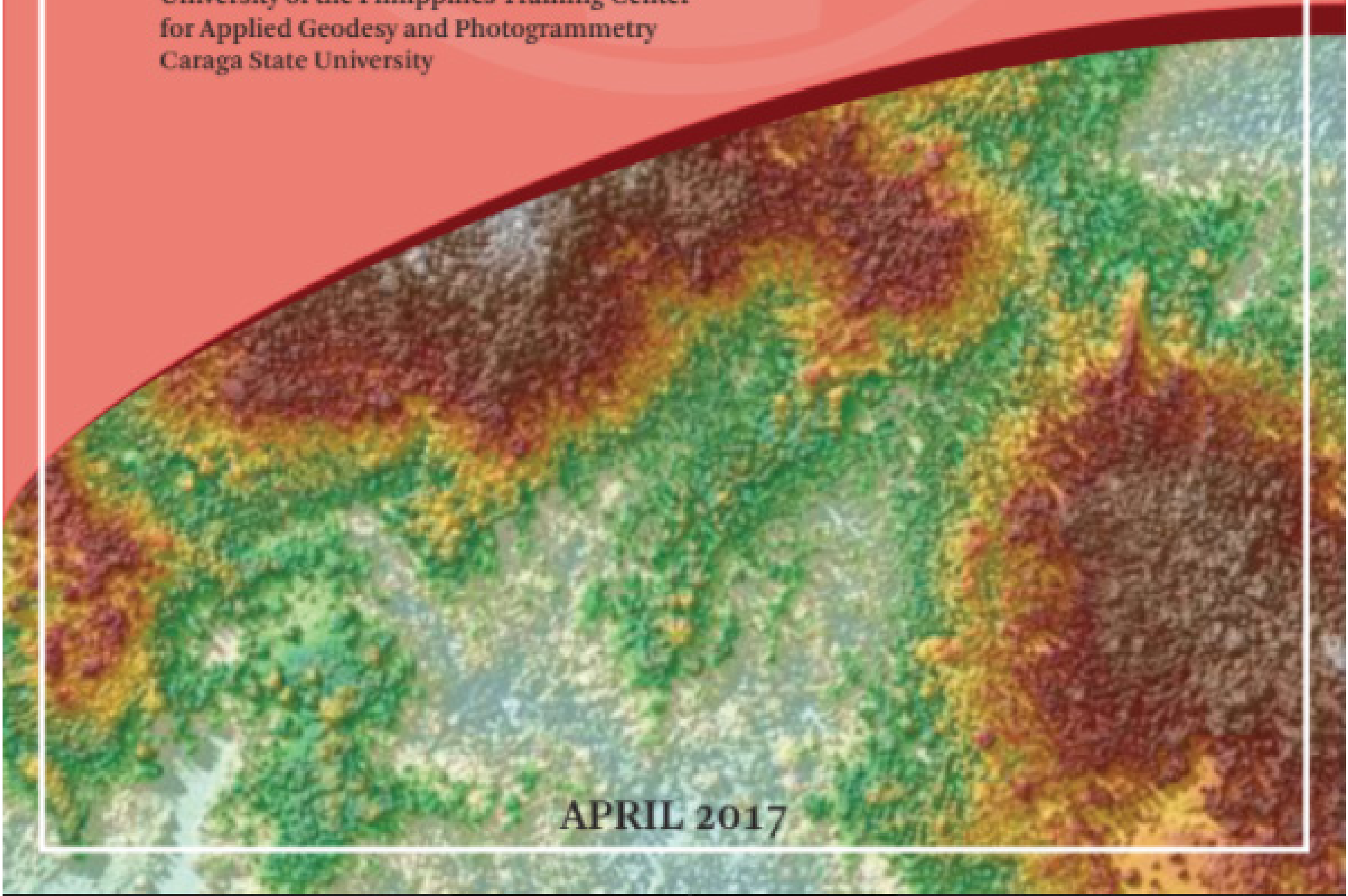
HAZARD MAPPING OF THE PHILIPPINES USING LIDAR (PHIL-LIDAR 1)

LiDAR Surveys and Flood Mapping of Tandag River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
Caraga State University



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LIST OF ACRONYMS AND ABBREVIATIONS

AAC	Asian Aerospace Corporation
Ab	abutment
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
ATQ	Antique
AWLS	Automated Water Level Sensor
BA	Bridge Approach
BM	benchmark
CAD	Computer-Aided Design
CN	Curve Number
CSRS	Chief Science Research Specialist
CSU	Caraga State University
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
NAMRIA	National Mapping and Resource Information Authority
NSTC	Northern Subtropical Convergence
PAF	Philippine Air Force
PAGASA	Philippine Atmospheric Geophysical and Astronomical Services Administration
PDOP	Positional Dilution of Precision
PPK	Post-Processed Kinematic [technique]
PRF	Pulse Repetition Frequency
PTM	Philippine Transverse Mercator
QC	Quality Check
QT	Quick Terrain [Modeler]
RA	Research Associate
RIDF	Rainfall-Intensity-Duration-Frequency
RMSE	Root Mean Square Error
SAR	Synthetic Aperture Radar
SCS	Soil Conservation Service
SRTM	Shuttle Radar Topography Mission
SRS	Science Research Specialist
SSG	Special Service Group
TBC	Thermal Barrier Coatings
UP-TCAGP	University of the Philippines – Training Center for Applied Geodesy and Photogrammetry
UTM	Universal Transverse Mercator
WGS	World Geodetic System

CHAPTER 1: OVERVIEW OF THE PROGRAM AND TAGO RIVER

Meriam Makinano-Santillan, Janice C. Baay, Jojene R. Santillan, Arthur A. Amora

1.1 Background of the Phil-LiDAR 1 Program

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

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

The implementing partner university for the Phil-LiDAR 1 Program is the Caraga State University (CSU). CSU 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 11 river basins in the CARAGA Region. The university is located in Butuan City in the province of Agusan del Norte.

1.2 Overview of the Tandag River Basin

The Tandag River Basin is located in the eastern portion of the Island of Mindanao, Philippines. It lies generally between 126°02' to 126°11'' east longitude and 9°03' to 9°08' north latitude. It is bounded on the north by the Municipalities of Cortes and Lanuza, on the west and south by the Municipality of Tago and on the east by the Pacific Ocean (Philippine Cities, n.d.). The basin covers an area of approximately 189 square kilometers, and is about 27 kilometers long and averages about 10 kilometers in width.

The Tandag River is the principal drainage way of the basin. It originates in Barangay Pakwan, Municipality of Lanuza, Surigao del Sur at the upstream portion of the river basin, and traverses the entire length of the basin in a northeasterly direction. It drains to Barangay Dagocdoc, Tandag City, Surigao del Sur and discharges into the Philippine Sea. The portion of the river channel located near the Philippine Sea is navigable by the motor boats up to about 6 kilometers. There are also minor tributaries that connect to the river basin. Some of these are the Telaje River passing Barangay Bagong Lungsod Poblacion and the Momong River located at Barangay San Agustin Norte, Tandag City, Surigao del Sur which contribute directly to the Tandag River.

The area falls under the Type II of climate in the country, which is characterized by rainfall distributed throughout the year, with a negligible short dry season. Wet season is highly pronounced from September to February and dry season are months from March to August (Incorporated, 2017).

The basin's highest point is at 900 meters above mean sea level situated along the mountain ridges of Barangay Pakwan, Municipality of Lanuza, Surigao del Sur (Center, n.d.). The most abundant soil type in the basin based on maps published by the Department of Agriculture was clay which accounts for 88% of the basin's land area. The basin is mostly covered by open canopy forests and brushland leaving the built-up areas only covering less than 2 % of the basin.

Built-up areas and communities in the basin are concentrated in Tandag City, the downtown area in which considered as the bustling capital town of Surigao del Sur. The city is mostly inhabited by the Manobos and Mamanwas who lived along the river banks. Many years ago, Tandag became a port of call to the Spanish Galleon that sailed along the southern part of Mindanao. Until today, it is generally believed that somewhere underneath the deep sea near Tandag's Twin Linongao Islands lies the sunken galleon.

Based on Caraga Region 2015 Census of Population, City of Tandag ranked number eight in the Top 10 Most Populous Cities/Municipalities in the Region with 56,364 people residing. Major language spoken in the city is Tandaganon, a language closely related to Surigaonon. Tandag City is a fifth income class city on the island of Mindanao and is into small businesses, tourism, and producing good quality products from agriculture and fishery.

Tandag City Water District is providing the people, particularly in the urban areas, with clean water sourced from the basin's upstream watersheds. Tandag Water District is now serving 5,059 connections and covering almost 70% of the entire area of Tandag City. Many people in Tandag have benefited in the District water systems in which there are approximately 41,573 populations from the 14 different areas in the city such as Awasian, Bag-ong Lungsod, Bioto, Bontud, Buenavista, Dagocdoc, Mabua, Pangi, Quezon, Rosario, Salvacion, San Agusin Norte, San Agustin Sur and Telaje (District, n.d.).

Tropical Storm Ruby is one of the typhoons that entered in the Philippine Area of Responsibility. As reported, Ruby was the 18th tropical cyclone in the country. Tandag City is one of the localities which was affected by this calamity. Tropical Storm Ruby was spotted in December 3, 2014 and intensified at 215 kilometers per hour on December 5, 2014 moving towards Eastern Samar-Northern Samar area over the rest of Southern Luzon, Visayas, and Northeastern Mindanao to the extent that a 'state of calamity' was declared by the City government. The unceasing movement of "Ruby" in almost 6 days of staying in the country together with the continuous rain and strong winds that it brought along has caused flooding and landslides affecting numerous individuals and damaged infrastructures not only in Tandag City but also in other localities and areas of the Philippines (NDRRMC, n.d.).

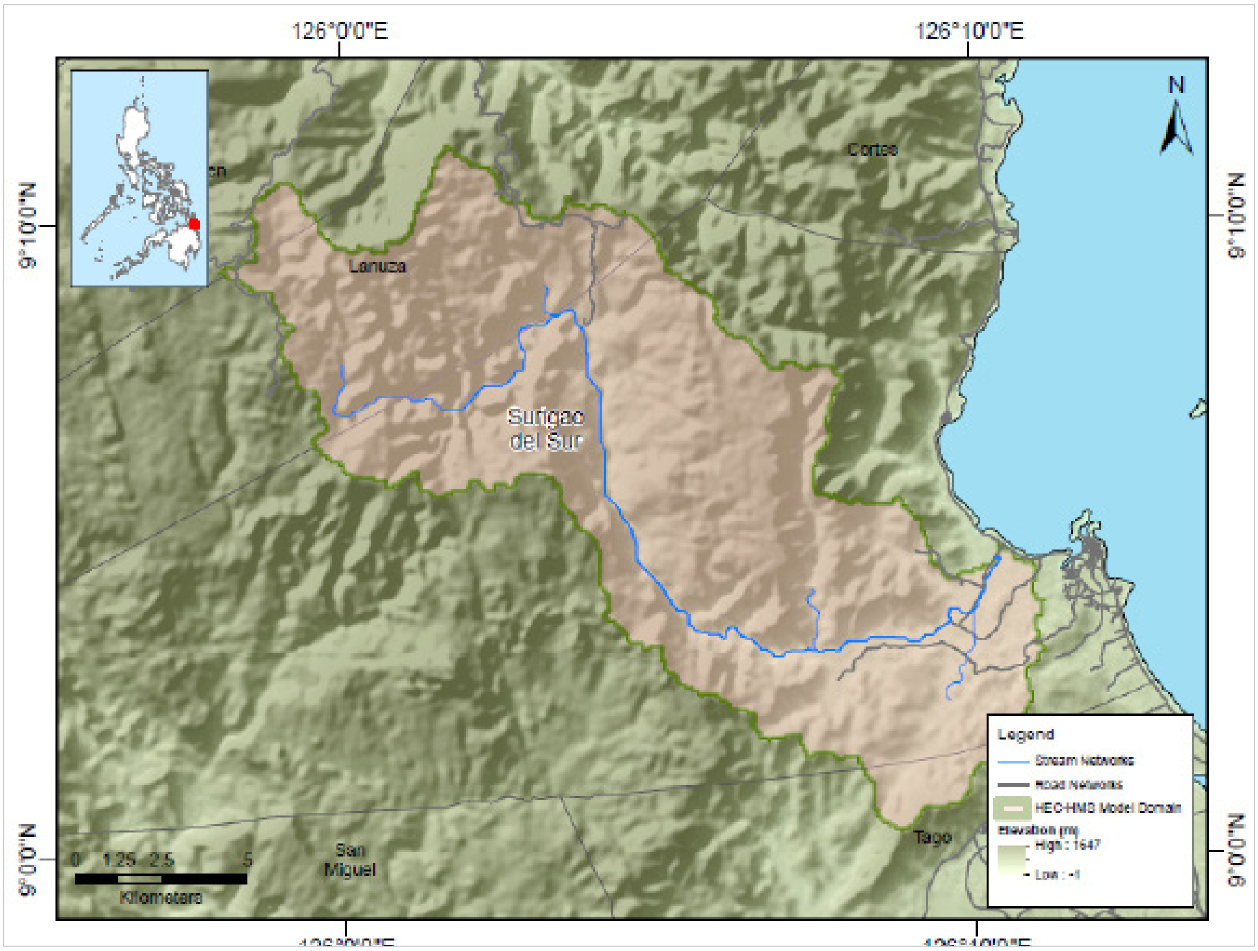

Figure 1. Map of the Tandag River Basin (in brown)

CHAPTER 2: LIDAR ACQUISITION IN TANDAG FLOODPLAIN

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

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Tandag Floodplain in Surigao del Sur. These missions were planned for 19 lines and ran for at most four and a half (4.5) hours including take-off, landing, and turning time. The flight planning parameters for the LiDAR system are found in Table 1. Figure 2 shows the flight plan for Tandag Floodplain survey.

Table 1. Flight planning parameters for Aquarius LiDAR system

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (KHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK61A	500	25,50	36	50	45	120	5
BLK61B	500	60	36	50	45	120	5
	600	60	36	50	45	120	5
BLK61C	600	60	36	50	45	120	5
BLK61D	600	60,65	36	50	45	120	5
BLK61G	600	60,65,70	36	50	45	120	5
BLK61H	600	70	36	50	45	120	5
BLK61M	600	70	36	50	45	120	5
BLK61N	500	50,70	36	50	45	120	5
	600	50,70	36	50	45	120	5
BLK61O	500	50	36	50	45	120	5
	600	50	36	50	45	120	5

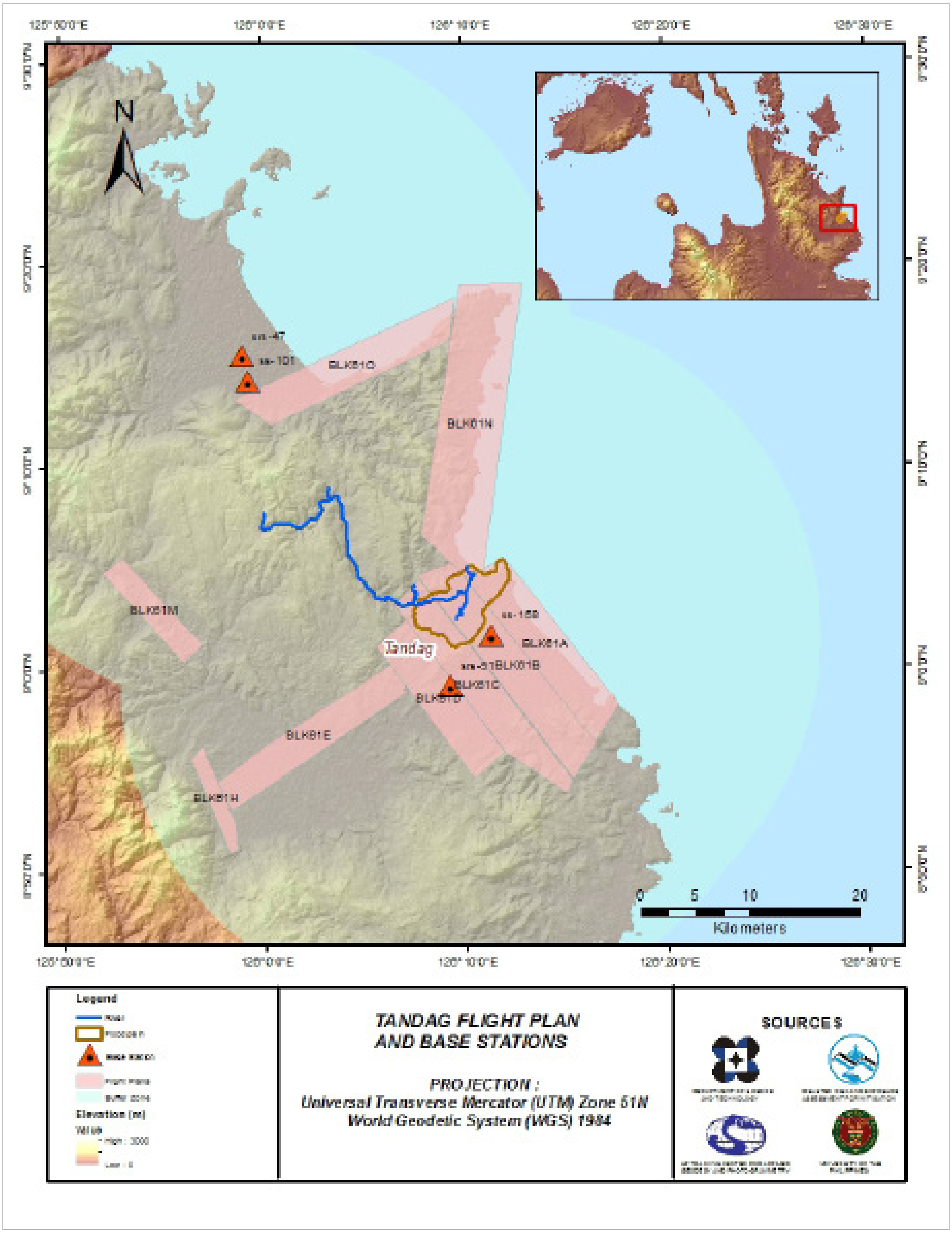

Figure 2. Flight plan and base stations used to cover Tandag Floodplain

2.2 Ground Base Stations

The project team was able to recover two (2) NAMRIA ground control points: SRS-51 and SRS-47 which are of second (2nd)-order accuracy and two (2) NAMRIA benchmarks, SS-158 and SS-101. These benchmarks were used as vertical reference points and were also established as ground control points. The certifications for the NAMRIA reference points are found in ANNEX 2 while the baseline processing reports for the established control points are found in ANNEX 3 These points were used as base stations during flight operations for the entire duration of the survey (July 5–31, 2014). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 882, SPS 852, and SPS 985. Flight plans and location of base stations used during the aerial LiDAR acquisition in Tandag Floodplain are shown in Figure 2.

Figure 3 to Figure 6 show the recovered NAMRIA reference points within the area. In addition, Table 2 to Table 5 present the details about the following NAMRIA control stations and establish points, while Table 6 shows the list of all ground control points occupied during the acquisition with the corresponding dates of utilization.

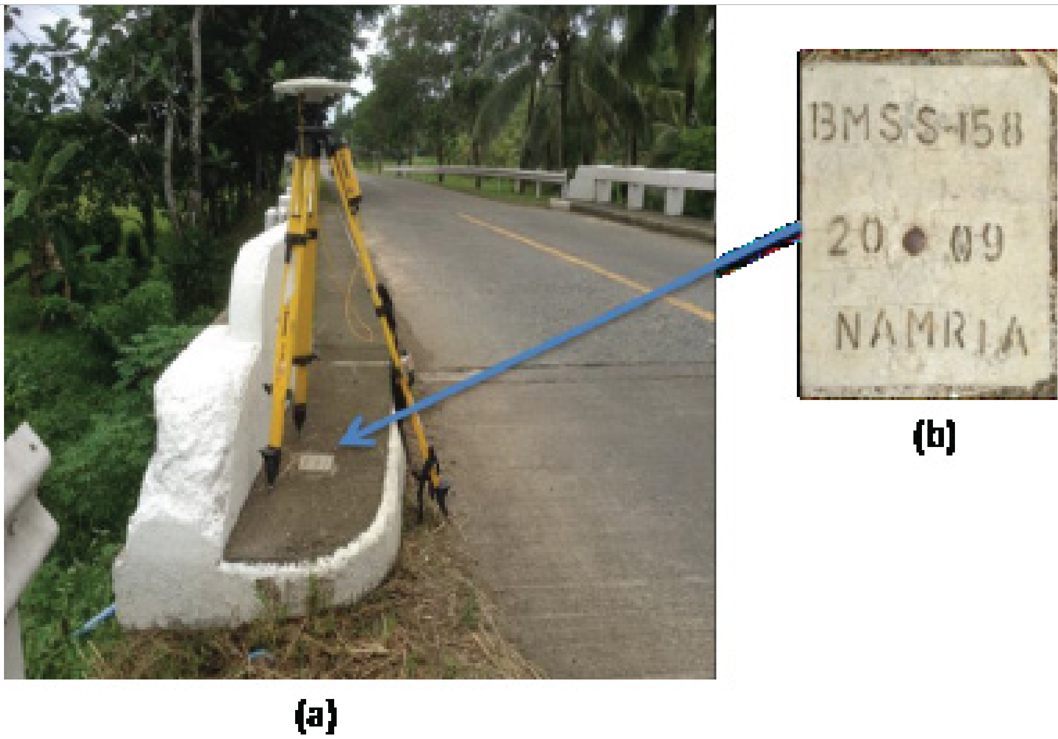

Figure 3. Figure 3. GPS set-up over SS-158 located at the second approach of Batang Bridge in Brgy. Dayo-an, Surigao del Sur (a) and NAMRIA reference point SS-158 (b) as recovered by the field team

Table 2. Details of the recovered NAMRIA benchmark SS-158 used as base station for the LiDAR acquisition

Station Name	SS-158	
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	9°01'43.29494" North 126°11'10.19014" East 1.842 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	850353.357 meters 999491.438 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9°01'39.70405" North 126°11'15.53082" East 76.97 meters

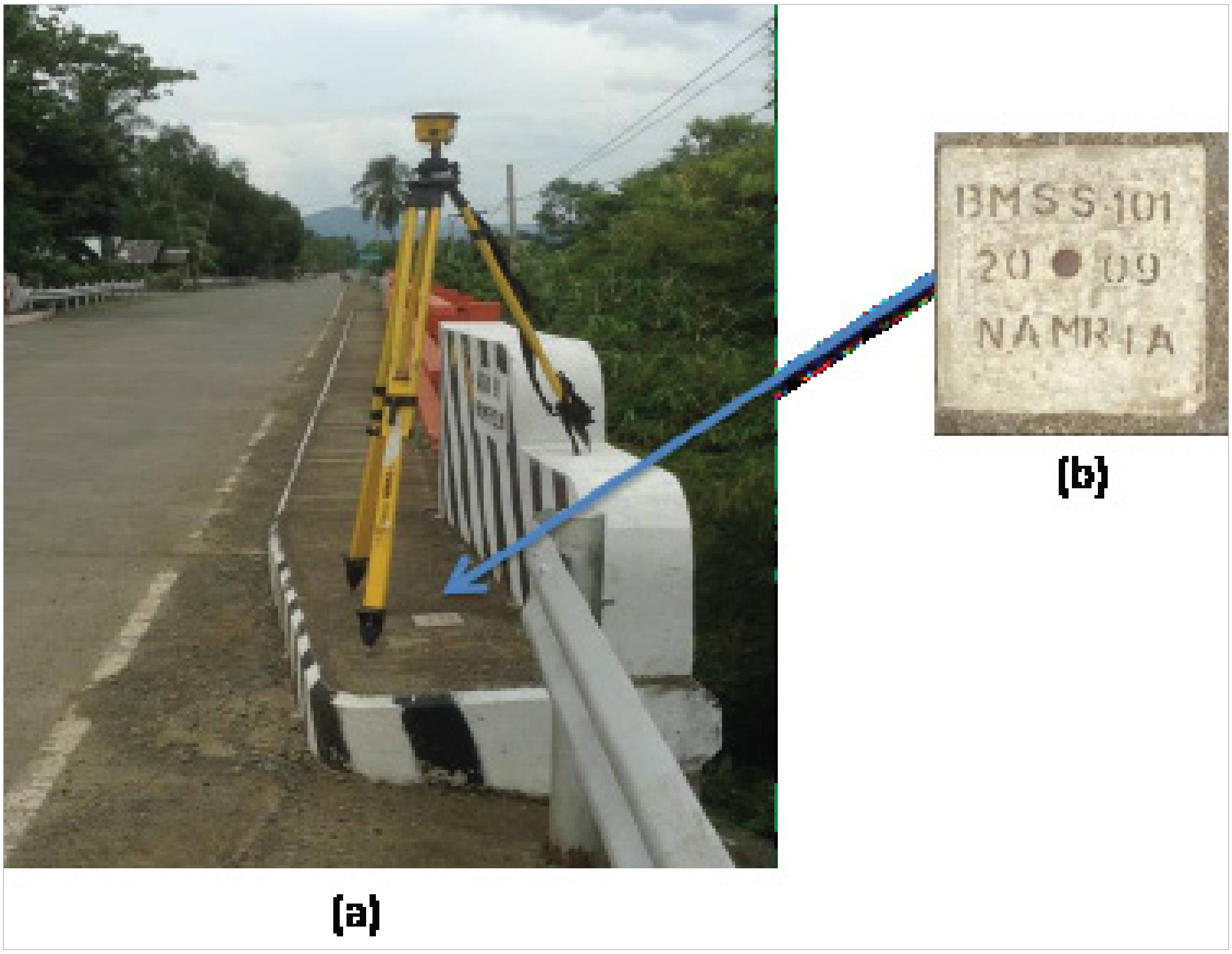

Figure 4. GPS set-up over SS-101 located at the first approach of Antao Bridge KM. Post 1249+122.90 near a concrete electric post in Brgy. Antao, Carmen, Surigao del Sur (a) and NAMRIA reference point SS-101 (b) as recovered by the field team

Table 3. Details of the recovered NAMRIA vertical control point SS-101 used as base station with established coordinates

Station Name	SS-101	
Order of Accuracy	2^{nd}	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9°14'21.88056" North 125°59'11.96188" East 8.363 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	828202.434 meters 1022631.093 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9°14'18.21639" North 125°59'17.28524"East [ ] meters

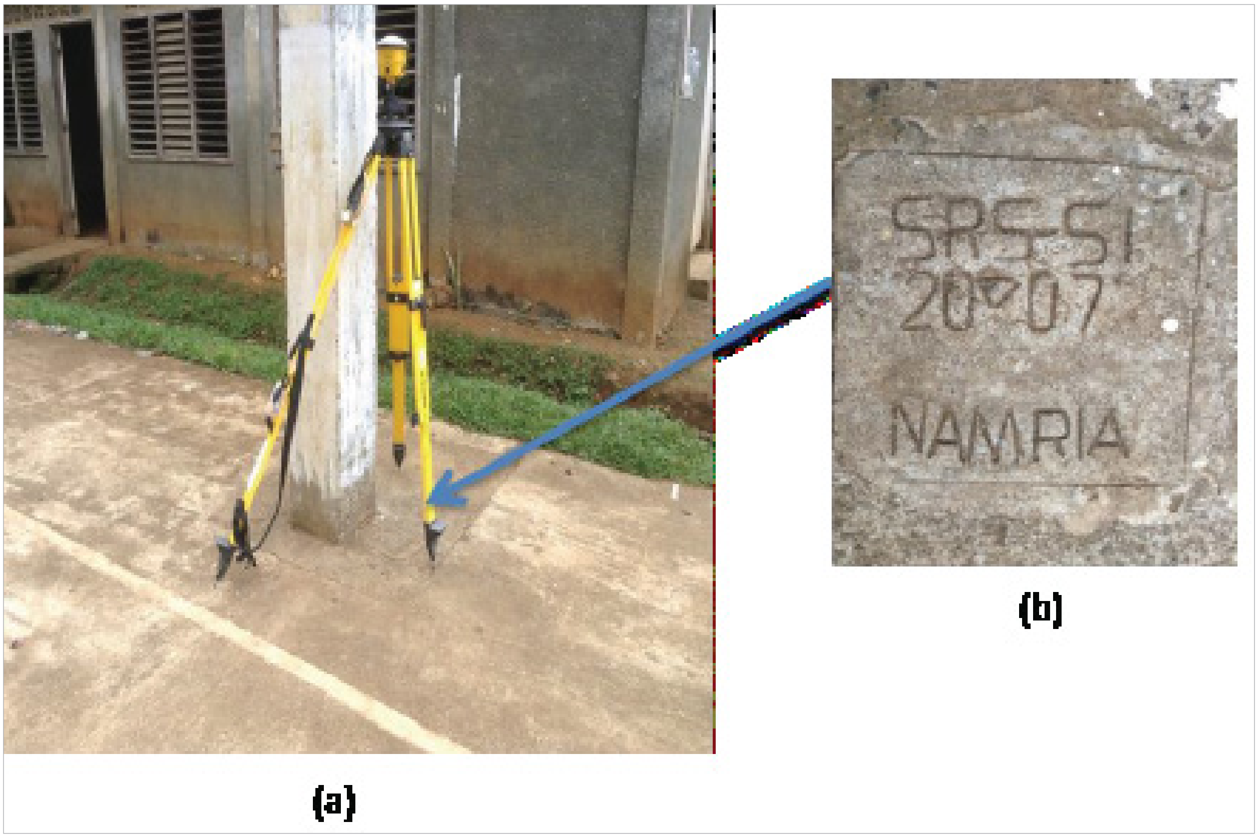

Figure 5. GPS set-up over SRS-51 located inside the compound of the barangay hall, beside the basketball court Brgy. Bajao, Tandag, Surigao del Sur (a) and NAMRIA reference point SS-101 (b) as recovered by the field team

Table 4. Details of the recovered NAMRIA horizontal control point SRS-51 used as base station for the LiDAR acquisition

Station Name	**SRS-51**	
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	8° 59’ 14.14996” North 126° 9’ 6.83415” East 3.97000 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	406741.509 meters 99387.182 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8°59’ 10.56678” North 126° 9’ 12.17833” East 74.22300 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS92)	Easting Northing	186815.64 meters 994598.26 meters

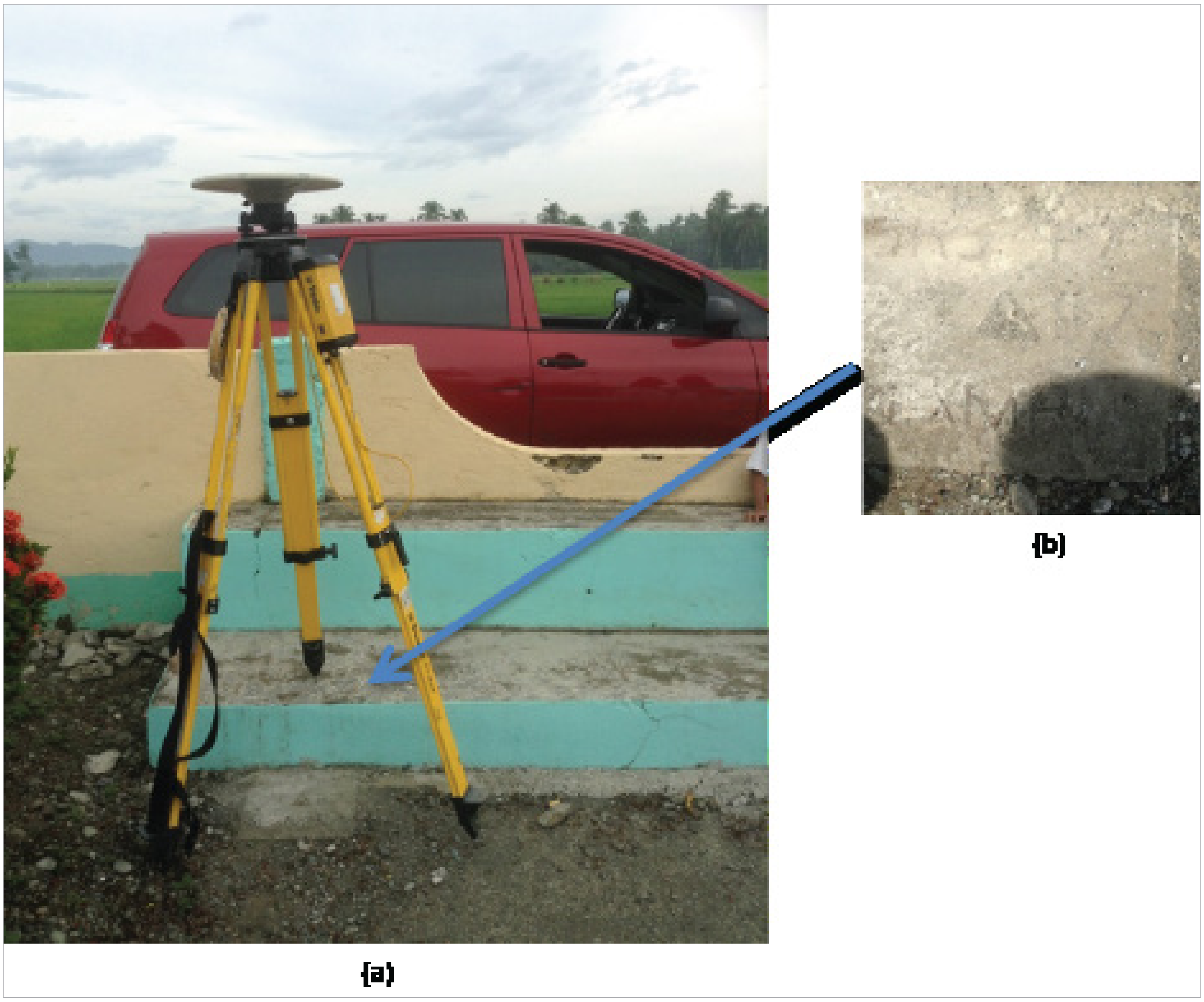

Figure 6. GPS set-up over SRS-47 located on the left side ground corner of the barangay hall about 60 m from the crossing in Brgy. Manga, Madrid, Surigao del Sur (a) NAMRIA reference point SS-101 (b) as recovered by the field team

Table 5. Table 5. Details of the recovered NAMRIA horizontal control point SRS-47 used as base station for the LiDAR acquisition

Station Name	SRS-47	
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	9° 15’ 35.53566” 125° 58’ 53.39602” 5.36600 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	607846.421 meters 1024025.604 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9° 15’ 31.86566” North 125° 58’ 58.71761” East 74.61000 meters

Table 6. Ground contrvol points used during LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
5 JULY 14	1664A	3BLK61A186A	SS-158 and SRS-51
6 JULY 14	1666A	3BLK61ASB187A	SS-158 and SRS-51
7 JULY 14	1670A	3BLK61BSC188A	SS-158 and SRS-51
8 JULY 14	1674A	3BLK61CSD189A	SS-158 and SRS-51
9 JULY 14	1678A	3BLK61DSG190A	SS-158 and SRS-51
29 JULY 14	1758A	3BLK61FGHKMSN210A	SS-158 and SRS-51
30 JULY 14	1762A	3BLK61NS211A	SS-101 and SRS-47
31 JULY 14	1766A	3BLK61NSO212A	SS-101 and SRS-47

2.3 Flight Missions

Eight (8) missions were conducted to complete the LiDAR data acquisition in Tandag Floodplain, for a total of thirty two hours and fifty one minutes (32+51) hours for RP-C9122. All missions were acquired using the Aquarius LiDAR system. Table 7 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 8 presents the actual parameters used during the LiDAR data acquisition.

Table 7. Flight missions for LiDAR data acquisition in Tandag Floodplain

Date Surveyed	Flight Number	Flight Plan Area (km^2)	Surveyed Area (km^2)	Area Surveyed within the Floodplain (km^2)	Area Surveyed outside the Floodplain (km^2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
5 JULY 14	1664A	68	31.10	1.94	29.16	365	1	59
6 JULY 14	1666A	134.478	82.44	11.06	71.38	704	4	88
7 JULY 14	1670A	131.649	96.81	20.41	76.40	428	4	5
8 JULY 14	1674A	115.94	93.17	5.70	87.47	393	4	23
9 JULY 14	1678A	102.348	88.48	0.00	88.48	672	4	17
29 JULY 14	1758A	213.44	112.42	1.04	111.38	218	4	23
30 JULY 14	1762A	126	79.84	2.22	77.62	1175	4	5
31 JLUY 14	1766A	211.18	69.84	0.00	69.84	991	4	11
TOTAL		**1103.04**	**654.10**	**42.37**	**611.73**	**4946.00**	**32**	**51**

Table 8. Actual parameters used during LiDAR data acquisition

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (KHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
1664A	500	25,50	36	50	45	120	5
1666A	500	60	36	50	45	120	5
1670A	600	60	36	50	45	120	5
1674A	600	60	36	50	45	120	5
1678A	600	60,65	36	50	45	120	5
1758A	600	70	36	50	45	120	5
1762A	600	50	36	50	45	120	5
1766A	500,600	50	36	50	45	120	5

2.4 Survey Coverage

Tandag Floodplain is located in Surigao del Sur. Municipalities of Bayabas and Cortes are mostly covered by the survey. The list of municipalities and cities surveyed, with at least (1) square kilometer coverage, is shown in Table 9. The actual coverage of the LiDAR acquisition for Tandag Floodplain is presented in Figure 7.

Table 9. List of municipalites and cities surveyed during Tandag Floodplain LiDAR survey

Province	Municipality/City	Area of Municipality/ City (km^2)	Total Area Surveyed (km^2)	Percentage of Area Surveyed
Surigao del Sur	Bayabas	48.29	43.65	90%
	Cortes	82.48	52.93	64%
	Tago	293.49	139.27	47%
	Tandag	392.39	106.38	27%
	San Miguel	410.02	67.66	17%
	Cagwait	200.13	32.91	16%
	Lanuza	231.62	34.72	15%
	Carmen	172.33	6.34	4%
Agusan del Sur	Sibagat	640.31	2.42	1%
Total		**2,471.06**	**486.28**	**19.68%**

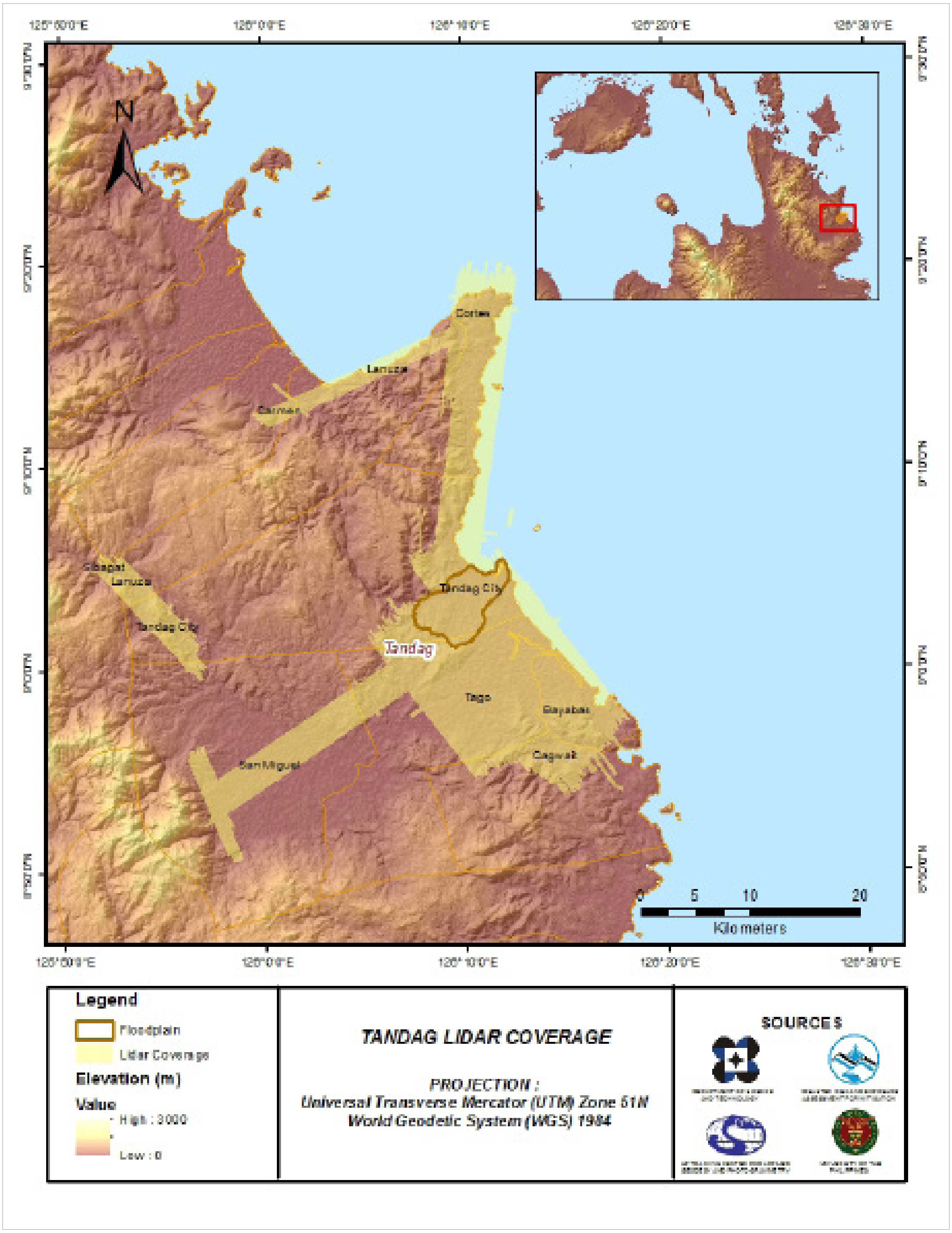

Figure 7. Actual LiDAR data acquisition for Tandag Floodplain

CHAPTER 3: LIDAR DATA PROCESSING FOR TANDAG FLOODPLAIN

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

3.1 Overview of the LiDAR Data Pre-Processing

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

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

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

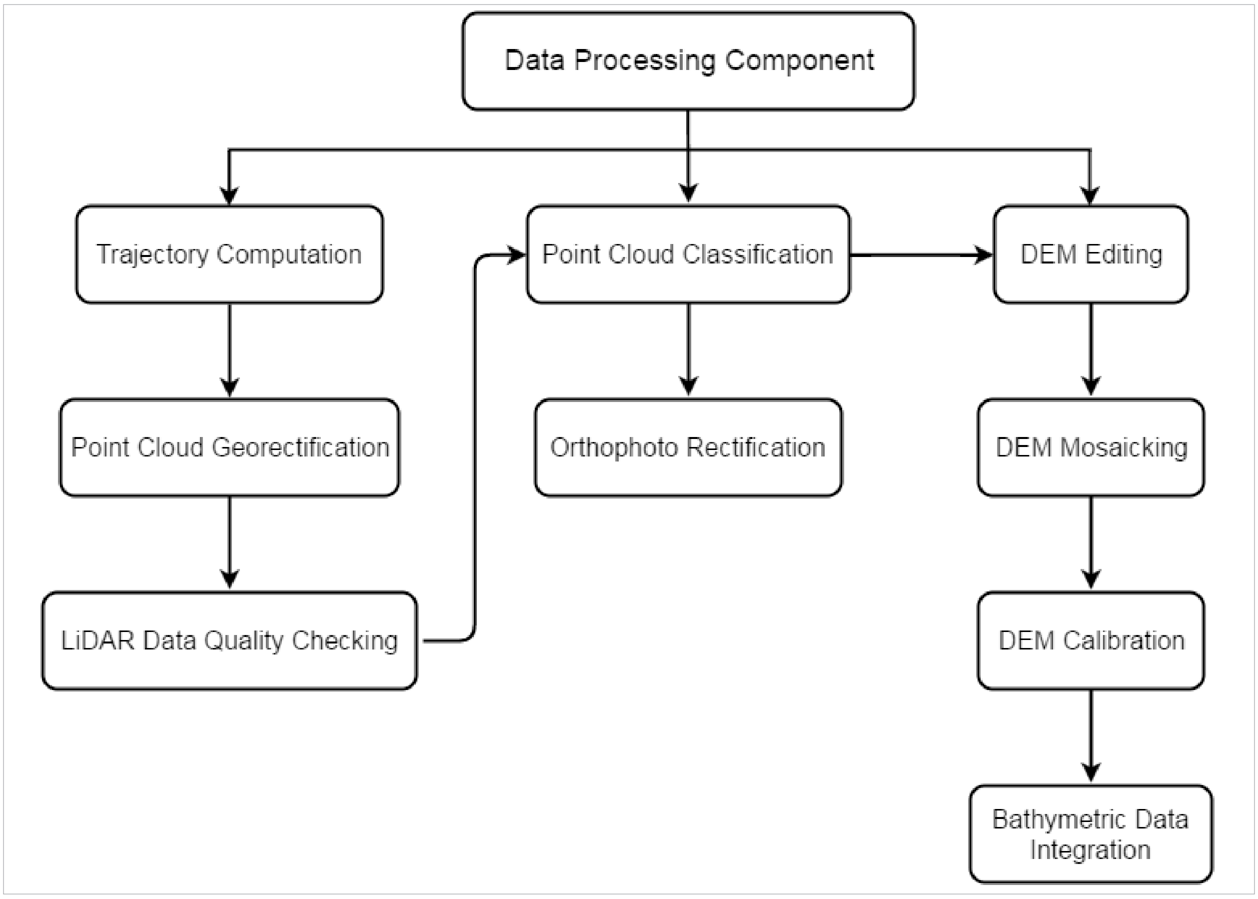

Figure 8. Schematic diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Tandag Floodplain can be found in ANNEX 5. Missions flown during the first, second, and third surveys conducted on July and August 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Aquarius system over Surigao del Sur. The Data Acquisition Component (DAC) transferred a total of 92.54 Gigabytes of Range data, 1.794 Gigabytes of POS data, 76.90 Megabytes of GPS base station data, and 320.88 Gigabytes of raw image data to the data server on July 23, 2014 for the first, August 14, 2014 for the second, and September 1, 2014 for the third survey. The Data Pre-Processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Tandag was fully transferred on September 1, 2014, as indicated on the data transfer sheets for Tandag Floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for flight 1674A, one of the Tandag flights, which is the North, East, and Down positions RMSE values are shown in Figure 9. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on July 8, 2014 00:00 AM. The y-axis is the RMSE value for that particular position.

