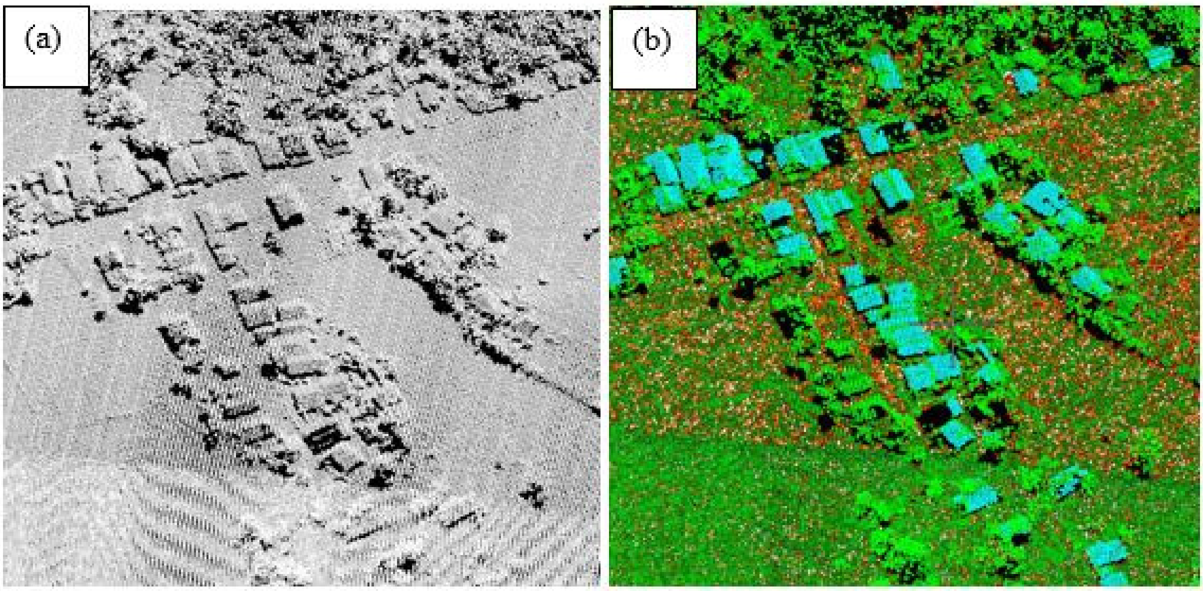

Figure 21. Point cloud before (a) and after (b) classification

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

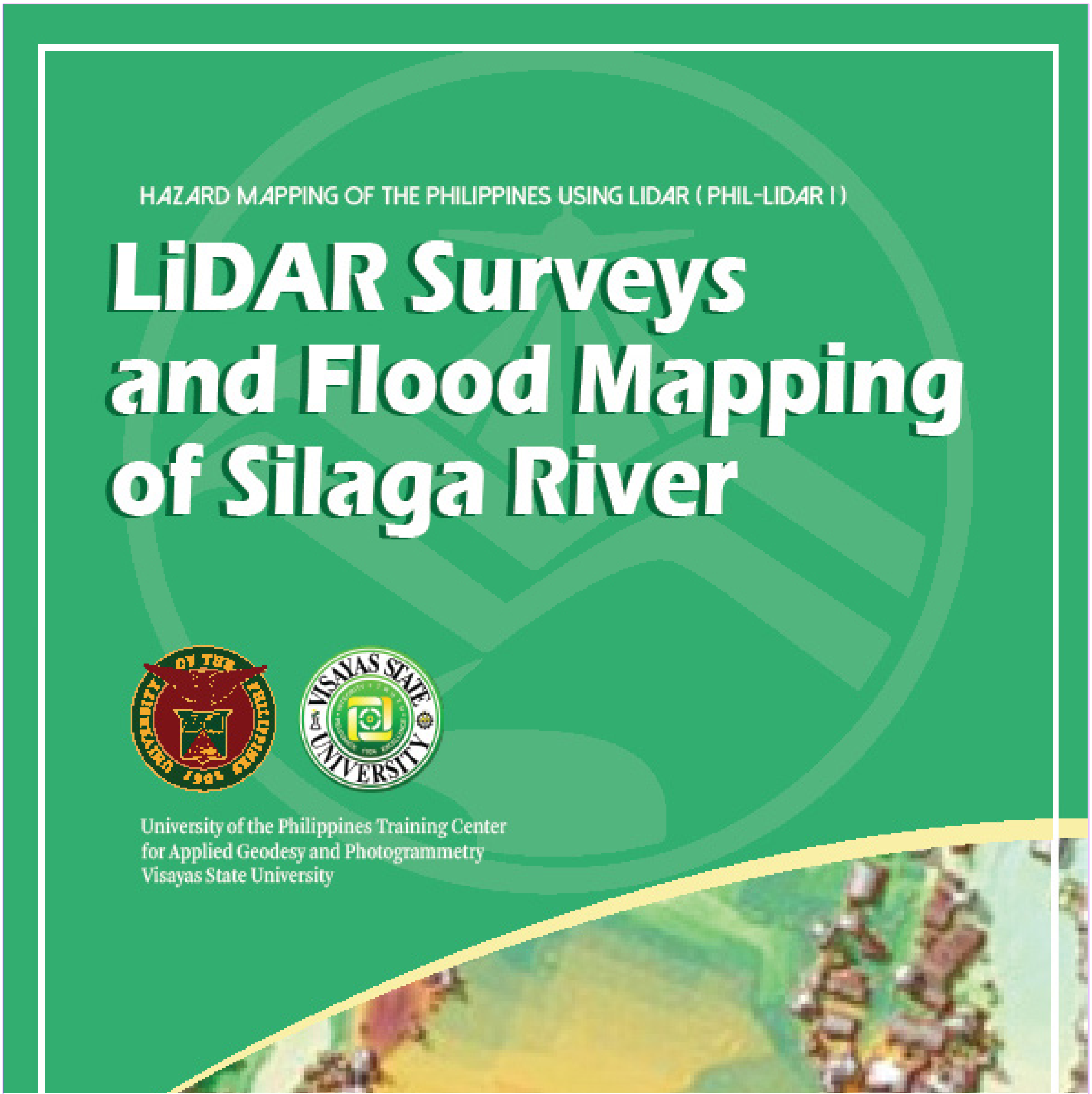

Figure 22. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Silaga floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 1,163 1km by 1km tiles area covered by Silaga floodplain is shown in Figure 23. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Silaga floodplain attained a total of 620.52 sq.km in orthophotogaph coverage comprised of 8,889 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 24.

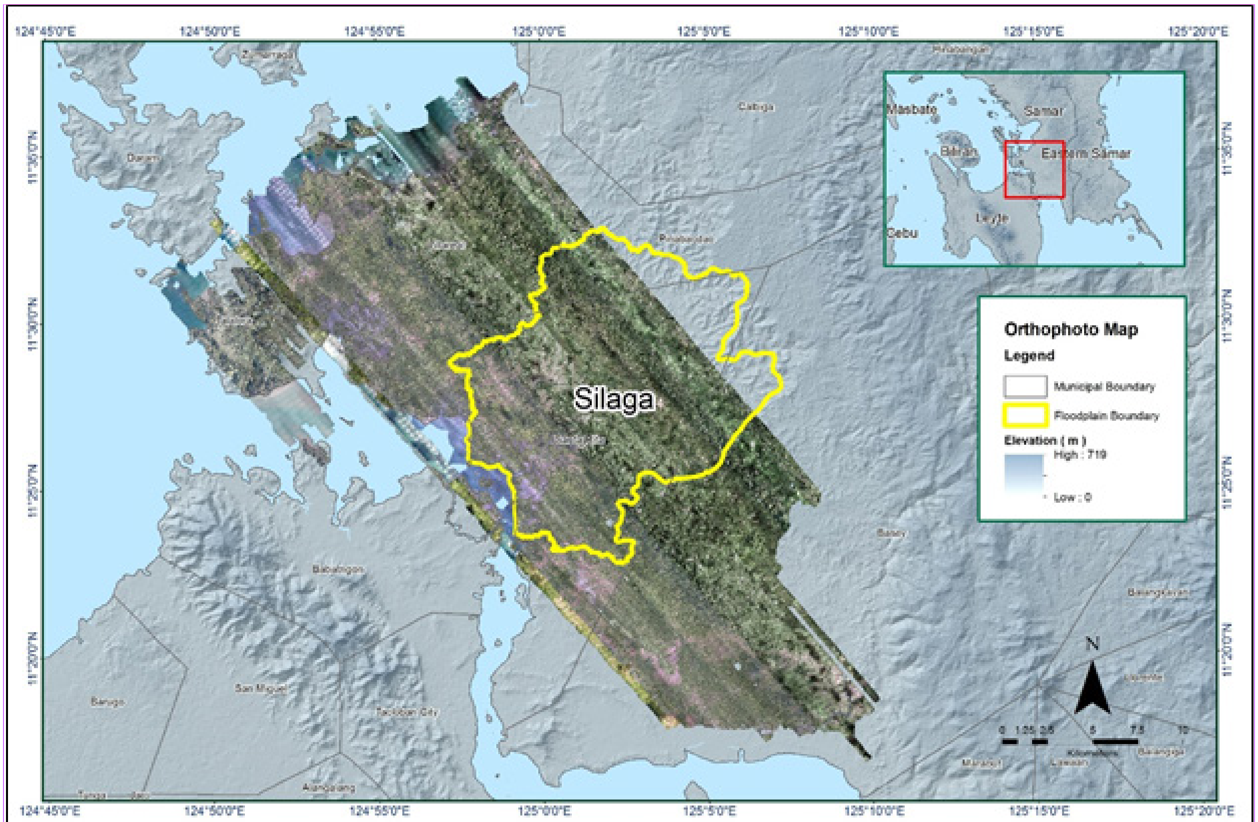

Figure 23. Silaga Floodplain with the available orthophotographs.

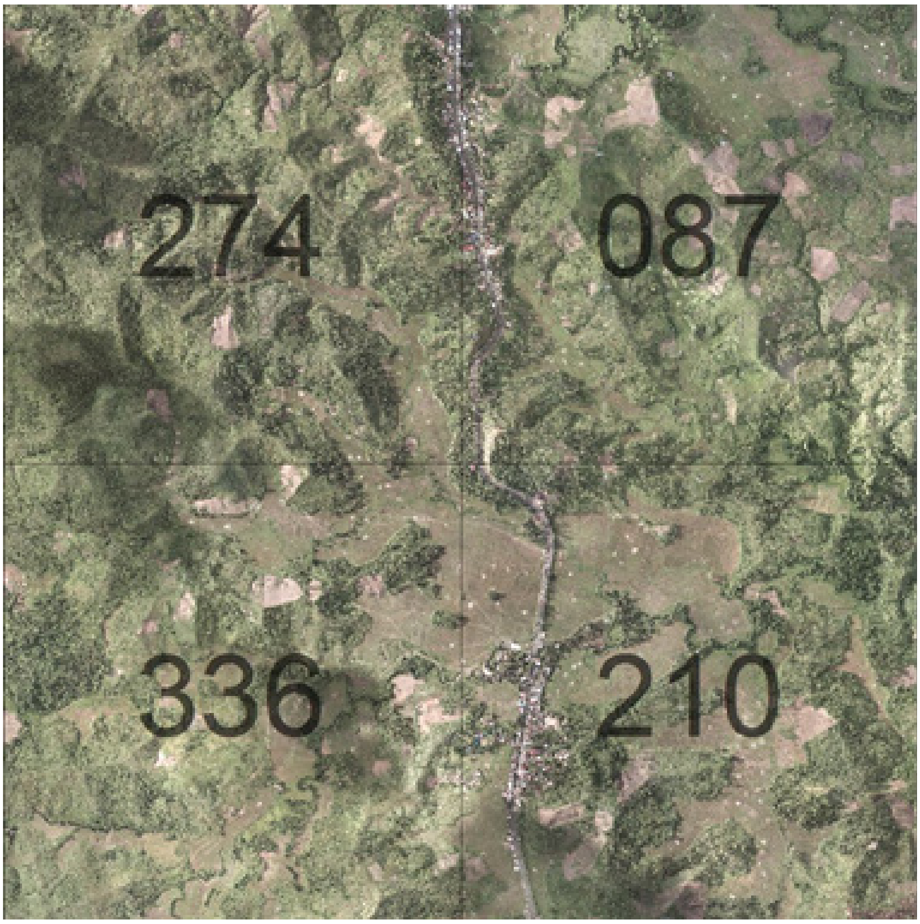

Figure 24. Sample orthophotograph tiles for Silaga Floodplain.

3.8 DEM Editing and Hydro-Correction

Eight (8) mission blocks were processed for Silaga flood plain. These blocks are composed of SamarLeyte and Leyte blocks with a total area of 1,070.01 square kilometers. Table 18 shows the name and corresponding area of each block in square kilometers.

Table 18. LiDAR blocks with its corresponding areas.

LiDAR Blocks	Area (sq.km)
Samar_Leyte_Blk33H	174.97
Samar_Leyte_Blk33G	217.86
Samar_Leyte_Blk33F	227.31
Samar_Leyte_Blk33E_additional	92.55
Samar_Leyte_Blk33E	161.35
Leyte_Blk33F	88.74
Leyte_Blk33H	78.99
Leyte_Blk33H_additional	28.24
TOTAL	1070.01 sq.km

Figure 25 shows portions of a DTM before and after manual editing. As evident in the figure, the bridge (Figure 25a) has obstructed the flow of water along the river. To correct the river hydrologically, the bridge was removed through manual editing (Figure 25b). Likewise, the paddy field (Figure 25c) was misclassified and removed during the classification process. To complete the surface, the paddy field (Figure 25d) was retrieved and reclassified through manual editing to allow the correct water flow. As well, a lone building (Figure 25e) was still present in the DTM after the classification process. To correct this, the building was removed through manual editing (Figure 25f).

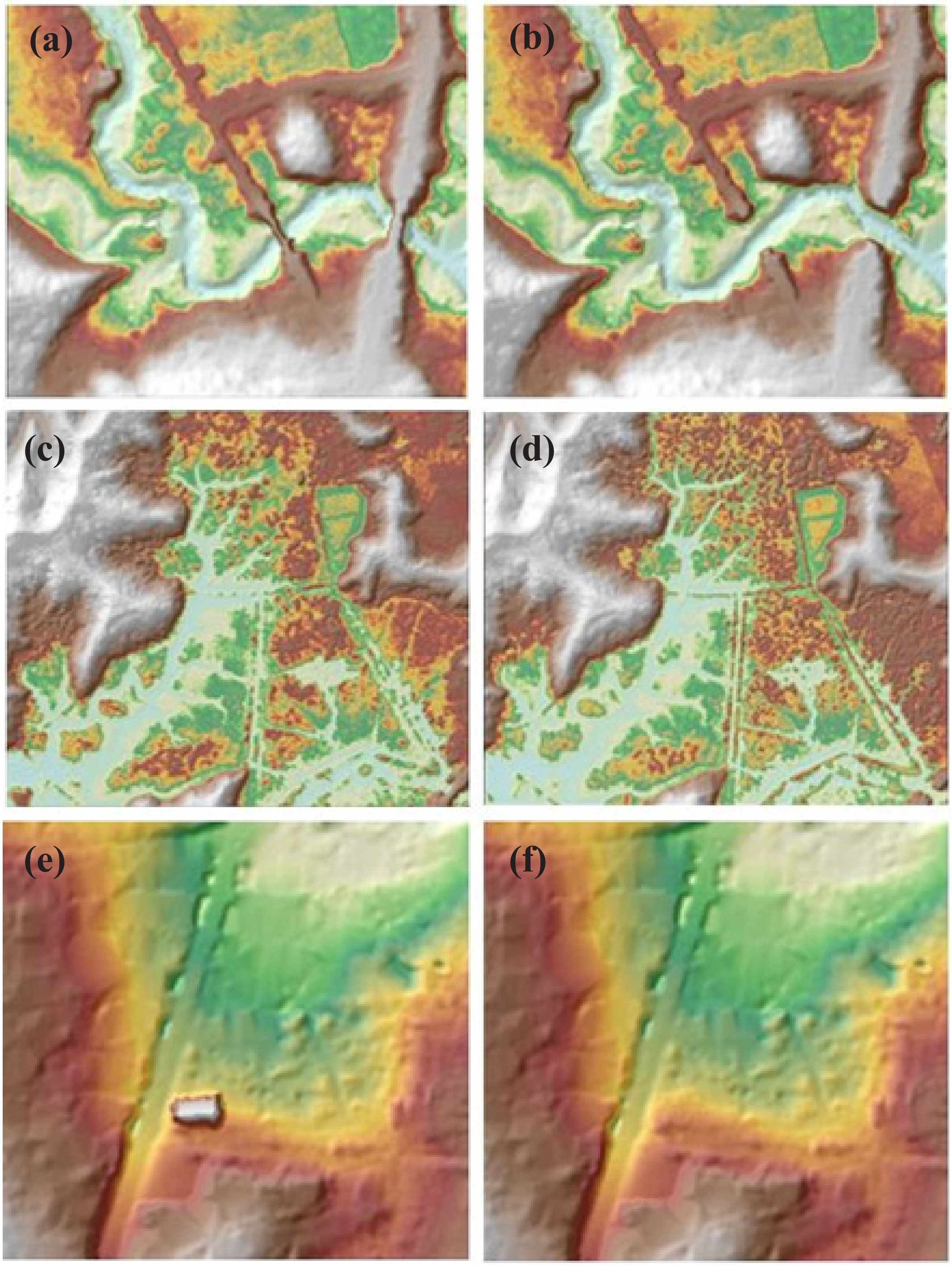

Figure 25. Portions in the DTM of Silaga Floodplain – a bridge before (a) and after (b) manual editing; a paddy field before (c) and after (d) data retrieval; and a building before (e) and after (f) manual editing.

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 Silaga floodplain is shown in Figure 26. It can be seen that the entire Silaga floodplain is 100% covered by LiDAR data.

Table 19. Shift values of each LiDAR block of Silaga Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Samar_Leyte_Blk33H	1.00	0.00	-0.62
Samar_Leyte_Blk33G	0.00	0.00	-0.62
Samar_Leyte_Blk33F	0.00	0.00	-0.62
Samar_Leyte_Blk33E_additional	0.00	0.00	-0.36
Samar_Leyte_Blk33E	0.00	0.00	-0.54
Leyte_Blk33F	-1.00	1.00	-4.56
Leyte_Blk33H	1.00	0.00	-1.00
Leyte_Blk33H_additional	1.00	0.00	-0.94

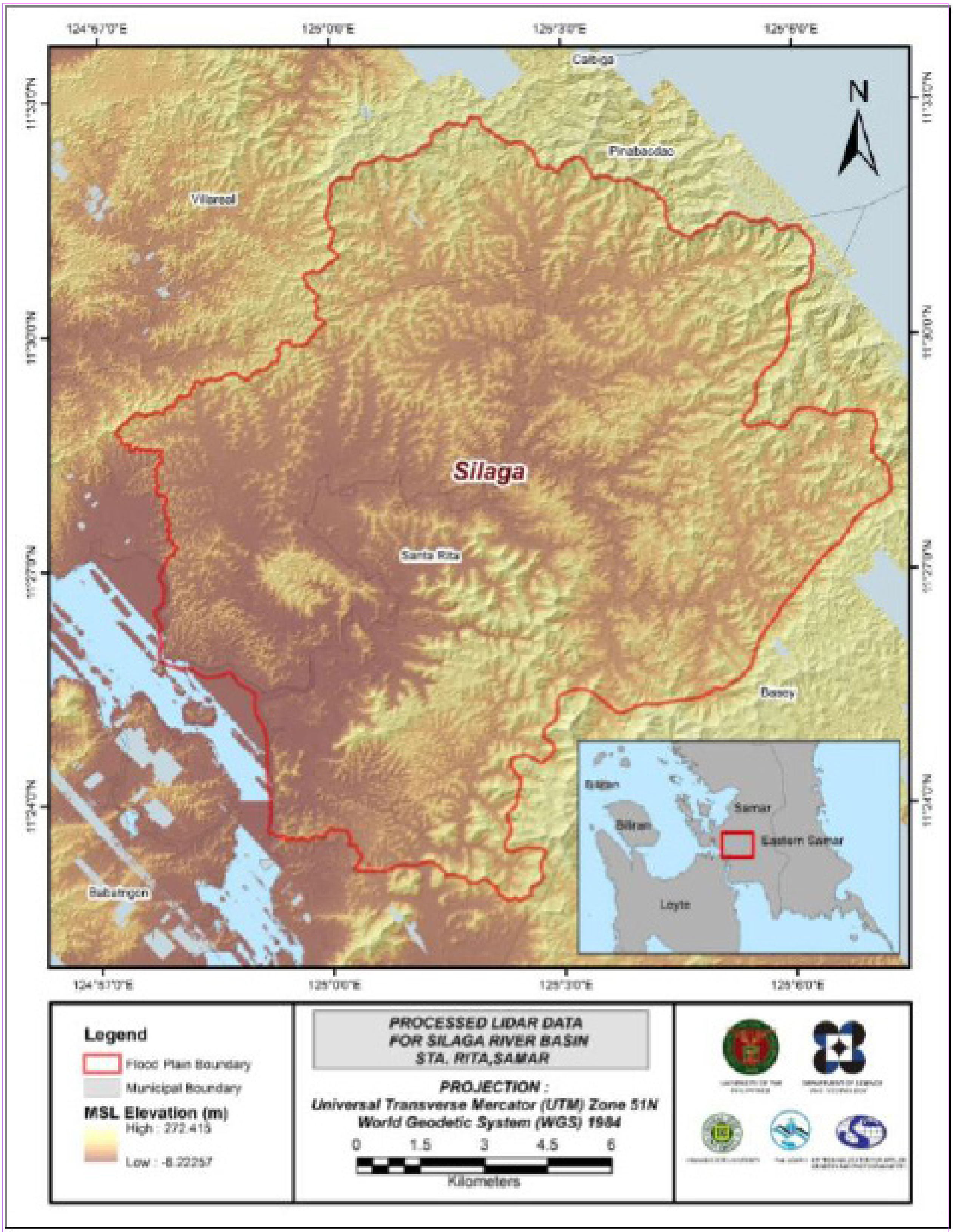

Figure 26 . Map of Processed LiDAR Data for Silaga Floodplain.

3.10 Calibration and Validation of Mosaicked LiDAR DEM

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Samar to collect points with which the LiDAR dataset is validated is shown in Figure 27, with the validation survey points highlighted in green. A total of 28,096 survey points were gathered for all the floodplains within Eastern and Western Samar wherein Silaga is located. However, this point dataset was not used for the calibration of the LiDAR data for the Silaga Floodplain because during the mosaicking process, each LiDAR block was referred to the calibrated Tacloban DEM. Therefore, the mosaicked DEM of Silaga 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 27. 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 Silaga DEM.

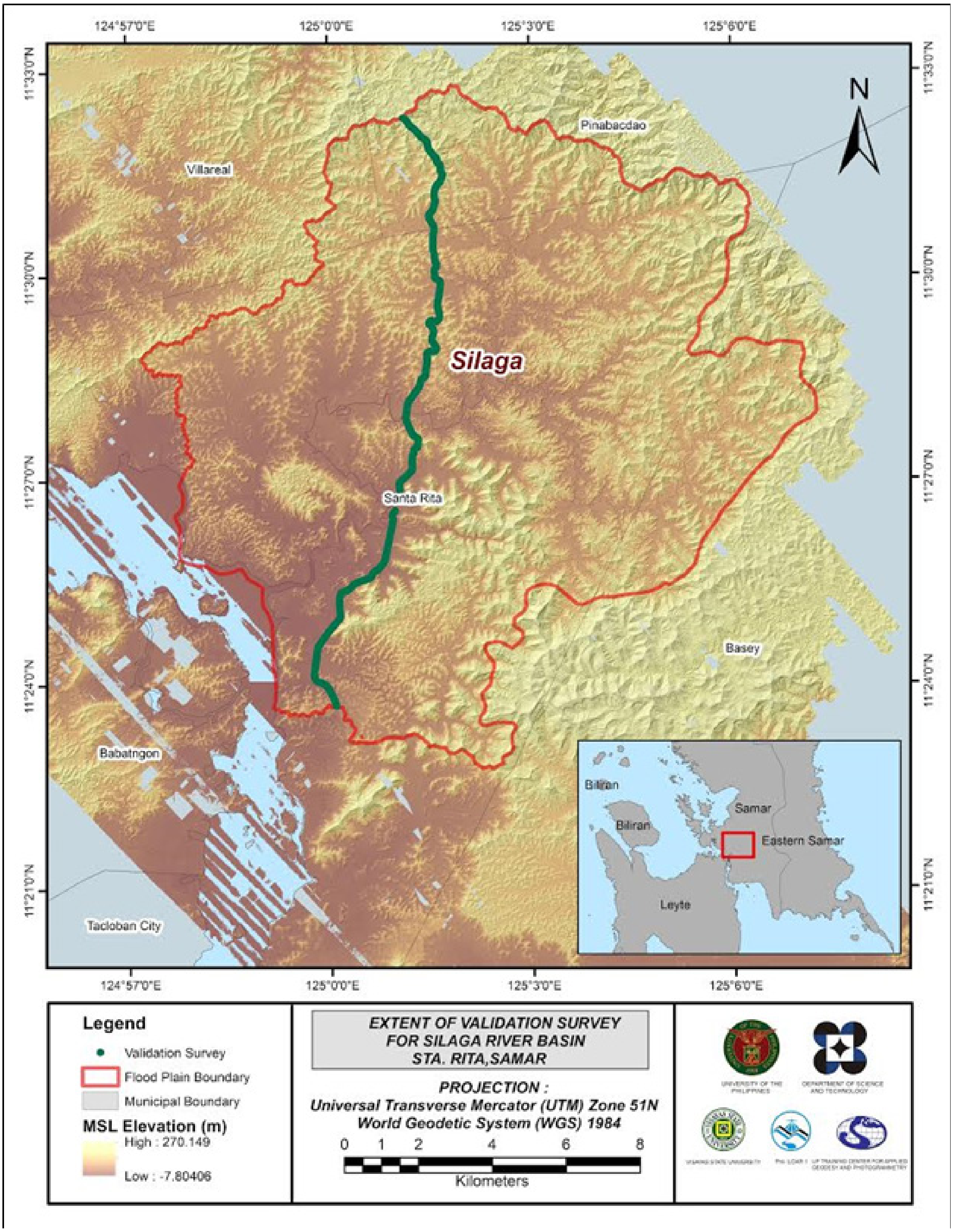

Figure 27. Map of Silaga Floodplain with validation survey points in green.

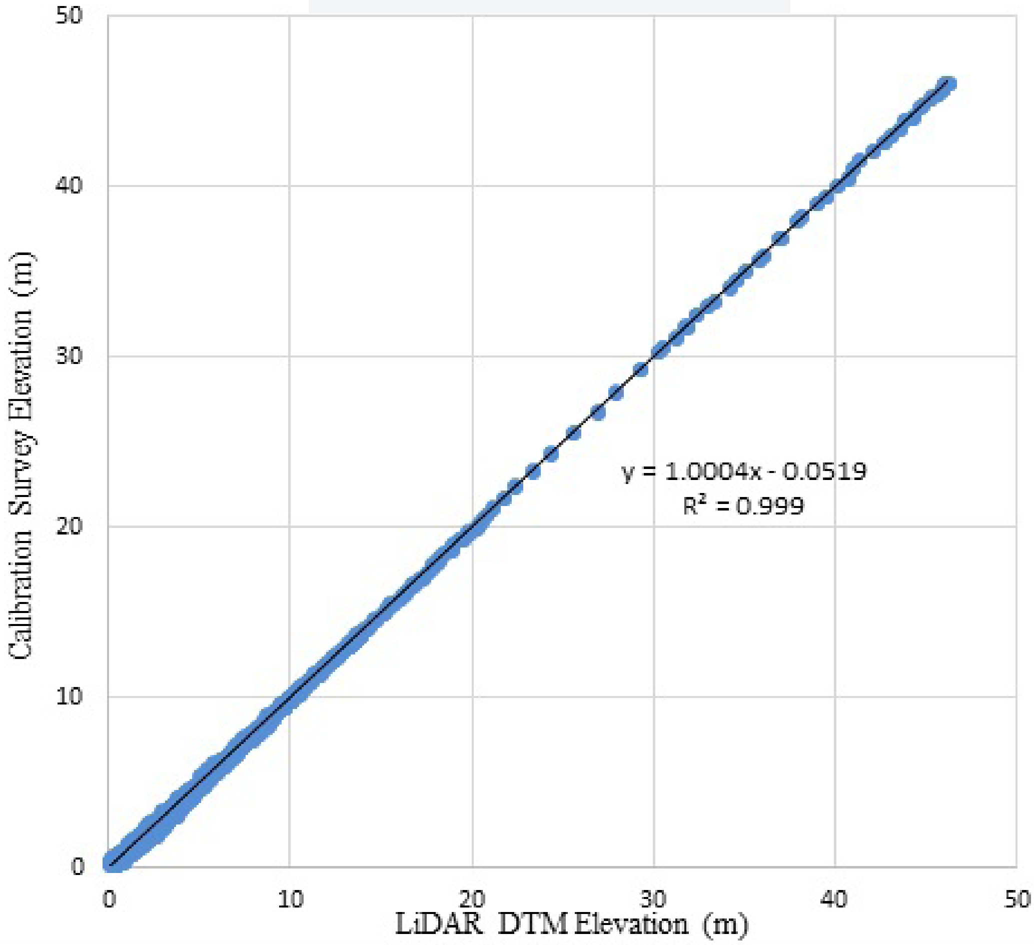

Figure 28. Correlation plot between calibration survey points and LiDAR data.

Table 20. Calibration Statistical Measures

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

A total of 2,158 survey points lie within Silaga flood plain and were used for the validation of the calibrated Silaga 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 28. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.20 meters with a standard deviation of 0.12 meters, as shown in Table 21.

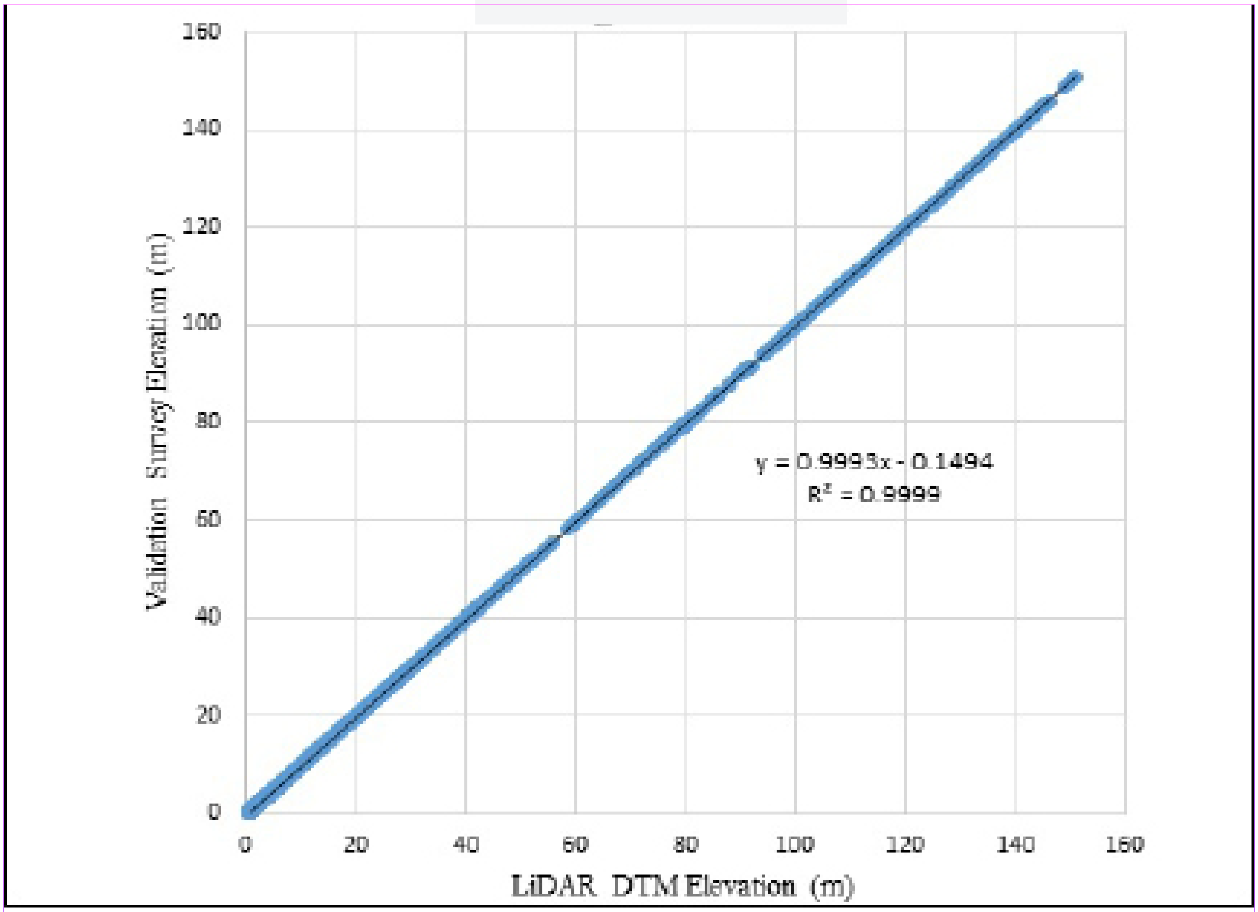

Figure 29. Correlation plot between validation survey points and LiDAR data.

Table 21. Validation Statistical Measures

Validation Statistical Measures	Value (meters)
RMSE	0.20
Standard Deviation	0.12
Average	-0.17
Minimum	-0.37
Maximum	0.10

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data was available for Silaga with 947 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 0.07 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Silaga integrated with the processed LiDAR DEM is shown in Figure 30.

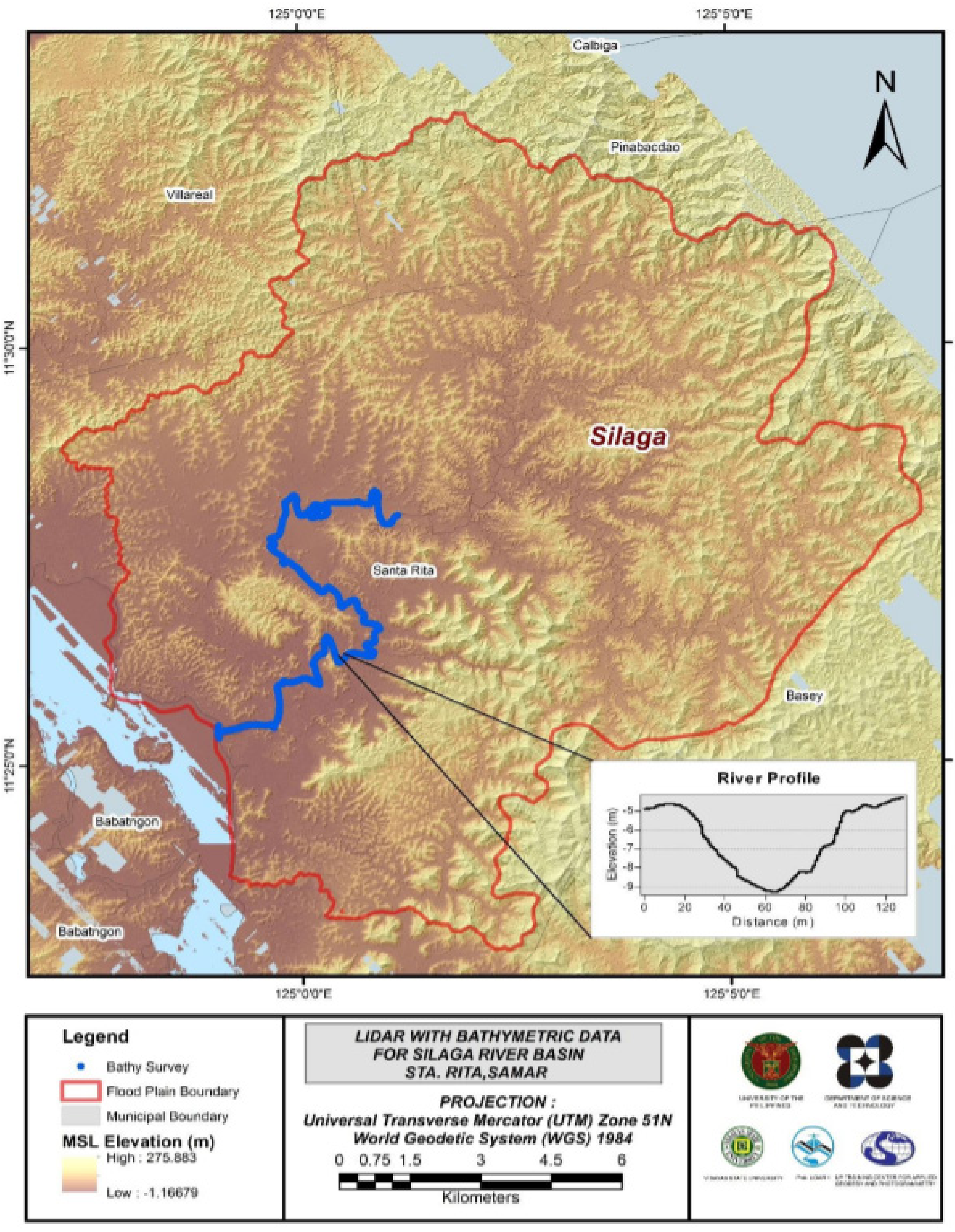

Figure 30. Map of Silaga floodplain.

3.12 Feature Extraction

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

3.12.1 Quality Checking of Digitized Features' Boundary

Silaga floodplain, including its 200 m buffer, has a total area of 208.01 sq km. For this area, a total of 6.0 sq. km., corresponding to a total of 1031 building features, are considered for QC. Figure 31 shows the QC blocks for Silaga floodplain.

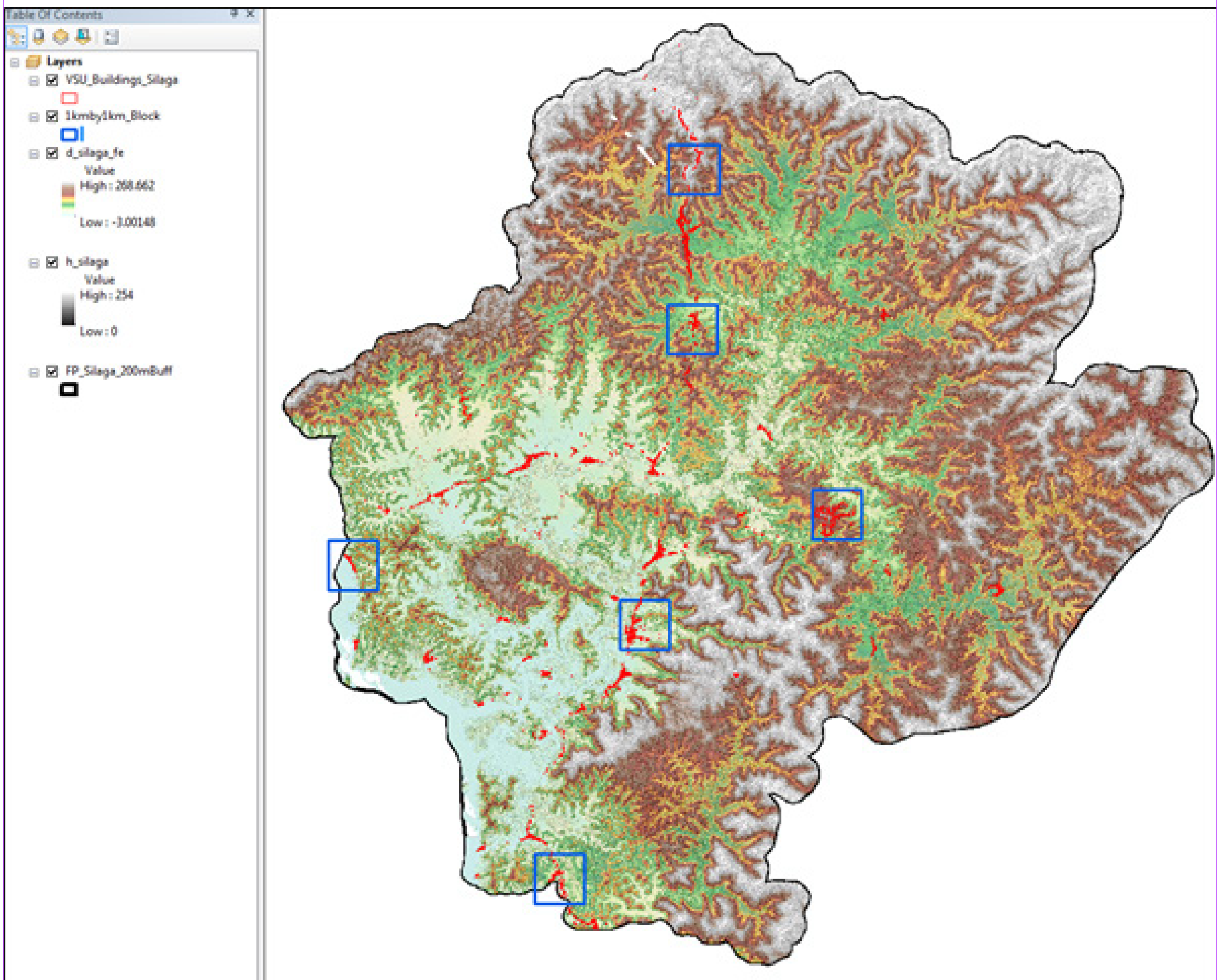

Figure 31. Blocks (in blue) of Silaga building features that were subjected to QC

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

Table 22. Quality Checking Ratings for Silaga Building Features

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Silaga	89.53	99.92	86.89	PASSED

3.12.2 Height Extraction

Height extraction was done for 5,690 building features in Silaga floodplain. Of these building features, none was filtered out after height extraction, resulting to 5,690 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 8.74 m.

3.12.3 Feature Attribution

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

Table 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 Silaga floodplain.

Facility Type	No. of Features
Residential	5,486
School	83
Market	1
Agricultural/Agro-Industrial Facilities	16
Medical Institutions	2
Barangay Hall	9
Military Institution	14
Sports Center/Gymnasium/Covered Court	10
Telecommunication Facilities	1
Transport Terminal	0
Warehouse	4
Power Plant/Substation	3
NGO/CSO Offices	0
Police Station	0
Water Supply/Sewerage	0
Religious Institutions	18
Bank	0
Factory	0
Gas Station	1
Fire Station	0
Other Government Offices	21
Other Commercial Establishments	21
Total	5,690

Table 24. Total length of extracted roads for Silaga floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Silaga	22.95	13.63	0.00	19.77	0.00	56.35

Table 25. Number of extracted water bodies for Silaga floodplain.

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Silaga	157	49	0	0	0	206

A total of 44 bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

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

Figure 32 shows the Digital Surface Model (DSM) of Silaga floodplain overlaid with its ground features.

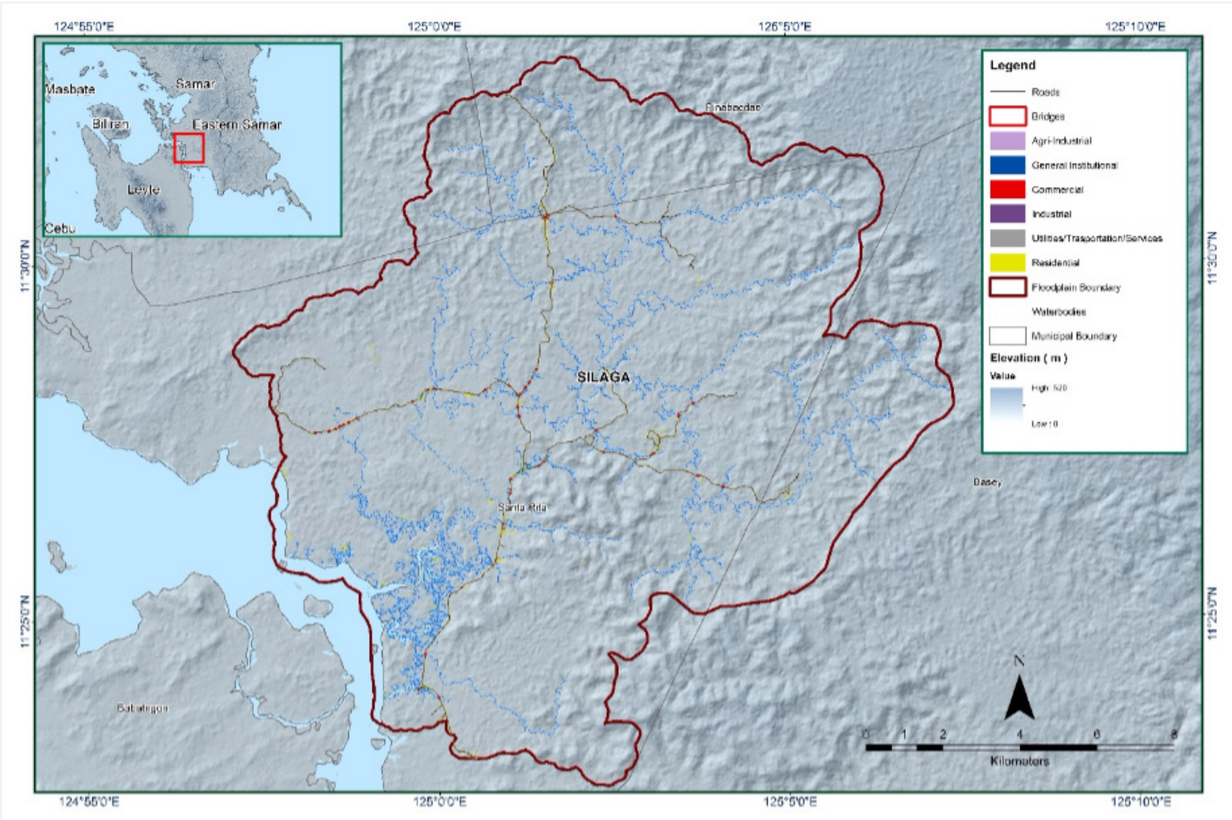

Figure 32. Extracted features of the Silaga Floodplain.

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS OF THE SILAGA 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 first and second river survey in the Silaga River were conducted on September 10 to 24, 2014 (Samar Phase 1) and on December 4 to 18, 2014 (Samar Phase 2) respectively. Generally, the scope of work was comprised of (i) initial reconnaissance; (ii) control point survey for the establishment of a control point; (ii) the cross-section survey, bridge as-built survey, and water level marking in the Mean Sea Level (MSL) of the Silaga Bridge (for Samar Phase 1) and (iv) the bathymetric survey of the Silaga River (for Samar Phase 2) from Brgy. Tulay down to Brgy. La Paz, where the mouth of the river is located; which reached an estimated length of 16.34 kms. using the PPK GNSS Survey Technique. Figure 33 illustrates the extent of the Silaga River Bathymetric Survey.

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

4.2 Control Survey

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

Two control points were established along the approach of two bridges, namely UP-CNG at the Can-Obing Bridge in Barangay Can-Abong, Borongan City, Eastern Samar and UP-SLG at the Silaga Bridge, Brgy. Tominamos in the Municipality of Sta. Rita, Samar. Alongside this, the respective NAMRIA-established control points were also used as markers in the survey: SME-12 in Brgy. San Miguel, Municipality of Balangiga and SE-49 in Brgy. Aguinaldo, Municipality of General MacArthur; both located in the province of Eastern Samar; and SMR-3322 in Brgy. Binongtu-an, Municipality of Basey and SM-335 in Pinalanga, Municipality of Marabut; both located in the province of Samar. Table 26 depicts the summary of reference and control points utilized, with their corresponding locations, while Figure 34 shows the GNSS network established in the Silaga River Survey.

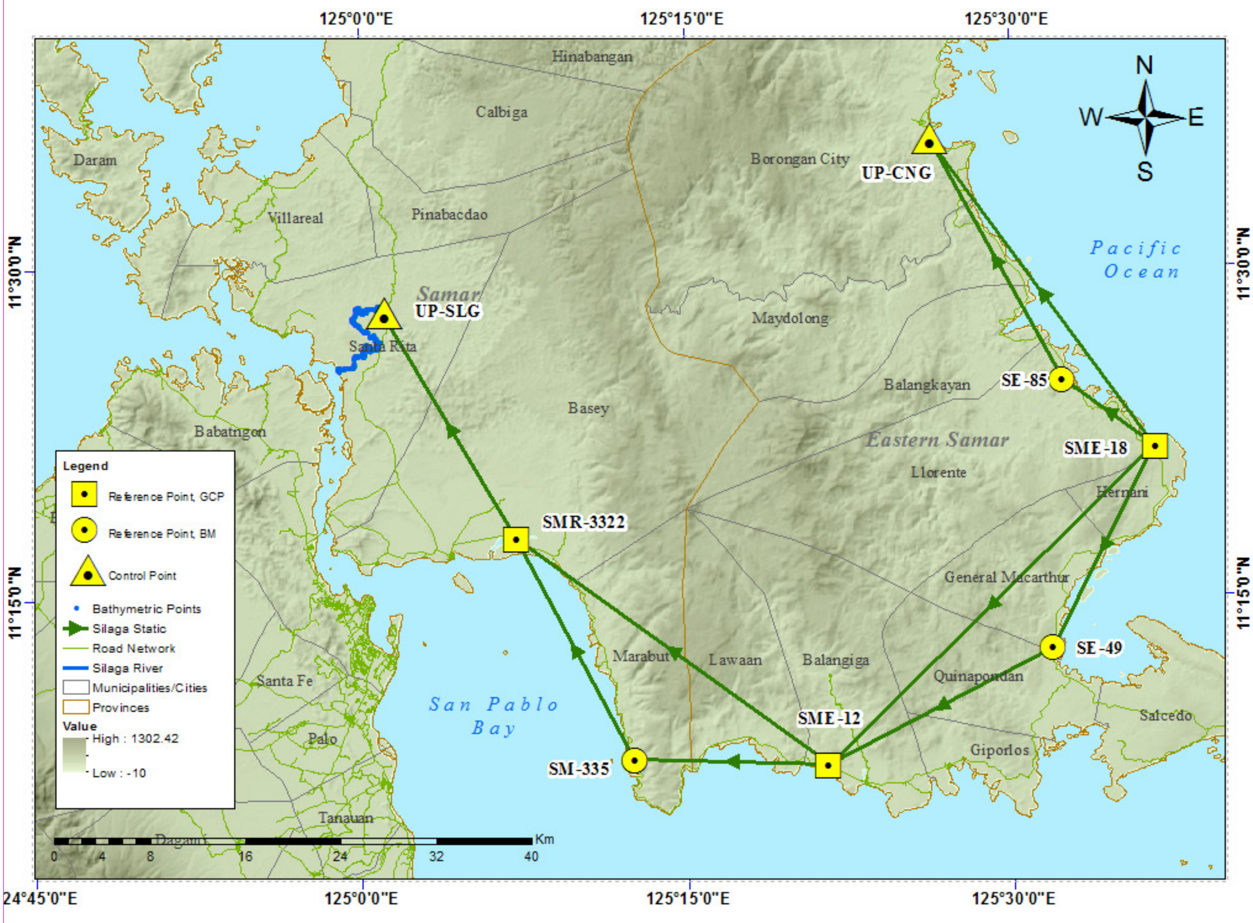


Figure 34. The GNSS Network established in the Silaga River Survey.

Table 26. References used and control points established in the Silaga River Survey (Source: NAMRIA, UP-TCAGP).

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (Meter)	Elevation in MSL (Meter)	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-SLG	UP Established	11°27'57.66166"	125°01'08.84182"	73.078	9.958	Sep 19, 2014

Figure 35 to Figure 42 depict the setup of the GNSS on recovered reference points and established control points in the Silaga River.

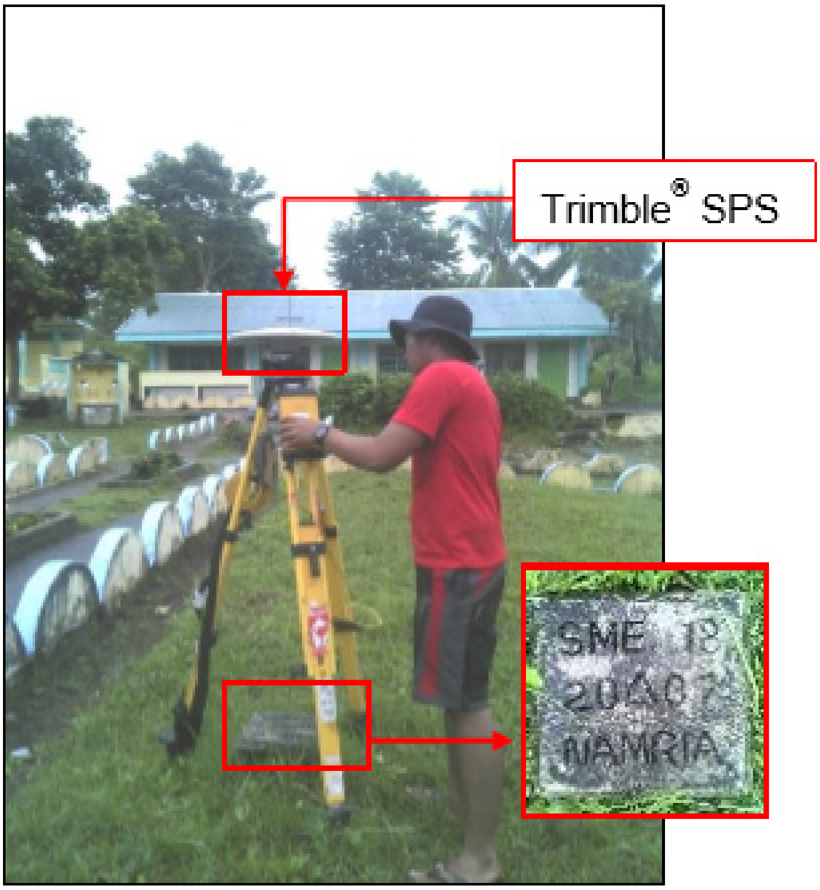


Figure 35. The GNSS base receiver setup, Trimble® SPS 852, at SME-18, located inside San Jose Elementary School, Brgy. Canciledes in the Municipality of Hernani, Eastern Samar.

Figure 36. The GNSS (Trimble® SPS 882) receiver setup at SE-85, located at the approach of Llorente Bridge in Brgy. 11, Municipality of Llorente, Eastern Samar

Figure 37. The GNSS (Trimble® SPS 882) receiver occupation, at SME-12, located in Brgy. San Miguel, Municipality of Balangiga, Eastern Samar.

Figure 38. The GNSS (Trimble® SPS 852) base occupation at SMR-3322, located at the approach of Golden Bridge in Brgy. Binongtu-an in the Municipality of Basey, Samar.

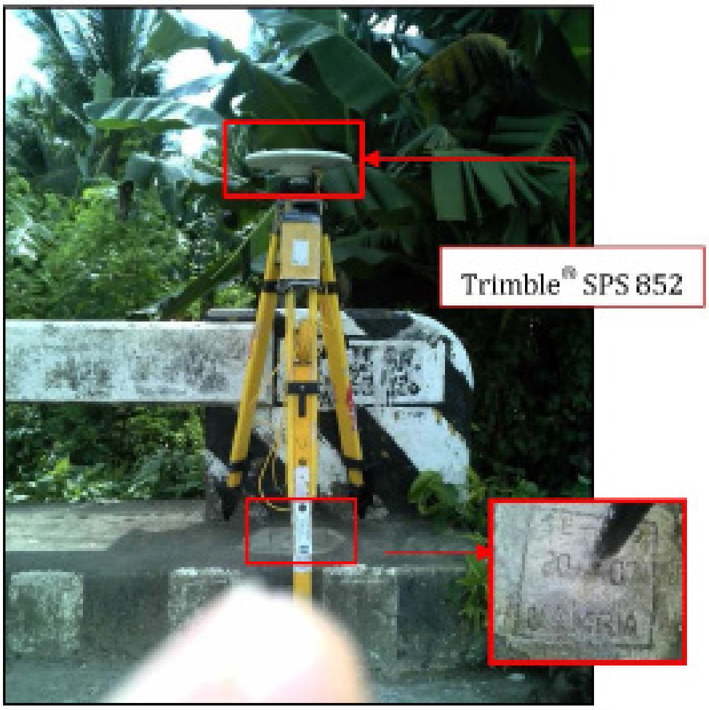


Figure 39. The GNSS (Trimble® SPS 852) base occupation at SE-49, located in Brgy. Aguinaldo, Municipality of General MacArthur, Eastern Samar.

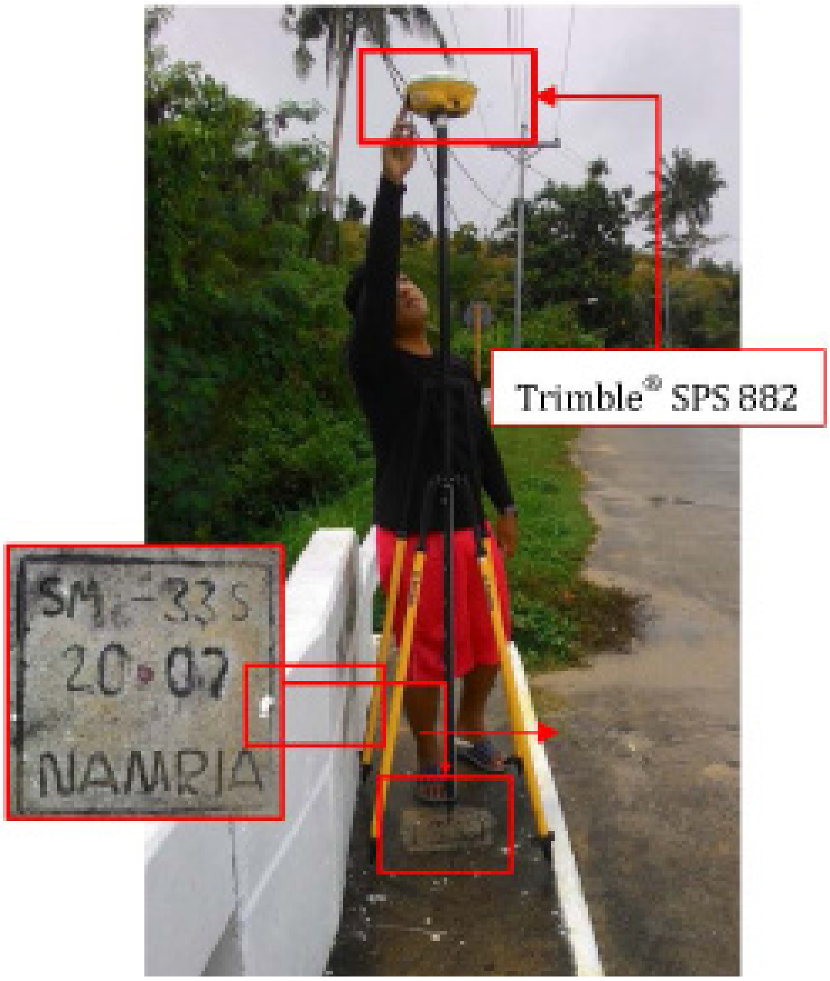


Figure 40. The GNSS (Trimble® SPS 882) base occupation , at SM-33S, located in Brgy. Pinalanga in the Municipality of Marabut, Samar.

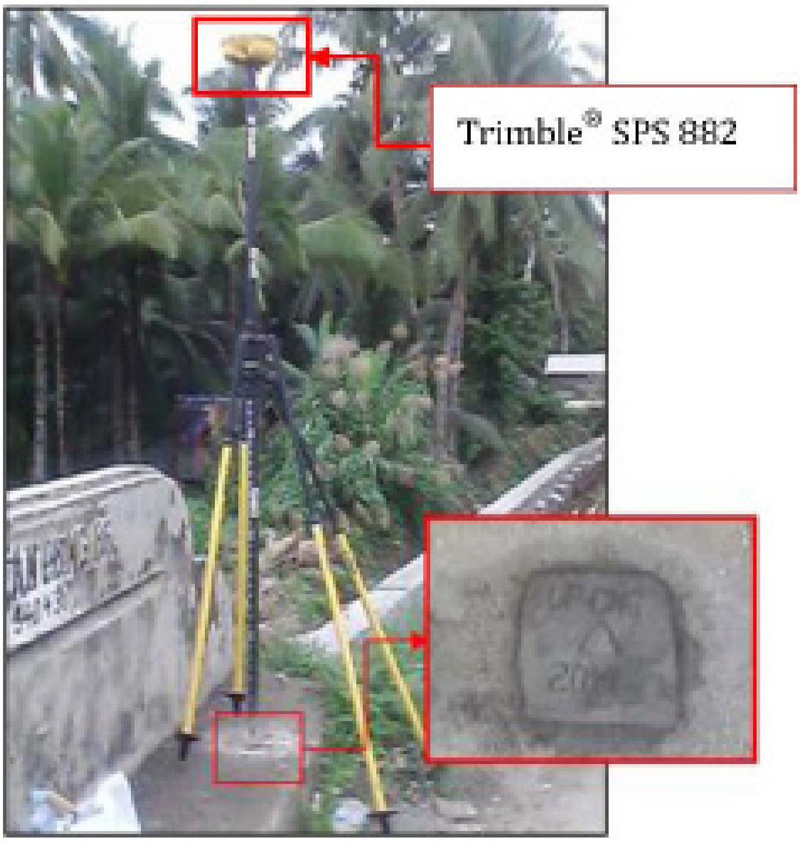


Figure 41. The GNSS receiver occupation, Trimble® SPS 882, at UP-CNG, located at the approach of Can-Obing Bridge in Brgy. Can-Abong, Borongan City, Eastern Samar.

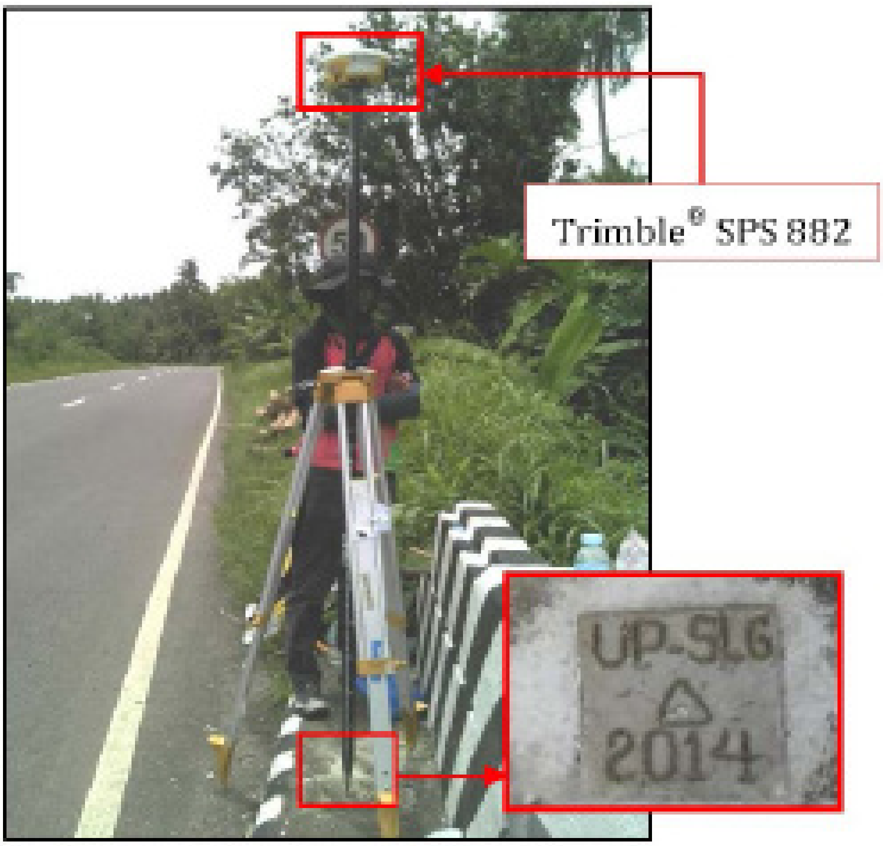


Figure 42. The GNSS receiver occupation, Trimble® SPS 882, at UP-SLG, located at the approach of Silaga Bridge in Brgy. Tominamos in the Municipality of Sta Rita, Samar.

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 was performed. Masking is the removal or covering of portions of the baseline data using the same processing software. The data is then repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, a resurvey is initiated. Table 27 presents the baseline processing results of control points in the Silaga River Basin, as generated by the TBC software.

Table 27. The Baseline processing report for the Silaga River GNSS static observation survey.

Observation	Date of Observation	Solution Type	H. 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-SLG	09-19-14	Fixed	0.005	0.018	329°56'57"	21908.828	2.417
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 the coordinates of SME-18 and the elevation value of reference point SE-85 held fixed; it is apparent that all baselines passed the required accuracy.

4.4 Network Adjustment

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

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

where:

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

For complete details, see the Network Adjustment Report shown in Table 28 to Table 31.

The eight (8) control points: SME-18, SE-85, SME-12, SMR-3322, SE-49, SM-33S, UP-CNG, and UP-CLG 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. Constraints applied to the adjustment of the control points.

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)					

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

Table 29. Adjusted grid coordinates for the control points used in the Silaga River flood plain survey.

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-33S	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	
SME18	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	

The results of the computation for 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-33S		
	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 for control points used in the Silaga River Flood Plain validation.

Point ID	Latitude	Longitude	Ellipsoid	Height	Constraint
SE-49	N11°12'34.48802"	E125°31'52.42238	Height	Error	
SE-85	N11°24'45.65441"	E125°32'20.98934	(Meter)	(Meter)	e
SM-33S	N11°07'33.79721"	E125°12'32.14831	66.981	0.050	
SME-12	N11°07'19.15395"	E125°21'29.28283	67.520	?	
SME18	N11°21'43.08127"	E125°36'37.41862	68.705	0.061	LL
SMR-3322	N11°17'40.55190"	E125°07'10.82309	67.212	0.051	
UP-CNG	N11°35'44.92939"	E125°26'23.62776	78.217	0.032	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 30. Based on the results of the computation, the accuracy conditions are satisfied; hence, the required accuracy for the program was met. The computed coordinates of the reference and control points utilized in the Silaga River GNSS Static Survey are seen in Table 31.

Table 31. The reference and control points utilized in the Silaga River Static Survey, with their corresponding locations (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
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-33S	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-SLG	UP Established	11°27'57.66166"	125°01'08.84182"	73.078	1268279.714	720265.267	9.958

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

The cross-section and as-built survey were conducted on September 19, 2014 on the upstream side of Silaga Bridge in Brgy. Tominamos in the Municipality of Santa Rita, Samar, using Trimble® SPS 882 GNSS PPK Survey Technique, (Figure 43 and Figure 44)

Figure 43. Downstream side of the Silaga Bridge

Figure 44. The Cross-section survey conducted at Silaga Bridge in Brgy. Tominamos, Sta. Rita, Samar.

