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

LiDAR Surveys and Flood Mapping of Siocon River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
Ateneo de Zamboanga University

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LIST OF ACRONYMS AND ABBREVIATIONS

AAC	Asian Aerospace Corporation
Ab	abutment
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
ATQ	Antique
AWLS	Automated Water Level Sensor
BA	Bridge Approach
BM	benchmark
CAD	Computer-Aided Design
CN	Curve Number
CSRS	Chief Science Research Specialist
DAC	Data Acquisition Component
DEM	Digital Elevation Model
DENR	Department of Environment and Natural Resources
DOST	Department of Science and Technology
DPPC	Data Pre-Processing Component
DREAM	Disaster Risk and Exposure Assessment for Mitigation [Program]
DRRM	Disaster Risk Reduction and Management
DSM	Digital Surface Model
DTM	Digital Terrain Model
DVBC	Data Validation and Bathymetry Component
FMC	Flood Modeling Component
FOV	Field of View
GiA	Grants-in-Aid
GCP	Ground Control Point
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HEC-HMS	Hydrologic Engineering Center - Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center - River Analysis System
HC	High Chord
IDW	Inverse Distance Weighted [interpolation method]

IMU	Inertial Measurement Unit
kts	knots
LAS	LiDAR Data Exchange File format
LC	Low Chord
LGU	local government unit
LiDAR	Light Detection and Ranging
LMS	LiDAR Mapping Suite
m AGL	meters Above Ground Level
MMS	Mobile Mapping Suite
MSL	mean sea level
NSTC	Northern Subtropical Convergence
PAF	Philippine Air Force
PAGASA	Philippine Atmospheric Geophysical and Astronomical Services Administration
PDOP	Positional Dilution of Precision
PPK	Post-Processed Kinematic [technique]
PRF	Pulse Repetition Frequency
PTM	Philippine Transverse Mercator
QC	Quality Check
QT	Quick Terrain [Modeler]
RA	Research Associate
RIDF	Rainfall-Intensity-Duration-Frequency
RMSE	Root Mean Square Error
SAR	Synthetic Aperture Radar
SCS	Soil Conservation Service
SRTM	Shuttle Radar Topography Mission
SRS	Science Research Specialist
SSG	Special Service Group
TBC	Thermal Barrier Coatings
UPC	University of the Philippines Cebu
UP-TCAGP	University of the Philippines – Training Center for Applied Geodesy and Photogrammetry
UTM	Universal Transverse Mercator
WGS	World Geodetic System

CHAPTER 1: OVERVIEW OF THE PROGRAM AND THE SIOCON RIVER

Enrico C. Paringit, Dr. Eng., Mr. Mario Rodriguez, and Mr. Emir Epino

1.1 Background of the Phil-LIDAR 1 Program

The University of the Philippines Training Center for Applied Geodesy and Photogrammetry (UP TCAGP) launched a research program entitled "Nationwide Hazard Mapping using LiDAR" or Phil-LiDAR 1 in 2014, supported by the Department of Science and Technology (DOST) 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.

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

The implementing partner university for the Phil-LiDAR 1 Program is the Ateneo de Zamboanga University (ADZU). ADZU 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 18 river basins in the Zamboanga Peninsula. The university is located in Zamboanga City in the Zamboanga Peninsula.

1.2 Overview of the Siocon River Basin

The Siocon River Basin covers one (1) municipality in Zamboanga del Norte, namely the Municipality of Siocon. The DENR River Basin Control Office (RBCO) states that the Siocon River Basin has a drainage are of 603 km^2 and an estimated 452 cubic meter (MCM) annual run-off (RBCO, 2015).

Considered as one of the major drainage systems in Zamboanga del Norte, Siocon River has total catchment area of 597.28 sq.km, which covers tributaries from the neighboring Municipality of Baliguian of Zamboanga del Norte, and as far as the Municipalities of Roseller T. Lim and Tungawan in Zamboanga Sibugay.

Its main stem, Siocon River, is part of the eighteen (18) river systems under the PHIL-LiDAR 1 Program partner HEI, Ateneo de Zamboanga University.

According to the 2015 national census of PSA, a total of 6,328 persons are residing in Brgy. Poblacion in the Municipality of Siocon, which is within the immediate vicinity of the river. The municipality of Siocon consists of inhabitants with diverse backgrounds. In the hinterlands, the first settlers were the Subanons, Maguindanaons, and Kalibugans. In the shorelines, on the other hand, the first settlers were the Tausugs. Several ancient relics were discovered in the area which confirms that these tribes have already settled there even before the Spaniards came in the Island.

Figure 1. Siocon River

Figure 2. Road leading to the Municipality of Siocon

Being surrounded by forest lands, the municipality of Siocon is abundant in natural resources. According to the Department of Environment and Natural Resources, the municipality has a total of 32,605 hectares of forest and watershed area, and a total of 20,699 hectares of unclassified public forest.

One of the identified natural resources in the area is Mt. Canatuan, which is rich in minerals such as gold, silver and copper. Small-scale mining was prominent in the area back in the 1980's and through these, the reported potential of minerals paved way to the opening of TVI Pacific Inc., a Canadian-based mining company in 1996. The operations of this large scale mining activity have reportedly caused several negative environmental impacts, health issues of the community, and prominent human rights violations. Due to the exhaustion of ore reserves, the mining operations were officially closed in 2014.

According to the Municipal Disaster Risk Reduction and Management Office (MDRRMO) of Siocon, the earliest recorded flood incidence were in 1952 and in 1978, which were testified by old residents using portions of the old houses as indicators.

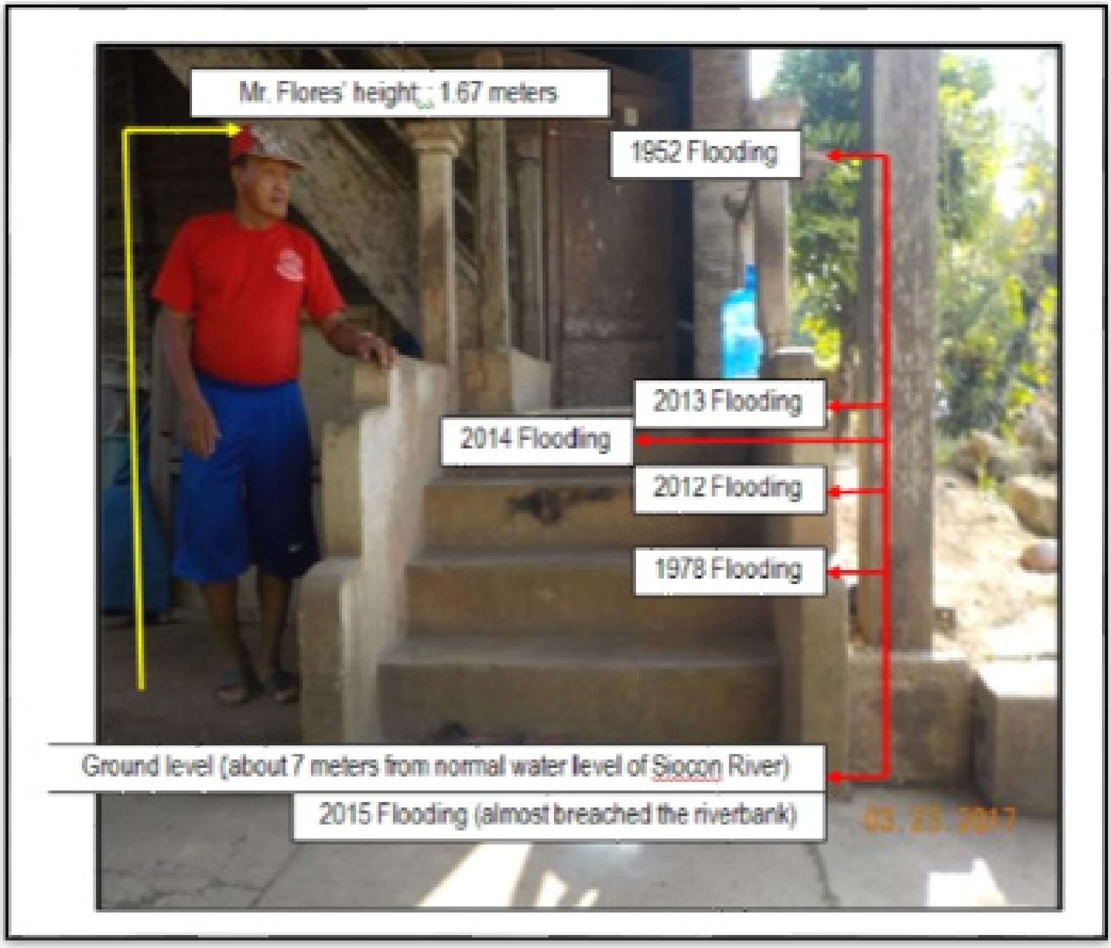

Figure 3. Flores testifying on the levels of flood in one of the old houses in the municipality. (Picture by MDRRMO of Siocon)

It was also reported by the MDRRM Office that in the river has overflowed in 3 years in a row (2012-2014), in the last 5 years. However, it was in flooding on October 4-8, 2013 that most damages were recorded. A total of Php 91,600,000.00 covers the damages in infrastructure, agriculture, residences and livelihood during this flood event.

More recently, on February 1, 2017, the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) issued a flood advisory for Siocon River and its tributaries due to the moderate to heavy rains brought by the presence of a trough of low pressure area affecting Mindanao as per NDRRMC report (Source: http://www.ndrrmc.gov.ph/attachments/article/3/ADVISORY_GFA_No.06-REGII,_No.05-REG_III,_No.01-REG_IX,_No.02-REG_X,_No.02-REG_XI,_No.02-CARAGA,_No.05-CAR,_No.01-ARMM.pdf)

Sources:
Department of Environment and Natural Resources, Flood History Reports of Siocon MDRRM Office, EJ Atlas, ABS-CBN News, Municipal Profile of Ipil, MPDO of Ipil, Provincial Profile of Zamboanga Sibugay, GMA News, Zamboanga Sibugay Website, Asian Development Bank, Department of Agriculutre

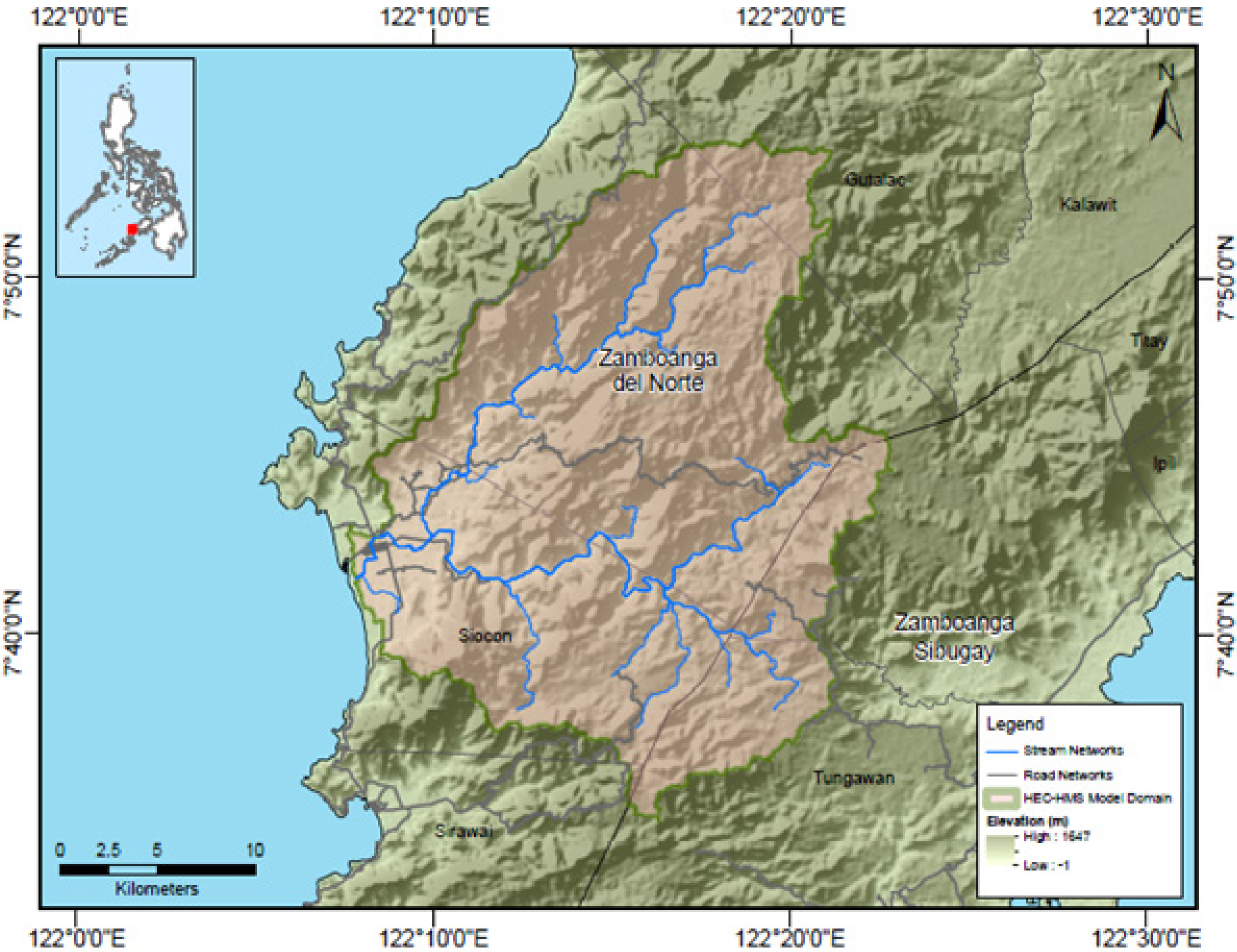

Figure 4. Map of Siocon River Basin (in brown)

CHAPTER 2: LIDAR ACQUISITION OF THE VIGA 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 Siocon Floodplain in Zamboanga. Each flight mission has an average of 14 lines and run for at most four and a half (4.5) hours including take-off, landing and turning time. The parameter used in the LiDAR system for acquisition is found in Table 1. Figure 5 shows the flight plans and base stations for Siocon Floodplain.

Table 1. Flight planning parameters for Pegasus LiDAR system

Block Name	Flying Height (AGL)	Overlap (%)	Field of View	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency	Average Speed	Average Turn Time (Minutes)
BLK75C	1100	30	50	200	30	130	5
BLK75D	1100	30	50	200	30	130	5
BLK75H	1100	30	50	200	30	130	5
BLK75I	1100	30	50	200	30	130	5

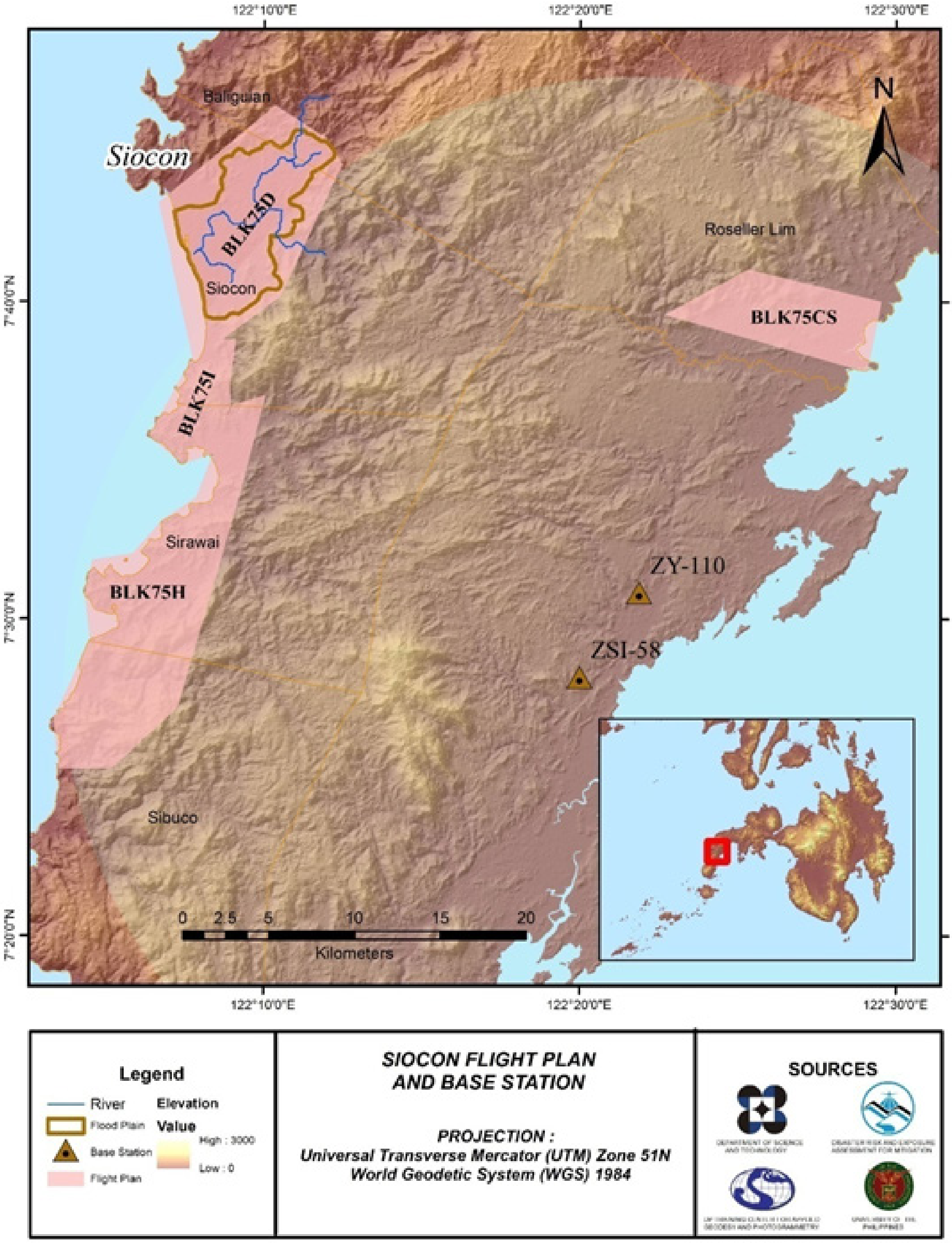

Figure 5. Flight plans and base stations used for Siocon Floodplain.

2.2 Ground Base Station

The project team was able to recover two (2) NAMRIA ground control points: ZSI-58 (2nd order accuracy) and one (1) benchmark: ZY-110.

The certifications for the NAMRIA reference points are found in Annex 2 while the baseline processing report for the benchmark is found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey (May 27-30, 2016). Base stations were observed using dual frequency

GPS receivers, SPS 852 and TOPCON GR-5. Flight plans and location of base stations used during the aerial LiDAR acquisition in Siocon Floodplain are shown in Figure 5.

Figure 6 to Figure 7 shows the recovered NAMRIA control stations within the area. In addition, Table 2 to Table 3 show the details about the following NAMRIA control station and established point while Table 4 lists all ground control points occupied during the acquisition together with the dates they are utilized during the survey.

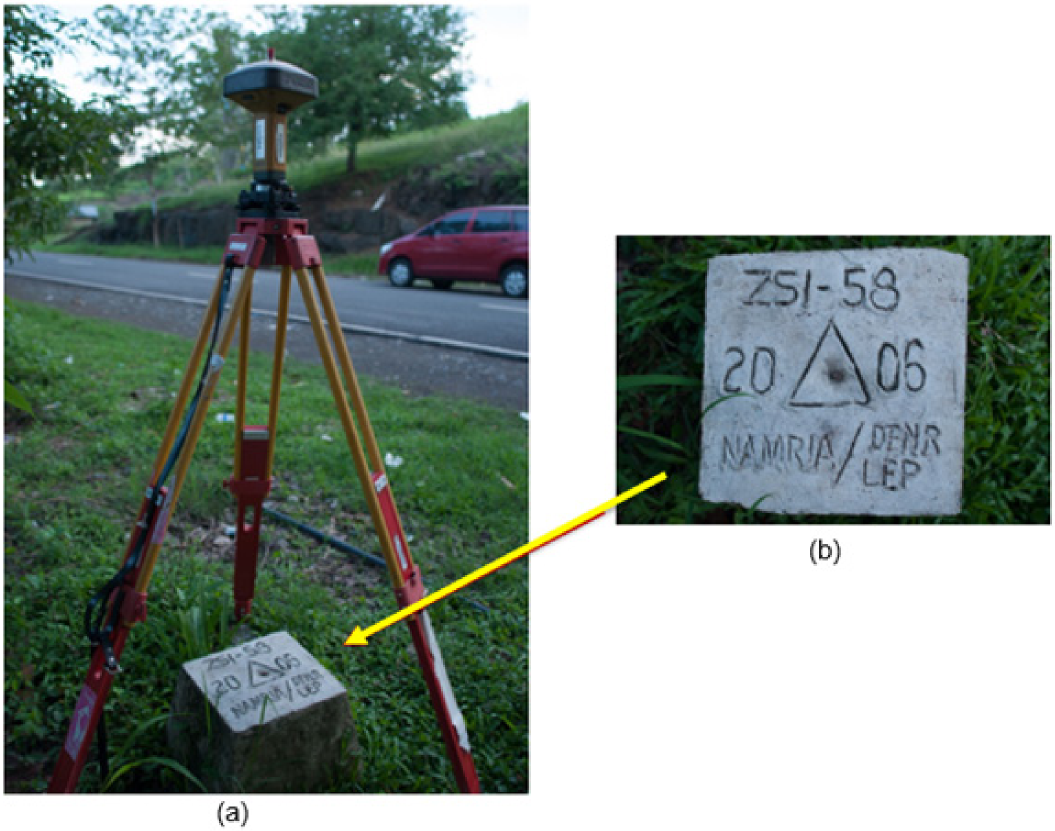

Figure 6. GPS set-up over ZSI-58 (a) in Brgy. Licomo, Zamboanga Sibugay and NAMRIA reference point ZSI-58 (b) as recovered by the field team.

Table 2. Details of the recovered NAMRIA horizontal control point ZSI-58 used as base station for the LiDAR data acquisition.

Station Name	ZSI-58	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	7° 28' 13.32387"North 122° 19' 53.76709"East 82.90600 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	426222.848 meters 826039.734 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7° 28' 9.79725" North 122° 19' 59.28169" East 146.76200 meters

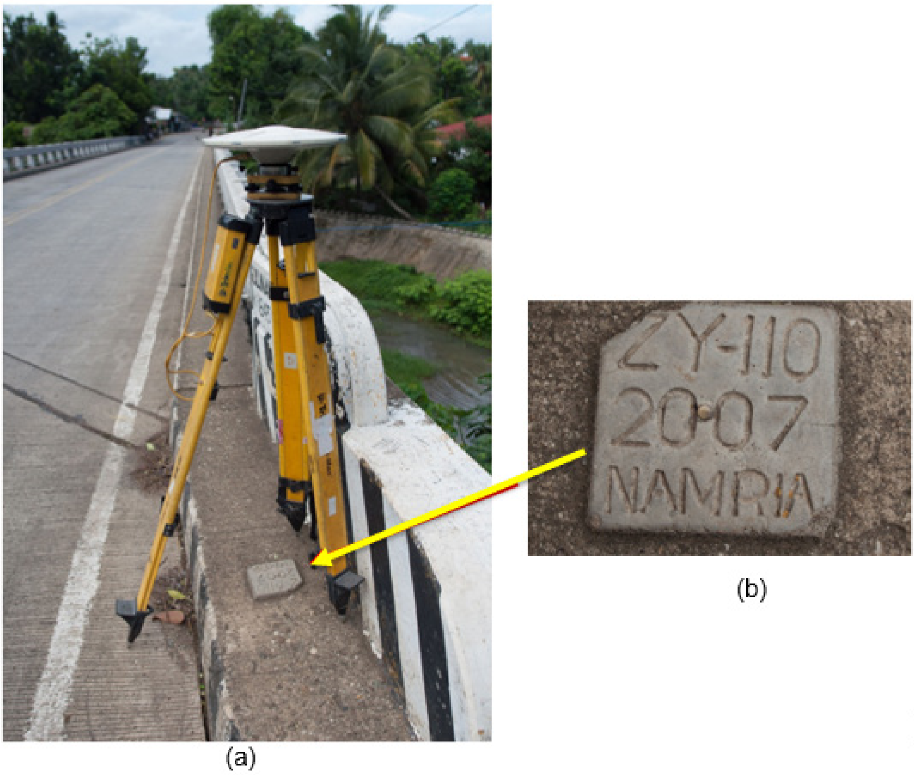

Figure 7. (a) GPS set-up over ZY-110 in Zamboanga Sibugay and BM reference point ZY-110 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA vertical control point ZY-110 used as base station for the LiDAR data acquisition with established coordinates.

Station Name	**ZY-110**	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	7°30'53.56720"North 122°21'46.79881"East 17.925 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7°30'50.03168" North122°21'52.30920"East 81.775 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	429720.383 meters 830666.222 meters

2.3 Flight Missions

Two (2) missions were conducted to complete LiDAR data acquisition in Siocon floodplain, for a total of six hours and fifty-eight minutes (6+58) of flying time for RP-C9022. All missions were acquired using the Pegasus system. Table 5 shows the total area of actual coverage and the corresponding flying hours per mission while Table 6 presents the actual parameters used during the LiDAR data acquisition.

Table 4. Ground control points used during LiDAR Data Acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
May 27, 2016	23398P	1BLK75CSDE148B	ZSI-58 & ZY-110
May 30, 2016	23408P	1BLK75HI151A	ZSI-58 & ZY-110

Table 5. Flight missions for LiDAR data acquisition in Siocon Floodplain.

Date Surveyed	Flight Number	Flight Plan Area (km2)	Surveyed Area (km2)	Area Surveyed within the Floodplain (km2)	Area Surveyed Outside the Floodplain (km2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
May 27, 2016	23398P	121.12	201.55	51.00	150.55	557	4	11
May 30, 2016	23408P	126.90	68.21	0	68.21	138	2	47
TOTAL		248.02	269.76	51.00	218.76	695	6	58

Table 6. Actual parameters used during LiDAR data acquisition

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes
23398P	1100	30	50	200	30	130	5
23408P	1100	30	50	200	30	130	5

2.4 Survey Coverage

This certain LiDAR acquisition survey covered the Siocon Floodplain (See Annex 7). Siocon Floodplain is located in the province of Zamboanga Sibugay with the floodplain situated within the municipalities of Siocon and Baliguian. The list of municipalities and cities surveyed with at least one (1) square kilometer coverage, is shown in Table 7. The actual coverage of the LiDAR acquisition for Siocon Floodplain is presented in Figure 8.

Table 7. List of municipalities and cities surveyed in Siocon Floodplain LiDAR survey.

Province	Municipality/City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Zamboanga del Norte	Siocon	248.94	99.12	39.81%
	Sirawai	222.04	27.66	12.46%
	Baliguian	462.61	32.31	6.99%
	Sibuco	600.11	9.75	1.62%
Zamboanga Sibugay	Roseller Lim	272.39	51.37	18.86%

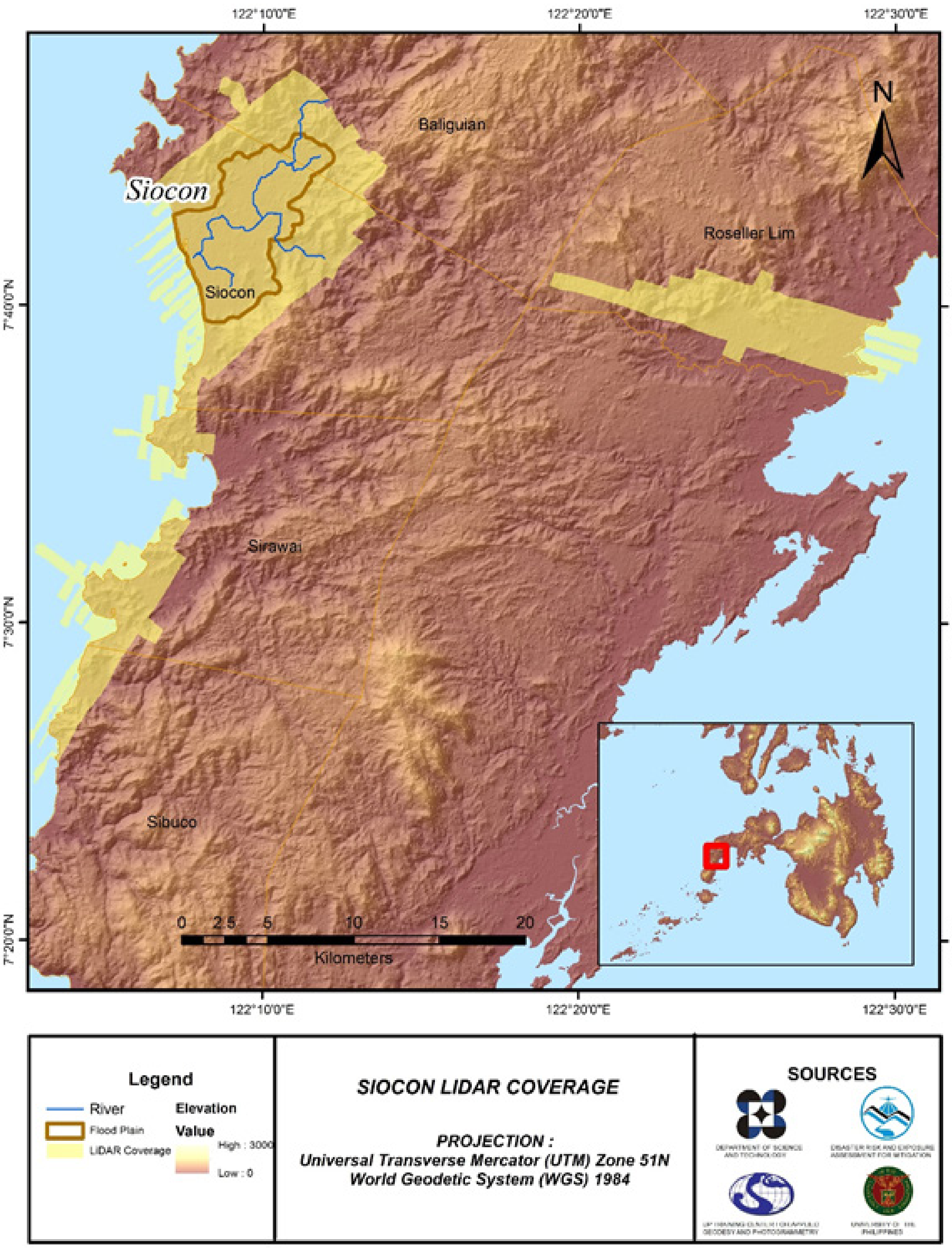

Figure 8. Actual LiDAR survey coverage for Siocon Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE SIOCON FLOODPLAIN

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

3.1 Overview of LiDAR Data Pre-Processing

The data transmitted by the Data Acquisition Component were checked for completeness based on the list of raw files required to proceed with the pre-processing of the LiDAR data. Upon acceptance of the LiDAR field data, georeferencing of the flight trajectory was done 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 were subjected 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 were calibrated. Portions of the river that are barely penetrated by the LiDAR system were replaced by the actual river geometry measured from the field by the Data Validation and Bathymetry Component. LiDAR acquired temporally were then mosaicked to completely cover the target river systems in the Philippines. Orthorectification of images acquired simultaneously with the LiDAR data was done through the help of the georectified point clouds and the metadata containing the time the image was captured.

These processes are summarized in the flowchart shown in Figure 9.

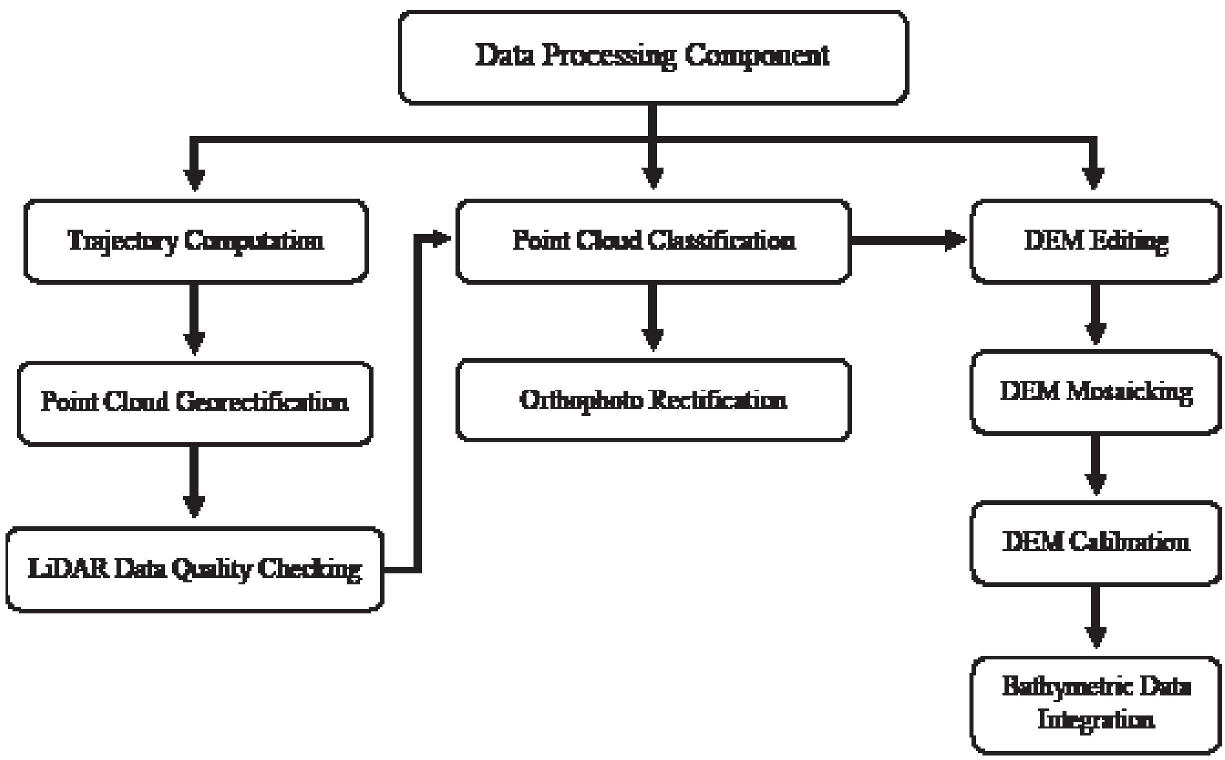


Figure 9. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Siocon floodplain can be found in Annex 5. Missions flown during the survey conducted on May 2016 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system over Siocon and Baliguan, Zamboanga del Norte. The Data Acquisition Component (DAC) transferred a total of 30.48 Gigabytes of Range data, 0.454 Gigabytes of POS data, 324 Megabytes of GPS base station data, and 38.73 Gigabytes of raw image data to the data server on July 11, 2016. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Siocon was fully transferred on July 14, 2016, as indicated on the Data Transfer Sheets for Siocon Floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 23408P, one of the Siocon flights, which is the North, East, and Down position RMSE values are shown in Figure 10. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on May 30, 2016 00:00AM. The y-axis is the RMSE value for that particular position.

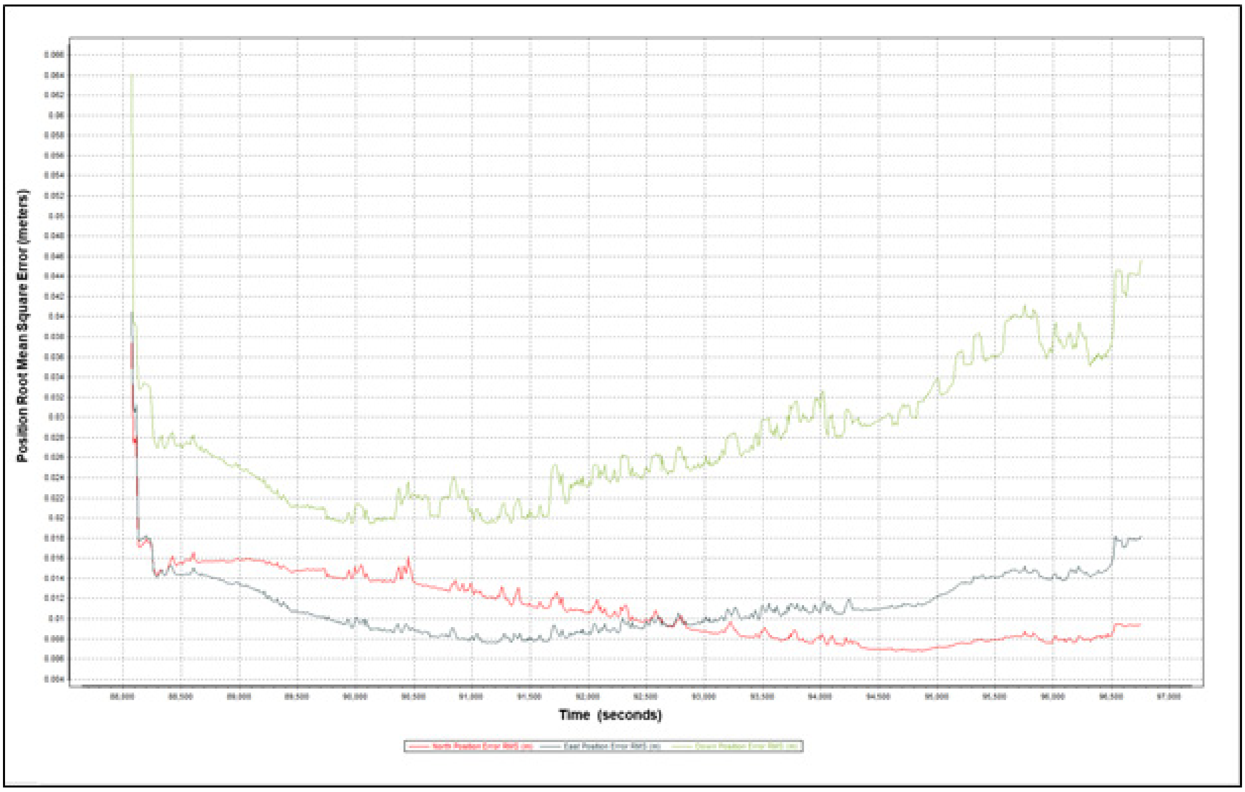


Figure 10. Smoothed Performance Metrics of a Siocon Flight 23408P.

The time of flight was from 88000 seconds to 97000 seconds, which corresponds to morning of May 30, 2016. 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 10 shows that the North position RMSE peaks at 1.62 centimeters, the East position RMSE peaks at 1.51 centimeters, and the Down position RMSE peaks at 4.13 centimeters, which are within the prescribed accuracies described in the methodology.

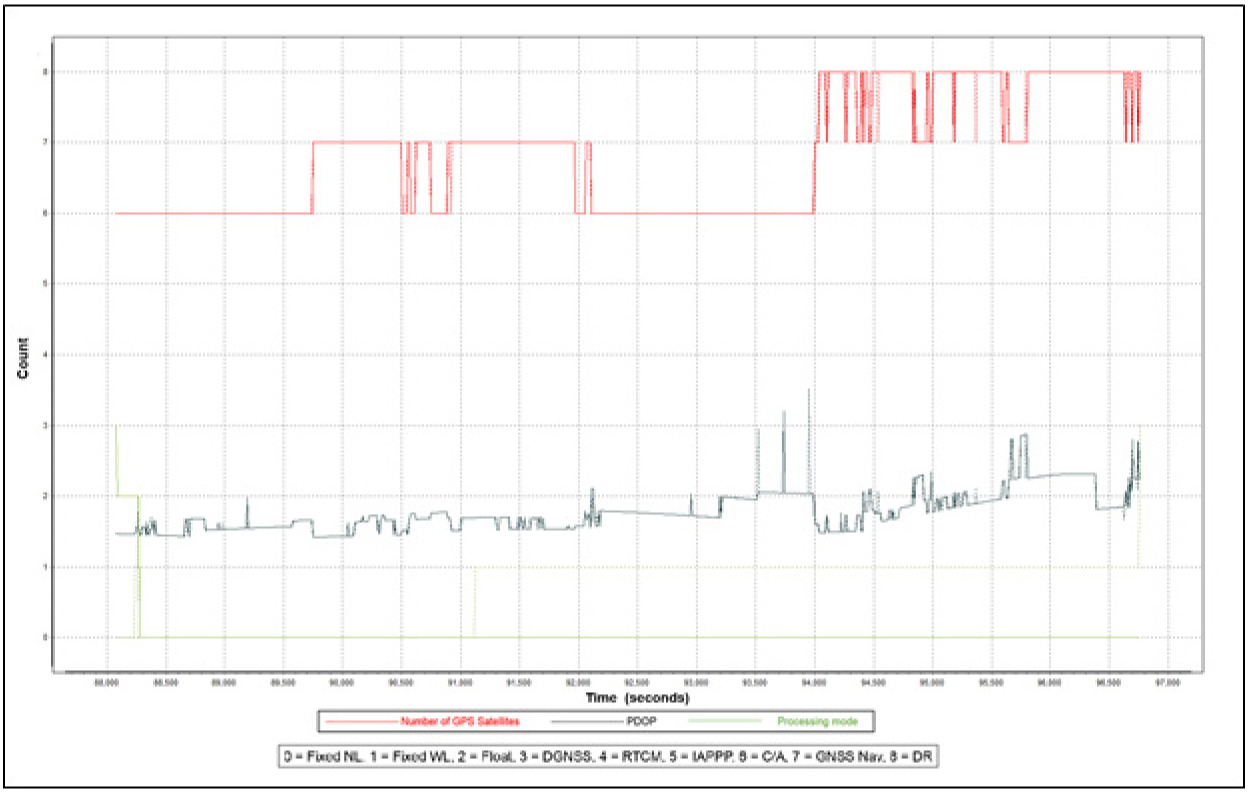


Figure 11. Solution Status Parameters of Siocon Flight 23408P.

The Solution Status parameters of flight 23408P, one of the Siocon flights, which indicate the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 11. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Most of the time, the number of satellites tracked was between 6 and 8. The PDOP value also did not go above the value of 4, which indicates optimal GPS geometry. The processing mode remained at 0 for majority of the survey. 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 Siocon flights is shown in Figure 12.

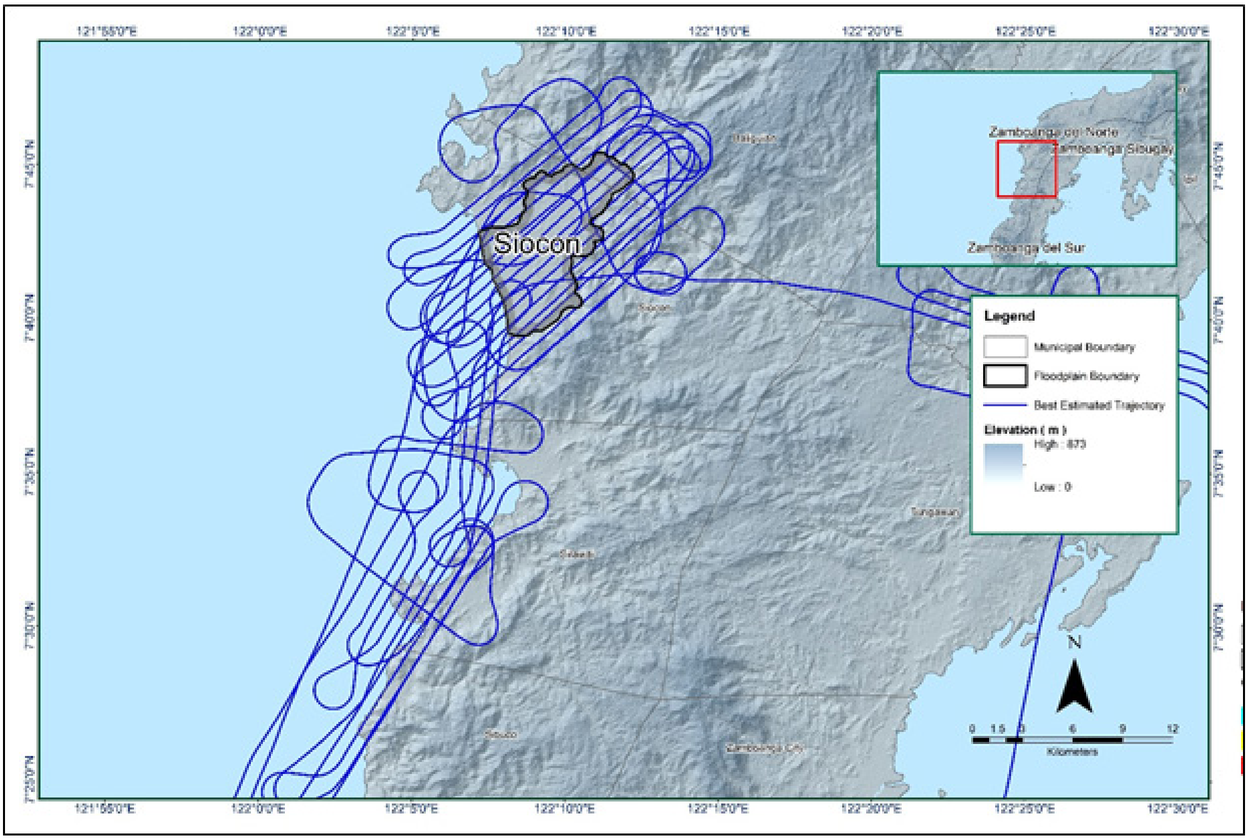


Figure 12. Figure 12. Best estimated trajectory for Siocon Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 36 flight lines, with each flight line containing two channels, since the Pegasus systems contains two channels. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Siocon Floodplain are given in Table 8.

Table 8. Self-Calibration Results values for Siocon flights.

Parameter	Acceptable Value	Value
Boresight Correction stdev	(<0.001degrees)	0.000218
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.000422
GPS Position Z-correction stdev	(<0.01meters)	0.0013

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

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data is shown in Figure 13. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

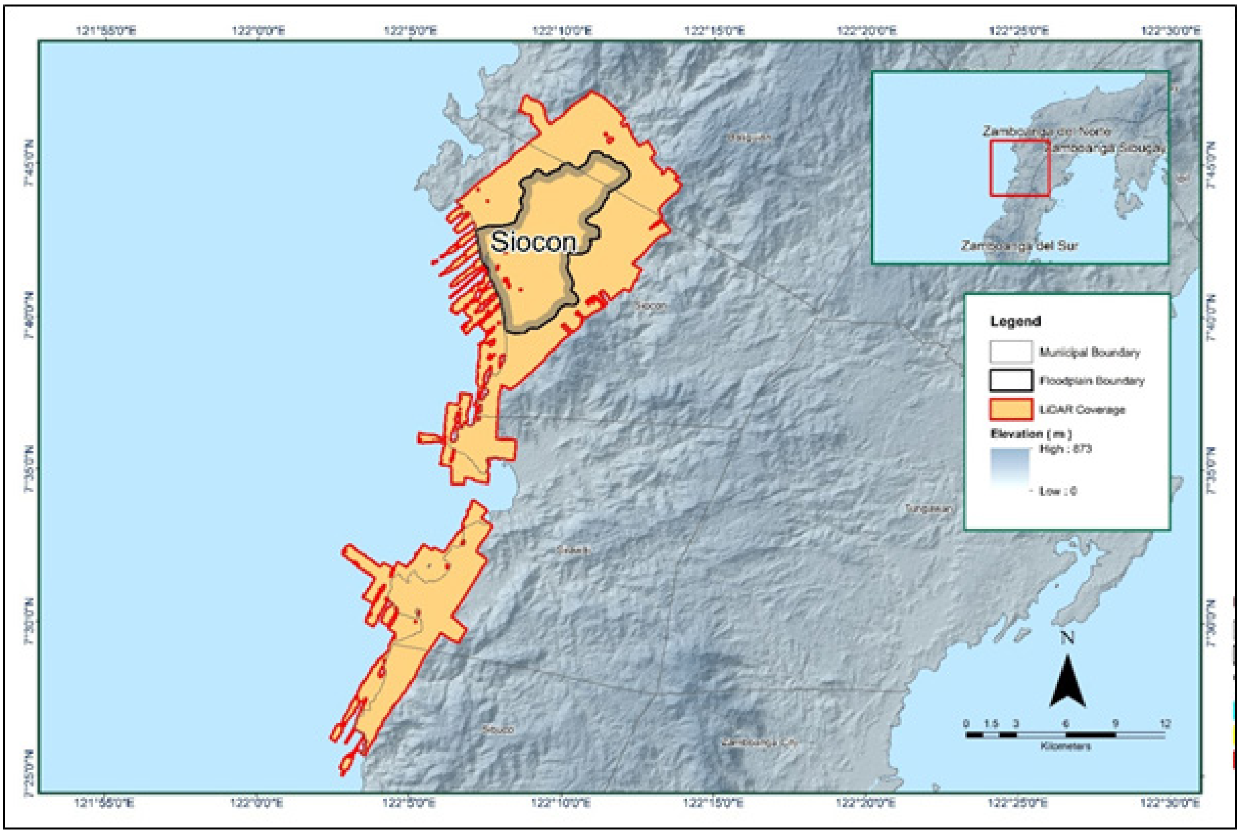


Figure 13. Boundary of the processed LiDAR data on top of a SAR Elevation Data over Siocon Floodplain.

The total area covered by the Siocon missions is 197.83 sq.km that is comprised of two (2) flight acquisitions grouped and merged into three (3) blocks as shown in Table 9.

Table 9. List of LiDAR blocks for Siocon floodplain

LiDAR Blocks	Flight Numbers	Area (sq. km)
Zamboanga_reflights_Blk75L	23398P	135.29
Zamboanga_reflights_Blk75K	23408P	17.29
Zamboanga_reflights_Blk75J	23408P	45.25
TOTAL		**197.83 sq.km**

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 14. Since the Pegasus system employs two channels, an average value of 2 (blue) for areas where there is limited overlap, and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines are expected.

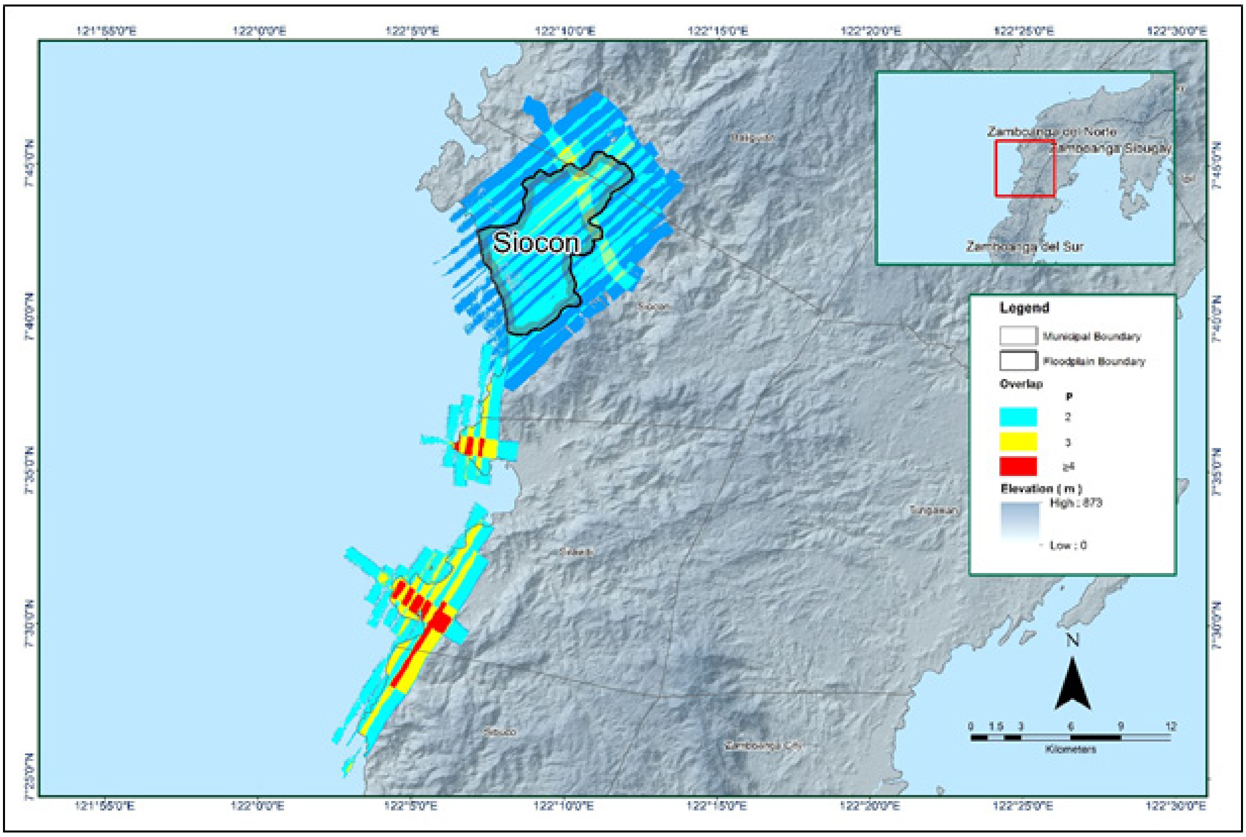


Figure 14. Image of data overlap for Siocon Floodplain.

The overlap statistics per block for the Siocon Floodplain can be found in Annex 8. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 26.80% and 46.99% respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 15. It was determined that all LiDAR data for Siocon Floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.12 points per square meter.

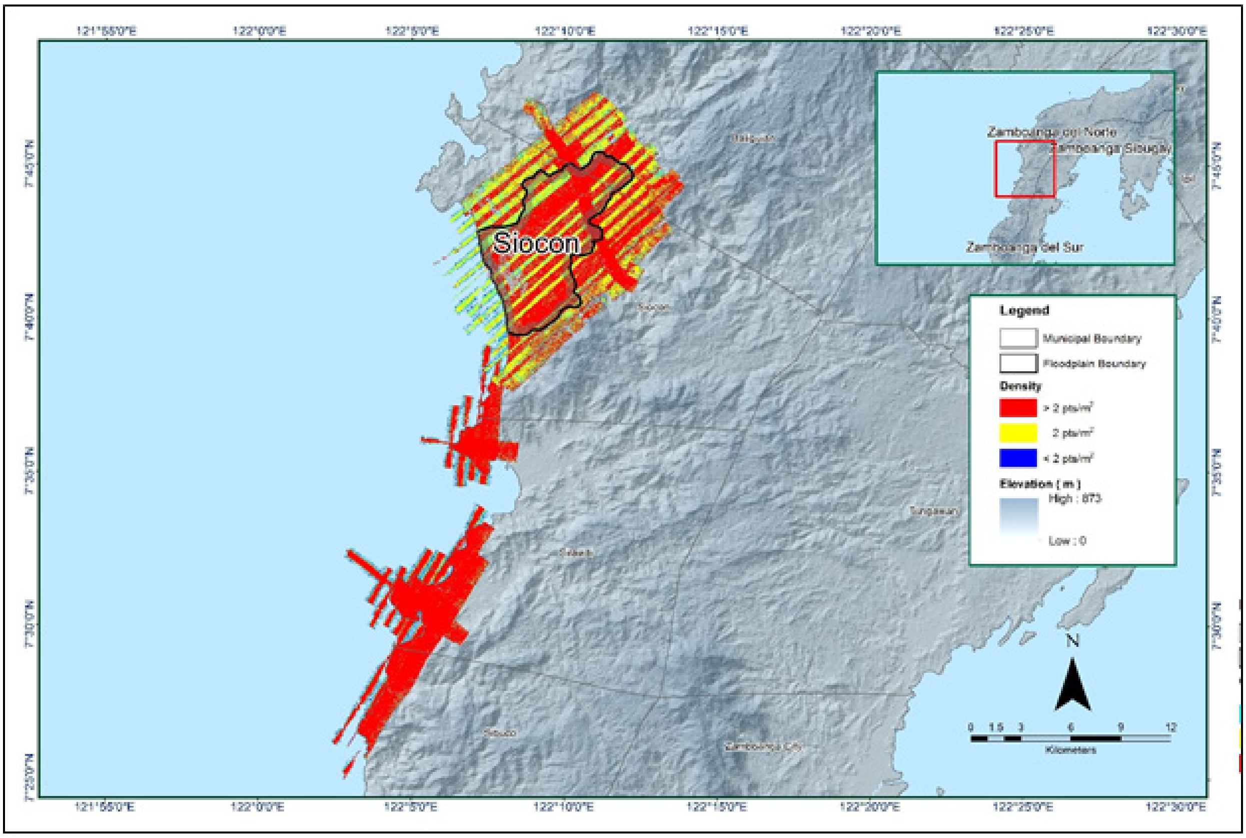


Figure 15. Pulse density map of merged LiDAR data for Siocon Floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 16. 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.