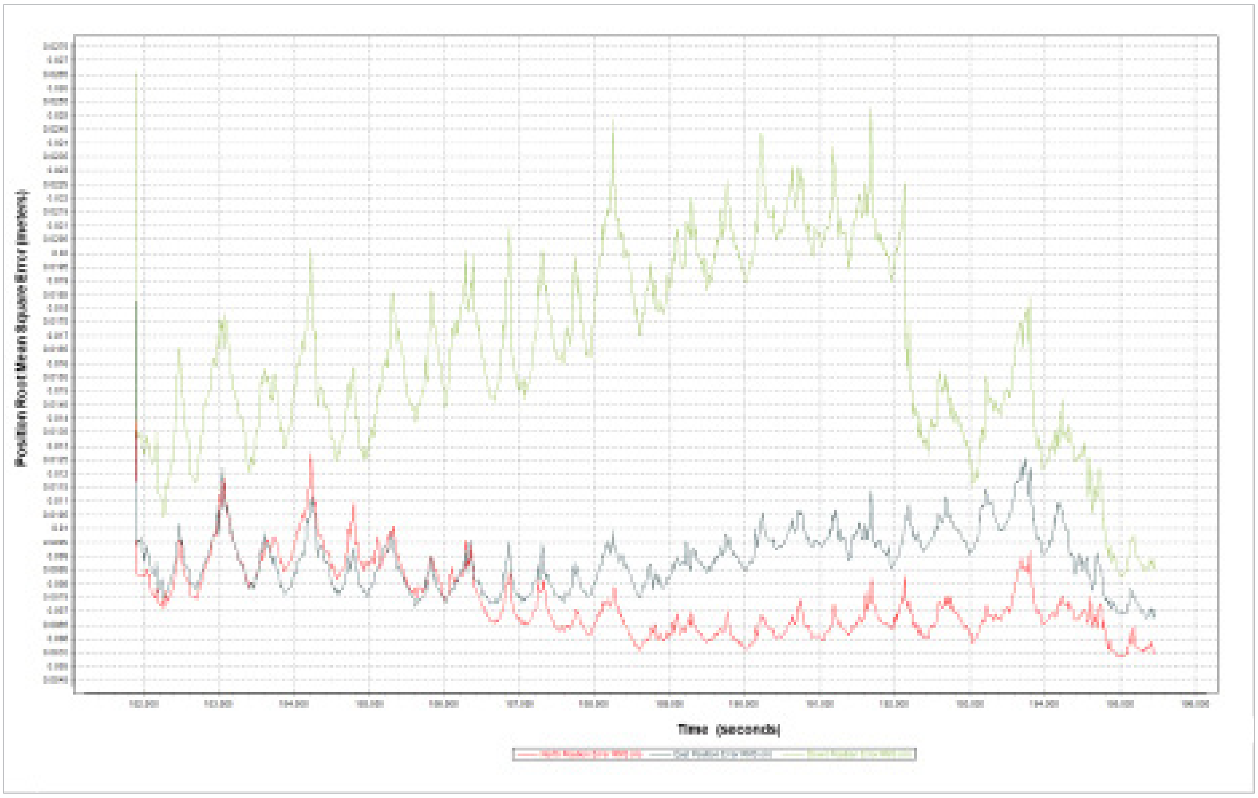

Figure 9. Smoothed Performance Metric parameters of a Tandag Flight 1674A

The time of flight was from 181800 seconds to 195500 seconds, which corresponds to morning of July 8, 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 time the POS system started computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 9 shows that the North position RMSE peaks at 1.40 centimeters, the East position RMSE peaks at 1. 80 centimeters, and the Down position RMSE peaks at 2.55 centimeters, which are within the prescribed accuracies described in the methodology.

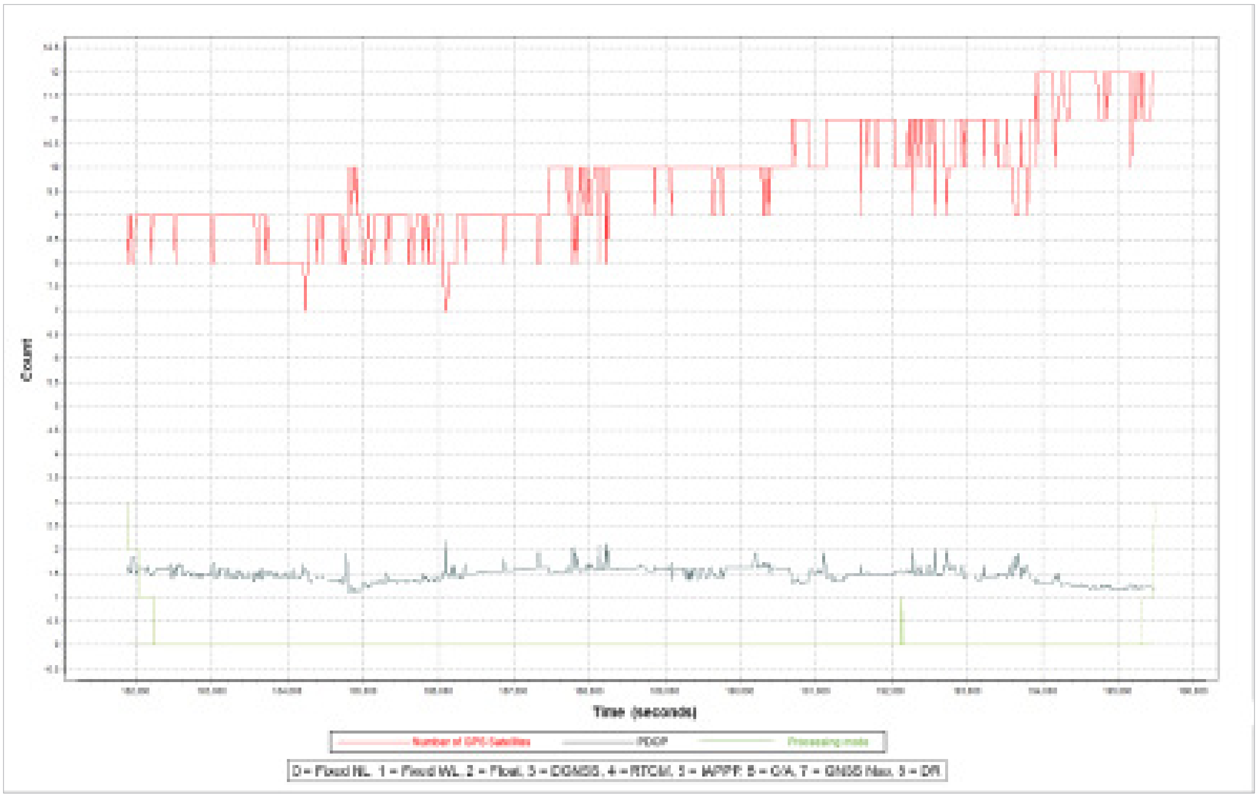

Figure 10. Solution Status Parameters of Tandag Flight 1674A.

The Solution Status parameters of flight 1674A, one of the Tandag flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 10. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Majority of the time, the number of satellites tracked was between 7 and 12. 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 Tandag flights is shown in Figure 11.

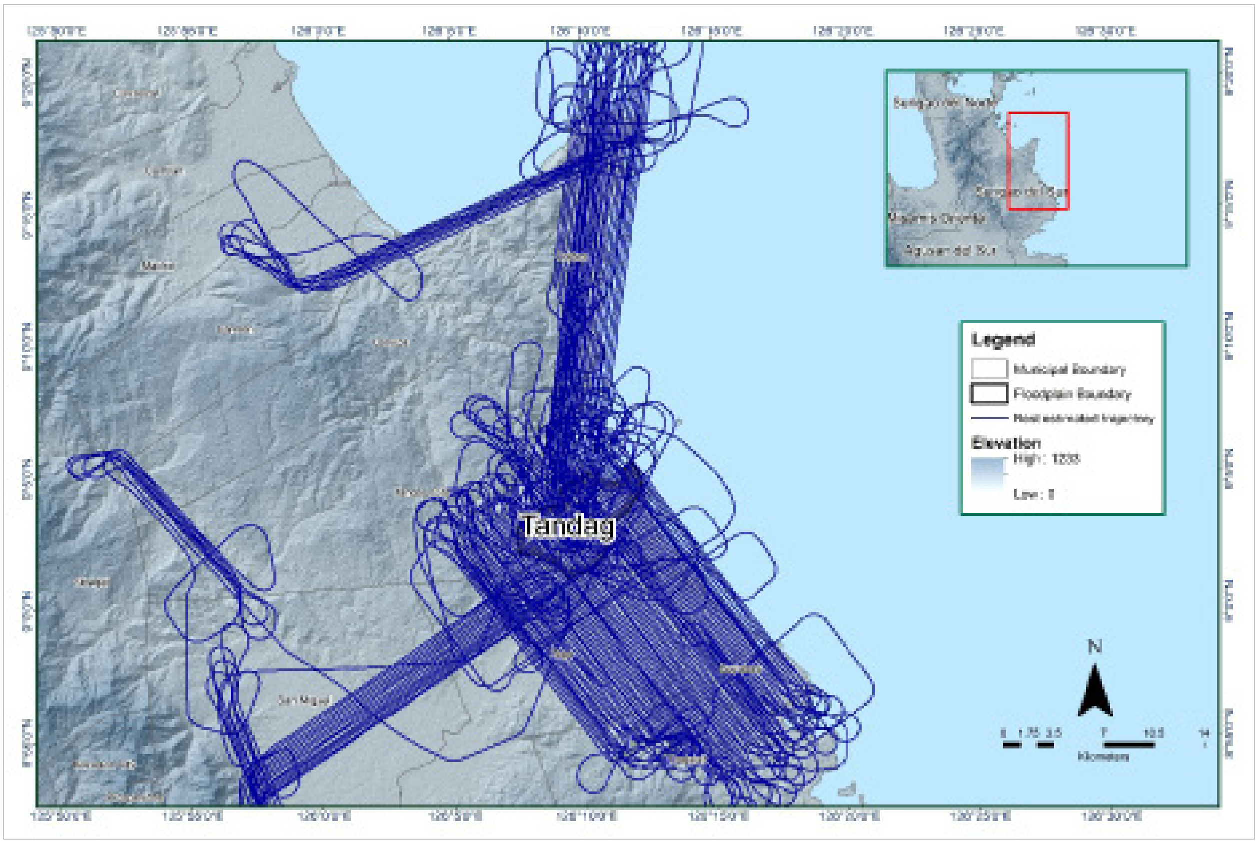

Figure 11. Best estimated trajectory of LiDAR missions conducted over Tandag Floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 117 flight lines, with each flight line containing one channel, since the Aquarius system contains one channel only. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Tandag Floodplain are given in Table 10.

Table 10. Self-calibration results values for Tandag flights

Parameter	Acceptable Value
Boresight Correction stdev (<0.001degrees)	0.000668
IMU Attitude Correction Roll and Pitch Corrections stdev (<0.001degrees)	0.000977
GPS Position Z-correction stdev (<0.01meters)	0.0059

The optimum accuracy was obtained for all Tandag flights based on the computed standard deviations of the corrections of the orientation parameters. Standard deviation values for individual blocks are available in the ANNEX 5.

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Tandag Floodplain is shown in Figure 12. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

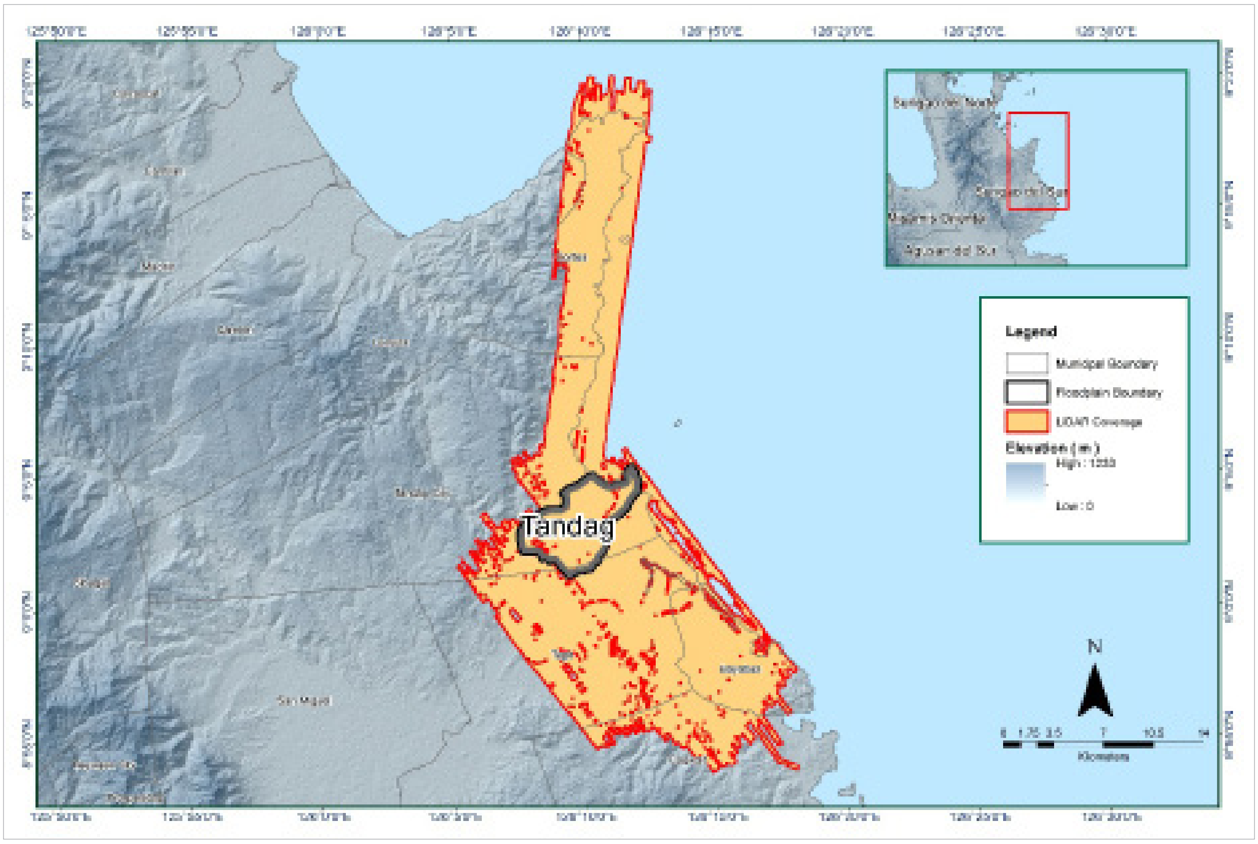

Figure 12. Boundary of the processed LiDAR data over Tandag Floodplain

The total area covered by the Tandag missions is 416.59 sq km that is comprised of eight (8) flight acquisitions grouped and merged into four (4) blocks as shown in Table 11.

Table 11. List of LiDAR blocks for Tandag Floodplain

LiDAR Blocks	Flight Numbers	Area (sq. km)
SurigaodelSur_Blk61A	1664A	91.35
	1666A	
SurigaodelSur_Blk61B	1670A	94.84
SurigaodelSur_Blk61CD	1674A	102.49
	1678A	
SurigaodelSur_Blk61N	1758A	127.91
	1762A	
	1766A	
TOTAL		**416.59 sq.kmsq km**

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location, is shown in Figure 13. Since the Aquarius system employs one channel only, an average value of 1 (blue) would be expected 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.

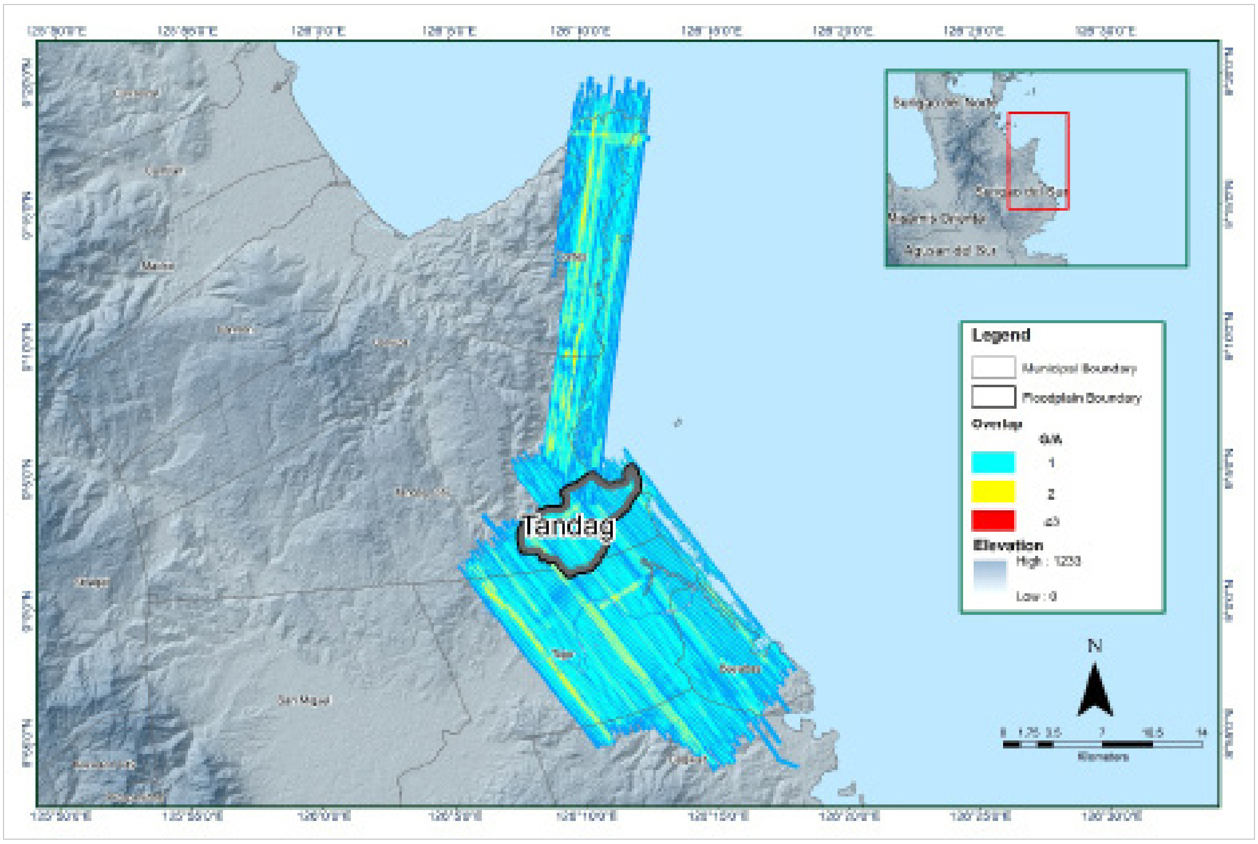

Figure 13. Data overlap between missions and flight lines for Tandag Floodplain survey

The overlap statistics per block for the Tandag Floodplain can be found in ANNEX 8. It should be noted that one pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 47.47% and 68.11%, 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 14. It was determined that all LiDAR data for Tandag Floodplain satisfy the point density requirement, and the average density for the entire survey area is 4.07 points per square meter.

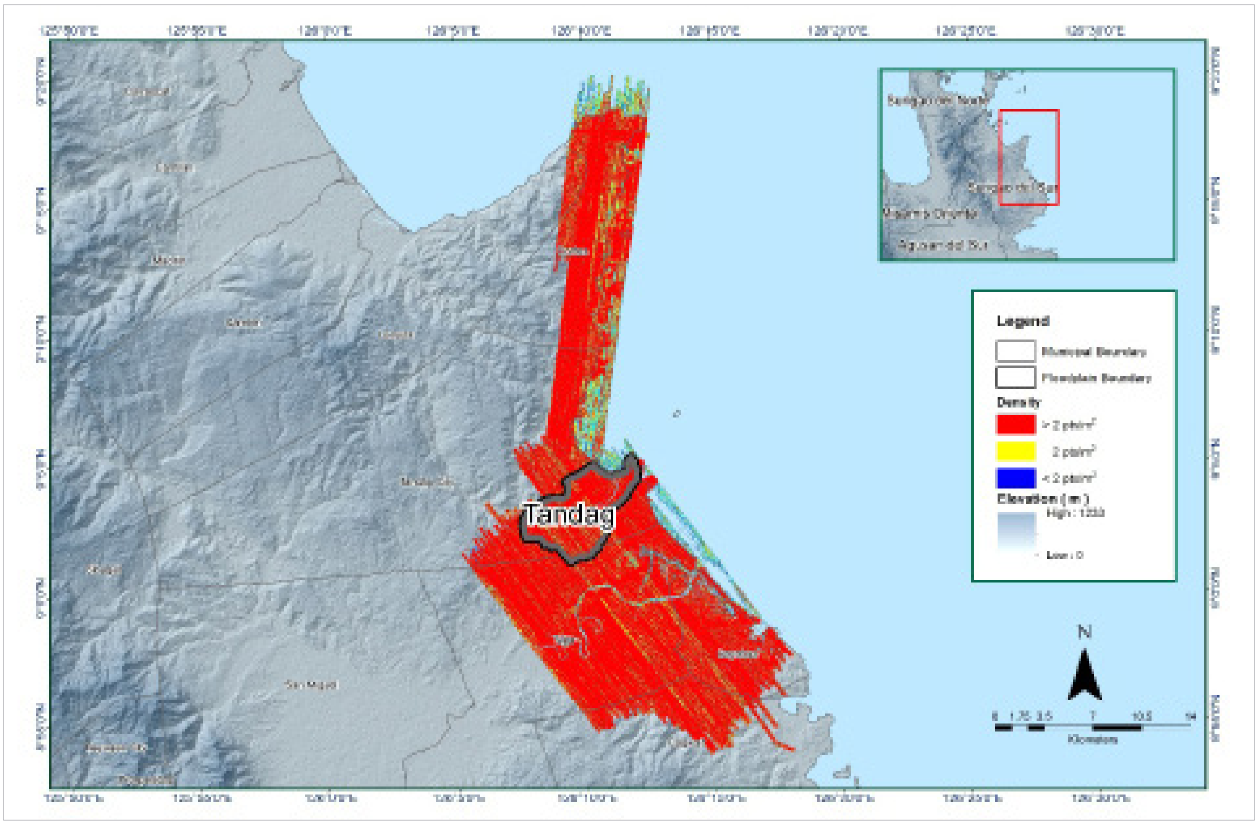

Figure 14. Pulse density map of merged LiDAR data for Tandag Floodplain

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

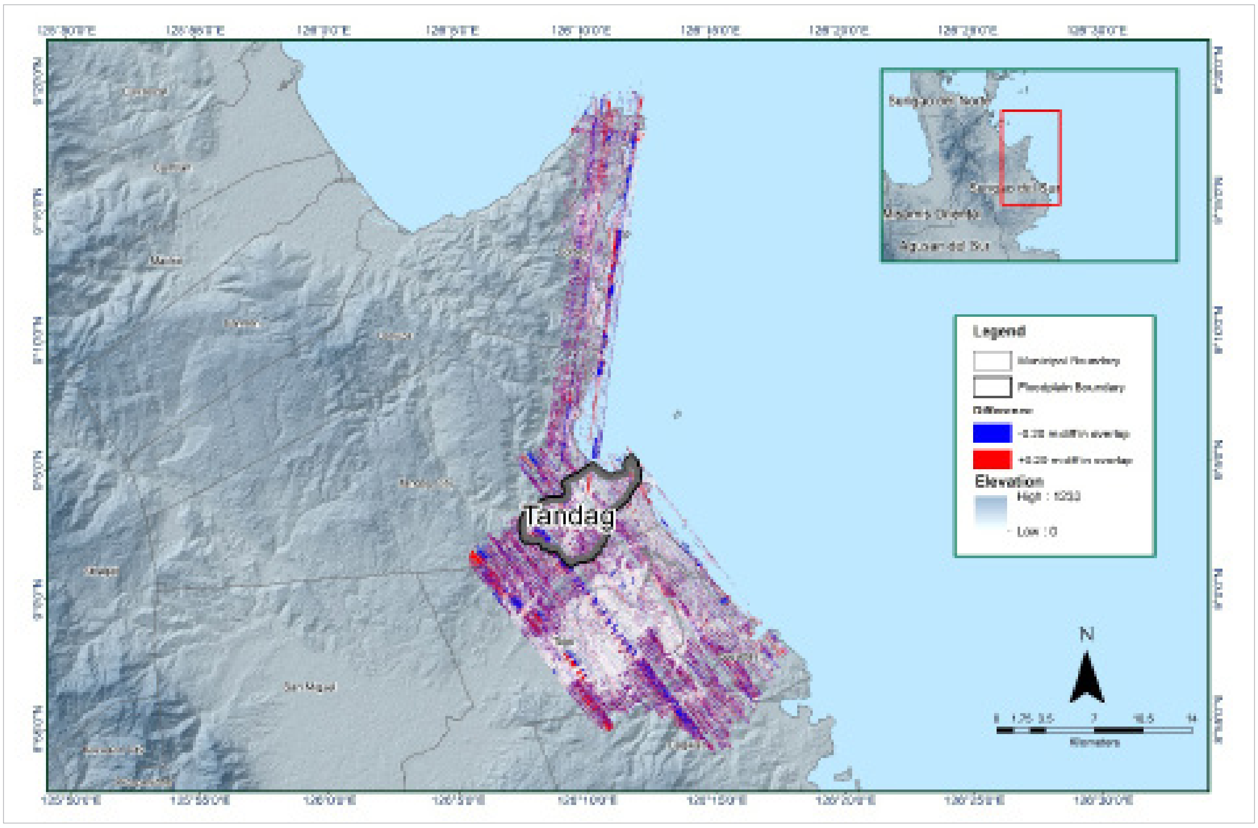

Figure 15. Elevation difference map between flight lines for Tandag Floodplain

A screen capture of the processed LAS data from a Tandag flight 1674A loaded in QT Modeler is shown in Figure 16. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed yellow line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

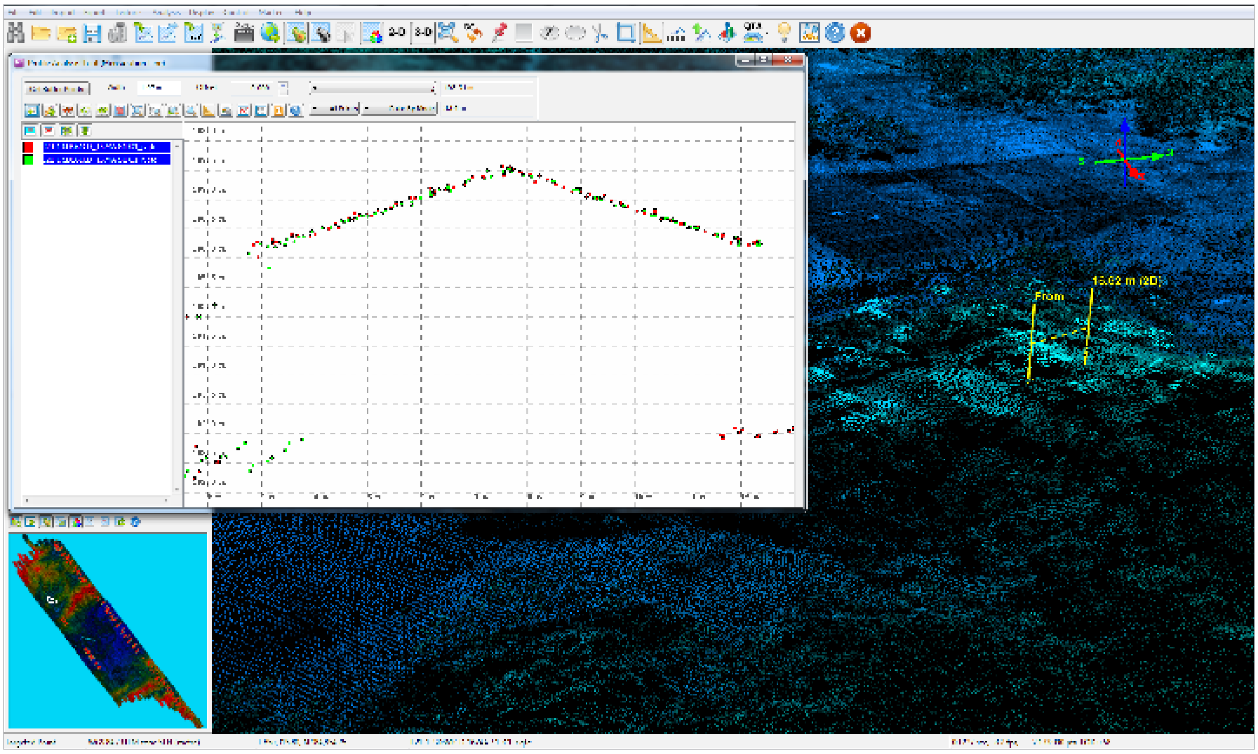

Figure 16. Quality checking for a Tandag flight 1674A using the Profile Tool of QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 12. Tandag classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	240,570,118
Low Vegetation	297,146,040
Medium Vegetation	401,725,924
High Vegetation	839,179,032
Building	52,923,874

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Tandag Floodplain is shown in Figure 17. A total of 622 1 km by 1 km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 12. The point cloud has a maximum and minimum height of 630.35 meters and 46.6 meters, respectively.

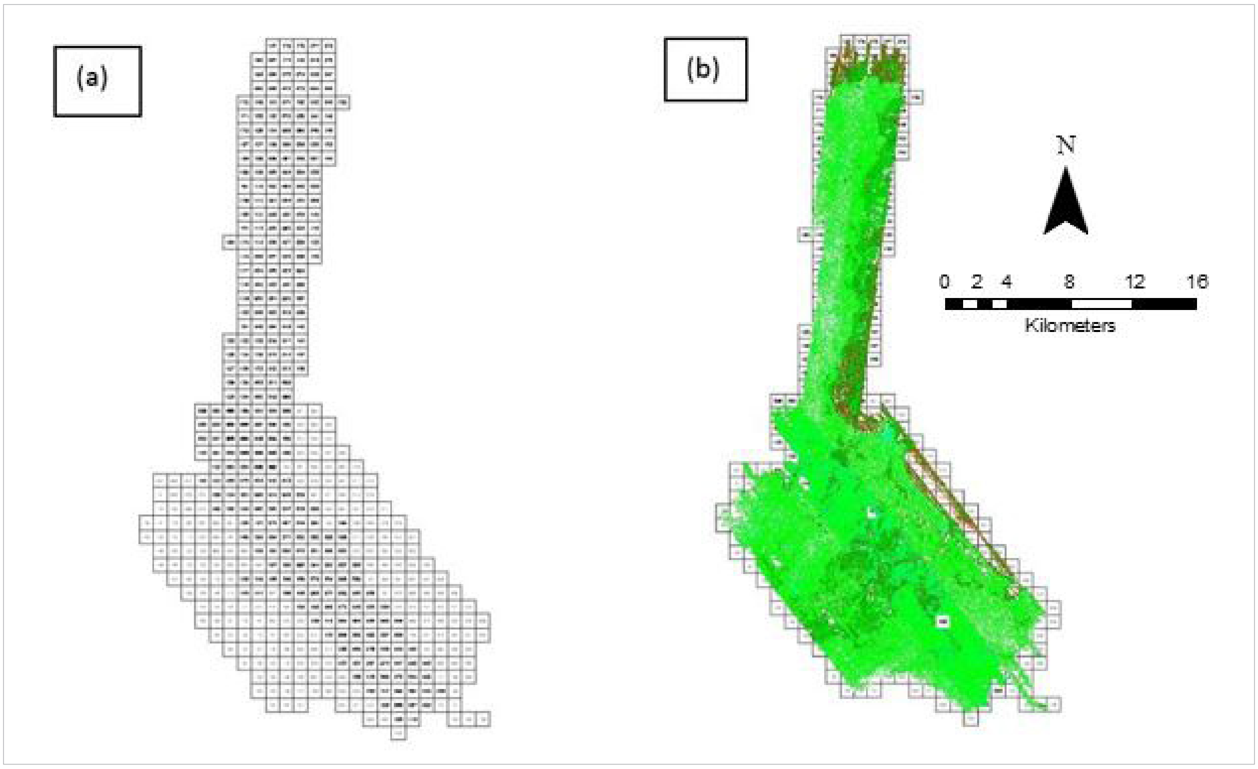

Figure 17. Tiles for Tandag Floodplain (a) and classification results (b) in TerraScan

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

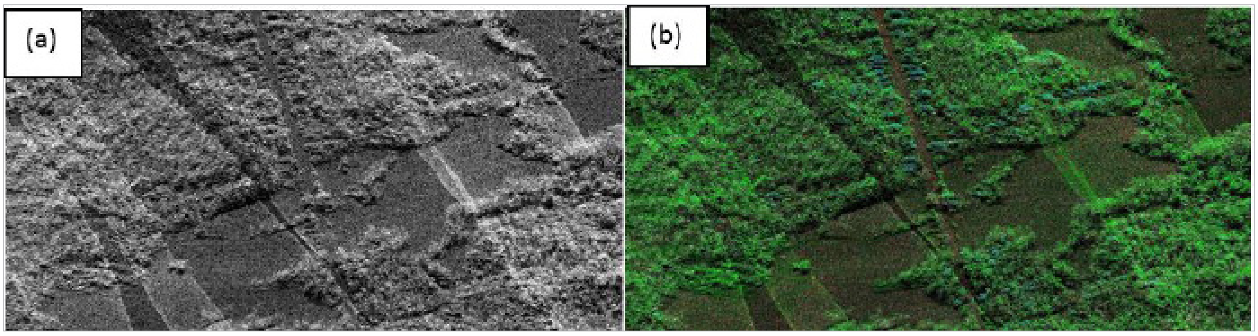

Figure 18. Point cloud before (a) and after (b) classification.

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

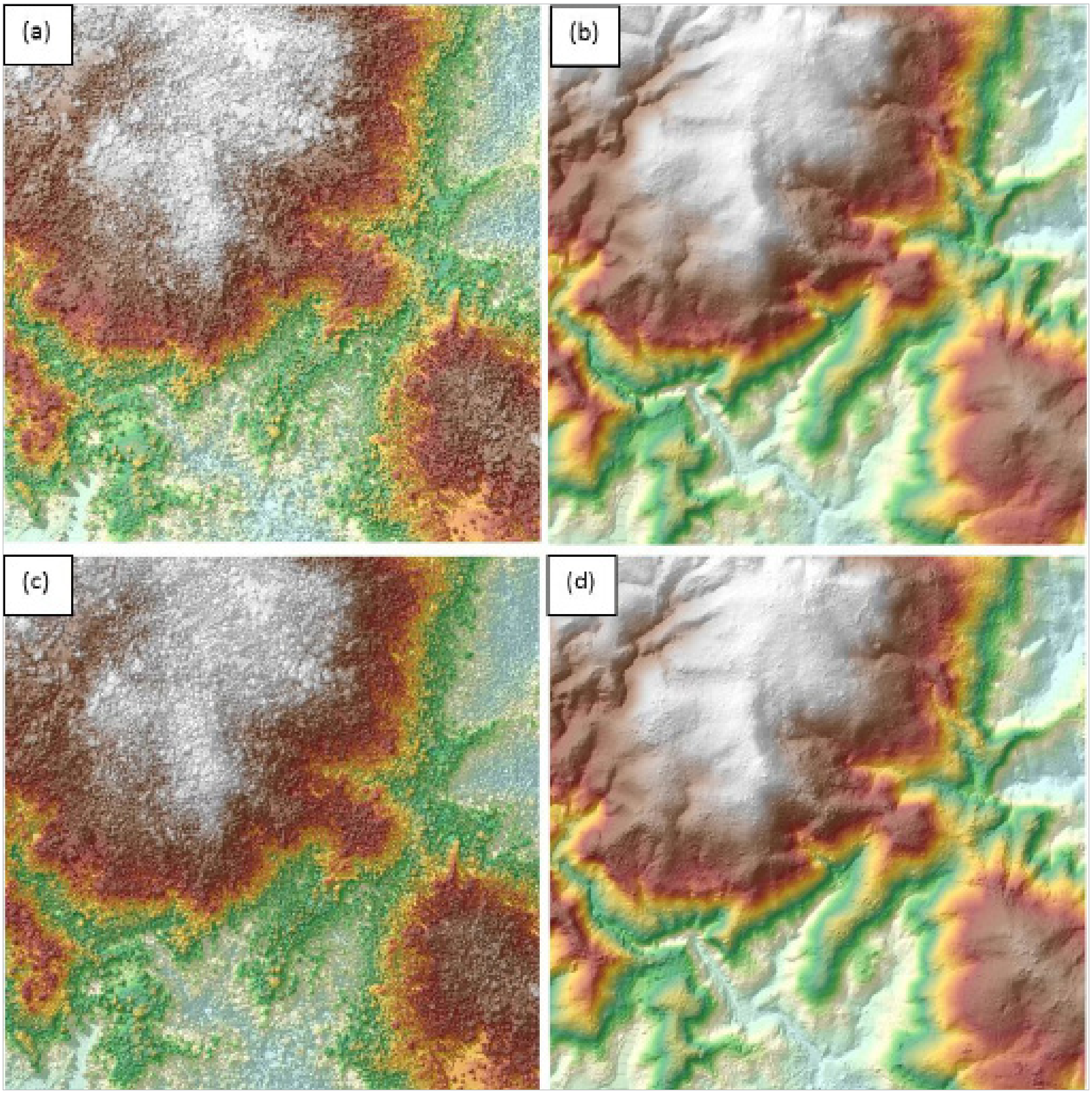

Figure 19. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Tandag Floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 473 1 km by 1 km tiles area covered by Tandag Floodplain is shown in Figure 20. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Tandag Floodplain attained a total of 268.21 sq km in orthophotogaph coverage comprised of 3,380 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 21.

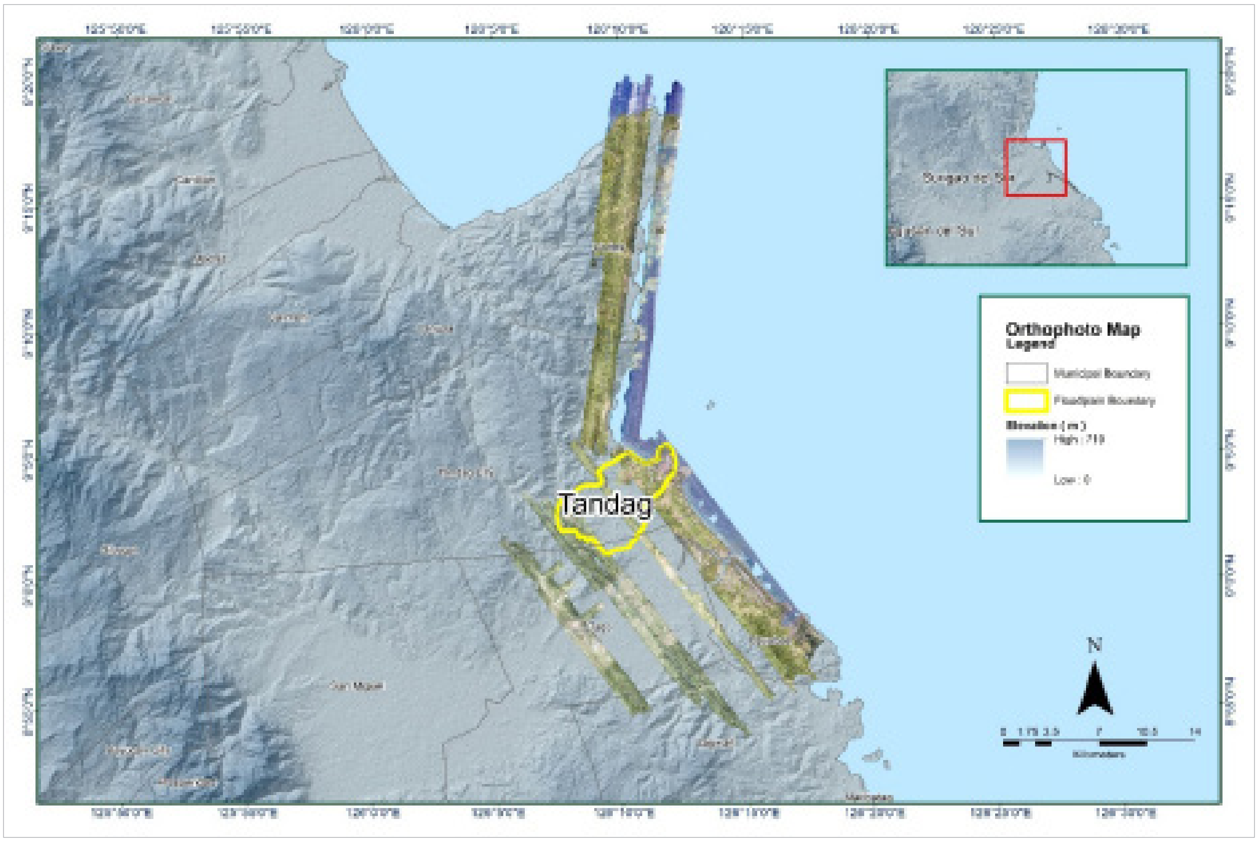

Figure 20. Tandag Floodplain with available orthophotographs

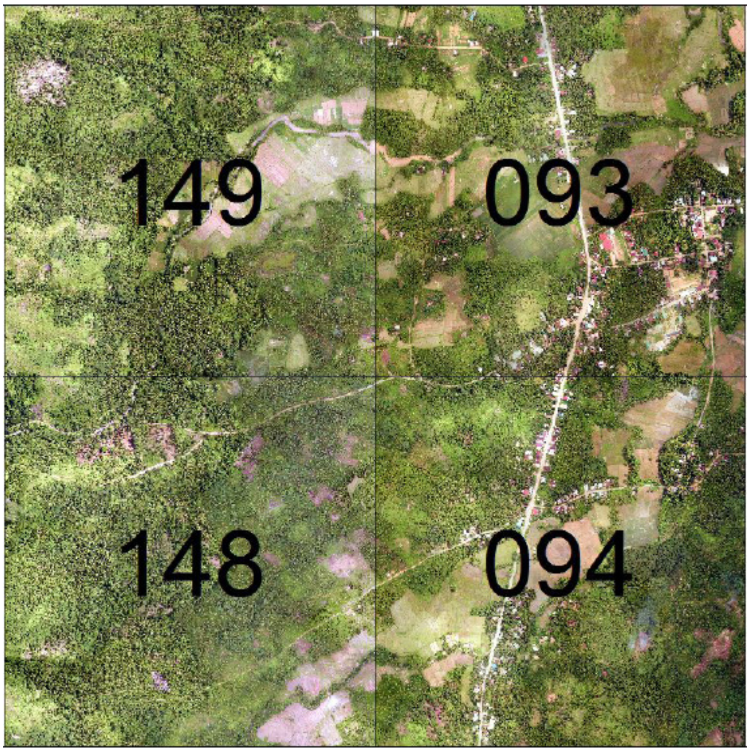

Figure 21. Tandag Floodplain with available orthophotographs

3.8 DEM Editing and Hydro-Correction

Four (4) mission blocks were processed for Tandag Floodplain. These blocks are composed of SurigaodelSur blocks with a total area of 416.48 square kilometers. Table 13 shows the name and corresponding area of each block in square kilometers.

Table 13. LiDAR blocks with their corresponding area

LiDAR Blocks	Area (sq.km)
SurigaodelSur_Blk61A	91.35
SurigaodelSur_Blk61B	94.84
SurigaodelSur_Blk61CD	102.49
SurigaodelSur_Blk61N	127.91
TOTAL	**416.59 sq.kmsq km**

Portions of DTM before and after manual editing are shown in Figure 22. Embankments of fishponds (Figure22a) had been misclassified and removed during classification process and had to be retrieved to complete the surface (Figure 22b) to allow the correct flow of water. The bridge (Figure 22c) was also considered to be an impedance to the flow of water along the river and had to be removed (Figure 22d) in order to hydrologically correct the river.

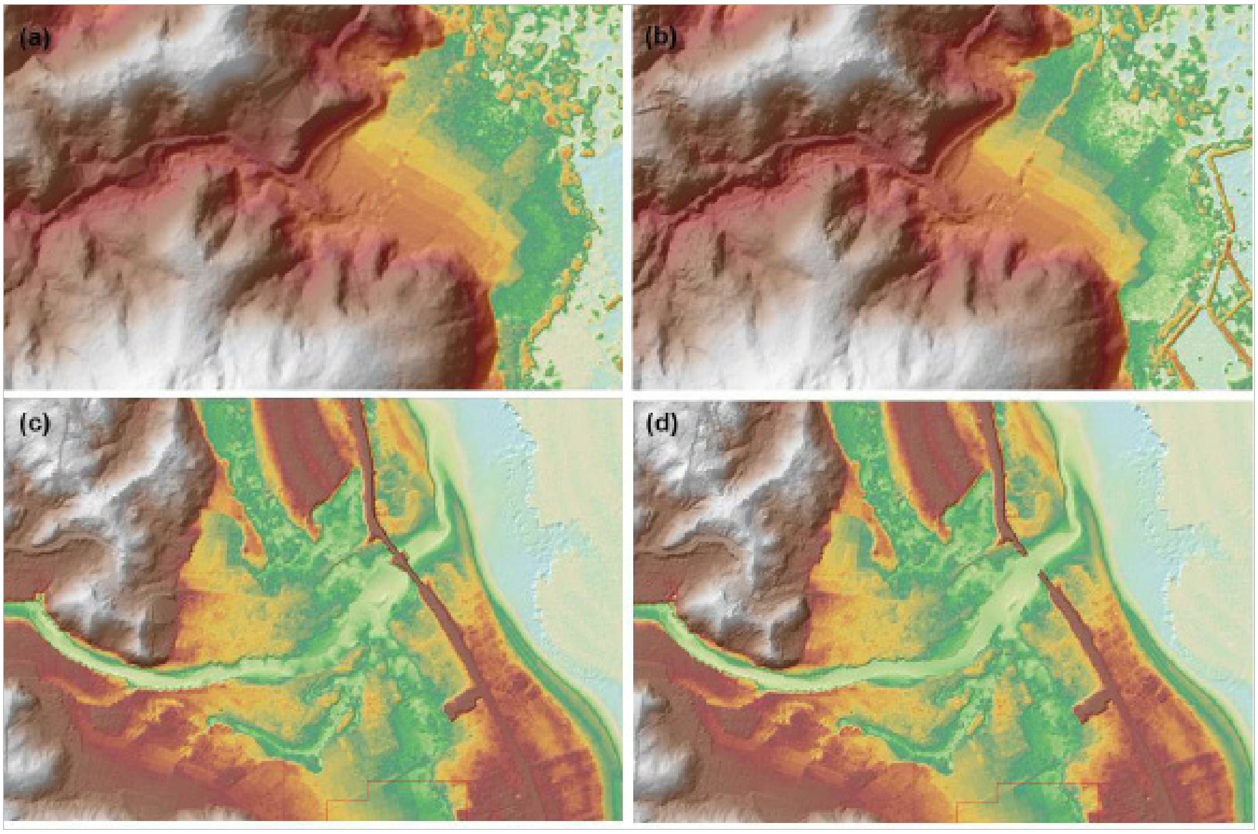

Figure 22. Portions in the DTM of Tandag Floodplain—embankments before (a) and after (b) data retrieval; and a bridge before (c) and after (d) manual editing

3.9 Mosaicking of Blocks

SurigaodelSur_Blk61CD was used as the reference block at the start of mosaicking because this block contained national highway in which the validation surveys passed through this road.

