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

LiDAR Surveys and Flood Mapping of Sanito River

University of the Philippines Training Center
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For questions/queries regarding this report, contact:

Mr. Mario S. Rodriguez
Project Leader, PHIL-LiDAR 1 Program
Ateneo de Zamboanga University
Zamboanga City, Philippines 7000
E-mail: rodriguezmars@adzu.edu.ph

Enrico C. Paringit, Dr. Eng.
Program Leader, PHIL-LiDAR 1 Program
University of the Philippines Diliman
Quezon City, Philippines 1101
E-mail: ecparingit@up.edu.ph

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LIST OF ACRONYMS AND ABBREVIATIONS

AAC	Asian Aerospace Corporation
Ab	abutment
ADZU	Ateneo de Zamboanga University
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

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 SANITO RIVER

Enrico C. Paringit, Dr. Eng., Mr. Mario S. Rodriguez, and Engr. Omar P. Jayag

1.1 Background of the Phil-LiDAR 1 Program

The University of the Philippines Training Center for Applied Geodesy and Photogrammetry (UP TCAGP) launched a research program in 2014 entitled "Nationwide Hazard Mapping using LiDAR" or Phil-LiDAR 1, supported by the Department of Science and Technology (DOST) Grant-in-Aid (GiA) Program. The program was primarily aimed at acquiring a national elevation and resource dataset at sufficient resolution to produce information necessary to support the different phases of disaster management. Particularly, it targeted to operationalize the development of flood hazard models that would produce updated and detailed flood hazard maps for the major river systems in the country.

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 San Jose river basin in the Zamboanga Peninsula Region. The university is located in Zamboanga City in the province of Zamboanga Sibugay.

1.2 Overview of the Buaya River Basin

Sanito River Basin is located in the upper eastern part of Zamboanga Sibugay near the Moro Gulf. It encompasses the barangays of Bangkerohan, Poblacion, Sanito, Lower Ipil Heights, Lower Taway, Upper Pangi and edge of Guituan. The basin has a catchment area of 125.7 km2. It is recorded to have a total population of 64,939 people based on the 2010 census of the National Statistics Office.

Its main stream, Sanito River, was delineated with an estimated length of 10.38 km and an area of 8.64 sq. km. that traverses the Municipalities of Titay and Ipil Zamboanga Sibugay. The basin is bounded on the north by Municipality of Titay; on the east by Ipil Town Proper; on the west by Naga; on the south by Moro Gulf.

The river was named after the former name of the Municipality of Ipil which was "Sanito." The word is said to have originated from the usual answer of early inhabitants when asked where they were going, in which they would answer "Sa Nito" or "To Nito", referring to the river which was abundant with nito vines used for weaving hats and baskets.

The early settlers of the area were the Subanon, or the river people, who were engaged with barter trade and agriculture. In the early 1900's, the Ilocanos started migrating in the area. They started cultivating the area, which used to be a wetland for agriculture.

Being one of the major river basins in the province, Sanito River is also one of the sources of water supply for irrigation in the municipality. One notable communal irrigation system in the area is the Pangi Communal Irrigation System which was funded by the Asian Development Bank in 1995.

Aside from this, the Department of Agriculture through the Zamboanga Peninsula Integrated Agricultural Research Center (ZAMPIARC) has also proposed in 2015 the construction of another irrigation system in

the area.
Hazards that frequently occur in the area are storm surges, typhoons, and heavy rains which caused floods and landslides. As the river traverses through the populated barangays in the municipality, several residences raised their experience on flooding during the flood validation survey of ADZU Phil LiDAR 1. In the interviews conducted, it was mentioned that some of the flood incidents in the areas are caused by clogged drainage system.

The recent typhoon, Ineng, which occurred last August 7, 2015 caused great flooding events damaging the fish ponds in the community. Among all the flood incidents in the area, however, the most notable was when the river swelled as an effect of the 2-hour heavy rain due to Habagat in the Province. It was reported that the floodwaters reached up to 10ft high and around 170 families were affected. The municipal respondents were able to rescue several victims who were trapped inside their houses during the flood event.

To raise funds for the rehabilitation and preservation of the river, the barangay officials of Sanito organized a fun-run activity in January 2017. According to Mr. Richard Olegario, the Barangay Chairperson of Sanito, the river is already degenerating, and thus, they are planning for a long-term rehabilitation of river which includes tree planting and a clean-up drive.

Sources:

- Municipal Profile of Ipil, MPDO of Ipil
- Provincial Profile of Zamboanga Sibugay
- GMA News
- Zamboanga Sibugay Website
- Asian Development Bank
- Department of Agriculture

Figure 1. Sanito River

Figure 2. Sanito River

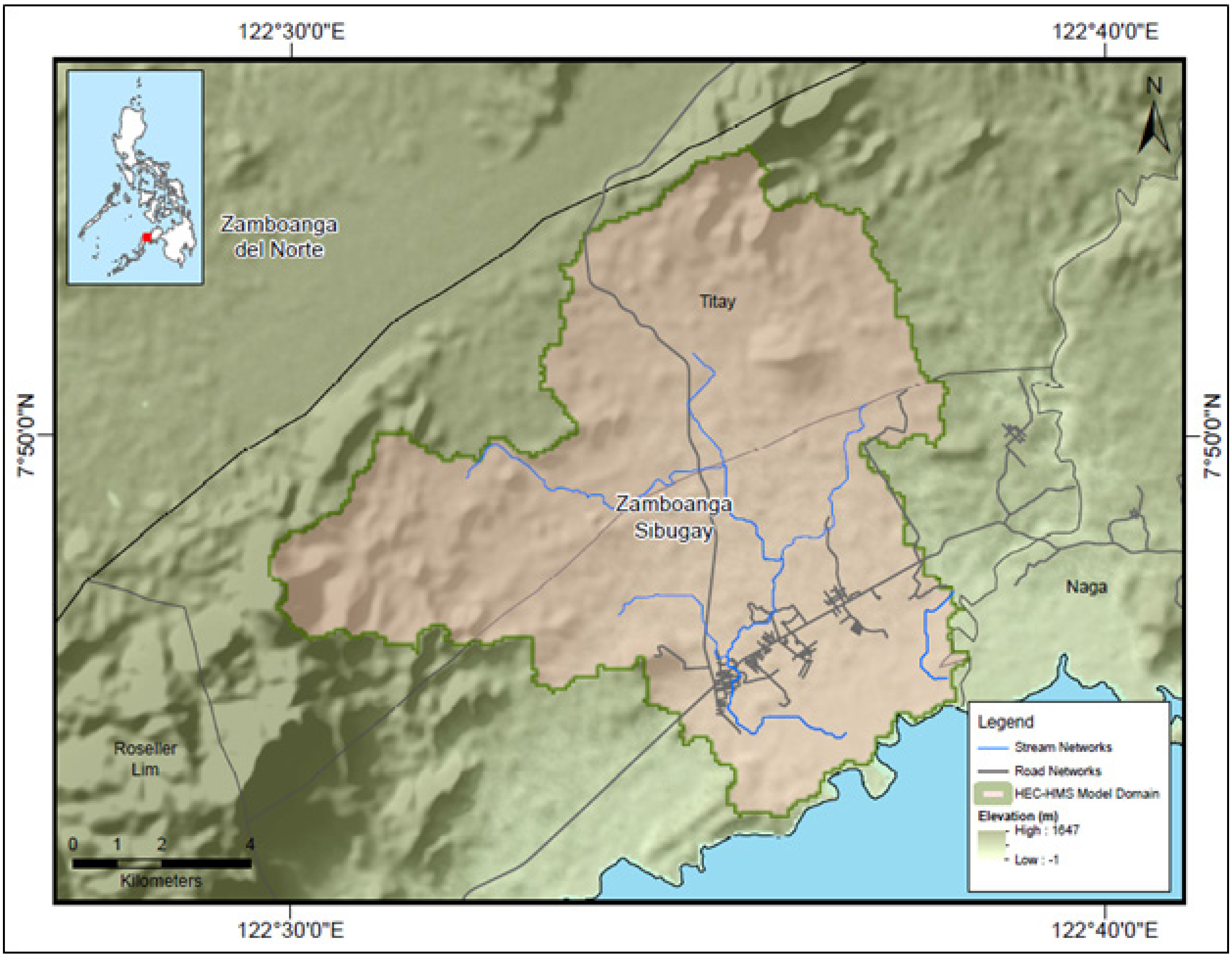


Figure 3. Map of Sanito River Basin (in brown)

CHAPTER 2: LIDAR DATA ACQUISITION OF THE SANITO FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Gracia Acuña, Engr. Gerome Hipolito, Engr. Grace B. Sinadjan, Ms. Sandra C. Poblete

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 Sanito Floodplain in Zamboanga Sibugay. These missions were planned for 12 lines that run for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR system is found in Table 1. Figure 4 shows the flight plan for Sanito Floodplain survey.

Table 1. Flight planning parameters for Pegasus LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of view (ø)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK73A	800,1200	30	50	200	30	130	5
BLK73B	800,1200	30	50	200	30	130	5
BLK75A	1100	15	50	200	30	130	5
BLK75AS	1100	15	50	200	30	130	5

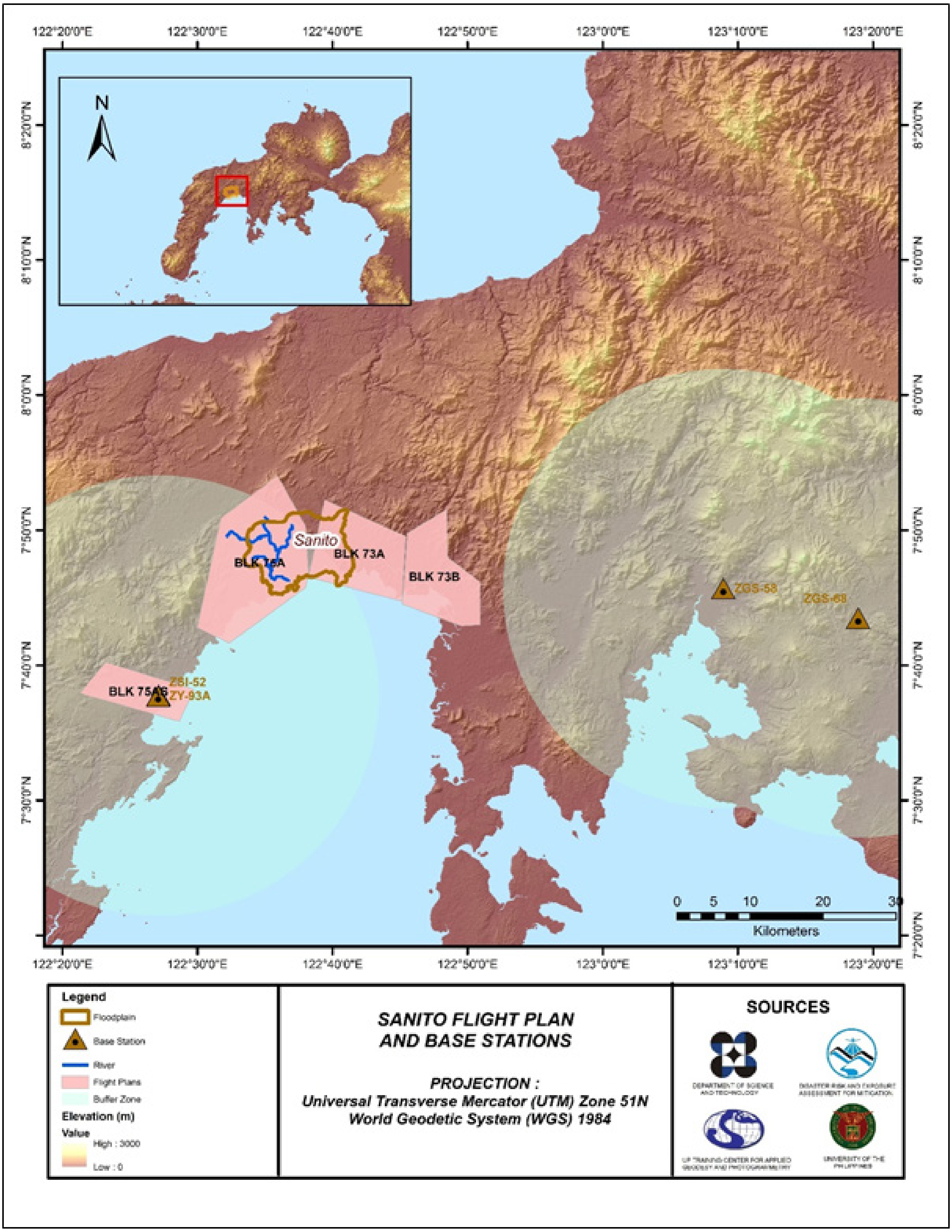


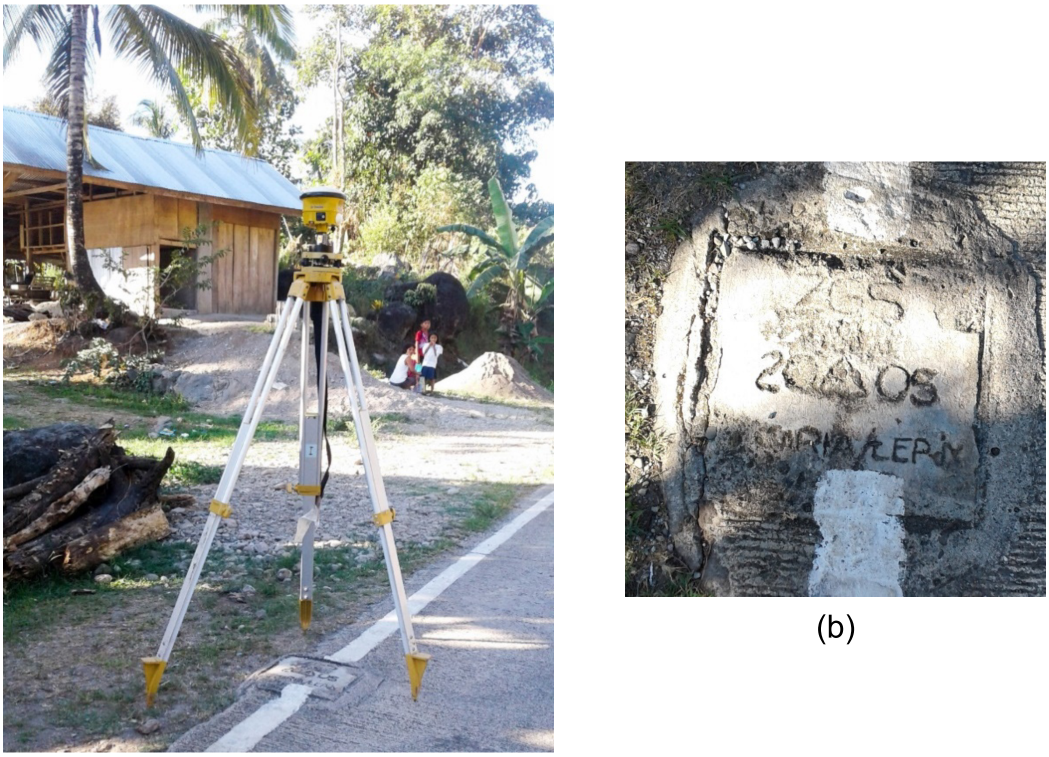
Figure 4. Flight plan and base stations used for Sanito Floodplain.

2.2 Ground Base Stations

The project team was able to recover three (3) NAMRIA ground control points: ZGS-58, ZGS-68 and ZSI-52, which are all of second (2nd) order accuracy. The project team also established one (1) ground control point, ZY-93A.

The certifications for the NAMRIA reference points are found in Annex 2while the baseline processing report for the established control pointis found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey (February 9 – 10, 2015 and February 26, 2016). Base stations were observed using dual frequency GPS receivers: TRIMBLE SPS 852, TRIMBLE SPS 882, TRIMBLE SPS 985 and TOPCON GR5. Flight plans and location of base stations used during the aerial LiDAR acquisition in Sanito Floodplain are shown in Figure 4.

Figure 5 to Figure 7 show the recovered NAMRIA reference points within the area. In addition, Table 2 to Table 5 show the details about the following NAMRIA control stations and established point, while Table 6 shows the list of all ground control points occupied during the acquisition together with the corresponding dates of utilization.



(b)

(a)

Figure 5. GPS set-up over ZGS-58 at Brgy. Sicade, Municipality of Kumalarang, Zamboanga del Sur (a) and NAMRIA reference point ZGS-58 (b) as recovered by the field team.

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

Station Name	ZGS-58	
Order of Accuracy	2nd	
Relative Error (Horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	7° 45' 44.20587" North 123° 8' 50.40994" East 31.65 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting Northing	516,245.79 meters 857,966.20 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7° 45' 40.67639" North 123° 8' 55.89231" East 96.974 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	516,245.79 meters 857,966.20 meters

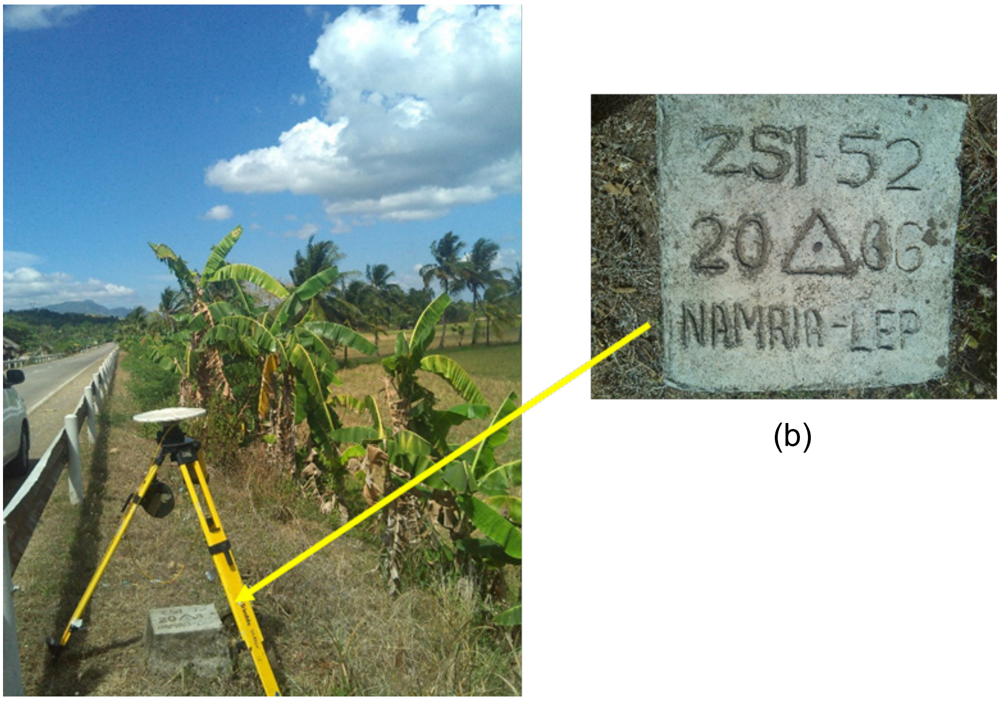
(a)

(b)

Figure 6. GPS set-up over ZGS-68 at CENRO, Brgy. Poblacion, Municipality of Guipos, Zamboanga del Sur (a) and NAMRIA reference point ZGS-68 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point ZGS-68 used as base station for the LiDAR acquisition.

Station Name	ZGS-68	
Order of Accuracy	2nd	
Relative Error (Horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	7° 43’ 33.12722” North 123°18’488.96041” East 205.941 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 3 PRS 92)	Easting Northing	534,593.845 meters 854,250.138 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7° 43’ 29.62251” North 123° 18’ 54.44472” East 271.748 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	534,581.74 meters 853,951.14 meters



(a) (b)

Figure 7. GPS set-up over ZSI-52 at Barangay Tupilac, Zamboanga Sibugay (a) and NAMRIA reference point ZSI-52 (b) as recovered by the field team.

Table 4. Details of the recovered NAMRIA horizontal control point ZSI-52 used as base station for the LiDAR acquisition.

Station Name	ZSI-52	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	7° 37' 50.78279" North 122° 27' 1.47785" East 10.413 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 3 PRS 92)	Easting Northing	439,359.616 meters 843,760.188 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7° 37' 47.22473" North 122° 27' 6.97710" East 74.257 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	439,380.84 meters 843,464.86 meters

Table 5. Details of the established horizontal control point ZY-93A used as base station for the LiDAR acquisition.

Station Name	ZY-93A	
Order of Accuracy	2nd (established point)	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	7° 37' 46.78582" North 122° 27' 0.08763" East 10.662 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 3 PRS 92)	Easting Northing	439,338.09 meters 843,342.174 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7° 37' 43.22802" North 122° 27' 5.58699"East 74.508 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	439,512.45 meters 843,285.98 meters

Table 6. Ground Control points used during LiDAR data acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
February 9, 2015	2549P	1BLK75A40A	ZSI-52, ZY-93A
February 10, 2015	2553P	1BLK75AS41A	ZSI-52, ZY-93A
February 24, 2016	23132P	1BLK73A055A	ZGS-58 and ZGS-68

2.3 Flight Missions

Three (3) missions were conducted to complete the LiDAR data acquisition in Sanito floodplain, for a total of twelve hours and forty-five minutes (12+45) of flying time for RP-C9022 and RP-C9122. All missions were acquired using the Pegasus LiDAR system. Table 7 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 8 presents the actual parameters used during the LiDAR data acquisition.

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

Date Surveyed	Flight Number	Flight Plan Area (km^2)	Surveyed Area (km^2)	Area Surveyed within the Floodplain (km^2)	Area Surveyed Outside the Floodplain (km^2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
9-Feb-15	2549P	150.54	165.82	13.51	152.31	482	4	23
10-Feb-15	2553P	150.54	204.62	74.62	130.00	488	4	11
24-Feb-16	23132P	228	221.62	57.76	163.88	0	4	11
TOTAL		529.08	592.06	145.89	446.19	970	12	45

Table 8. 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)
2549P	1100	15	50	200	30	130	5
2553P	1100	15	50	200	30	130	5
23132P	800,1200	30	50	200	30	130	5

2.4 Survey Coverage

This certain LiDAR acquisition survey covered the Sanito Floodplain (See Annex 7). Sanito Floodplain is located in the province of Zamboanga Sibugay, with majority of the floodplain situated within the municipalities of Ipil, Titay and Naga. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 9. The actual coverage of the LiDAR acquisition for Sanito Floodplain is presented in Figure 8.

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

Province	Municipality/ City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Zamboanga Sibugay	Ipil	130.9	128.69	98.31%
	Titay	176.5	101.11	57.29%
	Naga	164.18	87.17	53.10%
	Kabasalan	317.28	59.16	18.65%
	Roseller Lim	272.39	45.28	16.62%
	Tungawan	441.86	23.7	5.36%
Zamboanga del Norte	Kalawit	329.51	6.46	1.96%
	TOTAL	1832.62	451.57	24.64%

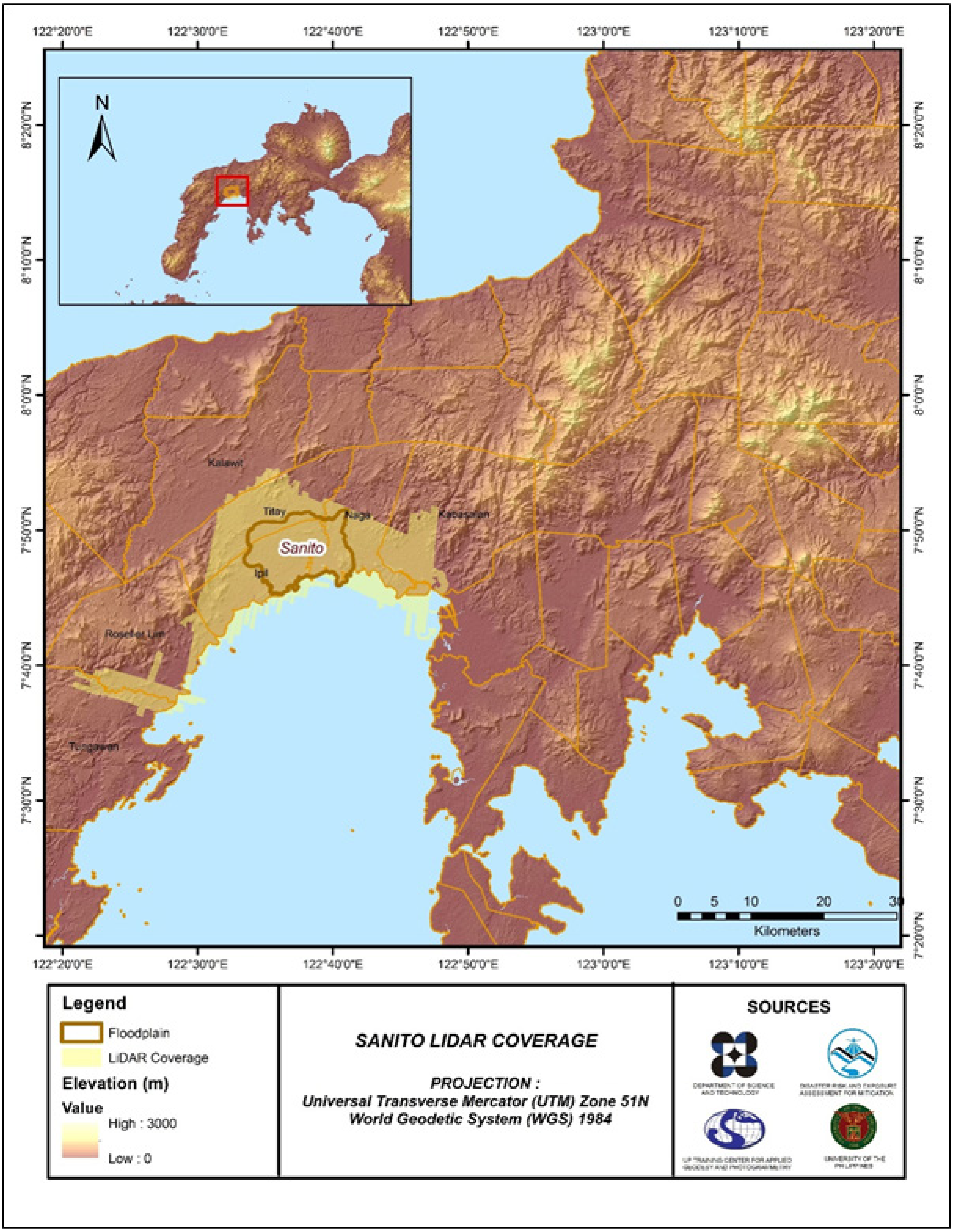


Figure 8. Actual LiDAR survey coverage for Sanito Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE SANITO FLOODPLAIN

Engr. Ma. Rosario Concepcion O. Ang, Engr. John Louie D. Fabila, Engr. Sarah Jane D. Samalburo , Engr. Gladys Mae Apat , Engr. Ma. Ailyn L. Olanda , Engr. Don Matthew B. Banatin, Engr. Antonio B. Chua Jr., Engr. Christy Lubiano , Deane Leonard M. Bool, Eriasha Loryn C. Tong

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

3.1 Overview of the LiDAR Data Pre-Processing

The data transmitted by the Data Acquisition Component 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 in order to obtain the exact location of the LiDAR sensor when the laser was shot.

Point cloud georectification is performed to incorporate correct position and orientation for each point acquired. The georectified LiDAR point clouds 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.

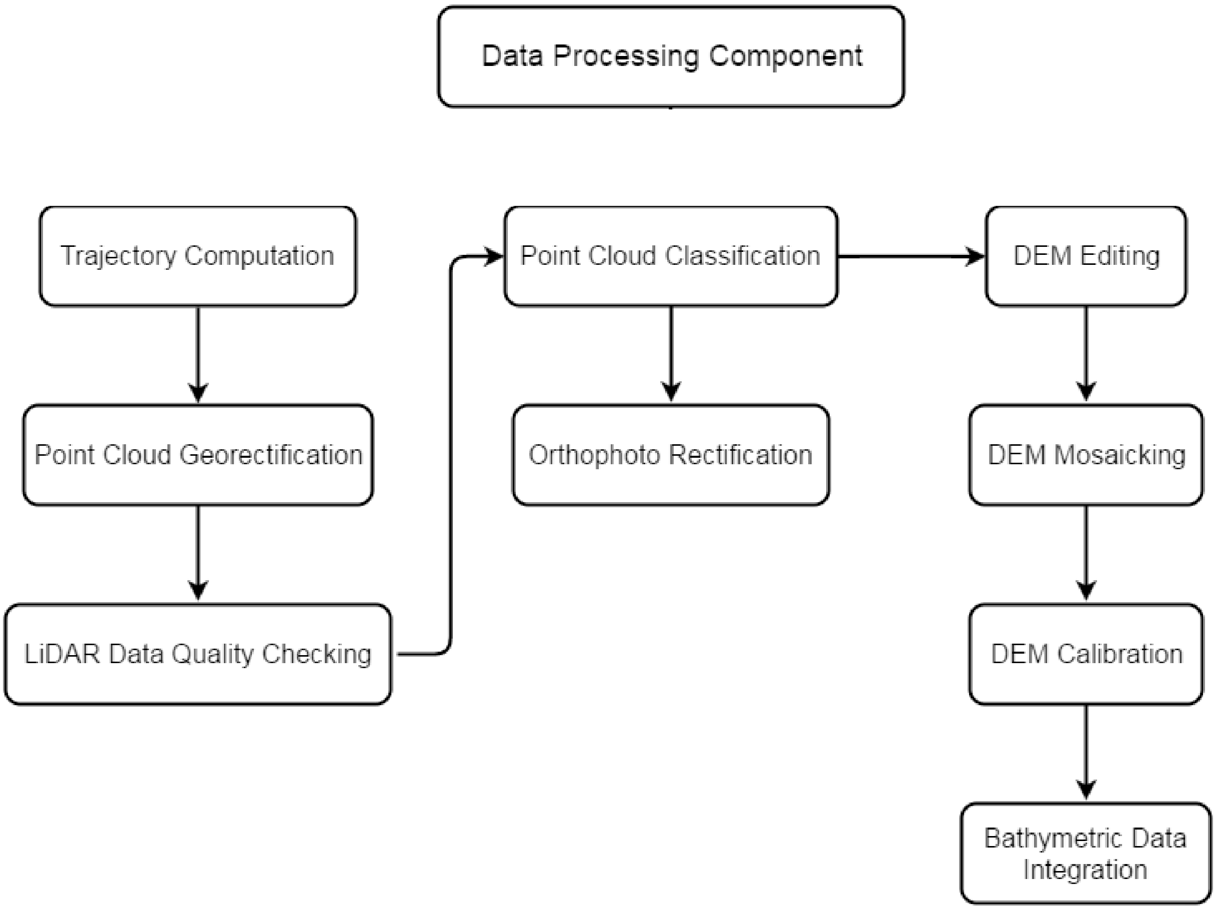


Figure 9. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Sanito floodplain can be found in Annex 5. Data Transfer Sheets. Missions flown during the first and second survey conducted in February 2015 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system in Ipil, Zamboanga Sibugay.

The Data Acquisition Component (DAC) transferred a total of 46.70 Gigabytes of Range data, 0.50 Gigabytes of POS data, 54.07 Megabytes of GPS base station data, and 32.60 Gigabytes of raw image data to the data server on February 9, 2015 for the first survey and February 24, 2016 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Sanito was fully transferred on March 10, 2016, as indicated in the Data Transfer Sheets for Sanito Floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 2549P, one of the Sanito 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 February 8, 2015 00:00AM. The y-axis is the RMSE value for that particular position.

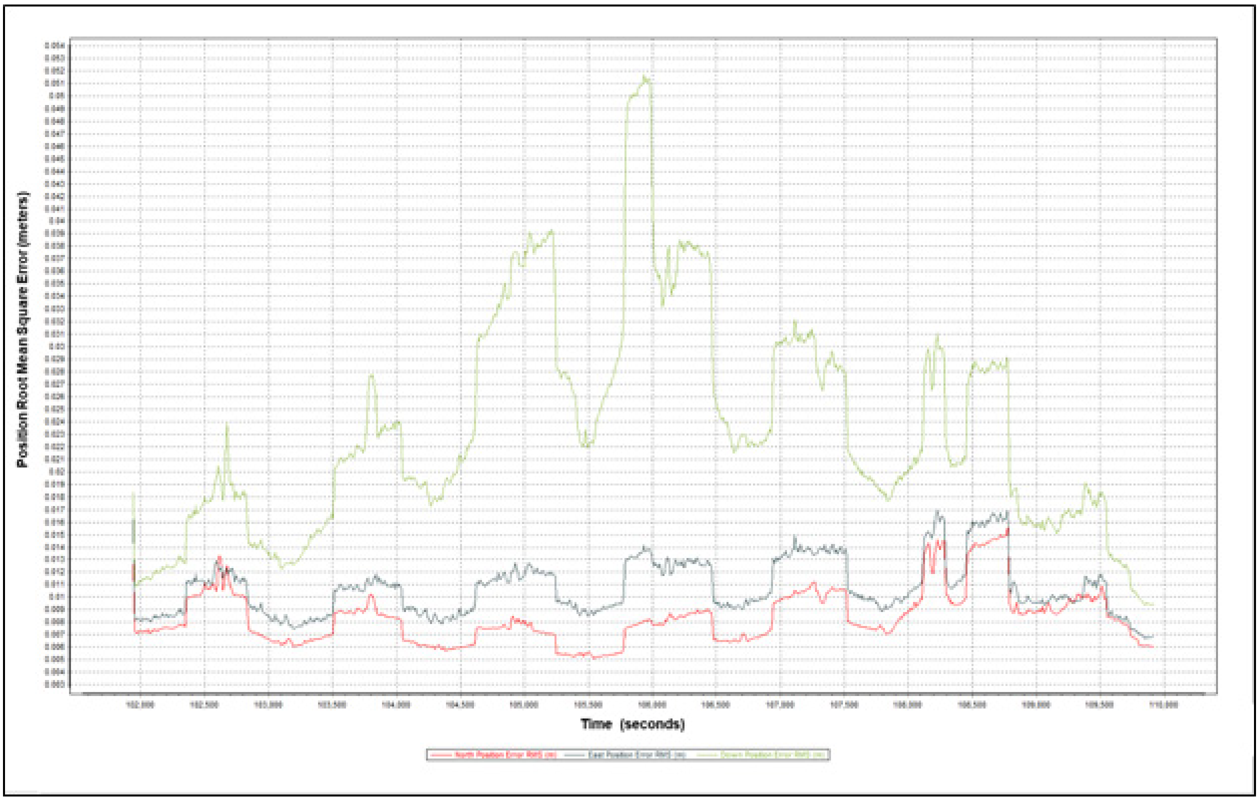


Figure 10. Smoothed Performance Metrics of a Sanito Flight 2549P.

The time of flight was from 102000 seconds to 110000 seconds, which corresponds to morning of February 9, 2015. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft.

Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 10 shows that the North position RMSE peaks at 1.50 centimeters, the East position RMSE peaks at 1.70centimeters, and the Down position RMSE peaks at 3.90centimeters, which are within the prescribed accuracies described in the methodology.

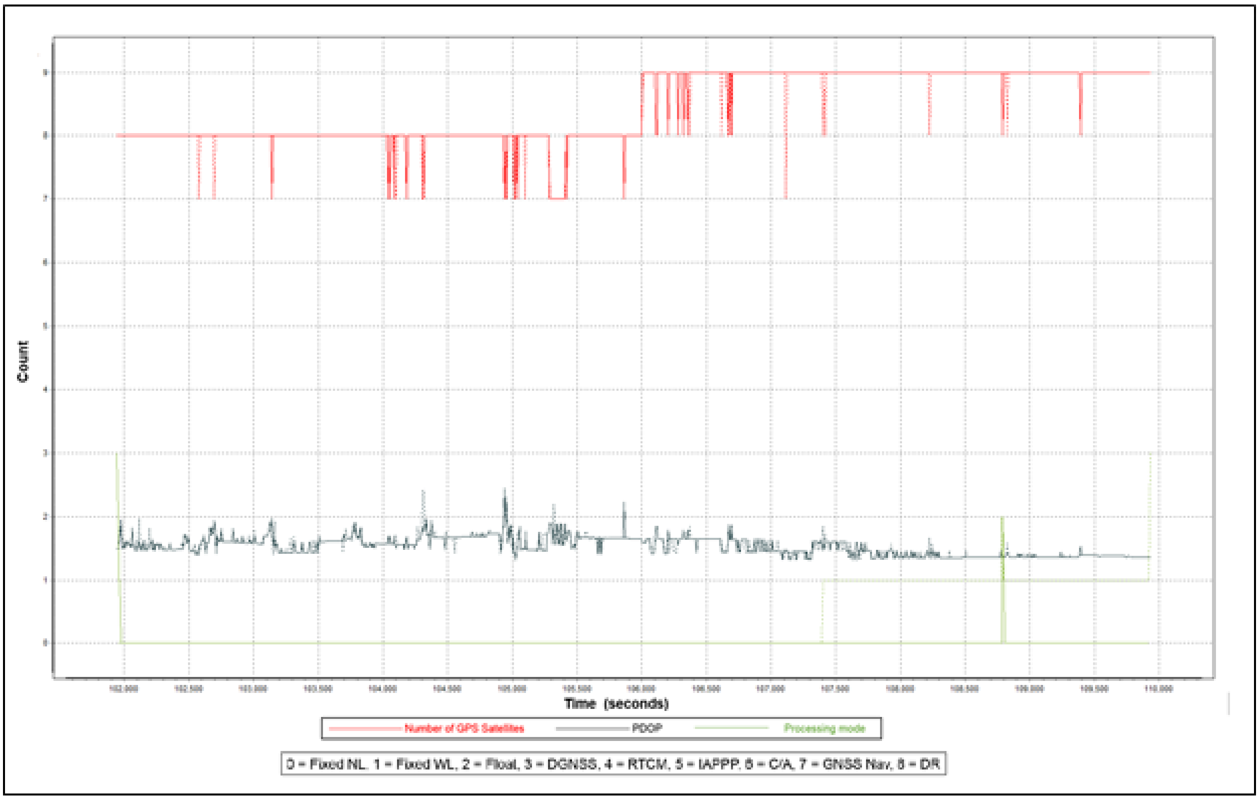


Figure 11. Solution Status Parameters of Sanito Flight 2549P.

The Solution Status parameters of flight 2549P, one of the Sanitoflights, 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 7 and 9. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode remained at 0 for majority of the survey with some peaks up to 3 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Sanito flights is shown in Figure 12.

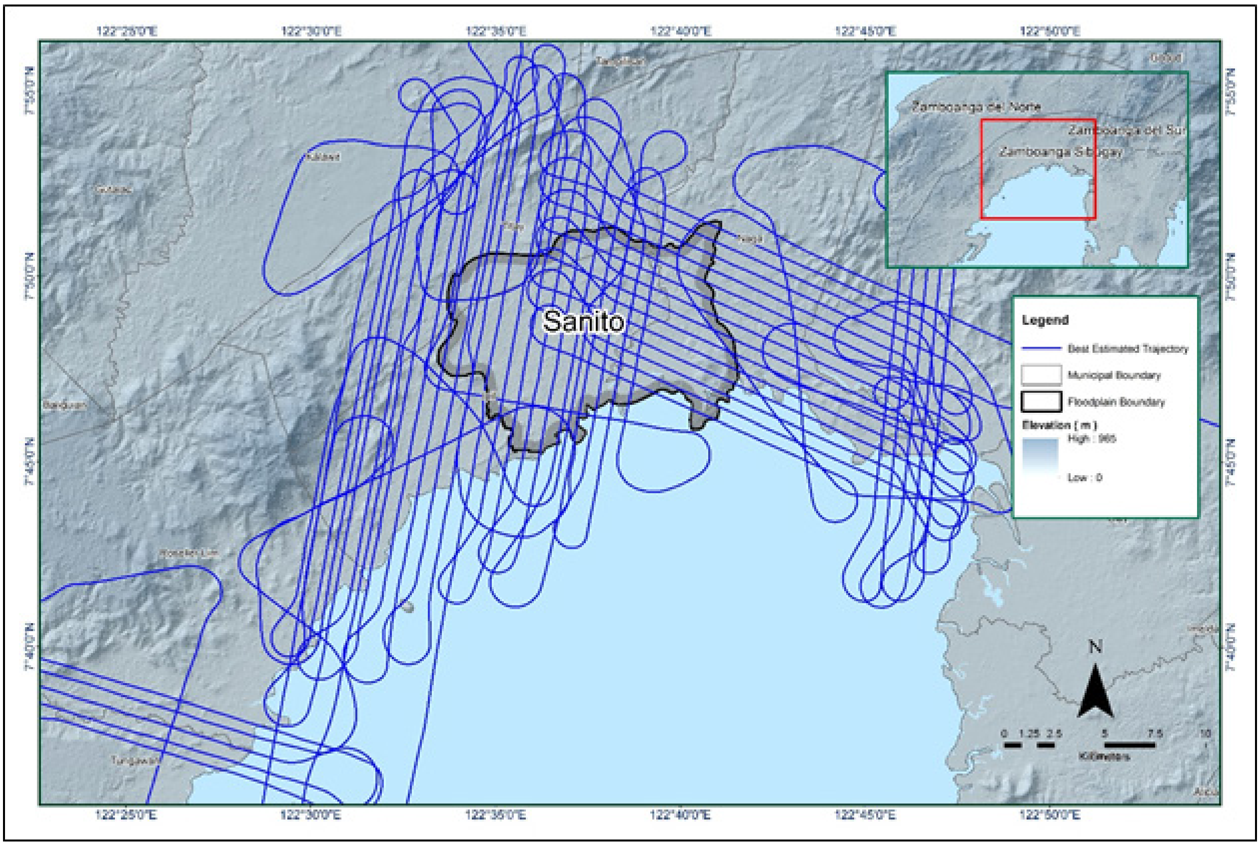


Figure 12. Best estimated trajectory of the LiDAR missions conducted over the Sanito Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 42 flight lines, with each flight line containing two channels, since the Pegasus system contains two channels. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Sanito Floodplain are given in Table 10.

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

Parameter	Acceptable Value	Value
Boresight Correction stdev)	<0.001degrees	0.000157
IMU Attitude Correction Roll and Pitch Correction stdev)	<0.001degrees	0.000581
GPS Position Z-correction stdev)	<0.01meters	0.0015

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

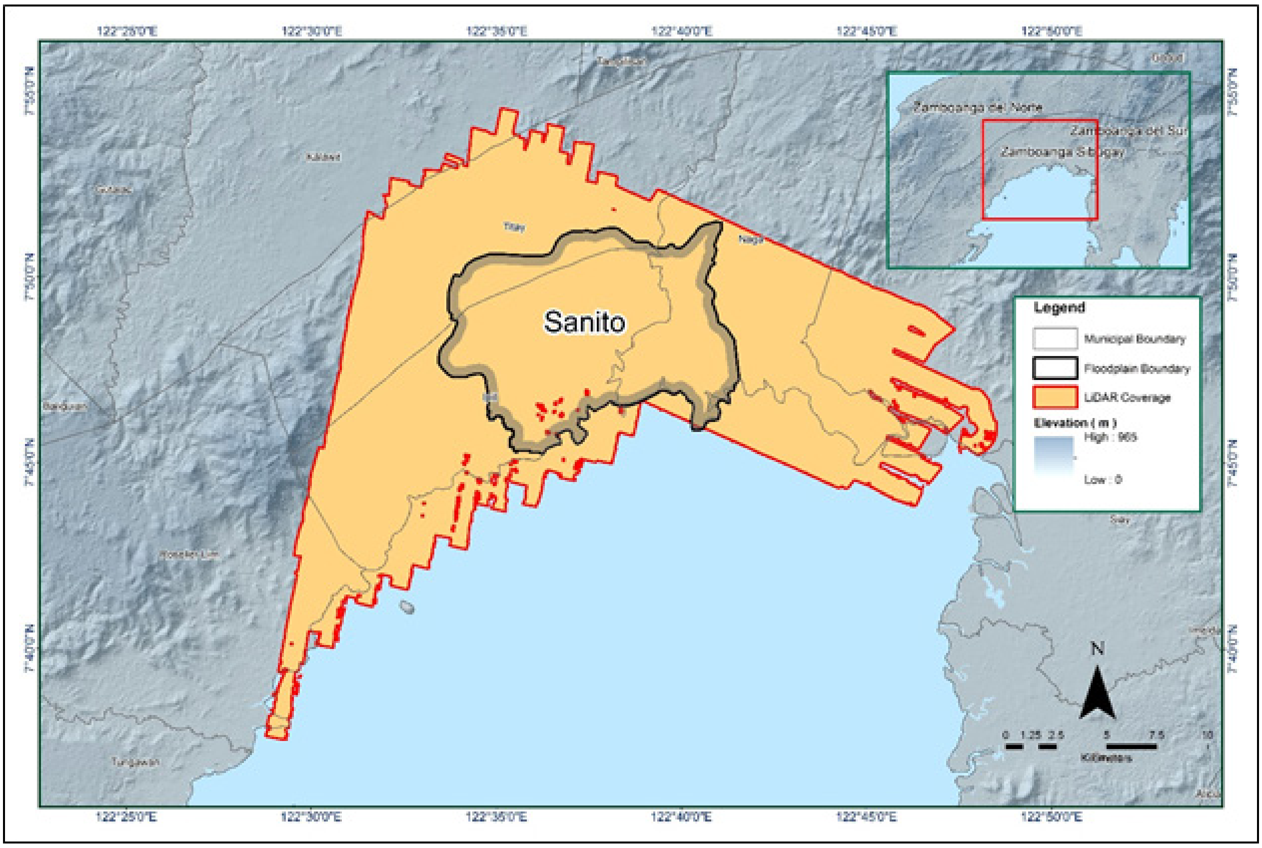


Figure 13. Boundary of the processed LiDAR data on top of a SAR Elevation Data over Sanito Floodplain.

The total area covered by the Sanito missions is 516.18 sq.km that is comprised of two (2) flight acquisitions grouped and merged into two (2) blocks as shown in Table 11.

Table 11. List of LiDAR blocks for Sanito Floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Zamboanga_Blk75A	2549P	331.71
Pagadian_Blk73A	23132P	184.47
TOTAL		516.18 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.

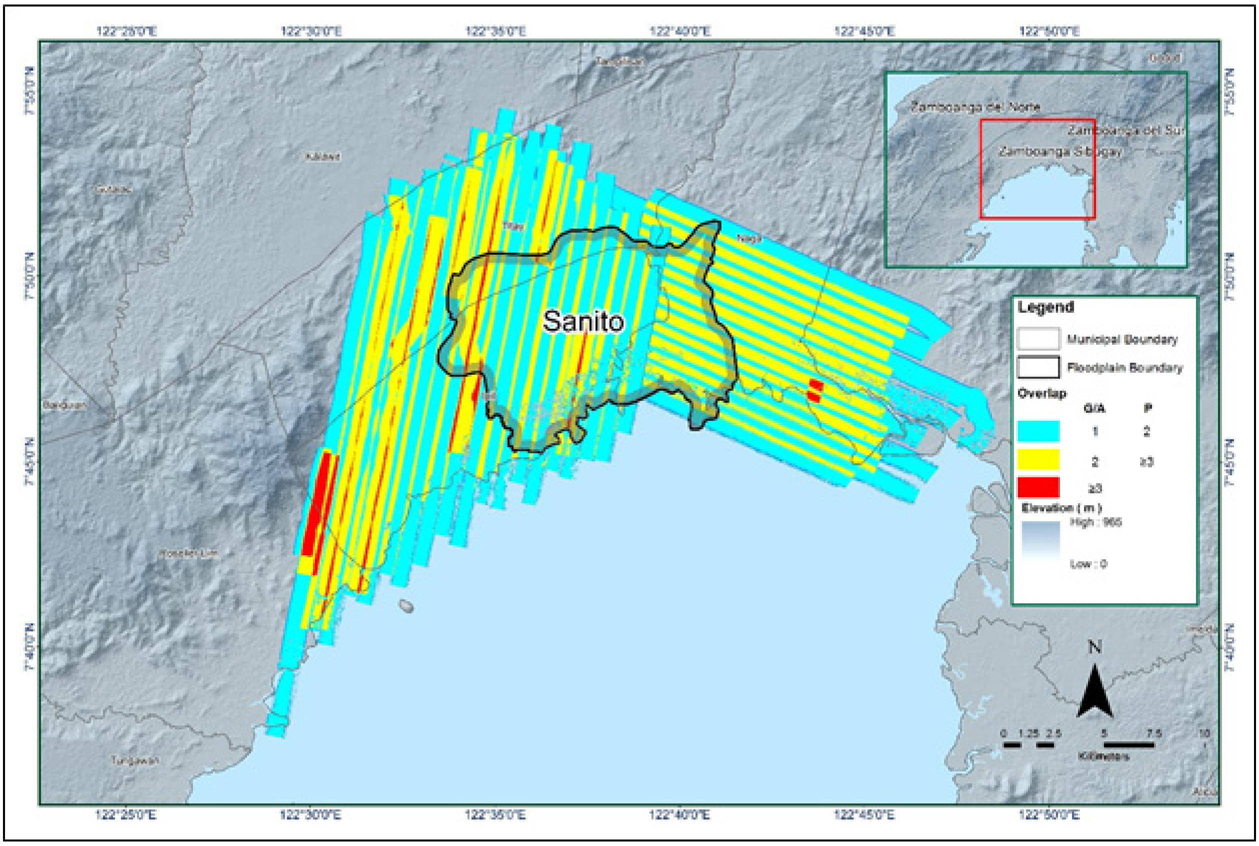


Figure 14. Image of data overlap for Sanito Floodplain.