The length of the cross-sectional line surveyed Silaga Bridge is about 237.791 meters (Figure 45) with thirty (30) cross-sectional points using the control point SMR-3322 as the GNSS base station. The location map (Figure 44), cross-section diagram (Figure 45), and the accomplished bridge data form (Figure 46). An automated water level sensor is found installed in the bridge.

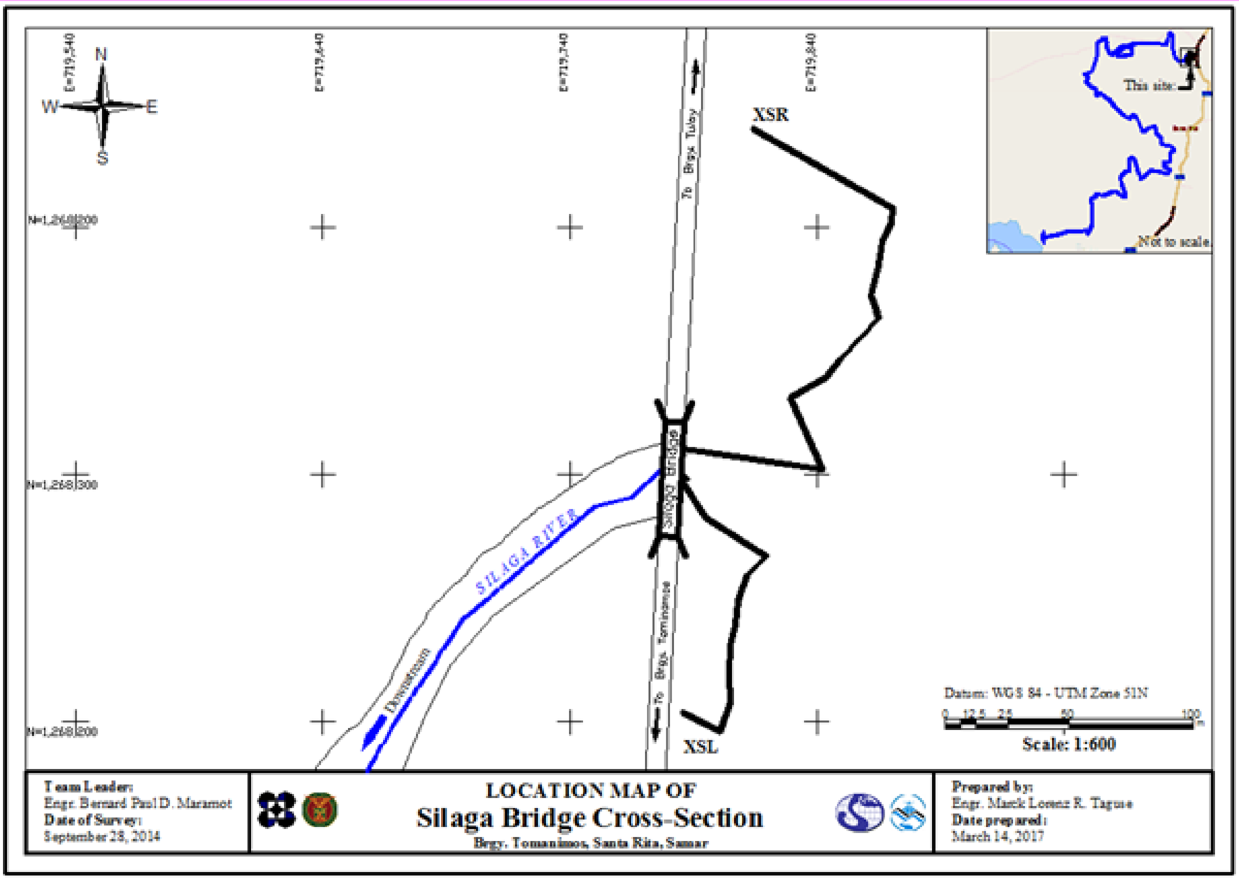


Figure 45. Location map of the Silaga Bridge cross-section survey.

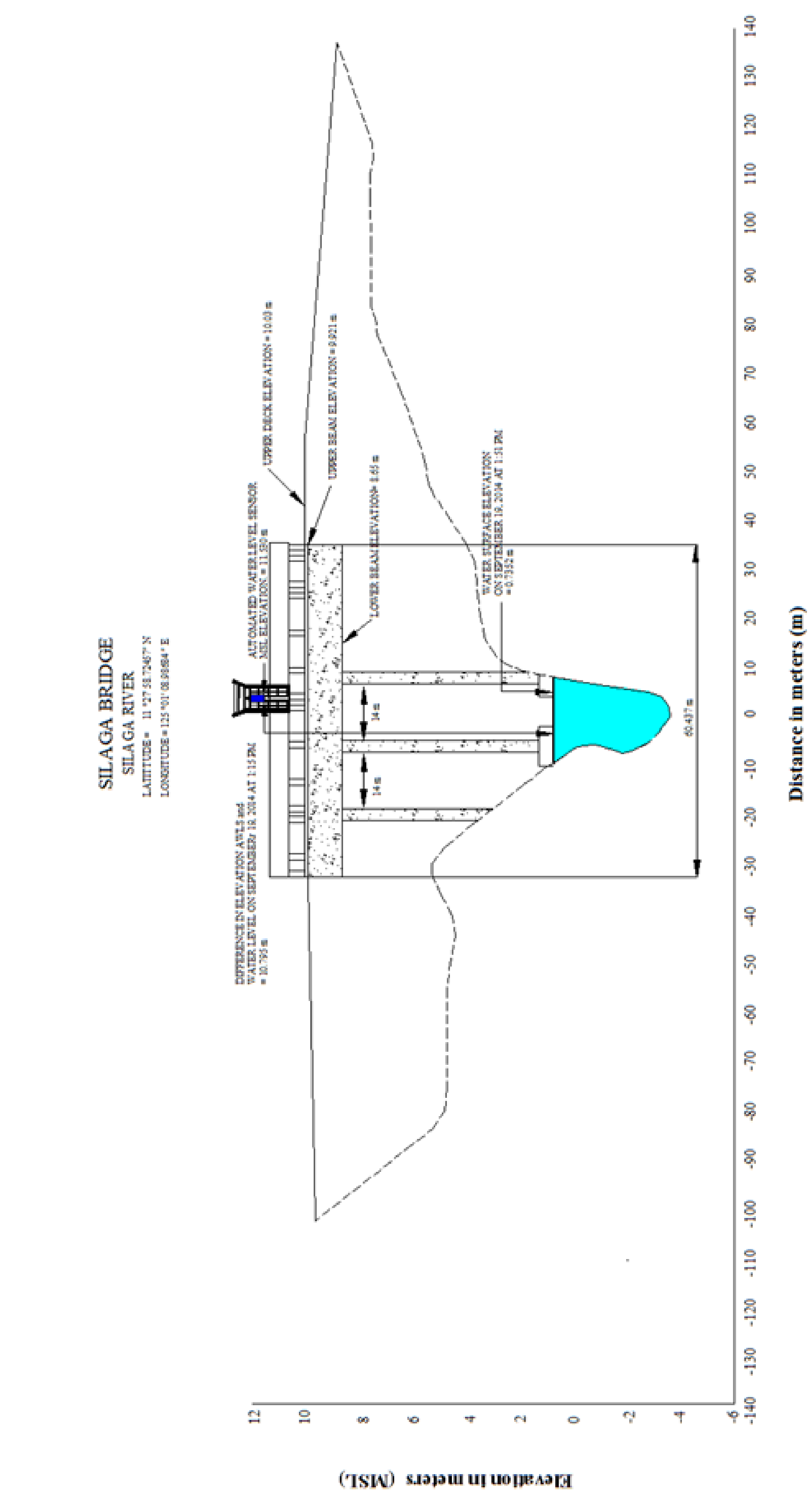


Figure 46. The Silaga Bridge cross-section survey drawn to scale.

Bridge Data Form

Bridge Name: SILAGA BRIDGE Date: September 19, 2014

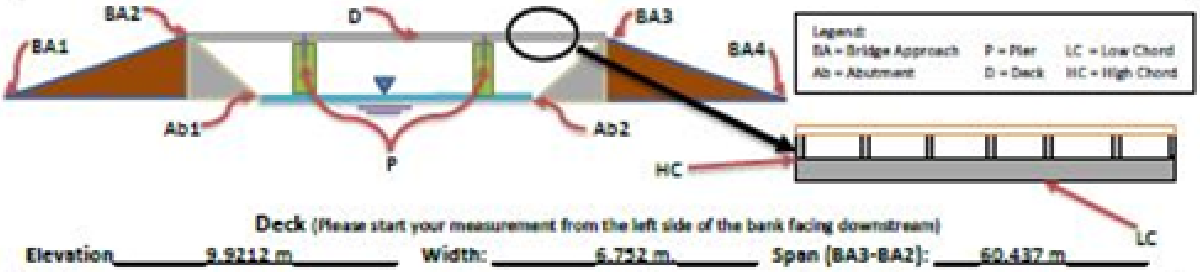
River Name: SILAGA RIVER BASIN Time: 11:06 AM

Location (Brgy, City, Region): Barangay Tulay Sta. Rita Western Samar

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

Flow condition: low (normal) high Weather Condition: (fair) rainy

Latitude: 11 – 27 – 58.72457 " N Longitude: 125 – 01 – 08.98684 " E.



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

Elevation: 9.9212 m Width: 6.752 m. Span (BA3-BA2): 60.437 m

	Station	High Chord Elevation	Low Chord Elevation
1	PIER 1	10.0342 M.	8.6342 M.
2	PIER 2	10.0972 M.	8.6972 M.
3	PIER 3	10.0412 M.	8.6212 M.
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	8.7962 M.	BA3	130.677 M.	9.9332 M.
BA2	70.240 M.	9.7822 M.	BA4	237.800 M.	7.9692 M.

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

	Station (Distance from BA1)	Elevation
Ab1	79.536 M.	4.0312 M.
Ab2		

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

Shape: Oblong Number of Piers: 3 Height of column footing: N/A

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	86.437 M.		
Pier 2	100.499 M.		
Pier 3	114.473 M.		
Pier 4			
Pier 5			
Pier 6			

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

Figure 47. The Silaga Bridge as-built survey data.

The water surface elevation of Silaga River was determined using a survey grade GNSS receiver Trimble® SPS 882 in PPK survey technique on September 19, 2014 at 1:51 PM with a value of 0.7352 m (MSL) as shown in Figure 46. This was translated into marking on the bridge's pier using the same technique as shown in Figure 47. It now serves as the reference for flow data gathering and depth gauge deployment of the Visayas State University (VSU), the partner HEI responsible for the monitoring of Silaga River.

Figure 48. Painting of water level markings on Silaga Bridge

4.6 Validation Points Acquisition Survey

The validation points acquisition survey was conducted on September 14 to 15 and 17 - 20, 2014 using a survey grade GNSS rover receiver, Trimble® SPS 882 mounted on a pole which was attached in front of the vehicle. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced as shown in Figure 48.

Figure 49. The validation point acquisition survey setup using a GNSS receiver fixed in a van along the Silaga River Basin

The survey started from Brgy. Purok D1, Borongan City, going south through 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 49.

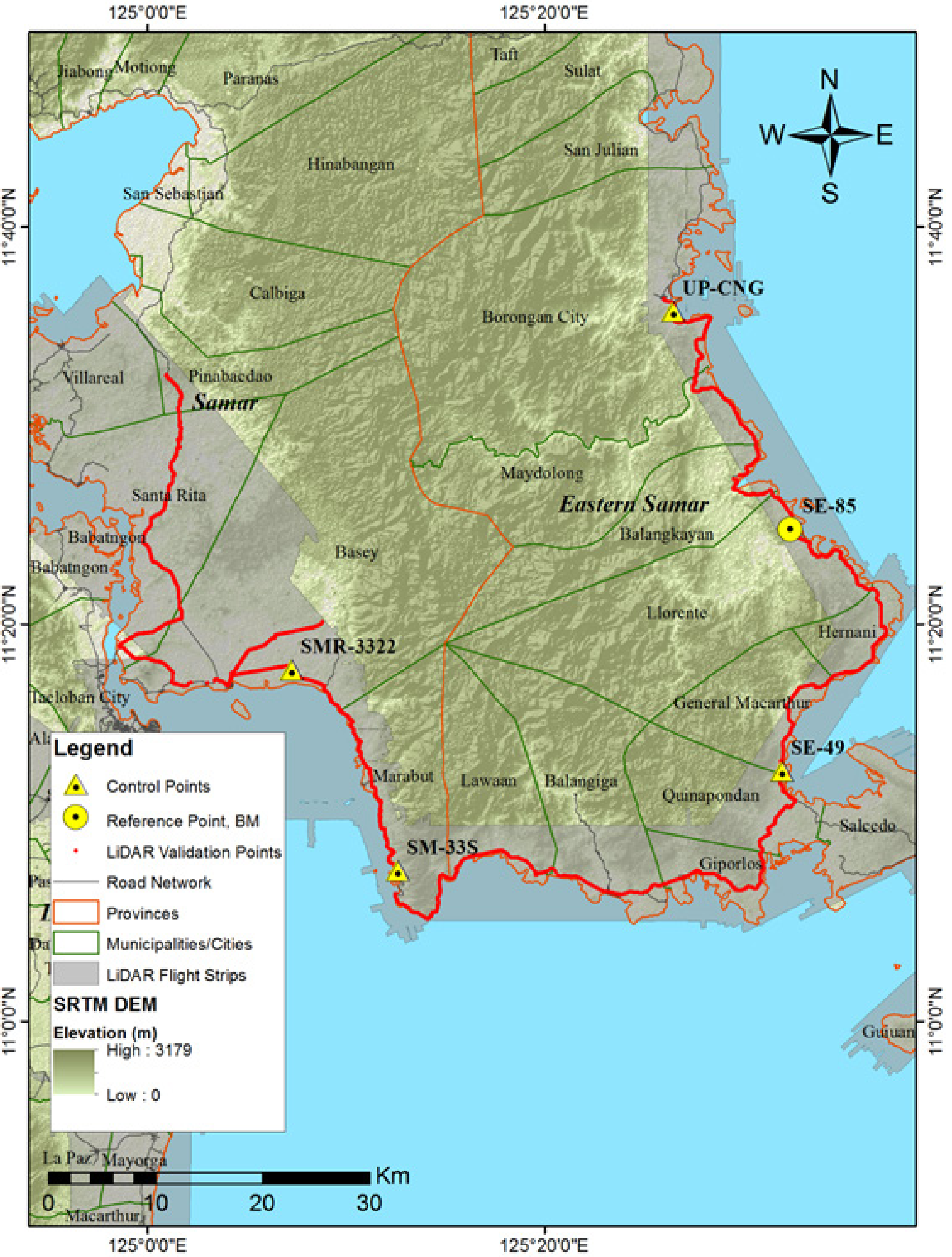


Figure 50. Extent of the LiDAR ground validation survey along Samar and Eastern Samar

4.7 River Bathymetric Survey

A manual bathymetric survey was performed on December 11 and 16, 2014 using the Trimble® SPS 882 in GNSS PPK survey technique. A portable depth sounder was also used to measure the deeper potions of the river. Along with this, bamboo poles and paddles were utilized to fix the position of the boat while encoding and entering the readings, as shown in Figure 50. The team also deployed a stadia rod every 100 meters to check if the portable depth sounder is accurate and functioning properly.

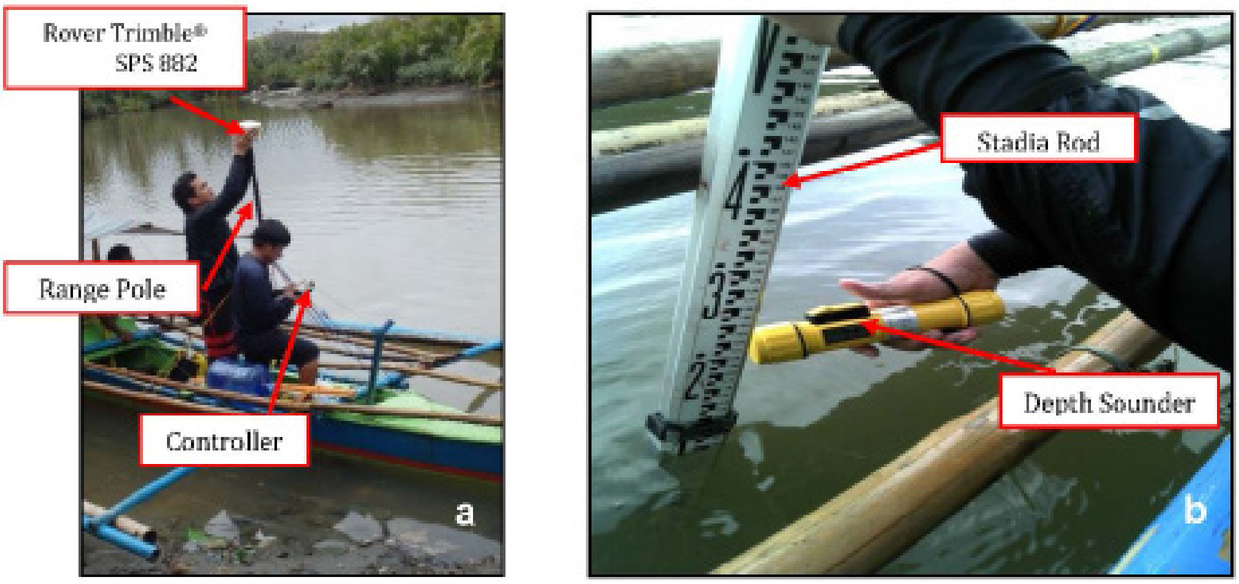


Figure 51. Photos showing (a) setup for the Bathymetric Survey in Silaga River; (b) use of portable sounder in measuring the deeper parts of the river.

The survey started in Brgy. Tulay, Municipality of Santa Rita; with the coordinates 11°27’58.15752”N, 120°01’08.13964”E; and went down to the mouth of the river in Brgy. La Paz; with the coordinates 11°25’21.78886”N, 124°59’00.99025”E; also in Santa Rita, Samar. The established control point, UP-SLG, was occupied as the base station throughout the bathymetric survey.

Overall, the bathymetric survey for the Silaga River gathered a total of 704 points, covering 16.34 km of the river, traversing nine (9) barangays in the Municipality of Santa Rita, Samar (Figure 51). To further illustrate this, a CAD drawing of the riverbed profile of the Silaga River was produced. As seen in Figure 52, the highest and lowest elevation has a 9-m difference. The highest elevation observed was -0.3348 m below MSL, located at Brgy. New Manunca, while the lowest was -9.725 m below MSL, located at the downstream portion of the river in Brgy. La Paz; both situated in Santa Rita, Samar.

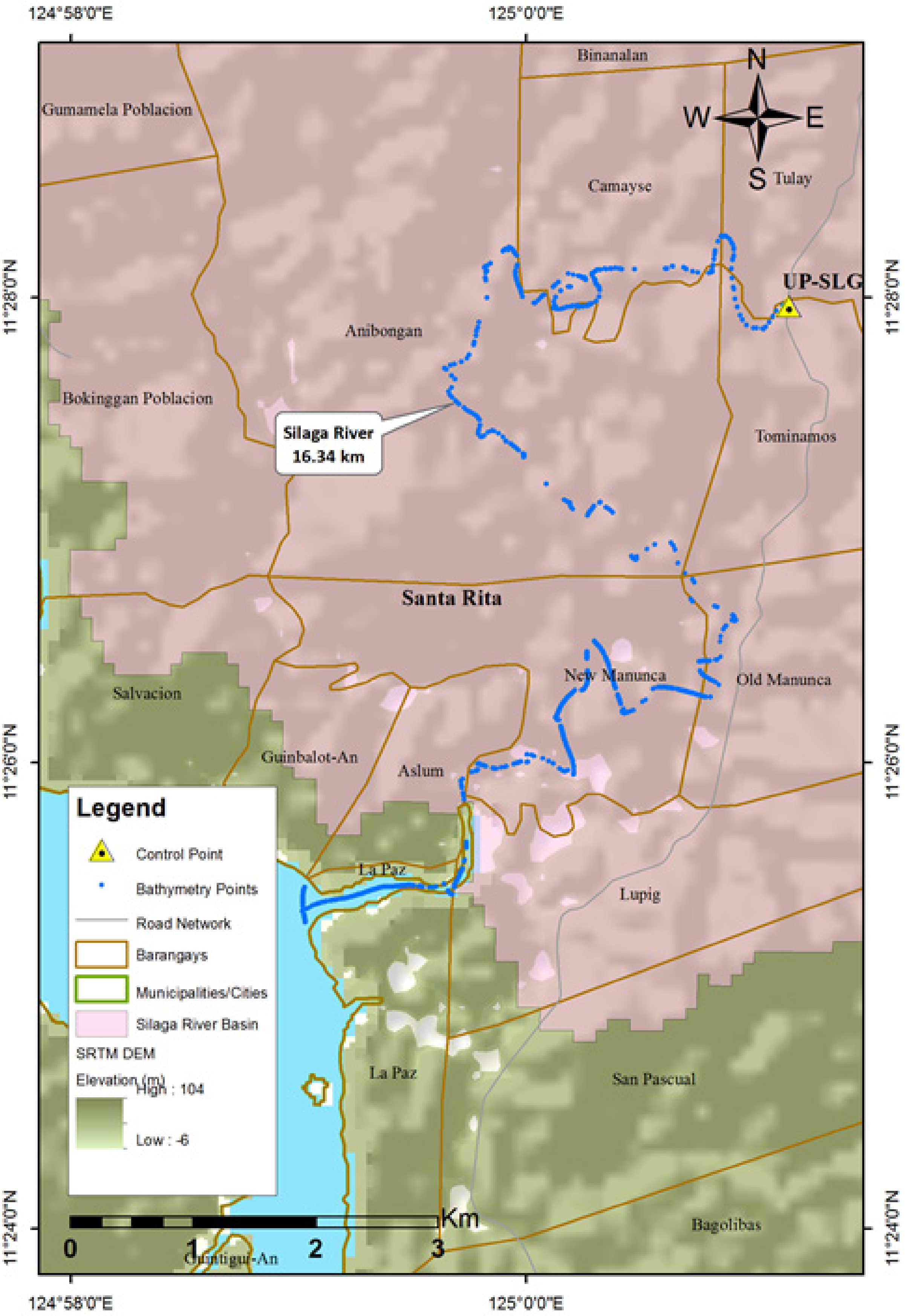


Figure 52. Extent of the Silaga River Bathymetry Survey in Sta. Rita, Samar.

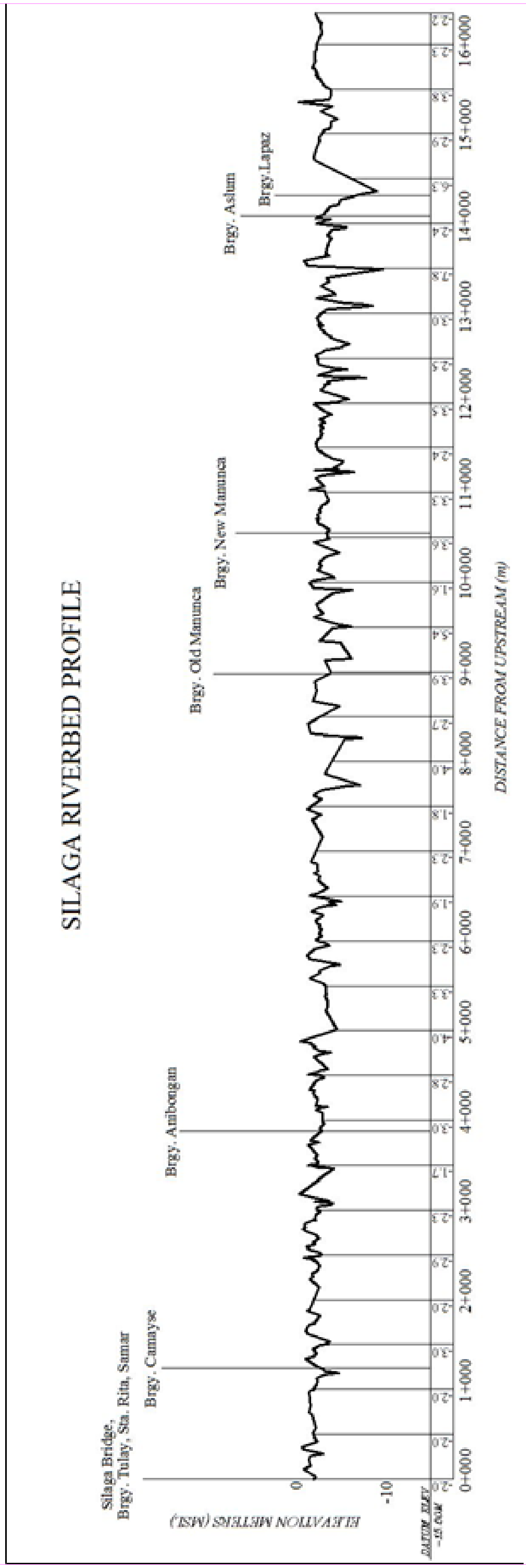


Figure 53. The Silaga river bed profile.

CHAPTER 5: FLOOD MODELING AND MAPPING

Alfredo Mahar Francisco A. Lagmay, Enrico C. Paringit, Dr. Eng., Christopher Noel L. Uichanco, Sylvia Sueno, Marc Moises, Hale Ines, Miguel del Rosario, Kenneth Punay, and Neil R. 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 Silaga 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 Silaga River Basin were monitored, collected, and analyzed.

5.1.2 Precipitation

Precipitation data was taken from an automatic rain gauge (ARG) deployed by the VSU Flood Modeling Component (FMC) team. The ARG was installed at Brgy. Binanalan, Sta. Rita, Samar, as illustrated in Figure 52. The precipitation data collection started from July 29, 2016 at 2:20 PM to July 30, 2016 at 12:10 with a recording interval of 10 minutes.

The total precipitation for this event in the Binanalan ARG was 74.6 mm, with a peak rainfall rate of 3 mm. on July 30, 2016 at 12:00 midnight. The lag time between the peak rainfall and discharge is 10 hours and 50 minutes.

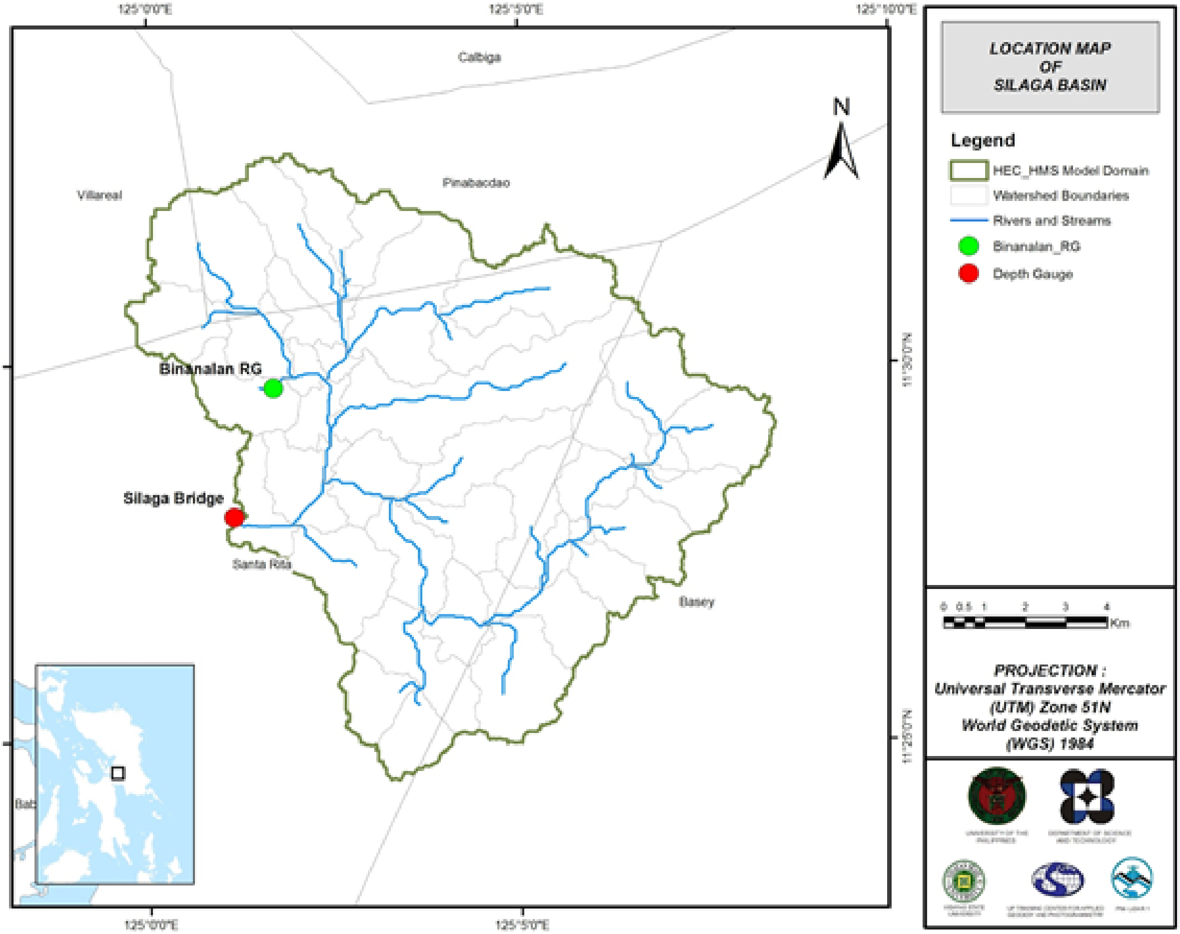


Figure 54. Location map of the Silaga HEC-HMS model used for calibration.

5.1.3 Rating Curves and River Outflow

A rating curve was computed using the prevailing cross-section (Figure 54) at Silaga Bridge, Sta. Rita, Samar (11°27'58.91"N, 125° 1'9.13"E) to establish the relationship between the observed water levels (H) at Silaga Bridge and the outflow (Q) of the watershed at this location.

For Silaga Bridge, the rating curve is expressed as: Q = 9.6834e1.0441H as shown in Figure 55.

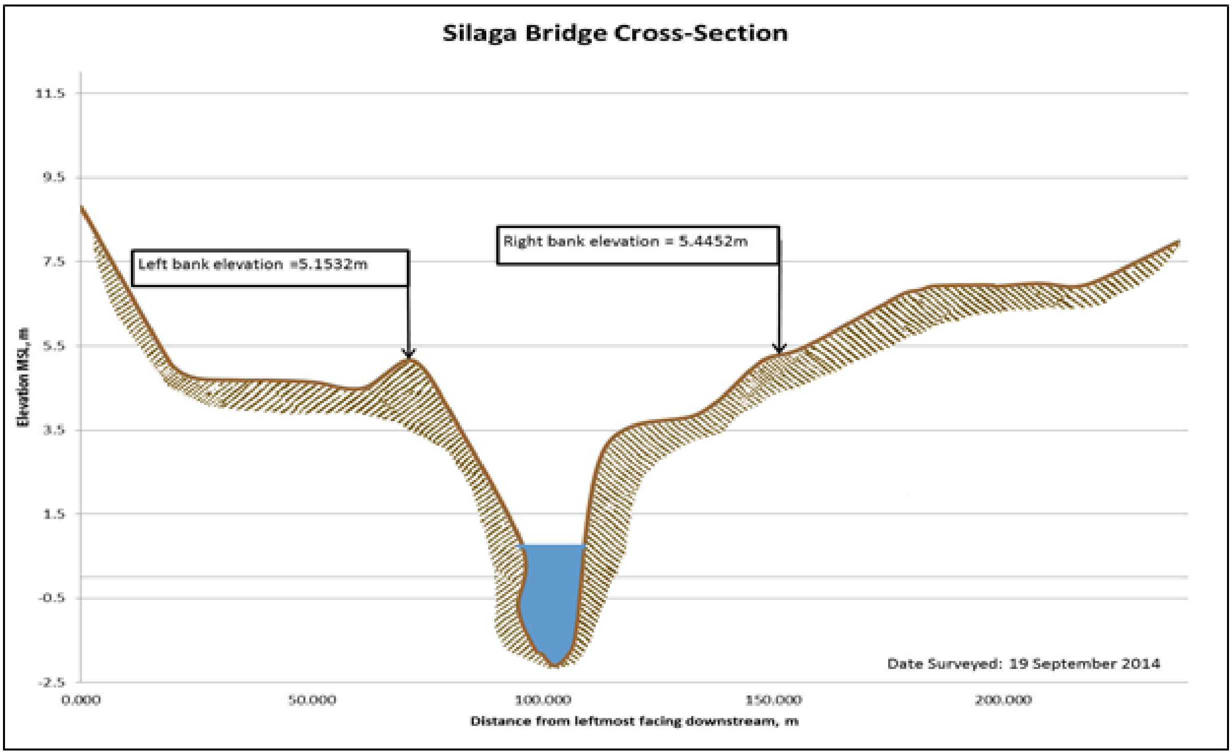


Figure 55. Cross-section plot of the Silaga Bridge

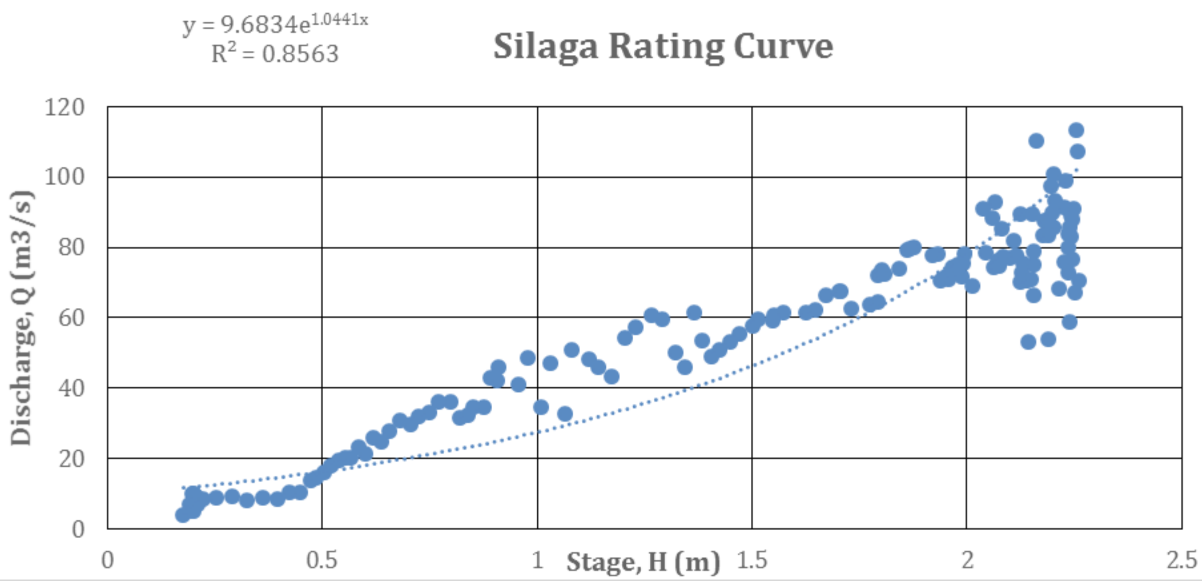


Figure 56. Rating curve of the Silaga Bridge in Sta. Rita, Samar.

This rating curve equation was used to compute the river outflow at Silaga Bridge for the calibration of the HEC-HMS model shown in Figure 56. The total rainfall for this event is 74.6mm and the peak discharge is 102.5 m3 at 12:00 noon, July 30, 2016.

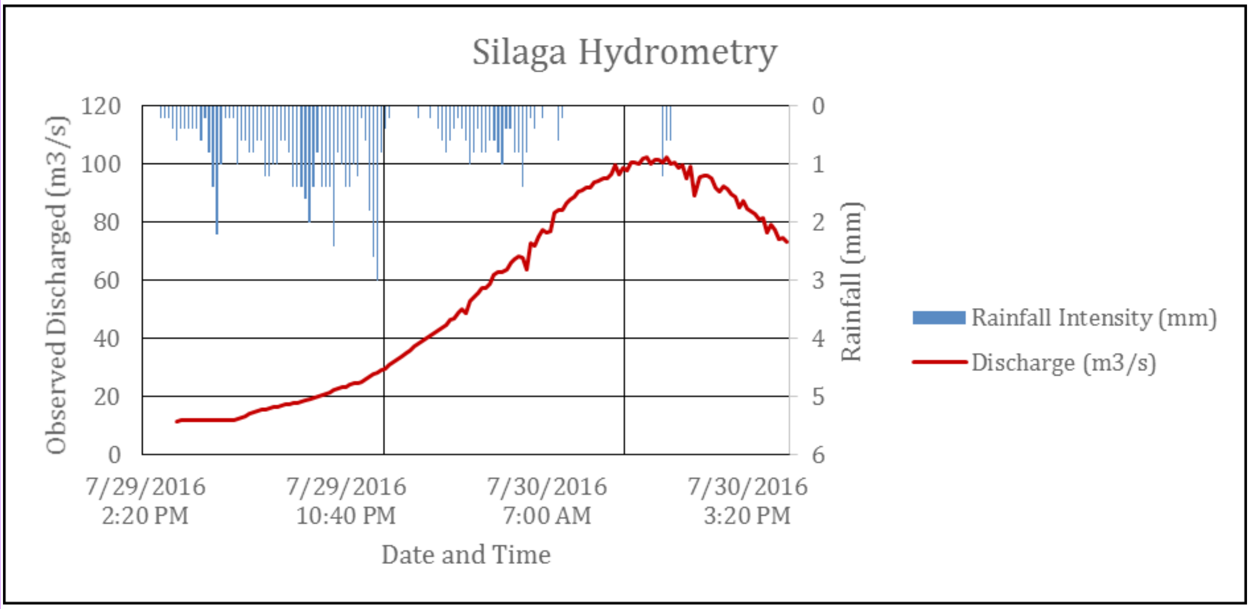


Figure 57. Rainfall and outflow data of the Silaga River Basin, which was used for modeling.

5.2 RIDF Station

PAGASA computed the Rainfall Intensity Duration Frequency (RIDF) values for the Tacloban Rain Gauge (Figure 56). The RIDF rainfall amount for 24 hours was converted into a synthetic storm by interpolating and re-arranging the values in such a way that certain peak values will be attained at a certain time (Figure 57). This station was selected based on its proximity to the Silaga watershed. The extreme values for this watershed were computed based on a 59-year record.

Table 32. RIDF values for the Tacloban Rain Gauge, as 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

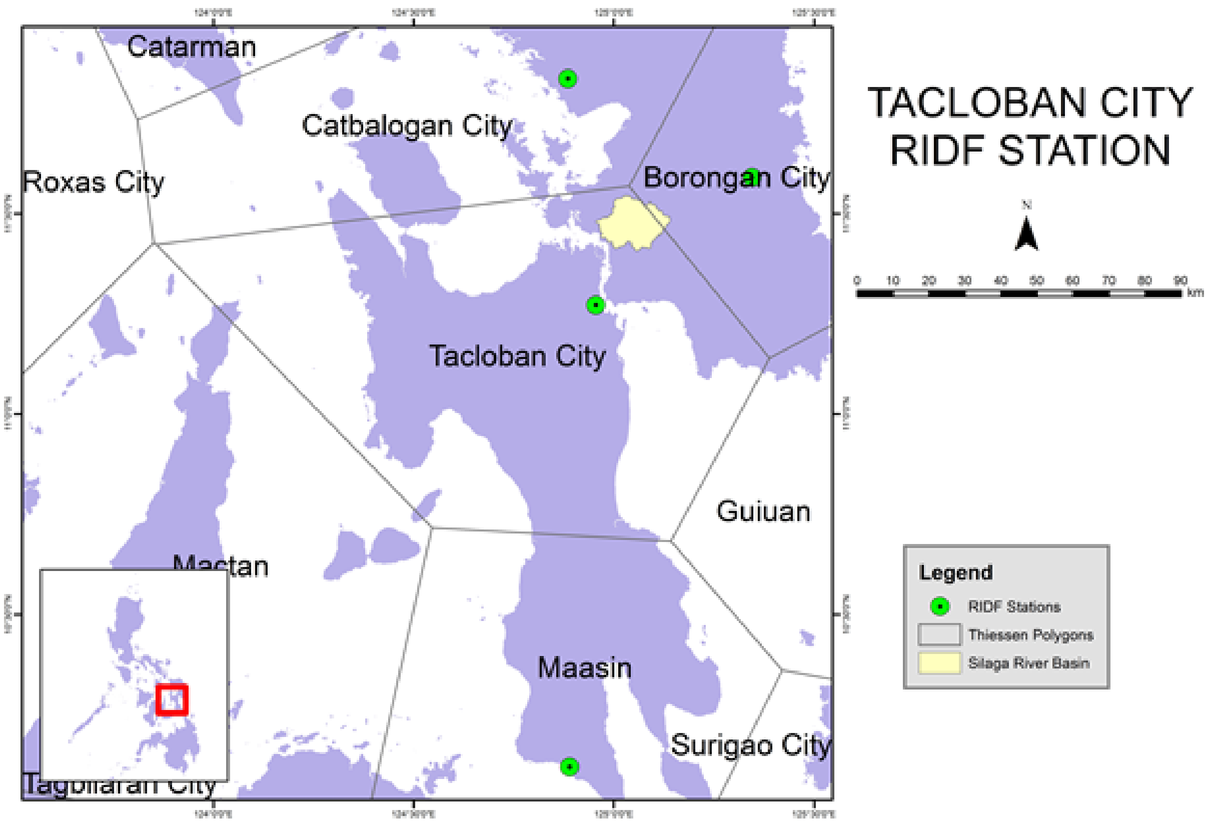


Figure 58. Location of the Tacloban RIDF station relative to the Silaga River Basin.

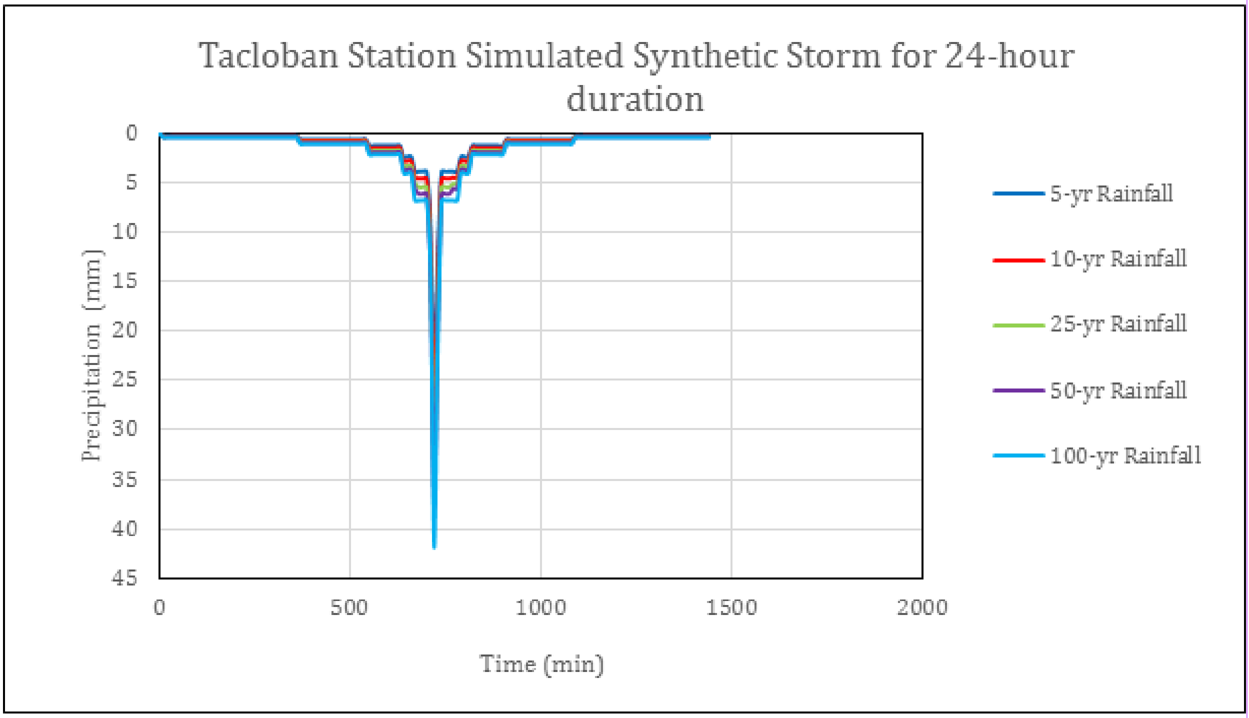


Figure 59. Synthetic storm generated for a 24-hour period rainfall for various return periods

5.3 HMS Model

The soil dataset was generated before 2004 by the Bureau of Soils under the Department of Agriculture (DA). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Silaga River Basin are shown in Figures 60 and 61, respectively.

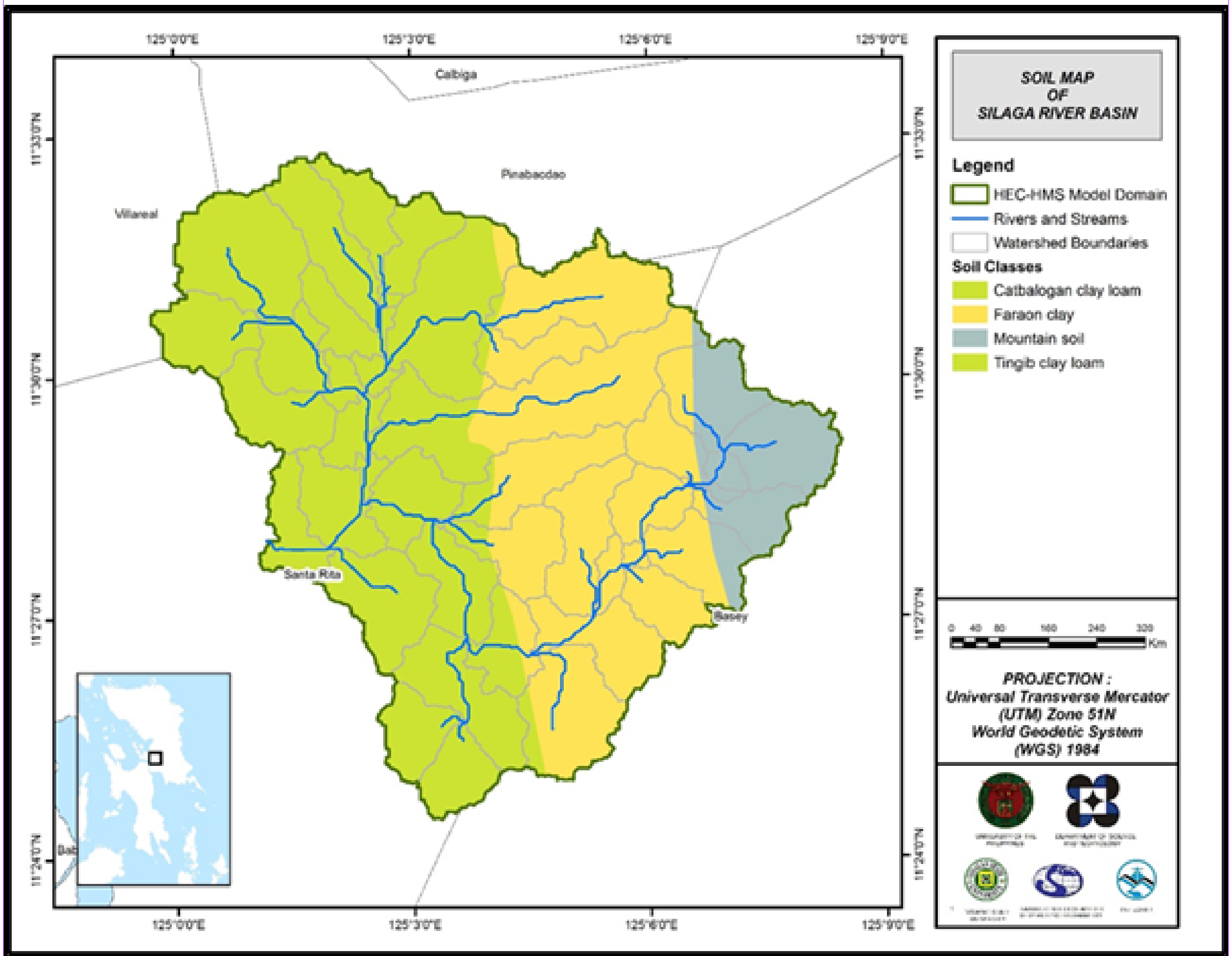


Figure 60. Soil Map of Silaga River Basin

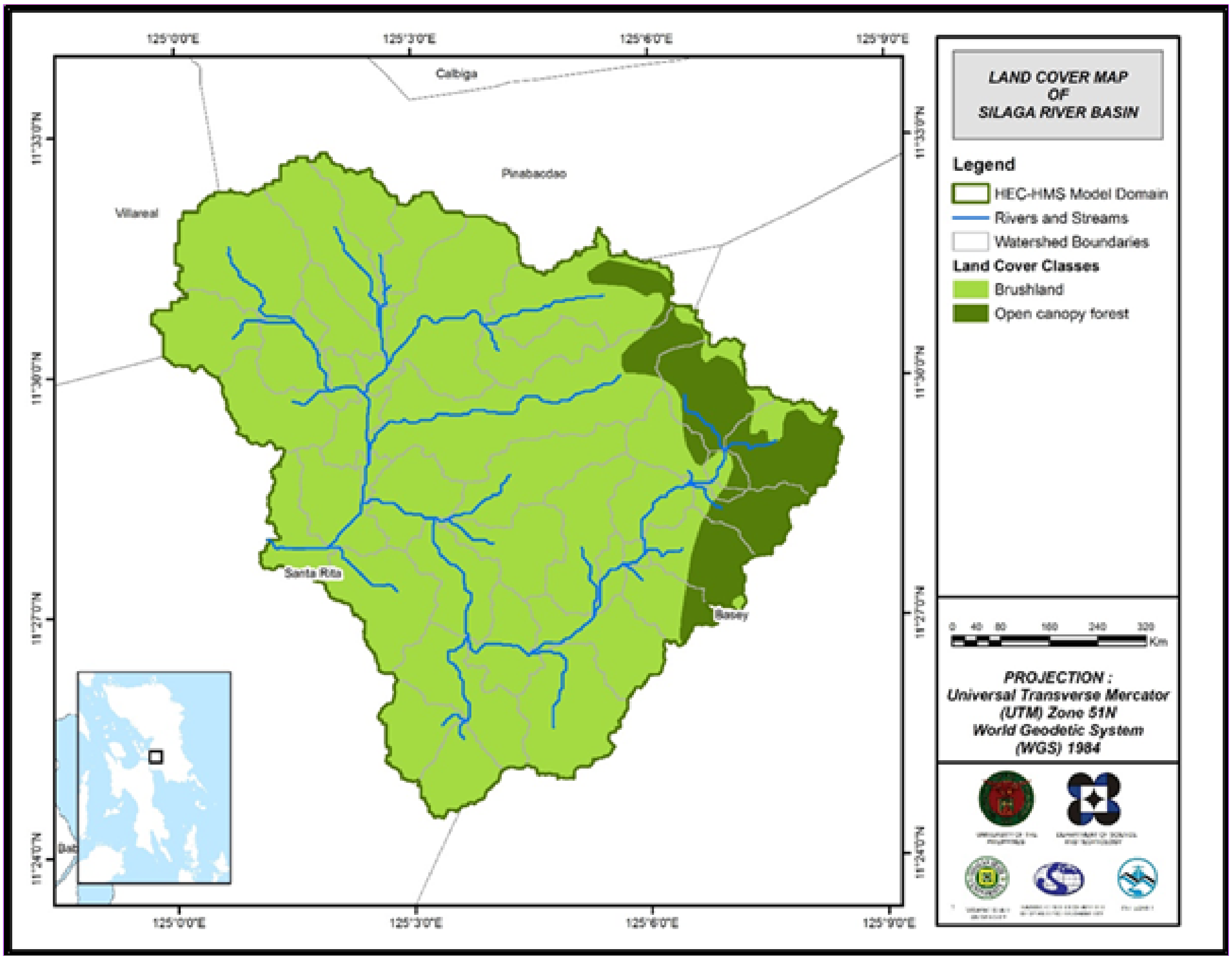


Figure 61. Land Cover Map of Silaga River Basin

For Silaga, three soil classes were identified. These are clay loam, clay, and mountain soil. Moreover, two land cover classes were identified. These are brushland, and open canopy forest.

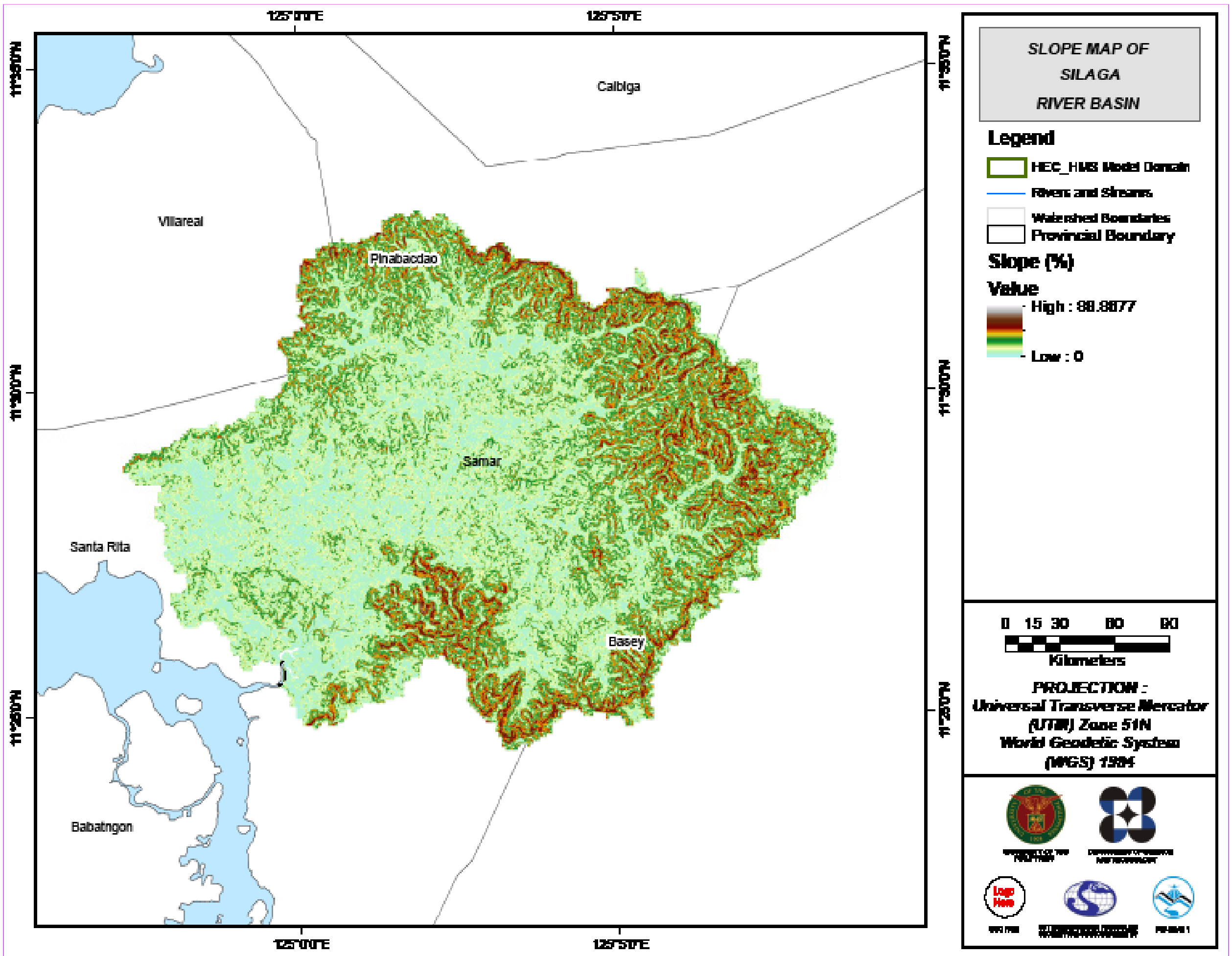


Figure 62. Slope Map of Silaga River Basin

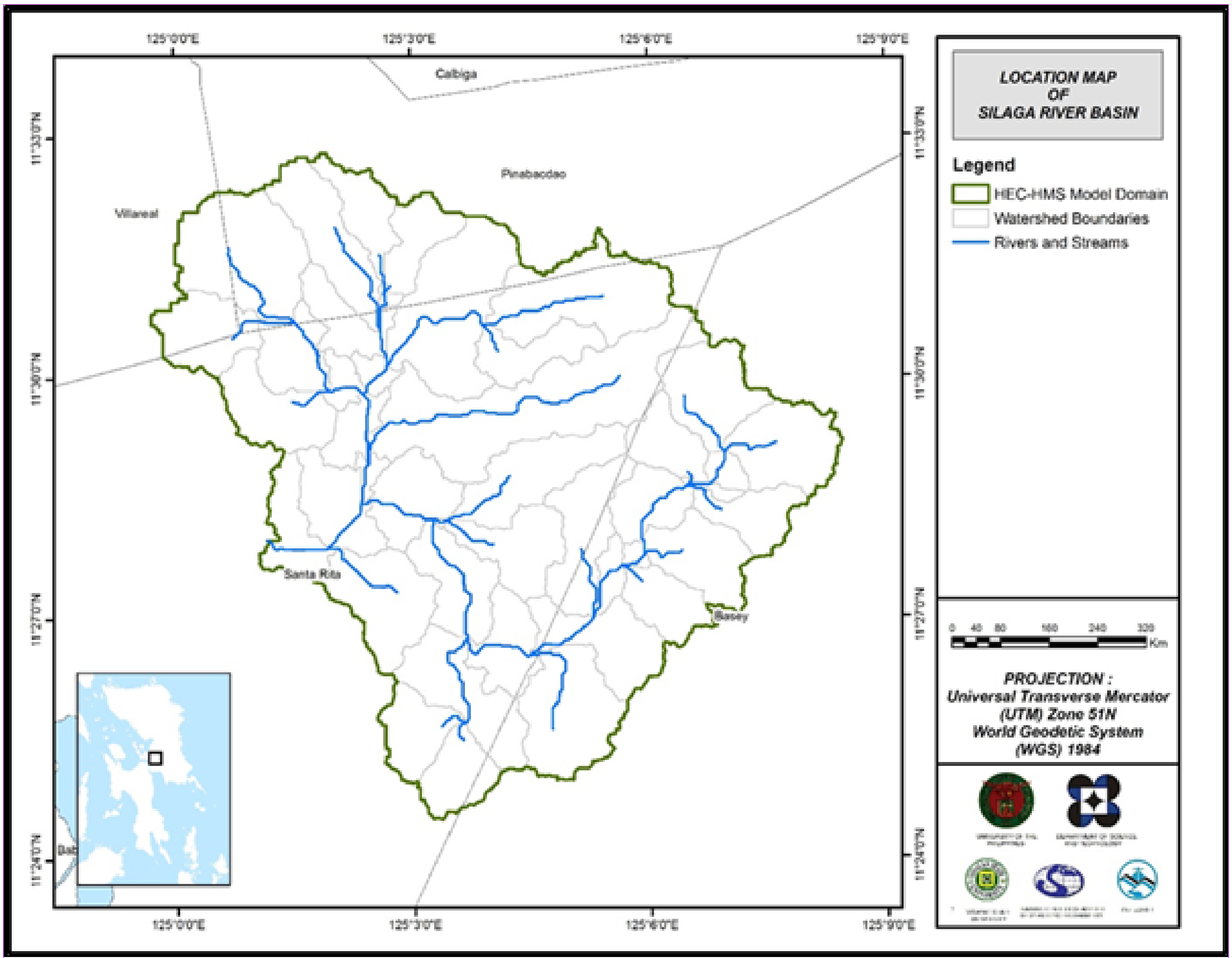


Figure 63. Stream Delineation Map of Silaga River Basin

Using the SAR-based DEM, the Silaga basin was delineated and further subdivided into subbasins. The model consists of 43 sub basins, 21 reaches, and 20 junctions as shown in Figure 63 (See Annex 10). The main outlet is at Silaga Bridge.

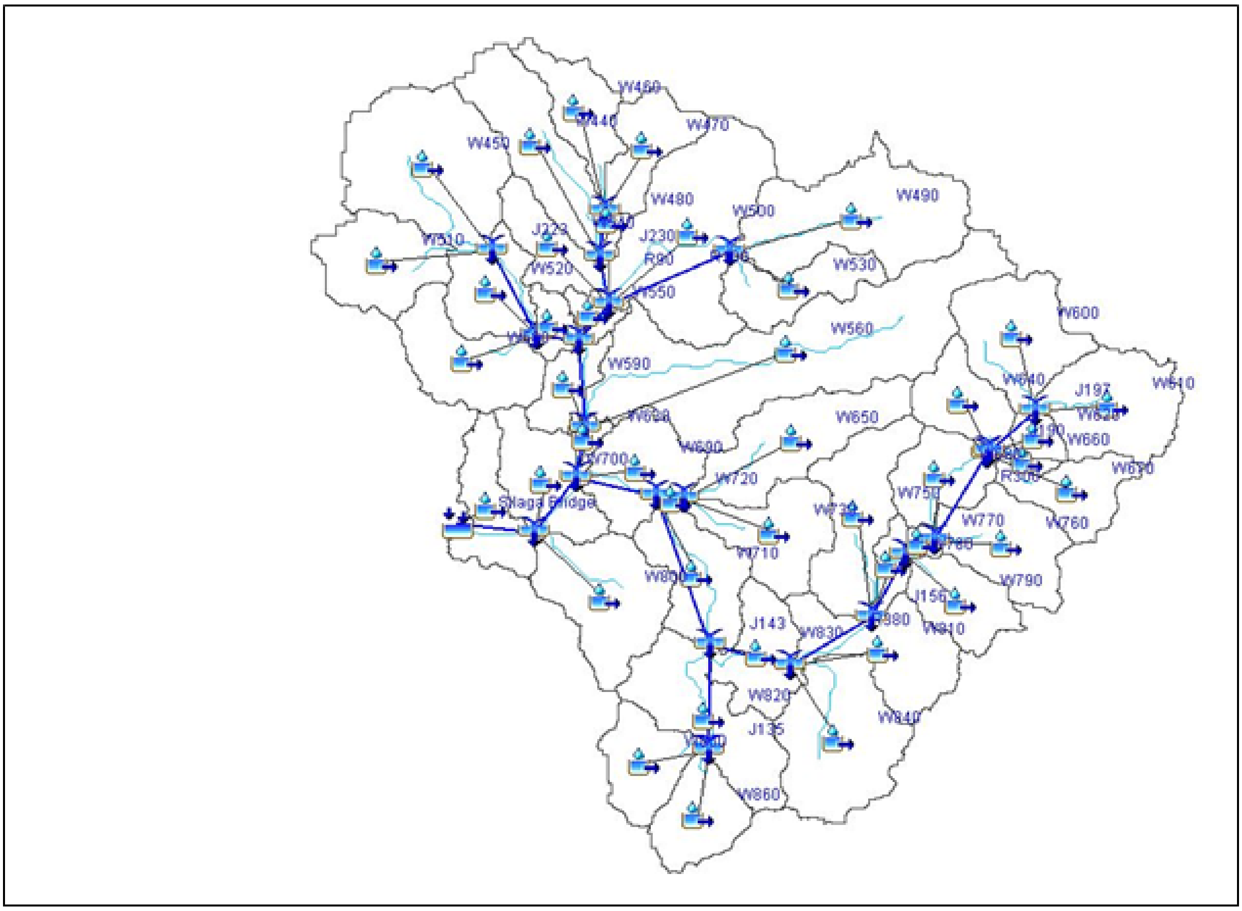


Figure 64. Silaga river basin model generated in HEC-HMS

5.4 Cross-section Data

The riverbed cross-sections of the watershed were necessary in the HEC-RAS model setup. The cross-section data for the HEC-RAS model was derived from the LiDAR DEM data, which was defined using the Arc GeoRAS tool and was post-processed in ArcGIS (Figure 64).

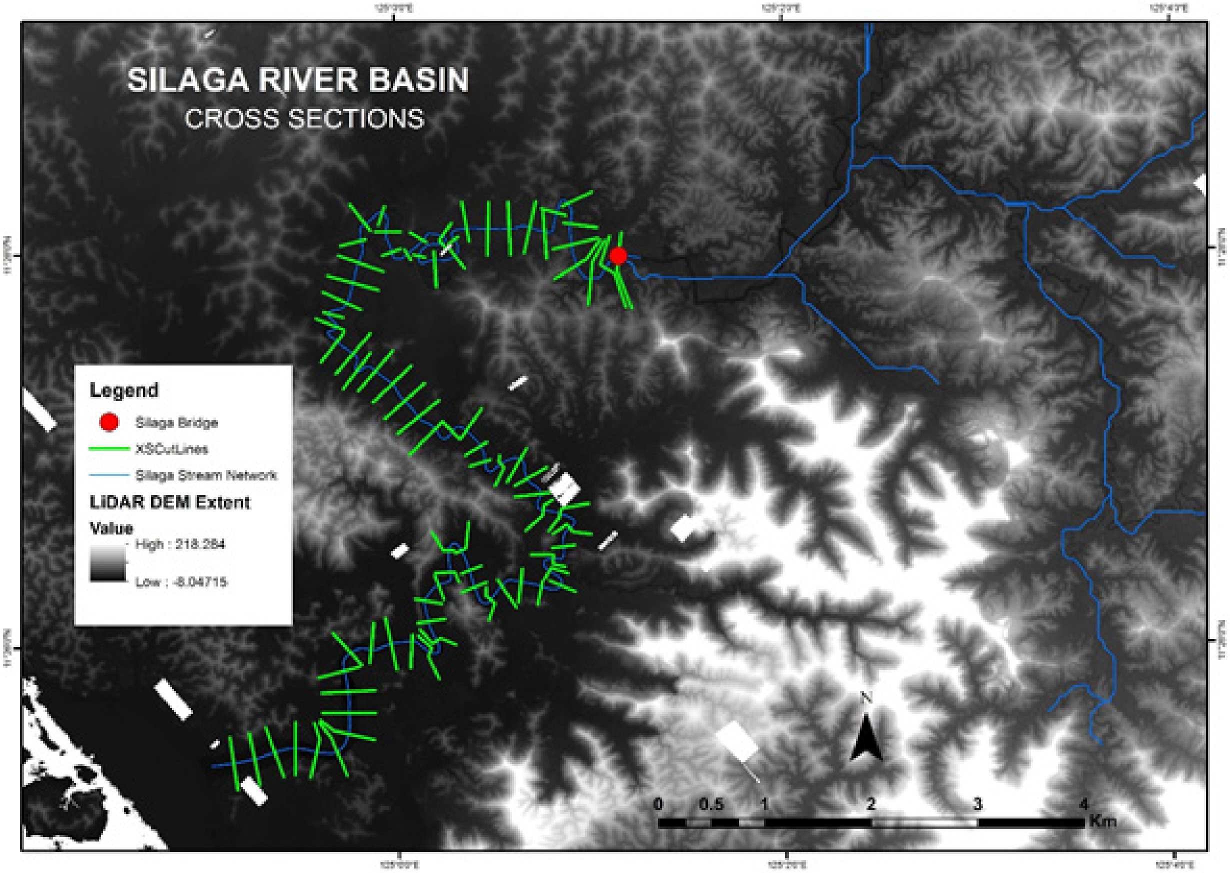


Figure 65. River cross-section of the Silaga River through the ArcMap HEC GeoRas tool

5.5 Flo 2D Model

The automated modelling process allows for the creation of a model with boundaries that are almost exactly coincidental with that of the catchment area (Figure 65). As such, they have approximately the same land area and location. The entire area is divided into square grid elements, 10 meter by 10 meter in size. Each element is assigned a unique grid element number which serves as its identifier, then attributed with the parameters required for modelling such as x-and y-coordinate of centroid, names of adjacent grid elements, Manning coefficient of roughness, infiltration, and elevation value. The elements are arranged spatially to form the model, allowing the software to simulate the flow of water across the grid elements and in eight directions (north, south, east, west, northeast, northwest, southeast, southwest).