Mosaicked LiDAR DTM for Tandag Floodplain is shown in Figure 23. It can be seen that the entire Tandag Floodplain is 97.33% covered by LiDAR data.

Table 14. Shift values of each LiDAR Block of Tandag Floodplain

Mission Blocks	Shift Values (meters)		
	x	y	z
SurigaodelSur_Blk61B	0.00	0.00	0.06
SurigaodelSur_Blk61A	0.00	3.00	-1.11
SurigaodelSur_Blk61CD	0.00	0.00	0.00
SurigaodelSur_Blk61N	0.00	0.00	0.21

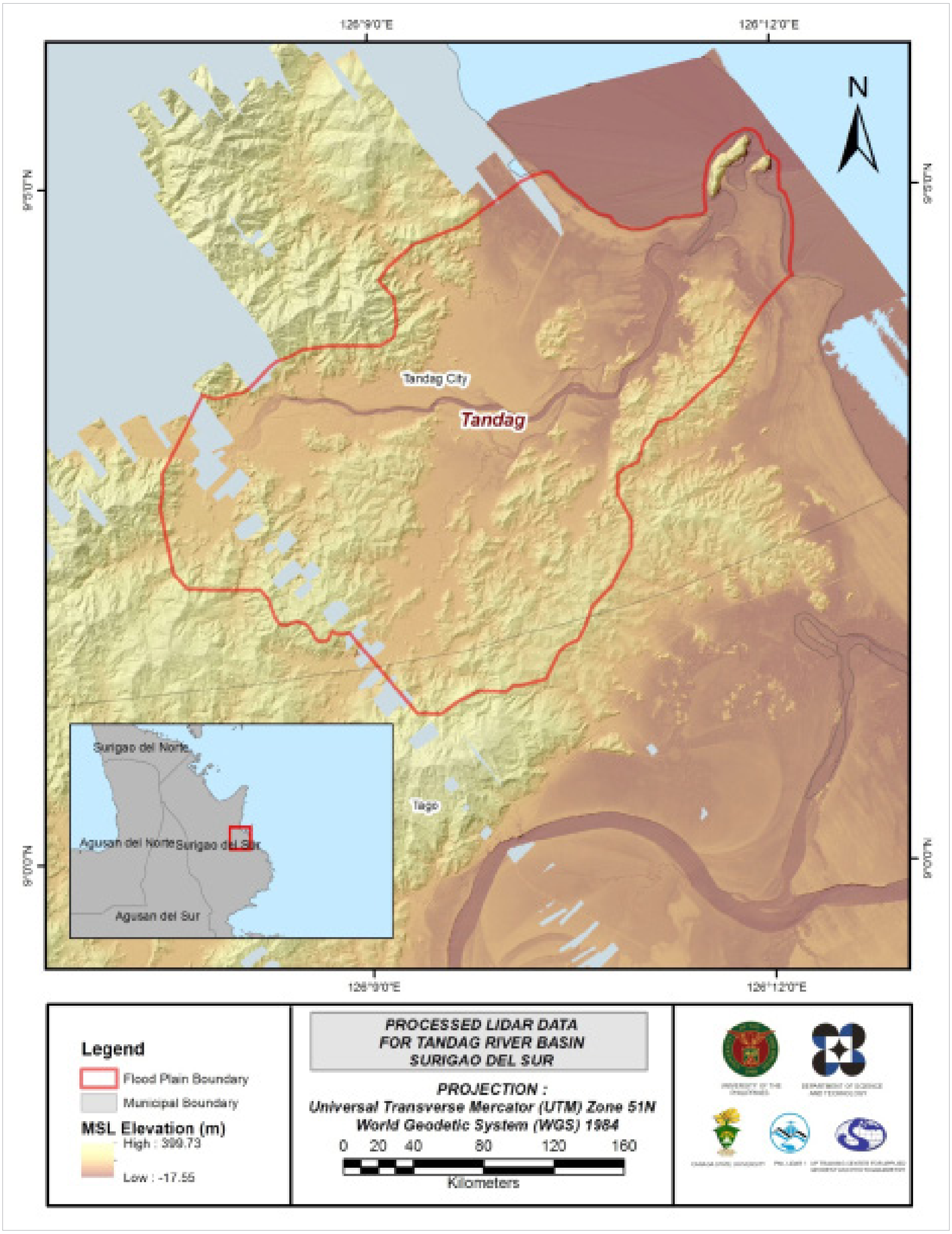

Figure 23. Map of processed LiDAR Data for Tandag Floodplain

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model

CSU's Field Survey Team (FST) in coordination with the Data Validation and Bathymetry Component (DVBC) in Tandag conducted surveys to collect points for the LiDAR validation. However, the collected datasets were not utilized because the mosaicked LIDAR DEM of Tandag was already calibrated using the datasets of Tago (Figure 24). As such, the DEM of Tandag can already be considered as a calibrated DEM. A total of 3,800 survey points were used for calibration and validation of Tago and Tandag LiDAR data. Eighty percent of the survey points, which were randomly selected and resulting in 3,040 points, were used for calibration. A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure 25. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration elevation values is 0.75 meters with a standard deviation of 0.17 meters. Calibration of Tago and Tandag LiDAR data was done by adding the height difference value, 0.75 meters, to Tago and Tandag mosaicked LiDAR data. Table 15 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

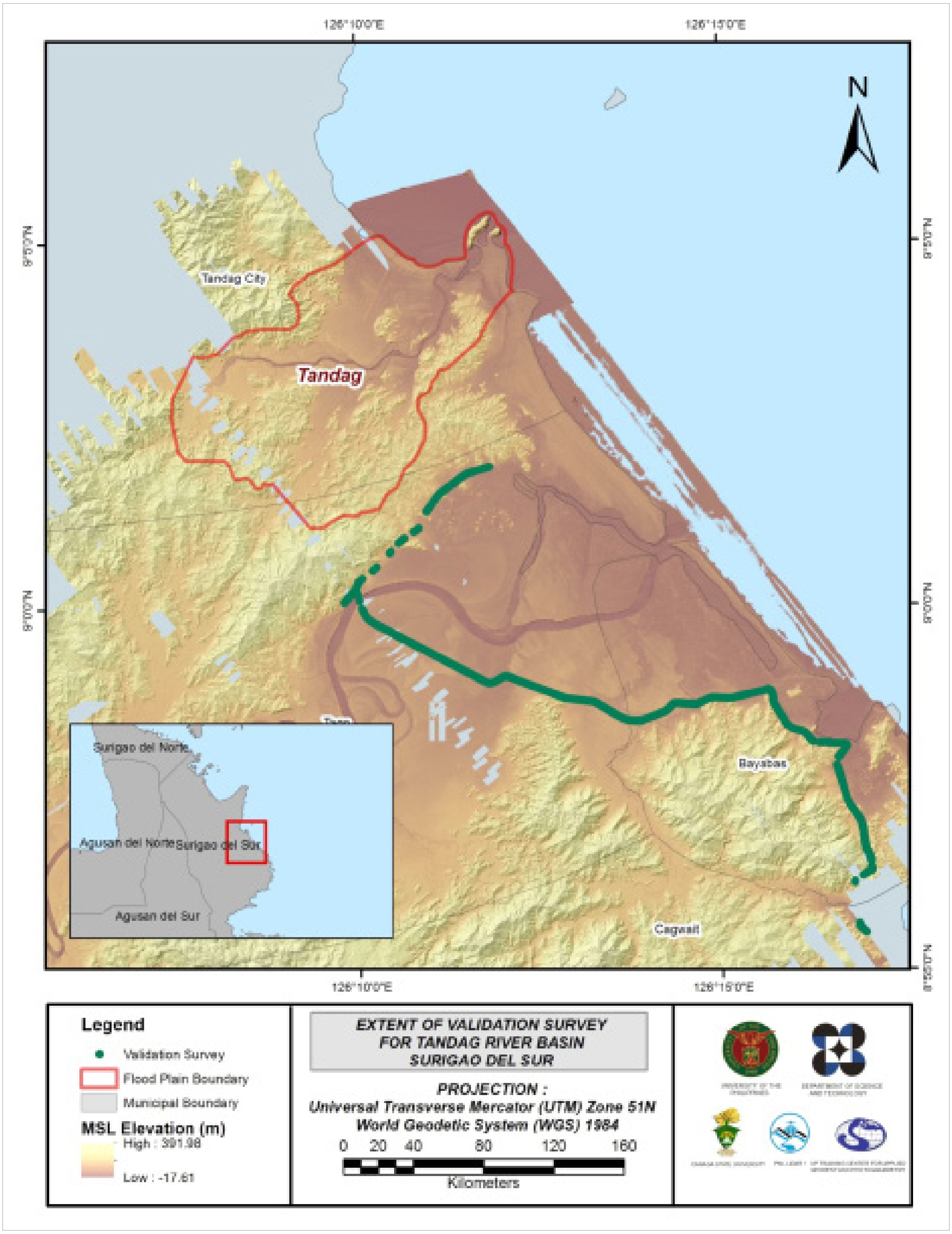

Figure 24. Map of Tandag Floodplain with validation survey points in green

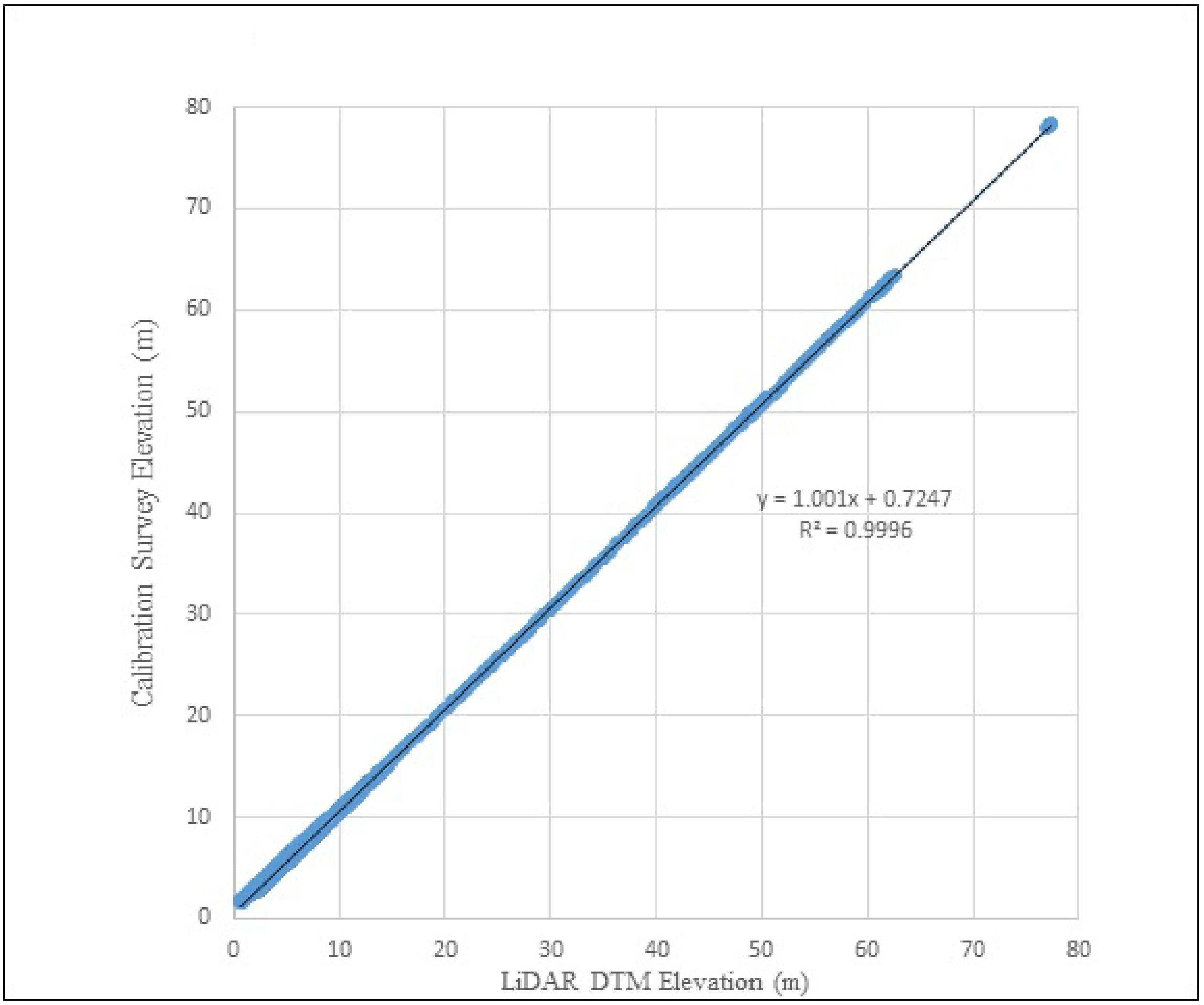

Figure 25. Correlation plot between calibration survey points and LiDAR data

Table 15. Calibration Statistical measures

Calibration Statistical Measures	Value (meters)
Height Difference	0.75
Standard Deviation	0.17
Average	0.73
Minimum	0.39
Maximum	1.07

The remaining 20% of the total survey points, resulting in 760 points, were used for the validation of calibrated Tandag 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 26. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.17 meters with a standard deviation of 0.17 meters, as shown in Table 16.

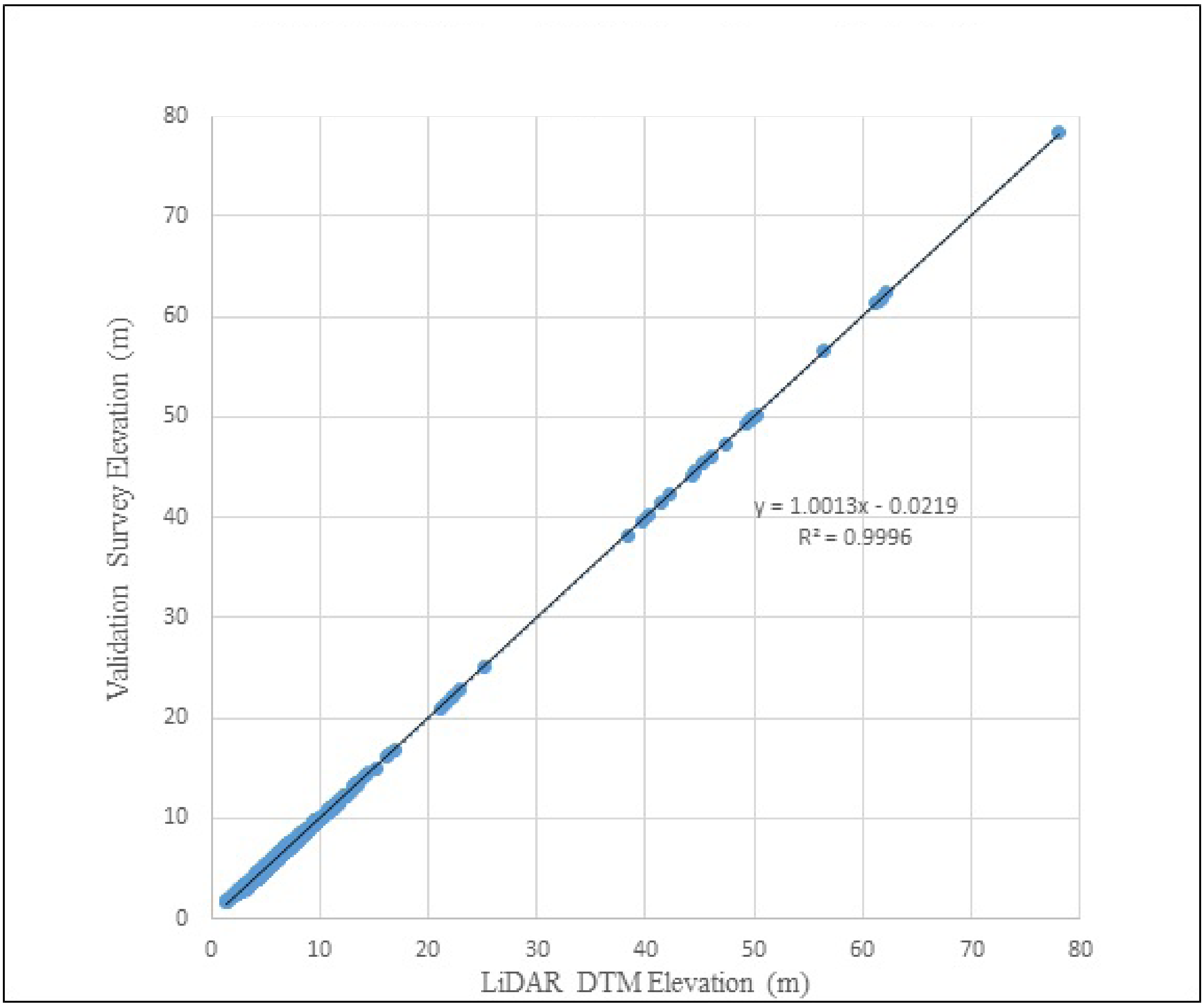

Figure 26. Correlation plot between validation survey points and LiDAR data

Table 16. Validation statistical measures

Validation Statistical Measures	Value (meters)
RMSE	0.17
Standard Deviation	0.17
Average	-0.01
Minimum	-0.35
Maximum	0.32

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and zigzag data were available for Tandag with 21,296 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 was represented by the computed RMSE value of 0.20 meters. The extent of the bathymetric survey done by the CSU's Field Survey Team (FST) in coordination with Data Validation and Bathymetry Component (DVBC) in Tandag integrated with the processed LiDAR DEM is shown in Figure 27.

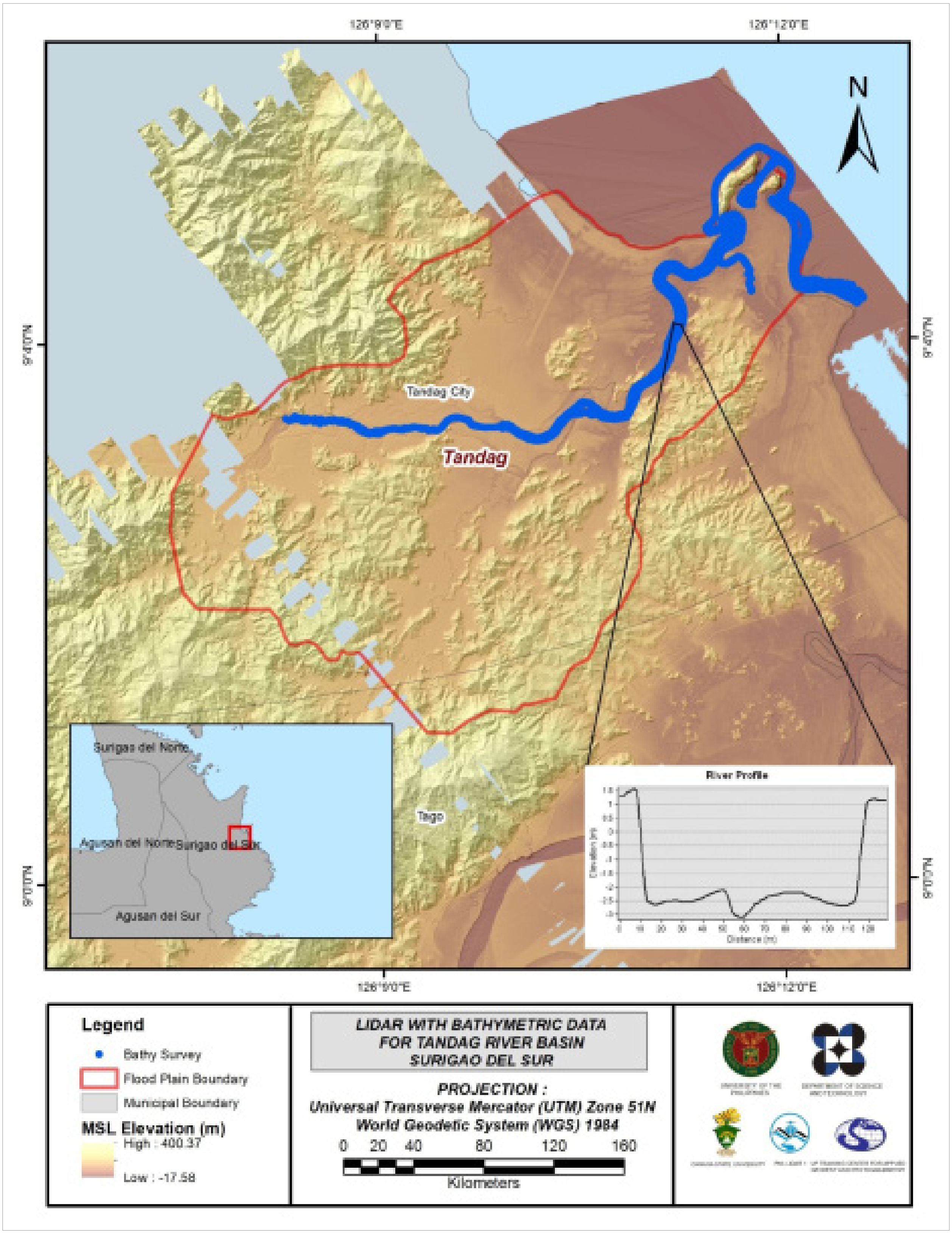

Figure 27. Map of Tandag Floodplain with bathymetric survey points shown in blue

3.12 Feature Extraction

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

3.12.1 Quality Checking of Digitized Features' Boundary

Tandag Floodplain, including its 200 m buffer, has a total area of 42.02 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 2,250 building features, are considered for QC. Figure 28 shows the QC blocks for Tandag Floodplain.

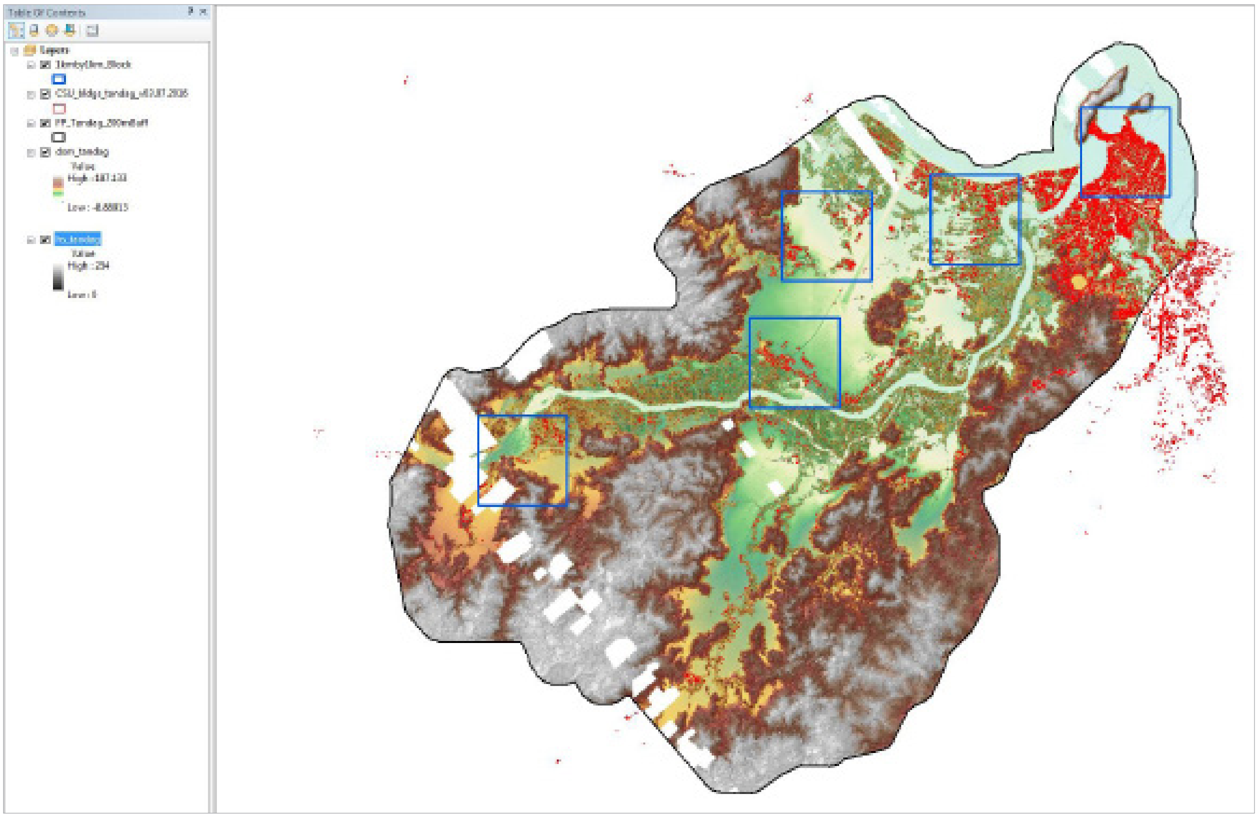

Figure 28. Blocks (in blue) of Tandag building features subjected to QC

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

Table 17. Quality Checking ratings for Tandag building features

Floodplain	Completeness	Correctness	Quality	Remarks
Tandag	96.05	99.56	80.09	PASSED

3.12.2 Height Extraction

Height extraction was done for 8,172 building features in Tandag Floodplain. Of these building features, 127 buildings were filtered out after height extraction, resulting in 8,045 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 8.01 m.

3.12.3 Feature Attribution

Field surveys, familiarity with the area, and free online web maps such as Wikimapia (http://wikimapia.org/) and Google Maps (https://www.google.com/maps) were used to gather information such as name and type of the features within the river basin.

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

Table 18. Building features extracted for Tandag Floodplain

Facility Type	No. of Features
Residential	7,858
School	81
Market	20
Agricultural/Agro-Industrial Facilities	0
Medical Institutions	2
Barangay Hall	1
Military Institution	0
Sports Center/Gymnasium/Covered Court	2
Telecommunication Facilities	0
Transport Terminal	7
Warehouse	2
Power Plant/Substation	7
NGO/CSO Offices	1
Police Station	3
Water Supply/Sewerage	0
Religious Institutions	8
Bank	1
Factory	0
Gas Station	2
Fire Station	0
Other Government Offices	25
Other Commercial Establishments	25
Total	**8,045**

Table 19. Total length of extracted roads for Tandag Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/ Municipal Road	Provincial Road	National Road	Others	
Tandag	9.89	13.28	54.83	6.22	1.56	**85.78**

Table 20. Number of extracted water bodies for Tandag Floodplain

Floodplain	Water Body Type					Total
	Rivers/ Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Tandag	49	0	0	0	0	**49**

A total of 14 bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

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

Figure 29 shows the Digital Surface Model (DSM) of Tandag Floodplain overlaid with its ground features.

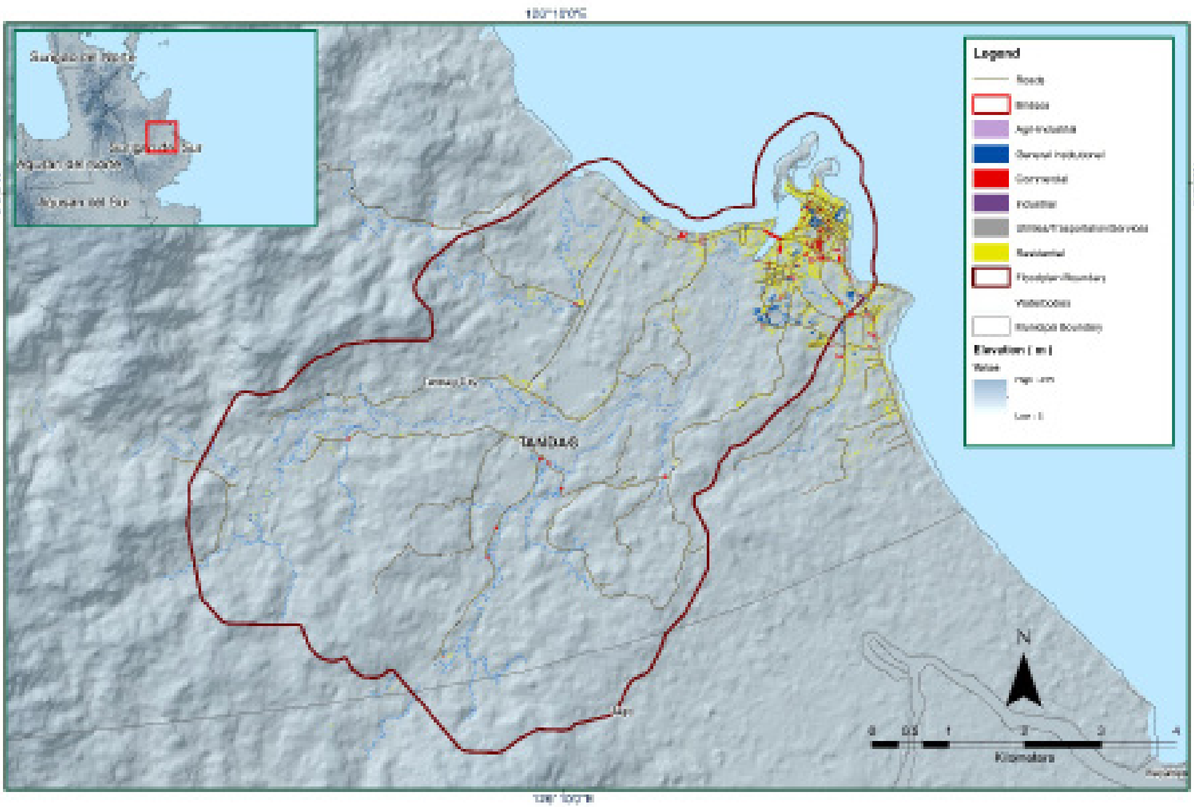

Figure 29. Extracted features for Tandag Floodplain

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS IN THE TANDAG RIVER BASIN

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

4.1 Summary of Activities

Caraga State University conducted a field survey in Tandag River on February 17–20, 2016 with the following scope of work: reconnaissance; control survey; cross-section survey of selected riverbed in Brgy. Mabuhay, Tandag City; validation points acquisition of about 20.13 covering the Tandag River Basin; and bathymetric survey from its upstream in Brgy. Maitum, Tandag City down to the mouth of the river located in the Brgy. Bongtod Poblacion in the same City, with an approximate length of 9.799 km using Ohmex™ single-beam echo sounder and South® S86T GNSS RTK survey technique (Figure 30).

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

4.2 Control Survey

The GNSS network used for Tandag River survey is composed of a single loop established on February 17, 2016 occupying the following reference points: SRS-72, a second-order GCP in Brgy. Pangi, Tandag City, Surigao del Sur; and SS-148, a first-order BM in Brgy. San Agustin Norte, Tandag City, Surigao del Sur.

A control point was established on the New Tandag City Hall rooftop, namely CP, in Brgy. Awasian, Tandag City, Surgao del Sur.

The summary of reference and control points is shown in Table 21, while the GNSS network established is illustrated in Figure 31.

Figure 31. GNSS network of Tandag River field survey

Table 21. List of references and control points occupied in Tandag survey (Source: NAMRIA; UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS UTM Zone 52N)				
		Latitude	Longitude	Ellipsoid Height (m)	Elevation (MSL) (m)	Date of Establishment
SRS-72	2nd order, GCP	9°06'14.68164"	126°09'27.58231"	70.74	-	2007
SS-148	1st order, BM	-	-	71.6635	4.0972	2007
CP	UP established	-	-	-	-	Feb 17, 2016

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

Figure 32. GNSS base receiver set-up, South® S86T, at SRS-72 in Brgy. Pangi, Tandag City, Surigao del Sur

Figure 33. GNSS base receiver set-up, South® S86T, at SS-148 in Brgy. San Agustin Norte, Tandag City, Surigao del Sur

Figure 34. GNSS base receiver set-up, South® S86T, on T-1 on top of the New Tandag City Hall in Brgy. Awasian, Tandag City

4.3 Network Adjustment

After the baseline processing procedure, network adjustment is was performed using TBC. Looking at the Adjusted Grid Coordinates (Table 23) Table C-of the TBC generated Network Adjustment Report, it is observed that the square root of the sum of the squares of x and y must be less than 20 cm and z less than 10 cm or in equation from:

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

Where:

x_e is the Easting Error,
y_e is the Northing Error, and
z_e is the Elevation Error

for each control point. See the Network Adjustment Report shown in Table 23 to Table 26 for complete details.

The three control points, SRS-72, SS-148, and CP were occupied and observed simultaneously to form a GNSS loop. Coordinates of SRS-72; and elevation value of SS-148 were held fixed during the processing of the control points as presented in Table 22. Through these reference points, the coordinates and elevation of the unknown control points will were be computed.

Table 22. Control point constraints

Point ID	Type	North (Meter)	East (Meter)	Height (Meter)	Elevation (Meter)
SRS-72	Global	Fixed	Fixed	Fixed	
Fixed = 0.000001 (Meter)					

The list of adjusted grid coordinates, i.e., Northing, Easting, Elevation, and computed standard errors of the control points in the network, is indicated in Table 23. The fixed control NGW-50 has no values for and elevation error yet.

Table 23. Adjusted grid coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
SRS-72	847139.511	?	1007873.524	?	2.430	?	LLh
SS-148	848377.990	0.001	1005661.772	0.001	3.523	0.003	
CP	848409.987	0.001	1004465.146	0.001	11.783	0.003	

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

SRS-72

horizontal accuracy = Fixed
vertical accuracy = Fixed

SS-148

horizontal accuracy $= \sqrt{((0.1)^2 + (0.1)^2}$
$= \sqrt{(0.1 + 0.1)}$
$= 0.45 < 20$ cm
vertical accuracy $= 0.3$ cm < 10 cm

CP

horizontal accuracy $= \sqrt{((0.1)^2 + (0.1)^2}$
$= \sqrt{(0.1 + 0.1)}$
$= 0.45 < 20$ cm
vertical accuracy $= 0.3$ cm < 10 cm

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

Table 24. Adjusted geodetic coordinates

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
SRS-72	9°06'14.68164"	126°09'27.58231"	70.740	?	LLh
SS-148	9°05'02.42094"	126°10'07.46239"	71.664	0.003	
CP	9°04'23.50705"	126°10'08.16708"	79.930	0.003	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 24. Based on the result of the computation, the accuracy condition is satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table 25.

Table 25. Table 25. Reference and control points used and its location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoid Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
SRS-72	2nd order, GCP	9°06'14.68164"	126°09'27.58231"	70.740	1007873.524	847139.511	3.005
SS-148	1st order BM	9°05'02.42094"	126°10'07.46239"	71.664	1005661.772	848377.990	4.097
CP	UP Established	9°04'23.50705"	126°10'08.16708"	79.930	1004465.146	848409.987	12.358

4.4 Cross-section and Bridge As-built Survey

Cross-section and bridge as-built survey were conducted on March 2016 in Brgy. Mabuhay, Tandag City, Surigao del Sur using the GNSS receiver South® S86T utilizing GNSS RTK survey technique.

The cross-section line of Tandag River is about 364.62 m with 161 points acquired using CP as GNSS base station. The location map and its cross-section diagram are illustrated in Figure 35 and Figure 36, respectively.

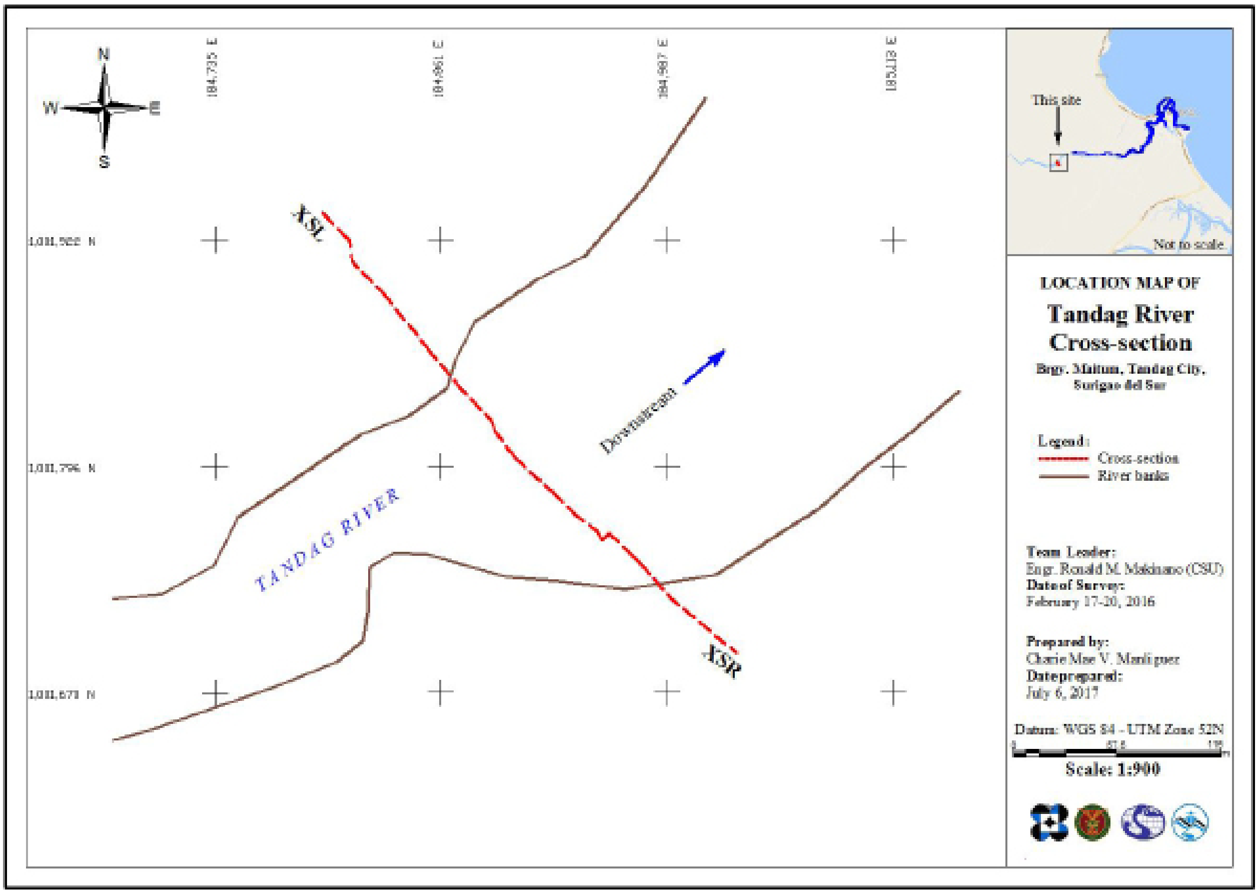

Figure 35. Tandag River cross-section location map

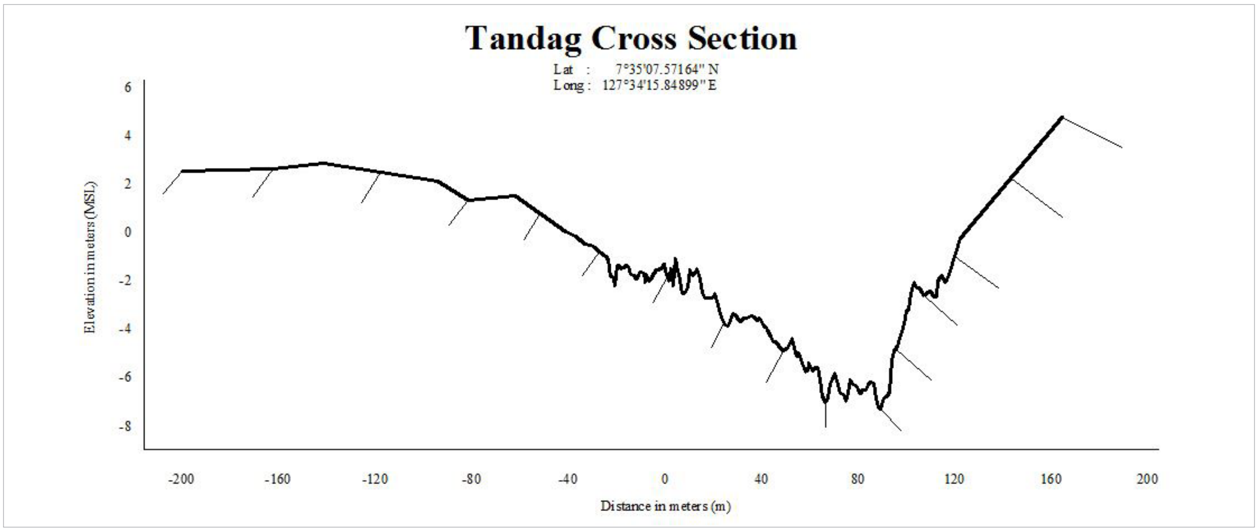

Figure 36. C-section diagram of Tandag River

4.5 Validation Points Acquisition Survey

A validation points acquisition survey was conducted on February 18, 2016 using a survey GNSS rover receiver South® S86T mounted on a pole, which was attached in front of the vehicle as shown in Figure 37. It was secured with a steel rod and tied with cable ties to ensure that it was horizontally and vertically balanced. Points were gathered along concrete roads of national highway so that data to be acquired would have a relatively minimal change in elevation and observing vehicle speed of 10 to 20 kph. Cutting across the flight strips of the Data Acquisition Component (DAC) with the aid of available topographic maps and Google Earth™ images. Gathered data were processed using Trimble® Business Center Software.

The GNSS base station set-up over CP gathered validation points from Brgy. Maitum to Bongtod Poblacion, Tandag City; and from Brgy. San Agustin, Norte down to Brgy. Victoria in Municipality of Tago. The ground validation line is approximately 20.13 km in length with 4,974 points. Figure 38 shows the ground validation survey result.

Figure 37. GNSS Receiver South® S86T installed on a vehicle for ground validation survey

In addition to ground validation survey, LiDAR Aquarius validation survey was done on March 8 to 11, 2016 along the coastal areas of Municipality of San Agustin. South™ Echo Sounder integrated with a roving GNSS receiver, South® S86T, installed on a boat utilizing RTK survey technique was used for the survey.

A total of 5,428 points were acquired with an approximate length of 14.71 km occupying T-1 as the GNSS base station. Figure 38 shows the ground and Aquarius validation survey result.

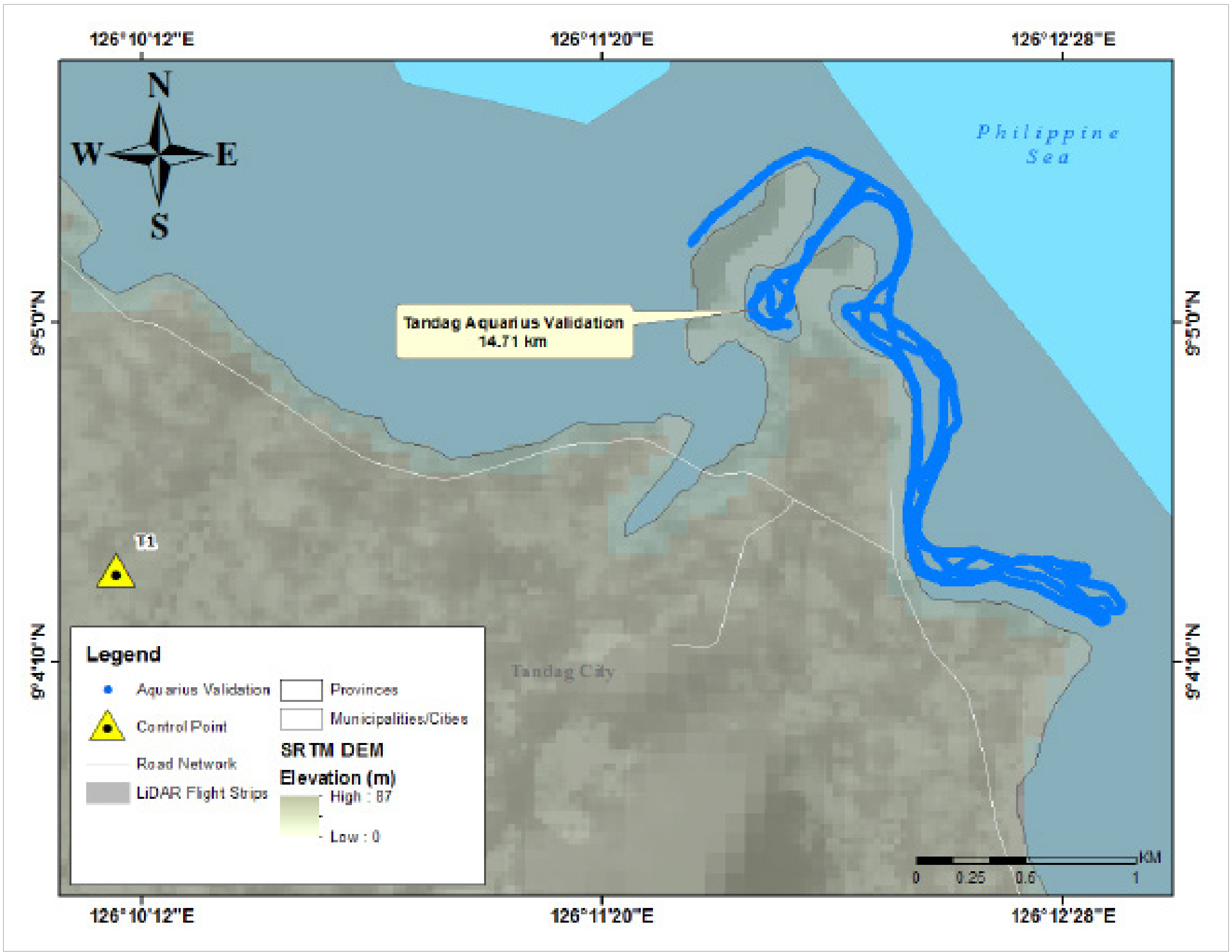

Figure 38. Validation points acquisition survey for Tandag River survey

4.6 River Bathymetric Survey

Bathymetric survey was executed on February 17, 2016 using South™ Echo Sounder integrated with a roving GNSS receiver, South® S86T, installed on a boat utilizing RTK survey technique as shown in Figure 39. The survey began in the upstream part of the river in Brgy. Maitum, Tandag with coordinates 7d37'15.50282" 127d33'09.87045", down to the mouth of the river in Brgy. Mabua, Tandag City with coordinates 7d41'29.15854" 127d34'04.73958".