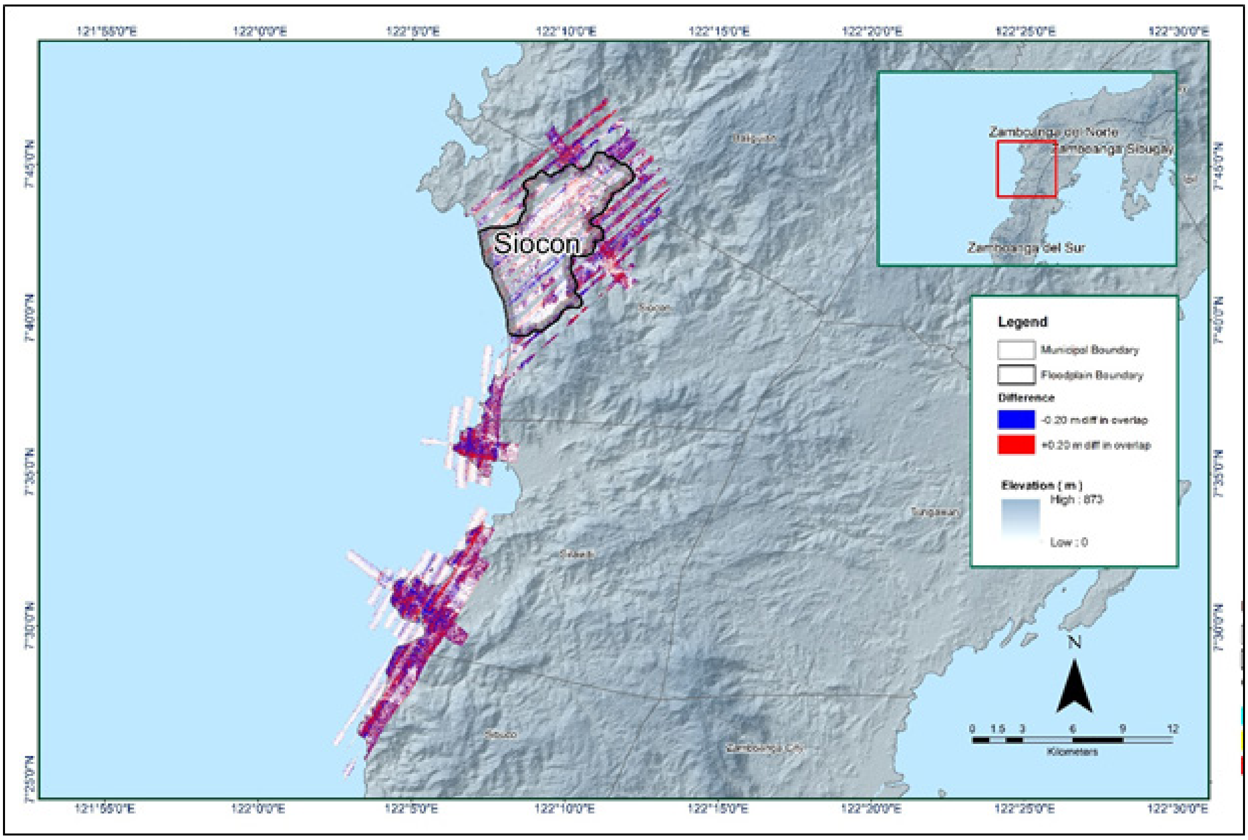


Figure 16. Elevation difference map between flight lines for Siocon Floodplain.

A screen capture of the processed LAS data from a Siocon flight 23408P loaded in QT Modeler is shown in Figure 17. 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.

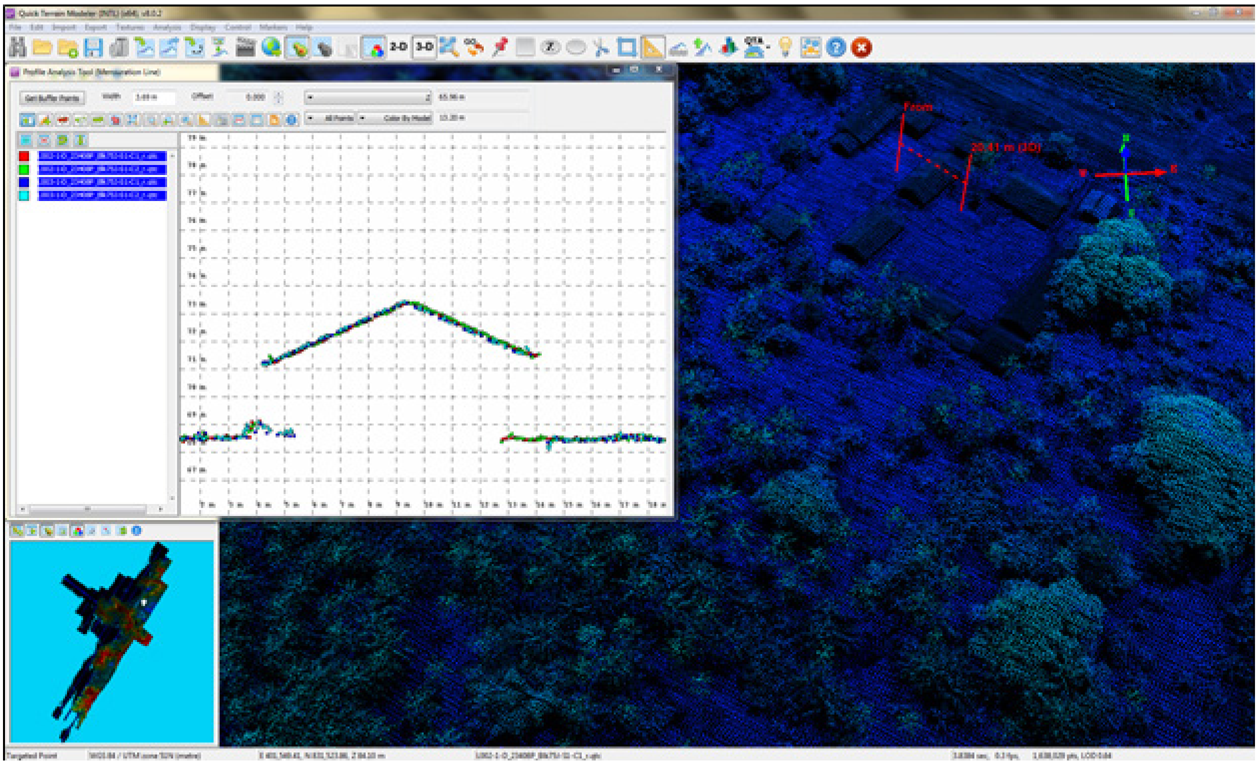


Figure 17. Quality checking for Siocon flight 23408P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 10. Siocon classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	167,379,230
Low Vegetation	68,832,298
Medium Vegetation	137,579,327
High Vegetation	363,921,897
Building	3,014,420

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Siocon Floodplainis shown in Figure 18. A total of 321 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 10. The point cloud has a maximum and minimum height of 625.38 meters and 59.22 meters, respectively.

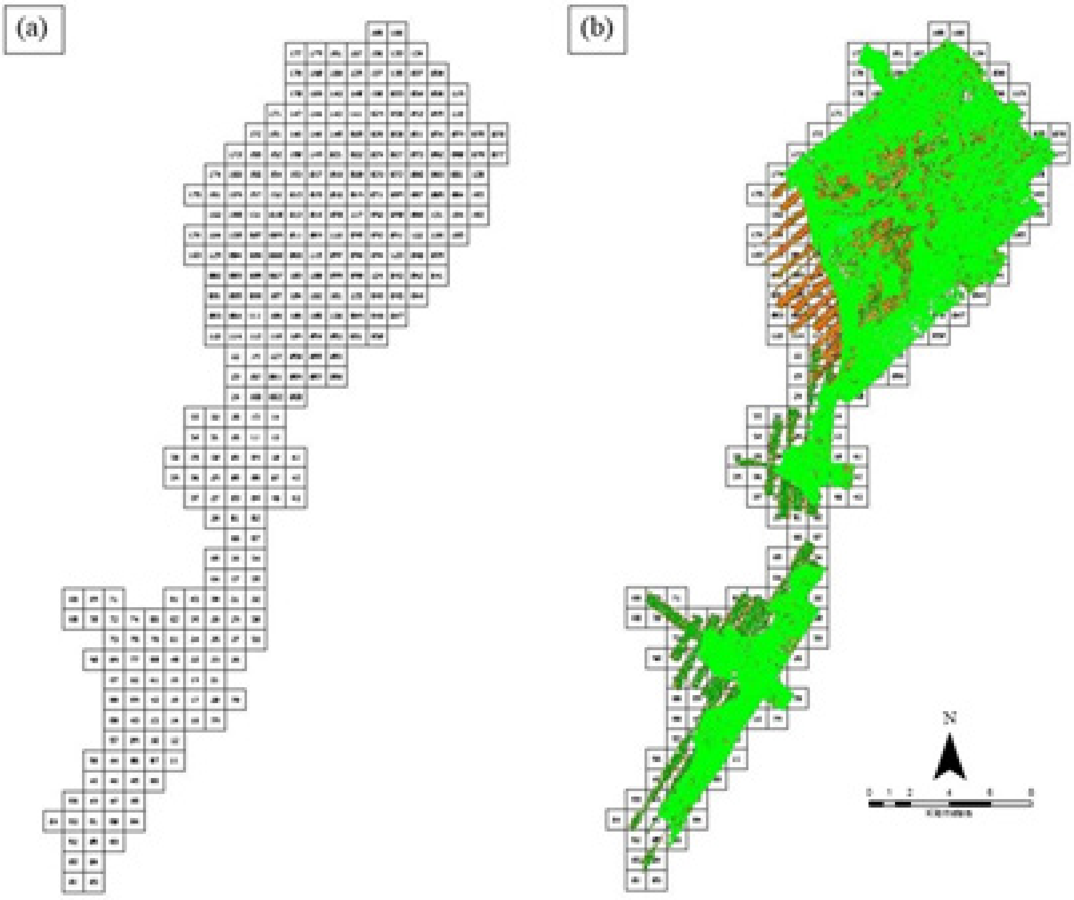


Figure 18. Tiles for Siocon Floodplain (a) and classification results (b) in TerraScan

An isometric view of an area before and after running the classification routines is shown in Figure 19. 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.

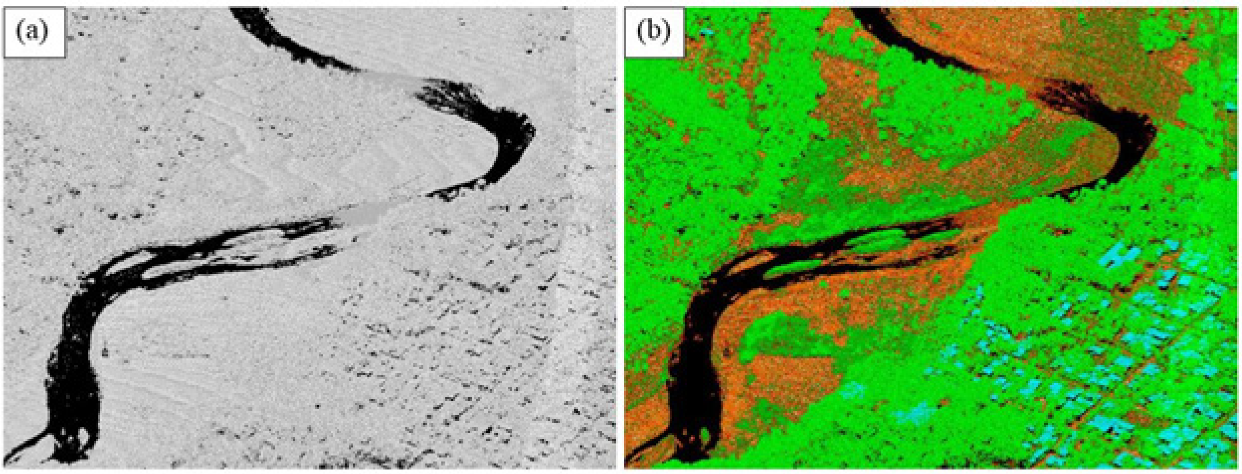


Figure 19. Point cloud before (a) and after (b) classification.

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

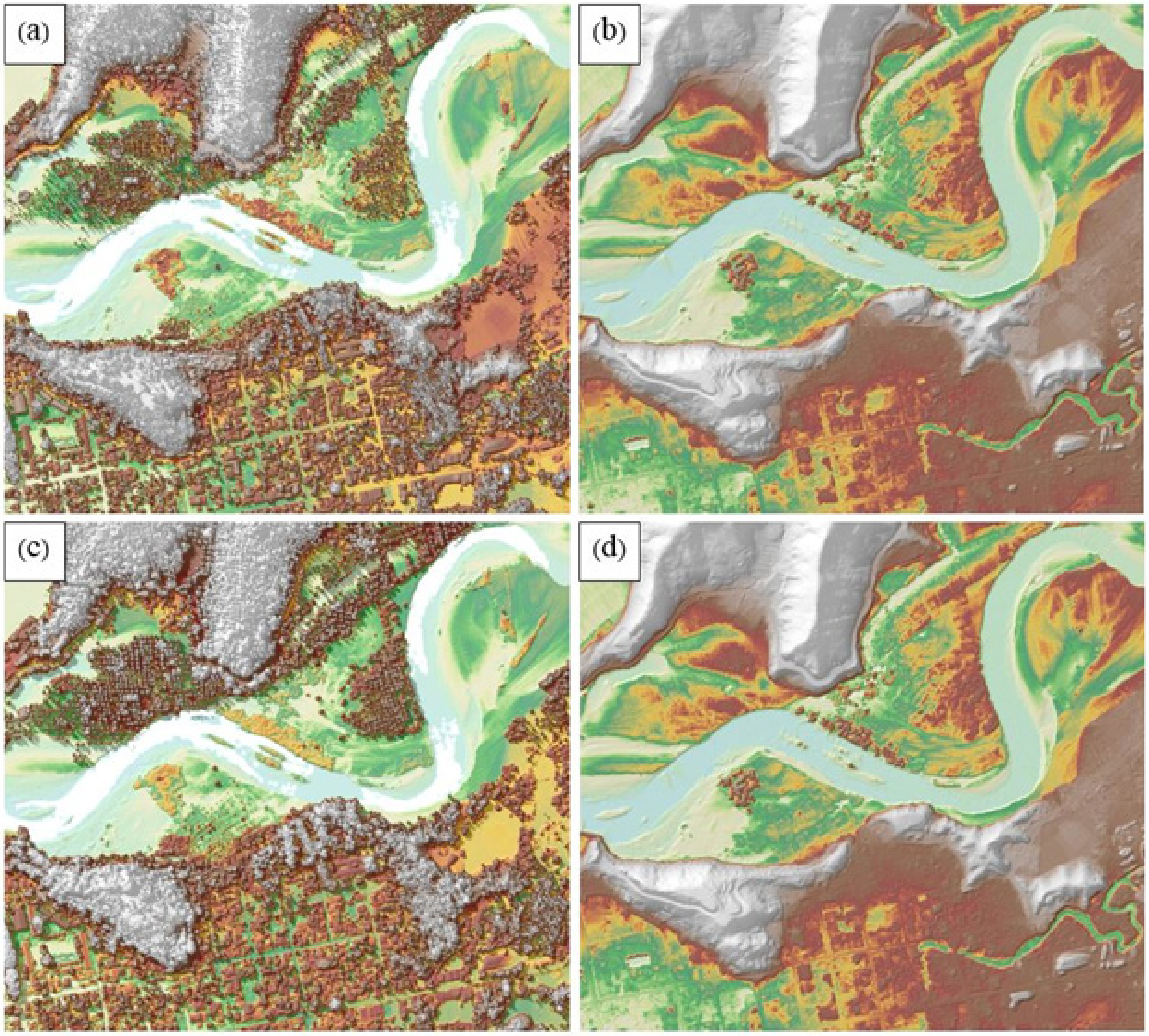


Figure 20. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Siocon Floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

There are no available orthophotographs for the Siocon floodplain.

3.8 DEM Editing and Hydro-Correction

Three (3) mission blocks were processed for Siocon Floodplain. These blocks are composed of Zamboanga_reflights blocks with a total area of 197.83 square kilometers. Table 11 shows the name and corresponding area of each block in square kilometers.

Table 11. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq.km)
Zamboanga_reflights_Blk75L	135.29
Zamboanga_reflights_Blk75K	17.29
Zamboanga_reflights_Blk75J	45.25
TOTAL	**197.83 sq.km**

Portions of DTM before and after manual editing are shown in Figure 21. The part of the mountain (Figure 21a) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 21b) to allow the correct flow of water. The bridge (Figure 21c) is also considered to be an impedance to the flow of water along the river and has to be removed (Figure 21d) in order to hydrologically correct the river.

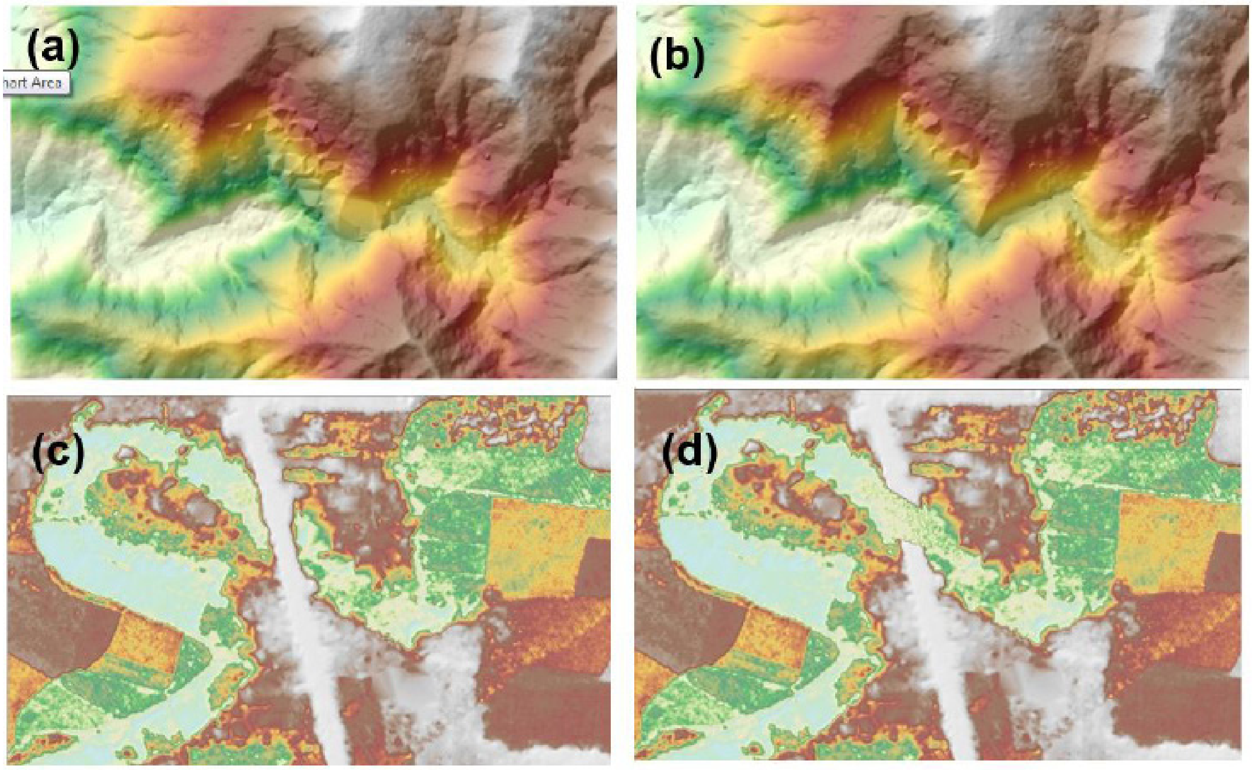


Figure 21. Portions in the DTM of Siocon Floodplain – a part of mountain was removed before (a) and after (b) data retrieval; a bridge before (c) and after (d) manual editing.

3.9 Mosaicking of Blocks

Zamboanga_reflights_Blk75L was used as the reference block at the start of mosaicking because it was the only available data at that time. Table 12 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Siocon floodplain is shown in Figure 22. It can be seen that the entire San Jose floodplain is 100% covered by LiDAR data.

Table 12. Shift Values of each LiDAR Block of Siocon Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Zamboanga_reflights_Blk75L	Reference block		
Zamboanga_reflights_Blk75K	1.00	1.00	0.24
Zamboanga_reflights_BLK75J	1.00	1.00	0.94

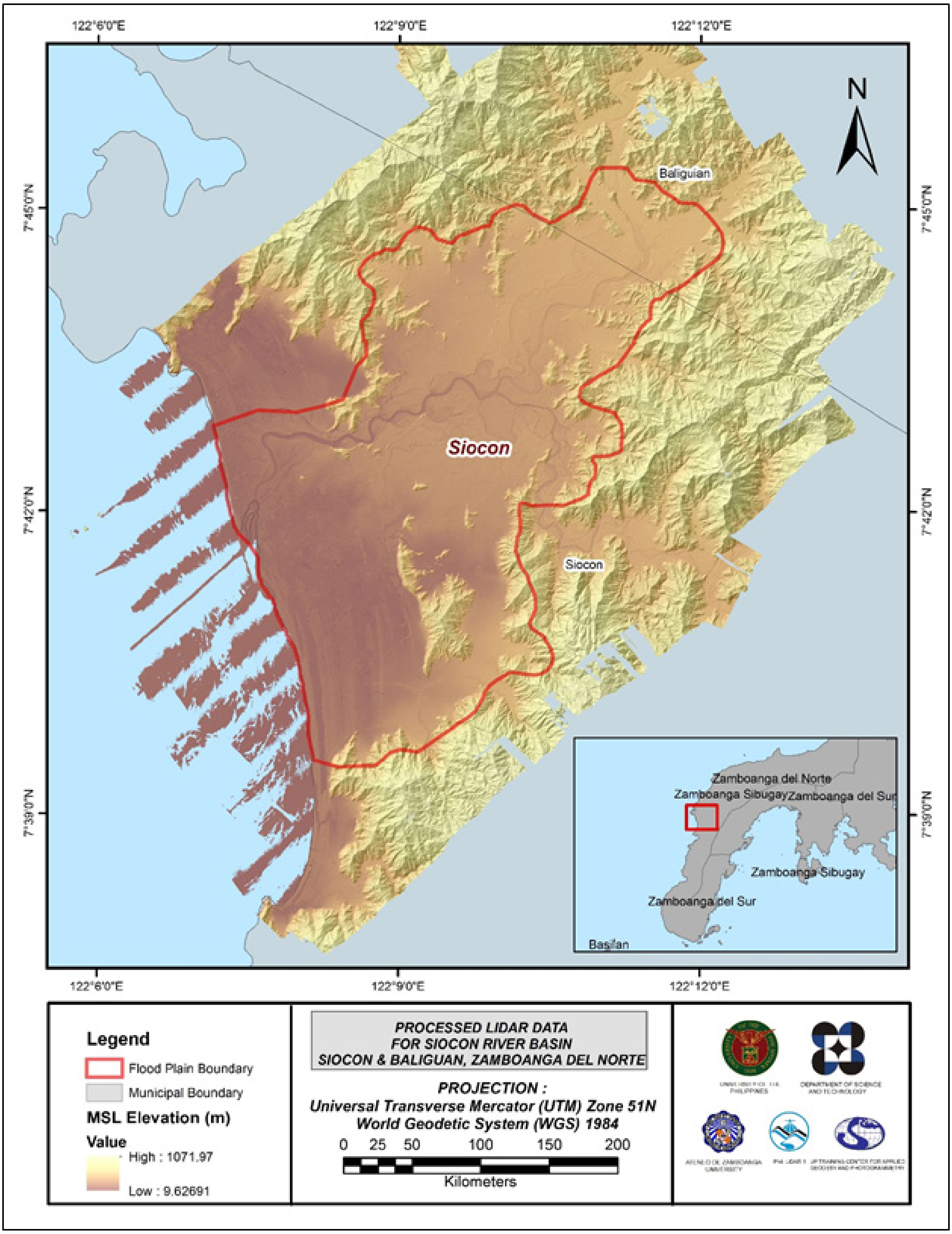


Figure 22. Map of Processed LiDAR Data for Siocon Floodplain.

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 Siocon to collect points with which the LiDAR dataset is validated is shown in Figure 23. A total of 3,266 survey points were used for calibration and validation of Siocon LiDAR data. Random selection of 80% of the survey points, resulting to 2,613 points, were used for calibration. A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure 24. 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 elevation values is 9.16 meters with a standard deviation of 0.09 meters. Calibration of Siocon LiDAR data was done by adding the height difference value, 9.16 meters, to Siocon mosaicked LiDAR data. Table 13 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

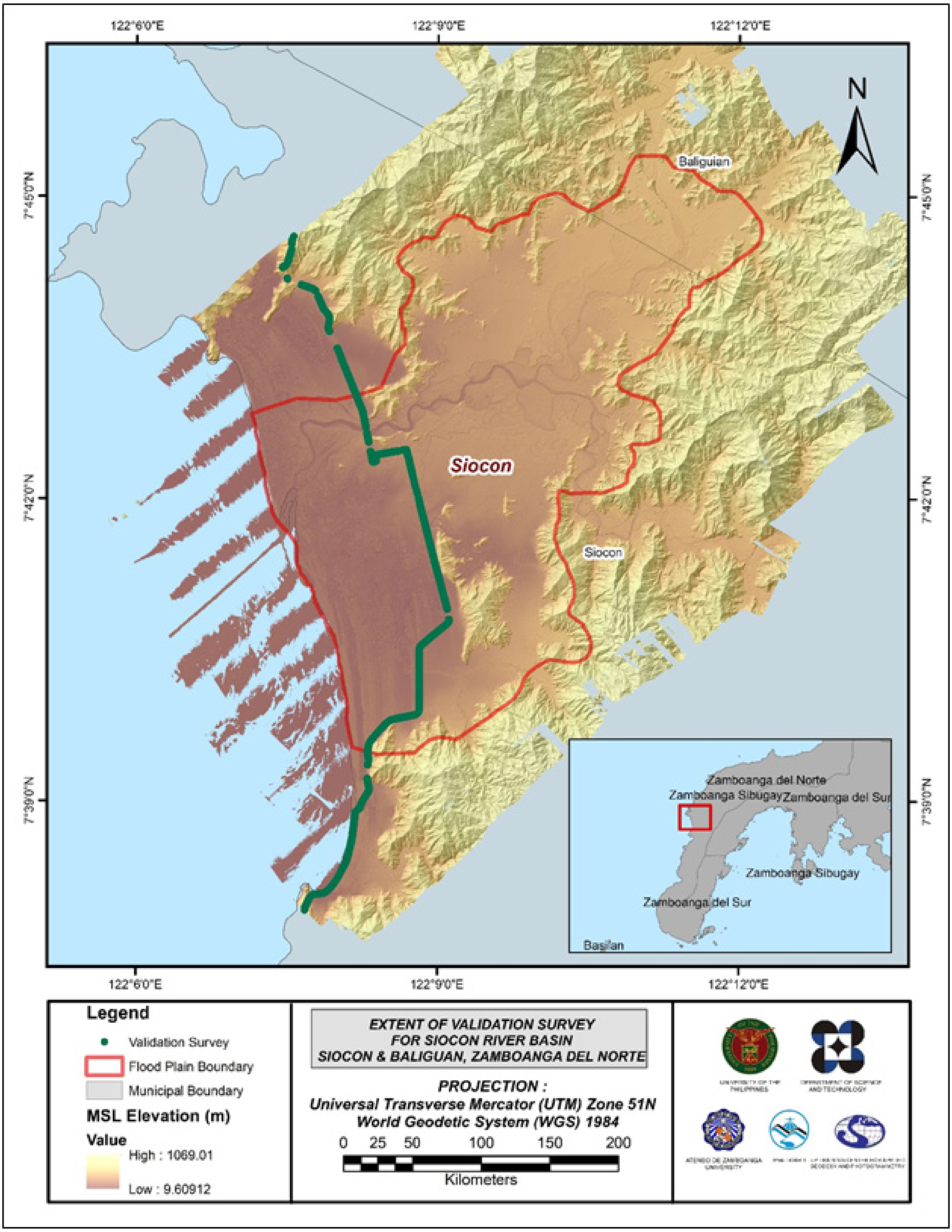


Figure 23. Map of Siocon Floodplain with validation survey points in green.

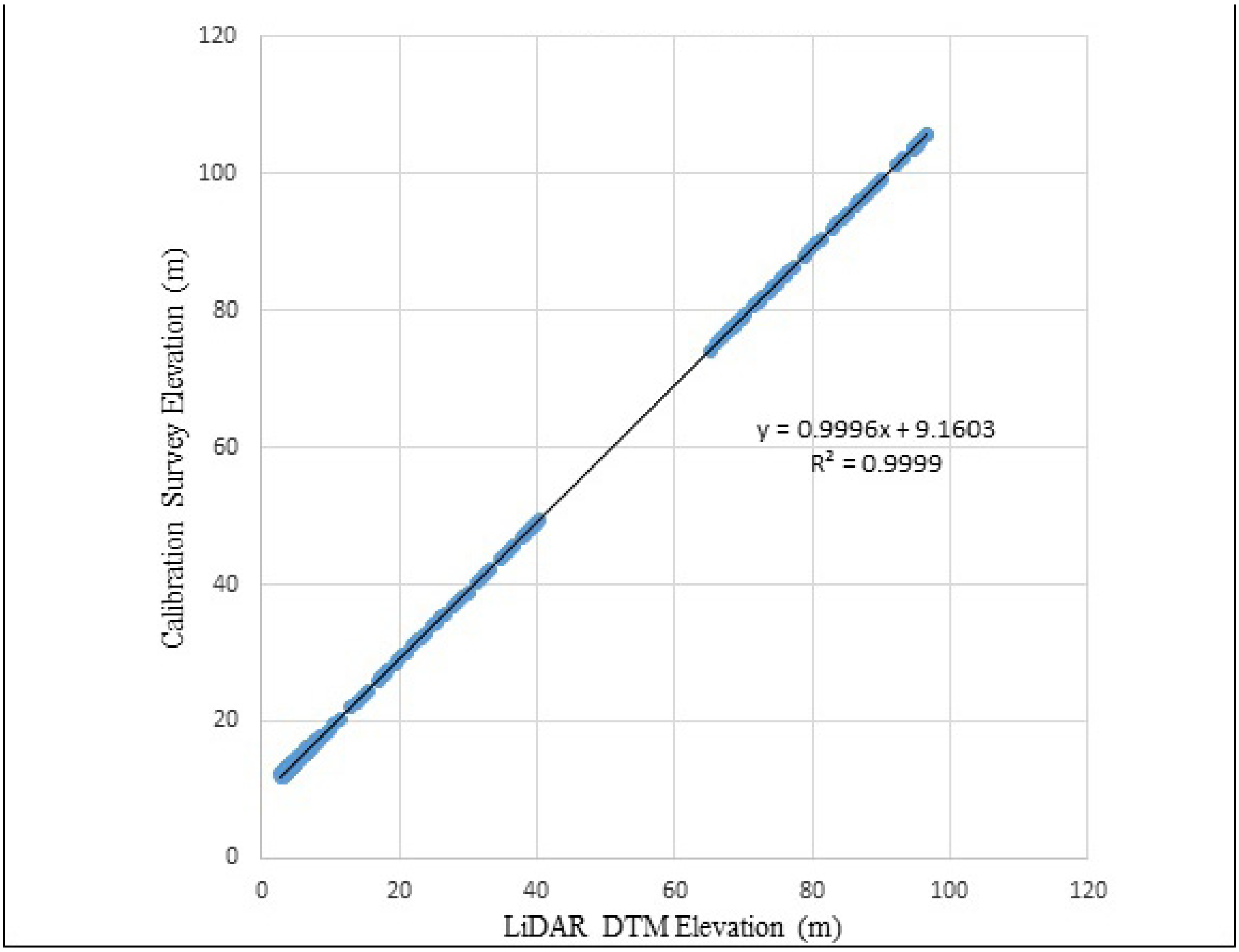


Figure 24. Correlation plot between calibration survey points and LiDAR data.

Table 13. Calibration Statistical Measures

Calibration Statistical Measures	Value (meters)
Height Difference	9.16
Standard Deviation	0.09
Average	9.16
Minimum	8.97
Maximum	9.34

The remaining 20% of the total survey points, resulting to 653 points, were used for the validation of calibrated Siocon DTM. A good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM is shown in Figure 25. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.09 meters with a standard deviation of 0.09 meters, as shown in Table 14.

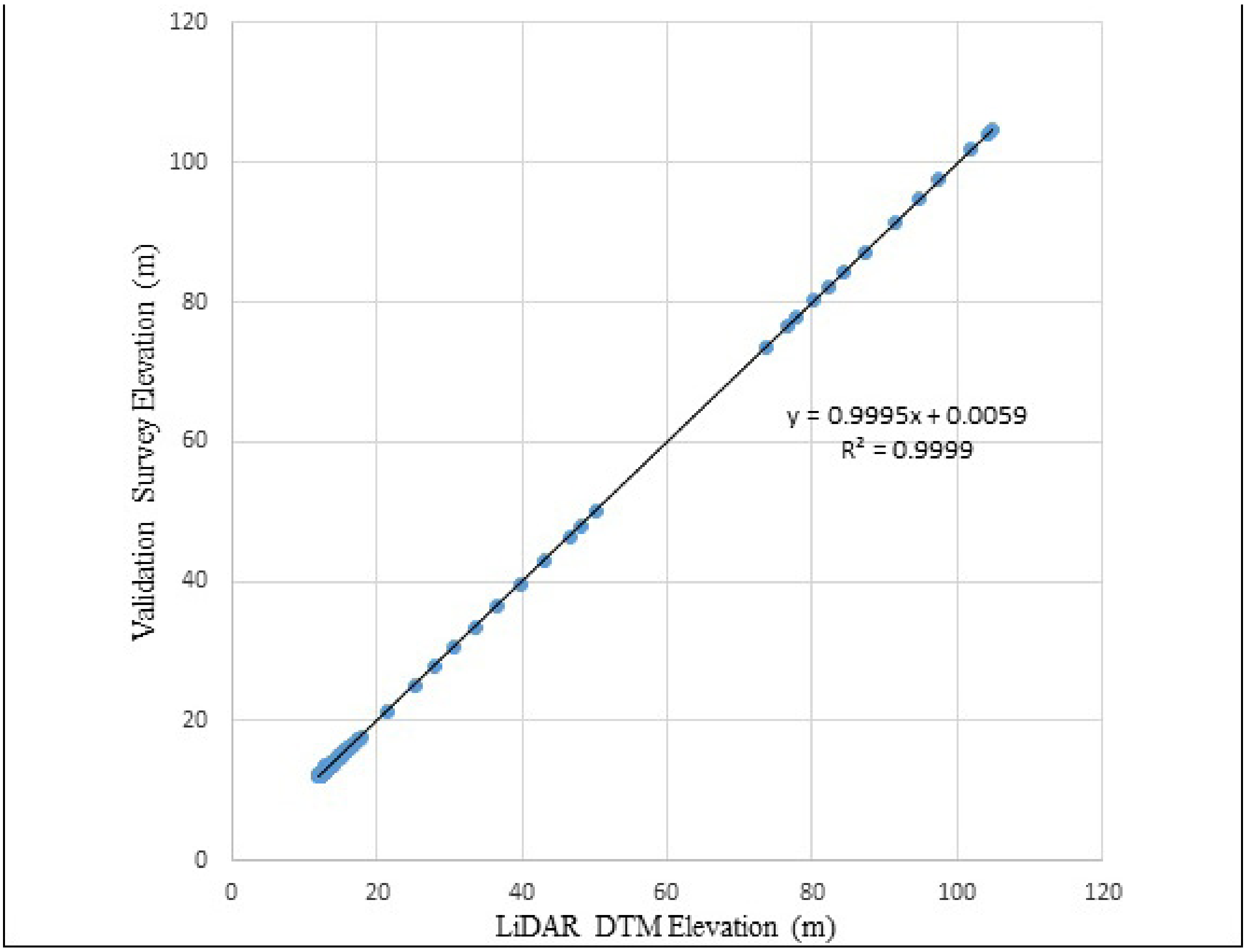


Figure 25. Correlation plot between validation survey points and LiDAR data.

Table 14. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.09
Standard Deviation	0.09
Average	-0.003
Minimum	-0.19
Maximum	0.18

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, cross-section data and center line was available for Siocon with 10092 bathymetric survey points. The resulting raster surface produced was done by Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.23 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Siocon integrated with the processed LiDAR DEM is shown in Figure 26.

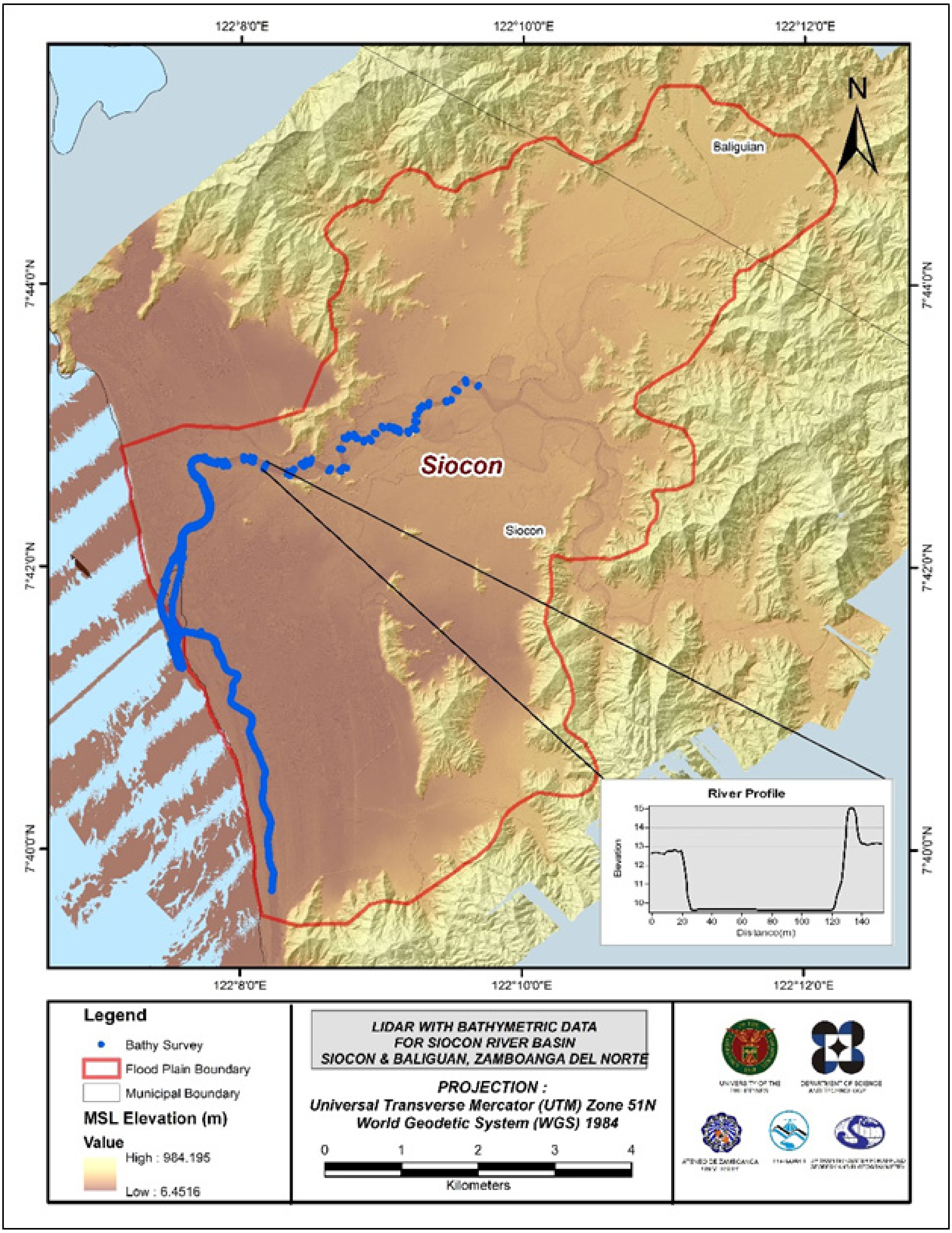


Figure 26. Map of Siocon Floodplain with bathymetric survey points shown in blue.

3.12 Feature Extraction

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

3.12.1 Quality Checking (QC) of Digitized Features' Boundary

Siocon Floodplain, including its 200 m buffer, has a total area of 58.47 sq km. For this area, a total of 5.00 sq km, corresponding to a total of 846 building features, are considered for QC. Figure 27 shows the QC blocks for Siocon floodplain.

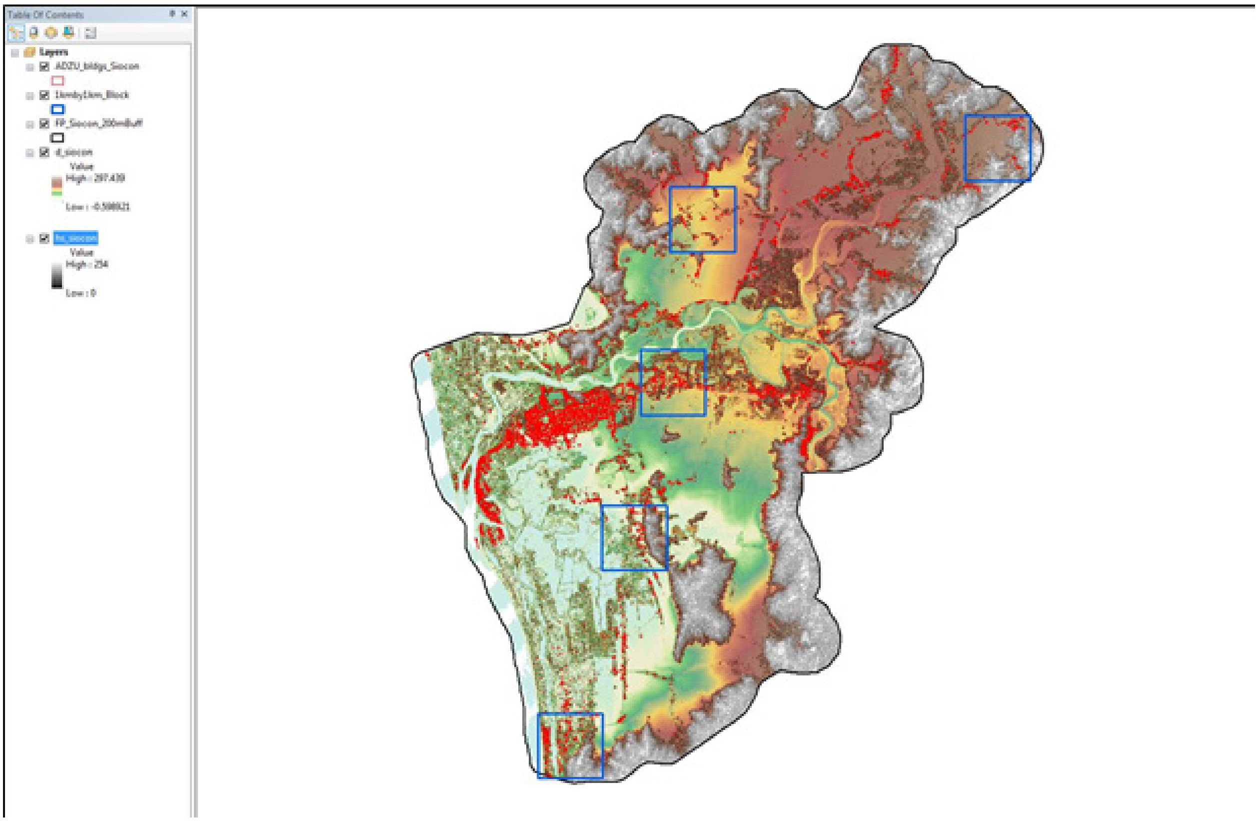


Figure 27. Blocks (in blue) of Siocon building features that were subjected in QC.

Quality checking of Siocon building features resulted in the ratings shown in Table 15.

Table 15. Quality Checking Ratings for Siocon Building Features.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Siocon	89.53	99.92	86.89	PASSED

3.12.2 Height Extraction

Height extraction was done for 7051 building features in Siocon Floodplain. Of these building features, 200 was filtered out after height extraction, resulting in 6851 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 6.86 m.

3.12.3 Feature Attribution

One of the Research Associates of ADZU Phil LiDAR 1 was able to develop GEONYT, an offline web-based application for feature attribution extracted from a LiDAR-based Digital Surface Model and which attribution is conducted by combining automatic data consolidation, geotagging and offline navigation. The app is conveniently integrated in a smart phone/ tablet. The data collected are automatically stored in database and can be viewed as CSV (or excel) and KML (can viewed via google earth). The Geonyt App was the main tool used in all feature attribution activity of the team.

The team conducted a 2-day Feature Attribution thru Community based Mapping. With the help of the Mayor's Office and the Local Disaster Risk Reduction and Management Office, 2-3 representatives from the barangay identified as included in the riverbasin floodplain were invited in the said activity. The representatives aided in identifying the features in the floodplain through the use of GEONYT.

For the features which were not covered, the LGUs, thru LDRRM, endorsed a number of enumerators and hired them to conduct the house-to-house survey of the features also using the GEONYT application. The team provided the enumerators smart tablets where the GEONYT is integrated. The number of days by which the survey was conducted was dependent on the number of the remaining features which is yet to be covered in floodplain of the river basin; likewise, the number of enumerators are also dependent on the availability of the tablet and the number of features of the floodplain.

Table 16 summarizes the number of building features per type. On the other hand, Table 17 shows the total length of each road type, while Table 18 shows the number of water features extracted per type.

Table 16. Building Features Extracted for Siocon Floodplain.

Facility Type	No. of Features
Residential	6407
School	90
Market	86
Agricultural/Agro-Industrial Facilities	55
Medical Institutions	13
Barangay Hall	14
Military Institution	2
Sports Center/Gymnasium/Covered Court	11
Telecommunication Facilities	1
Transport Terminal	2
Warehouse	37
Power Plant/Substation	1
NGO/CSO Offices	2
Police Station	2
Water Supply/Sewerage	1
Religious Institutions	44
Bank	1
Factory	1
Gas Station	3
Fire Station	1
Other Government Offices	16
Other Commercial Establishments	32
N/A	29
Total	**6851**

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

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Siocon	5.82	17.23	0.00	50.21	0.00	73.26

Table 18. Number of Extracted Water Bodies for Siocon Floodplain.

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Siocon	11	0	0	0	0	11

A total of 25 bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

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

Figure 28 shows the Digital Surface Model (DSM) of Siocon Floodplain overlaid with its ground features.

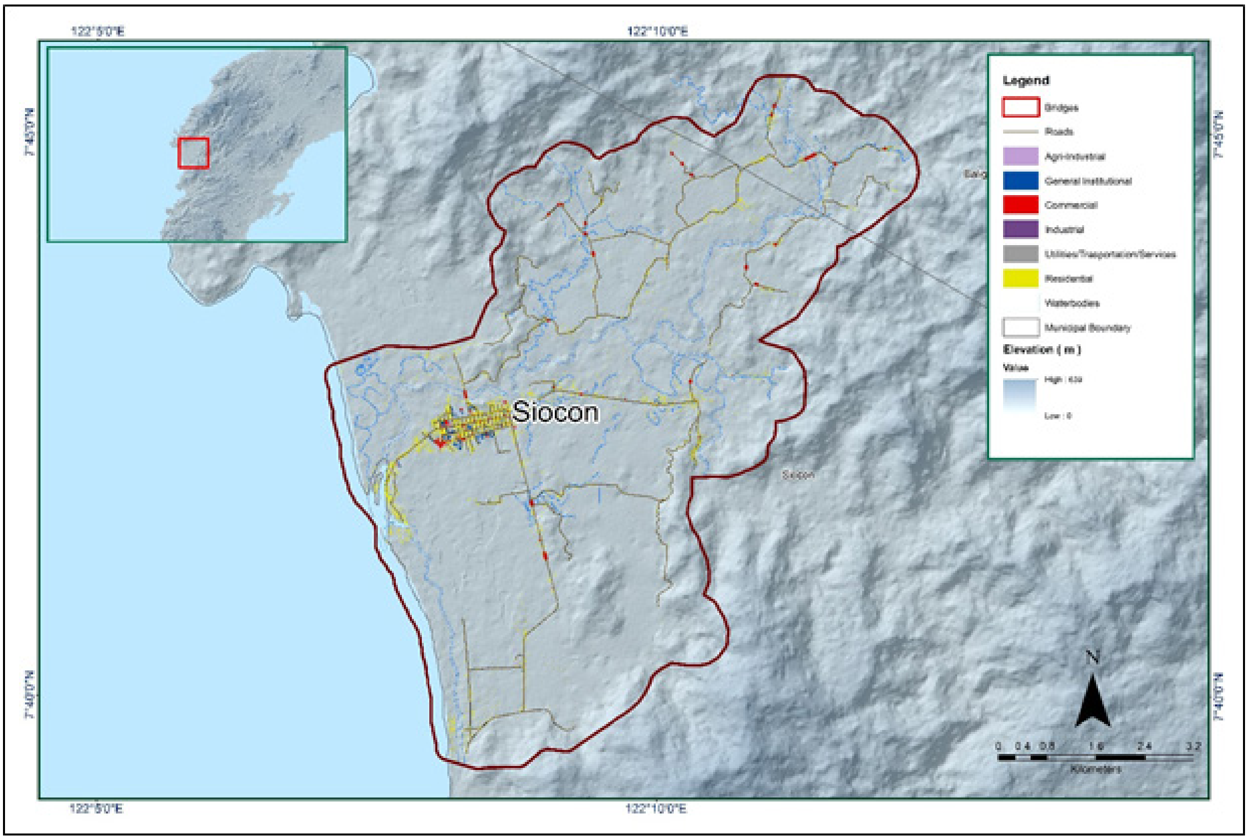


Figure 28. Extracted features for Siocon Floodplain.

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

Engr. Louie P. Balicanta, Engr. Joemarie S. Caballero, Ms. Patrizcia Mae. P. dela Cruz, Engr. Kristine Ailene B. Borromeo, Ms. Jeline M. Amante, Marie Angelique R. Estipona, Charie Mae V. Manliguez, Engr. Janina Jupiter, Vie Marie Paola M. Rivera

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

4.1 Summary of Activities

The AB Surveying and Development (ABSD) conducted a field survey in Siocon River onApril 10, 13, 14, 15 and 30, 2016 with the following scope: cross-section, bridge as-built and water level marking in MSL of Siocon Bridge, bathymetric survey from the downstream in Brgy. Bucana to upstream in Brgy. SuhaileArabi and manual bathymetric from downstream in Brgy. SuhaileArabi to upstream in Brgy. Malipot. Random checking points for the contractor's cross-section and bathymetry data were gathered by DVC on August 16-28, 2016 using an Ohmex™ Single Beam Echo Sounder and Trimble® SPS 882 GNSS PPK sAugust 21-31, 2016 survey technique. In addition to this, validation points acquisition survey was conducted covering the Siocon River Basin area. The entire survey extent is illustrated in Figure 29.

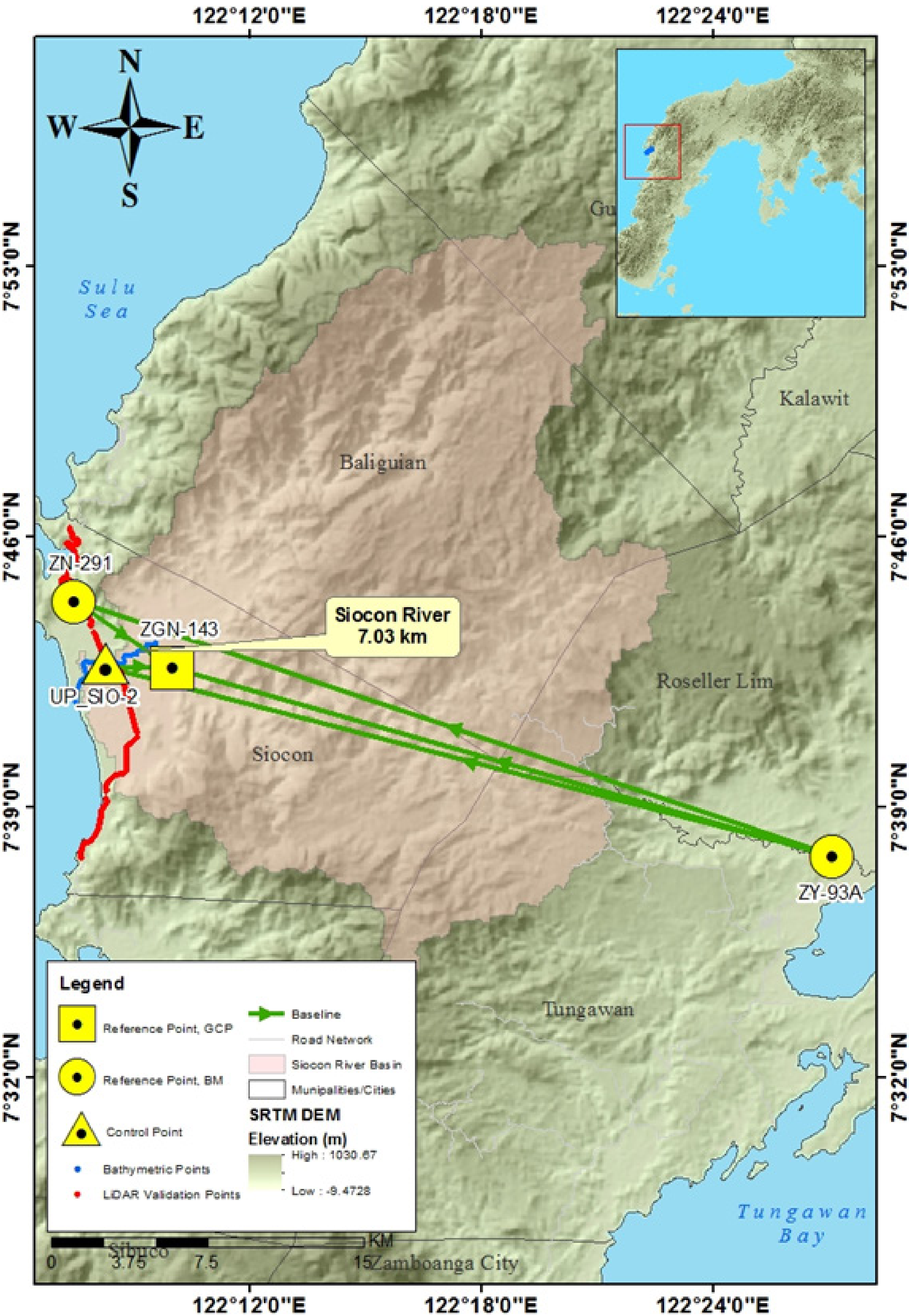


Figure 29. Extent of the bathymetric survey (in blue line) in Siocon River and the LiDAR data validation survey (in red)

4.2 Control Survey

The GNSS network used for Siocon River is composed of two (2) loops established on October 27, 2016 occupying the following reference points: ZGN-143, a second-order GCP, in Brgy. Lituban, Siocon, Zamboanga del Norte; ZN-291, a first-order BM, in Brgy. Matiag, Siocon, Zamboanga Del Norte; and ZY-93A, a first-order BM, in Tupilac, Roseller Lim, Zamboanga Sibugay.