The overlap statistics per block for the Sanito Floodplaincan 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 44.09% and 45.26% 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 Sanito Floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.64 points per square meter.

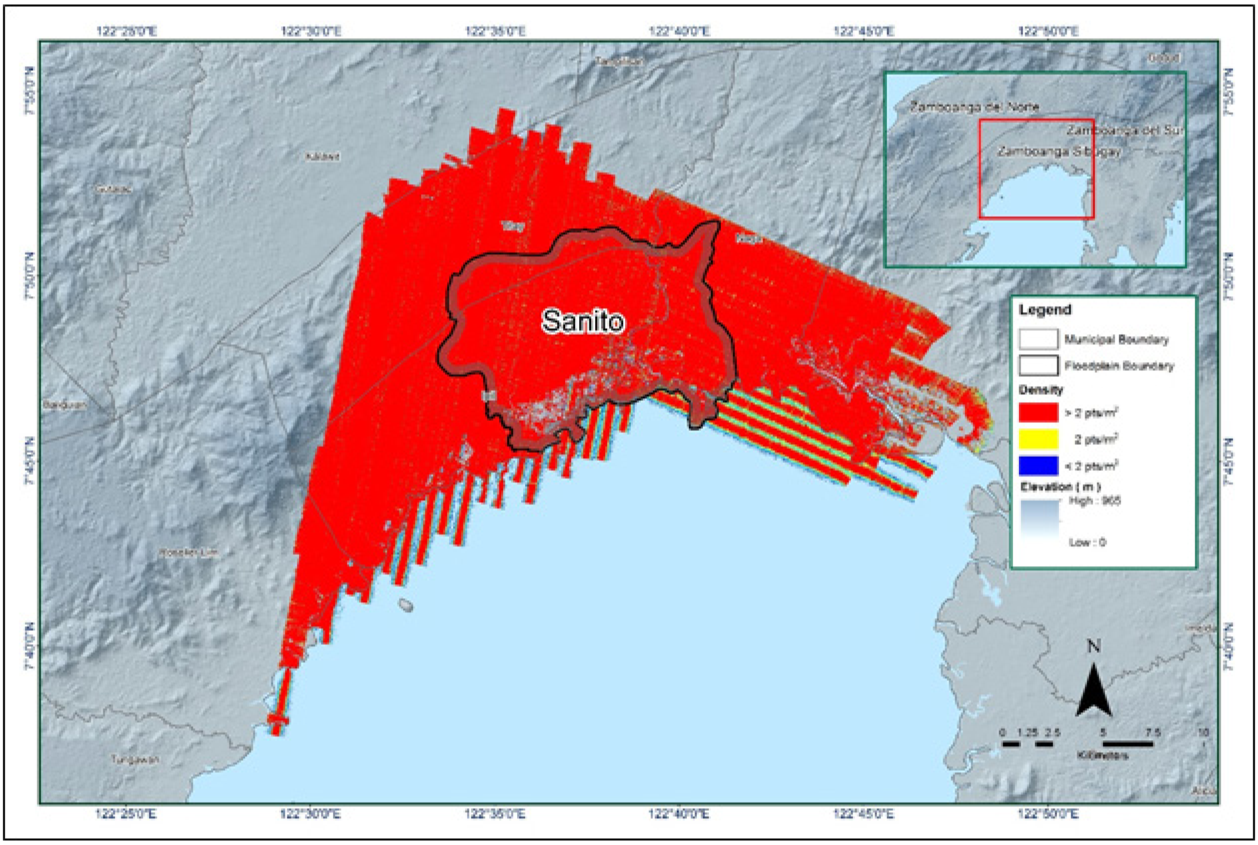


Figure 15. Pulse density map of merged LiDAR data for Sanito Floodplain.

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.

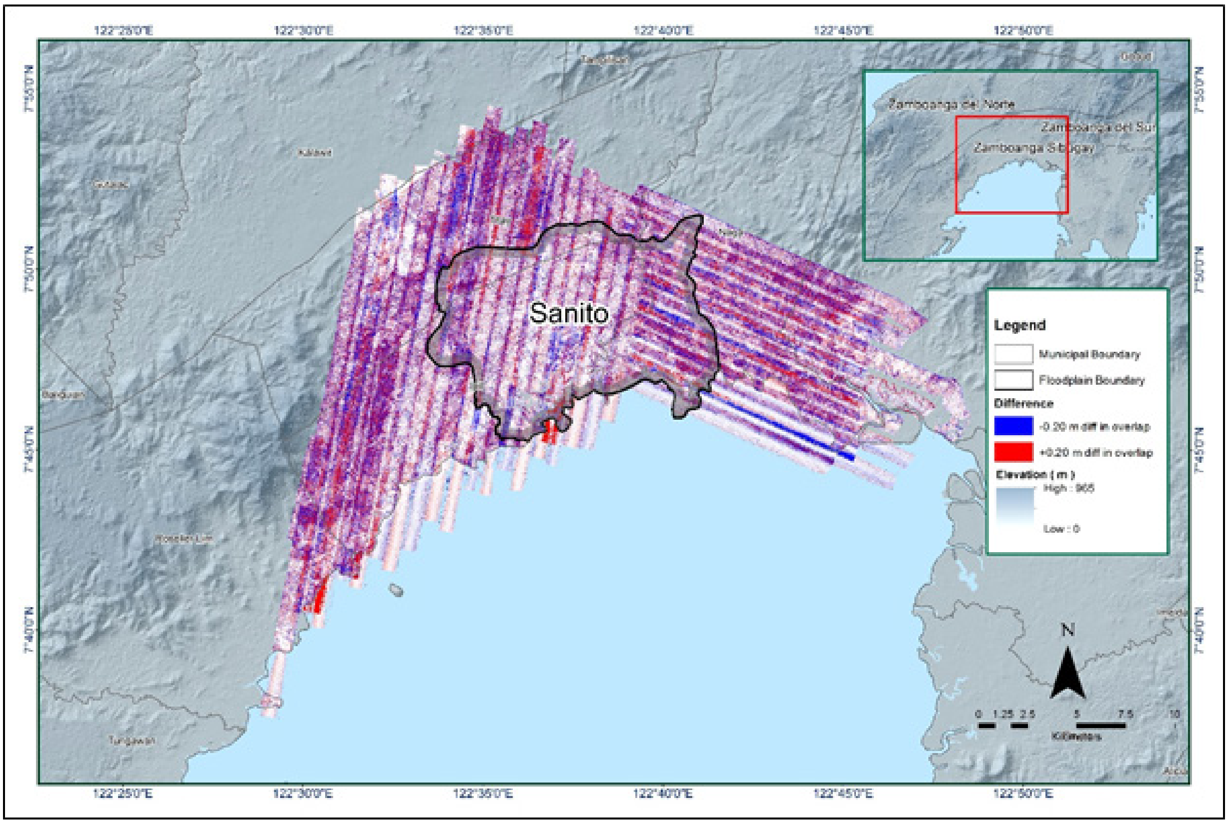


Figure 16. Elevation difference map between flight lines for Sanito Floodplain.

A screen capture of the processed LAS data from a Sanito flight 2549P 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 yellow line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

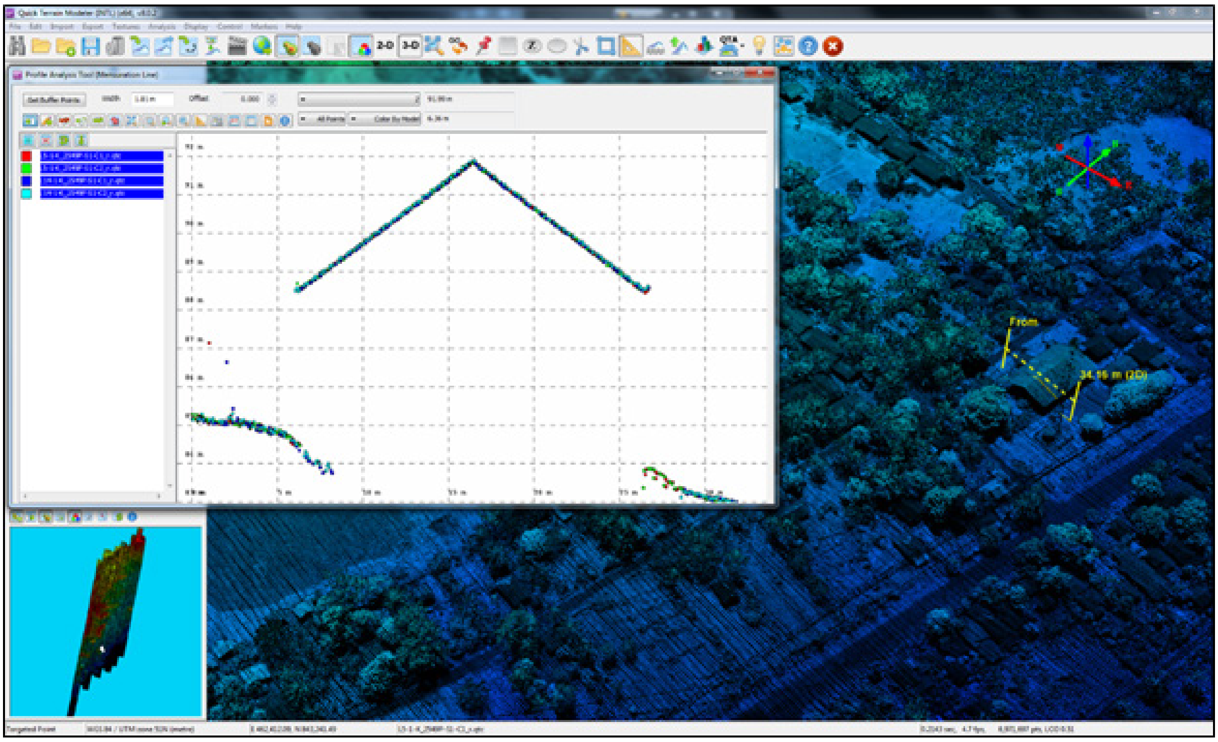


Figure 17. Quality checking for a Sanito flight 2549P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 12. Sanito classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	355,679,778
Low Vegetation	318,502,412
Medium Vegetation	535,729,726
High Vegetation	1,113,357,049
Building	14,521,069

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Sanito Floodplainis shown in Figure 18. A total of 452 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 12. The point cloud has a maximum and minimum height of 557.68 meters and 56.73 meters, respectively.

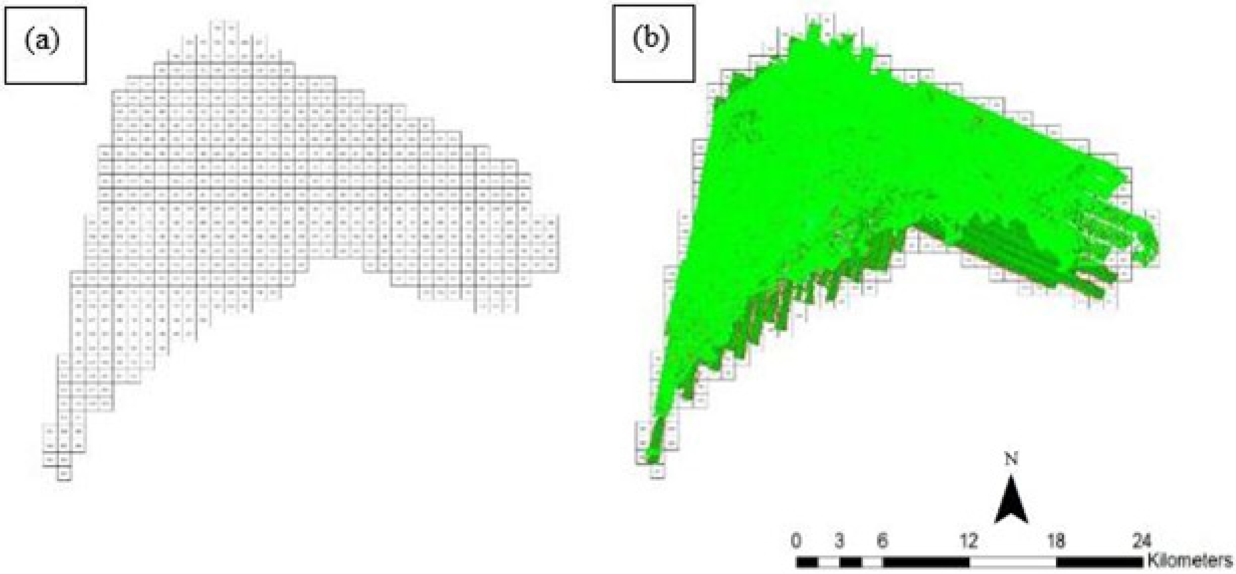


Figure 18. Tiles for Sanito Floodplain (a) and classification results (b) in TerraScan.

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.

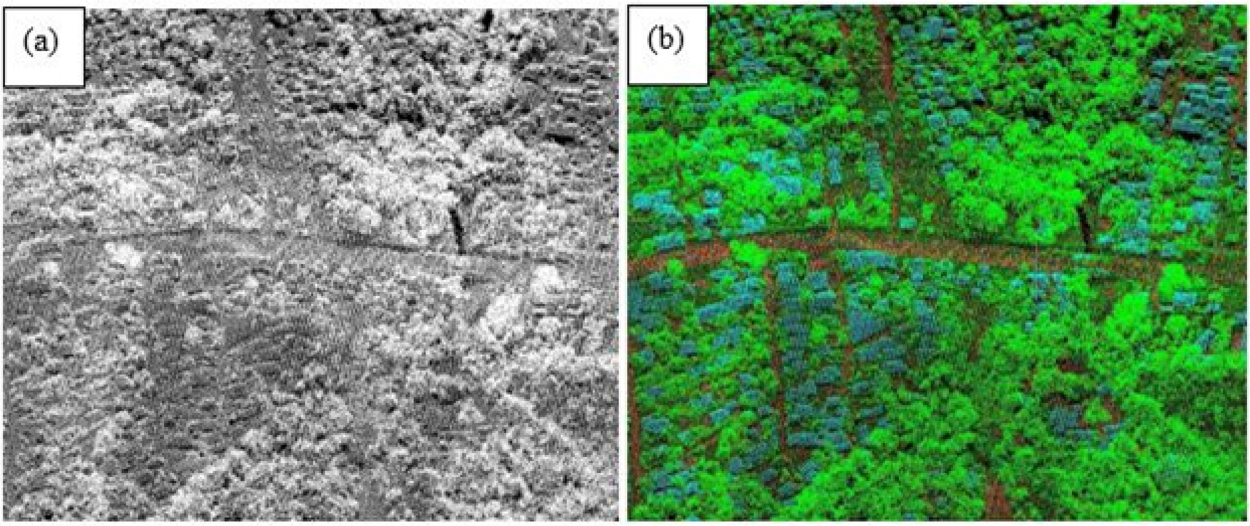


Figure 19. Point cloud before (a) and after (b) classification.

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.

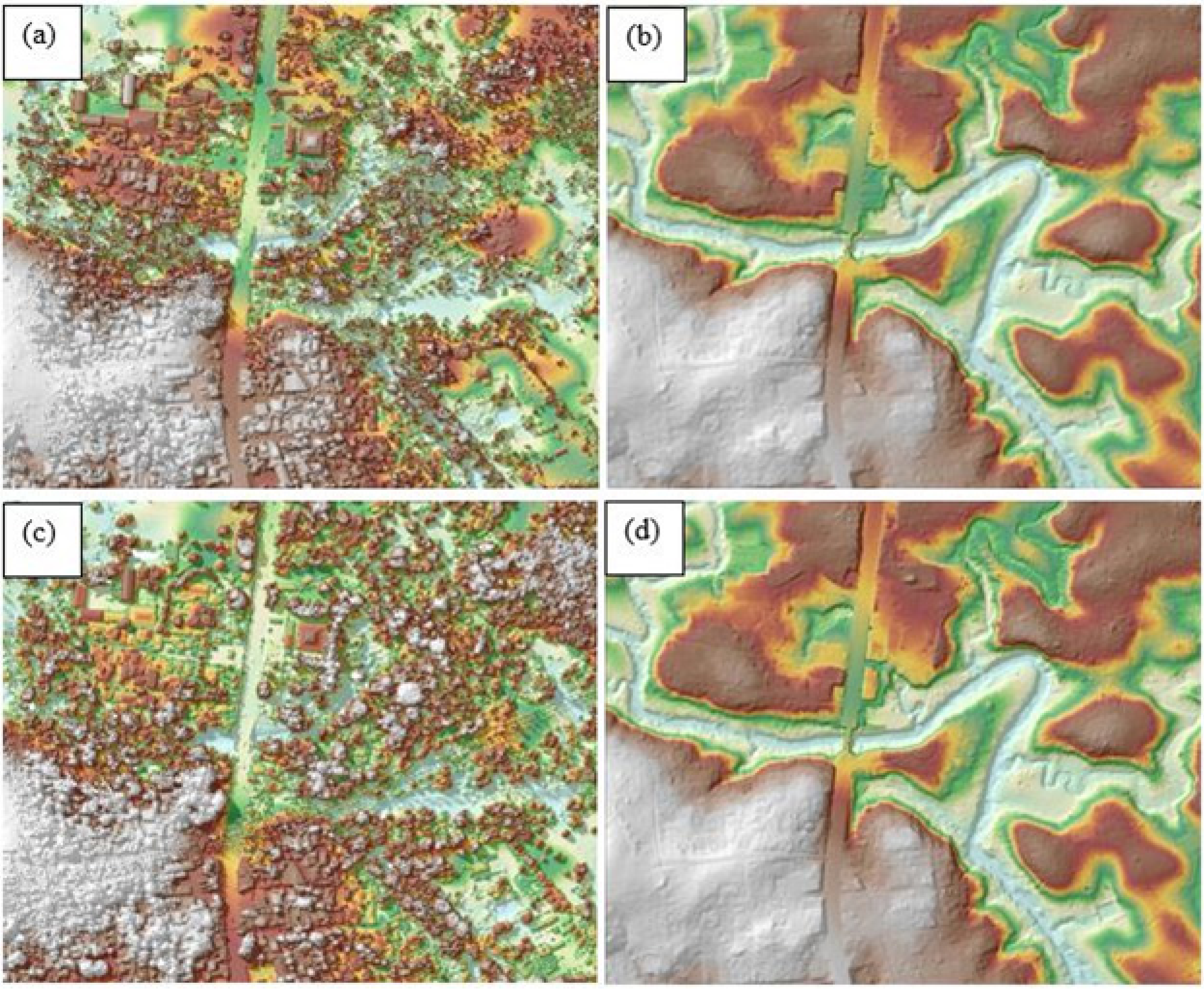


Figure 20. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Sanito Floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 349 1km by 1km tiles area covered by Sanito Floodplainis shown in Figure 21. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Sanito Floodplain has a total of 288.60 sq.km orthophotogaph coverage comprised of 835 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 22.

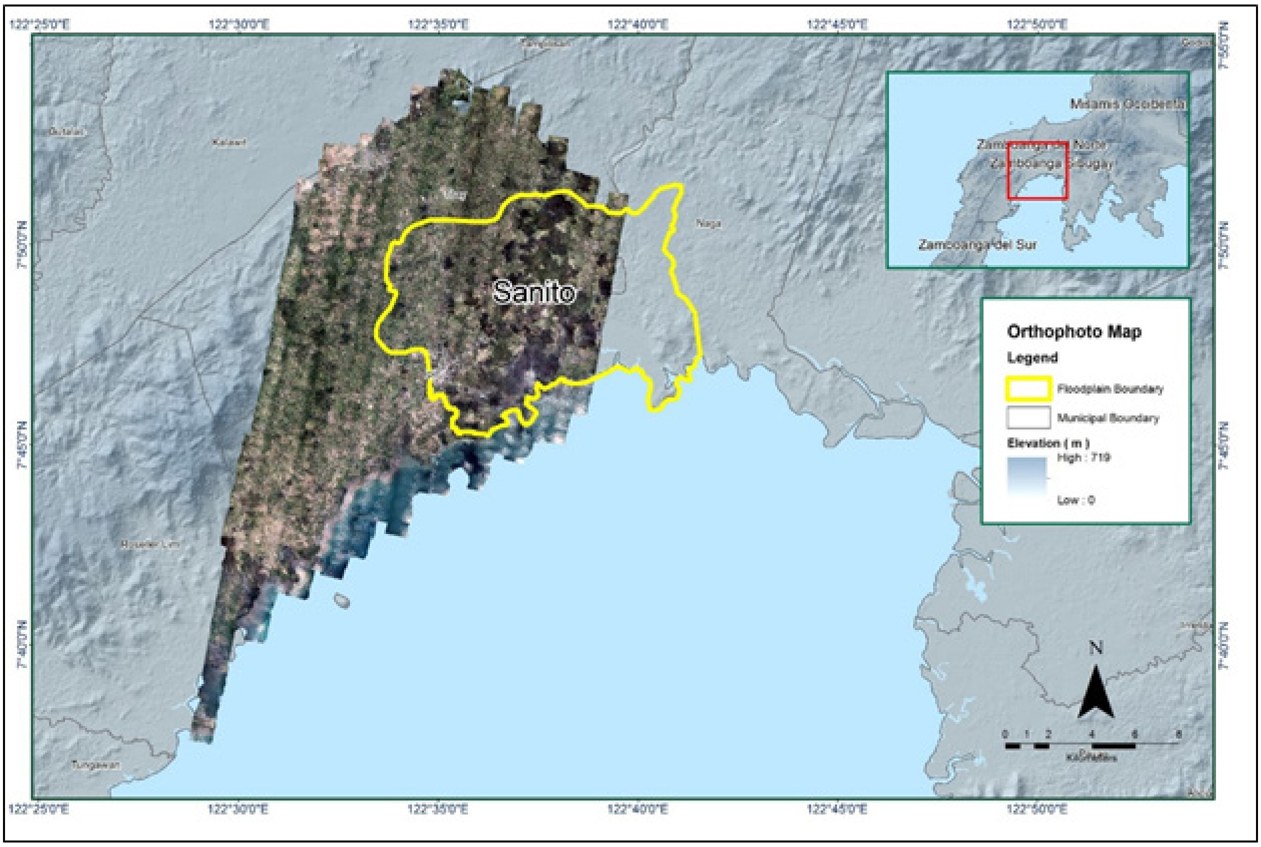


Figure 21. Sanito Floodplain with available orthophotographs.

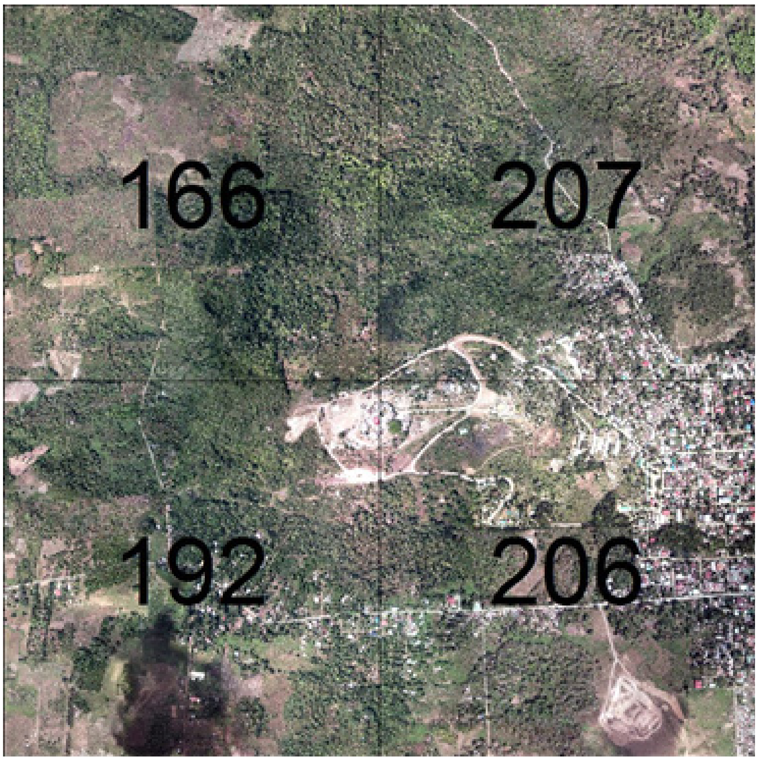


Figure 22. Sample orthophotograph tiles for Sanito Floodplain.

3.8 DEM Editing and Hydro-Correction

Two (2) mission blocks were processed for Sanito Floodplain. These blocks are composed of Zamboanga and Pagadian blocks with a total area of 516.18 square kilometers. Table 13 shows the name and corresponding area of each block in square kilometers.

Table 13. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq.km)
Zamboanga_Blk75A	331.71
Pagadian_Blk73A	184.47
TOTAL	516.18 sq.km

Portions of DTM before and after manual editing are shown in Figure 23. The paddy field (Figure 23a) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 23b) to allow the correct flow of water. The bridge (Figure 23c) is also considered to be an impedance to the flow of water along the river and has to be removed (Figure 23d) in order to hydrologically correct the river.

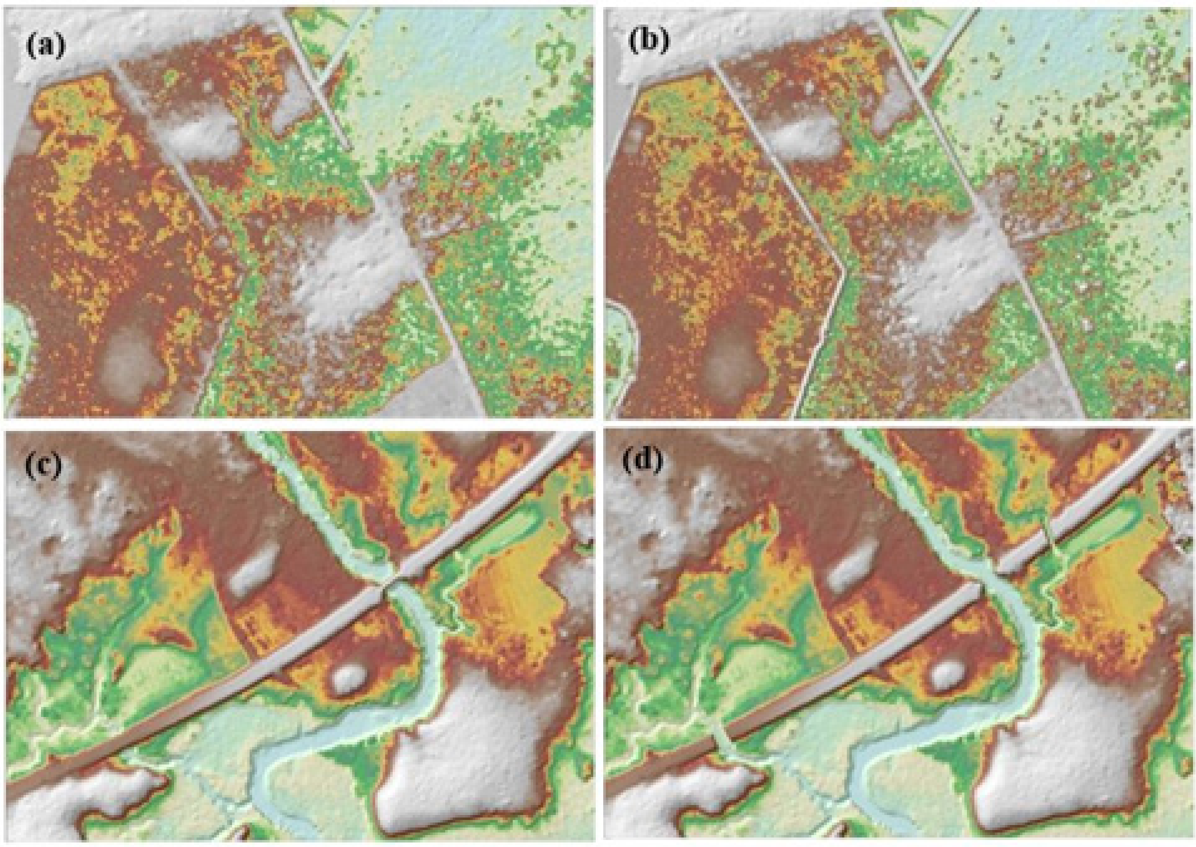


Figure 23.Portions in the DTM of Sanito floodplain – a paddy field before (a) and after (b) data retrieval; a bridge before (c) and after (d) manual editing.

3.9 Mosaicking of Blocks

Zamboanga_Blk75A was used as the reference block at the start of mosaicking because it was the only available data. After which, it was mosaicked with Pagadian_Blk73A. Table 14 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Sanito Floodplain is shown in Figure 24. It can be seen that the entire Sanito Floodplain is 100% covered by LiDAR data.

Table 14. Shift Values of each LiDAR Block of Sanito Floodplain.

Mission Blocks	**Shift Values (meters)**		
	x	**y**	**z**
Zamboanga_Blk75A	0.00	0.00	0.00
Pagadian_Blk73A	0.44	1.00	0.00

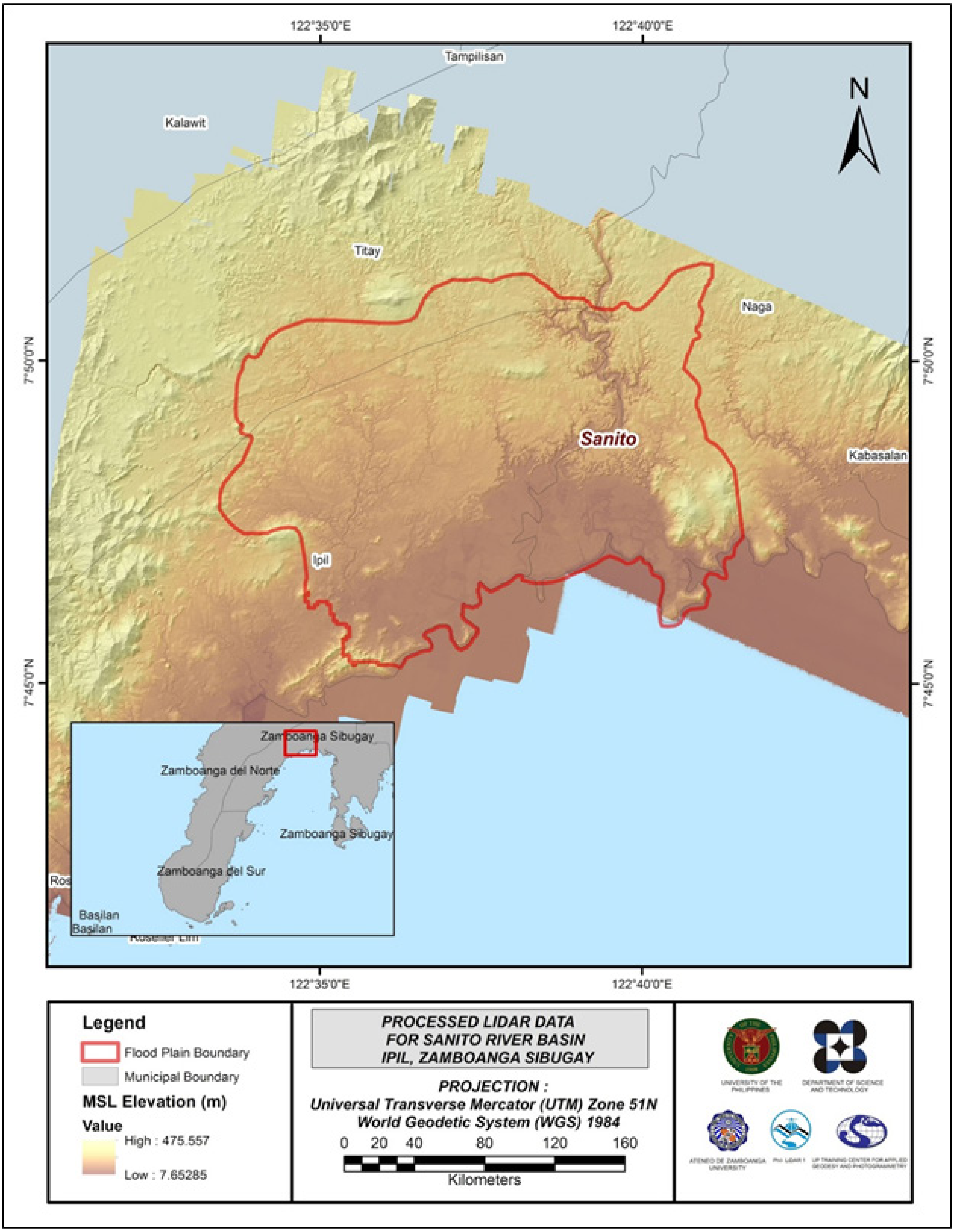


Figure 24. Map of Processed LiDAR Data for Sanito Floodplain.

3.10 Calibration and Validation of Mosaicked LiDAR DEM

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Sanito to collect points with which the LiDAR dataset is validated is shown in Figure 25. A total of 3,526 survey points were used for calibration and validation of Sanito LiDAR data. Random selection of 80% of the survey points, resulting in 2,820 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 26. 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 9.10 meters with a standard deviation of 0.05 meters. Calibration of Sanito LiDAR data was done by adding the height difference value, 9.10 meters, to Sanito mosaicked LiDAR data. Table 15 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

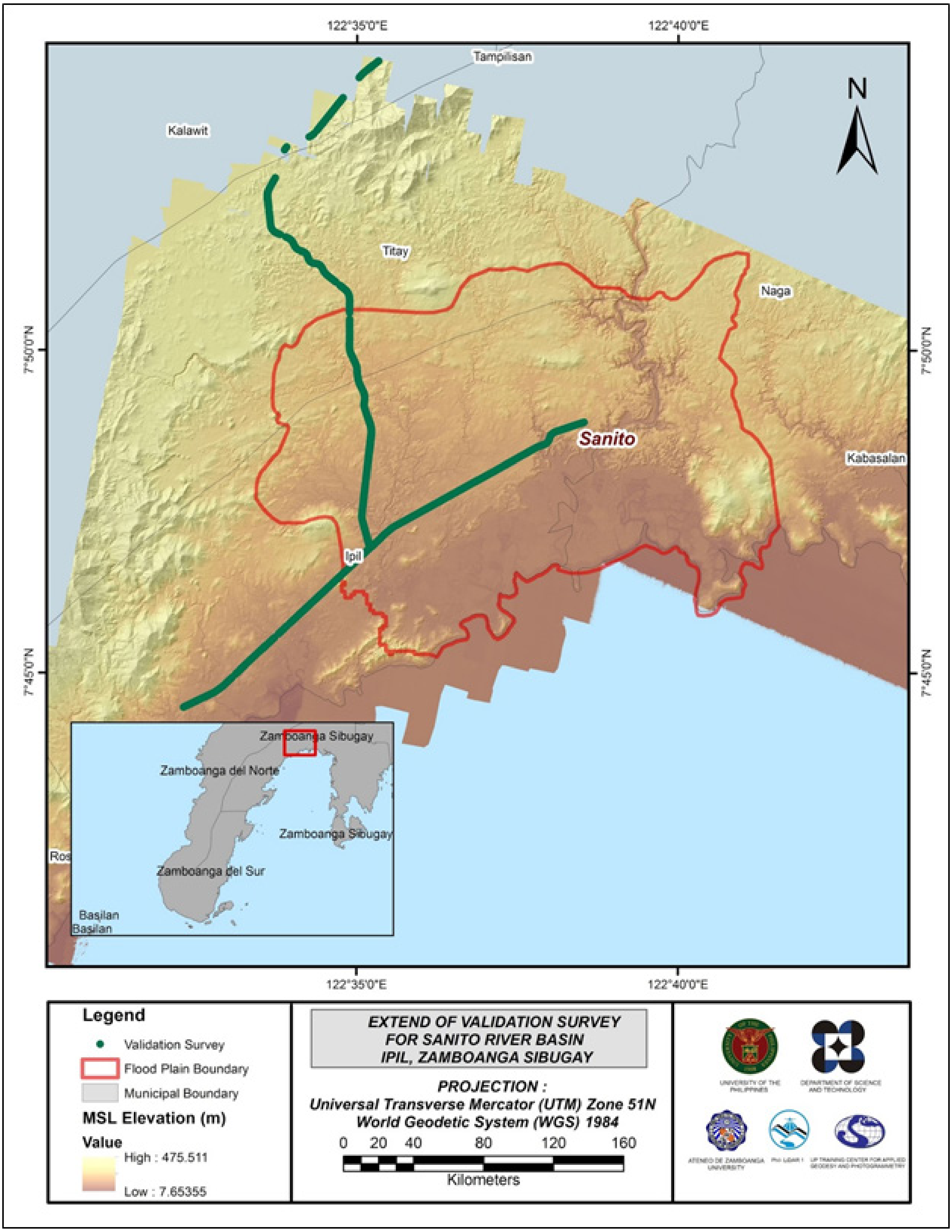


Figure 25. Map of Sanito Floodplain with validation survey points in green.

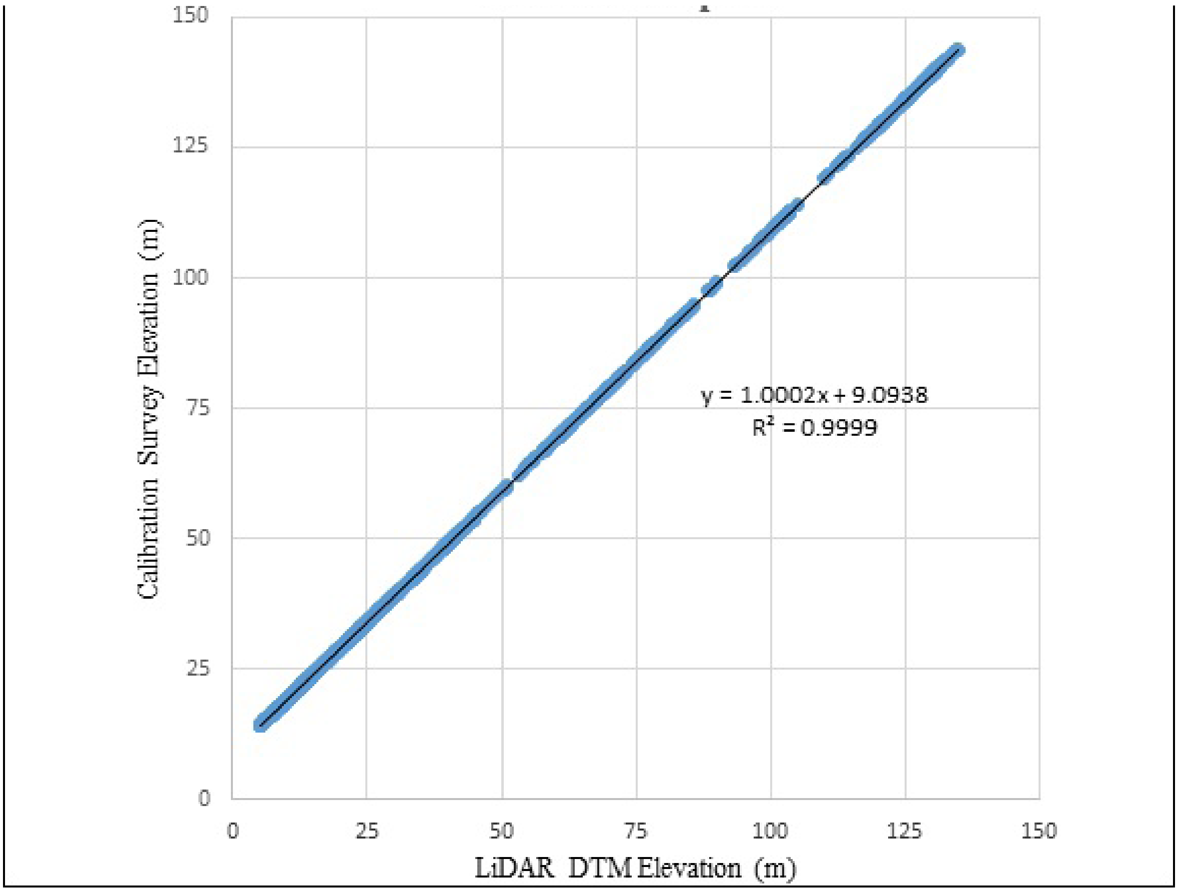


Figure 26. Correlation plot between calibration survey points and LiDAR data.

Table 15. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	9.10
Standard Deviation	0.05
Average	9.10
Minimum	8.99
Maximum	9.20

The remaining 20% of the total survey points, resulting in 706 points, were used for the validation of calibrated Sanito 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 27. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.05meters with a standard deviation of 0.05meters, as shown in Table 16.

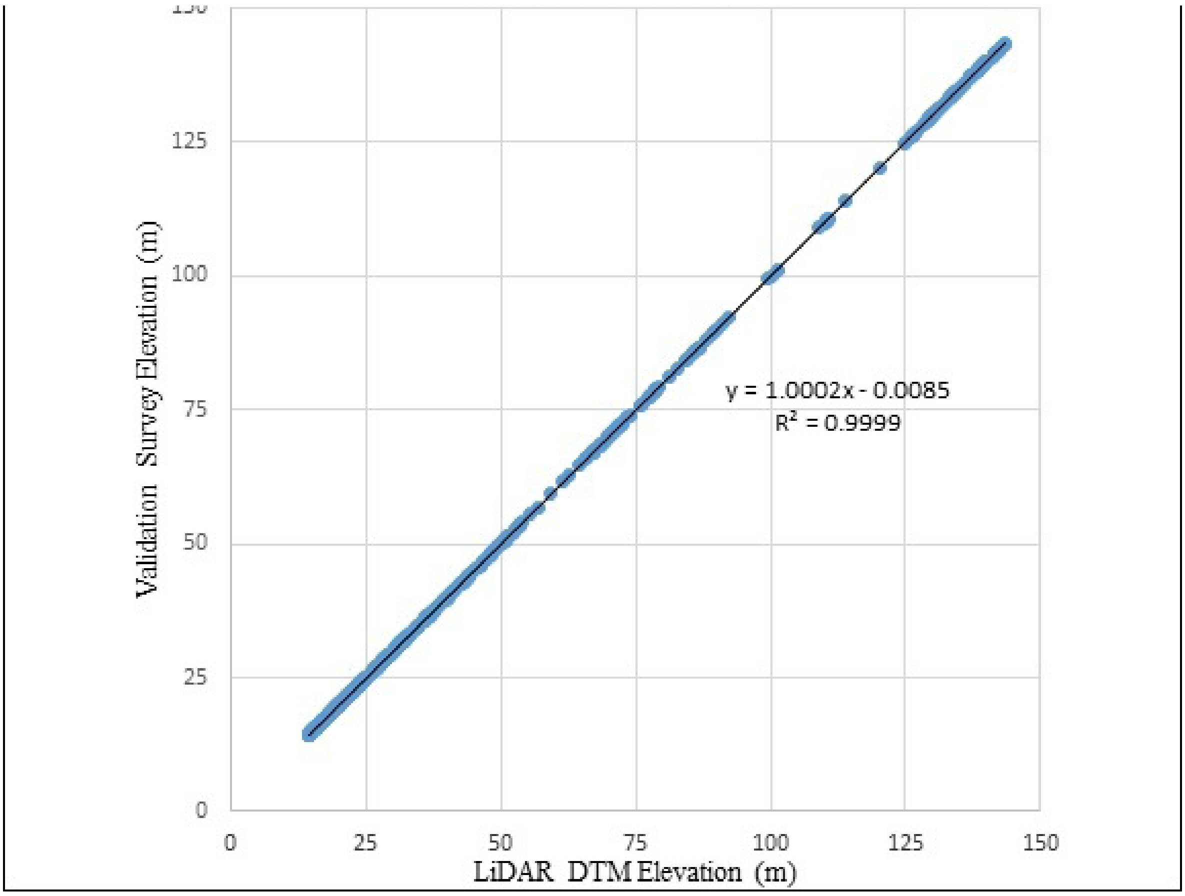


Figure 27. Correlation plot between validation survey points and LiDAR data.

Table 16. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.05
Standard Deviation	0.05
Average	-0.0003
Minimum	-0.10
Maximum	0.10

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and zigzag data were available for Sanito with 11,986 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 0.05 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Sanito integrated with the processed LiDAR DEM is shown in Figure 28.

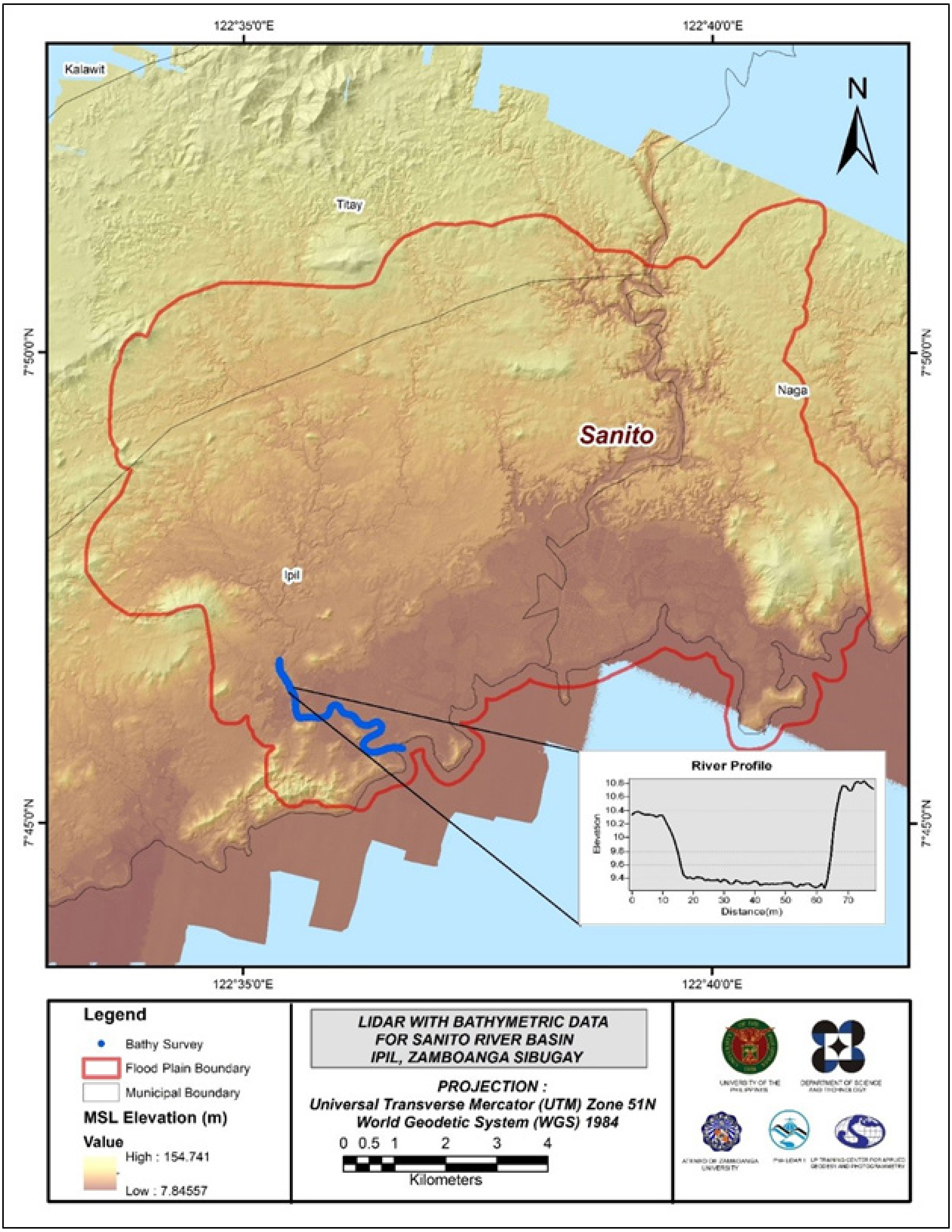


Figure 28. Map of Sanito Floodplain with bathymetric survey points shown in blue.

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 of Digitized Features' Boundary

Sanito Floodplain, including its 200 m buffer, has a total area of 125.69sq km. For this area, a total of 5.0 sq km, corresponding to a total of 1838 building features, are considered for QC. Figure 29 shows the QC blocks for Sanito floodplain.

