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

LiDAR Surveys and Flood Mapping of Loom 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
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
MCM	
MMS	Mobile Mapping Suite
MSL	mean sea level
NAMRIA	National Mapping and Resource Information Authority
NSTC	Northern Subtropical Convergence
PAF	Philippine Air Force
PAGASA	Philippine Atmospheric Geophysical and Astronomical Services Administration
PDOP	Positional Dilution of Precision
PPK	Post-Processed Kinematic [technique]
PRF	Pulse Repetition Frequency
PTM	Philippine Transverse Mercator
QC	Quality Check
QT	Quick Terrain [Modeler]
RA	Research Associate
RCBO	River Basin Control Office
RIDF	Rainfall-Intensity-Duration-Frequency
RMSE	Root Mean Square Error
SAR	Synthetic Aperture Radar
SCS	Soil Conservation Service
SRTM	Shuttle Radar Topography Mission
SRS	Science Research Specialist
SSG	Special Service Group
TBC	Thermal Barrier Coatings
UP-TCAGP	University of the Philippines – Training Center for Applied Geodesy and Photogrammetry
VSU	Visayas State University
UTM	Universal Transverse Mercator
WGS	World Geodetic System

CHAPTER 1: OVERVIEW OF THE PROGRAM AND LOOM RIVER

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

1.1 Background of the Phil-LiDAR 1 Program

The University of the Philippines Training Center for Applied Geodesy and Photogrammetry (UP-TCAGP) launched a research program entitled "Nationwide Hazard Mapping using LiDAR" or Phil-LiDAR 1, supported by the Department of Science and Technology (DOST) Grants-in-Aid (GiA) Program. The program was primarily aimed at acquiring a national elevation and resource dataset at sufficient resolution to produce information necessary to support the different phases of disaster management. Particularly, it targeted to operationalize the development of flood hazard models that would produce updated and detailed flood hazard maps for the major river systems in the country. Also, the program was aimed at producing an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through DOST. The implementing partner university for the Phil-LiDAR 1 Program is the Visayas State University (VSU). VSU is in charge of processing LiDAR data and conducting data validation reconnaissance, cross section, bathymetric survey, validation, river flow measurements, flood height and extent data gathering, flood modeling, and flood map generation for the 22 river basins in the ____________________ (LiDAR covered area, you may leave this blank). The university is located in Baybay City in the province of Leyte.

1.2 Overview of the Loom River Basin

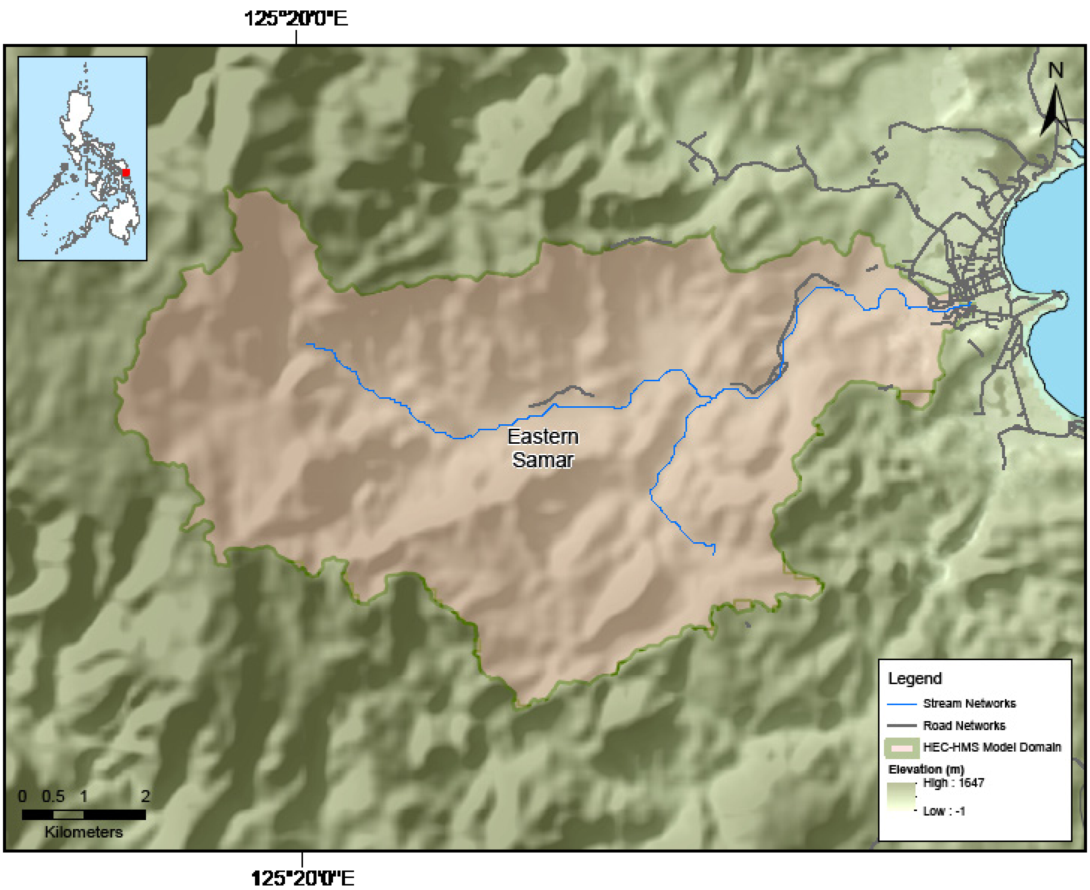

Figure 1. Map of the Loom River Basin

CHAPTER 2: LIDAR DATA ACQUISITION OF THE LOOM FLOODPLAIN

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

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Loom Floodplain in Eastern Samar. These missions were planned for 10 lines that run for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the Aquarius LiDAR system is found in Table 1. Figure 2 shows the flight plan for Loom floodplain.

Table 1. Flight planning parameters for Aquarius LiDAR System

Block Name	Flying Height (AGL)	Overlap (%)	Field of View	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency	Average Speed	Average Turn Time (Minutes)
BLK33P	600	30	44	50	45	130	5
BLK33M	600	30	44	50	45	130	5
BLK33J	600	30	44	50	45	130	5

2.2 Ground Base Stations

The project team was able to recover two (2) NAMRIA horizontal ground control points which are of second (2nd), SME-3139 and SME-3117, respectively. Two (2) NAMRIA benchmarks were recovered, SE-16 and SE-102, which are of first (1st) order vertical accuracy. These benchmarks were used as vertical reference points and were also established as ground control point. The certification for the base station is found in ANNEX 2 while the baseline processing reports for established ground control points are found in ANNEX 3. These were used as base stations during flight operations for the entire duration of the survey (April 15 – June 11, 2014) especially on the days that flight missions were conducted. Base stations were observed using dual frequency GPS receivers: TRIMBLE SPS 852 and SPS985. Flight plans and location of base stations used during the aerial LiDAR acquisition in Loom floodplain are shown in Figure 2.

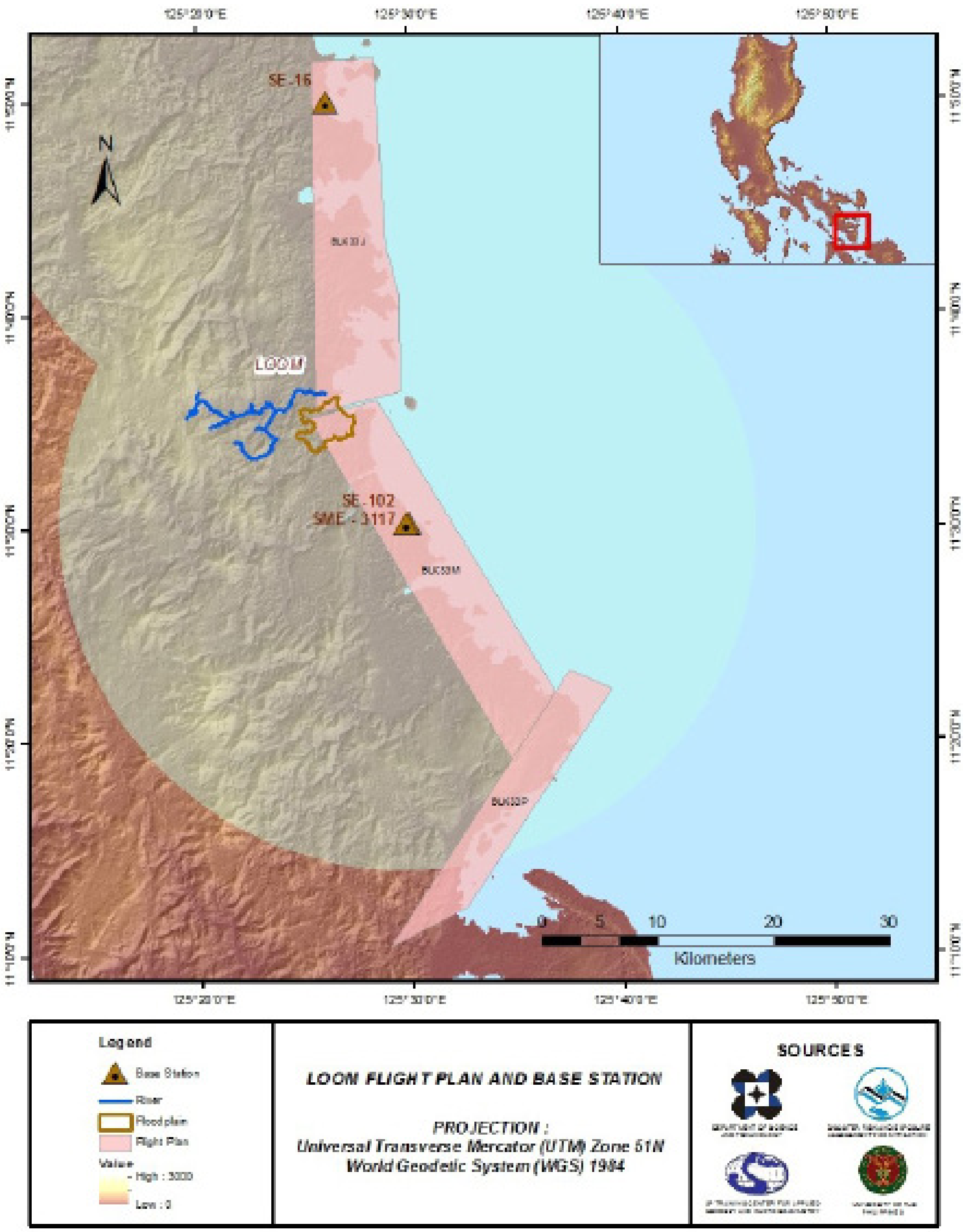

Figure 2. Flight plan and base station used for Loom Floodplain.

Figure 3 to Figure 6 show the recovered NAMRIA reference points within the area. In addition, Table 2 to Table 5 show the details about the following NAMRIA control stations and established points while Table 6 shows the list of all ground control points occupied during the acquisition with the corresponding dates of utilization.

(a) (b)

Figure 3. GPS set-up over SME-3139 located along the highway in Brgy. Sto. Nino, Sulat, Eastern Samar (a) and NAMRIA reference point SME-3139 (b) as recovered by the field team.

Table 2. Details of the reprocessed NAMRIA horizontal control point SME-3139 used as base station for the LiDAR Acquisition.

Station Name	**SME-3139**	
Order of Accuracy	**4th**	
Relative Error (horizontal positioning)	**1 in 10,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11° 50' 2.95701" North 125° 18' 14.44217"East 0.35600 m meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting Northing	547309.911 meters 1308628.152 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 49' 58.57713" North 125° 26' 8.12160" East 62.18500 m meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	765219.59 meters 1309289.26 meters

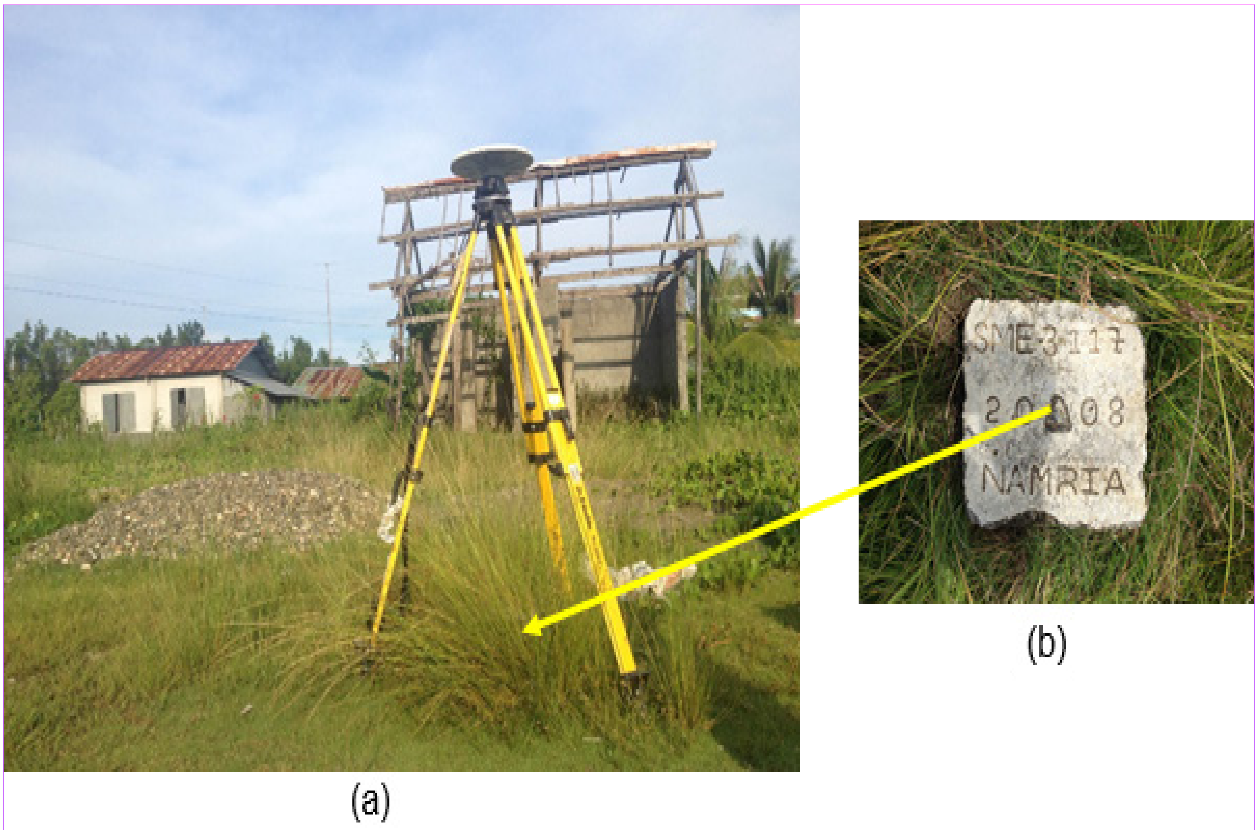

Figure 4. GPS set-up over SME-3117 inside the premises of Maydolong National High School, Maydolong, Eastern Samar (a) and NAMRIA reference point SME-3117 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point SME-3117 used as base station for the LiDAR Acquisition.

Station Name	SME-3117	
Order of Accuracy	4th	
Relative Error (horizontal positioning)	1 in 10,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11° 30’ 19.94572” North 125° 29’ 48.45875” East -0.71500 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting Northing	554197.385 meters 1272291.016 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 30’ 15.65415” North 125° 29’ 53.58658”East 62.09300 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	772367.30 meters 1272983.11 meters

(a)

Figure 5. GPS set-up over SE-16 located in the Province of Eastern Samar, Town of Balangiga in Brgy. San Miguel along the national highway near Km post 974 and NAMRIA reference point SE-16 (a) as recovered by the field team.

Table 4. Details of the recovered NAMRIA horizontal control point ZGN-132 used as base station for the LiDAR Acquisition.

Station Name	SE - 16	
Order of Accuracy	1st	
Relative Error (horizontal positioning)	1 in 100,000	
Elevation (Mean Sea Level)	1.7415 meters	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11° 50’ 03.05106”North 125° 26’ 03.03429 ”East 0.472 m meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 49’ 58.67117”North 125° 26’ 08.13400” East 62.301 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	765219.942 meters 1309292.154 meters

(a) (b)

Figure 6. GPS set-up over SE-102 located along the National Highway, in front of Maydolong High School, in Maydolong, Eastern Samar (a) and NAMRIA reference point SE-102 (b) as recovered by the field team.

Table 5. Details of the recovered NAMRIA horizontal control point ZGN-132 used as base station for the LiDAR Acquisition.

Station Name	SE-102	
Order of Accuracy	1st	
Relative Error (horizontal positioning)	2.5962 meters	
Elevation (Mean Sea Level)	1:100,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11° 30’ 18.33686”North 125° 29’ 43.39145” East 0.393 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 30’ 14.04528”North 125° 29’ 48.51933” East 63.198 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	772214.094 meters 12.72932.317 meters

Table 6. Details of the recovered NAMRIA vertical control point SE-102 used as vertical reference point for the LiDAR acquisition with established coordinates.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
08-Jun-14	1554A	3BLK33PSM159A	SME-3117; SE-102
08-Jun-14	1556A	3BLK33MS159B	SME-3117; SE-102
09-Jun-14	1558A	3BLK33J160A	SME-3139; SE-16
09-Jun-14	1560A	3BLK33JS160B	SME-3139; SE-16

2.3 Flight Missions

Four (4) missions were conducted to complete the LiDAR data acquisition in Loom floodplain, for a total of eighteen hours and three minutes (18+3) of flying time for RP-C9122. All missions were acquired using the Aquarius LiDAR system. Table 7 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 8 presents the actual parameters used during the LiDAR data acquisition.

Table 7. Flight missions for LiDAR data acquisition in Loom floodplain.

Date Surveyed	Flight Number	Mission Name	Ground Control Points	Area Surveyed with in Floodplain (km2)	Area Surveyed Outside Floodplain (km2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
08-Jun-14	1554A	269.79	123.51	0.06	123.45	1,527	41	4
08-Jun-14	1556A	171.23	133.83	8.21	125.62	1,679	47	4
09-Jun-14	1558A	190.90	117.98	5.11	112.87	96	41	4
09-Jun-14	1560A	190.90	127.54	1.98	125.56	1,292	53	3
TOTAL		822.82	502.86	15.36	487.51	4, 594	18	3

Table 8. Flight missions for LiDAR data acquisition in Loom floodplain.

Flight Number	Flying Height (M AGL)	Overlap (%)	FOV (Θ)	PRF (KHZ)	Scan Frequency (HZ)	Average Speed	Average Turn Time (Minutes)
1554A	600	30	44	50	45	130	5
1556A	600	30	44	50	45	130	5
1558A	600	30	44	50	45	130	5
1560A	600	25	44	50	45	130	5

2.4 Survey Coverage

Loom Floodplain is located in the province of Eastern Samar with majority of the floodplain situated within the municipality of Hernani. The list of municipalities and cities surveyed is shown in Table 9. The actual coverage of the LiDAR acquisition for Loom Floodplain is presented in Figure 7.

Table 9. List of municipalities and cities surveyed during Loom floodplain LiDAR survey.

Province	Municipality/City	Area of Municipality/City km²	Total Area Surveyed (km²)	Percentage of Area Surveyed
Eastern Samar	Hernani	46.44	37.55	81%
	General Macarthur	114.65	22.16	19%
	Quinapondan	136.47	19.60	14%
	Loom	344.09	42.98	12%
	Maydolong	202.95	19.33	10%
	Balangkayan	170.56	9.33	5%
	Borongan City	596.08	26.21	4%
Total		1611.24	177.16	11%

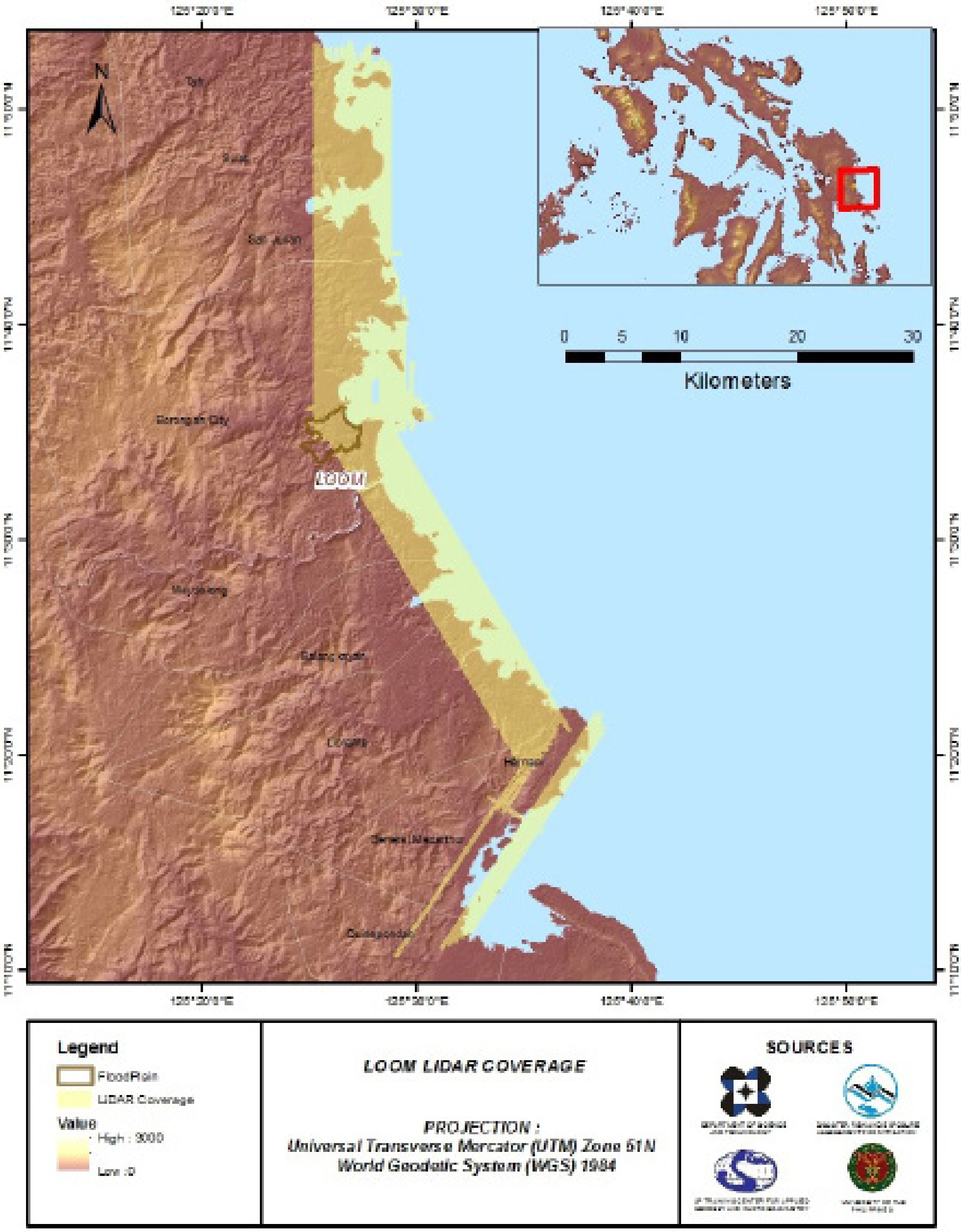

Figure 7. Actual LiDAR survey coverage for Loom floodplain

CHAPTER 3: LIDAR DATA PROCESSING OF THE LOOM FLOODPLAIN

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

3.1 Overview of the LiDAR Data Pre-Processing

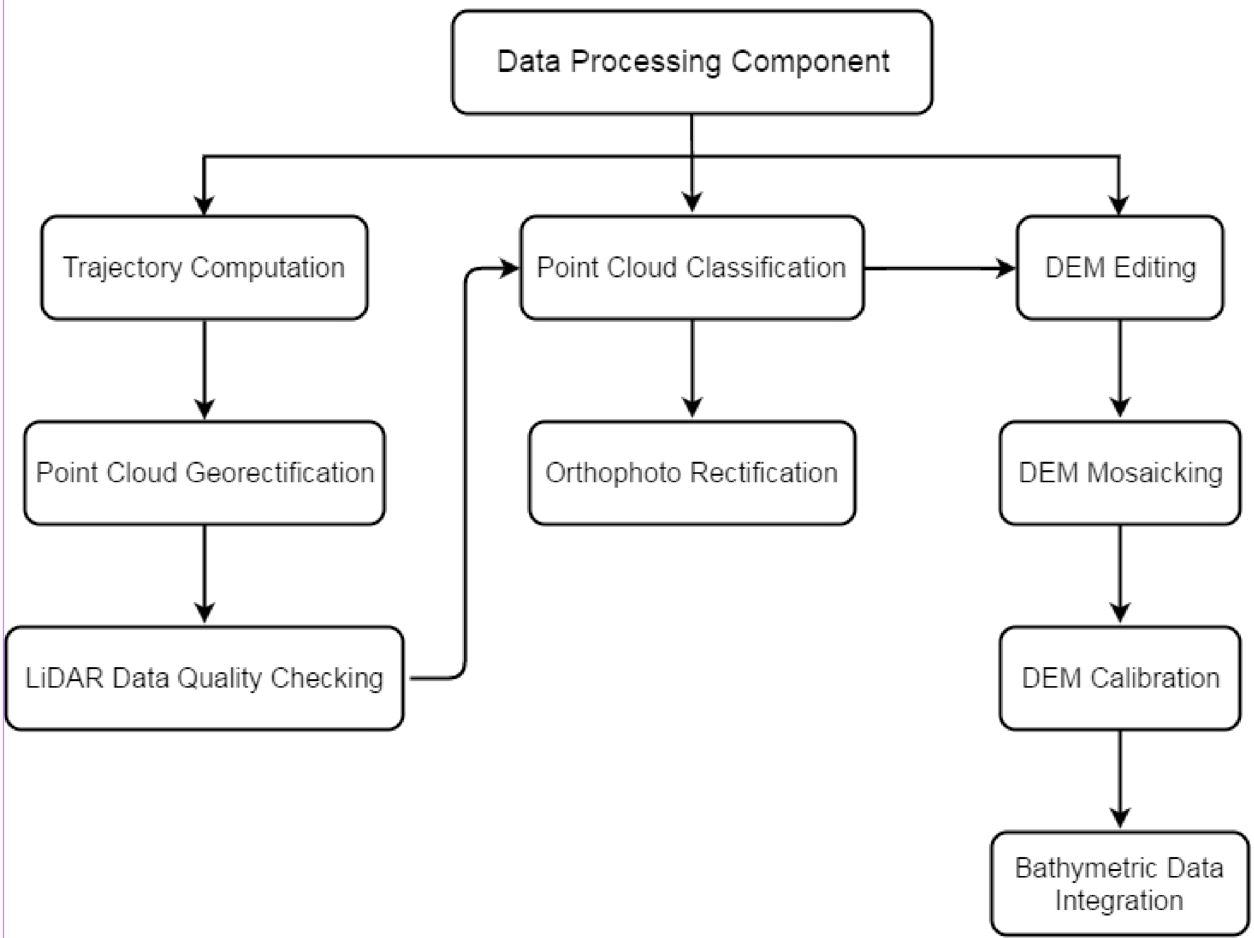

Figure 8. Schematic Diagram for Data Pre-Processing Component

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

Component. LiDAR acquired temporally are then mosaicked to completely cover the target river systems in the Philippines. Orthorectification of images acquired simultaneously with the LiDAR data is done through the help of the georectified point clouds and the metadata containing the time the image was captured.

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

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Loom floodplain can be found in Annex 5. Missions flown during the survey conducted on June 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Aquarius system Borongan City, Eastern Samar. The Data Acquisition Component (DAC) transferred a total of 56.70 Gigabytes of Range data, 1.05 Gigabytes of POS data, 65.00 Megabytes of GPS base station data, and 364.90 Gigabytes of raw image data to the data server on June 19, 2014. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Loom was fully transferred on June 19, 2014, as indicated on the Data Transfer Sheets for Loom floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for flight 1556A, one of the Loom flights, which is the North, East, and Down position RMSE values are shown in Figure 9. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on June 8, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

Figure 9. Smoothed Performance Metric Parameters of Loom Flight 1556A.

The time of flight was from 200,000 seconds to 320,000 seconds, which corresponds to afternoon of June 8, 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 9 shows that the North position RMSE peaks at 1.20 centimeters, the East position RMSE peaks at 1.55 centimeters, and the Down position RMSE peaks at 2.90 centimeters, which are within the prescribed accuracies described in the methodology.

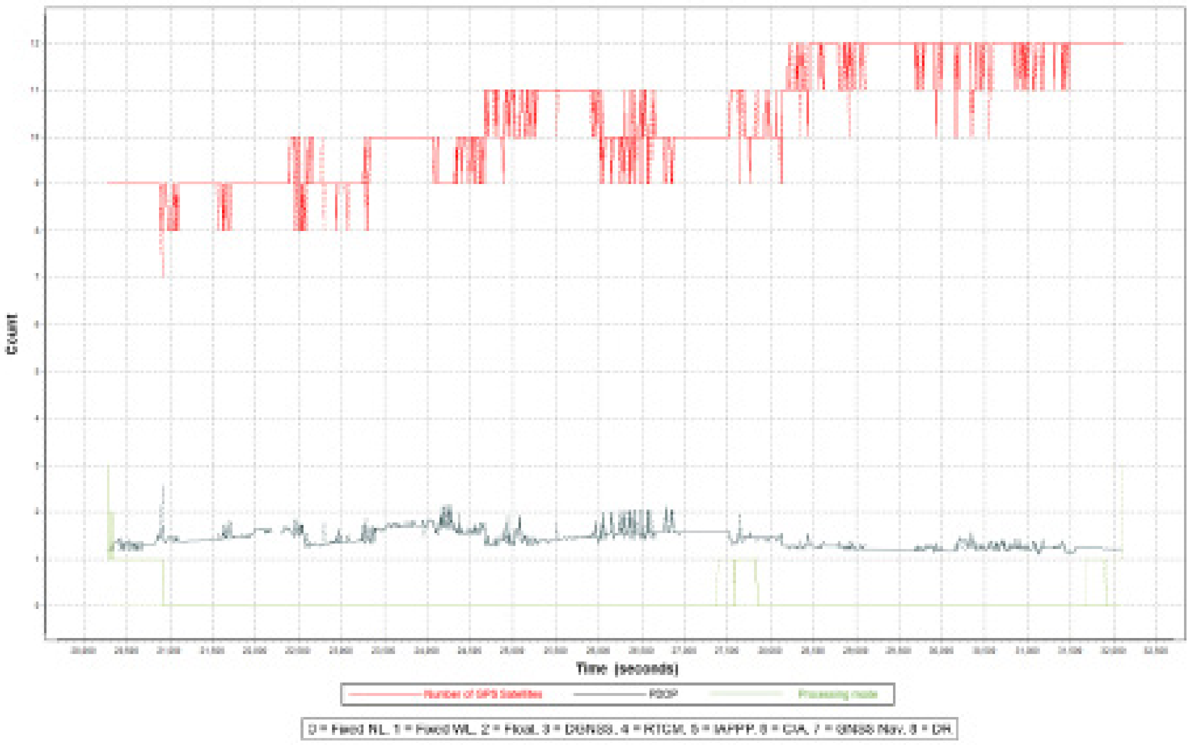

Figure 10. Solution Status Parameters of Loom Flight 1556A.

The Solution Status parameters of flight 1556A, one of the Loom flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 10. The graphs indicate that the number of satellites during the acquisition did not go below 7. Majority of the time, the number of satellites tracked was between 7 and 12. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 1 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 Loom flights is shown in Figure 11.

Figure 11. Best Estimated Trajectory for Loom Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 56 flight lines, with each flight line containing one channel, since the Aquarius system contains one channel only. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Loom floodplain are given in Table 10.

Table 10. Self-Calibration Results values for Loom flights.

Parameter	Acceptable Value	Computed Value
Boresight Correction stdev	(<0.001degrees)	0.000680
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.000100
GPS Position Z-correction stdev	(<0.01meters)	0.0052

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

3.5 LiDAR Data Quality Checking

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

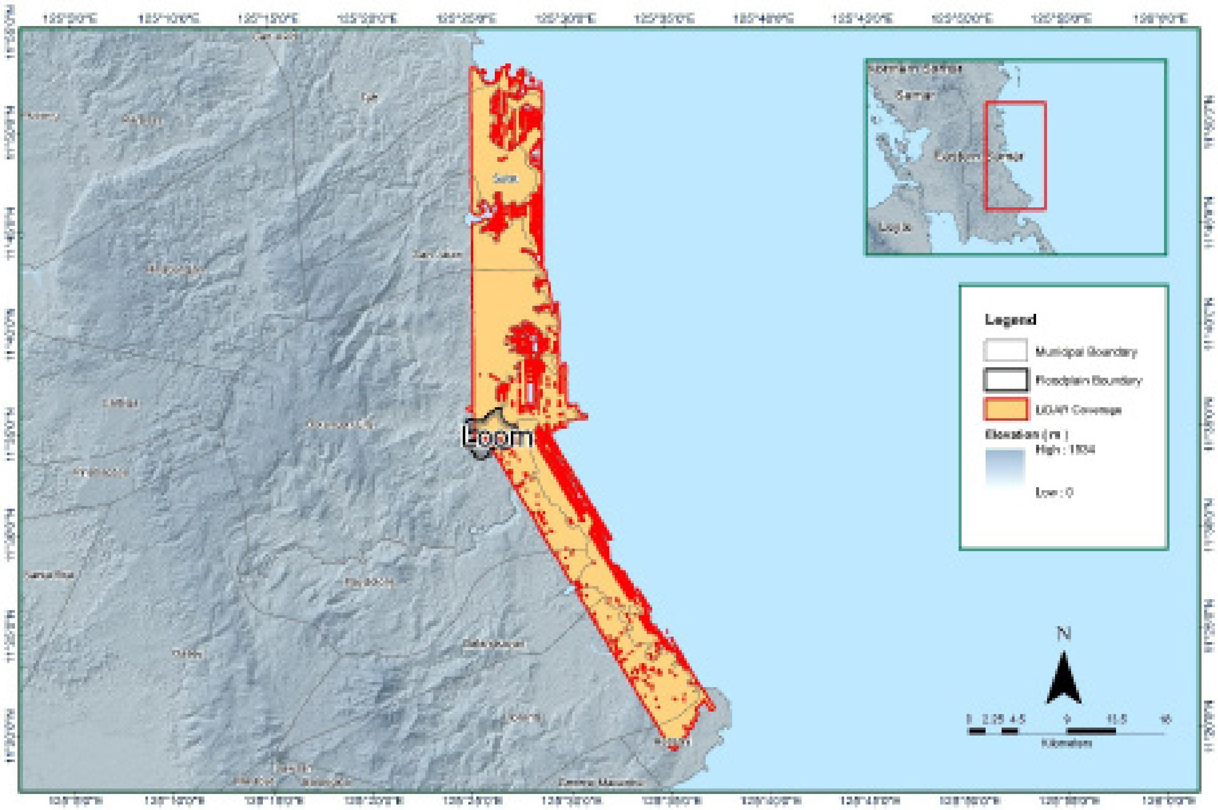

Figure 12. Boundary of the processed LiDAR data over Loom Floodplain.

The total area covered by the Loom missions is 346.64 sq.km that is comprised of four (4) flight acquisitions grouped and merged into three (3) blocks as shown in Table 11.

Table 11. Self-Calibration Results values for Loom flights.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Samar_Leyte_Blk33J	1558A	191.58
	1560A	
Samar_Leyte_Blk33M	1554A	154.63
	1556A	
	1554A	0.43
TOTAL		**346.64 sq. km.**

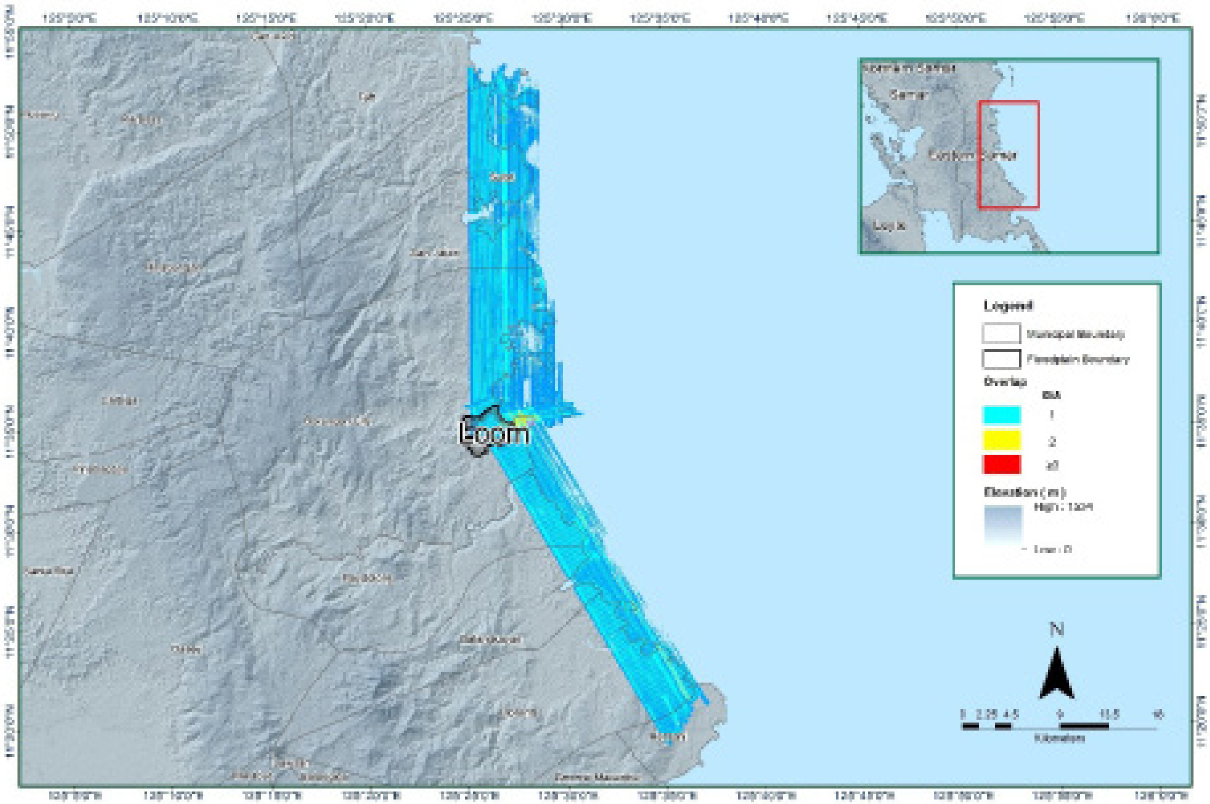

Figure 13. Boundary of the processed LiDAR data over Loom Floodplain.

The overlap statistics per block for the Loom 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 36.01% and 41.81% respectively, which passed the 25% requirement.

The 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 14. It was determined that all LiDAR data for Loom floodplain satisfy the point density requirement, and the average density for the entire survey area is 2.67 points per square meter.

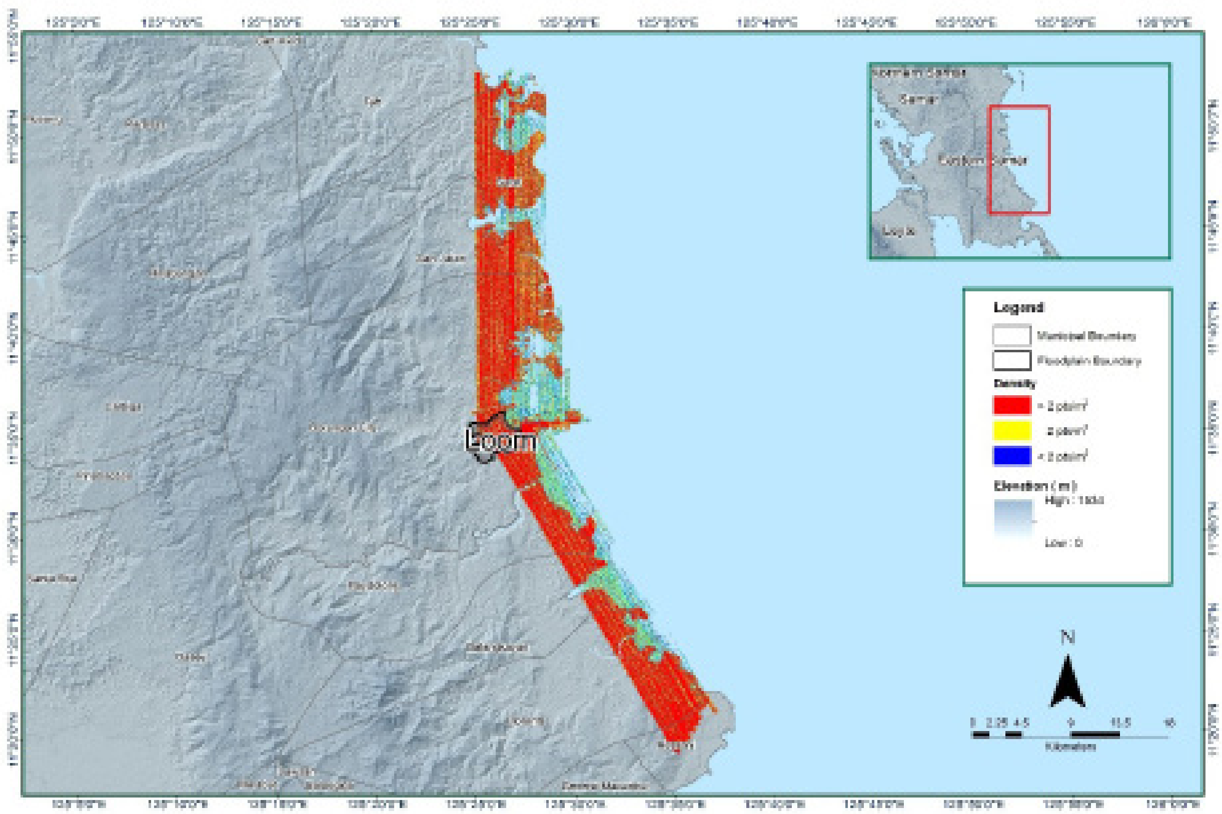

Figure 14. Density map of merged LiDAR data for Loom floodplain.

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

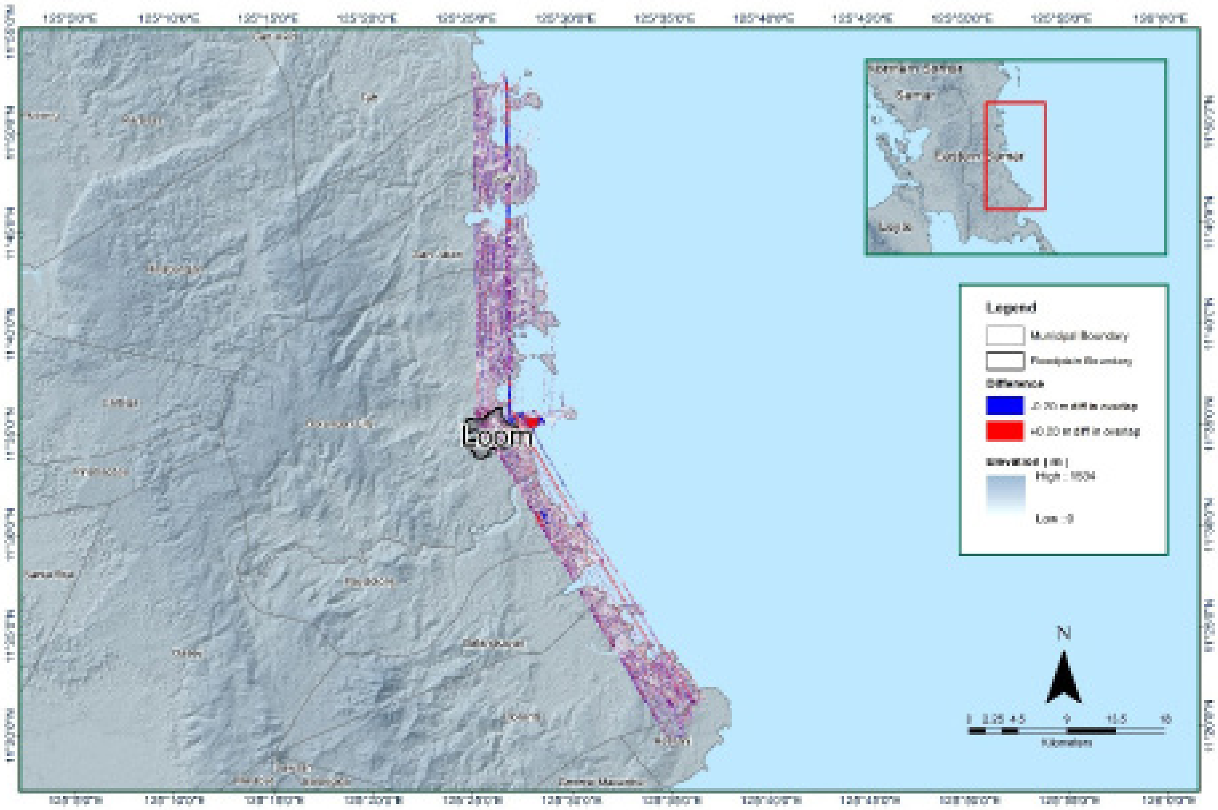

Figure 15. Elevation difference map between flight lines for Loom floodplain.

A screen capture of the processed LAS data from Loom flight 1556A loaded in QT Modeler is shown in Figure 16. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

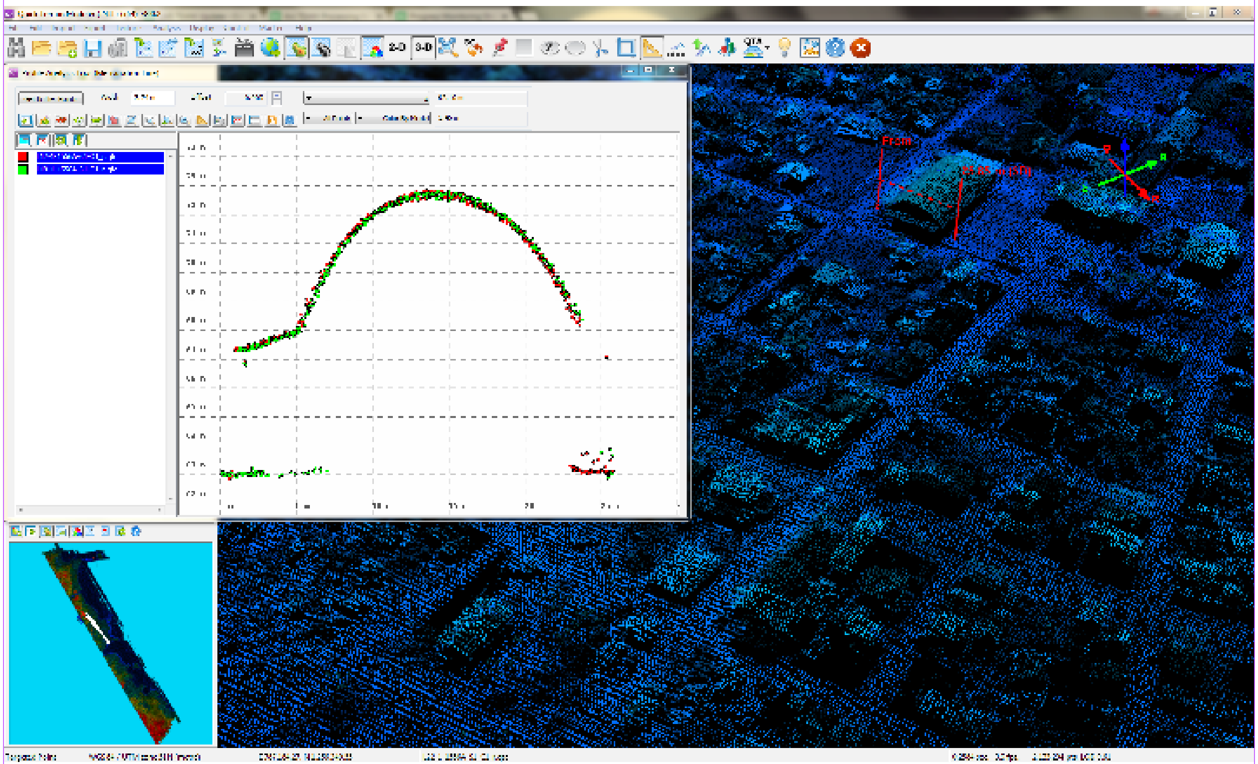

Figure 16. Quality checking for Loom flight 1556A using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

The produced LAS data contains 56 flight lines, with each flight line containing one channel, since the Aquarius system contains one channel only. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Loom Floodplain are given in Table 12.

Table 12. Loom classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	171,976,833
Low Vegetation	100,113,761
Medium Vegetation	151,423,871
High Vegetation	315,861,891
Building	5,257,791

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Loom floodplain is shown in Figure 19. A total of 5401km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 12. The point cloud has a maximum and minimum height of 306.43 meters and 49.30 meters respectively.

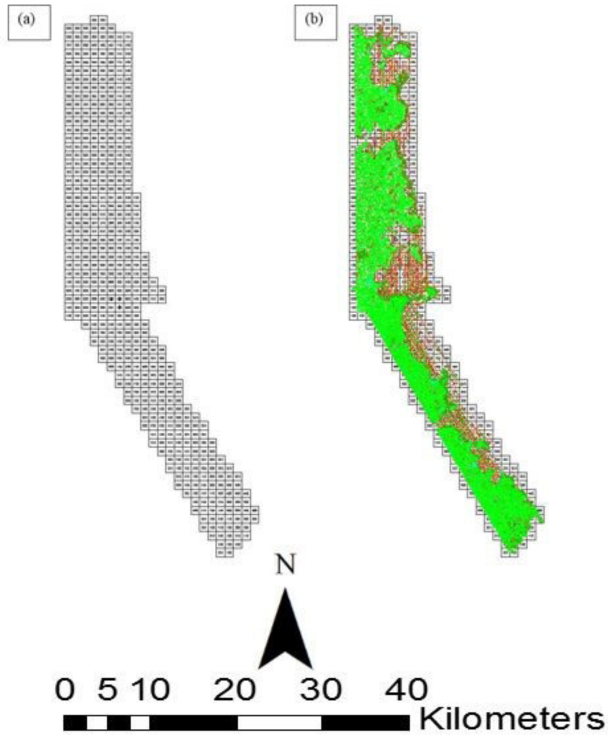

Figure 17. Tiles for Loom floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 18. The ground points are in orange, 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.

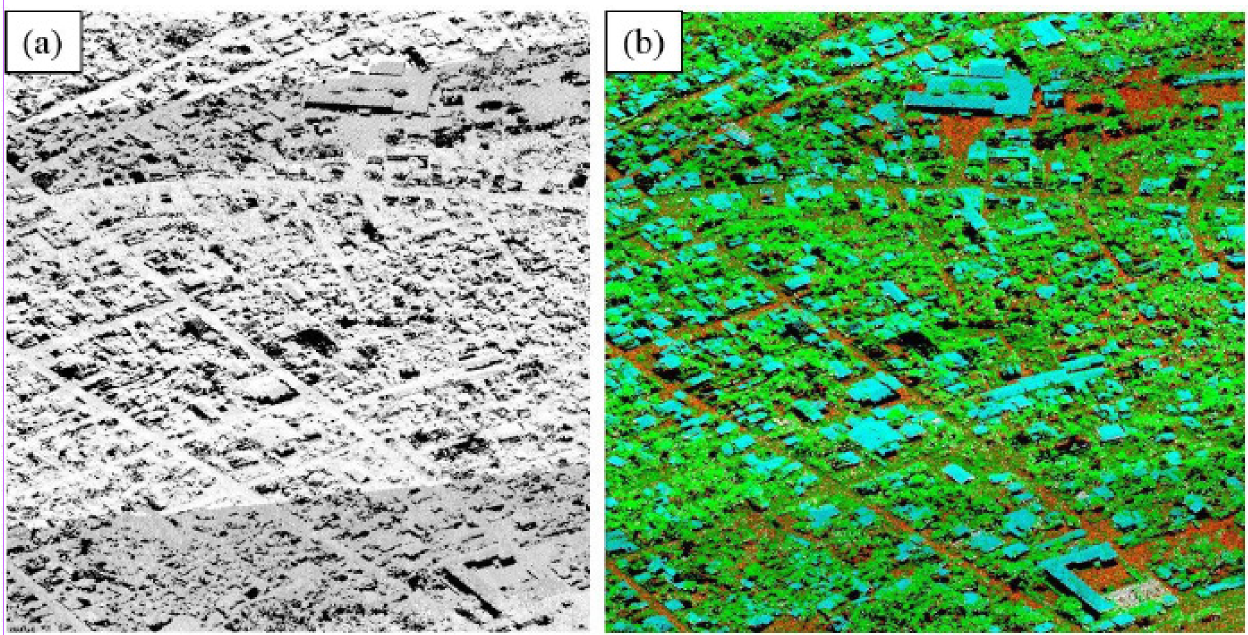

Figure 18. Point cloud before (a) and after (b) classification.