One (1) control point established in the area by ABSD was also occupied: UP_SIO-1 at side of Limpapa Bridge foot walk in Brgy. Limpapa, Sibuco, Province of Zamboanga Del Norte.
Table C-1 List of reference and control points used during the survey in Siocon River (Source: NAMRIA, UP-TCAGP)

The summary of reference and control points and its location is summarized in Table 19 while GNSS network established is illustrated in Figure 30.

Table 19. List of Reference and Control Points used in Siocon River

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (Meter)	Elevation in MSL (Meter)	Date Established
ZGN-143	2nd order, GCP	7°42'35.88195"N	122°10'00.72650"E	83.626	17.541	2009
ZN-291	1st order, BM	7°44'18.26836"N	122°07'28.17844"E	142.519	77.495	2009
ZY-93A	1st order, BM	7°37'43.22502N	122°27'05.57376"E	83.892	15.716	2013
UP_SIO-2	Established	7°42'42.92836"N	122°08'17.14229"E	81.544	16.044	04/14/16

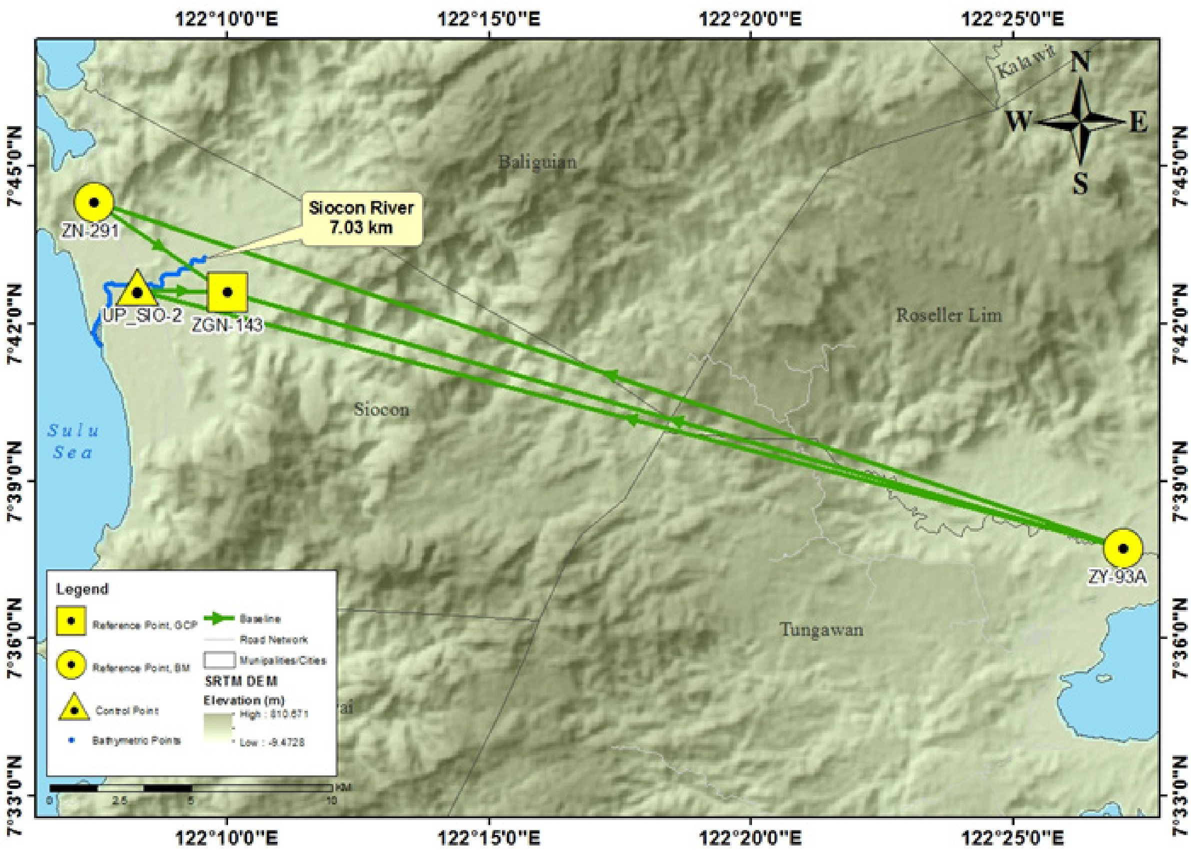


Figure 30. Siocon River Basin Control Survey Extent

The GNSS set-ups on recovered reference points and established control points in Siocon River are shown from Figure 31 to Figure 34.

Figure 31. GNSS base set up, Trimble® SPS 852, at ZGN-143, located inBrgy. Lituban, Siocon, Zamboanga del Norte

Figure 32. GNSS receiver set up, Trimble® SPS 985, at ZN-291, located in Brgy. Matiag, Siocon, Zamboanga Del Norte

Figure 33. GNSS base set up, Trimble® SPS 852, at ZY-93A, located in Brgy.Tupilac, Roseller Lim, Zamboanga Sibugay

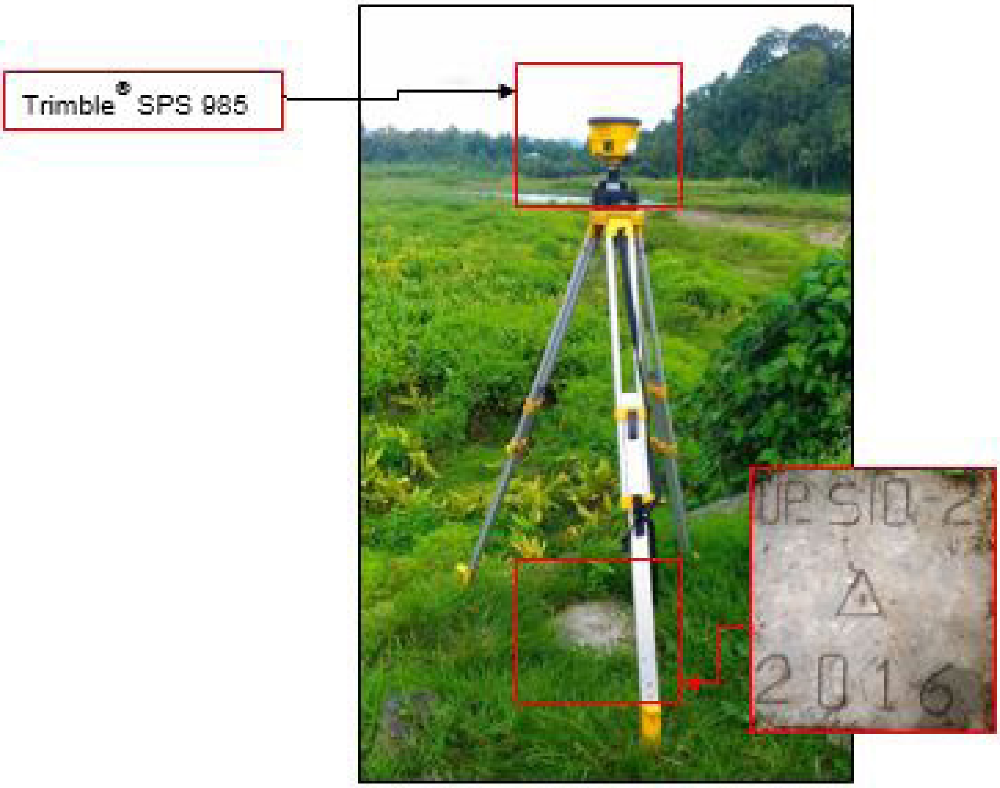


Figure 34. GNSS base set up, Trimble® SPS 852, at UP_SIO-1 at the side of Limpapa Bridge foot walk in Brgy. Limpapa, Sibuco, Province of Zamboanga Del Norte

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 Siocon River Basin is summarized in Table 20 generated by TBC software.

Table 20. Baseline Processing Report for Siocont River Static Survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	Height (m)
UP_SIO-2 --- ZY-93A	10-24-2016	Fixed	0.003	0.018	284°55'44"	35787.953	-2.34
ZN-291 --- ZY-93A	10-24-2016	Fixed	0.008	0.008	288°36'41" 3	38069.051	58.628
ZGN-143 --- ZY-93A	10-24-2016	Fixed	0.004	0.004	285°59'33"	32670.258	-0.290
UP_SIO-2 --- ZN-291	10-24-2016	Fixed	0.006	0.006	332°52'33"	3290.862	60.974
UP_SIO-2 --- ZGN-143 (	10-24-2016	Fixed	0.003	0.003	93°53'58"	3181.642	2.090
ZN-291 --- ZGN-143	10-24-2016	Fixed	0.007	0.007	123°55'57"	5634.290	-58.888

As shown in Table 20 a total of six (6) baselines were processed with coordinate and ellipsoidal height values of ZY-93A 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 21 to Table 23 for the complete details. Refer to Annex A for the computation for the accuracy of ABSD.

The four (4) control points, ZGN-143, ZN-291, ZY-93A, and UP_SIO-2 were occupied and observed simultaneously to form a GNSS loop. The coordinates and ellipsoidal height of ZY-93A were held fixed during the processing of the control points as presented in Table 21. Through this reference point, the coordinates and ellipsoidal height of the unknown control points will be computed.

Table 21. Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
ZY-93A	Grid				Fixed
ZY-93A	Global	Fixed	Fixed		
Fixed = 0.000001(Meter)					

The list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 22. All fixed control points have no values for grid errors and elevation error.

Table 22. Adjusted Grid Coordinates

Point ID	Easting	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
ZGN-143	408122.723	0.004	852324.121	0.004	17.541	0.032	
ZN-291	403455.805	0.006	855477.945	0.007	77.495	0.038	
ZY-93A	39506.741	?	843285.944	?	15.716	?	LLe
UP_SIO-2	404949.817	0.004	852546.826	0.004	16.044	0.030	

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

a. ZGN-143

horizontal accuracy	=	$\sqrt{(0.4)^2 + (0.4)^2}$
	=	$\sqrt{0.16 + 0.16}$
	=	0.57< 20 cm
vertical accuracy	=	3.2< 10 cm

b. ZN-291

horizontal accuracy	=	$\sqrt{(0.6)^2 + (0.7)^2}$
	=	$\sqrt{0.36 + 0.49}$
	=	0.92< 20 cm
vertical accuracy	=	3.8< 10 cm

c. ZY-93A

horizontal accuracy	=	fixed
vertical accuracy	=	fixed

d. UP_SIO-2

horizontal accuracy	=	$\sqrt{(0.4)^2 + (0.4)^2}$
	=	$\sqrt{0.16 + 0.16}$
	=	0.57< 20 cm
vertical accuracy	=	3.0< 10 cm

Following the given formula, the horizontal and vertical accuracy result of the four (4) occupied control points are within the required precision.

Table 23. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
ZGN-143	N7°42'35.88195"	E122°10'00.72650"	83.626	0.032	
ZN-291	N7°44'18.26836"	E122°07'28.17844"	142.519	0.038	
ZY-93A	N7°37'43.22502"	E122°27'05.57376"	83.892	?	LLe
UP_SIO-2	N7°42'42.92836"	E122°08'17.14229"	81.544	0.030	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 23. 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 24.

Table 24. Reference and control points used and its location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing	Easting	BM Ortho (m)
ZGN-143	2nd order, GCP	7°42'35.88195" N	122°10'00.72650" E	83.626	852324.121	408122.723	17.541
ZN-291	1st order, BM	7°44'18.26836" N	122°07'28.17844" E	142.519	855477.945	403455.805	77.495
ZY-93A	1st order, BM	7°37'43.22502" N	122°27'05.57376" E	83.892	843285.944	39506.741	15.716
UP_SIO-2	Established	7°42'42.92836" N	122°08'17.14229" E	81.544	852546.826	404949.817	16.044

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

Cross-section and as-built surveys were conducted on April 10, 2016at the upstream side of Siocon Bridge in Brgy. Poblacion, Municipality of Siocon,as shown in Figure 35. A Horizon® Total Station was utilized for this survey as shown in Figure 36.

Figure 35. Siocon Bridge facing upstream

Figure 36. As-built survey of Siocon Bridge

The cross-sectional line of Siocon Bridge is about 230.633 m with seventy-eight (78)cross-sectional points using the control pointsUP_SIO -1 and UP_SIO-2as the GNSS base stations. The location map, cross-section diagram, and the bridge data form are shown in Figure 37 to Figure 39.

No bridge cross-section or bridge points checking data were gathered for Siocon Bridge because the contractor's data passed the quality assessment.

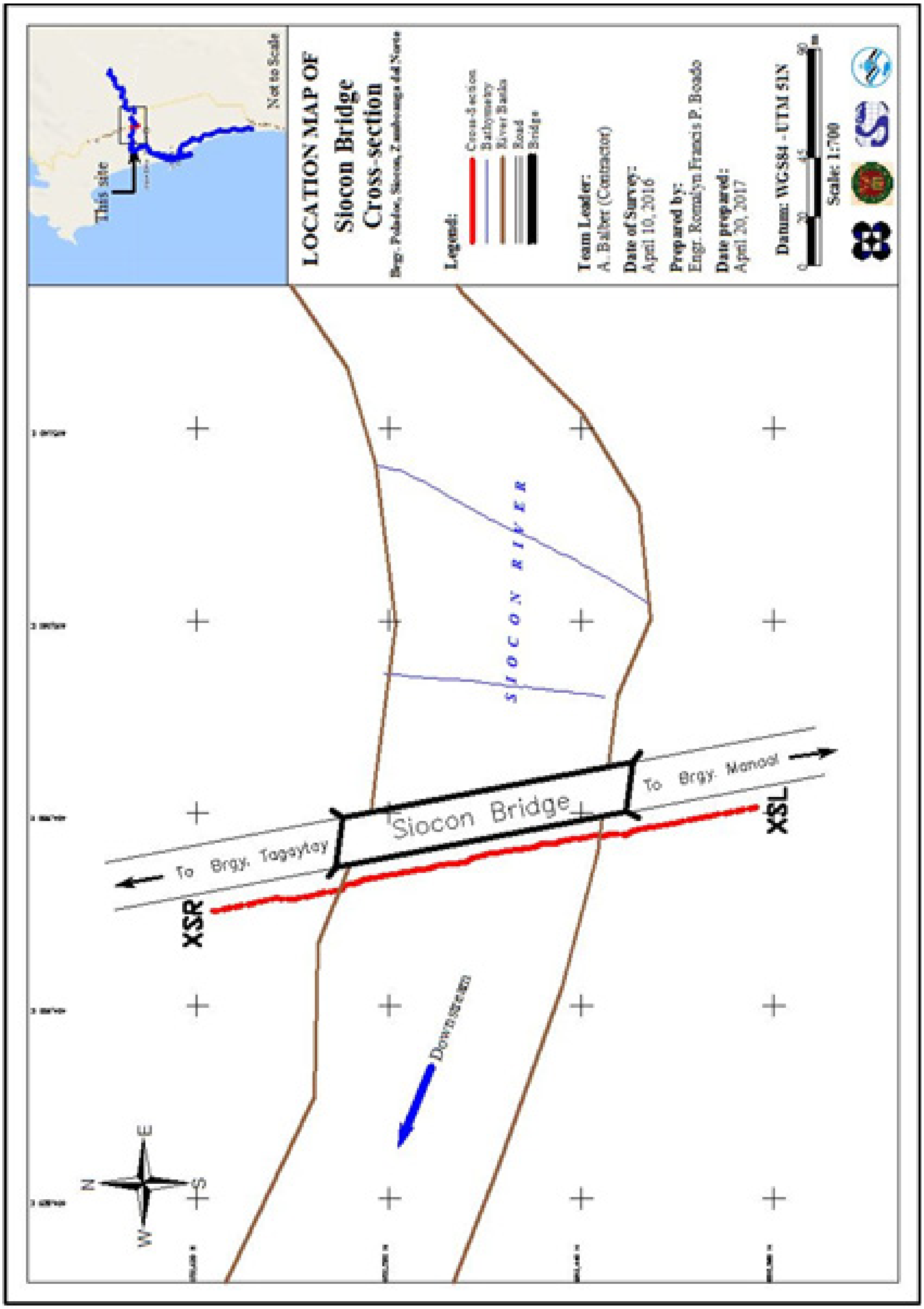


Figure 37. Location map of the Siocon Bridge cross section

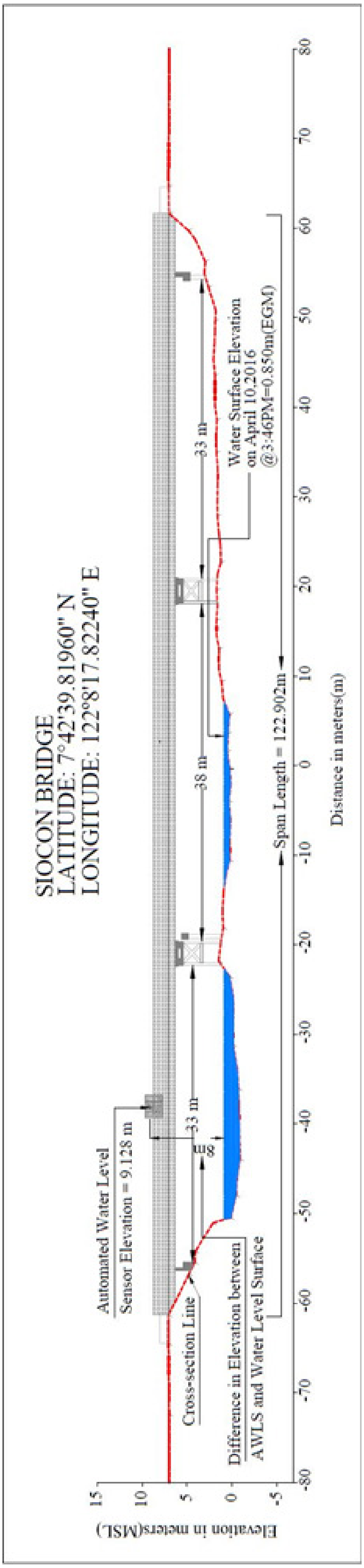


Figure 38. Siocon Bridge Cross-section Diagram

Bridge Data Form

Bridge Name: Siocon

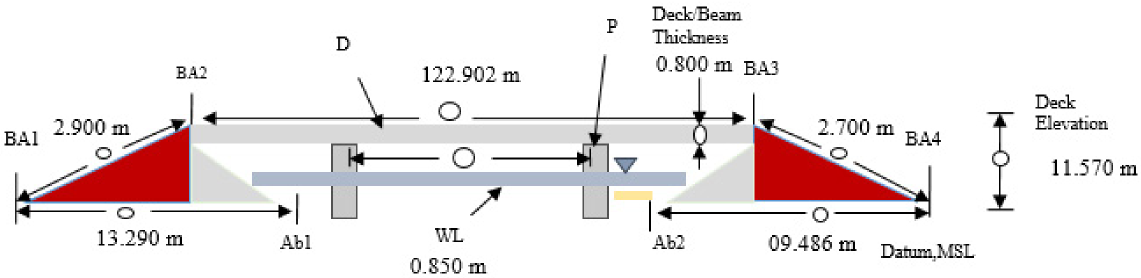
River Name: Siocon River
Location (Brgy,City,Region): Brgy. Poblacion, Siocon, Zamboanga Del Norte

Survey Team: A. Balber
Date and Time: April 10, 2016, 3:46 P.M.

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	2.900 m	
2. BA2-BA3	122.902 m	
3. BA3-BA4	2.700 m	
4. BA1-Ab1	13.290 m	
5. Ab2-BA4	9.486 m	
6. Deck/beam thickness	0.800 m	
7. Deck elevation	11.570 m	

Note: Observer should be facing downstream

Figure 39. Pilot bridge as-built form

Water surface elevation of Siocon River was determined by a Horizon® Total Station on April 10, 2016, 3:46 Pm at Siocon Bridge area with a value of 0.850 m in MSL as shown in Figure 38. This was translated into marking on the bridge's pier as shown in Figure 40. The marking will serve as reference for flow data gathering and depth gauge deployment of the partner HEI responsible for Siocon River, the Ateneo de Zamboanga University.

Figure 40. Water-level markings on Siocon Bridge

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted by DVBC on August 22, 2016 using a survey grade GNSS Rover receiver, Trimble® SPS 985, mounted on a range pole which was attached on the side of the vehicle as shown in Figure 41. It was secured with cable ties and ropes to ensure that it was horizontally and vertically balanced. The antenna height was 1.90 m and measured from the ground up to the bottom of the quick release of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with ZGS-99 occupied as the GNSS base station in the conduct of the survey.

Figure 41. Validation points acquisition survey set-up for Siocon River

The survey started from Brgy. Sta. Maria, Municipality of Siocon, Zamboanga del Norte going south along national high way covering eight (8) barangays in the Municipality of Siocon, Zamboanga del Norte, and ending in Brgy. Latabon, Municipality of Siocon, Zamboanga del Norte. The survey gathered a total of 3, 266 points with approximate length of 20.88 km using UP_SIO-2 as GNSS base station for the entire extent of validation points acquisition survey as illustrated in the map in Figure 42.

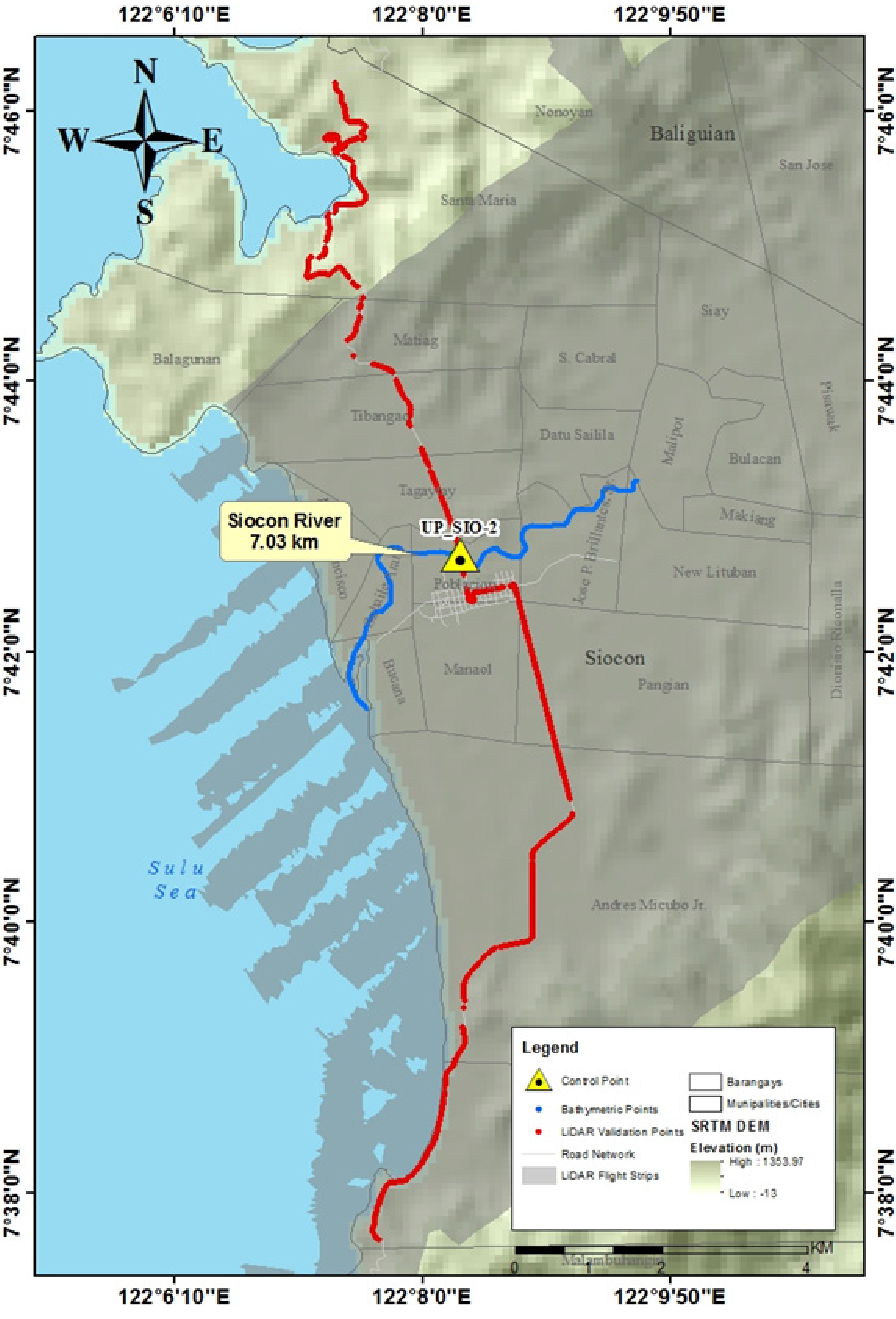


Figure 42. Validation points acquisition covering the Siocon River Basin Area

4.7 River Bathymetric Survey

Bathymetric survey was executed on April 13 and 14, 2016using a Hi-Target™ Echo Sounderand a Horizon® Total Station as illustrated in Figure 43. The survey started in Brgy. Andres Micubo, Jr., Municipality of Siocon, Zamboanga del Norte with coordinates 7°39'42.30967"N, 122°8'13.52472"E and ended at the mouth of the river in Brgy. Malipot, Municipality of Siocon as well, with coordinates 7°43'17.36026"N, 122°9'41.34981"E. The control points UP_SIO-1 and UP_SIO-2 were used as GNSS base stations all throughout the entire survey.

Gathering of random points for the checking of ABSD's bathymetric data was performed by DVBC on August 21-31, 2016 using an Ohmex™ Single Beam Echo Sounder and Trimble® SPS 882 GNSS PPK survey technique. A map showing the DVC bathymetric checking points is shown in Figure 45.

Linear square correlation (R2) and RMSE analysis were also performed on the two (2) datasets. The computed R2 value of 0.93 is within the required range for R2, which is 0.85 to 1. Additionally, an RMSE value of 0.145 was obtained. Both the computed R2 and RMSE values are within the accuracy required by the program.

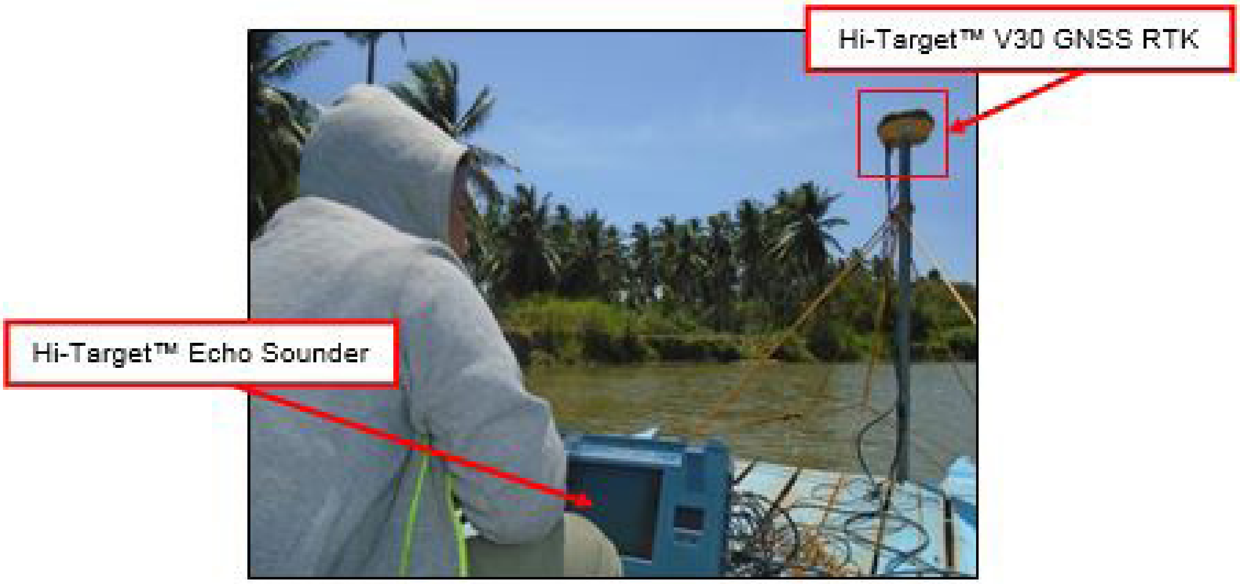


Figure 43. Bathymetric survey of ABSD at Siocon River using Hi-Target™ Echo Sounder (upstream)

The bathymetric survey for Siocon River gathered a total of 10,776 points covering 7.102 km km of the river traversing the barangays of Andres Micubo, Jr., Bucana, SuhaileArabi, and Mateo Francisco in the Municipality of Siocon, as shown in Figure 44. The manual bathymetric survey for Siocon River gathered a total of 1,386 points covering 4.286 km of the river traversing the barangays of Bucana, Poblacion, Jose P. Brillantes, Sr., and Malipot, in the Municipality of Siocon. A CAD drawing was also produced to illustrate the riverbed profile of Siocon River. As shown in Figure 46, the highest and lowest elevation has a 5-m difference. The highest elevation observed was 2.58 m above MSL located in Brgy. Malipot, Municipality of Siocon while the lowest was -3.55 m below MSL located in Brgy. Mateo Francisco, Municipality of Siocon.

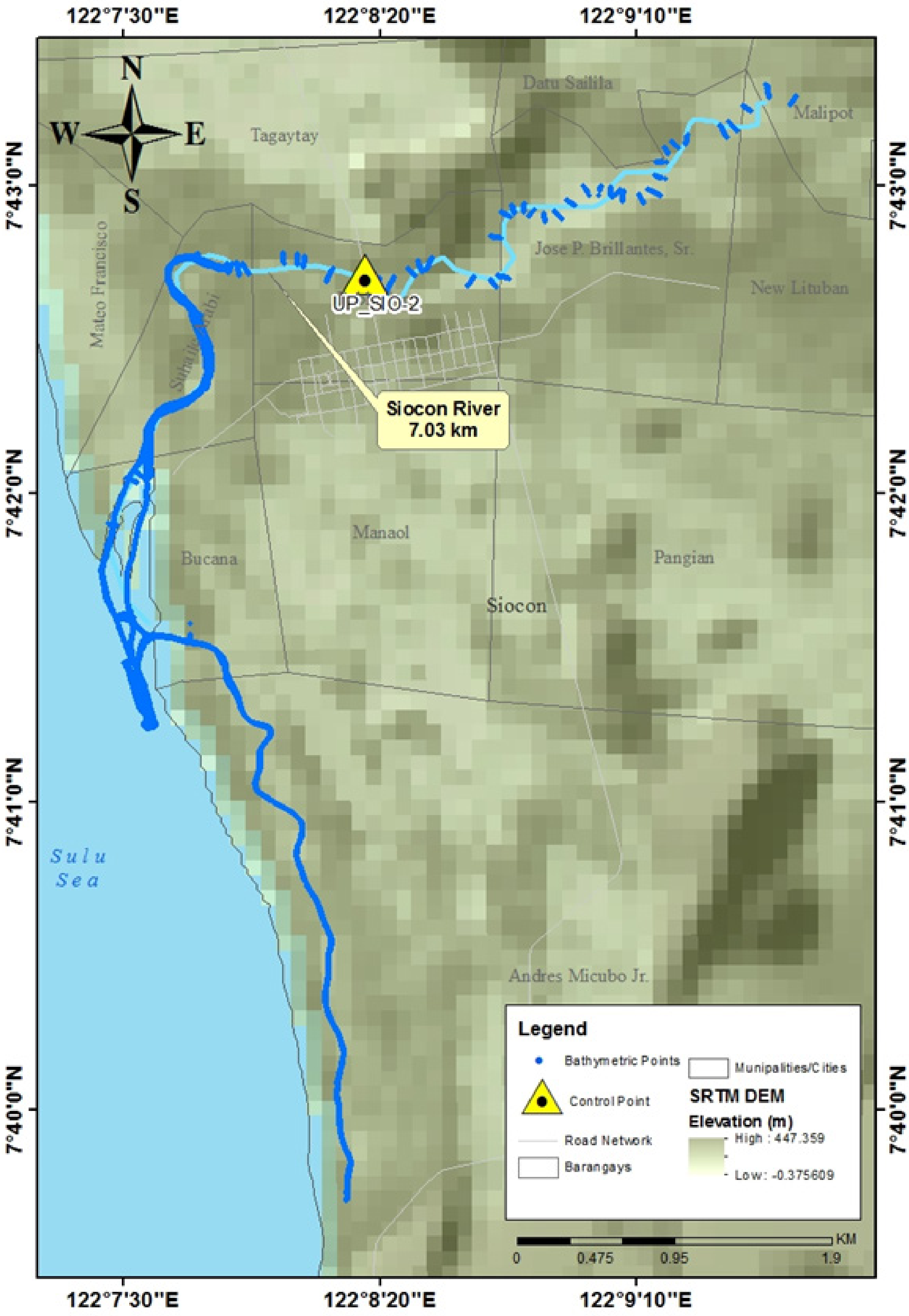


Figure 44. Bathymetric survey of Siocon River

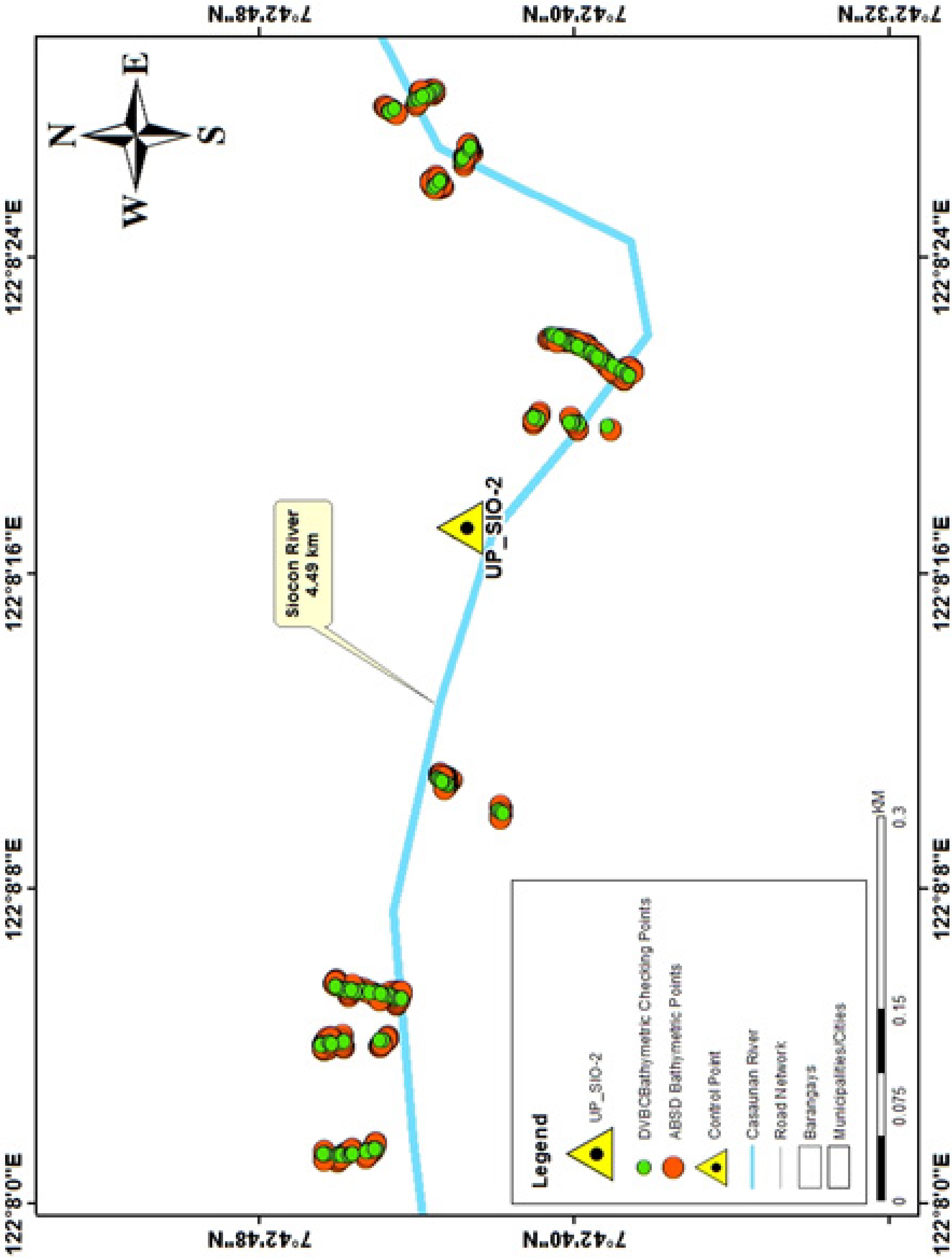


Figure 45. Quality checking points gathered along Siocon River by DVBC

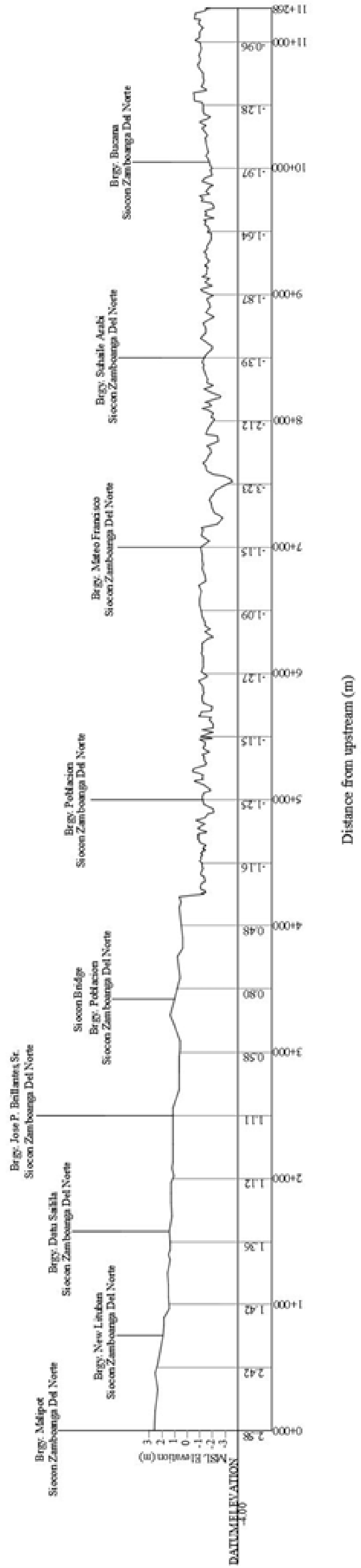


Figure 46. Siocon Riverbed Profile

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 Hydologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

Precipitation data was taken from a manually read Rain Gauge at Brgy. Poblacion, Siocon, Zamboanga del Norte (7° 42' 39.57" N, 122° 8' 18.76" E). (Figure 47). The precipitation data collection started from September 28, 2016 at 4:00 PM to September 29, 2016 at 10:00 PM with 10 minutes recording interval.

The total precipitation for this event in Siocon Bridge was 16.4 mm. It has a peak rainfall of 4.2 mm. on September 28, 2016 at 9:30 PM. The lag time between the peak rainfall and discharge is 5 hours and 10 minutes.

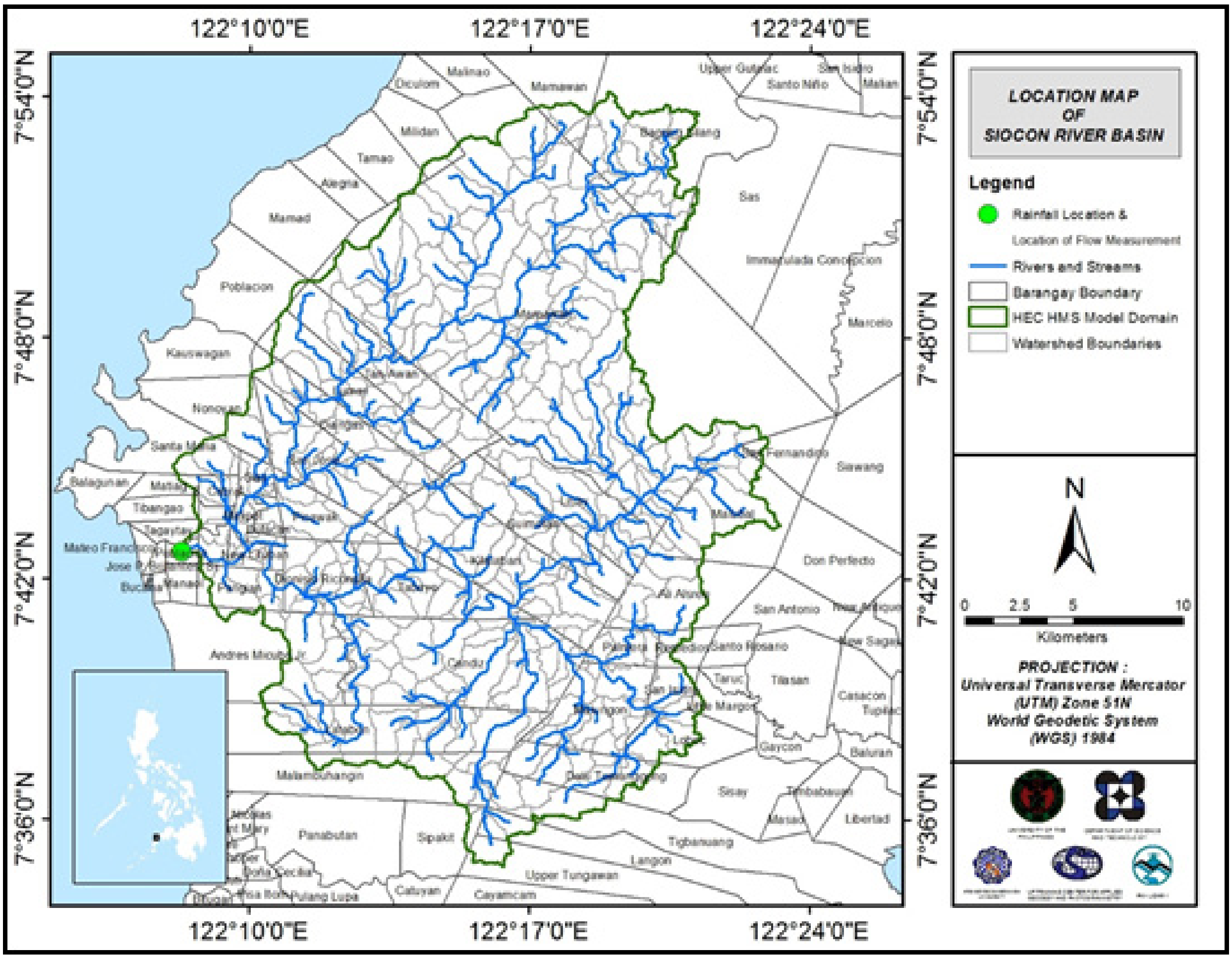


Figure 47. The location map of Siocon HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at a spillway at Siocon Bridge, Brgy. Malipot, Siocon, Zamboanga del Norte (7° 42’ 38.94” N, 122° 8’ 17.79” E). It gives the relationship between the observed water levels at Siocon Bridge and outflow of the watershed at this location.

For Siocon Bridge, the rating curve is expressed as Q = 1E-11e2.6164h as shown in Figure 49.

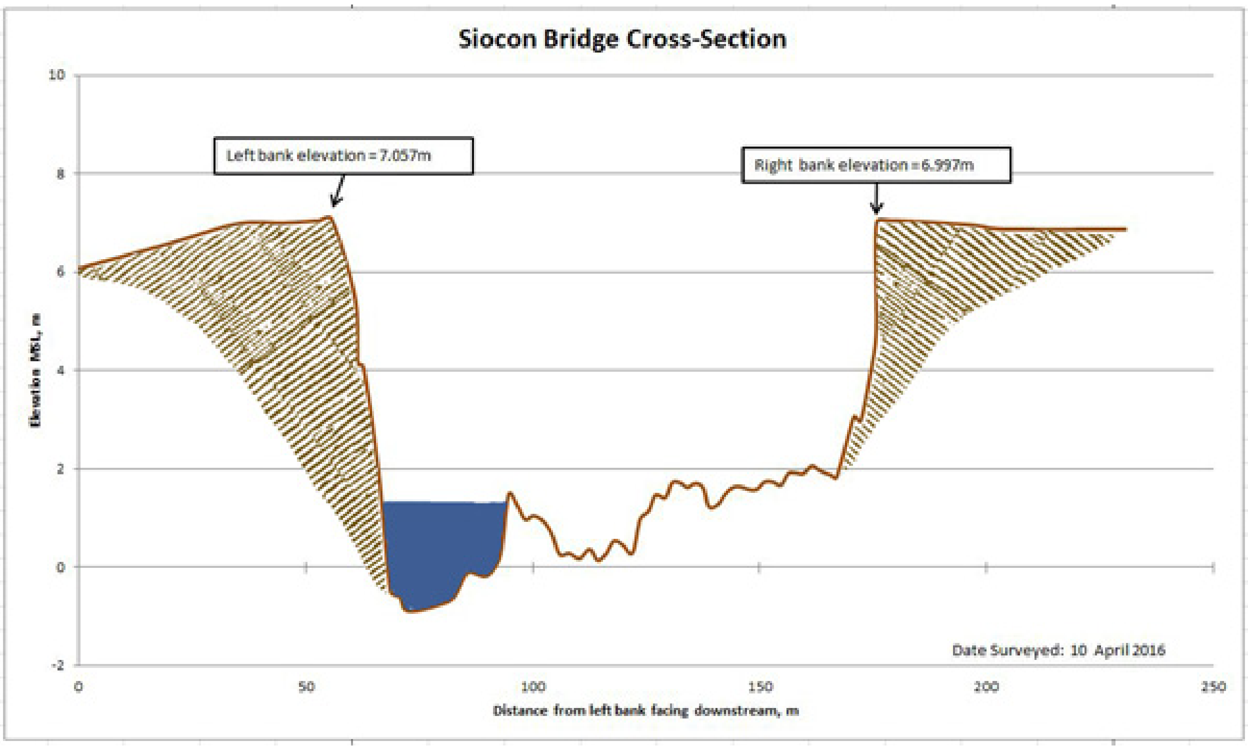


Figure 48. Cross-Section Plot of Siocon Bridge

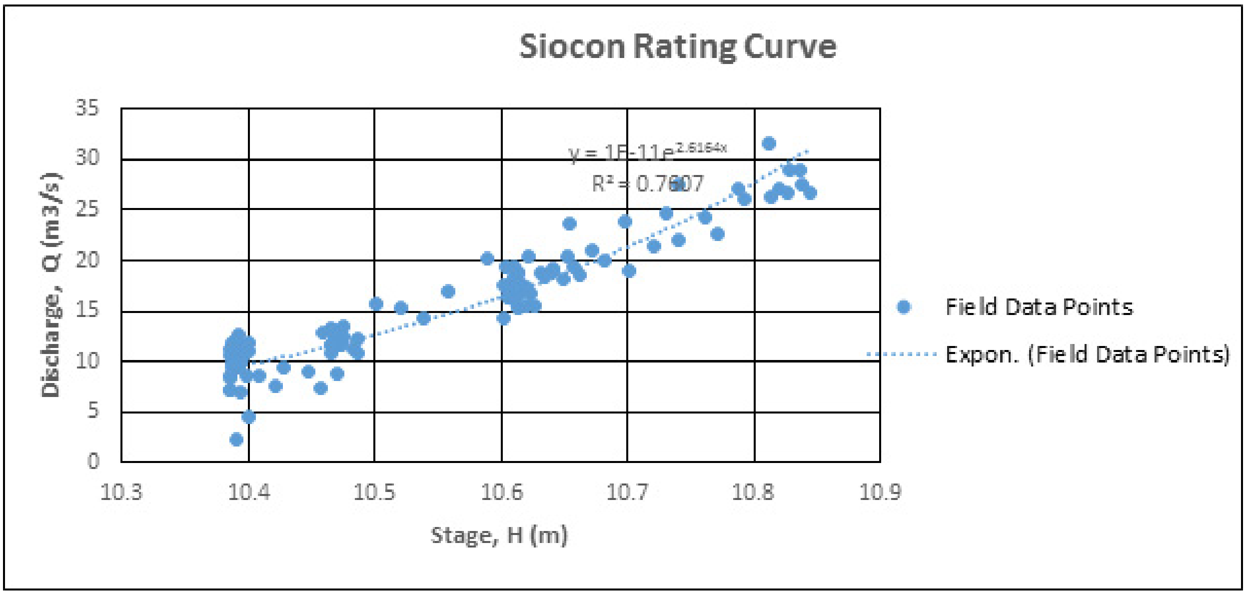


Figure 49. Rating Curve at Siocon Bridge, Brgy. Malipot, Siocon, Zamboanga del Norte

This rating curve equation was used to compute the river outflow at Siocon Bridge for the calibration of the HEC-HMS model shown in Figure 50. Peak discharge is 31.6 cubic meters per second at 2:40 PM, September 29, 2016.

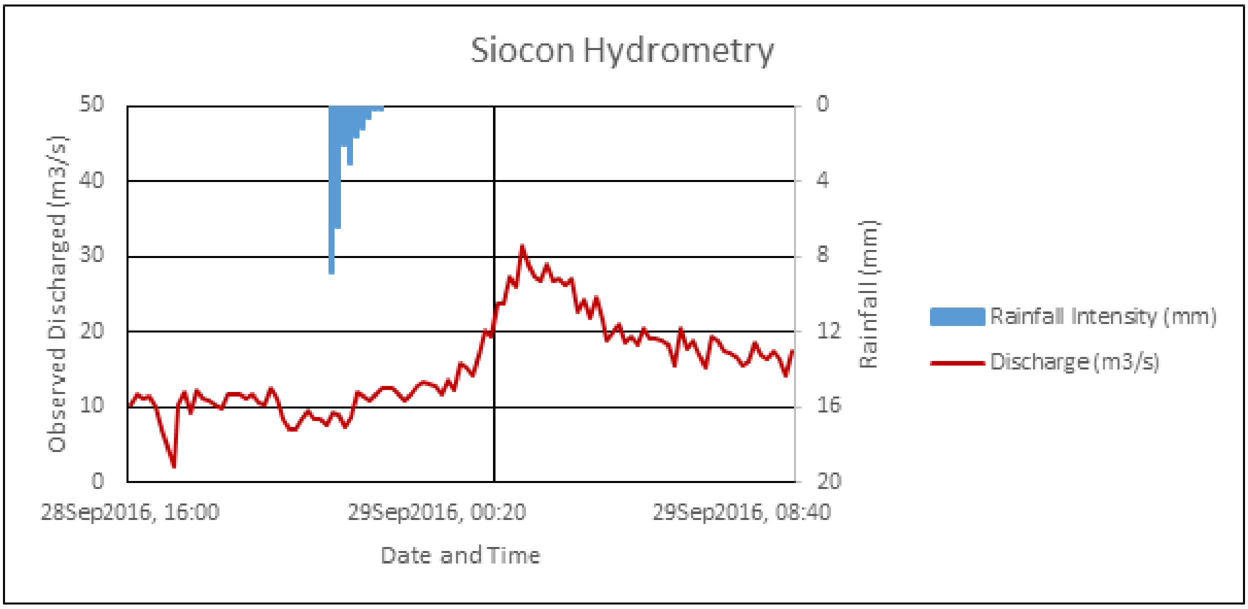


Figure 50. Rainfall and outflow data at Siocon Bridge used for modeling

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Zamboanga City 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 Siocon watershed. The extreme values for this watershed were computed based on a 59-year record.

