LiDAR Surveys and Flood Mapping of Linugos River

Published by the UP Training Center for Applied Geodesy and Photogrammetry (TCAGP)
College of Engineering
University of the Philippines – Diliman
Quezon City
1101 PHILIPPINES

This research project is supported by the Department of Science and Technology (DOST) as part of its Grants-in-Aid Program and is to be cited as:

E.C. Paringit, and G.R. Puno, (Eds.). (2017), LiDAR Surveys and Flood Mapping Report of Linugos River, Quezon City: University of the Philippines Training Center for Applied Geodesy and Photogrammetry-146pp

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National Library if the Philippines
ISBN: 978-621-430-013-6

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LIST OF ACRONYMS AND ABBREVIATIONS

AAC	Asian Aerospace Corporation
Ab	abutment
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
AWLS	Automated Water Level Sensor
BA	Bridge Approach
BM	benchmark
CAD	Computer-Aided Design
CMU	Central Mindanao University
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 LINUGOS RIVER

Enrico C. Paringit, Dr. Eng., Dr. George Puno, and Eric Bruno

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 methods described in this report are thoroughly described in a separate publication entitled "Flood Mapping of Rivers in the Philippines Using Airborne LiDAR: Methods (Paringit, et. al., 2017) available separately.

The implementing partner university for the Phil-LiDAR 1 Program is the Isabela State University (ISU). ISU 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 13 river basins in the Central Mindanao Region. The university is located in the Municipality of Maramag in the province of Bukidnon.

1.2 Overview of the Linugos River Basin

Linugos river basin is located within the political boundaries of Municipality of Magsaysay in Misamis Oriental and the Municipality of Carmen in Agusan Del Norte. It has a total area of 19,640 hectares. The river traverses Municipality of Buenavista and Carmen in Agusan Del Norte, and Municipality of Magsaysay in Misamis Oriental, and drains to Gingoog Bay. The river is approximately 152 kilometers northeast of Cagayan De Oro and 44 kilometers west of Butuan City.

Much of the interaction within the basin is mobilized by the people within the Municipality of Magsaysay which depends on subsistence of upland farming. Coconut serves as the primary product of the 54% agricultural land use in the Municipality, along with some banana, corn and rice which are mostly intercropped to coconut. Moreover, the mid-stream of Linugos is tapped for irrigation system, which supplies water for rice fields down the valley.

The increasing population and changing climate is of great concern since much of the flood prone areas are residential built-ups. This is especially evident on the recurring flood events in the area in the last couple of years. List of flood occurrences in the river can be traced back as early as 1970, 1989, and on 2009, 2011, 2012 (Typhoon Pablo), 2013, 2014 (Typhoon Seniang). Of the six (6) noted flood prone barangays of Magsaysay, Tibon-tibon has recounted one casualty which damaged a household property during a flood event.

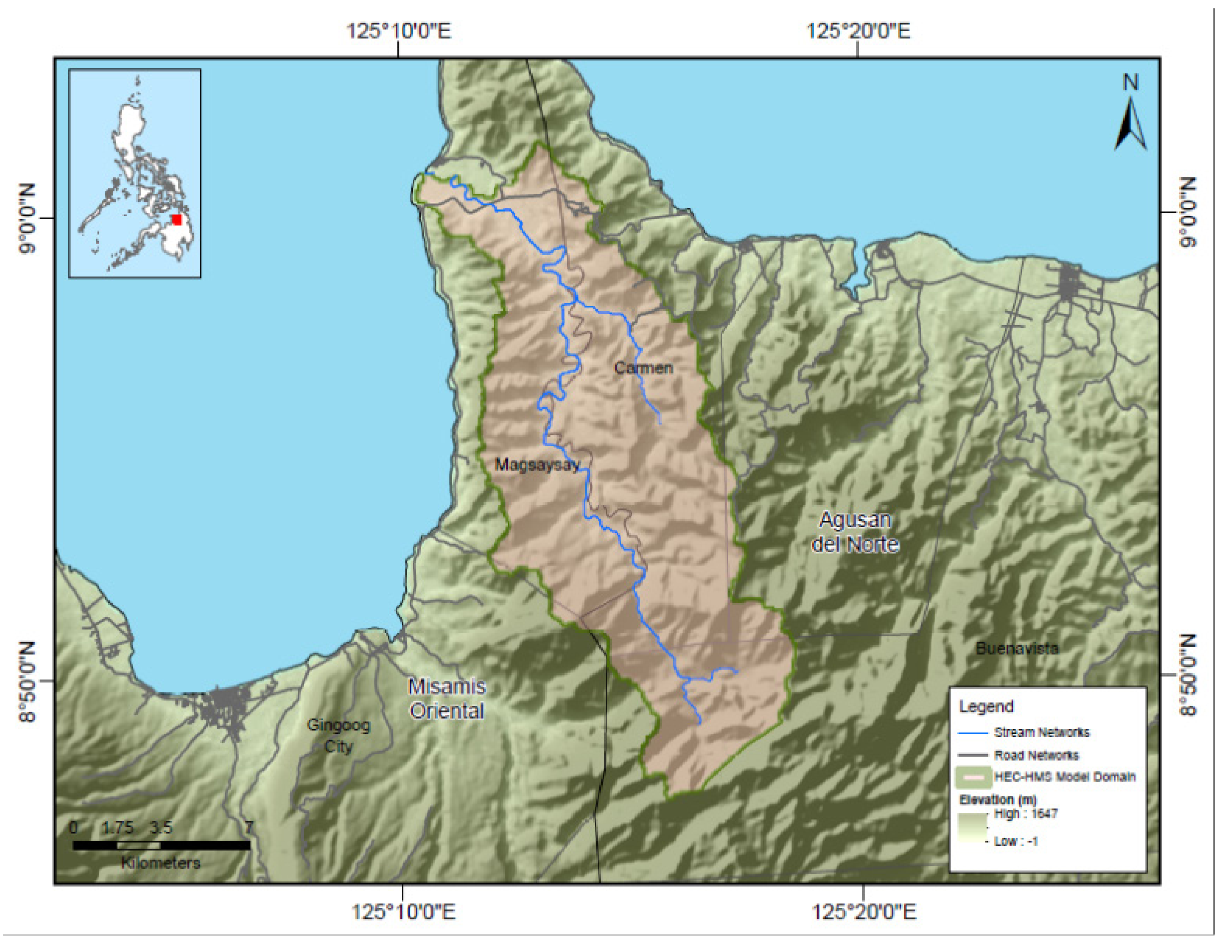


Figure 1. Map of the Linugos River Basin (in brown)

Phil-LiDAR 1 Program co-implemented by Central Mindanao University (CMU) included Linugos river for the generation of up-to-date, detailed, and high-resolution three-dimensional (3D) flood hazard maps using Light Detection and Ranging (LiDAR) technology. Flood hazard maps generated through flood modeling involves two simulations, the hydrologic and hydraulic. These are performed using standalone softwares of Hydrologic Modeling System (HMS) and River Analysis System (RAS) developed by the Hydrologic Engineering Center of the US Army Corps of Engineers. HEC-HMS models the upstream and simulates the complete hydrologic processes of dendritic watershed systems while HEC-RAS models the flood plain to perform one-dimensional (1D) unsteady flow river hydraulics calculations.

Basin model was created using Synthetic Aperture Radar (SAR) 10m Digital Elevation Model (DEM) and digitized river centerline. Basin model consists of 35 sub basins, 18 reaches, and 16 junctions. It was calibrated using an actual data collected during the Tropical Depression Onyok on December 19, 2015. Using statistical tests, model efficiency was evaluated which subsequently revealed a satisfactory model performance. Using the calibrated model, hypothetical discharge scenarios were simulated using Rainfall Intensity Duration Frequency (RIDF) data of Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) based on a 21-year historical data of Butuan rain gauge. Flood hydraulic simulation was performed using LiDAR Digital Terrain Model (DTM) consequently showing flood extent and depth information. Flood hazard maps were generated projecting the flood scenarios for the 5-, 25-, and 100-year return periods.

CHAPTER 2: LIDAR DATA ACQUISITION OF THE LINUGOS FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Acuna, Engr. Gerome Hipolito, Engr. Renan D. Punto, and Ms. Pauline Joanne G. Arceo

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

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Linugos floodplain in Misamis Oriental. These missions were planned for 16 lines and ran 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 2 shows the flight plan for Linugos floodplain. Annex 1 shows the technical specifications of the Aquarius LiDAR system.

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)
BLK63A	600	30	36	50	50	120	5
BLK63B	600	30	40	50	50	120	5
BLK63C	600	30	40	50	50	120	5
BLK63D	600	30	36	50	50	120	5

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

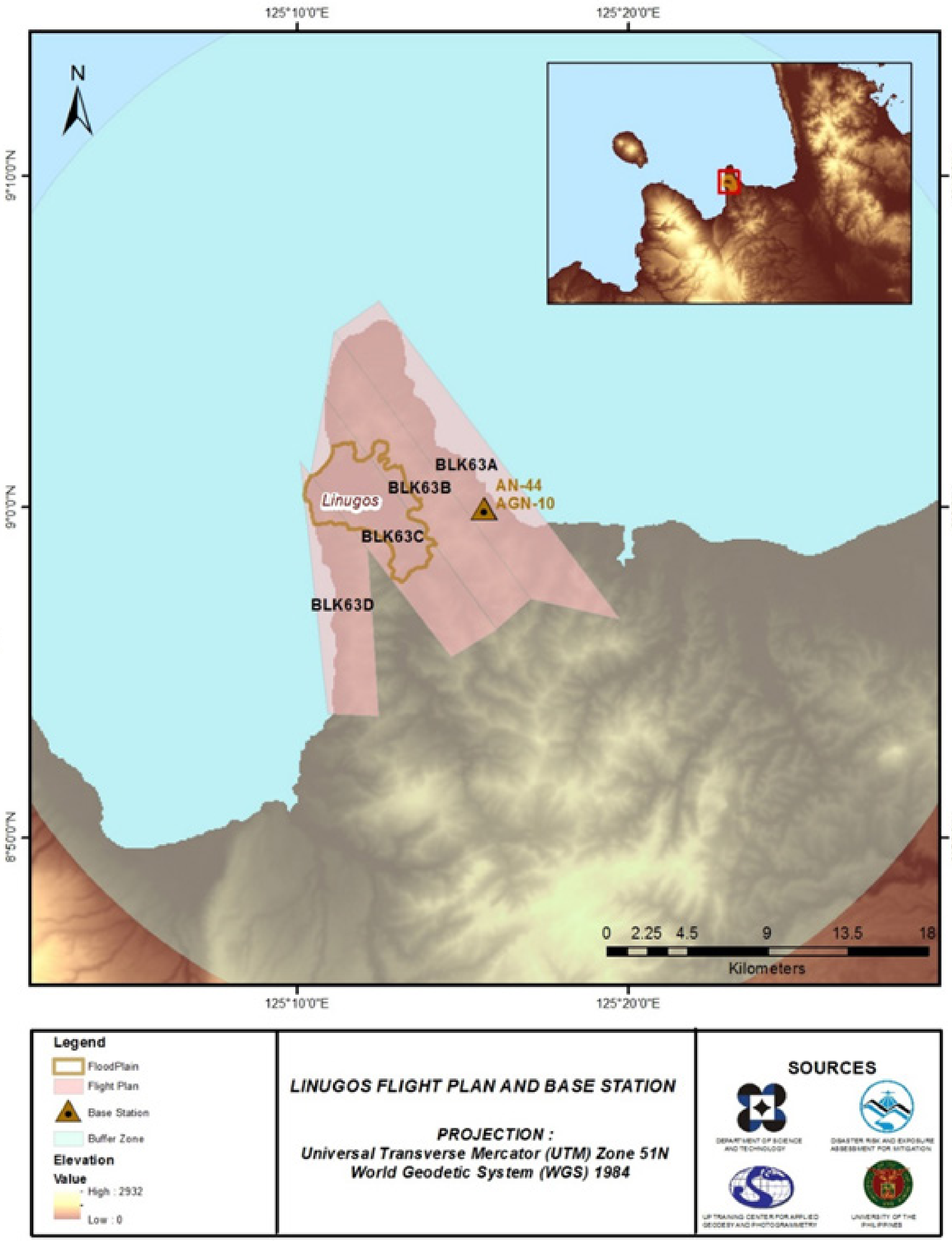


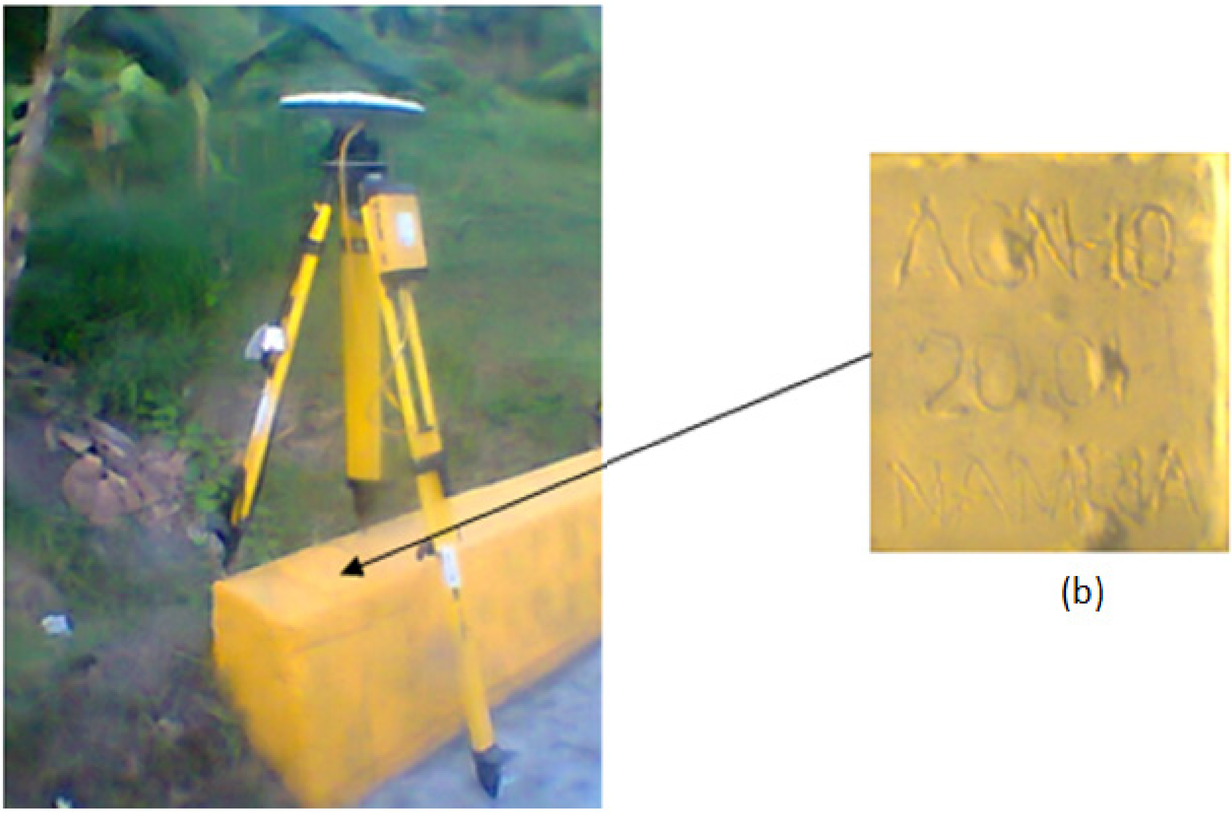
Figure 2. Flight Plan and base stations used for the Linugos Floodplain survey.

2.2 Ground Base Stations

The project team was able to recover one (1) NAMRIA ground control point: AGN-10, which is of third (3rd) order accuracy and one (1) NAMRIA benchmark: AN-44 which is of first (1st) order accuracy. The project team re-established AGN-10 as 1st order GCP. The benchmark was used as vertical reference point and was also established as ground control point.

The certification for the NAMRIA reference point and benchmark are found in Annex 2 while the baseline processing reports for the established control points are found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey (June 23 – July 1 and October 21, 2014). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and SPS 985. Flight plans and location of base stations used during the aerial LiDAR acquisition in Linugos floodplain are shown in Figure 3.The list of team members are found in Annex 4.

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



(a) (b)

Figure 3. GPS set-up over AGN-10 on top of the concrete gutter of a culvert in Brgy. Tagcatong, Municipality of Carmen, Agusan del Norte (a) and NAMRIA reference point AGN-10 (b) as recovered by the field team.

Table 2. Details of the recovered NAMRIA control point AGN-10 used as base station for the LiDAR acquisition with established coordinates.

Station Name	**AGN-10**	
Order of Accuracy	**1st**	
Relative Error (Horizontal positioning)	**1 in 100,000**	
Geographic Coordinates, Philippine Reference 0f 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9°00'00.89229" North 125°15'35.40896" East 9.936 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8°59'57.22658" North 125°15'40.76119" East 77.961 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing Elevation (based on EGM08 Geoid)	748452.013 meters 995583.712 meters 11.097 meters

(b)

(a)

Figure 4. GPS set-up over CGY-87 located on a solar dryer at Brgy. Cabayabasan, fronting the barangay hall, in municipality of Lal-lo.

Table 3. Details of the recovered NAMRIA horizontal reference point CGY-87 used as base station for the LiDAR acquisition.

Station Name	**AN-44**	
Order of Accuracy	**1ST**	
Relative Error (Horizontal positioning)	**1 in 100,000**	
Geographic Coordinates, Philippine Reference 0f 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9°00’00.88602” North 125°15’35.34429” East 10.014 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8°59’57.22031” North 125°15’40.69652” East 78.039 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing Elevation (based on EGM08 Geoid)	610204.602 meters 884431.706 meters 11.176 meters
Elevation (mean sea level)	10.9546 meters	

Table 4. Ground control points that were used during the LiDAR data acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
June 23,2014	1614A	3BLK63A174A	AGN-10 & AN-44
May 29,2014	1638A	3BLK63DS180A	AGN-10 & AN-44
July 1, 2014	1648A	3BLK63DS182A	AGN-10 & AN-44
October 21, 2014	2094A	3BLK63R294A	AGN-10 & AN-44
October 21, 2014	2096A	3BLK63R294B	AGN-10 & AN-44

2.3 Flight Missions

Five (5) missions were conducted to complete the LiDAR data acquisition in Linugos Floodplain, for a total of seventeen hours and thirty seven minutes (17+37) of flying time for RP-C9122. All missions were acquired using the Aquarius LiDAR system. Table 5 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 6 presents the actual parameters used during the LiDAR data acquisition.

Table 5. Flight missions for the LiDAR data acquisition of the Linugos Floodplain.

Date Surveyed	Flight Number	Flight Plan Area (km2)	Surveyed Area (km2)	Area Surveyed within the Floodplain (km2)	Area Surveyed Outside the Floodplain (km2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
June 23,2014	1614A	64.3	59.01	0	59.01	1128	4	23
May 29,2014	1638A	43.37	39.51	6.02	33.49	834	2	35
July 1, 2014	1648A	16.87	20.26	1.8	18.46	207	2	29
October 21, 2014	2094A	56.28	66.12	24.70	41.42	NA	4	23
October 21, 2014	2096A	98.87	116.8	24.78	92.02	NA	3	47
TOTAL		**279.69**	**301.7**	**57.3**	**244.4**	**1962**	**17**	**37**

Table 6. Actual parameters used during the LiDAR data acquisition of the Linugos Floodplain.

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (khz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
1614A	500	60	40	50	50	130	5
1638A	500	60	40	50	50	130	5
1648A	600	60	36	50	45	130	5
2094A	600	60	36	50	45	130	5
2096A	600	60	36	50	45	130	5

2.4 Survey Coverage

Linugos floodplain is located in the province of Misamis Oriental with majority of the floodplain situated within the municipality of Magsaysay. 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 Linugos floodplain is presented in Figure 6.

Table 7. List of municipalities and cities surveyed of the Linugos Floodplain LiDAR acquisition.

Province	Municipality/ City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Misamis Oriental	Magsaysay	118.05	81.60	69%
	Gingoog City	538.03	2.09	0.4%
Agusan del Norte	Carmen	122.64	65.86	54%
	Nasipit	147.45	11.48	8%
TOTAL		**926.17**	**161.03**	**33%**

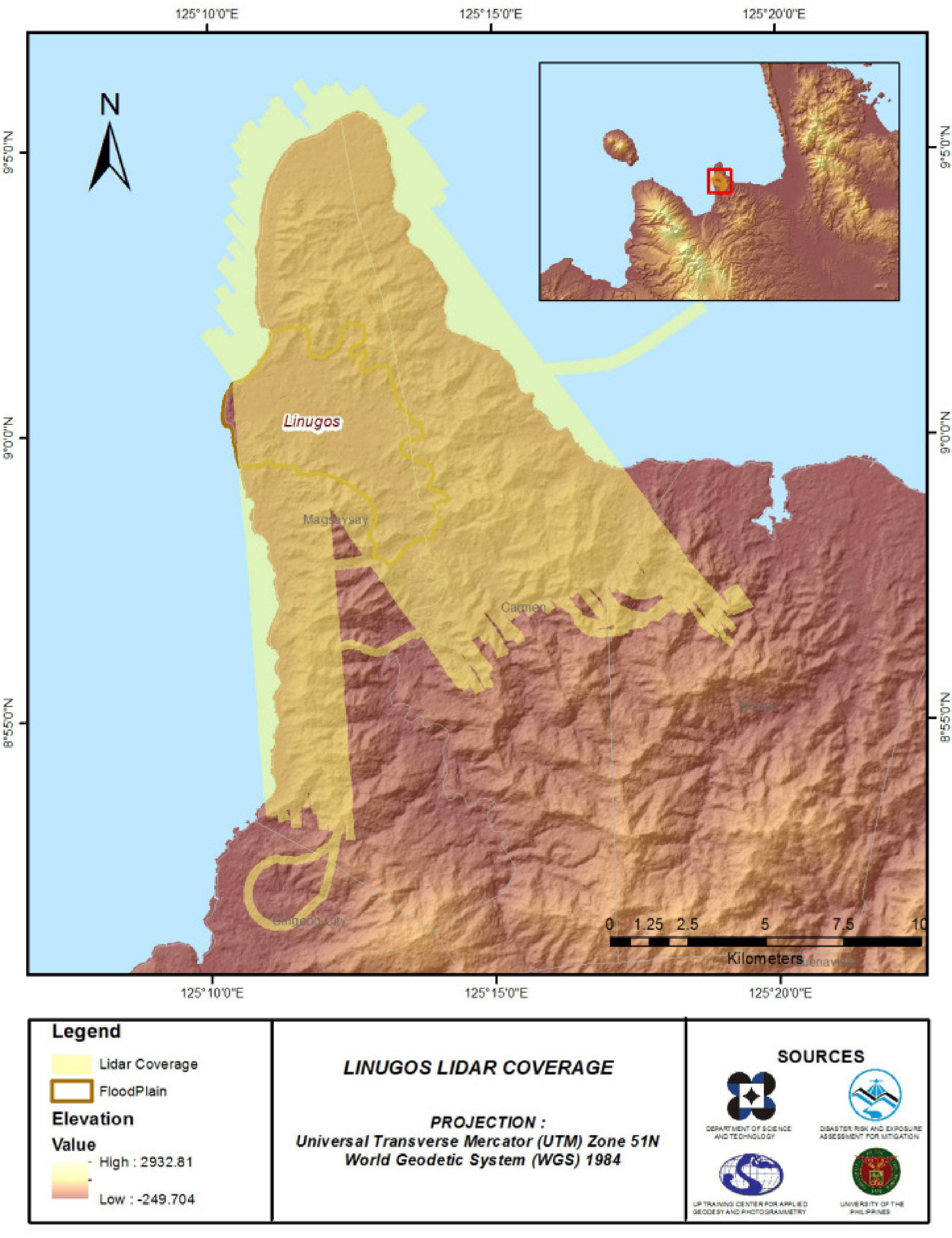


Figure 5. Actual LiDAR survey coverage of the Linugos Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE LINUGOS FLOODPLAIN

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

3.1 Overview of the LiDAR Data Pre-Processing

The data transmitted by the Data Acquisition Component are checked for completeness based on the list of raw files required to proceed with the pre-processing of the LiDAR data. Upon acceptance of the LiDAR field data, georeferencing of the flight trajectory is done in order to obtain the exact location of the LiDAR sensor when the laser was shot. Point cloud georectification is performed to incorporate correct position and orientation for each point acquired. The georectified LiDAR point clouds are subject for quality checking to ensure that the required accuracies of the program, which are the minimum point density, vertical and horizontal accuracies, are met. The point clouds are then classified into various classes before generating Digital Elevation Models such as Digital Terrain Model and Digital Surface Model.

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

These processes are summarized in the flowchart shown in Figure 6.

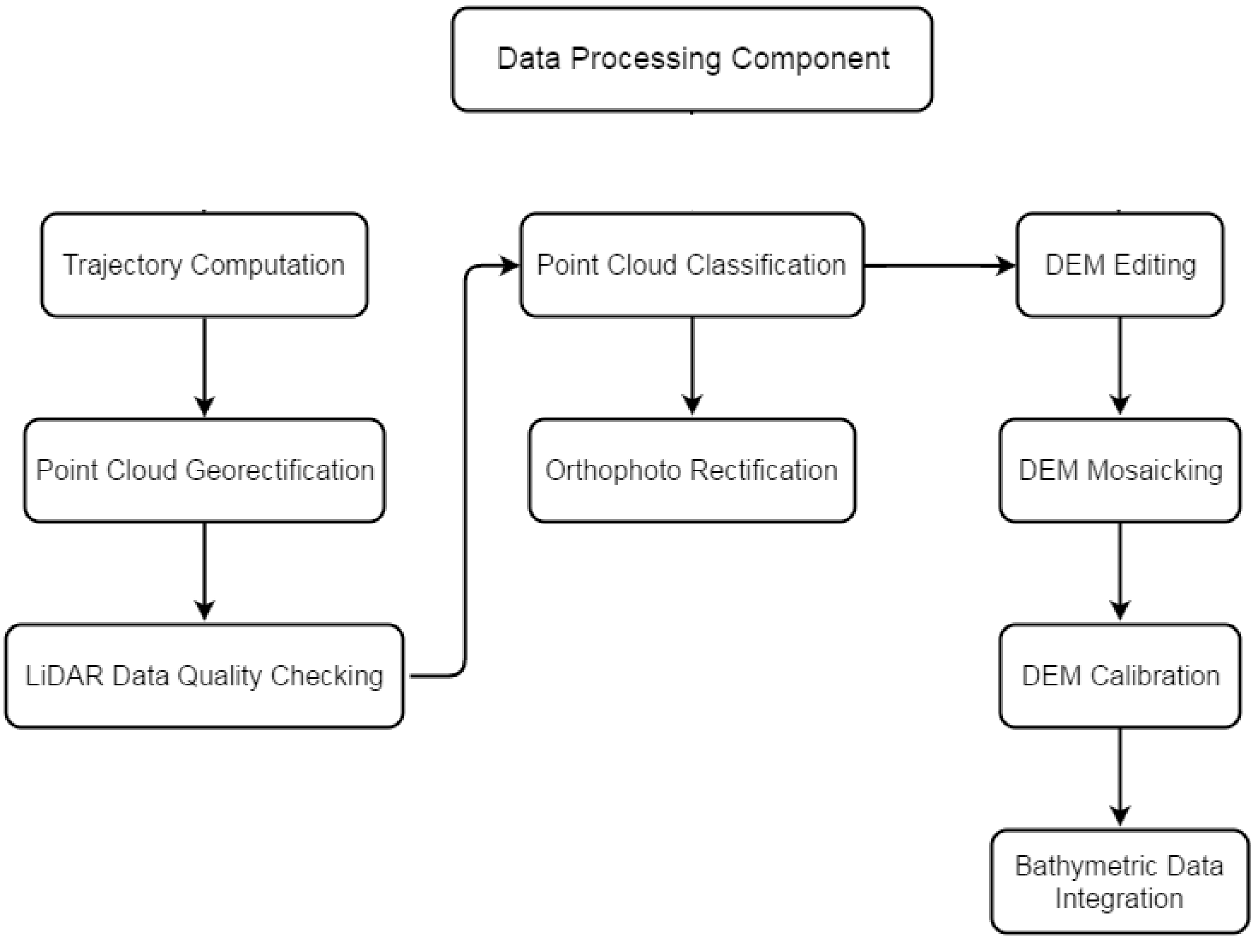


Figure 6. Schematic diagram for Data Pre-Processing Component.

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Linugos floodplain can be found in Annex A-5. Data Transfer Sheets. Missions flown during the first survey conducted on June 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Aquarius system over Municipality of Magsaysay, Misamis Oriental.

The Data Acquisition Component (DAC) transferred a total of 38.28 Gigabytes of Range data, 846 Megabytes of POS data, 147.34 Megabytes of GPS base station data, and 136.60 Gigabytes of raw image data to the data server on October 30, 2014. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Linugos was fully transferred on October 31, 2014 as indicated on the Data Transfer Sheets for Linugos floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 1638A, one of the Linugos flights, which is the North, East, and Down position RMSE values are shown in Figure 7. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on June 29, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

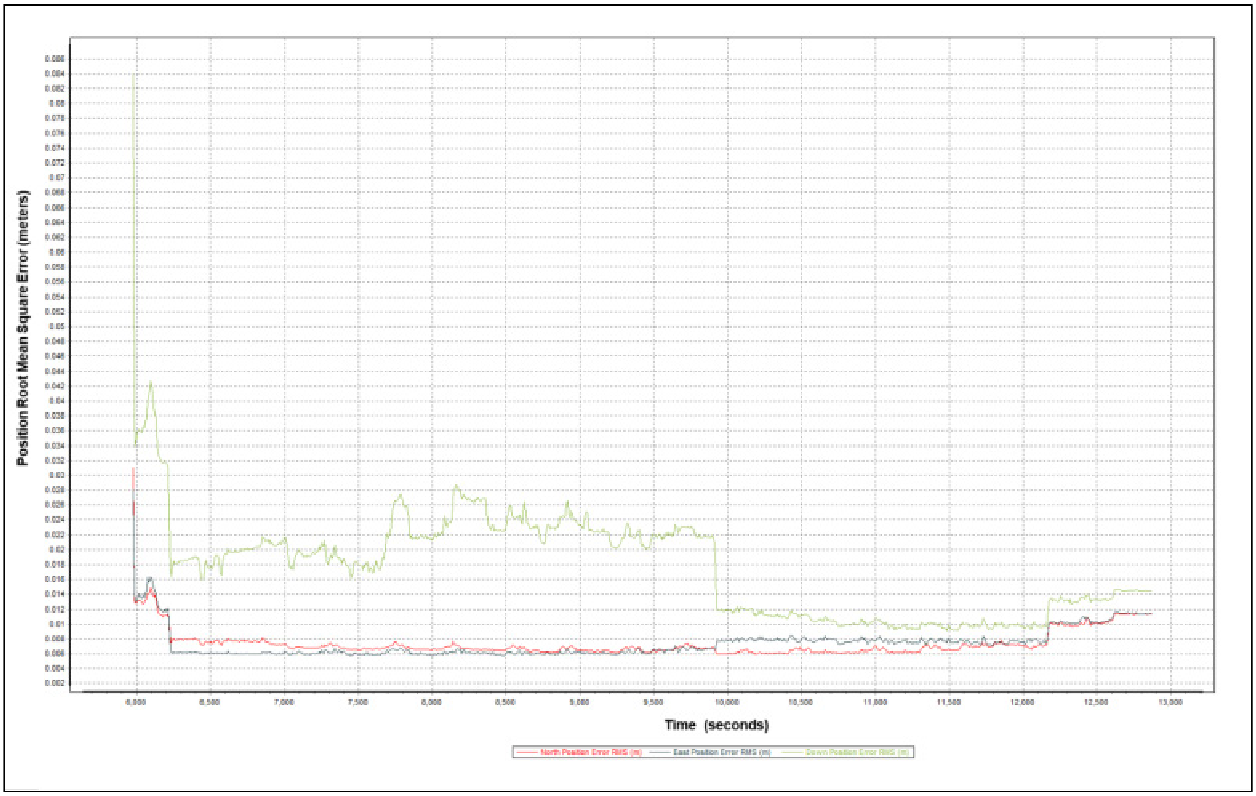


Figure 7. Smoothed Performance Metrics of Linugos Flight 1638A.

The time of flight was from 6,000 seconds to 13,000 seconds, which corresponds to morning of June 29, 2014. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft.

Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 8 shows that the North position RMSE peaks at 1.40 centimeters, the East position RMSE peaks at 1.50 centimeters, and the Down position RMSE peaks at 2.84 centimeters, which are within the prescribed accuracies described in the methodology.

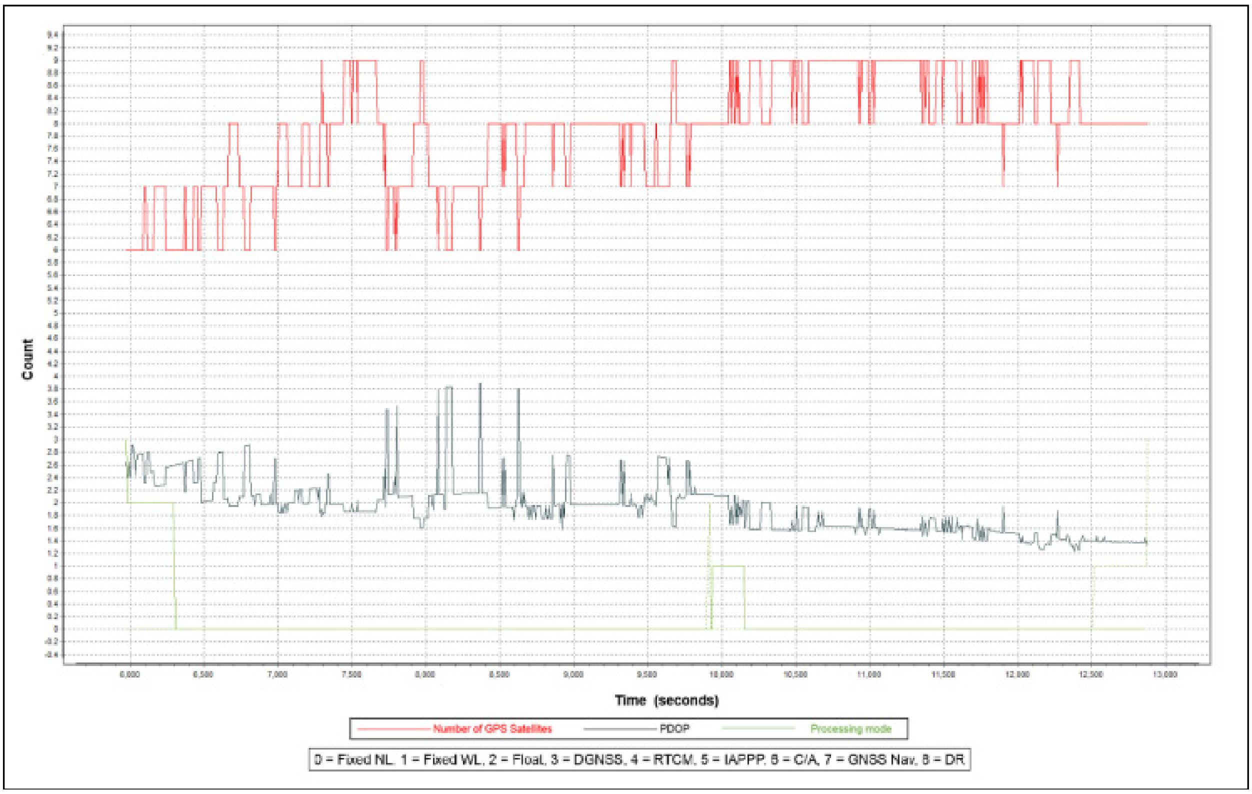


Figure 8. Solution Status Parameters of Linugos Flight 1638A.

The Solution Status parameters of flight 1638A, one of the Linugos flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 8. The graphs indicate that the number of satellites during the acquisition did not go down below 6. Majority of the time, the number of satellites tracked was between 6 and 9. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 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 Linugos flights is shown in Figure 9.

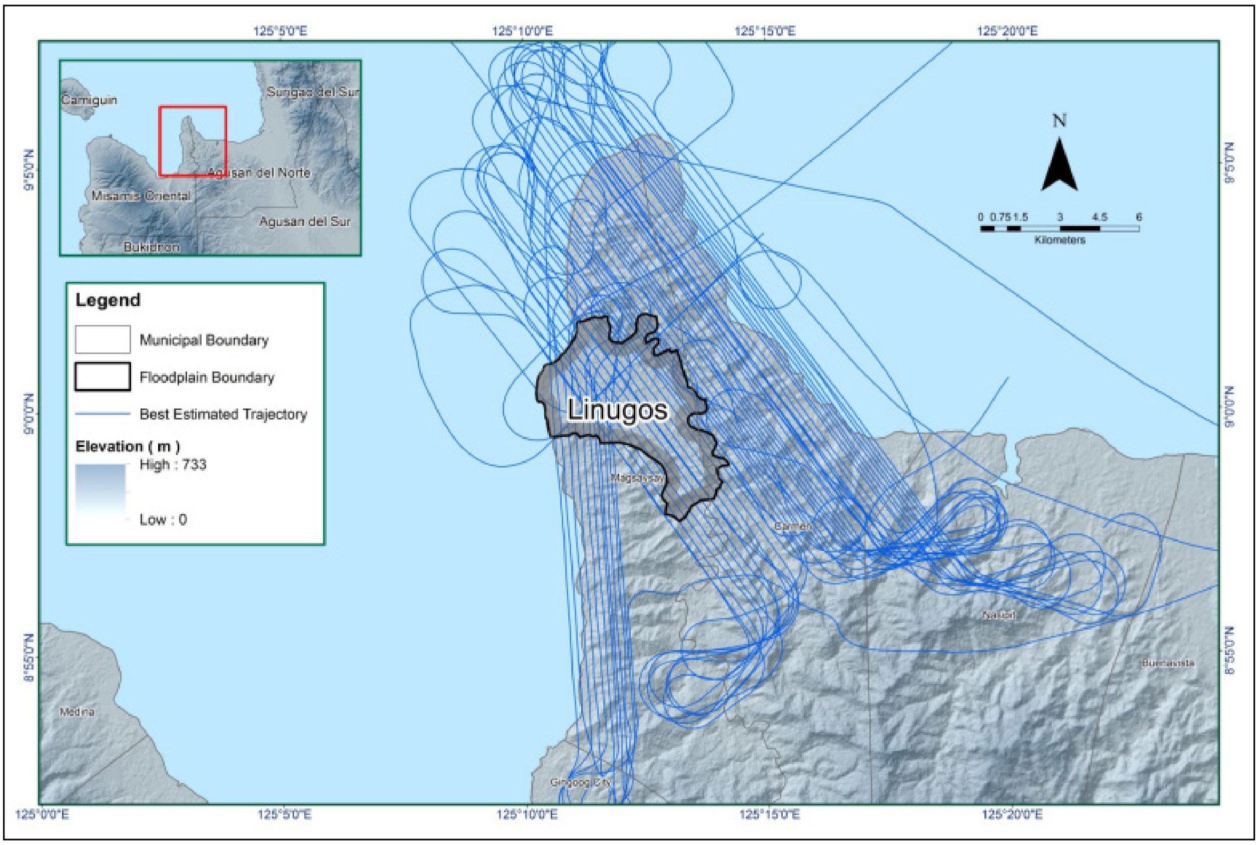


Figure 9. Best Estimated Trajectory of the LiDAR missions conducted over the Linugos Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 77 flight lines, with each flight line containing one channel, since the Aquarius system contains only one channel. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Linugos floodplain are given in Table 8.

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

Parameter	Acceptable Value	Computed Value
Boresight Correction stdev	<0.001degrees	0.000206
IMU Attitude Correction Roll and Pitch Correction stdev	<0.001degrees	0.000762
GPS Position Z-correction stdev	<0.01meters	0.0029

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

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Linugos Floodplain is shown in Figure 10. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

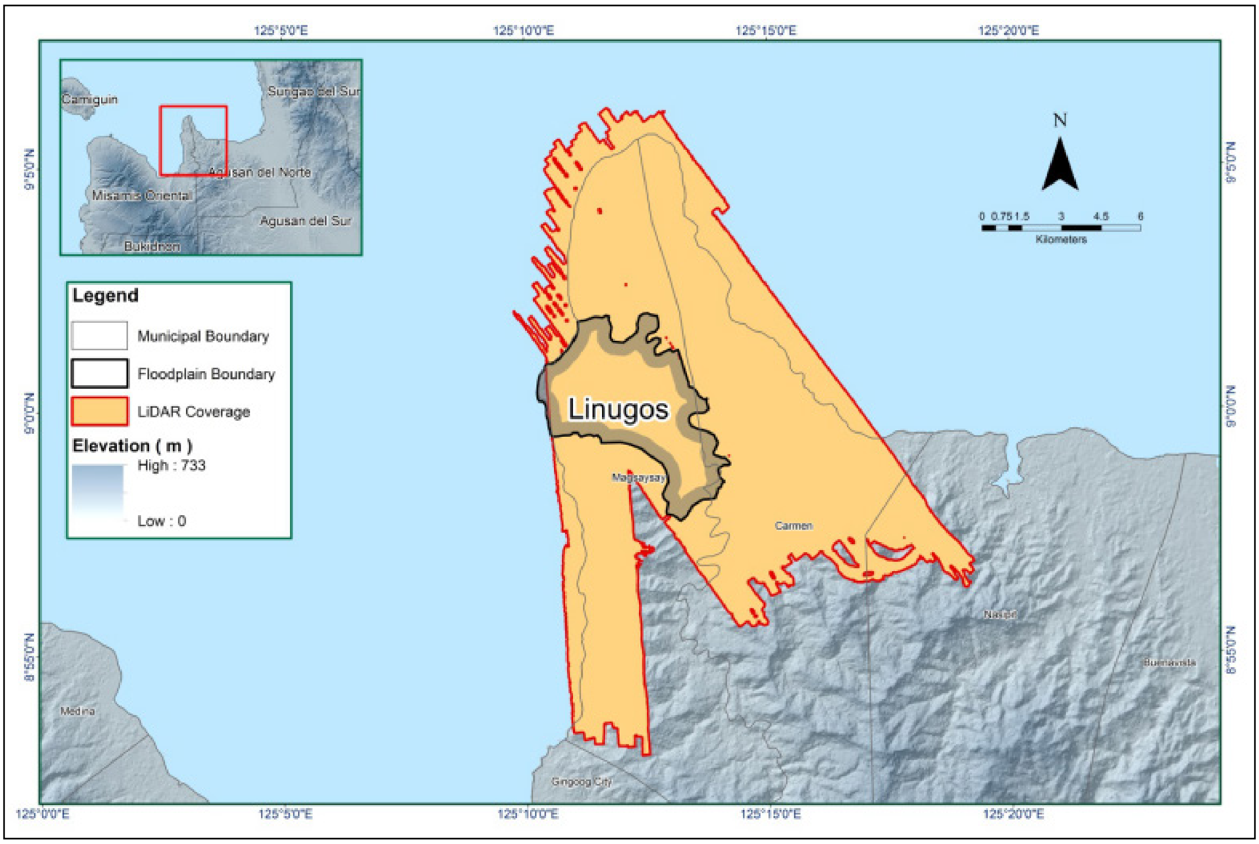


Figure 10. Boundary of the processed LiDAR data over Linugos Floodplain

The total area covered by the Linugos missions is 224.96 sq.km that is comprised of five (5) flight acquisitions grouped and merged into four (4) blocks as shown in Table 9.

Table 9. List of LiDAR blocks for Linugos Floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Cagayan_reflights_Tugegarao_Blk2A	2848P	131.64
	2852P	
Cagayan_reflights_Tugegarao_ Blk2A_supplement	2846P	199.64
Cagayan_reflights_Tugegarao_Blk2B	2842P	130.71
Cagayan_reflights_Tugegarao_ Blk2B_supplement	2846P	19.29
Cagayan_reflights_Tugegarao_ Blk2D	2854P	72.26
Cagayan_reflights_Tuguegarao_Blk2D_supplement_Blk2E	2850P	193.17
Cagayan_reflights_Tugegarao_Blk2A_additional	2848P	54.49
Cagayan_reflights_Blk1D	23696P	29.08
TOTAL		830.28 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 11. Since the Pegasus system employs two channels, we would expect an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines.

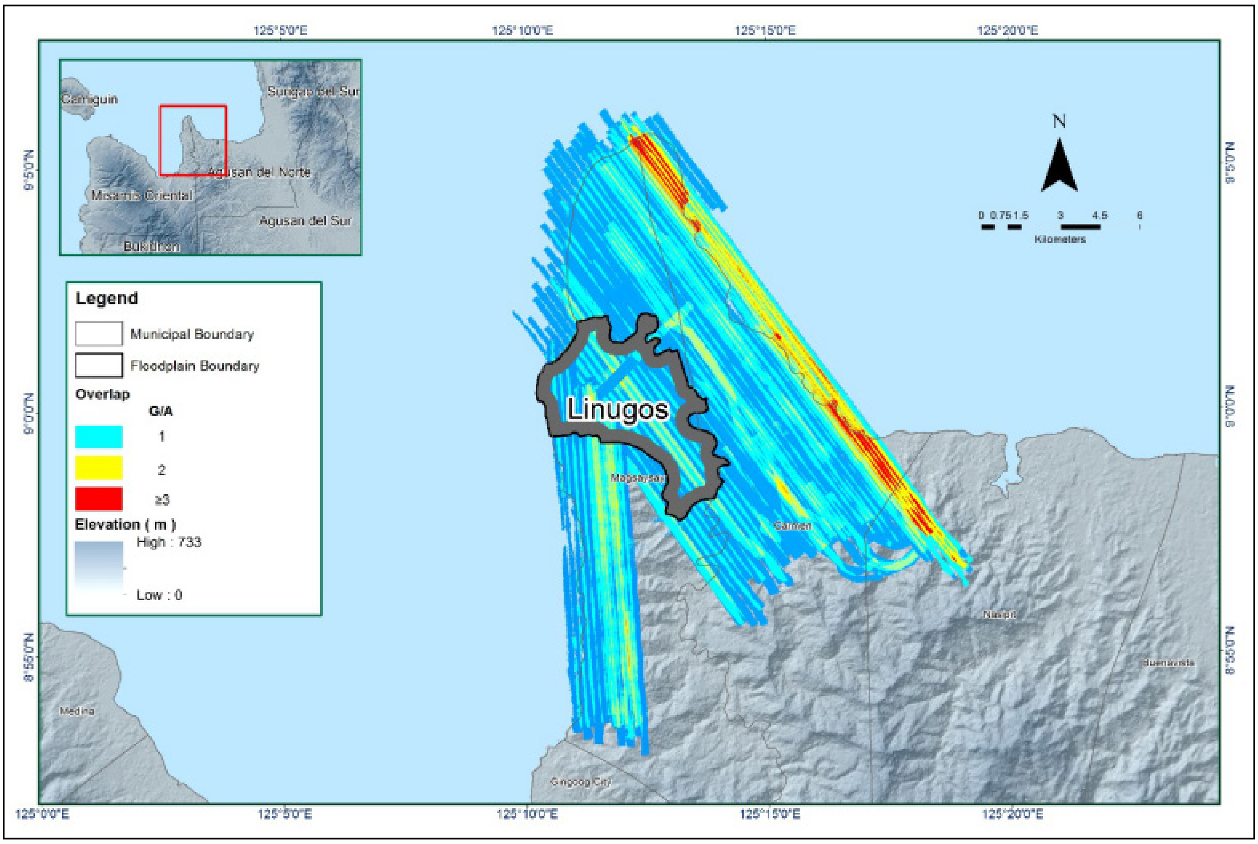


Figure 11. Image of data overlap for Linugos Floodplain.

The overlap statistics per block for the Linugos floodplain can be found in Annex 8. It should be noted that one pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 37.01% and 72.90% respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 13. It was determined that all LiDAR data for Linugos floodplain satisfy the point density requirement, and the average density for the entire survey area is 4.335 points per square meter.

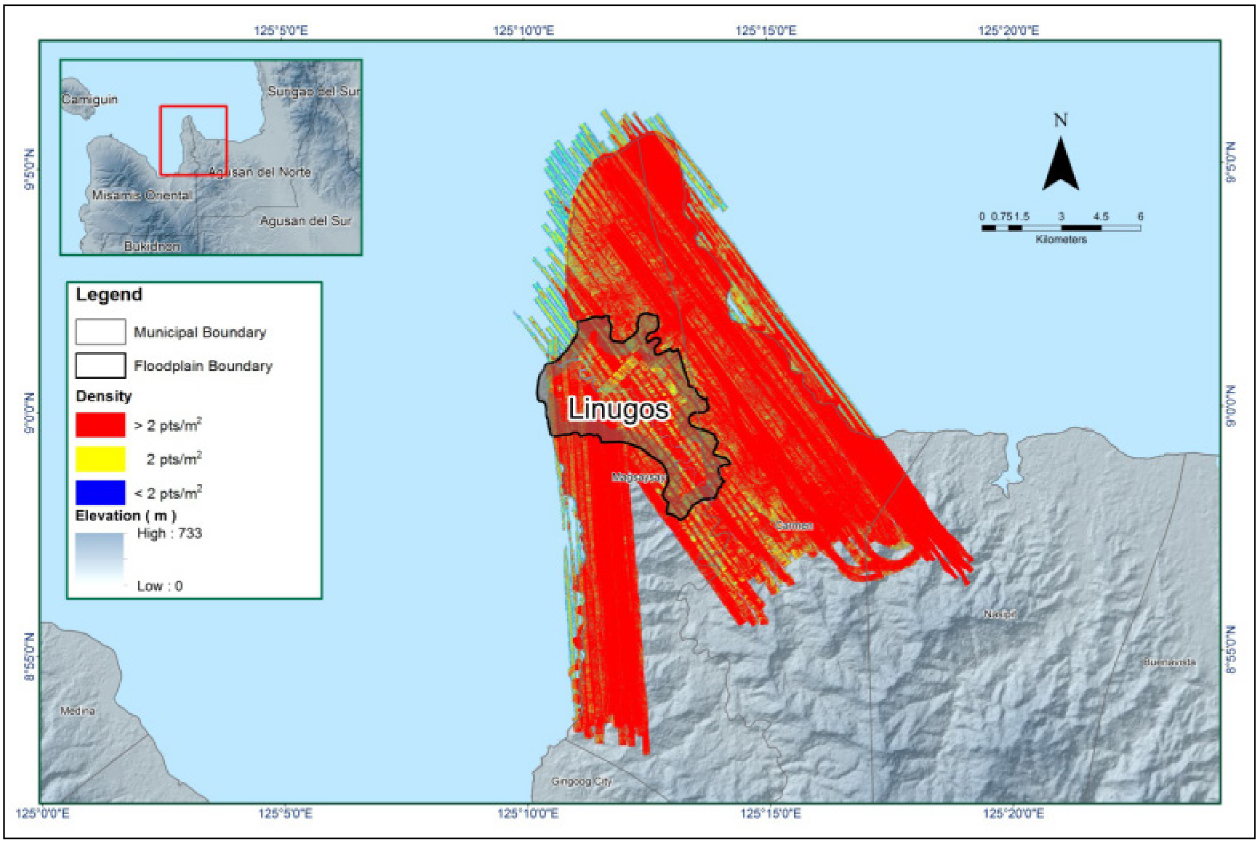


Figure 12. Pulse density map of merged LiDAR data for Linugos Floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 13. 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.

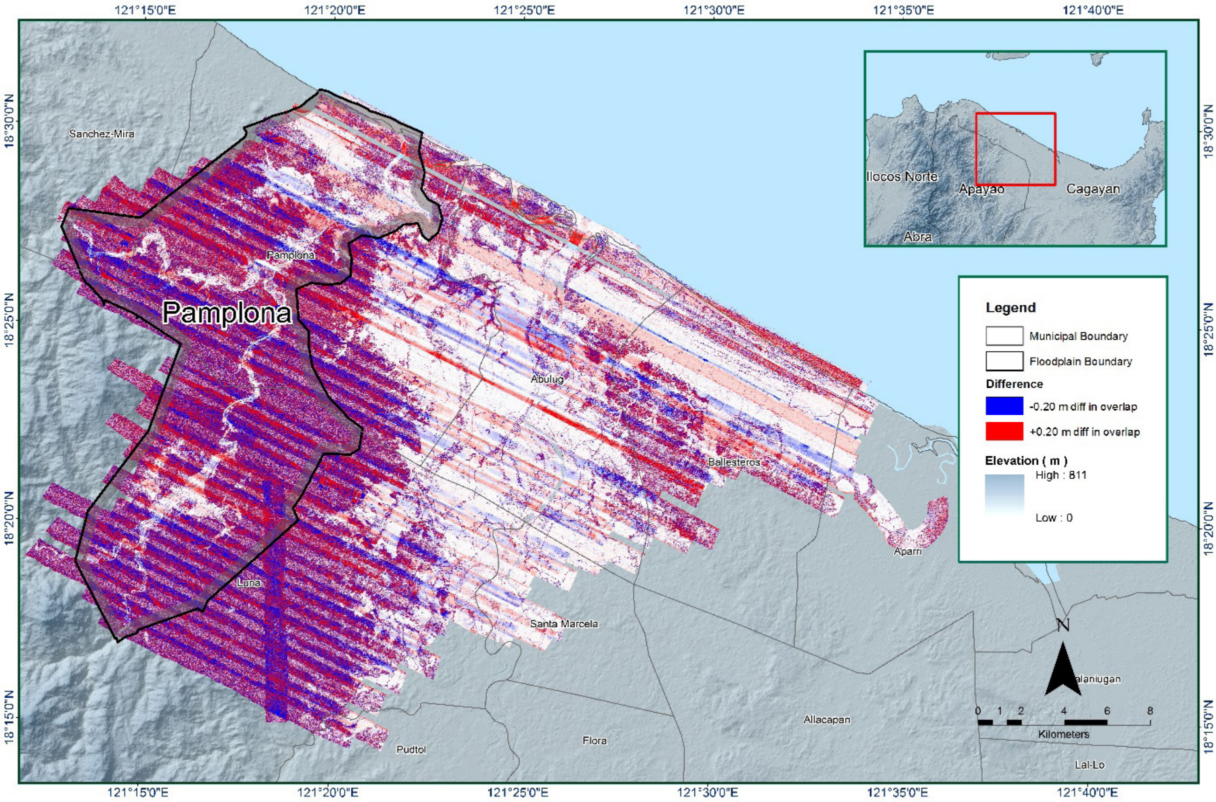


Figure 13. Elevation Difference Map between flight lines for Linugos Floodplain Survey.