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

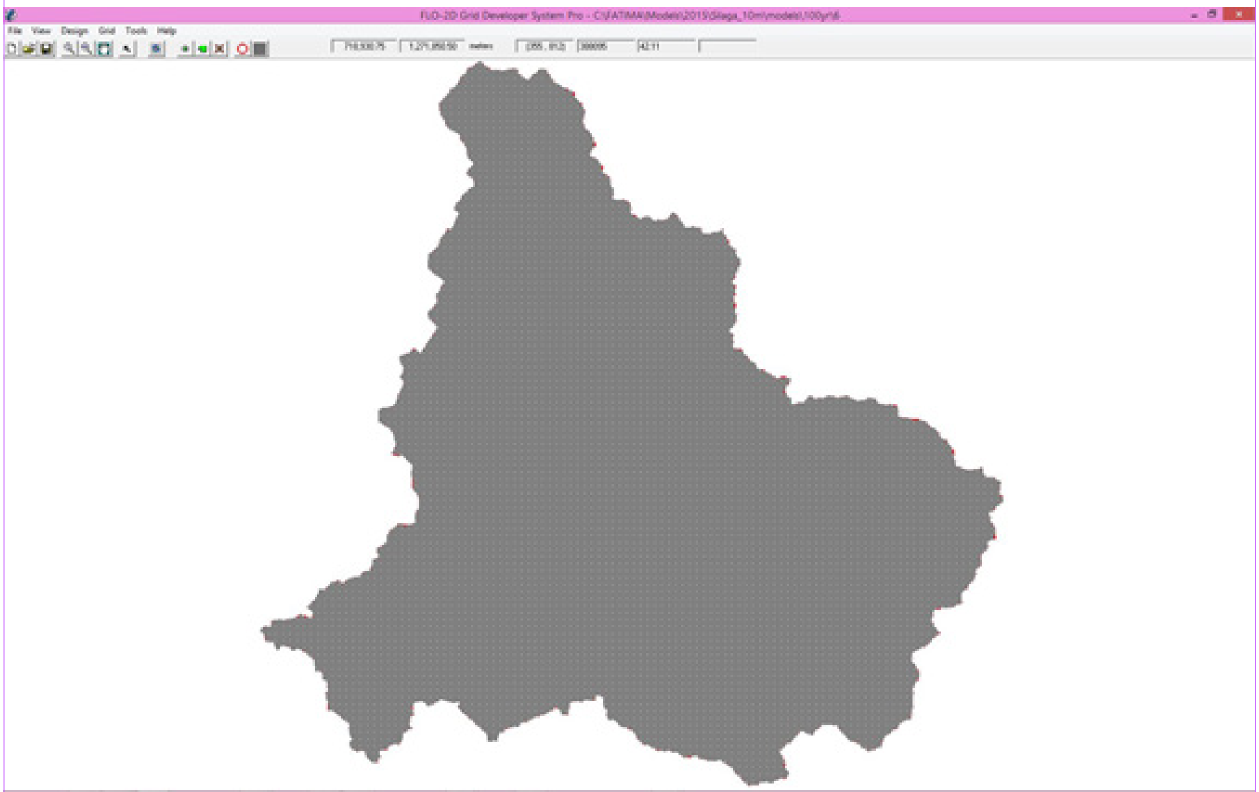


Figure 66. A screenshot of the river sub-catchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro)

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 39.55225 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 Silaga are in Figures 69, 71, and 73.

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 39 385 900.00 m2. The generated flood depth maps for Silaga are in Figures 70, 72, and 74.

There is a total of 18 419 757.72 m3 of water entering the model. Of this amount, 10 725 727.85 m3 is due to rainfall while 7 694 029.87 m3 is inflow from other areas outside the model. 3 960 626.75 m3 of this water is lost to infiltration and interception, while 12 447 417.07 m3 is stored by the flood plain. The rest, amounting up to 2 011 714.06 m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Silaga HEC-HMS river basin model (See Annex 9), its accuracy was measured against the observed values. Figure 66 shows the comparison between the two discharge data.

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

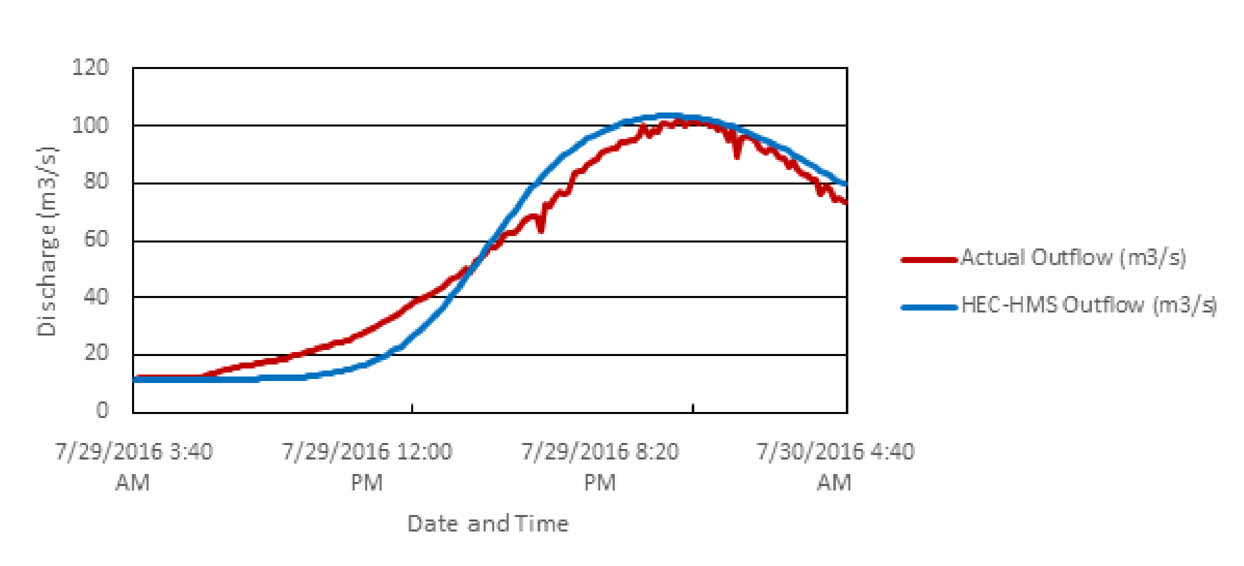


Figure 67. Outflow hydrograph of Silaga produced by the HEC-HMS model compared with observed outflow

Table 33. Range of calibrated values for the Silaga River Basin.

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	5 - 20
			Curve Number	65 - 90
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	4 - 12
			Storage Coefficient (hr)	2 - 7
	Baseflow	Recession	Recession Constant	0.9
			Ratio to Peak	0.2
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 5mm to 20mm signifies that there is minimal to average amount of infiltration or rainfall interception by vegetation.

The curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 65 to 90 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For Silaga, the basin mostly consists of brushlands and the soil consists of clay, clay loam, and mountain soil.

The 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 2 hours to 12 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, while 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 0.2 indicates a steeper receding limb of the outflow hydrograph.

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

Table 34. Efficiency Test of the Silaga HMS Model

Accuracy measure	Value
RMSE	7.00
r2	0.9809
NSE	0.95
PBIAS	0.17
RSR	0.21

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 7.00 (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 0.9809.

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 0.95.

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 0.17.

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

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

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph (Figure 67) shows the Silaga outflow using the synthetic storm events 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 show increasing outflow magnitude as the rainfall intensity increases for a range of durations and return periods from 321m3 in a 5-year return period to 590.6m3 for a 100-year return period.

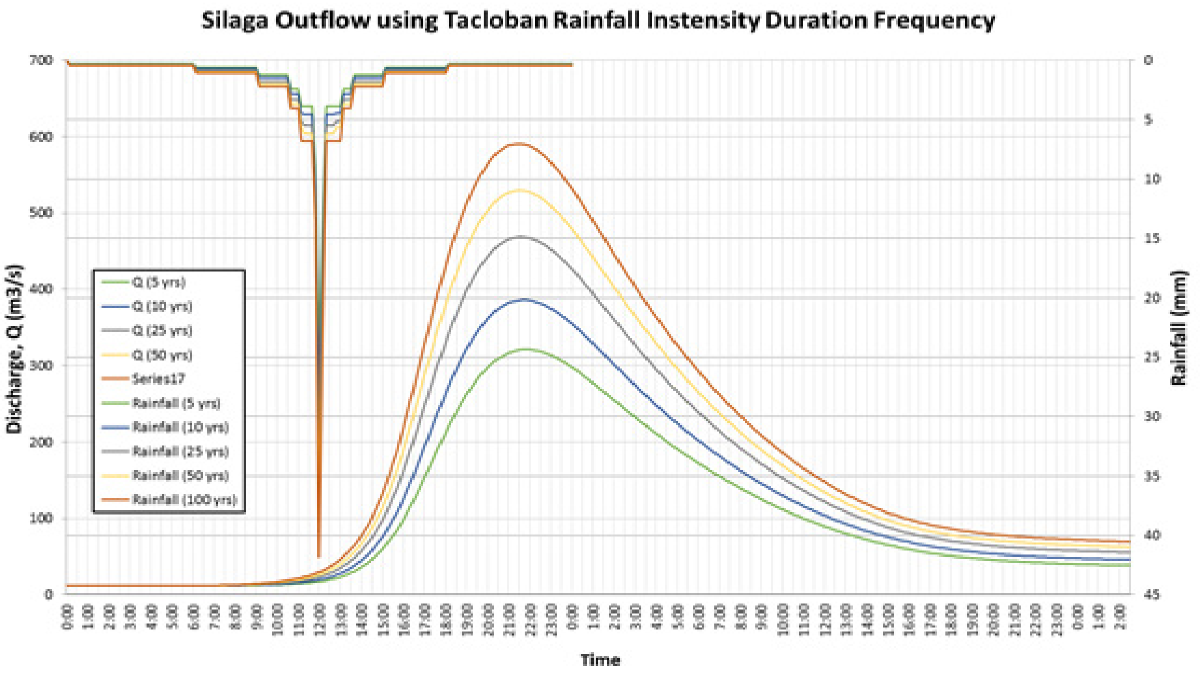


Figure 68. The Outflow hydrograph at the Silaga Station, generated using the simulated rain events for 24-hour period for Tacloban station

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Silaga 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 Silaga HEC-HMS Model outflow using the Tacloban RIDF 24-hour values.

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	161.40	24.30	321.2	22 hours
10-Year	188.40	28.25	386.10	21 hours 50 minutes
25-Year	222.60	33.90	468.50	21 hours, 40 minutes
50-Year	247.90	37.90	529.40	21 hours, 40 minutes

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. For this publication, only a sample output map river was to be shown, since only the VSU-FMC base flow was calibrated. Figure 68 shows a generated sample map of the Silaga River using the calibrated HMS base flow.

Figure 69. Sample output map of the Silaga RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figure 68 to Figure 73 shows the 5-, 25-, and 100-year rain return scenarios of the Silaga floodplain. The floodplain, with an area of 218.63 sq. km., covers four municipalites namely Santa Rita, Basey, Pinabacdao, and Villareal. Table shows the percentage of area affected by flooding per municipality.

Table 36. Municipalities affected in Silaga floodplain

Municipality	Total Area	Area Flooded	% Flooded
Basey	627.97	34.83	6%
Pinabacdao	118.38	19.20	16%
Santa Rita	250.37	160.08	64%
Villareal	130.22	4.43	3%

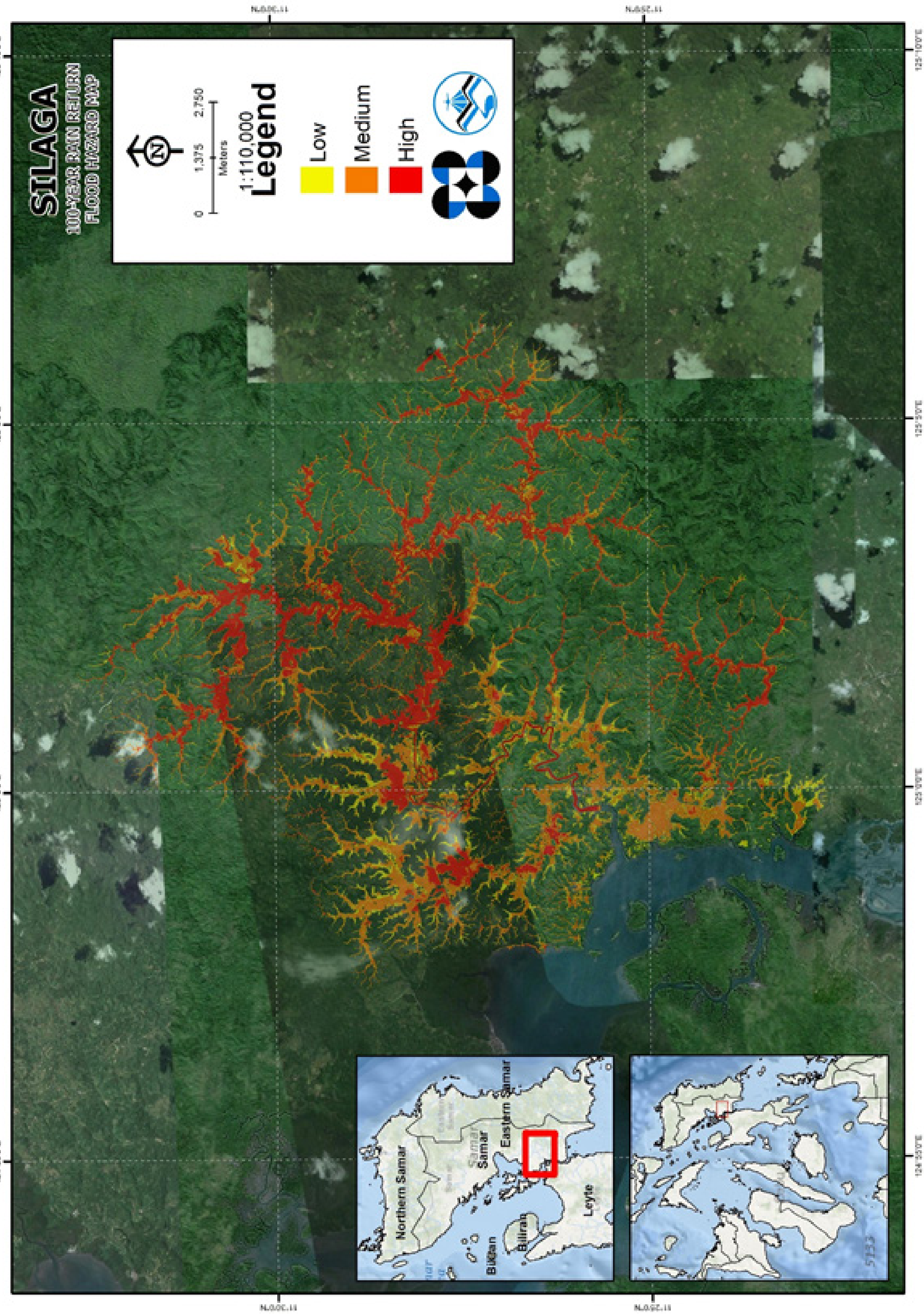


Figure 70. A 100-year flood hazard map for the Silaga floodplain

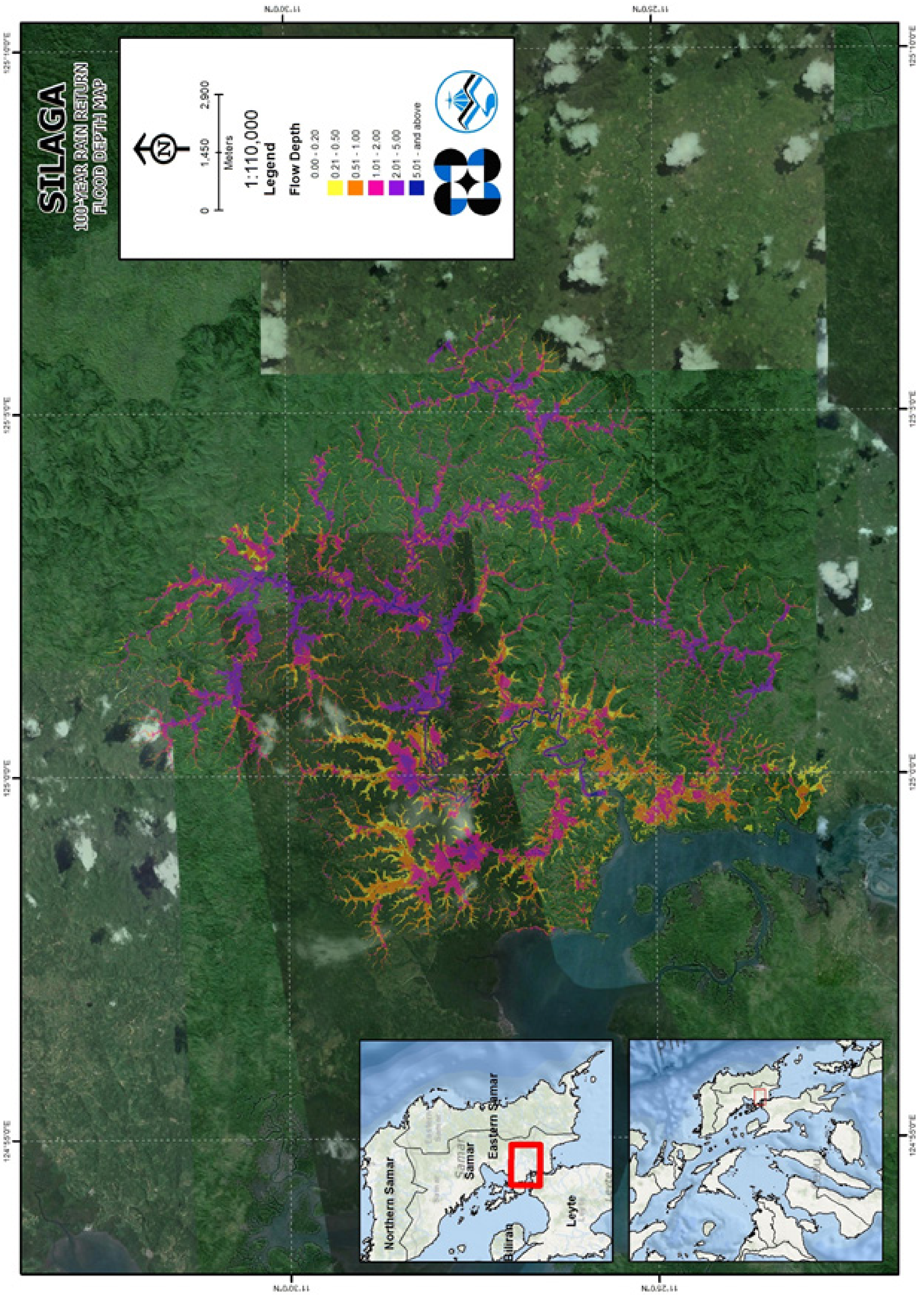


Figure 71. A 100-year Flow Depth Map for the Silaga Floodplain

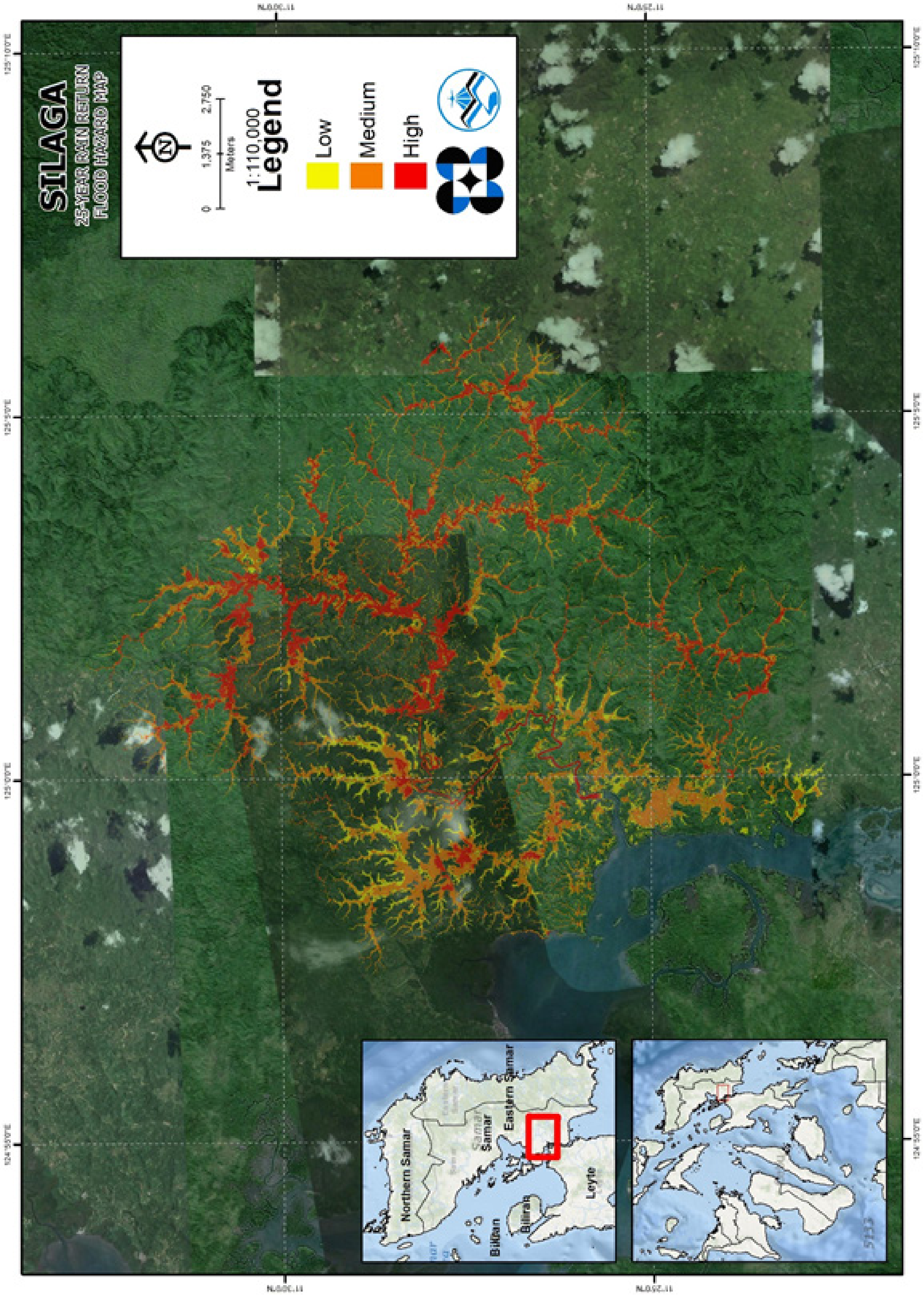


Figure 72. A 25-year Flood Hazard Map for Silaga Floodplain

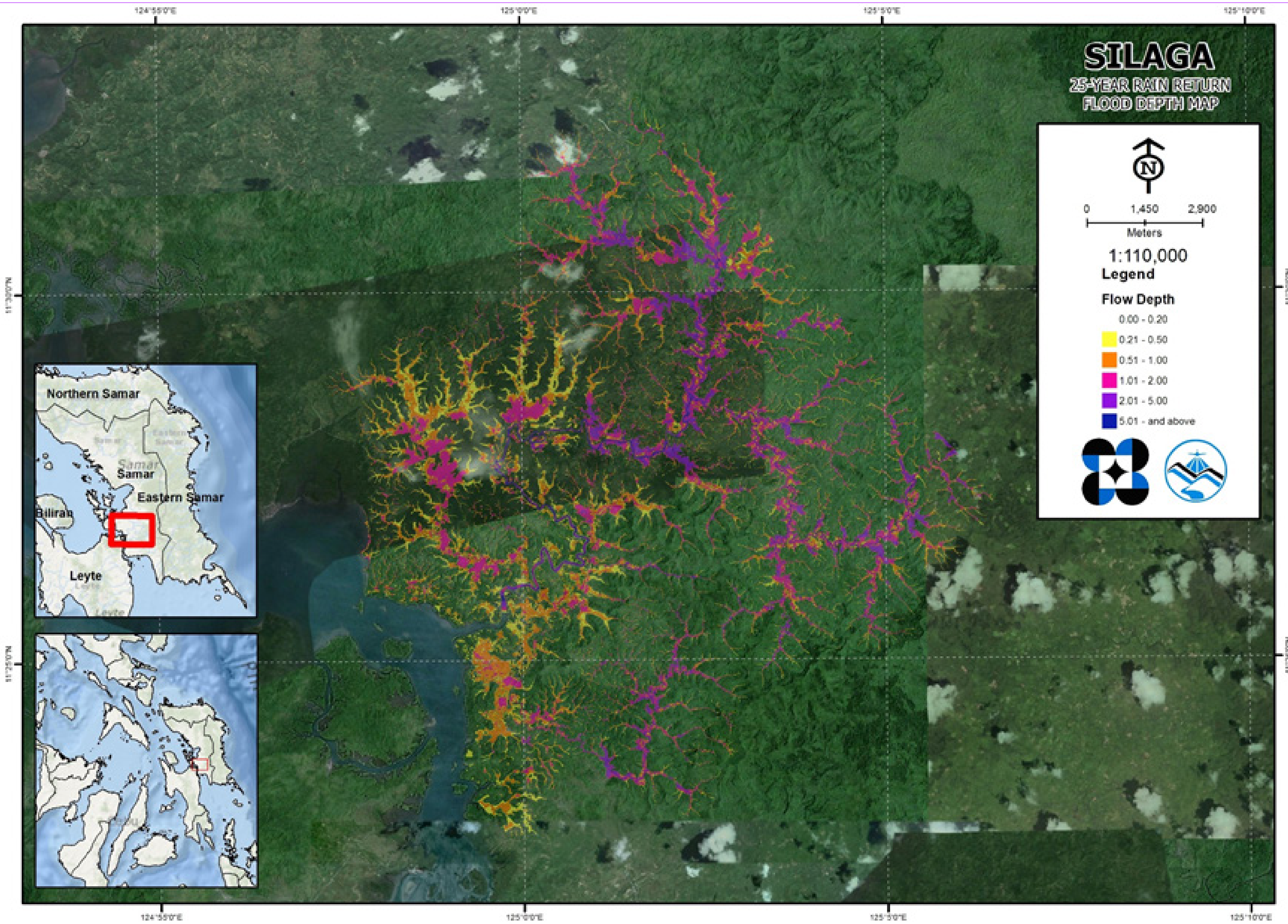


Figure 73. A 25-year Flow Depth Map for Silaga Floodplain

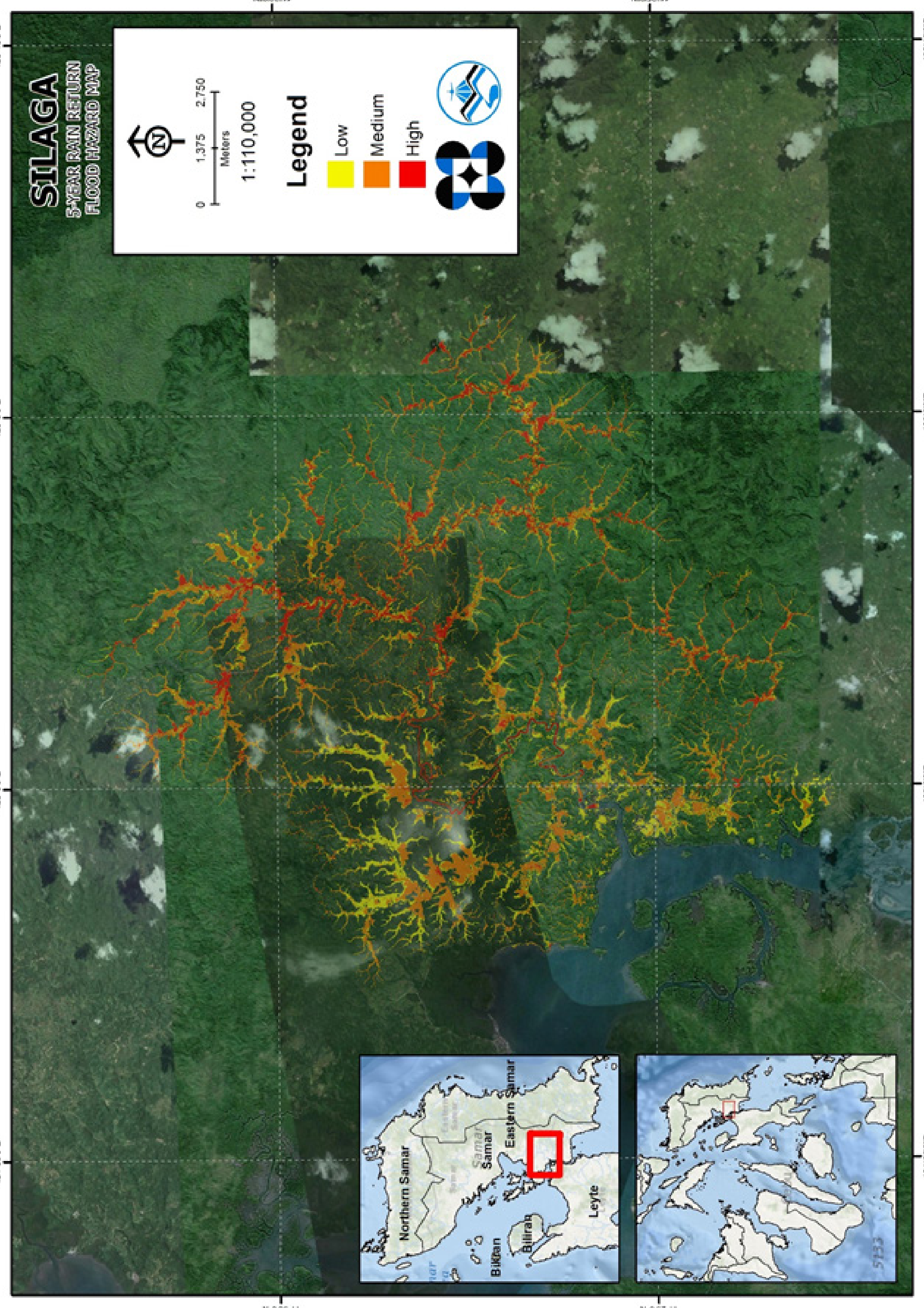


Figure 74. A 5-year Flood Hazard Map for Silaga Floodplain

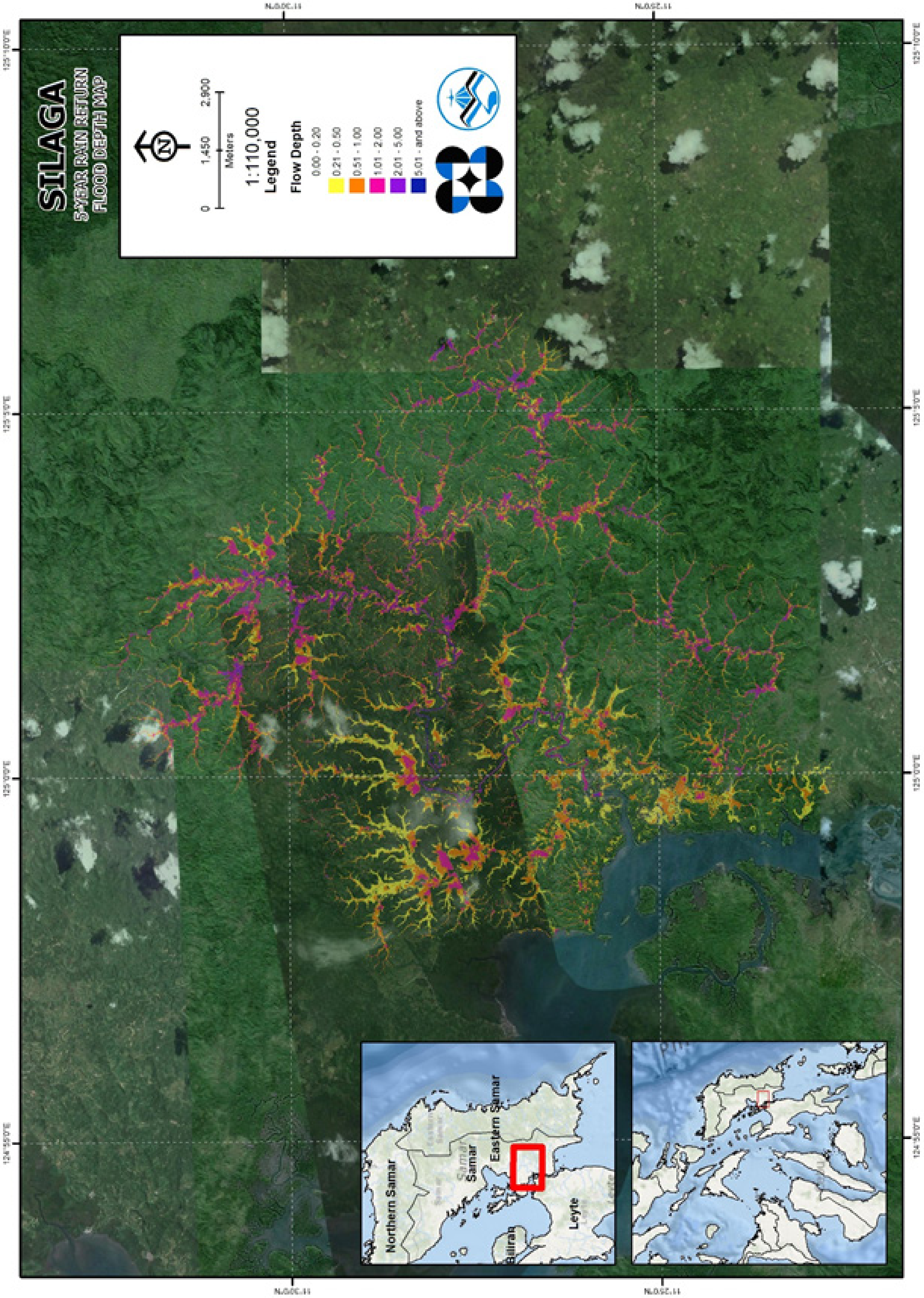


Figure 75. A 5-year Flow depth map for Silaga floodplain.

5.10 Inventory of Areas Exposed to Flooding

Listed below are the barangays affected by the Silaga River Basin, grouped accordingly by municipality. For the said basin, four (4) municipalities consisting of 35 barangays are expected to experience flooding when subjected to a 5-year rainfall return period.

For the 5-year return period, 4.9% of the municipality of Basey with an area of 627.97 sq. km. will experience flood levels of less 0.20 meters, while 0.16% of the area will experience flood levels of 0.21 to 0.50 meters; 0.16%, 0.18%, 0.14%, and 0.003% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and more than 2 meters respectively. Table 37 depicts the areas affected in Basey in square kilometers by flood depth per barangay. Annex 12 and Annex 13 show the educational and health institutions exposed to flooding, respectively.

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

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Basey (in sq. km.)			
	Bulao	Cancaiyas	Mabini	Villa Aurora
0.03-0.20	17.22	9.98	1.95	1.64
0.21-0.50	0.41	0.47	0.092	0.035
0.51-1.00	0.35	0.59	0.038	0.015
1.01-2.00	0.42	0.70	0.017	0.010
2.01-5.00	0.50	0.36	0.007	0.001
> 5.00	0.019	0.001	0	0

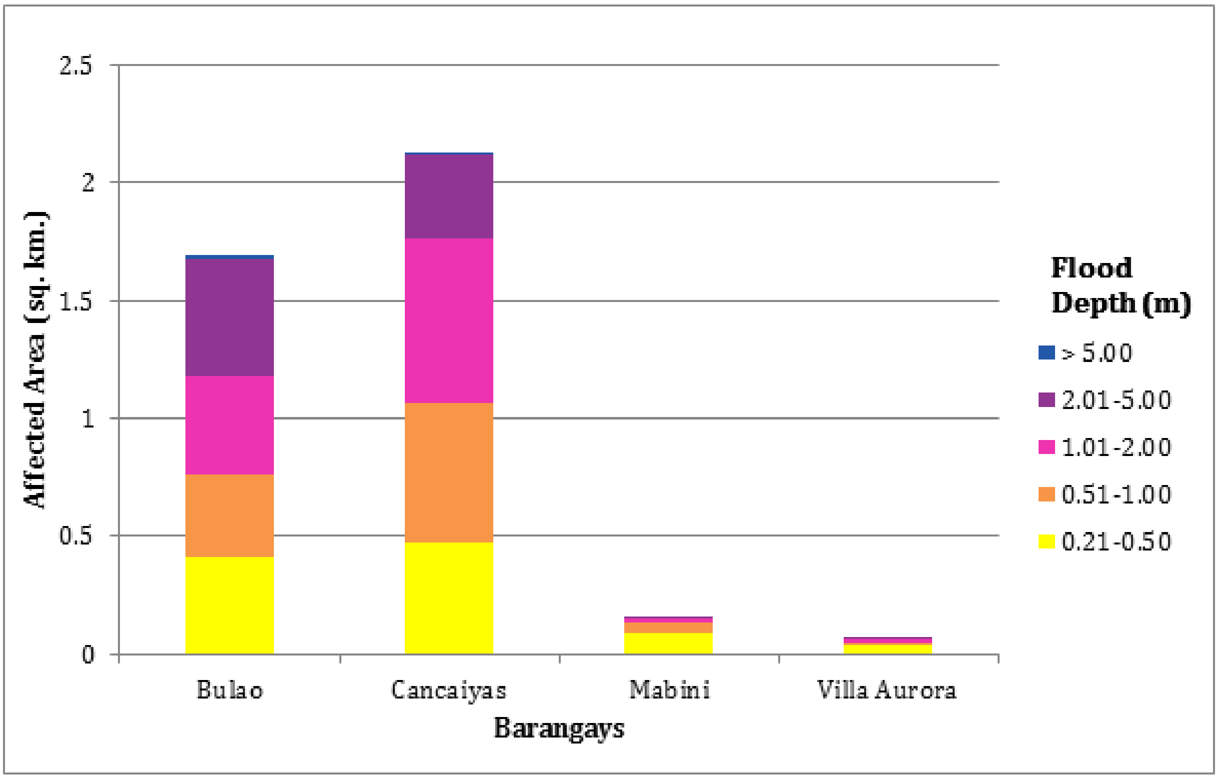


Figure 76. Affected areas in Basey, Samar during a 5-Year Rainfall Return Period

For the municipality of Pinabacdao, with an area of 118.377 sq. km., 14.04% will experience flood levels of less 0.20 meters. 0.52% of the area will experience flood levels of 0.21 to 0.50 meters while 0.77%, 0.76%, and 0.13% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, respectively. Table 38 depicts the affected areas in square kilometers by flood depth per barangay.

Table 38. Affected areas in Pinabacdao, Samar during a 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pinabacdao (in sq. km.)				
	Bugho	Laygayon	Magdawat	Parasanon	Pelaon
0.03-0.20	0.51	3.45	0.60	3.40	8.66
0.21-0.50	0.011	0.086	0.0070	0.18	0.33
0.51-1.00	0.0036	0.10	0.00055	0.32	0.49
1.01-2.00	0.00012	0.094	0	0.40	0.41
2.01-5.00	0	0.011	0	0.089	0.055
> 5.00	0	0	0	0	0

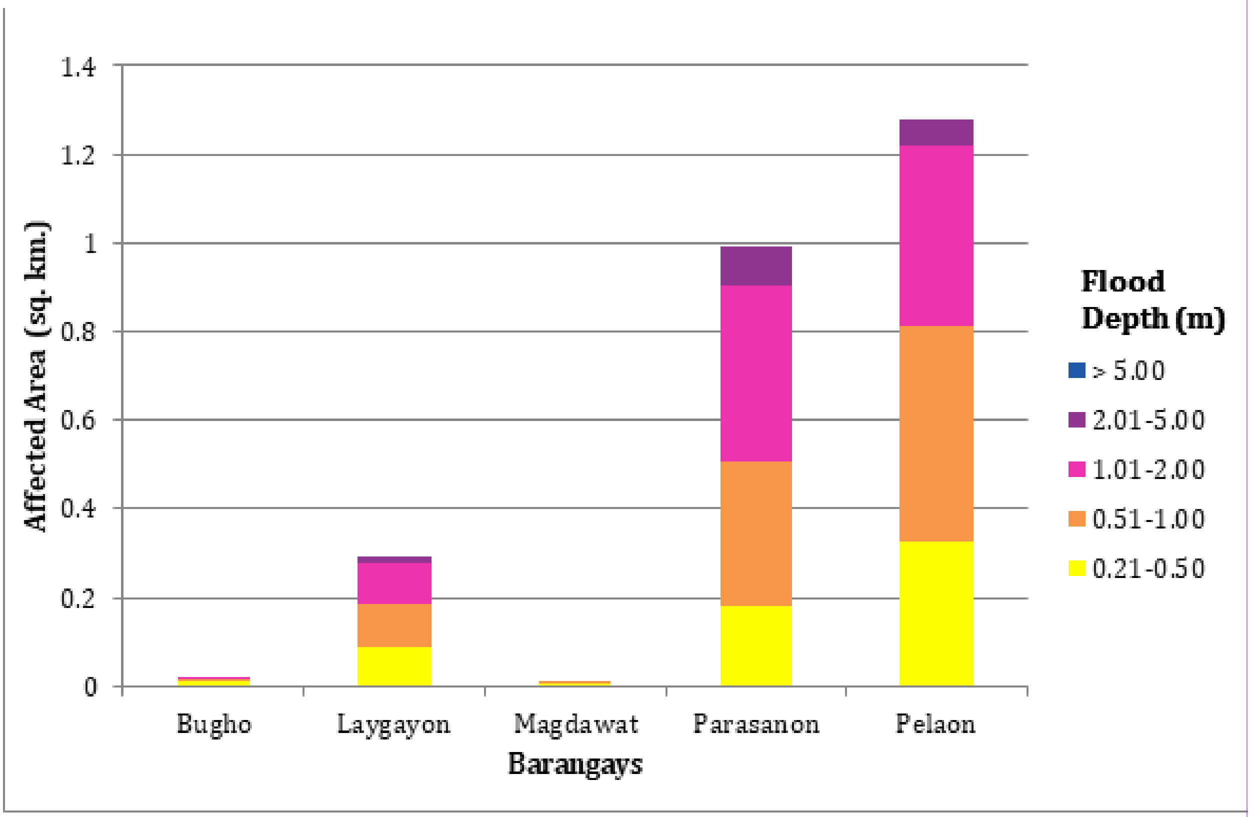


Figure 77. Affected areas in Pinabacdao, Samar during a 5-Year Rainfall Return Period

For the municipality of Villareal, with an area of 130.22 sq. km., 3.05% will experience flood levels of less 0.20 meters. 0.10% of the area will experience flood levels of 0.21 to 0.50 meters while 0.14%, 0.11%, and 0.003% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, respectively. Illustrated in Table 39 are the affected areas in square kilometers by flood depth per barangay.

Table 39. Affected areas in Villareal, Samar during a 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Villareal (in sq. km.)	
	Bulao	Cancaiyas
0.03-0.20	1.16	2.82
0.21-0.50	0.037	0.089
0.51-1.00	0.059	0.12
1.01-2.00	0.041	0.11
2.01-5.00	0.00090	0.0026
> 5.00	0	0

Among the barangays in the municipality of Villareal, Inasudlan is projected to have the highest percentage of area that will experience flood levels of at 2.41%. On the other hand, Igot posted the percentage of area that may be affected by flood depths of at 1.0%.

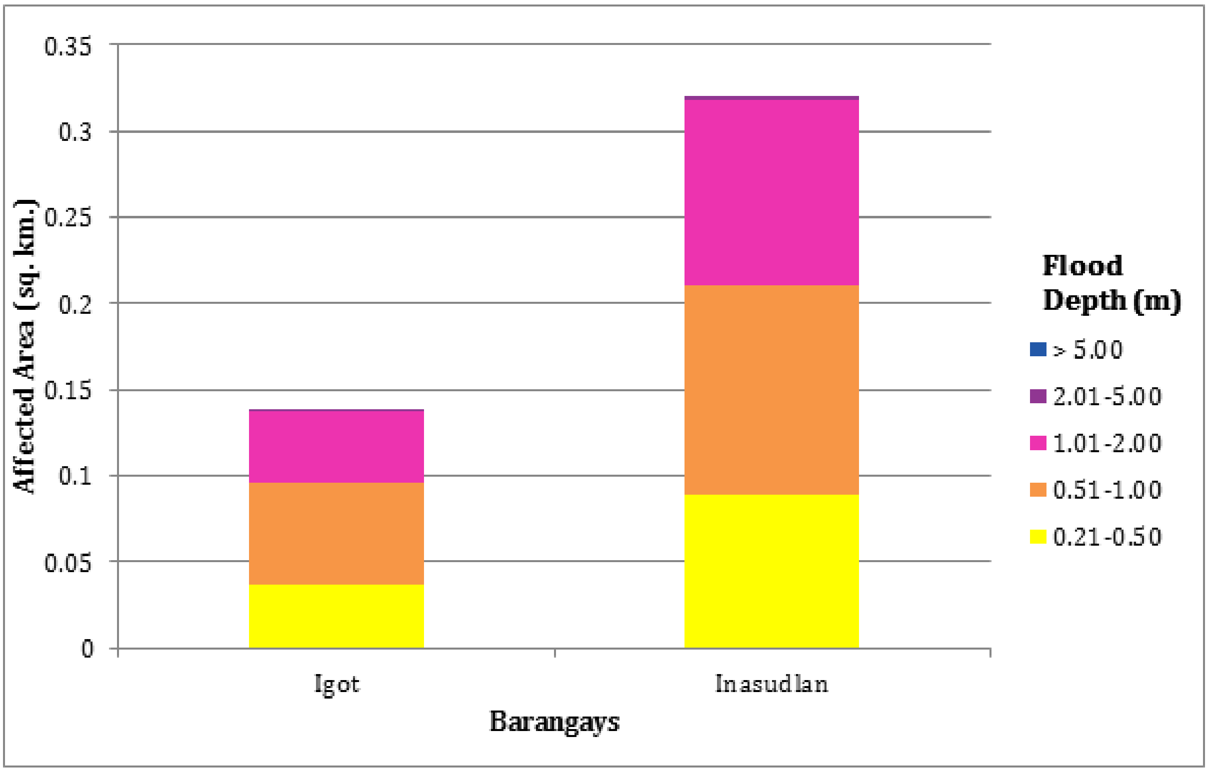


Figure 78. The specifically affected areas in Villareal, Samar during a 5-Year Rainfall Return Period.

For the municipality of Santa Rita, with an area of 250.37 sq. km., 45.63% will experience flood levels of less 0.20 meters, as 3.44% of the area will experience flood levels of 0.21 to 0.50 meters, while 3.33%, 2.40%, 0.68%, and 0.04% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and more than 2 meters respectively. Outlined in Table 40 and Table 41 are the affected areas in square kilometers by flood depth per barangay.

Table 40. Affected areas in Santa Rita, Samar by flood level for a 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Santa Rita (in sq. km.)											
	Alegria	Anibongan	Aslum	Bagolibas	Binanalan	Bokinggan Poblacion	Cabacungan	Camayse	Guinbalot-An	Gumamela Poblacion	La Paz	Lupig
0.03-0.20	0.51	3.45	0.60	3.40	8.66	4.19	3.54	2.06	1.13	2.09	1.74	7.28
0.21-0.50	0.011	0.086	0.0070	0.18	0.33	0.70	0.14	0.48	0.17	0.37	0.49	0.84
0.51-1.00	0.0036	0.10	0.00055	0.32	0.49	0.49	0.11	0.24	0.17	0.18	0.19	0.67
1.01-2.00	0.00012	0.094	0	0.40	0.41	0.13	0.13	0.12	0.018	0.033	0.00080	0.32
2.01-5.00	0	0.011	0	0.089	0.055	0.00070	0.037	0.027	0.00020	0.0012	0	0.11
> 5.00	0	0	0	0	0	0	0.00040	0.033	0	0	0	0.00080

Table 41. Affected areas in Santa Rita, Samar by flood level for a 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Santa Rita (in sq. km.)											
	Maligaya	New Manunca	Old Manunca	Pagsulhogon	Rosal Poblacion	Salvacion	San Eduardo	San Isidro	San Pascual	Tominamos	Tulay	Union
0.03-0.20	4.41	3.10	11.85	0.44	0.010	2.37	18.52	13.59	12.18	3.77	3.19	2.15
0.21-0.50	0.17	0.48	0.66	0.010	0	0.27	0.84	0.80	0.76	0.39	0.25	0.17
0.51-1.00	0.22	0.37	0.67	0.0055	0	0.23	1.02	1.05	0.95	0.44	0.25	0.18
1.01-2.00	0.31	0.13	0.51	0.0047	0	0.10	1.00	1.06	0.61	0.33	0.17	0.14
2.01-5.00	0.087	0.038	0.21	0.00010	0	0.0014	0.39	0.33	0.15	0.073	0.046	0.041
> 5.00	0.00050	0.00040	0.0020	0	0	0	0.015	0.00070	0.00090	0.018	0.018	0.00010

Among the barangays in the municipality of Santa Rita, Binanalan is projected to have the highest percentage of area that will experience flood levels at 4.0%. On the other hand, Lupig posted the second highest percentage of area that may be affected by flood depths of at 3.69%.

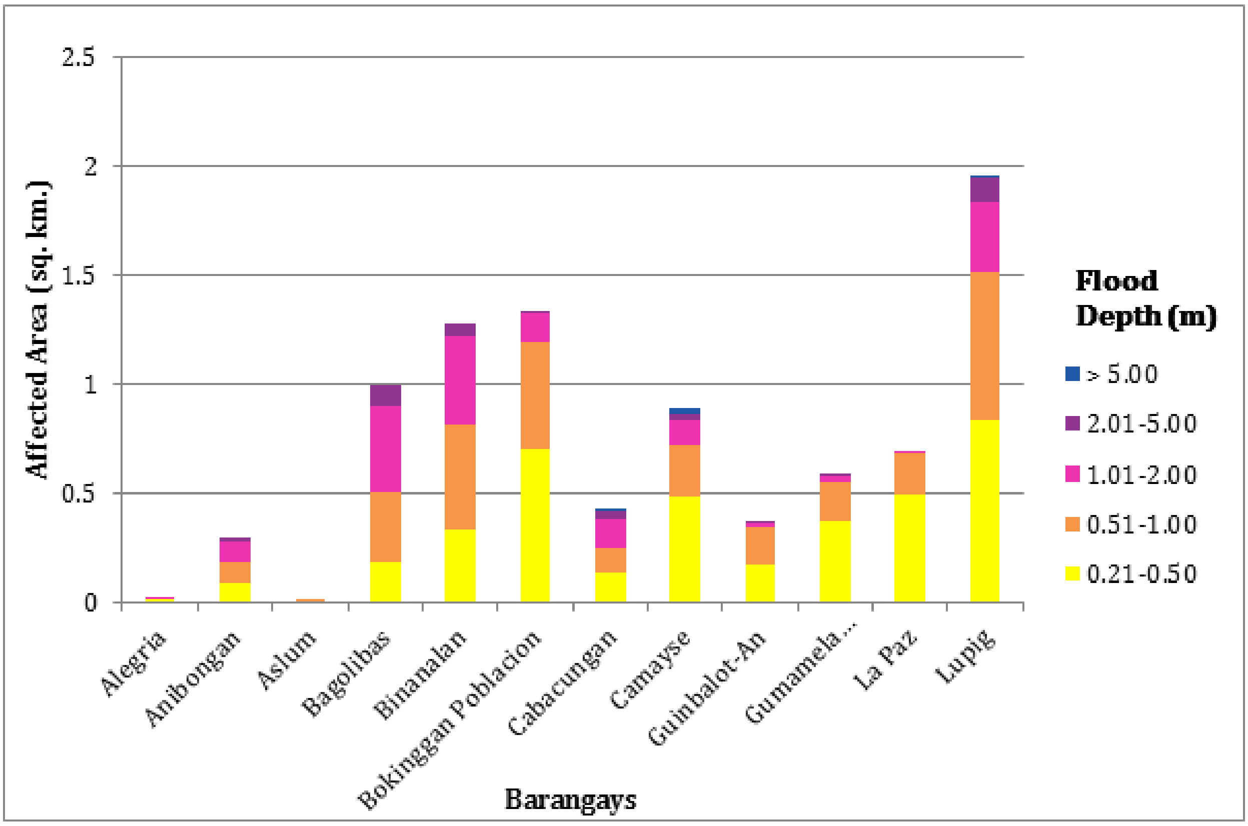


Figure 79. The affected Areas in Santa Rita, Samar during 5-Year Rainfall Return Period

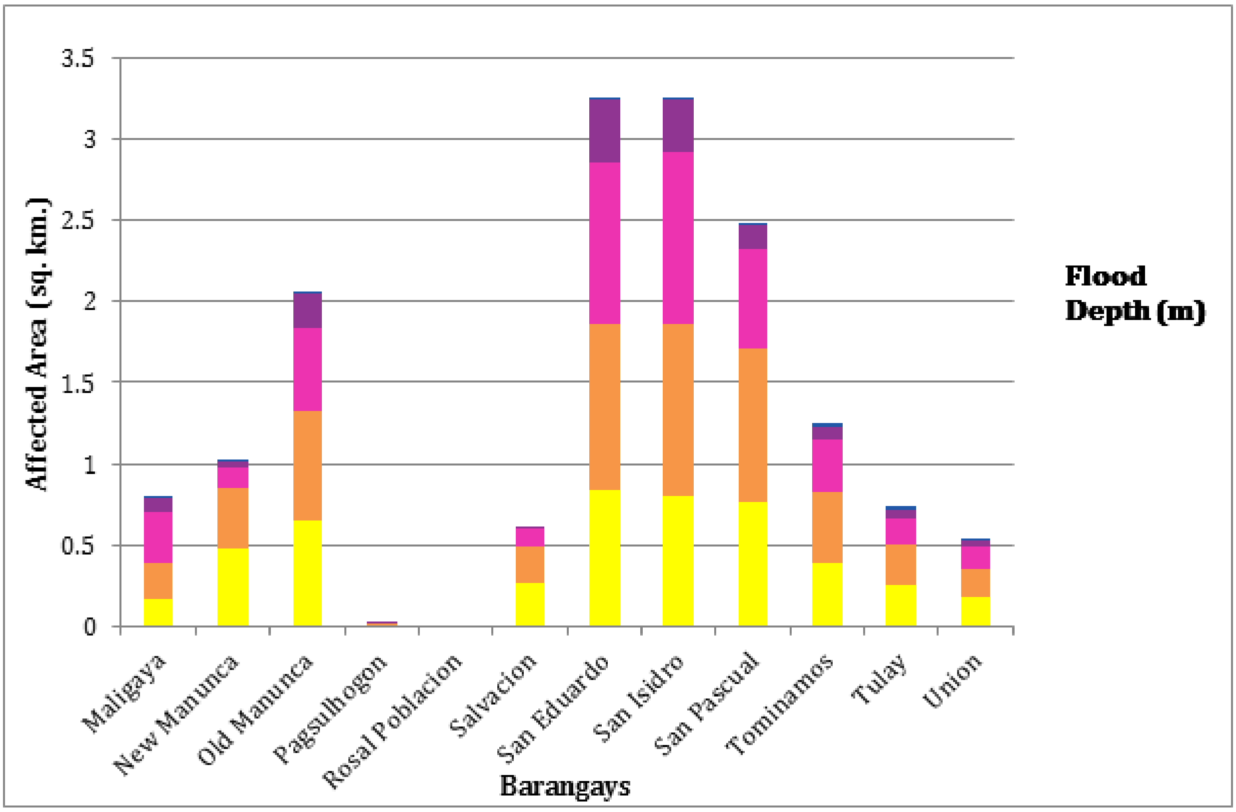


Figure 80. The specifically affected areas in Santa Rita, Samar during a 5-Year Rainfall Return Period.

For the 25-year return period, 4.80% of the municipality of Basey with an area of 627.97 sq. km. will experience flood levels of less 0.20 meters. 0.16% of the area will experience flood levels of 0.21 to 0.50 meters while 0.15%, 0.21%, 0.14%, and 0.02% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 42 are the affected areas in square kilometres by flood depth per barangay.

Table 42. Affected Areas in Basey, Samar during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Basey (in sq. km.)			
	Bulao	Cancaiyas	Mabini	Villa Aurora
0.03-0.20	16.92	9.66	1.90	1.63
0.21-0.50	0.44	0.37	0.12	0.041
0.51-1.00	0.36	0.53	0.048	0.018
1.01-2.00	0.44	0.84	0.019	0.013
2.01-5.00	0.67	0.69	0.013	0.0023
> 5.00	0.10	0.0057	0	0

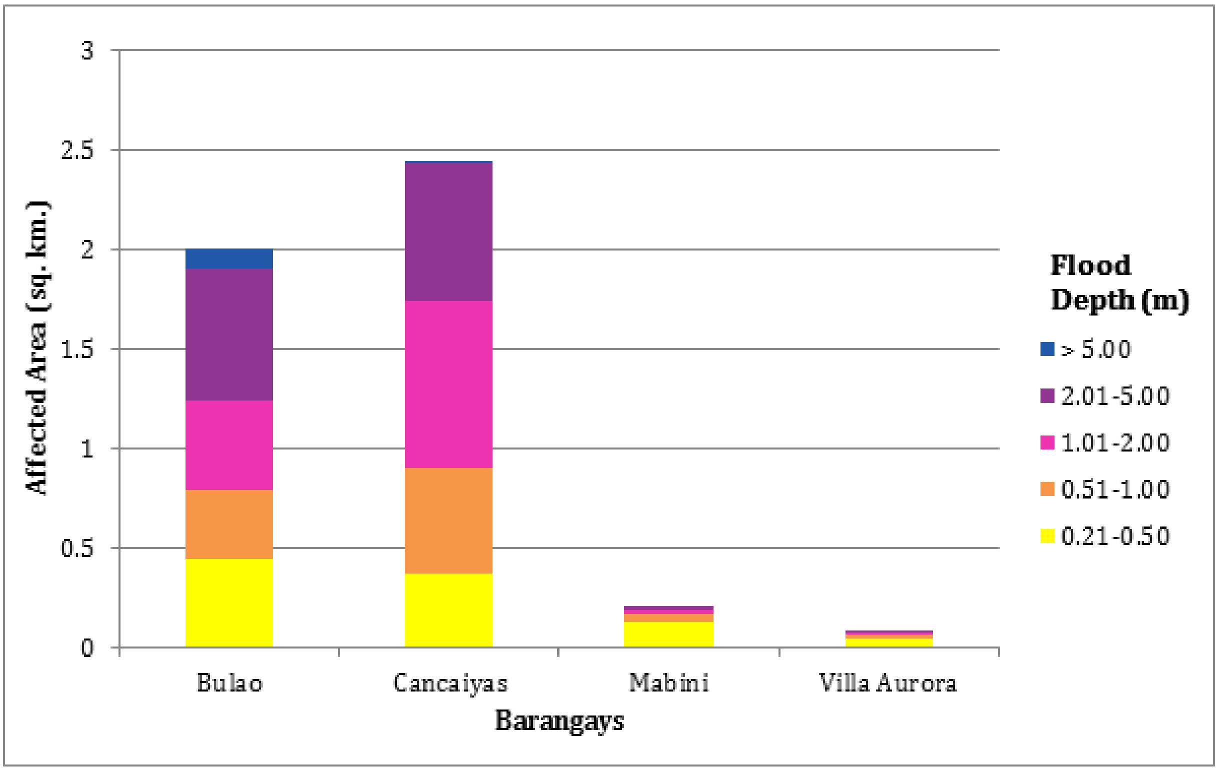


Figure 81. Affected Areas in Basey, Samar during 25-Year Rainfall Return Period

For the municipality of Pinabacdao, with an area of 118.377 sq. km., 13.80% will experience flood levels of less 0.20 meters. 0.45% of the area will experience flood levels of 0.21 to 0.50 meters while 0.66%, 0.93%, and 0.39% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively.

Table 43. Affected Areas in Pinabacdao, Samar during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pinabacdao (in sq. km.)				
	Bugho	Laygayon	Magdawat	Parasanon	Pelaon
0.03-0.20	0.51	3.41	0.60	3.31	8.51
0.21-0.50	0.012	0.091	0.010	0.13	0.29
0.51-1.00	0.0054	0.084	0.00065	0.25	0.44
1.01-2.00	0.00032	0.12	0	0.41	0.57
2.01-5.00	0	0.031	0	0.29	0.13
> 5.00	0	0	0	0	0

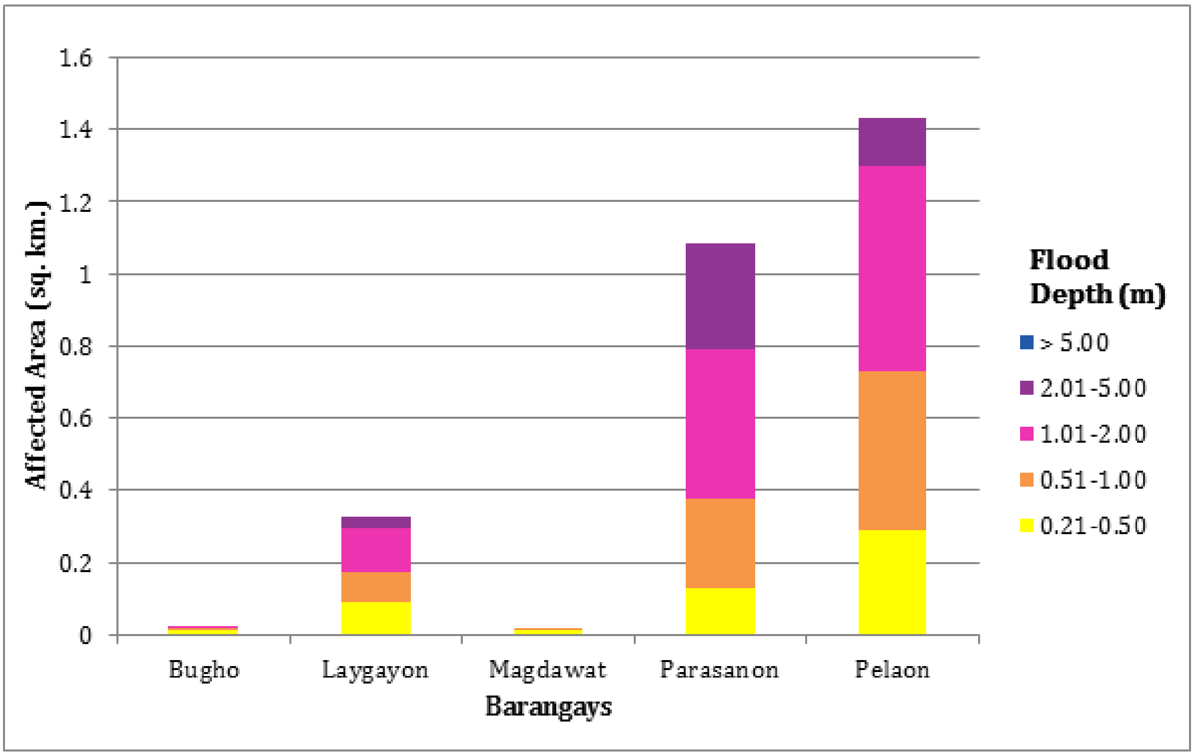


Figure 82. Affected Areas in Pinabacdao, Samar during 25-Year Rainfall Return Period

For the municipality of Villareal, with an area of 130.22 sq. km., 3.02% will experience flood levels of less 0.20 meters. 0.10% of the area will experience flood levels of 0.21 to 0.50 meters while 0.13%, 0.16%, and 0.014% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters respectively. Listed in Table 44 are the affected areas in square kilometres by flood depth per barangay.

Table 44. Affected Areas in Villareal, Samar during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Villareal (in sq. km.)	
	Bulao	Cancaiyas
0.03-0.20	1.15	2.78
0.21-0.50	0.034	0.080
0.51-1.00	0.055	0.11
1.01-2.00	0.060	0.15
2.01-5.00	0.0027	0.016
> 5.00	0	0

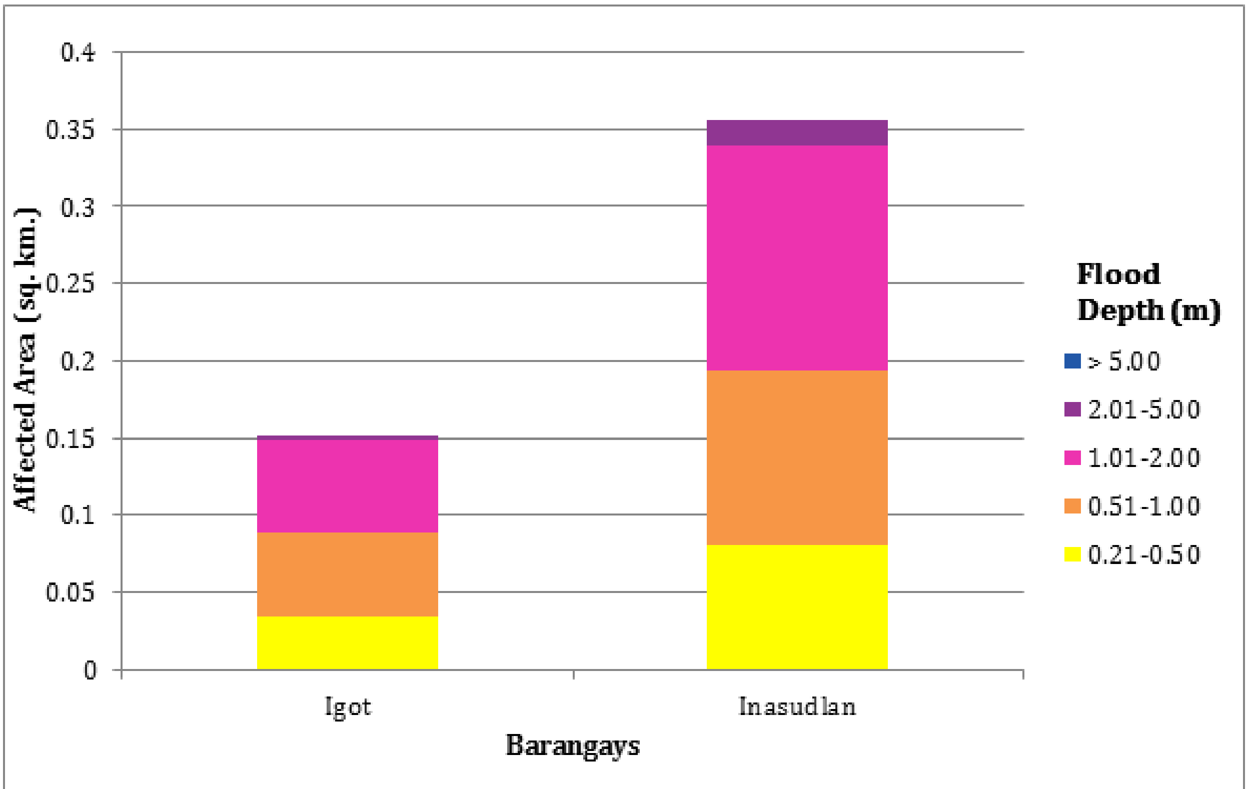


Figure 83. Affected Areas in Villareal, Samar during 25-Year Rainfall Return Period

For the municipality of Santa Rita, with an area of 250.37 sq. km., 49.26% will experience flood levels of less 0.20 meters. 3.90% of the area will experience flood levels of 0.21 to 0.50 meters while 4.56%, 4.21%, 1.92%, and 0.12% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 45 and Table 46 an are the affected areas in square kilometres by flood depth per barangay.