Table 25. RIDF values for Zamboanga City Rain Gauge computed by PAGASA

COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION									
T (yrs)	10 mins	20 mins	30 mins	1 hr	2 hrs	3 hrs	6 hrs	12 hrs	24 hrs
2	15.5	23.3	28.4	36.9	45.6	50.7	60	66.1	77.3
5	21.4	31.6	38.3	50.4	61.2	38.2	82.5	91.5	107.8
10	25.3	37.1	44.8	59.4	71.6	79.8	97.5	108.3	127.9
15	27.5	40.2	48.5	64.4	77.4	86.4	105.9	117.8	139.3
20	29	42.3	51.1	68	81.5	91	111.8	124.4	147.3
25	30.2	44	53.1	70.7	84.7	94.5	116.3	129.5	153.4
50	33.9	49.1	59.2	79.1	94.4	105.4	130.4	145.3	172.3
100	37.5	54.2	65.3	87.4	104	116.2	144.3	161	191.1

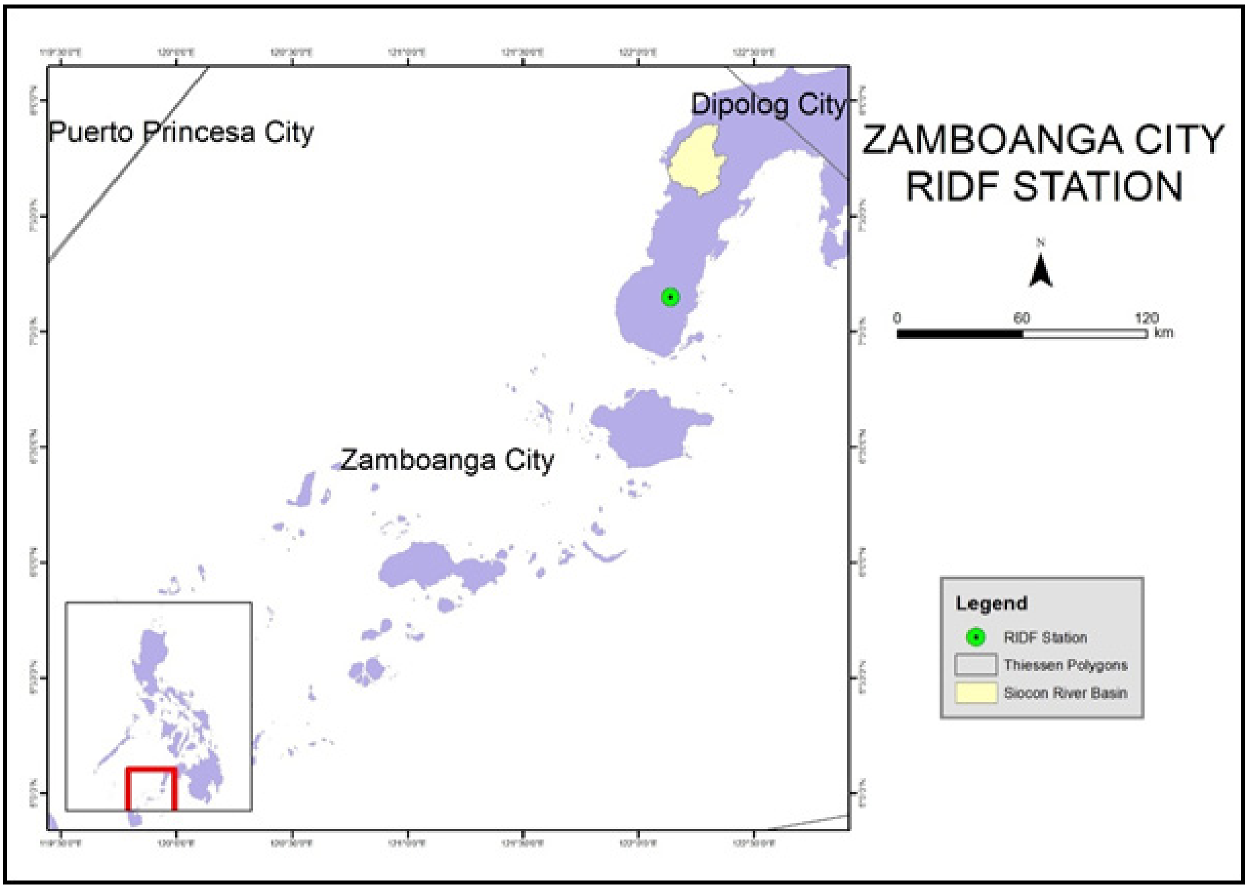


Figure 51. Dipolog City RIDF location relative to Siocon River Basin

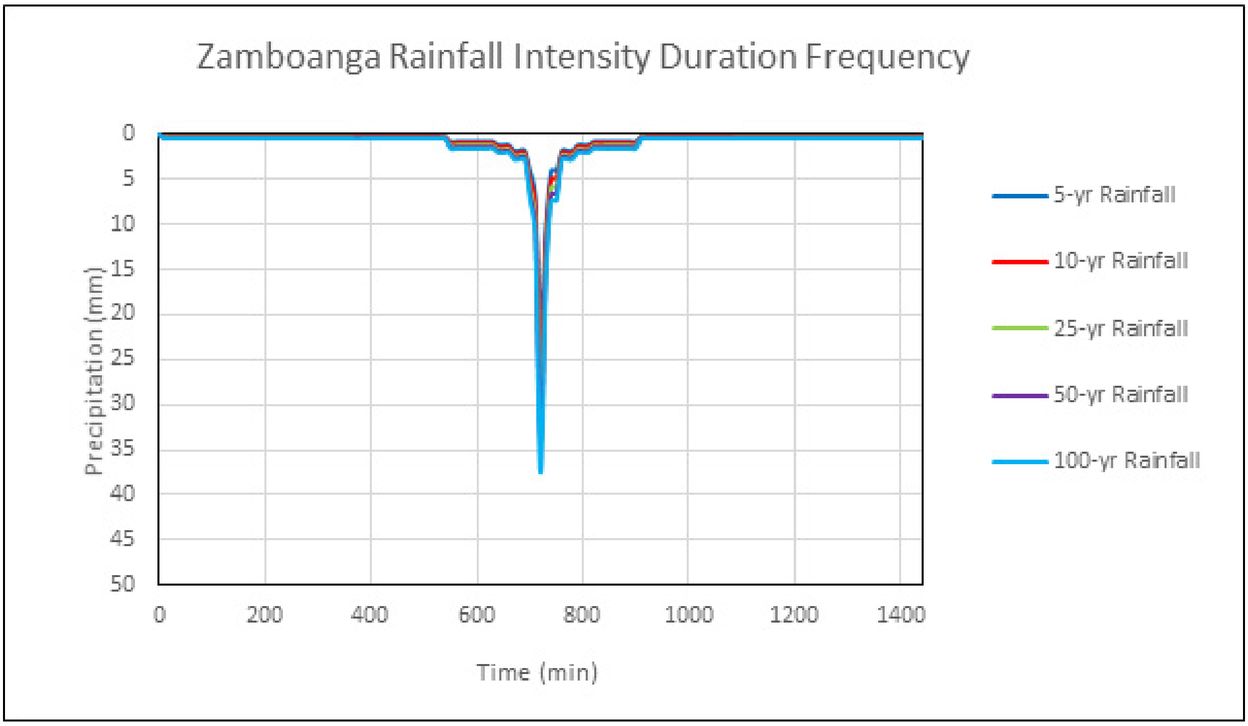


Figure 52. Synthetic storm generated for a 24-hr period rainfall for various return periods

5.3 HMS Model

The soil dataset was generated before 2004 by the Bureau of Soils under the Department of Agriculture (DA). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Siocon River Basin are shown in Figures 53 and 54, respectively.

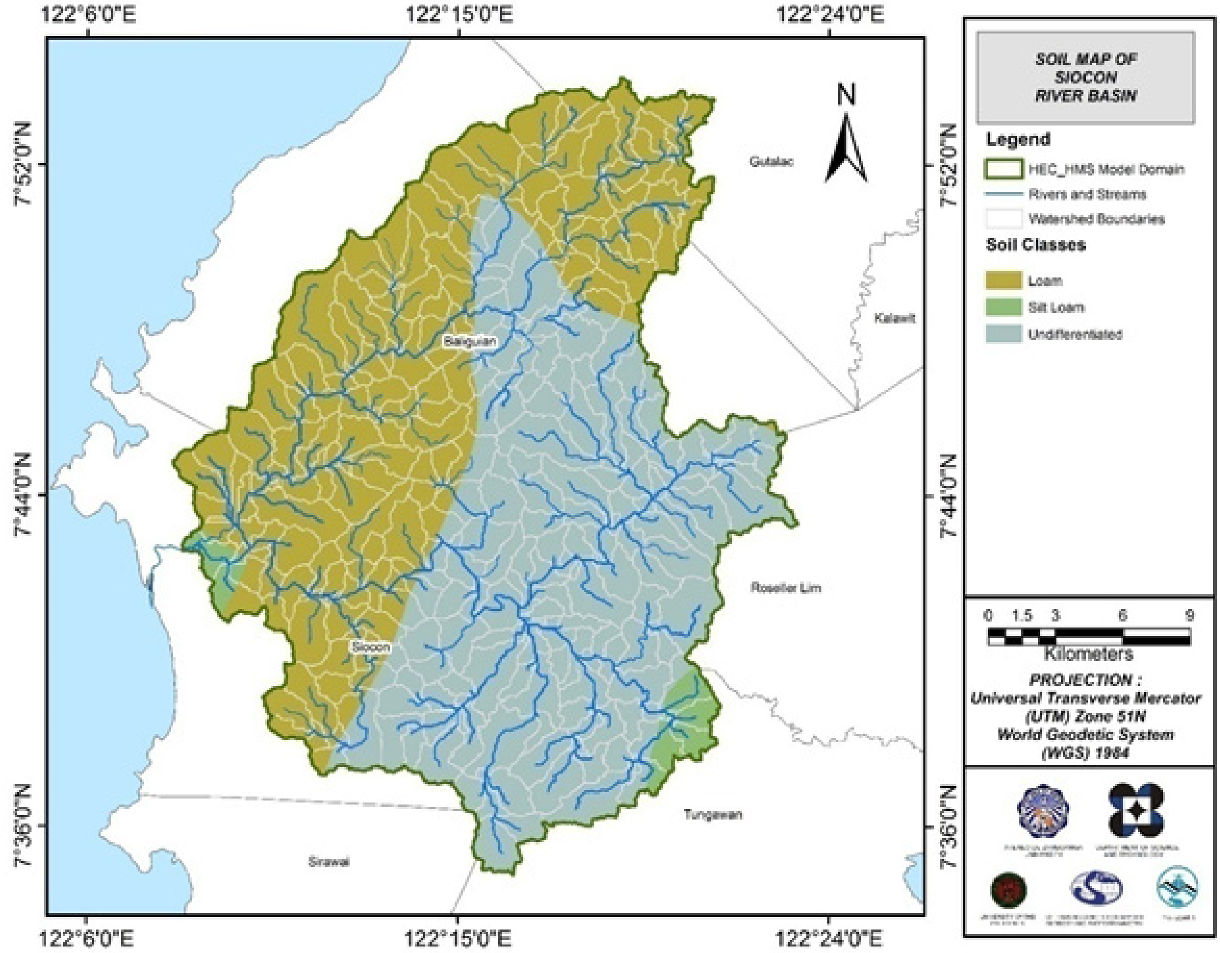


Figure 53. Soil Map of Siocon River Basin

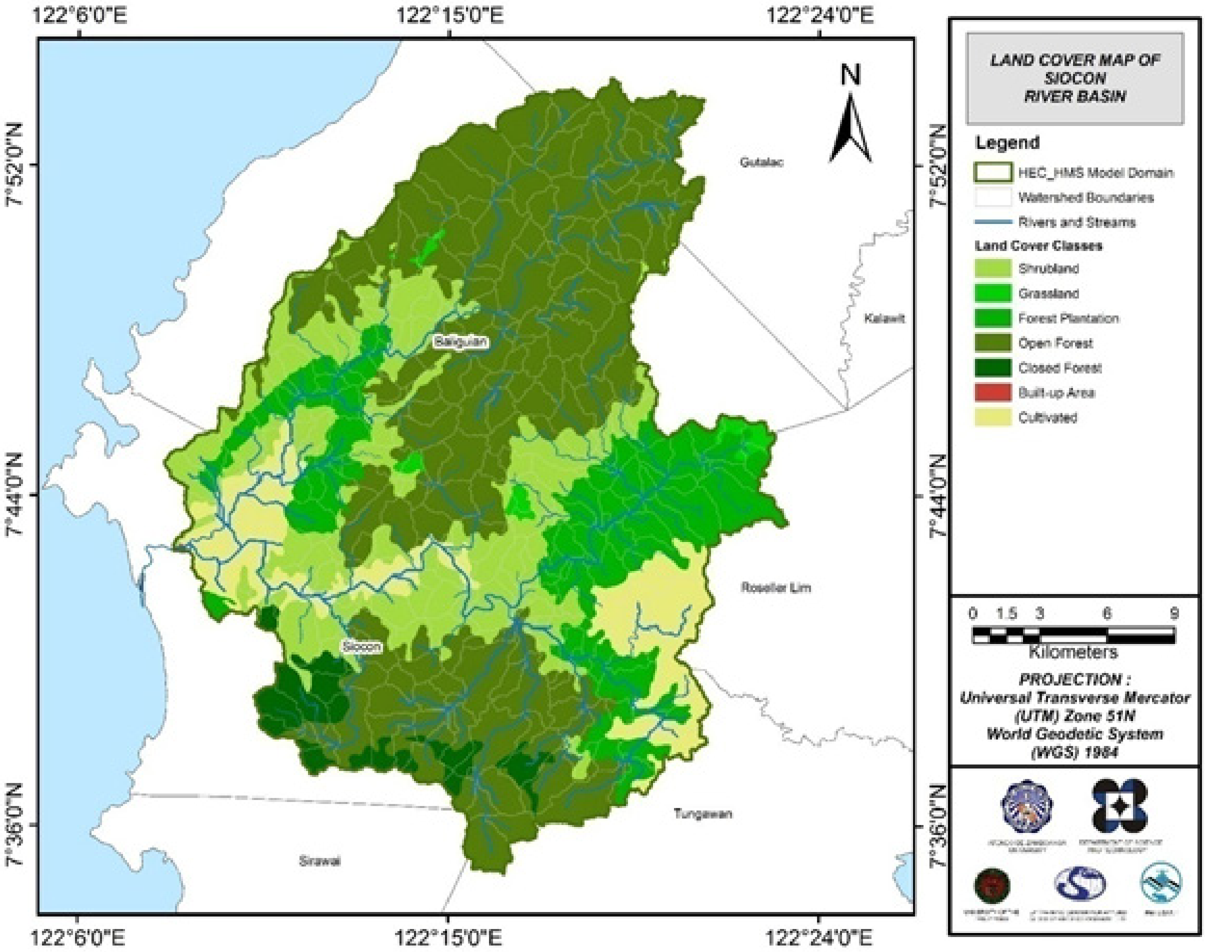


Figure 54. Land Cover Map of Siocon River Basin

For Siocon, the soil classes identified were loam, silt loam and undifferentiated mountain soil. The land cover types identified were shrubland, grassland, forest plantations, open and closed canopy forests, built-up areas and cultivated areas.

Figure 55. Slope Map of Siocon River Basin

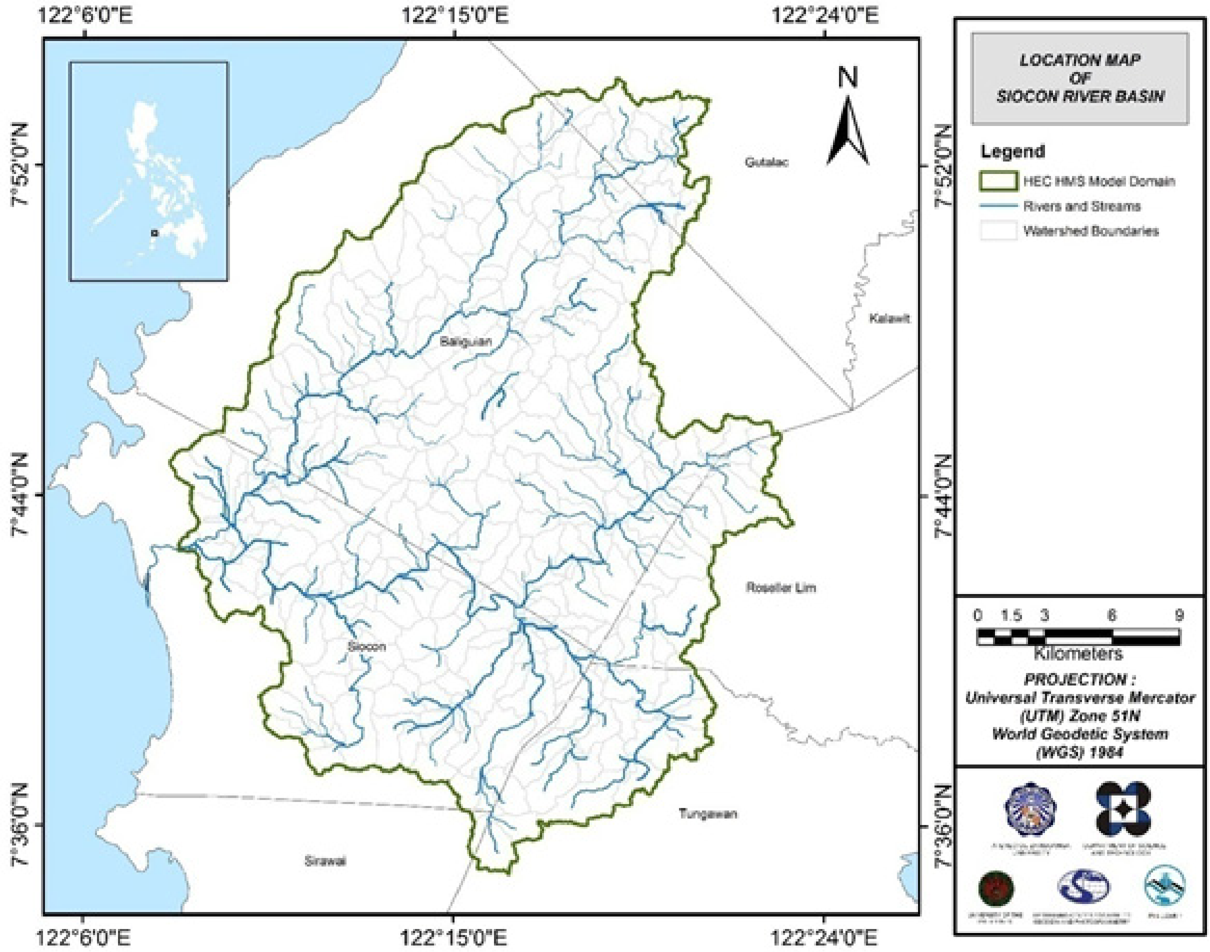


Figure 56. Stream delineation map of Siocon river basin

Using the SAR-based DEM, the Siocon basin was delineated and further subdivided into subbasins. The model consists of 309 sub basins, 154 reaches, and 154 junctions as shown in Figure 57. The main outlet is at Siocon Bridge, Brgy. Malipot, Siocon, Zamboanga del Norte. The model reach parameters are shown in Annex 10.

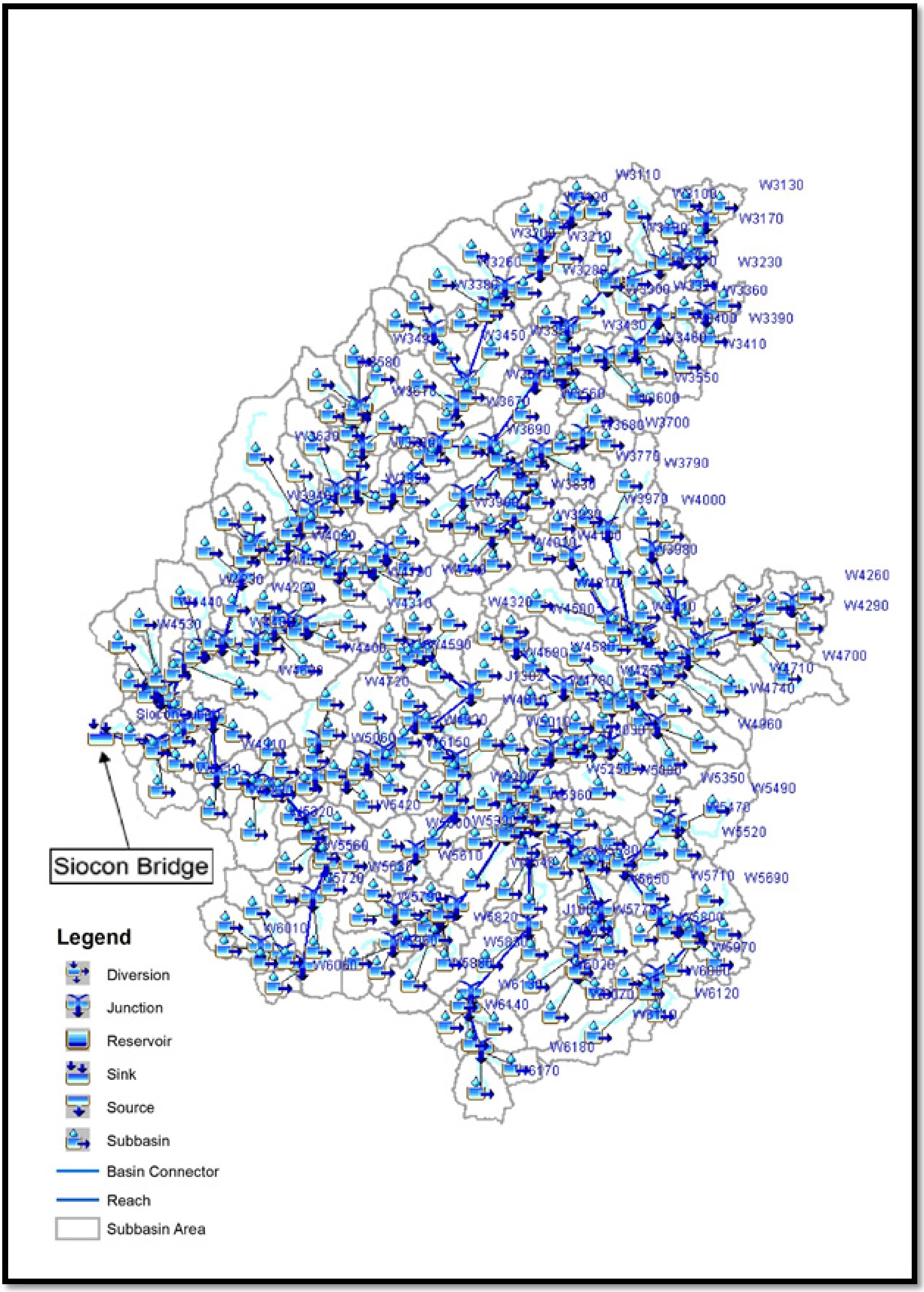


Figure 57. The Siocon river basin model generated using HEC-HMS

5.4 Cross-section Data

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

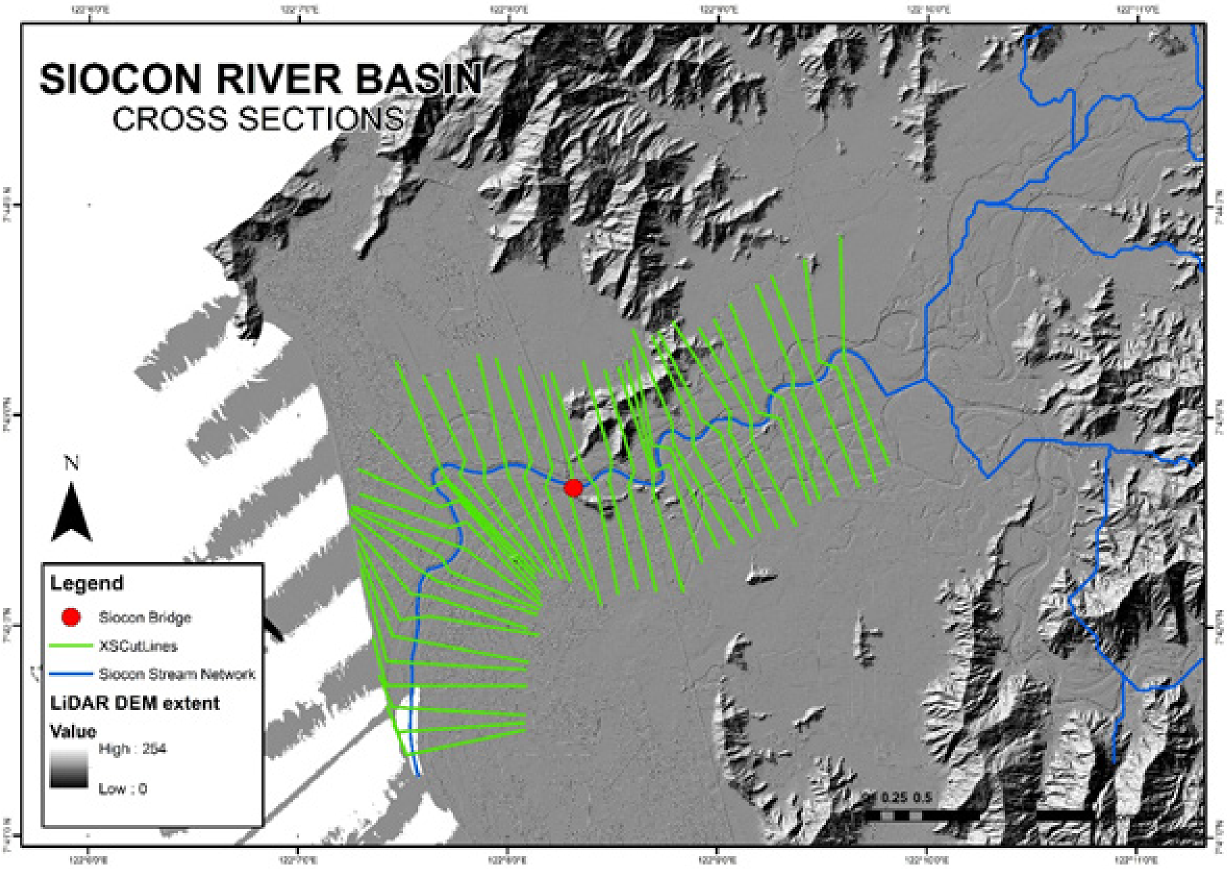


Figure 58. River cross-section of Siocon River generated through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

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

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

Figure 59. 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 52.89160 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.

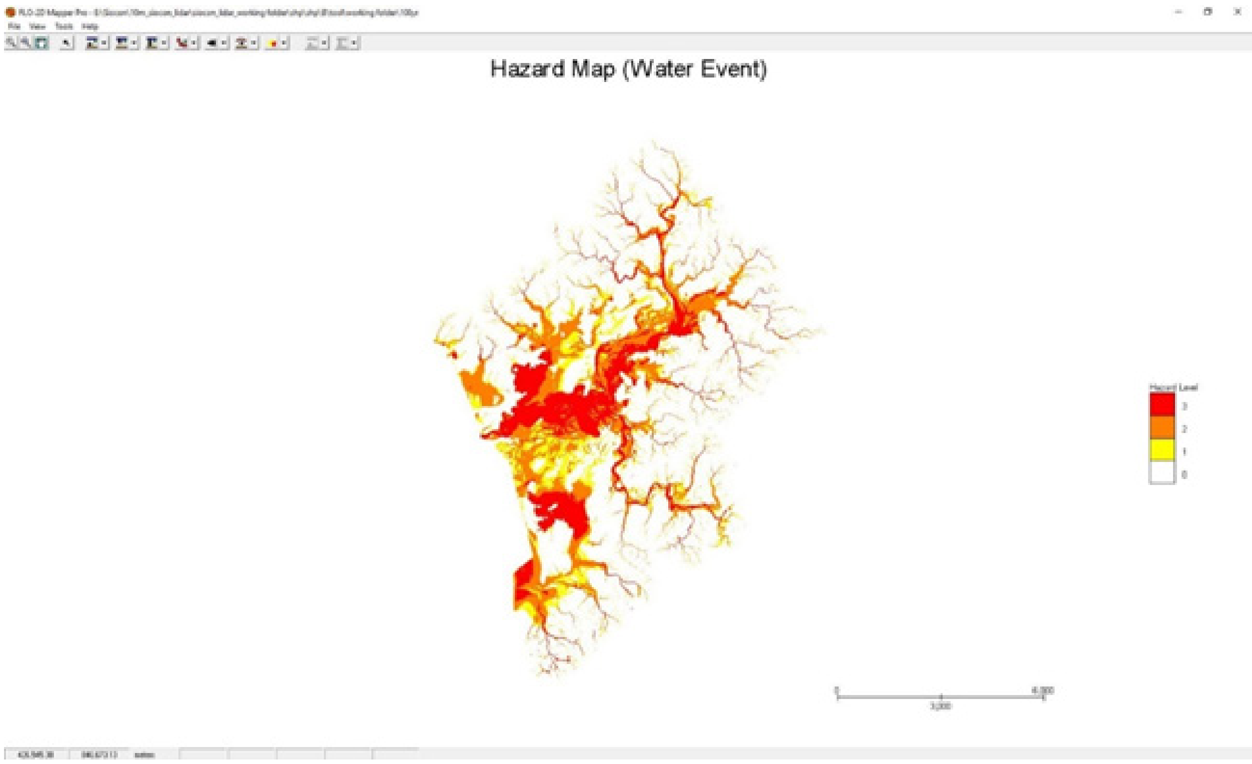


Figure 60. Generated 100-year rain return hazard map from FLO-2D Mapper

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 90708288.00 m2.

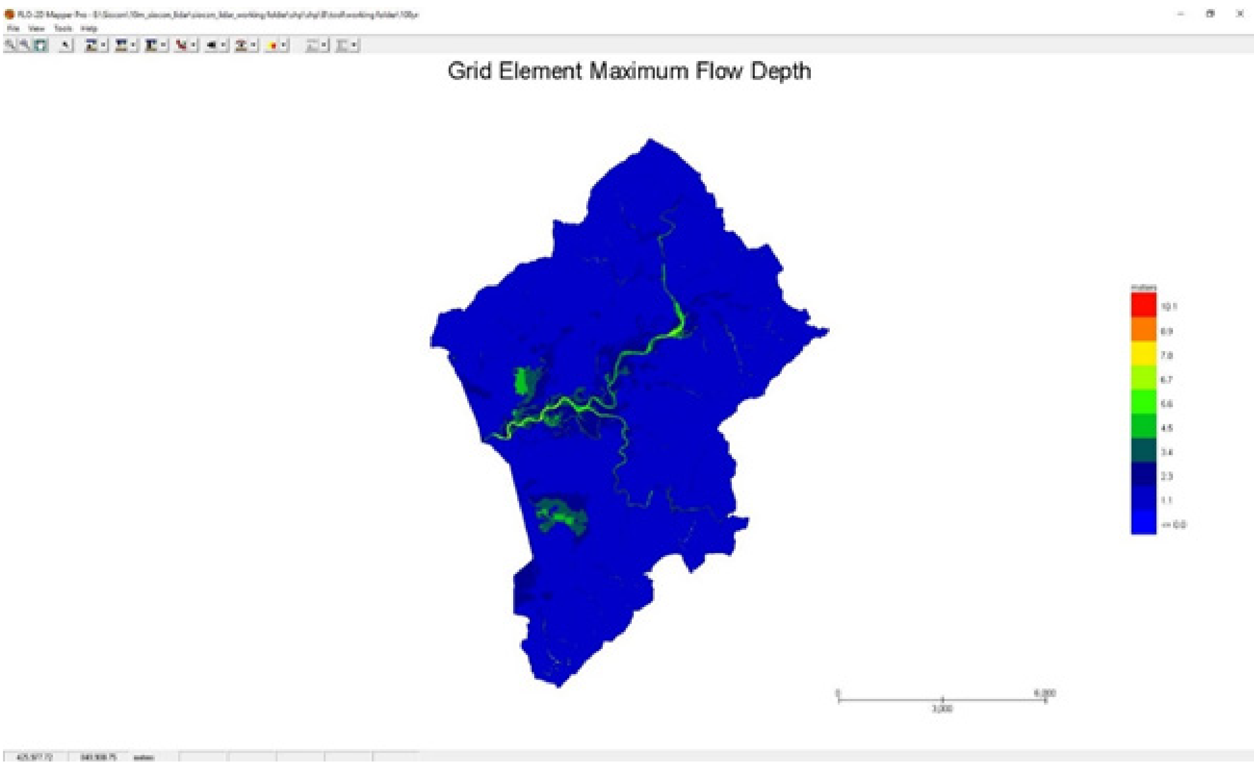


Figure 61. Generated 100-year rain return flow depth map from FLO-2D Mapper

There is a total of 63090433.92 m3 of water entering the model. Of this amount, 17737152.87 m3 is due to rainfall while 45353281.05 m3 is inflow from other areas outside the model. 8646352.00 m3 of this water is lost to infiltration and interception, while 15718643.21 m3 is stored by the flood plain. The rest, amounting up to 38725401.93 m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Siocon HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 62 shows the comparison between the two discharge data.

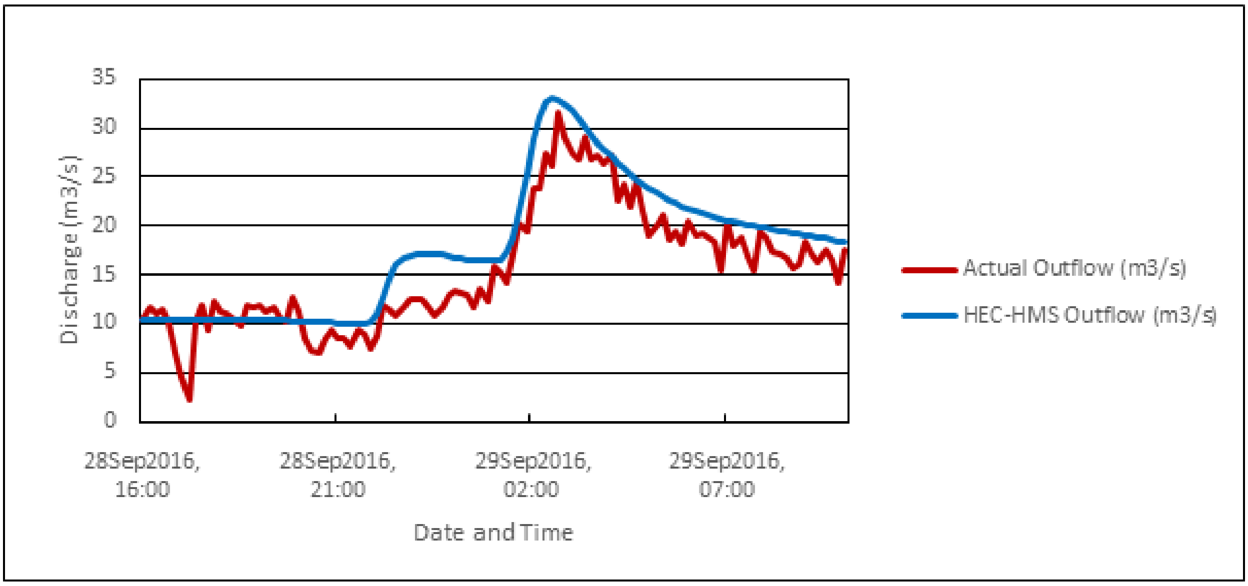


Figure 62. Outflow Hydrograph of Siocon produced by the HEC-HMS model compared with observed outflow

Enumerated in Table 26 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 26. Range of Calibrated Values for Siocon

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	7.16 – 27.52
			Curve Number	48 - 78
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.017 – 0.51
			Storage Coefficient (hr)	0.019 – 0.83
	Baseflow	Recession	Recession Constant	0.4
			Ratio to Peak	0.25
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.0135

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 7.16mm to 27.52mm means that there is some infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The range of curve numbers in this area is 48 – 78.The magnitude of the outflow hydrograph increases as curve number increases. For Siocon, the soil classes identified were loam, silt loam and undifferentiated mountain soil. The land cover types identified were shrubland, grassland, forest plantations, open and closed canopy forests, built-up areas and cultivated areas.

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.017 hours to 0.83 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 0.4 indicates that the basin is not likely to quickly go back to its original discharge. Ratio to peak of 0.25 indicates a shallower receding limb of the outflow hydrograph.

Table 27. Summary of the Efficiency Test of Siocon HMS Model

ACCURACY MEASURE	VALUE
RMS Error	2.524
r2	0.841
NSE	0.836
RSR	2.098
PBIAS	0.405

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 32.53197 (m3/s).

The Pearson correlation coefficient (r2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.7607.

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 0.768536.

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 -14.3558.

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 0.481107.

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 63) shows the Siocon outflow using the Zamboanga City Rainfall Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the 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.

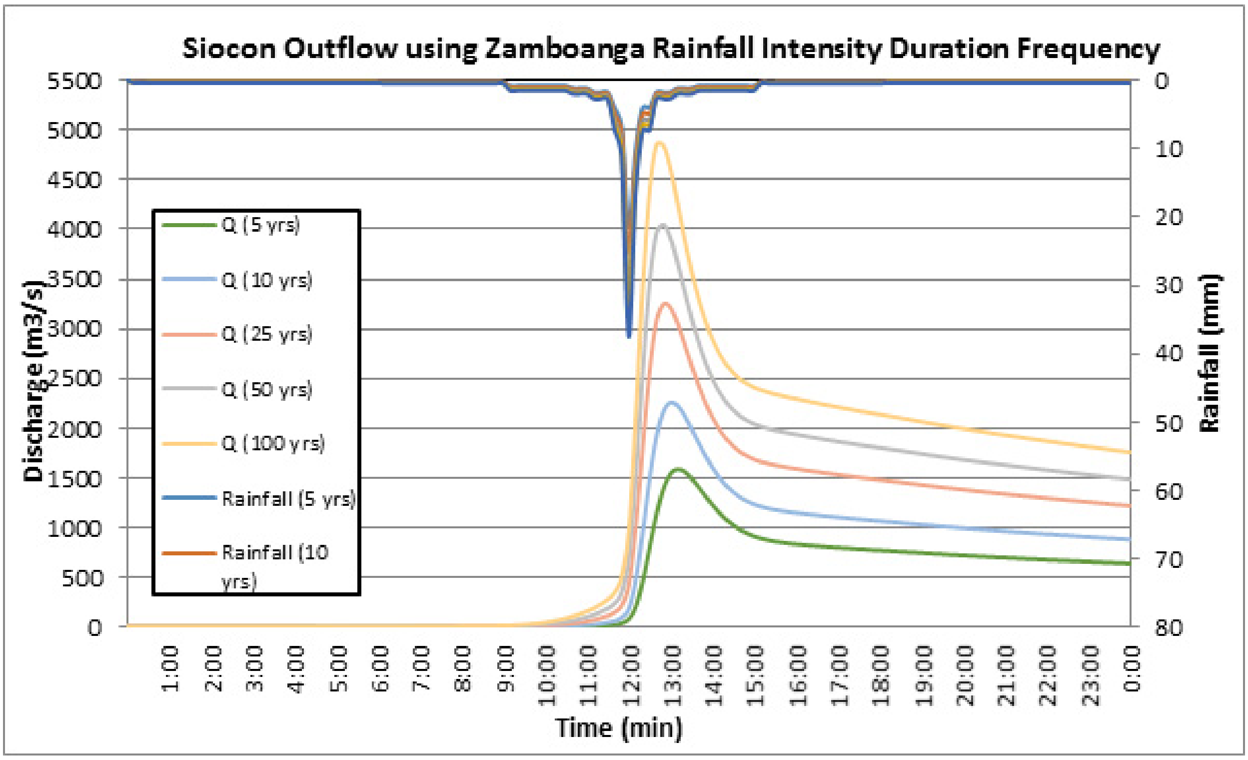


Figure 63. Outflow hydrograph at Siocon Bridge Station generated using Zamboanga City RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Siocon discharge using the Zamboanga City Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 28.

Table 28. Peak values of the Siocon HECHMS Model outflow using the Zamboanga City RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	107.8	21.4	1591.79	13 hours 10 minutes
10-Year	127.9	25.3	2260.55	13 hours
25-Year	153.4	30.2	3249.56	12 hours 50 minutes
50-Year	172.3	33.9	4046.45	12 hours 50 minutes
100-Year	191.1	37.5	4851.87	12 hours 40 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 was used in determining the flooded areas within the model. The simulated model was an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. The sample generated map of Siocon River using the calibrated HMS base flow is shown in Figure 64.

Figure 64. Sample output of Siocon RAS Model

5.9 Flood Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figure 65 to Figure 70 show the 100-, 25-, and 5-year rain return scenarios of the Siocon Floodplain.

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

Table 29. Municipalities affected in Siocon Floodplain

City / Municipality	Total Area	Area Flooded	% Flooded
Siocon	371.36	89.03	23.97%
Baliguian	391.21	26.88	6.87%

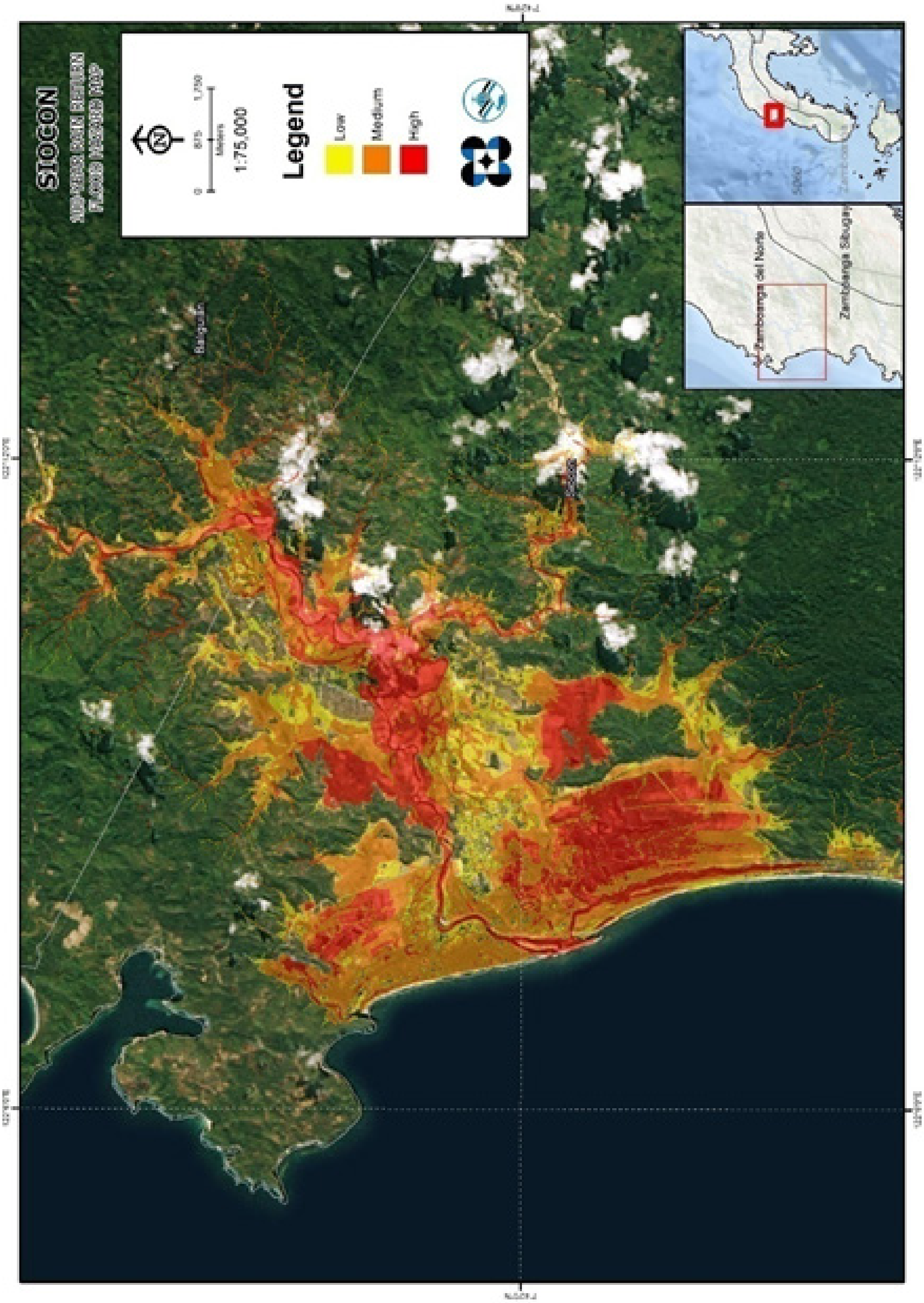


Figure 65. 100-year Flood Hazard Map for Siocon Floodplain

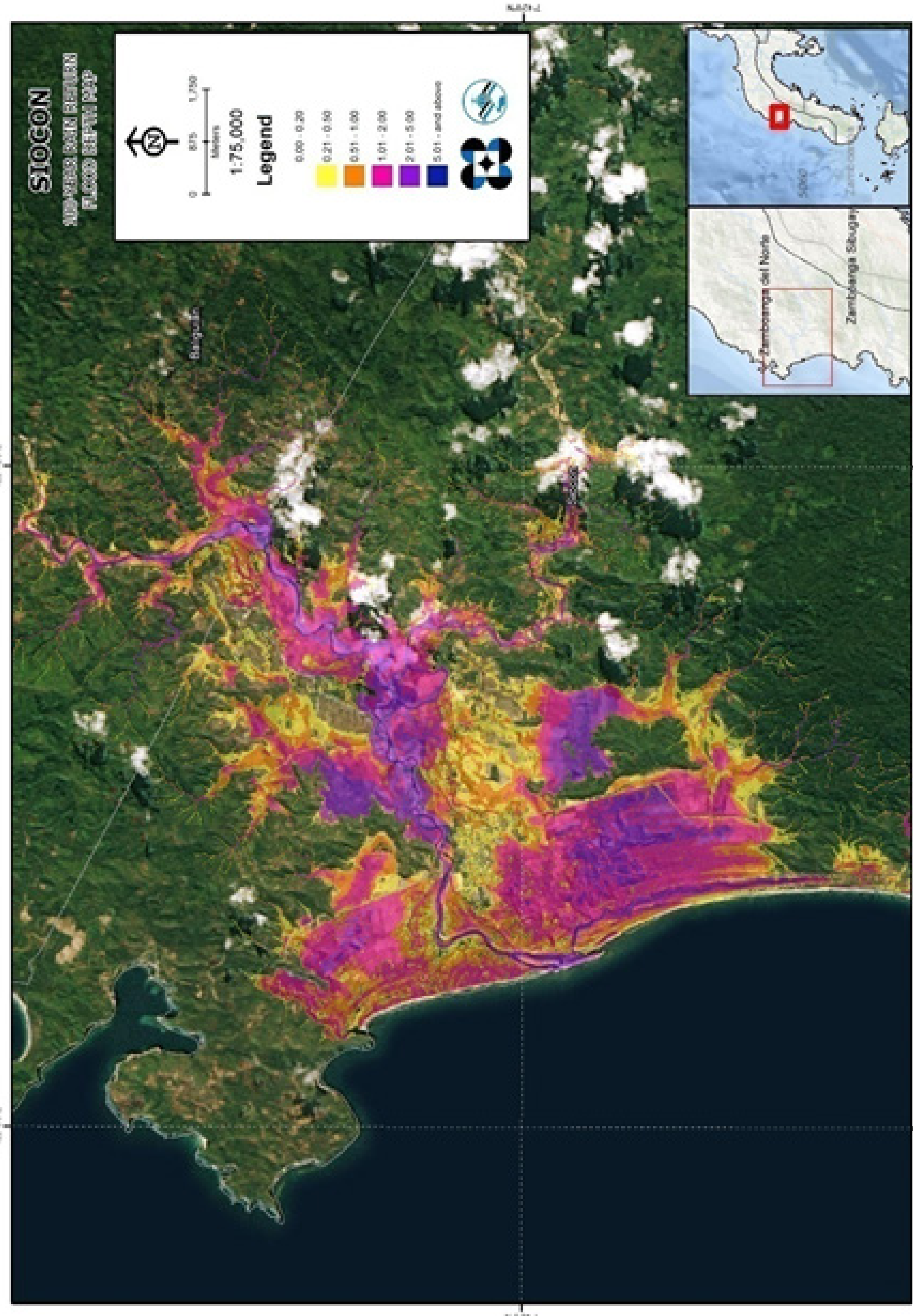


Figure 66. 100-year Flow Depth Map for Siocon Floodplain

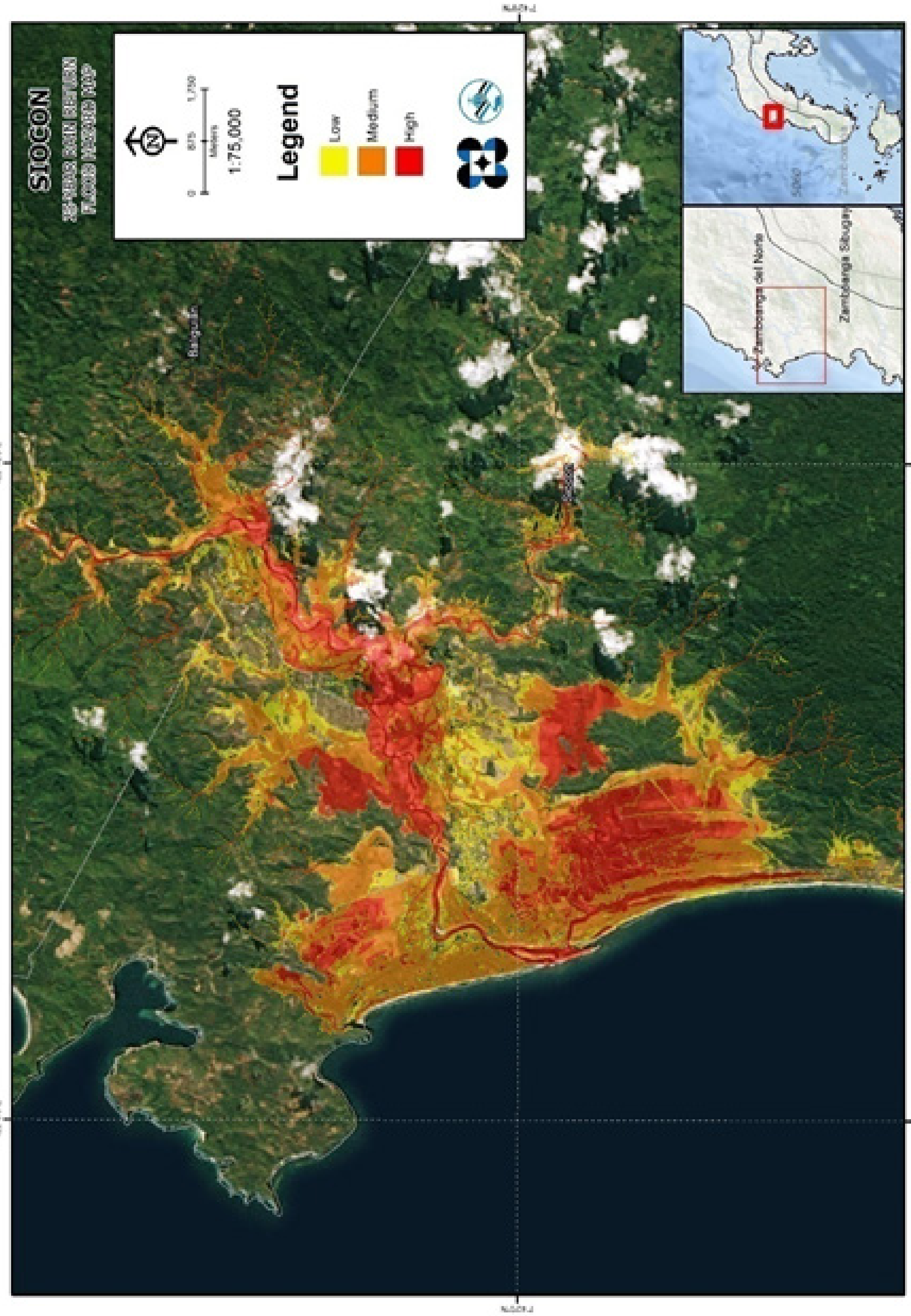


Figure 67. 25-year Flood Hazard Map for Siocon Floodplain

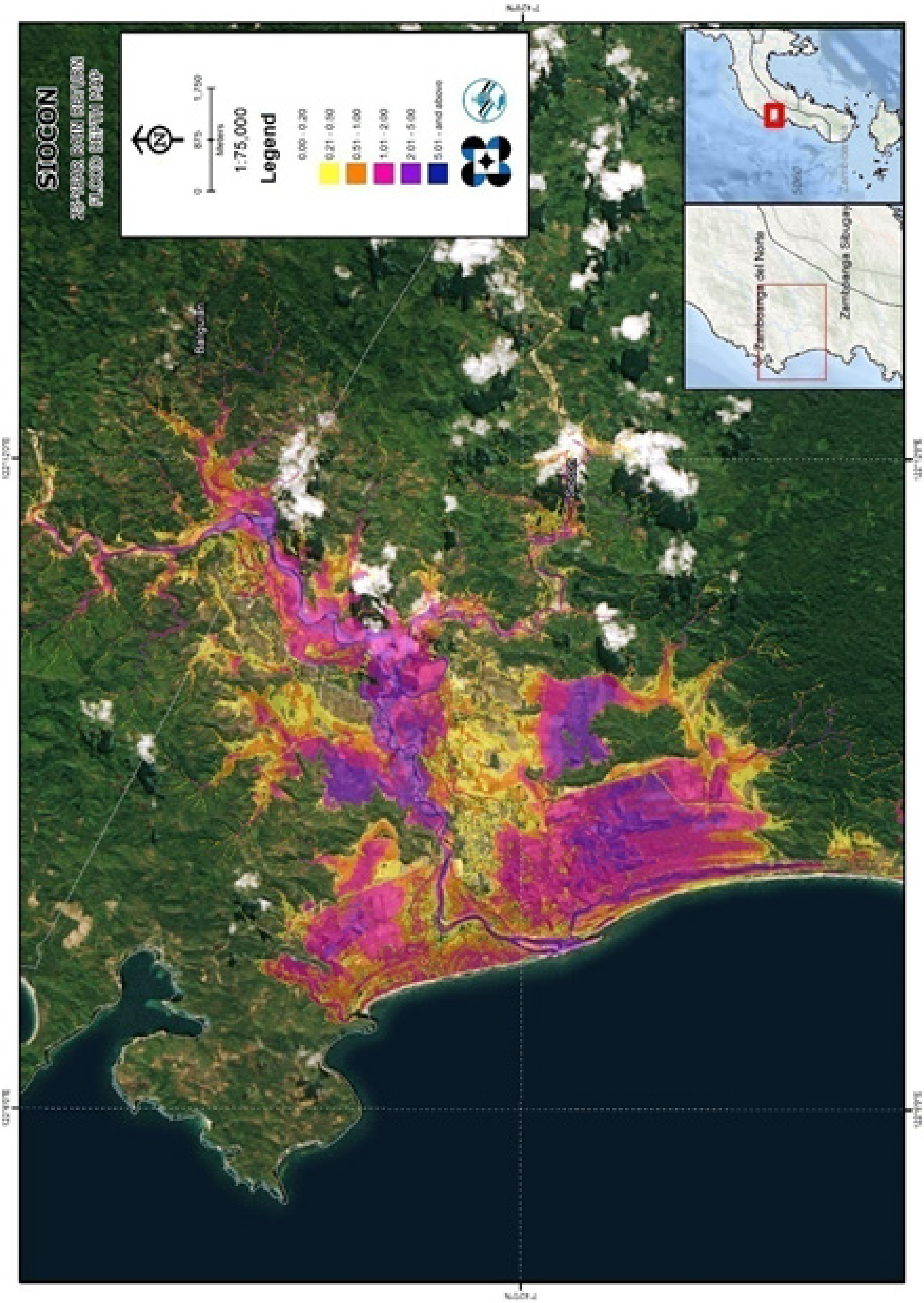


Figure 68. 25-year Flow Depth Map for Siocon Floodplain

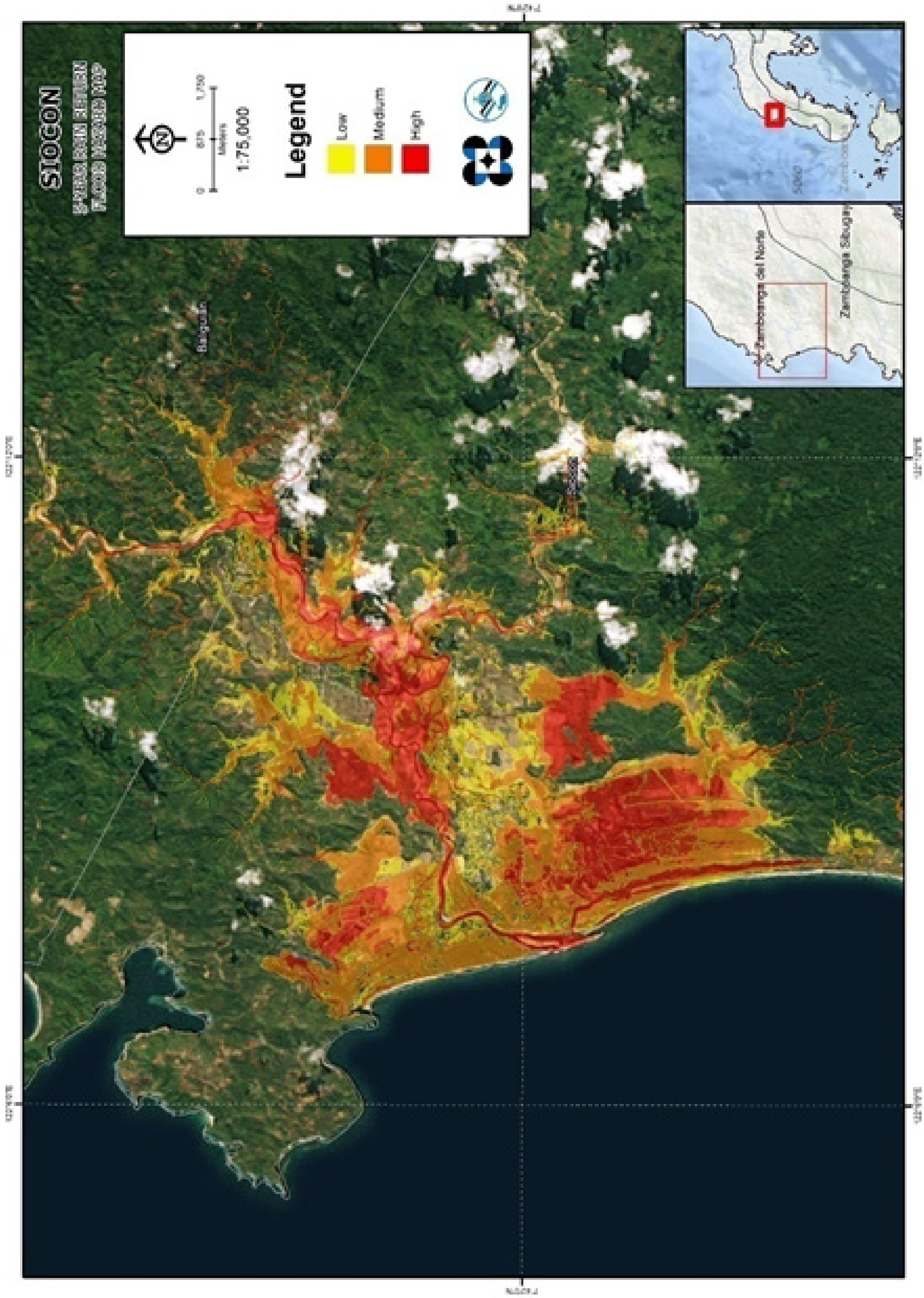


Figure 69. 5-year Flood Hazard Map for Siocon Floodplain

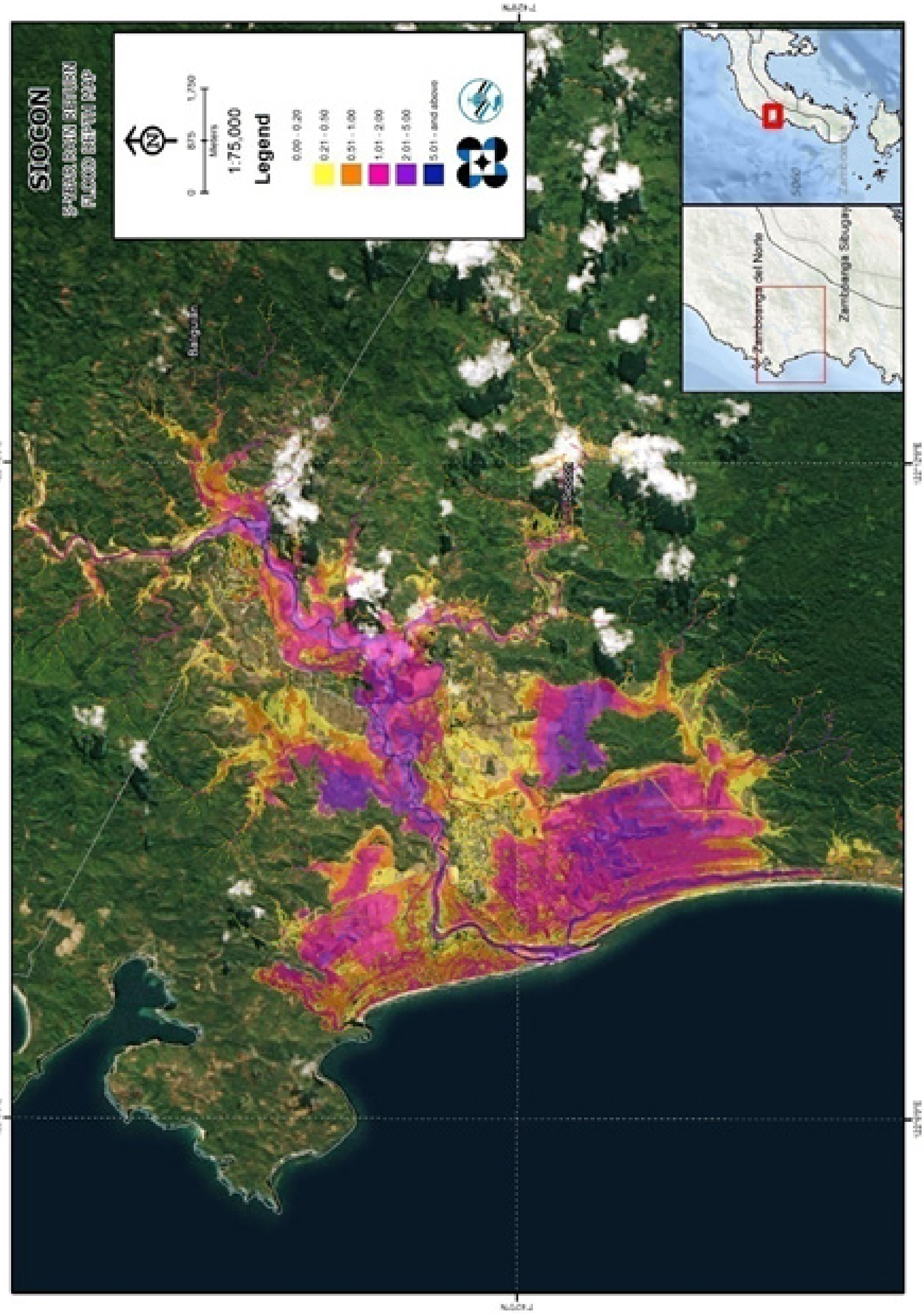


Figure 70. 5-year Flood Depth Map for Siocon Floodplain

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Siocon river basin, grouped by municipality, are listed below. For the said basin, 28 barangays in two municipalities are expected to experience flooding when subjected to the flood hazard scenarios.