A screen capture of the processed LAS data from a Linugos flight 1638A loaded in QT Modeler is shown in Figure 14. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed yellow line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

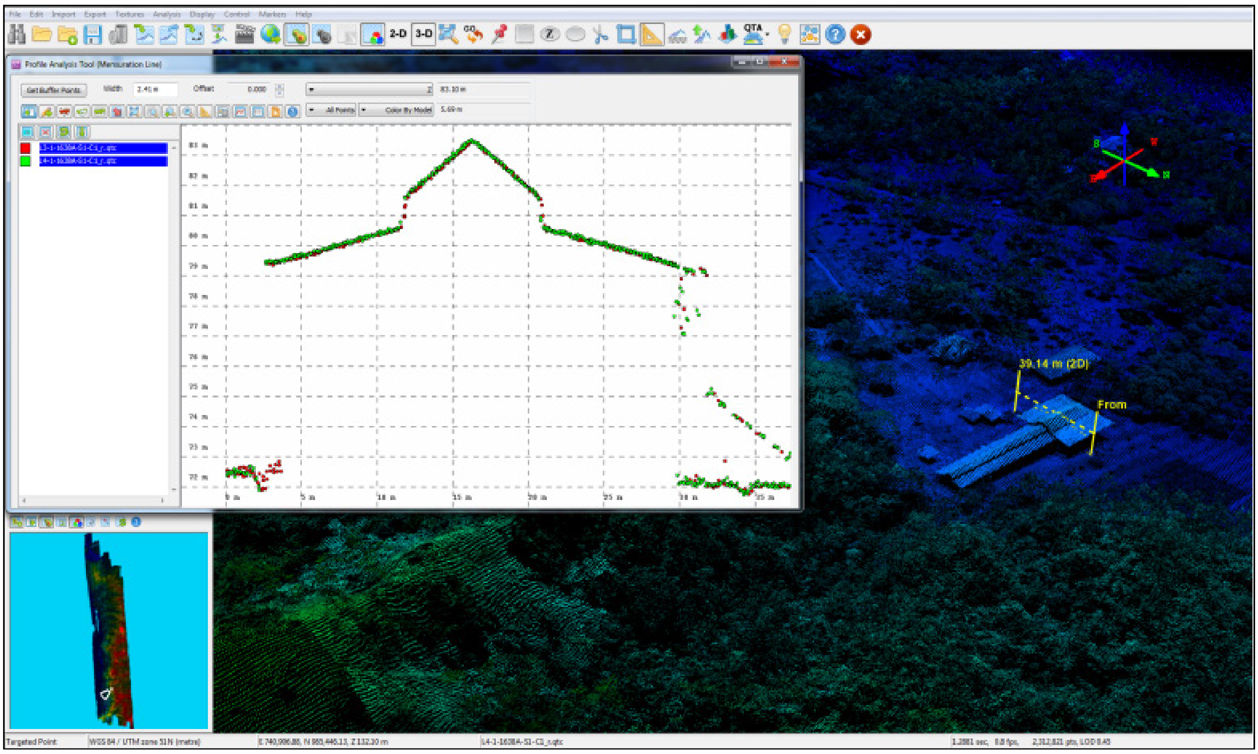


Figure 14. Quality checking for Linugos flight 2842P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 10. Linugos classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	140,779,906
Low Vegetation	138,951,147
Medium Vegetation	228,510,019
High Vegetation	255,408,486
Building	9,913,924

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Linugos floodplain is shown in Figure 15. A total of 368 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 497.23 meters and 46.35 meters respectively.

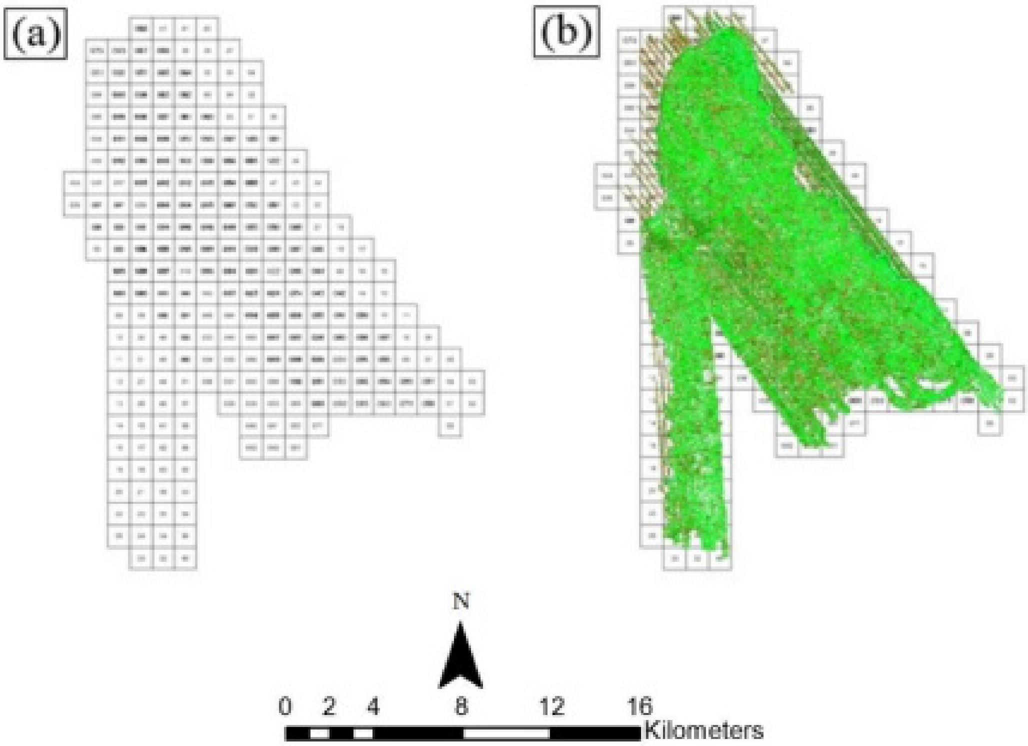


Figure 15. Tiles for Pamplona Floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 16. 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.

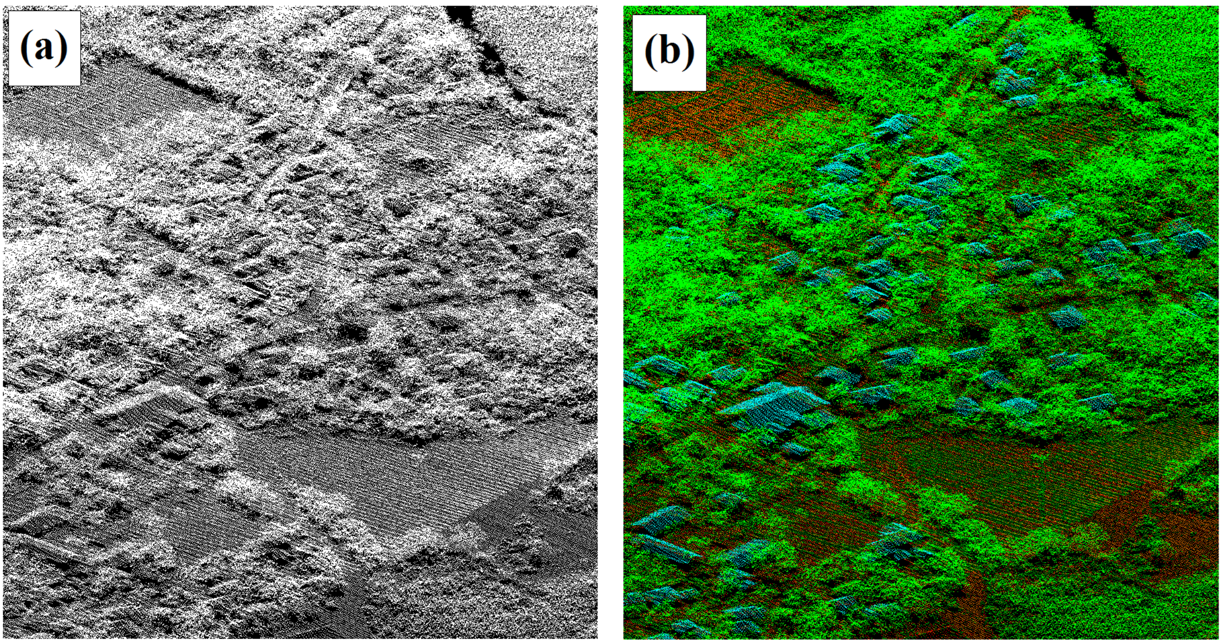


Figure 16. Point cloud before (a) and after (b) classification

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

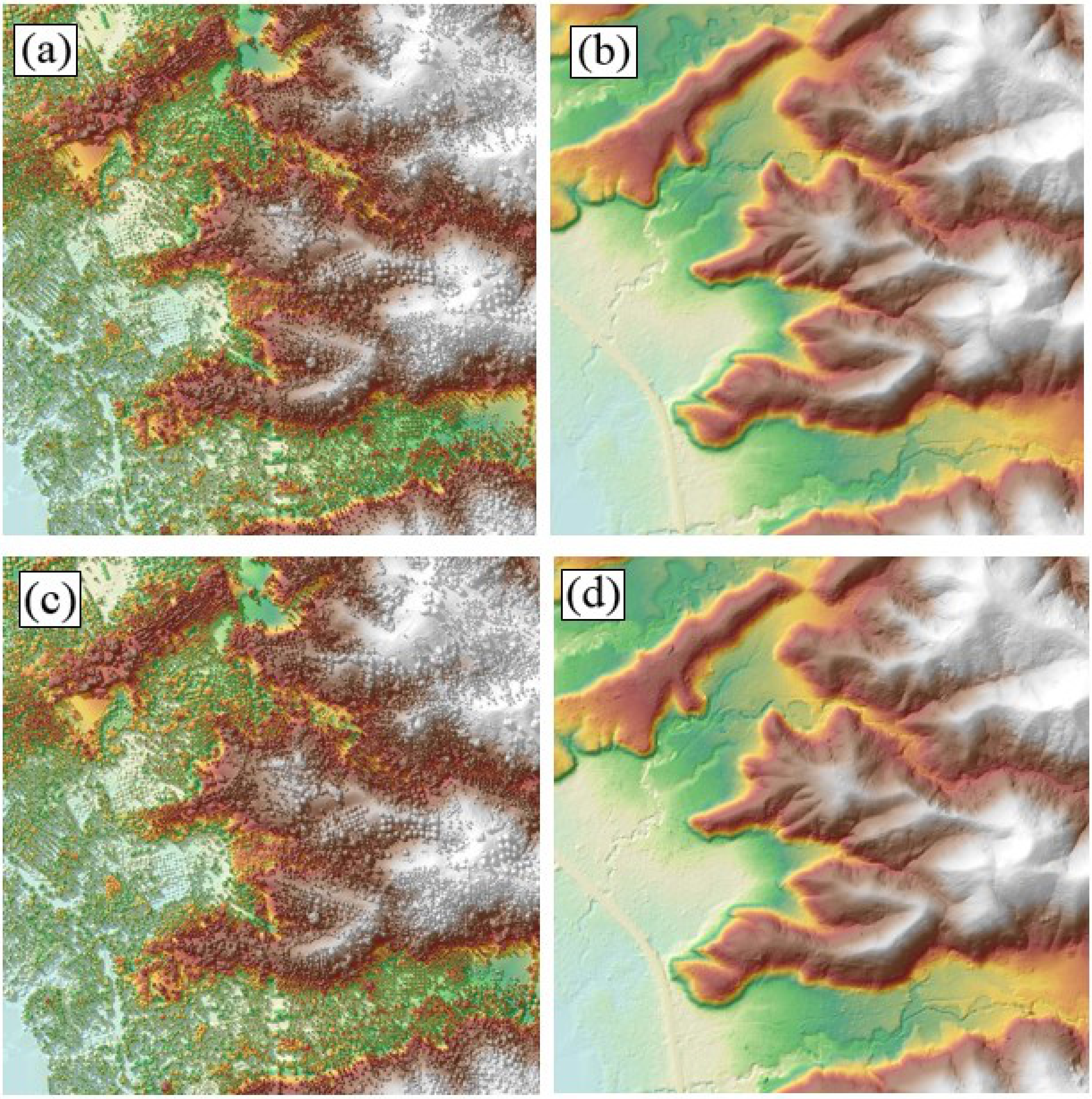


Figure 17. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Linugos Floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 148 1km by 1km tiles area covered by Linugos floodplain is shown in Figure 18. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Linugos floodplain has a total of 94.01 sq.km orthophotogaph coverage comprised of 1,679 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 19.

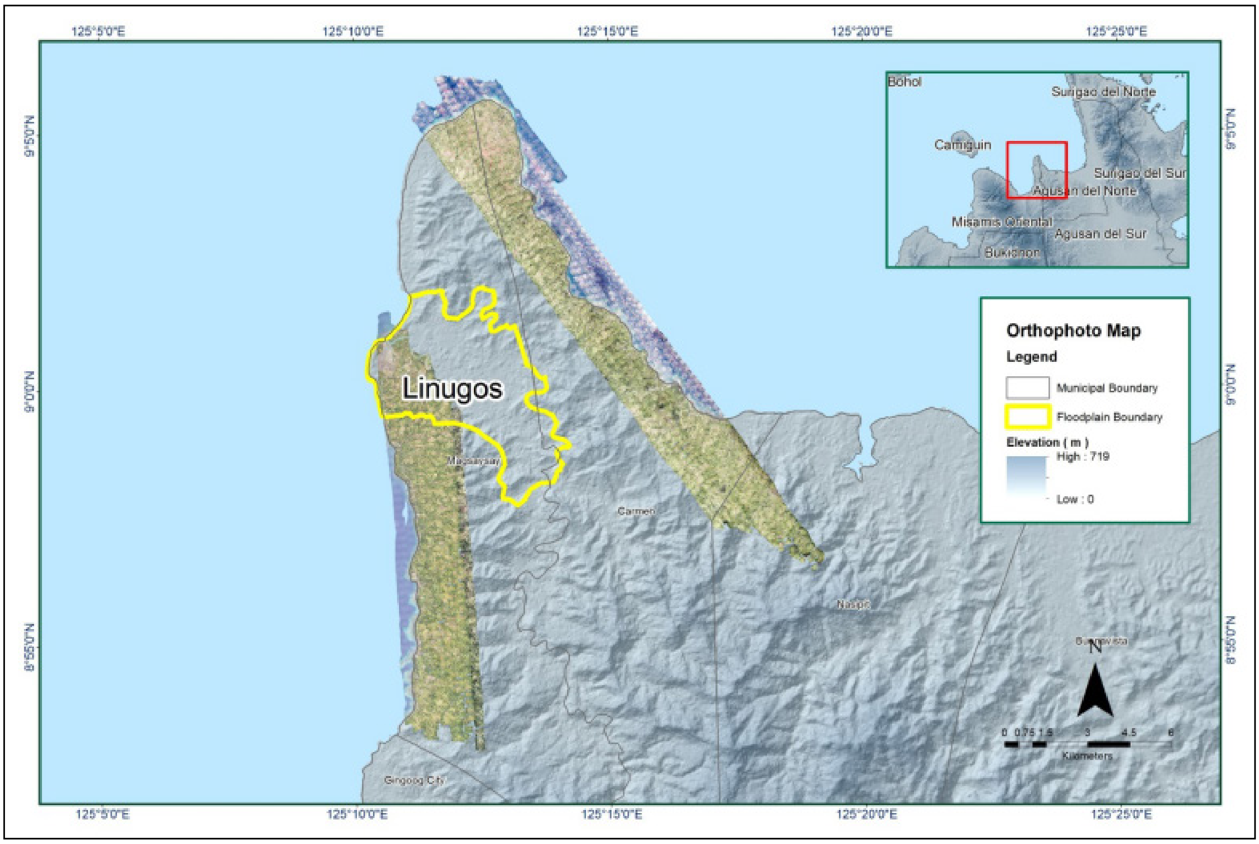


Figure 18. Linugos Floodplain with available orthophotographs.

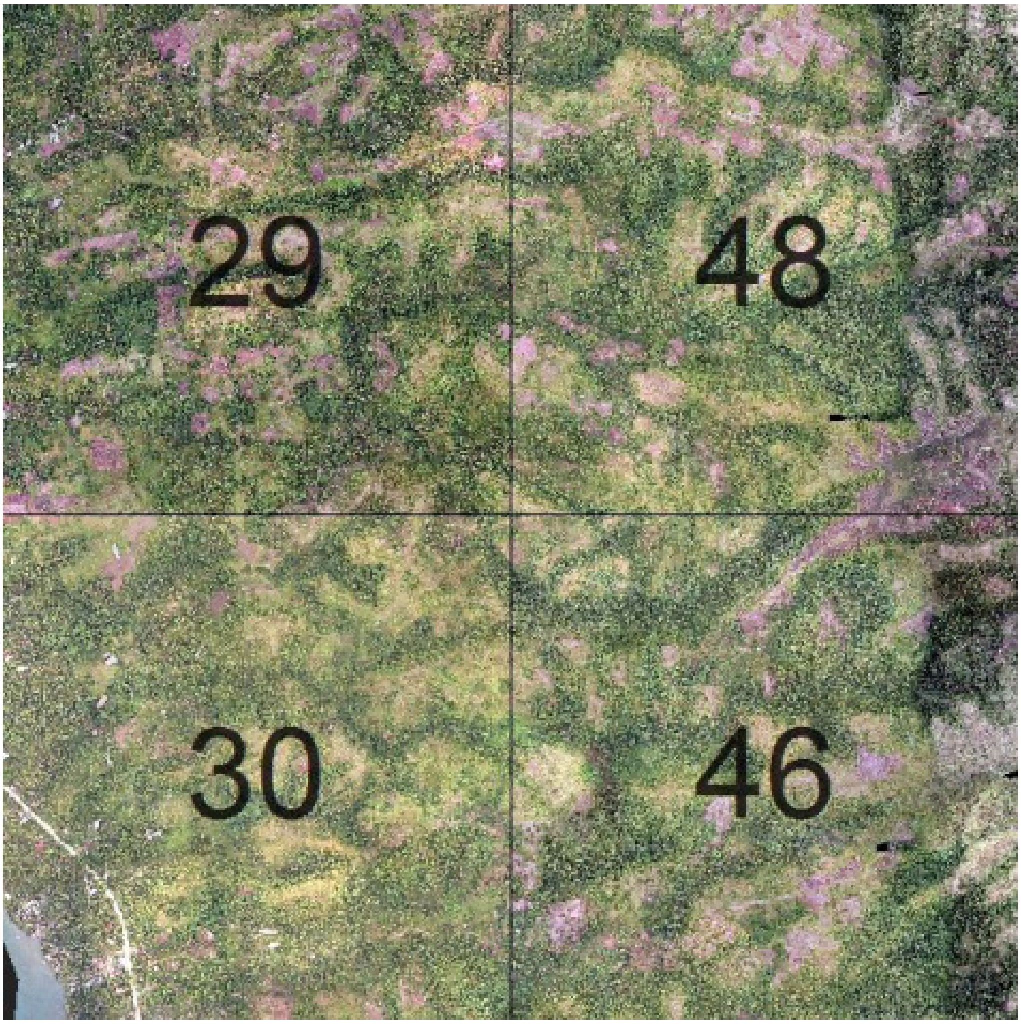


Figure 19. Sample orthophotograph tiles for Linugos Floodplain.

3.8 DEM Editing and Hydro-Correction

Four (4) mission blocks were processed for Linugos flood plain. These blocks are composed of Butuan and Siargao blocks with a total area of 224.96 square kilometers. Table 11 shows the name and corresponding area of each block in square kilometers.

Table 11. LiDAR blocks with its corresponding areas.

LiDAR Blocks	Area (sq.km)
Butuan_Blk63D	37.91
Butuan_Blk63A	55.69
Siargao_Blk63B	66.39
Siargao_Blk63C	64.97
TOTAL	**224.96**

Portions of DTM before and after manual editing are shown in Figure 20. The bridge (Figure 20a) and misclassified portions of a tributary (Figure 20c) are considered to be impedance to the flow of water along the river/stream and has to be removed (Figure 20b and 20d), respectively, in order to hydrologically correct the water flow. This was done through interpolation process wherein a specific polygon determines the upstream and downstream elevation values to generate an interpolated portion of a river and eventually remove the bridge and misclassified footprints. On the other hand, object retrieval was done in areas such as the ridge (Figure 20e) which have been removed during classification process and have to be retrieved to complete the surface (Figure 20f). Object retrieval uses the secondary DTM (t_layer) to fill in these areas.

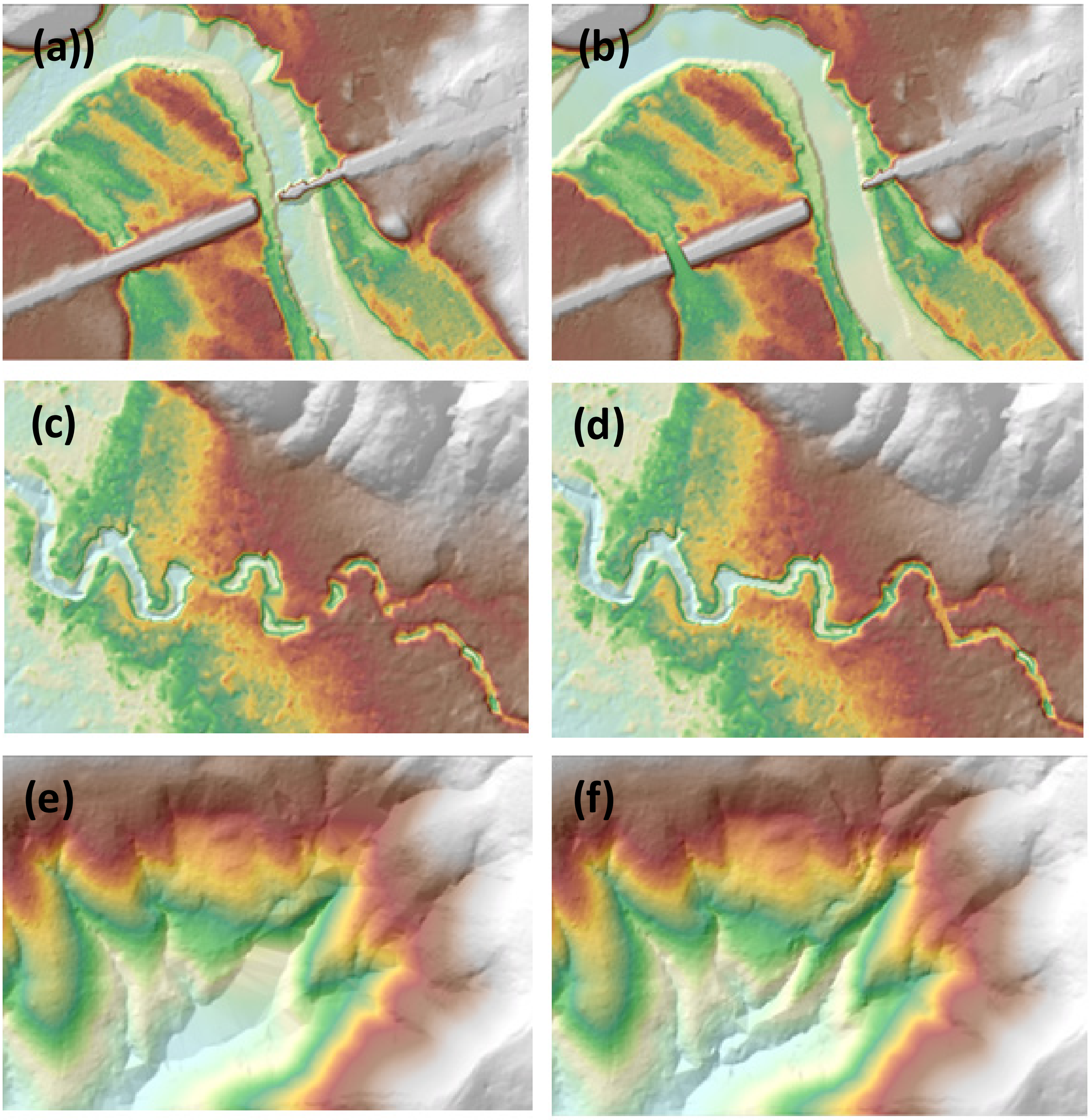


Figure 20. Portions in the DTM of Linugos floodplain – – bridge and misclassified terrain before (a), (c) and after (b), (d) interpolation and a misclassified ridge before (e) and after (f) data retrieval.

3.9 Mosaicking of Blocks

The Linugos floodplain lies within the Siargao_Blk63C block. No assumed reference block was used in mosaicking because the identified reference for shifting was an existing calibrated Butuan DEM overlapping with the blocks to be mosaicked (Figure 22). Table 12 shows the area of each LiDAR blocks and the shift values applied during mosaicking. Shifting values were derived from the height difference of the calibrated block and the overlapping adjacent block.

Mosaicked LiDAR DTM for Linugos floodplain is shown in Figure 22. It can be seen that the entire Linugos floodplain is 98% covered by LiDAR data.

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

Mission Blocks	Shift Values (meters)		
	x	y	z
Butuan_Blk63D	2.74	-1.37	0.52
Butuan_Blk63A	1.41	-1.84	0.70
Siargao_Blk63B	0.06	-0.56	-0.26
Siargao_Blk63C	1.83	-1.52	-0.35

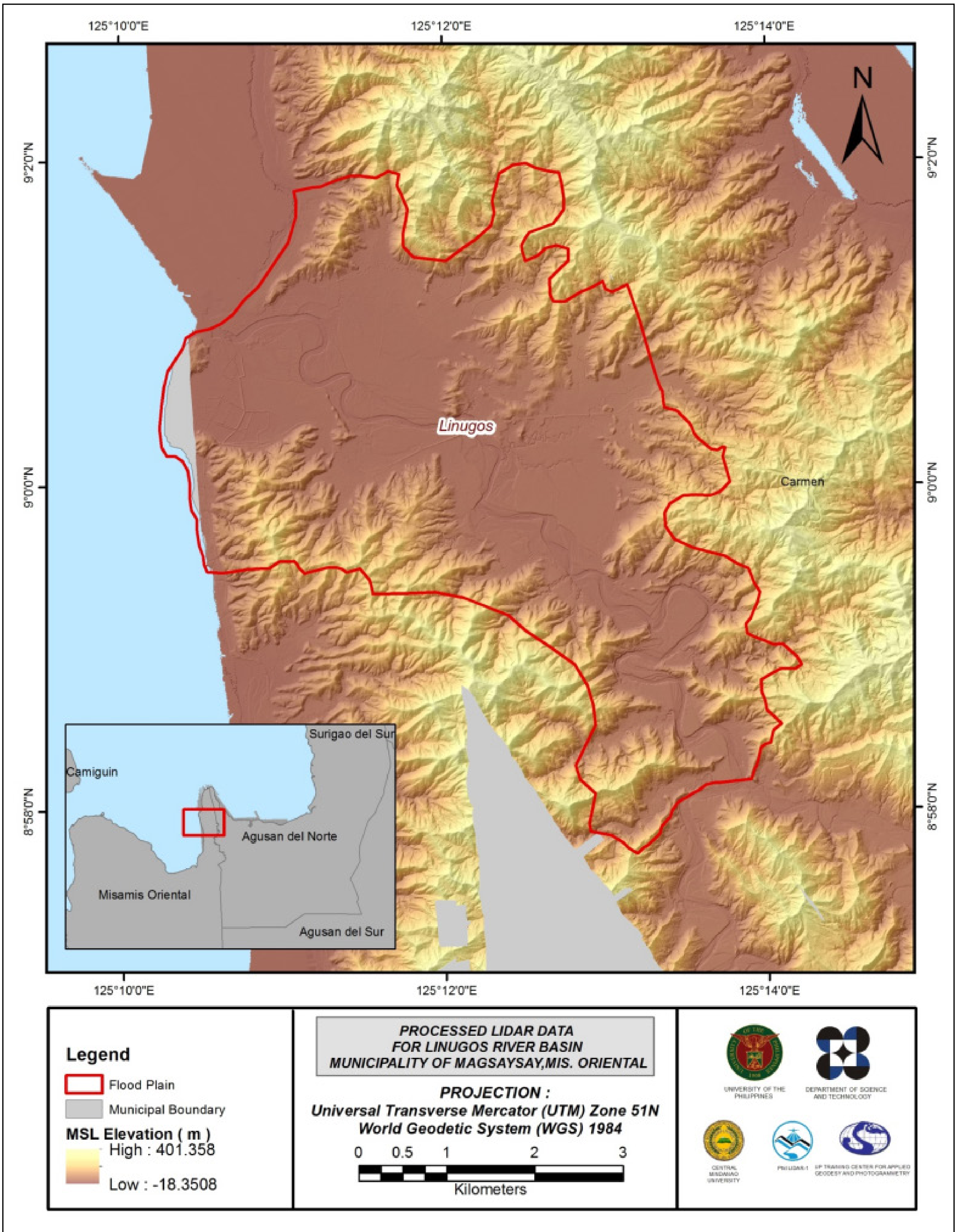


Figure 21. Map of Processed LiDAR Data for Linugos Floodplain.

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model (DEM)

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Linugos to collect points with which the LiDAR dataset is validated is shown in Figure 22. A total of 5,140 survey points were gathered for calibration and validation of Linugos LiDAR data. However, the point dataset was not used for the calibration of the LiDAR data for Linugos because during the mosaicking process, each LiDAR block was referred to the calibrated Agusan DEM.

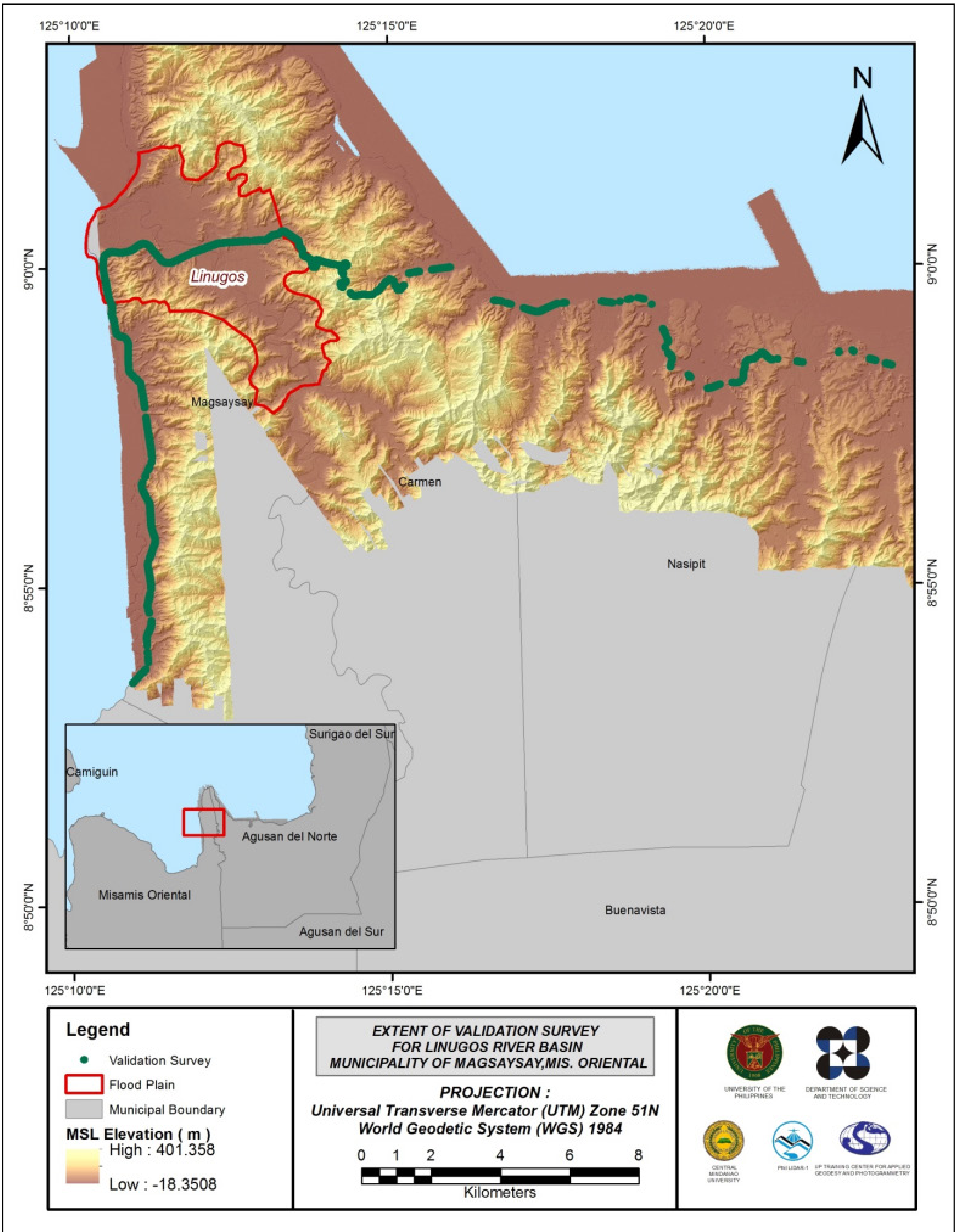


Figure 22. Map of Linugos Floodplain with validation survey points in green.

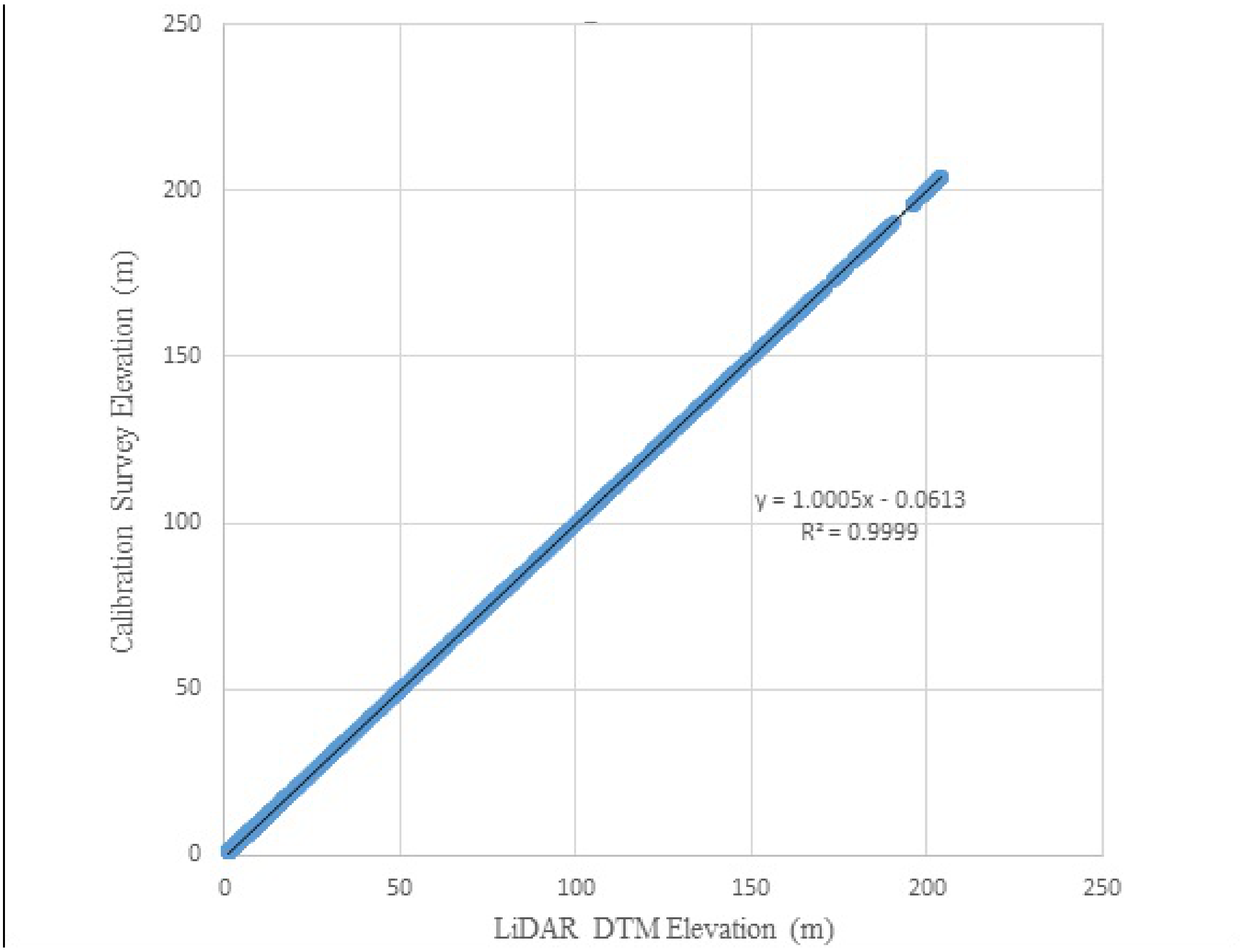


Figure 23. Correlation plot between calibration survey points and LiDAR data.

Table 13. Calibration Statistical Measures

Calibration Statistical Measures	Value (meters)
Height Difference	0.12
Standard Deviation	0.11
Average	-0.19
Minimum	-0.32
Maximum	0.41

A good correlation between the uncalibrated Agusan LiDAR DTM and ground survey elevation values is shown in Figure 23. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration points is 0.12 meters with a standard deviation of 0.10 meters. Calibration of Agusan LiDAR data was done by subtracting the height difference value, 0.12 meters, to Agusan mosaicked LiDAR data. Table 13 shows the statistical values of the compared elevation values between Agusan LiDAR data and calibration data. These values were also applicable to the Linugos DEM.

Only 271 points that lie within the Linugos floodplain, derived from the 20% of the total survey points, were used for the validation of calibrated Linugos 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 24. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.11 meters with a standard deviation of 0.07 meters, as shown in Table 14.

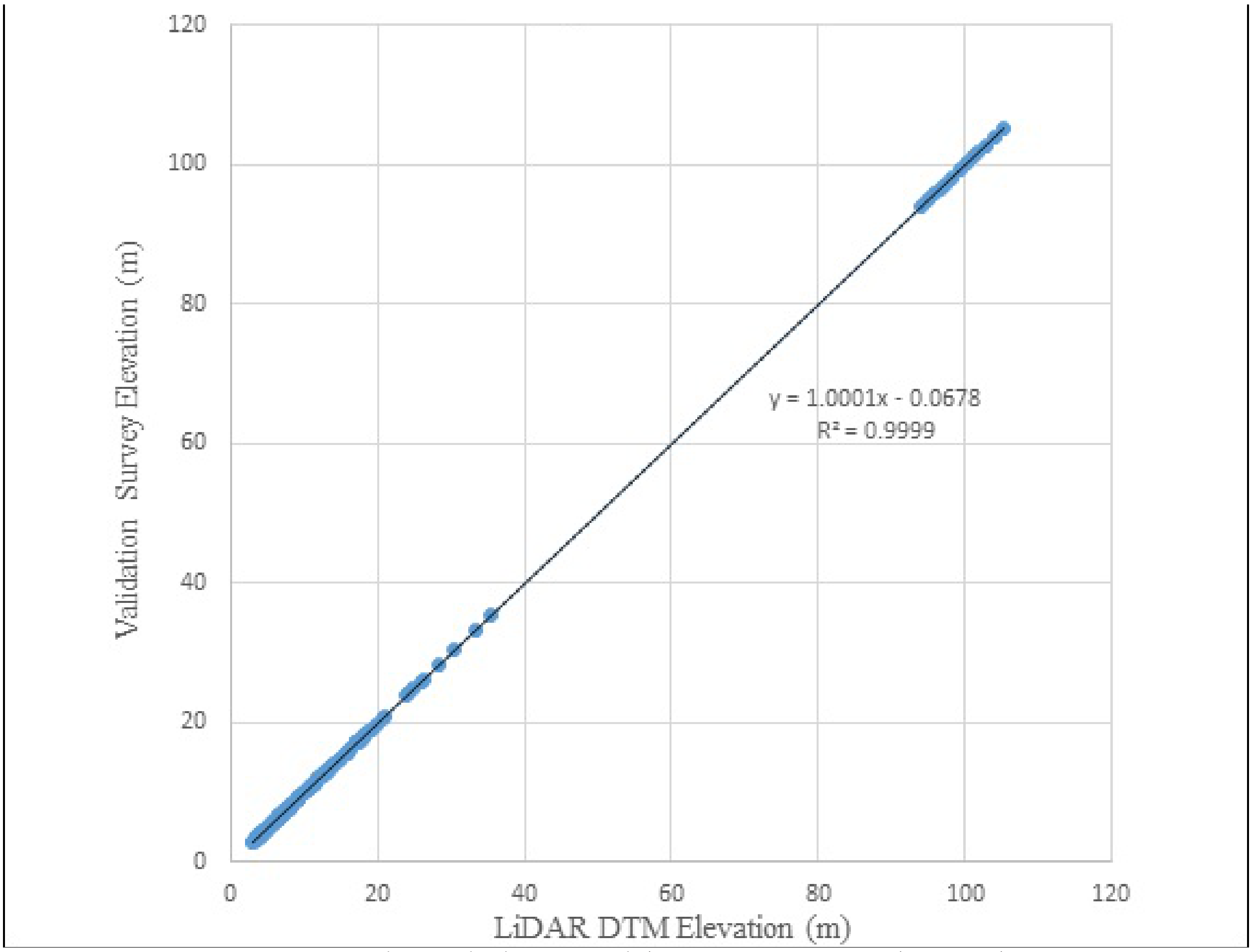


Figure 24. Correlation plot between validation survey points and LiDAR data.

Table 14. Validation Statistical Measures

Validation Statistical Measures	Value (meters)
RMSE	0.11
Standard Deviation	0.07
Average	-0.08
Minimum	-0.25
Maximum	0.14

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and zigzag data were available for Linugos with 9,751 bathymetric survey points. The resulting raster surface produced was done by Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.34 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Linugos integrated with the processed LiDAR DEM is shown in Figure 25.

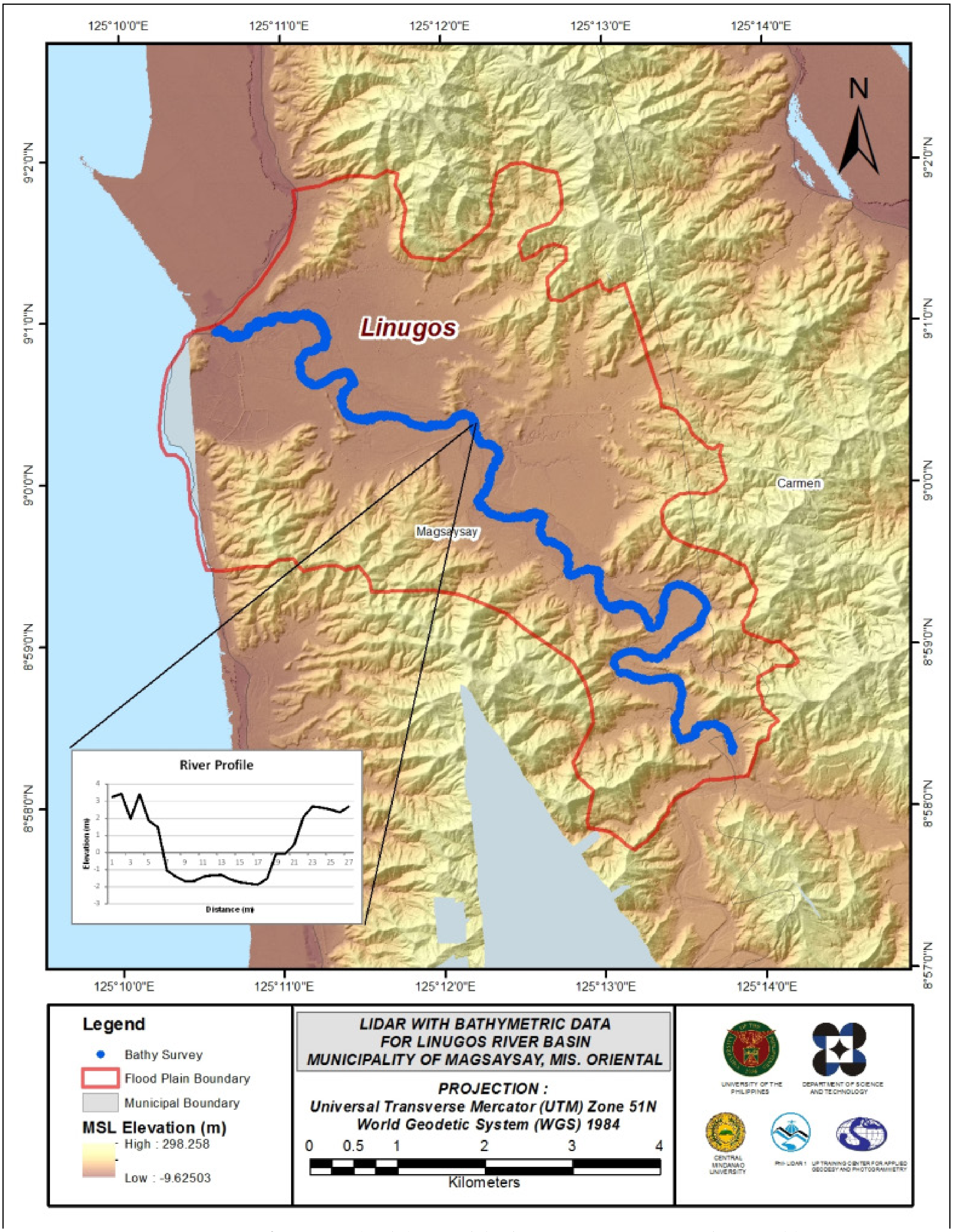


Figure 25. Map of Linugos Floodplain with bathymetric survey points shown in blue.

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

Linugos floodplain, including its 200 m buffer, has a total area of 33.45 sq km. For this area, a total of 5.00 sq km, corresponding to a total of 1,033 building features, are considered for QC. Figure 27 shows the QC blocks for Linugos floodplain.

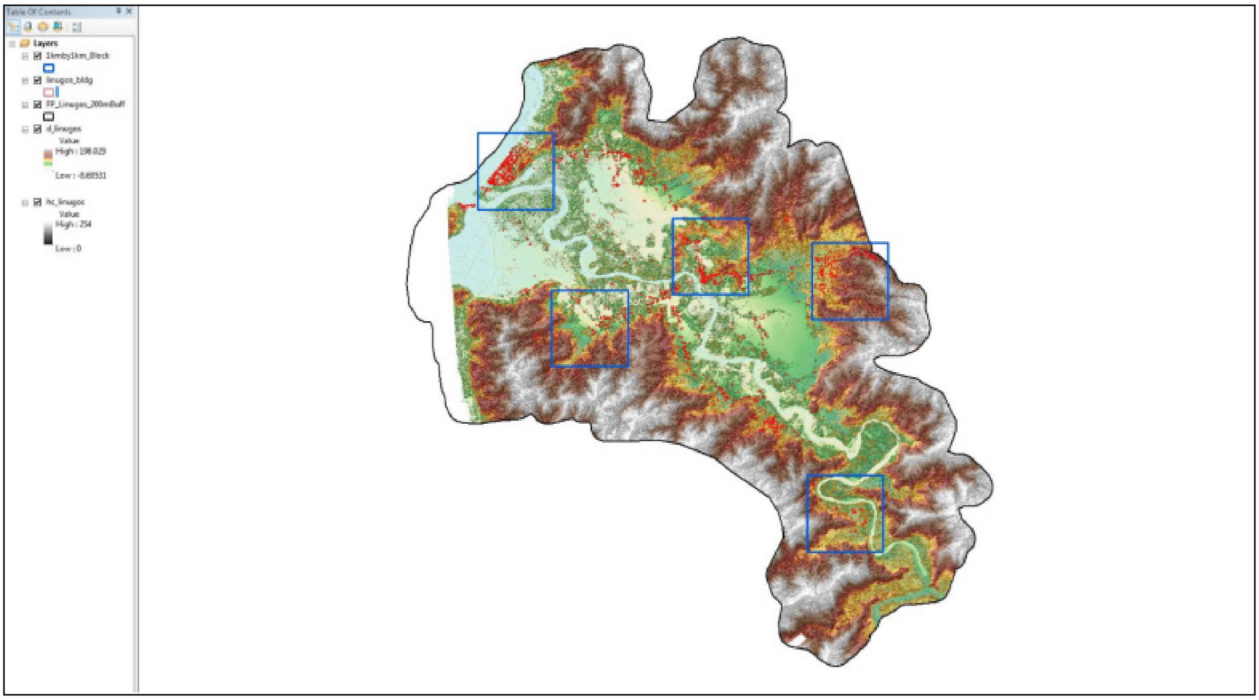


Figure 26. Blocks (in blue) of Linugos building features that were subjected to QC

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

Table 15. Quality Checking Ratings for Linugos Building Features

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Linugos	98.31	98.16	97.19	PASSED

3.12.2 Height Extraction

Height extraction was done for 2,200 building features in Linugos floodplain. Of these building features, none was filtered out after height extraction, resulting to 2,163 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 7.73 m.

3.12.3 Feature Attribution

Field data collection for the attribution process was done through Geotagging (point to a specific feature and shoot method) using a handheld GPS with a built-in camera. The x,y,z and the viewing direction of the GPS in 0-359 degrees during the photo capture were the essential information in the process. Using Arcmap's tool "Geotagged Photos to Points", the symbology of the imported point shapefile was set as "Airfield" and the viewing angle was set as "Direction". The "Path" is automatically created in the points' attribute table wherein the photo's directory is linked every after the "Identify" button is clicked to a specific point.

Table 16 summarizes the number of building features per type. From the total features identified, approximately 1, 951 of it are residential establishments while the commercial establishments and schools are the most common in non-residential features. On the other hand, Table 17 shows the total length of each road type. However, road networks other than the national road (NA) were considered unclassified (Others). Table 18 shows the extracted water feature which is the Linugos River and Fishpens. Fishpens are mostly for small-scale business while the others are intended for household consumption.

Table 16. Building Features Extracted for Linugos Floodplain.

Facility Type	No. of Features
Residential	1,951
School	65
Market	1
Agricultural/Agro-Industrial Facilities	2
Medical Institutions	3
Barangay Hall	5
Military Institution	0
Sports Center/Gymnasium/Covered Court	2
Telecommunication Facilities	0
Transport Terminal	0
Warehouse	9
Power Plant/Substation	0
NGO/CSO Offices	0
Police Station	1
Water Supply/Sewerage	0
Religious Institutions	13
Bank	0
Factory	0
Gas Station	1
Fire Station	0
Other Government Offices	17
Other Commercial Establishments	93
Total	**2,163**

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

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Linugos	0	0	0	7.89	27.15	35.04

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

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Linugos	1	0	0	0	22	23

The Kibungsod Bridge is the only bridge identified and extracted that is part of the river network 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 27 shows the Digital Surface Model (DSM) of Linugos floodplain overlaid with its ground features.

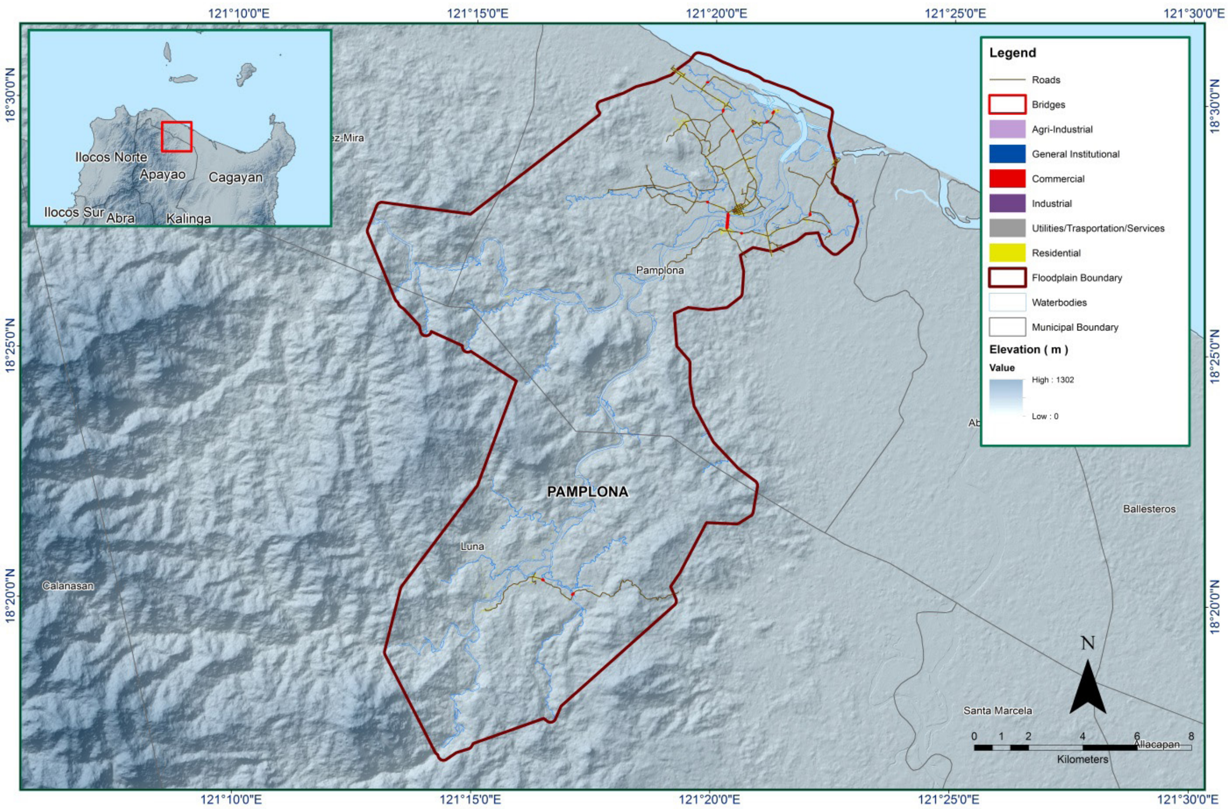


Figure 27. Extracted features for Linugos Floodplain.