Table 45. Affected Areas in Santa Rita, Samar during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Santa Rita (in sq. km.)											
	Alegria	Anibongan	Aslum	Bagolibas	Binanalan	Bokinggan Poblacion	Cabacungan	Camayse	Guinbalot-An	Gumamela Poblacion	La Paz	Lupig
0.03-0.20	0.93	12.29	0.98	9.75	6.82	3.93	3.42	1.74	1.04	2.01	1.48	6.83
0.21-0.50	0.29	1.56	0.20	0.44	0.57	0.56	0.12	0.50	0.16	0.26	0.32	0.70
0.51-1.00	0.16	1.41	0.17	0.45	0.73	0.65	0.12	0.33	0.15	0.34	0.56	0.94
1.01-2.00	0.0020	1.19	0.095	0.51	0.72	0.37	0.18	0.30	0.15	0.065	0.061	0.51
2.01-5.00	0.17	0.0085	0	0.34	0.46	0.0022	0.12	0.045	0.00020	0.0018	0	0.23
> 5.00	0.071	0.0043	0	0.0089	0.0086	0	0.0018	0.046	0	0	0	0.0068

Table 46. Affected Areas in Santa Rita, Samar during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Santa Rita (in sq. km.)											
	Maligaya	New Manunca	Old Manunca	Pagsulhogon	Rosal Poblacion	Salvacion	San Eduardo	San Isidro	San Pascual	Tominamos	Tulay	Union
0.03-0.20	4.41	3.10	11.85	0.44	0.010	2.37	18.52	13.59	12.18	3.77	3.19	2.15
0.21-0.50	4.28	2.84	11.46	0.44	0.010	2.23	17.70	13.05	11.77	3.49	2.83	2.01
0.51-1.00	0.15	0.44	0.62	0.011	0	0.25	0.70	0.65	0.63	0.34	0.16	0.13
1.01-2.00	0.19	0.48	0.71	0.0067	0	0.30	0.94	0.96	1.00	0.43	0.24	0.18
2.01-5.00	0.37	0.22	0.75	0.0060	0	0.18	1.46	1.38	0.97	0.44	0.34	0.26
> 5.00	0.20	0.14	0.35	0.00050	0	0.0041	0.93	0.79	0.28	0.28	0.32	0.10

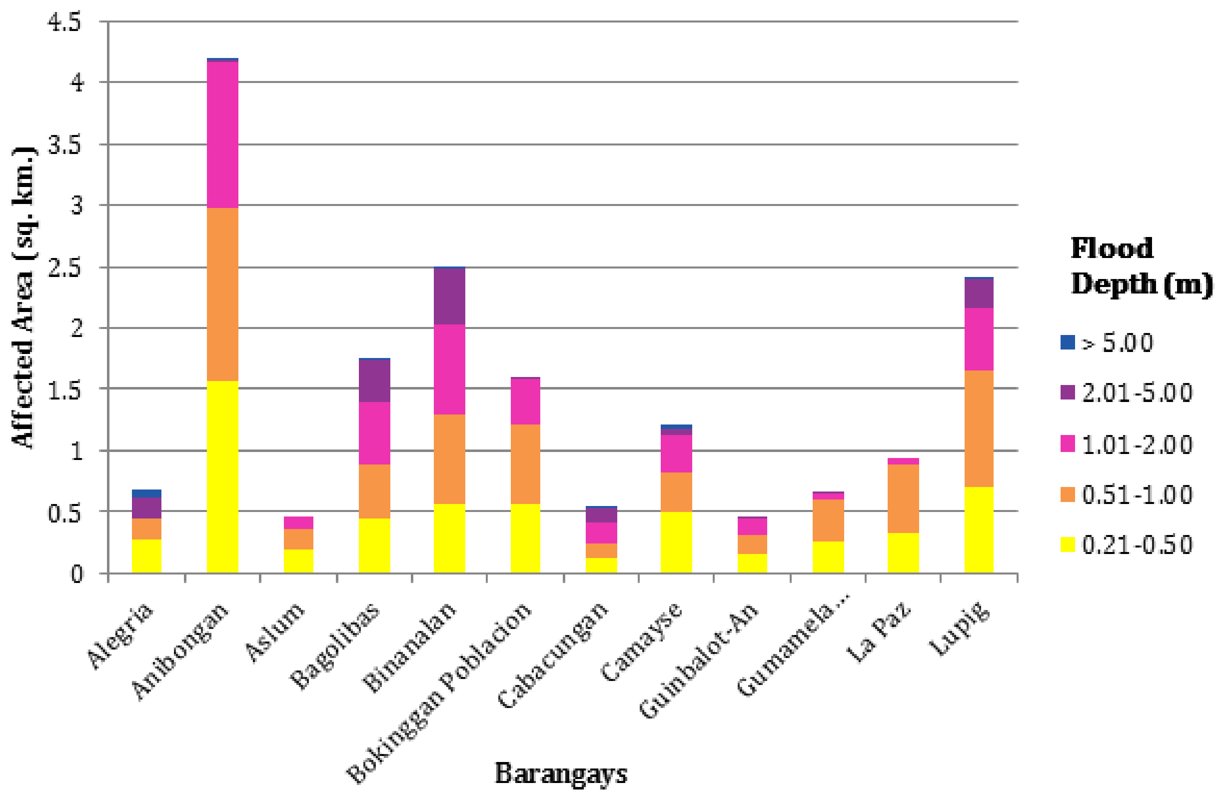


Figure 84. Affected Areas in Santa Rita, Samar during 25-Year Rainfall Return Period

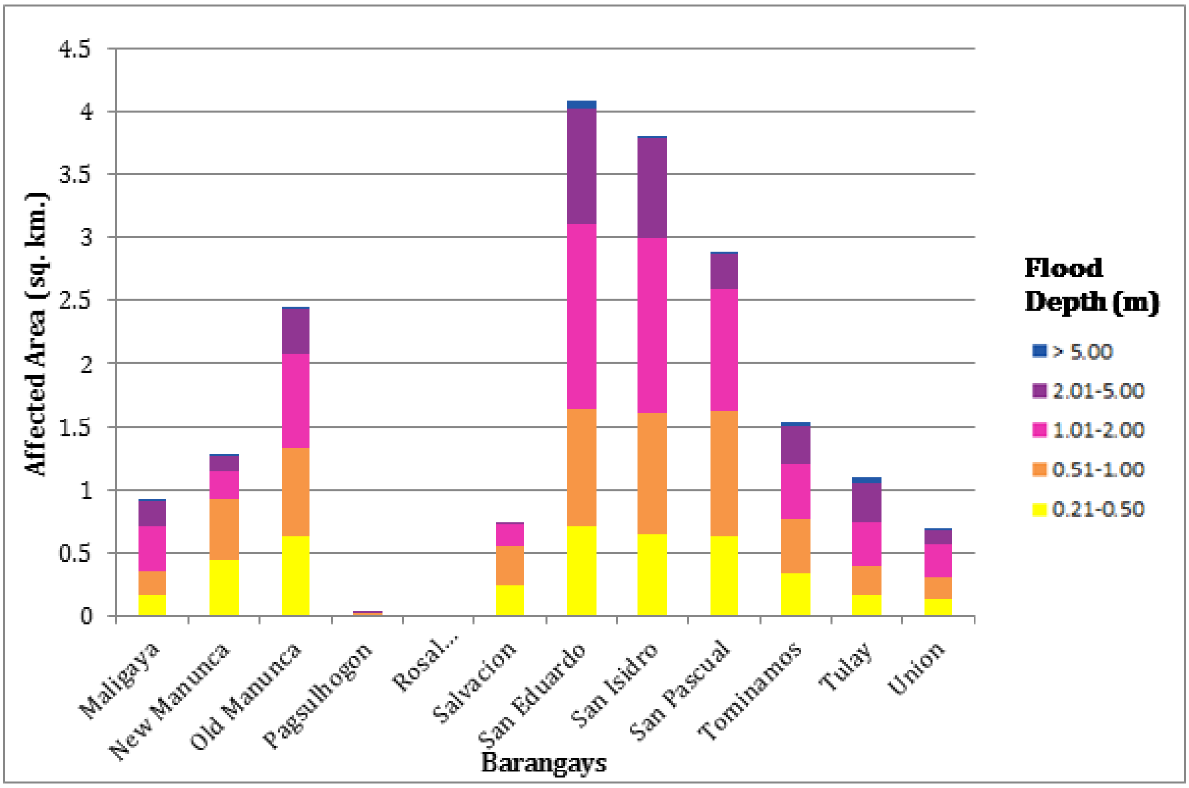


Figure 85. Affected Areas in Santa Rita, Samar during 25-Year Rainfall Return Period

For the 100-year return period, 4.73% of the municipality of Basey with an area of 627.97 sq. km. will experience flood levels of less 0.20 meters. 0.16% of the area will experience flood levels of 0.21 to 0.50 meters while 0.14%, 0.21%, 0.27%, and 0.03% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 47 are the affected areas in square kilometres by flood depth per barangay.

Table 47. Affected Areas in Basey, Samar during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Basey (in sq. km.)			
	Bulao	Cancaiyas	Mabini	Villa Aurora
0.03-0.20	16.73	9.51	1.87	1.62
0.21-0.50	0.46	0.34	0.14	0.046
0.51-1.00	0.36	0.47	0.057	0.020
1.01-2.00	0.45	0.85	0.021	0.014
2.01-5.00	0.73	0.92	0.018	0.0036
> 5.00	0.20	0.024	0	0

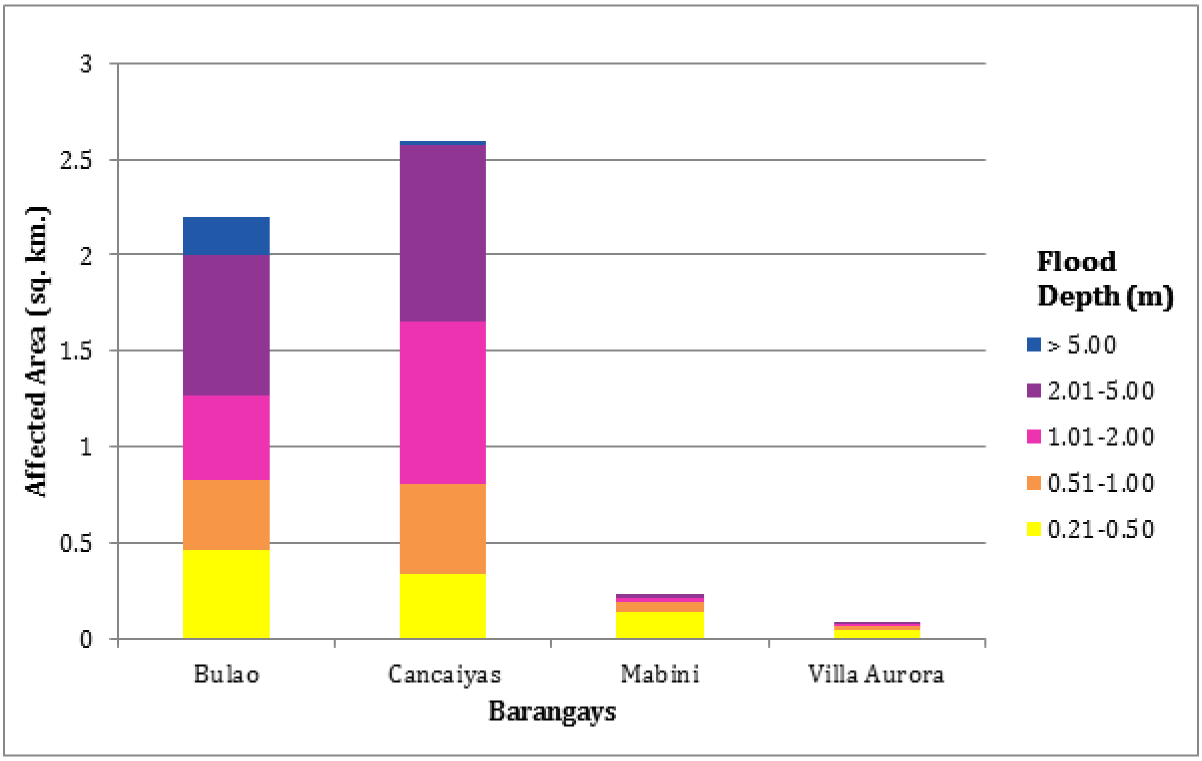


Figure 86. Affected Areas in Basey, Samar during 100-Year Rainfall Return Period

For the municipality of Pinabacdao, with an area of 118.377 sq. km., 13.65% will experience flood levels of less 0.20 meters. 0.44% of the area will experience flood levels of 0.21 to 0.50 meters while 0.58%, 0.99%, and 0.57% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2, and 2.01 to 5 meters, respectively (Table 48).

Table 48. Affected Areas in Pinabacdao, Samar during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pinabacdao (in sq. km.)				
	Bugho	Laygayon	Magdawat	Parasanon	Pelaon
0.03-0.20	0.50	3.38	0.60	3.26	8.42
0.21-0.50	0.012	0.10	0.012	0.12	0.28
0.51-1.00	0.0067	0.083	0.00075	0.20	0.39
1.01-2.00	0.00042	0.13	0	0.39	0.65
2.01-5.00	0	0.049	0	0.42	0.20
> 5.00	0	0	0	0	0

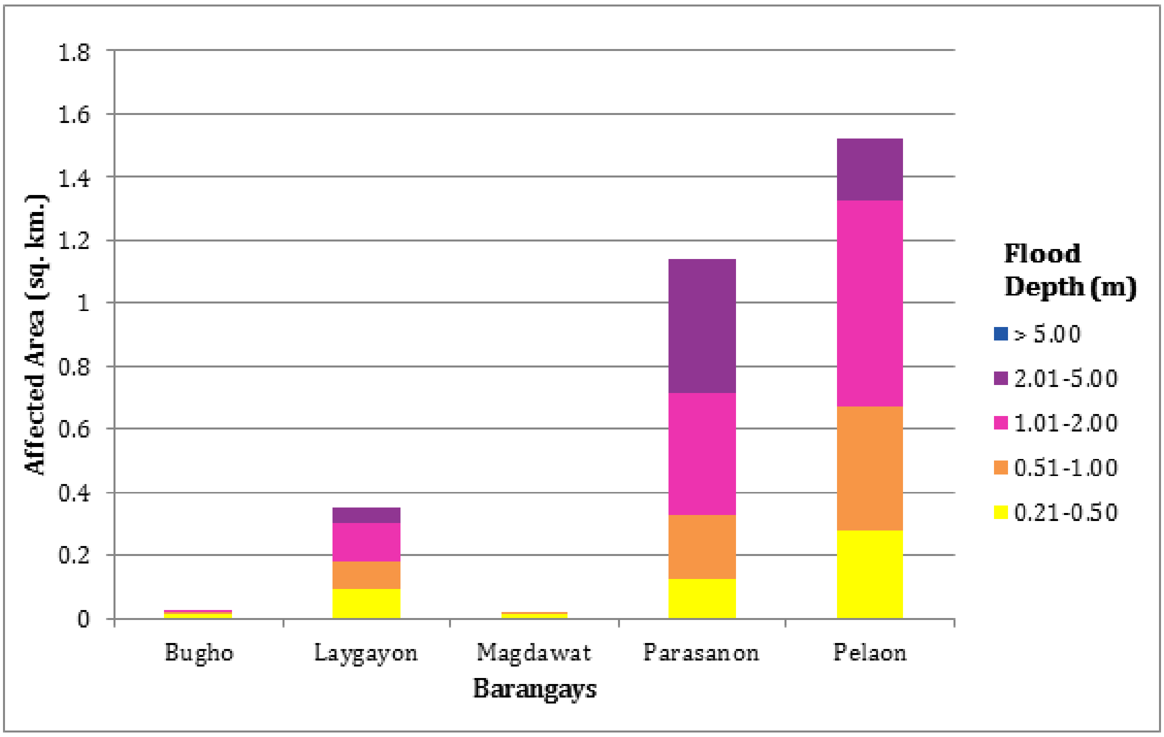


Figure 87. Affected Areas in Pinabacdao, Samar during 100-Year Rainfall Return Period

For the municipality of Villareal, with an area of 130.22 sq. km., 3.00% will experience flood levels of less 0.20 meters. 0.09% of the area will experience flood levels of 0.21 to 0.50 meters while 0.12%, 0.18%, and 0.03% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in Table 49 are the affected areas in square kilometres by flood depth per barangay.

Table 49. Affected Areas in Villareal, Samar during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Villareal (in sq. km.)	
	Bulao	Cancaiyas
0.03-0.20	1.14	2.76
0.21-0.50	0.033	0.081
0.51-1.00	0.045	0.10
1.01-2.00	0.075	0.16
2.01-5.00	0.0075	0.035
> 5.00	0	0

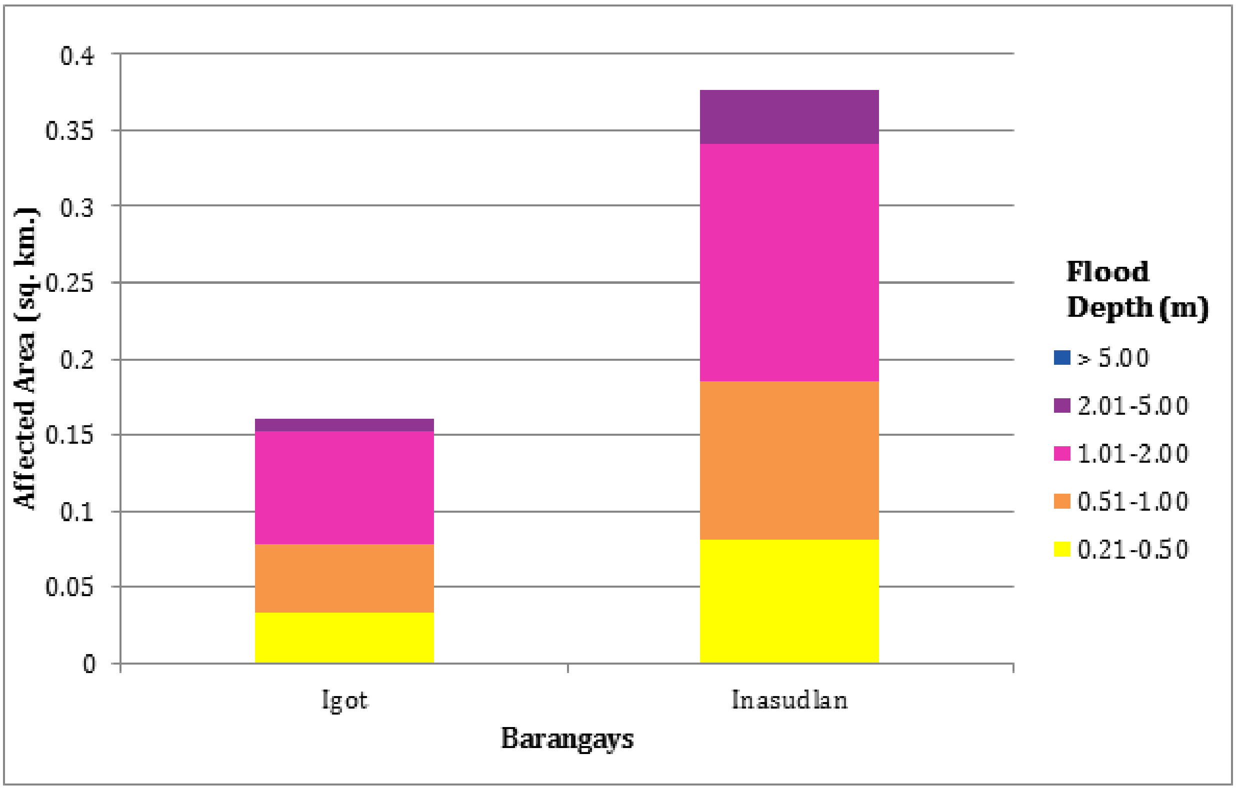


Figure 88. Affected Areas in Villareal, Samar during 100-Year Rainfall Return Period

For the municipality of Santa Rita, with an area of 250.37 sq. km., 47.81% will experience flood levels of less 0.20 meters. 3.46% of the area will experience flood levels of 0.21 to 0.50 meters while 4.62%, 4.86%, 3.02%, and 0.20% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 50 and Table 51 are the affected areas in square kilometres by flood depth per barangay.

Table 50. Affected Areas in Santa Rita, Samar during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Santa Rita (in sq. km.)											
	Alegria	Anibongan	Aslum	Bagolibas	Binanalan	Bokinggan Poblacion	Cabacungan	Camayse	Guinbalot-An	Gumamela Poblacion	La Paz	Lupig
0.03-0.20	0.87	11.70	0.94	9.59	6.64	3.81	3.38	1.33	1.01	1.97	1.40	6.63
0.21-0.50	0.26	1.41	0.17	0.44	0.51	0.44	0.12	0.38	0.14	0.19	0.28	0.60
0.51-1.00	0.23	1.58	0.20	0.43	0.74	0.71	0.088	0.51	0.16	0.41	0.52	0.95
1.01-2.00	0.010	1.50	0.12	0.52	0.75	0.54	0.18	0.49	0.18	0.10	0.22	0.69
2.01-5.00	0.41	0.013	0	0.50	0.65	0.012	0.19	0.20	0.0015	0.0029	0	0.34
> 5.00	0.10	0.0049	0	0.020	0.024	0	0.0033	0.051	0	0	0	0.010

Table 51. Affected Areas in Santa Rita, Samar during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Santa Rita (in sq. km.)											
	Maligaya	New Manunca	Old Manunca	Pagsulhogon	Rosal Poblacion	Salvacion	San Eduardo	San Isidro	San Pascual	Tominamos	Tulay	Union
0.03-0.20	4.41	3.10	11.85	0.44	0.010	2.37	18.52	13.59	12.18	3.77	3.19	2.15
0.21-0.50	4.22	2.68	11.20	0.43	0.010	2.17	17.36	12.76	11.55	3.36	2.70	1.96
0.51-1.00	0.14	0.42	0.60	0.012	0	0.21	0.64	0.59	0.58	0.30	0.13	0.11
1.01-2.00	0.17	0.51	0.71	0.0072	0	0.33	0.80	0.85	0.92	0.41	0.19	0.14
2.01-5.00	0.35	0.32	0.86	0.0072	0	0.22	1.51	1.41	1.17	0.45	0.27	0.29
> 5.00	0.31	0.17	0.48	0.00070	0	0.030	1.38	1.21	0.42	0.45	0.60	0.18

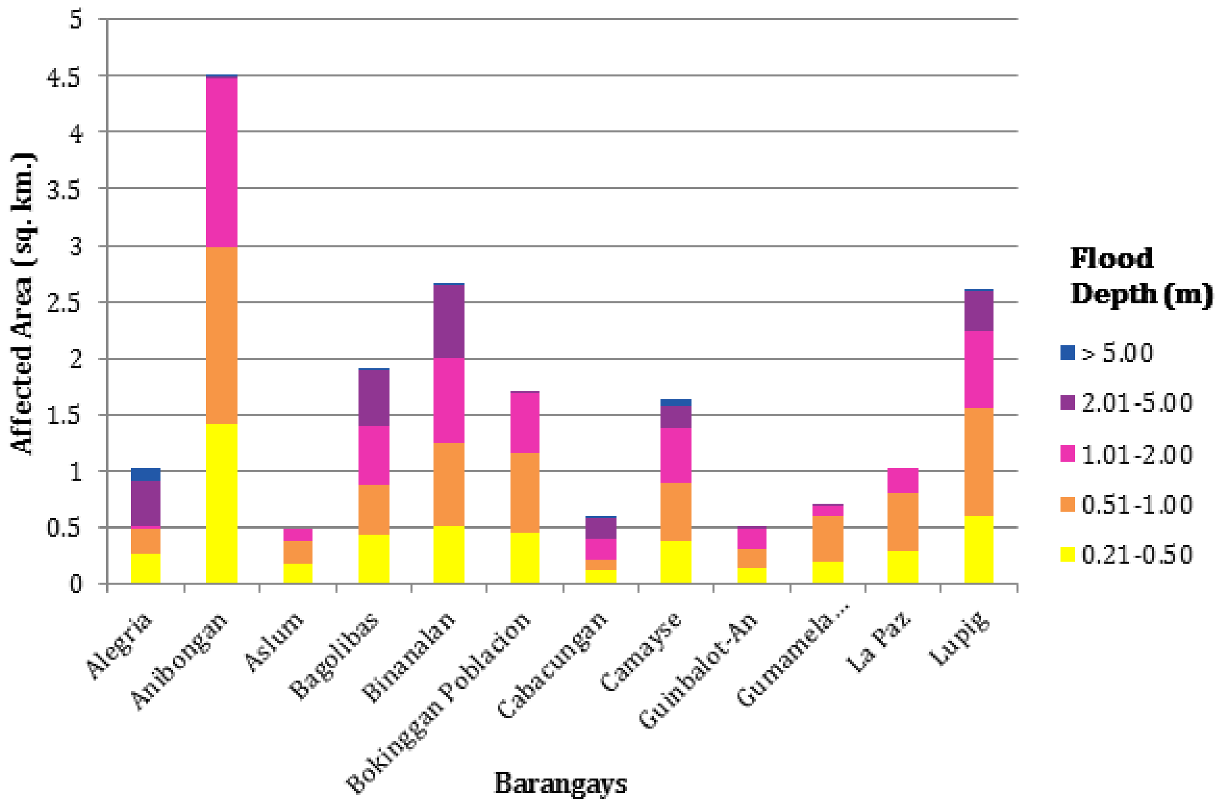


Figure 89. Affected Areas in Santa Rita, Samar during 100-Year Rainfall Return Period

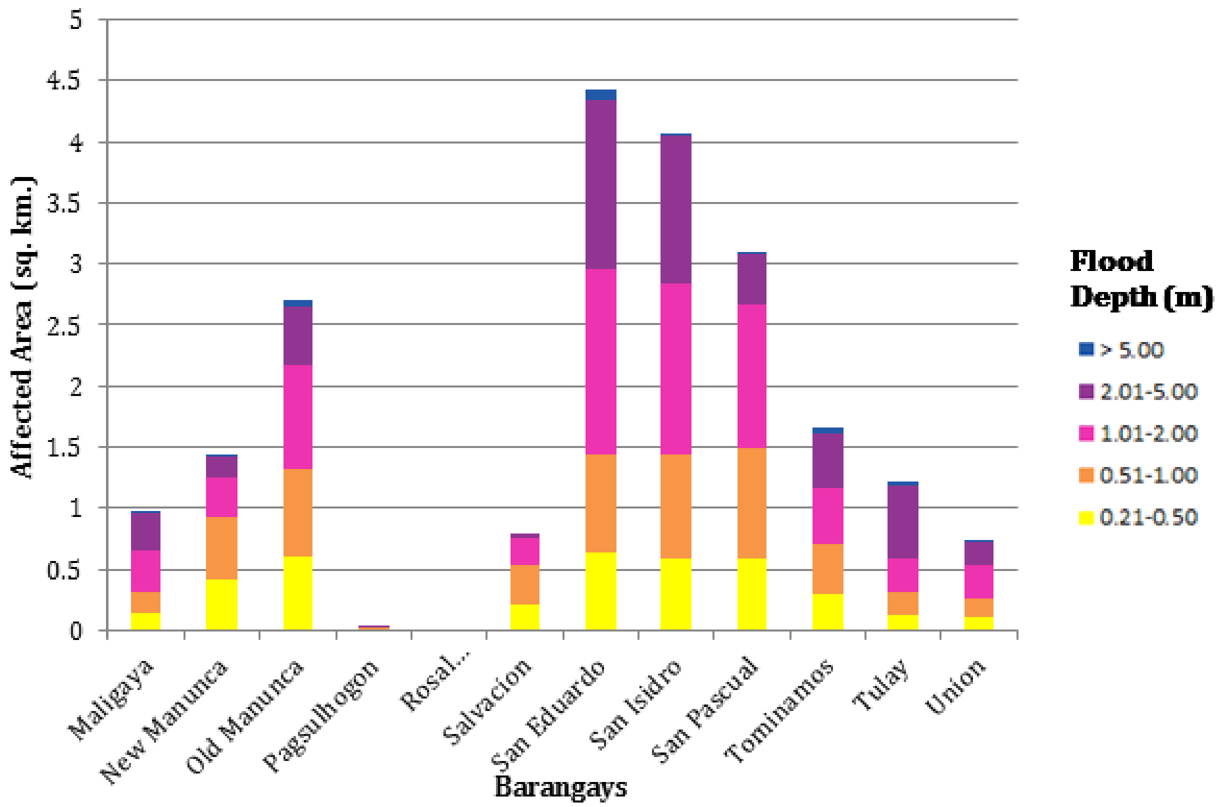


Figure 90. Affected Areas in Santa Rita, Samar during 100-Year Rainfall Return Period

Among the barangays in the municipality of Basey, Bulao is projected to have the highest percentage of area that will experience flood levels at 3.01%. Meanwhile, Cancaiyas posted the second highest percentage of area that may be affected by flood depths at 1.93%.

Among the barangays in the municipality of Pinabacdao, Pelaon is projected to have the highest percentage of area that will experience flood levels at 8.40%. Meanwhile, Parasanon posted the second highest percentage of area that may be affected by flood depths at 3.71%.

Among the barangays in the municipality of Villareal, Inasudlan is projected to have the highest percentage of area that will experience flood levels of at 2.41%. Meanwhile, Igot posted the percentage of area that may be affected by flood depths of at 1.0%.

Among the barangays in the municipality of Santa Rita, San Eduardo is projected to have the highest percentage of area that will experience flood levels at 8.70%. Meanwhile, San Isidro posted the second highest percentage of area that may be affected by flood depths of at 6.73%.

Moreover, the generated flood hazard maps for the Silaga 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-year, 25-year, and 10-year).

Table 52. Areas covered by each warning level with respect to the rainfall scenarios

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	13.15	11.41	10.31
Medium	18.1	21.55	22.03
High	6.3	12.41	17.24
TOTAL	37.55	45.37	49.58

Of the 24 identified Education Institute in Silaga Flood plain, three (3) schools were discovered exposed to Low-level flooding during a 5-year scenario, while three (3) schools were found exposed to Medium-level flooding in the same scenario.

In the 25-year scenario, three (3) schools were found exposed to Low-level flooding, while four (4) schools were discovered exposed to Medium-level flooding.

For the 100-year scenario, one (1) school was discovered exposed to Low-level flooding, while four (4) schools were exposed to Medium-level flooding. In the same scenario, two (2) schools were found exposed to High-level flooding; both of which are located in Barangay Parasanon, Pinabacdao.

Apart from this, two (2) Medical Institutions were identified in the Silaga Floodplain, yet only one (1) was discovered exposed to Medium-level flooding in the three (3) different scenarios in Barangay Tominamos, Santa Rita, Samar.

5.11 Flood Validation

In order to check and validate the extent of flooding in different river systems, there is a need to perform validation survey work. Field personnel gathered secondary data regarding flood occurrences in the respective areas within the major river systems 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 the river basin and gathered data regarding the actual flood level in each location. Data gathering was done through a local DRRM office to obtain maps or situation reports about the past flooding events or interview of some residents with knowledge of or have had experienced flooding in a particular area.

The actual data from the field were compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed. The points in the flood map versus its corresponding validation depths are shown in Figure 91.

The flood validation consists of 235 points randomly selected all over the Silaga flood plain (Figure 90). Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 0.96m. Table 53 shows a contingency matrix of the comparison. The validation points are found in Annex 11.

The flood validation data were obtained on May 25-27, 2016.

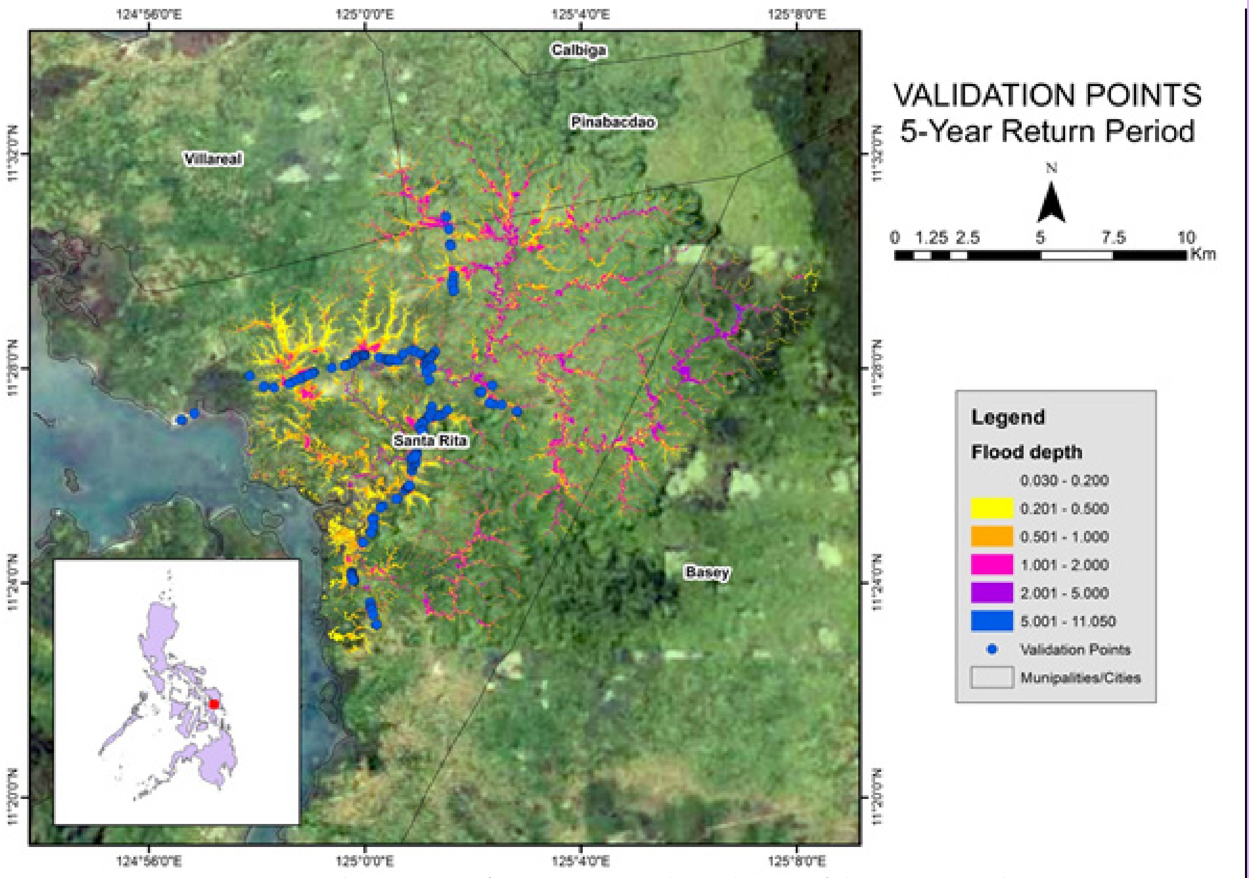


Figure 91. Validation points for a 5-year Flood Depth Map of the Silaga Floodplain.

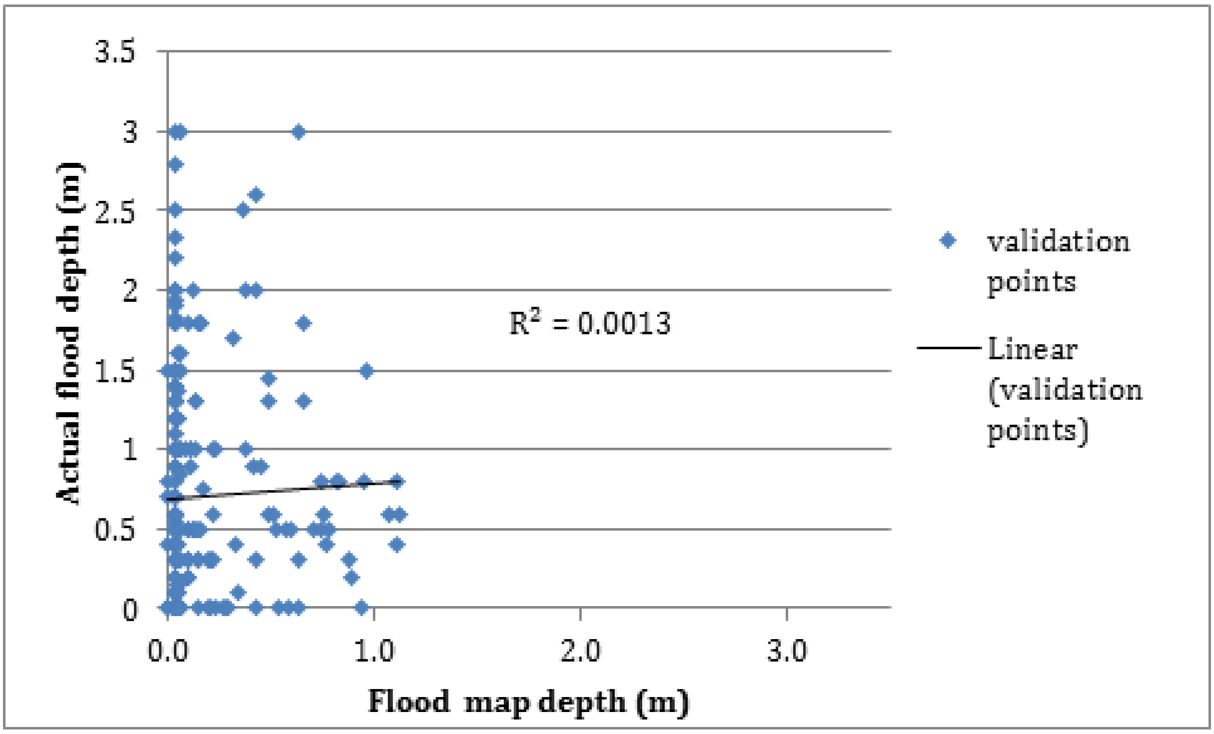


Figure 92 . Flood map depth vs actual flood depth

Table 53. Actual flood vs simulated flood depth at differnent levels in the Silaga River Basin.

Actual Flood Depth (m)	Modeled Flood Depth (m)						
	0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
0-0.20	63	7	5	0	0	0	75
0.21-0.50	39	4	9	1	0	0	53
0.51-1.00	34	7	6	3	0	0	50
1.01-2.00	40	5	3	0	0	0	48
2.01-5.00	6	2	1	0	0	0	9
> 5.00	0	0	0	0	0	0	0
Total	182	25	24	4	0	0	235

On the whole, the overall accuracy generated by the flood model is estimated at 31.06%, with 73 points correctly matching the actual flood depths. In addition, there were 68 points estimated one level above and below the correct flood depths, while there were 46 points and 42 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 25 points were overestimated, while a total of 137 points were underestimated in the modeled flood depths of Silaga Baganga. Table 54 depicts the summary of the Accuracy Assessment in the Silaga River Basin Flood Depth Map.

Table 54. Summary of the Accuracy Assessment in the Silaga River Basin Survey

	No. of Points	%
Correct	73	31.06
Overestimated	25	10.64
Underestimated	137	58.30
Total	235	100

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UP TCAGP 2016. Acceptance and Evaluation of Synthetic Aperture Radar Digital Surface Model (SAR DSM)

ANNEXES

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

1. AQUARIUS SENSOR

Figure A-1.1. Aquarius Sensor

Table A-1.1. Parameters and Specification of Aquarius Sensor

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

2. GEMINI SENSOR

Figure A-1.2. Parameters and Specification of Gemini Sensor

Table A-1.2. Parameters and Specification of Gemini Sensor

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

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

1. SMR-53

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

April 23, 2014

CERTIFICATION

To whom it may concern:

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

Province: **SAMAR (WESTERN SAMAR)**
Station Name: **SMR-53**
Order: **2nd**

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

PRS92 Coordinates

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

WGS84 Coordinates

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

PTM Coordinates

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

UTM Coordinates

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

Location Description

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

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

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

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Branch : 421 Barraca St. San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3494 to 98
www.namria.gov.ph

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.1. SMR-53

2. SMR-56

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

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CIP/4701/12/09/814

Figure A-2.2. SMR-56

3. SMR-58

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: **514288.239 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

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Figure A-2.3. SMR-58

4. SM-271

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: **SAMAR (WESTERN SAMAR)**
Station Name: **SM-271**

Island: **VISAYAS**	Municipality: **PINABACDAO**	Barangay: **LAYGAYON**
Elevation: **80.1571 +/- 0.05 m.**	Order: **1st Order**	Datum: **Mean Sea Level**
Latitude:	Longitude:	

Location Description

SM-271 is in the Province of Western Samar, town of Pinabakdaw, Brgy. Laygayon along right side of the National highway. It is located beside km post 864 and about 5.00m E from the centerline of the national highway. Station mark is the head of 4" copper nail centered on a 0.30m x 0.30m concrete block and mark with "SM-271,2007,NAMRIA."

Requesting Party:	**UP DREAM**
Purpose:	**Reference**
OR Number:	**8089687 I**
T.N.:	**2016-0241**

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

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Figure A-2.4. SMR-271

5. SM-286

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

9906062014164047

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Figure A-2.5. SM-286

6. SM-309

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, 4.50m 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

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Figure A-2.6. SM-309

7. LYT-101

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, 4.50m 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

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Figure A-2.7. LYT-101

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

1. LYT-104

Table A-3.1. LYT-104

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

2. SM-271

Table A-3.2. SM-271

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
SM-271 --- SMR-53 (B2)	SMR-53	SM-271	Fixed	0.004	0.018	5°23'32"	2272.463	55.956
SM-271 --- SMR-53 (B1)	SMR-53	SM-271	Fixed	0.004	0.014	5°23'31"	2272.470	55.944

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:	SM-271				
Grid		Local		Global	
Easting	721071.745 m	Latitude	N11°31'31.48932"	Latitude	N11°31'27.15275"
Northing	1274777.717 m	Longitude	E125°01'36.88440"	Longitude	E125°01'42.01496"
Elevation	80.707 m	Height	82.090 m	Height	143.697 m

Vector					
ΔEasting	197.612 m	NS Fwd Azimuth	5°23'32"	ΔX	52.927 m
ΔNorthing	2264.321 m	Ellipsoid Dist.	2272.463 m	ΔY	-447.483 m
ΔElevation	55.957 m	ΔHeight	55.956 m	ΔZ	2228.061 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.005 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.008 m
σ ΔElevation	0.009 m	σ ΔHeight	0.009 m	σ ΔZ	0.002 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000261223		
Y	-0.0000356331	0.0000567847	
Z	-0.0000091774	0.0000140863	0.0000048698

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:	SM-271				
Grid		Local		Global	
Easting	721071.738 m	Latitude	N11°31'31.48956"	Latitude	N11°31'27.15300"
Northing	1274777.724 m	Longitude	E125°01'36.88417"	Longitude	E125°01'42.01474"
Elevation	80.695 m	Height	82.078 m	Height	143.685 m

Vector					
ΔEasting	197.605 m	NS Fwd Azimuth	5°23'31"	ΔX	52.941 m
ΔNorthing	2264.328 m	Ellipsoid Dist.	2272.470 m	ΔY	-447.490 m
ΔElevation	55.945 m	ΔHeight	55.944 m	ΔZ	2228.066 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.004 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.006 m
σ ΔElevation	0.007 m	σ ΔHeight	0.007 m	σ ΔZ	0.002 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000168455		
Y	-0.0000221649	0.0000355369	
Z	-0.0000052344	0.0000087190	0.0000031341

3. SM-286

Table A-3.3. SM-286

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

4. SM-309

Table 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°17'55.05616"	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

Annex 4. The LIDAR Survey Team Composition

Table A-4.1. The LiDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader - I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
Survey Supervisor	Data Component Project Leader – I	ENGR. LOUIE P. BALICANTA	UP-TCAGP
	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
		LOVELY GRACIA ACUÑA	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELYN ASUNCION	UP-TCAGP

FIELD TEAM

LiDAR Operation	Senior Science Research Specialist (SSRS)	ENGR. GEROME HIPOLITO	UP-TCAGP
	Senior Science Research Specialist (SSRS) 2016/ RA (2014)	PAULINE JOANNE ARCEO	UP-TCAGP
	Research Associate (RA)	ENGR. IRO NIEL ROXAS	UP-TCAGP
	RA	GRACE SINADJAN	UP-TCAGP
	RA	JONATHAN ALMALVEZ	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	JERIEL PAUL ALAMBAN, GEOL.	UP-TCAGP
LiDAR Operation	Airborne Security	SSG RANDY SISON	PHILIPPINE AIR FORCE (PAF)
		SSG RAYMUND DOMINE	PAF
	Pilot	CAPT. ALBERT PAUL LIM	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. RANDY LAGCO	AAC
		CAPT. JACKSON JAVIER	AAC
		CAPT. NIEL AGAWIN	AAC

Annex 5. Data Transfer Sheet for Silaga Floodplain

DATA TRANSFER SHEET
6/22/2014 (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	6KB	773/12KB	Z:\Airborne_Raw\1358A
4/20/2014	1360A	3BLK34FS110B	AQUARIUS	NA	NA	7.75MB	174MB	41.1GB	206KB	8.26GB	NA	11.3MB	1KB	1KB	6KB	649/12KB	Z:\Airborne_Raw\1360A
4/22/2014	1366A	3BLK34E112A	AQUARIUS	NA	NA	1.37MB	257MB	95.5GB	4/18/1/283KB	14.9GB	NA	[illegible]	1KB	1KB	5KB	889/10KB	Z:\Airborne_Raw\1366P
5/11/2014	1442A	3BLK33GS131A	AQUARIUS	NA	NA	5.86MB	275MB	108GB	59/897KB	16.6GB	NA	14.3MB	1KB	1KB	NA	2652KB	Z:\Airborne_Raw\1442A
5/11/2014	1444A	3BLK33GSH131B	AQUARIUS	NA	NA	2.82MB	254MB	79.3GB	1/1/5/15/1/139KB	15.2GB	229GB	14.3MB	1KB	1KB	5/5KB	2813/700KB	Z:\Airborne_Raw\1444A
5/13/2014	1450A	3BLK33HS133A	AQUARIUS	NA	NA	906KB	132MB	34.1GB	257KB	6.07GB	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	86.8GB	11.2MB	1KB	1KB	6/10KB	512KB	Z:\Airborne_Raw\1452A
5/14/2014	1454A	3BLK34D134A	AQUARIUS	NA	NA	1.86MB	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	0.98MB	212MB	68.6GB	276/226KB	11.6GB	58.6GB	7.92MB	1KB	1KB	5KB	841KB	Z:\Airborne_Raw\1456P
5/15/2014	1460A	3BLK35CD135B	AQUARIUS	NA	NA	1.24MB	273MB	74.8GB	622KB	14.7GB	235GB	11.4MB	1KB	1KB	5/5KB	476/607KB	Z:\Airborne_Raw\1460A
5/16/2014	1462A	3BLK35DSE136A	AQUARIUS	NA	NA	1.29MB	275MB	91.2GB	665KB	15.2GB	NA	11.6MB	1KB	1KB	5/4KB	842KB	Z:\Airborne_Raw\1462A
5/16/2014	1464A	3BLK35ES136B	AQUARIUS	NA	NA	1.20MB	251MB	76.9GB	637KB	14.0GB	NA	11.4MB	1KB	1KB	4KB	786KB	Z:\Airborne_Raw\1464A

Received from

Name: Dan Alberto
Position: Research Associate
Signature:

Received by

Name: JOIDA F. PRIETO
Position: SSRS
Signature:
3/28/2014

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

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	592	0.97	243	NA	NA	20.3	NA	608	1KB	1KB	209	NA	Z:\DAC\RAW DATA
30-Jan	3731G	2BLK34LM030B	GEMINI	NA	29	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	239/293/293	NA	Z:\DAC\RAW DATA
5-Feb	3753G	2BLK34K33AB036A	GEMINI	NA	853	712	227	NA	NA	16.2	NA	4.1	1KB	1KB	293/431/293	NA	Z:\DAC\RAW DATA
6-Feb	3757G	2BLK34K037A	GEMINI	NA	772	483	177	NA	NA	10.2	NA	4.61	1KB	1KB	378	NA	Z:\DAC\RAW DATA

Received from

Name
Position
Signature

Received by

Name
Position
Signature

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

Annex 6. Flight Logs for the Flight Missions

1. Flight Log for Mission 1410A

DREAM Data Acquisition Flight Log

AQUATACTF[23A

Flight Log No.: 1410

1 LiDAR Operator: Iro Roxas	2 ALTM Model: Aqua	3 Mission Name:	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RPC9122
7 Pilot: J. Javier	8 Co-Pilot: N. Acawin	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 24 N (15 lines completed)

21 Problems and Solutions:

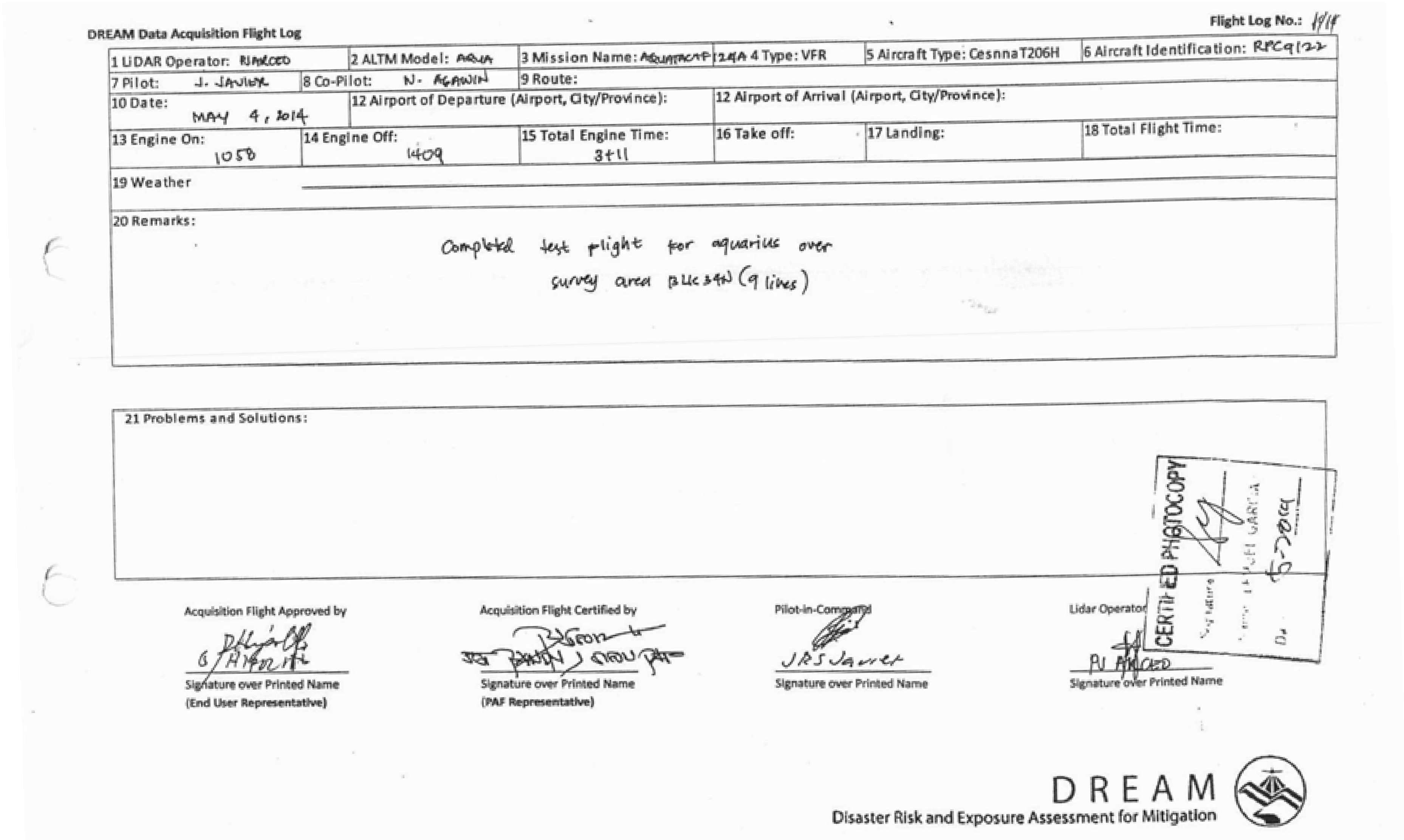
CERTIFIED PHOTOCOPY

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
G. Hipolito		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 A-6.1. Flight Log for Mission 1410A

2. Flight Log for 1414A Mission



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 BLK 34N (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 A-6.2. Flight Log for Mission 1414A

3. Flight Log for 1438A Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1448

1 LiDAR Operator: RJ ARCOZ	2 ALTM Model: AQUARIUS	3 Mission Name: 5BLK340130A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RPC9122
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.

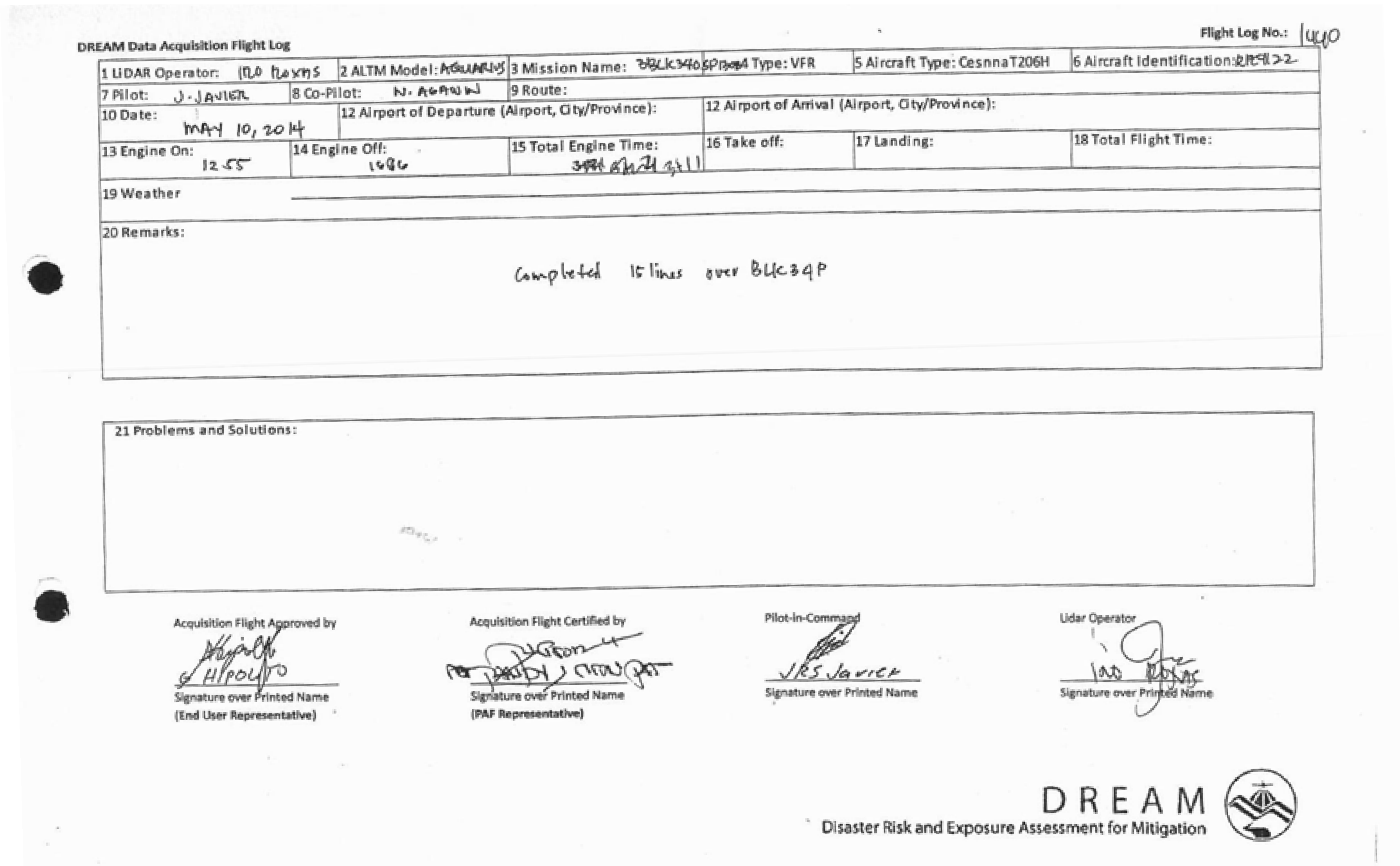
21 Problems and Solutions:

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

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.3. Flight Log for Mission 1438A

4. Flight Log for 1440A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1440

1 LiDAR Operator: I.R.O. Roxas	2 ALTM Model: Aquarius	3 Mission Name: 3BLK34OSP134	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9122
7 Pilot: J. Javier	8 Co-Pilot: N. Aganon	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: 1606	15 Total Engine Time: 3+11	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: G. Hipolito, Signature over Printed Name (End User Representative)

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

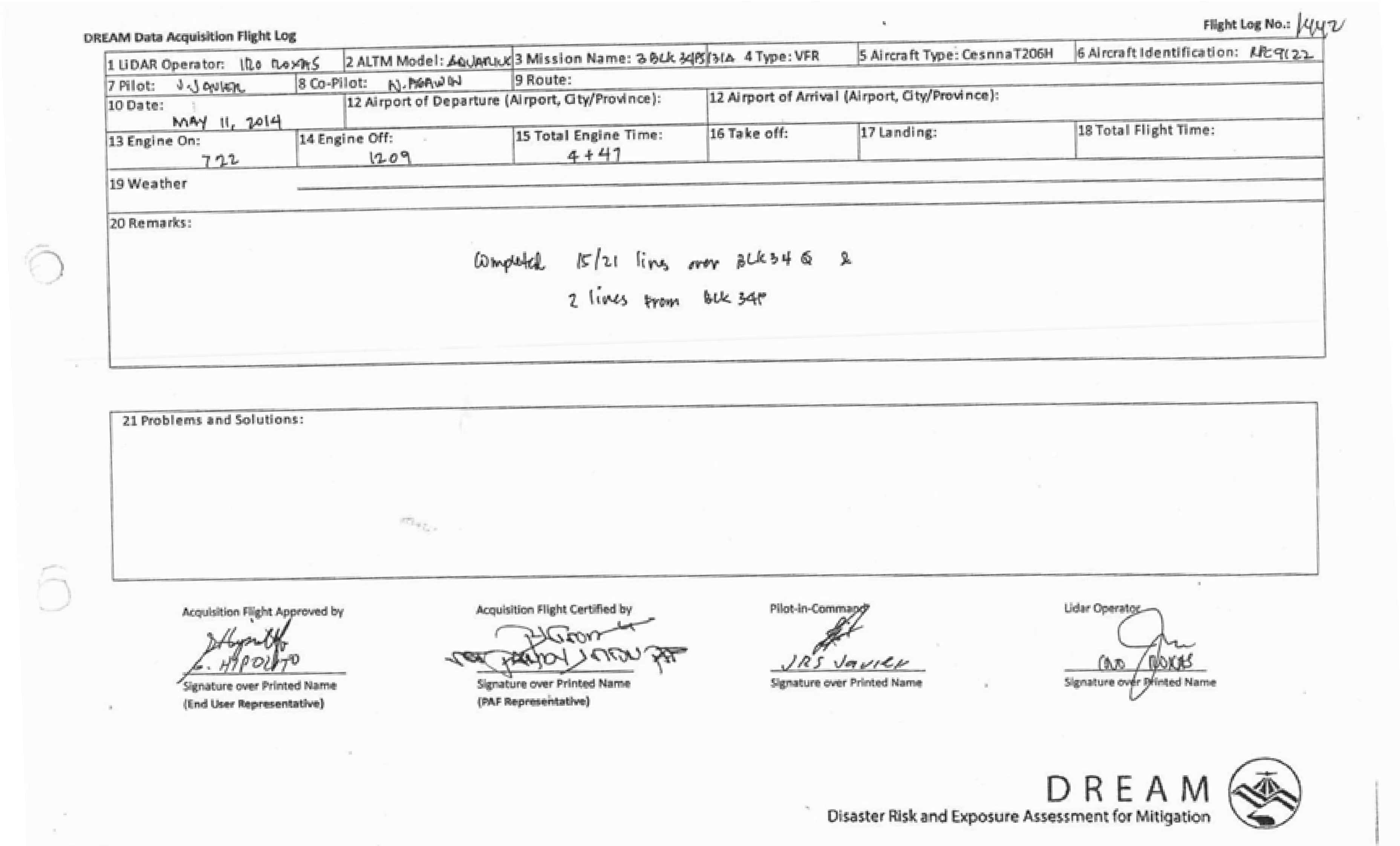
Pilot-in-Command: J.R.S. Javier, Signature over Printed Name

Lidar Operator: I.R.O. Roxas, Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.4. Flight Log for Mission 1440A

5. Flight Log for 1442A Mission


DREAM Data Acquisition Flight Log

Flight Log No.: 1442

1 LiDAR Operator: I. Roxas	2 ALTM Model: Aquarius	3 Mission Name: 3BLK34PS131A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RPC9122
7 Pilot: J. Javier	8 Co-Pilot: N. Pagawan	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
L. 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
I. Roxas
Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.5. Flight Log for Mission 1442A

6. Flight Log for 1444A Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1444

1 LIDAR Operator: N. ARCEO	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: N. 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: 1734	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.