For the 5-year return period, 14.97% of the municipality of Siocon with an area of 371.36 sq. km. will experience flood levels of less than 0.20 meters; 2.19% of the area will experience flood levels of 0.21 to 0.50 meters while 2.74%, 3.69%, 1.44%, and 0.04% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively.

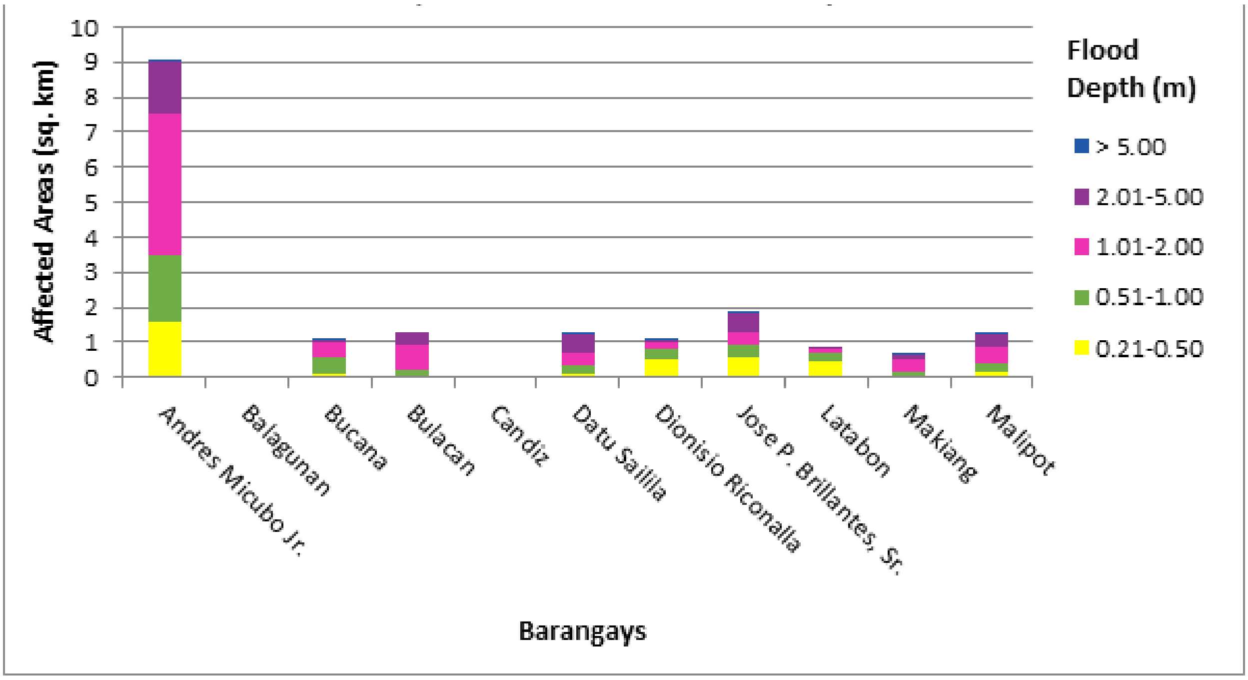


Figure 71. Affected Areas in Siocon, Zamboanga del Norte during 5-Year Rainfall Return Period

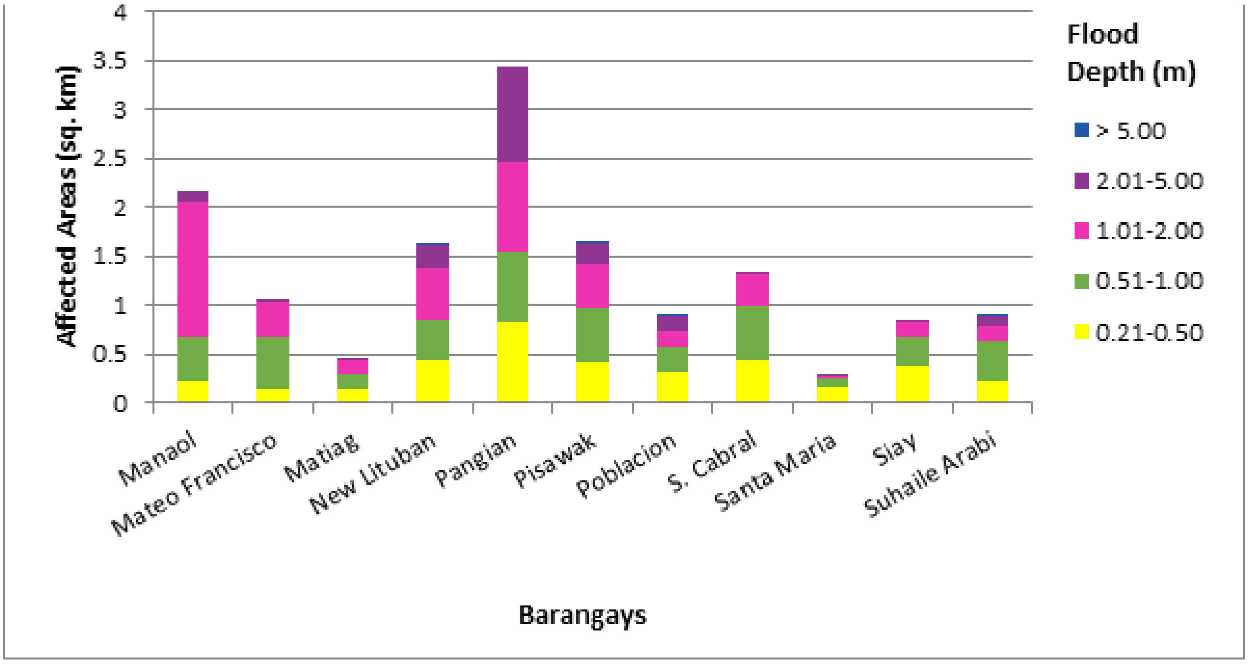


Figure 72. Affected Areas in Siocon, Zamboanga del Norte during 5-Year Rainfall Return Period

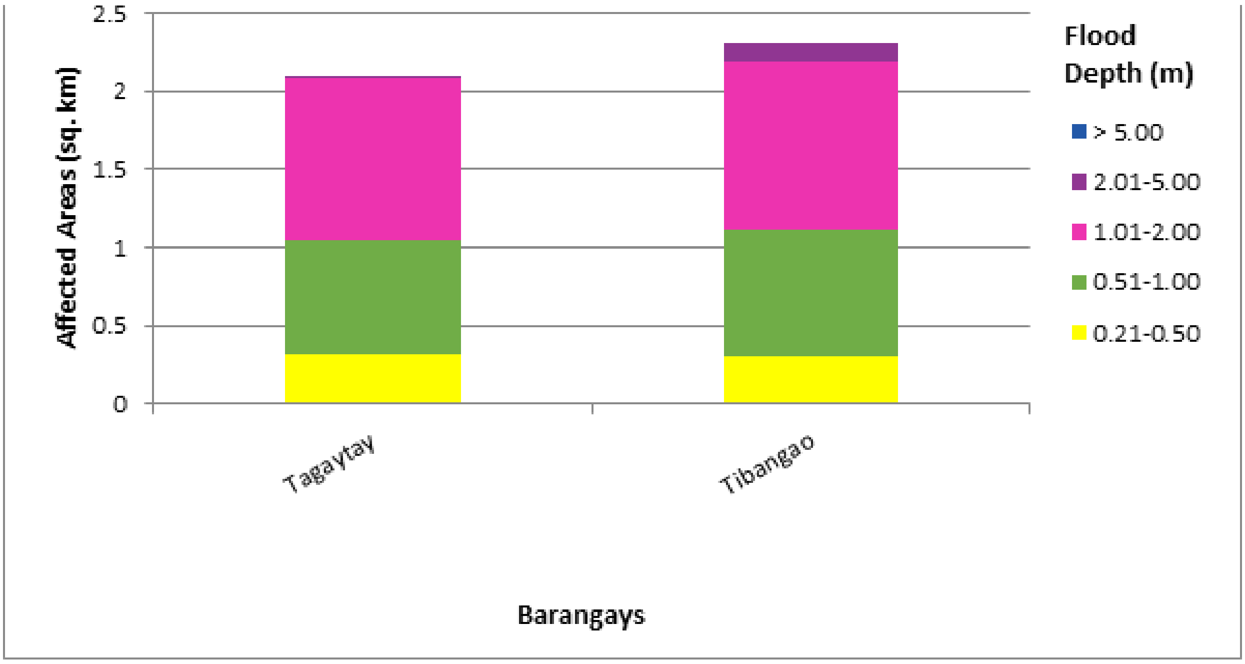


Figure 73. Affected Areas in Siocon, Zamboanga del Norte during 5-Year Rainfall Return Period

Table 30. Affected Areas in Dipolog City, Zamboanga del Norte during 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Siocon (in sq. km.)											
	Andres Mic-ubo Jr.	Balagunan	Bucana	Bulacan	Candiz	DatuSail-ila	Dionisio Riconalla	Jose P. Brillan-tes, Sr.	Latabon	Makiang	Malipot	Manaol
0.03-0.20	13.4	0.0023	0.085	0.59	0.13	0.36	7.62	0.36	4.04	0.2	0.82	0.29
0.21-0.50	1.6	0	0.11	0.073	0.011	0.094	0.51	0.56	0.44	0.049	0.19	0.22
0.51-1.00	1.92	0	0.47	0.17	0.0073	0.25	0.31	0.37	0.26	0.14	0.21	0.46
1.01-2.00	4.04	0	0.42	0.71	0.0017	0.36	0.17	0.34	0.1	0.35	0.46	1.37
2.01-5.00	1.43	0	0.048	0.32	0	0.55	0.048	0.57	0.0042	0.097	0.36	0.11
> 5.00	0.0076	0	0.0021	0	0	0.00013	0.0004	0.066	0	0.0017	0.015	0

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Siocon (in sq. km.)											
	Mateo Francisco	Matiag	New Lituban	Pangian	Pisawak	Poblacion	S. Cabral	Santa Maria	Siay	SuhaileArabi	Tagaytay	Tibangao
0.03-0.20	0.13	2.37	1.63	4.04	5.89	0.52	1.14	3.77	1.96	0.1	0.6	1.79
0.21-0.50	0.15	0.14	0.45	0.82	0.42	0.31	0.45	0.16	0.38	0.22	0.31	0.3
0.51-1.00	0.52	0.16	0.39	0.72	0.56	0.25	0.55	0.1	0.29	0.41	0.73	0.81
1.01-2.00	0.37	0.15	0.54	0.93	0.45	0.18	0.31	0.016	0.15	0.15	1.04	1.08
2.01-5.00	0.0026	0.0001	0.24	0.96	0.2	0.14	0.018	0.0012	0.022	0.1	0.018	0.12
> 5.00	0	0	0.0076	0	0.02	0.027	0	0	0	0.0026	0	0

For the 5-year return period, 5.93% of the municipality of Baliguian with an area of 391.21 sq. km. will experience flood levels of less than 0.20 meters; 0.32% of the area will experience flood levels of 0.21 to 0.50 meters while 0.31%, 0.22%, 0.09%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed Table 31 are the affected areas in square kilometers by flood depth per barangay.

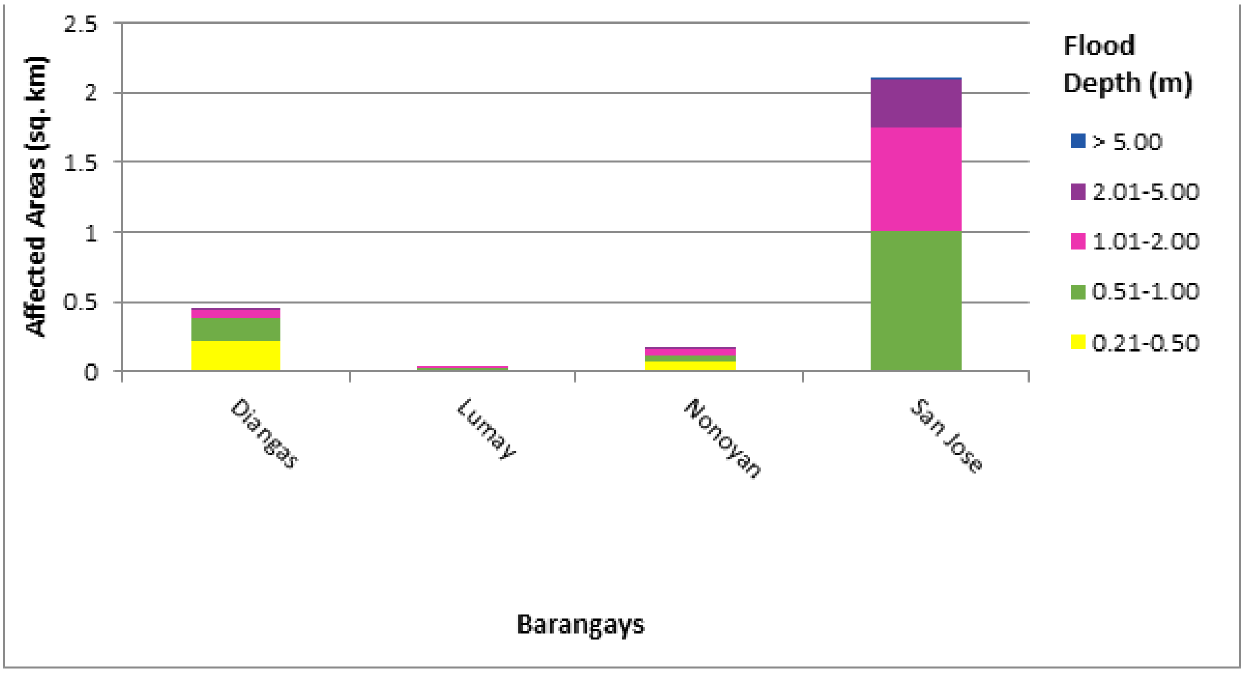


Figure 74. Affected Areas in Baliguian, Zamboanga del Norte during 5-Year Rainfall Return Period.

Table 31. Affected Areas in Baliguian, Zamboanga del Norte during 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Baliguian (in sq. km.)			
	Diangas	Lumay	Nonoyan	San Jose
0.03-0.20	6.07	0.47	3.64	13.02
0.21-0.50	0.22	0.015	0.078	0.92
0.51-1.00	0.16	0.0089	0.04	1
1.01-2.00	0.057	0.0014	0.048	0.75
2.01-5.00	0.0064	0	0.013	0.34
> 5.00	0	0	0	0.021

For the 25-year return period, 14.33% of the municipality of Siocon with an area of 371.36 sq. km. will experience flood levels of less than 0.20 meters; 2.31% of the area will experience flood levels of 0.21 to 0.50 meters while 2.84%, 3.91%, 1.65%, and 0.04% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 32 are the affected areas in square kilometers by flood depth per barangay.

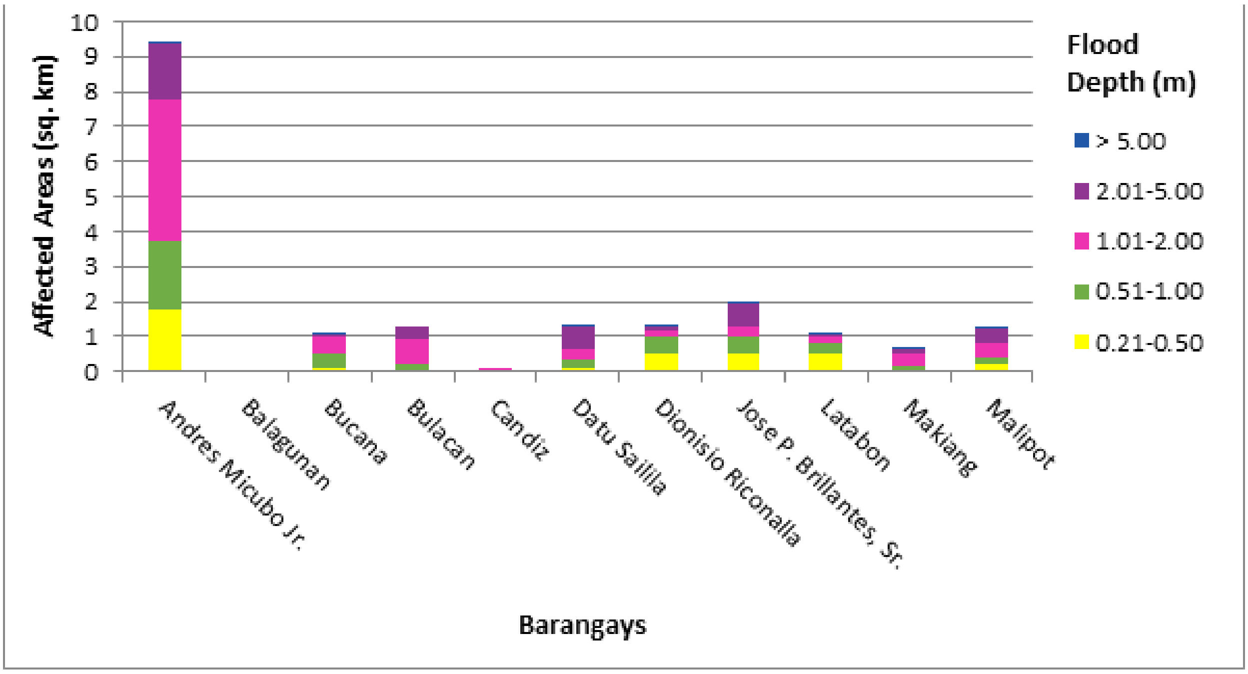


Figure 75. Affected Areas in Siocon, Zamboanga del Norte during 25-Year Rainfall Return Period

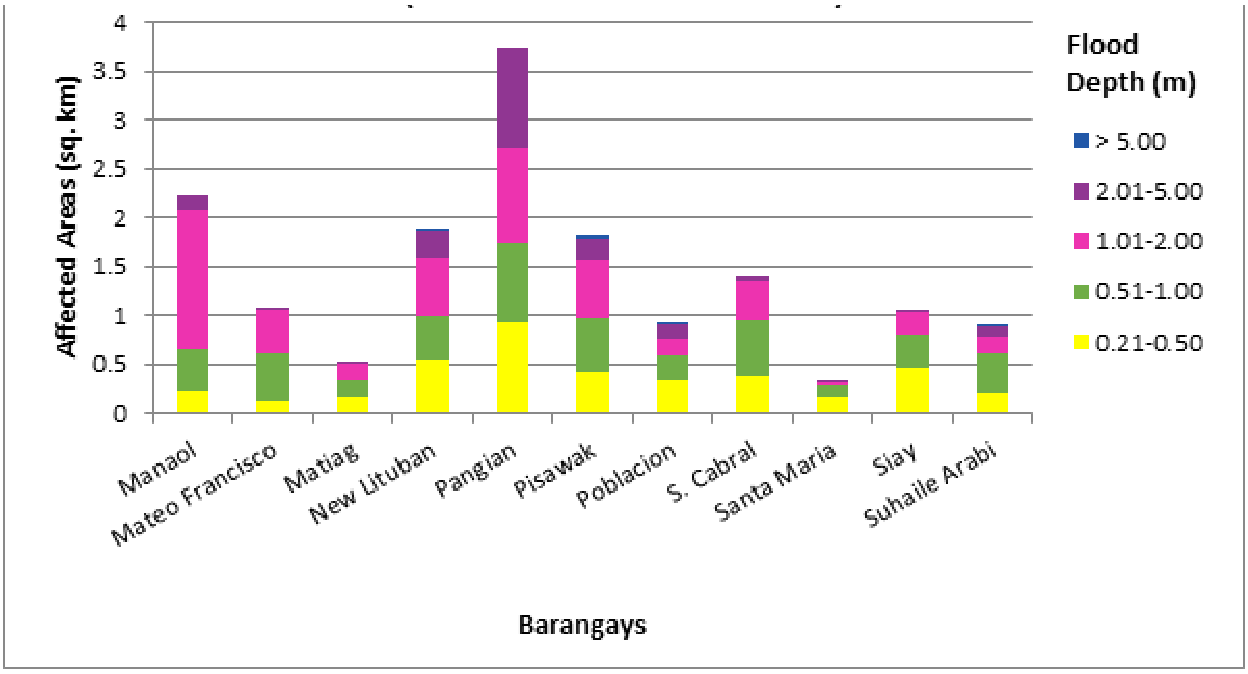


Figure 76. Affected Areas in Siocon, Zamboanga del Norte during 25-Year Rainfall Return Period

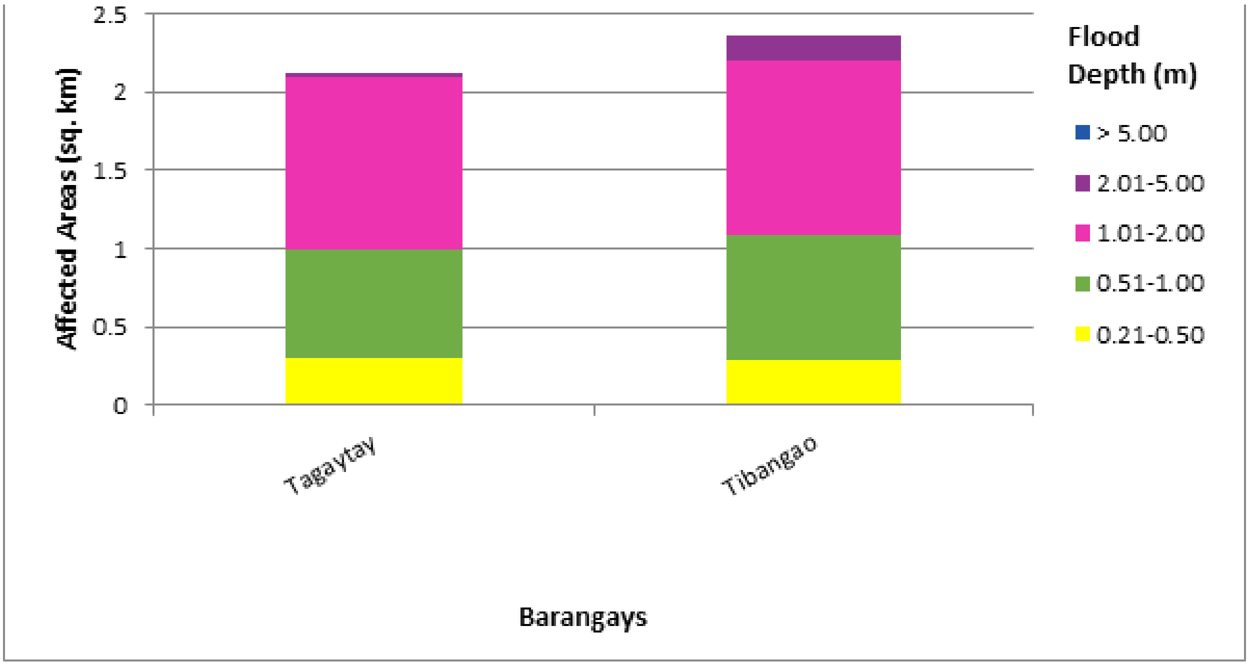


Figure 77. Affected Areas in Siocon, Zamboanga del Norte during 25-Year Rainfall Return Period

Table 32. Affected Areas in Siocon, Zamboanga del Norte during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Siocon (in sq. km.)											
	Andres Mic-ubo Jr.	Balagunan	Bucana	Bulacan	Candiz	DatuSail-ila	Dionisio Riconalla	Jose P. Brillan-tes, Sr.	Latabon	Makiang	Malipot	Manaol
0.03-0.20	13.04	0.0023	0.075	0.57	0.13	0.32	7.36	0.25	3.81	0.18	0.79	0.24
0.21-0.50	1.78	0	0.095	0.067	0.013	0.089	0.53	0.53	0.52	0.034	0.2	0.23
0.51-1.00	1.97	0	0.45	0.14	0.0099	0.23	0.44	0.47	0.32	0.11	0.2	0.42
1.01-2.00	4	0	0.47	0.72	0.004	0.35	0.21	0.32	0.18	0.38	0.41	1.42
2.01-5.00	1.61	0	0.049	0.36	0	0.64	0.12	0.63	0.013	0.12	0.43	0.15
> 5.00	0.0087	0	0.0021	0	0	0.00013	0.0004	0.069	0.0001	0.0036	0.019	0

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Siocon (in sq. km.)											
	Mateo Francisco	Matiag	New Lituban	Pangian	Pisawak	Poblacion	S. Cabral	Santa Maria	Siay	SuhaileArabi	Tagaytay	Tibangao
0.03-0.20	0.12	2.33	1.38	3.73	5.72	0.48	1.07	3.72	1.75	0.091	0.58	1.75
0.21-0.50	0.13	0.16	0.54	0.94	0.42	0.33	0.38	0.17	0.46	0.2	0.3	0.29
0.51-1.00	0.48	0.17	0.45	0.8	0.55	0.26	0.57	0.12	0.35	0.41	0.7	0.79
1.01-2.00	0.44	0.17	0.6	0.97	0.6	0.18	0.41	0.034	0.22	0.18	1.1	1.12
2.01-5.00	0.0026	0.00013	0.28	1.02	0.22	0.14	0.034	0.0027	0.023	0.1	0.027	0.16
> 5.00	0	0	0.0077	0	0.023	0.029	0	0	0	0.0025	0	0

For the 25-year return period, 5.75% of the municipality of Baliguian with an area of 391.21 sq. km. will experience flood levels of less than 0.20 meters; 0.33% of the area will experience flood levels of 0.21 to 0.50 meters while 0.37%, 0.29%, 0.12%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 33 are the affected areas in square kilometers by flood depth per barangay.

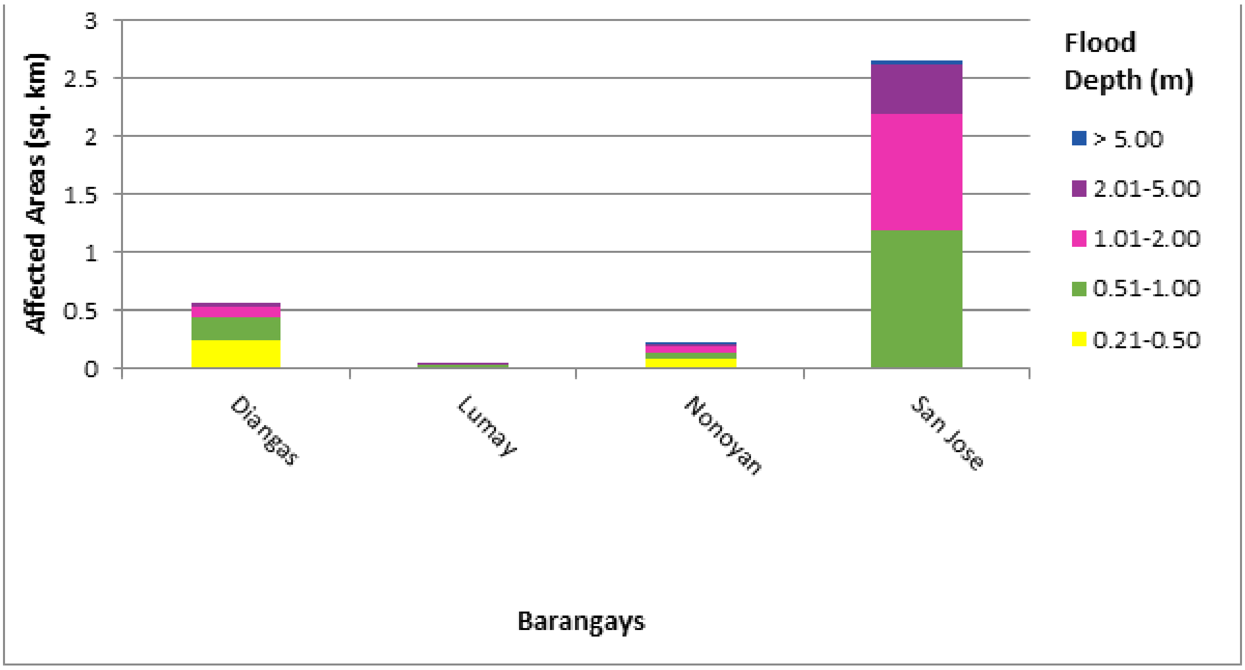


Figure 78. Affected Areas in Baliguian, Zamboanga del Norte during 25-Year Rainfall Return Period

Table 33. Affected Areas in Baliguian, Zamboanga del Norte during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Baliguian (in sq. km.)			
	Diangas	Lumay	Nonoyan	San Jose
0.03-0.20	**5.96**	**0.47**	**3.61**	**12.45**
0.21-0.50	**0.25**	**0.016**	**0.092**	**0.93**
0.51-1.00	**0.19**	**0.01**	**0.044**	**1.19**
1.01-2.00	**0.1**	**0.0029**	**0.055**	**0.99**
2.01-5.00	**0.02**	**0.0001**	**0.022**	**0.44**
> 5.00	**0**	**0**	**0.0002**	**0.027**

For the 100-year return period, 13.87% of the municipality of Siocon with an area of 371.36 sq. km. will experience flood levels of less than 0.20 meters; 2.30% of the area will experience flood levels of 0.21 to 0.50 meters while 2.87%, 4.12%, 1.85%, and 0.05% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 34 are the affected areas in square kilometers by flood depth per barangay.

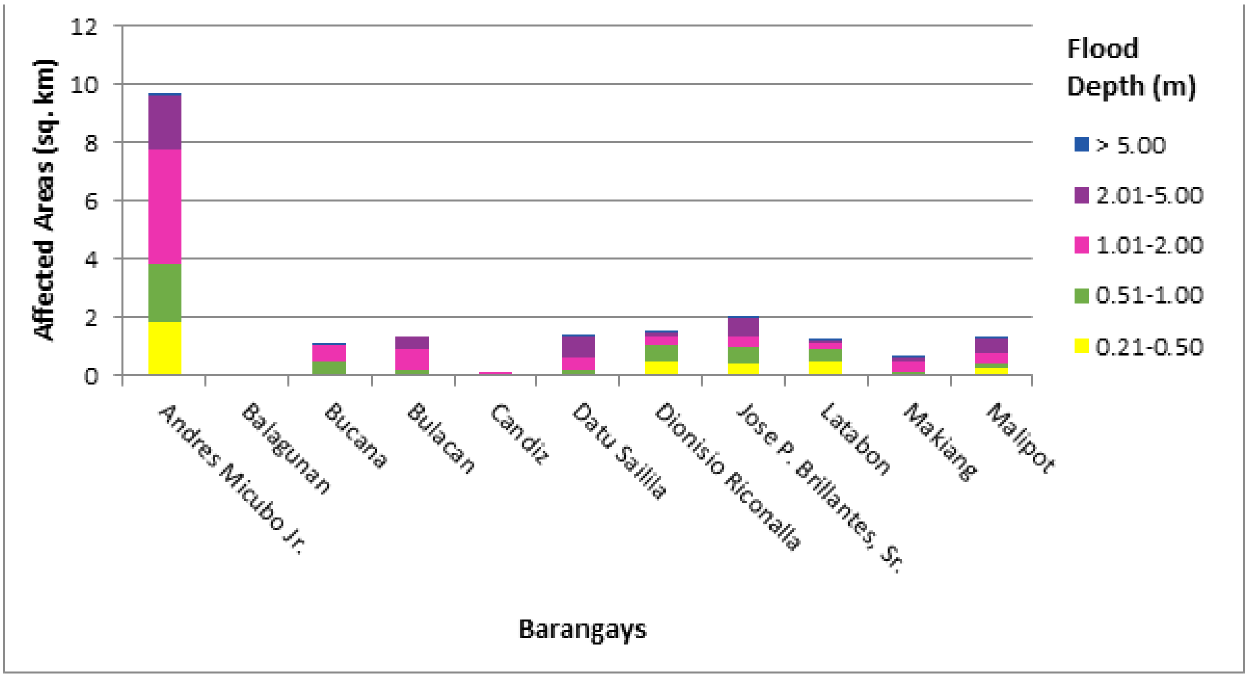


Figure 79. Affected Areas in Siocon, Zamboanga del Norte during 100-Year Rainfall Return Period

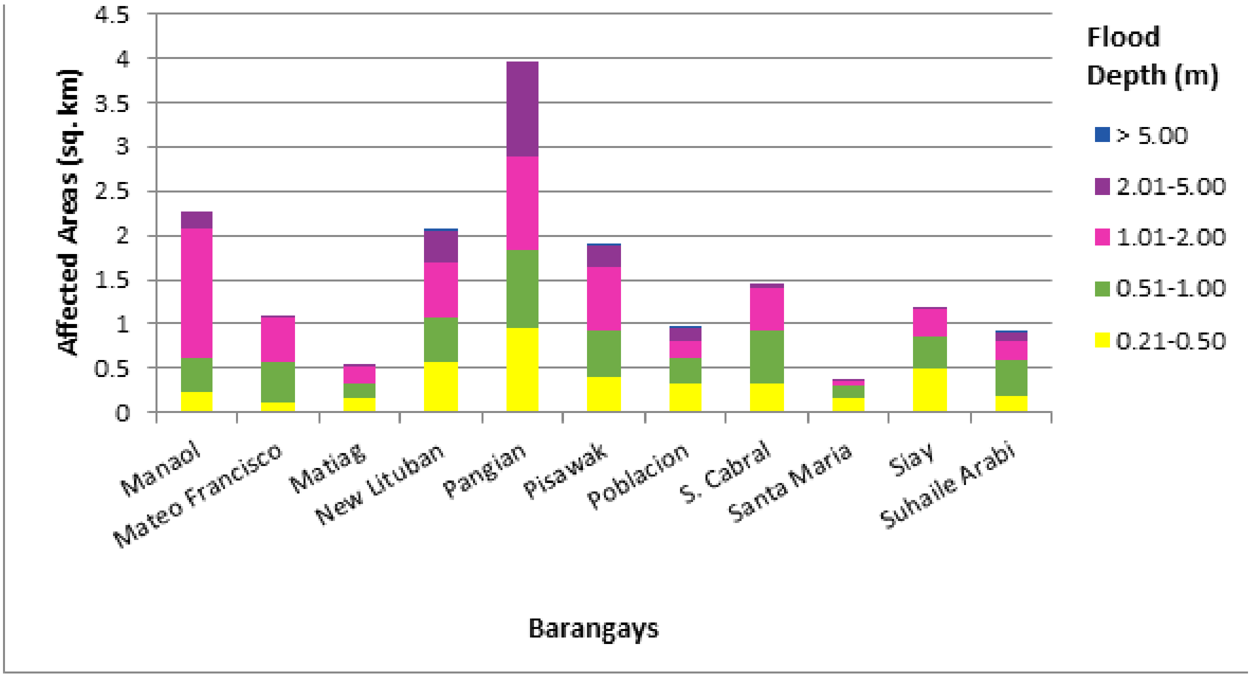


Figure 80. Affected Areas in Siocon, Zamboanga del Norte during 100-Year Rainfall Return Period

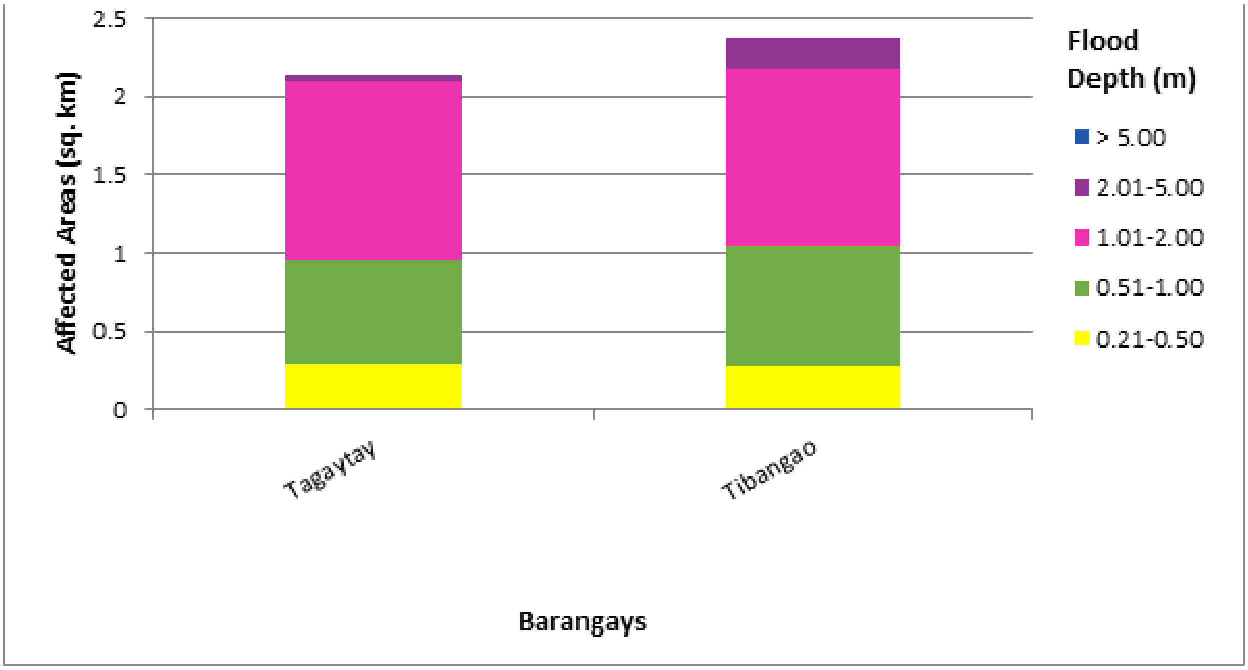


Figure 81. Affected Areas in Siocon, Zamboanga del Norte during 100-Year Rainfall Return Period

Table 34. Affected Areas in Siocon, Zamboanga del Norte during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Siocon (in sq. km.)											
	Andres Mic-ubo Jr.	Balagunan	Bucana	Bulacan	Candiz	DatuSail-ila	Dionisio Riconalla	Jose P. Brillan-tes, Sr.	Latabon	Makiang	Malipot	Manaol
0.03-0.20	12.81	0.0023	0.066	0.55	0.12	0.3	7.19	0.19	3.66	0.17	0.73	0.19
0.21-0.50	1.83	0	0.083	0.059	0.014	0.066	0.51	0.44	0.52	0.025	0.25	0.24
0.51-1.00	2.01	0	0.42	0.12	0.011	0.17	0.52	0.58	0.4	0.082	0.18	0.37
1.01-2.00	3.95	0	0.52	0.71	0.0053	0.39	0.28	0.31	0.24	0.41	0.37	1.46
2.01-5.00	1.8	0	0.05	0.42	0	0.69	0.16	0.67	0.022	0.14	0.49	0.2
> 5.00	0.0095	0	0.0024	0	0	0.0002	0.0007	0.072	0.0001	0.0057	0.029	0

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Siocon (in sq. km.)											
	Mateo Francisco	Matiag	New Lituban	Pangian	Pisawak	Poblacion	S. Cabral	Santa Maria	Siay	SuhaileArabi	Tagaytay	Tibangao
0.03-0.20	**0.1**	**2.3**	**1.2**	**3.48**	**5.61**	**0.44**	**1.02**	**3.7**	**1.6**	**0.077**	**0.56**	**1.73**
0.21-0.50	**0.12**	**0.17**	**0.56**	**0.96**	**0.41**	**0.34**	**0.34**	**0.17**	**0.49**	**0.19**	**0.29**	**0.28**
0.51-1.00	**0.44**	**0.17**	**0.5**	**0.87**	**0.52**	**0.27**	**0.58**	**0.13**	**0.37**	**0.4**	**0.66**	**0.77**
1.01-2.00	**0.5**	**0.18**	**0.64**	**1.06**	**0.72**	**0.19**	**0.48**	**0.051**	**0.3**	**0.22**	**1.15**	**1.13**
2.01-5.00	**0.0026**	**0.00056**	**0.34**	**1.08**	**0.24**	**0.15**	**0.055**	**0.0044**	**0.027**	**0.1**	**0.041**	**0.2**
> 5.00	**0**	**0**	**0.0082**	**0**	**0.027**	**0.031**	**0**	**0**	**0**	**0.0026**	**0**	**0**

For the 100-year return period, 5.65% of the municipality of Baliguian with an area of 391.21 sq. km. will experience flood levels of less than 0.20 meters; 0.31% of the area will experience flood levels of 0.21 to 0.50 meters while 0.38%, 0.37%, 0.15%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 35 are the affected areas in square kilometers by flood depth per barangay.

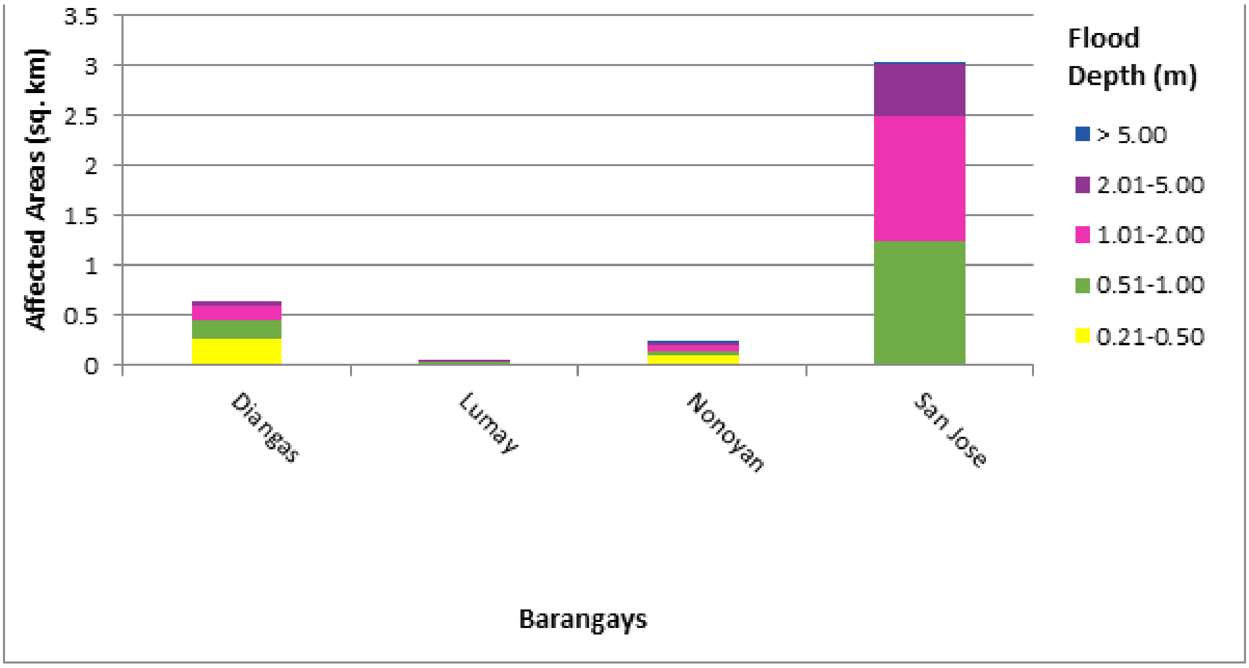


Figure 82. Affected Areas in Baliguian, Zamboanga del Norte during 100-Year Rainfall Return Period

Table 35. Affected Areas in Baliguian, Zamboanga del Norte during 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Baliguian (in sq. km.)			
	Diangas	Lumay	Nonoyan	San Jose
0.03-0.20	5.88	0.46	3.58	12.18
0.21-0.50	0.27	0.017	0.097	0.84
0.51-1.00	0.18	0.012	0.05	1.24
1.01-2.00	0.15	0.004	0.05	1.25
2.01-5.00	0.032	0.0003	0.036	0.52
> 5.00	0	0	0.0006	0.03

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

Table 36. 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	9.19	9.58	9.42
Medium	19.90	21.14	21.94
High	12.46	13.91	15.31
TOTAL	41.55	44.63	46.67

Of the 34 identified educational institutions and buildings in Siocon Floodplain plain, 12 were assessed for low flood hazard levels, 8 for medium, and 1 for high for the 5-year scenario. For the 25-year scenario, 9 were assessed for low flood hazard levels, 11 for medium, and 1 for. For the 100-year scenario, 9 were assessed for low, 12 for medium and 1 for high flood hazard levels.

Of the 14 identified medical institutions in Siocon Floodplain plain, 3 were assessed for low, 3 for medium flood hazard levels for the 5-year scenario. For the 25-year scenario, 4 were assessed for low and 3 for medium flood hazard levels. For the 100-year scemaro, 4 were assessed for low and 4 for medium flood hazard levels.

The educational and health institutions exposed to flooding in the Siocon Floodplain are found in Annex 12 and Annex 13, respectively.

5.11 Flood Validation

The flood validation consists of 97 points randomly selected all over the Siocon Floodplain. It has an RMSE value of 0.63.