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 20. It shows that DTMs are the representation of the bare earth while on the DSMs, all features are present such as buildings and vegetation.

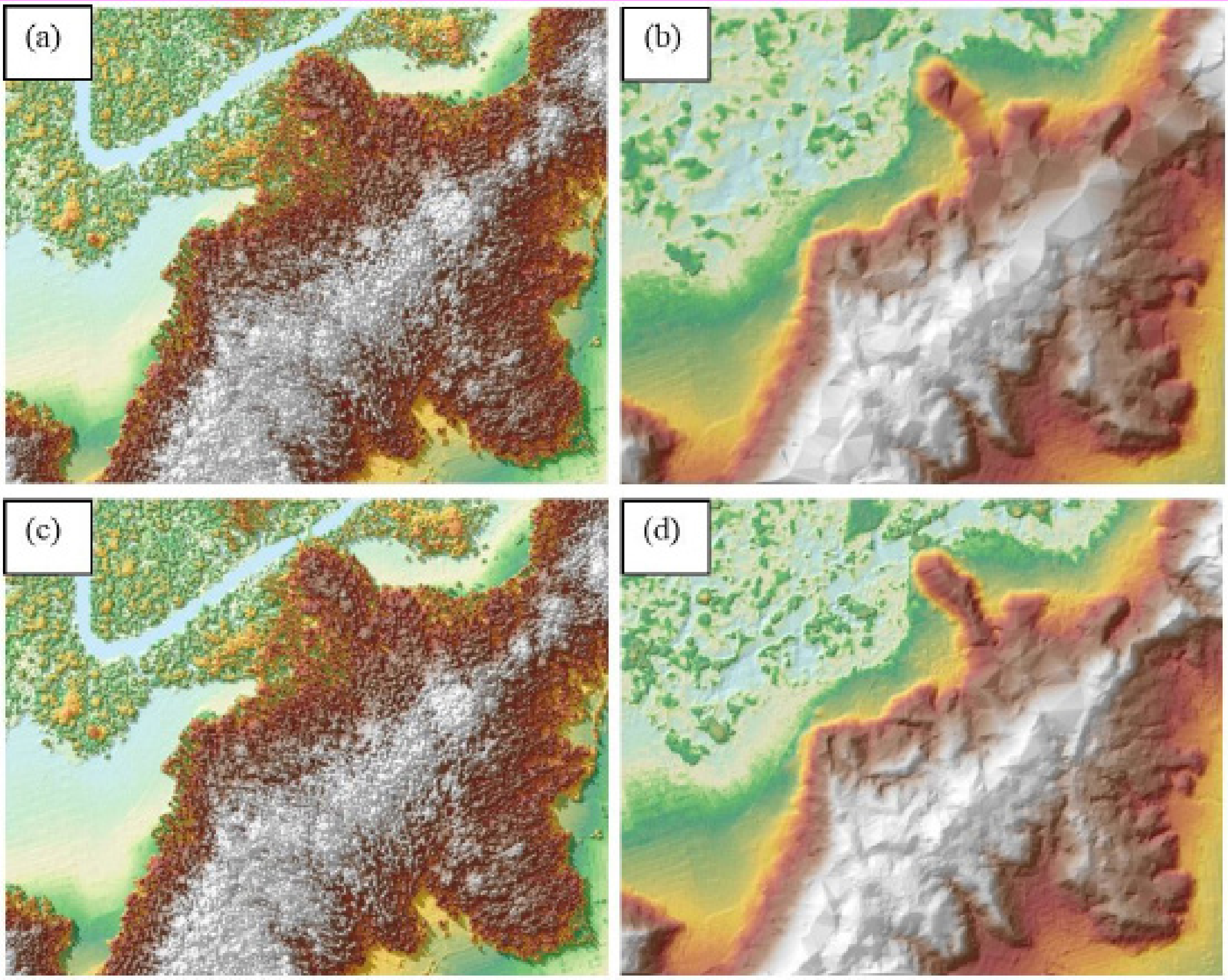

Figure 19. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Loom Floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 536 1km by 1km tiles area covered by Loom Floodplain is shown in Figure 20. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Loom floodplain has a total of 384.72 sq.km orthophotogaph coverage comprised of 5,192 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 21.

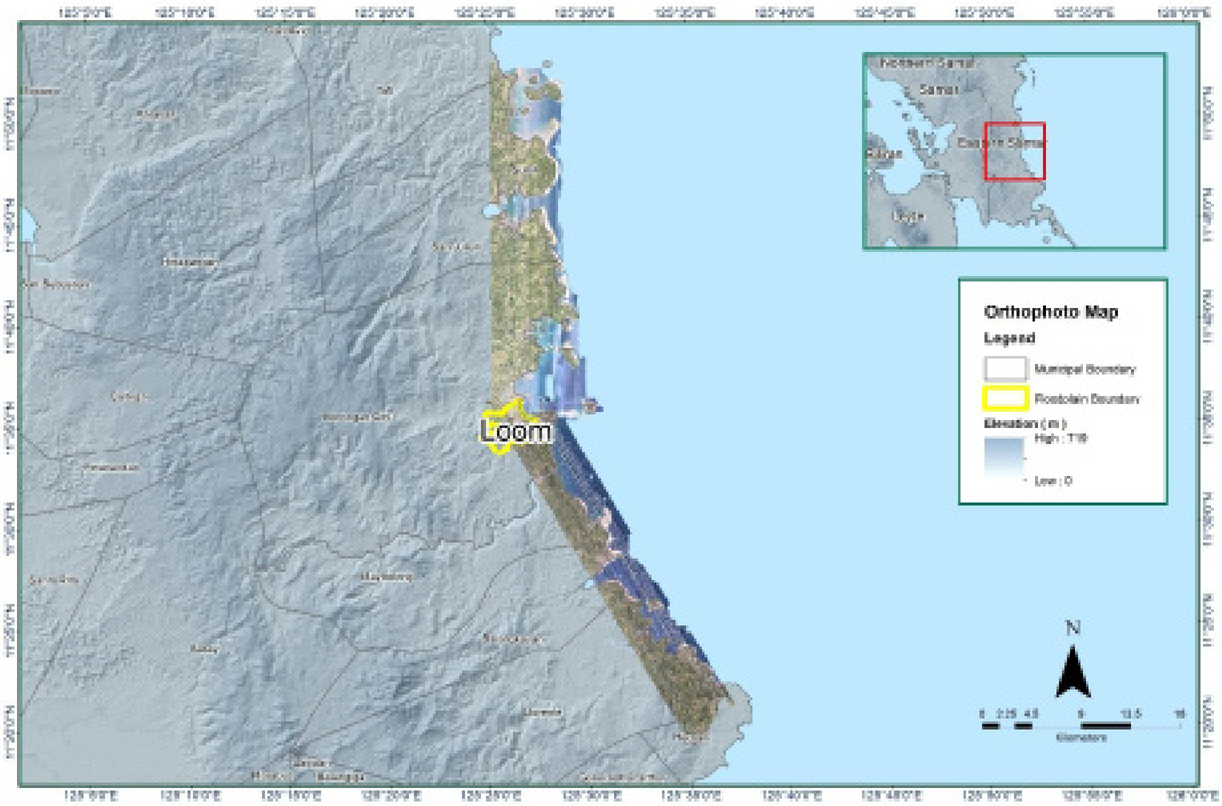

Figure 20. Loom Floodplain with available orthophotographs.

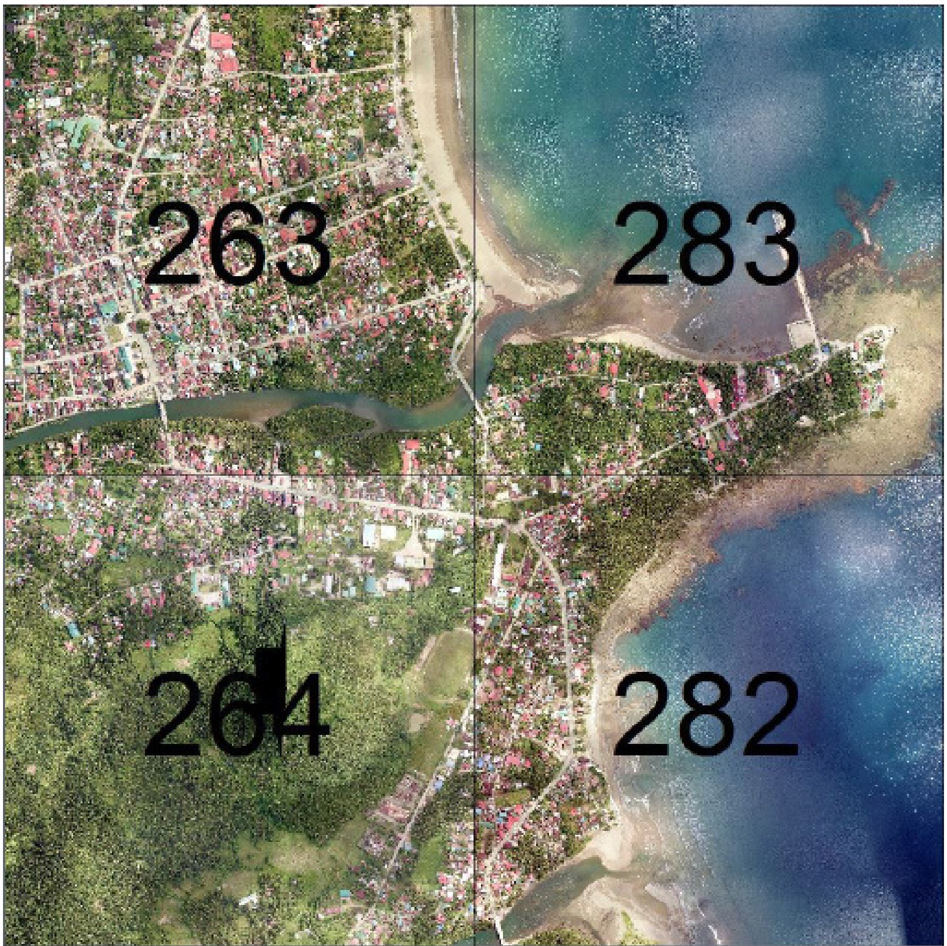

Figure 21. Sample orthophotograph tiles for Loom Floodplain.

3.8 DEM Editing and Hydro-Correction

Three (3) mission blocks were processed for Loom Floodplain. These blocks are composed of SamarLeyte blocks with a total area of 346.64 square kilometers. Table 13 shows the name and corresponding area of each block in square kilometers.

Table 13. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq. km)
Samar_Leyte_Blk33J	191.58
Samar_Leyte_Blk33M	154.63
Samar_Leyte_Blk33M_ additional	0.43
TOTAL	346.64 sq. km.

Portions of DTM before and after manual editing are shown in Figure 22. Areas with no data along water bodies has to be interpolated for hydrologic correction. The bridge (Figure 22a) is considered to be an impedance to the flow of water along the river and has to be removed (Figure 22b) in order to hydrologically correct the river. The road (Figure 22c) has been misclassified during classification process and has to be retrieved to complete the surface (Figure 22d) to allow the correct flow of water.

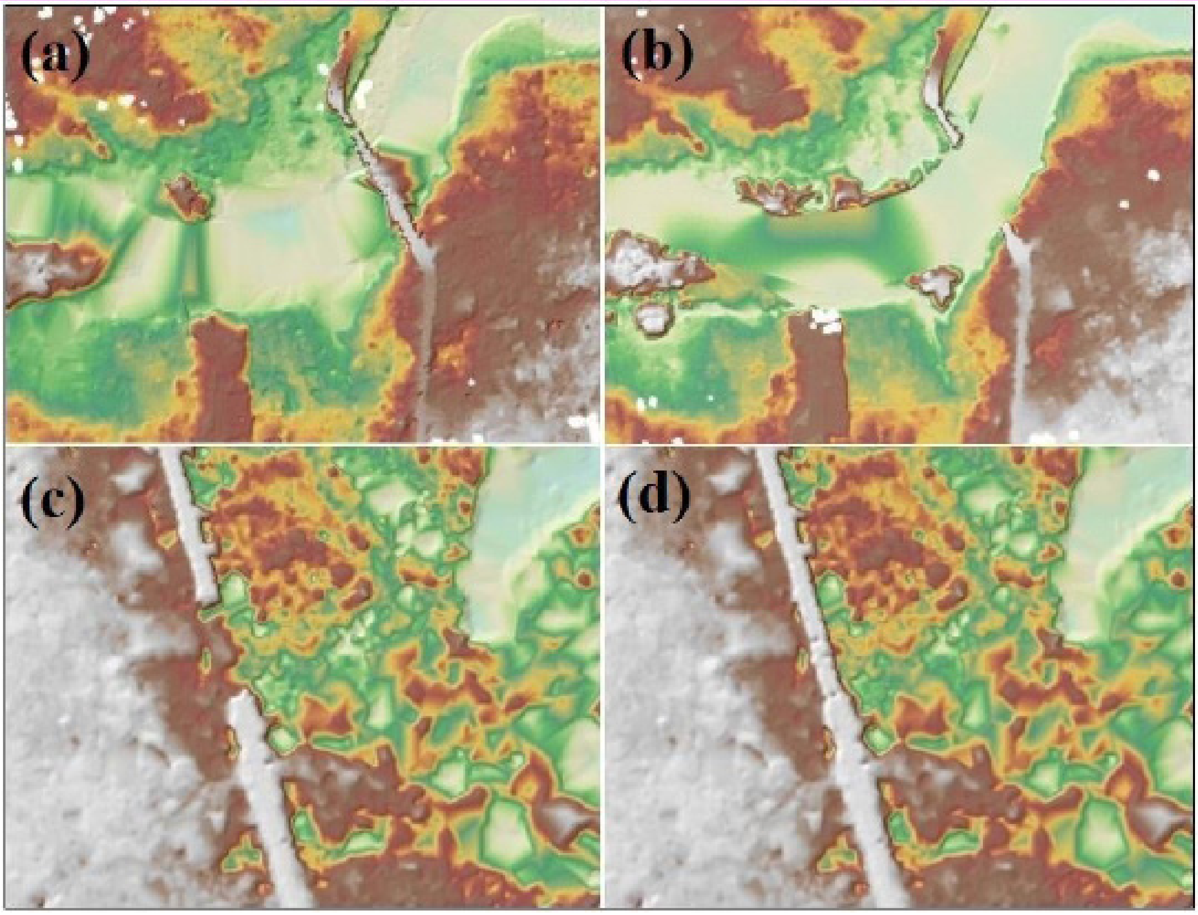

Figure 22. Portions in the DTM of Loom floodplain – a bridge before (a) and after (b) manual editing; and a road before (c) and after (d) data retrieval.

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 14 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Loom Floodplain is shown in Figure B-16. It can be seen that the entire Loom Floodplain is 20.05% covered by LiDAR data while portions with no LiDAR data were patched with the available IFSAR data.

Table 14. LiDAR blocks with its corresponding area.

Mission Blocks	Shift Values (meters)		
	x	y	z
SamarLeyte_Blk33M	-1.00	2.00	-1.00
SamarLeyte_Blk33J	-1.00	2.00	-1.00
Samar_Leyte_Blk33M_ additional	-1.00	2.00	-1.20

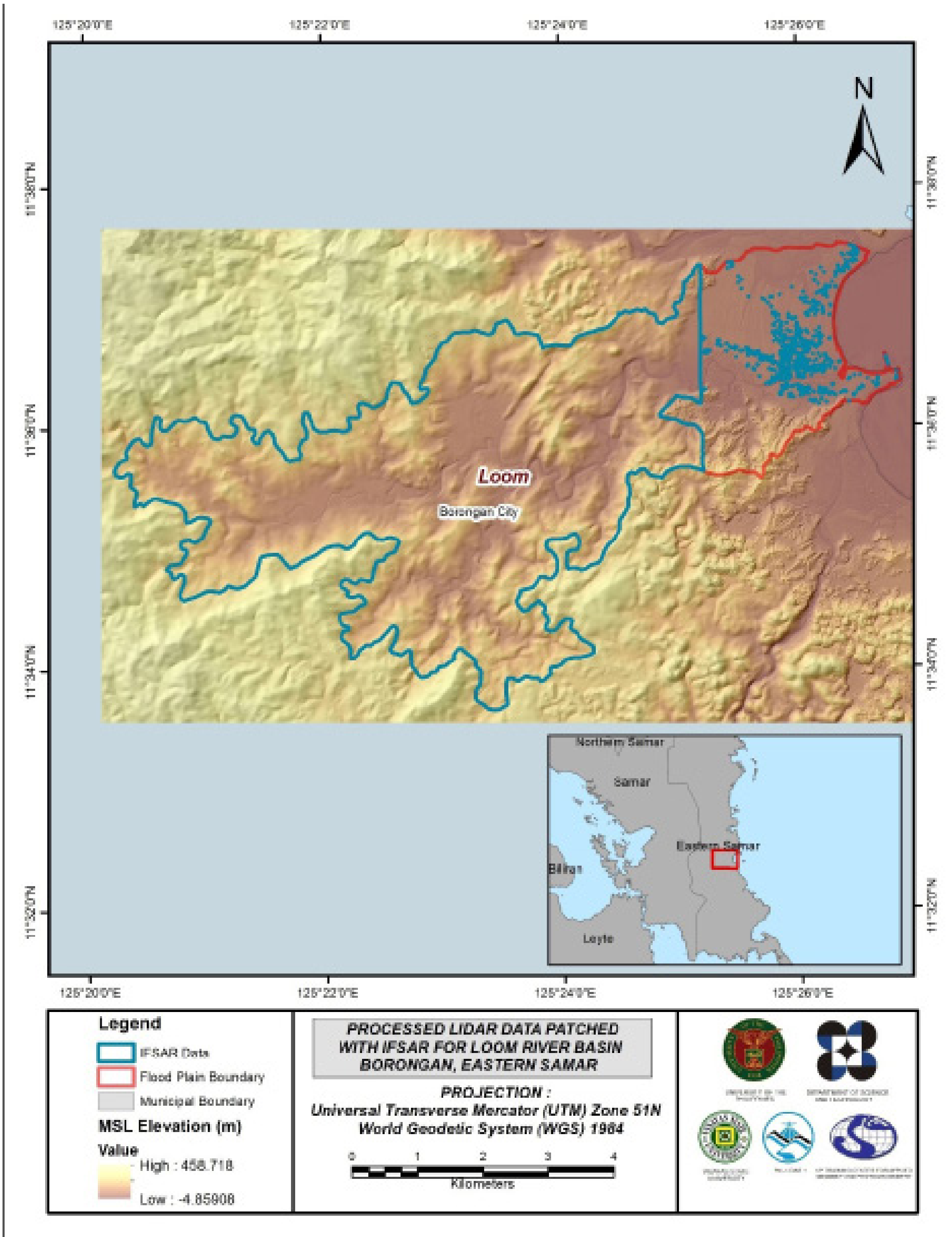

Figure 23. Map of Processed LiDAR Data for Loom Floodplain

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Loom to collect points with which the LiDAR dataset is validated is shown in Figure 24. A total of 105 survey points were gathered from Loom and Sulat Floodplains. However, the point dataset was not used for the calibration of the LiDAR data for Loom because during the mosaicking process, each LiDAR block was referred to the calibrated Tacloban DEM. Therefore, the mosaicked DEM of Loom 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 25. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration points is 0.14 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 15 shows the statistical values of the compared elevation values between Tacloban LiDAR data and calibration data. These values were also applicable to the Loom DEM.

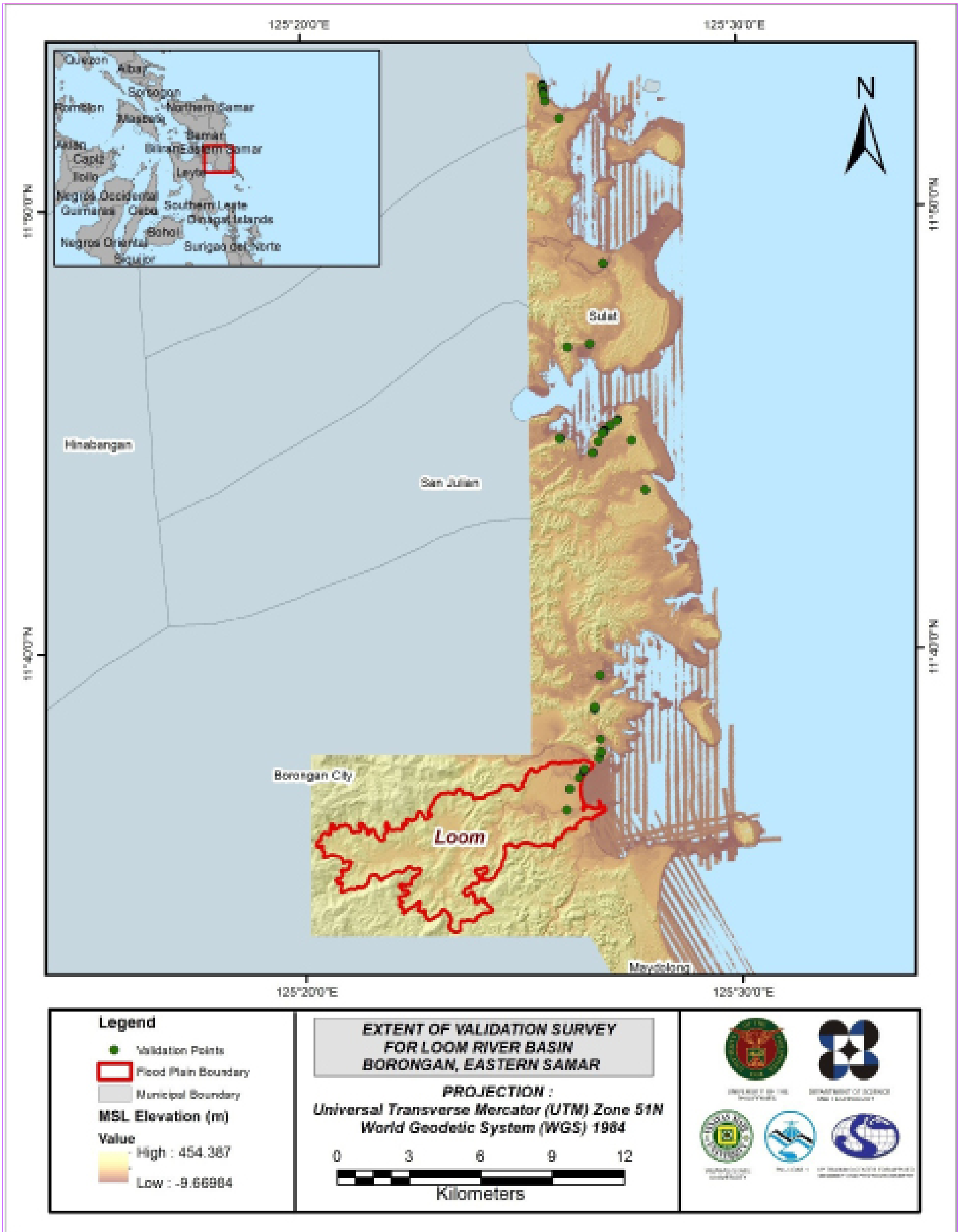

Figure 24. Map of Loom Floodplain with validation survey points in green.

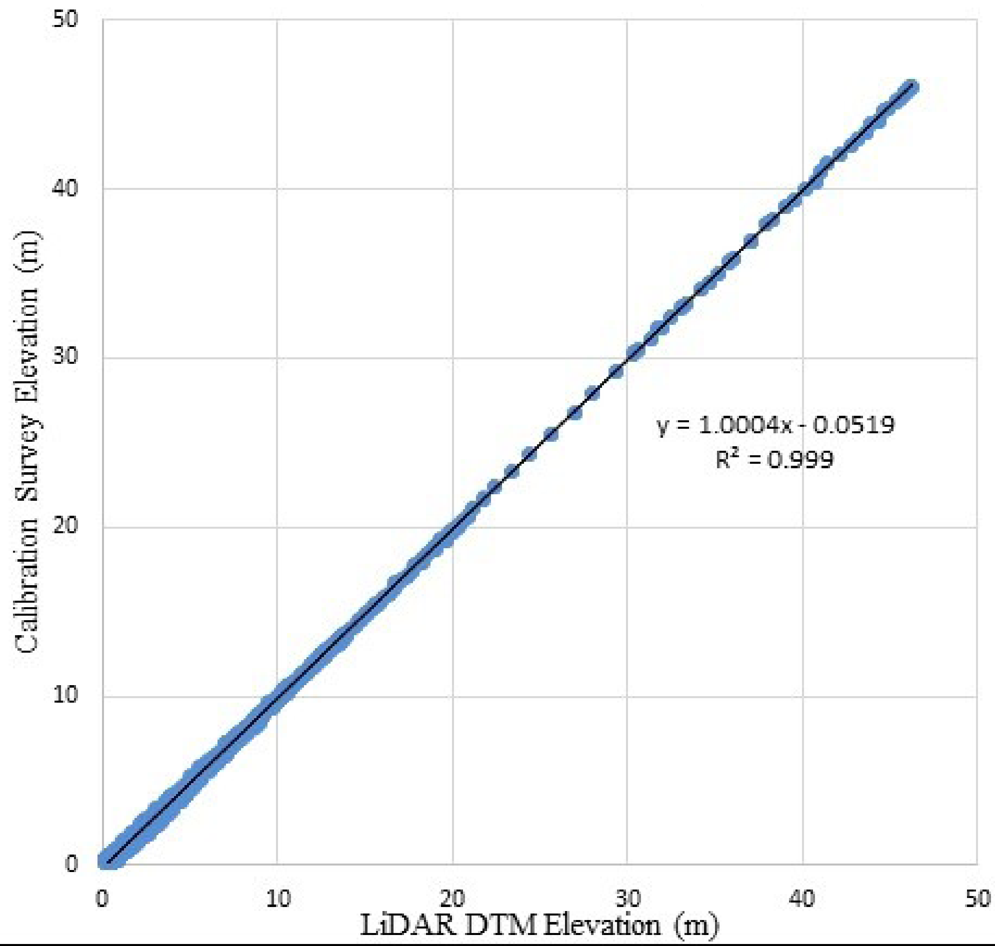

Figure 25. Correlation plot between calibration survey points and LiDAR data.

Table 15. Calibration Statistical Measures.

	Value (meters)
Height Difference	0.14
Standard Deviation	0.13
Average	-0.05
Minimum	-0.32
Maximum	0.22

the calibrated LiDAR DTM and validation elevation values is 0.20 meters with a standard deviation of 0.05 meters, as shown in Table 16.

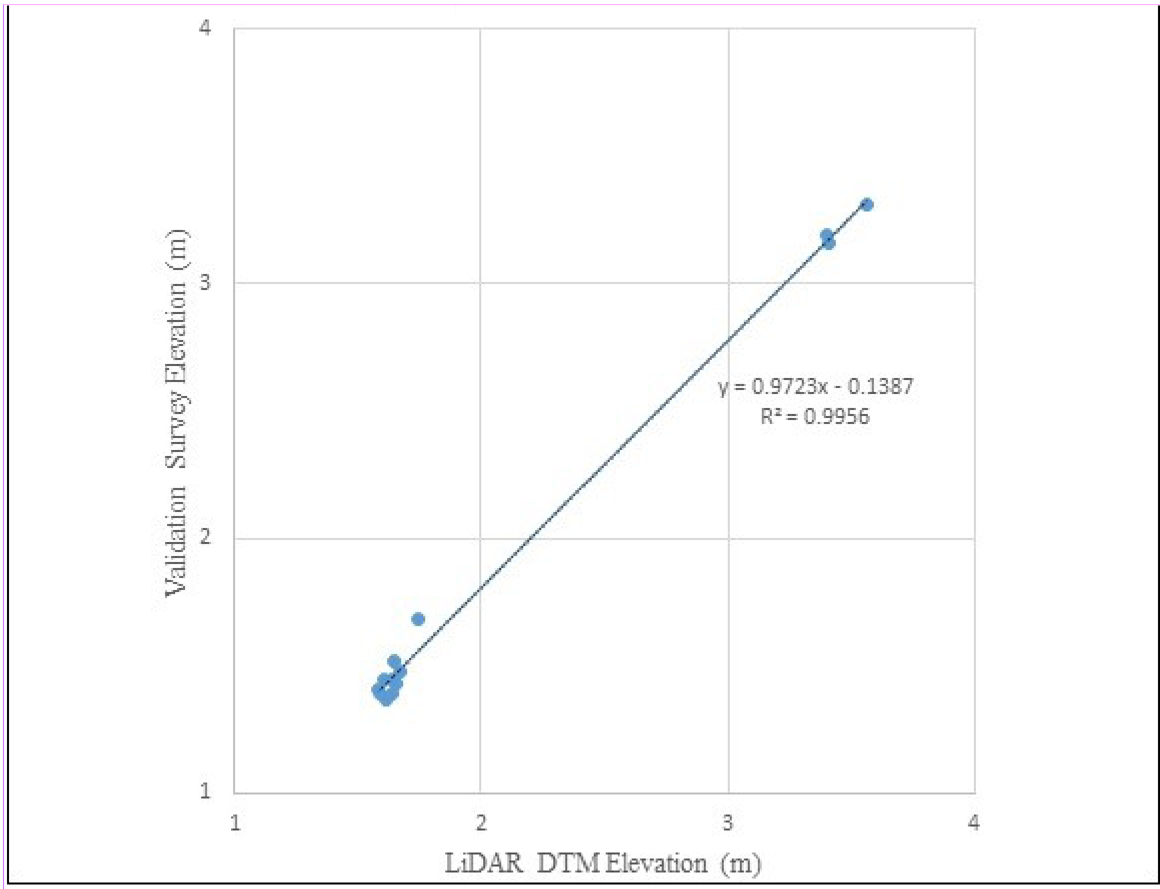

Figure 26. Correlation plot between validation survey points and LiDAR data.

Table 16. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.20
Standard Deviation	0.05
Average	0.20
Minimum	0.08
Maximum	0.31

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and zigzag data was available for Loom with 1,675 bathymetric survey points. The resulting raster surface produced was done by Kernel interpolation with barriers method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.46 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Loom integrated with the processed LiDAR DEM is shown in Figure 27.

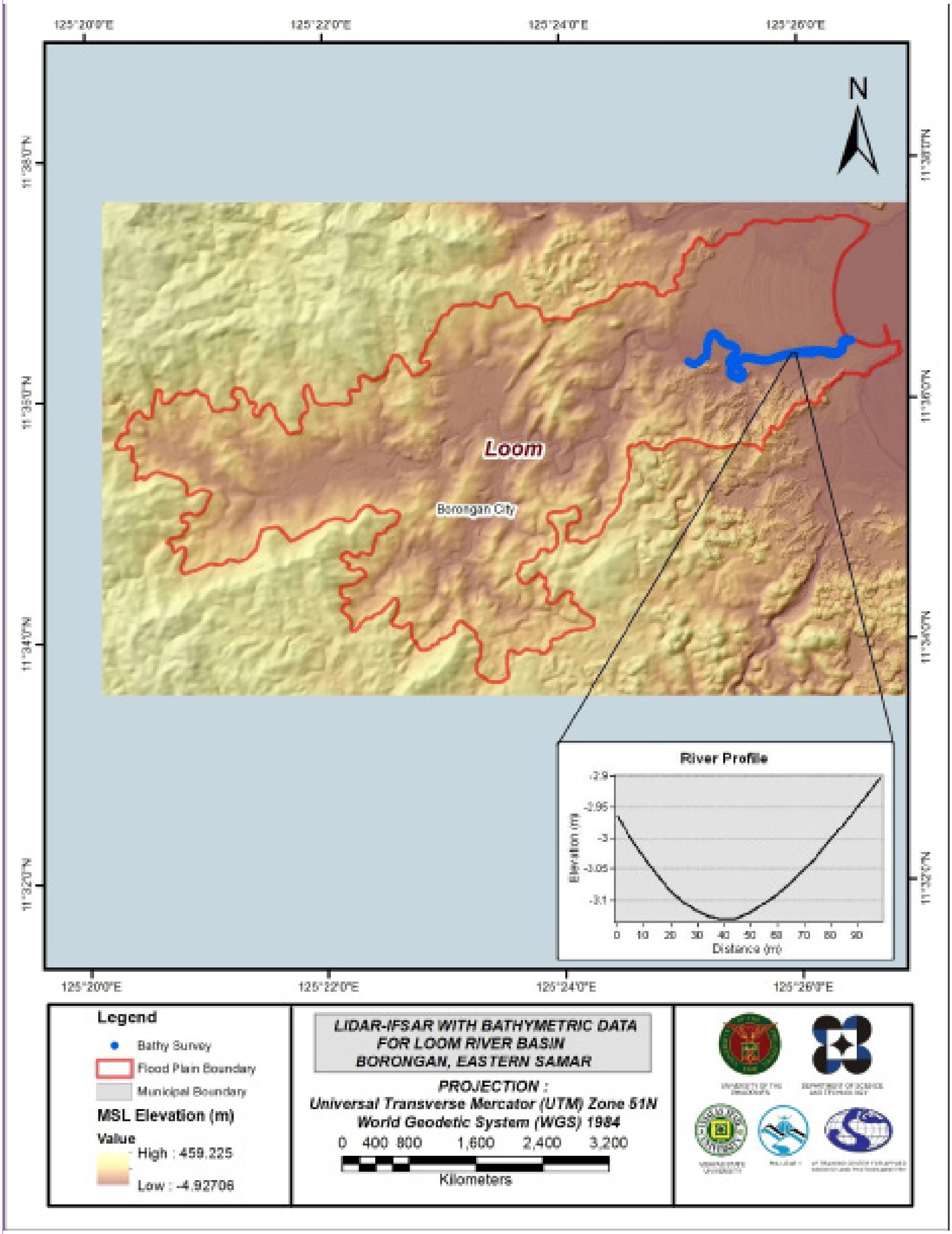

Figure 27. Map of Loom Flood Plain with bathymetric survey points shown in blue.

3.12 Feature Extraction

The features salient in flood hazard exposure analysis include buildings, road networks, bridges and water bodies within the floodplain area with 200 m buffer zone. Mosaicked LiDAR DEM with 1-meter resolution was used to delineate footprints of building features, which consist of residential buildings, government offices, medical facilities, religious institutions, and commercial establishments, among others. Road networks 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

Loom Floodplain, including its 200 m buffer, has a total area of 43.85 sq km. For this area, a total of 1.0 sq km, corresponding to a total of 709 building features, are considered for QC. Figure 28 shows the QC blocks for Loom Floodplain.

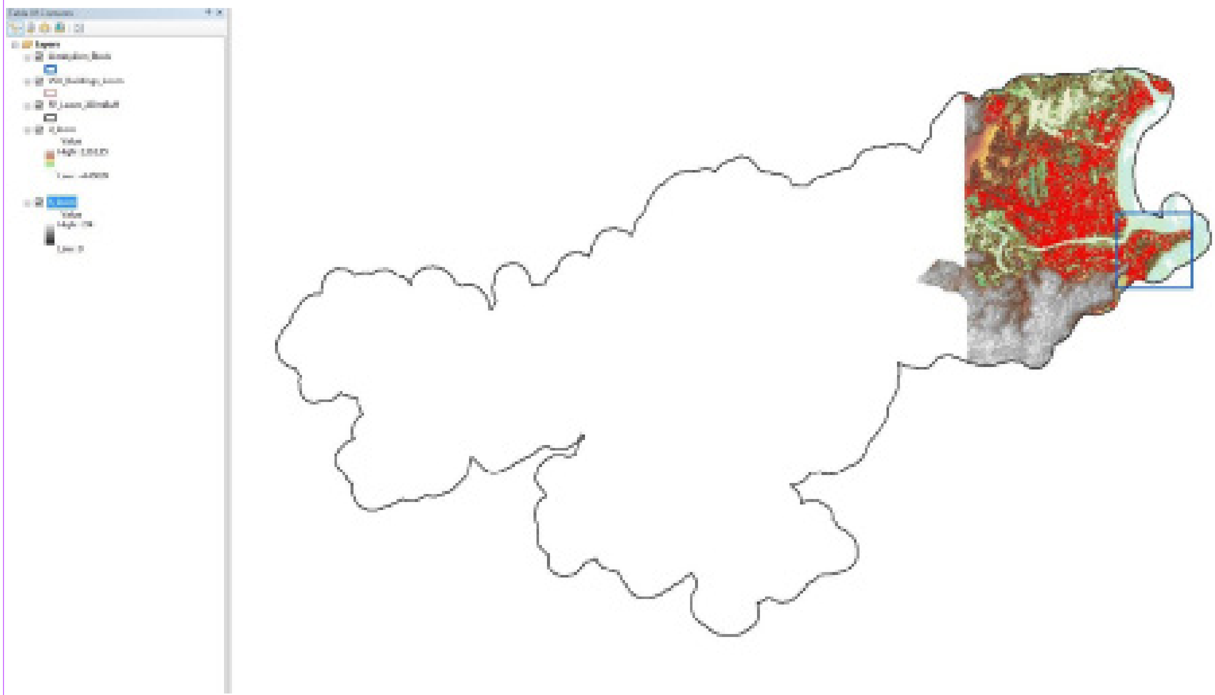

Figure 28. QC blocks for Loom building features

Quality checking of Loom building features resulted in the ratings shown in Table 16.

Table 17. Total Length of Extracted Roads for Dipolog Floodplain.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Loom	92.68	97.02	85.39	PASSED

3.12.2 Height Extraction

Loom Floodplain, including its 200 m buffer, has a total area of 43.85 sq km. For this area, a total of 1.0 sq km, corresponding to a total of 709 building features, are considered for QC. Figure 28 shows the QC blocks for Loom Floodplain.

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 18 summarizes the number of building features per type. On the other hand, Table 19 shows the total length of each road type, while Table 20 shows the number of water features extracted per type.

Table 18. Building Features Extracted for Loom Floodplain.

Facility Type	No. of Features
Residential	6,908
School	109
Market	12
Agricultural/Agro-Industrial Facilities	1
Medical Institutions	17
Barangay Hall	15
Military Institution	0
Sports Center/Gymnasium/Covered Court	6
Telecommunication Facilities	4
Transport Terminal	8
Warehouse	12
Power Plant/Substation	0
NGO/CSO Offices	2
Police Station	0
Water Supply/Sewerage	0
Religious Institutions	31
Bank	10
Factory	0
Gas Station	7
Fire Station	0
Other Government Offices	49
Other Commercial Establishments	184
Abandoned Buildings	0
Total	7,375

Table 19. Total Length of Extracted Roads for Dipolog Floodplain.

Flood Plain	Road Network Length (km)					Total
	Barangay Road	City/ Municipal Road	Provincial Road	National Road	Others	
Loom	3.25	15.44	0	3.75	0.00	22.44

Table 20. Number of Extracted Water Bodies for Loom Floodplain.

Flood Plain	Water Body Type					Total
	Rivers/ Streams	Lakes/Ponds	Sea	Irrigation	Fish Pen	
Loom	3	0	0	0	0	3

A total of three (3) bridges were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

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

Figure 29 shows the Digital Surface Model (DSM) of Loom Floodplain overlaid with its ground features.

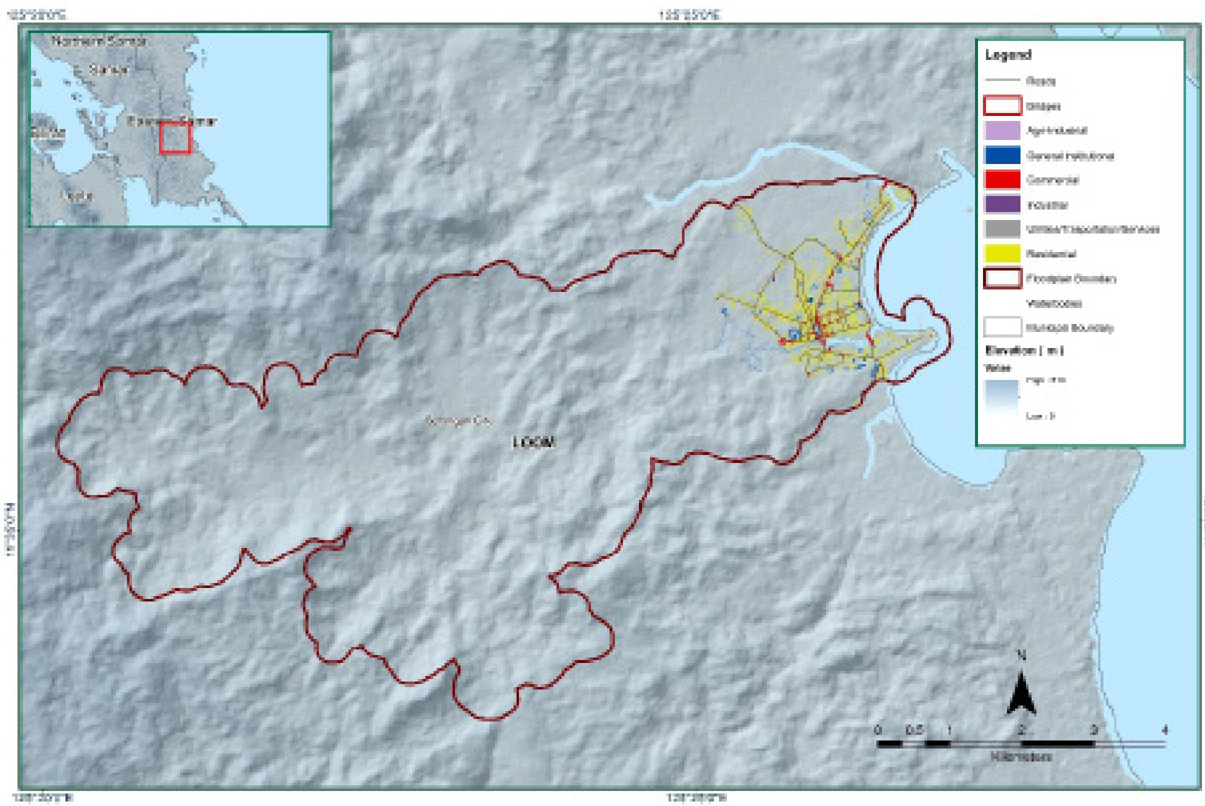

Figure 29. Extracted features for Loom Floodplain.

CHAPTER 4: LiDAR VALIDATION SURVEY AND MEASUREMENTS OF THE LOOM RIVER BASIN

Engr. Louie P. Balicanta, Engr. Joemarie S. Caballero, Ms. Patrizcia Mae. P. dela Cruz,
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The methods applied in this Chapter were based on the DREAM methods manual (Sarmiento, et al., 2014) and further enhanced and updated in Paringit, et al. (2017).

4.1 Summary of Activities

The Loom River Basin covers the City of Borongan in Eastern Samar. The Flood Modelling Component (FMC) of the Phil-LiDAR 1 Program has computed that the Loom River Basin has a drainage area of 67 km². Its main stem, Loom River, is among the 28 river systems in Eastern Visayas Region. According to the 2015 national census of PSA, a total of 8,286 persons are residing within the immediate vicinity of the river, which is distributed among barangays Alang-alang, Purok D1 (Poblacion), Purok B (Poblacion), Purok D2 (Poblacion), Purok F (Poblacion), Purok H (Poblacion), and Taboc, in the City of Borongan. The economy of Eastern Samar Province largely rests on livestock and agriculture with coconut, rice, and banana as the main crops and top products (Philippine Statistics Authority, 2017). Last Dec. 7, 2014, Typhoon Ruby (international name: Hagupit) brought heavy rains which resulted to flashfloods in two (2) barangays in Eastern Samar and killing sixteen (16) people in Borongan City as per ABS-CBN News (Mogato, 2014).

In line with this, H.O. Noveloso Surveying (HONS) conducted a field survey in Loom River on Dec. 17, 2016, Feb. 20-21, 2107, Feb. 24, 2017, and Feb. 27, 2017 with the following scope: reconnaissance; control survey; cross-section and as-built survey Detour Bridge in Brgy. Alang-alang and Loom Bridge in Brgy. Purok D1 (Poblacion), City of Borongan, Eastern Samar; and bathymetric survey of the river from the upstream in Brgy. Purok G (Poblacion), Borongan City to the mouth of the river in Brgy. Alang-alang, Borongan City, Eastern Samar with an approximate length of 5.10 km. Random checking points for the contractor's cross-section and bathymetry data were gathered by DVBC on January 27 – February 9, 2017 using an Ohmex™ Single Beam Echo Sounder and Trimble® SPS 985 GNSS PPK survey technique. In addition to this, validation points acquisition survey was conducted covering the Loom River Basin area. The entire survey extent is illustrated in Figure 30.

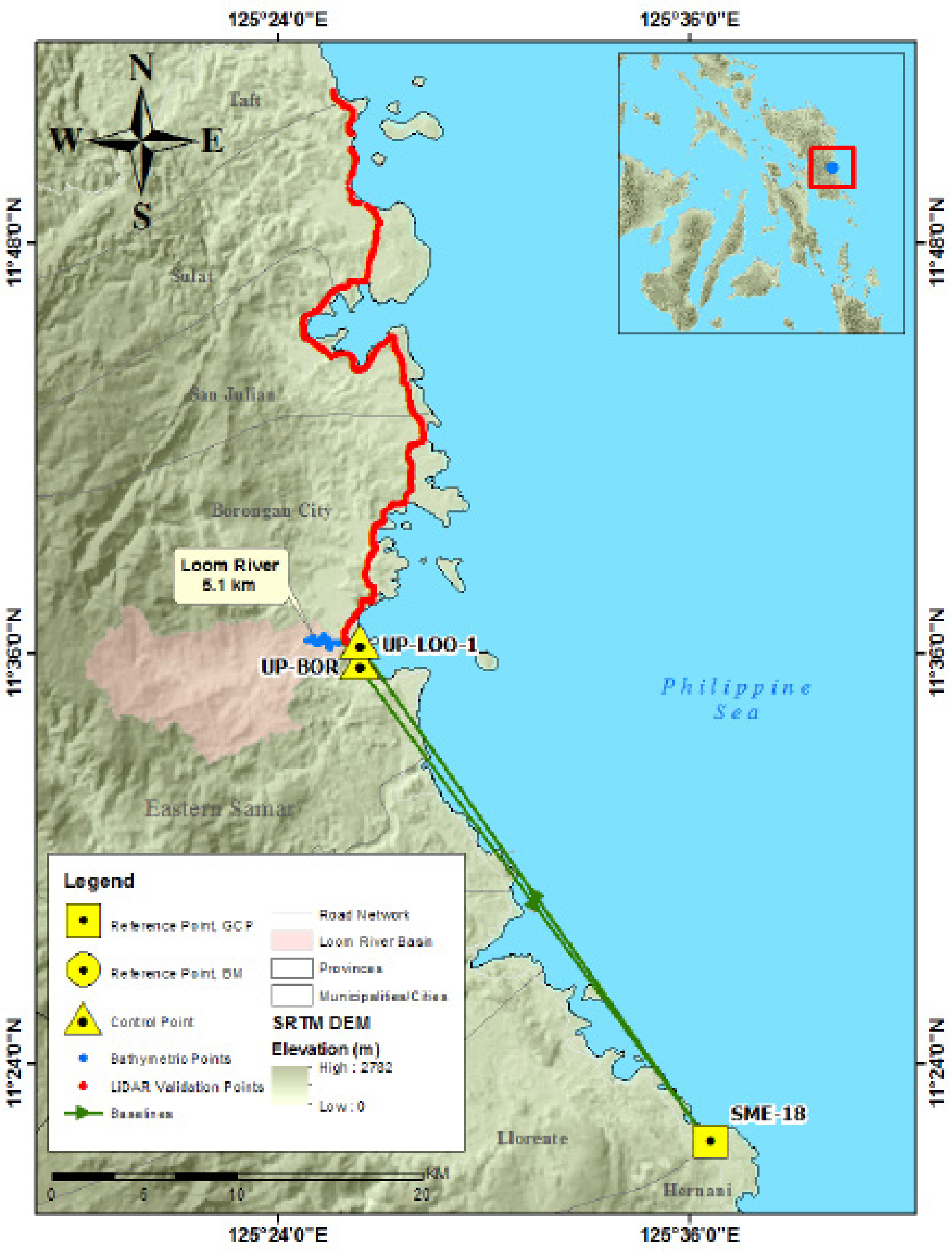


Figure 30. Loom River Survey Extent

4.2 Control Survey

The GNSS network used for Loom River is composed of one (1) loop established on January 27, 2017 occupying the following reference points: SME-18, a second-order GCP, in Brgy. San Jose, Hernani, Eastern Samar and UP-BOR, a DVBC established point on December 2016, in Brgy. Can-Abong, Borongan City, Eastern Samar.

One (1) control point established in the area by HONS was also occupied: UP-LOO-1, located at the approach of Detour Bridge in Brgy. Alang-alang, Borongan City, Eastern Samar.

The summary of reference and control points and its location is summarized in Table 21 while GNSS network established is illustrated in Figure 32.