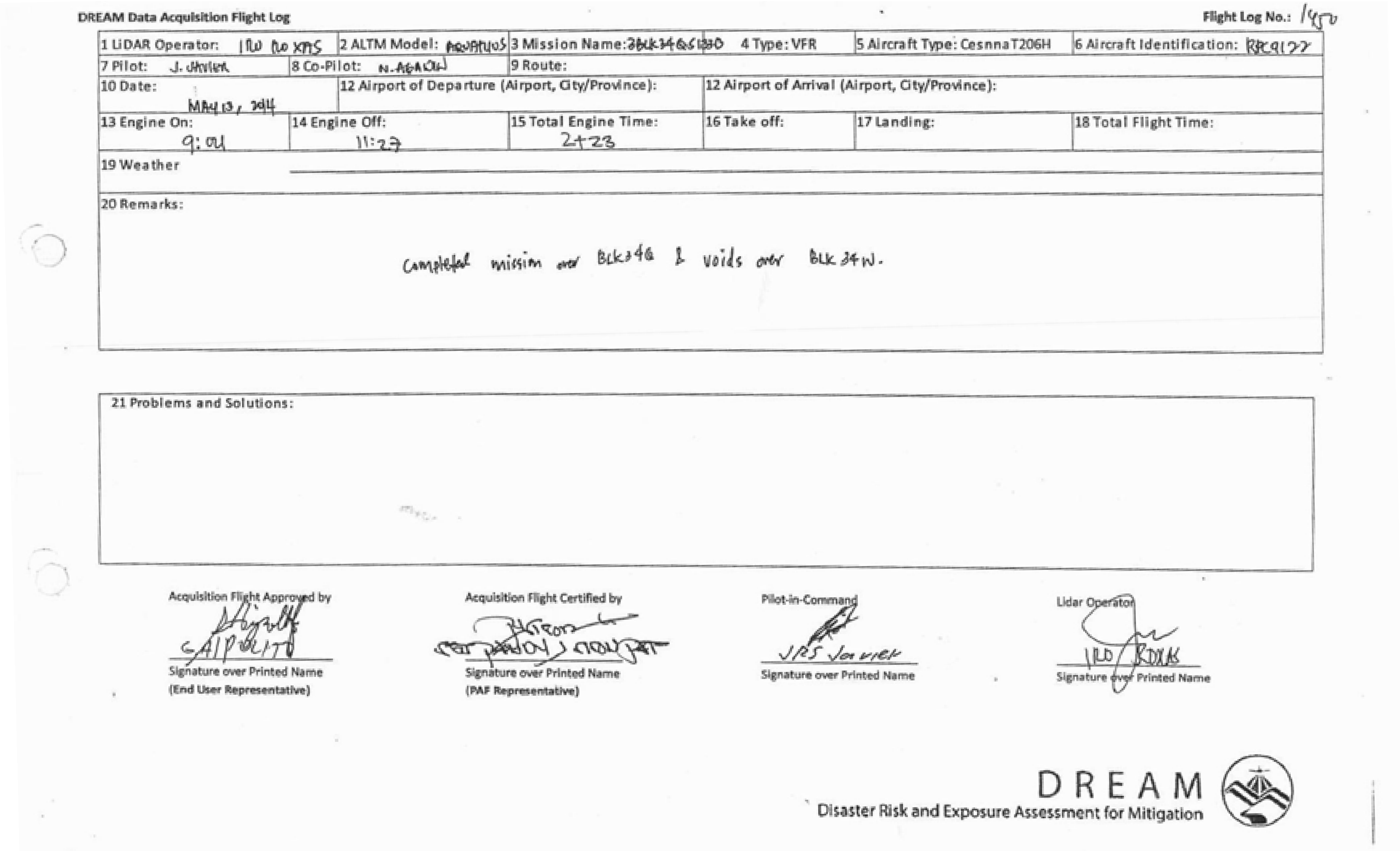
21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
E. HIPOLITO		J.BS JAVIER	N. ARCEO
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 A-6.6. Flight Log for Mission 1444A

7. Flight Log for 1450A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1450

1 LiDAR Operator: ILO RO XAS	2 ALTM Model: AQUARIUS	3 Mission Name: 3BLK34G&S133O	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RPC9122
7 Pilot: J. JAVIER	8 Co-Pilot: N. AGAON	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)

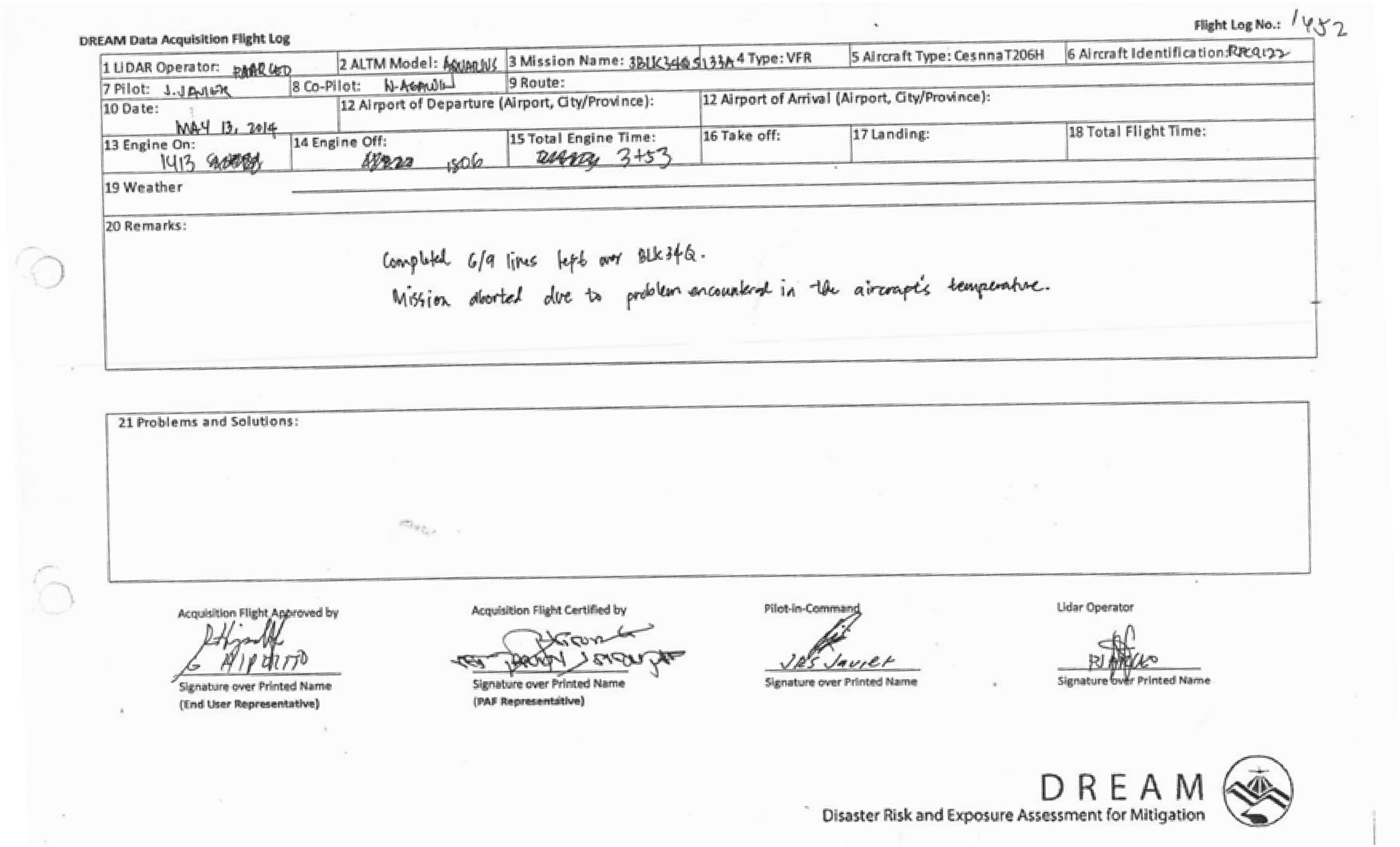
Pilot-in-Command: J.R.S. Javier, Signature over Printed Name

Lidar Operator: ILO R. XAS, Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.7. Flight Log for Mission 1450A

8. Flight Log for 1452A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1452

1 LiDAR Operator: BJAARCED	2 ALTM Model: AQUARIUS	3 Mission Name: 3BLK34Q5133A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	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: 1806	15 Total Engine Time: 3+53	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Completed 6/9 lines left over BLK34Q.
Mission aborted due to problem encountered in the aircraft's temperature.

21 Problems and Solutions:

Acquisition Flight Approved by: G. Alipalito — 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: BJ Alarcio — Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.8. Flight Log for Mission 1452A

9. Flight Log for 3727G Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3727

1 LiDAR Operator: J. Almalvez	2 ALTM Model: Gemini	3 Mission Name: 2BLK34O29B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RPC-9022
7 Pilot: A. Lim	8 Co-Pilot: R. Cagro	9 Route: Tacloban Local			
10 Date: 1-29-16	12 Airport of Departure (Airport, City/Province): Tacloban		12 Airport of Arrival (Airport, City/Province): Tacloban		
13 Engine On: 14:12	14 Engine Off: 18:17	15 Total Engine Time: 4:05	16 Take off: 14:17	17 Landing: 18:12	18 Total Flight Time: 03:55
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.
completed BLK 34I & 34J

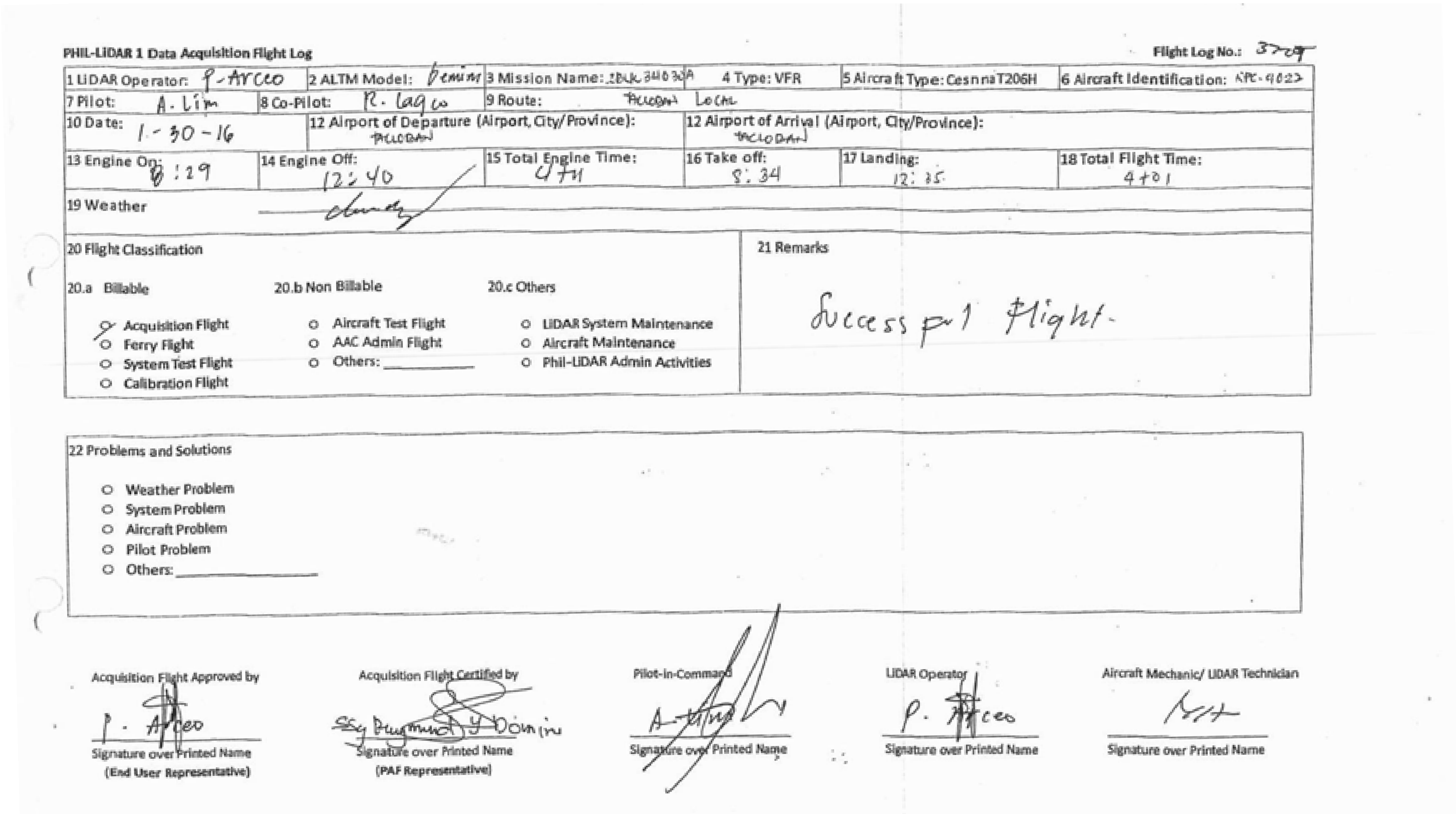
22 Problems and Solutions

- ○ 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
[signature]	[signature]	[signature] A. Lim	[signature] J. Almalvez	[signature]
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.9. Flight Log for Mission 3727G

10. Flight Log for 3729G Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3729

1 LIDAR Operator: P. Arceo	2 ALTM Model: Gemini	3 Mission Name: 2BLK34B030A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RPC-9022
7 Pilot: A. Lim	8 Co-Pilot: R. Lagco	9 Route: Tacloban Local			
10 Date: 1-30-16	12 Airport of Departure (Airport, City/Province): Tacloban		12 Airport of Arrival (Airport, City/Province): Tacloban		
13 Engine On: 8:29	14 Engine Off: 12:40	15 Total Engine Time: 4+11	16 Take off: 8:34	17 Landing: 12:35	18 Total Flight Time: 4+01
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: P. Arceo — Signature over Printed Name (End User Representative)

Acquisition Flight Certified by: SSg Bugmmay Domini — Signature over Printed Name (PAF Representative)

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

LIDAR Operator: P. Arceo — Signature over Printed Name

Aircraft Mechanic/ LIDAR Technician — Signature over Printed Name

Figure A-6.10. Flight Log for Mission 3729G

11. Flight Log for 3753G Mission

PHIL-LIDAR 1 Data Acquisition Flight Log — Flight Log No.: 3753G

1 LiDAR Operator: G. Sinadjan	2 ALTM Model: Gemini	3 Mission Name: 2BLK34K34B036A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	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: 14:15	15 Total Engine Time: 4+17	16 Take off: 10:03	17 Landing: 14:20	18 Total Flight Time: 4+07
19 Weather: low clouds 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	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Technician
P. Tabao	SSg Raymund J Domini	A. Lim	C. Sinadjan	[signature]
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.11. Flight Log for Mission 3753G

12. Flight Log for 3757G Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3757

1 LiDAR Operator: J. Almalvez	2 ALTM Model: Gemini	3 Mission Name: 2BLK03?A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: A - Lim	8 Co-Pilot: K - 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
- o Ferry Flight
- o System Test Flight
- o Calibration Flight

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

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

21 Remarks

Successful Flight

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LIDAR Operator	Aircraft Mechanic/ LIDAR Technician
J - Alceo	SSg Raymund Dominic	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 A-6.12. Flight Log for Mission 3757G

Annex 7. Flight Status Reports

Tacloban Mission
May 3 -13, 2014 and January 29 - February 6, 2016

Table A-7.1. Flight Status Report

FLIGHT NO.	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1410A	BLK33E	AQUATACTF123A	I. ROXAS	May 3, 2014	Completed test flight for Aquarius over survey area BLK33E.
1414A	BLK33E	AQUATACTF124A	P. ARCEO	May 4, 2014	Completed test flight for Aquarius over survey area BLK33E.
1438A	BLK33f	3BLK34O130A	P. ARCEO	May 10, 2014	Completed 18 lines over BLK34F.
1440A	BLK33F BLK33G	3BLK34OSP130B	I. ROXAS	May 10, 2014	Completed 15 lines over BLK33G.
1442A	BLK33G	3BLK34PS131A	I. ROXAS	May 11, 2014	Completed 15/21 lines over BLK33G.
1444A	BLK33G BLK33H	3BLK34PSQ131B	P. ARCEO	May 11, 2014	Completed 16 lines over BLK33H and 2 lines over BLK33G.
1450A	BLK33H	3BLK34QS133A	P. 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	3BLK34QS133Bf	I. ROXAS	May 13, 2014	Completed mission over BLK34H and some voids over BLK33E.
3727G	BLK34I BLK34J	2BLK34IJ029B	J. ALMALVEZ	January 29, 2016	Completed BLK34I and surveyed 15 lines at BLK34J.
3729G	BLK34H BLK34J	2BLK34HJ030A	P. ARCEO	January 30, 2016	Completed BLK34H and BLK34J.
3753G	BLK34K BLK33A BLK33B	2BLK34K33AB036A	G. SINADJAN	February 5, 2016	Surveyed BLK34K and completed BLK33A & 33B
3757G	BLK34K	2BLK34K037A	J. ALMALVEZ	February 6, 2016	Completed BLK34K

SWATH PER FLIGHT MISSION

Flight No. :	1410A		
Area:	BLK33E		
Mission Name:	3BLK33E123A		
Total Area:	124.21 sq. km.		
Altitude:	600m		
PRF:	50 kHz	SCF:	50 Hz
Lidar FOV:	18 deg	Sidelap:	30%

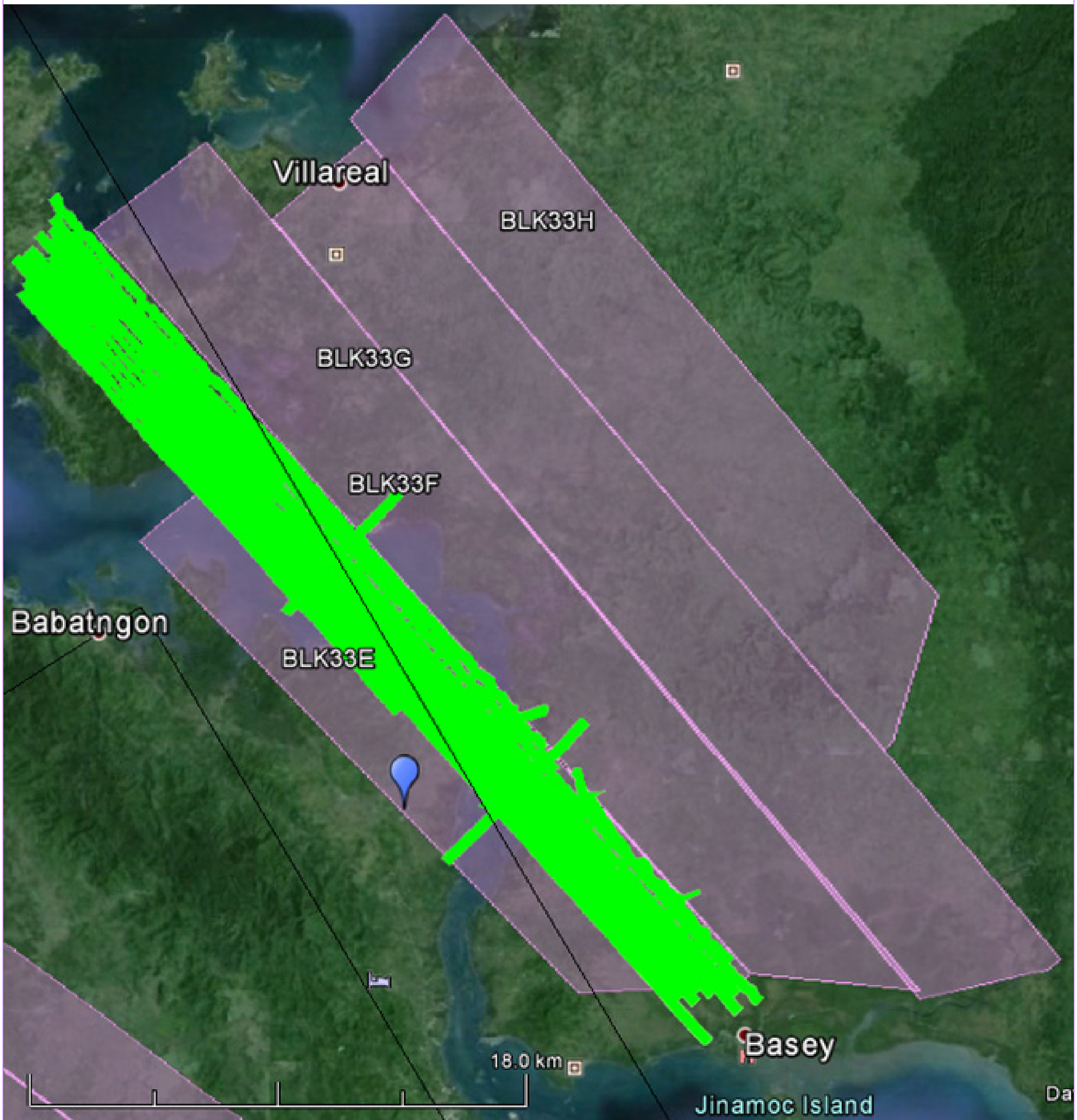


Figure A-7.1. Swath for Flight No. 1410A

Flight No. :	1414A		
Area:	BLK33E		
Mission Name:	3BLK33E124A		
Total Area:	67.279 sq. km.		
Altitude:	600m		
PRF:	50 kHz	SCF:	50 Hz
Lidar FOV:	18 deg	Sidelap:	30%

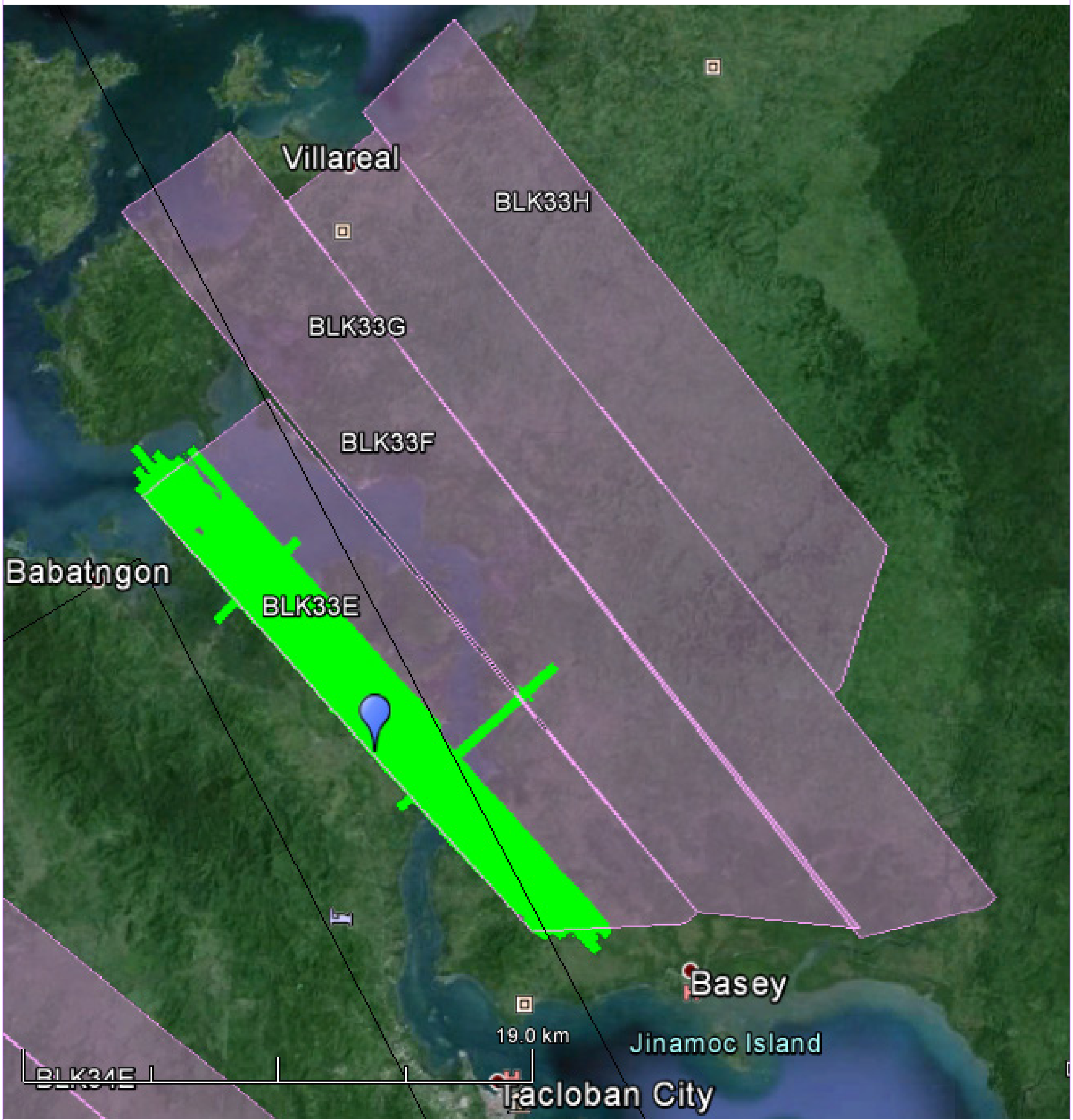


Figure A-7.2. Swath for Flight No. 1414A

Flight No. :	1438A		
Area:	BLK33F		
Total Area:	160.52 sq km		
Mission Name:	3BLK33F130A		
Altitude:	600m		
PRF:	50 kHz	SCF:	50 Hz
Lidar FOV:	18 deg	Sidelap:	30%

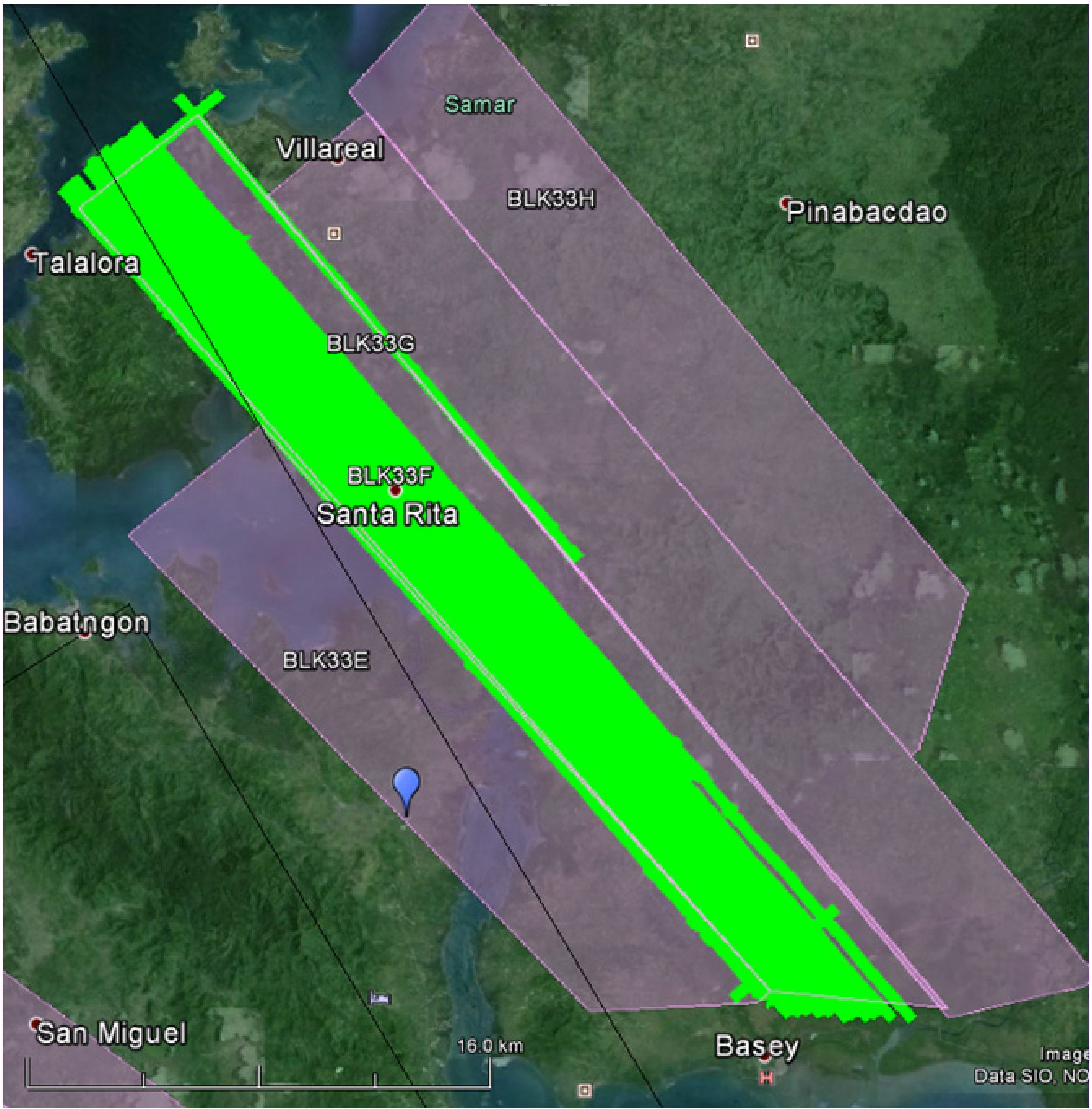


Figure A-7.3. Swath for Flight No. 1438A

Flight No. :	1440A		
Area:	BLK33F & BLK33G		
Total Area:	107.08 sq km		
Mission Name:	3BLK33FSG130B		
Altitude:	600m		
PRF:	50 kHz	SCF:	50 Hz
Lidar FOV:	18 deg	Sidelap:	30%

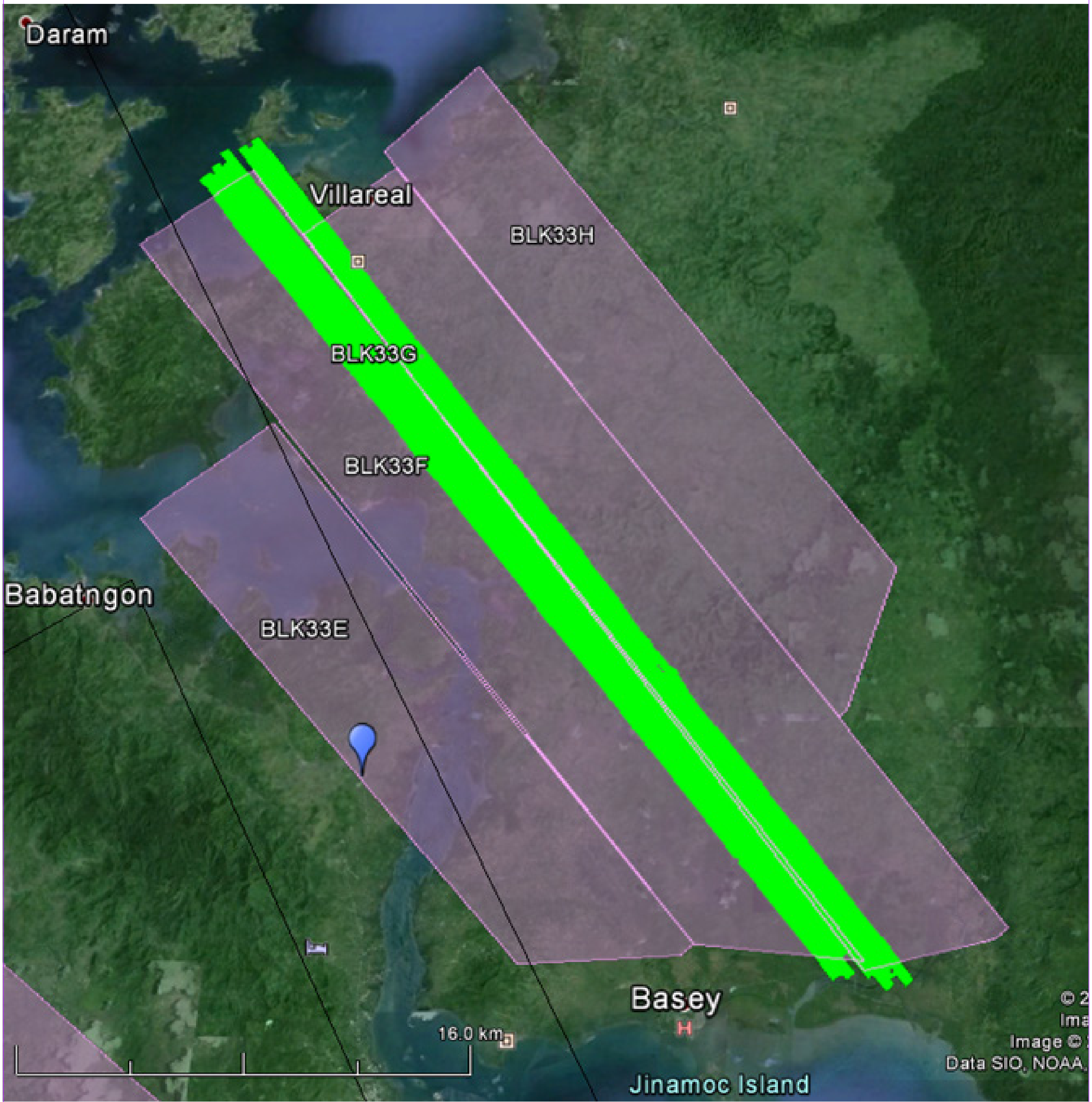


Figure A-7.4. Swath for Flight No. 1440A

Flight No. :	1442A		
Area:	BLK33G		
Total Area:	154.2 sq km		
Mission Name:	3BLK33GS131A		
Altitude:	600m		
PRF:	50 kHz	SCF:	50 Hz
Lidar FOV:	18 deg	Sidelap:	30%

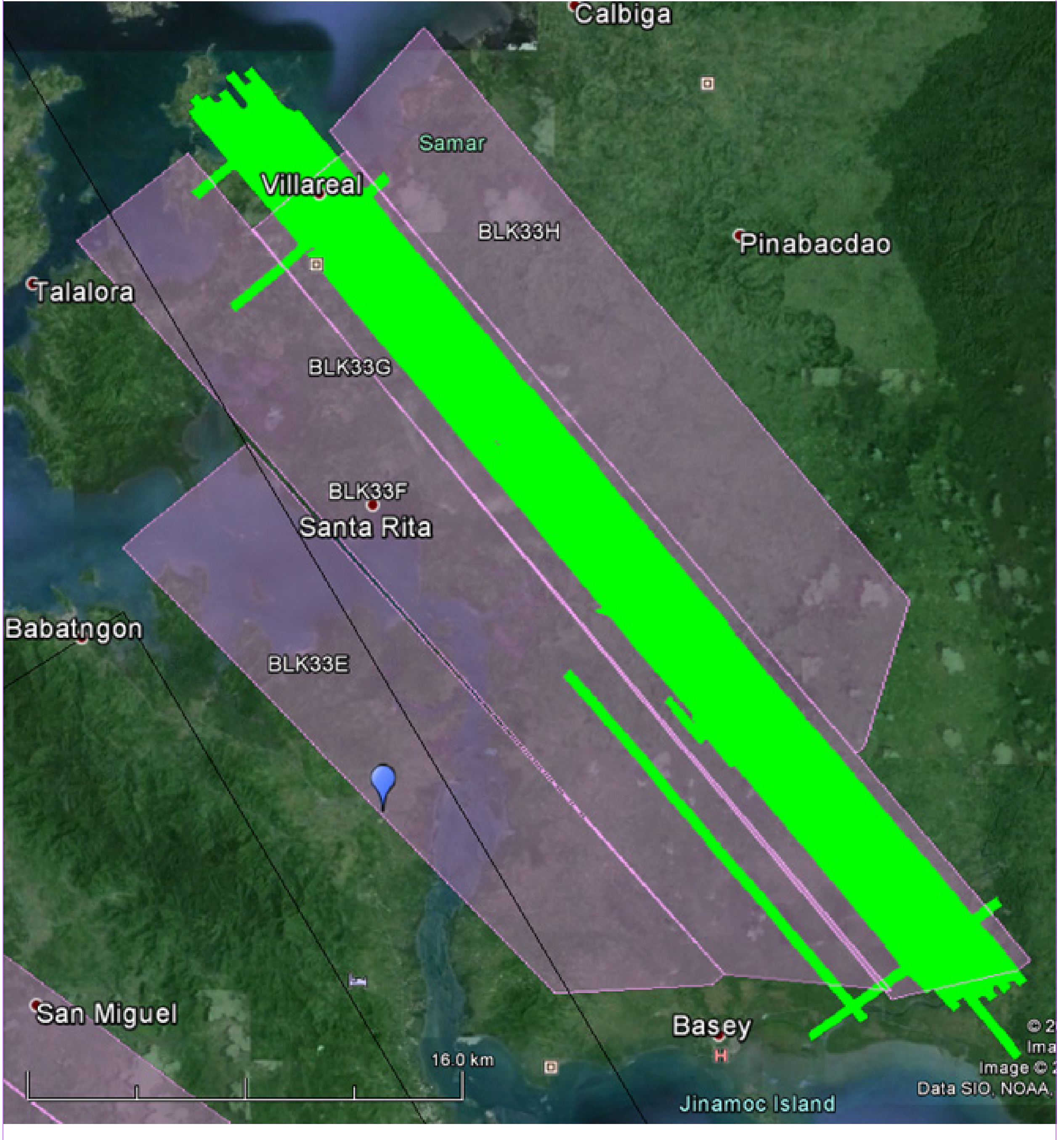


Figure A-7.5. Swath for Flight No. 1442A

Flight No. :	1450A		
Area:	BLK33H		
Total Area:	52.534 sq km		
Mission Name:	3BLK33HS133A		
Altitude:	600m		
PRF:	50 kHz	SCF:	50 Hz
Lidar FOV:	18 deg	Sidelap:	30%

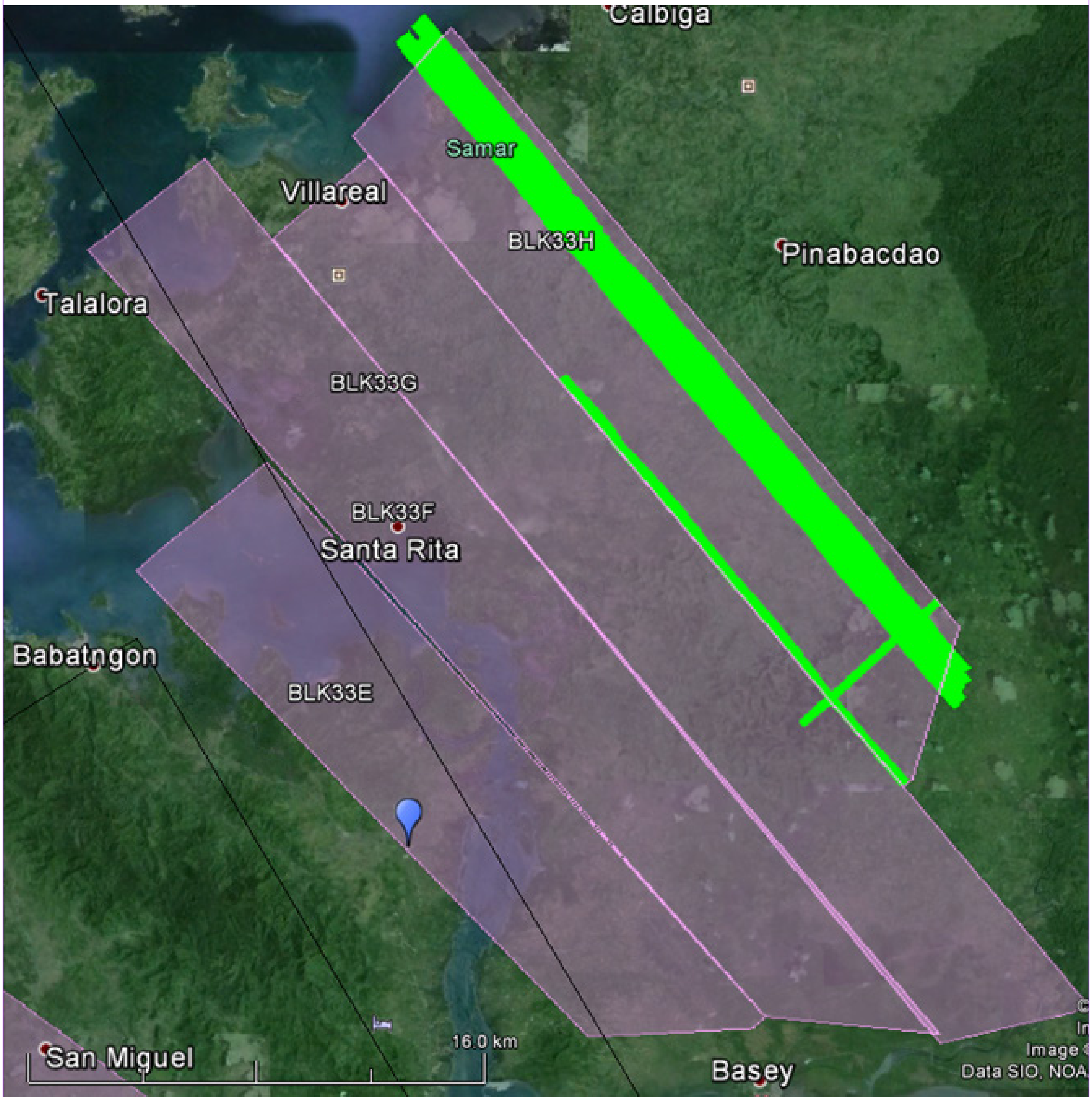


Figure A-7.6. Swath for Flight No. 1450A

Flight No. :	1452A		
Area:	BLK33H, BLK33E		
Total Area:	75.806 sq. km.		
Mission Name:	3BLK33HSES133B		
Altitude:	600m		
PRF:	50 kHz	SCF:	50 Hz
Lidar FOV:	18 deg	Sidelap:	30%

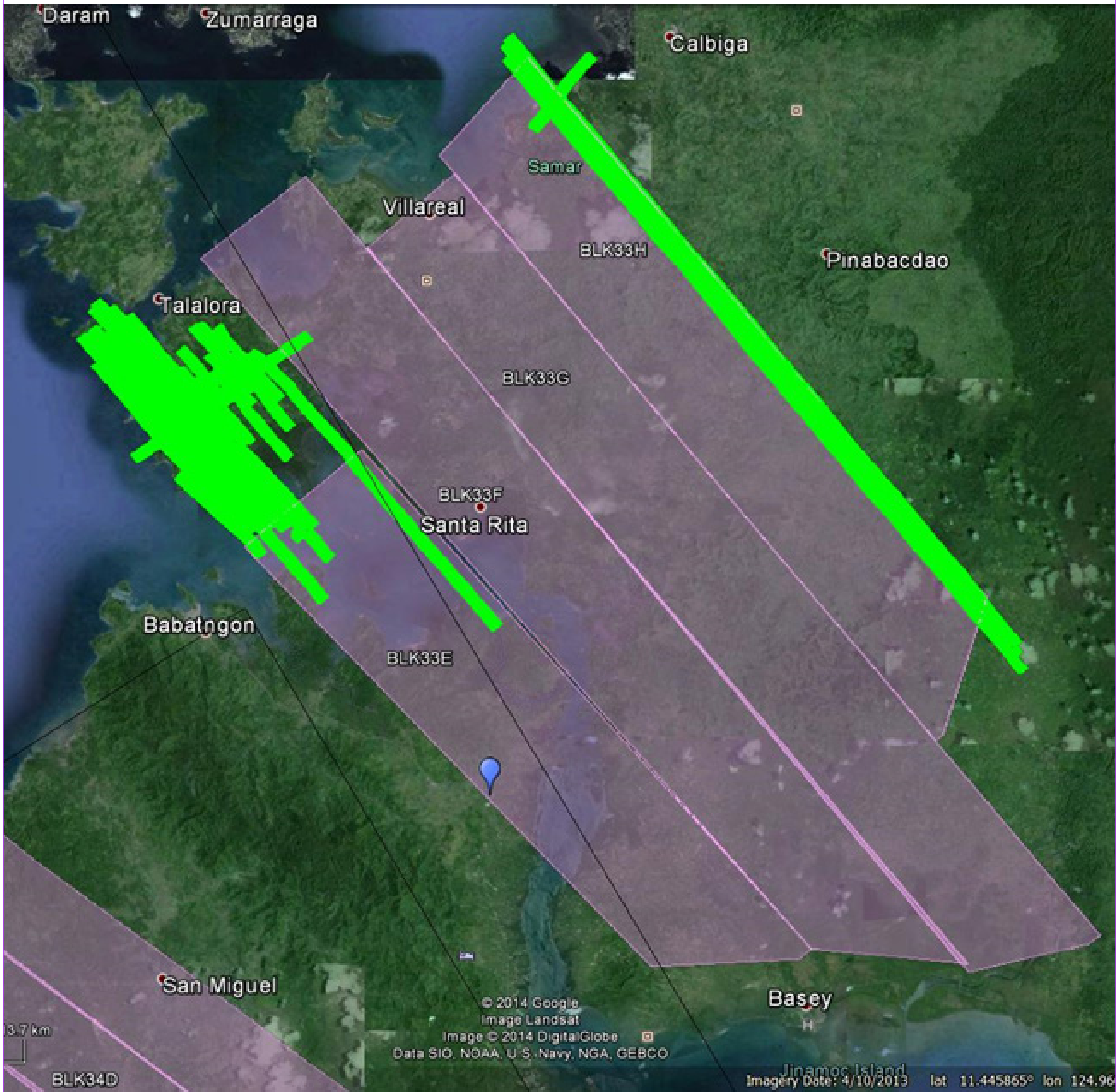


Figure A-7.7. Swath for Flight No. 1452A

FLIGHT NO.:	3727G		
AREA:	Samar		
MISSION NAME:	2BLK34IJ029B		
ALT:	800m	SCAN FREQ:	40Hz
SCAN ANGLE:	25 deg	SURVEYED AREA:	144.55 sq.km.

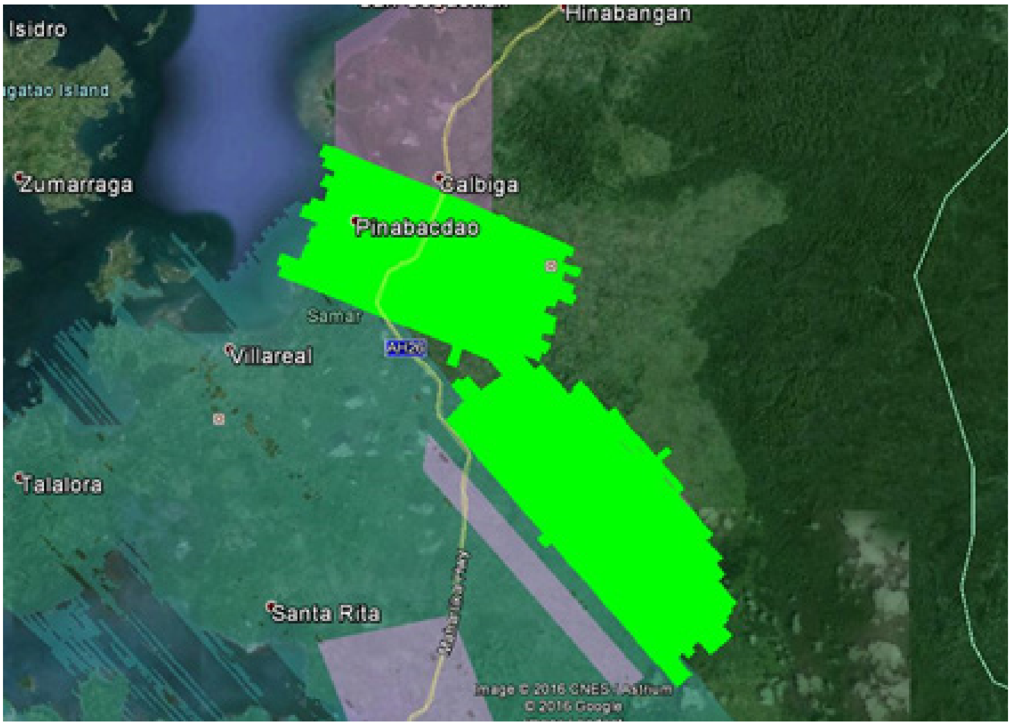


Figure A-7.8. Swath for Flight No. 3727G

FLIGHT NO.:	3729G		
AREA:	Samar		
MISSION NAME:	2BLK34HJ030A		
ALT:	650m	SCAN FREQ:	50Hz
SCAN ANGLE:	20deg	SURVEYED AREA:	105.73 km2

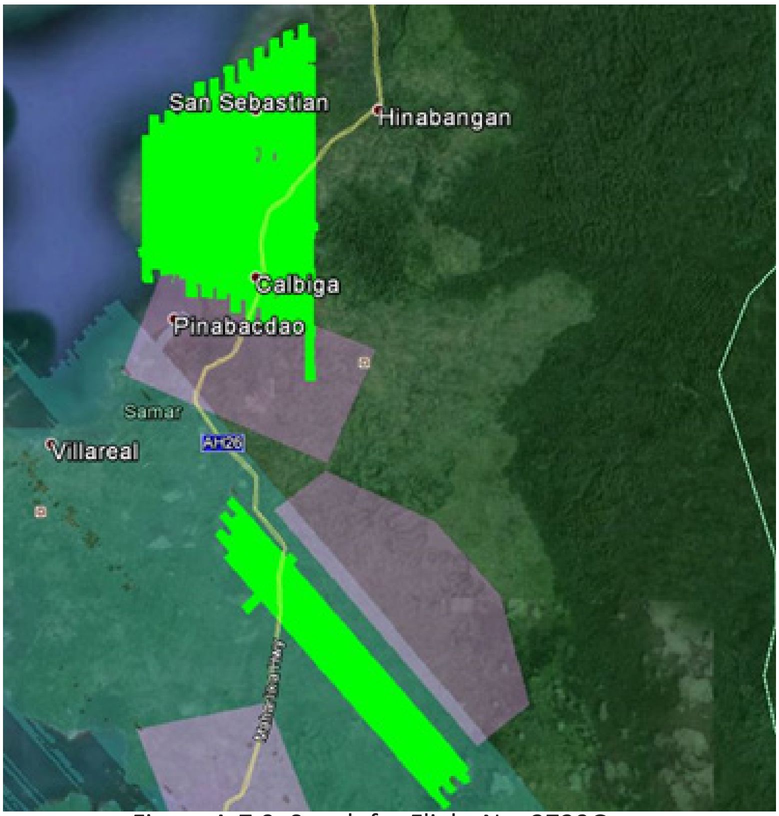


Figure A-7.9. Swath for Flight No. 3729G

FLIGHT NO.:	3753G		
AREA:	Samar		
MISSION NAME:	2BLK34K33AB036A		
ALT:	850 m	SCAN FREQ:	50 Hz
SCAN ANGLE:	20 deg	SURVEYED AREA:	79.46 km2

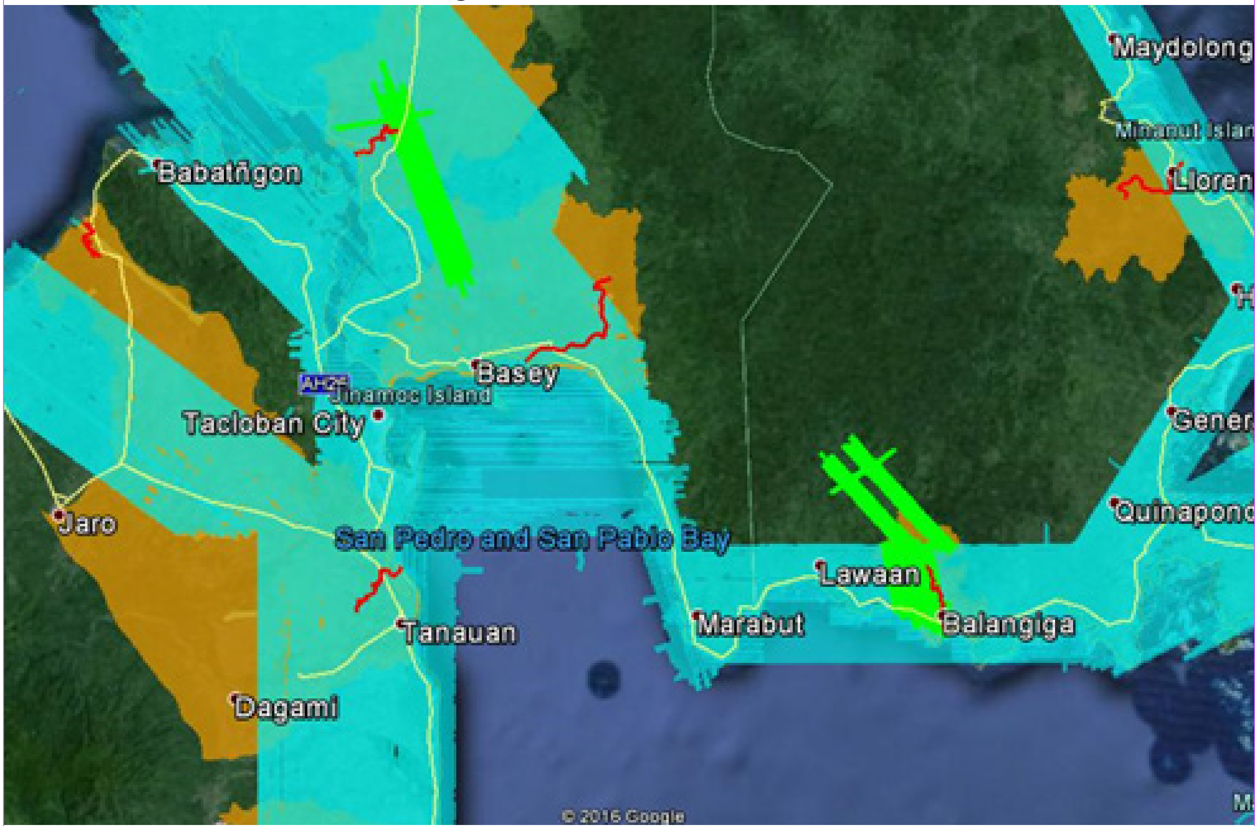


Figure A-7.10. Swath for Flight No. 3753G

FLIGHT NO.:	3757G		
AREA:	Samar		
MISSION NAME:	2BLK34K037A		
ALT: 850 m	SCAN	FREQ:	50 Hz
SCAN ANGLE:	20	SURVEYED AREA:	75.3 km2

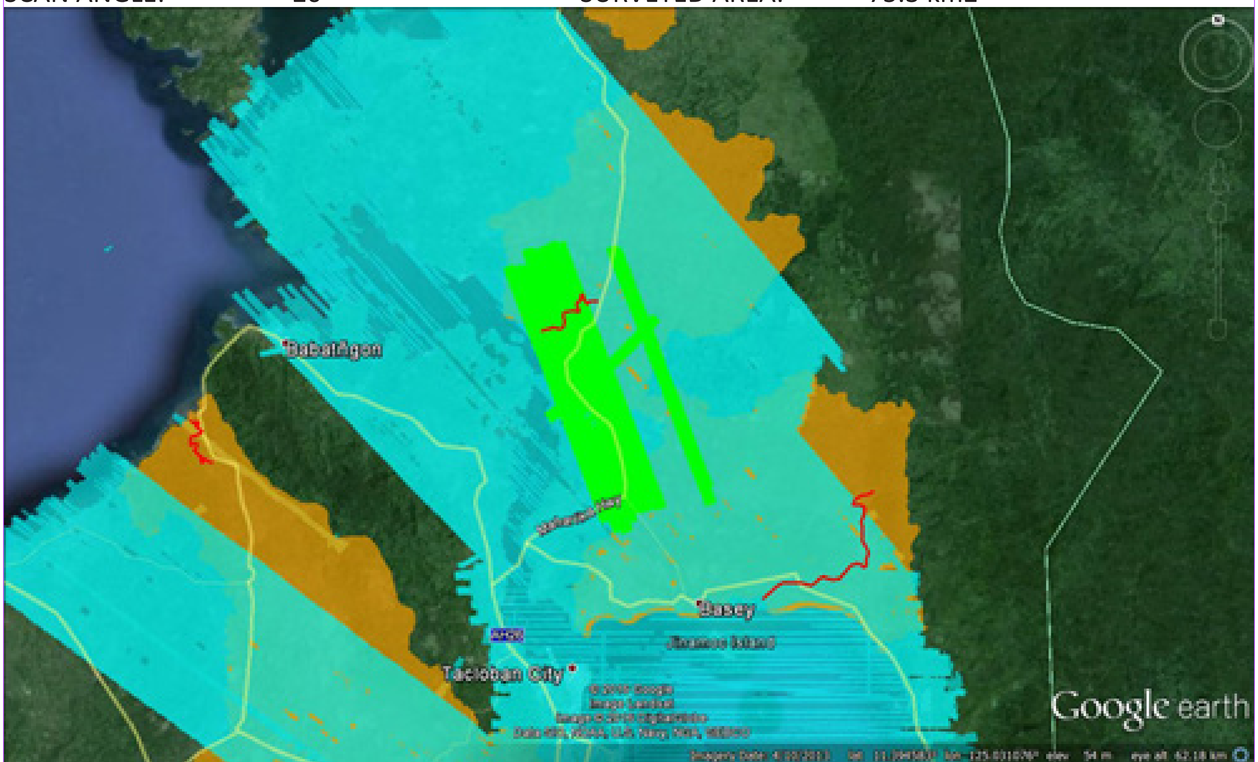


Figure A-7.11. Swath for Flight No. 3757G

Annex 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission 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	Aljon Araneta

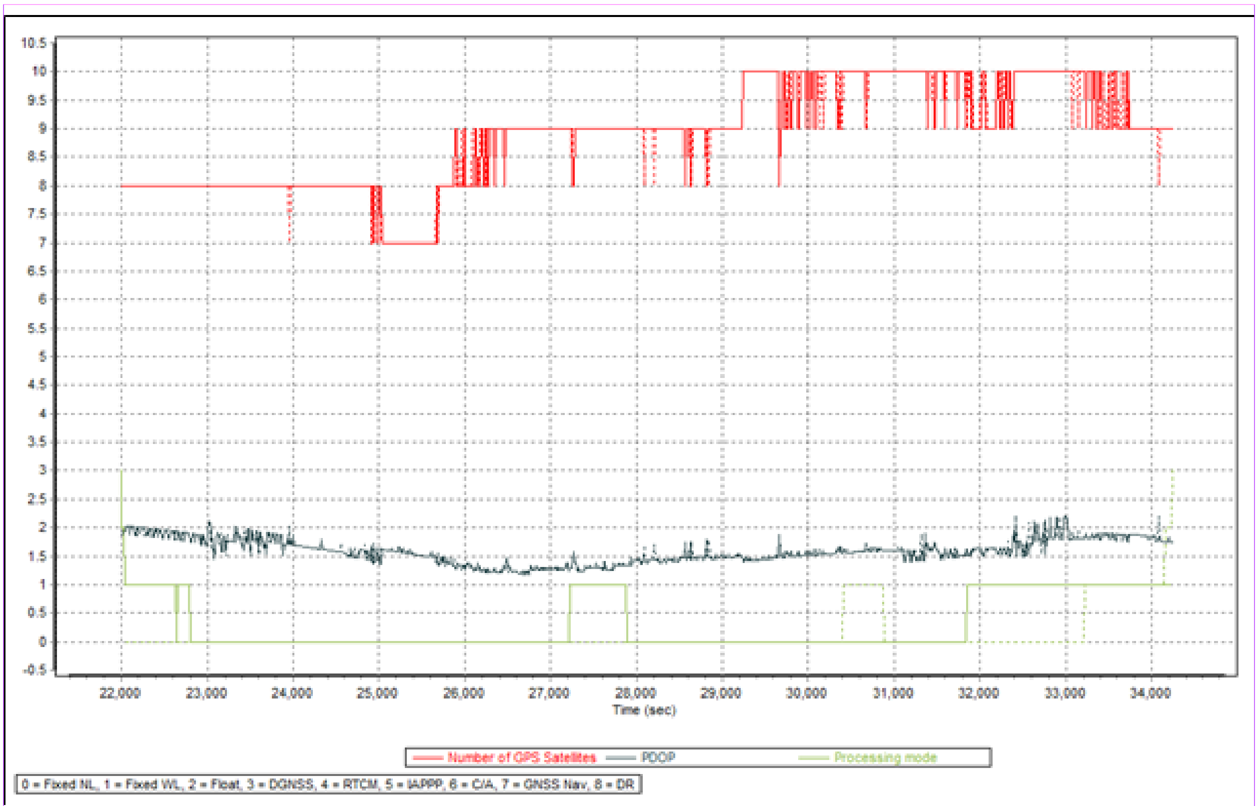


Figure A-8.1. Solution Status

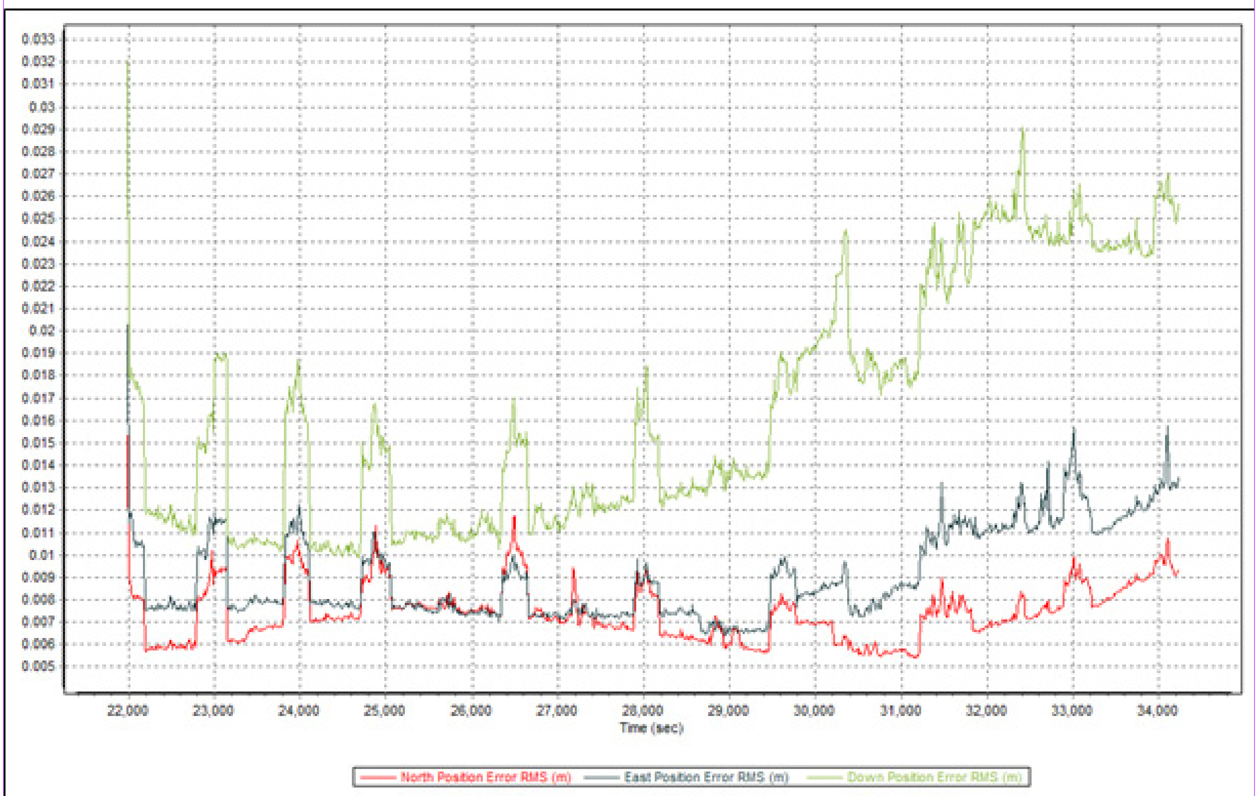


Figure A-8.2. Smoothed Performance Metrics Parameters

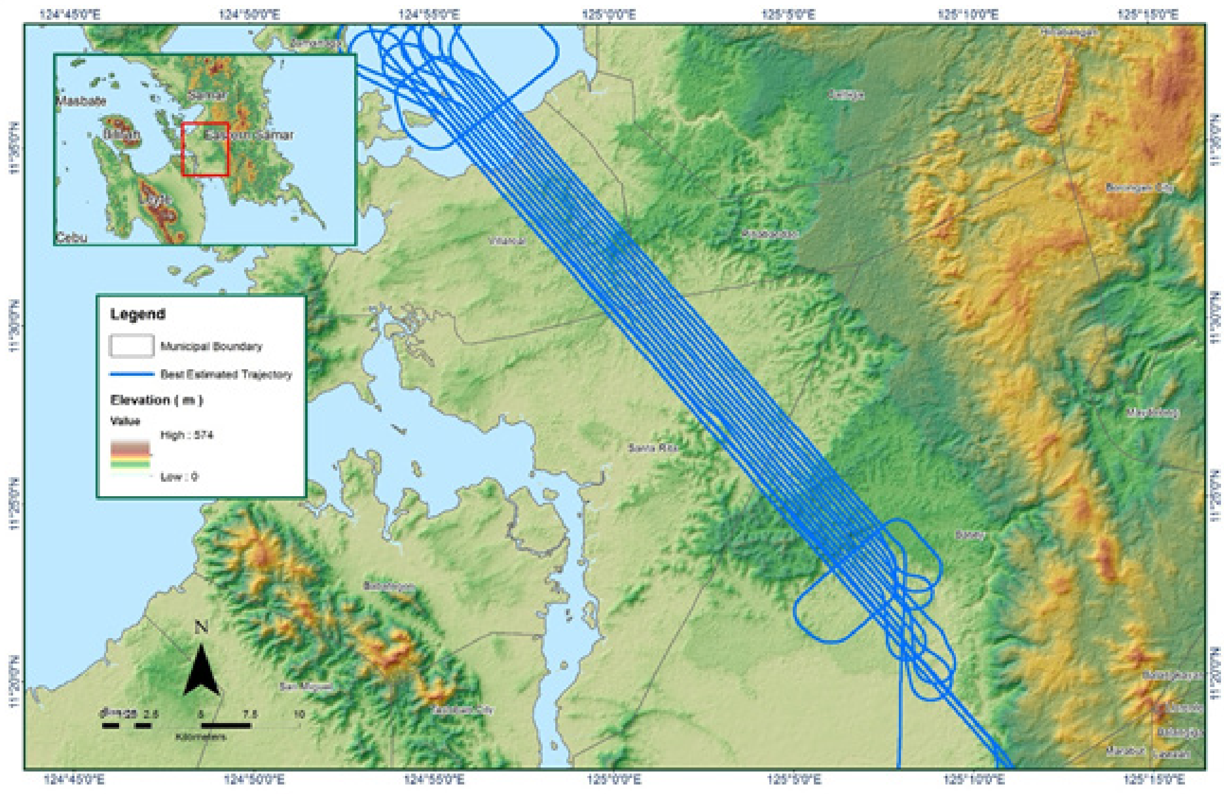


Figure A-8.3. Best Estimated Trajectory

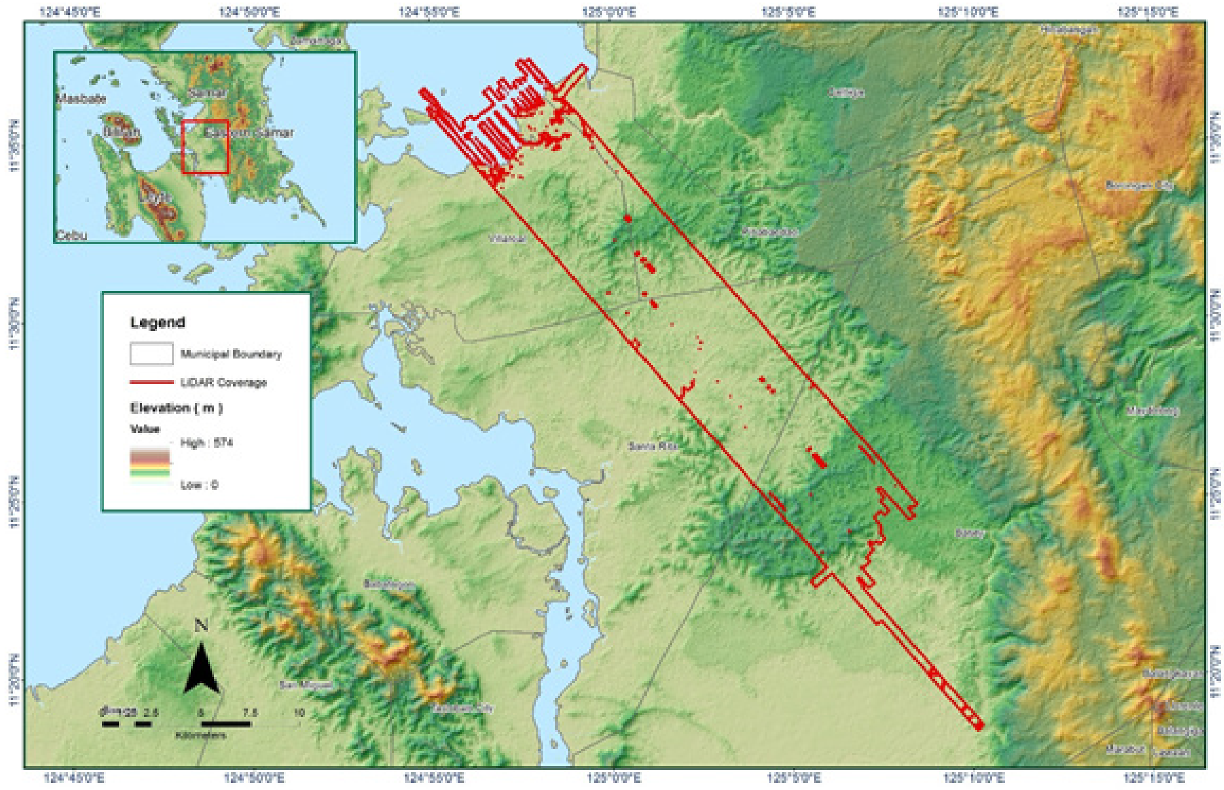


Figure A-8.4. Coverage of LiDAR data

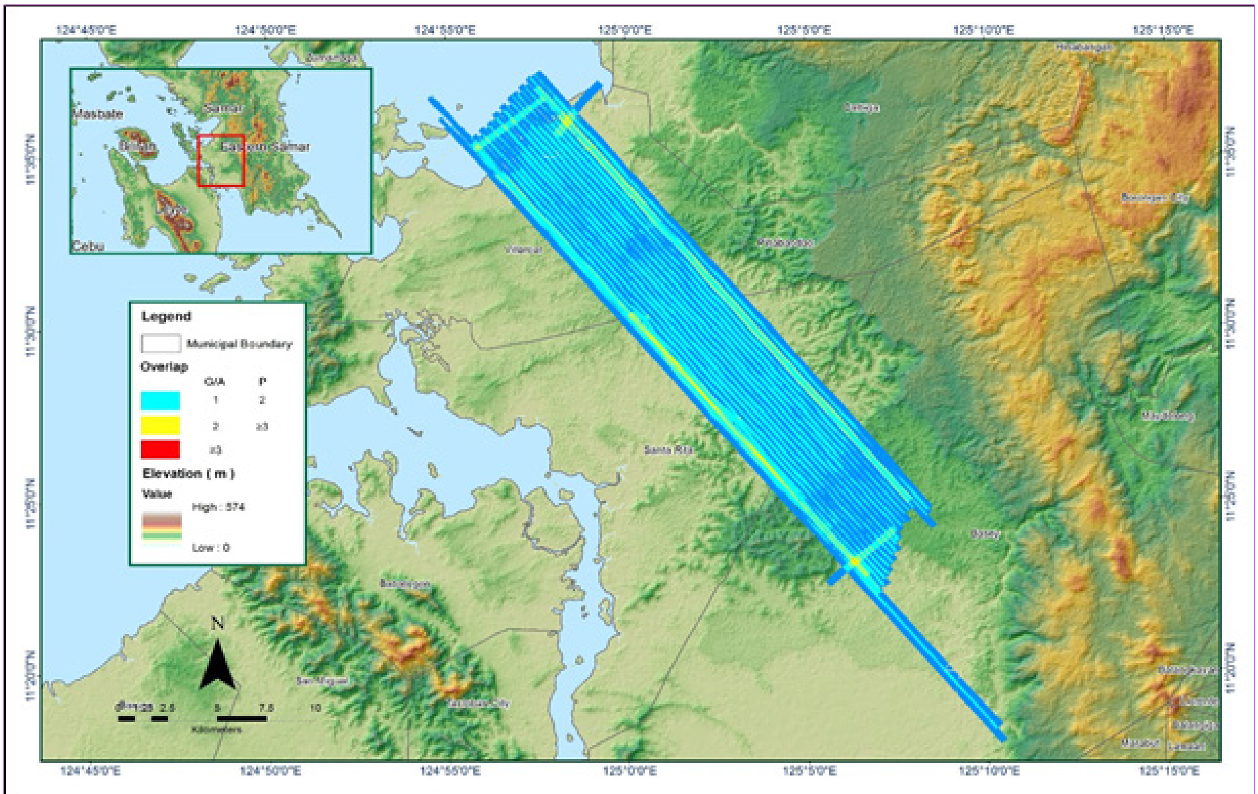


Figure A-8.5. Image of Data Overlap

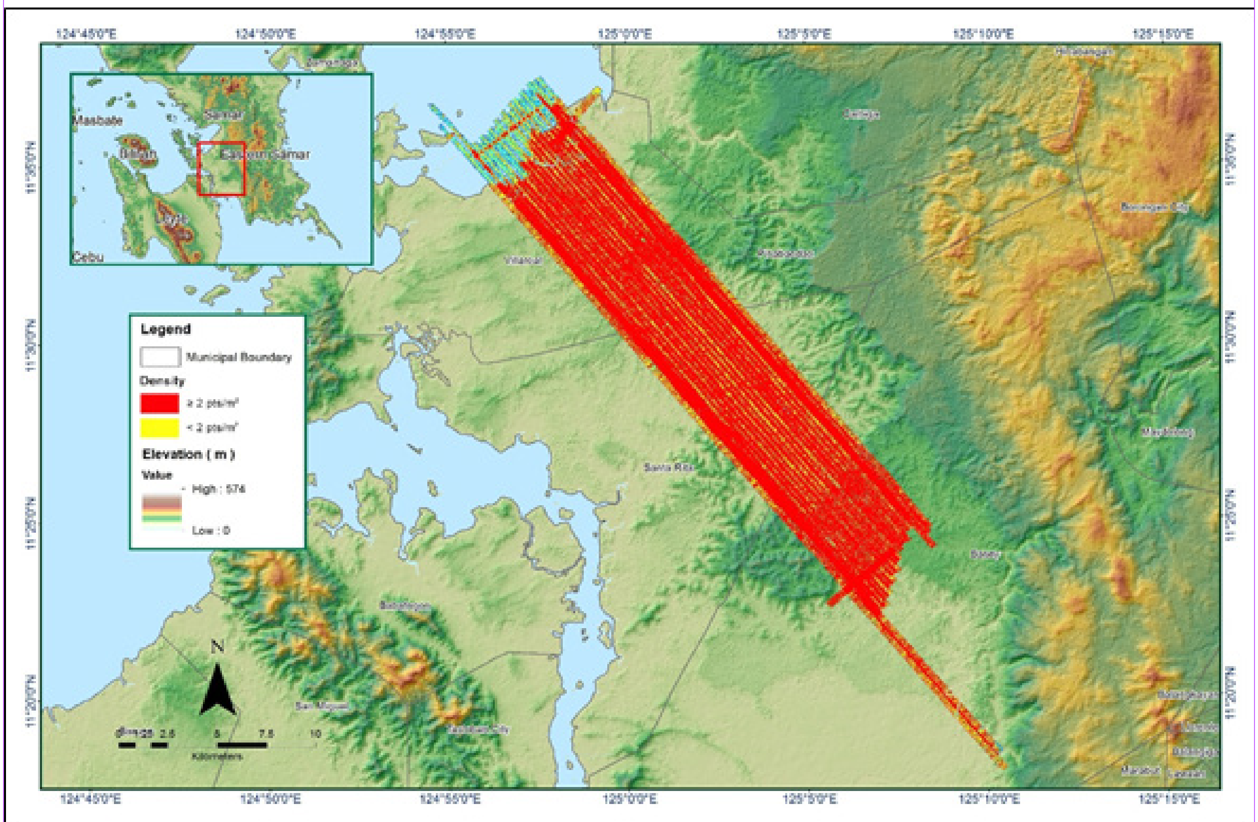


Figure A-8.6. Density map of merged LiDAR data

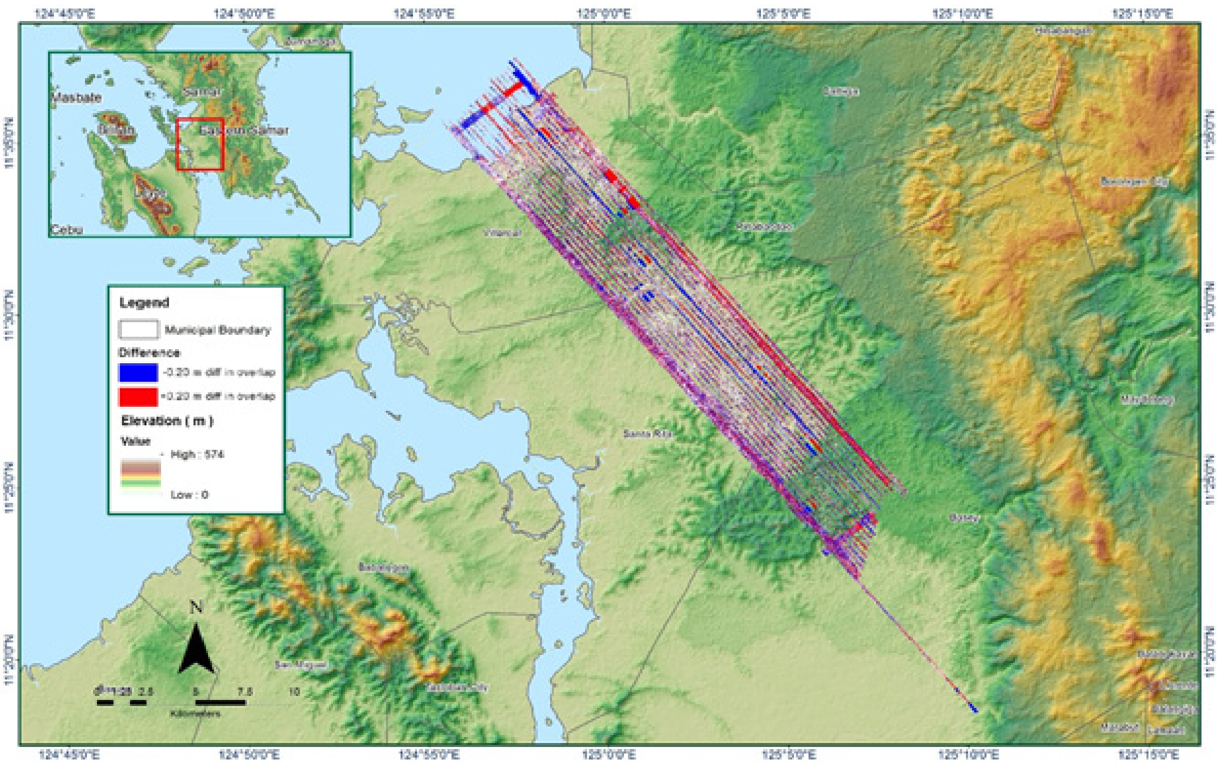


Figure A-8.7. Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission 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	Antonio Chua Jr., Ailyn Biñas