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

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

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

4.1 Summary of Activities

The Data Validation and Bathymetry Component (DVBC) of PHIL-LIDAR 1 together with its partner for the area, PHIL-LIDAR1 personnel of Central Mindanao University conducted surveys for Linugos River Basin on September 28 to October 12, 2015 with the following scope of work: reconnaissance of NAMRIA controls; control survey for the establishment of an accessible control point to be used in other survey types; cross-section survey, determination of bridge as-built features and water-level marking with respect to MSL on the pier of Kibungsod Bridge; LiDAR ground validation points acquisition with approximate length of 65 km; and bathymetry survey using Trimble® GNSS PPK survey technique and OHMEX Echosounder covering an estimated 14.51 km length over Brgys. Manoligao of Carmen to Brgy. Poblacion, Magsaysay.

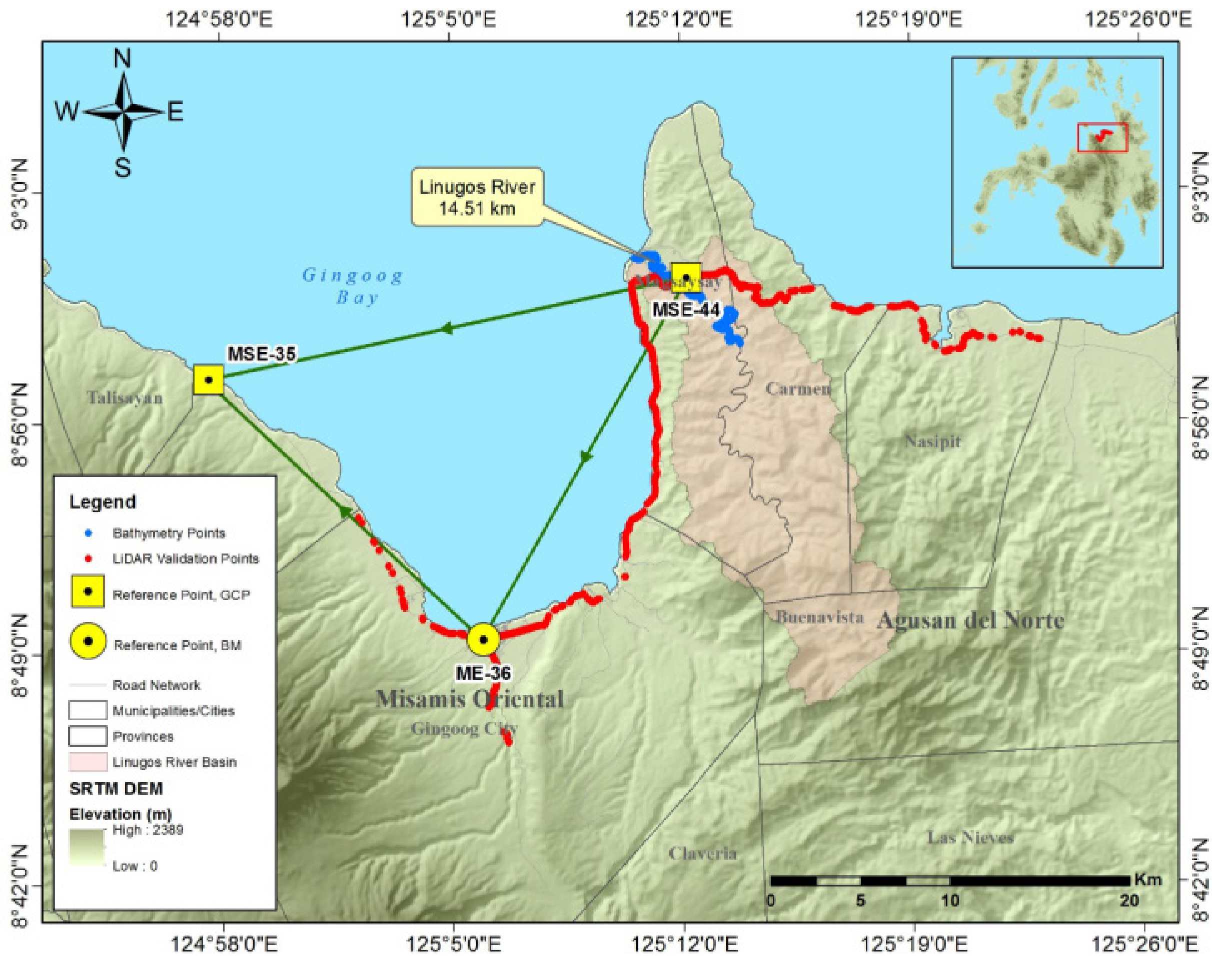


Figure 28. Extent of the bathymetric survey (in blue line) in Linugos River and the LiDAR data validation survey (in red).

4.2 Control Survey

The GNSS network used for Linugos River Basin is composed of a single loop established on September 9 – October 5, 2015 occupying the following reference points: MSE-35, a second-order GCP in Brgy. Pahindong, Municipality of Medina; and ME-36, a first-order BM in Brgy. Barangay 1 Poblacion, Gingoog City; Misamis Oriental.

A NAMRIA established control poins: MSE-44 in Brgy. Kibungsod, Municipality of Magsaysay was also used as marker during the survey.

The summary of reference and control points and its location is summarized in Table 19 while the GNSS network established is illustrated in Figure 29.

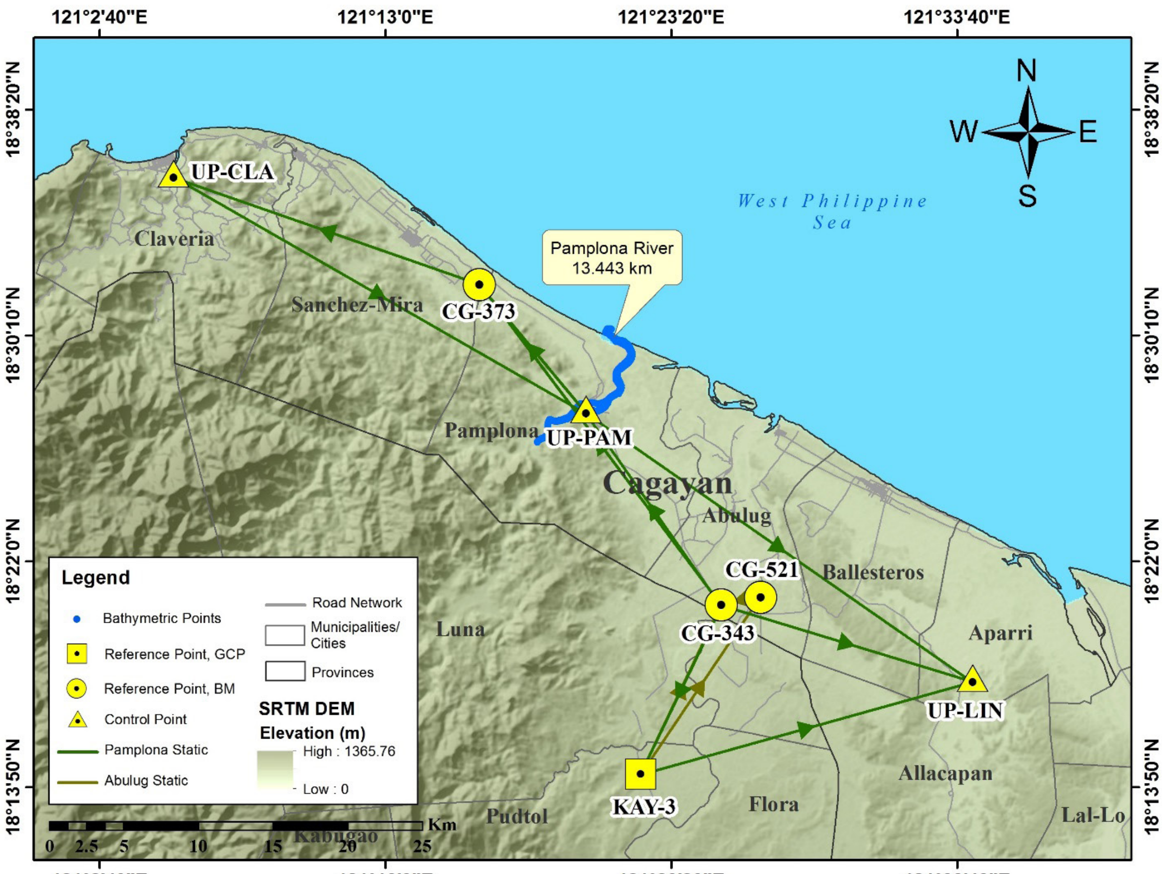


Figure 29. The GNSS Network established in the Linugos River Survey.

Table 19. List of Reference and Control Points occupied for Linugos River Survey

(Source: NAMRIA; UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (Meter)	Elevation in MSL (Meter)	Date Established
MSE-35	2nd Order, GCP	08°57'19.75841"N	124°57'19.75841"E	68.009	0.009	2003
ME-36	1st Order, BM	14°33'52.21121"N	121°36'54.79419"E	75.333	9.474	2007
MSE-44	Used as marker	-	-	76.146	-	2003

The GNSS set-ups on recovered reference and control points in Linugos River are shown in Figure 30 to Figure 32.

Figure 30. Trimble® SPS 882 GPS setup at MSE-35 located on a seawall within Mandahilag Elementary School in Brgy.Pahindong, Municipality of Medina, Misamis Oriental

Figure 31. Trimble® SPS 852 Base setup at ME-36 located at the approach of Gahub Bridge in Brgy. Poblacion 1, Gingoog City, Misamis Oriental

Figure 32. Trimble® SPS 852 Base setup at MSE-44, Kibungsod Bridge, located in Brgy. Kibungsod, Municipality of Magsaysay, Misamis Oriental

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 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 Linugos river basin survey is summarized in Table 20 generated by TBC software.

Table 20. Baseline Processing Summary Report for Linugos River Survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
ME-36 --- MSE-35	09-29-2015	Fixed	0.007	0.033	313°47'45"	21122.989	-7.312
ME-36 --- MSE-44	09-29-2015	Fixed	0.006	0.027	29°30'54"	23174.977	0.966
MSE-44 --- MSE-35	09-29-2015	Fixed	0.008	0.046	78°13'25"	27235.149	8.297

As shown in Table 20, a total of three (3) baselines were processed with coordinates of MSE-35 and elevation value of ME-36 held fixed. All of them passed the required accuracy.

4.4 Network Adjustment

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

<20cm and

Where:

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

See the Network Adjustment Report shown in Table 21 to Table 23 for complete details.

Table 21. Constraints applied to the adjustment of the control points.

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
ME-36	Grid				Fixed
MSE-35	Local	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 and elevation errors.

Table 22. Adjusted grid coordinates for the control points used in the Linugos River Floodplain survey.

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
ME-36	730883.858	0.009	975969.756	0.006	6.512	?	e
MSE-35	715551.148	?	990505.339	?	-0.349	0.056	LL
MSE-44	742189.569	0.009	996207.709	0.006	9.268	0.048	

With the mentioned equation, for horizontal and for the vertical; the computation for the accuracy are as follows:

a.MSE-35

horizontal accuracy	=	Fixed
vertical accuracy	=	5.6 < 10 cm

b.ME-36

horizontal accuracy	=	$\sqrt{((0.9)^2 + (0.6)^2}$
	=	$\sqrt{(0.81 + 0.36)}$
	=	1.08 < 20 cm
vertical accuracy	=	Fixed

c.MSE-44

horizontal accuracy	=	$\sqrt{((0.9)^2 + (0.6)^2}$
	=	$\sqrt{(0.81 + 0.36)}$
	=	1.08 < 20 cm
vertical accuracy	=	4.8 < 10 cm

Following the given formula, the horizontal and vertical accuracy result of the two occupied control points are within the required precision.

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 accuracy conditions is satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table 24.

Table 23. Adjusted geodetic coordinates for control points used in the Linugos River Floodplain validation.

Point ID	Latitude	Longitude	Ellipsoid	Height	Constraint
ME-36	N8°49'24.00979"	E125°05'56.85831"	74.935	?	e
MSE-35	N8°57'19.75841"	E124°57'37.74118"	67.619	0.056	LL
MSE-44	N9°00'20.39882"	E125°12'10.65876"	75.908	0.048	

Table 24. The reference and control points utilized in the Linugos River Static Survey, with their corresponding locations (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
ME-36	1st Order, BM	8°49'24.00979"	125°05'56.85831"	74.935	975969.756	730883.858	6.512
MSE-35	2nd Order, GCP	8°57'19.75841"	124°57'37.74118"	67.619	990505.339	715551.148	-0.349
MSE-44	Used as Marker	9°00'20.39882"	125°12'10.65876"	75.908	996207.709	742189.569	9.268

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

Cross-section and as-built survey were conducted on October 8, 2015 at the downstream side of Kibungsod Bridge in Brgy. Kibungsod, Municipality of Magsaysay, Misamis Oriental using Trimble® SPS 985 receiver in PPK survey technique as shown in Figure 33.

Figure 33. Cross Section and As-built survey at the downstream portion of Kibungsod Bridge, Brgy. Kibungsod, Magsaysay, Misamis Oriental

Figure 34. Acquisition of AWLS sensor elevation at Kibungsod Bridge, Brgy. Kibungsod, Magsaysay, Misamis Oriental

The cross-sectional line of Kibungsod Bridge is about 173.45 meters with thirty (30) cross-sectional points using the control point MSE-44 as the GNSS base station. The cross-section diagram, planimetric map and bridge data form are shown in Figure 35 to Figure 37, respectively.

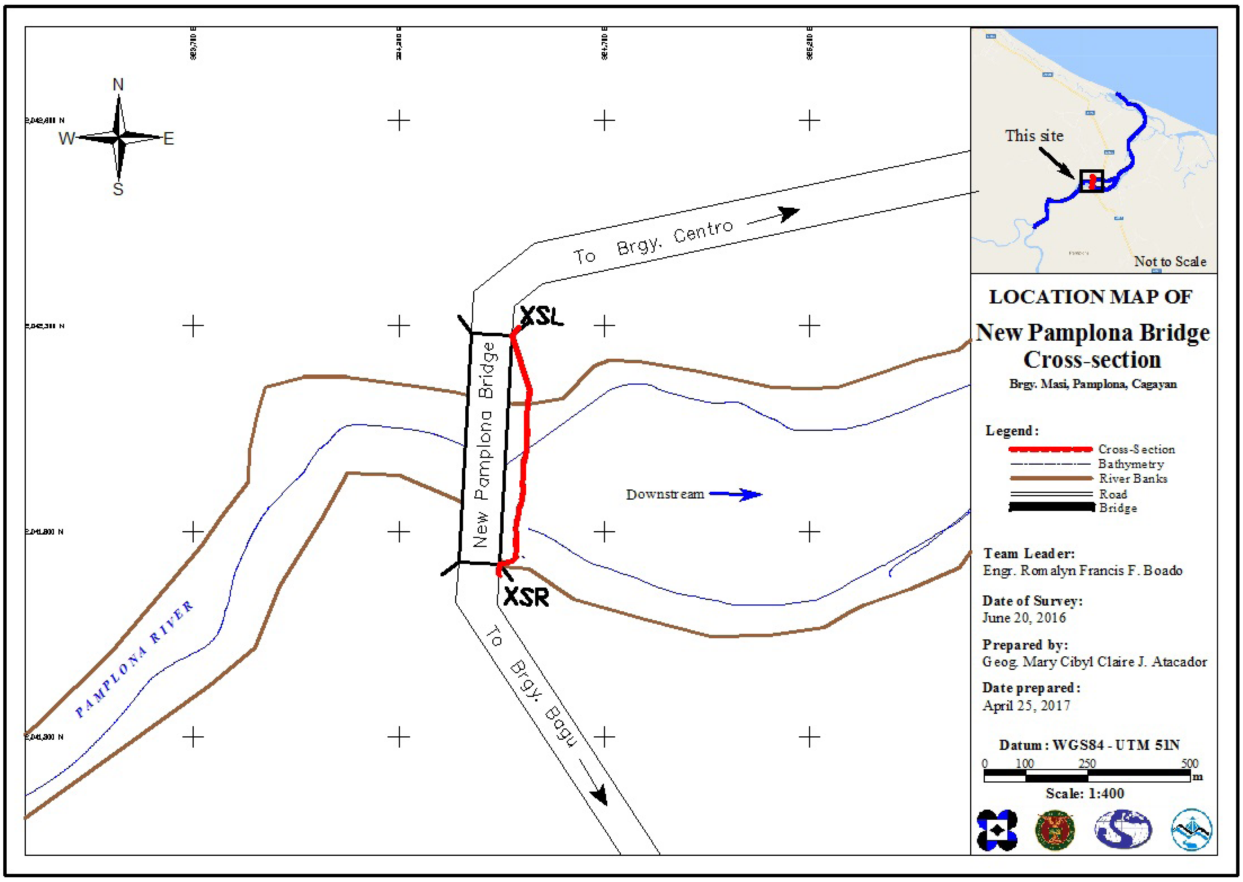


Figure 35. Location map of Kibungsod Bridge cross-section survey

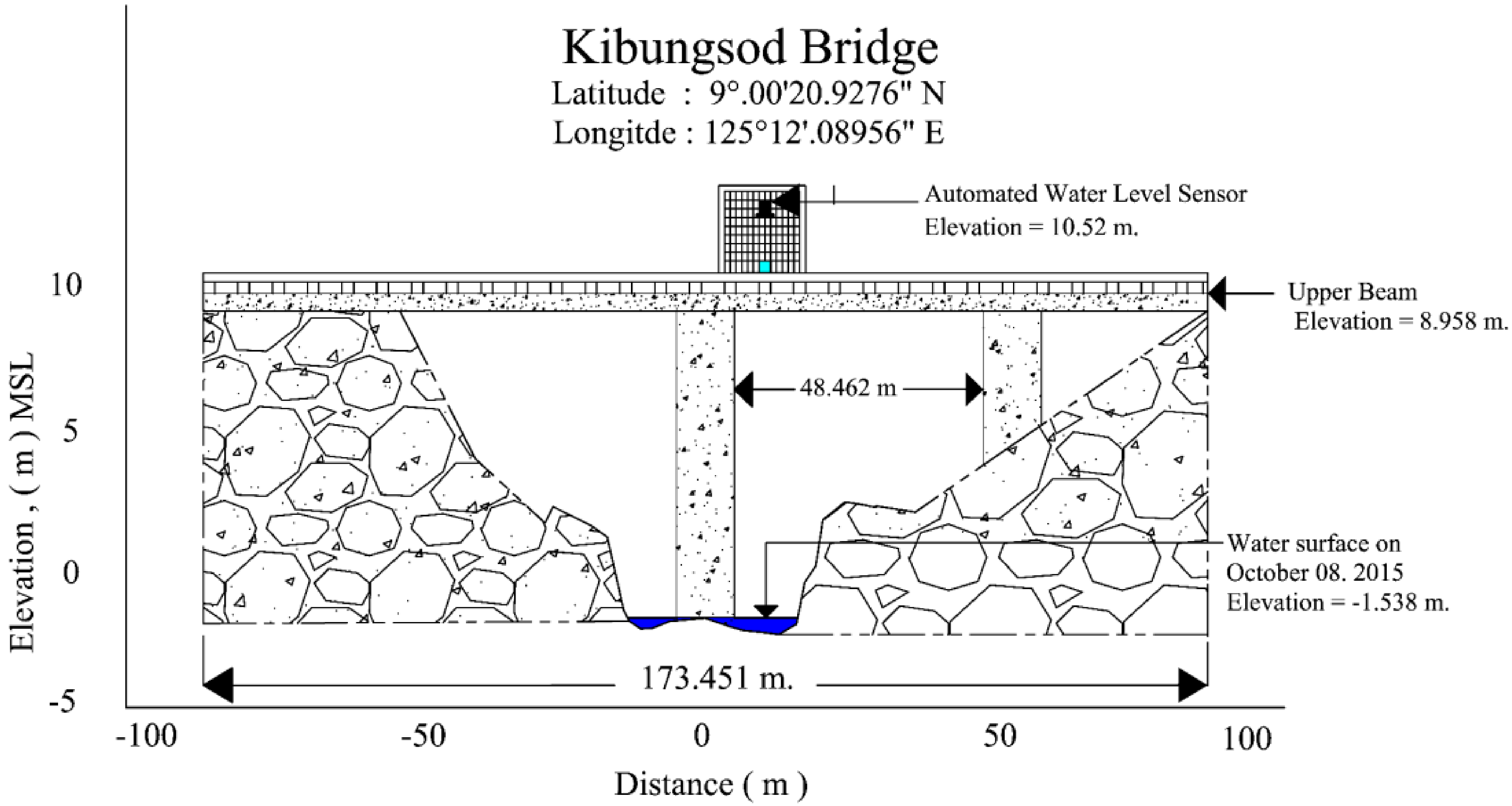


Figure 36. Cross-sectional diagram of Lubayat River along Kibungsod Bridge with marked water-level

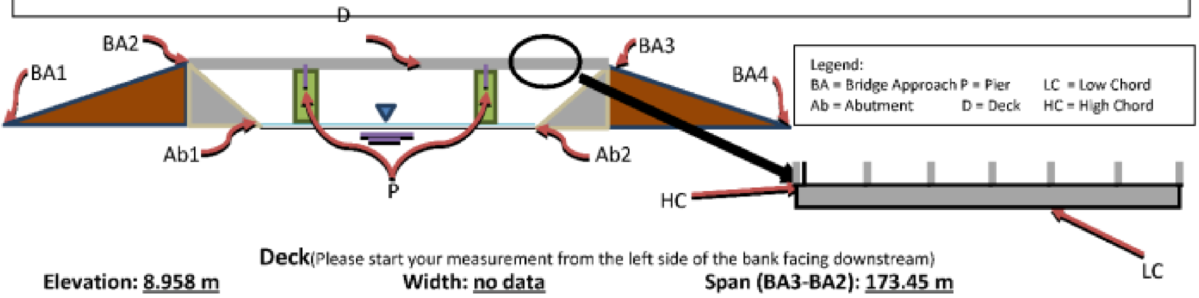
Bridge Data Form

Bridge Name: Kibungsod Bridge **Date:** October,26 2015
River Name: LINUGOS RIVER

Location (Brgy, City,Region): Brgy. Kibungsod, Magsaysay, Misamis Oriental
Survey Team: Gingoog, Gahub, Linugos Survey Team

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

Latitude: 9d00'20.9276"N **Longitude:** 125d12'.08956"E



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

Elevation: 8.958 m **Width:** no data **Span (BA3-BA2):** 173.45 m

	Station	High Chord Elevation	Low Chord Elevation
1	Pier 1 (69.45)	8.96	7.94
2	Pier 2 (117.79)	8.96	7.94
3	Pier 6 (329.24)	8.96	7.94

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	9.265	BA3	62.006	9.366
BA2	13.61	9.269	BA4	63.435	9.399

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

	Station (Distance from BA1)	Elevation
Ab1	13.605	8.946
Ab2	19.281	8.958

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

Shape: Rectangular **Number of Piers:** Two (2) **Height of column footing:** n/a

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	25.433	9.412	1.2
Pier 2	61.997	9.394	1.2

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

Figure 37. Bridge data form for Kibungsod Bridge

4.6 Validation Points Acquisition Survey

LiDAR validation points acquisition survey was conducted on October 1, 2 and 7 2015 using a survey-grade GNSS rover receiver Trimble® SPS 985 mounted on a pole attached at the back of a vehicle as seen in Figure 39. It was secured with a nylon rope and cable ties to ensure that it was horizontally and vertically balanced. The antenna height was measured and recorded to be 2.428 m from the ground up to the bottom of antenna mount of the receiver.

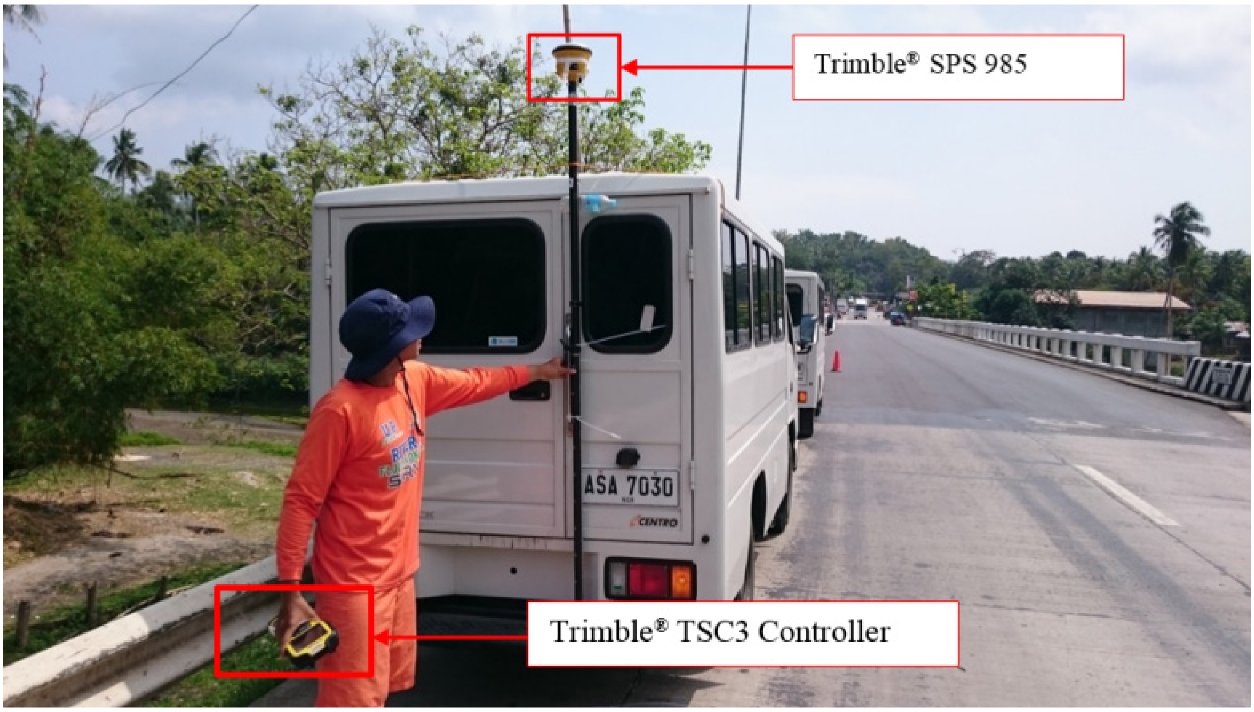


Figure 38. Set up for LiDAR ground validation survey

The survey started from Brgy. San Luis, Gingoog City, going south through National high-way traversing 27 barangays in Borongan City; seven barangays in Municipality of Magsaysay; three (3) barangays in Municpality of Carmen; and ten (10) barangays in Municipaliy of Nasipit. It ended in Brgy. Cubi cubi, Mun. of Nasipit, Misamis Oriental. A total of 7,477 points were gathered with approximate length of 65 km using ME-36 and MSE-44 as GNSS base stations for the entire extent validation points acquisition survey as illustrated in the map in Figure 39.

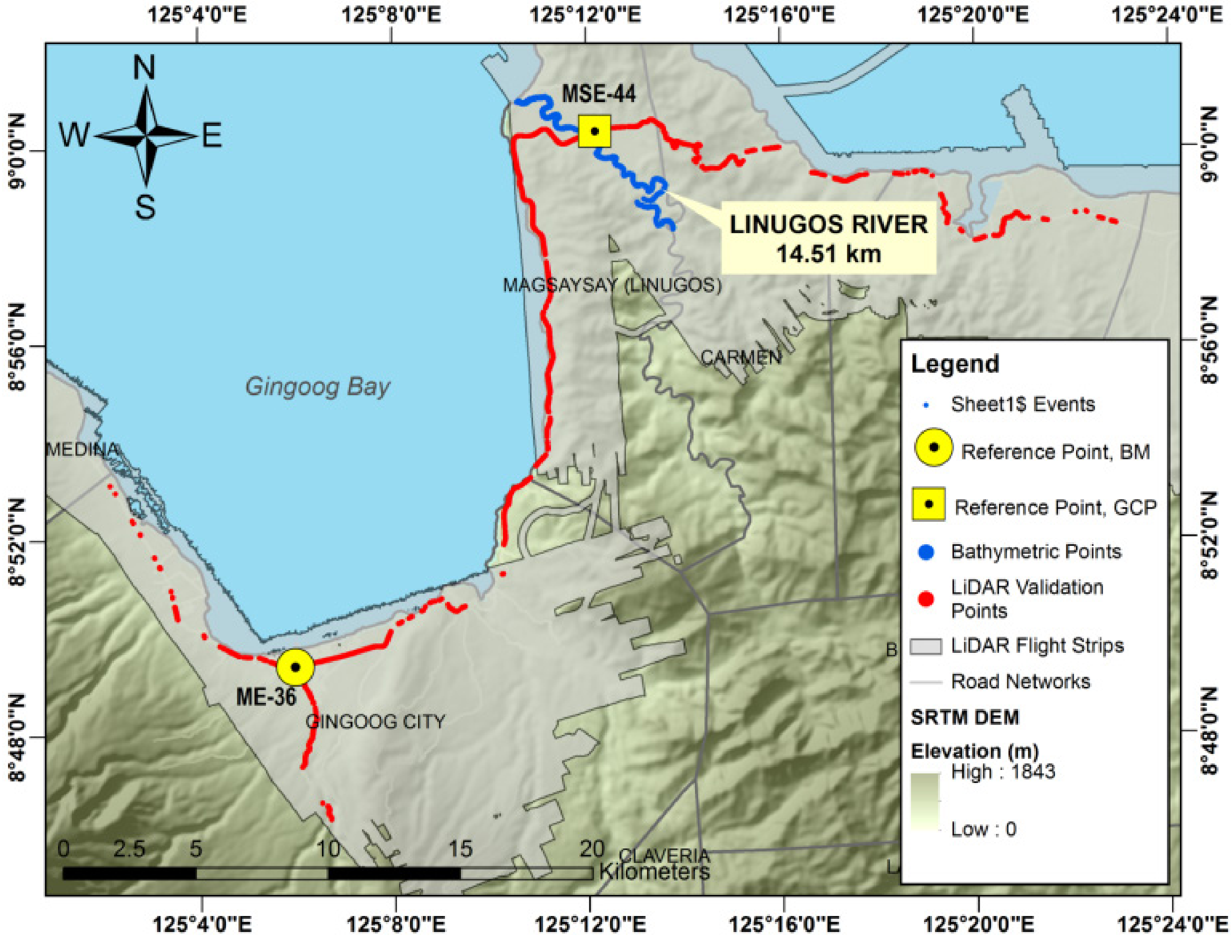


Figure 39. Validation points acquisition survey for Linugos River Basin

4.7 River Bathymetric Survey

Bathymetric survey was executed on October 7, 2015 using Trimble® SPS 882 in GNSS PPK survey technique and an Ohmex™ single-beam echo sounder mounted on a pole as shown in Figure 41. The survey started in Brgy. Kabungsod, Mun. of Magsaysay with coordinates 9°00’39.47735”N, 125°11’25.60257”E, down to the mouth of the river in Brgy. Poblacion, also in Mun. of Magsaysay with coordinates 9°00’56.64258”N, 125°10’35.47020”E.

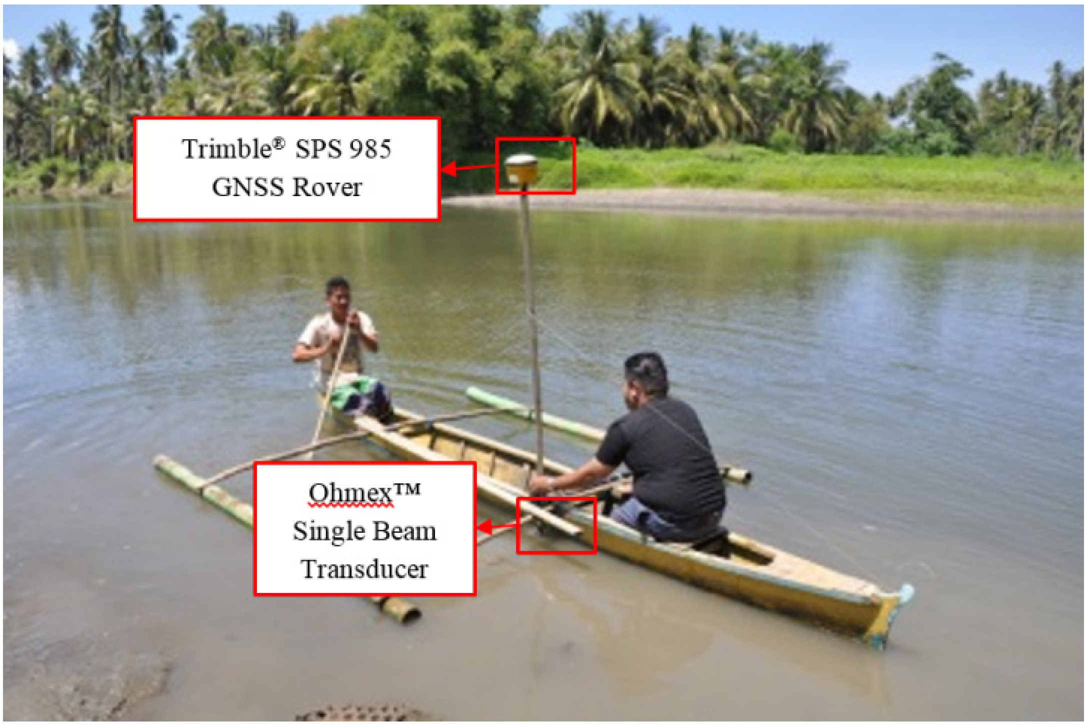


Figure 40. Bathymetric survey using Trimble SPS 985 GNSS Rover and OHMEX Echosounder in Linugos River

Manual bathymetric survey on the other hand was conducted on September 30 and October 1, 2015 using Trimble® SPS 882 and Trimble® SPS 985 in GNSS PPK survey technique as shown in Figure 42. It started in Brgy. Manoligao, Mun. of Carmen in Agusan Del Norte with coordinates 8°58’19.76136”N, 125°13’47.03525”E, walked down the river by foot and ended at the starting point of bathymetric survey using boat. The control point MSE-44 was used as the GNSS base receiver all throughout the survey.

Figure 41. Manual Bathymetric survey in Linugos River using a Trimble® SPS 985 Rover

The bathymetric survey for Linugos River gathered a total of 9,872 bathymetric points covering 14.51 km of the river traversing seven (7) barangays in Municipality of Magsaysay, Misamis Oriental and Brgy. Manoligao, Mun. of Carmen, Misamis Oriental. A CAD drawing was also produced to illustrate the riverbed profile of Linugos river. The highest and lowest elevation has 15-m difference. The highest elevation observed was 7.126 m in MSL located at the upper portion of the river while the lowest elevation observed was -8.202 located near the mouth of the river.

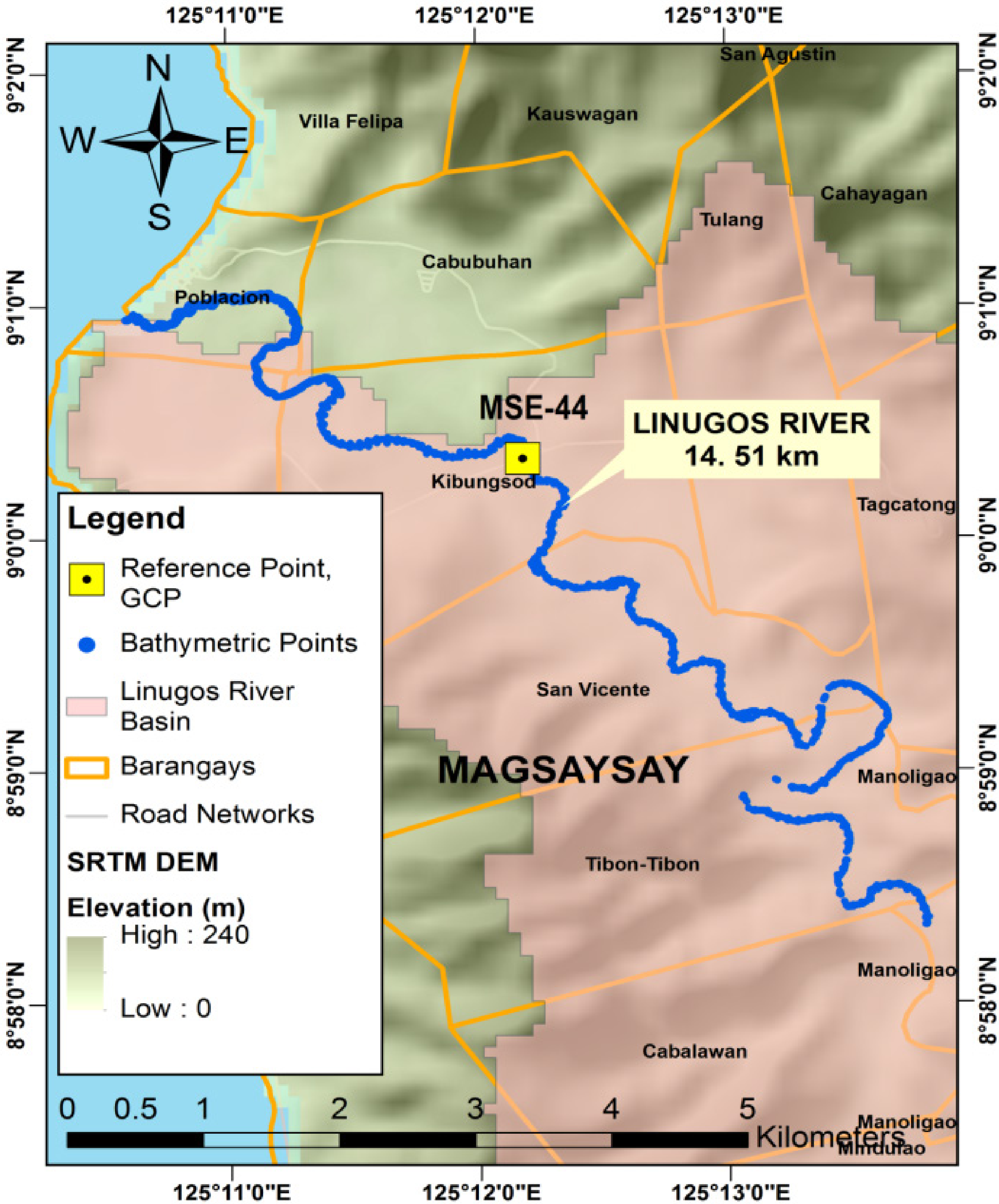


Figure 42. Extent of Linugos River Bathymetry Survey

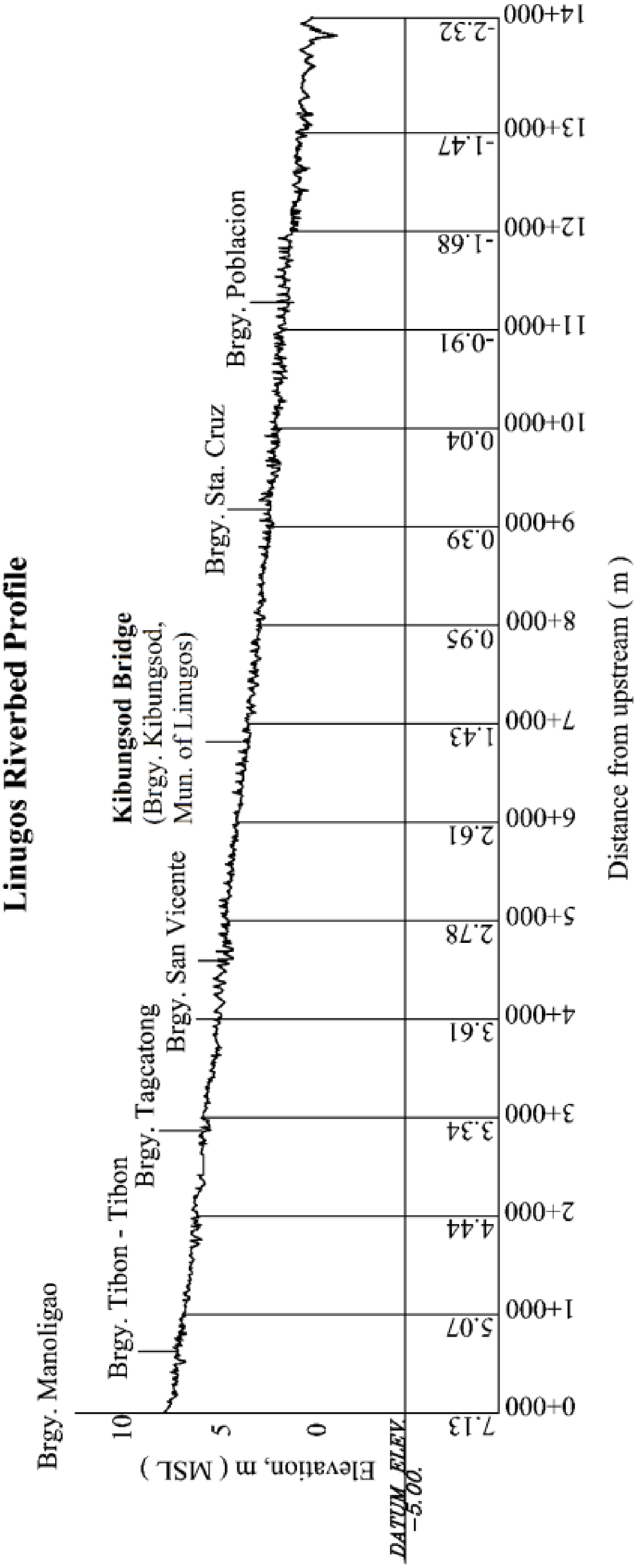


Figure 43. Linugos riverbed profile.

CHAPTER 5: FLOOD MODELING AND MAPPING

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

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

Precipitation data can be downloaded from the Automatic Rain Gauge (ARG) installed by the Department of Science and Technology – Advanced Science and Technology Institute (DOST-ASTI). However, the location of the installed ARG is not appropriate for the purpose of flood modeling. Thus, the CMU-Phil LiDAR1 team installed manual rain gauge at Brgy. Cabalawan, Magsaysay, Misamis Oriental. The precipitation data taken from manual rain gauge during Tropical Depression Onyok event on December 19, 2015 served as input data.

The total precipitation for this event is 48.1 mm which peaked at 7.5 mm on 19 December 2015, 07:30. The lag time between the peak rainfall and discharge is three (3) hours and twenty (20) minutes.

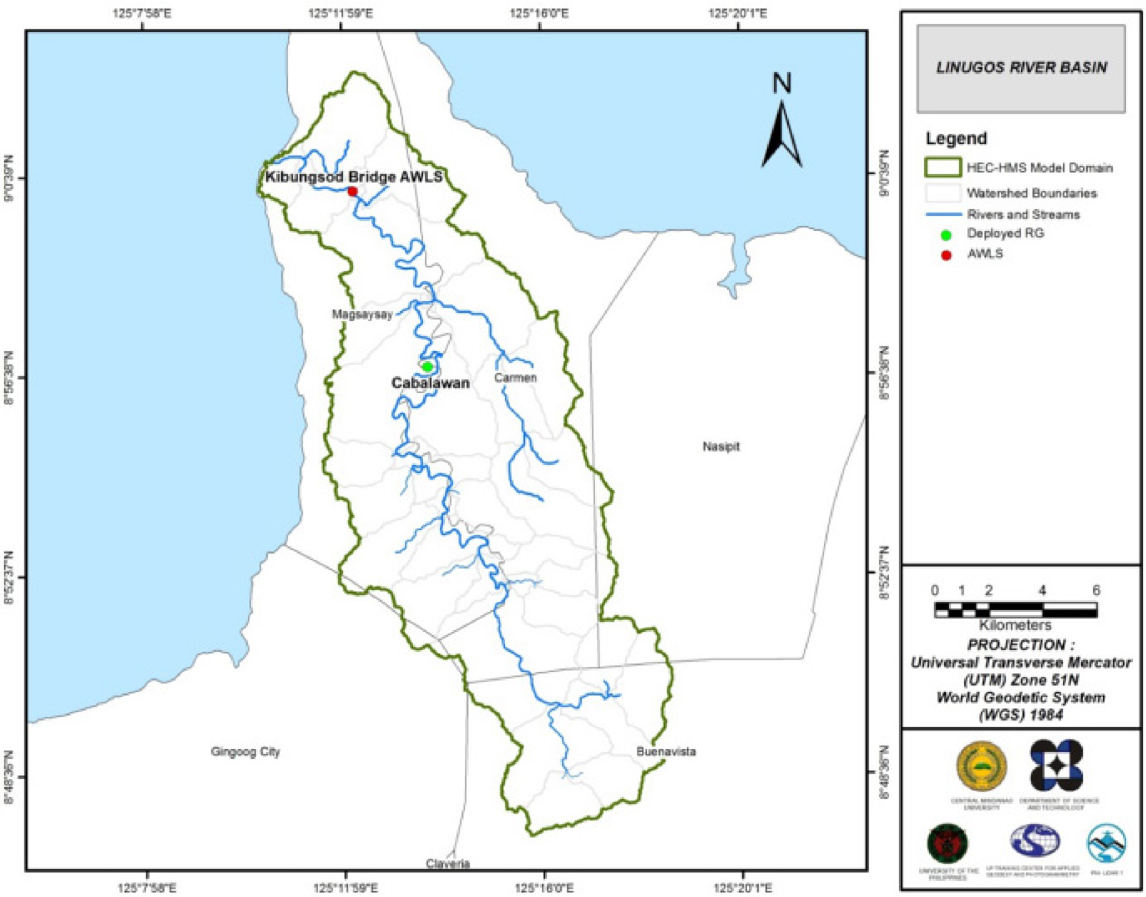


Figure 44. Location map of Linugos HEC-HMS model used for calibration.

5.1.3 Rating Curves and River Outflow

Simultaneous with the rainfall event, is the measurement of water level and velocity at the flow site. Flow measurements specifically conducted at the Kibungsod Bridge at Barangay Kibungsod, Magsaysay, Misamis Oriental (9°0'21.00"N, 125°12'12.07"E). These flow data are necessary in the calculation of river discharge. During the event, the peak discharge is 14.3 m3/s on 19 December 2015 at 10:50. Figure 51 shows river discharge as affected by the rainfall. The ITCZ event resulted to 1.97 meter of water level rise.

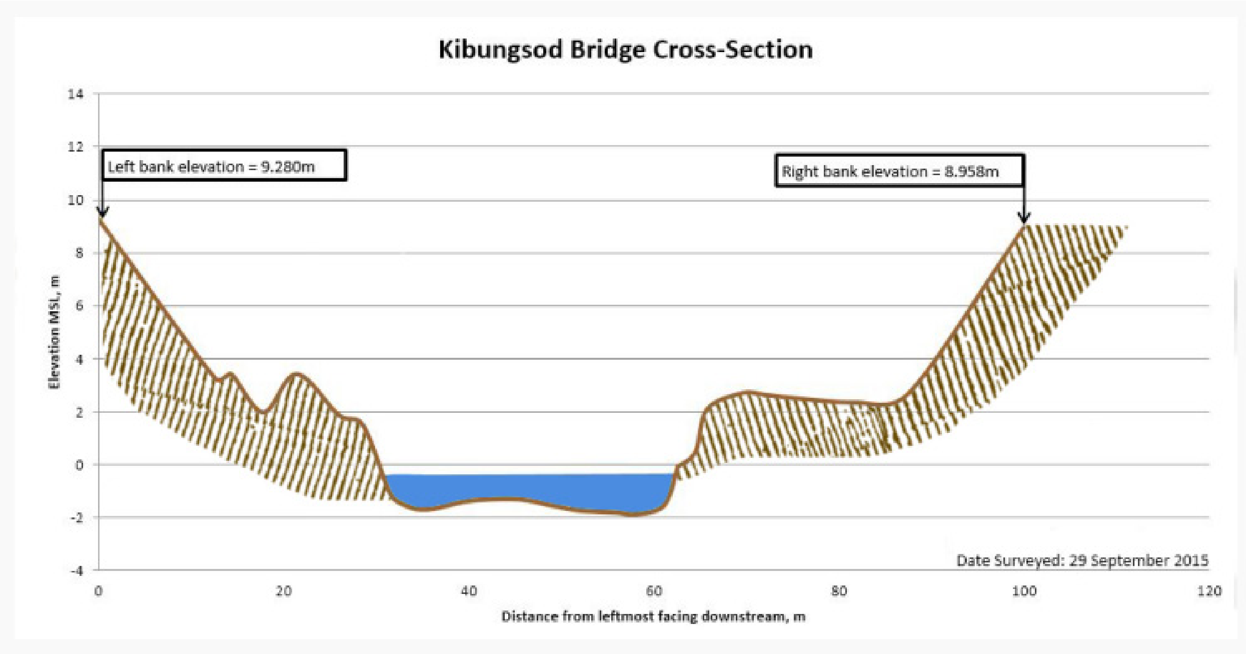


Figure 45. Cross-section plot of Linugos Bridge

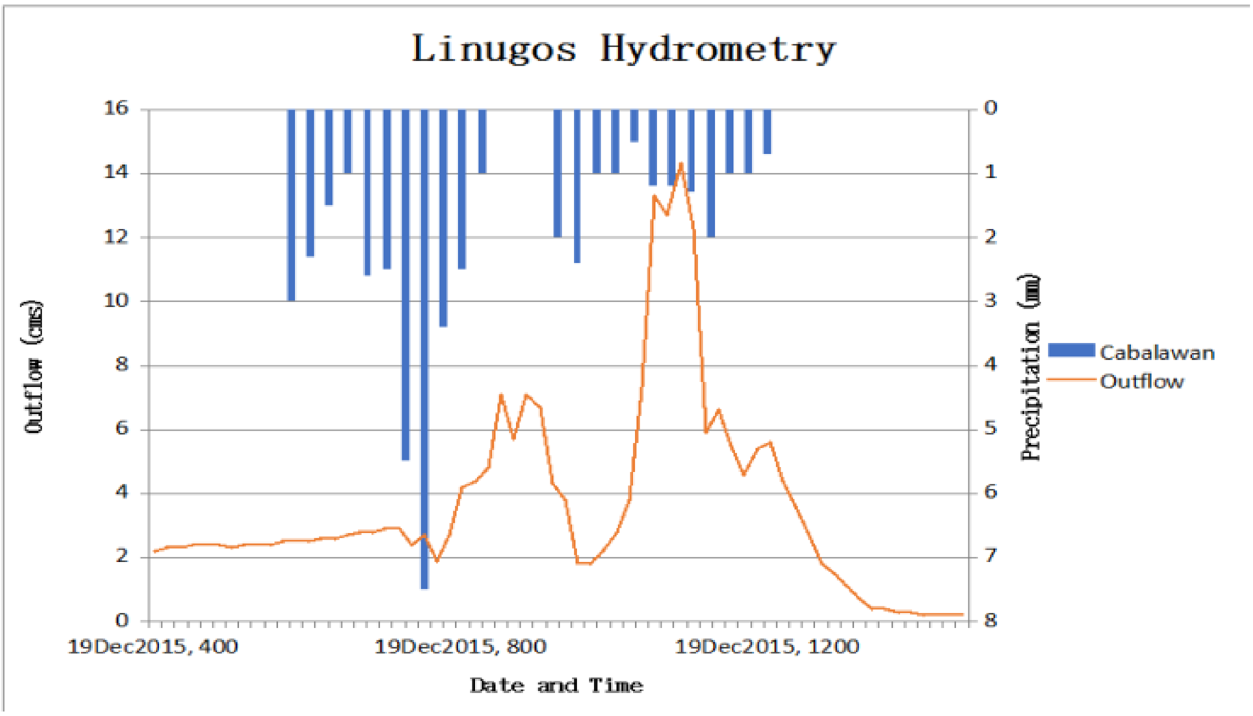


Figure 46. Rainfall and outflow data used for modeling.

The river outflow data were then used to generate rating curve. The curve gives the relationship between the observed water level and river outflow at the flow site location. It is expressed in the form of the following equation: Q=anh

where, Q : Discharge (m3/s),
h : Gauge height (reading from Kibungsod AWLS), and
a and n : Constants.

The Rating Curve for the data collected at the Kibungsod Bridge is expressed as Q = 1.6424e0.534h as shown in Figure 48. This equation is helpful in calculating discharge using water level data.

