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

LiDAR Surveys and Flood Mapping of Silway River

University of the Philippines Training Center for Applied Geodesy and Photogrammetry
Central Mindanao University

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For questions/queries regarding this report, contact:

Dr. George R. Puno
Project Leader, Phil-LIDAR 1 Program
Central Mindanao University
Maramag, Bukidnon 8714
geopuno@yahoo.com

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

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LIST OF ACRONYMS AND ABBREVIATIONS

AAC	Asian Aerospace Corporation
Ab	abutment
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
ATQ	Antique
AWLS	Automated Water Level Sensor
BA	Bridge Approach
BM	benchmark
CAD	Computer-Aided Design
CN	Curve Number
CSRS	Chief Science Research Specialist
DAC	Data Acquisition Component
DEM	Digital Elevation Model
DENR	Department of Environment and Natural Resources
DOST	Department of Science and Technology
DPPC	Data Pre-Processing Component
DREAM	Disaster Risk and Exposure Assessment for Mitigation [Program]
DRRM	Disaster Risk Reduction and Management
DSM	Digital Surface Model
DTM	Digital Terrain Model
DVBC	Data Validation and Bathymetry Component
FMC	Flood Modeling Component
FOV	Field of View
GiA	Grants-in-Aid
GCP	Ground Control Point
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HEC-HMS	Hydrologic Engineering Center - Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center - River Analysis System
HC	High Chord
IDW	Inverse Distance Weighted [interpolation method]
IMU	Inertial Measurement Unit
kts	knots
LAS	LiDAR Data Exchange File format
LC	Low Chord
LGU	local government unit
LiDAR	Light Detection and Ranging
LMS	LiDAR Mapping Suite
m AGL	meters Above Ground Level
MMS	Mobile Mapping Suite
MSL	mean sea level
NSTC	Northern Subtropical Convergence
PAF	Philippine Air Force
PAGASA	Philippine Atmospheric Geophysical and Astronomical Services Administration
PDOP	Positional Dilution of Precision
PPK	Post-Processed Kinematic [technique]
PRF	Pulse Repetition Frequency
PTM	Philippine Transverse Mercator
QC	Quality Check
QT	Quick Terrain [Modeler]
RA	Research Associate
RIDF	Rainfall-Intensity-Duration-Frequency
RMSE	Root Mean Square Error
SAR	Synthetic Aperture Radar
SCS	Soil Conservation Service
SRTM	Shuttle Radar Topography Mission
SRS	Science Research Specialist
SSG	Special Service Group
TBC	Thermal Barrier Coatings
UPC	University of the Philippines Cebu
UP-TCAGP	University of the Philippines – Training Center for Applied Geodesy and Photogrammetry
UTM	Universal Transverse Mercator
WGS	World Geodetic System

CHAPTER 1: OVERVIEW OF THE PROGRAM AND SILWAY RIVER

Enrico C. Paringit, Dr. Eng., Dr. George R. Puno, and Mr. 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, supported by the Department of Science and Technology (DOST) Grants-in-Aid (GiA) Program. The program was primarily aimed at acquiring a national elevation and resource dataset at sufficient resolution to produce information necessary to support the different phases of disaster management. Particularly, it targeted to operationalize the development of flood hazard models that would produce updated and detailed flood hazard maps for the major river systems in the country.

Also, the program was aimed at producing an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through DOST.

The implementing partner university for the Phil-LiDAR 1 Program is the Central Mindanao University (CMU). CMU 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 Maramag in the province of Bukidnon.

1.2 Overview of the Silway River Basin

Silway river basin, with a total area of 63,758 hectares, covers the Municipalities of Tupi, T'Boli, Polomok in South Cotabato and Malungon in Sarangani. The river is composed of three major tributaries namely Silway, Sinawal and Klinan rivers that drain to the Sarangani Bay in General Santos City. The head water originates from Mount Matutum and Mount Parker which both still has high biodiversity and aesthetic values especially to the nomadic groups of B'laan and T'boli. Much of the flood plain is within General Santos City, putting the 66% population to risk and damages of flooding.

The volcanic soil materials in the basin make it suitable for agricultural production evidently seen on the cultivated upstream areas whichgradually intensifies towards the plains of the river basin. The basin support agri-based industries with General Santos City acting as the hub for the institutional and transportation services for agri-based industry operations. Pineapple and banana plantations are among the dominating agricultural products in the area along with corn and rice as the major products.

Though no major flooding was yet experienced in the basin, the encroachments along river banks and flood plains resulted to occasional rising of water from river and canals. According to validation interviews, some of the flood incidents were intermittently caused by the simultaneous occurrence of high tide and heavy rain. Some of the experiences in increased runoff and inundation were on 2012 during Typhoon Pablo, 2013, 2014, 2015 and 2016.

Phil-LiDAR 1 Program included Silway 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. Central Mindanao University (CMU) co-implemented the generation of flood hazard maps of Silway river through flood modeling. The activity involves two simulations, the hydrologic and hydraulic which are performed using standalone softwares of Hydrologic Modeling System (HMS) and Hydrologic River Analysis System (RAS) of 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.

In creating basin model, Synthetic Aperture Radar (SAR) 10m Digital Elevation Model (DEM) along with digitized river centerline were used. The model consists of seventy-three (73) sub-basins, thirty-seven (37) reaches and thirty-eight (38) junctions. It was calibrated using the actual meteorologic and hydrologic data during an actual event on August 4, 2016. Statistical analysis employed to test the model efficiency 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 (PAG-ASA) based on a 31-year historical data of General Santos Airport rain gauge. Flood hydraulic simulation was performed using LiDAR Digital Terrain Model (DTM) consequently showing flood extent and depth information. These were later developed to flood hazard maps projecting the flood scenarios for the 5-, 25-, and 100-year return periods.

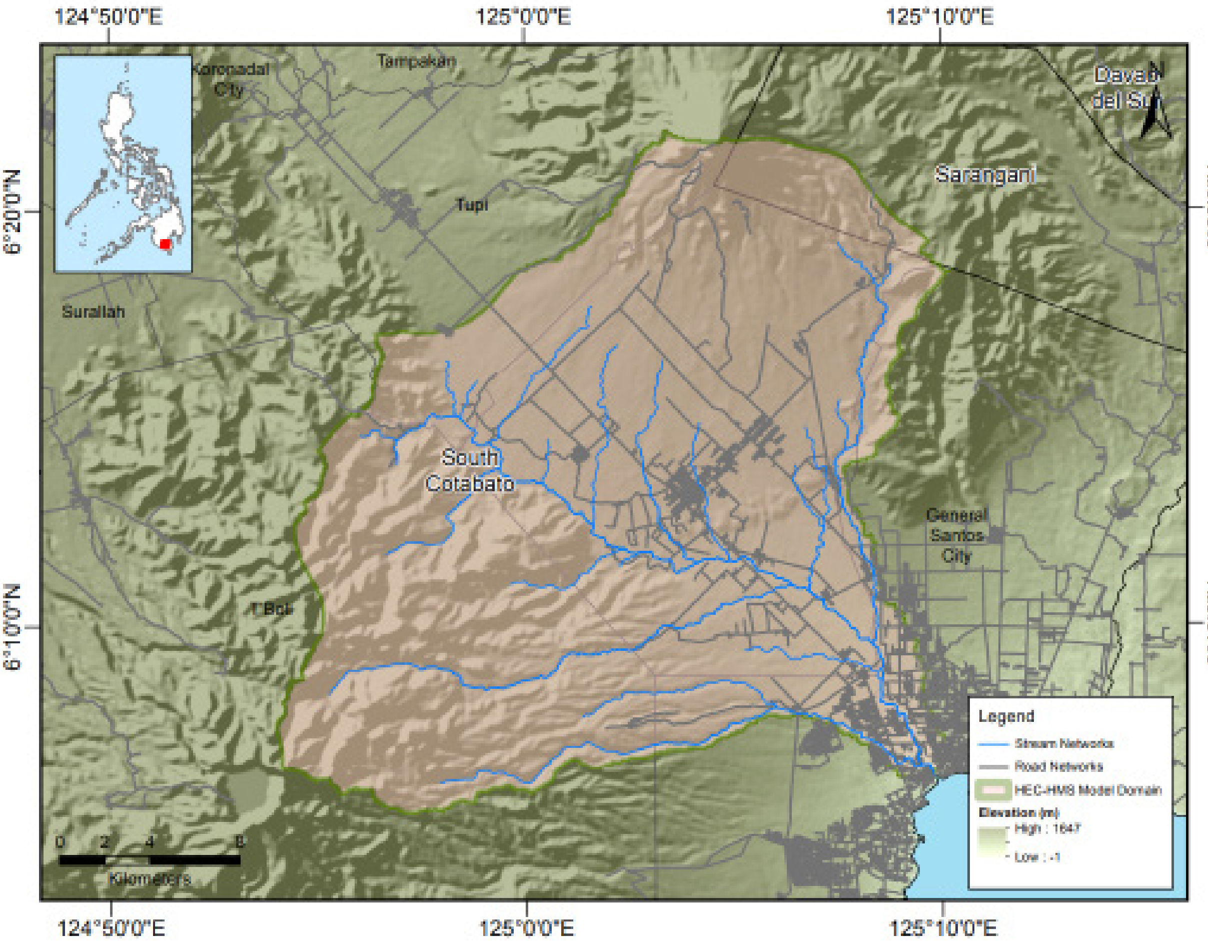


Figure 1. Map of Silway River Basin

CHAPTER 2: LIDAR ACQUISITION IN SILWAY FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Gracia Acuña, Engr. Gerome Hipolito, Ms. Julie Pearl S. Mars, Jeriel Paul A. Alamban, Geol.

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 Silway floodplain in South Cotabato. These missions were planned for 16 lines that run for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR system is found in Table 1. Figure 2 shows the flight plan for Silway Floodplain.

Table 1. Flight planning parameters for the Aquarius LiDAR System.

Block Name	Flying Height (AGL)	Overlap (%)	Field of View	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency	Average Speed	Average Turn Time (Minutes)
BYN 1E	600	30	36	70	50	120	5
BYN 2D	600	30	36	70	50	120	5

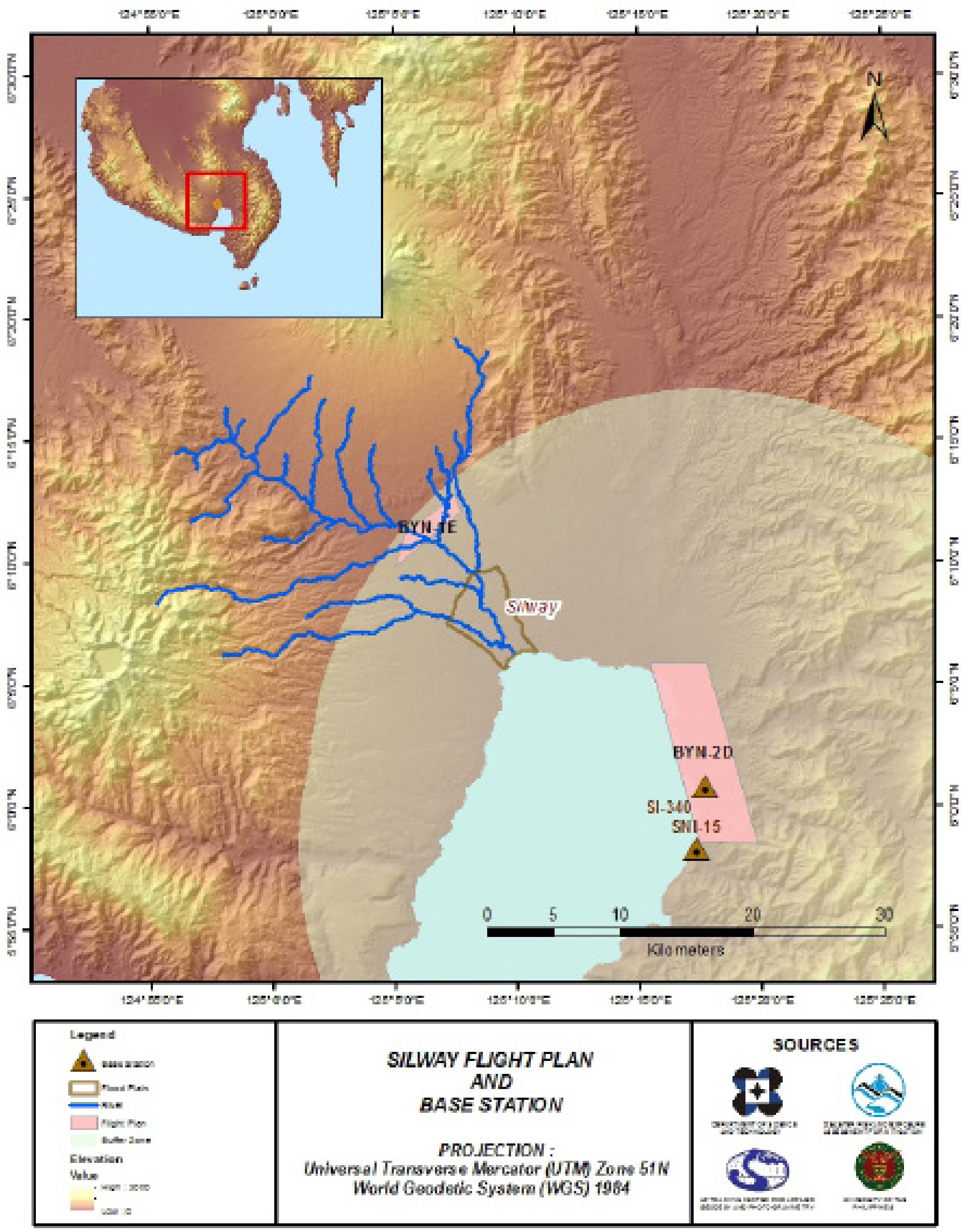


Figure 2. Flight plans and base stations used for Silway Floodplain

2.2 Ground Base Station

The project team was able to recover one (1) NAMRIA ground control point: SNI-15 which is of second (2nd) order accuracy. One (1) NAMRIA benchmark was also recovered: SI-340 which is of first (1st) order accuracy. This benchmark was used as vertical reference point and was also established as ground control point. The certifications for the NAMRIA reference point and benchmark are found in Annex A-2 while the baseline processing reports for the established control point is found in Annex A-3. These were used as base stations during flight operations on November 4, 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 Silway floodplain are shown in Figure 2. The list of team members are shown in Annex 4.

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

(b)

(a)

Figure 3. GPS set-up over SNI-15 outside the municipal hall of Malapatan, Sarangani and NAMRIA reference point SNI-15 (b) as recovered by the field team.

Table 2. Details of the recovered NAMRIA horizontal control point SNI-15 used as base station for the LiDAR acquisition.

Station Name	SNI-15	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	5° 58’ 16.93809’’ 125° 17’ 11.94043’’ 1.09600 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	531,736.654 meters 660,237.374 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	5° 58’ 14.08407’’ North 125° 17’ 17.56874’’ East 75.01600 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	753,144.51 meters 660,523.74 meters

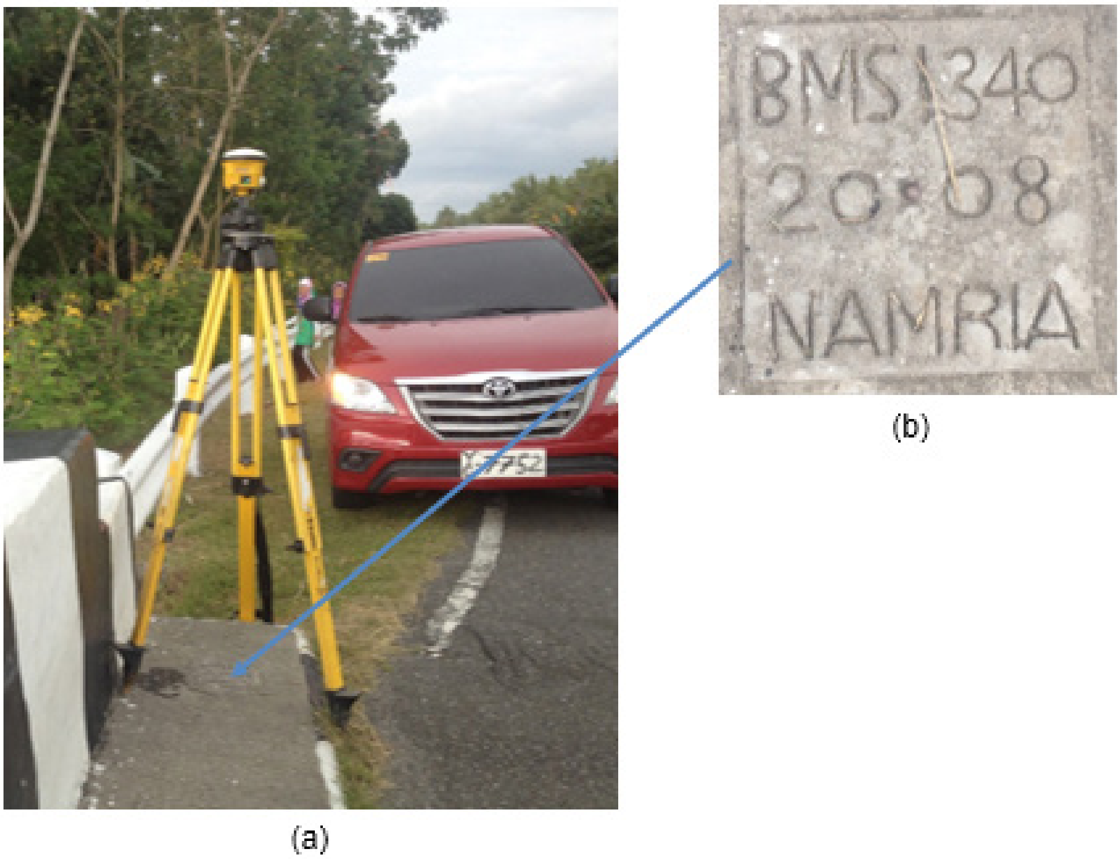


Figure 4. GPS set-up over SI-340 at Molo Bridge along Malapatan-General Santos City National Highway (a) and NAMRIA reference point SI-340 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point SI-340 used as base station for the LiDAR acquisition.

Station Name	**SI-340**	
Order of Accuracy	**1st**	
Relative Error (horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	6° 00’ 49.33497” 125° 17’ 41.96935” 11.130 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	6° 00’ 46.47026” North 123° 17’ 47.59361” East 84.998 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	754,048.831 m 665,210.517 m

Table 4. Ground control points used during LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
November 4, 2014	2150A	3BLK90S308A	SNI-15 and SI-340

2.3 Flight Missions

One (1) mission was conducted to complete the LiDAR aata acquisition in Silway floodplain, for a total of three hours and twenty-nine minutes (3+29) of flying time for RP-C9022. The mission was acquired using the Aquarius LiDAR system. Majority of the floodplain was already surveyed during DREAM Program. Table 5 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 6 shows the actual parameters used during the LiDAR data acquisition.

Table 6. Flight missions for the LiDAR data acquisition of the Silway 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
November 4, 2014	2150A	66.69	33.13	NA	33.13	NA	3	29
TOTAL		66.69	33.13	NA	33.13	NA	3	29

Table 5. Actual parameters used during LiDAR data acquisition.

Flight Number	Flying Height (AGL) (m)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (kHz)	Scan Frequency (Hz)	Average Speed (Kts)	Average Turn Time (Minutes)
2150A	600	45	36	50	45	130	5

2.4 Survey Coverage

This certain LiDAR acquisition survey covered the Silway floodplain (See Annex 7). It is located in the province of Agusan del Norte with majority of the floodplain situated within the city of Silway City. The list of municipalities and cities surveyed with at least one (1) square kilometer coverage is shown in Table 14. Figure 10, on the other hand, shows the actual coverage of the LiDAR acquisition for the Silway floodplain.

Table 7. The list of municipalities and cities surveyed of the Silway Floodplain LiDAR acquisition.

Province	Municipality/City	Area of Municipality/City	Total Area Surveyed	Percentage of Area Surveyed
Sarangani	Alabel	479.67	106.61	22.23%
	Glan	722.62	4.12	0.57%
	Malapatan	507.6	5.48	56.02%
	Malungon	459.5	7.45	1.08%
South Cotabato	General Santos City	474.73	297.47	64.71%
	Polomolok	287.02	78.99	27.52%
		773.31	3.59	0.46%
Total		3704.45	503.71	13.59%

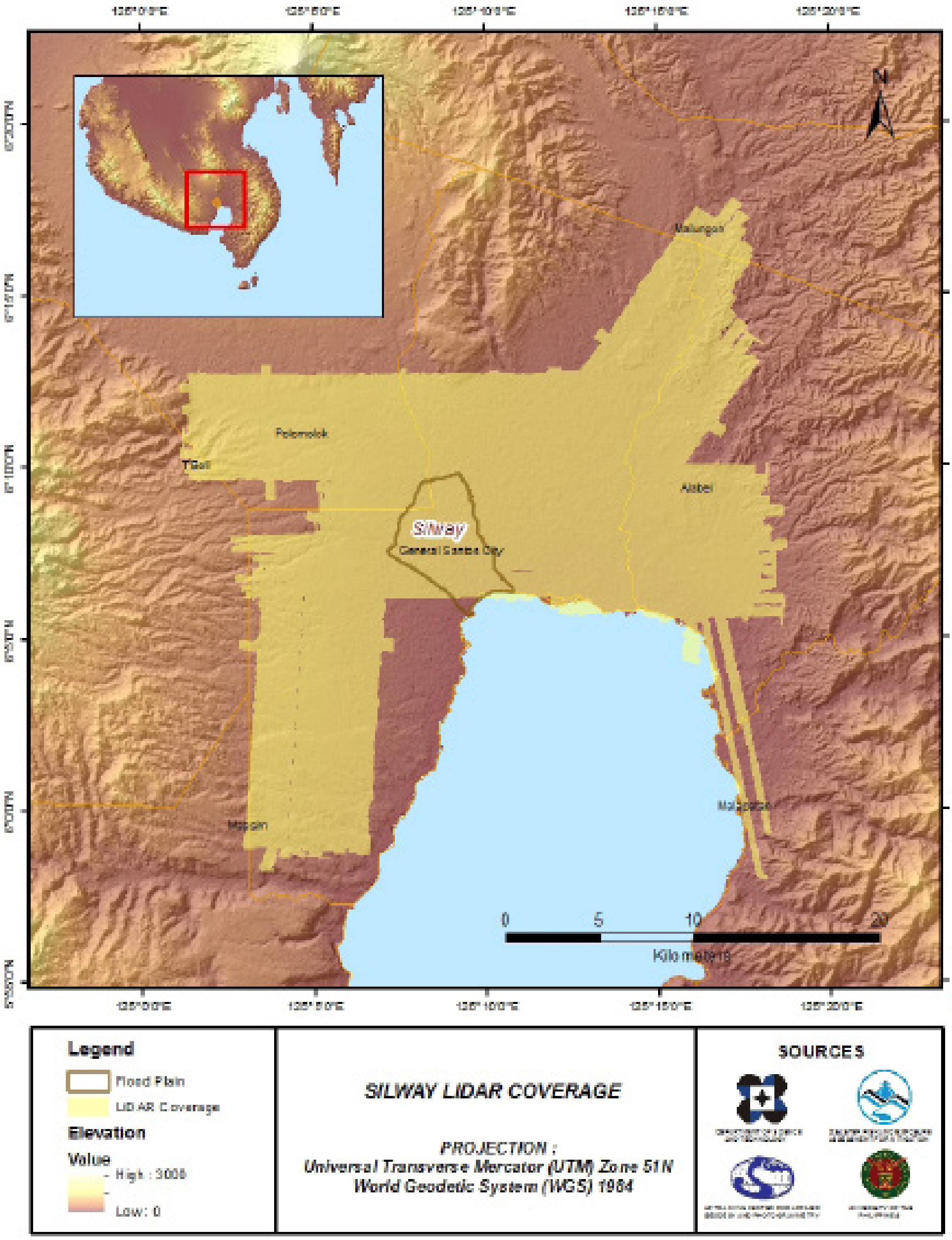


Figure 5. Actual LiDAR survey coverage for Silway Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING FOR SILWAY FLOODPLAIN

Engr. Ma. Rosario Concepcion O. Ang, Engr. John Louie D. Fabila, Engr. Sarah Jane D. Samalburo , Engr. Gladys Mae Apat , Alex John B. Escobido , Engr. Ma. Ailyn L. Olanda, Engr. Merven Mattew D. Natino, Jovy Anne S. Narisma , Engr. Jommer M. Medina, Esmael L. Guardian

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

3.1 Overview of LiDAR Data Pre-Processing

The data transmitted by the Data Acquisition Component 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.

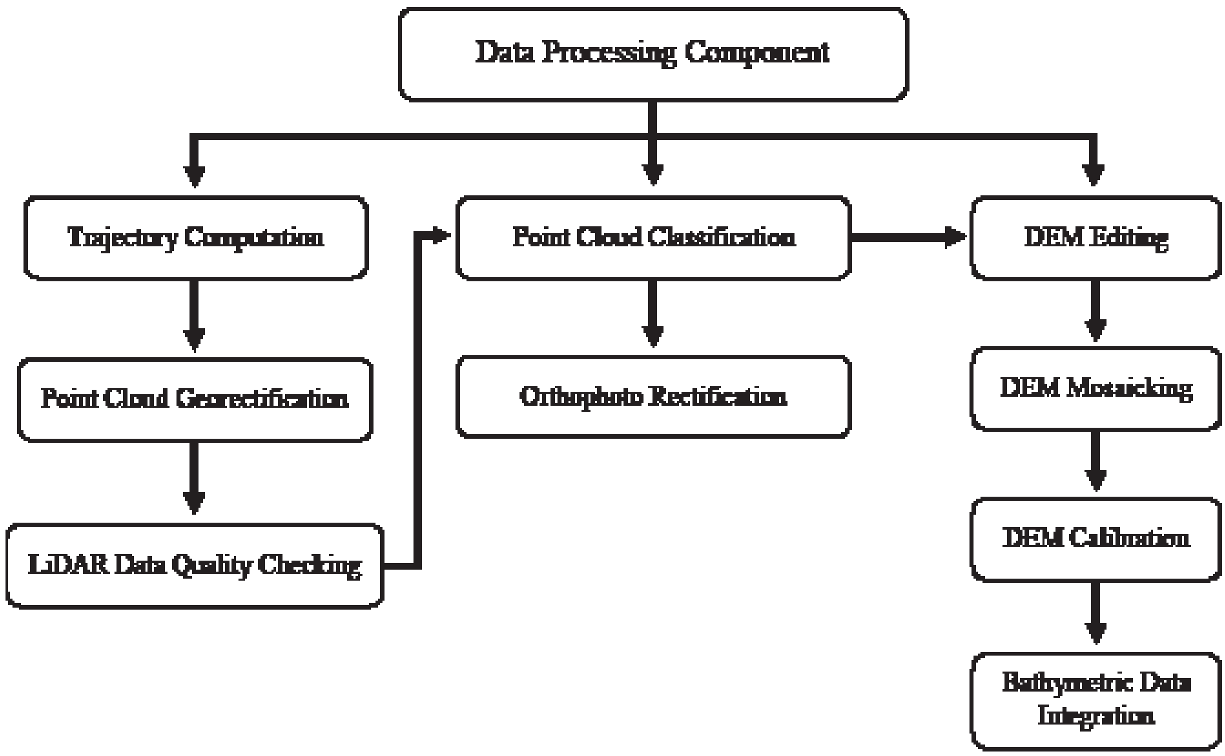


Figure 6. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Silway floodplain can be found in Annex 5. Missions flown during the first survey conducted on July 2013 and second survey conducted on November 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Gemini system and Aquarius system respectively over General Santos City, SOCSARGEN.

The Data Acquisition Component (DAC) transferred a total of 75.17 Gigabytes of Range data, 2.236 Gigabytes of POS data, 290.7 Megabytes of GPS base station data, and 220.1 Gigabytes of raw image data to the data server on July 3, 2013 for the first survey and November 4, 2014 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Silway was fully transferred on November 19, 2014 as indicated on the Data Transfer Sheets for Silway floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for flight 252G, one of the Silway 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 February 23, 2016 00:00AM. The y-axis is the RMSE value for that particular position.

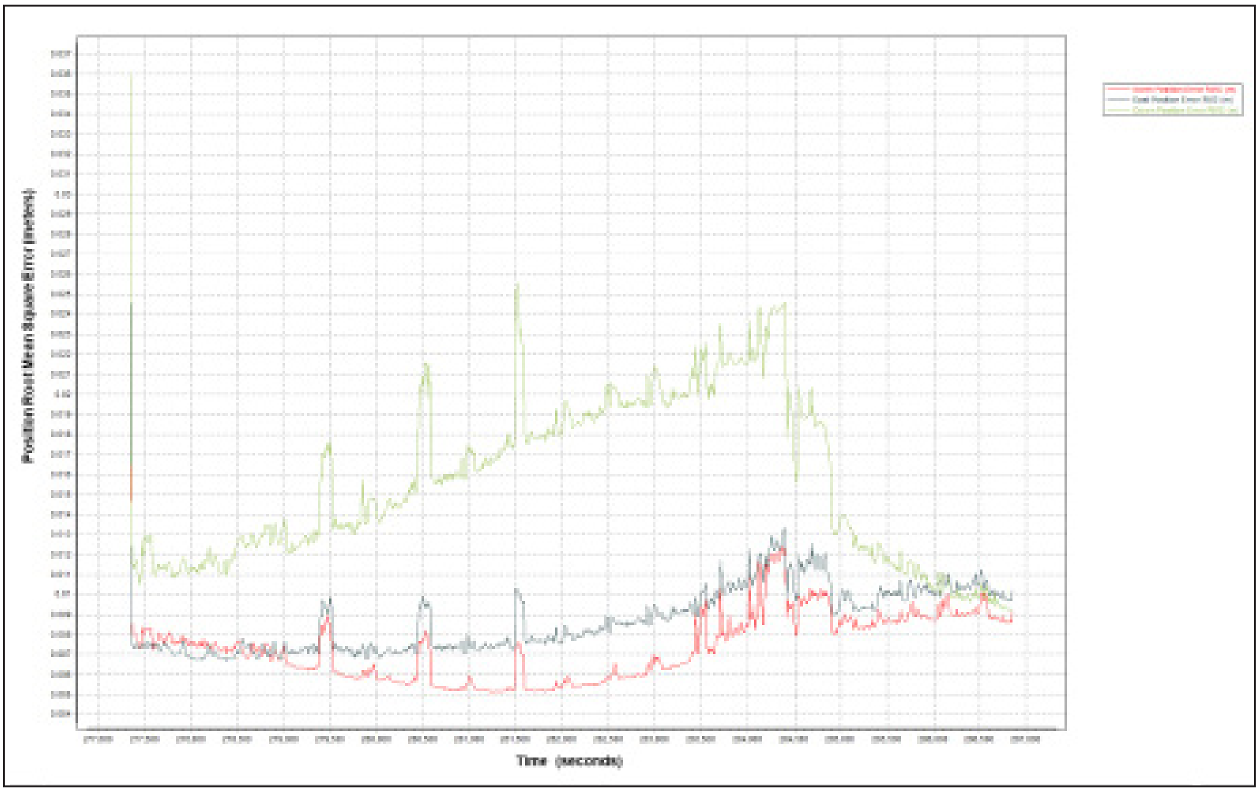


Figure 7. Smoothed Performance Metric Parameters of Silway Flight 252G.

The time of flight was from 277,500 seconds to 287,000 seconds, which corresponds to morning of February 23, 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 7 shows that the North position RMSE peaks at 1.20 centimeters, the East position RMSE peaks at 1.30 centimeters, and the Down position RMSE peaks at 2.60 centimeters, which are within the prescribed accuracies described in the methodology.

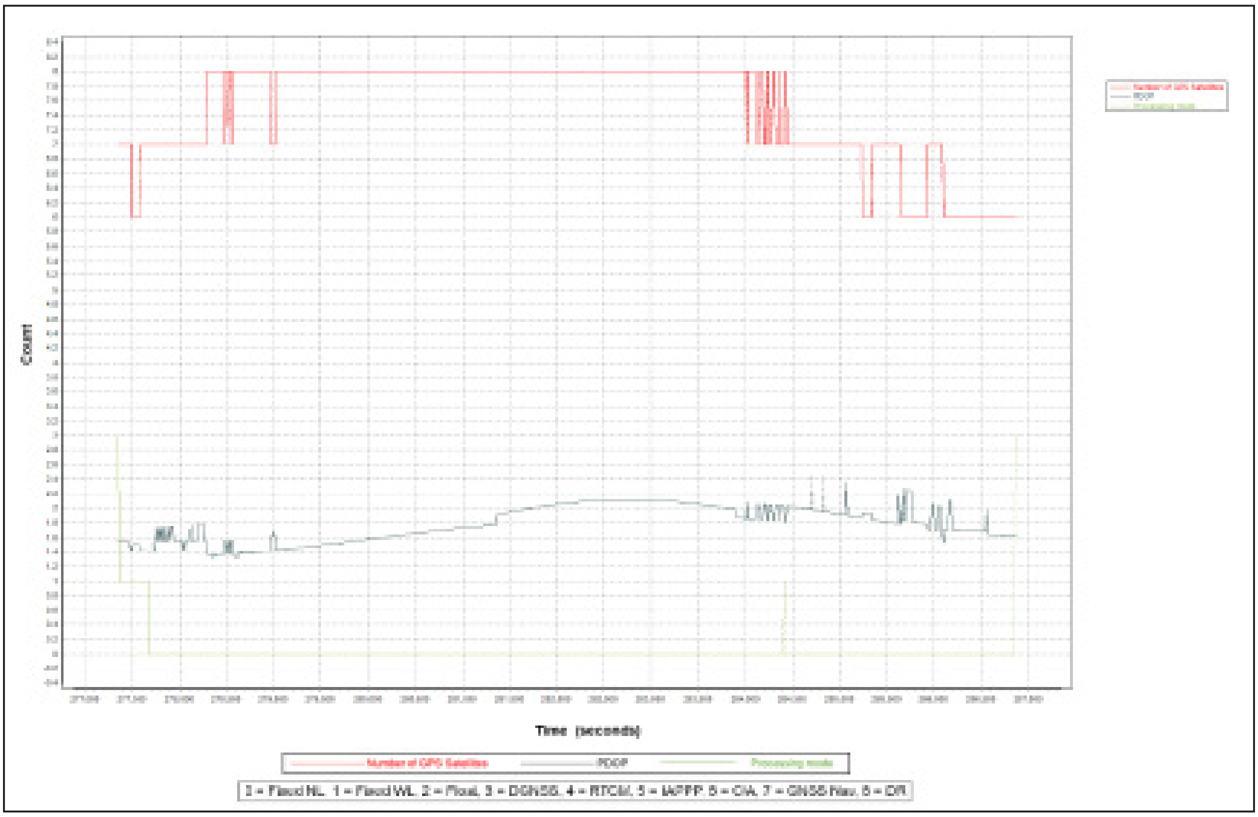


Figure 8. Solution Status Parameters of Silway Flight 252G.

The Solution Status parameters of flight 252G, one of the Silway 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 8. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 1 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Silway flights is shown in Figure 9.

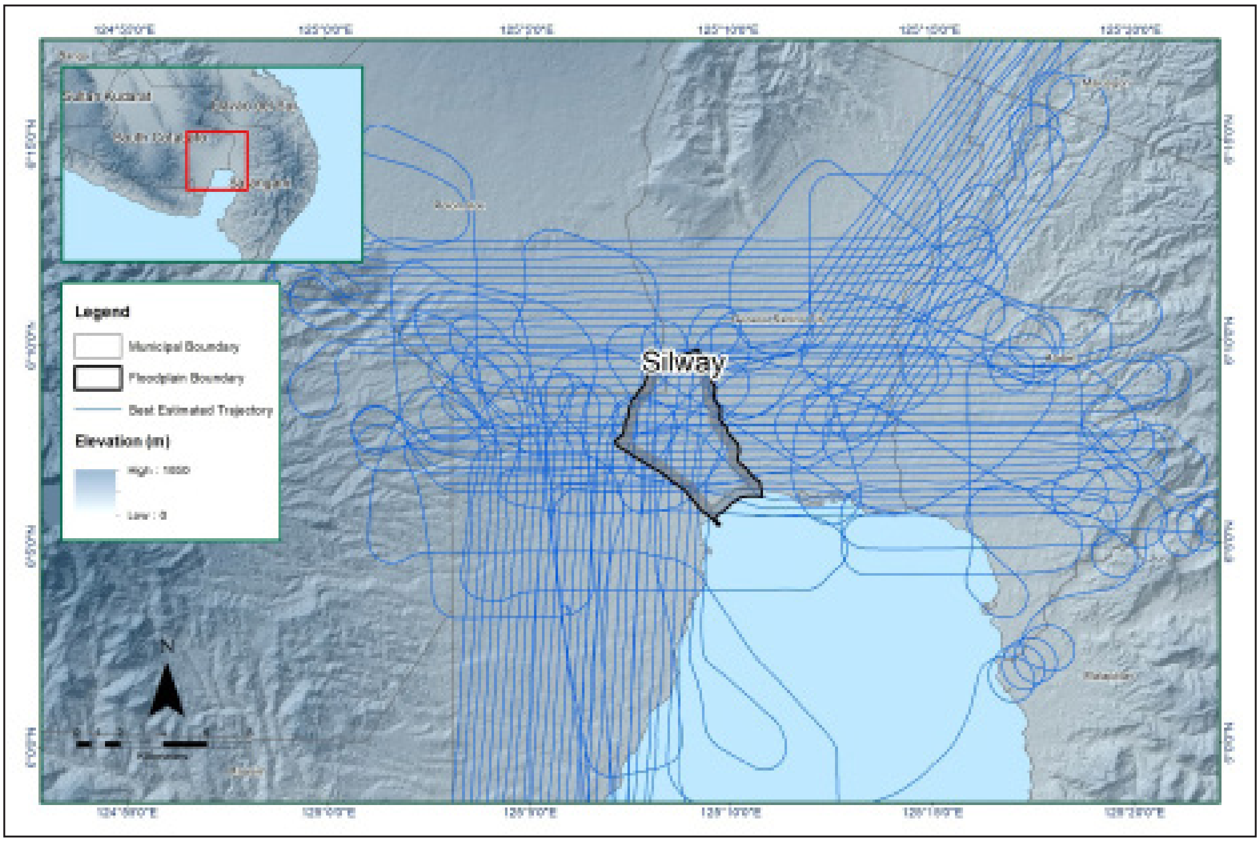


Figure 9. Best Estimated Trajectory for Silway Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 96 flight lines, with each flight line containing one channel, since the Gemini and Aquarius systems both contain one channel only. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Silway floodplain are given in Table 8.

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

Parameter	Acceptable Value	Value
Boresight Correction stdev	(<0.001degrees)	0.00801
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.000986
GPS Position Z-correction stdev	(<0.01meters)	0.0074

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

3.5 LiDAR Data Quality Checking

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

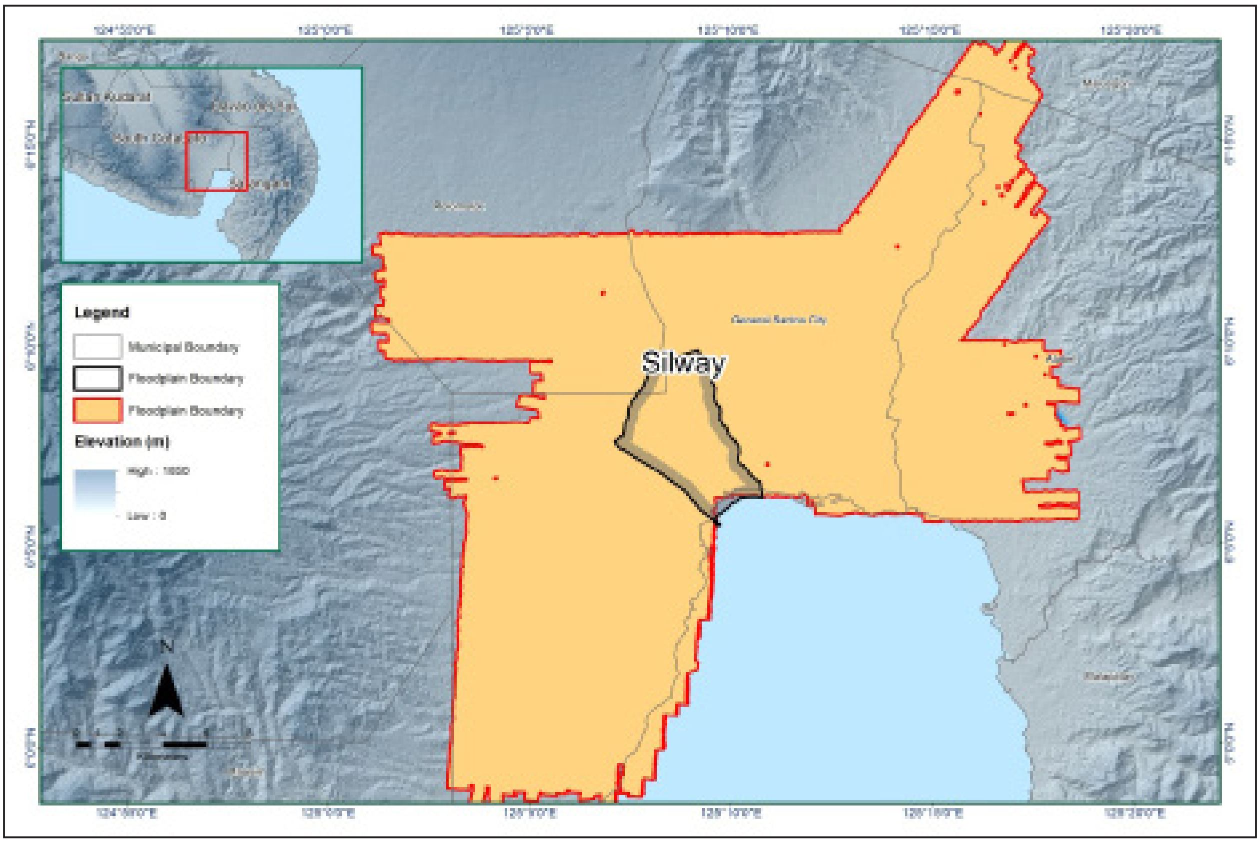


Figure 10. Boundaries of the processed LiDAR data over the Silway Floodplain.

The total area covered by the Silway missions is 638.46 sq.km that is comprised of seven (7) flight acquisitions grouped and merged into nine (9) blocks as shown in Table 9.

Table 9. List of LiDAR blocks for the Silway floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Buayan_Blk1E	258G	131.87
Buayan_Blk1E_additional	2150A	8.64
Buayan_BlkF	254G	97.23
Buayan_Blk2D	262G	110.82
Buayan_Blk2C	256G	109.20
Buayan_BlkA	252G	76.43
Buayan_BlkB	260G	96.96
Buayan_Blk2D_additional	2150A	4.84
Buayan_B_additional	260G	2.47
TOTAL		638.46 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 Aquarius system employs one channel, 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.

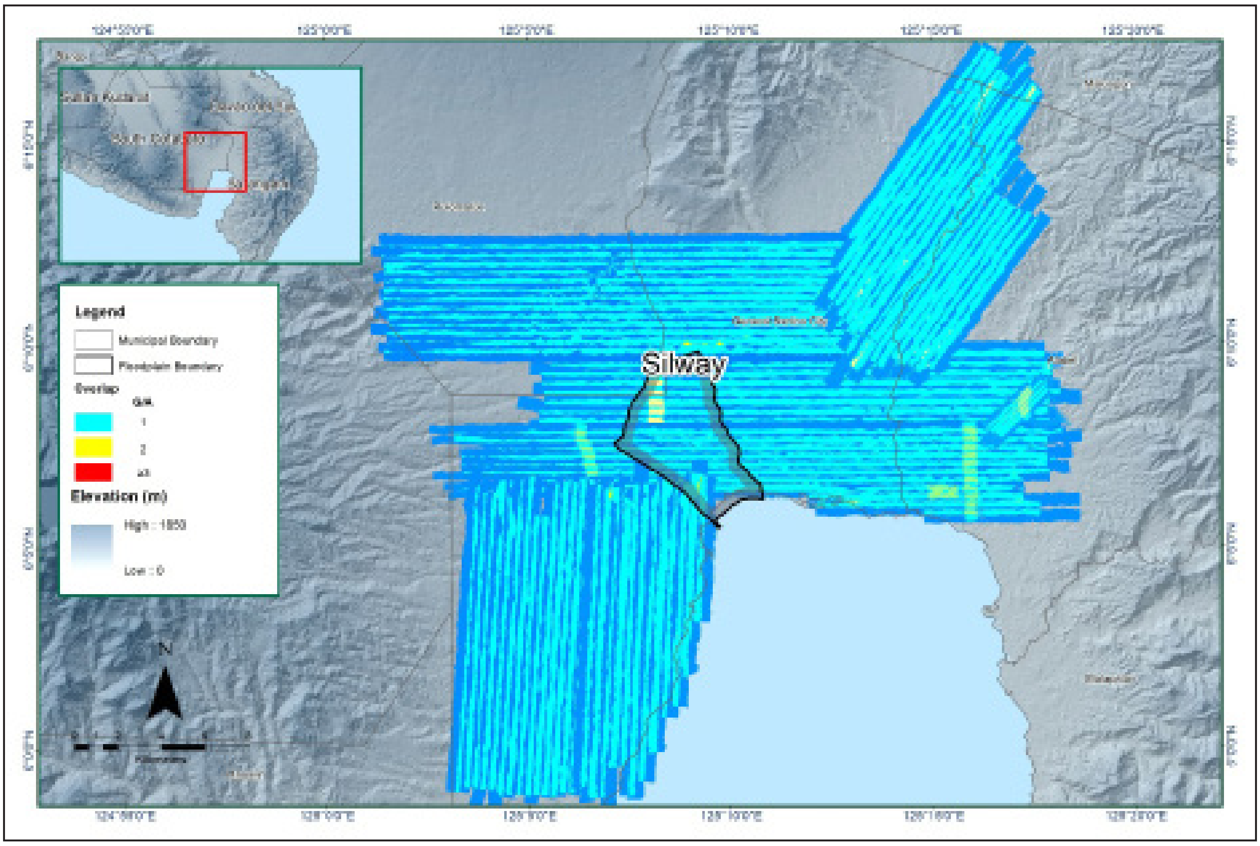


Figure 11. Image of data overlap for Silway Floodplain.

The overlap statistics per block for the Silway floodplain can be found in Annex 8: Mission Summary Reports 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 45.19% and 59.11% 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 12. It was determined that all LiDAR data for Silway floodplain satisfy the point density requirement, and the average density for the entire survey area is 2.61 points per square meter.

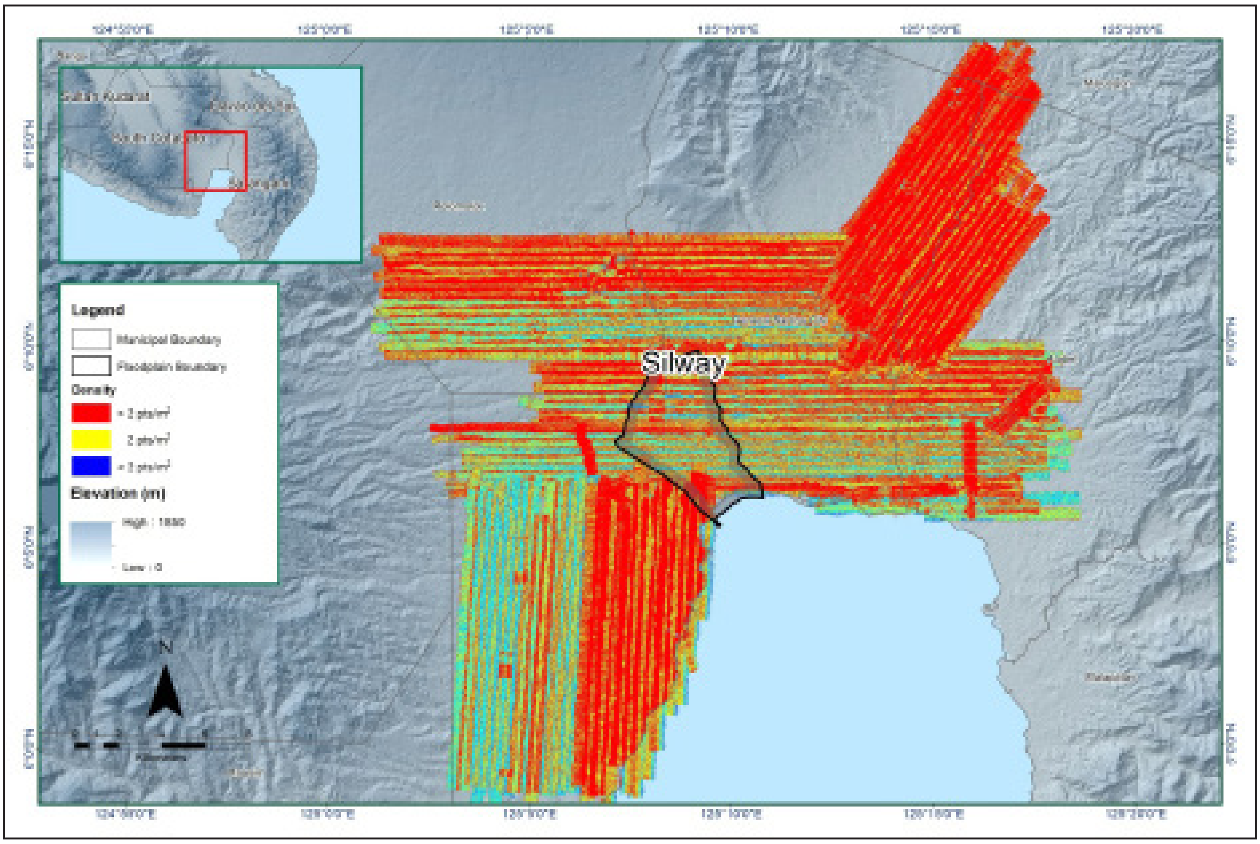


Figure 12. Pulse density map of merged LiDAR data for Silway Floodplain.

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.

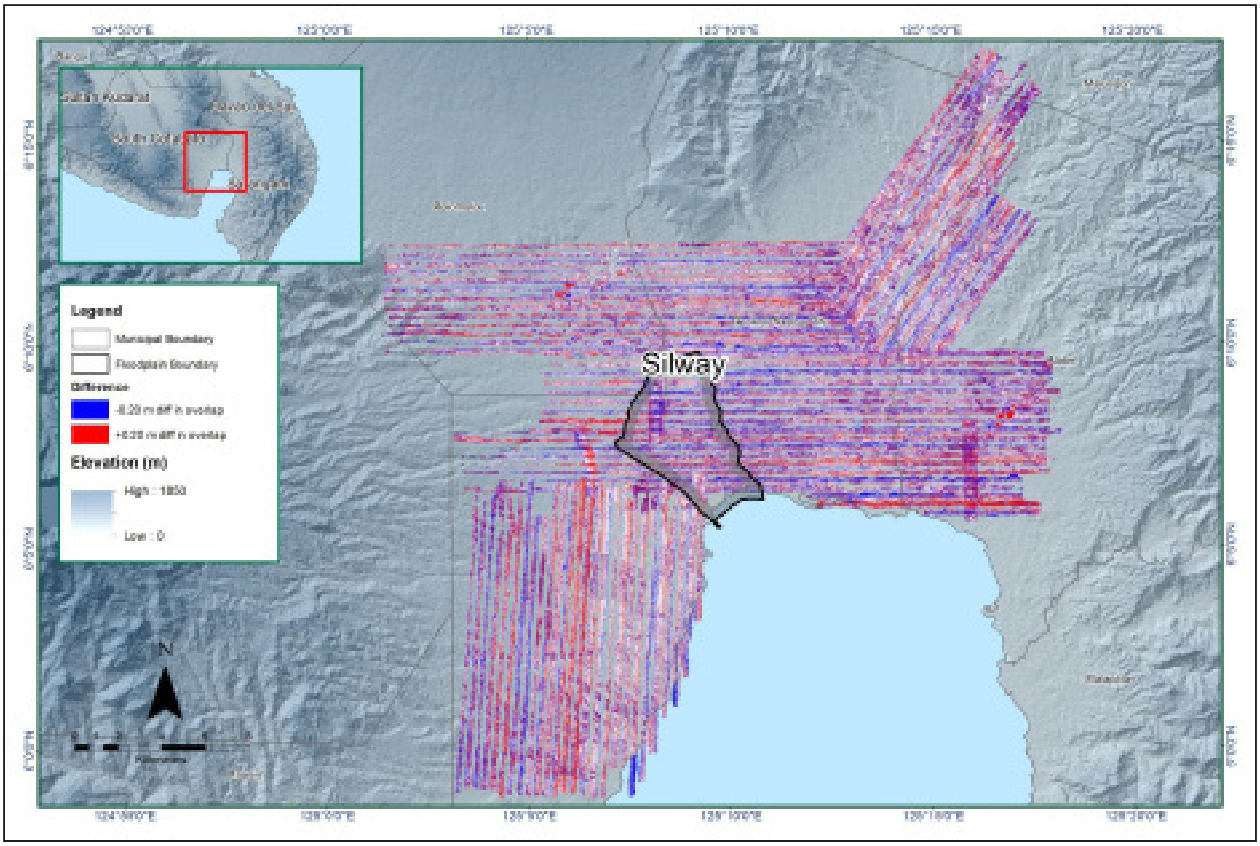


Figure 13. Elevation difference map between flight lines for Silway Floodplain.

A screen capture of the processed LAS data from a Silway flight 252G 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 red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

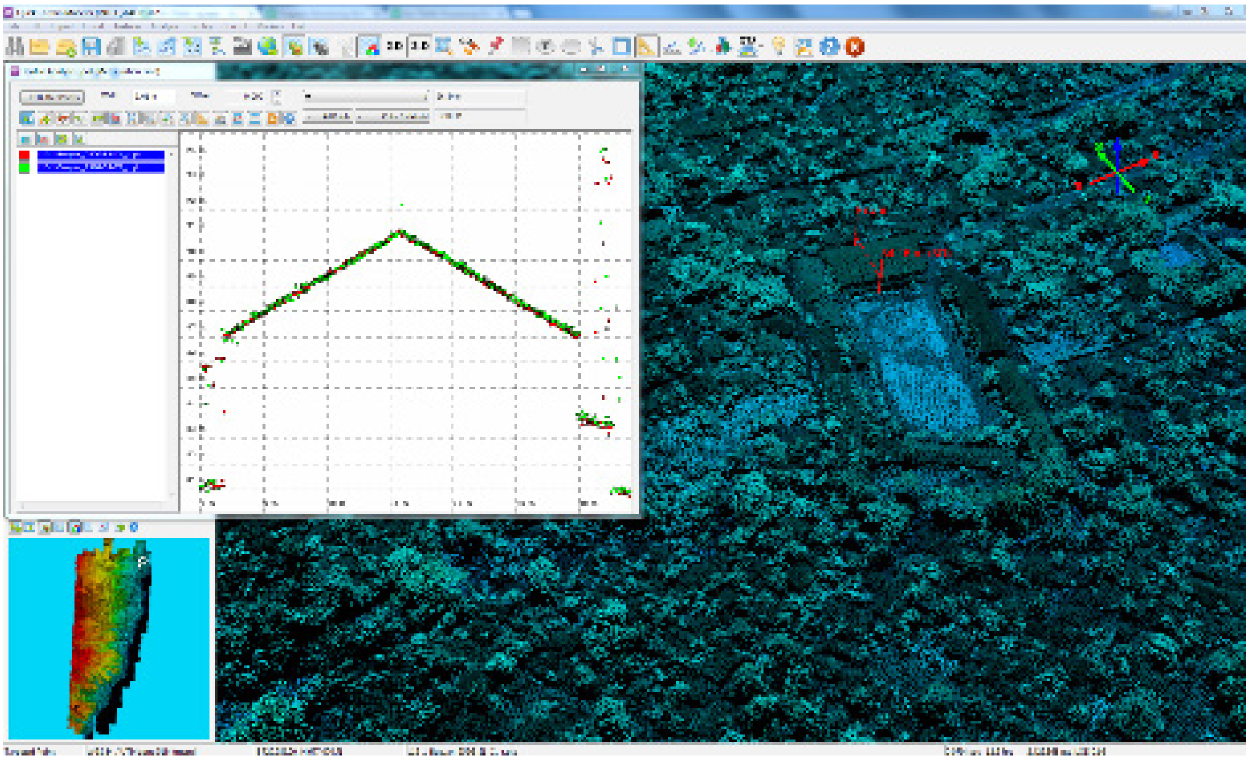


Figure 14. Quality checking for Silway flight 252G using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 10. Silway classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	243,811,862
Low Vegetation	207,387,071
Medium Vegetation	541,263,929
High Vegetation	405,953,988
Building	14,416,936

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Silway floodplain is shown in Figure 15. A total of 660 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 576.89 meters and 20.91 meters respectively.

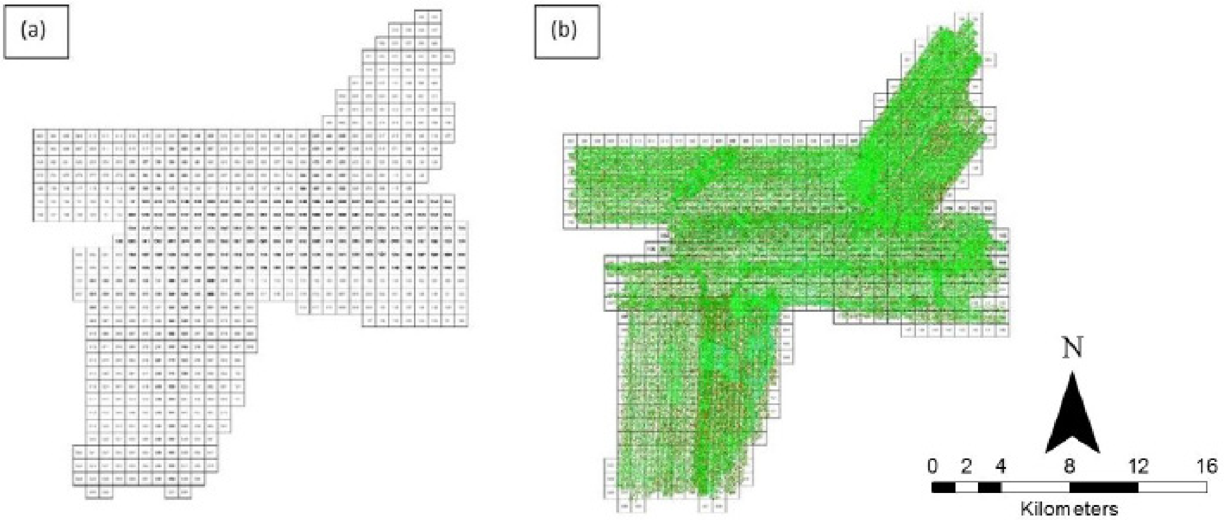


Figure 15. Tiles for Silway Floodplain (a) and classification results (b) in TerraScan.

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.

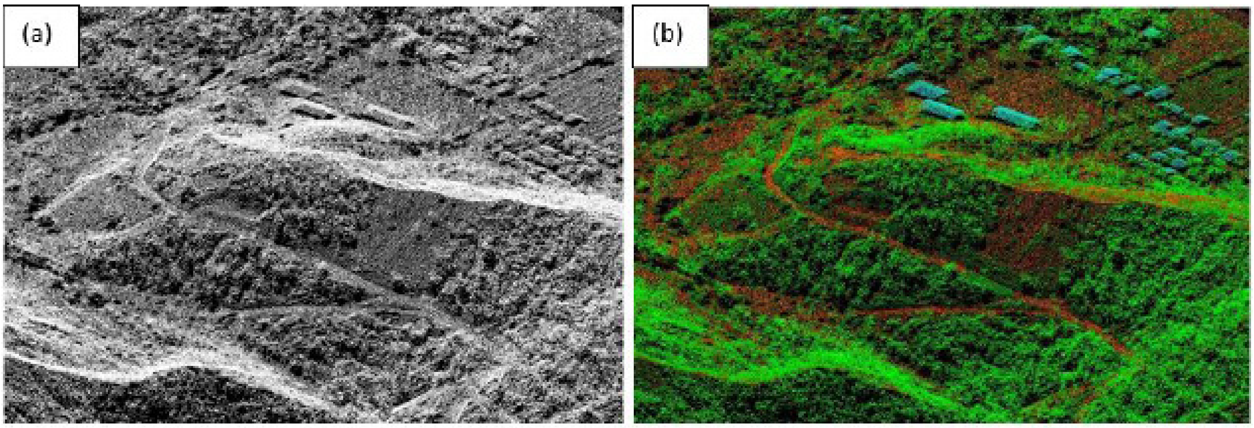


Figure 16. Point cloud before (a) and after (b) classification.