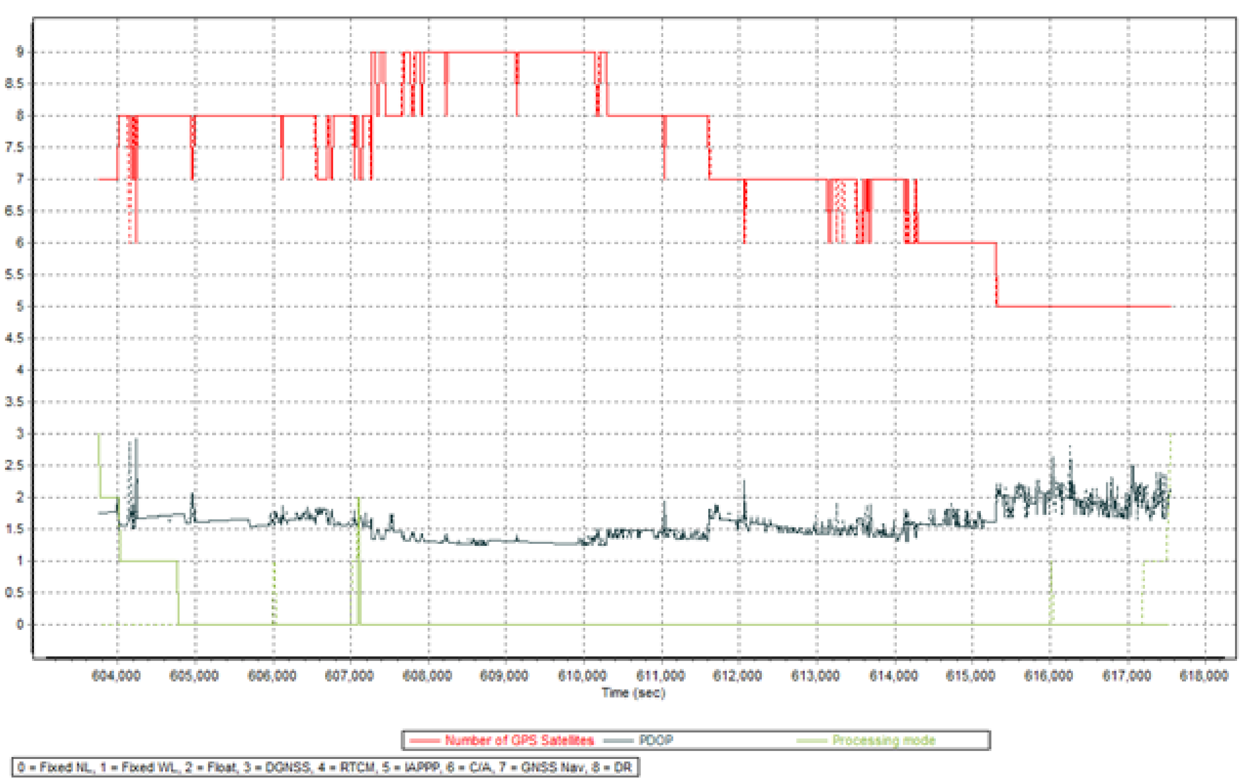


Figure A-8.8. Solution Status Parameters

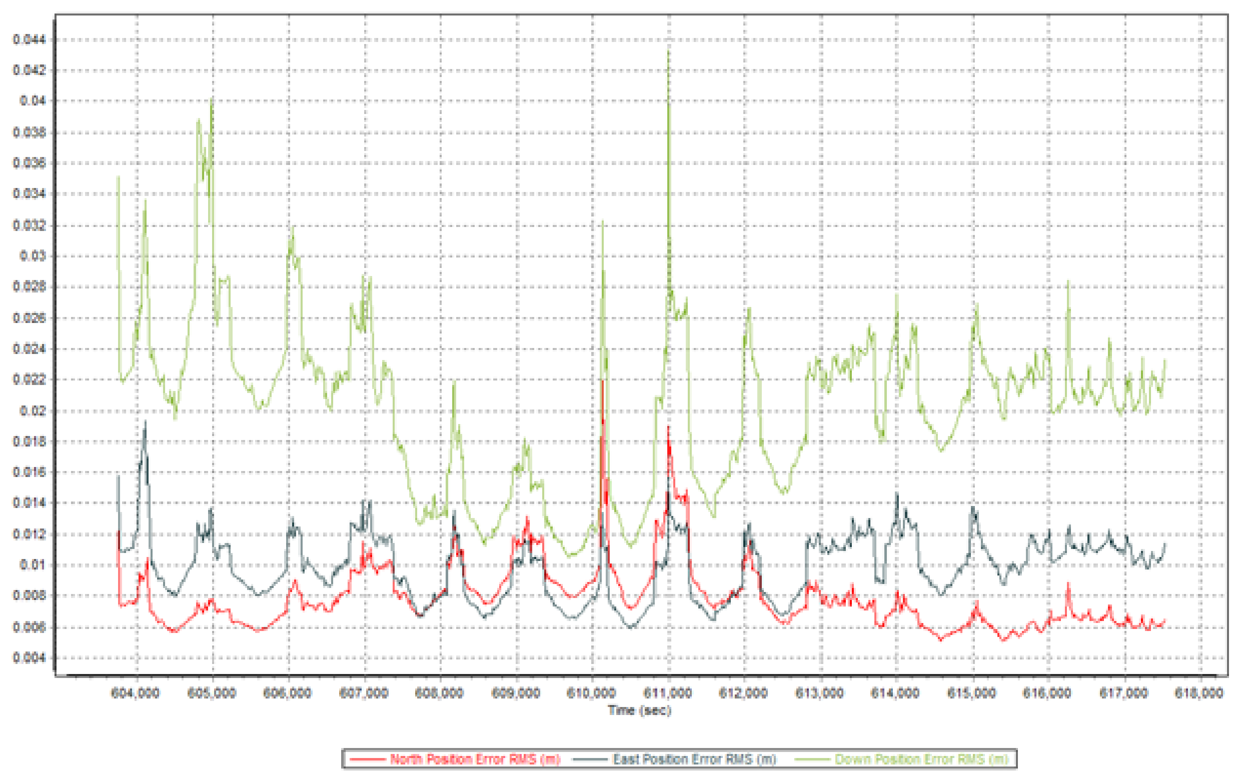


Figure A-8.9. Smoothed Performance Metrics Parameters

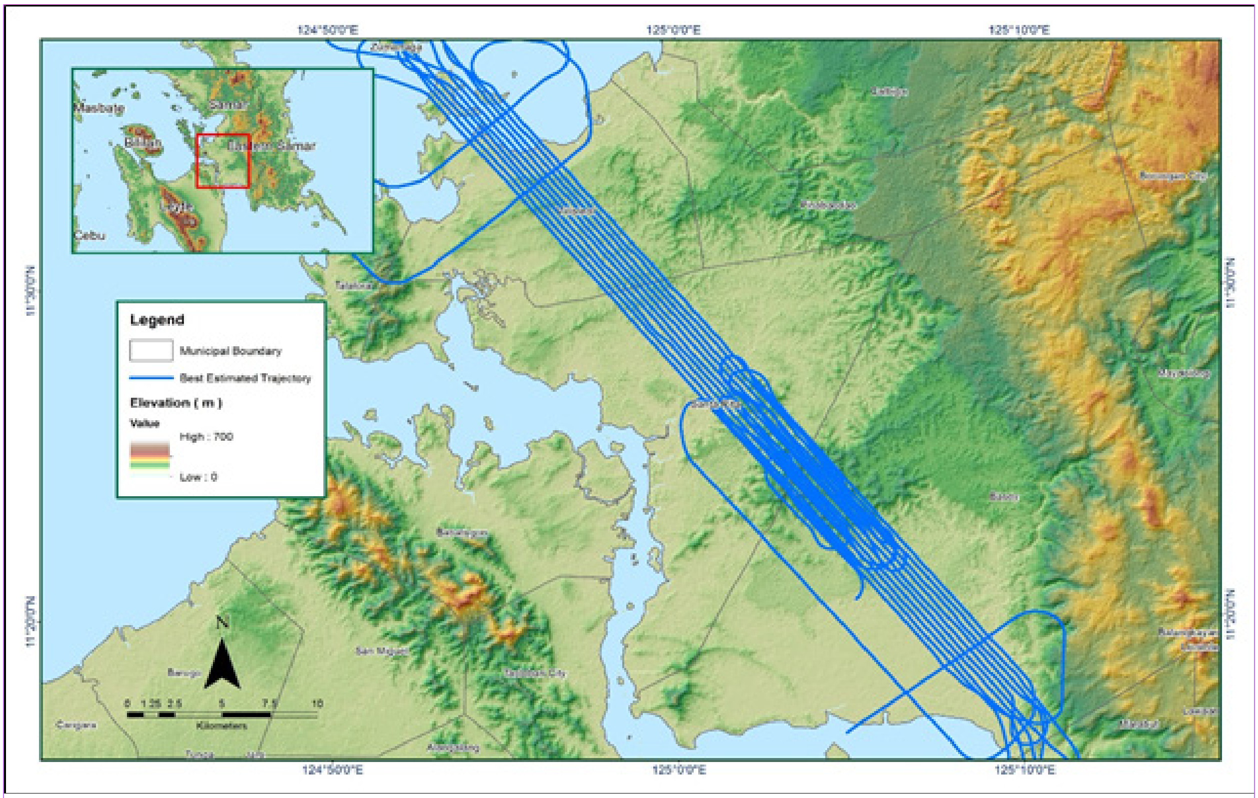


Figure A-8.10. Best Estimated Trajectory

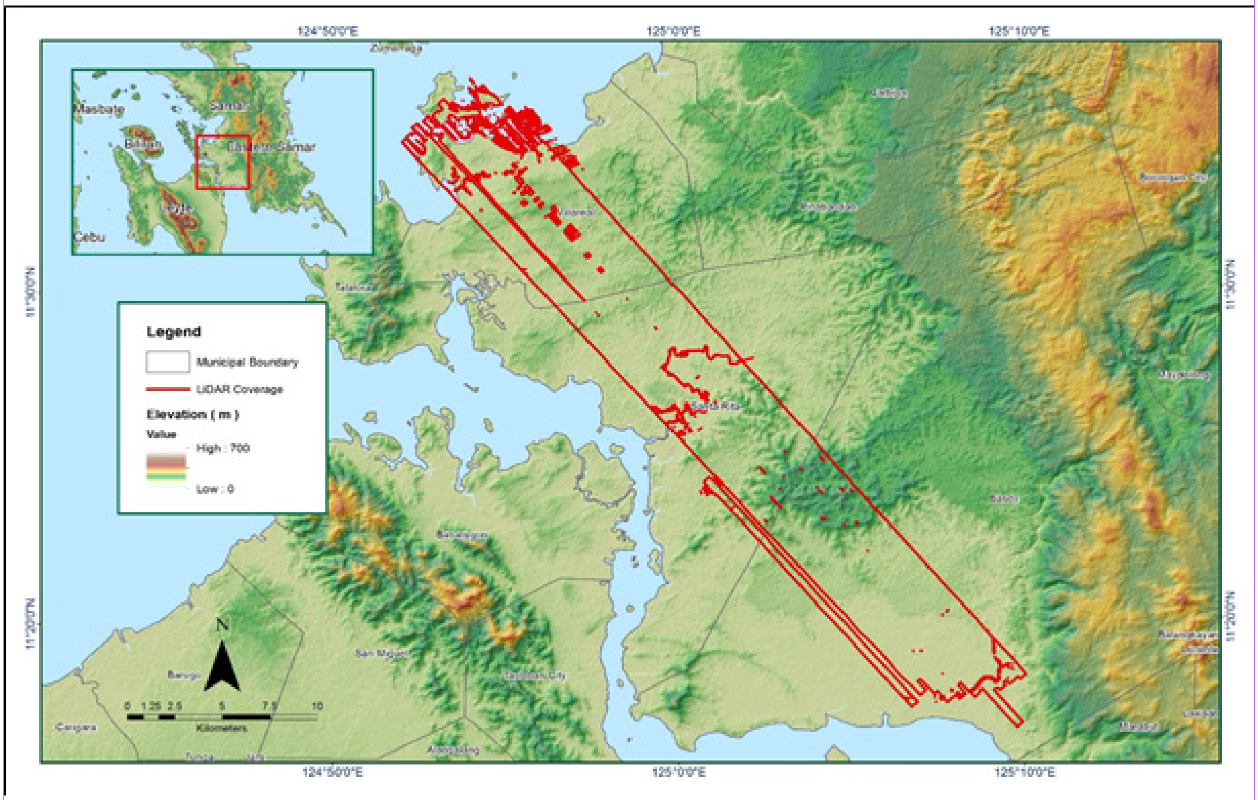


Figure A-8.11. Coverage of LiDAR data

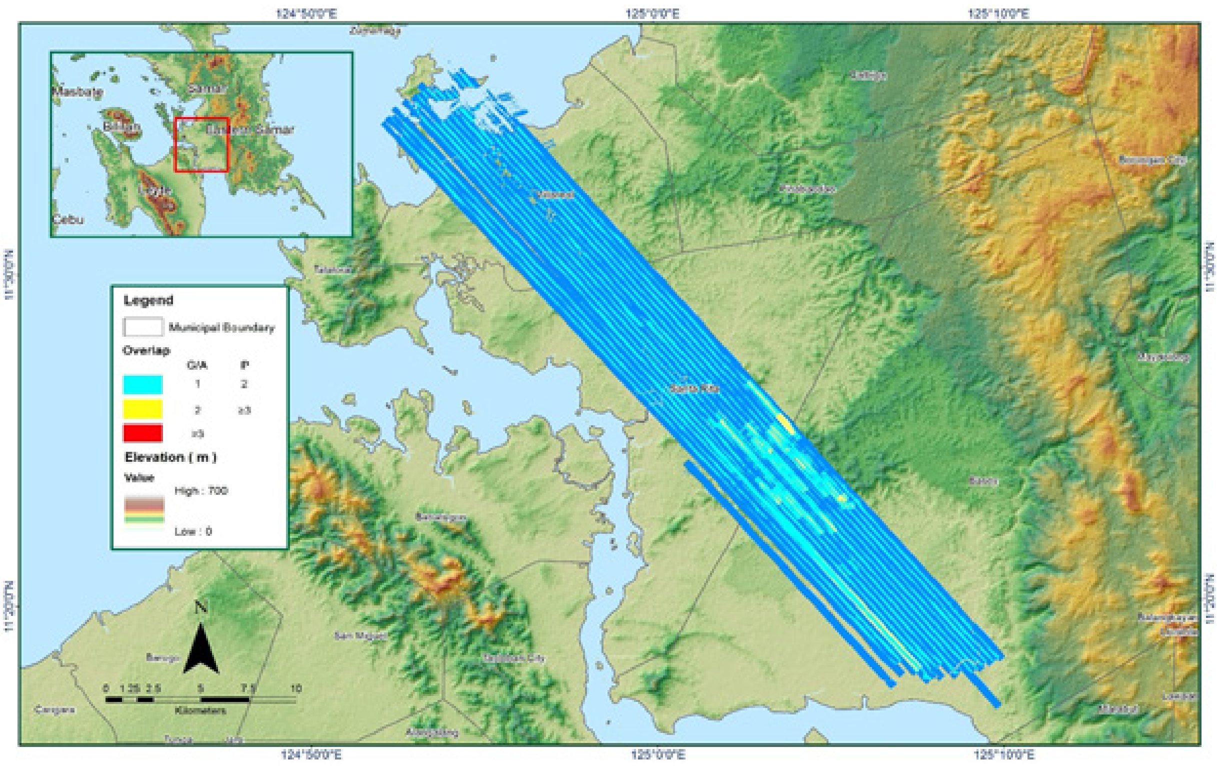


Figure A-8.12. Image of Data Overlap

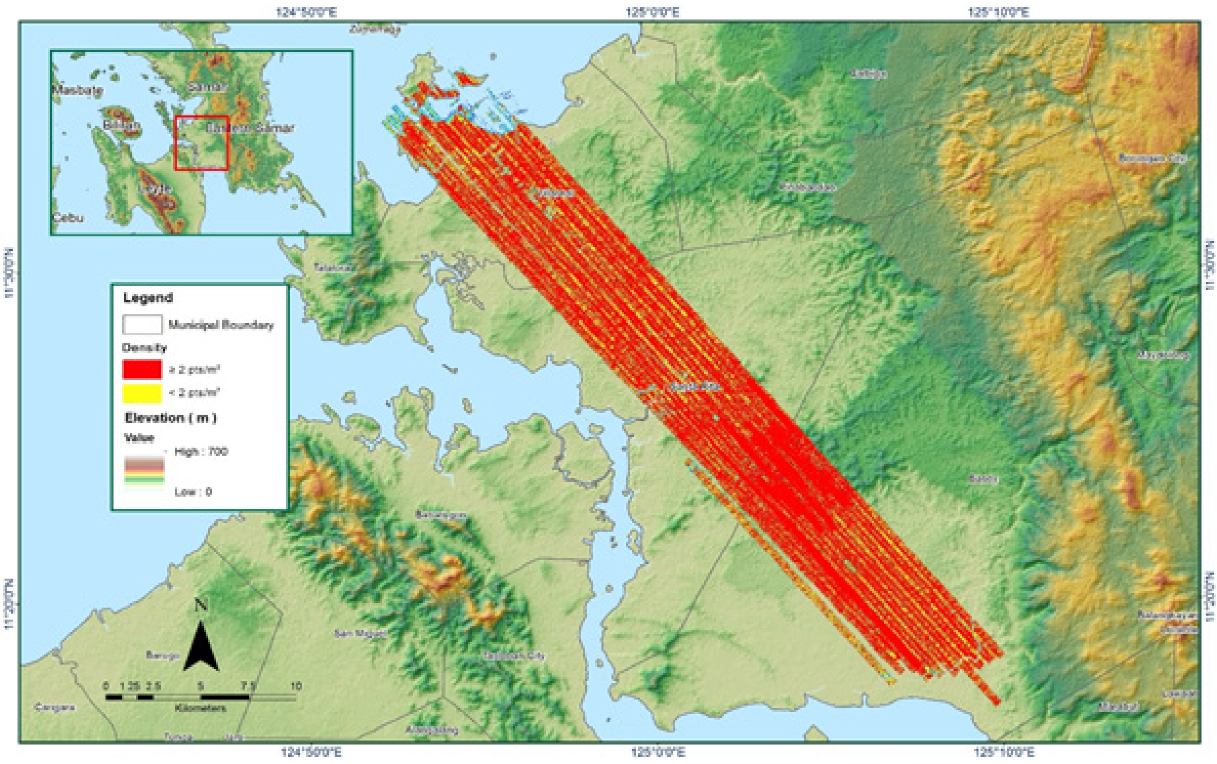


Figure A-8.13. Density map of merged LiDAR data

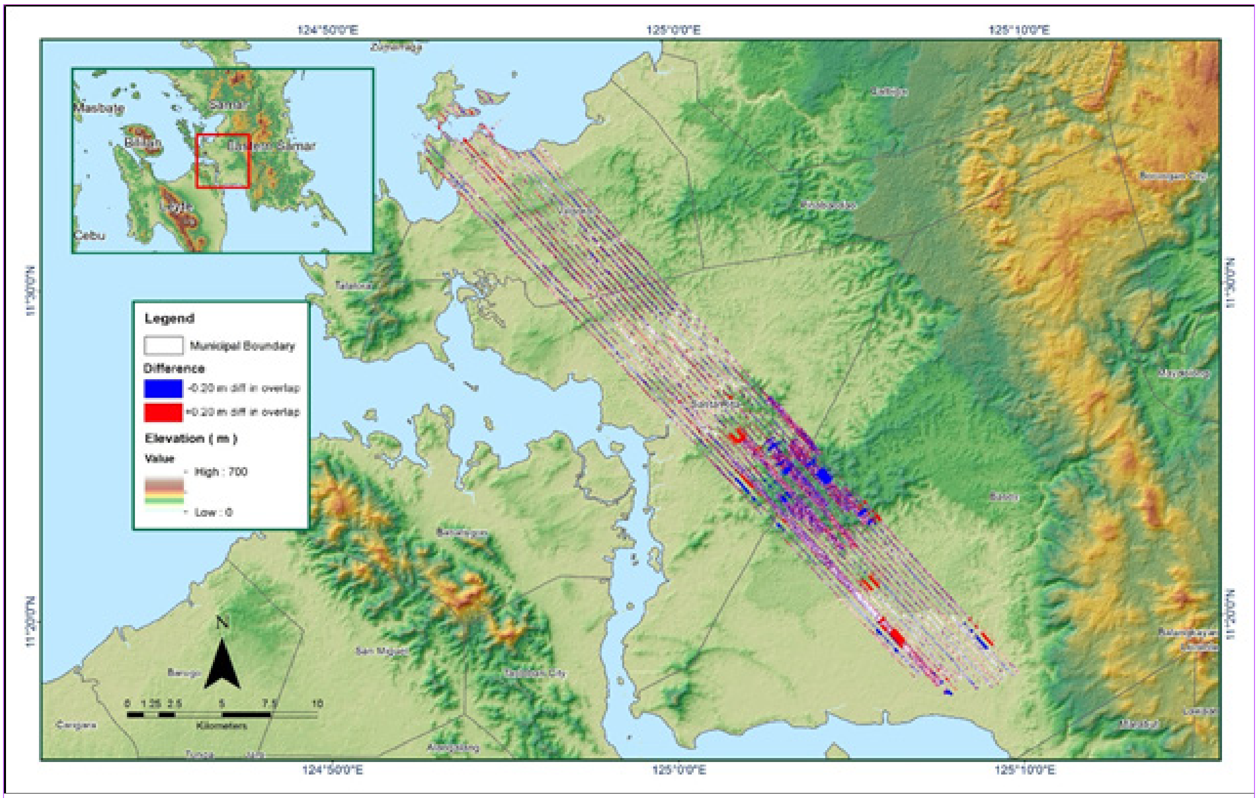


Figure A-8.14. Elevation difference between flight lines

Table A-8.3. Mission Summary Report for Mission Blk33F

Flight Area	Leyte
Mission Name	Blk33F
Inclusive Flights	3781G, 23773G
Range data size	
POS data size	
Base data size	13.57 MB
Image	n/a
Transfer date	March 02, 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	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	Melanie Hingpit, Monalyne Rabino

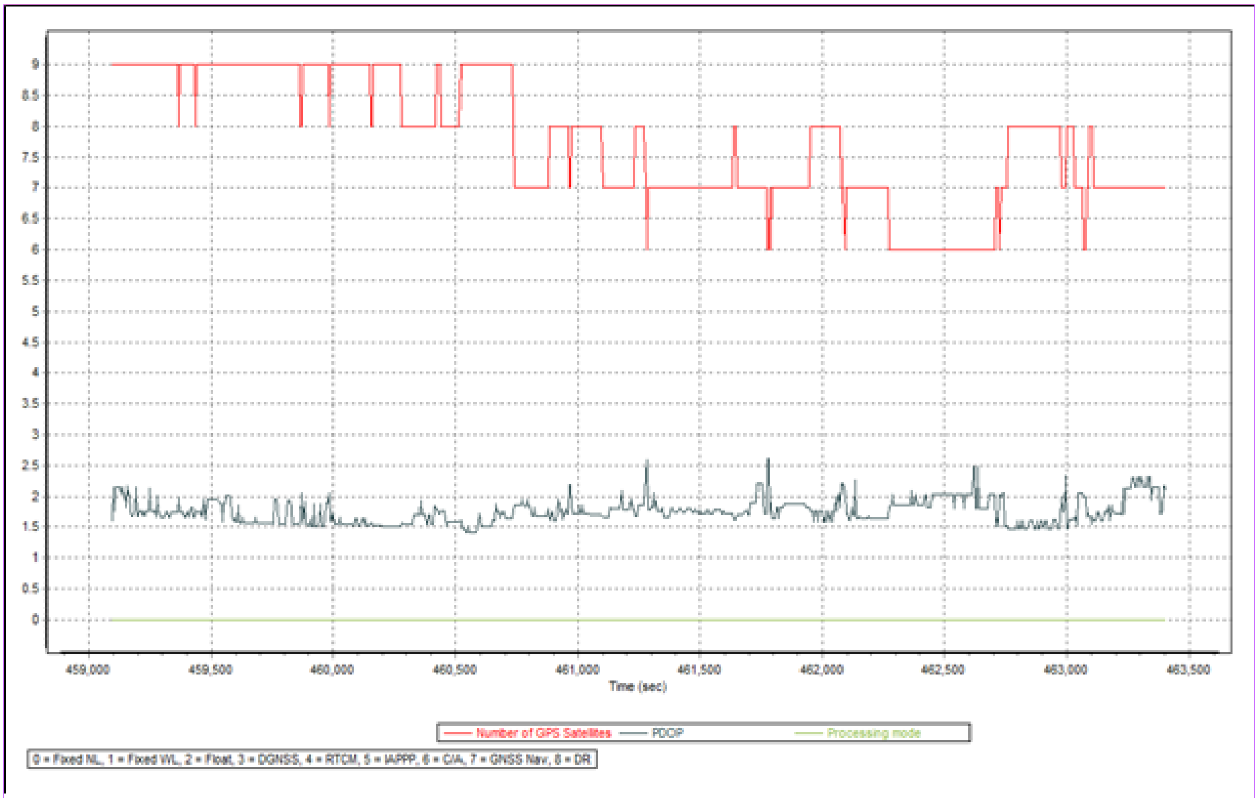


Figure A-8.15. Solution Status

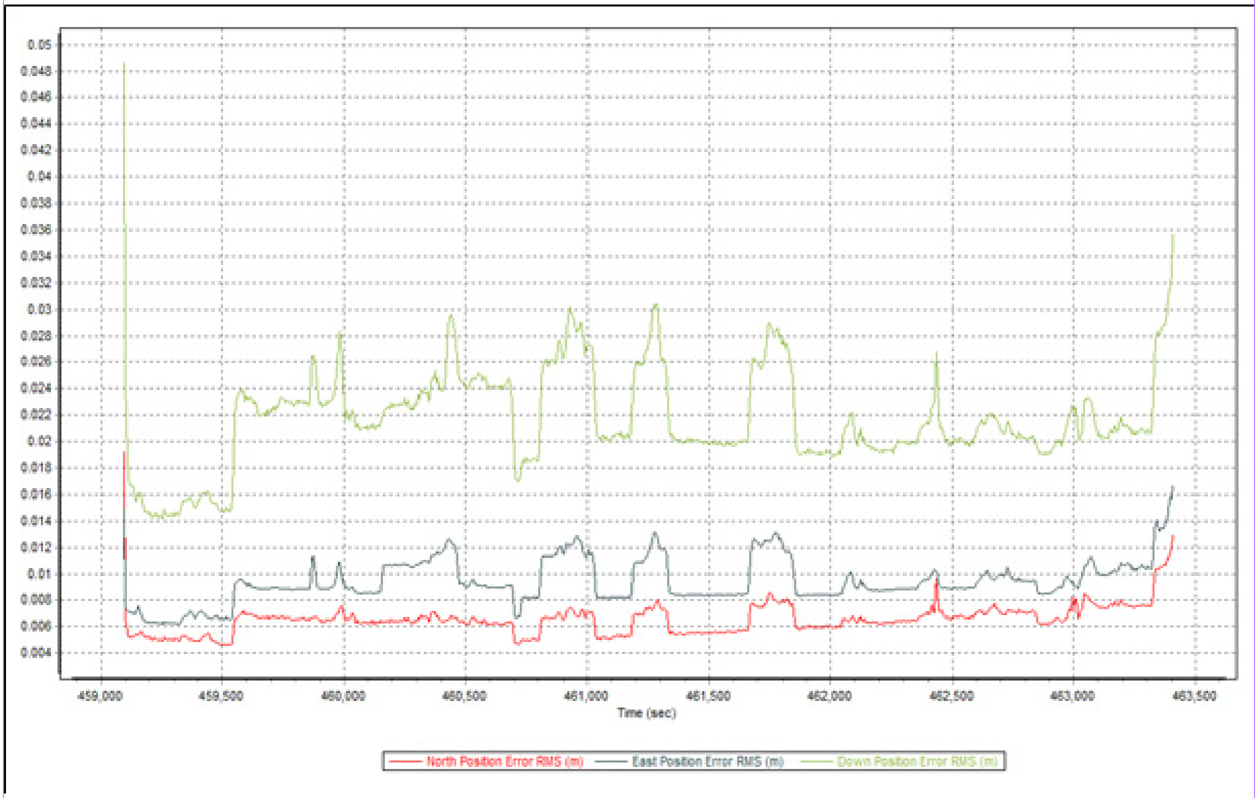


Figure A-8.16. Smoothed Performance Metric Parameters

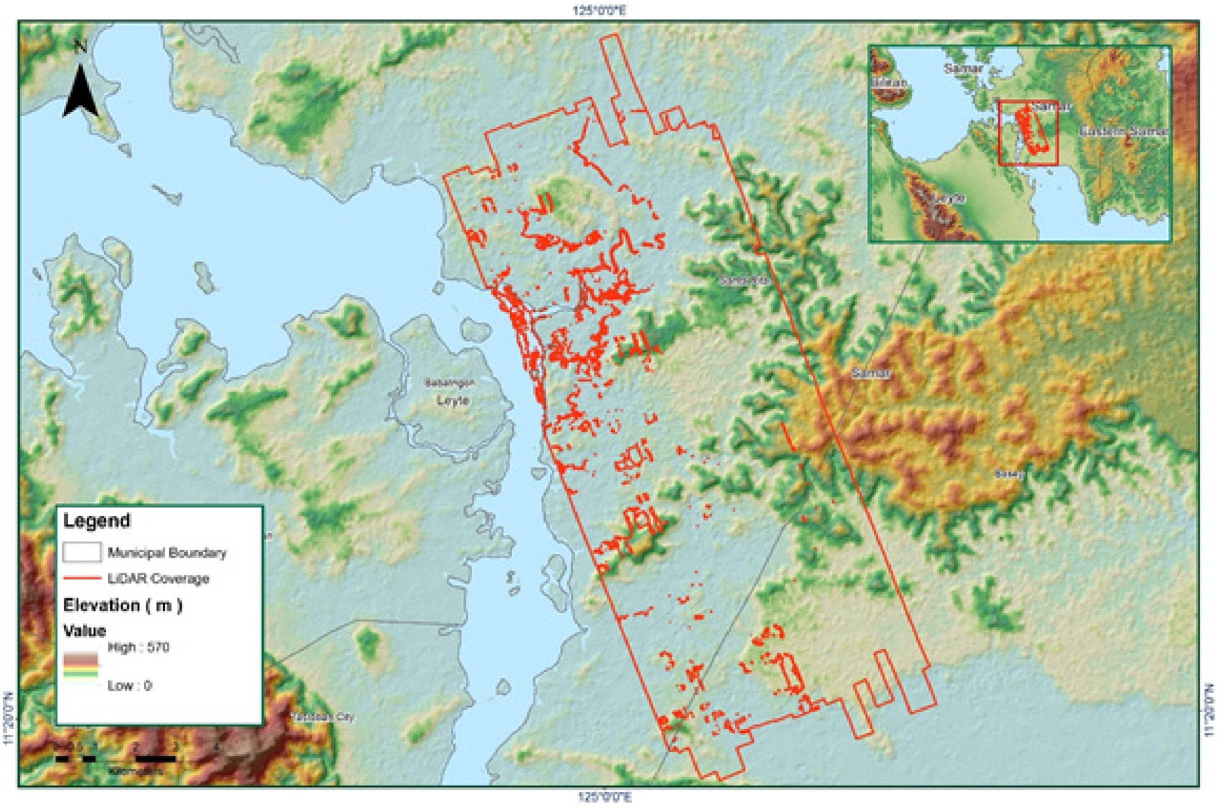


Figure A-8.17. Best Estimated Trajectory

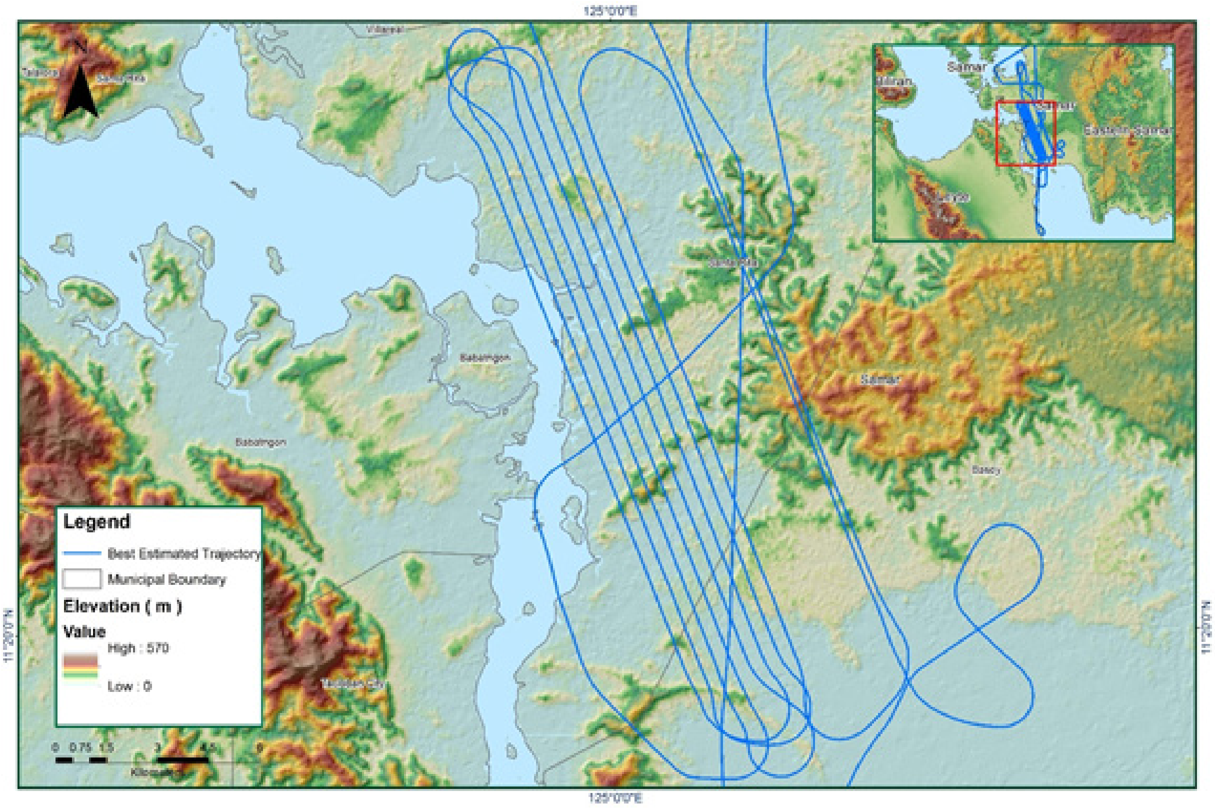


Figure A-8.18. Coverage of LiDAR data

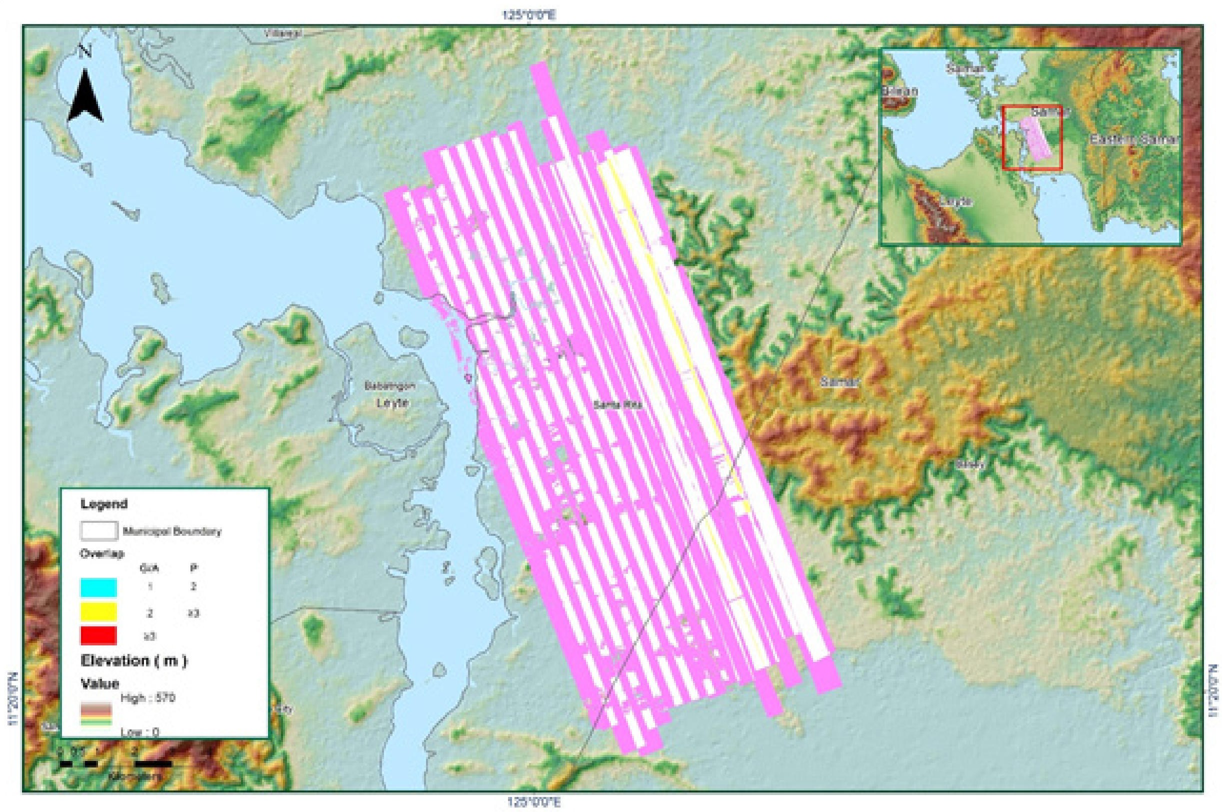


Figure A-8.19. Image of Data Overlap

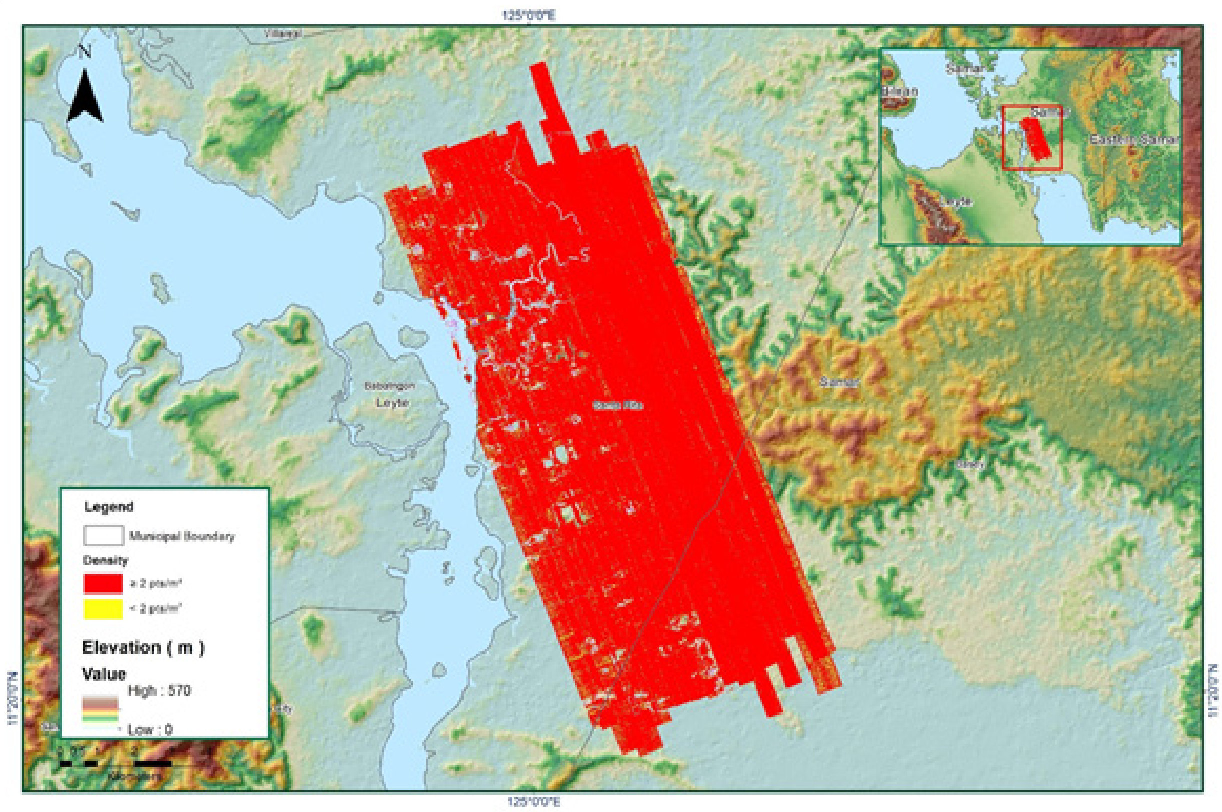


Figure A-8.20. Density map of merged LiDAR data

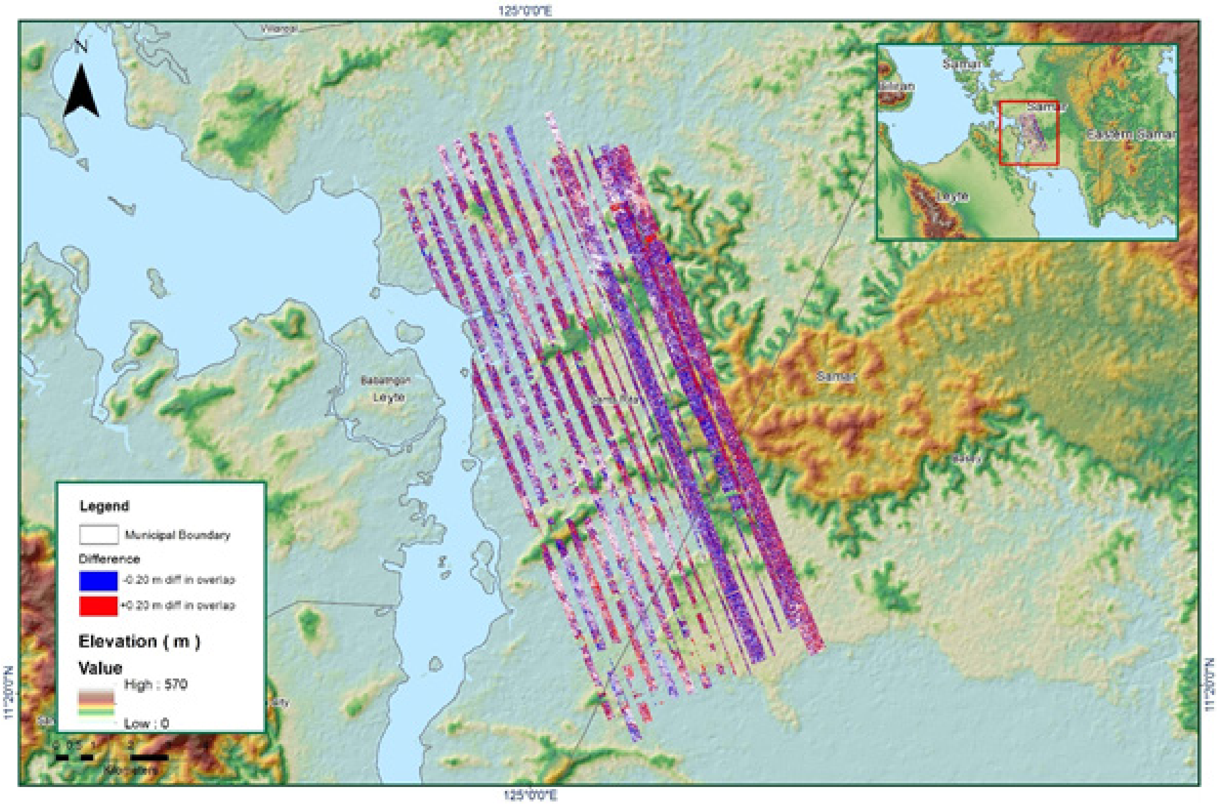


Figure A-8.21. Elevation difference between flight lines

Table A-8.4. Mission Summary Report for Mission 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	Melanie Hingpit

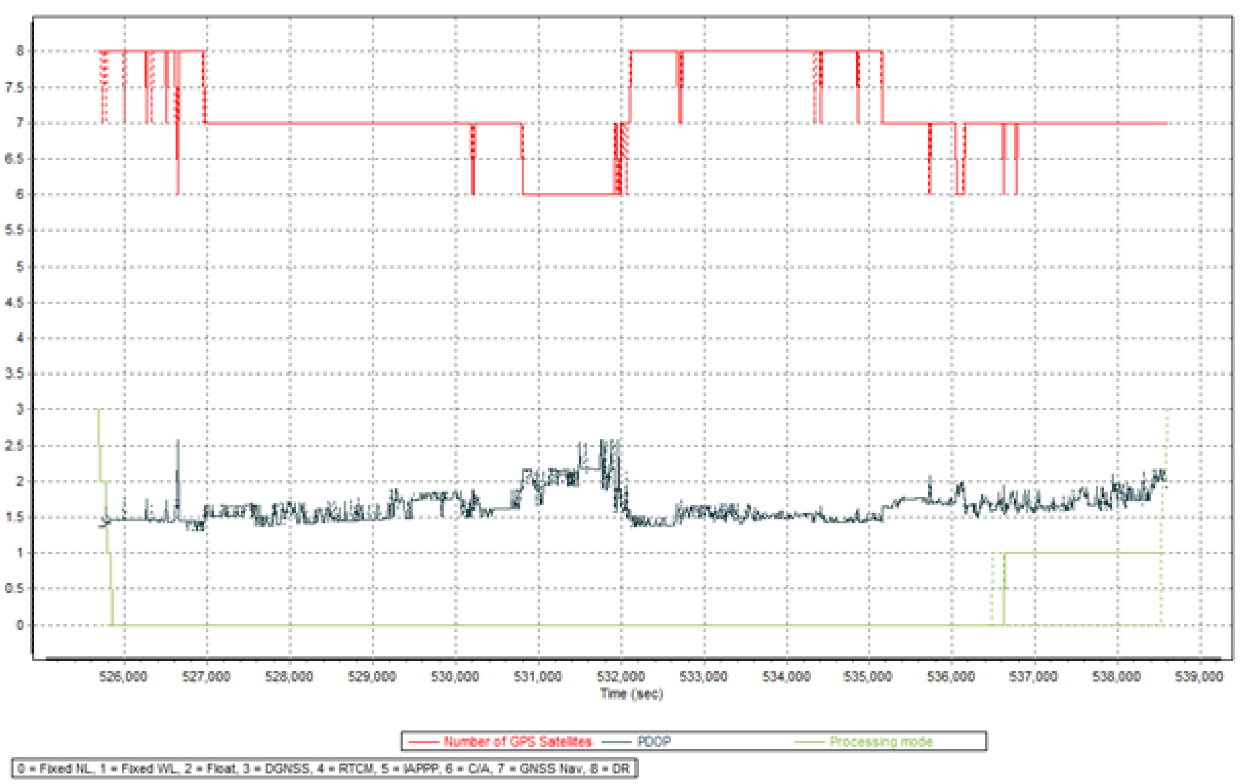


Figure A-8.22. Solution Status

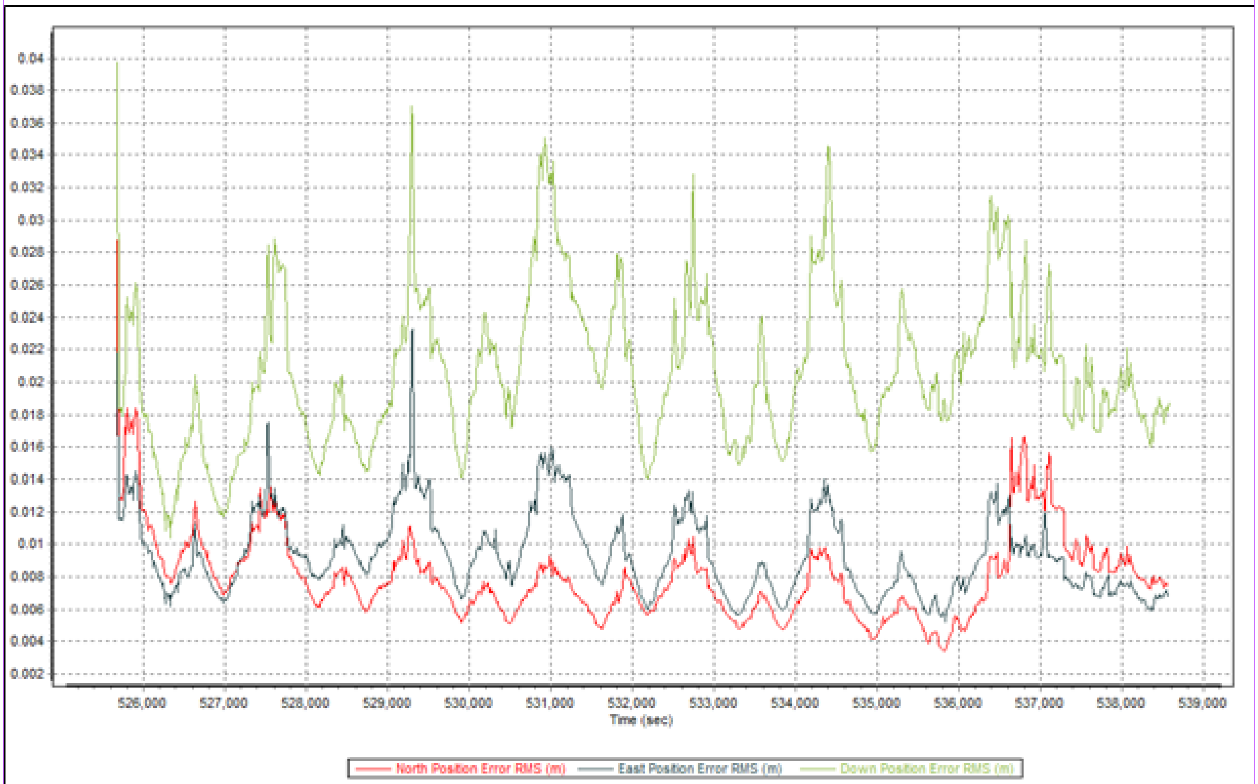


Figure A-8.23. Smoothed Performance Metric Parameters

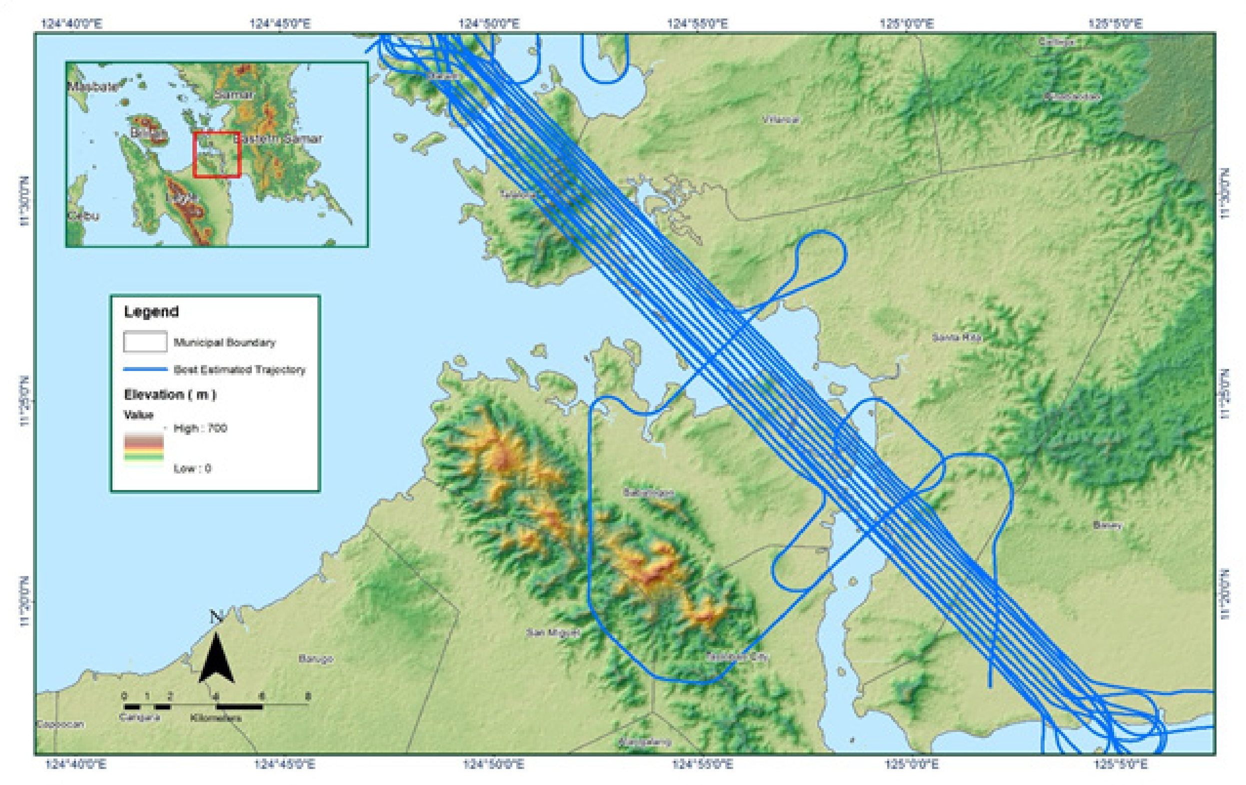


Figure A-8.24. Best Estimated Trajectory

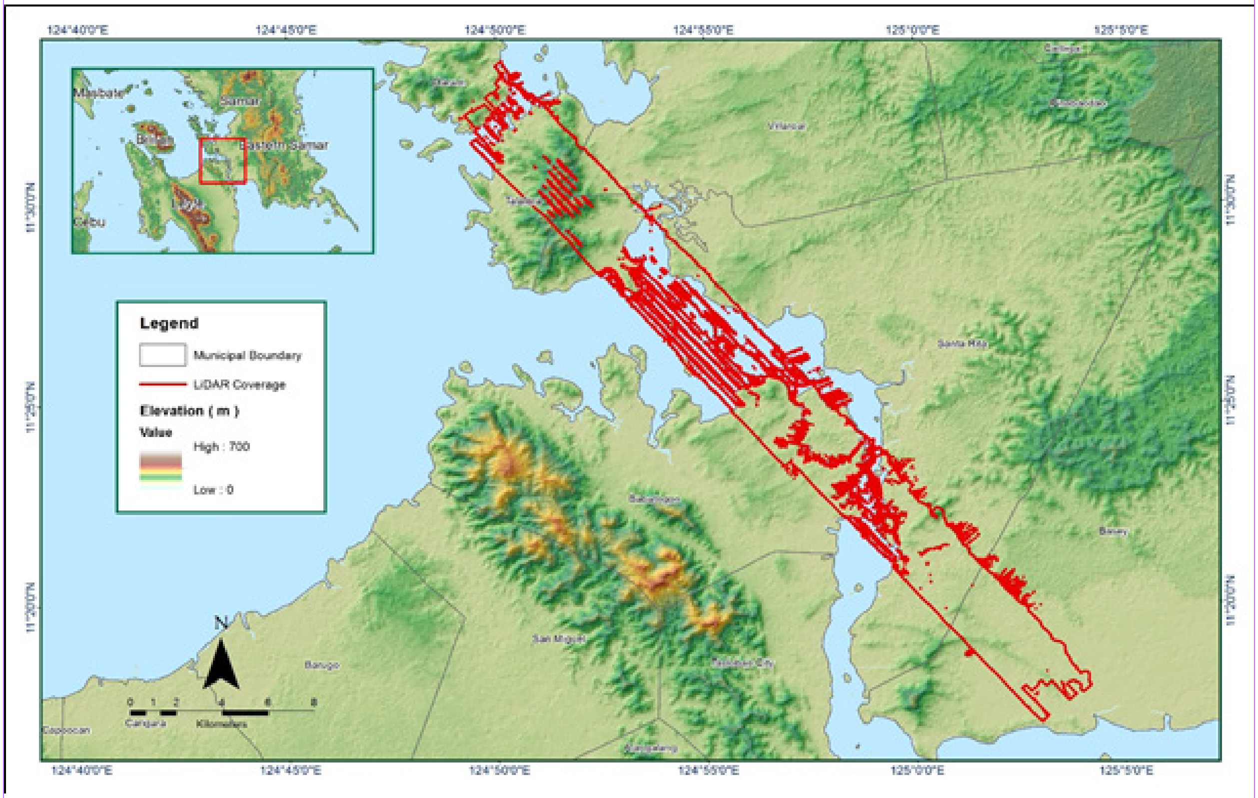


Figure A-8.25. Coverage of LiDAR data

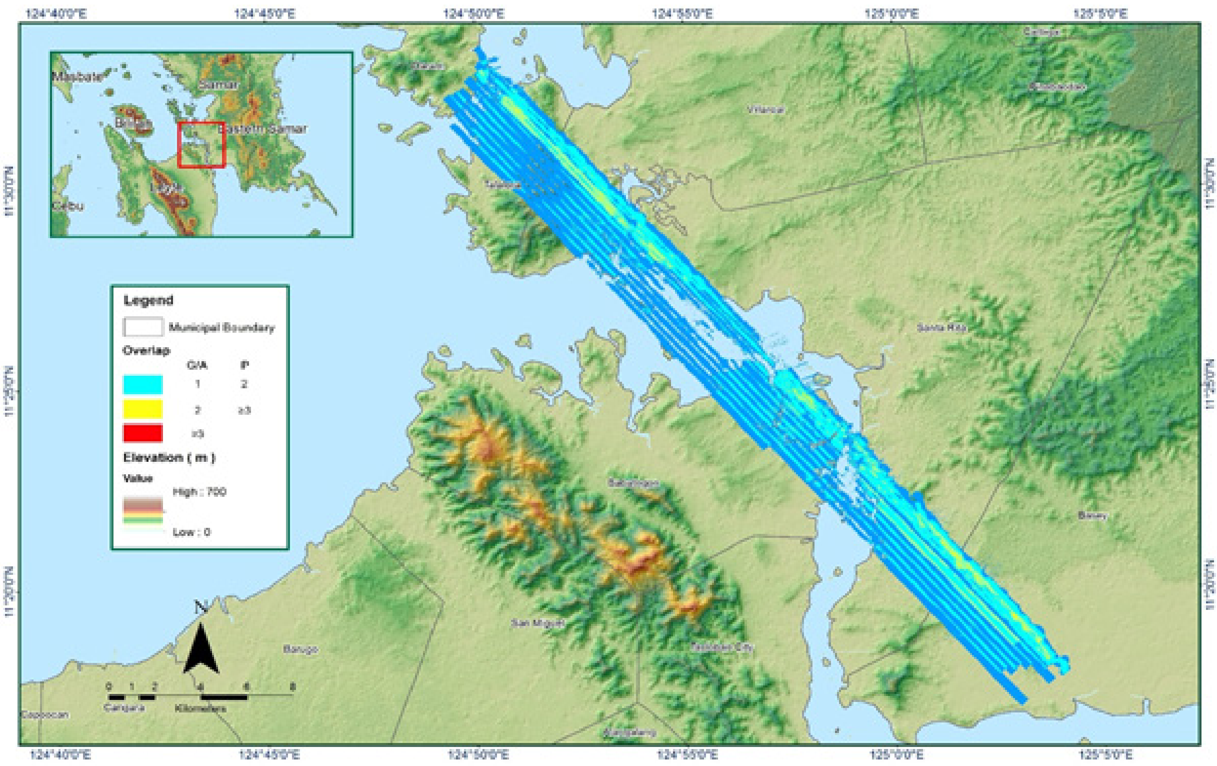


Figure A-8.26. Image of Data Overlap

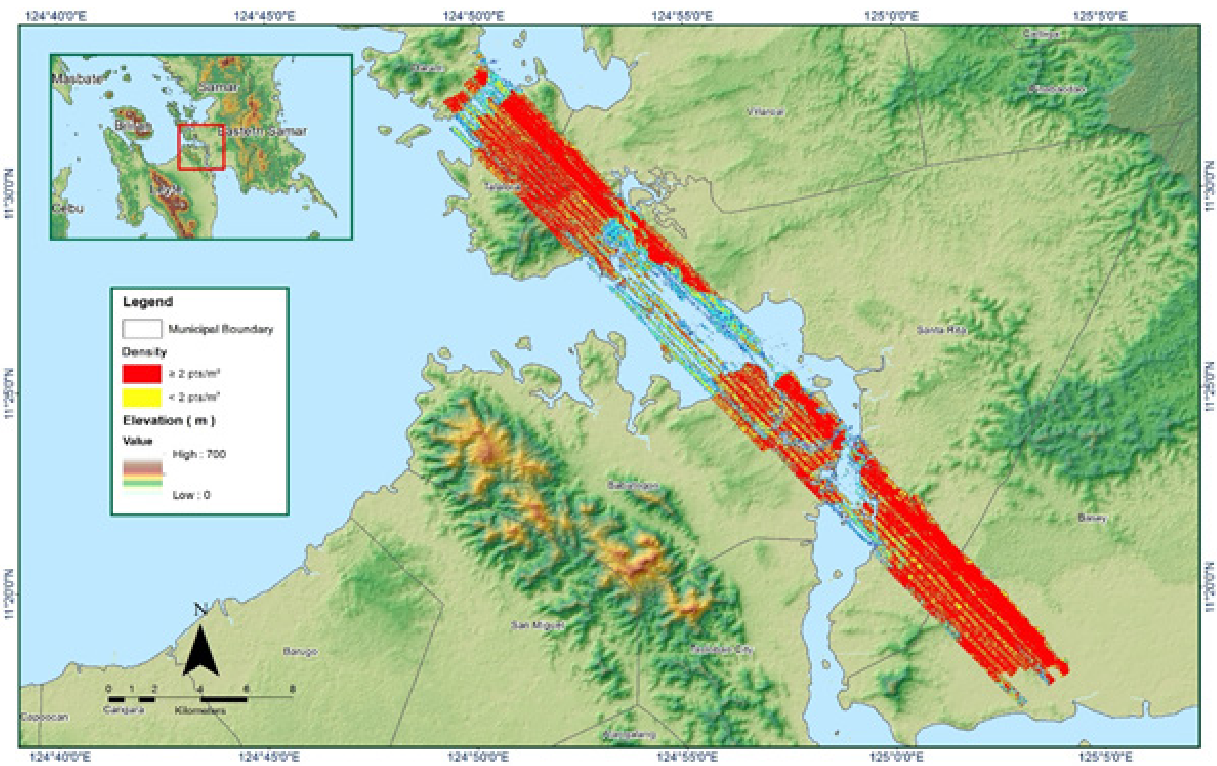


Figure A-8.27. Density map of merged LiDAR data

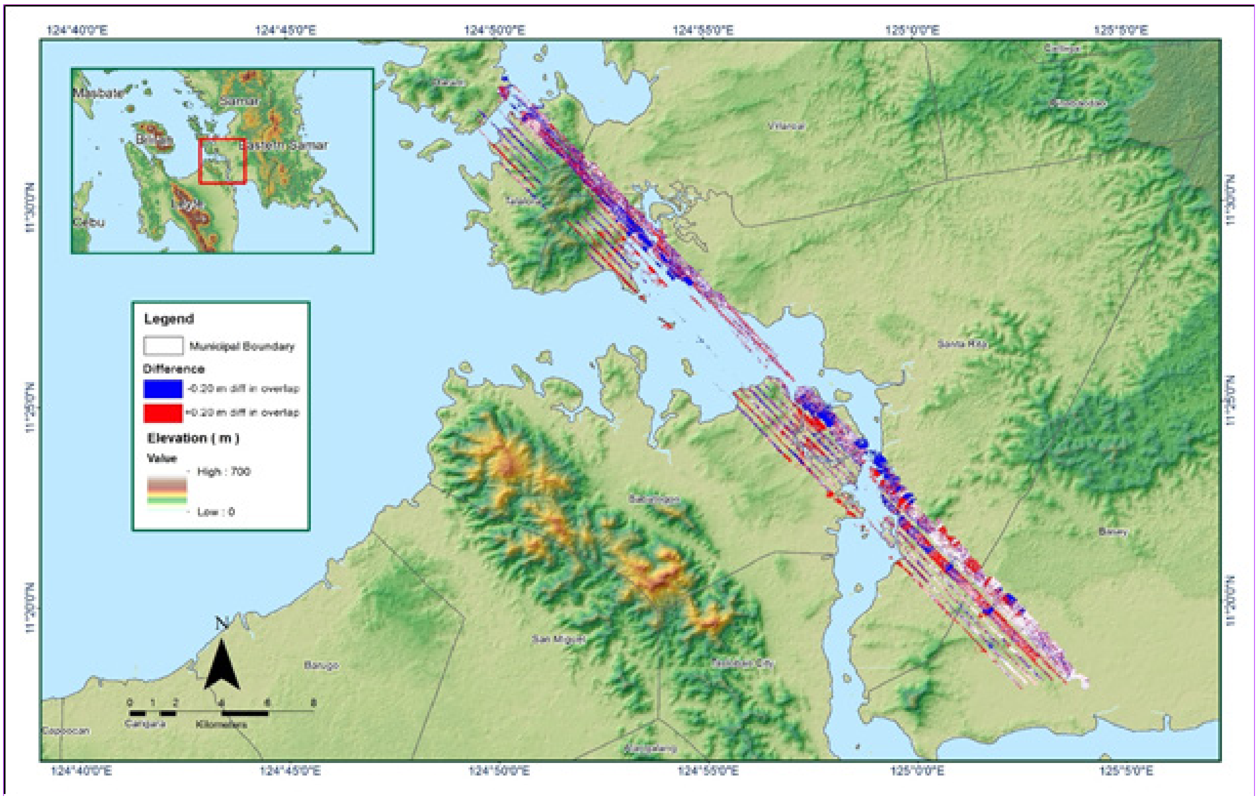


Figure A-8.28. Elevation difference between flight lines

Table A-8.5. Mission Summary Report for Mission 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	Tox Salvacion, Ma. Ailyn Olanda