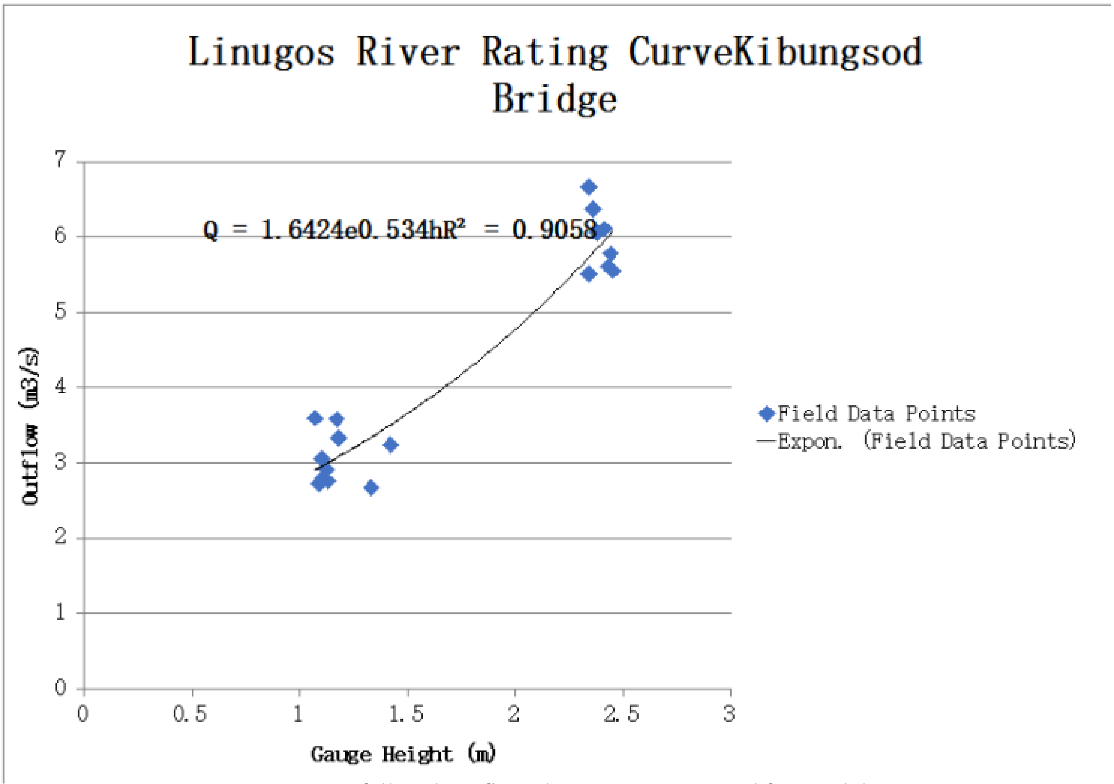


Figure 47. Rainfall and outflow data at Linugos used for modeling.

5.2 RIDF Station

The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) has data on Rainfall Intensity Duration Frequency (RIDF) for the Butuan Rain Gauge. It is the rain gauge station that covers the area of Linugos river basin with 21-year record of RIDF values. For this modeling, the Butuan station is chosen as basis for RIDF data for the simulations of five return periods.

Table 25. RIDF values for Butuan 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	18.2	28.2	32.4	40.8	55.5	63.7	81.7	100	126.4
5	23.9	36.6	41.7	52.9	71.2	81.3	104.6	142.6	175.2
10	27.6	42.1	47.9	60.8	81.5	93	119.7	170.8	207.5
15	29.7	45.3	51.4	65.3	87.4	99.6	128.3	186.7	225.7
20	31.1	47.4	53.8	68.5	91.5	104.2	134.2	197.9	238.5
25	32.3	49.1	55.7	70.9	94.6	107.7	138.8	206.5	248.3
50	35.8	54.3	61.5	78.4	104.3	118.7	153	232.9	278.6
100	39.2	59.5	67.3	85.8	114	129.5	167.1	259.1	308.6

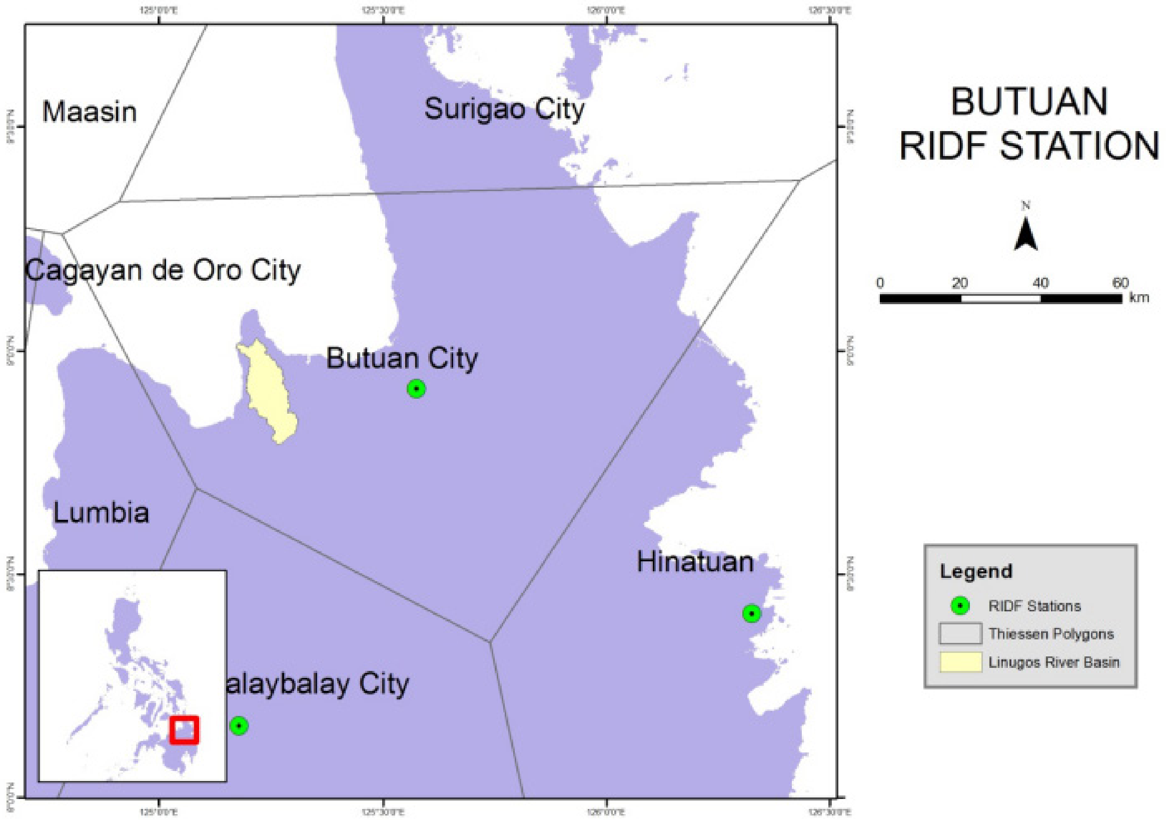


Figure 48. Location of Butuan RIDF Station relative to Linugos River Basin

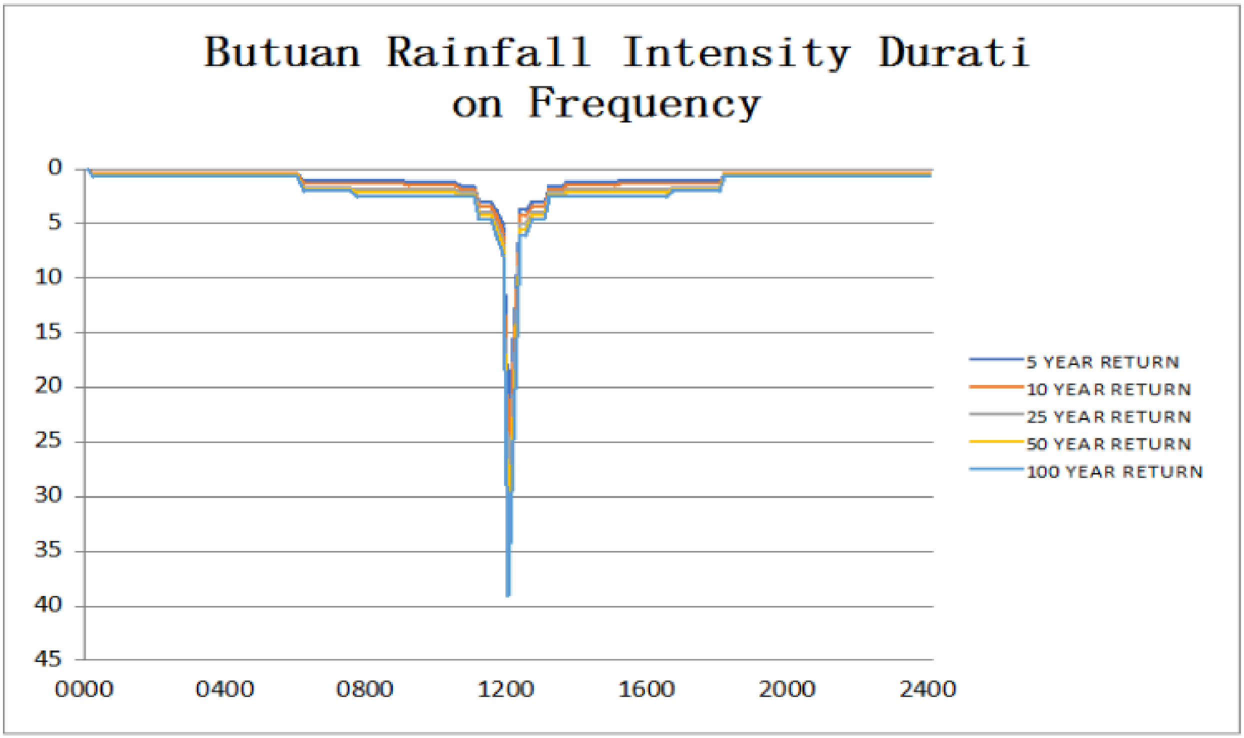


Figure 49. Synthetic storm generated for a 24-hr period rainfall for various return periods.

5.3 HMS Model

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

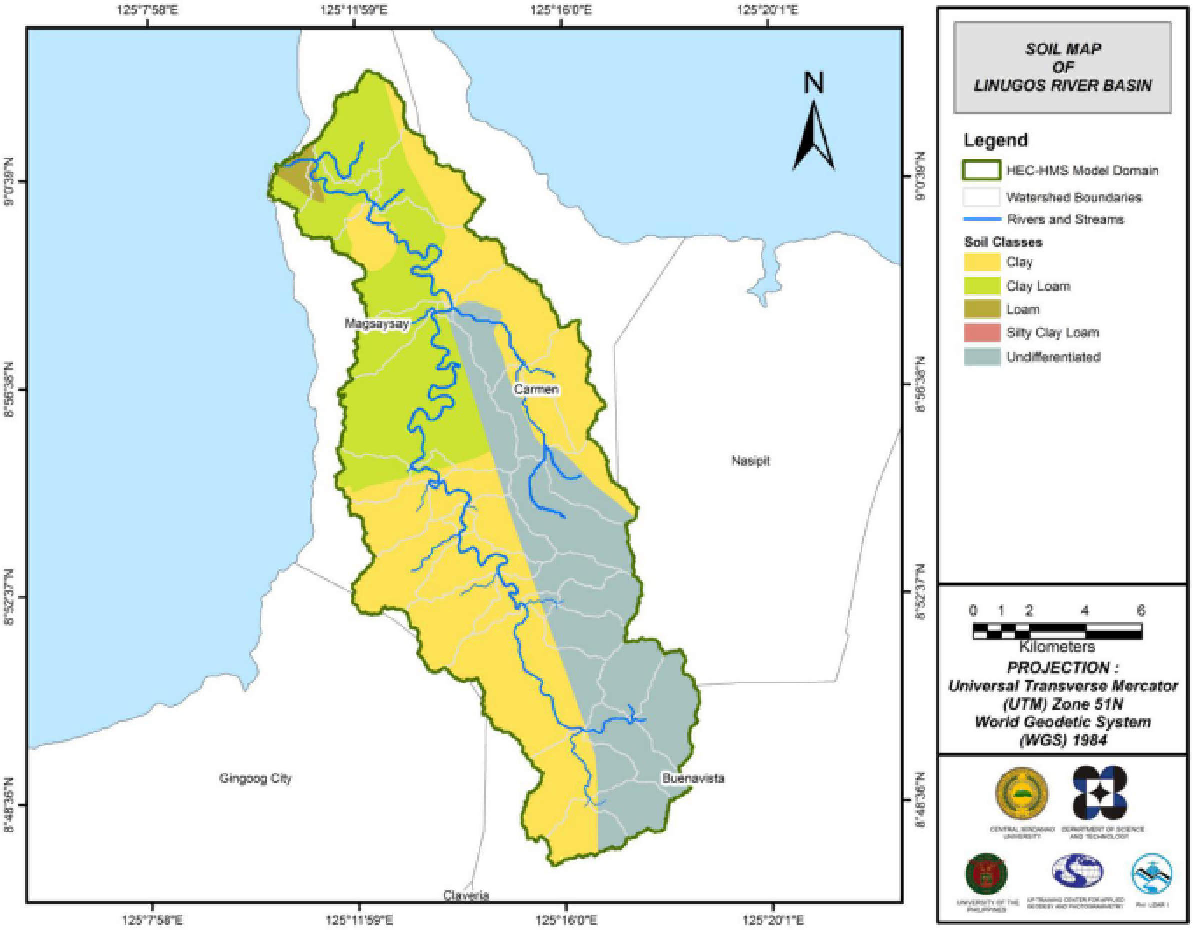


Figure 50. Soil Map of Linugos River Basin

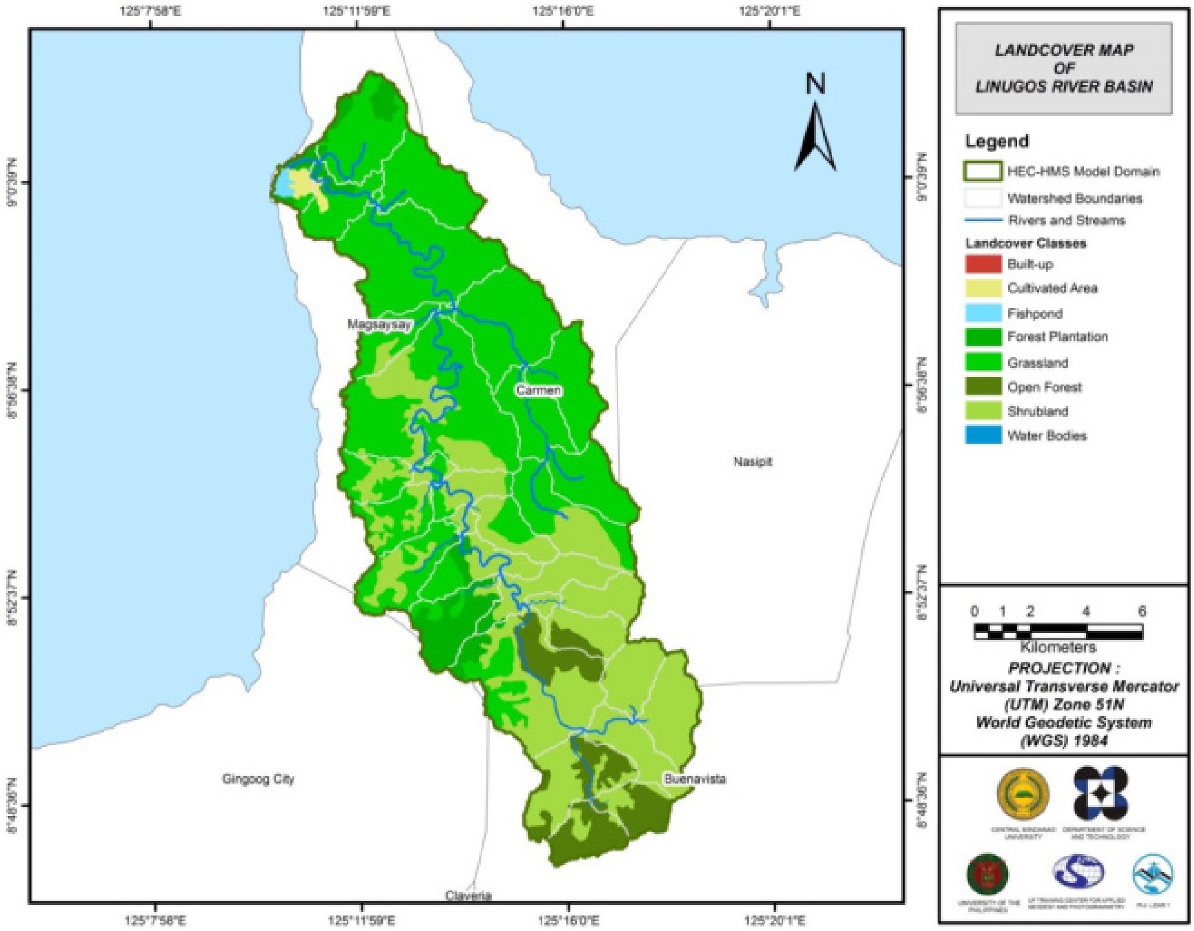


Figure 51. Land Cover Map of Linugos River Basin

For Linugos, five soil classes were identified. These are clay loam, clay, loam, silty clay loam and undifferentiated soil. Moreover, eight land cover classes were identified. These are built-up, cultivated area, fishpond, forest plantation, grassland, open forest, shrubland and water bodies.

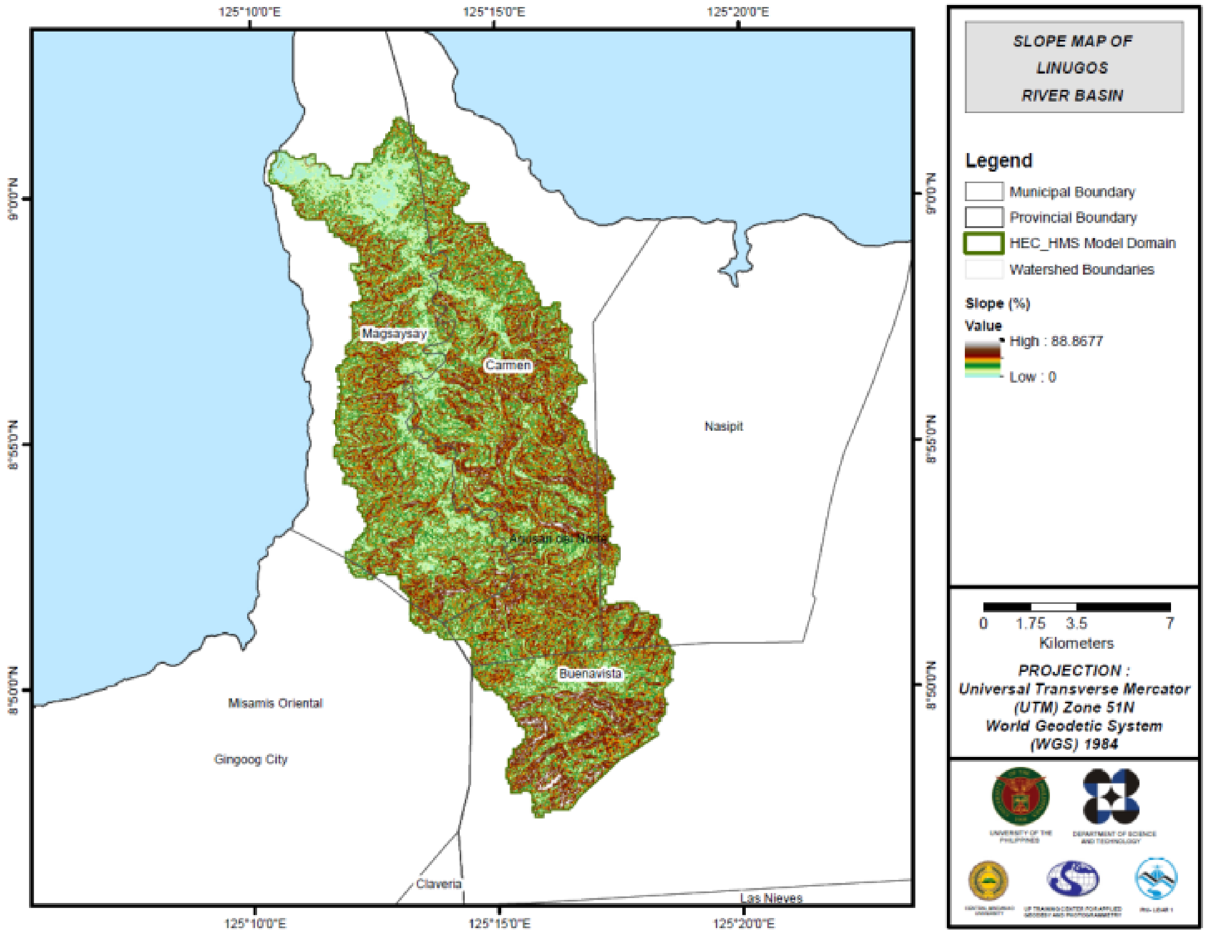


Figure 52. Slope Map of Linugos River Basin

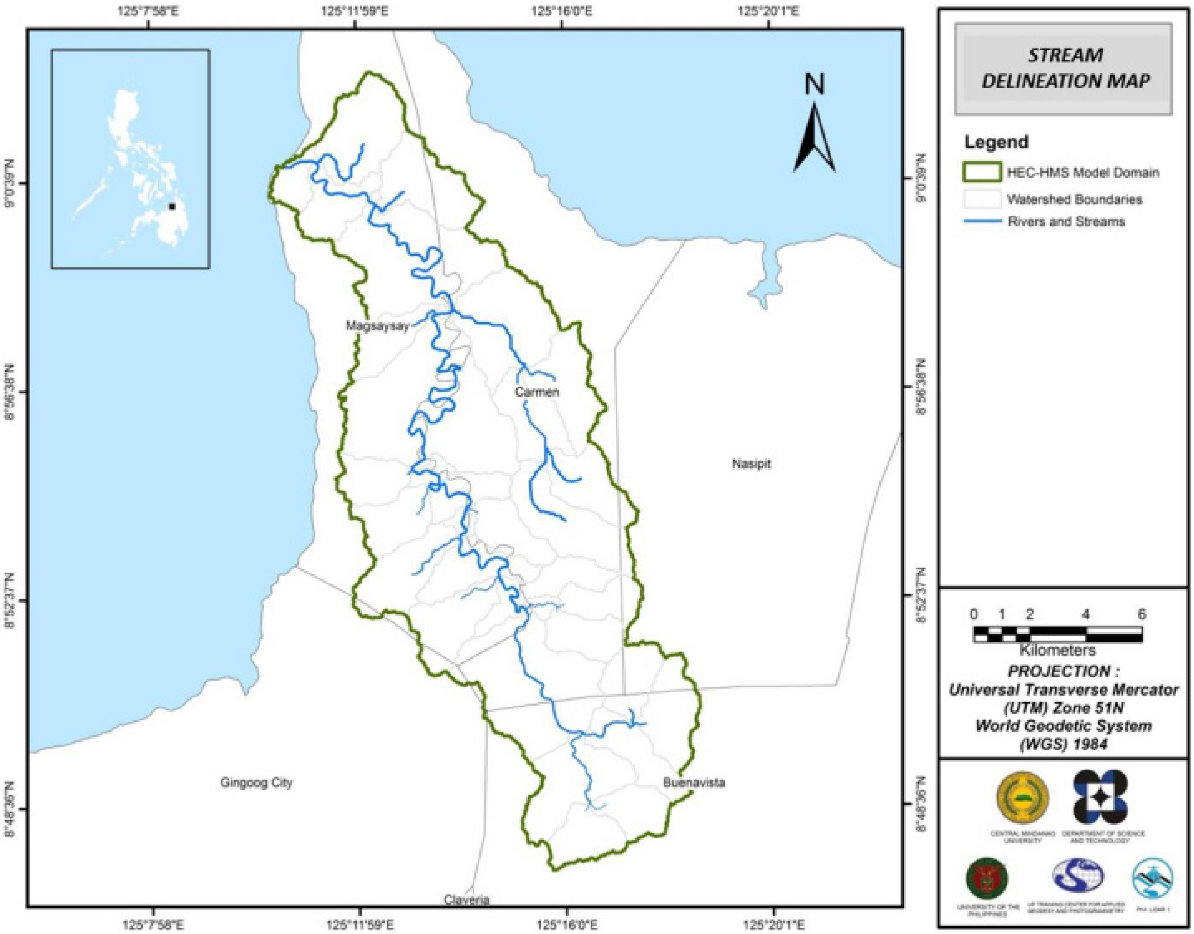


Figure 53. Stream Delineation Map of Linugos River Basin

Using the SAR-based DEM, the Linugos basin was delineated and further subdivided into subbasins.The model consists of 35 sub basins, 18 reaches, and 16 junctions. The main outlet located at the estuary of Barangay Poblacion is illustrated in Figure 54. Finally, it was calibrated using 19 December 2015 (Tropical Depression Onyok) hydrologic data. Hydrologic data such as precipitation data from manual rain gauge installed upstream, and discharge data calculated using the velocity data gathered through manual flow meter and water level data downloaded from AWLS at the Kibungsod Bridge, Brgy. Kibungsod.

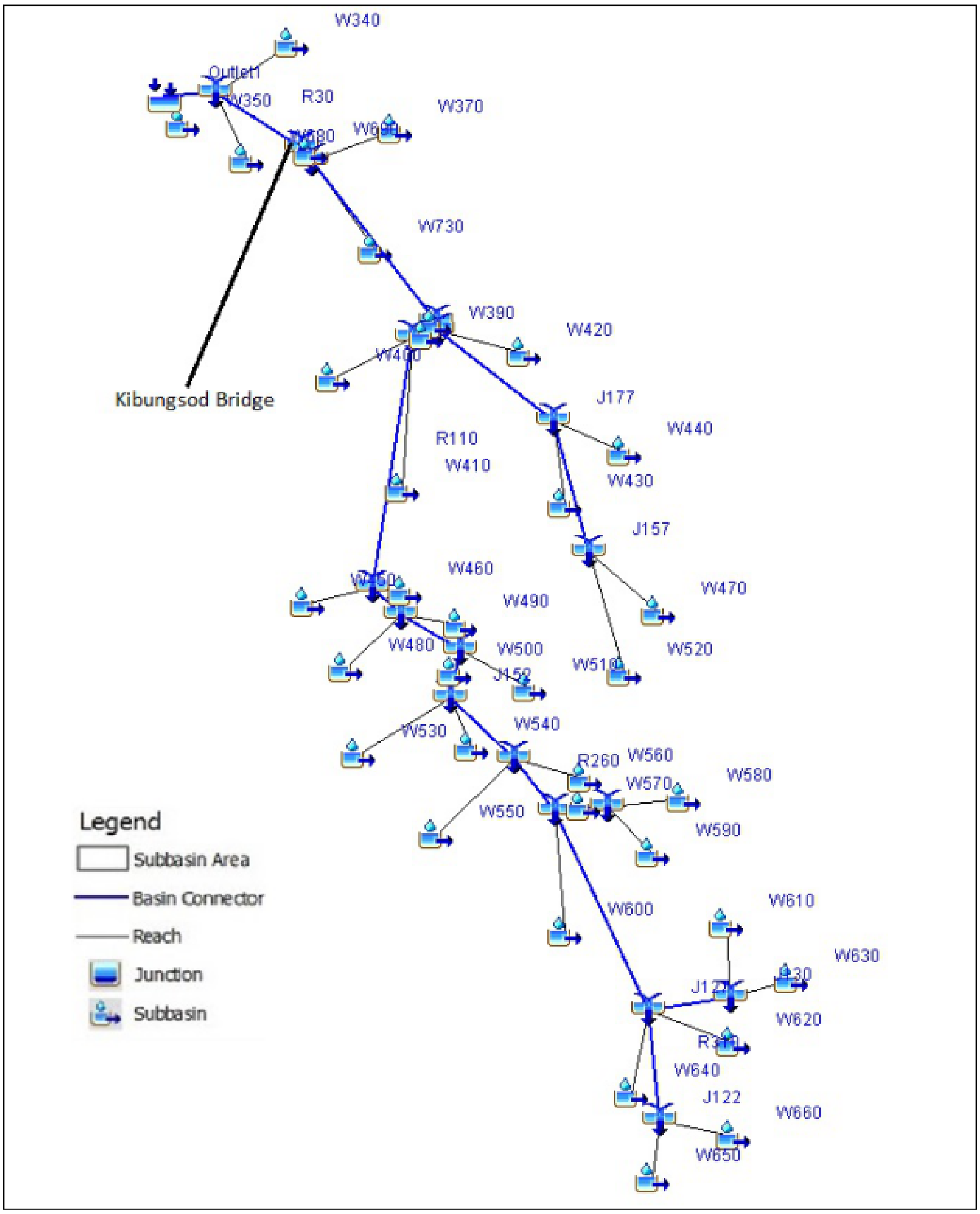


Figure 54. Linugos River Basin model generated in HEC-HMS

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.

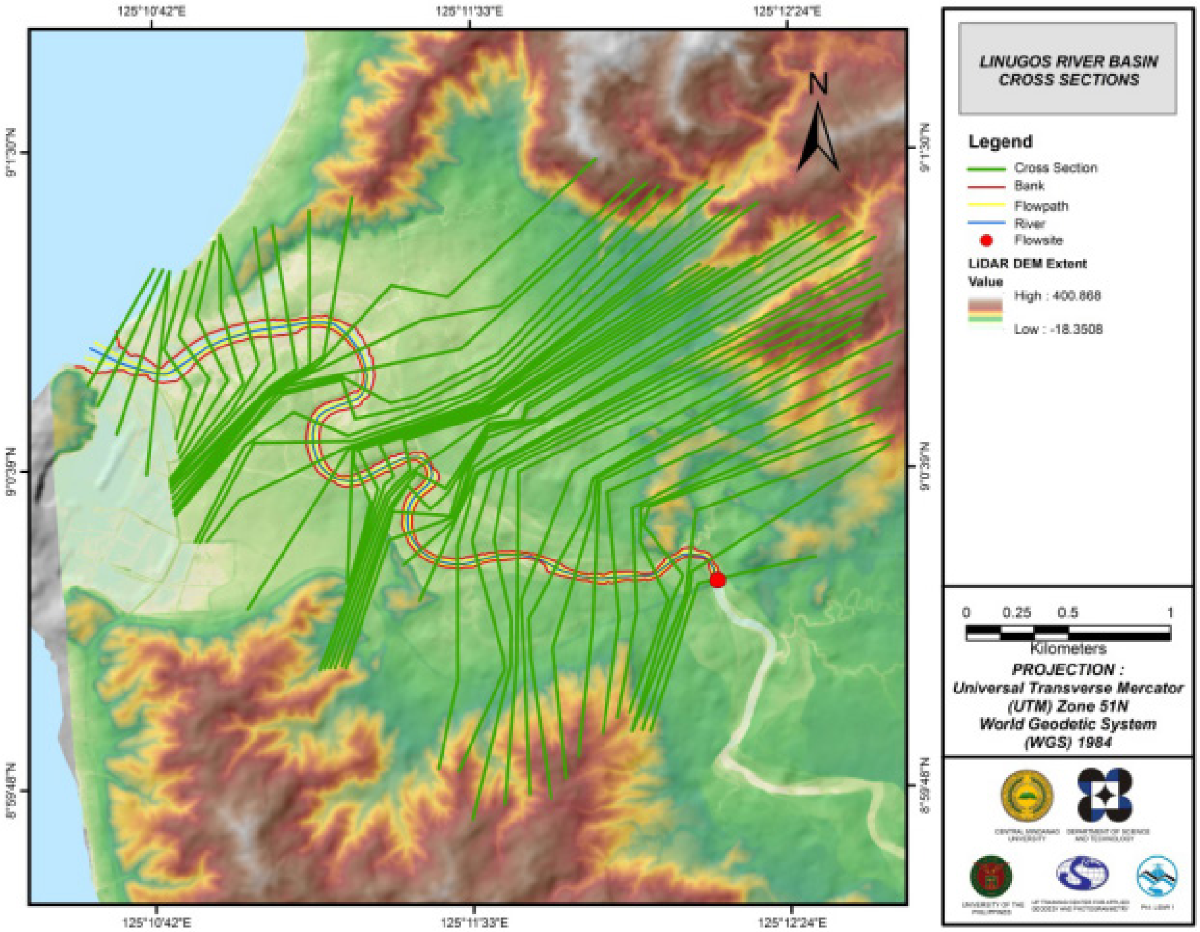


Figure 55. Linugos River Cross-section generated using HEC GeoRAS tool.

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 southeast of the model to the northwest, following the main channel. As such, boundary elements in those particular regions of the model are assigned as inflow and outflow elements respectively.

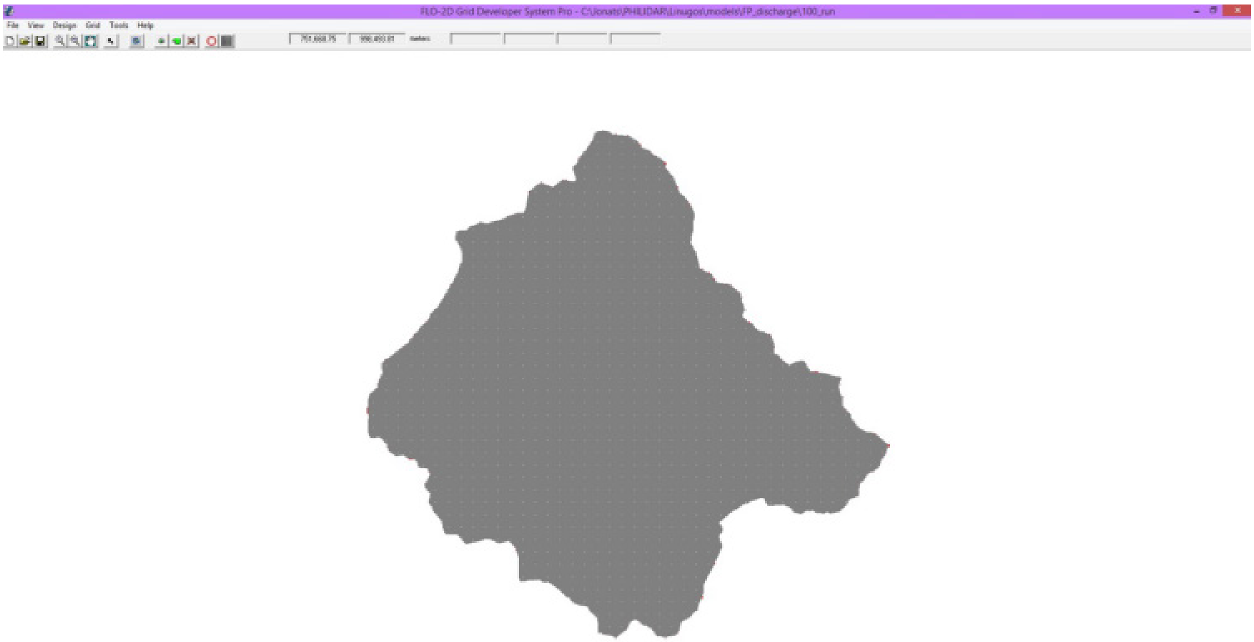


Figure 56. Screenshot of the river sub-catchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro)

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 48.46875 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 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 67 028 900.00 m2.

There is a total of 20157546.86 m3 of water entering the model. Of this amount, 20157546.86 m3 is due to rainfall while 0.00 m3 is inflow from other areas outside the model. 3267681.75 m3 of this water is lost to infiltration and interception, while 2062298.94 m3 is stored by the flood plain. The rest, amounting up to 14827569.87 m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Linugos HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 57 shows the comparison between the two discharge data.

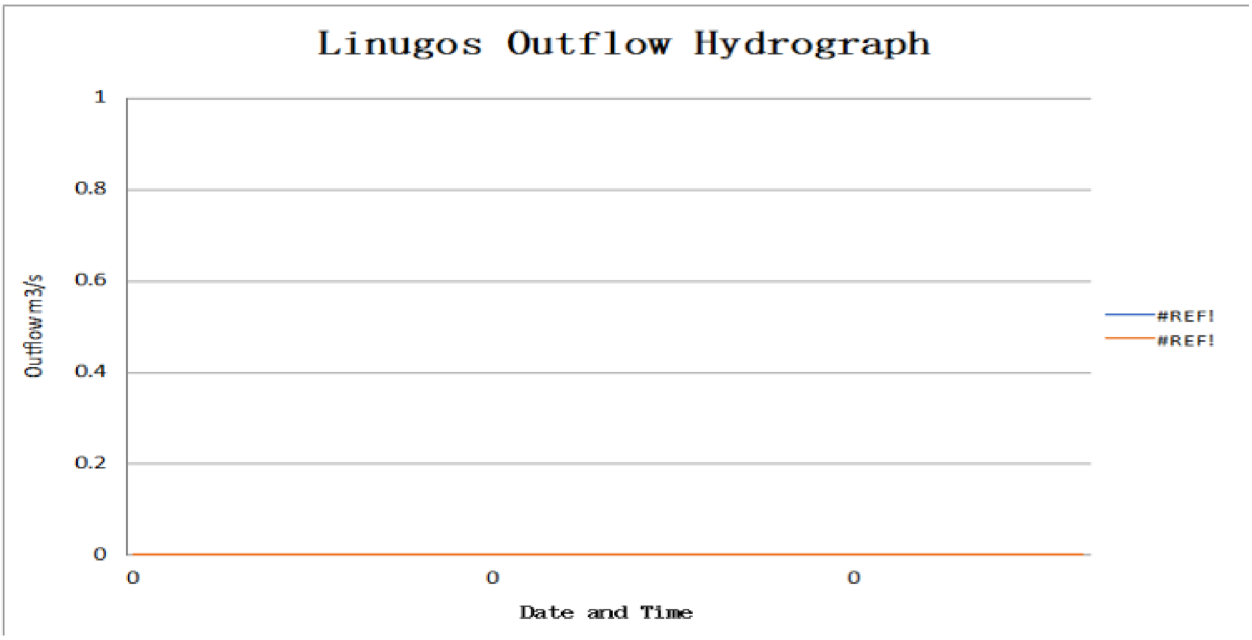


Figure 57. Outflow hydrograph of Linugos produced by the HEC-HMS model compared with observed outflow

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

Table 26. Range of calibrated values for the Linugos River Basin.

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	19.07 - 50
			Curve Number	35 – 97.02
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.01667 – 1.1
			Storage Coefficient (hr)	0.01667 – 2
	Baseflow	Recession	Recession Constant	0.00001
			Ratio to Peak	0.00001
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.0001 – 0.02

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 19.07mm to 50mm signifies that there is average amount of infiltration or rainfall interception by vegetation.

The curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 35 to 97.02 is wider than the range of curve number that is advisable for Philippine watersheds (70-80) depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For Linugos, the basin mostly consists of grassland and the soil consists of clay, clay loam, loam, silty clay loam, and undifferentiated soil.

The time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.01667 hour (1 minute) to 2 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events, while ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.00001 indicates that the basin will quickly go back to its original discharge. Ratio to peak of 0.00001 indicates a steeper receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.0001-0.02 in Linugos is less than the common roughness of 0.04 which is determined to be cultivated with mature field crops (Brunner, 2010).

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

Accuracy measure	Value
RMSE	0.8
r2	0.9313
NSE	0.93
PBIAS	-2.07
RSR	1.30

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 0.8 (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 0.9313.

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 0.93.

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 -2.07.

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 1.30.

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 58) shows the Linugos outflow using the Butuan 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.

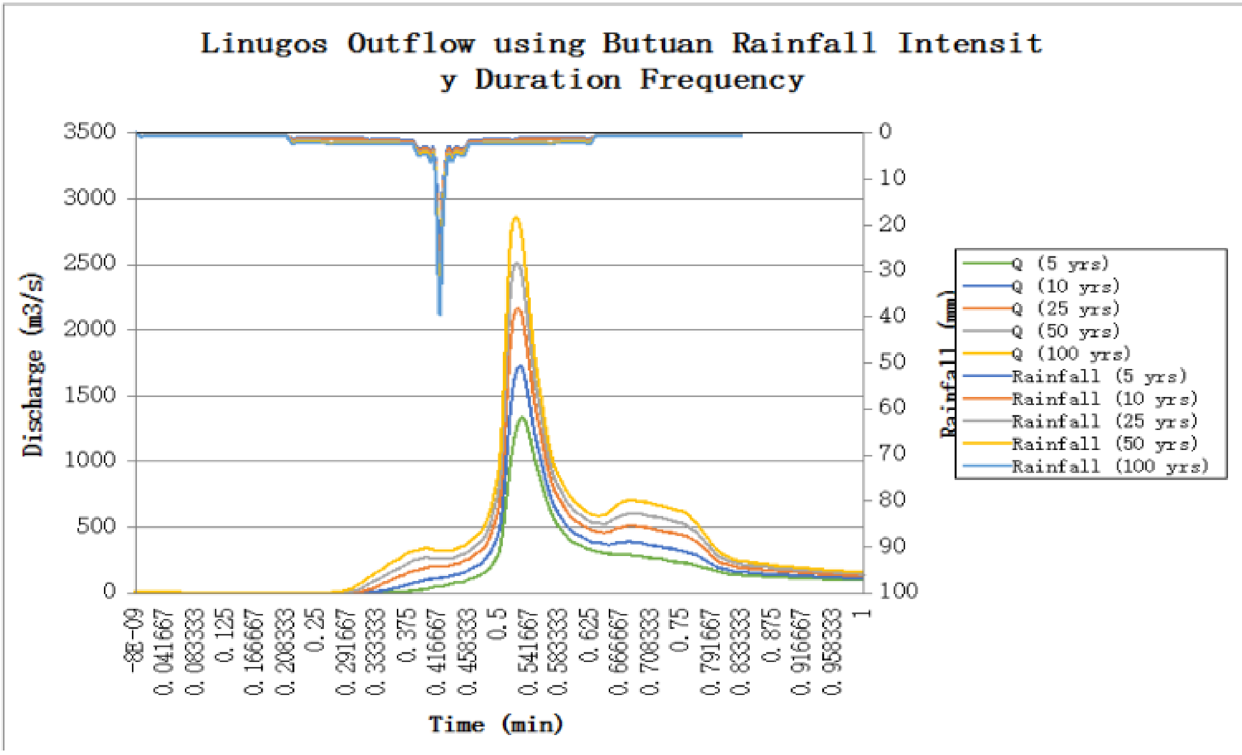


Figure 58. The Outflow hydrograph at Linugos Station generated using Butuan RIDF simulated in HEC-HMS

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

Table 28. Peak values of the Linugos HEC-HMS Model outflow using the Butuan RIDF 24-hour values.

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	175.2	23.9	1326.5	40 minutes
10-Year	207.5	27.6	1727.6	40 minutes
25-Year	248.3	32.3	2147.1	40 minutes
50-Year	278.6	35.8	2487.3	30 minutes
100-Year	308.6	39.2	2849	30 minutes

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. For this publication, only a sample output map river was to be shown. The sample generated map of Linugos River using the calibrated HMS base flow is shown in Figure 59.

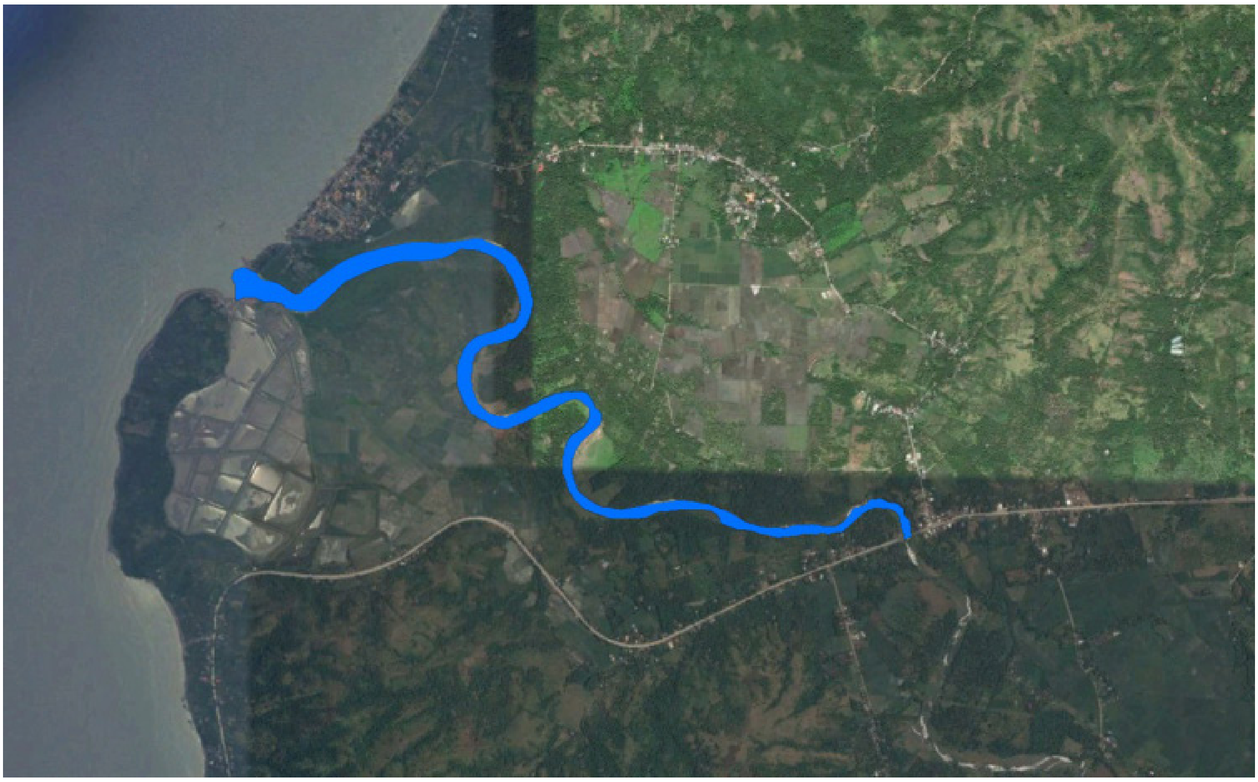


Figure 59. Sample output map of Linugos RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figure 60 to Figure 65 shows the 5-, 25-, and 100-year rain return scenarios of the Linugos floodplain. The floodplain, with an area of 29.76 sq. km., covers two municipalities namely Magsaysay and Carmen. Table shows the percentage of area affected by flooding per municipality.

Table 29. Municipalities affected in Linugos Floodplain

Municipality	Total Area	Area Flooded	% Flooded
Carmen	129.17	0.74	0.57%
Magsaysay	112.20	28.99	25.84%

