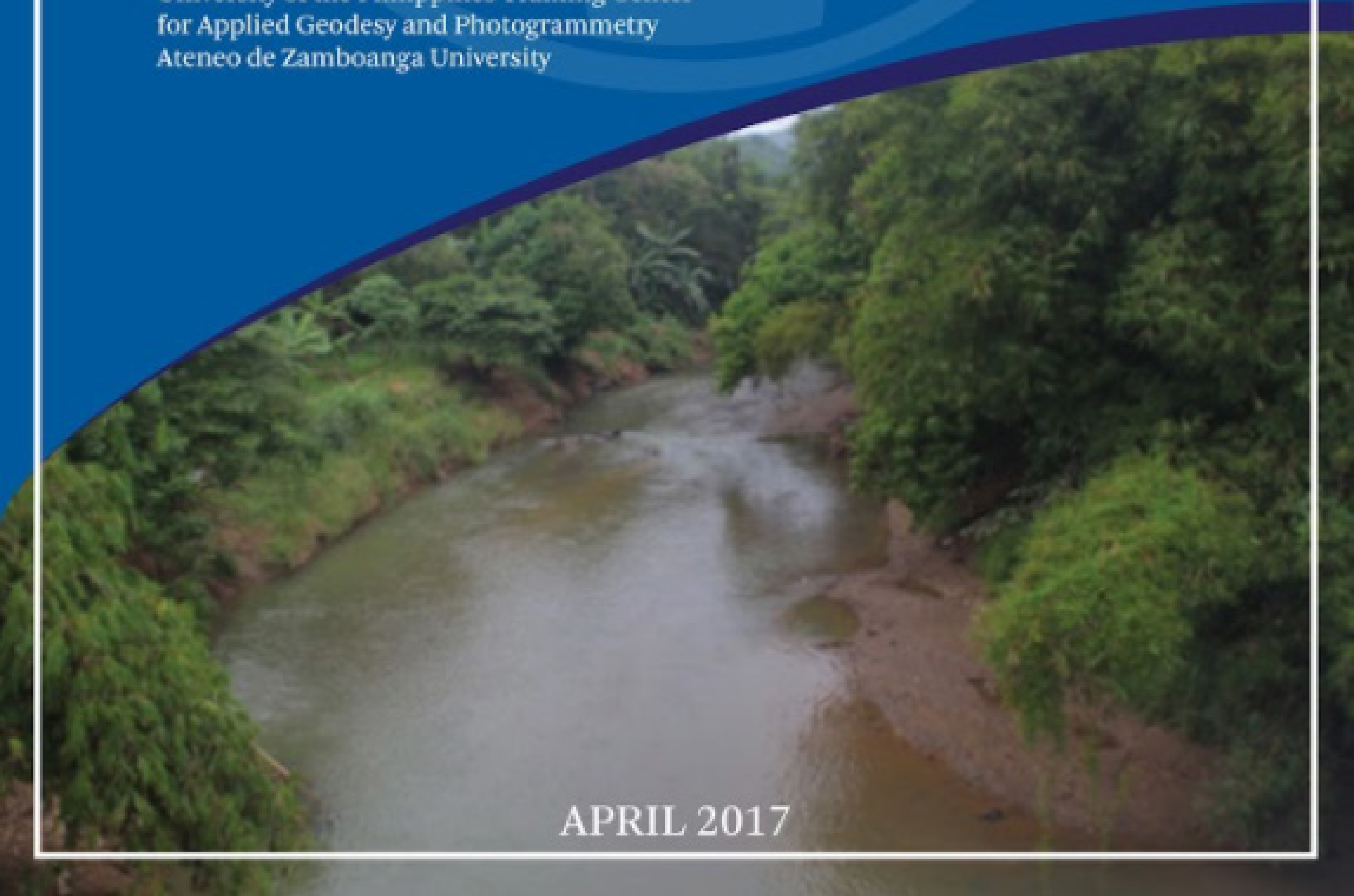
HAZARD MAPPING OF THE PHILIPPINES USING LIDAR (PHIL-LIDAR I)

LiDAR Surveys and Flood Mapping of Buluan River

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



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LIST OF ACRONYMS AND ABBREVIATIONS

AAC	Asian Aerospace Corporation
Ab	abutment
ADZU	Ateneo de Zamboanga University
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
AWLS	Automated Water Level Sensor
BA	Bridge Approach
BM	benchmark
CAD	Computer-Aided Design
CN	Curve Number
CSRS	Chief Science Research Specialist
DAC	Data Acquisition Component
DEM	Digital Elevation Model
DENR	Department of Environment and Natural Resources
DOST	Department of Science and Technology
DPPC	Data Pre-Processing Component
DREAM	Disaster Risk and Exposure Assessment for Mitigation [Program]
DRRM	Disaster Risk Reduction and Management
DSM	Digital Surface Model
DTM	Digital Terrain Model
DVBC	Data Validation and Bathymetry Component
FMC	Flood Modeling Component
FOV	Field of View
GiA	Grants-in-Aid
GCP	Ground Control Point
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HEC-HMS	Hydrologic Engineering Center - Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center - River Analysis System
HC	High Chord
IDW	Inverse Distance Weighted [interpolation method]
IMU	Inertial Measurement Unit
kts	knots
LAS	LiDAR Data Exchange File format
LC	Low Chord
LGU	local government unit
LiDAR	Light Detection and Ranging
LMS	LiDAR Mapping Suite
m AGL	meters Above Ground Level
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
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 BULUAN RIVER

Enrico C. Paringit, Dr. Eng. and Mario Rodriguez

1.1 Background of the Phil-LIDAR 1 Program

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

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

The implementing partner university for the Phil-LiDAR 1 Program is the Ateneo de Zamboanga University (ADZU) is in charge of processing LiDAR data and conducting data validation reconnaissance, cross section, bathymetric survey, validation, river flow measurements, flood height and extent data gathering, flood modeling, and flood map generation for the 18 river basins in the Western Mindanao Region. The university is located in Zamboanga City in the province of Zamboanga del Sur.

1.2 Overview of the Buluan River Basin

Buluan River is located in the southern of the municipality of Ipil, the capital of Zamboanga Sibugay. The Buluan River Basin covers some parts of the municipality of Titay and flows down to Ipil. It has an area of 5.19 square kilometers and stretches 11.94 kilometers from its source to its mouth (Figure 1).

Buluan River lies in the southern part of the Municipality of Ipil, Zamboanga Sibugay. The watershed area of Buluan River Basin has a total of 5.19 sqkm, covering parts of the Municipality of Titay. The river stretches at 11.94 km from the source to its mouth.

Buluan River was named after Barangay Buluan, one of the oldest barangays of the municipality. Like Sanito, the early settlers of the area were also the Subanon. According to history, a former datu of the Subanon decided to convert into Islam which led to inter-marriages with Muslims, and thus, their off-springs were now called Kalibugans. Ilocanos also started migrating in the area after seeing a potential on land cultivation.

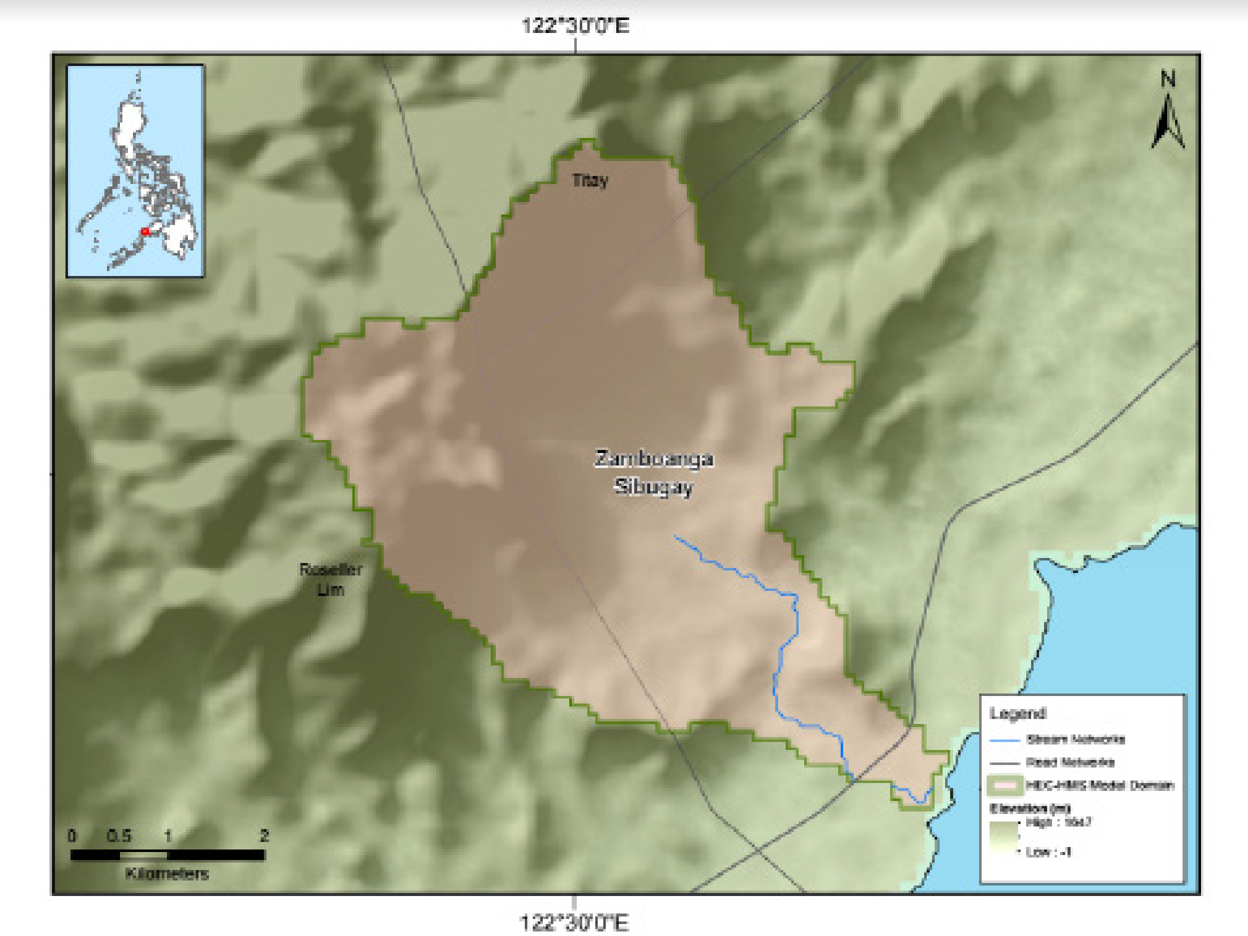

Figure 1. Map of the Buluan River Basin (in brown)

Figure 2. Buluan River, January 2017

According to Geo-hazard map released by the Mines and Geosciences Bureau (MGB) Region 9, Buluan River is highly susceptible to flooding, especially in the areas towards the mouth of the river. This was also validated by the residents of the area during the conduct of flood validation survey by the ADZU LiDAR 1 team.

One of the tributaries of the river is the Doña Josefa waterfalls, an uninhabited and protected watershed area. It is considered as one of the potential sources of potable water supply of the municipality. Aside from this, the river is also the primary source of water supply for agriculture purposes such as irrigation, livestock watering and etc.

Figure 3. Spring coming from Doña Josefa Falls

In 2004, the municipality of Ipil established the Buluan Island Marine Sanctuary. A total of 63.1 hectares of water surrounding the island was part of the protected area as it was the only part of the municipality where corals were not damaged by dynamite fishing, commercial fishing and siltation. In 2015, the marine sanctuary won as the Most Outstanding Marine Protected Area, bested 11 other Marine Protected Areas in the country.

Buluan Island also serves as one of the tourist destinations of the municipality, and even in the Province of Zamboanga Sibugay. As one of the unspoiled beaches in the country, many tourists from within and outside the region flock the island for a glimpse of a crystal clear waters. As it is a protected area, coordination and permission from the municipal tourism office is needed before proceeding to the island.

Figure 4. Marine Biodiversity in Buluan Island

CHAPTER 2: LIDAR DATA ACQUISITION OF THE BULUAN FLOODPLAIN

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

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Bulu-an floodplain in Zamboanga Sibugay. These missions were planned for 8 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 5 shows the flight plan for Bulu-an floodplain survey.

Table 1. Flight planning parameters for the 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)
BLK75A	1100	15	50	200	30	130	5

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

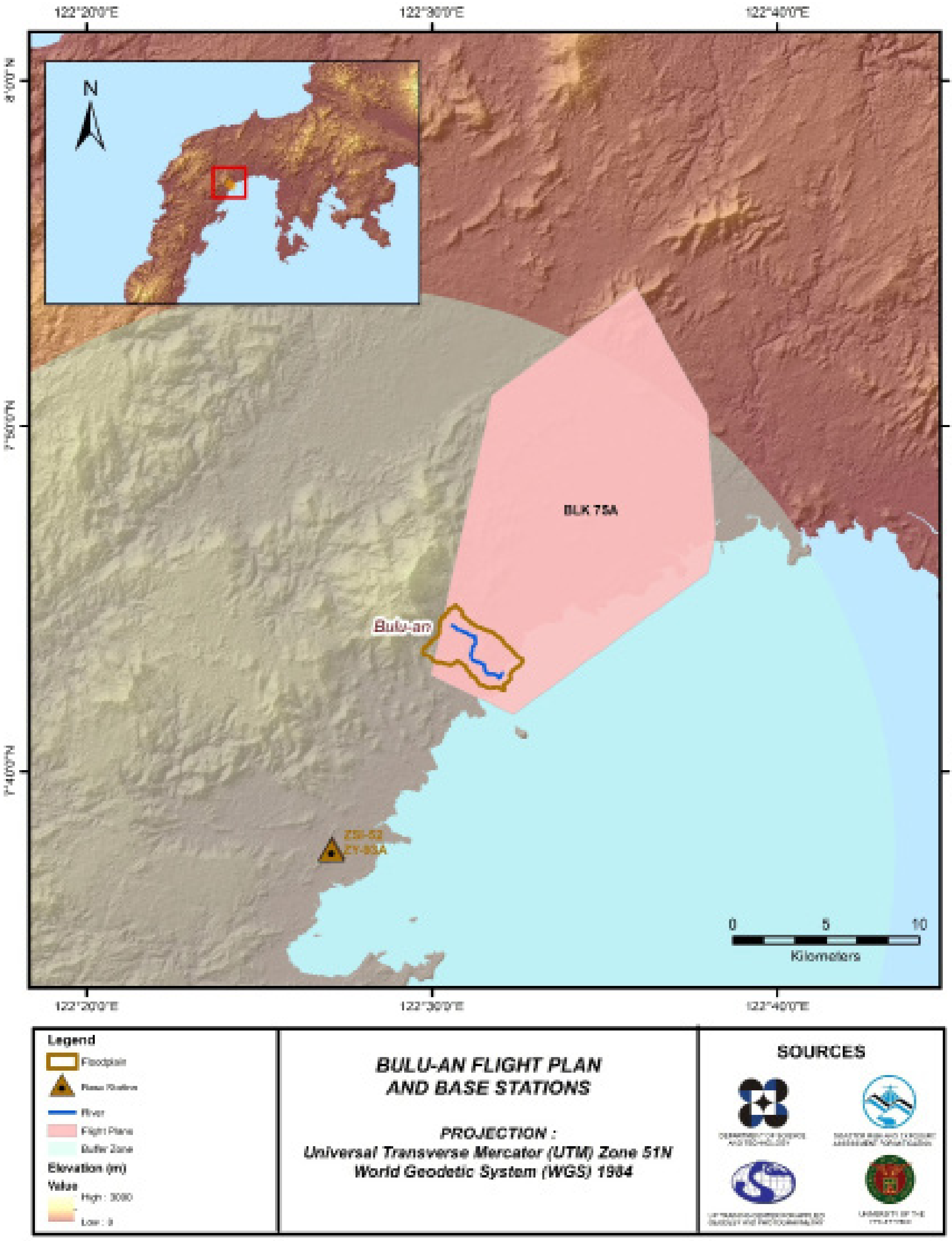

Figure 5. Flight Plan and base stations used for the Buluan Floodplain survey.

2.2 Ground Base Stations

The project team was able to recover one (1) NAMRIA ground control point ZSI-52 which is of second (2nd) order accuracy. The project team also established one (1) ground control point, ZY-93A.The certification for the NAMRIA reference point is found in Annex A-2while the baseline processing report for the established control pointis found in Annex A-3. These were used as base stations during flight operations for the entire duration of the survey (February 5 to 11, 2015). Base stations were observed using dual frequency GPS receivers:TRIMBLE SPS 852 andTRIMBLE SPS 882. Flight plans and location of base stations used during the aerial LiDAR acquisition in Bulu-an floodplain are shown in Figure 5.

Figure 6 shows the recovered NAMRIA reference point within the area. In addition, Table 2 to Table 3 show the details about the following NAMRIA control stations, while Table 4 shows the list of all ground control points occupied during the acquisition together with the corresponding dates of utilization.

Figure 6. 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 2. 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 in 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 3 (PTM Zone 5 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, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	439,380.84 meters 843,464.86 meters

Table 3. 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 in 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 5 (PTM Zone 5 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 4. 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

2.3 Flight Missions

One (1) mission was conducted to complete the LiDAR data acquisition in Bulu-an floodplain, for a total of four hours and twenty-three minutes (4+23) of flying time for RP-9022. The mission was acquired using the Pegasus LiDAR system. Table 5 shows the total area of actual coverage and the corresponding flying hours of the mission, while Table 6 presents the actual parameters used during the LiDAR data acquisition.

Table 5. Flight mission for LiDAR data acquisition in Bulu-an Floodplain.

Date Surveyed	Flight Number	Flight Plan Area (km^2)	Surveyed Area (km^2)	Area Surveyed within the Floodplain (km2)	Area Surveyed Outside the Floodplain (km2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
February 9, 2015	2549P	271.02	165.82	11.57	154.25	482	4	23
TOTAL		271.02	165.82	11.57	154.25	482	4	23

Table 6. Actual parameters used during LiDAR data acquisition

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
2549P	1100	15	50	200	30	130	5

2.4 Survey Coverage

Buluan floodplain is located along the province of Zamboanga Sibugay with majority of the floodplain situated within the municipality ofIpil. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 7. The actual coverage of the LiDAR acquisition for Buluan floodplain is presented in Figure 7.

Table 7. List of municipalities and cities surveyed during Bulu-an Floodplain LiDAR survey.

Province	Municipality/ City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Zamboanga Sibugay	Ipil	130.90	63.15	48.25%
	Titay	176.50	65.62	37.18%
	Roseller Lim	272.39	16.36	6.01%

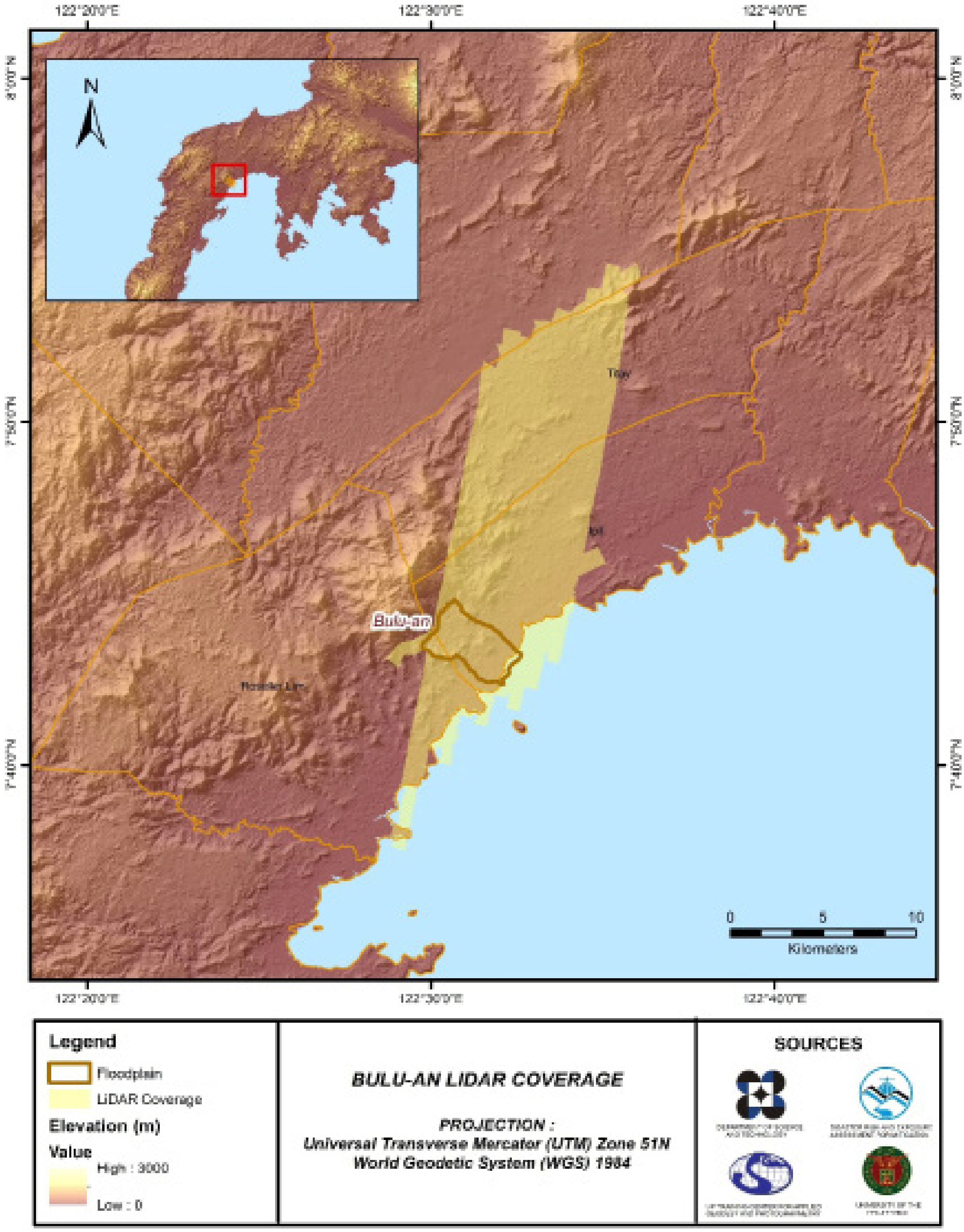

Figure 7. Actual LiDAR survey coverage for Buluan Floodplain

CHAPTER 3: LIDAR DATA PROCESSING OF THE BULUAN FLOODPLAIN

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

3.1 Overview of the LiDAR Data Pre-Processing

The data transmitted by the Data Acquisition Component are checked for completeness based on the list of raw files required to proceed with the pre-processing of the LiDAR data. Upon acceptance of theLiDAR field data, georeferencing of the flight trajectoryis 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 georectifiedLiDARpoint clouds are subject for quality checking to ensure that the required accuracies of the program,which are the minimum point density, vertical and horizontal accuracies, are met. The point clouds are then classified into various classes before generating Digital Elevation Models such as Digital Terrain Model and Digital Surface Model.

Using the elevation of points gathered in the field, the LiDAR-derived digital models are calibrated. Portions of the river that are barely penetrated by the LiDAR system are replaced by the actual river geometry measured from the field by the Data Validation and Bathymetry Component. LiDAR acquired temporally are then mosaicked to completely cover the target river systems in the Philippines. Orthorectification of images acquired simultaneously with the LiDAR data is done through the help of the georectified point clouds and the metadata containing the time the image was captured.

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

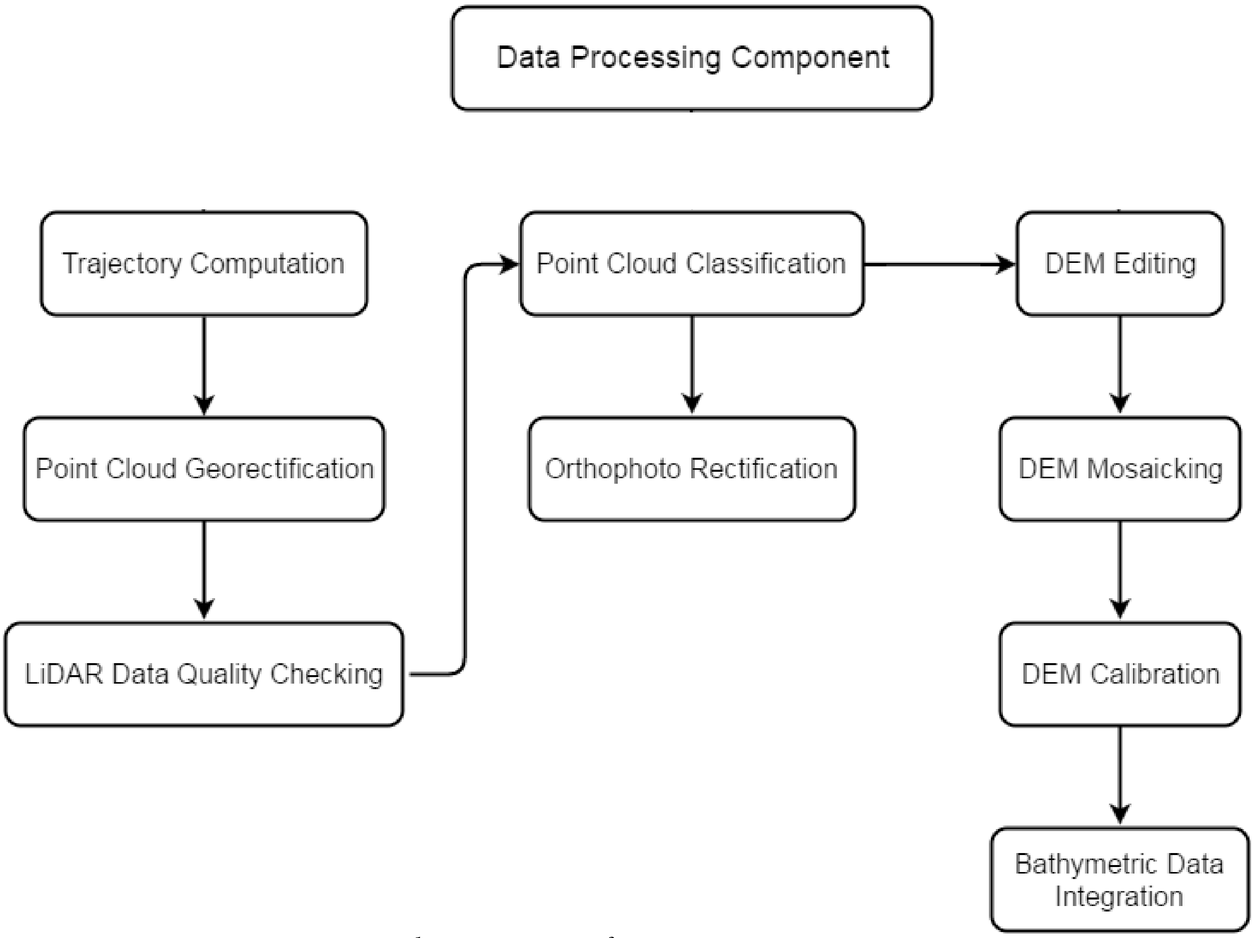


Figure 8. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Buluan floodplain can be found in Annex 6. Data Transfer Sheets. Missions flown during the survey conducted on February 2015 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system over Ipil, Zamboanga Sibugay.

The Data Acquisition Component (DAC) transferred a total of 22.3 Gigabytes of Range data, 230 Megabytes of POS data, 4.37 Megabytes of GPS base station data, and 32.6 Gigabytes of raw image data to the data server on March 13, 2015. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Buluan was fully transferred on March 13, 2015, as indicated on the Data Transfer Sheets for Buluan floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 2549P, one of the Buluanflights, which is the North, East, and Down position RMSE values are shown in Figure 9. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell onFebruary 9, 2015 00:00AM. The y-axis is the RMSE value for that particular position.

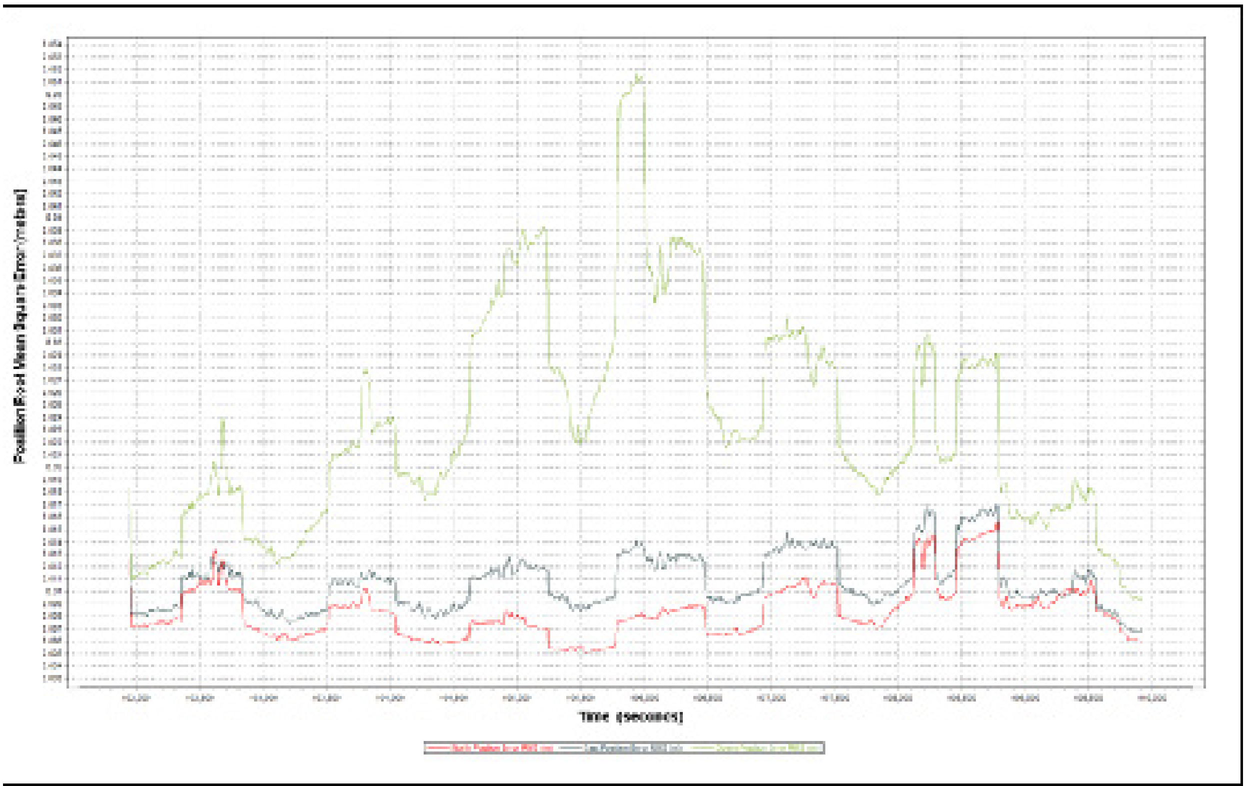


Figure 9. Smoothed Performance Metrics of a Buluan Flight2549P

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 9 shows that the North position RMSE peaks at 1.55 centimeters, the East position RMSE peaks at 1.60 centimeters, and the Down position RMSE peaks at 5.08 centimeters, which are within the prescribed accuracies described in the methodology

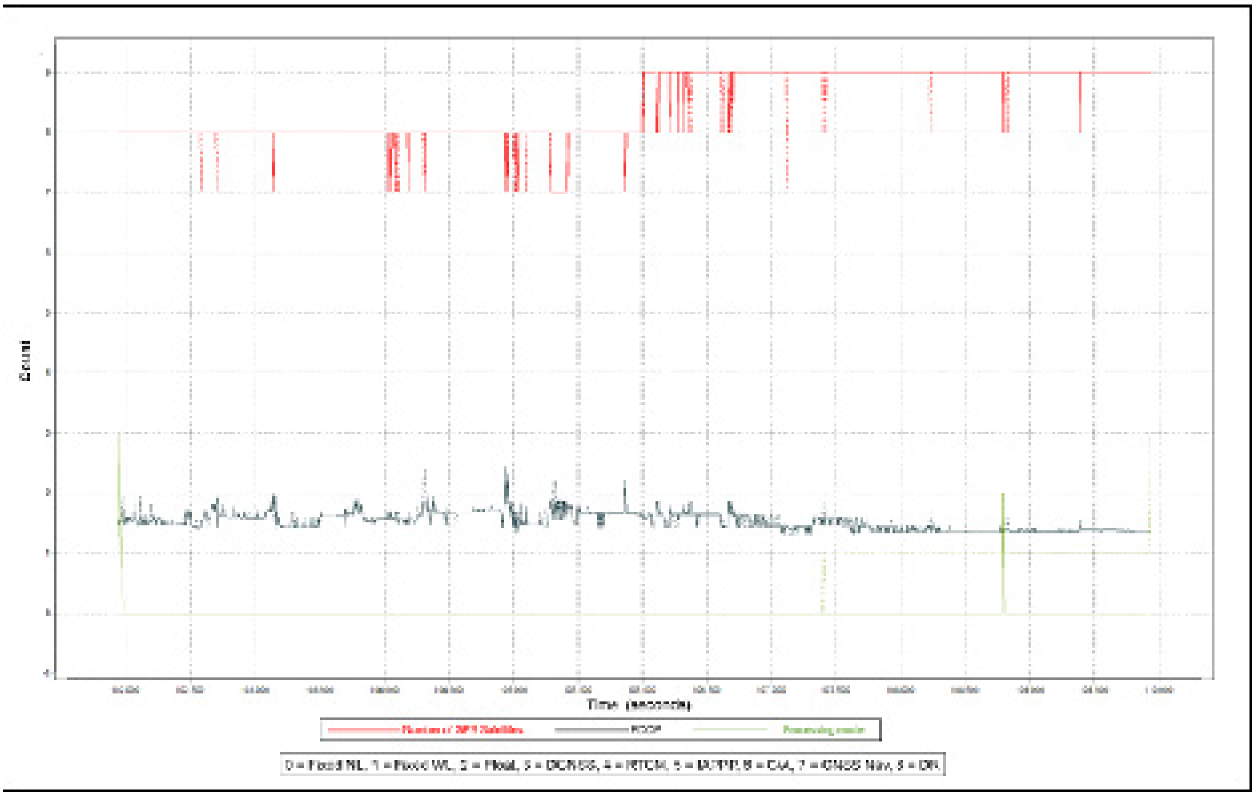


Figure 10. Solution Status Parameters of Buluan Flight 2549P.

The Solution Status parameters of flight 2549P,one of the Buluan flights, which indicate the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 10. The graphs indicate that the number of satellites during the acquisition did not go down to 7. 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 2 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Buluan flights is shown in Figure 11.

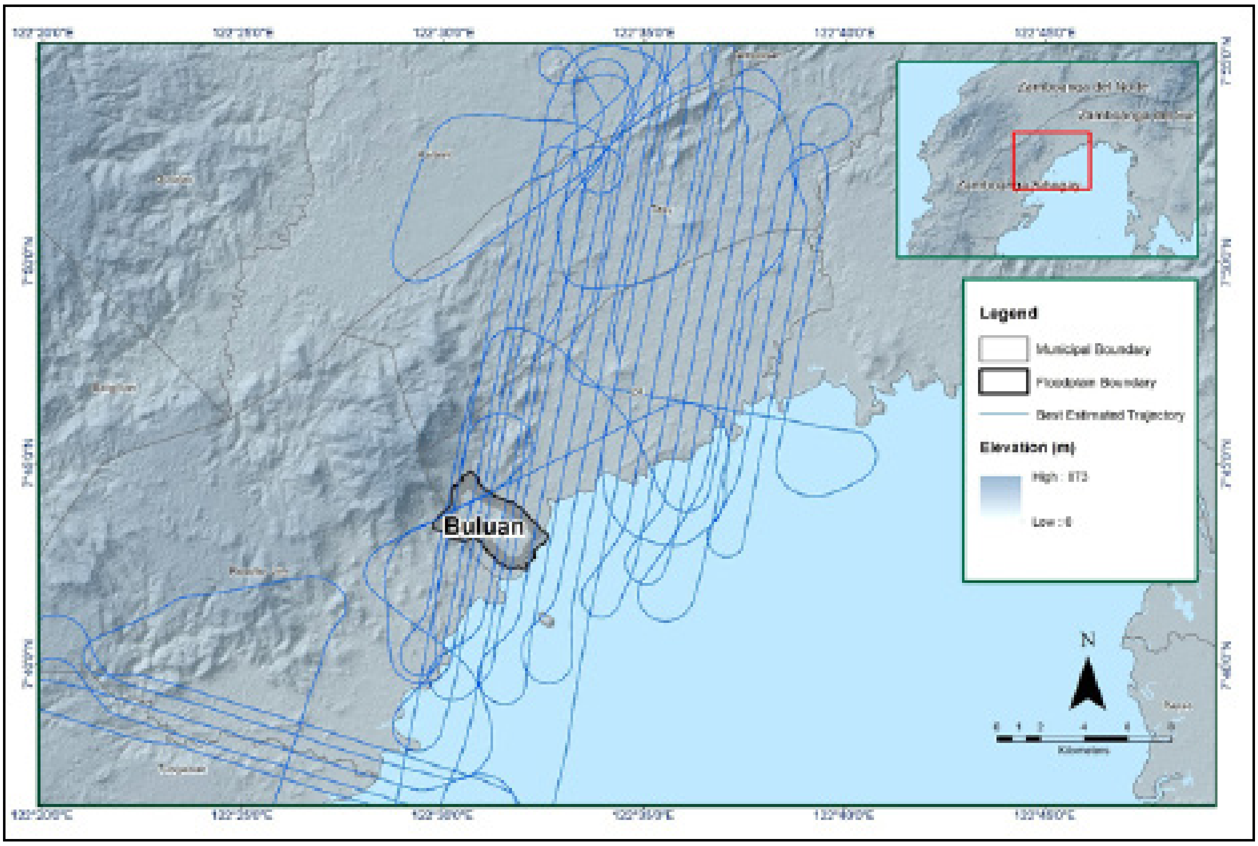


Figure 11. Best estimated trajectory for Buluan Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 27 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 Buluan floodplain are given in Table 8.

Table 8. Self-calibration Results values for Buluan flights.