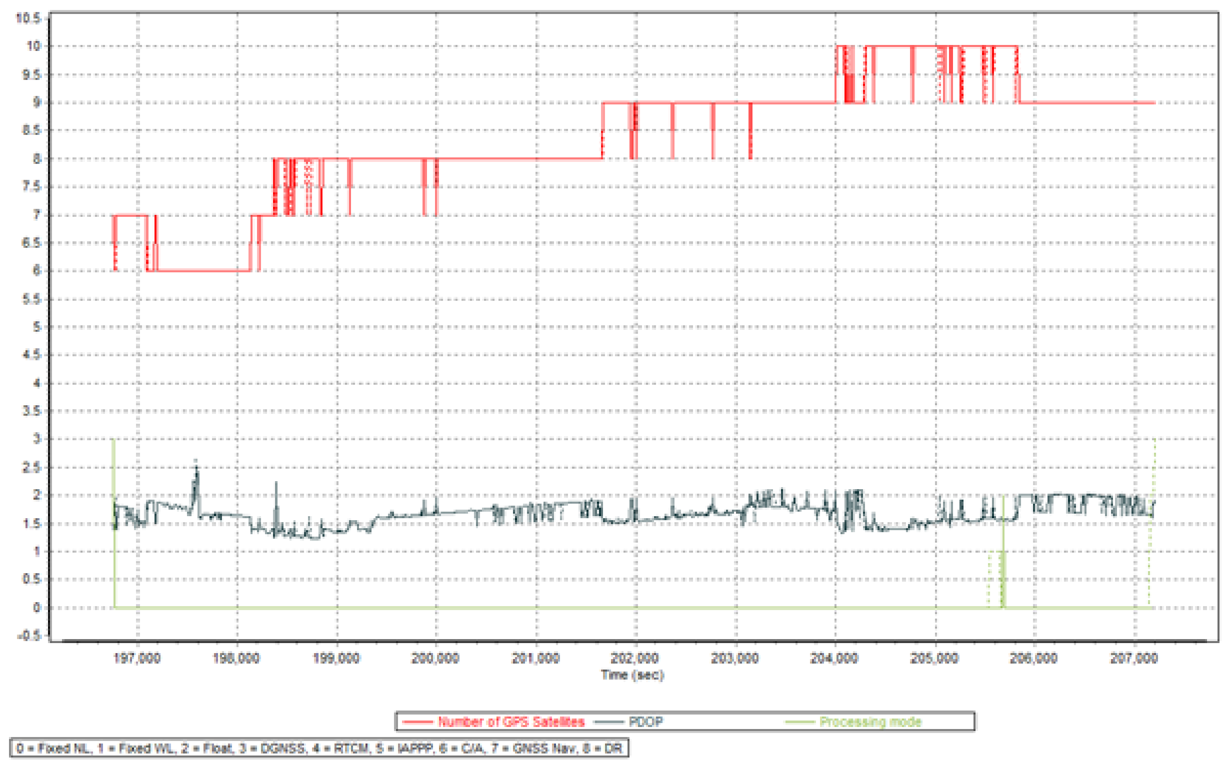


Figure A-8.29. Solution Status

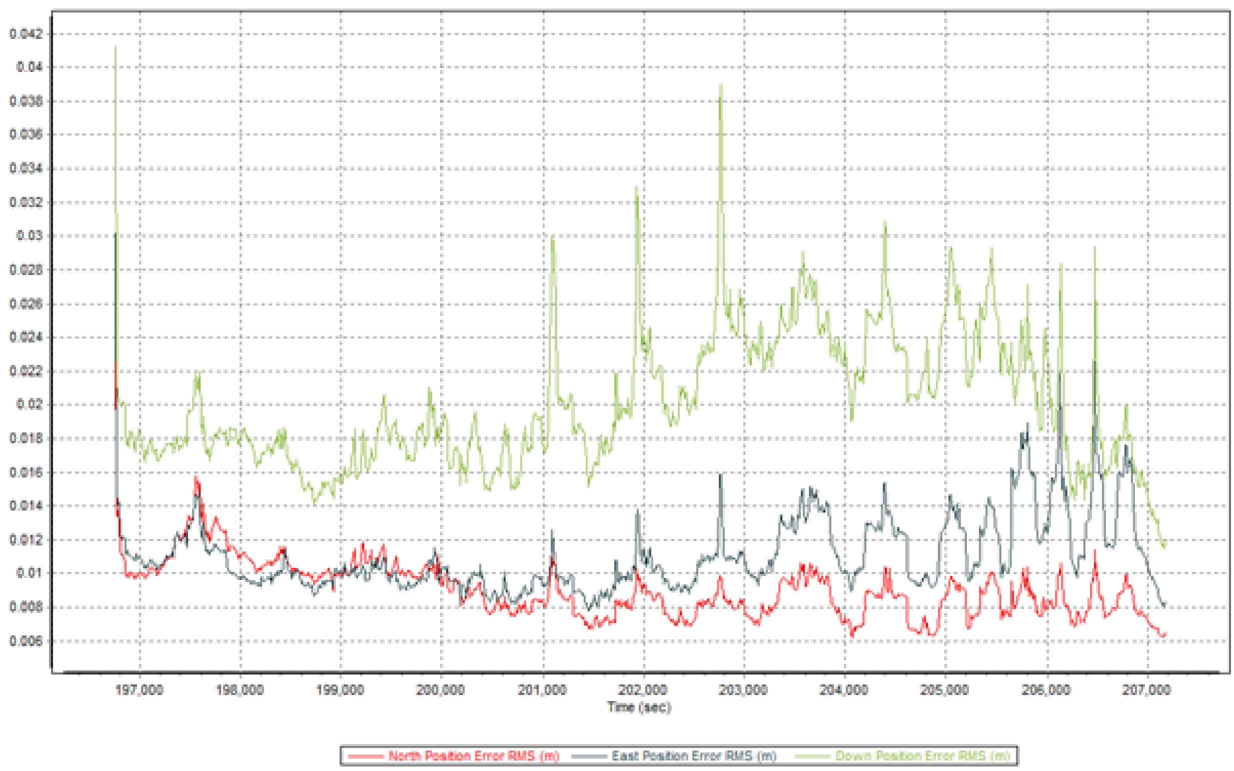


Figure A-8.30. Smoothed Performance Metric Parameters

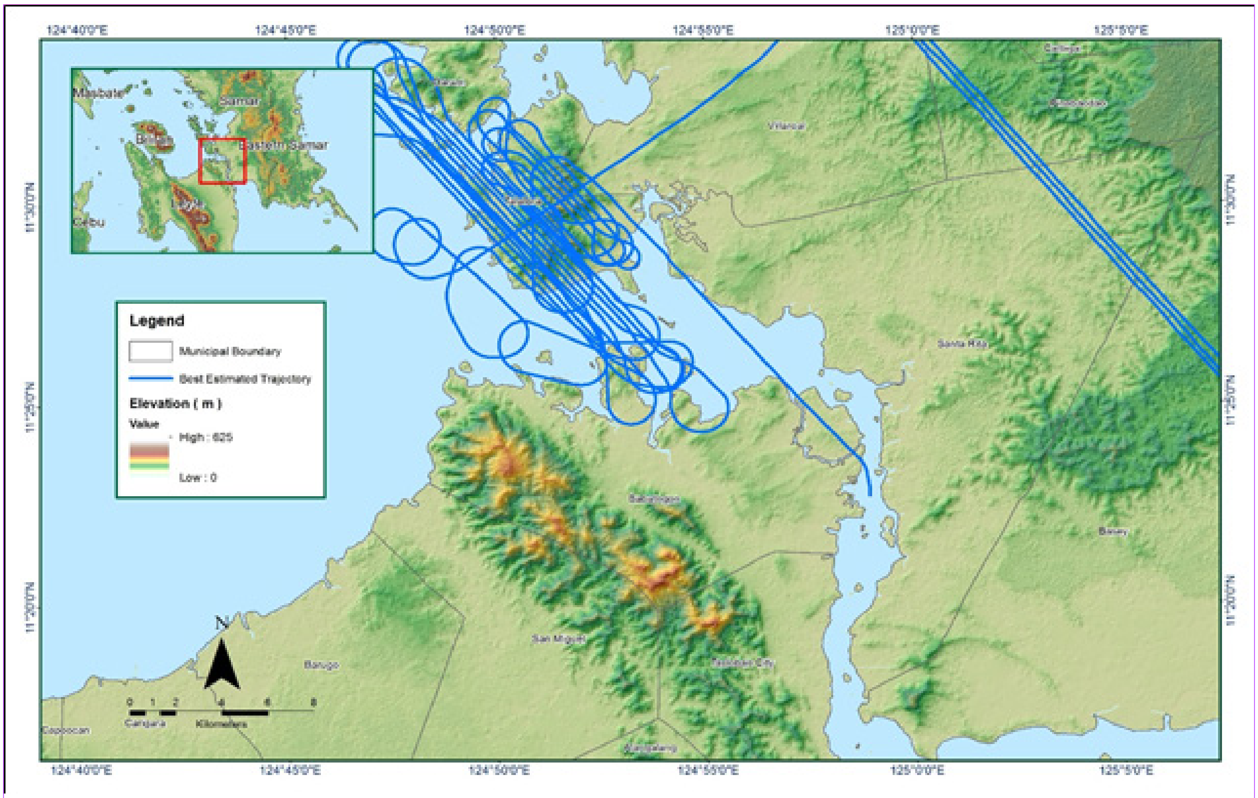


Figure A-8.31. Best Estimated Trajectory

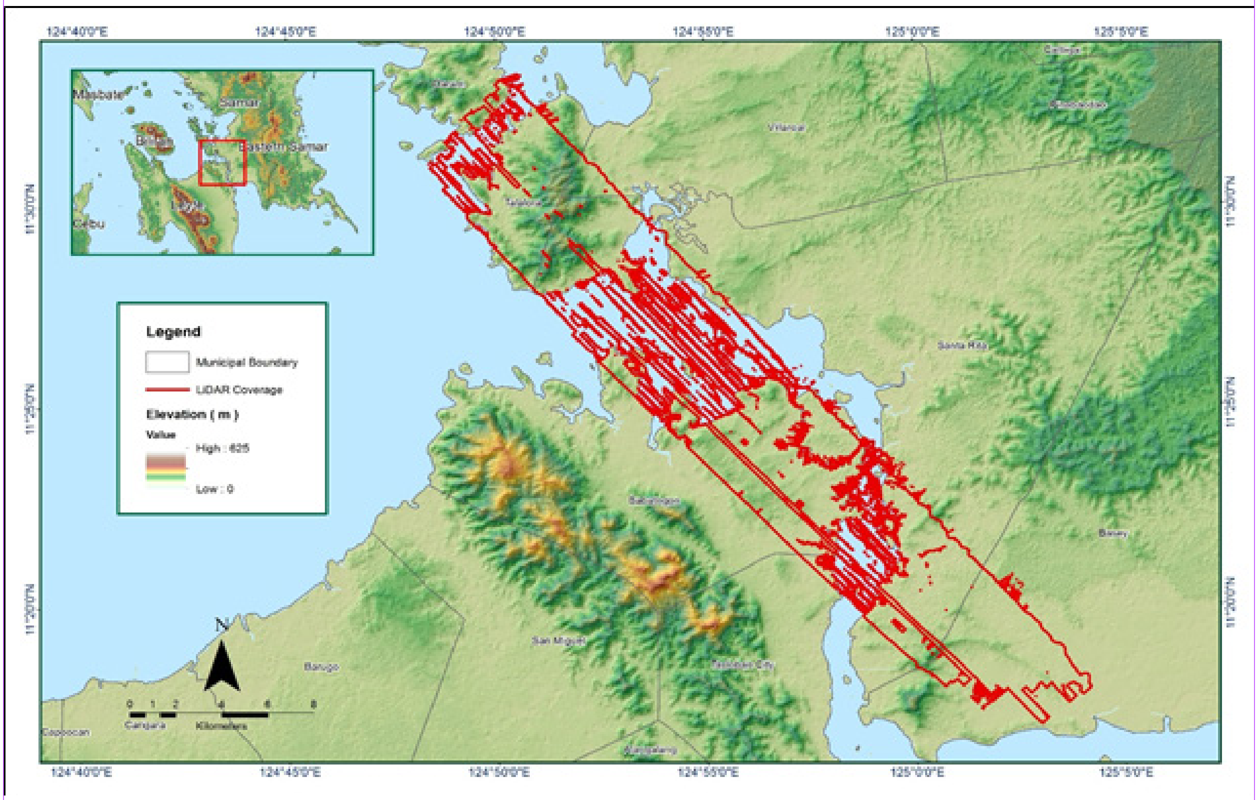


Figure A-8.32. Coverage of LiDAR data

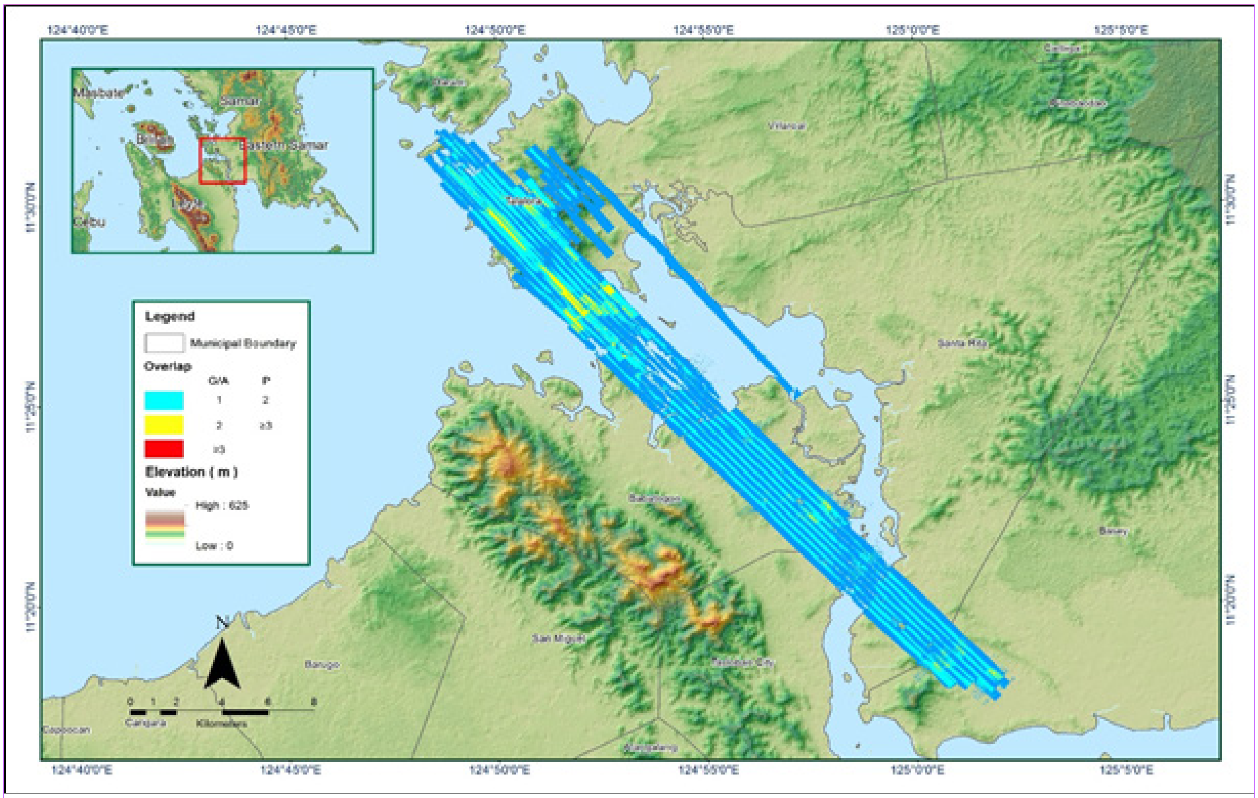


Figure A-8.33. Image of Data Overlap

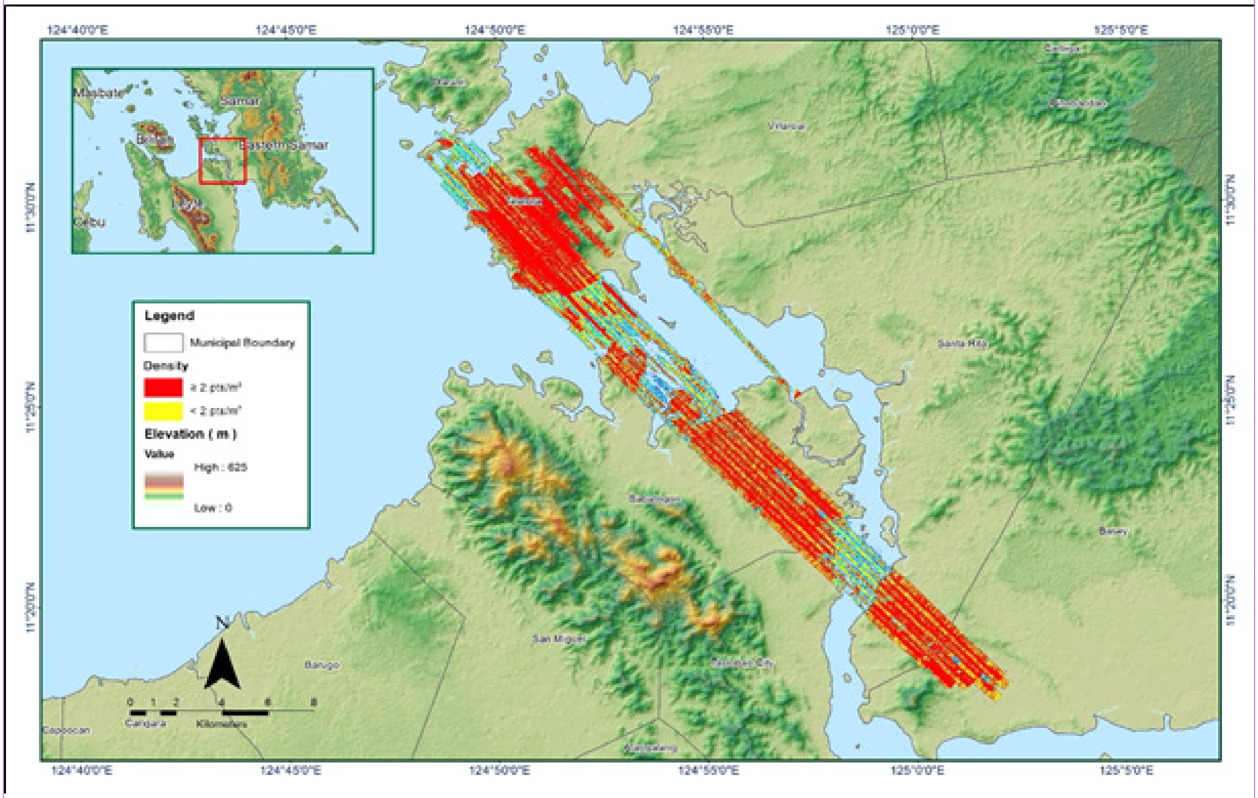


Figure A-8.34. Density map of merged LiDAR data

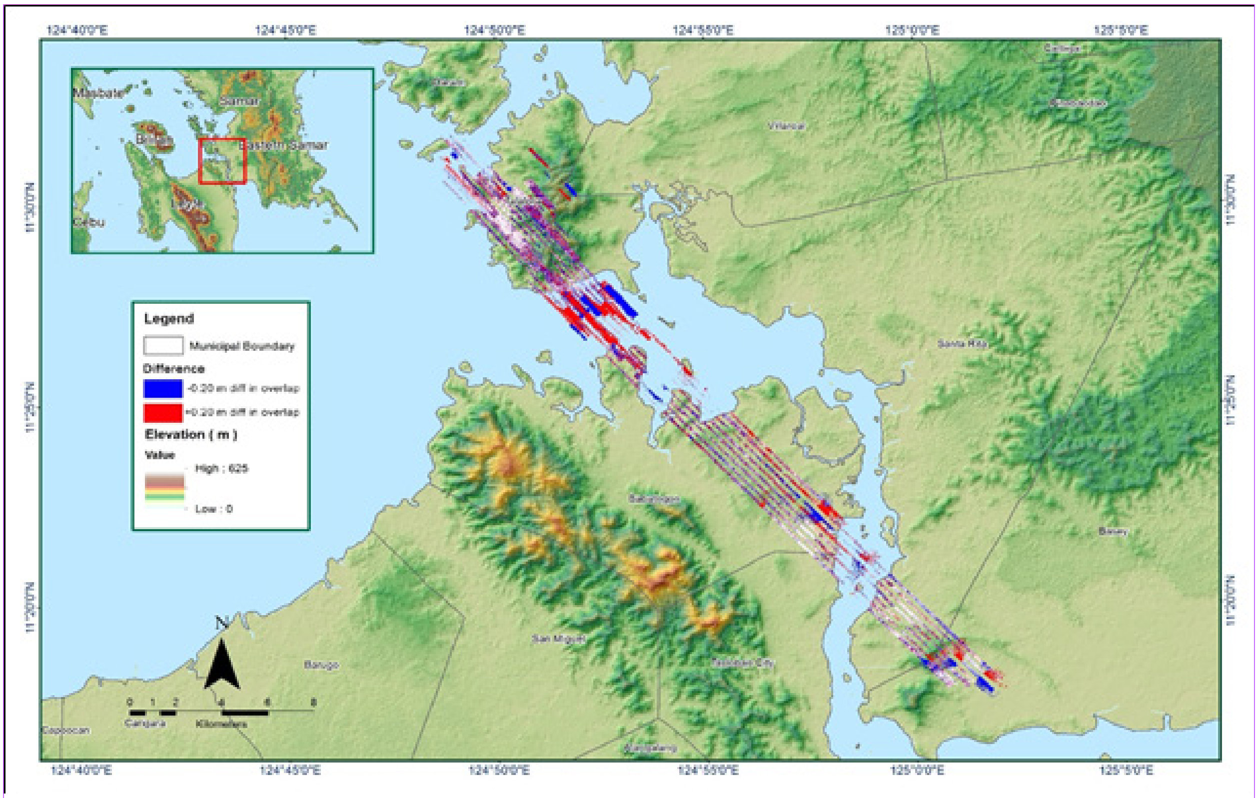


Figure A-8.35. Elevation difference between flight lines

Table A-8.6. Mission Summary Report for Mission 33F

Flight Area	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

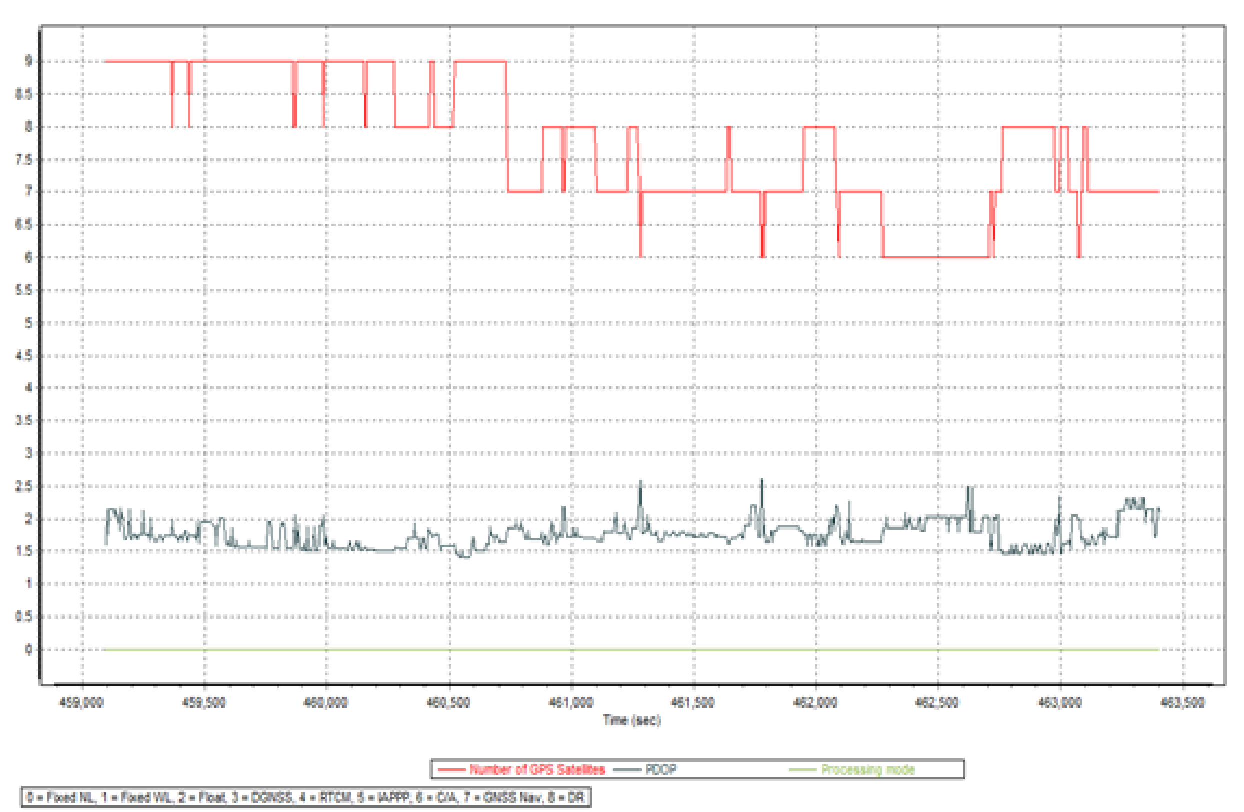


Figure A-8.36. Solution Status

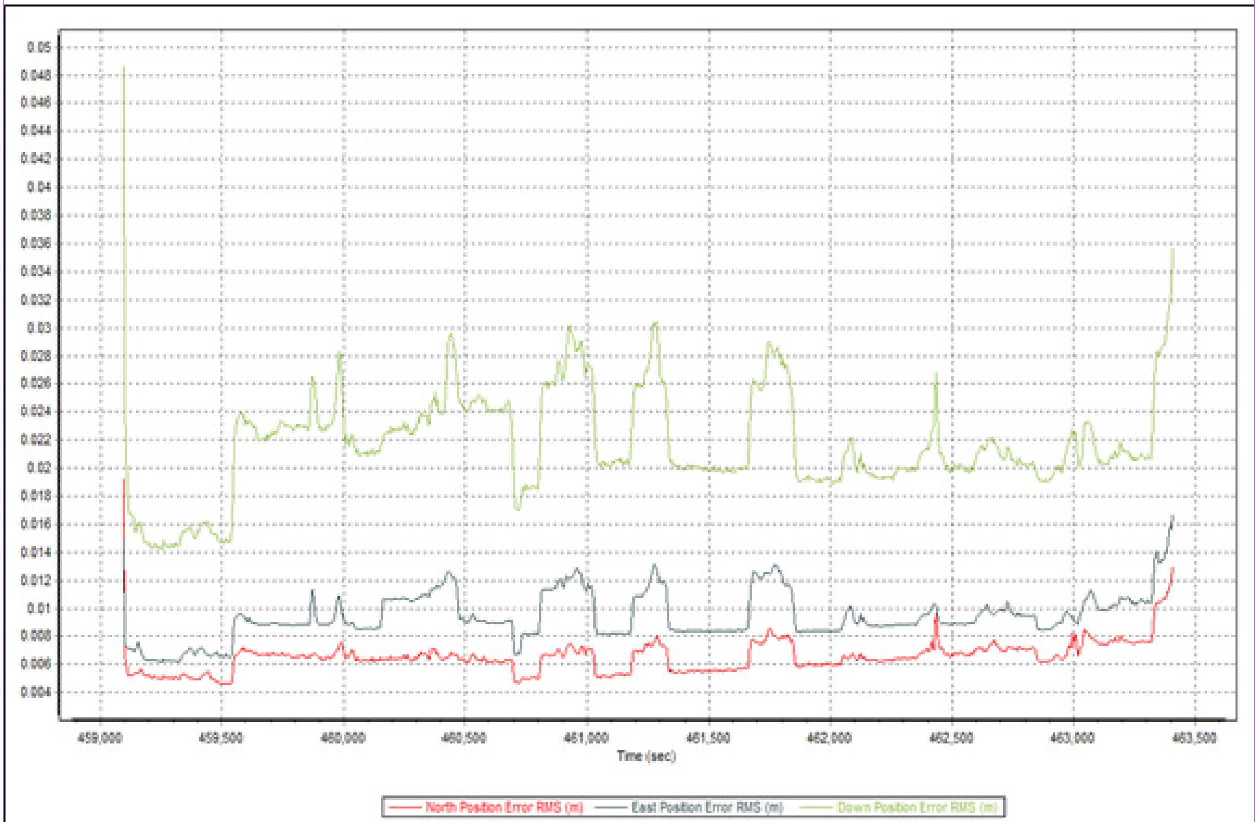


Figure A-8.37. Smoothed Performance Metric Parameters

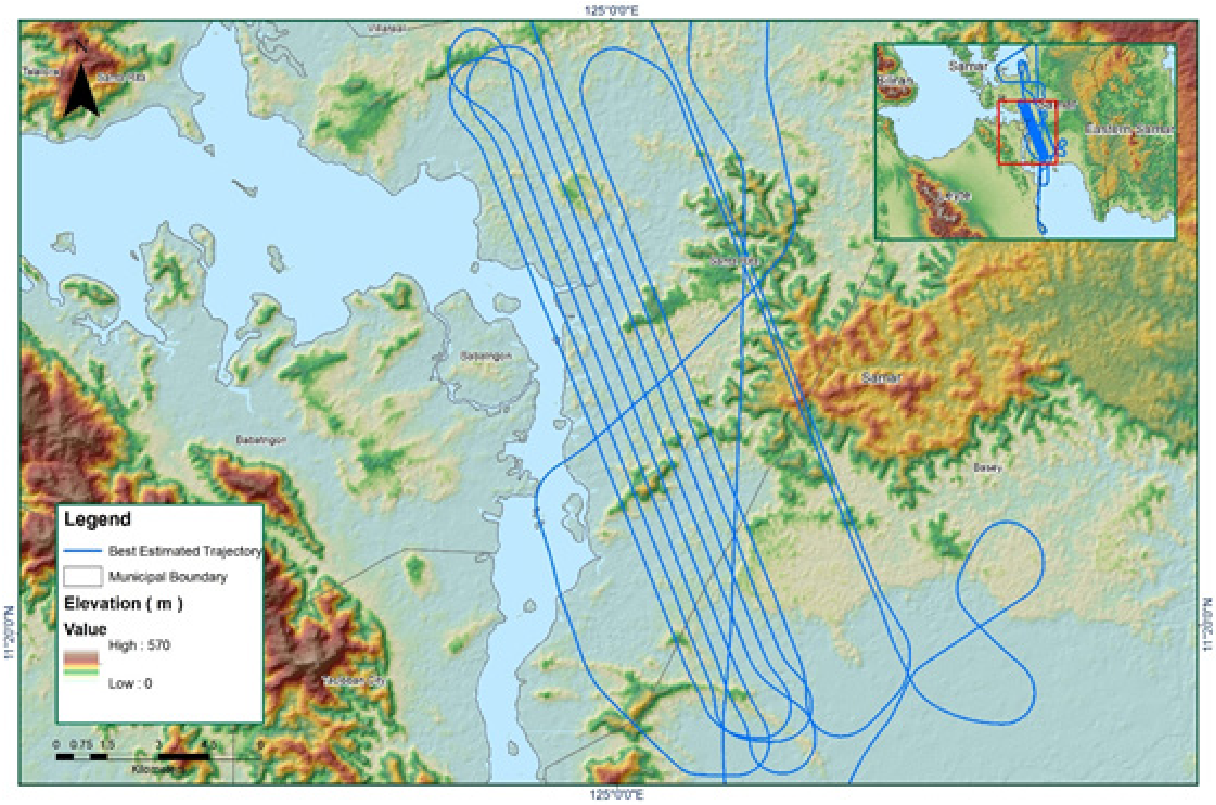


Figure A-8.38. Best Estimated Trajectory

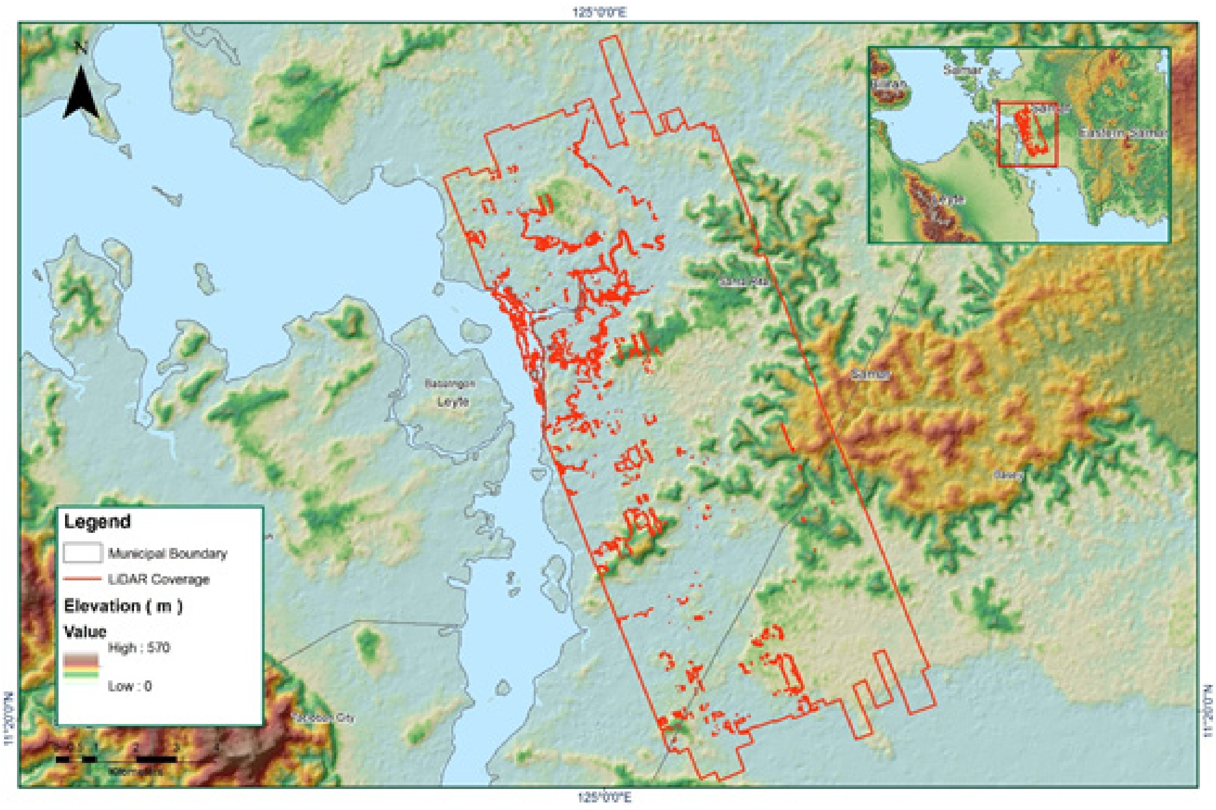


Figure A-8.39. Coverage of LiDAR data

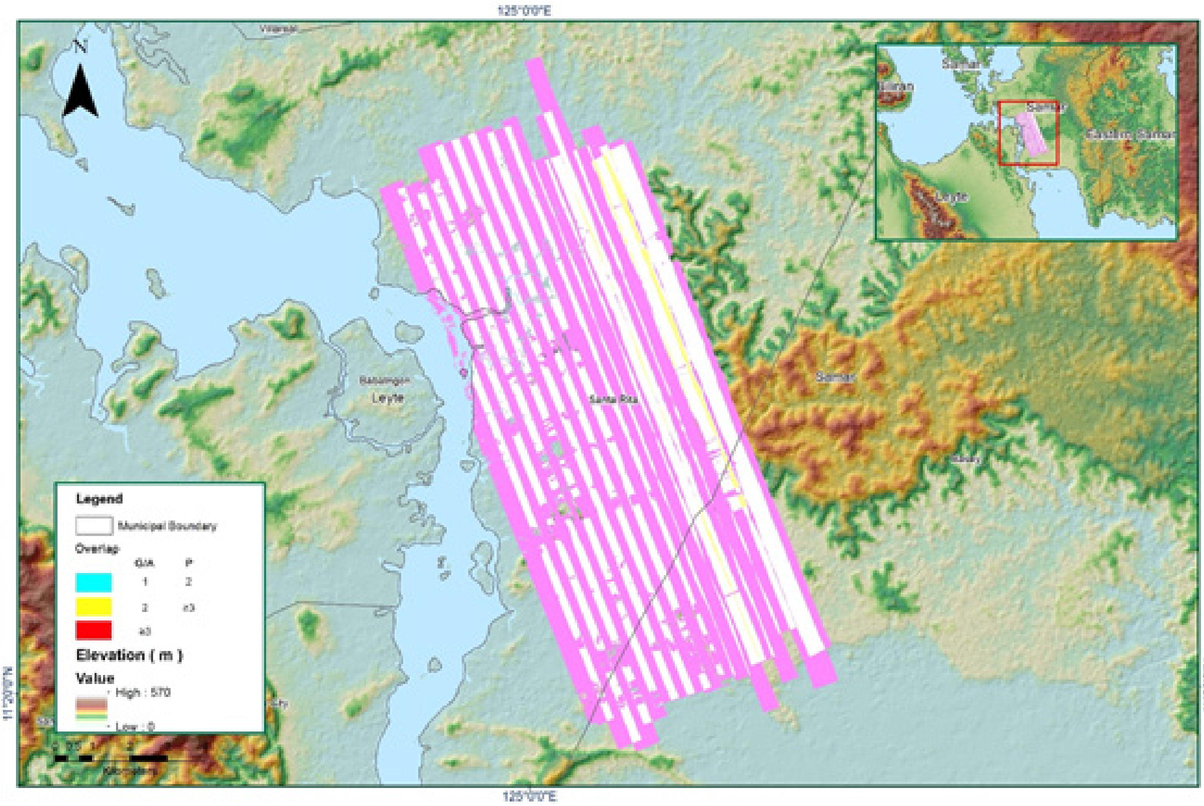


Figure A-8.40. Image of Data Overlap

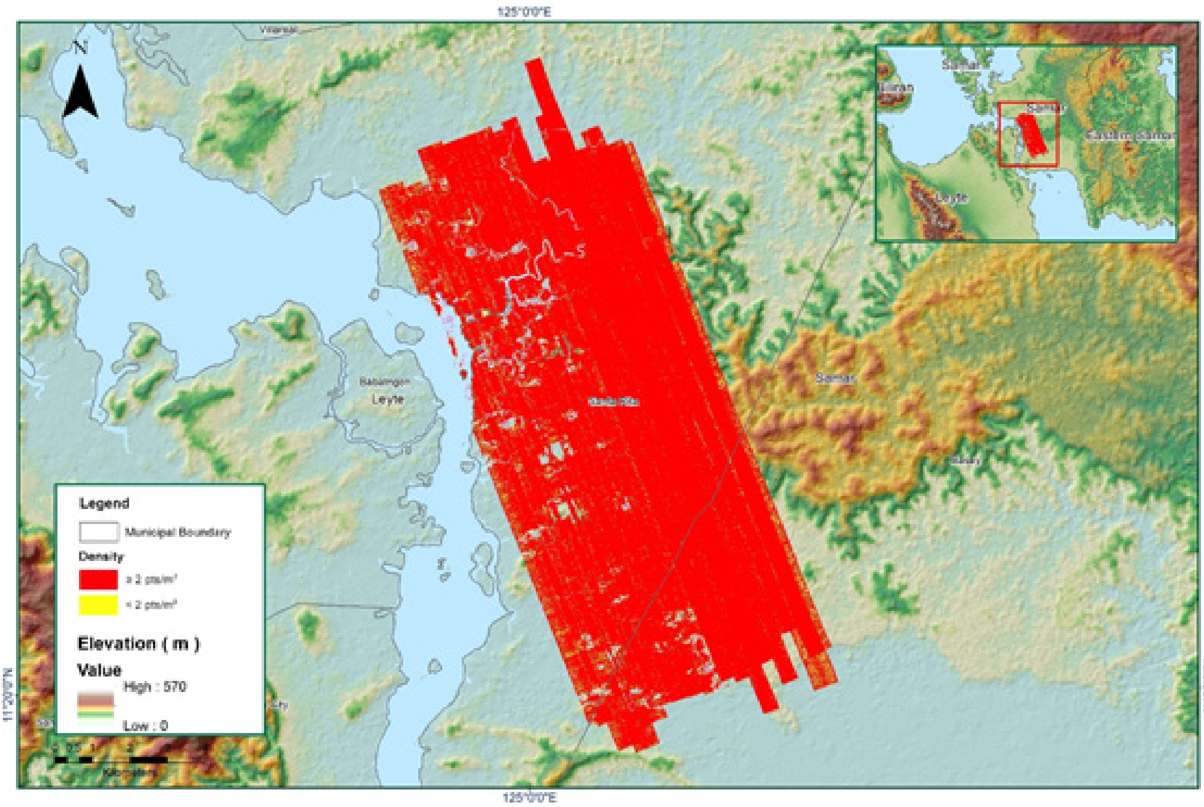


Figure A-8.41. Density map of merged LiDAR data

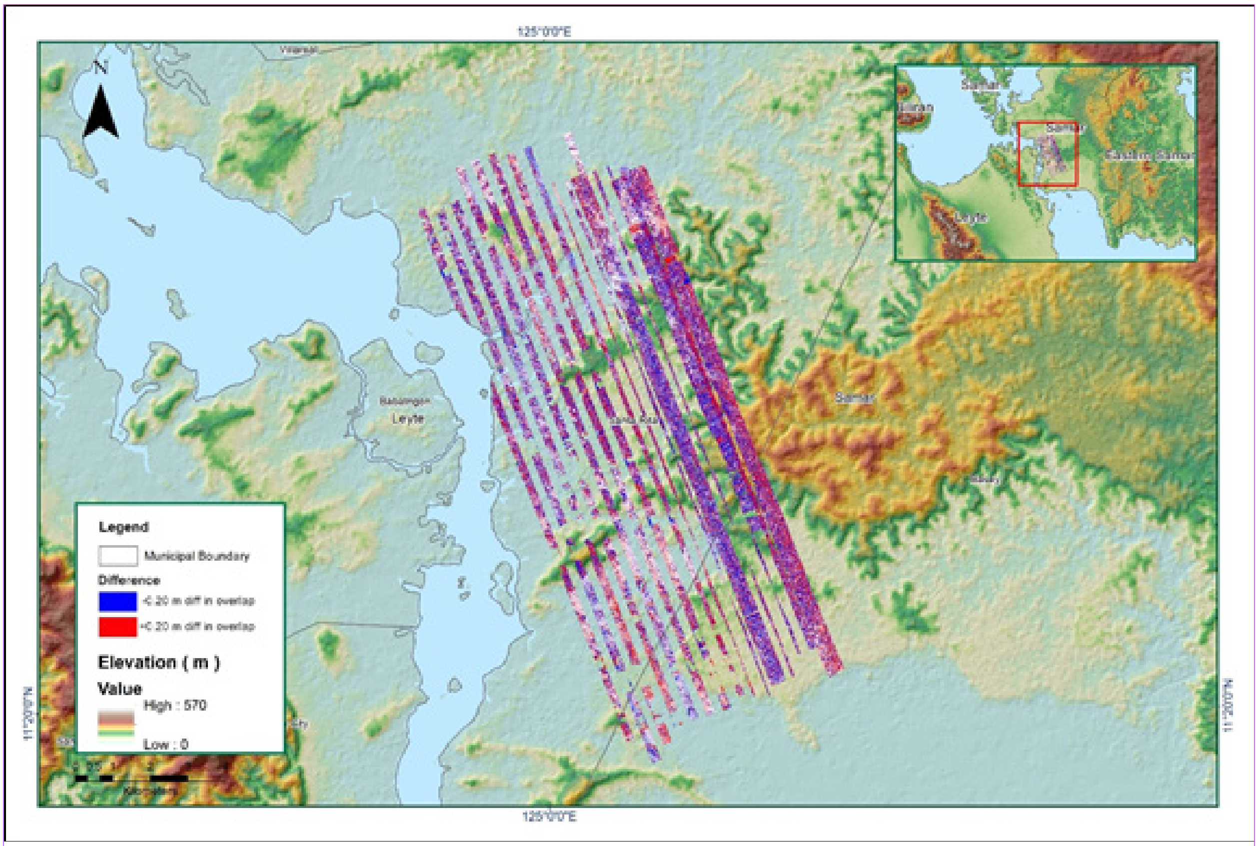


Figure A-8.42. Elevation difference between flight lines

Table A-8.7. Mission Summary Report for Mission 33H

Flight Area	Leyte
Mission Name	33H
Inclusive Flights	3727G
Range data size	22.8
POS data size	243
Base data size	4.2
Image	n/a
Transfer date	February 26, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	0.1
RMSE for East Position (<4.0 cm)	1.0
RMSE for Down Position (<8.0 cm)	2.3
Boresight correction stdev (<0.001deg)	0.000793
IMU attitude correction stdev (<0.001deg)	0.033296
GPS position stdev (<0.01m)	0.0295
Minimum % overlap (>25)	26.89
Ave point cloud density per sq.m. (>2.0)	4.90
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	109
Maximum Height	383.19 m
Minimum Height	70.46 m
Classification (# of points)	
Ground	26,577,714
Low vegetation	11,614,537
Medium vegetation	149,608,781
High vegetation	257,635,432
Building	10,608,460
Orthophoto	No