Figure 39. Set up of bathymetric survey in Tandag River

The bathymetric line is approximately 9.799 km in length with 21,296 points acquired using CP as GNSS base station covering eleven barangays in Tandag City as shown in Figure 40. A CAD drawing of the centerline riverbed profile was also produced as shown in Figure 41. The lowest elevation was -17.94 m (below MSL) located in the mouth of the river; and the highest was 2.526 m in MSL. Both were recorded in Brgy. Pandanon.

Additional Aquarius validation survey was executed covering the shoreline of Tandag City in Tandag as shown in Figure 40.

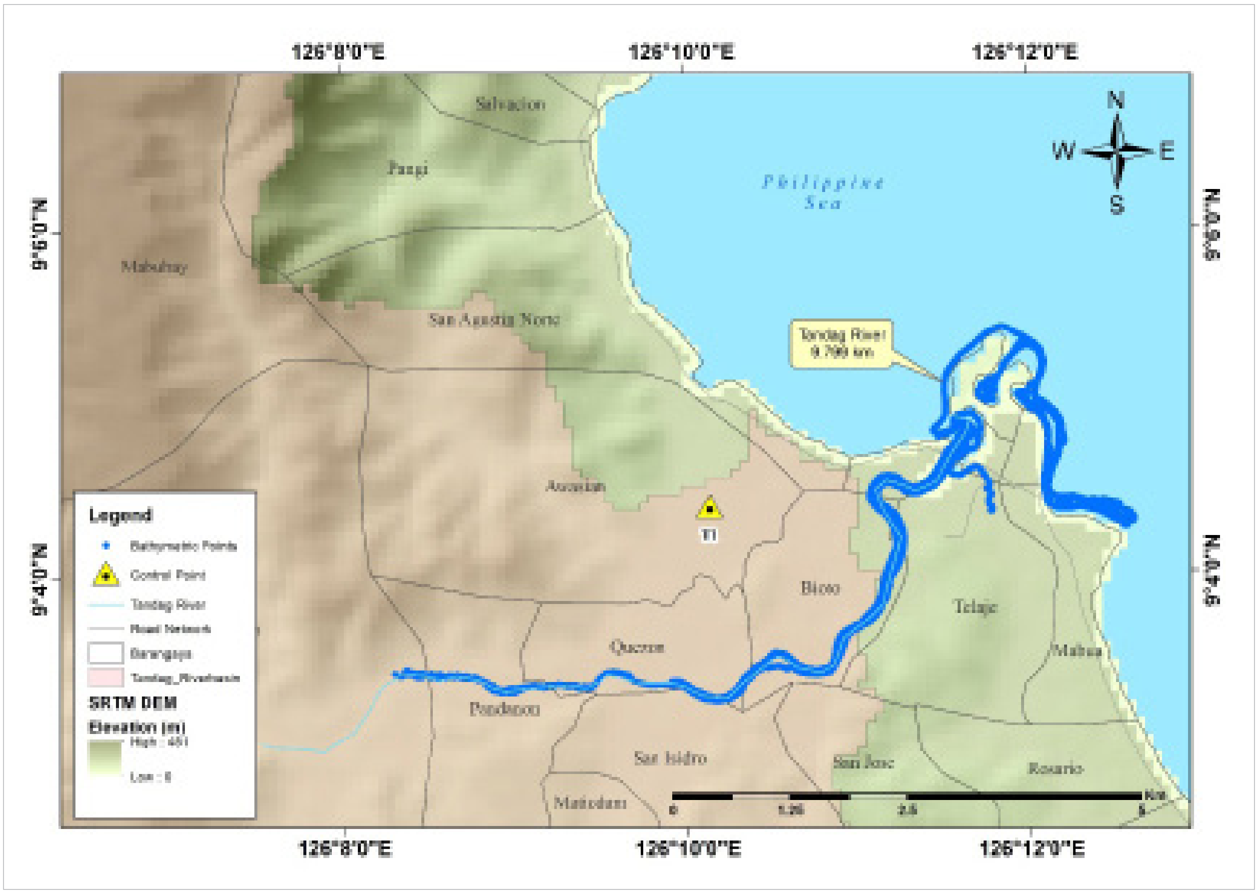

Figure 40. Bathymetric and Aquarius validation points gathered for Tandag River

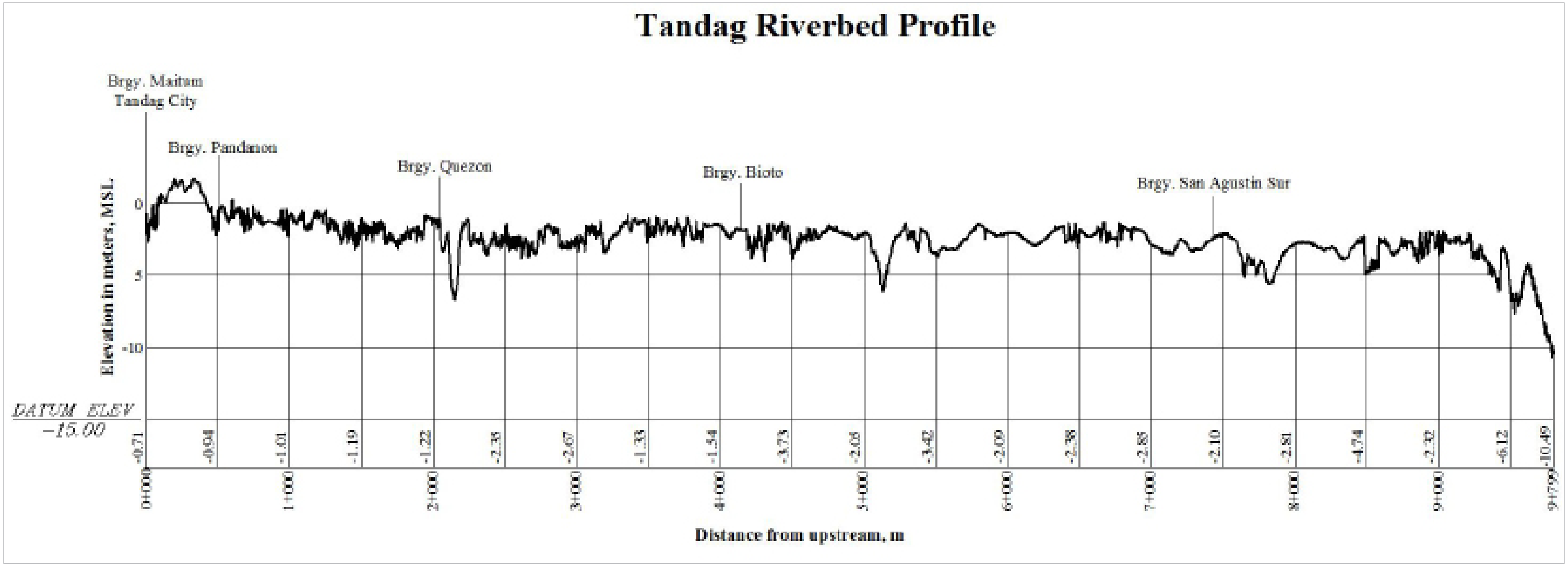

Figure 41. Riverbed profile of Tandag River

CHAPTER 5: FLOOD MODELING AND MAPPING

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

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

Rainfall, water level, and flow in a certain period of time, which may affect the hydrologic cycle of the river basin, were monitored, collected, and analyzed.

5.1.2 Precipitation

Precipitation data was taken from one automatic rain gauge (ARG) installed by the Department of Science and Technology – Advanced Science and Technology Institute (DOST-ASTI). This is the Awasian ARG which is being installed in the City of Tandag. The location of the rain gauge is shown in Figure 42.

Total rain recorded from Awasian rain gauge from 10 February 2015 17:00 to 23 February 2015 15:20 is 142.8 mm. It peaked to 8.2 mm on 13 February 2015 22:10. The lag time between the peak rainfall and its corresponding peak discharge at Pandanon Station is 14 hours.

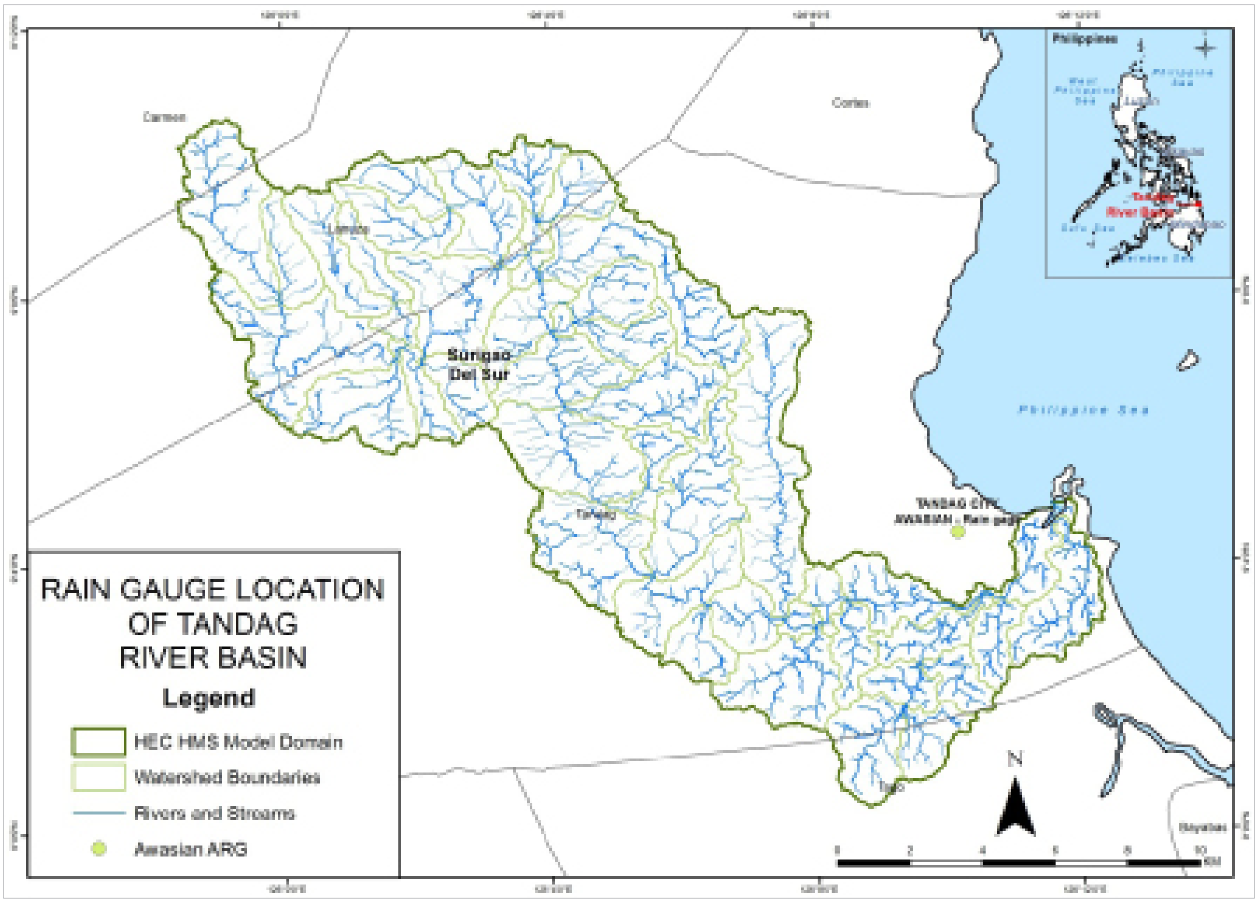

Figure 42. Location map of rain gauge used for the calibration of the Tandag HEC-HMS model

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Pandanon, Tandag City, Surigao del Sur (9°03'4.67"N, 126°08'2.32"E). It gives the relationship between the observed water levels from the Pandanon and outflow of the watershed at this location.

For Pandanon station, the rating curve is expressed as Q = (6E-11) $H^{16.237}$ as shown in Figure 43.

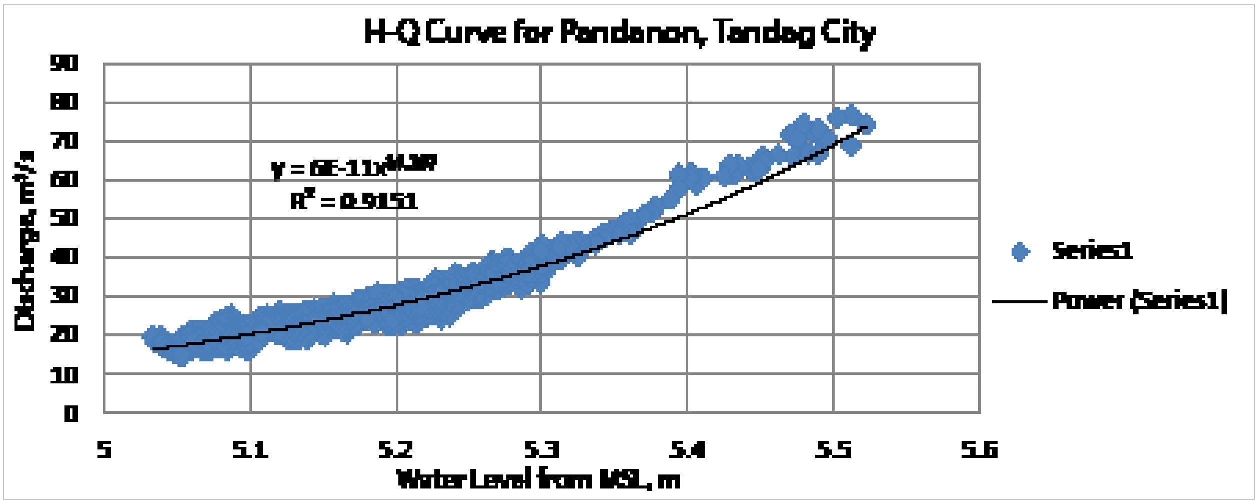

Figure 43. Rating Curve at Pandanon, Tandag City, Surigao del Sur

The river outflow measured at Pandanon (Figure 44) was utilized for the calibration of the HEC-HMS model. Peak discharge is 57.166 cubic meter per second (cms) at 12:10 PM, February 14, 2015.

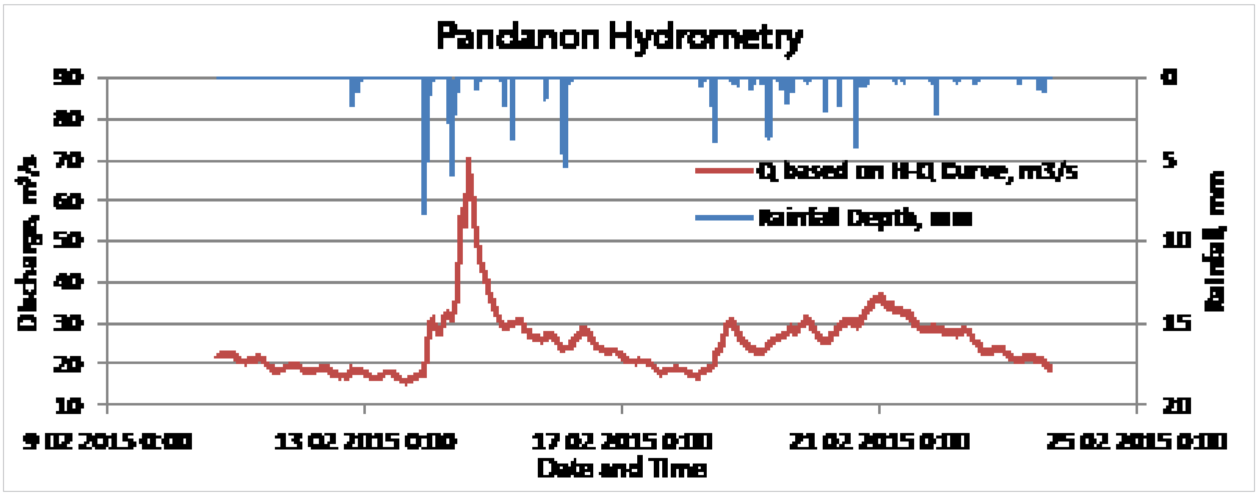

Figure 44. Rainfall at Awasian ARG and outflow data at Pandanon used for modeling.

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Hinatuan Rain Gauge. This station was chosen based on its proximity to the Tandag watershed. The extreme values for this watershed were computed based on a 42-year record.

Table 26. RIDF values for Hinatuan 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
5	31.9	47.8	60.4	82.8	116.9	141.9	190.6	230.6	276.5
10	36.9	55.5	70.2	96.6	137.5	167.2	228.9	274.4	326.5
25	43.3	65.3	82.7	114.2	163.5	199.1	277.3	329.8	389.7
50	48.1	72.5	92	127.2	182.8	222.8	313.2	370.9	436.6
100	52.8	79.7	101.2	140.1	202	246.3	348.8	411.7	483.1

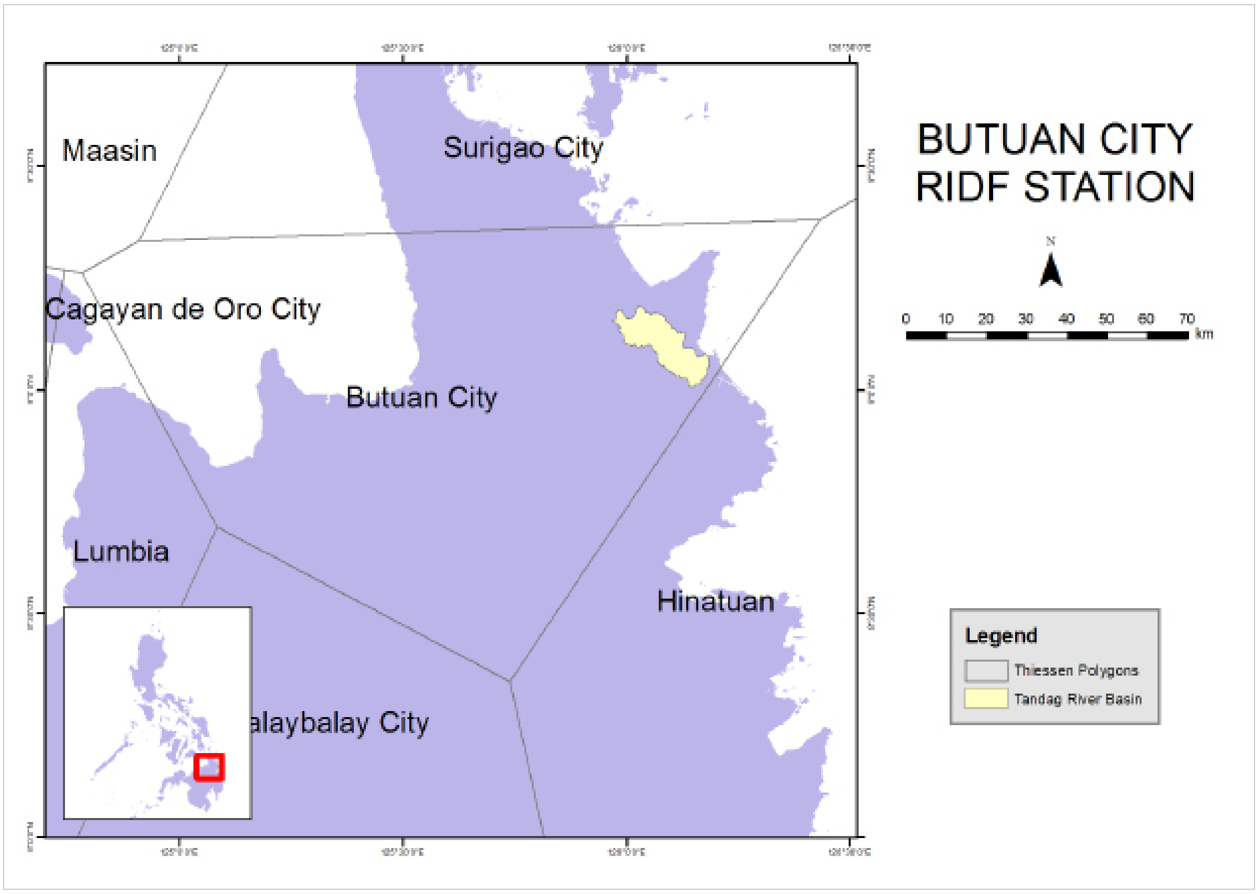

Figure 45. Location of Baguio RIDF Station relative to Aringay River Basin

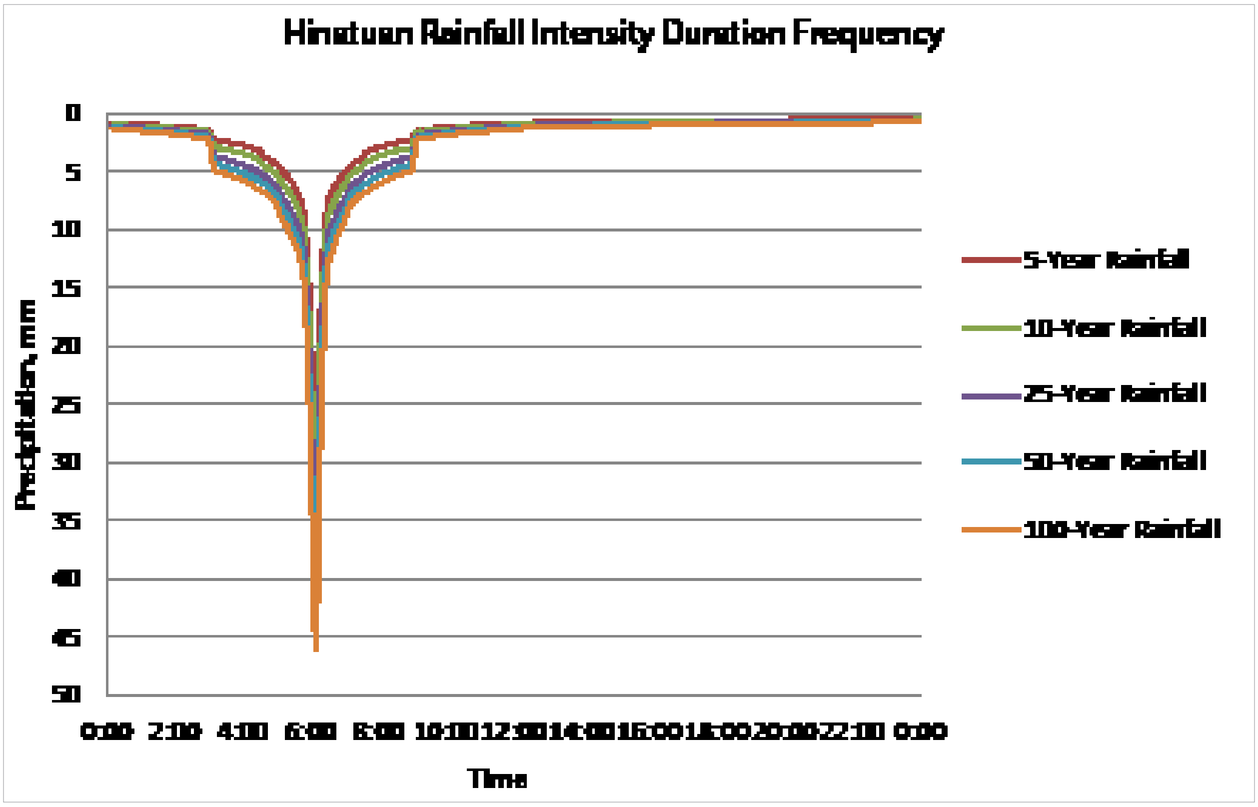

Figure 46. Figure 46. Hinatuan RIDF curves

5.3 HMS Model

The soil dataset (dated 2004) was obtained from the Department of Agriculture – Bureau of Soils and Water Management (DA-BSWM). The land cover dataset was from the National Mapping and Resource Information Authority (NAMRIA).

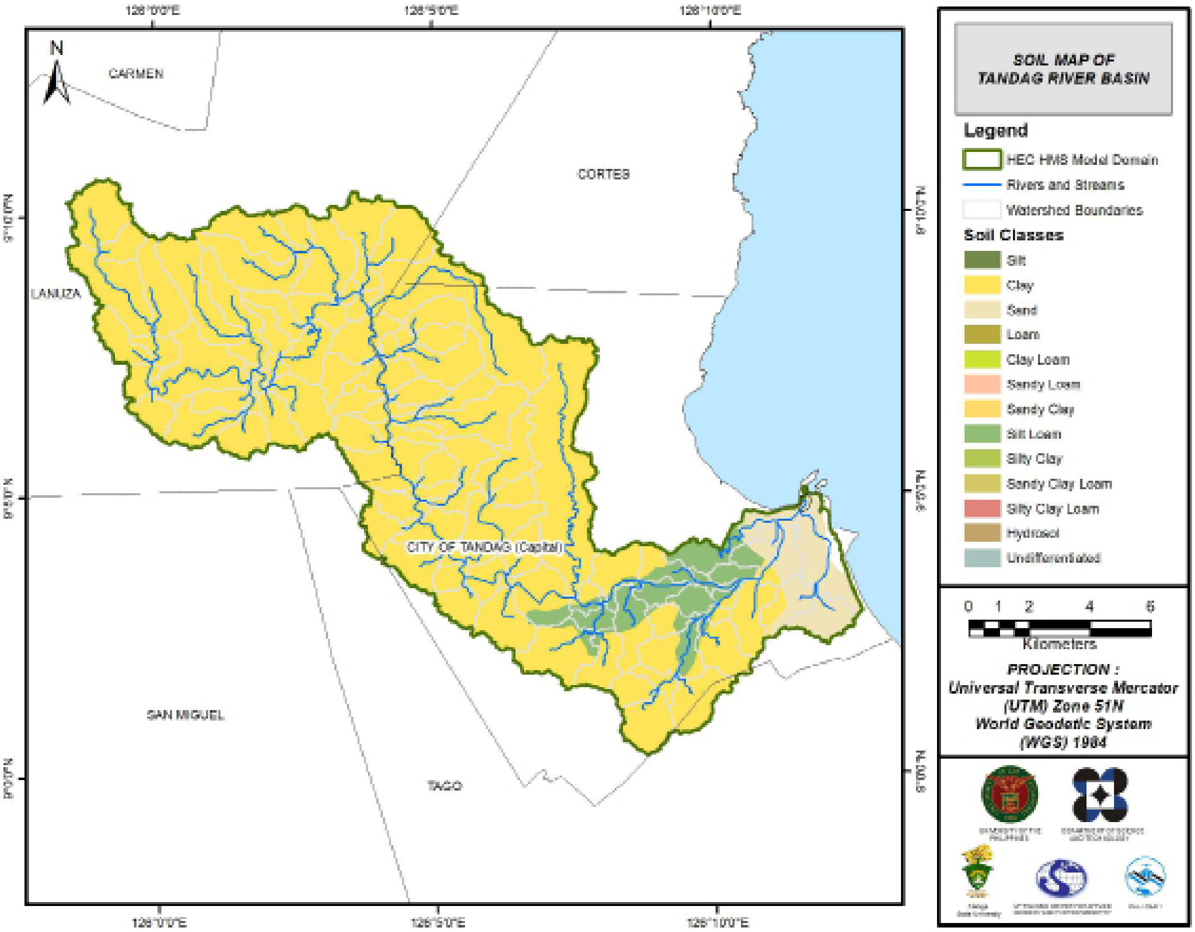

Figure 47. Soil map of the Tandag River Basin used for the estimation of the CN parametern
(Source: Department of Agriculture – Bureau of Soil and Water Management)

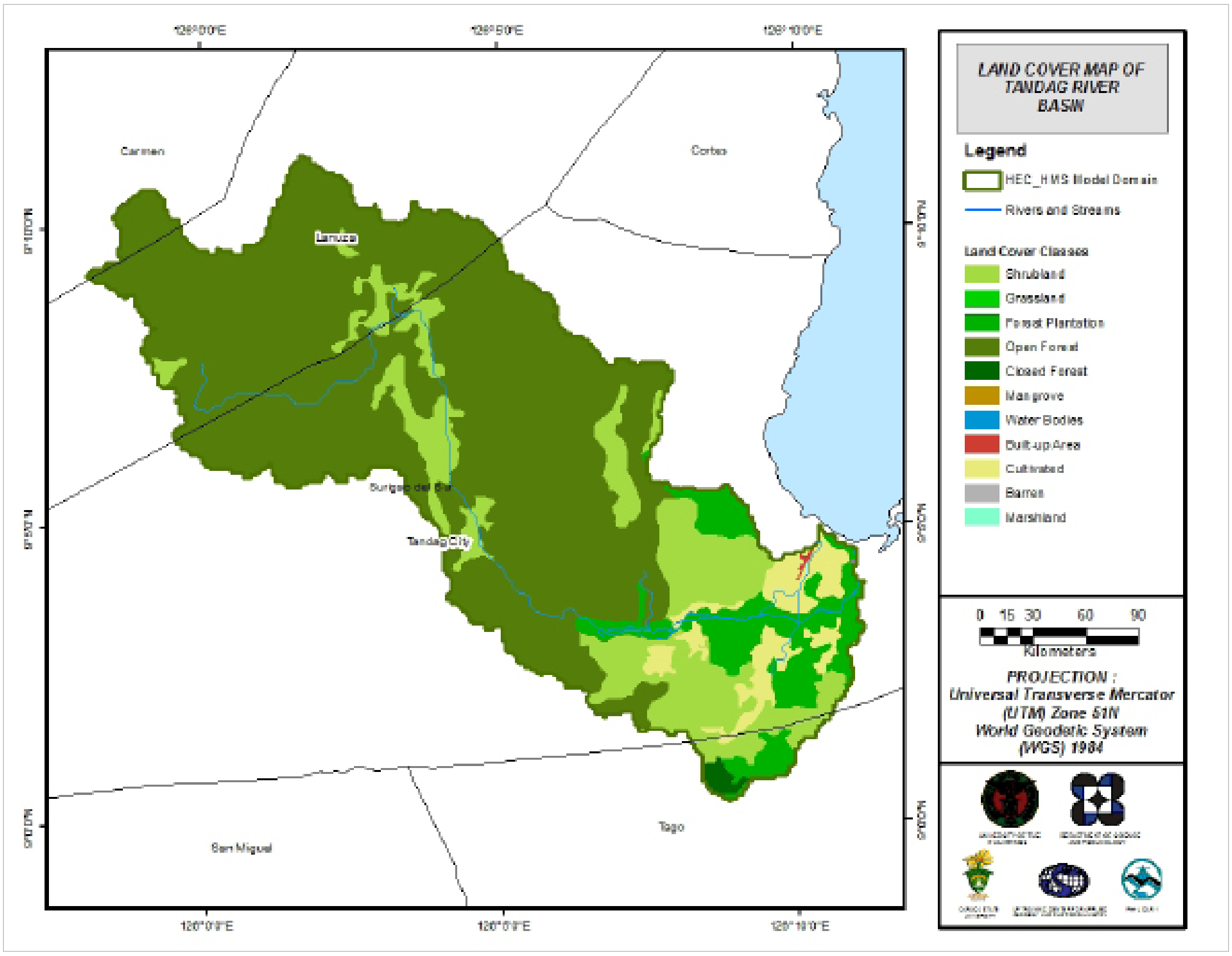

Figure 48. Land cover map of the Tandag River Basin used for the estimation of the CN and watershed lag parameters of the rainfall-runoff model

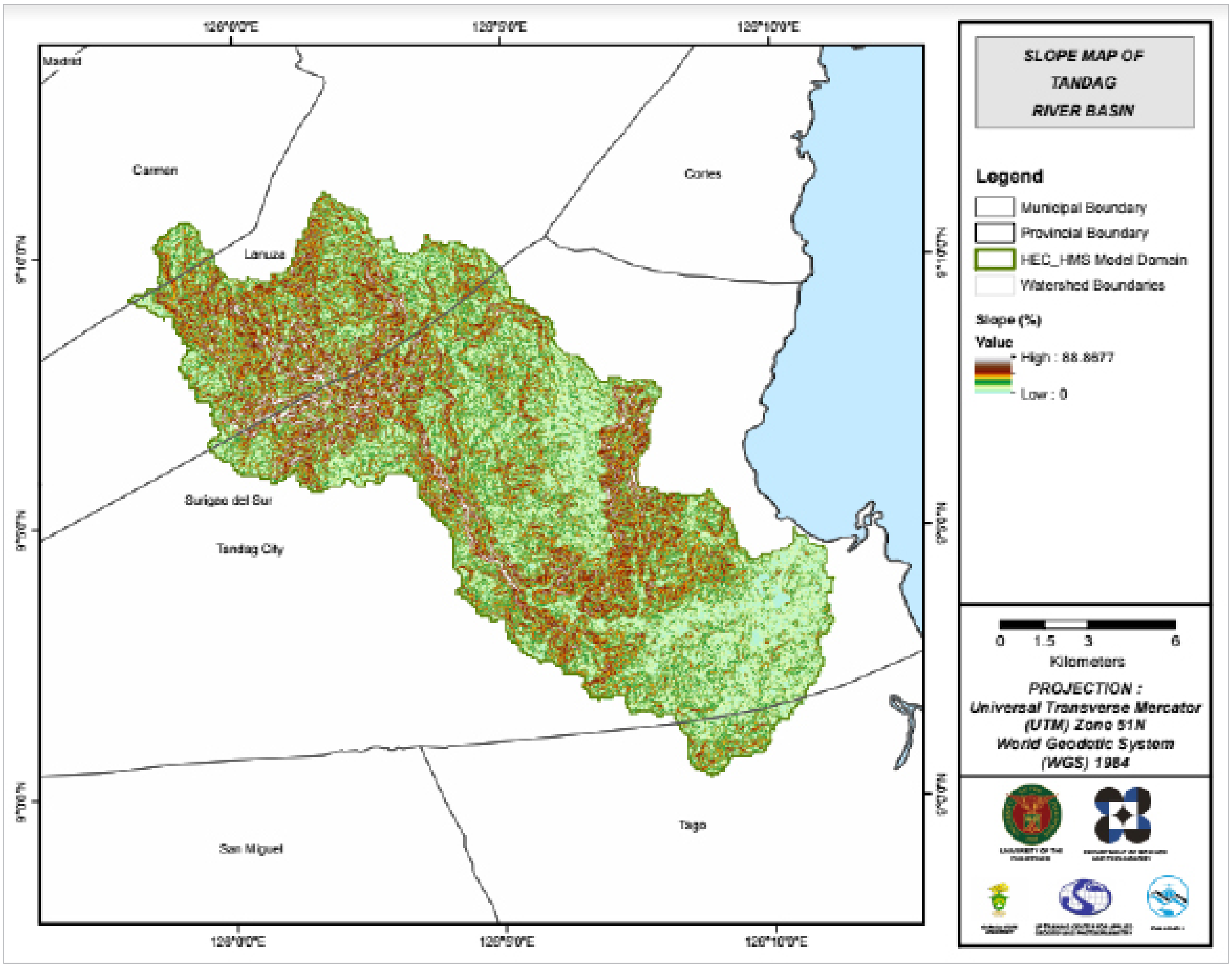

Figure 49. Figure 49. Slope map of Tandag River Basin

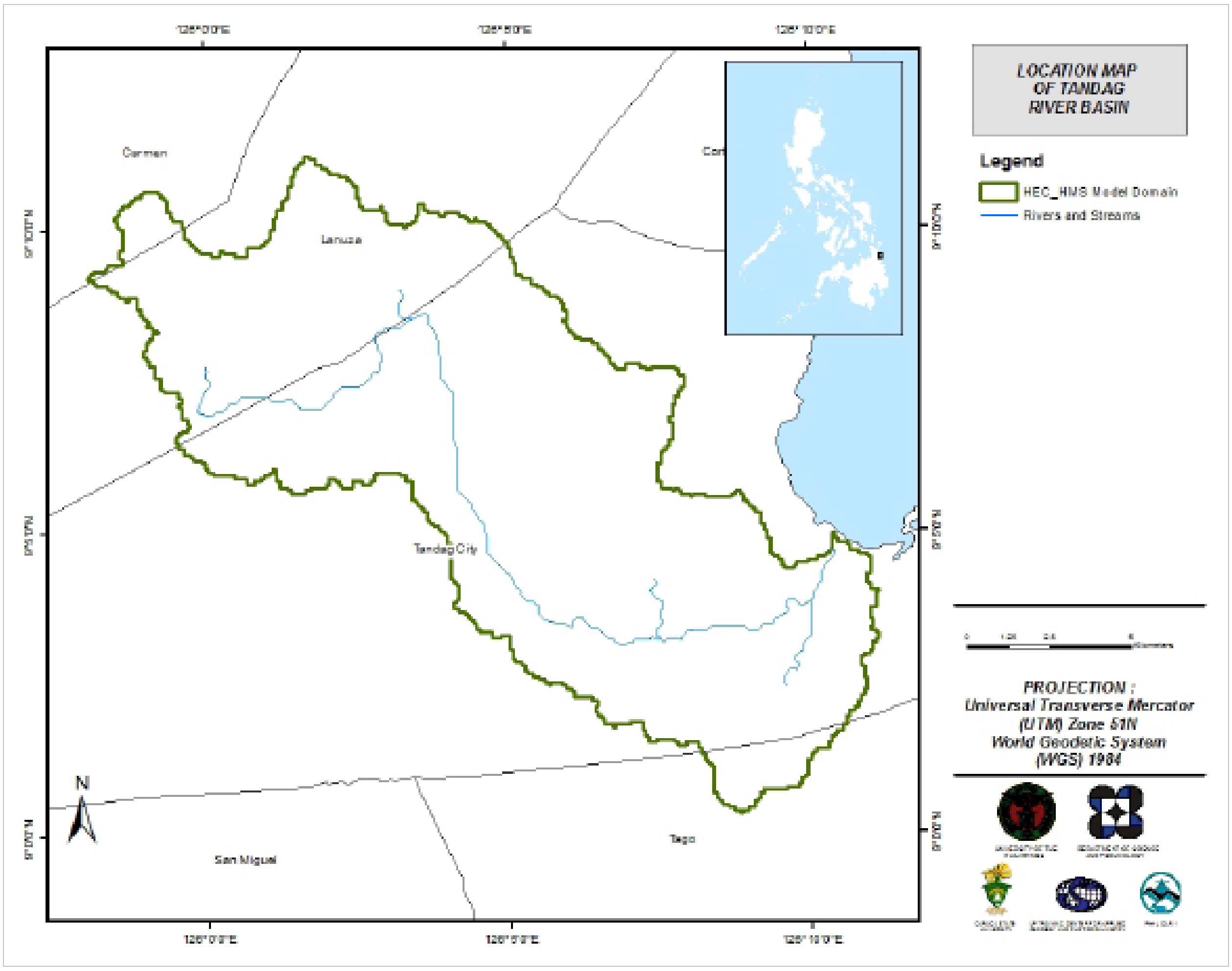

Figure 50. Land cover map of the Tandag River Basin used for the estimation of the CN and watershed lag parameters of the rainfall-runoff model

The Tandag basin model consists of 50 subbasins, 25 reaches and 26 junctions. This basin model is illustrated in Figure 51. The basins were identified based on the delineation using the 10 meter SAR DEM. Precipitation was taken from DOST rain gauges. Finally, it was calibrated using data gathered through hydrological measurement at Pandanon station as shown Figure 51.

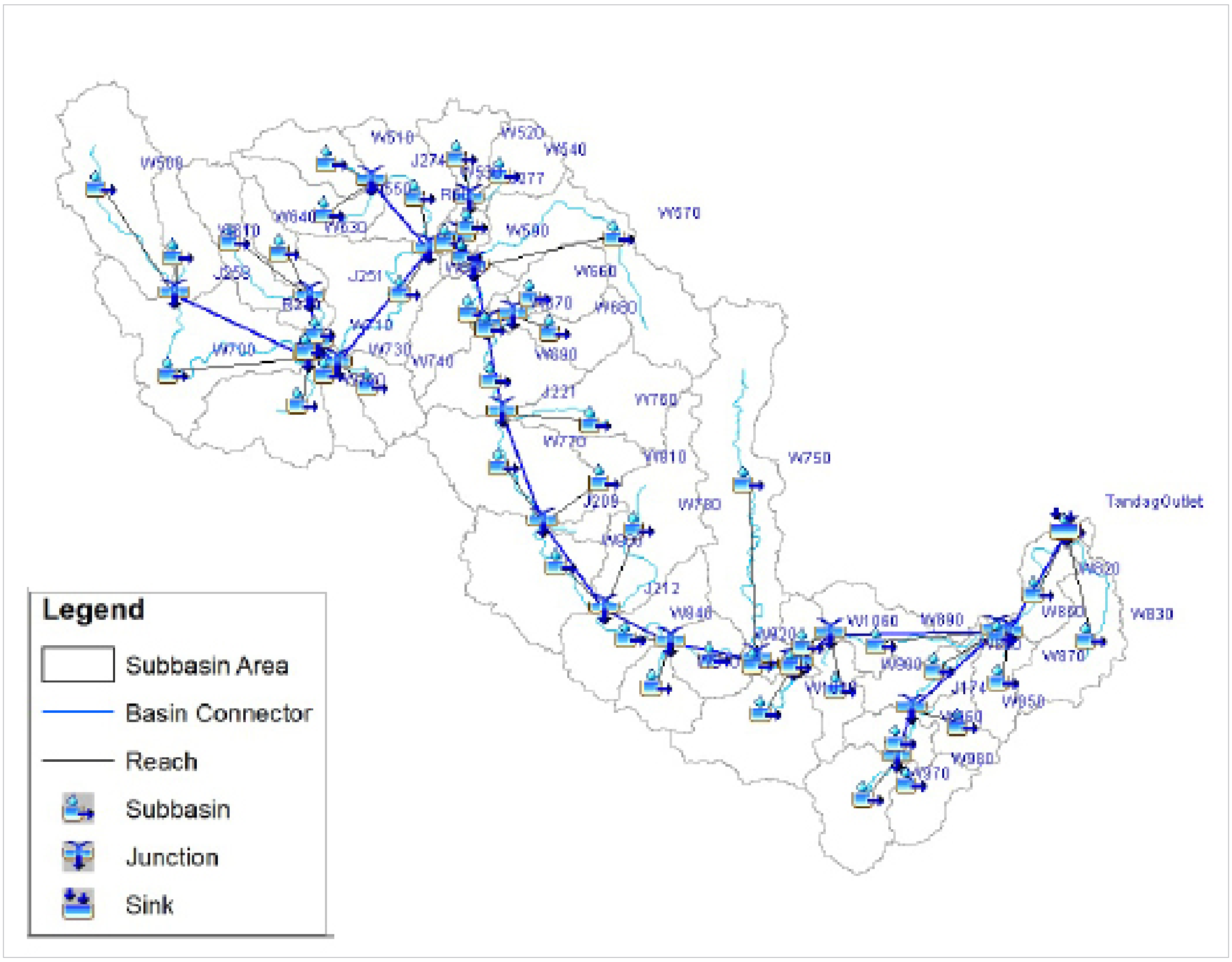

Figure 51. Tandag River Basin model generated using HEC-HMS

5.4 Cross-section Data

HEC-RAS model was developed by first creating geometric representations of the rivers and the floodplains. Those geometries are the river centerlines, banks, flow paths, cross-sections and the floodplain domain. River centerlines, banks, and flow paths should be digitized from upstream to downstream direction and the cross-section lines should be from left to right direction when facing downstream. The cross-section lines should also be created in a manner that it will always be perpendicular to all flow directions within the floodplain domain. For Tandag River Basin, there were a total of 18 reaches and 824 cross-section lines as shown in Figure 52.