Parameter	Acceptable Value	Value
Boresight Correction stdev	<0.001degrees	0.000157
IMU Attitude Correction Roll and Pitch Corrections stdev	<0.001degrees	0.000786
GPS Position Z-correction stdev	<0.01meters	0.0051

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

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data is shown in Figure 12. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

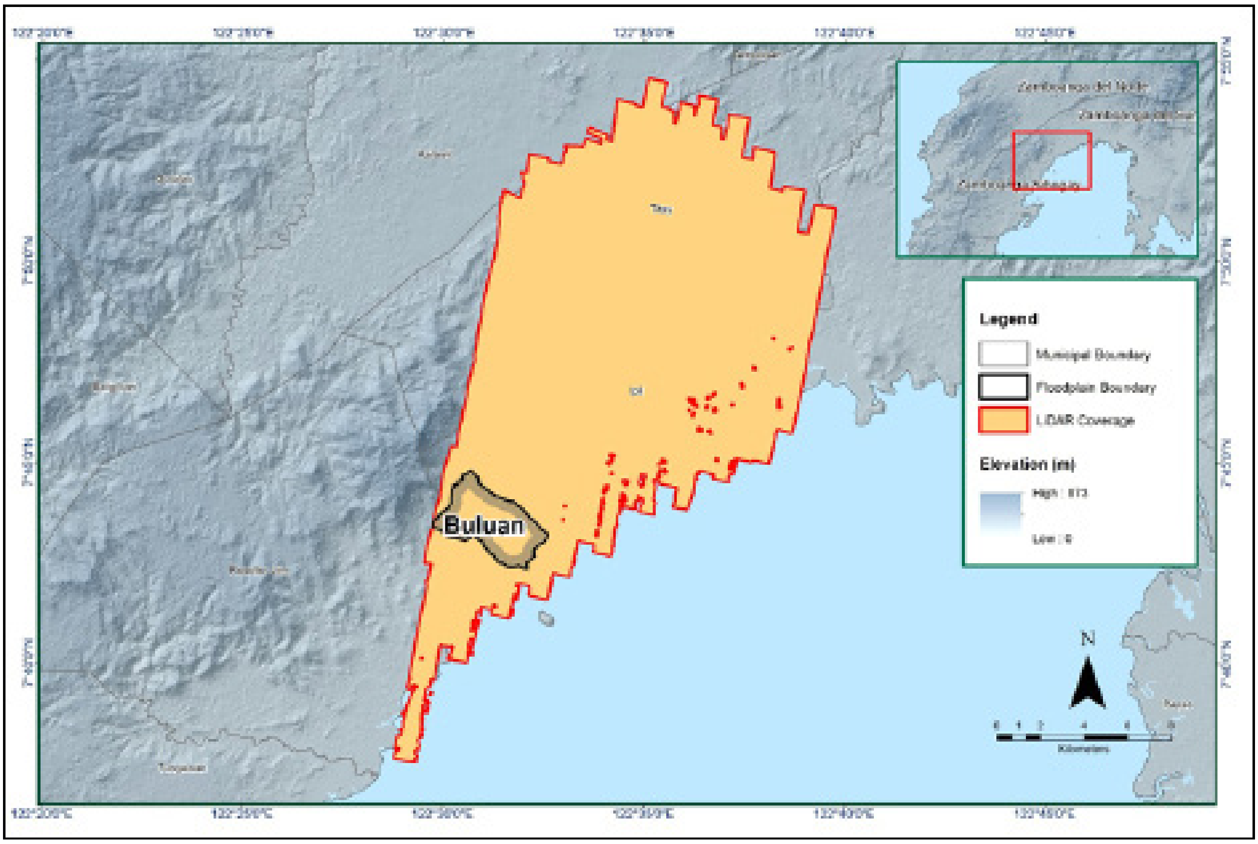


Figure 12. Boundary of the processed LiDAR data on top of a SAR Elevation Data over Buluan Floodplain.

The total area covered by the Buluan mission is 284.34sq.km that is comprised of one (1) flight acquisition grouped and merged into one (1) block as shown in Table 9.

Table 9. List of LiDAR blocks for Buluan Floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Zamboanga_Blk75A	2549P	284.34
	TOTAL	**284.34 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 10. Since Pegasus system employs two channels, we would expect 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.

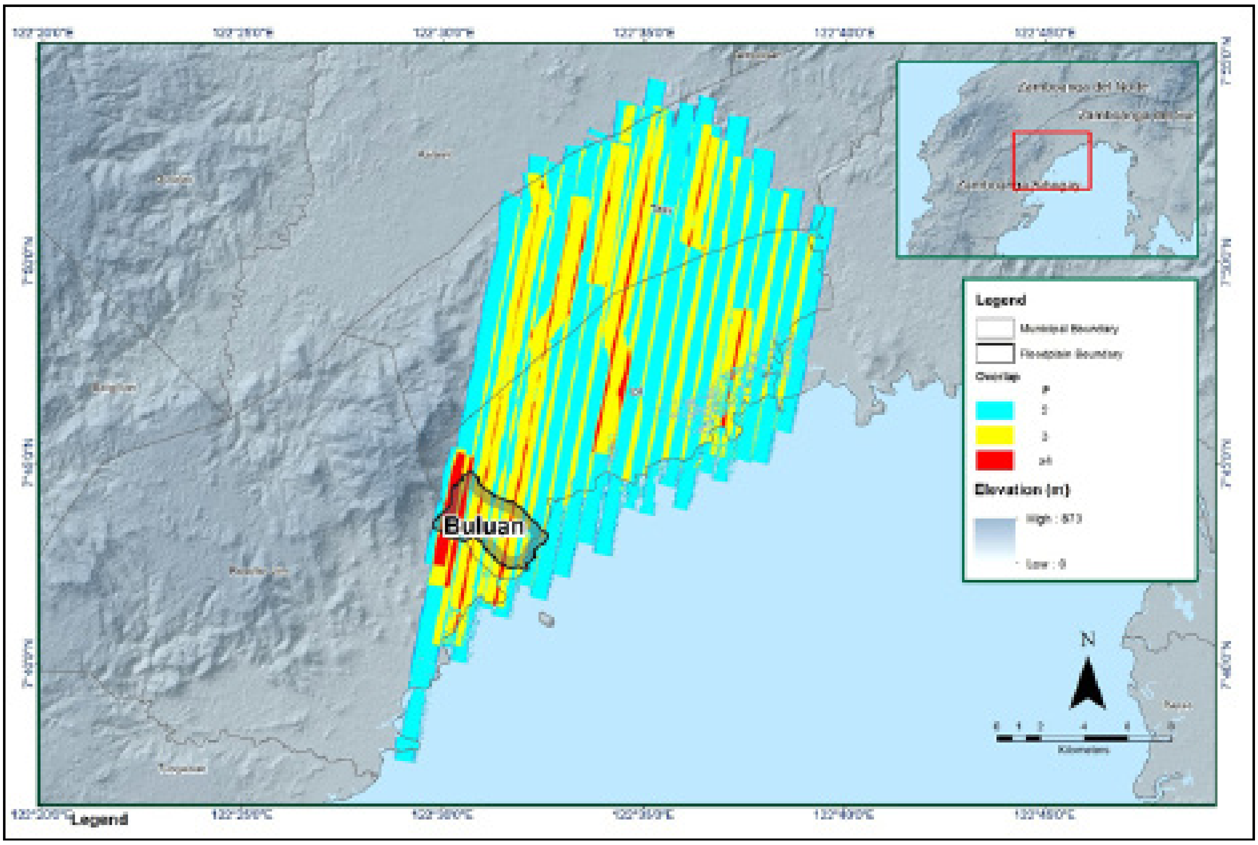


Figure 13. Image of data overlap for Buluan Floodplain.

The overlap statistics per block for the Buluan floodplain can be found in Annex 8. One pixel corresponds to 25.0 square meters on the ground. For this area, the percent overlap is 44.09% 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 14. It was determined that all LiDAR data for Buluan floodplain satisfy the point density requirement, and the average density for the entire survey area is 4.24 points per square meter.

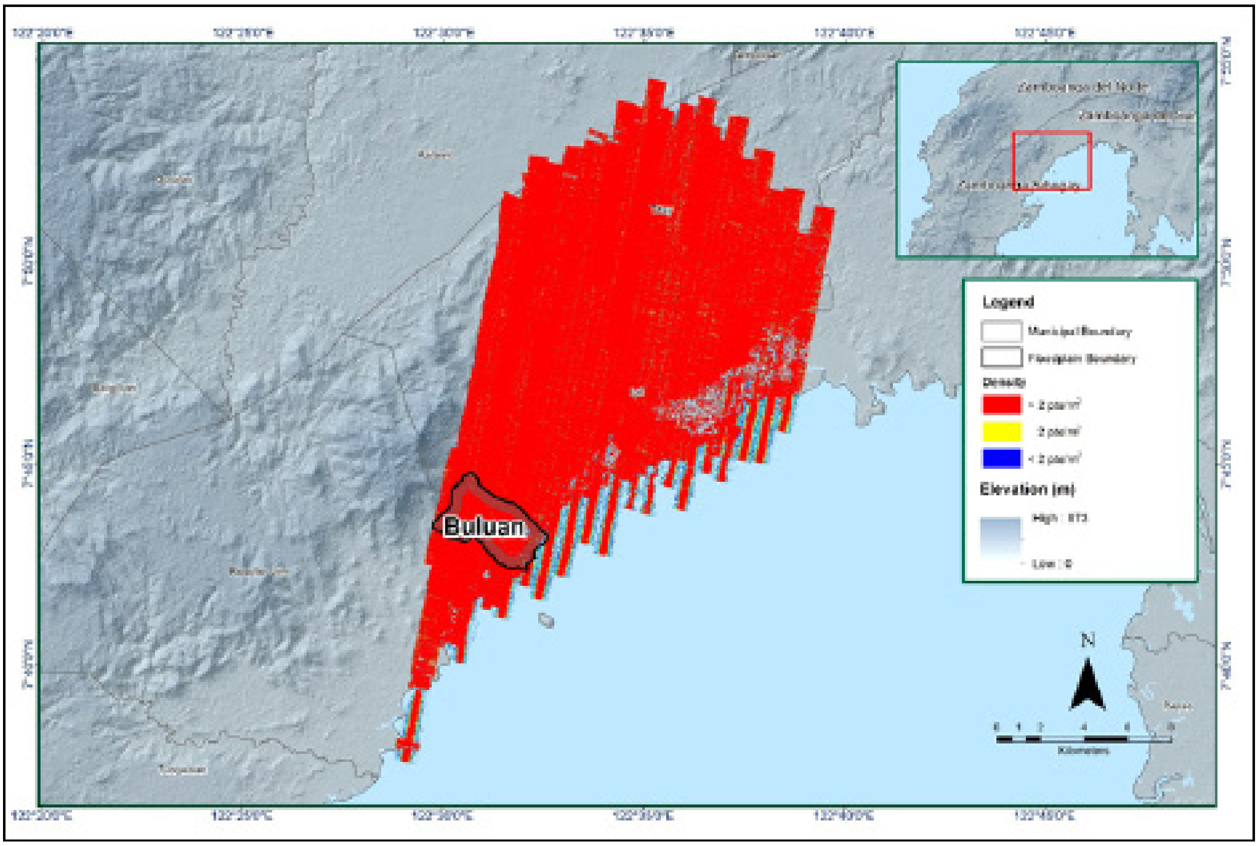


Figure 14. Pulse density map of merged LiDAR data for Buluan Floodplain.

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

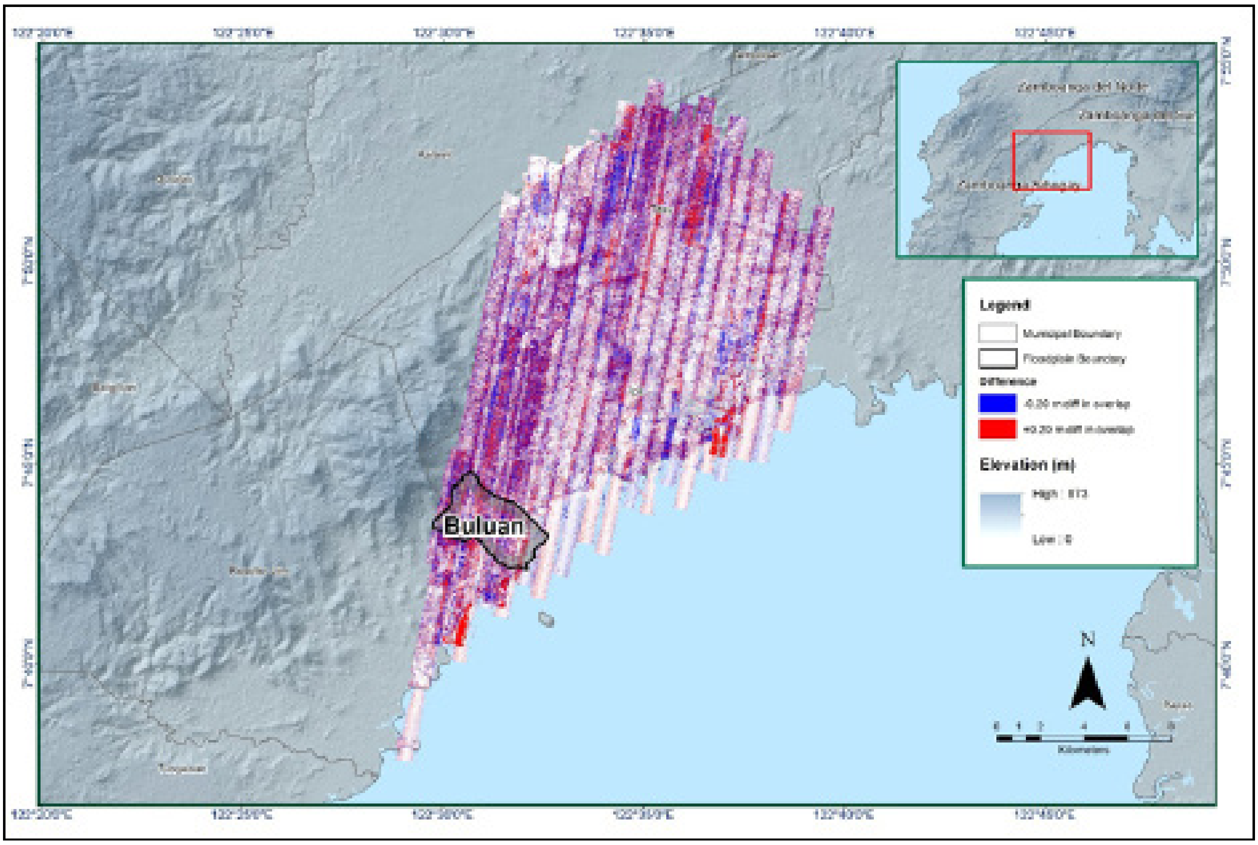


Figure 15. Elevation Difference Map between flight lines for Buluan Floodplain.

A screen capture of the processed LAS datafrom a Buluan flight 2549P loaded in QT Modeler is shown in Figure 16. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

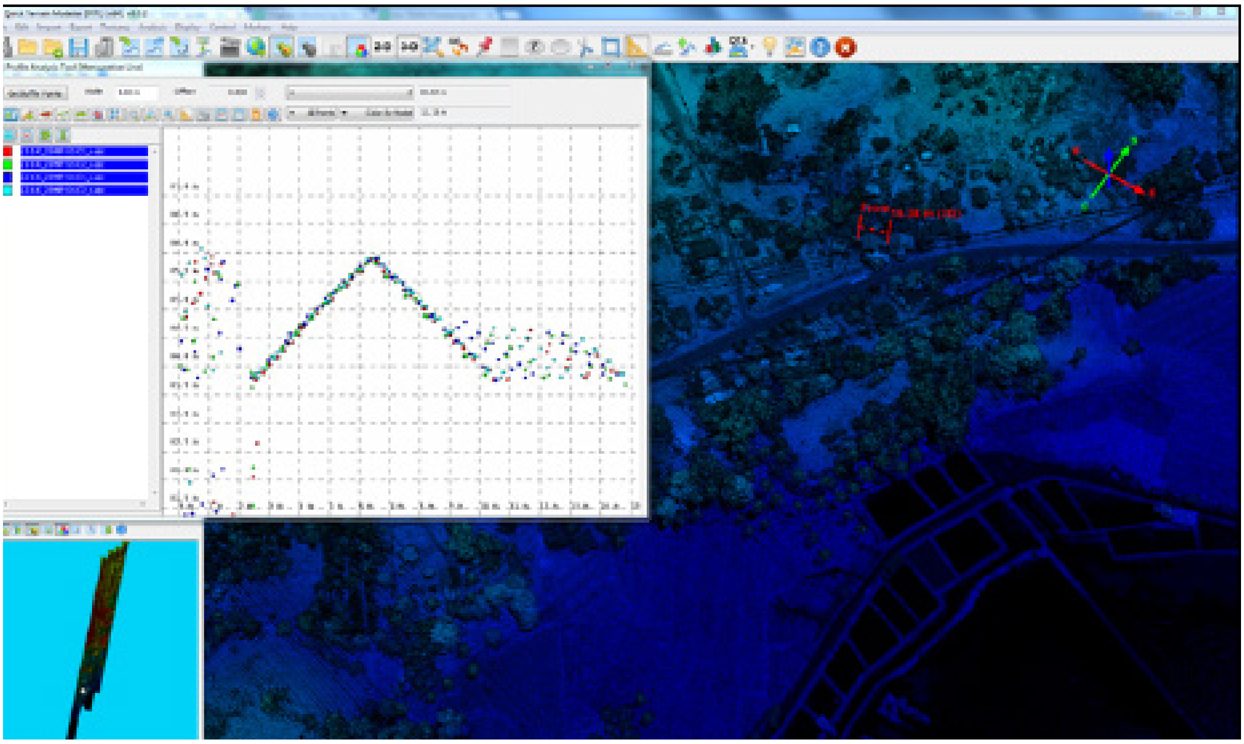


Figure 16. Quality checking for a Buluan flight 2549P using the Profile Tool of QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 10. Buluan classification results in TerraScan

Pertinent Class	Total Number 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

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Buluan floodplain is shown in Figure 17. A total of 354 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 10. The point cloud has a maximum and minimum height of 557.68 meters and 66.36 meters, respectively.

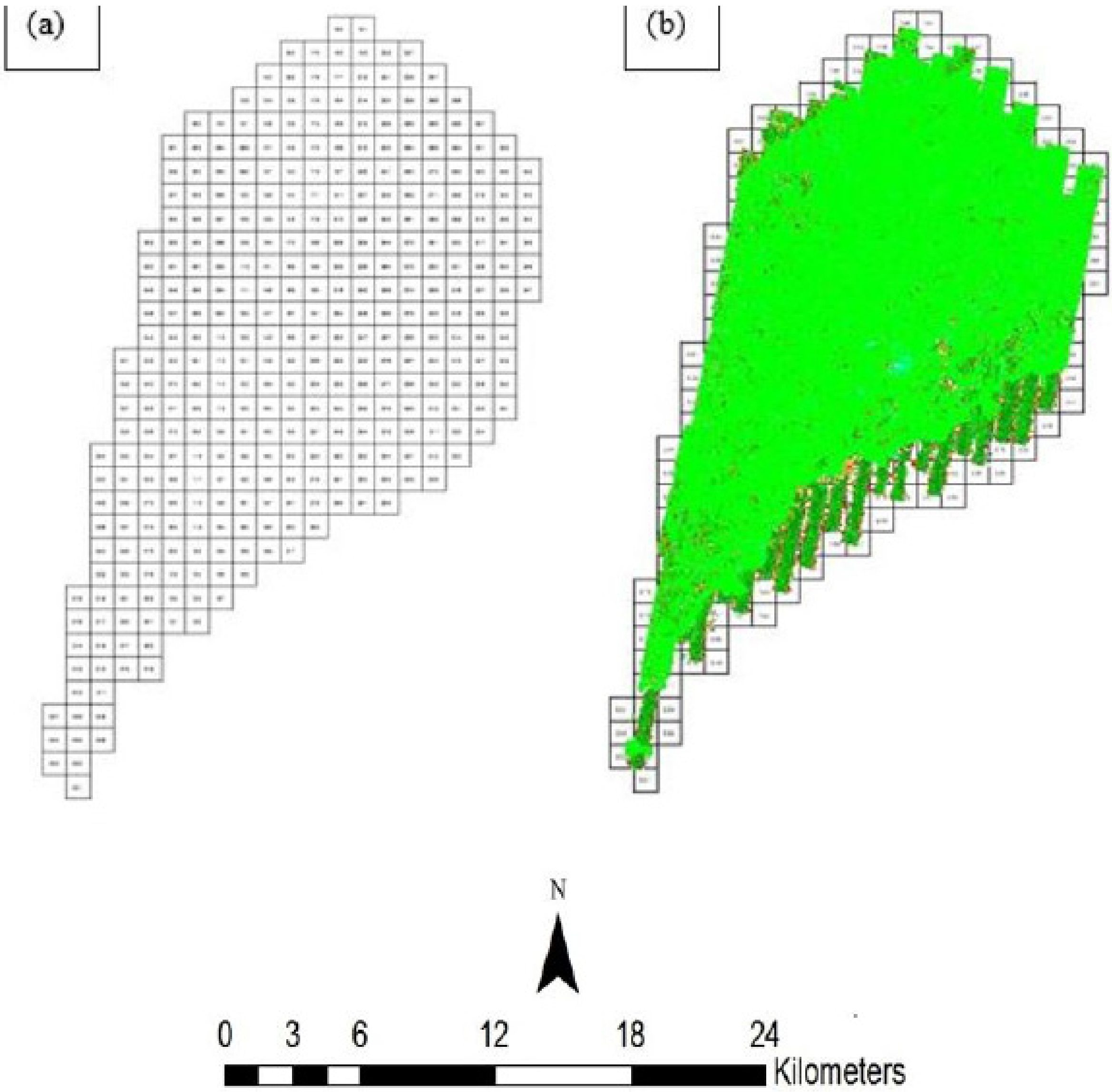


Figure 17. Tiles for Buluan floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 18. The ground points are in orange, the vegetation is in different shades of green, and the buildings are in cyan. It can be seen that residential structures adjacent or even below canopy are classified correctly, due to the density of the LiDAR data.

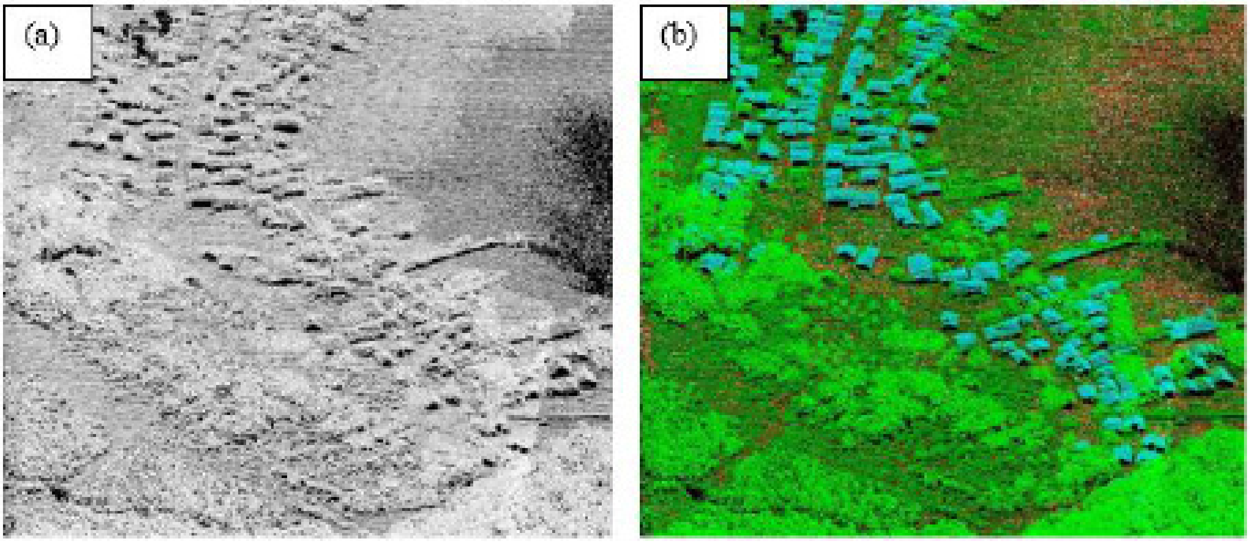


Figure 18. Point cloud before (a) and after (b) classification

The production of last return (V_ASCII) and the secondary (T_ ASCII) DTM, first (S_ ASCII) and last (D_ ASCII) return DSM of the area in top view display are shown in Figure 19. It shows that DTMs are the representation of the bare earth while on the DSMs, all features are present such as buildings and vegetation.

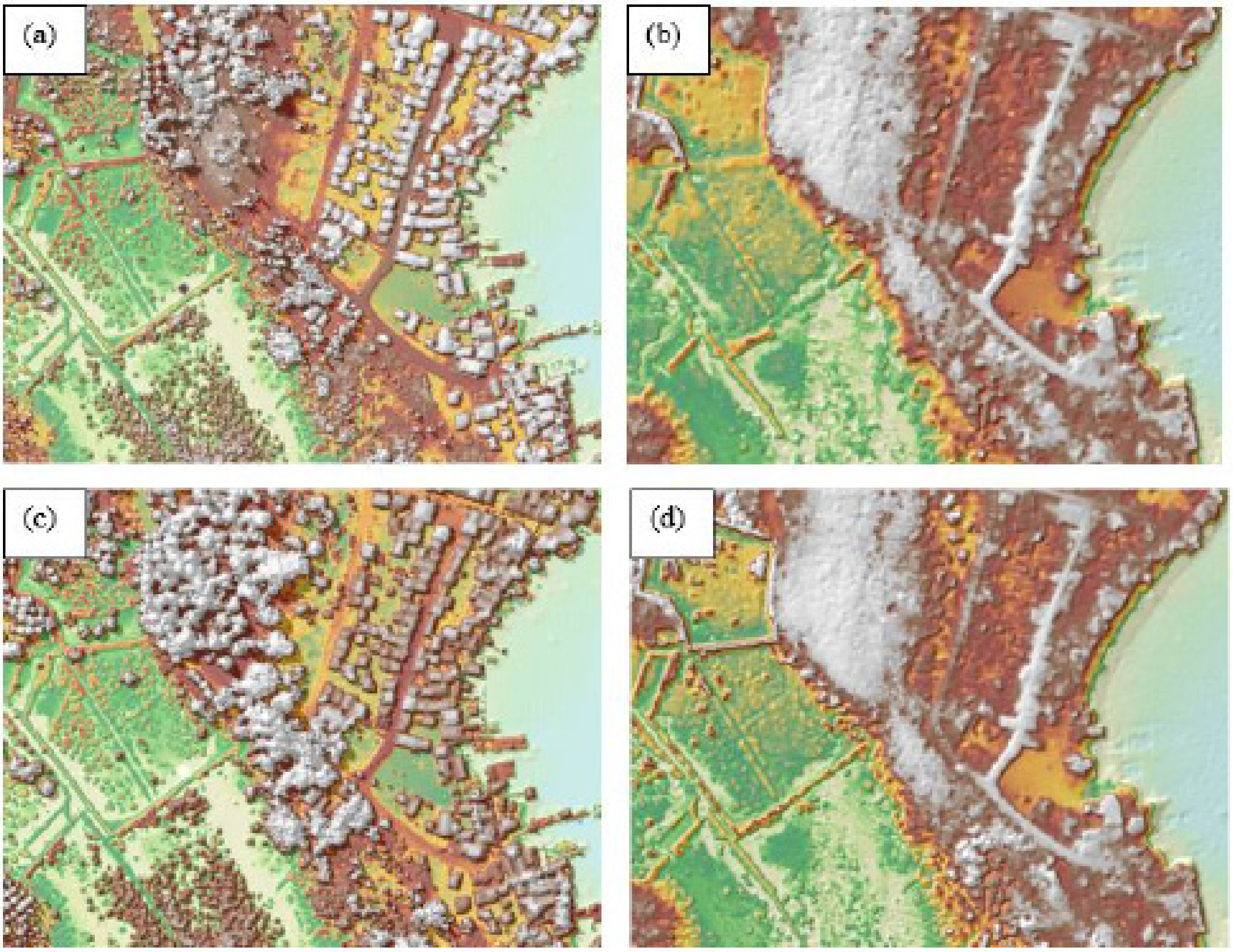


Figure 19. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Buluan Floodplain

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 349 1km by 1km tiles area covered by Buluan floodplain is shown in Figure 20. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Buluan floodplain has a total of 288.60 sq.km orthophotogaph coverage comprised of835 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 21.

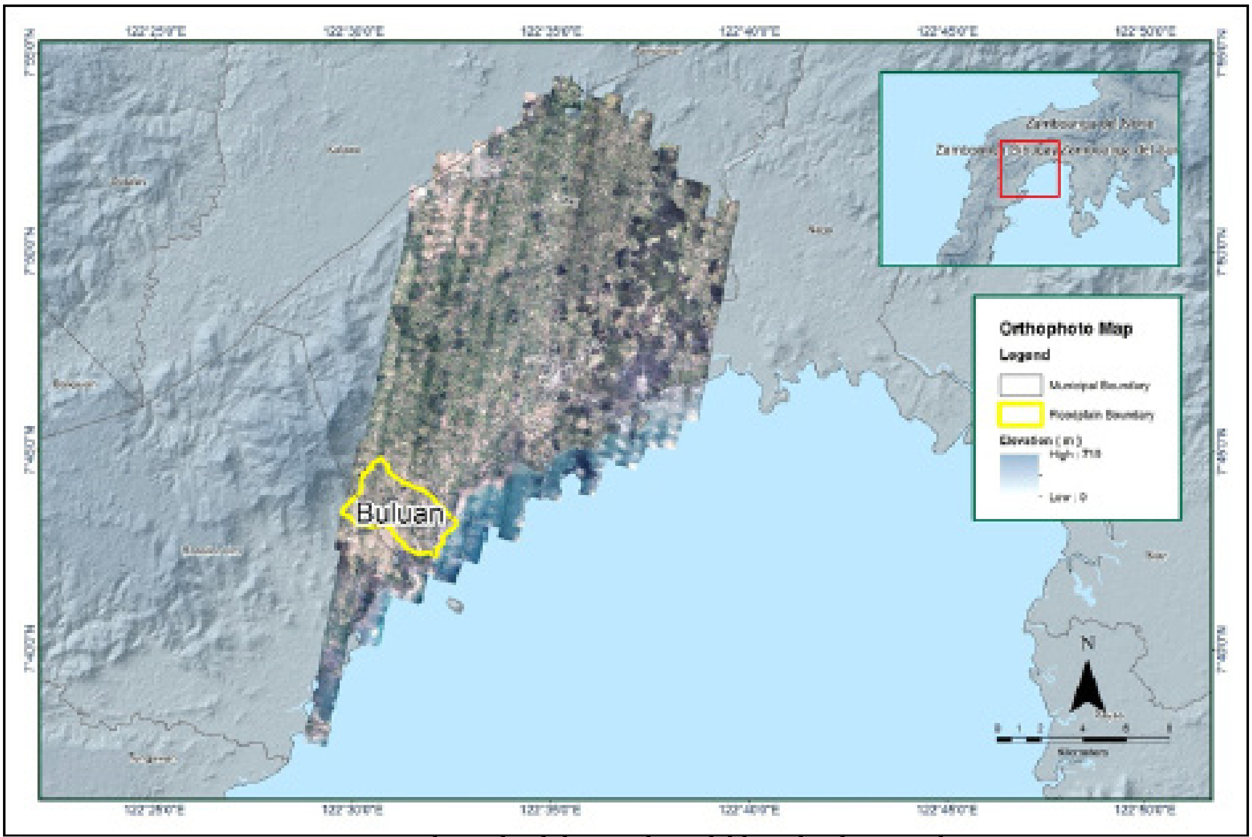


Figure 20. Buluan Floodplain with available orthophotographs

Figure 21. Sample orthophotograph tiles for Buluan Floodplain.

3.8 DEM Editing and Hydro-Correction

One (1) mission block was processed for Buluan flood plain which is Zamboanga_Blk75A. Table 11 shows the name and corresponding area of the block in square kilometers.

Table 11. LiDAR blocks with its corresponding areas.

LiDAR Blocks	Area (sq.km)
Zamboanga_Blk75A	284.34
TOTAL	**284.34 sq.km**

Portions of DTM before and after manual editing are shown in Figure 22. The rice field or fishpond embankment (Figure 22a) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 22b) to allow the correct flow of water. The bridge (Figure 22c) is also considered to be an impedance to the flow of water along the river and has to be removed (Figure 22d) in order to hydrologically correct the river.

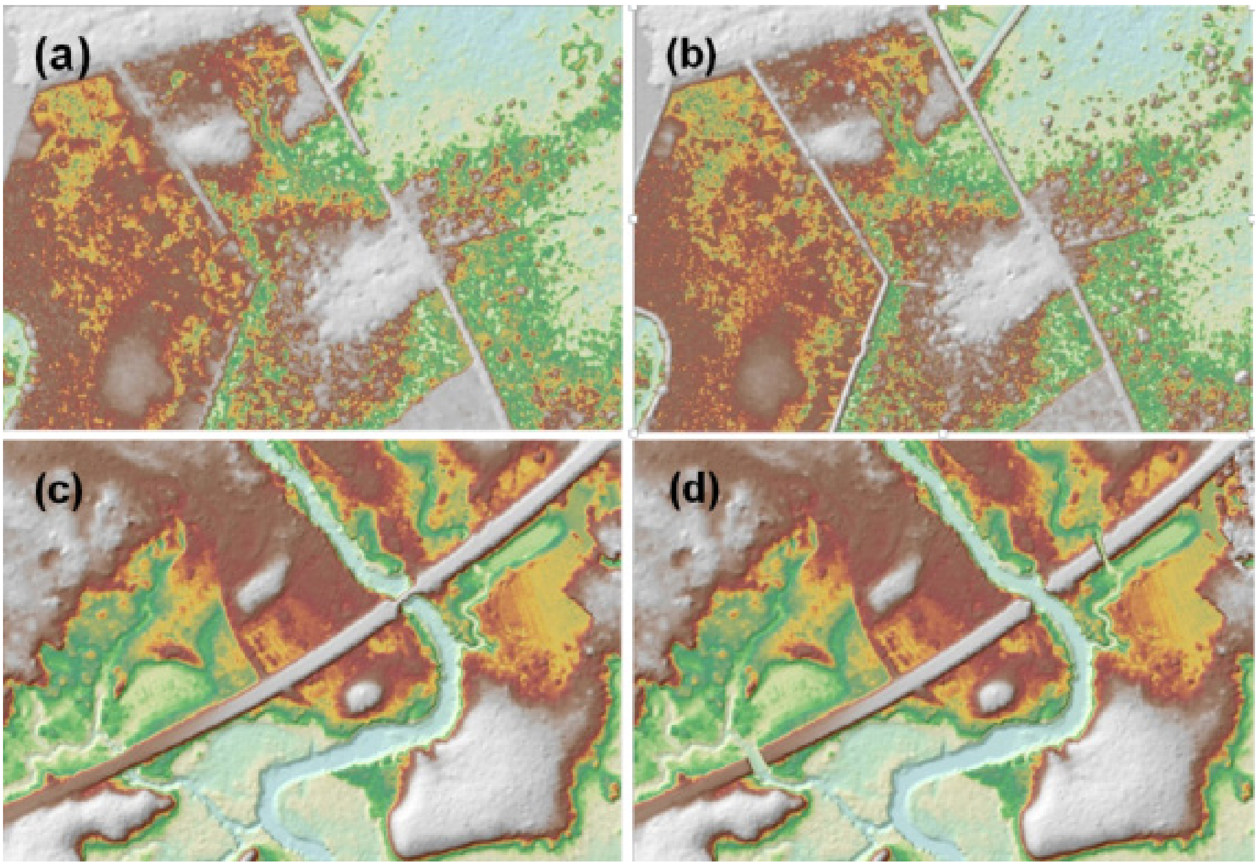


Figure 22. Portions in the DTM of Buluan Floodplain – a bridge before (a) and after (b) manual editing; a paddy field before (c) and after (d) data retrieval.

3.9 Mosaicking of Blocks

Zamboanga_Blk75A was used as the reference block at the start of mosaicking because it was the first available data at that time. Table 12 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Buluan floodplain is shown in Figure 23. It can be seen that the entire Buluan floodplain is 100% covered by LiDAR data.

Table 12. Shift values of each LiDAR block of Buluan Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Zamboanga_Blk75A	0.00	0.00	0.00

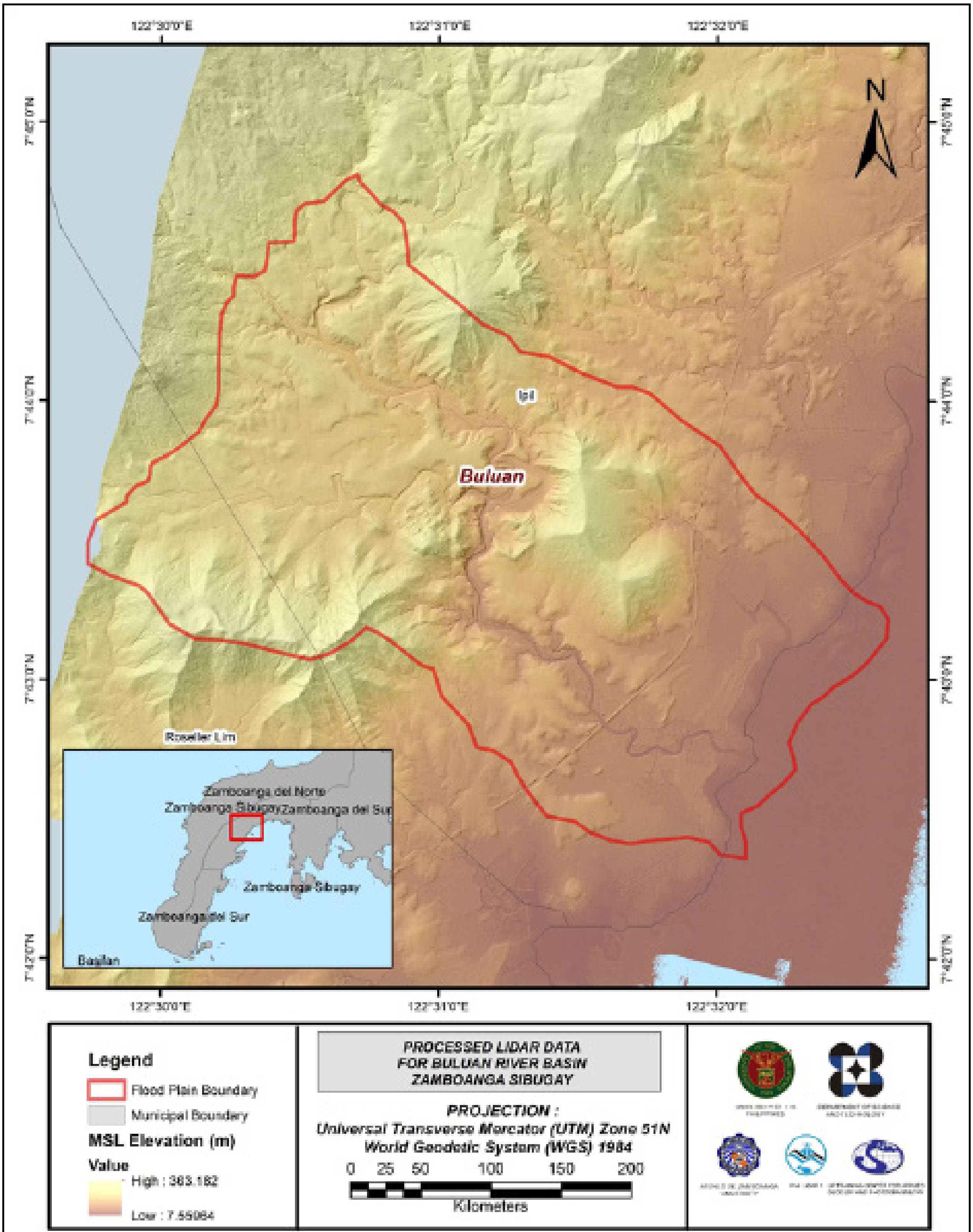


Figure 23. Map of Processed LiDAR Data for Buluan Floodplain

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 Buluan to collect points with which the LiDAR dataset is validated is shown in Figure 24.