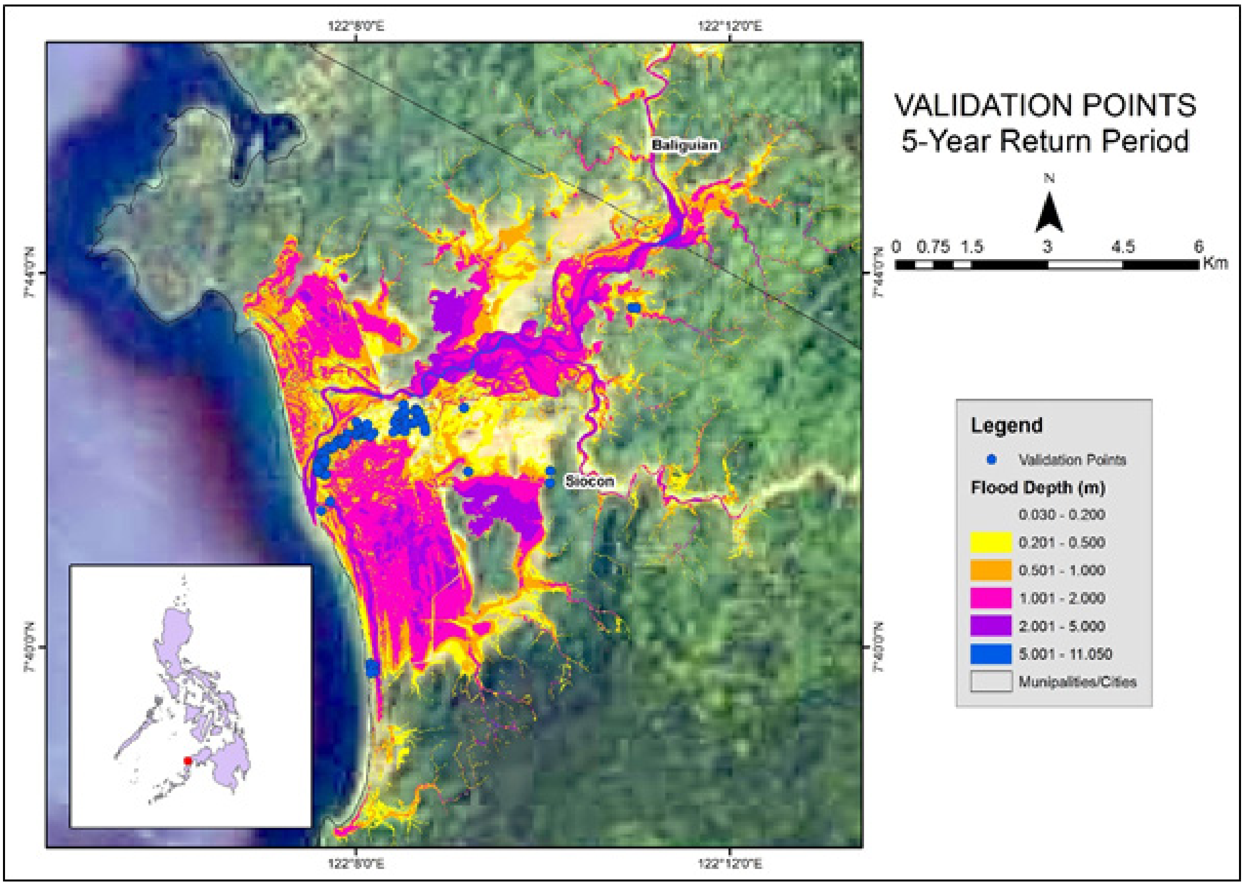


Figure 83. Validation points for 5-year Flood Depth Map of Siocon Floodplain

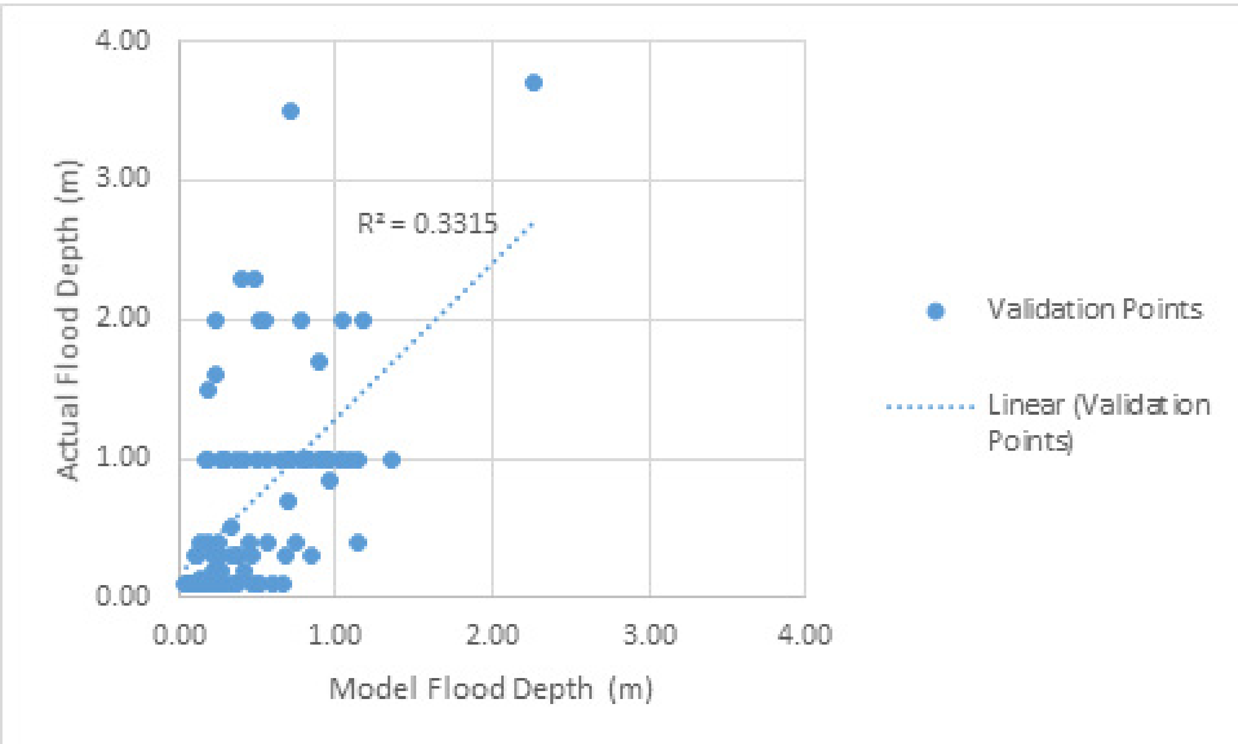


Figure 84. Flood map depth vs actual flood depth

Table 37. Actual Flood Depth vs Simulated Flood Depth in Siocon

Areas Affected (in sq. km) by flood depth (in m.)	Modeled Flood Depth (m)						
	0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
0-0.20	18	12	3	0	0	0	33
0.21-0.50	4	11	4	1	0	0	20
0.51-1.00	2	6	19	5	0	0	32
1.01-2.00	1	2	4	2	0	0	9
2.01-5.00	0	2	1	0	1	0	4
> 5.00	0	0	0	0	0	0	0
Total	25	33	31	8	1	0	98

The overall accuracy generated by the flood model is estimated at 52.04% with 51 points correctly matching the actual flood depths. In addition, there were 29 points estimated one level above and below the correct flood depths while there were 9 points and 3 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 4 points were overestimated while a total of 22 points were underestimated in the modeled flood depths of Siocon.

Table 38. Summary of Accuracy Assessment in Siocon River Basin Survey

	No. of Points	%
Correct	51	52.04
Overestimated	25	25.51
Underestimated	22	22.45
Total	98	100.00

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

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

ANNEXES

Annex 1. Technical Specification of the LiDAR Sensor used in the Siocon Floodplain Survey

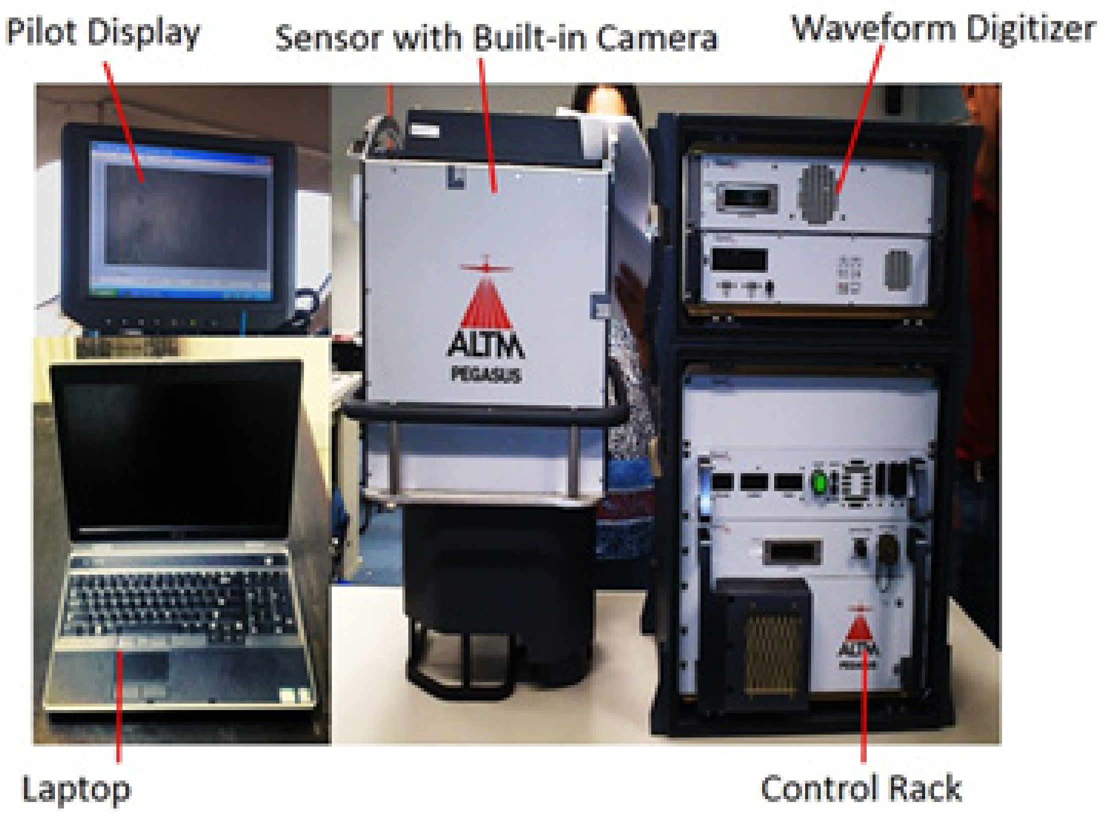

Figure A-1.1 Pegasus Sensor

Table A-1.1 Parameters and Specifications of the Pegasus Sensor

Parameter	Specification
Operational envelope (1,2,3,4)	150-5000 m AGL, nominal
Laser wavelength	1064 nm
Horizontal accuracy (2)	1/5,500 x altitude, 1σ
Elevation accuracy (2)	< 5-20 cm, 1σ
Effective laser repetition rate	Programmable, 100-500 kHz
Position and orientation system	POS AV ™AP50 (OEM)
Scan width (FOV)	Programmable, 0-75 ˚
Scan frequency (5)	Programmable, 0-140 Hz (effective)
Sensor scan product	800 maximum
Beam divergence	0.25 mrad (1/e)
Roll compensation	Programmable, ±37˚ (FOV dependent)
Vertical target separation distance	<0.7 m
Range capture	Up to 4 range measurements, including 1st, 2nd, 3rd, and last returns
Intensity capture	Up to 4 intensity returns for each pulse, including last (12 bit)
Image capture	5 MP interline camera (standard); 60 MP full frame (optional)
Full waveform capture	12-bit Optech IWD-2 Intelligent Waveform Digitizer
Data storage	Removable solid state disk SSD (SATA II)
Power requirements	28 V, 800 W, 30 A
Dimensions and weight	Sensor: 630 x 540 x 450 mm; 65 kg; Control rack: 650 x 590 x 490 mm; 46 kg
Operating Temperature	-10°C to +35°C
Relative humidity	0-95% non-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. ZSI-58

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

June 14, 2016

CERTIFICATION

To whom it may concern:

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

Province: **ZAMBOANGA SIBUGAY**
Station Name: **ZSI-58**
Order: **2nd**

Island:	**MINDANAO**	Barangay:	**LICOMO**		
Municipality:	**TUNGAWAN**	MSL Elevation:			
PRS92 Coordinates					
Latitude:	**7° 28' 13.32387"**	Longitude:	**122° 19' 53.76709"**	Ellipsoidal Hgt:	**82.90600 m.**
WGS84 Coordinates					
Latitude:	**7° 28' 9.79725"**	Longitude:	**122° 19' 59.28169"**	Ellipsoidal Hgt:	**146.76200 m.**
PTM / PRS92 Coordinates					
Northing:	**826039.734 m.**	Easting:	**426222.848 m.**	Zone:	**4**
UTM / PRS92 Coordinates					
Northing:	**825,750.61**	Easting:	**426,248.67**	Zone:	**51**

Location Description

ZSI-58
From Ipil City proper, travel south on the national highway going to Zamboanga City for approximately 45 mins. Station is located on the E side of the national highway about 150 m before reaching the provincial boundary between Zamboanga Sibugay and Zamboanga City. It is situated at about 1.5 m W of an unmarked concrete slab, 6 m from a pile of rocks and boulders, about 6 m from the road centerline and about 15 m SW of the nearest house. Station is intervisible with ZSI-57. Mark is the head of a 2" concrete nail flushed in a 30 cm x 30 cm x 20 cm cement block with inscriptions ZSI-58 2006 NAMRIA/LEP.

Requesting Party:	**UP Lidar 1**
Purpose:	**Reference**
OR Number:	**8094772**
T.N.:	**2016-1262**

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

9 9 0 6 1 4 2 0 1 6 1 6 2 8 5 4

CIP/4701/12/09/814

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.1 ZSI-58

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

1. ZY-110

Vector Components (Mark to Mark)

From:	ZSI-58				
Grid		Local		Global	
Easting	426248.671 m	Latitude	N7°28'13.32388"	Latitude	N7°28'09.79725"
Northing	825750.606 m	Longitude	E122°19'53.76709"	Longitude	E122°19'59.28169"
Elevation	78.880 m	Height	82.906 m	Height	146.762 m

To:	ZY-110				
Grid		Local		Global	
Easting	429720.359 m	Latitude	N7°30'53.56728"	Latitude	N7°30'50.03176"
Northing	830666.225 m	Longitude	E122°21'46.79802"	Longitude	E122°21'52.30841"
Elevation	13.942 m	Height	18.006 m	Height	81.856 m

Vector					
ΔEasting	3471.688 m	NS Fwd Azimuth	35°08'41"	ΔX	-2549.783 m
ΔNorthing	4915.619 m	Ellipsoid Dist.	6019.989 m	ΔY	-2450.835 m
ΔElevation	-64.938 m	ΔHeight	-64.900 m	ΔZ	4872.062 m

Standard Errors

Vector errors:					
σ ΔEasting	0.005 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.007 m
σ ΔNorthing	0.002 m	σ Ellipsoid Dist.	0.003 m	σ ΔY	0.009 m
σ ΔElevation	0.011 m	σ ΔHeight	0.011 m	σ ΔZ	0.003 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000451909		
Y	-0.0000400210	0.0000867246	
Z	-0.0000097402	0.0000144329	0.0000080220

Figure A-3.1 ZY-110

Annex 4. The LiDAR Survey Team Composition

Table A-4.1 LiDAR Survey Team Composition

Data Acquisition Component Sub -Team	Designation	Name	Agency / Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUNA	UP TCAGP
		LOVELYN ASUNCION	UP TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	ENGR. IRO ROXAS	UP-TCAGP
	Research Associate (RA)	JONATHAN ALMALVEZ	UP-TCAGP
		SANDRA POBLETE	
Ground Survey, Data Download and Transfer	RA	FRANK NICOLAS ILEJAY	UP-TCAGP
LiDAR Operation	Airborne Security	SSG. JAYCO MANZANO	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. SHERWIN CESAR ALFONSO	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. ANTON RETSE DAYO	AAC

Annex 5. Data Transfer Sheet for Siocon Floodplain

DATA TRANSFER SHEET
ZAMBOANGA 7/11/2016

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
May 25, 2016	23390P	1BLK75BS146A	PEGASUS	518	NA	4.08	91	NA	NA	5.63	NA	95.8	1KB	NA	53	NA	Z:\DAC\RAW DATA
May 26, 2016	23392P	1BLK75FG147A	PEGASUS	2.28	NA	11	253	NA	NA	24.7	NA	133	1KB	NA	89	NA	Z:\DAC\RAW DATA
May 26, 2016	23394P	1BLK75AS147B	PEGASUS	506	NA	3.37	101	NA	NA	5.13	NA	133	1KB	NA	NA	NA	Z:\DAC\RAW DATA
May 27, 2016	23398P	1BLK75CSDE148B	PEGASUS	2.09	NA	11.6	281	30	274	22.6	NA	153	1KB	NA	NA	NA	Z:\DAC\RAW DATA
May 30, 2016	23408P	1BLK75HI151A	PEGASUS	546	NA	6.09	173	8.73	69	7.88	NA	171	1KB	NA	NA	NA	Z:\DAC\RAW DATA
May 30, 2016	23410P	1BLK75CS151B	PEGASUS	1.1	NA	6.75	192	15.3	139	12.6	NA	171	1KB	NA	NA	NA	Z:\DAC\RAW DATA

Received from

Name R. PUNTO
Position RA
Signature

Received by

Name AC Bongat
Position SSRS
Signature 7/14/16

Figure A-5.1 Data Transfer Shee for Siocon Floodplain - A

Annex 6. Flight logs for the flight missions

Flight Log for 23398P Mission

Data Acquisition Flight Log

Flight Log No.: 23398P

1 LiDAR Operator: I. ROXAS & S. POBLETE	2 ALTM Model: PEGASUS	3 Mission Name: BLK75CSDE148B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9122
7 Pilot: C. ALFONSO III	8 Co-Pilot: A. DAYO	9 Route: ZAMBOANGA CITY - ZAMBOANGA CITY			
10 Date: MAY 29, 2016	12 Airport of Departure (Airport, City/Province): ZAMBOANGA CITY		12 Airport of Arrival (Airport, City/Province): ZAMBOANGA CITY		
13 Engine On: 1339 H	14 Engine Off: 1749 H	15 Total Engine Time: 4 + 11	16 Take off: 1343 H	17 Landing: 1744 H	18 Total Flight Time: 4 + 01
19 Weather: CLOUDY					

20 Flight Classification

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

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

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

21 Remarks

Successful flight
Completed BLK 7DE and BLK75E ;
Covered BLK 75CS

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator	Aircraft Mechanic/ Technician
I. PAXIAS	AIC JOSEPH S. MAANO PAF	C. ALFONSO III	S. POBLETE / I. ROXAS	—
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.1 Flight Log for Mission 23398P

Flight Log for 23408P Mission

Data Acquisition Flight Log — Flight Log No.: 23408 P

1 LiDAR Operator: S. POBLETE	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK75HI151A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9122
7 Pilot: C. ALFONSO III	8 Co-Pilot: A. DAYO	9 Route: ZAMBOANGA CITY – ZAMBOANGA CITY			
10 Date: MAY 30, 2016	12 Airport of Departure (Airport, City/Province): ZAMBOANGA CITY		12 Airport of Arrival (Airport, City/Province): ZAMBOANGA CITY		
13 Engine On: 0816 H	14 Engine Off: 1103 H	15 Total Engine Time: 2 + 47	16 Take off: 0821 H	17 Landing: 1058 H	18 Total Flight Time: 02 + 37
19 Weather	CLOUDY				

20 Flight Classification

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

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

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

21 Remarks

Successful flight

Covered BLK 75HI

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator	Aircraft Mechanic/ Technician
I. PAGS	AIC JAUSO S MANZANO PAF	C. ALFONSO III	S. POBLETE	—
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.2 Flight Log for Mission 23408P

Annex 7. Flight Status

FLIGHT STATUS REPORT
Zamboanga-Zamboanga Sibugay
February 9-10, 2015; May 27 and 30, 2016

Table A-7.1 Flight Status Report

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
23398P	BLK75CS BLK75D BLK75E	1BLK75CSDE148B	I. ROXAS	May 27, 2016	COMPLETED BLK7DE and BLK75E. COVERED BLK75CS
23408P	BLK75H, BLK75I	1BLK75HI151A	S. POBLETE	May 30, 2016	COVERED BLK75HI

LAS/SWATH BOUNDARIES PER MISSION FLIGHT

Flight No. : 23398P
Area: BLK75CS, BLK75D, BLK75E
Mission Name: 1BLK75CSDE148B
Parameters: Altitude: 1100 m; Scan Frequency: 30 Hz;
Scan Angle: 25 deg; Overlap: 30%

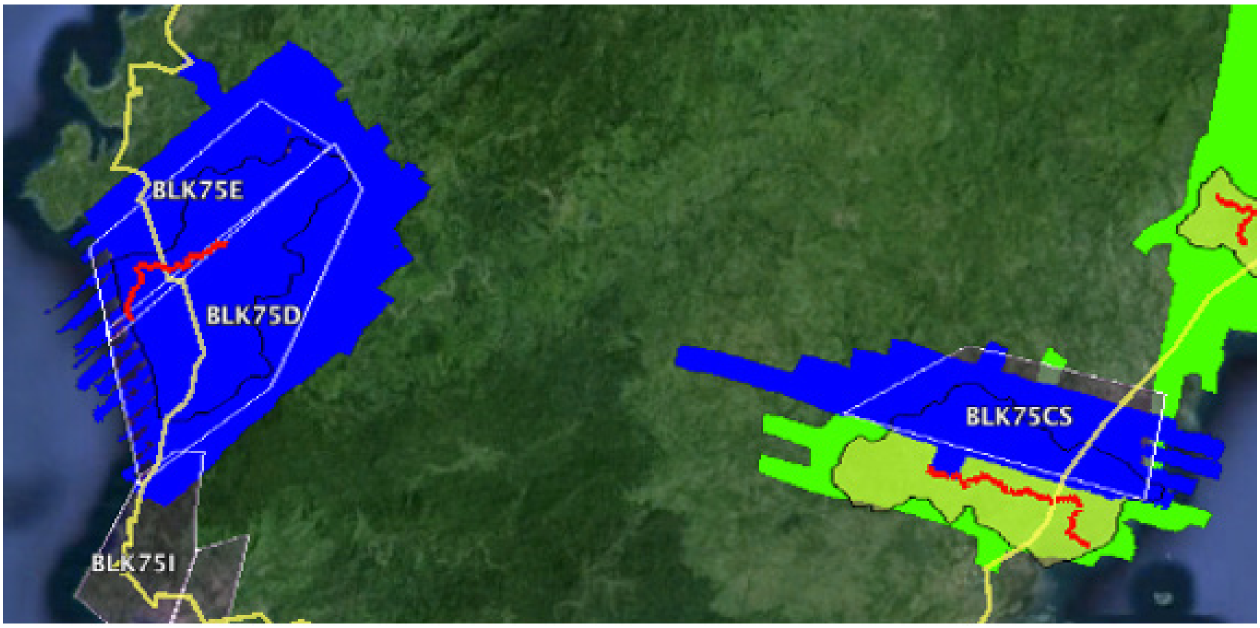

Figure A-7.1 Swath for Flight No. 23398P

Flight No. :	23408P	
Area:	BLK75H, BLK75I	
Mission Name:	1BLK75HI151A	
Parameters:	Altitude: 1100 m;	Scan Frequency: 30 Hz;
	Scan Angle: 25 deg;	Overlap: 30%

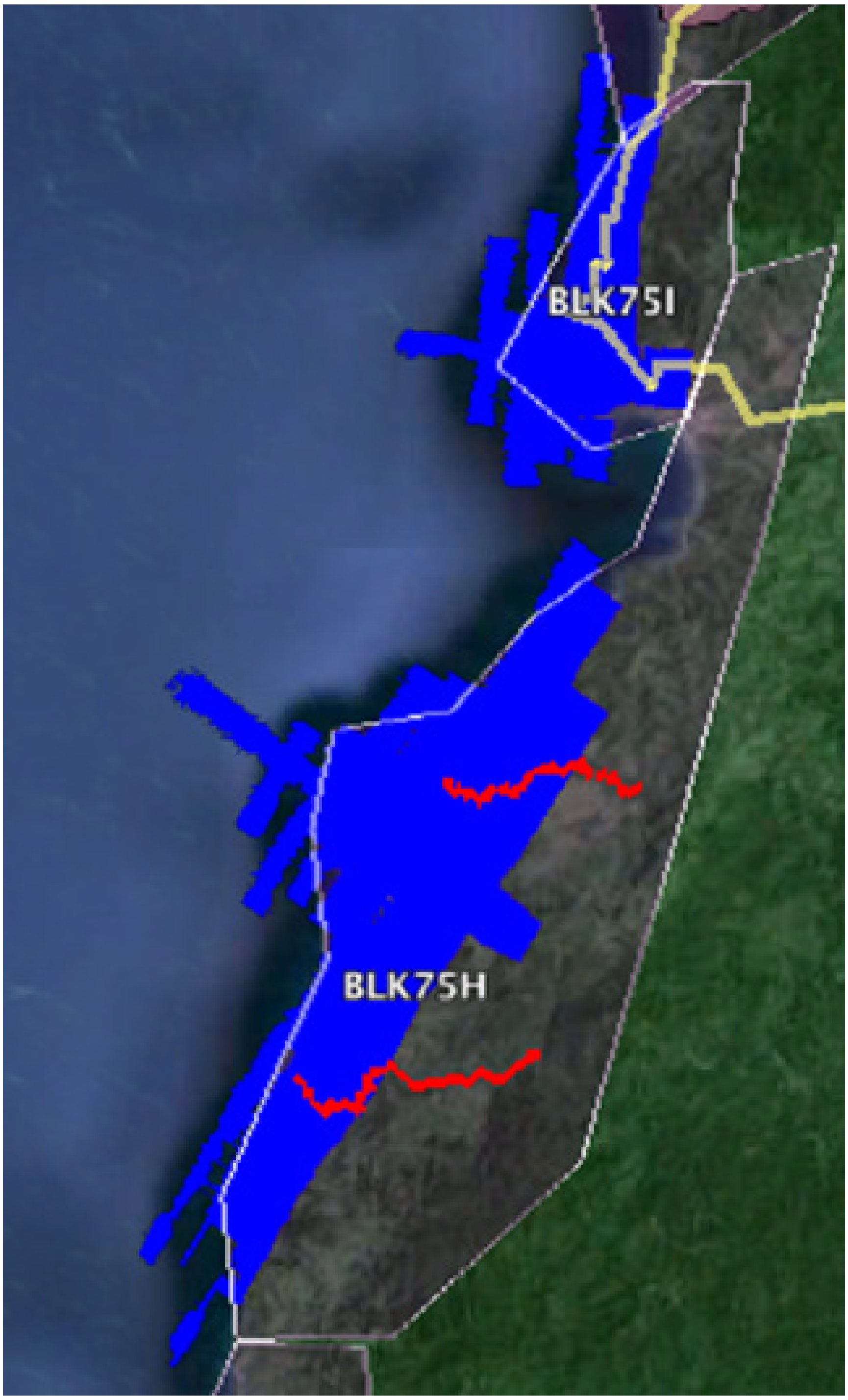

Figure A-7.2 Swath for Flight No. 23408P

Annex 8. Mission Summary Reports

Table A-8.1 Mission Summary Report for Mission Blk75L

FLIGHT AREA	ZAMBOANGA REFLIGHTS
Mission Name	Blk75L
Inclusive Flights	23398P
Range data size	22.6 GB
POS data size	281 MB
Base data size	153 MB
Image	30 MB
Transfer date	July 14, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.3
RMSE for East Position (<4.0 cm)	1.6
RMSE for Down Position (<8.0 cm)	4.6
Boresight correction stdev (<0.001deg)	n/a
IMU attitude correction stdev (<0.001deg)	n/a
GPS position stdev (<0.01m)	n/a
Minimum % overlap (>25)	5.59
Ave point cloud density per sq.m. (>2.0)	1.89
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	188
Maximum Height	1171.16 m
Minimum Height	59.22 m
Classification (# of points)	
Ground	113,795,945
Low vegetation	29,231,405
Medium vegetation	66,041,168
High vegetation	180,836,332
Building	2,122,547
Orthophoto	No
Processed by	Engr. James Dimaculangan, Engr. Erica Erin Elazegui, AlexEscobido

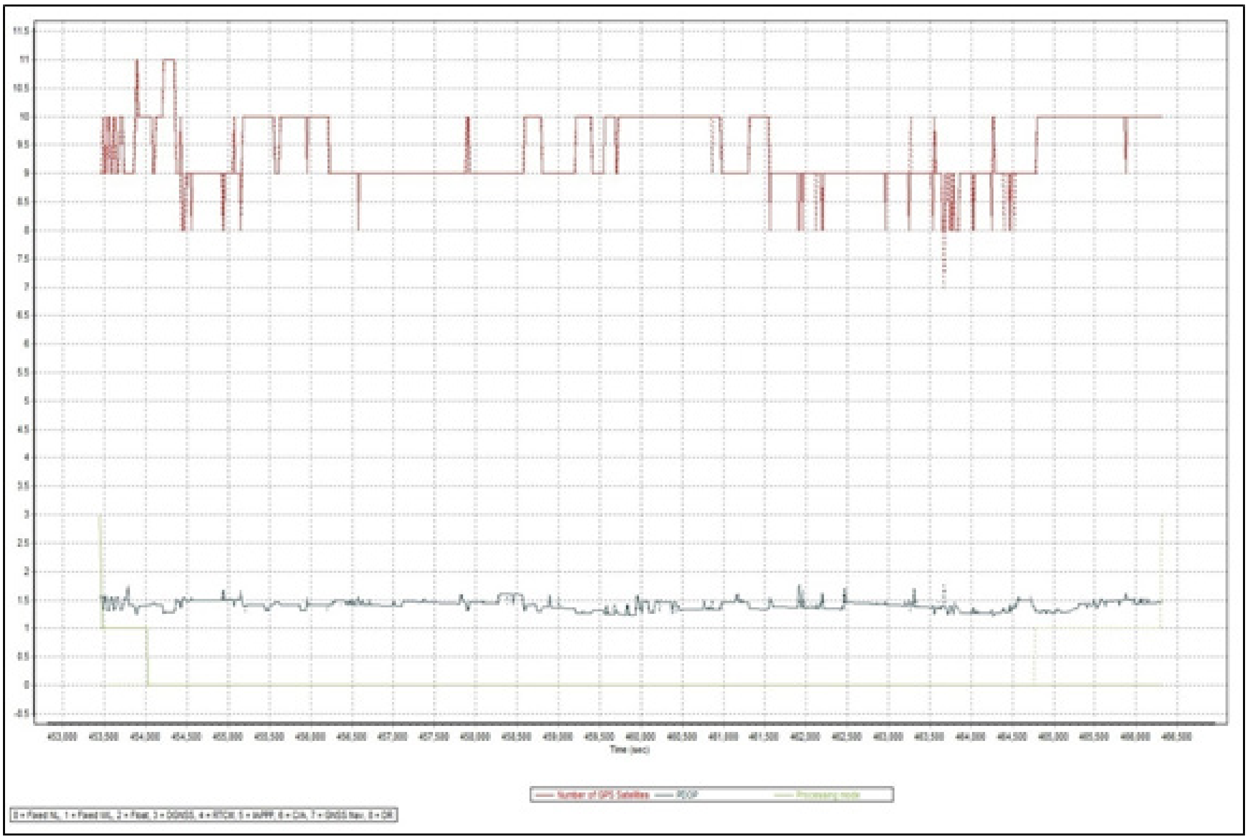

Figure A-8.1 Solution Status

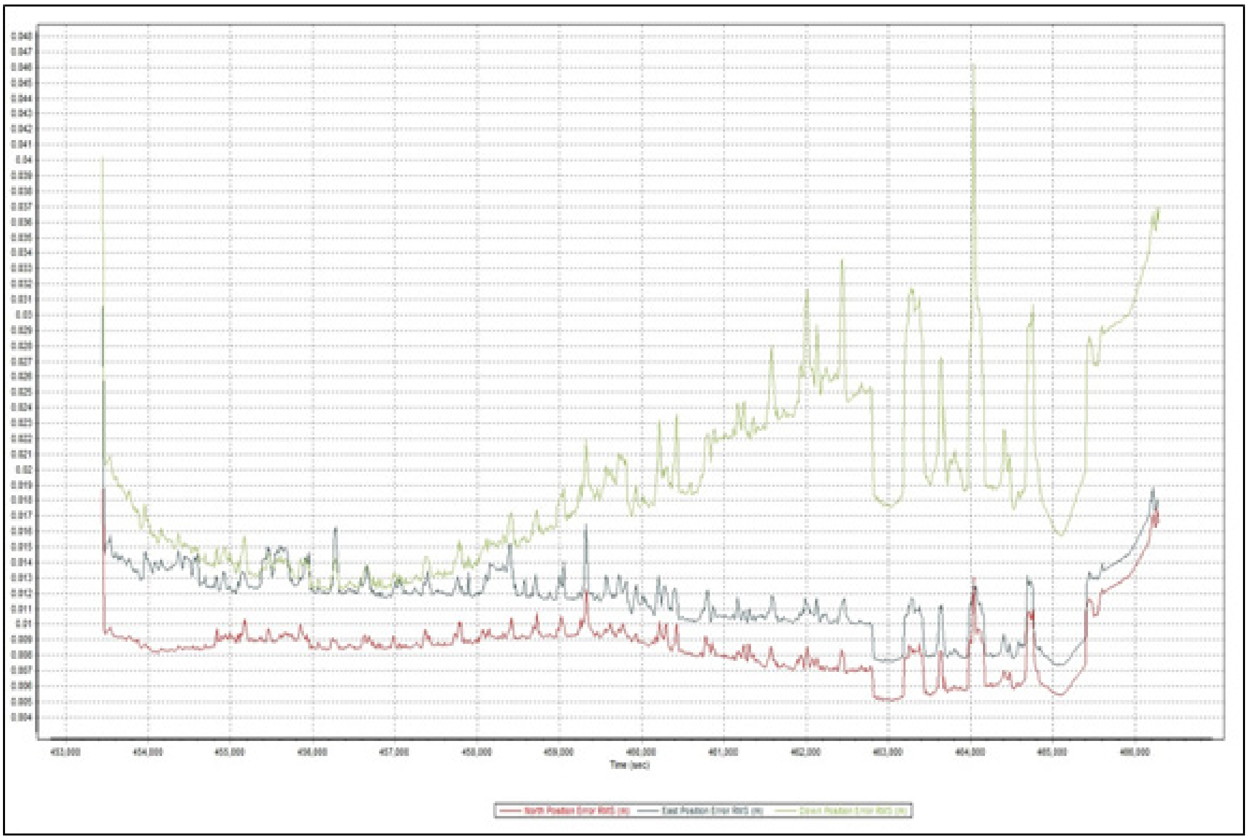

Figure A-8.2 Smoothed Performance Metric Parameters

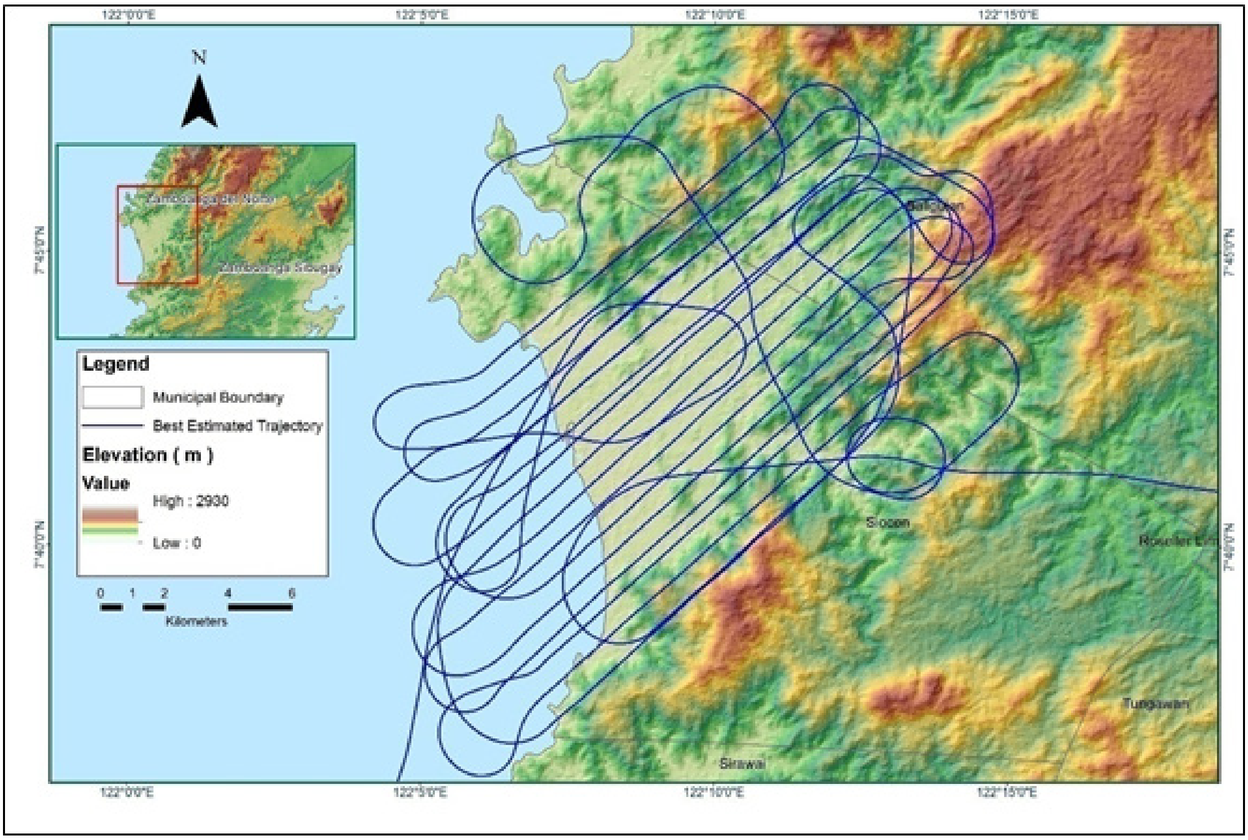

Figure A-8.3 Best Estimated Trajectory

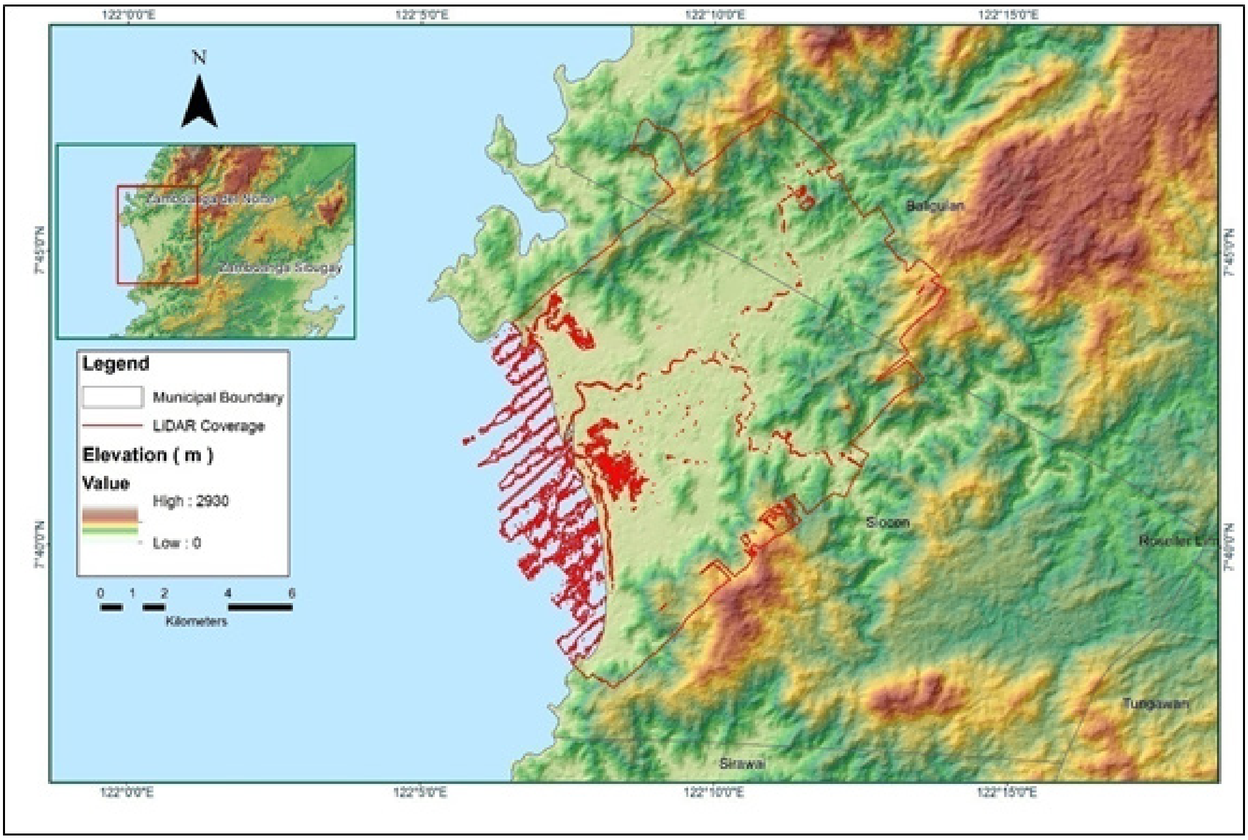

Figure A-8.4 Coverage of LiDAR Data

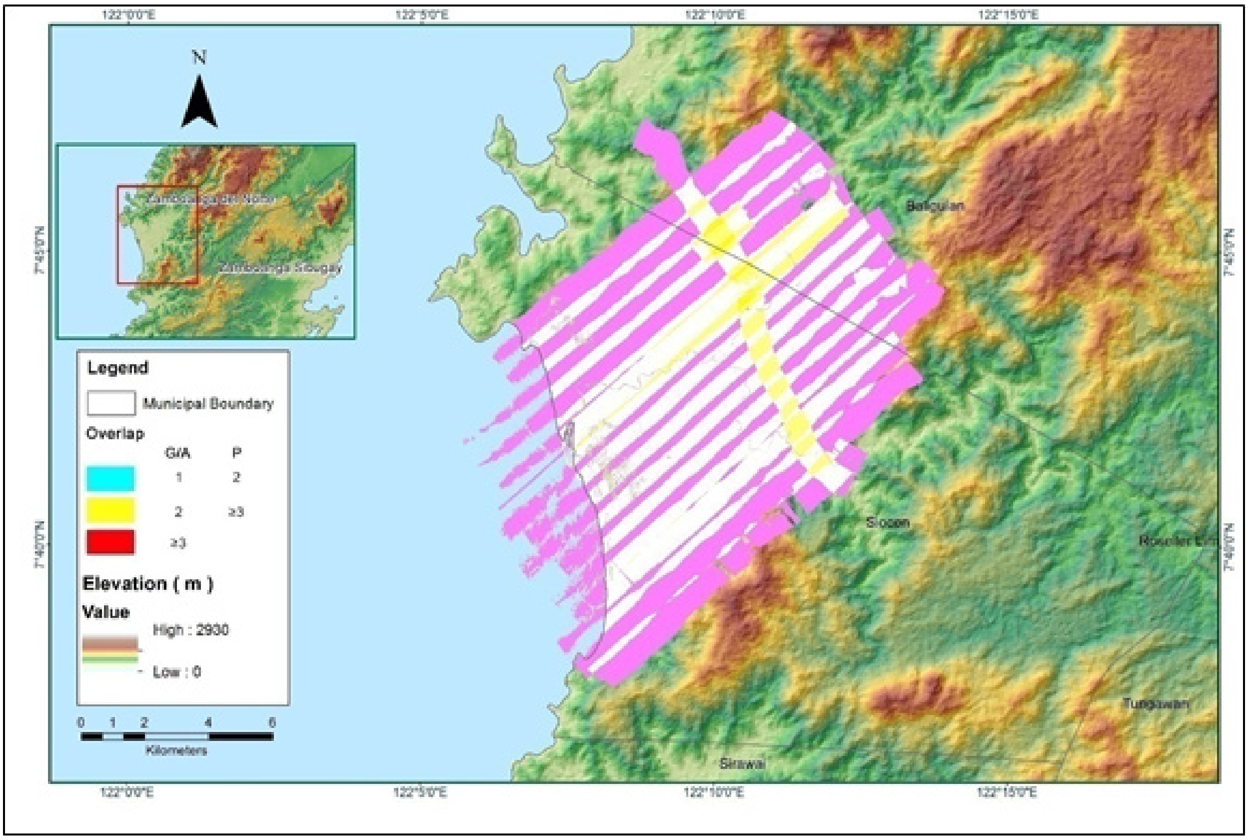

Figure A-8.5 Image of data overlap

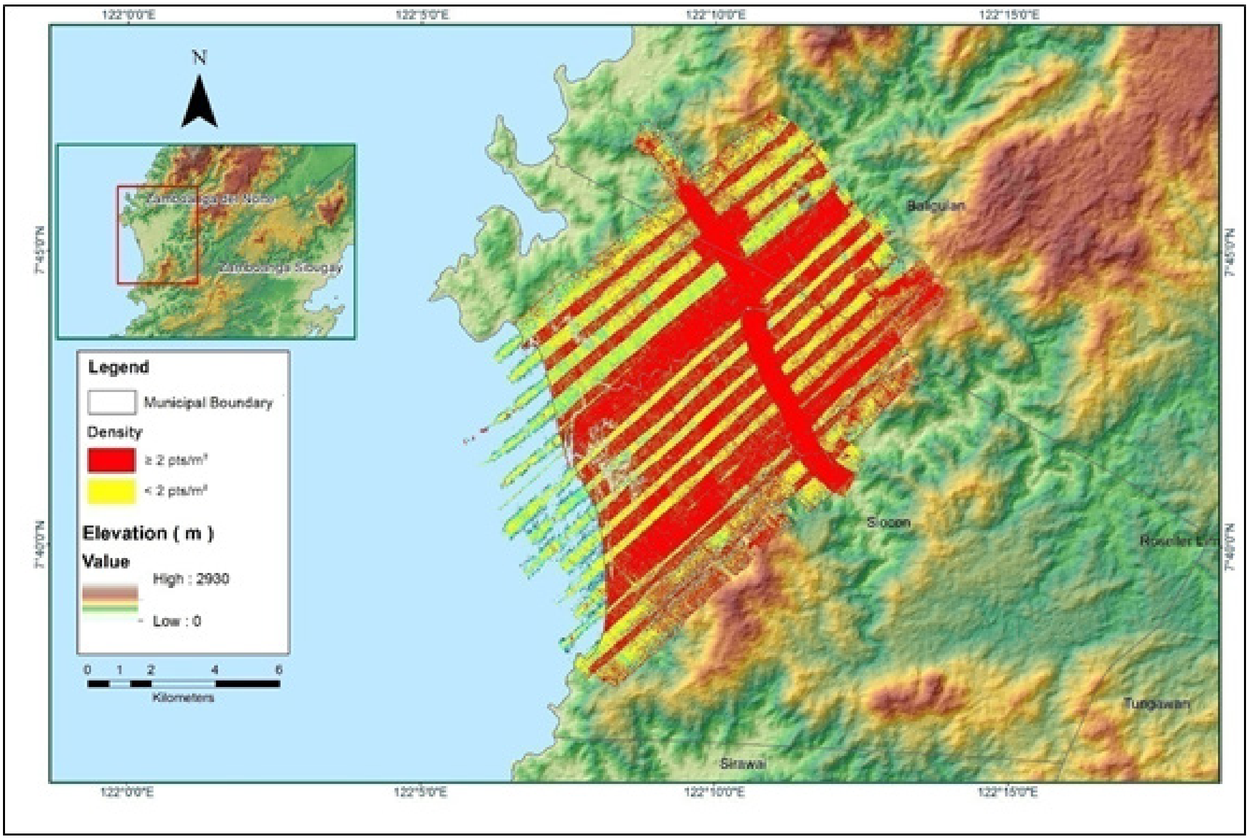

Figure A-8.6 Density map of merged LiDAR data

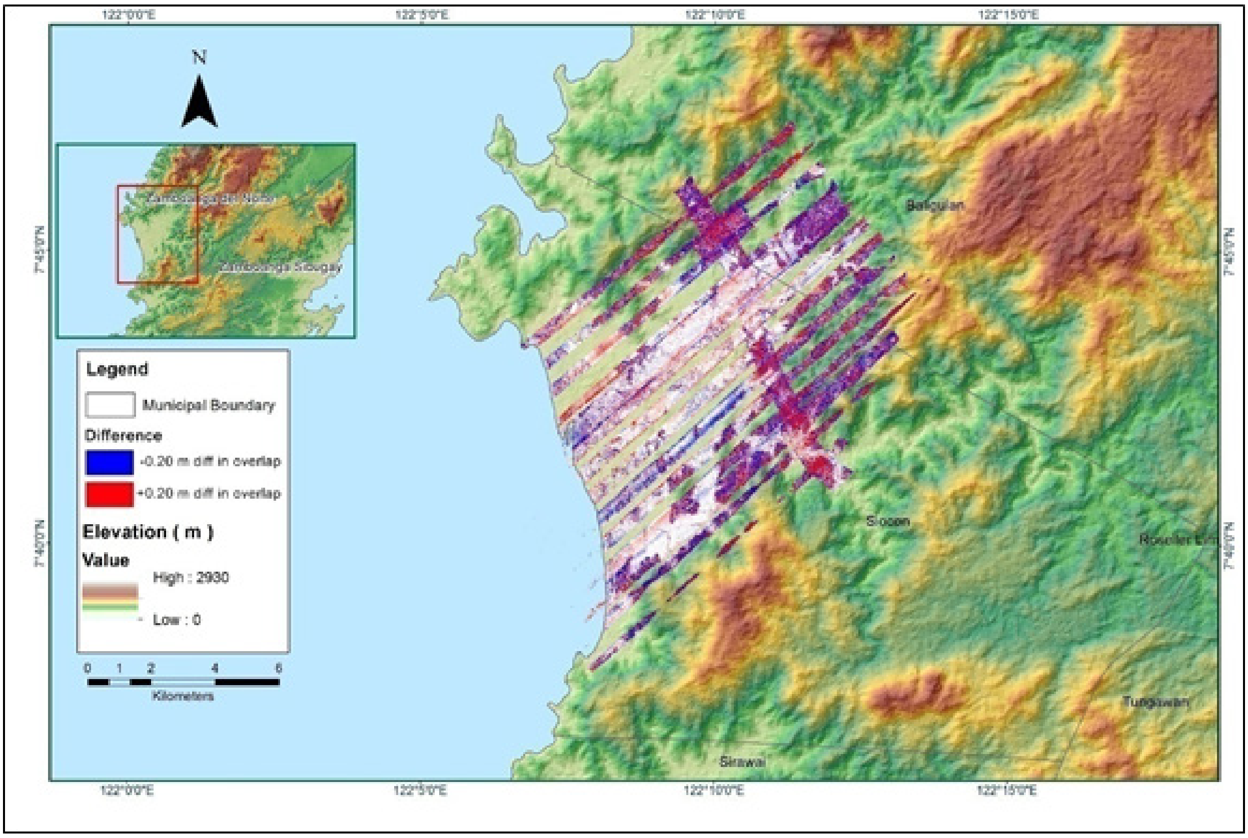

Figure A-8.7 Elevation difference between flight lines

Table A-8.2 Mission Summary Report for Mission Blk75J

FLIGHT AREA	ZAMBOANGA REFLIGHTS
Mission Name	Blk75J
Inclusive Flights	23408P
Range data size	7.88 GB
POS data size	173 MB
Base data size	171 MB
Image	8.73 MB
Transfer date	July 14, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.7
RMSE for East Position (<4.0 cm)	1.5
RMSE for Down Position (<8.0 cm)	4.1
Boresight correction stdev (<0.001deg)	0.000218
IMU attitude correction stdev (<0.001deg)	0.000422
GPS position stdev (<0.01m)	0.0013
Minimum % overlap (>25)	41.14
Ave point cloud density per sq.m. (>2.0)	3.08
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	90
Maximum Height	465.70 m
Minimum Height	64.45 m
Classification (# of points)	
Ground	36,614,275
Low vegetation	29,343,309
Medium vegetation	56,737,192
High vegetation	143,782,295
Building	729,445
Orthophoto	No
Processed by	Engr. Don Matthew Banatin, Aljon Rei Araneta, Engr. MonalynRabino