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoid Height (m)	Elevation (MSL) (m)	Date of Establishment
SME-18	2nd Order, GCP	11°21'43.08128"N	125°36'37.41861"E	-	17.659	2007
UP-BOR	Established	11°35'44.89710"N	125°26'23.64084"E	-	5.989	2016
UP-LOO-1	Established	-	-	-	-	10-17-16
UP-LOO-1	Established	-	-	-	-	10-17-16

Table 21. List of reference and control points used during the survey in Loom River (Source: NAMRIA, UP-TCAGP)

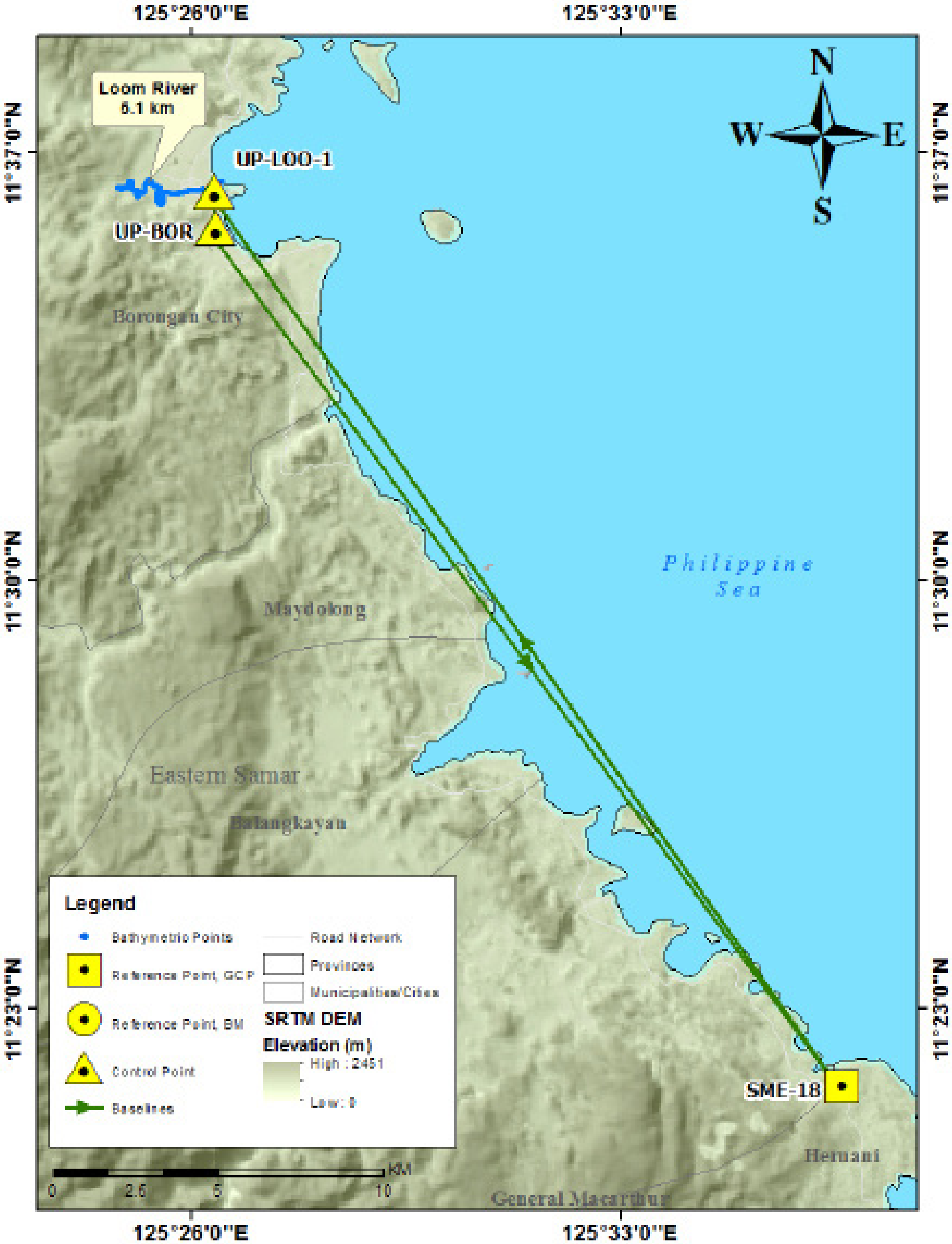


Figure 31. Loom River Basin Control Survey Extent

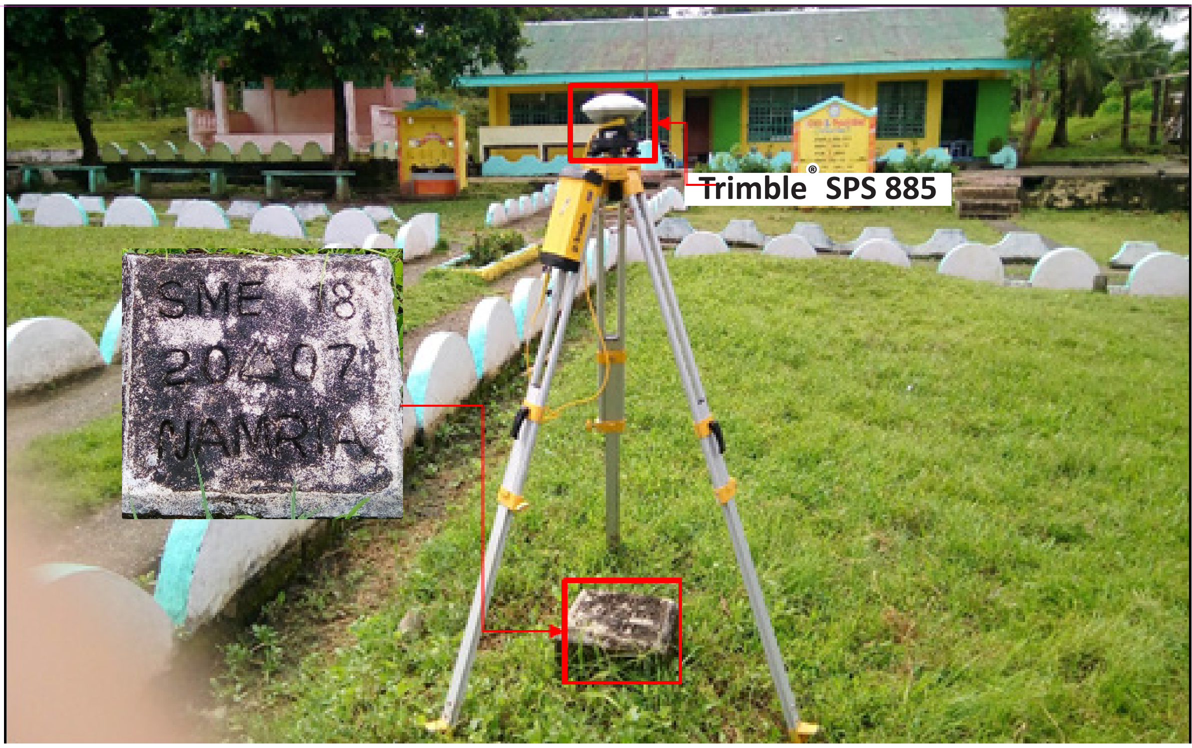


Figure 32. GNSS base set up, Trimble® SPS 885, at SME-18, located 20 m W from the entrance of San Jose Elementary School in Brgy. San Jose, Hernani, Eastern Samar.

Figure 33. GNSS receiver set up, Trimble® SPS 885, at UP-BOR, located at the approach of a bridge along the National Highway in Brgy. Can-Abong, Borongan City, Eastern Samar.

Figure 34. GNSS receiver set up, Trimble® SPS 985, at UP-LOO-1, located at the approach of Detour Bridge in Brgy. Alang-alang, Borongan City, Eastern Samar.

4.3 Baseline Processing

GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement, respectively. In case where one or more baselines did not meet all of these criteria, masking is performed. Masking is done by removing/masking portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. Baseline processing result of control points in Loom River Basin is summarized in Table 21 generated by TBC software.

Table 22. Baseline Processing Report for Loom River Static Survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	Height (m)
UP-BOR --- SME-18	1-27-2017	Fixed	0.002	0.013	144°15'42"	31862.088	11.113
UP-BOR--- UP-LOO-1	1-27-2017	Fixed	0.002	0.003	357°47'42"	1127.722	-0.358
SME-18--- UP-LOO-1	1-27-2017	Fixed	0.003	0.015	325°23'01"	32808.039	-11.353

As shown Table 22, a total of three (3) baselines were processed with coordinate and elevation values of SME-18 and UP-BOR held fixed. All of them passed the required accuracy.

4.4 Network Adjustment

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

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

Where:

x_e is the Easting Error,
y_e is the Northing Error, and
z_e is the Elevation Error

for each control point. See the Network Adjustment Report shown from Table 23 to Table 25 for the complete details. Refer to Appendix C for the computation for the accuracy of HONS.

The three (3) control points, SME-18, UP-BOR, and UP-LOO-1 were occupied and observed simultaneously to form a GNSS loop. The coordinate and elevation values of SME-18 and UP-BOR were held fixed during the processing of the control points as presented in Table 23. Through this reference point, the coordinates and elevations of the unknown control points will be computed.

Table 23. Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
SME-18	Grid	Fixed	Fixed		Fixed
UP-BOR	Grid	Fixed	Fixed		Fixed
Fixed = 0.000001(Meter)					

Table 24. Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
SME-18	784907.431	?	1257282.043	?	17.659	?	ENe
UP-BOR	766068.889	?	1282998.400	?	5.989	?	ENe
UP-LOO-1	766015.814	0.007	1284125.374	0.006	5.705	0.018	

With the mentioned equation, $\sqrt{((X_e)^2+(Y_e)^2)}<20cm$ for horizontal and $Z_e<10cm$ for the vertical; the computation for the accuracy are as follows:

a. SME-18
horizontal accuracy = Fixed
vertical accuracy = Fixed

b. UP-BOR
horizontal accuracy = Fixed
vertical accuracy = Fixed

c. UP-LOO-1

horizontal accuracy = $\sqrt{((0.7)^2 + (0.6)^2}$
= $\sqrt{(0.49 + 0.36)}$
= 0.92 < 20 cm

vertical accuracy = 1.8 < 10 cm

Following the given formula, the horizontal and vertical accuracy result of the occupied control point is within the required precision.

Table 25. Adjusted Grid Coordinates

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
SME-18	N11°21'43.08128"	E125°36'37.41861"	78.216	?	ENe
UP-BOR	N11°35'44.89710"	E125°26'23.64084"	67.048	?	ENe
UP-LOO-1	N11°36'21.56943"	E125°26'22.20835"	66.690	0.018	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 25. Based on the result of the computation, the equation is satisfied; hence, the required accuracy for the program was met.

The summary of reference control points used is indicated in Table 26.

Table 26. Reference and control points used and its location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoid Height (Meter)	Northing (m)	Easting (m)	BM Ortho (m)
SME-18	2nd Order, GCP	11°21'43.08128" N	125°36'37.41861" E	78.216	1257282.043	784907.431	17.659
UP-BOR	Established	11°35'44.89710" N	125°26'23.64084" E	67.048	1282998.400	766068.889	5.989
UP-LOO-1	Established	11°36'21.56943" N	125°26'22.20835" E	66.690	1284125.374	766015.814	5.705

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

Cross-section and as-built surveys were conducted on February 21, 2017 at the downstream side of Detour Bridge in Brgy. Alang-alang, Borongan City, Eastern Samar as shown in Figure 35. A Hi-Target™ GNSS and a Sokkia™ Set CX Total Station were utilized for this survey as shown in Figure 36.

Figure 35. Downstream side of Detour Bridge

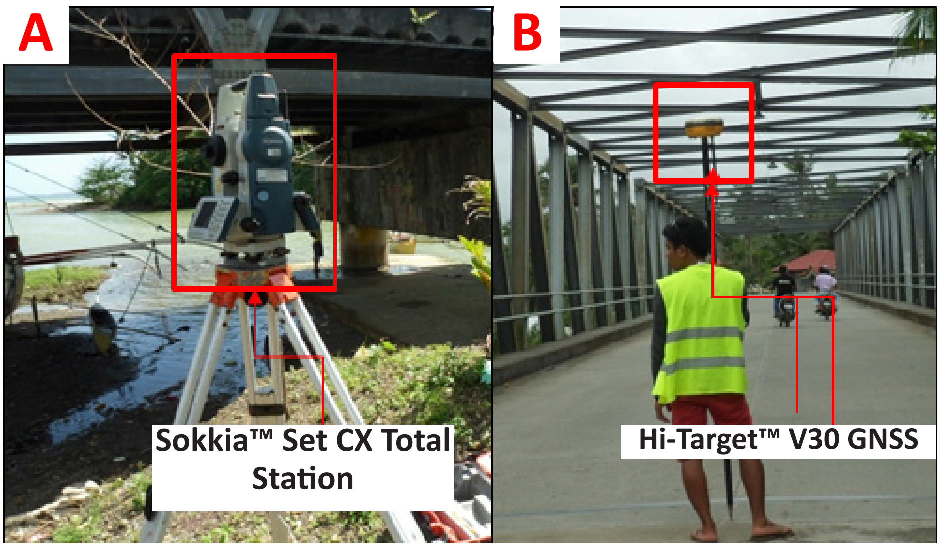


Figure 36. (A) Cross-section and (B) As-built survey of Detour Bridge

The cross-sectional line of Detour Bridge is about 1222 m with three hundred fifty-six (356) cross-sectional points using the control points UP-LOO-2 as the GNSS base station. The cross-section diagram, location map, and the bridge data form are shown from Figure 37 to Figure 39.

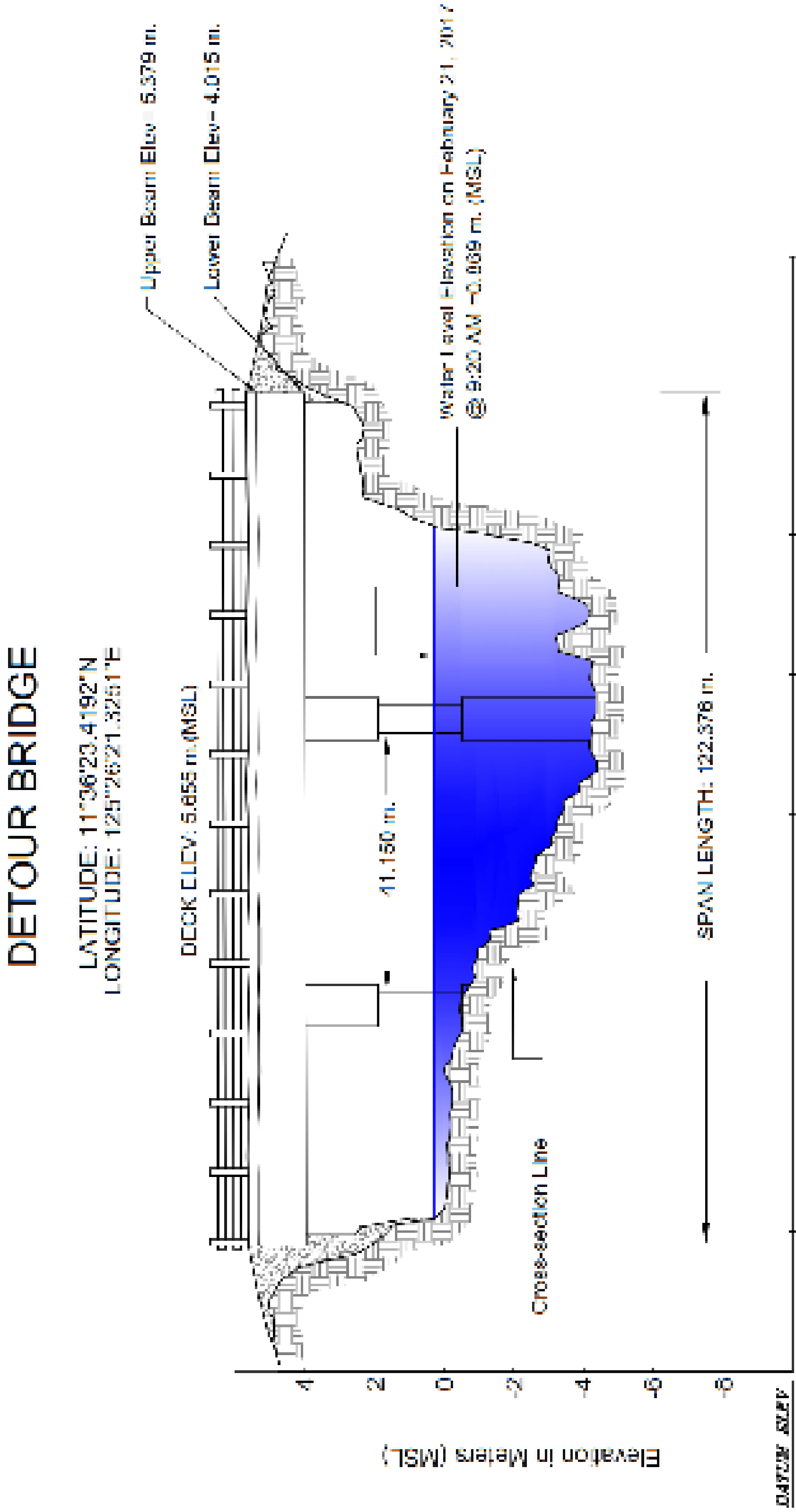


Figure 37. Detour Bridge Cross-section Diagram

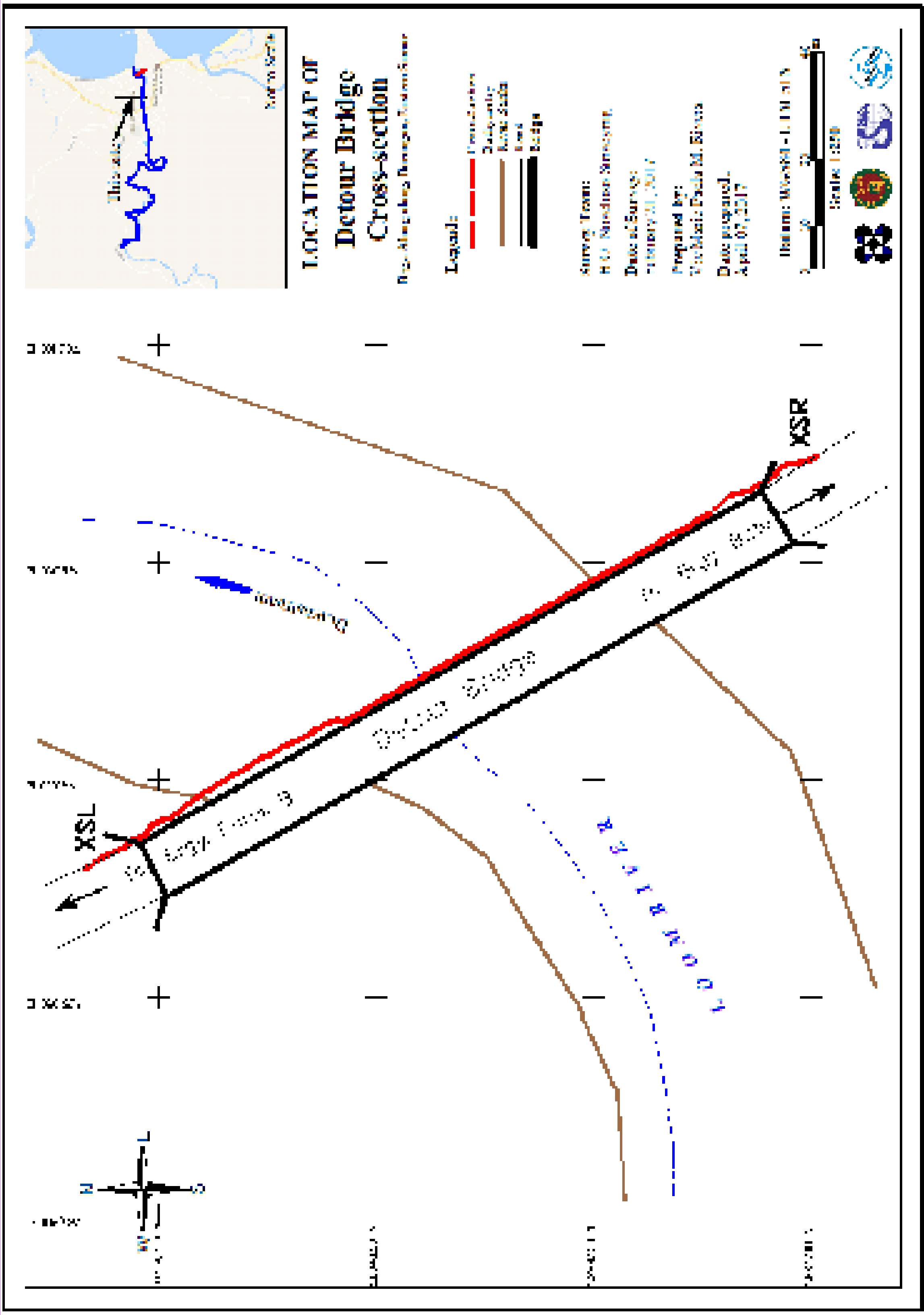


Figure 38. Location Map of Detour Bridge Cross-Section

BRIDGE DATA FORM

Bridge Name: Detour Bridge

River Name: Loom River

Location (Brgy., City, Region): Brgy. Alang alang, Borongan, Eastern Samar

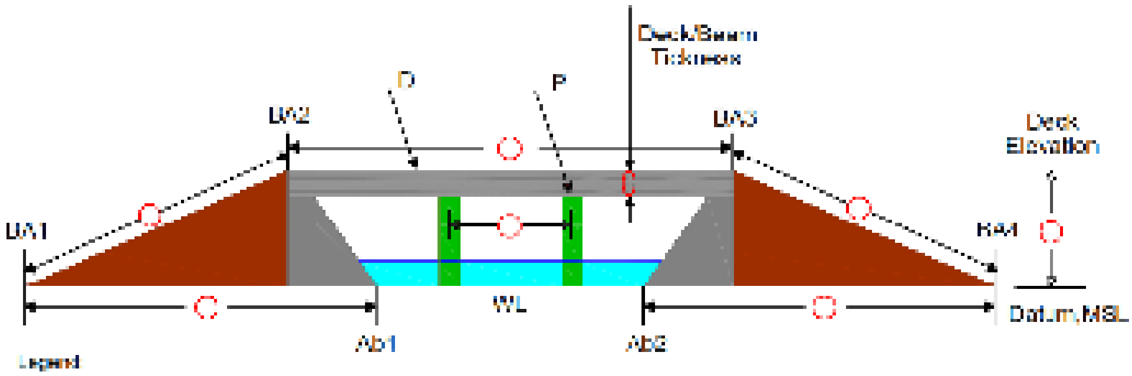
Survey Team: Julieto Cabilin, Jodel dela Cruz, and Oscar Agustin

Date and Time: February 21, 2017 @ 9:00 am - 5:00 pm

Flow Condition: Low Normal High

Weather Condition: Fair Rainy

Cross-sectional View (not to scale)



Legend:
BA = Bridge Approach
P = Pier
Ab = Abutment
D = Deck
WL = Water Level/Surface
MSL = Mean Sea Level
= Measurement Value

Line Segment	Measurement, m	Remarks
1. BA1-BA2	7.053 m.	Concrete
2. BA2-BA3	122.376 m.	Concrete
3. BA3-BA4	7.549 m.	Concrete
4. BA1-Ab1	11.083 m.	Concrete
5. Ab2-BA4	10.378 m.	Concrete
6. Deck/Beam Thickness	1.306 m.	Concrete
7. Deck Elevation	5.556 m. MSL	Concrete
8. P1-P2	41.150 m.	Concrete

Note: Observer should be facing downstream

Figure 39. Detour Bridge Data Sheet

Cross-section and as-built surveys were conducted on February 20, 2017 at the downstream side of Loom Bridge in Brgy. Purok D1, Borongan City, Eastern Samar as shown in Figure 40. A Hi-Target™ GNSS and a Sokkia™ Set CX Total Station were utilized for this survey as shown in Figure 41. The Automated Water Level System (AWLS) is located on the upstream side of the bridge and its elevation was measured 6.688 m above MSL.

Figure 40. Downstream side of Loom Bridge

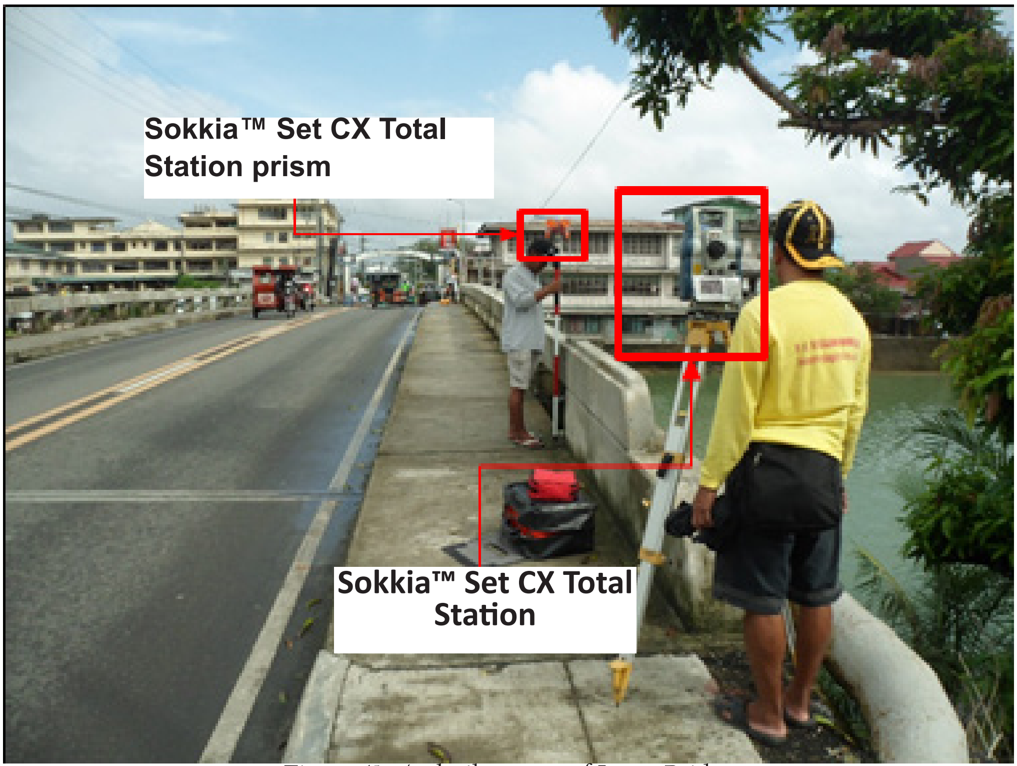


Figure 41. As-built survey of Loom Bridge

The cross-sectional line of Loom Bridge is about 52 m with two hundred twenty (220) cross-sectional points using the control points UP-LOO-2 as the GNSS base station. The cross-section diagram, location map, and the bridge data form are shown in Figure 42 to Figure 44.

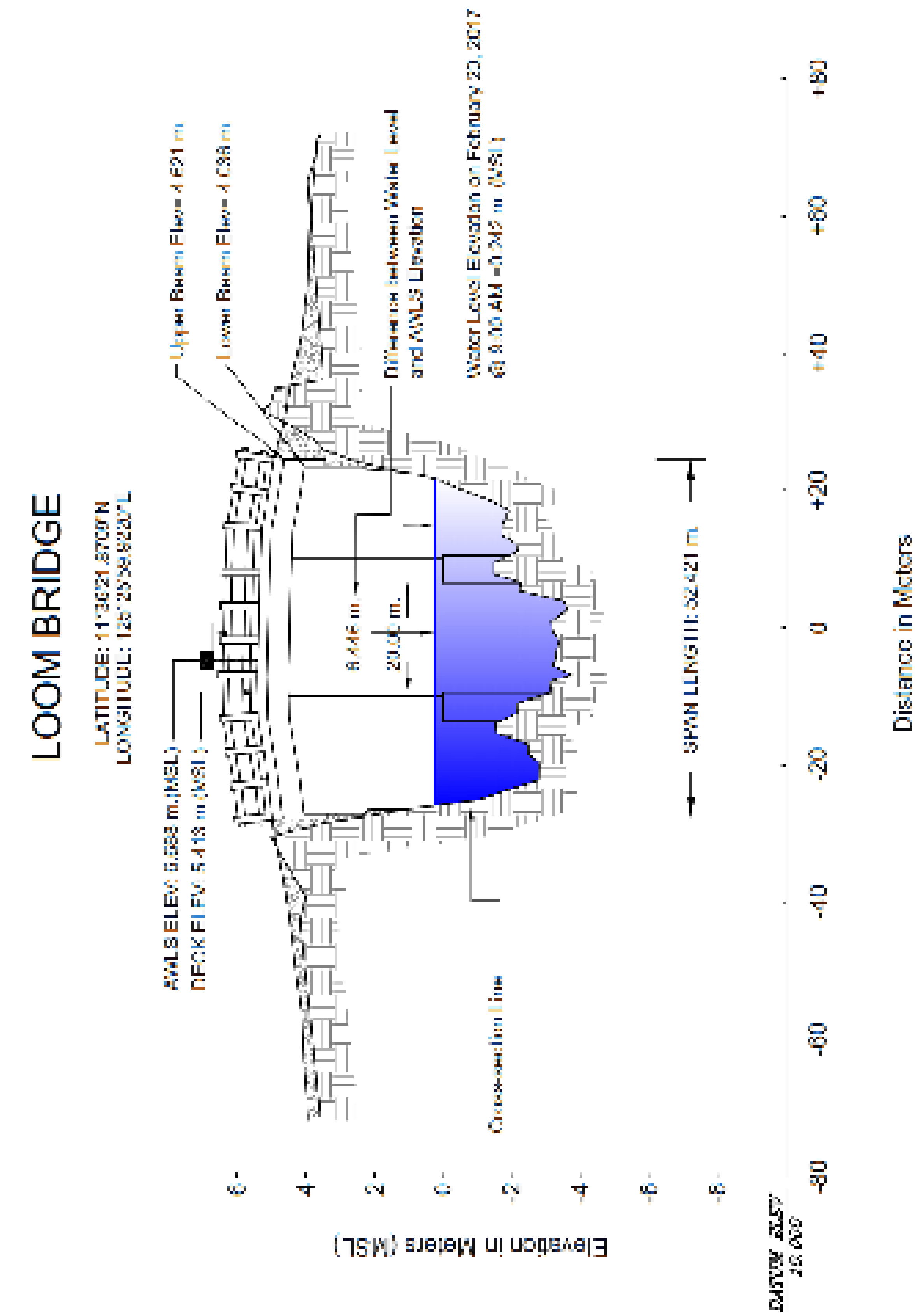


Figure 42. Loom Bridge Cross-section Diagram

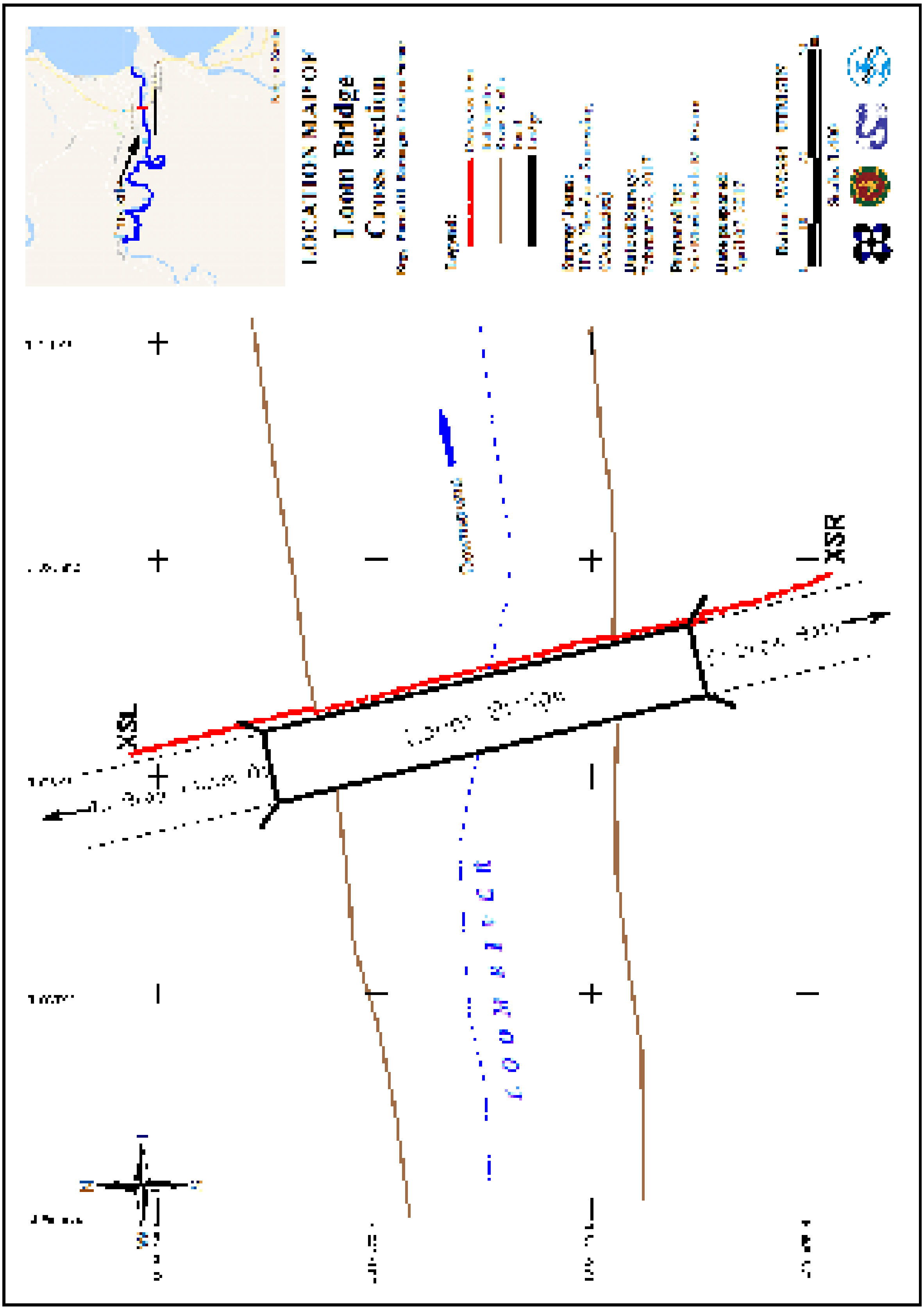


Figure 43. Location Map of Loom Bridge Cross-Section

BRIDGE DATA FORM

Bridge Name: Loom Bridge

River Name: Loom River

Location (Brgy., City, Region): Purok D1 (Poblacion), Borongan, Eastern Samar

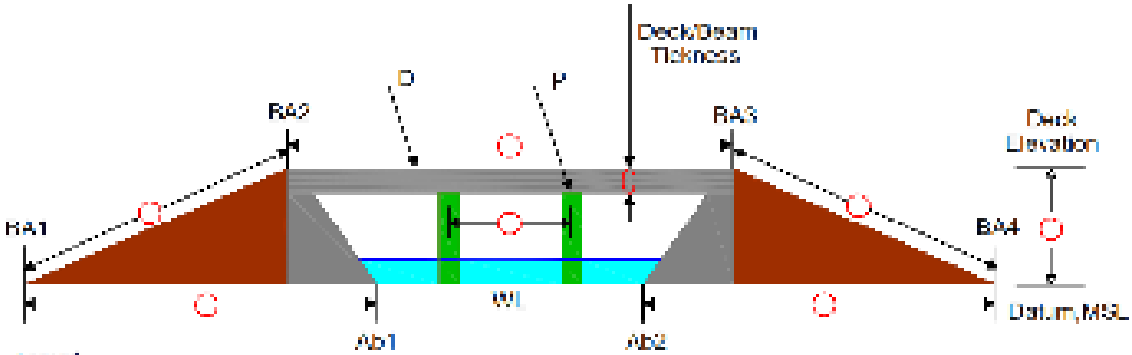
Survey Team: Urbano Castillo, Rhey Joseph Domingo, and Eduardo Culzon

Date and Time: February 20, 2017 @ 9:00 am - 5:00 pm

Flow Condition: Low Normal High

Weather Condition: Fair Rainy

Cross-sectional View (not to scale)



Legend
BA = Bridge Approach
P = Pier
Ab = Abutment
D = Deck
WL = Water Level/Surface
MSL = Mean Sea Level
= Measurement Value

Line Segment	Measurement m	Remarks
1. BA1-BA2	2.359 m	Concrete
2. BA2-BA3	52.421 m.	Concrete
3. BA3-BA4	4.372 m.	Concrete
4. BA1-Ab1	3.599 m.	Concrete
5. Ab2-BA4	8.545 m.	Concrete
6. Deck/Beam thickness	0.565 m	Concrete
7. Deck Elevation	5.413 m. MSL	Concrete
8. P1-P2	20.000 m.	Concrete

Note: Observer should be facing downstream

Figure 44. Loom Bridge Data Sheet

Gathering of random points for the checking of HONS's bridge cross-section data was performed by DVBC on January 27, 2017 at Detour Bridge and on January 28, 2017 at Loom Bridge using a survey grade GNSS Rover receiver attached to a 2-m pole as seen in Figure 45.

Figure 45. Gathering of random cross-section points along (A) Detour Bridge and (B) Loom Bridge

Linear square correlation (R2) and RMSE analysis were performed on the two (2) datasets for the two (2) bridges. The linear square coefficient range is determined to ensure that the submitted data of the contractor is within the accuracy standard of the project which is ±20 cm and ±10 cm for horizontal and vertical, respectively. The R2 value must be within 0.85 to 1. An R2 approaching 1 signifies a strong correlation between the vertical (elevation values) of the two (2) datasets. A computed R2 values of 0.992 and 0.864 for the cross-section data of Detour Bridge and Loom Bridge, respectively, were obtained by comparing the data of the contractor and DVBC; signifying a strong correlation between the two (2) datasets.

In addition to the Linear Square correlation, Root Mean Square (RMSE) analysis is also performed in order to assess the difference in elevation between the DVBC checking points and the contractor's. The RMSE value should only have a maximum radial distance of 5 m and the difference in elevation within the radius of five (5) meters should not be beyond 0.50 m. For the cross-section data of Detour Bridge and Loom Bridge, a computed values of 0.183 and 0.230, respectively, were acquired. The computed R2 and RMSE values are within the accuracy requirement of the program.

Water surface elevation of Loom River was determined by a Sokkia™ Set CX Total Station on February 20, 2017 at the railings of Loom Bridge in Brgy. Purok D1, Borongan City, Eastern Samar with a value of 5.6798 m in MSL. This was translated into marking on the bridge's sidewalk 3.628 m away from the AWLS as shown in Figure 46.

Figure 46. Gathering of random cross-section points along (A) Detour Bridge and (B) Loom Bridge

Water surface elevation of Loom River was also determined by a Sokkia™ Set CX Total Station on February 20, 2017 at 9:00 AM at Loom Bridge area with a value of 0.242 m in MSL as shown in Figure 47. This was translated into marking on the bridge's pier as shown in Figure 47. The markings will serve as reference for flow data gathering and depth gauge deployment of the partner HEI responsible for Loom River, the Visayas State University.

Figure 47. Water level markings on the pier of Loom Bridge

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted by DVBC on January 30, 2017 using a survey grade GNSS Rover receiver, Trimble® SPS 882, mounted on a range pole which was attached on the front of the vehicle as shown in Figure 48. It was secured with cable ties and ropes to ensure that it was horizontally and vertically balanced. The antenna height was 2.305 m and measured from the ground up to the bottom of the antenna mount of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with UP-SUL, a DVBC established point for the survey of Sulat River last December 2016, occupied as the GNSS base station in the conduct of the survey.

Figure 48. Validation points acquisition survey set-up for Loom River

The survey started from Brgy. Maramara, Sulat, Eastern Samar going south along the national highway, covering three (3) barangays in Sulat, 12 barangays in San Julian, 15 barangays in Borongan City, and ended in Brgy. Purok D1, Borongan City, Eastern Samar. The survey gathered a total of 8,323 points with an approximate length of 34.61 km using UP-SUL as GNSS base station for the entire extent of validation points acquisition survey as illustrated in the map in Figure 49.

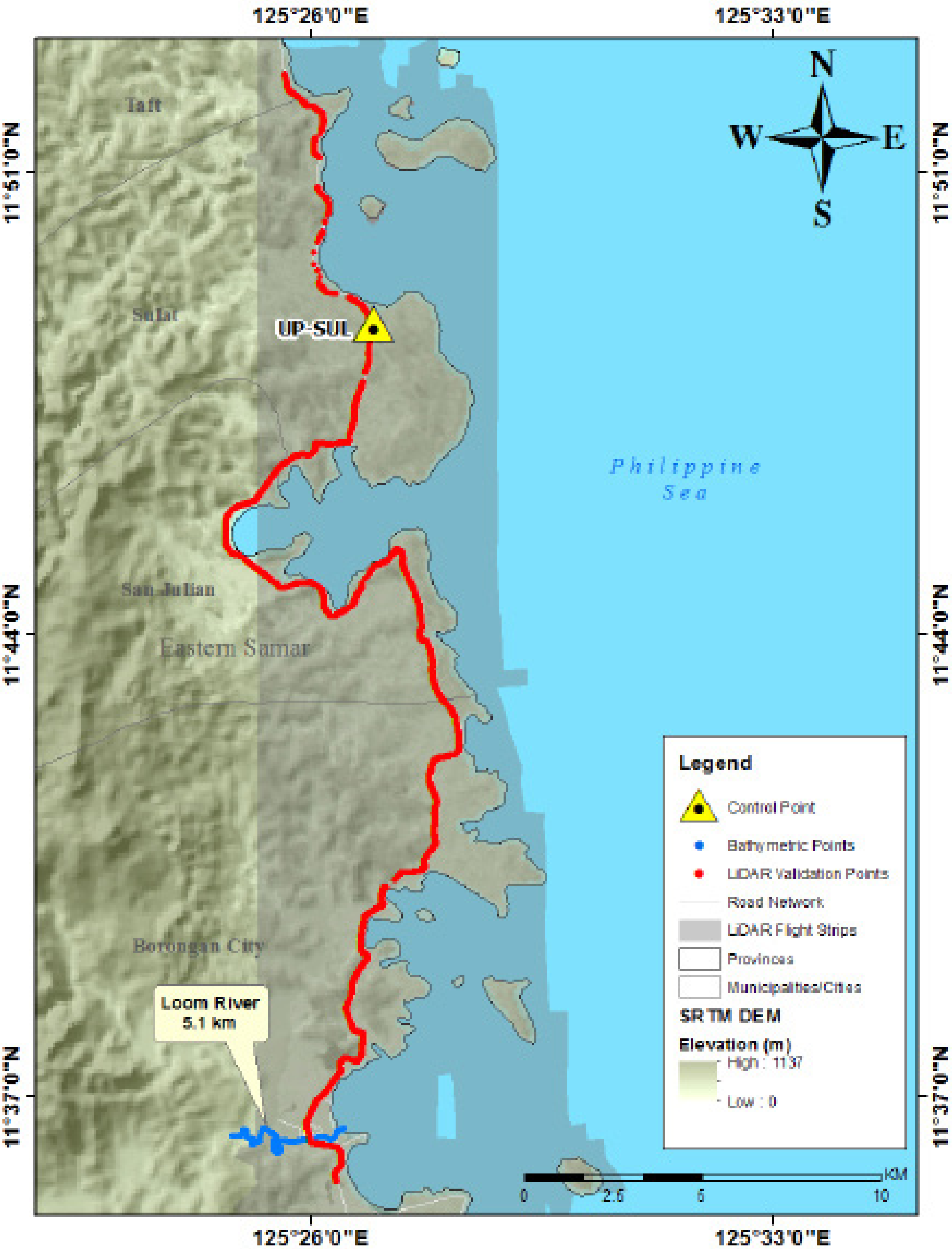


Figure 49. Validation points acquisition covering the Loom Basin Area

4.7 River Bathymetric Survey

Bathymetric survey was executed on February 21 and 27, 2017 using a dual frequency Hi-Target™ V30 GNSS and a Hi-Target™ Single Beam Echo Sounder mounted in a motor boat as illustrated in Figure 50. The survey started in Brgy. Purok F, Borongan City, Eastern Samar with coordinates 11° 36' 18.65048" N, 125° 25' 04.04442" E and ended in Brgy. Alang-alang, Borongan City with coordinates 11° 36' 20.21905" N, 125° 25' 51.11739" E. The survey continued in Brgy. Purok D1 (Poblacion), Borongan City with coordinates 11° 36' 21.69592" N, 125° 25' 53.78171" E and ended at the mouth of the river in Brgy. Alang-alang, Borongan City, Eastern Samar with coordinates 11° 36' 28.47821" N, 125° 26' 26.68441" E.

Figure 50. Bathymetric survey of HONS along Loom River

Manual bathymetric survey, on the other hand, was also executed on February 21 and 24, 2017 using a Sokkia™ Set CX Total Station as illustrated in Figure 51. The survey started in Brgy. Purok G (Poblacion), Borongan City, Eastern Samar with coordinates 11° 36' 33.24570" N, 125° 24' 40.84639" E, traversing down the river and ended at starting point of the bathymetric survey using a boat in Brgy. Purok F (Poblacion). The survey continued in Brgy. Alang-alang with coordinates 11° 36' 20.05628" N, 125° 25' 49.51708" E and ended at the starting point of the continuation of the survey using a boat in Brgy. Purok D1, Borongan City. The survey further continued at the mouth of the river in Brgy. Alang-alang, Borongan City, Eastern Samar. The control points UP-LOO-1, UP-LOO-2, UP-LOO-3, and UP-LOO-4 were used as GNSS base stations all throughout the entire survey.

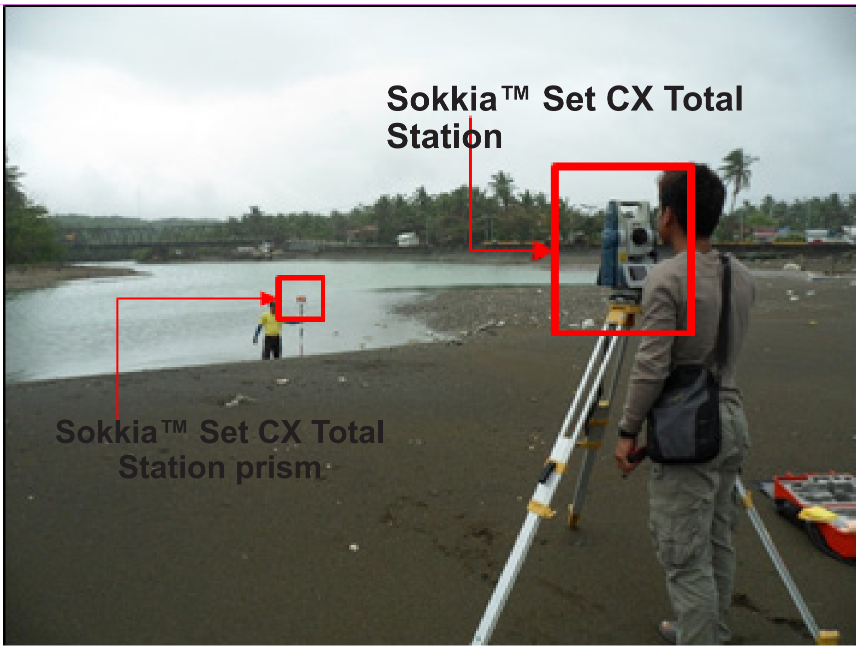


Figure 51. Manual bathymetric survey of HONS along Loom River

Gathering of random points for the checking of HONS's bathymetric data was performed by DVBC on January 28, 2017 using a survey grade GNSS Rover receiver attached to a boat as seen in Figure 52. A map showing the DVBC bathymetric checking points is shown in Figure 53.

Figure 52. Gathering of random bathymetric points along Loom River

Linear square correlation (R2) and RMSE analysis were also performed on the two (2) datasets and a computed R2 value of 0.906 for the bathymetric data is within the required range for R2, which is 0.85 to 1. Additionally, an RMSE value of 0.311 for the bathymetric data was obtained. Both the computed R2 and RMSE values are within the accuracy required by the program.

The bathymetric survey for Loom River gathered a total of 2,240 points covering 5.10 km of the river traversing barangays Alang-alang, Purok D1 (Poblacion), Purok B (Poblacion), Purok D2 (Poblacion), Purok F (Poblacion), Purok H (Poblacion), Purok G (Poblacion), and Taboc, in the City of Borongan A CAD drawing was also produced to illustrate the riverbed profile of Loom River.

As shown in Figure 55, the highest and lowest elevation has a 4.60-m difference. The highest elevation observed was 0.876 m above MSL located in Brgy. Purok F, Borongan City, Eastern Samar while the lowest was –3.725 m below MSL located in Brgy. Alang-alang, Borongan City, Eastern Samar.

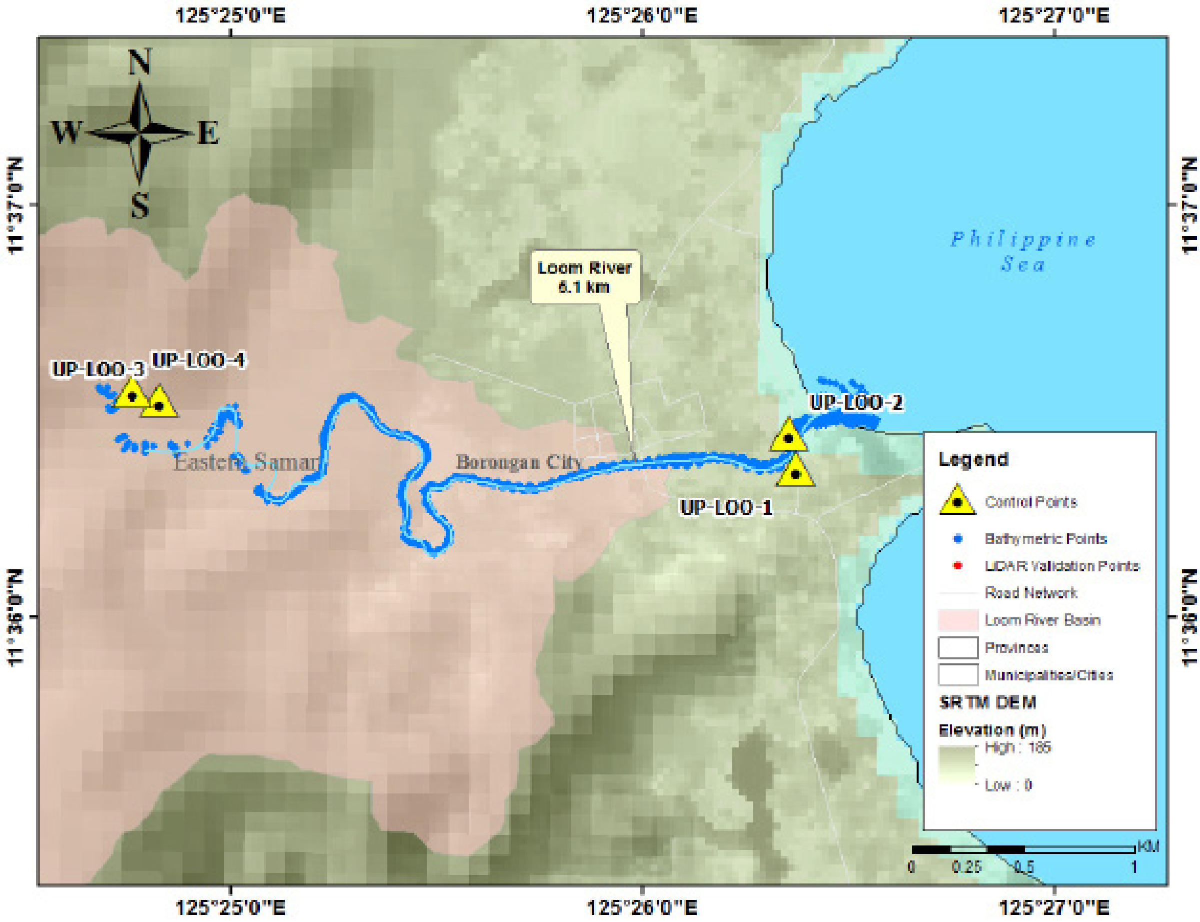


Figure 53. Bathymetric survey of Loom River

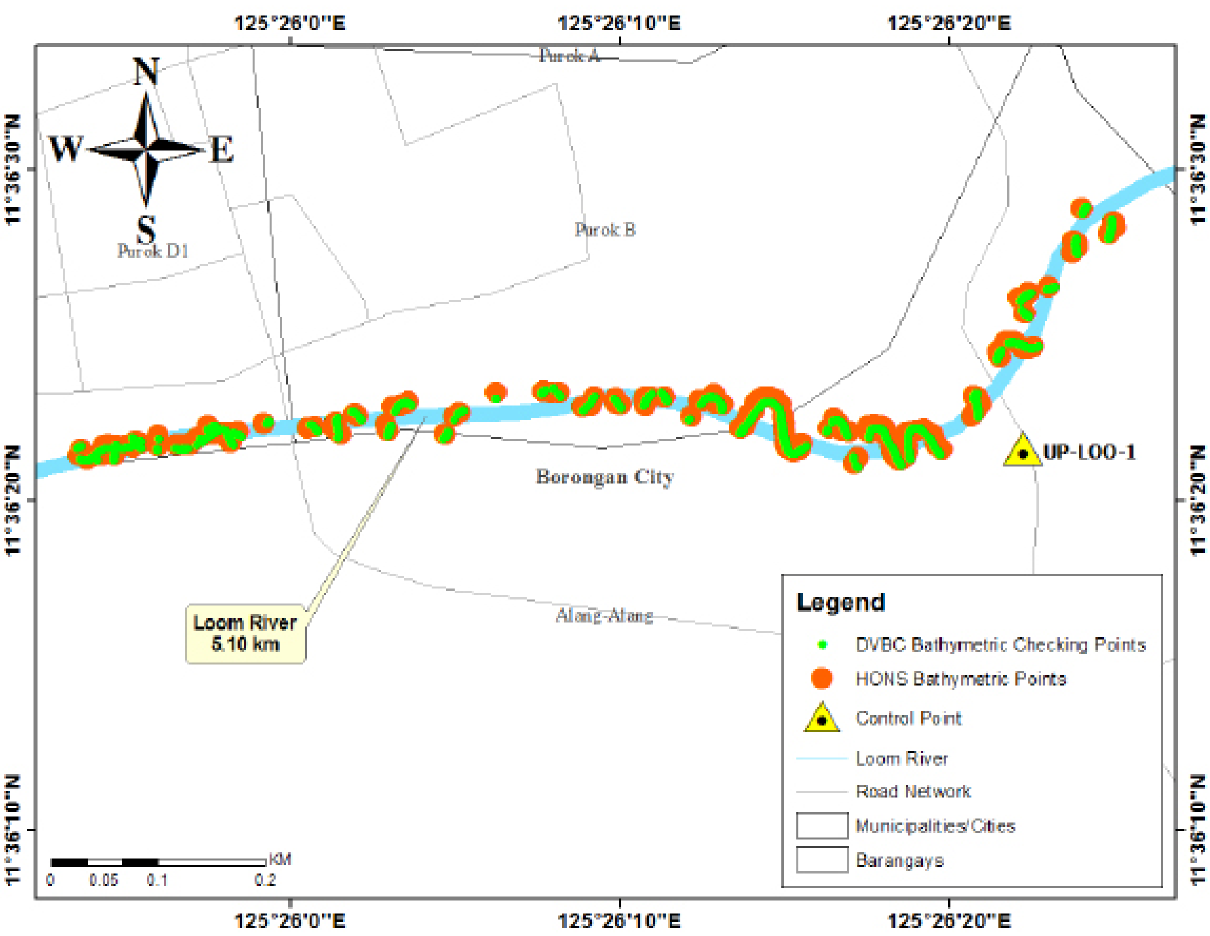


Figure 54. Quality checking points gathered along Loom River

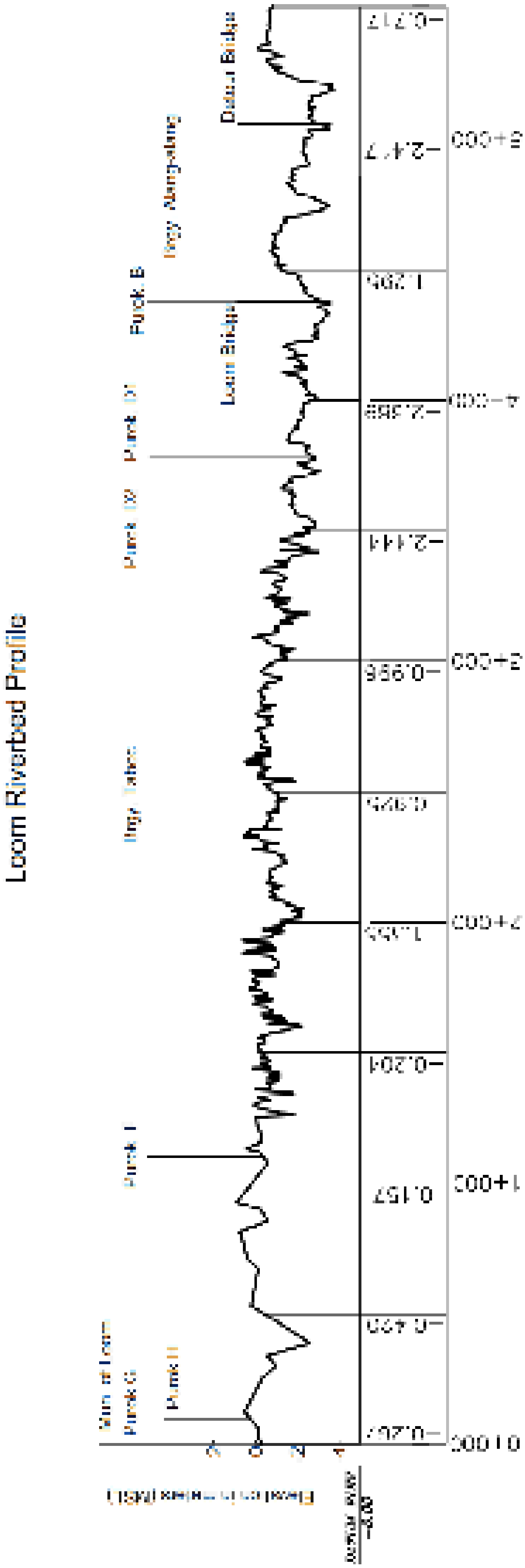


Figure 55. Loom Riverbed Profile

CHAPTER 5: FLOOD MODELING AND MAPPING

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

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

Rainfall, water level, and flow in a certain period of time, which may affect the hudrologic cycle of the Loom River Basin were monitored, colledcted, and analyzed.