Simultaneous mosaicking was done for the Zamboanga_PagadianLiDAR blocks and the only available data that time was for Sanito. The Buluan flood plain is included in the set of blocks previously mosaicked, therefore, the Sanito calibration data and methodology was used.

A total of 3,526 survey points from Sanito data were used for calibration and validation of all the blocks of Zamboanga_PagadianLiDAR data. Random selection of 80% of the survey points, resulting to 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 25. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration elevation values is 9.10meters with a standard deviation of 0.05 meters. Calibration for Zamboanga_PagadianLiDAR data was done by adding the height difference value, 9.10 meters, to Zamboanga mosaicked LiDAR data. Table 13 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

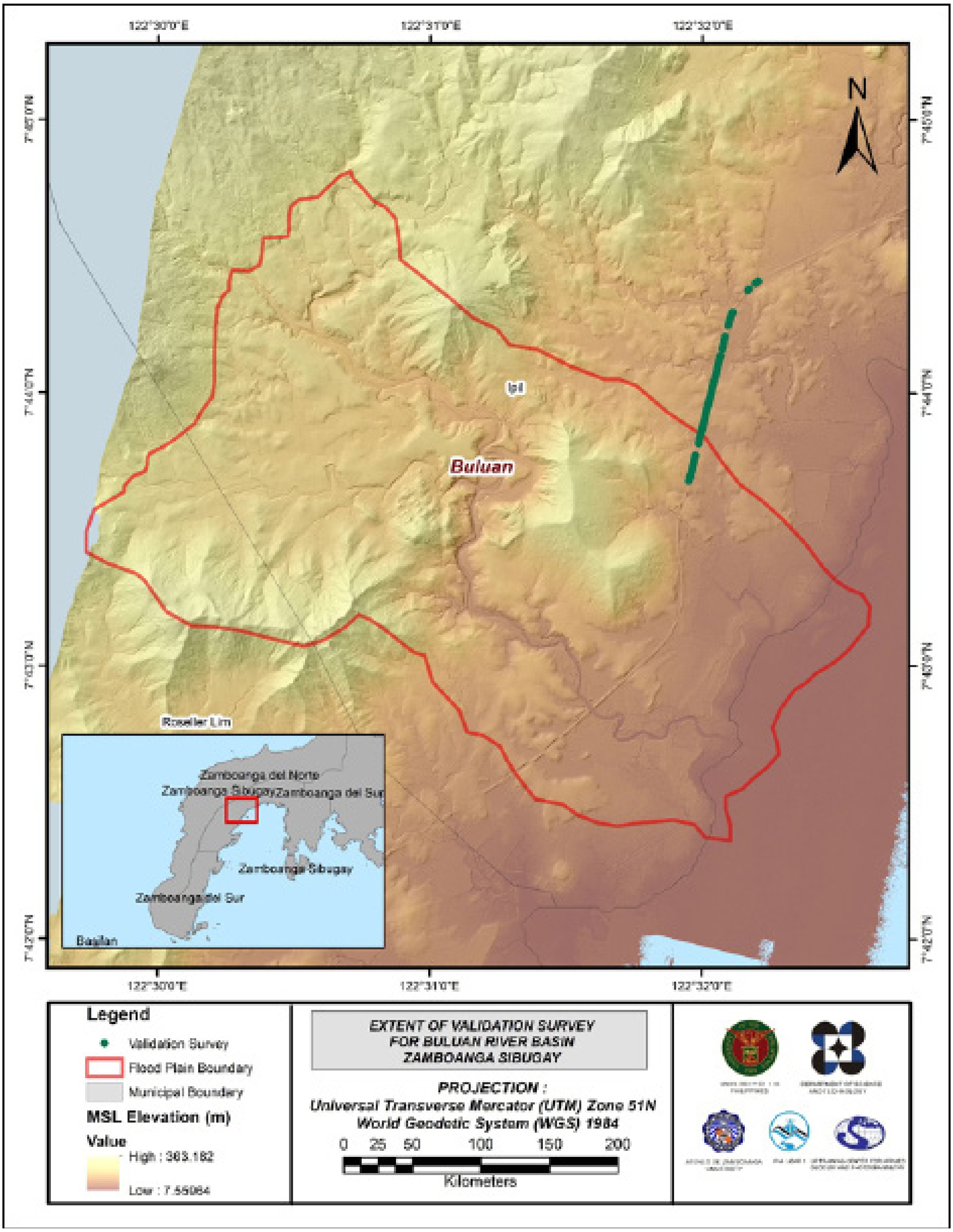


Figure 24. Map of Buluan Floodplain with validation survey points in green

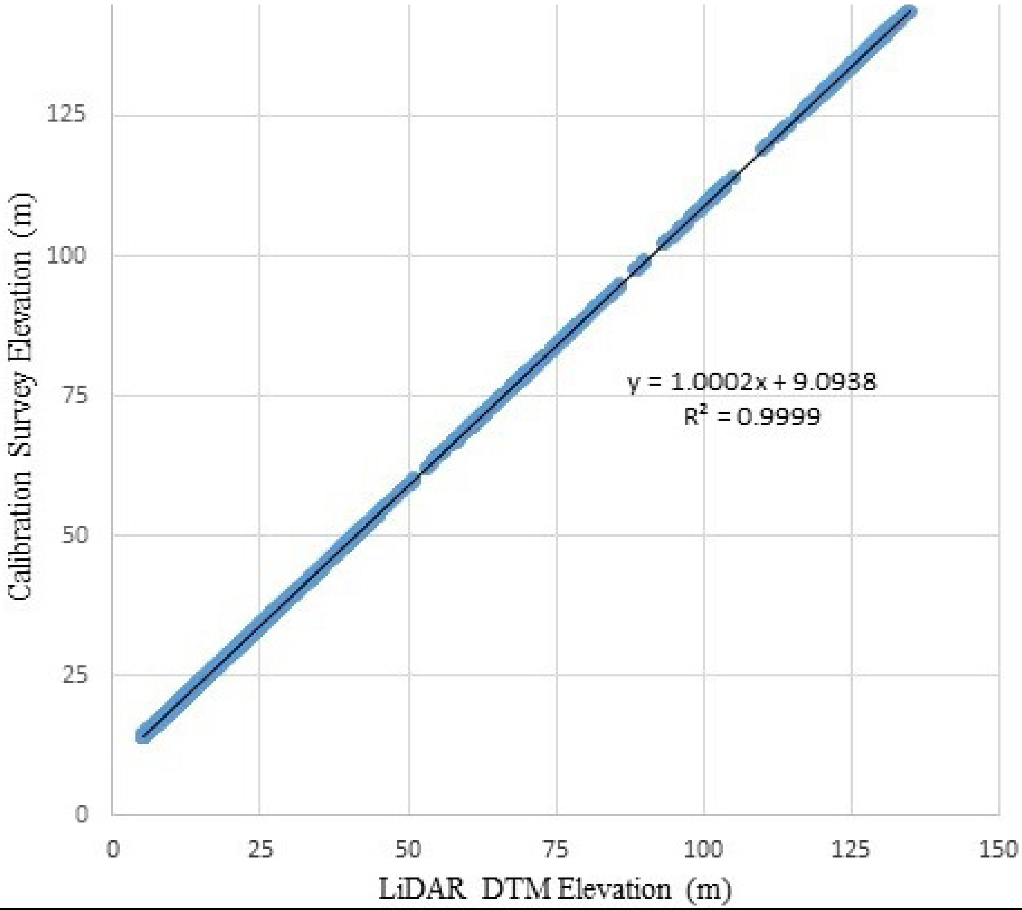


Figure 25. Correlation plot between calibration survey points and LiDAR data.

Table 13. 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

No validation data was collected for Buluan since the flood plain is between Sanito and Tupilac flood plains with sufficient validation data. 23 points from a total of 654 survey points for Tupilac lie on the Buluan floodplain were used for the validation of the calibrated Buluan 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 23. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.13meters with a standard deviation of 0.03meters, as shown in Table 14.

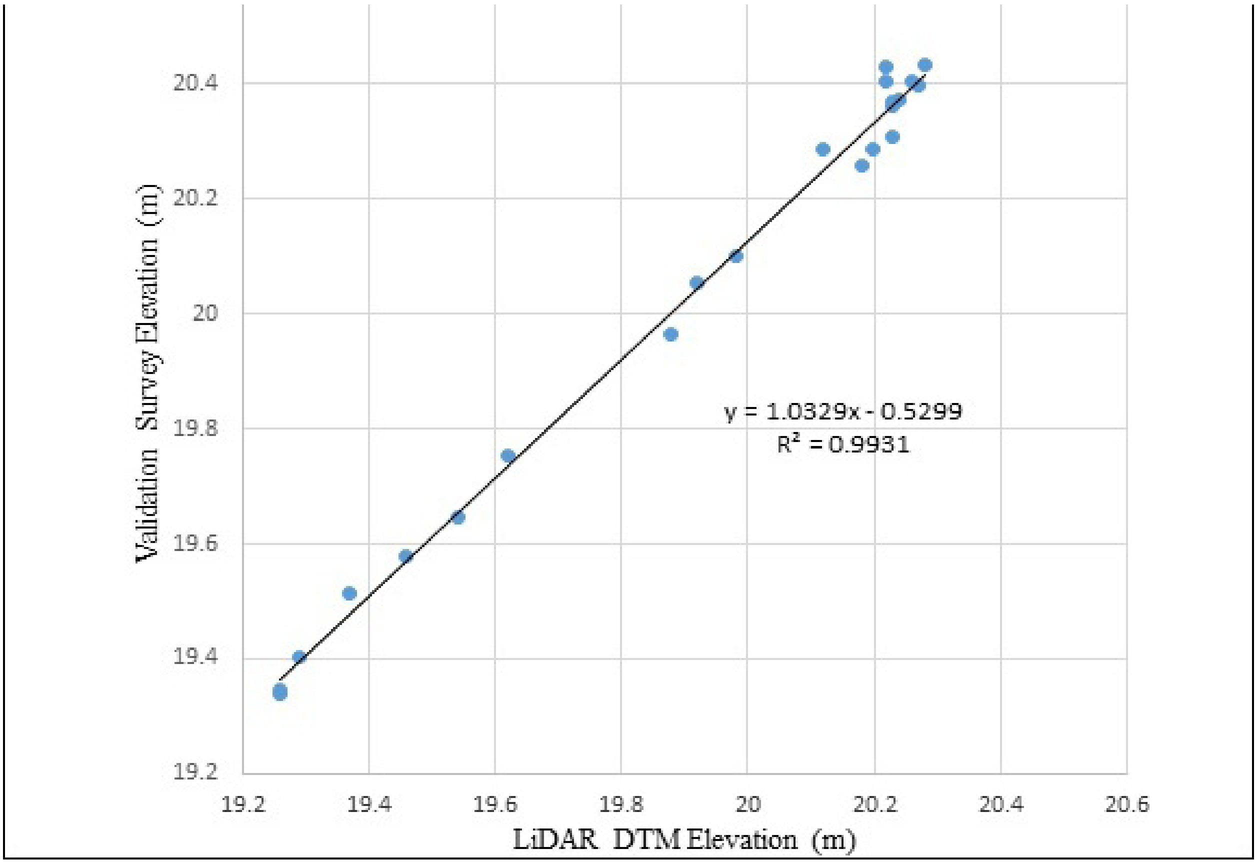


Figure 26. Correlation plot between validation survey points and LiDAR data

Table 14. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.13
Standard Deviation	0.03
Average	0.12
Minimum	0.05
Maximum	0.19

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and zigzag data were available for Buluan with 1,501 bathymetric survey points. The resulting raster surface produced was done by Kernel Interpolation with barriersmethod. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.27 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Buluan integrated with the processed LiDAR DEM is shown in Figure 27.

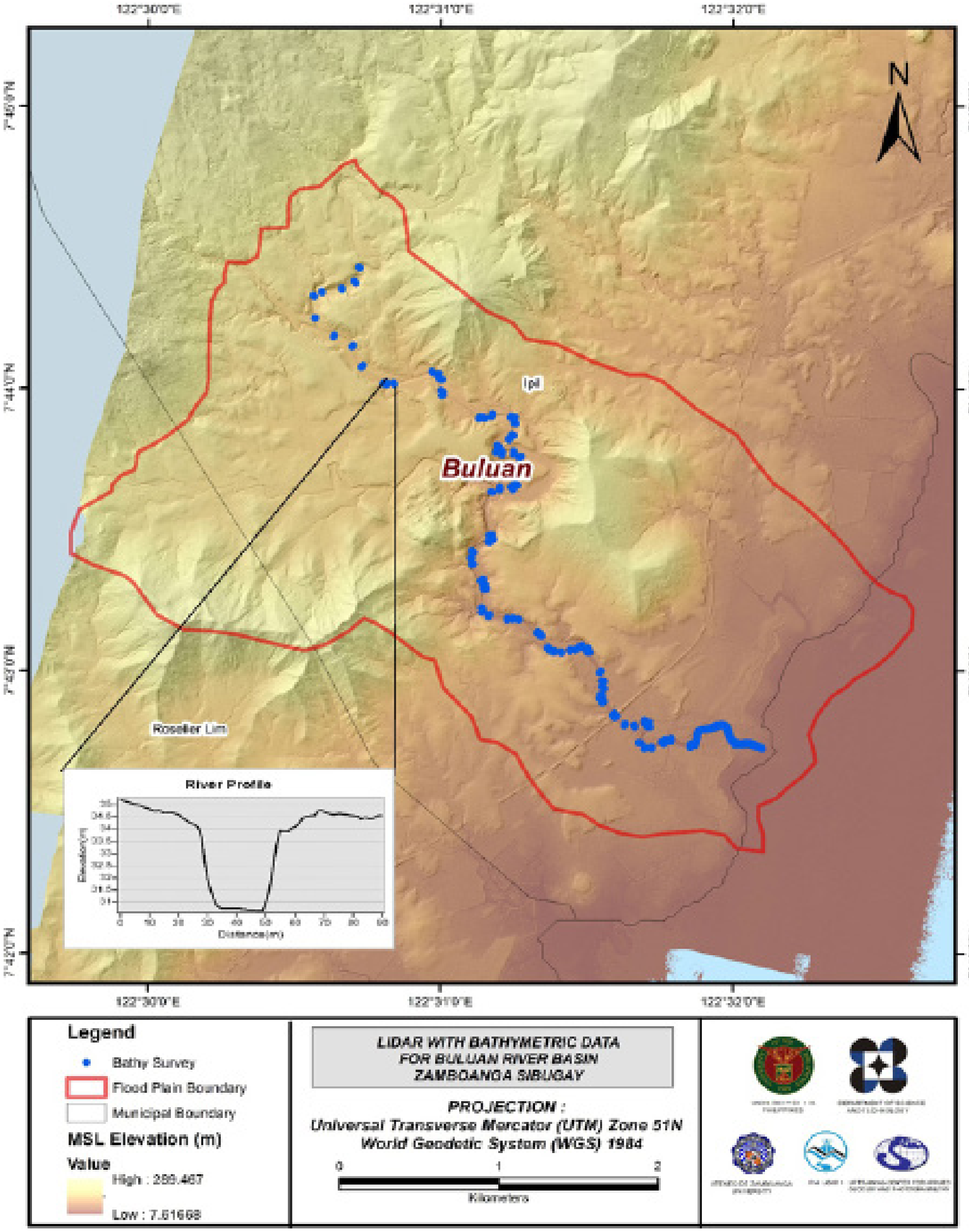


Figure 27. Map of Buluan Floodplain with bathymetric survey points shown in blue

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

Buluan floodplain, including its 200 m buffer, has a total area of 14.81 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 1,099 building features, are considered for QC. Figure 28 shows the QC blocks for Buluan floodplain.

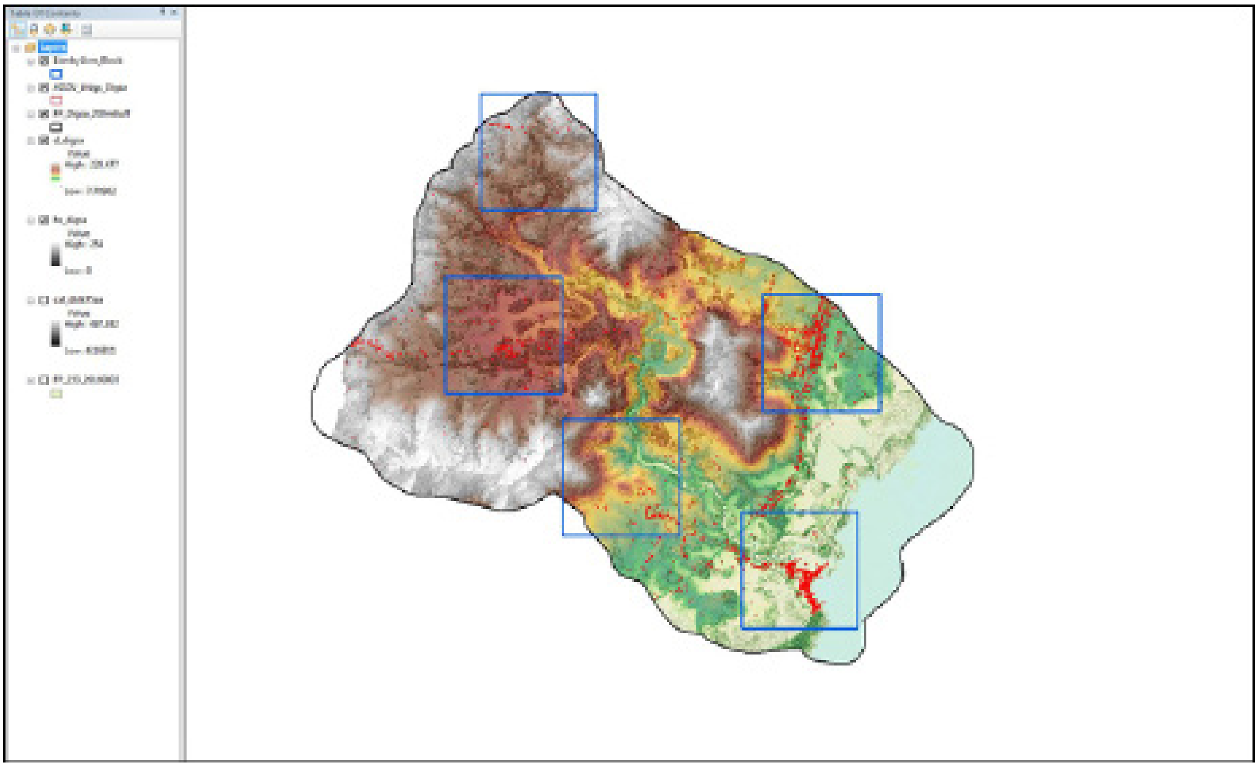


Figure 28. QC blocks for Buluan building features

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

Table 15. Quality Checking Ratings for Buluan Building Features

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Buluan	100.00	100.00	96.82	PASSED

3.12.2 Height Extraction

Height extraction was done for 1,669 building features in Buluan floodplain. Of these building features, none was filtered out after height extraction, resulting to 1,669 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 7.09 m.

3.12.3 Feature Attribution

One of the Research Associate 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, thru 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 flood plain of the river basin; likewise, the number of enumerators are also dependent on the availability of the tablet and the number of features of the flood plain.

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

Table 16. Building features extracted for Buluan floodplain.

Facility Type	No. of Features
Residential	v
School	16
Market	11
Agricultural/Agro-Industrial Facilities	7
Medical Institutions	1
Barangay Hall	1
Military Institution	0
Sports Center/Gymnasium/Covered Court	1
Telecommunication Facilities	0
Transport Terminal	0
Warehouse	5
Power Plant/Substation	0
NGO/CSO Offices	0
Police Station	0
Water Supply/Sewerage	0
Religious Institutions	6
Bank	0
Factory	0
Gas Station	0
Fire Station	0
Other Government Offices	3
Other Commercial Establishments	2
Total	1,669

Table 17. Total length of extracted roads for Buluan floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Buluan	3.20	0.22	0.00	3.21	0.00	6.63

Table 18. Number of extracted water bodies for Buluan floodplain.

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Buluan	28	0	0	0	18	46

A total of 3 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 29 shows the Digital Surface Model (DSM) ofBuluan floodplain overlaid with its ground features.

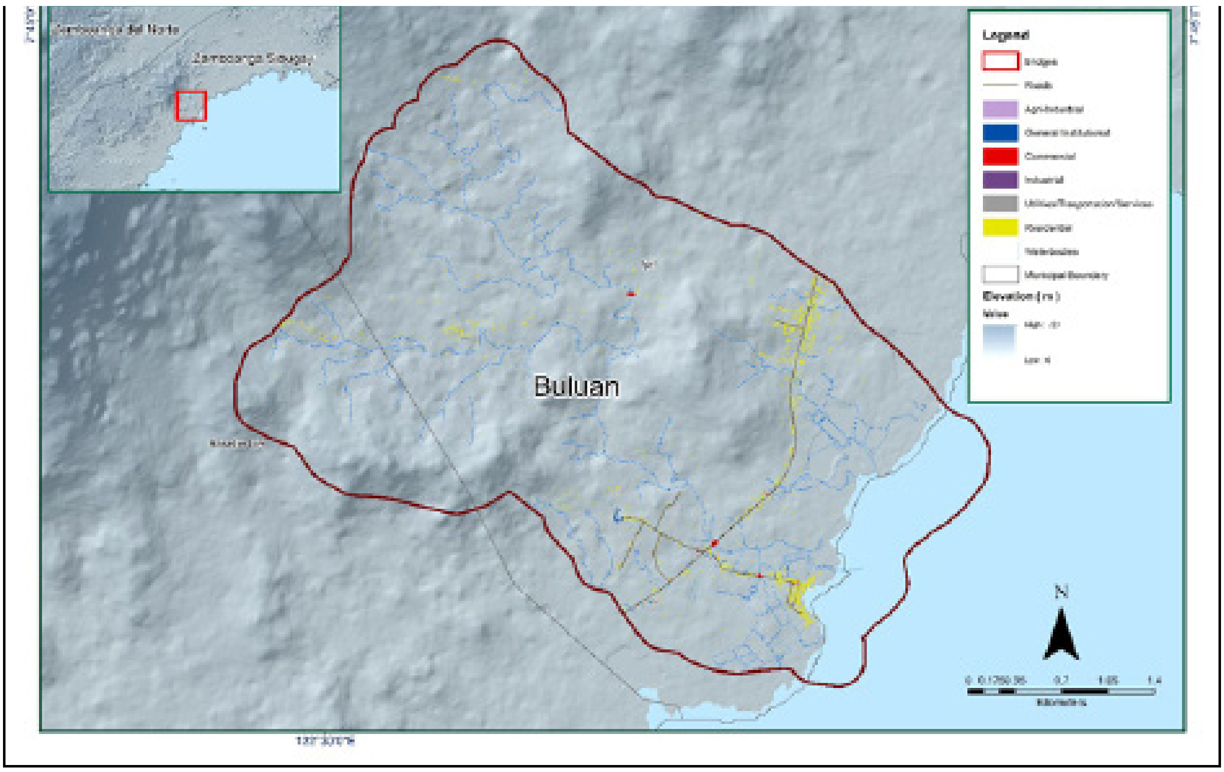


Figure 29. Extracted features of the Buluan Floodplain.

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

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

4.1 Summary of Activities

AB Surveying and Development (ABSD) conducted a field survey in Buluan River on April 14 and 18 to 21, 2016 with the following scope: reconnaissance; control survey; cross-section and as-built survey at Bulu-An Bridge in Brgy. Bulu-An, Municipality of Ipil, Zamboanga Sibugay; and bathymetric survey from its upstream in Brgy. Tomitom to the mouth of the river located in Brgy. Bulu-An, Ipil, with an approximate length of 6.00 km using Hi-Target™ echo sounder and Hi-Target ™ V30.In addition to this, validation points acquisition survey was conducted covering the Digsa River Basin area. The entire survey extent is illustrated in Figure 30.

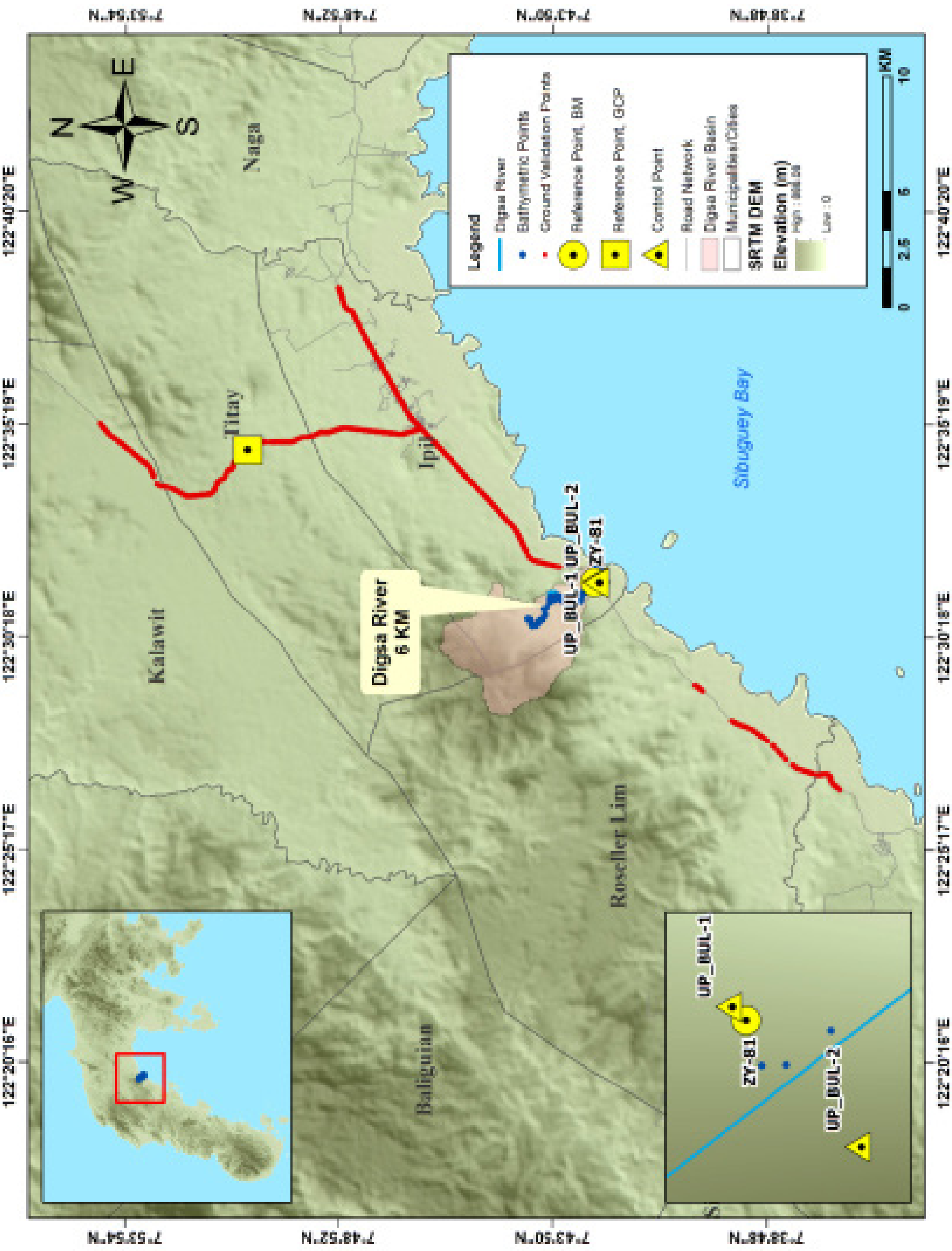


Figure 30. Extent of the bathymetric survey (in blue line) in Buluan River and the LiDAR data validation survey (in red).

4.2 Control Survey

The GNSS network used for Buluan River is composed of two (2)loops established on May 31, 2016 occupying the following reference points: ZSI-40 a second-order GCP, in Brgy. Kitabog, Titay, Zamboanga Sibugay and ZY-81, a first-order BM, in Brgy. Bulu-An, Ipil, Zamboanga Sibugay.

Two (2) control points established in the area by ABSD were also occupied: UP_BUL-1, located on the side of the National Road near the bridge in Brgy. Bulu-An, Ipil, Province of Zamboanga Sibugay, and UP_BUL-2 alsolocated on the side of the National Road near the bridge in Brgy. Bulu-An, Ipil, Province of Zamboanga Sibugay.

The summary of reference and control points and its location is summarized in Table 19 while GNSS network established is illustrated in Figure 31.

Table 19. List of reference and control points used during the survey in Buluan River

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (Meter)	Elevation in MSL (Meter)	Date Established
ZSI-40	2nd order, GCP	7°51' 1.60129"N	122°34' 42.54805"E	126.508	56.659	2006
ZY-81	1st order, BM	7°42'50.98886"N	122° 31' 36.06239"E	74.858	4.914	2007
UP_BUL-1	Established	7°42' 51.15696"N	122°31' 36.18507"E	74.535	4.590	04-19-16
UP_BUL-2	Established	7°42' 49.93785"N	122°31' 34.86158"E	74.464	4.560	04-19-16

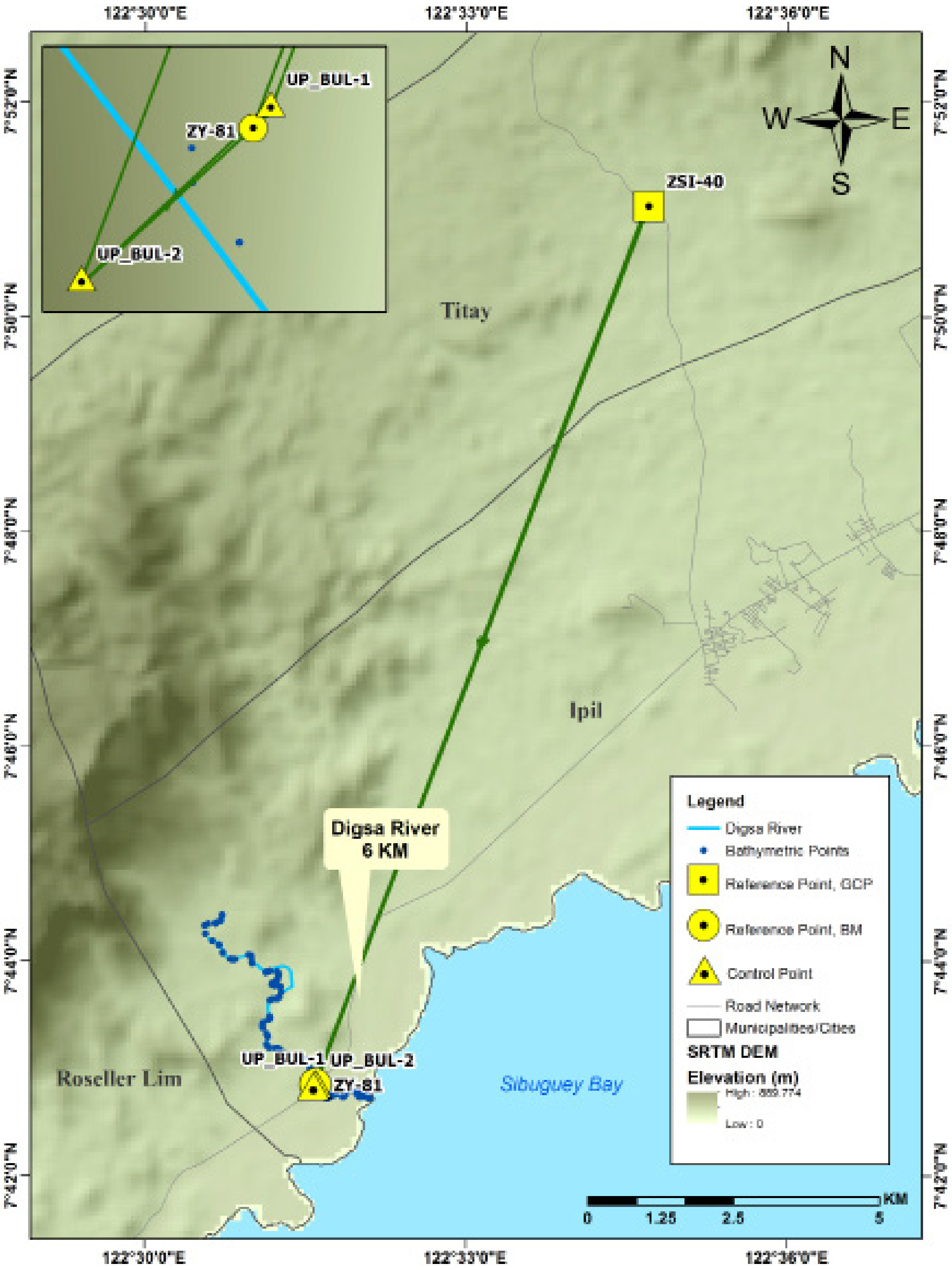


Figure 31. Buluan (also known as Digsa) River Basin Control Survey Extent

The GNSS set-ups on recovered reference points and established control points in Buluan River are shown from Figure 32 to Figure 34.

Figure 32. Ground Control Point ZSI-81, located along the shoulder of the opposite lane of the road Brgy. Kitabog, Municipality of Titay, Province of Zamboanga Sibugay

Figure 33. GNSS receiver set up, Hi-Target ™ V30, at ZY-81, located at the approach of Bulu-An Bridge inBrgy. Bulu-An, Municipality of Ipil, Province of Zamboanga Sibugay

Figure 34. GNSS receiver set up, Hi-Target ™ V30, at UP_BUL-2, located on the side of the National Road near the bridge in Brgy. Bulu-An, Ipil, Province of Zamboanga Sibugay.

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 DigsaRiver Basin is summarized in Table 20 generated by TBC software.

Table 20. Baseline Processing Report for Buluan River Static Survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
UP_BUL-1 --- ZY-81	5-31-2016	Fixed	0.003	0.005	216°03'53"	6.388	-0.322
UP_BUL-2 --- ZY-81	5-31-2016	Fixed	0.003	0.005	48°42'32"	48.967	0.387
UP_BUL-1 --- UP_BUL-2	5-31-2016	Fixed	0.004	0.007	227°16'47"	55.206	-0.072
ZSI-40 --- UP_BUL-1	5-31-2016	Fixed	0.015	0.027	200°45'35"	16112.622	-52.178
ZSI-40 --- ZY-81	5-31-2016	Fixed	0.017	0.030	200°45'53"	16118.648	-51.593
ZSI-40 --- UP_BUL-2	5-31-2016	Fixed	0.018	0.032	200°50'46"	16161.930	-52.032

As shown in Table 20, a total of fourteen (14) baselines were processed with the coordinates of SME-18 and the elevation value of reference point SE-85 held fixed; it is apparent that all baselines passed the required accuracy.

4.4 Network Adjustment

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

$\sqrt{((x_e)^2 + (y_e)^2)}$ <20cm 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 from Table 21 to Table 24 for the complete details.

The five (5) control points, PLW-137, PL-689, UP-IWA-1, UP_PAN-1, and UP-IRA-2 were occupied and observed simultaneously to form a GNSS loop. The coordinates and ellipsoidal height of PLW-137 were held fixed during the processing of the control points as presented in Table 21. Through this reference point, the coordinates and ellipsoidal height of the unknown control points will be computed.

Table 21. Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
ZSI-40	Global	Fixed	Fixed	Fixed	
Fixed = 0.000001 (Meter)					

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

Table 22. Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
ZY-81	447804.797	0.011	852727.318	0.009	6.500	0.024	
ZSI-40	453532.275	?	867787.699	?	58.297	?	LLhv
UP_BUL-1	447808.562	0.011	852732.475	0.009	6.177	0.024	
UP_BUL-2	447767.967	0.011	852695.080	0.009	6.104	0.024	

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

a. **ZY-81**

horizontal accuracy	=	$\sqrt{((1.1)^2 + (0.9)^2}$
	=	$\sqrt{(1.21 + 0.81)}$
	=	2.02< 20 cm
vertical accuracy	=	0.024< 10 cm

b. **ZSI-40**

horizontal accuracy	=	Fixed
vertical accuracy	=	Fixed

c. **UP_BUL-1**

horizontal accuracy	=	$\sqrt{((1.1)^2 + (0.9)^2}$
	=	$\sqrt{(1.21 + 0.81)}$
	=	2.02< 20 cm
vertical accuracy	=	0.024< 10 cm

d. **UP_BUL-2**

horizontal accuracy	=	$\sqrt{((1.1)^2 + (0.9)^2}$
	=	$\sqrt{(1.21 + 0.81)}$
	=	2.02< 20 cm
vertical accuracy	=	0.024< 10 cm

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

Table 23. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Ellipsoid	Height	Constraint
ZY-81	N7°42'50.98793"	E122°31'36.06555"	74.895	0.024	
ZSI-40	N7°51'01.60129"	E122°34'42.54805"	126.508	?	LLh
UP_BUL-1	N7°42'51.15600"	E122°31'36.18827"	74.573	0.024	
UP_BUL-2	N7°42'49.93681"	E122°31'34.86442"	74.499	0.024	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 23. Based on the result of the computation, the equation is satisfied; hence, the required accuracy for the program was met.The summary of reference control points used is indicated in Table 24.

Table 24. Reference and control points used and its location

(Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
ZSI-40	2nd order, GCP	7° 51' 1.60129"N	122°34'42.54805"E	126.508	867787.699	453532.275	56.659
ZY-81	1st order, BM	7°42'50.98886"N	122°31'36.06239"E	74.858	852727.317	447804.818	4.914
UP_BUL-1	Established	7°42'51.15696"N	122°31'36.18507"E	74.535	852732.475	447808.584	4.590
UP_BUL-2	Established	7°42'49.93785"N	122°31'34.86158"E	74.464	852695.068	447767.966	4.560

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

Cross-section and as-built surveys were conducted on April 18, 2016 at the upstream side of Bulu-An Bridge in Brgy. Bulu-An, Municipality of Ipil as shown in Figure 35. A Horizon®Total Station was utilized for this survey as shown in Figure 36.

Figure 35. Buluan Bridge facing upstream

Figure 36. The Cross-section survey conducted at Buluan Bridge facing upstream

The cross-sectional line of Bulu-An Bridge is about 172 m with thirty-seven (37) cross-sectional points using the control points UP_BUL-1 and UP_BUL-2 as the GNSS base stations. The location map, cross-section diagram, and the bridge data form are shown in Figure 37 to Figure 39.