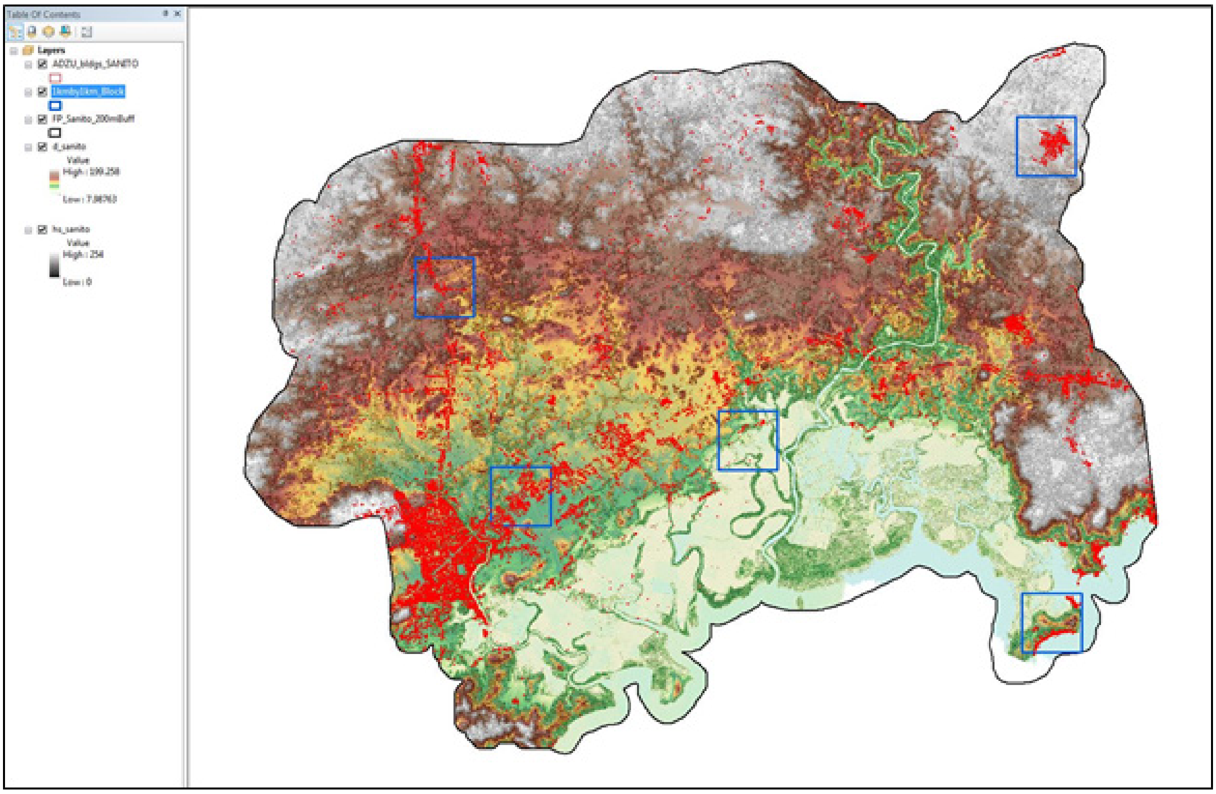


Figure 29. Blocks (in blue) of Sanito building features that were subjected in QC.

Quality checking of Sanito building features resulted in the ratings shown in Table 17.

Table 17. Quality Checking Ratings for Sanito Building Features.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Sanito	99.02	99.35	82.26	PASSED

3.12.2 Height Extraction

Height extraction was done for 19,794 building features in Sanito Floodplain. Of these building features, 288 was filtered out after height extraction, resulting in 19,506 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 9.25 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, through the endorsement of the Local Government Units of the Municipality/ City, hired a number of enumerators who conducted the house-to-house survey of the features 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 features of the floodplain of the riverbasin; likewise, the number of enumerators was also dependent on the availability of the tablet and the number of features of the floodplain.

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

Table 18. Number of Building Features Extracted for Sanito Floodplain.

Facility Type	No. of Features
Residential	18,761
School	139
Market	107
Agricultural/Agro-Industrial Facilities	6
Medical Institutions	11
Barangay Hall	11
Military Institution	1
Sports Center/Gymnasium/Covered Court	8
Telecommunication Facilities	0
Transport Terminal	12
Warehouse	15
Power Plant/Substation	10
NGO/CSO Offices	8
Police Station	3
Water Supply/Sewerage	3
Religious Institutions	60
Bank	19
Factory	19
Gas Station	9
Fire Station	1
Other Government Offices	53
Other Commercial Establishments	250
Total	19,506

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

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Sanito	18.13	125.53	0.00	2.5	0.00	146.16

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

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Buaya	116	0	1	0	378	495

A total of 9 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 30 shows the Digital Surface Model (DSM) of Sanito Floodplain overlaid with its ground features.

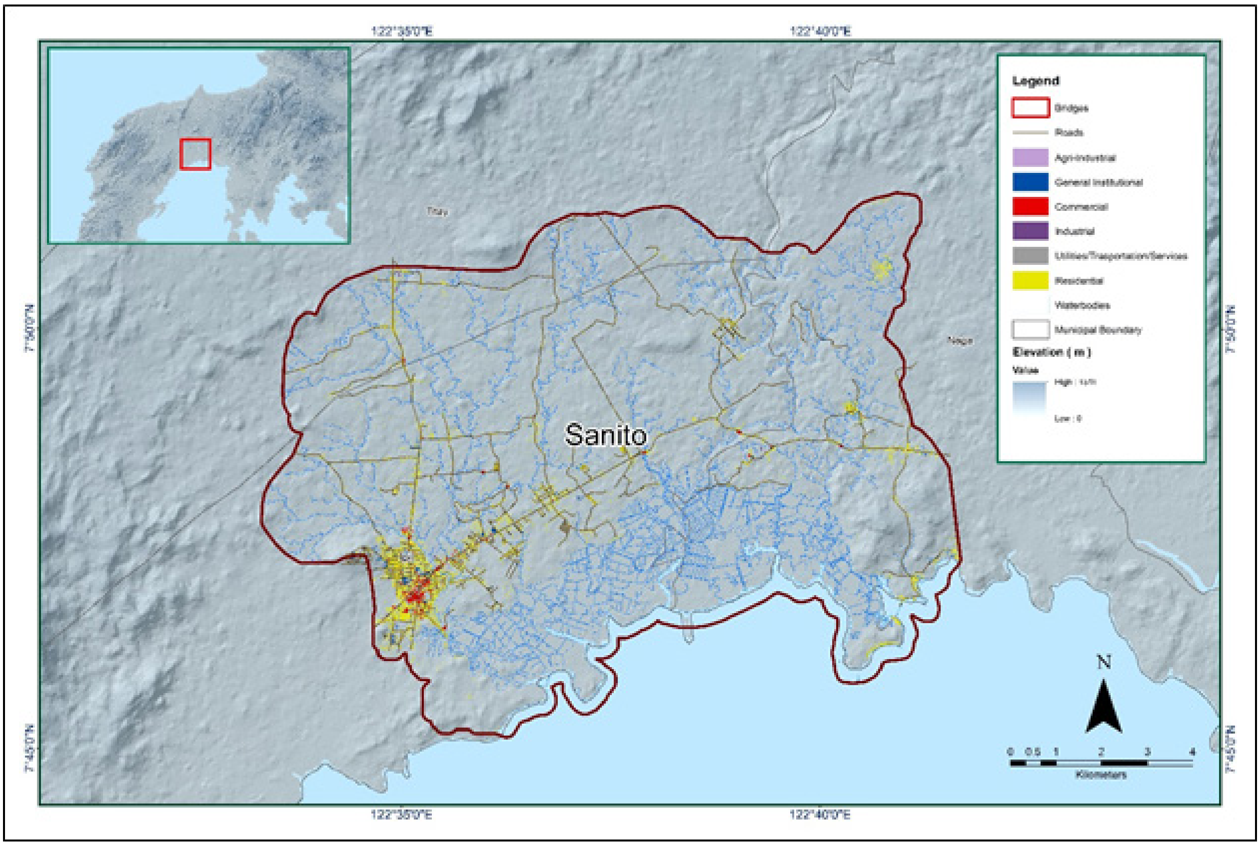


Figure 30. Extracted features for Sanito Floodplain.

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

Engr. Louie P. Balicanta, Engr. Joemarie S. Caballero, Ms. Patrizcia Mae. P. dela Cruz, Engr. Dexter T. Lozano, Engr. Kristine Ailene B. Borromeo, For. Dona Rina Patricia C. Tajora, Elaine Bennet Salvador, For. Rodel C. Alberto

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 DVBC conducted field survey in Sanito River on July 23, 2015 to August 7, 2015 with the following scope of work: reconnaissance survey to locate NAMRIA points and determine the viability of traversing the planned routes for bathymetric survey; courtesy call with ADZU, LGU of Ipil and PNP; control survey for the establishment of control point UP-SAN at the approach of the Guituan Bridge occupied as base station for GNSS surveys; cross-section and bridge-as-built survey of Guituan Bridge with coordinates Lat 7°48’17.70628”N and Long 122°35’58.16793”E; ground validation points acquisition survey for LiDAR data with a total distance of 32.35 km; and bathymetric survey of Sanito River starting from Brgy. Poblacion to Brgy. Bangkerohan with an approximate length of 5.207 km utilizing GNSS PPK survey technique. Due to difficulties in acquiring signals and other technical problems, no bathymetric data were gathered of the downstream of the river from Barangay Upper Pangi to Guituan measuring an estimated distance of 5 km.

4.2 Control Survey

A GNSS network from Manicahan River Survey was established on September 26 and October 3, 2015 occupying the control points ZGS-101, a second order GCP in Brgy. Bolong, Zamboanga City; and ZG-177, a first order BM in Brgy. Poblacion, both in Zamboanga City.

The GNSS network for Sanito survey is composed of three (3) loops established on August 1, 2015 and January 15, 2016 occupying the following reference points fixed from the static survey in Zamboanga Del Sur: UP-TIG, located at the approach of Tigbao Bridge in Brgy. Tictapul, Zamboanga City; and UP-VIT, located at the approach of Vitali Bridge in Brgy. Vitali, Zamboanga City.

Two (2) control points were established along the approach of bridges namely SAN-1 located on a bridge along Maharlikha Highway, Brgy. Sanito, Municipality of Ipil; and UP-SAN at Sanito Bridge in Brgy. Sanito, also in Municipality of Ipil, all of which in Zamboanga Sibugay. The NAMRIA control points ZSI-36, in Brgy. Bacalan and ZY-93A, in Brgy. Tupilac, Municipality of Roseller Lim, were also occupied to use as markers for the network.

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

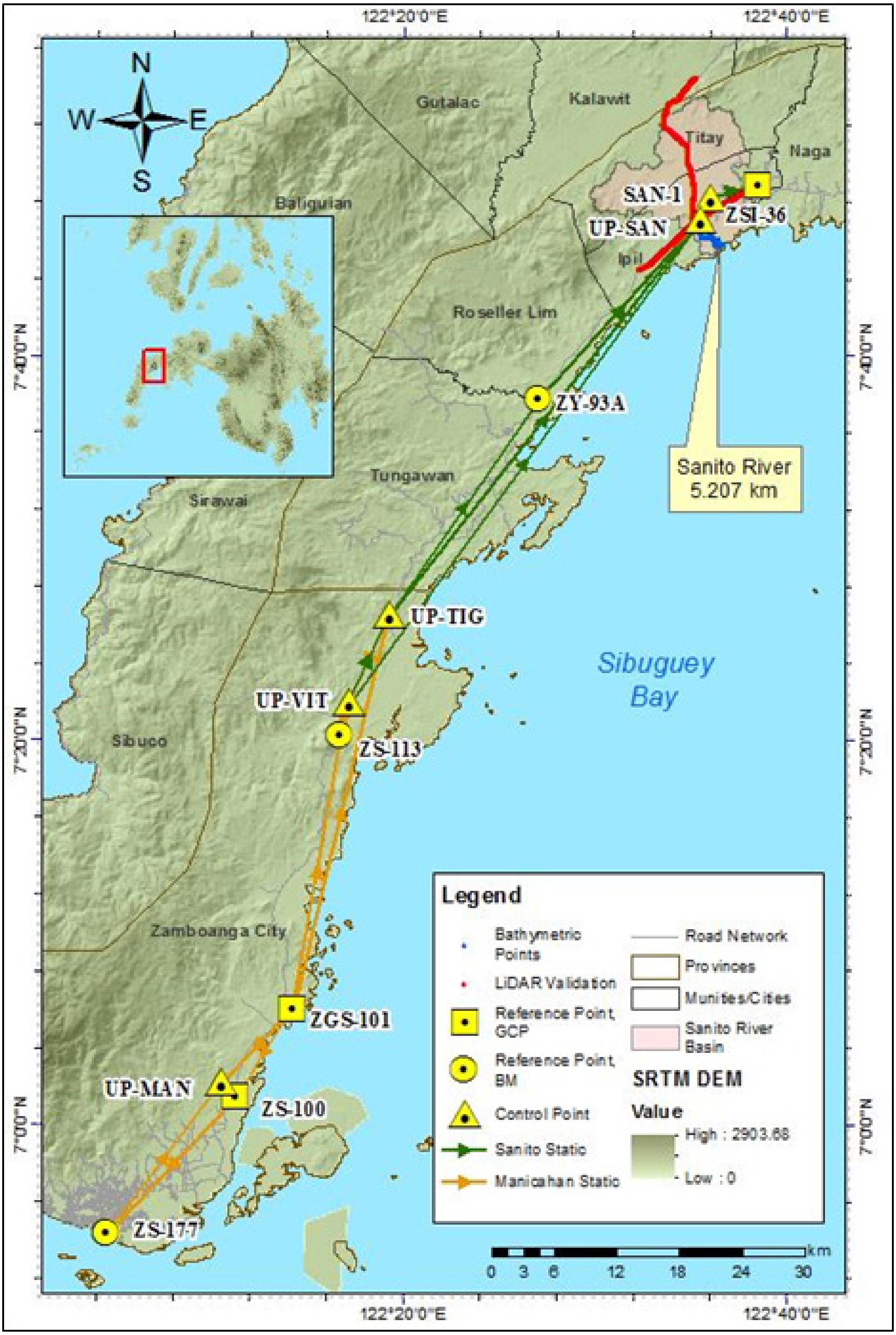


Figure 31. Extent of the bathymentric survey (in blue line) in Sanito River and the LiDAR data validation survey (in red)

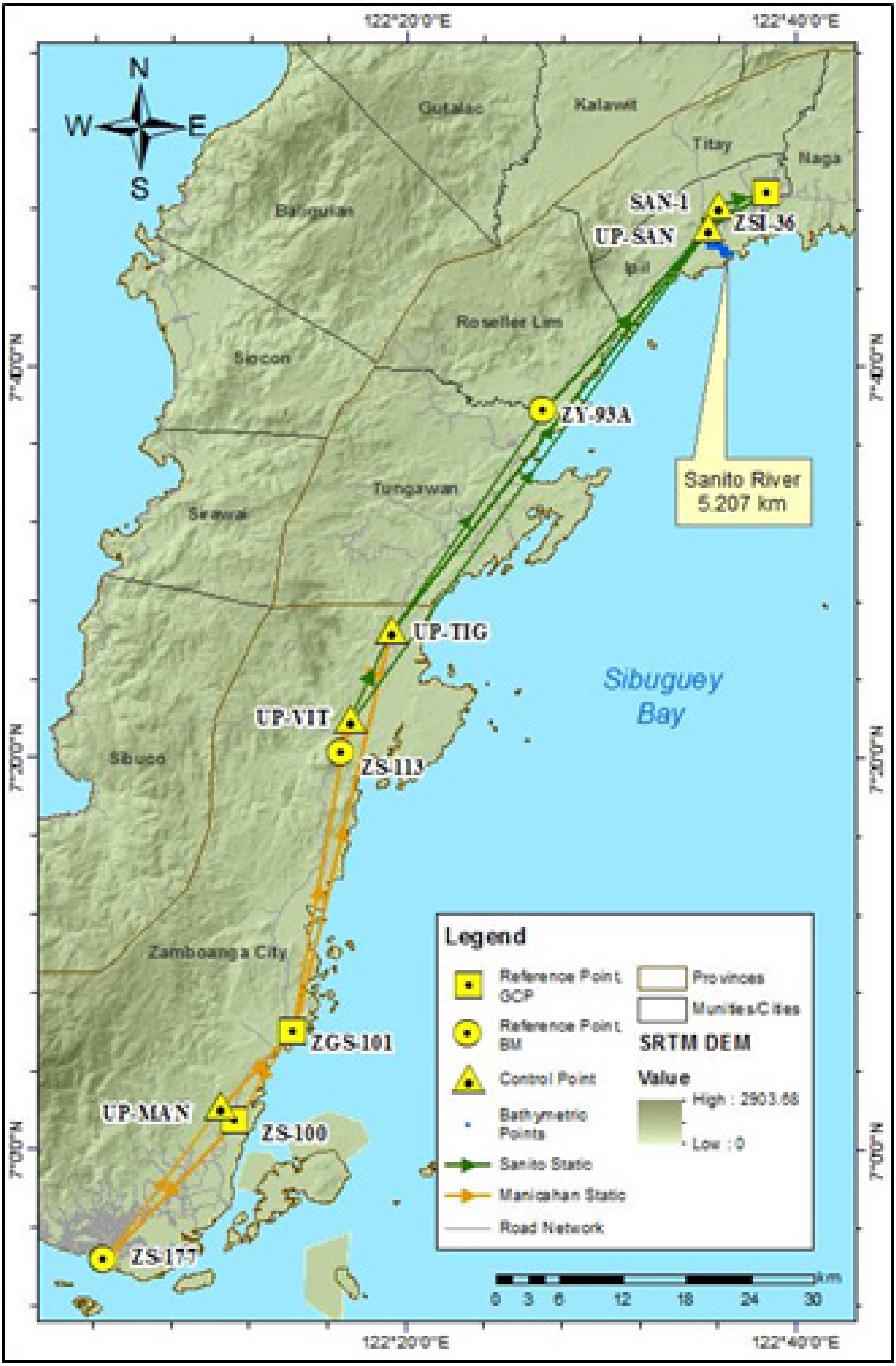


Figure 32. GNSS Network covering Sanito River

Table 21. List of Reference and Control Points used in Sanito River (Source: NAMRIA; UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (Meter)	Elevation in MSL (Meter)	Date Established
UP-TIG	UP established	7°26'33.60923"	122°19'15.00843"	89.917	22.039	Aug. 1, 2015
UP-VIT	UP established	7°21'59.09659"	122°17'09.03461"	86.703	18.819	Aug. 1, 2015
ZSI-36	Used as marker	-	-	-	-	2006
ZY-93A	Used as marker	-	-	-	-	2013
SAN-1	UP Established	-	-	-	-	Aug. 1, 2015
UP-SAN	UP Established	-	-	-	-	Aug. 1, 2015

The GNSS set up made in the location of the reference and control points are exhibited in Figure 33 to Figure 40.

Figure 33. GNSS base set up, Trimble® SPS 882, at UP-TIG, located at the approach of Tigbao Bridge, Brgy. Tictapul, Zamboanga City, Zamboanga Del Sur

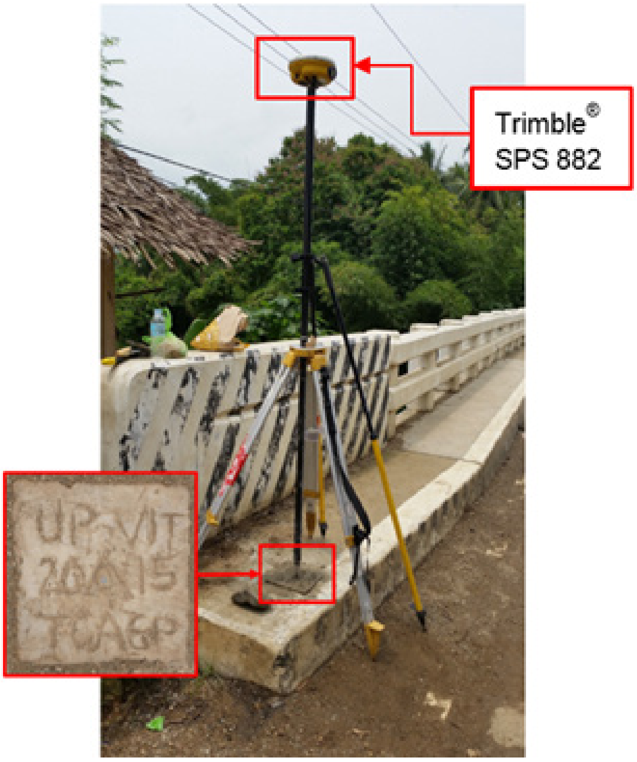


Figure 34. GNSS base set up, Trimble® SPS 882, at UP-VIT, located at the approach of Vitali Bridge in Brgy. Vitali, Zamboanga City, Zamboaga Del Sur

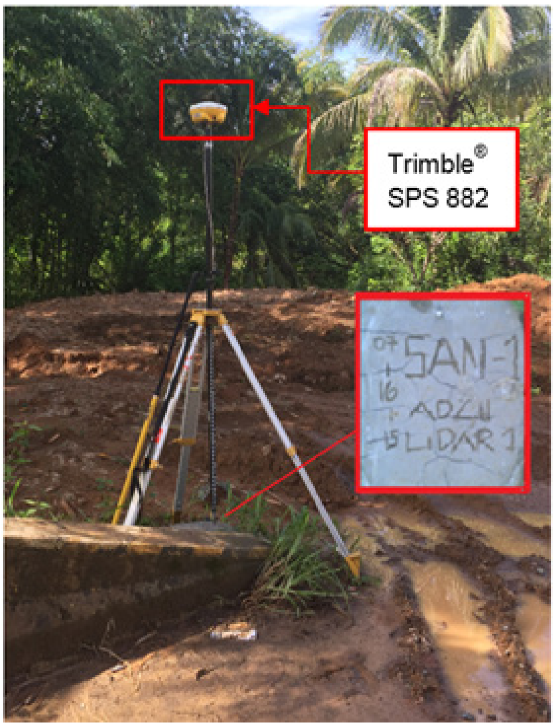


Figure 35. GNSS base set up, Trimble® SPS 882, at SAN-1, located at the approach of an unknown bridge found between Alibutdan and Diversion Rd, in Brgy. Pangi, Municipality of Ipi, Zamboanga Sibugay

Figure 36. GNSS base set up, Trimble® SPS 882, at UP-SAN, located at the approach of Sanito Bridge in Brgy. Sanito, Municipality of Ipil, Zamboanga Sibugay

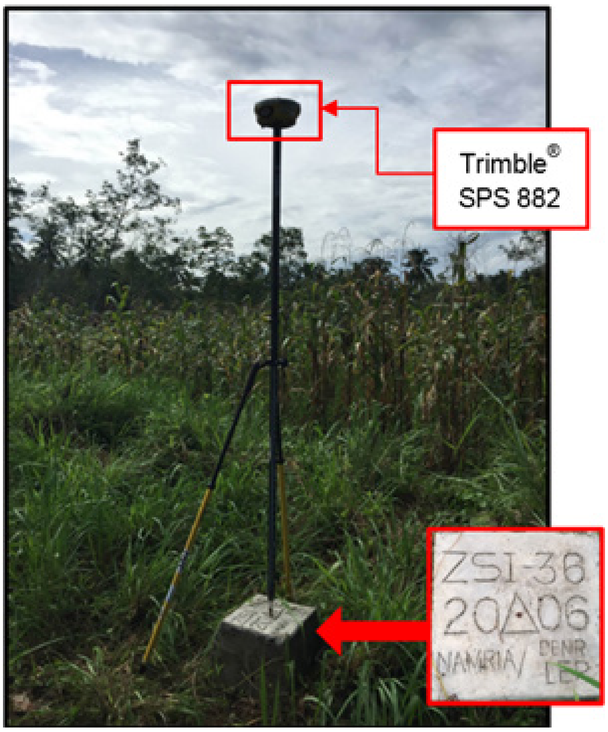


Figure 37. GNSS base set up, Trimble®SPS 882, at ZSI-36, located in front of an Iglesia ni Cristo church along the national highway in Brgy. Bacalan, Municipality of Ipil, Zamboanga Sibugay

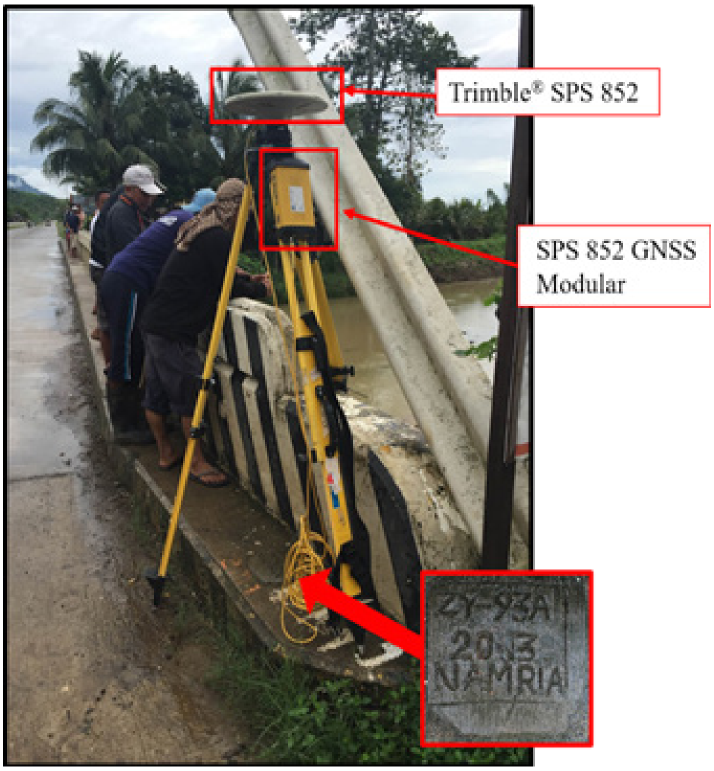


Figure 38. GNSS base set up, Trimble® SPS 852, at ZY-93A, located at the approach of Tupilac Bridge, in Brgy. Tupilac, Municipality of Roseller Lim, Zamboanga Sibugay

Figure 39. GNSS base set up, Trimble® SPS 852, at ZGS-101, located inside Brgy. Bolong Elementary School, Zamboanga City, Zamboanga Del Sur

Figure 40. GNSS base set up, Trimble® SPS 852, at ZS-177, located at the stair of Rizal's Park along the Butuan-Zamboanga National Road, Brgy Zone 4, Zamboanga City, Zamboanga Del Sur

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 Sanito River Basin is summarized in Table 22 generated by TBC software.

Table 22. Baseline Processing Summary Report for Sanito River Survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
SAN1 --- ZSI36	08-01-2015	Fixed	0.009	0.034	77°13'23"	4622.418	12.148
UPTIG --- ZY93A	01-15-2016	Fixed	0.003	0.013	35°01'58"	25125.083	-5.986
UPSAN --- UPTIG	01-15-2016	Fixed	0.003	0.016	38°05'58"	48232.804	-1.932
UPSAN --- ZY93A	01-15-2016	Fixed	0.003	0.015	221°27'34"	23182.704	-4.059
UPSAN --- ZSI36	08-01-2015	Fixed	0.006	0.022	60°18'25"	6301.271	15.905
UPSAN --- SAN1	08-01-2015	Fixed	0.007	0.028	24°42'41"	2310.557	3.792
UPVIT --- UPTIG	01-15-2016	Fixed	0.004	0.015	24°36'35"	9275.798	3.190
UPVIT --- ZY93A	01-15-2016	Fixed	0.003	0.015	32°13'27"	34289.007	-2.792
UPVIT --- UPSAN	01-15-2016	Fixed	0.007	0.024	35°55'53"	57293.714	1.246

As shown in Table 22, a total of eight (8) baselines were processed. The reference points UP-TIG and UP-VIT with values from ZGS-101 and ZS-177 were held fixed. All of them passed the required accuracy.

4.4 Network Adjustment

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

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

where:

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

for each control point. See the Network Adjustment Report shown in Table 23 to Table 25 for complete details.

The reference points UP-TIG and UP-VIT were held fixed during the processing of the control point as presented in Table 23. Through these reference point, the coordinates of the unknown control points will be computed.

Table 23. Constraints applied to the adjustment of the control points.

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
UPTIG	Grid				Fixed
UPTIG	Global	Fixed	Fixed		
UPVIT	Grid				Fixed
UPVIT	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 24. All fixed control points UP-TIG and UP-VIT has no values for standard error.

Table 24. Adjusted grid coordinates for the control points used in the Sanito River flood plain survey.

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
SAN1	-3404725.823	0.042	5323941.850	0.056	860405.799	0.025	
UPSAN	-3404063.348	0.027	5324698.912	0.026	858325.690	0.022	
UPTIG	-3381639.907	?	5344921.030	?	820713.025	?	LLe
UPVIT	-3378953.745	?	5347901.429	?	812349.736	?	LLe
ZSI36	-3408454.446	0.040	5321404.865	0.050	861420.032	0.026	
ZY93A	-3392374.040	0.018	5334910.856	0.020	841105.700	0.013	

The network is fixed at reference points UP-TIG and UP-VIT with known coordinates. Using the equation $\sqrt{(x_e)^2+(y_e)^2}<20cm$ for horizontal and $z_e<10$ cm for the vertical; the computation for the accuracy of other control points are as follows:

a. SAN-1

Horizontal Accuracy	=	$\sqrt{((4.2)^2 + (2.5)^2}$
	=	$\sqrt{(17.64 + 6.25)}$
	=	4.89 cm < 20 cm
Vertical Accuracy	=	2.5 cm < 10 cm

b. UP-SAN

Horizontal Accuracy	=	$\sqrt{((2.7)^2 + (2.6)^2}$
	=	$\sqrt{(7.29 + 6.76)}$
	=	3.75 cm < 20 cm
Vertical Accuracy	=	2.2 cm < 10 cm

c. UP-TIG

Horizontal Accuracy	=	Fixed
Vertical Accuracy	=	Fixed

d. UP-VIT

Horizontal Accuracy	=	Fixed
Vertical Accuracy	=	Fixed

e. ZSI-36

Horizontal Accuracy	=	$\sqrt{((4)^2 + (5)^2}$
	=	$\sqrt{(16 + 25)}$
	=	6.40 cm < 20 cm
Vertical Accuracy	=	2.6 cm < 10 cm

f. ZY-93A

Horizontal Accuracy	=	$\sqrt{((1.8)^2 + (2)^2}$
	=	$\sqrt{(3.24 + 4)}$
	=	2.69 cm < 20 cm
Vertical Accuracy	=	1.3 cm < 10 cm

Table 25. Adjusted geodetic coordinates for control points used in the Sanito River Flood Plain validation.

Point ID	Latitude	Longitude	Ellipsoid	Height	Constraint
SAN1	N7°48'17.16863"	E122°35'57.88173"	91.755	0.063	
UPSAN	N7°47'08.84467"	E122°35'26.35418"	87.976	0.026	
UPTIG	N7°26'33.60923"	E122°19'15.00843"	89.917	?	LLe
UPVIT	N7°21'59.09659"	E122°17'09.03461"	86.703	?	LLe
ZSI36	N7°48'50.43758"	E122°38'25.02370"	103.890	0.056	
ZY93A	N7°37'43.22499"	E122°27'05.57385"	83.921	0.022	

The adjusted geodetic coordinates is presented in Table 25. The network is fixed at the reference points UP-TIG and UP-VIT. After the processing has been made, the geodetic coordinates of the control point were derived.

Based on the result of the computation, the horizontal and vertical accuracies of the occupied control points are within the required accuracy of the program.

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

Table 26. The reference and control points utilized in the Sanito River Static Survey, with their corresponding locations (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N			
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)	Date Established
UP-TIG	UP established	7°26'33.60923"	122°19'15.00843"	89.917	822742.4	425056.8	22.039	2007
UP-VIT	UP established	7°21'59.09659"	122°17'09.03461"	86.703	814318.2	421181.8	18.819	2010
ZSI-36	Used as marker	7°48'50.43758"	122°38'25.02370"	103.89	863753.4	460341.6	35.673	2007
ZY-93A	Used as marker	7°37'43.22499"	122°27'05.57385"	83.921	843285.9	439506.7	15.745	2010
SAN-1	UP Established	7°48'17.16863"	122°35'57.88173"	91.755	862735.8	455834.4	23.469	2016
UP-SAN	UP Established	7°47'08.84467"	122°35'26.35418"	87.976	860638.6	454866.8	19.651	2016

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

Cross-section and as-built survey were conductedon August 1, 2015 along the downstream side of Guituan Bridge in Barangay Sanito, Municipality of Ipil using GNSS receiver Trimble® SPS 882 in PPK survey technique Figure 42. The control point UP-SAN was used as the GNNS base station.

Figure 41. Guituan bridge in Brgy. Sanito, Ipil, Zamboanga

Figure 42. Cross-section and bridge as-built survey for Guituan Bridge, Brgy. Sanito, Ipil Zamboanga Sibugay

The cross-sectional line for the Guituan Bridge is about 106.10 meters with 50 cross-sectional points. The summary of gathered cross-section in diagram, location map, and as-built data for Gituan Bridge are displayed in Figure 43 to Figure 45, respectively.

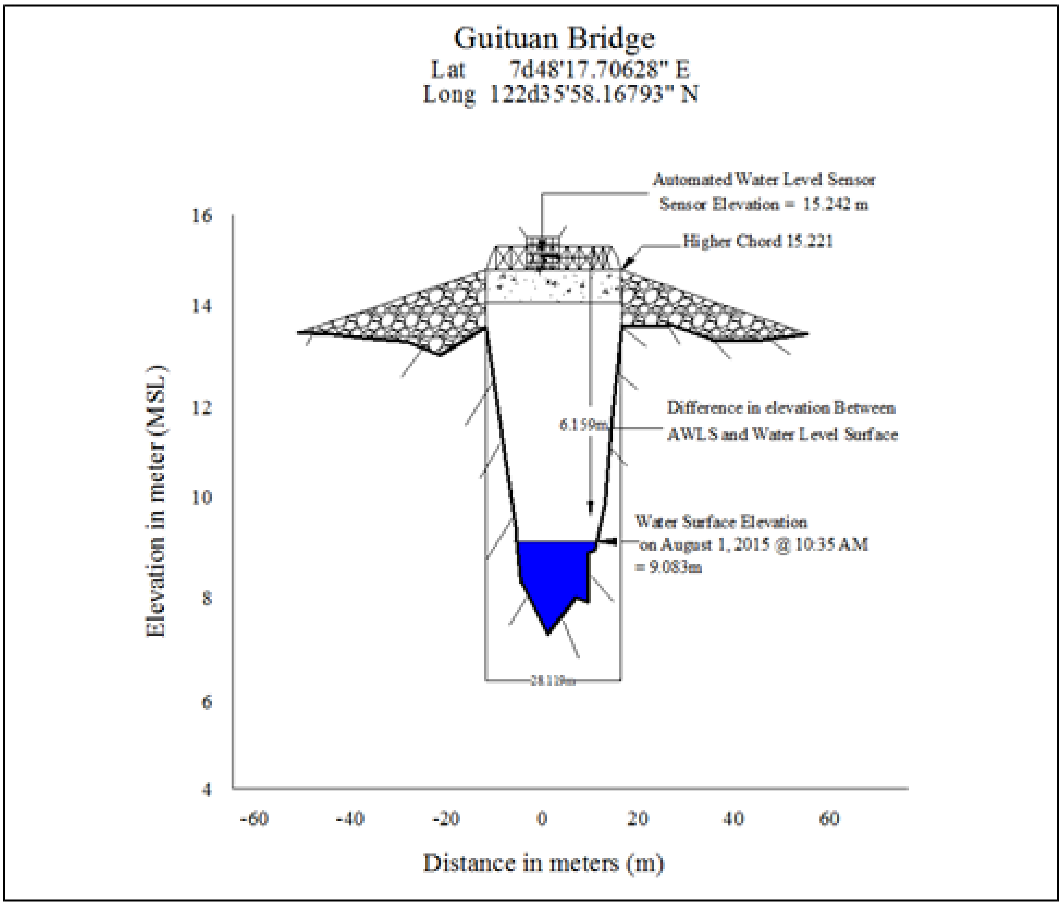


Figure 43. Guituan Bridge cross-sectional diagram

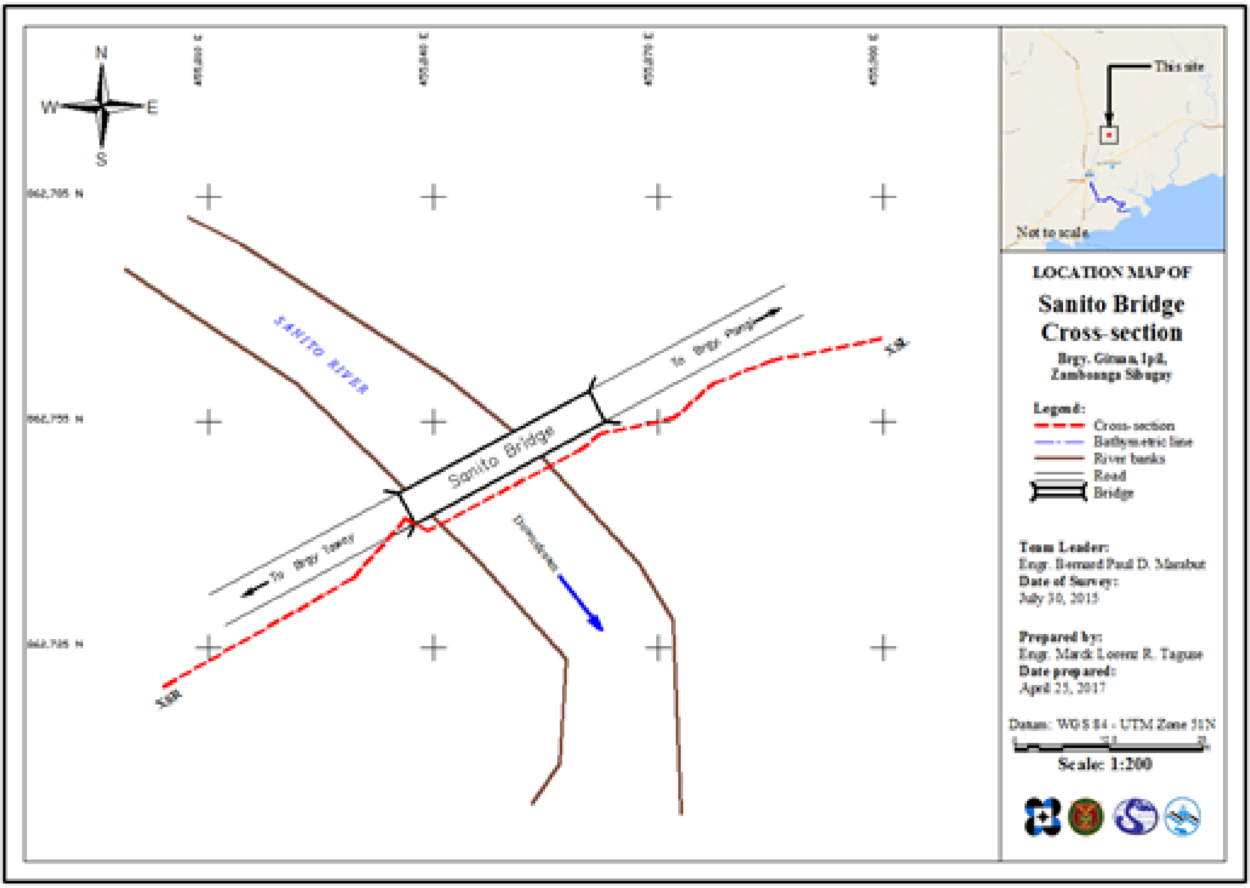


Figure 44. Sanito bridge cross-section location map

Bridge Data Form

Bridge Name: Guituan Bridge **Date:** July 30, 2015

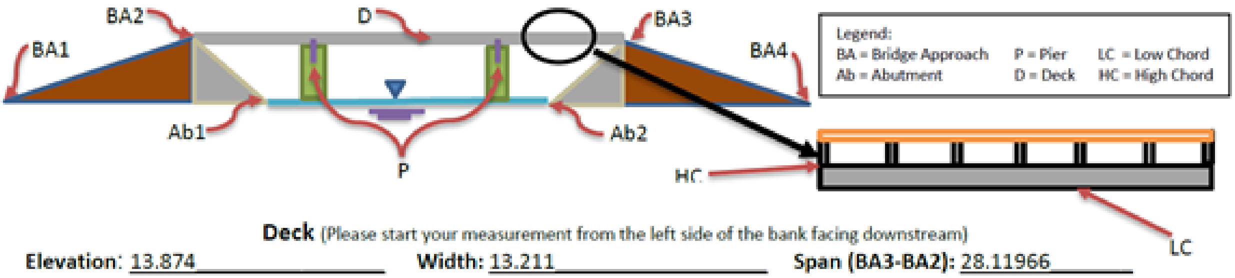
River Name: Sanito River **Time:** 2:32 P.M.

Location (Brgy, City, Region): Barangay Sanito, Ipil, Zamboanga Sibugay

Survey Team: Team Bernard

Flow condition: low normal high **Weather Condition:** fair rainy

Latitude: 7d48'17.23497" **Longitude:** 122d35'57.89099"



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

Elevation: 13.874 Width: 13.211 Span (BA3-BA2): 28.11966

	Station	High Chord Elevation	Low Chord Elevation
1		15.221	14.455
2			
3			
4			
5			

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	13.634	BA3	67.61749	13.762
BA2	39.49783	13.751	BA4	106.0189	13.602

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

	Station (Distance from BA1)	Elevation
Ab1	29.5171	13.151
Ab2	65.51879	11.77

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

Shape: ________ Number of Piers: 0 Height of column footing: ________

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1			
Pier 2			
Pier 3			
Pier 4			
Pier 5			
Pier 6			

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

Figure 45. Guituan Bridge Data Form

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on July 30, 2015 using a survey-grade GNSS Rover receiver, Trimble®SPS 882 in PPK survey technique, mounted on a range pole which was attached in front of the vehicle as shown in Figure 46. It was secured with a cable-tie to ensure that it was horizontally and vertically balanced. The antenna height was measured and recorded to be 2.293m from the ground up to the bottom of notch of the GNSS rover receiver. The control point ZSI-36 was used as the base station.

Figure 46. Trimble® SPS882 set-up for validation points acquisition survey for Sanito River

The ground validation for this area has 2 segments as shown in Figure 47. The first segment started from Barangay Makilas to Bacaran with a total distance of 15 km with 4049 LiDAR validation points. The second segment started from Sanito to Gatals with a total distance of 17.35km with 4,050 LiDAR validation points. The gaps in the validation lines were due to some difficulties in acquiring satellite because of the presence of obstruction such as dense canopy cover of trees along the roads.

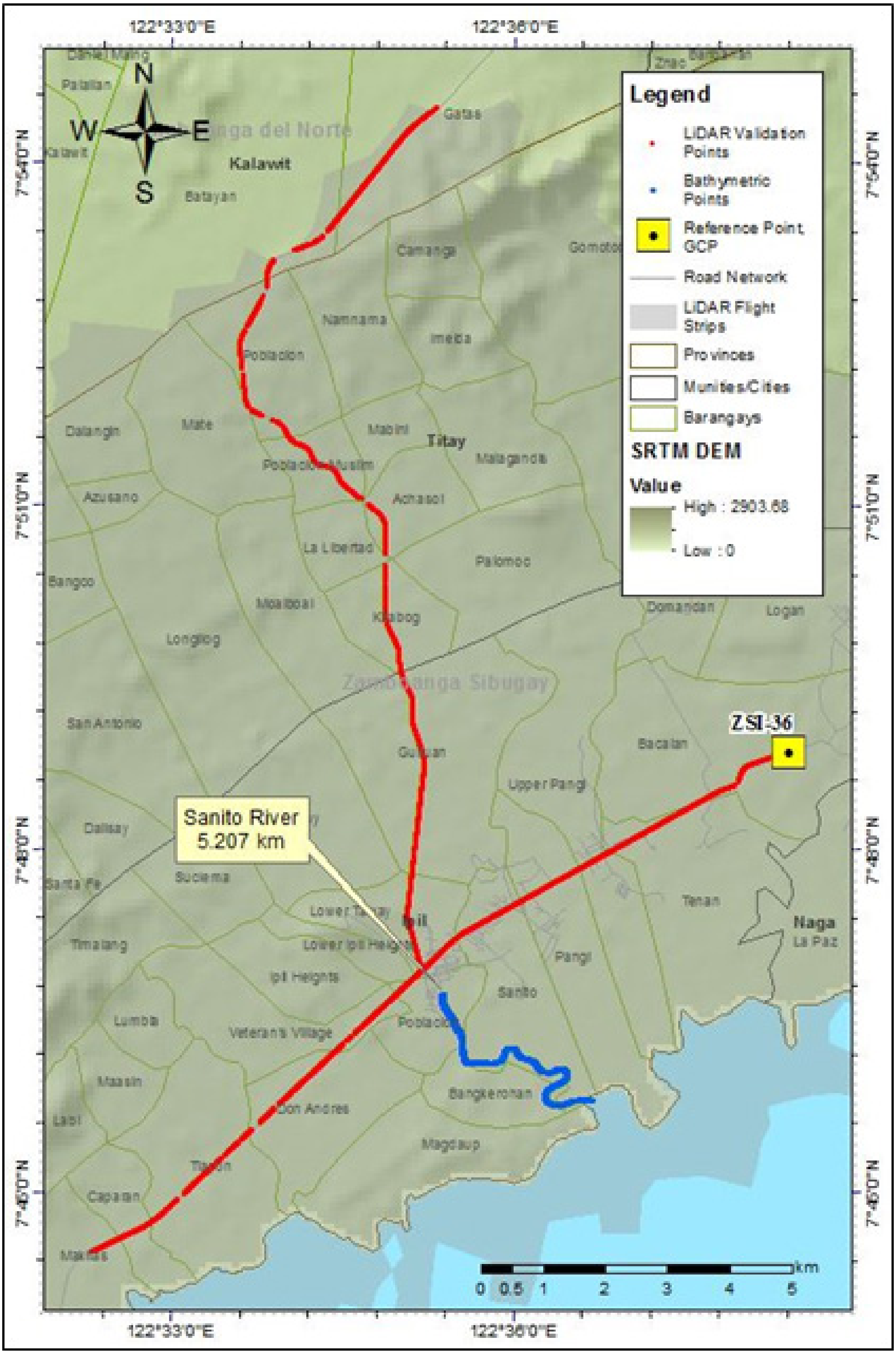


Figure 47. LiDAR ground validation survey coverage for Sanito River Basin

4.7 River Bathymetric Survey

Bathymetric survey was conducted on July 30, 2015using an Ohmex™ single beam echo sounder and Trimble® SPS 882 in PPK survey techniqueas shown in Figure 48. The survey began in the upstream part of the river in Brgy. Poblacion, Municipality of Ipil, with coordinates 7˚46'42.94963"122˚35'23.43509", down to the mouth of the river in Brgy. Sanito, also in Municipality of Ipil with coordinates 7˚45'47.50089"122˚36'41.79844". The control point ZSI-36 was used as GNSS base station all throughout the survey.

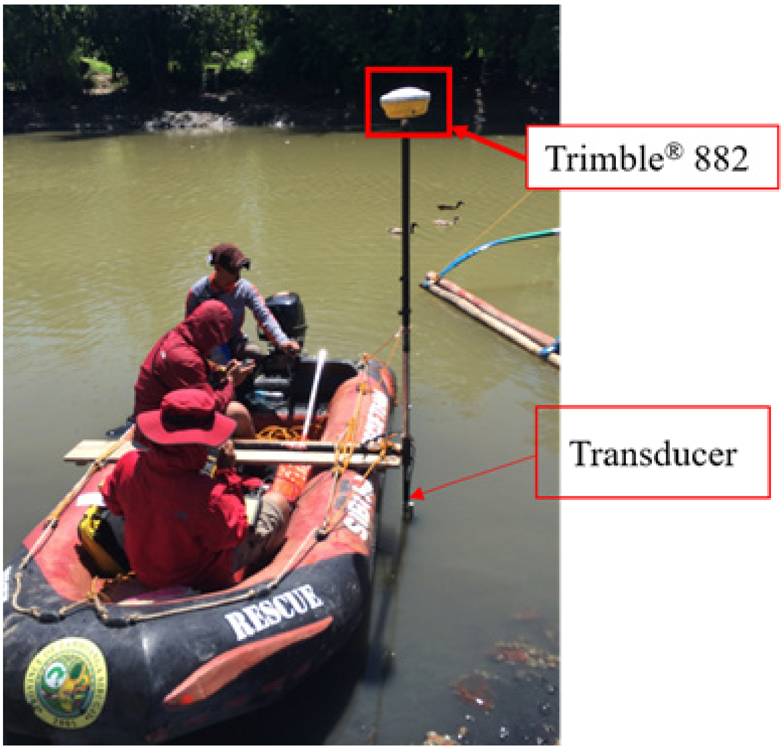


Figure 48. Bathymetric survey in Sanito River

An elevation drop of 4.28 meters in MSL was observed within the distance of approximately 5, 207.33 km with a total of 9,035 bathymetric points gathered. The surveyed portion of the river passed at Brgy. Poblacion Brgy. Bangkerohan and Brgy. Sanito. A CAD profile was also produced to illustrate the rivebed profile of Sanito River. As shown in Figure 50, the highest elevation was 7.731 m in Brgy, Poblacion while the lowest elevation was MSL 3.582 m in MSL in Brgy. Sanito. The gaps of survey were due to poor satellite signals in the area.