5.1.2 Precipitation

Precipitation data was taken from two automatic rain gauges (ARGs) installed by the Department of Science and Technology – Advanced Science and Technology Institute (DOST-ASTI) and the VSU Phil-LiDAR 1 Flood Modeling Component. These were the Loom Bridge and Sohuton ARGs. The location of the rain gauges is seen in Figure 56.

Total rain from Loom Bridge ARG is 367.5 mm. It peaked to 16.5 mm on 16 December 2016, 8:30 PM. For Sohuton ARG, total rain for this event is 262.5 mm. Peak rain of 10.6 mm was recorded on 16 December 2016, 10:50 PM. A summary of the data is seen in Table 27. The lag time between the peak rainfall and discharge is four hours and fifty minutes.

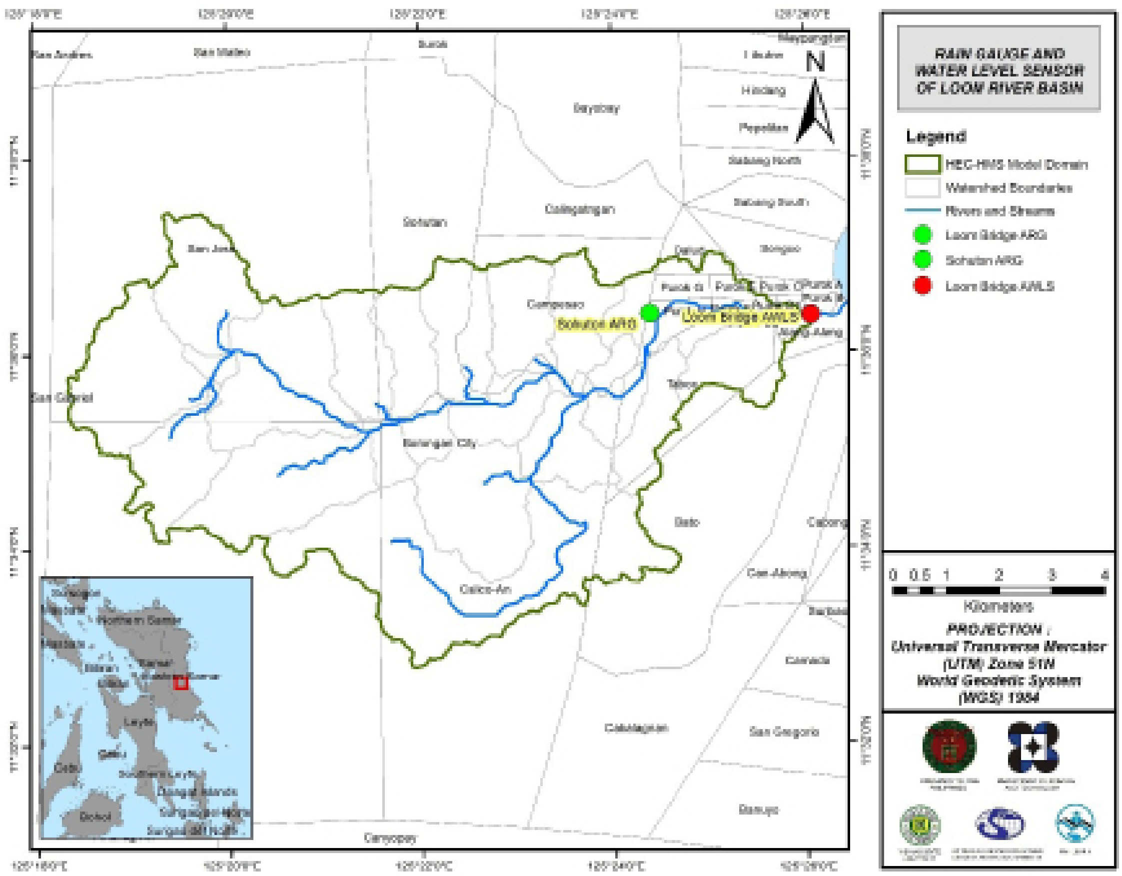


Figure 56. The location map of Loom HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Loom Bridge, Borongan City, Eastern Samar (11°36'21.81"N, 125°25'59.97"E). It gives the relationship between the observed water levels at Loom Bridge and outflow of the watershed at this location.

For Loom Bridge, the rating curve is expressed as $Q = 191.68e^{0.7946h}$ as shown in Figure 58.

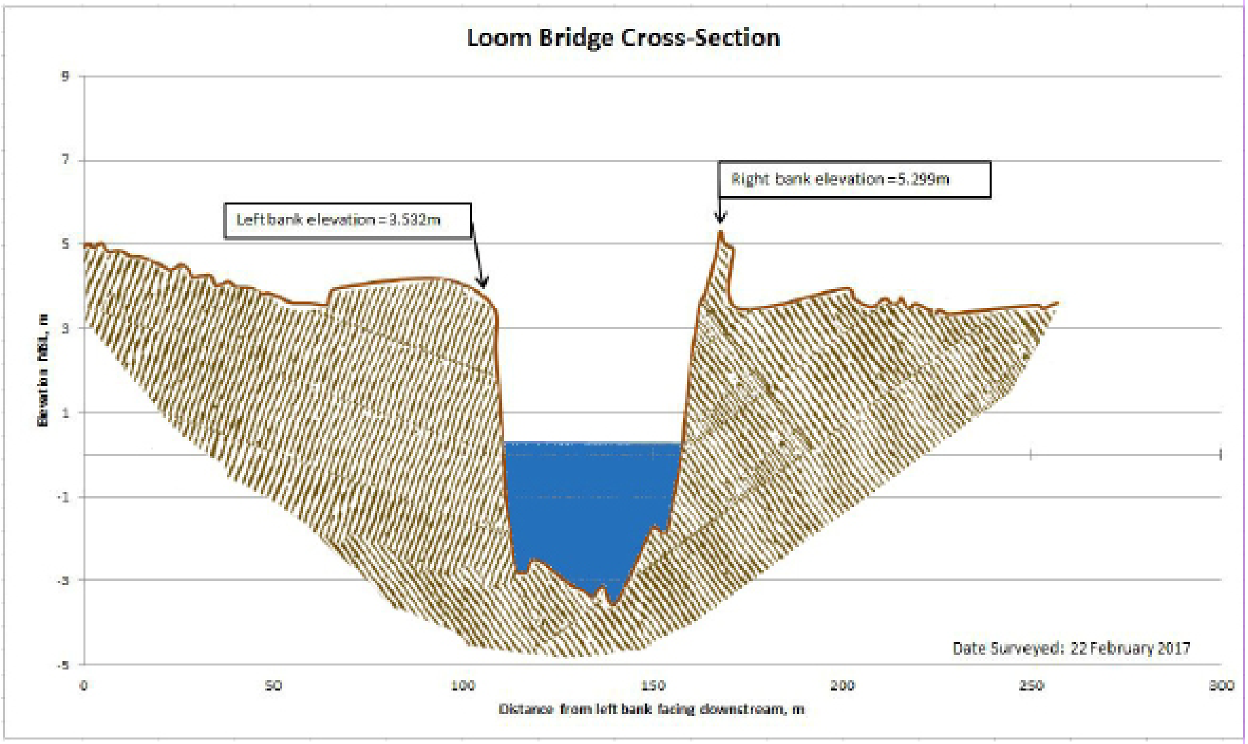


Figure 57. Cross-Section Plot of Loom Bridge

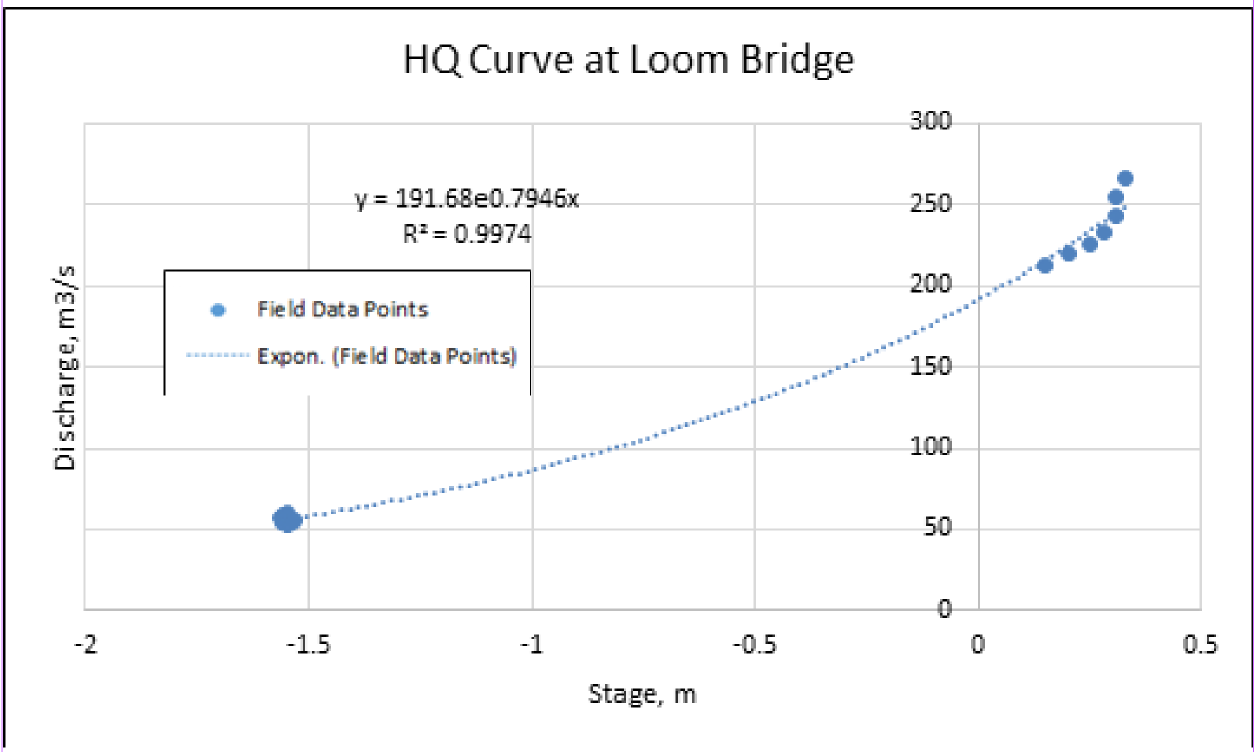


Figure 58. Rating Curve at Loom Bridge, Loom, Samar

This rating curve equation was used to compute the river outflow at Loom Bridge for the calibration of the HEC-HMS model.

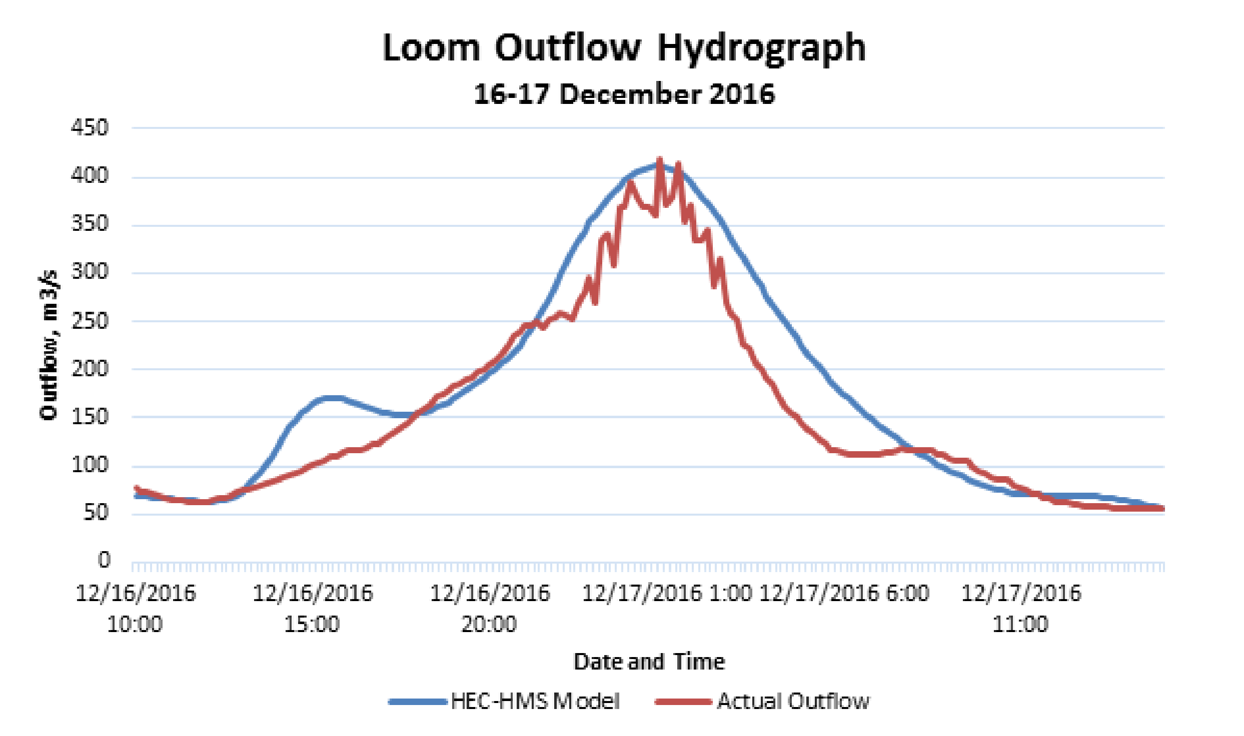


Figure 59. Rainfall and outflow data at Loom used for modeling

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Borongan Rain Gauge. The RIDF rainfall amount for 24 hours was converted to a synthetic storm by interpolating and re-arranging the value in such a way certain peak value will be attained at a certain time. This station chosen based on its proximity to the Loom watershed. The extreme values for this watershed were computed based on a 36-year record.

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	22.5	35.3	44.5	60.6	83.7	100.8	133.7	170.7	201.4
5	31.5	49.1	61	82.3	116.1	140.8	186.5	241	283.8
10	37.4	58.2	71.9	96.6	137.6	167.2	221.4	287.6	338.4
15	40.7	63.3	104.7	104.7	149.8	182.1	241.2	313.9	369.2
20	43	66.9	110.4	110.4	158.3	192.6	255	332.3	390.8
25	44.8	69.7	114.8	114.8	164.8	200.6	265.6	346.4	407.4
50	50.4	78.2	128.3	128.3	185	225.4	298.4	390.1	458.6
100	55.9	86.7	141.6	141.6	205	205	330.9	433.4	509.4

Table 27. RIDF values for Borongan Rain Gauge computed by PAGASA

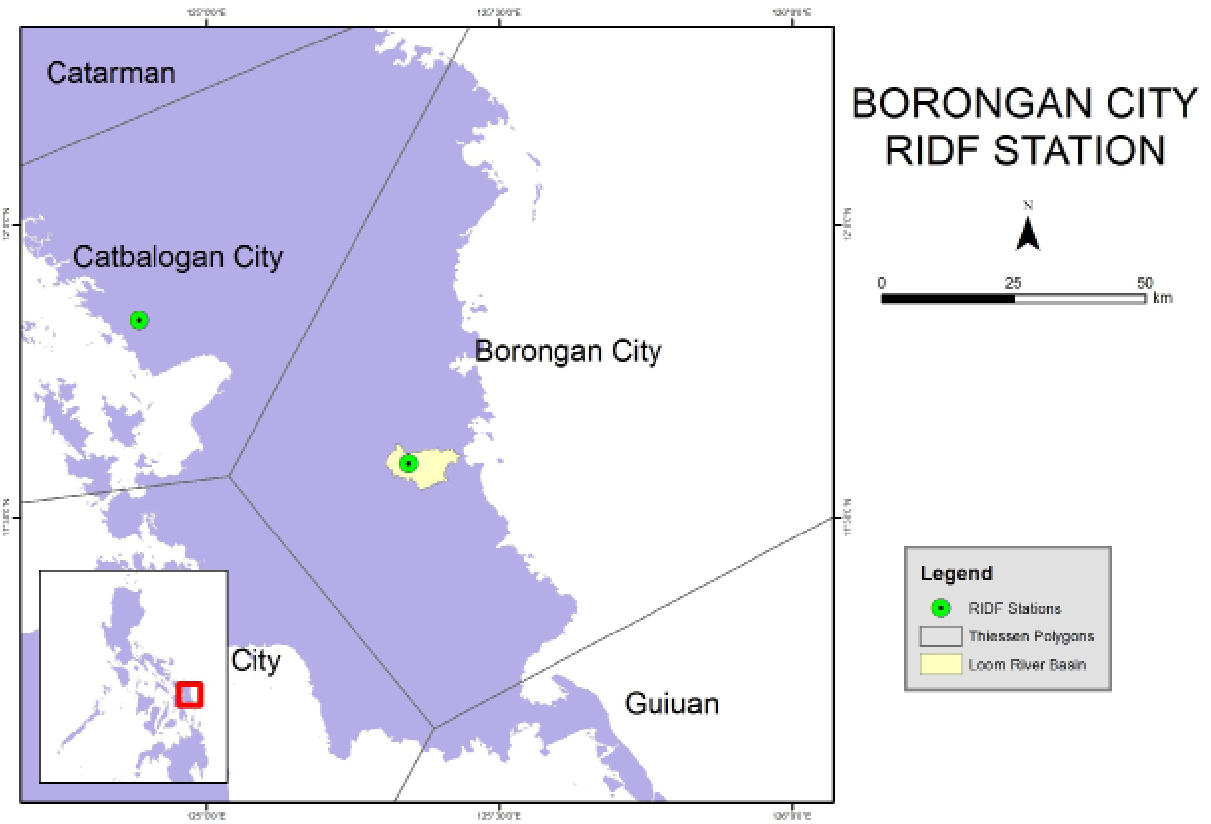


Figure 60. Location of Tacloban RIDF Station relative to Loom River Basin

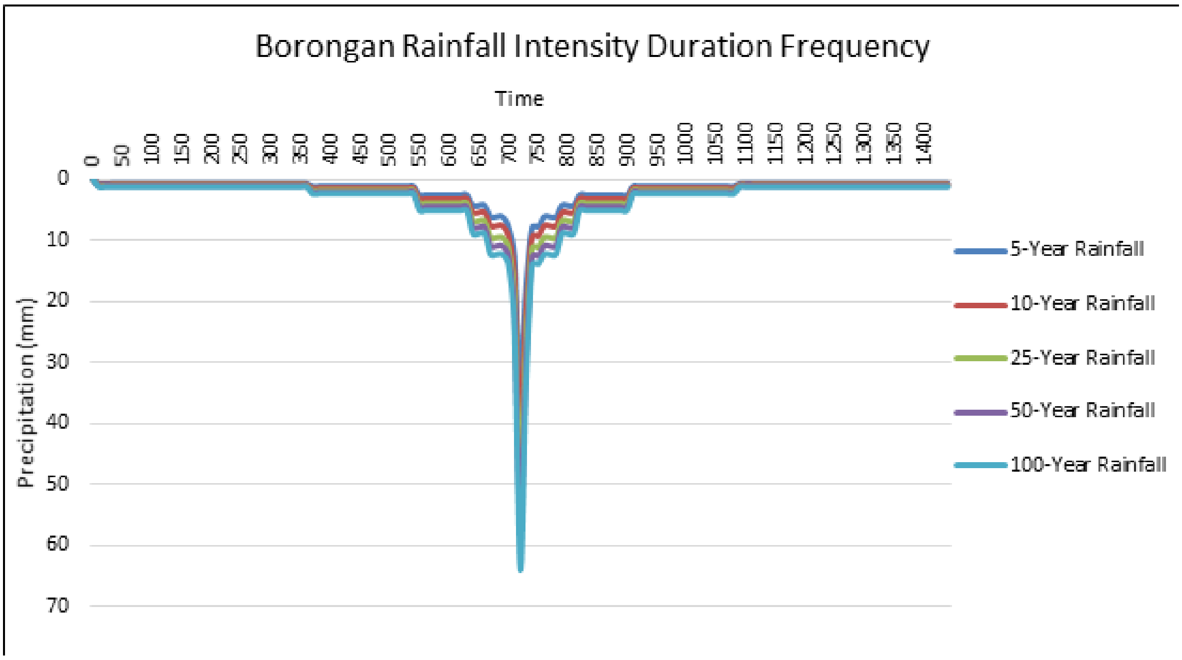


Figure 61. Synthetic storm generated for a 24-hr period rainfall for various return periods

5.3 HMS Model

The soil shapefile was taken on 2004 from the Bureau of Soils; this is under the Department of Environment and Natural Resources Management. The land cover shape file is from the National Mapping and Resource Information Authority (NAMRIA). The soil and land cover of the Loom River Basin are shown in Figures 63 and 64, respectively.

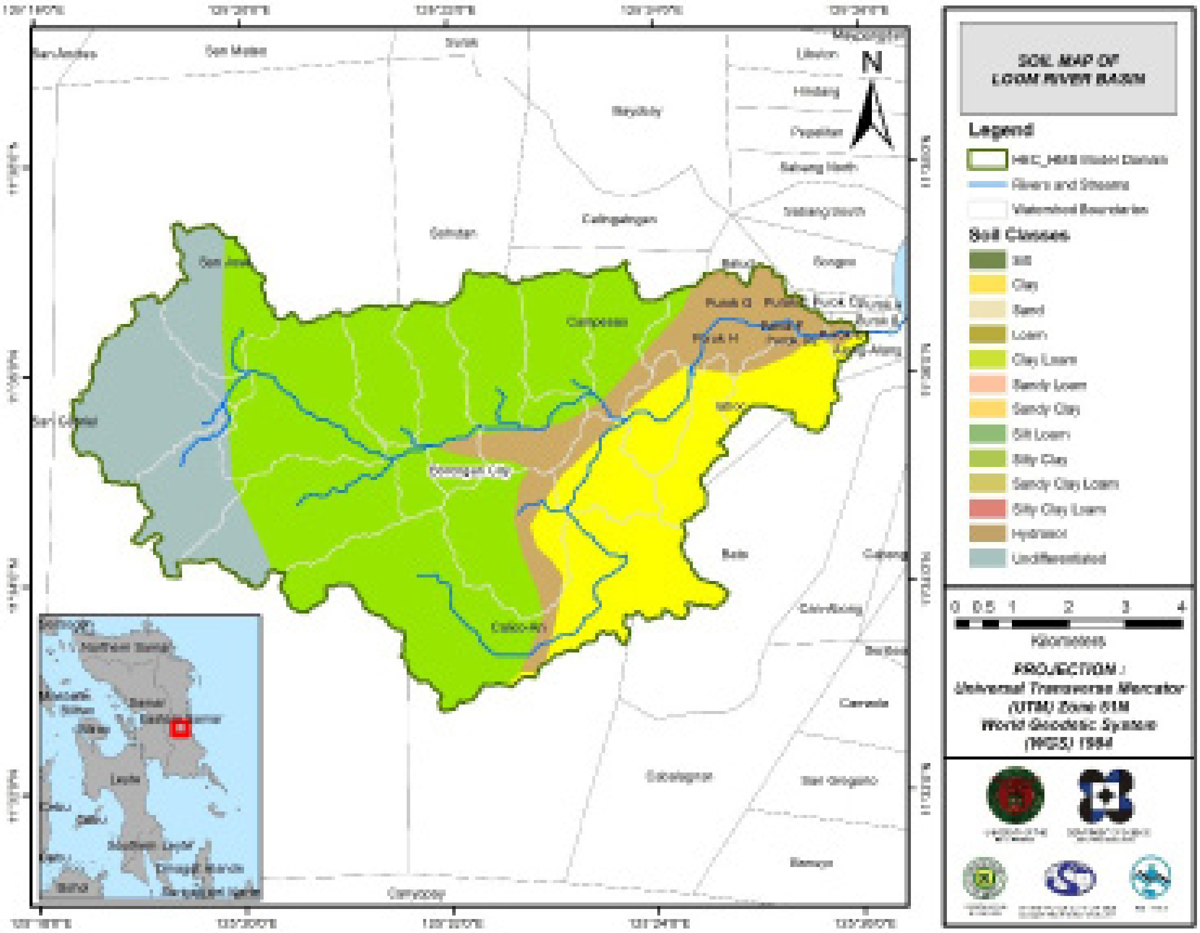


Figure 62. Soil Map of Loom River Basin

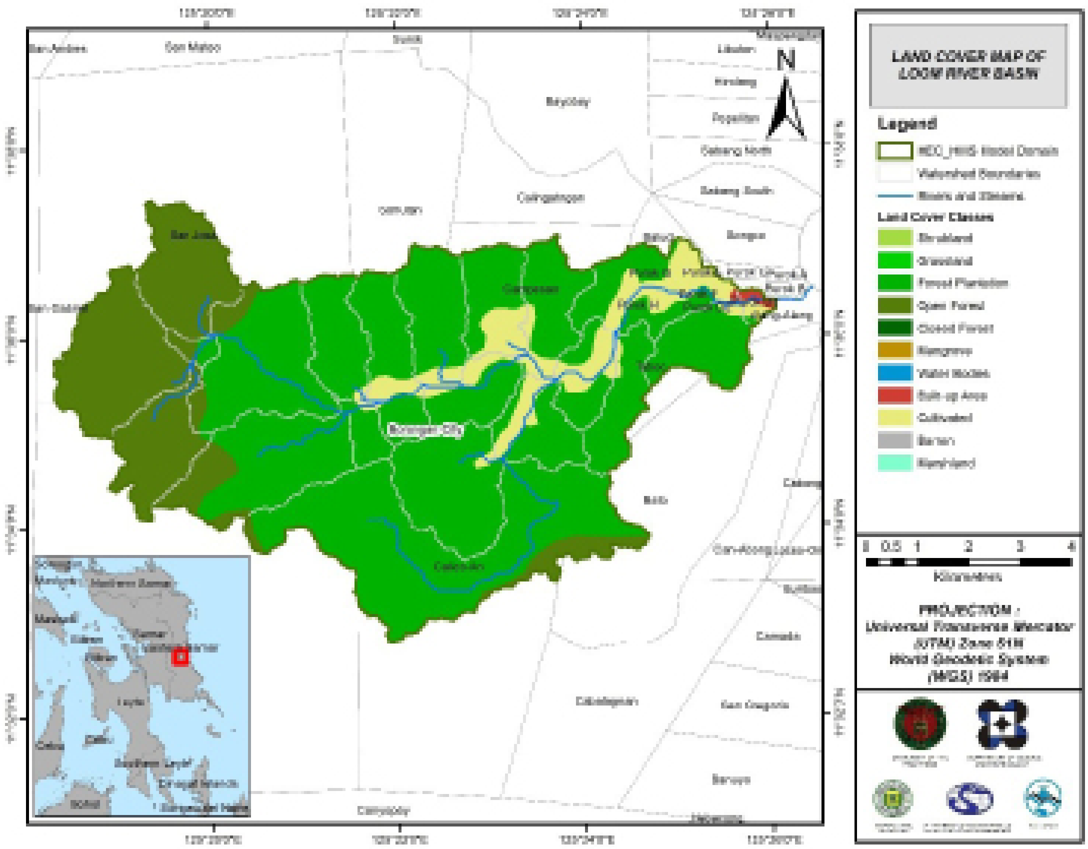


Figure 63. Land Cover Map of Loom River Basin

For Loom, the soil classes identified were clay, clay loam, hydrosol, and undifferentiated. The land cover types identified were forest plantation, open forest, closed forest, and cultivated.

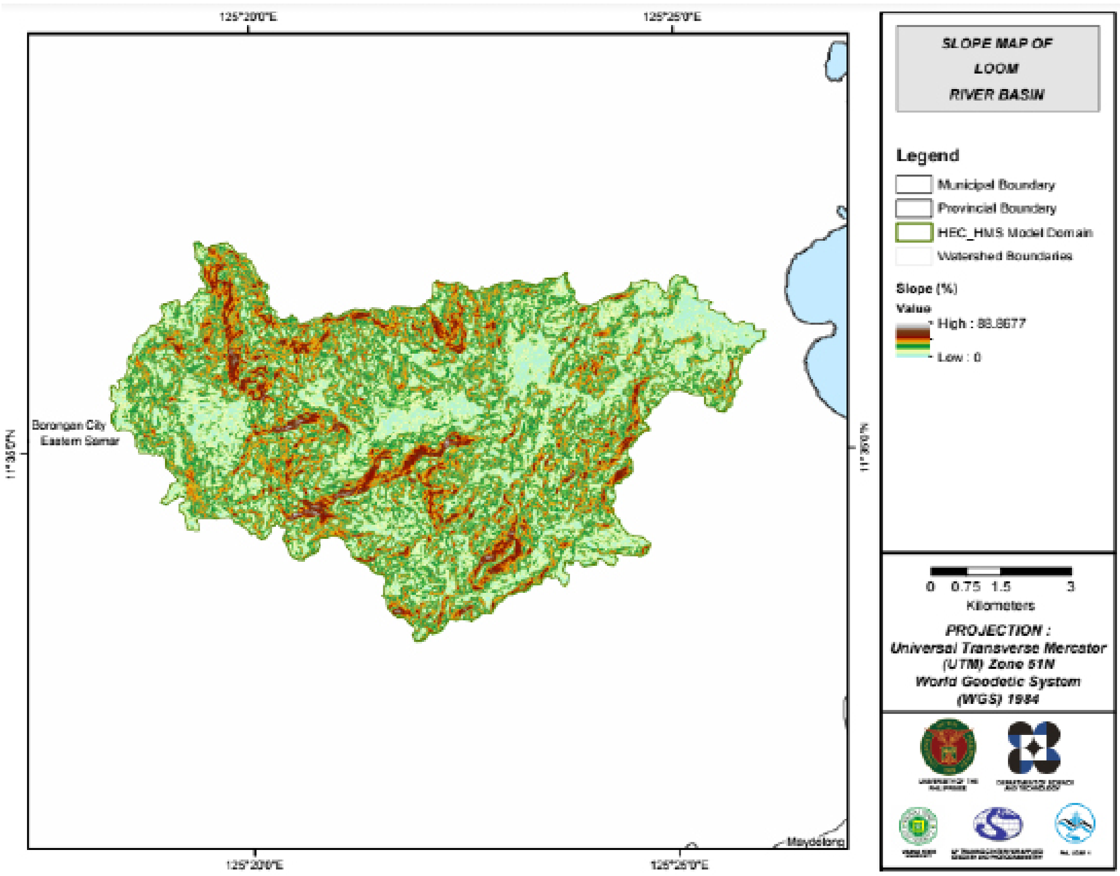


Figure 64. Slope Map of the Loom River Basin

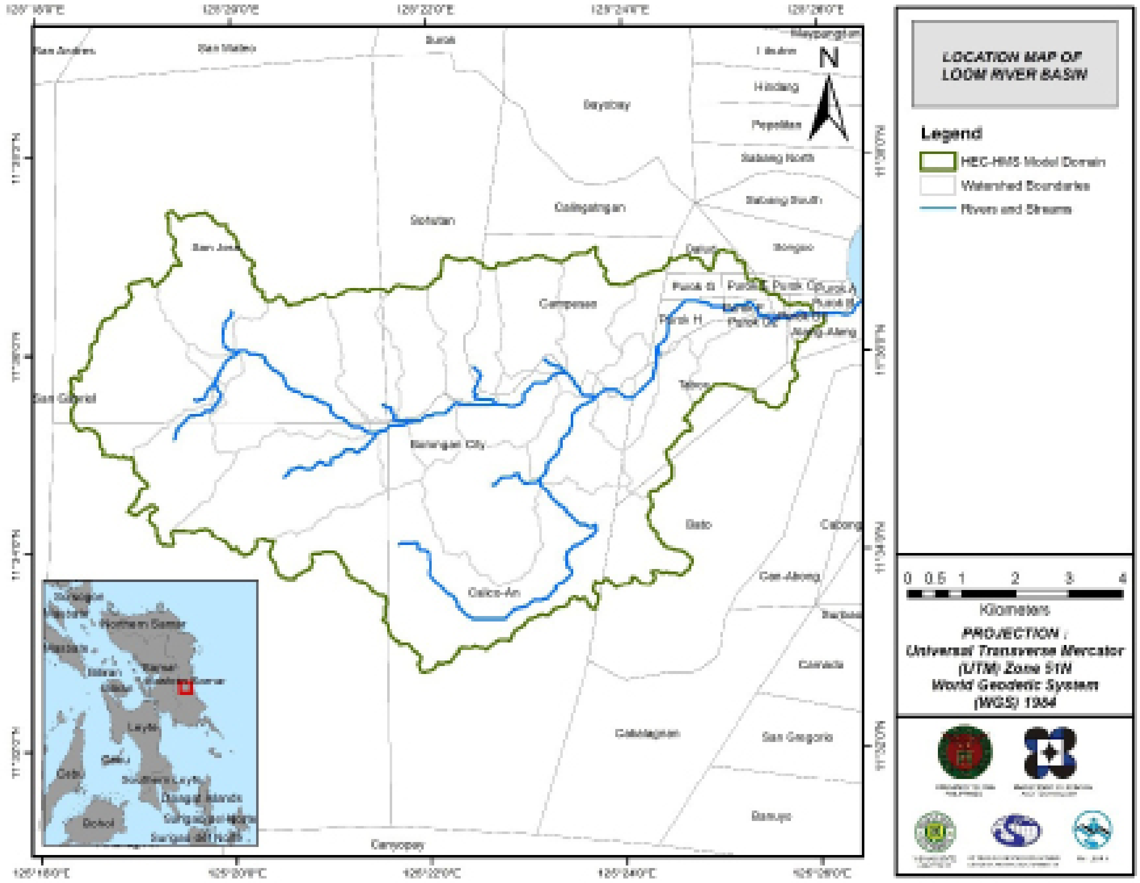


Figure 65. Stream Delineation Map of the Loom River Basin

Using the SAR-based DEM, the Loom basin was delineated and further subdivided into subbasins. The model consists of 21 sub basins, 10 reaches, and 10 junctions. The main outlet is Loom Bridge. This basin model is illustrated in Figure 67.

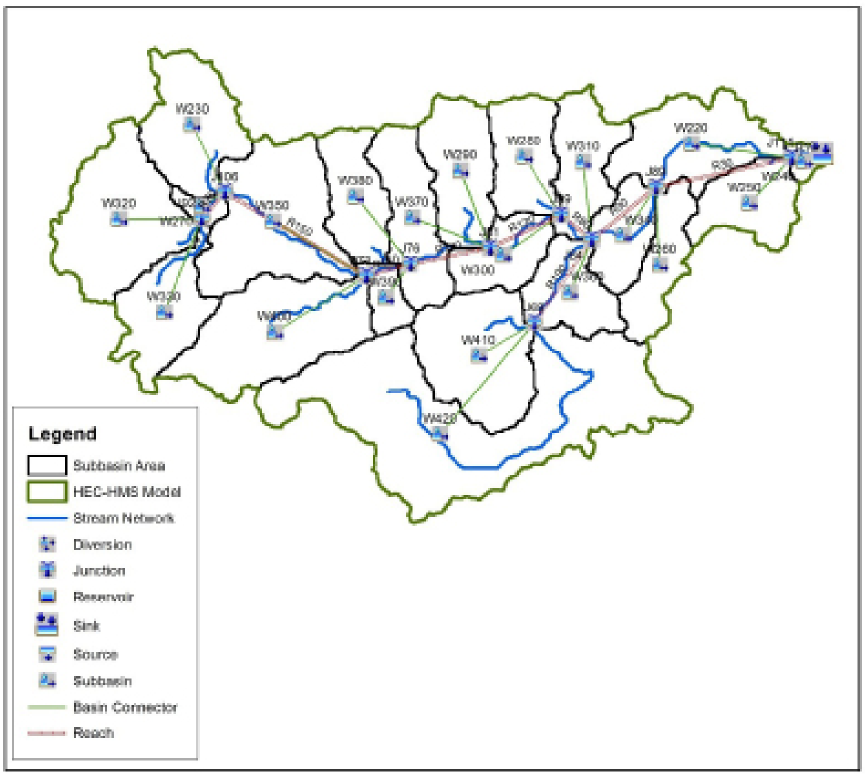


Figure 66. The Loom river basin model generated using HEC-HMS

5.4 Cross-section Data

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

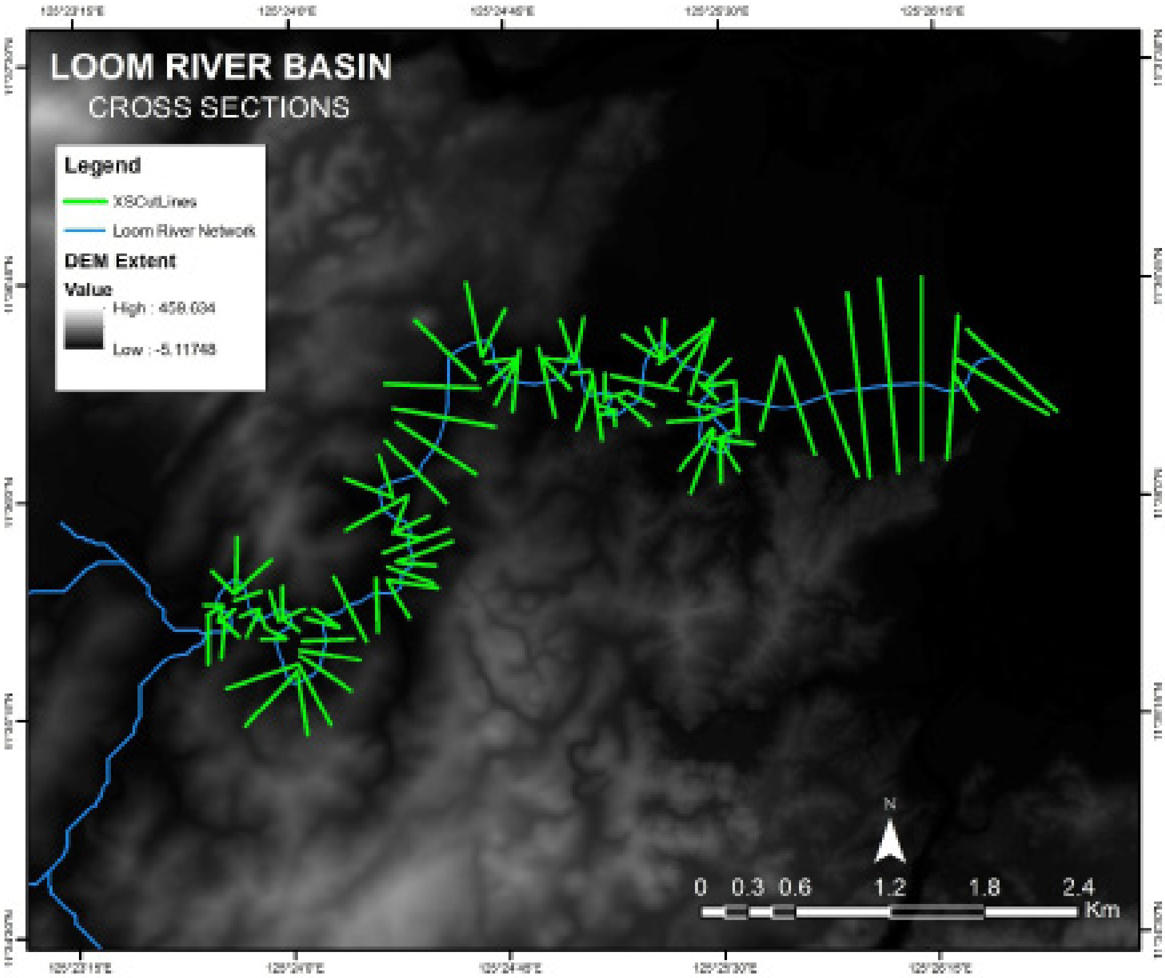


Figure 67. River cross-section of Loom River generated through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

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

Based on the elevation and flow direction, it is seen that the water will generally flow from the west of the model to the east, following the main channel. As such, boundary elements northwest of the model are assigned as outflow elements.

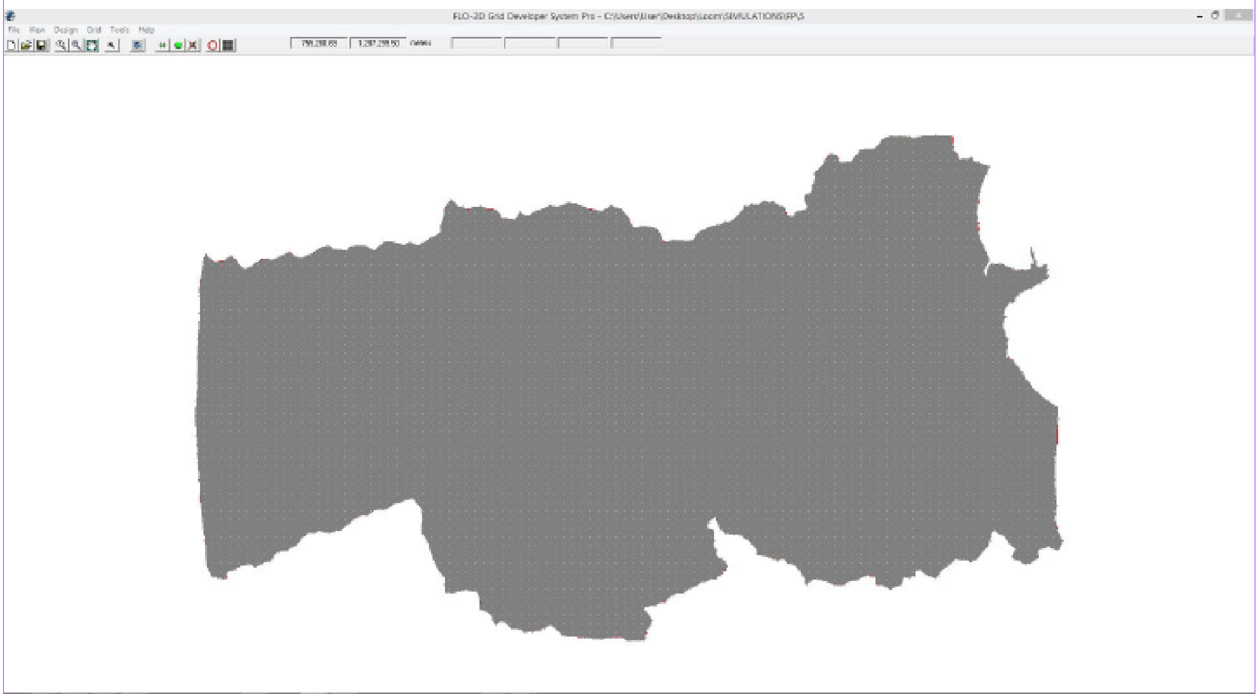


Figure 68. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 132.68 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 Loom are in Figures 72, 74, and 76.

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 60,744,400.00 m². The generated flood depth maps for Loom are in Figures 73, 75, and 77.

There is a total of 56,603,419.02 m³ of water entering the model, of which 30,729,444.15 m³ is due to rainfall and 25,873,974.86 m³ is inflow from basins upstream. 6217532.50 m³ of this water is lost to infiltration and interception, while 12,079,786.95 m³ is stored by the floodplain. The rest, amounting up to 38,306,089.02 m³ , is outflow.

5.6 Results of HMS Calibration

After calibrating the Loom HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 69 shows the comparison between the two discharge data.

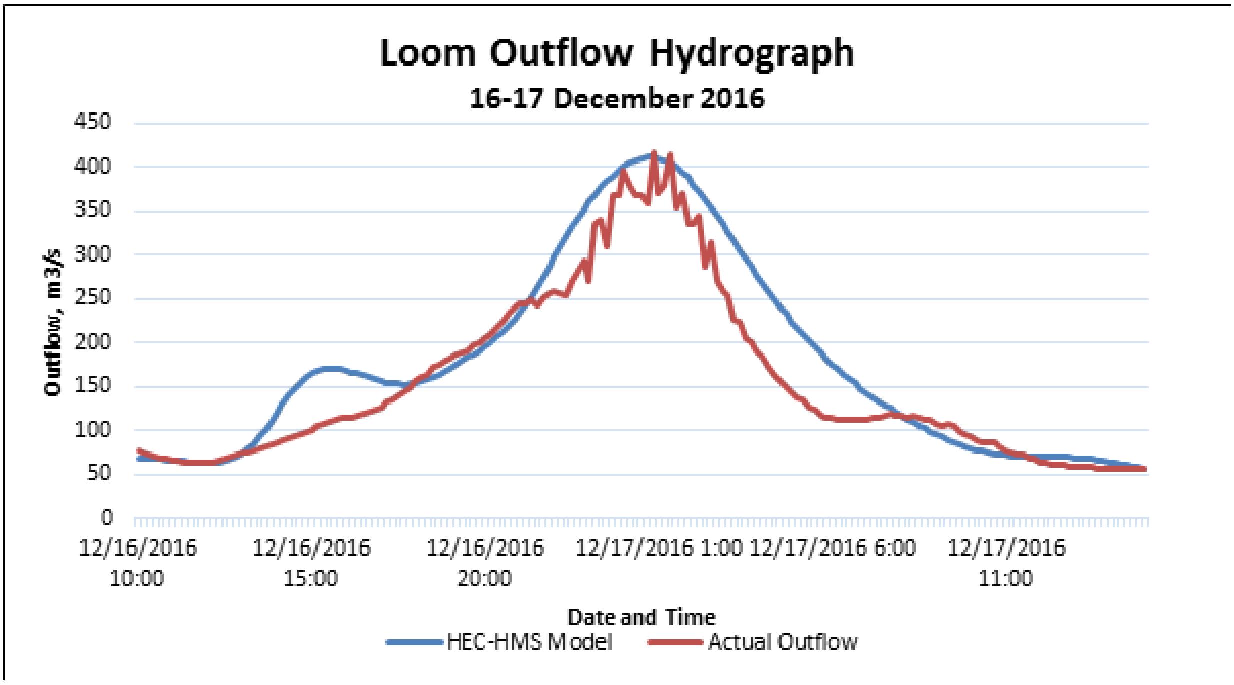


Figure 69. Outflow Hydrograph of Loom produced by the HEC-HMS model compared with observed outflow

Enumerated in Table 28 are the adjusted ranges of values of the parameters used in calibrating the model.

Basin/Reach Charactertistic	Method	Parameter	Range of Calibrated Values
Loss	SCS Curve number	Initial Abstraction (mm)	0.001
		Curve Number	99
Transform	Clark Unit Hydrograph	Time of Concentration (hr)	1 - 9
		Storage Coefficient (hr)	1 - 7
Baseflow	Recession	Recession Constant	0.08
		Ratio to Peak	0.01
Routing	Muskingum-Cunge	Slope	0.0006 - 0.1
		Manning's n	0.04

Table 28. Range of Calibrated Values for Loom

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 value of 0.001mm means that there is minimal amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The value of 99 for curve number is at the highest range for Philippine watersheds depending on the soil and land cover of the area.

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 one (1) to nine (9) hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.08 indicates that the basin is likely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.01 indicates a steeper receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.04 corresponds to the common roughness of Philippine watersheds. Loom river basin is determined to be cultivated with mature field crops.

Table 29. Summary of the Efficiency Test of Loom HMS Model

RMSE	35.7
r2	0.9974
NSE	0.83
PBIAS	-14.97
RSR	0.41

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 35.7 (m3/s).

The Pearson correlation coefficient (r^2) 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 0.9974.

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 0.83.

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 -14.97.

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 0.41.