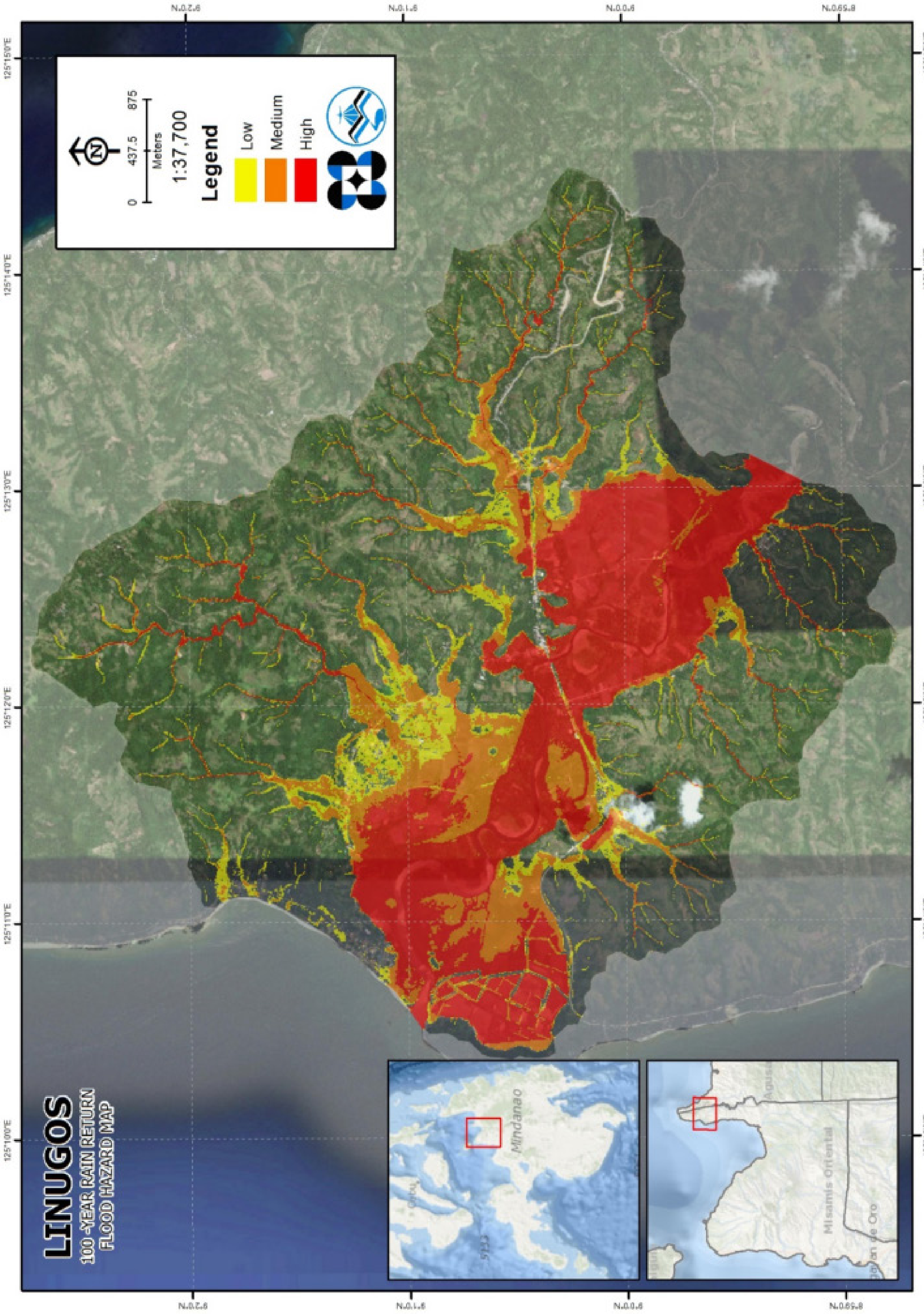


Figure 60. A 100-year flood hazard map for Linugos Floodplain

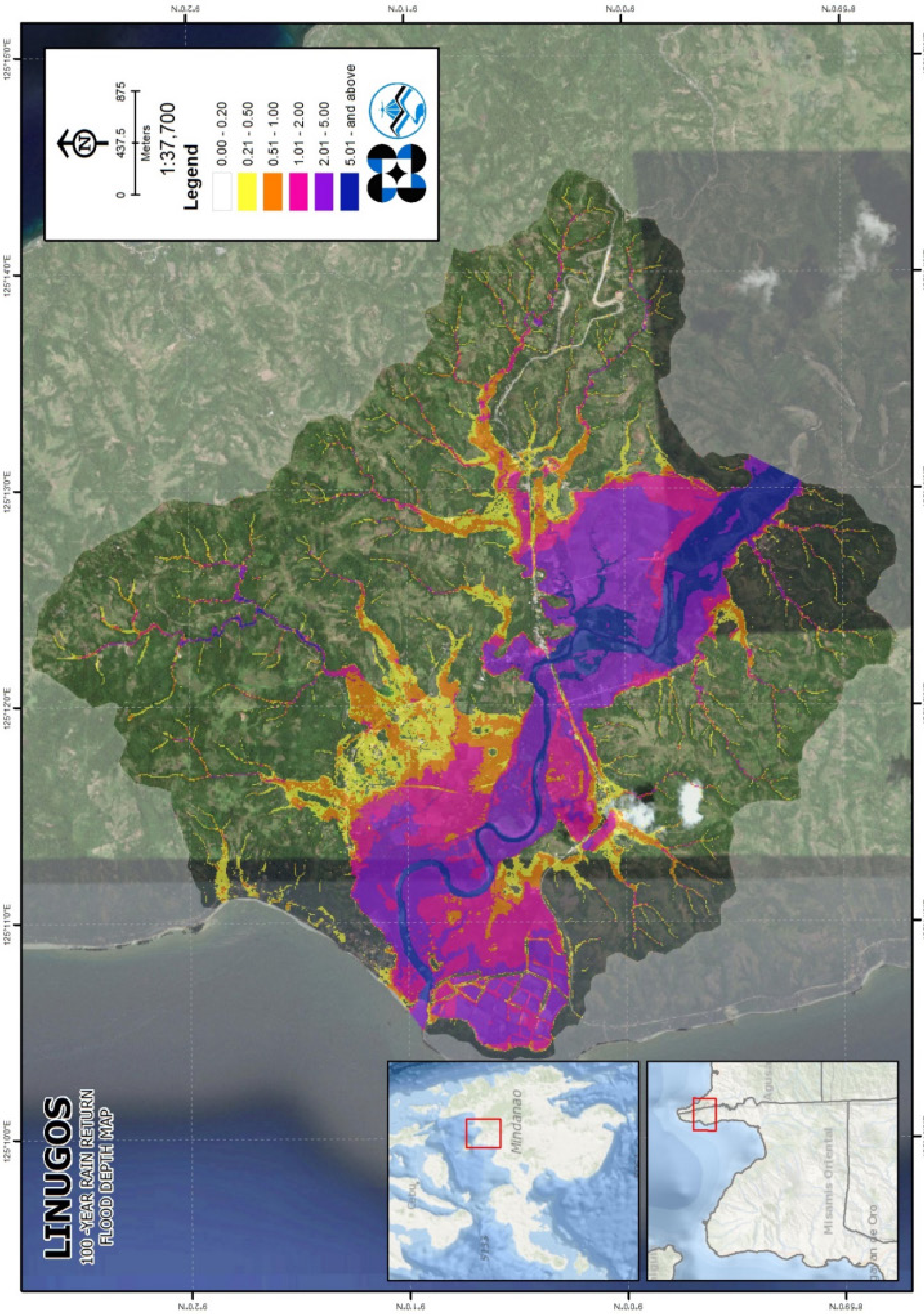


Figure 61. A 100-year Flow Depth Map for Linugos Floodplain

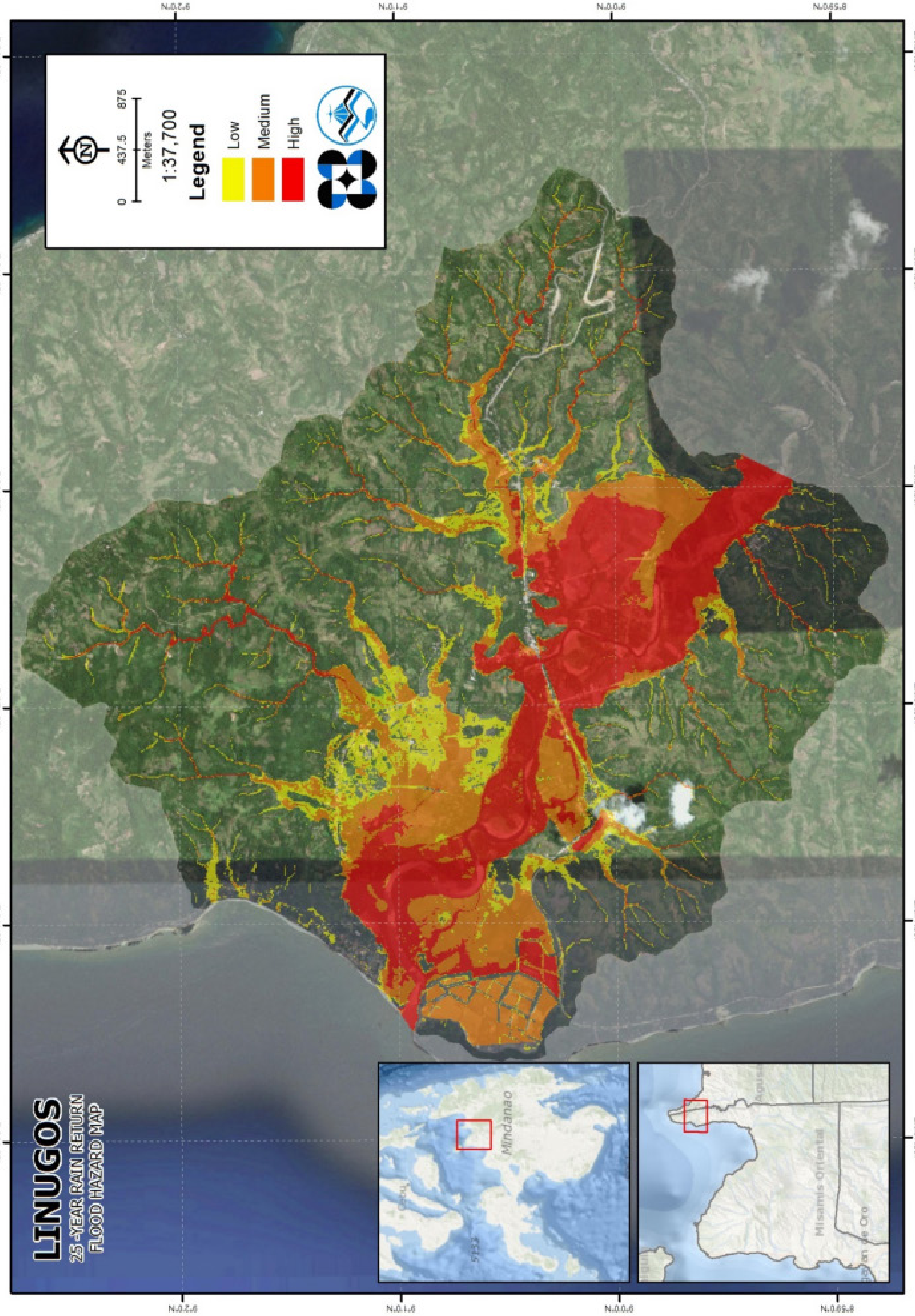


Figure 62. A 25-year Flood Hazard Map for Linugos Floodplain

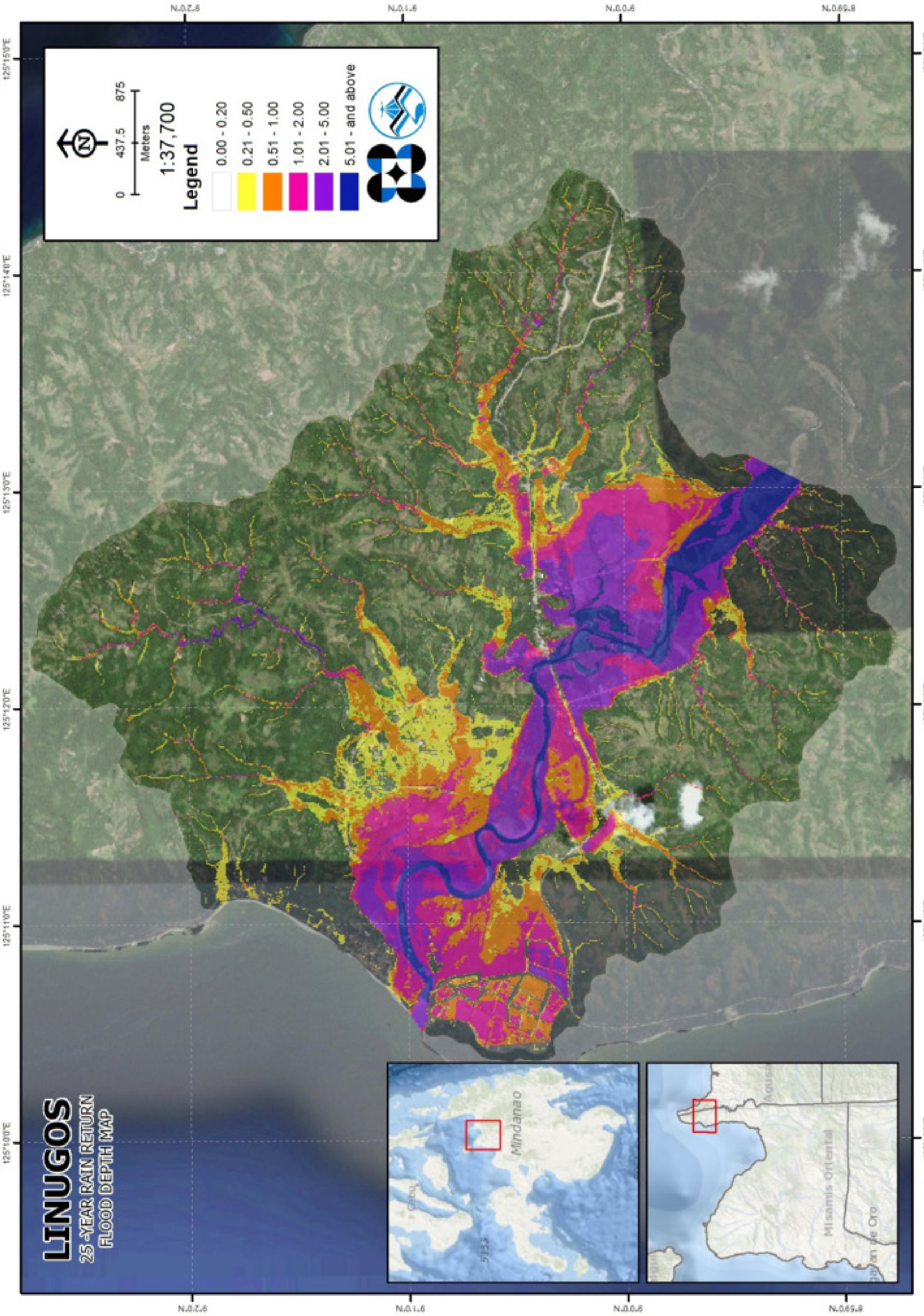


Figure 63. A 25-year Flow Depth Map for Linugos Floodplain

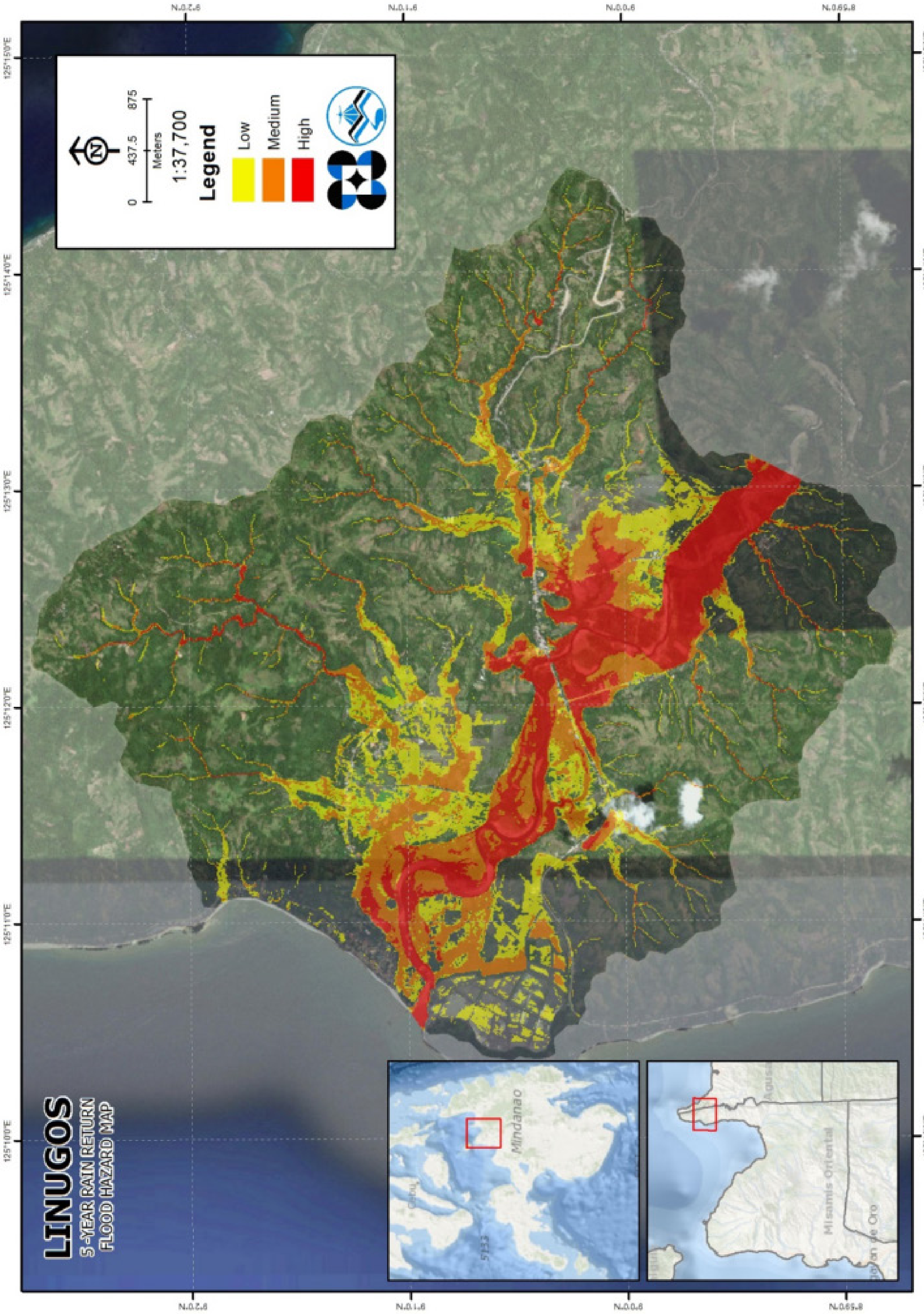


Figure 64. A 5-year Flood Hazard Map for Linugos Floodplain

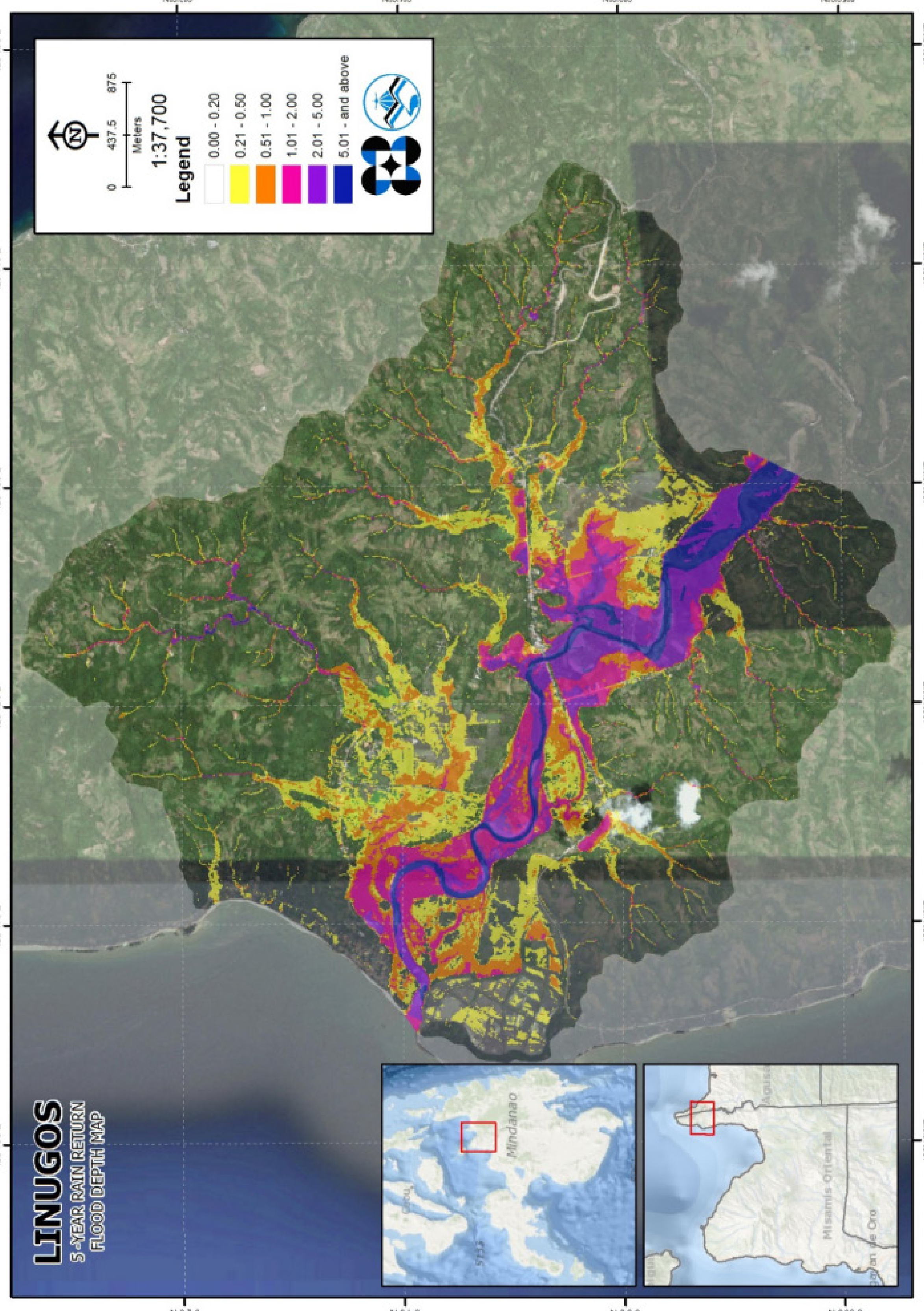


Figure 65. A 5-year Flow depth map for Linugos Floodplain.

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Linugos river basin, grouped by municipality, are listed below. For the said basin, two municipalities consisting of 13 barangays are expected to experience flooding when subjected to 5-, 25-, and 100-yr rainfall return period.

For the 5-year return period, 16.03% of the municipality of Magsaysay with an area of 118.0532 sq. km. will experience flood levels of less than 0.20 meters. 2.32% of the area will experience flood levels of 0.21 to 0.50 meters while 1.38%, 1.20%, 1.05%, and 0.50% 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.

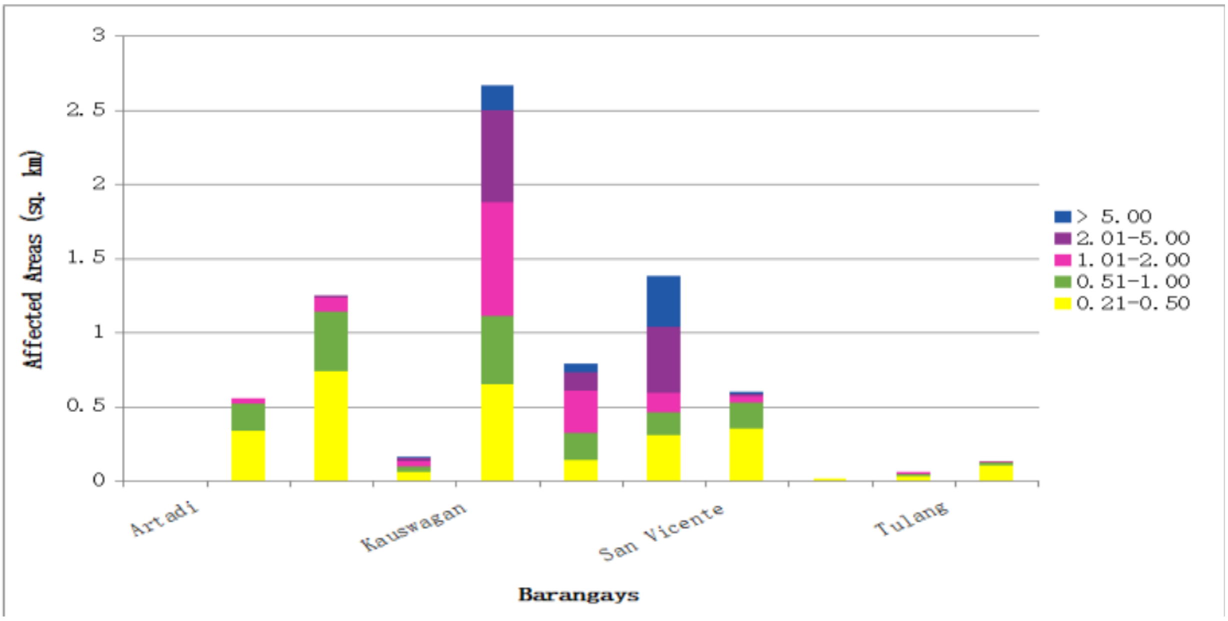


Figure 66. Affected Areas in Magsaysay, Misamis Oriental during 5-Year Rainfall Return Period

Table 30. Affected Areas in Magsaysay, Misamis Oriental during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Magsaysay (in sq. km.)										
	Artadi	Cabantian	Cabubuhan	Kauswagan	Kibungsod	Poblacion	San Vicente	Santa Cruz	Tibon-Tibon	Tulang	Villa Felipa
0.03-0.20	0.0024	2.08	2.14	3.23	3	0.57	2.64	1.75	0.53	1.12	1.86
0.21-0.50	0.0001	0.34	0.74	0.063	0.65	0.14	0.31	0.35	0.012	0.028	0.1
0.51-1.00	0	0.18	0.4	0.034	0.46	0.18	0.15	0.18	0.0037	0.019	0.028
1.01-2.00	0	0.035	0.099	0.033	0.77	0.29	0.13	0.044	0.0013	0.0097	0.0066
2.01-5.00	0	0.0017	0.014	0.027	0.62	0.12	0.45	0.0081	0.0006	0.0021	0.0013
> 5.00	0	0	0.0004	0.0059	0.17	0.059	0.34	0.015	0	0	0

For the 5-year return period, 2.47% of the municipality of Carmen with an area of 122.638235 sq. km. will experience flood levels of less than 0.20 meters. 0.06% of the area will experience flood levels of 0.21 to 0.50 meters while 0.05%, 0.02%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 31. Affected areas in Carmen, Agusan del Norte during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Carmen (in sq. km)	
	Cahayagan	Tagcatong
0.03-0.20	0.51	2.52
0.21-0.50	0.011	0.066
0.51-1.00	0.0078	0.051
1.01-2.00	0.0029	0.027
2.01-5.00	0.0001	0.014
> 5.00	0	0.0002

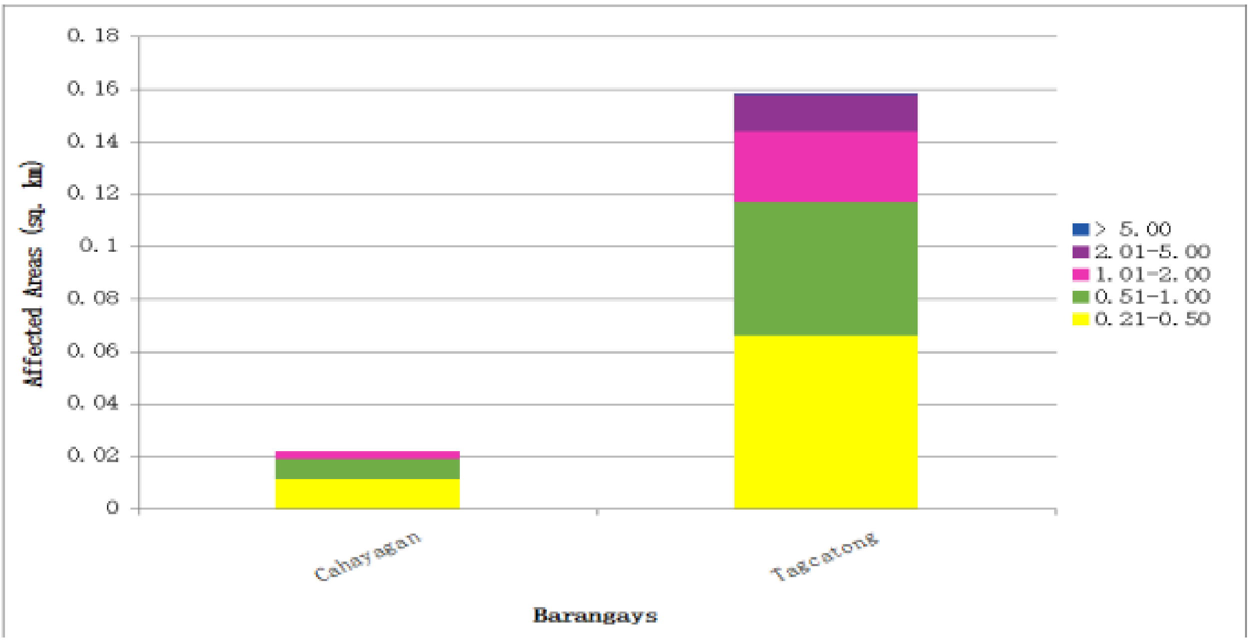


Figure 67. Affected Areas in Carmen, Agusan del Norte during 5-Year Rainfall Return Period

For the 25-year return period, 0.00% of the municipality of Magsaysay with an area of 118.0532 sq. km. will experience flood levels of less than 0.20 meters. 1.34% of the area will experience flood levels of 0.21 to 0.50 meters while 1.78%, 2.08%, 1.82%, and 0.75% 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.

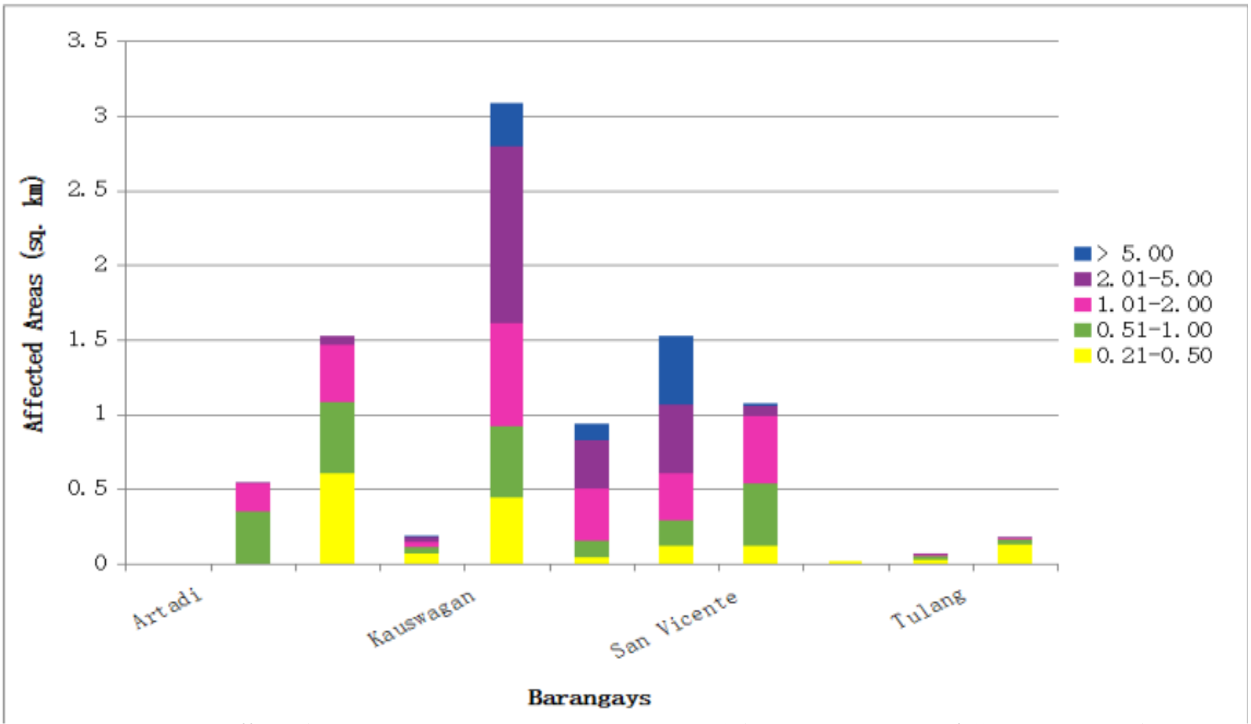


Figure 68. Affected Areas in Magsaysay, Misamis Oriental during 25-Year Rainfall Return Period

Table 32. Affected Areas in Magsaysay, Misamis Oriental during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Magsaysay (in sq. km.)										
	Artadi	Cabantian	Cabubuhan	Kauswagan	Kibungsod	Poblacion	San Vicente	Santa Cruz	Tibon-Tibon	Tulang	Villa Felipa
0.03-0.20	0	0	0	0	0	0	0	0	0	0	0
0.21-0.50	0	0	0.61	0.073	0.44	0.047	0.12	0.12	0.014	0.029	0.13
0.51-1.00	0	0.35	0.47	0.035	0.48	0.11	0.17	0.42	0.0055	0.021	0.036
1.01-2.00	0	0.19	0.39	0.037	0.69	0.35	0.32	0.45	0.0017	0.014	0.0087
2.01-5.00	0	0.006	0.057	0.034	1.19	0.32	0.46	0.071	0.0006	0.0028	0.0024
> 5.00	0	0	0.0034	0.008	0.29	0.11	0.46	0.015	0	0	0

For the 25-year return period, 0.00% of the municipality of Carmen with an area of 122.638235 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 0.05%, 0.04%, and 0.02% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

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

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Carmen (in sq. km)	
	Cahayagan	Tagcatong
0.03-0.20	0	0
0.21-0.50	0	0
0.51-1.00	0.0084	0.055
1.01-2.00	0.0054	0.038
2.01-5.00	0.00019	0.019
> 5.00	0	0.0003

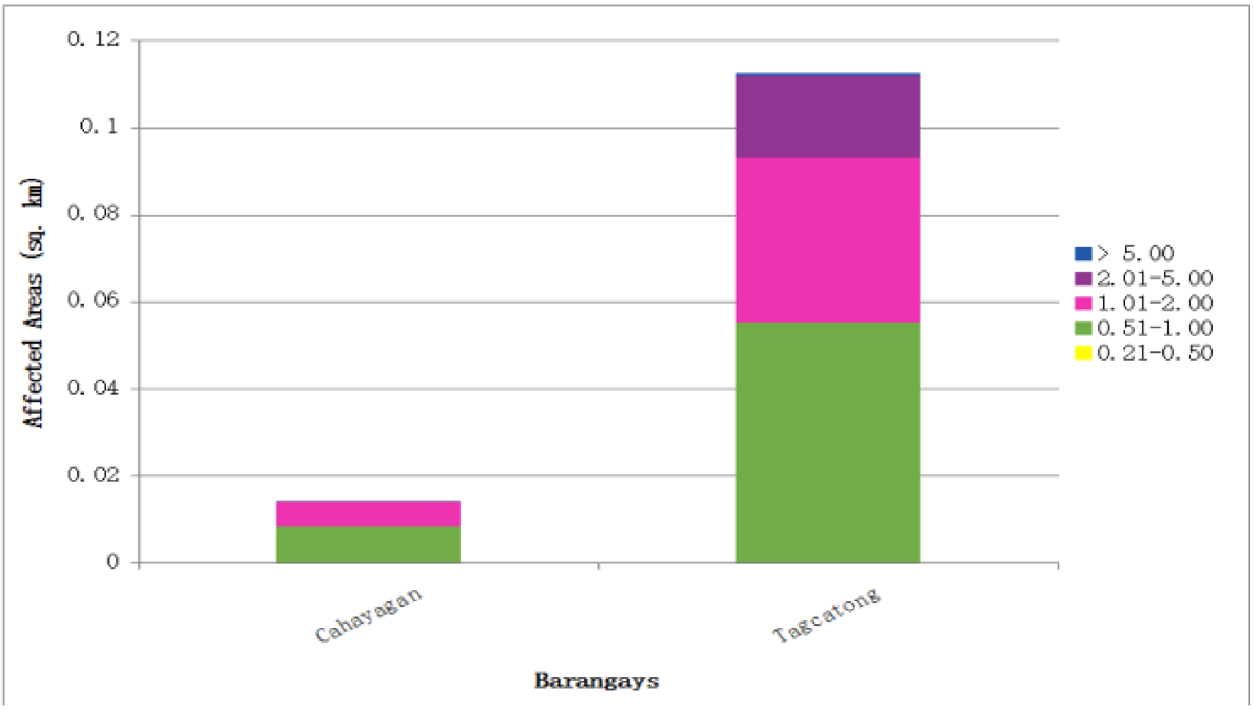


Figure 69. Affected Areas in Carmen, Agusan del Norte during 25-Year Rainfall Return Period

For the 100-year return period, 8.30% of the municipality of Magsaysay with an area of 118.0532 sq. km. will experience flood levels of less than 0.20 meters. 1.39% of the area will experience flood levels of 0.21 to 0.50 meters while 1.36%, 2.06%, 2.76%, and 0.95% 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.

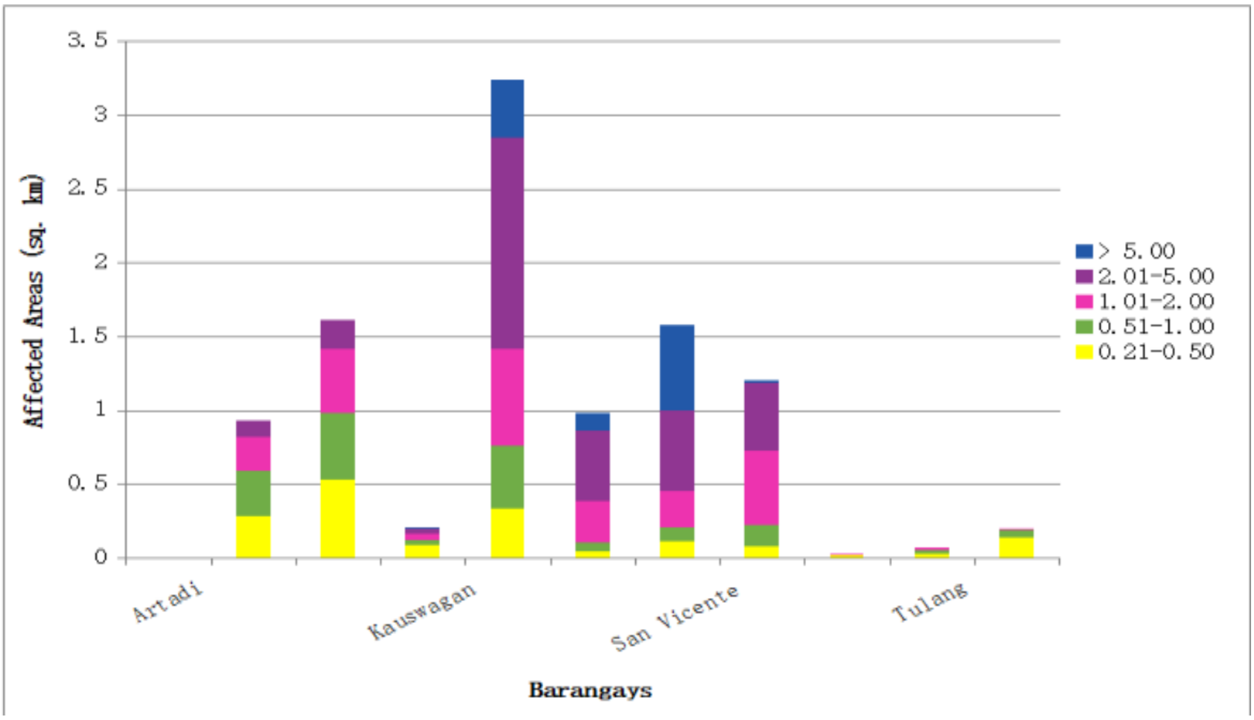


Figure 70. Affected Areas in Magsaysay, Misamis Oriental during 100-Year Rainfall Return Period

Table 34. Affected Areas in Magsaysay, Misamis Oriental during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Magsaysay (in sq. km.)										
	Artadi	Cabantian	Cabubuhan	Kauswagan	Kibungsod	Poblacion	San Vicente	Santa Cruz	Tibon-Tibon	Tulang	Villa Felipa
0.03-0.20	0	0	0	0	2.43	0.38	2.43	1.13	0.52	1.11	1.8
0.21-0.50	0.0001	0.28	0.53	0.083	0.33	0.042	0.11	0.079	0.014	0.03	0.14
0.51-1.00	0	0.31	0.45	0.04	0.43	0.061	0.097	0.14	0.0068	0.021	0.047
1.01-2.00	0	0.23	0.44		0.66	0.28	0.25	0.51	0.0018	0.017	0.01
2.01-5.00	0	0.11	0.19	0.038	1.43	0.48	0.54	0.46	0.00075	0.0038	0.0035
> 5.00	0	0	0.0052	0.011	0.39	0.12	0.58	0.015	0	0.0001	0

For the 100-year return period, 0.00% of the municipality of Carmen with an area of 122.638235 sq. km. will experience flood levels of less than 0.20 meters. 0.07% of the area will experience flood levels of 0.21 to 0.50 meters while 0.05%, 0.04%, and 0.02% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

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

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Carmen (in sq. km)	
	Cahayagan	Tagcatong
0.03-0.20	0	0
0.21-0.50	0.012	0.068
0.51-1.00	0.0097	0.055
1.01-2.00	0.0067	0.047
2.01-5.00	0.00029	0.022
> 5.00	0	0.0006

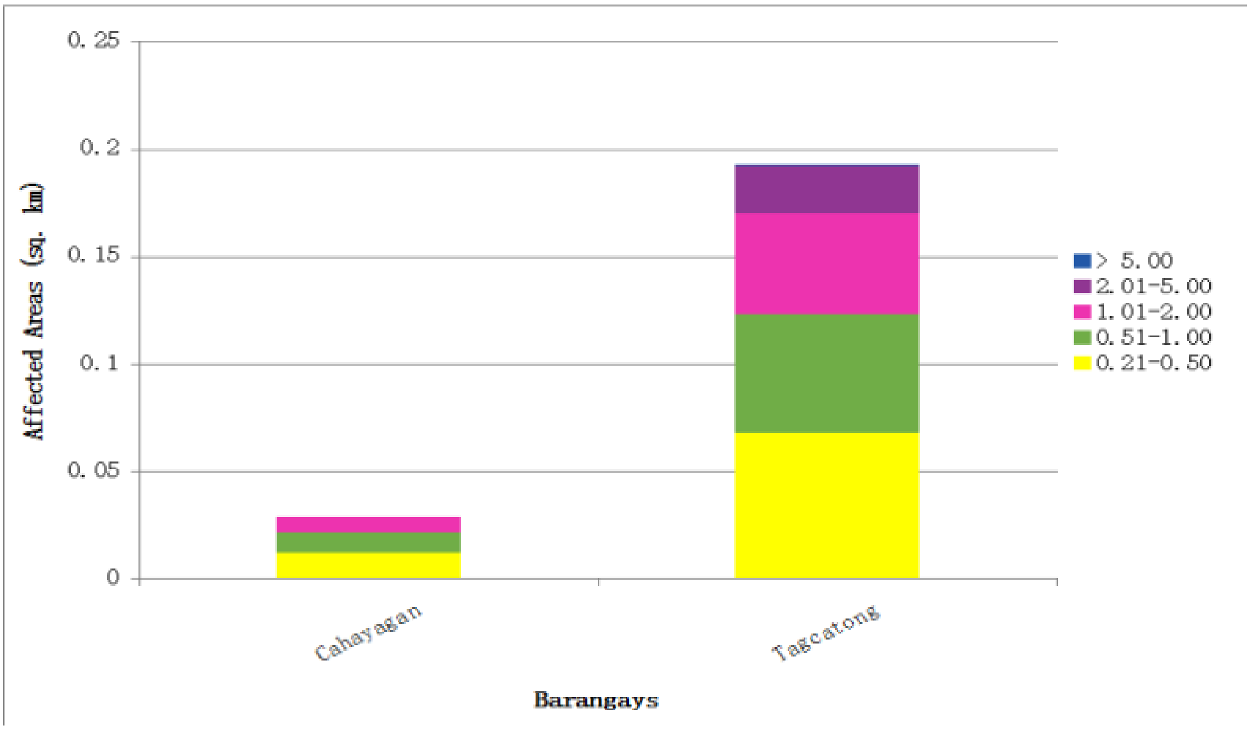


Figure 71. Affected Areas in Carmen, Agusan del Norte during 100-Year Rainfall Return Period

Among the barangays in the municipality of Magsaysay in Misamis Oriental, Kibungsod is projected to have the highest percentage of area that will experience flood levels at 4.80%. Meanwhile, San Vicente posted the second highest percentage of area that may be affected by flood depths at 3.39%.

Among the barangays in the municipality of Carmen in Agusan del Norte, Tagcatong is projected to have the highest percentage of area that will experience flood levels at 0.16%. Meanwhile, Cahayagan posted the second highest percentage of area that may be affected by flood depths at 0.02%.

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

Table 36. Areas covered by each warning level with respect to the rainfall scenarios

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	2.83	1.94	1.7
Medium	2.57	3.58	2.84
High	2.52	4.22	5.81
TOTAL	**7.92**	**9.74**	**10.35**

Of the 12 identified Education Institute in Linugos Flood plain, three (3) schools were discovered exposed to Low-level flooding during a 5-year scenario while one (1) school was found exposed to Medium-level and two (2) schools were found exposed to High-level flooding in the same scenario.

In the 25-year scenario, two schools were found exposed to Low-level flooding while two (2) schools were discovered exposed to Medium-level flooding and two (2) schools were discovered exposed to High-level flooding.

For the 100-year scenario, one school was discovered exposed to Low-level flooding while four (4) schools were found exposed to Medium-level and two (2) schools were found exposed to High-level flooding. See Appendix D for a detailed enumeration of schools in the Linugos floodplain.

Apart from this, two (2) Medical Institutions were identified in the Linugos Floodplain, one was found exposed to High-level flooding in all scenarios while the other one was discovered exposed to Low-level flooding in the 25-year and 100-year scenario. See Appedix E for a detailed enumeration of hospitals and clinics in the Linugos floodplain.

5.11 Flood Validation

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

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

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

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

The flood validation consists of 239 points randomly selected all over the Linugos flood plain. It has an RMSE value of 0.98.

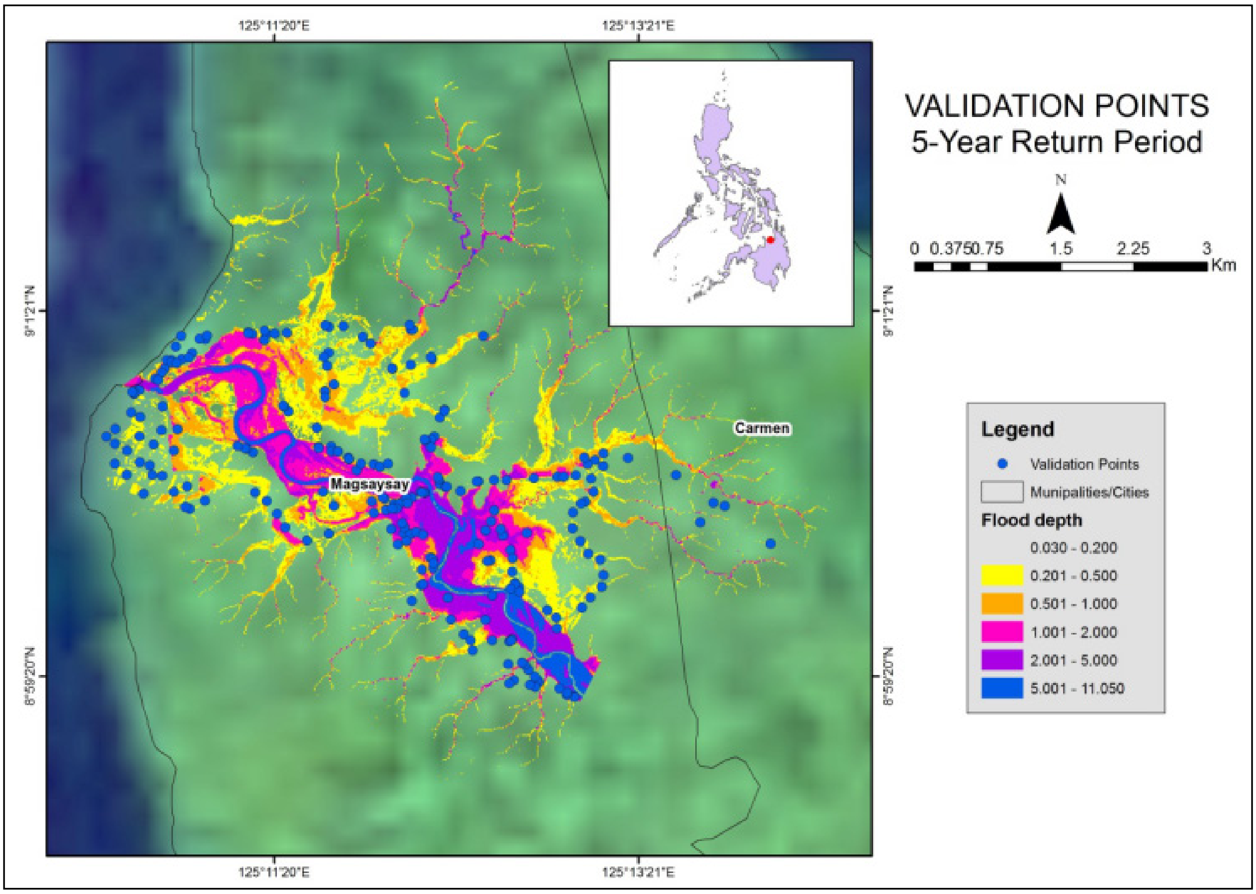


Figure 72. Linugos Flood Validation Points

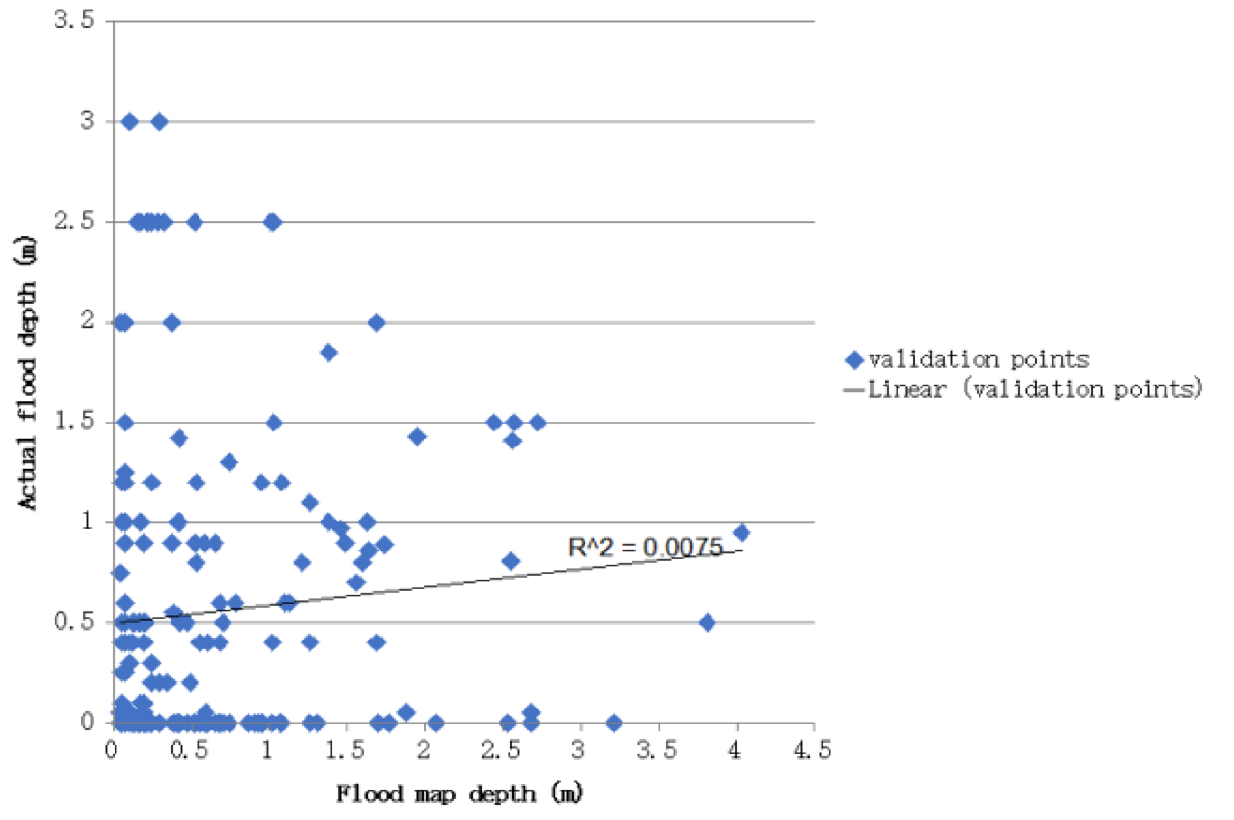


Figure 73. Flood map depth vs. actual flood depth

Table 37. Actual flood vs simulated flood depth at different levels in the Linugos River Basin.

Actual Flood Depth (m)	Modeled Flood Depth (m)						
	0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
0-0.20	77	16	21	9	5	0	128
0.21-0.50	20	3	4	3	1	0	31
0.51-1.00	9	4	6	11	2	0	32
1.01-2.00	19	3	3	6	4	0	35
2.01-5.00	4	6	1	2	0	0	13
> 5.00	0	0	0	0	0	0	0
Total	129	32	35	31	12	0	239

The overall accuracy generated by the flood model is estimated at 38.49%, with 92 points correctly matching the actual flood depths. In addition, there were 64 points estimated one level above and below the correct flood depths while there were 39 points and 44 points estimated two levels above and below, and three or more levels above and below the correct flood depth. A total of 76 points were overestimated while a total of 71 points were underestimated in the modelled flood depths of Linugos. Table depicts the summary of the Accuracy Assessment in the Linugos River Basin Survey.

Table 38. The summary of the Accuracy Assessment in the Linugos River Basin Survey

	No. of Points	%
Correct	92	38.49
Overestimated	76	31.80
Underestimated	71	29.71
Total	239	100

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 Aquarius Sensor

Table A-1.1. Parameters and Specification of Aquarius Sensor

Parameter	Specification
Operational altitude	300-600 m AGL
Laser pulse repetition rate	33, 50. 70 kHz
Scan rate	0-70 Hz
Scan half-angle	0 to ± 25 ˚
Laser footprint on water surface	30-60 cm
Depth range	0 to > 10 m (for k < 0.1/m)
Topographic mode	
Operational altitude	300-2500
Range Capture	Up to 4 range measurements, including 1st, 2nd, 3rd, and last returns
Intensity capture	12-bit dynamic measurement range
Position and orientation system	POS AVTM 510 (OEM) includes embedded 72-channel GNSS receiver (GPS and GLONASS)
Data Storage	Ruggedized removable SSD hard disk (SATA III)
Power	28 V, 900 W, 35 A
Image capture	5 MP interline camera (standard); 60 MP full frame (optional)
Full waveform capture	12-bit Optech IWD-2 Intelligent Waveform Digitizer (optional)
Dimensions and weight	Sensor:250 x 430 x 320 mm; 30 kg;
Control rack: 591 x 485 x 578 mm; 53 kg	Removable solid state disk SSD (SATA II)
Operating temperature	0-35˚C
Relative humidity	0-95% no-condensing
	Control rack: 650 x 590 x 490 mm; 46 kg
Operating Temperature	-10°C to +35°C
Relative humidity	0-95% non-condensing

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

1. AGN-10

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

June 26, 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: **AGUSAN DEL NORTE**
Station Name: **AGN-10**
Order: **3rd**

Island: **MINDANAO**
Municipality: **CARMEN**
Barangay: **TAGCATONG**

		PRS92 Coordinates			
Latitude:	**9° 0' 0.89032"**	Longitude:	**125° 15' 35.40217"**	Ellipsoidal Hgt:	**9.27600 m.**
		WGS84 Coordinates			
Latitude:	**8° 59' 57.22480"**	Longitude:	**125° 15' 40.75438"**	Ellipsoidal Hgt:	**77.30100 m.**
		PTM Coordinates			
Northing:	**995175.315 m.**	Easting:	**528569.795 m.**	Zone:	**5**
		UTM Coordinates			
Northing:	**995,583.65**	Easting:	**748,451.81**	Zone:	**51**

Location Description

AGN-10
Is located on the SE side of the reinforced concrete pipe culvert. It is about 40 m. SE of Km. Post 1275 and is about 200 m. W of Tagcatong Elem. School. Station mark is the head of a 4" concrete nail set flush on a 0.10 m. x 0.10 m. cement putty set on top of the concrete gutter, 1 m. dia. reinforced concrete pipe culvert. It is inscribed with the station name "AGN-10 2001 NAMRIA".

Requesting Party: **UP-TCAGP**
Pupose: **Reference**
OR Number: **8796391 A**
T.N.: **2014-1473**

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

99042620141113912

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.1. AGN-10

2. AN-44

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

June 26, 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: **AGUSAN DEL NORTE**
Station Name: **AN-44**

Island: **Mindanao**	Municipality: **CARMEN**	Barangay: **TAGCATONG**
Elevation: **10.9546 m.**	Order: **1st Order**	Datum: **Mean Sea Level**

Location Description

AN-44
Along the Butuan-Zamboanga National road. The station is located on top of the head wall of a box culvert at the side of the road, about 30 meters south east of KM Post 1275, and about 3 meters south west of the centerline of the road. A brass rod is set on a drilled hole and cemented flushed on top o a 15cm x 15cm cement putty with inscription "AN-44 2007 NAMRIA".