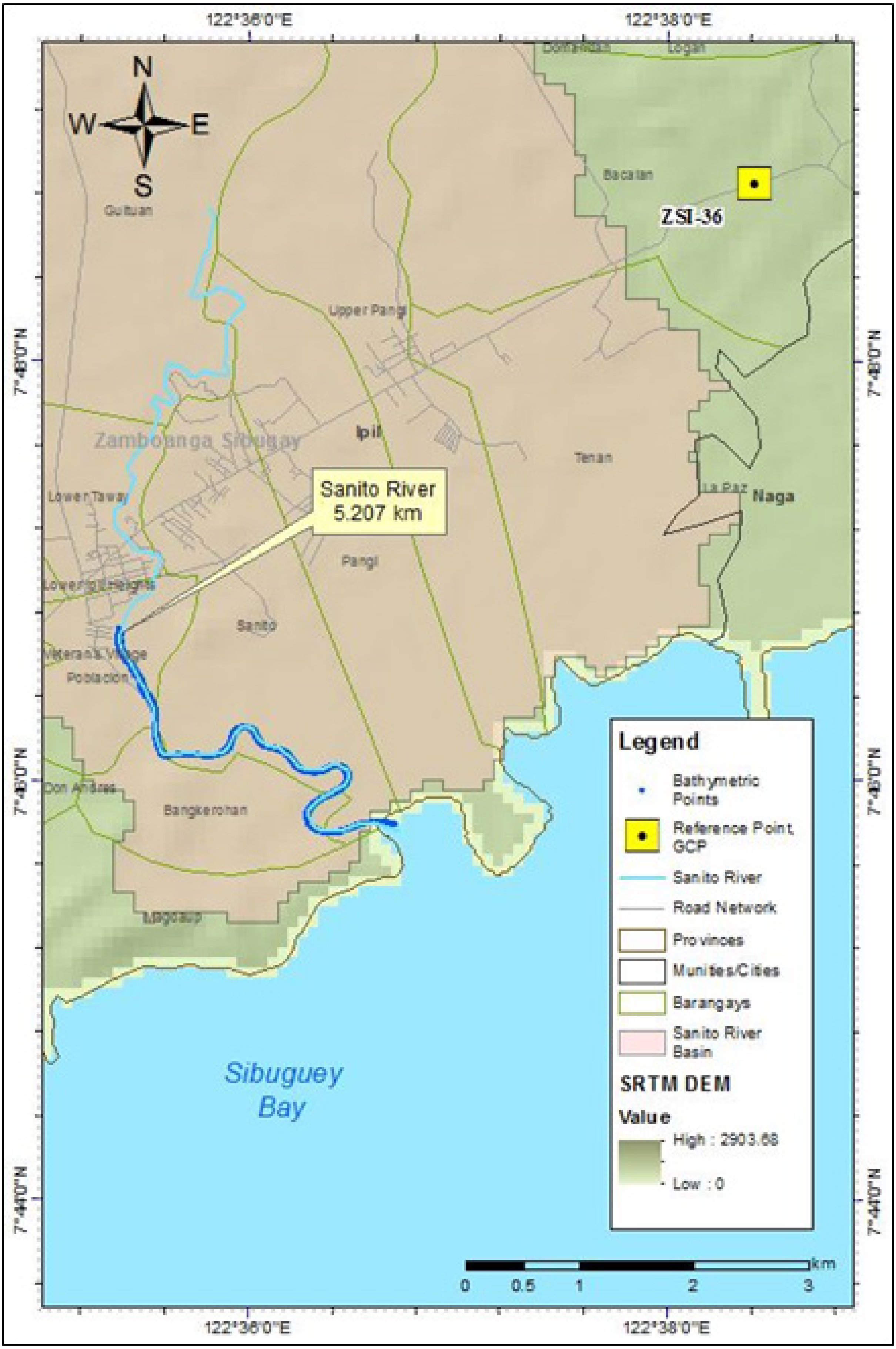


Figure 49. Extent of the bathymetric survey (in blue line) in Sanito River

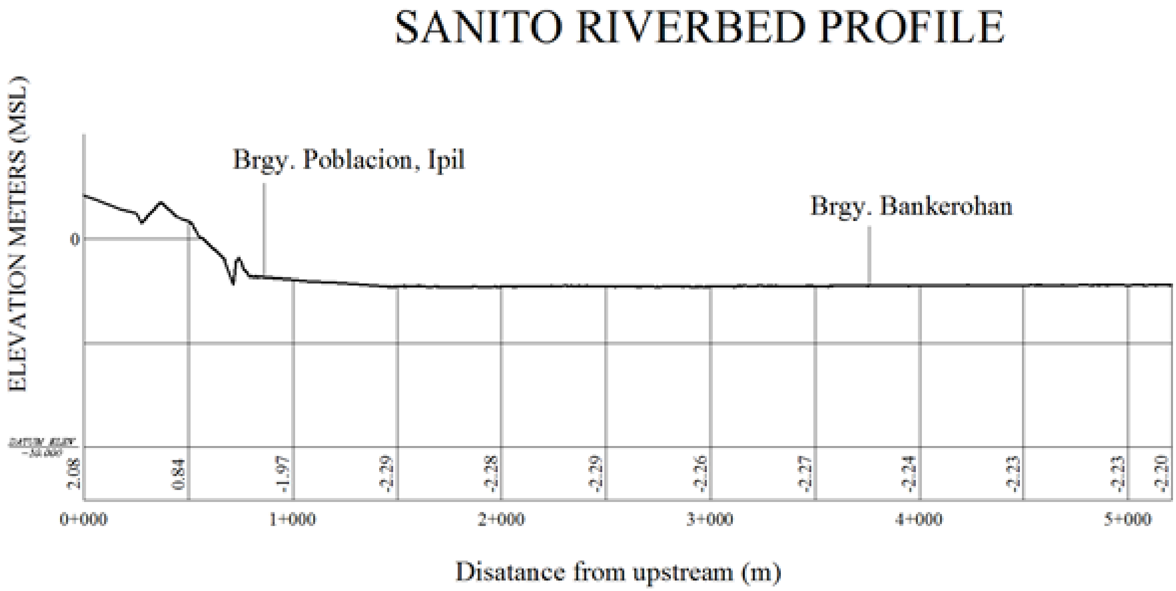


Figure 50. Riverbed Profile of Sanito River

CHAPTER 5: FLOOD MODELING AND MAPPING

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

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

Components and data that affect the hydrologic cycle of the Sanito 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 Sanito River Basin were monitored, collected, and analyzed.

5.1.2 Precipitation

Precipitation data was taken from an automatic rain gauge (ARG) installed by the Department of Science and Technology – Advanced Science and Technology Institute (DOST-ASTI). The ARG was installed in the Tandem Station in Guitu-an Bridgeat Brgy. Guitu-an, Ipil, Zamboanga Sibugay (Figure 51). The precipitation data collection started from June 29, 2015 at 12:00 noon to June 30, 2015 at 9:50 PM with 10 minutes recording interval.

The total precipitation for this event in Guitu-an Bridge ARG was 5.5 mm. It has a peak rainfall of 3.5 mm. on June30, 2015 at 10:50 AM. The lag time between the peak rainfall and discharge is 6 hours and 10 minutes.

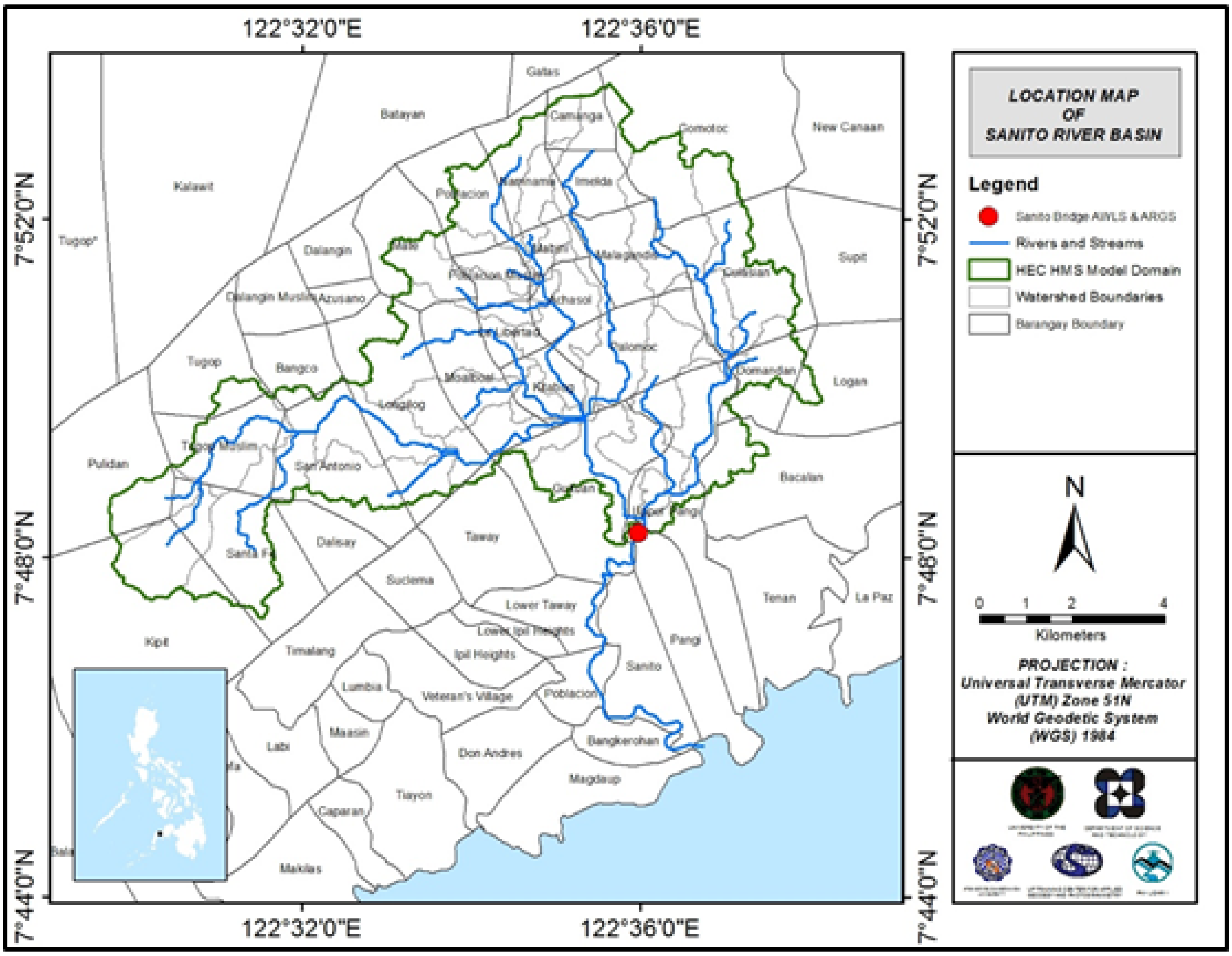


Figure 51. The location map of Sanito HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Guitu-an Bridge, Guitu-an, Ipil, Zamboanga Sibugay(7° 48’ 17.68” N, 122° 35’ 58.01” E). It gives the relationship between the observed water levels at Guitu-an Bridgeand outflow of the watershed at this location.

For Guitu-an Bridge, the rating curve is expressed as Q = 26.999e0.0002h as shown in Figure 53.

Figure 52. [insert bridge cross-section]

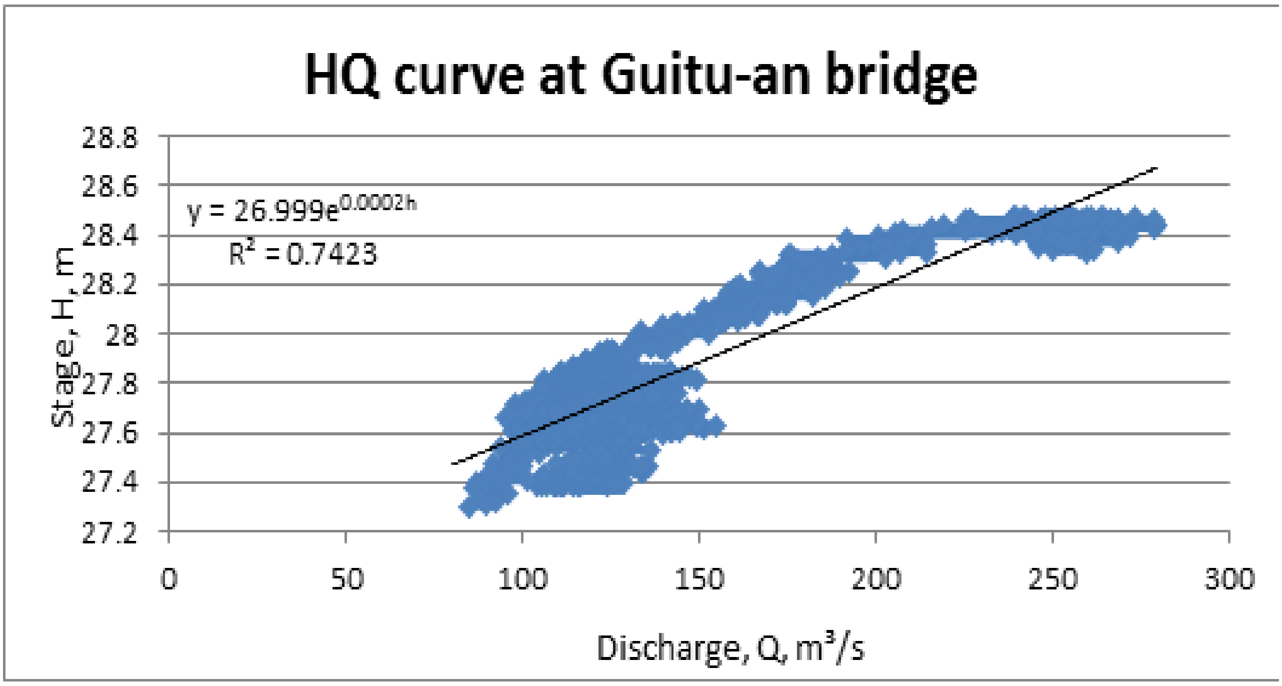


Figure 53. Rating Curve at Guitu-an Bridge, Guitu-an, Ipil, Zamboanga Sibugay

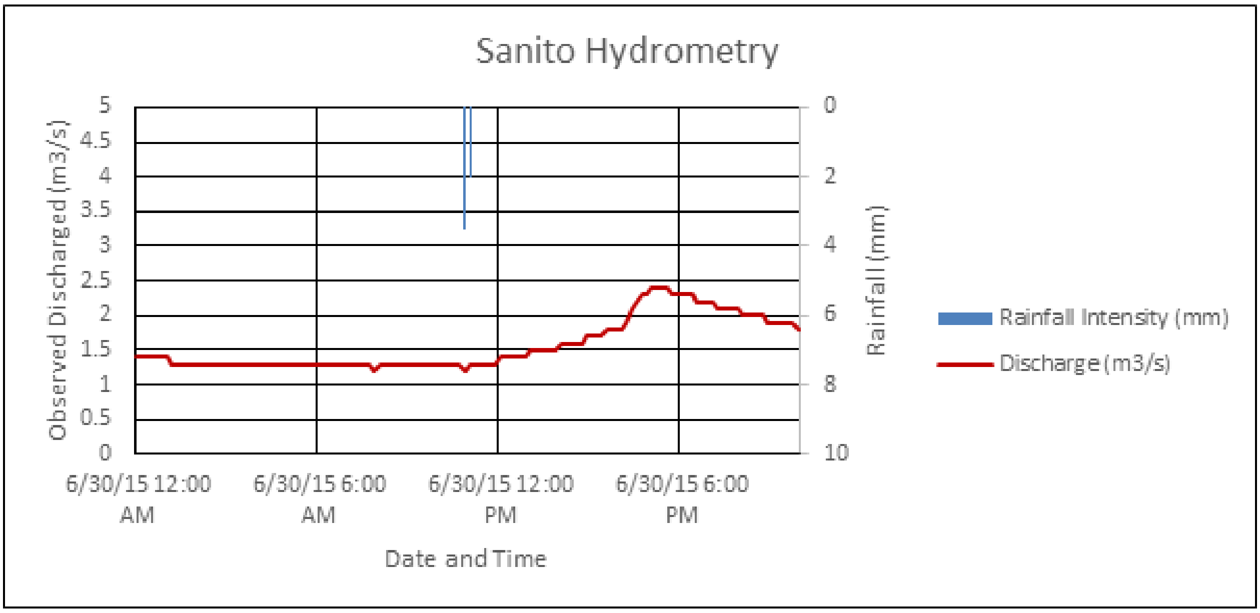


Figure 54. Rainfall and outflow data at Guitu-an Bridge Spillway used for modeling

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 Sanito watershed. The extreme values for this watershed were computed based on a 59-year record.

Table 27. 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

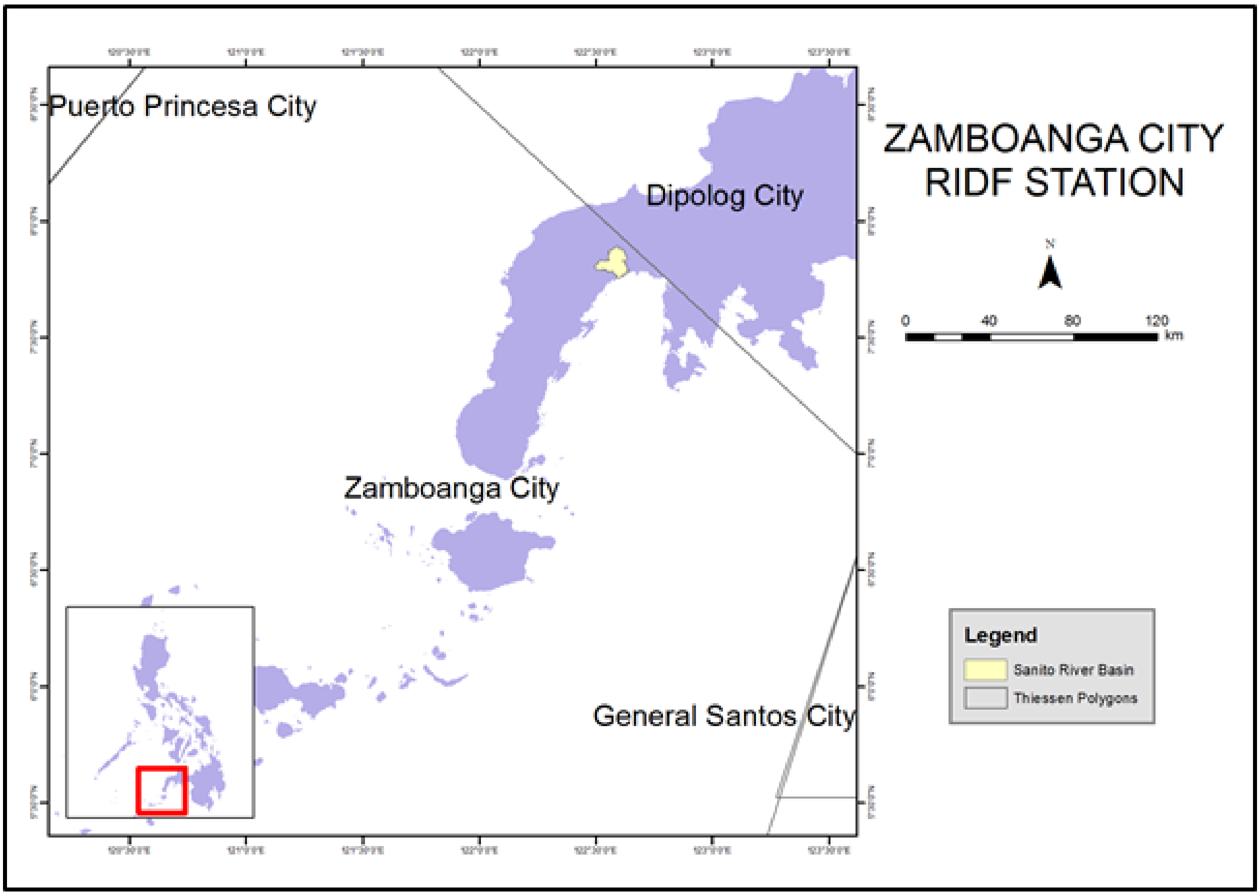


Figure 55. Zamboanga City RIDF location relative to Sanito River Basin

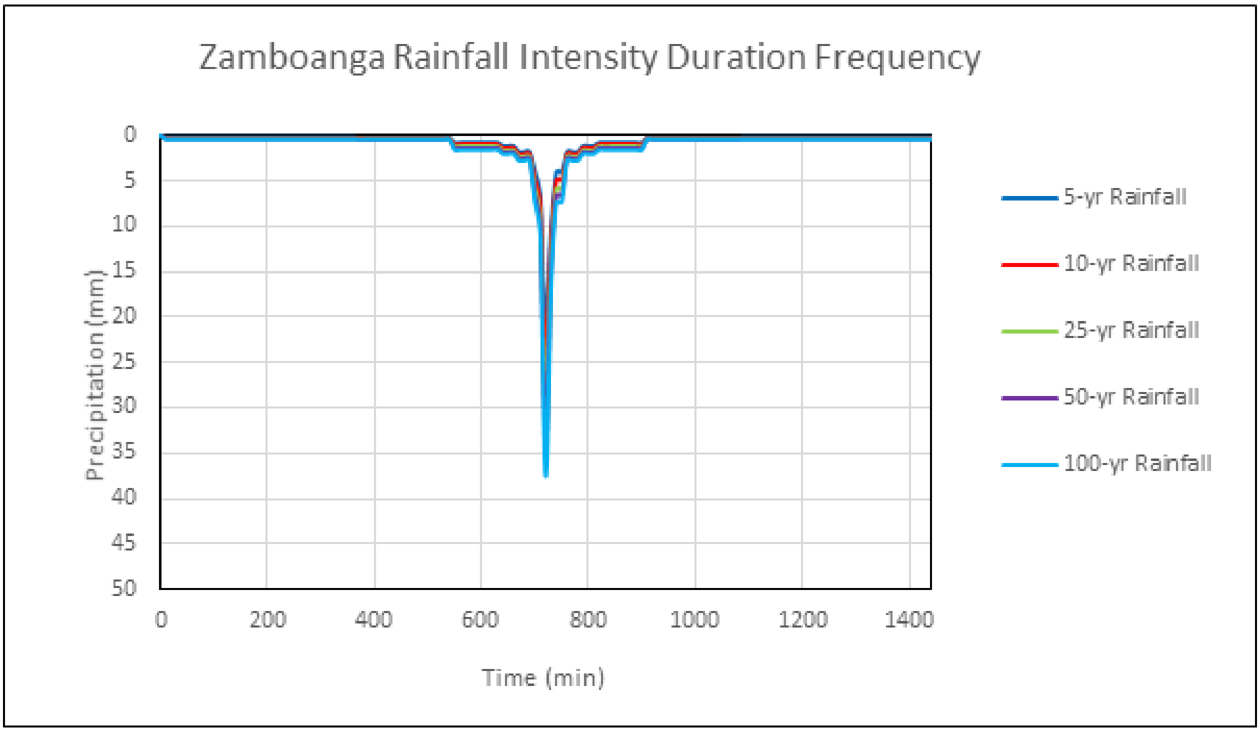


Figure 56. Synthetic storm generated for a 24-hr period rainfall for various return periods

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 Sanito River Basin are shown in Figure 57 and Figure 58, respectively.

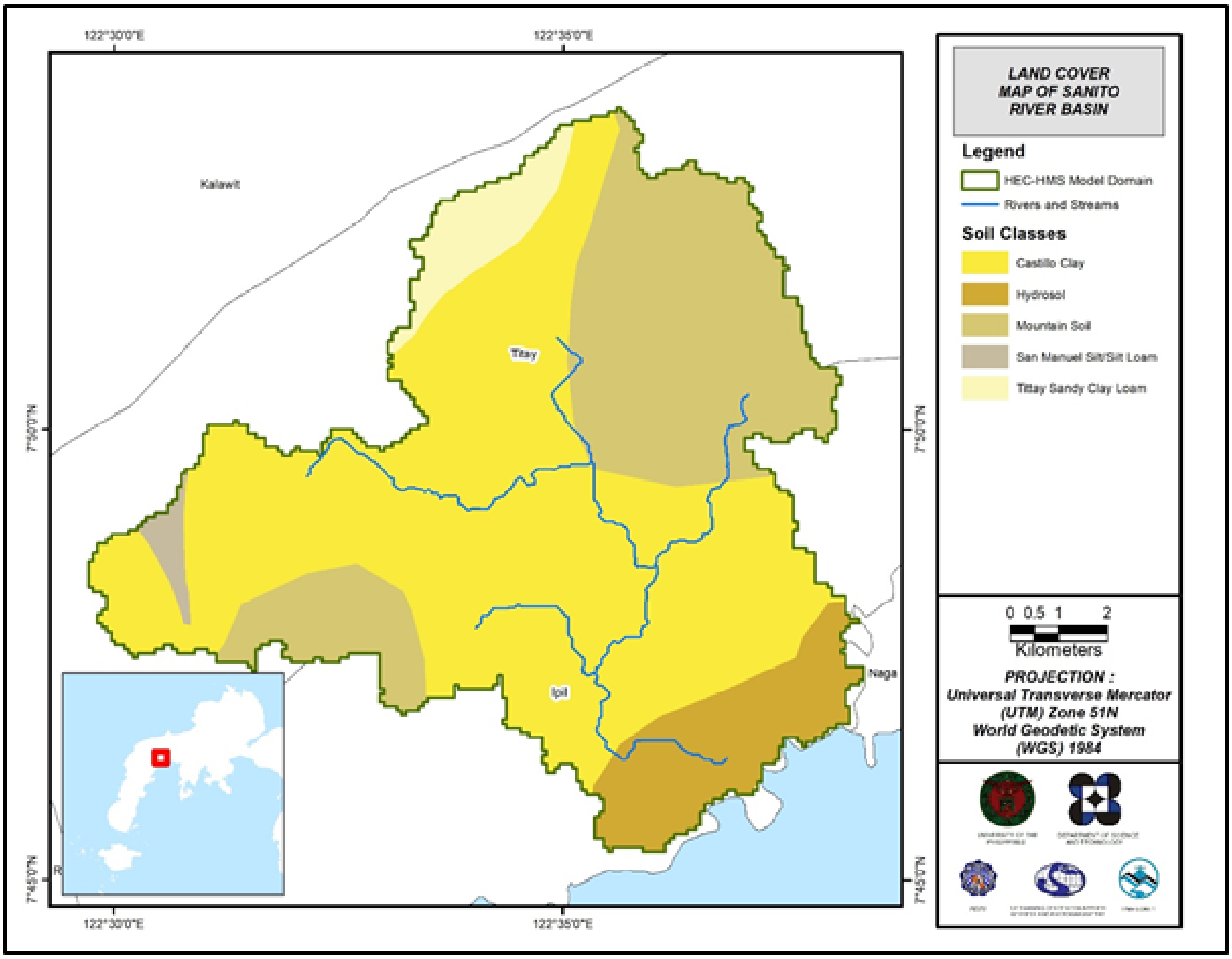


Figure 57. Soil Map of Sanito River Basin

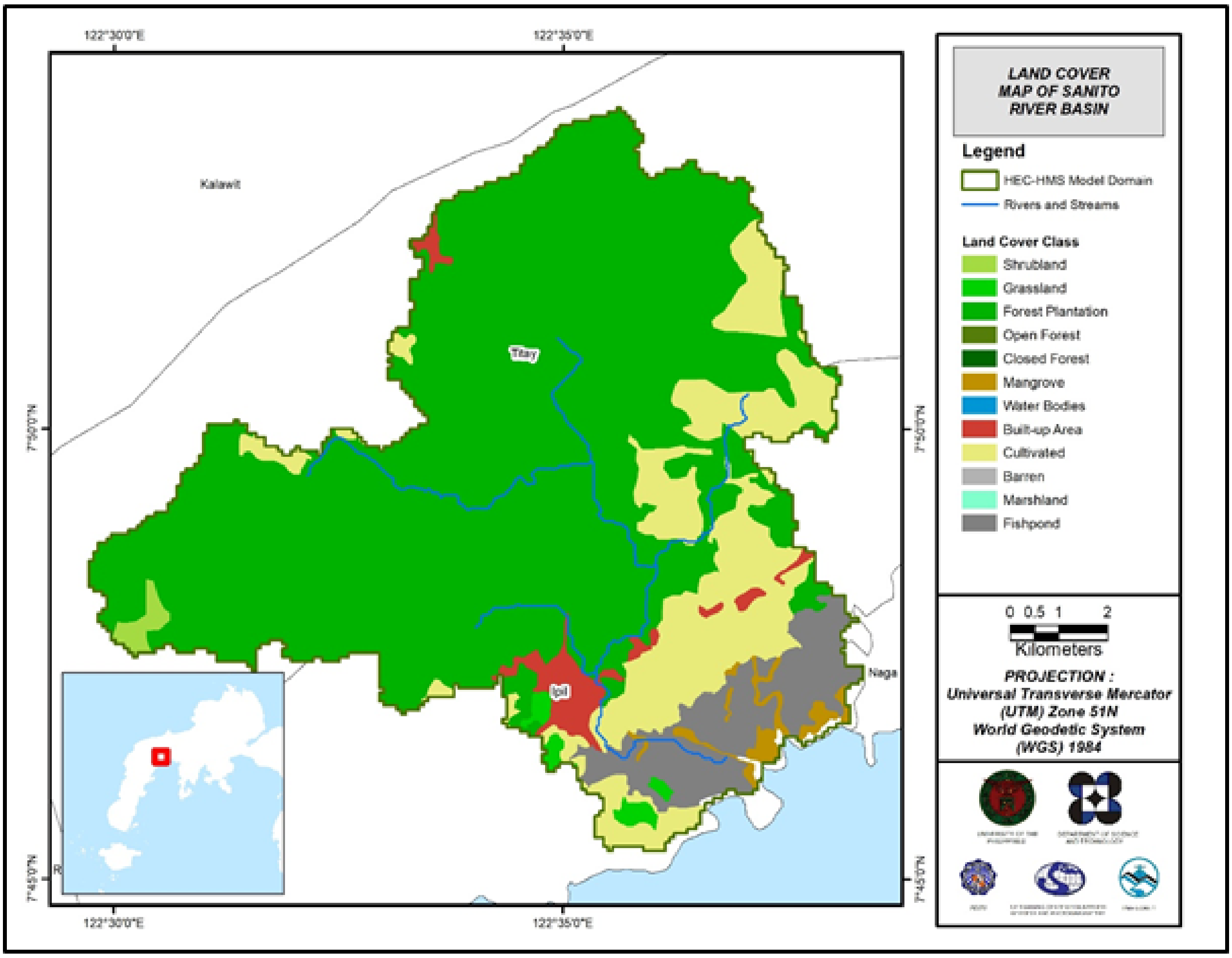


Figure 58. Land Cover Map of Sanito River Basin

For Sanito, the soil classes identified were clays, hydrosols, silt, silt loam, sandy clay loam and undifferentiated mountain soil. The land cover types identified were mangroves, grassland, cultivated areas, fishponds, built-up areas, brushland and tree plantations.

Figure 59. [insert Slope Map]

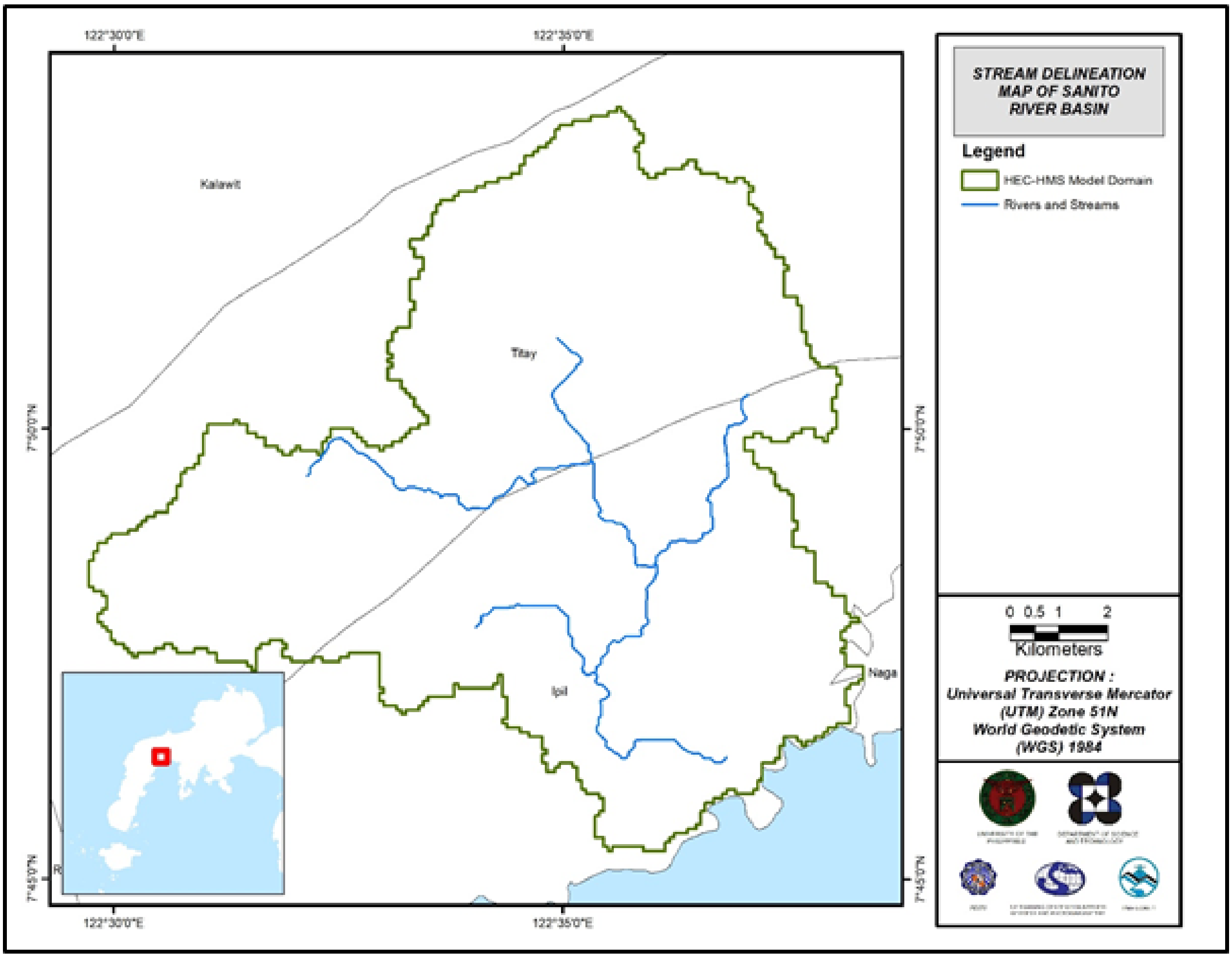


Figure 60. Stream delineation map of Sanito river basin

Using the SAR-based DEM, the Sanito basin was delineated and further subdivided into subbasins. The model consists of 31 sub basins, 15 reaches, and 15 junctions as shown in Figure 61 (See Annex 10). The main outlet is at Guitu-an Bridge.

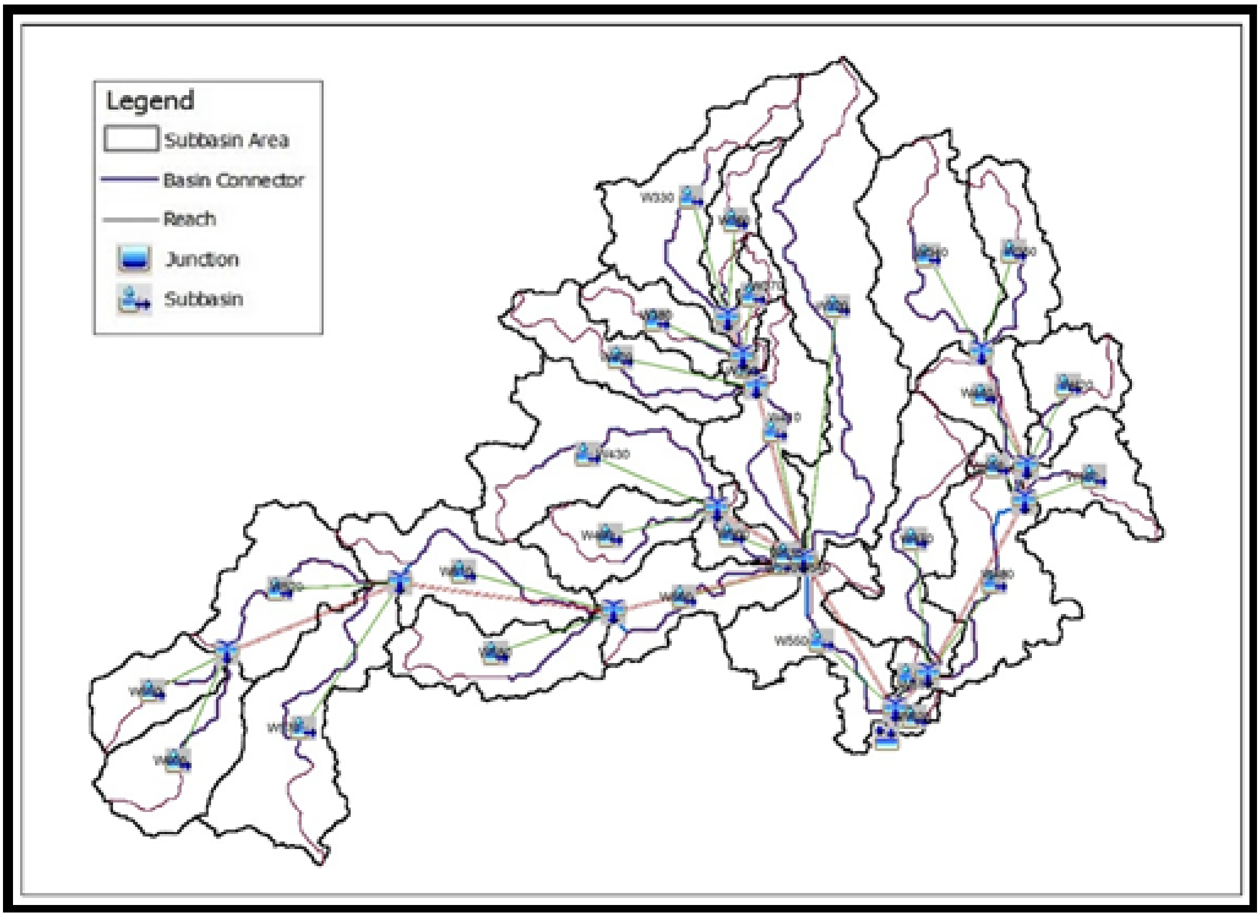


Figure 61. The Sanito river basin model generated using HEC-HMS

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.

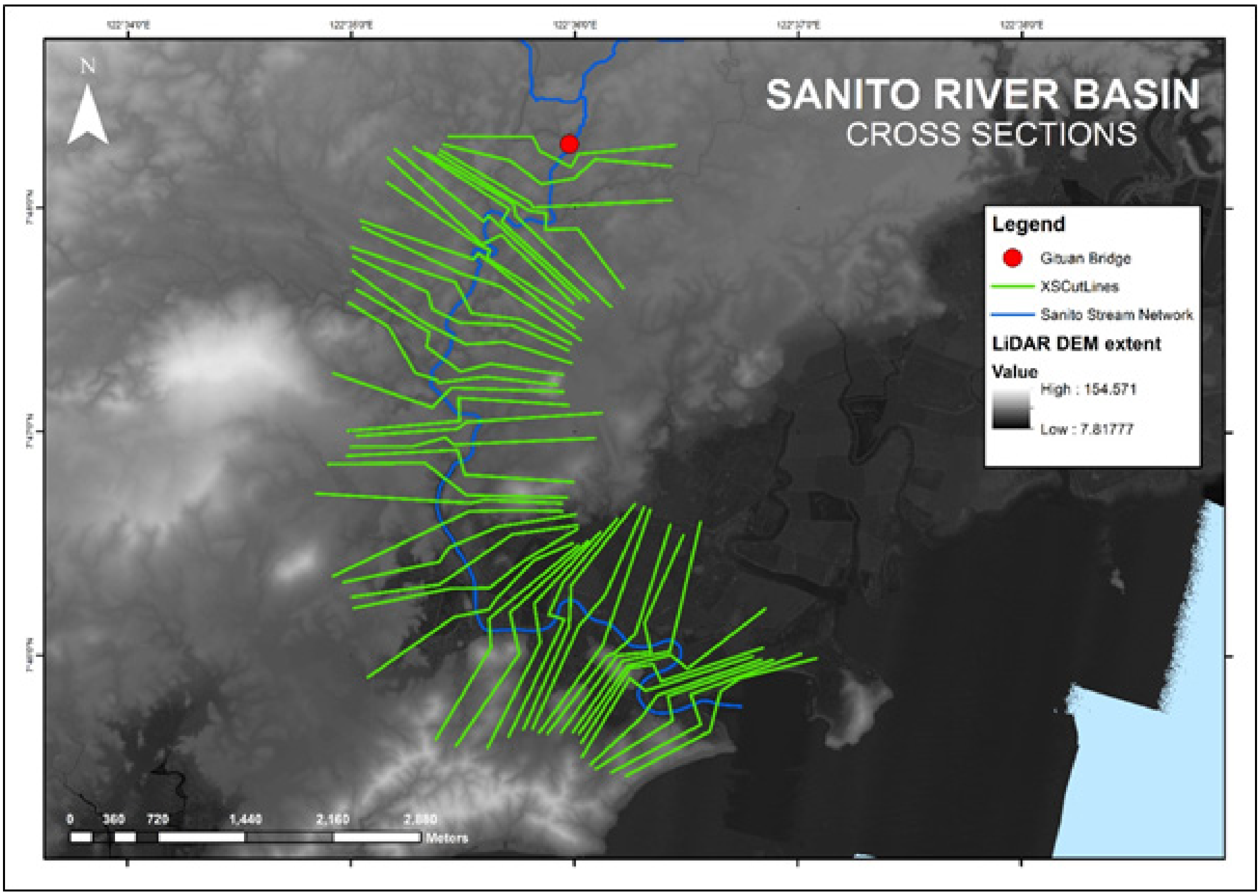


Figure 62. River cross-section of Sanito River generated through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

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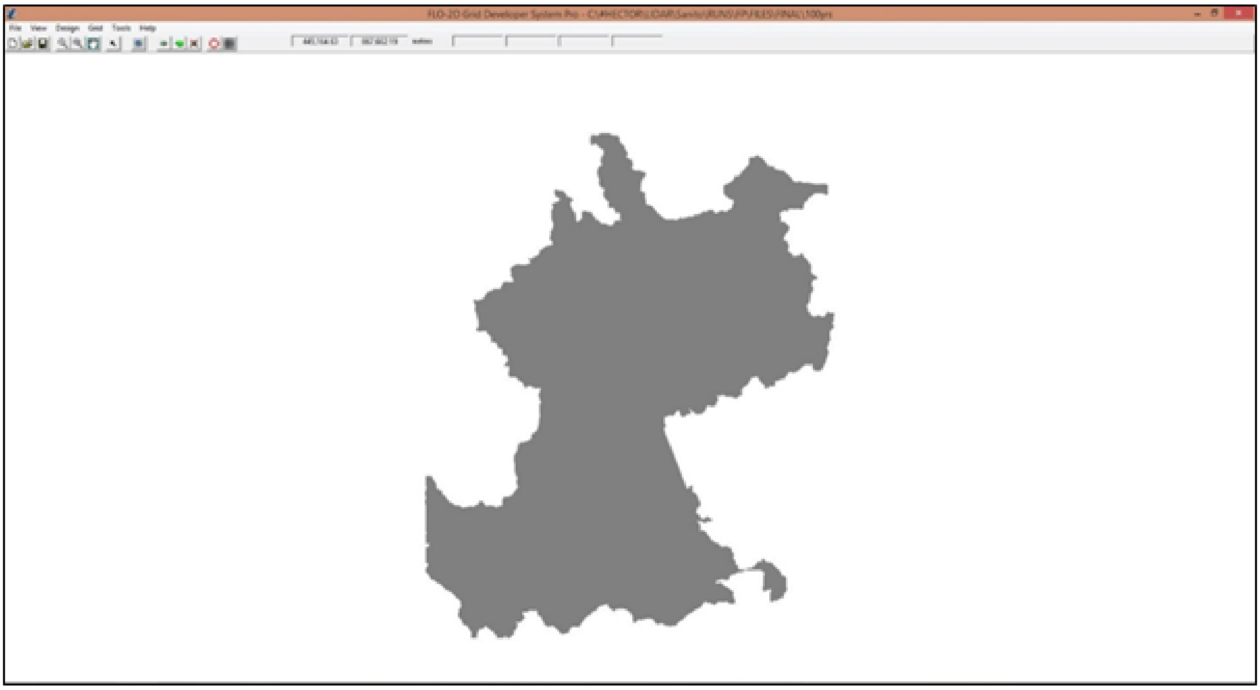

Figure 63. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

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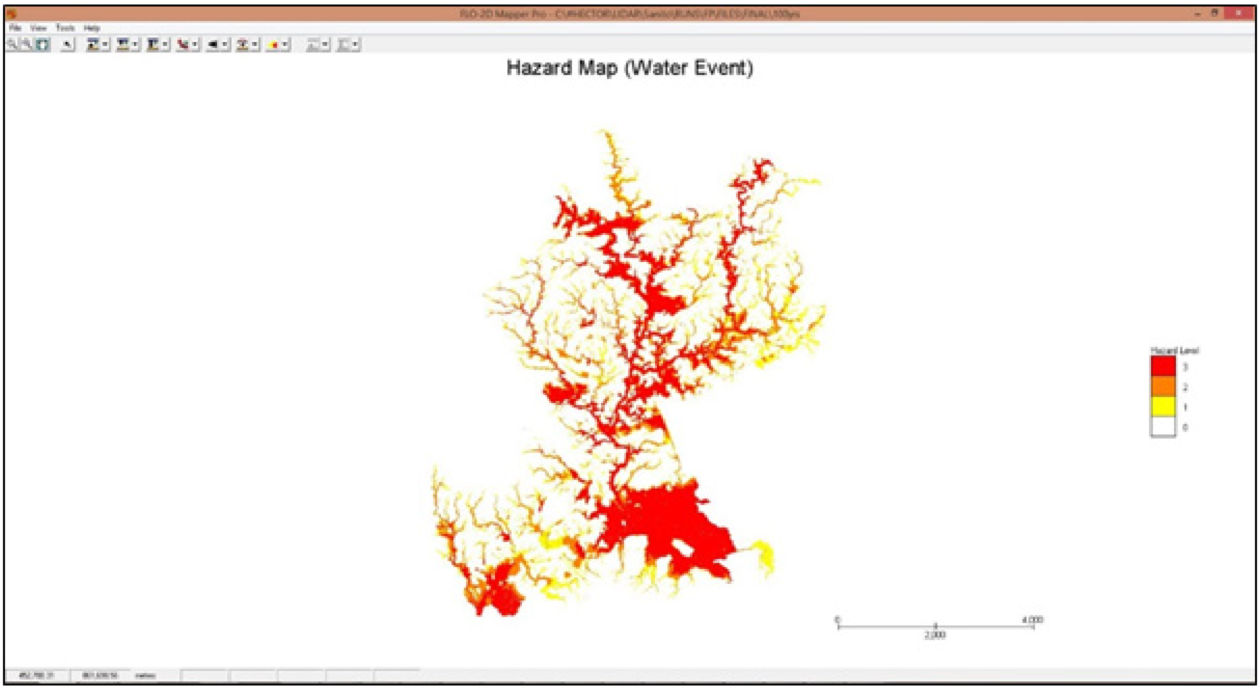


Figure 64. Generated 100-year rain return hazard map from FLO-2D Mapper

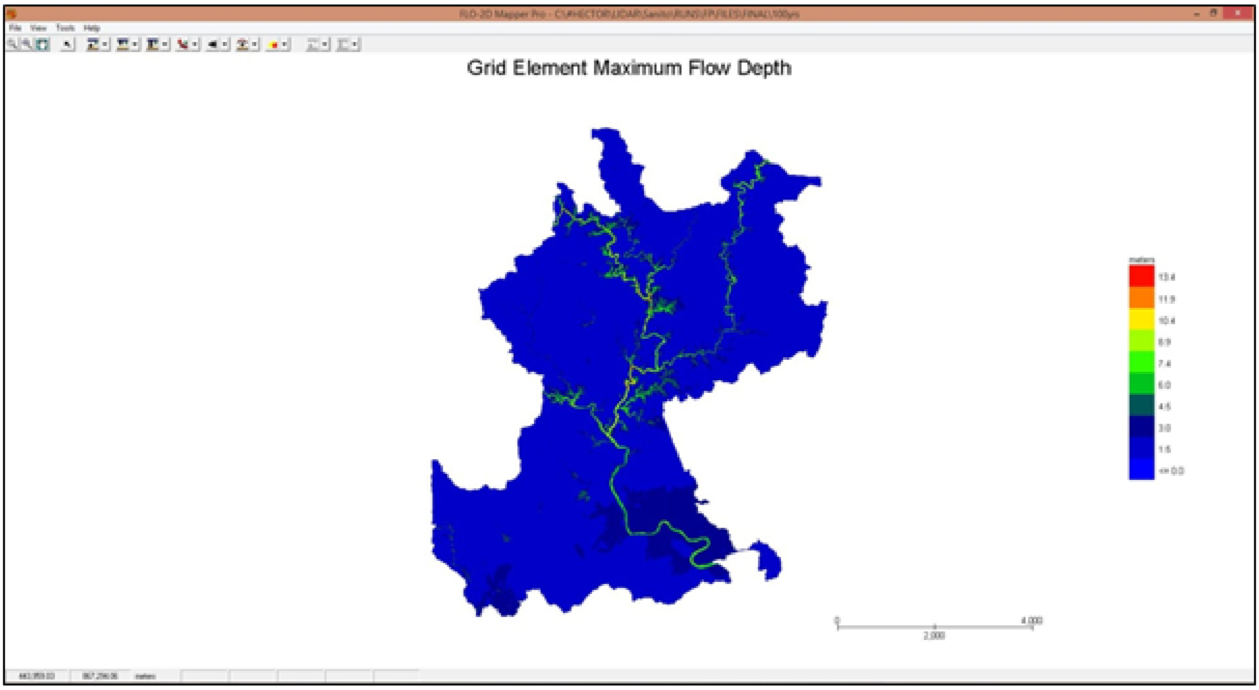


Figure 65. Generated 100-year rain return flow depth map from FLO-2D Mapper

5.6 Results of HMS Calibration

After calibrating the Sanito HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 66 shows the comparison between the two discharge data.