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

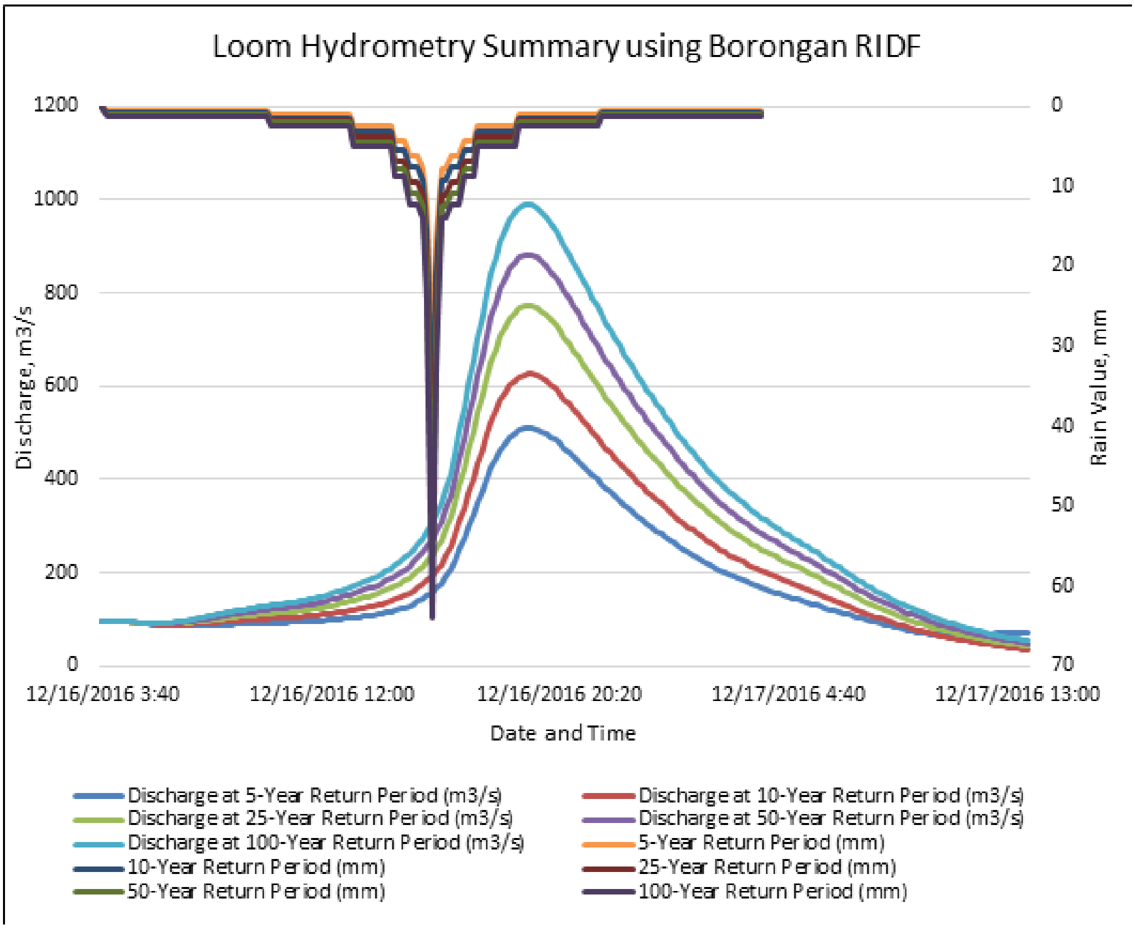


Figure 70. Outflow hydrograph at Loom Station generated using Borongan RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Loom discharge using the Borongan Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 30.

Table 30. Peak values of the Loom HEC-HMS Model outflow using the Tacloban RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	278.6	33.2	510.4	3 hours, 30 minutes
10-Year	344.7	40.6	626.6	3 hours, 30 minutes
25-Year	428.2	50.1	773.2	3 hours, 30 minutes
50-Year	490.2	57.1	882.4	3 hours, 30 minutes
100-Year	551.7	64	990.6	3 hours, 30 minutes

5.8 River Analysis Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. For this publication, only a sample output map river was to be shown, since only the DVC base flow was calibrated. The sample generated map of Maayon River using the calibrated HMS base flow is shown in Figure 71.

Figure 71. Sample output of Loom RAS Model

5.9 Flood Hazard and Flow Depth Map

The resulting hazard and flow depth maps have a 10m resolution. Figure 72 to Figure 77 shows the 5-, 25-, and 100-year rain return scenarios of the Loom Floodplain.

The floodplain, with an area of 60.74 sq. km., covers Borongan City. Table 31 shows the percentage of area affected by flooding per municipality.

Table 31. Municipalities affected in Loom Floodplain

City / Municipality	Total Area	Area Flooded	% Flooded
Borongan City	596.08	60.73	10%

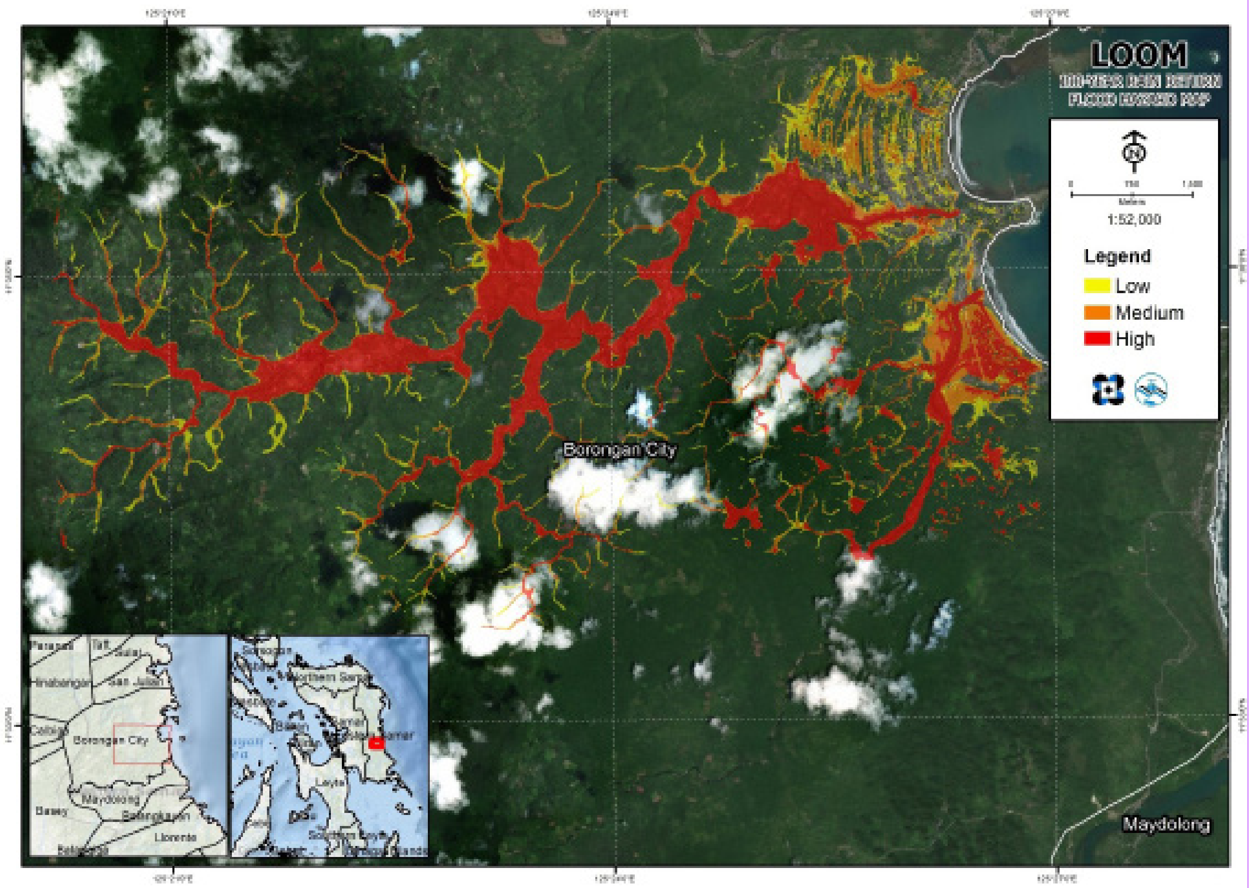


Figure 72. 100-year Flood Hazard Map for Loom Floodplain

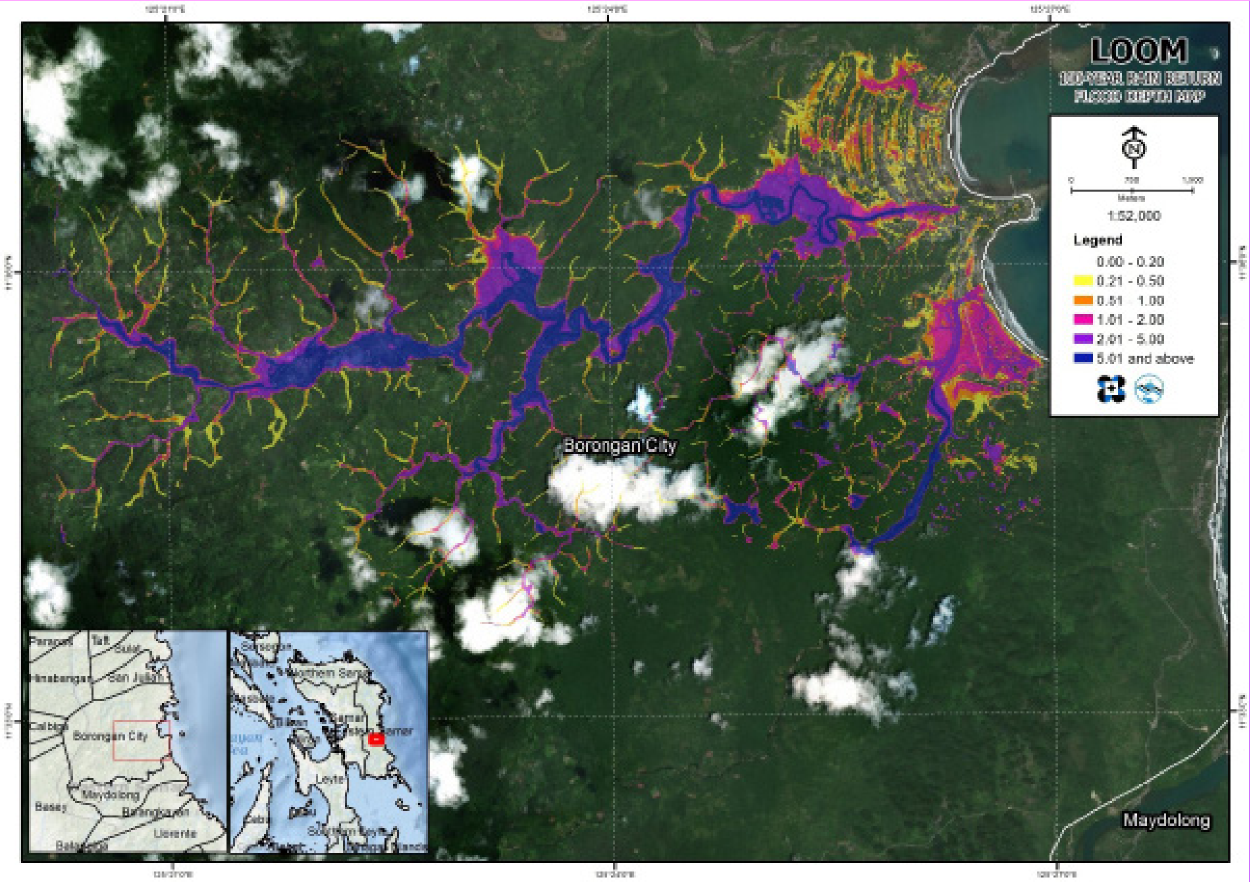


Figure 73. 100-year Flood Depth Map for Loom Floodplain

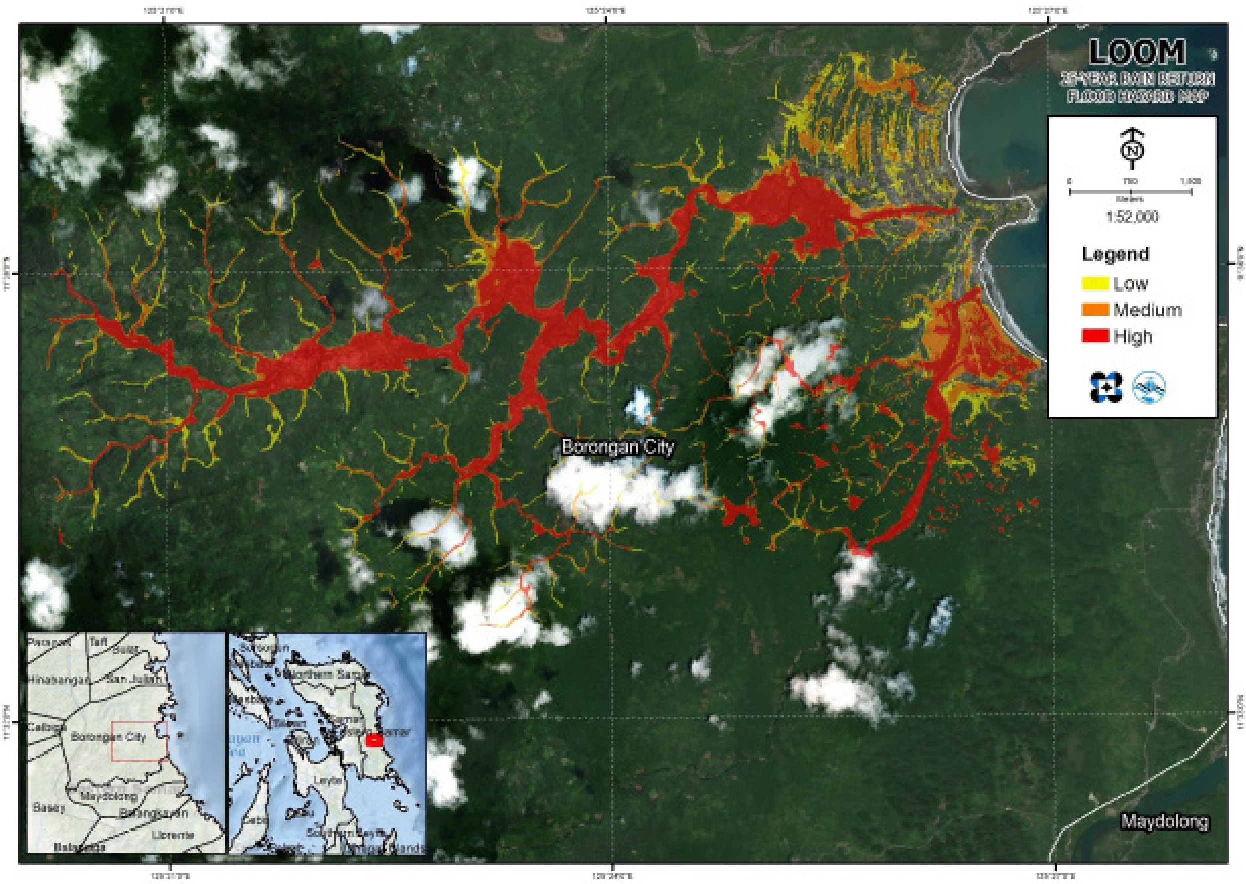


Figure 74. 25-year Flood Hazard Map for Loom Floodplain

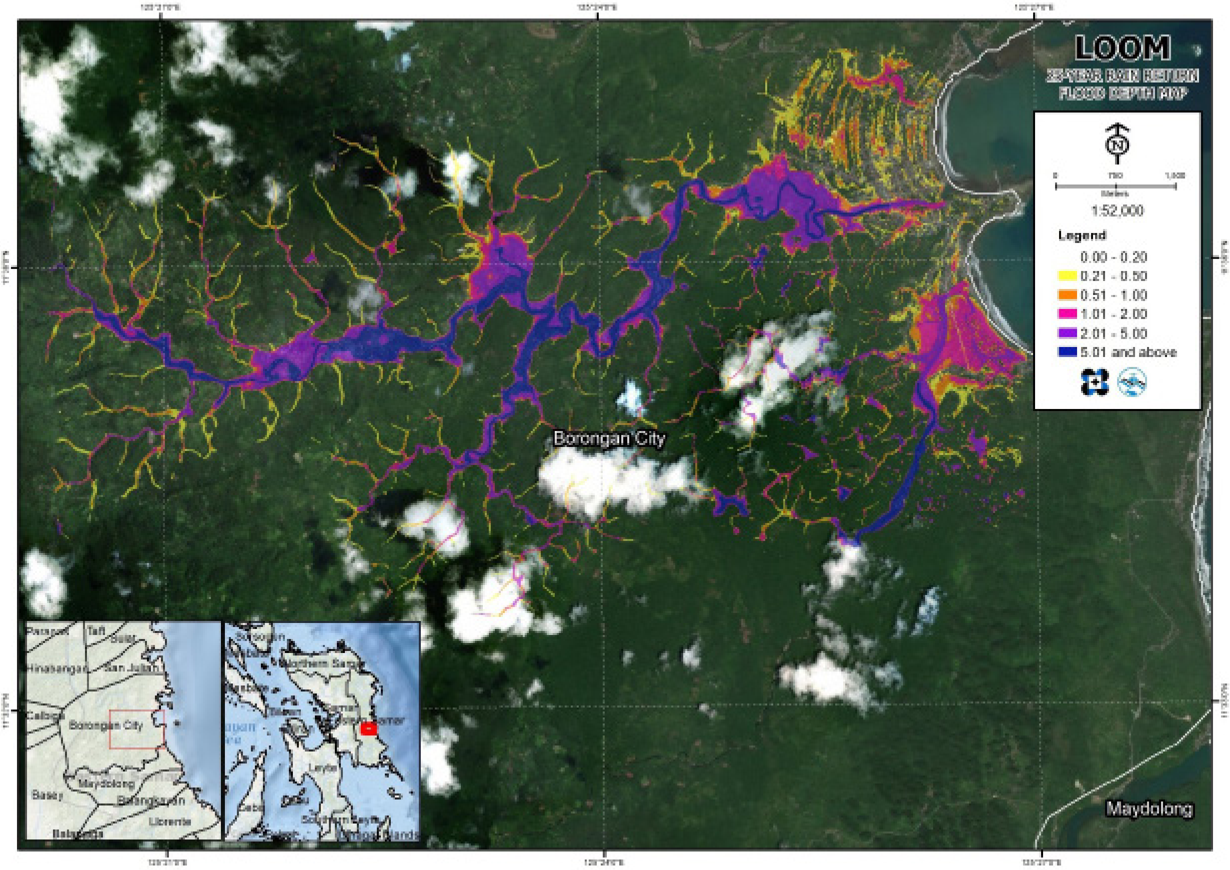


Figure 75. 25-year Flood Depth Map for Loom Floodplain

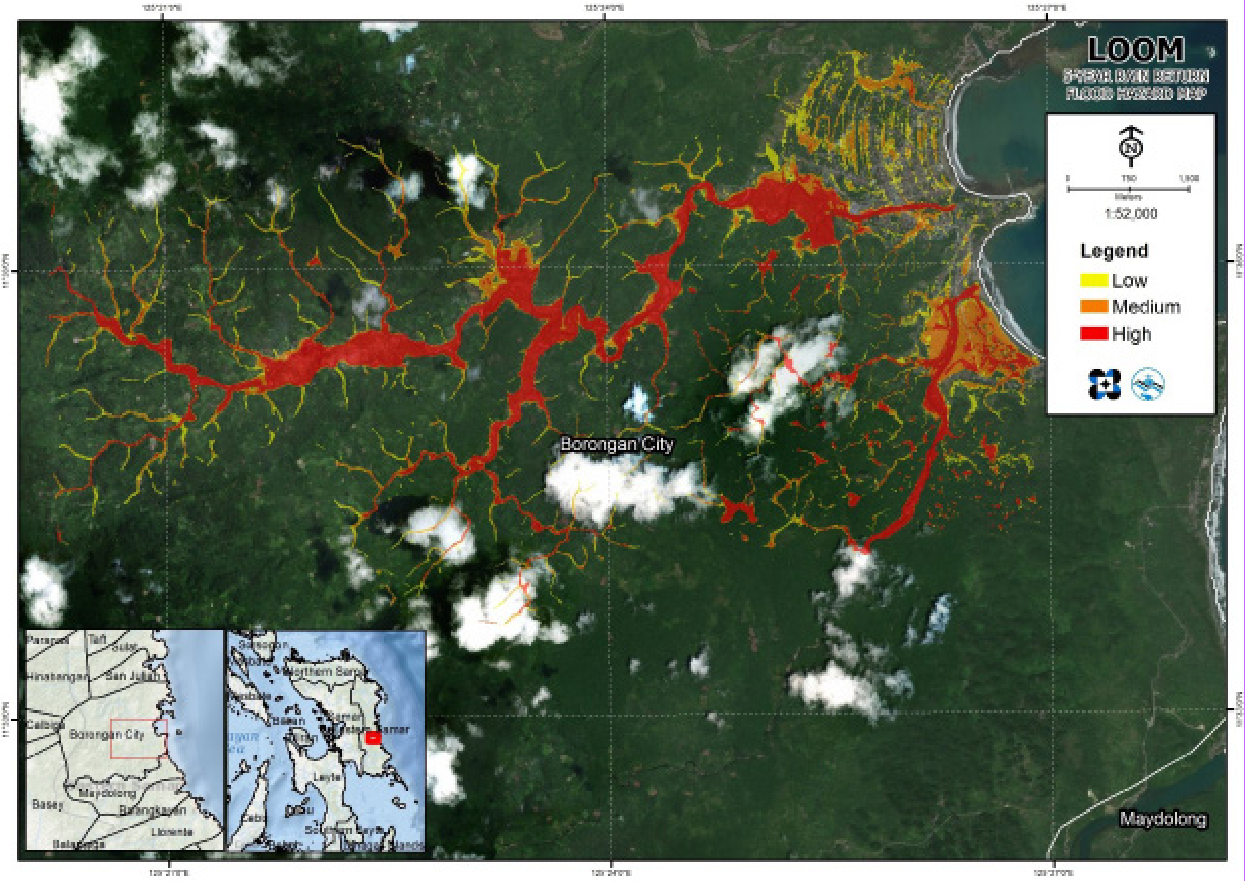


Figure 76. 5-year Flood Hazard Map for Loom Floodplain

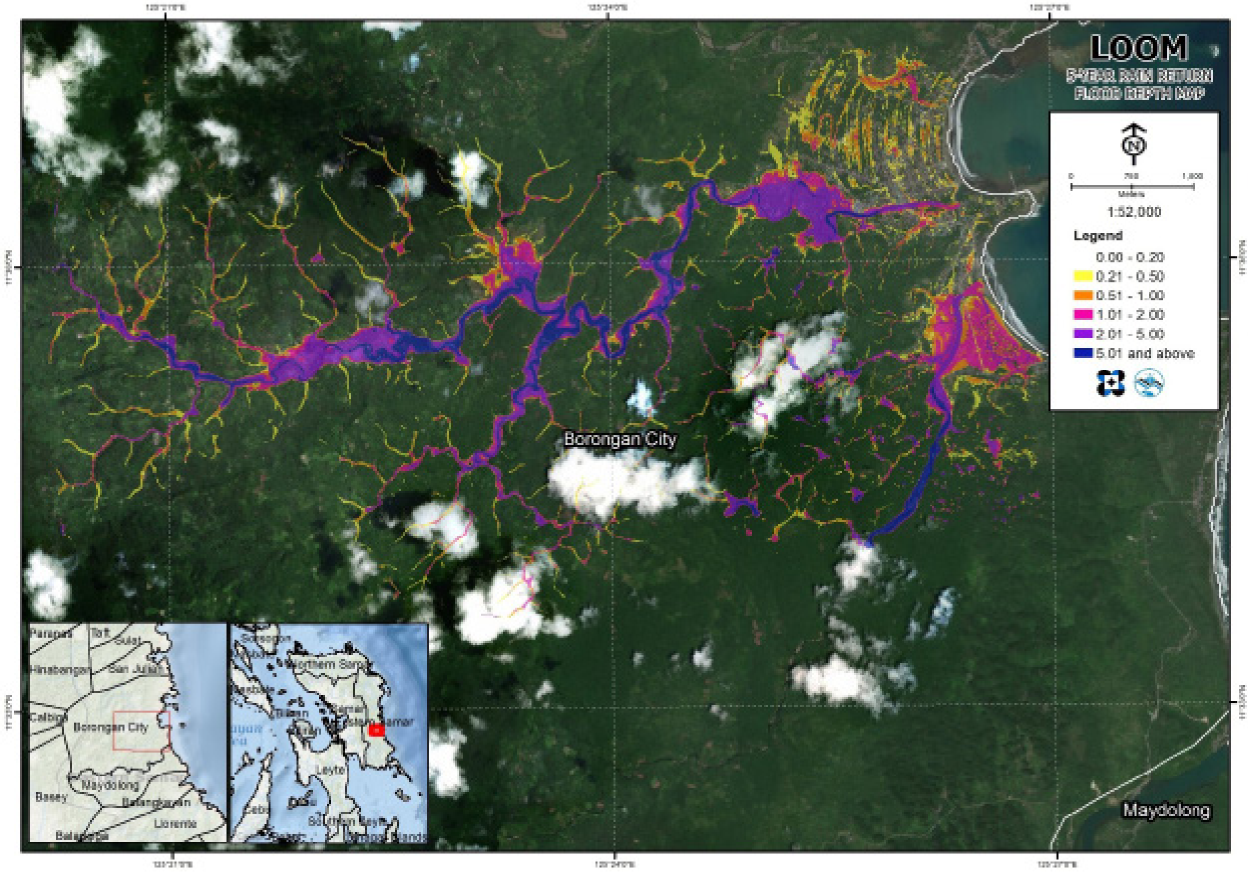


Figure 77. 5-year Flood Depth Map for Loom Floodplain

5.10 Inventory of Affected Areas

Affected barangays in Loom river basin are listed below. For the said basin, the city of Borongan consisting of 24 barangays are expected to experience flooding when subjected to 5-yr, 25-yr and 100-yr rainfall return period.

For the 5-year return period, 8.48% of the city of Borongan with an area of 596.08 sq. km. will experience flood levels of less 0.20 meters. 0.43% of the area will experience flood levels of 0.21 to 0.50 meters while 0.29%, 0.34%, 0.44%, and 0.20% of the area will experience flood depths of 0.51 to one (1) meter, 1.01 to two (2) meters, 2.01 to five (5) meters, and more than five (5) meters, respectively. Listed in Table 32 are the affected areas in square kilometres by flood depth per barangay.

Table 32. Affected Areas in Borongan City, Eastern Samar during 5-Year Rainfall Return Period

	LOOM BASIN	Affected Barangays in Borongan City							
		Alang-Alang	Balud	Bato	Cabong	Calico-An	Campesao	Can-Abong	Lalawigan
Affected Area (sq.km.)	0.03-0.20	1.05	0.46	7.19	1.3	11.24	6.12	1.68	0.3
	0.21-0.50	0.093	0.014	0.25	0.12	0.36	0.28	0.13	0.016
	0.51-1.00	0.062	0.00088	0.16	0.12	0.24	0.17	0.22	0.0034
	1.01-2.00	0.05	0.00015	0.16	0.24	0.34	0.18	0.42	0.0051
	2.01-5.00	0.027	0	0.17	0.056	0.84	0.18	0.23	0.0051
	> 5.00	0.0087	0	0.041	0.0017	0.52	0.084	0.18	0.0025

Table 33. Affected Areas in Borongan City, Eastern Samar during 5-Year Rainfall Return Period

	LOOM BASIN	Affected Barangays in Borongan City							
		Locso-On	Purok A	Purok B	Purok C	Purok D1	Purok D2	Purok E	Purok F
Affected Area (sq.km.)	0.03-0.20	0.13	0.15	0.17	0.18	0.17	0.072	0.25	0.0024
	0.21-0.50	0.0014	0.017	0.024	0.043	0.026	0.015	0.066	0.00085
	0.51-1.00	0.0018	0.0013	0.0075	0.015	0.0047	0.011	0.036	0.007
	1.01-2.00	0.0027	0.000017	0.011	0.001	0.0049	0.019	0.069	0.025
	2.01-5.00	0.0031	0	0.014	0	0.013	0.019	0.02	0.27
	> 5.00	0.0007	0	0	0	0	0	0.0019	0.0074

Table 34. Affected Areas in Borongan City, Eastern Samar during 5-Year Rainfall Return Period

	LOOM BASIN	Affected Barangays in Borongan City							
		Purok G	Purok H	Sabang South	San Jose	Siha	Sohutan	Songco	Taboc
Affected Area (sq.km.)	0.03-0.20	0.47	0.55	0.43	5.06	4.05	3.72	1.34	4.5
	0.21-0.50	0.04	0.031	0.078	0.18	0.16	0.13	0.34	0.14
	0.51-1.00	0.02	0.033	0.045	0.13	0.076	0.066	0.21	0.11
	1.01-2.00	0.0033	0.046	0.021	0.092	0.058	0.09	0.043	0.14
	2.01-5.00	0.0071	0.14	0	0.13	0.075	0.1	0	0.31
	> 5.00	0.011	0.098	0	0.052	0.043	0.0069	0	0.13

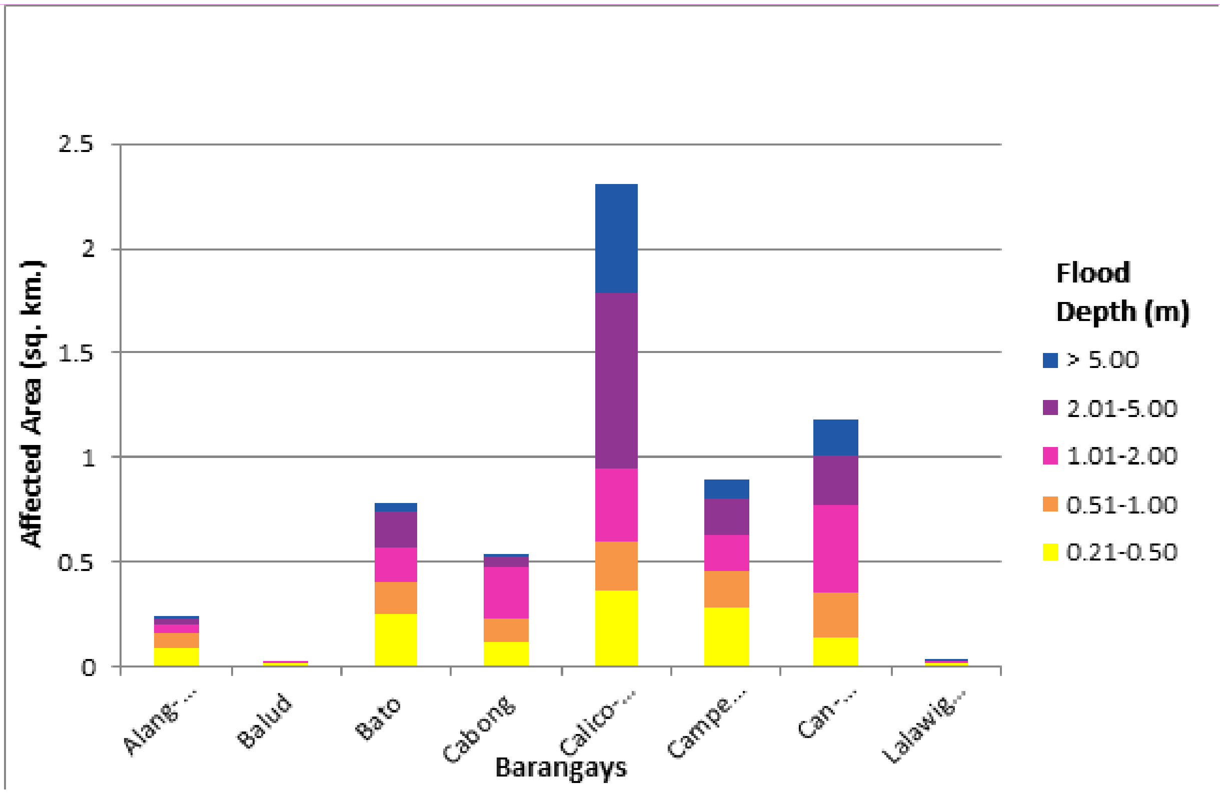


Figure 78. Affected Areas in Borongan City, Eastern Samar during 5-Year Rainfall Return Period

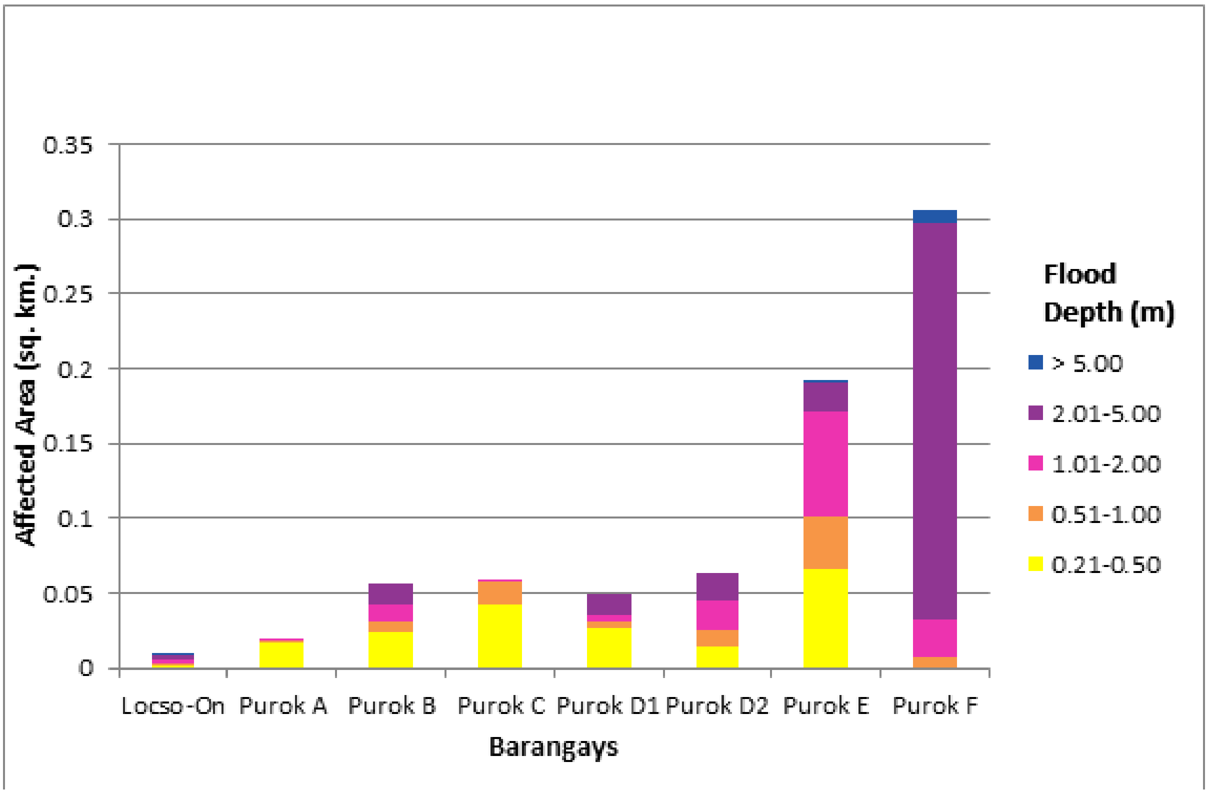


Figure 79. Affected Areas in Borongan City, Eastern Samar during 5-Year Rainfall Return Period

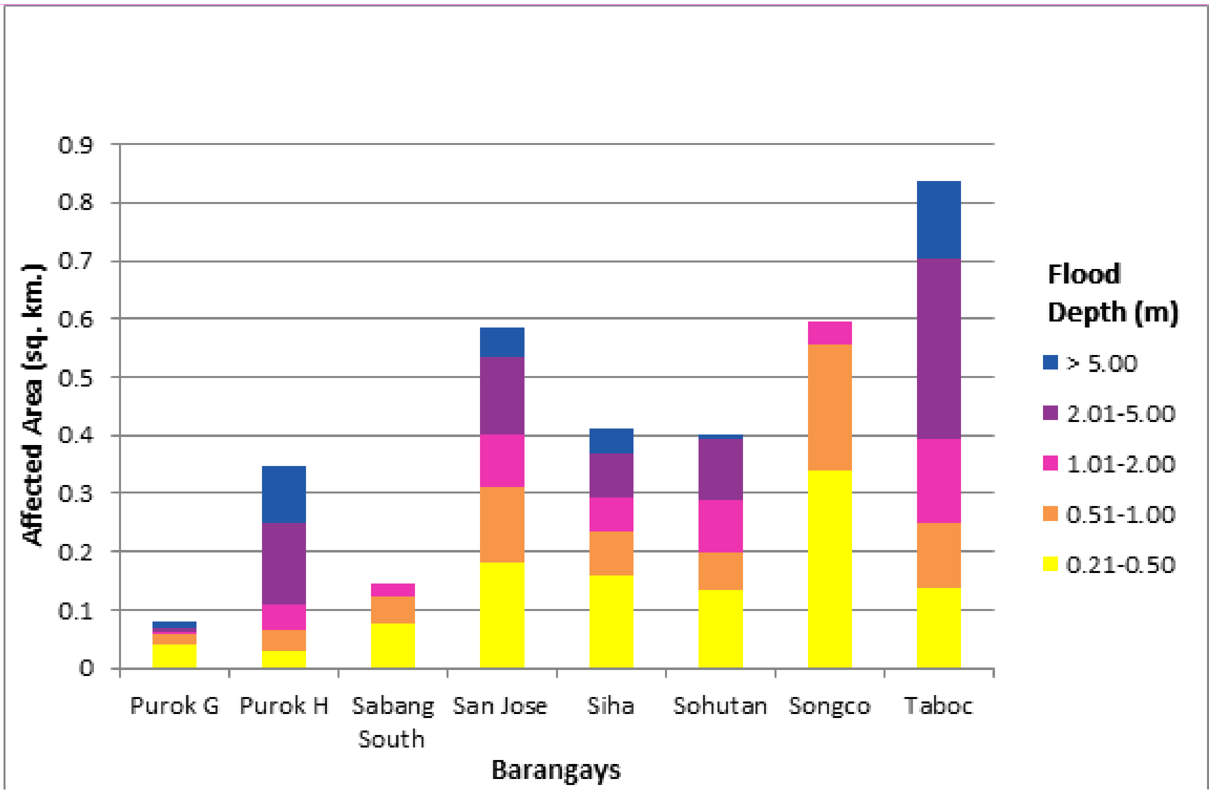


Figure 80. Affected Areas in Borongan City, Eastern Samar during 5-Year Rainfall Return Period

For the 25-year return period, 8.17% of the city of Borongan with an area of 596.08 sq. km. will experience flood levels of less 0.20 meters. 0.48% of the area will experience flood levels of 0.21 to 0.50 meters while 0.32%, 0.36%, 0.50%, and 0.35% of the area will experience flood depths of 0.51 to one (1) meter, 1.01 to two (2) meters, 2.01 to five (5) meters, and more than five (5) meters, respectively. Listed in Table 35 are the affected areas in square kilometres by flood depth per barangay.

Table 35. Affected Areas in Borongan City, Eastern Samar during 25-Year Rainfall Return Period

LOOM BASIN		Affected Barangays in Borongan City							
		Alang-Alang	Balud	Bato	Cabong	Calico-An	Campesao	Can-Abong	Lalawigan
Affected Area (sq.km.)	0.03-0.20	0.98	0.45	7.02	1.2	10.91	5.95	1.54	0.28
	0.21-0.50	0.11	0.024	0.28	0.13	0.4	0.3	0.14	0.024
	0.51-1.00	0.07	0.00069	0.19	0.11	0.22	0.18	0.23	0.0046
	1.01-2.00	0.074	0.00034	0.18	0.26	0.29	0.19	0.47	0.0063
	2.01-5.00	0.035	0	0.2	0.12	0.81	0.26	0.28	0.0067
	> 5.00	0.017	0	0.089	0.0052	0.91	0.15	0.21	0.0041

Table 36. . Affected Areas in Borongan City, Eastern Samar during 25-Year Rainfall Return Period

LOOM BASIN		Affected Barangays in Borongan City							
		Locso-On	Purok A	Purok B	Purok C	Purok D1	Purok D2	Purok E	Purok F
Affected Area (sq.km.)	0.03-0.20	0.13	0.14	0.15	0.15	0.13	0.045	0.2	0.00082
	0.21-0.50	0.0021	0.025	0.033	0.05	0.036	0.018	0.052	0.0002
	0.51-1.00	0.0022	0.002	0.01	0.028	0.022	0.019	0.023	0.00076
	1.01-2.00	0.003	0.00013	0.0088	0.0028	0.012	0.015	0.07	0.005
	2.01-5.00	0.0038	0	0.022	0	0.01	0.038	0.094	0.24
	> 5.00	0.0016	0	0.000016	0	0.0084	0	0.0032	0.058

Table 37. Affected Areas in Borongan City, Eastern Samar during 25-Year Rainfall Return Period

LOOM BASIN		Affected Barangays in Borongan City							
		Purok G	Purok H	Sabang South	San Jose	Siha	Sohutan	Songco	Taboc
Affected Area (sq.km.)	0.03-0.20	0.45	0.48	0.39	4.94	3.97	3.63	1.18	4.34
	0.21-0.50	0.041	0.024	0.095	0.21	0.2	0.15	0.38	0.14
	0.51-1.00	0.029	0.04	0.054	0.13	0.086	0.065	0.28	0.11
	1.01-2.00	0.0049	0.058	0.038	0.12	0.061	0.064	0.091	0.16
	2.01-5.00	0.0064	0.13	0.0006	0.12	0.095	0.17	0.0007	0.33
	> 5.00	0.013	0.16	0	0.12	0.058	0.04	0	0.25

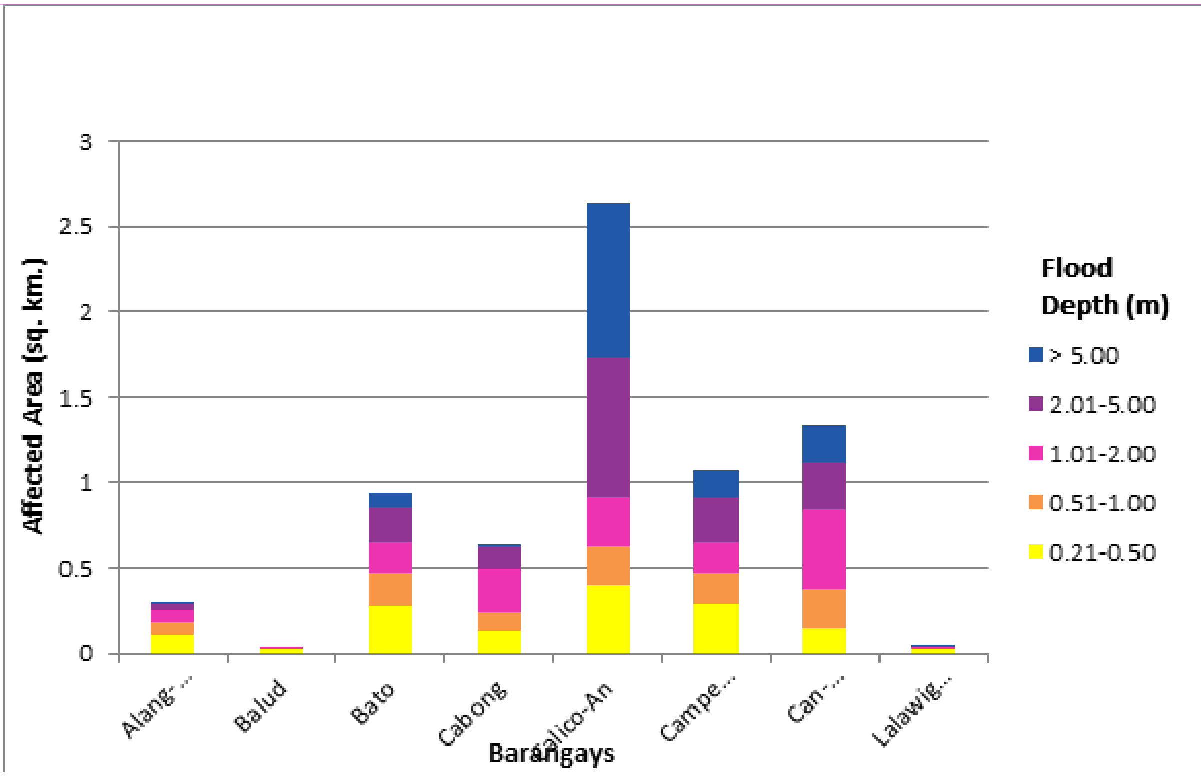


Figure 81. Affected Areas in Borongan City, Eastern Samar during 25-Year Rainfall Return Period

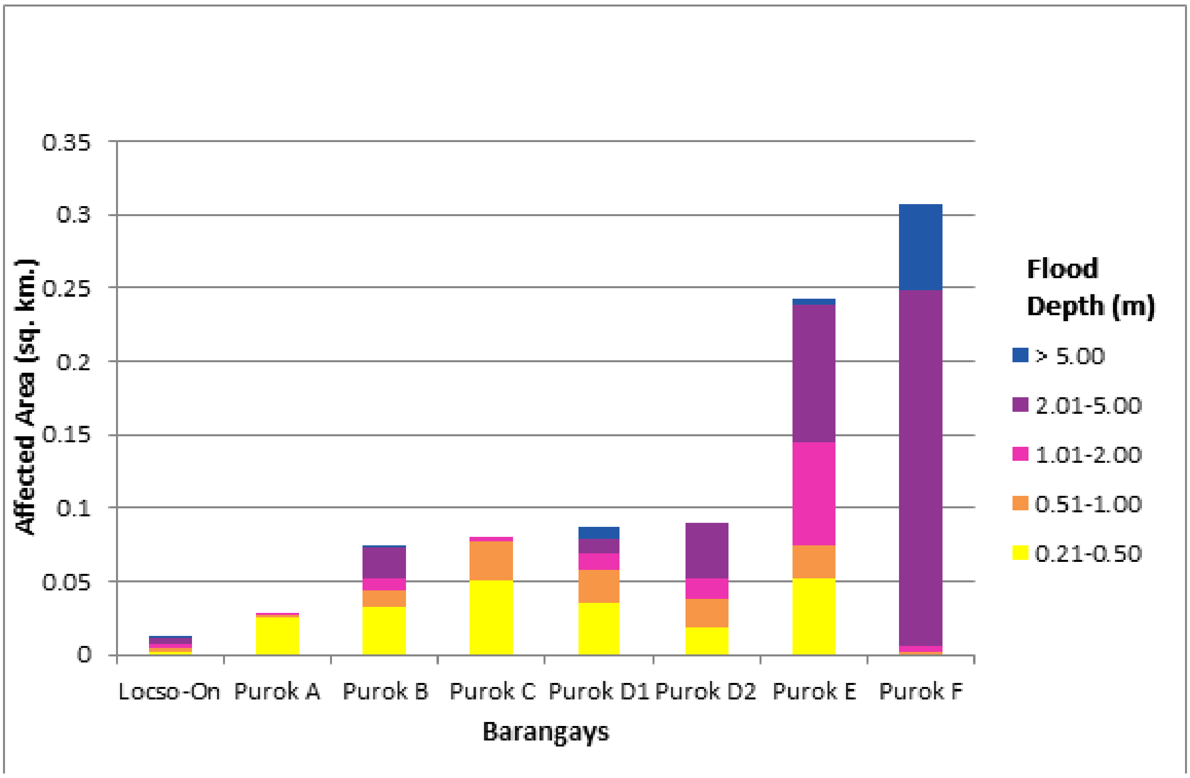


Figure 82. Affected Areas in Borongan City, Eastern Samar during 25-Year Rainfall Return Period

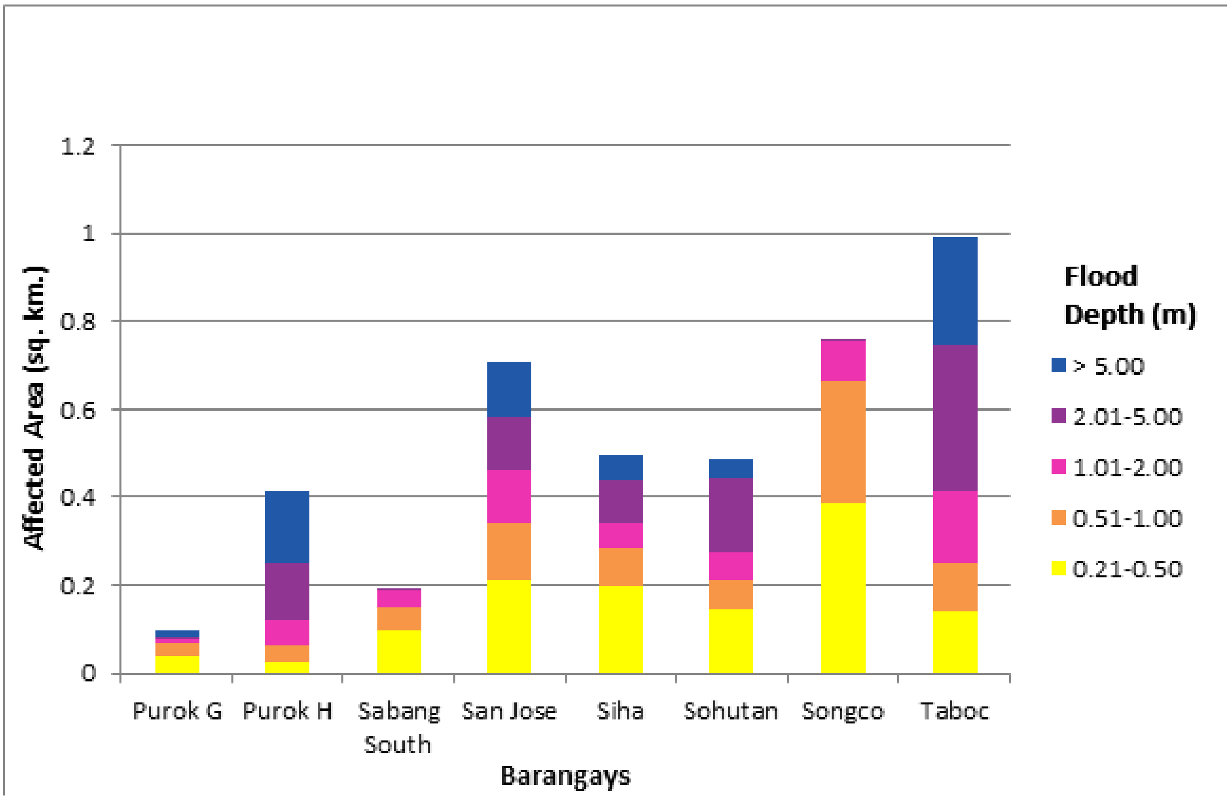


Figure 83. Affected Areas in Borongan City, Eastern Samar during 25-Year Rainfall Return Period

For the 100-year return period, 7.83% of the city of Borongan with an area of 596.08 sq. km. will experience flood levels of less 0.20 meters. 0.48% of the area will experience flood levels of 0.21 to 0.50 meters while 0.31%, 0.36%, 0.45% and 0.44% of the area will experience flood depths of 0.51 to one (1) meter, 1.01 to two (2) meters, 2.01 to five (5) meters, and more than five (5) meters, respectively. Listed in Table 38 are the affected areas in square kilometres by flood depth per barangay.