Requesting Party: **UP-TCAGP**
Pupose: **Reference**
OR Number: **8796391 A**
T.N.: **2014-1471**

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

9 9 0 6 2 6 2 0 1 4 1 1 3 8 1 3

CIP/4701/12/01/814

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.2. AN-44

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

1. AGN-10

Table A-3.1. AGN-10

Project information		Coordinate System	
Name:		Name:	UTM
Size:		Datum:	PRS 92
Modified:	8/7/2014 11:04:25 AM (UTC:8)	Zone:	51 North (123E)
Time zone:	Malay Peninsula Standard Time	Geoid:	EGMPH
Reference number:		Vertical datum:	
Description:			

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
AGN10 — LE50 (B1)	LE50	AGN10	Fixed	0.022	0.073	56°59'17"	169944.486	3.036

Acceptance Summary

Processed	Passed	Flag	Fail
1	1	0	0

AGN10 - LE50 (8:39:49 AM-2:03:58 PM) (S1)

Baseline observation:	AGN10 — LE50 (B1)
Processed:	8/7/2014 4:26:44 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.022 m
Vertical precision:	0.073 m
RMS:	0.006 m
Maximum PDOP:	4.839
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	6/28/2014 8:40:36 AM (Local: UTC+8hr)
Processing stop time:	6/28/2014 2:03:58 PM (Local: UTC+8hr)
Processing duration:	05:23:22
Processing interval:	1 second

1

Vector Components (Mark to Mark)

From:	LE50				
Grid		Local		Global	
Easting	606180.417 m	Latitude	N8°09'54.67217"	Latitude	N8°09'51.11024"
Northing	902629.434 m	Longitude	E123°57'49.02699"	Longitude	E123°57'55.36634"
Elevation	4.394 m	Height	6.900 m	Height	73.452 m

To:	AGN10				
Grid		Local		Global	
Easting	748452.013 m	Latitude	N9°00'00.89229"	Latitude	N8°59'57.22658"
Northing	995583.712 m	Longitude	E125°15'35.40896"	Longitude	E125°15'40.76119"
Elevation	11.097 m	Height	9.936 m	Height	77.961 m

Vector					
ΔEasting	142271.596 m	NS Fwd Azimuth	56°59'17"	ΔX	-109579.778 m
ΔNorthing	92954.278 m	Ellipsoid Dist.	169944.486 m	ΔY	-92370.048 m
ΔElevation	6.703 m	ΔHeight	3.036 m	ΔZ	91320.725 m

Standard Errors

Vector errors:					
σ ΔEasting	0.009 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.023 m
σ ΔNorthing	0.006 m	σ Ellipsoid Dist.	0.009 m	σ ΔY	0.030 m
σ ΔElevation	0.037 m	σ ΔHeight	0.037 m	σ ΔZ	0.008 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0005234069		
Y	-0.0006111431	0.0009178384	
Z	-0.0001475441	0.0001742207	0.0000698666

2. AN-44

Table A-3.2. AN-44

Project information		Coordinate System	
Name:		Name:	UTM
Size:		Datum:	PRS 92
Modified:	10/12/2012 4:40:11 PM (UTC:-6)	Zone:	51 North (123E)
Time zone:	Mountain Standard Time	Geoid:	EGMPH
Reference number:		Vertical datum:	
Description:			

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
AGN-10 --- AN-44 (B1)	AGN-10	AN-44	Fixed	0.001	0.002	264°25'39"	1.985	0.079

Acceptance Summary

Processed	Passed	Flag	Fail
1	1	0	0

AGN-10 - AN-44 (8:44:41 AM-12:46:43 PM) (S1)

Baseline observation:	AGN-10 --- AN-44 (B1)
Processed:	10/22/2014 4:04:12 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.001 m
Vertical precision:	0.002 m
RMS:	0.002 m
Maximum PDOP:	4.363
Ephemeris used:	Broadcast
Antenna model:	Trimble Relative
Processing start time:	10/21/2014 8:45:03 AM (Local: UTC+8hr)
Processing stop time:	10/21/2014 12:46:43 PM (Local: UTC+8hr)
Processing duration:	04:01:40
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	AGN-10				
Grid		Local		Global	
Easting	748452.013 m	Latitude	N9°00'00.89229"	Latitude	N8°59'57.22658"
Northing	995583.712 m	Longitude	E125°15'35.40896"	Longitude	E125°15'40.76119"
Elevation	11.097 m	Height	9.936 m	Height	77.961 m

To:	AN-44				
Grid		Local		Global	
Easting	748450.039 m	Latitude	N9°00'00.88602"	Latitude	N8°59'57.22031"
Northing	995583.507 m	Longitude	E125°15'35.34429"	Longitude	E125°15'40.69652"
Elevation	11.176 m	Height	10.014 m	Height	78.039 m

Vector					
ΔEasting	-1.975 m	NS Fwd Azimuth	264°25'39"	ΔX	1.551 m
ΔNorthing	-0.205 m	Ellipsoid Dist.	1.985 m	ΔY	1.228 m
ΔElevation	0.079 m	ΔHeight	0.079 m	ΔZ	-0.178 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'43"	σ ΔX	0.001 m
σ ΔNorthing	0.000 m	σ Ellipsoid Dist.	0.001 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	0.0000007315		
Y	-0.0000004492	0.0000007879	
Z	-0.0000001476	0.0000001647	0.0000002158

Annex 4. The LIDAR Survey Team Composition

Table A-4.1. The LiDAR Survey Team Composition

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

FIELD TEAM

LiDAR Operation	Supervising Science Research Specialist	AUBREY MATIRA PAGADOR	UP-TCAGP
	(Sup.SRS)	LOVELY GRACIA ACUNA	UP-TCAGP
	Senior Science Research Specialist (SSRS)	JASMINE ALVIAR	UP-TCAGP
	Research Associate (RA)	RENAN PUNTO	UP-TCAGP
	RA	DAN CHRISTOFFER ALDOVINO	UP-TCAGP
	RA	MARY CATHERINE ELIZABETH BALIGUAS	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	KRISTINE JOY ANDAYA	UP-TCAGP
LiDAR Operation	Airborne Security	TSG MICHAEL BERONILLA	PHILIPPINE AIR FORCE (PAF)
		TSG ANTONIO VALENCIANO	PAF
	Pilot	CAPT. JEFFREY JEREMY ALAJAR	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. CESAR ALFONSO III	AAC
		CAPT. NEIL ACHILLES AGAWIN	AAC
		CAPT. MARK GARCHITORENA	AAC

Annex 5. Data Transfer Sheet for Linugos Floodplain

DATA TRANSFER SHEET
07/03/2014(BUTUAN - ready)

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	
20-Jun-14	1604A	3AGUS171A	AQUARIUS	NA	564	978	245	67.9	457	10.8	149	61.4	2KB	1KB	8	16	Z:\Airborne_Raw\1604A
22-Jun-14	1612A	3AGU1AB173A	AQUARIUS	NA	232/215	807	262	43.4	322	10	67.7	59.7	1KB	1KB	4	6	Z:\Airborne_Raw\1612A
23-Jun-14	1614A	3BLK63A174A	AQUARIUS	NA	637	1.04MB	196	86.4	551	10.3	48.8	63.2	1KB	1KB	6	14	Z:\Airborne_Raw\1614A
28-Jun-14	1634A	3BLK63BC179A	AQUARIUS	NA	661	1.07MB	244	77.7	313	12.6	NA	13.1	1KB	1KB	9	NA	Z:\Airborne_Raw\1634A
28-Jun-14	1636A	3BLK63CSD179B	AQUARIUS	NA	982	1.05MB	164	30.2	259	6.48	NA	91.6	1KB	1KB	12	NA	Z:\Airborne_Raw\1636A

Received from
Name: C.JOAQUIN
Position: RA
Signature:

Received by
Name: JOIDA F. PRIETO
Position: SSRS
Signature: 7/3/2014

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

DATA TRANSFER SHEET
07/22/2014(Butuan - ready)

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	
5/29/2014	1638A	3BLK63DS180A	Aquarius	NA	282/10	550	130	37.7	271	5.99	79.2	53.6	1KB	1KB	4	282/10	Z:\Airborne_Raw
7/1/2014	1648A	3BLK63DS182A & 3ADS1A183A	Aquarius	NA	98/378/9	1.32	125	12.5	105	4.4	NA	10.5	1KB	1KB	4/3	98/378/9	Z:\Airborne_Raw
7/2/2014	1652A	3ADS1A183A	Aquarius	NA	517	732	160	45	337	8.1	120	6.88	1KB	1KB	3	517	Z:\Airborne_Raw
7/3/2014	1654A	3ADS1AB184A	Aquarius	NA	187/13/49/8	52	187	54.2	388	8.62	10.9	6.67	1KB	1KB	3/5/3/4	187/13/49/8	Z:\Airborne_Raw

Received from

Name IN ANDAYA
Position RA/IO
Signature

Received by

Name JOIDA PRIETO
Position SRS
Signature 7/23/2014

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

DATA TRANSFER SHEET
10/30/2014(Surigao-Dinagat)

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	
14-Sep	1946A	3BLK59BS257A	Aquarius	na	844	0.98	170	na	na	8.45	na	9.26	1KB	1KB	5/6	na	Z:\DAC\RAW DATA
15-Sep	1950A	3BLK59D258A	Aquarius	na	286	577	209	na	na	11.2	na	9.14	1KB	1KB	7	na	Z:\DAC\RAW DATA
19-Sep	1966A	3BLK59C262A	Aquarius	na	1167	2.14	214	na	na	12	na	10.3	1KB	1KB	10	na	Z:\DAC\RAW DATA
19-Sep	1968A	3BLK59D262B	Aquarius	na	231	1.99	137	na	na	6.56	na	10.3	1KB	1KB	10/7	na	Z:\DAC\RAW DATA
20-Sep	1970A	3BLK59S263A	Aquarius	na	341	2.98	153	na	na	6.25	na	9.05	1KB	1KB	11	na	Z:\DAC\RAW DATA
21-Sep	1974A	3BLK59S264A	Aquarius	na	204	867	182	na	na	8.2	na	13.4	1KB	1KB	8	na	Z:\DAC\RAW DATA
23-Sep	1982A	3BLK59DS266A	Aquarius	na	149	324	142	na	na	6.44	na	8.44	1KB	1KB	10	na	Z:\DAC\RAW DATA
24-Sep	1986A	3BLK59E267A	Aquarius	na	332	643	220	na	na	13.5	na	22.7	1KB	1KB	14.8	na	Z:\DAC\RAW DATA
24-Sep	1988A	3BLK59ES267B	Aquarius	na	630	0.98	186	na	na	11.6	na	22.7	1KB	1KB	7	na	Z:\DAC\RAW DATA
27-Sep	1998A	3BLK59F270A	Aquarius	na	537/119	1.3	278	na	na	15.7	na	12.4	1KB	1KB	12/18	na	Z:\DAC\RAW DATA
28-Sep	2002A	3BLK59FDS271A	Aquarius	na	226	619	207	na	na	11.7	na	9.74	1KB	1KB	10/18	na	Z:\DAC\RAW DATA
11-Oct	2054A	3BLK59S284A	Aquarius	na	na	486	212	na	na	6.7	na	8.54	1KB	1KB	10/20/21	na	Z:\DAC\RAW DATA
12-Oct	2060A	3BLK59FS285B	Aquarius	na	40	1.33	120	na	na	2.36	na	13.7	1KB	1KB	21/24	na	Z:\DAC\RAW DATA
18-Oct	2082A	3BLK59S291A	Aquarius	na	431	724	152	na	na	4.73	na	6.1	1KB	1KB	na	na	Z:\DAC\RAW DATA
20-Oct	2090A	3BLK59DS293A	Aquarius	na	89	240	117	na	na	5.04	na	5.43	1KB	1KB	11	na	Z:\DAC\RAW DATA
21-Oct	2094A	3BLK63R294A	Aquarius	na	193	691	205	na	na	8.75	na	10.4	1KB	1KB	5/6	na	Z:\DAC\RAW DATA
21-Oct	2096A	3BLK63R294B	Aquarius	na	405	875	190	na	na	8.84	na	9.64	1KB	1KB	5/6	na	Z:\DAC\RAW DATA
22-Oct	2098A	3BLK59S295A	Aquarius	na	na	329	106	na	na	2.48	na	8.9	1KB	1KB	15/23	na	Z:\DAC\RAW DATA

Received from

Name C. Joaquin
Position RA
Signature [signature]

Received by

Name JUDIDA F. PRIETO
Position SUPSRS
Signature [signature] 10/31/2014

Figure A-5.3. Transfer Sheet for Linugos Floodplain - C

Annex 6. Flight Logs for the Flight Missions

1. Flight Log for Mission 1614A

DREAM Data Acquisition Flight Log

Flight Log No.: 1614

1 LiDAR Operator: MCE Baliguas	2 ALTM Model: Aquarius	3 Mission Name: 3BLK63A174A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: JJ Alajar	8 Co-Pilot: NA Agawin	9 Route:			
10 Date: 06-23-2014	12 Airport of Departure (Airport, City/Province): Butuan		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 932	14 Engine Off: 1355	15 Total Engine Time: 423	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Mission completed over BLK63A.

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Lovely Acuna	SSG Bernille	JJ Alajar	Cath Baliguas
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.1. Flight Log for Mission 1614A

2. Flight Log for 1638A Mission

DREAM Data Acquisition Flight Log Flight Log No.: 1638

1 LiDAR Operator: MCE Baliguas	2 ALTM Model: Aquarius	3 Mission Name: 3BLK63D180A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: JJ Alajar	8 Co-Pilot: NA Agawin	9 Route:			
10 Date: 06-29-2014	12 Airport of Departure (Airport, City/Province): Butuan City		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0922	14 Engine Off: 1157	15 Total Engine Time: 0235	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Completed 12 lines over BLK 63D, laser turn could not be turn off.

21 Problems and Solutions:

Acquisition Flight Approved by
LOVELY ACUNA
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
CATH BALIGUAS
Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.2. Flight Log for Mission 1638A

3. Flight Log for 1648A Mission

DREAM Data Acquisition Flight Log 3BLK63DS182A **Flight Log No.:** 1648

1 LIDAR Operator: MCE Baliguas	2 ALTM Model: Aquarius	3 Mission Name: 3ADSIA183A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: JJ Alajar	8 Co-Pilot: NA Agawin	9 Route:			
10 Date: 07 - 01 - 2014	12 Airport of Departure (Airport, City/Province): Butuan City		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1353	14 Engine Off: 1622	15 Total Engine Time: 2+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Mission successful					

21 Problems and Solutions:

Acquisition Flight Approved by
LOVELYN PAGUNA
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
CATH BALIGUAS
Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.3. Flight Log for Mission 1648A

4. Flight Log for 2094A Mission

Flight Log No. 205

PHIL-LiDAR 1 Data Acquisition Flight Log

1 LiDAR Operator: J. ALVIAR	2 ALTM Model: AQUARIUS	3 Mission Name: 3BLK63R294A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: C. ALFONSO	8 Co-Pilot: M.A. GARCHITORENA	9 Route:			
10 Date: OCT. 21, 2014	12 Airport of Departure (Airport, City/Province): SURIGAO		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 8:44	14 Engine Off: 1:07	15 Total Engine Time: 4+23	16 Take off: 8:49	17 Landing: 1:02	18 Total Flight Time: 4+13

19 Weather

20 Remarks:

MISSION SUCCESSFUL.

21 Problems and Solutions:

CERTIFIED PHOTOCOPY
Signature
Name LEMUEL GARCIA
Date 11-24-14

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

Figure A-6.4. Flight Log for Mission 2094A

5. Flight Log for 2096A Mission

Flight Log No.:2

PHIL-LIDAR 1 Data Acquisition Flight Log

1 LIDAR Operator: R. PUNTO	2 ALTM Model: AQUARIUS	3 Mission Name: 3BLK67R	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: C. ALFONSO	8 Co-Pilot: M.A. CARCHITORENA	9 Route:			
10 Date: OCT. 21, 2014	12 Airport of Departure (Airport, City/Province): SURIGAO		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1:40	14 Engine Off: 5:27	15 Total Engine Time: 3:47	16 Take off: 1:45	17 Landing: 5:22	18 Total Flight Time: 3+37

19 Weather

20 Remarks:

MISSION SUCCESSFUL.

21 Problems and Solutions:

CERTIFIED PHOTOCOPY
Signature
Name LEMUEL VARIA
Date 11.24.14

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
J. Alviar	JE CACANINDIN	C. Alfonso III	R. PUNTO
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.5. Flight Log for Mission 2096A

Annex 7. Flight Status Reports

Northern Mindanao Mission
May 22 - July 10, 2015

Table A-7.1. Flight Status Report

FLIGHT NO.	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1614A	BLK63A	3BLK63A174A	MCE. BALIGUAS	June 23, 2014	Mission completed over BLK63A
1638A	BLK 63D	3BLK63DS180A	MCE. BALIGUAS	May 23,	SURVEYED 16 LINES FOR BLK2F, BLK2B AND BLK2A
2014	Completed 12 lines over BLK63D, laser could not be turn off	1BLK2AS317B	G SINADJAN	November 13, 2015	SURVEYED 2 LINES FOR BLK2A
1648A	BLK63D	3BLK63DS182A	MCE. BALIGUAS	July 1, 2014	Completed mission over BLK63D and covered 2 lines over ADS1A
2094A	BLK63B	3BLK63R294A	J. ALVIAR	October 21, 2014	Reflight of BLK63B which was affected by the unmatched POS and range issues from Butuan fieldwork
2096A	BLK63C	3BLK63R294B	R.PUNTO	October 21, 2014	Reflight of BLK63C which was affected by the unmatched POS and range issues from Butuan fieldwork

LAS BOUNDARIES PER FLIGHT

Flight No. :	1614A		
Area:	BLK 63A		
Mission Name:	3BLK63A174A		
Parameters:	Altitude:	500m;	Scan Frequency: 50Hz;
Scan Angle:	20deg;	Overlap: 60%	

Figure A-7.1. Swath for Flight No. 1614A

Flight No. :	1638A		
Area:	BLK 63D		
Mission Name:	3BLK63DS180A		
Parameters:	Altitude:	500m;	Scan Frequency: 50Hz;
Scan Angle:	20deg;	Overlap: 25-40%	

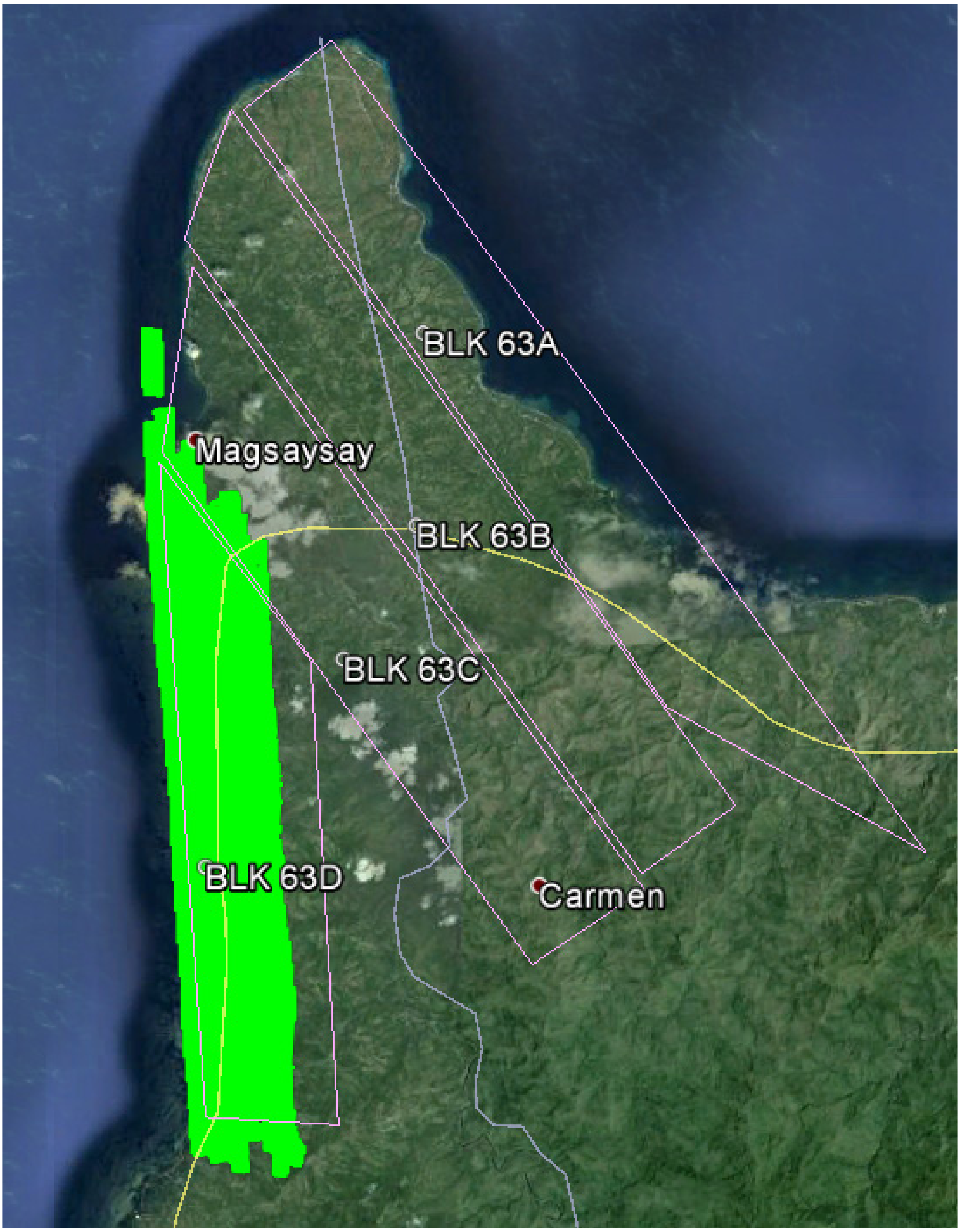


Figure A-7.2. Swath for Flight No. 1638A

Flight No. :	1648A		
Area:	BLK 63D & ADS1A		
Mission Name:	3BLK63DS182A & 3ADS1A182A		
Parameters:	Altitude:	600 m;	Scan Frequency: 45Hz;
Scan Angle:	18deg;	Overlap: 60%	

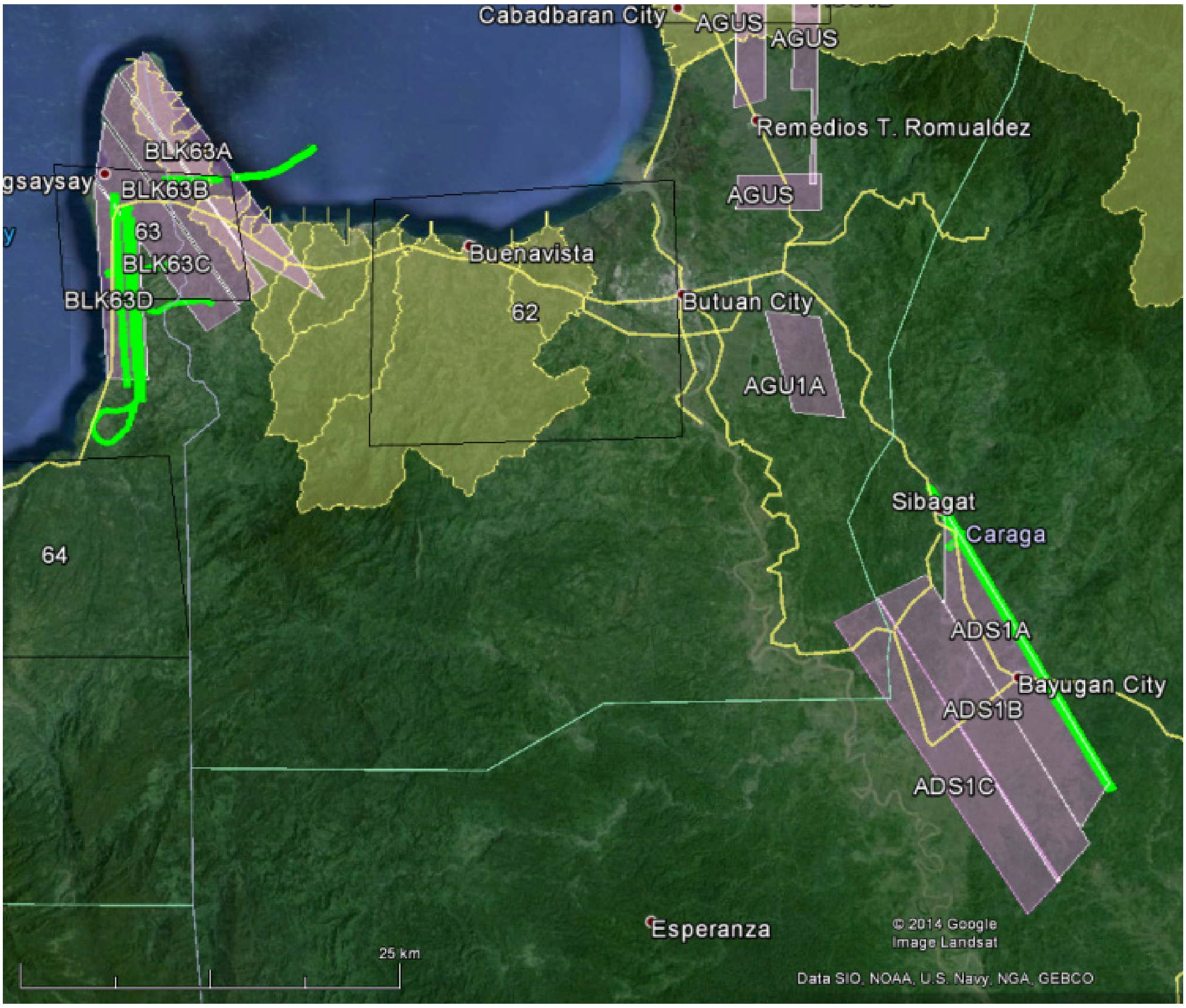


Figure A-7.3. Swath for Flight No. 1648A

Flight No. :	2094A		
Area:	BLK 63C		
Mission Name:	3BLK63R294A		
Parameters:	Altitude:	600m;	Scan Frequency: 45Hz;
Scan Angle:	18 deg;	Overlap: 60%	

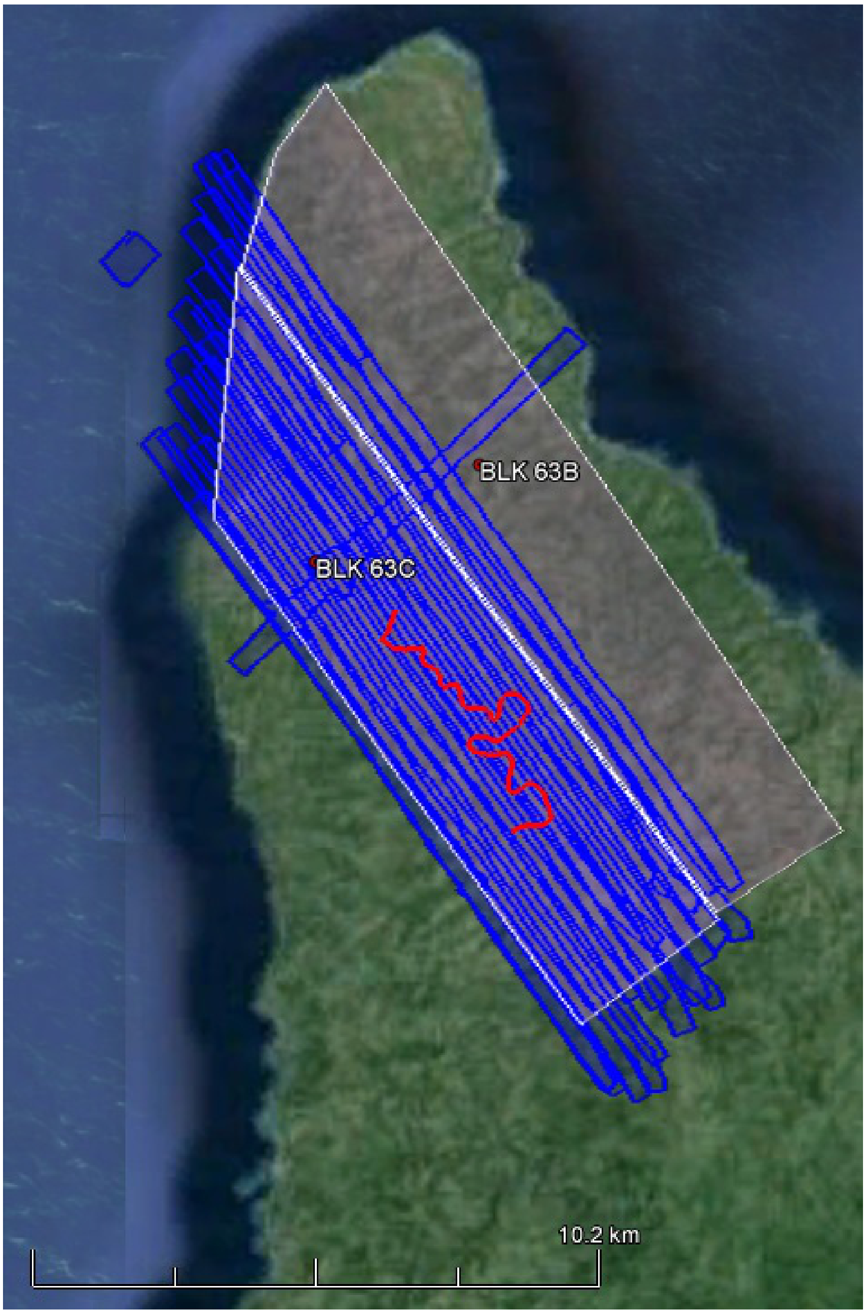


Figure A-7.4. Swath for Flight No. 2094A

Flight No. :	2096A		
Area:	BLK 63C		
Mission Name:	3BLK63R294B		
Parameters:	Altitude:	600m;	Scan Frequency: 45Hz;
Scan Angle:	18 deg;	Overlap: 60%	

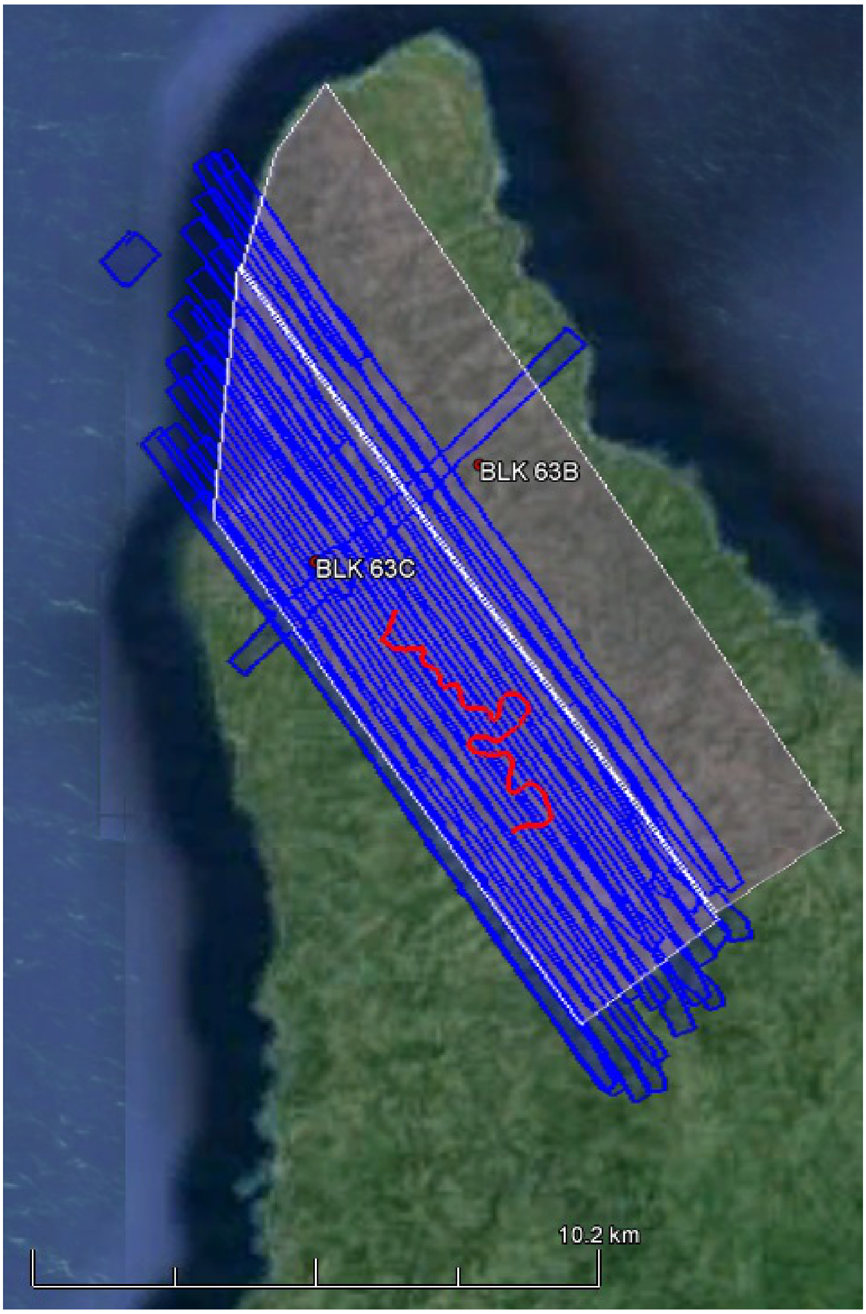


Figure A-7.5. Swath for Flight No. 2096A

Annex 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission 1638A

Flight Area	Butuan
Mission Name	Blk63D
Inclusive Flights	1638A
Range data size	10.39 GB
Base data size	53.6 MB
POS	255 MB
Image	57.5 GB
Transfer date	July 23, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.5
RMSE for East Position (<4.0 cm)	1.6
RMSE for Down Position (<8.0 cm)	4.2
Boresight correction stdev (<0.001deg)	0.000206
IMU attitude correction stdev (<0.001deg)	0.000762
GPS position stdev (<0.01m)	0.0029
Minimum % overlap (>25)	47.82%
Ave point cloud density per sq.m. (>2.0)	5.22
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	63
Maximum Height	415.07m
Minimum Height	53.87m
Classification (# of points)	
Ground	24,684,197
Low vegetation	23,298,623
Medium vegetation	44,360,558
High vegetation	55,827,473
Building	1,762,800
Orthophoto	Yes
Processed by	Engr. Angelo Carlo Bongat, Engr. Harmond Santos, Engr. Melissa Fernandez

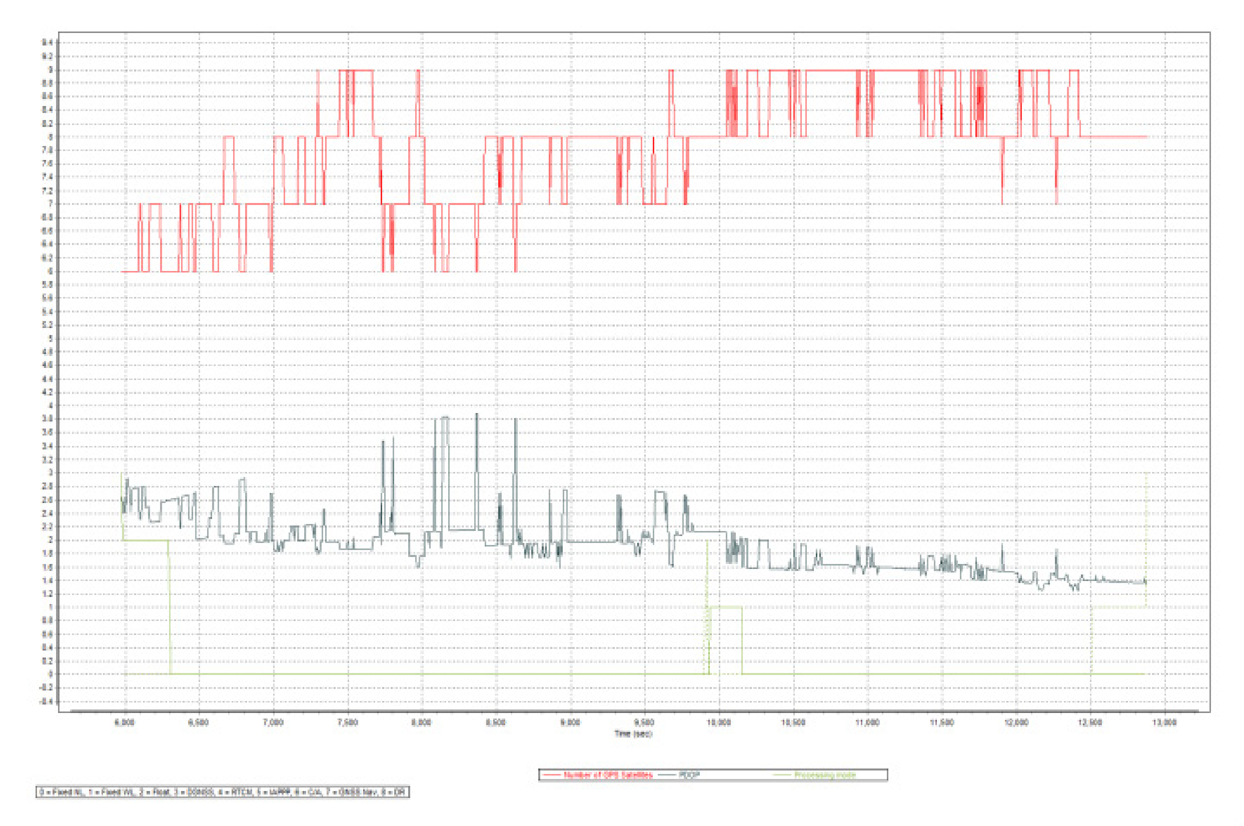


Figure A-8.1. Solution Status

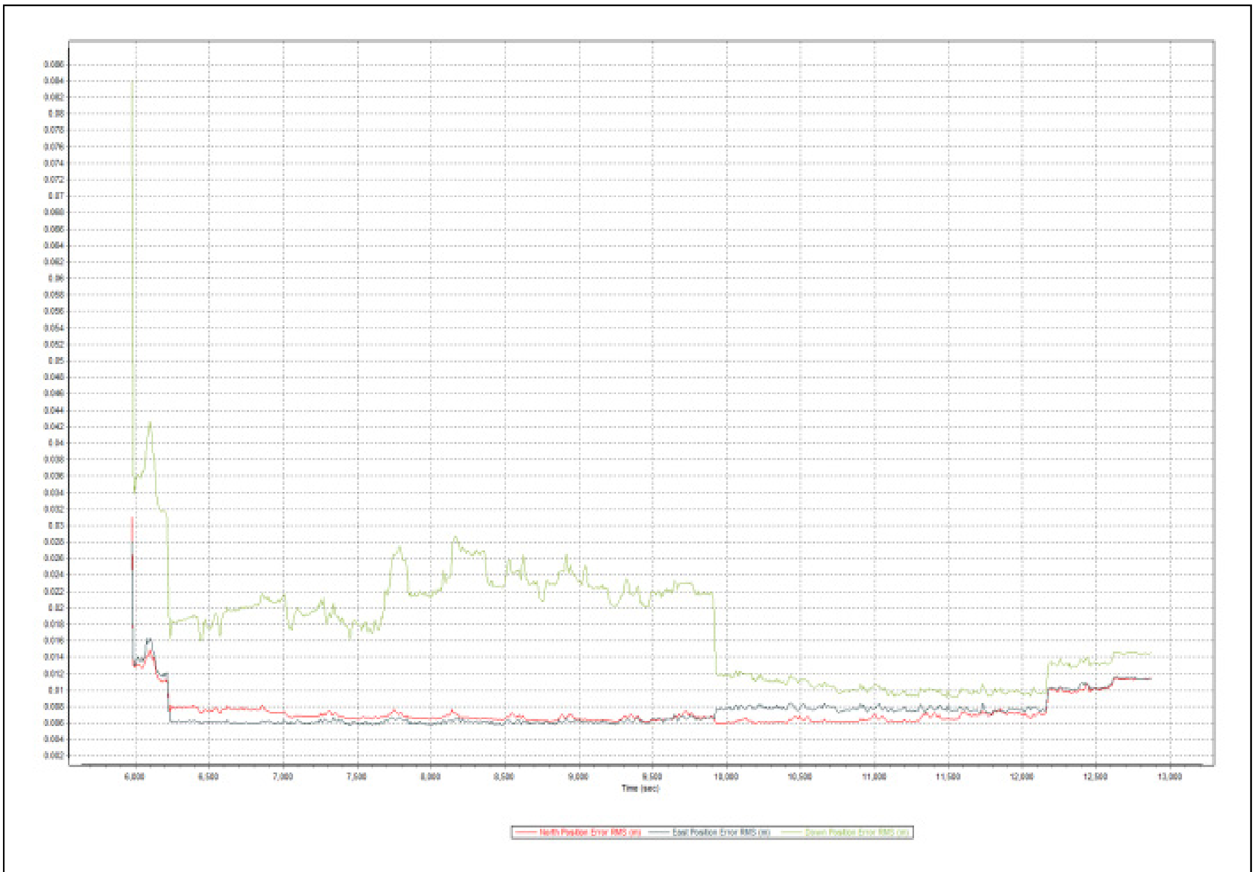


Figure A-8.2. Smoothed Performance Metrics Parameters

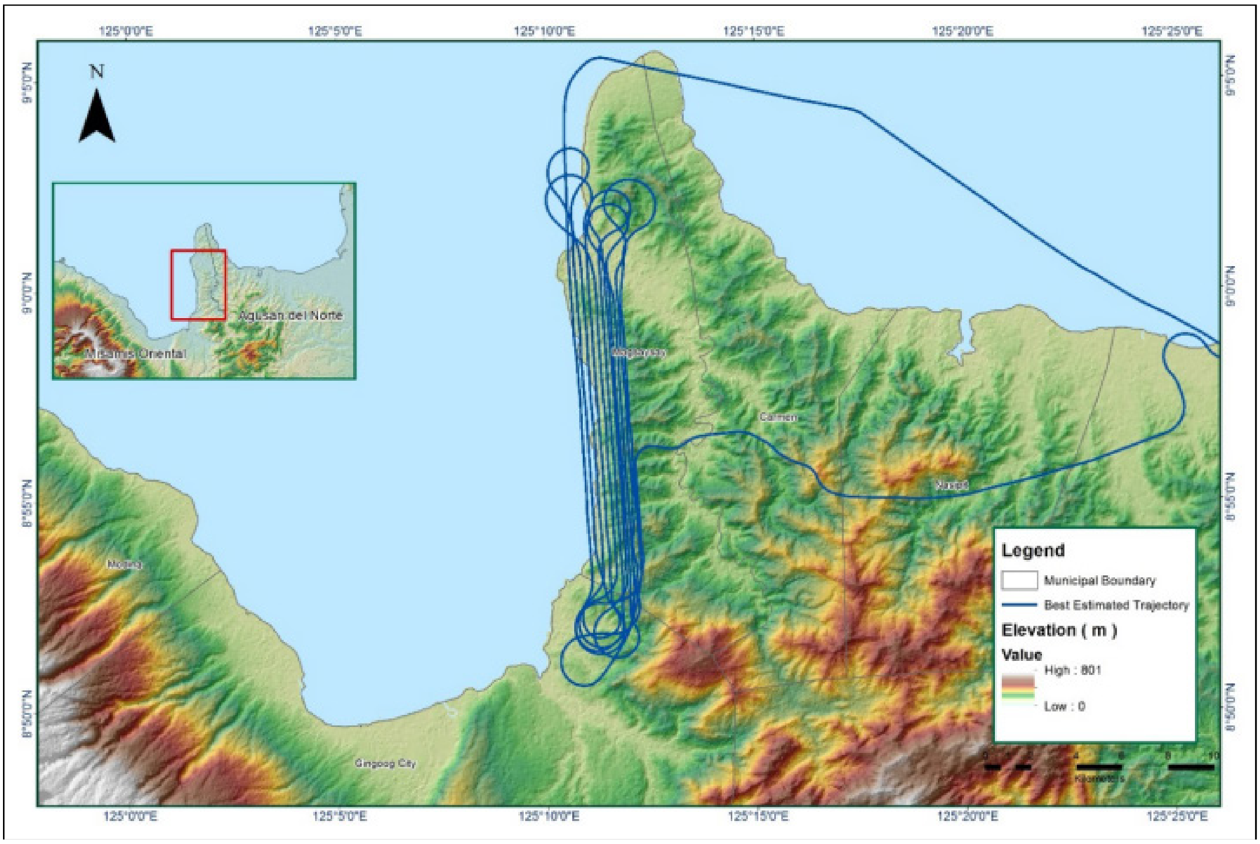


Figure A-8.3. Best Estimated Trajectory

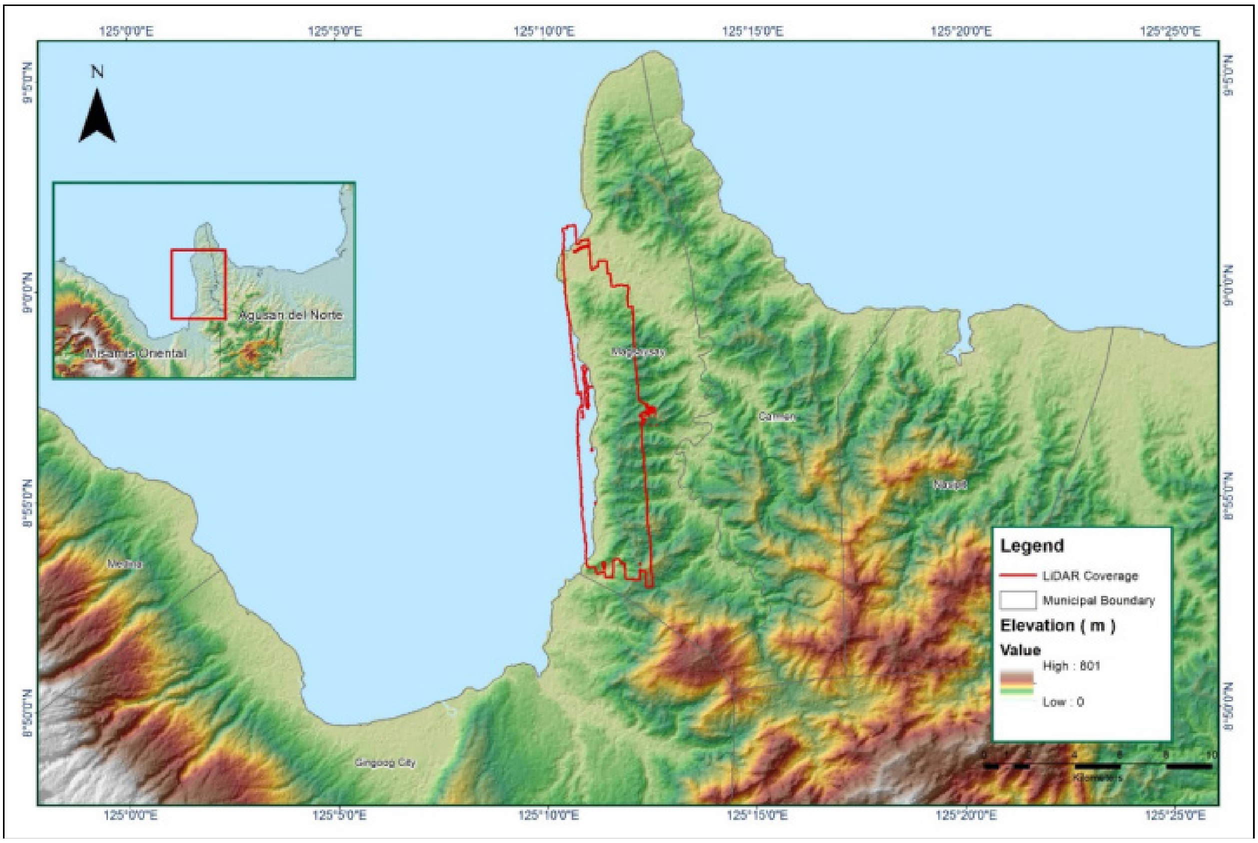


Figure A-8.4. Coverage of LiDAR data

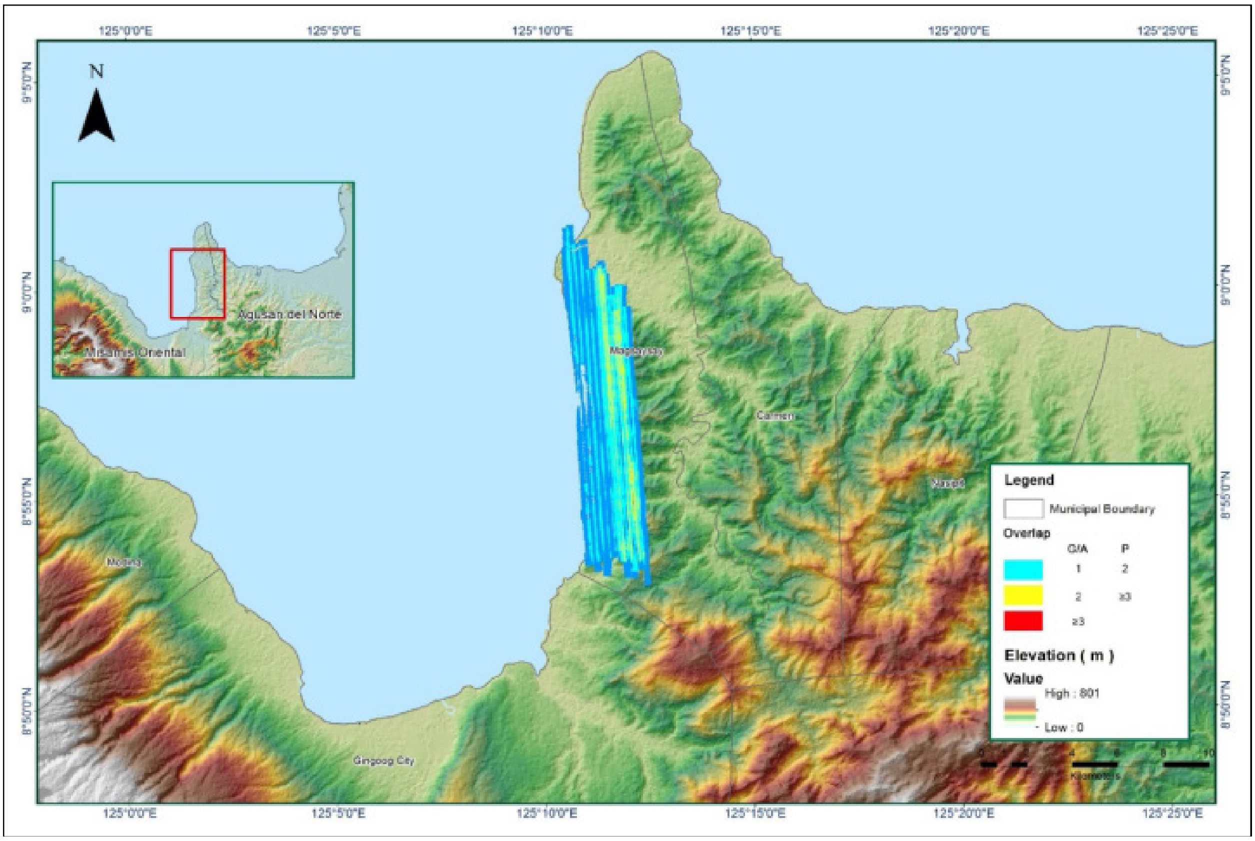


Figure A-8.5. Image of Data Overlap

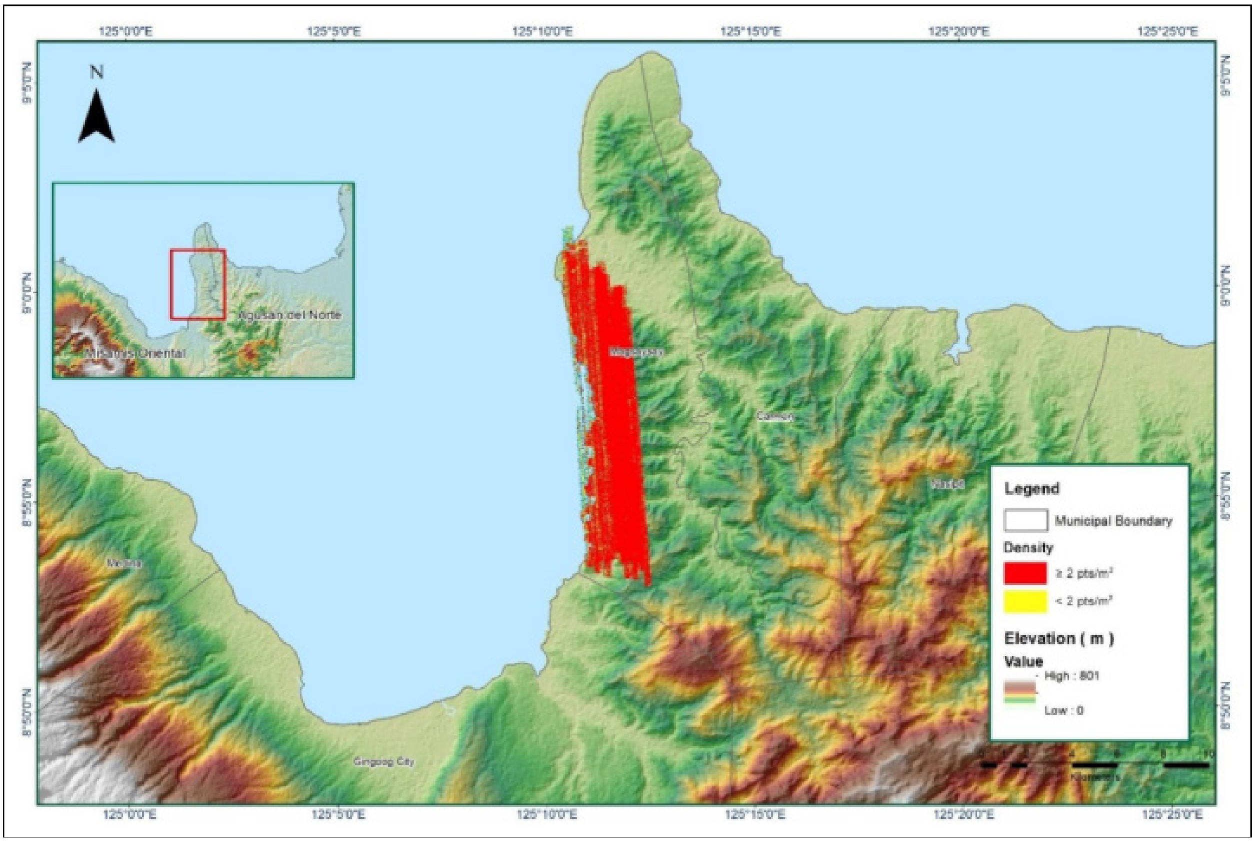


Figure A-8.6. Density map of merged LiDAR data

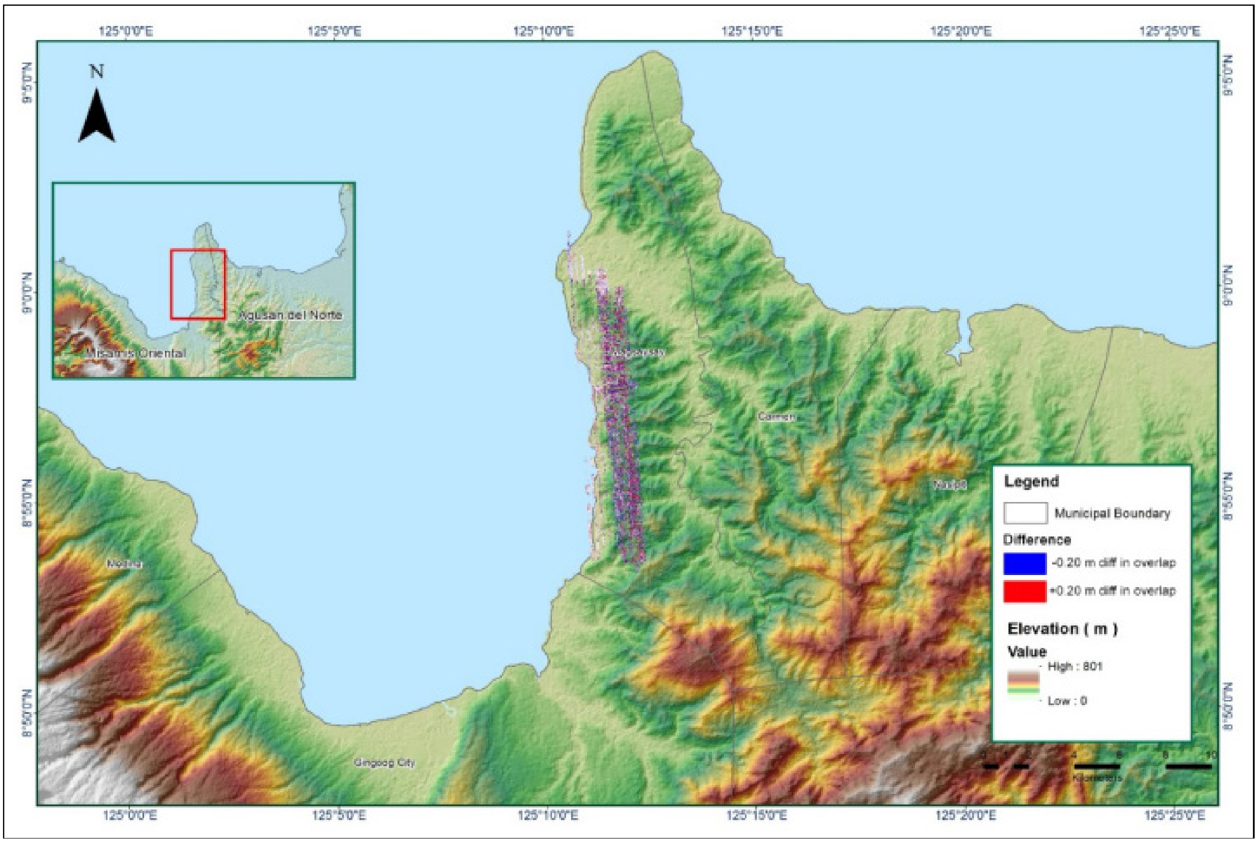


Figure A-8.7. Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Blk63A

Flight Area	Butuan
Mission Name	Blk63A
Inclusive Flights	1614A
Range data size	10.3 GB
Base data size	63.2 MB
POS	196 MB
Image	86.4 GB
Transfer date	July 23, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics(in cm)	
RMSE for North Position (<4.0 cm)	3.9
RMSE for East Position (<4.0 cm)	2.2
RMSE for Down Position (<8.0 cm)	1.0
Boresight correction stdev (<0.001deg)	0.000233
IMU attitude correction stdev (<0.001deg)	0.027405
GPS position stdev (<0.01m)	0.0225
Minimum % overlap (>25)	72.90%
Ave point cloud density per sq.m. (>2.0)	5.42
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	91
Maximum Height	497.23m
Minimum Height	46.35m
Classification (# of points)	
Ground	36,328,018
Low vegetation	48,941,631
Medium vegetation	81,868,738
High vegetation	72,554,801
Building	4,887,415
Orthophoto	Yes
Processed by	Engr. Carlyn Ann Ibañez, Engr. Chelou Prado, Engr. Jeffrey Delica