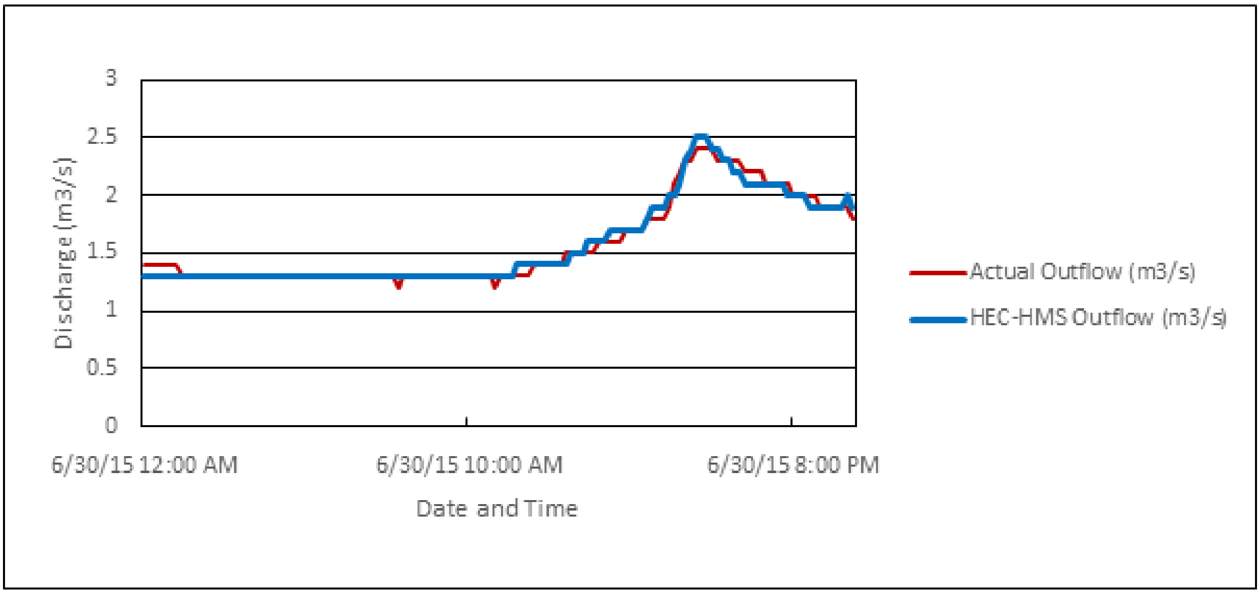


Figure 66. Outflow Hydrograph of Sanito produced by the HEC-HMS model compared with observed outflow

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

Table 28. Range of Calibrated Values for Sanito River Basin

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.66 – 2.14
			Curve Number	69.3 – 90.66
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.50 – 4.81
			Storage Coefficient (hr)	0.38 – 3.70
	Baseflow	Recession	Recession Constant	0.9
			Ratio to Peak	0.4
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.051

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 0.66mm to 2.14mm means that there is a minimal amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The range of curve numbers in this area is 69.3 – 90.66.The magnitude of the outflow hydrograph increases as curve number increases. For Sanito, the soil classes identified were clays, hydrosols, silt, silt loam, sandy clay loam and undifferentiated mountain soil. The land cover types identified were mangroves, grassland, cultivated areas, fishponds, built-up areas, brushland and tree plantations.

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 0.38 hours to 4.81 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 0.9indicates that the basin is not likely to quickly go back to its original discharge. Ratio to peak of 0.4 indicates a shallower receding limb of the outflow hydrograph.

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

Accuracy measure	Value
RMSE	0.632
r2	0.9773
NSE	0.977
PBIAS	-0.0962
RSR	0.15

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as0.632 (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 0.9773.

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 0.977.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is -0.0962.

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 0.15.

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

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph (Figure 67) shows the Sanito 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.

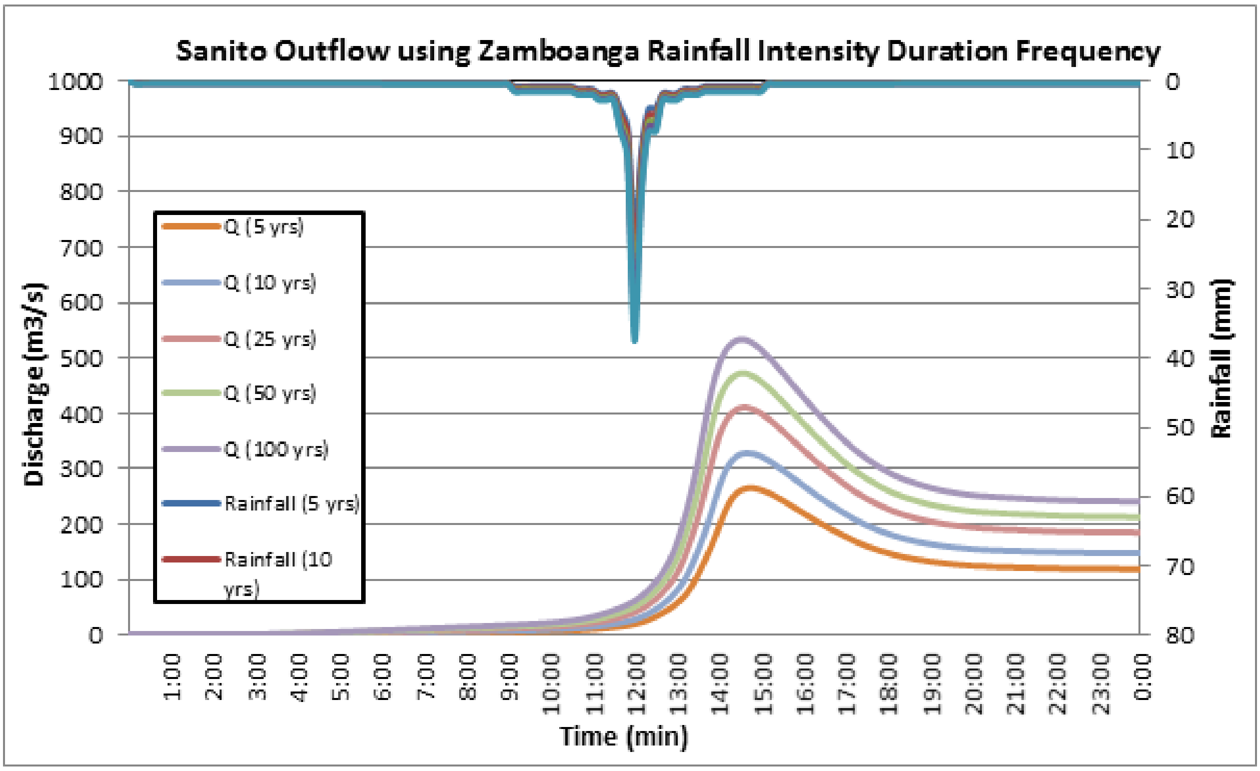


Figure 67. Outflow hydrograph at Sanito Station generated using the Zamboanga City RIDF simulated in HEC-HMS.

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

Table 30. Peak values of the Sanito 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	107.80	21.40	265.4	2 hours, 50 minutes
10-Year	127.90	25.30	328.9	2 hours, 40 minutes
25-Year	153.40	30.20	410.7	2 hours, 40 minutes
50-Year	172.30	33.90	472.2	2 hours, 30 minutes
100-Year	191.10	37.50	533.5	2 hours, 30 minutes

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model 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 Sanito River using the calibrated HMS base flow is shown in Figure 68.

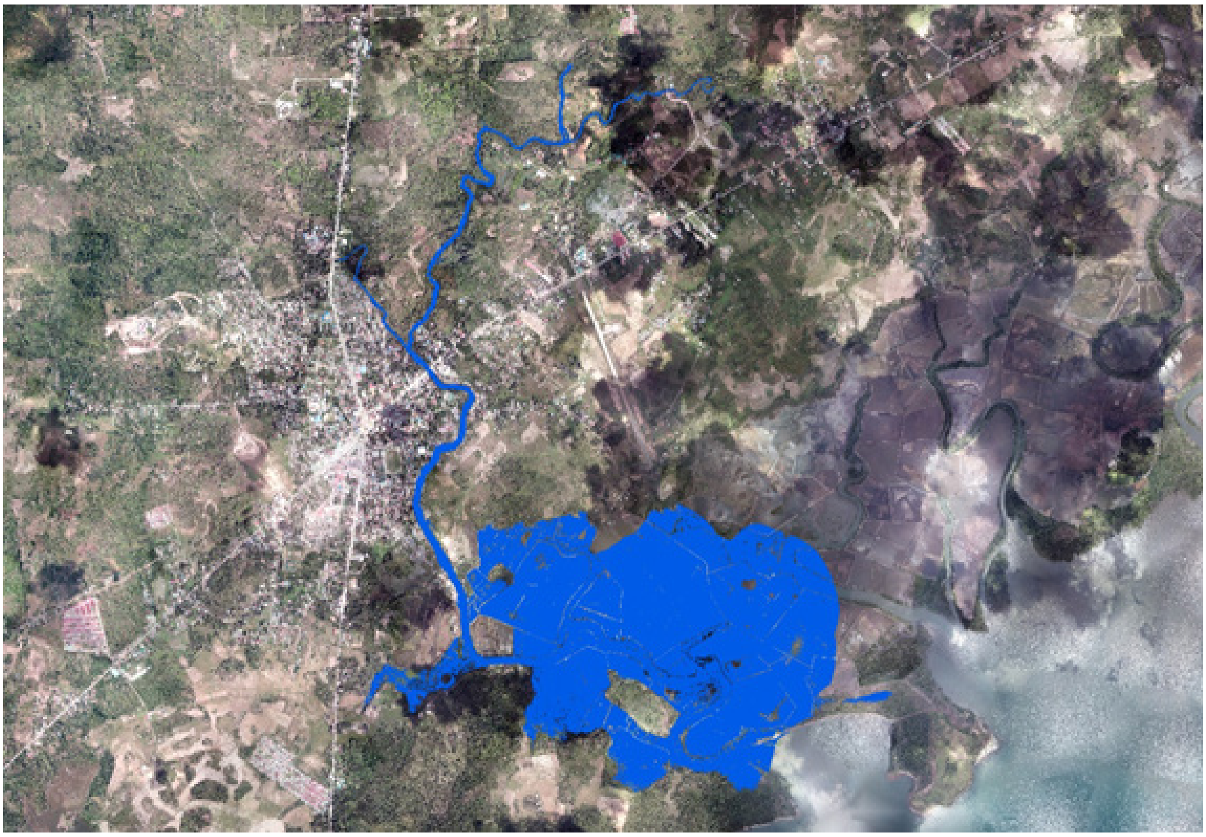


Figure 68. Sample output of Sanito RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figure 69 to Figure 74 show the 5-, 25-, and 100-year rain return scenarios of the Sanito floodplain.

The generated flood hazard maps for the Sanito 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 31. Municipalities affected in Sanito floodplain

Municipality	Total Area	Area Flooded	% Flooded
Ipil	158.06	49.89	31.56%
Titay	248.64	20.88	8.40%

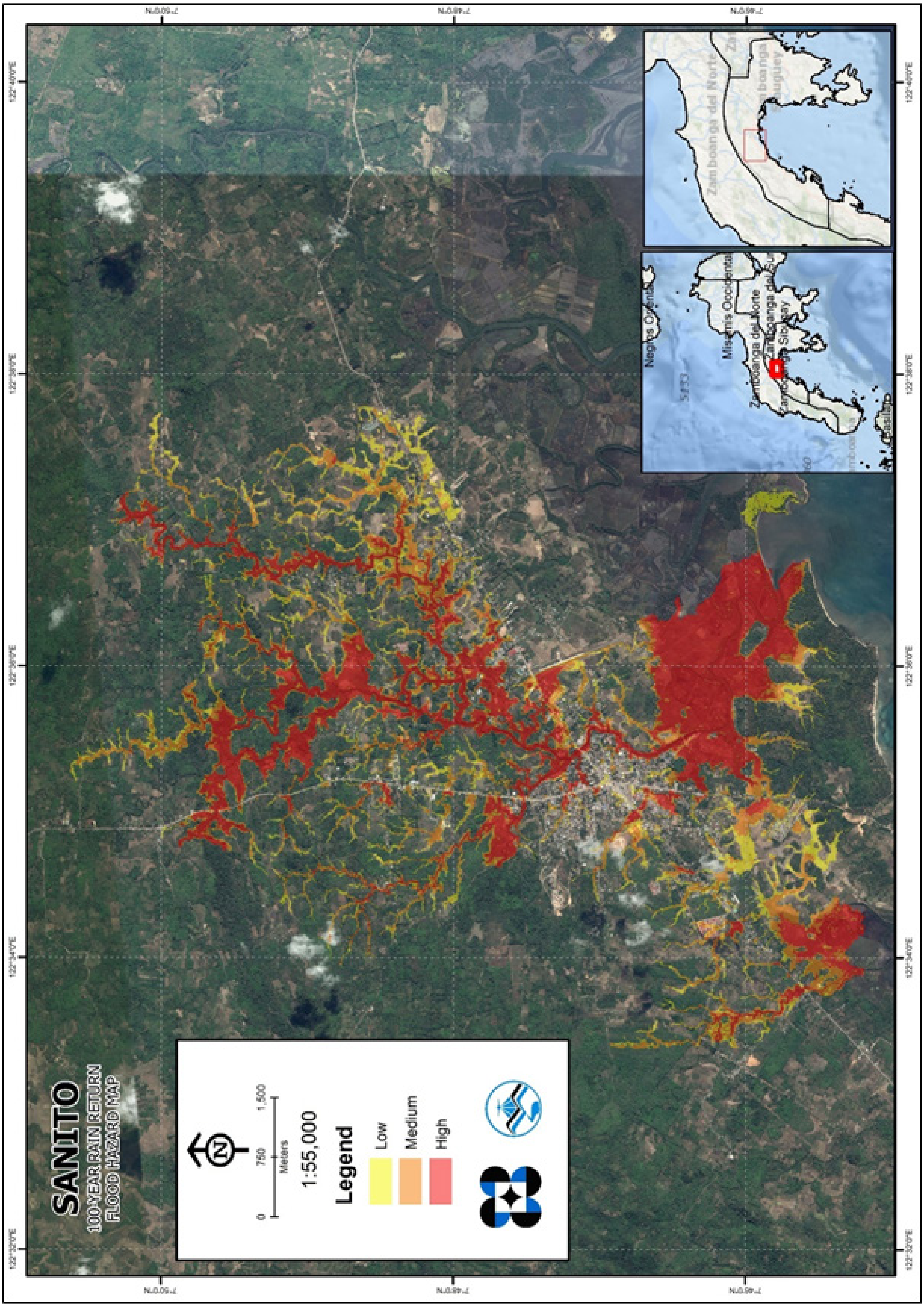


Figure 69. 100-year Flood Hazard Map for Sanito Floodplain

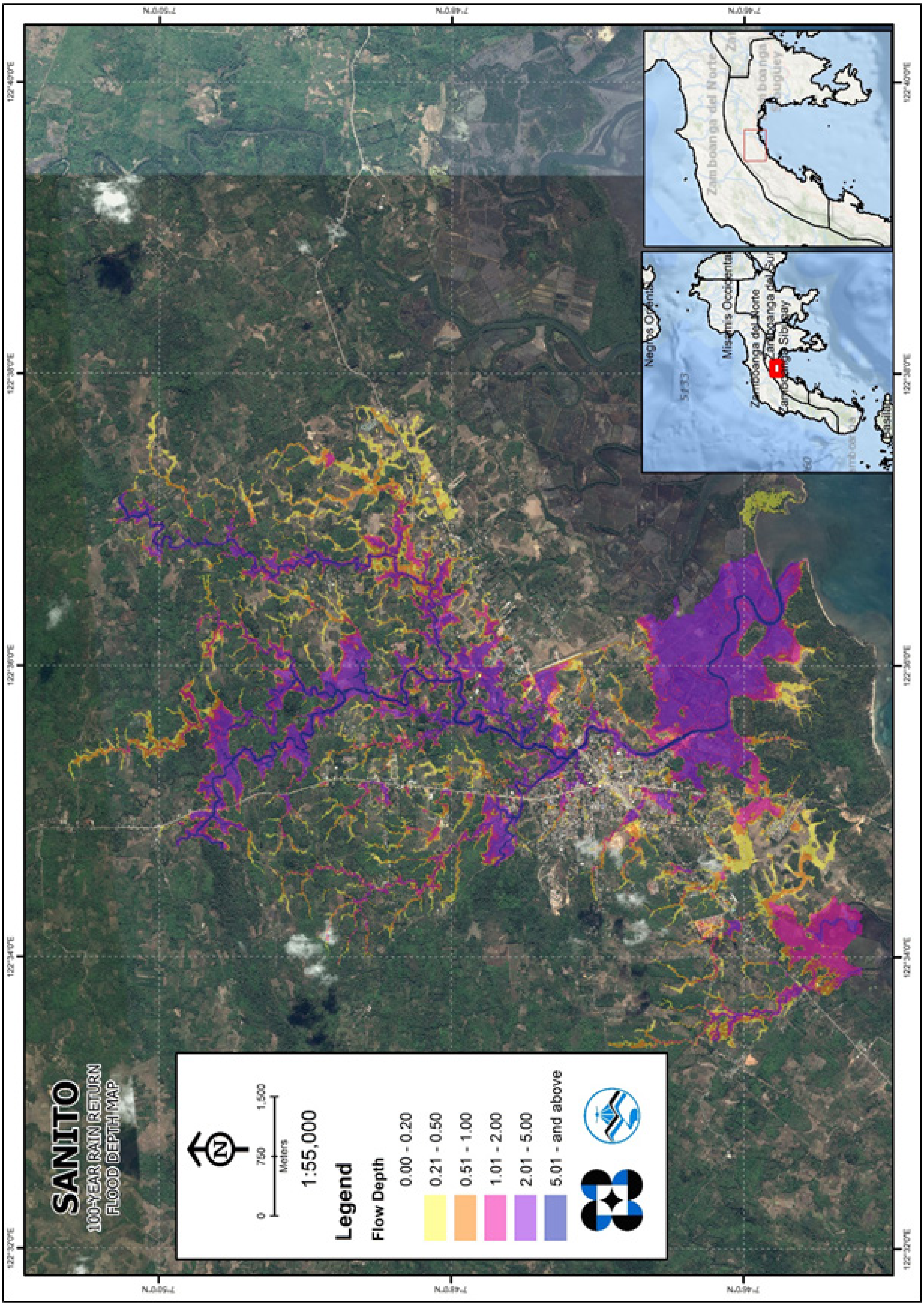


Figure 70. 100-year Flow Depth Map for Sanito Floodplain

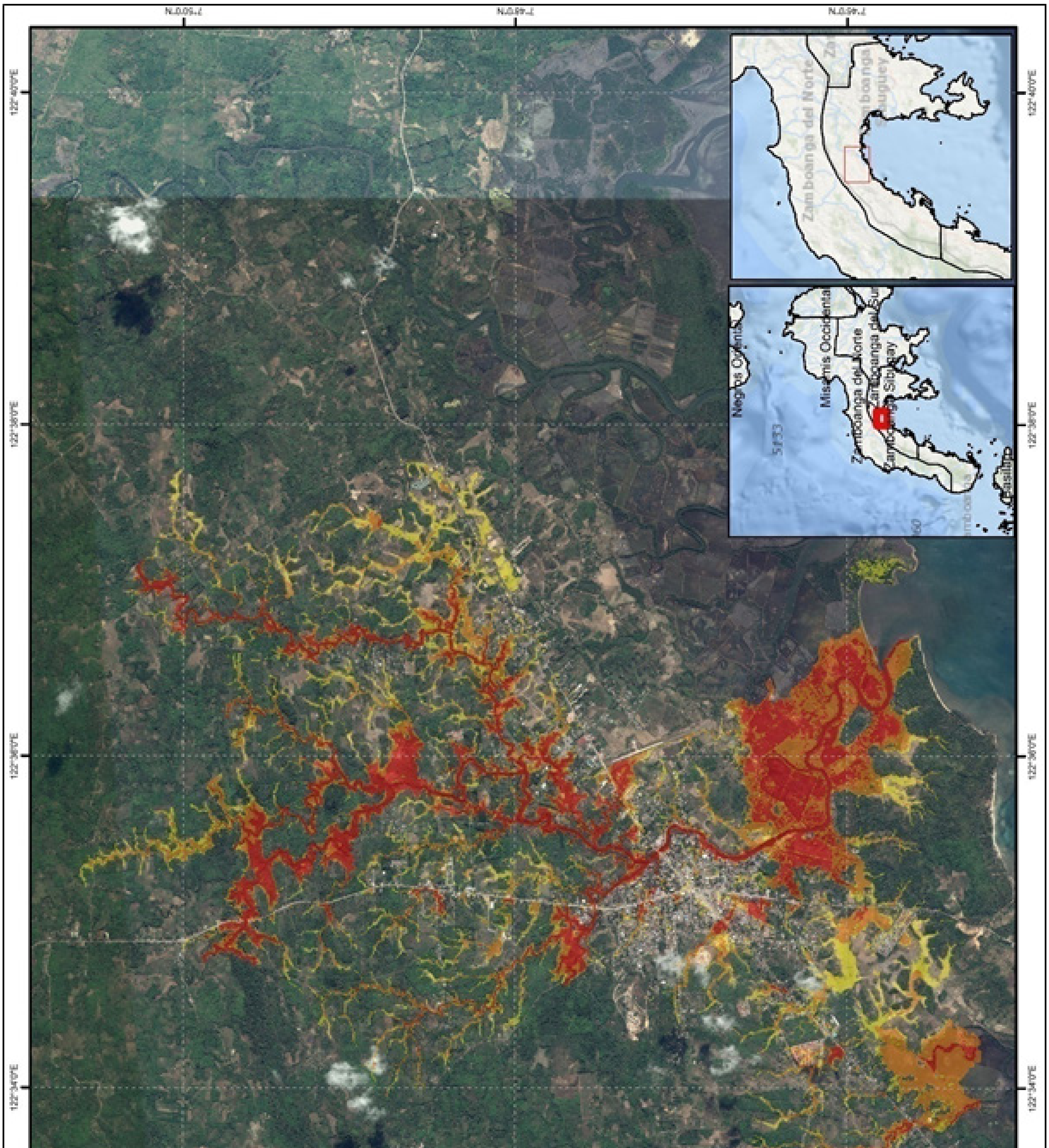


Figure 71. 25-year Flood Hazard Map for Sanito Floodplain

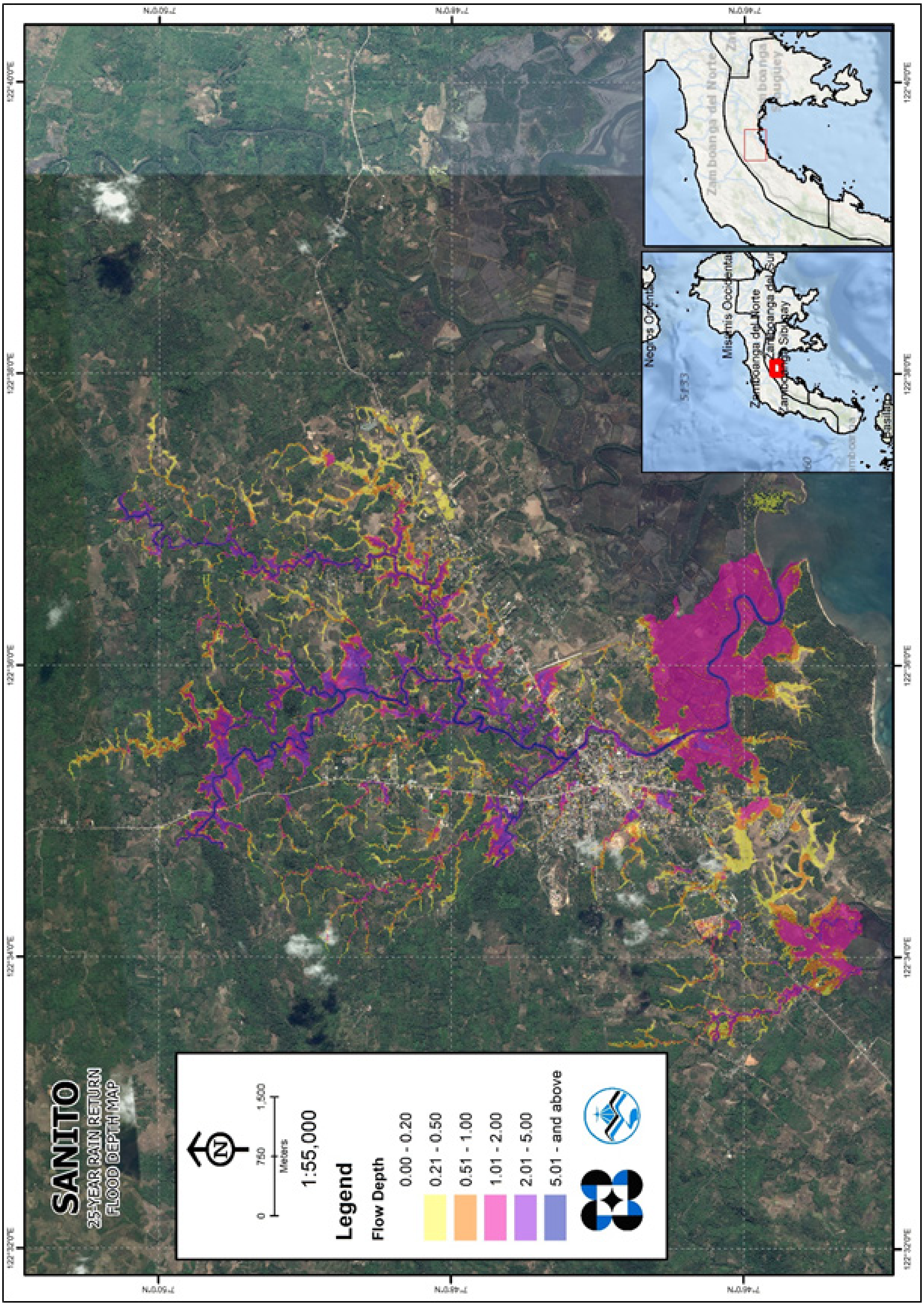


Figure 72. 25-year Flow Depth Map for Sanito Floodplain

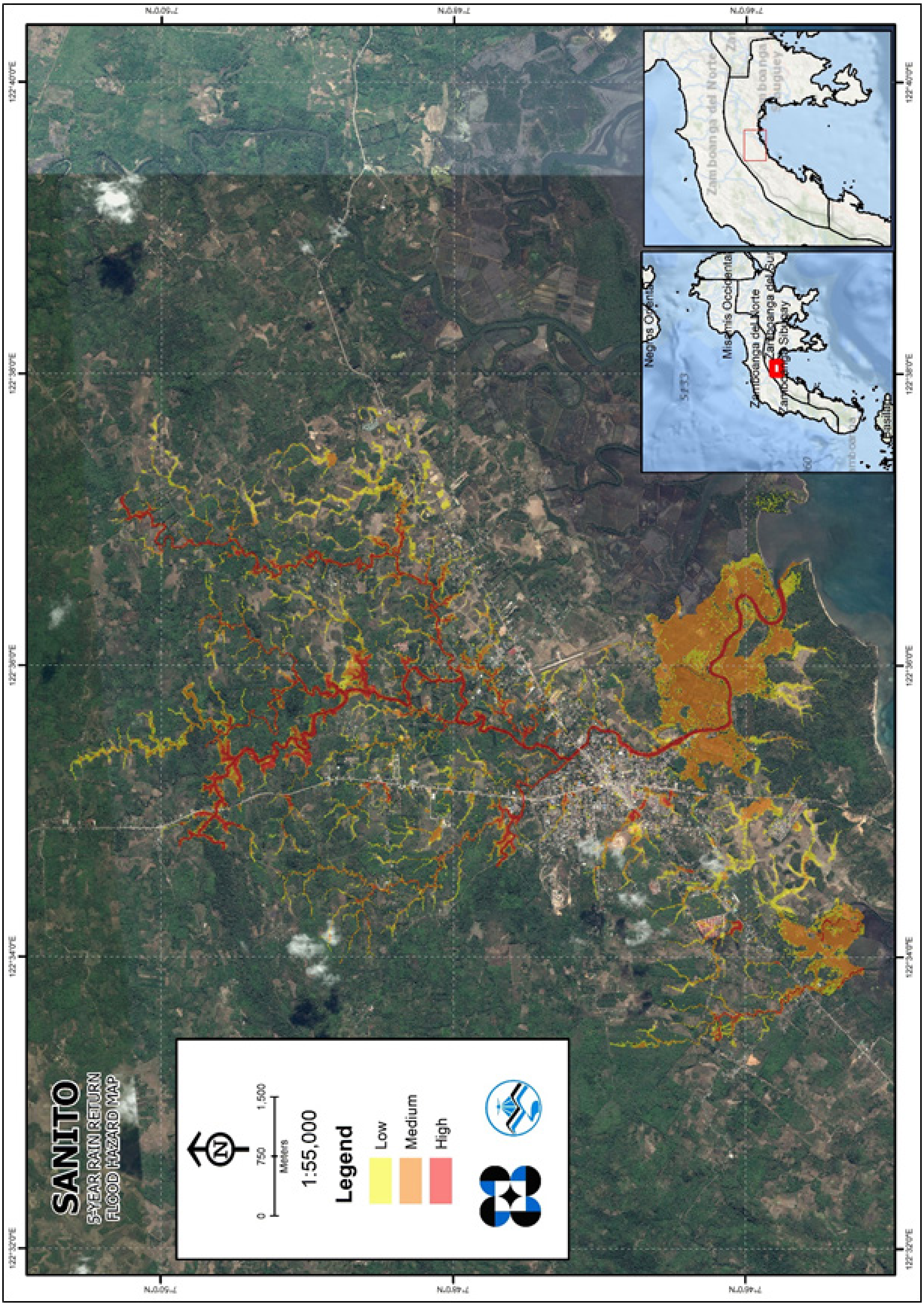


Figure 73. 5-year Flood Hazard Map for Sanito Floodplain

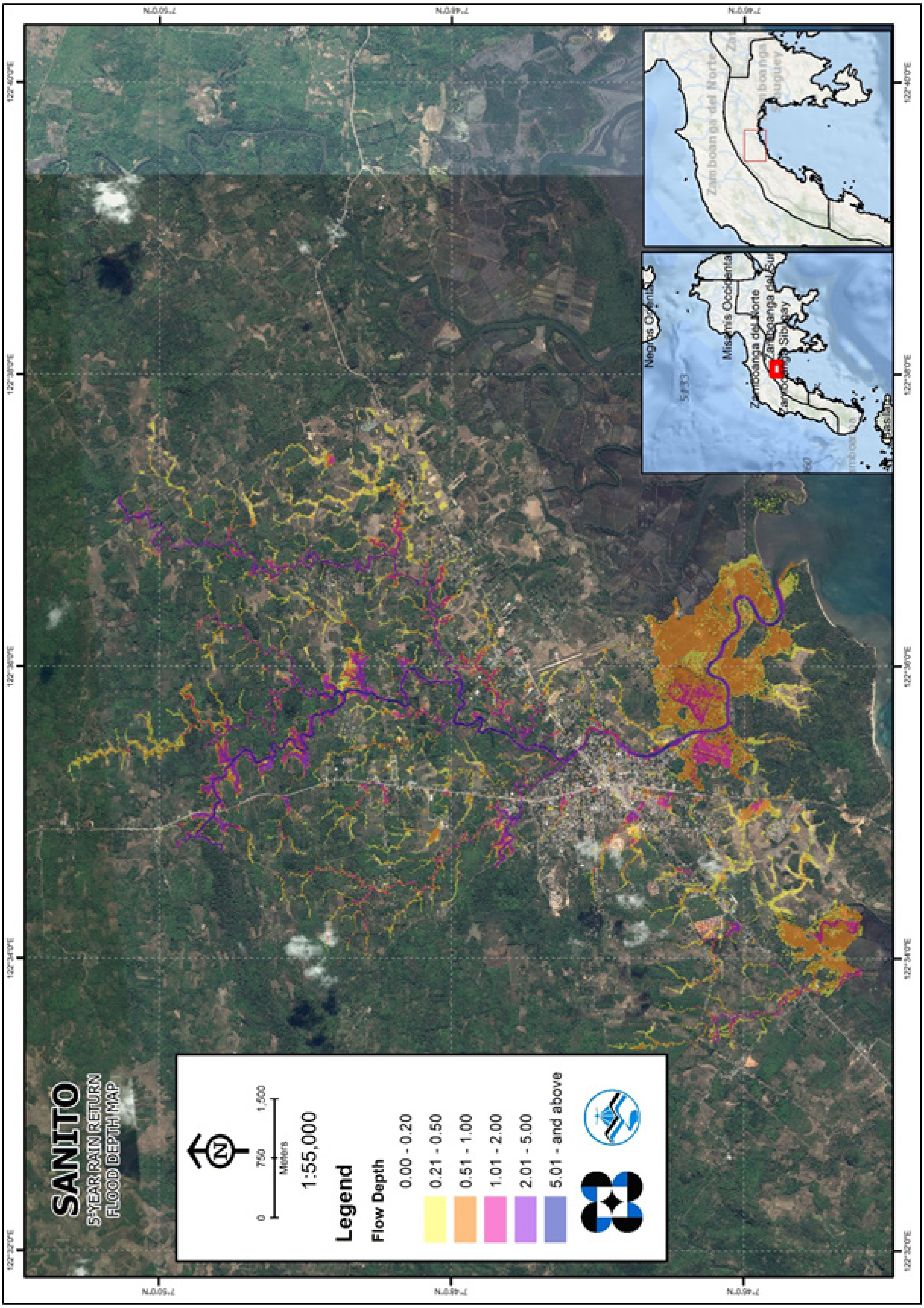


Figure 74. 5-year Flood Depth Map for Sanito Floodplain

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Sanito river basin, grouped by municipality, are listed below. For the said basin, 11 barangays in two municipalities are expected to experience flooding when subjected to the flood hazard scenarios.

For the 5-year return period, 25.05% of the municipality of Ipil with an area of 158.0554 sq. km. will experience flood levels of less than 0.20 meters; 2.42% of the area will experience flood levels of 0.21 to 0.50 meters while 2.39%, 0.90%, 0.59%, and 0.12% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 32. Affected Areas in Ipil, Zamboanga Sibugay during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)		Area of affected barangays in Ipil (in sq. km.)										
		Bacalan	Bangkerohan	Domandan	Don Andres	Guituan	Ipil Heights	Lower Ipil Heights	Lower Taway	Magdaup	Pangi	Poblacion
Affected Area (sq. km.)	1	2.96	1.18	0.76	2.47	7.12	2.24	0.88	2.36	1.42	1.31	1.41
	2	0.34	0.25	0.055	0.49	0.48	0.14	0.058	0.082	0.13	0.16	0.14
	3	0.11	0.38	0.017	0.49	0.36	0.083	0.049	0.084	0.026	0.1	0.17
	4	0.057	0.028	0.0069	0.087	0.32	0.018	0.01	0.094	0.0006	0.072	0.15
	5	0.033	0.032	0.0057	0.021	0.29	0.0001	0.0002	0.11	0	0.054	0.058
	6	0.0064	0.007	0.0017	0	0.11	0	0	0.017	0	0.012	0.013

Table 33. Affected Areas in Ipil, Zamboanga Sibugay during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)		Area of affected barangays in Ipil (in sq. km.)						
		Sanito	Suclema	Taway	Tenan	Tiayon	Upper Pangi	Veteran's Village
Affected Area (sq. km.)	1	1.860557	0.945189	4.576389	0.782779	0.252735	4.791659	2.277992
	2	0.442687	0.069015	0.269596	0.072417	0.030739	0.385777	0.223213
	3	1.287924	0.030481	0.240679	0.003006	0.014086	0.218947	0.113016
	4	0.17394	0.01977	0.152872	0	0.016133	0.183139	0.03925
	5	0.116809	0.0021	0.024411	0	0.011047	0.161356	0.010555
	6	0.007157	0	0.000698	0	0	0.015919	0

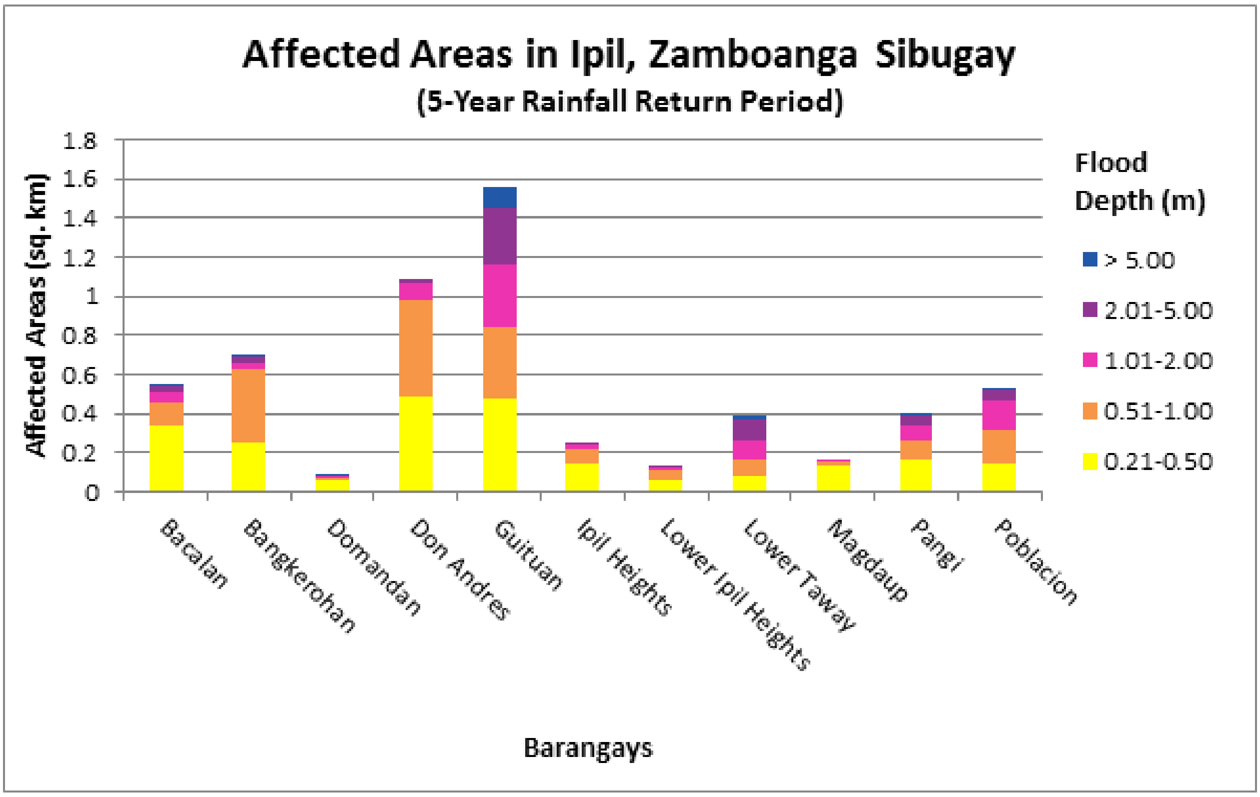


Figure 75. Affected Areas in Ipil, Zamboanga Sibugay during 5-Year Rainfall Return Period

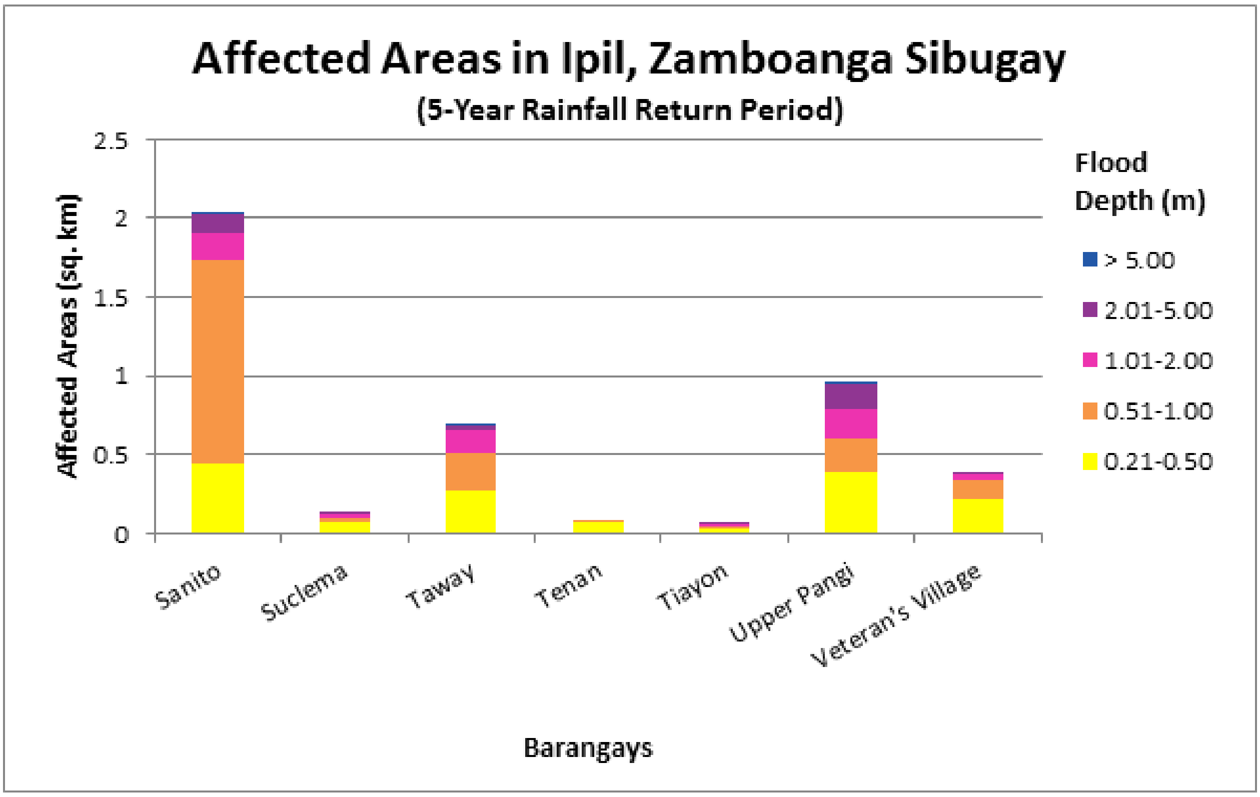


Figure 76. Affected Areas in Ipil, Zamboanga Sibugay during 5-Year Rainfall Return Period

For the 5-year return period, 6.16% of the municipality of Titay with an area of 297.4381 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 0.23%, 0.15%, 0.10%, and 0.02% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 34. Affected Areas in Titay, Zamboanga Sibugay during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)		Area of affected barangays in Titay (in sq. km.)							
		Achasol	Culasian	Kitabog	La Libertad	Longilog	Mabini	Malagandis	Mate
Affected Area (sq. km.)	1	1.72	0.76	1.99	1.27	2.46	0.099	0.63	0.18
	2	0.077	0.033	0.13	0.11	0.19	0.0028	0.01	0.0031
	3	0.053	0.027	0.12	0.047	0.096	0.0034	0.016	0.0015
	4	0.028	0.037	0.13	0.014	0.036	0.0062	0.019	0.00017
	5	0.042	0.059	0.072	0.0005	0.027	0.0021	0.017	0
	6	0.0023	0.0009	0.019	0	0.013	0	0	0

Table 35. Affected Areas in Titay, Zamboanga Sibugay during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)		Area of affected barangays in Titay (in sq. km.)		
		Moalboal	Palomoc	Poblacion Muslim
Affected Area (sq. km.)	1	3.95	4.83	0.44
	2	0.16	0.25	0.026
	3	0.16	0.14	0.013
	4	0.1	0.057	0.013
	5	0.032	0.035	0.0059
	6	0.0041	0.006	0

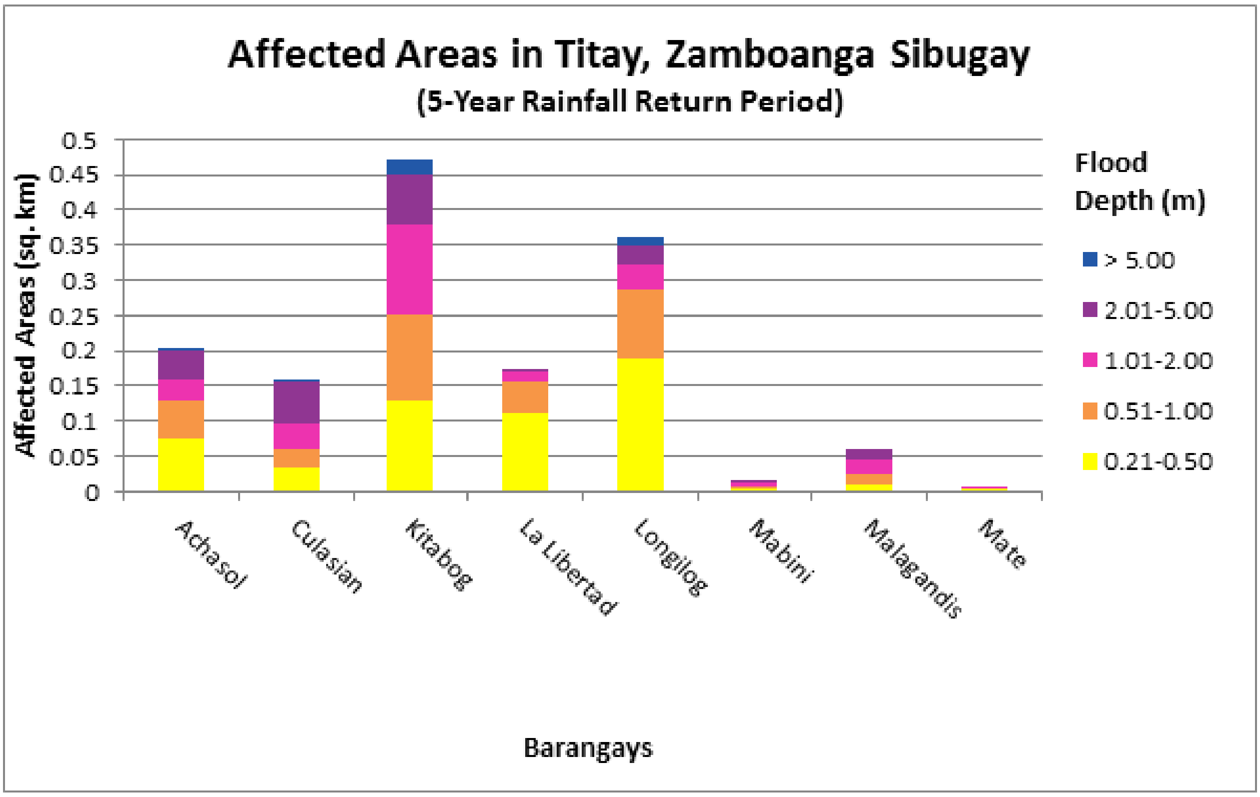


Figure 77. Affected Areas in Titay, Zamboanga Sibugay during 5-Year Rainfall Return Period

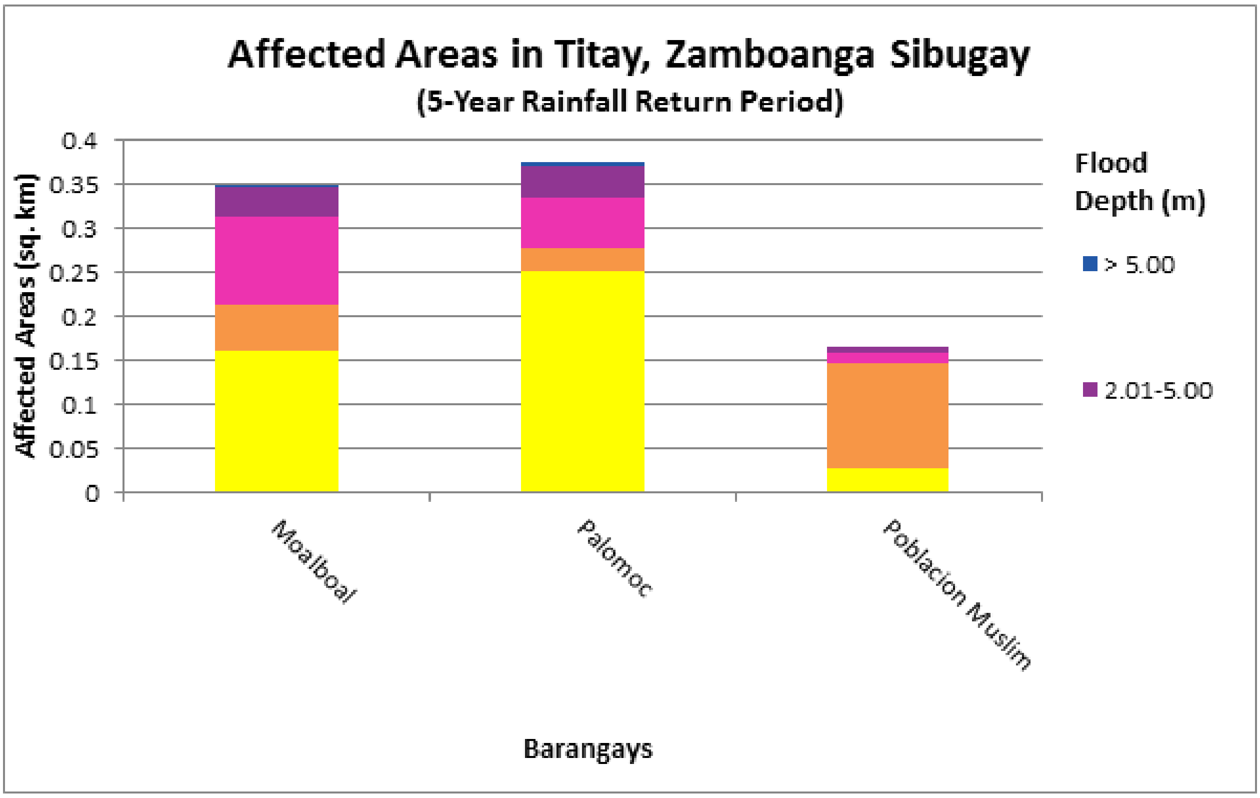


Figure 78. Affected Areas in Titay, Zamboanga Sibugay during 5-Year Rainfall Return Period

For the 25-year return period, 22.64% of the municipality of Ipil with an area of 158.0554 sq. km. will experience flood levels of less than 0.20 meters; 2.35% of the area will experience flood levels of 0.21 to 0.50 meters while 1.85%, 3.17%, 1.20%, and 0.29% 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 the table are the affected areas in square kilometers by flood depth per barangay.