Table 38. Affected Areas in Borongan City, Eastern Samar during 100-Year Rainfall Return Period

LOOM BASIN		Affected Barangays in Borongan City							
		Alang-Alang	Balud	Bato	Cabong	Calico-An	Campesao	Can-Abong	Lalawigan
Affected Area (sq.km.)	0.03-0.20	0.92	0.44	6.92	1.14	10.71	5.84	1.47	0.28
	0.21-0.50	0.13	0.034	0.31	0.14	0.46	0.3	0.12	0.027
	0.51-1.00	0.076	0.00085	0.21	0.11	0.22	0.17	0.22	0.0061
	1.01-2.00	0.084	0.00058	0.19	0.26	0.25	0.18	0.49	0.006
	2.01-5.00	0.053	0	0.23	0.17	0.71	0.3	0.33	0.0094
	> 5.00	0.021	0	0.12	0.0084	1.21	0.22	0.23	0.0049

Table 39. . Affected Areas in Borongan City, Eastern Samar during 100-Year Rainfall Return Period

LOOM BASIN		Affected Barangays in Borongan City							
		Locso-On	Purok A	Purok B	Purok C	Purok D1	Purok D2	Purok E	Purok F
Affected Area (sq.km.)	0.03-0.20	0.12	0.13	0.14	0.14	0.11	0.029	0.17	0.00038
	0.21-0.50	0.0024	0.031	0.037	0.056	0.043	0.021	0.049	0.00023
	0.51-1.00	0.0022	0.0025	0.012	0.034	0.021	0.018	0.029	0.0003
	1.01-2.00	0.0027	0.00013	0.01	0.0055	0.027	0.022	0.049	0.0017
	2.01-5.00	0.0045	0	0.026	0	0.013	0.044	0.13	0.19
	> 5.00	0.0022	0	0.00049	0	0.0099	0.00097	0.0059	0.11

Table 40. Affected Areas in Borongan City, Eastern Samar during 100-Year Rainfall Return Period

LOOM BASIN		Affected Barangays in Borongan City							
		Purok G	Purok H	Sabang South	San Jose	Siha	Sohutan	Songco	Taboc
Affected Area (sq.km.)	0.03-0.20	0.44	0.46	0.36	4.87	3.92	3.57	1.08	4.27
	0.21-0.50	0.041	0.016	0.11	0.24	0.22	0.16	0.4	0.15
	0.51-1.00	0.031	0.03	0.064	0.14	0.095	0.072	0.32	0.11
	1.01-2.00	0.011	0.063	0.046	0.13	0.068	0.059	0.13	0.15
	2.01-5.00	0.0056	0.13	0.0017	0.14	0.11	0.14	0.0035	0.35
	> 5.00	0.015	0.19	0	0.14	0.051	0.12	0	0.3

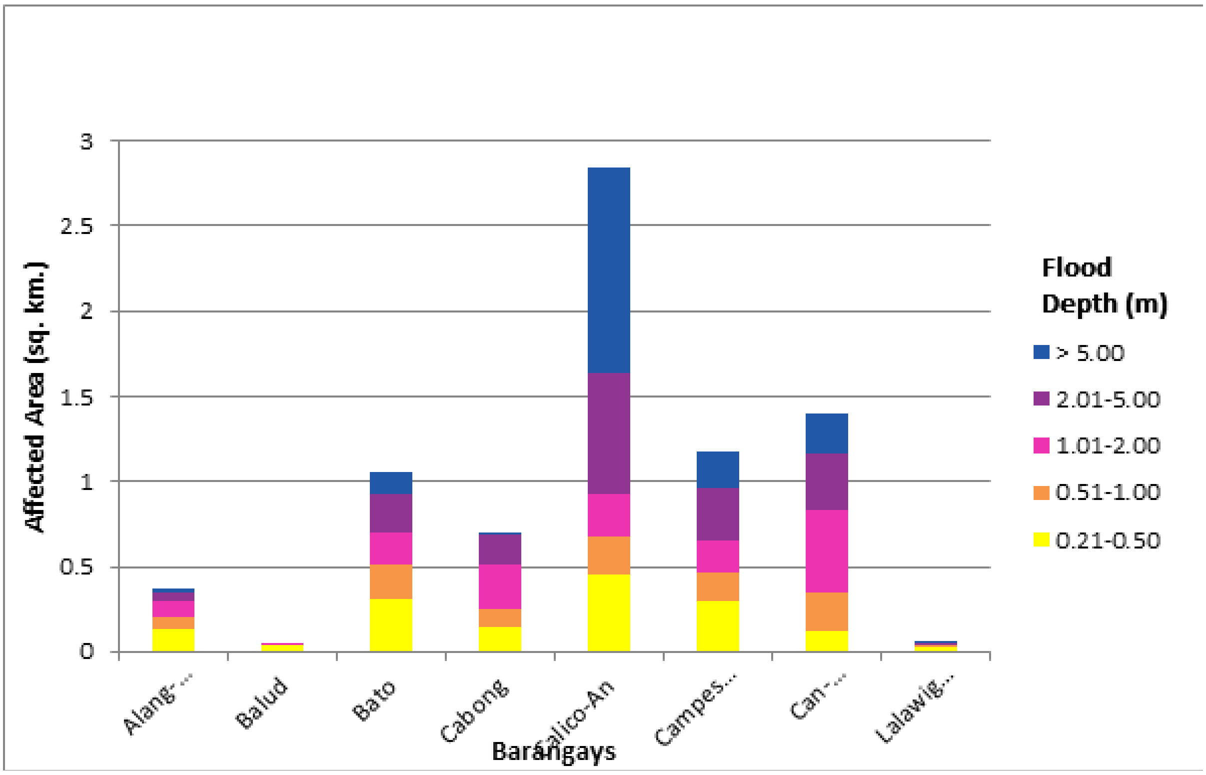


Figure 84. Affected Areas in Borongan City, Eastern Samar during 100-Year Rainfall Return Period

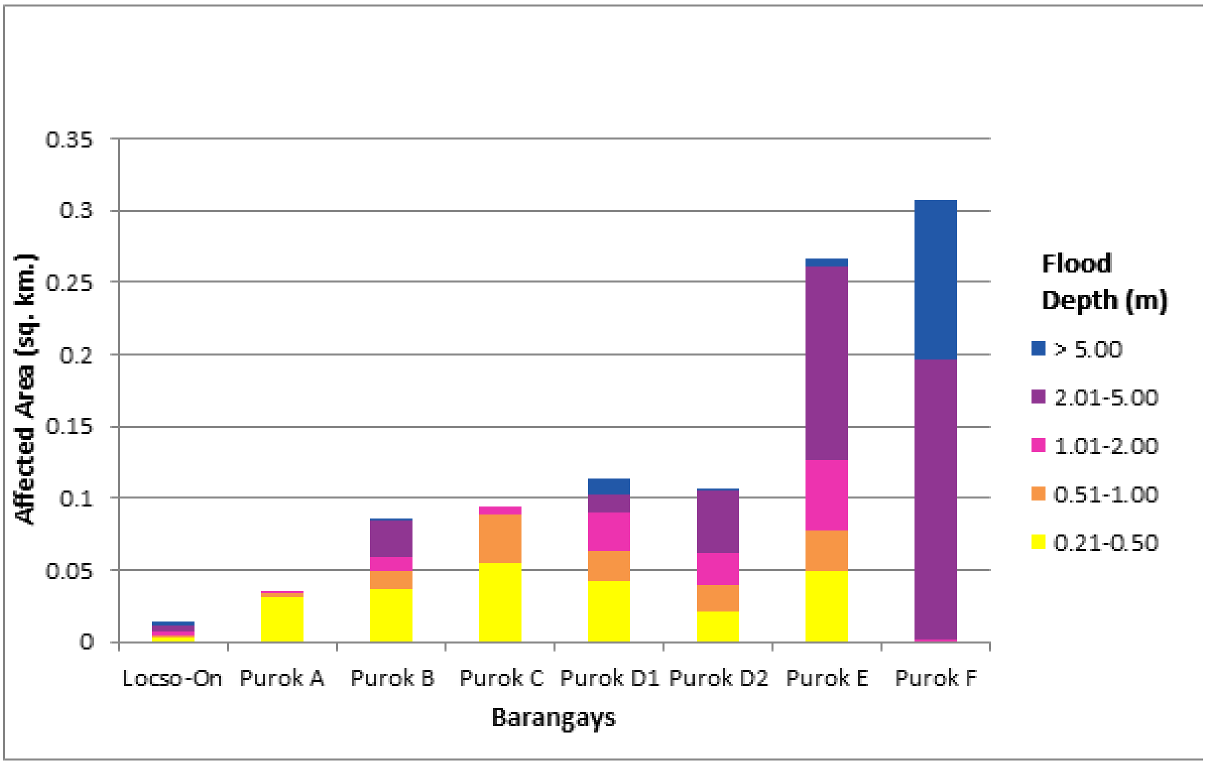


Figure 85. Affected Areas in Borongan City, Eastern Samar during 100-Year Rainfall Return Period

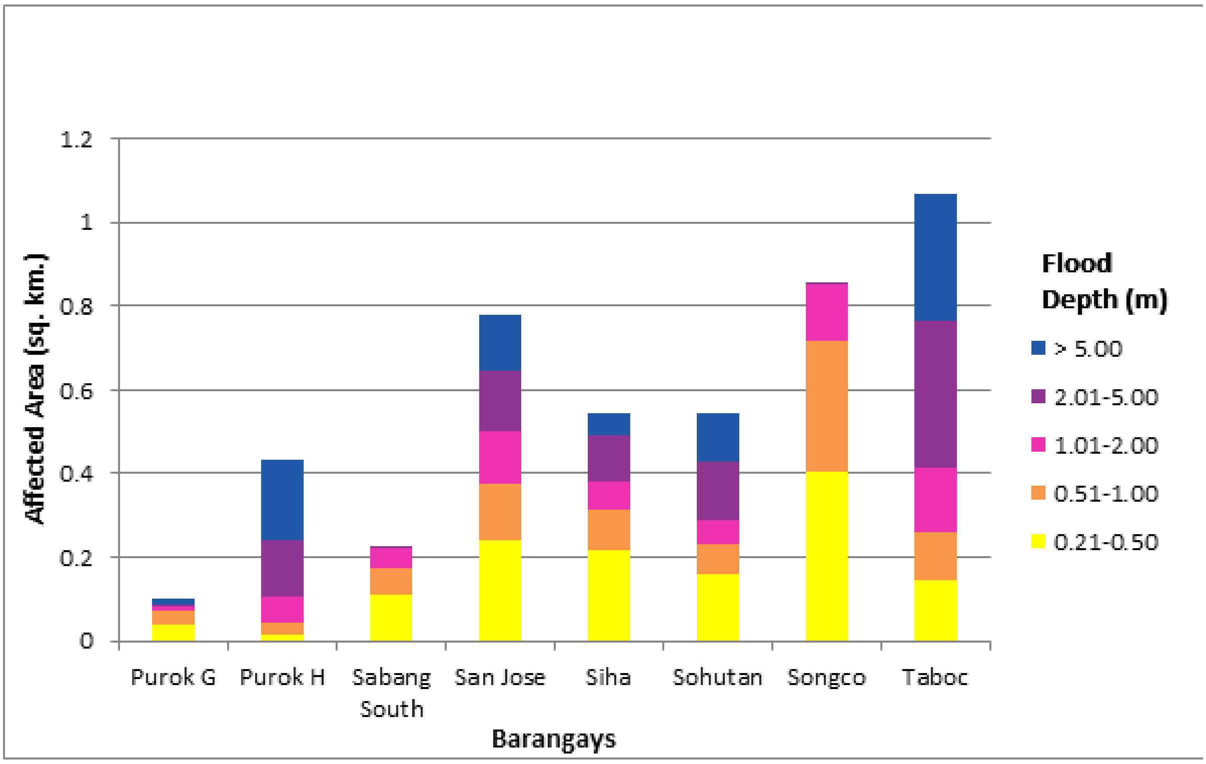


Figure 86. Affected Areas in Borongan City, Eastern Samar during 100-Year Rainfall Return Period

Among the barangays in the municipality of Borongan City, Calico-an is projected to have the highest percentage of area that will experience flood levels at 2.27%. Meanwhile, Bato posted the second highest percentage of area that may be affected by flood depths at 1.34%.

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

Table 41. Area covered by each warning level with respect to the rainfall scenario

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	2.59	2.90	3.09
Medium	2.85	3.02	3.14
High	4.84	6.28	7.10
Total	**10.28**	**12.2**	**13.33**

Of the 11 identified Education Institutions in Loom Flood plain, three (3) schools were assessed to be exposed to the Low level flooding during five (5) year and 25 year scenario. For the 100 year scenario, four (4) schools were assessed for Low level flooding. See Annex 12 for a detailed enumeration of schools inside Loom Floodplain.

Of the 15 identified Medical Institutions in Loom Flood plain, eight (8) were assessed to be exposed to the Low level flooding during a five (5) year scenario. In the 25 and 100 year scenario, 10 were assessed to be exposed to the Low level. See Annex 13 for a detailed enumeration of medical institutions inside Loom Floodplain.

5.11 Flood Validation

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

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

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

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

The flood validation consists of 306 points randomly selected all over the Loom flood plain. The points were grouped depending on the RIDF return period of the event.

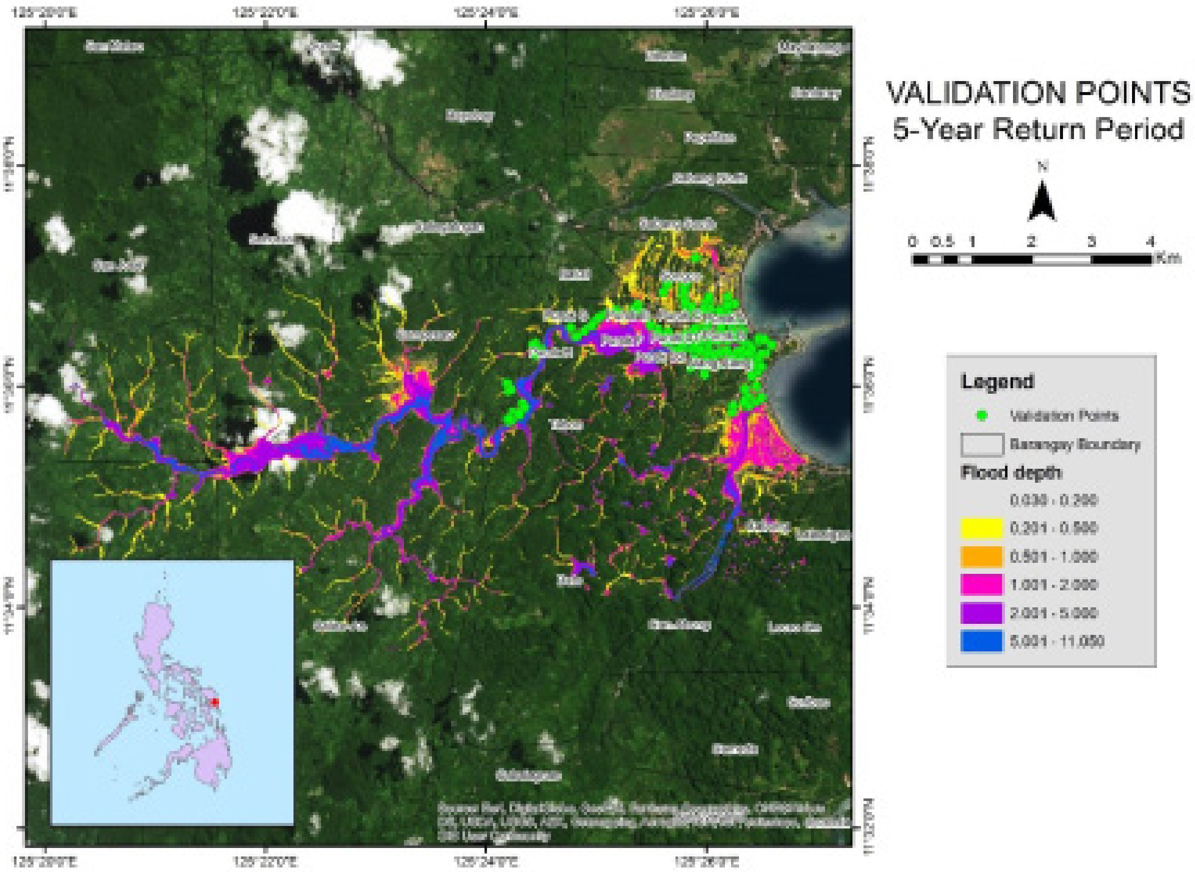


Figure 87. Validation points for 5-year Flood Depth Map of Loom Floodplain

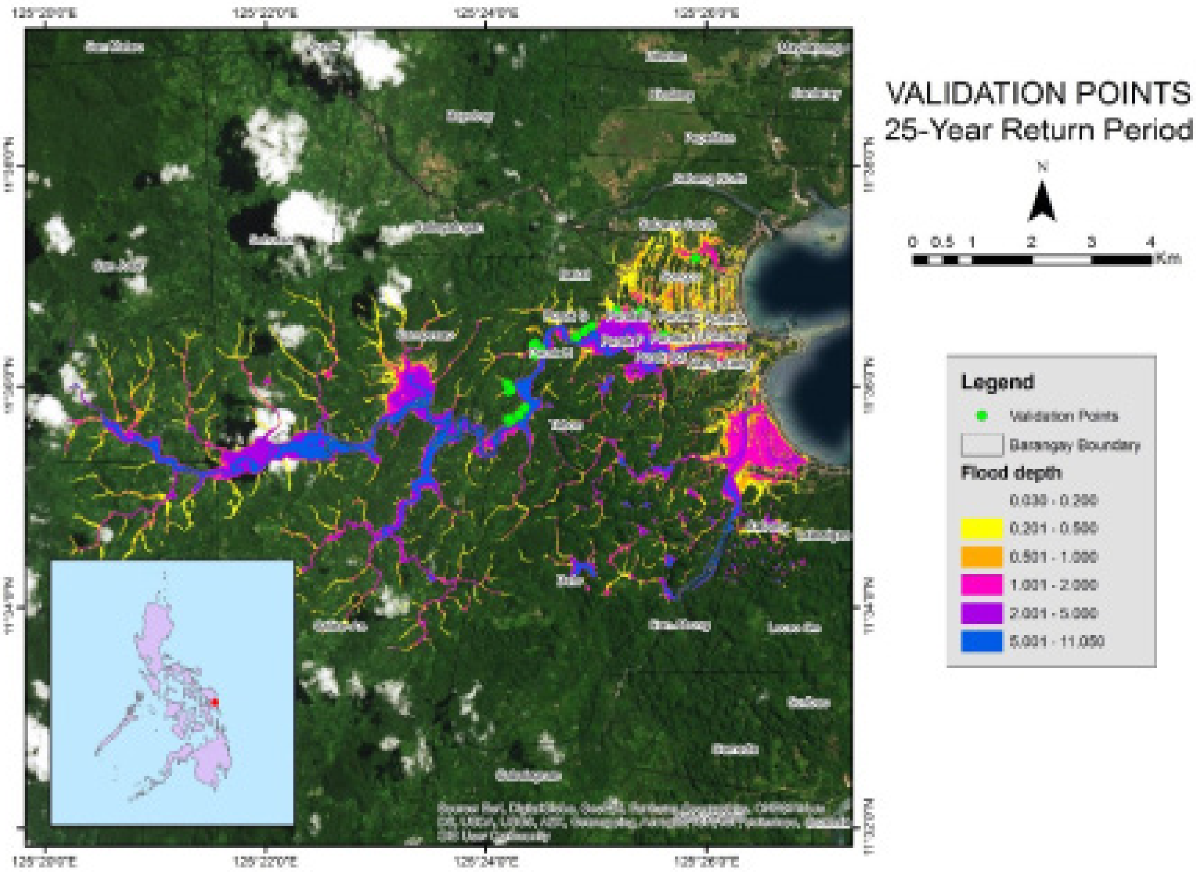


Figure 88. Validation points for 25-year Flood Depth Map of Loom Floodplain

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

Table 42. Area covered by each warning level with respect to the rainfall scenario

Return Period	RMSE
5-year	1.03
25-year	2.16

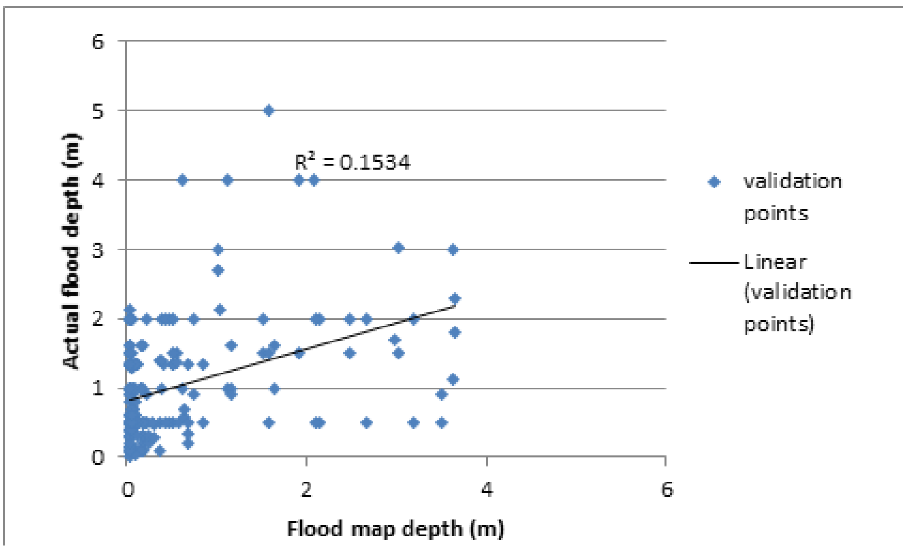


Figure 89. Flood map depth vs actual flood depth

Table 43. Actual Flood Depth vs Simulated Flood Depth for 5-yr RP in Loom

	LOOM BASIN	Modeled Flood Depth (m)						
		0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
Actual Flood Depth (m)	0-0.20	25	2	1	0	0	0	28
	0.21-0.50	71	10	5	1	5	0	92
	0.51-1.00	45	2	4	4	1	0	56
	1.01-2.00	53	7	9	6	10	0	85
	2.01-5.00	1	0	1	6	4	0	12
	> 5.00	0	0	0	0	0	0	0
	Total	195	21	20	17	20	0	273

The overall accuracy generated by the 5-yr flood model is estimated at 17.95%, with 119 points correctly matching the actual flood depths. In addition, there were 109 points estimated one level above and below the correct flood depths while there were 56 points and 59 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 29 points were overestimated while a total of 195 points were underestimated in the modelled flood depths of Loom.

Table 44. Area covered by each warning level with respect to the rainfall scenario

	No. of Points	%
Correct	49	17.95
Overestimated	29	10.62
Underestimated	195	71.43
Total	273	100

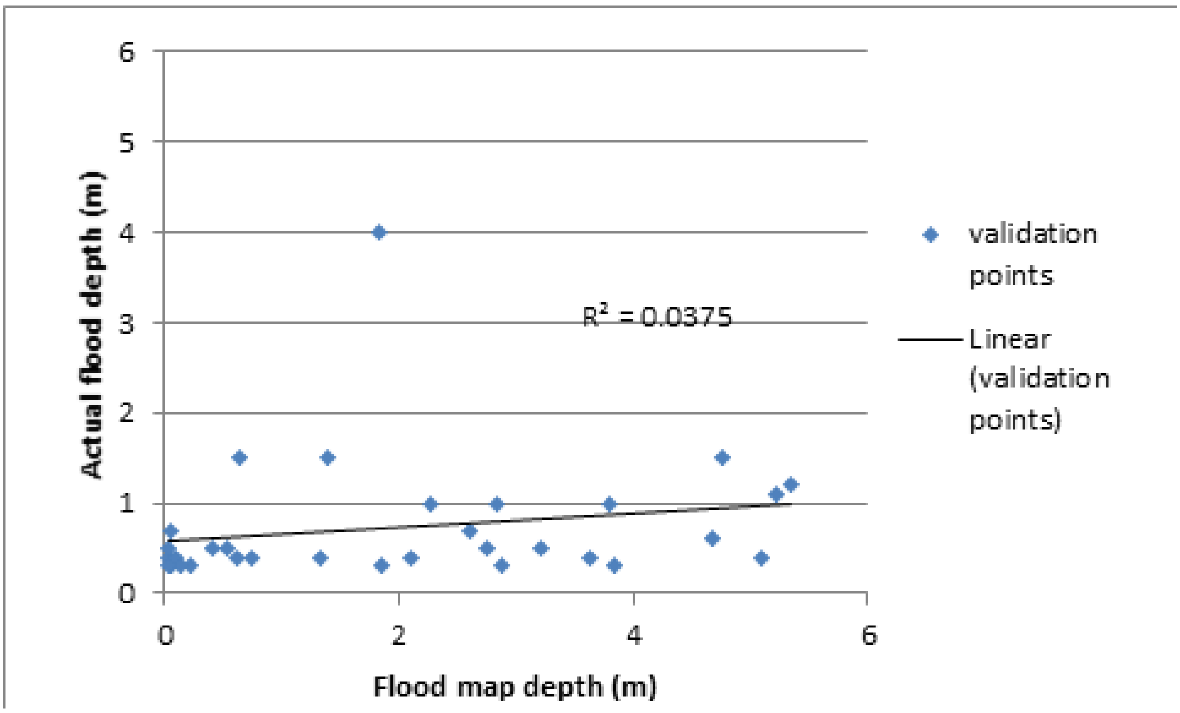


Figure 90. Flood map depth vs actual flood depth

Table 45. Actual Flood Depth vs Simulated Flood Depth for 25-yr RP in Loom

LOOM BASIN		Modeled Flood Depth (m)						
		0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
Actual Flood Depth (m)	0-0.20	0	0	0	0	0	0	0
	0.21-0.50	7	2	3	2	6	1	21
	0.51-1.00	1	0	0	0	5	0	6
	1.01-2.00	0	0	1	1	1	2	5
	2.01-5.00	0	0	0	1	0	0	1
	> 5.00	0	0	0	0	0	0	0
	Total	8	2	4	4	12	3	33

The overall accuracy generated by the 25-yr flood model is estimated at 9.09%, with three (3) points correctly matching the actual flood depths. In addition, there were 13 points estimated one level above and below the correct flood depths while there were 10 points and seven (7) points estimated two (2) levels above and below, and three or more levels above and below the correct flood. A total of 20 points were overestimated while a total of 10 points were underestimated in the modelled flood depths of Loom.

Table 46. Summary of Accuracy Assessment in Loom

	No. of Points	%
Correct	3	9.09
Overestimated	20	60.61
Underestimated	10	30.30
Total	33	100

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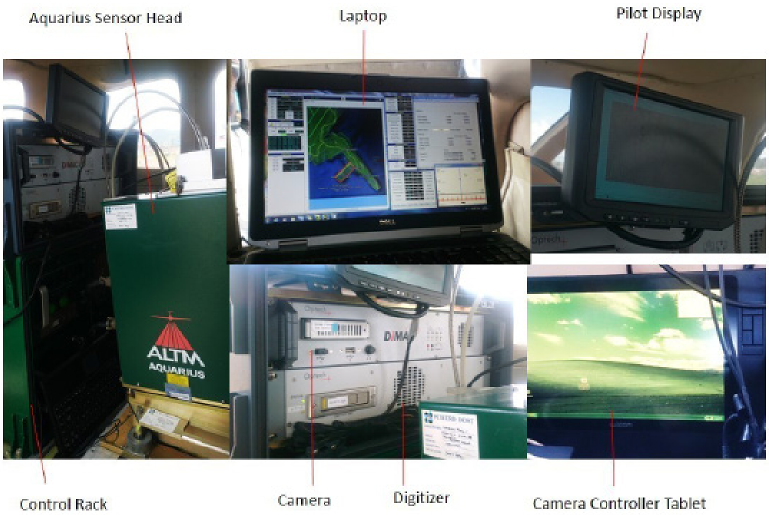
ANNEXES

Annex 1. OPTECH Technical Specification of the Aquarius Sensor



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

1. Target reflectivity ≥20%
2. Dependent on selected operational parameters using nominal FOV of up to 40° in standard atmospheric conditions with 24-km visibility
3. Angle of incidence ≤20˚
4. Target size ≥ laser footprint5 Dependent on system configuration

Annex 2. NAMRIA Certificates of Reference Points Used

1. SME - 3117

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: **EASTERN SAMAR**
Station Name: **SME-3117**
Order: **4th**

Island: **VISAYAS**
Municipality: **MAYDOLONG**
Barangay: **BARANGAY POBLACION 4**

PRS92 Coordinates

Latitude: **11° 30' 19.94572"**	Longitude: **125° 29' 48.45875"**	Ellipsoidal Hgt: **-0.71500 m.**

WGS84 Coordinates

Latitude: **11° 30' 15.65415"**	Longitude: **125° 29' 53.58658"**	Ellipsoidal Hgt: **62.69300 m.**

PTM Coordinates

Northing: **1272291.016 m.**	Easting: **664197.385 m.**	Zone: **5**

UTM Coordinates

Northing: **1,272,983.11**	Easting: **772,367.30**	Zone: **51**

Location Description

SME-3117

From Tacloban City, travel about 70 Km. NE towards the junction of Buena Vista, Quinapondan. Then travel about 80 Km. N pass Gen. Mc Arthur, Hernani, Llorente and Balangkayan towards Poblacion 4, Maydolong until reaching Maydolong Nat'l High School. Station is located inside the compound of school about 2 m S of the flagpole. Mark is the head of a 4 in. copper nail centered on a 0.20 m x 0.20 m x 1.00 m concrete monument with inscriptions, "SME-3117, 2008, NAMRIA".

Requesting Party: **UP-TCAGP**
Purpose: **Reference**
OR Number: **8796290 A**
T.N.: **2014-1304**

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

2. SME – 3139

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

June 24, 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: **EASTERN SAMAR**
Station Name: **SME-3139**
Order: **4th**

Island: **VISAYAS**
Municipality: **SULAT**
Barangay: **SANTO NIÑO**

PRS92 Coordinates

Latitude:	11° 50' 2.95701"	Longitude:	125° 26' 3.02189"	Ellipsoidal Hgt:	0.35600 m.

WGS84 Coordinates

Latitude:	11° 49' 58.57713"	Longitude:	125° 26' 8.12160"	Ellipsoidal Hgt:	62.18500 m.

PTM Coordinates

Northing:	1308428.152 m.	Easting:	647309.911 m.	Zone:	5

UTM Coordinates

Northing:	1,309,289.26	Easting:	765,219.59	Zone:	51

Location Description

SME-3139

From Tacloban City, travel about 70 Km. NE towards the junction of Buena Vista, Quinapondan. Then travel about 170 Km. NW pass Gen. Mc Arthur, Hernani, Llorente, Balangkayan, Maydolong, Borongan and San Julian pass Sulat proper towards Brgy. Sto. Niño until reaching a bridge near the Km. post 900 S-4. Station is located at the right side of the road about 1 m S of the bridge, about 100 m S of Km. post 900 S-4, about 500 m S of the brgy. basketball court. Mark is the head of a 4 in. copper nail centered on a 0.20 m x 0.20 m x 1.00 m concrete monument with inscriptions, "SME-3139, 2008, NAMRIA".

Requesting Party: **Engr. Cruz**
Pupose: **Reference**
OR Number: **8796376 A**
T.N.: **2014-1442**

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

NAMRIA OFFICES:
Main : Lawton Avenue, Fort Bonifacio, 1634 Taguig City, Philippines
Branch : 421 Barraca St. San Nicolas, 1010 Manila, Philippines
www.namria.gov.ph

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

3. SE - 102

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: **EASTERN SAMAR**
Station Name: **SE-102**

Island: **VISAYAS**	Municipality: **MAYDOLONG**	Barangay: **BARANGAY**
Elevation: **2.5962 m.**	Order: **1st Order**	Datum:

Location Description

SE-102 is in the Province of Eastern Samar, town of Maydolong, Brgy. 4 along right side of the National highway going to Borongan. It is located in front of Maydolong National High School near the gate, and about 8.50m 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
"SE-102, 2007, NAMRIA."

Requesting Party:	**UP-TCAGP**
Pupose:	**Reference**
OR Number:	**8796290 A**
T.N.:	**2014-1305**

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

4. SE – 16

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

June 24, 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: **EASTERN SAMAR**
Station Name: **SE-16**

Island: **VISAYAS**	Municipality: **BALANGIGA**	Barangay: **SAN MIGUEL**
Elevation: **1.7415 m.**	Order: **1st Order**	Datum: **Mean Sea Level**

Location Description

SE-16
Is in the Province of Eastern Samar, town of Balangiga, Brgy. San Miguel along the National highway. It is located near Km post 974, 6.20m E from the centerline of the national highway cemented on top of a riprap. Station mark is the head of 4" copper nail on a drilled hole flush on a 0.10m x 0.10m cement putty inscribed "SE-16, 2007, NAMRIA."

Requesting Party:	**Engr. Cruz**
Pupose:	**Reference**
OR Number:	**8796376 A**
T.N.:	**2014-1444**

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Annex 3. Baseline Processing Report

1. SE – 102

SME-3117 - SE-102 A (6:47:42 AM-11:17:03 AM) (S2)

Baseline observation:	SME-3117 --- SE-102 A (B2)
Processed:	6/17/2014 10:44:29 AM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.004 m
Vertical precision:	0.004 m
RMS:	0.000 m
Maximum PDOP:	2.769
Ephemeris used:	Broadcast
Antenna model:	Trimble Relative
Processing start time:	6/8/2014 6:47:51 AM (Local: UTC+8hr)
Processing stop time:	6/8/2014 11:17:03 AM (Local: UTC+8hr)
Processing duration:	04:29:12
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	SME-3117				
Grid		Local		Global	
Easting	772367.303 m	Latitude	N11°30'19.94672"	Latitude	N11°30'16.66415"
Northing	1272983.110 m	Longitude	E126°29'48.46876"	Longitude	E126°29'53.68658"
Elevation	1.116 m	Height	-0.714 m	Height	62.093 m

To:	SE-102 A				
Grid		Local		Global	
Easting	772214.094 m	Latitude	N11°30'18.33686"	Latitude	N11°30'14.04528"
Northing	1272932.317 m	Longitude	E126°29'43.39146"	Longitude	E126°29'48.61933"
Elevation	2.198 m	Height	0.393 m	Height	63.198 m

Vector					
ΔEasting	-153.209 m	NS Fwd Azimuth	252°09'24"	ΔX	118.689 m
ΔNorthing	-50.793 m	Ellipsoid Dist.	161.526 m	ΔY	98.078 m
ΔElevation	1.081 m	ΔHeight	1.107 m	ΔZ	-48.228 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'01"	σ ΔX	0.001 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.002 m	σ ΔY	0.002 m
σ ΔElevation	0.002 m	σ ΔHeight	0.002 m	σ ΔZ	0.001 m

2. SE – 16

SME-3139 - SE-16 (6:11:03 AM-11:04:02 AM) (S2)

Baseline observation:	SME-3139 --- SE-16 (B2)
Processed:	6/30/2014 6:42:19 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.001 m
Vertical precision:	0.002 m
RMS:	0.000 m
Maximum PDOP:	3.434
Ephemeris used:	Broadcast
Antenna model:	Trimble Relative
Processing start time:	6/9/2014 6:11:10 AM (Local: UTC+8hr)
Processing stop time:	6/9/2014 11:04:02 AM (Local: UTC+8hr)
Processing duration:	04:52:52
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	SME-3139				
Grid		Local		Global	
Easting	765219.591 m	Latitude	N11°50'02.95701"	Latitude	N11°49'58.57713"
Northing	1309289.260 m	Longitude	E125°26'03.02189"	Longitude	E125°26'08.12160"
Elevation	2.987 m	Height	0.356 m	Height	62.185 m

To:	SE-16				
Grid		Local		Global	
Easting	765219.942 m	Latitude	N11°50'03.05106"	Latitude	N11°49'58.67117"
Northing	1309292.154 m	Longitude	E125°26'03.03429"	Longitude	E125°26'08.13400"
Elevation	3.103 m	Height	0.472 m	Height	62.301 m

Vector					
ΔEasting	0.350 m	NS Fwd Azimuth	7°23'58"	ΔX	-0.028 m
ΔNorthing	2.894 m	Ellipsoid Dist.	2.914 m	ΔY	-0.608 m
ΔElevation	0.116 m	ΔHeight	0.116 m	ΔZ	2.852 m

Standard Errors

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

Annex 4. The LIDAR Survey Team Composition

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. LOUIE P. BALICANTA	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	UP-TCAGP
		LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	ENGR. GEROME HIPOLITO	UP-TCAGP
	Research Associate (RA)	PAULINE JOANNE ARCEO	
		FAITH JOY SABLE	
		MARY CATHERINE ELIZABETH BALIGUAS	
		ENGR. GRACE SINADJAN	
		ENGR. IRO NIEL ROXAS	
Ground Survey, Data Download and Transfer		JERIEL PAUL ALAMBAN	
LiDAR Operation	Airborne Security	SGT. RANDY SISON	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. JACKSON RHOD JAVIER	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. NEIL ACHILLES AGAWIN	

Annex 5. Data Transfer Sheets for Loom Floodplain Flights

DATA TRANSFER SHEET
6/19/2014 (Samar - Leyte)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES	MISSION LOG FILE	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
30-May-14	1520A	3BLK33VSS150A	Aquarius	NA	424/802	1.40	289	88.5	748	14	164	13.5	1KB	1KB	4	NA	X:\Airborne_Raw\1520A
31-May-14	1522A	3BLK33SS151A	Aquarius	NA	398	469KB	110	8.78/21	104/89	4.87	59.1	4.33	1KB	1KB	5	NA	X:\Airborne_Raw\1522A
1-Jun-14	1526A	3BLK33SSR152A	Aquarius	NA	456/784	1.68	277	119	403	15.5	204	8.36	1KB	1KB	6	NA	X:\Airborne_Raw\1526A
2-Jun-14	1530A	3BLK33RSQ153A	Aquarius	NA	353/680	1.48	284	36.9/58.2	555/246	15.8	166	7.88	1KB	1KB	5	NA	X:\Airborne_Raw\1530A
4-Jun-14	1534A	3BLK33CS154A	Aquarius	NA	1175	1.49	330	86.9/28.1	308/154	14.5	114/55.5	6.6	1KB	1KB	7	NA	X:\Airborne_Raw\1534A
7-Jun-14	1550A	3BLK33PS158A	Aquarius	NA	887	1.05	198	52.9	85	10.8	149	7	1KB	1KB	3	NA	X:\Airborne_Raw\1550A
8-Jun-14	1554A	3BLK33PSM159A	Aquarius	NA	533/1012	1.78	287	98.8	806	14.5	27.3/58/33.2	16.4	1KB	1KB	3	NA	X:\Airborne_Raw\1554A
8-Jun-14	1556A	3BLK33MS159B	Aquarius	NA	982	1.02	291	97.2	477	15.9	215	16.4	1KB	1KB	5	NA	X:\Airborne_Raw\1556A
9-Jun-14	1558A	3BLK33J160A	Aquarius	NA	833	1.77	277	95.7	452	14.2	95.6/50.5	16.1	1KB	1KB	4	NA	X:\Airborne_Raw\1558A
9-Jun-14	1560A	3BLK33J	Aquarius	NA	1580	1.47	223	72.2	357	12.1	120	16.1	1KB	1KB	5	NA	X:\Airborne_Raw\1560A

Received from

Name O. Jardinel
Position
Signature

Received by

Name JOIDA PRIETO
Position SRS
Signature

6/19/14

Annex 6. Flight Logs

Flight Log for 1554 A Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1554

1 LiDAR Operator: [illegible]	2 ALTM Model: AQUA	3 Mission Name: [illegible]	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 9122
7 Pilot: J. [illegible]	8 Co-Pilot: N- [illegible]	9 Route:			
10 Date: 08 Jun 16	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0449	14 Engine Off: 1130	15 Total Engine Time: 6+41	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Completed mission over BLK 33F and covered 7 lines BLK 33 M					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
[illegible]	[illegible]	[illegible]	[illegible]
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

Flight Log for 1556 A Mission

DREAM Data Acquisition Flight Log Flight Log No.: 1556

1 LiDAR Operator:	2 ALTM Model:	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification:
7 Pilot:	8 Co-Pilot:	9 Route:			
10 Date:	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1247	14 Engine Off: 1734	15 Total Engine Time: 4+47	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: [illegible]					

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

Flight Log for 1560 A Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1560

1 LiDAR Operator: [illegible]	2 ALTM Model: AQUA	3 Mission Name: [illegible]	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: [illegible]
7 Pilot: [illegible]	8 Co-Pilot: [illegible]	9 Route:			
10 Date: [illegible] JUN 14	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1426	14 Engine Off: 1919	15 Total Engine Time: 3+53	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks:					

Mission completed over BLK 9J.

21 Problems and Solutions:

Acquisition Flight Approved by

[illegible]

Signature over Printed Name

(End User Representative)

Acquisition Flight Certified by

[illegible]

Signature over Printed Name

(PAF Representative)

Pilot-in-Command

[illegible]

Signature over Printed Name

Lidar Operator

[illegible]

Signature over Printed Name

DREAM

Disaster Risk and Exposure Assessment for Mitigation

Annex 7. Flight Status Report

SOUTHERN SAMAR – NORTHERN LEYTE FLIGHT LOGS
(April 15 – June 11, 2014)

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1554A	BLK33P	1BLK69B295A	G. Sinadjan	Oct. 22, 2014	Surveyed BLK 69B, cloudy
BLK33M	3BLK33PSM159A	MCE BALIGUAS	8 JUN 14	Completed mission over BLK33P and surveyed 7 lines over BLK33M	Surveyed BLK 69 B, still cloudy
1556A	BLK33M	3BLK33MS159B	PJ ARCEO	8 JUN 14	Completed mission over BLK33M
1558A	BLK33J	3BLK33J1160A	PJ ARCEO	9 JUN 14	Completed 12 lines over BLK33J
1560A	BLK33J	3BLK33J160B	MCE BALIGUAS	9 JUN 14	Mission completed over BLK33J

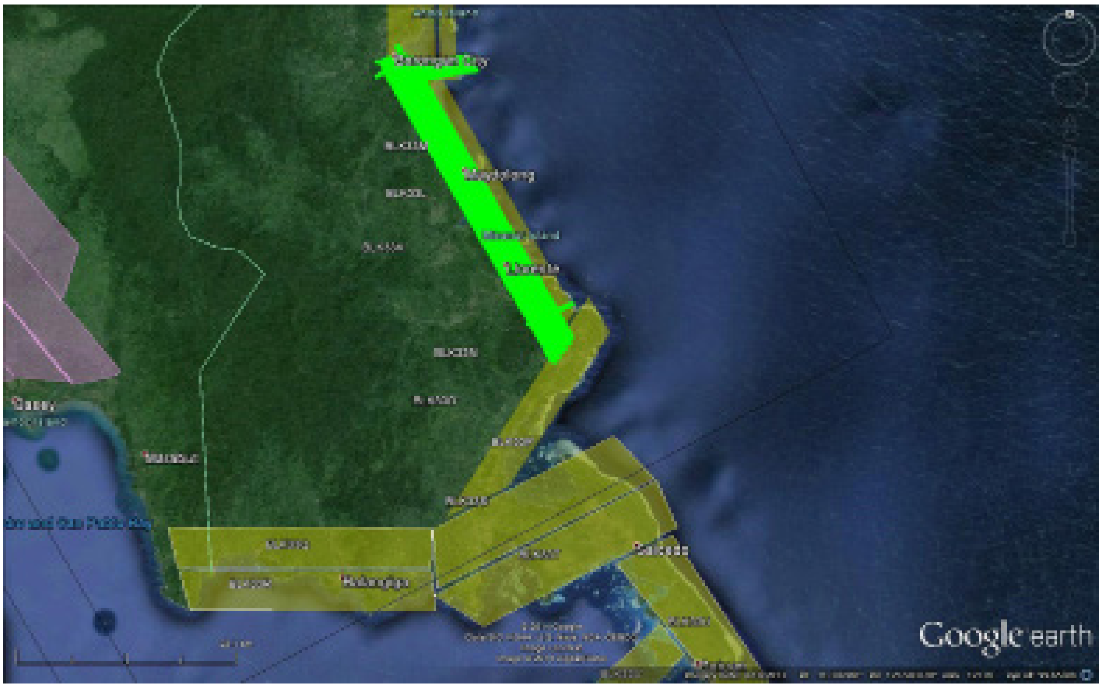
LAS/SWATH BOUNDARIES PER MISSION FLIGHT

Flight No. : 1554 A
Area: BLK33P and BLK33M
Mission Name: 3BLK33PSM159A
Parameters: PRF: 50 kHz SF: 45 Hz FOV: 44 Degrees
Flying Height: 600 m

LAS/SWATH

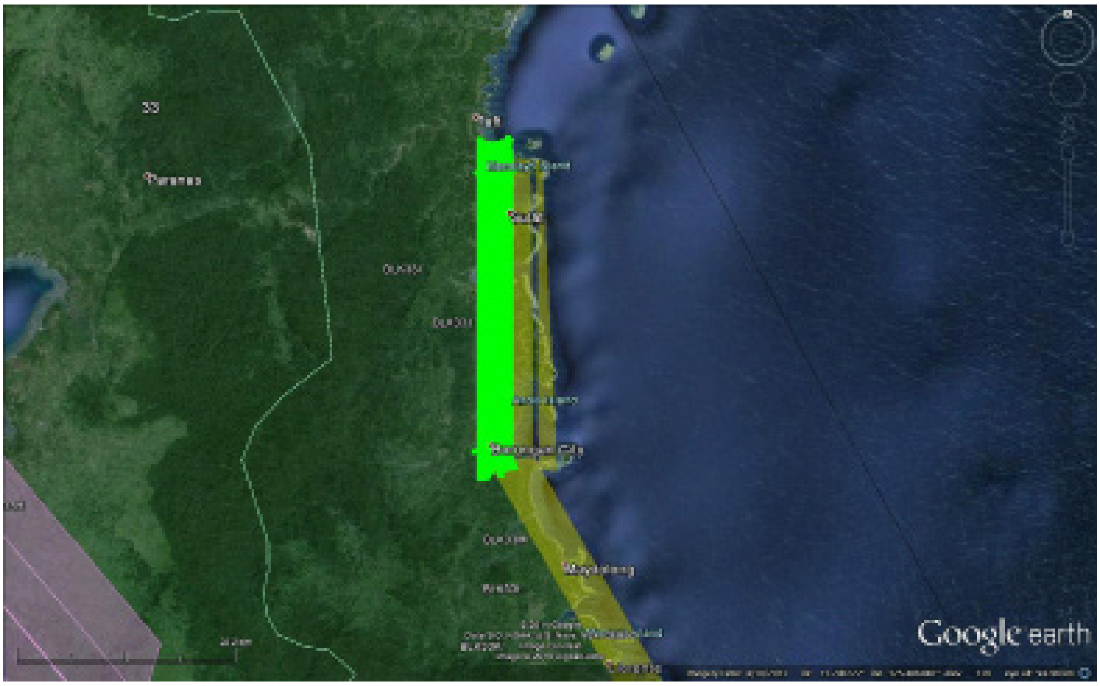
Flight No. :	1556 A		
Area:	BLK33P and BLK33M		
Mission Name:	3BLK33PSM159A		
Parameters:	PRF: 50 kHz	SF: 45 Hz	FOV: 44 Degrees
Flying Height:	600 m		

LAS/SWATH



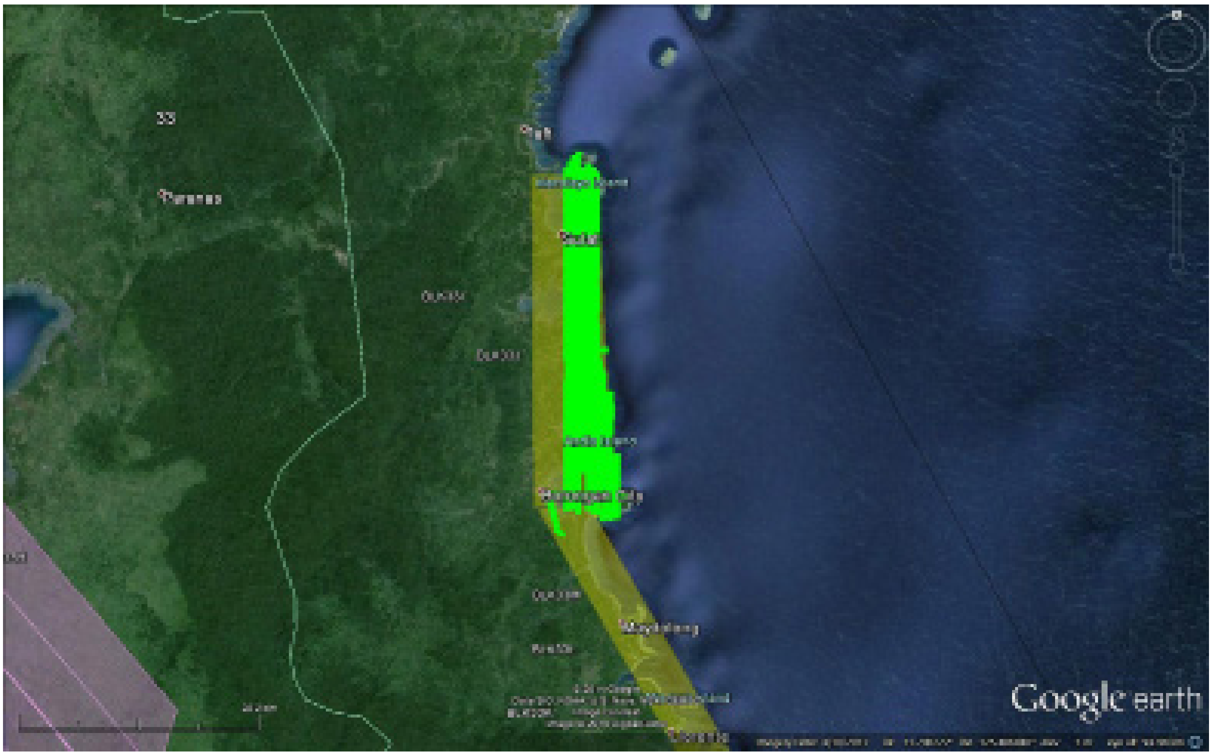
Flight No. :	1558 A		
Area:	BLK33J		
Mission Name:	3BLK33J160A		
Parameters:	PRF: 50 kHz	SF: 45 Hz	FOV: 44 Degrees
Flying Height:	600 m		

LAS/SWATH



Flight No. :	1560 A		
Area:	BLK33J		
Mission Name:	3BLK33J160B		
Parameters:	PRF: 50 kHz	SF: 45 Hz	FOV: 44 Degrees
Flying Height:	600 m		

LAS/SWATH



Annex 8. Mission Summary Report

FLIGHT AREA	SAMAR-LEYTE
MISSION NAME	**BLK33J**
INCLUSIVE FLIGHTS	1560A, 1558A
RANGE DATA SIZE	26.3 GB
POS	500 MB
IMAGE	167.9 GB
TRANSFER DATE	JUNE 19, 2014
SOLUTION STATUS	
NUMBER OF SATELLITES (>6)	YES
PDOP (<3)	YES
BASELINE LENGTH (<30KM)	NO
PROCESSING MODE (<=1)	NO
SMOOTHED PERFORMANCE METRICS (IN CM)	
RMSE FOR NORTH POSITION (<4.0 CM)	2.1
RMSE FOR EAST POSITION (<4.0 CM)	2.2
RMSE FOR DOWN POSITION (<8.0 CM)	3.1
BORESIGHT CORRECTION STDEV (<0.001DEG)	0.000327
IMU ATTITUDE CORRECTION STDEV (<0.001DEG)	0.000898
GPS POSITION STDEV (<0.01M)	0.0098
MINIMUM % OVERLAP (>25)	36.01%
AVE POINT CLOUD DENSITY PER SQ.M. (>2.0)	2.71
ELEVATION DIFFERENCE BETWEEN STRIPS (<0.20 M)	YES
NUMBER OF 1KM X 1KM BLOCKS	291
MAXIMUM HEIGHT	248.48 M
MINIMUM HEIGHT	49.30 M
CLASSIFICATION (# OF POINTS)	
GROUND	110,486,647
LOW VEGETATION	51,277,620
MEDIUM VEGETATION	61,095,498
HIGH VEGETATION	151,119,077
BUILDING	2,518,830
ORTHOPHOTO	YES
PROCESSED BY	ENGR. JOMMER MEDINA, ENGR. VELINA ANGELA BEMIDA