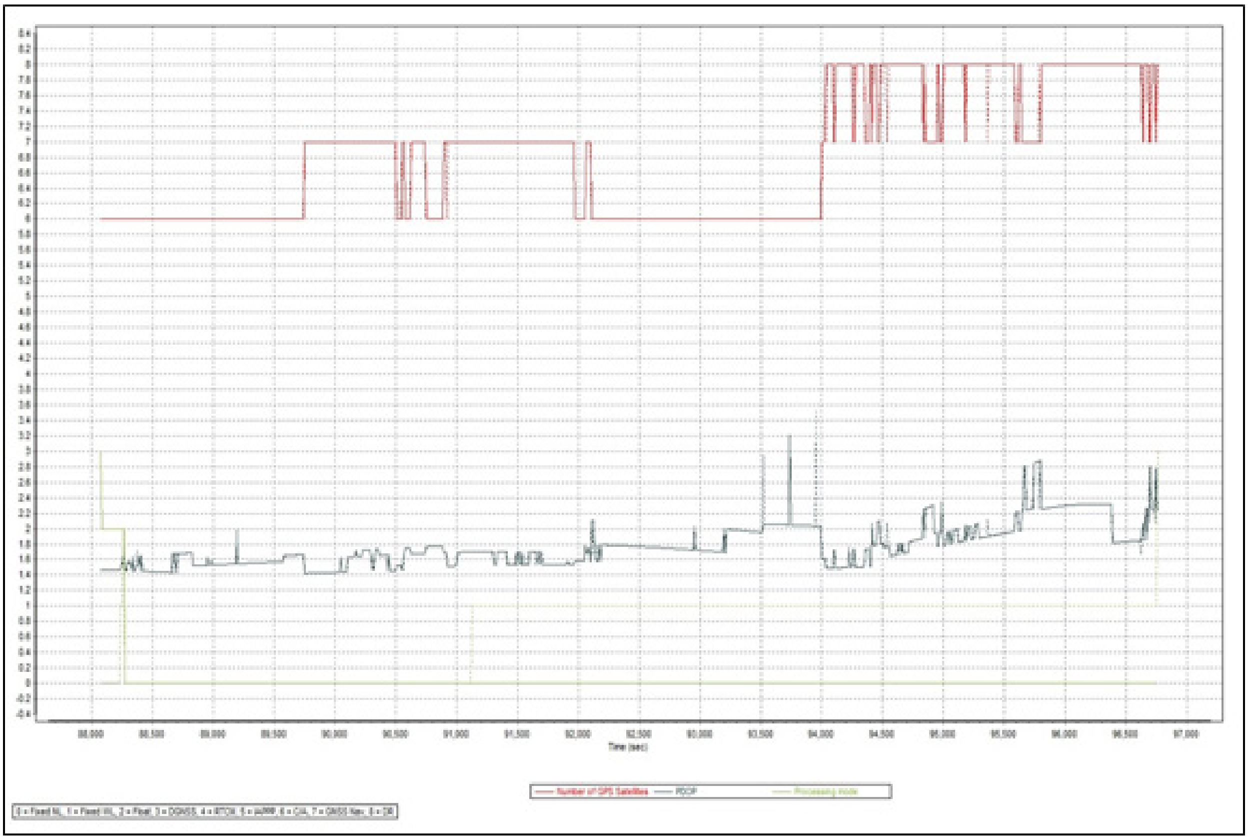

Figure A-8.8 Solution Status

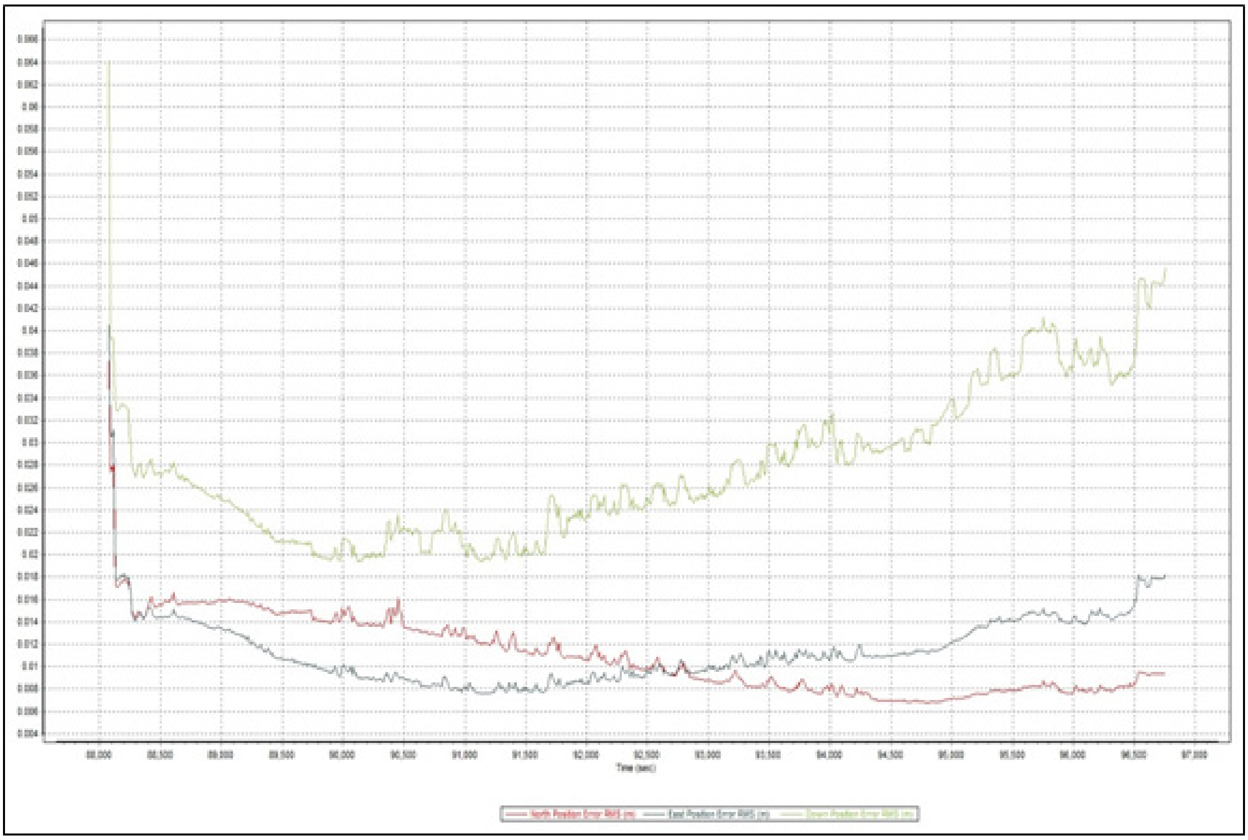

Figure A-8.9 Smoothed Performance Metric Parameters

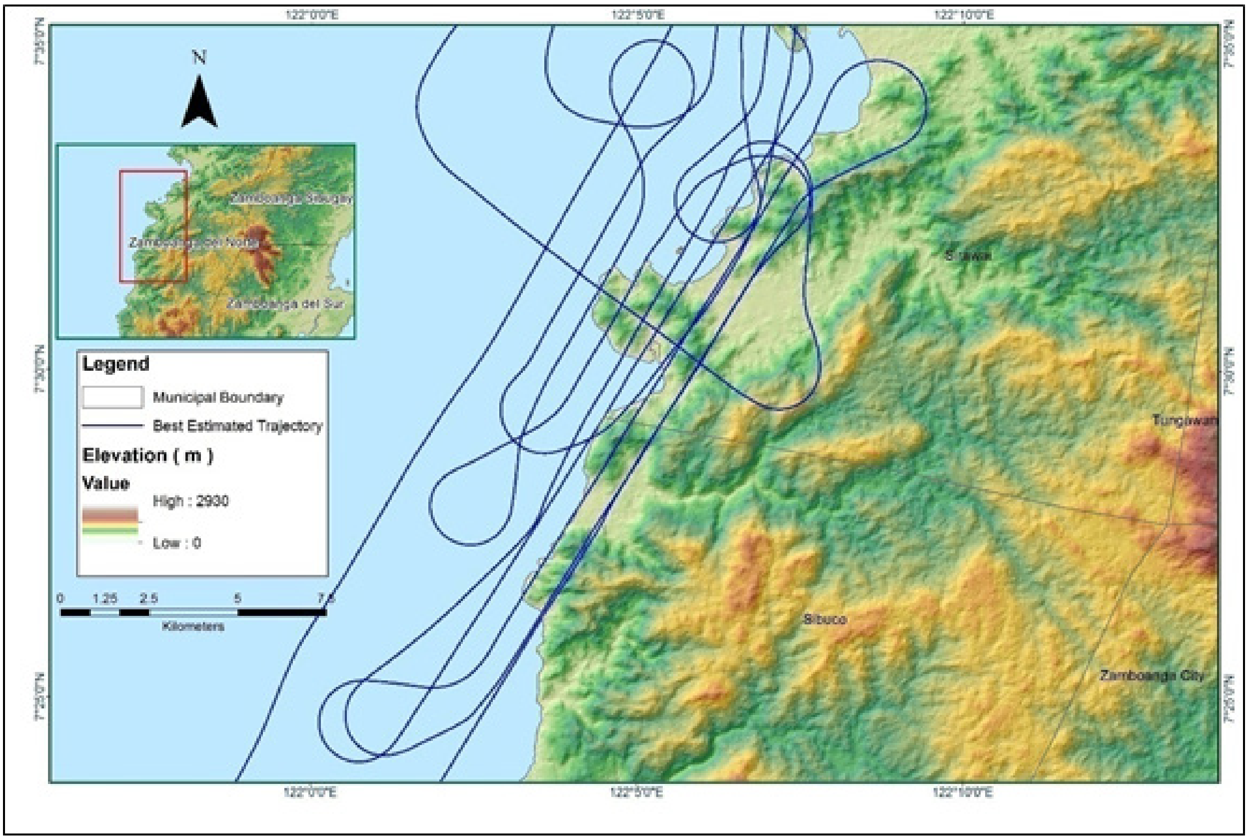

Figure A-8.10 Best Estimated Trajectory

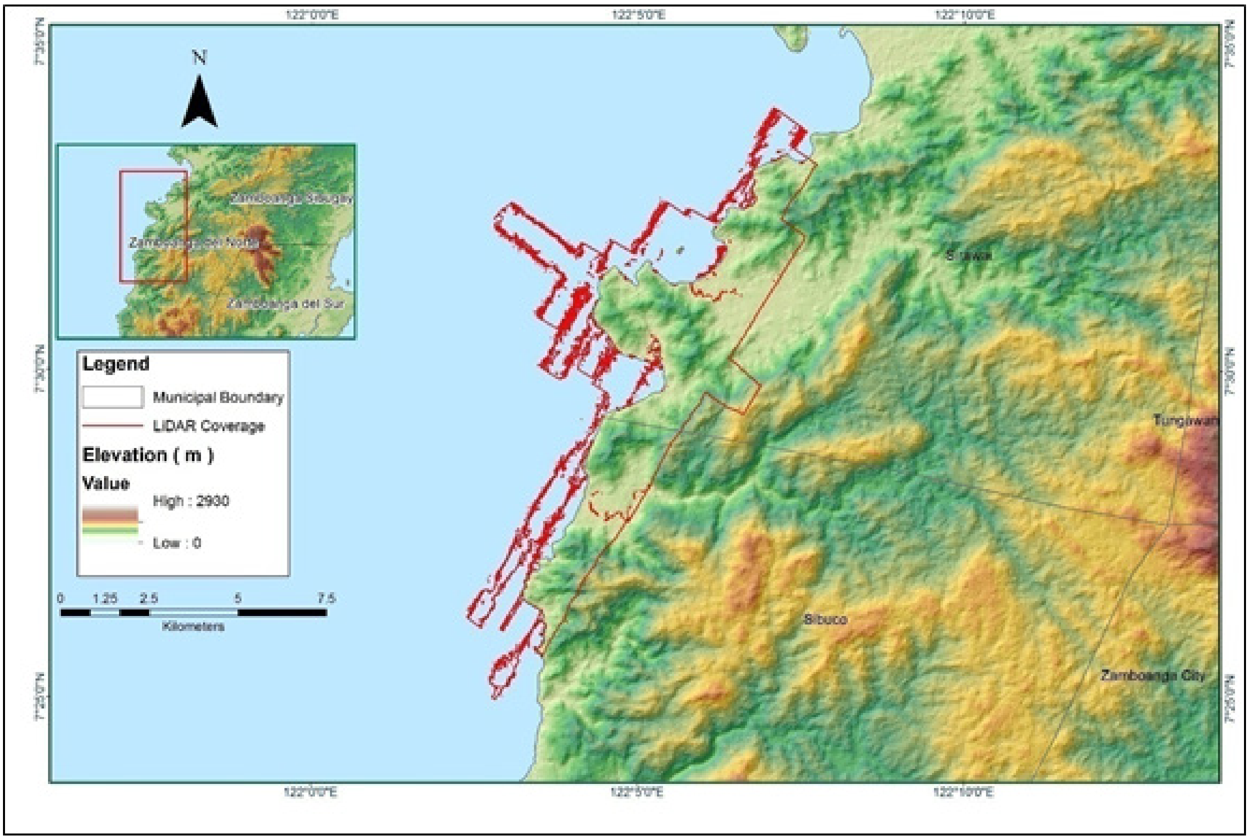

Figure A-8.11 Coverage of LiDAR Data

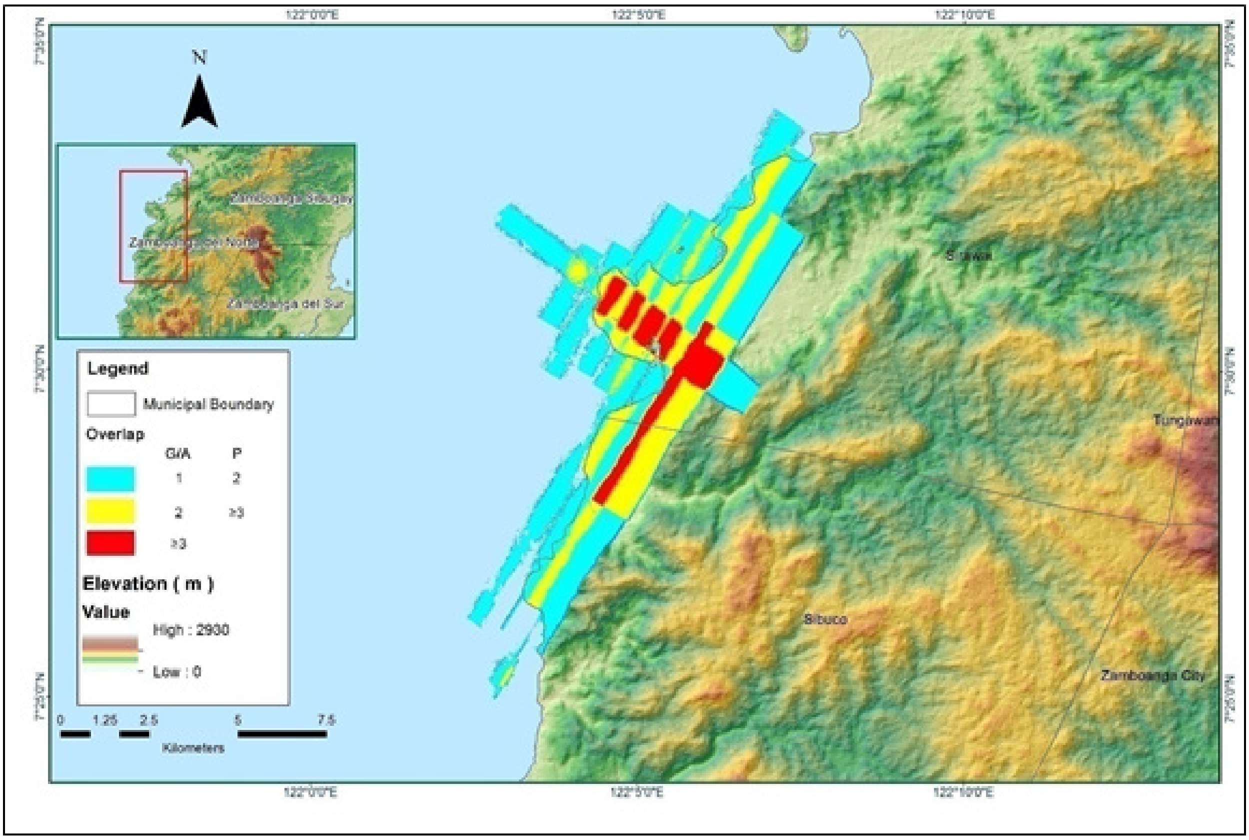

Figure A-8.12 Image of data overlap

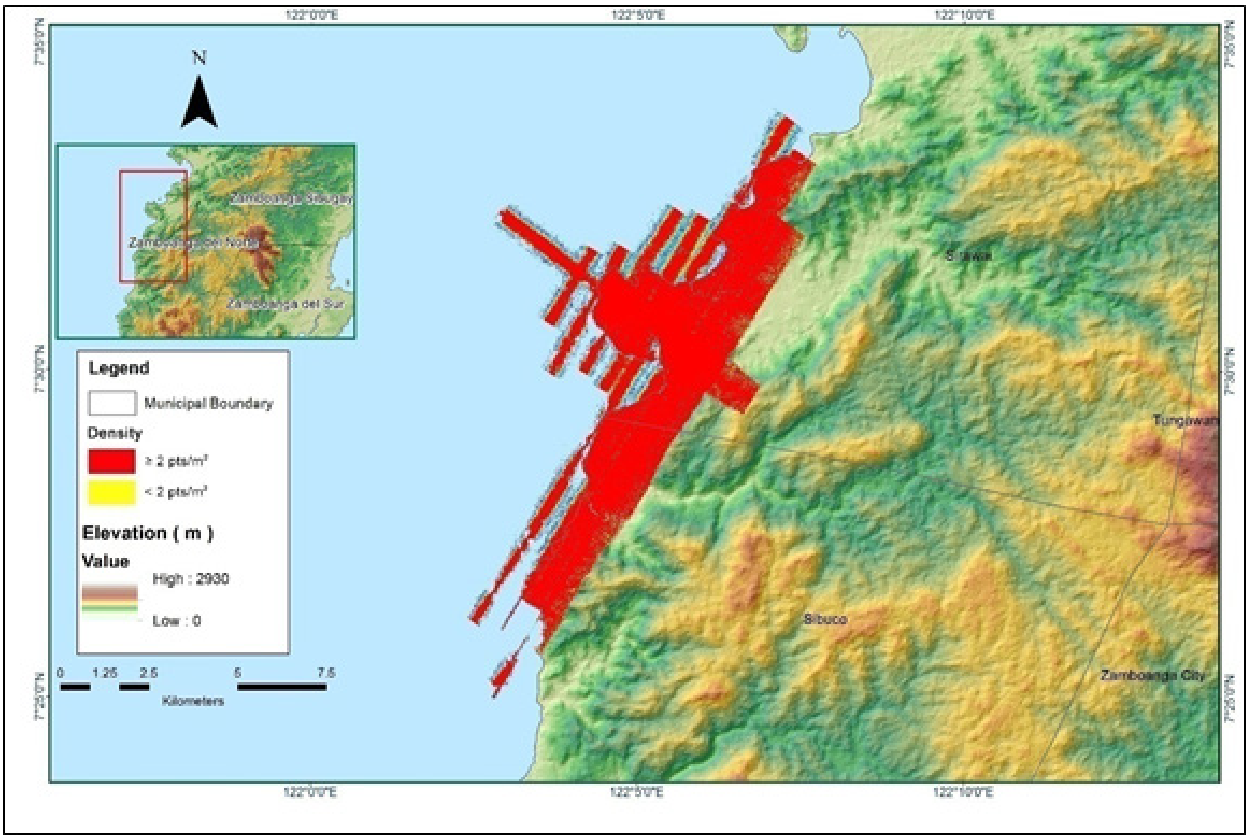

Figure A-8.13 Density map of merged LiDAR data

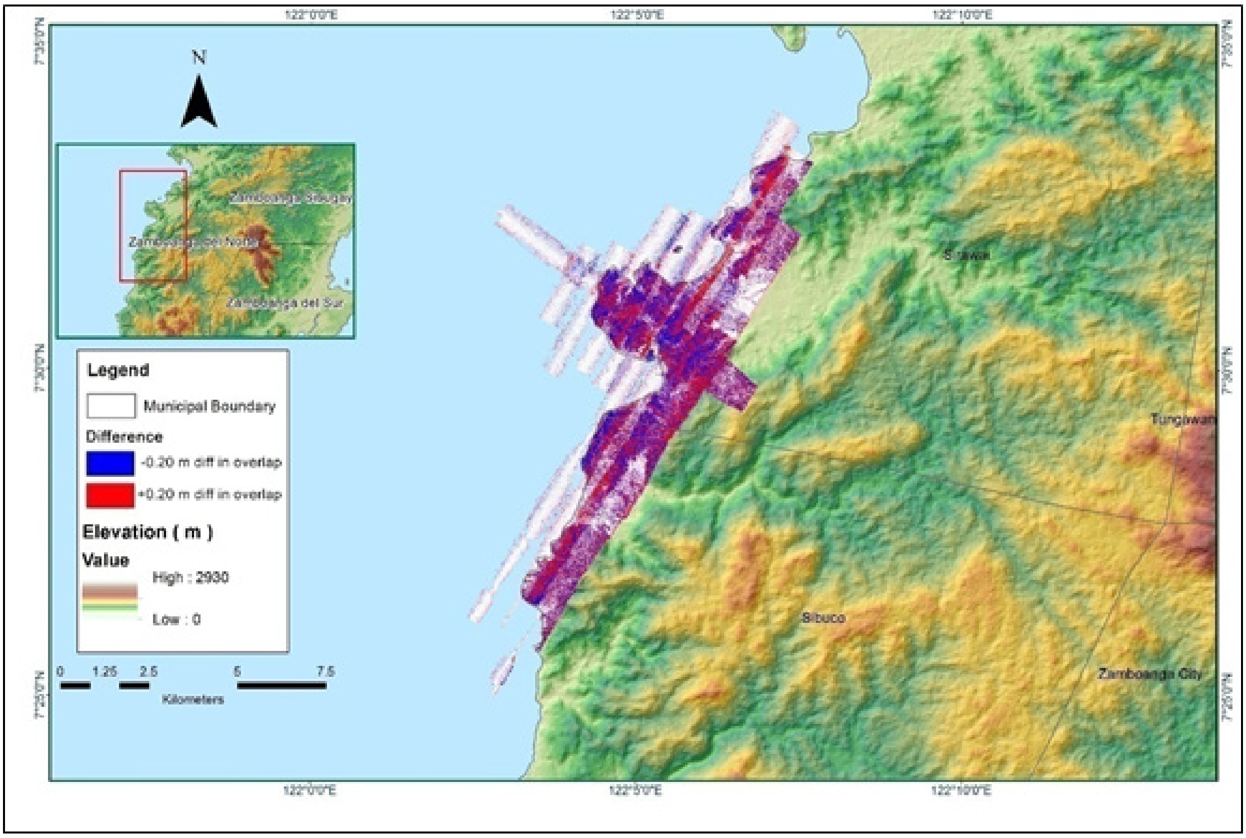

Figure A-8.14 Elevation difference between flight lines

Table A-8.3 Mission Summary Report for Mission Blk75K

FLIGHT AREA	ZAMBOANGA REFLIGHTS
Mission Name	Blk75K
Inclusive Flights	23408P
Range data size	7.88 GB
POS data size	173 MB
Base data size	171 MB
Image	8.73 MB
Transfer date	July 14, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.7
RMSE for East Position (<4.0 cm)	1.5
RMSE for Down Position (<8.0 cm)	4.1
Boresight correction stdev (<0.001deg)	0.000281
IMU attitude correction stdev (<0.001deg)	0.000736
GPS position stdev (<0.01m)	0.0018
Minimum % overlap (>25)	26.8
Ave point cloud density per sq.m. (>2.0)	2.51
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	43
Maximum Height	384.17 m
Minimum Height	64.58 m
Classification (# of points)	
Ground	16,969,010
Low vegetation	10,257,584
Medium vegetation	14,800,967
High vegetation	39,303,270
Building	162,428
Orthophoto	No
Processed by	Engr. Don Matthew Banatin, Chelou, Tam

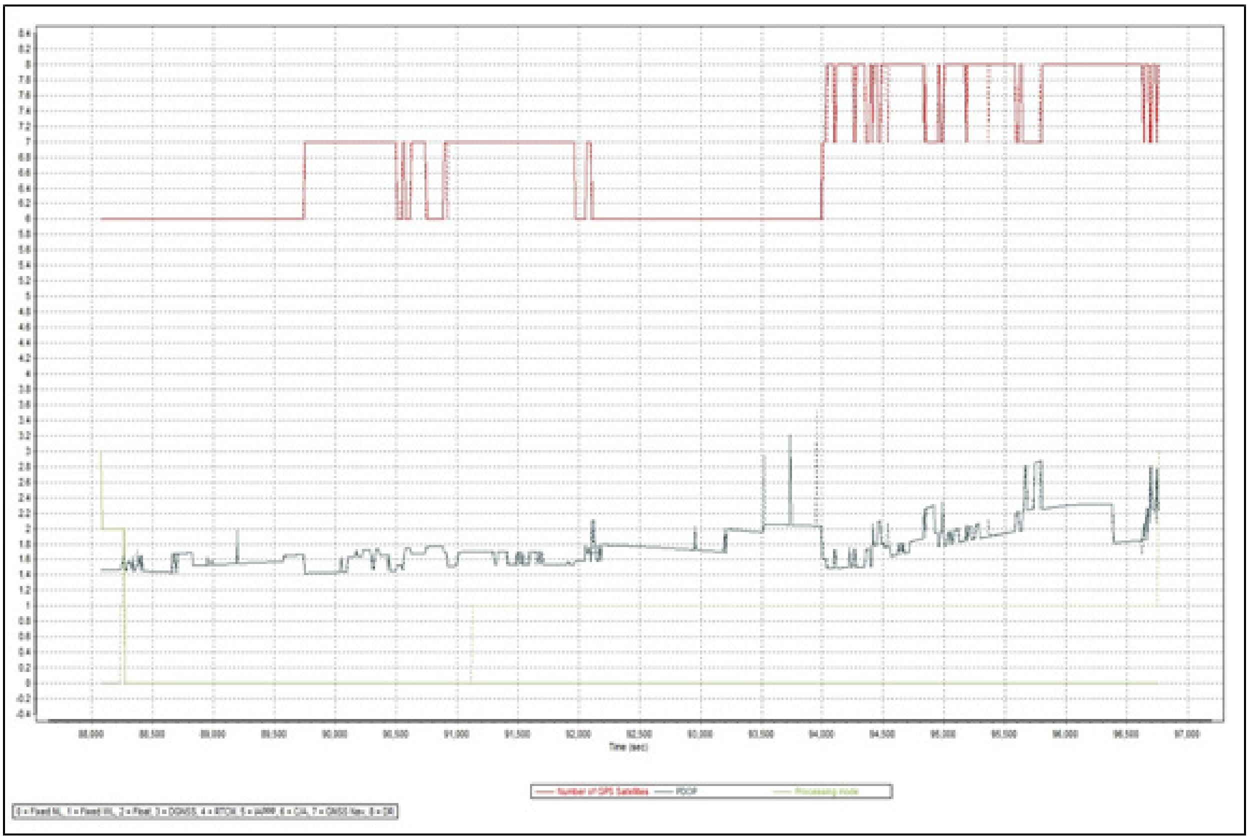

Figure A-8.15 Solution Status

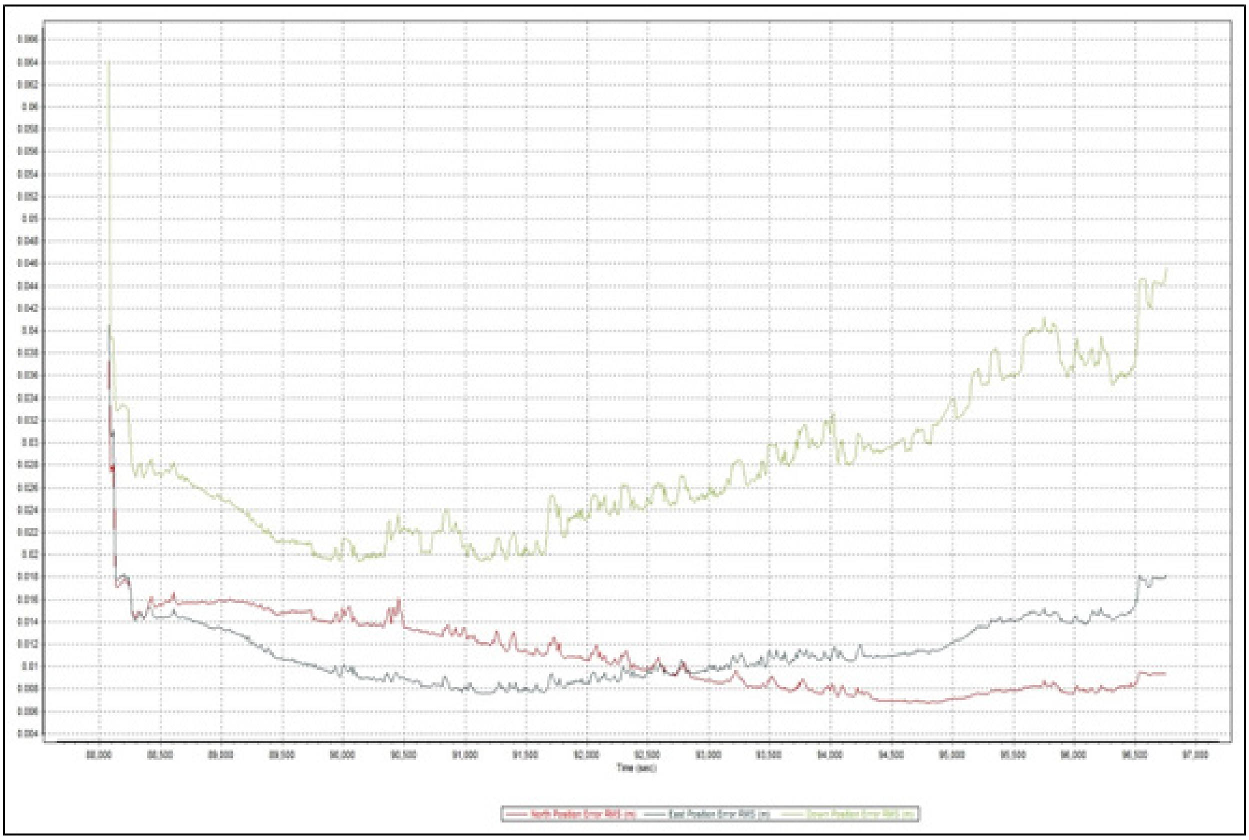

Figure A-8.16 Smoothed Performance Metric Parameters

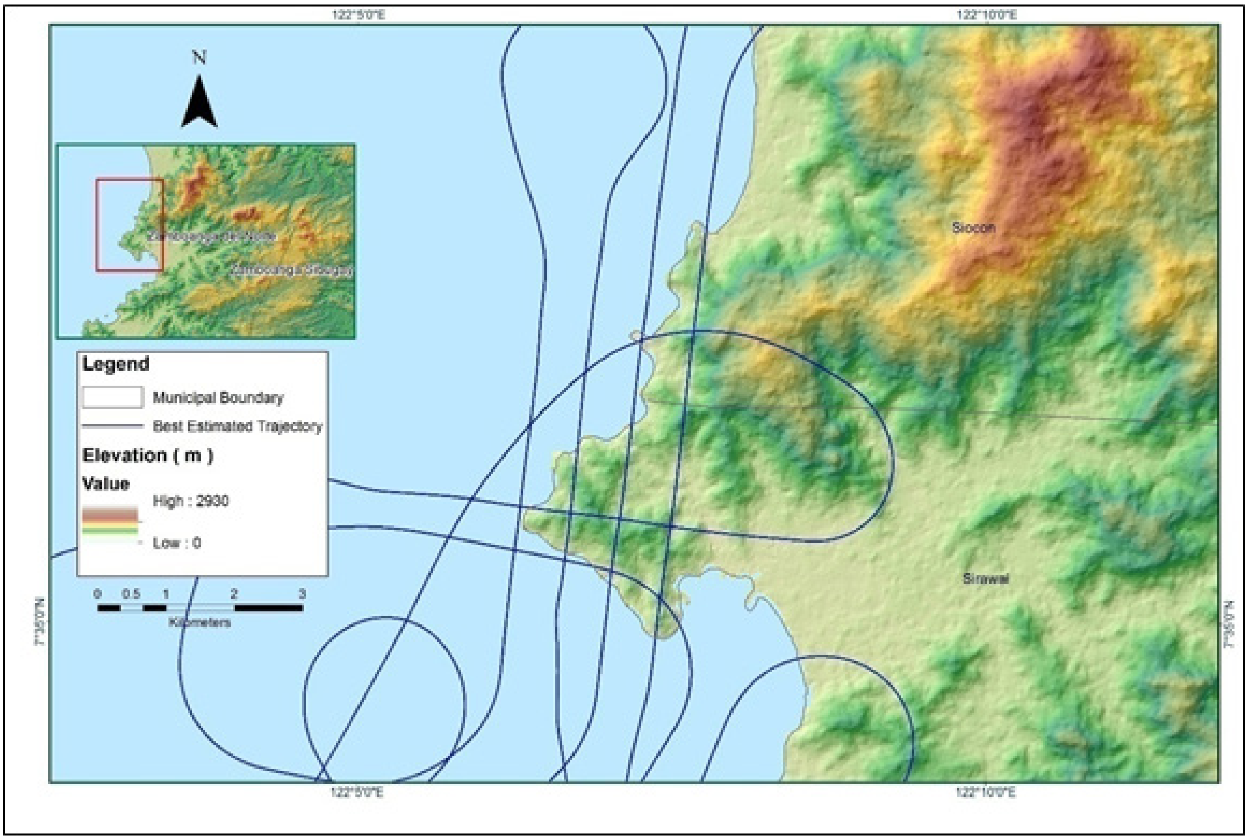

Figure A-8.17 Best Estimated Trajectory

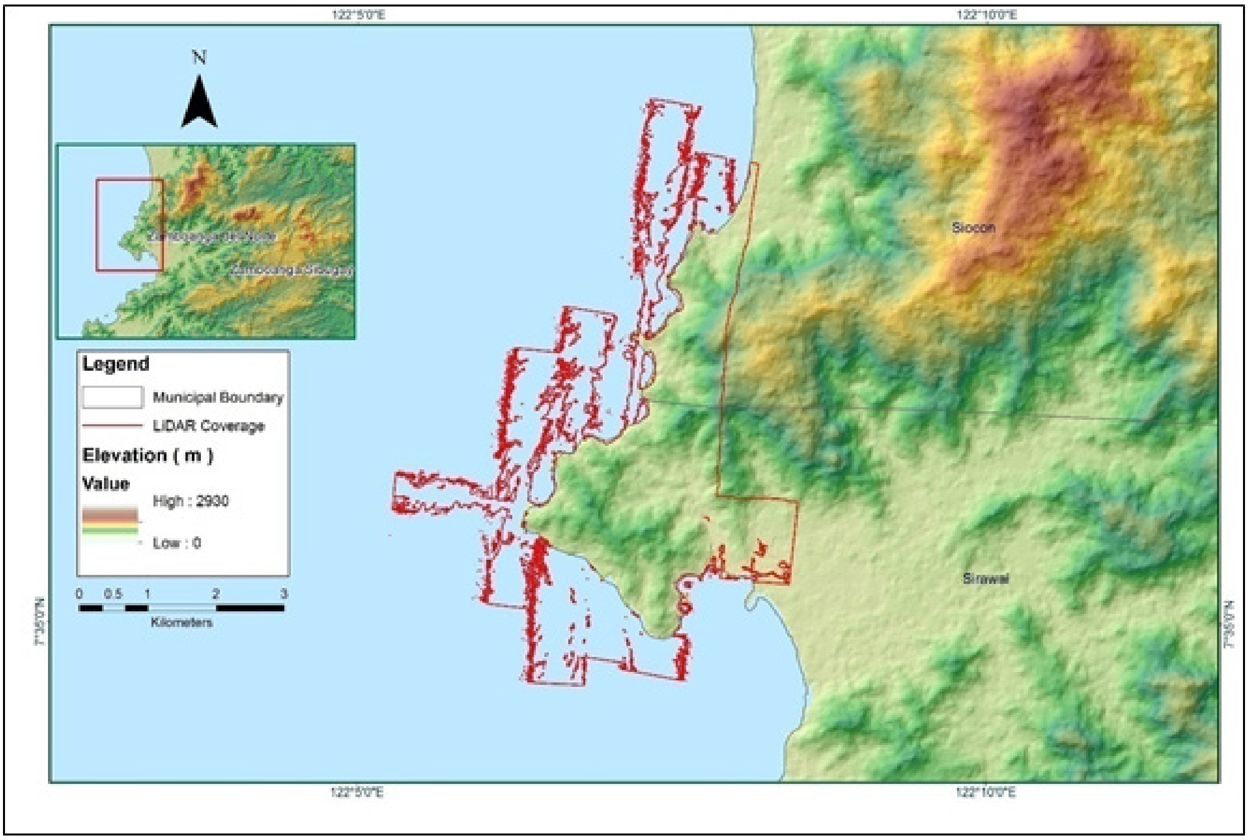

Figure A-8.18 Coverage of LiDAR Data

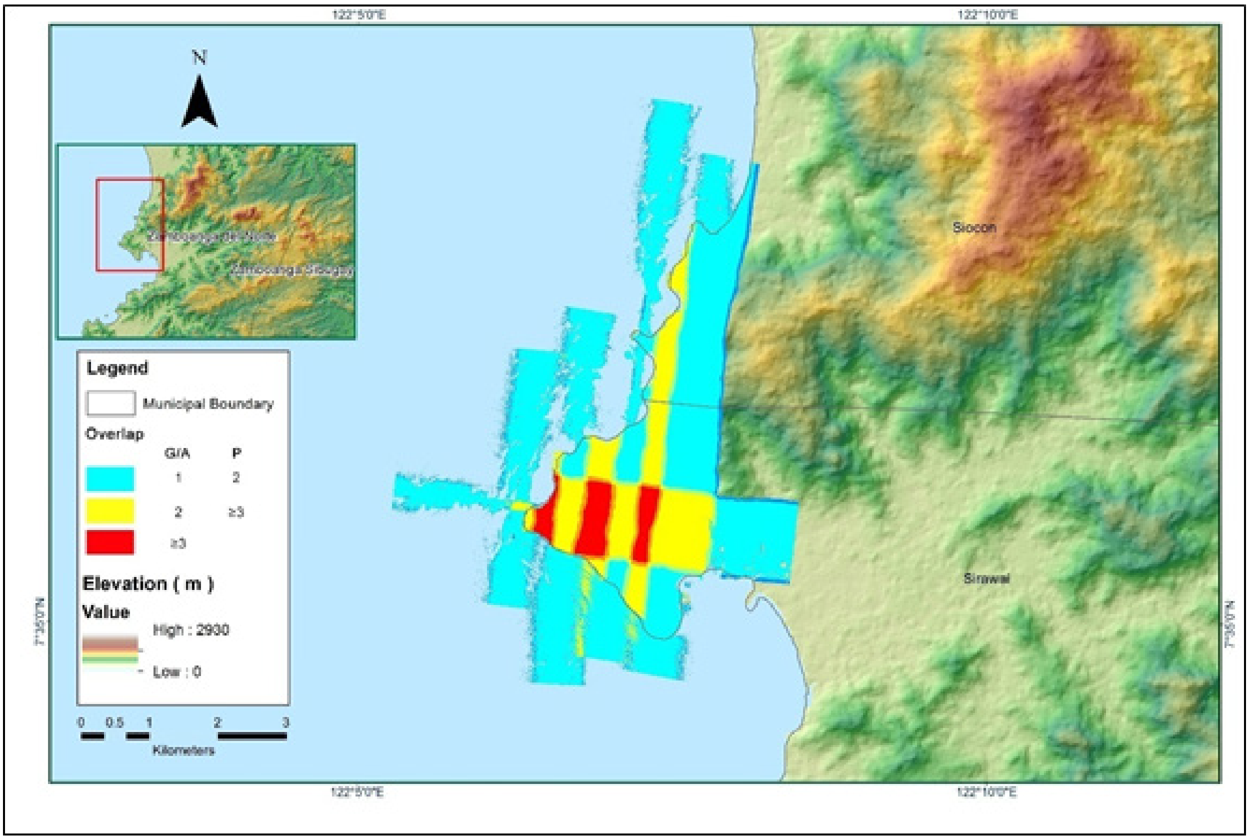

Figure A-8.19 Image of data overlap

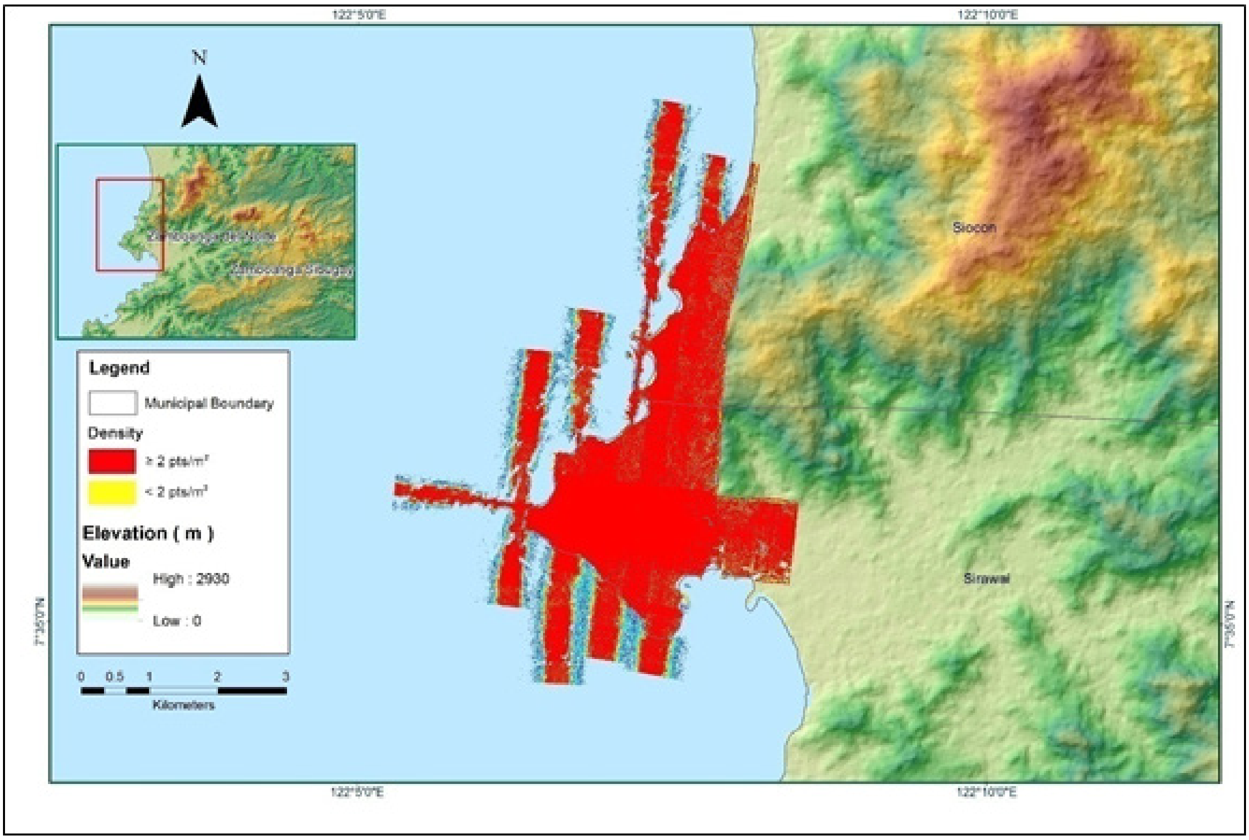

Figure A-8.20 Density map of merged LiDAR data

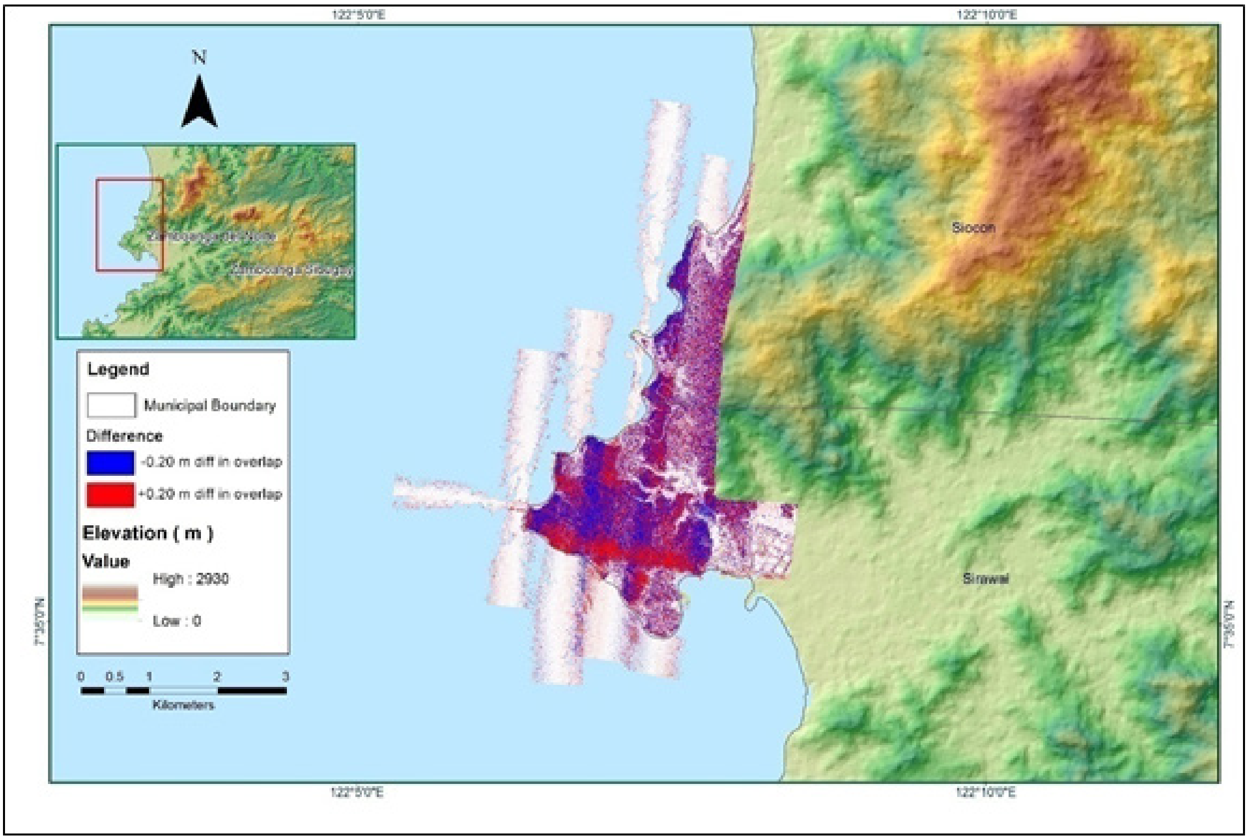

Figure A-8.21 Elevation difference between flight lines

Annex 9. Siocon Model Basin Parameters

Table A-9.1 Siocon 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
W6180	16.9335	60	0.0	0.18688	0.30499	Discharge	0.0375791	0.4	Ratio to Peak	0.25
W6170	16.9335	60	0.0	0.24701	0.40311	Discharge	0.0682086	0.4	Ratio to Peak	0.25
W6160	16.9625	59.959	0.0	0.17963	0.29316	Discharge	0.0507104	0.4	Ratio to Peak	0.25
W6150	16.9355	59.997	0.0	0.12392	0.20224	Discharge	0.0206671	0.4	Ratio to Peak	0.25
W6140	19.0325	57.165	0.0	0.14336	0.23396	Discharge	0.0306604	0.4	Ratio to Peak	0.25
W6130	20.5995	55.218	0.0	0.049825	0.081314	Discharge	0.0041617	0.4	Ratio to Peak	0.25
W6120	13.8585	64.699	0.0	0.22335	0.36451	Discharge	0.0421709	0.4	Ratio to Peak	0.25
W6110	17.1615	59.678	0.0	0.29923	0.48834	Discharge	0.0963370	0.4	Ratio to Peak	0.25
W6100	20.324	55.551	0.0	0.19096	0.31165	Discharge	0.0275404	0.4	Ratio to Peak	0.25
W6090	13.7045	64.954	0.0	0.11331	0.18493	Discharge	0.0278943	0.4	Ratio to Peak	0.25
W6080	13.958	64.536	0.0	0.060813	0.099247	Discharge	0.0047080	0.4	Ratio to Peak	0.25
W6070	18.1135	58.372	0.0	0.19276	0.31459	Discharge	0.0719928	0.4	Ratio to Peak	0.25
W6060	19.319	56.799	0.0	0.13115	0.21403	Discharge	0.0276693	0.4	Ratio to Peak	0.25
W6050	18.7245	57.565	0.0	0.1051	0.17152	Discharge	0.0065375	0.4	Ratio to Peak	0.25
W6040	17.271	59.525	0.0	0.090826	0.14823	Discharge	0.0115686	0.4	Ratio to Peak	0.25
W6030	17.911	58.646	0.0	0.10153	0.16569	Discharge	0.0145670	0.4	Ratio to Peak	0.25
W6020	18.4715	57.896	0.0	0.19426	0.31704	Discharge	0.0632755	0.4	Ratio to Peak	0.25
W6010	20.6025	55.214	0.0	0.13234	0.21597	Discharge	0.0208414	0.4	Ratio to Peak	0.25
W6000	7.5245	77.146	0.0	0.18203	0.29707	Discharge	0.0353049	0.4	Ratio to Peak	0.25
W5990	18.1275	58.354	0.0	0.23623	0.38552	Discharge	0.0995568	0.4	Ratio to Peak	0.25
W5980	17.6415	59.013	0.0	0.11105	0.18123	Discharge	0.0265277	0.4	Ratio to Peak	0.25
W5970	9.7936146	72.172	0.0	0.25691	0.41928	Discharge	0.0643209	0.4	Ratio to Peak	0.25

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
W5960	17.921	58.632	0.0	0.16707	0.27266	Discharge	0.0567524	0.4	Ratio to Peak	0.25
W5950	9.9805	71.791	0.0	0.17309	0.28248	Discharge	0.0336787	0.4	Ratio to Peak	0.25
W5940	10.672	70.415	0.0	0.038421	0.062702	Discharge	0.0015046	0.4	Ratio to Peak	0.25
W5930	16.9335	60	0.0	0.12143	0.19817	Discharge	0.0193676	0.4	Ratio to Peak	0.25
W5920	17.573	59.107	0.0	0.25336	0.41348	Discharge	0.10284	0.4	Ratio to Peak	0.25
W5910	12.062	67.802	0.0	0.061238	0.09994	Discharge	0.0032760	0.4	Ratio to Peak	0.25
W5900	10.632	70.493	0.0	0.075325	0.12293	Discharge	0.0110387	0.4	Ratio to Peak	0.25
W5890	16.9335	60	0.0	0.12894	0.21043	Discharge	0.0182369	0.4	Ratio to Peak	0.25
W5880	17.923	58.629	0.0	0.21672	0.35369	Discharge	0.0642555	0.4	Ratio to Peak	0.25
W5870	17.010	59.892	0.0	0.12491	0.20386	Discharge	0.0275785	0.4	Ratio to Peak	0.25
W5860	16.9008293	60.046	0.0	0.20048	0.32718	Discharge	0.0387370	0.4	Ratio to Peak	0.25
W5850	16.9335	60	0.0	0.088642	0.14466	Discharge	0.0020727	0.4	Ratio to Peak	0.25
W5840	20.782	55	0.0	0.15809	0.258	Discharge	0.0454324	0.4	Ratio to Peak	0.25
W5830	17.955	58.586	0.0	0.17383	0.28369	Discharge	0.0434795	0.4	Ratio to Peak	0.25
W5820	16.9335	60	0.0	0.12762	0.20828	Discharge	0.0065285	0.4	Ratio to Peak	0.25
W5810	20.940	54.812	0.0	0.2319	0.37846	Discharge	0.0651993	0.4	Ratio to Peak	0.25
W5800	12.2985	67.377	0.0	0.12315	0.20099	Discharge	0.0276784	0.4	Ratio to Peak	0.25
W5790	16.9335	60	0.0	0.17537	0.2862	Discharge	0.0422345	0.4	Ratio to Peak	0.25
W5780	16.9335	60	0.0	0.055503	0.09058	Discharge	0.0011380	0.4	Ratio to Peak	0.25
W5770	16.9335	60	0.0	0.15943	0.26019	Discharge	0.0266402	0.4	Ratio to Peak	0.25
W5760	16.9335	60	0.0	0.156	0.25459	Discharge	0.0257037	0.4	Ratio to Peak	0.25
W5750	16.9335	60	0.0	0.07896	0.12886	Discharge	0.0065775	0.4	Ratio to Peak	0.25
W5740	16.9335	60	0.0	0.12387	0.20216	Discharge	0.0216545	0.4	Ratio to Peak	0.25
W5730	16.9335	60	0.0	0.1434	0.23403	Discharge	0.0207524	0.4	Ratio to Peak	0.25

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
W5720	21.9955	53.592	0.0	0.11794	0.19248	Discharge	0.0296258	0.4	Ratio to Peak	0.25
W5710	13.1215	65.937	0.0	0.19356	0.31589	Discharge	0.0705553	0.4	Ratio to Peak	0.25
W5700	16.9555	59.969	0.0	0.3136	0.5118	Discharge	0.0752489	0.4	Ratio to Peak	0.25
W5690	8.056	75.921	0.0	0.18829	0.30729	Discharge	0.0661250	0.4	Ratio to Peak	0.25
W5680	18.7834891	57.488	0.0	0.10096	0.16477	Discharge	0.0348076	0.4	Ratio to Peak	0.25
W5670	12.3605	67.266	0.0	0.10025	0.16361	Discharge	0.0265567	0.4	Ratio to Peak	0.25
W5660	17.3985	59.348	0.0	0.088856	0.14501	Discharge	0.0220029	0.4	Ratio to Peak	0.25
W5650	18.711	57.582	0.0	0.24151	0.39415	Discharge	0.0473636	0.4	Ratio to Peak	0.25
W5640	13.085	66	0.0	0.066914	0.1092	Discharge	0.0107338	0.4	Ratio to Peak	0.25
W5630	10.7985	70.169	0.0	0.074961	0.12234	Discharge	0.0194039	0.4	Ratio to Peak	0.25
W5620	16.9335	60	0.0	0.19283	0.3147	Discharge	0.0232244	0.4	Ratio to Peak	0.25
W5610	17.3662531	59.393	0.0	0.14961	0.24416	Discharge	0.0314481	0.4	Ratio to Peak	0.25
W5600	23.887	51.535	0.0	0.16077	0.26238	Discharge	0.0460768	0.4	Ratio to Peak	0.25
W5590	18.111	58.376	0.0	0.18414	0.30052	Discharge	0.0291358	0.4	Ratio to Peak	0.25
W5580	22.9495	52.534	0.0	0.17581	0.28693	Discharge	0.0205419	0.4	Ratio to Peak	0.25
W5570	21.7455	53.876	0.0	0.093318	0.1523	Discharge	0.0247399	0.4	Ratio to Peak	0.25
W5560	24.5805	50.820	0.0	0.17321	0.28268	Discharge	0.0436973	0.4	Ratio to Peak	0.25
W5550	8.5355	74.848	0.0	0.15178	0.24771	Discharge	0.0577144	0.4	Ratio to Peak	0.25
W5540	17.1875	59.642	0.0	0.33849	0.55242	Discharge	0.0990595	0.4	Ratio to Peak	0.25
W5530	22.6755	52.833	0.0	0.15378	0.25096	Discharge	0.0187451	0.4	Ratio to Peak	0.25
W5520	8.071	75.886	0.0	0.11415	0.1863	Discharge	0.0187033	0.4	Ratio to Peak	0.25
W5510	26.963	48.507	0.0	0.50656	0.82671	Discharge	0.0204729	0.4	Ratio to Peak	0.25
W5500	25.57	49.833	0.0	0.21618	0.35281	Discharge	0.0212624	0.4	Ratio to Peak	0.25
W5490	7.164	78	0.0	0.16117	0.26304	Discharge	0.11685	0.4	Ratio to Peak	0.25

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
W5480	26.5571493	48.886	0.0	0.078266	0.12773	Discharge	0.0082309	0.4	Ratio to Peak	0.25
W5470	7.164	78	0.0	0.038911	0.063502	Discharge	0.0039149	0.4	Ratio to Peak	0.25
W5460	17.3105	59.470	0.0	0.14598	0.23823	Discharge	0.0234150	0.4	Ratio to Peak	0.25
W5450	25.371	50.028	0.0	0.12806	0.20899	Discharge	0.0074523	0.4	Ratio to Peak	0.25
W5440	20.397	55.462	0.0	0.10288	0.1679	Discharge	0.0044249	0.4	Ratio to Peak	0.25
W5430	23.1315	52.337	0.0	0.17645	0.28796	Discharge	0.0064577	0.4	Ratio to Peak	0.25
W5420	20.444	55.405	0.0	0.13318	0.21735	Discharge	0.0379548	0.4	Ratio to Peak	0.25
W5410	20.7559398	55.031	0.0	0.088992	0.14523	Discharge	0.0028840	0.4	Ratio to Peak	0.25
W5400	26.272	49.156	0.0	0.17327	0.28278	Discharge	0.0184383	0.4	Ratio to Peak	0.25
W5390	24.045	51.370	0.0	0.20891	0.34094	Discharge	0.0640178	0.4	Ratio to Peak	0.25
W5380	17.7615	58.849	0.0	0.13289	0.21687	Discharge	0.0397588	0.4	Ratio to Peak	0.25
W5370	26.273	49.155	0.0	0.37602	0.61367	Discharge	0.0586328	0.4	Ratio to Peak	0.25
W5360	27.5165	48	0.0	0.095814	0.15637	Discharge	0.0021544	0.4	Ratio to Peak	0.25
W5350	7.223	77.859	0.0	0.10455	0.17062	Discharge	0.0348185	0.4	Ratio to Peak	0.25
W5340	27.5165	48	0.0	0.15988	0.26092	Discharge	0.0201843	0.4	Ratio to Peak	0.25
W5330	27.5165	48	0.0	0.039459	0.064397	Discharge	8.34888E-5	0.4	Ratio to Peak	0.25
W5320	23.404	52.045	0.0	0.21608	0.35265	Discharge	0.0810913	0.4	Ratio to Peak	0.25
W5310	13.8995	64.632	0.0	0.069411	0.11328	Discharge	0.0031036	0.4	Ratio to Peak	0.25
W5300	7.164	78	0.0	0.040198	0.065603	Discharge	0.0015972	0.4	Ratio to Peak	0.25
W5290	9.0325	73.768	0.0	0.046316	0.075587	Discharge	0.0040655	0.4	Ratio to Peak	0.25
W5280	27.4795	48.034	0.0	0.16482	0.26898	Discharge	0.0339092	0.4	Ratio to Peak	0.25
W5270	26.581	48.864	0.0	0.13558	0.22127	Discharge	0.0221100	0.4	Ratio to Peak	0.25
W5260	20.8205	54.954	0.0	0.11475	0.18728	Discharge	0.0434650	0.4	Ratio to Peak	0.25
W5250	23.753	51.675	0.0	0.1903	0.31057	Discharge	0.0252717	0.4	Ratio to Peak	0.25