Table 36. Affected Areas in Ipil, Zamboanga Sibugay during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)		Area of affected barangays in Ipil (in sq. km.)										
		Bacalan	Bangkerohan	Domandan	Don Andres	Guituan	Ipil Heights	Lower Ipil Heights	Lower Taway	Magdaup	Pangi	Poblacion
Affected Area (sq. km.)	1	2.69	0.99	0.74	2.1	6.5	2.16	0.85	2.14	1.31	1.07	1.26
	2	0.42	0.14	0.066	0.46	0.5	0.17	0.059	0.09	0.15	0.15	0.11
	3	0.22	0.17	0.034	0.41	0.43	0.099	0.054	0.09	0.053	0.11	0.14
	4	0.11	0.53	0.011	0.53	0.51	0.047	0.029	0.14	0.055	0.22	0.29
	5	0.053	0.023	0.0084	0.058	0.57	0.0014	0.0006	0.21	0	0.13	0.12
	6	0.013	0.024	0.0042	0	0.18	0	0	0.081	0	0.024	0.022

Table 37. Affected Areas in Ipil, Zamboanga Sibugay during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)		Area of affected barangays in Ipil (in sq. km.)						
		Sanito	Suclema	Taway	Tenan	Tiayon	Upper Pangi	Veteran's Village
Affected Area (sq. km.)	1	1.422283	0.905789	4.294178	0.688611	0.219782	4.281808	2.167529
	2	0.137877	0.081045	0.309447	0.158815	0.035478	0.429414	0.248415
	3	0.201489	0.036795	0.312543	0.010595	0.033561	0.337744	0.176707
	4	1.833024	0.032498	0.27184	0.000182	0.025852	0.31505	0.060489
	5	0.249328	0.010428	0.093218	0	0.019149	0.331992	0.024705
	6	0.045072	0	0.002123	0	0.0001	0.069496	0

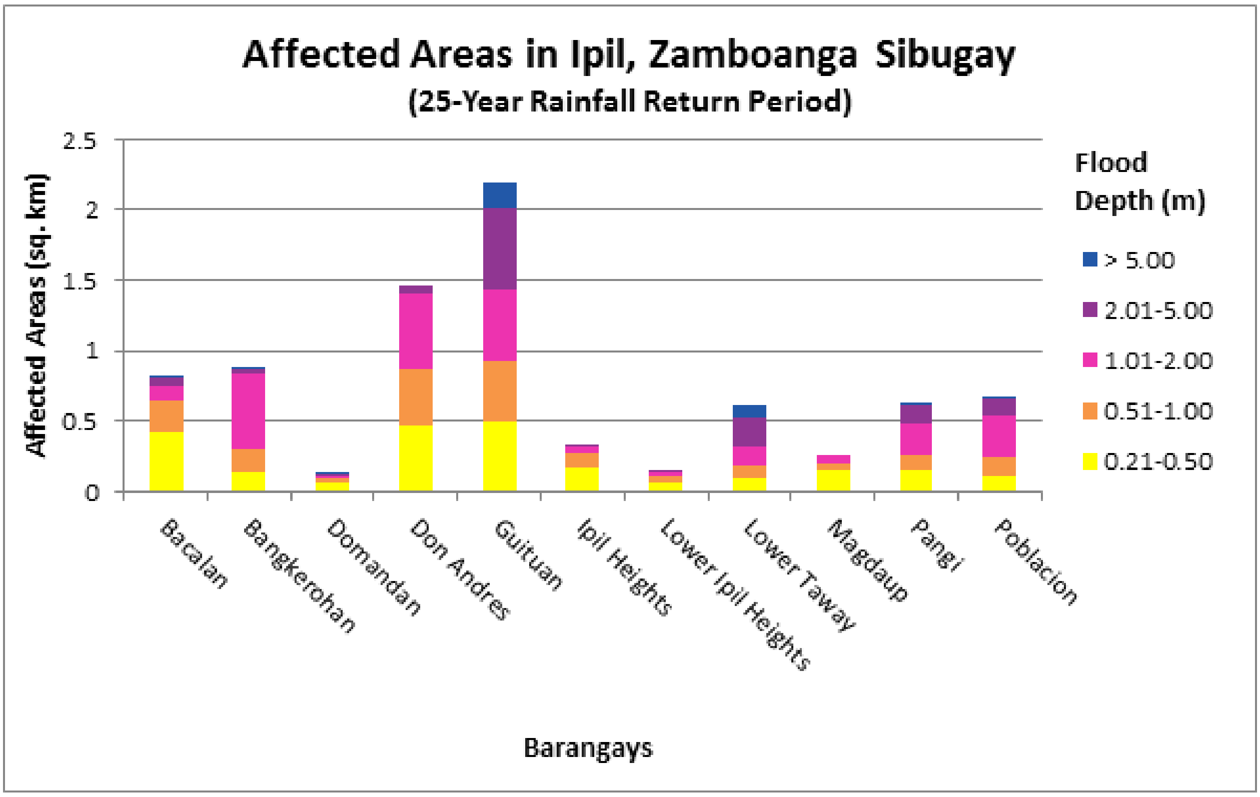


Figure 79. Affected Areas in Ipil, Zamboanga Sibugay during 25-Year Rainfall Return Period

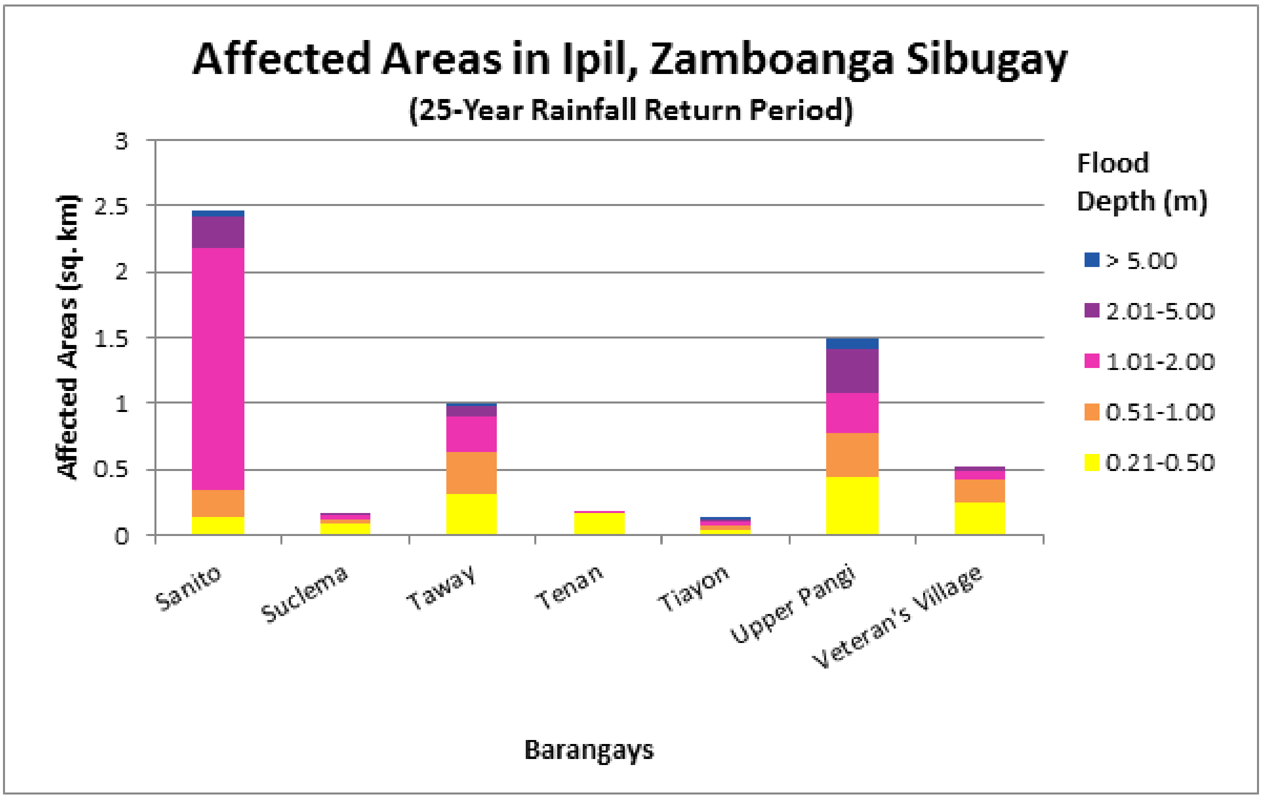


Figure 80. Affected Areas in Ipil, Zamboanga Sibugay during 25-Year Rainfall Return Period

For the 25-year return period, 5.88% of the municipality of Titay with an area of 297.4381 sq. km. will experience flood levels of less than 0.20 meters; 0.35% of the area will experience flood levels of 0.21 to 0.50 meters while 0.31%, 0.24%, 0.18%, and 0.03% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 38. Affected Areas in Titay, Zamboanga Sibugay during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)		Area of affected barangays in Titay (in sq. km.)							
		Achasol	Culasian	Kitabog	La Libertad	Longilog	Mabini	Malagandis	Mate
Affected Area (sq. km.)	1	1.65	0.71	1.85	1.2	2.25	0.095	0.61	0.18
	2	0.079	0.034	0.14	0.12	0.2	0.0023	0.012	0.0031
	3	0.069	0.028	0.14	0.09	0.18	0.0023	0.016	0.0021
	4	0.038	0.039	0.17	0.031	0.13	0.0063	0.017	0.00088
	5	0.072	0.089	0.15	0.0056	0.051	0.0073	0.033	0
	6	0.0094	0.0099	0.028	0	0.021	0	0	0

Table 39. Affected Areas in Titay, Zamboanga Sibugay during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)		Area of affected barangays in Titay (in sq. km.)		
		Moalboal	Palomoc	Poblacion Muslim
Affected Area (sq. km.)	1	3.82	4.7	0.42
	2	0.16	0.26	0.029
	3	0.18	0.2	0.021
	4	0.17	0.1	0.012
	5	0.063	0.058	0.015
	6	0.015	0.013	0

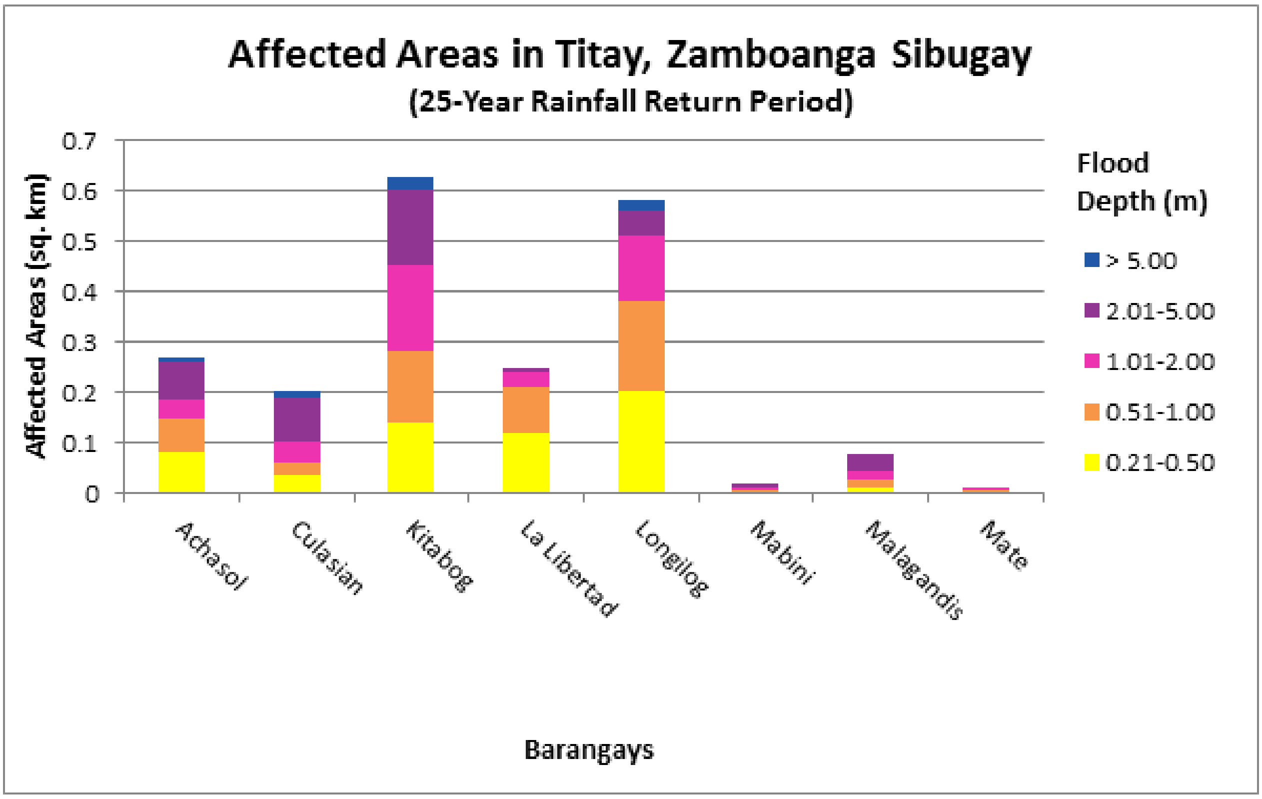


Figure 81. Affected Areas in Titay, Zamboanga Sibugay during 25-Year Rainfall Return Period

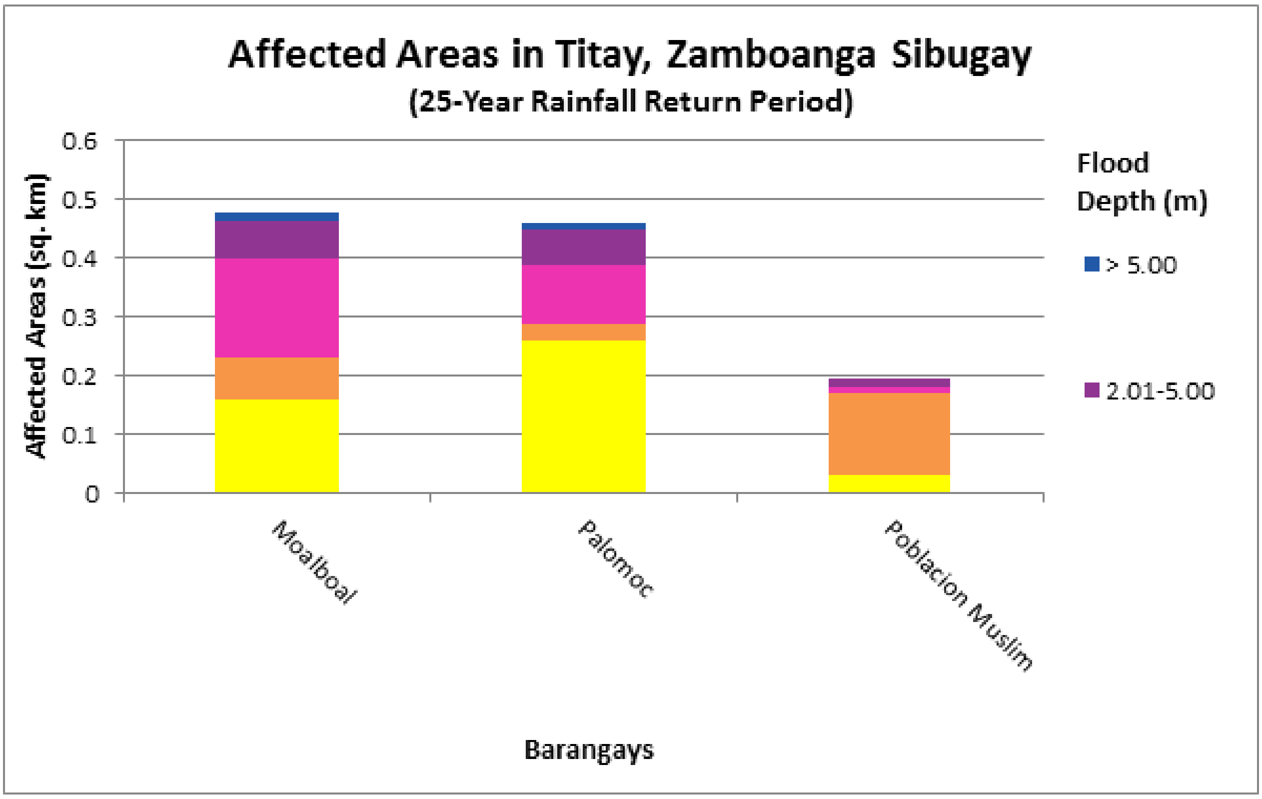


Figure 82. Affected Areas in Titay, Zamboanga Sibugay during 25-Year Rainfall Return Period

For the 100-year return period, 21.27% of the municipality of Ipil with an area of 158.0554 sq. km. will experience flood levels of less than 0.20 meters; 2.38% of the area will experience flood levels of 0.21 to 0.50 meters while 1.87%, 2.39%, 3.19%, and 0.46% 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 the table are the affected areas in square kilometers by flood depth per barangay.

Table 40. Affected Areas in Ipil, Zamboanga Sibugay during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)		Area of affected barangays in Ipil (in sq. km.)										
		Bacalan	Bangkerohan	Domandan	Don Andres	Guituan	Ipil Heights	Lower Ipil Heights	Lower Taway	Magdaup	Pangi	Poblacion
Affected Area (sq. km.)	1	2.57	0.92	0.73	1.95	6.12	2.11	0.83	1.99	1.26	0.85	1.17
	2	0.42	0.1	0.071	0.39	0.51	0.18	0.058	0.099	0.17	0.2	0.098
	3	0.29	0.085	0.039	0.36	0.44	0.11	0.06	0.099	0.053	0.11	0.088
	4	0.14	0.28	0.015	0.77	0.54	0.074	0.042	0.14	0.05	0.2	0.22
	5	0.079	0.46	0.012	0.1	0.83	0.0033	0.0017	0.3	0.039	0.31	0.32
	6	0.018	0.031	0.006	0	0.26	0	0	0.13	0	0.036	0.04

Table 41. Affected Areas in Ipil, Zamboanga Sibugay during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)		Area of affected barangays in Ipil (in sq. km.)						
		Sanito	Suclema	Taway	Tenan	Tiayon	Upper Pangi	Veteran's Village
Affected Area (sq. km.)	1	1.189289	0.884002	4.112008	0.627691	0.201393	4.003888	2.104796
	2	0.134793	0.07908	0.322804	0.199868	0.040786	0.433383	0.251476
	3	0.164567	0.047868	0.333919	0.028514	0.03516	0.40078	0.214567
	4	0.416254	0.035677	0.358456	0.002129	0.035163	0.372436	0.084802
	5	1.891987	0.019928	0.166254	0	0.026741	0.450935	0.030267
	6	0.092183	0	0.003569	0	0.0007	0.114966	0.0001

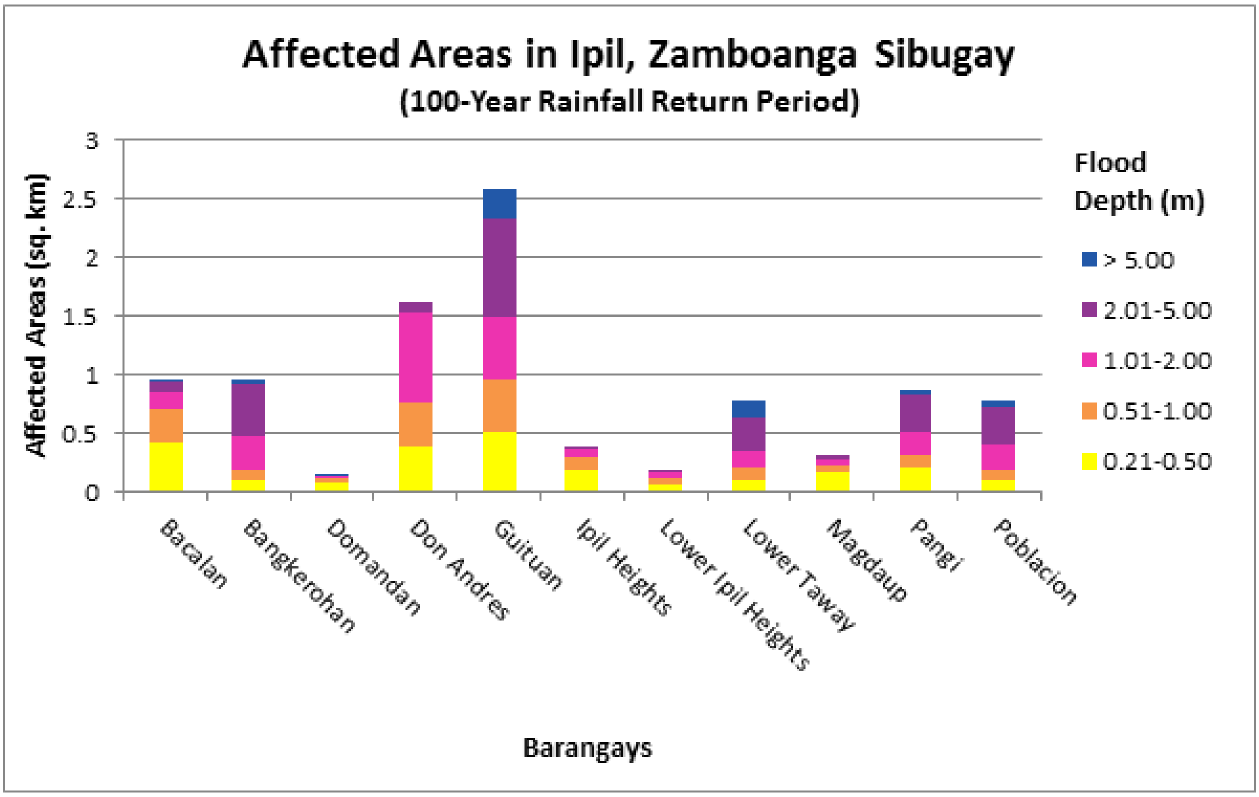


Figure 83. Affected Areas in Ipil, Zamboanga Sibugay during 100-Year Rainfall Return Period

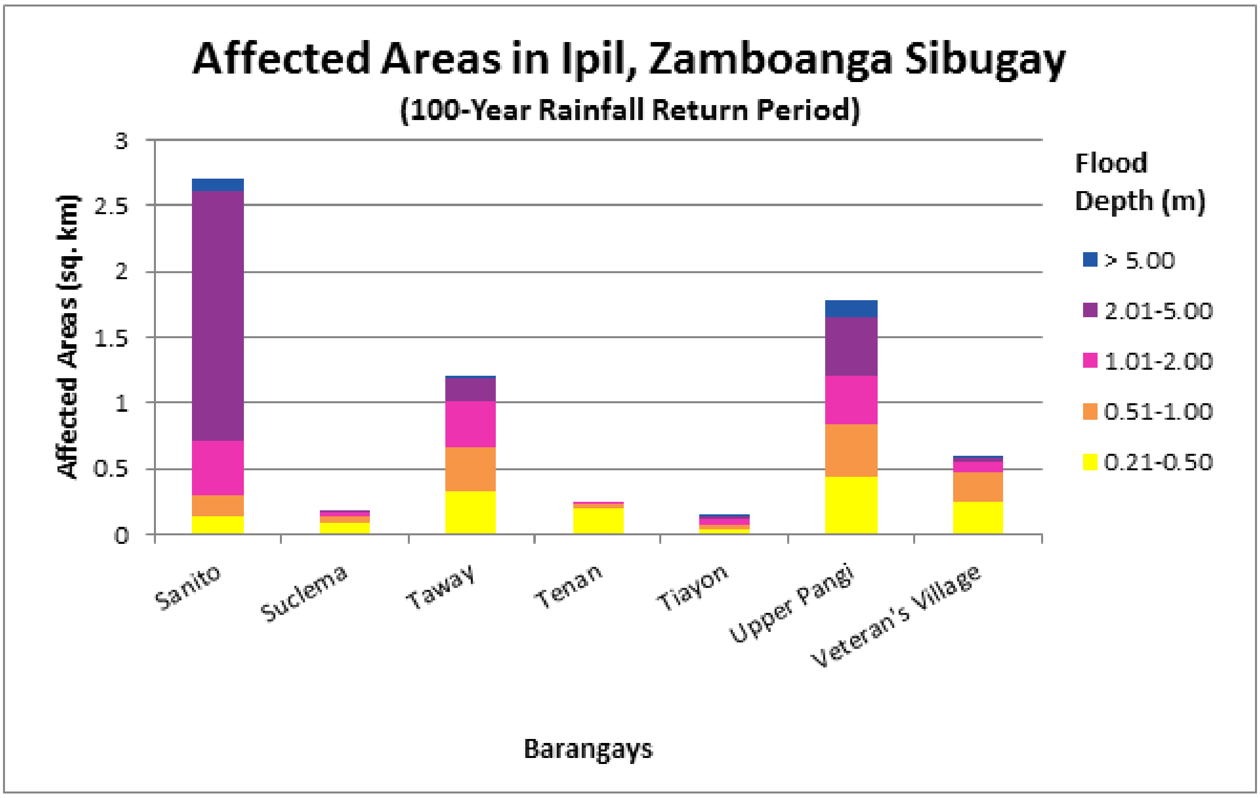


Figure 84. Affected Areas in Ipil, Zamboanga Sibugay during 100-Year Rainfall Return Period

For the 100-year return period, 5.70% of the municipality of Titay with an area of 297.4381 sq. km. will experience flood levels of less than 0.20 meters; 0.37% of the area will experience flood levels of 0.21 to 0.50 meters while 0.35%, 0.30%, 0.26%, 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 the table are the affected areas in square kilometers by flood depth per barangay.

Table 42. Affected Areas in Titay, Zamboanga Sibugay during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)		Area of affected barangays in Titay (in sq. km.)							
		Achasol	Culasian	Kitabog	La Libertad	Longilog	Mabini	Malagandis	Mate
Affected Area (sq. km.)	1	1.62	0.69	1.75	1.16	2.14	0.092	0.6	0.18
	2	0.081	0.033	0.16	0.13	0.2	0.0029	0.012	0.0031
	3	0.07	0.031	0.16	0.11	0.19	0.0028	0.016	0.0024
	4	0.051	0.039	0.18	0.04	0.19	0.005	0.02	0.0012
	5	0.087	0.1	0.22	0.01	0.084	0.011	0.037	0
	6	0.017	0.022	0.037	0	0.025	0	0.0033	0

Table 43. Affected Areas in Titay, Zamboanga Sibugay during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)		Area of affected barangays in Titay (in sq. km.)		
		Moalboal	Palomoc	Poblacion Muslim
Affected Area (sq. km.)	1	3.71	4.6	0.41
	2	0.18	0.27	0.029
	3	0.19	0.23	0.026
	4	0.21	0.13	0.013
	5	0.11	0.088	0.02
	6	0.03	0.015	0

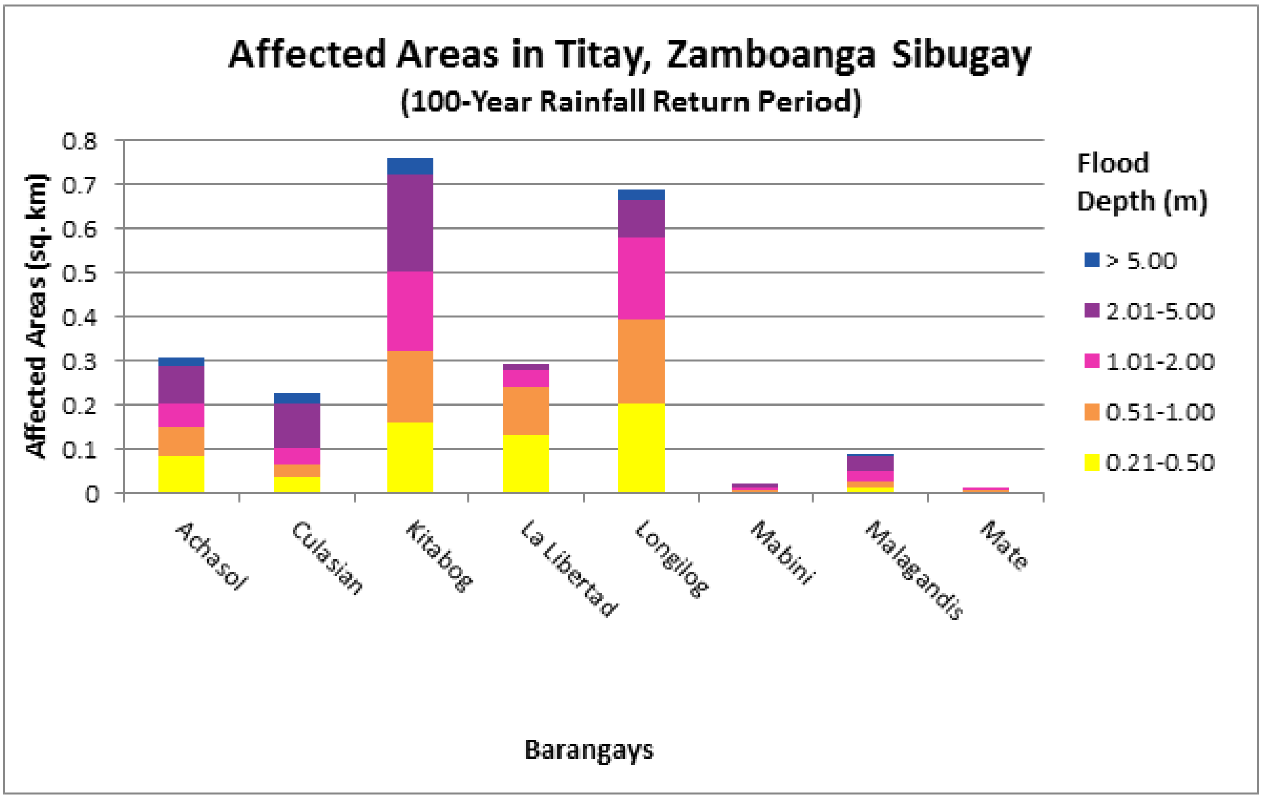


Figure 85. Affected Areas in Titay, Zamboanga Sibugay during 100-Year Rainfall Return Period

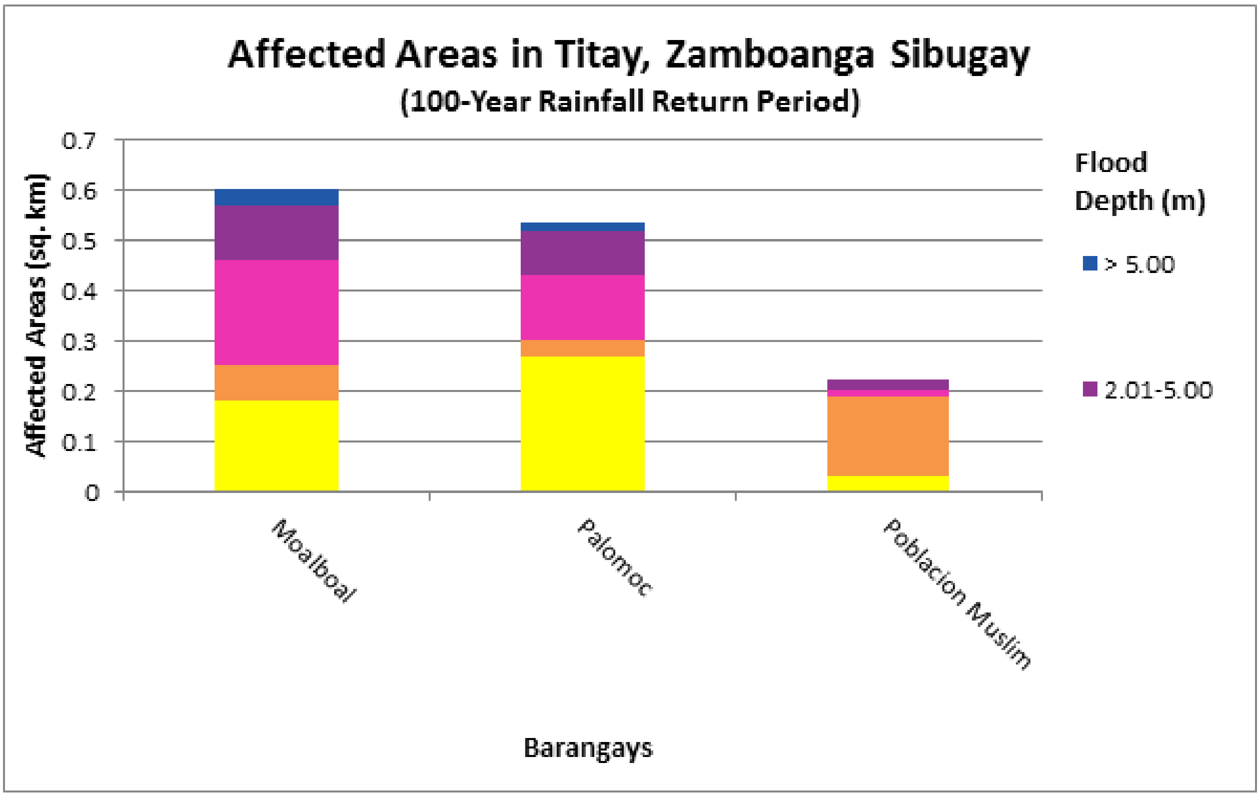


Figure 86. Affected Areas in Titay, Zamboanga Sibugay during 100-Year Rainfall Return Period

Moreover, the generated flood hazard maps for the Sanito 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 44. 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	4.90	4.84	4.95
Medium	5.73	7.0039	6.40
High	2.19	5.70	9.019
TOTAL	12.73	17.54	20.37

Of the 26 identified educational institutions and buildings in Sanito Floodplain, 1 institution each was assessed to be exposed to the three flood hazard levels for the 25-year scenario. One institution was exposed to low flood hazard levels for the 100-year scenario while 2 were exposed to high flood hazard levels for the same scenario.

Of the 6 identified medical institutions in Sanito Floodplain, none was assessed to be exposed to any flood hazard level in any rainfall scenario.

See Annex 12 and Annex 13 for a detailed enumeration of schools, hospitals and clinics in the Sanito.

5.11 Flood Validation

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

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

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

The actual data from the field were compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and improve on the results of the flood map.

The flood validation consists of 189 points randomly selected all over the Sanito Floodplain. It has an RMSE value of 0.29.

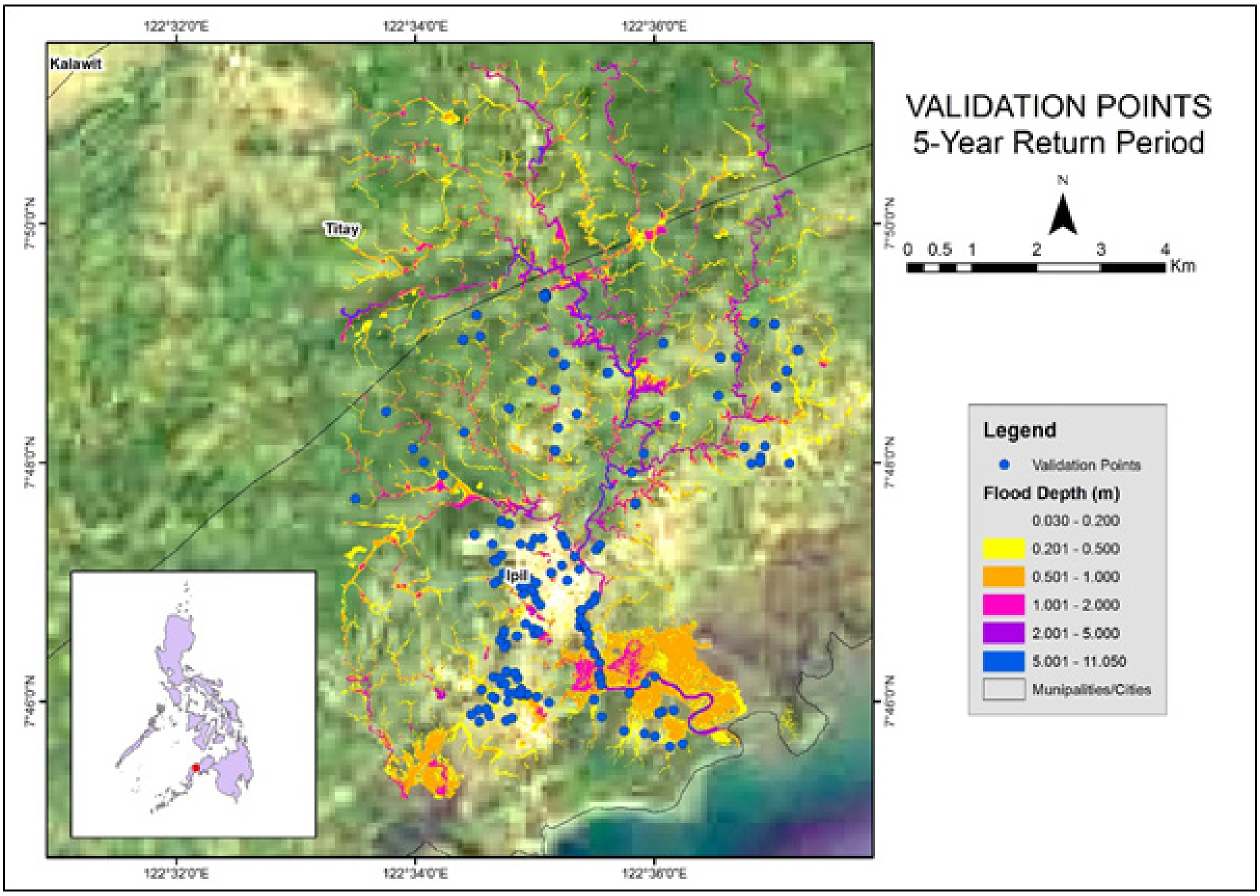


Figure 87. Validation points for 5-year Flood Depth Map of Sanito Floodplain

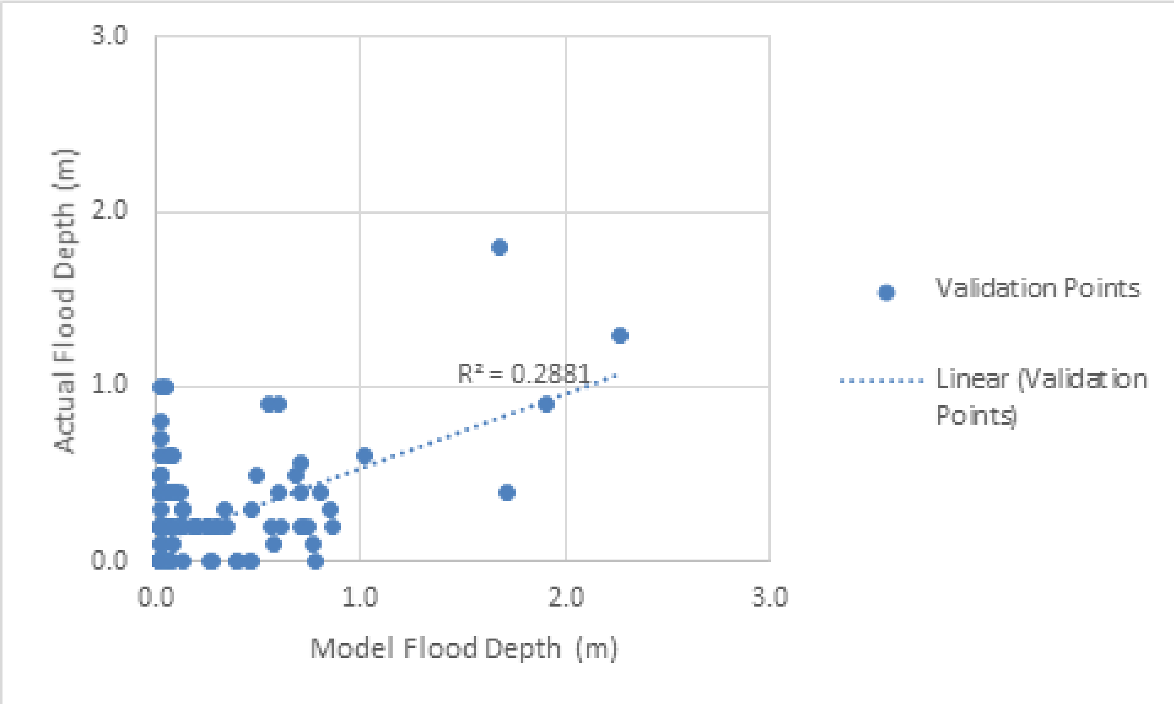


Figure 88. Flood map depth vs actual flood depth

Table 45. Actual Flood Depth vs Simulated Flood Depth in Sanito

Actual Flood Depth (m)	Modeled Flood Depth (m)						
	0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
0-0.20	119	15	9	0	0	0	143
0.21-0.50	22	3	5	1	0	0	31
0.51-1.00	8	0	3	2	0	0	13
1.01-2.00	0	0	0	1	1	0	2
2.01-5.00	0	0	0	0	0	0	0
> 5.00	0	0	0	0	0	0	0
Total	149	18	17	4	1	0	189

The overall accuracy generated by the flood model is estimated at 66.67%, with 126 points correctly matching the actual flood depths. In addition, there were 45 points estimated one level above and below the correct flood depths while there were 18 points estimated two levels above and below the correct flood. A total of 33 points were overestimated while a total of 30 points were underestimated in the modelled flood depths of Sanito.

Table 46. Summary of Accuracy Assessment in Sanito

	No. of Points	%
Correct	126	66.67
Overestimated	33	17.46
Underestimated	30	15.87
Total	189	100.00

REFERENCES

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

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

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

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

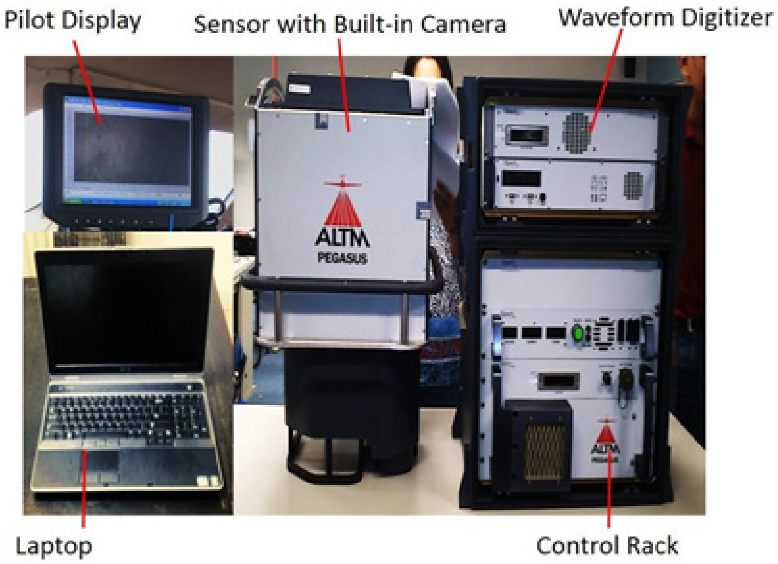
Paringit, E.C., Balicanta, L.P., Ang, M.C., Lagmay, A.F., Sarmiento, C. 2017, Flood Mapping of Rivers in the Philippines Using Airborne LiDAR: Methods. Quezon City, Philippines: UP Training Center for Applied Geodesy and Photogrammetry

Sarmiento C.J.S., Paringit E.C., et al. 2014. DREAM Data Aquisition 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)

ANNEXES

ANNEX 1. Technical Specifications of the LiDAR Sensors used in the Sanito Floodplain Survey



Parameter	Specification
Parameter	Specification
Operational envelope (1,2,3,4)	150-4000 m AGL, nominal
Laser wavelength	1064 nm
Horizontal accuracy (2)	1/5,500 x altitude, (m AGL)
Elevation accuracy (2)	<5-35 cm, 1 σ
Effective laser repetition rate	Programmable, 33-167 kHz
Position and orientation system	POS AV™ AP50 (OEM); 220-channel dual frequency GPS/GNSS/Galileo/L-Band receiver
Scan width (WOV)	Programmable, 0-50˚
Scan frequency (5)	Programmable, 0-70 Hz (effective)
Sensor scan product	1000 maximum
Beam divergence	Dual divergence: 0.25 mrad (1/e) and 0.8 mrad (1/e), nominal
Roll compensation	Programmable, ±5˚ (FOV dependent)
Range capture	Up to 4 range measurements, including 1st, 2nd, 3rd, and last returns
Intensity capture	Up to 4 intensity returns for each pulse, including last (12 bit)
Video Camera	Internal video camera (NTSC or PAL)
Image capture	Compatible with full Optech camera line (optional)
Full waveform capture	12-bit Optech IWD-2 Intelligent Waveform Digitizer (optional)
Data storage	Removable solid state disk SSD (SATA II)
Power requirements	28 V; 900 W;35 A(peak)

Dimensions and weight	Sensor: 260 mm (w) x 190 mm (l) x 570 mm (h); 23 kg Control rack: 650 mm (w) x 590 mm (l) x 530 mm (h); 53 kg
Operating temperature	-10˚C to +35˚C (with insulating jacket)
Relative humidity	0-95% no-condensing

ANNEX 2. NAMRIA Certification of Reference Points Used in the LiDAR Survey

1. ZGS-58

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

February 24, 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 DEL SUR**
Station Name: **ZGS-58**
Order: **2nd**

Island: **MINDANAO**
Municipality: **KUMALARANG**
Barangay: **SICADE**
MSL Elevation:

PRS92 Coordinates

Latitude: **7° 45' 44.20587"**	Longitude: **123° 8' 50.40994"**	Ellipsoidal Hgt: **31.65000 m.**

WGS84 Coordinates

Latitude: **7° 45' 40.67639"**	Longitude: **123° 8' 55.89231"**	Ellipsoidal Hgt: **96.97400 m.**

PTM / PRS92 Coordinates

Northing: **858266.608 m.**	Easting: **516251.478 m.**	Zone: **4**

UTM / PRS92 Coordinates

Northing: **857,966.20**	Easting: **516,245.79**	Zone: **51**

Location Description

ZGS-58
Is located about 200 m. NNE of the intersection of the national highway and the road going to Poblacion, Kumalarang. It is about 190 m. NE of the PNP Checkpoint and Collection post, 190 m. NNE of a waiting shed and 400 m. NNE of ZGS-59. Mark is the head of a 3 in. copper nail embedded and centered on a 30 cm. x 30 cm. cement putty, with inscriptions "ZGS-58 2005 NAMRIA/LEP-IX".