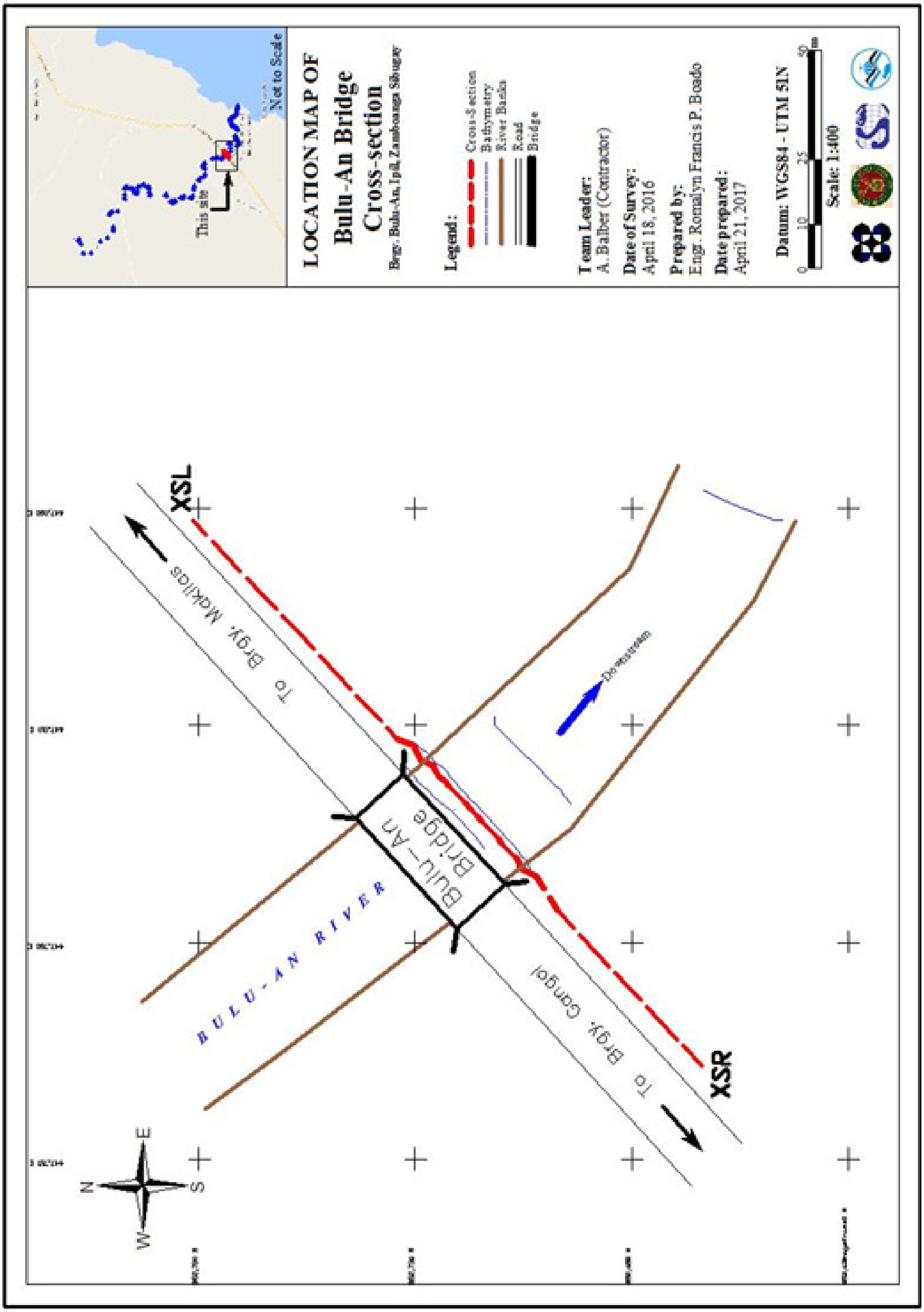


Figure 37. Location map of Buluan Bridge cross-section survey

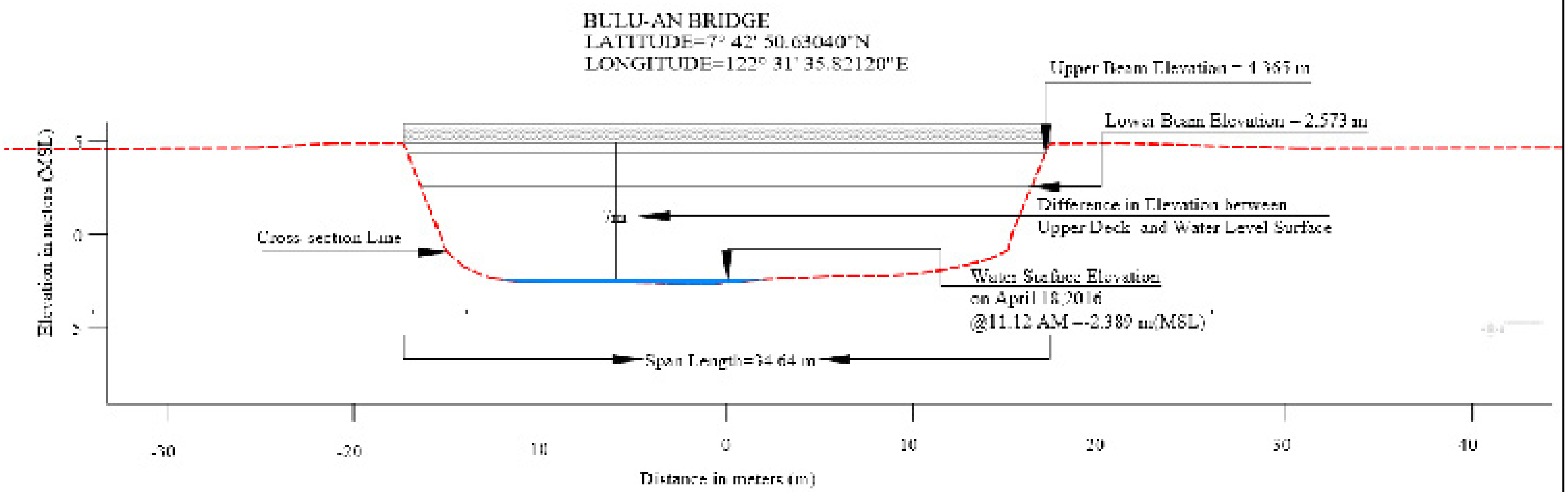
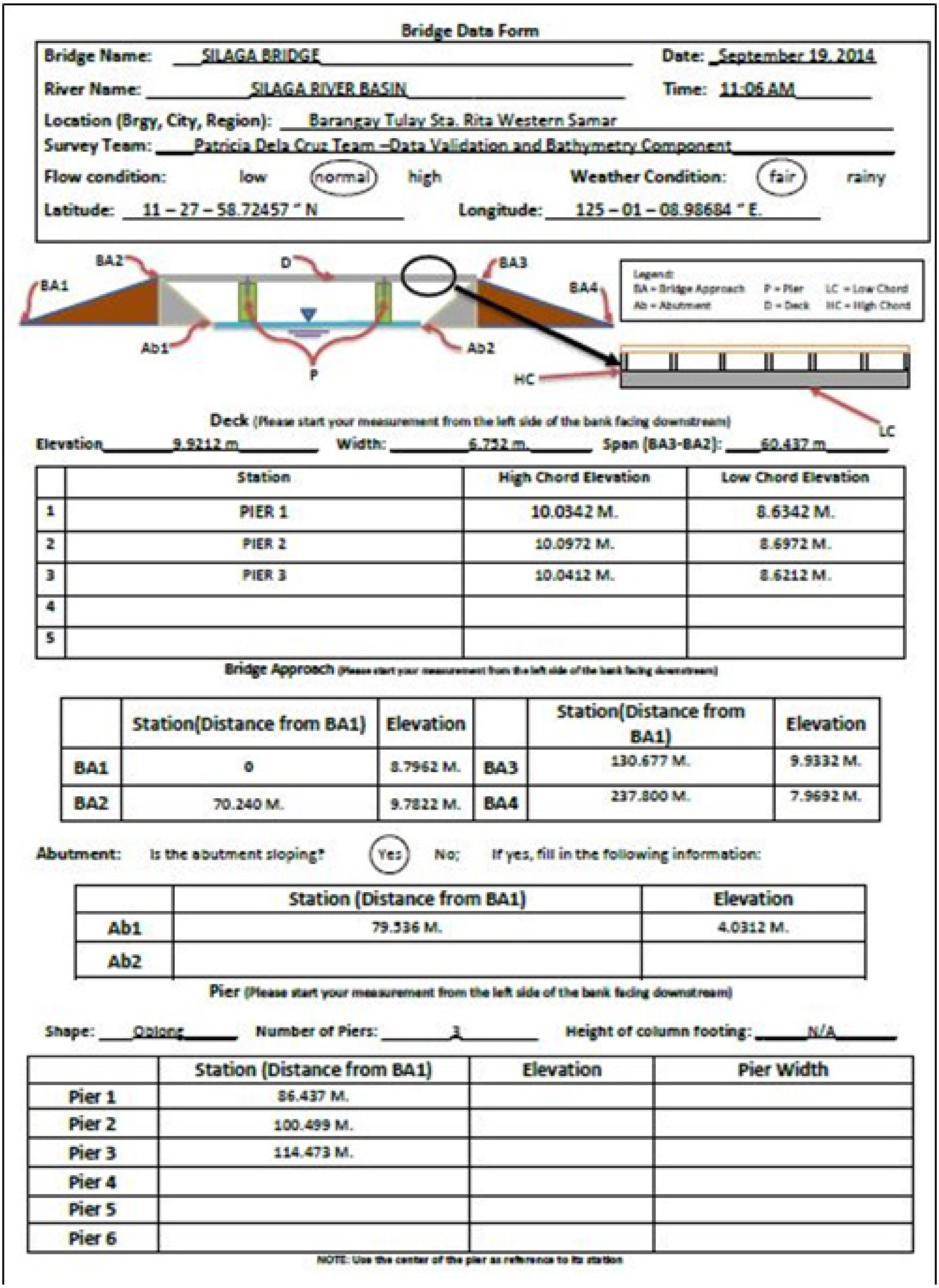


Figure 38. Bulu-An Bridge Cross-section Diagram



Bridge Data Form

Bridge Name: SILAGA BRIDGE Date: September 19, 2014

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

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

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

Flow condition: low normal high Weather Condition: fair rainy

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

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

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

	Station	High Chord Elevation	Low Chord Elevation
1	PIER 1	10.0342 M.	8.6342 M.
2	PIER 2	10.0972 M.	8.6972 M.
3	PIER 3	10.0412 M.	8.6212 M.
4			
5			

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	8.7962 M.	BA3	130.677 M.	9.9332 M.
BA2	70.240 M.	9.7822 M.	BA4	237.800 M.	7.9692 M.

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

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

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

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

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

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

Figure 39. Buluan Bridge Data Sheet

Water surface elevation of Buluan River was determined by a Horizon® Total Station on April 18, 2016 at 11:12 AM at Bulu-An Bridge area with a value of -2.389 m in MSL as shown in Figure 36. This was translated into marking on the bridge's retaining wall as shown in Figure 40. The marking will serve as reference for flow data gathering and depth gauge deployment of the partner HEI responsible for Digsa River, Ateneo de Zamboanga University.

Figure 40. Water-level markings on Buluan Bridge

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was already conducted by DVBC on July 30, 2015 and August 3, 2015using a survey grade GNSS Rover receiver, Trimble® SPS 882, mounted on a range pole which was attached to the front of the vehicle as shown in Figure 41 for Sanito and Tupilac Rivers, which already covered the area around the Buluan (also known as Digsa) River. It was secured with cable ties and ropes to ensure that it was horizontally and vertically balanced. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with ZSI-36 and ZY-93A occupied as the GNSS base station in the conduct of the survey.

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

The survey started from Brgy. Gatas, Municipality of Kalawit, Zamboanga Sibugay going south west along national high way covering twenty-two(22) barangays in the Municipalities of Kalawit, Titay, Ipil and Tungawan, and ended in Brgy. Buluran, Municipality of Tungawan, Zamboanga Sibugay. ZSI-36 and ZY-93A are used as GNSS base stations for the entire extent of validation points acquisition survey as illustrated in the map in Figure 42.

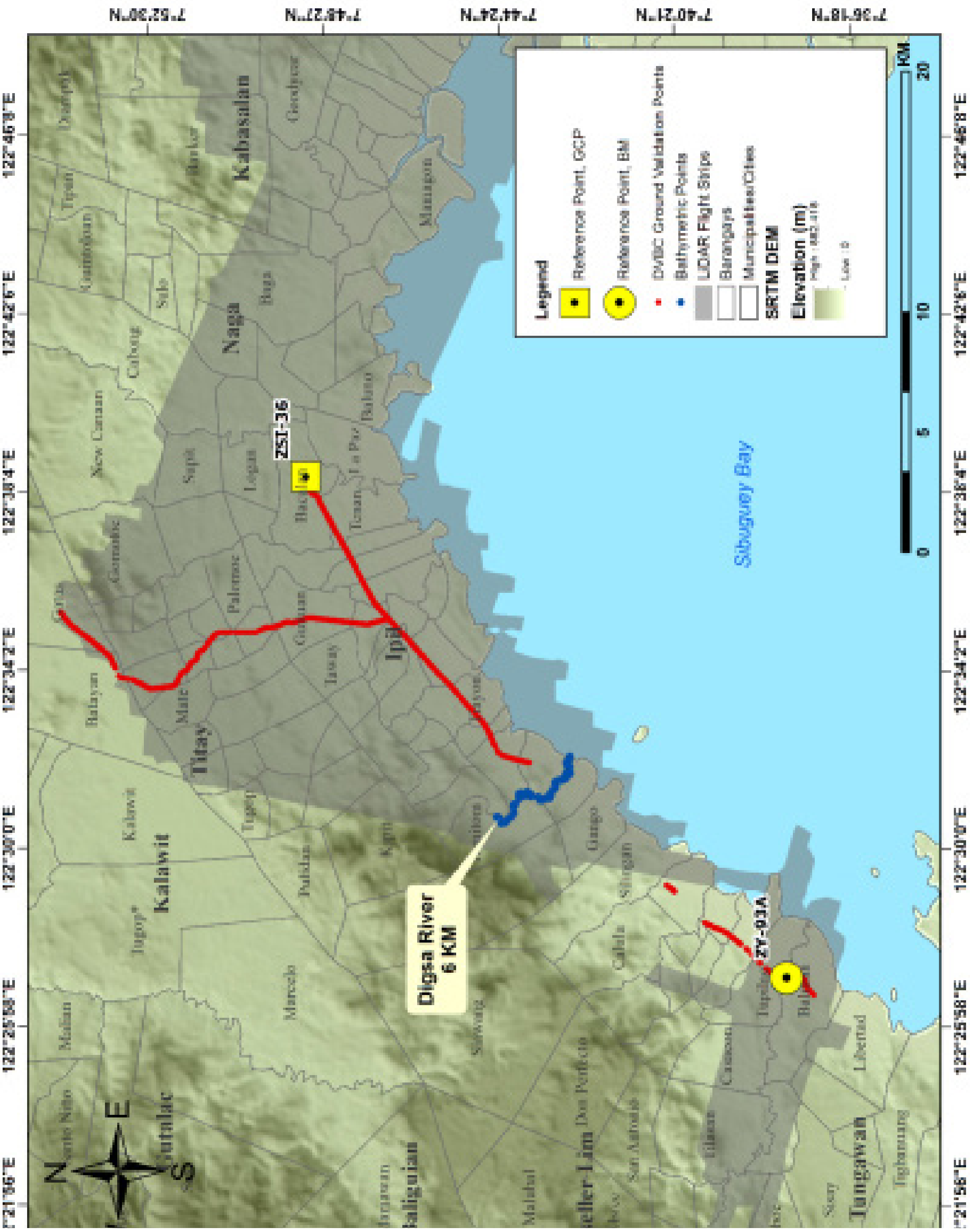


Figure 42. Validation points acquisition covering the Buluan (also known as (Digsa) River Basin Area

4.7 River Bathymetric Survey

Bathymetric survey was executed manually on April 14, 18, 19, and 21, 2016using Horizon® Total Stationas seen in Figure 43. The survey started in Brgy. Tomitom, Municipality of Ipil, Zamboanga Sibugay with coordinates 7° 44' 25.90480"N, 122° 30' 43.17991"Eand ended in Brgy. Buluan, Municipality of Ipil as well with coordinates7° 42' 44.79448"N, 122° 31' 51.87414"E.

Figure 43. Manual bathymetric survey of ABSD at Buluan River using Horizon® Total Station

Bathymetric survey on the other hand was executed on April 19, 2016 using Hi-Target™ echo sounder and Hi-Target ™ V30as illustrated in Figure 44. The survey started in Brgy. Buluan, Municipality of Ipil with coordinates 7° 42' 44.59554"N, 122° 31' 52.21411"E and ended at the mouth of the river in Brgy. Buluan, Municipality of Ipil as well with coordinates 7° 42' 43.43086"N, 122° 32' 6.04266"E.The control pointsUP_BUL-1 and UP_BUL-2 were used as GNSS base stations all throughout the entire survey.

Figure 44. Bathymetric survey of ABSD at Buluan (also known as Digsa) River using Hi-Target™ Echo Sounder (upstream)

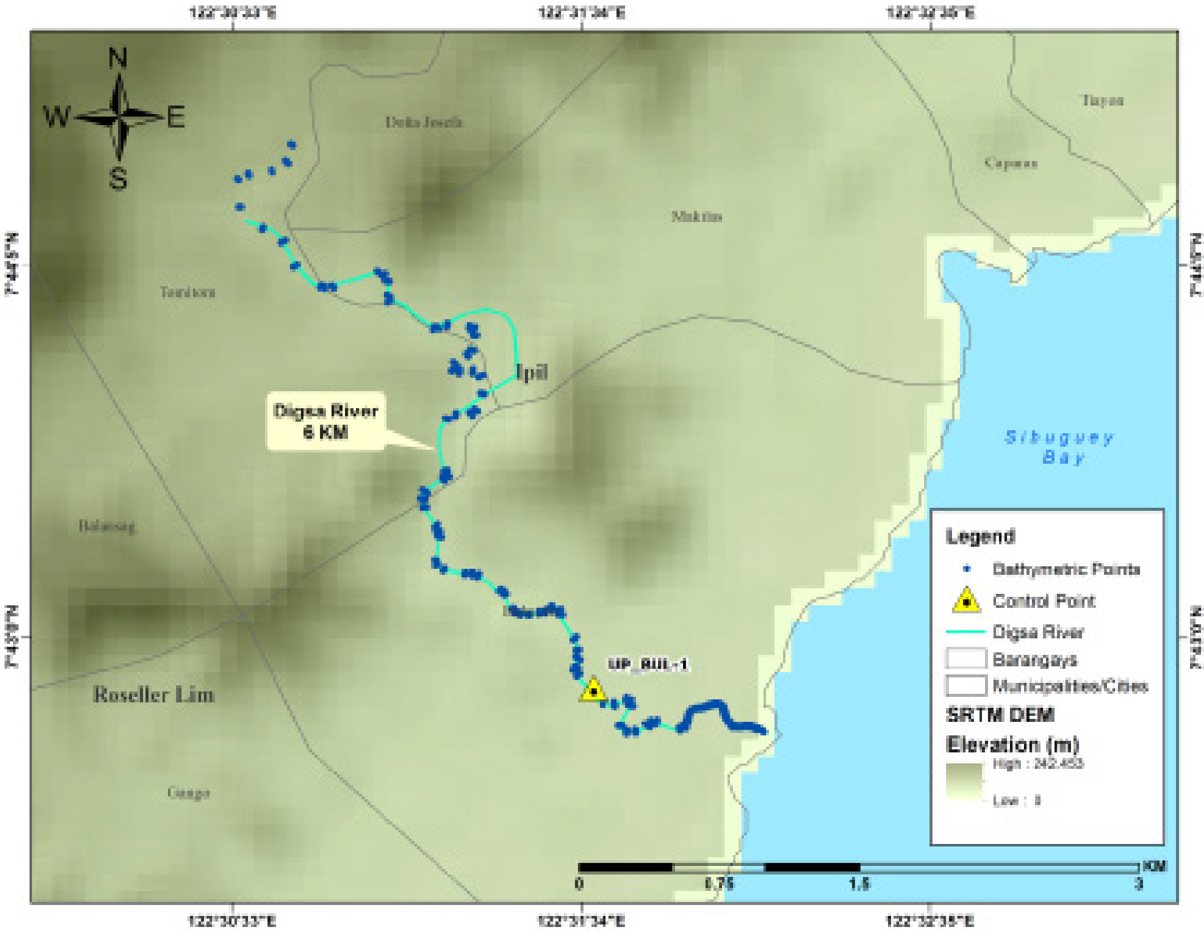


Figure 45. Bathymetric survey of Buluan (also known as Digsa) River

The bathymetric survey for Buluan River gathered a total of 2,186 points covering 6.393 km of the river traversing Brgy. Buluan, Brgy. Makilas, Brgy. Tomitom in the Municipality of Ipil. A CAD drawing was also produced to illustrate the riverbed profile of Buluan (also known as Digsa) River. As shown in Figure 46, the highest and lowest elevation has a 33-m difference. The highest elevation observed was 39.651 m below MSL, located in Brgy. Tomitom, Municipality of Ipil while the lowest was -6.556 m below MSL located in Brgy. Buluan, Municipality of Ipil.

Static survey for checking of ABSD's bathymetric data for Buluan River was conducted on August 21-31, 2016. This was adjusted from the July 23-August 6, 2015 Sanito and Tupilac Rivers interconnected static network.

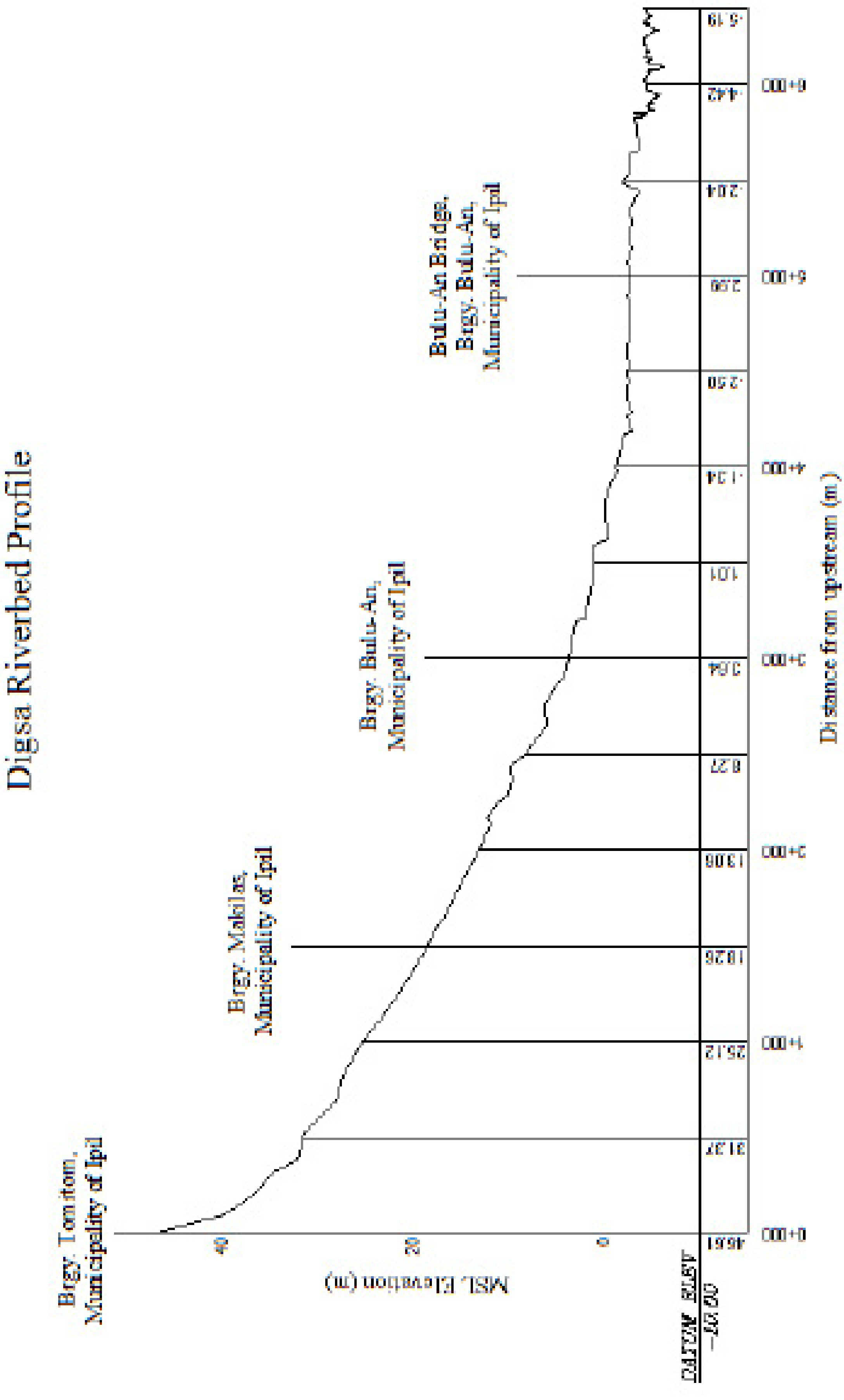


Figure 46. Buluan (also knwon as Digsa) Riverbed Profile

CHAPTER 5: FLOOD MODELING AND MAPPING

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

All components and data that affect the hydrologic cycle of the Buluan 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 Buluan 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 Brgy. Tomitom, Ipil,Zamboanga Sibugay(7° 44' 47.7" N, 122° 31' 6.88" E). (Figure 47). The precipitation data collection started from June25, 2016 at 11:00 AM to June25, 2016 at 5:00PM with 10 minutes recording interval.

The total precipitation for this event inIpil was 30.0 mm. It has a peak rainfall of 10.4 mm. on June 25, 2016 at 2:10 PM. The lag time between the peak rainfall and discharge is 1 hour and 10 minutes (Figure 50).

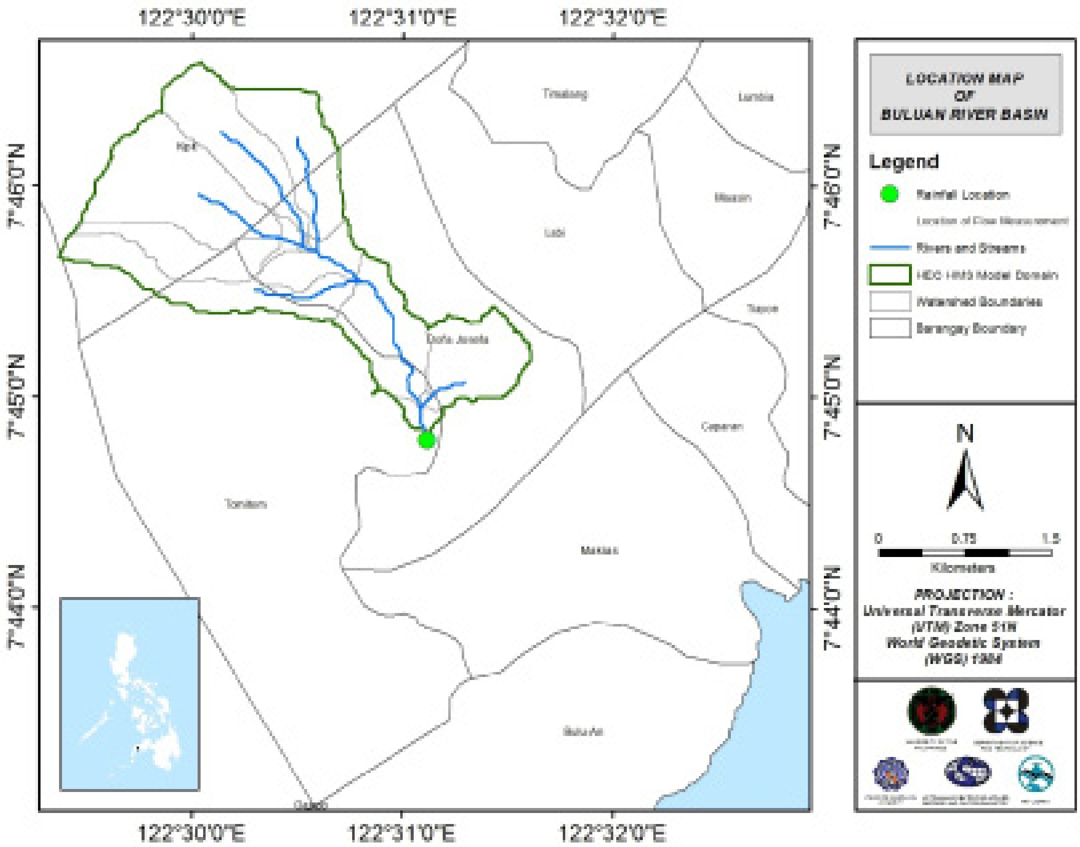


Figure 47. Location map of Buluan HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at a Spillway inBrgy. Doña Josefa, Ipil, Zamboanga Sibugay (7° 18’ 41.72” N, 122° 31’ 14.98” E). It gives the relationship between the observed water levels at Buluan Bridge and outflow of the watershed at this location.

For Buluan Bridge, the rating curve is expressed as Q = 0e13.194h as shown in Figure 49.

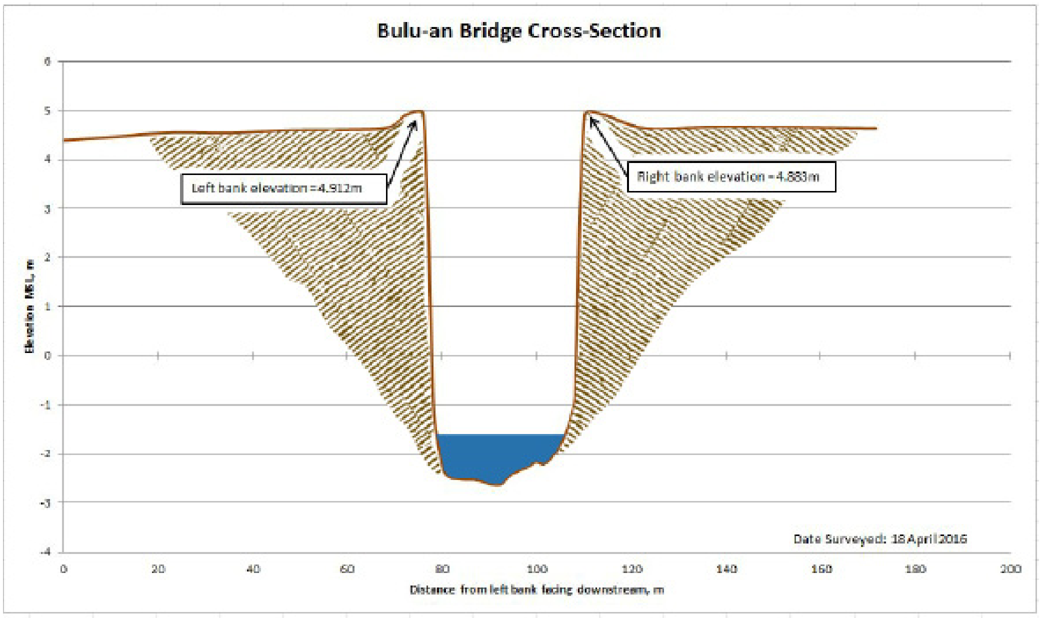


Figure 48. Cross-Section Plot of Buluan Bridge

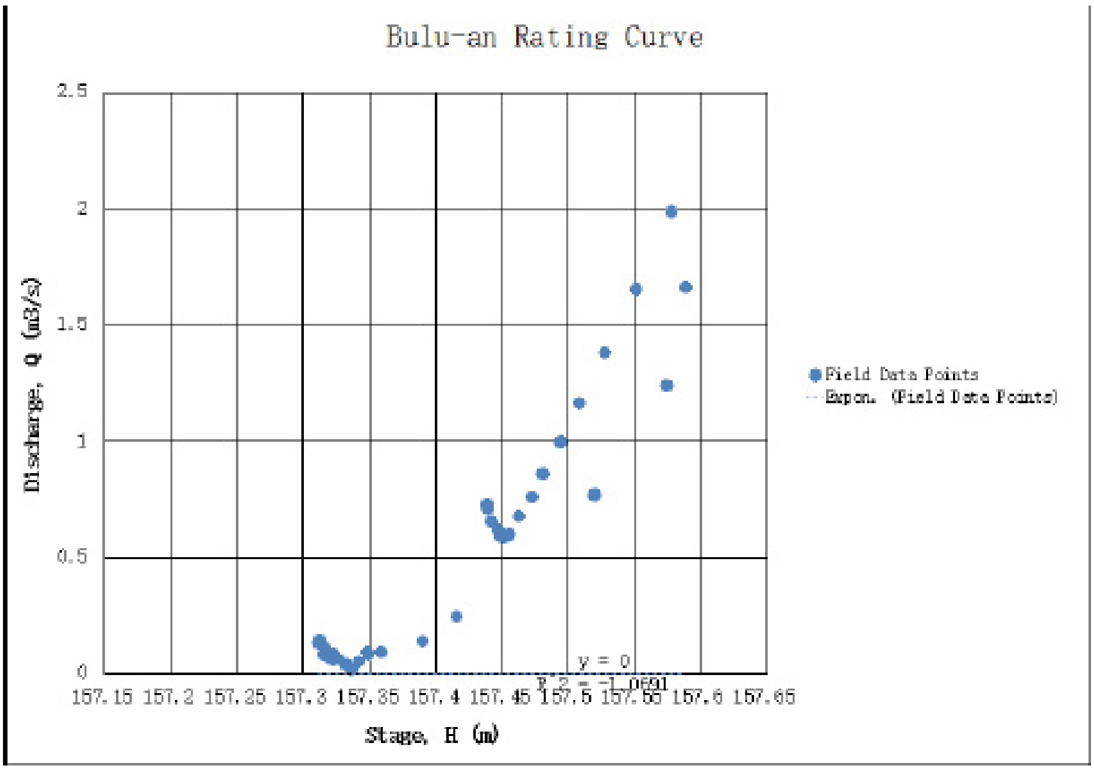


Figure 49. Rating Curve at Spillway, Brgy. Doña Josefa, Ipil, Zamboanga Sibugay

This rating curve equation was used to compute the river outflow at Buluan Bridgefor the calibration of the HEC-HMS model shown in Figure 50. Peak discharge is 2 cubic meters per second at 3:20 PM, June25, 2016.

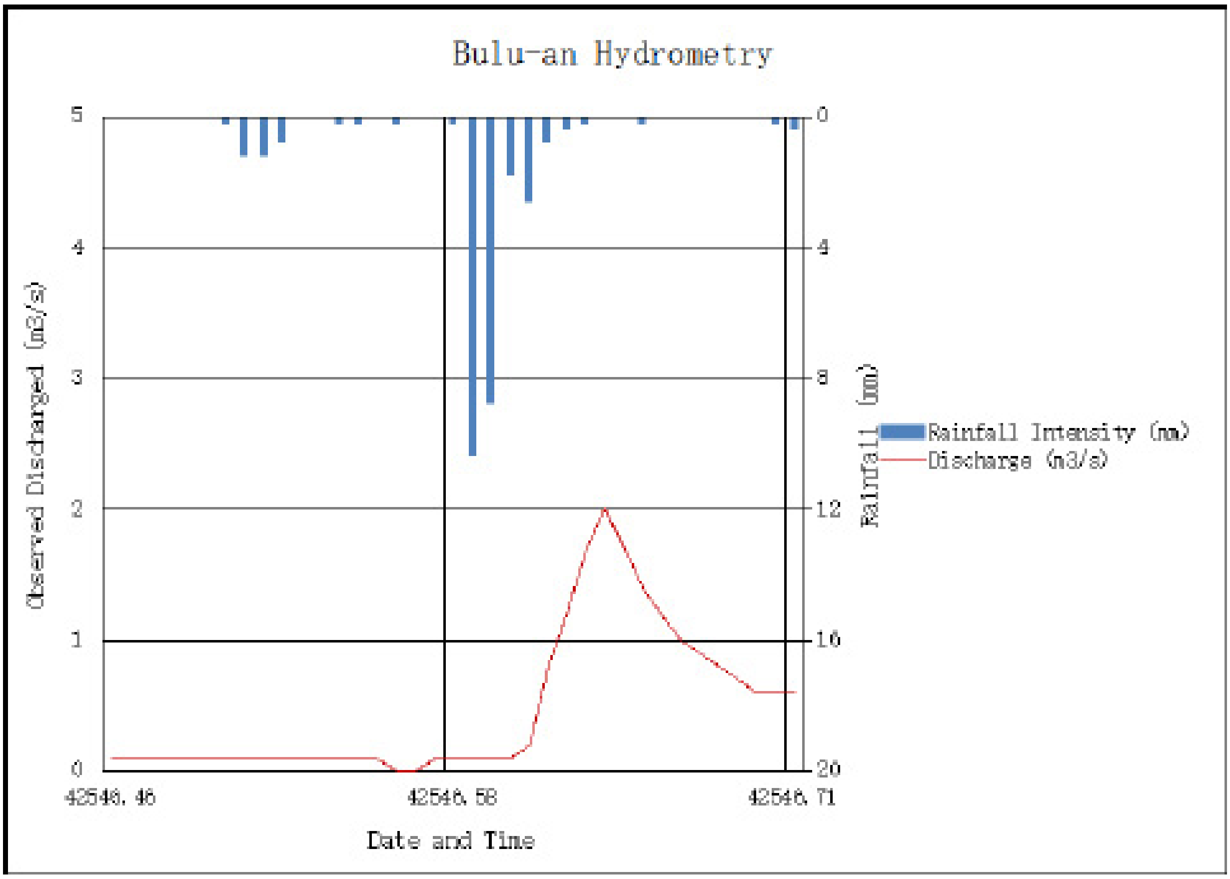


Figure 50. Rainfall and outflow data at Buluan Bridge used for modeling

5.2 RIDF Station

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

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

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

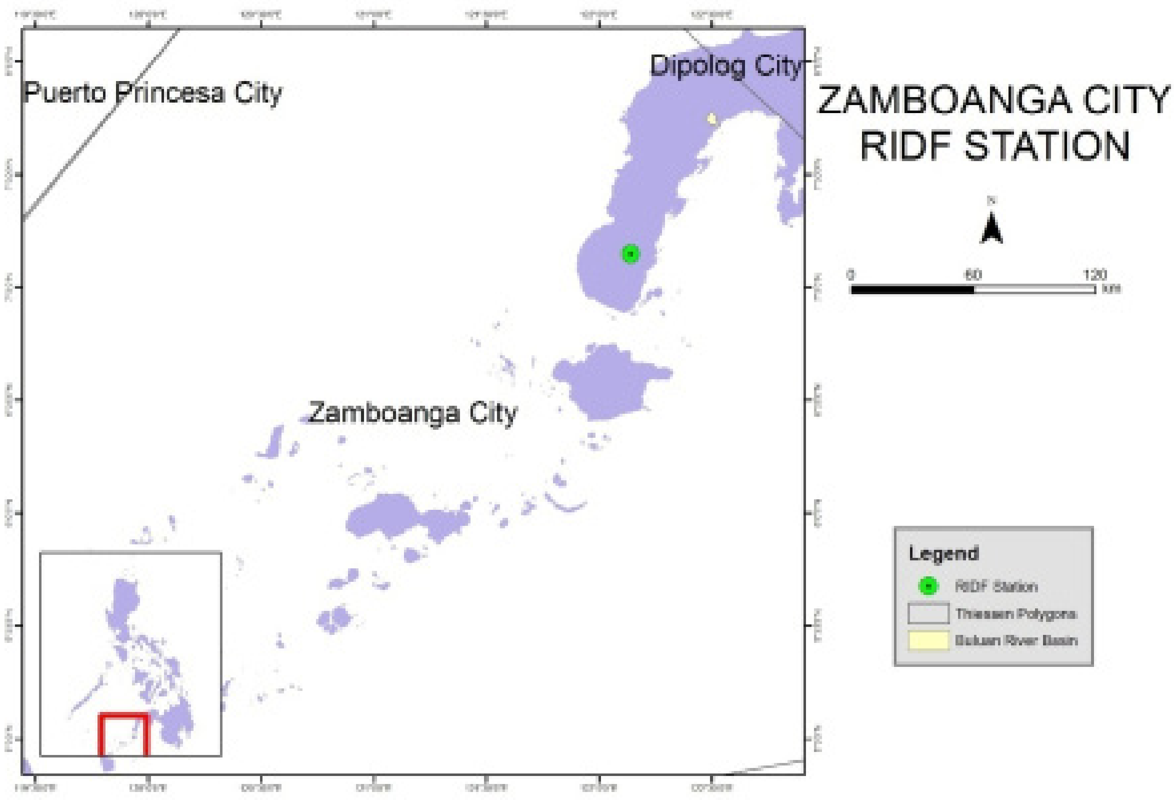


Figure 51. Zamboanga City RIDF location relative to Buluan River Basin

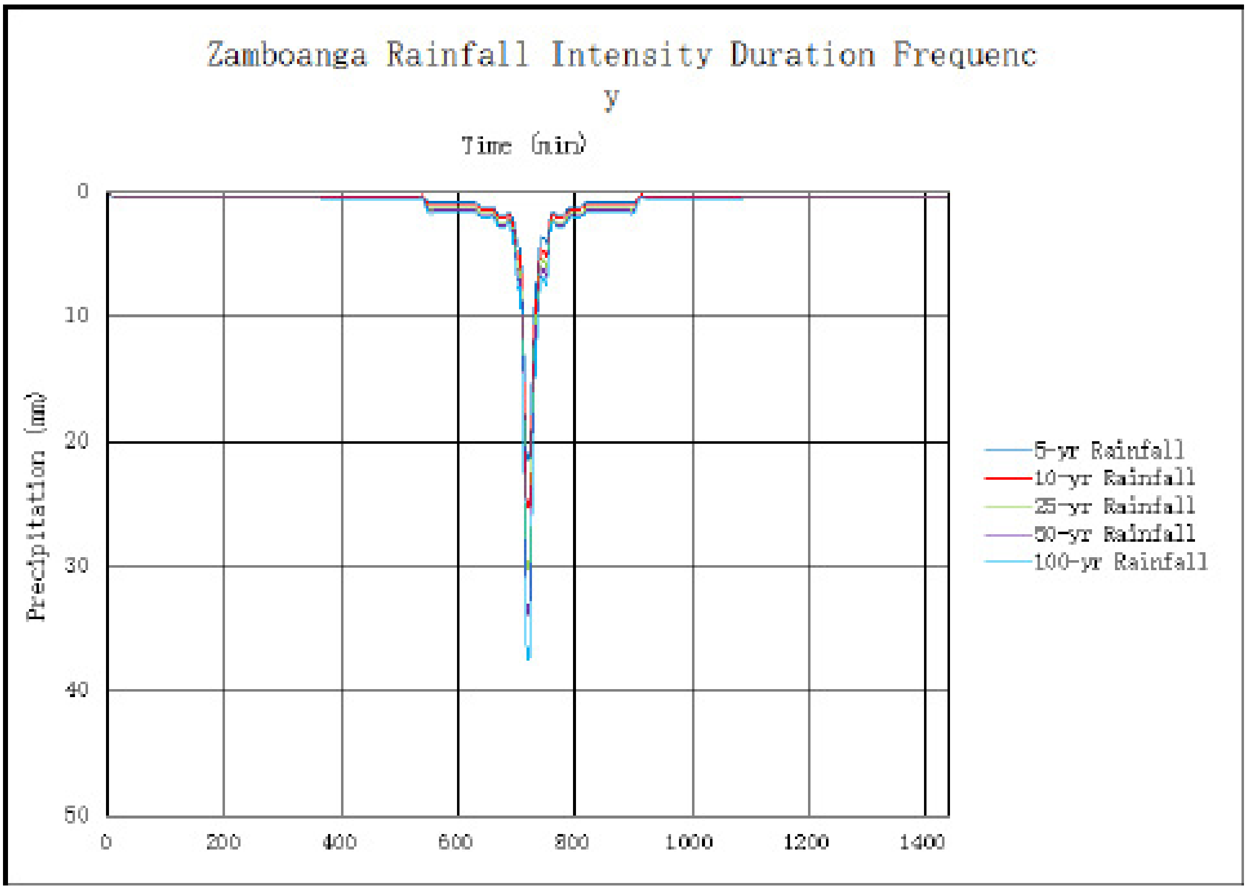


Figure 52. Synthetic storm generated for a 24-hr period rainfall for various return periods

5.3 HMS Model

The soil dataset was taken before 2004 from the Bureau of Soils; this is 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 Buluan River Basin are shown in Figures 53 and 54, respectively.