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

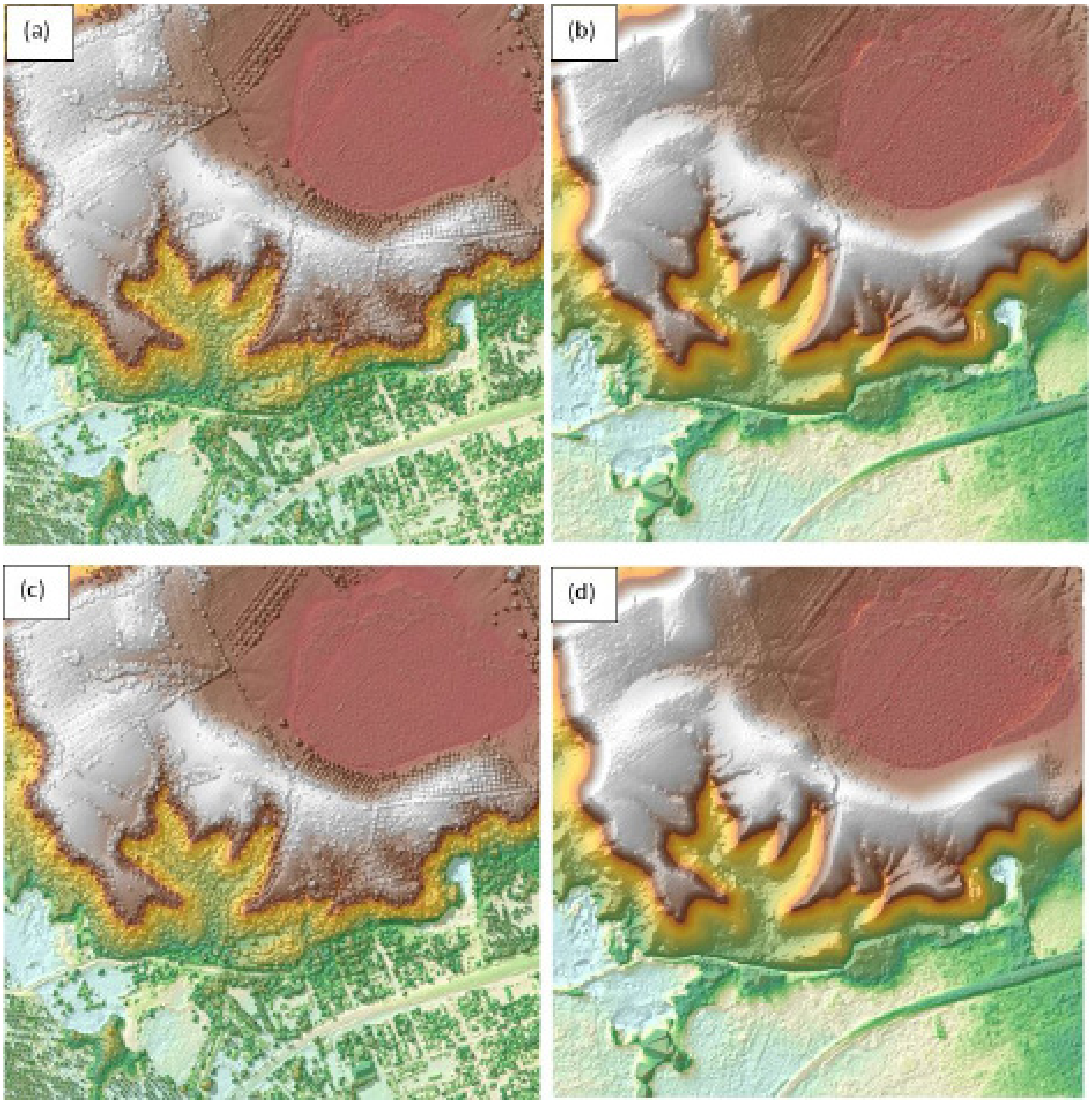


Figure 17. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Silway Floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 809 1km by 1km tiles area covered by Silway 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 Silway floodplain has a total of 542.81 sq.km orthophotogaph coverage comprised of 3481 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 19.

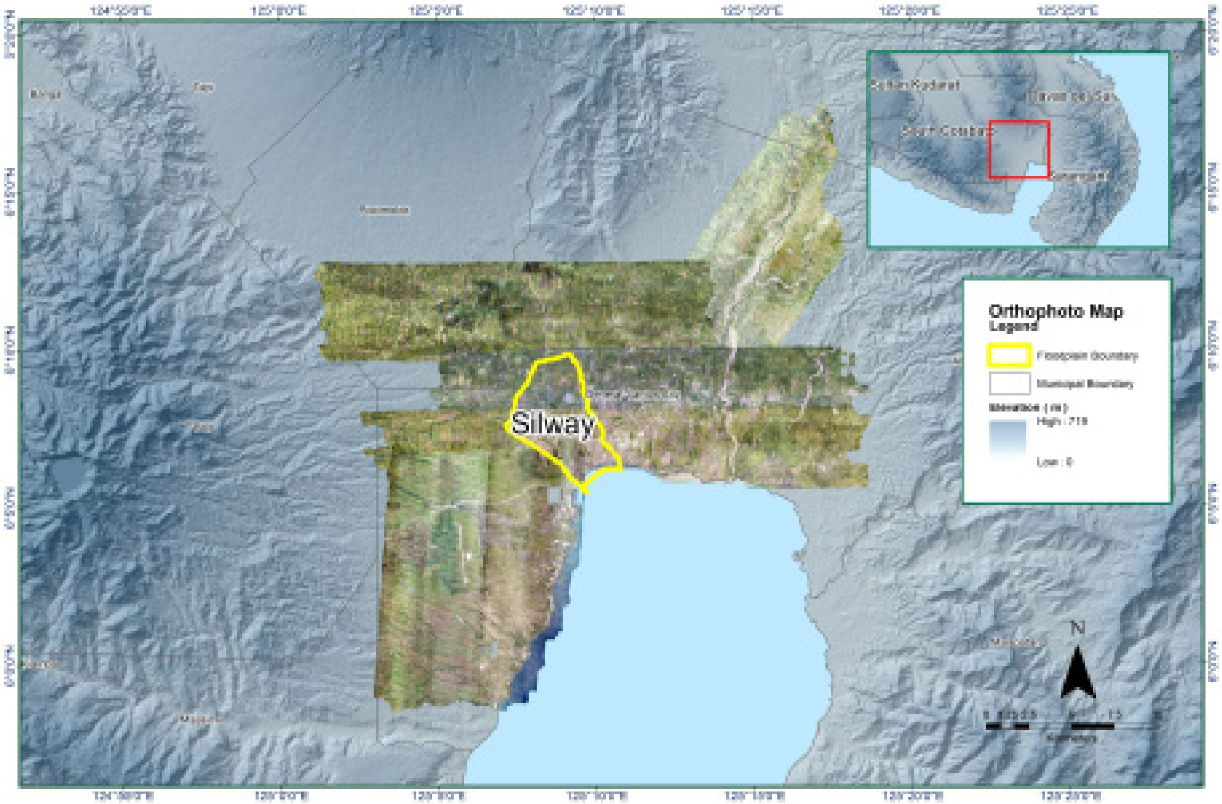


Figure 18. Silway Floodplain with available orthophotographs.

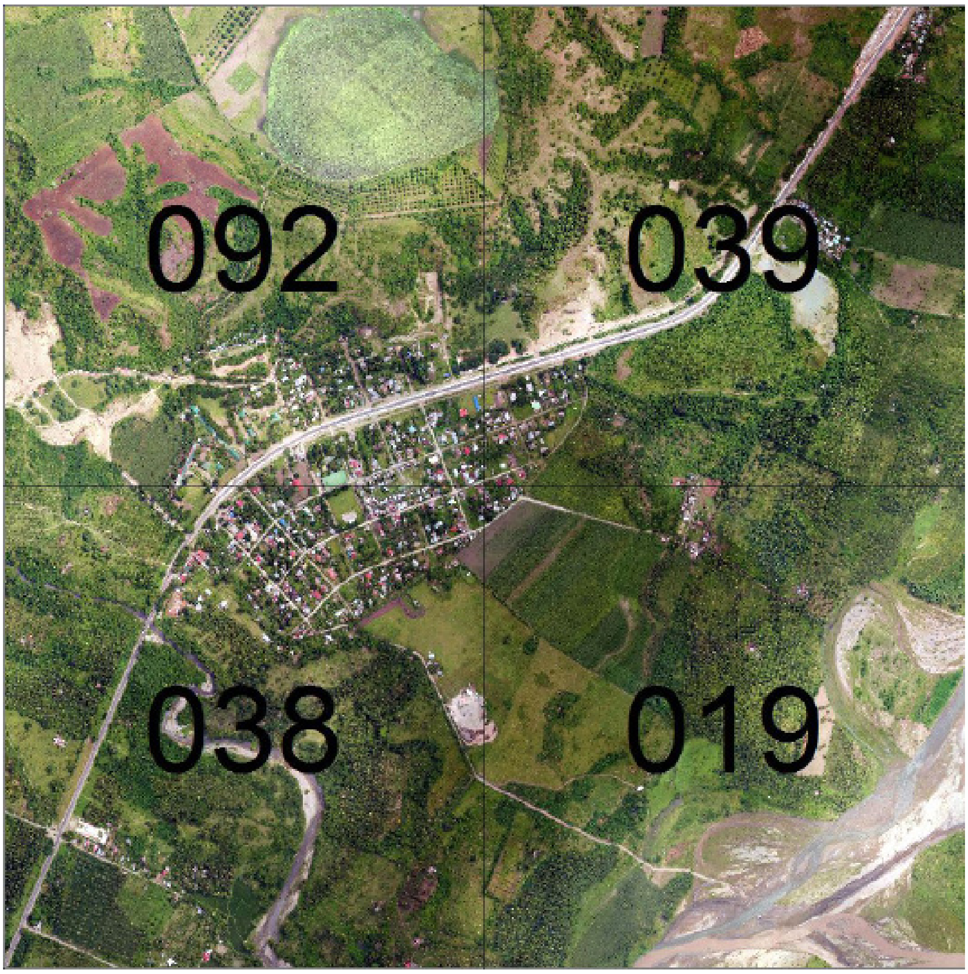


Figure 19. Sample orthophotograph tiles for Silway Floodplain.

3.8 DEM Editing and Hydro-Correction

Nine (9) mission blocks were processed for Silway flood plain. These blocks are composed of Buayan with a total area of 638.46 square kilometers. Table 11 shows the name and corresponding area of each block in square kilometers.

Table 11. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq.km)
Buayan_Blk1E	131.87
Buayan_Blk1E_additional	8.64
Buayan_BlkF	97.23
Buayan_Blk2D	110.82
Buayan_Blk2C	109.20
Buayan_BlkA	76.43
Buayan_Blk2D_additional	4.84
Buayan_BlkB	96.96
Buayan_B_additional	2.47
TOTAL	638.46

Portions of DTM before and after manual editing are shown in Figure 20. The bridge (Figure 20a) is considered to be an impedance to the flow of water along the river and has to be removed (Figure 20b) in order to hydrologically correct the river. 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 footprint. Portion of ridge also (Figure 20c) has been misclassified that needs to be retrieved to retain the correct terrain (Figure 20d). Object retrieval uses the secondary DTM (t_layer) to fill in these areas.

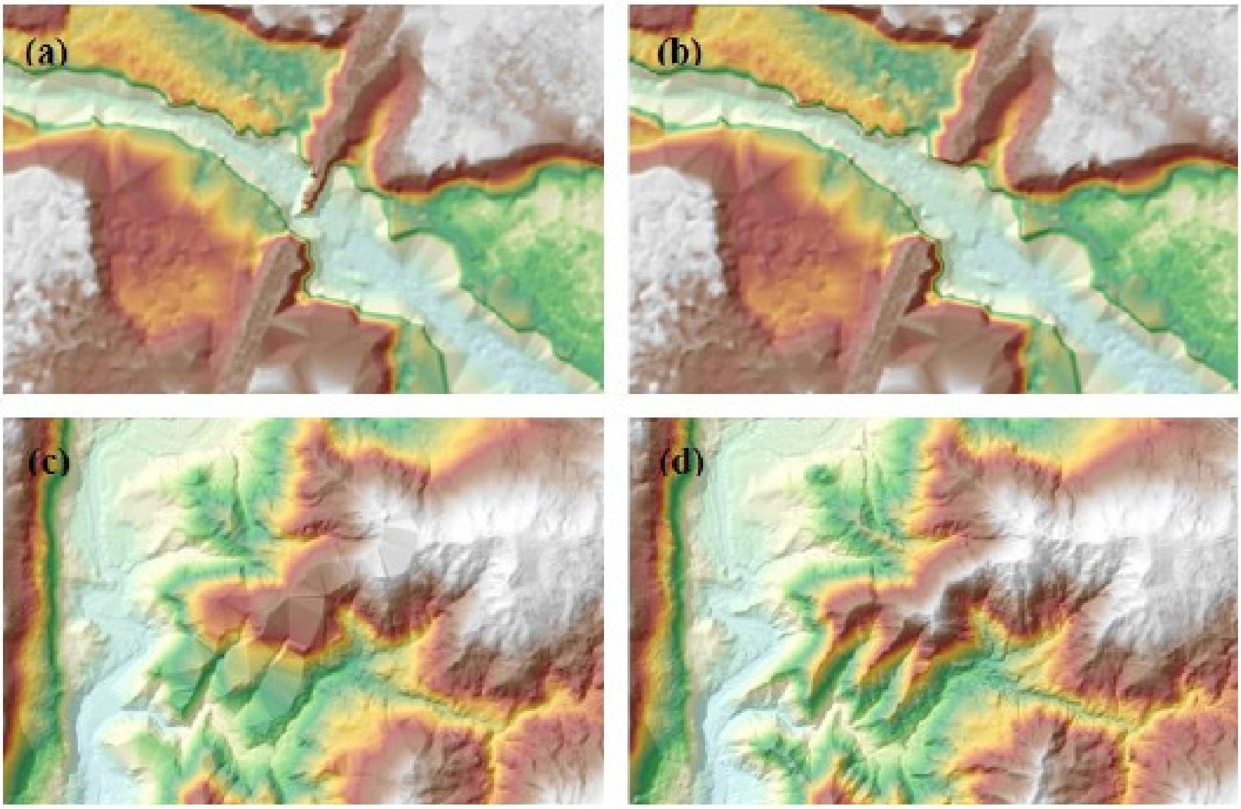


Figure 20. Portions in the DTM of Silway Floodplain - a bridge before (a) and after (b) manual editing; a mountain ridge before (c) and after (d) data retrieval.

3.9 Mosaicking of Blocks

BYN_A was used as the reference block at the start of mosaicking due to the availability of validation points that was used to calibrate such block. 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 Silway floodplain is shown in Figure 21. It can be seen that the entire Silway floodplain is 97.05% covered by LiDAR data.

Table 12. Shift Values of each LiDAR Block of Silway floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Buayan_Blk1E	0	0	0
Buayan_Blk1E_additional	0	0	0
Buayan_BlkF	0	0	0
Buayan_Blk2D	0	0	0
Buayan_Blk2C	0	0	0
Buayan_BlkA	0	0	0
Buayan_Blk2D_additional	0	0	0
Buayan_BlkB	0	0	0
Buayan_B_additional	0	0	2.1

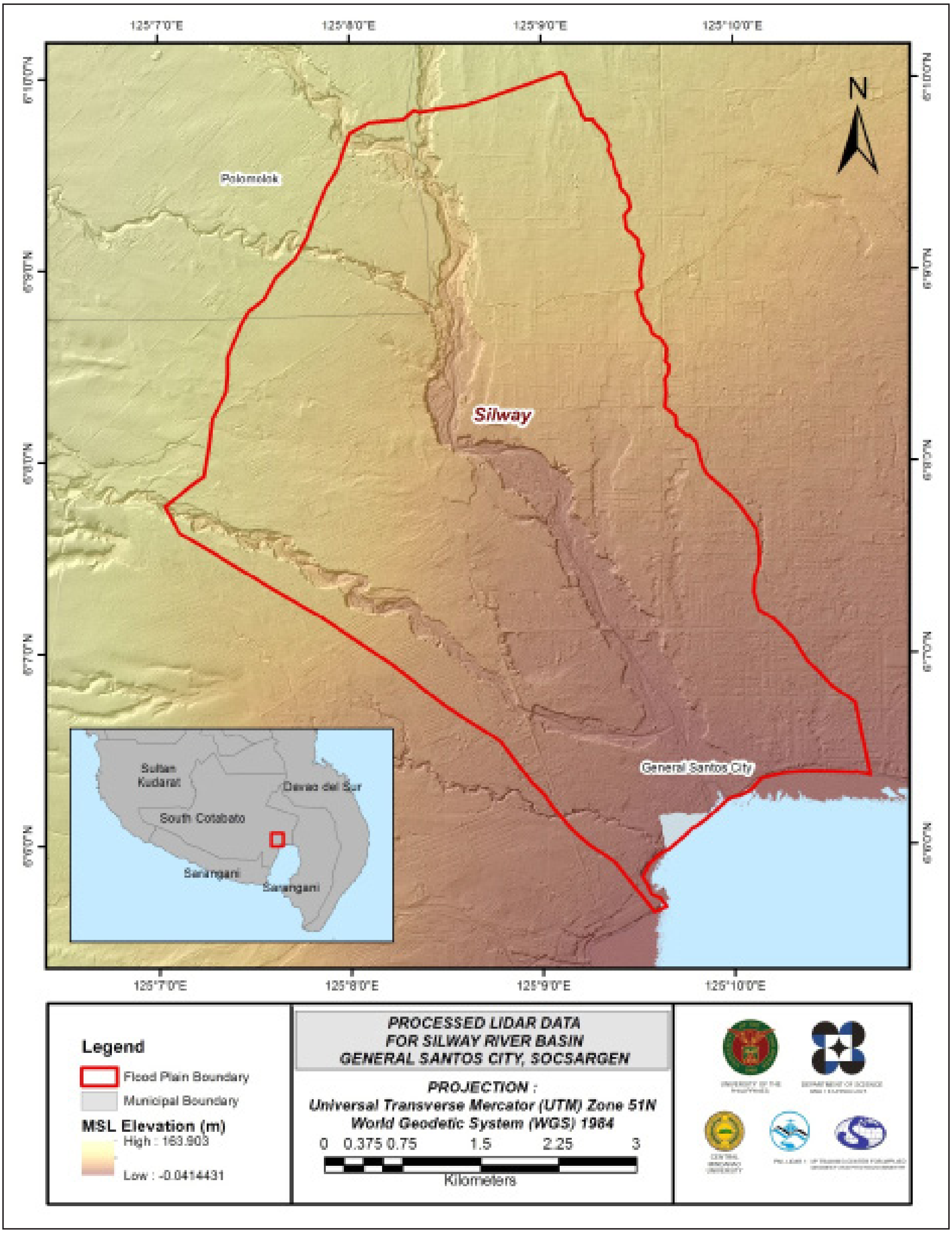


Figure 21. Map of Processed LiDAR Data for Silway Flood Plain.

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Silway to collect points with which the LiDAR dataset is validated is shown in Figure 22. A total of 9662 survey points were used for calibration and validation of Silway LiDAR data. The 80% of the total survey points were extracted through equal selection at a certain interval, resulting to 7730 points were used for calibration.

A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure 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 elevation values is 0.07 meters with a standard deviation of 0.07 meters. Calibration of Silway LiDAR data was done by adding the height difference value, 0.07 meters, to Silway mosaicked LiDAR data. Table 13 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

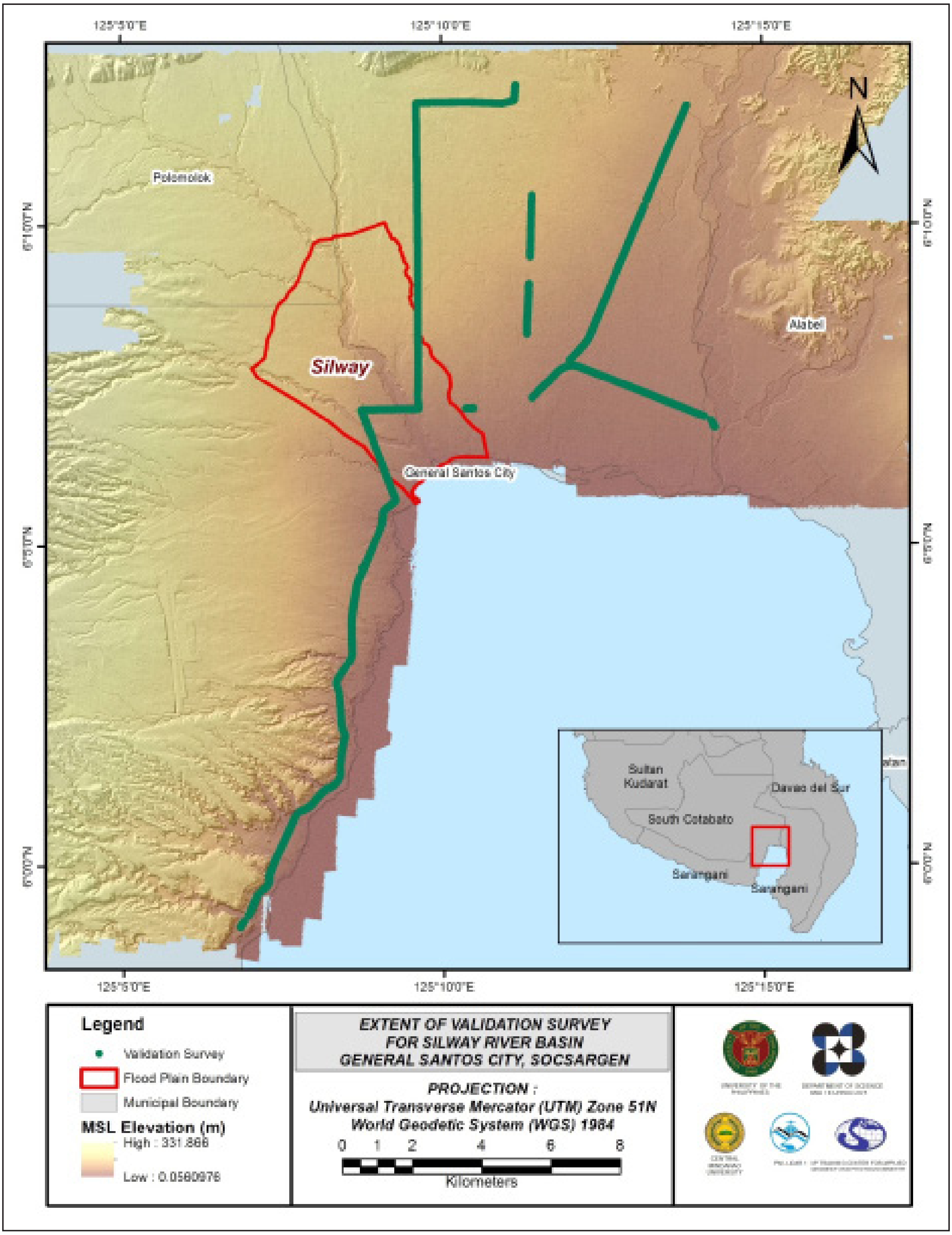


Figure 22. Map of Silway Flood Plain with validation survey points in green.

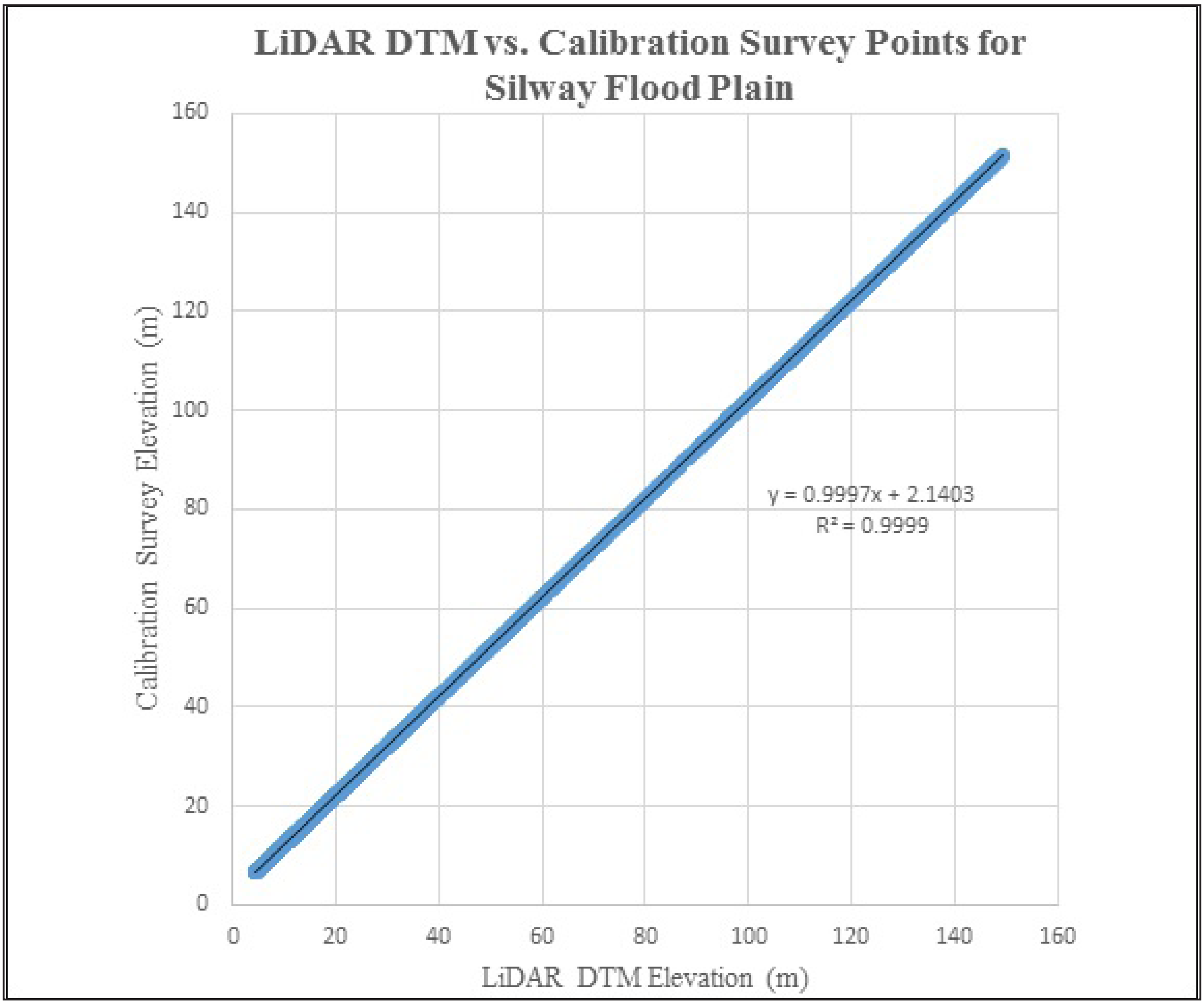


Figure 23. Correlation plot between calibration survey points and LiDAR data.

Table 13. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	0.07
Standard Deviation	0.07
Average	-0.00123
Minimum	-0.14
Maximum	0.14

The remaining 20% of the total survey points is equivalent to 1932. 231 of the said points lie within the Silway flood plain and were used for the validation of calibrated Silway 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 0.07 meters with a standard deviation of 0.07 meters, as shown in Table 14.

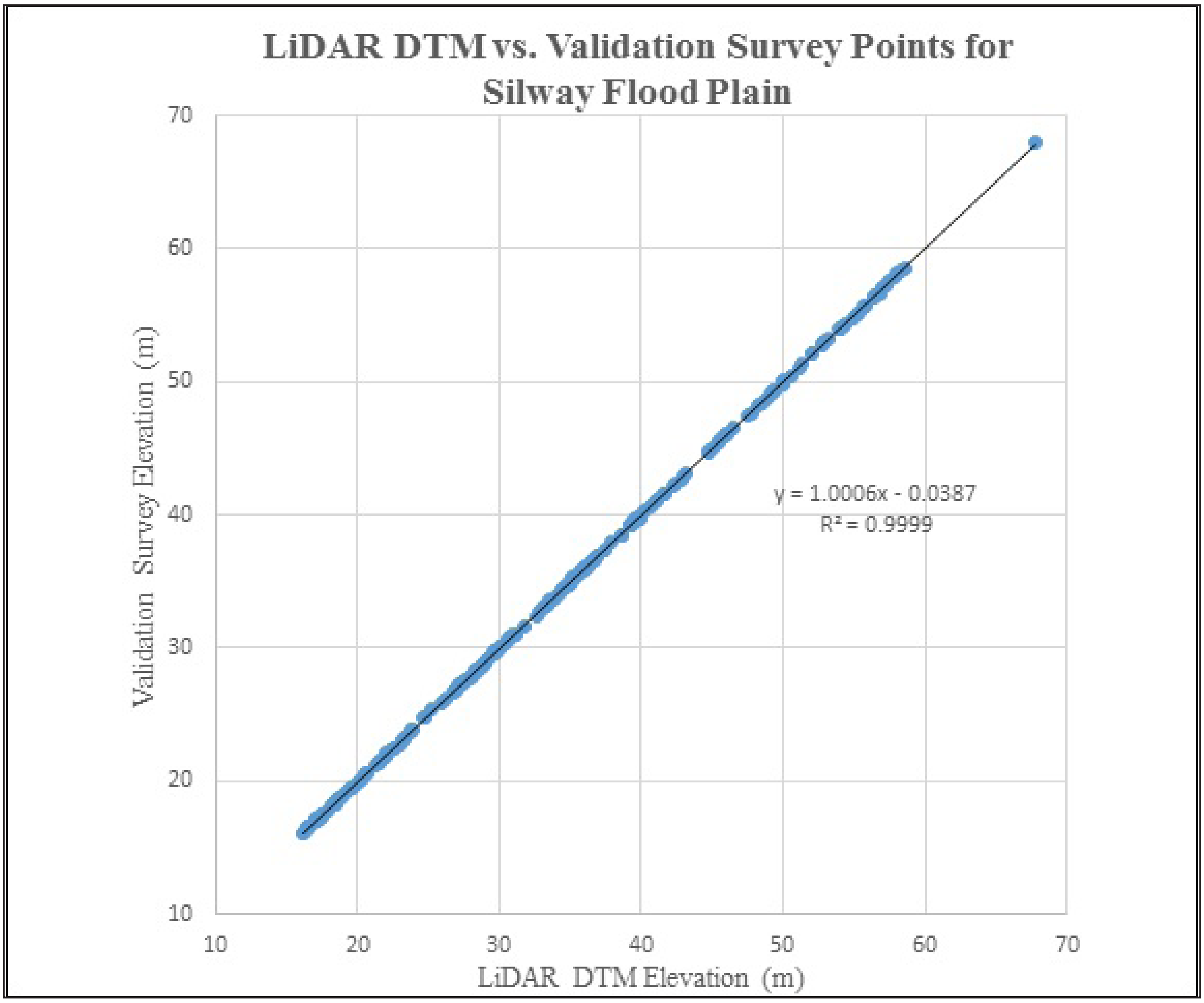


Figure 24. Correlation plot between the validation survey points and the LiDAR data.

Table 14. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.07
Standard Deviation	0.07
Average	-0.02
Minimum	-0.14
Maximum	0.14

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, cross-section and centerline data was available for Silway with 1048 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 0.13 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Silway integrated with the processed LiDAR DEM is shown in Figure 25.

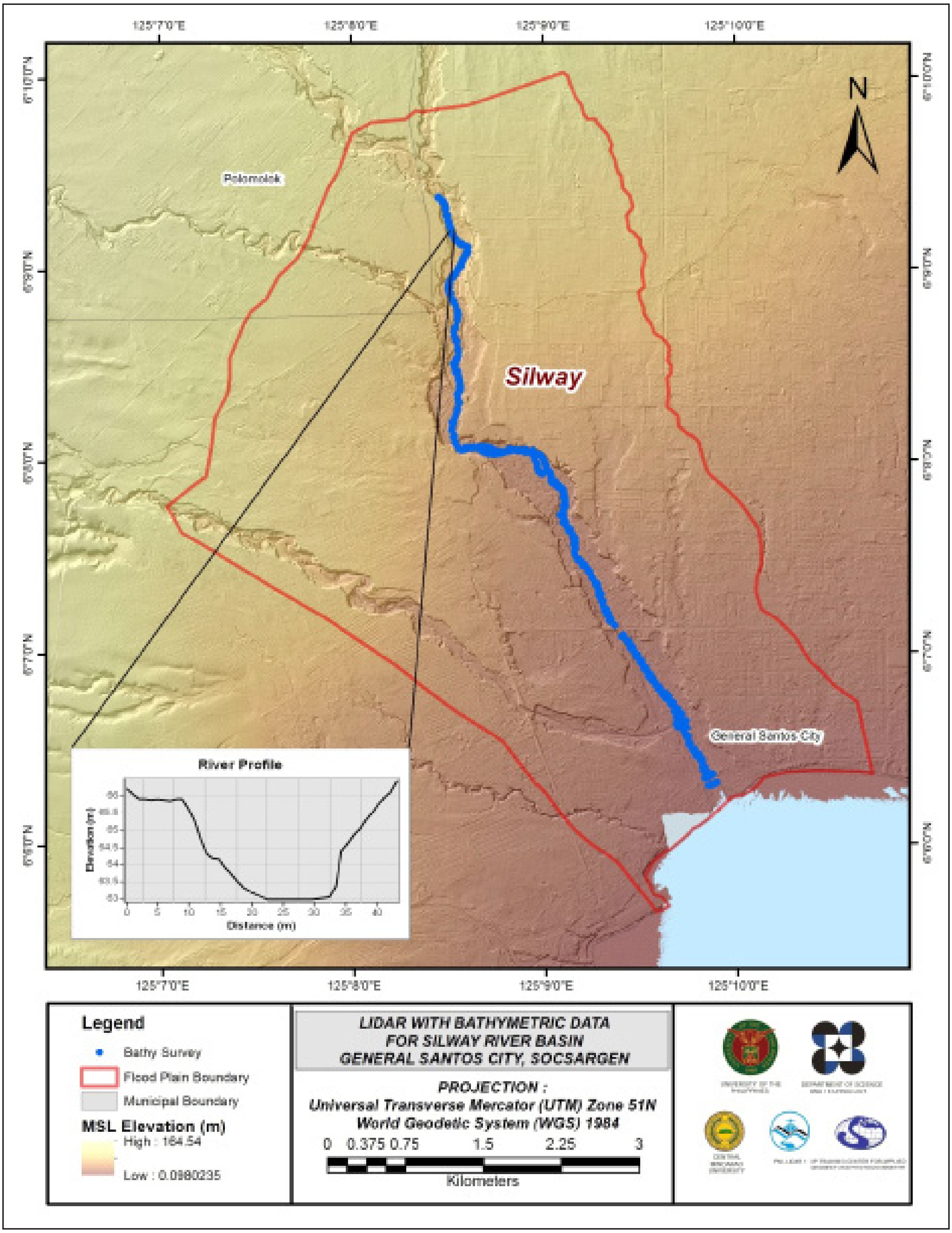


Figure 25. Map of Silway Flood Plain with bathymetric survey points shown in blue.

3.12 Feature Extraction

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

3.12.1 Quality Checking (QC) of Digitized Features' Boundary

Silway floodplain, including its 200 m buffer, has a total area of 31.63 sq km. For this area, a total of 5.00 sq km, corresponding to a total of 4425 building features, are considered for QC. Figure 26 shows the QC blocks for Silway floodplain.

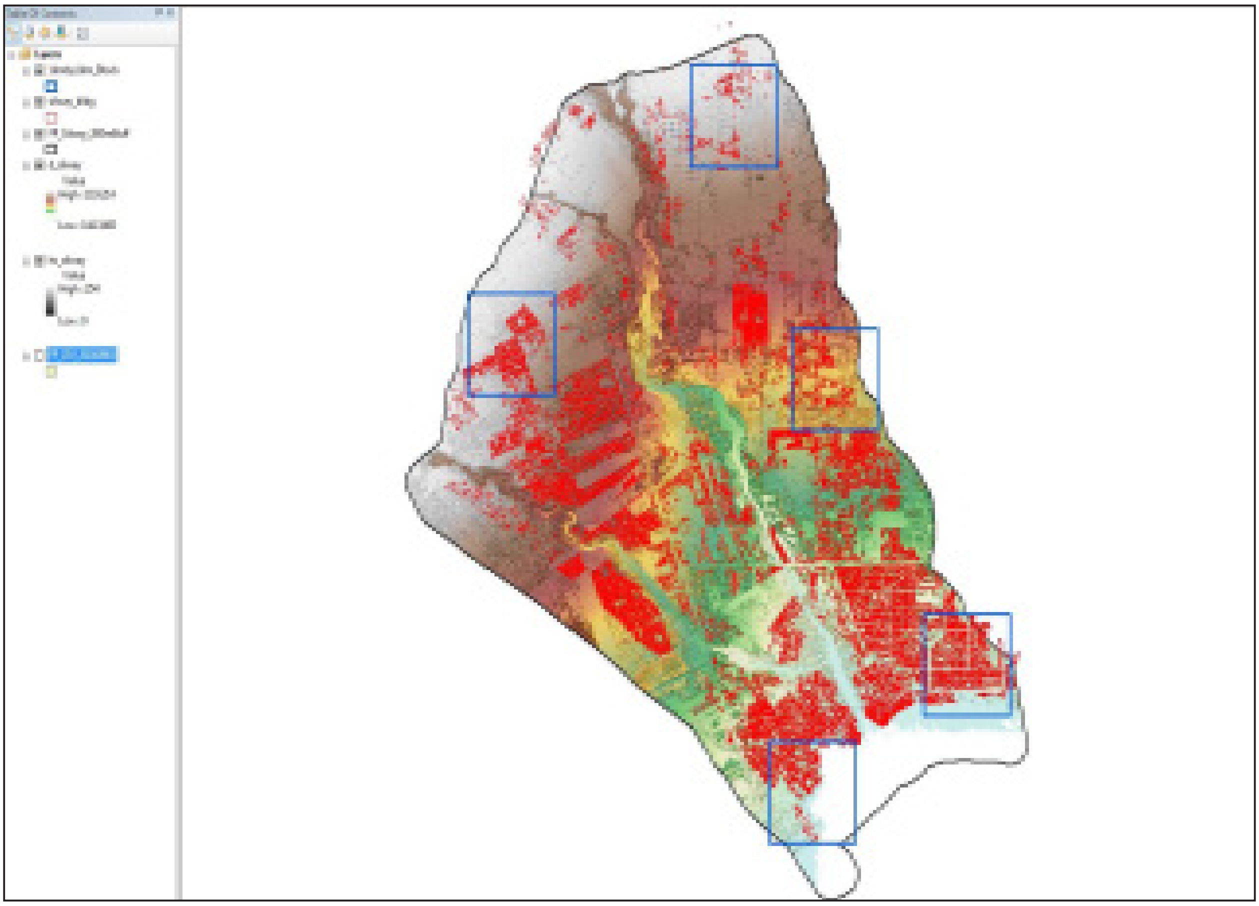


Figure 26. QC blocks for Silway building features.

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

Table 15. Details of the quality checking ratings for the building features extracted for the Silway River Basin

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Silway	99.68	99.82	93.08	PASSED

3.12.2 Height Extraction

Height extraction was done for 27,119 building features in Silway floodplain. Of these building features, 354 were filtered out after height extraction, resulting to 26,765 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 11.01 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. Alternatively, some information on the building classifications were also based from the existing geotagging data of LGU of General Santos City in shapefile format.

Table 16 summarizes the number of building features per type. Silway buildings within the floodplain are mostly residential. For instance, commercial establishments are usually present in the poblacion area of the municipality proper. On the other hand, Table 17 shows the total length of each road type, while Table 18 shows the number of water features extracted per type.

Table 16. Number of Building Features Extracted for Silway Floodplain.

Facility Type	No. of Features
Residential	23,464
School	513
Market	18
Agricultural/Agro-Industrial Facilities	7
Medical Institutions	32
Barangay Hall	6
Military Institution	0
Sports Center/Gymnasium/Covered Court	16
Telecommunication Facilities	5
Transport Terminal	6
Warehouse	99
Power Plant/Substation	7
NGO/CSO Offices	34
Police Station	1
Water Supply/Sewerage	4
Religious Institutions	211
Bank	18
Factory	108
Gas Station	52
Fire Station	0
Other Government Offices	191
Other Commercial Establishments	1, 973
Total	**26, 765**

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

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Silway	271.57		0	10.97	0	282.54

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

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Silway	3	0	0	0	0	3

A total of 6 bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

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

Figure 27 shows the Digital Surface Model (DSM) of Silway floodplain overlaid with its ground features.

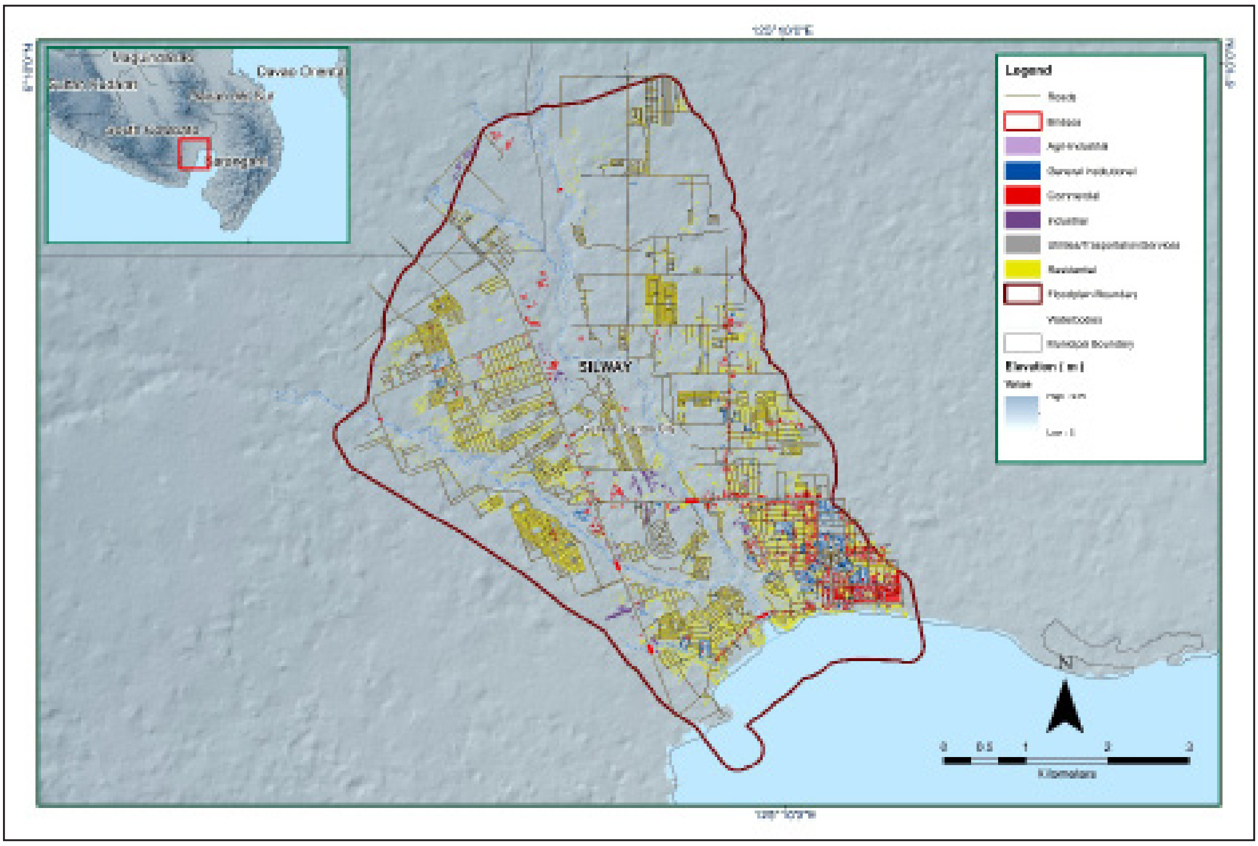


Figure 27. Extracted features for Silway Floodplain.

CHAPTER 4: DATA VALIDATION SURVEY AND MEASUREMENTS IN THE SILWAY RIVER BASIN

Engr. Louie P. Balicanta, Engr. Joemarie S. Caballero, Engr. Dexter Lozano, Ms. Patrizcia Mae. P. dela Cruz, Engr. Kristine Ailene B. Borromeo, Ms. Jeline M. Amante, Engr. Bernard D. Maramot, Engr. JMson J. Calalang, Engr. Melchor Nery, For. Dona Rina Patricia C. T ajora, Elaine Bennet Salvador, For. Rodel Alberto, Marie Angelique R. Estipona, Charie Mae V. Manliguez, Carl Vincent Caro, and Jojo Morillo

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 Basin Overview

The Data Validation and Bathymetry Component (DVBC), under the Nationwide DREAM Program, conducted field surveys in the Buayan-Malungon, Makar, and Silway Rivers on June 11-22, 2013. Field surveys were also conducted by RASA Surveying in Silway River on July 9 to September 2, 2013 with the following scope of work: reconnaissance; control survey; and cross-section surveys for sixteen (16) delineated cross-section lines. Among the rivers surveyed is the PHIL-LIDAR 1 River, Silway River, with the following scope of work: reconnaissance, bathymetric survey from the upstream in Brgy. Mabuhay down to Brgy. Dadiangas South in General Santos City. The entire survey extent is illustrated in Figure 28.

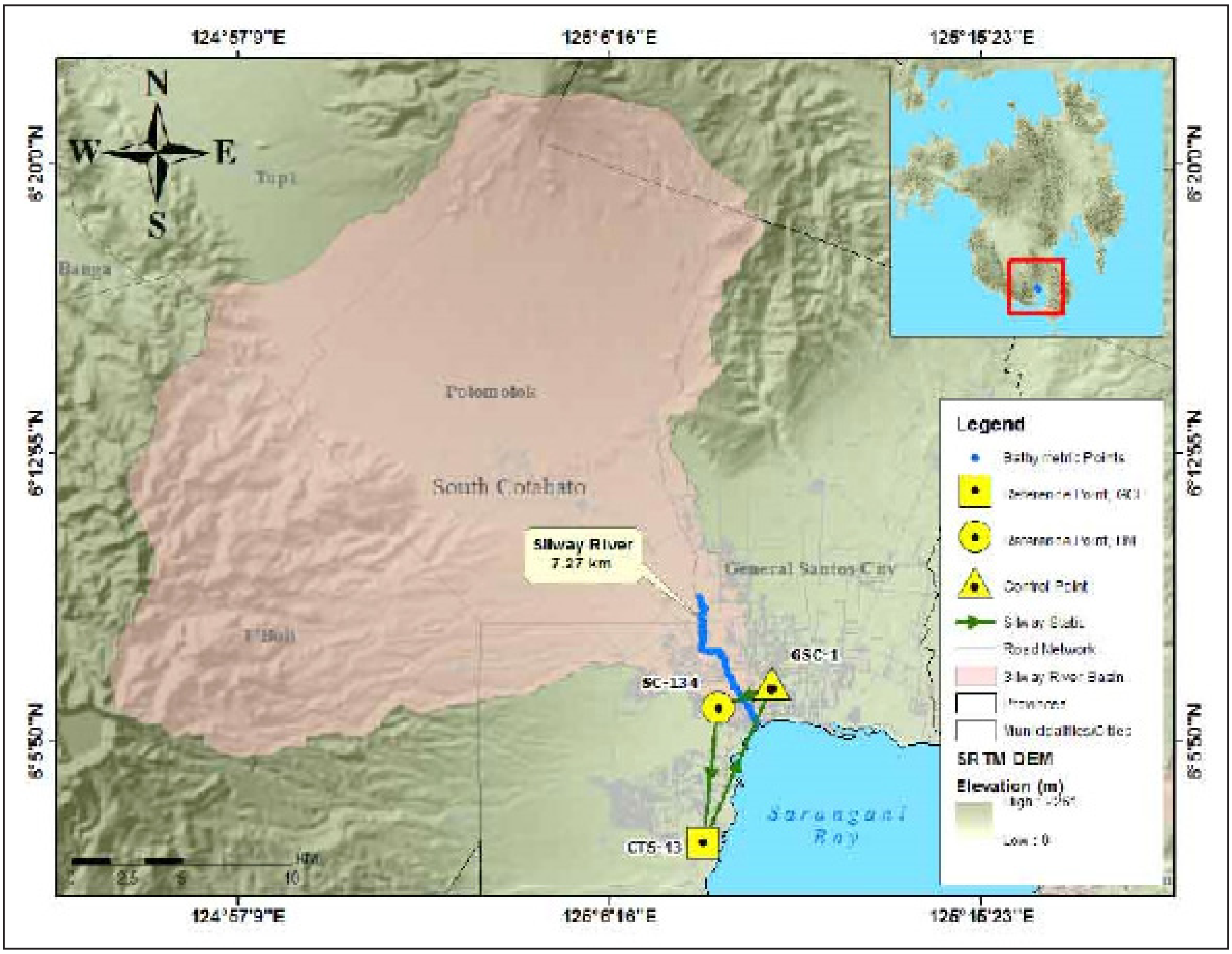


Figure 28. Silway River Survey Extent

4.2 Control Survey

The GNSS network used for Silway river is composed of one (1) loop established on June 11, 2013 occupying the following reference point: CTS-43, a 2nd order GCP in Brgy. Tambler, General Santos City and SC-134, a 1st Order Benchmark located in Brgy. Sinawal, General Santos City.

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

Table 19. List of reference and control points used during the survey in Silway River (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)
CTS-43	2nd	06°03' 21.48507"N	125°08' 33.05028"E	97.233	669859.338	737140.92	26.713
SC-134	1st	06°06' 39.95883"N	125°08' 54.60317"E	101.652	675960.563	737779.63	30.953
GSC-1	Established	06°07' 16.67814"N	125°10' 14.17232"E	98.54	677098.698	740222.36	28.053

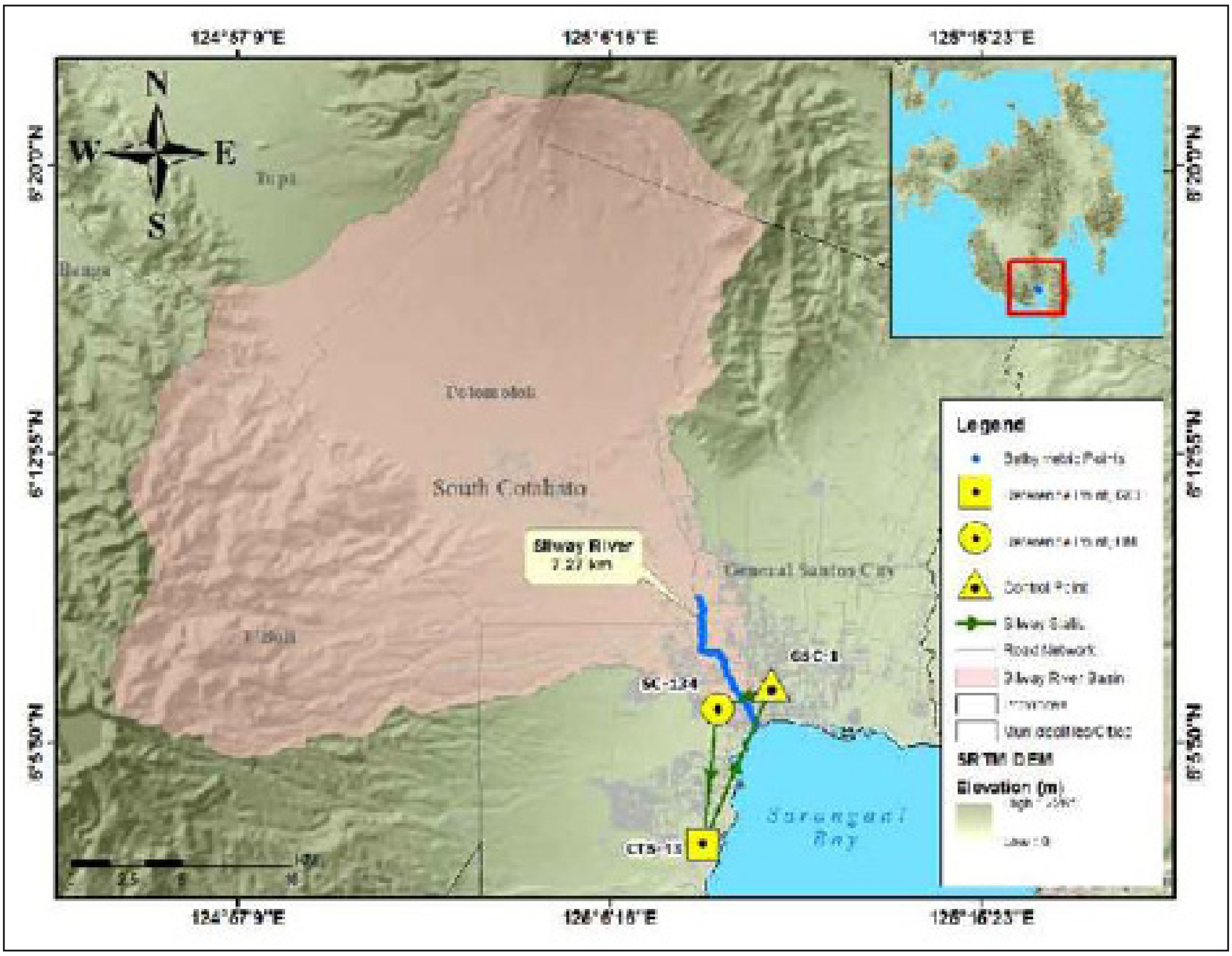


Figure 29. The GNSS Network established in the Silway River Survey.

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

Figure 30. GNSS base set up, Trimble® SPS 852, at CTS-43, in Brgy. Tambler, General Santos City

Figure 31. GNSS base set up, Trimble® SPS 882, at SC-134-43, at the approach of Sinawal Bridge in Brgy. Sinawal, General Santos City

Figure 32. Trimble SPS® 882 set-up at AN-9 located at the approach of Silway Bridge, Brgy. Kauswagan, Silway City, Agusan Del Norte

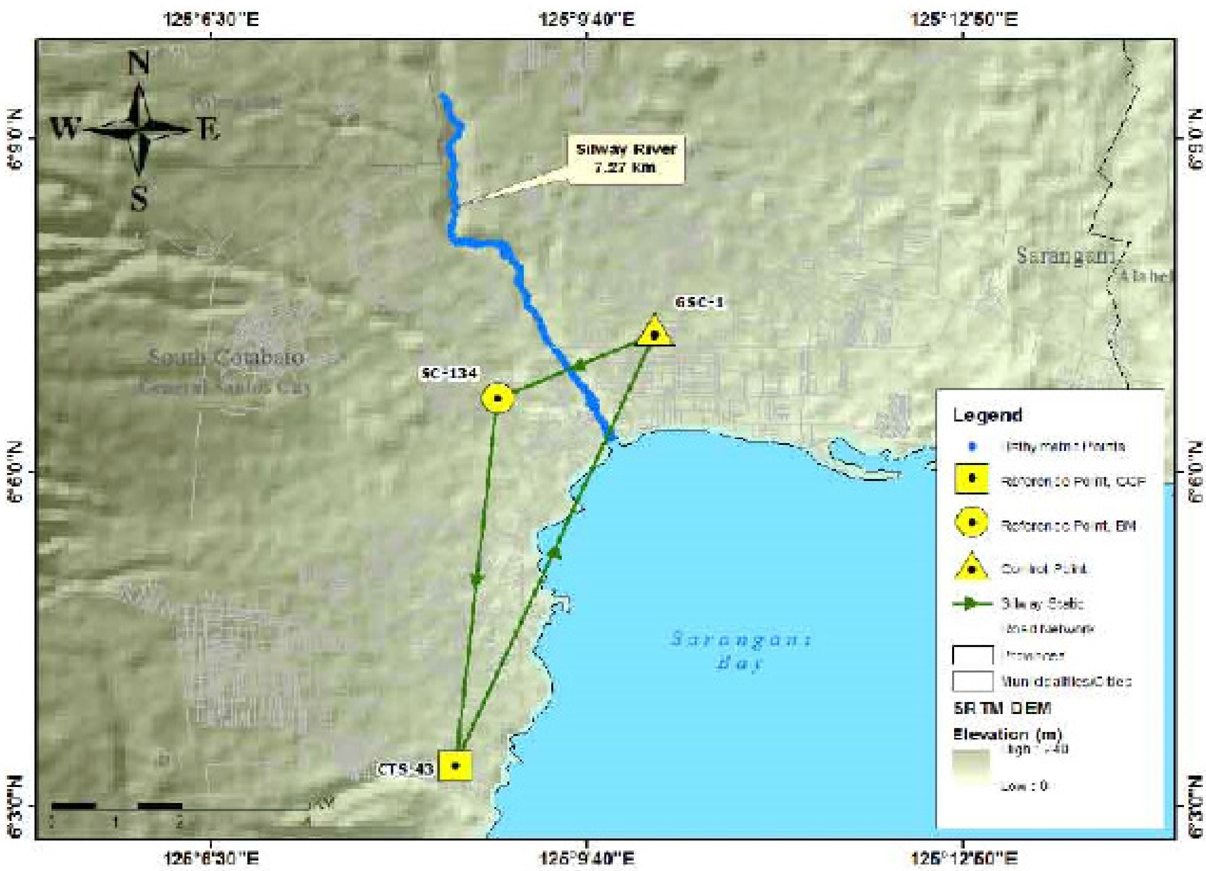


Figure 33. Silway River control survey map

4.3 Cross-section

There are sixteen (16) cross-sections conducted by Rasa Surveying. It contains cross-section diagrams as elaborated in the DREAM report, Buayan-Malungon River: DREAM Ground Surveys Report (Balicanta, et.al., 2014).

4.4 Bathymetric Survey

The bathymetry of Silway River was surveyed by traversing the river by foot using the Trimble SPS882 GPS Rover in PPK survey technique because of the shallow waters in Silway River, as shown in Figure 34. The entire bathymetry of Silway River, together with Buayan-Malungon River and Makar River, took four (4) days to complete from June 16-19, 2013.

Figure 34. Manual bathymetric survey at Silway River using PPK GNSS technique

The bathymetric survey for Silway River gathered a total of 1,048 points covering 7.27 km of the river traversing Barangays Mabuhay, San Isidro, City Heights, Dadiangas North, Dadiangas West, and Dadiangas South as illustrated in Figure 35.

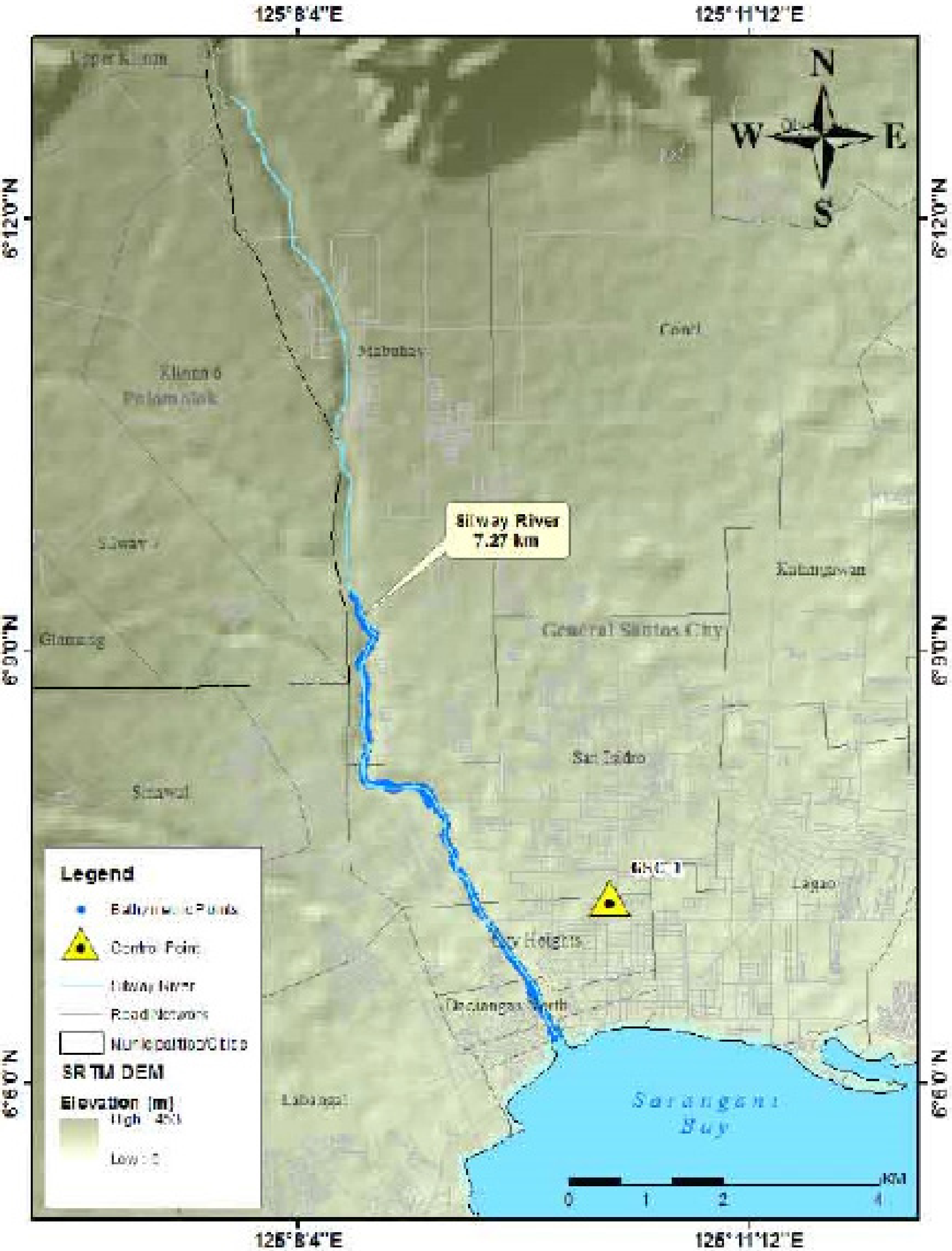


Figure 35. Bathymetric survey of Silway River

A CAD drawing was also produced to illustrate the riverbed profile of Silway River. As shown in Figure 36, the highest and lowest elevation has a 17.385-m difference. The highest elevation observed was 77.437 m above MSL located in Brgy. Mabuhay in General Santos City while the lowest was 60.052 m above MSL located in Brgy. Dadiangas in General Santos City.