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8089868 I**
T.N.: **2016-0411**

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

9 9 0 2 2 4 2 0 1 6 1 4 0 3 2 1

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

2. ZGS-68

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

February 10, 2016

CERTIFICATION

To whom it may concern:

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

Province: **ZAMBOANGA DEL SUR**
Station Name: **ZGS-68**
Order: **2nd**

Island: **MINDANAO**	Barangay: **POBLACION**		
Municipality: **GUIPOS**	MSL Elevation:		
	PRS92 Coordinates		
Latitude: **7° 43' 33.12722"**	Longitude: **123° 18' 48.96041"**	Ellipsoidal Hgt:	**205.94100 m.**
	WGS84 Coordinates		
Latitude: **7° 43' 29.62251"**	Longitude: **123° 18' 54.44472"**	Ellipsoidal Hgt:	**271.74800 m.**
	PTM / PRS92 Coordinates		
Northing: **854250.138 m.**	Easting: **534593.845 m.**	Zone:	**4**
	UTM / PRS92 Coordinates		
Northing: **853,951.14**	Easting: **534,581.74**	Zone:	**51**

Location Description

ZGS-68
Is located on the lot of the CENRO of Guipos. It is on the E end of the S sidewalk along the entrance way of CENRO from the national road, 15 m. E of the said office and 2.5 m. from the centerline of the driveway. Mark is the head of a 3 in. copper nail embedded and centered on a 30 cm. x 30 cm. cement putty, with inscriptions "ZGS-68 2005 NAMRIA/LEP-IX".

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8089774 I**
T.N.: **2016-0335**

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

2. ZSI-52

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

August 29, 2014

CERTIFICATION

To whom it may concern:

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

Province: **ZAMBOANGA SIBUGAY**
Station Name: **ZSI-52**
Order: **2nd**

Island: **MINDANAO**	Barangay: **TUPILAC**	
Municipality: **TUNGAWAN**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **7° 37' 50.78279"**	Longitude: **122° 27' 1.47785"**	Ellipsoidal Hgt: **10.41300 m.**
	WGS84 Coordinates	
Latitude: **7° 37' 47.22473"**	Longitude: **122° 27' 6.97710"**	Ellipsoidal Hgt: **74.25700 m.**
	PTM / PRS92 Coordinates	
Northing: **843760.188 m.**	Easting: **439359.616 m.**	Zone: **4**
	UTM / PRS92 Coordinates	
Northing: **843,464.86**	Easting: **439,380.84**	Zone: **51**

Location Description

ZSI-52
Station is along the national highway (Zamboanga City - Ipil), right side when Ipil bound and about 50 m N of Tupilac Br. (KM 1824 + 692.738 m). 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-52 2006 NAMRIA/LEP.

Requesting Party: **ENGR. CHRISTOPHER CRUZ**
Purpose: **Reference**
OR Number: **8799780 A**
T.N.: **2014-1900**

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

9 9 0 8 2 9 2 0 1 4 1 3 4 1 1 4

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

ANNEX 3. Baseline Processing Reports of Reference Points Used

ZY-93A

Vector Components (Mark to Mark)

From:	ZSI-52				
Grid		Local		Global	
Easting	439380.842 m	Latitude	N7°37'50.78279"	Latitude	N7°37'47.22473"
Northing	843464.857 m	Longitude	E122°27'01.47785"	Longitude	E122°27'06.97710"
Elevation	6.077 m	Height	10.412 m	Height	74.257 m

To:	ZY-93A				
Grid		Local		Global	
Easting	439338.090 m	Latitude	N7°37'46.78582"	Latitude	N7°37'43.22802"
Northing	843342.174 m	Longitude	E122°27'00.08763"	Longitude	E122°27'05.58699"
Elevation	6.332 m	Height	10.662 m	Height	74.508 m

Vector					
ΔEasting	-42.752 m	NS Fwd Azimuth	199°08'21"	ΔX	27.074 m
ΔNorthing	-122.683 m	Ellipsoid Dist.	129.965 m	ΔY	36.828 m
ΔElevation	0.255 m	ΔHeight	0.250 m	ΔZ	-121.662 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'01"	σ ΔX	0.001 m
σ ΔNorthing	0.000 m	σ Ellipsoid Dist.	0.000 m	σ ΔY	0.001 m
σ ΔElevation	0.001 m	σ ΔHeight	0.001 m	σ ΔZ	0.000 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000003923		
Y	-0.0000001965	0.0000005184	
Z	-0.0000000755	0.0000000586	0.0000000887

ANNEX 4. The LiDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency/ Affiliation
PHIL-LiDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
		ENGR. LOUIE P. BALICANTA	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
LiDAR Operation	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	UP-TCAGP
		LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	JASMINE ALVIAR	UP-TCAGP
		PAULINE JOANNE ARCEO	
	Research Associate (RA)	ENGR. IRO NIEL ROXAS	UP-TCAGP
		KRISTINE JOY ANDAYA	
		ENGR. KENNETH QUISADO	
		ENGR. GRACE SINADJAN	
Ground Survey, Data Download and Transfer	RA	ENGR. RENAN PUNTO	UP-TCAGP
		JASMIN DOMINGO	
LiDAR Operation	Airborne Security	SSG. RONALD MONTENEGRO	PHILIPPINE AIR FORCE (PAF)
		SSG. LEE JAY PUNZALAN	
	Pilot	CAPT. CESAR SHERWIN ALFONSO III	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. JOHN BRYAN DONGUINES	
		CAPT. JERICHO JECIEL	

ANNEX 5. Data Transfer Sheet for Sanito Floodplain

DATA TRANSFER SHEET
02/24/2015(Zamboanga)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
5-Feb-15	2535P	1BLK75E36A	PEGASUS	2.95	2608	12.7	232	43.6	360	30.7	NA	7.53	1KB	1KB	38	NA	Z:\DAC\RAW DATA
6-Feb-15	2537P	1BLK75C37A	PEGASUS	3.55	1872	13.9	263	52.4	410	35.8	NA	8.2	1KB	1KB	38	NA	Z:\DAC\RAW DATA
6-Feb-15	2539P	1BLK75C37B	PEGASUS	1.37	332	7.95	175	25.2	222	17.6	NA	8.2	1KB	1KB	38	NA	Z:\DAC\RAW DATA
7-Feb-15	2545P	1BLK75C39A	PEGASUS	2.33	473	11.3	259	41.7	305	26.2	NA	7.77	1KB	1KB	70/76	NA	Z:\DAC\RAW DATA
9-Feb-15	2549P	1BLK75A40A	PEGASUS	3.95	2608	10.9	230	32.6	244	22.3	NA	4.37	1KB	1KB	NA	NA	Z:\DAC\RAW DATA
10-Feb-15	2553P	1BLK75S41A	PEGASUS	2.03	566	11.3	256	31.9	247	22.4	NA	6.81	1KB	1KB	89	NA	Z:\DAC\RAW DATA
11-Feb-15	2557P	1BLK75S42A	PEGASUS	1.62	301	10.6	255	34.9	240	20.5	NA	8.47	1KB	1KB	31/88	NA	Z:\DAC\RAW DATA

Received from

Name C JOAQUIN
Position
Signature

Received by

Name AC BONGAT
Position GSRS
Signature

DATA TRANSFER SHEET
PAGADIAN 3/7/16

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
02/20/2016	23116P	1BLK76NO051A	Pegasus	2.29 GB	NA	11.9 MB	294 MB	NA	NA	24.4 GB	0 B	63.8 MB	2KB	2KB	148/252/232	NA	Z:\DAC\RAW DATA
02/21/2016	23120P	1BLK69D052A	Pegasus	2.6 GB	NA	12 MB	298 MB	22.5 GB	NA	25.9 GB	0 B	59.6 MB	2KB	1KB	580/100/91/8 2	NA	Z:\DAC\RAW DATA
02/22/2016	23124P	1BLK69AB053A	Pegasus	1.89 GB	NA	11.4 MB	270 MB	NA	NA	21.1 GB	0 B	3.12 MB	1KB	NA	125/108/98/8 7/78/76	NA	Z:\DAC\RAW DATA
02/23/2016	23128P	1BLK70B054A	Pegasus	2.22 GB	NA	12.8 MB	273 MB	311 MB	NA	23.3	0 B	44.4 MB	1KB	NA	92/90/80/73	NA	Z:\DAC\RAW DATA
02/24/2016	23132P	1BLK73A055A	Pegasus	10.3 MB	NA	12.5 MB	266 MB	NA	NA	24.4 GB	0 B	49.7 MB	2KB	1KB	84/84/72/76/5 7	NA	Z:\DAC\RAW DATA
02/26/2016	23140P	1BLK73BS057A	Pegasus	2.47 GB	NA	13.5 MB	305 MB	NA	NA	26.5 GB	0 B	65.9 MB	2KB	1KB	85/83	NA	Z:\DAC\RAW DATA

Received from

Name R. PUNTO
Position RA
Signature

Received by

Name AC Bongat
Position SSRS
Signature 3/10/16

ANNEX 6. Flight logs for the flight missions

1. Flight Log for 1BLK75A40A Mission

Flight Log No.: 25441

PHIL-LIDAR 1 Data Acquisition Flight Log

1 LiDAR Operator: I. Roxas	2 ALTM Model: Pegasus	3 Mission Name: 1BLK 75A40A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9022
7 Pilot: C. Alfonso	8 Co-Pilot: B. Donguines	9 Route: Zambo - Zambo			
10 Date: Feb 9, 2015	12 Airport of Departure (Airport, City/Province): Zambo		12 Airport of Arrival (Airport, City/Province): Zambo		
13 Engine On: 1103 H	14 Engine Off: 1524 H	15 Total Engine Time: 4+21	16 Take off: 1108 H	17 Landing: 1521 H	18 Total Flight Time: 4+13
19 Weather	Partly Cloudy				

20 Remarks:

Surveyed gaps in BLK 75 C, D, E, FS;

21 Problems and Solutions:

abnormal program termination; POS still writing

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
S. Aviar	Ed Santos	Alfonso III	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

2. Flight Log for 1BLK75AS41A Mission

Data Acquisition Flight Log

Flight Log No.: 2553

Operator: I. Roxas	2 ALTM Model: Pegasus	3 Mission Name: 1BLK75AS41A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
C. Alfonso	8 Co-Pilot: B. Donguines	9 Route: Zambo – Zambo			
Date: Feb. 10, 2015	12 Airport of Departure (Airport, City/Province): Zamboanga		12 Airport of Arrival (Airport, City/Province): Zambo		
Engine On: 0919 H	14 Engine Off: 1330 H	15 Total Engine Time: 4+11	16 Take off: 0929 H	17 Landing: 1325 H	18 Total Flight Time: 4+01
Weather	partly cloudy				

Remarks:

Surveyed BLK 75AS; shortened mission due to security alert in Ipil-Tungawan area

Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
J. Alviar		Alfonso III	I. Roxas
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

3. Flight Log for 1BLK73A055A Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 23132P

1 LiDAR Operator: PJ Arceo	2 ALTM Model: Pegasus	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RPC9122
7 Pilot: C. Alfonso	8 Co-Pilot: J. Jeciel	9 Route:			
10 Date: 2/24/2016	12 Airport of Departure (Airport, City/Province): Pagadian, Zamboanga del Sur		12 Airport of Arrival (Airport, City/Province): Pagadian, Zamboanga del Sur		
13 Engine On: 7:54	14 Engine Off: 12:05	15 Total Engine Time: 4+11	16 Take off: 7:59	17 Landing: 12:00	18 Total Flight Time: 4+01
19 Weather: Fair					

20 Flight Classification

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

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

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

21 Remarks

Successful flight

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LIDAR Operator	Aircraft Mechanic/ LIDAR Technician
[signature]	Lee Jayne Pungalan	Alfonso III / C. Alfonso III	Pauline Joanne Arceo	NA
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

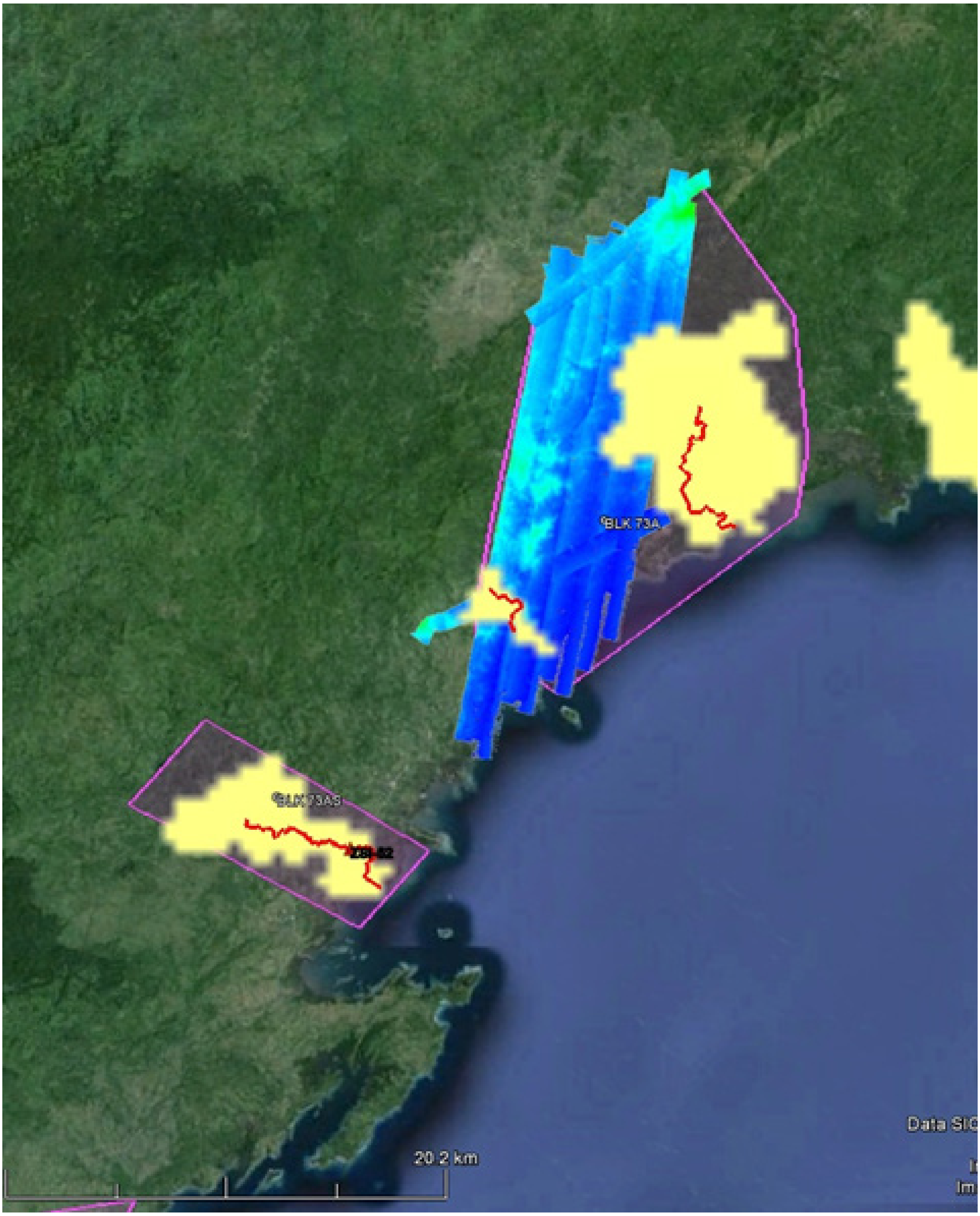
ANNEX 7. Flight status reports

ZAMBOANGA CITY-ZAMBOANGA SIBUGAY AND PAGADIAN-DIPOLOG REFLIGHTS
(February 9 - 10, 2015 and February 24, 2016)

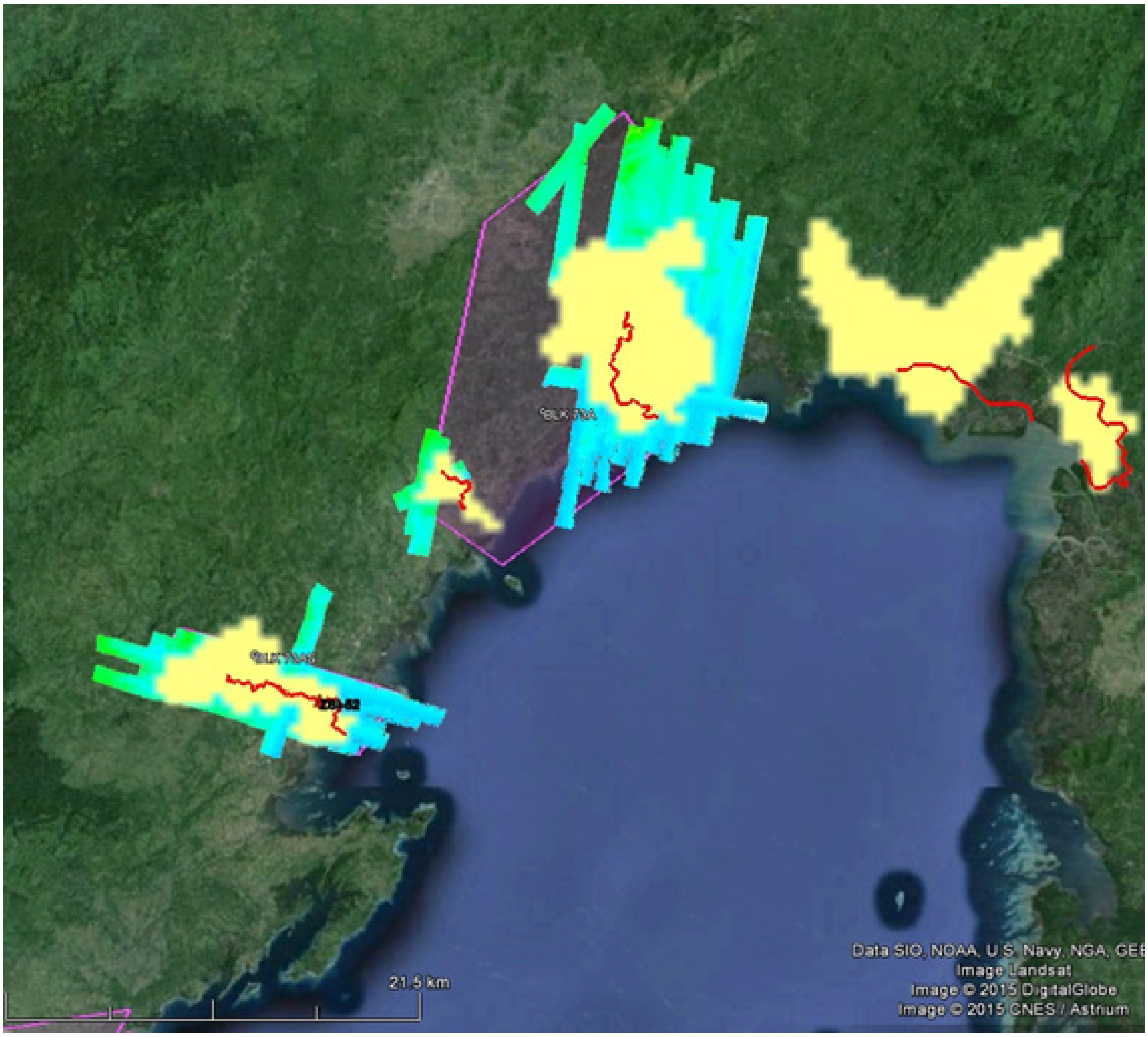
FLIGHT NO.	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
2549P	BLK 75A	1BLK75A40A	I. Roxas	February 9, 2015	AVPOSVIEW: Assertion failed; Abnormal program termination
2553P	BLK 75A, 75AS	1BLK75AS41A	I. Roxas	February 10, 2015	AVPOSVIEW Error; Assertion failed
23132P	BLK 73A, 73B	1BLK73A055A	PJ Arceo	February 24, 2016	Restarted the system several times due to sensor temperature increase. Encountered lost Channel A error. No LAS output. Surveyed floodplains over Zamboanga Sibugay.

LAS BOUNDARIES PER FLIGHT

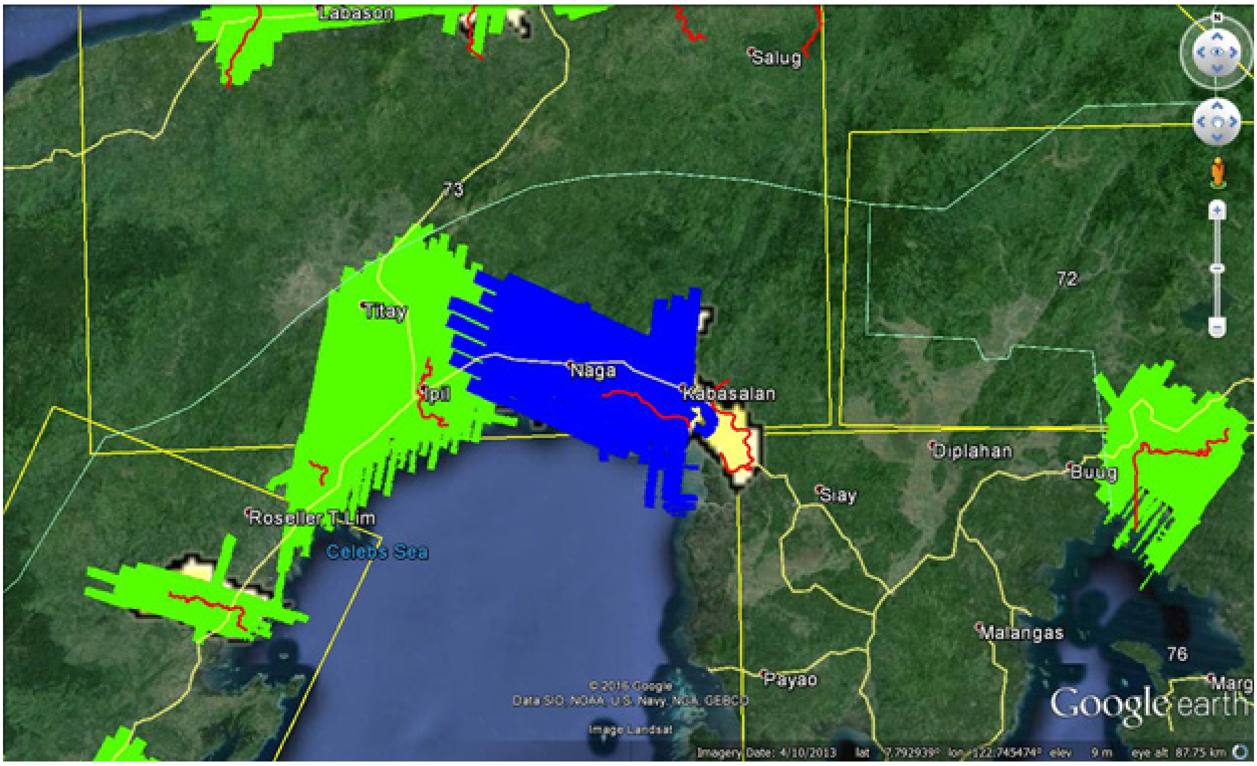
Flight No.:	2549P		
Area:	BLK 75A		
Mission Name:	1BLK75A40A		
Parameters:	Altitude: 1100 m;		Scan Frequency: 30 Hz;
	Scan Angle: 25 deg;		Overlap: 15%



Flight No.: 2553P
Area: BLK 75A, 75AS
Mission Name: 1BLK75AS41A
Parameters: Altitude: 1100 m; Scan Frequency: 30 Hz;
Scan Angle: 25 deg; Overlap: 15%



Flight No.:	23132P		
Area:	BLK 73A, 73B		
Mission Name:	1BLK73A055A		
Parameters:	Altitude:	800/1200 m;	Scan Frequency: 30 Hz;
	Scan Angle:	25 deg;	Overlap: 30%



ANNEX 8. Mission Summary Reports

Flight Area	Zamboanga
Mission Name	Blk75A
Inclusive Flights	2549P
Mission Name	1BLK75A040A
Range data size	22.3 GB
Base data size	4.37 MB
POS	230 MB
Image	32.6 GB
Transfer date	February 27 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.56
RMSE for East Position (<4.0 cm)	1.70
RMSE for Down Position (<8.0 cm)	5.17
Boresight correction stdev (<0.001deg)	0.000157
IMU attitude correction stdev (<0.001deg)	0.000581
GPS position stdev (<0.01m)	0.0015
Minimum % overlap (>25)	97.72%
Ave point cloud density per sq.m. (>2.0)	8.48
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	354
Maximum Height	557.68 m
Minimum Height	66.36 m
Classification (# of points)	
Ground	304,598,448
Low vegetation	274,936,506
Medium vegetation	485,051,123
High vegetation	1,075,136,316
Building	13,124,081
Orthophoto	YES
Processed by	Engr. Kenneth Solidum, Engr. Chelou Prado, Engr. Krisha Marie Bautista

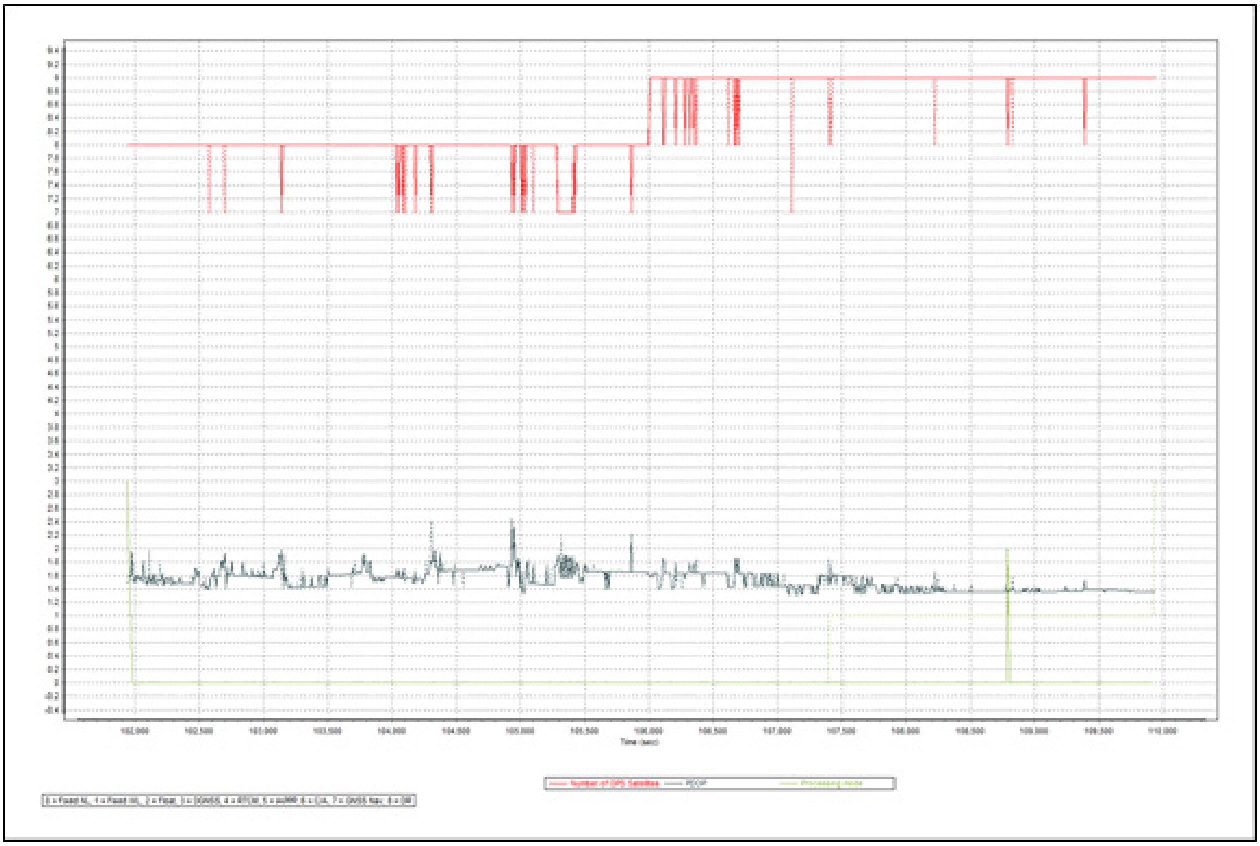


Figure A-8.1 Solution Status

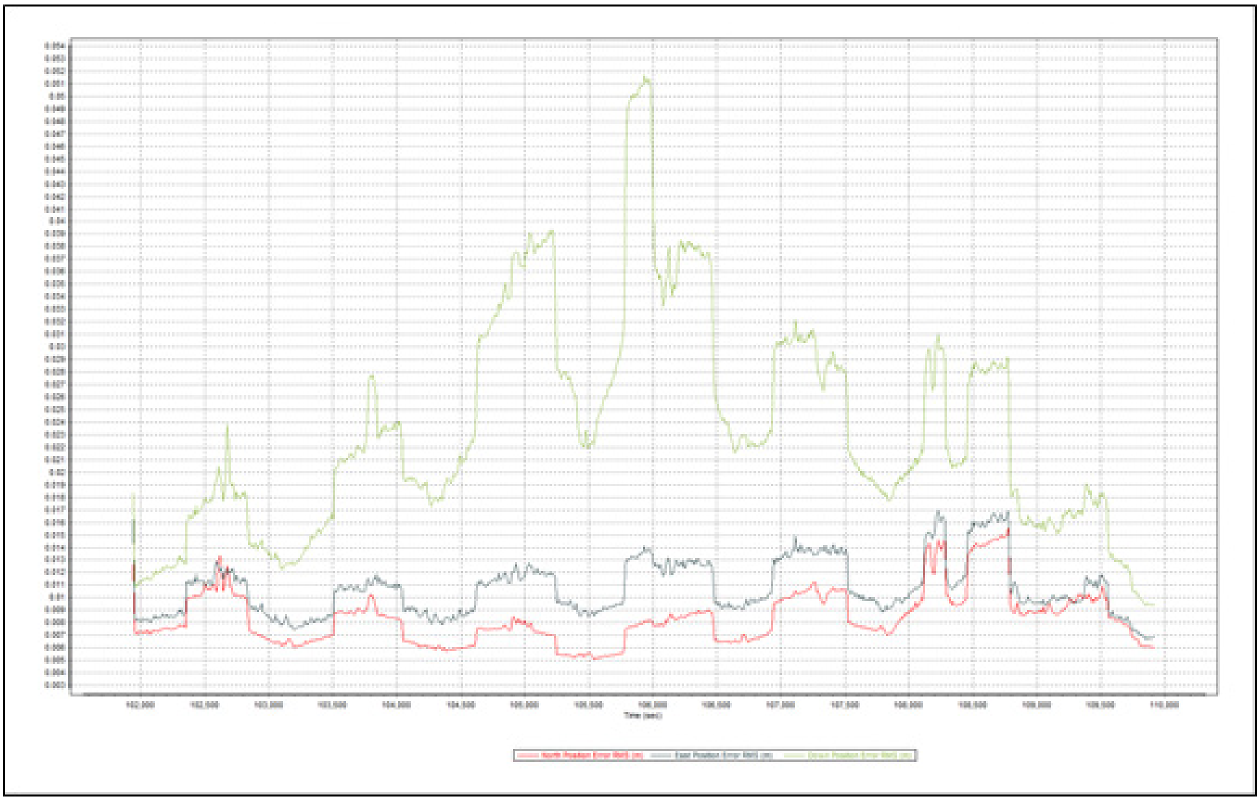


Figure A-8.2 Smoothed Performance Metric Parameters

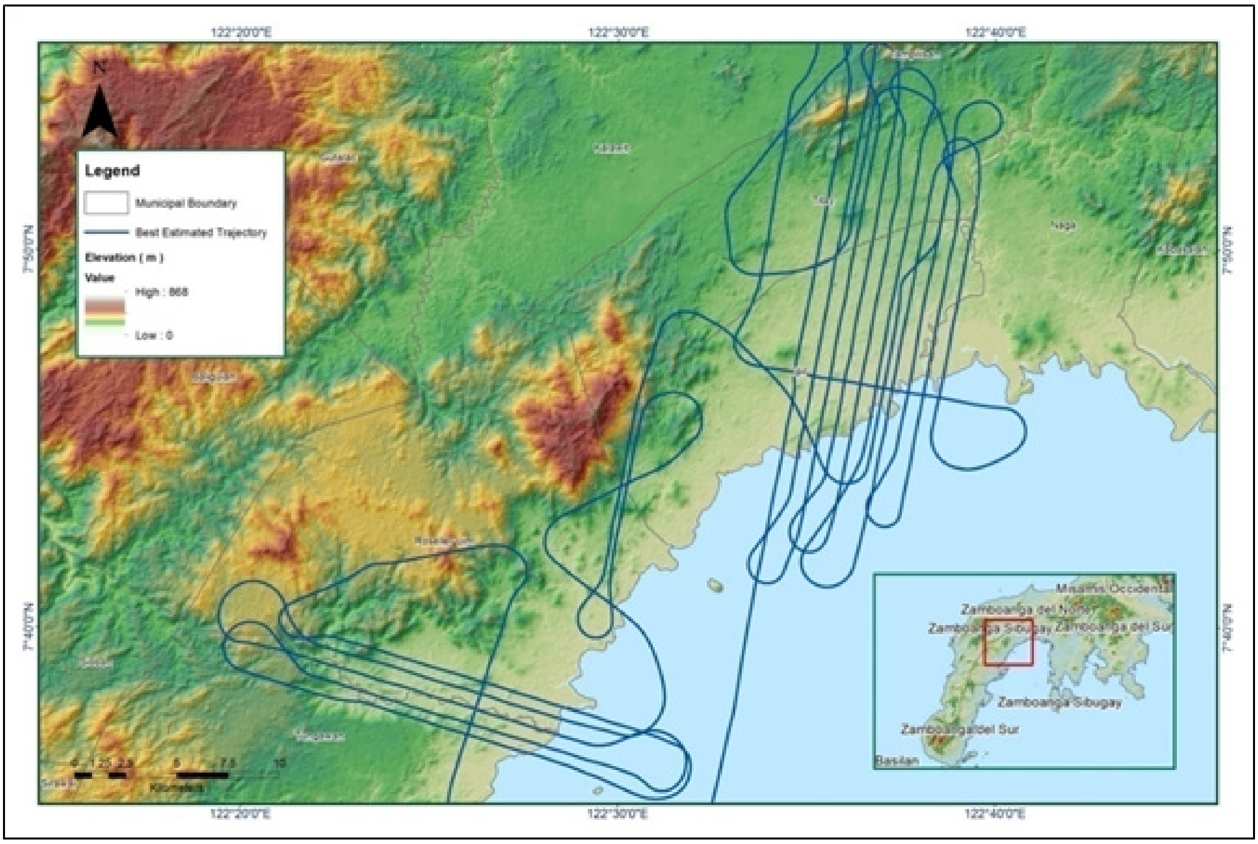


Figure A-8.3 Best Estimated Trajectory

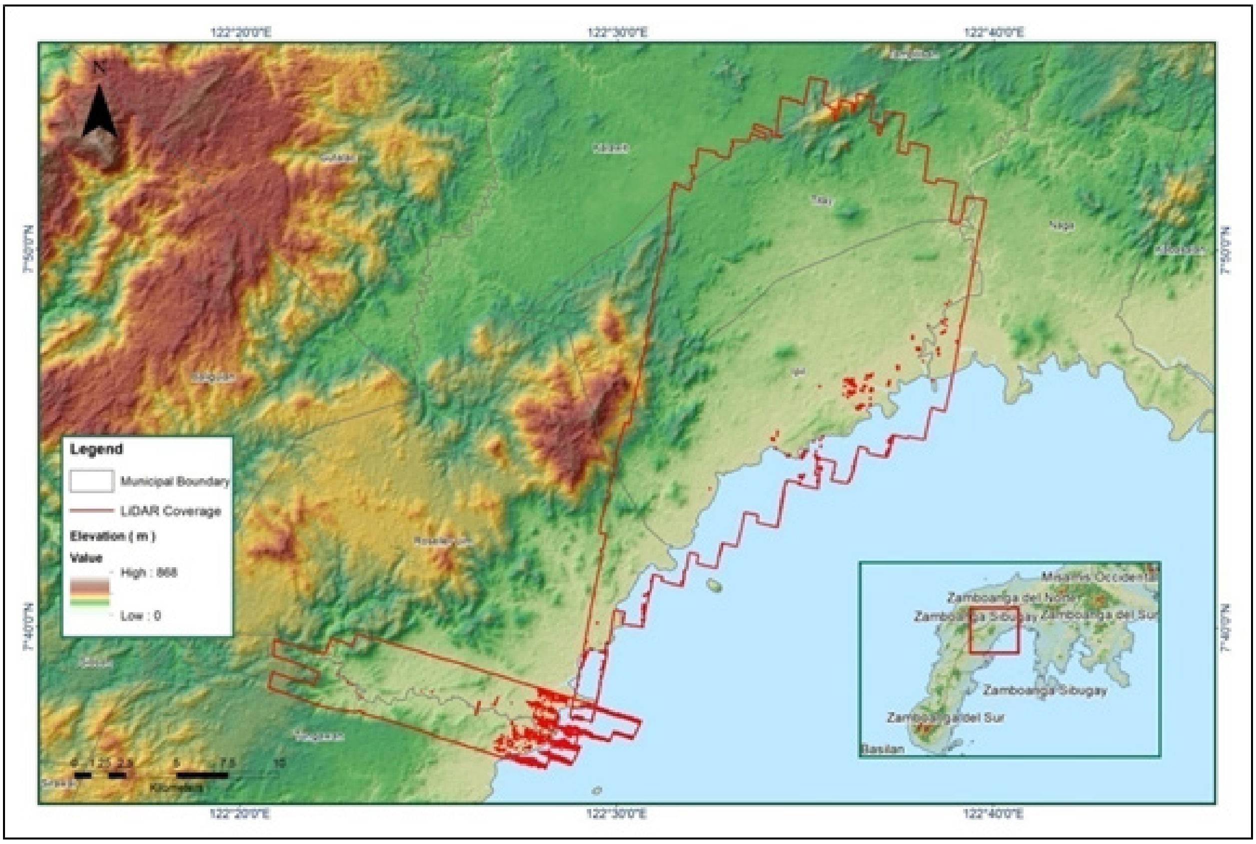


Figure A-8.4 Coverage of LiDAR data

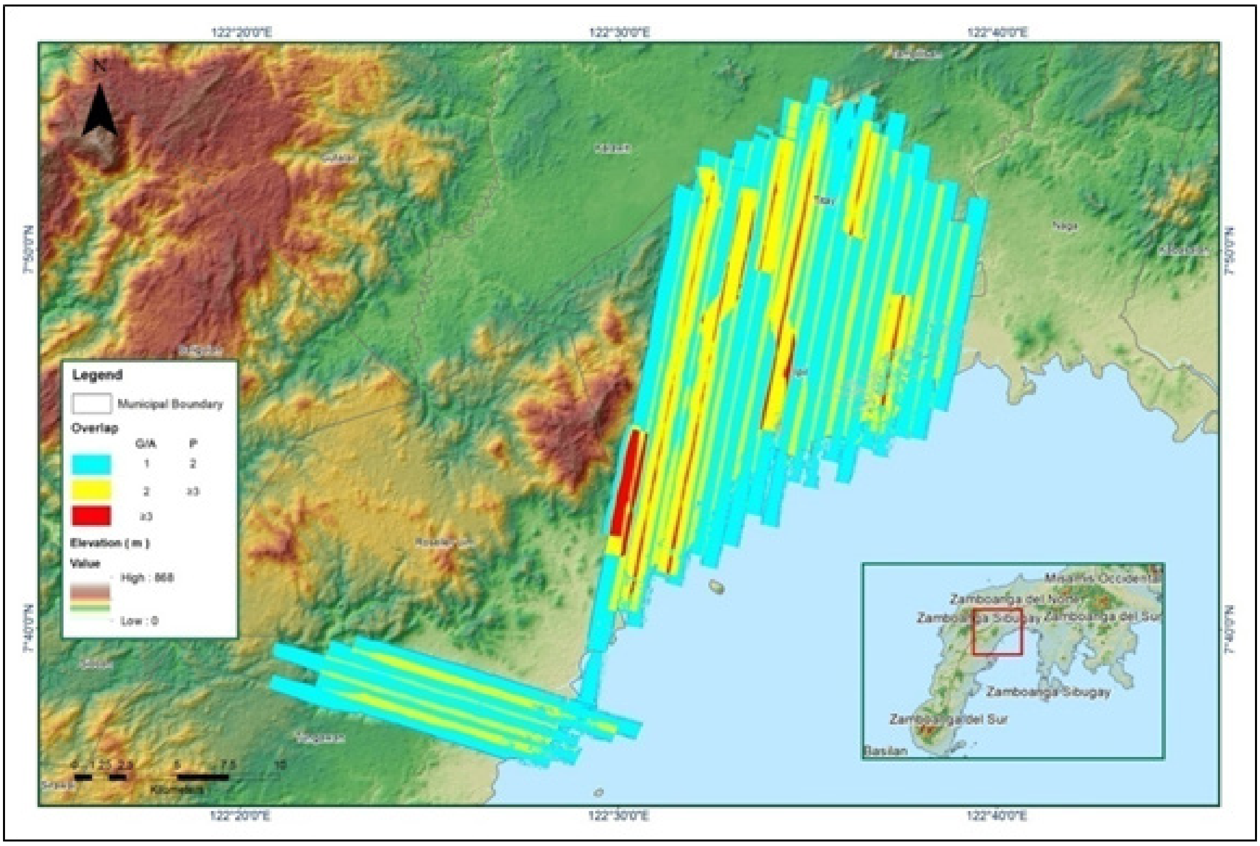


Figure A-8.5 Image of Data Overlap

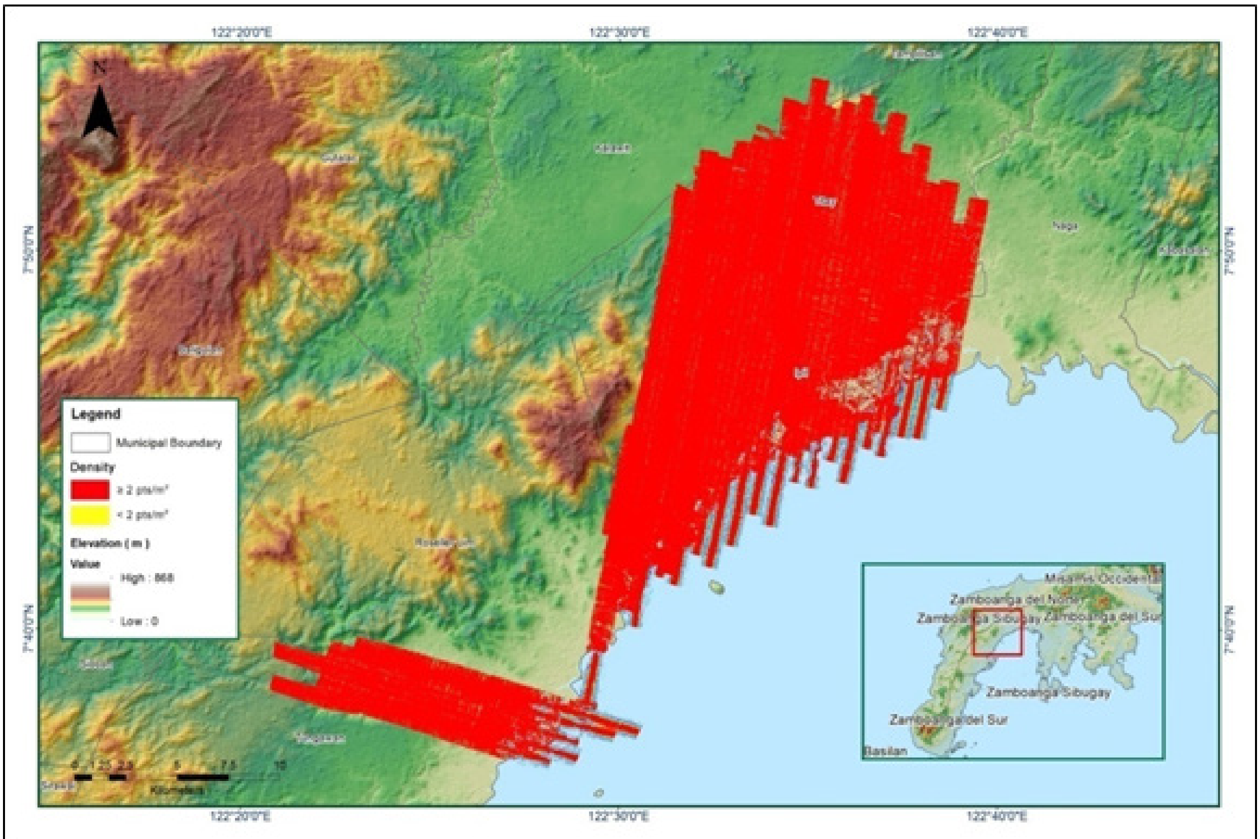


Figure A-8.6 Density map of merged LiDAR data

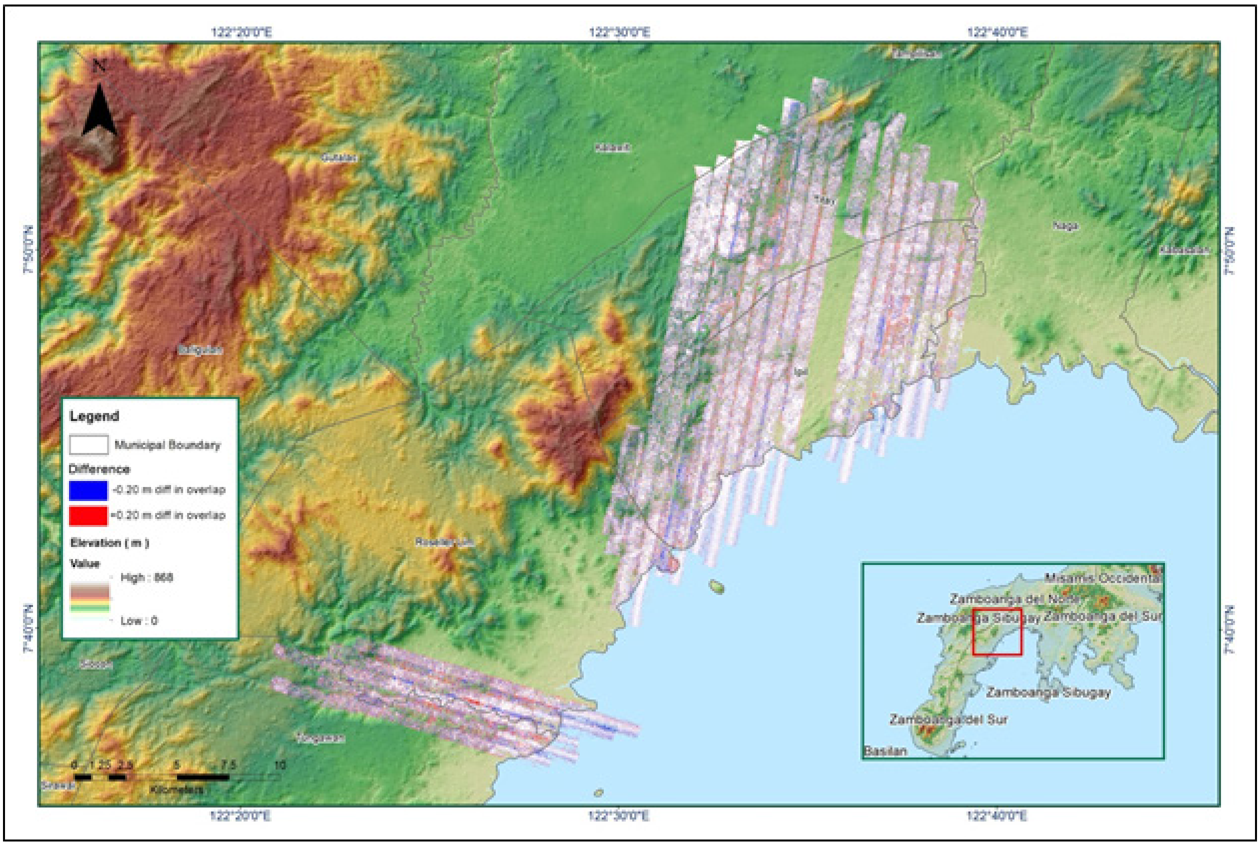


Figure A-8.7 Elevation difference between flight lines

Flight Area	Zamboanga
Mission Name	73A
Inclusive Flights	23132P
Mission Name	10.3 MB
Range data size	24.4
Base data size	266
POS	49.7
Image	n/a
Transfer date	March 10, 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)	3.3
RMSE for East Position (<4.0 cm)	2.6
RMSE for Down Position (<8.0 cm)	5.1
Boresight correction stdev (<0.001deg)	0.000238
IMU attitude correction stdev (<0.001deg)	0.002381
GPS position stdev (<0.01m)	0.0086
Minimum % overlap (>25)	45.26%
Ave point cloud density per sq.m. (>2.0)	3.04
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	235
Maximum Height	356.21 m
Minimum Height	58.38 m
Classification (# of points)	
Ground	151,535,157
Low vegetation	140,778,106
Medium vegetation	205,446,183
High vegetation	523,304,913
Building	5,697,858
Orthophoto	No
Processed by	Engr. Kenneth Solidum, Engr. Mark Joshua Salvacion, Engr. Ma. Ailyn Olanda