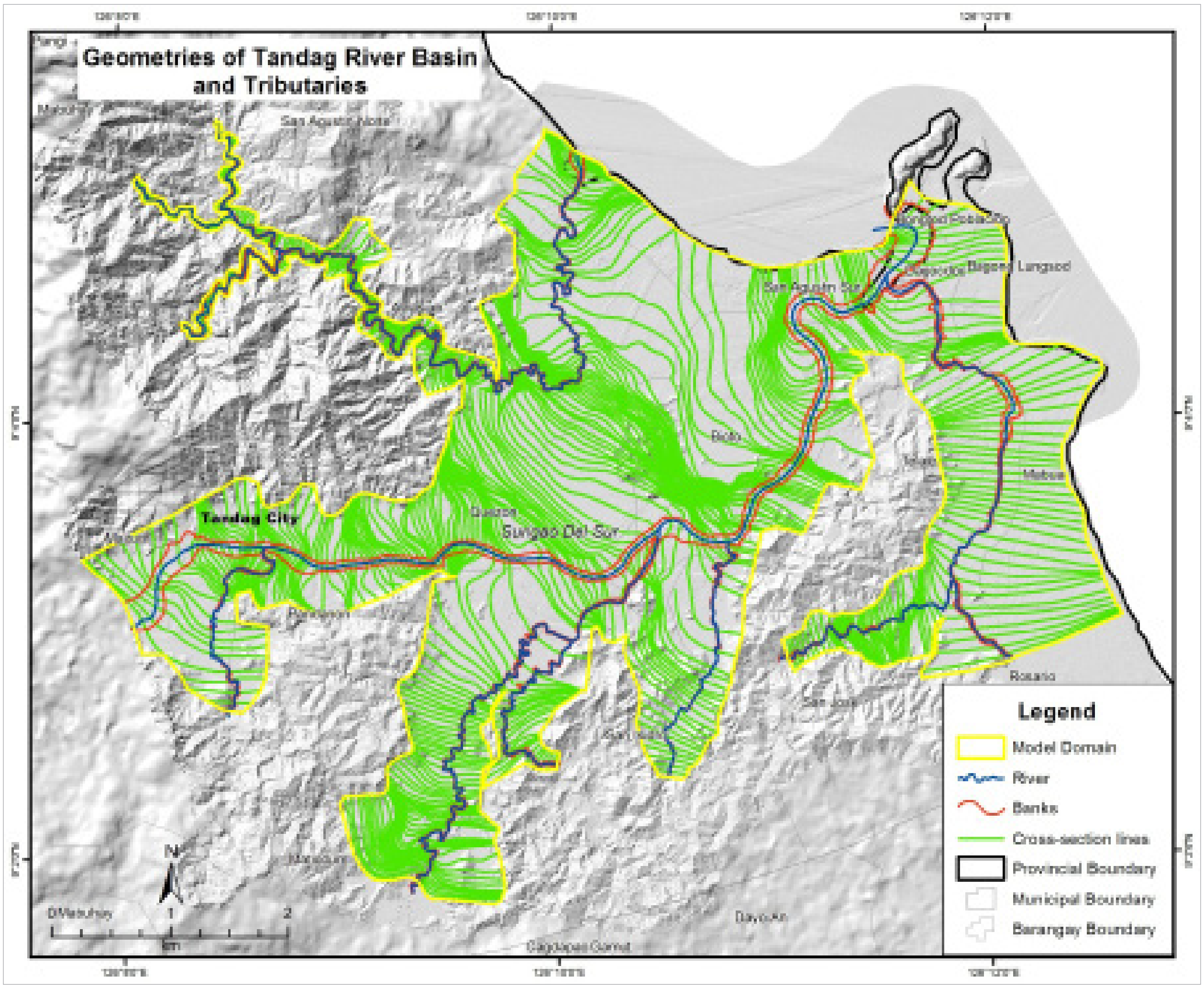

Figure 52. River cross-section of Tandag River generated through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

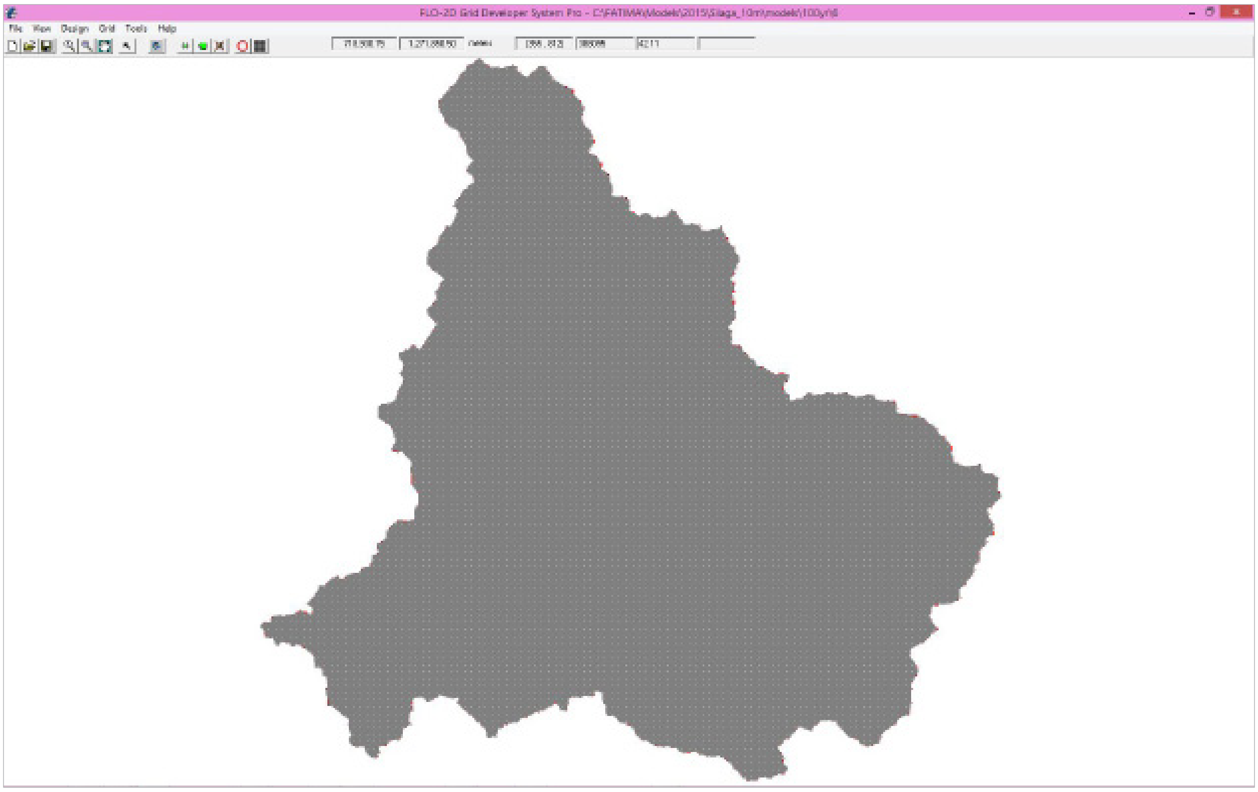

Figure 53. Screenshot of subcatchment with the computational area to be modeled in Flo 2D GDS Pro

(insert 5 paragraphs)

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5.6 Results of HMS Calibration

After calibrating the Tandag HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 54 shows the comparison between the two discharge data.

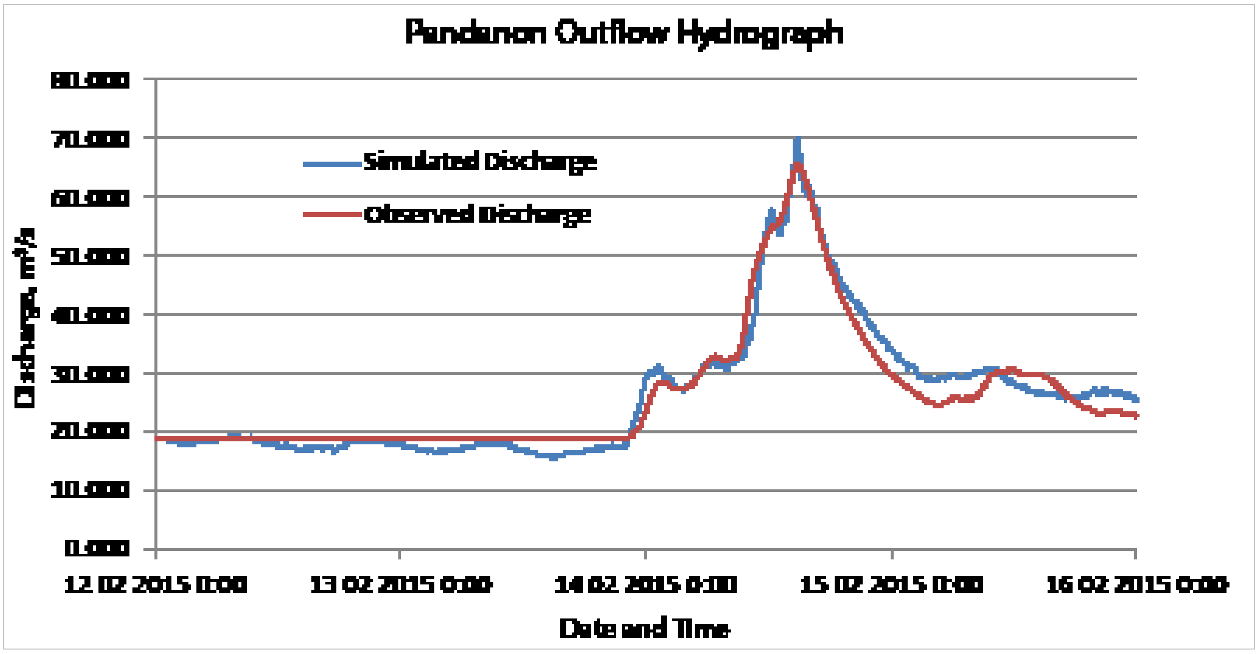

Figure 54. Outflow hydrograph of Pandanon produced by the HEC-HMS model compared with observed outflow

Table 27. Range of calibrated values for Tandag

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	1.01-20.61
			Curve Number	83.01-92.35
			Impervious (%)	0-61.03
	Transform	Clark Unit Hydrograph	Time of Concentration (HR	0.1717-2.789
			Storage Coefficient (HR)	0.1685-8.5672
	Baseflow	Recession	Recession Constant	1
			Ratio to Peak	0.05-0.0758
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	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 1.01 to 20.61 mm means that there is minimal to average amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 83 to 92 for curve number is within the advisable value for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012).

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 0.17 to 2.79 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 1 indicates that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.05 to 0.08 indicates a steeper receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.05 corresponds to the common roughness in Malinao Inlet, which is determined to be cultivated with mature field crops (Brunner, 2010).

Table 28. Summary of the efficiency test of Tandag HMS Model

r^2	0.9427
NSE	0.84
PBIAS	-22.17
RSR	0.40

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified to be 2.4214 m^3/s.

The Pearson correlation coefficient (r^2) assesses the strength of the linear relationship between the observations and the model. A value 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 0.9562.

The Nash-Sutcliffe (E) method was also used to assess the predictive power of the model, with E = 1 being the optimal value. The model attained an efficiency coefficient of 0.9550.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. The optimal value is 0. In the model, the PBIAS is -0.1623.

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 0.2122.

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 55) shows the Tandag outflow using the Hinatuan RIDF in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the PAGASA data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

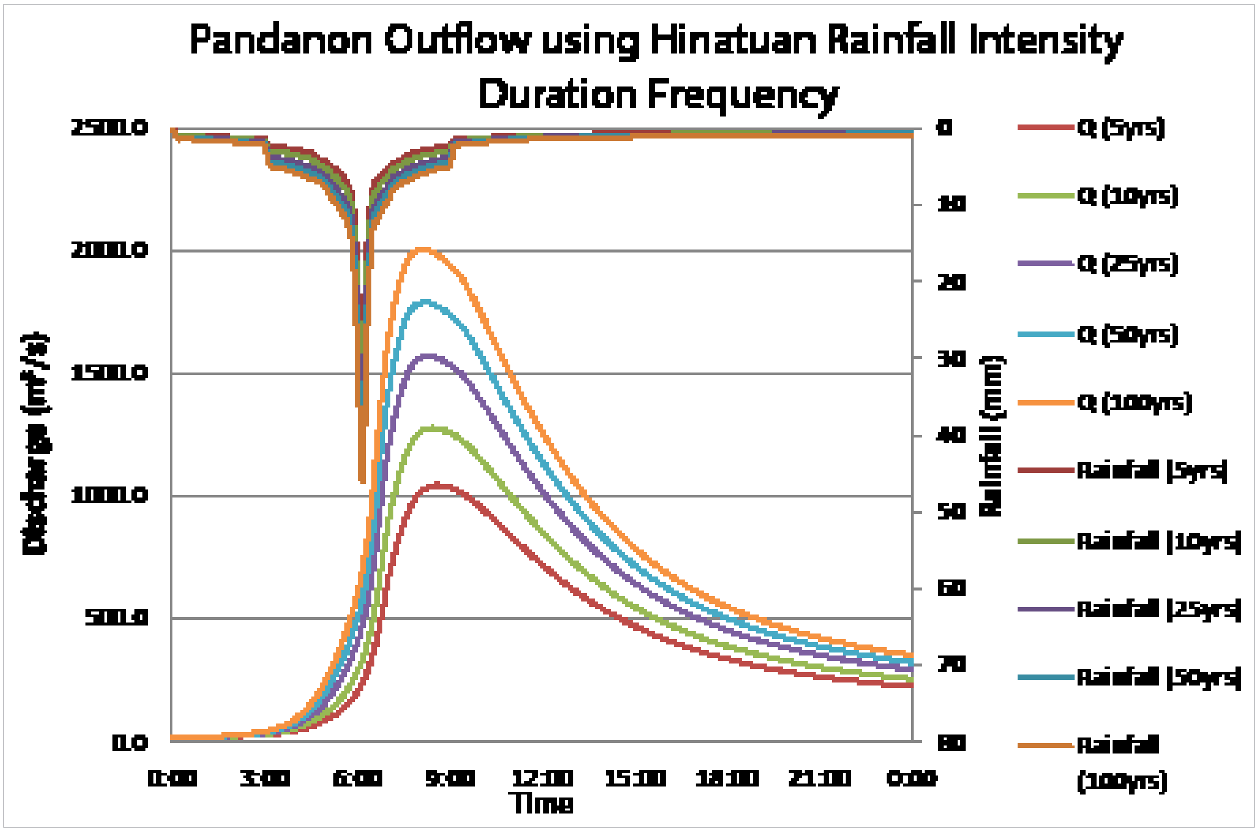

Figure 55. Outflow hydrograph at Tandag Station generated using the Hinatuan RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow, and time to peak of the Pandanon discharge using the Hinatuan RIDF in six different return periods is shown in Table 29.

Table 29. Peak outflows of the Tandag HEC-HMS model at Pandanon using the Hinatuan RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m^3/s)	Time to Peak
5-Year	276.46	27.68	1,044.35	2 hours and 40 minutes
10-Year	326.45	32.16	1,277.48	2 hours and 30 minutes
25-Year	389.64	37.77	1,572.25	2 hours and 20 minutes
50-Year	436.53	41.94	1,790.56	2 hours and 10 minutes
100-Year	483.02	46.07	2,006.95	2 hours and 10 minutes

5.8 River Analysis Model Simulation

The HEC-RAS flood model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. The sample generated map of Tandag River using the calibrated HMS flow of Typhoon Agaton is shown in Figure 56.

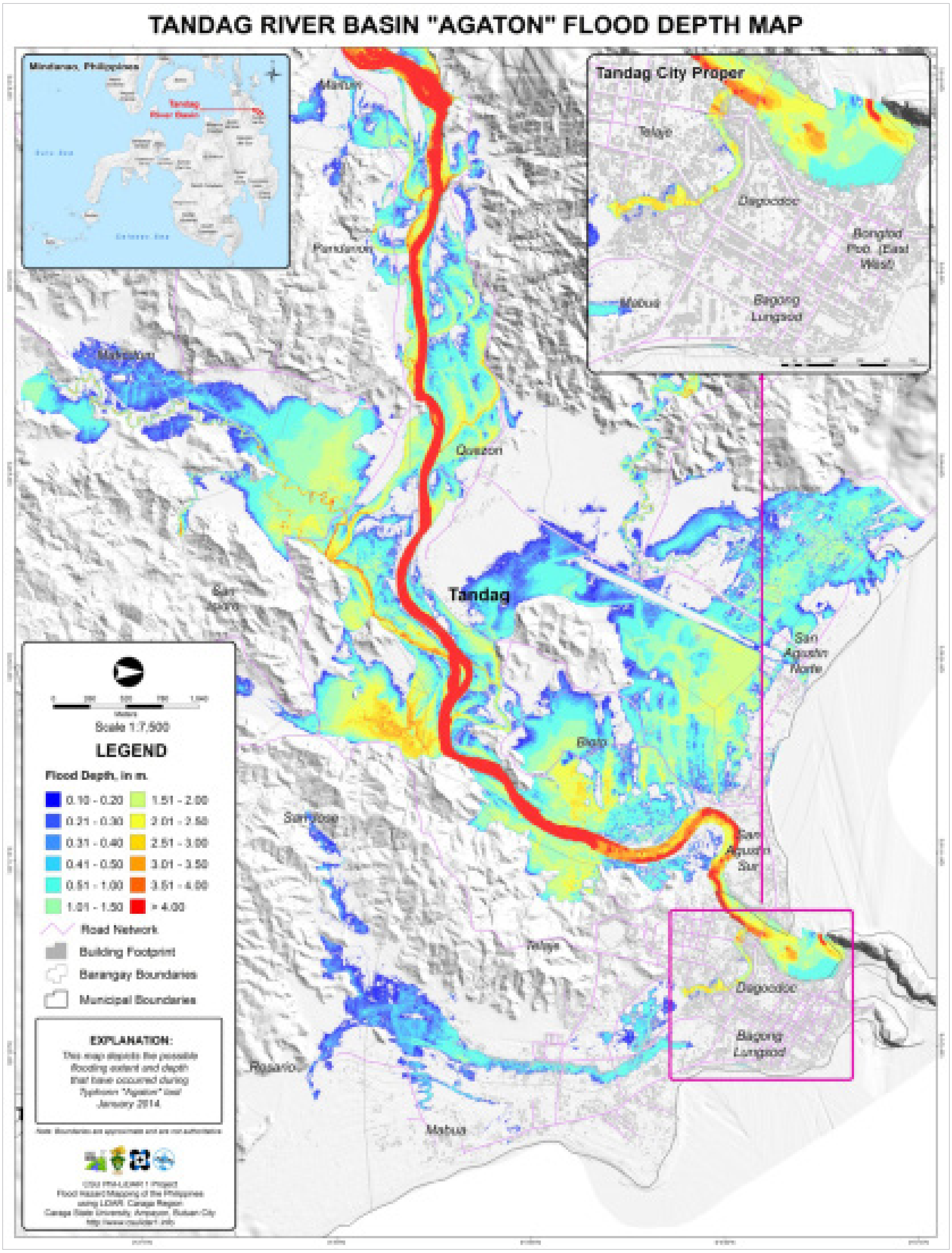

Figure 56. Flood depth and extent at Tandag River Basin during typhoon "Agaton"

5.9 Flood Hazard and Flow Depth Map

The resulting hazard and flow depth maps for the 100-, 25-, and 5-year rain return scenarios of the Malinao Inlet floodplain are shown in Figure 57 to Figure 62. The floodplain, with an area of 30.67 sq km., covers two municipalites namel Tago and Tandag. Table 30 shows the percentage of area affected by flooding per municipality.

Table 30. Municipalities affected in Tandag Floodplain

Municipality	Total Area	Area Flooded	% Flooded
Tago	293.4891	0.066304	0.02%
Tandag City	392.3874	30.53848	7.78%

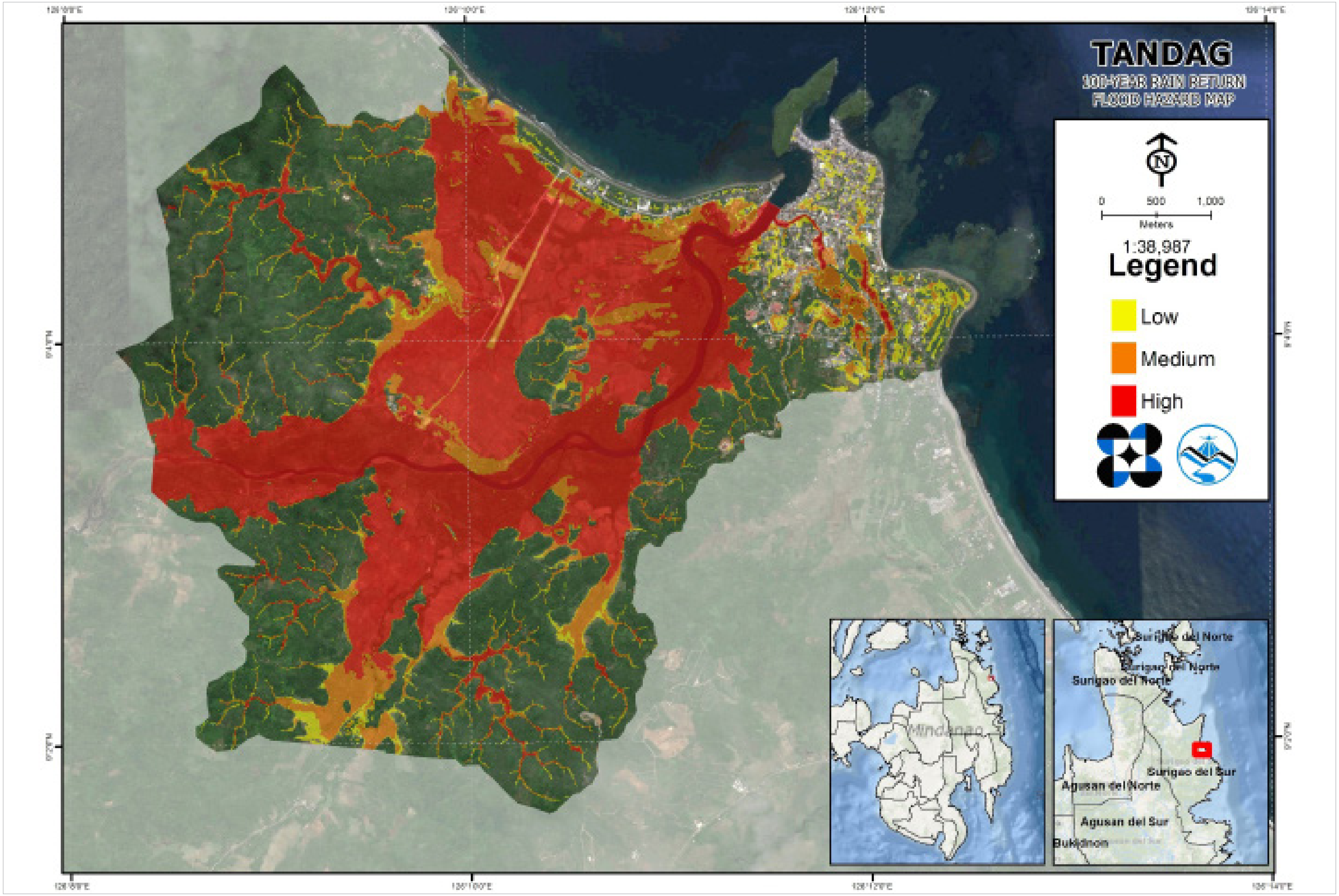

Figure 57. 100-year flood hazard Map for Tandag Floodplain

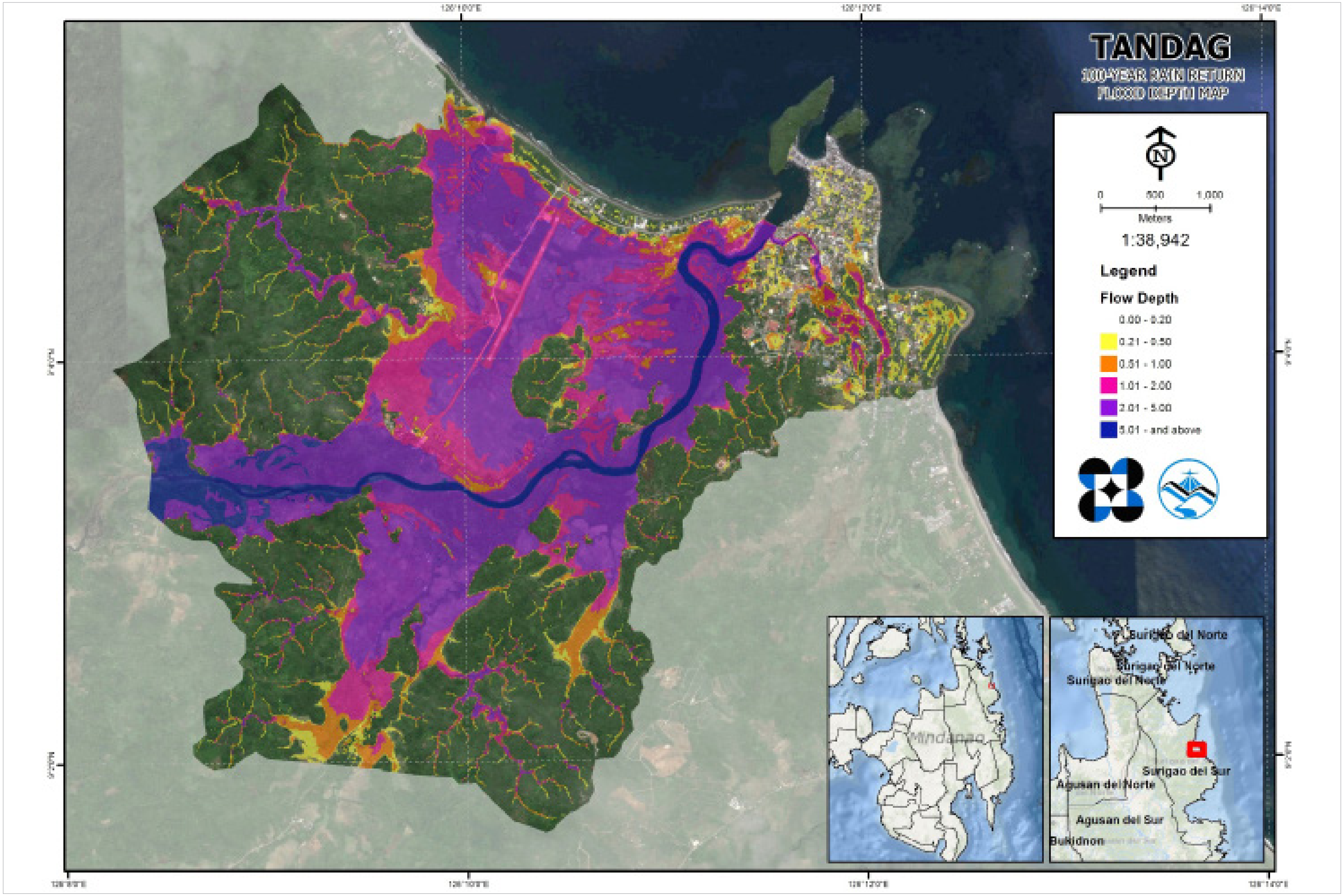

Figure 58. 100-year flow depth map for Tandag Floodplain

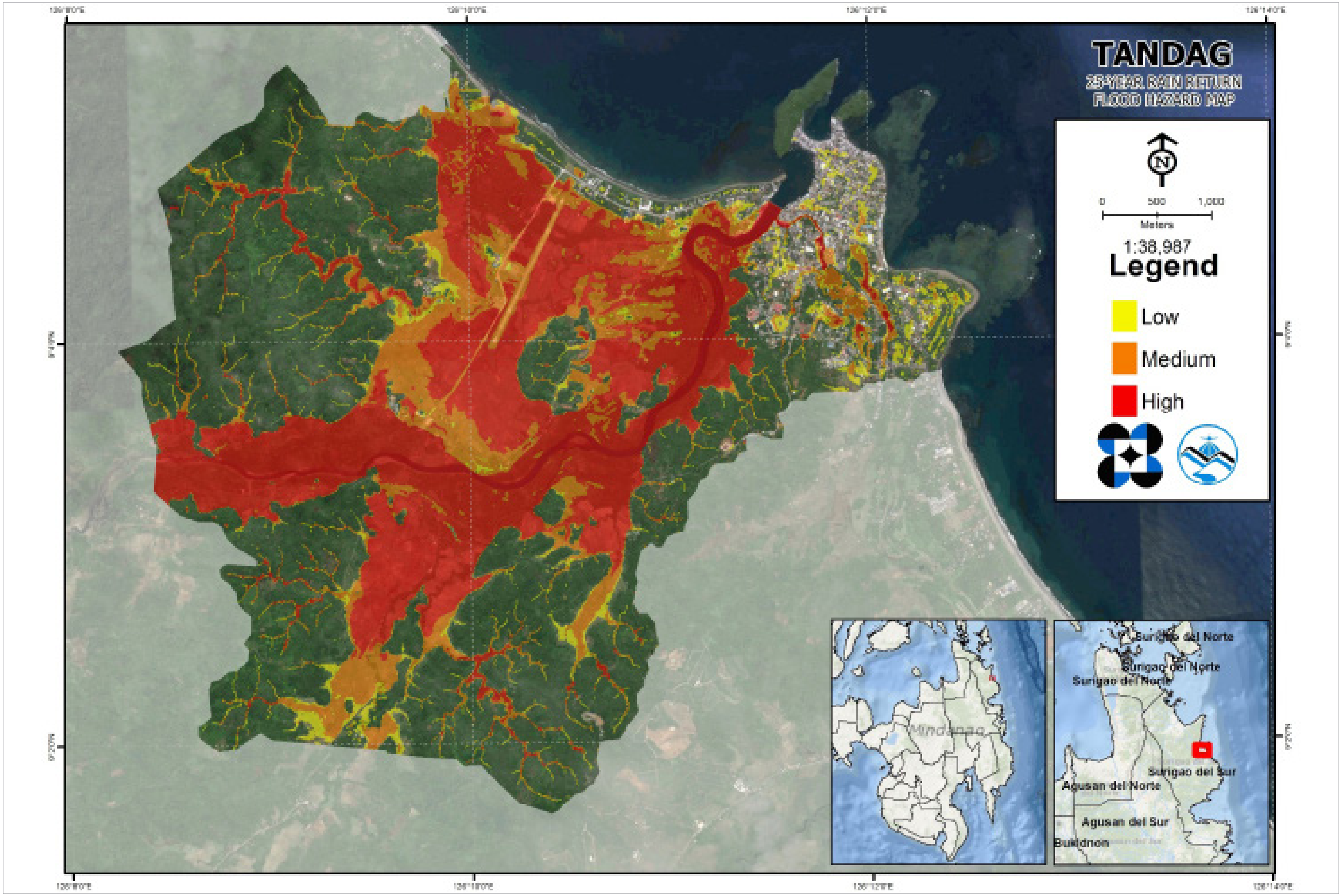

Figure 59. 25-year flood hazard map for Tandag Floodplain

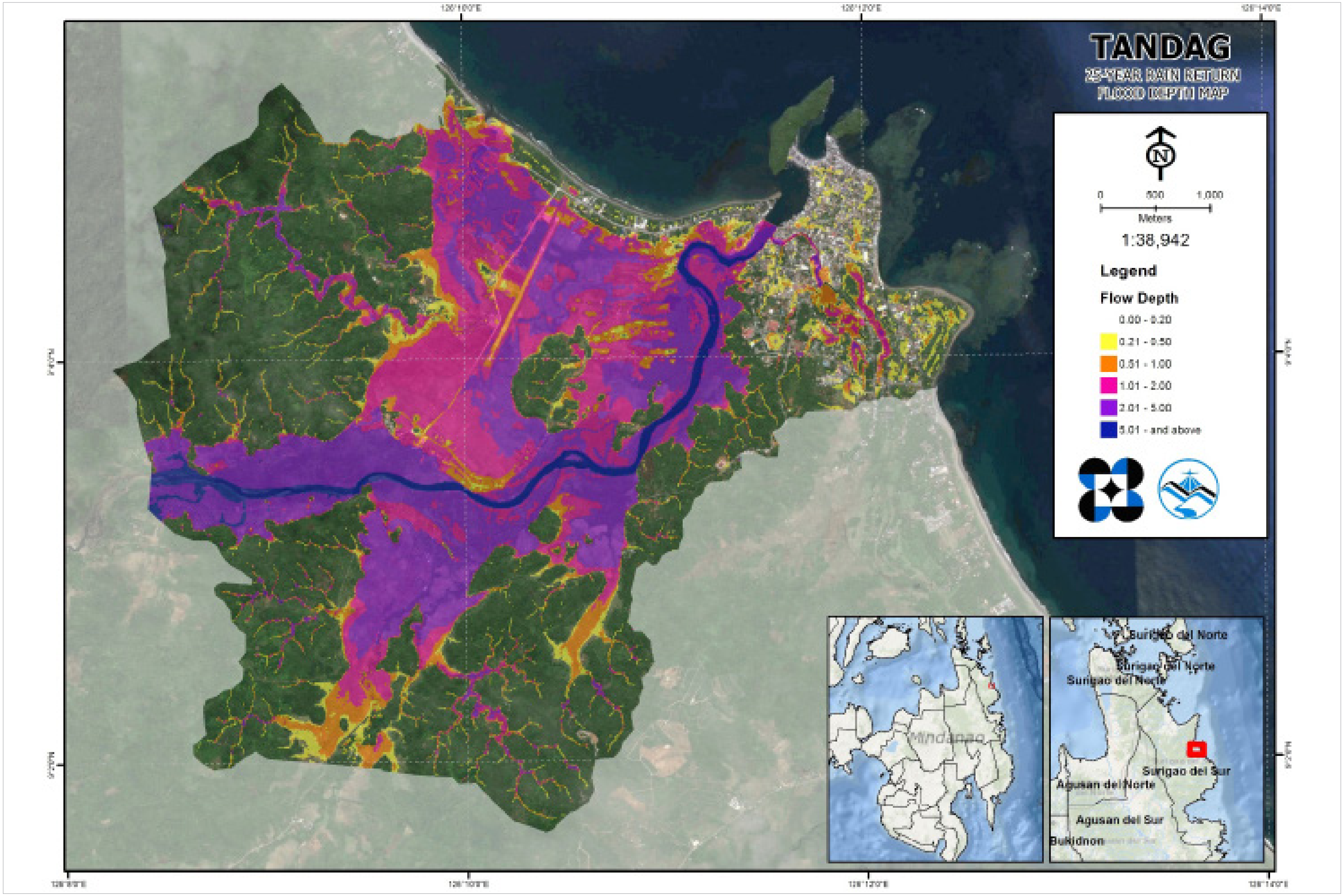

Figure 60. 25-year flow depth map for Tandag Floodplain

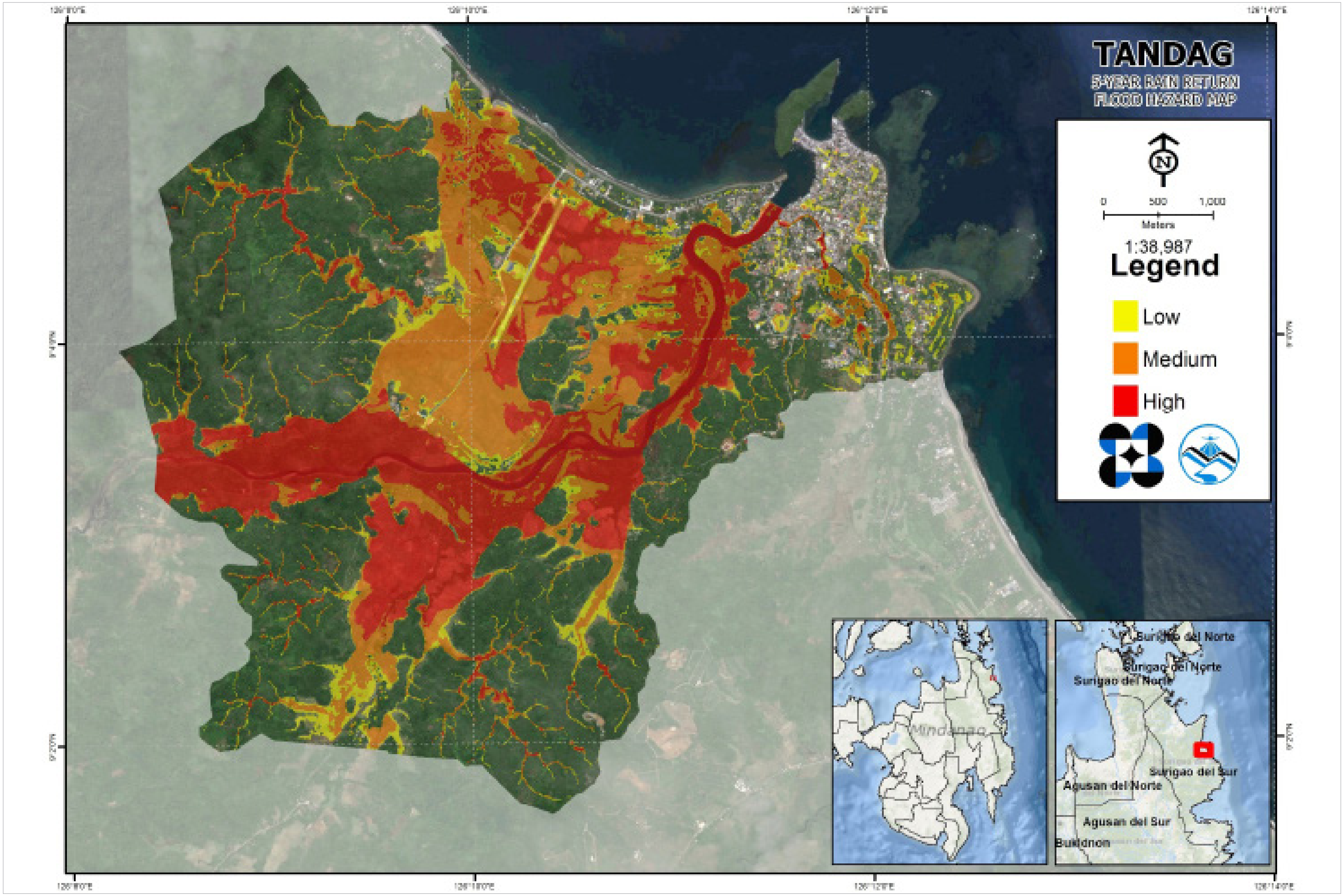

Figure 61. 5-year flood hazard map for Tandag Floodplain

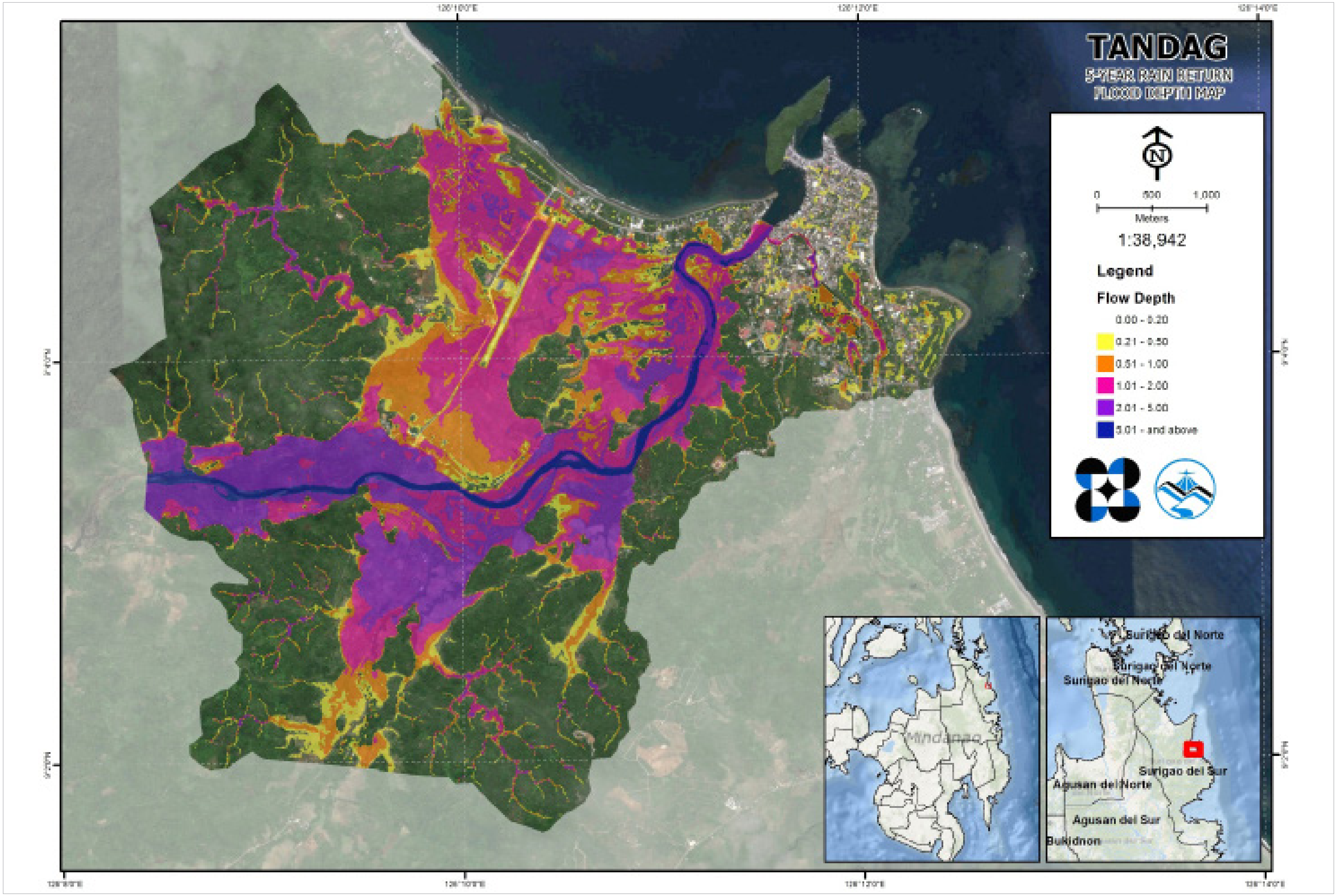

Figure 62. 5-year flow depth map for Tandag Floodplain

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in the Tandag River Basin, grouped by municipality, are listed below. For the said basin, two municipalities consisting of 16 barangays are expected to experience flooding when subjected to 5-year rainfall return period.

For the 5-year return period, 0.02% of the municipality of Tago with an area of 321.22 sq km will experience flood levels of less 0.20 meters; 0.0006% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.0002% and 0.0000003% of the area will experience flood depths of 0.51 to 1 meter and 1.01 to 2 meters, respectively. Listed in Table 31 are the affected areas in square kilometers by flood depth per barangay.

Table 31. Affected areas in Tago, Surigao del Norte during a 5-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tago (in sq km.)
	Dayo-An
0.03-0.20	0.064
0.21-0.50	0.002
0.51-1.00	0.0007
1.01-2.00	1E-06
2.01-5.00	0
> 5.00	0

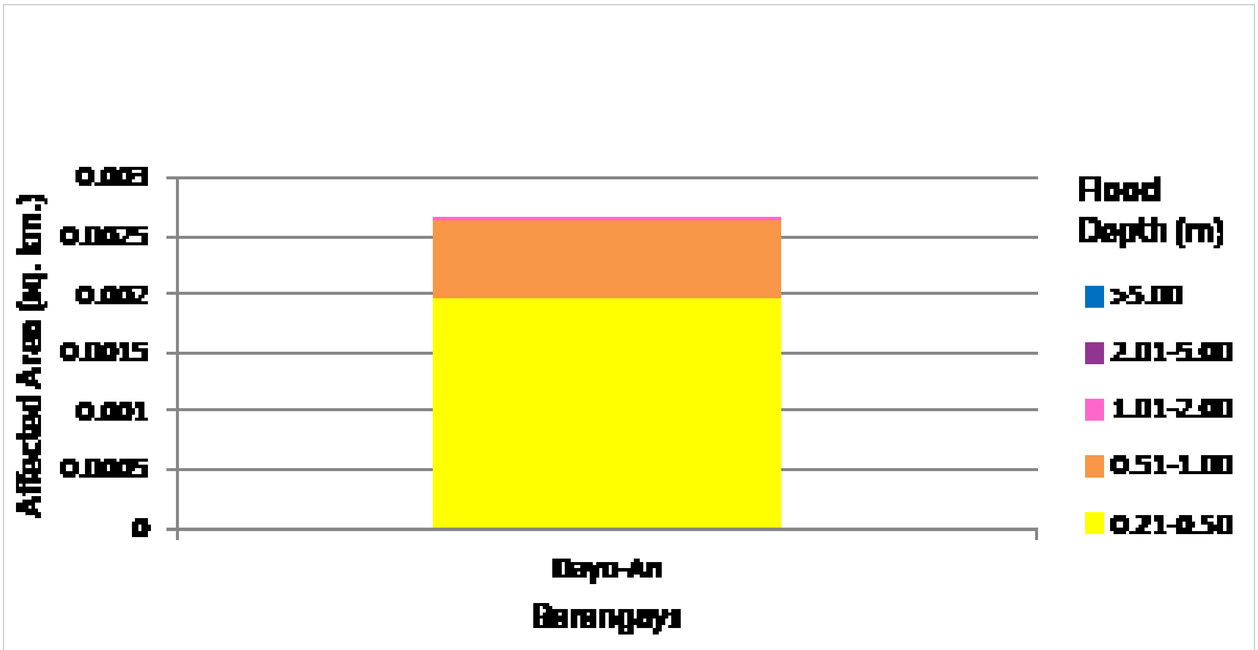

Figure 63. Affected areas in Tago, Surigao del Norte during a 5-year rainfall return period

For the city of Tandag, with an area of 181.51 sq km, 9.54% will experience flood levels of less 0.20 meters; 1.07% of the area will experience flood levels of 0.21 to 0.50 meters; while 1.51%, 2.6%, 1.9%, and 0.26% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 32 and Table 33 are the affected areas in square kilometers by flood depth per barangay.