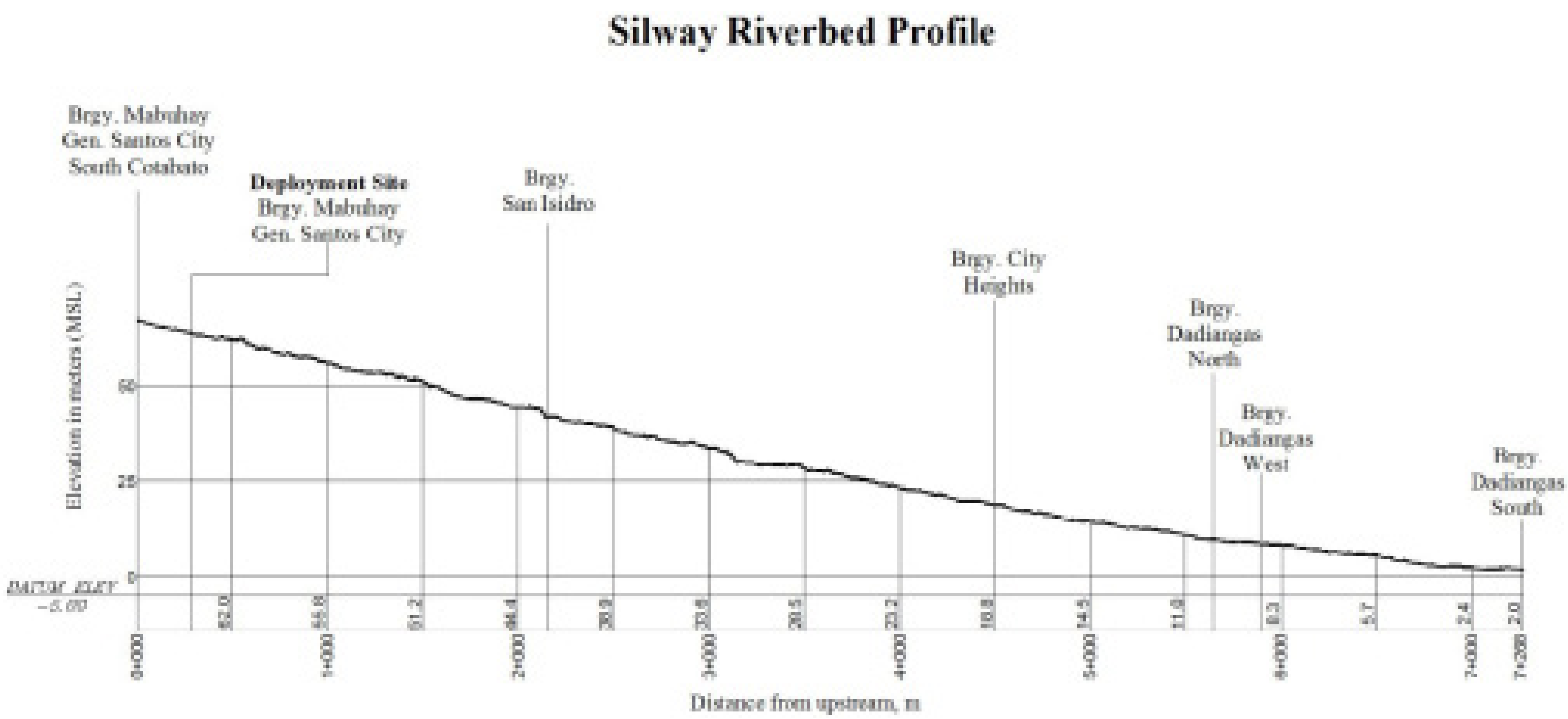


Figure 36. The Silway River Bed Profile

CHAPTER 5: FLOOD MODELING AND MAPPING

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

5.1.1 Hydrometry and Rating Curves

All components and data that affect the hydrologic cycle of the Silway 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 Silway River Basin were monitored, collected, and analyzed.

5.1.2 Precipitation

Rainfall data with a duration of 13 hours and 40 minutes during an event on 04 August 2016 from 2130 hours of 04 August 2016 to 1110 hours of 05 August 2016 was collected from the rain gauges installed by CMU Phil-LiDAR 1 at Barangay Magsaysay, Polomolok (6°11’53”N, 125° 3’36”E), Barangay Poblacion, Polomolok (6°13’14”N, 125° 3’50”E) and Upper Klinan, Polomolok (6°13’33”N, 125° 7’21”E). Two automated rain gauges (ARGs) located at General Santos City Airport (6° 3’19.20”N, 125° 5’50.80”E) and Polomolok, South Cotabato (6°13’12.62”N, 125° 3’45.92”E) installed by the Department of Science and Technology – Advanced Science and Technology Institute (DOST-ASTI) Region XII are found within the Silway River Basin, but were not functioning during the period of data collection. The three rain gauges in the Silway River Basin are shown in Figure 37.

Total rain for this event in Magsaysay rain gauge is 124.7mm. It peaked to 32 mm on 04 August 2016 23:30. For Poblacion, total precipitation for this event is 25.0 mm. Peak rain of 6.8 mm was recorded on 04 August 2016, 21:45. No rainfall was recorded in the Upper Kilnan rain gauge. The lag time between peak rainfall and peak discharge is 1 hour for Magsaysay and 2 hours and 40 minutes for Poblacion rain gauges. These data are depicted in Figure 39.

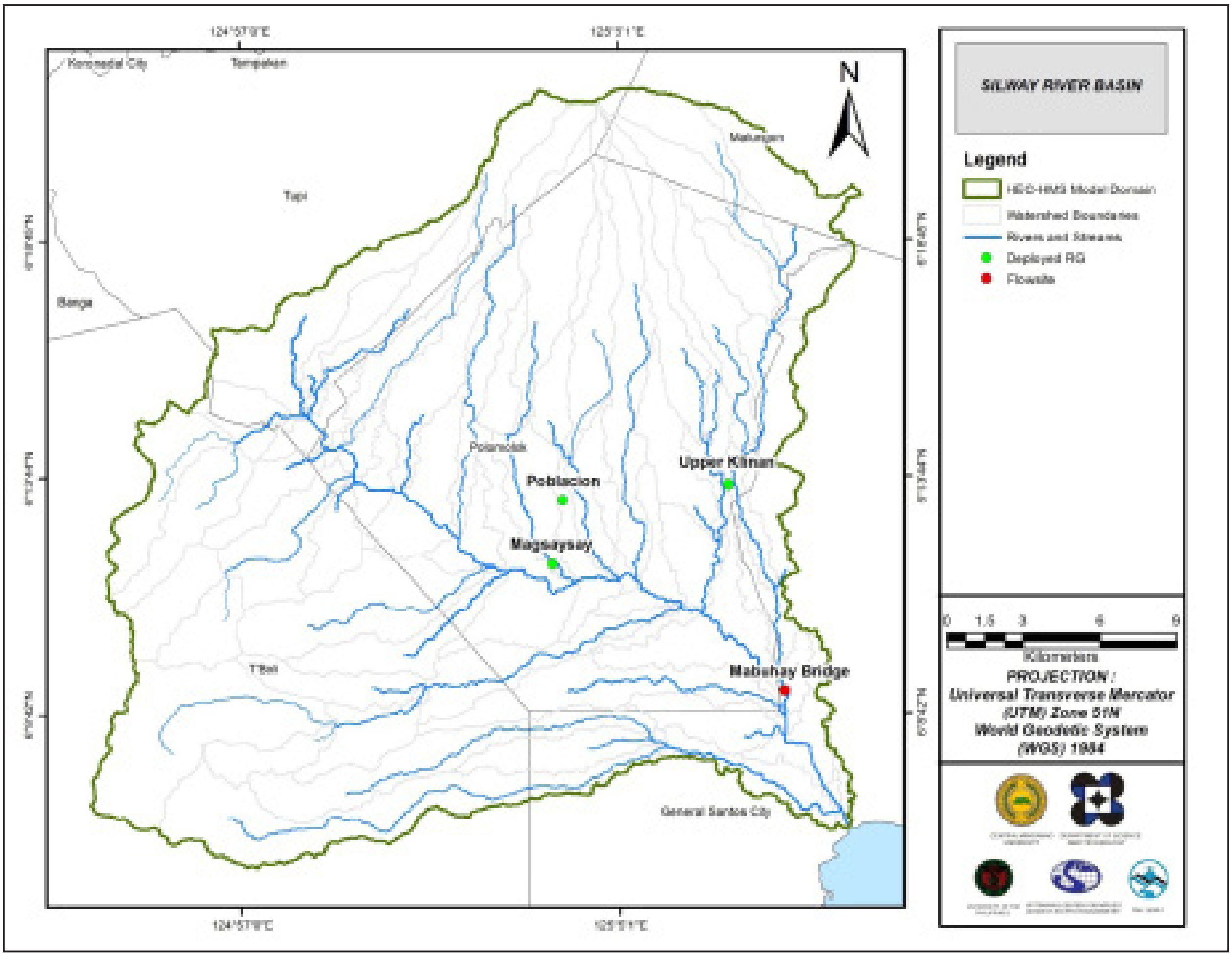


Figure 37. The location map of Silway HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

The event on 04 August 2016 resulted to a water level rise of 1.187 meter and peak discharge of 24.06 m3/s recorded at 0040 hours on 05 August 2016 (Table 25) taken from Mabuhay Bridge, Brgy Mabuhay, General Santos City. Lag time between peak rainfall and peak discharge is 1 hour for Magsaysay and 2 hours and 40 minutes for Poblacion rain gauges (Figure 42). The collected hydrologic data are inputted in HEC-HMS for the basin model calibration.

Figure 38. The Cross-section plot of Silway Bridge

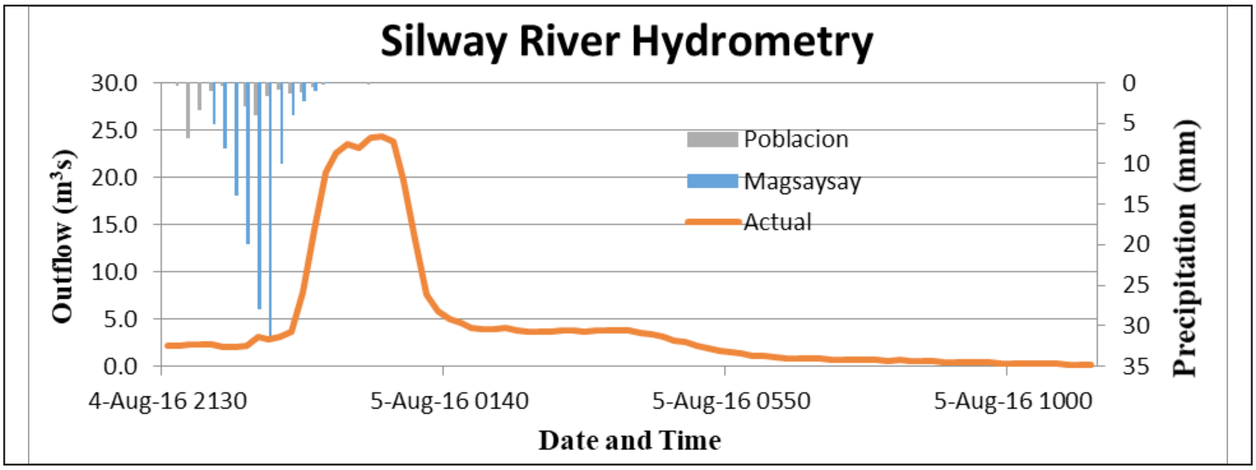


Figure 39. Rainfall and outflow data used for modeling

A rating curve was generated to illustrate the relationship of the observed flow and water level. It is expressed in the form of the following equation:

Q=anh

where, Q : Discharge (m3/s),
h : Gauge height (reading from Mabuhay Bridge depth gauge sensor), and
a and n : Constants.

The Silway River Rating Curve measured at Mabuhay Bridge is expressed as Q = 2E-31e1.172x (Figure 40).

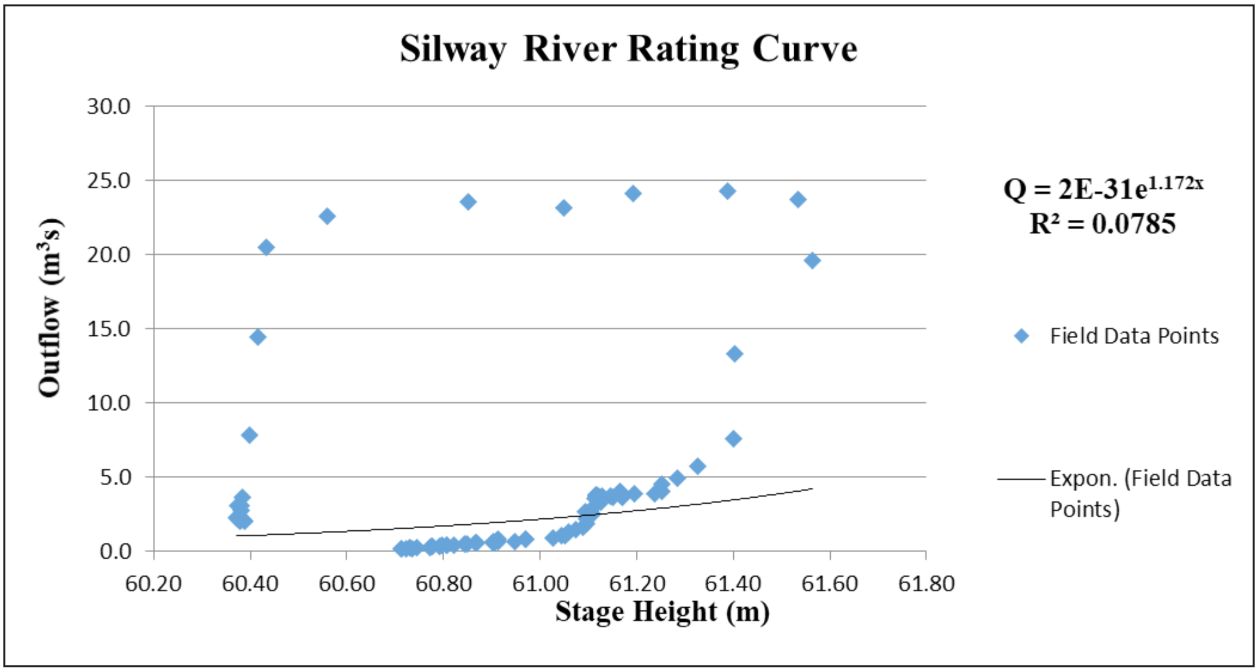


Figure 40. HQ Curve of HEC-HMS model

5.2 RIDF Station

The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed for Rainfall Intensity Duration Frequency (RIDF) values for the General Santos City Rain Gauge. The RIDF rainfall amount for 24 hours was converted to a synthetic storm by interpolating and re-arranging the values in such a way a certain peak value will be attained at a certain time. This station is chosen based on its proximity to the Silway watershed. The extreme values for this watershed were computed based on a 31-year record, with the computed extreme values shown in Table 25.

Table 20. RIDF values for General Santos City Rain Gauge computed by PAGASA

COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION									
T (yrs)	**10 mins**	**20 mins**	**30 mins**	**1 hr**	**2 hrs**	**3 hrs**	**6 hrs**	**12 hrs**	**24 hrs**
2	8.9	13.5	16.9	22.5	32.4	38.7	50.1	60.9	68.9
5	12.7	19.5	24.3	32.5	47.1	56.6	74	90.4	102.7
10	15.3	23.4	29.3	39.1	56.8	68.4	89.8	109.9	125.1
15	16.7	25.6	32.1	42.8	62.3	75.1	98.8	120.9	137.7
20	17.7	27.2	34	45.4	66.1	79.8	105	128.6	146.5
25	18.5	28.4	35.5	47.4	69.1	83.4	109.8	134.5	153.4
50	20.9	32.1	40.2	53.6	78.2	94.5	124.7	152.8	174.3
100	23.3	35.8	44.8	59.8	87.2	105.5	139.4	170.9	195.2

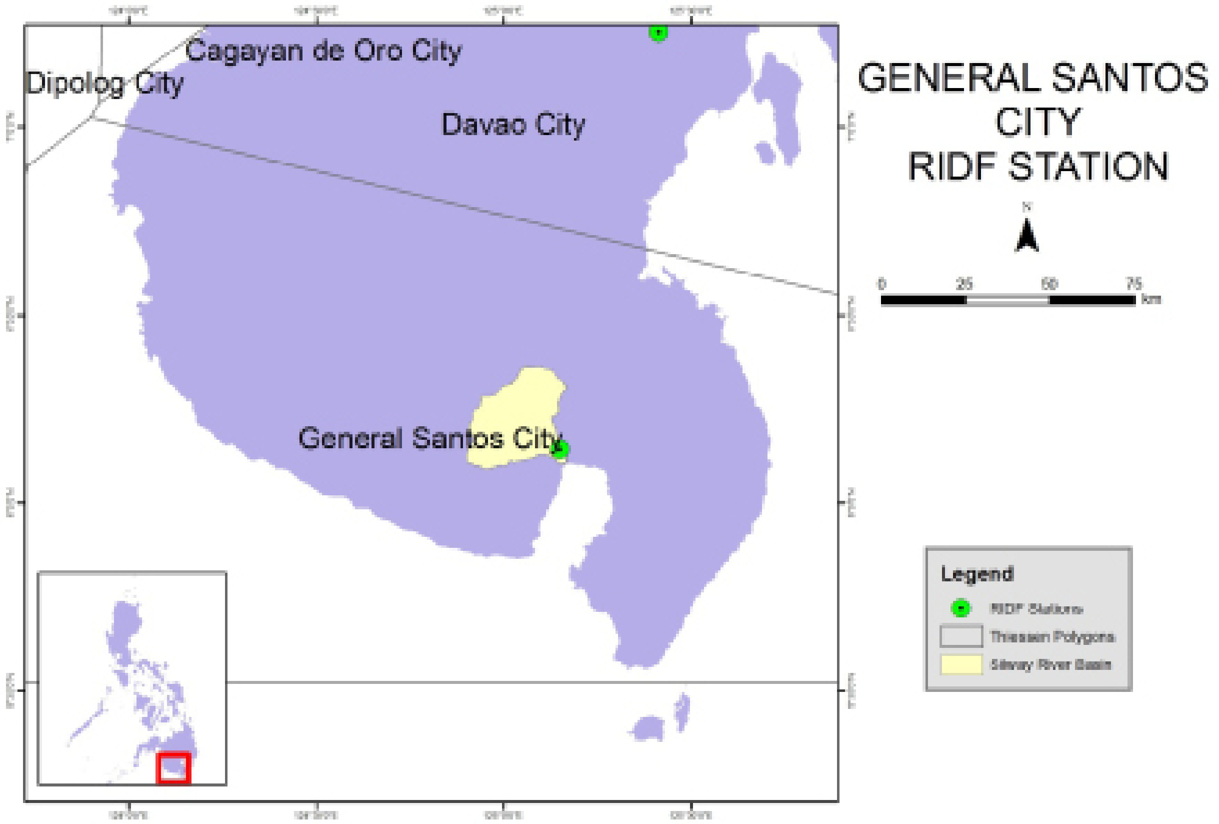


Figure 41. .Location of General Santos City RIDF relative to Silway River Basin

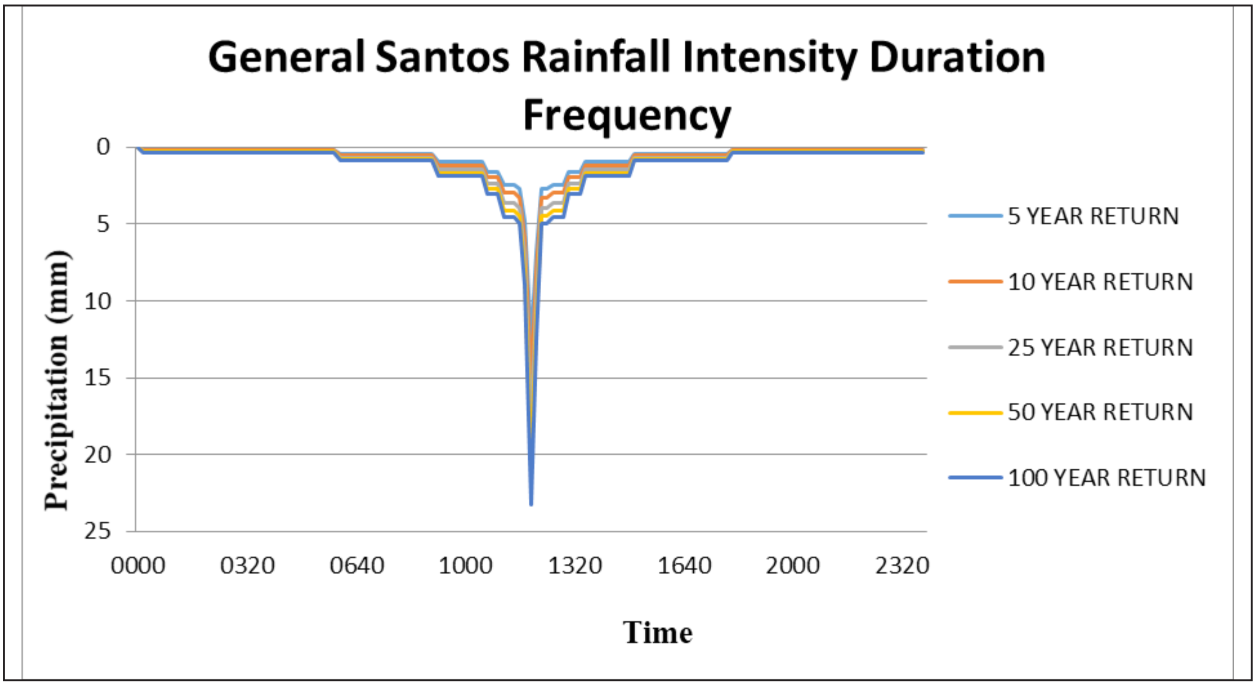


Figure 42. Synthetic storm generated for a 24-hr period rainfall for various return periods.

5.3 HMS Model

The soil dataset was generated before 2004 by the Bureau of Soils and Water Management under the Department of Agriculture (DA-BSWM). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Silway River Basin are shown in Figure 43 and Figure 44, respectively.

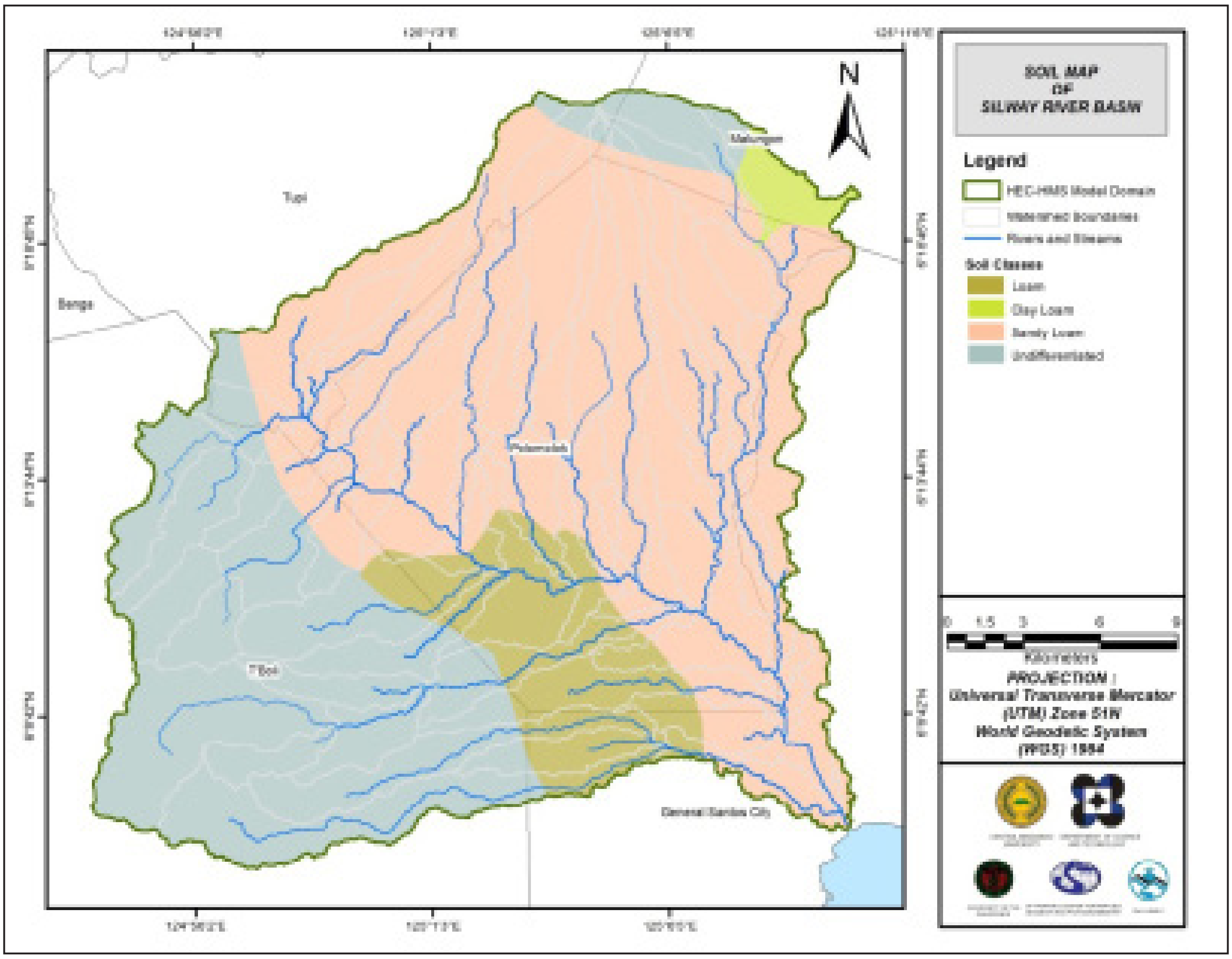


Figure 43. Soil map of Silway River Basin used for the estimation of the CN parameter. (Source: DA)

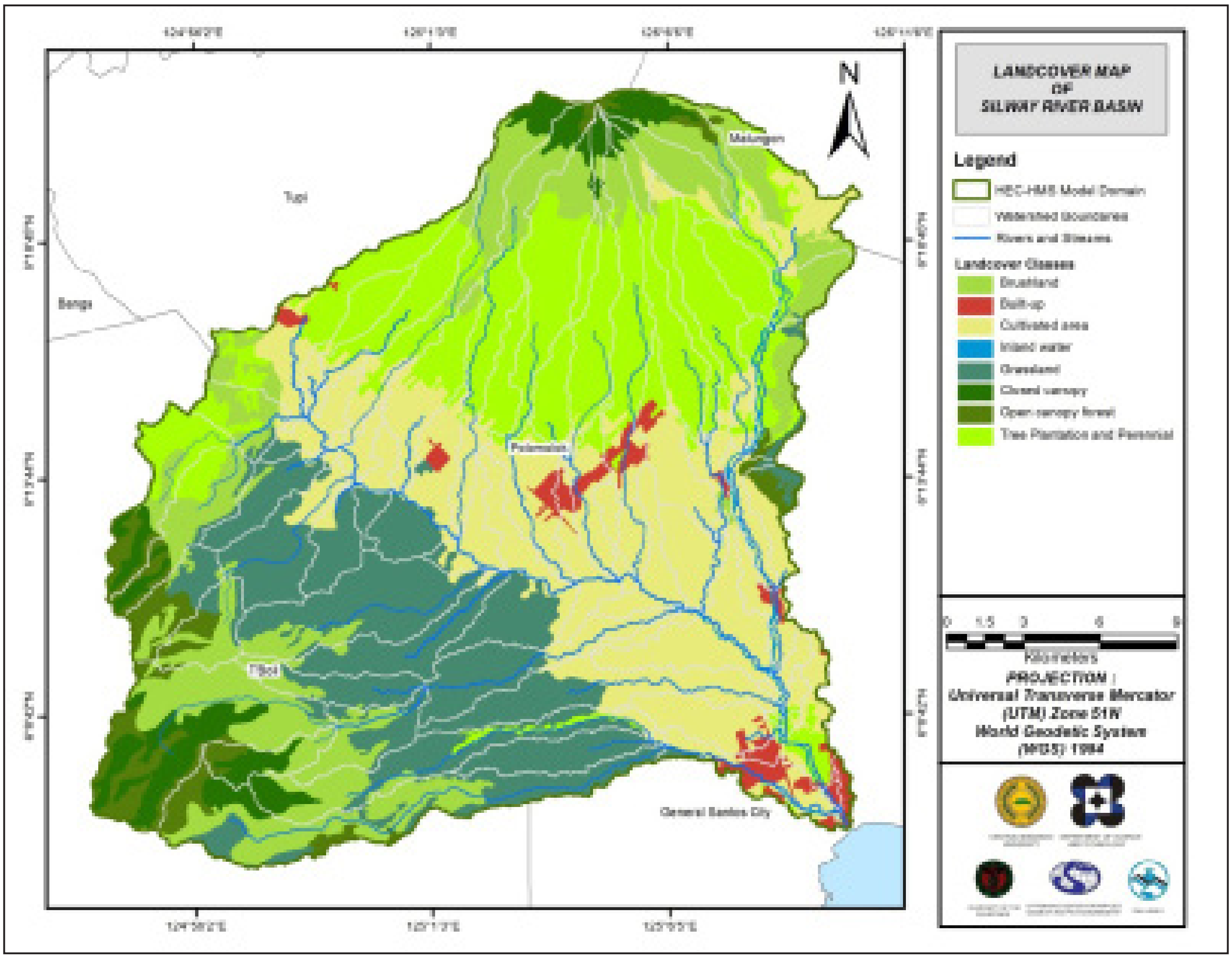


Figure 44. Land cover map of Silway River Basin used for the estimation of the CN and watershed lag parameters of the rainfall-runoff model. (Source: NAMRIA)

For Silway, four (4) soil classes were identified. These are clay loam, loam, sandy loam, and undifferentiated soil. Moreover, eight (8) land cover classes were identified. These are brushland, built-up, cultivated area, inland water, grassland, closed canopy, open canopy forest, and tree plantaion and perennial.

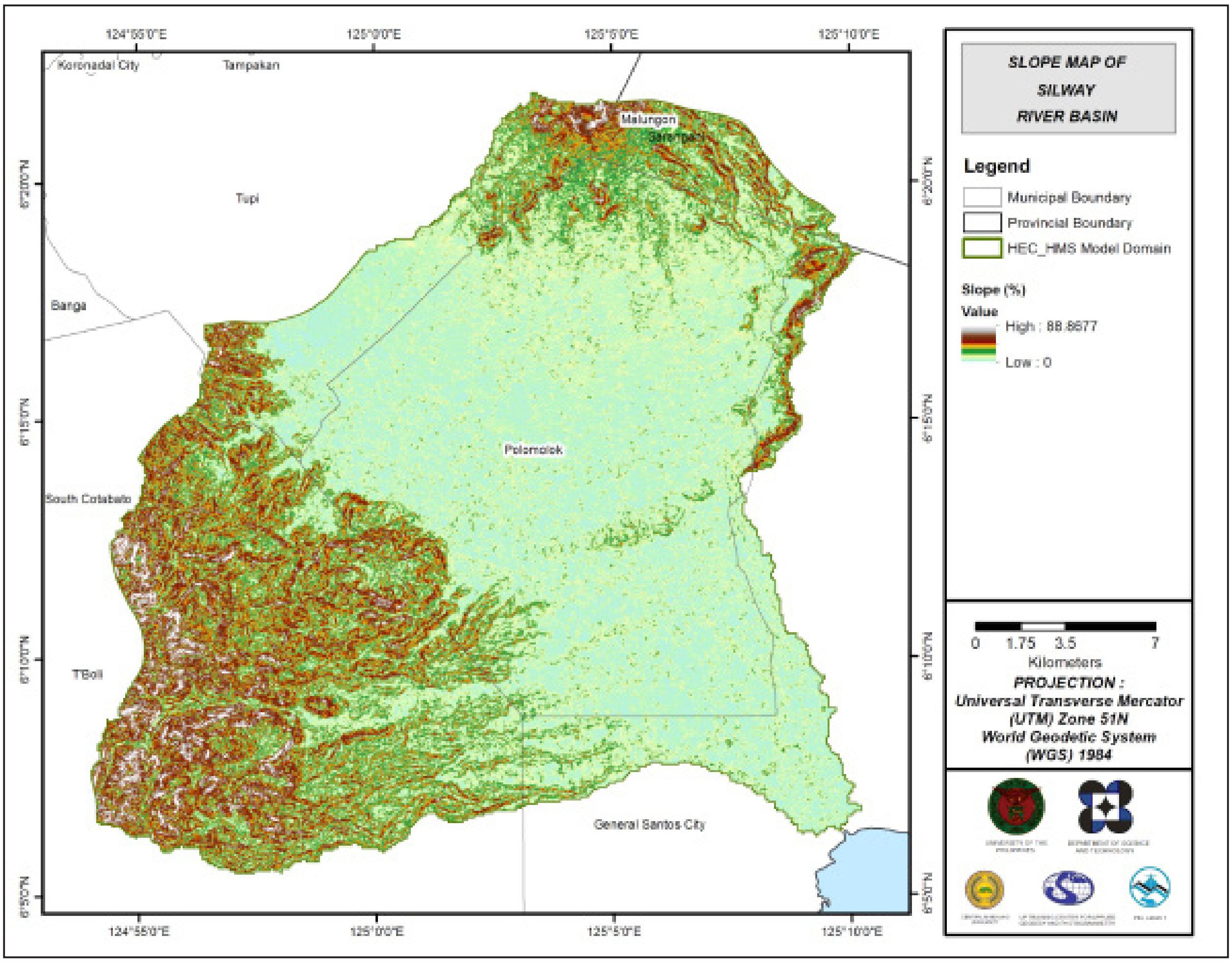


Figure 45. Slope map of Silway River Basin

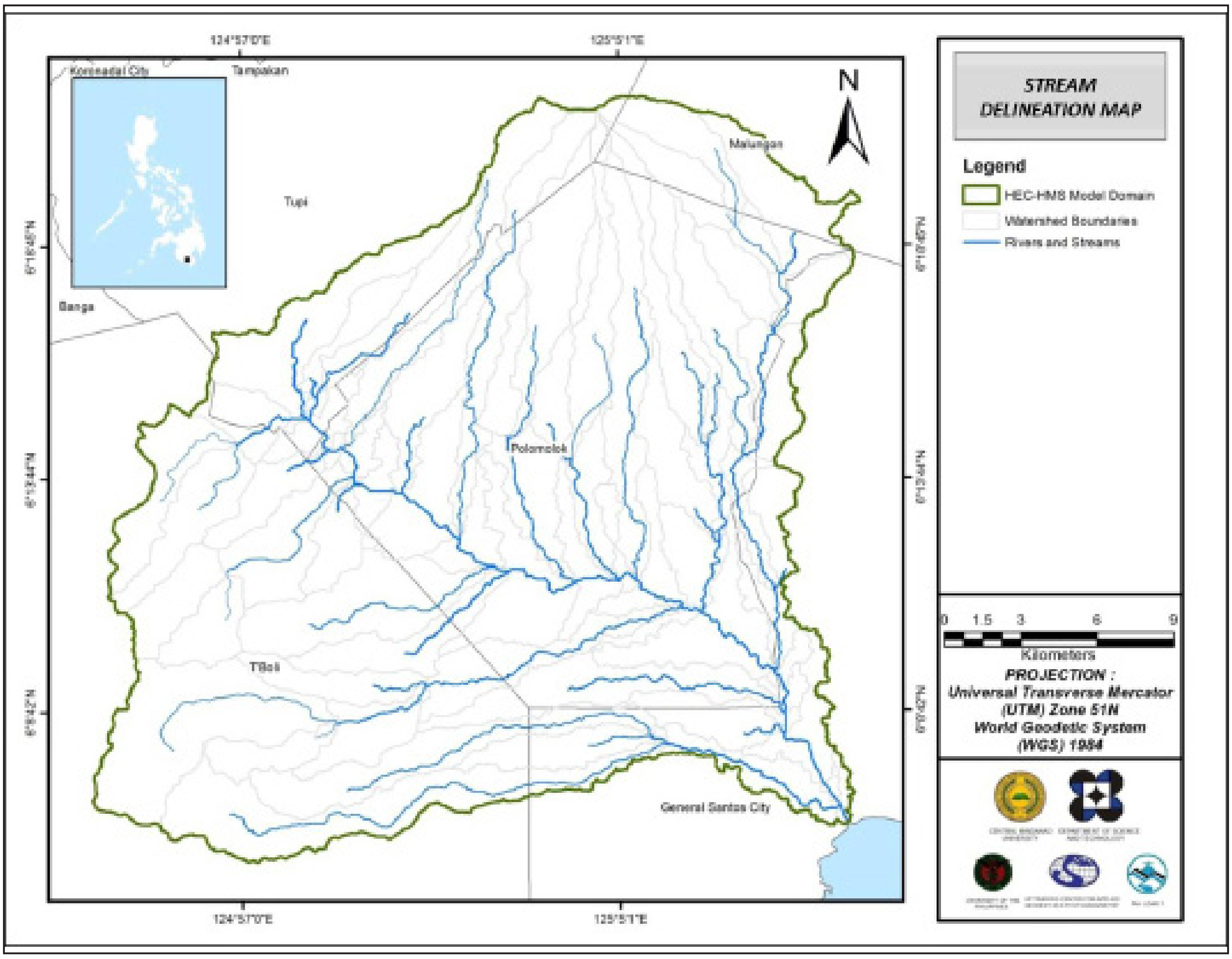


Figure 46. Stream Delineation Map of the Silway River Basin

Using ArcMap 10.1 with HEC-GeoHMS version 10.1 extension, the drainage system of Silway river was delineated using the river's centreline and SAR-DEM 10m resolution as primary input data. Delineated drainage system includes the basin boundary, subbasin and the stream networks. The river centreline was digitized starting from upstream towards downstream in Google Earth (2014).

Using the 10m SAR-DEM with default threshold area of 500 hectares, the delineated drainage system of Silway River Basin generated seventy-three (73) sub-basins, thirty-seven (37) reaches and thirty-eight (38) junctions including the main outlet. Silway drainage system is illustrated in Figure 47.

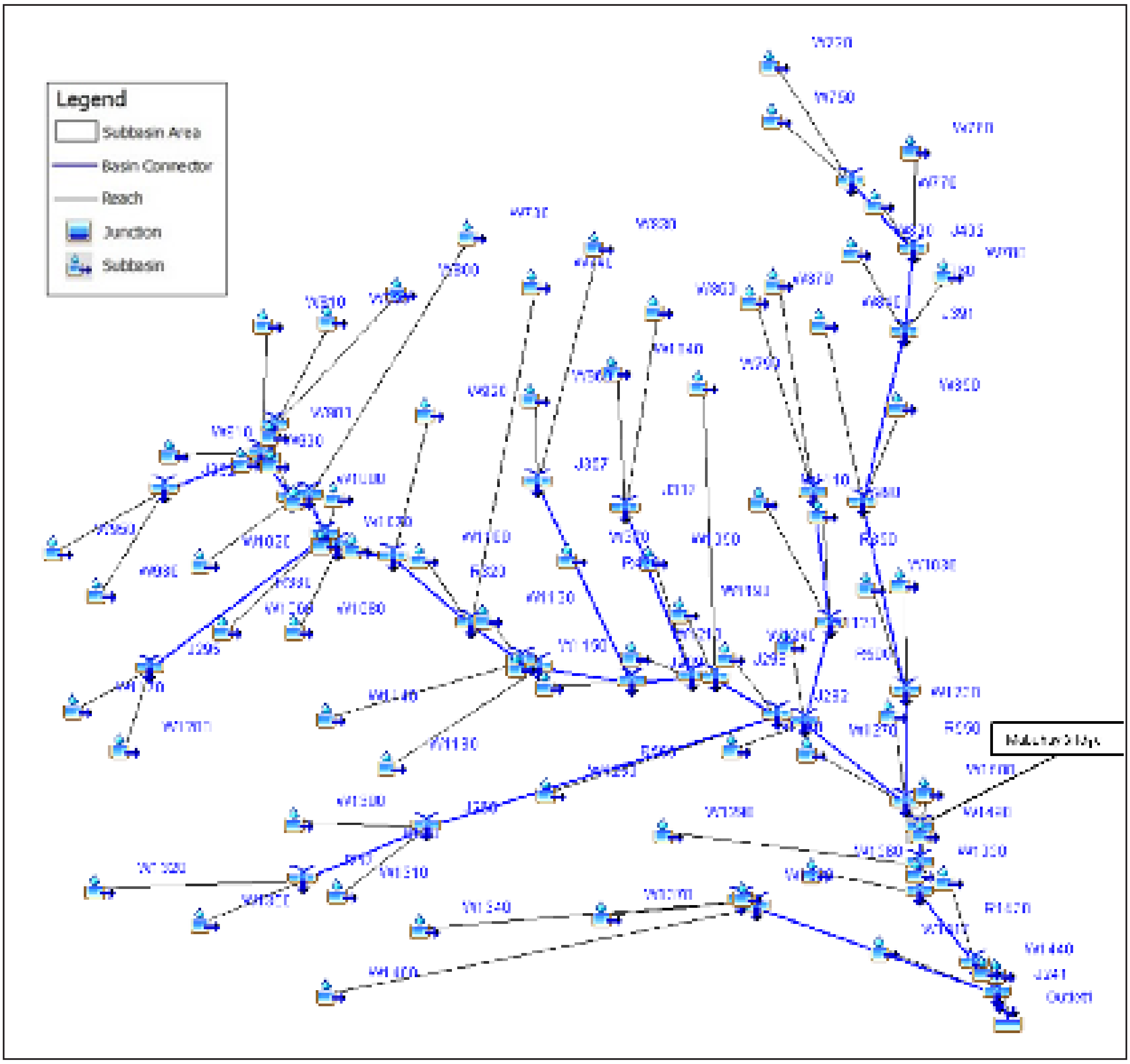


Figure 47. HEC-HMS generated Silway River Basin Model.

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.

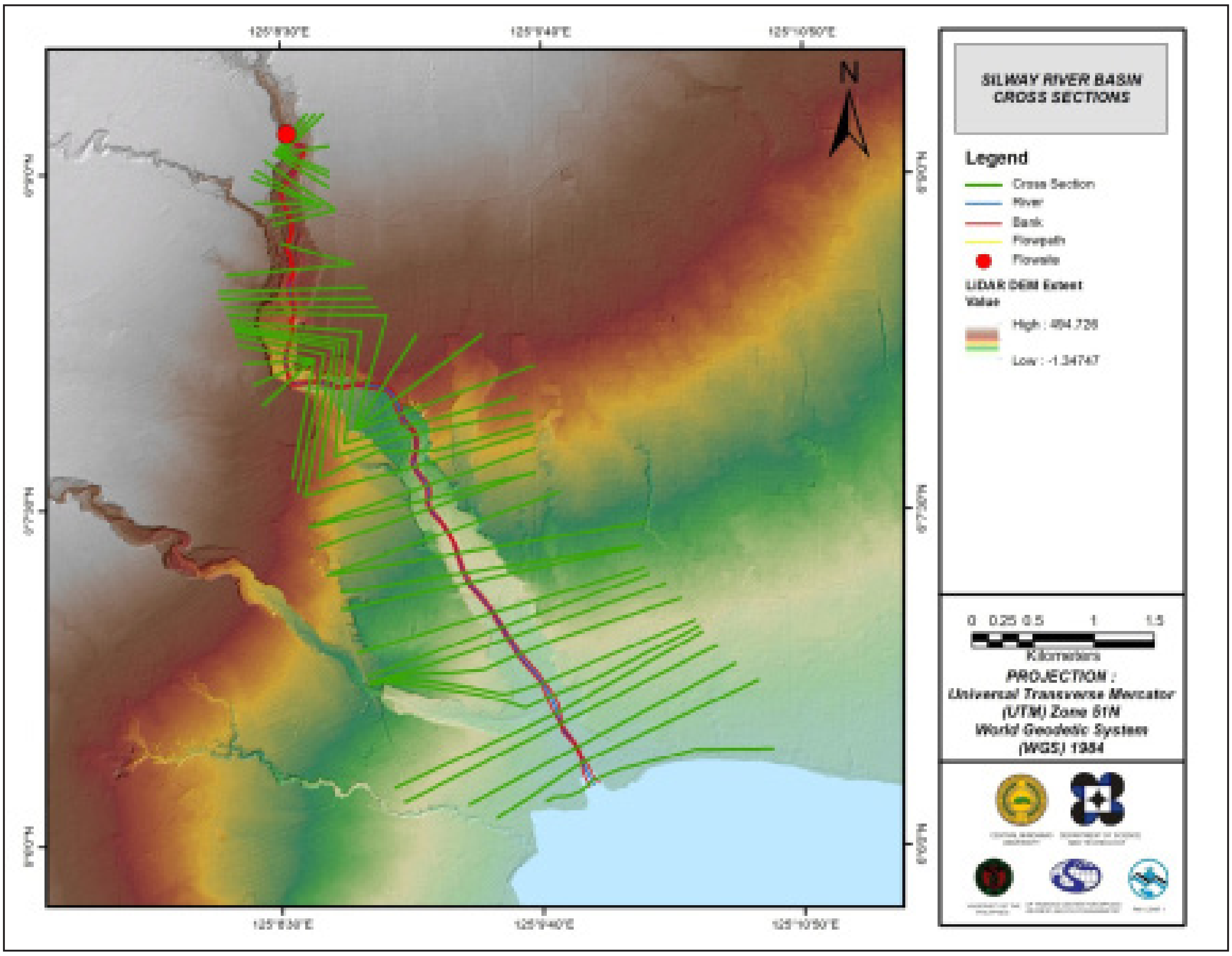


Figure 48. River cross-section of the Silway River through the ArcMap HEC GeoRas tool.

5.5 Flo 2D Model

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

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

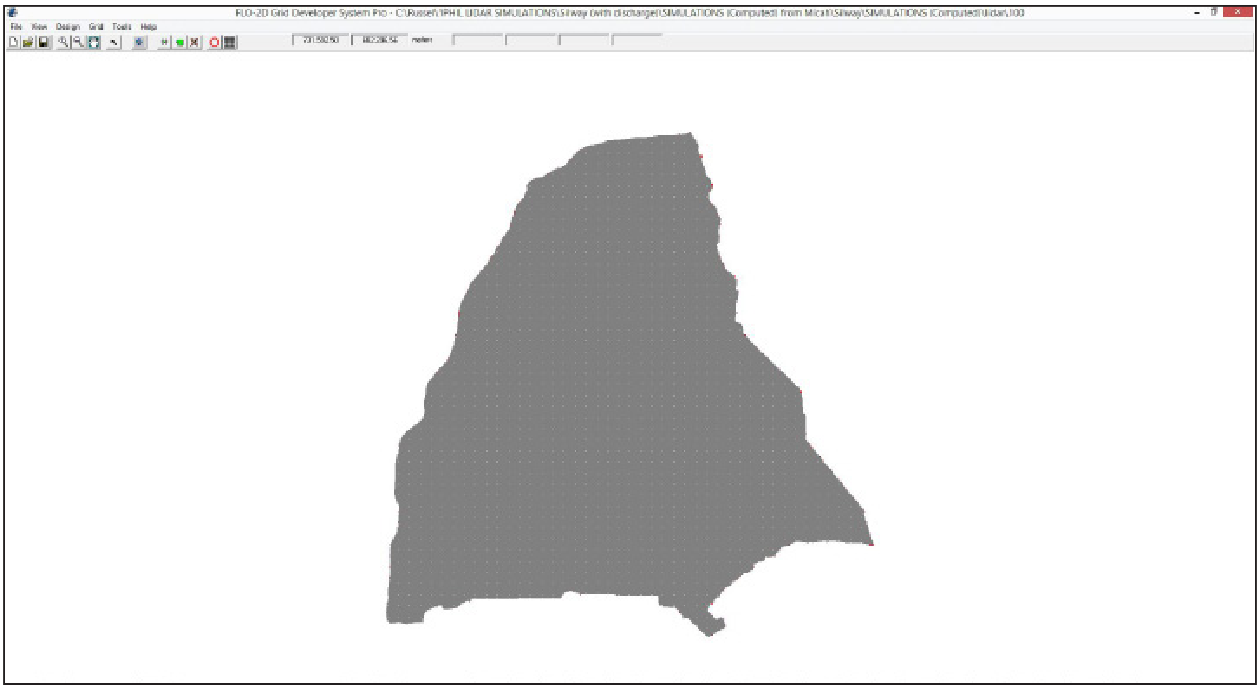


Figure 49. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 28.32373 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 30 871 500.00 m2.

There is a total of 208 903 237.15 m3 of water entering the model. Of this amount, 11 957 813.56 m3 is due to rainfall while 196 945 423.58 m3 is inflow from other areas outside the model. 3 829 085.00 m3 of this water is lost to infiltration and interception, while 2 099 733.22 m3 is stored by the flood plain. The rest, amounting up to 202 974 422.96 m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Silway HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 50 shows the comparison between the two discharge data.

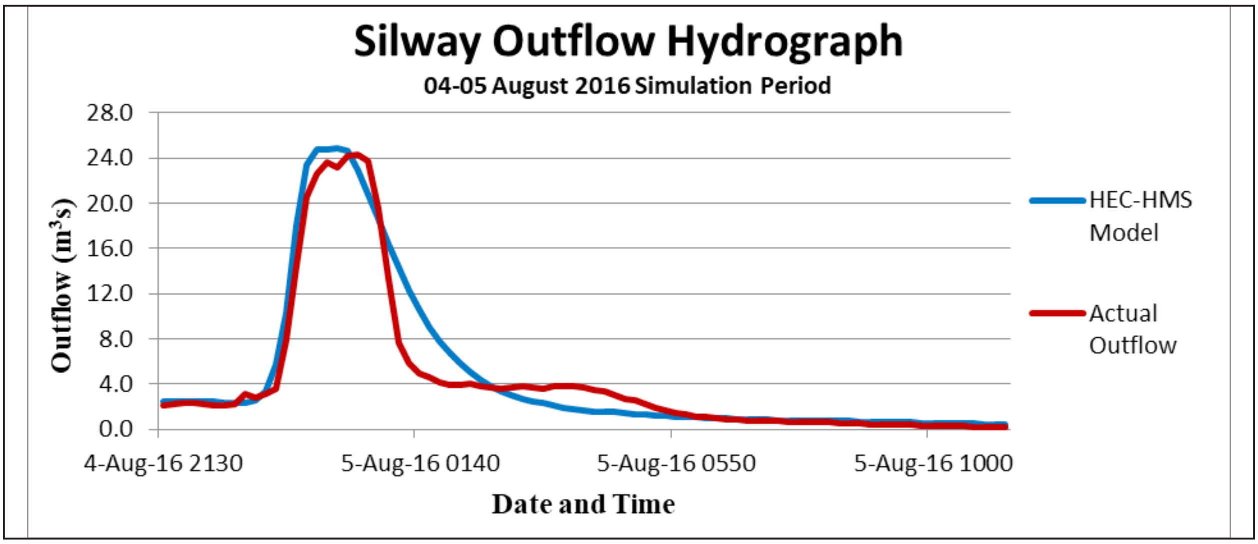


Figure 50. Outflow Hydrograph of Silway produced by the HEC-HMS model compared with observed outflow.

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

Table 21. Range of calibrated values for the Silway River Basin.

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	300
			Curve Number	32.13 – 66.73
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.019 – 0.29
			Storage Coefficient (hr)	0.069 – 1.28
	Baseflow	Recession	Recession Constant	0.01
			Ratio to Peak	0.00001 – 0.5
Reach	Routing	Muskingum-Cunge	Manning’s Coefficient	0.0001 – 0.05

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 5mm to 20mm signifies that there is minimal to 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 32 to 67 for curve number is less than the advisable range for Philippine watersheds (70 to 80) depending on the soil and land cover of the area (Horritt, personal communication, 2012). For Silway, the basin mostly consists of grassland, cultivated area, ad tree plantation and perennial; the soil consists mostly of sandy loam.

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 0.019 hours to 1.28 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 0.01 indicates that the basin is likely to 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 0.05 is slightly higher than the Manning's value (0.04) corresponding to the land cover of Silway watershed which is determined to be cultivated with mature field crops (Brunner, 2010).

Table 22. Summary of the Efficiency Test of Silway HMS Model

Accuracy measure	Value
RMSE	1.8
r2	0.05
NSE	0.93
PBIAS	24.16
RSR	0.27

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 1.8 (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 0.05.

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 24.16.

The Observation Standard Deviation Ratio, RSR, is an error index. A perfect model attains a value of 0 when the error in the units of the valuable a quantified. The model has an RSR value of 0.27.

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 51) shows the Silway River outflow using the Cagayan de Oro 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.

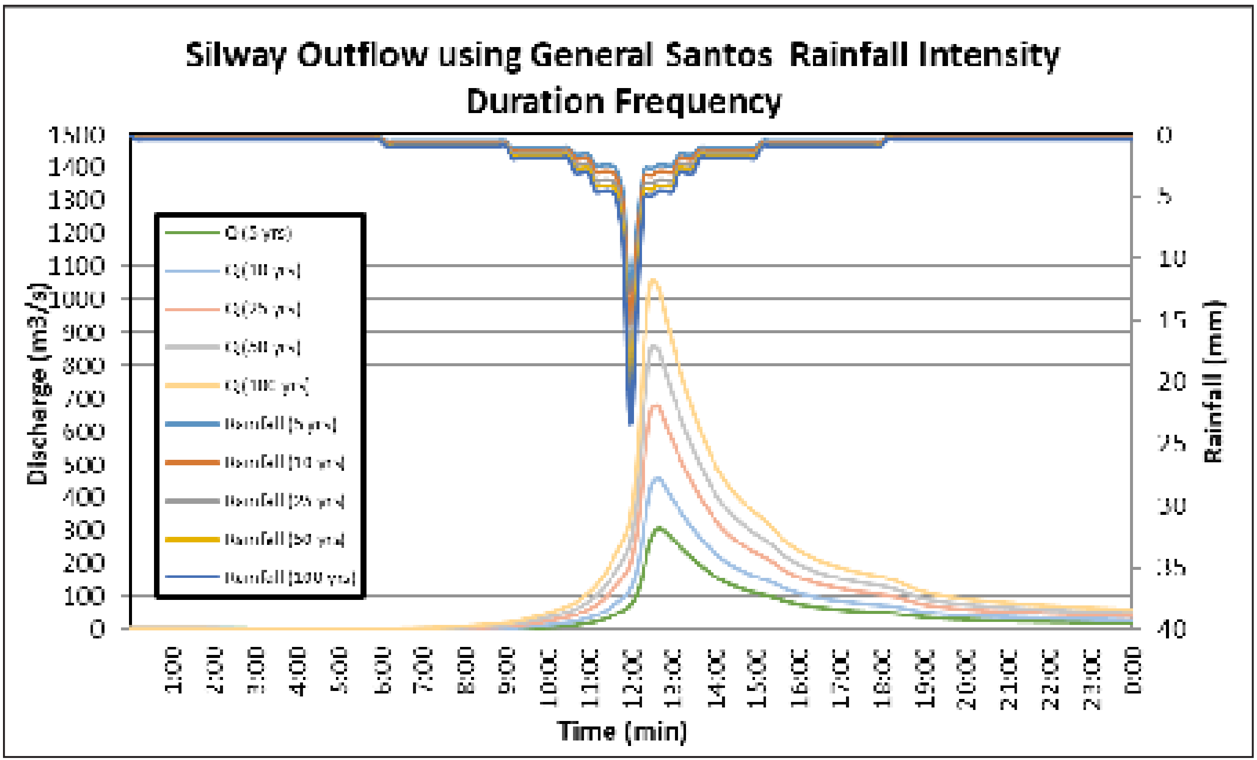


Figure 51. Outflow hydrograph at Silway Station generated using General Santos City RIDF simulated in HEC-HMS

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

Table 23. Peak values of the Silway HEC-HMS Model outflow using the General Santos City RIDF 24-hour values

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	102.7	12.7	305.4	40 minutes
10-Year	125.1	15.3	458.6	40 minutes
25-Year	153.4	18.5	675.9	40 minutes
50-Year	174.3	20.9	855.3	30 minutes
100-Year	195.2	23.3	1057.1	30 minutes

5.7.2 Discharge data using Dr. Horritt's recommended hydrologic method

The river discharge values for the nine rivers entering the floodplain are shown in Figure 52 to Figure 54 and the peak values are summarized in Table 29 to Table 31.

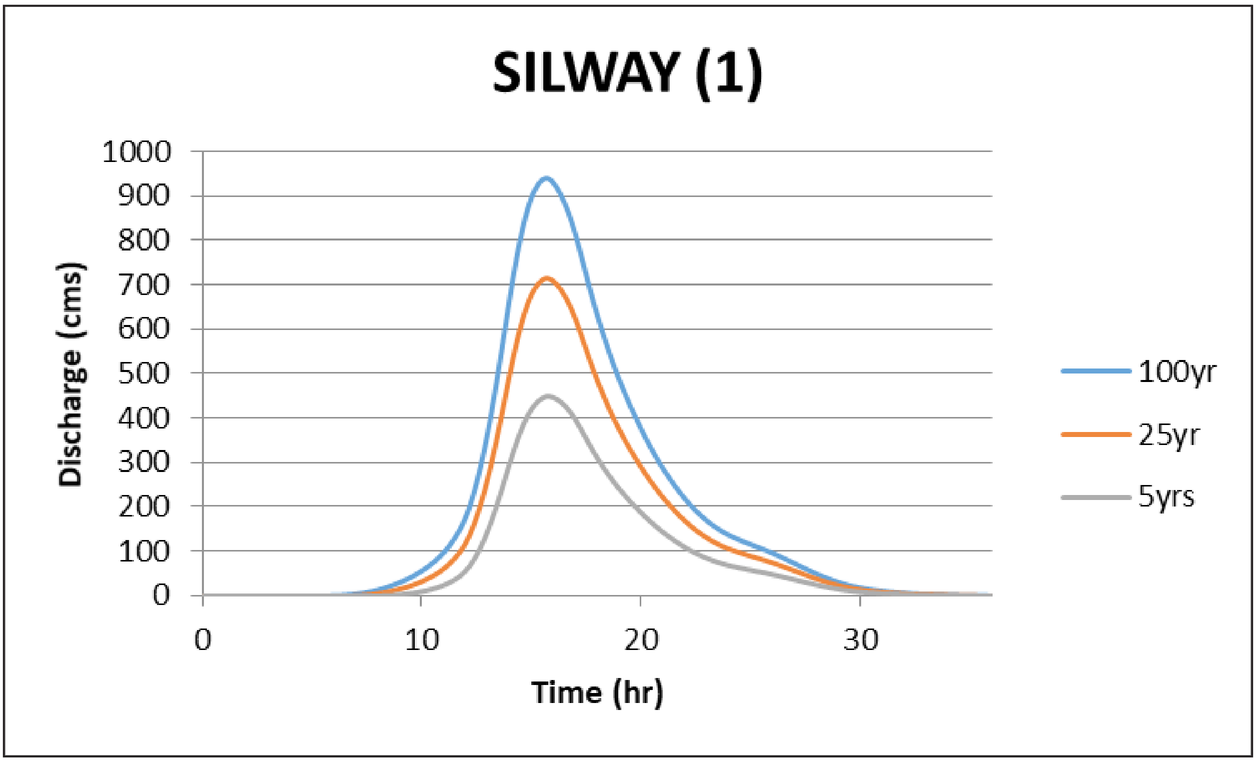


Figure 52. Silway River (1) generated discharge using 5-, 25-, and 100-year General Santos City rainfall intensity-duration-frequency (RIDF) in HEC-HMS

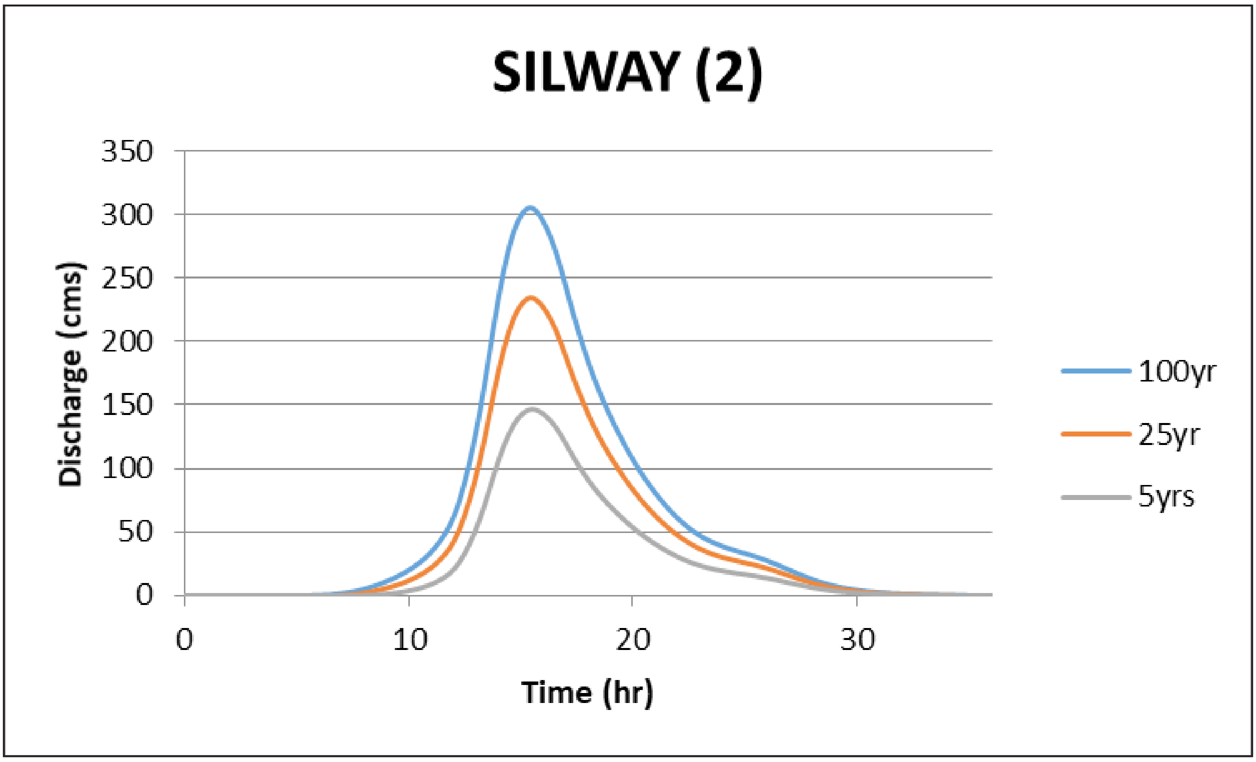


Figure 53. Silway River (2) generated discharge using 5-, 25-, and 100-year General Santos City rainfall intensity-duration-frequency (RIDF) in HEC-HMS.