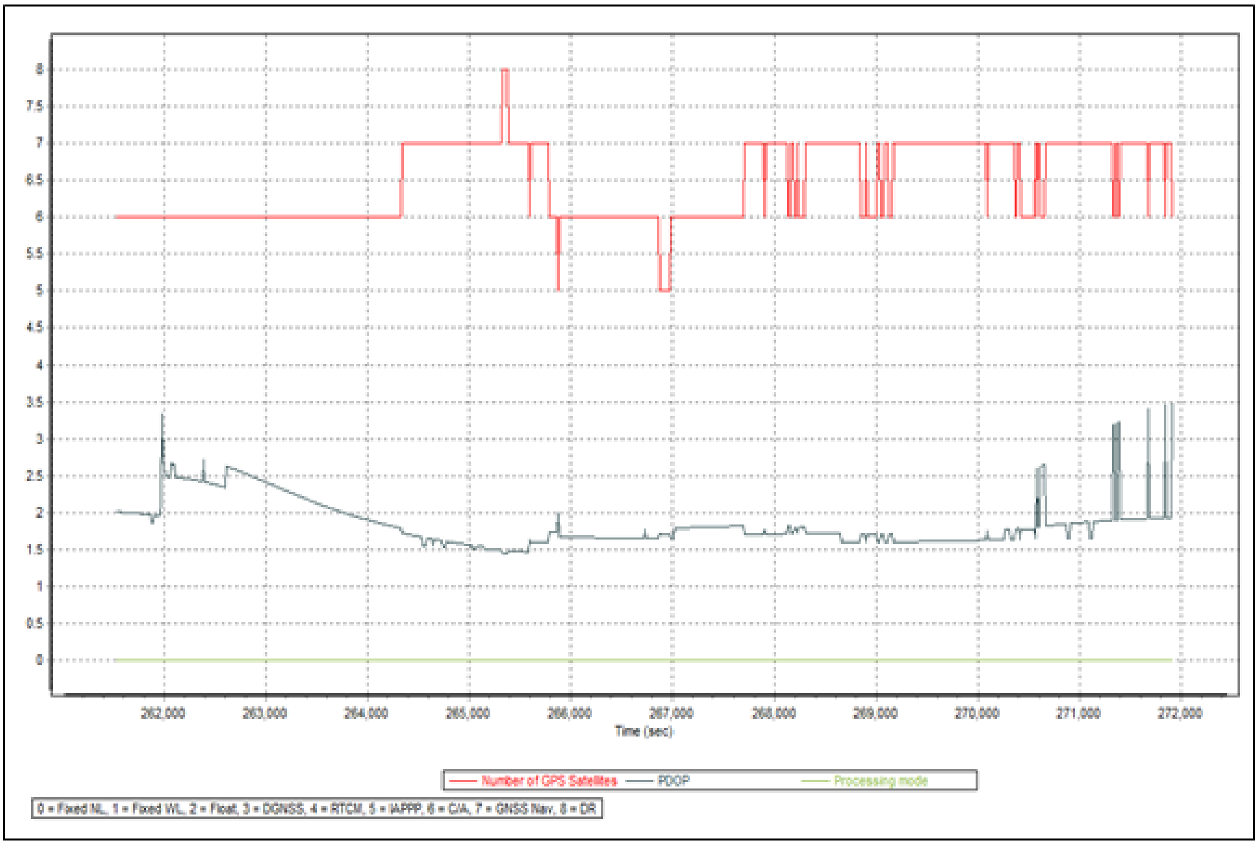


Figure A-8.8 Solution Status

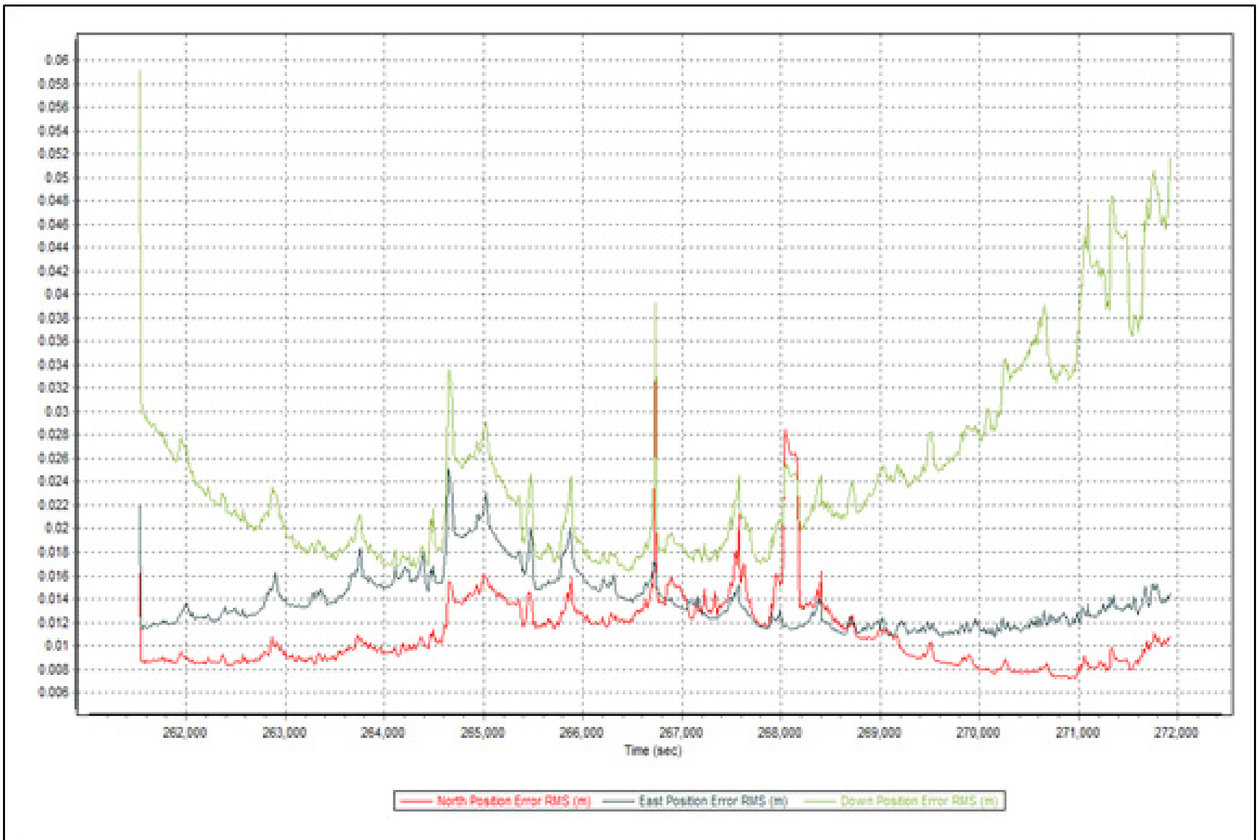


Figure A-8.9 Smoothed Performance Metric Parameters

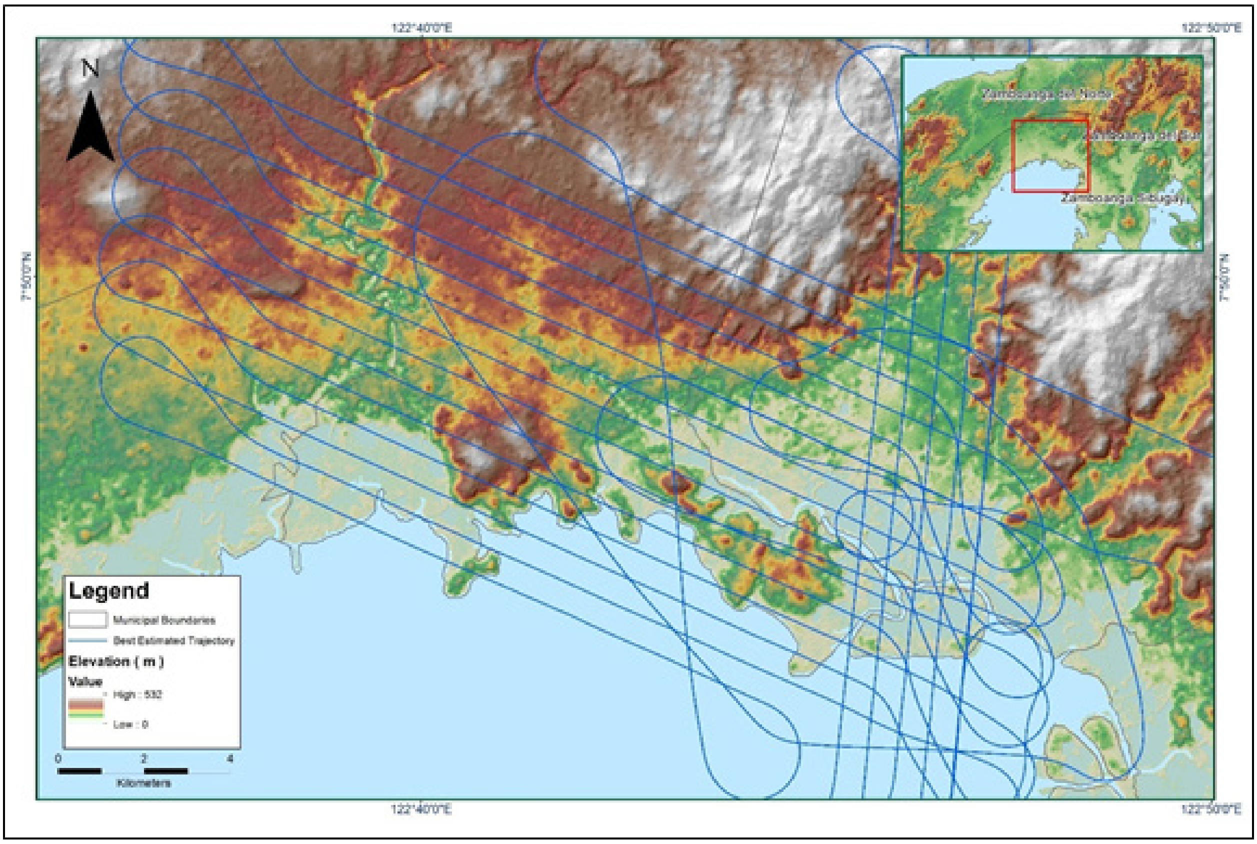


Figure A-8.10 Best Estimated Trajectory

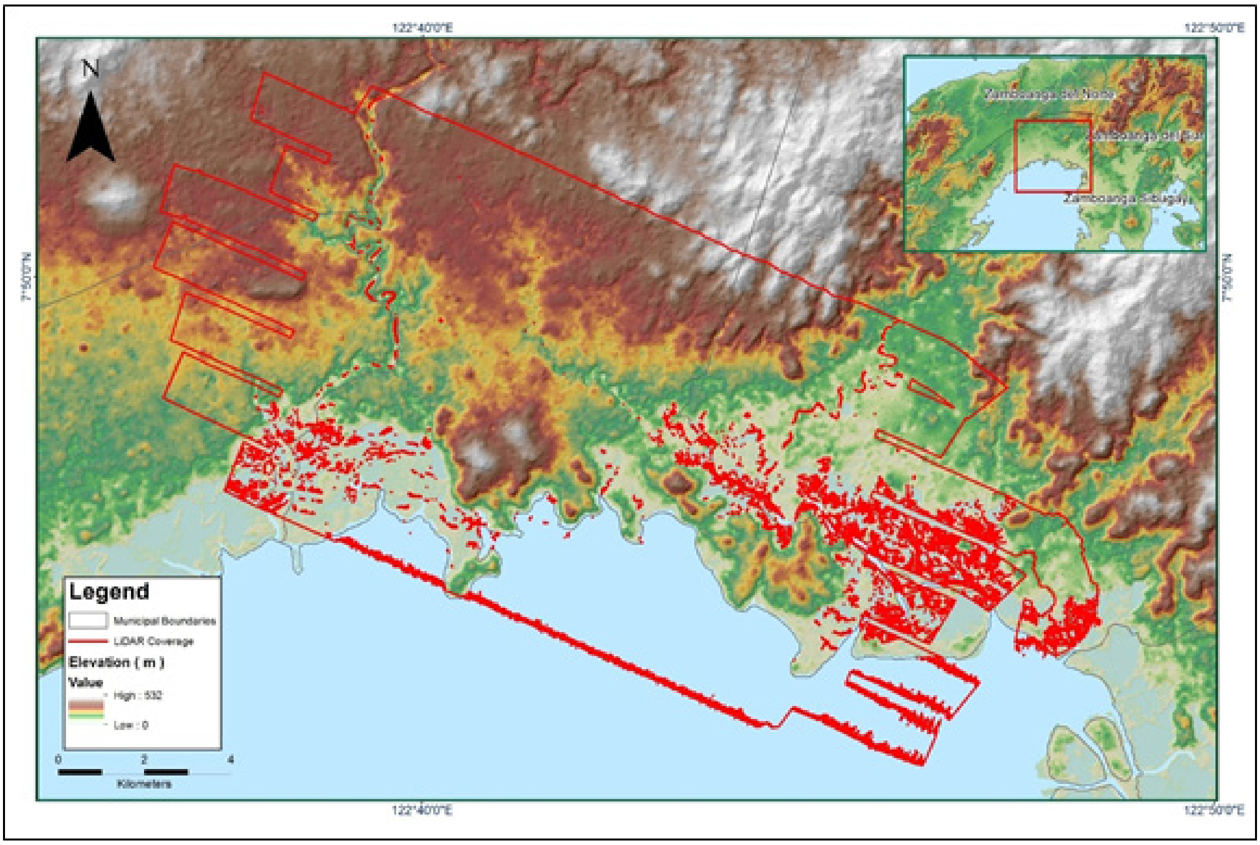


Figure A-8.11 Coverage of LiDAR data

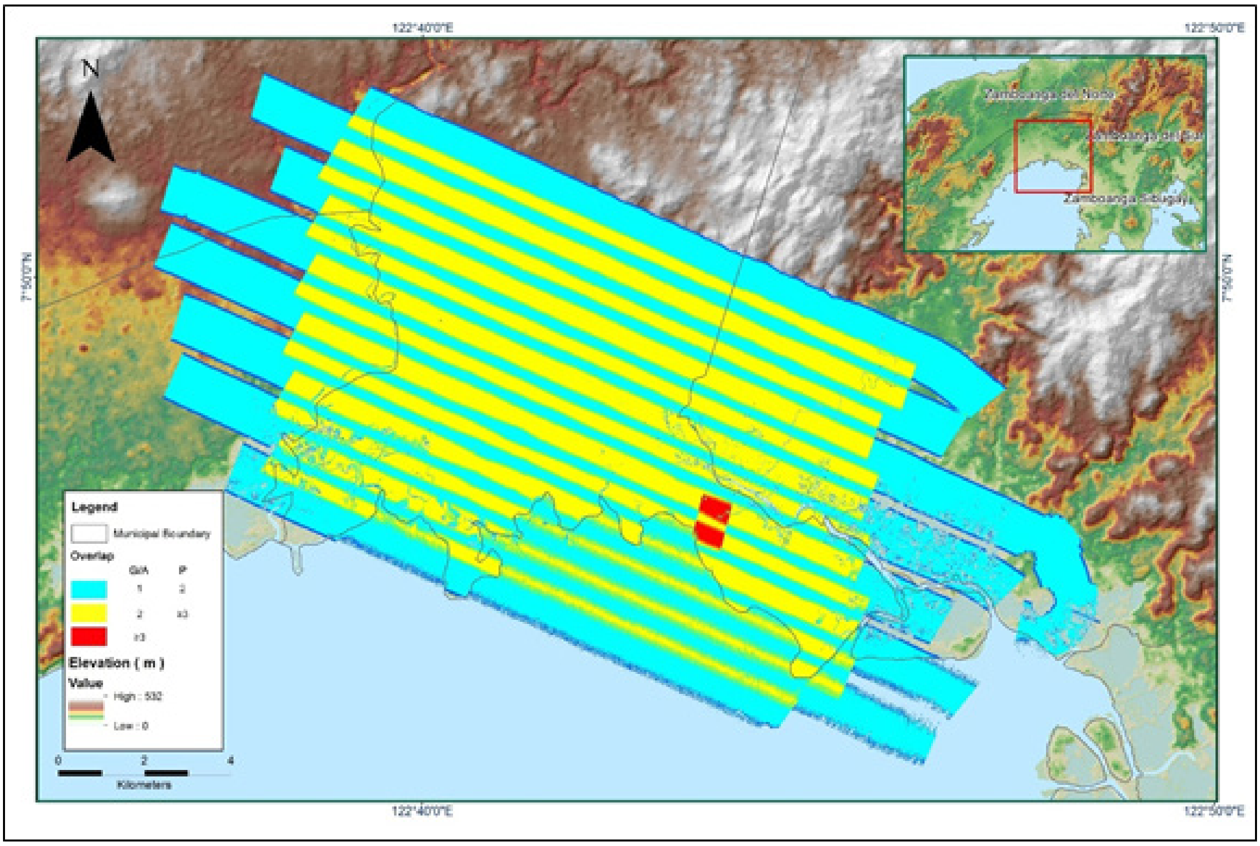


Figure A-8.12 Image of Data Overlap

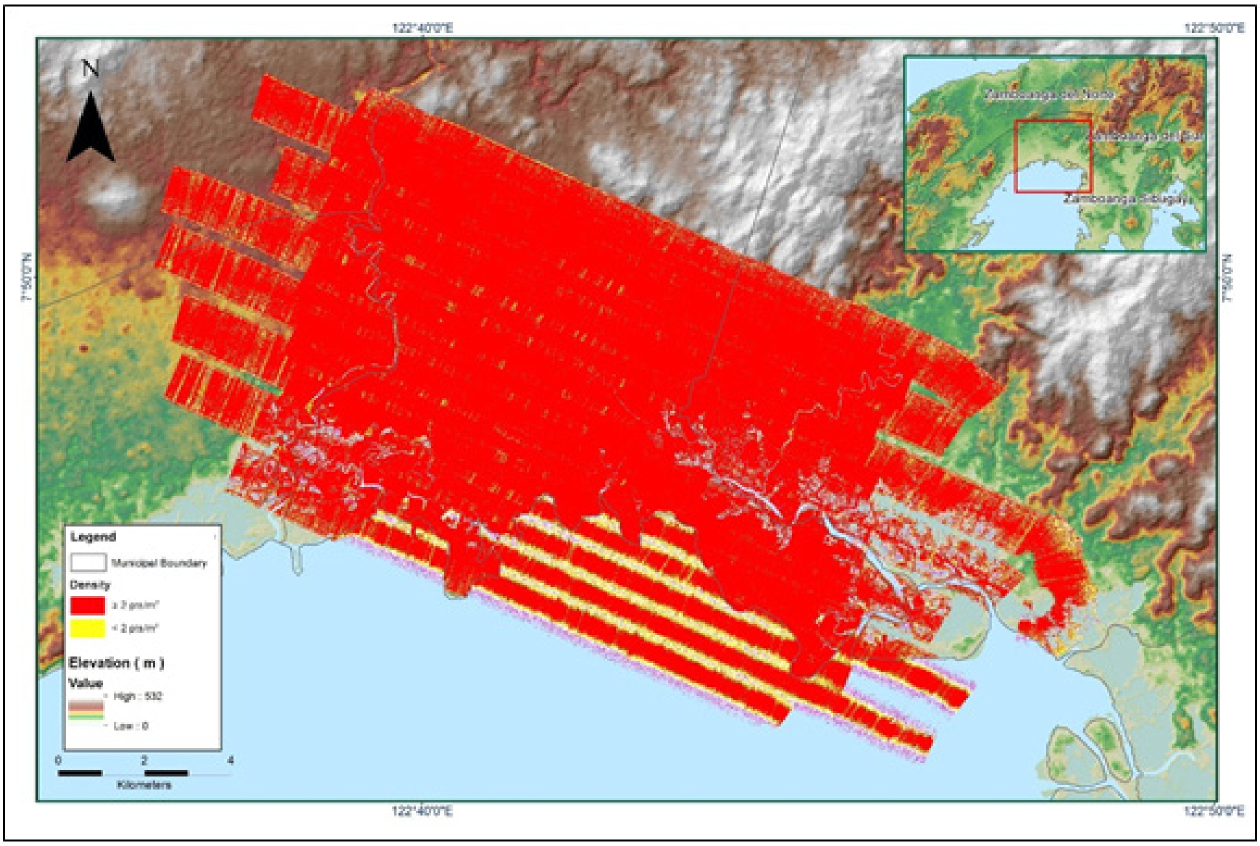


Figure A-8.13 Density map of merged LiDAR data

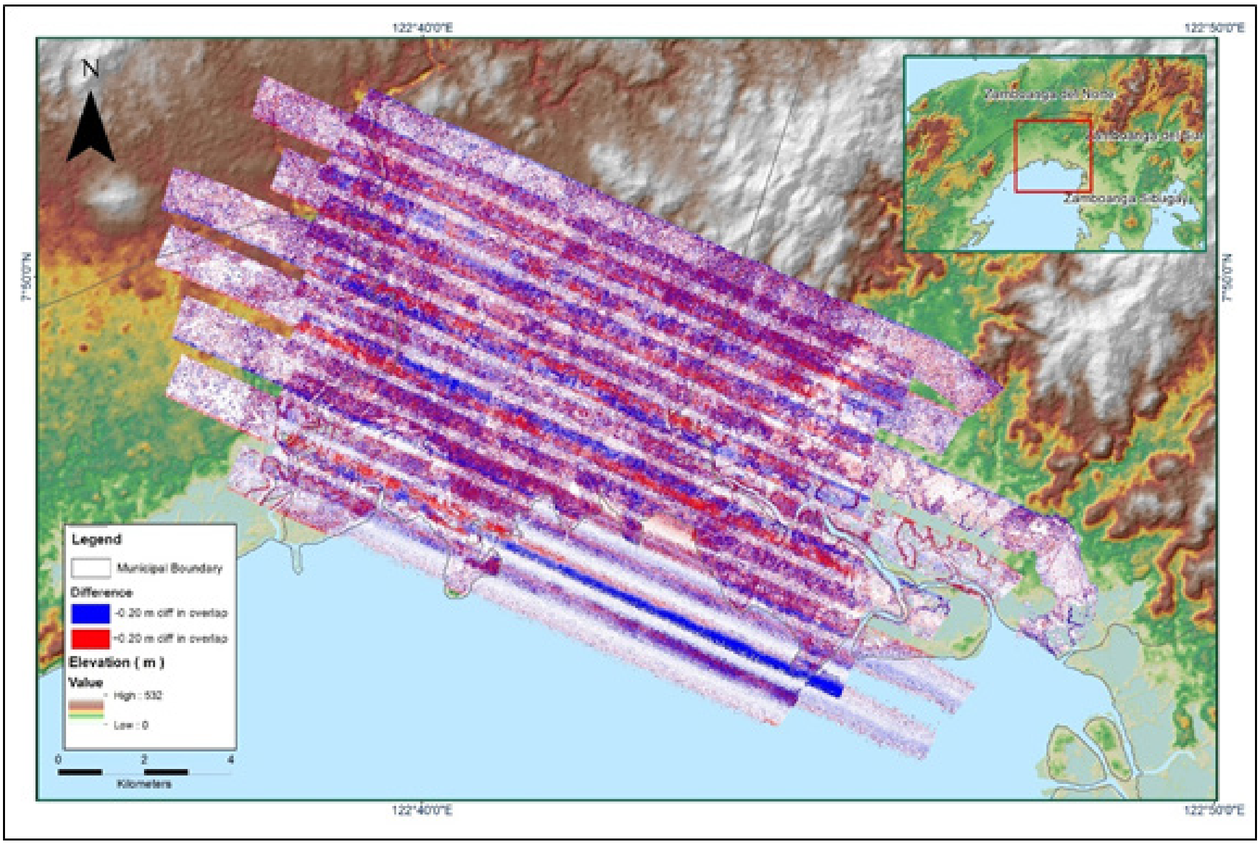


Figure A-8.14 Elevation difference between flight lines

ANNEX 9. Sanito 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
W320	1.8907434	72.7923	0	4.809294	3.697704	Discharge	0.1429131	0.9	Ratio to Peak	0.4
W330	1.1600316	82.194	0	2.019024	1.5523	Discharge	0.0629854	0.9	Ratio to Peak	0.4
W340	2.143323	69.3	0	3.288222	2.5281	Discharge	0.0764877	0.9	Ratio to Peak	0.4
W350	1.9741176	71.4987	0	3.154788	2.425492	Discharge	0.0372482	0.9	Ratio to Peak	0.4
W360	0.9873045	84.9702	0	1.468278	1.1289	Discharge	0.0229544	0.9	Ratio to Peak	0.4
W370	0.8649459	86.9736	0	1.31985	1.0148	Discharge	0.0128694	0.9	Ratio to Peak	0.4
W380	0.8604414	87.19725	0	1.7703	1.3610824	Discharge	0.0271418	0.9	Ratio to Peak	0.4
W390	0.8521695	87.15	0	0.4983048	0.38312	Discharge	0.0045476	0.9	Ratio to Peak	0.4
W400	0.9796059	85.0941	0	2.67876	2.0595	Discharge	0.0456559	0.9	Ratio to Peak	0.4
W410	1.518426	77.93835	0	3.838086	2.950828	Discharge	0.0571868	0.9	Ratio to Peak	0.4
W420	1.6422588	75.80895	0	2.772882	2.131872	Discharge	0.0326841	0.9	Ratio to Peak	0.4
W430	0.78776	88.3659	0	2.704086	2.0790	Discharge	0.0864256	0.9	Ratio to Peak	0.4
W440	2.0688759	70.26705	0	1.954134	1.5024546	Discharge	0.0297493	0.9	Ratio to Peak	0.4
W450	1.844388	73.18395	0	1.725696	1.3268	Discharge	0.0052698	0.9	Ratio to Peak	0.4
W460	1.5270255	77.3934	0	2.03616	1.5655	Discharge	0.0319884	0.9	Ratio to Peak	0.4
W470	1.5399657	77.868	0	2.83374	2.178724	Discharge	0.0653385	0.9	Ratio to Peak	0.4
W480	1.1863215	82.6392	0	3.396204	2.611204	Discharge	0.0627226	0.9	Ratio to Peak	0.4
W490	0.8372637	87.4272	0	1.748124	1.3441	Discharge	0.0382529	0.9	Ratio to Peak	0.4
W500	0.8527428	87.1416	0	1.83204	1.4085916	Discharge	0.0140790	0.9	Ratio to Peak	0.4

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
W510	0.75149	89.02635	0	2.631132	2.0230	Discharge	0.0633026	0.9	Ratio to Peak	0.4
W520	0.9327591	86.1294	0	1.915704	1.4728806	Discharge	0.0586922	0.9	Ratio to Peak	0.4
W530	1.170351	82.75155	0	0.809284	0.62222	Discharge	0.0019714	0.9	Ratio to Peak	0.4
W540	1.0521693	84.3843	0	2.120706	1.6305	Discharge	.000117325	0.9	Ratio to Peak	0.4
W550	1.0272717	84.7413	0	3.84804	2.958672	Discharge	0.0537712	0.9	Ratio to Peak	0.4
W560	0.8529066	87.1395	0	2.548224	1.9592	Discharge	0.0440548	0.9	Ratio to Peak	0.4
W570	1.1069604	83.6178	0	2.936682	2.258012	Discharge	0.0836890	0.9	Ratio to Peak	0.4
W580	0.8521695	87.15	0	2.137338	1.6433	Discharge	0.0487526	0.9	Ratio to Peak	0.4
W590	1.3012272	80.8689	0	0.8500464	0.65356	Discharge	0.0306136	0.9	Ratio to Peak	0.4
W600	1.1721528	82.54575	0	1.1241104	0.864271	Discharge	0.0475331	0.9	Ratio to Peak	0.4
W610	0.66377	90.66225	0	1.0551492	0.8112498	Discharge	0.0081070	0.9	Ratio to Peak	0.4
W620	0.8475831	87.23505	0	1.104894	0.84950	Discharge	0.0048963	0.9	Ratio to Peak	0.4

ANNEX 10. Sanito Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R50	Automatic Fixed Interval	671.84	0.0122038	0.051	Trapezoid	40	45
R70	Automatic Fixed Interval	522.84	0.0362031	0.051	Trapezoid	40	45
R90	Automatic Fixed Interval	2035.1	0.0055199	0.051	Trapezoid	40	45
R110	Automatic Fixed Interval	624.56	0.0068815	0.051	Trapezoid	40	45
R150	Automatic Fixed Interval	1804.7	0.0043220	0.051	Trapezoid	40	45
R160	Automatic Fixed Interval	3346.6	0.0046015	0.051	Trapezoid	40	45
R170	Automatic Fixed Interval	42.426	0.0531015	0.051	Trapezoid	40	45
R190	Automatic Fixed Interval	14.142	0.0193797	0.051	Trapezoid	40	45
R200	Automatic Fixed Interval	4307.3	0.0133340	0.051	Trapezoid	40	45
R210	Automatic Fixed Interval	3833.6	0.0053582	0.051	Trapezoid	40	45
R220	Automatic Fixed Interval	3874.3	0.0126106	0.051	Trapezoid	40	45
R240	Automatic Fixed Interval	3771.8	0.0047622	0.051	Trapezoid	40	45
R270	Automatic Fixed Interval	828.41	0.0056813	0.051	Trapezoid	40	45
R280	Automatic Fixed Interval	3174.8	0.0039906	0.051	Trapezoid	40	45
R290	Automatic Fixed Interval	499.20	0.00001	0.051	Trapezoid	40	45

ANNEX 11. Sanito Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
1	7.789801	122.58701	1.7	1.8	-0.12	Not Defined	5 -Year
2	7.786908	122.58887	0.6	0.9	-0.35	Sendong	5 -Year
3	7.789229	122.58738	1.9	0.9	1.01	Sendong	5 -Year
4	7.788549	122.58762	0.0	0.0	0.03	Not Defined	5 -Year
5	7.785605	122.58705	0.0	0.0	0.03	Not Defined	5 -Year
6	7.791795	122.57867	0.0	0.0	0.03	Not Defined	5 -Year
7	7.791788	122.57869	0.0	0.0	0.03	Not Defined	5 -Year
8	7.788614	122.5813	0.0	0.0	0.03	Not Defined	5 -Year
9	7.774666	122.57928	0.0	0.0	0.03	Not Defined	5 -Year
10	7.774665	122.57928	0.0	0.0	0.03	Not Defined	5 -Year
11	7.775799	122.58084	0.0	0.0	0.03	Not Defined	5 -Year
12	7.774181	122.57907	0.0	0.0	0.03	Not Defined	5 -Year
13	7.777479	122.582	0.1	0.0	0.13	Not Defined	5 -Year
14	7.776097	122.58329	0.0	0.0	0.03	Not Defined	5 -Year
15	7.776096	122.58328	0.0	0.0	0.03	Not Defined	5 -Year
16	7.77676	122.58313	0.0	0.0	0.03	Not Defined	5 -Year
17	7.776467	122.58387	0.0	0.0	0.03	Not Defined	5 -Year
18	7.7752	122.57849	0.1	0.0	0.08	Not Defined	5 -Year
19	7.775202	122.57851	0.1	0.0	0.08	Not Defined	5 -Year
20	7.776045	122.57892	0.1	0.0	0.05	Not Defined	5 -Year
21	7.776481	122.57901	0.0	0.0	0.03	Not Defined	5 -Year
22	7.786339	122.57761	0.0	0.5	-0.47	Not Defined	5 -Year
23	7.789936	122.57493	0.0	0.8	-0.77	Yolanda	5 -Year
24	7.788606	122.5774	0.0	0.7	-0.67	Ondoy	5 -Year
25	7.784526	122.57897	0.1	0.4	-0.32	Yolanda	5 -Year
26	7.781754	122.58321	0.0	0.4	-0.37	Yolanda	5 -Year
27	7.783436	122.57807	0.1	0.3	-0.17	Julian	5 -Year
28	7.783133	122.57765	0.0	0.4	-0.37	Ondoy	5 -Year
29	7.78084	122.58348	0.0	0.5	-0.47	Yolanda	5 -Year
30	7.787055	122.57867	0.0	0.5	-0.47	Yolanda	5 -Year
31	7.786234	122.5779	0.0	0.4	-0.37	Ondoy	5 -Year
32	7.7838	122.58256	0.1	0.4	-0.34	Ondoy	5 -Year
33	7.784066	122.58103	0.1	0.4	-0.28	Not Defined	5 -Year
34	7.782285	122.58288	0.1	0.4	-0.30	Not Defined	5 -Year
35	7.781624	122.58172	0.1	0.4	-0.31	Not Defined	5 -Year
36	7.804178	122.57348	0.0	0.4	-0.37	Not Defined	5 -Year
37	7.782738	122.58126	0.1	0.4	-0.30	Not Defined	5 -Year
38	7.782261	122.5829	0.1	0.4	-0.30	Not Defined	5 -Year
39	7.78511	122.58949	0.1	0.4	-0.33	Not Defined	5 -Year
40	7.783532	122.58782	0.0	0.5	-0.47	Not Defined	5 -Year
41	7.78013	122.58405	0.1	0.4	-0.32	Not Defined	5 -Year

42	7.78932	122.58326	0.6	0.4	0.20	Not Defined	5 -Year
43	7.789394	122.58427	0.0	0.4	-0.37	Not Defined	5 -Year
44	7.788363	122.58275	0.0	0.1	-0.07	Not Defined	5 -Year
45	7.770696	122.57944	0.0	0.2	-0.17	Not Defined	5 -Year
46	7.7846	122.58557	0.0	0.1	-0.06	Not Defined	5 -Year
47	7.765466	122.57541	0.3	0.3	0.04	Not Defined	5 -Year
48	7.768315	122.57592	0.0	0.2	-0.17	Not Defined	5 -Year
49	7.769909	122.58092	0.0	0.2	-0.17	Not Defined	5 -Year
50	7.770556	122.58051	0.0	0.2	-0.17	Not Defined	5 -Year
51	7.782857	122.5818	0.1	0.0	0.07	Not Defined	5 -Year
52	7.767039	122.57781	0.4	0.2	0.15	Not Defined	5 -Year
53	7.767592	122.58219	0.1	0.2	-0.08	Not Defined	5 -Year
54	7.7684	122.58142	0.2	0.2	0.00	Not Defined	5 -Year
55	7.768315	122.58142	0.1	0.2	-0.06	Not Defined	5 -Year
56	7.768229	122.58142	0.3	0.2	0.06	Not Defined	5 -Year
57	7.767677	122.58219	0.0	0.2	-0.16	Not Defined	5 -Year
58	7.767634	122.58129	0.1	0.2	-0.12	Not Defined	5 -Year
59	7.768315	122.58142	0.1	0.2	-0.06	Not Defined	5 -Year
60	7.7701	122.57755	0.0	0.2	-0.16	Not Defined	5 -Year
61	7.770866	122.57936	0.1	0.2	-0.15	Not Defined	5 -Year
62	7.763977	122.57927	0.0	0.2	-0.16	Not Defined	5 -Year
63	7.767847	122.57966	0.0	0.2	-0.17	Not Defined	5 -Year
64	7.767315	122.5836	0.3	0.2	0.06	Not Defined	5 -Year
65	7.764828	122.57446	0.0	0.2	-0.17	Not Defined	5 -Year
66	7.763807	122.57558	0.2	0.2	-0.01	Not Defined	5 -Year
67	7.764615	122.577	0.0	0.2	-0.17	Not Defined	5 -Year
68	7.767294	122.57734	0.1	0.2	-0.06	Not Defined	5 -Year
69	7.769207	122.5786	0.1	0.2	-0.13	Not Defined	5 -Year
70	7.769122	122.57918	0.1	0.2	-0.09	Not Defined	5 -Year
71	7.769867	122.5809	0.0	0.2	-0.17	Not Defined	5 -Year
72	7.767592	122.58129	0.1	0.2	-0.08	Not Defined	5 -Year
73	7.765636	122.57661	0.0	0.2	-0.17	Not Defined	5 -Year
74	7.767812	122.58055	0.0	0.2	-0.17	Not Defined	5 -Year
75	7.76993	122.57841	0.3	0.2	0.05	Not Defined	5 -Year
76	7.770632	122.58056	0.0	0.2	-0.17	Not Defined	5 -Year
77	7.764317	122.58013	0.0	0.3	-0.27	Not Defined	5 -Year
78	7.766614	122.57957	0.2	0.2	0.01	Not Defined	5 -Year
79	7.76651	122.58529	0.1	0.2	-0.15	Not Defined	5 -Year
80	7.767677	122.58129	0.1	0.2	-0.12	Not Defined	5 -Year
81	7.783176	122.58354	0.0	0.2	-0.17	Not Defined	5 -Year
82	7.781411	122.59181	0.5	0.3	0.17	Yolanda	5 -Year
83	7.779345	122.58981	1.7	0.4	1.31	Yolanda	5 -Year
84	7.779286	122.58971	0.0	0.0	0.03	Not Defined	5 -Year
85	7.777166	122.58957	0.1	0.3	-0.16	Yolands	5 -Year

86	7.770443	122.59225	0.5	0.5	-0.01	Yolanda	5 -Year
87	7.77205	122.59236	0.8	0.4	0.41	Yolanda	5 -Year
88	7.773331	122.59165	0.9	0.3	0.55	Yolanda	5 -Year
89	7.774464	122.59091	0.7	0.5	0.18	Yolanda	5 -Year
90	7.774892	122.59085	0.7	0.6	0.15	Not Defined	5 -Year
91	7.774904	122.59085	0.7	0.4	0.31	Yolanda	5 -Year
92	7.779385	122.58975	0.0	0.0	0.03	Not Defined	5 -Year
93	7.779302	122.58971	0.0	0.0	0.03	Not Defined	5 -Year
94	7.779325	122.58964	0.0	0.0	0.03	Not Defined	5 -Year
95	7.779432	122.58982	0.0	0.0	0.03	Not Defined	5 -Year
96	7.779454	122.58985	0.0	0.0	0.03	Not Defined	5 -Year
97	7.779419	122.58981	0.0	0.0	0.03	Not Defined	5 -Year
98	7.779309	122.58971	0.0	0.0	0.03	Not Defined	5 -Year
99	7.779466	122.58985	0.0	0.0	0.03	Not Defined	5 -Year
100	7.800763	122.61479	0.1	1.0	-0.95	Ondoy	5 -Year
101	7.799989	122.61472	0.1	0.4	-0.34	Ondoy	5 -Year
102	7.802251	122.61536	0.0	1.0	-0.97	Ondoy	5 -Year
103	7.800121	122.61473	0.0	0.0	0.03	Not Defined	5 -Year
104	7.799878	122.61879	0.0	0.0	0.03	Not Defined	5 -Year
105	7.819213	122.61673	0.0	0.0	0.03	Not Defined	5 -Year
106	7.819486	122.6139	0.0	0.0	0.04	Not Defined	5 -Year
107	7.819522	122.61385	0.0	0.0	0.03	Not Defined	5 -Year
108	7.812736	122.6184	0.0	0.0	0.03	Not Defined	5 -Year
109	7.815654	122.61993	0.0	0.0	0.03	Not Defined	5 -Year
110	7.810559	122.61696	0.0	0.0	0.03	Not Defined	5 -Year
111	7.810442	122.61696	0.0	0.0	0.03	Not Defined	5 -Year
112	7.787842	122.59187	0.1	0.6	-0.53	Yolanda	5 -Year
113	7.780733	122.59157	0.1	0.6	-0.51	Yolanda	5 -Year
114	7.780143	122.59093	2.3	1.3	0.97	Yolanda	5 -Year
115	7.777255	122.59023	1.0	0.6	0.42	Yolanda	5 -Year
116	7.777156	122.5903	0.6	0.9	-0.30	Ondoy	5 -Year
117	7.787862	122.59186	0.1	0.0	0.07	Not Defined	5 -Year
118	7.788475	122.59237	0.4	0.0	0.40	Not Defined	5 -Year
119	7.788485	122.59237	0.4	0.0	0.40	Not Defined	5 -Year
120	7.814711	122.61137	0.0	0.6	-0.57	Not Defined	5 -Year
121	7.814593	122.60923	0.0	0.0	0.03	Not Defined	5 -Year
122	7.814675	122.60913	0.0	0.0	0.03	Not Defined	5 -Year
123	7.80929	122.60888	0.0	0.0	0.03	Not Defined	5 -Year
124	7.801677	122.58607	0.0	0.0	0.03	Not Defined	5 -Year
125	7.801602	122.58614	0.0	0.0	0.03	Not Defined	5 -Year
126	7.801707	122.58615	0.0	0.0	0.03	Not Defined	5 -Year
127	7.804831	122.58653	0.0	0.0	0.03	Not Defined	5 -Year
128	7.81358	122.58734	0.0	0.0	0.03	Not Defined	5 -Year
129	7.813648	122.58741	0.0	0.0	0.04	Not Defined	5 -Year
130	7.817031	122.57327	0.0	0.0	0.03	Not Defined	5 -Year

131	7.817191	122.57332	0.0	0.0	0.03	Not Defined	5 -Year
132	7.817583	122.57573	0.0	0.0	0.03	Not Defined	5 -Year
133	7.810156	122.58618	0.8	0.0	0.78	Not Defined	5 -Year
134	7.815274	122.58598	0.0	0.0	0.03	Not Defined	5 -Year
135	7.820533	122.57523	0.0	0.0	0.03	Not Defined	5 -Year
136	7.823124	122.58495	0.0	0.0	0.03	Not Defined	5 -Year
137	7.823191	122.58496	0.0	0.0	0.03	Not Defined	5 -Year
138	7.823427	122.58488	0.0	0.0	0.03	Not Defined	5 -Year
139	7.82356	122.5849	0.0	0.0	0.03	Not Defined	5 -Year
140	7.82293	122.58481	0.0	0.0	0.03	Not Defined	5 -Year
141	7.823344	122.58462	0.0	0.0	0.03	Not Defined	5 -Year
142	7.823253	122.58459	0.0	0.0	0.03	Not Defined	5 -Year
143	7.80752	122.5798	0.0	0.0	0.03	Not Defined	5 -Year
144	7.807536	122.57963	0.0	0.0	0.03	Not Defined	5 -Year
145	7.801258	122.5985	0.0	0.0	0.03	Not Defined	5 -Year
146	7.798581	122.59685	0.0	0.0	0.03	Not Defined	5 -Year
147	7.806476	122.60282	0.0	0.0	0.03	Not Defined	5 -Year
148	7.806759	122.58918	0.0	0.0	0.03	Not Defined	5 -Year
149	7.812487	122.59343	0.0	0.0	0.03	Not Defined	5 -Year
150	7.812524	122.59352	0.0	0.0	0.03	Not Defined	5 -Year
151	7.815661	122.62002	0.0	0.0	0.03	Not Defined	5 -Year
152	7.812799	122.61842	0.0	0.0	0.03	Not Defined	5 -Year
153	7.816659	122.60124	0.0	0.0	0.03	Not Defined	5 -Year
154	7.814607	122.6092	0.0	0.0	0.03	Not Defined	5 -Year
155	7.762532	122.59575	0.1	0.6	-0.54	Yolanda	5 -Year
156	7.769888	122.5924	0.6	0.2	0.36	Ondoy	5 -Year
157	7.76975	122.59241	0.3	0.2	0.10	Ondoy	5 -Year
158	7.769867	122.59247	0.7	0.2	0.51	Ondoy	5 -Year
159	7.768995	122.59256	0.7	0.2	0.52	Ondoy	5 -Year
160	7.767815	122.59649	0.2	0.2	-0.02	Ondoy	5 -Year
161	7.769186	122.59873	0.7	0.2	0.54	Ondoy	5 -Year
162	7.770143	122.60004	0.3	0.2	0.05	Ondoy	5 -Year
163	7.76689	122.59157	0.3	0.2	0.14	Ondoy	5 -Year
164	7.764509	122.59264	0.1	0.2	-0.13	Ondoy	5 -Year
165	7.765253	122.60107	0.9	0.2	0.67	Ondoy	5 -Year
166	7.760767	122.60397	0.0	0.2	-0.17	Ondoy	5 -Year
167	7.760366	122.6021	0.3	0.2	0.09	Ondoy	5 -Year
168	7.76217	122.59858	0.1	0.2	-0.11	Ondoy	5 -Year
169	7.761787	122.60004	0.0	0.2	-0.17	Ondoy	5 -Year
170	7.765423	122.60259	0.0	0.2	-0.17	Ondoy	5 -Year
171	7.765019	122.60058	0.8	0.1	0.67	Ondoy	5 -Year
172	7.794196	122.59732	0.0	0.0	0.03	Not Defined	5 -Year
173	7.794363	122.59735	0.3	0.0	0.27	Not Defined	5 -Year
174	7.819335	122.6167	0.0	0.0	0.03	Not Defined	5 -Year
175	7.807092	122.56262	0.0	0.0	0.03	Not Defined	5 -Year

176	7.79489	122.55828	0.0	0.0	0.03	Not Defined	5 -Year
177	7.801905	122.5664	0.0	0.0	0.03	Not Defined	5 -Year
178	7.798249	122.57052	0.0	0.0	0.04	Not Defined	5 -Year
179	7.800034	122.56785	0.0	0.0	0.03	Not Defined	5 -Year
180	7.811312	122.5829	0.5	0.0	0.46	Not Defined	5 -Year
181	7.791372	122.57979	0.0	0.0	0.03	Not Defined	5 -Year
182	7.78076	122.59159	0.1	0.1	-0.01	Yolanda	5 -Year
183	7.777184	122.59038	0.5	0.0	0.47	Not Defined	5 -Year
184	7.777268	122.59033	0.3	0.0	0.28	Not Defined	5 -Year
185	7.777263	122.5904	0.0	0.0	0.03	Not Defined	5 -Year
186	7.77607	122.5908	0.6	0.2	0.41	Ondoy	5 -Year
187	7.778195	122.58963	0.6	0.1	0.48	Ondoy	5 -Year
188	7.802199	122.61255	0.0	0.1	-0.07	Not Defined	5 -Year
189	7.799806	122.6135	0.0	0.0	0.03	Not Defined	5 -Year

ANNEX 12. Educational Institutions Affected by flooding in Sanito Flood Plain

Ipil				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Lower Taway	Daycare	None	Low	Low
Lower Taway	Sibugay Technical Institute Incorporated	None	High	High
Poblacion	Bangkerohan Elementary School	None	Medium	High
Bacalan	School	None	None	None
Don Andres	Don Andres Elementary School	None	None	None
Lower Ipil Heights	MARIAN COLLEGE	None	None	None
Lower Ipil Heights	Excel May Garcia	None	None	None
Lower Ipil Heights	Jomar Luminario	None	None	None
Lower Ipil Heights	Ipil Heights Elementary School	None	None	None
Lower Taway	MARIAN COLLEGE	None	None	None
Lower Taway	Ipil Heights Elementary School	None	None	None
Lower Taway	WMSU -Ipil	None	None	None
Lower Taway	Daycare	None	None	None
Lower Taway	Ipil National High School	None	None	None
Poblacion	Marcelo Spinola School	None	None	None
Poblacion	Don Andres Elementary School	None	None	None
Poblacion	Mathew jackson school	None	None	None
Poblacion	AMMC	None	None	None
Poblacion	ICES BLDG.	None	None	None
Poblacion	Aurelio Mendoza Memorial College	None	None	None

Poblacion	Don Andres Elementary School	None	None	None
Sanito	ISDAES	None	None	None
Tenan	Zamboanga Sibugay National Highschool	None	None	None
Tenan	Zamboanga Sibugay National Highschool	None	None	None

ANNEX 13. Health Institutions affected by flooding in Sanito Floodplain

Ipil				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
Lower Taway	Old Simon hospital	None	None	None
Lower Taway	The Filipino Healthcare	None	None	None
Lower Taway	Simon hospital	None	None	None
Pangi	Ipil Doctor's Hospital	None	None	None
Sanito	Zamboanga Sibugay Provincial Hospital	None	None	None
Sanito	Provincial hospital	None	None	None