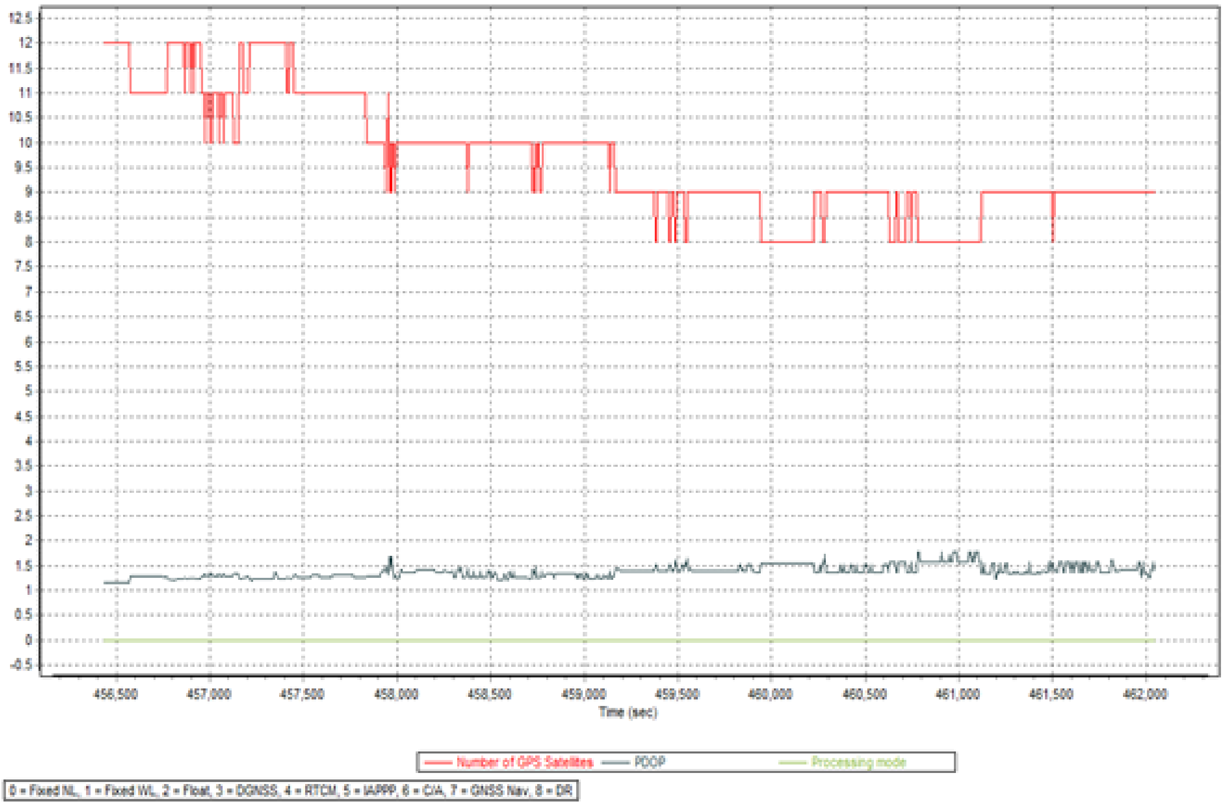


Figure A-8.43. Solution Status

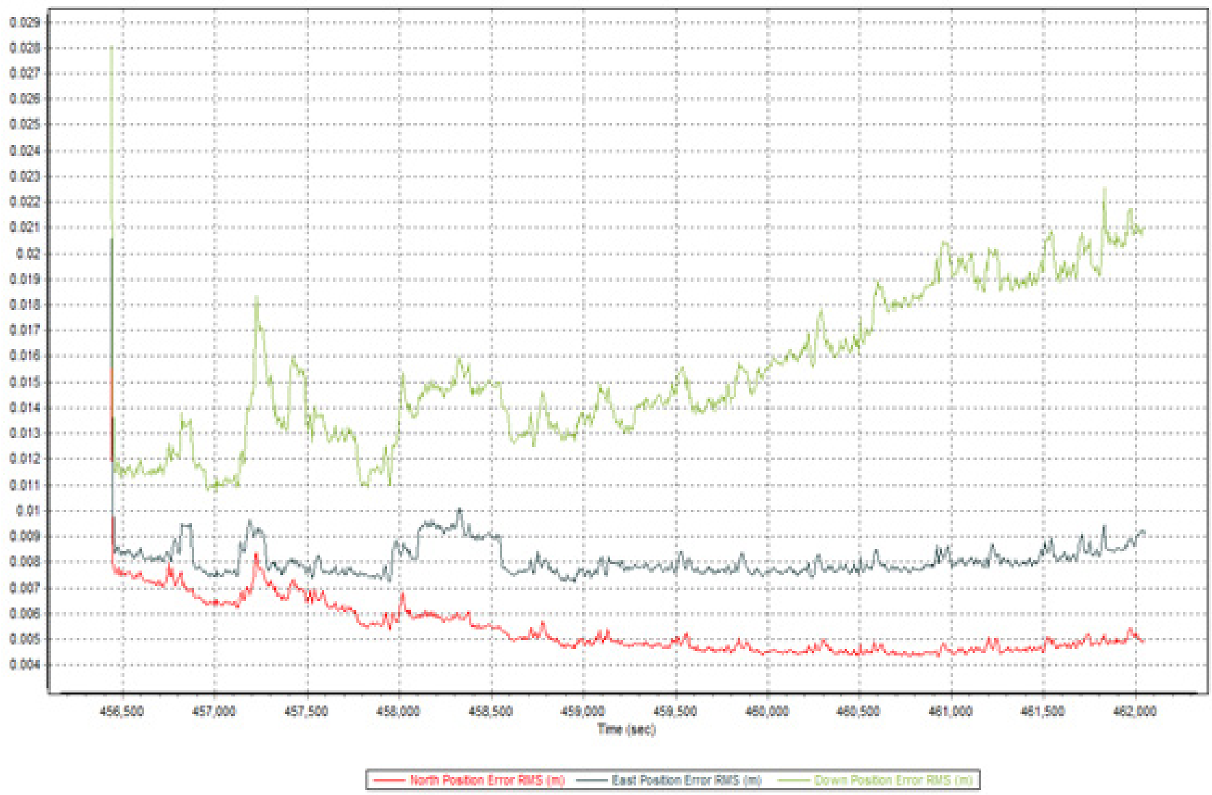


Figure A-8.44. Smoothed Performance Metric Parameters

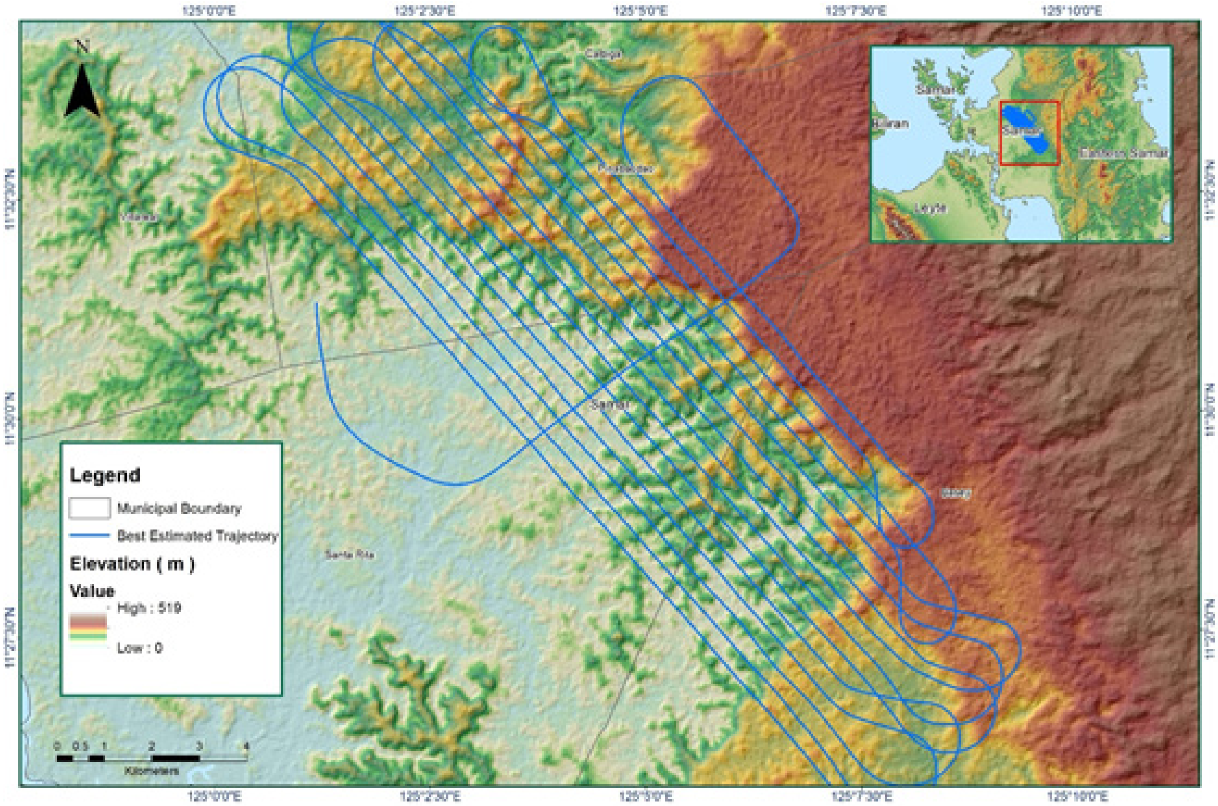


Figure A-8.45. Best Estimated Trajectory

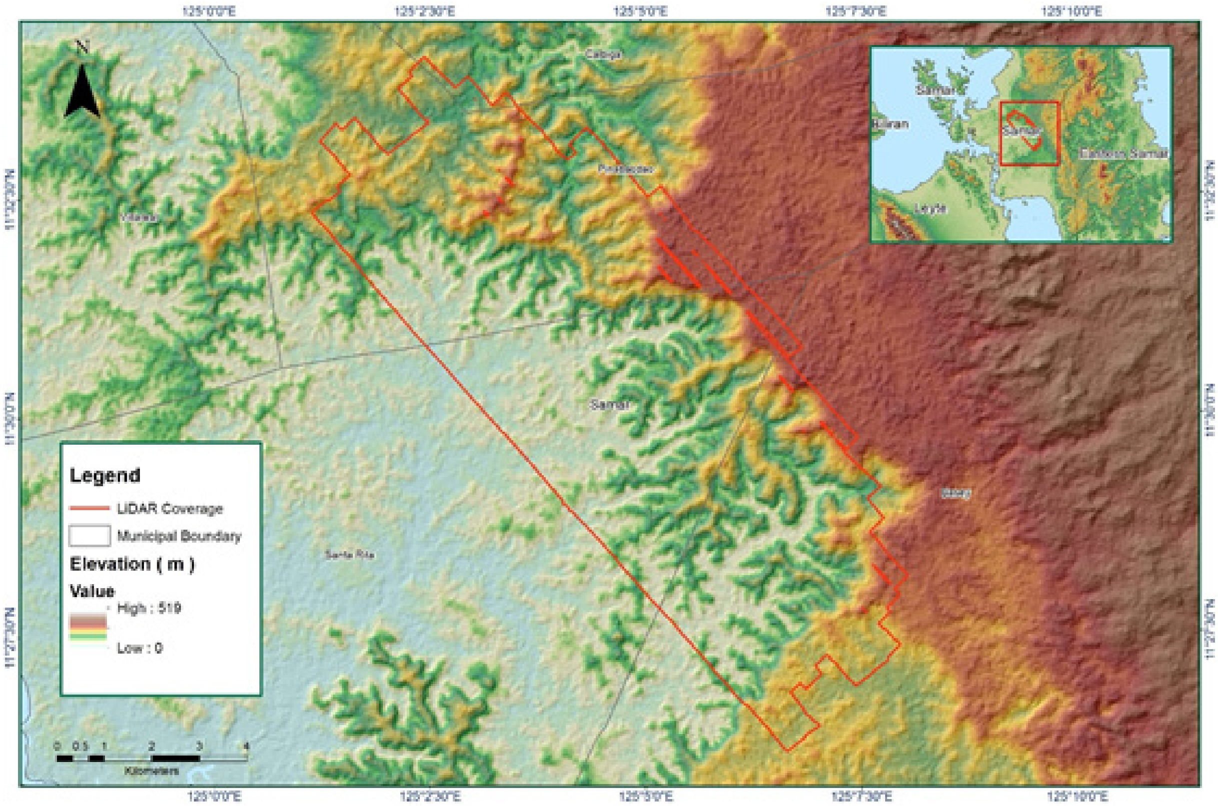


Figure A-8.46. Coverage of LiDAR data

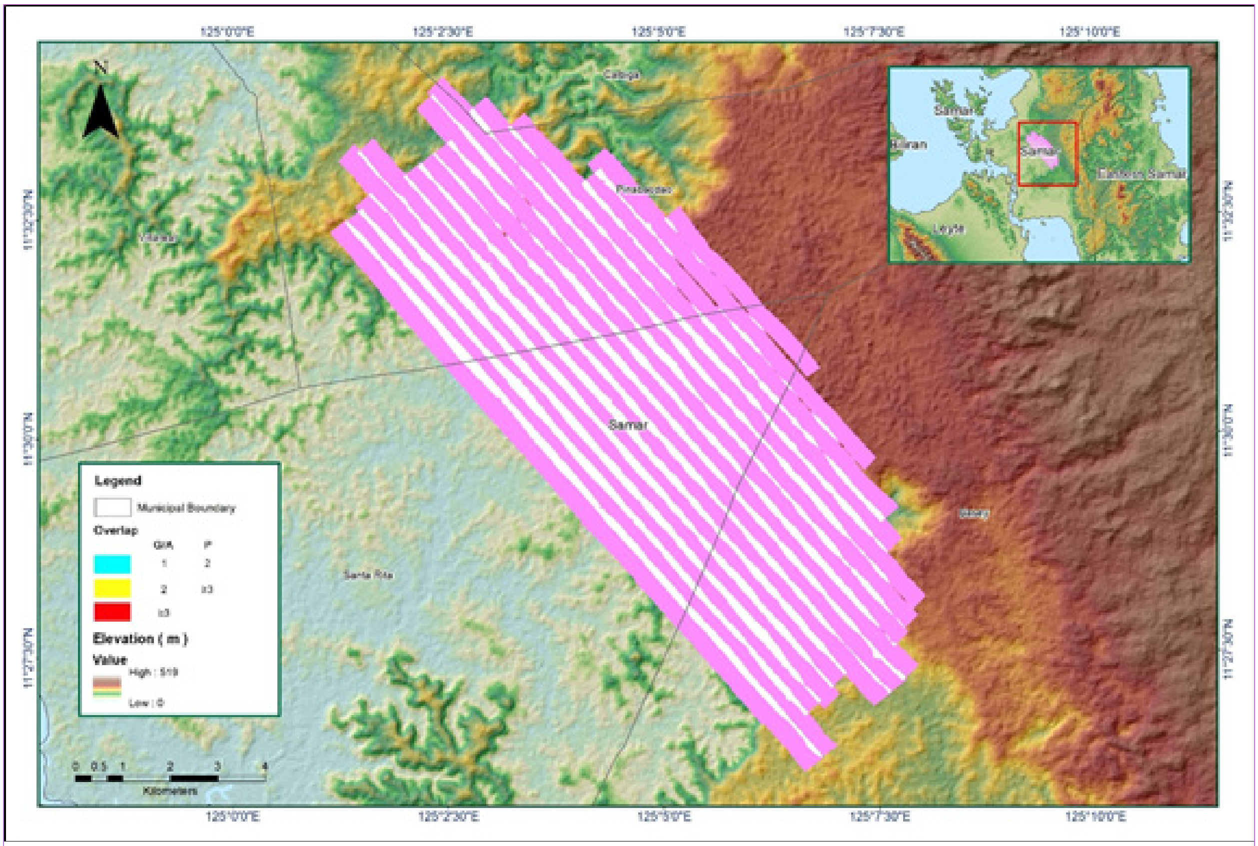


Figure A-8.47. Image of Data Overlap

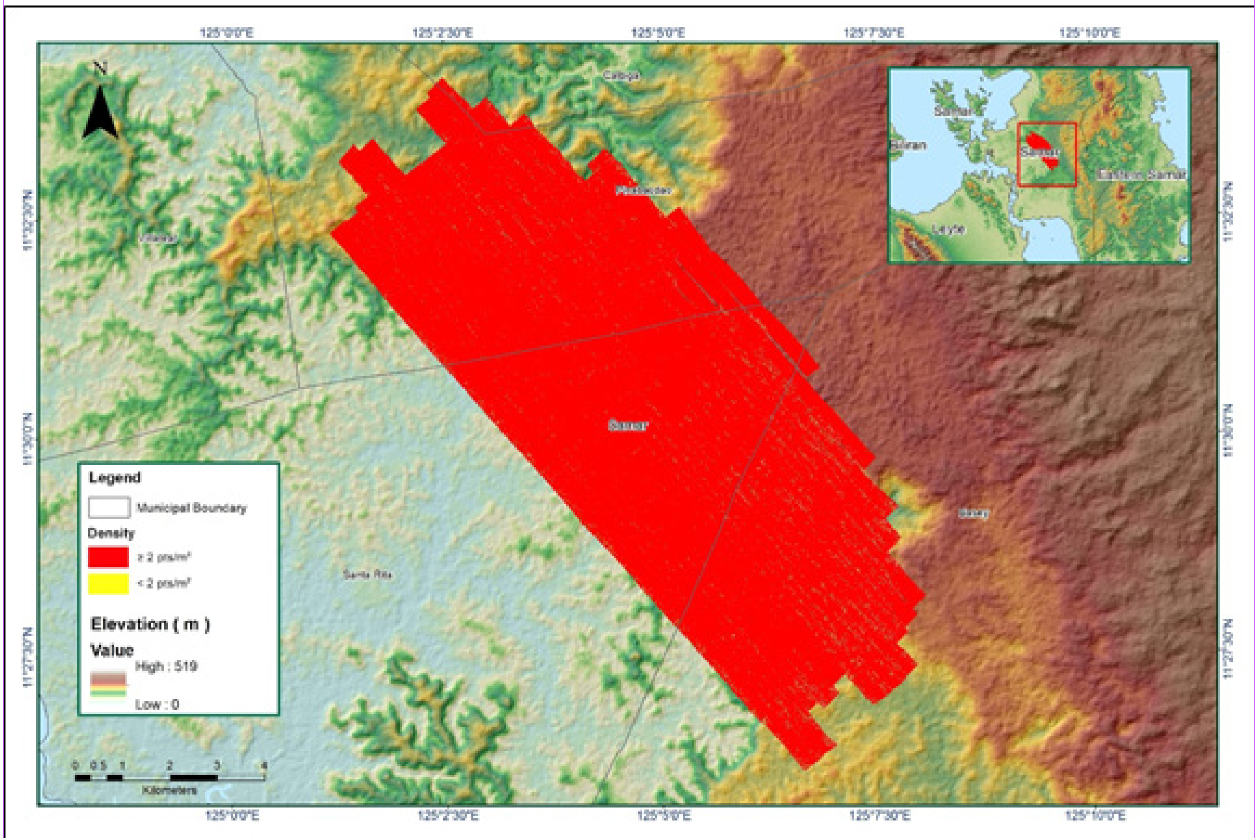


Figure A-8.48. Density map of merged LiDAR data

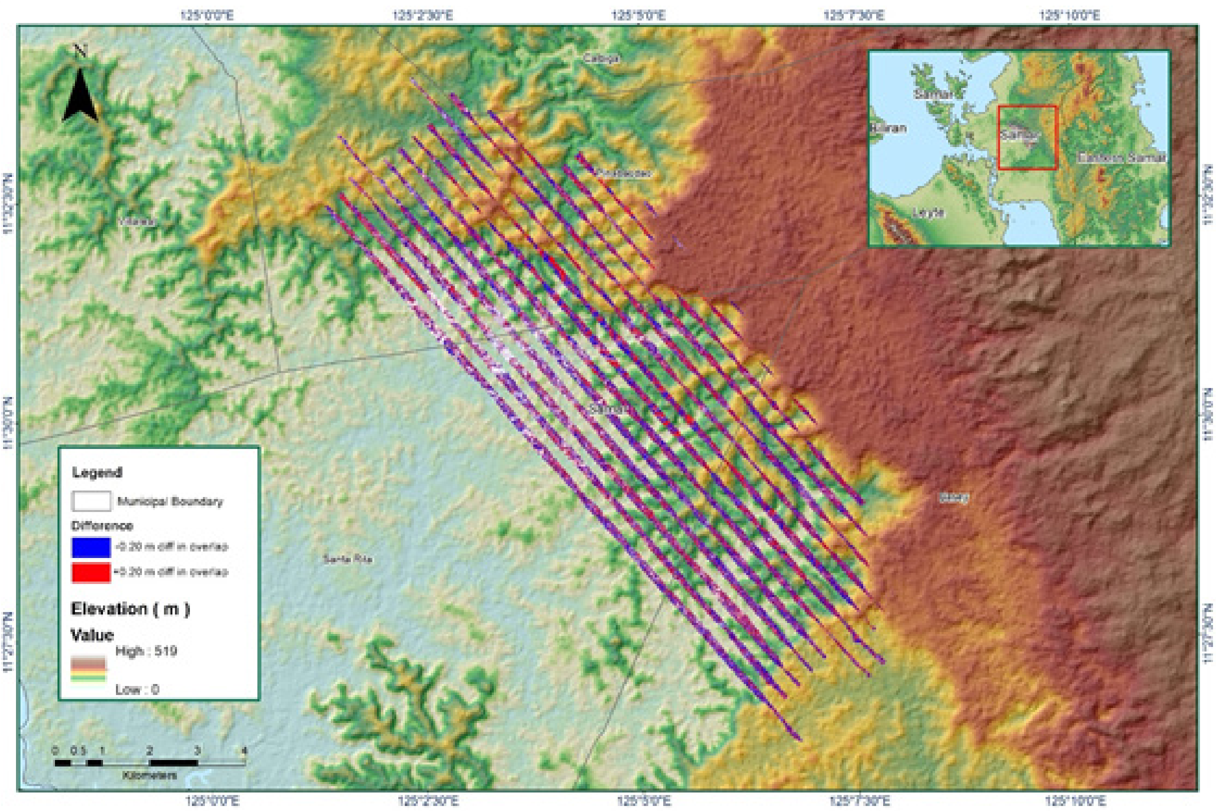


Figure A-8.49. Elevation difference between flight lines

Table A-8.8. Mission Summary Report for Mission 33H_Additional

Flight Area	Leyte
Mission Name	33H_Additional
Inclusive Flights	3729G
Range data size	20.3
POS data size	243
Base data size	608
Image	n/a
Transfer date	February 26, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.7
RMSE for East Position (<4.0 cm)	2.3
RMSE for Down Position (<8.0 cm)	4.1
Boresight correction stdev (<0.001deg)	0.003521
IMU attitude correction stdev (<0.001deg)	0.030644
GPS position stdev (<0.01m)	0.0206
Minimum % overlap (>25)	31.08
Ave point cloud density per sq.m. (>2.0)	5.18
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	58
Maximum Height	300.79 m
Minimum Height	63.31 m
Classification (# of points)	
Ground	15,617,162
Low vegetation	10,785,119
Medium vegetation	71,742,050
High vegetation	55,980,659
Building	1,280,550
Orthophoto	no

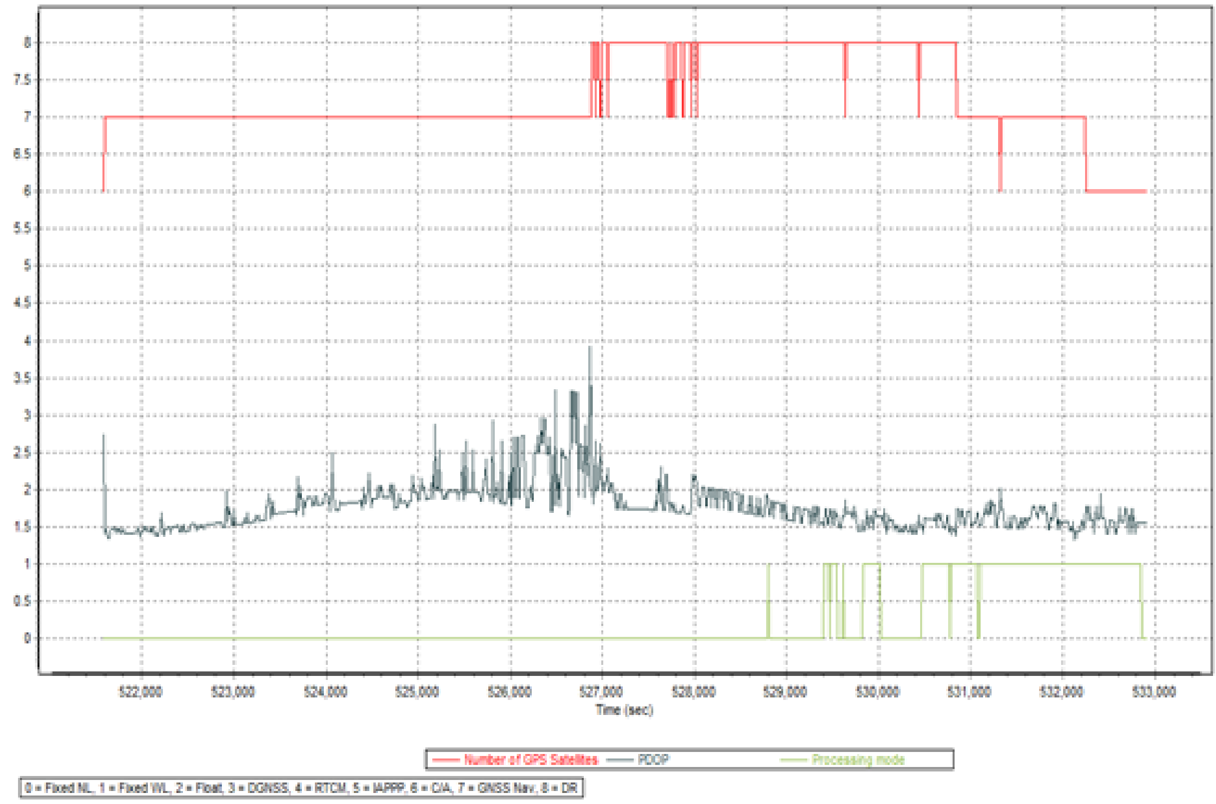


Figure A-8.50. Solution Status

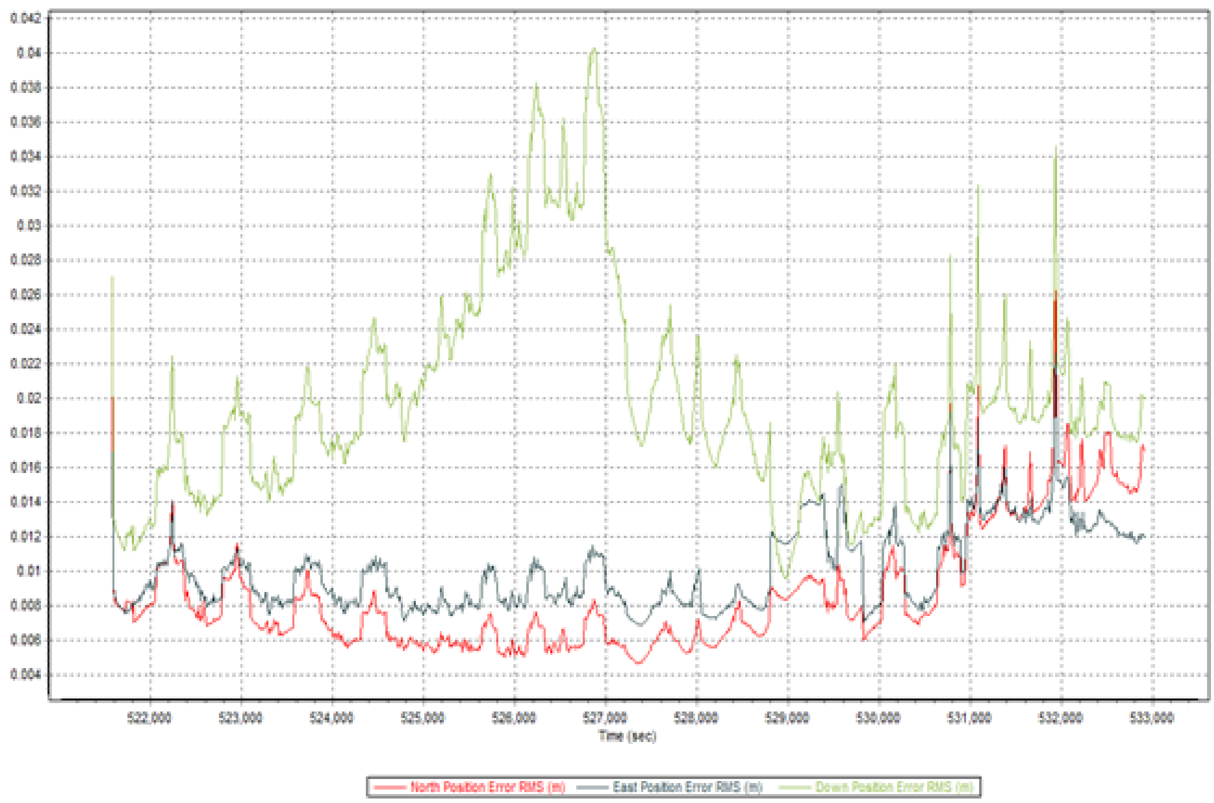


Figure A-8.51. Smoothed Performance Metric Parameters

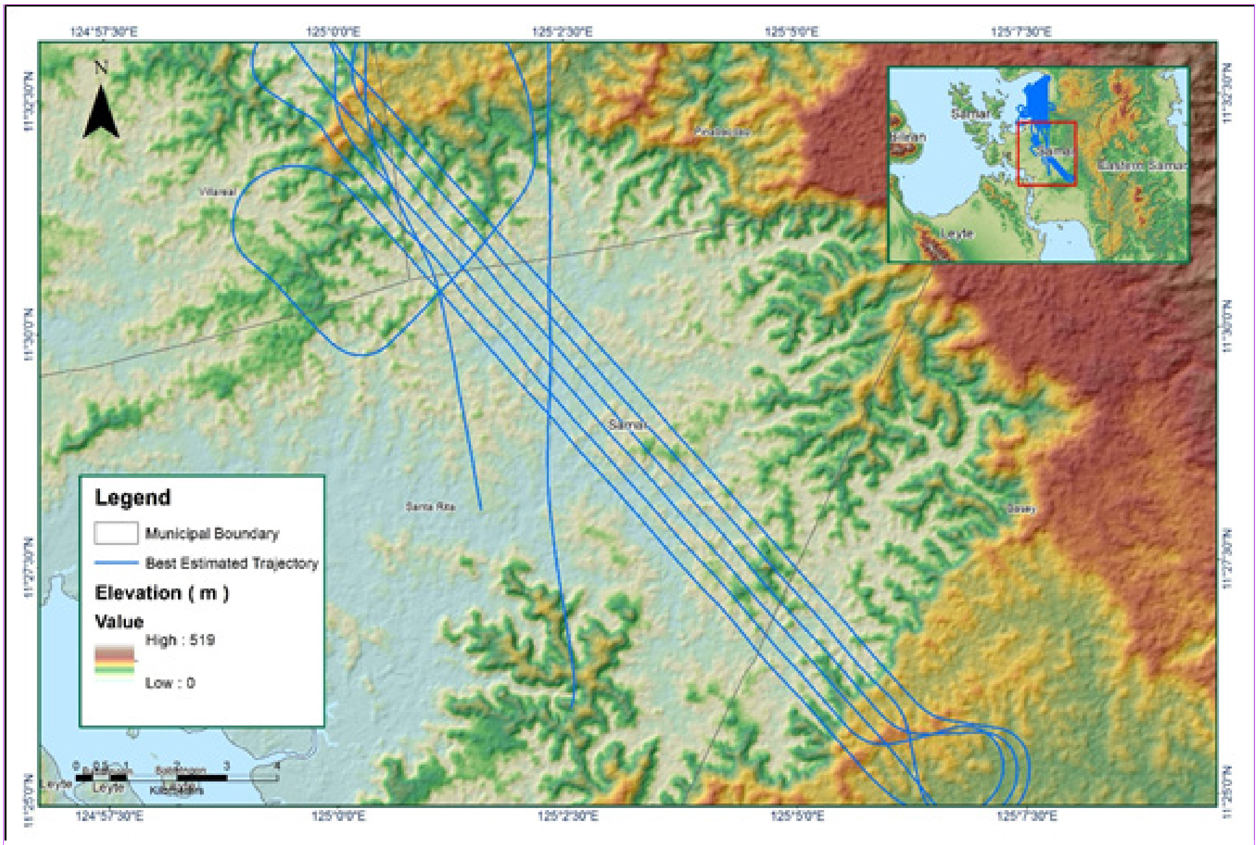


Figure A-8.52. Best Estimated Trajectory

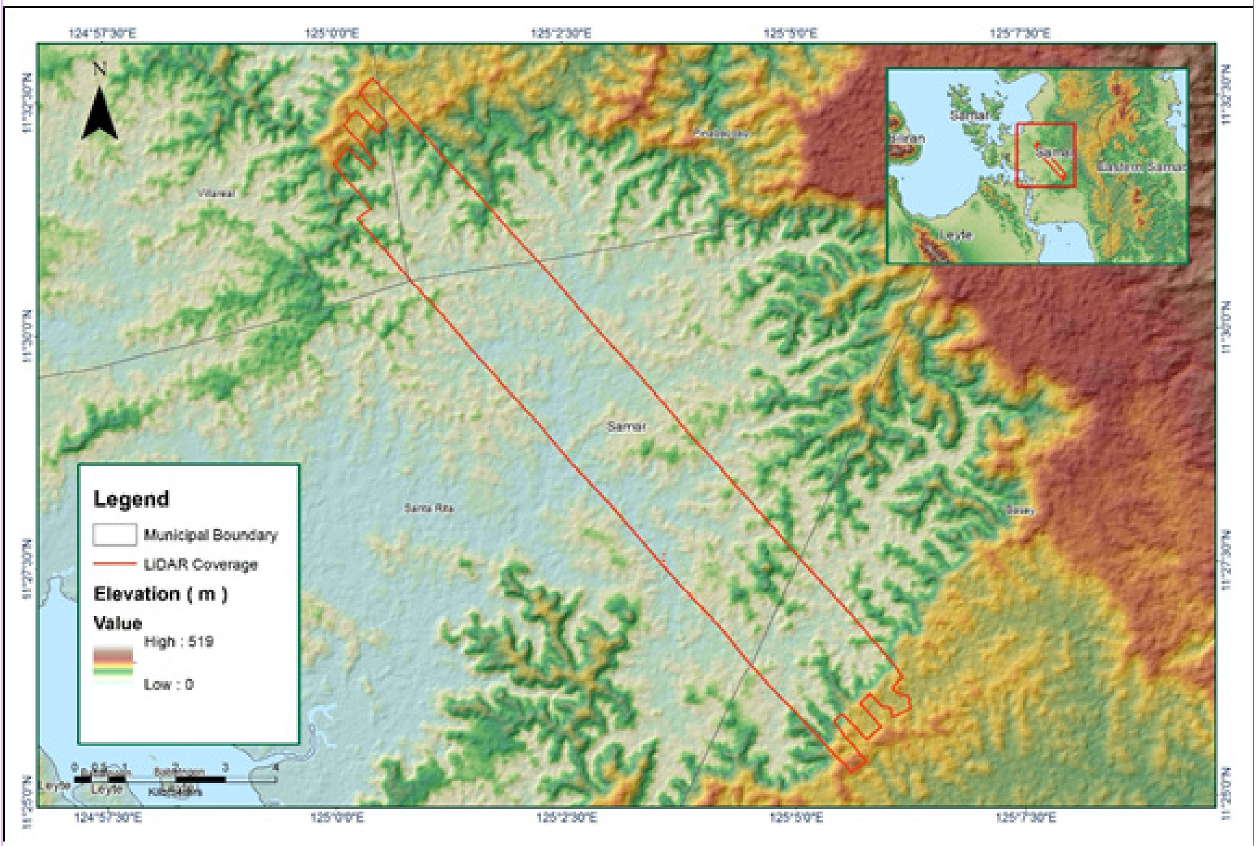


Figure A-8.53. Coverage of LiDAR data

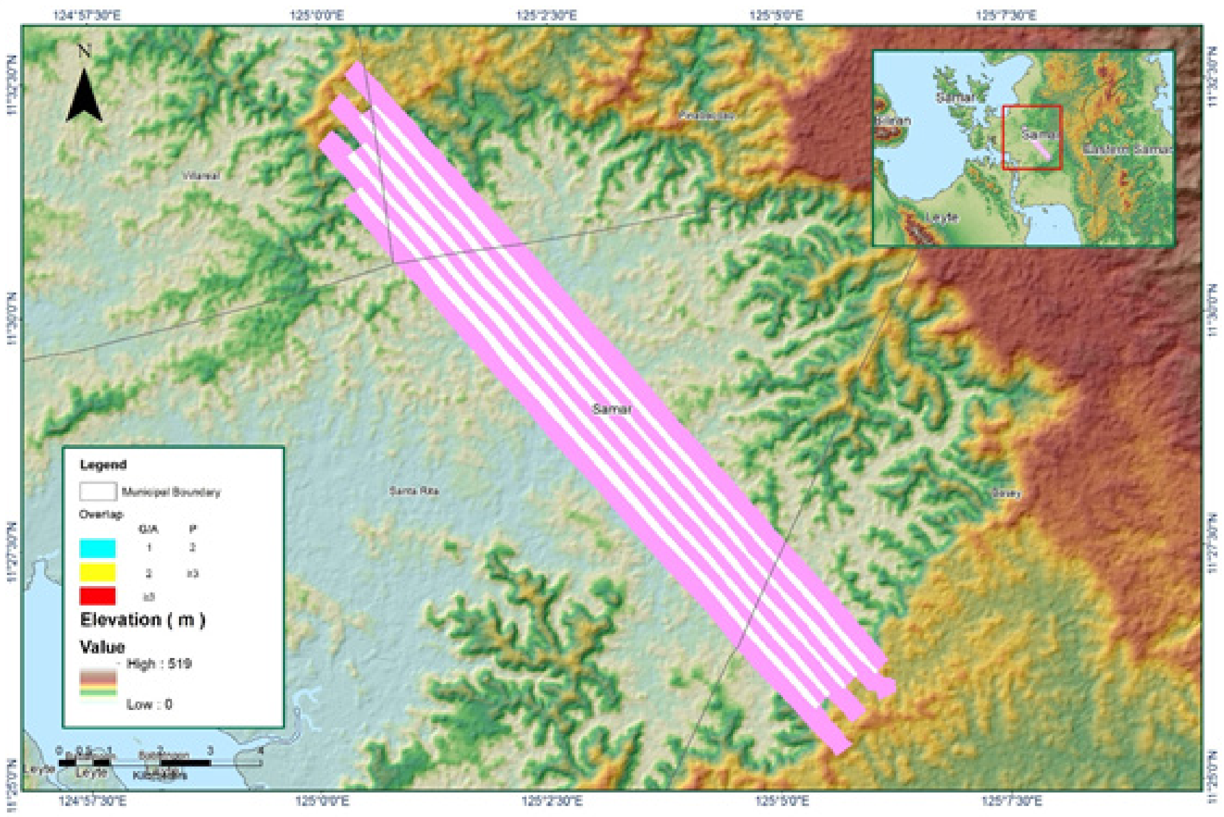


Figure A-8.54. Image of Data Overlap

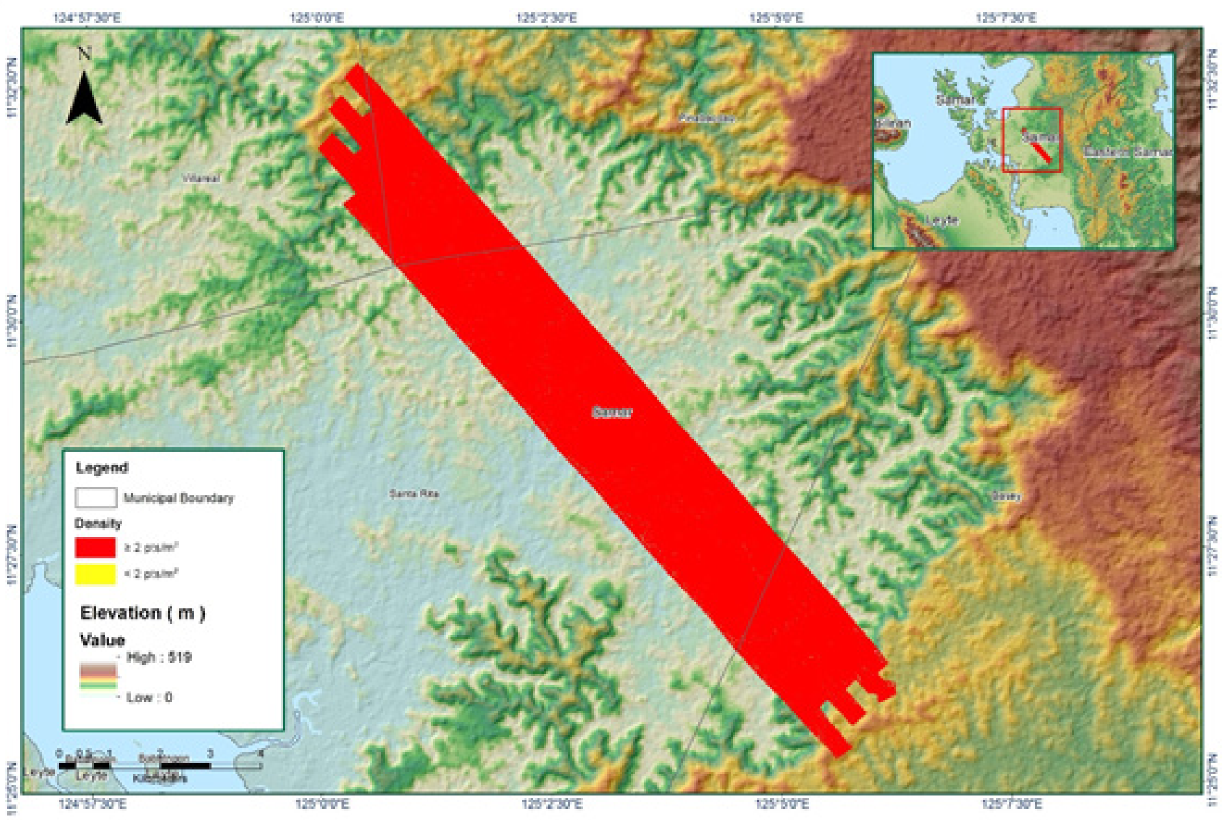


Figure A-8.55. Density map of merged LiDAR data

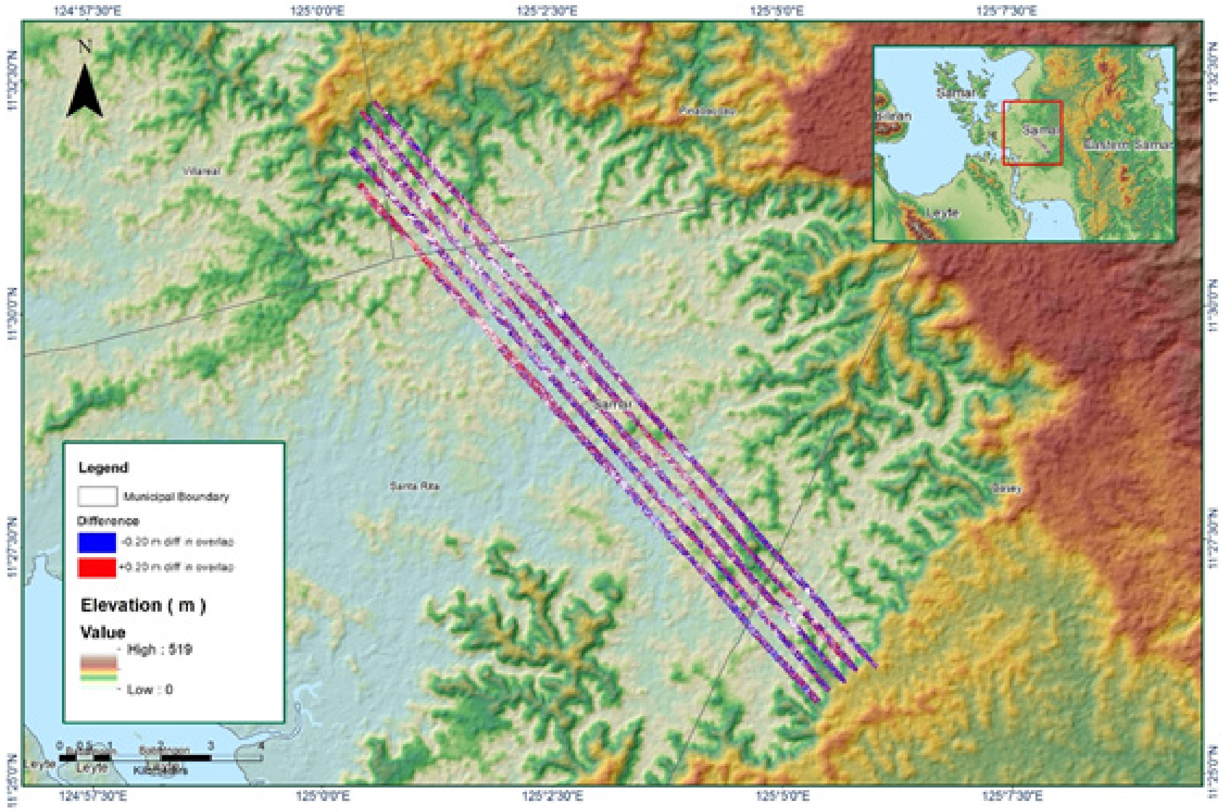


Figure A-8.56. Elevation difference between flight lines

Annex 9. Silaga Model Basin Parameters

Table A-9.1. Silaga 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
W440	5.776456	89.79	0	12.54626	7.166424	Discharge	0.366125	0.9	Ratio to Peak	0.2
W450	5.776456	89.79	0	10.40971	5.946029	Discharge	0.593621	0.9	Ratio to Peak	0.2
W460	5.776456	89.79	0	9.409797	5.374876	Discharge	0.205164	0.9	Ratio to Peak	0.2
W470	5.776456	89.79	0	6.123985	3.49802	Discharge	0.200238	0.9	Ratio to Peak	0.2
W480	5.776456	89.79	0	4.321331	2.468344	Discharge	0.01608	0.9	Ratio to Peak	0.2
W490	5.000705	91.03828	0	9.764839	5.577676	Discharge	0.56993	0.9	Ratio to Peak	0.2
W500	5.776456	89.79	0	11.77943	6.728412	Discharge	0.665369	0.9	Ratio to Peak	0.2
W510	5.776456	89.79	0	10.78423	6.15995	Discharge	0.292793	0.9	Ratio to Peak	0.2
W520	5.776456	89.79	0	9.905031	5.657754	Discharge	0.221365	0.9	Ratio to Peak	0.2
W530	5.776456	89.79	0	11.24833	6.425048	Discharge	0.218335	0.9	Ratio to Peak	0.2
W540	5.776456	89.79	0	11.68633	6.675232	Discharge	0.195648	0.9	Ratio to Peak	0.2
W550	5.776456	89.79	0	5.068391	2.895065	Discharge	0.058335	0.9	Ratio to Peak	0.2
W560	5.468635	90.2812	0	20.82002	11.8924	Discharge	1.062094	0.9	Ratio to Peak	0.2
W570	5.776456	89.79	0	8.236794	4.704857	Discharge	0.074077	0.9	Ratio to Peak	0.2
W580	5.776456	89.79	0	11.33821	6.476385	Discharge	0.315929	0.9	Ratio to Peak	0.2
W590	5.776456	89.79	0	9.19019	5.249436	Discharge	0.131252	0.9	Ratio to Peak	0.2
W600	14.8485	77.38181	0	10.18889	5.819896	Discharge	0.35292	0.9	Ratio to Peak	0.2
W610	20.78498	70.96461	0	9.047255	5.167792	Discharge	0.361908	0.9	Ratio to Peak	0.2
W620	26.51456	65.70561	0	5.256918	3.002752	Discharge	0.060275	0.9	Ratio to Peak	0.2
W630	5.776456	89.79	0	5.840223	3.335935	Discharge	0.038342	0.9	Ratio to Peak	0.2
W640	6.567476	88.55192	0	5.95623	3.402199	Discharge	0.197674	0.9	Ratio to Peak	0.2
W650	5.776456	0.391504	0	13.30978	7.602546	Discharge	0.391504	0.9	Ratio to Peak	0.2
W660	20.26012	0.021907	0	4.092506	2.337639	Discharge	0.021907	0.9	Ratio to Peak	0.2

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W670	17.47625	0.207182	0	10.10314	5.770915	Discharge	0.207182	0.9	Ratio to Peak	0.2
W680	5.776456	0.207797	0	6.8604	3.91866	Discharge	0.207797	0.9	Ratio to Peak	0.2
W690	5.776456	0.27273	0	9.49604	5.424138	Discharge	0.27273	0.9	Ratio to Peak	0.2
W700	5.776456	0.269327	0	9.667173	5.521889	Discharge	0.269327	0.9	Ratio to Peak	0.2
W710	5.776456	0.298811	0	9.865878	5.63539	Discharge	0.298811	0.9	Ratio to Peak	0.2
W720	5.776456	0.003429	0	2.82535	1.61384	Discharge	0.003429	0.9	Ratio to Peak	0.2
W730	5.776456	0.28506	0	10.50658	6.00136	Discharge	0.28506	0.9	Ratio to Peak	0.2
W740	5.776456	0.22495	0	10.97801	6.270637	Discharge	0.22495	0.9	Ratio to Peak	0.2
W750	5.776456	0.352652	0	12.19037	6.963138	Discharge	0.352652	0.9	Ratio to Peak	0.2
W760	7.890084	0.301339	0	8.827811	5.042446	Discharge	0.301339	0.9	Ratio to Peak	0.2
W770	5.776456	0.026739	0	2.946544	1.683066	Discharge	0.026739	0.9	Ratio to Peak	0.2
W780	5.776456	0.073012	0	7.095053	4.052694	Discharge	0.073012	0.9	Ratio to Peak	0.2
W790	4.629274	0.206255	0	5.902831	3.371697	Discharge	0.206255	0.9	Ratio to Peak	0.2
W800	5.776456	0.39715	0	10.31859	5.893977	Discharge	0.39715	0.9	Ratio to Peak	0.2
W810	5.776456	1322132	0	9.9635	5.691151	Discharge	1322132	0.9	Ratio to Peak	0.2
W820	5.776456	0.390716	0	9.652323	5.513407	Discharge	0.390716	0.9	Ratio to Peak	0.2
W830	5.776456	0.23399	0	8.549502	4.883476	Discharge	0.23399	0.9	Ratio to Peak	0.2
W840	5.776456	0.467694	0	9.381283	5.358589	Discharge	0.467694	0.9	Ratio to Peak	0.2
W850	5.776456	0.218404	0	6.671221	3.810602	Discharge	0.218404	0.9	Ratio to Peak	0.2
W860	5.776456	0.214213	0	5.680626	3.244774	Discharge	0.214213	0.9	Ratio to Peak	0.2

Annex 10. Silaga Model Reach Parameters

Table A-10.1. Silaga Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R100	Automatic Fixed Interval	3253.3	0.0010376	0.04	Trapezoid	2.9357	45
R110	Automatic Fixed Interval	1954.5	0.0023034	0.04	Trapezoid	2.9357	45
R120	Automatic Fixed Interval	895.98	0.0054850	0.04	Trapezoid	2.9357	45
R130	Automatic Fixed Interval	952.25	0.0030204	0.04	Trapezoid	2.9357	45
R170	Automatic Fixed Interval	1731.8	0.0028871	0.04	Trapezoid	2.9357	45
R200	Automatic Fixed Interval	1378.4	0.0061326	0.04	Trapezoid	3.7971	45
R210	Automatic Fixed Interval	70.711	0.0054850	0.04	Trapezoid	3.7971	45
R220	Automatic Fixed Interval	962.13	0.0054850	0.04	Trapezoid	5.1843	45
R240	Automatic Fixed Interval	1675.4	0.0054850	0.04	Trapezoid	5.1843	45
R260	Automatic Fixed Interval	545.56	0.0128885	0.04	Trapezoid	5.1843	45
R280	Automatic Fixed Interval	1328.9	.00041639212451911303	0.04	Trapezoid	7.1843	45
R290	Automatic Fixed Interval	1554.4	0.0054850	0.04	Trapezoid	7.1843	45
R300	Automatic Fixed Interval	2300.7	0.0026026	0.04	Trapezoid	17.496	45
R320	Automatic Fixed Interval	641.84	0.0060751	0.04	Trapezoid	17.496	45
R360	Automatic Fixed Interval	1498.8	.0003337698024512234	0.04	Trapezoid	8.2643	45
R370	Automatic Fixed Interval	3525.2	0.0016534	0.04	Trapezoid	8.2643	45
R380	Automatic Fixed Interval	1880.4	0.0028998	0.04	Trapezoid	8.2643	45
R390	Automatic Fixed Interval	1973.4	0.0029257	0.04	Trapezoid	8.2643	45
R400	Automatic Fixed Interval	2528.9	0.0025997	0.04	Trapezoid	13.793	45
R60	Automatic Fixed Interval	972.13	0.0054850	0.04	Trapezoid	13.793	45
R90	Automatic Fixed Interval	922.13	0.0054850	0.04	Trapezoid	13.793	45

Annex 11. Silaga Field Validation Points

Table A-11.1. Silaga Field Validation Points

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
1	11.469636	125.007264	0.03	0.4	-0.37	Seniang/ December 28, 2014	5 -Year
2	11.469636	125.007264	0.03	0.55	-0.52	Ruby/ December 06,2014	5 -Year
3	11.470091	125.004375	0.03	0.3	-0.27	Ruby/ December 06,2014	5 -Year
4	11.469637	125.006777	0.03	1.2	-1.17	Ruby/ December 06,2014	5 -Year
5	11.469637	125.006777	0.03	0.3	-0.27	Yolanda/ November 08,2013	5 -Year
6	11.46931	125.006658	0.03	0.7	-0.67	Ruby/ December 06,2014	5 -Year
7	11.469111	125.006946	0.04	1.6	-1.56	Ruby/ December 06,2014	5 -Year
8	11.469023	125.007442	0.03	1.8	-1.77	Ruby/ December 06,2014	5 -Year
9	11.469023	125.007442	0.03	1.8	-1.77	Seniang/ December 28,2014	5 -Year
10	11.46897	125.007775	0.03	1.83	-1.80	Ruby/ December 06,2014	5 -Year
11	11.46897	125.007775	0.03	1.8	-1.77	Seniang/ December 28,2014	5 -Year
12	11.469434	125.008009	0.03	1	-0.97	Ruby/ December 06,2014	5 -Year
13	11.469434	125.008009	0.03	1	-0.97	Seniang/ December 28,2014	5 -Year
14	11.46963	125.007948	0.06	1	-0.94	Ruby/ December 06,2014	5 -Year
15	11.46963	125.007948	0.06	1	-0.94	Seniang/ December 28,2014	5 -Year
16	11.469345	125.009246	0.03	0.5	-0.47	Ruby/ December 06,2014	5 -Year
17	11.469121	125.010176	0.03	0.5	-0.47	Ruby/ December 06,2014	5 -Year
18	11.469121	125.010176	0.03	0.5	-0.47	Seniang/ December 28,2014	5 -Year
19	11.470988	125.011678	0.03	0.4	-0.37	Yolanda/ November 08,2013	5 -Year
20	11.470988	125.011678	0.03	0.4	-0.37	Ruby/ December 06,2014	5 -Year
21	11.471258	125.011856	0.03	0.1	-0.07	Ruby/ December 06,2014	5 -Year
22	11.472299	125.014507	0.03	0	0.03	Ruby/ December 06,2014	5 -Year
23	11.471979	125.015616	0.03	0.1	-0.07	Ruby/ December 06,2014	5 -Year
24	11.470944	125.017604	0.03	2	-1.97	Ruby/ December 06,2014	5 -Year
25	11.470944	125.017604	0.03	1	-0.97	Seniang/ December 28,2014	5 -Year
26	11.471164	125.017316	0.03	2	-1.97	Ruby/ December 06,2014	5 -Year
27	11.471164	125.017316	0.03	1	-0.97	Seniang/ December 28,2014	5 -Year
28	11.46967	125.018798	0.14	1.8	-1.66	Ruby/ December 06,2014	5 -Year
29	11.469327	125.019109	0.63	3	-2.37	Ruby/ December 06,2014	5 -Year
30	11.469327	125.019109	0.63	0.3	0.33	Seniang/ December 28,2014	5 -Year
31	11.469065	125.018921	0.42	2	-1.58	Ruby/ December 06,2014	5 -Year
32	11.469065	125.018921	0.42	0.3	0.12	Seniang/ December 28,2014	5 -Year
33	11.469123	125.01918	0.06	3	-2.94	Ruby/ December 06,2014	5 -Year
34	11.469123	125.01918	0.06	0	0.06	Seniang/ December 28,2014	5 -Year
35	11.469123	125.01918	0.06	0	0.06	Yolanda/ November 08,2013	5 -Year
36	11.471914	125.021687	0.09	0.5	-0.41	Ruby/ December 06,2014	5 -Year
37	11.471914	125.021687	0.09	0.3	-0.21	Seniang/ December 28,2014	5 -Year
38	11.470777	125.020887	0.03	1.5	-1.47	Ruby/ December 06,2014	5 -Year
39	11.470536	125.020637	0.37	2	-1.63	Ruby/ December 06,2014	5 -Year
40	11.470536	125.020637	0.37	1	-0.63	Seniang/ December 28,2014	5 -Year
41	11.470239	125.020523	0.03	1.5	-1.47	Ruby/ December 06,2014	5 -Year
42	11.469678	125.02013	0.09	1.8	-1.71	Ruby/ December 06,2014	5 -Year
43	11.469079	125.019746	0.36	2.5	-2.14	Ruby/ December 06,2014	5 -Year
44	11.468933	125.019764	0.65	1.8	-1.15	Ruby/ December 06,2014	5 -Year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
45	11.468933	125.019764	0.65	1.3	-0.65	Ruby/ December 06,2014	5 -Year
46	11.467811	125.019335	0.03	1	-0.97	Seniang/ December 28,2014	5 -Year
47	11.468136	125.018893	0.03	3	-2.97	Ruby/ December 06,2014	5 -Year
48	11.467619	125.018588	0.03	0.5	-0.47	Ruby/ December 06,2014	5 -Year
49	11.467308	125.018813	0.04	1.2	-1.16	Ruby/ December 06,2014	5 -Year
50	11.466865	125.018939	0.05	0.5	-0.45	Ruby/ December 06,2014	5 -Year
51	11.466632	125.019775	0.08	1	-0.92	Ruby/ December 06,2014	5 -Year
52	11.466777	125.020018	0.03	2	-1.97	Ruby/ December 06,2014	5 -Year
53	11.466777	125.020018	0.03	1.9	-1.87	Seniang/ December 28,2014	5 -Year
54	11.466962	125.020648	0.03	1.5	-1.47	Yolanda/ November 08,2013	5 -Year
55	11.466962	125.020648	0.03	1.5	-1.47	Ruby/ December 06,2014	5 -Year
56	11.465517	125.01899	0.03	2.5	-2.47	Ruby/ December 06,2014	5 -Year
57	11.46308	125.019894	0.03	1.3	-1.27	Ruby/ December 06,2014	5 -Year
58	11.46308	125.019894	0.03	1.3	-1.27	Seniang/ December 28,2014	5 -Year
59	11.453217	125.047119	0.34	0.1	0.24	Ruby/ December 06,2014	5 -Year
60	11.453313	125.046954	0.88	0.2	0.68	Ruby/ December 06,2014	5 -Year
61	11.455404	125.042216	0.57	0.5	0.07	Ruby/ December 06,2014	5 -Year
62	11.455571	125.039597	0.78	0.5	0.28	Ruby/ December 06,2014	5 -Year
63	11.455962	125.038588	0.04	0.1	-0.06	Ruby/ December 06,2014	5 -Year
64	11.459373	125.035452	0.03	0	0.03	Ruby/ December 06,2014	5 -Year
65	11.459458	125.036073	0.03	0	0.03	Ruby/ December 06,2014	5 -Year
66	11.453623	125.025251	0.52	0.5	0.02	Ruby/ December 06,2014	5 -Year
67	11.453811	125.025556	0.45	0.9	-0.45	Ruby/ December 06,2014	5 -Year
68	11.452287	125.023689	0.03	0.6	-0.57	Ruby/ December 06,2014	5 -Year
69	11.452061	125.022668	0.22	1	-0.78	Ruby/ December 06,2014	5 -Year
70	11.451976	125.022163	0.23	1	-0.77	Ruby/ December 06,2014	5 -Year
71	11.451855	125.021247	0.51	0.6	-0.09	Ruby/ December 06,2014	5 -Year
72	11.451733	125.020264	0.75	0.6	0.15	Ruby/ December 06,2014	5 -Year
73	11.45469	125.02051	0.03	0	0.03	Ruby/ December 06,2014	5 -Year
74	11.454725	125.020701	0.03	0	0.03	Ruby/ December 06,2014	5 -Year
75	11.45298	125.020502	0.03	0	0.03	Ruby/ December 06,2014	5 -Year
76	11.452151	125.019888	0.70	0.5	0.20	Ruby/ December 06,2014	5 -Year
77	11.4511	125.019187	0.22	0.3	-0.08	Ruby/ December 06,2014	5 -Year
78	11.451026	125.019251	0.48	1.45	-0.97	Ruby/ December 06,2014	5 -Year
79	11.451026	125.019251	0.48	1.3	-0.82	Seniang/ December 28,2014	5 -Year
80	11.451026	125.019251	0.48	0.6	-0.12	Yolanda/ November 08,2013	5 -Year
81	11.450119	125.018005	0.09	0.2	-0.11	Ruby/ December 06,2014	5 -Year
82	11.449962	125.018032	0.14	0.3	-0.16	Yolanda/ November 08,2013	5 -Year
83	11.449962	125.018032	0.14	0.3	-0.16	Ruby/ December 06,2014	5 -Year
84	11.44993	125.017559	0.74	0.8	-0.06	Ruby/ December 06,2014	5 -Year
85	11.44993	125.017559	0.74	0.5	0.24	Seniang/ December 28,2014	5 -Year
86	11.449654	125.017804	1.10	0.8	0.30	Ruby/ December 06,2014	5 -Year
87	11.449654	125.017804	1.10	0.4	0.70	Seniang/ December 28,2014	5 -Year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
88	11.448587	125.016723	0.03	2.2	-2.17	Ruby/ December 06,2014	5 -Year
89	11.447442	125.017387	0.09	0.2	-0.11	Yolanda/ November 08,2013	5 -Year
90	11.447442	125.017387	0.09	0.5	-0.41	Ruby/ December 06,2014	5 -Year
91	11.447403	125.017929	0.03	0.6	-0.57	Ruby/ December 06,2014	5 -Year
92	11.447016	125.017595	0.58	0	0.58	Ruby/ December 06,2014	5 -Year
93	11.443535	125.016897	0.12	0.5	-0.38	Ruby/ December 06,2014	5 -Year
95	11.443561	125.017043	0.21	0.6	-0.39	Ruby/ December 06,2014	5 -Year
96	11.443115	125.016657	0.03	1.5	-1.47	Ruby/ December 06,2014	5 -Year
97	11.443115	125.016657	0.03	0.5	-0.47	Seniang/ December 28,2014	5 -Year
98	11.442941	125.01636	0.03	0.5	-0.47	Ruby/ December 06,2014	5 -Year
99	11.442599	125.01631	0.03	0.2	-0.17	Ruby/ December 06,2014	5 -Year
100	11.443903	125.013701	0.03	1.5	-1.47	Ruby/ December 06,2014	5 -Year
101	11.444192	125.01277	0.05	1.5	-1.45	Ruby/ December 06,2014	5 -Year
102	11.444041	125.012456	0.06	1.6	-1.54	Ruby/ December 06,2014	5 -Year
103	11.444371	125.012231	0.15	0.5	-0.35	Seniang/ December 28,2014	5 -Year
104	11.444371	125.012231	0.15	1.8	-1.65	Ruby/ December 06,2014	5 -Year
105	11.444371	125.012231	0.15	1.8	-1.65	Seniang/ December 28,2014	5 -Year
106	11.444433	125.012016	0.31	1.7	-1.39	Ruby/ December 06,2014	5 -Year
107	11.444421	125.011854	0.12	2	-1.88	Ruby/ December 06,2014	5 -Year
108	11.440143	125.015952	0.03	0	0.03	Ruby/ December 06,2014	5 -Year
109	11.439953	125.015973	0.04	0.1	-0.06	Ruby/ December 06,2014	5 -Year
110	11.434849	125.014525	0.19	0	0.19	Ruby/ December 06,2014	5 -Year
111	11.435787	125.014744	0.03	0.9	-0.87	Ruby/ December 06,2014	5 -Year
112	11.436648	125.01492	0.11	0.9	-0.79	Ruby/ December 06,2014	5 -Year
113	11.436791	125.01478	0.17	0.75	-0.58	Ruby/ December 06,2014	5 -Year
114	11.437219	125.015198	0.03	0	0.03	Ruby/ December 06,2014	5 -Year
115	11.437396	125.015654	0.03	0	0.03	Ruby/ December 06,2014	5 -Year
116	11.438176	125.015018	0.03	0.5	-0.47	Yolanda/ November 08,2013	5 -Year
117	11.438176	125.015018	0.03	1.3	-1.27	Ruby/ December 06,2014	5 -Year
118	11.438331	125.014507	0.13	1.3	-1.17	Ruby/ December 06,2014	5 -Year
119	11.438331	125.014507	0.13	0.5	-0.37	Yolanda/ November 08,2013	5 -Year
120	11.438331	125.014507	0.13	1.3	-1.17	Seniang/ December 28,2014	5 -Year
121	11.438731	125.014386	0.04	1	-0.96	Ruby/ December 06,2014	5 -Year
122	11.438922	125.014563	0.11	1	-0.89	Seniang/ December 28,2014	5 -Year
123	11.438922	125.014563	0.11	1	-0.89	Ruby/ December 06,2014	5 -Year
124	11.439961	125.015718	0.03	0	0.03	Ruby/ December 06,2014	5 -Year
125	11.439283	125.015658	0.03	1.3	-1.27	Ruby/ December 06,2014	5 -Year
126	11.452703	124.947367	0.00	1.5	-1.50	Ruby/ December 06,2014	5 -Year
127	11.452703	124.947367	0.00	0.4	-0.40	Yolanda/ November 08,2013	5 -Year
128	11.450617	124.943519	0.00	0.7	-0.70	Ruby/ December 06,2014	5 -Year
129	11.450617	124.943519	0.00	0	0.00	Yolanda/ November 08,2013	5 -Year
130	11.450617	124.943519	0.00	0	0.00	Seniang/ December 28,2014	5 -Year
131	11.450654	124.943256	0.00	0.8	-0.80	Ruby/ December 06,2014	5 -Year
132	11.450654	124.943256	0.00	0	0.00	Yolanda/ November 08,2013	5 -Year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
133	11.470802	125.000068	0.03	1.93	-1.90	Yolanda/ November 08,2013	5 -Year
134	11.470802	125.000068	0.03	2.34	-2.31	Ruby/ December 06,2014	5 -Year
135	11.470733	125.000033	0.03	0	0.03	Ruby/ December 06,2014	5 -Year
136	11.470757	124.999738	0.03	0	0.03	Ruby/ December 06,2014	5 -Year
137	11.470771	124.999538	0.03	0	0.03	Ruby/ December 06,2014	5 -Year
138	11.470776	124.998913	0.42	2.6	-2.18	Ruby/ December 06,2014	5 -Year
139	11.470776	124.998913	0.42	0	0.42	Yolanda/ November 08,2013	5 -Year
140	11.470666	124.998914	0.03	0.3	-0.27	Ruby/ December 06,2014	5 -Year
141	11.470504	124.998384	0.03	1.4	-1.37	Ruby/ December 06,2014	5 -Year
142	11.47056	124.998425	0.03	1	-0.97	Ruby/ December 06,2014	5 -Year
143	11.470424	124.997806	0.03	1.4	-1.37	Ruby/ December 06,2014	5 -Year
144	11.47028	124.997449	0.03	0.6	-0.57	Ruby/ December 06,2014	5 -Year
145	11.47028	124.997449	0.03	0	0.03	Yolanda/ November 08,2013	5 -Year
146	11.47028	124.997449	0.03	0.6	-0.57	Seniang/ December 28,2014	5 -Year
147	11.470357	124.997195	0.04	1.37	-1.33	Ruby/ December 06,2014	5 -Year
148	11.470138	124.997025	0.03	0	0.03	Ruby/ December 06,2014	5 -Year
149	11.469512	124.996898	0.03	1.2	-1.17	Ruby/ December 06,2014	5 -Year
150	11.469512	124.996898	0.03	0	0.03	Yolanda/ November 08,2013	5 -Year
151	11.469297	124.997	0.03	2.8	-2.77	Ruby/ December 06,2014	5 -Year
152	11.469297	124.997	0.03	0.6	-0.57	Yolanda/ November 08,2013	5 -Year
153	11.468949	124.996776	0.03	1	-0.97	Ruby/ December 06,2014	5 -Year
154	11.468949	124.996776	0.03	0.2	-0.17	Yolanda/ November 08,2013	5 -Year
155	11.468244	124.99573	0.03	0.1	-0.07	Ruby/ December 06,2014	5 -Year
156	11.468176	124.995287	0.04	1.2	-1.16	Ruby/ December 06,2014	5 -Year
157	11.467655	124.994448	0.03	1.3	-1.27	Ruby/ December 06,2014	5 -Year
158	11.467679	124.993825	0.03	1	-0.97	Ruby/ December 06,2014	5 -Year
159	11.467535	124.993688	0.03	0.8	-0.77	Ruby/ December 06,2014	5 -Year
160	11.466936	124.98977	0.03	0	0.03	Ruby/ December 06,2014	5 -Year
161	11.466936	124.98977	0.03	0	0.03	Yolanda/ November 08,2013	5 -Year
162	11.465524	124.98423	0.03	0	0.03	Ruby/ December 06,2014	5 -Year
163	11.465524	124.98423	0.03	0	0.03	Yolanda/ November 08,2013	5 -Year
164	11.463908	124.980895	0.03	0.1	-0.07	Ruby/ December 06,2014	5 -Year
165	11.463818	124.980673	0.03	0.2	-0.17	Ruby/ December 06,2014	5 -Year
166	11.461979	124.976764	0.03	0	0.03	Ruby/ December 06,2014	5 -Year
167	11.461902	124.976741	0.03	0.3	-0.27	Ruby/ December 06,2014	5 -Year
168	11.460744	124.971963	0.04	0.4	-0.36	Ruby/ December 06,2014	5 -Year
169	11.461114	124.968854	0.03	0.5	-0.47	Ruby/ December 06,2014	5 -Year
170	11.464359	124.964488	0.03	0	0.03	Ruby/ December 06,2014	5 -Year
171	11.464359	124.964488	0.03	0	0.03	Yolanda/ November 08,2013	5 -Year
172	11.492136	125.027114	0.04	0.15	-0.11	Ruby/ December 06,2014	5 -Year
173	11.492136	125.027114	0.04	0.15	-0.11	Yolanda/ November 08,2013	5 -Year
174	11.513774	125.025118	0.03	0	0.03	Ruby/ December 06,2014	5 -Year
175	11.513774	125.025118	0.03	0	0.03	Yolanda/ November 08,2013	5 -Year
176	11.509965	125.025997	0.03	0	0.03	Ruby/ December 06,2014	5 -Year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
177	11.509965	125.025997	0.03	0	0.03	Yolanda/ November 08,2013	5 -Year
178	11.505259	125.026345	0.03	0	0.03	Ruby/ December 06,2014	5 -Year
179	11.504752	125.026523	0.76	0.4	0.36	Ruby/ December 06,2014	5 -Year
180	11.49549	125.027427	1.12	0.6	0.52	Ruby/ December 06,2014	5 -Year
181	11.493852	125.027178	0.26	0	0.26	Ruby/ December 06,2014	5 -Year
182	11.492681	125.026986	0.03	0.4	-0.37	Ruby/ December 06,2014	5 -Year
183	11.490751	125.027408	0.06	0.84	-0.78	Ruby/ December 06,2014	5 -Year
184	11.490824	125.027416	0.09	0.3	-0.21	Ruby/ December 06,2014	5 -Year
185	11.461426	125.039383	0.03	0.4	-0.37	Ruby/ December 06,2014	5 -Year
186	11.453405	125.046976	0.93	0	0.93	Ruby/ December 06,2014	5 -Year
187	11.428831	125.012431	0.03	0.4	-0.37	Ruby/ December 06,2014	5 -Year
188	11.42932	125.012837	0.03	0	0.03	Ruby/ December 06,2014	5 -Year
189	11.429864	125.013222	0.82	0.8	0.02	Ruby/ December 06,2014	5 -Year
190	11.430022	125.013345	0.59	0.5	0.09	Ruby/ December 06,2014	5 -Year
191	11.429926	125.013617	0.81	0.8	0.01	Ruby/ December 06,2014	5 -Year
192	11.430127	125.013632	0.32	0.4	-0.08	Ruby/ December 06,2014	5 -Year
193	11.430081	125.013863	0.96	1.5	-0.54	Ruby/ December 06,2014	5 -Year
194	11.430246	125.01369	0.41	0.9	-0.49	Ruby/ December 06,2014	5 -Year
195	11.426224	125.010081	0.03	0	0.03	Ruby/ December 06,2014	5 -Year
196	11.426196	125.009795	0.03	0.7	-0.67	Ruby/ December 06,2014	5 -Year
197	11.423967	125.005536	0.03	0.1	-0.07	Ruby/ December 06,2014	5 -Year
198	11.423479	125.004859	0.03	0.4	-0.37	Ruby/ December 06,2014	5 -Year
199	11.423408	125.004842	0.03	0	0.03	Ruby/ December 06,2014	5 -Year
200	11.420077	125.002661	1.07	0.6	0.47	Ruby/ December 06,2014	5 -Year
201	11.420062	125.00296	0.94	0.8	0.14	Ruby/ December 06,2014	5 -Year
202	11.419824	125.002143	0.06	0.3	-0.24	Ruby/ December 06,2014	5 -Year
203	11.417417	125.002467	0.13	1	-0.87	Ruby/ December 06,2014	5 -Year
204	11.415492	125.001831	0.23	0	0.23	Ruby/ December 06,2014	5 -Year
205	11.412609	124.999401	0.03	0.9	-0.87	Ruby/ December 06,2014	5 -Year
206	11.403375	124.996038	0.03	0.1	-0.07	Ruby/ December 06,2014	5 -Year
207	11.40329	124.995988	0.03	0	0.03	Ruby/ December 06,2014	5 -Year
208	11.40329	124.995988	0.03	0	0.03	Yolanda/ November 08,2013	5 -Year
209	11.402726	124.995964	0.19	0.3	-0.11	Yolanda/ November 08,2013	5 -Year
210	11.402611	124.99596	0.14	0	0.14	Yolanda/ November 08,2013	5 -Year
211	11.402436	124.996065	0.03	0	0.03	Yolanda/ November 08,2013	5 -Year
212	11.402358	124.995889	0.03	0.7	-0.67	Ruby/ December 06,2014	5 -Year
213	11.401701	124.996062	0.03	0	0.03	Ruby/ December 06,2014	5 -Year
214	11.401715	124.996043	0.03	0.4	-0.37	Ruby/ December 06,2014	5 -Year
215	11.401649	124.996035	0.03	0.4	-0.37	Ruby/ December 06,2014	5 -Year
216	11.400736	124.996778	0.04	0.3	-0.26	Ruby/ December 06,2014	5 -Year
217	11.400716	124.996718	0.20	0.3	-0.10	Ruby/ December 06,2014	5 -Year
218	11.400741	124.99664	0.03	0.3	-0.27	Ruby/ December 06,2014	5 -Year
219	11.400784	124.996481	0.03	0	0.03	Ruby/ December 06,2014	5 -Year

220	11.400823	124.99634	0.03	0	0.03	Ruby/ December 06,2014	5 -Year
221	11.393882	125.001567	0.03	0	0.03	Ruby/ December 06,2014	5 -Year
222	11.392575	125.001725	0.87	0.3	0.57	Ruby/ December 06,2014	5 -Year
223	11.392641	125.002038	0.20	0	0.20	Ruby/ December 06,2014	5 -Year
224	11.391933	125.002103	0.53	0	0.53	Ruby/ December 06,2014	5 -Year
225	11.391609	125.00214	0.63	0	0.63	Ruby/ December 06,2014	5 -Year
226	11.390185	125.0025	0.29	0	0.29	Ruby/ December 06,2014	5 -Year
227	11.386931	125.003498	0.03	0	0.03	Ruby/ December 06,2014	5 -Year
228	11.387099	125.003563	0.28	0	0.28	Ruby/ December 06,2014	5 -Year
229	11.465299	124.983828	0.03	0	0.03	Ruby/ December 06,2014	5 -Year
230	11.465146	124.983713	0.03	1.1	-1.07	Ruby/ December 06,2014	5 -Year
231	11.46461	124.982421	0.03	1.2	-1.17	Ruby/ December 06,2014	5 -Year
232	11.463318	124.979451	0.14	0.5	-0.36	Ruby/ December 06,2014	5 -Year
233	11.462595	124.977981	0.03	0.9	-0.87	Ruby/ December 06,2014	5 -Year
234	11.461928	124.976619	0.03	0	0.03	Ruby/ December 06,2014	5 -Year
235	11.461832	124.976654	0.03	0.6	-0.57	Ruby/ December 06,2014	5 -Year

Annex 12. Educational Institutions affected by flooding in Silaga Floodplain

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

Samar				
Pinabacdao				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
DAY CARE CENTER	Laygayon			
LAYGAYON ELEMENTARY SCHOOL	Laygayon			
ALTERNATIVE LEARNING SYSTEM	Parasanon	Low	Medium	High
PARASANON ELEMENTARY SCHOOL	Parasanon	Medium	Medium	High

Table A-12.2. Educational Institutions in Santa Rita, Samar affected by flooding in Silaga Floodplain

Santa Rita				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
ANIBANGON INTEGRATED SCHOOL	Anibongan			
CADARAGAN ELEMENTARY SCHOOL	Anibongan			
DAY CARE CENTER	Anibongan			
BAGOLIBAS ELEMENTARY SCHOOL	Bagolibas	Medium	Medium	Medium
DAY CARE CENTER	Bagolibas			
BINANALAN ELEMENTARY SCHOOL	Binanalan			
DAY CARE CENTER	Binanalan			
DAY CARE CENTER	Cabacungan			
CAMAYSE ELEMENTARY SCHOOL	Camayse			
LUPIC ELEMENTARY SCHOOL	Lupig	Medium	Medium	Medium
DAY CARE CENTER	Old Manunca			
OLD MANONGLA ELEMENTARY SCHOOL	Old Manunca	Low	Low	Medium
PARASANON NATIONAL HIGH SCHOOL	San Isidro			
SAN ISIDRO ELEMENTARY SCHOOL	San Isidro			
SAN PASCUAL ELEMENTARY SCHOOL	San Pascual	Low	Low	Low
TOMINAMOS INTEGRATED SCHOOL	Tominamos		Low	Medium
HITAAS ELEMENTARY SCHOOL	Tulay			
TULAY ELEMENTARY SCHOOL	Tulay			
DAY CARE CENTER	Union			

Annex 13. Health Institutions affected by flooding in Silaga Floodplain

Table A-13.1. Health Institutions in Santa Rita, Samar affected by flooding in Silaga Floodplain

Samar				
Santa Rita				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
HEALTH CARE CENTER	San Isidro	Medium	Medium	Medium
BRGY. TOMINAMOS BIRTHING FACILITY	Tominamos			