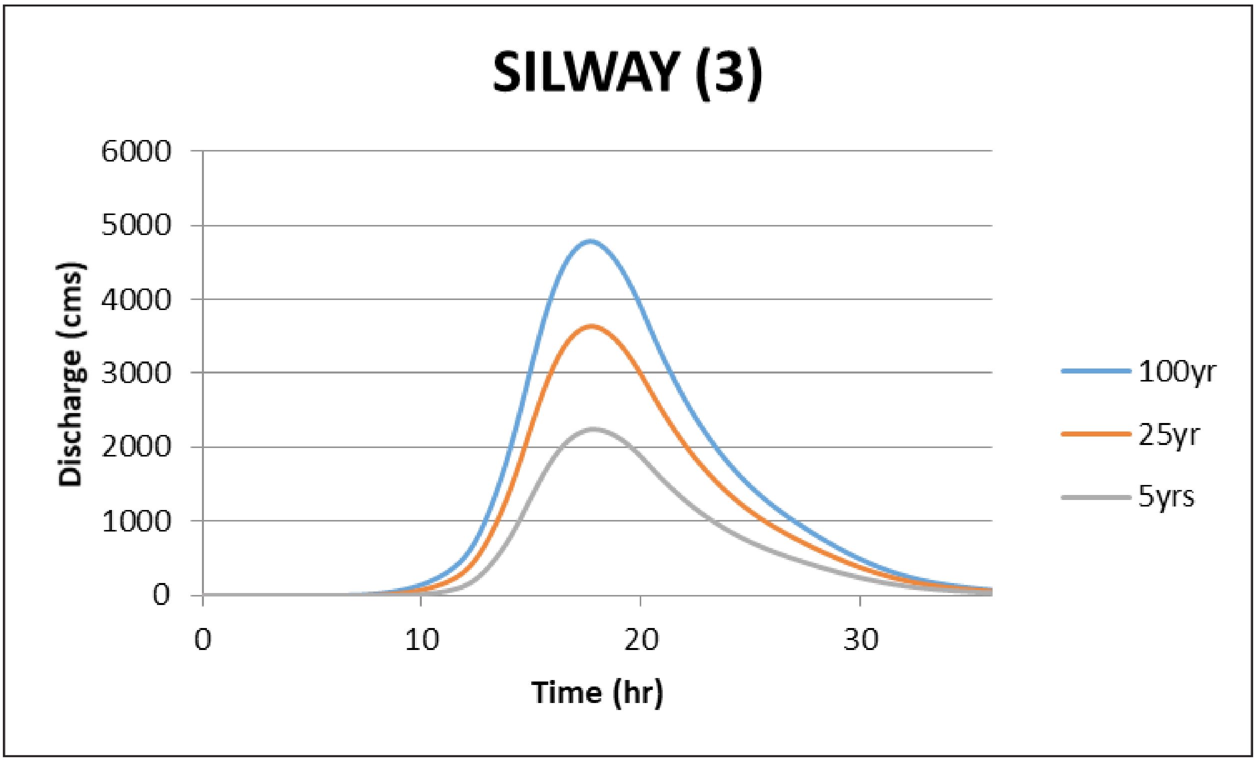


Figure 54. Silway River (3) generated discharge using 5-, 25-, and 100-year General Santos City rainfall intensity-duration-frequency (RIDF) in HEC-HMS

Table 24. Summary of Silway River (1) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	939.3	15 hours, 40 minutes
25-Year	716.4	15 hours, 40 minutes
5-Year	447.7	15 hours, 40 minutes

Table 25. Summary of Silway River (2) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	305.7	15 hours, 20 minutes
25-Year	233.8	15 hours, 30 minutes
5-Year	146.9	15 hours, 30 minutes

Table 26. Summary of Silway River (3) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	4790.8	17 hours, 40 minutes
25-Year	3631.5	17 hours, 40 minutes
5-Year	2245.5	17 hours, 50 minutes

Table 27. Validation of river discharge estimates

Discharge Point	QMED(SCS), cms	QBANKFUL, cms	QMED(SPEC), cms	VALIDATION	
				Bankful Discharge	Specific Discharge
Silway (1)	393.976	590.501	272.204	PASS	PASS
Silway (2)	129.272	198.891	122.210	PASS	PASS
Silway (3)	1976.040	3355.544	829.908	PASS	FAIL

Two from the HEC-HMS river discharge estimates were able to satisfy the conditions for validation using the bankful and specific discharge methods and one did not pass specific discharge methods and will need further recalculation. The passing values are based on theory but are supported using other discharge computation methods so they were good to use flood modeling. These values will need further investigation for the purpose of validation. It is therefore recommended to obtain actual values of the river discharges for higher-accuracy modeling.

5.8 River Analysis Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. For this publication, only a sample output map river was to be shown. The sample generated map of Silway River using the calibrated HMS base flow is shown in Figure 55.

Figure 55. Sample output of Silway RAS Model

5.9 Flood Hazard and Flow Depth Map

The resulting hazard and flow depth maps have a 10m resolution. Figure 56 to Figure 61 shows the 5-, 25-, and 100-year rain return scenarios of the Silway floodplain. The floodplain, with an area of 30.71 sq. km., is within General Santos City. Table 33 shows the percentage of area affected by flooding per municipality.

Table 28. Municipalities affected in Silway Floodplain

City / Municipality	Total Area	Area Flooded	% Flooded
General Santos City	521.42	30.71	5.89
Polomolok			

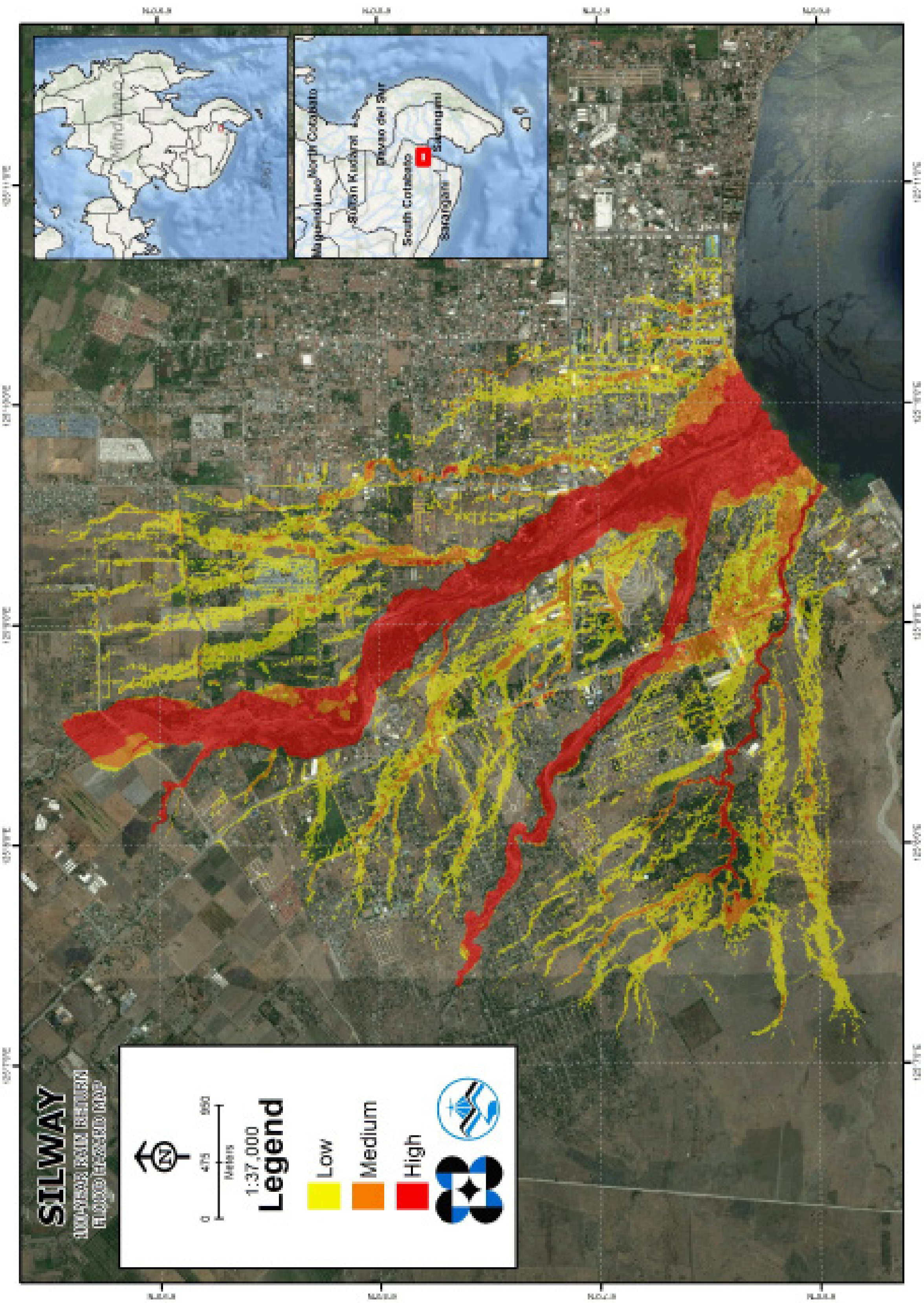


Figure 56. 100-year Flood Hazard Map for Silway Floodplain overlaid in Google Earth imagery

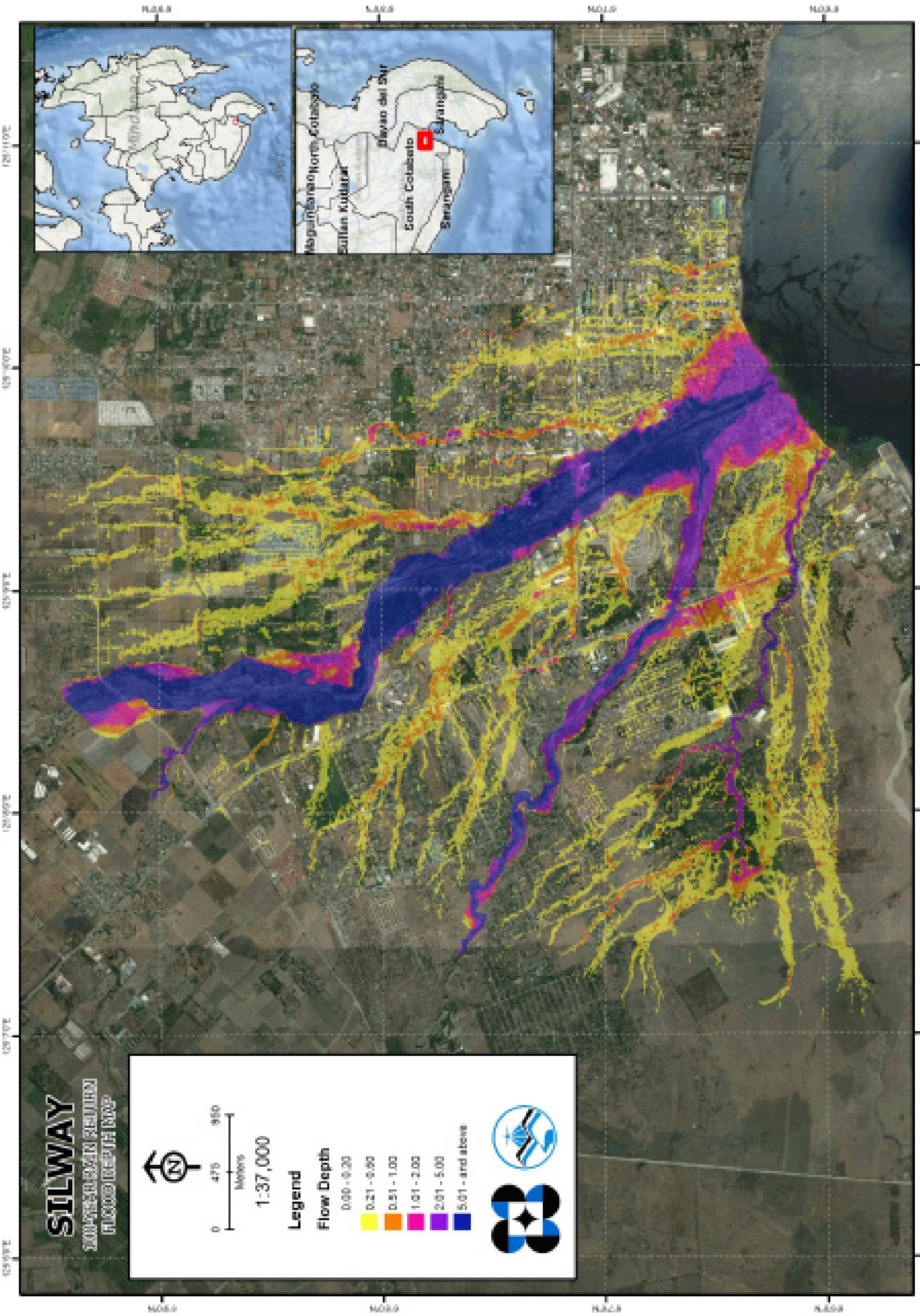


Figure 57. 100-year Flow Depth Map for Silway Floodplain overlaid in Google Earth imagery

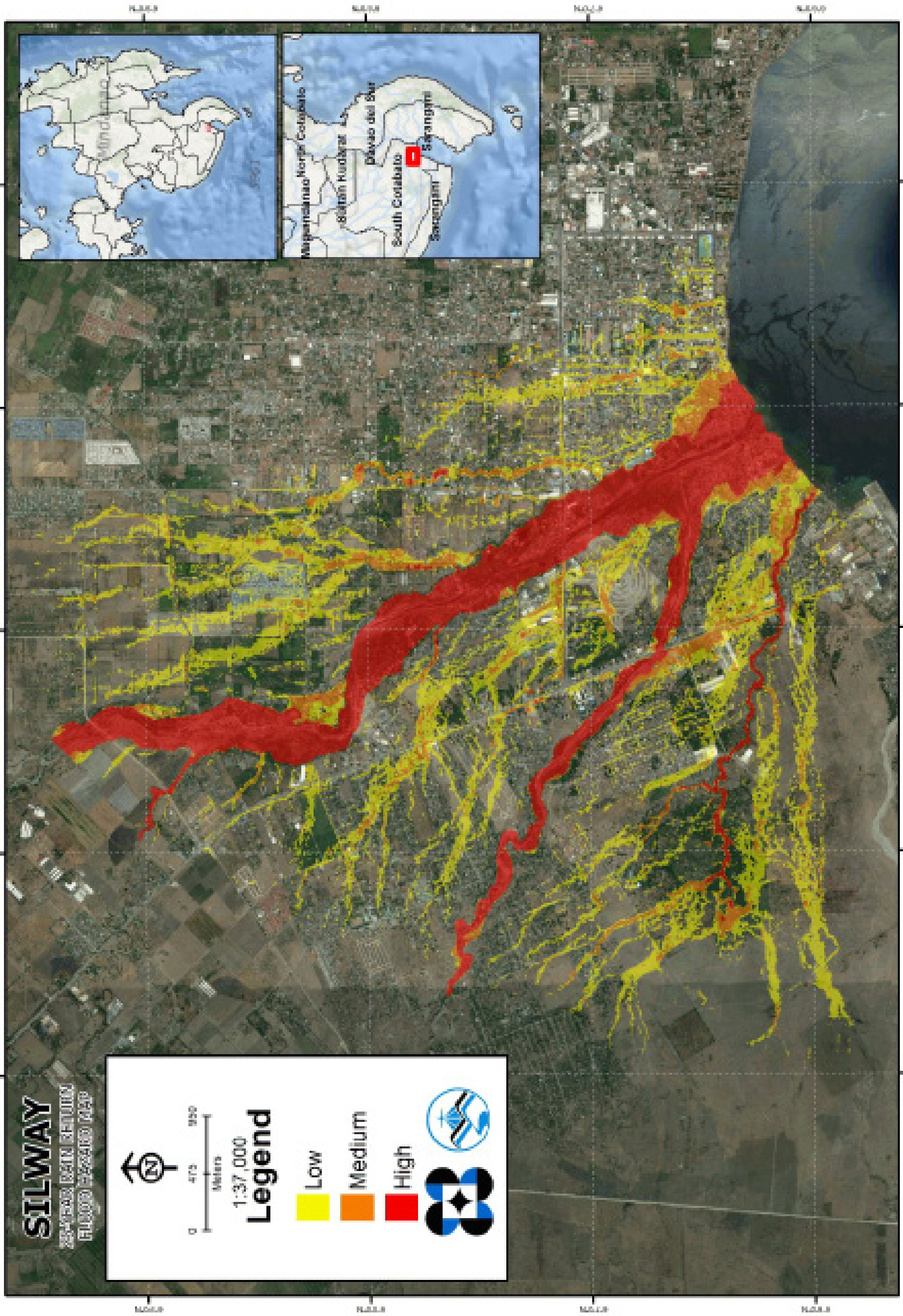


Figure 58. 25-year Flood Hazard Map for Silway Floodplain overlaid in Google Earth imagery

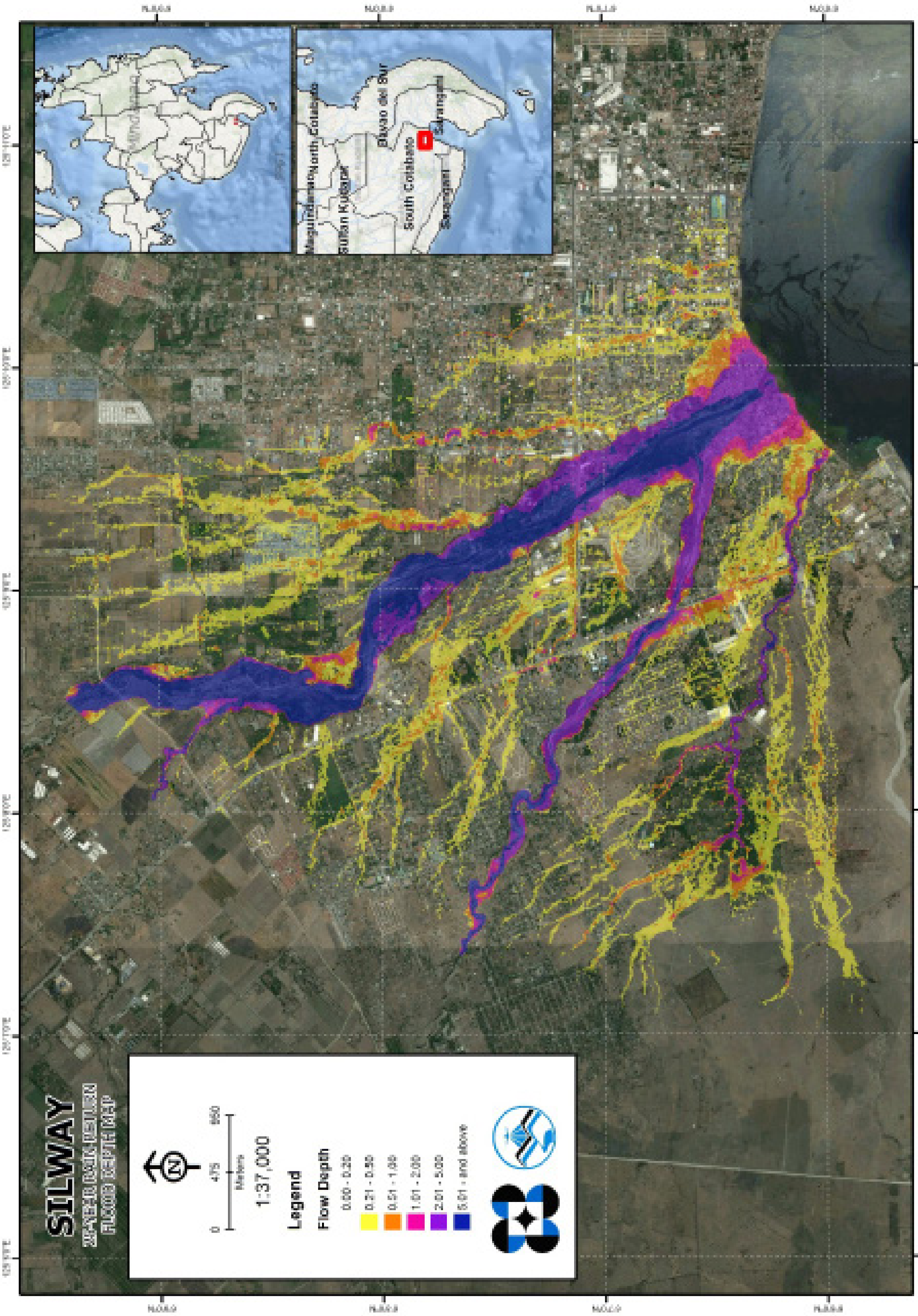


Figure 59. 25-year Flow Depth Map for Silway Floodplain overlaid in Google Earth imagery

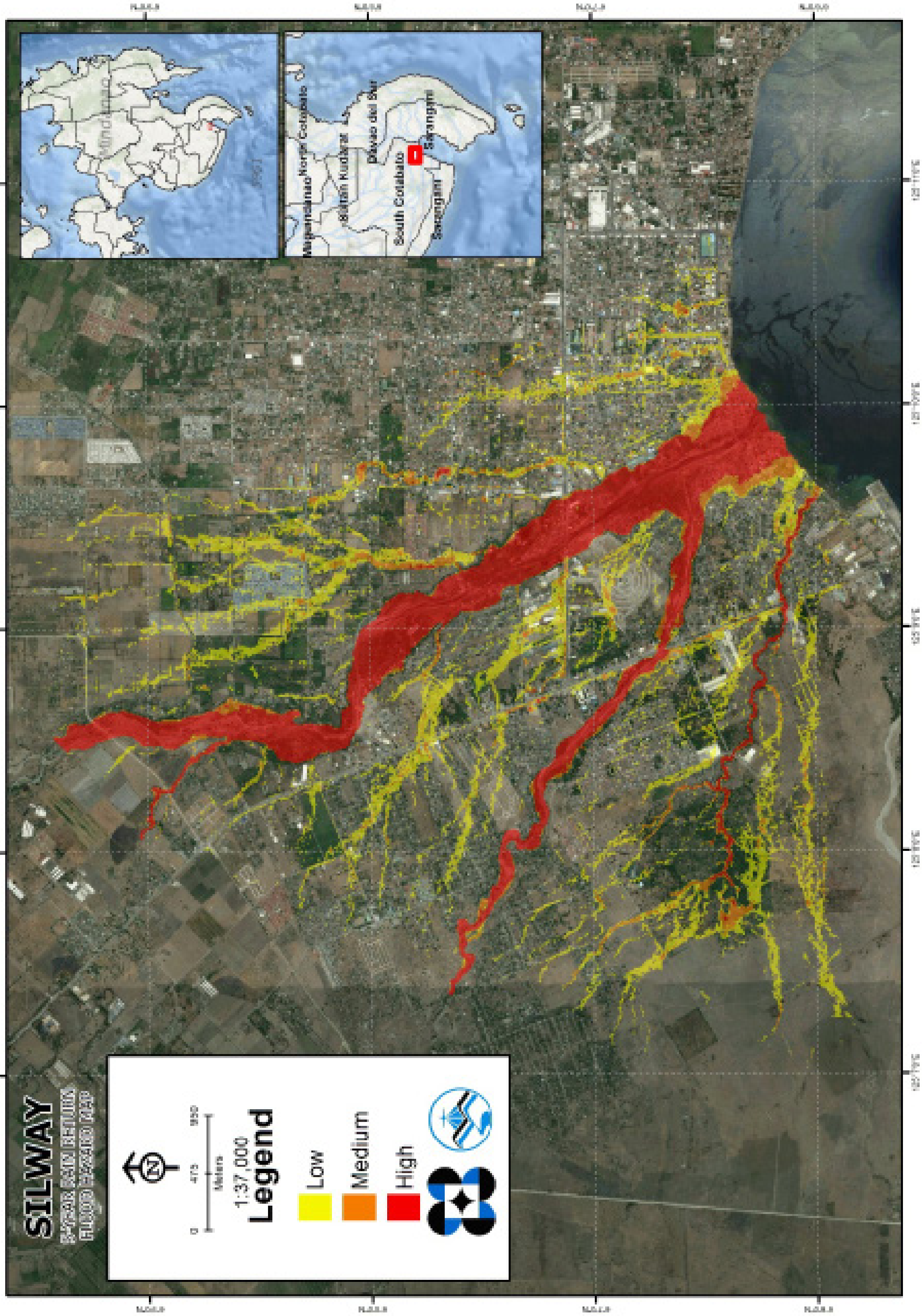


Figure 60. 5-year Flood Hazard Map for Silway Floodplain overlaid in Google Earth imagery

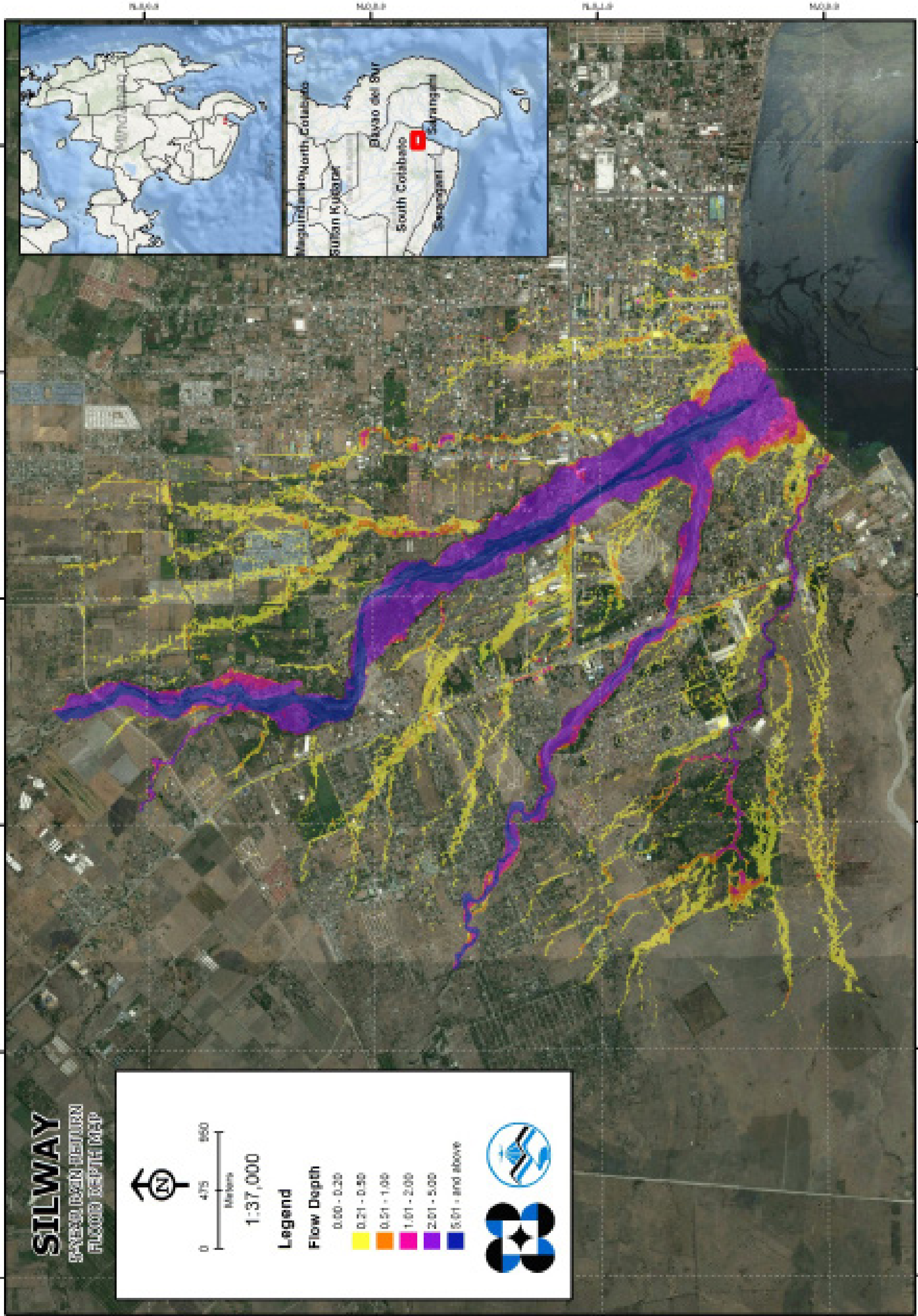


Figure 61. 5-year Flow Depth Map for Silway Floodplain overlaid in Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Silway river basin, grouped by municipality, are listed below. For the said basin, four municipalities consisting of 63 barangays are expected to experience flooding when subjected to 5-, 25-, and 100-yr rainfall return period.

For the 5-year return period, 4.79% of the municipality of General Santos City with an area of 474.732908 sq. km. will experience flood levels of less than 0.20 meters. 0.75% of the area will experience flood levels of 0.21 to 0.50 meters while 0.12%, 0.10%, 0.39%, and 0.18% 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.

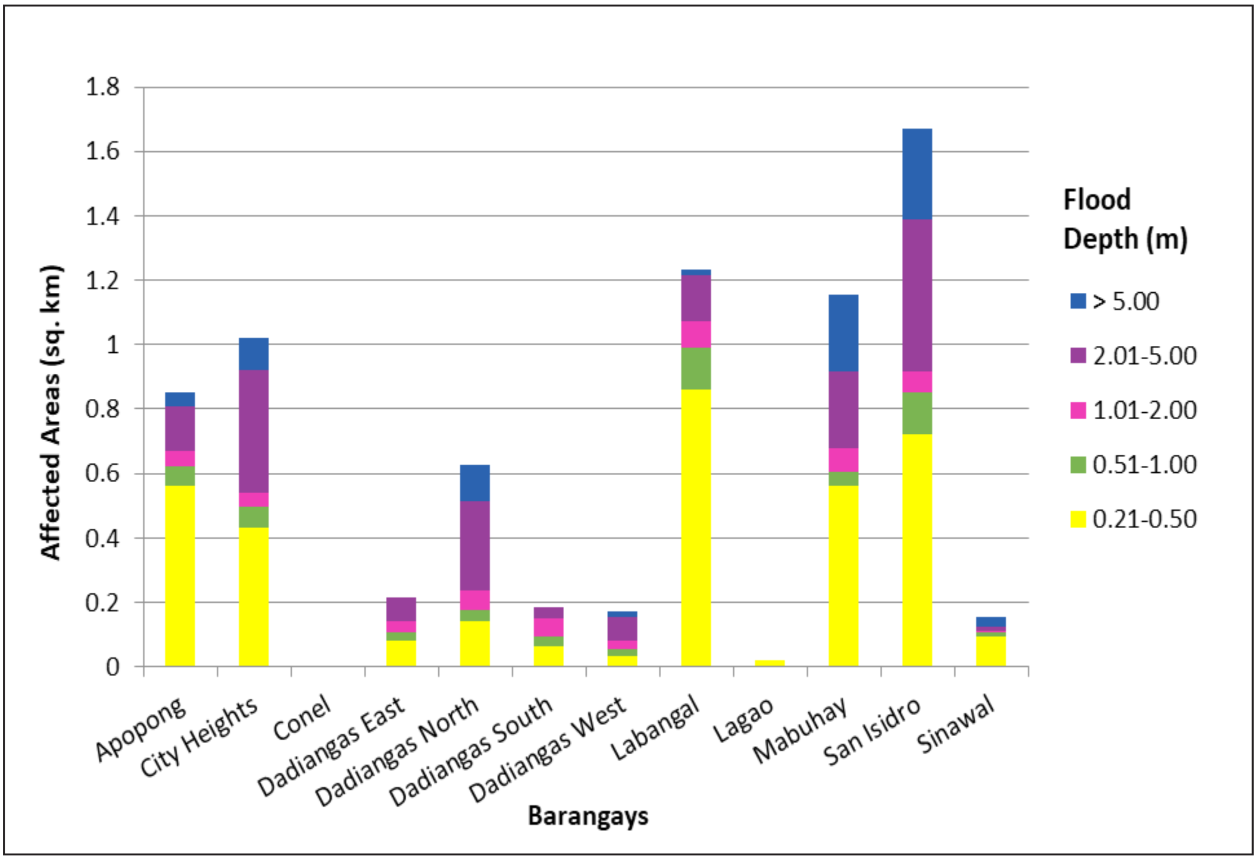


Figure 62. Affected Areas in Dapitan City, Zamboang

Table 29. Affected Areas in General Santos City, South Cotabato during 5-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in General Santos City (in sq. km)					
	Apopong	City Heights	Conel	Dadiangas East	Dadiangas North	Dadiangas South
0.03-0.20	5.55	1.98	0.04	0.23	0.69	0.18
0.21-0.50	0.56	0.43	0.0043	0.081	0.14	0.062
0.51-1.00	0.064	0.066	0	0.026	0.038	0.033
1.01-2.00	0.046	0.044	0	0.034	0.058	0.054
2.01-5.00	0.14	0.38	0	0.073	0.28	0.036
> 5.00	0.04	0.1	0	0	0.11	0

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in General Santos City (in sq. km)					
	Dadiangas West	Labangal	Lagao	Mabuhay	San Isidro	Sinawal
0.03-0.20	0.15	4.58	0.26	3.42	4.16	1.51
0.21-0.50	0.035	0.86	0.019	0.56	0.72	0.094
0.51-1.00	0.019	0.13	0	0.046	0.13	0.011
1.01-2.00	0.028	0.084	0	0.071	0.069	0.0084
2.01-5.00	0.074	0.14	0	0.24	0.47	0.011
> 5.00	0.015	0.02	0	0.24	0.28	0.03

For the 5-year return period, 0.19% of the municipality of Polomolok with an area of 287.02454 sq. km. will experience flood levels of less than 0.20 meters. 0.00% of the area will experience flood levels of 0.21 to 0.50 meters while 0.00% of the area will experience flood depths of 0.51 to 1 meter. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

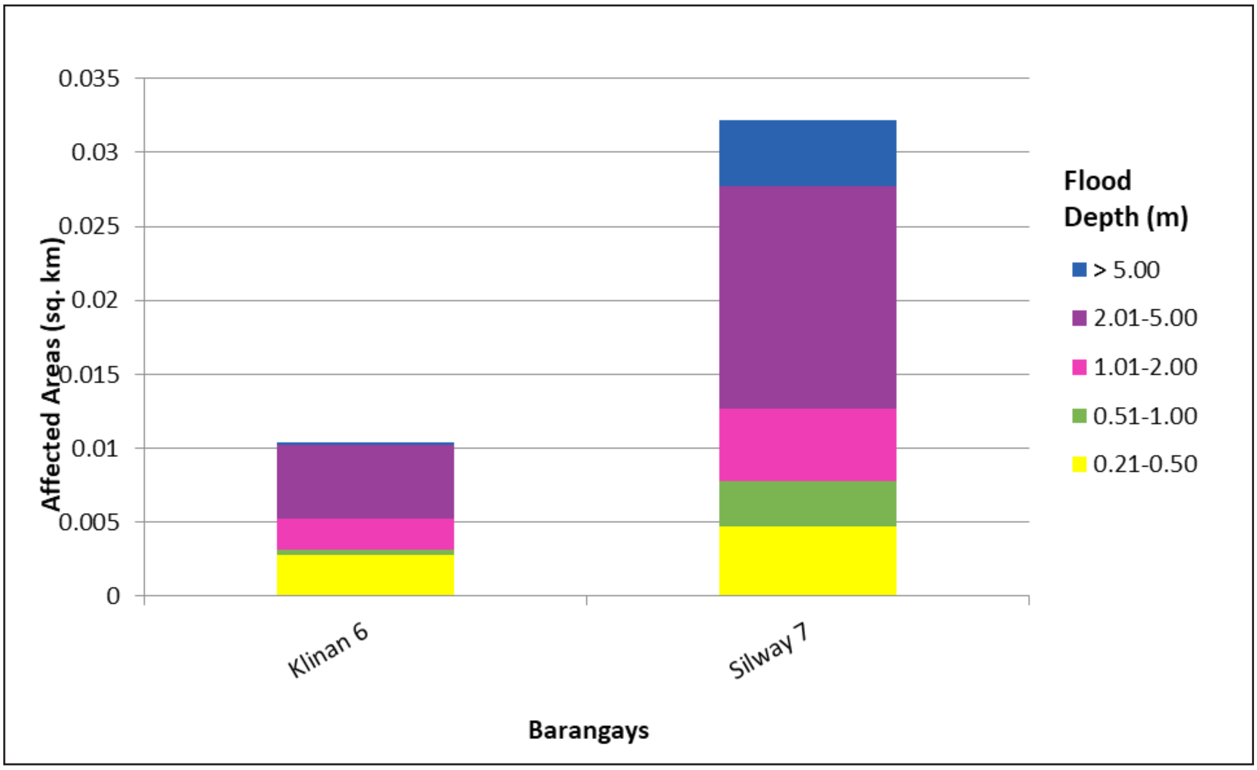


Figure 63. Affected Areas in Polomolok, South Cotabato during 5-Year Rainfall Return Period

Table 30. Affected Areas in Polomolok, South Cotabato during 5-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Polomolok (in sq. km)	
	Klinan 6	Silway 7
0.03-0.20	0.28	0.27
0.21-0.50	0.0028	0.0047
0.51-1.00	0.00035	0.0031
1.01-2.00	0.0021	0.0049
2.01-5.00	0.005	0.015
> 5.00	0.00017	0.0045

For the 25-year return period, 4.22% of the municipality of General Santos City with an area of 474.732908 sq. km. will experience flood levels of less than 0.20 meters. 1.12% of the area will experience flood levels of 0.21 to 0.50 meters while 0.23%, 0.10%, 0.29%, and 0.37% 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.

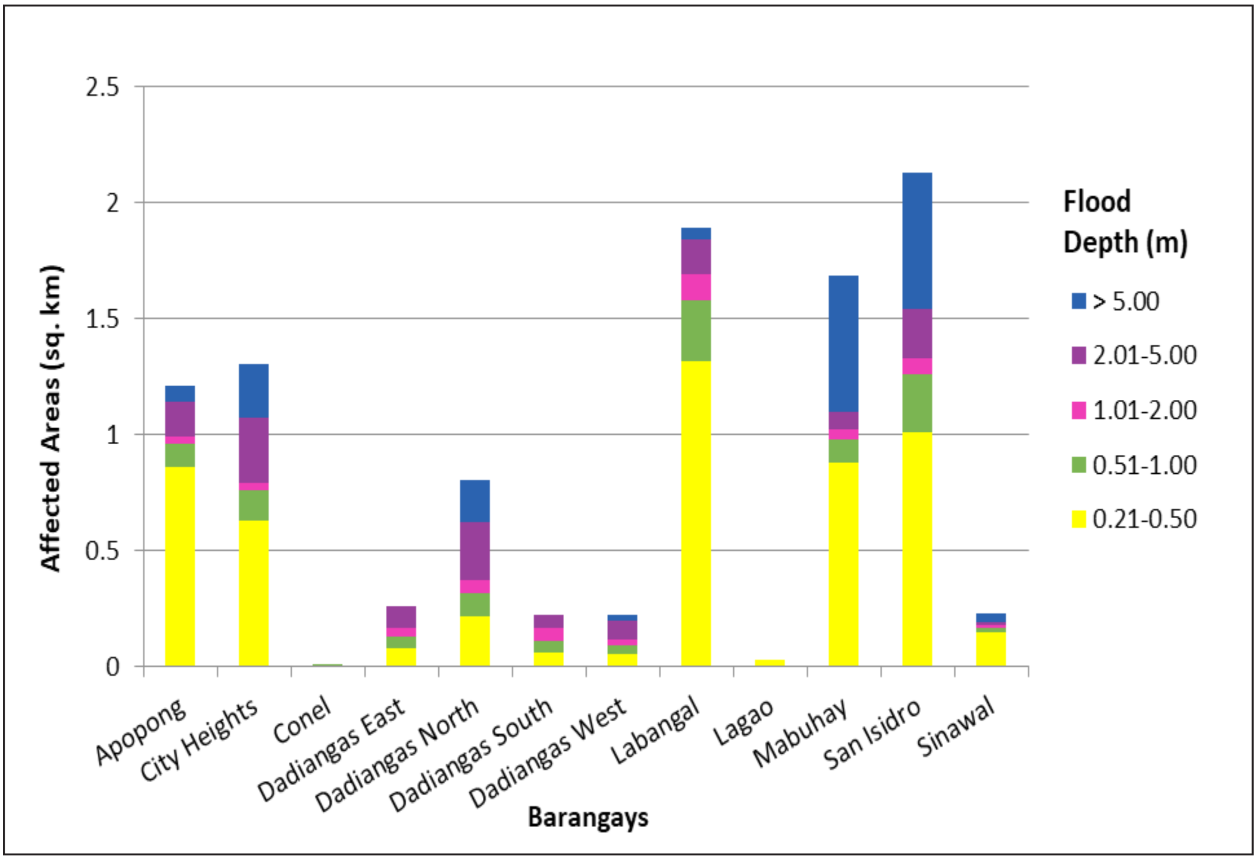


Figure 64. Affected Areas in General Santos City, South Cotabato during 25-Year Rainfall Return Period

Table 31. Affected Areas in General Santos City, South Cotabato during 25-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in General Santos City (in sq. km)					
	Apopong	City Heights	Conel	Dadiangas East	Dadiangas North	Dadiangas South
0.03-0.20	5.19	1.69	0.037	0.19	0.5	0.14
0.21-0.50	0.86	0.63	0.0071	0.081	0.22	0.059
0.51-1.00	0.1	0.13	0.0003	0.052	0.1	0.053
1.01-2.00	0.033	0.036	0	0.038	0.054	0.057
2.01-5.00	0.15	0.28	0	0.088	0.25	0.055
> 5.00	0.071	0.23	0	0	0.18	0

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in General Santos City (in sq. km)					
	Dadiangas West	Labangal	Lagao	Mabuhay	San Isidro	Sinawal
0.03-0.20	0.093	3.92	0.24	2.89	3.7	1.43
0.21-0.50	0.057	1.32	0.033	0.88	1.01	0.15
0.51-1.00	0.036	0.26	0	0.1	0.25	0.017
1.01-2.00	0.025	0.11	0	0.041	0.072	0.015
2.01-5.00	0.084	0.15	0	0.076	0.21	0.014
> 5.00	0.024	0.055	0	0.59	0.59	0.035

For the 25-year return period, 0.19% of the municipality of Polomolok with an area of 287.02454 sq. km. will experience flood levels of less than 0.20 meters. 0.00% of the area will experience flood levels of 0.21 to 0.50 meters while 0.00% of the area will experience flood depths of 0.51 to 1 meter. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

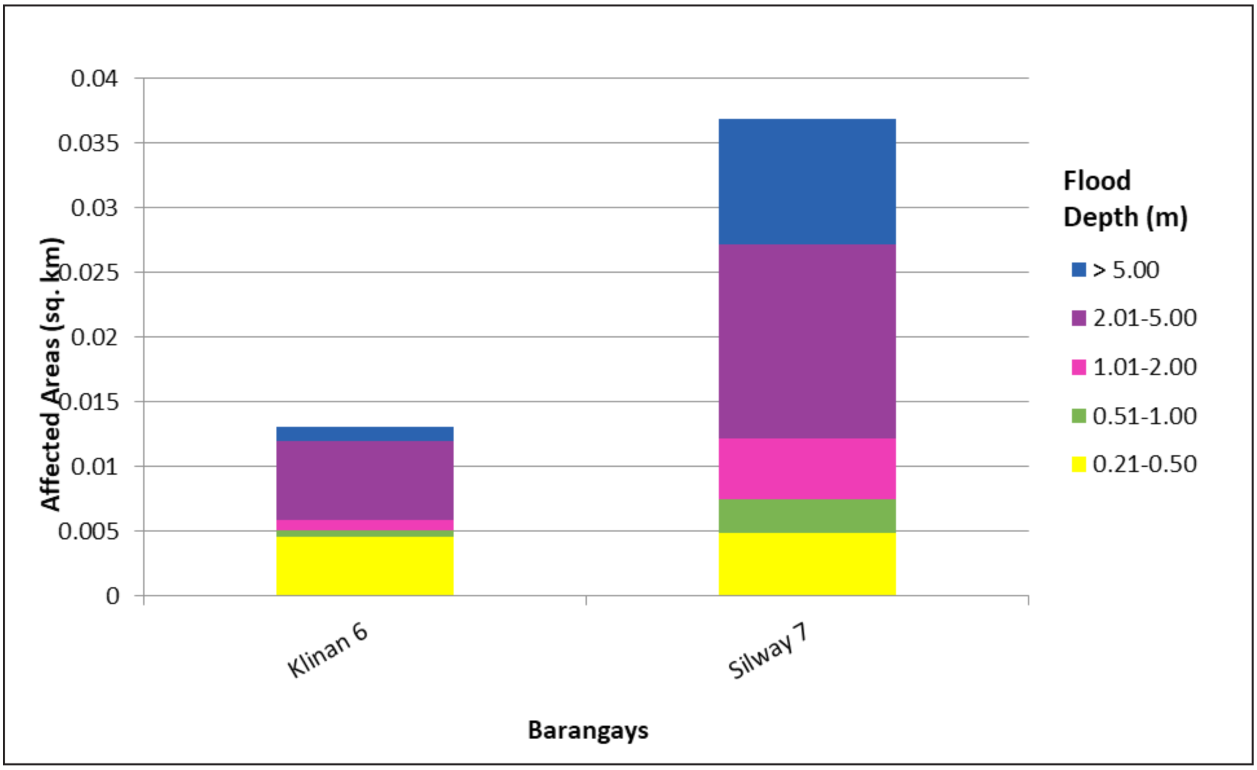


Figure 65. Affected Areas in Polomolok, South Cotabato during 25-Year Rainfall Return Period

Table 32. Affected Areas in Polomolok, South Cotabato during 25-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Polomolok (in sq. km)	
	Klinan 6	Silway 7
0.03-0.20	0.28	0.27
0.21-0.50	0.0046	0.0049
0.51-1.00	0.00052	0.0026
1.01-2.00	0.00077	0.0047
2.01-5.00	0.0061	0.015
> 5.00	0.0011	0.0097

For the 100-year return period, 3.81% of the municipality of General Santos City with an area of 474.732908 sq. km. will experience flood levels of less than 0.20 meters. 1.31% of the area will experience flood levels of 0.21 to 0.50 meters while 0.32%, 0.16%, and 0.24% 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.

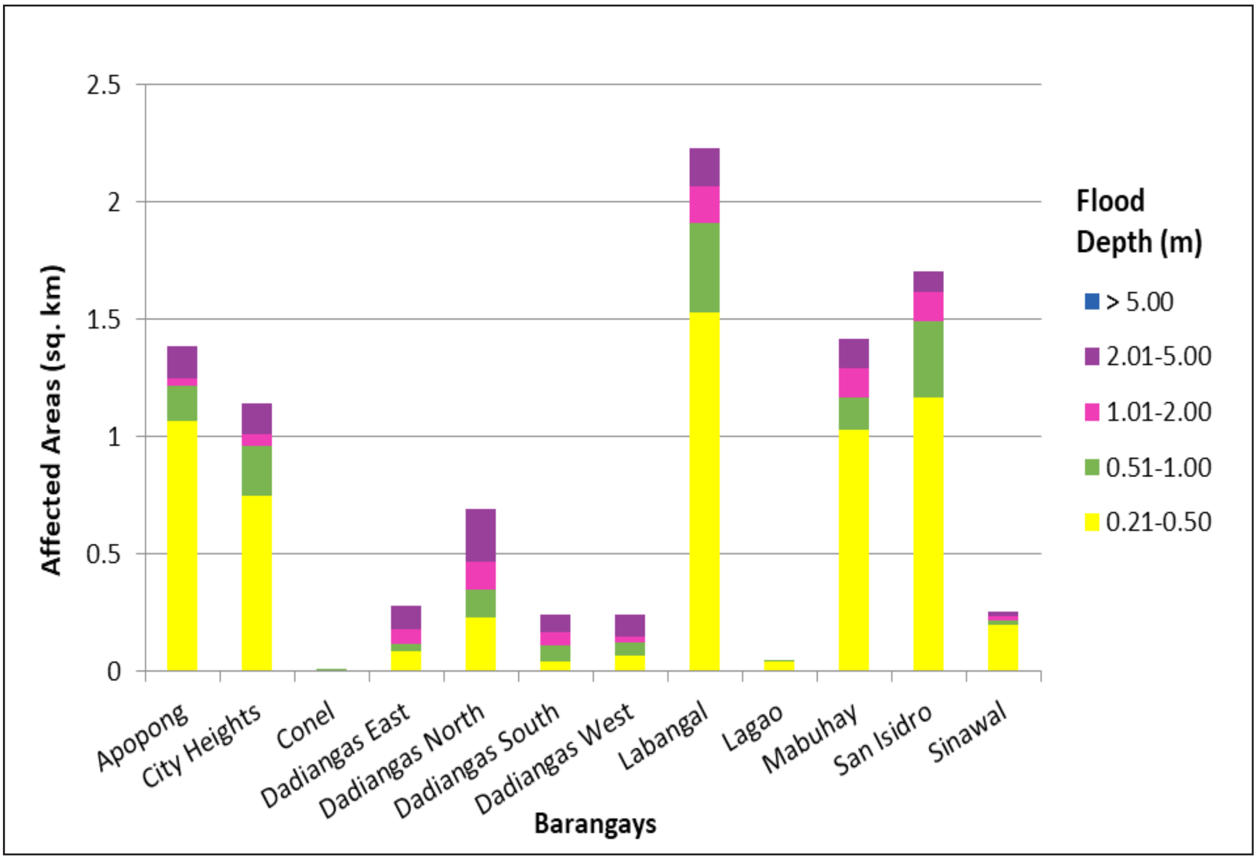


Figure 66. Affected Areas in General Santos City, South Cotabato during 100-Year Rainfall Return Period

Table 33. Affected Areas in General Santos City, South Cotabato during -Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in General Santos City (in sq. km)					
	Apopong	City Heights	Conel	Dadiangas East	Dadiangas North	Dadiangas South
0.03-0.20	4.92	1.44	0.036	0.16	0.38	0.12
0.21-0.50	1.07	0.75	0.0079	0.084	0.23	0.046
0.51-1.00	0.15	0.21	0.0006	0.037	0.12	0.065
1.01-2.00	0.029	0.054	0	0.062	0.12	0.054
2.01-5.00	0.14	0.13	0	0.1	0.22	0.078
> 5.00	0	0	0	0	0	0

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in General Santos City (in sq. km)					
	Dadiangas West	Labangal	Lagao	Mabuhay	San Isidro	Sinawal
0.03-0.20	0.045	3.51	0.23	2.5	3.38	1.37
0.21-0.50	0.066	1.53	0.044	1.03	1.17	0.2
0.51-1.00	0.058	0.38	0.0001	0.14	0.32	0.02
1.01-2.00	0.025	0.16	0	0.12	0.13	0.019
2.01-5.00	0.093	0.16	0	0.13	0.088	0.019
> 5.00	0	0	0	0	0	0

For the 100-year return period, 0.18% of the municipality of Polomolok with an area of 287.02454 sq. km. will experience flood levels of less than 0.20 meters. 0.01% of the area will experience flood levels of 0.21 to 0.50 meters while 0.01% of the area will experience flood depths of 0.51 to 1 meter. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

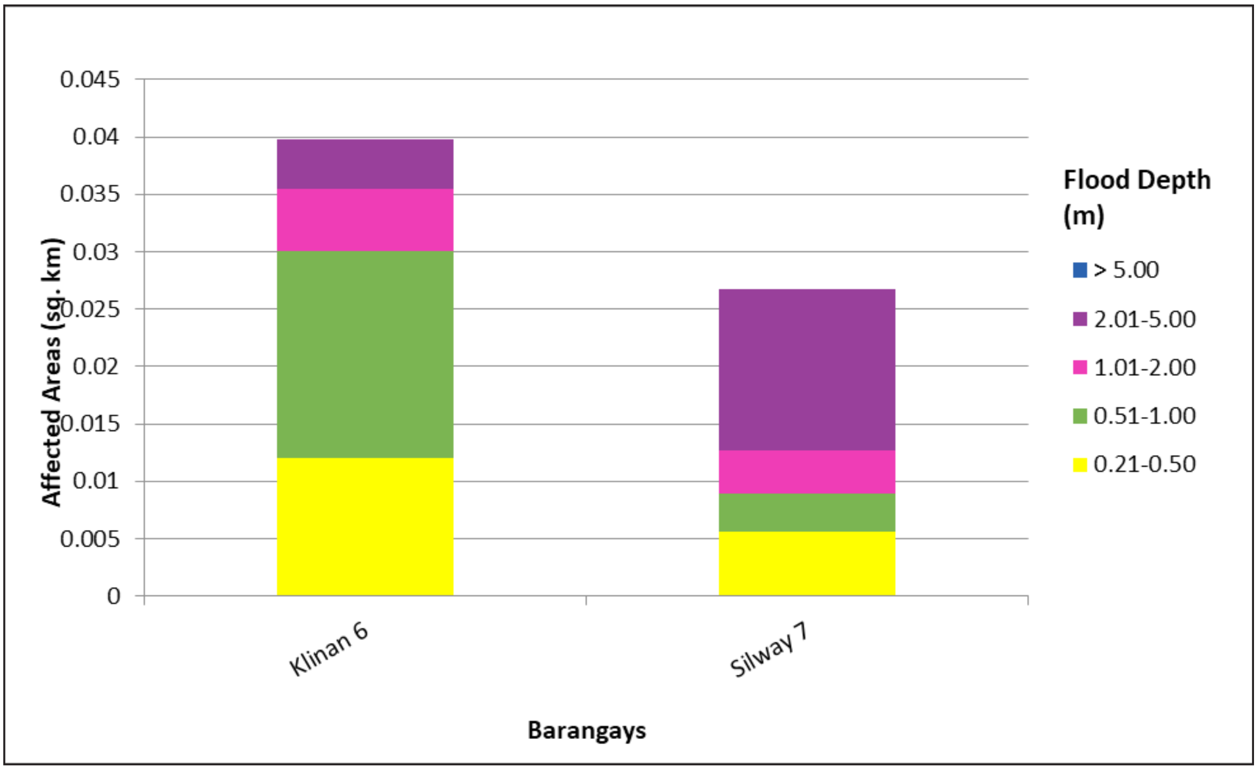


Figure 67. Affected Areas in Polomolok, South Cotabato during 100-Year Rainfall Return Period

Table 34. Affected Areas in Polomolok, South Cotabato during 100-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Polomolok (in sq. km)	
	Klinan 6	Silway 7
0.03-0.20	0.25	0.26
0.21-0.50	0.012	0.0056
0.51-1.00	0.018	0.0033
1.01-2.00	0.0055	0.0038
2.01-5.00	0.0043	0.014
> 5.00	0	0

Among the barangays in the municipality of General Santos City in South Cotabato, Apopong is projected to have the highest percentage of area that will experience flood levels at 1.33%. Meanwhile, Labangal posted the second highest percentage of area that may be affected by flood depths at 1.21%.

Among the barangays in the municipality of Polomolok in South Cotabato, Klinan 6 is projected to have the highest percentage of area that will experience flood levels at 0.06%. Meanwhile, Silway 7 posted the second highest percentage of area that may be affected by flood depths at 0.06%.

Moreover, the generated flood hazard maps for the Silway 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 10-year).

Table 35. 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	3.58	5.31	6.25
Medium	0.8	1.38	1.97
High	3.02	3.45	3.89
TOTAL	7.4	10.14	12.11

Of the 83 identified Education Institute in Silway Floodplain, 15 schools were discovered exposed to Low-level flooding during a 5-year scenario, while five (5) schools were found exposed to Medium-level flooding in the same scenario. In the same scenario, four (4) schools were found exposed to High-level flooding.

In the 25-year scenario, sixteen schools were found exposed to Low-level flooding, while fifteen schools were discovered exposed to Medium-level flooding. In the same scenario, four (4) schools were discovered exposed to High-level flooding.

For the 100-year scenario, seventeen schools were discovered exposed to Low-level flooding, while eighteen schools were exposed to Medium-level flooding. In the same scenario, seven (7) schools were found exposed to High-level flooding. The list of educational institutions affected by flooding in Silway floodplain is found in Annex 12.

Apart from this, fourteen Medical Institutions were identified in the Silway Floodplain, Two (2) clinics are found to be exposed to Low-level flooding during a 5-year scenario while one (1) center is found to be exposed to Medium-level flooding.

In a 25-year scenario, five (5) medical institutions were found to be exposed to Low-level flooding while the same center is found to be exposed to Medium-level flooding.

For the 100-year scenario, four (4) medical institutions were found to be exposed to Low-level flooding while two (2) centers were discovered to be exposed to Medium-level flooding. The list of medical or health institutions affected by flooding in Silway floodplain is found in Annex 13.

5.11 Flood Validation

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

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

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

After which, the actual data from the field was compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed. The points in the flood map versus its corresponding validation depths are shown in Figure 63.

The flood validation consisted of ___ points randomly selected all over the Silway floodplain. It has an RMSE value of ____. Table 36 shows a contingency matrix of the comparison.

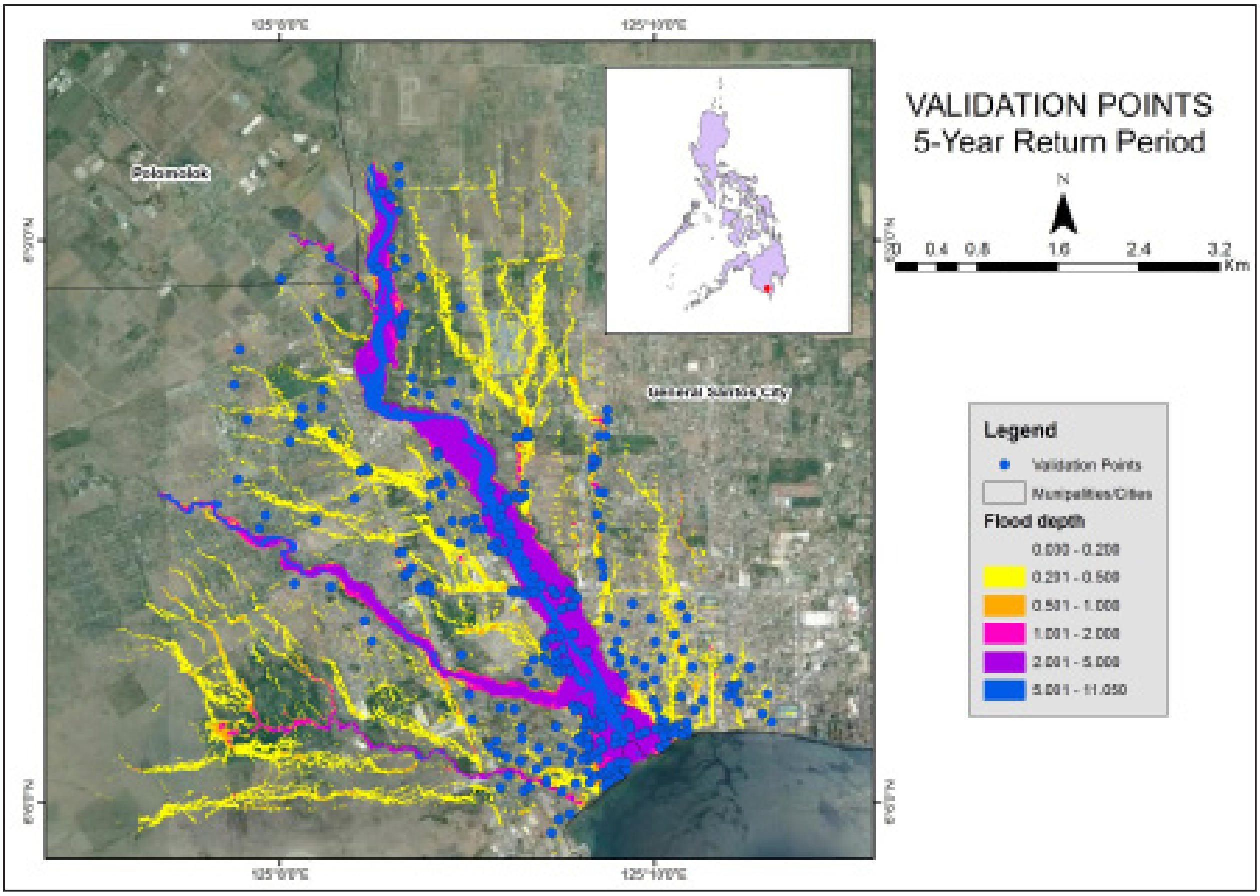


Figure 68. Validation Points for Flood Depth Map of the Silway Floodplain.

(CHECK - FIGURE SAME AS LUN MASLA)

Figure 69. Flood map depth versus actual flood depth.

Table 36. Actual Flood Depth versus Simulated Flood Depth at different levels in the Gandara River Basin.

Silway BASIN		Modeled Flood Depth (m)						
		0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
Actual Flood Depth (m)	0-0.20							
	0.21-0.50							
	0.51-1.00							
	1.01-2.00							
	2.01-5.00							
	> 5.00							
	Total							

The overall accuracy generated by the flood model is estimated at 35.29% with 54 points correctly matching the actual flood depths. In addition, there were 35 points estimated one level above and below the correct flood depths while there were 33 points and 31 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 4 points were overestimated while a total of 2 points were underestimated in the modelled flood depths of Lun Masla. Table 43 depicts the summary of the Accuracy Assessment in the Lun Masla River Basin Survey.