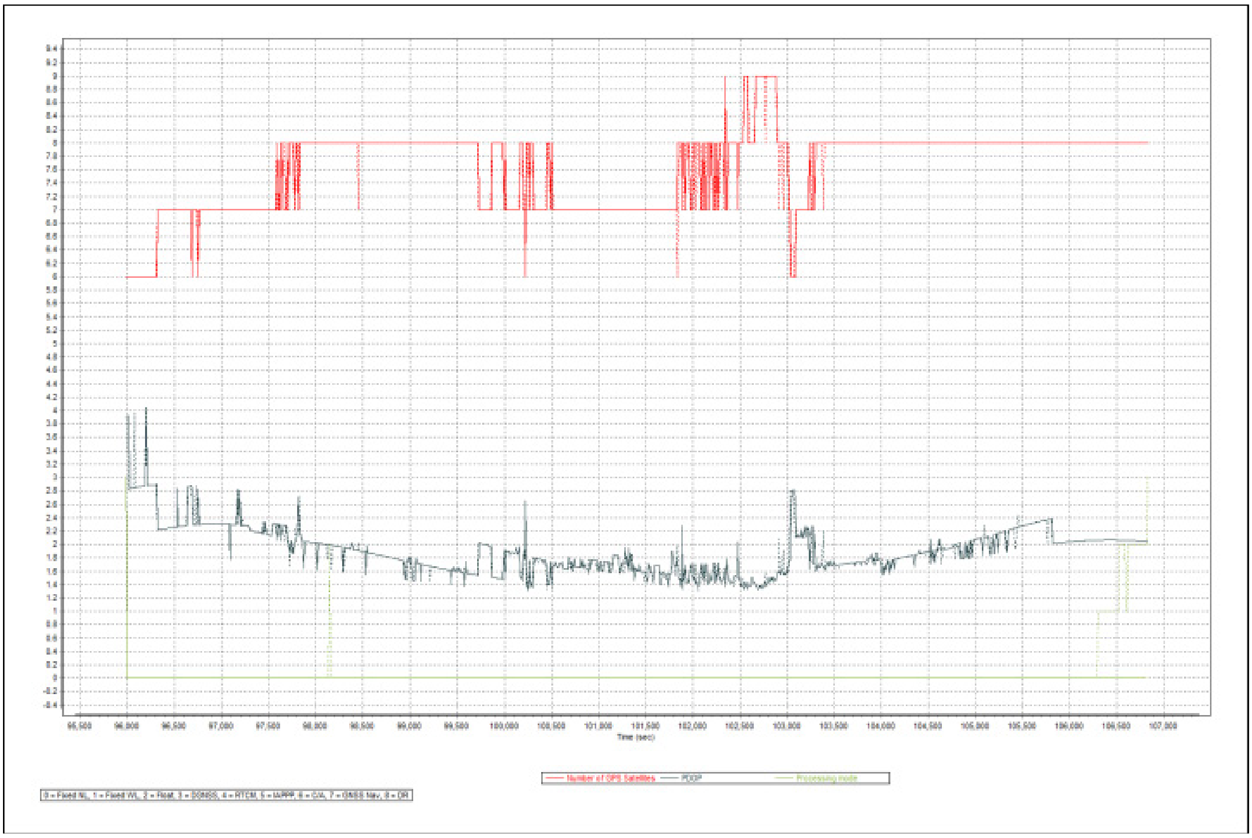


Figure A-8.8. Solution Status Parameters

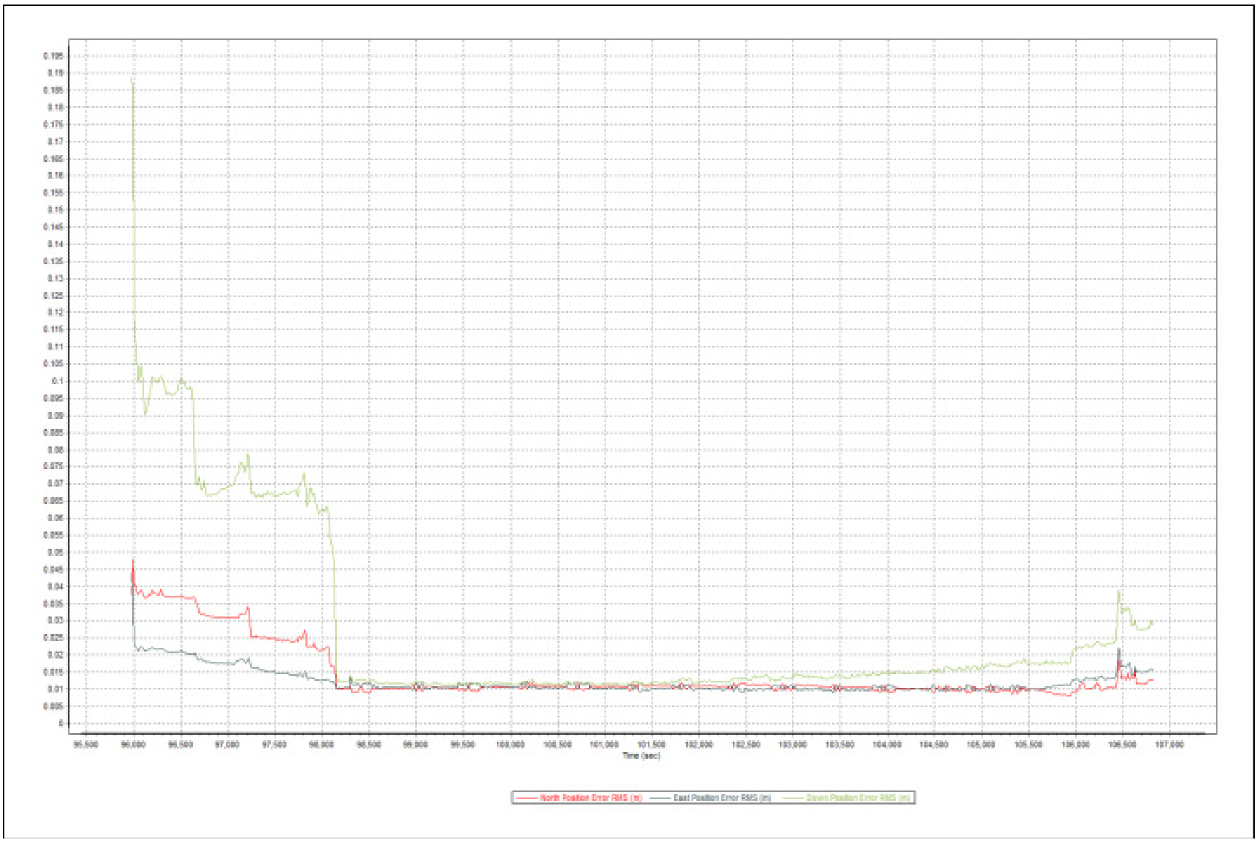


Figure A-8.9. Smoothed Performance Metrics Parameters

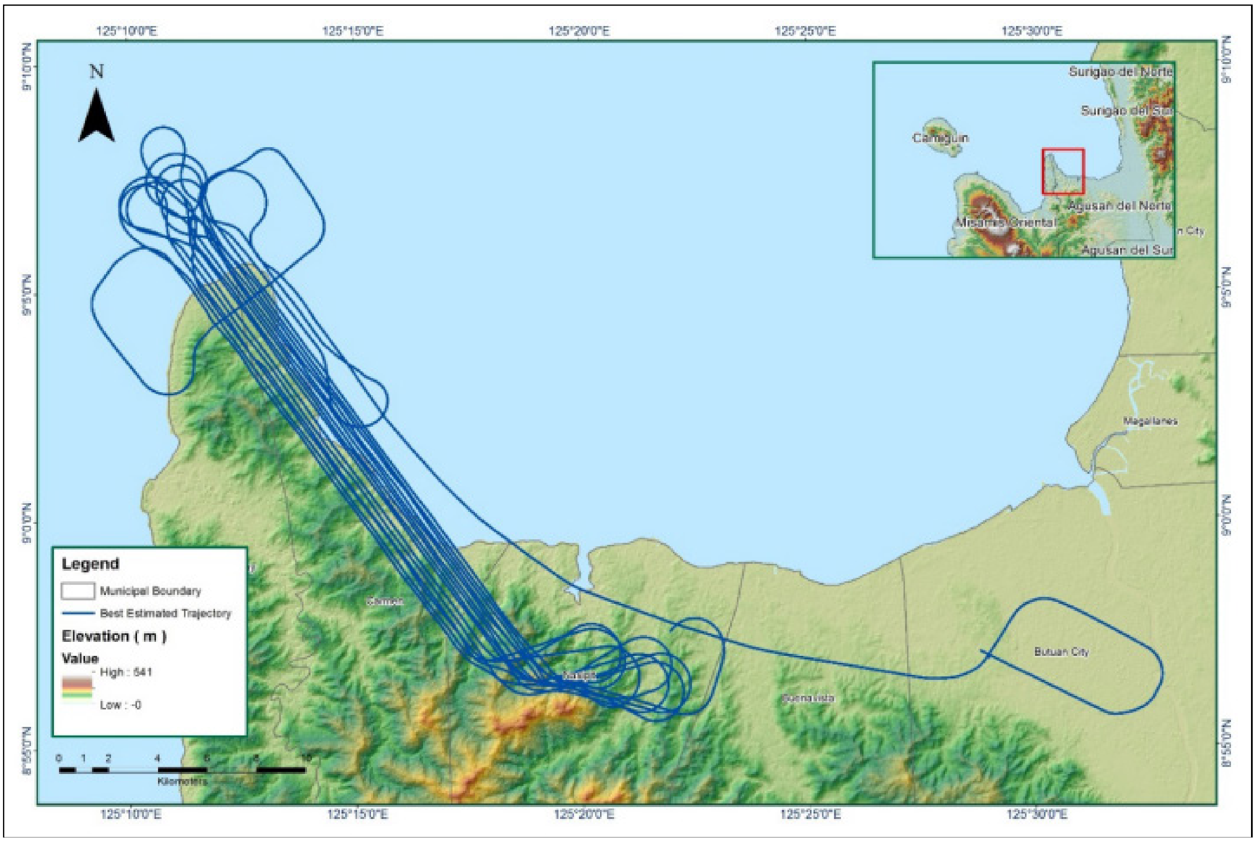


Figure A-8.10. Best Estimated Trajectory

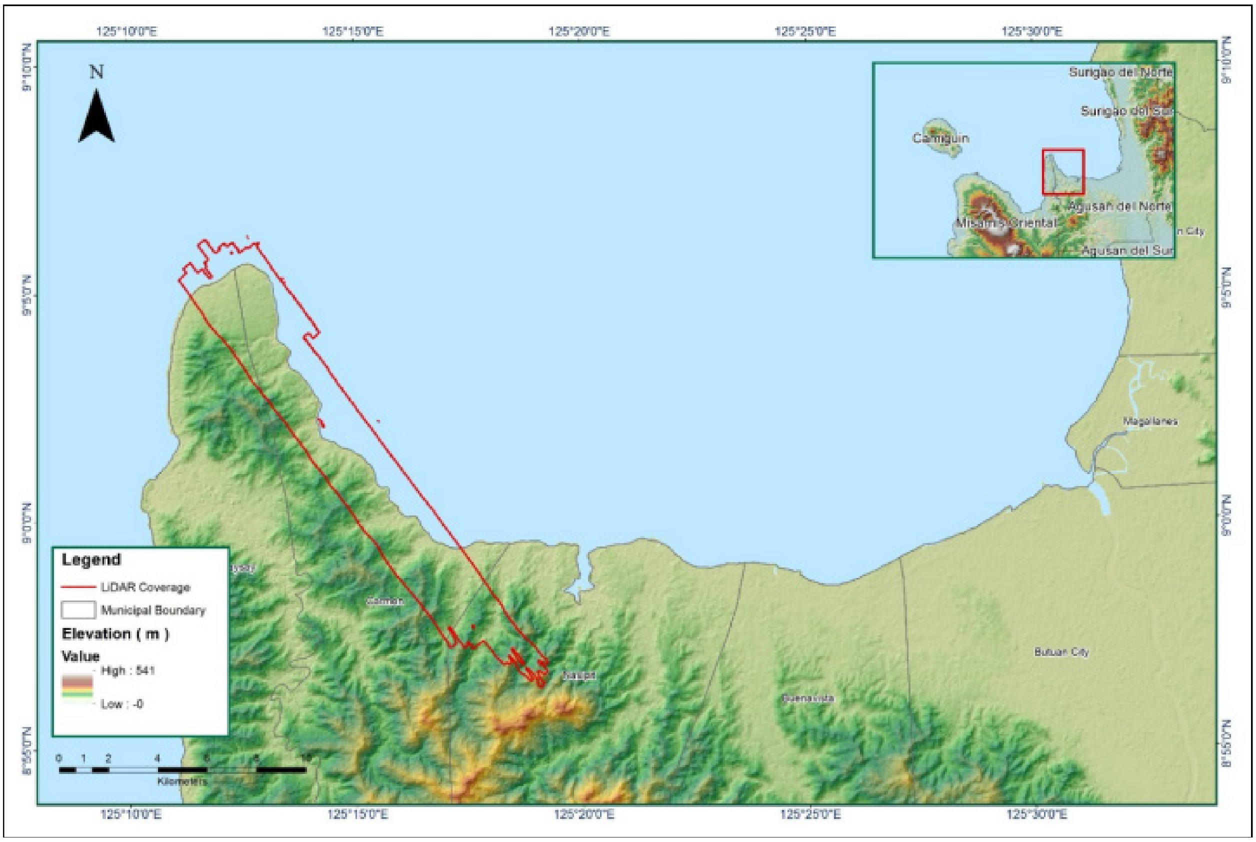


Figure A-8.11. Coverage of LiDAR data

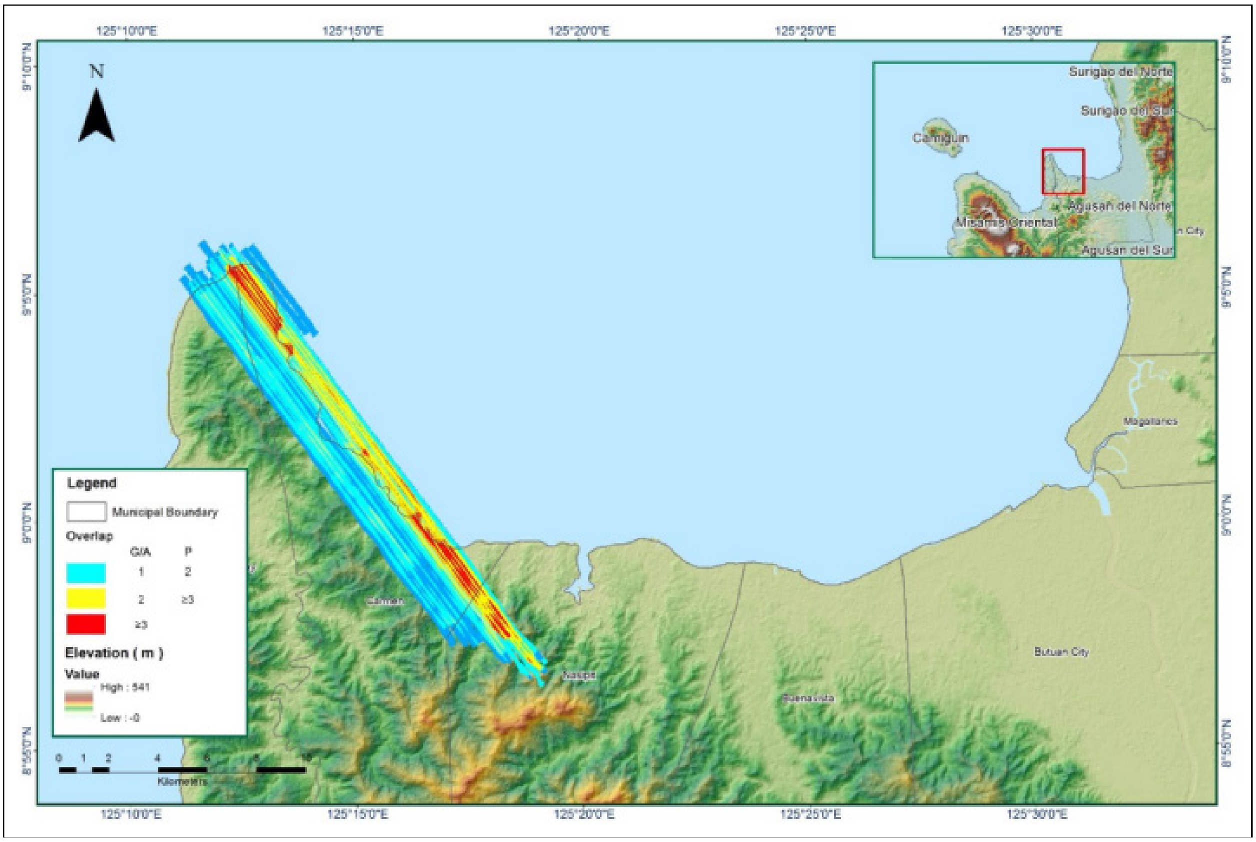


Figure A-8.12. Image of Data Overlap

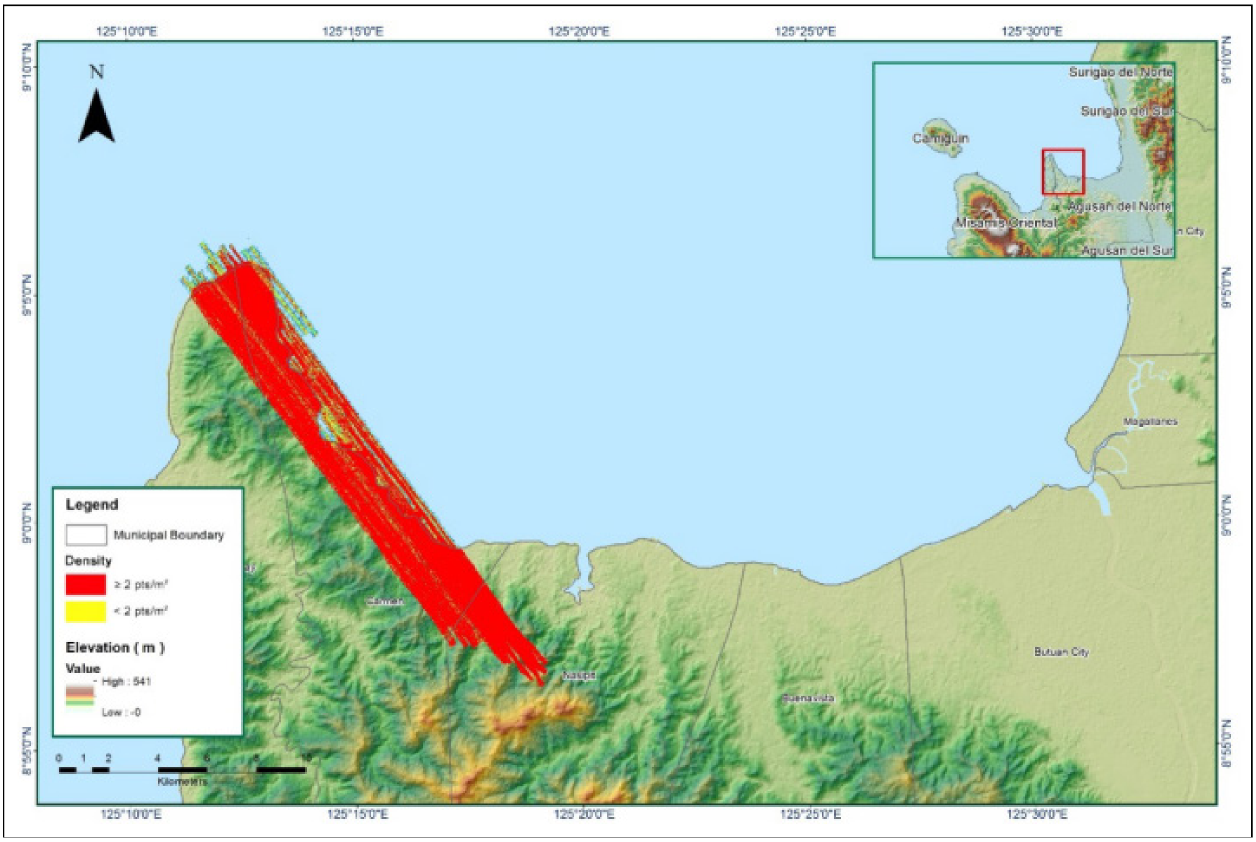


Figure A-8.13. Density map of merged LiDAR data

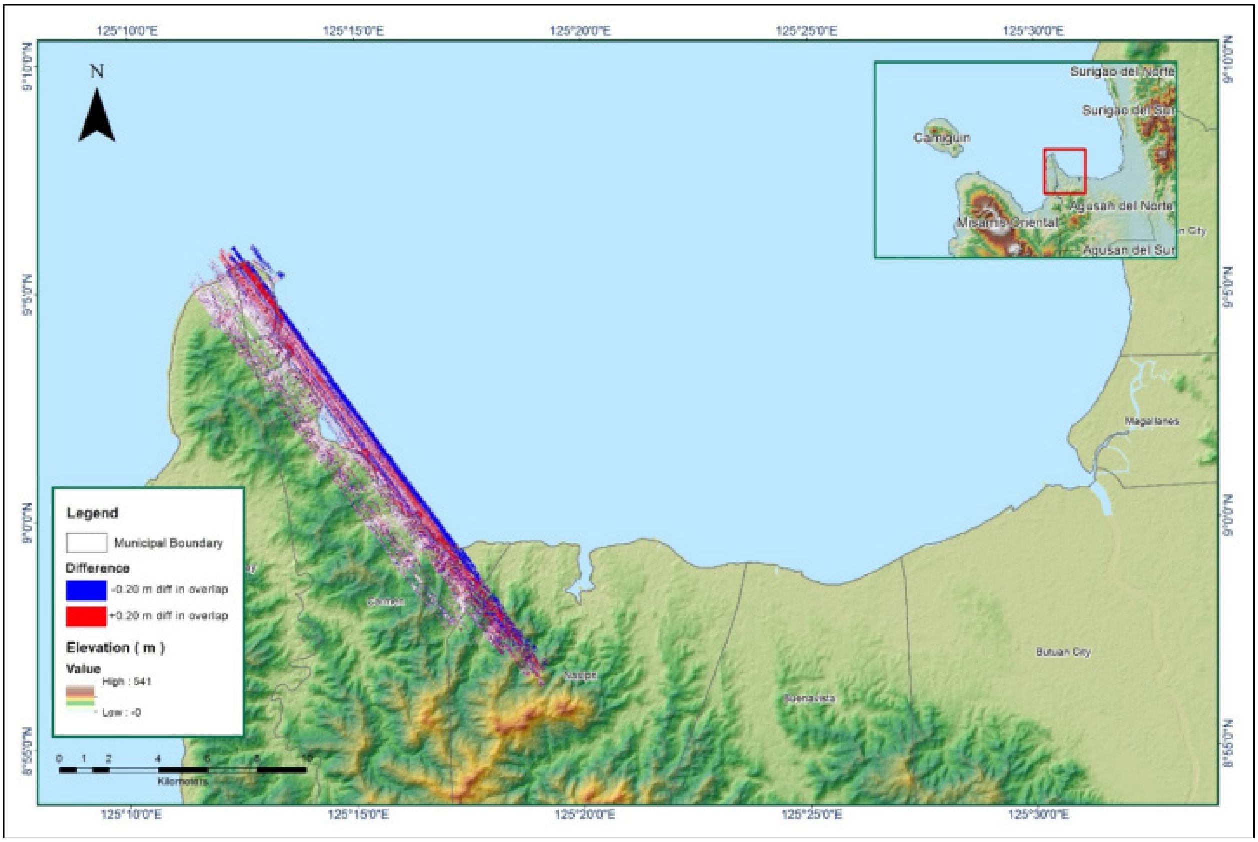


Figure A-8.14. Elevation difference between flight lines

Table A-8.3. Mission Summary Report for Mission Blk63B (Siargao)

Flight Area	Surigao City
Mission Name	Blk63B (Siargao)
Inclusive Flights	2096A
Range data size	8.84 GB
Base data size	9.64 MB
POS	190 MB
Image	NA
Transfer date	October 31, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics(in cm)	
RMSE for North Position (<4.0 cm)	1.50
RMSE for East Position (<4.0 cm)	3.00
RMSE for Down Position (<8.0 cm)	1.35
Boresight correction stdev (<0.001deg)	0.000154
IMU attitude correction stdev (<0.001deg)	0.000494
GPS position stdev (<0.01m)	0.0086
Minimum % overlap (>25)	37.01%
Ave point cloud density per sq.m. (>2.0)	3.59
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	111
Maximum Height	417.59 m
Minimum Height	50.57 m
Classification (# of points)	
Ground	44,577,934
Low vegetation	34,079,342
Medium vegetation	62,085,307
High vegetation	83,431,621
Building	2,104,638
Orthophoto	No
Processed by	Engr. Jommer Medina, Aljon Araneta, Kathryn Zarate

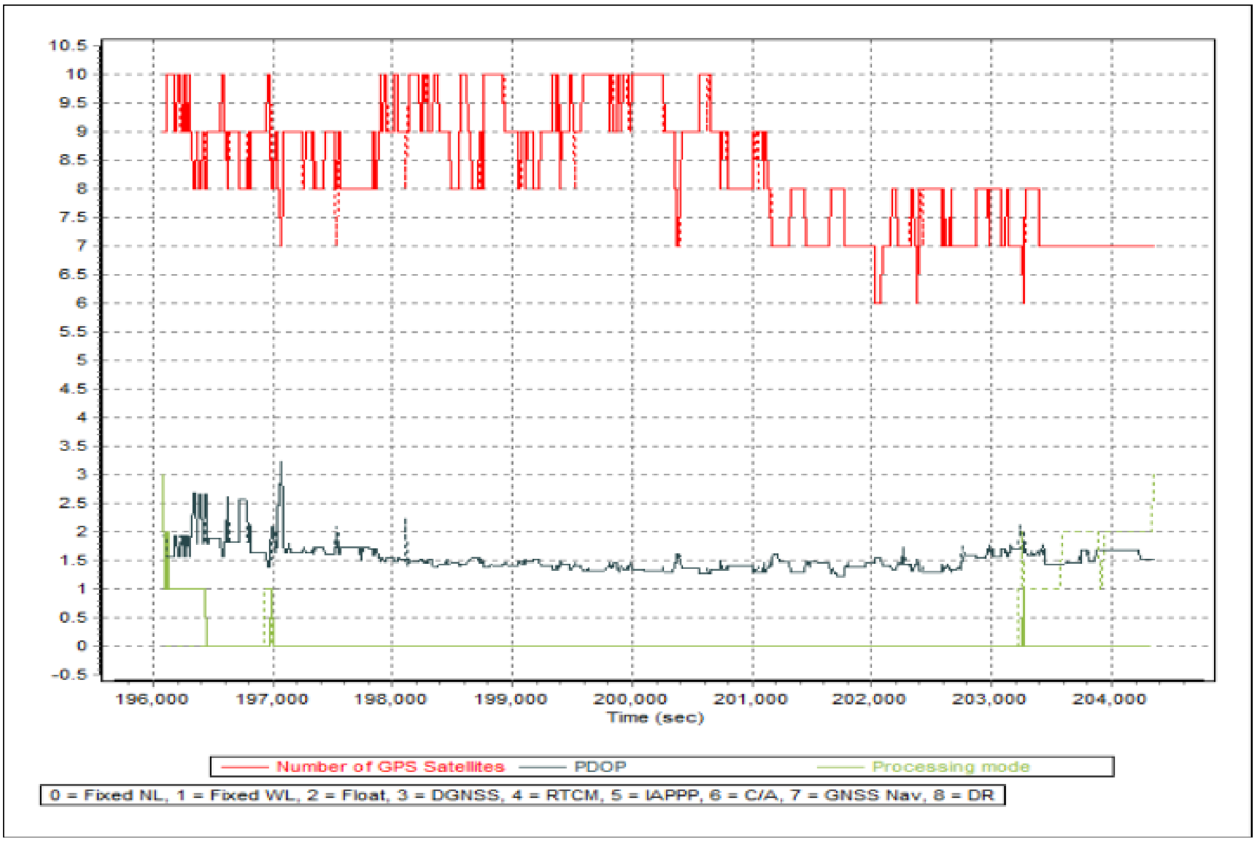


Figure A-8.15. Solution Status

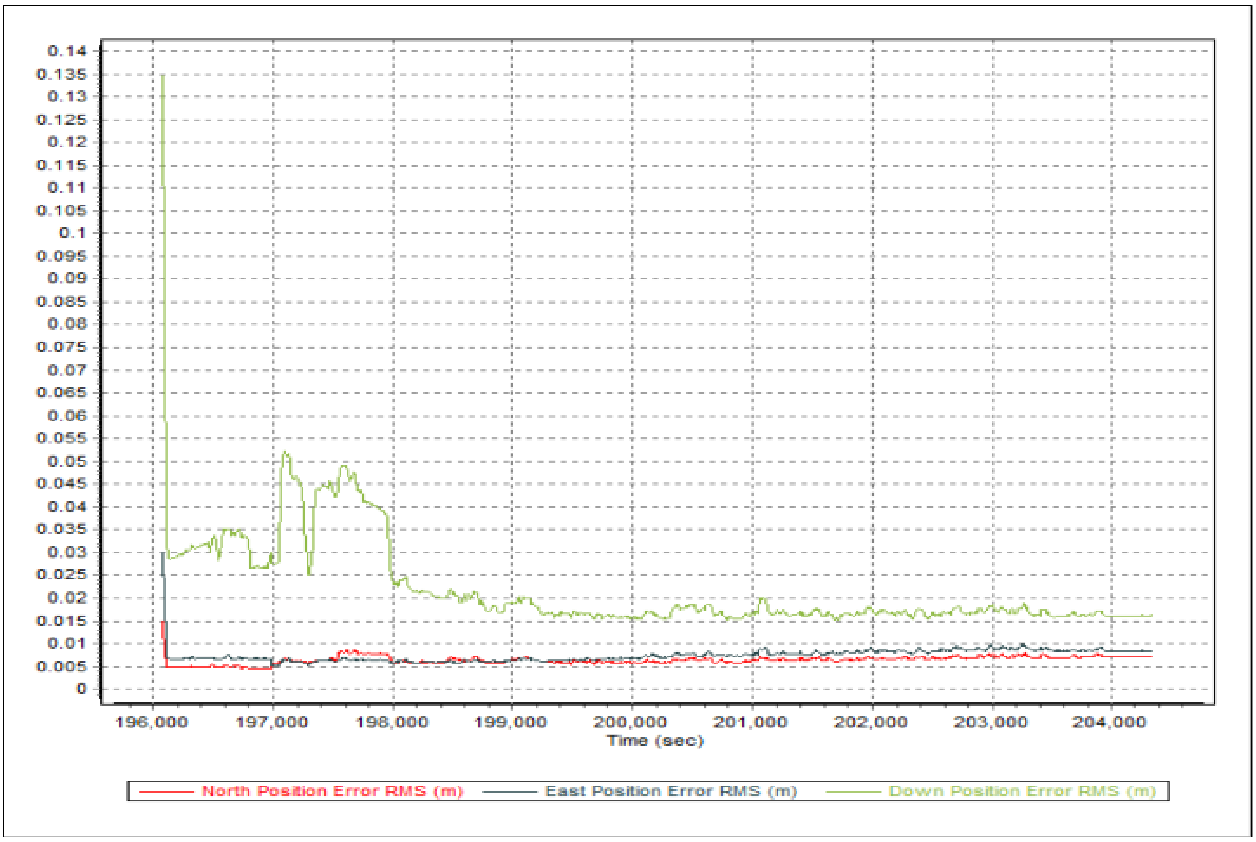


Figure A-8.16. Smoothed Performance Metric Parameters

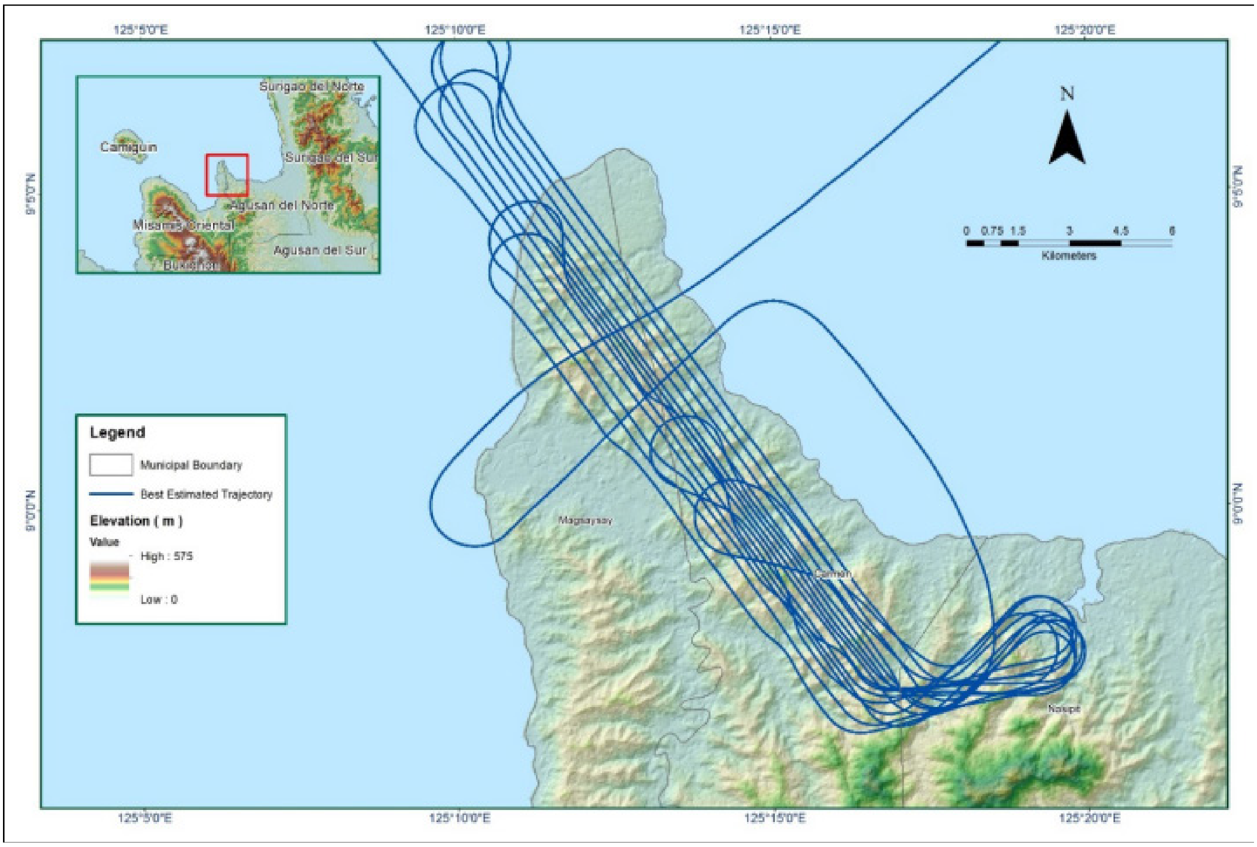


Figure A-8.17. Best Estimated Trajectory

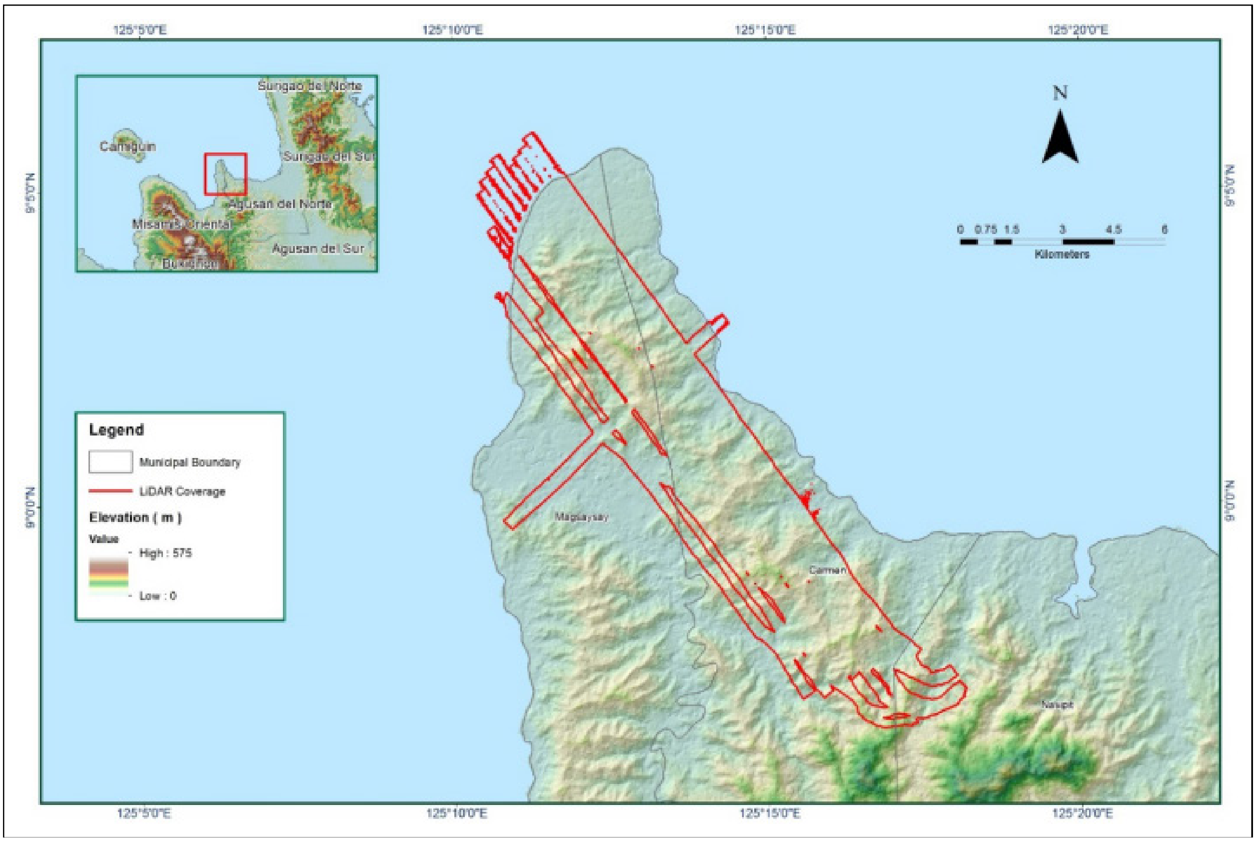


Figure A-8.18. Coverage of LiDAR data

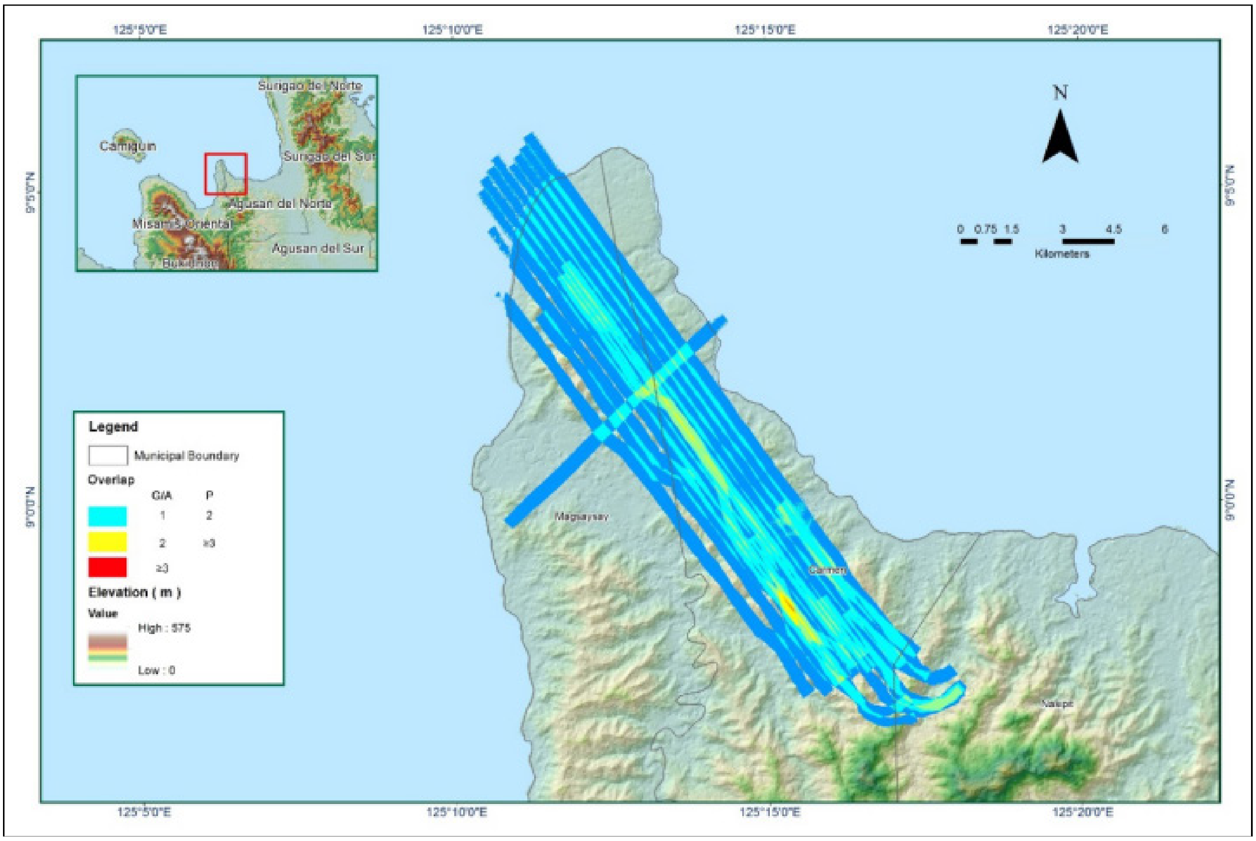


Figure A-8.19. Image of Data Overlap

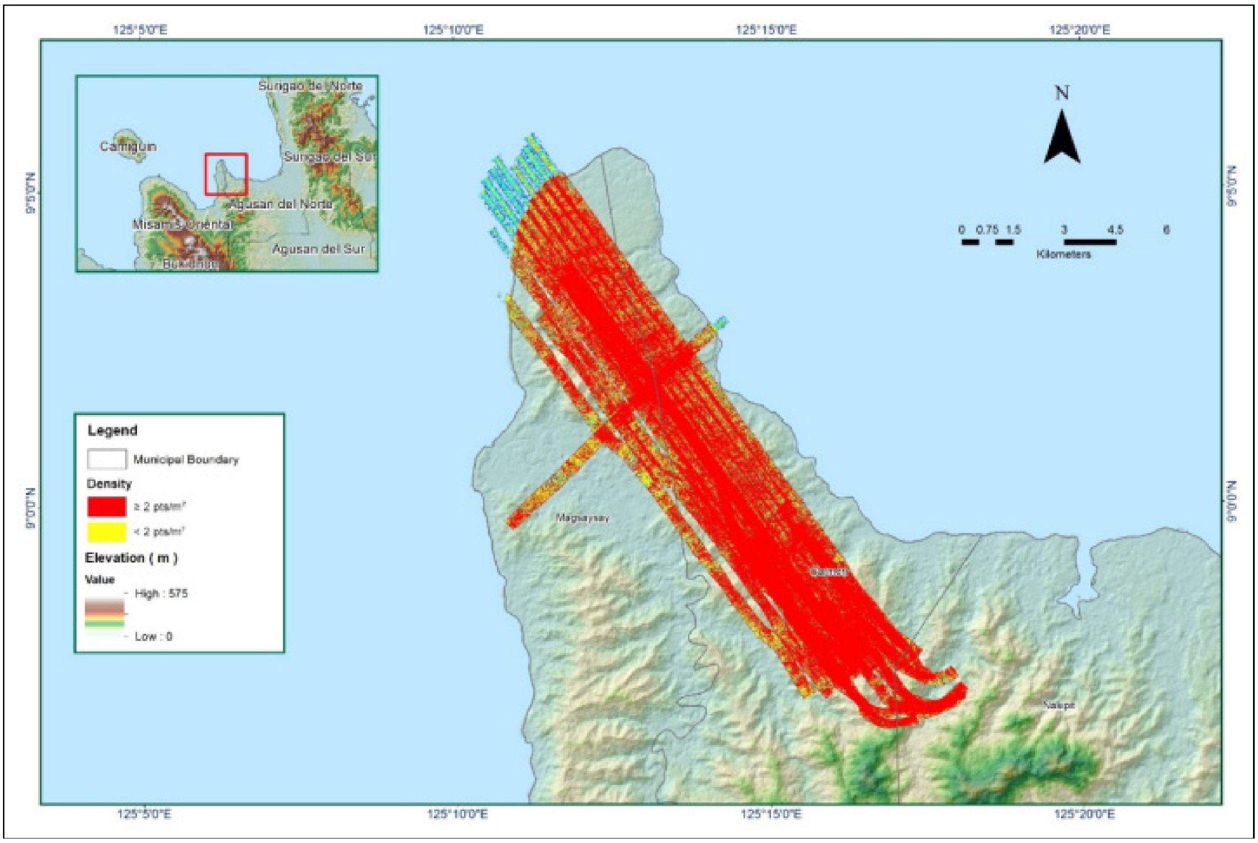


Figure A-8.20. Density map of merged LiDAR data

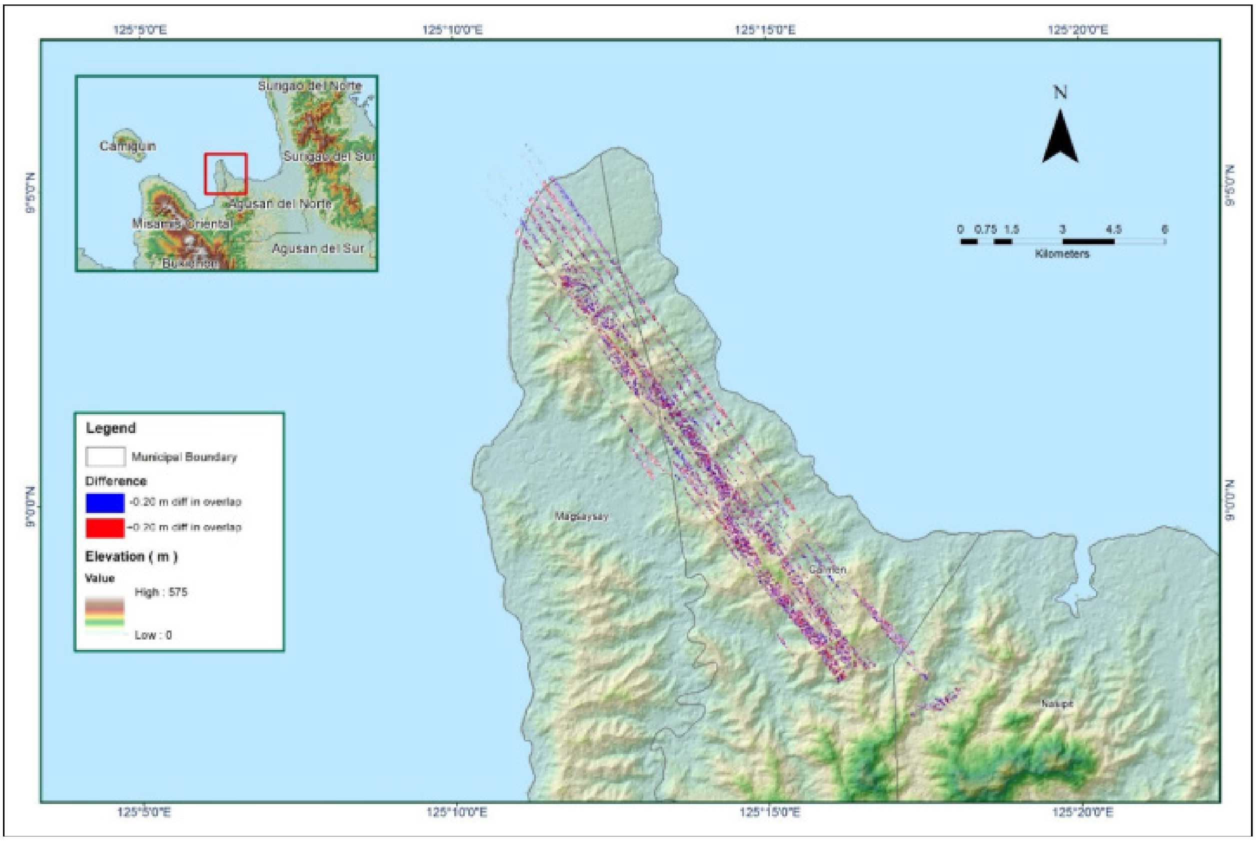


Figure A-8.21. Elevation difference between flight lines

Table A-8.4. Mission Summary Report for Mission Blk63C (Siargao)

Flight Area	Surigao City
Mission Name	Blk63C (Siargao)
Inclusive Flights	2094A
Range data size	8.75 GB
Base data size	10.4 MB
POS	205 MB
Image	NA
Transfer date	October 31, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics(in cm)	
RMSE for North Position (<4.0 cm)	1.30
RMSE for East Position (<4.0 cm)	1.45
RMSE for Down Position (<8.0 cm)	4.20
Boresight correction stdev (<0.001deg)	0.000205
IMU attitude correction stdev (<0.001deg)	0.000700
GPS position stdev (<0.01m)	0.0092
Minimum % overlap (>25)	45.66%
Ave point cloud density per sq.m. (>2.0)	3.11
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	103
Maximum Height	401.48 m
Minimum Height	51.77 m
Classification (# of points)	
Ground	35,189,757
Low vegetation	32,631,551
Medium vegetation	40,195,416
High vegetation	43,593,591
Building	1,159,071
Orthophoto	No
Processed by	Engr. Jommer Medina, Engr. Angelo Carlo Bongat, Engr. Christy Lubiano, Engr. Krisha Bautista