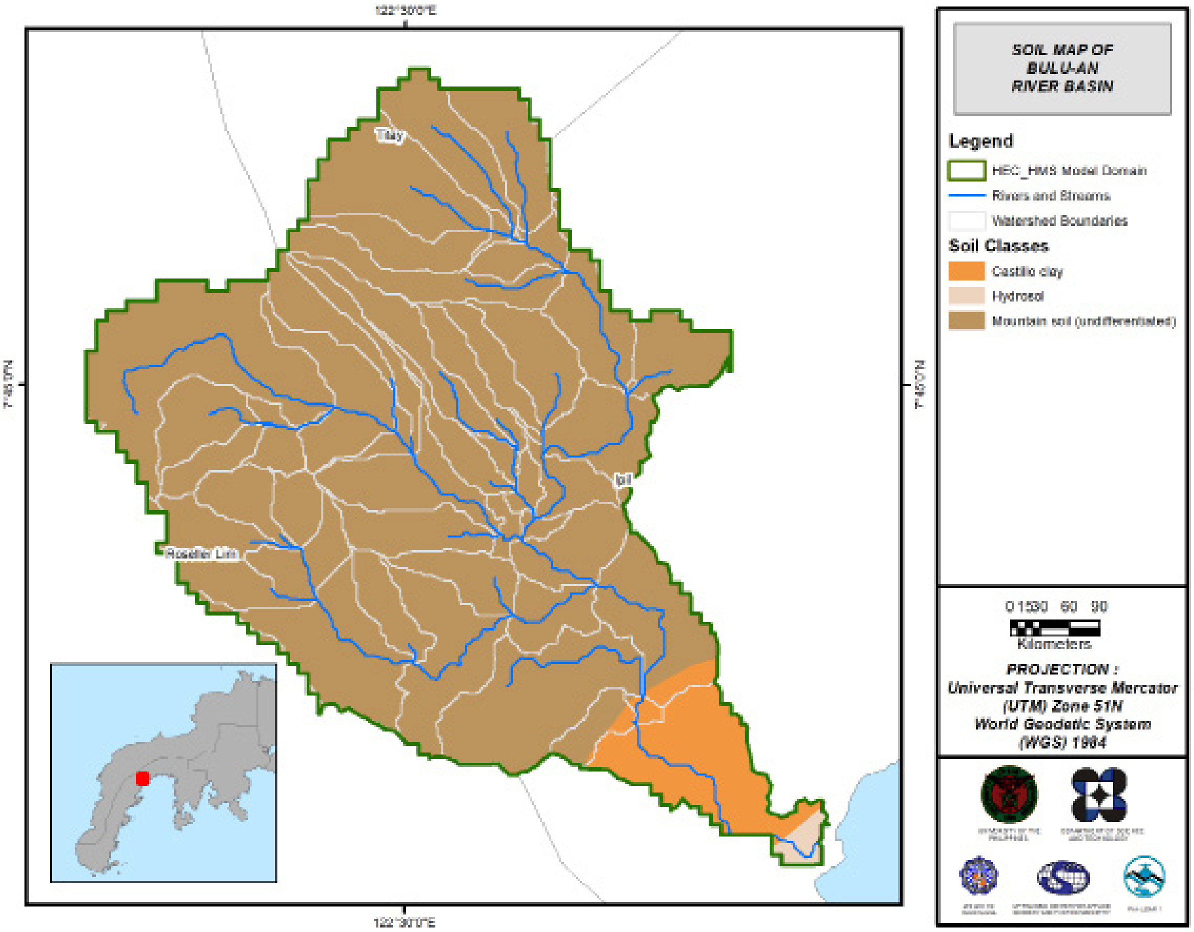


Figure 53. Soil Map of Buluan River Basin

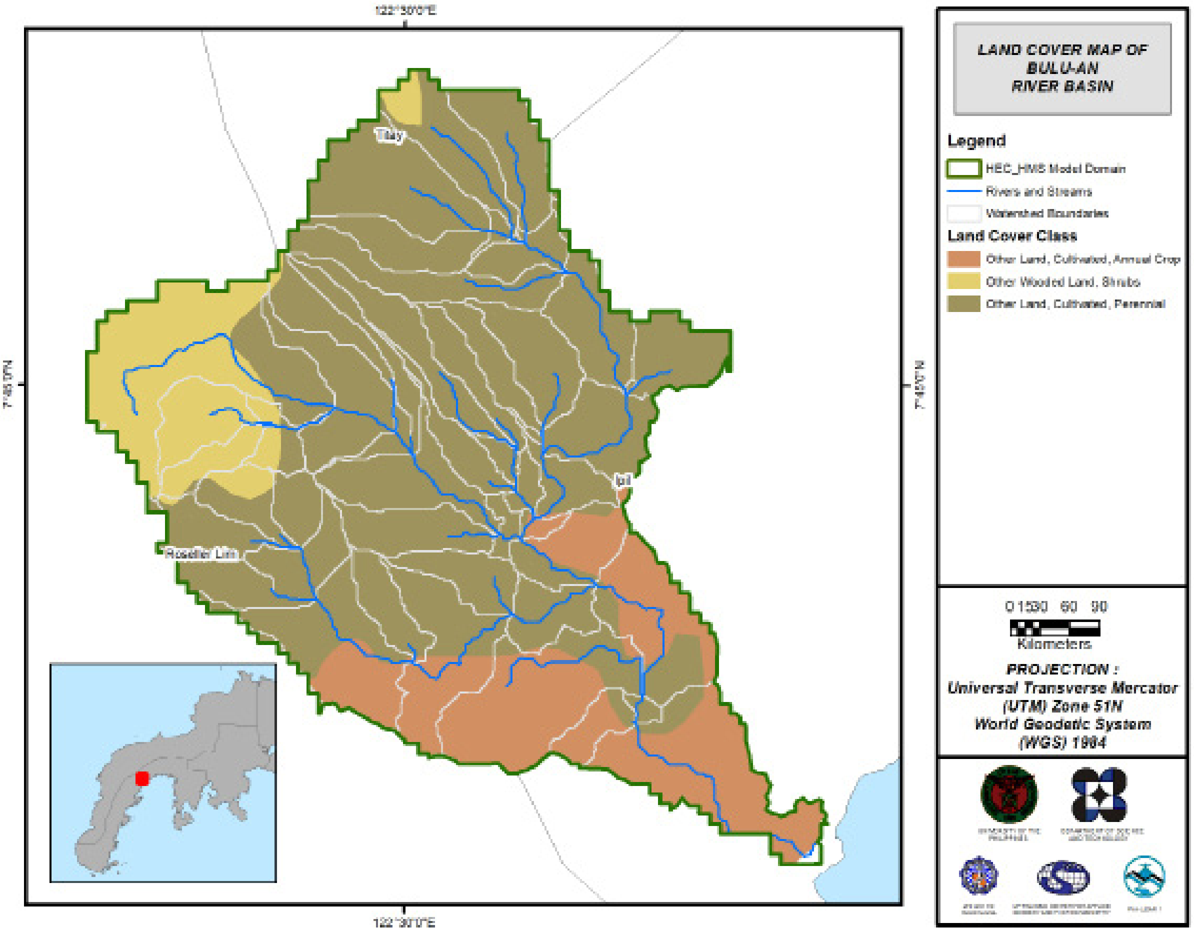


Figure 54. Land Cover Map of Buluan River Basin (source: NAMRIA)

For Buluan, three (3) soil classes were identified. These are clay, hydrosol, and mountain soil. Moreover, three (3) land cover classes were identified. These are cultivated annual crops, cultivated perennial crops and shrubland.

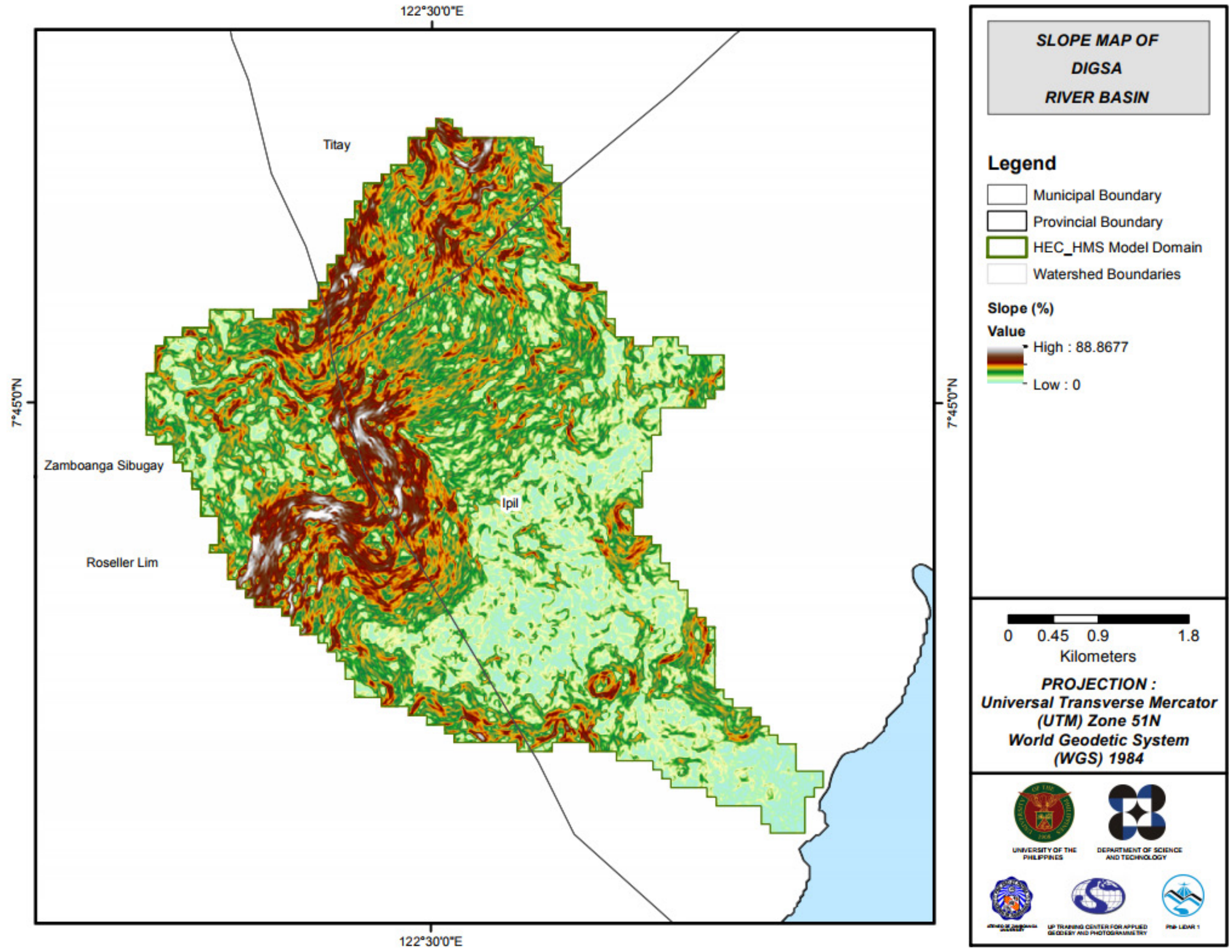


Figure 55. Slope Map of Buluan (also known as Digsa) River Basin

Using the SAR-based DEM, the Buluan basin was delineated and further subdivided into subbasins. The model consists of 11 sub basins,5 reaches, and 5 junctions as shown in Figure 56 (See Annex 10). The main outlet is at a Spillway in Brgy. Doña Josefa, Ipil, Zamboanga Sibugay.

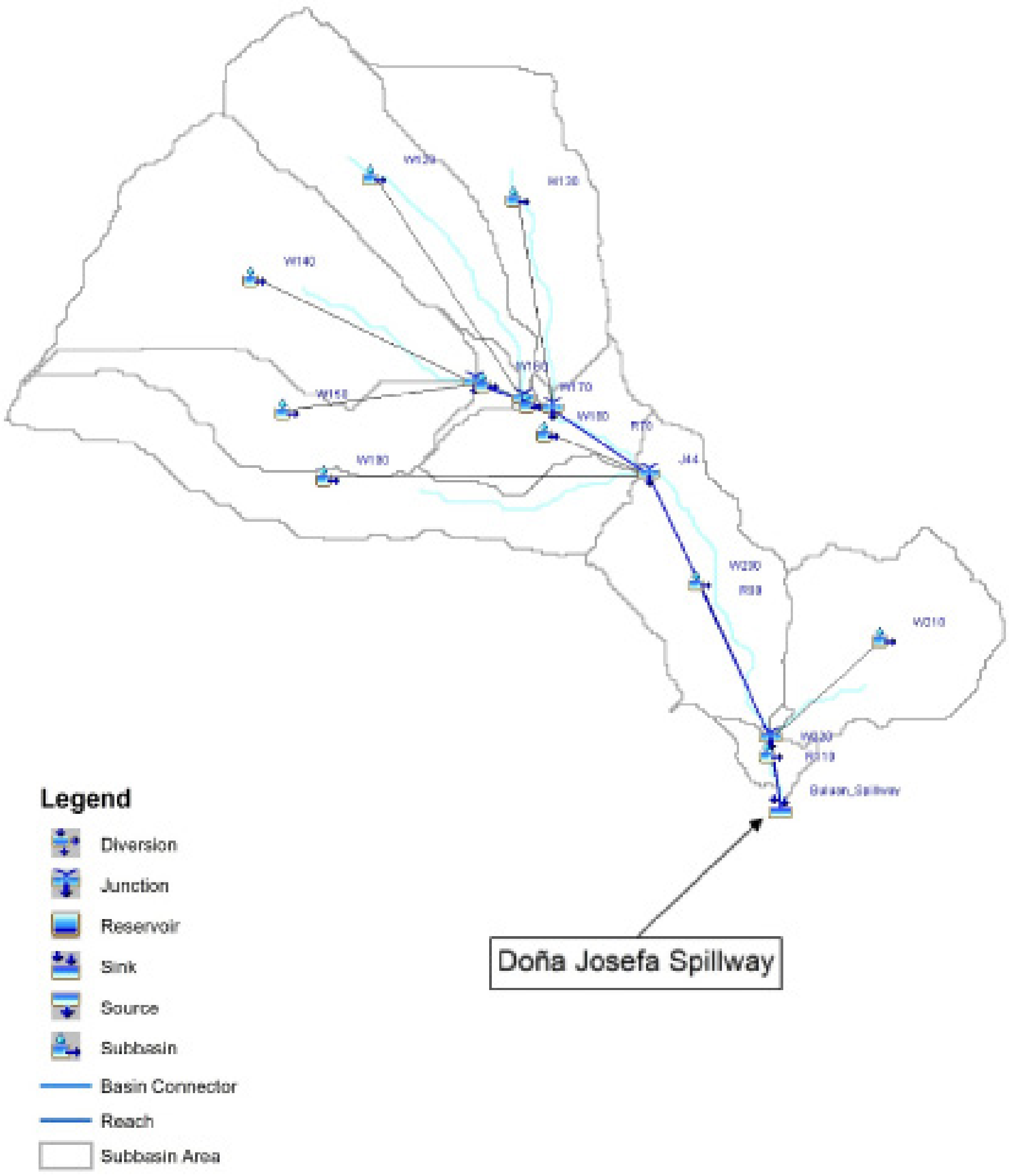


Figure 56. Buluan river basin model generated using HEC-HMS

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.

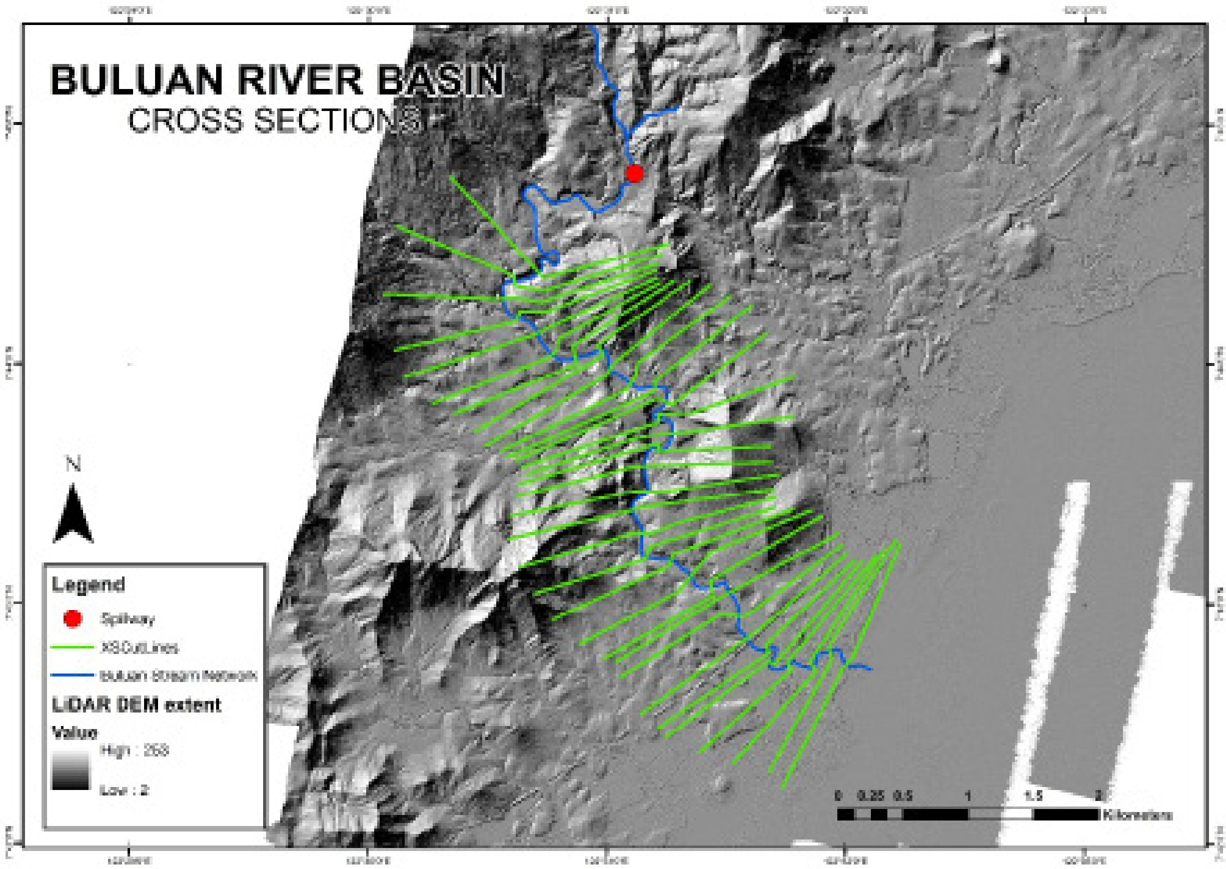


Figure 57. River cross-section of Buluan River generated through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

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

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

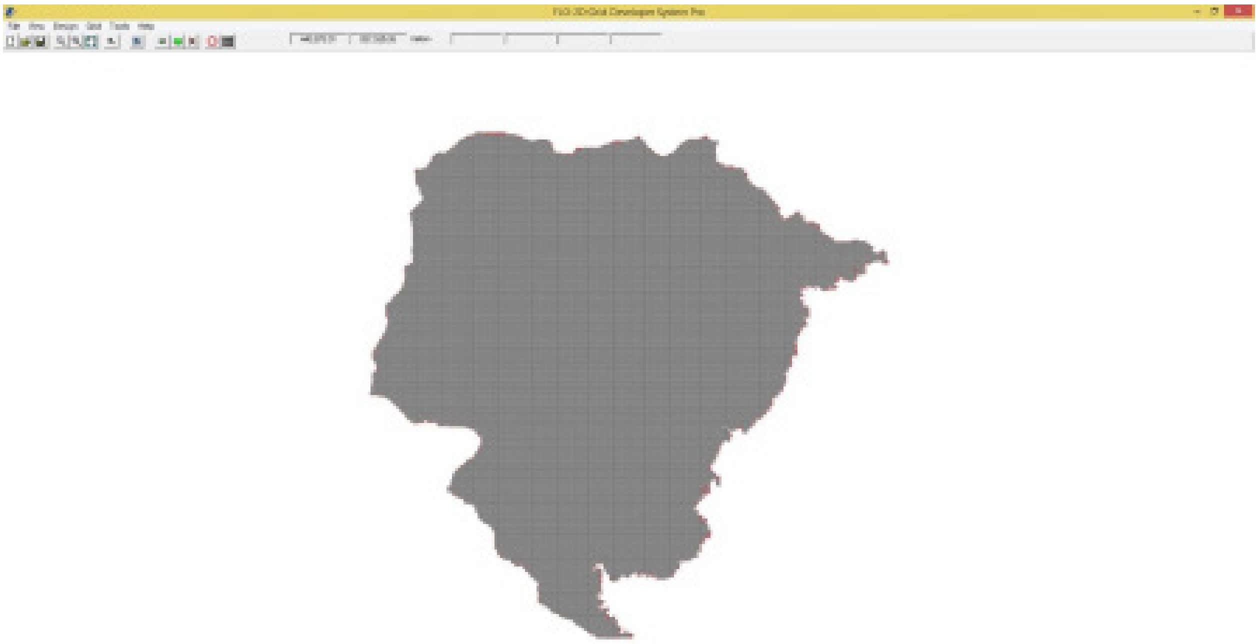


Figure 58. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 9.61426 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m2/s. The generated hazard maps for Bulu-an are in Figures 64, 66, and 68.

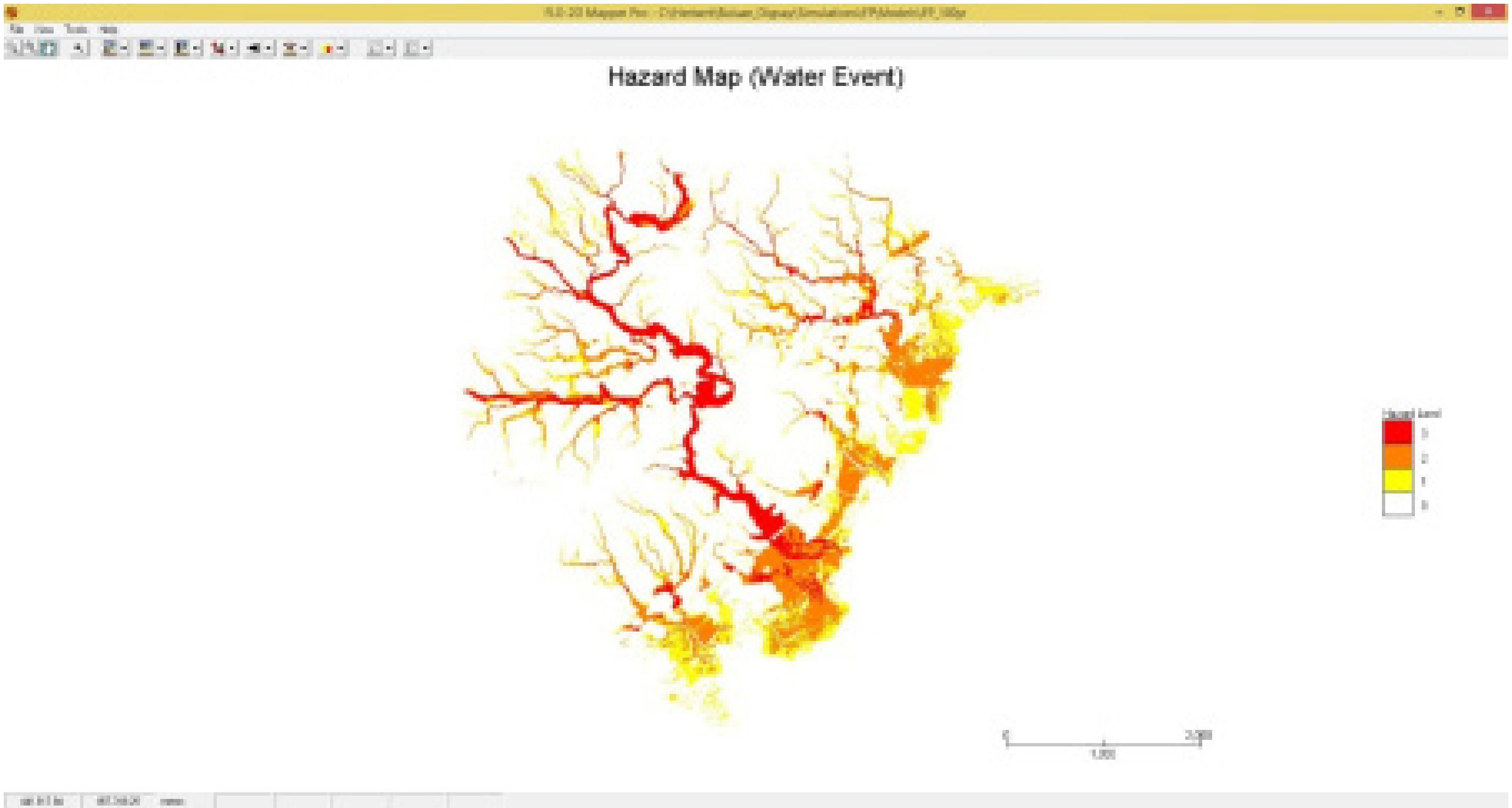


Figure 59. Generated 100-year rain return hazard map from FLO-2D Mapper

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 21 686 300.00 m2. The generated flood depth maps for Bulu-an are in Figures 65, 67, and 69.

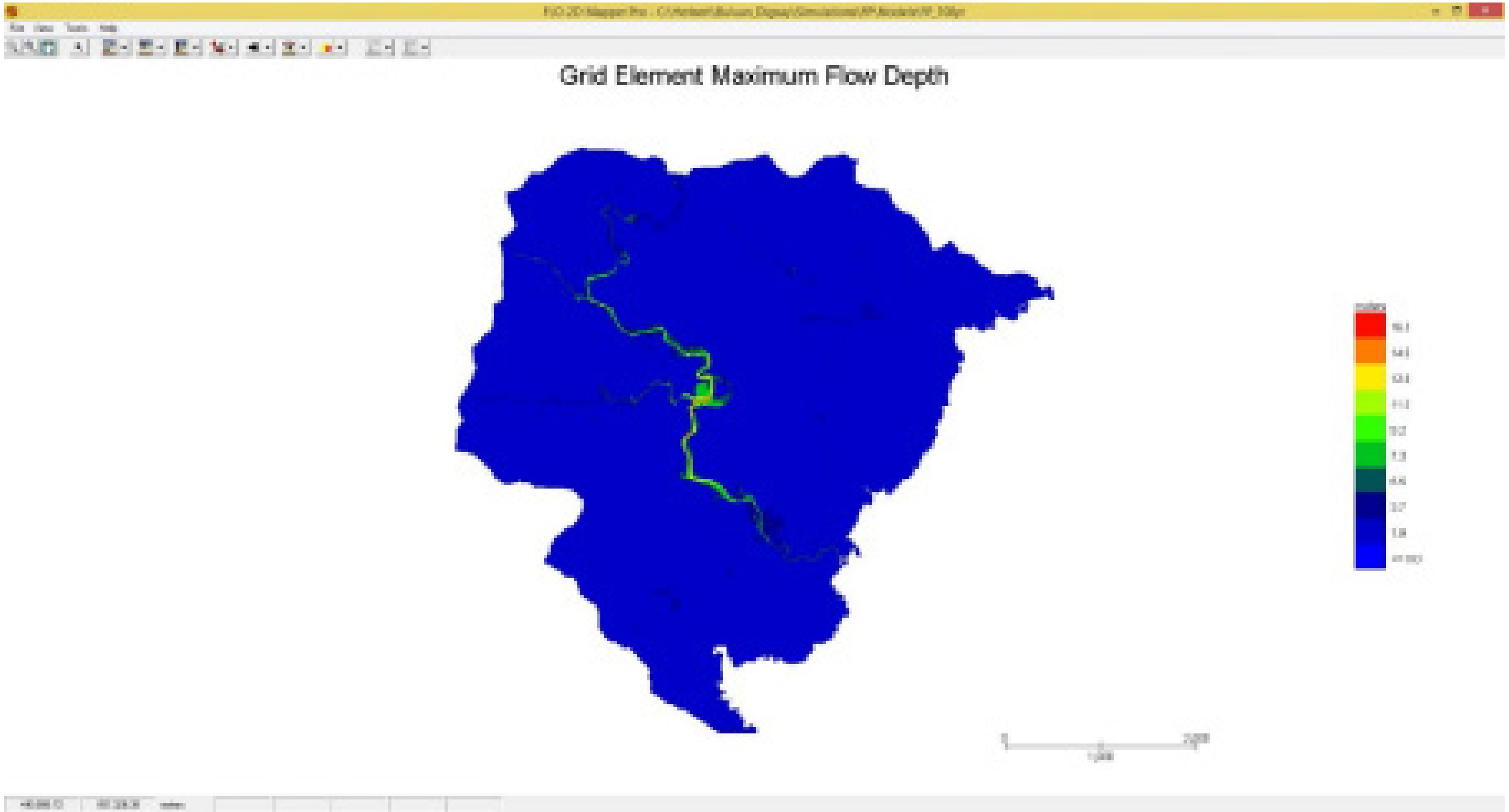


Figure 60. Generated 100-year rain return flow depth map from FLO-2D Mapper

There is a total of 6 140 144.50 m3 of water entering the model. Of this amount, 4 281 549.33m3 is due to rainfall while 1 858 595.17m3 is inflow from other areas outside the model. 1 393 649.00 m3 of this water is lost to infiltration and interception, while 1 018 179.87 m3 is stored by the flood plain. The rest, amounting up to 3 728 315.73m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Buluan HEC-HMS river basin model, its accuracy was measured against the observed values.

Figure 61 shows the comparison between the two discharge data.

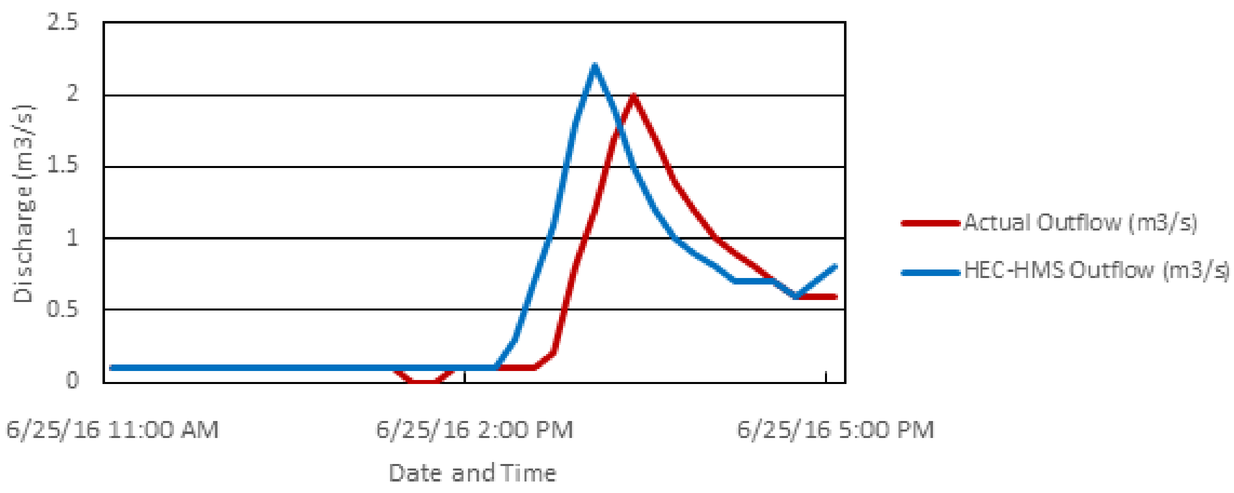


Figure 61. Outflow Hydrograph of Buluan produced by the HEC-HMS model compared with observed outflow

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

Table 26. Peak values of the Buluan HECHMS Model outflow using the Zamboanga CityRIDF

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	19.88 – 57.51
			Curve Number	56.75 – 99.00
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.0167 – 0.108
			Storage Coefficient (hr)	0.116 – 1.311
	Baseflow	Recession	Recession Constant	0.7
			Ratio to Peak	0.2
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.03

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 19.88mm to 57.51mm means that there is moderate to high amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 56.75 to 99.00 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012).. For Bulu-an, the basin mostly consists of cultivated areas and the soil consists of clay and mountain soil.

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.02 hours to 1.31 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 0.7 indicates that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.2 indicates a steeper receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.03 corresponds to the common roughness of Philippine watersheds (Brunner, 2010).

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

Accuracy Measure	Value
RMSE	2.039608
r2	0.8535
NSE	0.6331
PBIAS	-12.6437
RSR	0.6057

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as2.039608 (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 0.8535.

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 0.6331.

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 -12.6437.

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 0.6057.

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 62) shows the Buluan 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 Philippine Atmospheric Geophysical and Astronomical Services Administration (PAG-ASA) data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

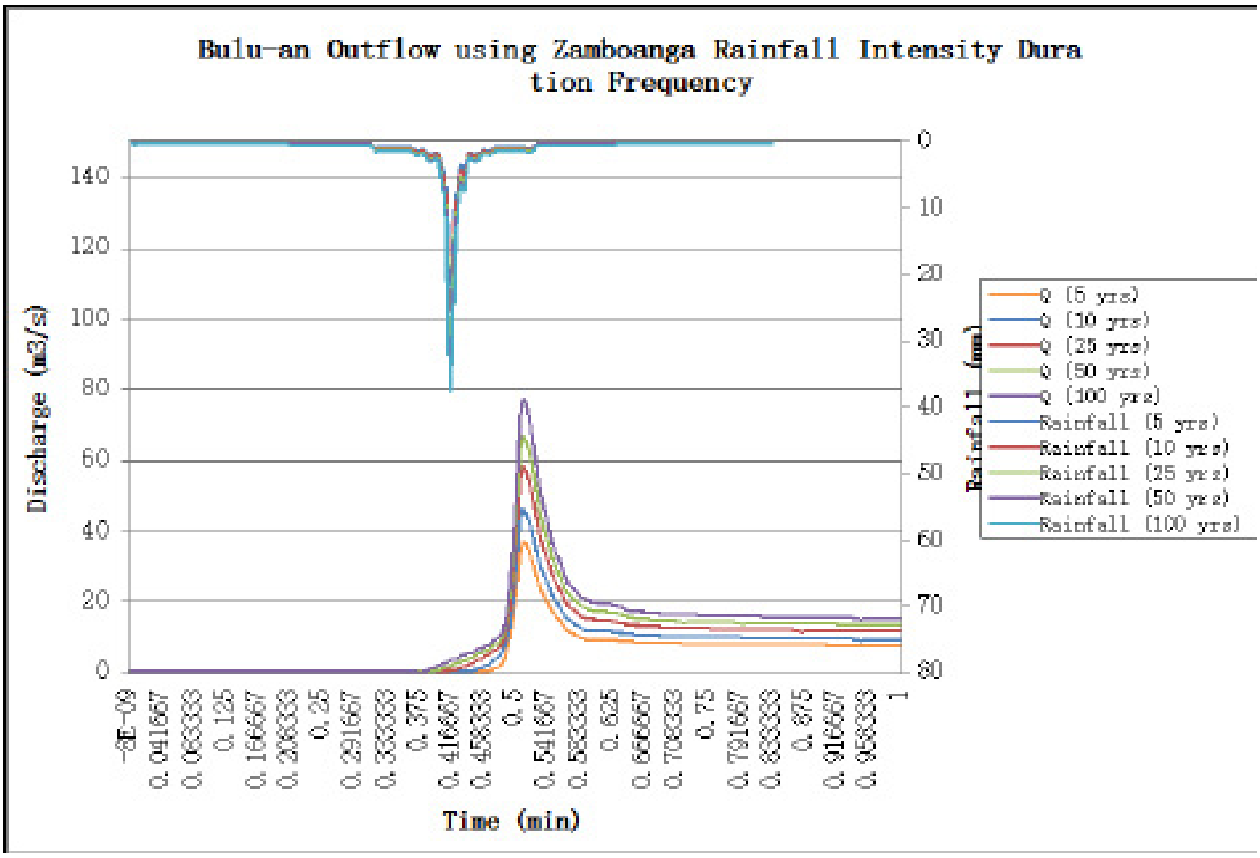


Figure 62. Outflow hydrograph at Buluan Bridge Station generated using Zamboanga City RIDF simulated in HEC-HMS

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

Table 28. Peak values of the Buluan HECHMS Model outflow using the Zamboanga CityRIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	107.80	21.40	36.60	12 hours and 20 minutes
10-Year	127.90	25.30	45.20	12 hours and 20 minutes
25-Year	153.40	30.20	57.40	12 hours and 20 minutes
50-Year	172.30	33.90	65.80	12 hours and 20 minutes
100-Year	191.10	37.50	76.10	12 hours and 20 minutes

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. The sample generated map of Buluan River using the calibrated HMS base flow is shown in Figure 63.