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

	No. of Points	%
Correct		
Overestimated		
Underestimated		
Total		

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

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

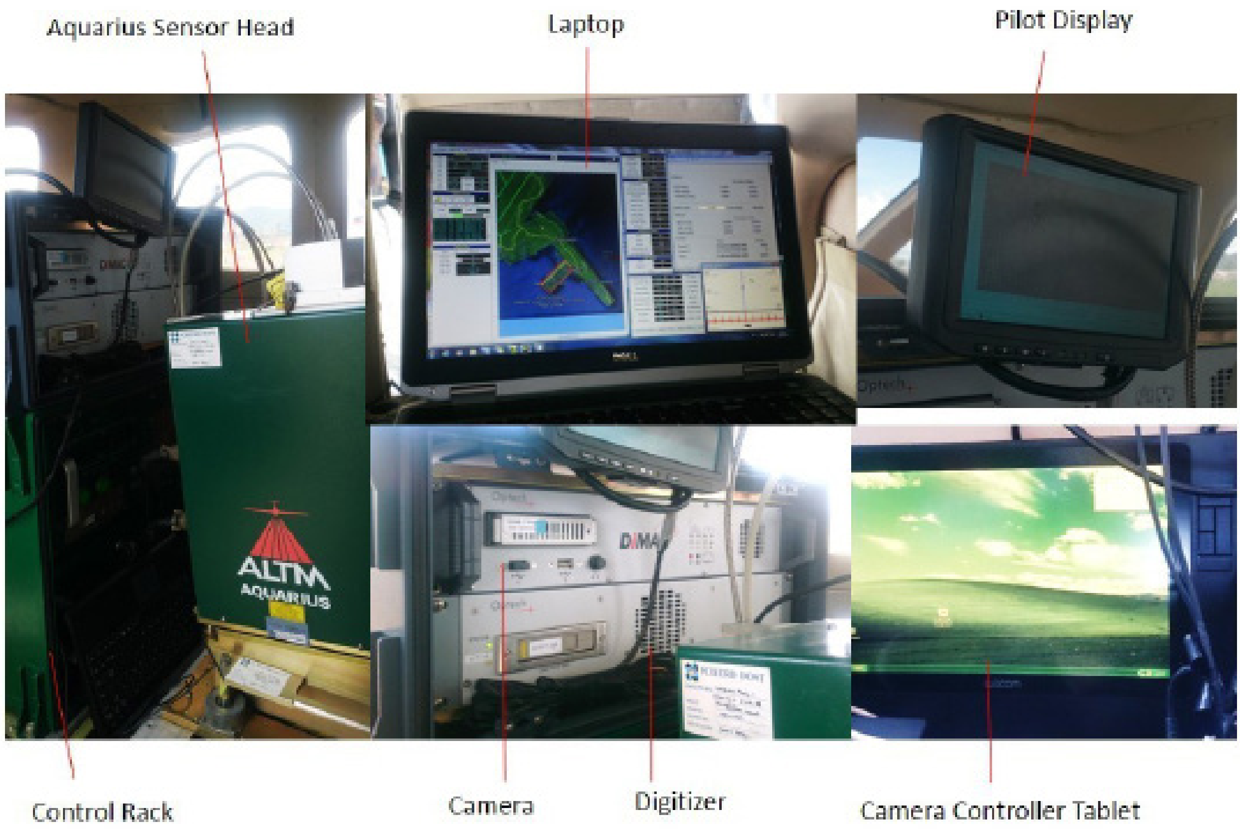
Paringit, E.C., Balicanta, L.P., Ang, M.C., Lagmay, A.F., Sarmiento, C. 2017, Flood Mapping of Rivers in the Philippines Using Airborne LiDAR: Methods. Quezon City, Philippines: UP Training Center for Applied Geodesy and Photogrammetry

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

Annex 1. Optech Technical Specification of the Sensor

1. AQUARIUS SENSOR



2. PARAMETERS AND SPECIFICATIONS OF THE AQUARIUS SENSOR

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

Annex 2. NAMRIA Certificates of Reference Points Used

1. SNI-15

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

November 05, 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: **SARANGANI**
Station Name: **SNI-15**
Order: **2nd**

Island:	**MINDANAO**	Barangay:	**POBLACION (MALAPATAN)**		
Municipality:	**MALAPATAN**	MSL Elevation:			
		PRS92 Coordinates			
Latitude:	**5° 58' 16.93809"**	Longitude:	**125° 17' 11.94043"**	Ellipsoidal Hgt:	**1.09600 m.**
		WGS84 Coordinates			
Latitude:	**5° 58' 14.08407"**	Longitude:	**125° 17' 17.56874"**	Ellipsoidal Hgt:	**75.01600 m.**
		PTM / PRS92 Coordinates			
Northing:	**660237.374 m.**	Easting:	**531736.654 m.**	Zone:	**5**
		UTM / PRS92 Coordinates			
Northing:	**660,523.74**	Easting:	**753,144.51**	Zone:	**51**

Location Description

SNI-15
Station is in Brgy. Poblacion, Malapatan, Sarangani. To reach the station travel for about 45 km from General Santos City towards Malapatan municipality taking the national highway until reaching the municipal hall of Malapatan. Mark is the head of a 4" copper nail embedded in a 0.30 x 0.30 x 1 m concrete monument with inscription SNI-15 2007 NAMRIA.

Requesting Party: **Christopher Cruz / PHIL-LIDAR I**
Purpose: **Reference**
OR Number: **8075142 I**
T.N.: **2014-2625**

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

2. SI-340

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

November 05, 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: **SARANGANI**
Station Name: **SI-340**

Island: **Luzon**	Municipality: **MALAPATAN**	Barangay:
Elevation: **18.7180 +/- 0.00 m.**	Order: **1st Order**	Datum: **Mean Sea Level**
Latitude:	Longitude:	

Location Description

The station is located at Molo Bridge about 290 m from KM post 1568, along Malapatan-Gensan National Highway.

The station is marked by an 4" copper nail with its head flushed at the center of an cement putty on a bridge with inscription "SI-340,NAMRIA,2008".

Requesting Party: **Christopher Cruz / PHIL-LIDAR I**
Purpose: **Reference**
OR Number: **8075142 I**
T.N.: **2014-2626**

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Annex 3. Baseline Processing Report of Reference Points Used

1. SI-340

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
NI-15 --- SI-340 31)	SNI-15	SI-340	Fixed	0.005	0.021	11°09'36"	4771.332	10.03
NI-15 --- SI-340 32)	SNI-15	SI-340	Fixed	0.005	0.016	11°09'36"	4771.328	9.93

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

Vector Components (Mark to Mark)

From:	SNI-15				
Grid		Local		Global	
Easting	753144.505 m	Latitude	N5°58'16.93808"	Latitude	N5°58'14.08407"
Northing	660523.744 m	Longitude	E125°17'11.94046"	Longitude	E125°17'17.56874"
Elevation	5.982 m	Height	1.096 m	Height	75.016 m

To:	SI-340				
Grid		Local		Global	
Easting	754048.831 m	Latitude	N6°00'49.33497"	Latitude	N6°00'46.47026"
Northing	665210.517 m	Longitude	E125°17'41.96935"	Longitude	E125°17'47.59361"
Elevation	15.960 m	Height	11.130 m	Height	84.998 m

Vector					
ΔEasting	904.326 m	NS Fwd Azimuth	11°09'36"	ΔX	-477.120 m
ΔNorthing	4686.773 m	Ellipsoid Dist.	4771.332 m	ΔY	-924.228 m
ΔElevation	9.979 m	ΔHeight	10.033 m	ΔZ	4656.593 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.006 m
σ ΔNorthing	0.002 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.009 m
σ ΔElevation	0.011 m	σ ΔHeight	0.011 m	σ ΔZ	0.002 m

Annex 4. The LiDAR Survey Team Composition

Data Acquisition Component Sub -Team	Designation	Name	Agency / Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. 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
		ENGR. LOVELYN ASUNCION	UP-TCAGP

FIELD TEAM

LiDAR Operation	Senior Science Research Specialist (SSRS)	JULIE PEARL MARS	UP-TCAGP
	Research Associate (RA)	ENGR. LARAH KRISELLE PARAGAS	UP-TCAGP
		GRACE SINADJAN	UP-TCAGP
Ground Survey, Data download and transfer	RA	JERIEL PAUL ALAMBAN, GEOL.	UP-TCAGP
LiDAR Operation	Airborne Security	TSG. MIKE DIAPANA	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. CESAR SHERWIN ALFONSO III	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. MARK GARCHITORENA	AAC

Annex 5. Data Transfer Sheet For Silway Floodplain

DATA TRANSFER SHEET
11/17/2014(gensan)

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	
26-Oct	2114	3BLK90B299A	AQUARIUS	NA	257	822	236	NA	NA	9.92	NA	16	1KB	1KB	4	NA	Z:\DAC\RAW DATA
26-Oct	2116	3BLK90A299B	AQUARIUS	NA	419	710	174	NA	NA	8.96	NA	16	1KB	1KB	3	NA	Z:\DAC\RAW DATA
27-Oct	2118	3BLK90CE300A	AQUARIUS	NA	232/317/103/56	599	239	NA	NA	12.4	NA	8.63	1KB	1KB	3/4	NA	Z:\DAC\RAW DATA
29-Oct	2126	3BLK90FCALIB302A	AQUARIUS	NA	198	446	197	NA	NA	7.77	NA	7.83	1KB	1KB	3/4	NA	Z:\DAC\RAW DATA
30-Oct	2130	3BLK90H303A	AQUARIUS	NA	344	682	265	NA	NA	14.9	158	9.04	1KB	1KB	11	NA	Z:\DAC\RAW DATA
4-Nov	2150	3BLK90V308A	AQUARIUS	NA	30	296	195	NA	NA	4.88	NA	13.1	1KB	1KB	21	NA	Z:\DAC\RAW DATA
4-Nov	2152	3BLK90BATHY308B	AQUARIUS	NA	143	331	131	NA	NA	6.21	1.52	13.1	1KB	1KB	10	NA	Z:\DAC\RAW DATA
6-Nov	2158	3BLK90GI310A	AQUARIUS	NA	327	566	179	NA	NA	5.69	13	9.12	1KB	1KB	6	NA	Z:\DAC\RAW DATA
7-Nov	2162	3BLK901311A	AQUARIUS	NA	17	360	156	NA	NA	3.16	NA	6.51	1KB	1KB	6	NA	Z:\DAC\RAW DATA
7-Nov	2164	3BLK90BATHY311B	AQUARIUS	NA	86	198	90.8	NA	NA	3.9	7.18	4.7	1KB	1KB	12	NA	Z:\DAC\RAW DATA

Received from

Name C. Joaquin
Position RA
Signature

Received by

Name Angelo Carlo Bongat
Position SSRS
Signature 11/19/2014

Annex 6. Flight Logs

1. Flight Log for 2150A Mission

II-LIDAR 1 Data Acquisition Flight Log — Flight Log No.: 2150

LiDAR Operator: G Sinadjan	2 ALTM Model: AQUA	3 Mission Name: 2BLK90S308A	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 9122
Pilot: C Alfonso	8 Co-Pilot: M Garduque	9 Route:			
Date: Nov 4 2019	12 Airport of Departure (Airport, City/Province): GenSan		12 Airport of Arrival (Airport, City/Province): GenSan		
Engine On:	14 Engine Off:	15 Total Engine Time:	16 Take off:	17 Landing:	18 Total Flight Time:

Weather

Remarks:

Completed voids in Buayan Floodplain & Block 90

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Signature over Printed Name (End User Representative)	MIKE DIPAZ PAF Signature over Printed Name (PAF Representative)	C. Alfonso Signature over Printed Name	GRACE SINADJAN Signature over Printed Name

Annex 7. Flight Status

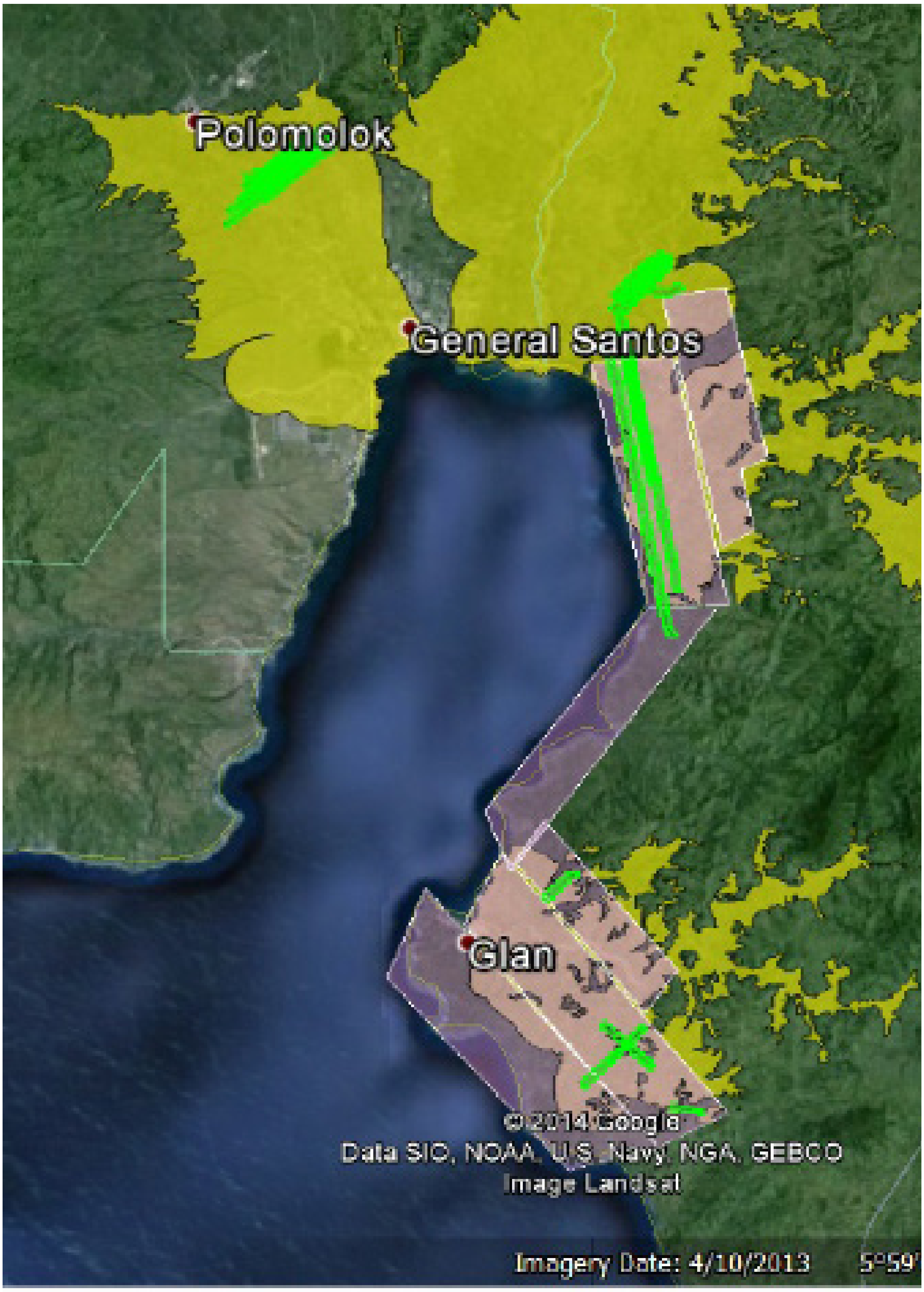
FLIGHT STATUS REPORT
SOUTH COTABATO
(November 4, 2014)

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
2150A	BYN_1E, BYN_2D	3BLK90V308A	G. Sinadjan	November 4	Mission completed; voids in Blk 90 and Buayan floodplain.

LAS/SWATH BOUNDARIES PER MISSION FLIGHT

Flight No. :	2150A	
Area:	BLK47A	
Mission Name:	1BLK47A210A	
Parameters:	Altitude: 600;	Scan Frequency: 45Hz;
	Scan Angle: 18deg;	Overlap: 45%

LAS



Annex 8. Mission Summary Reports

Flight Area	South Cotabato/Saranggani
Mission Name	Blk 90A
Inclusive Flights	2116A, 2164A
Range data size	12.88 GB
POS	264.8 MB
Image	n/a
Base Station Data	20.7 MB
Transfer date	November 19, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics(in cm)	
RMSE for North Position (<4.0 cm)	1.892
RMSE for East Position (<4.0 cm)	1.244
RMSE for Down Position (<8.0 cm)	3.67
Boresight correction stdev (<0.001deg)	0.000303
IMU attitude correction stdev (<0.001deg)	0.002288
GPS position stdev (<0.01m)	0.0075
Minimum % overlap (>25)	61.29
Ave point cloud density per sq.m. (>2.0)	3.77
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	99
Maximum Height	576.89
Minimum Height	62.87
Classification (# of points)	
Ground	48,831,977
Low vegetation	58,075,952
Medium vegetation	82,035,068
High vegetation	50,206,904
Building	3,063,181
Orthophoto	No
Processed by	Engr. Analyn Naldo, Engr. Carlyn Ann Ibañez, Engr. Melanie Hingpit, Engr. Melissa Fernandez

Figure A-8.1. Solution Status

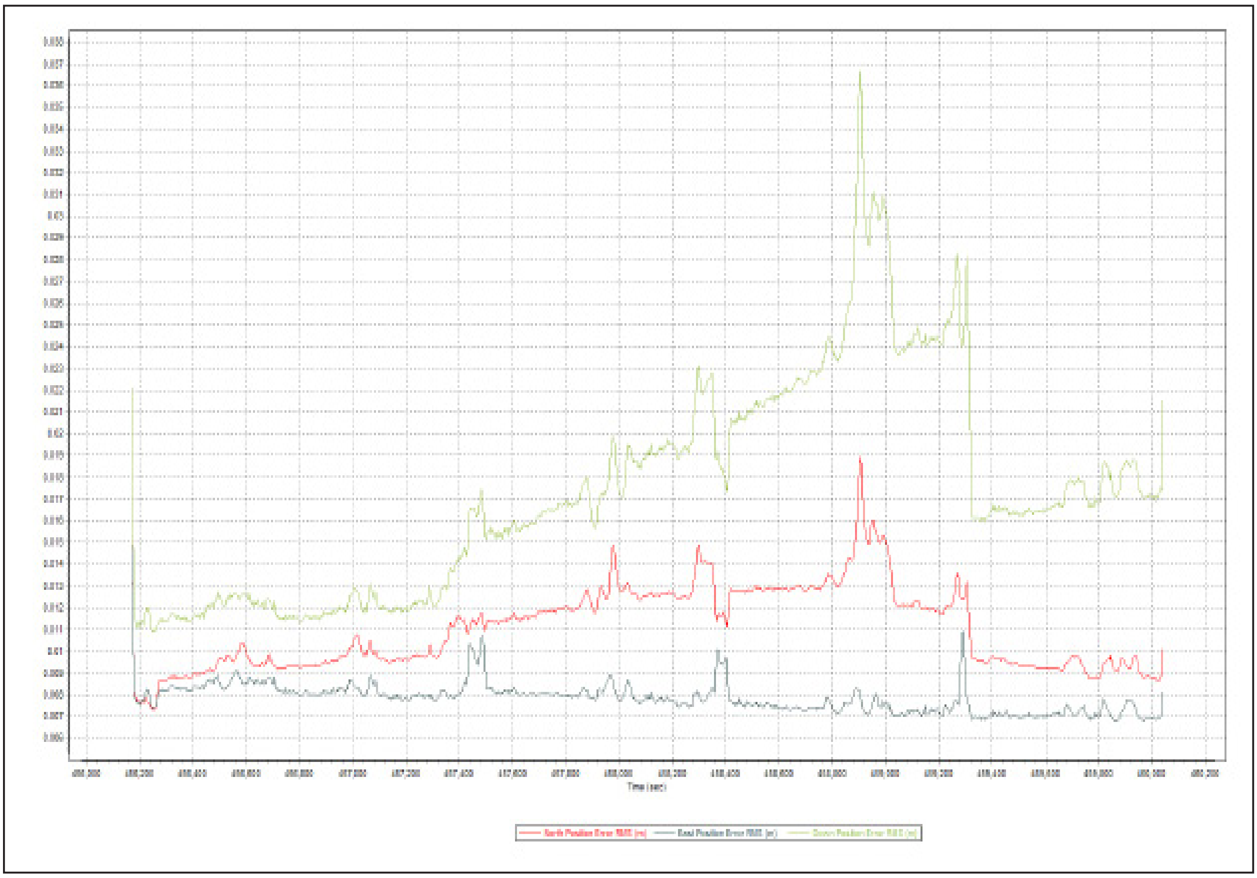


Figure A-8.2. Smoothed Performance Metric Parameters

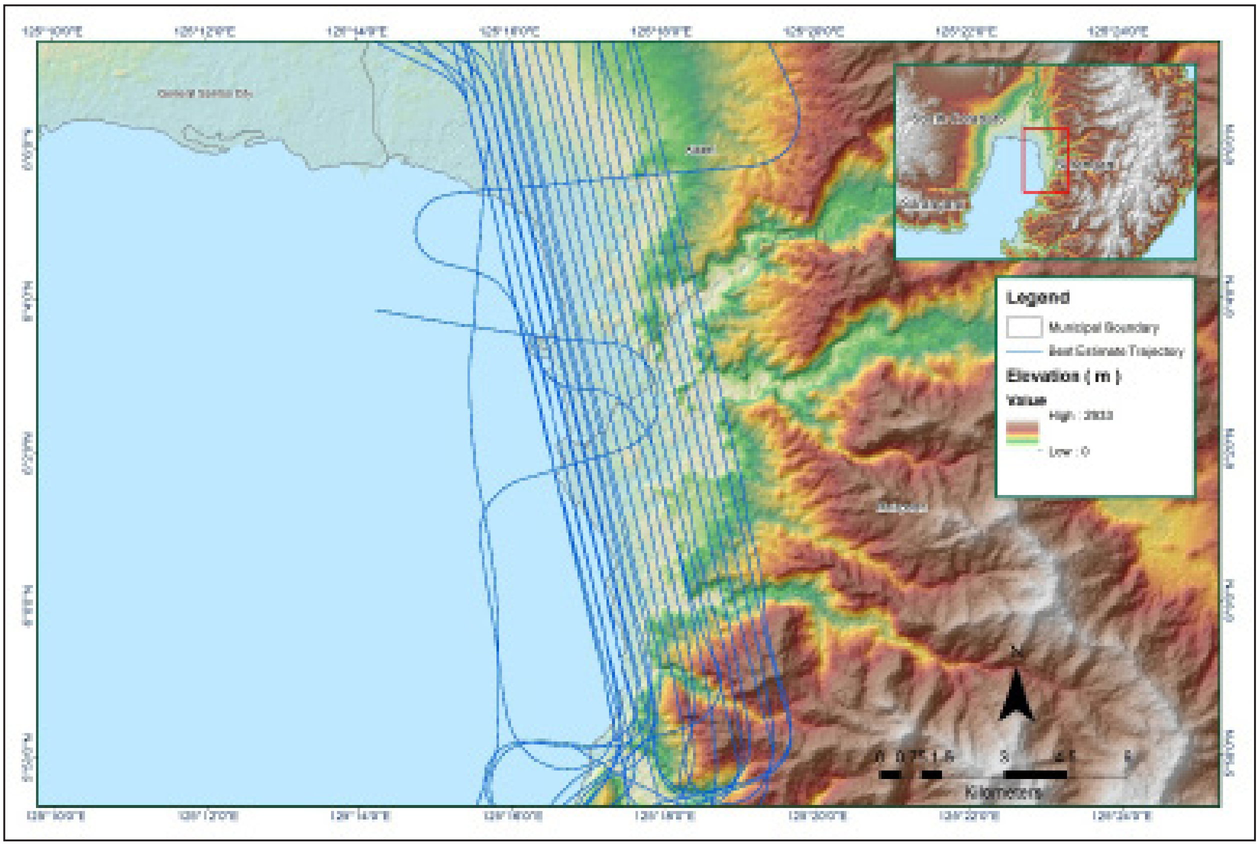


Figure A-8.3. Best Estimated Trajectory

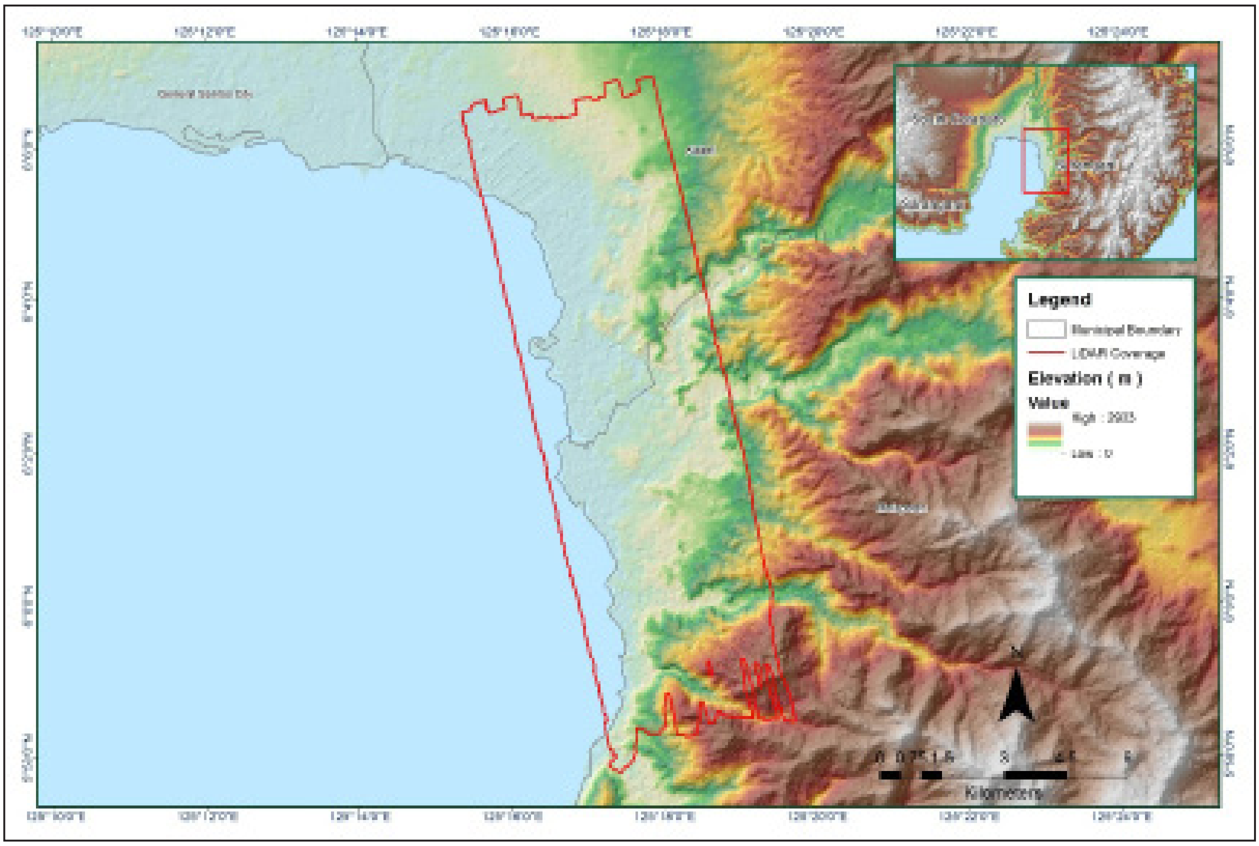


Figure A-8.4. Coverage of LiDAR data

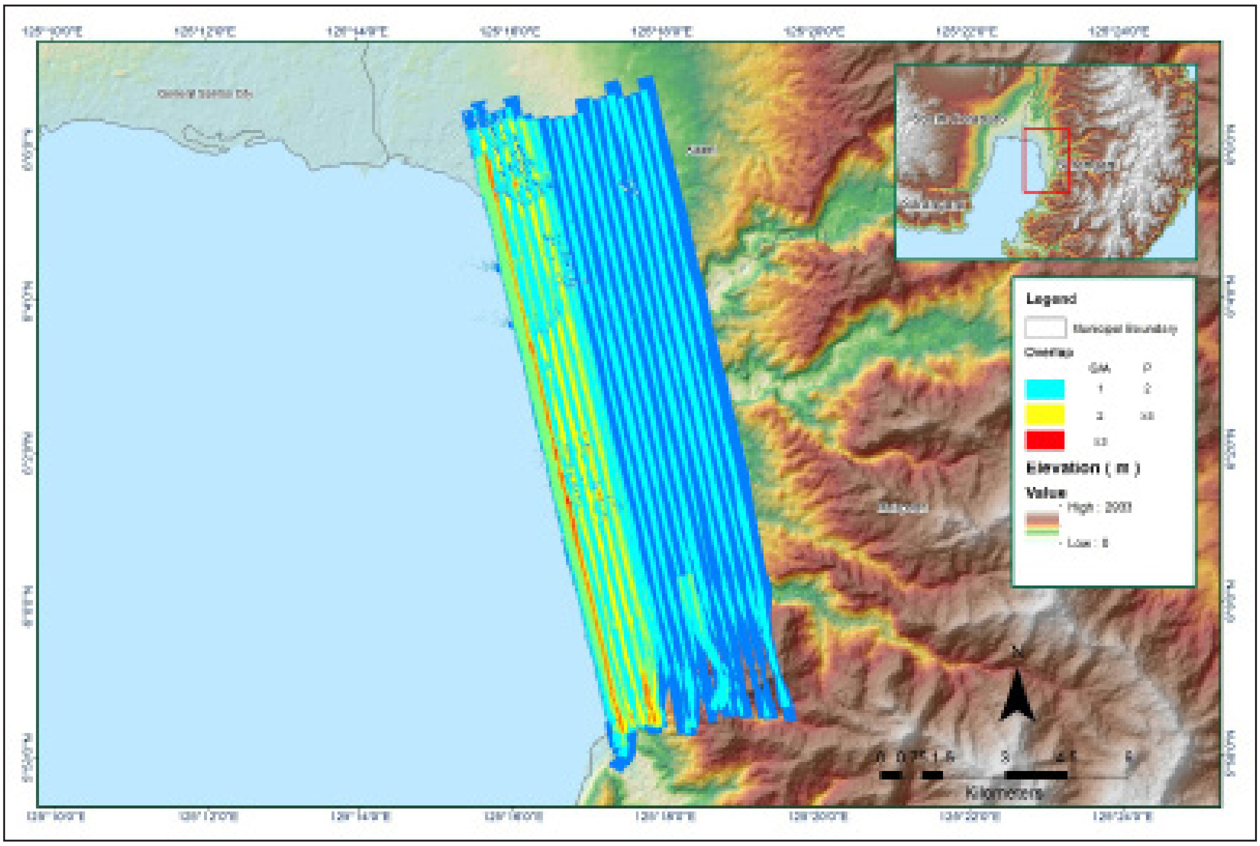


Figure A-8.5. Image of data overlap

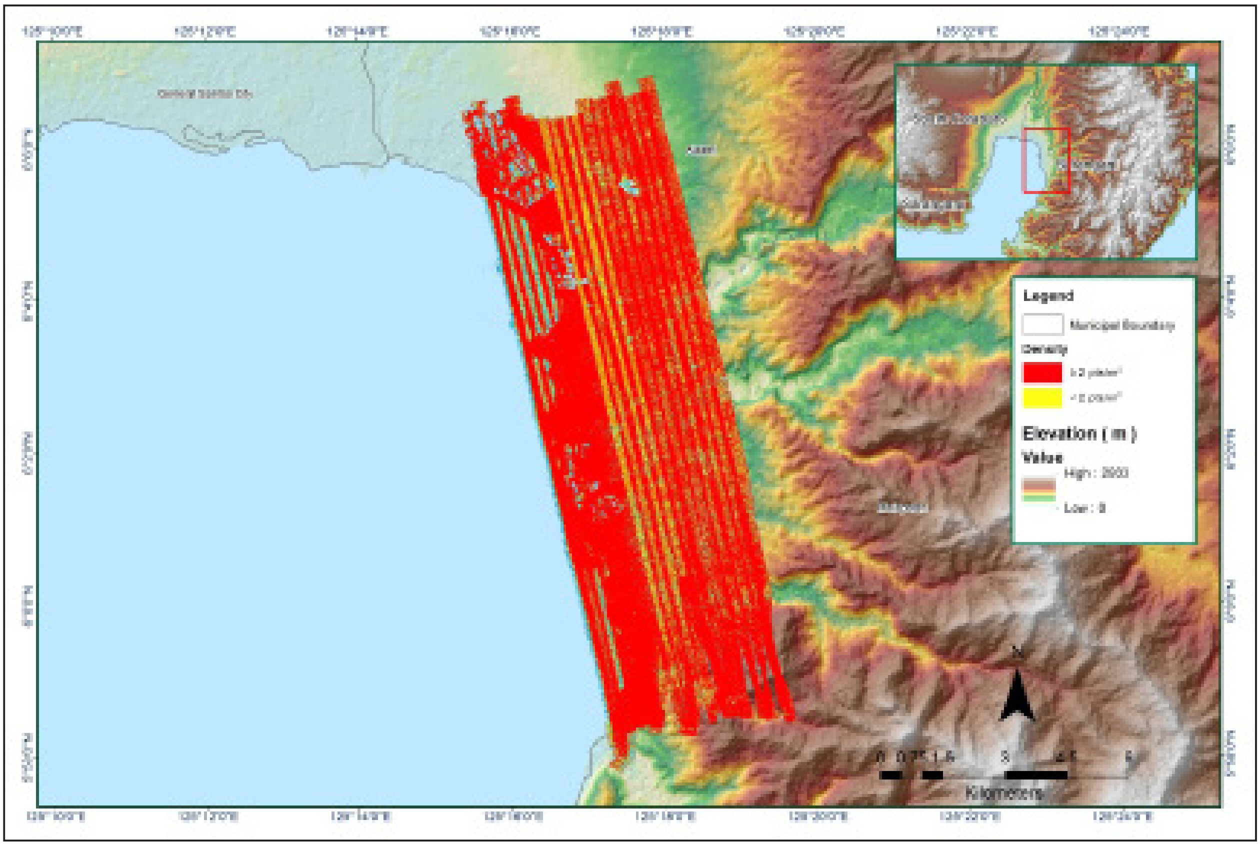


Figure A-8.6. Density map of merged LiDAR data

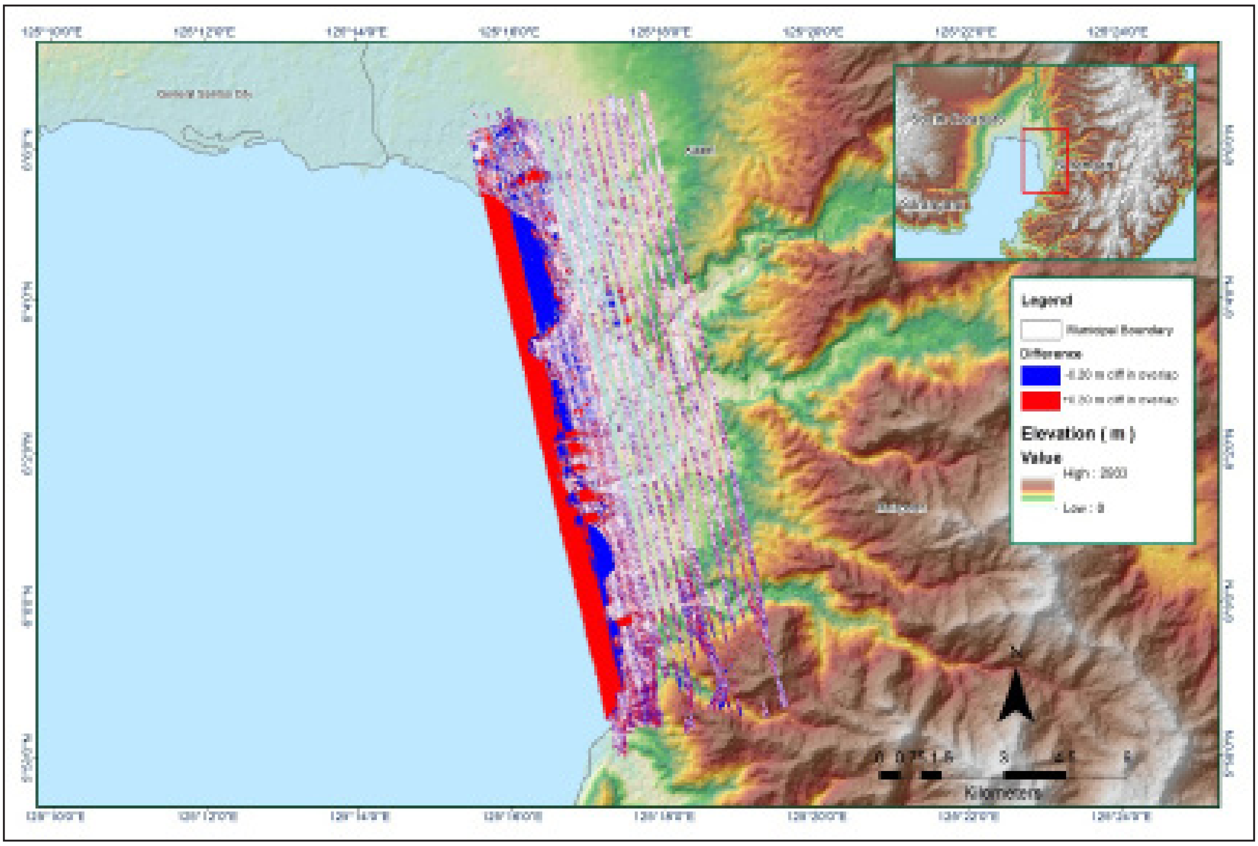


Figure A-8.7. Elevation difference between flight lines

Flight Area	South Cotabato/Saranggani
Mission Name	Blk 90B
Inclusive Flights	2114A
Range data size	9.92 GB
POS	236 MB
Image	na
Base Station Data	16 MB
Transfer date	November 19, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics(in cm)	
RMSE for North Position (<4.0 cm)	2.137
RMSE for East Position (<4.0 cm)	1.942
RMSE for Down Position (<8.0 cm)	5.126
Boresight correction stdev (<0.001deg)	0.000164
IMU attitude correction stdev (<0.001deg)	0.000550
GPS position stdev (<0.01m)	0.0063
Minimum % overlap (>25)	61.64
Ave point cloud density per sq.m. (>2.0)	4.46
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	89
Maximum Height	560.43 m
Minimum Height	90.94 m
Classification (# of points)	
Ground	47,028,761
Low vegetation	47,012,132
Medium vegetation	70,024,925
High vegetation	50,937,946
Building	848,463
Orthophoto	No
Processed by	Engr. Benjamin Jonah Magallon, Engr. Melanie Hingpit, Engr. Elainne Lopez

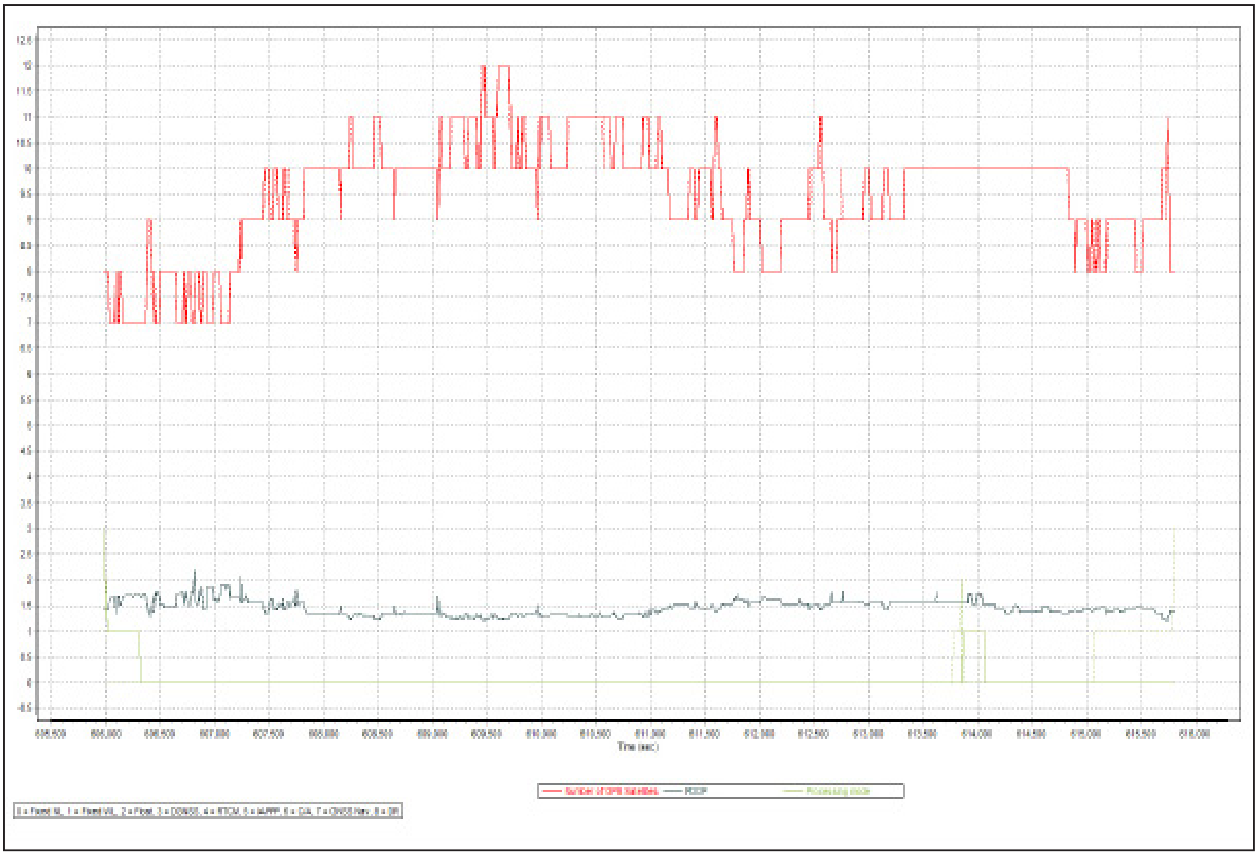


Figure A-8.8. Solution Status

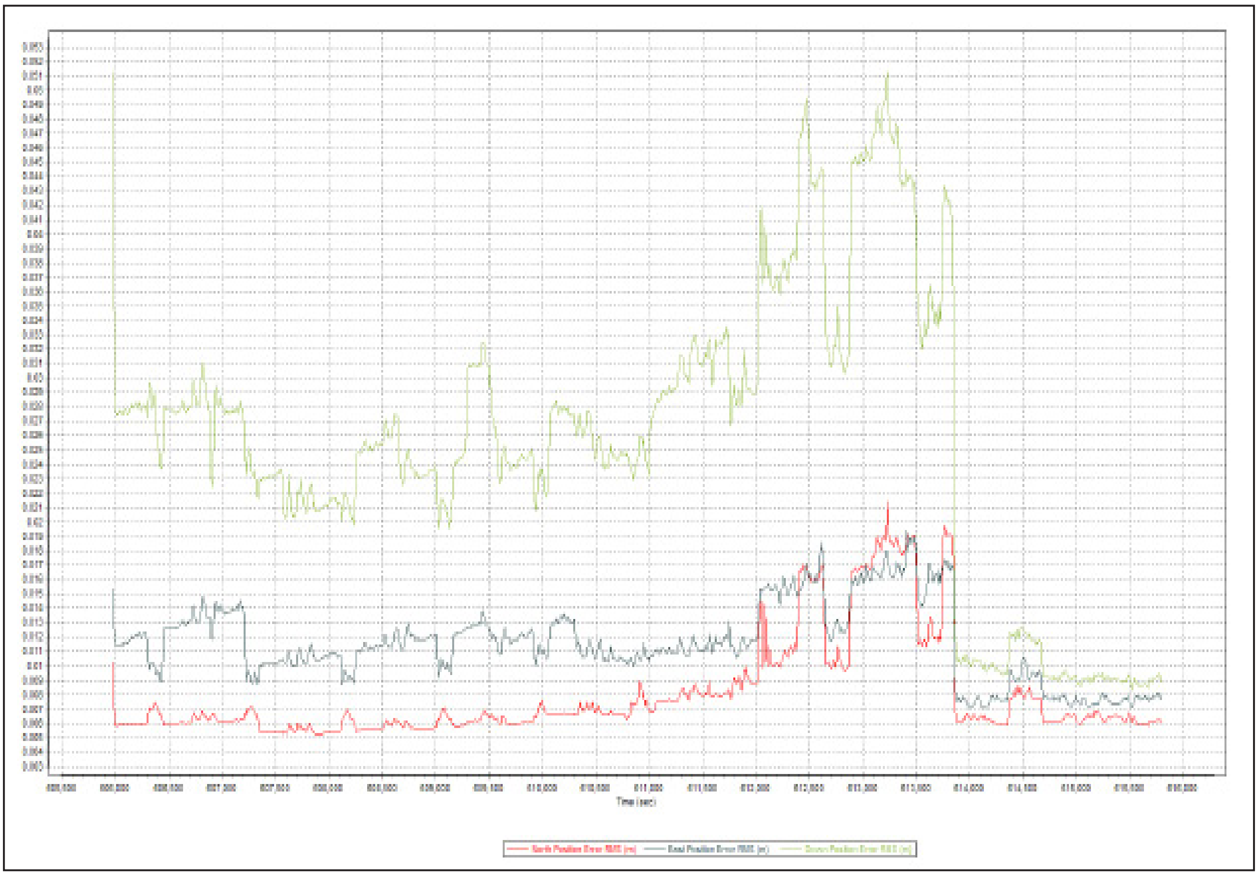


Figure A-8.9. Smoothed Performance Metric Parameters

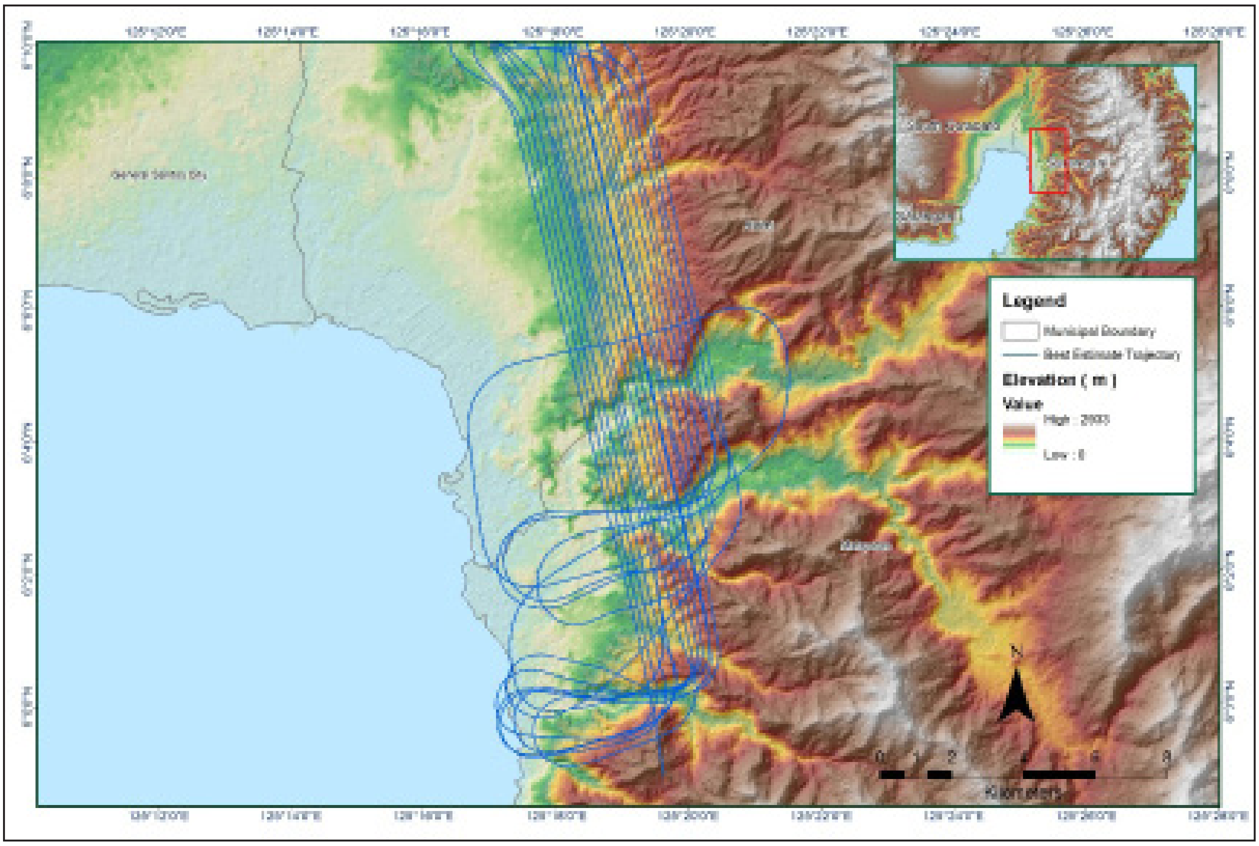


Figure A-8.10. Best Estimated Trajectory

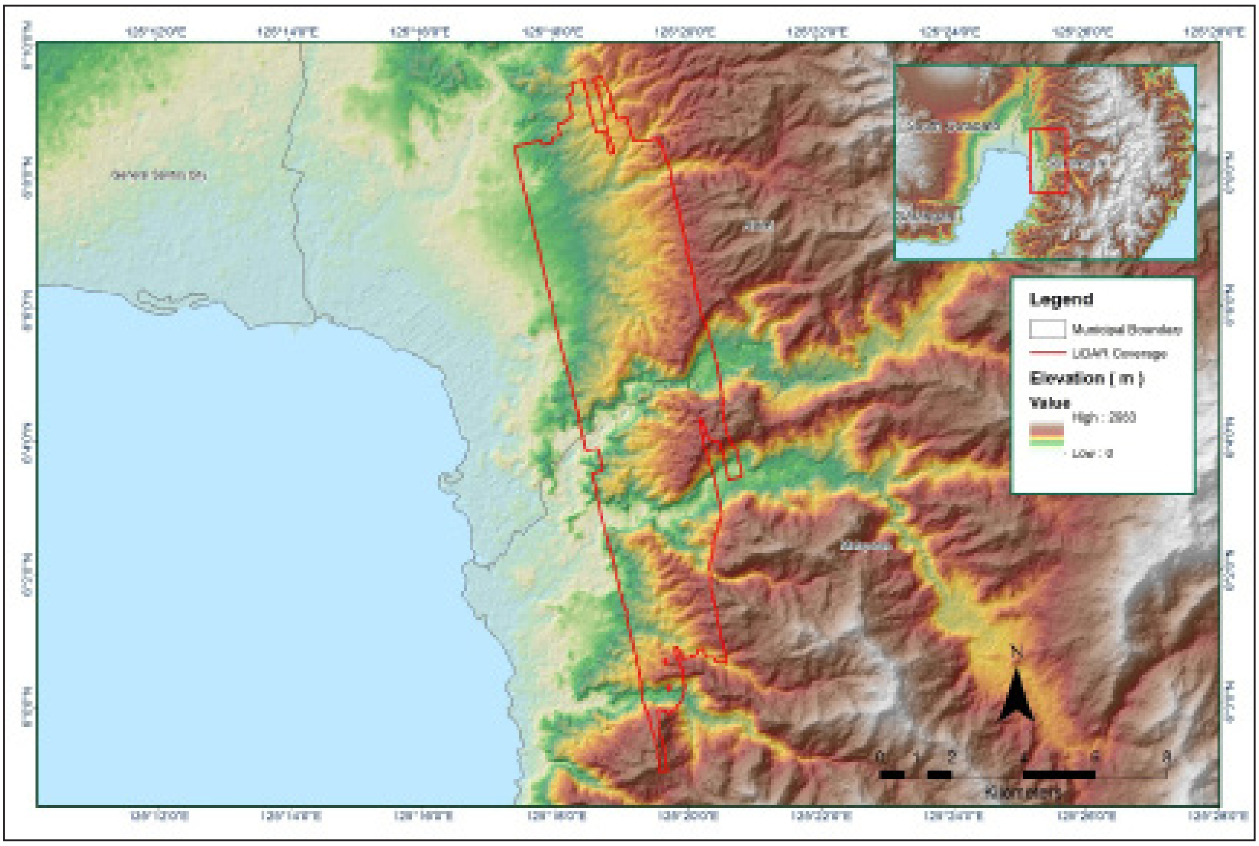


Figure A-8.11. Coverage of LiDAR data

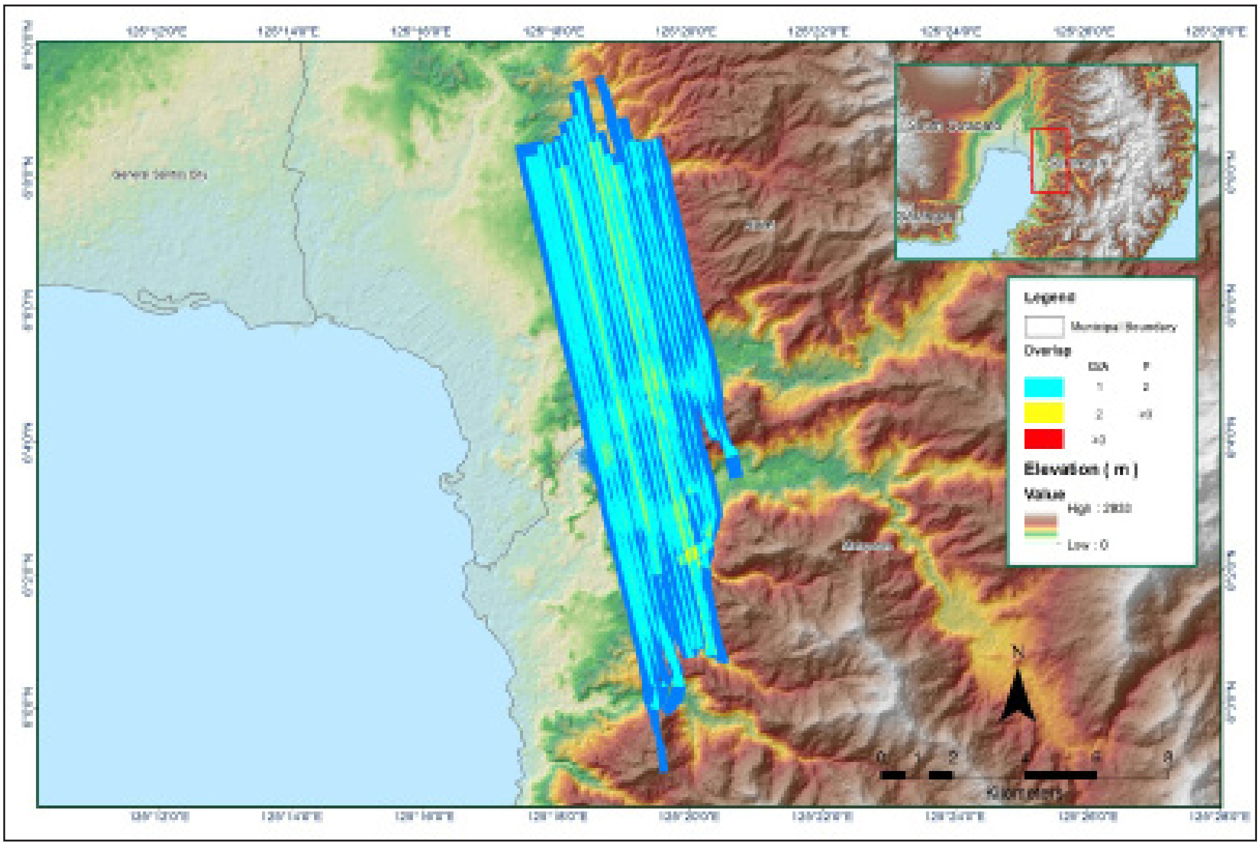


Figure A-8.12. Image of data overlap

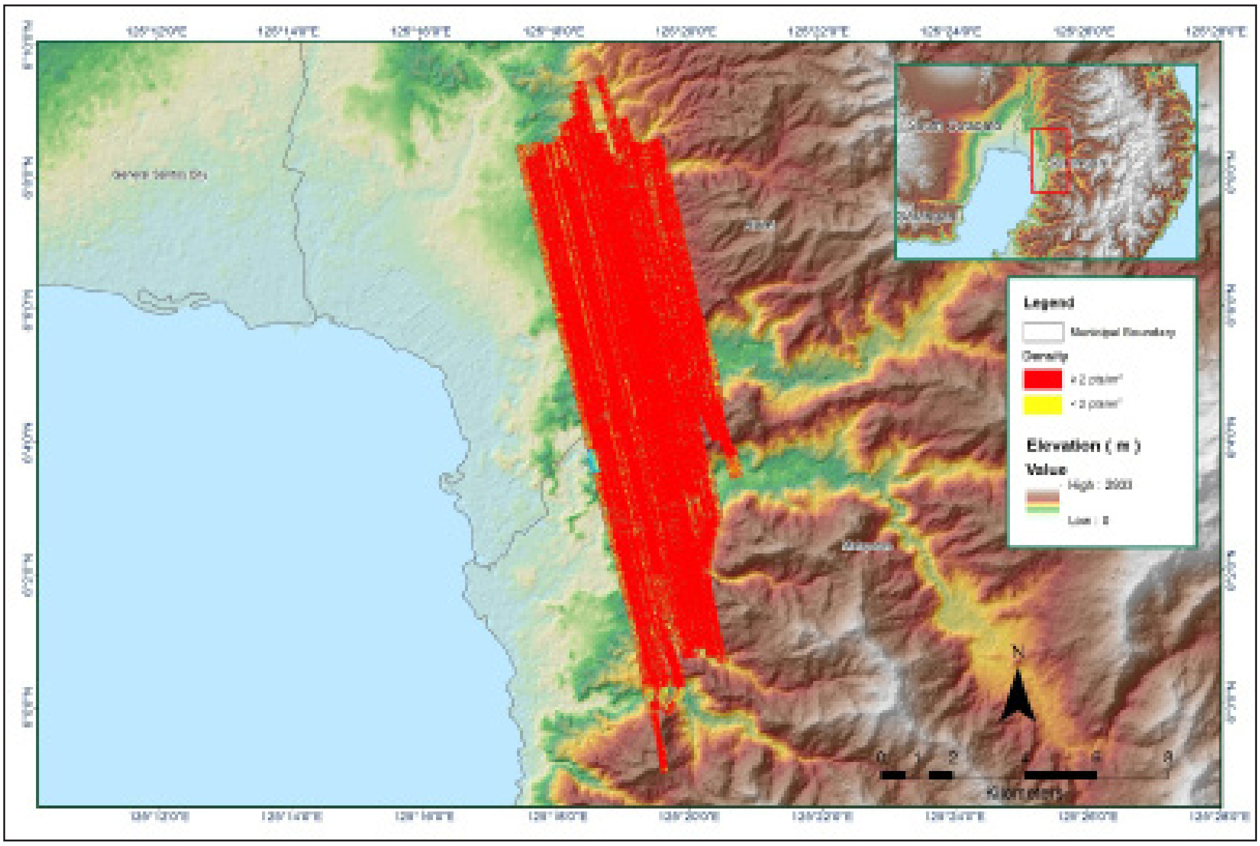


Figure A-8.13. Density map of merged LiDAR data

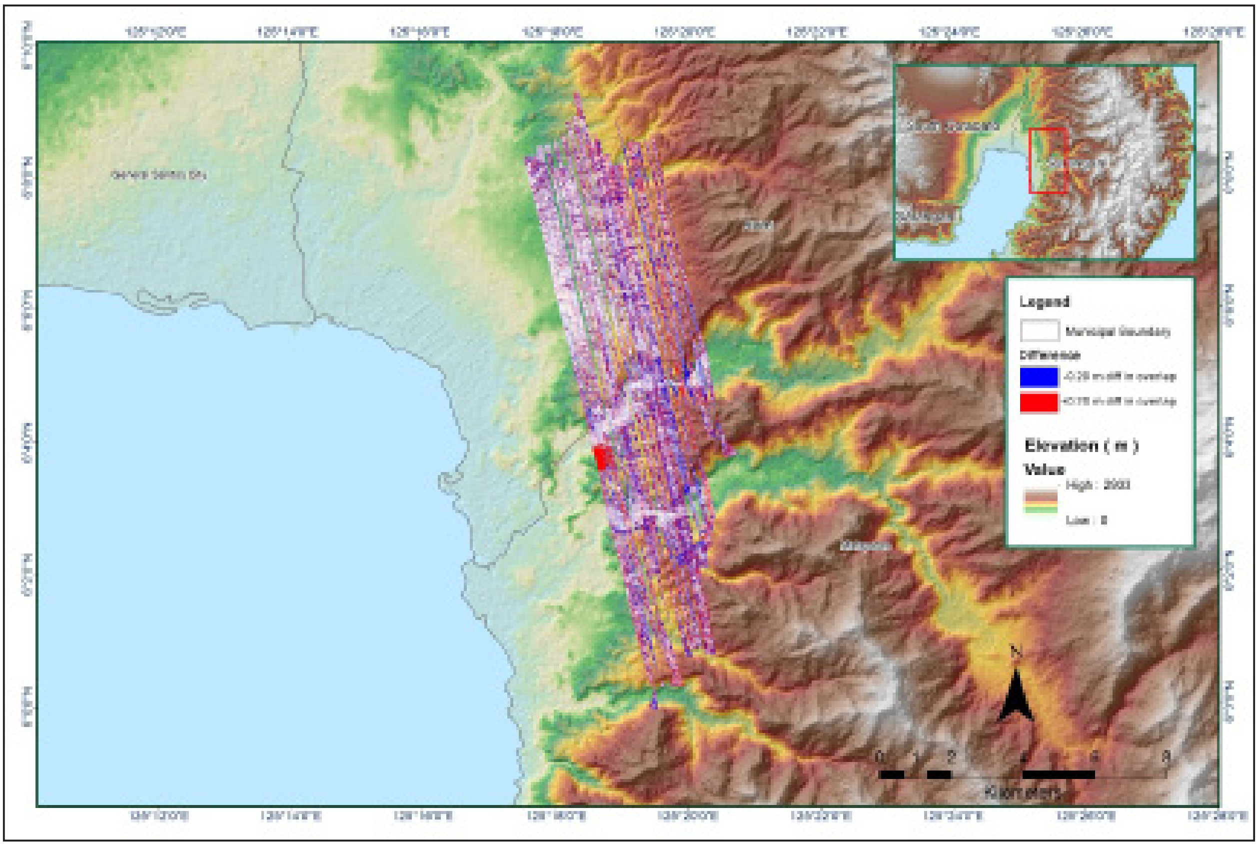


Figure A-8.14. Elevation difference between flight lines

Flight Area	South Cotabato/Saranggani
Mission Name	Blk 90C
Inclusive Flights	2118A, 2152A
Range data size	18.61 GB
POS	370 MB
Image	na
Base Station Data	21.73 MB
Transfer date	November 19, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics(in cm)	
RMSE for North Position (<4.0 cm)	1.322
RMSE for East Position (<4.0 cm)	1.471
RMSE for Down Position (<8.0 cm)	2.890
Boresight correction stdev (<0.001deg)	0.000215
IMU attitude correction stdev (<0.001deg)	0.001399
GPS position stdev (<0.01m)	0.0218
Minimum % overlap (>25)	60.95
Ave point cloud density per sq.m. (>2.0)	4.53
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	174
Maximum Height	576.49 m
Minimum Height	51.04 m
Classification (# of points)	
Ground	54948631
Low vegetation	63669401
Medium vegetation	95656635
High vegetation	120677828
Building	4641693
Orthophoto	No
Processed by	Engr. Jennifer Saguran, Engr. Edgardo Gubatanga Jr., Engr. Jeffrey Delica