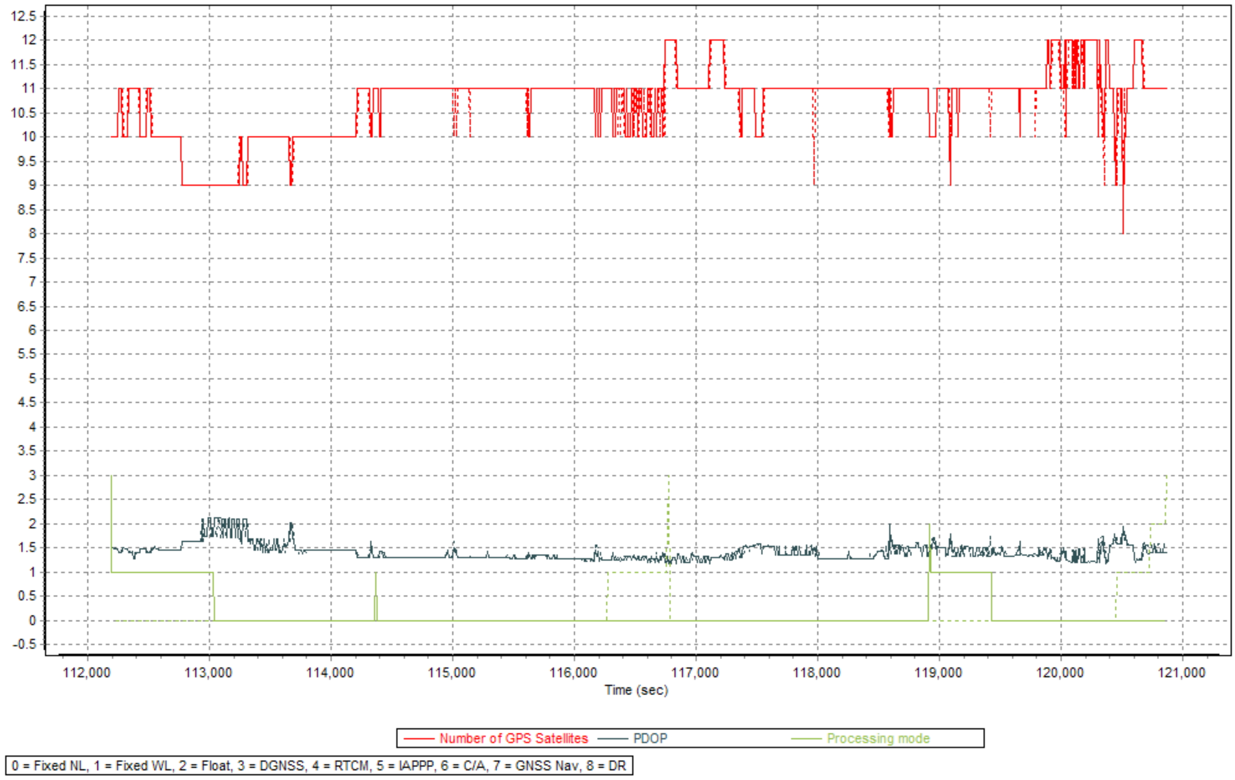


Figure 1.1.1. Solution Status

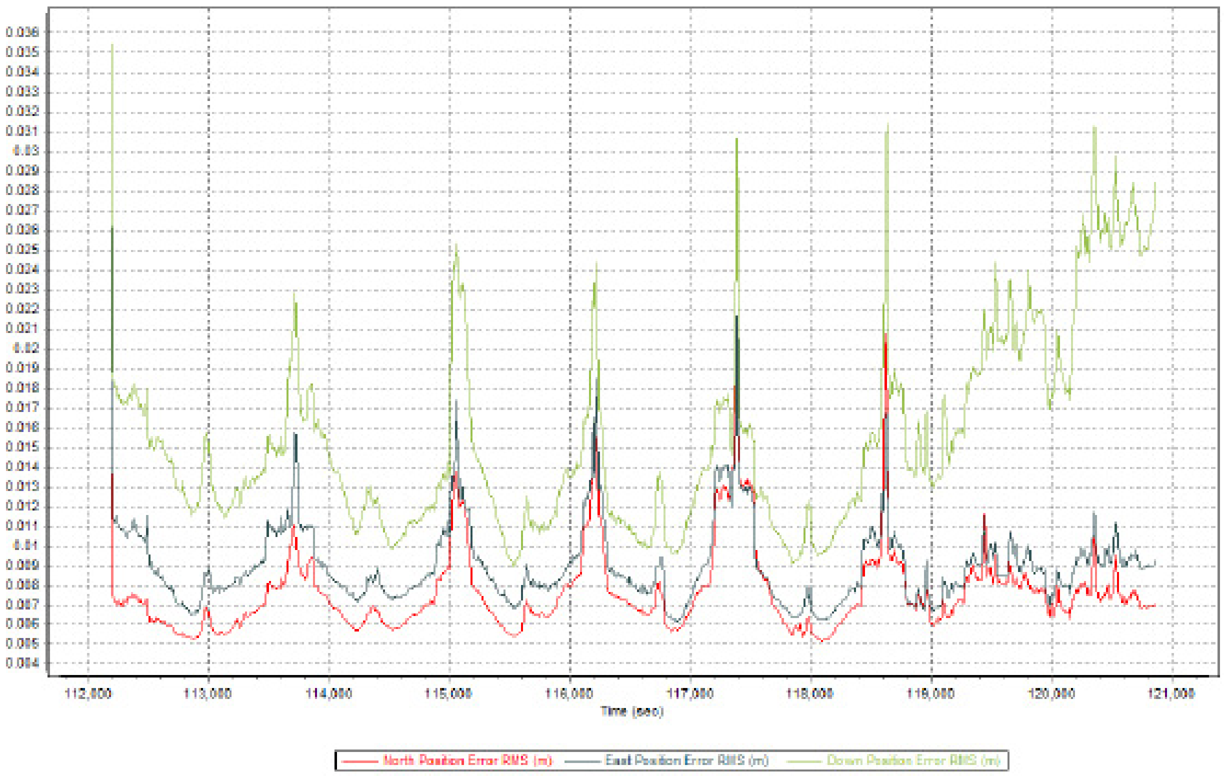


Figure 1.1.2. Smoothed Performance Metrics Parameters

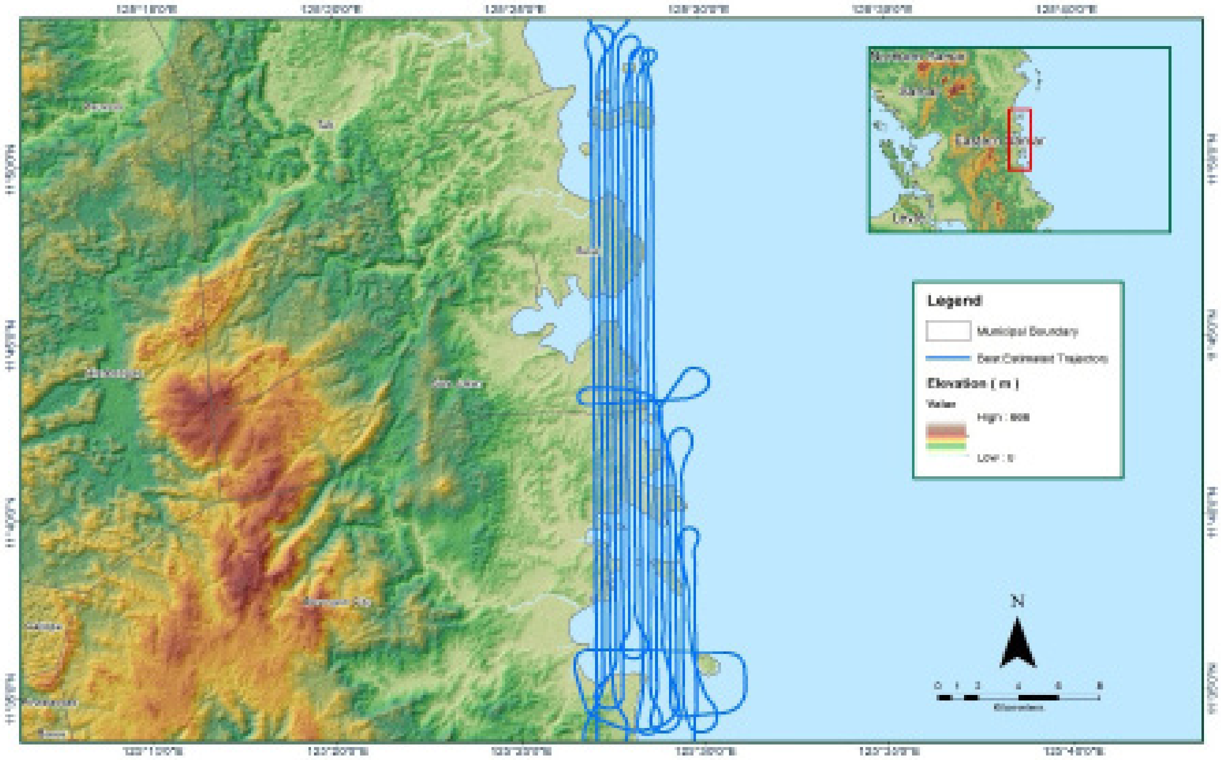


Figure 1.1.3. Best Estimated Trajectory

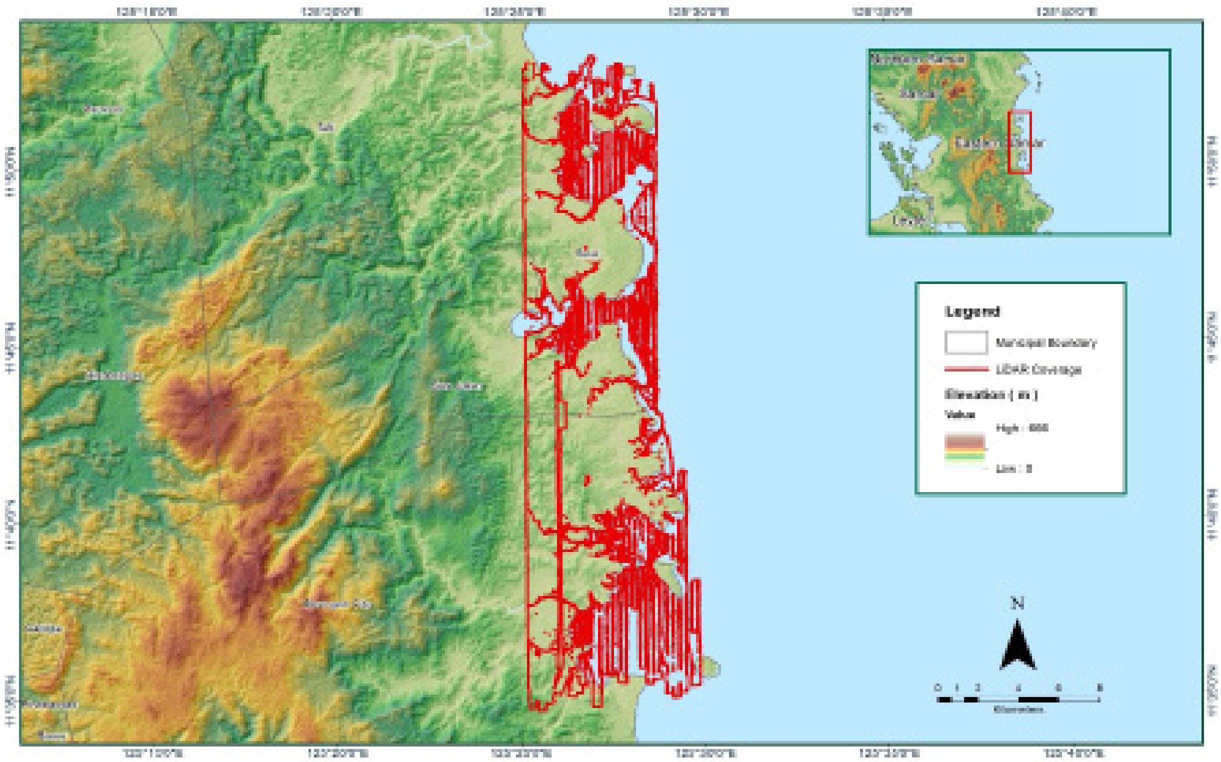


Figure 1.1.4. Coverage of LiDAR data

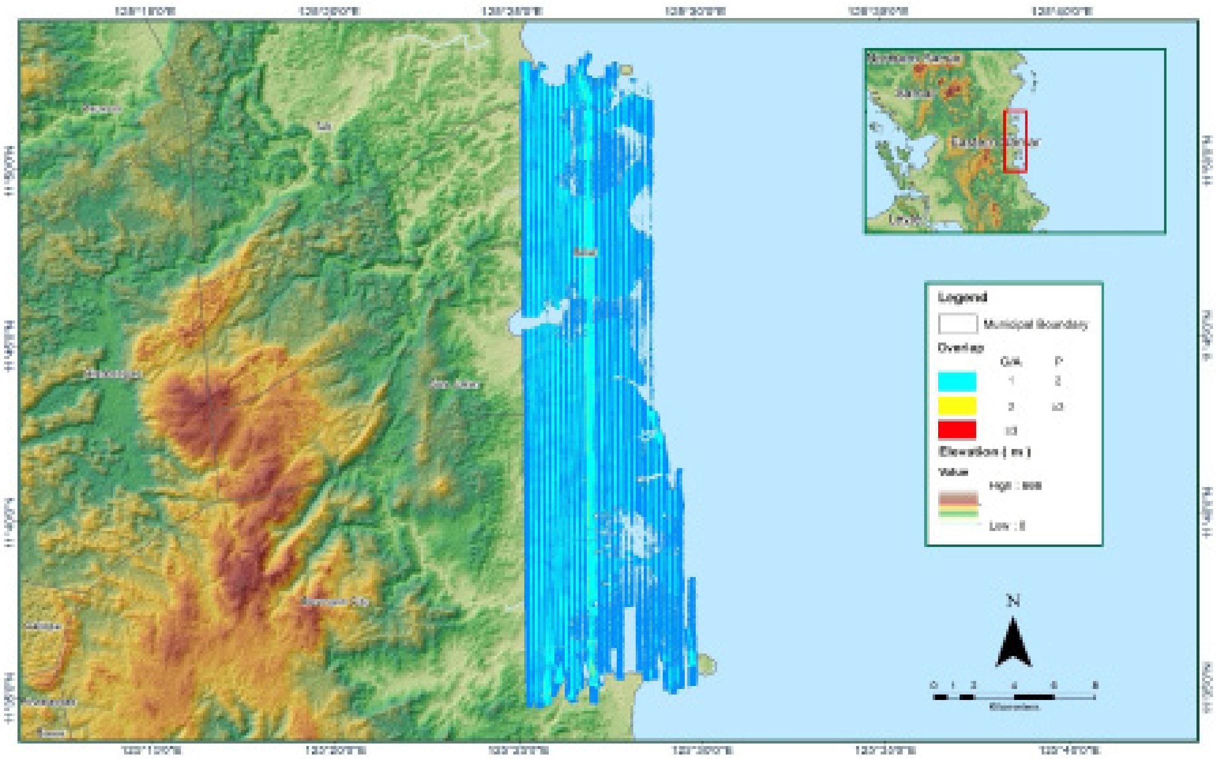


Figure 1.1.5. Image of data overlap

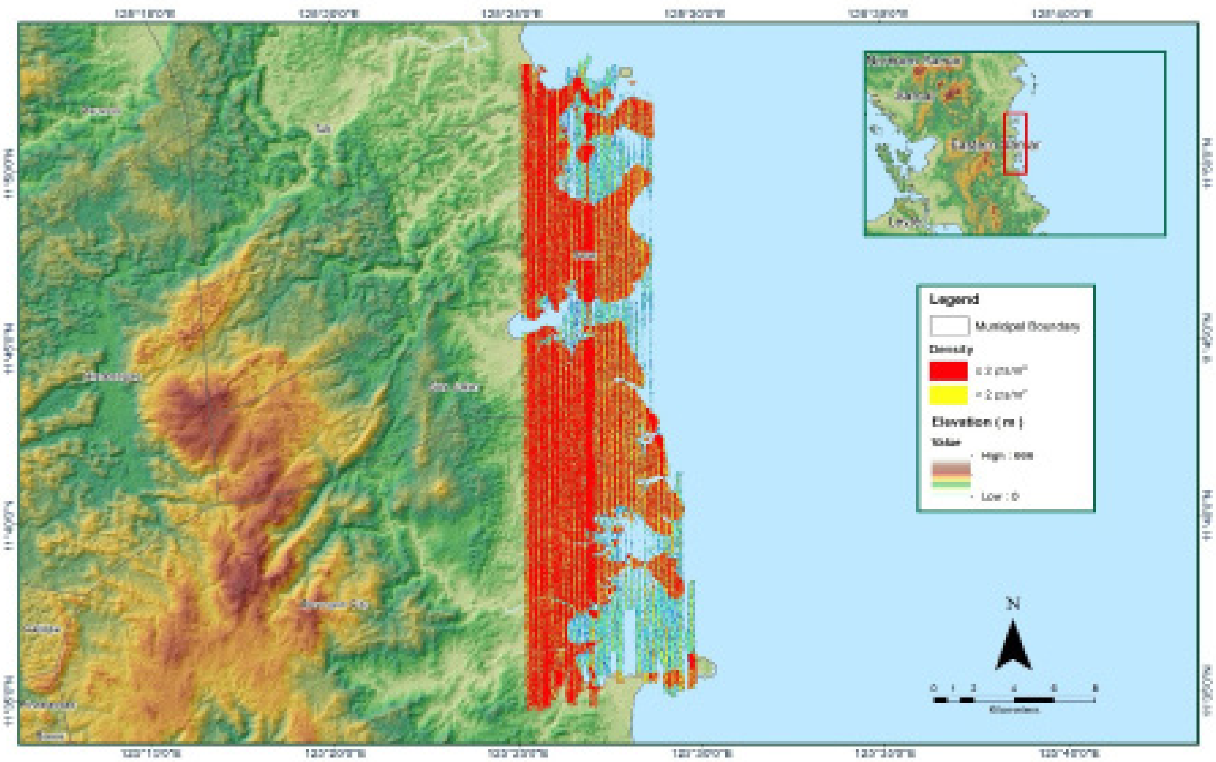


Figure 1.1.6. Density map of merged LiDAR data

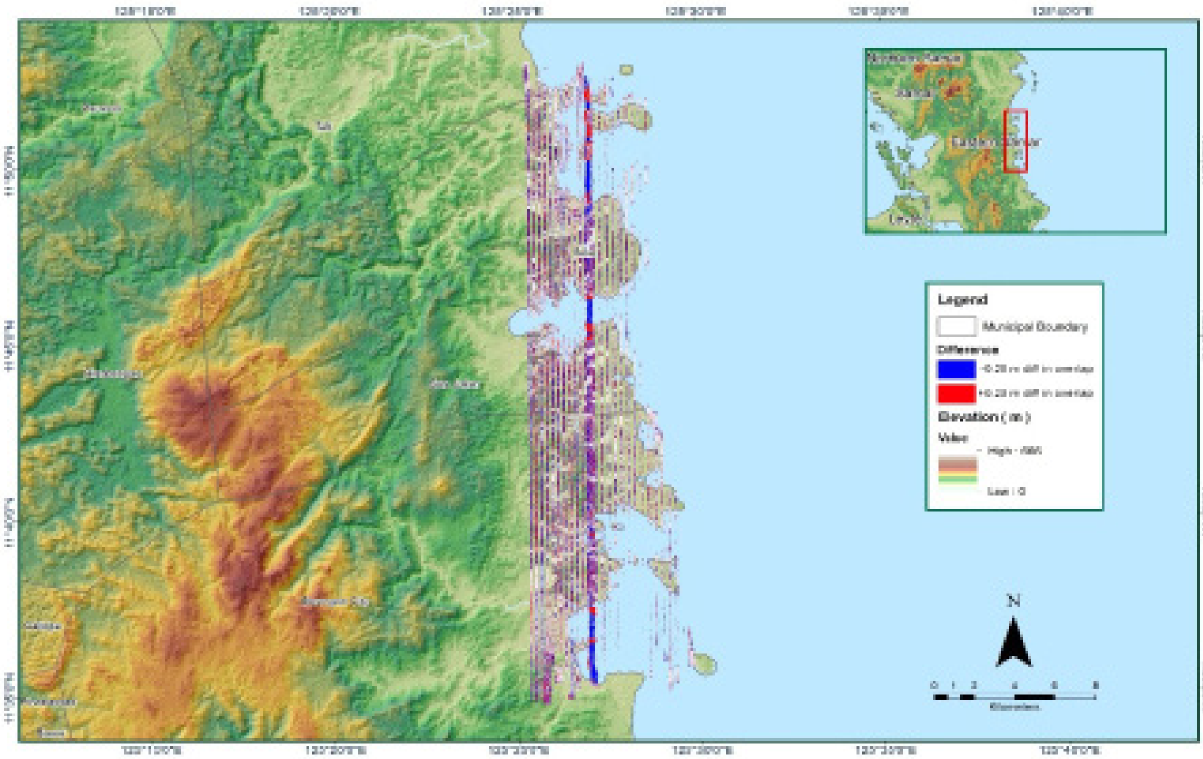


Figure 1.1.7. Elevation difference between flight lines

FLIGHT AREA	SAMAR-LEYTE
MISSION NAME	BLK33M
INCLUSIVE FLIGHTS	1554A,1556A
RANGE DATA SIZE	30.4 GB
POS	548 MB
IMAGE	197 GB
TRANSFER DATE	JUNE 19, 2014
SOLUTION STATUS	
NUMBER OF SATELLITES (>6)	YES
PDOP (<3)	YES
BASELINE LENGTH (<30KM)	YES
PROCESSING MODE (<=1)	YES
SMOOTHED PERFORMANCE METRICS (IN CM)	
RMSE FOR NORTH POSITION (<4.0 CM)	1.4
RMSE FOR EAST POSITION (<4.0 CM)	1.5
RMSE FOR DOWN POSITION (<8.0 CM)	2.9
BORESIGHT CORRECTION STDEV (<0.001DEG)	0.000680
IMU ATTITUDE CORRECTION STDEV (<0.001DEG)	0.000100
GPS POSITION STDEV (<0.01M)	0.0052
MINIMUM % OVERLAP (>25)	41.81%
AVE POINT CLOUD DENSITY PER SQ.M. (>2.0)	2.99
ELEVATION DIFFERENCE BETWEEN STRIPS (<0.20 M)	YES
NUMBER OF 1KM X 1KM BLOCKS	246
MAXIMUM HEIGHT	306.43 M
MINIMUM HEIGHT	50.90 M
CLASSIFICATION (# OF POINTS)	
GROUND	61,298,470
LOW VEGETATION	48,684,831
MEDIUM VEGETATION	90,178,182
HIGH VEGETATION	164,585,214
BUILDING	2,711,407
ORTHOPHOTO	YES
PROCESSED BY	ENGR. ANGELO CARLO BONGAT, ENGR. JOMMER MEDINA, ENGR. VELINA ANGELA BEMIDA

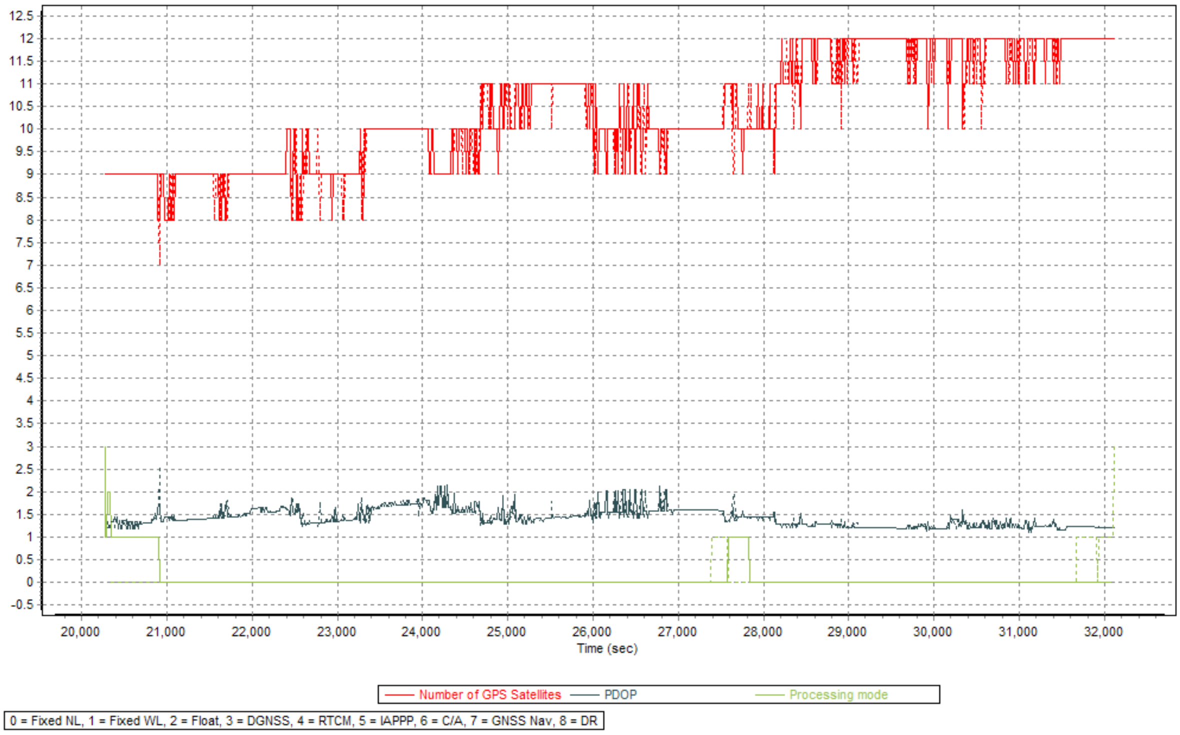


Figure 1.2.1. Solution Status

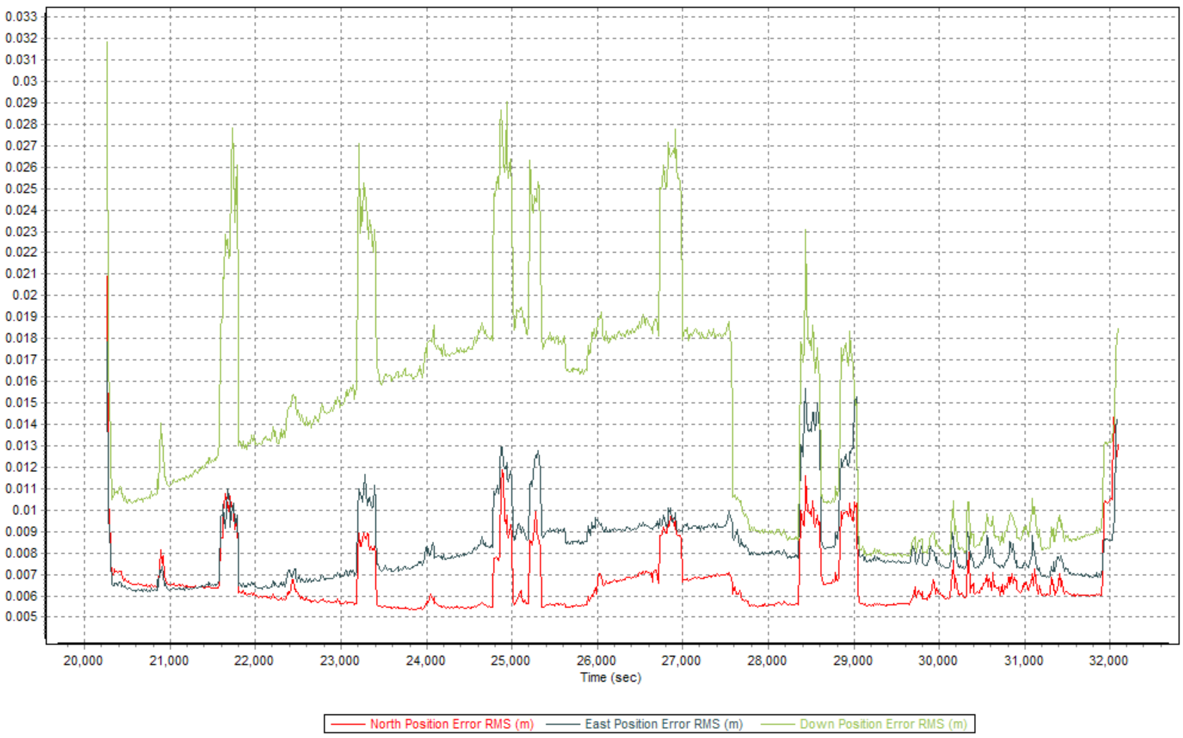


Figure 1.2.2. Smoothed Performance Metrics Parameters

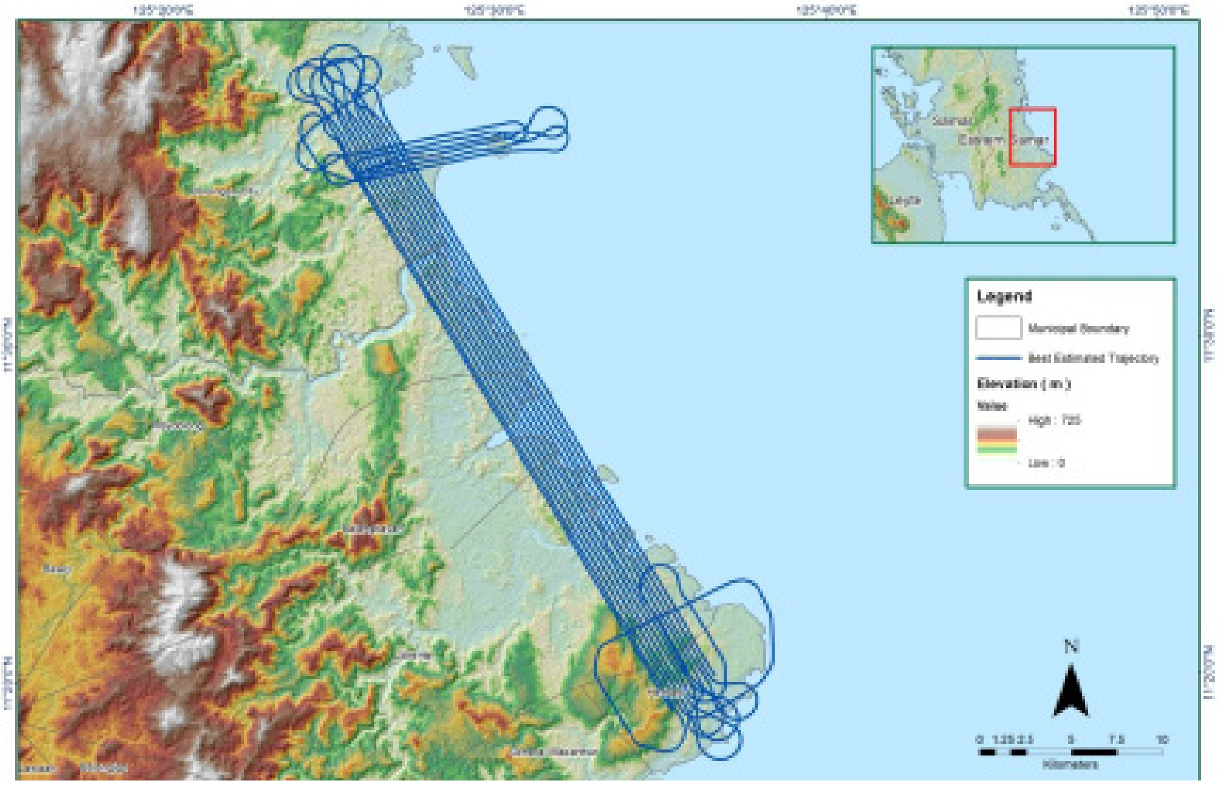


Figure 1.2.3. Best Estimated Trajectory

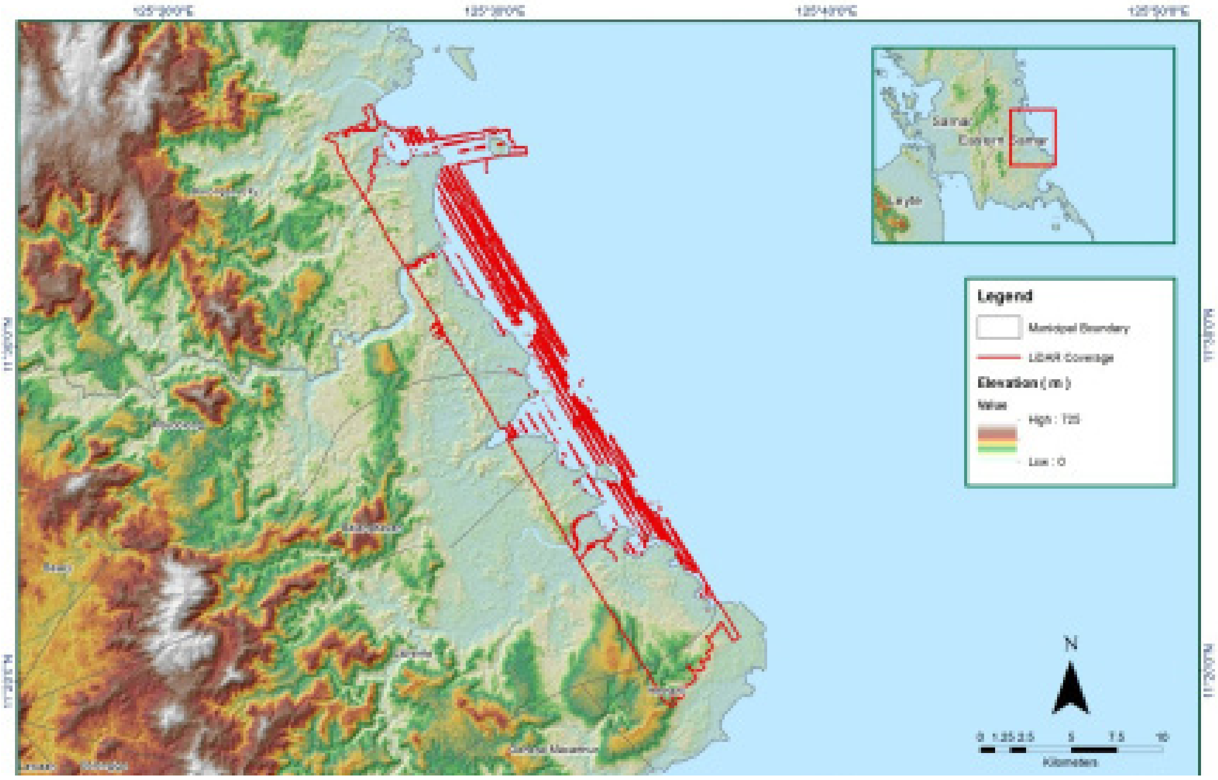


Figure 1.2.4. Coverage of LiDAR data

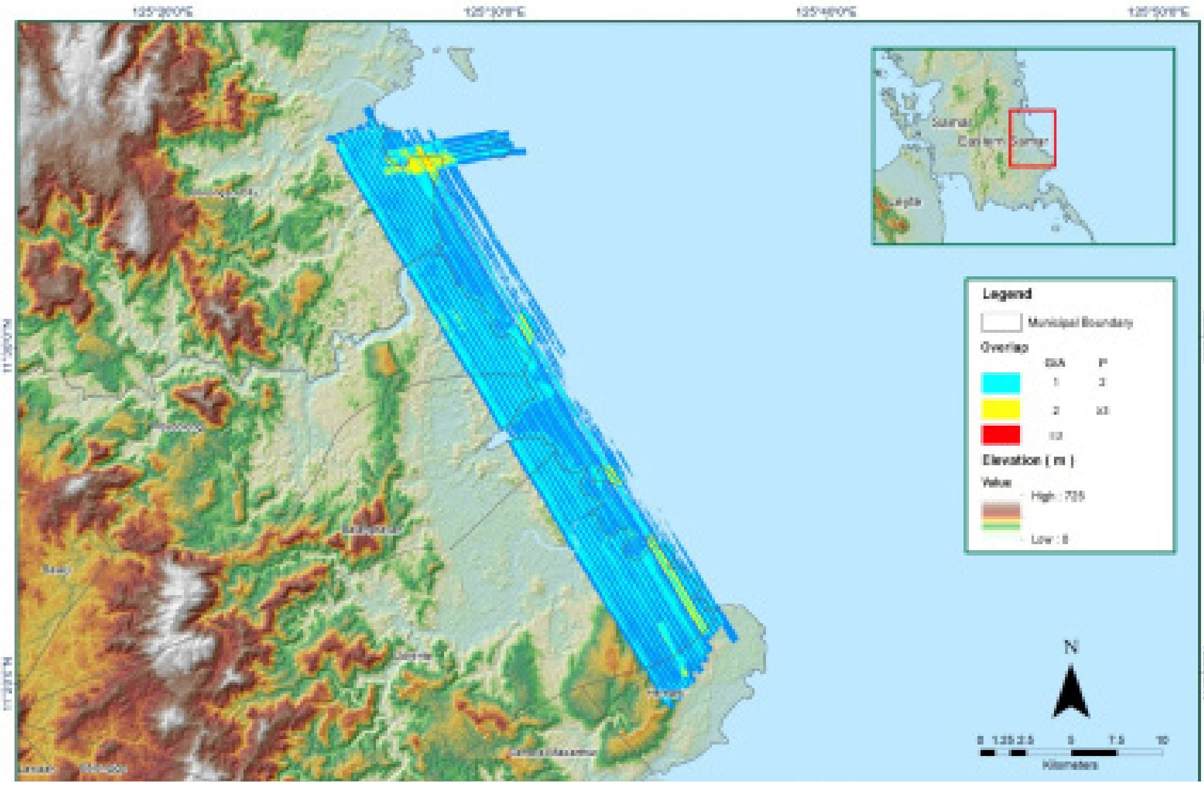


Figure 1.2.4. Best Estimated Trajectory

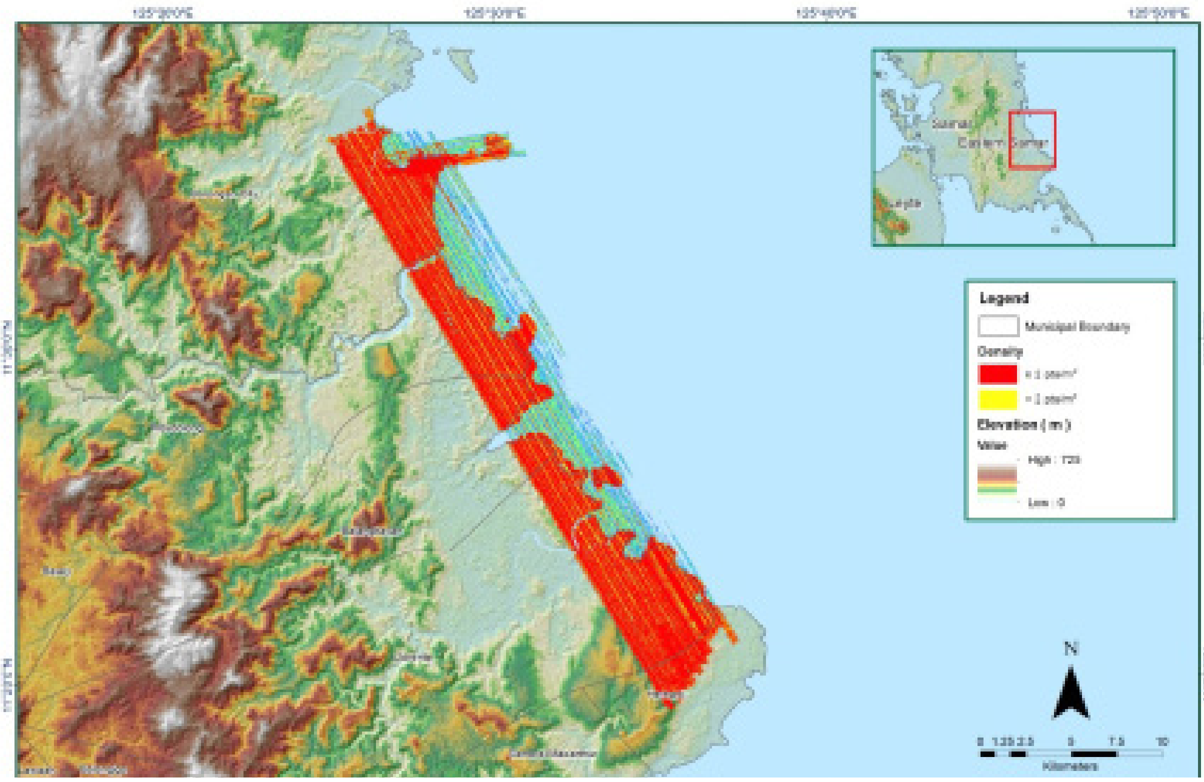


Figure 1.2.6. Coverage of LiDAR data

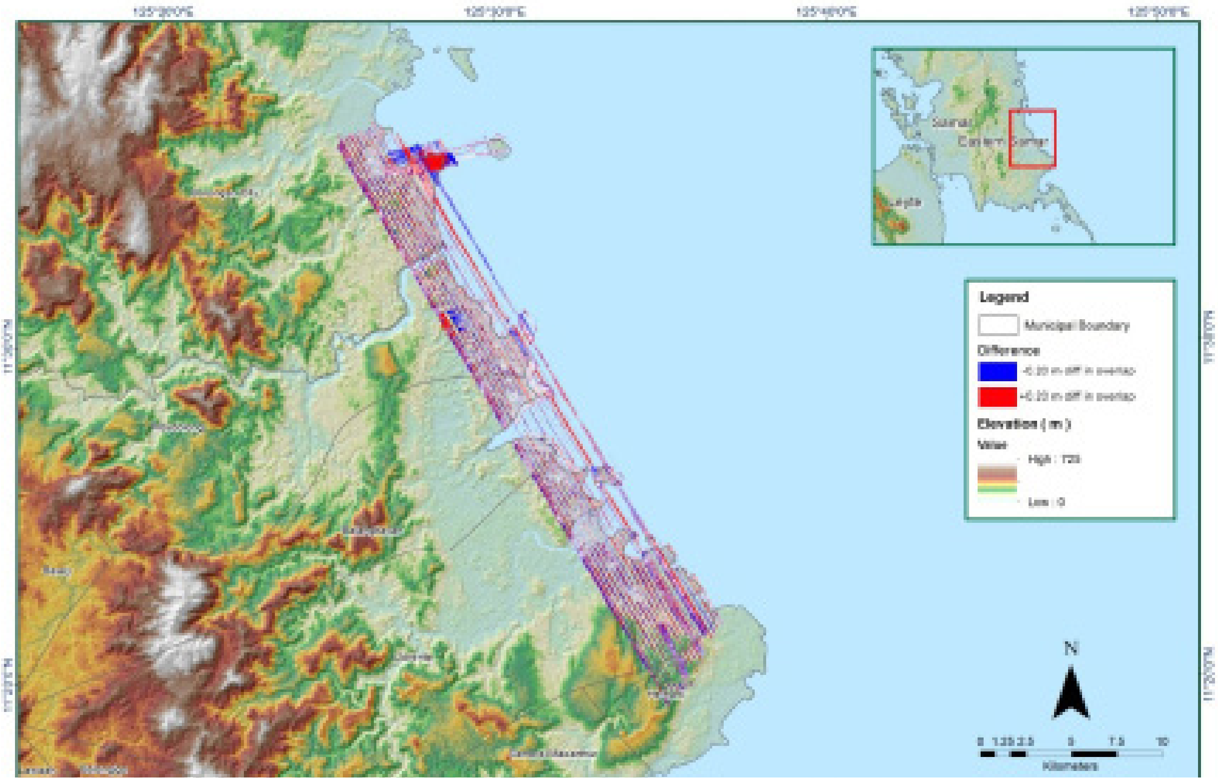


Figure 1.2.7. Coverage of LiDAR data

FLIGHT AREA	SAMAR-LEYTE
MISSION NAME	**BLK33M_add**
INCLUSIVE FLIGHTS	1554A
RANGE DATA SIZE	14.5 GB
POS	257 MB
IMAGE	99.8 GB
TRANSFER DATE	JUNE 19, 2014
SOLUTION STATUS	
NUMBER OF SATELLITES (>6)	NO
PDOP (<3)	YES
BASELINE LENGTH (<30KM)	NO
PROCESSING MODE (<=1)	YES
SMOOTHED PERFORMANCE METRICS (IN CM)	
RMSE FOR NORTH POSITION (<4.0 CM)	4.9
RMSE FOR EAST POSITION (<4.0 CM)	5.8
RMSE FOR DOWN POSITION (<8.0 CM)	8.9
BORESIGHT CORRECTION STDEV (<0.001DEG)	0.000680
IMU ATTITUDE CORRECTION STDEV (<0.001DEG)	0.000100
GPS POSITION STDEV (<0.01M)	0.0052
MINIMUM % OVERLAP (>25)	14.50%
AVE POINT CLOUD DENSITY PER SQ.M. (>2.0)	2.31
ELEVATION DIFFERENCE BETWEEN STRIPS (<0.20 M)	YES
NUMBER OF 1KM X 1KM BLOCKS	3
MAXIMUM HEIGHT	117.92 M
MINIMUM HEIGHT	50.34 M
CLASSIFICATION (# OF POINTS)	
GROUND	191,716
LOW VEGETATION	151,310
MEDIUM VEGETATION	150,191
HIGH VEGETATION	157,600
BUILDING	27,554
ORTHOPHOTO	NO
PROCESSED BY	ENGR. ANGELO CARLO BONGAT, ENGR. ANTONIO CHUA, JR.