Table 32. Affected areas in Tandag City, Surigao del Norte during a 5-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tandag City (in sq. kmsq km.)							
	Awasian	Bagong Lungsod	Bioto	Bongtod Poblacion	Dagocdoc	Mabua	Maitum	Maticdum
0.03-0.20	4.89	0.22	0.57	0.36	0.16	0.58	0.027	1.64
0.21-0.50	0.46	0.027	0.16	0.018	0.02	0.12	0.0006	0.3
0.51-1.00	0.79	0.0066	0.44	0.0001	0.0042	0.023	0.0013	0.29
1.01-2.00	1.56	0	1.03	0	0.0039	0.016	0.0072	0.24
2.01-5.00	0.22	0	0.51	0	0	0	0.065	0.065
> 5.00	0.00016	0	0.17	0	0	0	0.011	0

Table 33. Affected areas in Tandag City, Surigao del Norte during a 5-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tandag City (in sq. kmsq km.)						
	Pandanon	Quezon	San Agustin Norte	San Agustin Sur	San Isidro	San Jose	Telaje
0.03-0.20	1.82	0.4	0.58	0.26	3.39	0.38	2.03
0.21-0.50	0.079	0.11	0.091	0.056	0.26	0.018	0.23
0.51-1.00	0.074	0.44	0.12	0.057	0.28	0.037	0.17
1.01-2.00	0.18	0.63	0.18	0.032	0.5	0.11	0.21
2.01-5.00	0.59	0.69	0.036	0.051	0.9	0.23	0.084
> 5.00	0.12	0.12	0	0.014	0.021	0	0.0085

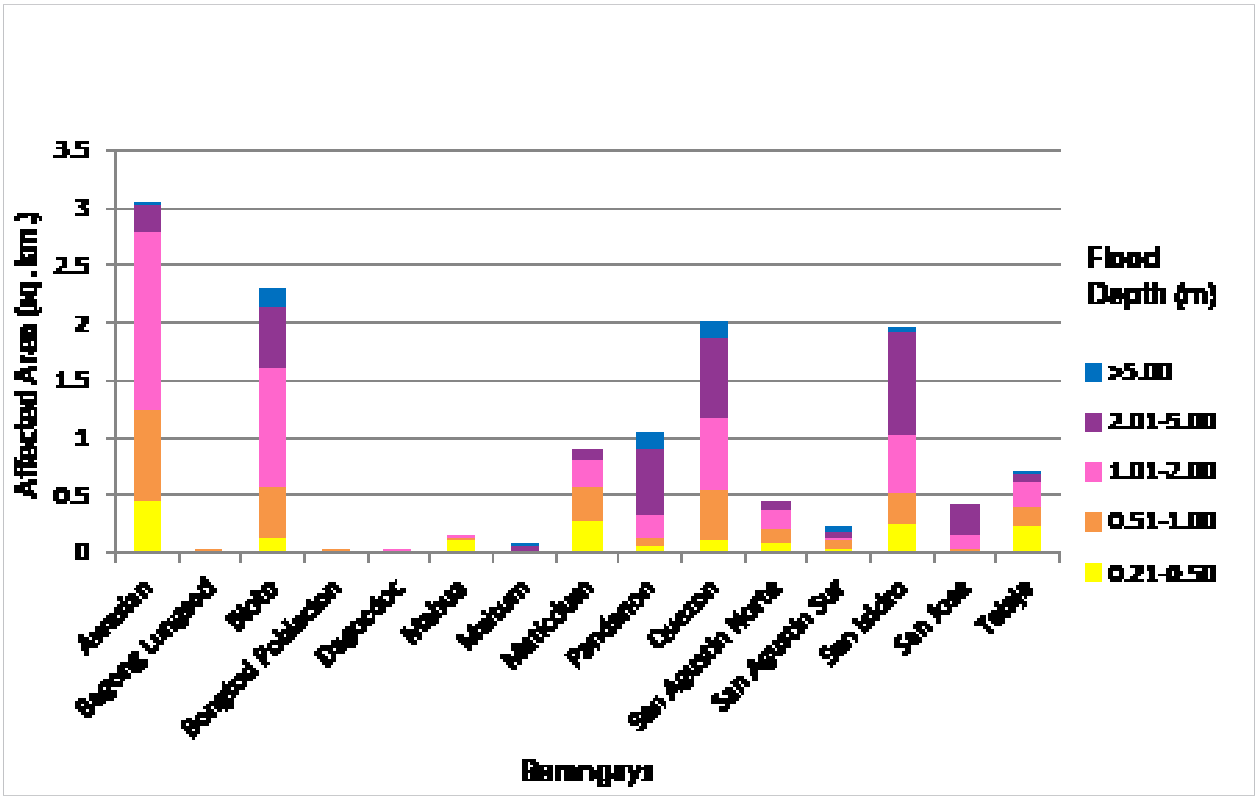

Figure 64. Affected areas in Tandag City, Surigao del Norte during a 5-year rainfall return period

For the 25-year return period, 0.02% of the municipality of Tago with an area of 321.22 sq km will experience flood levels of less 0.20 meters; 0.0006% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.0003% and 0.0006% of the area will experience flood depths of 0.51 to 1 meter and 1.01 to 2 meters, respectively. Listed in Table 34 are the affected areas in square kilometers by flood depth per barangay.

Table 34. Table 34. Affected areas in Tago, Surigao del Norte during a 25-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tago (in sq km.)
	Dayo-An
0.03-0.20	0.063
0.21-0.50	0.002
0.51-1.00	0.0009
1.01-2.00	0.0002
2.01-5.00	0
> 5.00	0

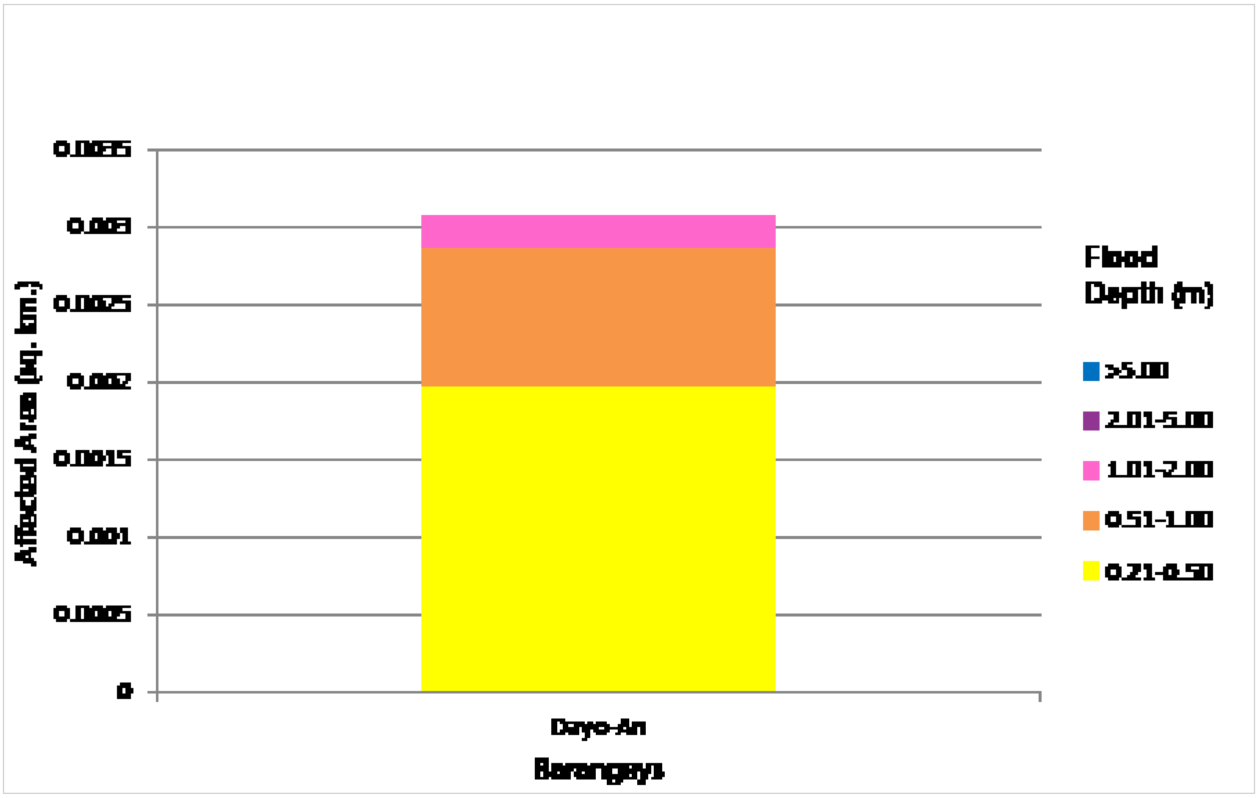

Figure 65. Affected areas in Tago, Surigao del Norte during a 25-year rainfall return period

For the city of Tandag, with an area of 181.51 sq km, 8.98% will experience flood levels of less 0.20 meters; 0.83% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.99%, 2.54%, 3.17%, and 0.36% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 35 and Table 36 are the affected areas in square kilometers by flood depth per barangay.

Table 35. Affected areas in Tandag City, Surigao del Norte during a 25-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tandag City (in sq. kmsq km.)							
	Awasian	Bagong Lungsod	Bioto	Bongtod Poblacion	Dagocdoc	Mabua	Maitum	Maticdum
0.03-0.20	4.7	0.21	0.45	0.35	0.15	0.52	0.024	1.53
0.21-0.50	0.28	0.04	0.062	0.027	0.023	0.15	0.00068	0.22
0.51-1.00	0.39	0.0087	0.18	0.0004	0.0058	0.037	0.0007	0.32
1.01-2.00	1.58	0	0.95	0	0.0049	0.025	0.0026	0.27
2.01-5.00	0.97	0	1.01	0	0.0008	0	0.053	0.19
> 5.00	0.0011	0	0.21	0	0	0	0.031	0.0001

Table 36. Affected areas in Tandag City, Surigao del Norte during a 25-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tandag City (in sq. kmsq km.)						
	Pandanon	Quezon	San Agustin Norte	San Agustin Sur	San Isidro	San Jose	Telaje
0.03-0.20	1.77	0.34	0.5	0.15	3.3	0.37	1.9
0.21-0.50	0.071	0.036	0.062	0.057	0.2	0.016	0.25
0.51-1.00	0.061	0.14	0.11	0.073	0.26	0.019	0.2
1.01-2.00	0.085	0.71	0.22	0.099	0.41	0.077	0.18
2.01-5.00	0.68	1.03	0.12	0.055	1.15	0.3	0.19
> 5.00	0.19	0.14	0	0.034	0.021	0	0.02

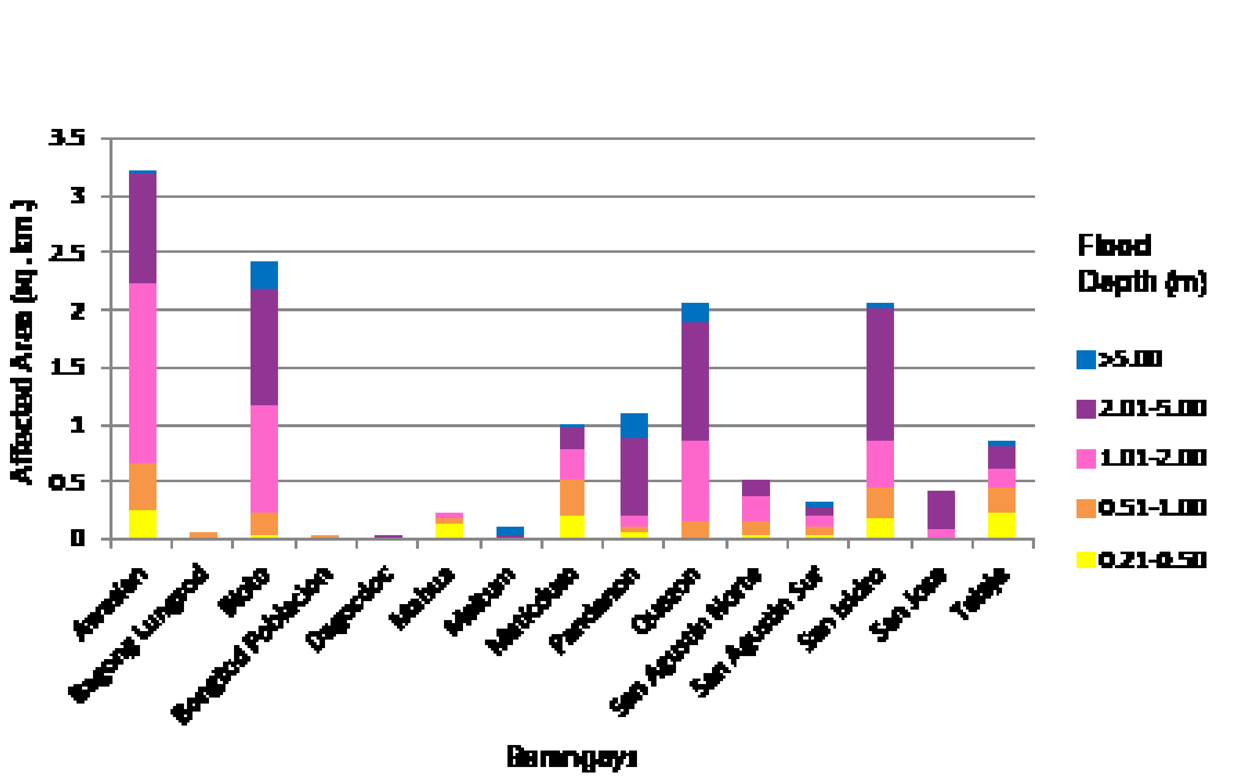

Figure 66. Affected areas in Tandag City, Surigao del Norte during a 25-year rainfall return period

For the 100-year return period, 0.02% of the municipality of Tago with an area of 321.22 sq km will experience flood levels of less 0.20 meters; 0.0006% of the area will experience flood levels of 0.21 to 0.50 meters while 0.0003% and 0.0006% of the area will experience flood depths of 0.51 to 1 meter and 1.01 to 2 meters, respectively. Listed in Table 37 are the affected areas in square kilometers by flood depth per barangay.

Table 37. Affected areas in Tago, Surigao del Norte during a 100-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tago (in sq km.)
	Dayo-An
0.03-0.20	0.063
0.21-0.50	0.002
0.51-1.00	0.0009
1.01-2.00	0.0002
2.01-5.00	0
> 5.00	0

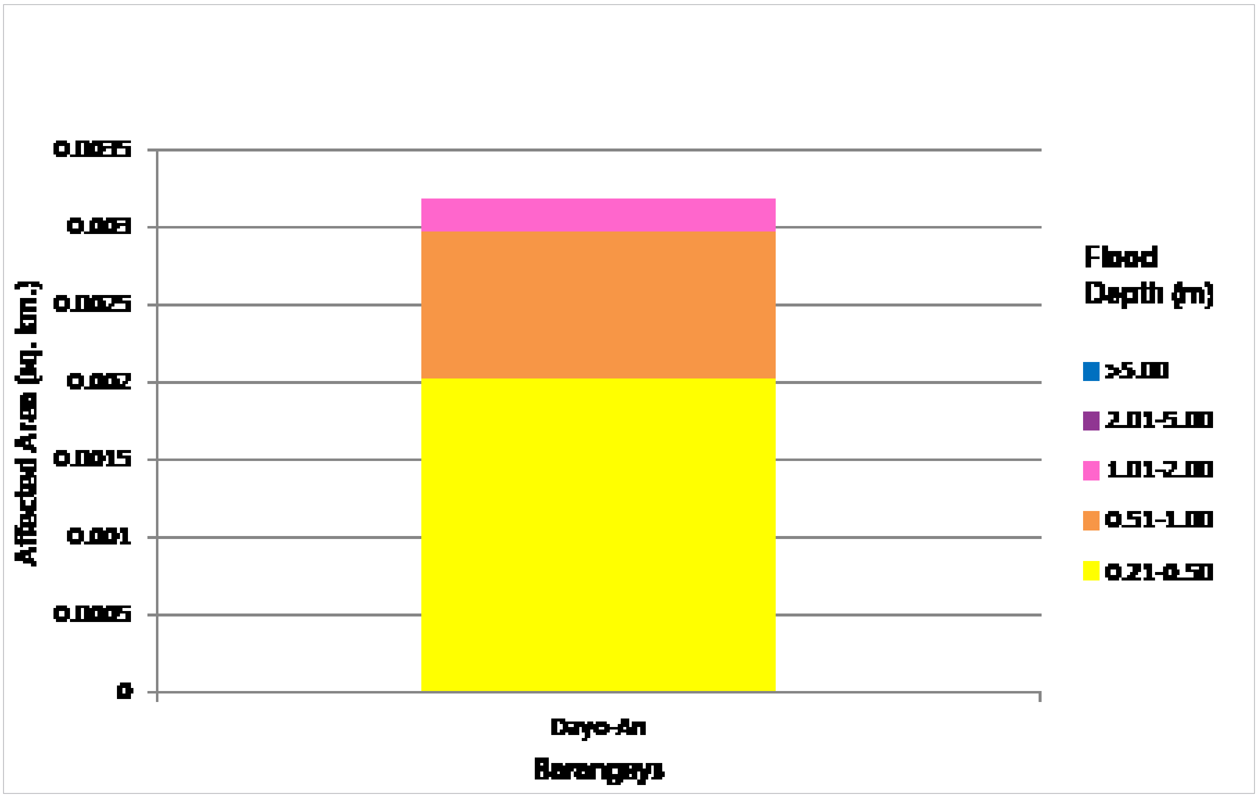

Figure 67. Affected areas in Tago, Surigao del Norte during a 100-year rainfall return period

For the city of Tandag, with an area of 181.51 sq km, 8.7% will experience flood levels of less 0.20 meters; 0.78% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.81%, 1.97%, 4.06%, and 0.55% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 38 and Table 39 are the affected areas in square kilometers by flood depth per barangay.

Table 38. Affected areas in Tandag City, Surigao del Norte during a 100-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tandag City (in sq. kmsq km.)							
	Awasian	Bagong Lungsod	Bioto	Bongtod Poblacion	Dagocdoc	Mabua	Maitum	Maticdum
0.03-0.20	4.62	0.19	0.43	0.35	0.14	0.49	0.022	1.48
0.21-0.50	0.24	0.048	0.038	0.034	0.031	0.18	0.0005	0.19
0.51-1.00	0.27	0.01	0.089	0.0007	0.0068	0.048	0.00057	0.28
1.01-2.00	1.1	0.0001	0.67	0	0.0054	0.027	0.0017	0.31
2.01-5.00	1.69	0	1.42	0	0.0021	0.0006	0.016	0.27
> 5.00	0.0012	0	0.23	0	0	0	0.072	0.0001

Table 39. Affected areas in Tandag City, Surigao del Norte during a 100-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tandag City (in sq. kmsq km.)						
	Pandanon	Quezon	San Agustin Norte	San Agustin Sur	San Isidro	San Jose	Telaje
0.03-0.20	1.73	0.33	0.45	0.12	3.24	0.37	1.82
0.21-0.50	0.069	0.018	0.076	0.038	0.18	0.014	0.26
0.51-1.00	0.059	0.06	0.076	0.077	0.25	0.018	0.21
1.01-2.00	0.068	0.48	0.22	0.11	0.35	0.049	0.19
2.01-5.00	0.51	1.31	0.19	0.087	1.3	0.34	0.24
> 5.00	0.42	0.19	0	0.044	0.022	0	0.024

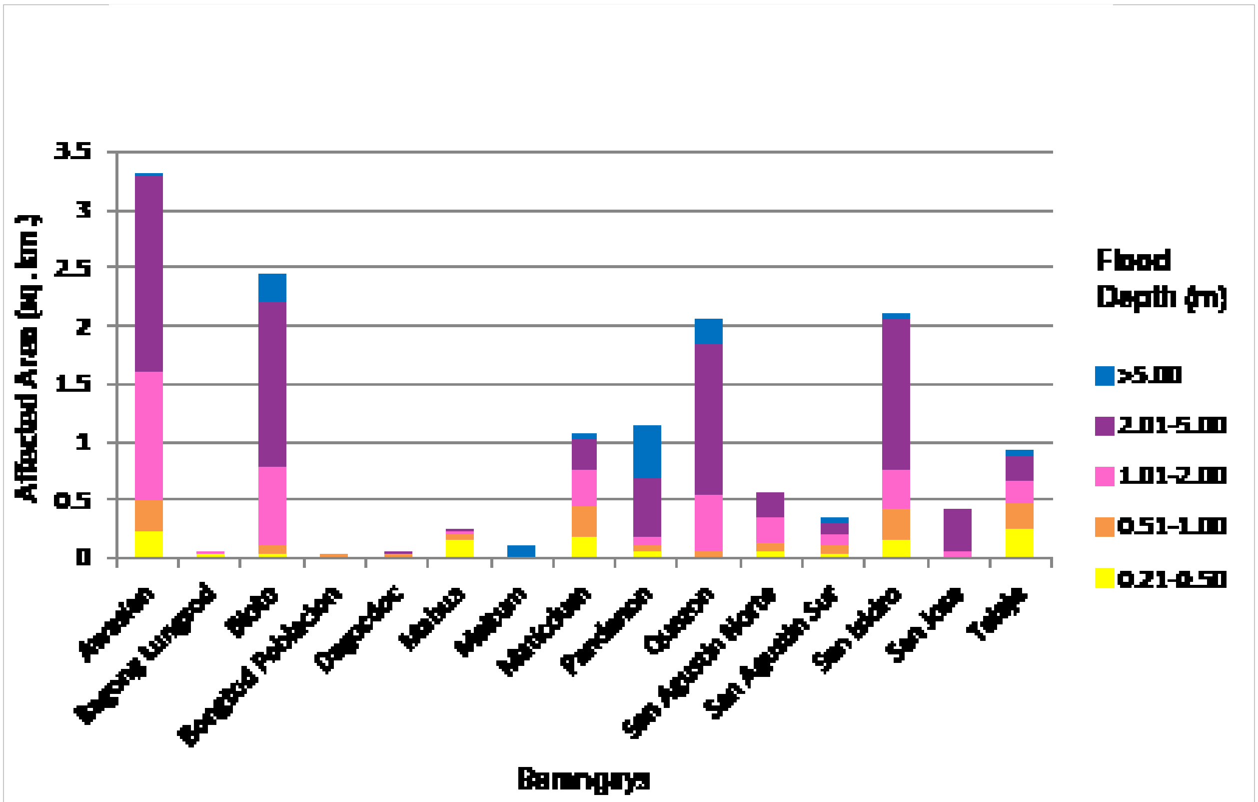

Figure 68. Affected areas in Tandag City, Surigao del Norte during a 100-year rainfall return period

Among the barangays in the municipality of Tago, Dayo-an is projected to have the highest percentage of area that will experience flood levels at 0.02%.

Among the barangays in the city of Tandag, Awasian is projected to have the highest percentage of area that will experience flood levels at 4.37%. Meanwhile, San Isidro posted the second highest percentage of area that may be affected by flood depths at 2.95%.

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

Table 40. Area covered by each warning level with respect to the rainfall scenario

Warning Level	Area Covered in sq. km		
	5 year	25 year	100 year
Low	1.96	4.49	1.4
Medium	5.4	3.91	2.93
High	6.03	9.02	10.6
TOTAL	**13.39**	**17.42**	**14.93**

Of the 22 identified educational institutions in the Tandag Floodplain, two schools were assessed to be exposed to low-level flooding during a 5-year scenario; 5 from schools were exposed to medium-level flooding; and one, the Jacinto P. Elpa National High School, is exposed to high-level flooding. The same number of buildings is exposed to flooding for the 25-year and 100-year scenarios. See ANNEX 12 for a detailed enumeration of schools in the Tandag Floodplain.

Meanwhile, the two medical institutions in the Tandag Floodplain are not found to be exposed to any of the flooding scenarios. See ANNEX 13 for a detailed enumeration of hospitals and clinics in the Tandag Floodplain.

Table 41. Area covered by each warning level with respect to the rainfall scenario

Warning Level	Area Covered in sq. km		
	5 year	25 year	100 year
Low	1.95	1.49	1.40
Medium	5.38	3.90	2.92
High	6.02	9.00	10.57

5.11 Flood Validation

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

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

The validation personnel 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 by contacting a local DRRM office to obtain maps or situation reports about the past flooding events or by interviewing some residents with knowledge of or have had experienced flooding in a particular area.

After which, the actual data from the field were compared to the simulated data to assess the accuracy of the flood depth maps produced and to improve on what is needed.

The flood validation consists of 606 points randomly selected all over the Tandag Floodplain. It has an RMSE value of 1.9242.

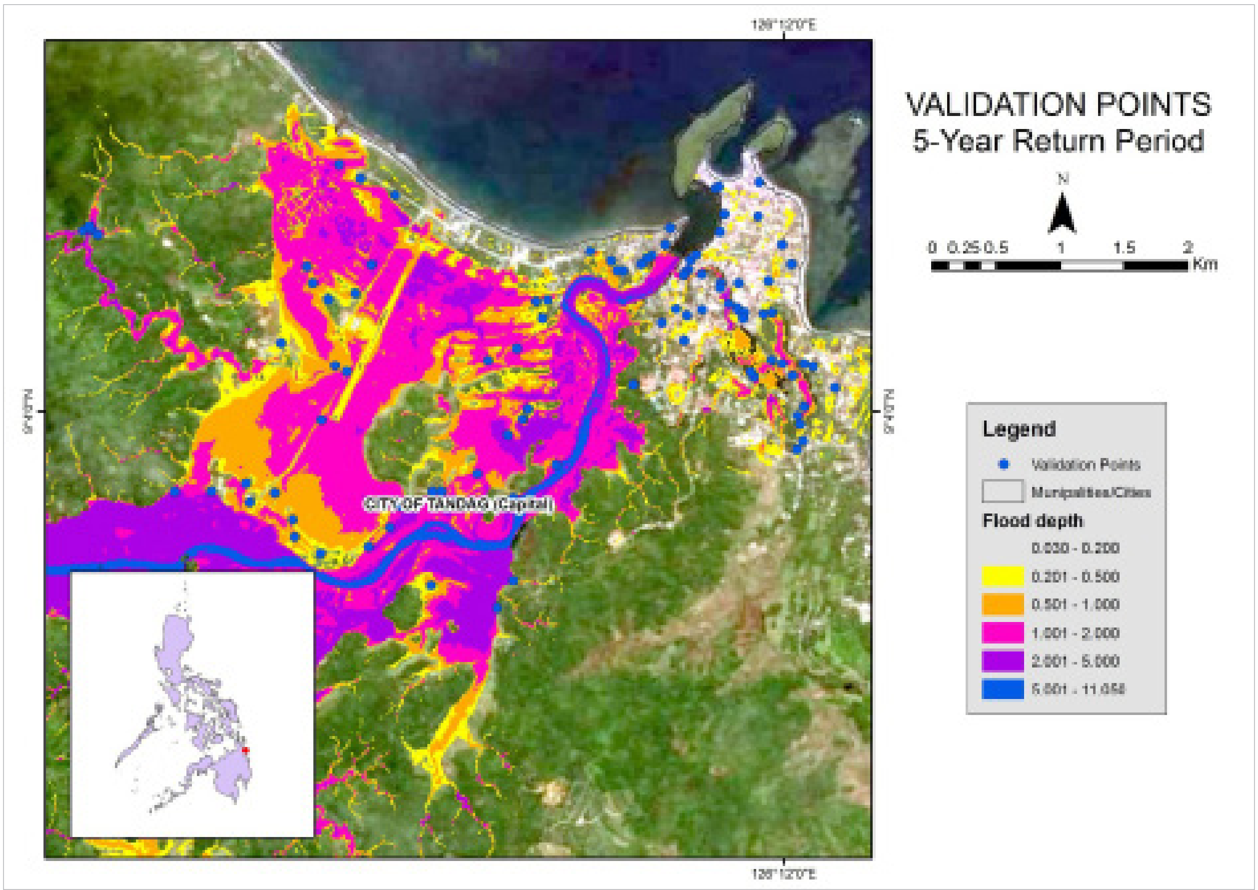

Figure 69. Affected areas in Tandag City, Surigao del Norte during a 100-year rainfall return period

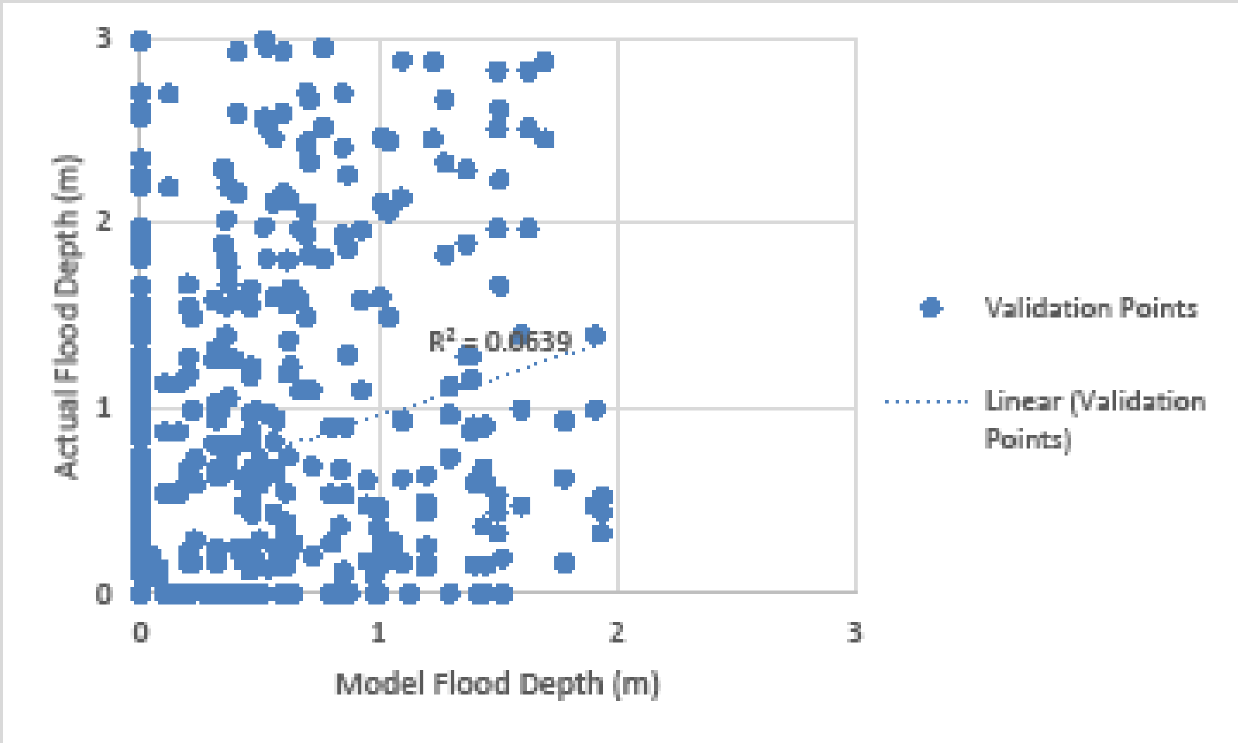

Figure 70. Flood map depth vs. actual flood depth

Table 42. Actual flood depth vs. simulated flood depth in Tandag

HINATUAN RIVER 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	157	32	43	24	0	0	**256**
	0.21-0.50	21	7	18	16	0	0	**62**
	0.51-1.00	42	29	16	21	0	0	**108**
	1.01-2.00	41	26	27	16	0	0	**110**
	2.01-5.00	12	8	22	25	0	0	**67**
	> 5.00	0	0	0	0	0	0	**0**
	Total	**273**	**102**	**126**	**102**	**0**	**0**	**603**

The overall accuracy generated by the flood model is estimated at 32.50% with 196 points correctly matching the actual flood depths. In addition, there were 144 points estimated one level above and below the correct flood depths while there were 149 points and 85 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 253 points were underestimated in the modeled flood depths of Tandag.

Table 43. Summary of accuracy assessment in Tandag

	No. of Points	%
Correct	196	32.50
Overestimated	154	25.54
Underestimated	253	41.96
Total	**603**	**100.00**

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ANNEX

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

Table A-1.1 Technical Specifications of the LiDAR Sensors used in the Malaking Ilog Floodplain Survey

Parameter	**Specification**
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 altitiude	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

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

Table A- 2.1 NAMRIA Certificates of Reference Points used in the LiDAR Survey

SRS-51

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

July 11, 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: **SURIGAO DEL SUR**
Station Name: **SRS-51**
Order: **2nd**

Island:	**MINDANAO**			Barangay:	**BAJAO**
Municipality:	**TAGO**			MSL Elevation:	
PRS92 Coordinates					
Latitude:	**8° 59' 14.14996"**	Longitude:	**126° 9' 6.83415"**	Ellipsoidal Hgt:	**3.97000 m.**
WGS84 Coordinates					
Latitude:	**8° 59' 10.56678"**	Longitude:	**126° 9' 12.17833"**	Ellipsoidal Hgt:	**74.22300 m.**
PTM / PRS92 Coordinates					
Northing:	**993837.182 m.**	Easting:	**406741.509 m.**	Zone:	**5**
UTM / PRS92 Coordinates					
Northing:	**994,598.28**	Easting:	**186,815.64**	Zone:	**52**

Location Description

SRS-51
From Tandag City travel to Brgy. Bajao municipality of Tago for 13 km south. The station is located inside the compound of Bajao Brgy. hall, beside the SW side of the basketball court. The basketball court is about 20 m after the main gate of barangay. Mark is the head of a 3" copper nail set at the center of a cement block embedded on the ground with inscriptions SRS-51 2007 NAMRIA.

Requesting Party: **UP TCAGP / Engr. Christopher Cruz**
Pupose: **Reference**
OR Number: **8796507 A**
T.N.: **2014-1594**

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

SRS-47

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

August 08, 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: SURIGAO DEL SUR
Station Name: SRS-47
Order: 2nd

Island: MINDANAO Municipality: MADRID		Barangay: MANGA MSL Elevation:
	PRS92 Coordinates	
Latitude: 9° 15' 35.63666"	Longitude: 125° 58' 53.39602"	Ellipsoidal Hgt: 5.36800 m.
	WGS84 Coordinates	
Latitude: 9° 15' 31.86666"	Longitude: 125° 58' 58.71761"	Ellipsoidal Hgt: 74.61000 m.
	PTM / PRS92 Coordinates	
Northing: 1024025.604 m.	Easting: 607846.421 m.	Zone: 5
	UTM / PRS92 Coordinates	
Northing:	Easting:	Zone:

Location Description

SRS-47
From Tandag City landmark travel towards Brgy. Manga municipality of Madrid crossing for 58 km north, then turn right to Manga Barangay Hall about 2 km away east side. The station is located on the left side ground corner of Manga Barangay Hall about 60 m from crossing. Mark is the head of a 3" copper nail set at the center of cement block embedded on the ground with inscriptions SRS-47 2007 NAMRIA.

Requesting Party: ENGR. CHRISTOPHER CRUZ
Pupose: Reference
OR Number: 8799670 A
T.N.: 2014-1783

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

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ANNEX 3. Baseline Processing Reports of Control Points Used in the LiDAR Survey

Table A-3.1 Baseline Processing Reports of Control Points Used in the LiDAR Survey

SS-101

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

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
SRS-47 --- BMSS-101 (B1)	SRS-47	BMSS-101	Fixed	0.002	0.009	165°56'23"	2332.652	2.997

Acceptance Summary

Processed	Passed	Flag	Fail
1	1	0	0

SRS-47 - BMSS-101 (8:09:33 AM-11:14:27 AM) (S1)

Baseline observation:	SRS-47 --- BMSS-101 (B1)
Processed:	8/15/2014 4:10:50 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.002 m
Vertical precision:	0.009 m
RMS:	0.001 m
Maximum PDOP:	4.904
Ephemeris used:	Broadcast
Antenna model:	Trimble Relative
Processing start time:	7/30/2014 8:09:33 AM (Local: UTC+8hr)
Processing stop time:	7/30/2014 11:14:27 AM (Local: UTC+8hr)
Processing duration:	03:04:54
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	SRS-47				
Grid		Local		Global	
Easting	827616.263 m	Latitude	N9°15'35.53566"	Latitude	N9°15'31.86566"
Northing	1024891.138 m	Longitude	E125°58'53.39602"	Longitude	E125°58'58.71761"
Elevation	5.093 m	Height	5.366 m	Height	74.610 m

To:	BMSS-101				
Grid		Local		Global	
Easting	828202.434 m	Latitude	N9°14'21.88056"	Latitude	N9°14'18.21639"
Northing	1022631.093 m	Longitude	E125°59'11.96188"	Longitude	E125°59'17.28624"
Elevation	8.066 m	Height	8.363 m	Height	77.664 m

Vector					
ΔEasting	586.171 m	NS Fwd Azimuth	165°56'23"	ΔX	-674.043 m
ΔNorthing	-2260.045 m	Ellipsoid Dist.	2332.652 m	ΔY	-36.300 m
ΔElevation	2.973 m	ΔHeight	2.997 m	ΔZ	-2232.851 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.003 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.004 m
σ ΔElevation	0.005 m	σ ΔHeight	0.005 m	σ ΔZ	0.001 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000089185		
Y	-0.0000104189	0.0000143342	
Z	-0.0000020879	0.0000029786	0.0000012148

Occupations

	From	To
Point ID:	SRS-47	BMSS-101
Data file:	C:\Users\Francis\Documents\Business Center - HCE\Unnamed\SRS47 (Modular) 7-30-14 [1.748m].T02	C:\Users\Francis\Documents\Business Center - HCE\Unnamed\BMSS101 (Rover) 7-30-14 [1.768m].T02
Receiver type:	SPS852	SPS985
Receiver serial number:	5203K81512	5245F15374
Antenna type:	Zephyr Geodetic 2	SPS985 Internal
Antenna serial number:	--------	--------
Antenna height (measured):	1.748 m	1.665 m
Antenna method:	Bottom of notch	Bottom of antenna mount

Tracking Summary

SS-158

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

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
SRS-51 --- BMSS-158 (B1)	SRS-51	BMSS-158	Fixed	0.004	0.012	39°25'42"	5932.043	-2.128
SRS-51 --- BMSS-158 (B2)	SRS-51	BMSS-158	Fixed	0.004	0.015	39°25'43"	5932.058	-2.183

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

SRS-51 - BMSS-158 (9:24:42 AM-2:08:07 PM) (S1)

Baseline observation:	SRS-51 --- BMSS-158 (B1)
Processed:	8/15/2014 4:24:54 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.004 m
Vertical precision:	0.012 m
RMS:	0.003 m
Maximum PDOP:	2.892
Ephemeris used:	Broadcast
Antenna model:	Trimble Relative
Processing start time:	7/28/2014 9:24:57 AM (Local: UTC+8hr)
Processing stop time:	7/28/2014 2:08:07 PM (Local: UTC+8hr)
Processing duration:	04:43:10
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	SRS-51				
Grid		Local		Global	
Easting	846621.372 m	Latitude	N8°59'14.14996"	Latitude	N8°59'10.56678"
Northing	994872.010 m	Longitude	E126°09'06.83415"	Longitude	E126°09'12.17832"
Elevation	5.763 m	Height	3.970 m	Height	74.223 m

To:	BMSS-158				
Grid		Local		Global	
Easting	850353.357 m	Latitude	N9°01'43.29494"	Latitude	N9°01'39.70387"
Northing	999491.438 m	Longitude	E126°11'10.19014"	Longitude	E126°11'15.53023"
Elevation	4.177 m	Height	1.842 m	Height	72.090 m

Vector					
ΔEasting	3731.985 m	NS Fwd Azimuth	39°25'42"	ΔX	-2616.860 m
ΔNorthing	4619.427 m	Ellipsoid Dist.	5932.043 m	ΔY	-2804.382 m
ΔElevation	-1.586 m	ΔHeight	-2.128 m	ΔZ	4525.105 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.004 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.002 m	σ ΔY	0.005 m
σ ΔElevation	0.006 m	σ ΔHeight	0.006 m	σ ΔZ	0.001 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000125388		
Y	-0.0000143345	0.0000249058	
Z	-0.0000035937	0.0000046454	0.0000022146

Occupations

	From	To
Point ID:	SRS-51	BMSS-158
Data file:	C:\Users\Francis\Documents\Business Center - HCE\Unnamed\SRS51 (Modular) 7-28-14 [1.754m].T02	C:\Users\Francis\Documents\Business Center - HCE\Unnamed\BMSS158 (Rover) 7-28-14 [1.797m].T02
Receiver type:	SPS852	SPS985
Receiver serial number:	5203K81512	5245F15374
Antenna type:	Zephyr Geodetic 2	SPS985 Internal
Antenna serial number:	--------	--------
Antenna height (measured):	1.754 m	1.694 m
Antenna method:	Bottom of notch	Bottom of antenna mount

Tracking Summary

ANNEX 4. The LiDAR Survey Team Composition

Table A-4.1. The LiDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency / Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, 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	ENGR. LOVELYN ASUNCION	UP-TCAGP
	Research Associate (RA)	MARY CATHERINE ELIZABETH BALIGUAS	UP-TCAGP
		MA. REMEDIOS VILLANUEVA	UP-TCAGP
Ground Survey	RA	JONATHAN ALMALVEZ	UP-TCAGP
LiDAR Operation	Airborne Security	SSG. MICHAEL BERONILLA	Philippine Air Force (PAF)
	Pilot	CAPT. JEFFREY JEREMY ALAJAR	Asian Aerospace Corporation (AAC)
		CAPT. NEIL ACHILLES AGAWIN	AAC

ANNEX 5. Data Transfer Sheet for Tandag Floodplain

Table A-5.1. Data Transfer Sheet for Tandag Floodplain

DATA TRANSFER SHEET
07/22/2014(Surigao del Sur- ready)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
/5/2014	1564A	3BLK61A186A	Aquarius	NA	224/8	386	102	20.7	185	4.49	31.8	5.67	1KB	1KB	4	224/8	Z:\Airborne_Raw
/6/2014	1666A	3BLK61ASB187A	Aquarius	NA	595/128	1.51	294	54.1	312	12.7	140	10.6	1KB	1KB	4	595/128	Z:\Airborne_Raw
/7/2014	1670A	3BLK61BSC188A	Aquarius	NA	261/83/376/11	892	241	6.28	12	13	NA	8.58	1KB	1KB	4/4	261/83/376/11	Z:\Airborne_Raw
/8/2014	1674A	3BLK61CSD189A	Aquarius	NA	317/250/11	1.06	254	28.7	200	14.9	NA	9.49	1KB	1KB	4/4	317/250/11	Z:\Airborne_Raw
/9/2014	1678A	3BLK61DSG190A	Aquarius	NA	159/159/383/12/9	884	251	46.3	328	13.2	NA	8.46	1KB	1KB	5/3	159/159/383/22/9	Z:\Airborne_Raw

Received from

Name: TJN ALMONA
Position:
Signature:

Received by

Name: JOIDA PRIETO
Position: SSRS
Signature:
7/23/2014

DATA TRANSFER SHEET

08/13/2014(Surigao del Sur(Tandag(Siuslu)- ready)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base info (.txt)		Actual	KML	
28/2014	1754A	3BLK61X5M209A	Aquarius	NA	23	497	173	16.1	0	5.87	NA	9.3	1KB	1KB	5/4	23/273	Z:\DAC\RAWDATA
30/2014	1762A	3BLK61N5211A	Aquarius	NA	680	1.11	232	82.3	365	11.6	137	7.55	1KB	1KB	6	14	Z:\DAC\RAWDATA
31/2014	1766A	3BLK61N5O212A	Aquarius	NA	890/292/850	1.91	209	80.8	487	9.95	NA	17.8	1KB	1KB	6/5	922/11	Z:\DAC\RAWDATA
31/2014	1768A	3BLK61O5B212B	Aquarius	NA	850	1.1	247	49.5	468	9.21	31.8	17.8	1KB	1KB	5	13	Z:\DAC\RAWDATA

Received from

Name: TIN ANDAYA
Position: RA
Signature: [signature]

Received by

Name: JOIDA F. PRIETO
Position: SSRS
Signature: [signature] 8/14/14

ANNEX 6. Flight Logs for the Flight Missions

Table A-6.1. Flight Logs for the Flight Missions

Flight Log for 3BLK61A186A Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1664A

1 LIDAR Operator: MCE Baliguas	2 ALTM Model: Aquarius	3 Mission Name: 3BLK61A186A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9122
7 Pilot: JJ Alajar	8 Co-Pilot: NA Aoawin	9 Route:			
10 Date: July 5, 2014	12 Airport of Departure (Airport, City/Province): Tandag City		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1439	14 Engine Off: 1638	15 Total Engine Time: 1+59	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Cloudy					

20 Remarks:

Surveyed 6 lines over BLK61A.

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Flight Log for 3BLK61ASB187A Mission.

DREAM Data Acquisition Flight Log

Flight Log No.: 1661

1 LIDAR Operator: MCE Balicuat	2 ALTM Model: Aquarius	3 Mission Name: 3BLK61ASB187A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9122
7 Pilot: JJ Alviar	8 Co-Pilot: NA Aquino	9 Route:			
10 Date: July 6, 2014	12 Airport of Departure (Airport, City/Province): Tandag City		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0920	14 Engine Off: 1319	15 Total Engine Time: 359	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	Partly cloudy				

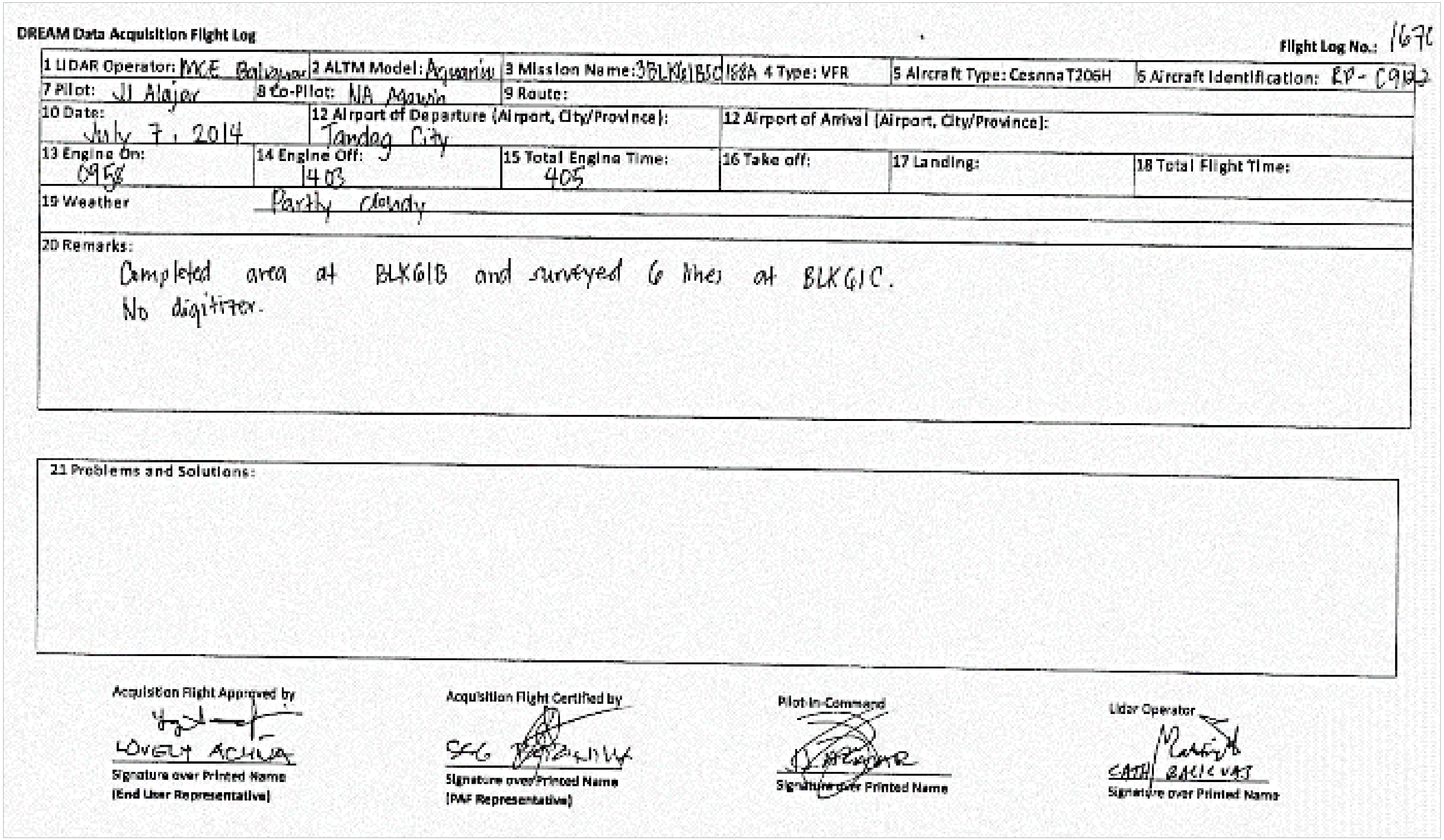
20 Remarks:

Completed mission over BLK61A and covered 4 lines over BLK61B.