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
W5240	13.962	64.529	0.0	0.10099	0.16481	Discharge	0.0216853	0.4	Ratio to Peak	0.25
W5230	19.0975	57.082	0.0	0.11933	0.19474	Discharge	0.0248053	0.4	Ratio to Peak	0.25
W5220	14.6715	63.387	0.0	0.11611	0.1895	Discharge	0.0405974	0.4	Ratio to Peak	0.25
W5210	12.93	66.266	0.0	0.092626	0.15117	Discharge	0.0302157	0.4	Ratio to Peak	0.25
W5200	22.4515	53.081	0.0	0.1369	0.22341	Discharge	0.0203622	0.4	Ratio to Peak	0.25
W5190	13.2595	65.701	0.0	0.047911	0.07819	Discharge	0.0018240	0.4	Ratio to Peak	0.25
W5180	14.199	64.143	0.0	0.10465	0.17079	Discharge	0.0324282	0.4	Ratio to Peak	0.25
W5170	7.168	77.991	0.0	0.044074	0.071929	Discharge	0.0118482	0.4	Ratio to Peak	0.25
W5160	27.5165	48	0.0	0.19476	0.31785	Discharge	0.0262790	0.4	Ratio to Peak	0.25
W5150	15.3085	62.395	0.0	0.11077	0.18078	Discharge	0.0262699	0.4	Ratio to Peak	0.25
W5140	24.4975	50.904	0.0	0.17632	0.28776	Discharge	0.0292792	0.4	Ratio to Peak	0.25
W5130	22.78	52.719	0.0	0.16082	0.26245	Discharge	0.0315679	0.4	Ratio to Peak	0.25
W5120	8.617	74.669	0.0	0.08967	0.14634	Discharge	0.0310397	0.4	Ratio to Peak	0.25
W5110	10.1015	71.546	0.0	0.17801	0.29051	Discharge	0.0588687	0.4	Ratio to Peak	0.25
W5100	12.271	67.426	0.0	0.11073	0.18071	Discharge	0.0548013	0.4	Ratio to Peak	0.25
W5090	7.164	78	0.0	0.046447	0.075802	Discharge	3.62995E-5	0.4	Ratio to Peak	0.25
W5080	13.155	65.880	0.0	0.20612	0.33639	Discharge	0.0848410	0.4	Ratio to Peak	0.25
W5070	13.085	66	0.0	0.081149	0.13243	Discharge	0.0031018	0.4	Ratio to Peak	0.25
W5060	22.792	52.706	0.0	0.11203	0.18283	Discharge	0.0174673	0.4	Ratio to Peak	0.25
W5050	16.9335	60	0.0	0.071383	0.1165	Discharge	0.0188884	0.4	Ratio to Peak	0.25
W5040	13.085	66	0.0	0.081002	0.1322	Discharge	0.0065466	0.4	Ratio to Peak	0.25
W5030	14.296	63.987	0.0	0.085848	0.1401	Discharge	0.0122347	0.4	Ratio to Peak	0.25
W5020	25.79	49.619	0.0	0.14874	0.24274	Discharge	0.0309308	0.4	Ratio to Peak	0.25
W5010	23.7585	51.670	0.0	0.18416	0.30054	Discharge	0.0386934	0.4	Ratio to Peak	0.25

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
W5000	13.828	64.749	0.0	0.079273	0.12937	Discharge	0.0246074	0.4	Ratio to Peak	0.25
W4990	14.5205	63.627	0.0	0.1204	0.19649	Discharge	0.0385482	0.4	Ratio to Peak	0.25
W4980	7.164	78	0.0	0.20742	0.33851	Discharge	0.0154799	0.4	Ratio to Peak	0.25
W4970	10.063	71.624	0.0	0.10563	0.17239	Discharge	0.0390655	0.4	Ratio to Peak	0.25
W4960	10.4095	70.931	0.0	0.12661	0.20663	Discharge	0.0658491	0.4	Ratio to Peak	0.25
W4950	13.7775	64.833	0.0	0.11694	0.19085	Discharge	0.0558105	0.4	Ratio to Peak	0.25
W4940	9.932	71.890	0.0	0.41476	0.67689	Discharge	0.0453326	0.4	Ratio to Peak	0.25
W4930	13.6985	64.965	0.0	0.049739	0.081174	Discharge	0.0063415	0.4	Ratio to Peak	0.25
W4920	13.563	65.190	0.0	0.16435	0.26822	Discharge	0.0227235	0.4	Ratio to Peak	0.25
W4910	11.7875	68.302	0.0	0.15171	0.24759	Discharge	0.0262318	0.4	Ratio to Peak	0.25
W4900	7.164	78	0.0	0.083781	0.13673	Discharge	0.0209303	0.4	Ratio to Peak	0.25
W4890	16.838	60.135	0.0	0.073595	0.12011	Discharge	0.0396518	0.4	Ratio to Peak	0.25
W4880	13.2205	65.768	0.0	0.15298	0.24966	Discharge	0.0302956	0.4	Ratio to Peak	0.25
W4870	7.164	78	0.0	0.17501	0.28562	Discharge	0.0244241	0.4	Ratio to Peak	0.25
W4860	13.085	66	0.0	0.023172	0.037817	Discharge	.000546307	0.4	Ratio to Peak	0.25
W4850	19.287	56.840	0.0	0.20514	0.33479	Discharge	0.0804687	0.4	Ratio to Peak	0.25
W4840	13.085	66	0.0	0.14553	0.2375	Discharge	0.0234150	0.4	Ratio to Peak	0.25
W4830	13.085	66	0.0	0.079036	0.12899	Discharge	0.0065938	0.4	Ratio to Peak	0.25
W4820	14.9105	63.011	0.0	0.2244	0.36622	Discharge	0.0476431	0.4	Ratio to Peak	0.25
W4810	20.074	55.856	0.0	0.17656	0.28814	Discharge	0.0604350	0.4	Ratio to Peak	0.25
W4800	9.825	72.108	0.0	0.38036	0.62074	Discharge	0.0053378	0.4	Ratio to Peak	0.25
W4790	13.0805	66.008	0.0	0.15384	0.25107	Discharge	0.0396699	0.4	Ratio to Peak	0.25
W4780	23.5935	51.843	0.0	0.15483	0.25269	Discharge	0.0315316	0.4	Ratio to Peak	0.25
W4770	19.0085	57.196	0.0	0.14089	0.22993	Discharge	0.0241755	0.4	Ratio to Peak	0.25

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
W4760	16.9335	60	0.0	0.14843	0.24223	Discharge	0.0556871	0.4	Ratio to Peak	0.25
W4750	18.090	58.404	0.0	0.15029	0.24527	Discharge	0.0303627	0.4	Ratio to Peak	0.25
W4740	12.2385	67.484	0.0	0.17095	0.27899	Discharge	0.0503528	0.4	Ratio to Peak	0.25
W4730	13.085	66	0.0	0.1028	0.16777	Discharge	0.0235802	0.4	Ratio to Peak	0.25
W4720	19.215	56.931	0.0	0.25715	0.41967	Discharge	0.0715118	0.4	Ratio to Peak	0.25
W4710	13.085	66	0.0	0.19519	0.31855	Discharge	0.0746644	0.4	Ratio to Peak	0.25
W4700	13.085	66	0.0	0.27202	0.44394	Discharge	0.10408	0.4	Ratio to Peak	0.25
W4690	17.8955	58.667	0.0	0.11156	0.18206	Discharge	0.0616111	0.4	Ratio to Peak	0.25
W4680	10.021	71.709	0.0	0.21903	0.35745	Discharge	0.10528	0.4	Ratio to Peak	0.25
W4670	13.085	66	0.0	0.077987	0.12728	Discharge	0.0107428	0.4	Ratio to Peak	0.25
W4660	13.085	66	0.0	0.047788	0.07799	Discharge	.000157903	0.4	Ratio to Peak	0.25
W4650	22.004	53.582	0.0	0.24223	0.39532	Discharge	0.0713503	0.4	Ratio to Peak	0.25
W4640	8.856	74.148	0.0	0.22385	0.36532	Discharge	0.0218087	0.4	Ratio to Peak	0.25
W4630	13.085	66	0.0	0.097376	0.15892	Discharge	0.0130206	0.4	Ratio to Peak	0.25
W4620	13.085	66	0.0	0.14567	0.23773	Discharge	0.0319998	0.4	Ratio to Peak	0.25
W4610	16.9335	60	0.0	0.017	0.023689	Discharge	.000341215	0.4	Ratio to Peak	0.25
W4600	16.9335	60	0.0	0.038559	0.062928	Discharge	0.0023849	0.4	Ratio to Peak	0.25
W4590	23.418	52.030	0.0	0.10544	0.17208	Discharge	0.0203259	0.4	Ratio to Peak	0.25
W4580	24.63	50.770	0.0	0.20745	0.33856	Discharge	0.0483909	0.4	Ratio to Peak	0.25
W4570	9.0925	73.640	0.0	0.12681	0.20695	Discharge	0.0122874	0.4	Ratio to Peak	0.25
W4560	16.9365	59.995	0.0	0.11009	0.17967	Discharge	0.0186380	0.4	Ratio to Peak	0.25
W4550	13.085	66	0.0	0.092445	0.15087	Discharge	0.0255675	0.4	Ratio to Peak	0.25
W4540	17.118	59.740	0.0	0.10752	0.17548	Discharge	0.0267818	0.4	Ratio to Peak	0.25
W4530	25.4075	49.993	0.0	0.25981	0.42401	Discharge	0.0504672	0.4	Ratio to Peak	0.25

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
W4520	8.33	75.304	0.0	0.095969	0.15662	Discharge	0.0296041	0.4	Ratio to Peak	0.25
W4510	19.132	57.038	0.0	0.088546	0.14451	Discharge	0.0225111	0.4	Ratio to Peak	0.25
W4500	20.6935	55.106	0.0	0.10481	0.17105	Discharge	0.0264278	0.4	Ratio to Peak	0.25
W4490	17.547	59.143	0.0	0.11405	0.18613	Discharge	0.0222625	0.4	Ratio to Peak	0.25
W4480	11.125	69.542	0.0	0.15332	0.25022	Discharge	0.0112274	0.4	Ratio to Peak	0.25
W4470	13.085	66	0.0	0.038142	0.062248	Discharge	.000388405	0.4	Ratio to Peak	0.25
W4460	16.605	60.469	0.0	0.099335	0.16212	Discharge	0.0193912	0.4	Ratio to Peak	0.25
W4450	13.085	66	0.0	0.0444	0.0724612	Discharge	0.0038859	0.4	Ratio to Peak	0.25
W4440	22.9095	52.578	0.0	0.29117	0.4752	Discharge	0.0540372	0.4	Ratio to Peak	0.25
W4430	14.871	63.073	0.0	0.043987	0.071787	Discharge	0.0023105	0.4	Ratio to Peak	0.25
W4420	13.085	66	0.0	0.11948	0.195	Discharge	0.0295042	0.4	Ratio to Peak	0.25
W4410	27.5165	48	0.0	0.094087	0.15355	Discharge	0.0086574	0.4	Ratio to Peak	0.25
W4400	15.481	62.132	0.0	0.16403	0.2677	Discharge	0.0691269	0.4	Ratio to Peak	0.25
W4390	13.3715	65.512	0.0	0.10619	0.1733	Discharge	0.0238125	0.4	Ratio to Peak	0.25
W4380	13.085	66	0.0	0.1472	0.24024	Discharge	0.0453889	0.4	Ratio to Peak	0.25
W4370	13.0905	65.990	0.0	0.14107	0.23023	Discharge	0.0226255	0.4	Ratio to Peak	0.25
W4360	16.1815	61.085	0.0	0.12571	0.20517	Discharge	0.0363449	0.4	Ratio to Peak	0.25
W4350	13.2205	65.768	0.0	0.057358	0.093608	Discharge	0.0055030	0.4	Ratio to Peak	0.25
W4340	23.764	51.664	0.0	0.11714	0.19118	Discharge	0.0103526	0.4	Ratio to Peak	0.25
W4330	13.085	66	0.0	0.039434	0.064357	Discharge	0.0022996	0.4	Ratio to Peak	0.25
W4320	16.9335	60	0.0	0.17158	0.28002	Discharge	0.0660397	0.4	Ratio to Peak	0.25
W4310	22.8015	52.696	0.0	0.20629	0.33666	Discharge	0.0475560	0.4	Ratio to Peak	0.25
W4300	13.125	65.931	0.0	0.097881	0.15974	Discharge	0.0265585	0.4	Ratio to Peak	0.25
W4290	15.094	62.725	0.0	0.15165	0.24749	Discharge	0.0245729	0.4	Ratio to Peak	0.25

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
W4280	15.077	62.752	0.0	0.18263	0.29805	Discharge	0.0446956	0.4	Ratio to Peak	0.25
W4270	19.755	56.250	0.0	0.24286	0.39635	Discharge	0.0374629	0.4	Ratio to Peak	0.25
W4260	16.766	60.238	0.0	0.14224	0.23214	Discharge	0.0233587	0.4	Ratio to Peak	0.25
W4250	15.604	61.946	0.0	0.14789	0.24135	Discharge	0.0497267	0.4	Ratio to Peak	0.25
W4240	18.0108185	58.511	0.0	0.22574	0.36841	Discharge	0.0632519	0.4	Ratio to Peak	0.25
W4230	21.356	54.325	0.0	0.29497	0.48139	Discharge	0.0806375	0.4	Ratio to Peak	0.25
W4220	20.977	54.768	0.0	0.17564	0.28664	Discharge	0.0407063	0.4	Ratio to Peak	0.25
W4210	21.431	54.238	0.0	0.37199	0.60709	Discharge	0.11117	0.4	Ratio to Peak	0.25
W4200	16.873	60.086	0.0	0.22618	0.36912	Discharge	0.0600611	0.4	Ratio to Peak	0.25
W4190	22.825	52.670	0.0	0.098707	0.16109	Discharge	0.0197741	0.4	Ratio to Peak	0.25
W4180	20.296	55.585	0.0	0.17984	0.29349	Discharge	0.0753087	0.4	Ratio to Peak	0.25
W4170	24.753	50.645	0.0	0.099225	0.16194	Discharge	0.0190681	0.4	Ratio to Peak	0.25
W4160	13.125	65.931	0.0	0.047643	0.077753	Discharge	0.0042870	0.4	Ratio to Peak	0.25
W4150	13.5833293	65.156	0.0	0.12758	0.20821	Discharge	0.0289942	0.4	Ratio to Peak	0.25
W4140	19.093	57.088	0.0	0.23242	0.37931	Discharge	0.0726861	0.4	Ratio to Peak	0.25
W4130	17.641	59.013	0.0	0.095011	0.15506	Discharge	0.0266021	0.4	Ratio to Peak	0.25
W4120	18.892	57.347	0.0	0.073332	0.11968	Discharge	0.0128718	0.4	Ratio to Peak	0.25
W4110	22.108	53.465	0.0	0.18327	0.2991	Discharge	0.0326641	0.4	Ratio to Peak	0.25
W4100	16.9335	60	0.0	0.13091	0.21365	Discharge	0.0353956	0.4	Ratio to Peak	0.25
W4090	16.178	61.089	0.0	0.11358	0.18536	Discharge	0.0255730	0.4	Ratio to Peak	0.25
W4080	16.541	60.561	0.0	0.10751	0.17546	Discharge	0.0346805	0.4	Ratio to Peak	0.25
W4070	13.085	66	0.0	0.021851	0.035661	Discharge	.000727805	0.4	Ratio to Peak	0.25
W4060	19.566	56.487	0.0	0.11257	0.18371	Discharge	0.0295823	0.4	Ratio to Peak	0.25
W4050	13.975	64.508	0.0	0.090551	0.14778	Discharge	0.0206254	0.4	Ratio to Peak	0.25

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
W4040	16.9335	60	0.0	0.21475	0.35047	Discharge	0.0486685	0.4	Ratio to Peak	0.25
W4030	16.9335	60	0.0	0.14271	0.2329	Discharge	0.0310869	0.4	Ratio to Peak	0.25
W4020	19.47	56.608	0.0	0.14533	0.23718	Discharge	0.0227616	0.4	Ratio to Peak	0.25
W4010	16.9335	60	0.0	0.20546	0.33531	Discharge	0.0307620	0.4	Ratio to Peak	0.25
W4000	16.9335	60	0.0	0.16889	0.27564	Discharge	0.0420747	0.4	Ratio to Peak	0.25
W3990	22.2055	53.355	0.0	0.11321	0.18477	Discharge	0.0221717	0.4	Ratio to Peak	0.25
W3980	19.035	57.162	0.0	0.27076	0.44188	Discharge	0.0686786	0.4	Ratio to Peak	0.25
W3970	16.9335	60	0.0	0.11003	0.17956	Discharge	0.0202606	0.4	Ratio to Peak	0.25
W3960	13.085	66	0.0	0.080547	0.13145	Discharge	0.0167522	0.4	Ratio to Peak	0.25
W3950	16.9335	60	0.0	0.12944	0.21125	Discharge	0.0140116	0.4	Ratio to Peak	0.25
W3940	22.0883645	53.487	0.0	0.12496	0.20393	Discharge	0.0461512	0.4	Ratio to Peak	0.25
W3930	16.9335	60	0.0	0.13618	0.22225	Discharge	0.0184764	0.4	Ratio to Peak	0.25
W3920	13.4915	65.310	0.0	0.056182	0.091689	Discharge	0.0116031	0.4	Ratio to Peak	0.25
W3910	16.9335	60	0.0	0.10033	0.16374	Discharge	0.0215946	0.4	Ratio to Peak	0.25
W3900	18.312	58.108	0.0	0.14926	0.24359	Discharge	0.0500389	0.4	Ratio to Peak	0.25
W3890	16.9335	60	0.0	0.13618	0.22224	Discharge	0.0515489	0.4	Ratio to Peak	0.25
W3880	20.4605	55.385	0.0	0.085373	0.13933	Discharge	0.0184202	0.4	Ratio to Peak	0.25
W3870	18.6355	57.681	0.0	0.10028	0.16366	Discharge	0.0262790	0.4	Ratio to Peak	0.25
W3860	22.946	52.538	0.0	0.14983	0.24452	Discharge	0.0564911	0.4	Ratio to Peak	0.25
W3850	13.085	66	0.0	0.073469	0.1199	Discharge	0.0119480	0.4	Ratio to Peak	0.25
W3840	16.9335	60	0.0	0.10359	0.16906	Discharge	0.0284751	0.4	Ratio to Peak	0.25
W3830	16.9335	60	0.0	0.0917	0.14965	Discharge	0.0159645	0.4	Ratio to Peak	0.25
W3820	16.9335	60	0.0	0.045118	0.073632	Discharge	0.0066410	0.4	Ratio to Peak	0.25
W3810	23.9015	51.520	0.0	0.16837	0.27479	Discharge	0.0404975	0.4	Ratio to Peak	0.25

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
W3800	19.397	56.700	0.0	0.19312	0.31516	Discharge	0.0703611	0.4	Ratio to Peak	0.25
W3790	16.9335	60	0.0	0.27704	0.45214	Discharge	0.0729947	0.4	Ratio to Peak	0.25
W3780	16.9335	60	0.0	0.058576	0.095596	Discharge	0.0071800	0.4	Ratio to Peak	0.25
W3770	16.9335	60	0.0	0.28687	0.46818	Discharge	0.0610884	0.4	Ratio to Peak	0.25
W3760	24.109	51.304	0.0	0.15589	0.25441	Discharge	0.0464416	0.4	Ratio to Peak	0.25
W3750	16.9335	60	0.0	0.086236	0.14074	Discharge	0.0210337	0.4	Ratio to Peak	0.25
W3740	27.5165	48	0.0	0.093298	0.15226	Discharge	0.0228886	0.4	Ratio to Peak	0.25
W3730	21.3075	54.381	0.0	0.13409	0.21884	Discharge	0.0327185	0.4	Ratio to Peak	0.25
W3720	16.9335	60	0.0	0.086979	0.14195	Discharge	0.0103417	0.4	Ratio to Peak	0.25
W3710	23.8515	51.572	0.0	0.065012	0.1061	Discharge	0.0164019	0.4	Ratio to Peak	0.25
W3700	16.9335	60	0.0	0.15769	0.25735	Discharge	0.0450586	0.4	Ratio to Peak	0.25
W3690	19.812	56.180	0.0	0.14859	0.24249	Discharge	0.0444850	0.4	Ratio to Peak	0.25
W3680	16.9335	60	0.0	0.16812	0.27438	Discharge	0.0153837	0.4	Ratio to Peak	0.25
W3670	20.4805	55.361	0.0	0.1295	0.21134	Discharge	0.0490769	0.4	Ratio to Peak	0.25
W3660	24.5535	50.847	0.0	0.16668	0.27203	Discharge	0.0466213	0.4	Ratio to Peak	0.25
W3650	24.1355	51.276	0.0	0.086538	0.14123	Discharge	0.0171642	0.4	Ratio to Peak	0.25
W3640	18.451	57.924	0.0	0.071227	0.11624	Discharge	0.0202025	0.4	Ratio to Peak	0.25
W3630	22.309	53.239	0.0	0.34986	0.57097	Discharge	0.16818	0.4	Ratio to Peak	0.25
W3620	24.4165	50.987	0.0	0.038552	0.062917	Discharge	0.0025736	0.4	Ratio to Peak	0.25
W3610	27.5165	48	0.0	0.017	0.019302	Discharge	3.26695E-5	0.4	Ratio to Peak	0.25
W3600	16.9335	60	0.0	0.27683	0.45178	Discharge	0.0448226	0.4	Ratio to Peak	0.25
W3590	17.543	59.149	0.0	0.13496	0.22025	Discharge	0.0526361	0.4	Ratio to Peak	0.25
W3580	18.3508031	58.056	0.0	0.14615	0.23852	Discharge	0.0570283	0.4	Ratio to Peak	0.25
W3570	16.9335	60	0.0	0.087608	0.14298	Discharge	0.0240121	0.4	Ratio to Peak	0.25

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
W3560	16.9335	60	0.0	0.20826	0.33988	Discharge	0.10680	0.4	Ratio to Peak	0.25
W3550	16.9335	60	0.0	0.22151	0.36151	Discharge	0.0634769	0.4	Ratio to Peak	0.25
W3540	16.9335	60	0.0	0.090086	0.14702	Discharge	0.0280541	0.4	Ratio to Peak	0.25
W3530	16.9335	60	0.0	0.063432	0.10352	Discharge	0.0120895	0.4	Ratio to Peak	0.25
W3520	16.9335	60	0.0	0.09359	0.15274	Discharge	0.0261465	0.4	Ratio to Peak	0.25
W3510	17.9185	58.635	0.0	0.14928	0.24363	Discharge	0.0501169	0.4	Ratio to Peak	0.25
W3500	16.9335	60	0.0	0.047235	0.077088	Discharge	0.0059059	0.4	Ratio to Peak	0.25
W3490	17.528	59.169	0.0	0.16716	0.2728	Discharge	0.0562443	0.4	Ratio to Peak	0.25
W3480	16.9335	60	0.0	0.13854	0.2261	Discharge	0.0373558	0.4	Ratio to Peak	0.25
W3470	16.9335	60	0.0	0.10251	0.1673	Discharge	0.0226473	0.4	Ratio to Peak	0.25
W3460	16.9335	60	0.0	0.12648	0.20642	Discharge	0.0264278	0.4	Ratio to Peak	0.25
W3450	17.025	59.871	0.0	0.12278	0.20038	Discharge	0.0429151	0.4	Ratio to Peak	0.25
W3440	16.9335	60	0.0	0.12441	0.20304	Discharge	0.0606837	0.4	Ratio to Peak	0.25
W3430	16.9335	60	0.0	0.10099	0.16481	Discharge	0.0188086	0.4	Ratio to Peak	0.25
W3420	16.9335	60	0.0	0.097423	0.15899	Discharge	0.0306059	0.4	Ratio to Peak	0.25
W3410	17.099	59.766	0.0	0.27514	0.44903	Discharge	0.0431220	0.4	Ratio to Peak	0.25
W3400	16.9335	60	0.0	0.23763	0.38782	Discharge	0.0431165	0.4	Ratio to Peak	0.25
W3390	16.9335	60	0.0	0.22546	0.36795	Discharge	0.0253516	0.4	Ratio to Peak	0.25
W3380	16.9335	60	0.0	0.11982	0.19555	Discharge	0.0289597	0.4	Ratio to Peak	0.25
W3370	16.9335	60	0.0	0.18556	0.30284	Discharge	0.0188812	0.4	Ratio to Peak	0.25
W3360	16.9335	60	0.0	0.25404	0.41459	Discharge	0.0355880	0.4	Ratio to Peak	0.25
W3350	16.9335	60	0.0	0.17221	0.28104	Discharge	0.0904747	0.4	Ratio to Peak	0.25
W3340	16.9335	60	0.0	0.072442	0.11823	Discharge	0.0199738	0.4	Ratio to Peak	0.25
W3330	16.9335	60	0.0	0.017	0.018753	Discharge	3.81145E-5	0.4	Ratio to Peak	0.25

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
W3320	16.9335	60	0.0	0.21308	0.34775	Discharge	0.0321886	0.4	Ratio to Peak	0.25
W3310	16.9335	60	0.0	0.078175	0.12758	Discharge	0.0119988	0.4	Ratio to Peak	0.25
W3300	16.9335	60	0.0	0.22752	0.37131	Discharge	0.0655260	0.4	Ratio to Peak	0.25
W3290	16.9335	60	0.0	0.047938	0.078234	Discharge	0.0015645	0.4	Ratio to Peak	0.25
W3280	16.9335	60	0.0	0.11933	0.19474	Discharge	0.0525435	0.4	Ratio to Peak	0.25
W3270	16.9335	60	0.0	0.14478	0.23629	Discharge	0.0318492	0.4	Ratio to Peak	0.25
W3260	16.9615	59.960	0.0	0.17308	0.28247	Discharge	0.0891080	0.4	Ratio to Peak	0.25
W3250	16.9335	60	0.0	0.16265	0.26544	Discharge	0.0478627	0.4	Ratio to Peak	0.25
W3240	16.9335	60	0.0	0.12976	0.21177	Discharge	0.0416083	0.4	Ratio to Peak	0.25
W3230	16.9335	60	0.0	0.17613	0.28744	Discharge	0.0234567	0.4	Ratio to Peak	0.25
W3220	16.9335	60	0.0	0.071765	0.11712	Discharge	0.0039421	0.4	Ratio to Peak	0.25
W3210	16.9335	60	0.0	0.062468	0.10195	Discharge	0.0144545	0.4	Ratio to Peak	0.25
W3200	16.9335	60	0.0	0.14335	0.23394	Discharge	0.0910555	0.4	Ratio to Peak	0.25
W3190	16.9335	60	0.0	0.20181	0.32936	Discharge	0.0644625	0.4	Ratio to Peak	0.25
W3180	16.9335	60	0.0	0.16967	0.27691	Discharge	0.0311468	0.4	Ratio to Peak	0.25
W3170	16.9335	60	0.0	0.17307	0.28244	Discharge	0.0206272	0.4	Ratio to Peak	0.25
W3160	16.9335	60	0.0	0.12198	0.19907	Discharge	0.0194130	0.4	Ratio to Peak	0.25
W3150	16.9335	60	0.0	0.14381	0.23471	Discharge	0.0196580	0.4	Ratio to Peak	0.25
W3140	16.9335	60	0.0	0.16869	0.2753	Discharge	0.0338965	0.4	Ratio to Peak	0.25
W3130	16.9335	60	0.0	0.22693	0.37035	Discharge	0.0252608	0.4	Ratio to Peak	0.25
W3120	16.9335	60	0.0	0.1574	0.25688	Discharge	0.0704573	0.4	Ratio to Peak	0.25
W3110	16.9335	60	0.0	0.14508	0.23677	Discharge	0.0272137	0.4	Ratio to Peak	0.25
W3100	16.9335	60	0.0	0.29129	0.47539	Discharge	0.0587344	0.4	Ratio to Peak	0.25

Annex 10. Siocon Model Reach Parameters

Table A-10.1 Siocon Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R60	Automatic Fixed Interval	1870.7	0.0936690	0.0135	Trapezoid	30	0.01
R70	Automatic Fixed Interval	1875.8	0.0191374	0.0135	Trapezoid	30	0.01
R90	Automatic Fixed Interval	599.71	0.0192313	0.0135	Trapezoid	30	0.01
R110	Automatic Fixed Interval	1182.3	0.0225960	0.0135	Trapezoid	30	0.01
R130	Automatic Fixed Interval	906.98	0.0821899	0.0135	Trapezoid	30	0.01
R150	Automatic Fixed Interval	2185.1	0.0151367	0.0135	Trapezoid	30	0.01
R170	Automatic Fixed Interval	169.71	0.0005	0.0135	Trapezoid	30	0.01
R190	Automatic Fixed Interval	1597.5	0.0448802	0.0135	Trapezoid	30	0.01
R210	Automatic Fixed Interval	1020.2	0.0071421	0.0135	Trapezoid	30	0.01
R230	Automatic Fixed Interval	88.284	0.0197853	0.0135	Trapezoid	30	0.01
R260	Automatic Fixed Interval	1829.4	0.0019490	0.0135	Trapezoid	30	0.01
R290	Automatic Fixed Interval	2825.6	0.0248603	0.0135	Trapezoid	30	0.01
R330	Automatic Fixed Interval	1938.9	0.0305759	0.0135	Trapezoid	30	0.01
R340	Automatic Fixed Interval	1479.5	0.0485230	0.0135	Trapezoid	30	0.01
R360	Automatic Fixed Interval	1466.4	0.0170595	0.0135	Trapezoid	30	0.01
R370	Automatic Fixed Interval	1666.8	0.0468131	0.0135	Trapezoid	30	0.01
R380	Automatic Fixed Interval	636.98	0.0832067	0.0135	Trapezoid	30	0.01
R410	Automatic Fixed Interval	1150.1	0.0626039	0.0135	Trapezoid	30	0.01
R420	Automatic Fixed Interval	2706.2	0.12731	0.0135	Trapezoid	30	0.01
R430	Automatic Fixed Interval	3510.9	0.0156503	0.0135	Trapezoid	30	0.01
R460	Automatic Fixed Interval	1081.5	0.0203239	0.0135	Trapezoid	30	0.01
R490	Automatic Fixed Interval	24.142	0.0005	0.0135	Trapezoid	30	0.01
R520	Automatic Fixed Interval	458.70	0.0243059	0.0135	Trapezoid	30	0.01

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R550	Automatic Fixed Interval	1988.9	0.0363381	0.0135	Trapezoid	30	0.01
R560	Automatic Fixed Interval	3660.2	0.0234000	0.0135	Trapezoid	30	0.01
R570	Automatic Fixed Interval	1321.5	0.0602971	0.0135	Trapezoid	30	0.01
R590	Automatic Fixed Interval	2466.2	0.0204080	0.0135	Trapezoid	30	0.01
R600	Automatic Fixed Interval	2079.2	0.0356926	0.0135	Trapezoid	30	0.01
R620	Automatic Fixed Interval	643.26	0.0046926	0.0135	Trapezoid	30	0.01
R630	Automatic Fixed Interval	1238.4	0.0621527	0.0135	Trapezoid	30	0.01
R640	Automatic Fixed Interval	722.84	0.0172353	0.0135	Trapezoid	30	0.01
R650	Automatic Fixed Interval	1338.8	0.16438	0.0135	Trapezoid	30	0.01
R670	Automatic Fixed Interval	540.12	0.10982	0.0135	Trapezoid	30	0.01
R680	Automatic Fixed Interval	2188.9	0.0286604	0.0135	Trapezoid	30	0.01
R710	Automatic Fixed Interval	2055.2	0.0093362	0.0135	Trapezoid	30	0.01
R730	Automatic Fixed Interval	892.55	0.0072331	0.0135	Trapezoid	30	0.01
R740	Automatic Fixed Interval	2312.1	0.0218130	0.0135	Trapezoid	30	0.01
R750	Automatic Fixed Interval	1816.9	0.0071051	0.0135	Trapezoid	30	0.01
R780	Automatic Fixed Interval	1289.9	0.0056564	0.0135	Trapezoid	30	0.01
R800	Automatic Fixed Interval	1695.1	0.12057	0.0135	Trapezoid	30	0.01
R830	Automatic Fixed Interval	538.41	0.0084542	0.0135	Trapezoid	30	0.01
R860	Automatic Fixed Interval	1210.2	0.0230691	0.0135	Trapezoid	30	0.01
R870	Automatic Fixed Interval	1265.7	0.0078137	0.0135	Trapezoid	30	0.01
R890	Automatic Fixed Interval	1297.7	0.0048933	0.0135	Trapezoid	30	0.01
R910	Automatic Fixed Interval	155.56	0.0005	0.0135	Trapezoid	30	0.01
R990	Automatic Fixed Interval	2111.7	0.0144946	0.0135	Trapezoid	30	0.01
R1010	Automatic Fixed Interval	771.54	0.0511420	0.0135	Trapezoid	30	0.01
R1020	Automatic Fixed Interval	610.12	0.0409059	0.0135	Trapezoid	30	0.01

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R1030	Automatic Fixed Interval	1527.8	0.0678713	0.0135	Trapezoid	30	0.01
R1060	Automatic Fixed Interval	1476.1	0.0040248	0.0135	Trapezoid	30	0.01
R1100	Automatic Fixed Interval	3128.1	0.0526879	0.0135	Trapezoid	30	0.01
R1140	Automatic Fixed Interval	2192.4	0.0376214	0.0135	Trapezoid	30	0.01
R1150	Automatic Fixed Interval	3141.2	0.0390718	0.0135	Trapezoid	30	0.01
R1180	Automatic Fixed Interval	782.84	0.0163520	0.0135	Trapezoid	30	0.01
R1200	Automatic Fixed Interval	419.71	0.0556117	0.0135	Trapezoid	30	0.01
R1210	Automatic Fixed Interval	590.12	0.0005	0.0135	Trapezoid	30	0.01
R1220	Automatic Fixed Interval	1045.0	0.0654342	0.0135	Trapezoid	30	0.01
R1230	Automatic Fixed Interval	4720.7	0.0516013	0.0135	Trapezoid	30	0.01
R1250	Automatic Fixed Interval	580.42	0.0426579	0.0135	Trapezoid	30	0.01
R1260	Automatic Fixed Interval	558.70	0.0284535	0.0135	Trapezoid	30	0.01
R1290	Automatic Fixed Interval	114.85	0.0005	0.0135	Trapezoid	30	0.01
R1300	Automatic Fixed Interval	3258.7	0.0047544	0.0135	Trapezoid	30	0.01
R1320	Automatic Fixed Interval	998.41	0.0069641	0.0135	Trapezoid	30	0.01
R1340	Automatic Fixed Interval	1938.2	0.0262840	0.0135	Trapezoid	30	0.01
R1350	Automatic Fixed Interval	2080.7	0.0170756	0.0135	Trapezoid	30	0.01
R1390	Automatic Fixed Interval	1080.5	0.0029361	0.0135	Trapezoid	30	0.01
R1420	Automatic Fixed Interval	374.85	0.0386178	0.0135	Trapezoid	30	0.01
R1430	Automatic Fixed Interval	1683.0	.0007113981884031881	0.0135	Trapezoid	30	0.01
R1440	Automatic Fixed Interval	152.43	0.0221476	0.0135	Trapezoid	30	0.01
R1470	Automatic Fixed Interval	728.11	0.0005	0.0135	Trapezoid	30	0.01
R1480	Automatic Fixed Interval	1039.8	0.0034136	0.0135	Trapezoid	30	0.01
R1490	Automatic Fixed Interval	1781.7	0.0074986	0.0135	Trapezoid	30	0.01
R1500	Automatic Fixed Interval	872.25	0.0091745	0.0135	Trapezoid	30	0.01

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R1510	Automatic Fixed Interval	28.284	0.0005	0.0135	Trapezoid	30	0.01
R1540	Automatic Fixed Interval	1055.7	0.0046824	0.0135	Trapezoid	30	0.01
R1550	Automatic Fixed Interval	2726.3	0.0600793	0.0135	Trapezoid	30	0.01
R1590	Automatic Fixed Interval	2745.6	0.0304942	0.0135	Trapezoid	30	0.01
R1620	Automatic Fixed Interval	268.70	0.0005	0.0135	Trapezoid	30	0.01
R1650	Automatic Fixed Interval	982.96	0.0111112	0.0135	Trapezoid	30	0.01
R1680	Automatic Fixed Interval	410.12	0.0005	0.0135	Trapezoid	30	0.01
R1690	Automatic Fixed Interval	1804.7	0.0005	0.0135	Trapezoid	30	0.01
R1700	Automatic Fixed Interval	2379.7	0.0439357	0.0135	Trapezoid	30	0.01
R1710	Automatic Fixed Interval	113.14	0.0005	0.0135	Trapezoid	30	0.01
R1720	Automatic Fixed Interval	798.41	0.0005	0.0135	Trapezoid	30	0.01
R1760	Automatic Fixed Interval	1685.1	0.0215833	0.0135	Trapezoid	30	0.01
R1770	Automatic Fixed Interval	1093.7	0.0005	0.0135	Trapezoid	30	0.01
R1780	Automatic Fixed Interval	1237.4	0.0005	0.0135	Trapezoid	30	0.01
R1790	Automatic Fixed Interval	549.41	0.0005	0.0135	Trapezoid	30	0.01
R1800	Automatic Fixed Interval	2895.8	0.0219189	0.0135	Trapezoid	30	0.01
R1850	Automatic Fixed Interval	367.28	0.0005	0.0135	Trapezoid	30	0.01
R1860	Automatic Fixed Interval	2774.4	0.0011138	0.0135	Trapezoid	30	0.01
R1870	Automatic Fixed Interval	1277.5	.0002556822678021013	0.0135	Trapezoid	30	0.01
R1880	Automatic Fixed Interval	962.13	0.0005	0.0135	Trapezoid	30	0.01
R1890	Automatic Fixed Interval	2095.8	0.0111045	0.0135	Trapezoid	30	0.01
R1900	Automatic Fixed Interval	28.284	0.0005	0.0135	Trapezoid	30	0.01
R1930	Automatic Fixed Interval	1130.5	0.0005	0.0135	Trapezoid	30	0.01
R1950	Automatic Fixed Interval	2186.1	0.0078116	0.0135	Trapezoid	30	0.01
R1980	Automatic Fixed Interval	1702.5	0.0005	0.0135	Trapezoid	30	0.01

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R1990	Automatic Fixed Interval	731.84	0.0005	0.0135	Trapezoid	30	0.01
R2010	Automatic Fixed Interval	257.28	0.0005	0.0135	Trapezoid	30	0.01
R2020	Automatic Fixed Interval	2365.5	0.0030098	0.0135	Trapezoid	30	0.01
R2030	Automatic Fixed Interval	1501.5	0.0207279	0.0135	Trapezoid	30	0.01
R2060	Automatic Fixed Interval	1467.5	0.0027257	0.0135	Trapezoid	30	0.01
R2070	Automatic Fixed Interval	1068.5	0.0062928	0.0135	Trapezoid	30	0.01
R2080	Automatic Fixed Interval	1713.1	.0005162961469796098	0.0135	Trapezoid	30	0.01
R2100	Automatic Fixed Interval	155.56	0.0005	0.0135	Trapezoid	30	0.01
R2120	Automatic Fixed Interval	648.99	0.0054353	0.0135	Trapezoid	30	0.01
R2140	Automatic Fixed Interval	482.13	0.0005	0.0135	Trapezoid	30	0.01
R2150	Automatic Fixed Interval	1399.8	0.0031009	0.0135	Trapezoid	30	0.01
R2160	Automatic Fixed Interval	2057.5	0.0107797	0.0135	Trapezoid	30	0.01
R2190	Automatic Fixed Interval	14.142	0.0005	0.0135	Trapezoid	30	0.01
R2230	Automatic Fixed Interval	754.97	0.0005	0.0135	Trapezoid	30	0.01
R2240	Automatic Fixed Interval	1776.4	0.0005	0.0135	Trapezoid	30	0.01
R2250	Automatic Fixed Interval	3461.6	0.0139021	0.0135	Trapezoid	30	0.01
R2260	Automatic Fixed Interval	728.99	0.0216011	0.0135	Trapezoid	30	0.01
R2280	Automatic Fixed Interval	183.85	0.0005	0.0135	Trapezoid	30	0.01
R2290	Automatic Fixed Interval	183.85	0.0005	0.0135	Trapezoid	30	0.01
R2310	Automatic Fixed Interval	1790.7	0.0061949	0.0135	Trapezoid	30	0.01
R2330	Automatic Fixed Interval	652.13	0.0005	0.0135	Trapezoid	30	0.01
R2350	Automatic Fixed Interval	450.42	0.0122291	0.0135	Trapezoid	30	0.01
R2370	Automatic Fixed Interval	862.84	0.0005	0.0135	Trapezoid	30	0.01
R2400	Automatic Fixed Interval	821.54	0.0020945	0.0135	Trapezoid	30	0.01
R2420	Automatic Fixed Interval	1555.1	0.0032177	0.0135	Trapezoid	30	0.01

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R2450	Automatic Fixed Interval	2506.6	0.0638257	0.0135	Trapezoid	30	0.01
R2460	Automatic Fixed Interval	1440.8	0.0005	0.0135	Trapezoid	30	0.01
R2480	Automatic Fixed Interval	730.83	0.0005	0.0135	Trapezoid	30	0.01
R2490	Automatic Fixed Interval	846.98	0.0005	0.0135	Trapezoid	30	0.01
R2500	Automatic Fixed Interval	1106.0	0.0125905	0.0135	Trapezoid	30	0.01
R2530	Automatic Fixed Interval	1010.8	0.0275750	0.0135	Trapezoid	30	0.01
R2540	Automatic Fixed Interval	3632.6	0.0429182	0.0135	Trapezoid	30	0.01
R2570	Automatic Fixed Interval	1866.5	0.0318475	0.0135	Trapezoid	30	0.01
R2600	Automatic Fixed Interval	3847.2	0.0138333	0.0135	Trapezoid	30	0.01
R2610	Automatic Fixed Interval	2365.2	0.0083225	0.0135	Trapezoid	30	0.01
R2630	Automatic Fixed Interval	3591.6	0.0109840	0.0135	Trapezoid	30	0.01
R2640	Automatic Fixed Interval	746.69	0.0297841	0.0135	Trapezoid	30	0.01
R2670	Automatic Fixed Interval	1780.2	0.0084220	0.0135	Trapezoid	30	0.01
R2680	Automatic Fixed Interval	282.84	0.0005	0.0135	Trapezoid	30	0.01
R2700	Automatic Fixed Interval	98.995	0.0005	0.0135	Trapezoid	30	0.01
R2710	Automatic Fixed Interval	514.85	0.0052917	0.0135	Trapezoid	30	0.01
R2730	Automatic Fixed Interval	932.55	0.0070796	0.0135	Trapezoid	30	0.01
R2740	Automatic Fixed Interval	3332.2	0.0112482	0.0135	Trapezoid	30	0.01
R2760	Automatic Fixed Interval	764.56	0.0090317	0.0135	Trapezoid	30	0.01
R2780	Automatic Fixed Interval	289.71	0.0005	0.0135	Trapezoid	30	0.01
R2800	Automatic Fixed Interval	1842.4	0.0052081	0.0135	Trapezoid	30	0.01
R2850	Automatic Fixed Interval	1758.9	0.0316026	0.0135	Trapezoid	30	0.01
R2870	Automatic Fixed Interval	1073.6	0.0344468	0.0135	Trapezoid	30	0.01
R2900	Automatic Fixed Interval	898.11	0.0162083	0.0135	Trapezoid	30	0.01
R2910	Automatic Fixed Interval	3951.6	0.0270778	0.0135	Trapezoid	30	0.01

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R2920	Automatic Fixed Interval	969.83	0.0328003	0.0135	Trapezoid	30	0.01
R2940	Automatic Fixed Interval	2263.2	0.0050032	0.0135	Trapezoid	30	0.01
R2970	Automatic Fixed Interval	483.85	0.0015101	0.0135	Trapezoid	30	0.01
R3000	Automatic Fixed Interval	3934.8	0.0261184	0.0135	Trapezoid	30	0.01
R3020	Automatic Fixed Interval	558.99	0.0005	0.0135	Trapezoid	30	0.01
R3070	Automatic Fixed Interval	1920.5	0.0374512	0.0135	Trapezoid	30	0.01

Annex 11. Siocon Field Validation Points

Table A-11.1 Siocon Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
1	7.708689	122.144383	0.23	2.00	-1.77	Lawin	5 -Year
2	7.709015	122.143988	0.71	3.50	-2.79	Lawin	5 -Year
3	7.70004	122.126862	0.96	0.85	0.11	Lawin	5 -Year
4	7.699347	122.126829	0.47	0.30	0.17	Lawin	5 -Year
5	7.699322	122.126437	2.26	3.70	-1.44	Lawin	5 -Year
6	7.708289	122.144085	0.29	1.00	-0.71	Lawin	5 -Year
7	7.708521	122.143818	0.30	1.00	-0.70	Lawin	5 -Year
8	7.708176	122.144489	0.26	0.10	0.16	Lawin	5 -Year
9	7.708497	122.144566	0.16	1.00	-0.84	Lawin	5 -Year
10	7.708489	122.141628	0.38	0.30	0.08	Lawin	5 -Year
11	7.709764	122.141836	0.07	0.10	-0.03	Lawin	5 -Year
12	7.70445	122.13329	0.42	0.20	0.22	Lawin	5 -Year
13	7.704215	122.133532	0.27	0.20	0.07	Lawin	5 -Year
14	7.704664	122.131771	0.71	1.00	-0.29	Lawin	5 -Year
15	7.700384	122.127213	0.79	1.00	-0.21	Lawin	5 -Year
16	7.700793	122.127493	0.64	1.00	-0.36	Lawin	5 -Year
17	7.70135	122.127286	1.17	2.00	-0.83	Lawin	5 -Year
18	7.701362	122.127789	0.71	1.00	-0.29	Lawin	5 -Year
19	7.700158	122.127864	0.77	2.00	-1.23	Lawin	5 -Year
20	7.699471	122.127309	0.82	1.00	-0.18	Lawin	5 -Year
21	7.699161	122.127635	1.05	2.00	-0.95	Lawin	5 -Year
22	7.704989	122.134737	0.21	0.20	0.01	Lawin	5 -Year
23	7.704655	122.134549	0.18	1.50	-1.32	Lawin	5 -Year
24	7.704808	122.134166	0.14	0.14	0.00	Lawin	5 -Year
25	7.704383	122.134767	0.18	1.00	-0.82	Lawin	5 -Year
26	7.704735	122.135092	0.36	1.00	-0.64	Lawin	5 -Year
27	7.704417	122.135337	0.54	2.00	-1.46	Lawin	5 -Year
28	7.704875	122.13564	0.52	0.10	0.42	Lawin	5 -Year
29	7.705446	122.135352	0.04	0.10	-0.06	Lawin	5 -Year
30	7.703584	122.130399	0.37	0.10	0.27	Lawin	5 -Year
31	7.703172	122.130812	0.69	1.00	-0.31	Lawin	5 -Year
32	7.703577	122.131013	0.50	1.00	-0.50	Lawin	5 -Year
33	7.70321	122.130422	0.70	1.00	-0.30	Lawin	5 -Year
34	7.707078	122.140433	0.18	0.10	0.08	Lawin	5 -Year
35	7.706653	122.140943	0.12	0.10	0.02	Lawin	5 -Year
36	7.70684	122.140614	0.12	0.10	0.02	Lawin	5 -Year
37	7.706714	122.14156	0.18	0.10	0.08	Lawin	5 -Year
38	7.707187	122.141065	0.19	0.10	0.09	Lawin	5 -Year
39	7.706622	122.140192	0.25	0.10	0.15	Lawin	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
40	7.705999	122.140659	0.34	0.10	0.24	Lawin	5 -Year
41	7.705458	122.141318	0.10	0.10	0.00	Lawin	5 -Year
42	7.705333	122.140852	0.08	0.10	-0.02	Lawin	5 -Year
43	7.704918	122.139985	0.09	0.10	-0.01	Lawin	5 -Year
44	7.705019	122.142051	0.11	0.10	0.01	Lawin	5 -Year
45	7.706112	122.142316	0.49	0.10	0.39	Lawin	5 -Year
46	7.706578	122.14249	0.36	0.10	0.26	Lawin	5 -Year
47	7.706452	122.143507	0.15	0.10	0.05	Lawin	5 -Year
48	7.703067	122.129932	1.05	1.00	0.05	Lawin	5 -Year
49	7.702747	122.129781	0.92	1.00	-0.08	Lawin	5 -Year
50	7.704838	122.133447	0.23	0.10	0.13	Lawin	5 -Year
51	7.70516	122.133759	0.46	0.10	0.36	Lawin	5 -Year
52	7.706859	122.144474	0.21	0.30	-0.09	Lawin	5 -Year
53	7.706805	122.143939	0.25	0.40	-0.15	Lawin	5 -Year
54	7.707324	122.145119	0.14	0.40	-0.26	Lawin	5 -Year
55	7.706376	122.145328	0.11	0.30	-0.19	Lawin	5 -Year
56	7.705046	122.145714	0.16	0.10	0.06	Lawin	5 -Year
57	7.705791	122.145646	0.68	0.30	0.38	Lawin	5 -Year
58	7.699804	122.127796	0.67	0.10	0.57	Lawin	5 -Year
59	7.697736	122.127555	0.89	1.70	-0.81	Lawin	5 -Year
60	7.697409	122.127504	0.59	0.10	0.49	Lawin	5 -Year
61	7.697229	122.127724	0.83	1.00	-0.17	Lawin	5 -Year
62	7.697343	122.127946	0.95	1.00	-0.05	Lawin	5 -Year
63	7.698745	122.12693	0.78	1.00	-0.22	Lawin	5 -Year
64	7.698347	122.126665	0.89	1.00	-0.11	Lawin	5 -Year
65	7.6983	122.126819	0.94	1.00	-0.06	Lawin	5 -Year
66	7.6977	122.126604	0.41	1.00	-0.59	Lawin	5 -Year
67	7.698049	122.12661	0.56	1.00	-0.44	Lawin	5 -Year
68	7.698794	122.12639	1.02	1.00	0.02	Lawin	5 -Year
69	7.702706	122.131101	0.83	1.00	-0.17	Lawin	5 -Year
70	7.702895	122.131034	0.91	1.00	-0.09	Lawin	5 -Year
71	7.702262	122.128342	1.14	1.00	0.14	Lawin	5 -Year
72	7.702098	122.128886	0.96	1.00	-0.04	Lawin	5 -Year
73	7.702186	122.129258	1.09	1.00	0.09	Lawin	5 -Year
74	7.66313	122.135766	0.24	0.30	-0.06	Lawin	5 -Year
75	7.663764	122.135907	0.26	0.30	-0.04	Lawin	5 -Year
76	7.663287	122.136565	0.75	0.40	0.35	Lawin	5 -Year
77	7.662712	122.13621	0.23	0.30	-0.07	Lawin	5 -Year
78	7.662136	122.136602	0.56	0.40	0.16	Lawin	5 -Year
79	7.662056	122.135924	0.19	0.40	-0.21	Lawin	5 -Year
80	7.697995	122.167908	0.27	1.00	-0.73	Lawin	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
81	7.695876	122.167839	0.05	0.10	-0.05	Lawin	5 -Year
82	7.704783	122.13647	0.85	0.30	0.55	Lawin	5 -Year
83	7.704118	122.135922	1.36	1.00	0.36	Lawin	5 -Year
84	7.70344	122.131536	1.14	0.40	0.74	Lawin	5 -Year
85	7.727068	122.182501	0.34	0.50	-0.16	Lawin	5 -Year
86	7.727029	122.183281	0.44	0.40	0.04	Lawin	5 -Year
87	7.697888	122.15334	0.37	0.30	0.07	Lawin	5 -Year
88	7.692534	122.128749	0.70	0.70	0.00	Lawin	5 -Year
89	7.690917	122.127137	0.29	0.10	0.19	Lawin	5 -Year
90	7.705924	122.133762	0.06	0.10	-0.04	Lawin	5 -Year
91	7.706516	122.133543	0.10	0.30	-0.20	Lawin	5 -Year
92	7.70671	122.133415	0.13	0.10	0.03	Lawin	5 -Year
93	7.706244	122.135362	0.05	0.10	-0.05	Lawin	5 -Year
94	7.707742	122.141238	0.24	1.60	-1.36	Yolanda	5 -Year
95	7.707972	122.140891	0.51	2.00	-1.49	Yolanda	5 -Year
96	7.708012	122.141916	0.48	2.30	-1.82	Yolanda	5 -Year
97	7.708585	122.142154	0.33	0.30	0.03	Yolanda	5 -Year
98	7.709222	122.15257	0.40	2.30	-1.90	Yolanda	5 -Year
99	7.708689	122.144383	0.23	2.00	-1.77	Lawin	5 -Year

Annex 12. Educational Institutions Affected by Flooding in Siocon Floodplain

Table A-12.1 Educational Institutions in Siocon affected by flooding in the Siocon Floodplain

SIOCON				
Barangay	Building Name	Rainfall Scenario		
		5-year	25-year	100-year
Bucana	Esmaweljehar	None	None	None
Bucana	Day Care Center	Medium	Medium	Medium
Bucana	Daycare Bucana	Medium	Medium	Medium
Bucana	Learning Center Bucana	Medium	Medium	Medium
DatuSailila	Day Care Center Tagaytay	High	High	High
Jose P. Brillantes, Sr.	Day Care Center	Low	Low	Medium
Makiang	Makiang Elementary School	Medium	Medium	Medium
Makiang	Day Care Center	None	None	None
Malipot	Malipot daycare center	None	None	None
Malipot	Malipot elementary sch	None	None	None
Manaol	JRMSU	Low	Low	Low
Manaol	Bliss Elementary School	Low	Medium	Medium
Manaol	Day care center	None	None	None
Manaol	Marlougabo	None	None	None
Manaol	SDA elem. School	None	None	None
Manaol	Siocon parochial academy,inc.	Medium	Medium	Medium
Manaol	Yu residence	Low	Low	Low
Manaol	SIT school	Low	Low	Low
New Lituban	Day care center	None	None	None
New Lituban	day care center	None	None	None
New Lituban	new litubanelemsch	Low	Medium	Medium
Pangian	Maria ybarsabal school	Low	Medium	Medium
Pangian	Stage	Medium	Medium	Medium
Pangian	Pamana daycare	None	None	None
Pisawak	Daycare	None	None	Low
Pisawak	Esterlitodavelos	None	None	None
Poblacion	Siocon Central School	Low	Low	Low
Poblacion	SIT office	Low	Low	Low
Poblacion	National High School	Low	Low	Low
Poblacion	Siocon Central School	Low	Low	Low
Poblacion	Julian soriano comprehensive high school	None	None	None
Poblacion	Elmer lobrigas	None	None	None
Poblacion	SIT school	Low	Low	Low
S. Cabral	S. Cabral Elementary School	Medium	Medium	Medium
SuhaileArabi	Day Care Center	Medium	Medium	Medium

Annex 13. Health Institutions Affected by Flooding in Siocon Floodplain

Table A-13.1 Health Institutions in Siocon affected by flooding in the Siocon Floodplain

SIOCON				
Barangay	Building Name	Rainfall Scenario		
		5-year	25-year	100-year
Bucana	Health Center Bucana	Medium	Medium	Medium
DatuSailila	Health Center	Low	Low	Medium
Malipot	Health center	None	None	None
Manaol	District hospital	None	Low	Low
Manaol	Eastern Sun hospital	Medium	Medium	Medium
Manaol	Dr. Emie Edera	None	None	Low
New Lituban	Health Center	None	None	None
New Lituban	health center	None	None	Low
Poblacion	Health center	Low	Low	Low
Poblacion	Dr. Emie Edera	None	None	Low
Poblacion	Birthing clinic	None	None	None

Table A-13.2 Health Institutions in Baliguian affected by flooding in the Siocon Floodplain

BALIGUIAN				
Barangay	Building Name	Rainfall Scenario		
		5-year	25-year	100-year
Bucana	Health Center Bucana	Medium	Medium	Medium
DatuSailila	Health Center	Low	Low	Medium
San Jose	Pisawak Health Center	None	None	None