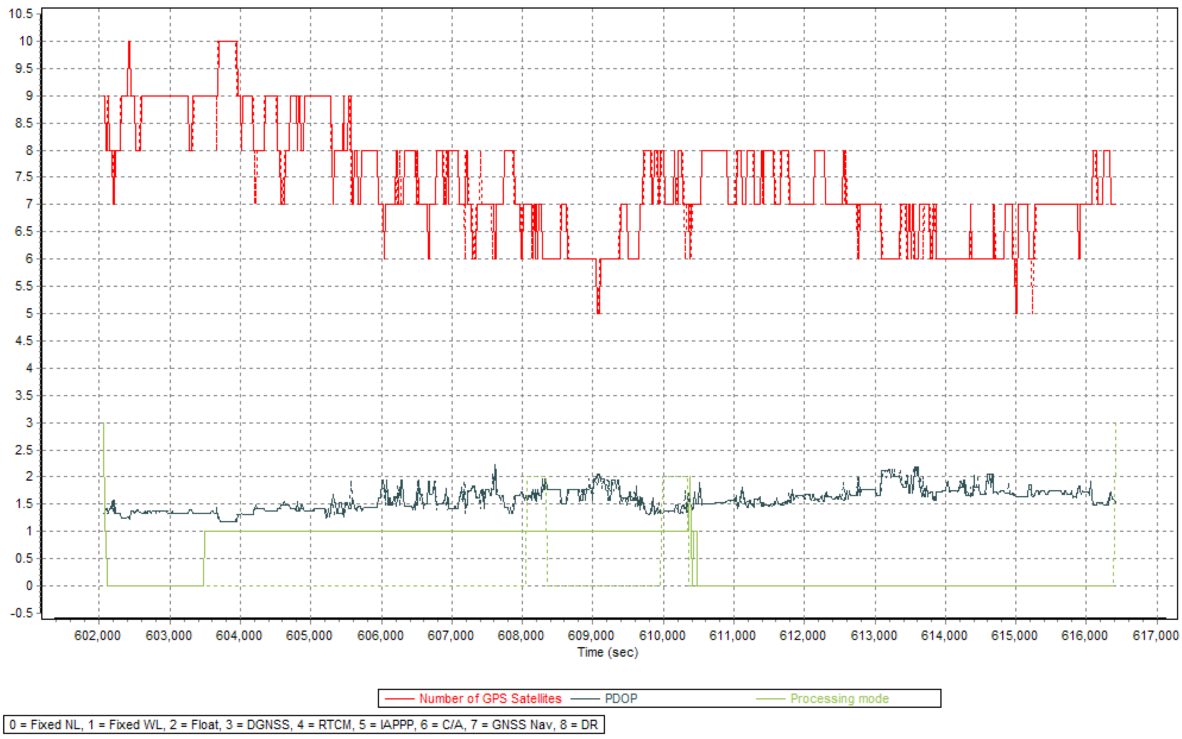


Figure 1.3.1. Solution Status

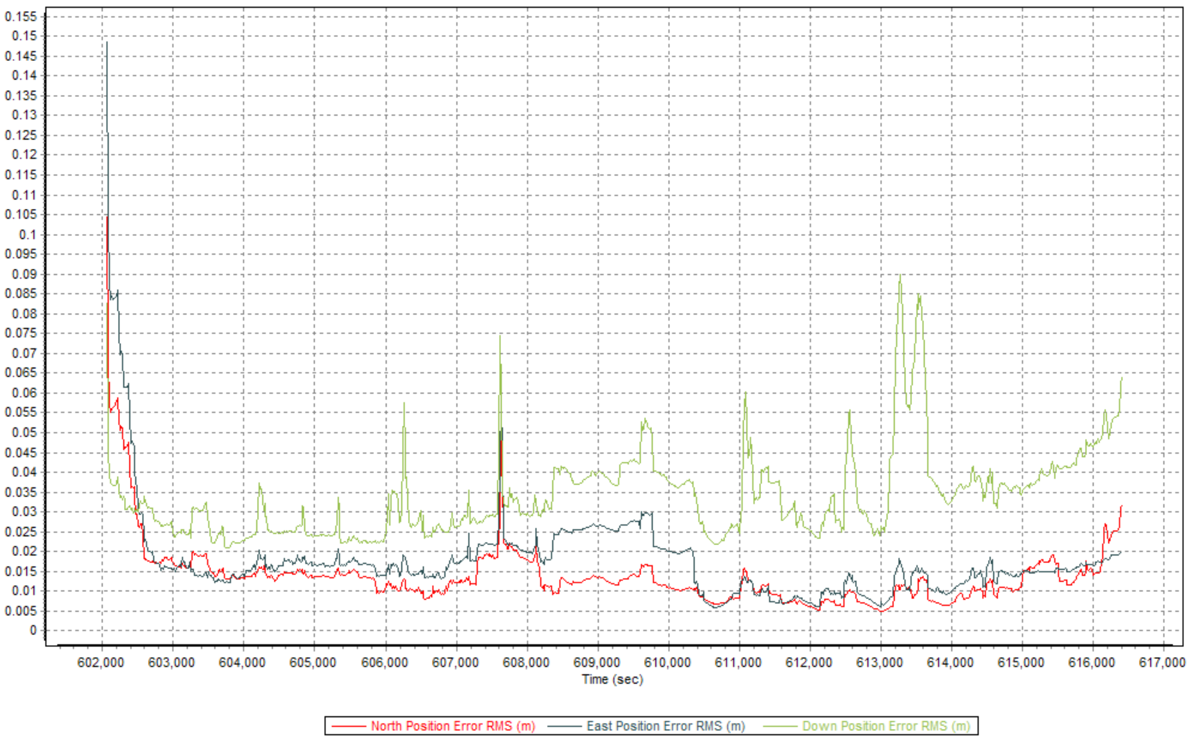


Figure 1.3.2. Smoothed Performance Metrics Parameters

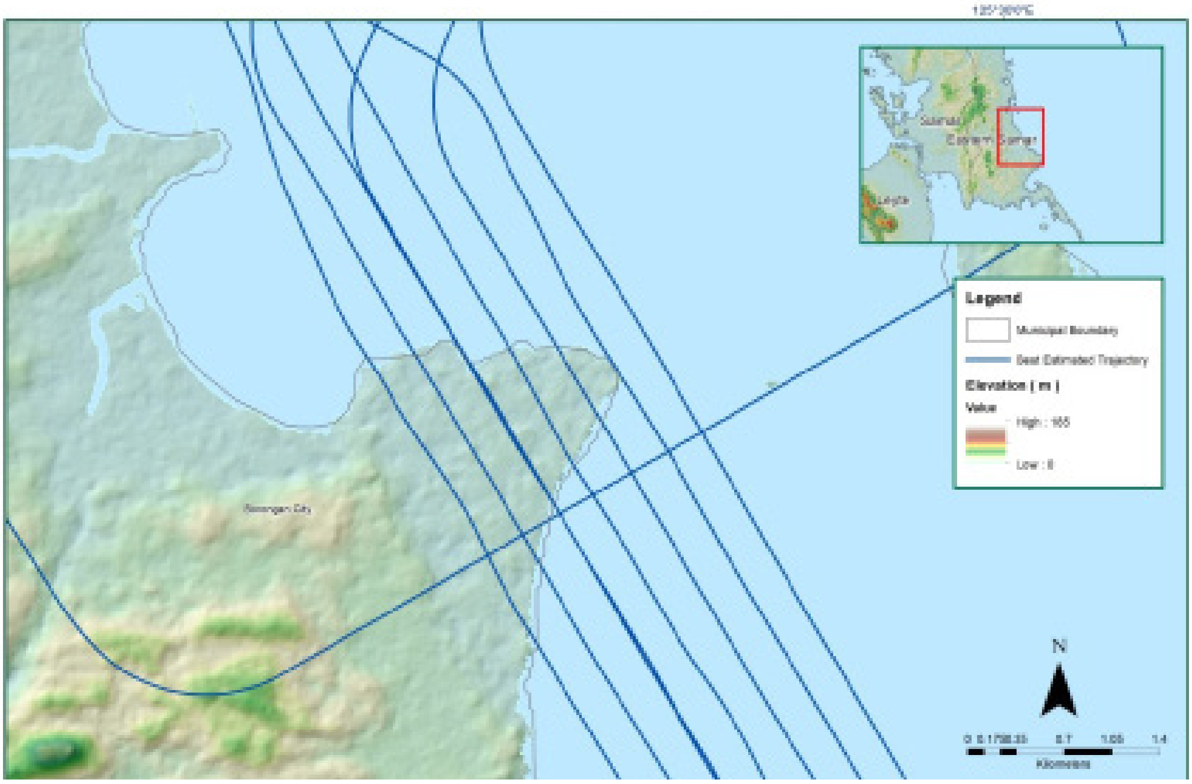


Figure 1.3.3. Best Estimated Trajectory

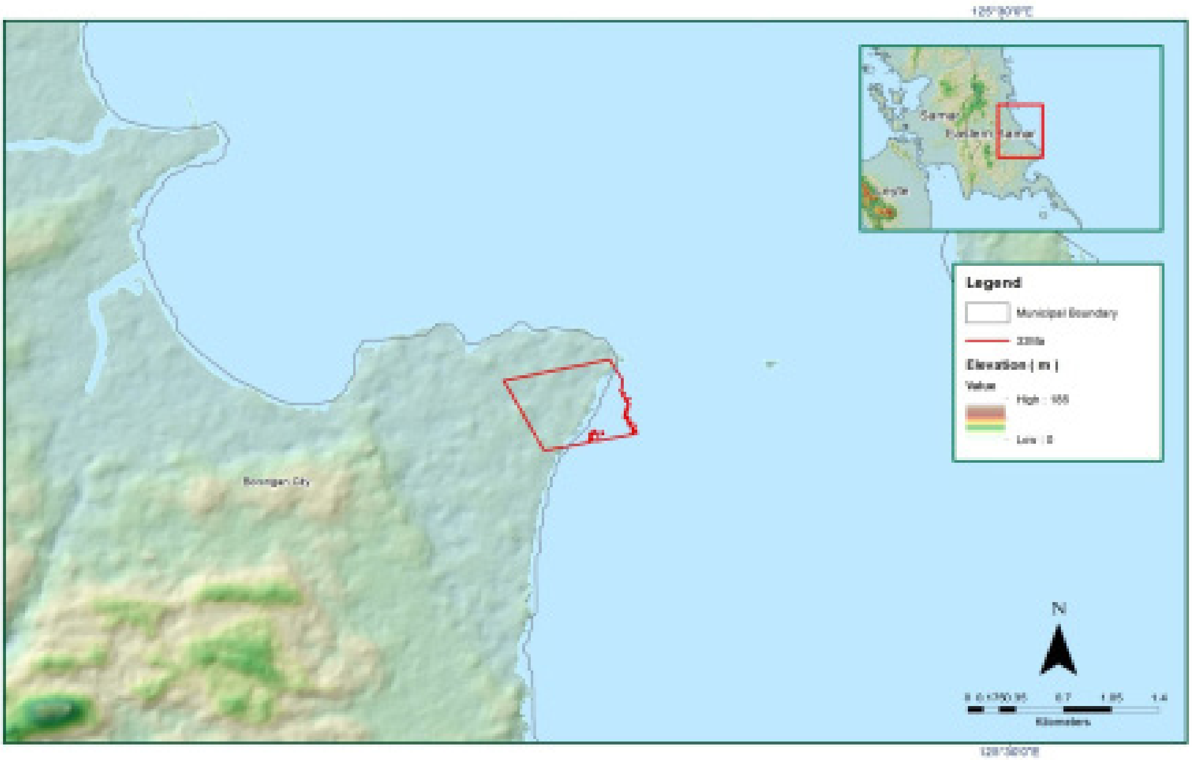


Figure 1.3.4. Coverage of LiDAR data

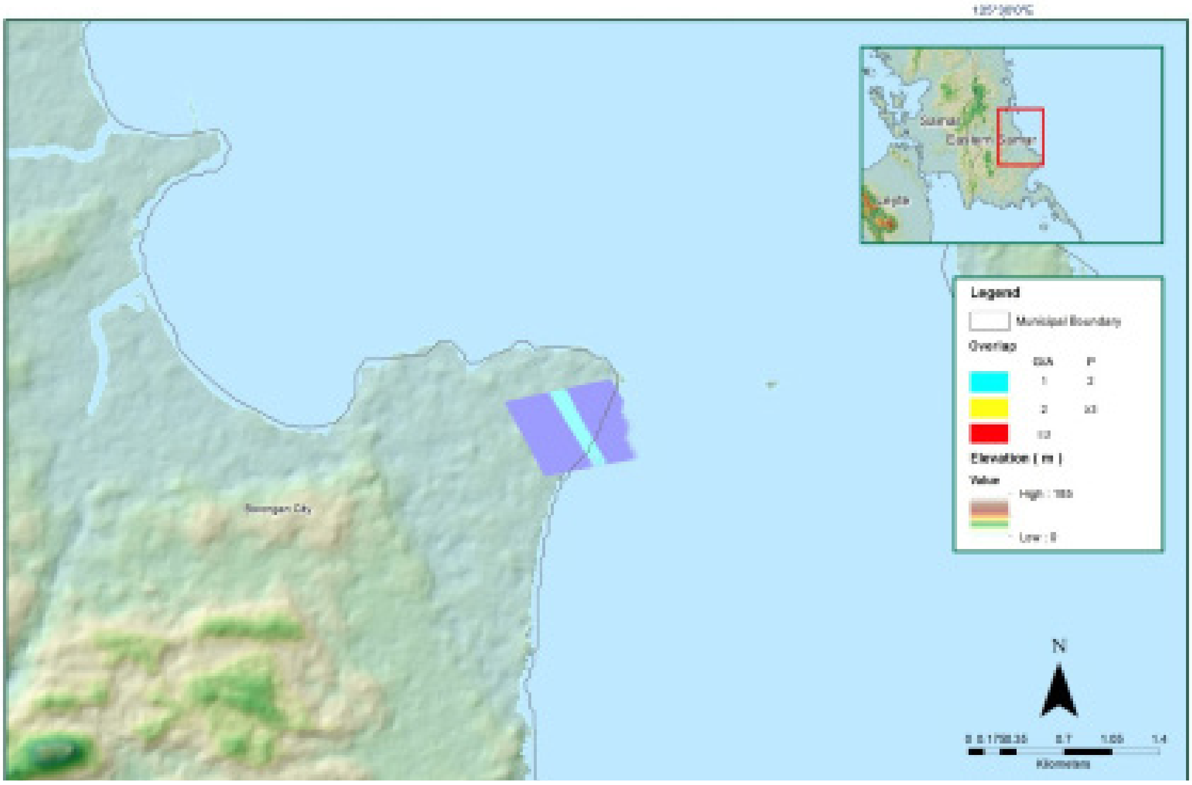


Figure 1.3.5. Best Estimated Trajectory

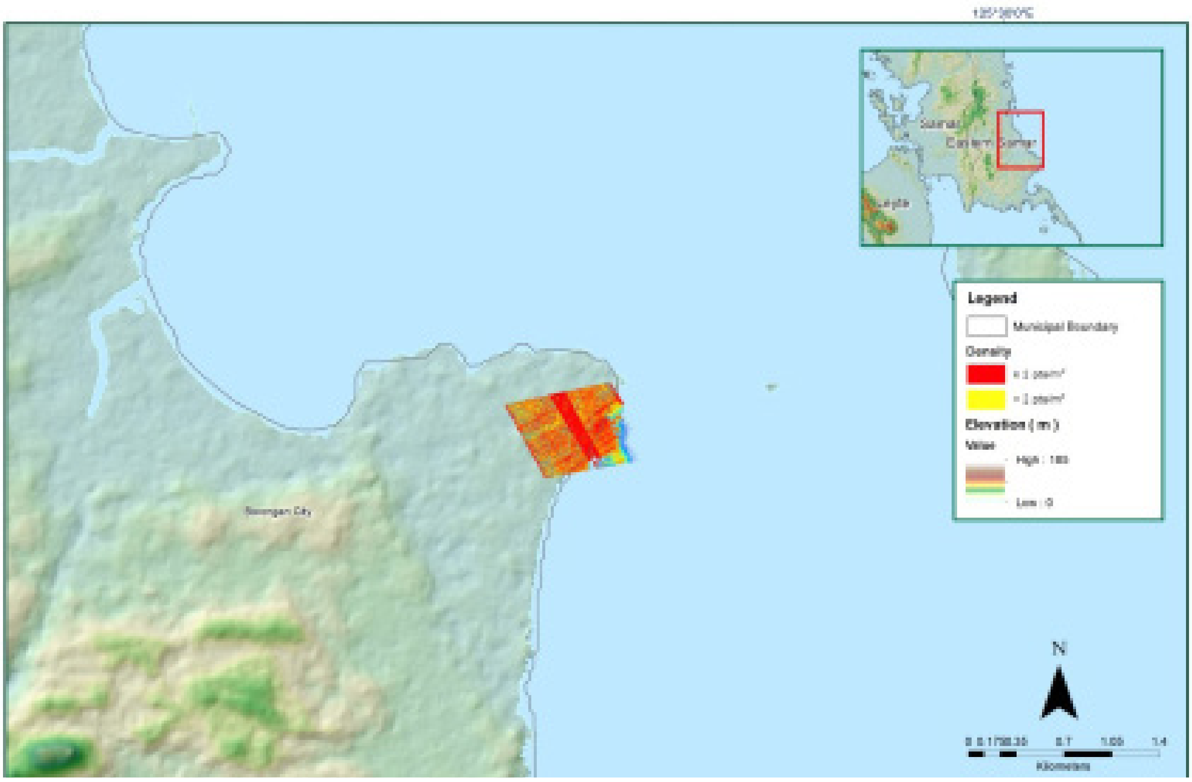


Figure 1.3.6. Coverage of LiDAR data

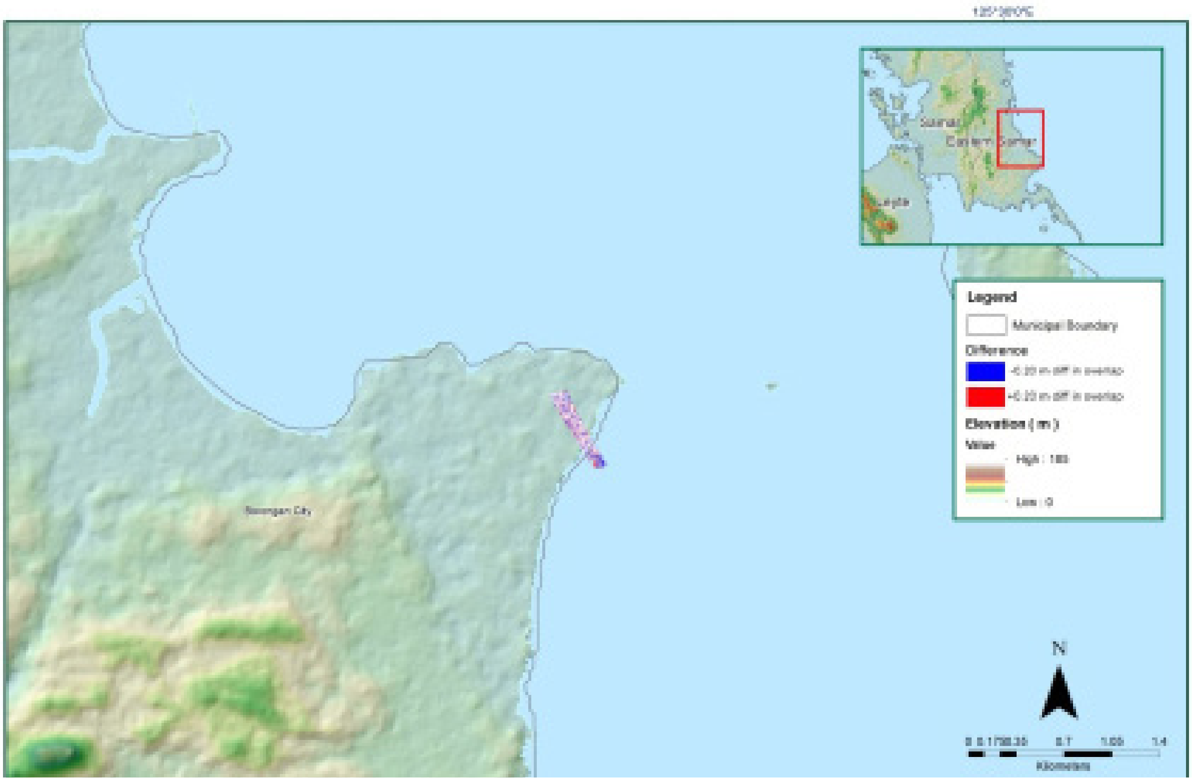


Figure 1.3.7. Coverage of LiDAR data

Annex 9. Loom 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
W420	0.001	99	0	8.95	6.38	Discharge	17.615	0.08	Ratio to Peak	0.009
W410	0.001	99	0	3.08	2.19	Discharge	6.2528	0.08	Ratio to Peak	0.009
W400	0.001	99	0	4.16	2.97	Discharge	7.5585	0.08	Ratio to Peak	0.009
W390	0.001	99	0	1.29	0.92	Discharge	1.2343	0.08	Ratio to Peak	0.009
W380	0.001	99	0	3.04	2.17	Discharge	3.3758	0.08	Ratio to Peak	0.009
W370	0.001	99	0	3.42	2.44	Discharge	4.2985	0.08	Ratio to Peak	0.009
W360	0.001	99	0	2.35	1.68	Discharge	3.2111	0.08	Ratio to Peak	0.009
W350	0.001	99	0	3.86	2.75	Discharge	7.8201	0.08	Ratio to Peak	0.009
W340	0.001	99	0	2.77	1.97	Discharge	2.611	0.08	Ratio to Peak	0.009
W330	0.001	99	0	5.96	4.25	Discharge	4.1271	0.08	Ratio to Peak	0.009
W320	0.001	99	0	6.51	4.64	Discharge	7.255	0.08	Ratio to Peak	0.009
W310	0.001	99	0	3.97	2.83	Discharge	3.5314	0.08	Ratio to Peak	0.009
W300	0.001	99	0	3	2.14	Discharge	2.6833	0.08	Ratio to Peak	0.009
W290	0.001	99	0	3.29	2.34	Discharge	4.2534	0.08	Ratio to Peak	0.009
W280	0.001	99	0	2.39	1.7	Discharge	3.5225	0.08	Ratio to Peak	0.009
W270	0.001	99	0	1.42	1.01	Discharge	0.59393	0.08	Ratio to Peak	0.009
W260	0.001	99	0	3.15	2.24	Discharge	2.9379	0.08	Ratio to Peak	0.009
W250	0.001	99	0	2.97	2.12	Discharge	3.2961	0.08	Ratio to Peak	0.009
W240	0.001	99	0	1.26	0.9	Discharge	0.48112	0.08	Ratio to Peak	0.009
W230	0.001	99	0	3.62	2.58	Discharge	5.0853	0.08	Ratio to Peak	0.009
W220	0.001	99	0	6.37	4.54	Discharge	5.3814	0.08	Ratio to Peak	0.009

Annex 10. Dipolog Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R10	Automatic Fixed Interval	706.84	0.007716	0.04	Trapezoid	30.65	1
R30	Automatic Fixed Interval	3334.9	0.001304	0.04	Trapezoid	22.77	1
R70	Automatic Fixed Interval	694.97	0.10497	0.04	Trapezoid	8.038	1
R80	Automatic Fixed Interval	810.83	0.007291	0.04	Trapezoid	9.678	1
R90	Automatic Fixed Interval	1984.8	0.003848	0.04	Trapezoid	21.942	1
R120	Automatic Fixed Interval	1629.5	0.005133	0.04	Trapezoid	7.91	1
R140	Automatic Fixed Interval	1609.1	0.000625	0.04	Trapezoid	9.126	1
R150	Automatic Fixed Interval	3402.9	0.028593	0.04	Trapezoid	8.246	1
R160	Automatic Fixed Interval	903.55	0.013032	0.04	Trapezoid	10.54	1
R190	Automatic Fixed Interval	2028.7	0.001055	0.04	Trapezoid	8.99	1

Annex 11. Loom Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Latitude	Longitude					
164	11.61126045	125.423434	0.03	0.50	-0.47	Heavy Rain2/ January 8-10, 2017	2-Year
167	11.60772588	125.4269718	0.05	0.50	-0.45	Heavy Rain2/ January 8-10, 2017	2-Year
270	11.5945077	125.4035987	1.57	0.50	1.07	Heavy Rain2/ January 8-10, 2017	2-Year
1	11.60500067	125.442314	0.03	0.47	-0.44	Ruby/December 3-10, 2014	5-Year
2	11.60500067	125.442314	0.03	0.28	-0.25	Yolanda/November 7-9, 2013	5-Year
3	11.60449525	125.4411585	0.03	0.50	-0.47	Ruby/December 3-10, 2014	5-Year
4	11.60449525	125.4411585	0.03	0.30	-0.27	Yolanda/November 7-9, 2013	5-Year
5	11.60375043	125.4405604	0.05	0.50	-0.45	Ruby/December 3-10, 2014	5-Year
6	11.60375043	125.4405604	0.05	0.30	-0.25	Yolanda/November 7-9, 2013	5-Year
7	11.60212711	125.4411821	0.03	0.50	-0.47	Ruby/December 3-10, 2014	5-Year
8	11.60212711	125.4411821	0.03	0.60	-0.57	Yolanda/November 7-9, 2013	5-Year
9	11.60433658	125.4385719	0.06	1.35	-1.29	Ruby/December 3-10, 2014	5-Year
10	11.60433658	125.4385719	0.06	0.50	-0.44	Yolanda/November 7-9, 2013	5-Year
11	11.60473505	125.4353785	0.52	1.35	-0.83	Ruby/December 3-10, 2014	5-Year
12	11.60473505	125.4353785	0.52	0.50	0.02	Yolanda/November 7-9, 2013	5-Year
13	11.60674403	125.4413596	0.04	0.40	-0.36	Ruby/December 3-10, 2014	5-Year
14	11.60674403	125.4413596	0.04	0.40	-0.36	Yolanda/November 7-9, 2013	5-Year
15	11.60634287	125.4397919	0.03	0.40	-0.37	Ruby/December 3-10, 2014	5-Year
16	11.60634287	125.4397919	0.03	0.40	-0.37	Yolanda/November 7-9, 2013	5-Year
17	11.60545036	125.4316642	0.06	1.35	-1.29	Ruby/December 3-10, 2014	5-Year
19	11.60317015	125.4339365	0.51	1.35	-0.84	Ruby/December 3-10, 2014	5-Year
20	11.60835017	125.4389507	0.21	0.50	-0.29	Ruby/December 3-10, 2014	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Latitude	Longitude					
21	11.60678283	125.4365549	0.03	0.50	-0.47	Ruby/December 3-10, 2014	5-Year
22	11.60877245	125.4372117	0.04	0.50	-0.46	Ruby/December 3-10, 2014	5-Year
23	11.60896112	125.4334063	0.14	0.50	-0.36	Ruby/December 3-10, 2014	5-Year
24	11.61011766	125.434122	0.03	1.00	-0.97	Ruby/December 3-10, 2014	5-Year
25	11.60748725	125.4352852	0.03	1.35	-1.32	Ruby/December 3-10, 2014	5-Year
26	11.60748725	125.4352852	0.03	0.50	-0.47	Yolanda/November 7-9, 2013	5-Year
28	11.60878376	125.4319613	0.03	0.50	-0.47	Ruby/December 3-10, 2014	5-Year
29	11.6078558	125.4302047	0.36	0.10	0.26	Ruby/December 3-10, 2014	5-Year
31	11.61085359	125.4366889	0.03	0.50	-0.47	Ruby/December 3-10, 2014	5-Year
32	11.61085359	125.4366889	0.03	0.10	-0.07	Yolanda/November 7-9, 2013	5-Year
33	11.6134819	125.4364616	0.04	0.50	-0.46	Ruby/December 3-10, 2014	5-Year
36	11.61528384	125.430355	0.06	1.35	-1.29	Ruby/December 3-10, 2014	5-Year
37	11.61528384	125.430355	0.06	1.35	-1.29	Yolanda/November 7-9, 2013	5-Year
42	11.61358257	125.4298163	0.03	1.35	-1.32	Ruby/December 3-10, 2014	5-Year
43	11.61358257	125.4298163	0.03	1.35	-1.32	Yolanda/November 7-9, 2013	5-Year
47	11.60858251	125.4260621	0.03	1.00	-0.97	Ruby/December 3-10, 2014	5-Year
48	11.60858251	125.4260621	0.03	1.60	-1.57	Yolanda/November 7-9, 2013	5-Year
49	11.60554692	125.4287868	0.48	2.00	-1.52	Ruby/December 3-10, 2014	5-Year
50	11.60554692	125.4287868	0.48	0.50	-0.02	Yolanda/November 7-9, 2013	5-Year
51	11.605733	125.4299049	3.18	2.00	1.18	Ruby/December 3-10, 2014	5-Year
52	11.605733	125.4299049	3.18	0.50	2.68	Yolanda/November 7-9, 2013	5-Year
53	11.60473421	125.4294751	0.05	1.35	-1.30	Ruby/December 3-10, 2014	5-Year
57	11.61164174	125.4223434	0.03	1.00	-0.97	Ruby/December 3-10, 2014	5-Year
59	11.61079525	125.4181384	0.03	1.00	-0.97	Ruby/December 3-10, 2014	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Latitude	Longitude					
60	11.60848738	125.4151341	0.03	0.50	-0.47	Yolanda/November 7-9, 2013	5-Year
61	11.60848738	125.4151341	0.03	0.60	-0.57	Ruby/December 3-10, 2014	5-Year
63	11.61014356	125.4169639	0.06	1.30	-1.24	Ruby/December 3-10, 2014	5-Year
64	11.60884244	125.4128176	0.03	1.50	-1.47	Ruby/December 3-10, 2014	5-Year
65	11.60744475	125.4134772	0.03	1.00	-0.97	Yolanda/November 7-9, 2013	5-Year
66	11.60744475	125.4134772	0.03	1.00	-0.97	Ruby/December 3-10, 2014	5-Year
68	11.60568489	125.4084074	2.48	1.50	0.98	Ruby/December 3-10, 2014	5-Year
69	11.60568489	125.4084074	2.48	2.00	0.48	Yolanda/November 7-9, 2013	5-Year
71	11.60617749	125.4074598	0.05	1.30	-1.25	Ruby/December 3-10, 2014	5-Year
72	11.60617749	125.4074598	0.05	2.00	-1.95	Yolanda/November 7-9, 2013	5-Year
74	11.60467344	125.4079351	0.75	0.90	-0.15	Ruby/December 3-10, 2014	5-Year
75	11.60467344	125.4079351	0.75	2.00	-1.25	Yolanda/November 7-9, 2013	5-Year
77	11.59923124	125.4037118	1.01	2.70	-1.69	Ruby/December 3-10, 2014	5-Year
78	11.59923124	125.4037118	1.01	3.00	-1.99	Yolanda/November 7-9, 2013	5-Year
80	11.60036531	125.4034499	3.50	0.90	2.60	Ruby/December 3-10, 2014	5-Year
81	11.60036531	125.4034499	3.50	0.50	3.00	Yolanda/November 7-9, 2013	5-Year
83	11.59647443	125.4057281	2.99	1.70	1.29	Ruby/December 3-10, 2014	5-Year
85	11.59749426	125.4055566	0.03	1.50	-1.47	Yolanda/November 7-9, 2013	5-Year
86	11.59749426	125.4055566	0.03	1.50	-1.47	Ruby/December 3-10, 2014	5-Year
87	11.5955163	125.4051457	3.03	3.01	0.02	Ruby/December 3-10, 2014	5-Year
88	11.5955163	125.4051457	3.03	1.50	1.53	Yolanda/November 7-9, 2013	5-Year
90	11.59474433	125.4034809	0.22	0.90	-0.68	Ruby/December 3-10, 2014	5-Year
91	11.59474433	125.4034809	0.22	2.00	-1.78	Yolanda/November 7-9, 2013	5-Year
93	11.59597462	125.4041419	0.04	2.13	-2.09	Ruby/December 3-10, 2014	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Latitude	Longitude					
94	11.59506686	125.4043134	1.13	4.00	-2.87	Ruby/December 3-10, 2014	5-Year
95	11.59506686	125.4043134	1.13	1.00	0.13	Yolanda/November 7-9, 2013	5-Year
100	11.61222939	125.4230423	0.08	1.00	-0.92	Ruby/December 3-10, 2014	5-Year
116	11.61127285	125.4332874	0.36	0.50	-0.14	Ruby/December 3-10, 2014	5-Year
117	11.61232763	125.4375064	0.05	0.50	-0.45	Ruby/December 3-10, 2014	5-Year
118	11.61232763	125.4375064	0.05	0.10	-0.05	Yolanda/November 7-9, 2013	5-Year
119	11.61090204	125.4355147	0.08	0.15	-0.07	Ruby/December 3-10, 2014	5-Year
120	11.61090204	125.4355147	0.08	0.10	-0.02	Yolanda/November 7-9, 2013	5-Year
122	11.60677848	125.4388244	0.39	2.00	-1.61	Ruby/December 3-10, 2014	5-Year
123	11.60677848	125.4388244	0.39	1.00	-0.61	Yolanda/November 7-9, 2013	5-Year
124	11.60739253	125.4385576	0.03	0.50	-0.47	Ruby/December 3-10, 2014	5-Year
125	11.60727888	125.4412923	0.08	1.00	-0.92	Ruby/December 3-10, 2014	5-Year
126	11.60727888	125.4412923	0.08	0.70	-0.62	Yolanda/November 7-9, 2013	5-Year
127	11.60720017	125.4370862	0.03	0.50	-0.47	Ruby/December 3-10, 2014	5-Year
128	11.60797826	125.4386527	0.04	0.50	-0.46	Ruby/December 3-10, 2014	5-Year
130	11.6081858	125.437402	0.03	0.50	-0.47	Ruby/December 3-10, 2014	5-Year
131	11.6074668	125.4344999	0.05	1.35	-1.30	Ruby/December 3-10, 2014	5-Year
132	11.6074668	125.4344999	0.05	0.50	-0.45	Yolanda/November 7-9, 2013	5-Year
133	11.60708098	125.4332931	0.03	1.35	-1.32	Ruby/December 3-10, 2014	5-Year
134	11.60646047	125.4337095	0.03	1.35	-1.32	Ruby/December 3-10, 2014	5-Year
136	11.60627523	125.432472	0.36	1.40	-1.04	Ruby/December 3-10, 2014	5-Year
137	11.60774625	125.4309775	0.17	0.10	0.07	Ruby/December 3-10, 2014	5-Year
138	11.60774625	125.4309775	0.17	0.10	0.07	Yolanda/November 7-9, 2013	5-Year
139	11.60787558	125.4352179	0.03	1.35	-1.32	Ruby/December 3-10, 2014	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Latitude	Longitude					
140	11.60787558	125.4352179	0.03	0.50	-0.47	Yolanda/November 7-9, 2013	5-Year
141	11.61019444	125.4369584	0.03	0.50	-0.47	Ruby/December 3-10, 2014	5-Year
142	11.61019444	125.4369584	0.03	0.10	-0.07	Yolanda/November 7-9, 2013	5-Year
143	11.6055724	125.4332864	0.43	2.00	-1.57	Ruby/December 3-10, 2014	5-Year
144	11.6055724	125.4332864	0.43	0.50	-0.07	Yolanda/November 7-9, 2013	5-Year
145	11.60564683	125.433638	0.03	2.00	-1.97	Ruby/December 3-10, 2014	5-Year
146	11.60564683	125.433638	0.03	0.50	-0.47	Yolanda/November 7-9, 2013	5-Year
147	11.60548783	125.4311489	2.14	2.00	0.14	Ruby/December 3-10, 2014	5-Year
148	11.60548783	125.4311489	2.14	0.50	1.64	Yolanda/November 7-9, 2013	5-Year
149	11.60553267	125.4294134	2.66	2.00	0.66	Ruby/December 3-10, 2014	5-Year
150	11.60553267	125.4294134	2.66	0.50	2.16	Yolanda/November 7-9, 2013	5-Year
151	11.60607314	125.431011	2.11	2.00	0.11	Ruby/December 3-10, 2014	5-Year
152	11.60607314	125.431011	2.11	0.50	1.61	Yolanda/November 7-9, 2013	5-Year
153	11.60651067	125.4305186	0.03	2.00	-1.97	Ruby/December 3-10, 2014	5-Year
154	11.60651067	125.4305186	0.03	0.50	-0.47	Yolanda/November 7-9, 2013	5-Year
155	11.60654521	125.4273202	1.17	1.00	0.17	Ruby/December 3-10, 2014	5-Year
156	11.60654521	125.4273202	1.17	1.60	-0.43	Yolanda/November 7-9, 2013	5-Year
157	11.60813475	125.4276094	0.18	1.00	-0.82	Ruby/December 3-10, 2014	5-Year
158	11.60813475	125.4276094	0.18	1.60	-1.42	Yolanda/November 7-9, 2013	5-Year
159	11.61540429	125.4274746	0.03	0.50	-0.47	Ruby/December 3-10, 2014	5-Year
160	11.61419939	125.4268168	0.58	0.50	0.08	Ruby/December 3-10, 2014	5-Year
163	11.61126045	125.423434	0.03	0.40	-0.37	Ruby/December 3-10, 2014	5-Year
166	11.60772588	125.4269718	0.05	0.40	-0.35	Ruby/December 3-10, 2014	5-Year
169	11.61192421	125.4302406	0.03	1.35	-1.32	Ruby/December 3-10, 2014	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Latitude	Longitude					
170	11.6091617	125.4248715	0.03	1.00	-0.97	Ruby/December 3-10, 2014	5-Year
171	11.6091617	125.4248715	0.03	1.60	-1.57	Yolanda/November 7-9, 2013	5-Year
172	11.60499246	125.4343331	0.03	1.35	-1.32	Ruby/December 3-10, 2014	5-Year
173	11.60499246	125.4343331	0.03	0.50	-0.47	Yolanda/November 7-9, 2013	5-Year
174	11.60446943	125.4334241	0.04	1.35	-1.31	Ruby/December 3-10, 2014	5-Year
175	11.60446943	125.4334241	0.04	0.50	-0.46	Yolanda/November 7-9, 2013	5-Year
176	11.60451335	125.4371992	0.03	1.35	-1.32	Ruby/December 3-10, 2014	5-Year
177	11.60451335	125.4371992	0.03	0.50	-0.47	Yolanda/November 7-9, 2013	5-Year
178	11.60306378	125.4349456	0.07	1.35	-1.28	Ruby/December 3-10, 2014	5-Year
179	11.6040728	125.4316644	0.04	1.35	-1.31	Ruby/December 3-10, 2014	5-Year
180	11.60533704	125.4380645	0.03	1.35	-1.32	Ruby/December 3-10, 2014	5-Year
181	11.60533704	125.4380645	0.03	0.50	-0.47	Yolanda/November 7-9, 2013	5-Year
182	11.60531265	125.4388594	0.12	1.35	-1.23	Ruby/December 3-10, 2014	5-Year
183	11.60531265	125.4388594	0.12	0.50	-0.38	Yolanda/November 7-9, 2013	5-Year
184	11.60253983	125.4329758	0.03	0.10	-0.07	Ruby/December 3-10, 2014	5-Year
185	11.60499598	125.4335049	0.40	1.35	-0.95	Ruby/December 3-10, 2014	5-Year
186	11.60262365	125.4309411	0.03	1.35	-1.32	Ruby/December 3-10, 2014	5-Year
187	11.60468409	125.4346056	0.03	1.35	-1.32	Ruby/December 3-10, 2014	5-Year
188	11.60468409	125.4346056	0.03	0.50	-0.47	Yolanda/November 7-9, 2013	5-Year
189	11.60323377	125.4370167	0.09	1.35	-1.26	Ruby/December 3-10, 2014	5-Year
190	11.60165428	125.4330832	0.03	0.10	-0.07	Ruby/December 3-10, 2014	5-Year
191	11.60408554	125.4412569	0.18	0.50	-0.32	Ruby/December 3-10, 2014	5-Year
192	11.60408554	125.4412569	0.18	0.30	-0.12	Yolanda/November 7-9, 2013	5-Year
193	11.60299438	125.4407888	0.68	0.20	0.48	Ruby/December 3-10, 2014	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Latitude	Longitude					
194	11.60299438	125.4407888	0.68	0.35	0.33	Yolanda/November 7-9, 2013	5-Year
195	11.6029321	125.4416838	0.03	0.50	-0.47	Ruby/December 3-10, 2014	5-Year
196	11.6029321	125.4416838	0.03	0.60	-0.57	Yolanda/November 7-9, 2013	5-Year
197	11.59994722	125.4408823	0.64	0.59	0.05	Ruby/December 3-10, 2014	5-Year
198	11.59994722	125.4408823	0.64	0.70	-0.06	Yolanda/November 7-9, 2013	5-Year
199	11.60150961	125.4402454	0.18	0.20	-0.02	Ruby/December 3-10, 2014	5-Year
200	11.60150961	125.4402454	0.18	0.30	-0.12	Yolanda/November 7-9, 2013	5-Year
201	11.59767858	125.4408768	0.04	0.60	-0.56	Ruby/December 3-10, 2014	5-Year
202	11.59767858	125.4408768	0.04	0.80	-0.76	Yolanda/November 7-9, 2013	5-Year
203	11.59838149	125.4397086	0.06	0.60	-0.54	Ruby/December 3-10, 2014	5-Year
204	11.59838149	125.4397086	0.06	0.40	-0.34	Yolanda/November 7-9, 2013	5-Year
205	11.59718656	125.4393204	0.03	0.30	-0.27	Ruby/December 3-10, 2014	5-Year
206	11.59718656	125.4393204	0.03	0.40	-0.37	Yolanda/November 7-9, 2013	5-Year
207	11.59952712	125.4391789	0.25	0.20	0.05	Ruby/December 3-10, 2014	5-Year
208	11.59952712	125.4391789	0.25	0.30	-0.05	Yolanda/November 7-9, 2013	5-Year
209	11.59705094	125.439409	0.03	0.30	-0.27	Ruby/December 3-10, 2014	5-Year
210	11.59705094	125.439409	0.03	0.40	-0.37	Yolanda/November 7-9, 2013	5-Year
211	11.59596171	125.4372077	0.55	1.36	-0.81	Ruby/December 3-10, 2014	5-Year
212	11.59596171	125.4372077	0.55	1.50	-0.95	Yolanda/November 7-9, 2013	5-Year
213	11.59690007	125.4398088	0.08	0.60	-0.52	Ruby/December 3-10, 2014	5-Year
214	11.59690007	125.4398088	0.08	0.80	-0.72	Yolanda/November 7-9, 2013	5-Year
215	11.59821075	125.4416878	0.09	0.60	-0.51	Ruby/December 3-10, 2014	5-Year
216	11.59821075	125.4416878	0.09	0.80	-0.71	Yolanda/November 7-9, 2013	5-Year
217	11.59705958	125.4374003	0.03	0.90	-0.87	Ruby/December 3-10, 2014	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Latitude	Longitude					
218	11.59705958	125.4374003	0.03	1.00	-0.97	Yolanda/November 7-9, 2013	5-Year
219	11.59774035	125.4390289	0.05	0.60	-0.55	Ruby/December 3-10, 2014	5-Year
220	11.59774035	125.4390289	0.05	0.40	-0.35	Yolanda/November 7-9, 2013	5-Year
221	11.6070534	125.4420748	0.03	0.60	-0.57	Ruby/December 3-10, 2014	5-Year
222	11.6070534	125.4420748	0.03	0.00	0.03	Yolanda/November 7-9, 2013	5-Year
223	11.60625955	125.4432004	0.09	0.60	-0.51	Ruby/December 3-10, 2014	5-Year
224	11.60625955	125.4432004	0.09	1.00	-0.91	Yolanda/November 7-9, 2013	5-Year
225	11.60569864	125.440224	0.07	0.70	-0.63	Ruby/December 3-10, 2014	5-Year
226	11.60569864	125.440224	0.07	0.50	-0.43	Yolanda/November 7-9, 2013	5-Year
228	11.60485944	125.4416635	0.30	0.47	-0.17	Ruby/December 3-10, 2014	5-Year
229	11.60485944	125.4416635	0.30	0.28	0.02	Yolanda/November 7-9, 2013	5-Year
230	11.60489716	125.43975	0.05	0.70	-0.65	Ruby/December 3-10, 2014	5-Year
231	11.60489716	125.43975	0.05	0.50	-0.45	Yolanda/November 7-9, 2013	5-Year
233	11.61217047	125.4364968	0.03	0.15	-0.12	Ruby/December 3-10, 2014	5-Year
234	11.61217047	125.4364968	0.03	0.10	-0.07	Yolanda/November 7-9, 2013	5-Year
235	11.61280775	125.4338072	0.22	0.50	-0.28	Ruby/December 3-10, 2014	5-Year
236	11.61236929	125.4331691	0.22	0.50	-0.28	Ruby/December 3-10, 2014	5-Year
237	11.61094378	125.4314801	0.29	0.50	-0.21	Ruby/December 3-10, 2014	5-Year
238	11.61151534	125.4339063	0.10	0.50	-0.40	Ruby/December 3-10, 2014	5-Year
240	11.60632284	125.4077945	0.51	1.50	-0.99	Ruby/December 3-10, 2014	5-Year
241	11.60632284	125.4077945	0.51	2.00	-1.49	Yolanda/November 7-9, 2013	5-Year
243	11.60652501	125.407568	0.05	1.50	-1.45	Ruby/December 3-10, 2014	5-Year
244	11.60652501	125.407568	0.05	2.00	-1.95	Yolanda/November 7-9, 2013	5-Year
246	11.60575555	125.4079181	1.51	1.50	0.01	Ruby/December 3-10, 2014	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Latitude	Longitude					
247	11.60575555	125.4079181	1.51	2.00	-0.49	Yolanda/November 7-9, 2013	5-Year
249	11.60622493	125.4071384	0.04	1.50	-1.46	Ruby/December 3-10, 2014	5-Year
250	11.60622493	125.4071384	0.04	2.00	-1.96	Yolanda/November 7-9, 2013	5-Year
252	11.60470035	125.4075823	0.04	0.90	-0.86	Yolanda/November 7-9, 2013	5-Year
253	11.60470035	125.4075823	0.04	2.00	-1.96	Ruby/December 3-10, 2014	5-Year
255	11.6003887	125.4031904	1.16	0.90	0.26	Yolanda/November 7-9, 2013	5-Year
257	11.59921381	125.4034363	0.05	0.90	-0.85	Ruby/December 3-10, 2014	5-Year
259	11.59951757	125.4038622	3.62	1.12	2.50	Yolanda/November 7-9, 2013	5-Year
260	11.59951757	125.4038622	3.62	3.00	0.62	Ruby/December 3-10, 2014	5-Year
262	11.59548126	125.4046676	1.91	1.50	0.41	Yolanda/November 7-9, 2013	5-Year
263	11.59548126	125.4046676	1.91	4.00	-2.09	Ruby/December 3-10, 2014	5-Year
265	11.59568955	125.4044704	1.03	2.13	-1.10	Ruby/December 3-10, 2014	5-Year
266	11.59570028	125.40508	2.09	4.00	-1.91	Ruby/December 3-10, 2014	5-Year
268	11.5945077	125.4035987	1.57	5.00	-3.43	Ruby/December 3-10, 2014	5-Year
269	11.5945077	125.4035987	1.57	1.50	0.07	Yolanda/November 7-9, 2013	5-Year
272	11.5950102	125.4033054	0.06	0.90	-0.84	Ruby/December 3-10, 2014	5-Year
273	11.5950102	125.4033054	0.06	2.00	-1.94	Yolanda/November 7-9, 2013	5-Year
275	11.59688356	125.4059177	3.65	2.30	1.35	Ruby/December 3-10, 2014	5-Year
276	11.59688356	125.4059177	3.65	1.80	1.85	Yolanda/November 7-9, 2013	5-Year
278	11.59483636	125.4039289	0.61	4.00	-3.39	Ruby/December 3-10, 2014	5-Year
279	11.59483636	125.4039289	0.61	1.00	-0.39	Yolanda/November 7-9, 2013	5-Year
281	11.59502529	125.4035791	0.03	0.90	-0.87	Ruby/December 3-10, 2014	5-Year
282	11.59502529	125.4035791	0.03	2.00	-1.97	Yolanda/November 7-9, 2013	5-Year
286	11.60800902	125.4260425	1.65	1.00	0.65	Ruby/December 3-10, 2014	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Latitude	Longitude					
287	11.60800902	125.4260425	1.65	1.60	0.05	Yolanda/November 7-9, 2013	5-Year
294	11.60628964	125.4316891	0.39	1.40	-1.01	Ruby/December 3-10, 2014	5-Year
295	11.60638805	125.4297954	0.04	2.00	-1.96	Ruby/December 3-10, 2014	5-Year
296	11.60638805	125.4297954	0.04	0.50	-0.46	Yolanda/November 7-9, 2013	5-Year
297	11.60689834	125.4343658	0.84	1.35	-0.51	Ruby/December 3-10, 2014	5-Year
298	11.60689834	125.4343658	0.84	0.50	0.34	Yolanda/November 7-9, 2013	5-Year
299	11.60682005	125.4351476	0.03	1.35	-1.32	Ruby/December 3-10, 2014	5-Year
300	11.60682005	125.4351476	0.03	0.50	-0.47	Yolanda/November 7-9, 2013	5-Year
301	11.60717997	125.4380922	0.12	0.50	-0.38	Ruby/December 3-10, 2014	5-Year
302	11.60896205	125.4355247	0.16	0.10	0.06	Ruby/December 3-10, 2014	5-Year
303	11.60896205	125.4355247	0.16	0.10	0.06	Yolanda/November 7-9, 2013	5-Year
304	11.60513646	125.4353891	0.12	1.35	-1.23	Ruby/December 3-10, 2014	5-Year
305	11.60513646	125.4353891	0.12	0.50	-0.38	Yolanda/November 7-9, 2013	5-Year
306	11.60528608	125.4363892	0.69	1.35	-0.66	Ruby/December 3-10, 2014	5-Year
307	11.60528608	125.4363892	0.69	0.50	0.19	Yolanda/November 7-9, 2013	5-Year
308	11.60972186	125.4384311	0.03	0.50	-0.47	Ruby/December 3-10, 2014	5-Year
309	11.60972186	125.4384311	0.03	0.10	-0.07	Yolanda/November 7-9, 2013	5-Year
311	11.60784977	125.4377294	0.04	0.50	-0.46	Ruby/December 3-10, 2014	5-Year
312	11.60779042	125.4363818	0.10	0.05	0.05	Ruby/December 3-10, 2014	5-Year
313	11.60730536	125.4375549	0.03	0.50	-0.47	Ruby/December 3-10, 2014	5-Year
314	11.60733327	125.435796	0.05	1.35	-1.30	Ruby/December 3-10, 2014	5-Year
315	11.60733327	125.435796	0.05	0.50	-0.45	Yolanda/November 7-9, 2013	5-Year
317	11.60974944	125.4336081	0.03	0.50	-0.47	Ruby/December 3-10, 2014	5-Year
318	11.60974944	125.4336081	0.03	1.00	-0.97	Yolanda/November 7-9, 2013	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Latitude	Longitude					
320	11.61042838	125.4337526	0.03	0.50	-0.47	Ruby/December 3-10, 2014	5-Year
321	11.61042838	125.4337526	0.03	1.00	-0.97	Yolanda/November 7-9, 2013	5-Year
322	11.61190921	125.4311072	0.03	0.50	-0.47	Ruby/December 3-10, 2014	5-Year
323	11.61190921	125.4311072	0.03	1.00	-0.97	Yolanda/November 7-9, 2013	5-Year
324	11.61149405	125.4329337	0.17	0.50	-0.33	Ruby/December 3-10, 2014	5-Year
325	11.61264103	125.4300958	0.03	1.35	-1.32	Ruby/December 3-10, 2014	5-Year
326	11.61509869	125.4298729	0.09	1.35	-1.26	Ruby/December 3-10, 2014	5-Year
327	11.61509869	125.4298729	0.09	1.35	-1.26	Yolanda/November 7-9, 2013	5-Year
332	11.61933934	125.431789	0.11	0.50	-0.39	Ruby/December 3-10, 2014	5-Year
333	11.61933934	125.431789	0.11	0.30	-0.19	Yolanda/November 7-9, 2013	5-Year
340	11.61346707	125.433741	0.07	0.50	-0.43	Ruby/December 3-10, 2014	5-Year
342	11.61136849	125.4353567	0.03	0.15	-0.12	Ruby/December 3-10, 2014	5-Year
343	11.61136849	125.4353567	0.03	0.10	-0.07	Yolanda/November 7-9, 2013	5-Year
359	11.61446585	125.4298781	0.03	1.35	-1.32	Ruby/December 3-10, 2014	5-Year
360	11.61446585	125.4298781	0.03	0.10	-0.07	Yolanda/November 7-9, 2013	5-Year
363	11.6086173	125.4315692	0.03	0.16	-0.13	Ruby/December 3-10, 2014	5-Year
364	11.6086173	125.4315692	0.03	0.16	-0.13	Yolanda/November 7-9, 2013	5-Year
365	11.6068897	125.4307564	0.03	0.10	-0.07	Ruby/December 3-10, 2014	5-Year
366	11.6068897	125.4307564	0.03	0.10	-0.07	Yolanda/November 7-9, 2013	5-Year
367	11.60532531	125.4324642	0.03	2.00	-1.97	Ruby/December 3-10, 2014	5-Year
368	11.60532531	125.4324642	0.03	0.50	-0.47	Yolanda/November 7-9, 2013	5-Year
369	11.60682416	125.4279854	0.16	1.00	-0.84	Ruby/December 3-10, 2014	5-Year
370	11.60682416	125.4279854	0.16	1.60	-1.44	Yolanda/November 7-9, 2013	5-Year
372	11.61075351	125.4219169	0.06	1.00	-0.94	Ruby/December 3-10, 2014	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Latitude	Longitude					
373	11.61137193	125.4197348	0.03	2.00	-1.97	Ruby/December 3-10, 2014	5-Year
374	11.61137193	125.4197348	0.03	0.20	-0.17	Yolanda/November 7-9, 2013	5-Year
380	11.60978414	125.4165043	0.04	1.50	-1.46	Ruby/December 3-10, 2014	5-Year
381	11.60910496	125.4161094	0.05	0.70	-0.65	Yolanda/November 7-9, 2013	5-Year
382	11.60910496	125.4161094	0.05	0.70	-0.65	Ruby/December 3-10, 2014	5-Year
384	11.60823089	125.4148725	0.06	0.50	-0.44	Yolanda/November 7-9, 2013	5-Year
385	11.60823089	125.4148725	0.06	0.60	-0.54	Ruby/December 3-10, 2014	5-Year
387	11.60748281	125.4137619	0.15	1.00	-0.85	Yolanda/November 7-9, 2013	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Latitude	Longitude					
62	11.60848738	125.4151341	0.03	0.40	-0.37	Heavy Rain1/ December 15-17, 2016	20-Year
67	11.60744475	125.4134772	0.64	1.50	-0.86	Heavy Rain1/ December 15-17, 2016	20-Year
70	11.60568489	125.4084074	3.83	0.30	3.53	Heavy Rain1/ December 15-17, 2016	20-Year
73	11.60617749	125.4074598	0.23	0.30	-0.07	Heavy Rain1/ December 15-17, 2016	20-Year
76	11.60467344	125.4079351	2.11	0.40	1.71	Heavy Rain1/ December 15-17, 2016	20-Year
79	11.59923124	125.4037118	2.61	0.70	1.91	Heavy Rain1/ December 15-17, 2016	20-Year
82	11.60036531	125.4034499	5.09	0.40	4.69	Heavy Rain1/ December 15-17, 2016	20-Year
84	11.59647443	125.4057281	4.68	0.60	4.08	Heavy Rain1/ December 15-17, 2016	20-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Latitude	Longitude					
89	11.5955163	125.4051457	4.75	1.50	3.25	Heavy Rain1/ December 15-17, 2016	20-Year
92	11.59474433	125.4034809	1.84	4.00	-2.16	Heavy Rain1/ December 15-17, 2016	20-Year
96	11.59506686	125.4043134	2.84	1.00	1.84	Heavy Rain1/ December 15-17, 2016	20-Year
165	11.61126045	125.423434	0.03	0.50	-0.47	Heavy Rain1/ December 15-17, 2016	20-Year
168	11.60772588	125.4269718	0.40	0.50	-0.10	Heavy Rain1/ December 15-17, 2016	20-Year
242	11.60632284	125.4077945	1.86	0.30	1.56	Heavy Rain1/ December 15-17, 2016	20-Year
245	11.60652501	125.407568	0.06	0.30	-0.24	Heavy Rain1/ December 15-17, 2016	20-Year
248	11.60575555	125.4079181	2.87	0.30	2.57	Heavy Rain1/ December 15-17, 2016	20-Year
251	11.60622493	125.4071384	0.05	0.30	-0.25	Heavy Rain1/ December 15-17, 2016	20-Year
254	11.60470035	125.4075823	1.33	0.40	0.93	Heavy Rain1/ December 15-17, 2016	20-Year
256	11.6003887	125.4031904	2.76	0.50	2.26	Heavy Rain1/ December 15-17, 2016	20-Year
258	11.59921381	125.4034363	0.53	0.50	0.03	Heavy Rain1/ December 15-17, 2016	20-Year
261	11.59951757	125.4038622	5.21	1.10	4.11	Heavy Rain1/ December 15-17, 2016	20-Year
264	11.59548126	125.4046676	3.62	0.40	3.22	Heavy Rain1/ December 15-17, 2016	20-Year
267	11.59570028	125.40508	3.80	1.00	2.80	Heavy Rain1/ December 15-17, 2016	20-Year
271	11.5945077	125.4035987	3.20	0.50	2.70	Heavy Rain1/ December 15-17, 2016	20-Year
274	11.5950102	125.4033054	0.09	0.40	-0.31	Heavy Rain1/ December 15-17, 2016	20-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Latitude	Longitude					
277	11.59688356	125.4059177	5.34	1.20	4.14	Heavy Rain1/ December 15-17, 2016	20-Year
280	11.59483636	125.4039289	2.26	1.00	1.26	Heavy Rain1/ December 15-17, 2016	20-Year
283	11.59502529	125.4035791	0.62	0.40	0.22	Heavy Rain1/ December 15-17, 2016	20-Year
334	11.61933934	125.431789	0.13	0.30	-0.17	Heavy Rain1/ December 15-17, 2016	20-Year
375	11.61137193	125.4197348	0.03	0.30	-0.27	Heavy Rain1/ December 15-17, 2016	20-Year
383	11.60910496	125.4161094	0.06	0.70	-0.64	Heavy Rain1/ December 15-17, 2016	20-Year
386	11.60823089	125.4148725	0.75	0.40	0.35	Heavy Rain1/ December 15-17, 2016	20-Year
389	11.60748281	125.4137619	1.40	1.50	-0.10	Heavy Rain1/ December 15-17, 2016	20-Year

Annex 12. Educational Institutions Affected in Loom Flood Plain

EASTERN SAMAR				
BORONGAN CITY				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Borongan City Learning School	Alang-Alang	Low	Low	Low
Brgy. Taboc Daycare Center	Alang-Alang			
Eastern Samar National Comprehensive High School	Alang-Alang			
Taboc Elementary School	Alang-Alang	Low	Low	Low
Eastern Samar National Comprehensive High School	Bato			
Brgy. A Daycare Center	Purok A			
St. Mary's College	Purok A			
Pilot Elementary School	Purok D1			Low
Eugenio A. Abunda Sr. Elementary School	Purok E			
Missionary Sisters of the Sacred Heart Academy	Songco			
Songco Elementary School	Songco	Low	Low	Low

Annex 13. Medical Institutions Affected in Loom Flood Plain

EASTERN SAMAR				
BORONGAN CITY				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Brgy. Taboc Health Center	Alang-Alang			
Neuro-Psychiatric Drug Testing and Medical Clinic	Alang-Alang	Low	Low	Low
Borongan Doctor's Hospital	Purok A			
Neuro and Mel Pharmacy and Clinic	Purok A	Low	Low	Low
De Los Reyes Optical Clinic	Purok B	Low	Low	Low
St. Anne's Maternity Clinic	Purok B	Low	Low	Low
Borongan PHO Staff House	Purok C	Low	Low	Low
Brgy. Balud Health Center	Purok C			
Eastern Samar Provincial Hospital	Purok C			
Neuro and Mel Pharmacy and Clinic	Purok C	Low	Low	Low
Provincial Health Center	Purok C	Low	Low	Low
Stance Physical Therapy Clinic	Purok D1		Low	Low
Borongan Physical Therapy Center	Songco		Low	Low
Brgy. Songco Health Center	Songco			
Montes Eye Center and Pharmacy	Songco	Low	Low	Low