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Lovely Acuna	SSG [illegible]	JJ Alviar	Cath Balicuat
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Flight Log for 3BLK61BSC188A Mission.



DREAM Data Acquisition Flight Log

Flight Log No.: 1670

1 LIDAR Operator: MCE Balicuatro	2 ALTM Model: Aquarius	3 Mission Name: 3BLK61BSC188A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9122
7 Pilot: JJ Alajar	8 Co-Pilot: NA Maurin	9 Route:			
10 Date: July 7, 2014	12 Airport of Departure (Airport, City/Province): Tandag City		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0958	14 Engine Off: 1403	15 Total Engine Time: 405	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Partly cloudy					

20 Remarks:

Completed area at BLK61B and surveyed 6 lines at BLK61C.
No digitizer.

21 Problems and Solutions:

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

Acquisition Flight Certified by
SSG [illegible]
Signature over Printed Name
(PAF Representative)

Pilot-in-Command
[illegible]
Signature over Printed Name

Lidar Operator
CATH BALICUAT
Signature over Printed Name

Flight Log for 3BLK61CSD189A Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1674

1 LIDAR Operator: MCE Baliguas	2 ALTM Model: Aquarius	3 Mission Name: 3BLK61CSD189A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9122
7 Pilot: J. Alajar	8 Co-Pilot: NA Aquino	9 Route:			
10 Date: July 8, 2014	12 Airport of Departure (Airport, City/Province): Tandag City		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1017	14 Engine Off: 1440	15 Total Engine Time: 423	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Partly cloudy					

20 Remarks:

Completed area at BLK61C and surveyed 12 lines at BLK61D.

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
LOVELY ACUÑA	SSG BETONIO	J. ALAJAR	CATH BALIGUAS
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Flight Log for 3BLK61DSG190A Mission.

DREAM Data Acquisition Flight Log

Flight Log No.: 1678

1 LIDAR Operator: MCE Baliguas	2 ALTM Model: Aquarius	3 Mission Name: 3BLK61DSG190A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C912
7 Pilot: JJ Alajar	8 Co-Pilot: NA Aquino	9 Route:			
10 Date: July 9, 2014	12 Airport of Departure (Airport, City/Province): Tandag City		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1036	14 Engine Off: 1453	15 Total Engine Time: 417	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Hazy					

20 Remarks:

Completed mission over BLK61D and BLK61G.
No Digitizer.

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
LOVELY ACUÑA	CSG BONILLA	JJ ALAJAR	CATH BALICUAT
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Flight Log for 3BLK61KSM210A Mission.

DREAM Data Acquisition Flight Log

Flight Log No.: 17..

3BLK61FGHKMGM210A

1 LIDAR Operator: MCE Balicuas	2 ALTM Model:	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RP-C9..
7 Pilot: JJ Alajar	8 Co-Pilot: MA Garchitorena	9 Route:			
10 Date: July 29, 2014	12 Airport of Departure (Airport, City/Province): Tandag City		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0714	14 Engine Off: 1137	15 Total Engine Time: 0423	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: windy					

20 Remarks: Completed over BLK61M, covered voids over BLK61F, G, H and surveyed 1 line over BLK61K; no digitizer.

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	JJ Alajar Signature over Printed Name	MCE Balicuas Signature over Printed Name

Flight Log for 3BLK61NS211A Mission.

DREAM Data Acquisition Flight Log

Flight Log No.: 167

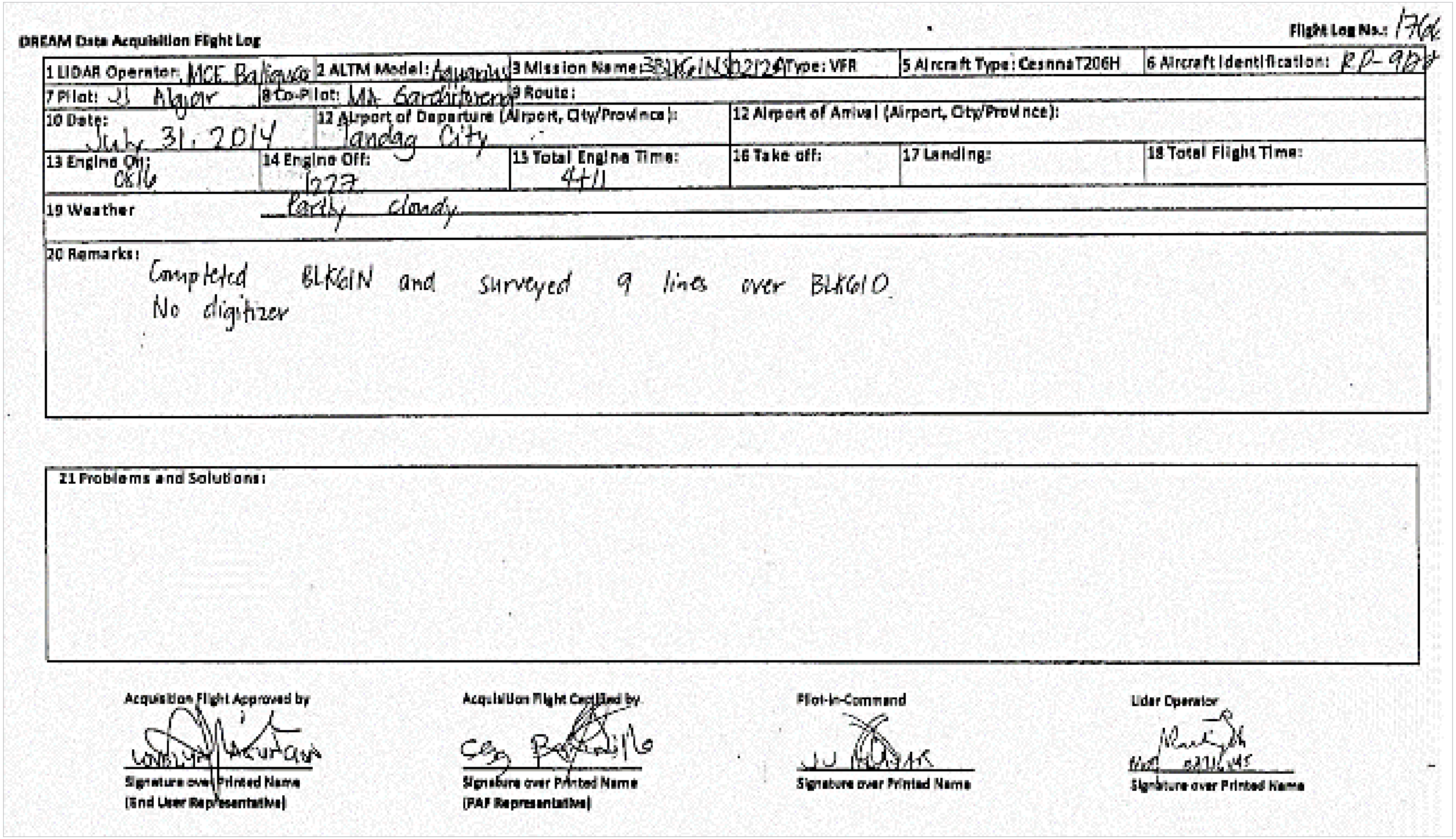
1 LIDAR Operator: MCE Baliguas	2 ALTM Model: Aquarius	3 Mission Name: 3BLKGIN211A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9
7 Pilot: JJ Alajar	8 Co-Pilot: MA Gatchalian	9 Route:			
10 Date: July 30, 2014	12 Airport of Departure (Airport, City/Province): Tandag City		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0840	14 Engine Off: 1245	15 Total Engine Time: 0405	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: windy					

20 Remarks: Bathy survey over coast line of BLKGIN

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	J. Alajar Signature over Printed Name	MCE Baliguas Signature over Printed Name

Flight Log for 3BLK61NSO212A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1766

1 LIDAR Operator: MCE Balicanta	2 ALTM Model: Aquarius	3 Mission Name: 3BLK61NSO212A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-9122
7 Pilot: JJ Alajar	8 Co-Pilot: MA Sarabitanen	9 Route:			
10 Date: July 31, 2014	12 Airport of Departure (Airport, City/Province): Tandag City		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0816	14 Engine Off: 1227	15 Total Engine Time: 4+11	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Partly cloudy					

20 Remarks:

Completed BLK61N and surveyed 9 lines over BLK61O

No digitizer

21 Problems and Solutions:

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

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

Pilot-in-Command: JJ Alajar — Signature over Printed Name

Lidar Operator: Signature over Printed Name

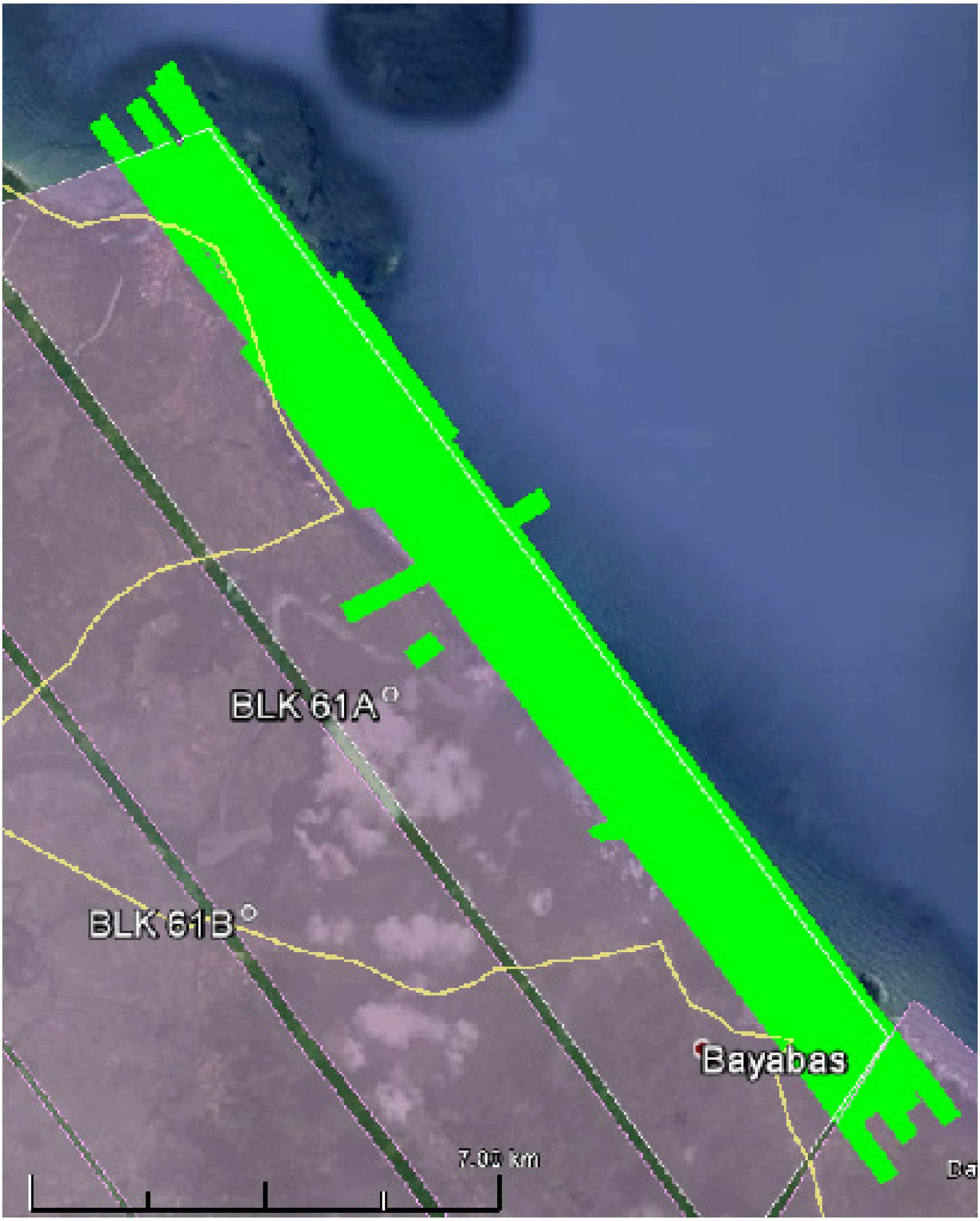
ANNEX 7. Flight Status Reports

Table A-7.1. Flight Status Reports

Flight No	Area	Mission	Operator	Date Flown	Remarks
1664	BLK61A	3BLK61A186A	MCE BALIGUAS	5 JULY 14	Surveyed 6 lines over BLK61A.
1666	BLK61A, BLK61B	3BLK61ASB187A	MCE BALIGUAS	6 JULY 14	Completed mission over BLK61A and covered 4 lines over BLK61B
1670	BLK 61B, BLK61C	3BLK61BSC188A	MCE BALIGUAS	7 JULY 14	Completed area at BLK61B and surveyed 6 lines at BLK61C. No digitizer
1674	BLK61C, BLK61D	3BLK61CSD189A	MCE BALIGUAS	8 JULY 14	Completed area at BLK61C and surveyed 12 lines at BLK61D
1678	BLK61D, BLK61G	3BLK61DSG190A	MCE BALIGUAS	9 JULY 14	Completed mission over BLK61D and BLK61G. No digitizer
1758	BLK61F, BLK61G, BLK61H, BLK61K, BLK61M, BLK61N	3BLK61FGHKMSN210A	MCE BALIGUAS	29 JULY 14	Completed over BLK61M, covered voids over BLK61F,G,H and surveyed 1 line over BLK61K; no digitizer
1762	BLK61N	3BLK61NS211A	MCE BALIGUAS	30 JULY 14	Bathy survey over coast line of BLK61N
1766	BLK61N, BLK61O	3BLK61NSO212A	MCE BALIGUAS	31 JULY 14	Completed BLK61N and surveyed 9 lines over BLK61O; no digitizer

Swath Coverage of Mission 3BLK61A186A

Flight No. : 1664
Area: BLK61A
Mission Name: 3BLK61A186A
Parameters: Alt: 500m Scan Freq: 45 kHz Scan Angle: 18 deg
Total Area Surveyed: 31.1 sq km

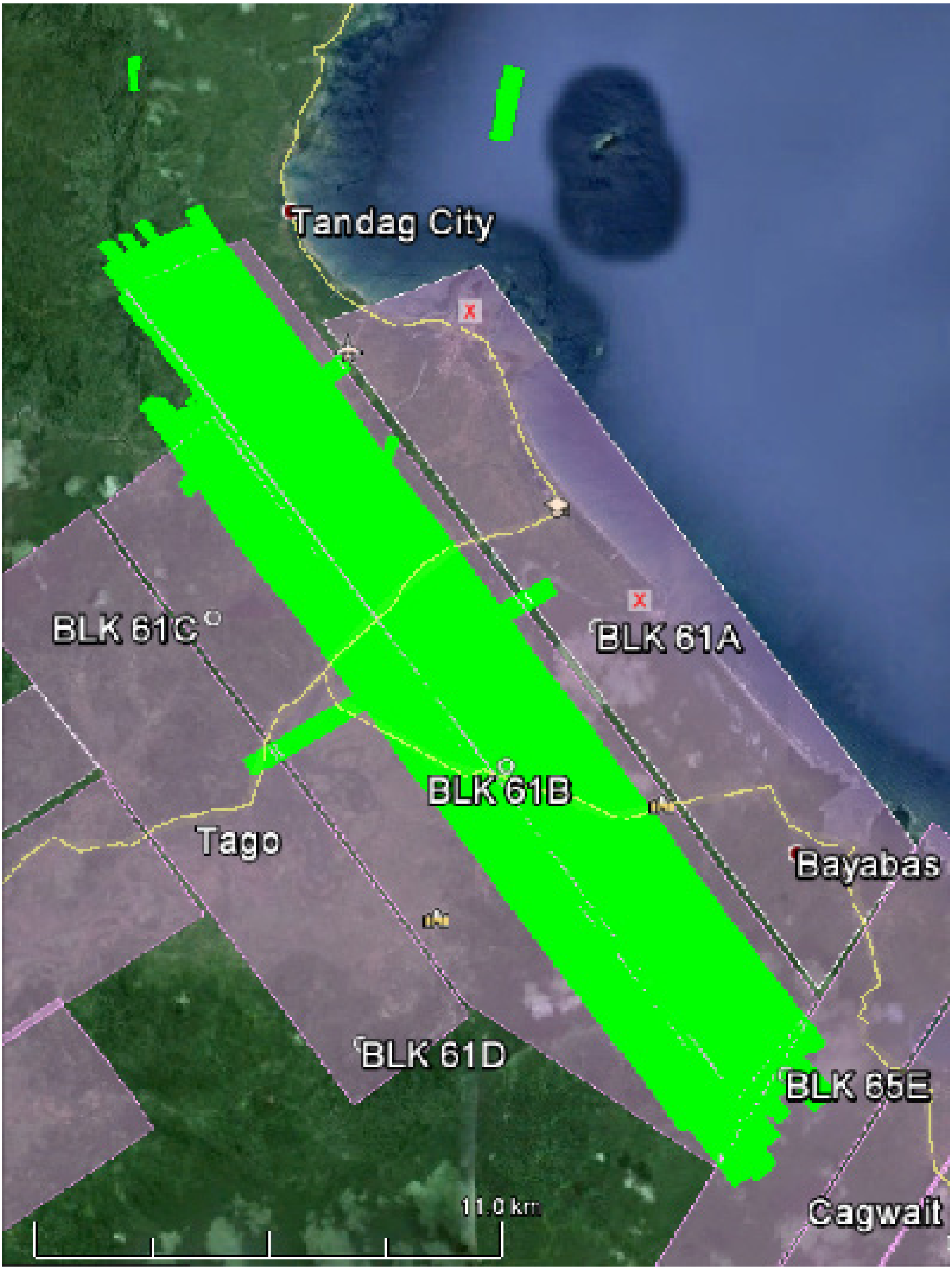


Swath Coverage of Mission 3BLK61ASB187A

Flight No. : 1666
Area: BLK61A, BLK61B
Mission Name: 3BLK61ASB187A
Parameters: Alt: 500m Scan Freq: 45 kHz Scan Angle: 18 deg
Total Area Surveyed: 79.2 sq km

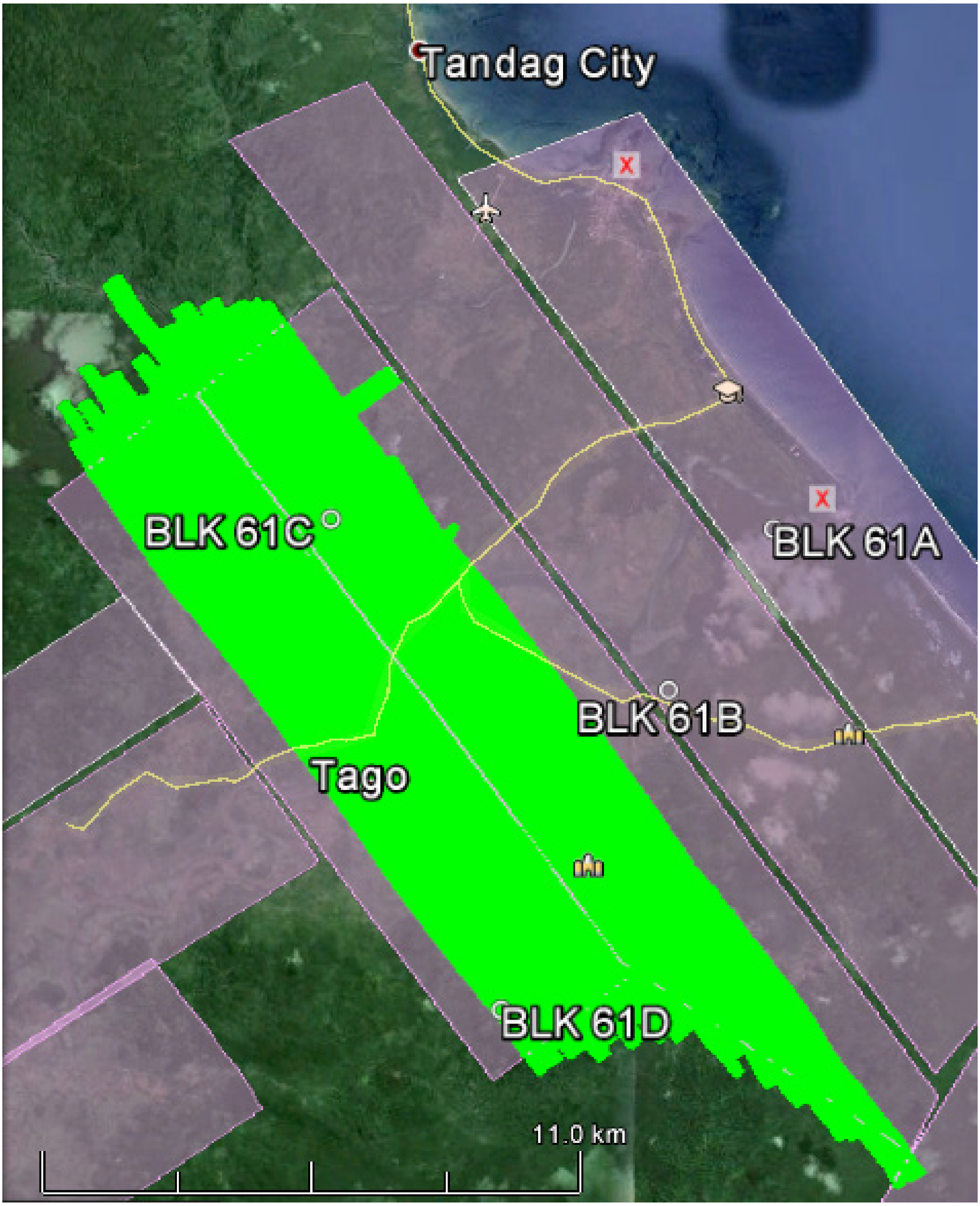
Swath Coverage of Mission 3BLK61BSC188A

Flight No. : 1670
Area: BLK61B, BLK61C
Mission Name: 3BLK61BSC188A
Parameters: Alt: 600m Scan Freq: 45 kHz Scan Angle: 18 deg
Total Area Surveyed: 93.4 sq km



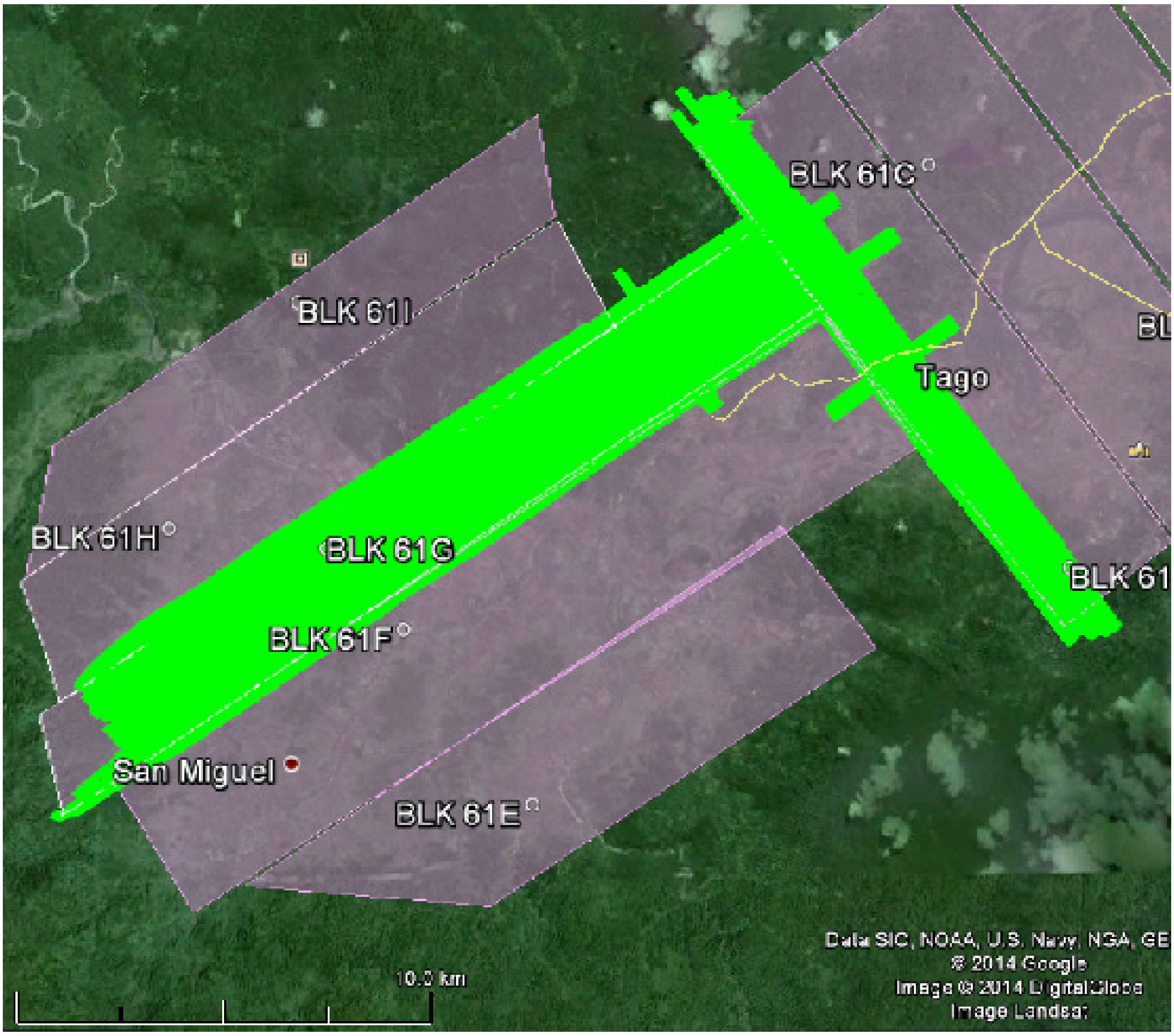
Swath Coverage of Mission 3BLK61CSD189A

Flight No. : 1674
Area: BLK61C, BLK61D
Mission Name: 3BLK61CSD189A
Parameters: Alt: 600m Scan Freq: 45 kHz Scan Angle: 18 deg
Total Area Surveyed: 91.3 sq km



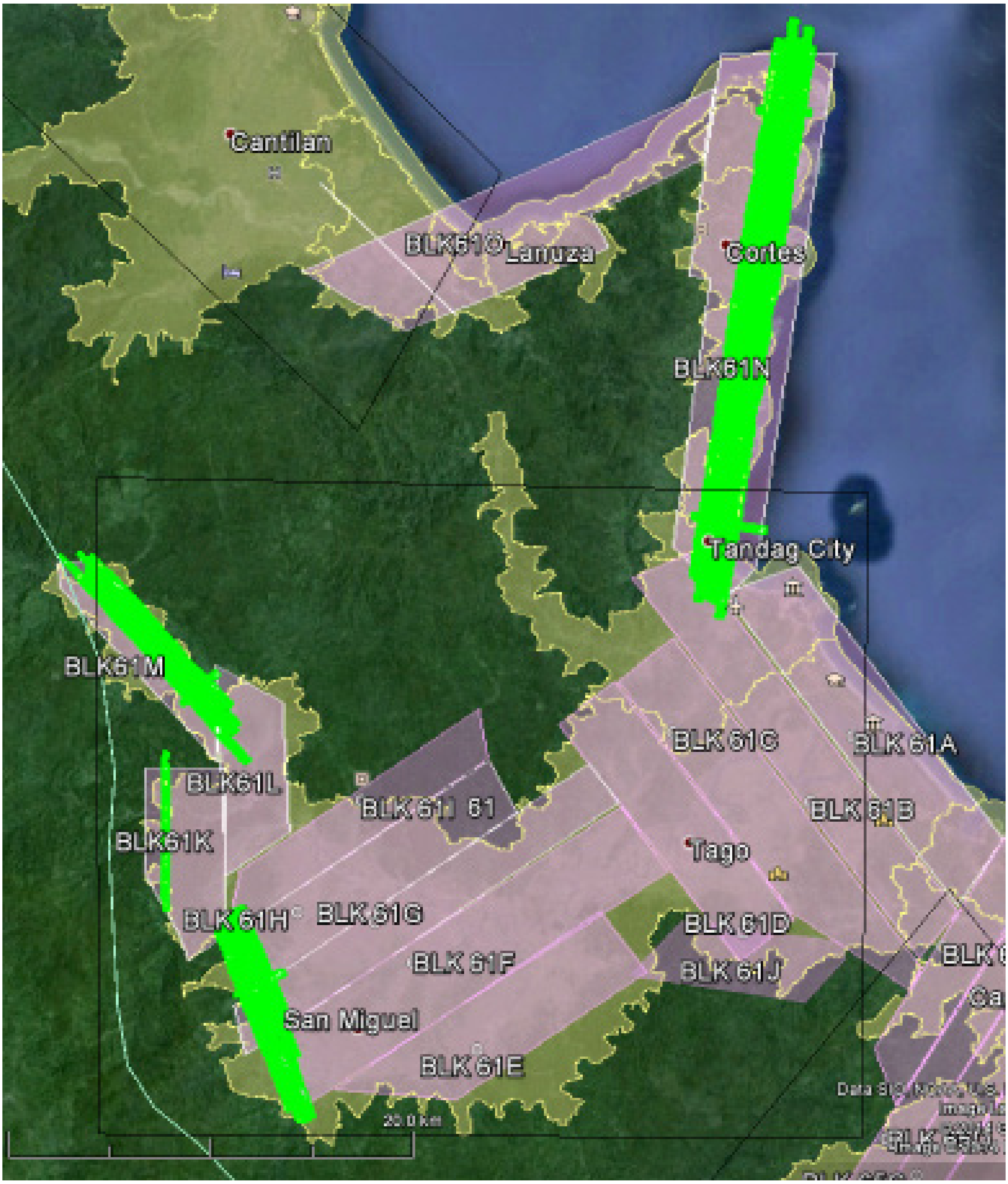
Swath Coverage of Mission 3BLK61DSG190A

Flight No. : 1678
Area: BLK61D, BLK61G
Mission Name: 3BLK61DSG190A
Parameters: Alt: 600m Scan Freq: 45 kHz Scan Angle: 18 deg
Total Area Surveyed: 84.5 sq km



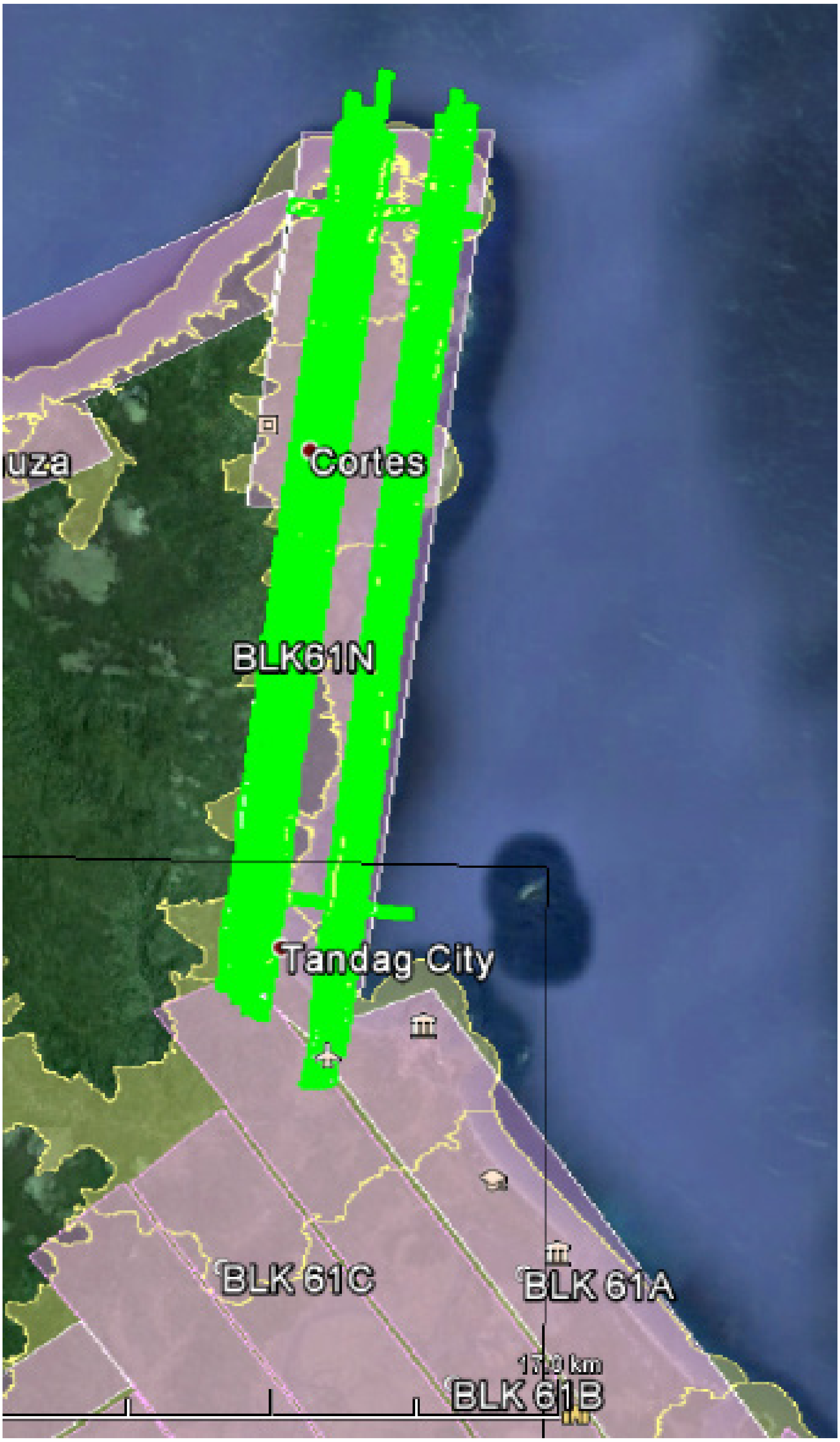
Swath Coverage of Mission 3BLK61FGHKMSN210A

Flight No. : 1758
Area: BLK61LF, BLK61G, BLK61H, BLK61K, BLK61M, BLK61N
Mission Name: 3BLK61FGHKMSN210A
Parameters: Alt: 600m Scan Freq: 45 kHz Scan Angle: 18 deg
Total Area Surveyed: 96.68 sq km



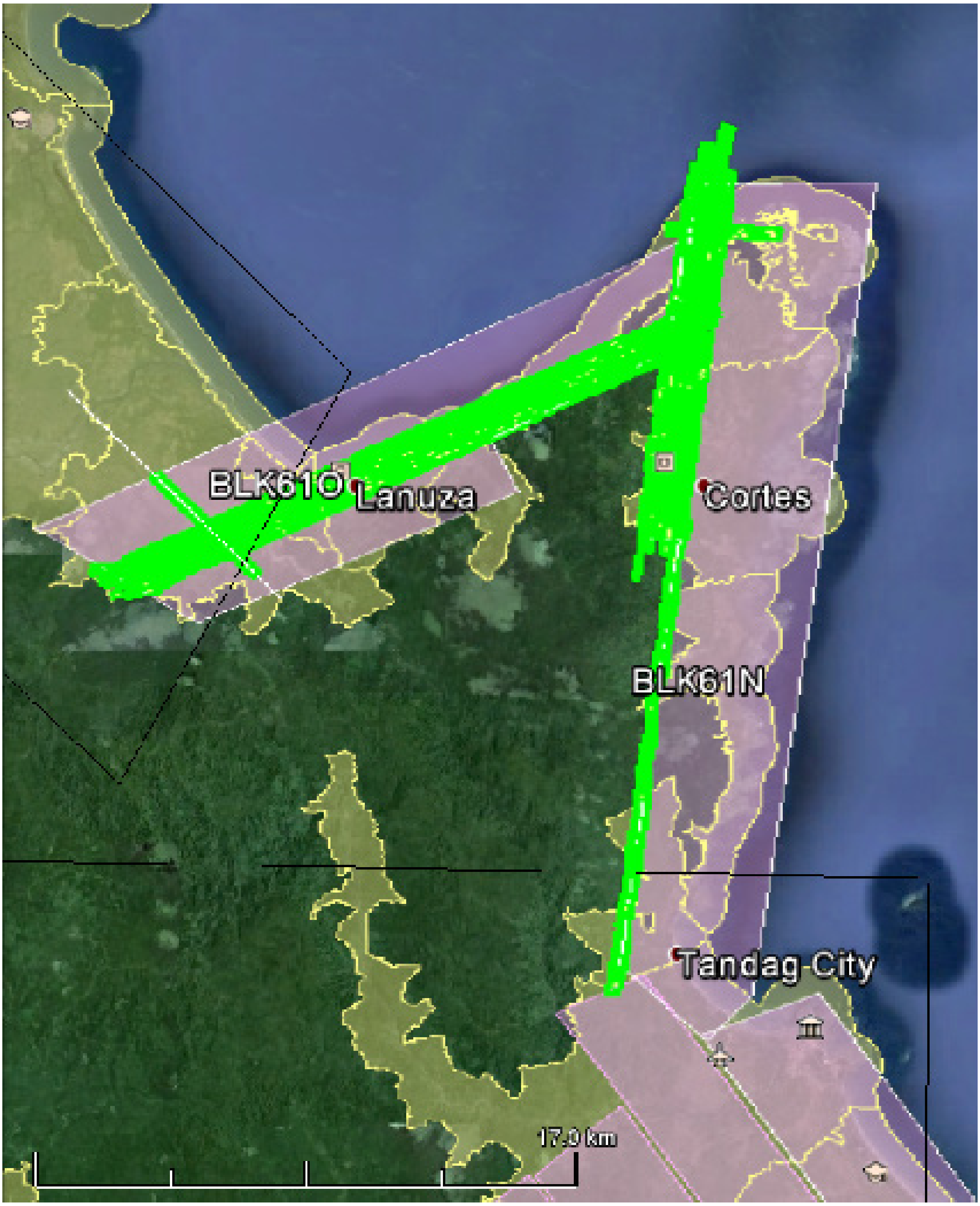
Swath Coverage of Mission 3BLK61NS211A

Flight No. : 1762
Area: BLK61N
Mission Name: 3BLK61NS211A
Parameters: Alt: 600m Scan Freq: 45 kHz Scan Angle: 18 deg
Total Area Surveyed: 79.64 sq km



Swath Coverage of Mission 3BLK61NSO212A

Flight No. : 1766
Area: BLK61N, BLK61O
Mission Name: 3BLK61NSO212A
Parameters: Alt: 600m Scan Freq: 45 kHz Scan Angle: 18 deg
Total Area Surveyed: 50.91 sq km



ANNEX 8. Mission Summary Reports

Table A-8.1. Mission Summary Reports

Flight Area	Tandag (Surigao Del SurSurigao del Sur)
Mission Name	Block 61CD
Inclusive Flights	1674A &1678A
Range data size	22.69 GB
POS	395 MB
Base Data size	17.94
Image	37.90 MB
Transfer date	July 23, 2014 & August 6, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.50
RMSE for East Position (<4.0 cm)	1.85
RMSE for Down Position (<8.0 cm)	2.70
Boresight correction stdev (<0.001deg)	0.000606
IMU attitude correction stdev (<0.001deg)	0.005630
GPS position stdev (<0.01m)	0.0085
Minimum % overlap (>25)	68.11
Ave point cloud density per sq.m. (>2.0)	4.48
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	151
Maximum Height	437.79 m
Minimum Height	63.78 m
Classification (# of points)	
Ground	46,043,085
Low vegetation	71,460,073
Medium vegetation	73,450,888
High vegetation	178,625,360
Building	8,063,567
Orthophoto	YES
Processed by	Engr. Jommer Medina, Engr. Melanie Hingpit, Engr. Elainne Lopez