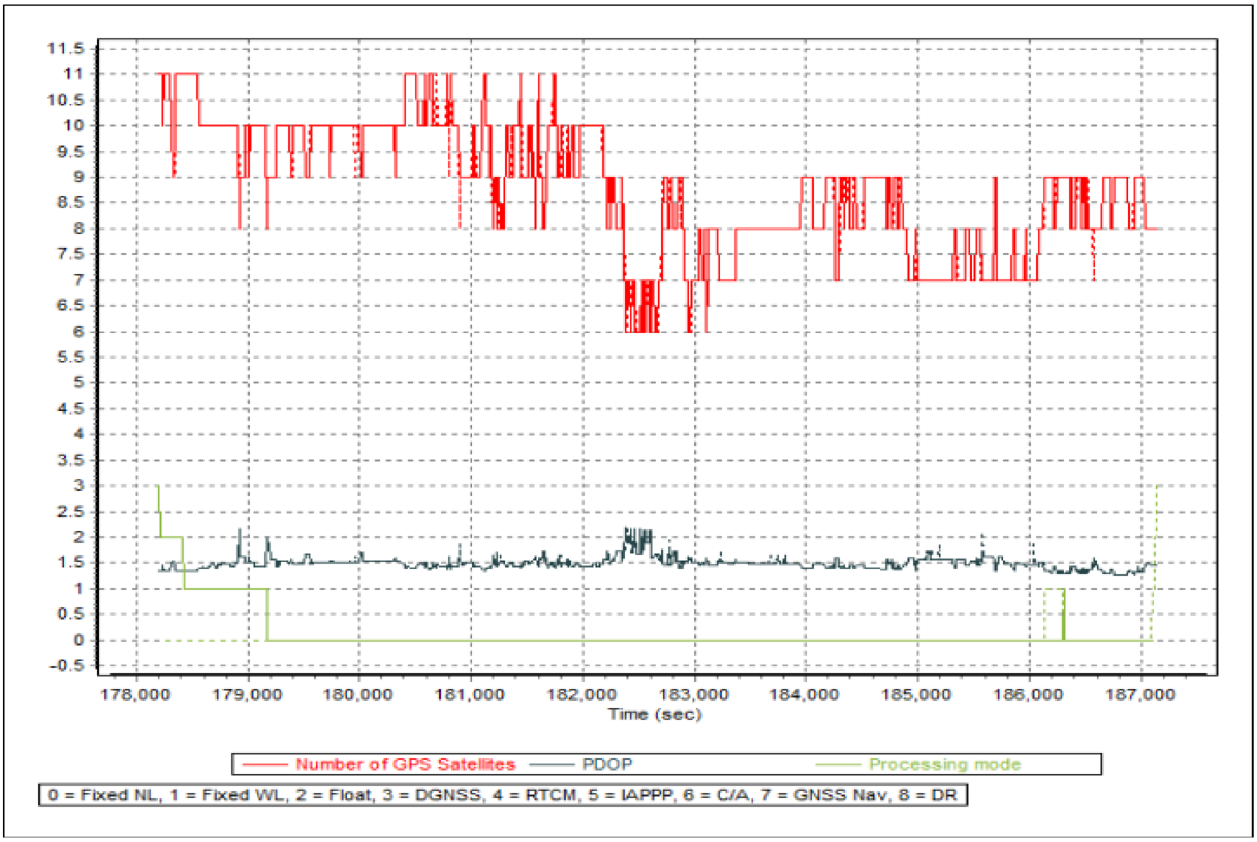


Figure A-8.22. Solution Status

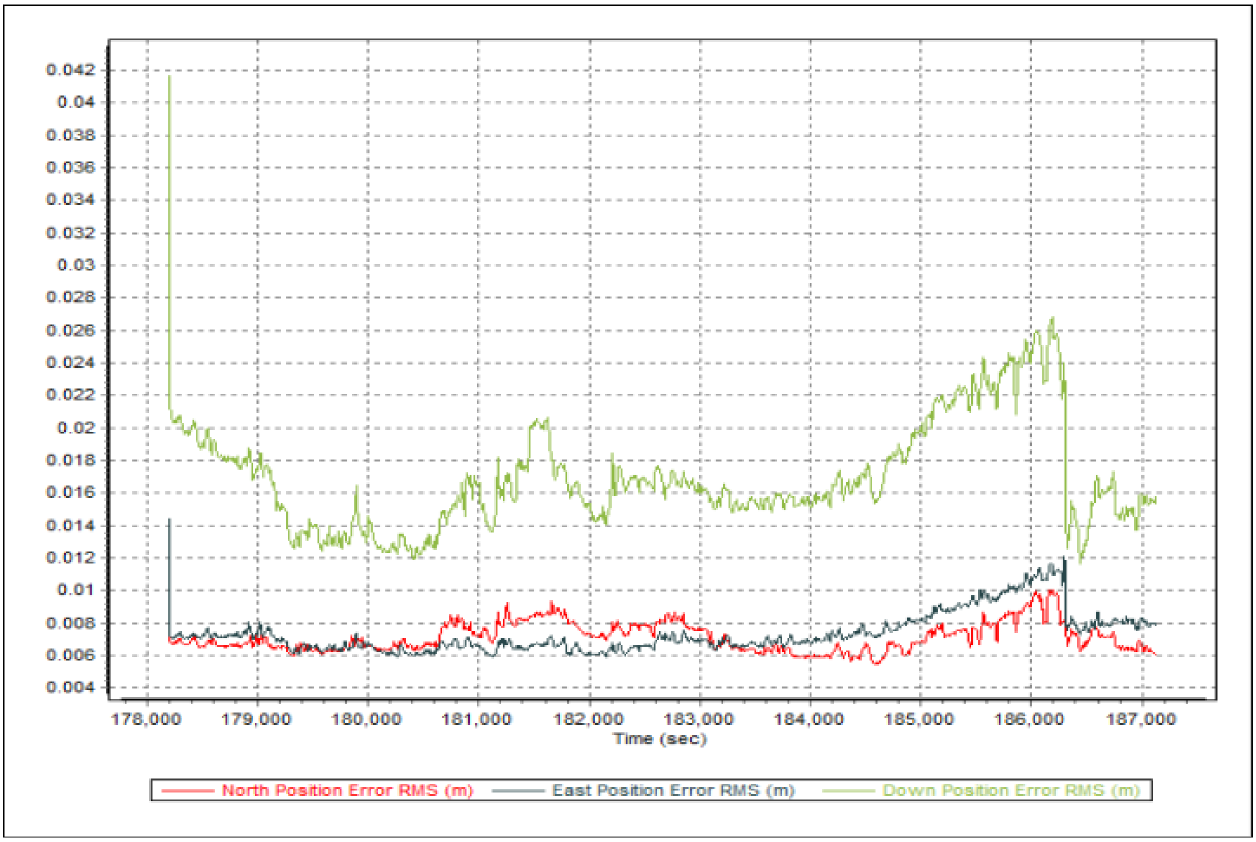


Figure A-8.23. Smoothed Performance Metric Parameters

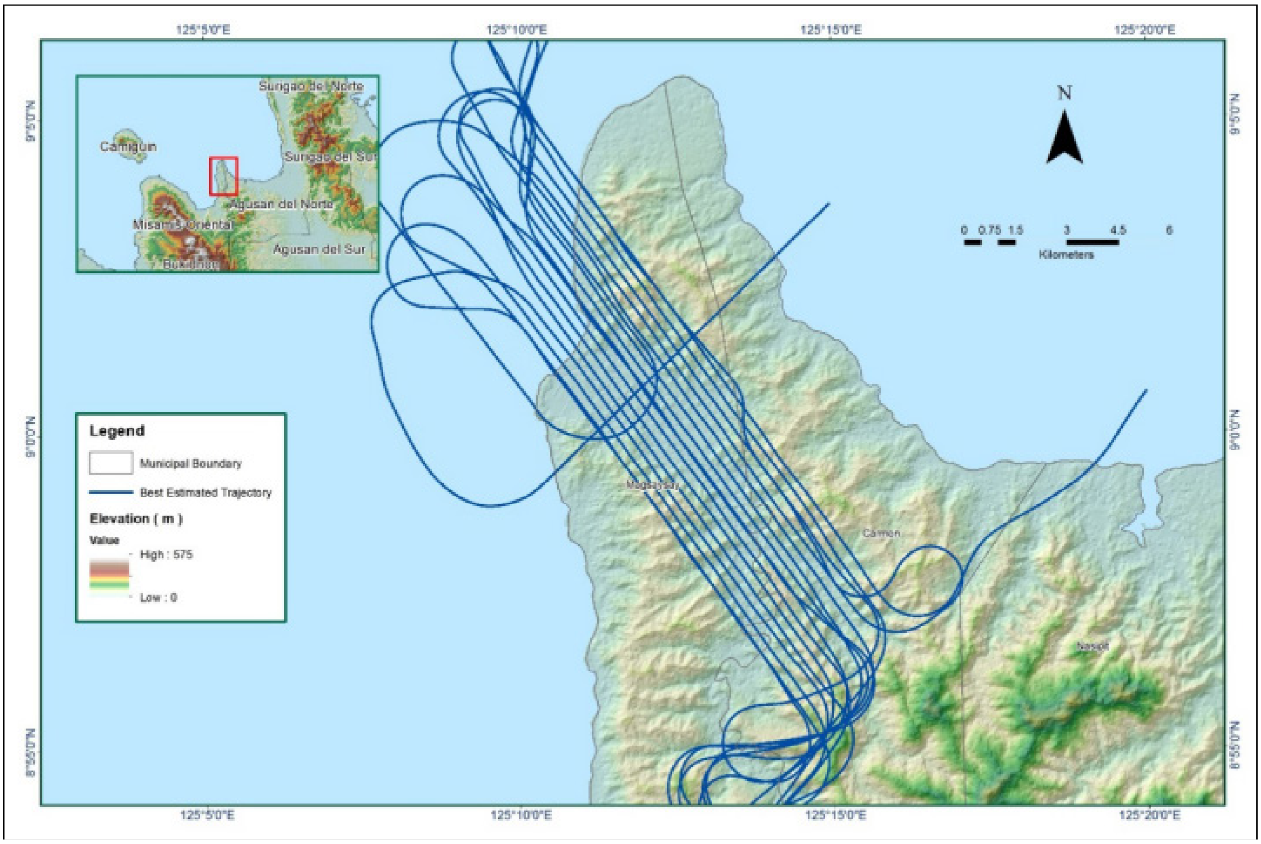


Figure A-8.24. Best Estimated Trajectory

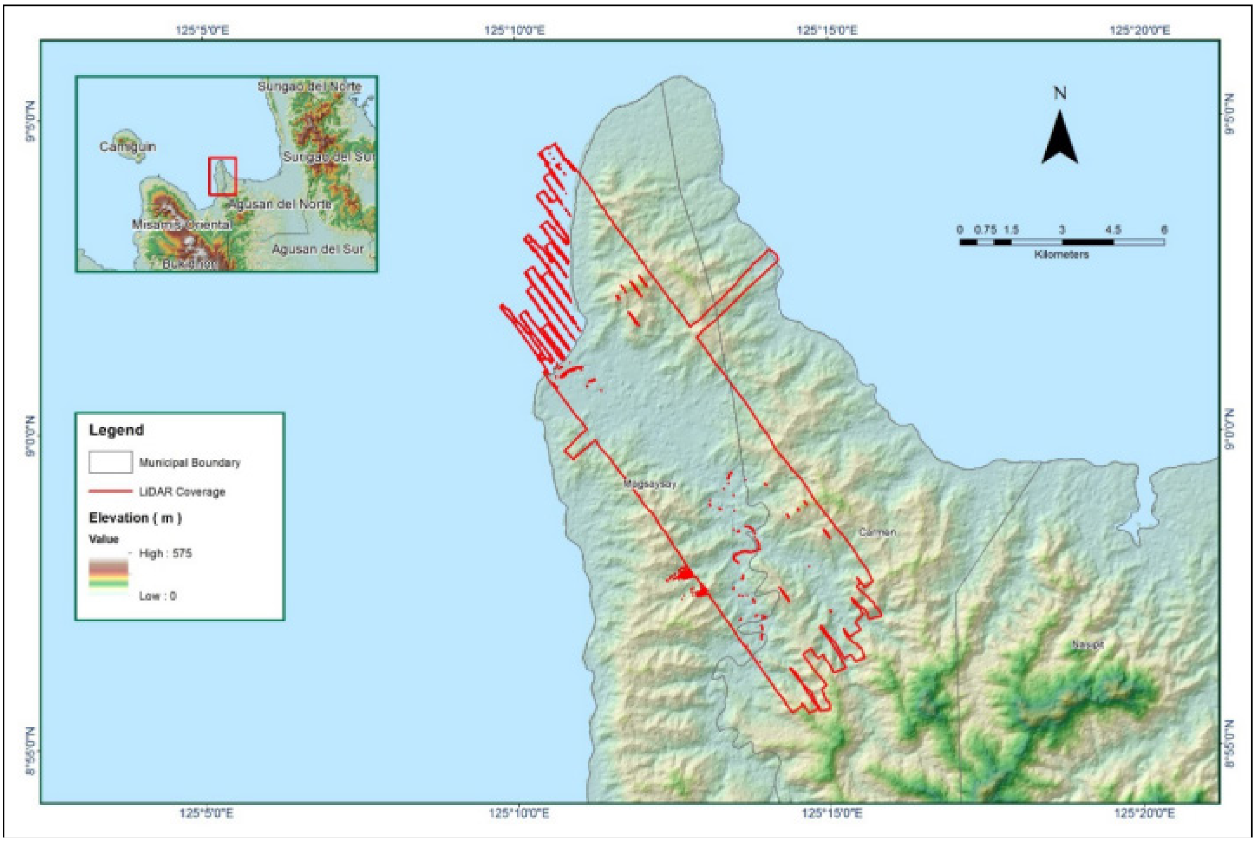


Figure A-8.25. Coverage of LiDAR data

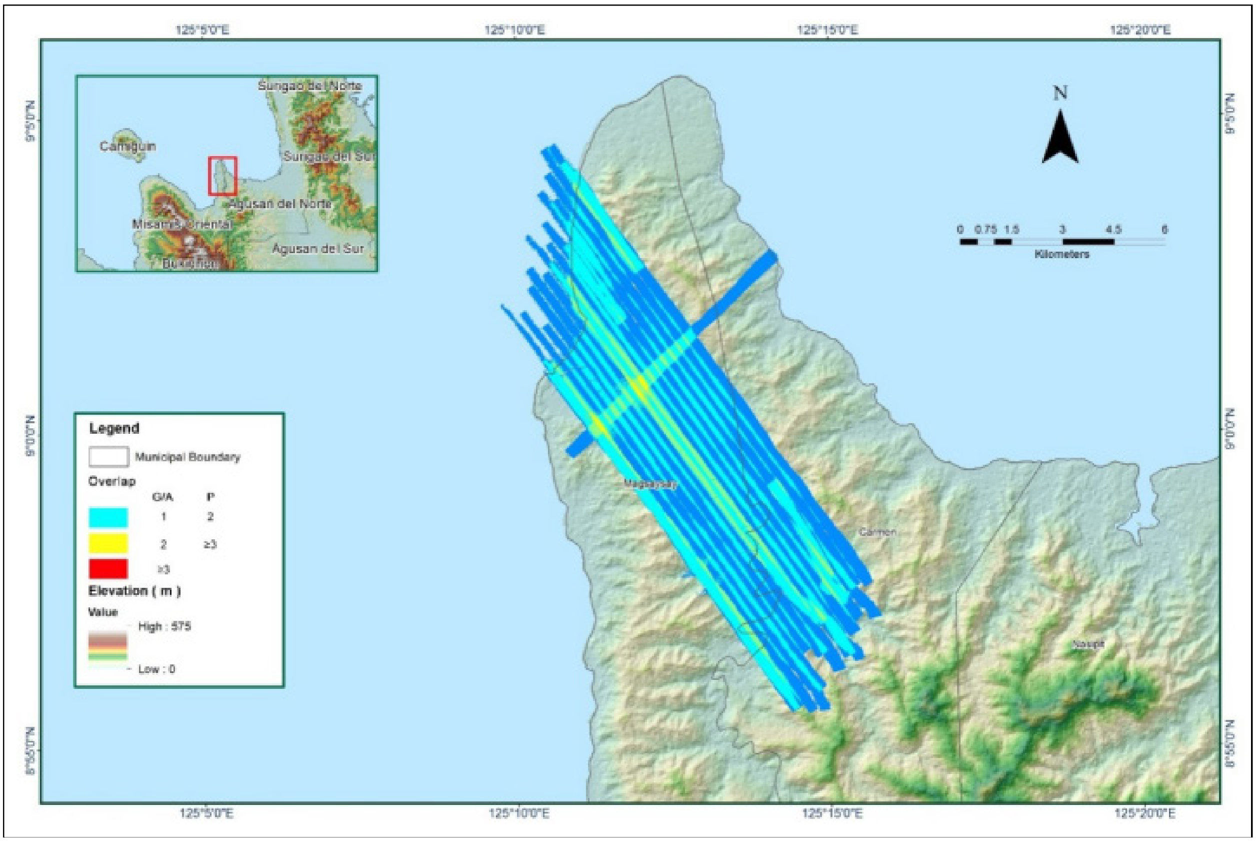


Figure A-8.26. Image of Data Overlap

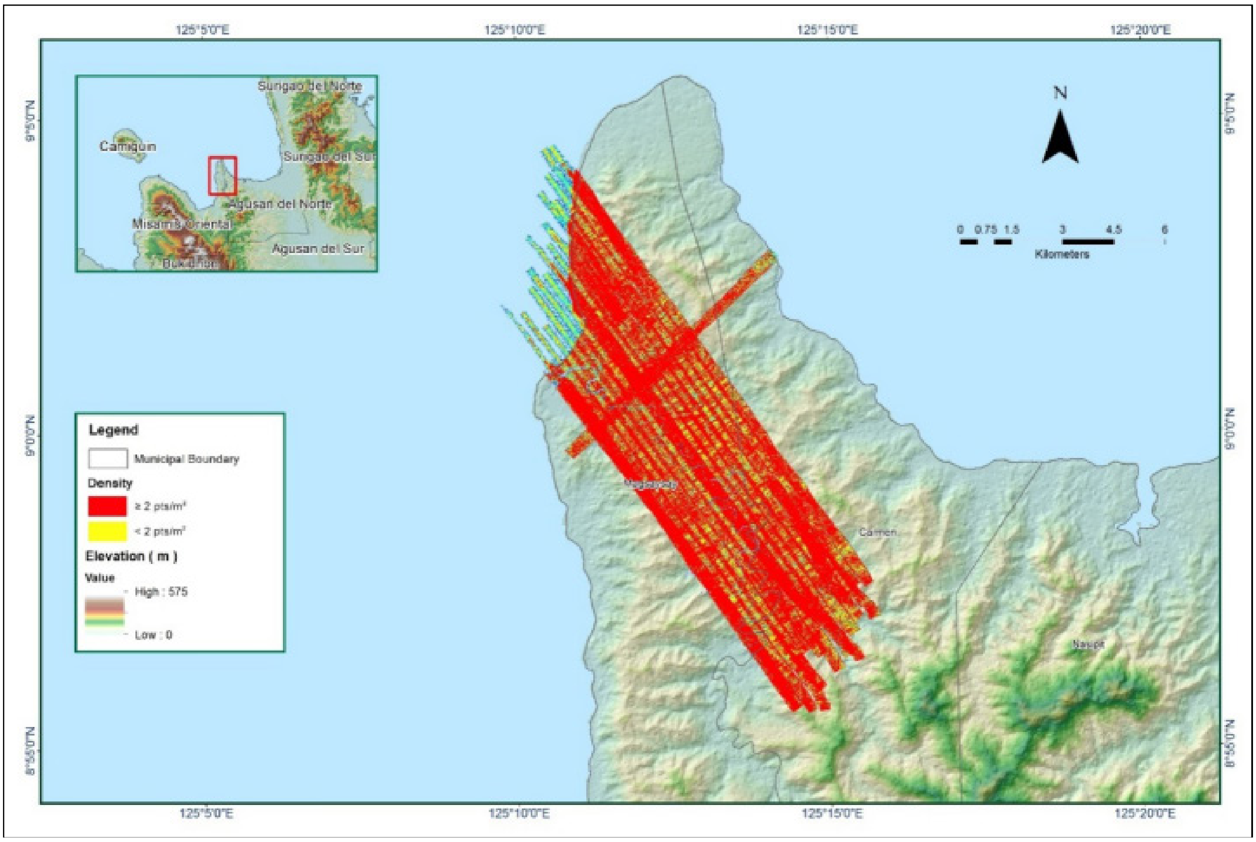


Figure A-8.27. Density map of merged LiDAR data

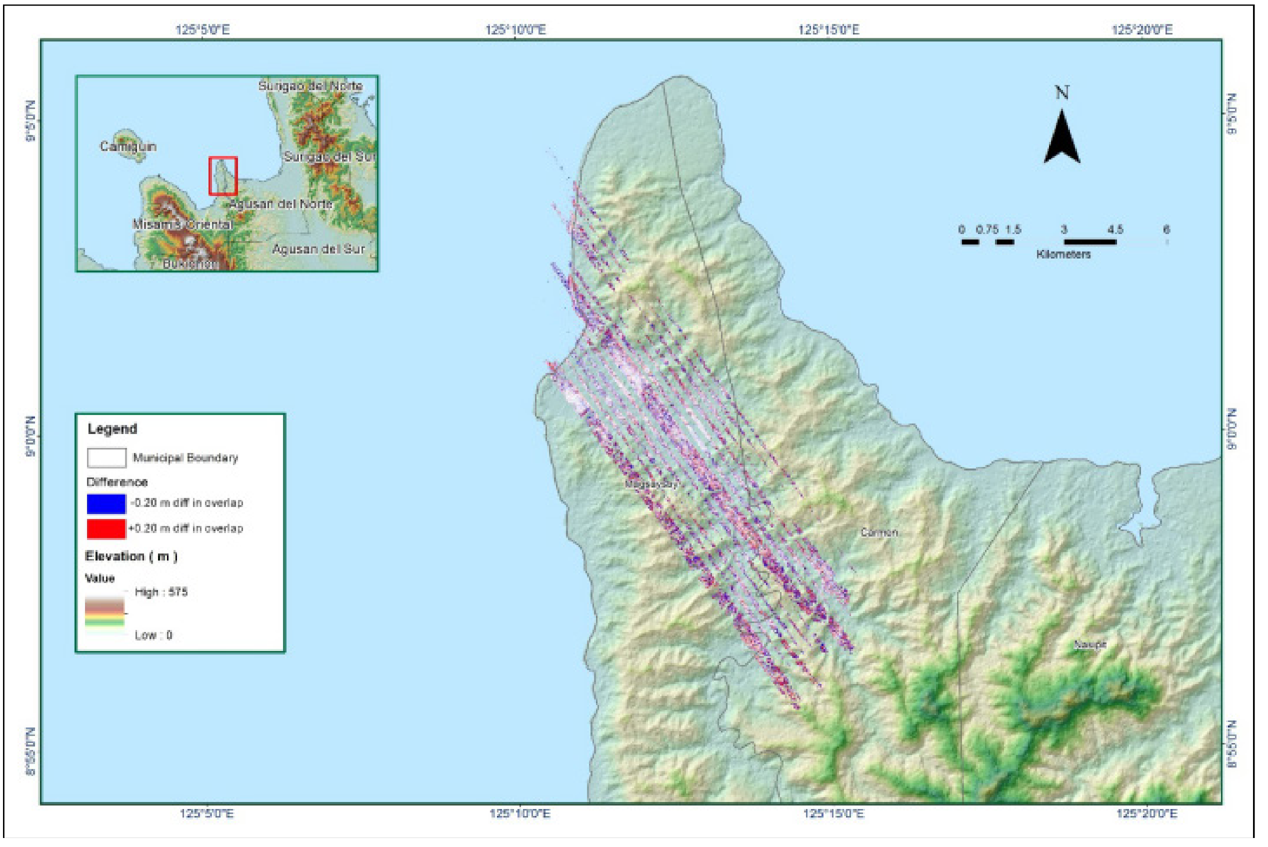


Figure A-8.28. Elevation difference between flight lines

Annex 9. Linugos Model Basin Parameters

Table A-9.1. Linugos Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W340	22.48	85	0	1	1	Discharge	0.10549	0.00001	Ratio to Peak	0.00001
W350	20	80	0	0.5	0.5	Discharge	0.034027	0.00001	Ratio to Peak	0.00001
W370	27	97.02	1.78	1.1	0.228	Discharge	0.061698	1	Ratio to Peak	0.00001
W390	24	35	2	0.01667	0.01667	Discharge	0.093307	0.00001	Ratio to Peak	0.00001
W400	24.25	39	8	0.01667	0.01667	Discharge	0.19437	0.00001	Ratio to Peak	0.00001
W410	50	35	0	0.01667	0.01667	Discharge	0.008417	0.00001	Ratio to Peak	0.00001
W420	38.85	38.8	0	0.5	0.5	Discharge	0.054554	0.00001	Ratio to Peak	0.00001
W430	35	40	0	0.5	2	Discharge	0.283034	0.00001	Ratio to Peak	0.00001
W440	23.85	80	0	0.01667	0.01667	Discharge	0.129973	0.00001	Ratio to Peak	0.00001
W450	27.18	75.928	0	0.01667	0.01667	Discharge	0.067153	0.00001	Ratio to Peak	0.00001
W460	27.70337	75.593	0	0.01667	0.01667	Discharge	0.083183	0.00001	Ratio to Peak	0.00001
W470	23.85	80.5	0	0.01667	0.01667	Discharge	0.049973	0.00001	Ratio to Peak	0.00001
W480	26.879	76.1	0	0.01667	0.01667	Discharge	0.019122	0.00001	Ratio to Peak	0.00001
W490	29.903	74.20514	0	0.01667	0.01667	Discharge	0.071677	0.00001	Ratio to Peak	0.00001
W500	30.891	73.598	0	0.01667	0.01667	Discharge	0.060043	0.00001	Ratio to Peak	0.00001
W510	28.851	80	0	0.01667	0.01667	Discharge	0.045255	0.00001	Ratio to Peak	0.00001
W520	35.24	79	0	0.75	0.6	Discharge	0.014703	0.00001	Ratio to Peak	0.00001
W530	26.41	91.52027	0	0.01667	0.01667	Discharge	0.054341	0.00001	Ratio to Peak	0.00001
W540	26.66	72	0	0.01667	0.01667	Discharge	0.10534	0.00001	Ratio to Peak	0.00001
W550	19.07	81.582	0	0.01667	0.01667	Discharge	0.083099	0.00001	Ratio to Peak	0.00001
W560	30.327	73.943	0	0.01667	0.01667	Discharge	0.066391	0.00001	Ratio to Peak	0.00001
W570	31.55	85	0	0.01667	0.01667	Discharge	0.076397	0.00001	Ratio to Peak	0.00001
W580	31.55	85	0	0.01667	0.01667	Discharge	0.064309	0.00001	Ratio to Peak	0.00001

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W590	29.24	84	0	0.01667	0.01667	Discharge	0.014101	0.00001	Ratio to Peak	0.00001
W600	27.193	85	0	0.01667	0.01667	Discharge	0.048029	0.00001	Ratio to Peak	0.00001
W610	31.79	85	0	0.01667	0.01667	Discharge	0.052194	0.00001	Ratio to Peak	0.00001
W620	31.766	73.069	0	0.01667	0.01667	Discharge	0.212297	0.00001	Ratio to Peak	0.00001
W630	31.55	73	0	0.01667	0.01667	Discharge	0.057739	0.00001	Ratio to Peak	0.00001
W640	38.927	85.449	0	5	0.01667	Discharge	0.064719	0.00001	Ratio to Peak	0.00001
W650	24.175	77.931	0	0.01667	0.01667	Discharge	0.075652	0.00001	Ratio to Peak	0.00001
W660	27.141	75.277	0	50	2	Discharge	0.10292	0.00001	Ratio to Peak	0.00001
W680	22.94119	78.783	0	0.01667	0.01667	Discharge	0.055108	0.00001	Ratio to Peak	0.00001
W690	23.85	78	0	0.01667	0.01667	Discharge	0.051011	0.00001	Ratio to Peak	0.00001
W730	36	78	0	0.01667	0.01667	Discharge	0.0076	0.00001	Ratio to Peak	0.00001
W740	23.85	78	0	0.01667	0.01667	Discharge	0.006024	0.00001	Ratio to Peak	0.00001

Annex 10. Linugos Model Reach Parameters

Table A-10.1. Linugos Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R10	Automatic Fixed Interval	1293.8	0.004773	0.0001	Trapezoid	35	1
R100	Automatic Fixed Interval	3545.9	0.02536	0.0089	Trapezoid	23	1
R110	Automatic Fixed Interval	14584	0.000941	0.0001	Trapezoid	35	1
R140	Automatic Fixed Interval	2159.7	0.000431	0.0001	Trapezoid	18	1
R150	Automatic Fixed Interval	3029.7	0.003036	0.00013	Trapezoid	35	1
R190	Automatic Fixed Interval	1605.2	0.000201	0.0001	Trapezoid	35	1
R210	Automatic Fixed Interval	4453.9	0.002587	0.0001	Trapezoid	25	1
R240	Automatic Fixed Interval	1470.7	0.052609	0.0001	Trapezoid	35	1
R260	Automatic Fixed Interval	3122.2	0.01049	0.000236	Trapezoid	35	1
R290	Automatic Fixed Interval	7616	0.019623	0.00016	Trapezoid	35	1
R30	Automatic Fixed Interval	3539.9	0.001102	0.0001	Trapezoid	35	1
R300	Automatic Fixed Interval	2474.8	0.022791	0.029	Trapezoid	35	1
R310	Automatic Fixed Interval	3385.9	0.033558	0.0001	Trapezoid	35	1
R50	Automatic Fixed Interval	9235	0.000831	0.01787	Trapezoid	35	1
R60	Automatic Fixed Interval	745.64	0.002076	0.1224	Trapezoid	35	1
R700	Automatic Fixed Interval	428.12	0.002801	0.02	Trapezoid	35	1
R750	Automatic Fixed Interval	231	0.011476	0.00022	Trapezoid	35	1
R80	Automatic Fixed Interval	3858.5	0.0061	0.007	Trapezoid	35	1

Annex 11. Linugos Field Validation Points

Table A-11.1. Linugos Field Validation Points

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Valid-ation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
1	9.01987	125.18253	0.07	0.00	-0.07	Ondoy/25Nov2009	5YR
2	9.01858	125.18130	0.07	0.00	-0.07	Ondoy/25Nov2009	5YR
3	9.01802	125.18035	0.07	0.00	-0.07	Ondoy/25Nov2009	5YR
4	9.01793	125.17940	0.05	1.00	0.95	Ondoy/25Nov2009	5YR
5	9.01794	125.17899	0.07	0.50	0.43	Ondoy/25Nov2009	5YR
6	9.01772	125.17940	0.07	1.00	0.93	Ondoy/25Nov2009	5YR
7	9.01919	125.17979	0.24	0.00	-0.24	Ondoy/25Nov2009	5YR
8	9.02016	125.18030	0.16	0.00	-0.16	Ondoy/25Nov2009	5YR
9	9.02049	125.18650	0.70	0.00	-0.70	Ondoy/25Nov2009	5YR
10	9.02037	125.18687	0.58	0.00	-0.58	Ondoy/25Nov2009	5YR
11	9.01980	125.18795	0.74	0.00	-0.74	Ondoy/25Nov2009	5YR
12	9.02033	125.18820	0.04	0.75	0.71	Ondoy/25Nov2009	5YR
13	9.02047	125.19008	0.17	0.50	0.33	Ondoy/25Nov2009	5YR
14	9.02038	125.18894	0.07	0.00	-0.07	Ondoy/25Nov2009	5YR
15	9.01506	125.19356	0.42	1.00	0.58	Ondoy/25Nov2009	5YR
16	9.01169	125.19283	0.42	0.00	-0.42	Ondoy/25Nov2009	5YR
17	9.00991	125.19296	0.96	0.00	-0.96	Ondoy/25Nov2009	5YR
18	9.00995	125.19415	0.07	0.00	-0.07	Ondoy/25Nov2009	5YR
19	9.01862	125.19392	0.23	0.00	-0.23	Ondoy/25Nov2009	5YR
20	9.02102	125.19392	0.21	0.00	-0.21	Ondoy/25Nov2009	5YR
21	9.02006	125.19707	0.19	0.10	-0.09	Ondoy/25Nov2009	5YR
22	9.01713	125.19978	0.12	0.00	-0.12	Ondoy/25Nov2009	5YR
23	9.01802	125.20346	0.15	0.00	-0.15	Ondoy/25Nov2009	5YR
24	9.01823	125.20336	0.07	0.00	-0.07	Ondoy/25Nov2009	5YR
25	9.01489	125.20092	0.07	0.00	-0.07	Ondoy/25Nov2009	5YR
26	9.01334	125.20460	0.07	0.00	-0.07	Ondoy/25Nov2009	5YR
27	9.01087	125.20366	0.07	0.00	-0.07	Ondoy/25Nov2009	5YR
28	9.01061	125.20339	0.92	0.00	-0.92	Ondoy/25Nov2009	5YR
29	9.01047	125.20287	1.26	0.00	-1.26	Ondoy/25Nov2009	5YR
30	9.01061	125.20277	0.16	0.00	-0.16	Ondoy/25Nov2009	5YR
31	9.00989	125.20336	1.70	0.00	-1.70	Ondoy/25Nov2009	5YR
32	9.00041	125.21069	1.69	0.40	-1.29	Ondoy/25Nov2009	5YR
33	8.99945	125.20887	0.90	0.00	-0.90	Ondoy/25Nov2009	5YR
34	8.99840	125.21086	0.29	0.00	-0.29	Ondoy/25Nov2009	5YR
35	8.99940	125.20856	0.29	0.00	-0.29	Ondoy/25Nov2009	5YR
36	9.00095	125.20777	1.26	0.40	-0.86	Ondoy/25Nov2009	5YR
37	8.99736	125.21112	0.19	0.00	-0.19	Ondoy/25Nov2009	5YR
38	8.99695	125.21149	0.17	0.00	-0.17	Ondoy/25Nov2009	5YR
39	8.99655	125.21153	0.55	0.00	-0.55	Ondoy/25Nov2009	5YR
40	8.99484	125.21411	0.10	0.40	0.30	Ondoy/25Nov2009	5YR

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Valid-ation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
41	8.99418	125.21491	0.67	0.00	-0.67	Ondoy/25Nov2009	5YR
42	8.99509	125.21728	0.07	0.00	-0.07	Ondoy/25Nov2009	5YR
43	9.01519	125.17622	0.07	0.40	0.33	Ondoy/25Nov2009	5YR
44	9.01517	125.17642	0.07	0.00	-0.07	Ondoy/25Nov2009	5YR
45	9.01480	125.17595	0.12	0.00	-0.12	Ondoy/25Nov2009	5YR
46	9.01494	125.17590	0.17	0.00	-0.17	Ondoy/25Nov2009	5YR
47	9.01309	125.17571	0.12	0.00	-0.12	Ondoy/25Nov2009	5YR
48	9.01159	125.17421	0.07	1.50	1.43	Ondoy/25Nov2009	5YR
49	9.01088	125.17340	0.07	2.00	1.93	Ondoy/25Nov2009	5YR
50	9.00421	125.18109	0.41	1.00	0.59	Ondoy/25Nov2009	5YR
51	9.00572	125.18711	0.05	0.40	0.35	Ondoy/25Nov2009	5YR
52	9.00942	125.18692	0.07	1.50	1.43	Ondoy/25Nov2009	5YR
53	9.00975	125.18634	0.17	1.00	0.83	Ondoy/25Nov2009	5YR
54	9.00192	125.19394	0.13	0.00	-0.13	Ondoy/25Nov2009	5YR
55	9.00129	125.19191	0.07	0.00	-0.07	Ondoy/25Nov2009	5YR
56	9.00375	125.18915	0.07	0.00	-0.07	Ondoy/25Nov2009	5YR
57	9.00526	125.20158	1.07	0.00	-1.07	Ondoy/25Nov2009	5YR
58	9.00486	125.20072	0.07	0.00	-0.07	Ondoy/25Nov2009	5YR
59	9.00465	125.19995	0.17	1.00	0.83	Ondoy/25Nov2009	5YR
60	9.00512	125.19911	0.41	0.00	-0.41	Ondoy/25Nov2009	5YR
61	9.00411	125.19921	0.37	2.00	1.63	Ondoy/25Nov2009	5YR
62	9.00568	125.20279	2.44	1.50	-0.94	Ondoy/25Nov2009	5YR
63	9.00572	125.20273	2.72	1.50	-1.22	Ondoy/25Nov2009	5YR
64	9.00577	125.20242	2.53	0.00	-2.53	Ondoy/25Nov2009	5YR
65	9.00651	125.20424	0.15	0.00	-0.15	Ondoy/25Nov2009	5YR
66	8.99877	125.20357	1.38	1.00	-0.38	Ondoy/25Nov2009	5YR
67	8.99970	125.20333	0.95	0.00	-0.95	Ondoy/25Nov2009	5YR
68	8.99971	125.20331	0.95	0.00	-0.95	Ondoy/25Nov2009	5YR
69	8.99957	125.20349	1.02	0.40	-0.62	Ondoy/25Nov2009	5YR
70	8.99721	125.20254	1.02	0.00	-1.02	Ondoy/25Nov2009	5YR
71	8.99715	125.20245	1.02	0.00	-1.02	Ondoy/25Nov2009	5YR
72	9.00193	125.20086	1.31	0.00	-1.31	Ondoy/25Nov2009	5YR
73	9.01146	125.17850	0.07	2.00	1.93	Ondoy/25Nov2009	5YR
74	9.01366	125.17860	0.07	2.00	1.93	Ondoy/25Nov2009	5YR
75	9.00735	125.17527	0.04	2.00	1.96	Ondoy/25Nov2009	5YR
76	9.00849	125.17649	0.04	2.00	1.96	Ondoy/25Nov2009	5YR
77	9.00734	125.17764	0.07	2.00	1.93	Ondoy/25Nov2009	5YR
78	9.01015	125.17777	0.07	2.00	1.93	Ondoy/25Nov2009	5YR
79	9.00578	125.17965	0.07	2.00	1.93	Ondoy/25Nov2009	5YR
80	9.00562	125.17682	0.17	2.50	2.33	Ondoy/25Nov2009	5YR
81	9.01090	125.17644	0.28	2.50	2.22	Ondoy/25Nov2009	5YR

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Valid-ation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
82	9.01023	125.17419	0.15	2.50	2.35	Ondoy/25Nov2009	5YR
83	9.00839	125.17418	0.32	2.50	2.18	Ondoy/25Nov2009	5YR
84	9.00629	125.18086	0.52	2.50	1.98	Ondoy/25Nov2009	5YR
85	9.01157	125.17997	1.01	2.50	1.49	Ondoy/25Nov2009	5YR
86	9.01268	125.17651	0.24	2.50	2.26	Ondoy/25Nov2009	5YR
87	9.00728	125.17856	0.22	2.50	2.28	Ondoy/25Nov2009	5YR
88	9.00820	125.17741	0.21	2.50	2.29	Ondoy/25Nov2009	5YR
89	9.00961	125.17531	0.15	2.50	2.35	Ondoy/25Nov2009	5YR
90	9.00958	125.17964	1.03	2.50	1.47	Ondoy/25Nov2009	5YR
91	9.00488	125.21760	0.42	0.00	-0.42	Ondoy/25Nov2009	5YR
92	9.00699	125.21814	0.20	0.00	-0.20	Ondoy/25Nov2009	5YR
93	9.00816	125.21926	0.07	0.00	-0.07	Ondoy/25Nov2009	5YR
94	9.00889	125.22156	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR
95	9.00734	125.22600	0.07	0.00	-0.07	Ondoy/25Nov2009	5YR
96	9.00475	125.22942	0.04	0.00	-0.04	Ondoy/25Nov2009	5YR
97	9.00449	125.23049	0.07	0.00	-0.07	Ondoy/25Nov2009	5YR
98	9.00717	125.21502	0.52	0.00	-0.52	Ondoy/25Nov2009	5YR
99	9.00675	125.20773	0.07	0.00	-0.07	Ondoy/25Nov2009	5YR
100	9.01990	125.18201	0.07	0.00	-0.07	Ondoy/25Nov2009	5YR
101	9.00953	125.19417	1.38	1.85	0.47	Ondoy/25Nov2009	5YR
102	9.00950	125.19478	0.07	0.00	-0.07	Ondoy/25Nov2009	5YR
103	9.00949	125.19477	0.07	0.25	0.18	Ondoy/25Nov2009	5YR
104	9.00877	125.19577	0.07	1.25	1.18	Ondoy/25Nov2009	5YR
105	9.00895	125.19573	0.07	0.00	-0.07	Ondoy/25Nov2009	5YR
106	9.00778	125.19652	1.69	2.00	0.31	Ondoy/25Nov2009	5YR
107	9.00838	125.19691	0.38	0.55	0.17	Ondoy/25Nov2009	5YR
108	9.00830	125.19808	0.12	0.00	-0.12	Ondoy/25Nov2009	5YR
109	9.00808	125.19863	0.07	0.00	-0.07	Ondoy/25Nov2009	5YR
110	9.00837	125.19939	0.07	0.00	-0.07	Ondoy/25Nov2009	5YR
111	9.00649	125.20417	0.15	0.00	-0.15	Ondoy/25Nov2009	5YR
112	8.98686	125.21655	2.68	0.00	-2.68	Ondoy/25Nov2009	5YR
113	8.98684	125.21661	2.68	0.05	-2.63	Ondoy/25Nov2009	5YR
114	8.98704	125.21592	0.12	0.00	-0.12	Ondoy/25Nov2009	5YR
115	8.98724	125.21592	0.59	0.00	-0.59	Ondoy/25Nov2009	5YR
116	8.98763	125.21523	0.19	0.05	-0.14	Ondoy/25Nov2009	5YR
117	8.98824	125.21336	0.04	0.00	-0.04	Ondoy/25Nov2009	5YR
118	8.98842	125.21318	0.05	0.25	0.20	Ondoy/25Nov2009	5YR
119	8.98872	125.21295	0.10	0.05	-0.05	Ondoy/25Nov2009	5YR
120	8.98934	125.21237	0.04	0.00	-0.04	Ondoy/25Nov2009	5YR
121	8.98980	125.21204	0.07	0.40	0.33	Ondoy/25Nov2009	5YR
122	8.98998	125.21178	0.51	0.00	-0.51	Ondoy/25Nov2009	5YR

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Valid-ation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
123	8.99196	125.21059	0.10	0.00	-0.10	Ondoy/25Nov2009	5YR
124	8.99220	125.21085	1.88	0.05	-1.83	Ondoy/25Nov2009	5YR
125	8.99205	125.21074	0.67	0.00	-0.67	Ondoy/25Nov2009	5YR
126	8.99401	125.20522	0.12	0.00	-0.12	Ondoy/25Nov2009	5YR
127	8.99702	125.21913	0.19	0.00	-0.19	Ondoy/25Nov2009	5YR
128	8.99809	125.21928	0.07	0.00	-0.07	Ondoy/25Nov2009	5YR
129	8.99952	125.21898	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR
130	9.00389	125.21646	0.07	0.00	-0.07	Ondoy/25Nov2009	5YR
131	9.00469	125.21721	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR
132	9.00730	125.21673	0.07	0.00	-0.07	Ondoy/25Nov2009	5YR
133	9.00688	125.20919	0.07	0.00	-0.07	Ondoy/25Nov2009	5YR
134	8.99605	125.21806	0.07	0.00	-0.07	Ondoy/25Nov2009	5YR
135	9.00009	125.21789	0.24	0.00	-0.24	Ondoy/25Nov2009	5YR
136	9.00121	125.21717	0.40	0.00	-0.40	Ondoy/25Nov2009	5YR
137	9.00239	125.21645	0.07	0.00	-0.07	Ondoy/25Nov2009	5YR
138	9.00578	125.21837	0.19	0.00	-0.19	Ondoy/25Nov2009	5YR
139	9.00704	125.21287	0.47	0.00	-0.47	Ondoy/25Nov2009	5YR
140	9.00688	125.21033	0.65	0.00	-0.65	Ondoy/25Nov2009	5YR
141	9.02021	125.18270	0.07	0.00	-0.07	Ondoy/25Nov2009	5YR
142	9.00622	125.20470	0.07	0.00	-0.07	Ondoy/25Nov2009	5YR
143	8.98776	125.21300	0.07	0.00	-0.07	Ondoy/25Nov2009	5YR
144	8.98796	125.21250	0.07	0.00	-0.07	Ondoy/25Nov2009	5YR
145	8.98840	125.21100	0.07	0.00	-0.07	Ondoy/25Nov2009	5YR
146	8.98809	125.21060	0.07	0.00	-0.07	Ondoy/25Nov2009	5YR
147	8.98986	125.21050	0.07	0.00	-0.07	Ondoy/25Nov2009	5YR
148	8.99203	125.21080	0.67	0.00	-0.67	Ondoy/25Nov2009	5YR
149	8.99207	125.20900	0.16	0.00	-0.16	Ondoy/25Nov2009	5YR
150	8.99113	125.20720	0.38	0.00	-0.38	Ondoy/25Nov2009	5YR
151	8.99205	125.20700	0.16	0.00	-0.16	Ondoy/25Nov2009	5YR
152	8.99397	125.20840	2.07	0.00	-2.07	Ondoy/25Nov2009	5YR
153	8.99620	125.20900	4.03	0.95	-3.08	Ondoy/25Nov2009	5YR
154	8.99264	125.20640	0.12	0.40	0.28	Ondoy/25Nov2009	5YR
155	8.99599	125.20490	3.81	0.50	-3.31	Ondoy/25Nov2009	5YR
156	8.99919	125.20360	1.56	0.70	-0.86	Ondoy/25Nov2009	5YR
157	8.99859	125.20250	0.68	0.00	-0.68	Ondoy/25Nov2009	5YR
158	8.99724	125.20260	1.21	0.80	-0.41	Ondoy/25Nov2009	5YR
159	8.99570	125.20160	0.07	0.00	-0.07	Ondoy/25Nov2009	5YR
160	9.00093	125.20030	0.53	0.80	0.27	Ondoy/25Nov2009	5YR
161	9.00189	125.20150	1.64	0.86	-0.78	Ondoy/25Nov2009	5YR
162	9.00209	125.20200	1.46	0.97	-0.49	Ondoy/25Nov2009	5YR
163	9.00182	125.20260	1.26	1.10	-0.16	Ondoy/25Nov2009	5YR

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Valid-ation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
164	9.00127	125.20110	1.10	0.60	-0.50	Ondoy/25Nov2009	5YR
165	9.00252	125.20090	1.95	1.43	-0.52	Ondoy/25Nov2009	5YR
166	9.00234	125.19970	0.07	0.60	0.53	Ondoy/25Nov2009	5YR
167	9.00288	125.20070	1.63	1.00	-0.63	Ondoy/25Nov2009	5YR
168	8.99320	125.21500	0.42	1.42	1.00	Ondoy/25Nov2009	5YR
169	8.99724	125.21110	0.12	0.00	-0.12	Ondoy/25Nov2009	5YR
170	8.99682	125.21070	1.60	0.80	-0.80	Ondoy/25Nov2009	5YR
171	8.99966	125.21090	0.60	0.00	-0.60	Ondoy/25Nov2009	5YR
172	9.00197	125.21220	1.49	0.90	-0.59	Ondoy/25Nov2009	5YR
173	9.00404	125.20920	3.21	0.00	-3.21	Ondoy/25Nov2009	5YR
174	9.00176	125.21000	2.55	0.81	-1.74	Ondoy/25Nov2009	5YR
175	9.00234	125.20980	1.74	0.89	-0.85	Ondoy/25Nov2009	5YR
176	9.00305	125.20890	1.77	0.00	-1.77	Ondoy/25Nov2009	5YR
177	9.00220	125.20840	2.56	1.41	-1.15	Ondoy/25Nov2009	5YR
178	9.00674	125.20760	0.07	0.40	0.33	Ondoy/25Nov2009	5YR
179	9.00100	125.23470	0.07	0.00	-0.07	Ondoy/25Nov2009	5YR
180	9.00295	125.22820	0.07	0.00	-0.07	Ondoy/25Nov2009	5YR
181	9.00932	125.21930	1.13	0.60	-0.53	Ondoy/25Nov2009	5YR
182	9.00871	125.21850	0.24	0.30	0.06	Ondoy/25Nov2009	5YR
183	9.00833	125.21780	0.59	0.05	-0.54	Ondoy/25Nov2009	5YR
184	9.00895	125.21750	0.78	0.60	-0.18	Ondoy/25Nov2009	5YR
185	9.00716	125.21560	0.07	0.60	0.53	Ondoy/25Nov2009	5YR
186	9.00586	125.20610	0.04	0.05	0.01	Ondoy/25Nov2009	5YR
187	9.00625	125.20480	0.07	0.00	-0.07	Ondoy/25Nov2009	5YR
188	9.01714	125.17880	0.65	0.90	0.25	Ondoy/25Nov2009	5YR
189	9.01679	125.17850	0.19	0.90	0.71	Ondoy/25Nov2009	5YR
190	9.01622	125.17790	0.53	1.20	0.67	Ondoy/25Nov2009	5YR
191	9.01610	125.17820	0.37	0.90	0.53	Ondoy/25Nov2009	5YR
192	9.01768	125.17990	0.07	0.90	0.83	Ondoy/25Nov2009	5YR
193	9.01815	125.18100	0.16	0.50	0.34	Ondoy/25Nov2009	5YR
194	9.02043	125.18650	0.70	0.50	-0.20	Ondoy/25Nov2009	5YR
195	9.02064	125.18800	0.05	0.50	0.45	Ondoy/25Nov2009	5YR
196	9.01977	125.18800	0.74	1.30	0.56	Ondoy/25Nov2009	5YR
197	9.02114	125.19360	0.12	0.50	0.38	Ondoy/25Nov2009	5YR
198	9.01822	125.19350	0.05	0.10	0.05	Ondoy/25Nov2009	5YR
199	9.01741	125.19380	0.20	0.50	0.30	Ondoy/25Nov2009	5YR
200	9.01504	125.19360	0.42	0.50	0.08	Ondoy/25Nov2009	5YR
201	9.01451	125.19360	0.07	0.50	0.43	Ondoy/25Nov2009	5YR
202	9.01321	125.19020	0.24	1.20	0.96	Ondoy/25Nov2009	5YR
203	9.01367	125.18980	0.07	1.20	1.13	Ondoy/25Nov2009	5YR
204	9.01372	125.18970	0.07	1.20	1.13	Ondoy/25Nov2009	5YR

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Valid-ation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
205	9.00981	125.19300	1.03	1.50	0.47	Ondoy/25Nov2009	5YR
206	9.00879	125.19580	0.07	1.50	1.43	Ondoy/25Nov2009	5YR
207	9.01571	125.19440	0.34	0.20	-0.14	Ondoy/25Nov2009	5YR
208	9.02018	125.20820	0.55	0.40	-0.15	Ondoy/25Nov2009	5YR
209	9.01749	125.20150	0.19	0.40	0.21	Ondoy/25Nov2009	5YR
210	9.01716	125.19980	0.12	0.50	0.38	Ondoy/25Nov2009	5YR
211	9.01946	125.19780	0.10	0.30	0.20	Ondoy/25Nov2009	5YR
212	9.02074	125.20150	0.68	0.40	-0.28	Ondoy/25Nov2009	5YR
213	9.02076	125.20170	0.60	0.40	-0.20	Ondoy/25Nov2009	5YR
214	9.02117	125.20140	0.24	0.20	-0.04	Ondoy/25Nov2009	5YR
215	9.02107	125.19530	0.29	0.20	-0.09	Ondoy/25Nov2009	5YR
216	9.01263	125.20420	0.13	0.50	0.37	Ondoy/25Nov2009	5YR
217	9.01326	125.20460	0.19	0.00	-0.19	Ondoy/25Nov2009	5YR
218	9.01489	125.17600	0.07	0.00	-0.07	Ondoy/25Nov2009	5YR
219	9.01501	125.17580	0.17	0.10	-0.07	Ondoy/25Nov2009	5YR
220	9.00437	125.18070	0.19	0.50	0.31	Ondoy/25Nov2009	5YR
221	9.00496	125.18250	0.04	0.00	-0.04	Ondoy/25Nov2009	5YR
222	9.00494	125.18820	0.10	3.00	2.90	Ondoy/25Nov2009	5YR
223	9.00980	125.18620	0.05	1.20	1.15	Ondoy/25Nov2009	5YR
224	9.01002	125.18550	0.07	1.20	1.13	Ondoy/25Nov2009	5YR
225	9.01001	125.18550	0.07	1.20	1.13	Ondoy/25Nov2009	5YR
226	9.00250	125.18990	0.07	2.00	1.93	Ondoy/25Nov2009	5YR
227	9.00580	125.19340	0.29	3.00	2.71	Ondoy/25Nov2009	5YR
228	9.00446	125.19440	0.49	0.20	-0.29	Ondoy/25Nov2009	5YR
229	9.00491	125.19790	1.08	1.20	0.12	Ondoy/25Nov2009	5YR
230	9.00526	125.19890	0.95	1.20	0.25	Ondoy/25Nov2009	5YR
231	9.00572	125.20250	2.57	1.50	-1.07	Ondoy/25Nov2009	5YR
232	9.00519	125.20110	0.58	0.90	0.32	Ondoy/25Nov2009	5YR
233	9.00384	125.19810	0.52	0.90	0.38	Ondoy/25Nov2009	5YR
234	9.00468	125.20040	0.07	1.20	1.13	Ondoy/25Nov2009	5YR
235	9.00691	125.20410	0.47	0.50	0.03	Ondoy/25Nov2009	5YR
236	9.00713	125.20400	0.68	0.60	-0.08	Ondoy/25Nov2009	5YR
237	9.00423	125.20020	0.86	0.00	-0.86	Ondoy/25Nov2009	5YR
238	9.00424	125.19980	1.08	0.00	-1.08	Ondoy/25Nov2009	5YR
239	9.00473	125.20120	0.59	0.00	-0.59	Ondoy/25Nov2009	5YR

Annex 12. Educational Institutions affected by flooding in Linugos Floodplain

Table A-12.1. Educational Institutions in Magsaysay, Misamis Oriental affected by flooding in Linugos Floodplain

Misamis Oriental				
Magsaysay				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
St. Leonard College	Cabantian	Medium	Medium	Medium
Elementary School	Cabubuhan			Medium
Brgy Day Care Center	Kibungsod	High	High	High
Day Care Center	Kibungsod	High	High	High
Kibungsod Central School	Kibungsod			
Kibungsud National High School	Kibungsod			
Trinity College of Science and Technology	Kibungsod			
Day Care Center	Poblacion	Low	Medium	Medium
Magsaysay Elem School	Poblacion	Low	Low	Low
San Roque Parish High School	Poblacion	Low	Low	Medium
Day Care Center	San Vicente			
Elementary School	San Vicente			

Annex 13. Health Institutions affected by flooding in Linugos Floodplain

Table A-13.1. Health Institutions in Magsaysay, Misamis Oriental affected by flooding in Linugos Floodplain

Misamis Oriental				
Magsaysay				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Hospital	Cabubuhan		Low	Low
Brgy Health Center	Kibungsod	High	High	High