Figure 63. Sample output of Buluan RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figure 64 to Figure 69 shows the 5-, 25-, and 100-year rain return scenarios of the Buluan floodplain.

The generated flood hazard maps for the Buluan 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 29. Municipalities affected in Buluan Floodplain

City / Municipality	Total Area (sq.m.)	Area Flooded (sq.m.)	% Flooded
Ipil	272.39		
Roseller Lim	58.65		

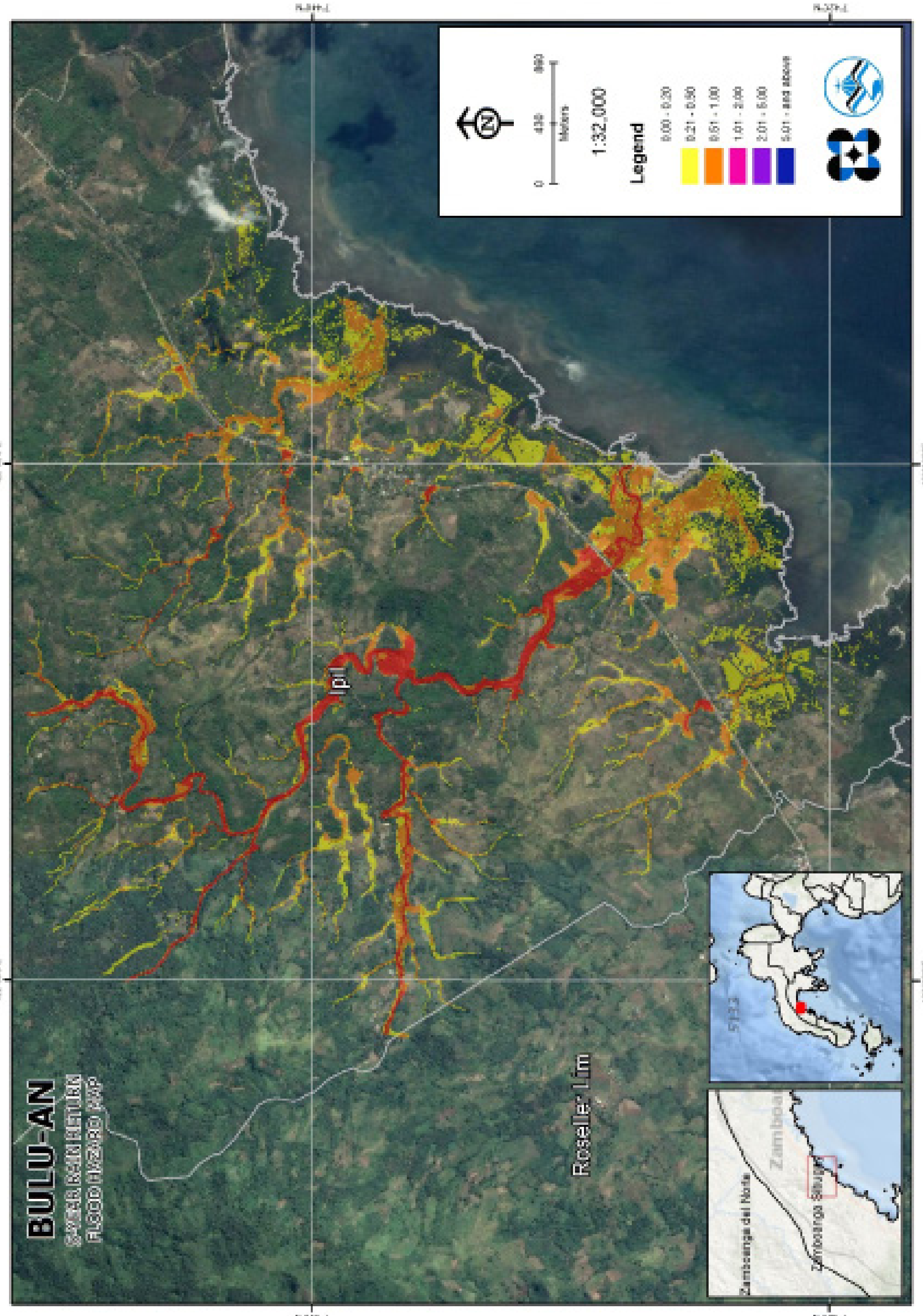


Figure 64. 5-year Flood Hazard Map for Buluan Floodplain

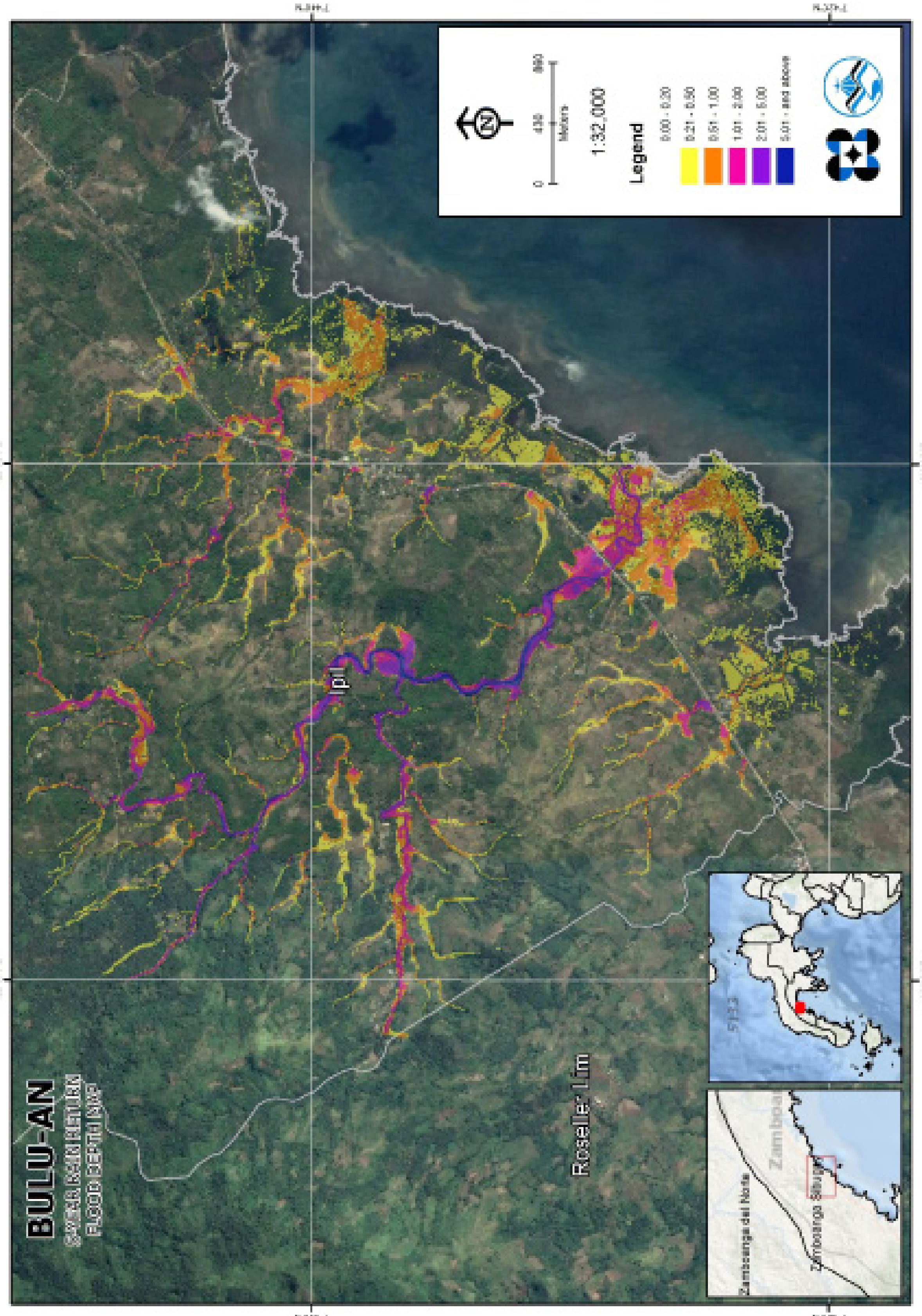


Figure 65. 5-year Flow Depth Map for Buluan Floodplain

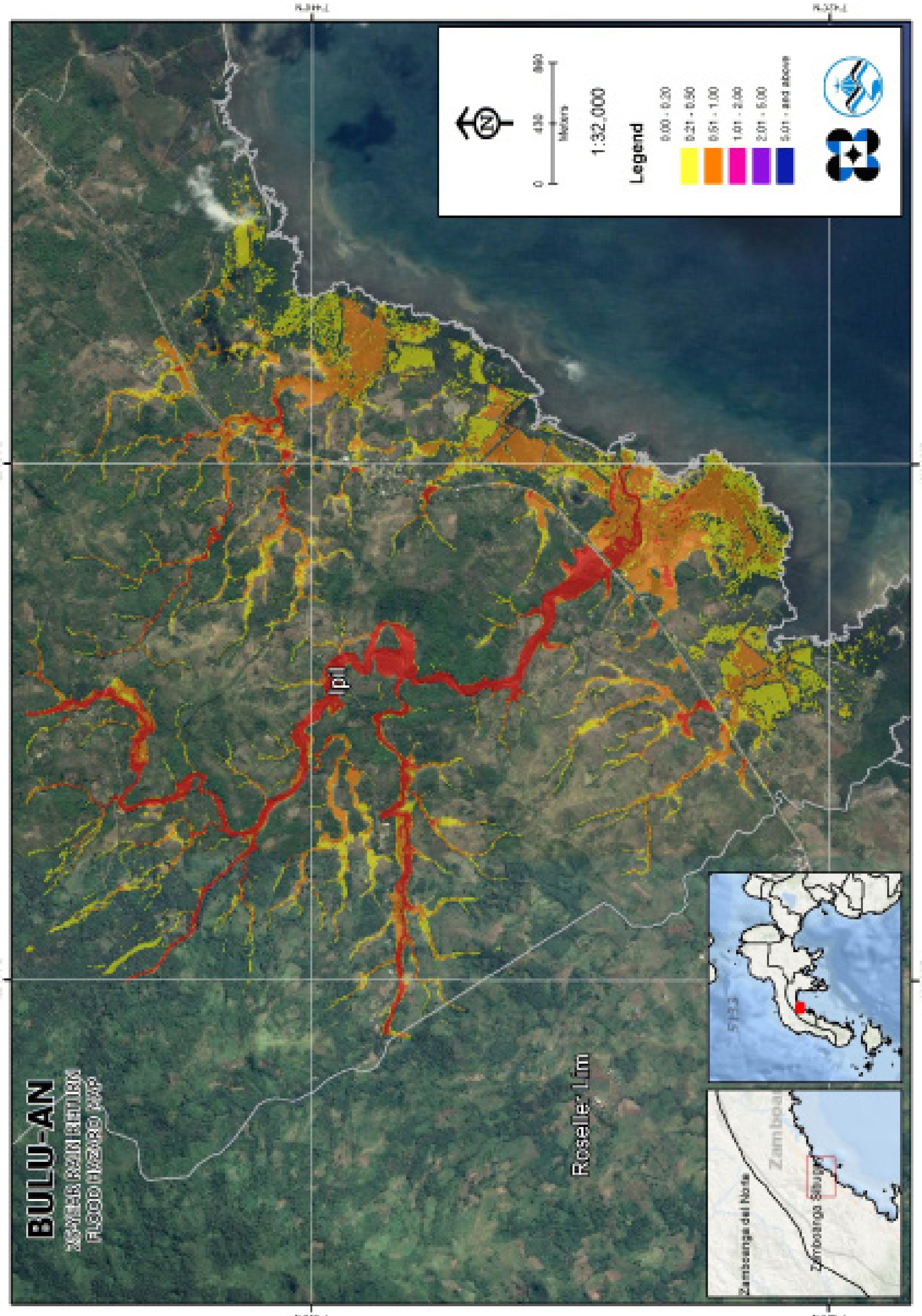


Figure 66. 25-year Flood Hazard Map for Buluan Floodplain

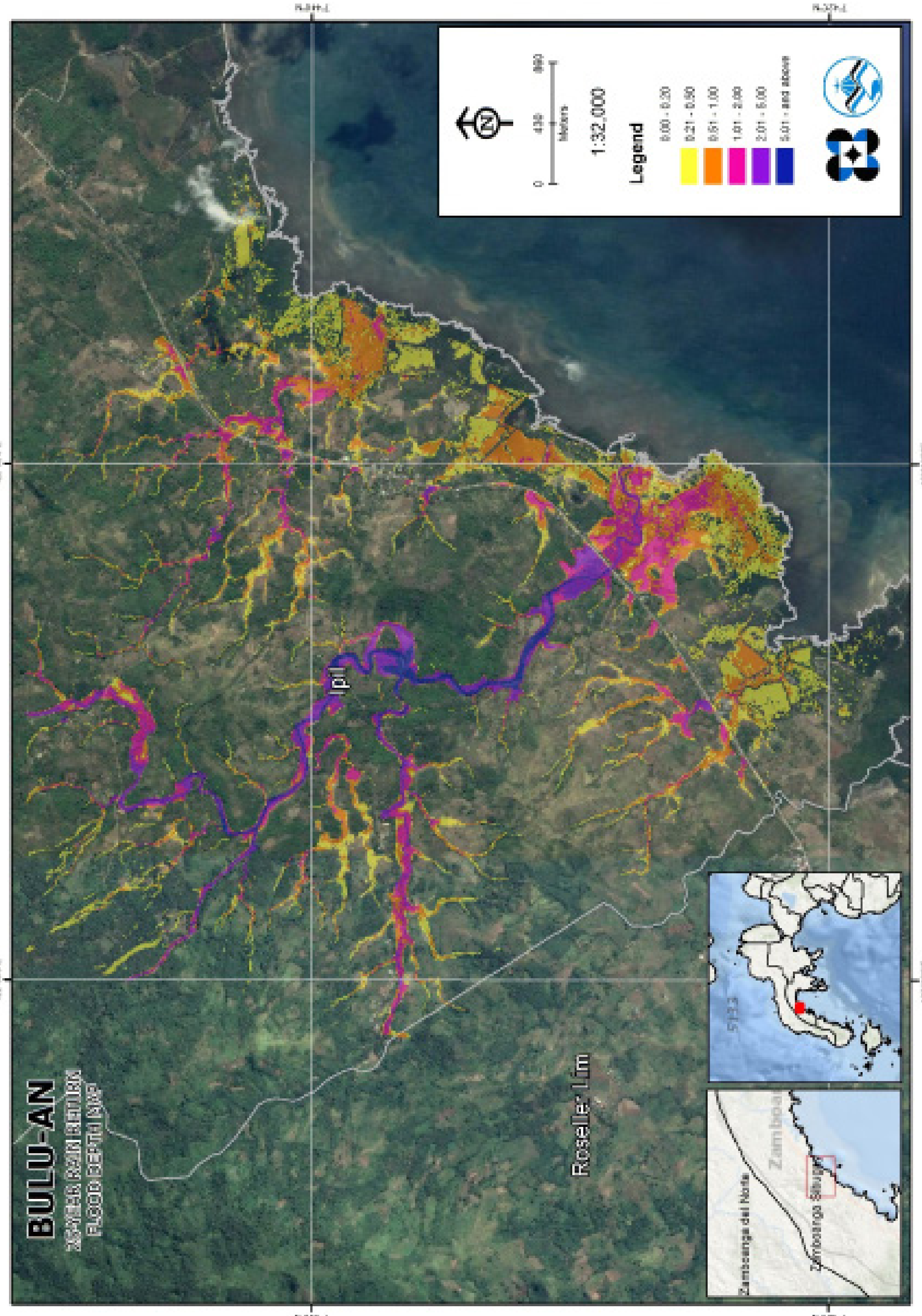


Figure 67. 25-year Flow Depth Map for Buluan Floodplain

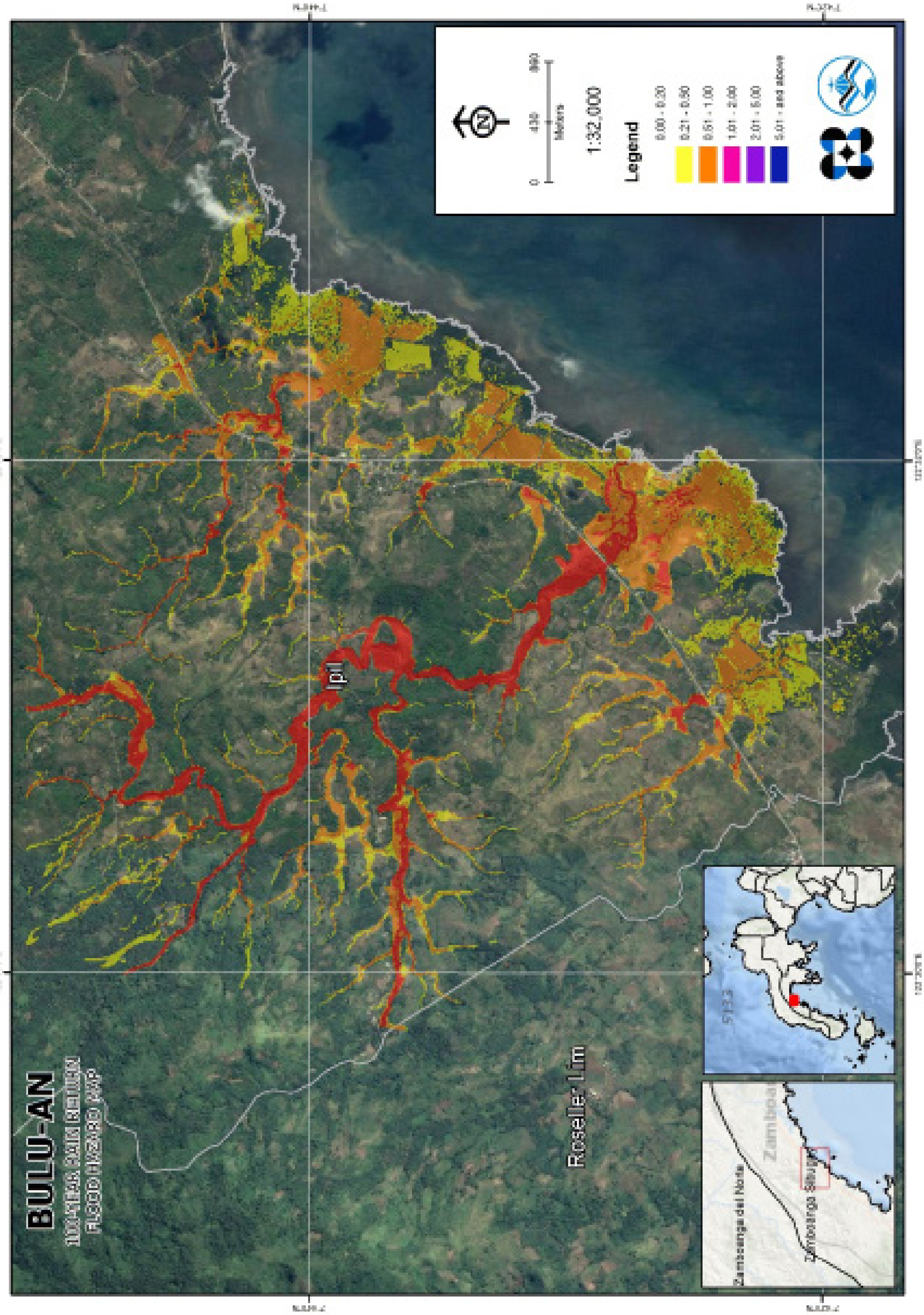


Figure 68. 100-year Flood Hazard Map for Buluan Floodplain

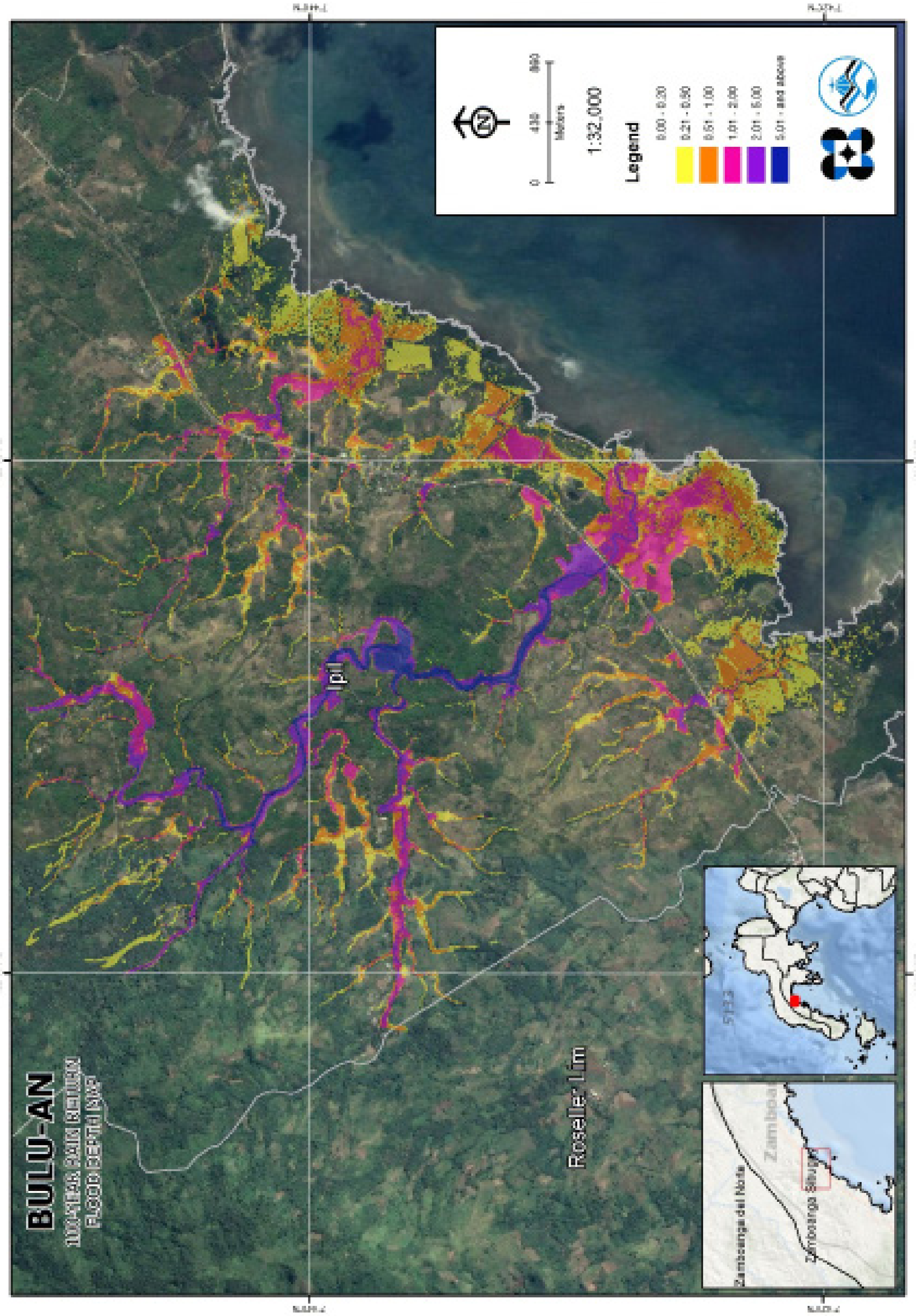


Figure 69. 100-year Flow Depth Map for Buluan Floodplain

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Buluan river basin, grouped by municipality, are listed below. For the said basin, 9 barangays in two municipalities are expected to experience flooding when subjected to the flood hazard scenarios.

For the 5-year return period, 0.00% of the municipality of Ipil with an area of 58.6492 sq. km. will experience flood levels of less than 0.20 meters. 0.00% of the area will experience flood levels of 0.21 to 0.50 meters while 0.00%, 0.00%, 0.00%, and 0.00% 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 29. 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.)						
	Buluan	Caparan	Doña Josefa	Labi	Makilas	Tiayon	Tomitom
0.03-0.20	5.47	0.36	1.66	0.015	3.96	0.0017	5.16
0.21-0.50	0.73	0.03	0.035	0.0001	0.37	0	0.27
0.51-1.00	0.44	0.0057	0.027	0	0.28	0	0.2
1.01-2.00	0.2	0	0.014	0	0.092	0	0.18
2.01-5.00	0.1	0	0.0031	0	0.04	0	0.14
> 5.00	0.029	0	0	0	0.0086	0	0.039

For the 5-year return period, 1.82% of the municipality of Roseller Lim with an area of 272.3884 sq. km. will experience flood levels of less than 0.20 meters. 0.16% of the area will experience flood levels of 0.21 to 0.50 meters while 0.06%, 0.02%, 0.00%, and 0.00% 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.

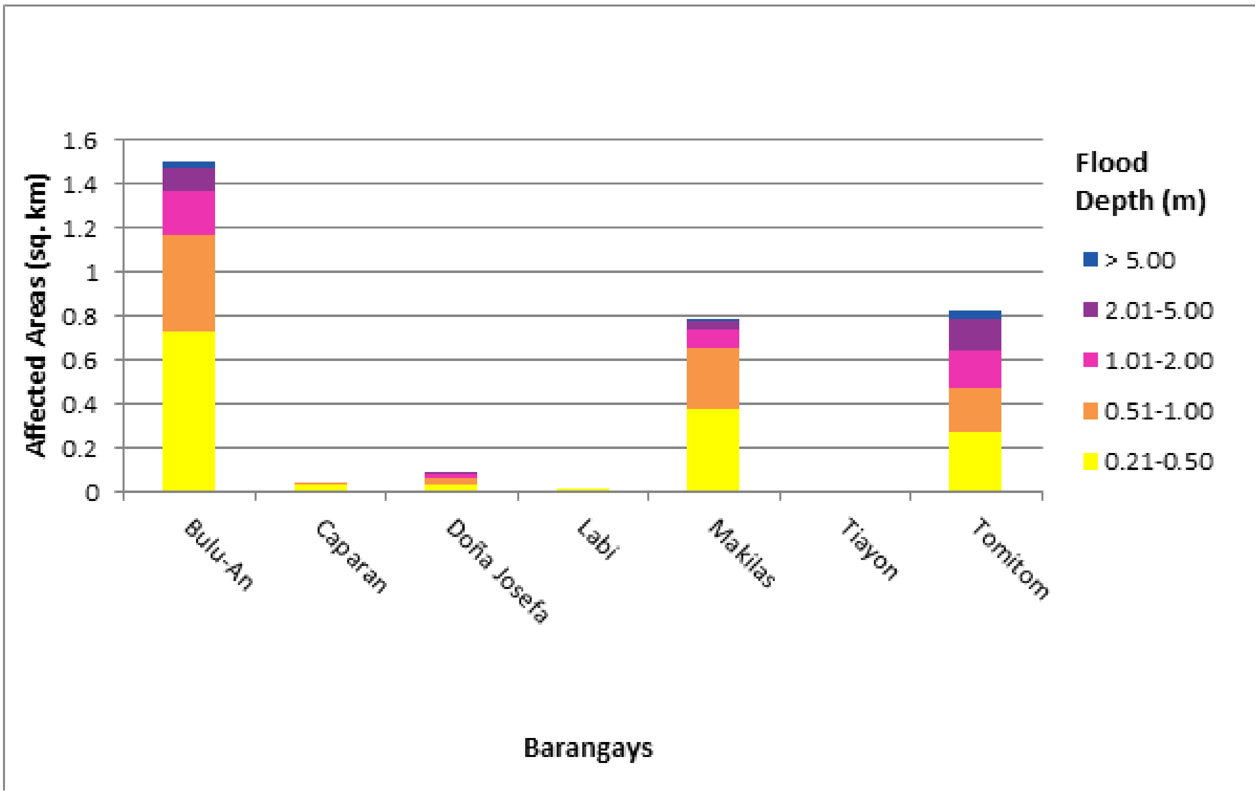


Figure 70. Affected Areas in Ipil, Zamboanga Sibugay during 5-year rainfall return period

Table 30. Affected Areas in Roseller Lim, Zamboanga Sibugay during 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Affected Barangays in Roseller Lim (in sq. km.)	
	Balansag	Gango
0.03-0.20	1.15	1.33
0.21-0.50	0.055	0.17
0.51-1.00	0.033	0.044
1.01-2.00	0.022	0.011
2.01-5.00	0.003	0.0001
> 5.00	0	0

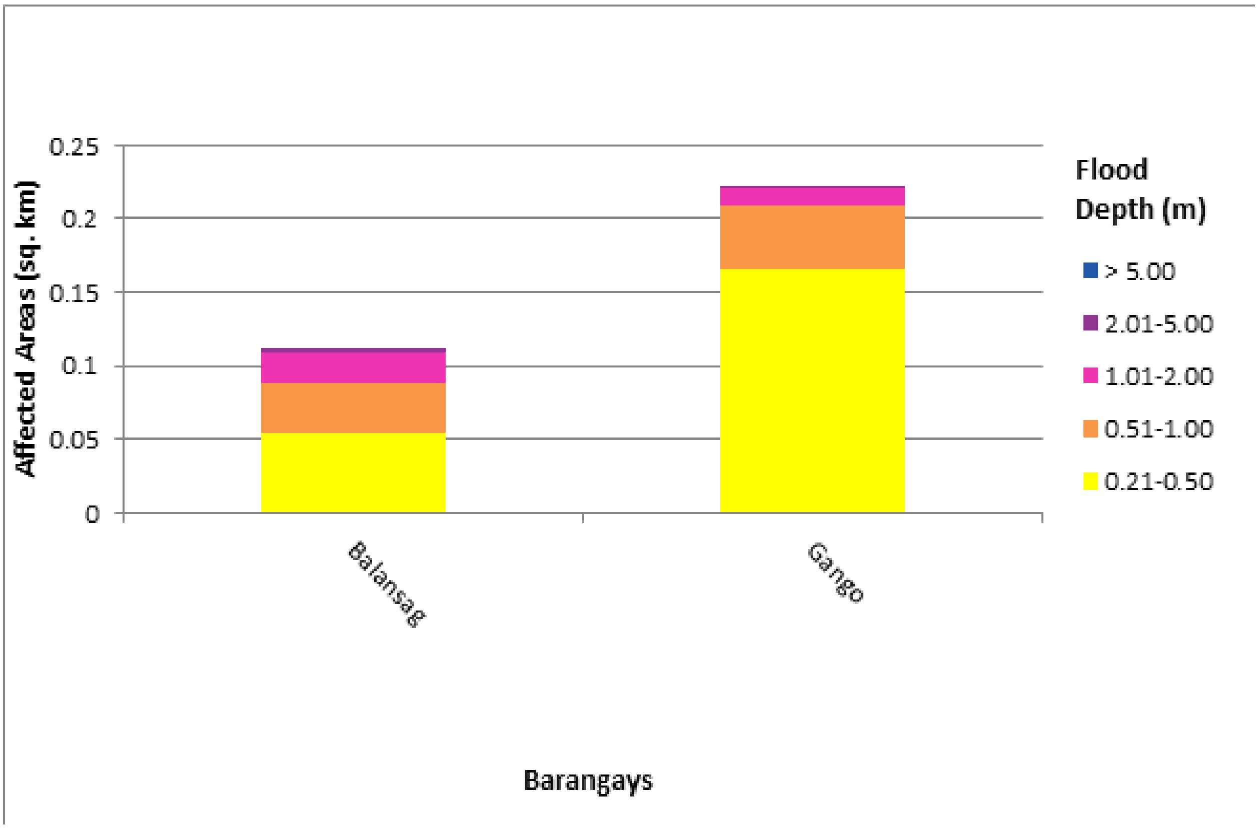


Figure 71. Affected Areas in Roseller Lim, Zamboanga Sibugay during 5-year rainfall return period

For the 25-year return period, 26.57% of the municipality of Ipil with an area of 58.6492 sq. km. will experience flood levels of less than 0.20 meters. 2.77% of the area will experience flood levels of 0.21 to 0.50 meters while 2.16%, 1.33%, 0.77%, and 0.26% 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 31. 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.)						
	Buluan	Caparan	Doña Josefa	Labi	Makilas	Tiayon	Tomitom
0.03-0.20	4.91	0.32	1.64	0.015	3.72	0.0017	4.98
0.21-0.50	0.81	0.068	0.04	0.0001	0.4	0	0.3
0.51-1.00	0.67	0.012	0.028	0	0.35	0	0.2
1.01-2.00	0.36	0.0009	0.021	0	0.18	0	0.22
2.01-5.00	0.17	0	0.0058	0	0.076	0	0.2
> 5.00	0.051	0	0.00088	0	0.021	0	0.082

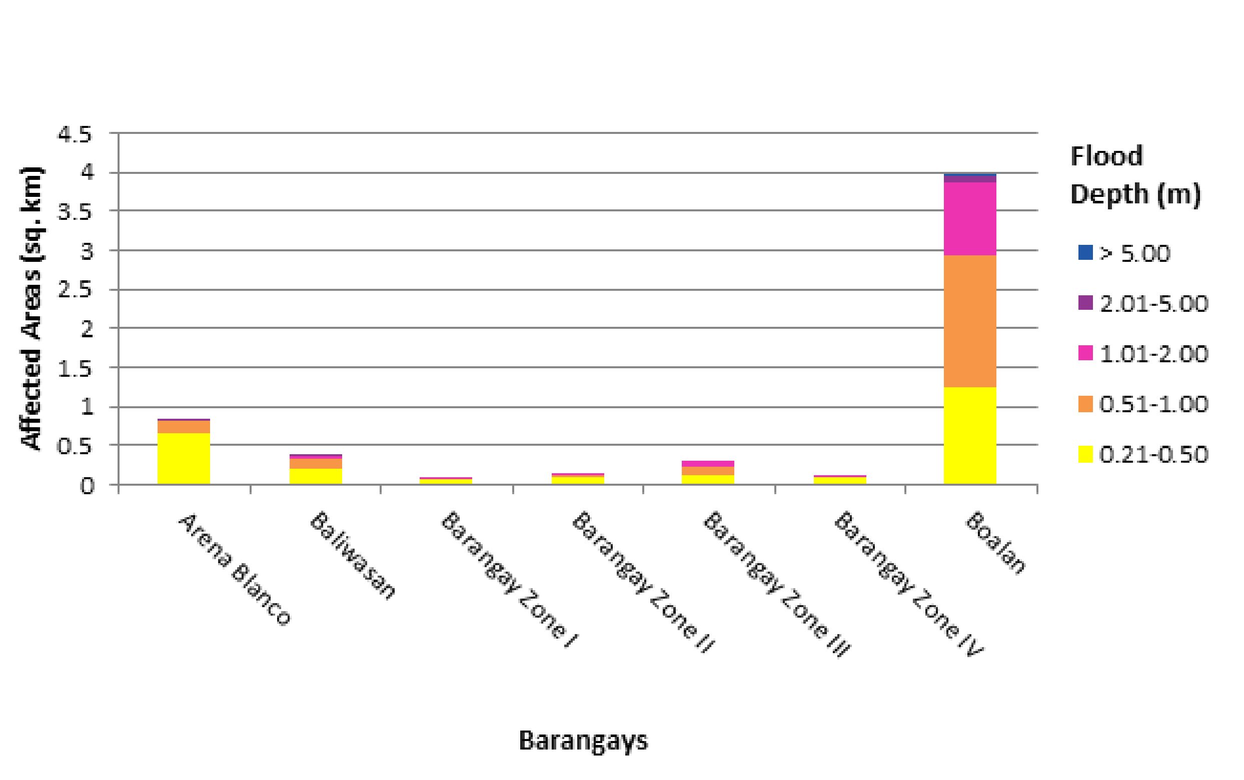


Figure 72. Affected Areas in Ipil, Zamboanga Sibugay during 25-year rainfall return periodv

For the 25-year return period, 1.73% of the municipality of Roseller Lim with an area of 272.3884 sq. km. will experience flood levels of less than 0.20 meters. 0.20% of the area will experience flood levels of 0.21 to 0.50 meters while 0.09%, 0.04%, 0.01%, and 0.00% 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 Roseller Lim, Zamboanga Sibugay during 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Affected Barangays in Roseller Lim (in sq. km.)	
	Balansag	Gango
0.03-0.20	1.13	1.23
0.21-0.50	0.056	0.22
0.51-1.00	0.039	0.082
1.01-2.00	0.03	0.021
2.01-5.00	0.0074	0.0007
> 5.00	0	0