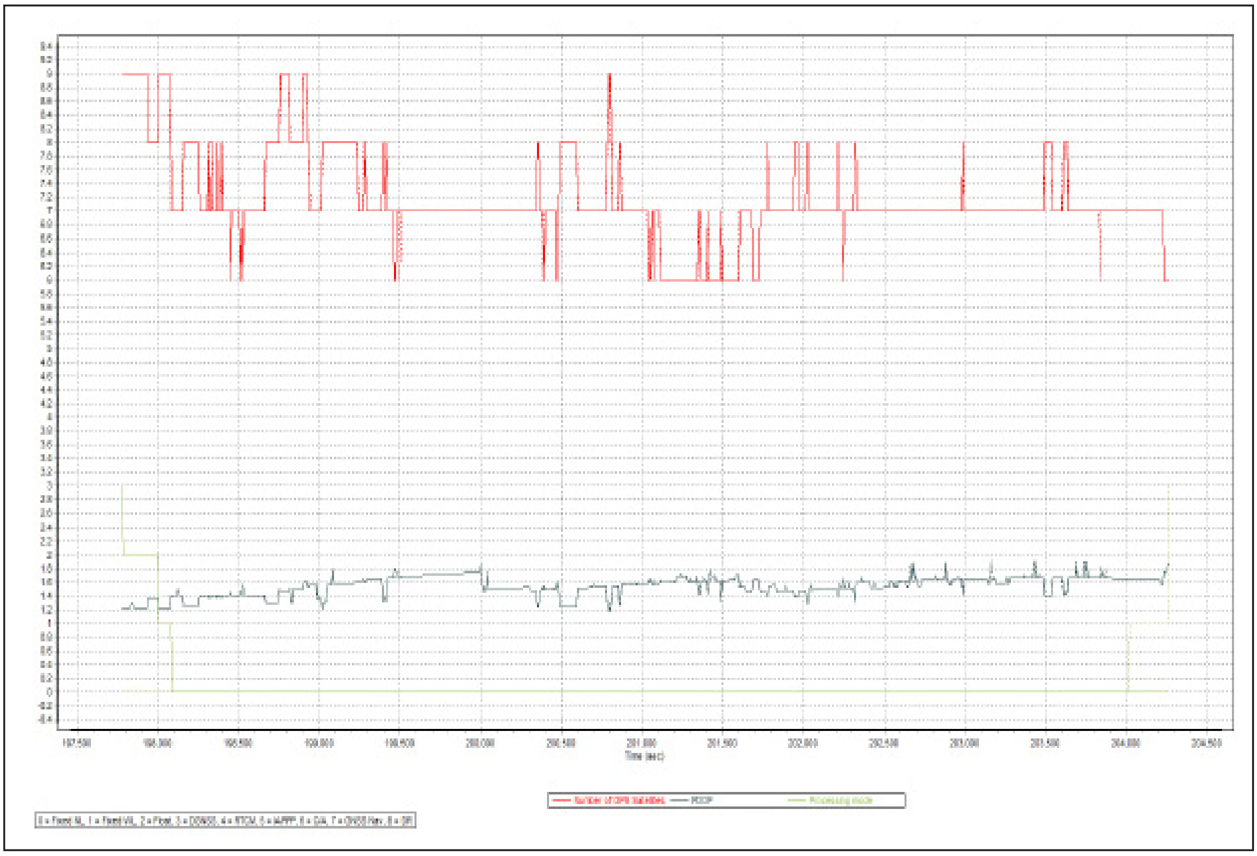


Figure A-8.15. Solution Status

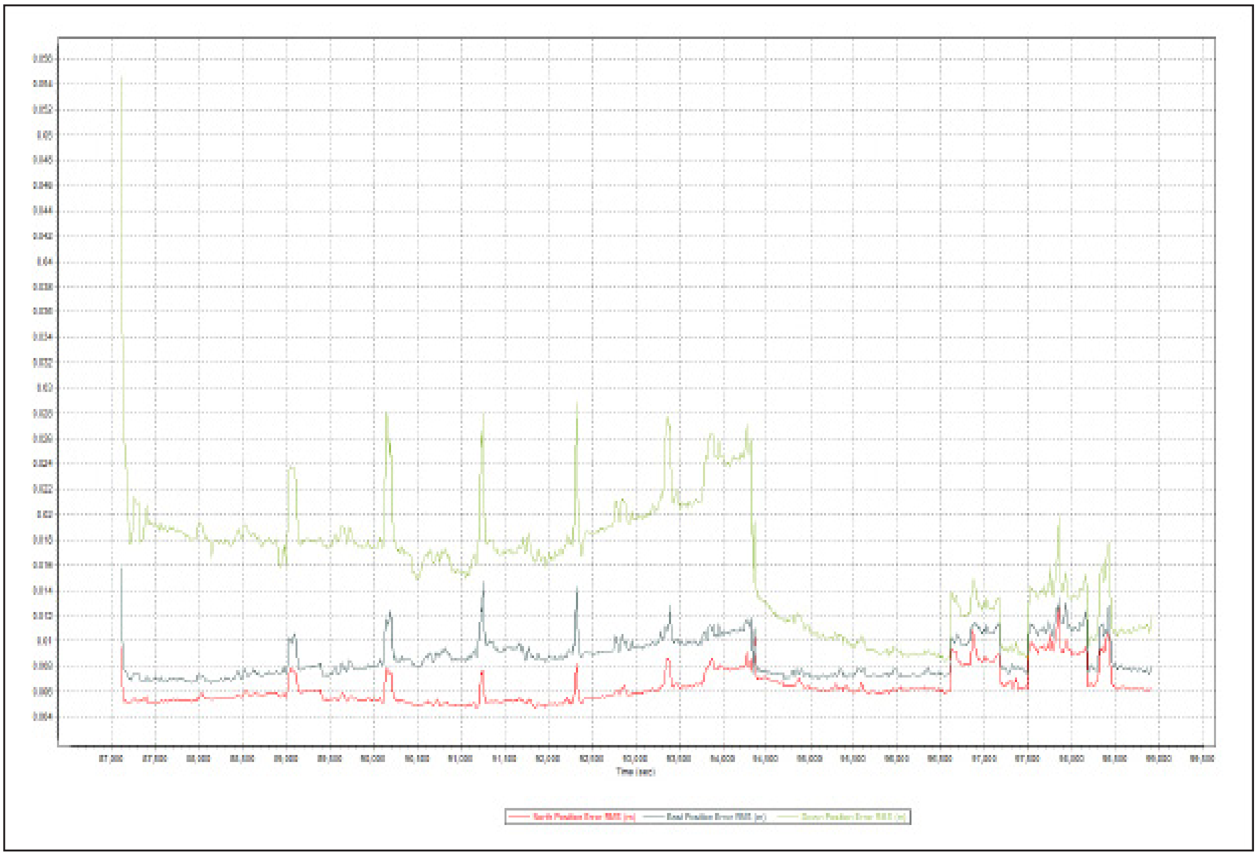


Figure A-8.16. Smoothed Performance Metric Parameters

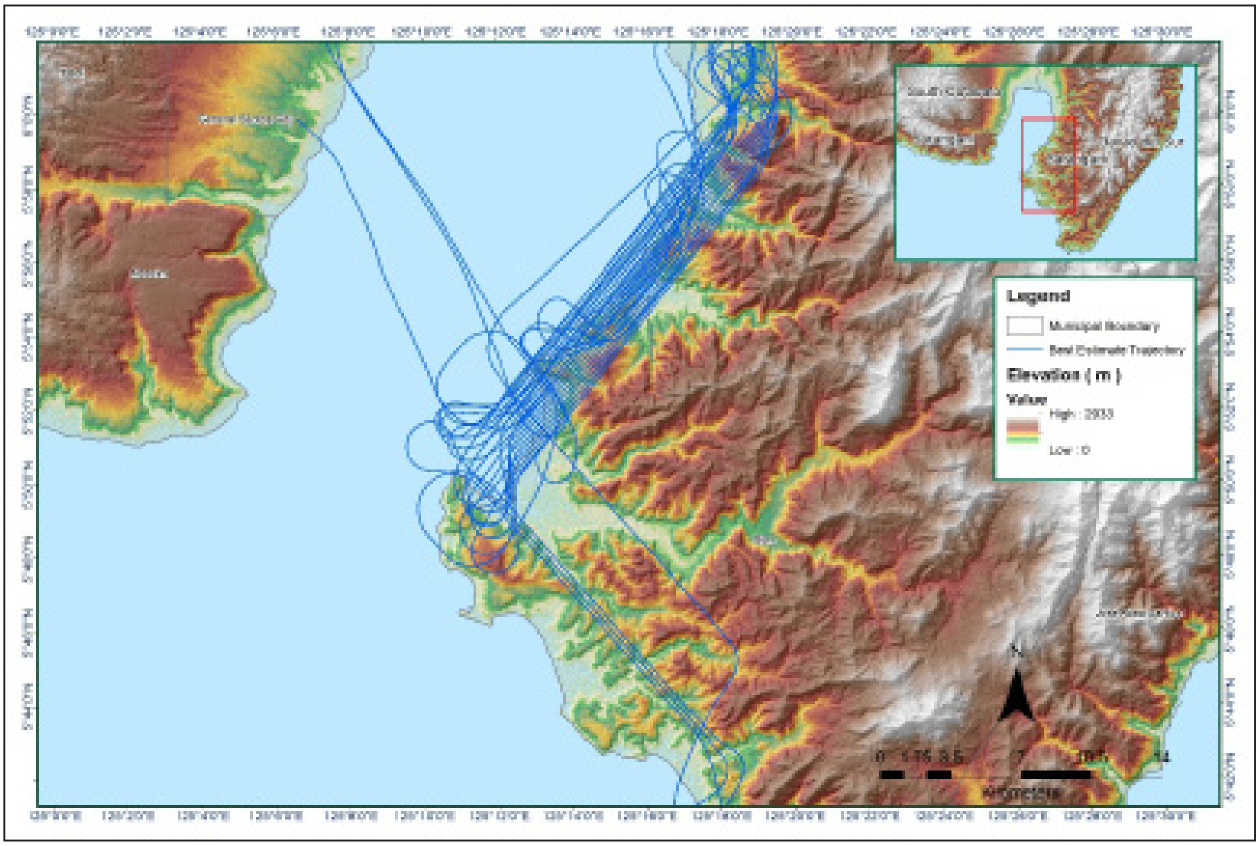


Figure A-8.17. Best Estimated Trajectory

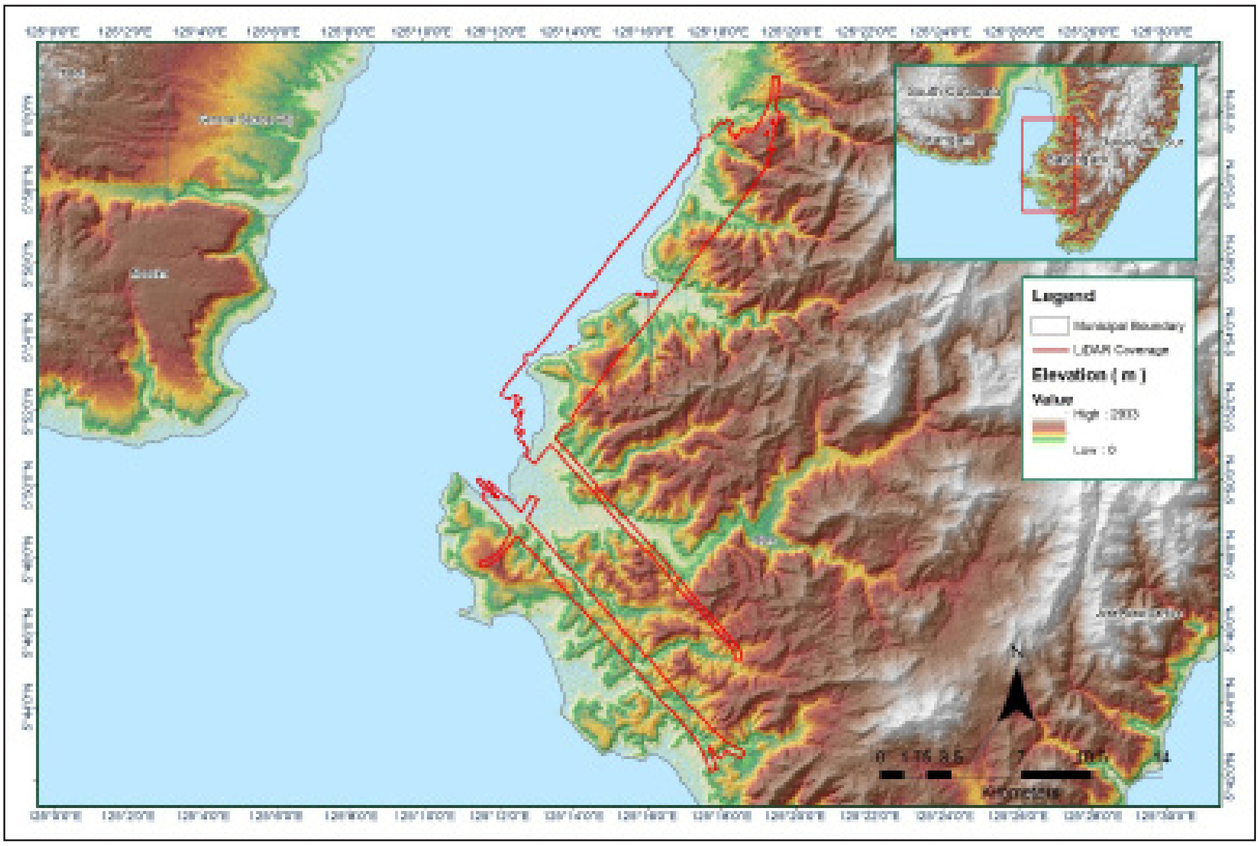


Figure A-8.18. Coverage of LiDAR data

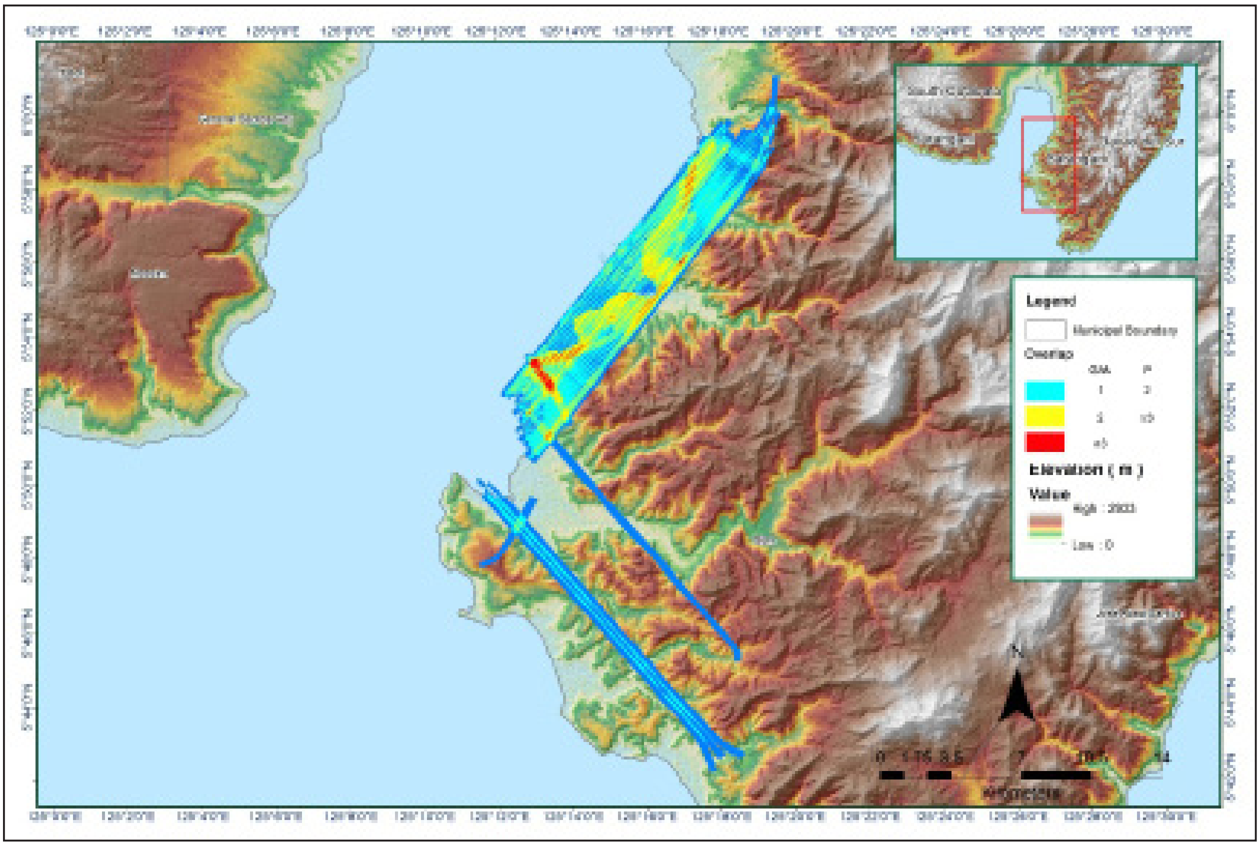


Figure A-8.19. Image of data overlap

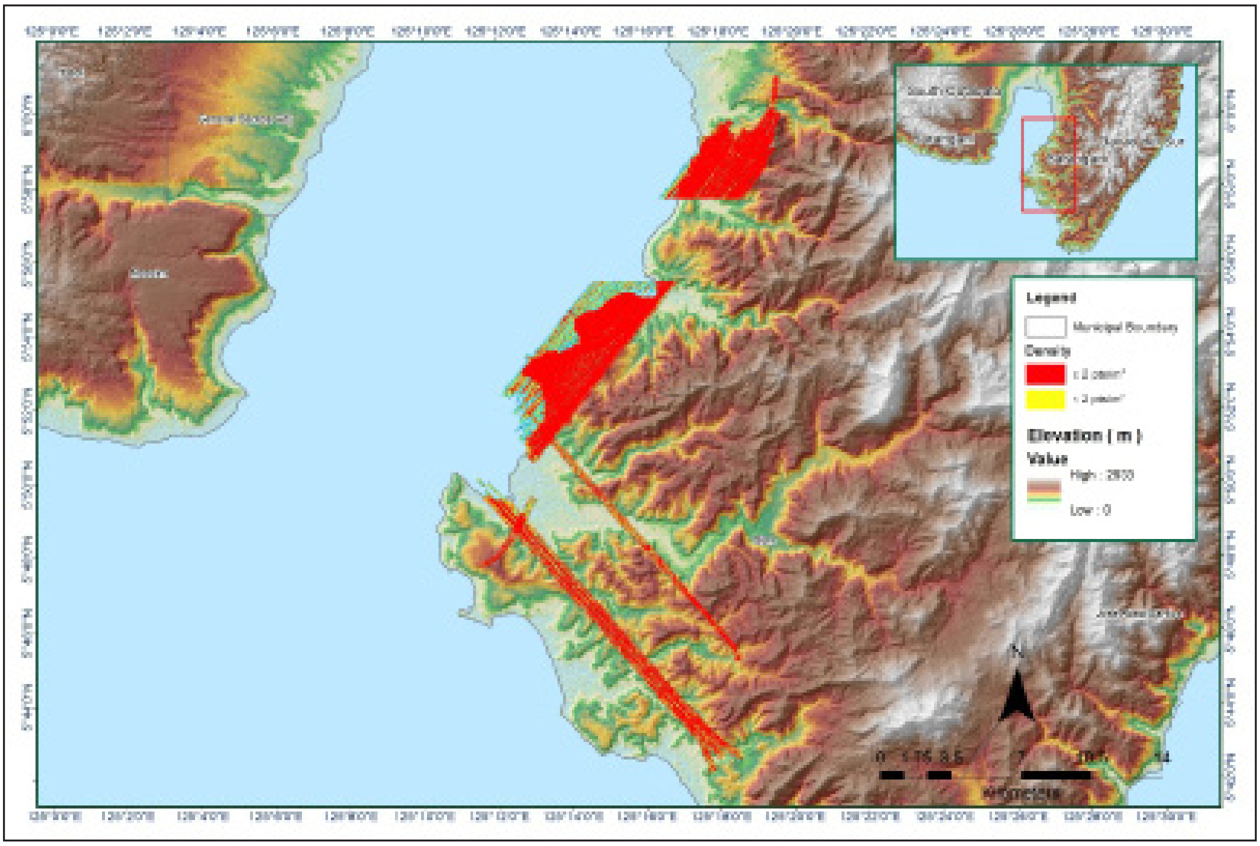


Figure A-8.20. Density map of merged LiDAR data

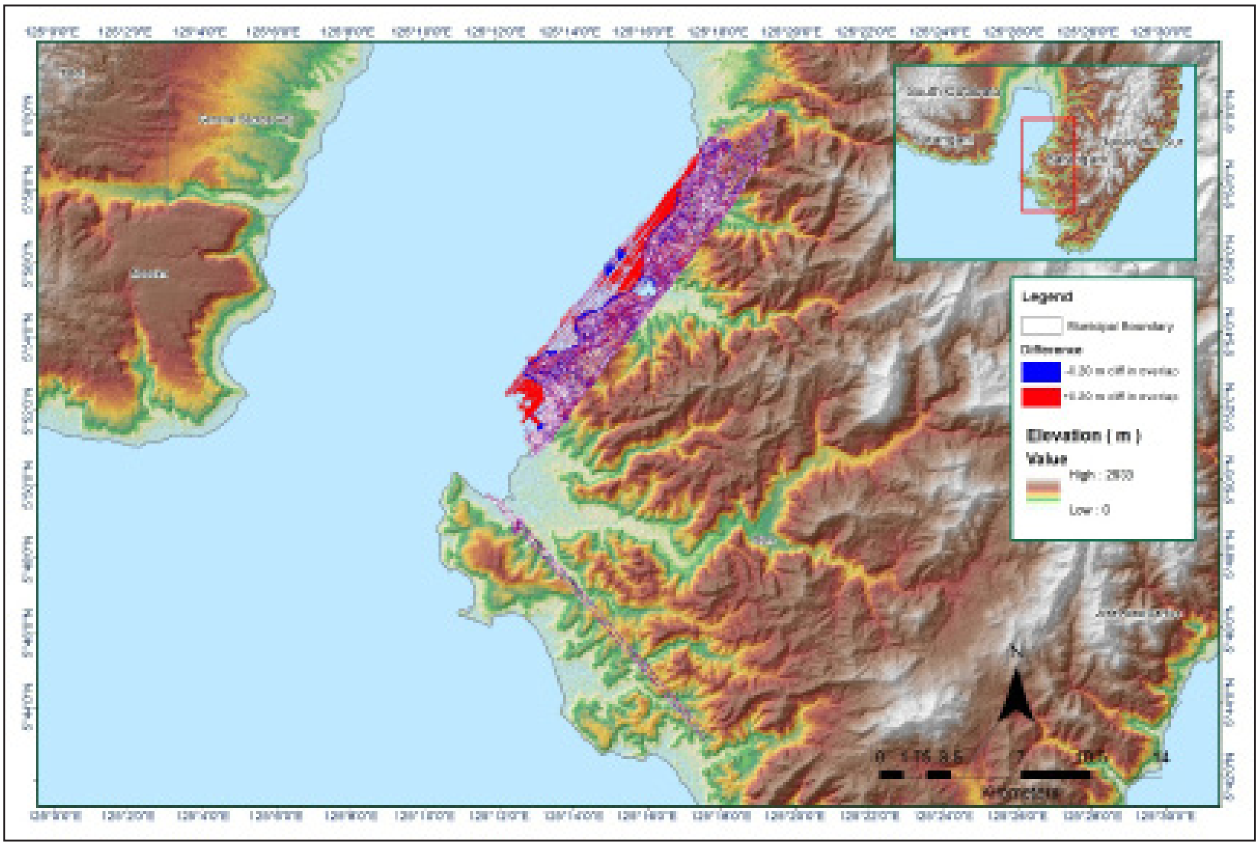


Figure A-8.21. Elevation difference between flight lines

Flight Area	South Cotabato/Saranggani
Mission Name	Blk 90F
Inclusive Flights	2126A
Range data size	7.77 GB
POS	197 MB
Image	na
Base Station Data	7.83 MB
Transfer date	November 19, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics(in cm)	
RMSE for North Position (<4.0 cm)	0.947
RMSE for East Position (<4.0 cm)	1.361
RMSE for Down Position (<8.0 cm)	3.265
Boresight correction stdev (<0.001deg)	0.000257
IMU attitude correction stdev (<0.001deg)	0.000739
GPS position stdev (<0.01m)	0.0093
Minimum % overlap (>25)	50.80
Ave point cloud density per sq.m. (>2.0)	3.65
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	65
Maximum Height	532.85 m
Minimum Height	63.16 m
Classification (# of points)	
Ground	25,453,075
Low vegetation	24,021,462
Medium vegetation	32,403,168
High vegetation	48,332,353
Building	1,081,345
Orthophoto	No
Processed by	Engr. Jommer Medina, Engr. Mark Joshua Salvacion, Engr. Elainne Lopez

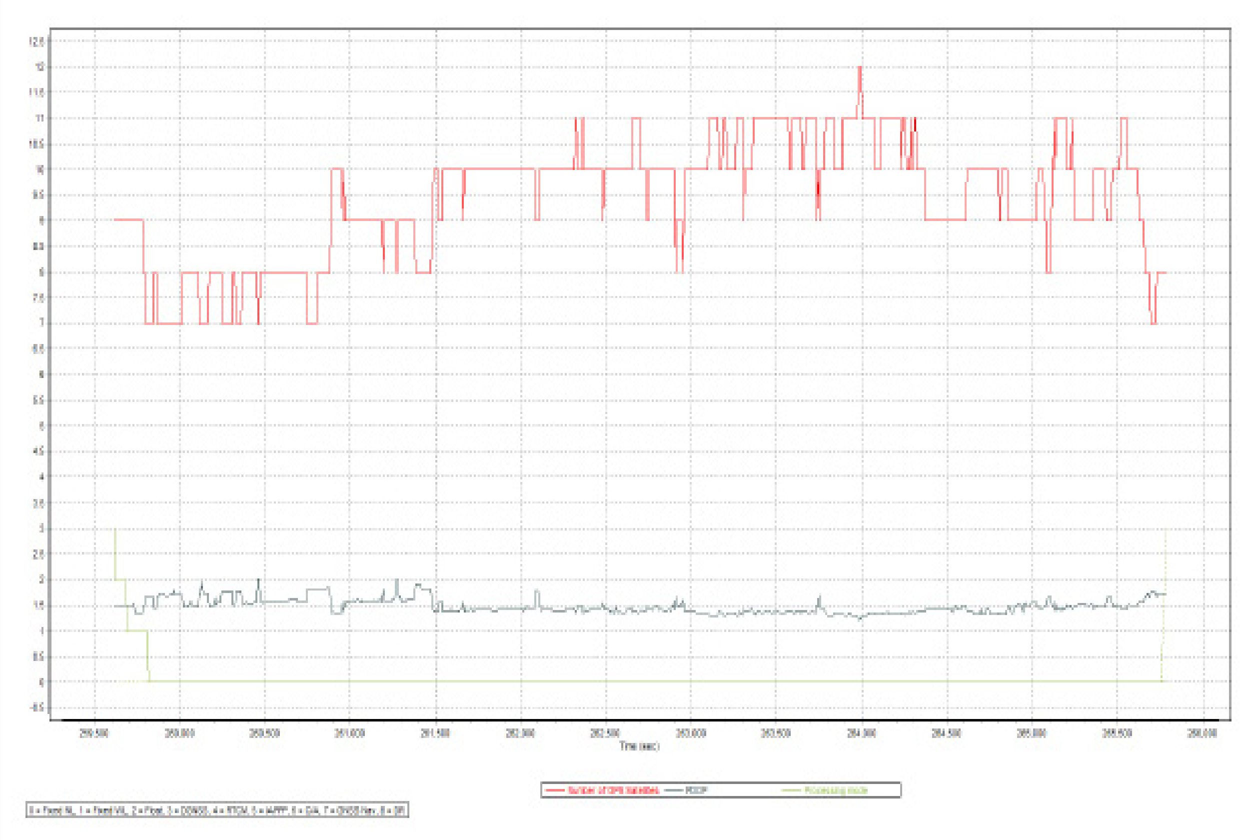


Figure A-8.22. Solution Status

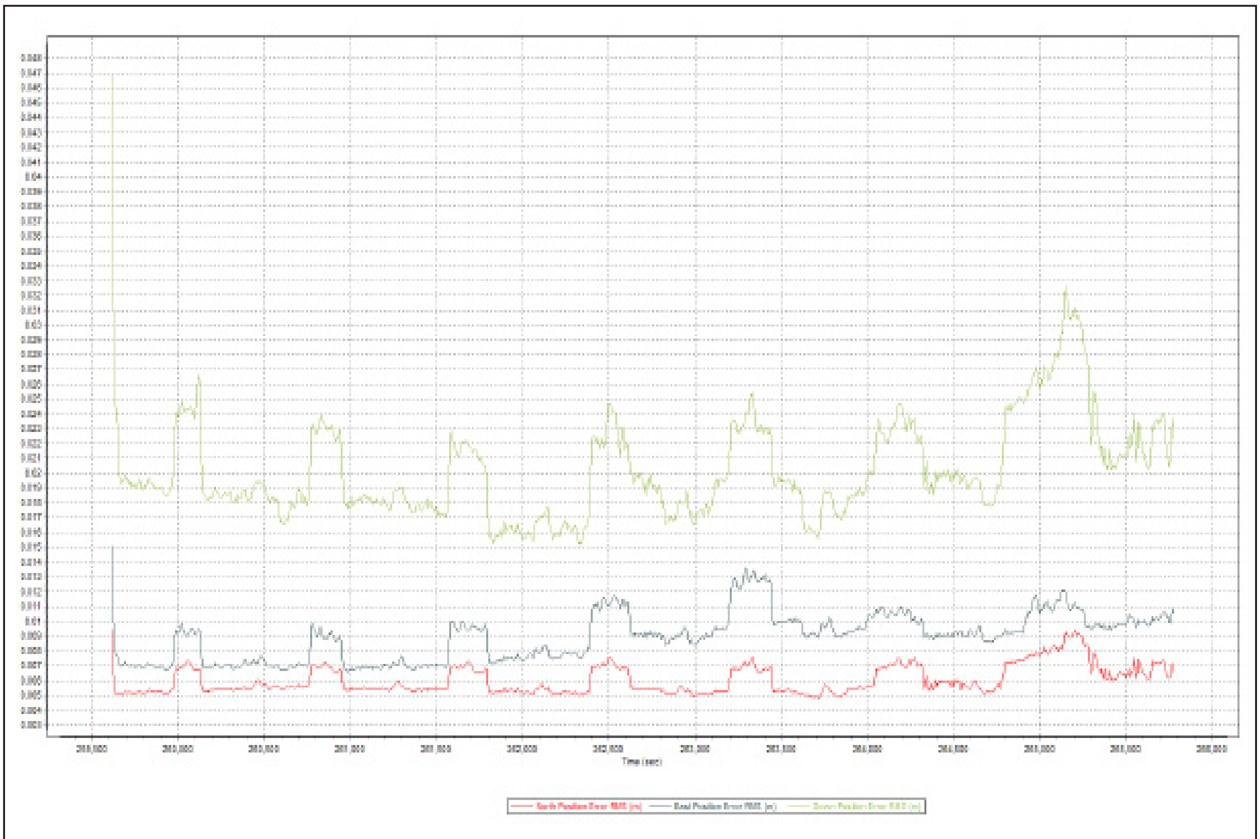


Figure A-8.23. Smoothed Performance Metric Parameters

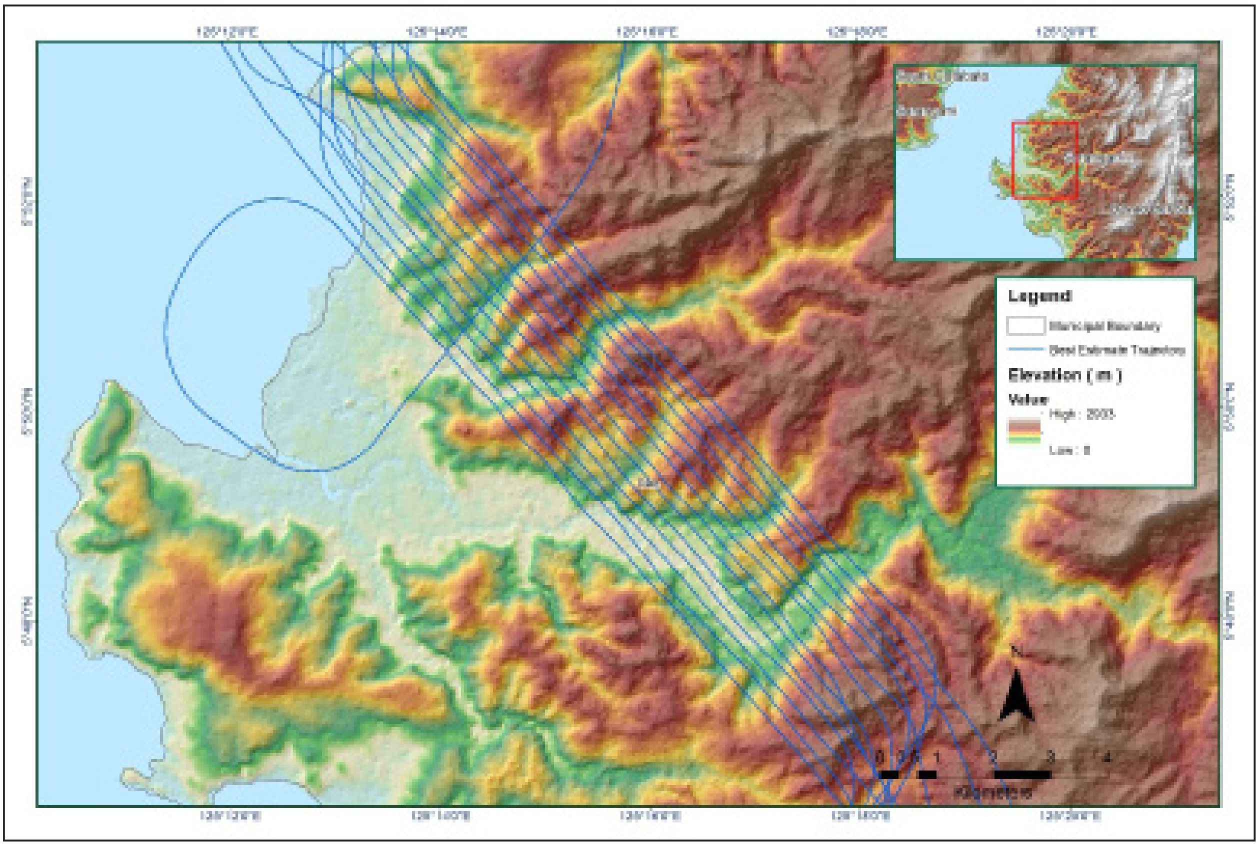


Figure A-8.24. Best Estimated Trajectory

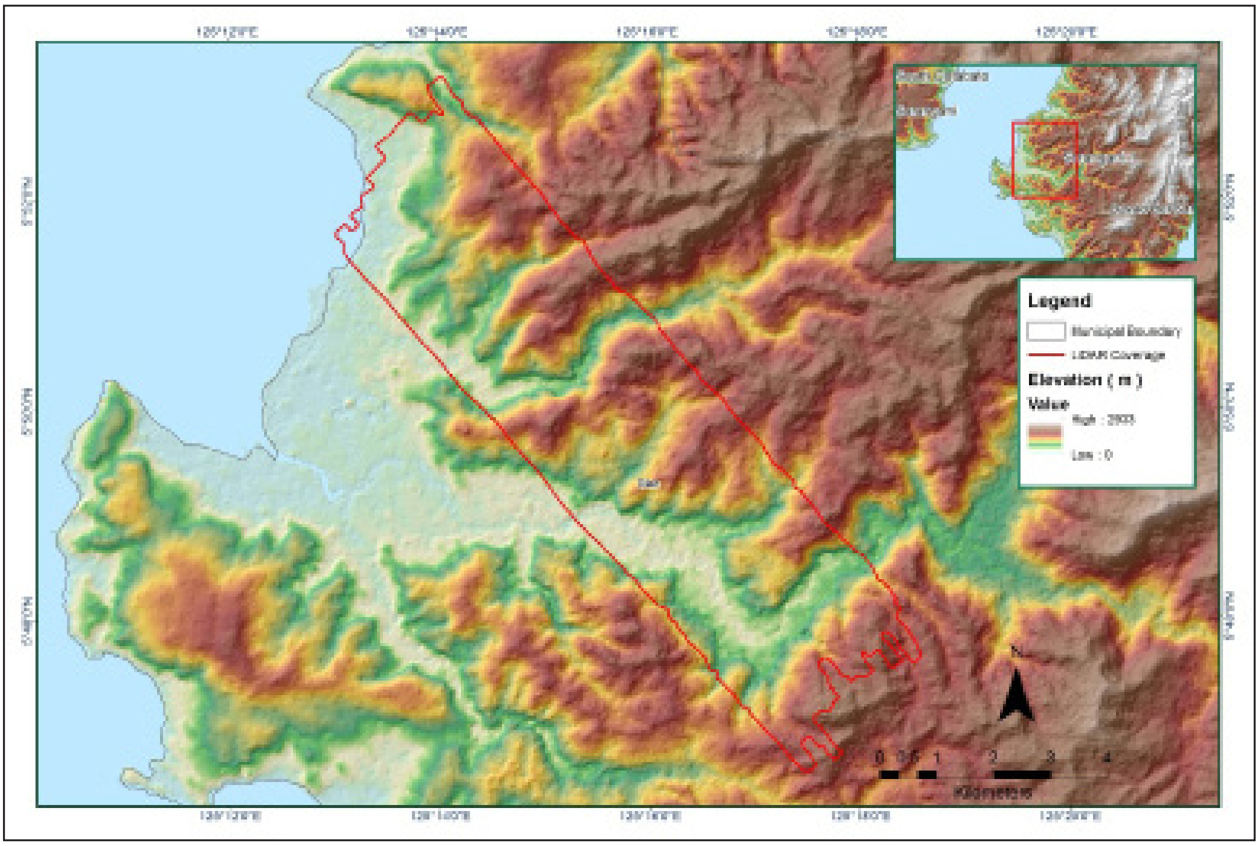


Figure A-8.25. Coverage of LiDAR data

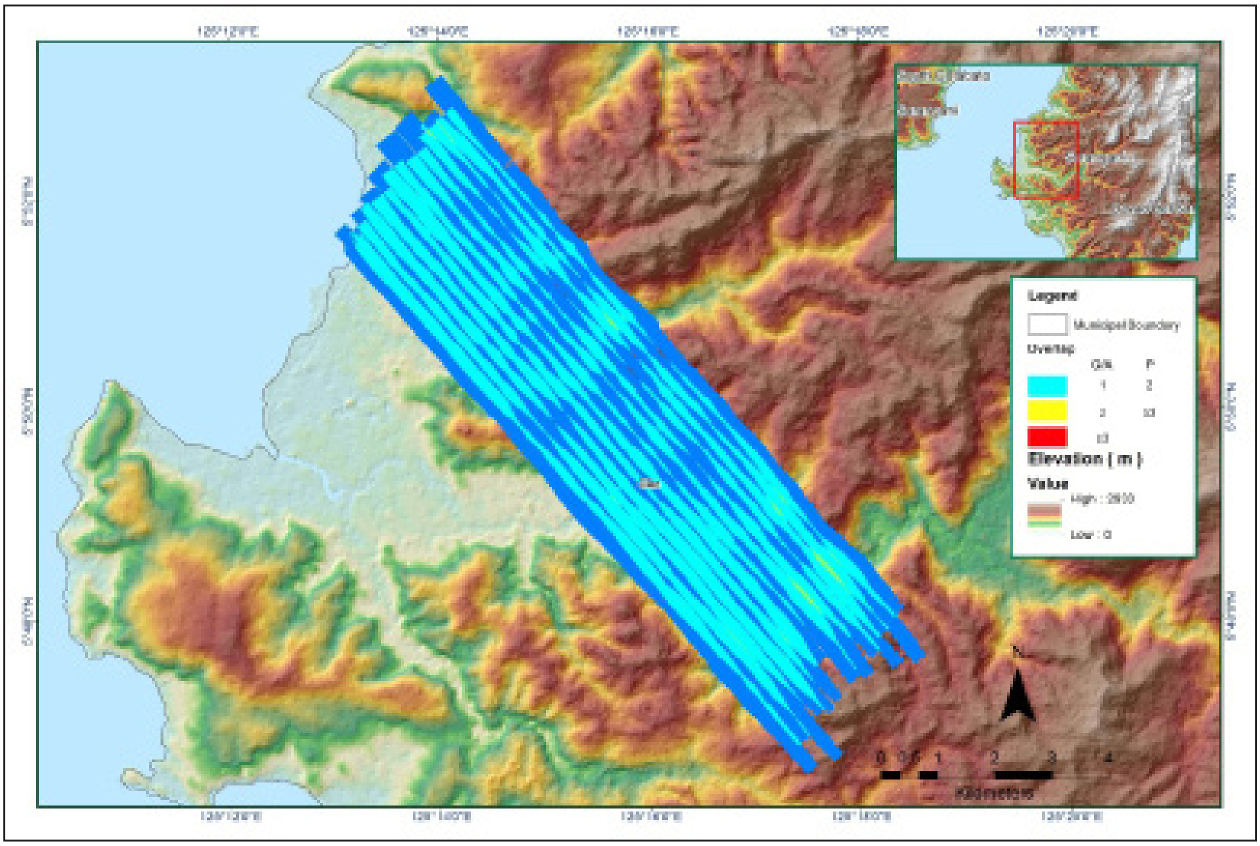


Figure A-8.26. Image of data overlap

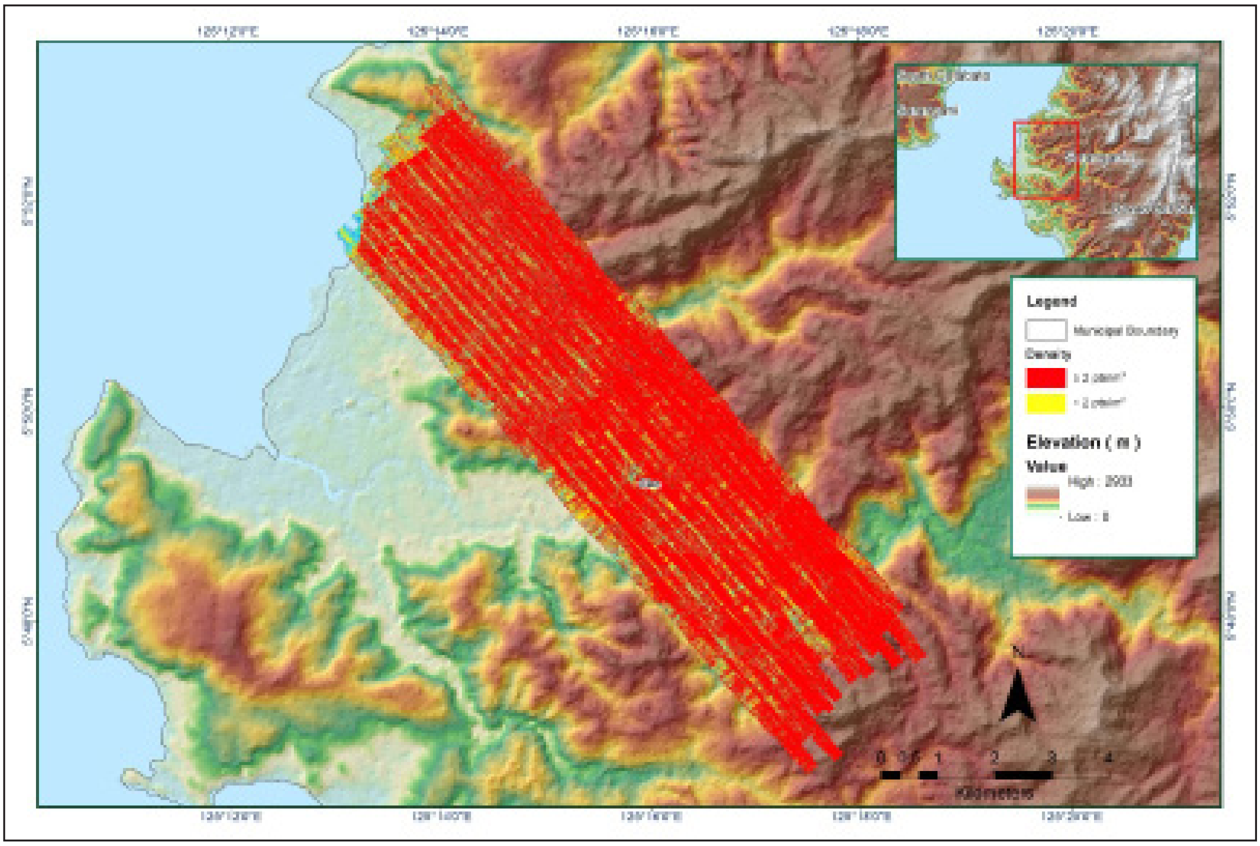


Figure A-8.27. Density map of merged LiDAR data

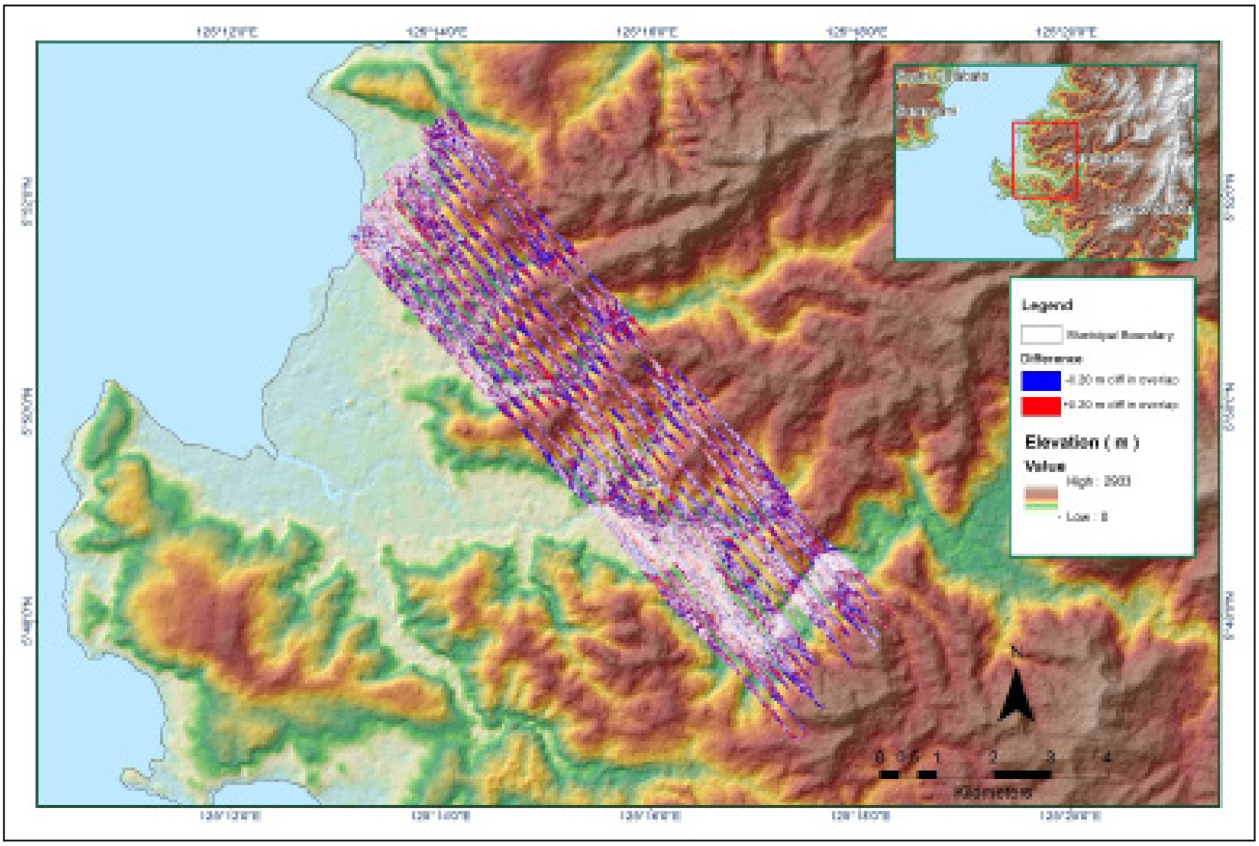


Figure A-8.28. Elevation difference between flight lines

Flight Area	**General Santos**
Mission Name	Blk 90D
Inclusive Flights	2120A, 2122A
Range data size	22.5 GB
POS	423 MB
Image	n/a
Base Station Data	14.48 MB
Transfer date	March 25, 2015
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)	1.3
RMSE for East Position (<4.0 cm)	1.25
RMSE for Down Position (<8.0 cm)	2.8
Boresight correction stdev (<0.001deg)	0.000303
IMU attitude correction stdev (<0.001deg)	0.001323
GPS position stdev (<0.01m)	0.0075
Minimum % overlap (>25)	49.63%
Ave point cloud density per sq.m. (>2.0)	2.98
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	130
Maximum Height	372.92 m
Minimum Height	50.45 m
Classification (# of points)	
Ground	53550595
Low vegetation	46662134
Medium vegetation	57119721
High vegetation	91014022
Building	1779534
Orthophoto	No
Processed by	Engr. Carlyn Ann Ibañez, Engr. Chelou Prado, Engr. Elainne Lopez