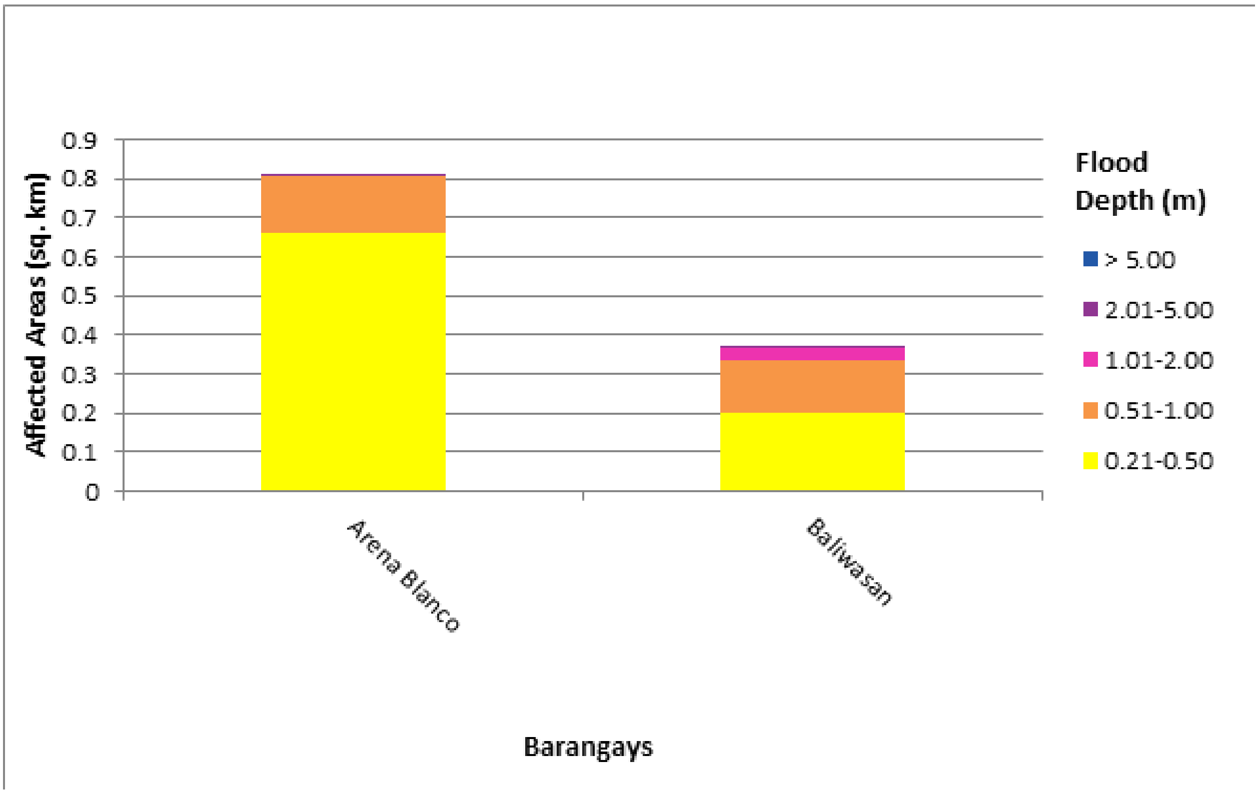


Figure 73. Affected Areas in Roseller Lim, Zamboanga Sibugay during 25-year rainfall return period

For the 100-year return period, 25.72% of the municipality of Ipil with an area of 58.6492 sq. km. will experience flood levels of less than 0.20 meters. 2.81% of the area will experience flood levels of 0.21 to 0.50 meters while 2.32%, 1.71%, 0.90%, and 0.39% 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 33. 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.)						
	Buluan	Caparan	Doña Josefa	Labi	Makilas	Tiayon	Tomitom
0.03-0.20	4.68	0.3	1.63	0.015	3.6	0.0017	4.86
0.21-0.50	0.8	0.078	0.041	0.0001	0.4	0	0.33
0.51-1.00	0.72	0.018	0.03	0	0.37	0	0.22
1.01-2.00	0.51	0.0016	0.023	0	0.24	0	0.23
2.01-5.00	0.18	0	0.01	0	0.11	0	0.23
> 5.00	0.075	0	0.0014	0	0.029	0	0.12

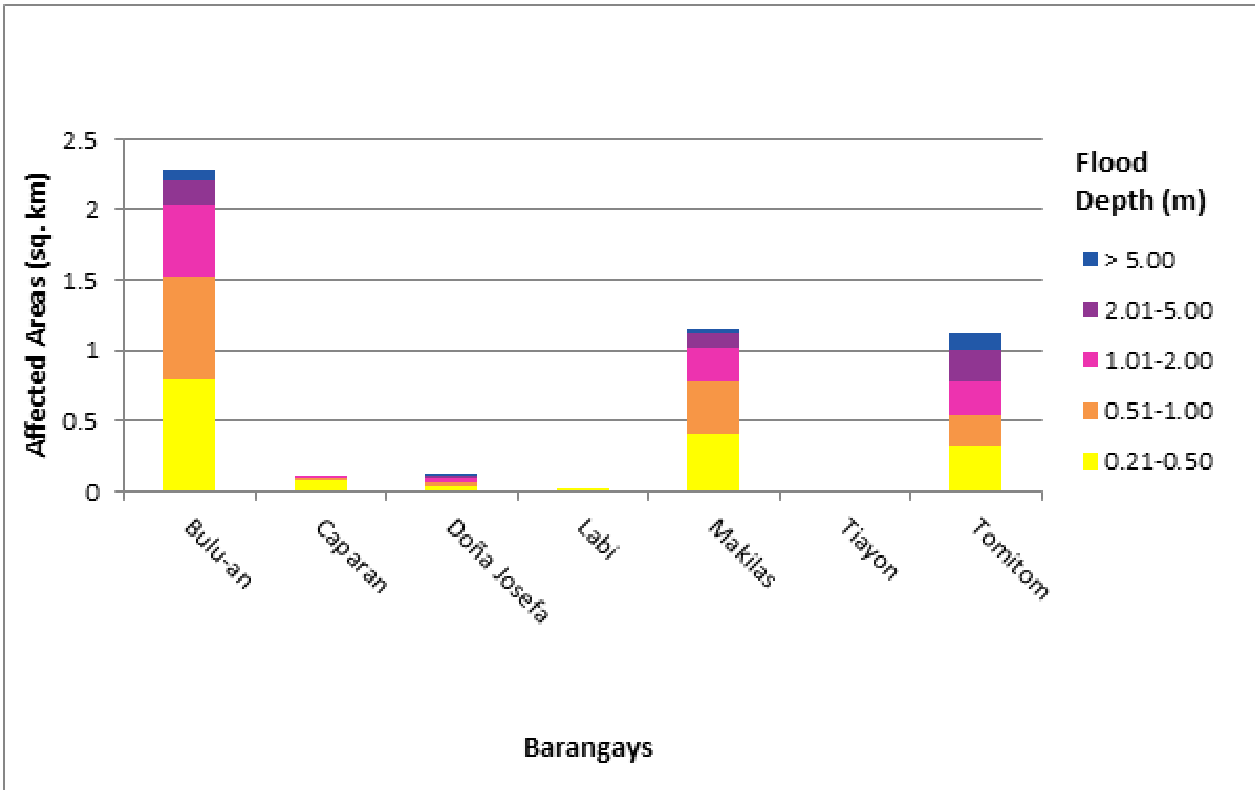


Figure 74. Affected Areas in Ipil, Zamboanga Sibugay during 25-year rainfall return period

For the 100-year return period, 5.54% of the municipality of Roseller Lim with an area of 272.3884 sq. km. will experience flood levels of less than 0.20 meters. 0.61% of the area will experience flood levels of 0.21 to 0.50 meters while 0.50%, 0.37%, 0.19%, and 0.08% 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 Roseller Lim, Zamboanga Sibugay during 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pinabacdao (in sq. km.)	
	Balansag	Gango
0.03-0.20	1.13	1.17
0.21-0.50	0.055	0.24
0.51-1.00	0.047	0.11
1.01-2.00	0.034	0.03
2.01-5.00	0.011	0.0008
> 5.00	0	0

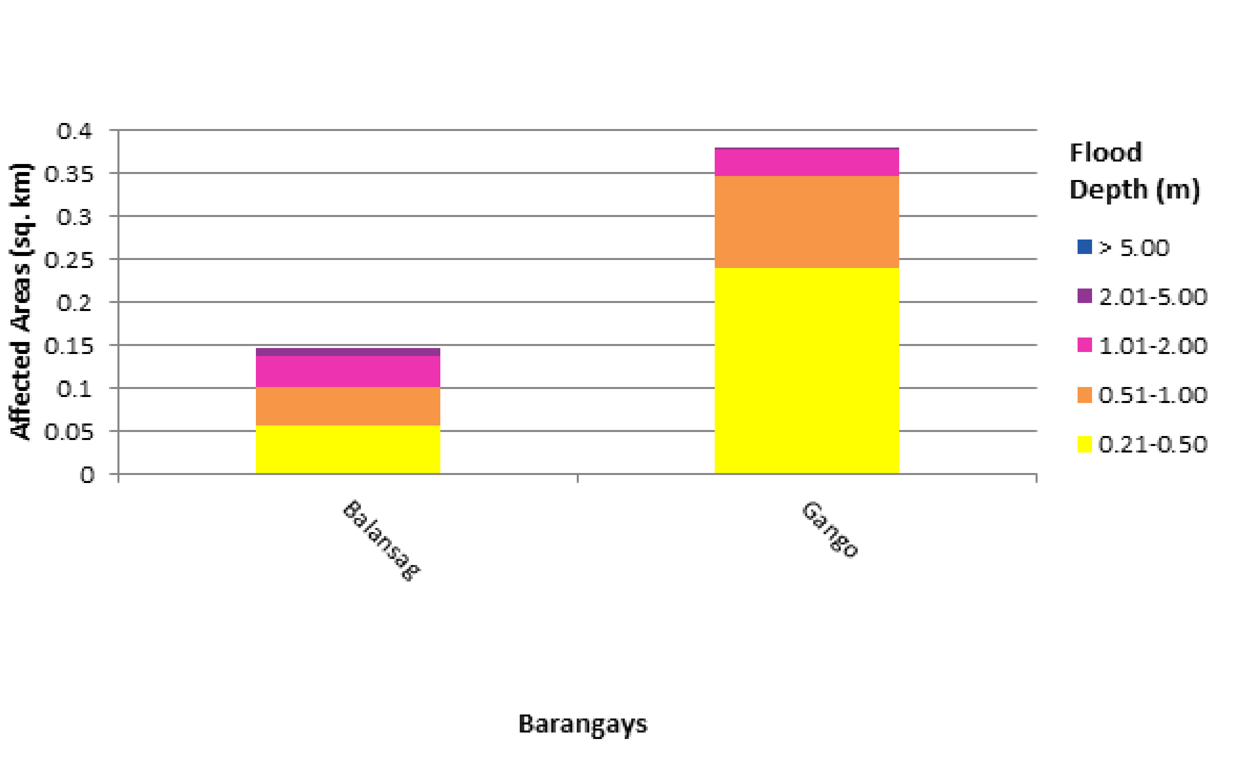


Figure 75. Affected Areas in Roseller Lim, Zamboanga Sibugay during 100-year rainfall return period

Moreover, the generated flood hazard maps for the Buluan 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 35. 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	1.71	1.93	1.96
Medium	1.33	1.95	2.25
High	0.61	0.94	1.17
TOTAL	**3.65**	**4.82**	**5.38**

Of the 4 identified educational institutes in Buluan floodplain, only the Buluan Daycare Center in Brgy. Buluan, Ipil was exposed to medium level flooding for the 25 year and 100 year scenarios and low level flooding for the 5 year scenario.

The sole medical or health institution identified in the floodplain is the Barangay Health Center in Brgy. Buluan in Ipil municipality. It was assessed to be exposed to medium level flooding for the 25 year and 100 year scenarios and low level flooding for the 5 year scenario.

5.11 Flood Validation

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

The flood validation points were obtained on June 23 to October 23, 2016. The actual data from the field were compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed.

The points in the flood map versus its corresponding validation depths are shown in Figure 77.

The flood validation consists of 256 points randomly selected all over the Buluan floodplain. It has an RMSE value of 0.29.

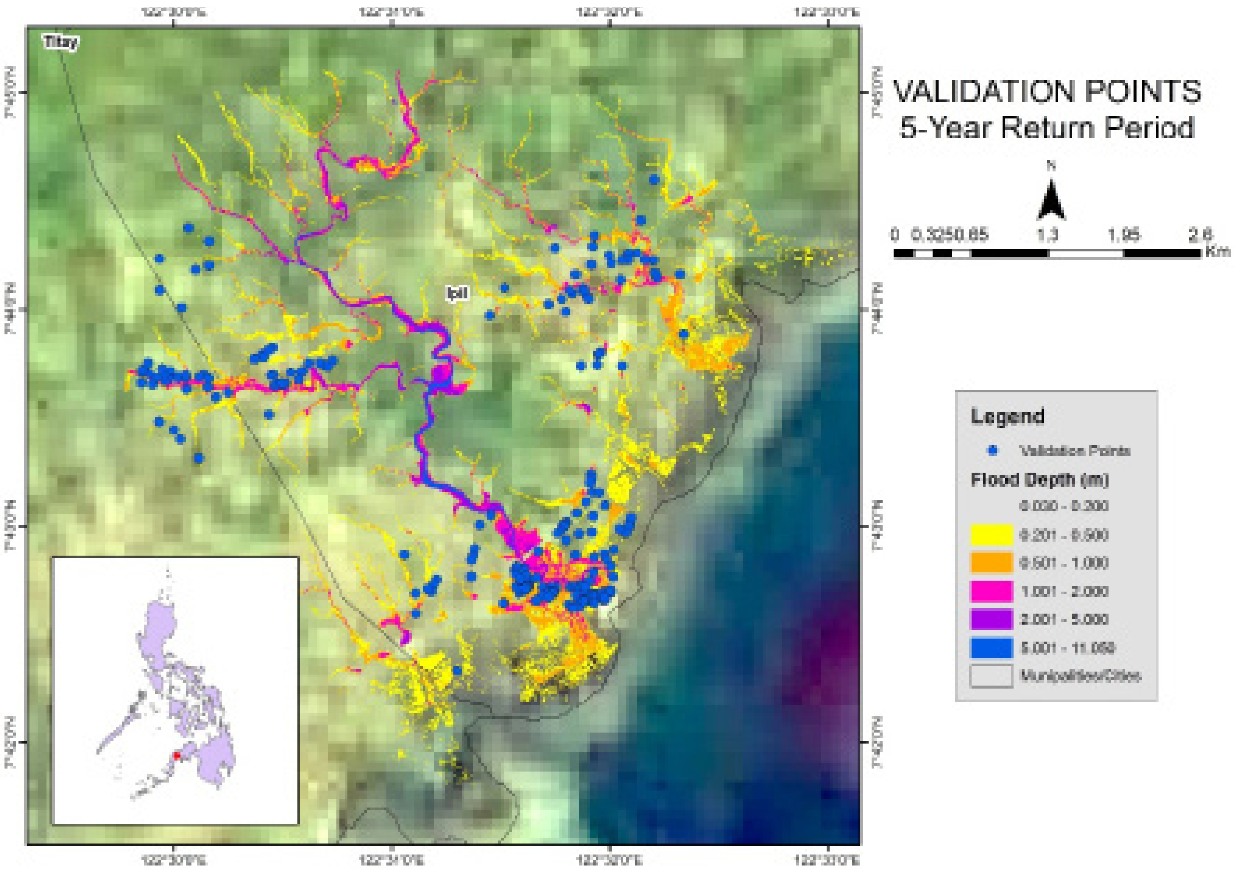


Figure 76. Validation points for a 5-year Flood Depth Map of the Buluan Floodplain

Table 36. Actual flood depth vs. simulated flood depth in Buluan

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	143	52	7	1	1	0	204
0.21-0.50	15	12	16	3	0	0	46
0.51-1.00	2	3	0	1	0	0	6
1.01-2.00	0	0	0	0	0	0	0
2.01-5.00	0	0	0	0	0	0	0
> 5.00	0	0	0	0	0	0	0
Total	160	67	23	5	1	0	256

The overall accuracy generated by the flood model is estimated at 60.55%, with 155 points correctly matching the actual flood depths. In addition, there were 84 points estimated one level above and below the correct flood depths while there were 12 points and 2 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 81 points were overestimated while a total of 20 points were underestimated in the modelled flood depths of Buluan.

Table 37. Summary of Accuracy Assessment in the Buluan River Basin Survey

	No. of Points	%
Correct	155	60.55
Overestimated	81	31.64
Underestimated	20	7.81
Total	256	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) and Ground Control Points (GCP). Quezon City, Philippines: UP Training Center for Applied Geodesy and Photogrammetry

ANNEXES

Annex 1. Optech Technical Specification of the Pegasus Sensor

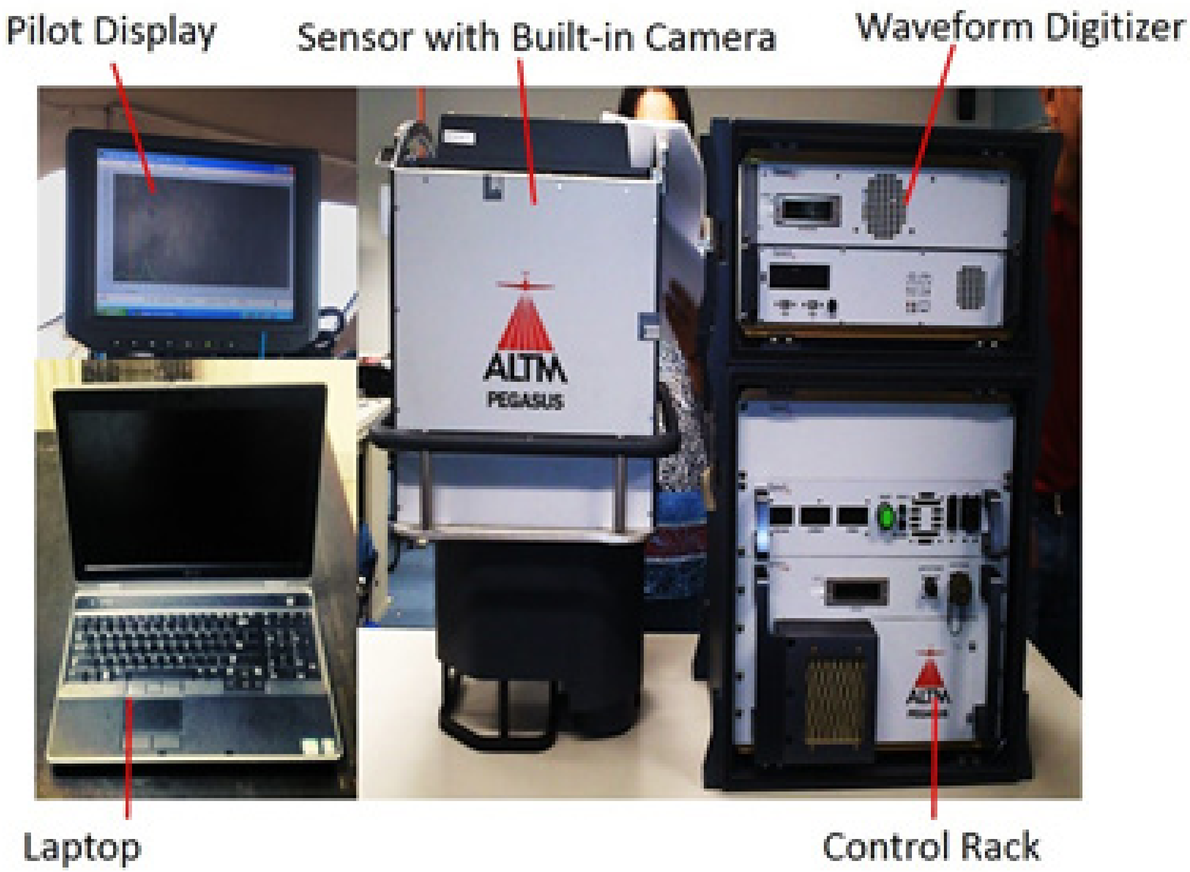


Figure A-1.1 Pegasus sensor

Table A-1.1 Parameters and specifications of the Pegasus sensor

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

Annex 2. NAMRIA Certificates of Reference Points Used

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 5 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

CIP/4701/12/09/814

Figure A-2.1 ZSI-52

Annex 3. Baseline Processing Reports

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

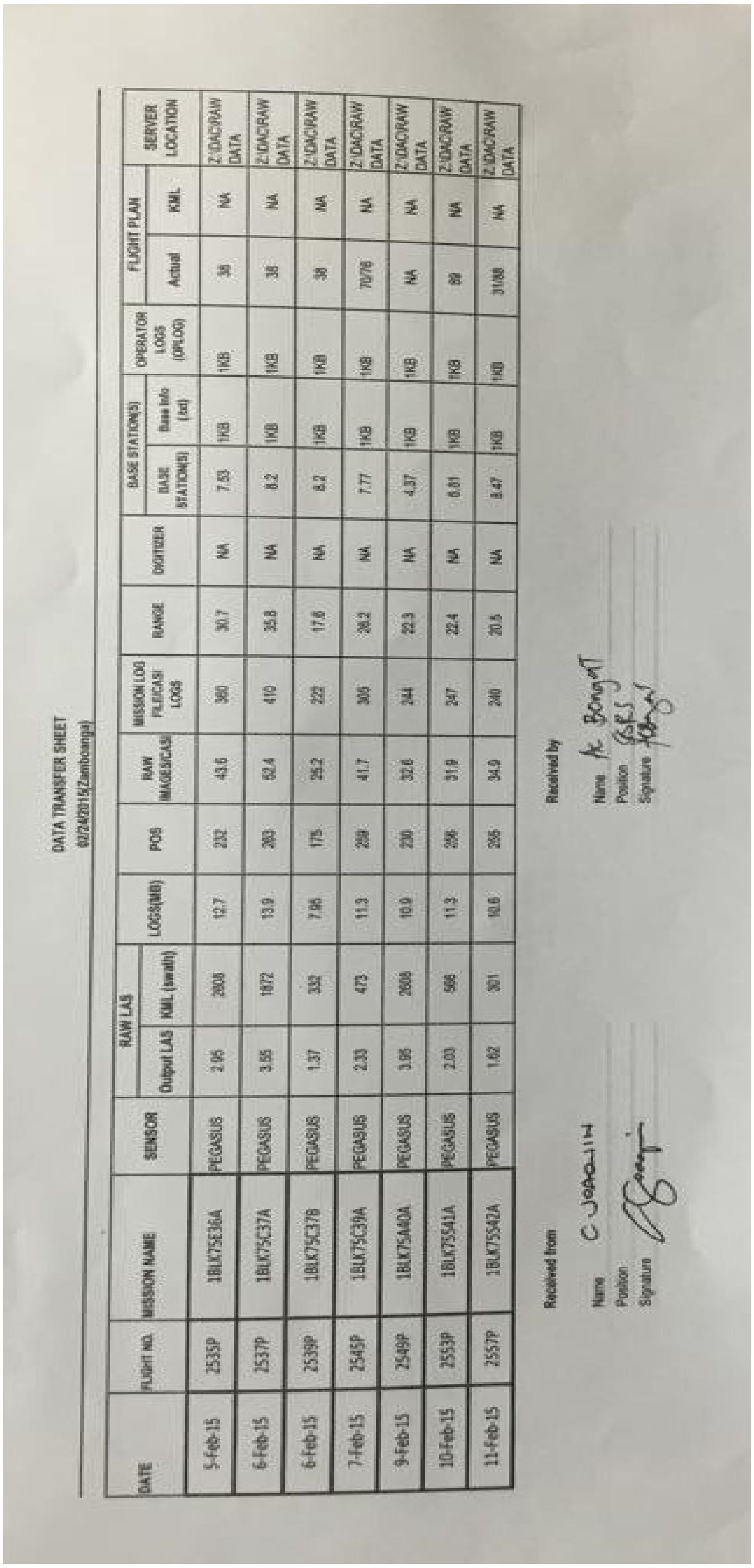
Figure A-3.1 ZY-93A

Annex 4. The LiDAR Survey Team Composition

Table A-4.1 LiDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
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
	Research Associate (RA)	ENGR. IRO NIEL ROXAS	UP-TCAGP
		KRISTINE JOY ANDAYA	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	ENGR. RENAN PUNTO	UP-TCAGP
LiDAR Operation	Airborne Security	SSG. RONALD MONTENEGRO	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. CESAR SHERWIN ALFONSO III	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. JOHN BRYAN DONGUINES	AAC

Annex 5. Data Transfer Sheet for Buluan 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	2808	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	28.2	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

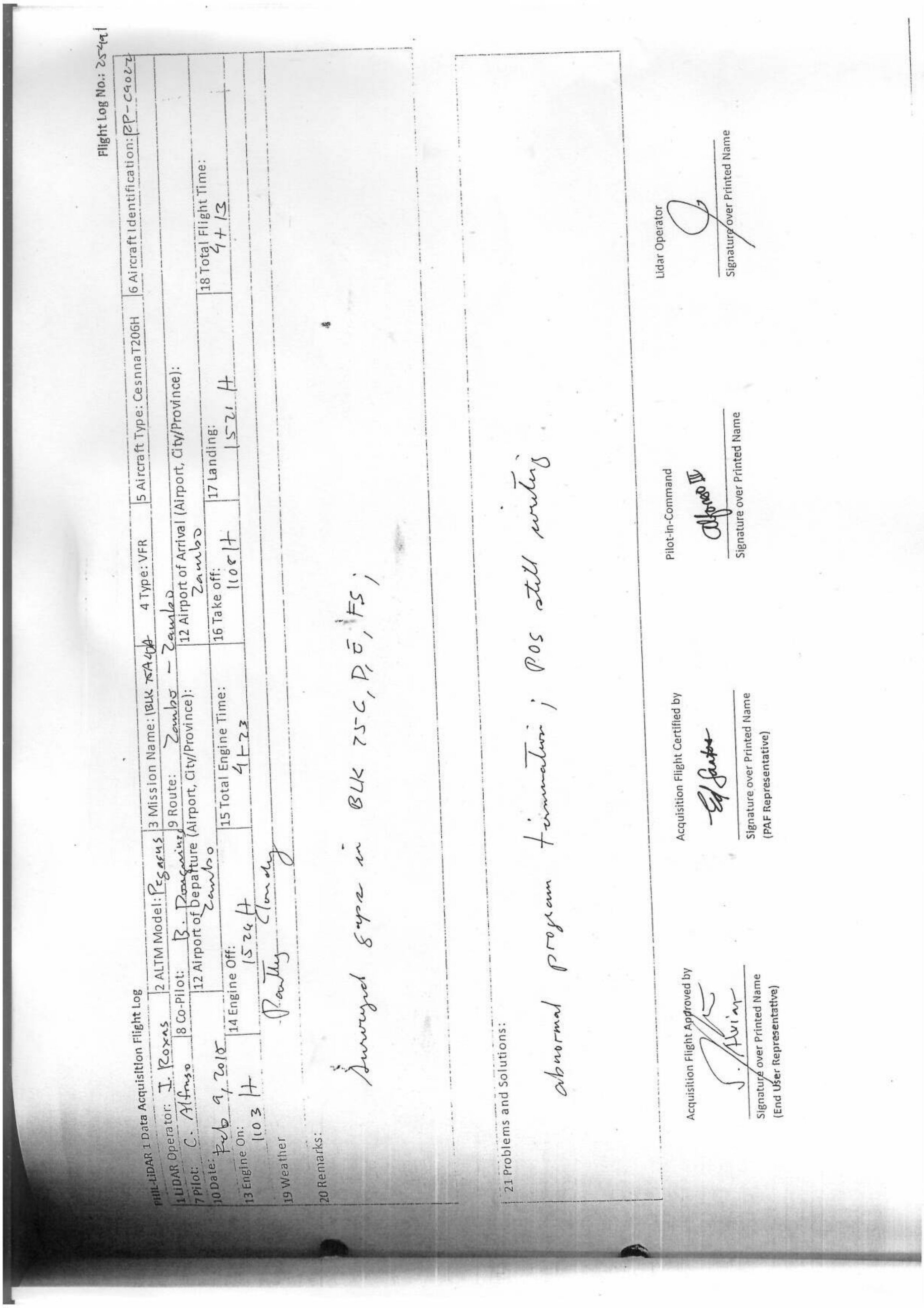
Received by

Name AC BONGAT
Position GSRS
Signature

Figure A-5.1 Data Transfer Sheet for Buluan Floodplain - A

Annex 6. Flight Logs

Flight Log for 1BLK75A40A Mission



Flight Log No.: 2549

PHIL-LIDAR 1 Data Acquisition Flight Log

1 LIDAR Operator: J. 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. Dongunio	9 Route: Zambo - Zambo			
10 Date: Feb 9, 2016	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+23	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 75C, D, E, F5;

21 Problems and Solutions:

abnormal program termination; POS still writing

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

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

Pilot-in-Command — Signature over Printed Name

Lidar Operator — Signature over Printed Name

Figure A-6.1 Flight Log for 1BLK75A40A Mission

Annex 7. Flight Status Report

Table A-7.1 Flight Status Report

ZAMBOANGA CITY-ZAMBOANGA SIBUGAY
(February 5 - 11, 2015)

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
2549P	BLK 75A	1BLK75A40A	I. Roxas	February 9, 2015	AVPOSVIEW: Assertion failed; Abnormal program termination

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%

LAS

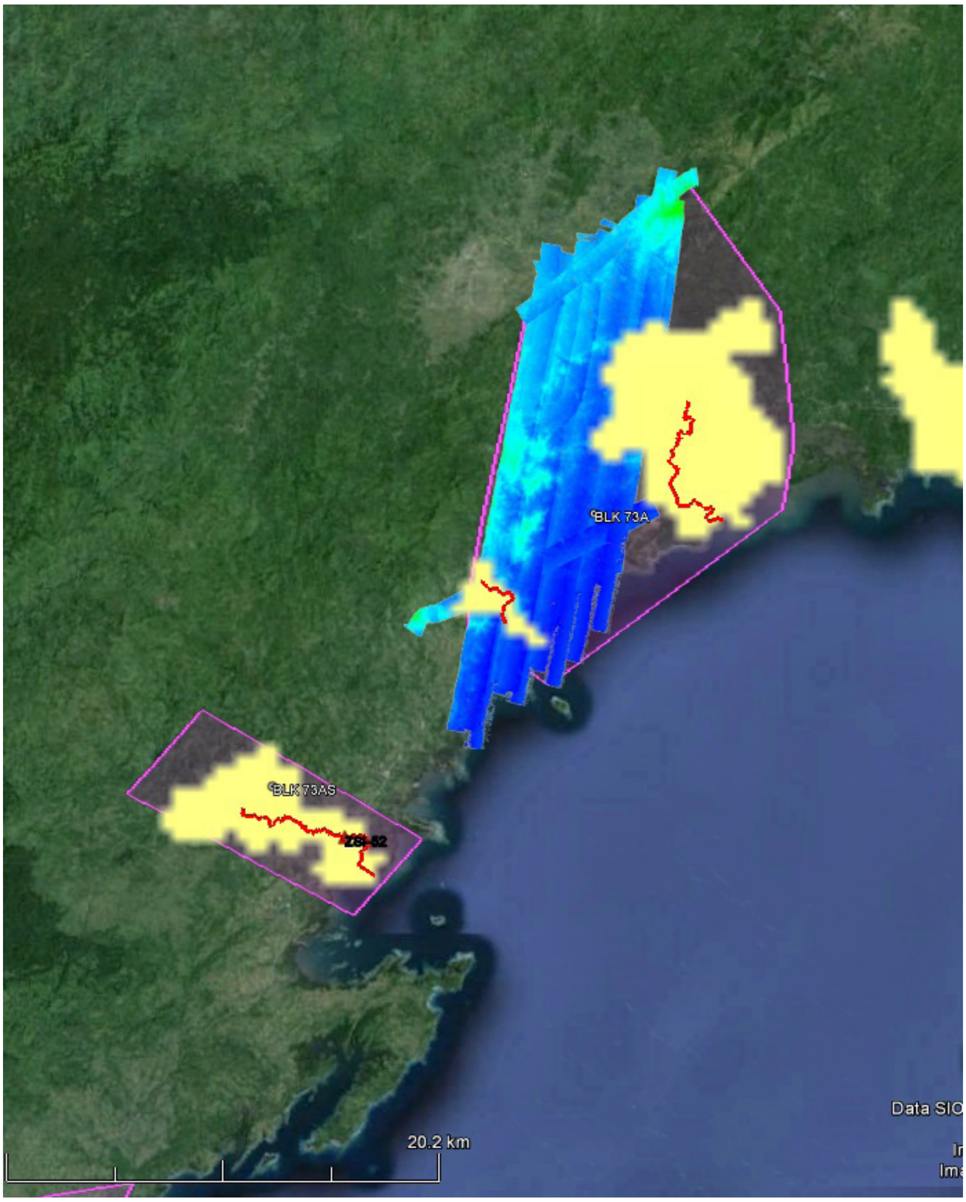


Figure A-7.1 Swath for Flight No. 2549P

Annex 8. Mission Summary Report

Table A-8.1 Mission Summary Report for Mission Blk75A

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

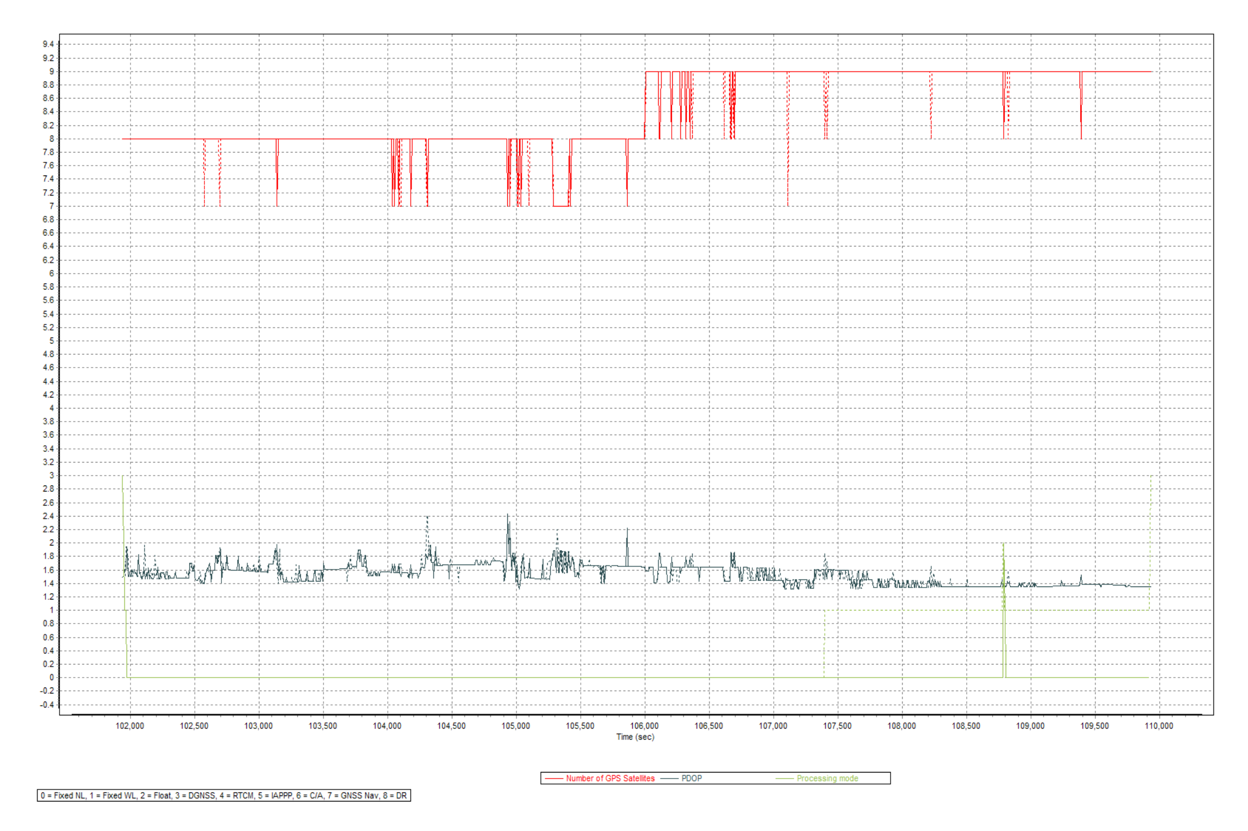


Figure A-8.1 Solution Status

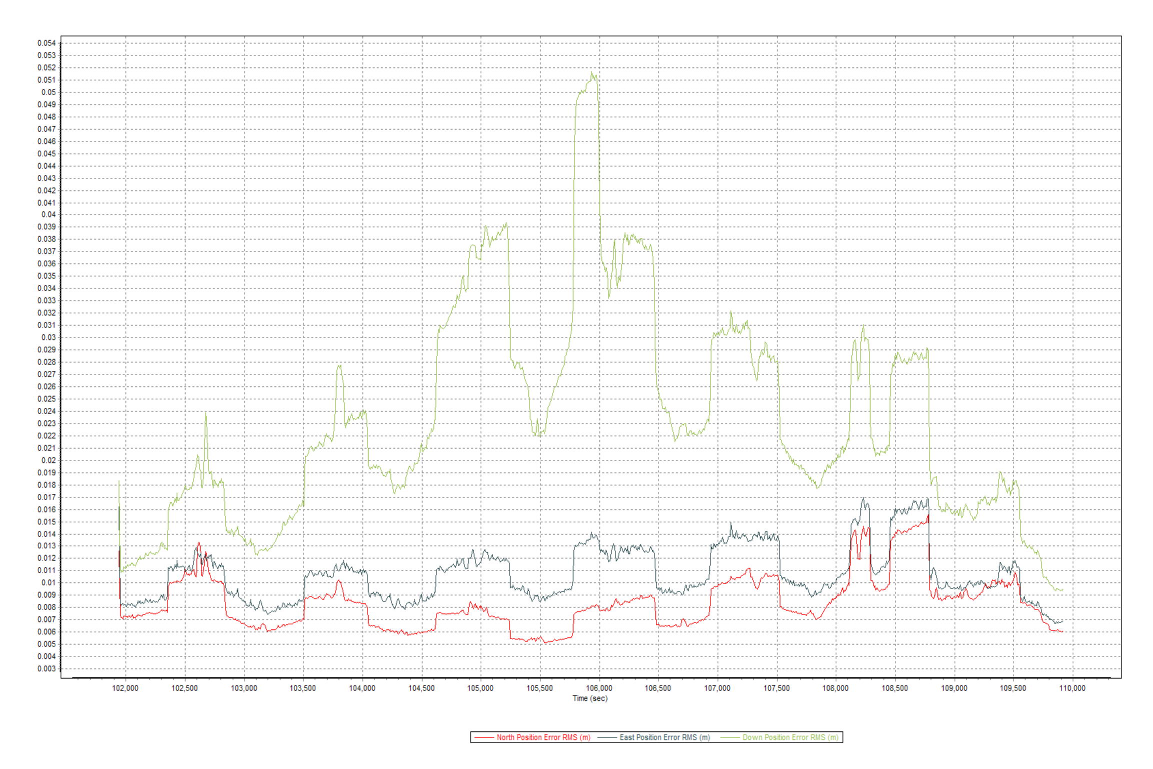


Figure A-8.2 Smoothed Performance Metric Parameters

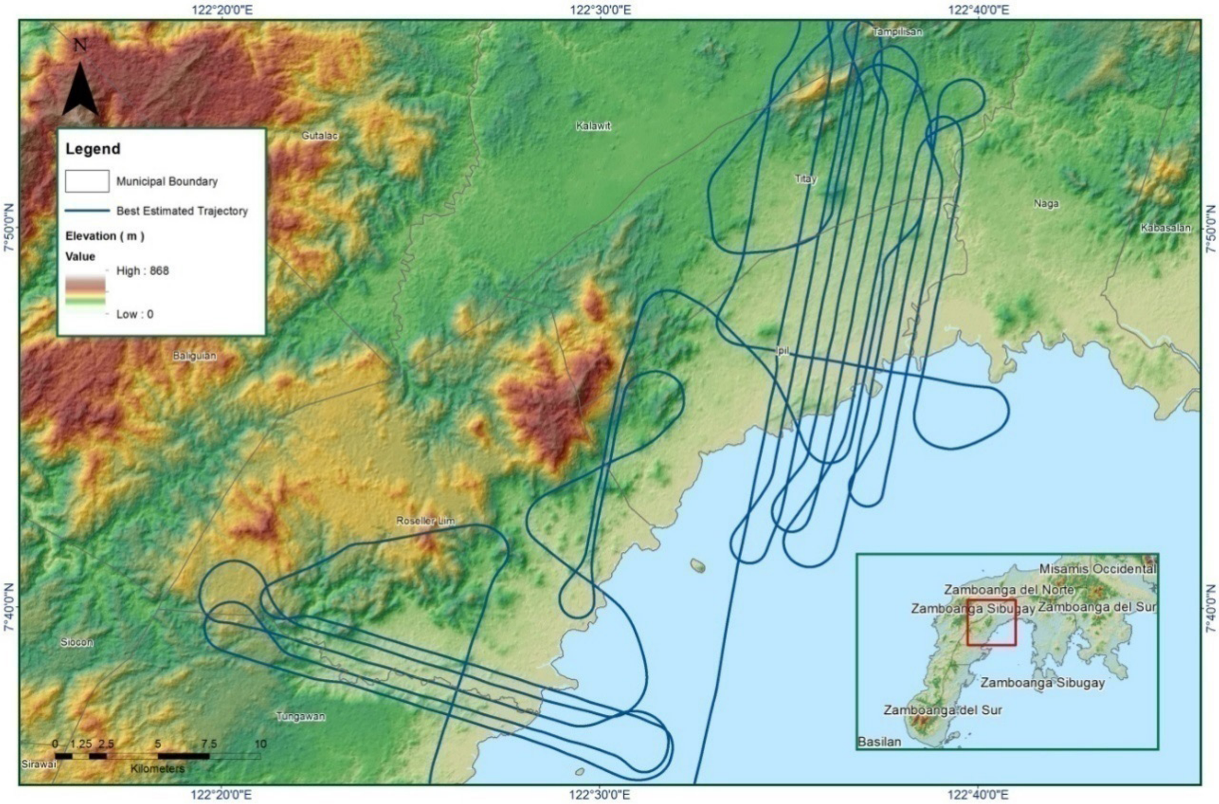


Figure A-8.3 Best Estimated Trajectory

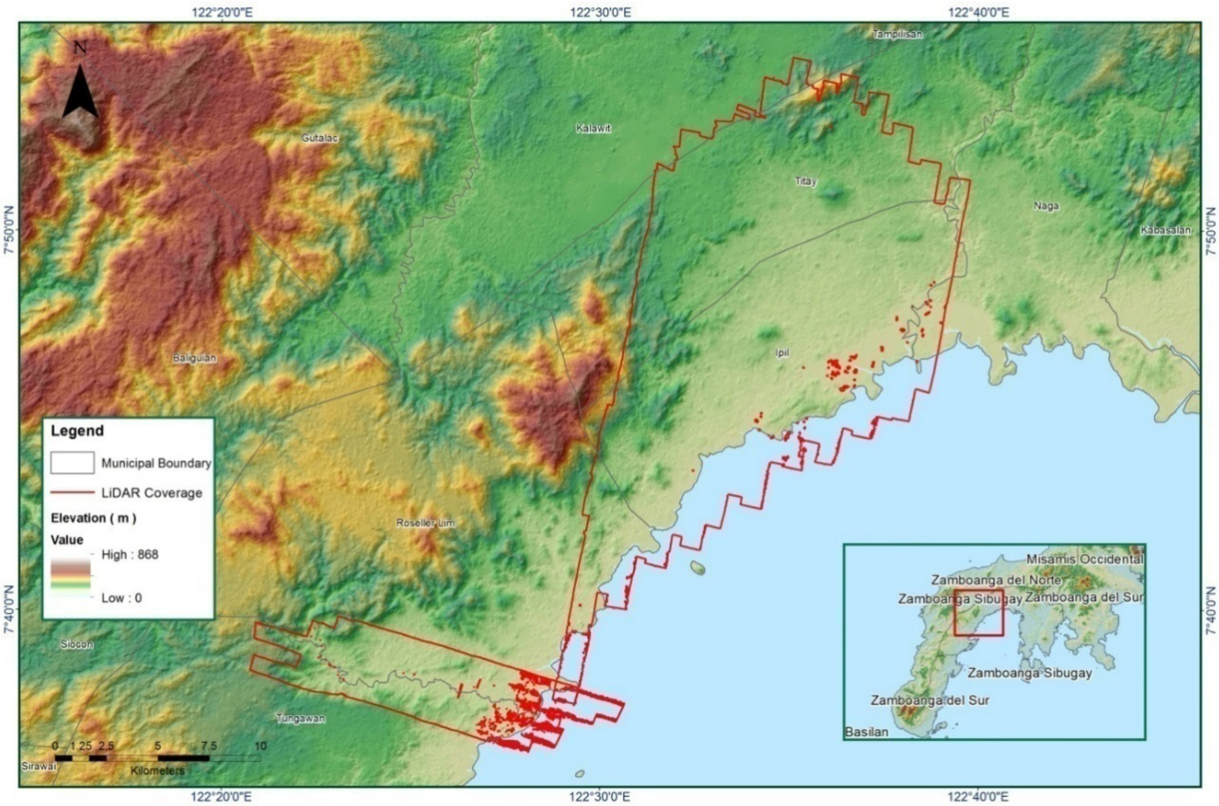


Figure A-8.4 Coverage of LiDAR data

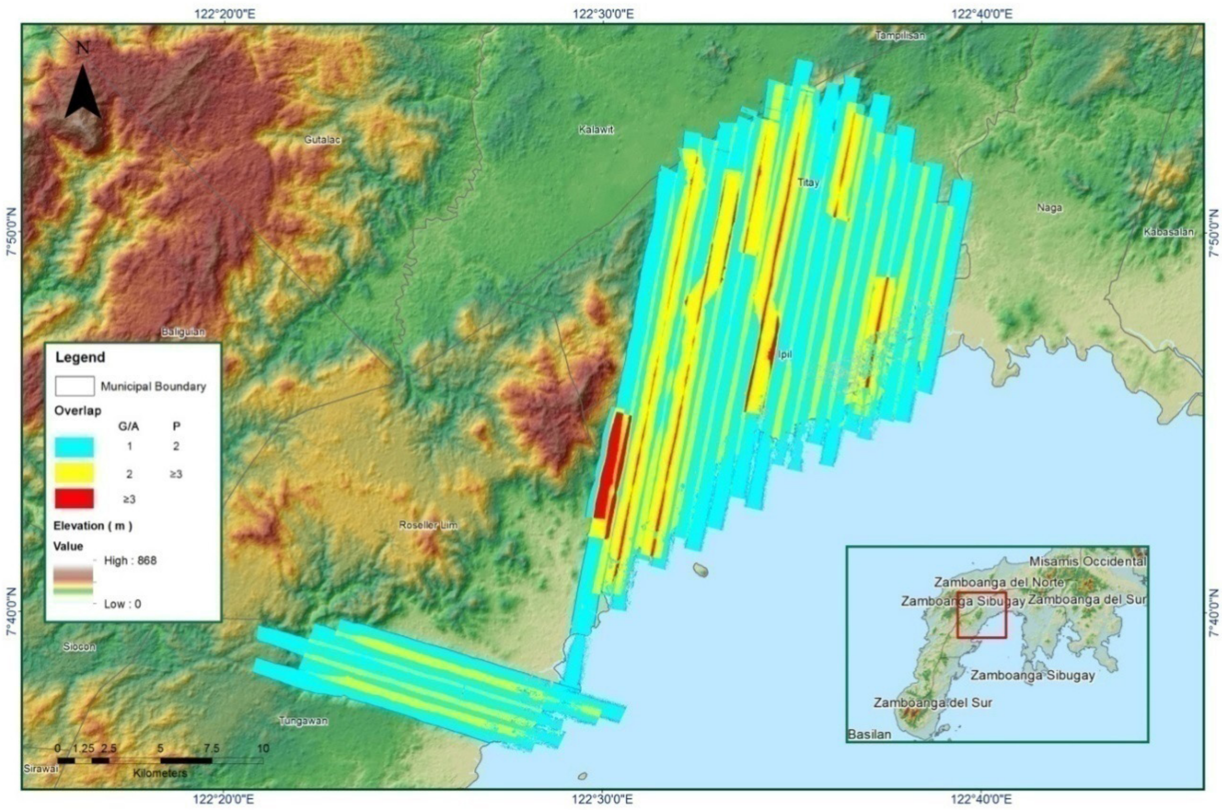


Figure A-8.5 Image of data overlap

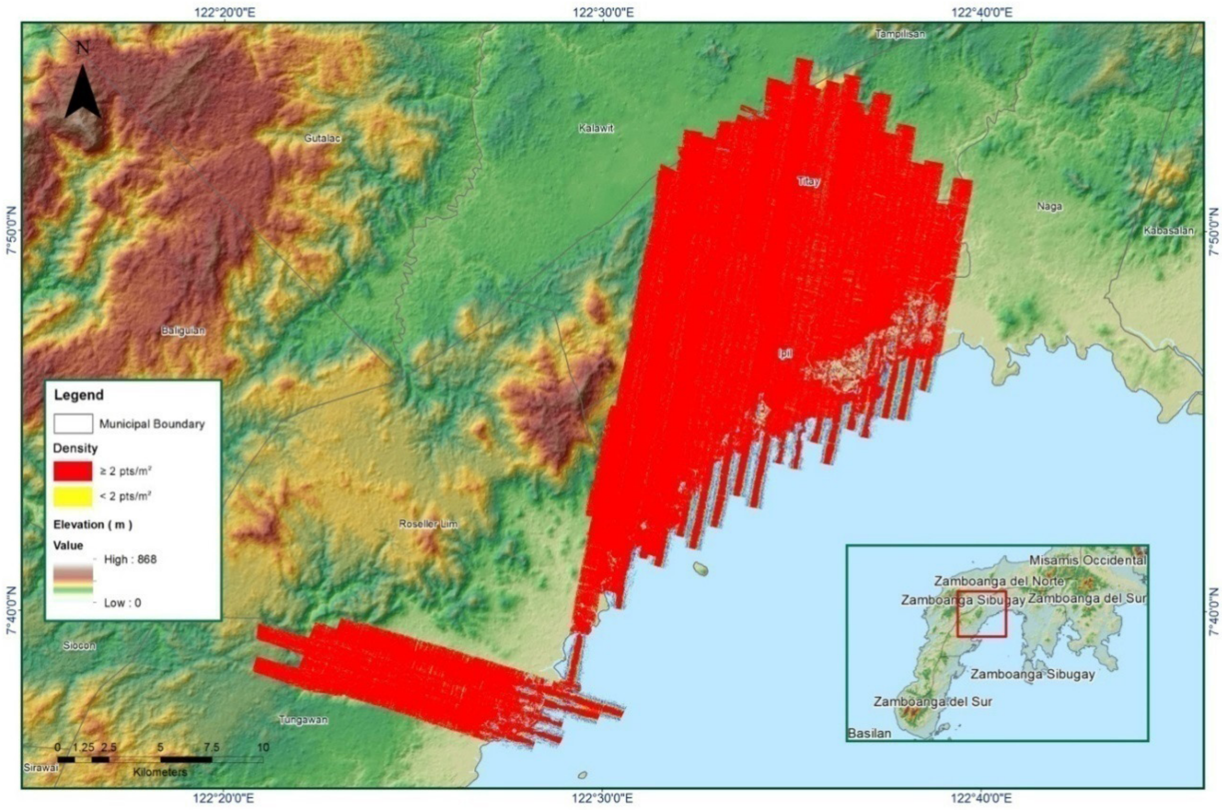


Figure A-8.6 Density map of merged LiDAR data

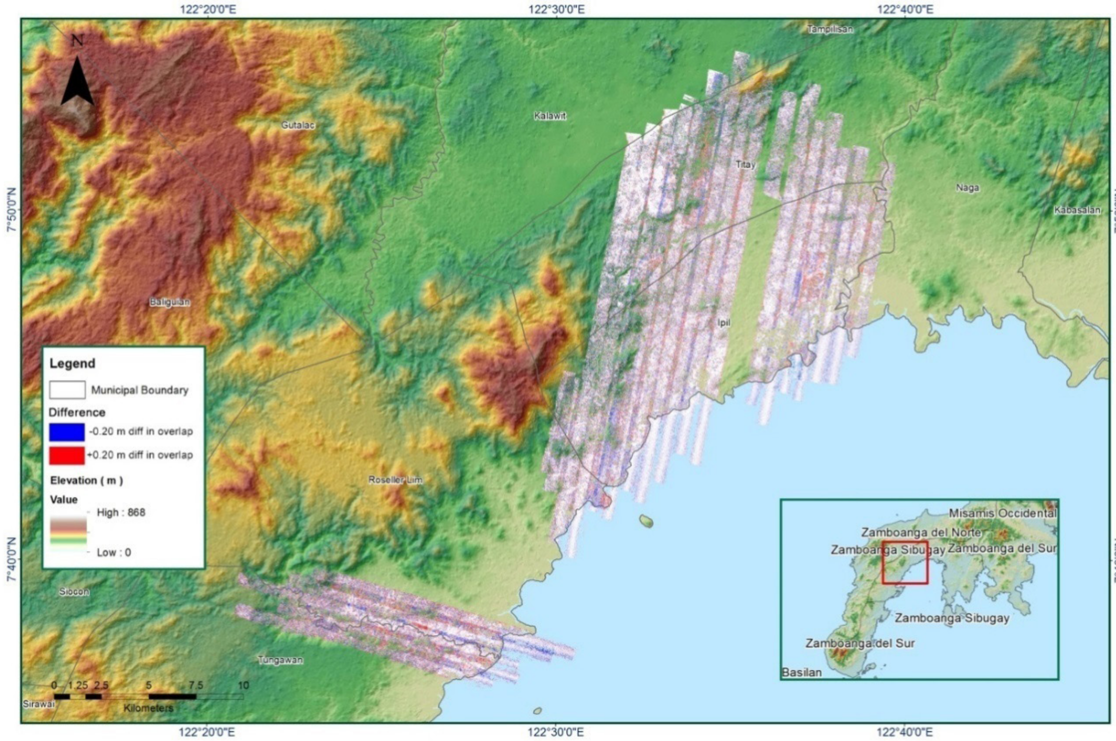


Figure A-8.7 Elevation difference between flight lines

Annex 9. Buluan Model Basin Parameters

Table A-9.1 Buluan Model Basin Parameters

Subbasin	SCS CURVE NUMBER LOSS			CLARK UNIT HYDROGRAPH TRANSFORM			RECESSION BASEFLOW			
	Initial Abstraction (MM)	Curve Number	Imperviousness (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (CU.M/S)	Recession Constant	Threshold Type	Ratio to Peak
W120	57.509	56.746	0	0.0999675	0.62959	Discharge	0.0129210	0.7	Ratio to Peak	0.2
W130	24.1902	99	0	0.0349925	0.49847	Discharge	0.0114757	0.7	Ratio to Peak	0.2
W140	51.385	60.565	0	0.0841388	1.311	Discharge	0.0199984	0.7	Ratio to Peak	0.2
W150	28.571	99	0	0.0325425	0.61649	Discharge	0.0083710	0.7	Ratio to Peak	0.2
W160	19.8773	99	0	0.0299475	0.24112	Discharge	0.0010518	0.7	Ratio to Peak	0.2
W170	24.2541	99	0	0.0166667	0.0925949	Discharge	.000146892	0.7	Ratio to Peak	0.2
W180	24.099	99	0	0.0277025	0.11585	Discharge	0.0052011	0.7	Ratio to Peak	0.2
W190	29.582	63.59	0	0.10841	0.9755	Discharge	0.0120524	0.7	Ratio to Peak	0.2
W200	19.8773	99	0	0.0945112	0.47847	Discharge	0.0110223	0.7	Ratio to Peak	0.2
W210	27.898	99	0	0.03818	0.67159	Discharge	0.0106289	0.7	Ratio to Peak	0.2
W220	21.6694	99	0	0.0166667	0.56848	Discharge	0.0013093	0.7	Ratio to Peak	0.2

Annex 10. Buluan Model Reach Parameters

Table A-10.1 Buluan Model Reach Parameters

REACH	MUSKINGUM CUNGE CHANNEL ROUTING						
	Time Step Method	Length (M)	Slope (M/M)	Manning's n	Shape	Width (M)	Side Slope (xH:1V)
R30	Automatic Fixed Interval	228.85	0.0990717	0.03	Trapezoid	10	0.01
R50	Automatic Fixed Interval	136.48	0.0658490	0.03	Trapezoid	10	0.01
R70	Automatic Fixed Interval	540.79	0.0593026	0.03	Trapezoid	10	0.01
R90	Automatic Fixed Interval	1382.1	0.0535258	0.03	Trapezoid	10	0.01
R110	Automatic Fixed Interval	291.39	0.0001	0.03	Trapezoid	10	0.01

Annex 11. Buluan Field Validation

Table A-11.1 Buluan Field Validation

Pount No.	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Lat	Long					
1	7.713198	122.526117	0.04	0	0.04	Not Defined	5 -Year
2	7.713232	122.526466	0.14	0	0.14	Not Defined	5 -Year
3	7.712459	122.526784	0.4	0	0.40	Not Defined	5 -Year
4	7.713077	122.526756	0.39	0	0.39	Not Defined	5 -Year
5	7.713338	122.526641	0.28	0	0.28	Not Defined	5 -Year
6	7.712517	122.526976	0.2	0	0.20	Not Defined	5 -Year
7	7.712386	122.527042	0.31	0	0.31	Not Defined	5 -Year
8	7.712485	122.527218	0.26	0	0.26	Not Defined	5 -Year
9	7.712309	122.52713	0.27	0	0.27	Not Defined	5 -Year
10	7.712122	122.527162	0.4	0	0.40	Not Defined	5 -Year
11	7.71183	122.528391	0.08	0	0.08	Not Defined	5 -Year
12	7.711856	122.528278	0.27	0	0.27	Not Defined	5 -Year
13	7.711719	122.52869	0.34	0	0.34	Not Defined	5 -Year
14	7.711809	122.529197	0.32	0	0.32	Not Defined	5 -Year
15	7.711961	122.529231	0.23	0	0.23	Not Defined	5 -Year
16	7.71181	122.528808	0.25	0	0.25	Not Defined	5 -Year
17	7.711945	122.528896	0.1	0	0.10	Not Defined	5 -Year
18	7.71194	122.528192	0.28	0	0.28	Not Defined	5 -Year
19	7.713499	122.526246	0.03	0	0.03	Not Defined	5 -Year
20	7.713444	122.526326	0.03	0	0.03	Not Defined	5 -Year
21	7.71331	122.526807	0.56	0	0.56	Not Defined	5 -Year
22	7.711677	122.529052	0.37	0	0.37	Not Defined	5 -Year
23	7.711486	122.528985	0.47	0	0.47	Not Defined	5 -Year
24	7.710613	122.530238	0.35	0	0.35	Not Defined	5 -Year
25	7.71196	122.530325	0.45	0	0.45	Not Defined	5 -Year
26	7.711996	122.530606	0.49	0	0.49	Not Defined	5 -Year
27	7.711661	122.530936	0.48	0	0.48	Not Defined	5 -Year
28	7.711707	122.530864	0.32	0	0.32	Not Defined	5 -Year
29	7.710964	122.531111	0.06	0	0.06	Not Defined	5 -Year
30	7.710923	122.53134	0.22	0	0.22	Not Defined	5 -Year
31	7.711141	122.531261	0.19	0	0.19	Not Defined	5 -Year
32	7.711286	122.531297	0.06	0	0.06	Not Defined	5 -Year
33	7.711627	122.531058	0.22	0	0.22	Not Defined	5 -Year
34	7.711905	122.531081	0.07	0	0.07	Not Defined	5 -Year
35	7.712115	122.531067	0.16	0	0.16	Not Defined	5 -Year
36	7.712023	122.530901	0.19	0	0.19	Not Defined	5 -Year
37	7.712134	122.531168	0.03	0	0.03	Not Defined	5 -Year
38	7.712004	122.531135	0.2	0	0.20	Not Defined	5 -Year

Pount No.	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Lat	Long					
39	7.711945	122.531495	0.18	0	0.18	Not Defined	5 -Year
40	7.712398	122.531797	0.34	0	0.34	Not Defined	5 -Year
41	7.711619	122.531625	0.15	0	0.15	Not Defined	5 -Year
42	7.711733	122.531094	0.17	0	0.17	Not Defined	5 -Year
43	7.711434	122.532087	0.2	0	0.20	Not Defined	5 -Year
44	7.711456	122.532301	0.03	0	0.03	Not Defined	5 -Year
45	7.711357	122.532352	0.23	0	0.23	Not Defined	5 -Year
46	7.7113	122.532644	0.14	0	0.14	Not Defined	5 -Year
47	7.712826	122.526975	0.3	0	0.30	Not Defined	5 -Year
48	7.713118	122.526394	0.25	0	0.25	Not Defined	5 -Year
49	7.714913	122.523029	0.03	0	0.03	Not Defined	5 -Year
50	7.714378	122.522932	0.03	0	0.03	Not Defined	5 -Year
51	7.714019	122.522806	0.03	0	0.03	Not Defined	5 -Year
52	7.712752	122.522759	0.03	0	0.03	Not Defined	5 -Year
53	7.716756	122.523387	0.03	0	0.03	Not Defined	5 -Year
54	7.717468	122.524256	0.03	0	0.03	Not Defined	5 -Year
55	7.712509	122.520114	0.03	0	0.03	Not Defined	5 -Year
56	7.712164	122.519854	0.03	0	0.03	Not Defined	5 -Year
57	7.711607	122.519698	0.03	0	0.03	Not Defined	5 -Year
58	7.709902	122.518501	0.03	0	0.03	Not Defined	5 -Year
59	7.711482	122.518484	0.03	0	0.03	Not Defined	5 -Year
60	7.711816	122.519416	0.48	0	0.48	Not Defined	5 -Year
61	7.714378	122.517662	0.03	0	0.03	Not Defined	5 -Year
62	7.720621	122.531906	0.04	0	0.04	Not Defined	5 -Year
63	7.720301	122.531938	0.22	0	0.22	Not Defined	5 -Year
64	7.720019	122.531859	0.03	0	0.03	Not Defined	5 -Year
65	7.71923	122.532022	0.03	0	0.03	Not Defined	5 -Year
66	7.719221	122.532519	0.03	0	0.03	Not Defined	5 -Year
67	7.718495	122.531521	0.03	0	0.03	Not Defined	5 -Year
68	7.717626	122.530842	0.13	0	0.13	Not Defined	5 -Year
69	7.716979	122.530085	0.03	0	0.03	Not Defined	5 -Year
70	7.716856	122.529988	0.05	0	0.05	Not Defined	5 -Year
71	7.716764	122.529852	0.06	0	0.06	Not Defined	5 -Year
72	7.716666	122.529716	0.05	0	0.05	Not Defined	5 -Year
73	7.716557	122.529846	0.03	0	0.03	Not Defined	5 -Year
74	7.716665	122.529811	0.06	0	0.06	Not Defined	5 -Year
75	7.716315	122.529564	0.03	0	0.03	Not Defined	5 -Year
76	7.716108	122.529313	0.03	0	0.03	Not Defined	5 -Year
77	7.714686	122.527866	0.25	0	0.25	Not Defined	5 -Year
78	7.718213	122.532972	0.03	0	0.03	Not Defined	5 -Year
79	7.716819	122.534865	0.03	0	0.03	Not Defined	5 -Year
80	7.717257	122.534998	0.07	0	0.07	Not Defined	5 -Year
81	7.7166	122.534839	0.03	0	0.03	Not Defined	5 -Year

Pount No.	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Lat	Long					
82	7.716137	122.534605	0.04	0	0.04	Not Defined	5 -Year
83	7.714812	122.53366	0.46	0	0.46	Not Defined	5 -Year
84	7.714463	122.532953	0.33	0	0.33	Not Defined	5 -Year
85	7.714052	122.53306	0.36	0	0.36	Not Defined	5 -Year
86	7.714214	122.532156	0.03	0	0.03	Not Defined	5 -Year
87	7.716167	122.531974	0.03	0	0.03	Not Defined	5 -Year
88	7.717391	122.532058	0.03	0	0.03	Not Defined	5 -Year
89	7.71605	122.530999	0.11	0	0.11	Not Defined	5 -Year
90	7.713092	122.53211	0.46	0	0.46	Not Defined	5 -Year
91	7.713561	122.533418	0.15	0	0.15	Not Defined	5 -Year
92	7.714379	122.530745	0.03	0	0.03	Not Defined	5 -Year
93	7.715579	122.53004	0.03	0	0.03	Not Defined	5 -Year
94	7.710988	122.53286	0.21	0.25	-0.04	Lawin	5 -Year
95	7.716414	122.534101	0.03	0.6	-0.57	Ondoy	5 -Year
96	7.711563	122.532824	1.02	0.6	0.42	Ondoy	5 -Year
97	7.712735	122.533607	0.33	0.6	-0.27	Ondoy	5 -Year
98	7.711409	122.53317	0.16	0.6	-0.44	Ondoy	5 -Year
99	7.711455	122.533152	0.23	0.6	-0.37	Ondoy	5 -Year
100	7.71117	122.532759	0.18	0.5	-0.32	Not Defined	5 -Year
101	7.710733	122.532118	0.48	0.6	-0.12	Pablo	5 -Year
102	7.710899	122.531596	0.31	0.3	0.01	Yolanda	5 -Year
103	7.710892	122.53143	0.27	0.3	-0.03	Yolanda	5 -Year
104	7.711208	122.5316	0.17	0.3	-0.13	Yolanda	5 -Year
105	7.711514	122.531266	0.21	0.1	0.11	Not Defined	5 -Year
106	7.711352	122.531287	0.76	0.5	0.26	Not Defined	5 -Year
107	7.711975	122.531483	0.21	0.3	-0.09	Not Defined	5 -Year
108	7.711308	122.530797	0.32	0.5	-0.18	Not Defined	5 -Year
109	7.710632	122.530864	0.18	0.25	-0.07	Yolanda	5 -Year
110	7.710346	122.53048	0.32	0.5	-0.18	Ondoy	5 -Year
111	7.710481	122.530664	0.34	0.5	-0.16	Yolanda	5 -Year
112	7.710372	122.530746	1.07	0.5	0.57	Yolanda	5 -Year
113	7.710488	122.531046	0.06	0.5	-0.44	Ondoy	5 -Year
114	7.710387	122.530633	1.04	0.5	0.54	Ondoy	5 -Year
115	7.711497	122.528938	0.57	0.1	0.47	Not Defined	5 -Year
116	7.711584	122.52893	0.39	0.5	-0.11	Not Defined	5 -Year
117	7.711559	122.528763	0.28	0.5	-0.22	Not Defined	5 -Year
118	7.711551	122.528922	0.39	0.1	0.29	Not Defined	5 -Year
119	7.711499	122.528479	0.5	0.25	0.25	Karen	5 -Year
120	7.711459	122.52848	0.5	0.25	0.25	Karen	5 -Year
121	7.711252	122.528156	0.79	0.2	0.59	Yolanda	5 -Year
122	7.711178	122.528656	1.14	0.2	0.94	Yolanda	5 -Year
123	7.710923	122.527701	0.69	0.5	0.19	Ondoy	5 -Year
124	7.712661	122.527723	1.52	0.5	1.02	Not Defined	5 -Year

Pount No.	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Lat	Long					
125	7.705484	122.521698	0.54	0.5	0.04	Not Defined	5 -Year
126	7.711967	122.527147	0.57	0.5	0.07	Not Defined	5 -Year
127	7.710763	122.525271	0.9	0.5	0.40	Not Defined	5 -Year
128	7.71193	122.527064	0.73	0.5	0.23	Not Defined	5 -Year
129	7.711925	122.527063	0.73	0.5	0.23	Not Defined	5 -Year
130	7.711526	122.526438	0.03	0.1	-0.07	Not Defined	5 -Year
131	7.711914	122.527059	0.73	0.5	0.23	Not Defined	5 -Year
132	7.710699	122.525196	0.84	0.1	0.74	Not Defined	5 -Year
133	7.712032	122.526252	0.73	0.5	0.23	Not Defined	5 -Year
134	7.712035	122.526292	0.73	0.5	0.23	Not Defined	5 -Year
135	7.711972	122.526195	0.71	0.5	0.21	Not Defined	5 -Year
136	7.712866	122.526257	0.51	0.1	0.41	Not Defined	5 -Year
137	7.712884	122.526206	0.42	0.1	0.32	Not Defined	5 -Year
138	7.712531	122.526551	0.65	0.5	0.15	Not Defined	5 -Year
139	7.712569	122.526543	0.65	0.5	0.15	Not Defined	5 -Year
140	7.71163	122.526785	0.76	0.5	0.26	Not Defined	5 -Year
141	7.743311	122.536697	0.03	0.2	-0.17	Not Defined	5 -Year
142	7.711026	122.531275	0.22	0.15	0.07	Juan	5 -Year
143	7.711021	122.531253	0.22	0.2	0.02	Not Defined	5 -Year
144	7.711012	122.531375	0.18	0.5	-0.32	Not Defined	5 -Year
145	7.710931	122.531415	0.27	0.1	0.17	Not Defined	5 -Year
146	7.710891	122.531396	0.22	0.2	0.02	Not Defined	5 -Year
147	7.728582	122.509891	0.03	0	0.03	Not Defined	5 -Year
148	7.729209	122.510323	0.03	0	0.03	Not Defined	5 -Year
149	7.729049	122.511579	0.03	0	0.03	Not Defined	5 -Year
150	7.72938	122.512157	0.03	0	0.03	Not Defined	5 -Year
151	7.728931	122.511756	0.03	0	0.03	Not Defined	5 -Year
152	7.729204	122.511196	0.03	0	0.03	Not Defined	5 -Year
153	7.728521	122.509765	0.03	0	0.03	Not Defined	5 -Year
154	7.727471	122.508373	2.55	0	2.55	Not Defined	5 -Year
155	7.727428	122.507687	0.81	0	0.81	Not Defined	5 -Year
156	7.727561	122.507896	0.52	0	0.52	Not Defined	5 -Year
157	7.727889	122.509583	0.25	0	0.25	Not Defined	5 -Year
158	7.727622	122.508609	0.4	0	0.40	Not Defined	5 -Year
159	7.727627	122.508277	0.4	0	0.40	Not Defined	5 -Year
160	7.725238	122.5073	0.31	0	0.31	Not Defined	5 -Year
161	7.728451	122.508959	0.05	0	0.05	Not Defined	5 -Year
162	7.721857	122.501936	0.09	0	0.09	Not Defined	5 -Year
163	7.729538	122.506291	0.03	0	0.03	Not Defined	5 -Year
164	7.729876	122.506808	0.03	0	0.03	Not Defined	5 -Year
165	7.730392	122.507558	0.03	0	0.03	Not Defined	5 -Year
166	7.729647	122.506894	0.21	0	0.21	Not Defined	5 -Year
167	7.729495	122.506151	0.36	0	0.36	Not Defined	5 -Year

Pount No.	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Lat	Long					
168	7.730194	122.507248	0.03	0	0.03	Not Defined	5 -Year
169	7.728297	122.507605	0.06	0	0.06	Not Defined	5 -Year
170	7.728247	122.507439	0.04	0	0.04	Not Defined	5 -Year
171	7.728301	122.502322	0.03	0	0.03	Not Defined	5 -Year
172	7.728115	122.502003	0.03	0	0.03	Not Defined	5 -Year
173	7.728126	122.500367	0.03	0	0.03	Not Defined	5 -Year
174	7.728123	122.500408	0.03	0	0.03	Not Defined	5 -Year
175	7.728158	122.500408	0.03	0	0.03	Not Defined	5 -Year
176	7.728022	122.50039	0.03	0	0.03	Not Defined	5 -Year
177	7.728031	122.499667	0.03	0	0.03	Not Defined	5 -Year
178	7.727782	122.499323	0.34	0	0.34	Not Defined	5 -Year
179	7.728244	122.499264	0.03	0	0.03	Not Defined	5 -Year
180	7.728563	122.499778	0.03	0	0.03	Not Defined	5 -Year
181	7.728744	122.499146	0.04	0	0.04	Not Defined	5 -Year
182	7.727152	122.501035	0.03	0	0.03	Not Defined	5 -Year
183	7.724047	122.500048	0.03	0	0.03	Not Defined	5 -Year
184	7.724685	122.498889	0.03	0	0.03	Not Defined	5 -Year
185	7.723292	122.500536	0.03	0	0.03	Not Defined	5 -Year
186	7.728014	122.500977	0.03	0	0.03	Not Defined	5 -Year
187	7.728262	122.50098	0.03	0	0.03	Not Defined	5 -Year
188	7.729193	122.498074	0.03	0	0.03	Not Defined	5 -Year
189	7.728087	122.498674	0.04	0	0.04	Not Defined	5 -Year
190	7.728385	122.498116	0.04	0	0.04	Not Defined	5 -Year
191	7.72763	122.49758	0.03	0	0.03	Not Defined	5 -Year
192	7.727545	122.498406	0.03	0	0.03	Not Defined	5 -Year
193	7.728481	122.497602	0.1	0	0.10	Not Defined	5 -Year
194	7.728661	122.497634	0.03	0	0.03	Not Defined	5 -Year
195	7.729831	122.532441	0.07	0	0.07	Not Defined	5 -Year
196	7.73	122.532658	0.14	0	0.14	Not Defined	5 -Year
197	7.72898	122.534316	0.11	0	0.11	Not Defined	5 -Year
198	7.729859	122.532427	0.07	0	0.07	Not Defined	5 -Year
199	7.729855	122.532473	0.03	0	0.03	Not Defined	5 -Year
200	7.728978	122.531156	0.03	0	0.03	Not Defined	5 -Year
201	7.737613	122.534809	0.08	0	0.08	Not Defined	5 -Year
202	7.738185	122.532032	0.03	0	0.03	Not Defined	5 -Year
203	7.735971	122.538732	0.03	0	0.03	Not Defined	5 -Year
204	7.736847	122.533436	0.03	0	0.03	Not Defined	5 -Year
205	7.736741	122.531942	0.03	0	0.03	Not Defined	5 -Year
206	7.73453	122.530483	0.05	0	0.05	Not Defined	5 -Year
207	7.735976	122.53074	0.03	0	0.03	Not Defined	5 -Year
208	7.734785	122.530311	0.03	0	0.03	Not Defined	5 -Year
209	7.735806	122.53692	0.03	0	0.03	Not Defined	5 -Year
210	7.734126	122.529659	0.03	0	0.03	Not Defined	5 -Year

Pount No.	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Lat	Long					
211	7.733701	122.528629	0.03	0	0.03	Not Defined	5 -Year
212	7.735572	122.534208	0.03	0	0.03	Not Defined	5 -Year
213	7.734806	122.531247	0.03	0	0.03	Not Defined	5 -Year
214	7.734934	122.53129	0.03	0	0.03	Not Defined	5 -Year
215	7.734338	122.53159	0.03	0	0.03	Not Defined	5 -Year
216	7.734764	122.531376	0.03	0	0.03	Not Defined	5 -Year
217	7.740148	122.535711	0.03	0	0.03	Not Defined	5 -Year
218	7.737086	122.536655	0.03	0	0.03	Not Defined	5 -Year
219	7.737681	122.535454	0.17	0	0.17	Not Defined	5 -Year
220	7.738984	122.532175	0.03	0	0.03	Not Defined	5 -Year
221	7.737113	122.534749	0.22	0	0.22	Not Defined	5 -Year
222	7.737453	122.53329	0.03	0	0.03	Not Defined	5 -Year
223	7.729065	122.532384	0.03	0	0.03	Not Defined	5 -Year
224	7.737103	122.534294	0.3	0	0.30	Not Defined	5 -Year
225	7.734976	122.525282	0.03	0	0.03	Not Defined	5 -Year
226	7.731404	122.539015	0.03	0	0.03	Not Defined	5 -Year
227	7.73285	122.524166	0.03	0	0.03	Not Defined	5 -Year
228	7.736099	122.536802	0.03	0	0.03	Not Defined	5 -Year
229	7.733122	122.530021	0.03	0	0.03	Not Defined	5 -Year
230	7.734142	122.531738	0.17	0	0.17	Not Defined	5 -Year
231	7.737119	122.536029	0.37	0	0.37	Not Defined	5 -Year
232	7.738038	122.529144	0.03	0	0.03	Not Defined	5 -Year
233	7.734806	122.498932	0.04	0	0.04	Not Defined	5 -Year
234	7.733448	122.500648	0.04	0	0.04	Not Defined	5 -Year
235	7.73634	122.501678	0.03	0	0.03	Not Defined	5 -Year
236	7.73668	122.502708	0.03	0	0.03	Not Defined	5 -Year
237	7.738551	122.502708	0.03	0	0.03	Not Defined	5 -Year
238	7.73719	122.498931	0.03	0	0.03	Not Defined	5 -Year
239	7.739571	122.501163	0.04	0	0.04	Not Defined	5 -Year
240	7.726556	122.503223	0.03	0	0.03	Not Defined	5 -Year
241	7.726897	122.504168	0.03	0	0.03	Not Defined	5 -Year
242	7.727322	122.502623	0.4	0	0.40	Not Defined	5 -Year
243	7.72796	122.502666	0.32	0	0.32	Not Defined	5 -Year
244	7.711805	122.52669	0.72	0.25	0.47	Not Defined	5 -Year
245	7.711848	122.526883	0.79	0.5	0.29	Not Defined	5 -Year
246	7.71155	122.533408	0.03	0.5	-0.47	Not Defined	5 -Year
247	7.711664	122.533409	0.03	0.25	-0.22	Not Defined	5 -Year
248	7.711674	122.533327	0.03	0.5	-0.47	Not Defined	5 -Year
249	7.711727	122.533319	0.11	0.5	-0.39	Not Defined	5 -Year
250	7.711586	122.533437	0.03	0.5	-0.47	Not Defined	5 -Year
251	7.711666	122.533324	0.03	0.5	-0.47	Not Defined	5 -Year
252	7.711753	122.533348	0.11	0.5	-0.39	Not Defined	5 -Year
253	7.711648	122.533324	0.03	0.25	-0.22	Not Defined	5 -Year

Pount No.	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Lat	Long					
254	7.711042	122.532855	0.21	0.5	-0.29	Not Defined	5 -Year
255	7.711038	122.533029	0.03	0.5	-0.47	Not Defined	5 -Year
256	7.711113	122.532934	0.03	0.5	-0.47	Not Defined	5 -Year
				RMSE	0.29		

Annex 12. Educational Institutions Affected in Buluan Floodplain

Table A-12.1 Educational Institutions in Ipil, Zamboanga Sibugay affected by flooding in Buluan Floodplain

ZAMBOANGA SIBUGAY				
IPIL				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Bulu-an	Buluan Elementary School	None	None	None
Bulu-an	Aimhigh Colleges	None	None	None
Bulu-an	Buluan Daycare Center	Low	Medium	Medium

Annex 13. Health Institutions Affected in Buluan Floodplain

Table A-13.1 Health Institutions in Ipil, Zamboanga Sibugay affected by flooding in Buluan Floodplain

ZAMBOANGA SIBUGAY				
IPIL				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Bulu-an	Bulu-an Brgy. Health Center	Low	Medium	Medium