Figure A-8.29. Solution Status

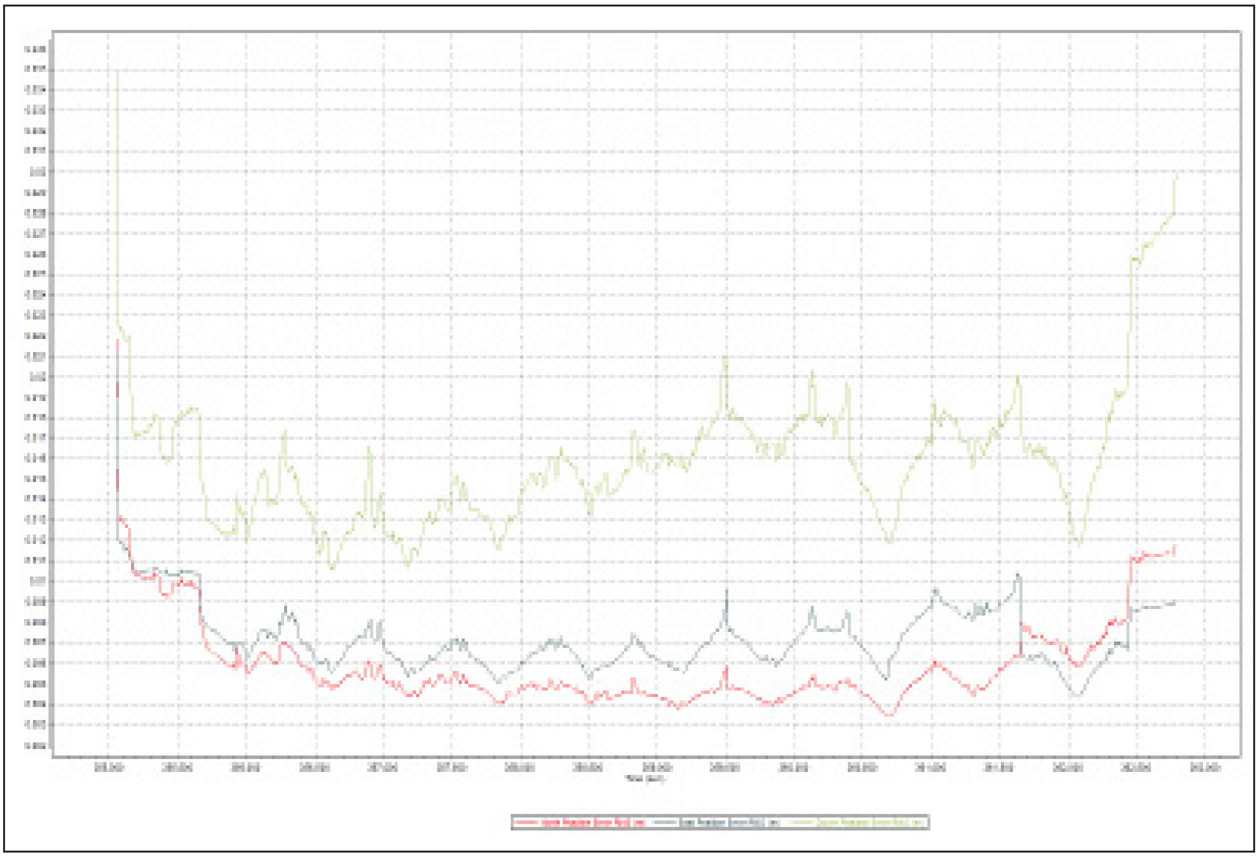


Figure A-8.30. Smoothed Performance Metric Parameters

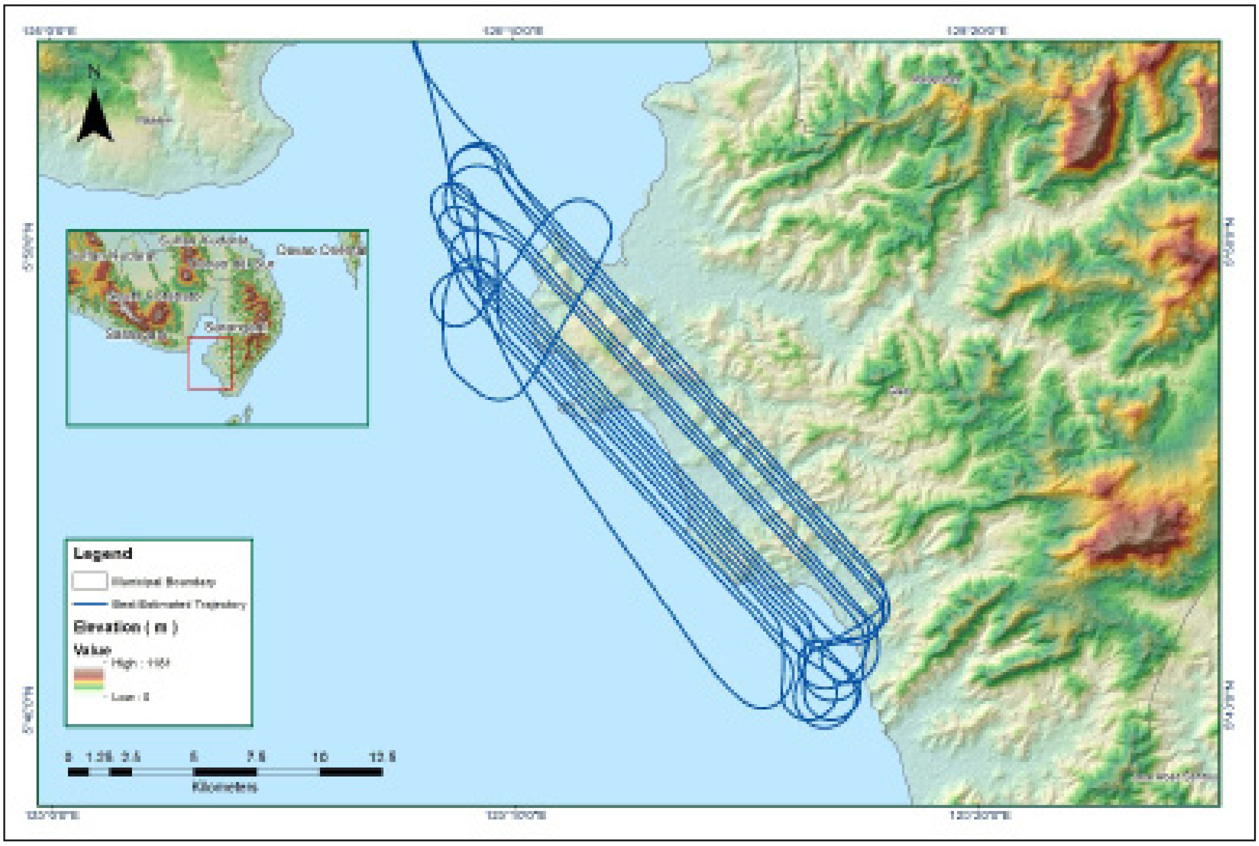


Figure A-8.31. Best Estimated Trajectory

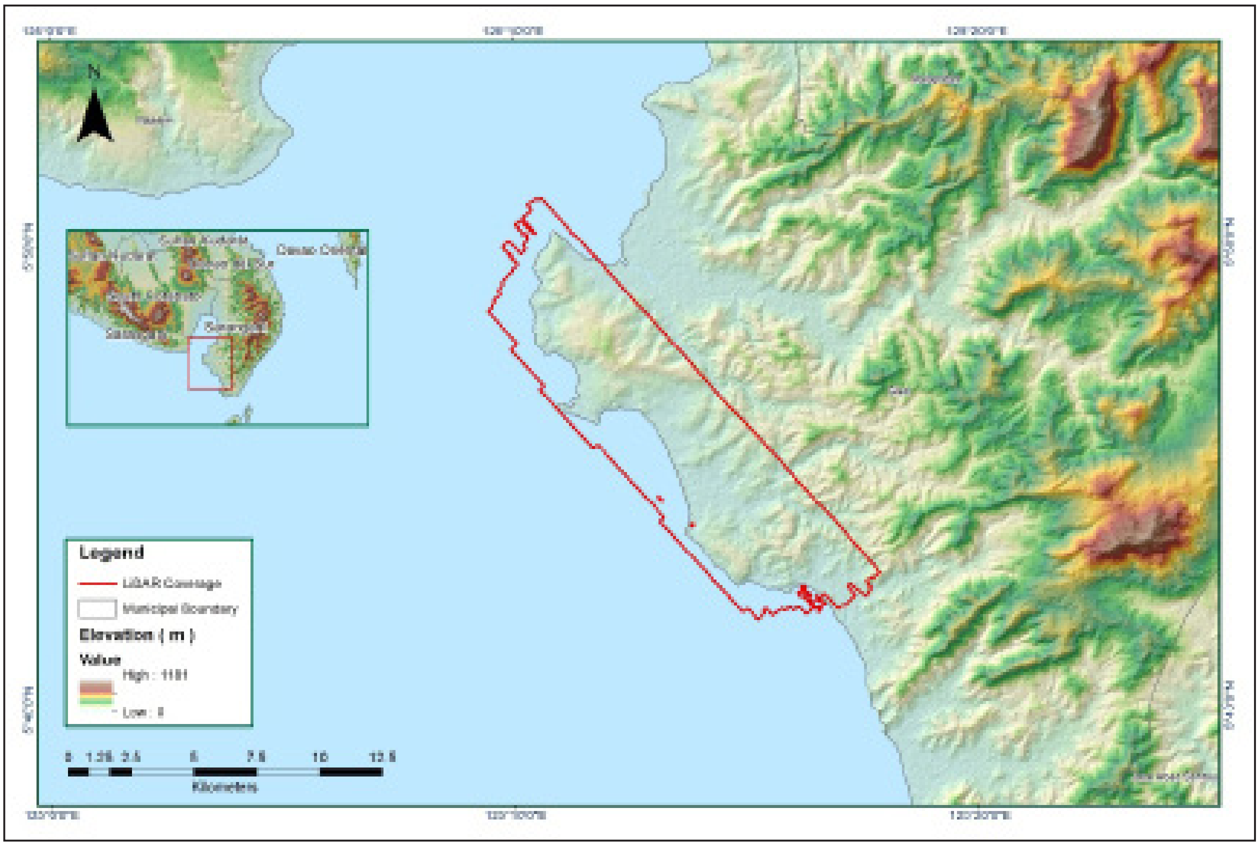


Figure A-8.32. Coverage of LiDAR data

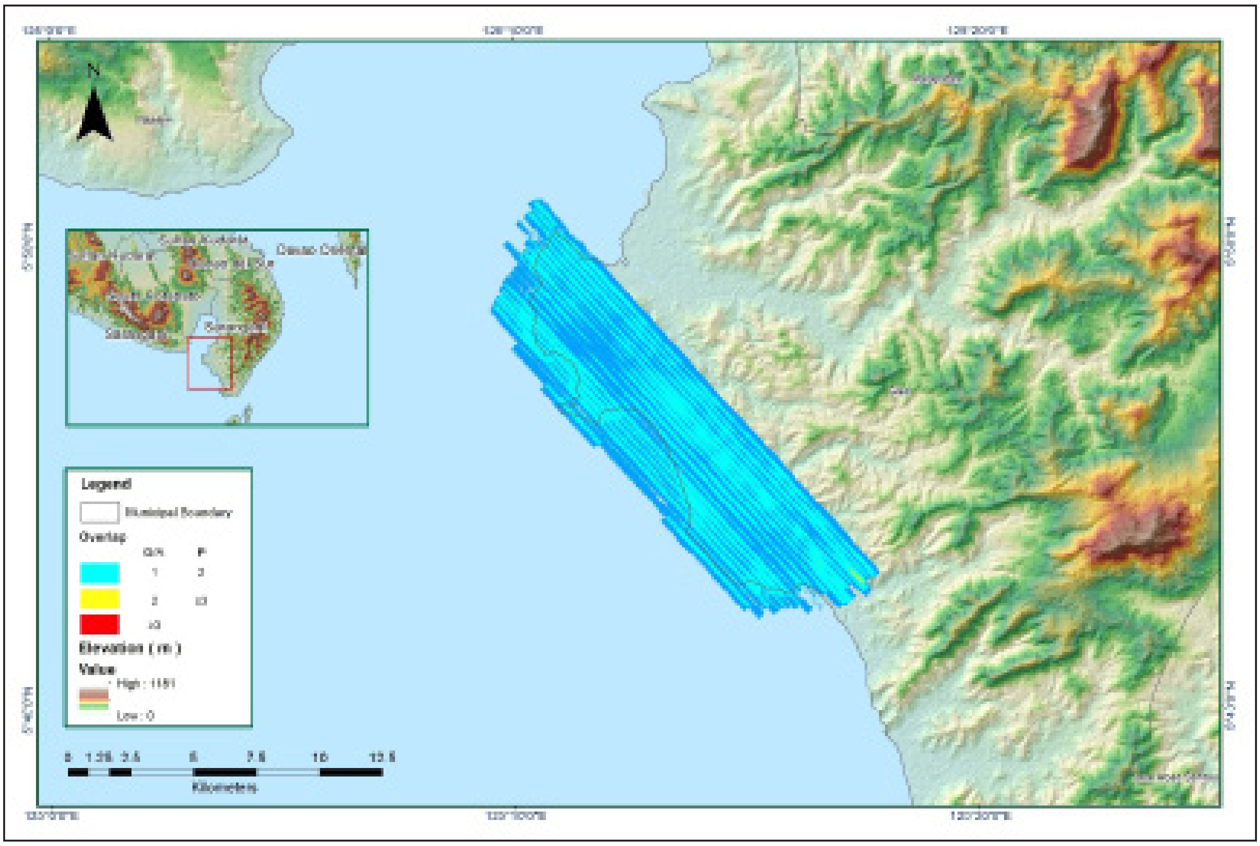


Figure A-8.33. Image of data overlap

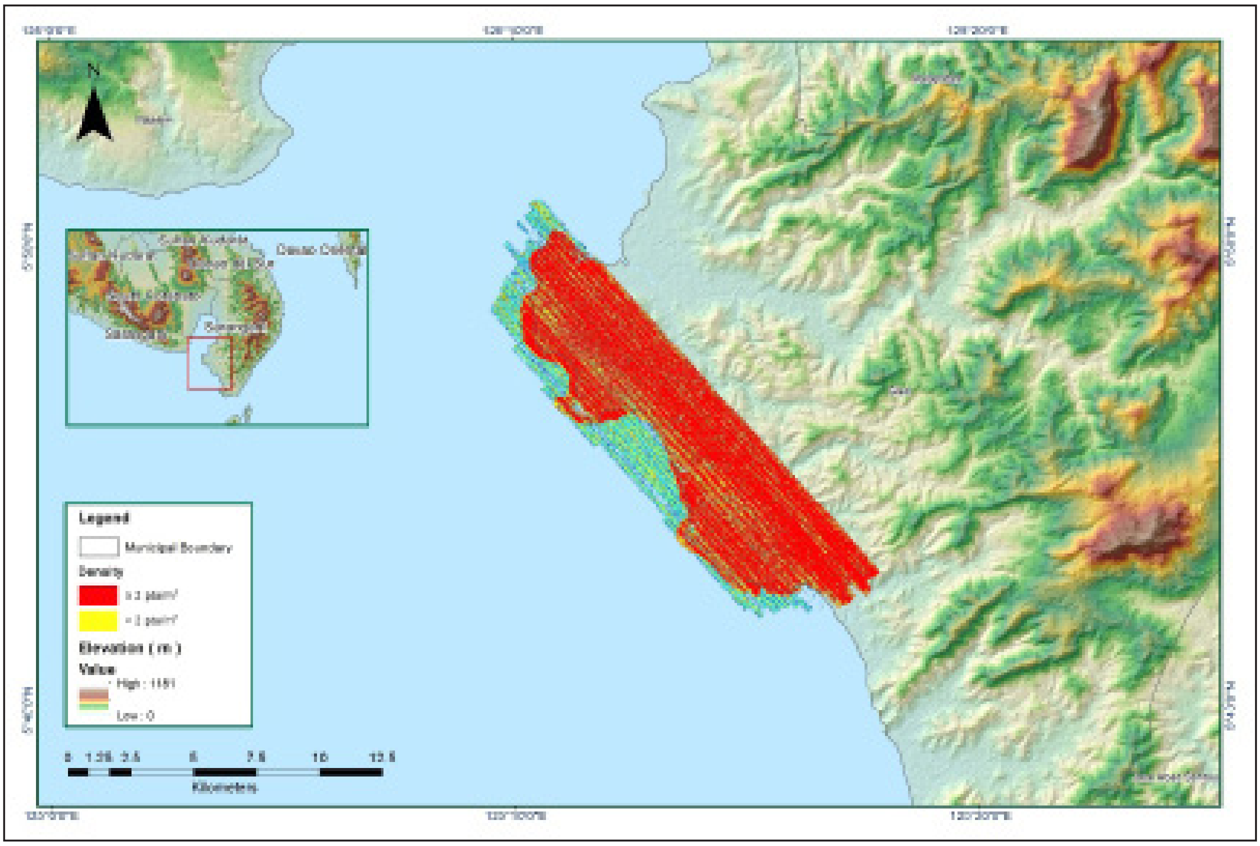


Figure A-8.34. Density map of merged LiDAR data

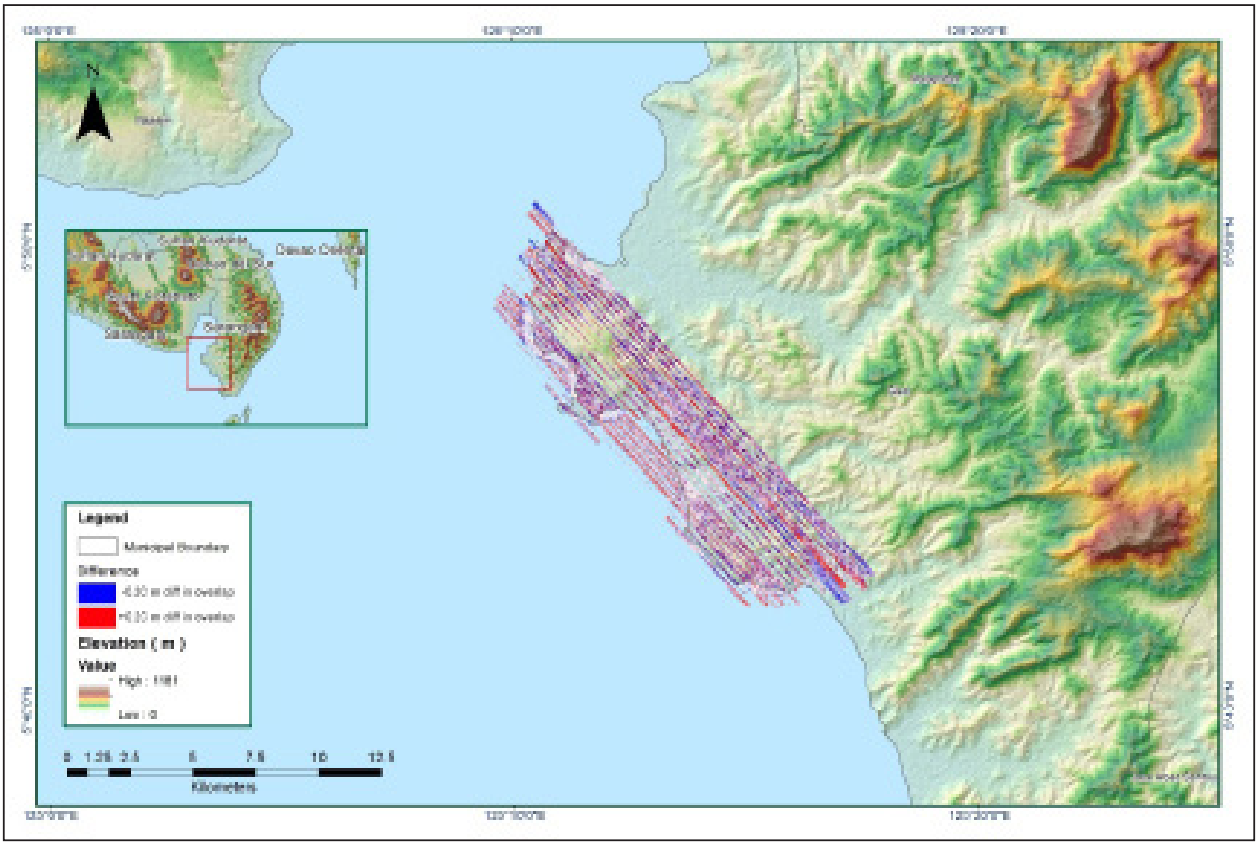


Figure A-8.35. Elevation difference between flight lines

Flight Area	General Santos
Mission Name	BLK 90E
Inclusive Flights	2122A
Range data size	13.7 GB
POS	251 MB
Image	n/a
Base station data	8.7 MB
Transfer date	March 25,2015
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)	1.44
RMSE for East Position (<4.0 cm)	1.62
RMSE for Down Position (<8.0 cm)	3.33
Boresight correction stdev (<0.001deg)	0.000221
IMU attitude correction stdev (<0.001deg)	0.001040
GPS position stdev (<0.01m)	0.0024
Minimum % overlap (>25)	52.60
Ave point cloud density per sq.m. (>2.0)	4.03
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	103
Maximum Height	539.61 m
Minimum Height	59.94 m
Classification (# of points)	
Ground	44116613
Low vegetation	41409470
Medium vegetation	60639483
High vegetation	59673030
Building	3459011
Orthophoto	No
Processed by	Engr. Jennifer Saguran, Engr. Edgardo Gubatanga Jr., Alex John Escobido

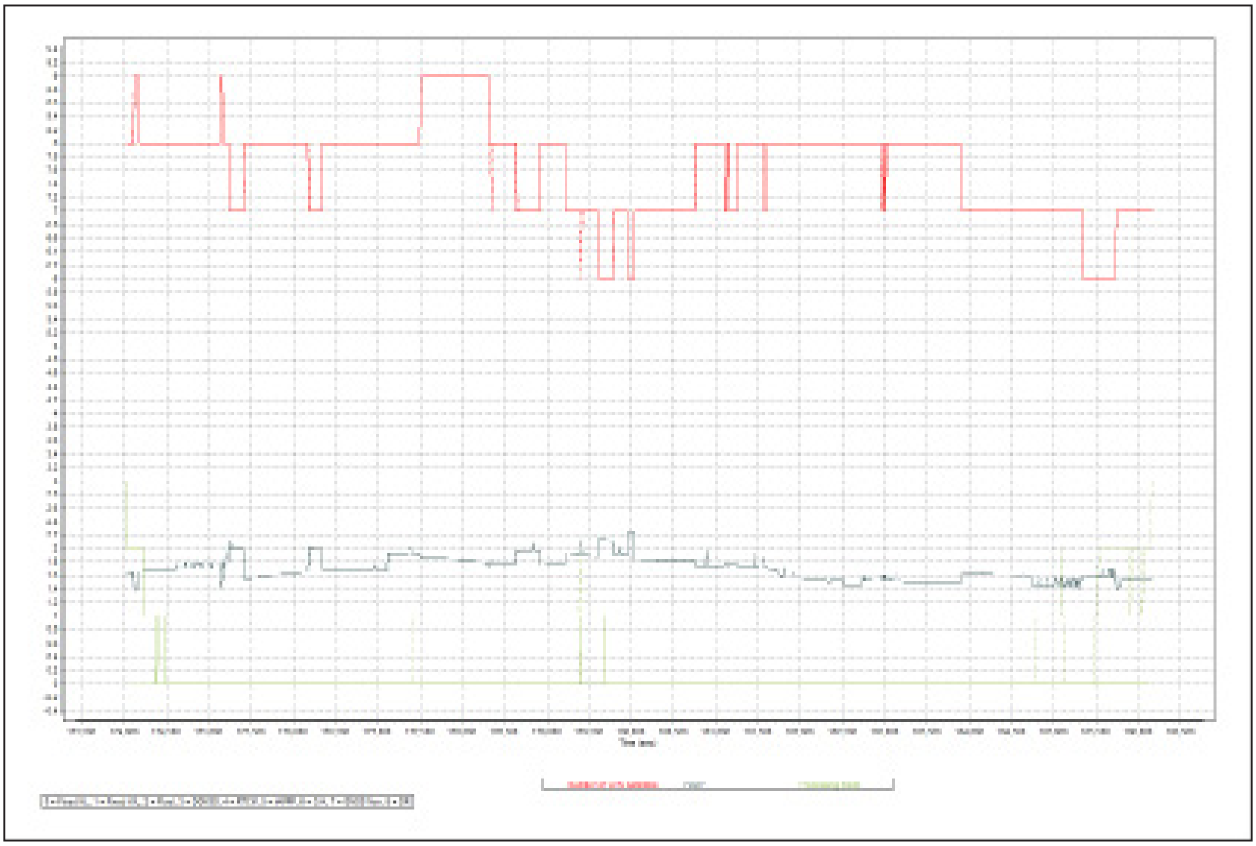


Figure A-8.36. Solution Status

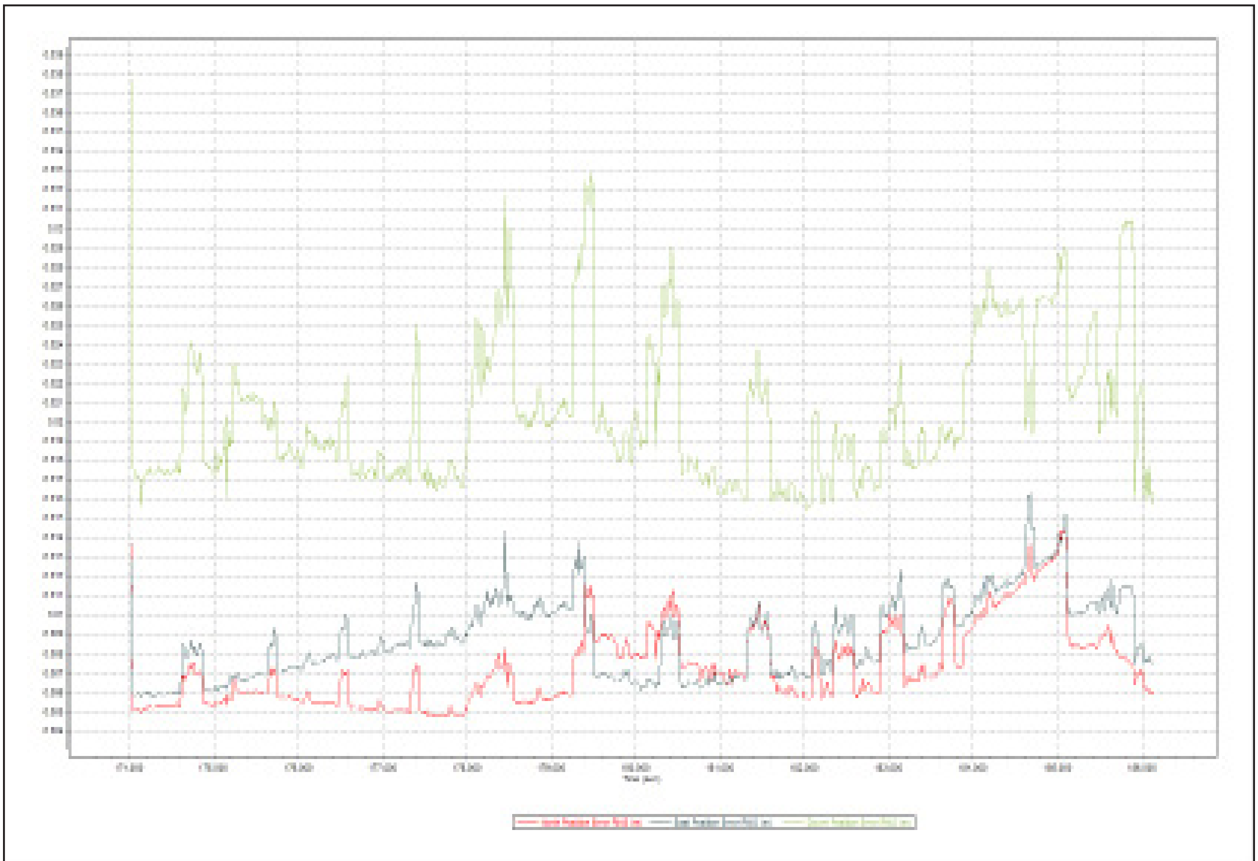


Figure A-8.37. Smoothed Performance Metric Parameters

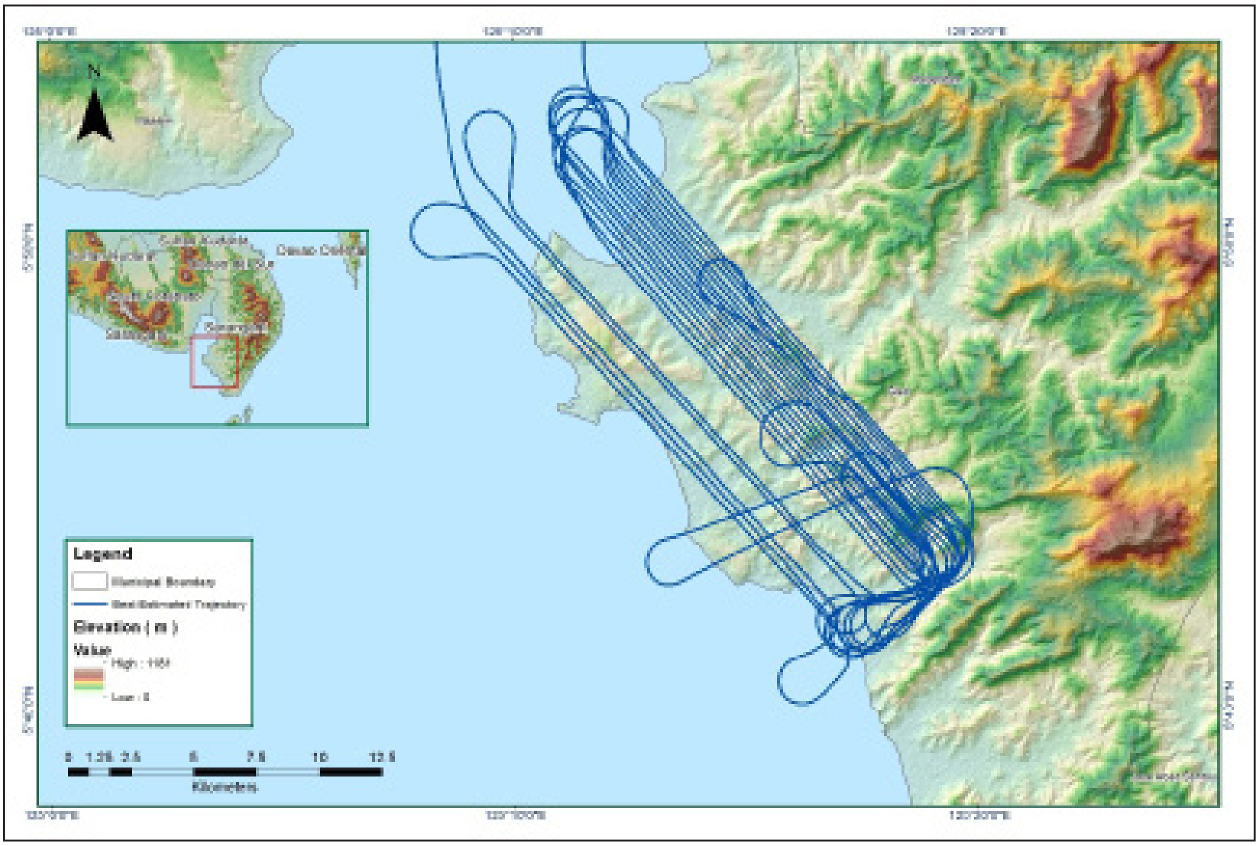


Figure A-8.38. Best Estimated Trajectory

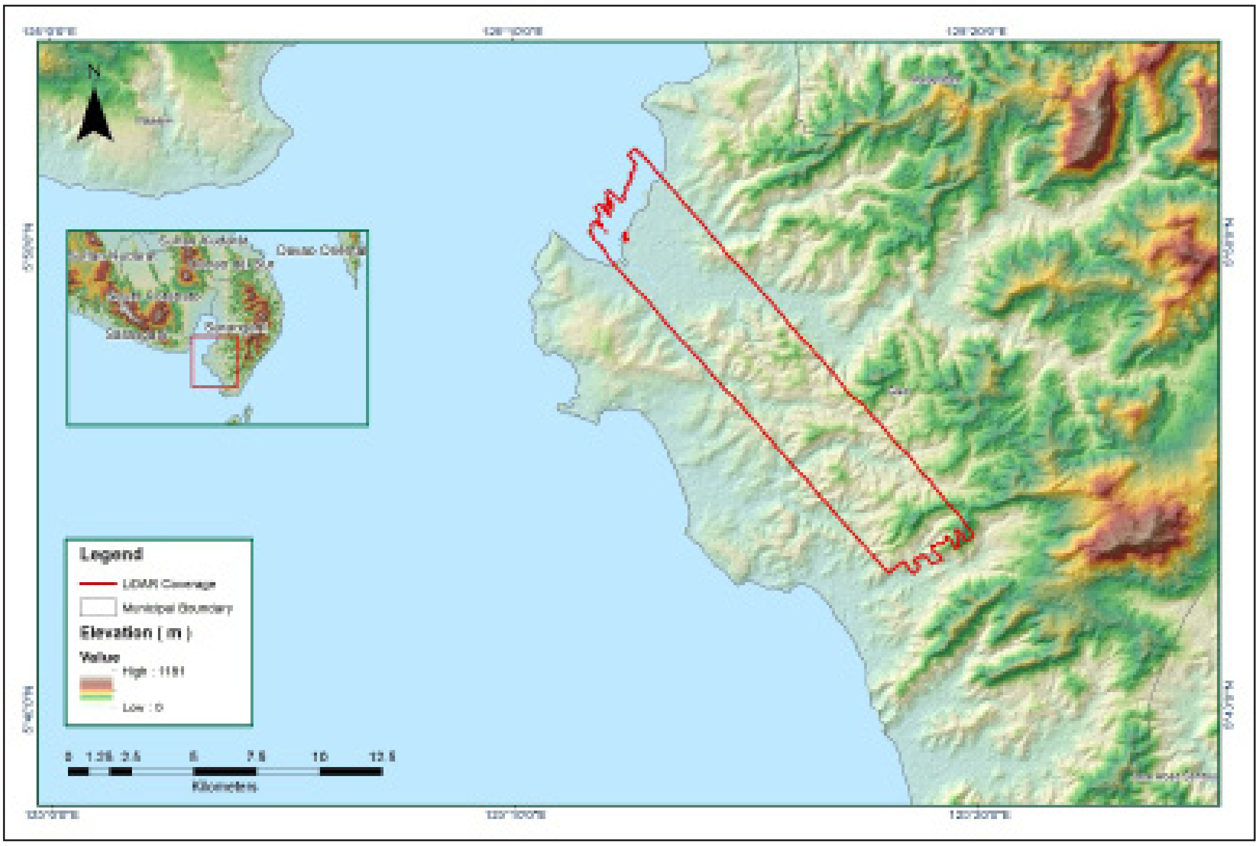


Figure A-8.39. Coverage of LiDAR data

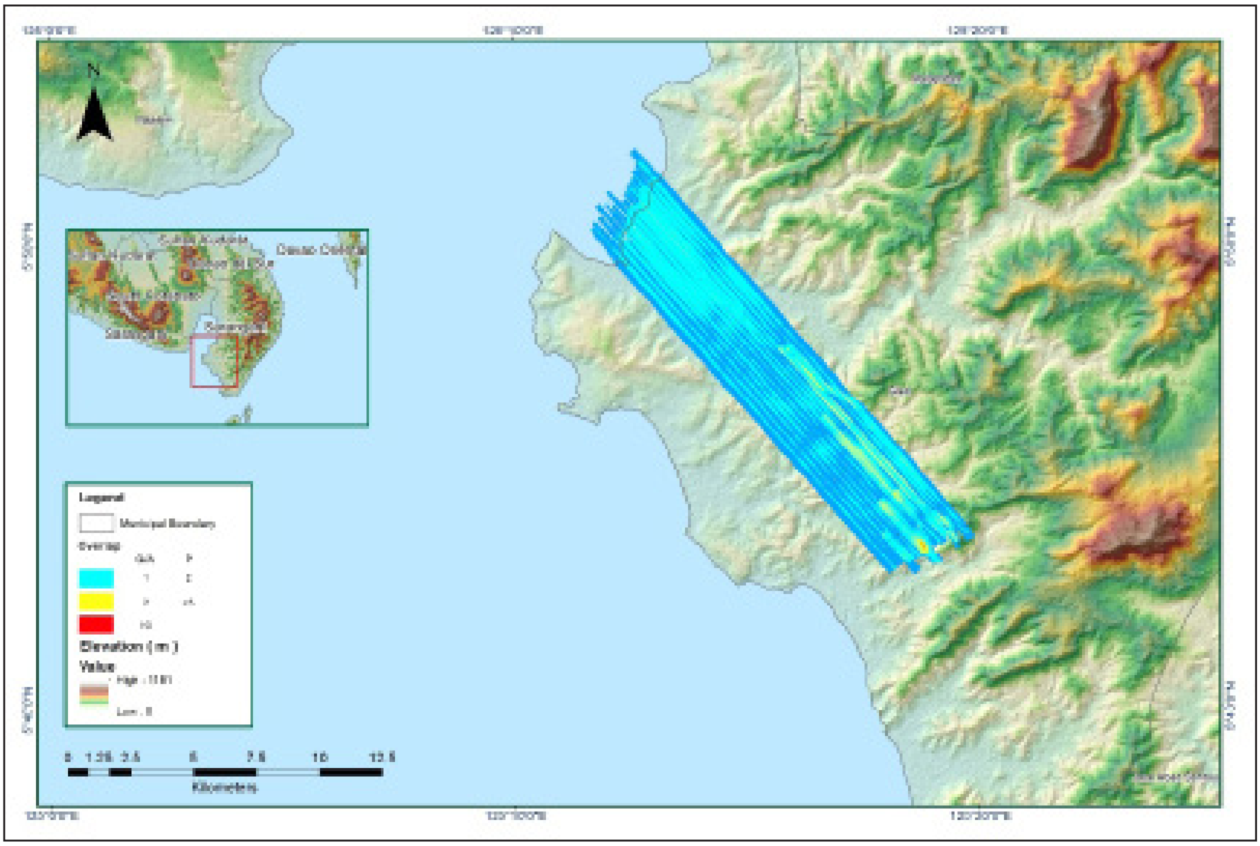


Figure A-8.40. Image of data overlap

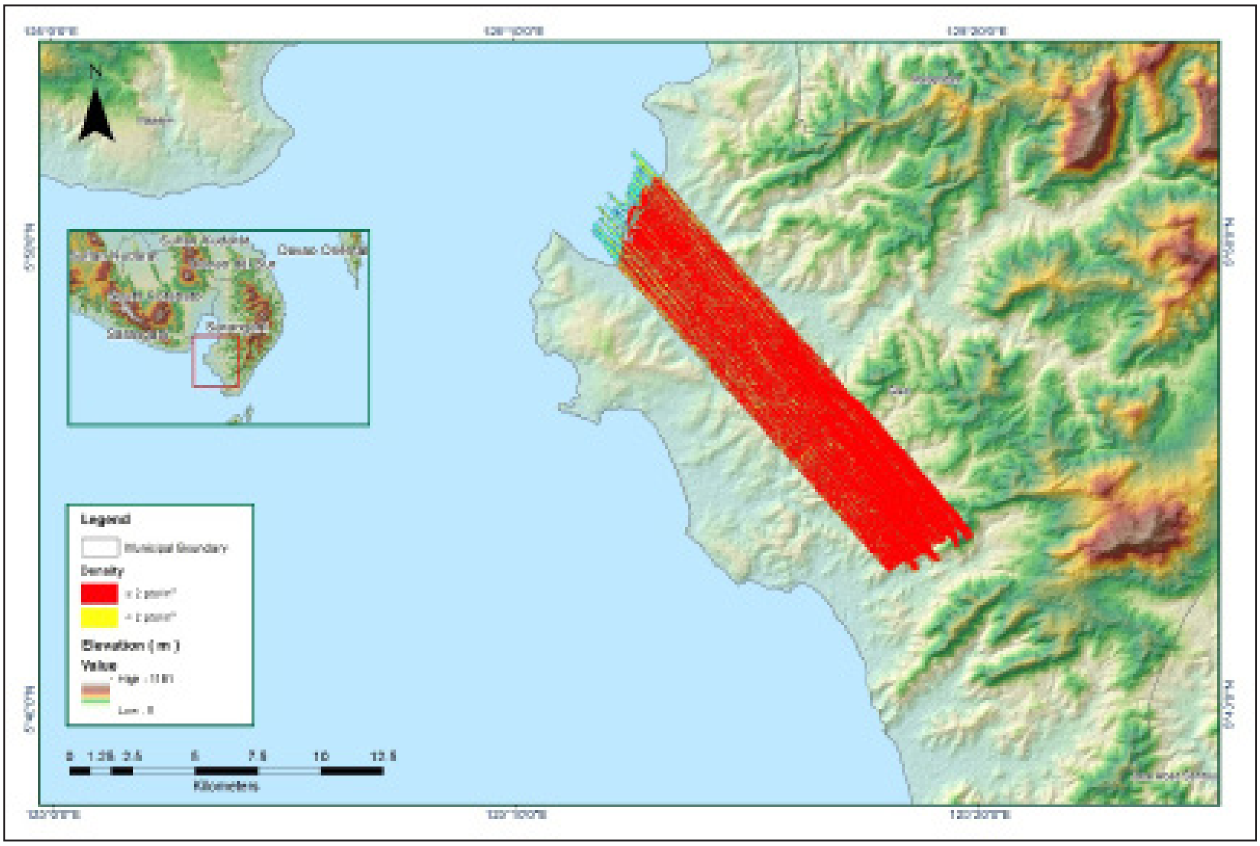


Figure A-8.41. Density map of merged LiDAR data

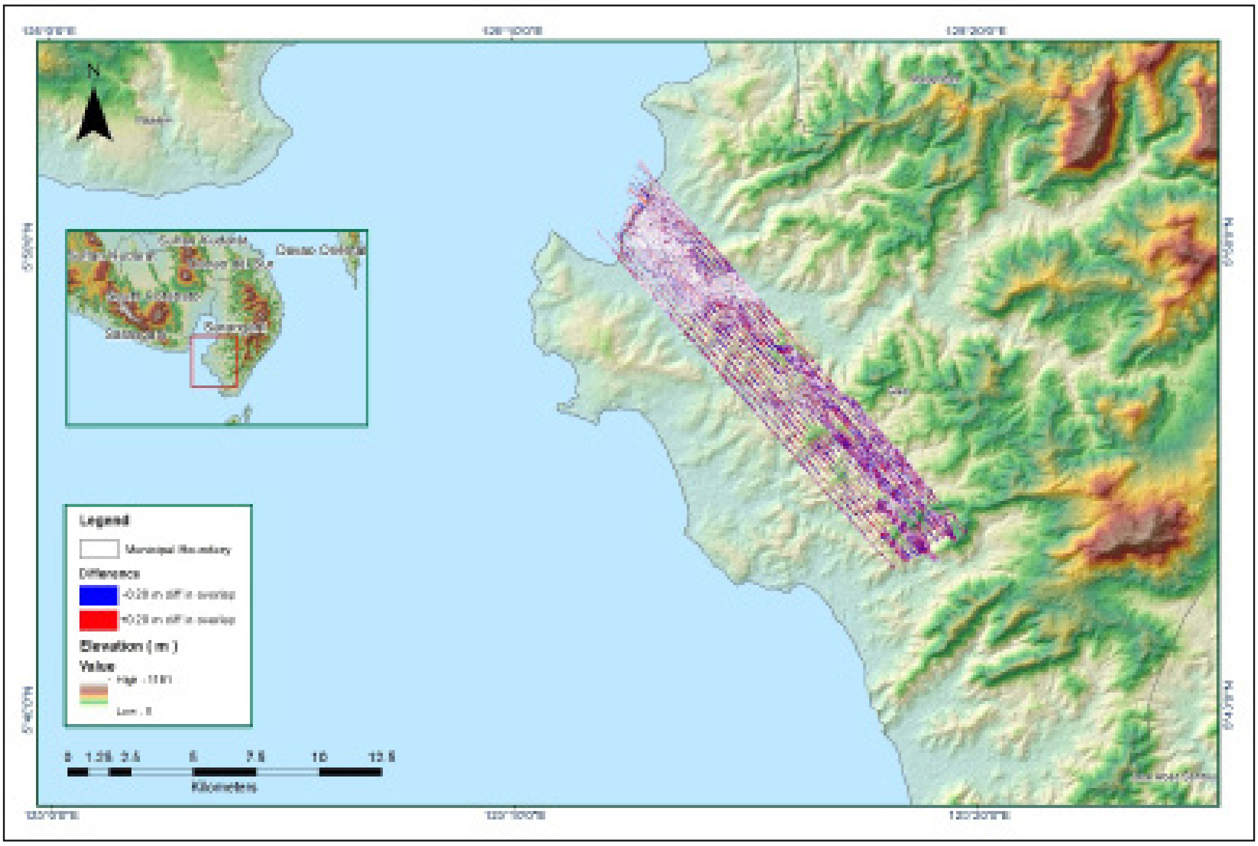


Figure A-8.42. Elevation difference between flight lines

Flight Area	Buayan
Mission Name	Blk 2C_additional
Inclusive Flights	2150A
Range data size	4.88 GB
POS	195 MB
Image	NA
Transfer date	November 19, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.19
RMSE for East Position (<4.0 cm)	1.13
RMSE for Down Position (<8.0 cm)	3.27
Boresight correction stdev (<0.001deg)	0.000720
IMU attitude correction stdev (<0.001deg)	0.002817
GPS position stdev (<0.01m)	0.0219
Minimum % overlap (>25)	11.14%
Ave point cloud density per sq.m. (>2.0)	2.86
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	43
Maximum Height	246.7
Minimum Height	63.68
Classification (# of points)	
Ground	7753451
Low vegetation	7672693
Medium vegetation	6205668
High vegetation	5200343
Building	423068
Orthophoto	no
Processed by	Engr. Carlyn Ann Ibañez, Engr. Chelou Prado, Engr. Jeffrey Delica

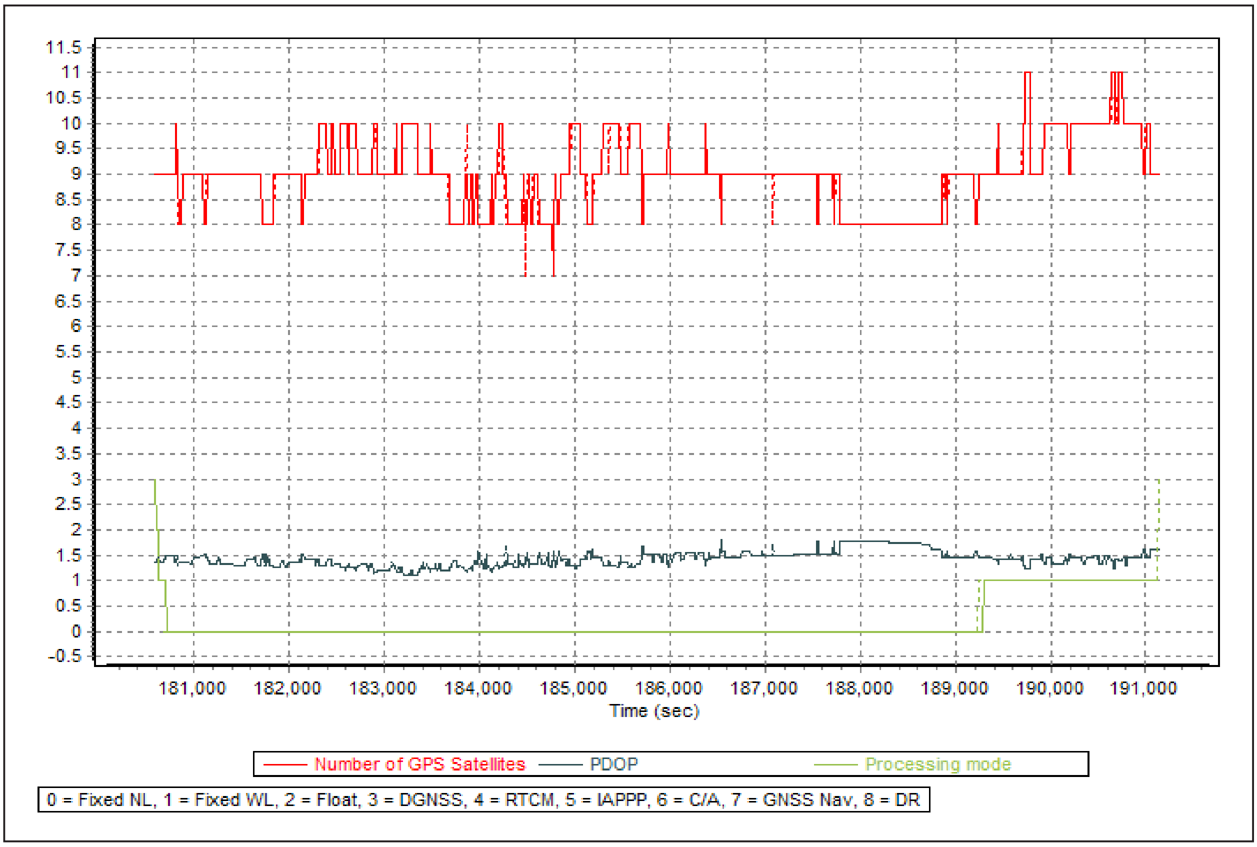


Figure A-8.43. Solution Status

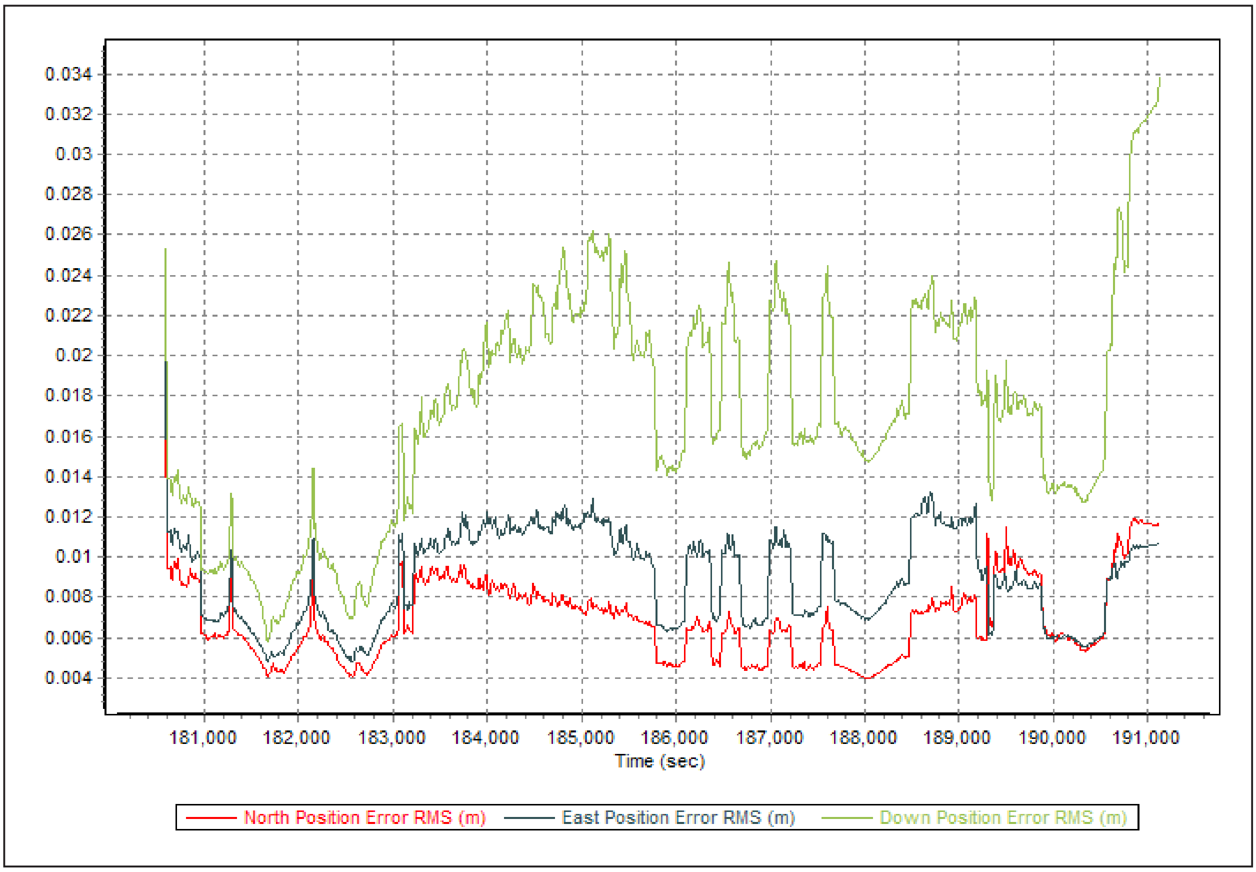


Figure A-8.44. Smoothed Performance Metric Parameters

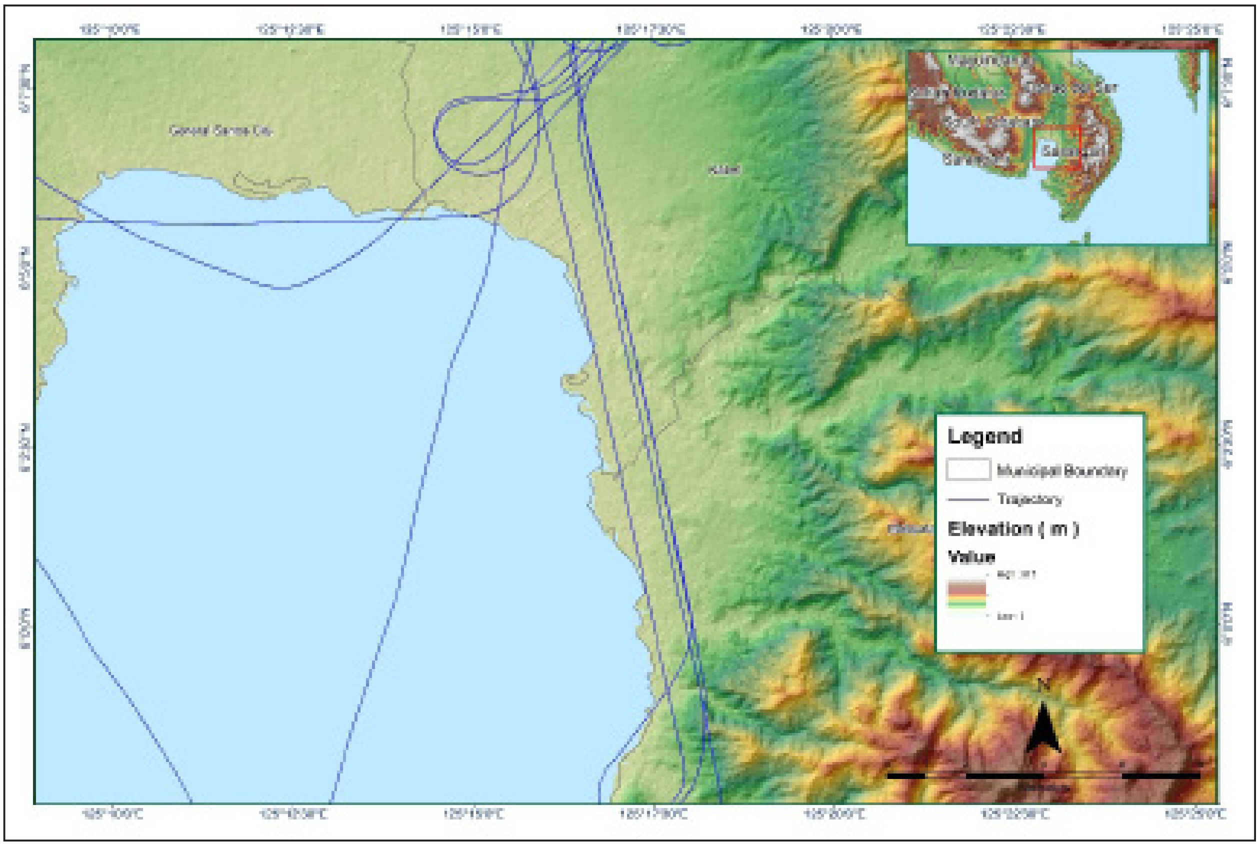


Figure A-8.45. Best Estimated Trajectory

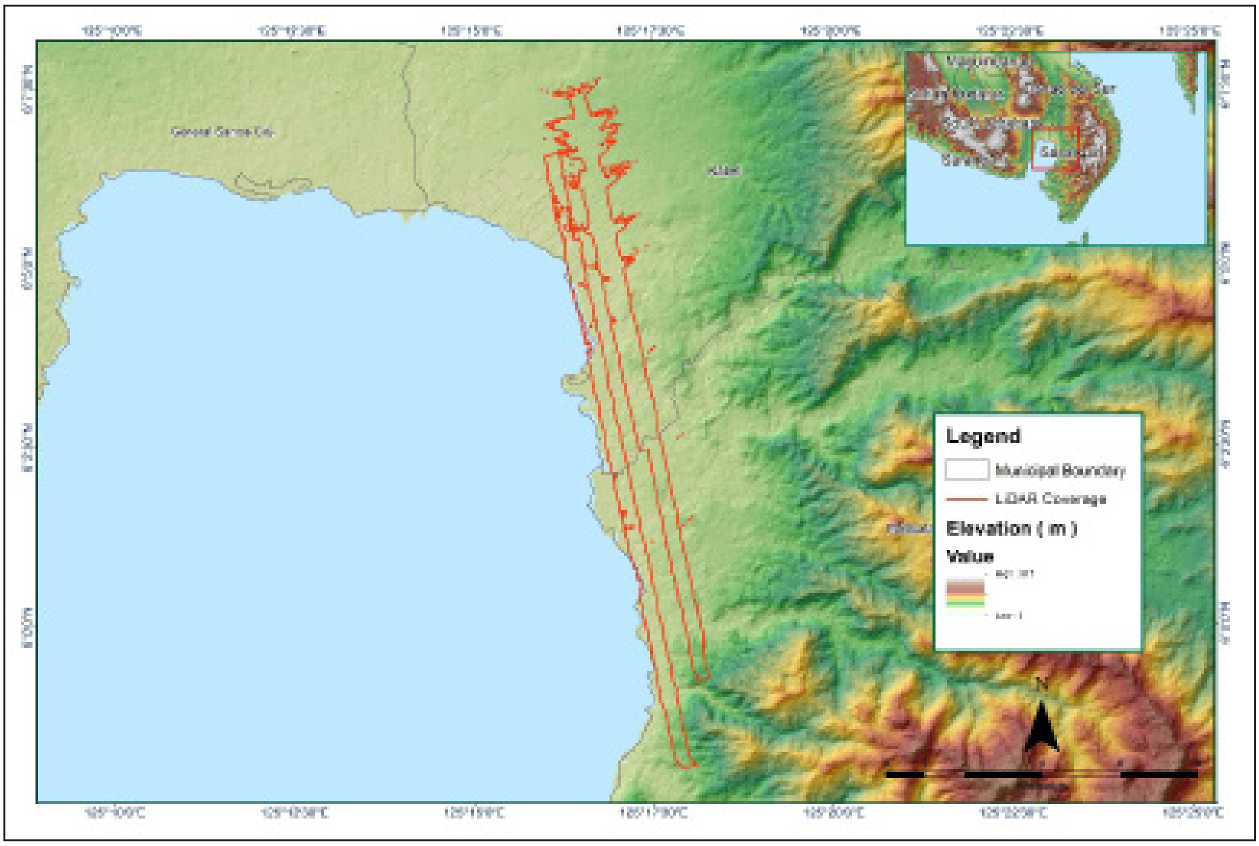


Figure A-8.46. Coverage of LiDAR data

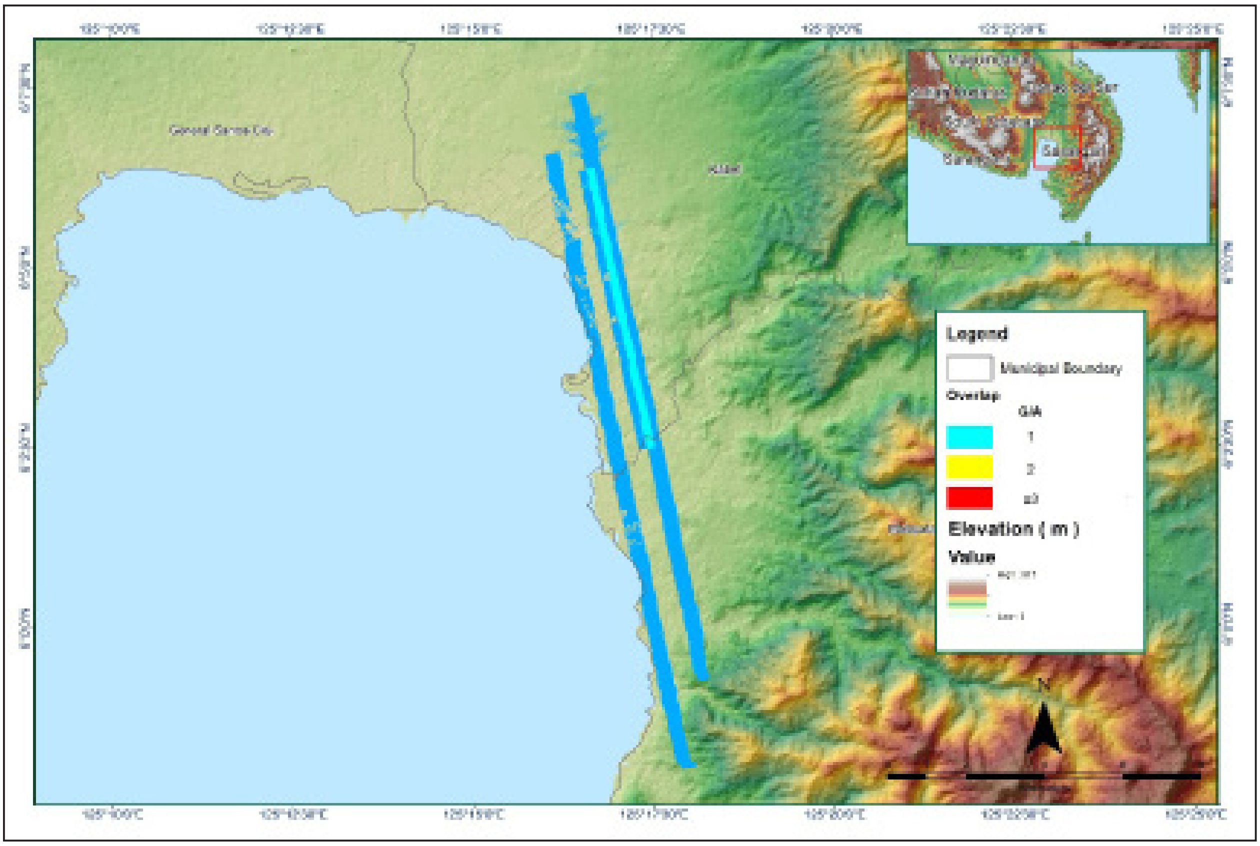


Figure A-8.47. Image of data overlap

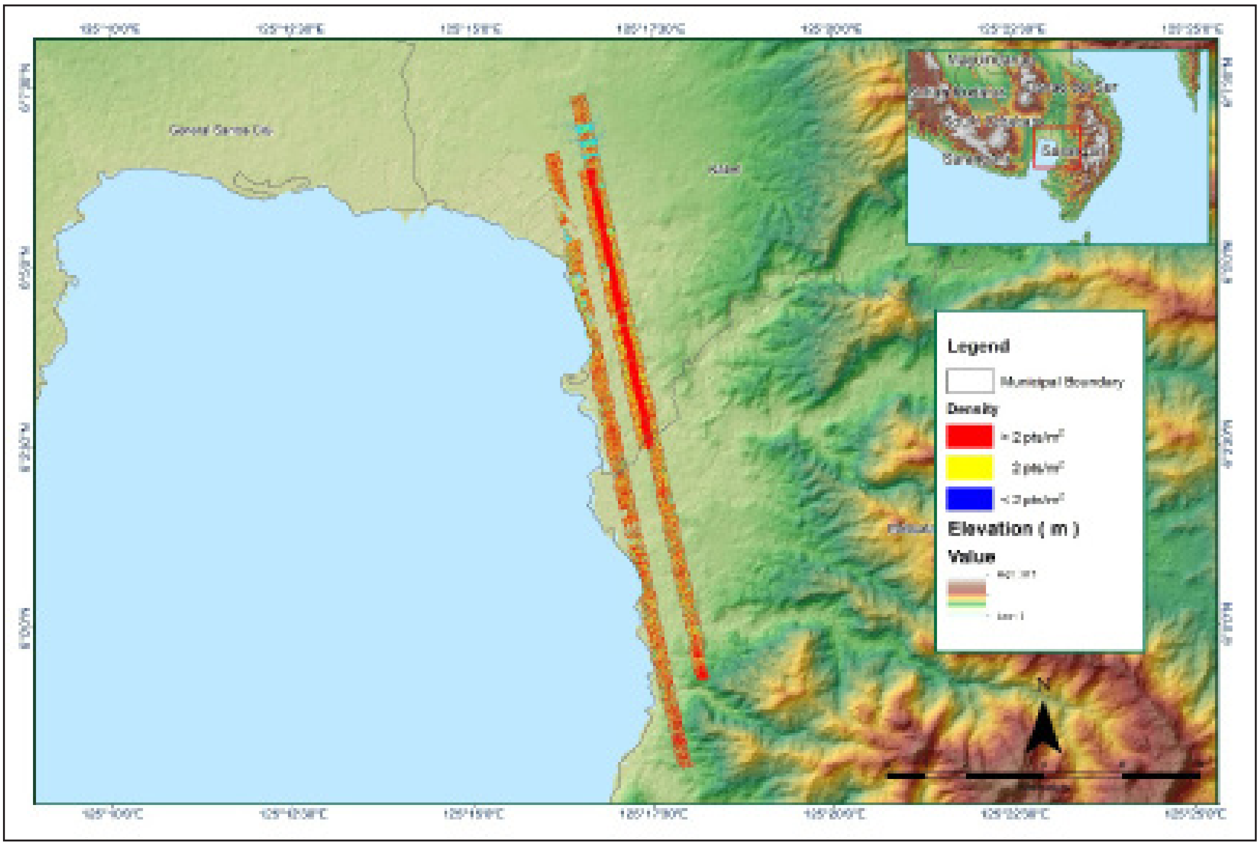


Figure A-8.48. Density map of merged LiDAR data

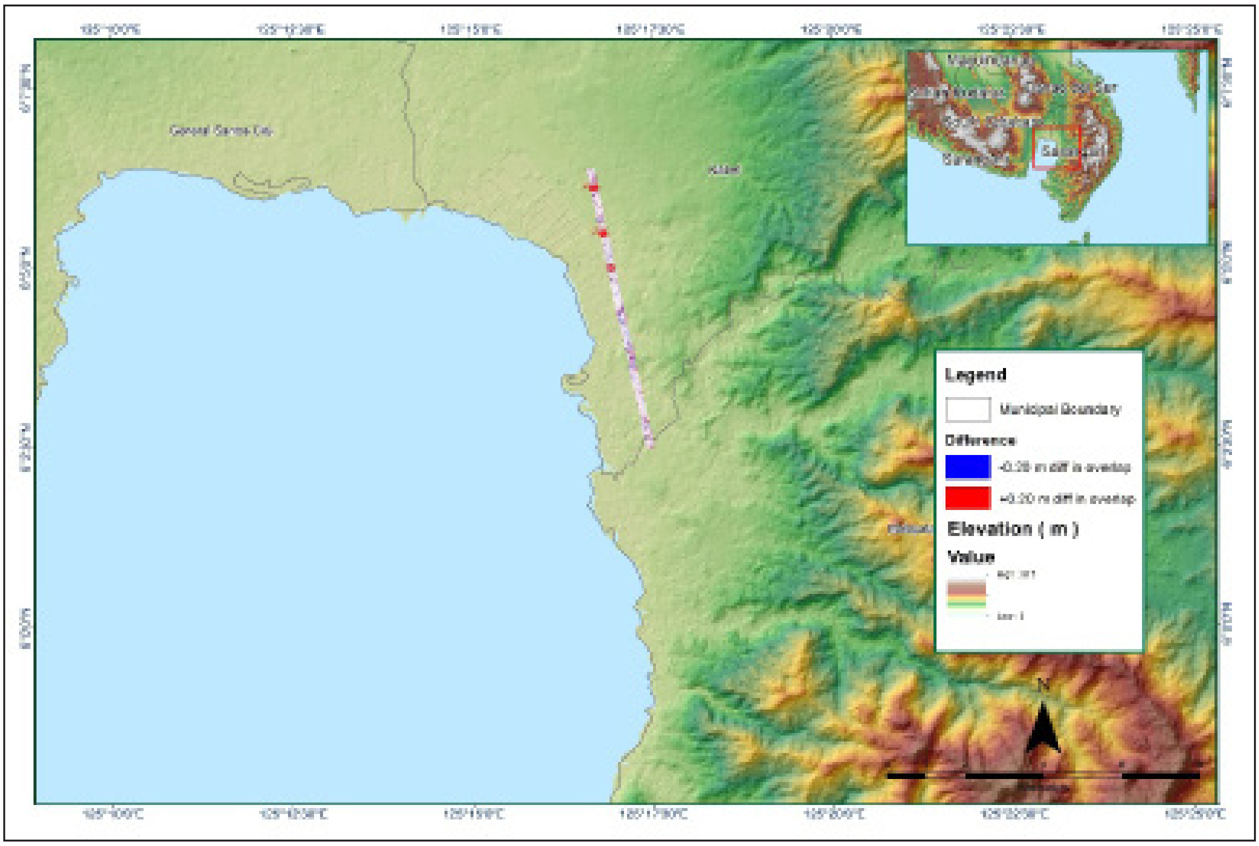


Figure A-8.49. Elevation difference between flight lines

Flight Area	Butuan
Mission Name	
Inclusive Flights	
Range data size	
POS	
Image	
Transfer date	
Solution Status	
Number of Satellites (>6)	
PDOP (<3)	
Baseline Length (<30km)	
Processing Mode (<=1)	
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	
RMSE for East Position (<4.0 cm)	
RMSE for Down Position (<8.0 cm)	
Boresight correction stdev (<0.001deg)	
IMU attitude correction stdev (<0.001deg)	
GPS position stdev (<0.01m)	
Minimum % overlap (>25)	
Ave point cloud density per sq.m. (>2.0)	
Elevation difference between strips (<0.20 m)	
Number of 1km x 1km blocks	
Maximum Height	
Minimum Height	
Classification (# of points)	
Ground	
Low vegetation	
Medium vegetation	
High vegetation	
Building	
Orthophoto	
Processed by	

Figure A-8.50. Solution Status

Figure A-8.51. Smoothed Performance Metric Parameters

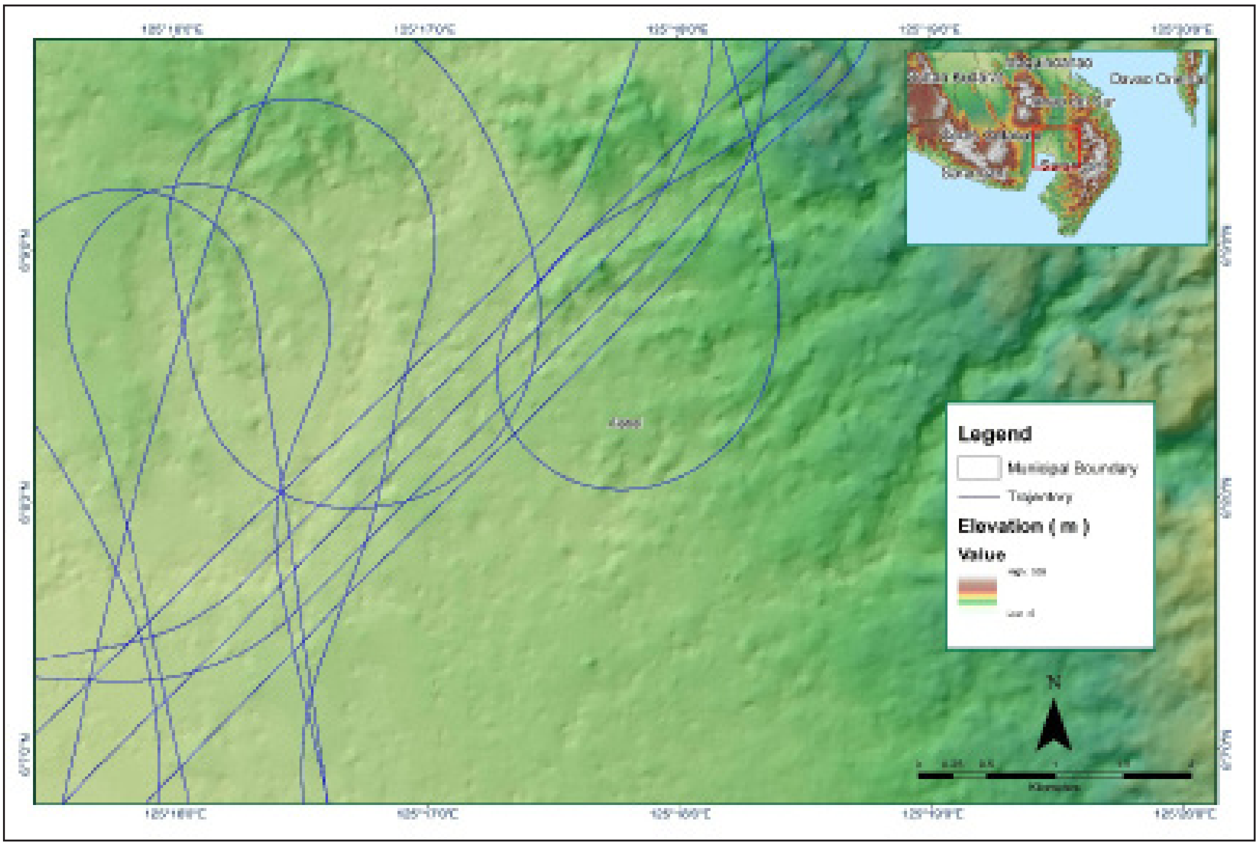


Figure A-8.52. Best Estimated Trajectory

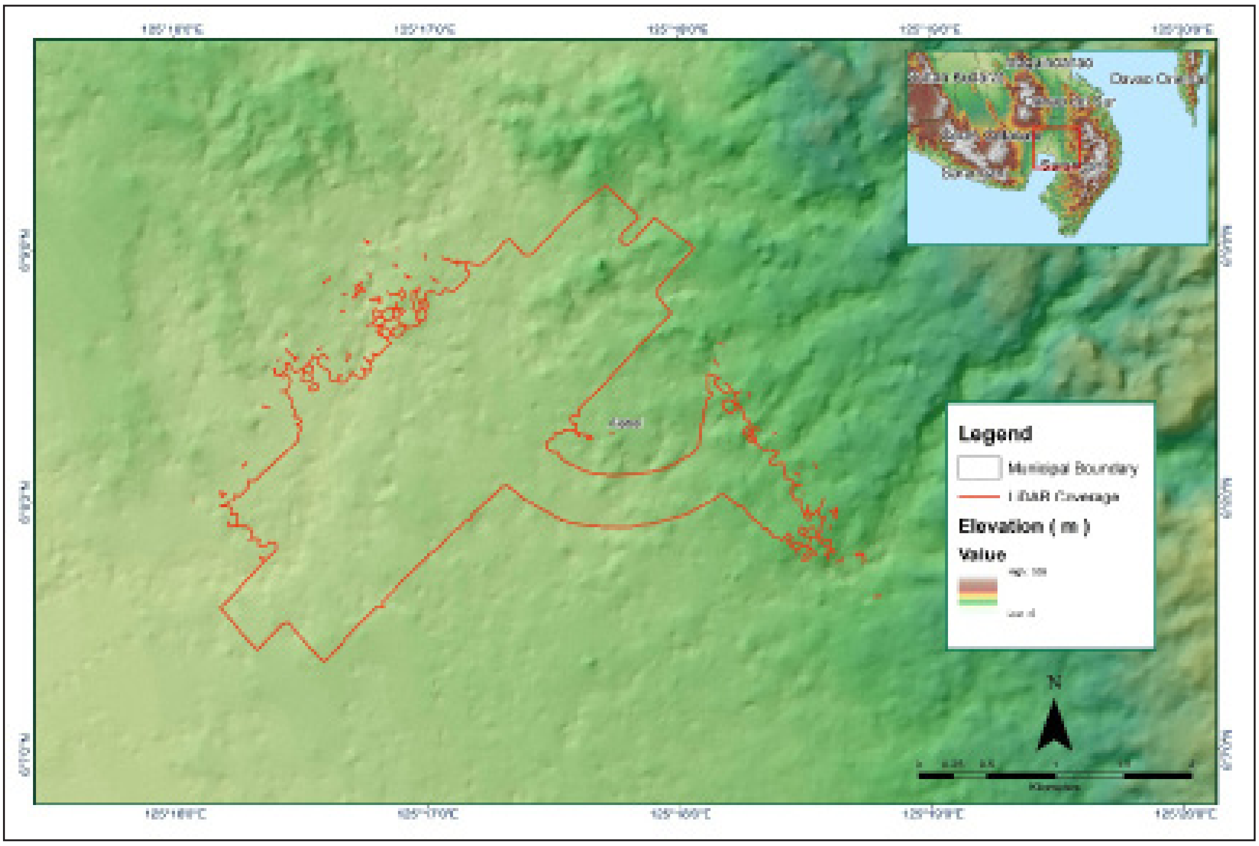


Figure A-8.53. Coverage of LiDAR data

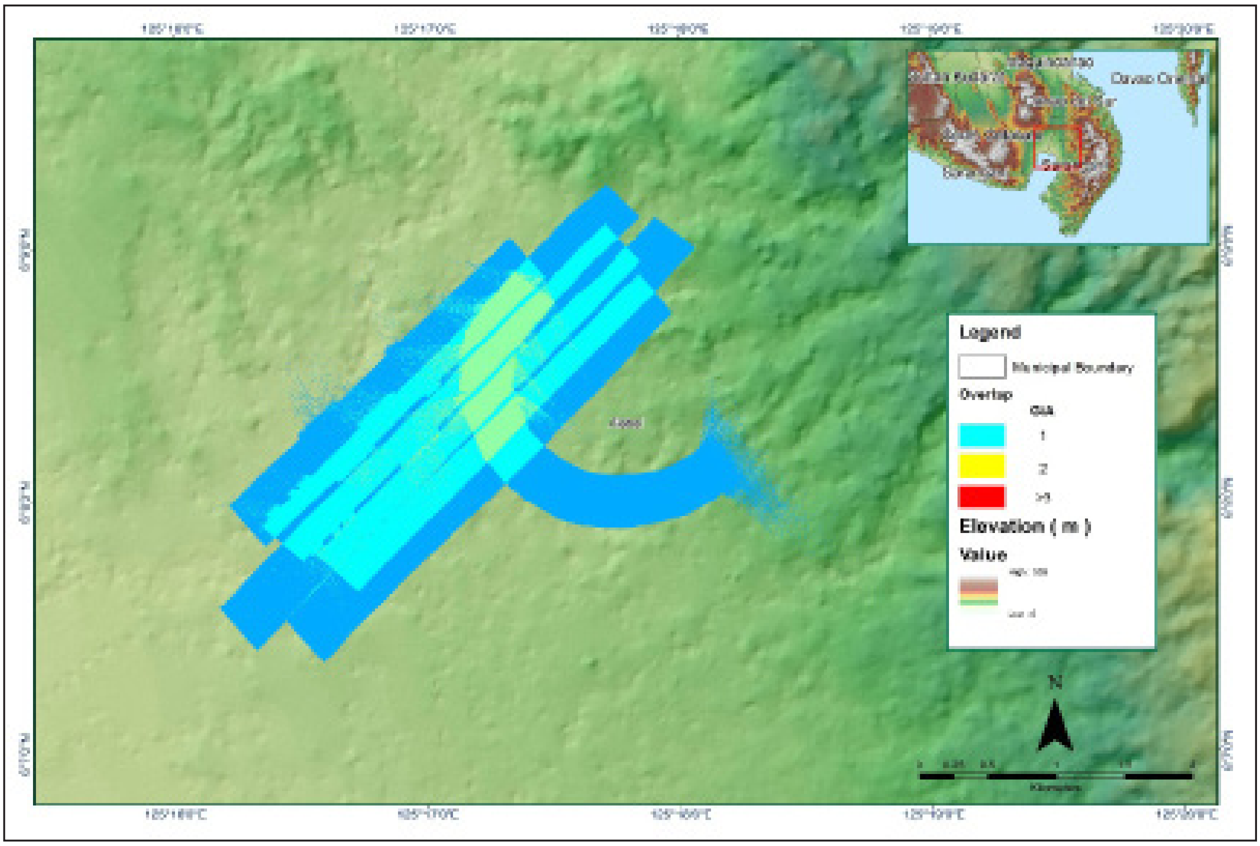


Figure A-8.54. Image of data overlap

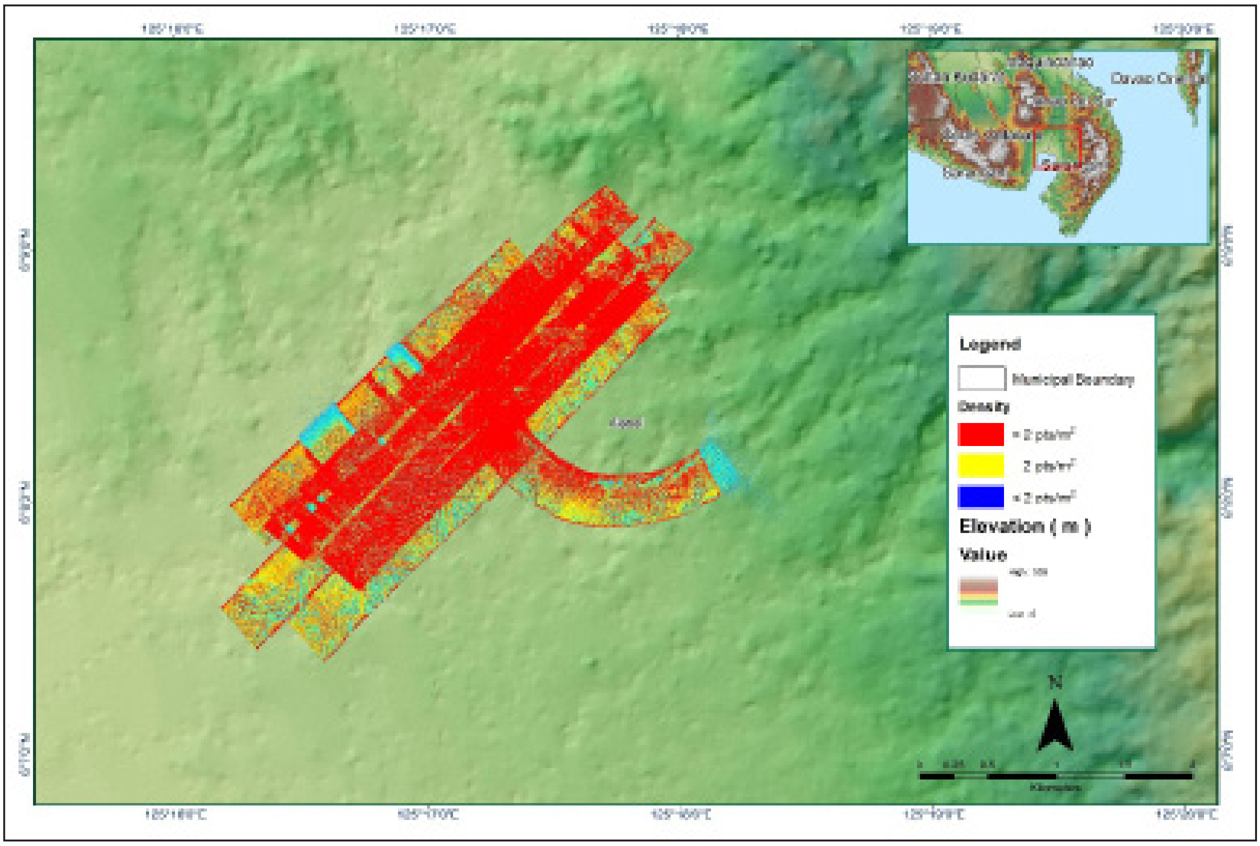


Figure A-8.55. Density map of merged LiDAR data

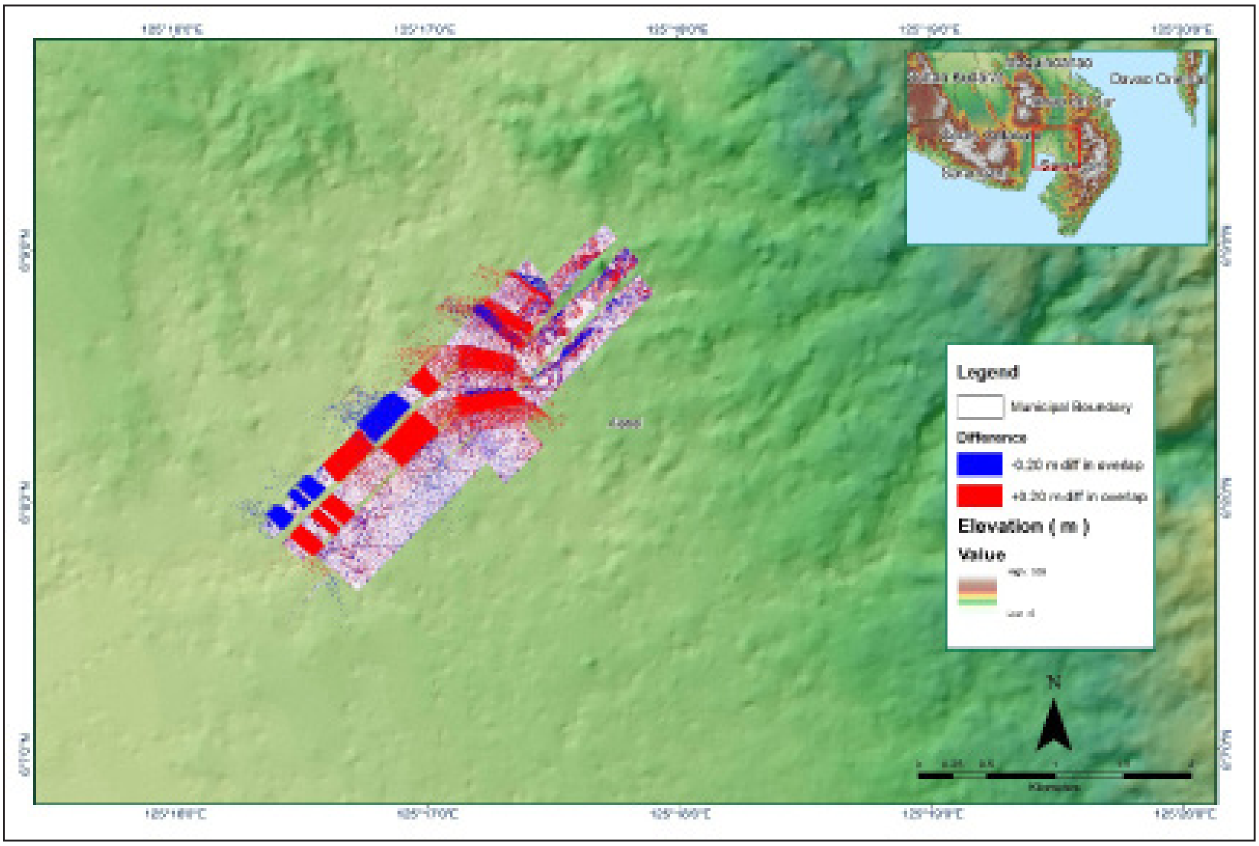


Figure A-8.56. Elevation difference between flight lines

Annex 9. Silway Model Basin Parameters

Basin Number	SCS Curve Number Loss			SCS 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
W1500	300	54.99269	0	0.071976	0.203606	Discharge	0.0081149	0.01	Ratio to Peak	0.5
W1450	300	50.08995	0	0.174816	0.49452	Discharge	0.0353735	0.01	Ratio to Peak	0.5
W1420	300	66.73209	0	0.0243297	0.068822	Discharge	0.0055737	0.01	Ratio to Peak	0.5
W1410	300	60.89399	0	0.121794	0.3445312	Discharge	0.038121	0.01	Ratio to Peak	0.5
W1400	300	42.30134	0	0.288486	0.816088	Discharge	0.1475	0.01	Ratio to Peak	0.5
W1440	300	57.87145	0	0.04773	0.2700464	Discharge	0.0028801	0.01	Ratio to Peak	0.5
W1380	300	61.58761	0	0.04773	0.0908388	Discharge	0.0013871	0.01	Ratio to Peak	0.5
W1370	300	45.91164	0	0.141666	0.801476	Discharge	0.0404405	0.01	Ratio to Peak	0.5
W1360	300	56.9353	0	0.133395	0.754676	Discharge	0.0398876	0.01	Ratio to Peak	0.5
W1350	300	42.56441	0	0.073806	0.4175704	Discharge	0.0287072	0.01	Ratio to Peak	0.5
W1340	300	44.85304	0	0.225885	1.277952	Discharge	0.0917664	0.01	Ratio to Peak	0.5
W1330	300	46.41803	0	0.0462	0.2613728	Discharge	0.0032781	0.01	Ratio to Peak	0.5
W1320	300	41.96401	0	0.162591	0.91988	Discharge	0.1496	0.01	Ratio to Peak	0.5
W1310	300	41.50265	0	0.110583	0.625612	Discharge	0.0406436	0.01	Ratio to Peak	0.5
W1300	300	43.2288	0	0.116043	0.6565	Discharge	0.0375724	0.01	Ratio to Peak	0.5
W1290	300	52.45995	0	0.225699	1.276912	Discharge	0.0830656	0.01	Ratio to Peak	0.5
W1490	300	54.72093	0	0.053793	0.3043456	Discharge	0.0075229	0.01	Ratio to Peak	0.5
W1270	300	54.72251	0	0.181209	1.025232	Discharge	0.0679026	0.01	Ratio to Peak	0.5
W1260	300	57.35716	0	0.092022	0.520624	Discharge	0.0090916	0.01	Ratio to Peak	0.5
W1250	300	49.79686	0	0.196257	1.110356	Discharge	0.0622727	0.01	Ratio to Peak	0.5
W1240	300	53.87247	0	0.125817	0.711828	Discharge	0.0297859	0.01	Ratio to Peak	0.5
W1230	300	56.74965	0	0.110907	0.627484	Discharge	0.0226682	0.01	Ratio to Peak	0.5

Basin Number	SCS Curve Number Loss			SCS 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
W1220	300	51.96304	0	0.185454	1.049204	Discharge	0.0694685	0.01	Ratio to Peak	0.5
W1210	300	61.43909	0	0.093885	0.53118	Discharge	0.0285447	0.01	Ratio to Peak	0.5
W1200	300	42.88831	0	0.072729	0.4114656	Discharge	0.0353983	0.01	Ratio to Peak	0.5
W1190	300	53.77214	0	0.083319	0.4713852	Discharge	0.0117119	0.01	Ratio to Peak	0.5
W1180	300	45.50716	0	0.148215	0.838552	Discharge	0.050434	0.01	Ratio to Peak	0.5
W1170	300	44.4375	0	0.065709	0.3717584	Discharge	0.038918	0.01	Ratio to Peak	0.5
W1160	300	41.37546	0	0.109071	0.617084	Discharge	0.0264726	0.01	Ratio to Peak	0.5
W1150	300	61.62	0	0.0235446	0.1332084	Discharge	0.000789848	0.01	Ratio to Peak	0.5
W1140	300	44.96522	0	0.165396	0.93574	Discharge	0.10382	0.01	Ratio to Peak	0.5
W1130	300	53.60308	0	0.127107	0.719108	Discharge	0.025492	0.01	Ratio to Peak	0.5
W1120	300	52.93	0	0.09783	0.553488	Discharge	0.0317188	0.01	Ratio to Peak	0.5
W1110	300	50.49601	0	0.149382	0.845156	Discharge	0.045938	0.01	Ratio to Peak	0.5
W1100	300	41.27671	0	0.214278	1.212276	Discharge	0.059375	0.01	Ratio to Peak	0.5
W1090	300	42.4309	0	0.057324	0.3243136	Discharge	0.0205747	0.01	Ratio to Peak	0.5
W1080	300	39.54503	0	0.09792	0.554008	Discharge	0.0290556	0.01	Ratio to Peak	0.5
W1070	300	52.93	0	0.019455	0.1100684	Discharge	0.000864686	0.01	Ratio to Peak	0.5
W1060	300	44.64685	0	0.115092	0.651144	Discharge	0.0612273	0.01	Ratio to Peak	0.5
W1050	300	53.37003	0	0.133827	0.757172	Discharge	0.0317989	0.01	Ratio to Peak	0.5
W1040	300	35.45678	0	0.214176	1.211704	Discharge	0.0371572	0.01	Ratio to Peak	0.5
W1030	300	53.84324	0	0.092766	0.524836	Discharge	0.0223293	0.01	Ratio to Peak	0.5
W1020	300	39.22192	0	0.110247	0.62374	Discharge	0.0334534	0.01	Ratio to Peak	0.5
W1010	300	52.90551	0	0.080415	0.4549584	Discharge	0.0120136	0.01	Ratio to Peak	0.5
W1000	300	51.74895	0	0.0214725	0.1214824	Discharge	0.0030436	0.01	Ratio to Peak	0.5
W990	300	48.13154	0	0.137148	0.775944	Discharge	0.0223322	0.01	Ratio to Peak	0.5

Basin Number	SCS Curve Number Loss			SCS 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
W980	300	43.95876	0	0.107409	0.607672	Discharge	0.0574382	0.01	Ratio to Peak	0.5
W970	300	53.49248	0	0.139176	0.78741	Discharge	0.0486136	0.01	Ratio to Peak	0.5
W960	300	36.21597	0	0.185565	1.04988	Discharge	0.0240668	0.01	Ratio to Peak	0.5
W950	300	47.21593	0	0.112692	0.637572	Discharge	0.0584979	0.01	Ratio to Peak	0.5
W940	300	48.08493	0	0.121806	0.689104	Discharge	0.0242236	0.01	Ratio to Peak	0.5
W930	300	52.6061	0	0.032988	0.186628	Discharge	0.0015049	0.01	Ratio to Peak	0.5
W920	300	43.68463	0	0.192525	1.089244	Discharge	0.0549772	0.01	Ratio to Peak	0.5
W910	15	39.84286	0	0.095679	0.54132	Discharge	0.0319243	0.01	Ratio to Peak	0.5
W900	15	52.93	0	0.043479	0.1229956	Discharge	0.0026522	0.01	Ratio to Peak	0.5
W890	10	38.9628	0	0.185205	0.5239	Discharge	0.0275484	0.01	Ratio to Peak	0.5
W880	10	36.78635	0	0.206184	0.583232	Discharge	0.0312545	0.01	Ratio to Peak	0.5
W870	10	34.56645	0	0.201168	0.569036	Discharge	0.0556421	0.01	Ratio to Peak	0.5
W860	10	34.58541	0	0.188379	0.532896	Discharge	0.0588725	0.01	Ratio to Peak	0.5
W850	10	37.03599	0	0.143727	0.4065724	Discharge	0.0474057	0.01	Ratio to Peak	0.01
W840	10	37.97451	0	0.207687	0.587496	Discharge	0.0559725	0.01	Ratio to Peak	0.01
W830	10	32.12772	0	0.19614	0.55484	Discharge	0.0854557	0.01	Ratio to Peak	0.00001
W820	10	35.55948	0	0.114714	0.3245008	Discharge	0.0297468	0.01	Ratio to Peak	0.00001
W810	10	40.72529	0	0.240693	0.680888	Discharge	0.0919165	0.01	Ratio to Peak	0.00001
W800	10	36.86456	0	0.228222	0.64558	Discharge	0.0489749	0.01	Ratio to Peak	0.00001
W790	10	40.53727	0	0.246624	0.697632	Discharge	0.0933051	0.01	Ratio to Peak	0.00001
W780	10	32.23753	0	0.098196	0.2777788	Discharge	0.0247599	0.01	Ratio to Peak	0.00001
W770	10	44.45804	0	0.064155	0.18148	Discharge	0.0133578	0.01	Ratio to Peak	0.00001
W760	10	54.35674	0	0.100767	0.2850484	Discharge	0.0676967	0.01	Ratio to Peak	0.00001
W750	10	34.12642	0	0.087951	0.2487992	Discharge	0.034821	0.01	Ratio to Peak	0.00001

Basin Number	SCS Curve Number Loss			SCS 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
W740	15	35.07837	0	0.277413	0.784732	Discharge	0.0874558	0.01	Ratio to Peak	0.00001
W730	15	33.68639	0	0.265407	0.750776	Discharge	0.0840991	0.01	Ratio to Peak	0.00001
W720	20	40.59257	0	0.100452	0.2841592	Discharge	0.041923	0.01	Ratio to Peak	0.00001

Annex 10. Silway Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R30	Automatic Fixed Interval	3155.3	0.0385527	0.01	Trapezoid	60	1
R60	Automatic Fixed Interval	3049.8	0.0323982	0.01	Trapezoid	60	1
R100	Automatic Fixed Interval	183.85	0.0159464	0.0001	Trapezoid	60	1
R110	Automatic Fixed Interval	1091.8	0.0102401	0.0001	Trapezoid	60	1
R140	Automatic Fixed Interval	3541.9	0.0103236	0.0001	Trapezoid	60	1
R180	Automatic Fixed Interval	1750.4	0.0023438	0.0001	Trapezoid	60	1
R190	Automatic Fixed Interval	651.13	0.0077501	0.0001	Trapezoid	60	1
R210	Automatic Fixed Interval	6522.6	0.0254793	0.0001	Trapezoid	60	1
R250	Automatic Fixed Interval	1515.4	0.0079861	0.0001	Trapezoid	60	1
R260	Automatic Fixed Interval	597.99	0.0063864	0.0001	Trapezoid	60	1
R270	Automatic Fixed Interval	1807.4	0.0051666	0.0001	Trapezoid	60	1
R320	Automatic Fixed Interval	3435.5	0.0096923	0.0001	Trapezoid	60	1
R350	Automatic Fixed Interval	5129.6	0.023192	0.0001	Trapezoid	60	1
R360	Automatic Fixed Interval	2261.7	0.0092336	0.0001	Trapezoid	60	1
R370	Automatic Fixed Interval	576.27	-0.0020069	0.0001	Trapezoid	60	1
R380	Automatic Fixed Interval	8085.8	0.0280424	0.0001	Trapezoid	60	1
R390	Automatic Fixed Interval	6163	0.0237465	0.0001	Trapezoid	60	1
R400	Automatic Fixed Interval	898.82	0.0069774	0.0001	Trapezoid	60	1
R420	Automatic Fixed Interval	7522.1	0.0190829	0.0001	Trapezoid	60	1
R430	Automatic Fixed Interval	2063	0.0127841	0.001	Trapezoid	60	1
R450	Automatic Fixed Interval	6841.3	0.0208414	0.009	Trapezoid	60	1
R470	Automatic Fixed Interval	3664.6	0.0047897	0.0001	Trapezoid	60	1
R480	Automatic Fixed Interval	2636.2	0.0128602	0.0001	Trapezoid	60	1

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R490	Automatic Fixed Interval	969.83	0.0110958	0.0001	Trapezoid	60	1
R500	Automatic Fixed Interval	3825.5	0.0174556	0.0001	Trapezoid	60	1
R540	Automatic Fixed Interval	4851.9	0.0127257	0.0001	Trapezoid	60	1
R550	Automatic Fixed Interval	3837.8	0.0196414	0.0001	Trapezoid	60	1
R560	Automatic Fixed Interval	12708	0.0208196	0.0001	Trapezoid	60	1
R600	Automatic Fixed Interval	4656.2	0.0266581	0.0001	Trapezoid	60	1
R610	Automatic Fixed Interval	876.27	0.0165127	0.0001	Trapezoid	60	1
R640	Automatic Fixed Interval	553.85	0.0262734	0.0001	Trapezoid	60	1
R690	Automatic Fixed Interval	8829.9	0.0147462	0.0001	Trapezoid	60	1
R700	Automatic Fixed Interval	823.76	0	0.0001	Trapezoid	60	1
R680	Automatic Fixed Interval	1096.8	0.0053862	0.05	Trapezoid	60	1
R1470	Automatic Fixed Interval	3211.8	0.0078151	0.05	Trapezoid	60	1
R1510	Automatic Fixed Interval	992.55	0.0117124	0.05	Trapezoid	60	1
R590	Automatic Fixed Interval	1174	0.0122414	0.05	Trapezoid	60	1

Annex 11. Silway Field Validation Data

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/ Date	Rain Return / Scenario
	Lat	Long					
1	6.10227	125.1626	1.151666641	0	-1.151666641	2013	5YR
2	6.10224	125.1629	1.228999972	0	-1.228999972	2013	5YR
3	6.10283	125.1631	1.904000044	0	-1.904000044	2013	5YR
4	6.10191	125.1624	0.775200009	0	-0.775200009	2013	5YR
5	6.10147	125.1622	0.973999977	0	-0.973999977	2013	5YR
6	6.10237	125.1616	1.010666609	0	-1.010666609	2013	5YR
7	6.10231	125.1612	0.621999979	0	-0.621999979	2013	5YR
8	6.10173	125.1609	0.279500008	0.1	-0.179500008	2013	5YR
9	6.10368	125.1608	0.455500007	0.1	-0.355500007	2013	5YR
10	6.10503	125.1609	1.421000004	0.1	-1.321000004	2013	5YR
11	6.10527	125.1603	1.008666635	0.1	-0.908666635	2013	5YR
12	6.10515	125.1606	1.136999965	0.1	-1.036999965	2013	5YR
13	6.10564	125.1599	0.760249972	0.15	-0.610249972	2013	5YR
14	6.10579	125.1601	0.802333355	0.15	-0.652333355	2013	5YR
15	6.10570	125.1607	1.578333378	0.15	-1.428333378	2013	5YR
16	6.10551	125.1607	1.542999983	0.3	-1.242999983	2013	5YR
17	6.10558	125.1603	1.182000041	0.2	-0.982000041	2013	5YR
18	6.10595	125.1603	1.026499987	0.4	-0.626499987	2013	5YR
19	6.10665	125.1605	0.569999993	0.1	-0.469999993	2013	5YR
20	6.10748	125.1606	1.315500021	0.1	-1.215500021	2013	5YR
21	6.10655	125.1615	1.756000042	0.1	-1.656000042	2013	5YR
22	6.10684	125.1612	1.481999993	0.1	-1.381999993	2013	5YR
23	6.10421	125.1607	0.727666676	0.1	-0.627666676	2013	5YR
24	6.11241	125.1579	0.417499989	0.3	-0.117499989	2013	5YR
25	6.11236	125.1579	0.417499989	0	-0.417499989	2013	5YR
26	6.11244	125.1589	3.976000071	0	-3.976000071	2013	5YR
27	6.11244	125.1589	3.976000071	0.4	-3.576000071	2013	5YR
28	6.11195	125.1585	0.870999992	0	-0.870999992	2013	5YR
29	6.11164	125.1584	0.477999985	0	-0.477999985	2013	5YR
30	6.12083	125.1451	0.036674418	0	-0.036674418	2013	5YR
31	6.12011	125.1445	0.104999997	0.1	-0.004999997	2013	5YR
32	6.12029	125.1447	1.532999992	0.2	-1.332999992	2013	5YR
33	6.12227	125.1440	1.194000006	0	-1.194000006	2013	5YR
34	6.12951	125.1411	0.122000001	0	-0.122000001	2013	5YR
35	6.12962	125.1410	0.39625001	0	-0.39625001	2013	5YR
36	6.14854	125.1378	4.160666466	0	-4.160666466	2013	5YR
37	6.14349	125.1445	0.419999987	0	-0.419999987	2013	5YR
38	6.14275	125.1438	1.512249947	0	-1.512249947	2013	5YR
39	6.14154	125.1441	1.114500046	0	-1.114500046	2013	5YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/ Date	Rain Return / Scenario
	Lat	Long					
40	6.13259	125.1618	0.036674418	0	-0.036674418	2013	5YR
41	6.13264	125.1624	0.183166668	0	-0.183166668	2013	5YR
42	6.13256	125.1555	0.32949999	0	-0.32949999	2013	5YR
43	6.13255	125.1550	0.464333326	0	-0.464333326	2013	5YR
44	6.13251	125.1544	0.147	0	-0.147	2013	5YR
45	6.12980	125.1611	0.595000029	1.2	0.604999971	2013	5YR
46	6.13022	125.1615	0.817333341	0	-0.817333341	2013	5YR
47	6.12141	125.1619	0.854499996	0	-0.854499996	2013	5YR
48	6.11046	125.1741	0.392333329	0	-0.392333329	2013	5YR
49	6.11017	125.1738	0.74000001	0.1	-0.64000001	2013	5YR
50	6.10957	125.1737	1.151666641	0.1	-1.051666641	2013	5YR
51	6.10949	125.1733	0.296000004	0.1	-0.196000004	2013	5YR
52	6.10597	125.1679	1.295666695	0	-1.295666695	2013	5YR
53	6.10609	125.1695	0.052499998	0	-0.052499998	2013	5YR
54	6.10612	125.1694	0.036674418	0	-0.036674418	2013	5YR
55	6.10607	125.1681	1.229500055	0	-1.229500055	2013	5YR
56	6.10497	125.1672	1.906000018	0	-1.906000018	2013	5YR
57	6.10482	125.1672	1.457000017	0	-1.457000017	2013	5YR
58	6.10648	125.1676	1.377500057	0.15	-1.227500057	2013	5YR
59	6.10659	125.1683	0.832499981	0.15	-0.682499981	2013	5YR
60	6.10681	125.1673	1.074000001	0.15	-0.924000001	2013	5YR
61	6.10654	125.1671	1.717333317	0.15	-1.567333317	2013	5YR
62	6.11864	125.1594	1.812666655	0	-1.812666655	2013	5YR
63	6.11882	125.1591	2.545666695	0.15	-2.395666695	2013	5YR
64	6.11854	125.1579	3.02940011	0	-3.02940011	2013	5YR
65	6.11873	125.1553	1.102333307	0	-1.102333307	2013	5YR
66	6.11873	125.1545	0.611500025	0	-0.611500025	2013	5YR
67	6.11873	125.1540	0.419999987	0	-0.419999987	2013	5YR
68	6.11916	125.1467	0.597333312	0.5	-0.097333312	2013	5YR
69	6.11938	125.1464	0.370249987	0.5	0.129750013	2013	5YR
70	6.11925	125.1466	0.838666677	0.5	-0.338666677	2013	5YR
71	6.11877	125.1468	0.244666666	0.5	0.255333334	2013	5YR
72	6.11887	125.1464	0.713	0.5	-0.213	2013	5YR
73	6.11894	125.1458	0.072750002	0.1	0.027249998	2013	5YR
74	6.11853	125.1591	1.928750038	0	-1.928750038	2013	5YR
75	6.11745	125.1590	3.437999964	0.3	-3.137999964	2013	5YR
76	6.11747	125.1594	3.426000118	0.3	-3.126000118	2013	5YR
77	6.11835	125.1596	1.430666685	0.2	-1.230666685	2013	5YR
78	6.11818	125.1598	1.481999993	0	-1.481999993	2013	5YR
79	6.10264	125.1621	1.13499999	0	-1.13499999	2013	5YR
80	6.10244	125.1623	1.309666634	0	-1.309666634	2013	5YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/ Date	Rain Return / Scenario
	Lat	Long					
81	6.10204	125.1627	0.963	0	-0.963	2013	5YR
82	6.10212	125.1629	1.182999969	0	-1.182999969	2013	5YR
83	6.10223	125.1632	1.332249999	0.8	-0.532249999	2013	5YR
84	6.10270	125.1626	1.305999994	0	-1.305999994	2013	5YR
85	6.10286	125.1631	1.904000044	0.1	-1.804000044	2013	5YR
86	6.10247	125.1637	1.35374999	0.5	-0.85374999	2013	5YR
87	6.10287	125.1639	1.859333277	0.3	-1.559333277	2013	5YR
88	6.10282	125.1641	1.47966671	0.5	-0.97966671	2013	5YR
89	6.10292	125.1641	1.47966671	0.5	-0.97966671	2013	5YR
90	6.10292	125.1642	1.673499942	0.5	-1.173499942	2013	5YR
91	6.10352	125.1635	2.383333445	0.3	-2.083333445	2013	5YR
92	6.10413	125.1612	1.100999951	0.2	-0.900999951	2013	5YR
93	6.10440	125.1616	1.890499949	0.1	-1.790499949	2013	5YR
94	6.10391	125.1605	0.108000003	0.2	0.091999997	2013	5YR
95	6.10539	125.1601	0.969500005	0	-0.969500005	2013	5YR
96	6.10533	125.1601	0.765666664	0.1	-0.665666664	2013	5YR
97	6.10561	125.1598	0.760249972	0.2	-0.560249972	2013	5YR
98	6.10576	125.1607	1.512249947	0.3	-1.212249947	2013	5YR
99	6.10697	125.1606	0.71450001	0.3	-0.41450001	2013	5YR
100	6.10714	125.1613	1.973999977	0.1	-1.873999977	2013	5YR
101	6.10679	125.1621	3.015000105	0.1	-2.915000105	2013	5YR
102	6.10764	125.1619	4.095499992	0.5	-3.595499992	2013	5YR
103	6.10699	125.1610	1.3646667	0.5	-0.8646667	2013	5YR
104	6.10858	125.1594	1.379999995	0	-1.379999995	2013	5YR
105	6.10849	125.1599	1.35800004	0	-1.35800004	2013	5YR
106	6.10815	125.1604	1.88499999	0.1	-1.78499999	2013	5YR
107	6.10806	125.1617	5.094500065	0.3	-4.794500065	2013	5YR
108	6.10522	125.1677	1.211666703	0	-1.211666703	2013	5YR
109	6.10608	125.1682	0.97633332	0.1	-0.87633332	2013	5YR
110	6.10622	125.1689	0.330666661	0	-0.330666661	2013	5YR
111	6.10606	125.1692	0.236666664	0.1	-0.136666664	2013	5YR
112	6.11041	125.1657	0.076166667	0	-0.076166667	2013	5YR
113	6.11038	125.1734	0.426499993	0.15	-0.276499993	2013	5YR
114	6.11030	125.1739	0.621999979	0.1	-0.521999979	2013	5YR
115	6.13114	125.1474	2.470249891	0	-2.470249891	2013	5YR
116	6.13084	125.1474	0.833000004	0	-0.833000004	2013	5YR
117	6.12942	125.1405	0.503499985	0	-0.503499985	2013	5YR
118	6.12945	125.1406	0.456999987	0	-0.456999987	2013	5YR
119	6.13389	125.1350	0.540000021	0	-0.540000021	2013	5YR
120	6.14732	125.1416	4.208000183	0	-4.208000183	2013	5YR
121	6.14286	125.1444	0.400666654	0.5	0.099333346	2013	5YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/ Date	Rain Return / Scenario
	Lat	Long					
122	6.14208	125.1441	1.093999982	0.3	-0.793999982	2013	5YR
123	6.14182	125.1442	0.063352942	0.3	0.236647058	2013	5YR
124	6.13305	125.1553	0.478666663	0	-0.478666663	2013	5YR
125	6.13260	125.1553	0.335000008	0	-0.335000008	2013	5YR
126	6.13486	125.1625	0.030999999	0.1	0.069000001	2013	5YR
127	6.13401	125.1625	0.036674418	0.1	0.063325582	2013	5YR
128	6.13037	125.1615	0.618499994	0.5	-0.118499994	2013	5YR
129	6.13056	125.1612	0.775200009	0	-0.775200009	2013	5YR
130	6.12757	125.1622	0.063000001	0.1	0.036999999	2013	5YR
131	6.12762	125.1618	2.061500072	0.1	-1.961500072	2013	5YR
132	6.12735	125.1544	0.036674418	0	-0.036674418	2013	5YR
133	6.12731	125.1543	0.036674418	0	-0.036674418	2013	5YR
134	6.12677	125.1537	3.156500101	0.1	-3.056500101	2013	5YR
135	6.12728	125.1551	0.745500028	0	-0.745500028	2013	5YR
136	6.12825	125.1551	0.708000004	0	-0.708000004	2013	5YR
137	6.12559	125.1616	0.927999973	0.5	-0.427999973	2013	5YR
138	6.12441	125.1620	0.036674418	0.5	0.463325582	2013	5YR
139	6.12092	125.1621	0.620999992	0	-0.620999992	2013	5YR
140	6.12006	125.1622	0.520500004	0	-0.520500004	2013	5YR
141	6.11854	125.1579	3.02940011	0	-3.02940011	2013	5YR
142	6.11849	125.1551	0.494666666	0	-0.494666666	2013	5YR
143	6.11243	125.1582	2.162250042	0	-2.162250042	2013	5YR
144	6.10939	125.1690	0.183166668	0.03	-0.153166668	2013	5YR
145	6.11203	125.1700	0.036674418	0	-0.036674418	2013	5YR
146	6.09727	125.1576	0.065250002	0	-0.065250002	2013	5YR
147	6.09889	125.1592	0.037	0	-0.037	2013	5YR
148	6.10098	125.1585	0.85650003	0	-0.85650003	2013	5YR
149	6.10268	125.1607	0.081500001	0	-0.081500001	2013	5YR
150	6.10317	125.1628	2.087500095	0	-2.087500095	2013	5YR
151	6.10350	125.1642	2.642750025	0.02	-2.622750025	2013	5YR
152	6.10532	125.1638	3.690333366	0.6	-3.090333366	2013	5YR
153	6.10676	125.1580	0.260250002	0	-0.260250002	2013	5YR
154	6.10816	125.1596	0.99666667	0.2	-0.79666667	2013	5YR
155	6.10434	125.1593	0.047666665	0	-0.047666665	2013	5YR
156	6.10549	125.1619	2.522249937	0.5	-2.022249937	2013	5YR
157	6.10585	125.1632	3.629333258	0.9	-2.729333258	2013	5YR
158	6.10755	125.1620	4.373000145	0.5	-3.873000145	2013	5YR
159	6.13213	125.1342	0.582000017	0.05	-0.532000017	2013	5YR
160	6.13278	125.1381	0.236666664	0.1	-0.136666664	2013	5YR
161	6.13507	125.1353	0.111333333	0.05	-0.061333333	2013	5YR
162	6.13404	125.1304	0.1215	0	-0.1215	2013	5YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/ Date	Rain Return / Scenario
	Lat	Long					
163	6.13715	125.1292	0.036674418	0	-0.036674418	2013	5YR
164	6.14025	125.1297	0.104000002	0	-0.104000002	2013	5YR
165	6.14653	125.1334	0.063333333	0	-0.063333333	2013	5YR
166	6.14644	125.1386	0.057999998	0	-0.057999998	2013	5YR
167	6.14533	125.1387	0.079333335	0	-0.079333335	2013	5YR
168	6.14310	125.1367	0.050749999	0	-0.050749999	2013	5YR
169	6.13667	125.1372	0.064285718	0	-0.064285718	2013	5YR
170	6.13512	125.1370	0.036674418	0	-0.036674418	2013	5YR
171	6.13351	125.1354	0.388749987	0	-0.388749987	2013	5YR
172	6.12872	125.1296	0.09966667	0	-0.09966667	2013	5YR
173	6.12435	125.1315	0.036674418	0	-0.036674418	2013	5YR
174	6.12549	125.1321	0.072999999	0	-0.072999999	2013	5YR
175	6.12503	125.1365	0.047666665	0	-0.047666665	2013	5YR
176	6.12705	125.1400	0.079999998	0	-0.079999998	2013	5YR
177	6.11641	125.1626	0.246250004	0	-0.246250004	2013	5YR
178	6.11720	125.1584	3.437999964	0	-3.437999964	2013	5YR
179	6.11494	125.1595	3.813499928	0	-3.813499928	2013	5YR
180	6.11341	125.1607	3.88499999	0	-3.88499999	2013	5YR
181	6.11592	125.1640	0.138500005	0	-0.138500005	2013	5YR
182	6.11424	125.1667	0.099857144	0.05	-0.049857144	2013	5YR
183	6.11272	125.1673	0.137666672	0.05	-0.087666672	2013	5YR
184	6.11748	125.1690	0.305750012	0	-0.305750012	2013	5YR
185	6.11487	125.1685	0.414499998	0.05	-0.364499998	2013	5YR
186	6.11276	125.1733	0.17825	0.08	-0.09825	2013	5YR
187	6.11199	125.1752	0.036674418	0	-0.036674418	2013	5YR
188	6.10956	125.1768	0.126142859	0	-0.126142859	2013	5YR
189	6.10786	125.1763	0.326999992	0.3	-0.026999992	2013	5YR
190	6.10885	125.1742	0.063352942	0	-0.063352942	2013	5YR
191	6.10717	125.1771	0.063666664	0	-0.063666664	2013	5YR
192	6.10901	125.1710	0.228333339	0	-0.228333339	2013	5YR
193	6.11090	125.1667	0.118000001	0.1	-0.018000001	2013	5YR
194	6.11201	125.1658	0.055399999	0.1	0.044600001	2013	5YR
195	6.10905	125.1666	0.057666667	0.1	0.042333333	2013	5YR
196	6.10740	125.1672	0.289666653	0.1	-0.189666653	2013	5YR
197	6.10648	125.1697	0.449999988	0	-0.449999988	2013	5YR
198	6.10588	125.1675	1.694000006	0.5	-1.194000006	2013	5YR
199	6.10601	125.1653	3.065999985	0.5	-2.565999985	2013	5YR
200	6.10483	125.1621	2.622999907	0.3	-2.322999907	2013	5YR
201	6.10361	125.1571	0.063352942	0.05	-0.013352942	2013	5YR
202	6.10562	125.1549	0.052999999	0.05	-0.002999999	2013	5YR
203	6.10544	125.1526	0.046599999	0.06	0.013400001	2013	5YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/ Date	Rain Return / Scenario
	Lat	Long					
204	6.10398	125.1535	0.133666664	0.05	-0.083666664	2013	5YR
205	6.10170	125.1571	0.536750019	0.05	-0.486750019	2013	5YR
206	6.10104	125.1551	0.0744	0.05	-0.0244	2013	5YR
207	6.10826	125.1542	0.036674418	0.05	0.013325582	2013	5YR
208	6.10734	125.1504	0.133666664	0.05	-0.083666664	2013	5YR
209	6.11430	125.1415	0.240666673	0	-0.240666673	2013	5YR
210	6.11612	125.1409	0.036674418	0	-0.036674418	2013	5YR
211	6.11914	125.1379	0.051857144	0	-0.051857144	2013	5YR
212	6.11942	125.1346	0.036674418	0	-0.036674418	2013	5YR
213	6.11311	125.1495	0.036674418	0	-0.036674418	2013	5YR
214	6.11172	125.1554	0.046599999	0.06	0.013400001	2013	5YR
215	6.11436	125.1570	2.515749931	0.05	-2.465749931	2013	5YR
216	6.11572	125.1576	3.72149992	0.02	-3.70149992	2013	5YR
217	6.12704	125.1547	0.258714288	0	-0.258714288	2013	5YR
218	6.12793	125.1522	5.257999897	0.5	-4.757999897	2013	5YR
219	6.12711	125.1535	3.551333427	0	-3.551333427	2013	5YR
220	6.12619	125.1531	4.207666874	0.9	-3.307666874	2013	5YR
221	6.12543	125.1531	5.637666702	0.7	-4.937666702	2013	5YR
222	6.12396	125.1540	6.482999802	0.7	-5.782999802	2013	5YR
223	6.12300	125.1545	6.287666798	0.8	-5.487666798	2013	5YR
224	6.12136	125.1553	5.256333351	0.8	-4.456333351	2013	5YR
225	6.12011	125.1560	4.988999844	0.01	-4.978999844	2013	5YR
226	6.11932	125.1566	5.060249805	0.9	-4.160249805	2013	5YR
227	6.11889	125.1576	4.096000195	0	-4.096000195	2013	5YR
228	6.11861	125.1559	1.904999971	0	-1.904999971	2013	5YR
229	6.11464	125.1582	4.090499878	0.15	-3.940499878	2013	5YR
230	6.11359	125.1585	4.823999882	0.2	-4.623999882	2013	5YR
231	6.11460	125.1576	3.09100008	0	-3.09100008	2013	5YR
232	6.11384	125.1569	0.132666662	0	-0.132666662	2013	5YR
233	6.11287	125.1568	0.198571429	0	-0.198571429	2013	5YR
234	6.11248	125.1577	0.232999995	0.3	0.067000005	2013	5YR
235	6.11248	125.1589	3.976000071	0.6	-3.376000071	2013	5YR
236	6.11166	125.1593	4.196000099	0.6	-3.596000099	2013	5YR
237	6.11270	125.1559	0.251333326	0	-0.251333326	2013	5YR
238	6.11055	125.1560	0.090666667	0.05	-0.040666667	2013	5YR
239	6.11164	125.1580	0.036674418	0	-0.036674418	2013	5YR
240	6.11316	125.1579	1.941666722	0.15	-1.791666722	2013	5YR
241	6.11255	125.1571	0.195250005	0	-0.195250005	2013	5YR
242	6.11432	125.1634	0.190500006	0	-0.190500006	2013	5YR
243	6.11234	125.1635	0.099857144	0	-0.099857144	2013	5YR
244	6.11138	125.1640	0.036674418	0	-0.036674418	2013	5YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/ Date	Rain Return / Scenario
	Lat	Long					
245	6.11338	125.1630	0.154666662	0	-0.154666662	2013	5YR
246	6.11279	125.1637	0.081333332	0	-0.081333332	2013	5YR
247	6.11260	125.1649	0.17583333	0	-0.17583333	2013	5YR
248	6.10826	125.1670	0.33524999	0	-0.33524999	2013	5YR
249	6.10721	125.1676	0.325333327	0	-0.325333327	2013	5YR
250	6.10713	125.1695	0.144500002	0	-0.144500002	2013	5YR
251	6.10673	125.1687	0.508333325	0	-0.508333325	2013	5YR
252	6.10651	125.1668	2.091333389	0	-2.091333389	2013	5YR
253	6.10706	125.1643	4.197333336	0.4	-3.797333336	2013	5YR
254	6.10824	125.1638	4.541333199	0.5	-4.041333199	2013	5YR
255	6.10906	125.1633	4.941999912	0.8	-4.141999912	2013	5YR
256	6.10664	125.1645	3.90350008	0.7	-3.20350008	2013	5YR
257	6.10381	125.1617	1.473999977	0	-1.473999977	2013	5YR
258	6.10490	125.1607	1.016000032	0.05	-0.966000032	2013	5YR
259	6.10379	125.1603	0.180749997	0.1	-0.080749997	2013	5YR
260	6.10351	125.1591	0.103500001	0.05	-0.053500001	2013	5YR
261	6.10490	125.1585	0.09966667	0	-0.09966667	2013	5YR
262	6.10478	125.1564	0.174333334	0	-0.174333334	2013	5YR
263	6.10660	125.1548	0.126142859	0	-0.126142859	2013	5YR
264	6.10837	125.1530	0.0744	0	-0.0744	2013	5YR
265	6.10955	125.1502	0.036674418	0	-0.036674418	2013	5YR
266	6.10497	125.1520	0.051857144	0.1	0.048142856	2013	5YR
267	6.10440	125.1527	0.1285	0.1	-0.0285	2013	5YR
268	6.10366	125.1548	0.061666667	0.1	0.038333333	2013	5YR
269	6.10290	125.1562	0.147666663	0	-0.147666663	2013	5YR
270	6.10203	125.1571	0.638000011	0.05	-0.588000011	2013	5YR
271	6.10137	125.1555	0.055399999	0.05	-0.005399999	2013	5YR
272	6.10238	125.1537	0.068142854	0	-0.068142854	2013	5YR
273	6.10127	125.1530	0.17583333	0	-0.17583333	2013	5YR
274	6.09846	125.1582	0.078749999	0.05	-0.028749999	2013	5YR
275	6.10167	125.1597	0.171333328	0.05	-0.121333328	2013	5YR
276	6.10180	125.1627	1.344333291	0	-1.344333291	2013	5YR
277	6.10517	125.1632	2.673333406	0.05	-2.623333406	2013	5YR
278	6.10626	125.1658	2.897666693	0	-2.897666693	2013	5YR
279	6.10618	125.1685	0.898000002	0.05	-0.848000002	2013	5YR
280	6.10821	125.1703	0.072999999	0	-0.072999999	2013	5YR
281	6.11355	125.1692	0.263500005	0	-0.263500005	2013	5YR
282	6.11644	125.1696	0.132666662	0	-0.132666662	2013	5YR
283	6.11769	125.1647	0.258714288	0	-0.258714288	2013	5YR
284	6.11633	125.1663	0.154666662	0	-0.154666662	2013	5YR
285	6.12909	125.1484	0.036674418	0	-0.036674418	2013	5YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/ Date	Rain Return / Scenario
	Lat	Long					
286	6.12842	125.1487	0.106666669	0.5	0.393333331	2013	5YR
287	6.12492	125.1498	0.064285718	0.6	0.535714282	2013	5YR
288	6.12240	125.1528	0.198571429	0.6	0.401428571	2013	5YR
289	6.12235	125.1534	3.601000071	0.5	-3.101000071	2013	5YR
290	6.12319	125.1527	0.076166667	0	-0.076166667	2013	5YR
291	6.12437	125.1528	4.752999783	0.6	-4.152999783	2013	5YR
292	6.12589	125.1516	3.767333269	0.5	-3.267333269	2013	5YR
293	6.12275	125.1522	0.063352942	0	-0.063352942	2013	5YR
294	6.12429	125.1513	0.036674418	0	-0.036674418	2013	5YR
295	6.12519	125.1507	0.036674418	0	-0.036674418	2013	5YR
296	6.12426	125.1507	0.064285718	0	-0.064285718	2013	5YR
297	6.12305	125.1494	0.231999993	0	-0.231999993	2013	5YR
298	6.12494	125.1487	0.1285	0	-0.1285	2013	5YR
299	6.12741	125.1478	0.061250001	0	-0.061250001	2013	5YR
300	6.12850	125.1474	0.648500025	0.05	-0.598500025	2013	5YR
301	6.12826	125.1467	0.036674418	0	-0.036674418	2013	5YR
302	6.12637	125.1466	0.147499993	0	-0.147499993	2013	5YR
303	6.12404	125.1476	0.101333335	0	-0.101333335	2013	5YR
304	6.12226	125.1443	0.116333336	0.1	-0.016333336	2013	5YR
305	6.15654	125.1439	0.054000001	0	-0.054000001	2013	5YR
306	6.15502	125.1440	0.036674418	0	-0.036674418	2013	5YR
307	6.15415	125.1430	0.950333357	0.05	-0.900333357	2013	5YR
308	6.15377	125.1432	1.396666646	0	-1.396666646	2013	5YR
309	6.15262	125.1439	0.068142854	0	-0.068142854	2013	5YR
310	6.15427	125.1424	3.382750034	0.4	-2.982750034	2013	5YR
311	6.14927	125.1433	0.036674418	0.05	0.013325582	2013	5YR
312	6.14761	125.1421	7.730500221	0.02	-7.710500221	2013	5YR
313	6.14756	125.1436	0.036674418	0	-0.036674418	2013	5YR
314	6.14835	125.1445	0.036674418	0	-0.036674418	2013	5YR
315	6.14672	125.1459	0.036674418	0.05	0.013325582	2013	5YR
316	6.14405	125.1495	0.036674418	0	-0.036674418	2013	5YR
317	6.14321	125.1443	1.369333386	0.6	-0.769333386	2013	5YR
318	6.13776	125.1451	0.063352942	0.05	-0.013352942	2013	5YR
319	6.13649	125.1453	0.036674418	0	-0.036674418	2013	5YR
320	6.13619	125.1466	0.037999999	0	-0.037999999	2013	5YR
321	6.13746	125.1486	0.108750001	0	-0.108750001	2013	5YR
322	6.13538	125.1491	0.280000001	0	-0.280000001	2013	5YR

Annex 12. Educational Institutions Affected in Silway Floodplain

South Cotabato				
General Santos City				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Day Care Center	Apopong			
Mindanao Polytehnic College	Apopong			
Our Lady of Lourdes Pre-School Center	Apopong	Medium	Medium	Medium
P. Kindat Elementary School	Apopong			
Purok Lansang Day Care Center	Apopong			
Shiloh Christian Learning Center	Apopong			
SSDMS	Apopong			
Alsir Learning Center	City Heights			Low
AMA Computer Learning Center	City Heights	Low	Low	Low
Dadiangas North Elementary School	City Heights		Low	Low
Dadiangas North High School	City Heights			
Day Care Center	City Heights	High	High	High
General Santos Doctors' Medical School Foundation	City Heights			Low
Gensan Christ Life Academy	City Heights			
Gensan College of Technology	City Heights			
Gensan Multiple Intelligence	City Heights	Medium	Medium	Medium
Gensantos Foundation College Inc.	City Heights			
Holy Trinity College	City Heights	Low	Medium	Medium
Jose P. Laurel Elementary School	City Heights			
Mindanao State University	City Heights			
Notre Dame of Dadiangas University	City Heights			
Saludin Anas Elementary School	City Heights			Low
Sampaguita Children's Learning Center	City Heights			
School	City Heights	Low	Medium	High
Sta. Maria School of Paramedics & Technology	City Heights			
Stage	City Heights		Low	Low
Villamor College	City Heights			
ACLC College	Dadiangas East			
Cronasia Foundation College	Dadiangas East			
Dadiangas South Central School	Dadiangas East	Low	Low	Low
Day Care Center	Dadiangas East	Low	Medium	High
Gerardo's School of Culinary Arts	Dadiangas East	Medium	Medium	Medium
Golden State College	Dadiangas East			
Irineo Santiago National High School	Dadiangas East			Low
Junior Cultural Academy	Dadiangas East			
San Juan Day Care Center	Dadiangas East	High	High	High
Southpoint College of Arts and Technology	Dadiangas East			

South Cotabato				
General Santos City				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Acharon Compound/PNP	Dadiangas North		Low	Low
City Alliance Church Kindergarten	Dadiangas North			
Cronasia Foundation College	Dadiangas North			
Dadiangas Learning Center	Dadiangas North			
Dadiangas South Central School	Dadiangas North		Low	Low
Dadiangas West City Central School	Dadiangas North			
Day C are Center	Dadiangas North	Low	Low	Medium
Day Care Center	Dadiangas North		Low	Medium
Emmanuel College	Dadiangas North	Low	Low	Low
General Santos City SPED Integrated School	Dadiangas North			
General Santos Doctors' Medical School Foundation	Dadiangas North		Medium	High
Junior Cultural Academy	Dadiangas North	Low	Low	Medium
Pedro Alarcon Sr. Central Elem School	Dadiangas North	Low	Medium	Medium
Ramon Magsaysay Memorial College	Dadiangas North			
SDA Elementary School	Dadiangas North			Low
Day Care Center	Dadiangas South		Low	Medium
Day Care Center/Multi Purpose Hall	Dadiangas South	High	High	High
Labangal Elementary School	Dadiangas South	Medium	Medium	Medium
Madrasah	Dadiangas South	Low	Medium	Medium
Saavedra Saway Elementary School	Dadiangas South		Low	Medium
Day Care Center	Dadiangas West			Low
Labangal Elementary School	Dadiangas West	Low	Medium	Medium
Labangal National Highschool	Dadiangas West	Low	Medium	Medium
Saavedra Saway Elementary School	Dadiangas West	Medium	Medium	Medium
Day Care Center	Labangal		Medium	Medium
Labangal National Highschool	Labangal	Low	Medium	Medium
Madrasah	Labangal		Low	Low
Mindanao Polytehnic College	Labangal			
Aviation Institute of Gen. Santos	Lagao			
Arizala Elementary School	Mabuhay			
Intake Day Care Center	Mabuhay			
Metro Gensan Harvest Christian Academy	Mabuhay			
Children Feeding, Educational and Development Fund	San Isidro	Low	Low	Low
Faith International Training School	San Isidro			
Francisco Oringo Elementary School	San Isidro			Low
P.I 16 Day Care Center	San Isidro	High	High	High
Purok Matatag Day Care Center	San Isidro	Low	Low	Medium
Shalom Crest Wizard Academy	San Isidro			
Apopong B Day Care Center	Sinawal			

South Cotabato				
General Santos City				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Division of City School	Sinawal			
GSC Elementary School for the Arts	Sinawal			
Litan I Day Care Center	Sinawal			
Litan II Day Care Center	Sinawal			
New Society Elementary School	Sinawal			
New Society National High School	Sinawal			
Roca Alliance Kindergarten School	Sinawal		Low	Low

Annex 13. Health Institutions Affected in Silway Flood Plain

AGUSAN DEL SUR				
Silway City				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Bonita Lying-Clinic	Apopong			
Poly Clinic	City Heights			
R.O. Diagan Cooperative Hospital	City Heights			
Veterenary Hospital	City Heights			
Golden State Maternity Clinic	Dadiangas East		Low	Low
Ramizo Clinic	Dadiangas East		Low	Low
Lying-in Center	Dadiangas North	Medium	Medium	Medium
Massage Center/Dental Clinic	Dadiangas North	Low	Low	Low
Health Center	Dadiangas West		Low	Medium
Medical Institution	Labangal			
Sirisula-Villanueva Dental Clinic	Lagao	Low	Low	Low
Mindanao Medical Center	San Isidro			
Health Center	Sinawal			
Lying-in Center	Sinawal			