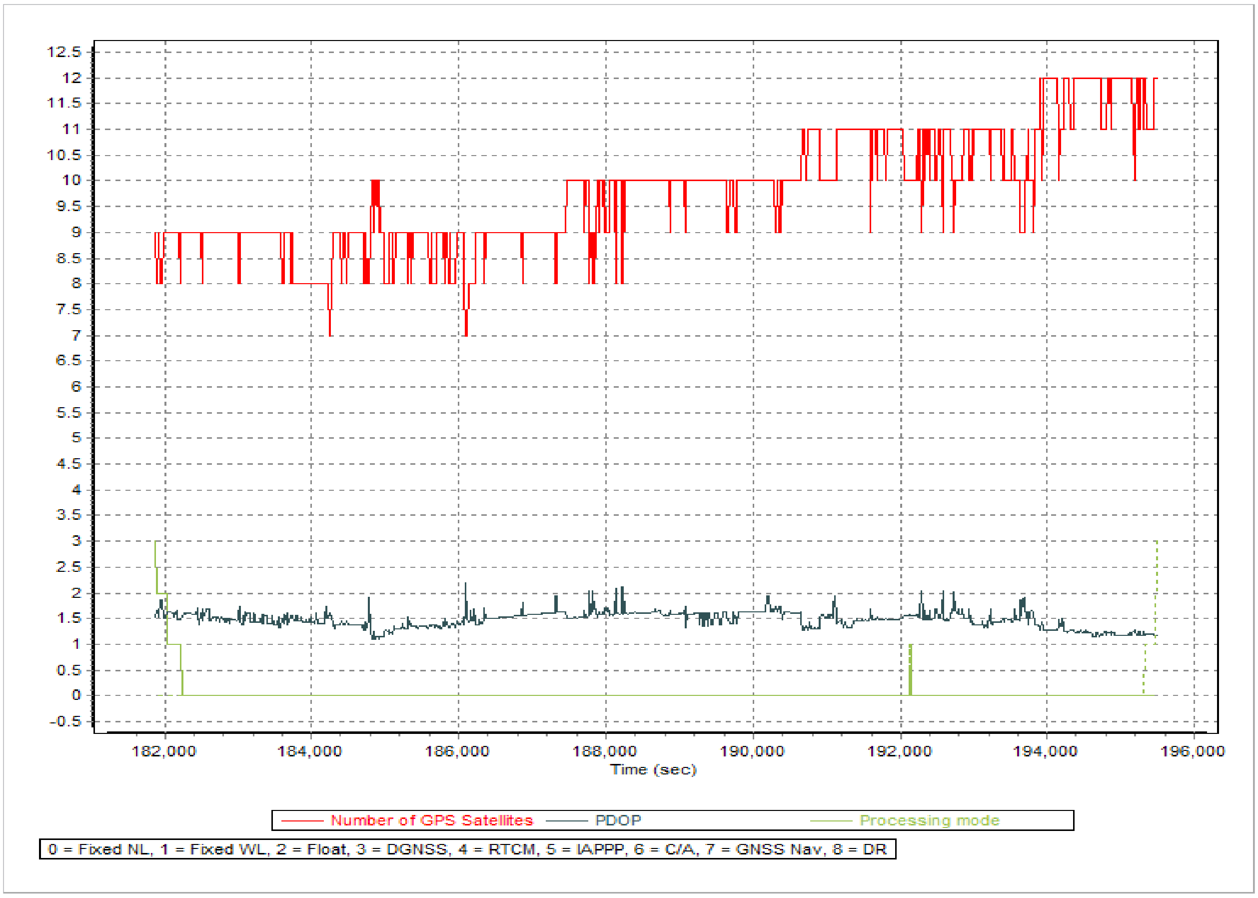


Figure 1.1.1 Solution Status

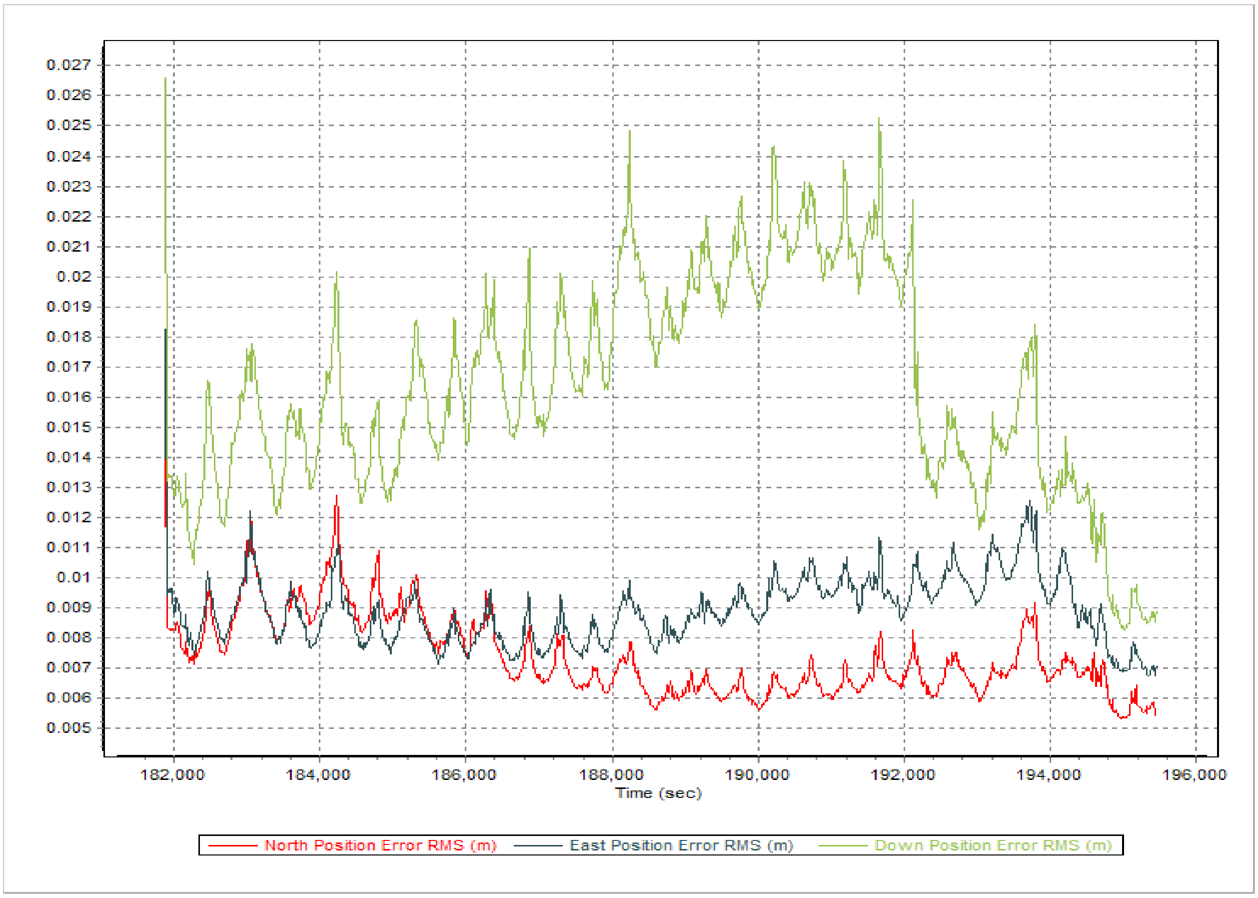


Figure 1.1.2 Smoothed Performance Metric Parameters

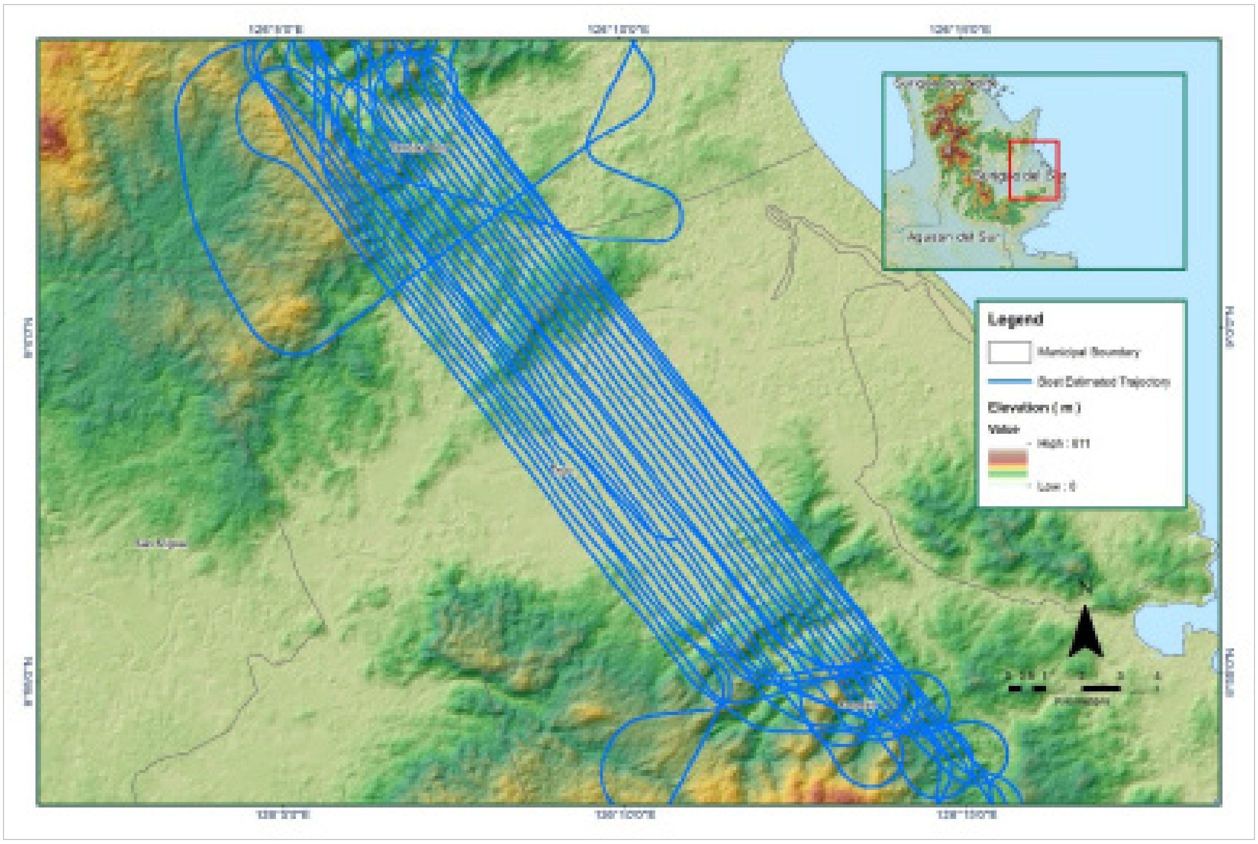


Figure 1.1.3 Best Estimated Trajectory

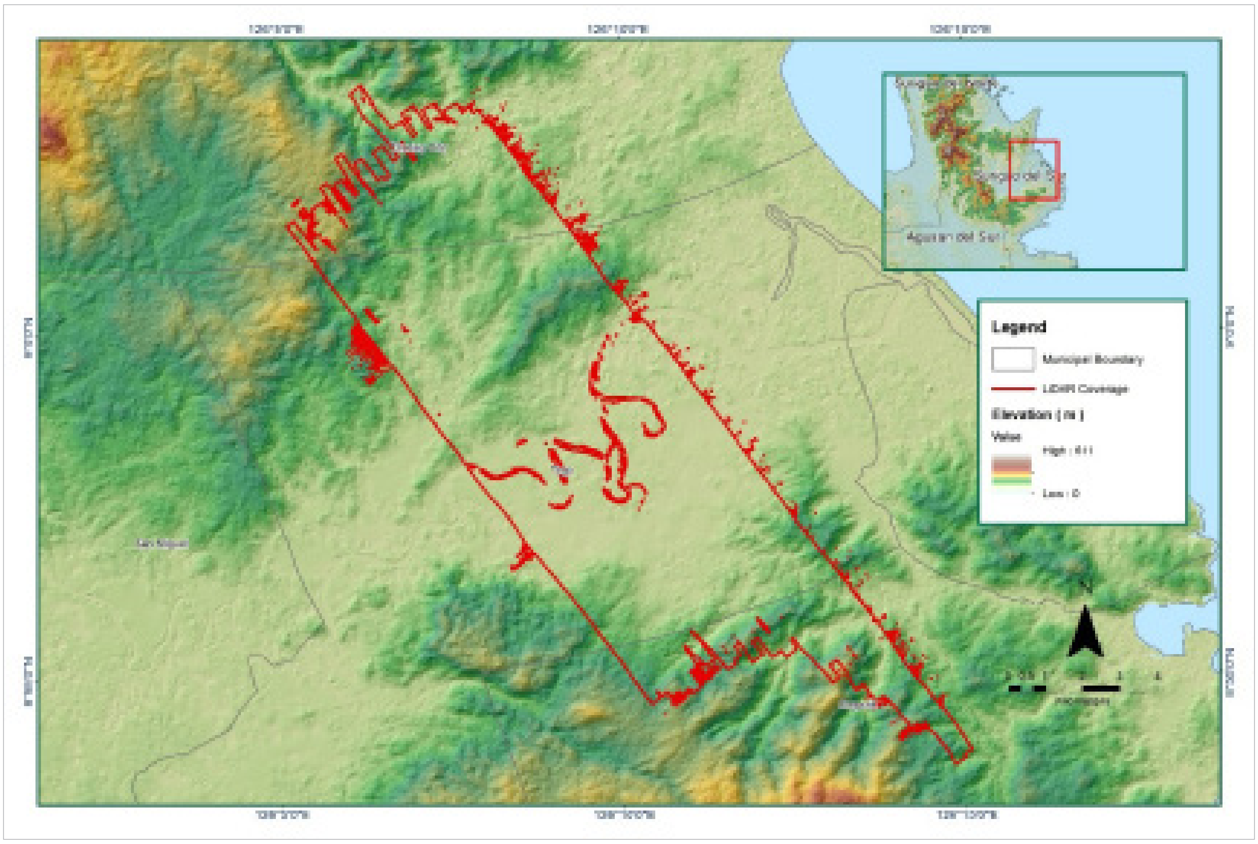


Figure 1.1.4 Coverage of LiDAR data

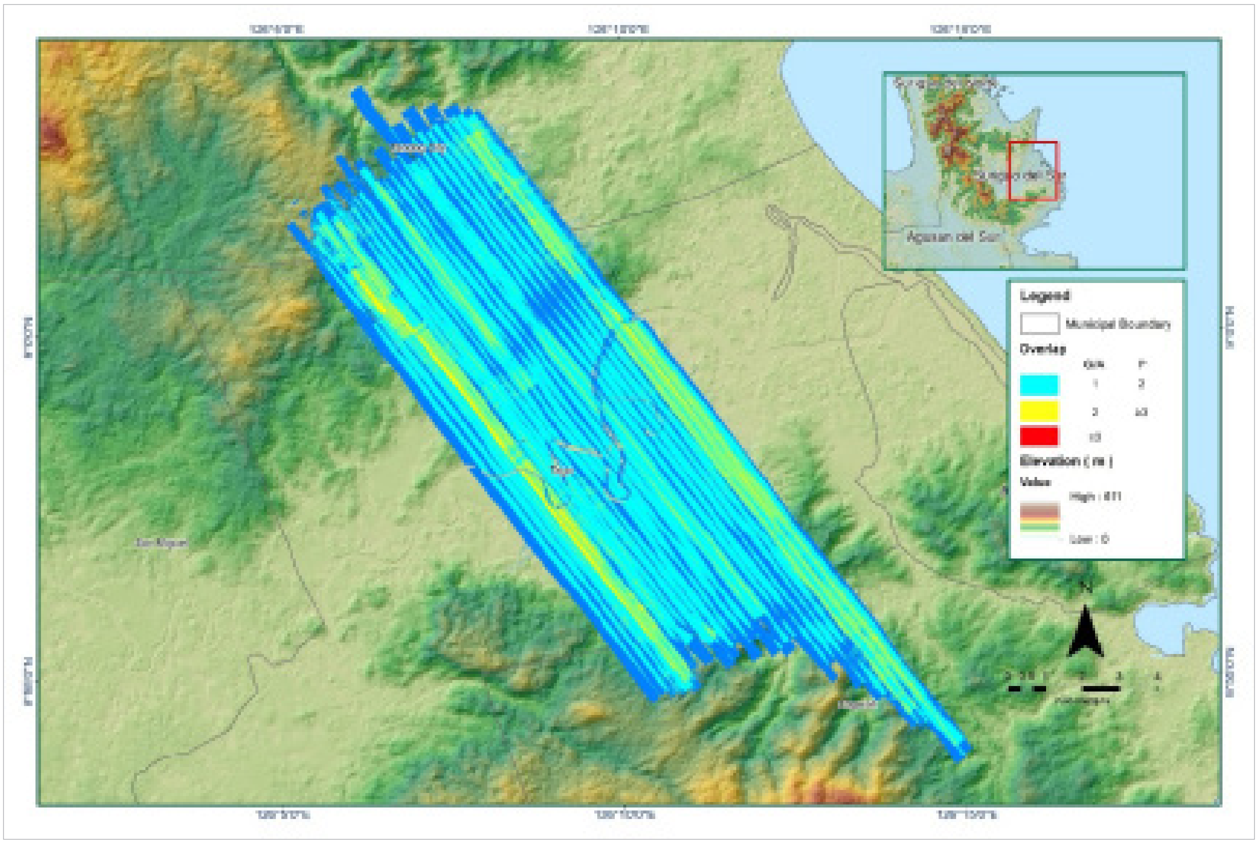


Figure 1.1.5 Image of data overlap

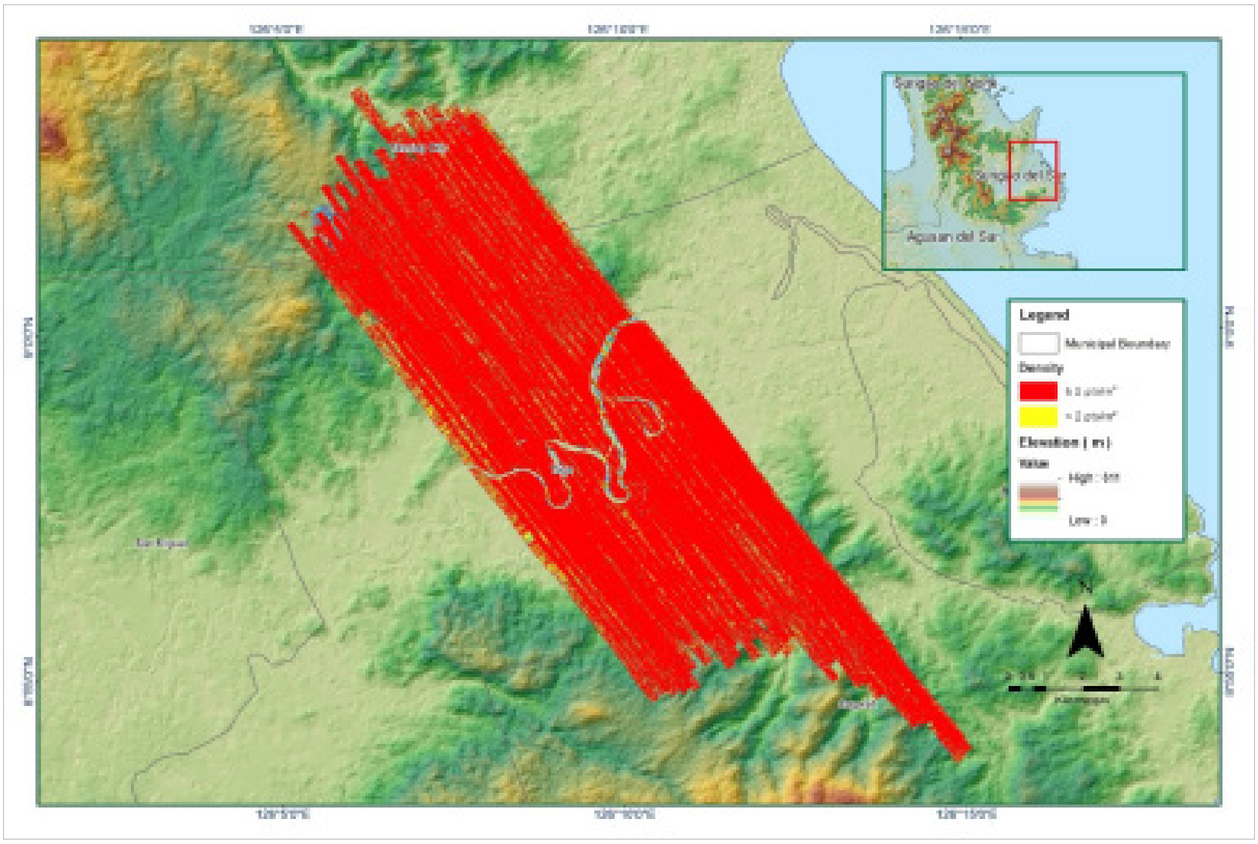


Figure 1.1.6 Density map of merged LiDAR data

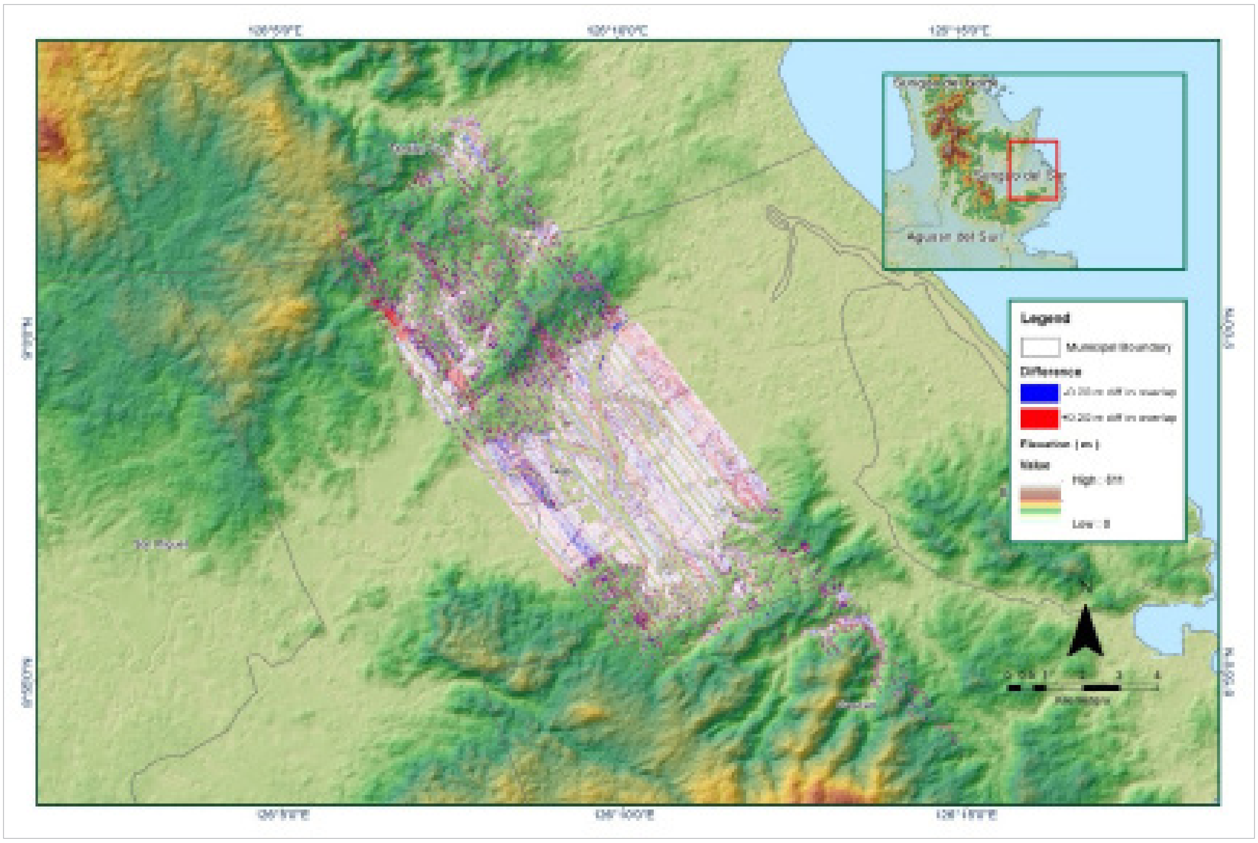


Figure 1.1.7 Elevation difference between flight lines

Flight Area	Tandag (Surigao Del SurSurigao del Sur)
Mission Name	Block 61B
Inclusive Flights	1670A
Range data size	13.00 GB
POS	241 MB
Base data size	8.58
Image	6.28 MB
Transfer date	July 23, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.50
RMSE for East Position (<4.0 cm)	3.10
RMSE for Down Position (<8.0 cm)	3.00
Boresight correction stdev (<0.001deg)	0.000449
IMU attitude correction stdev (<0.001deg)	0.001114
GPS position stdev (<0.01m)	0.0023
Minimum % overlap (>25)	56.75
Ave point cloud density per sq.m. (>2.0)	3.49
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	143
Maximum Height	527.31 m
Minimum Height	61.67 m
Classification (# of points)	
Ground	71,379,929
Low vegetation	49,277,234
Medium vegetation	45,969,458
High vegetation	118,976,653
Building	3,318,983
Orthophoto	YES
Processed by	Engr. Irish Cortez, Engr. Christy Lubiano, Engr. Melissa Fernandez

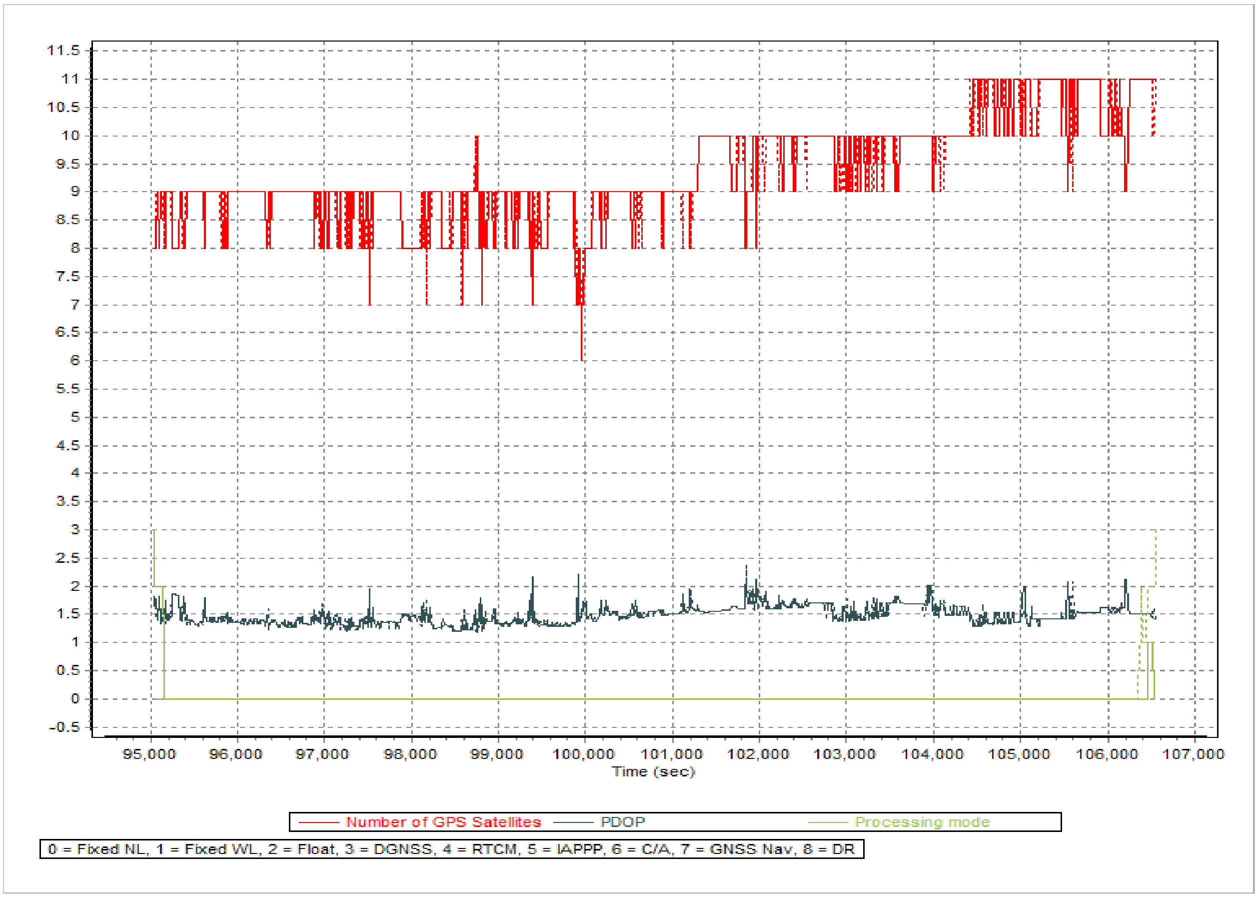


Figure 1.2.1 Solution Status

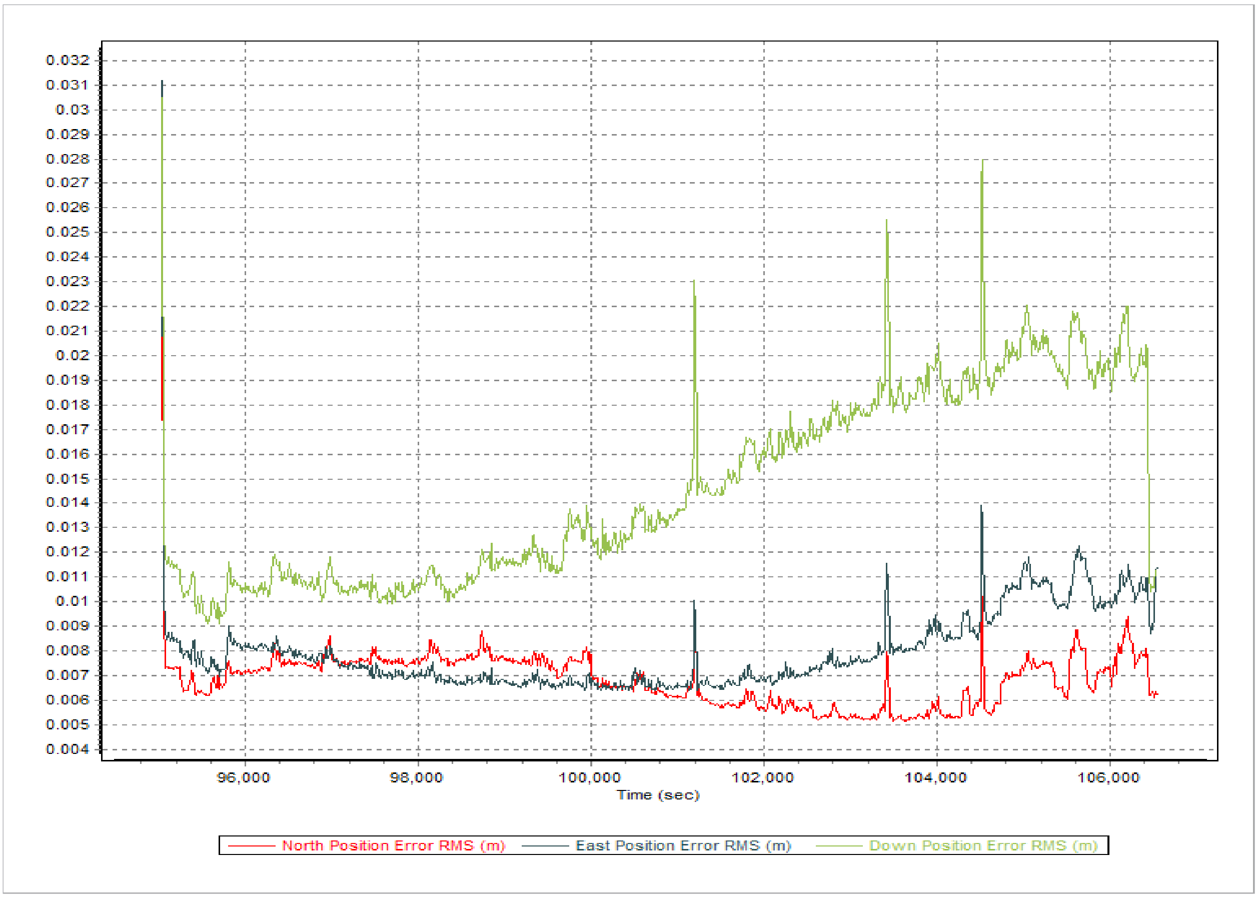


Figure 1.2.2 Smoothed Performance Metric Parameters

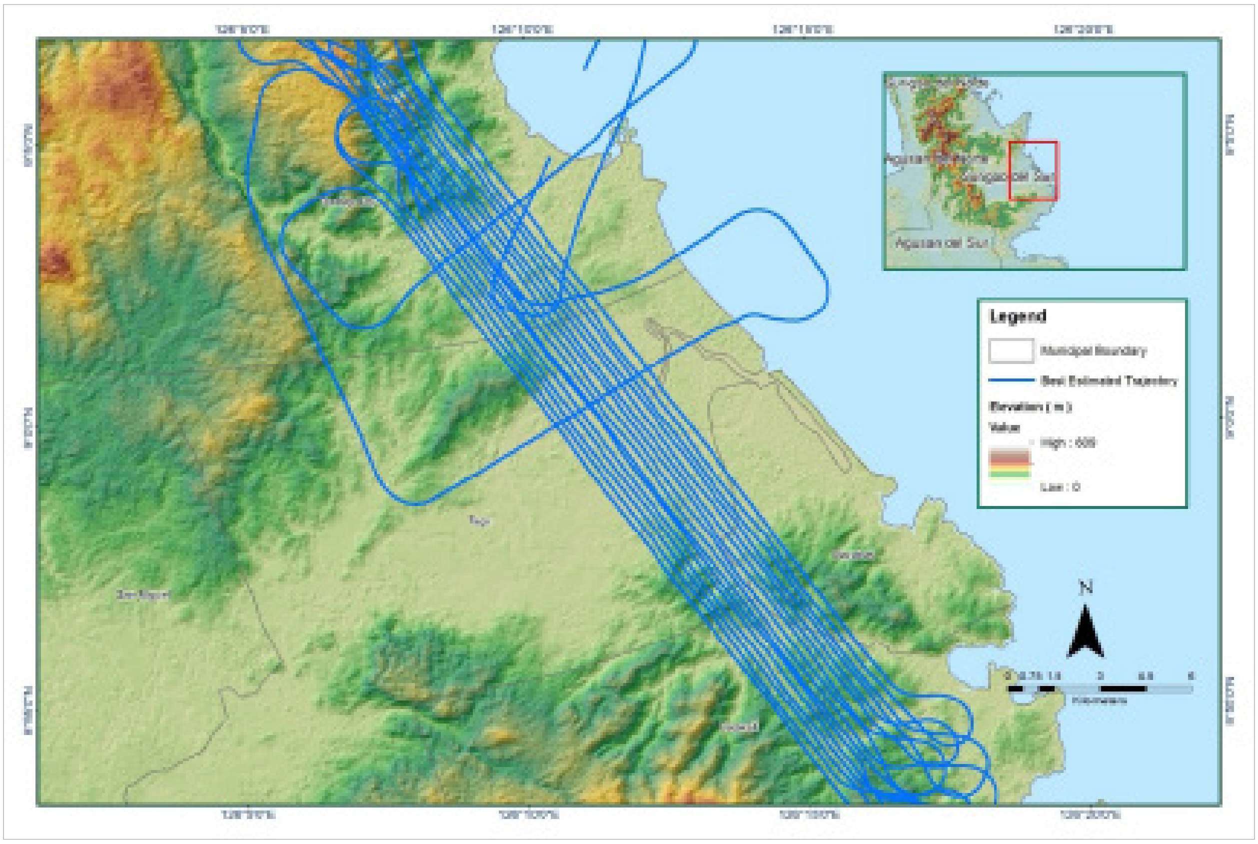


Figure 1.2.3 Best Estimated Trajectory

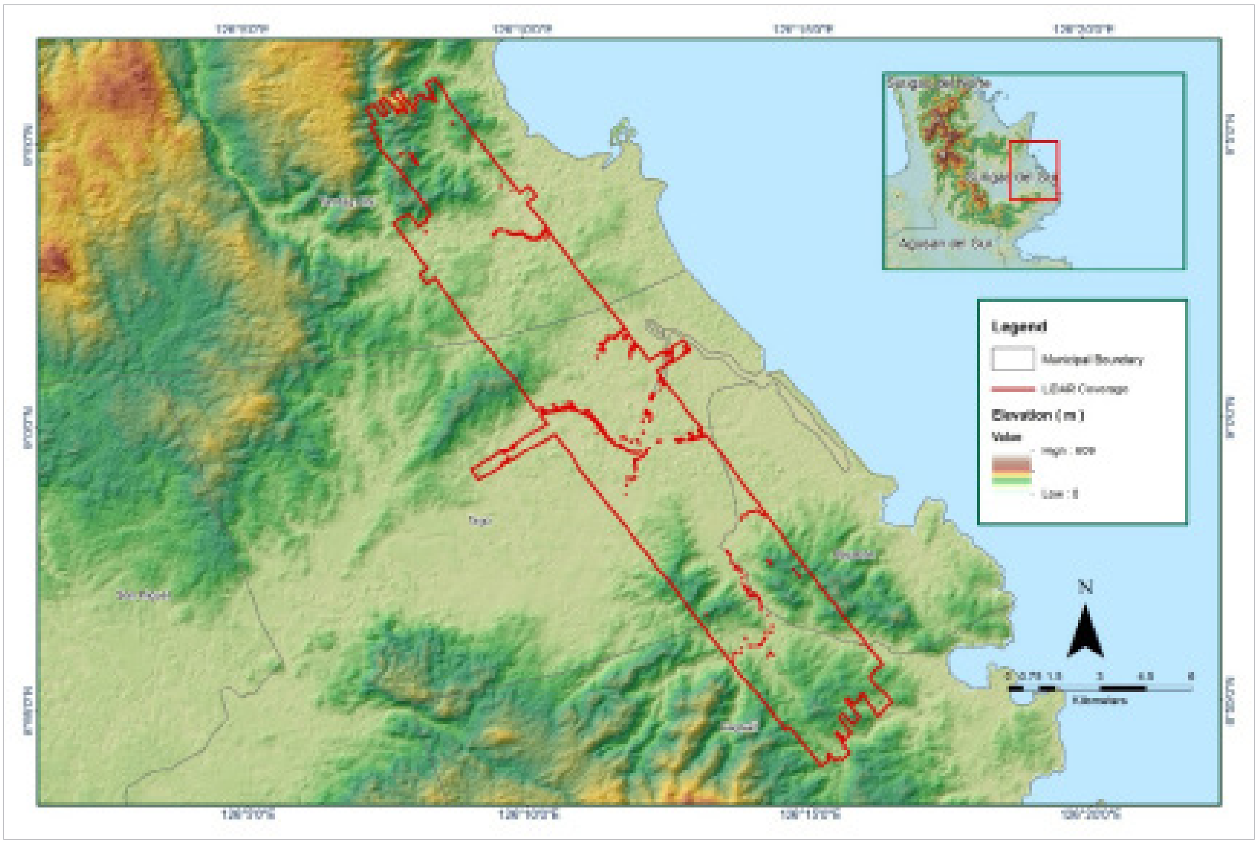


Figure 1.2.4 Coverage of LiDAR data

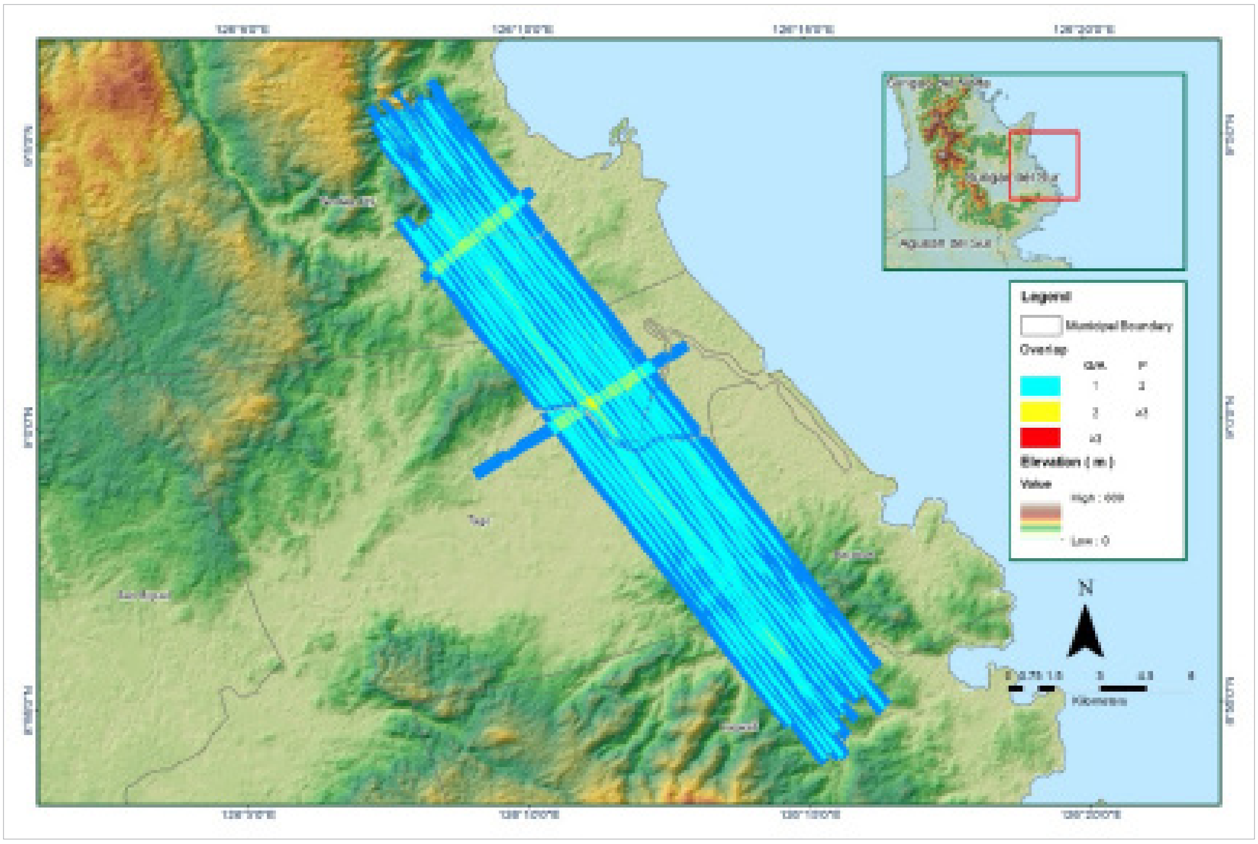


Figure 1.2.5 Image of data overlap

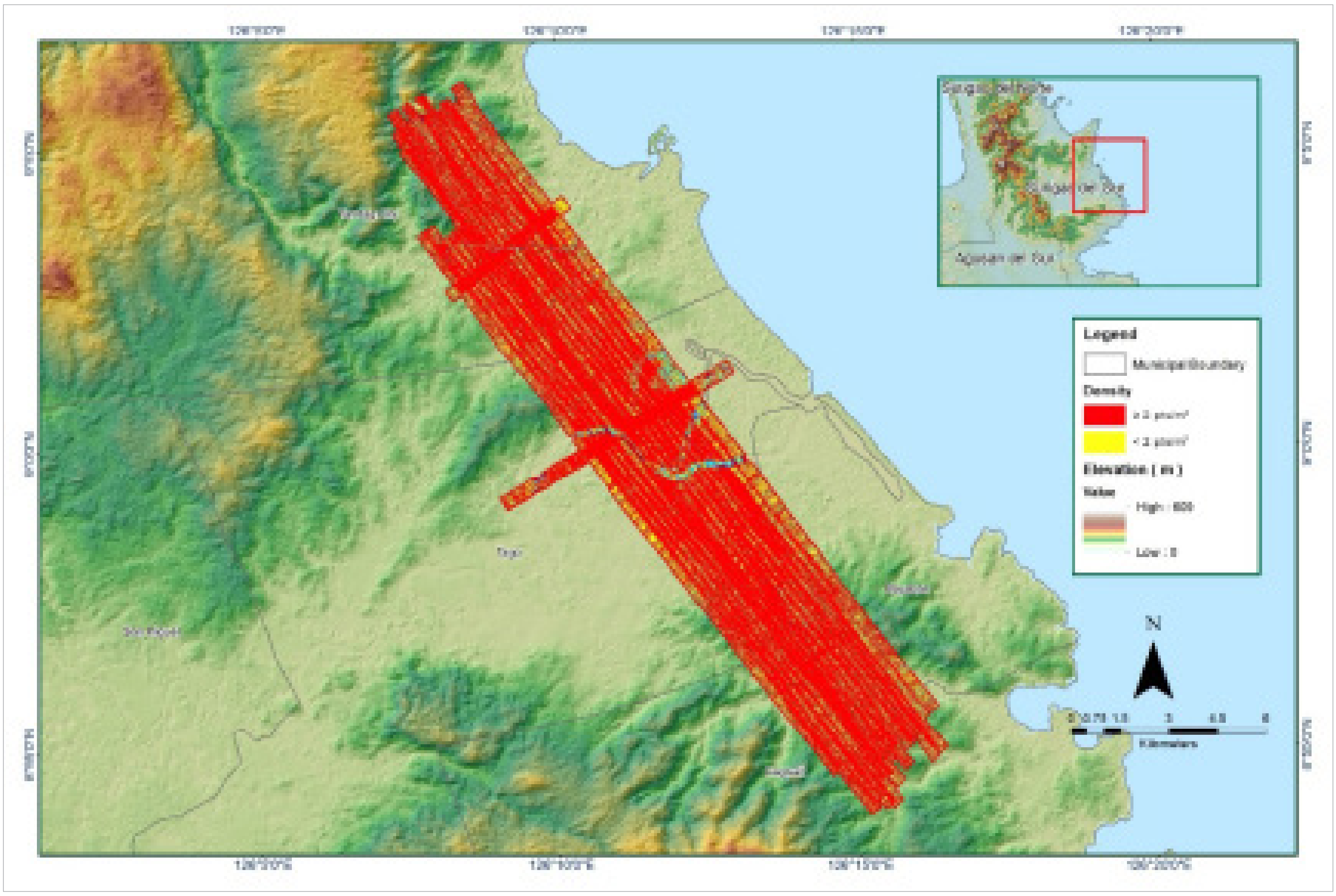


Figure 1.2.6 Density map of merged LiDAR data

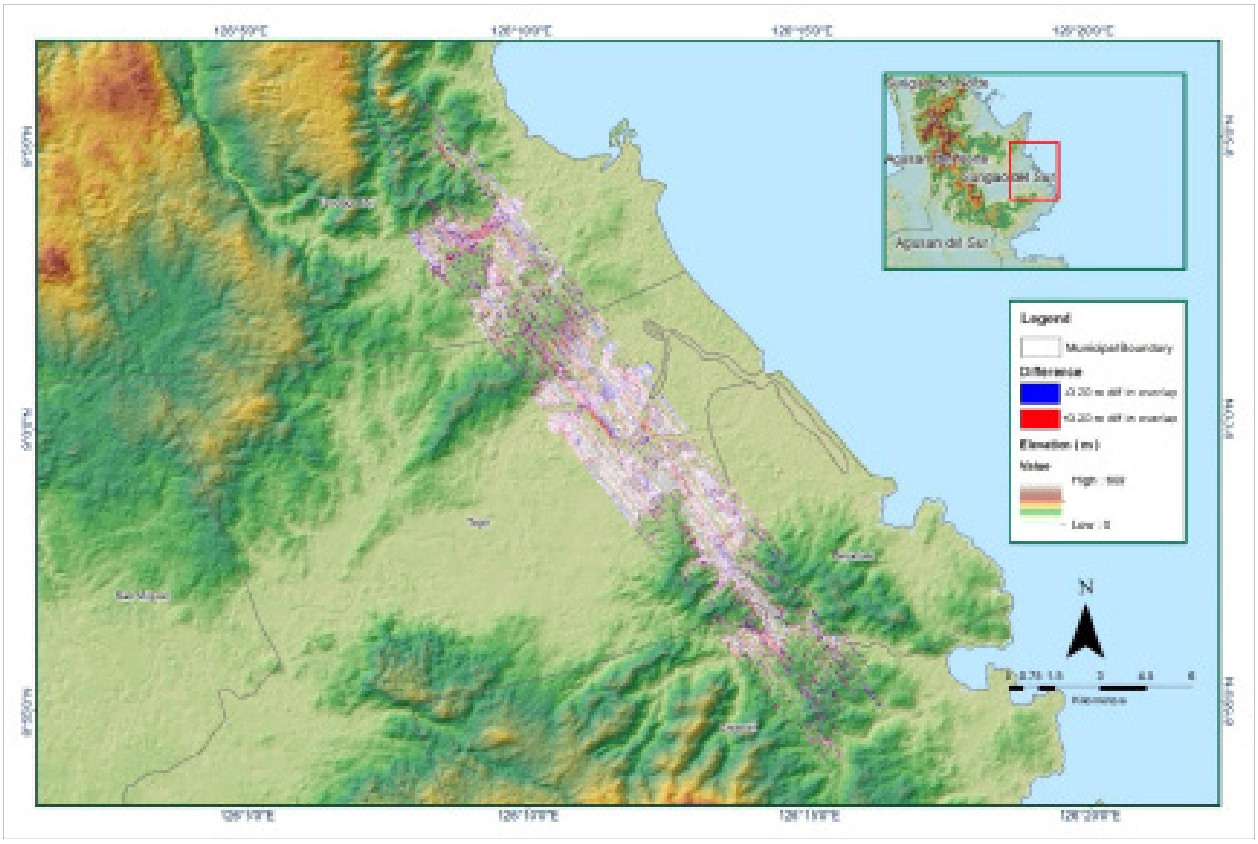


Figure 1.2.7 Elevation difference between flight lines

Flight Area	Tandag (Surigao Del SurSurigao del Sur)
Mission Name	Block 61A
Inclusive Flights	1664A & 1666A
Range data size	17.19 GB
POS	336 MB
Base data size	16.27
Image	74.80 MB
Transfer date	July 23, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	6.00
RMSE for East Position (<4.0 cm)	5.00
RMSE for Down Position (<8.0 cm)	10.50
Boresight correction stdev (<0.001deg)	0.000668
IMU attitude correction stdev (<0.001deg)	0.012522
GPS position stdev (<0.01m)	0.0190
Minimum % overlap (>25)	47.47
Ave point cloud density per sq.m. (>2.0)	4.01
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	152
Maximum Height	391.02 m
Minimum Height	55.44 m
Classification (# of points)	
Ground	41,603,699
Low vegetation	52,174,302
Medium vegetation	70,177,534
High vegetation	113,371,103
Building	4,387,894
Orthophoto	YES
Processed by	Engr. Analyn Naldo, Engr. Chelou Prado, Engr. Jeffrey Delica

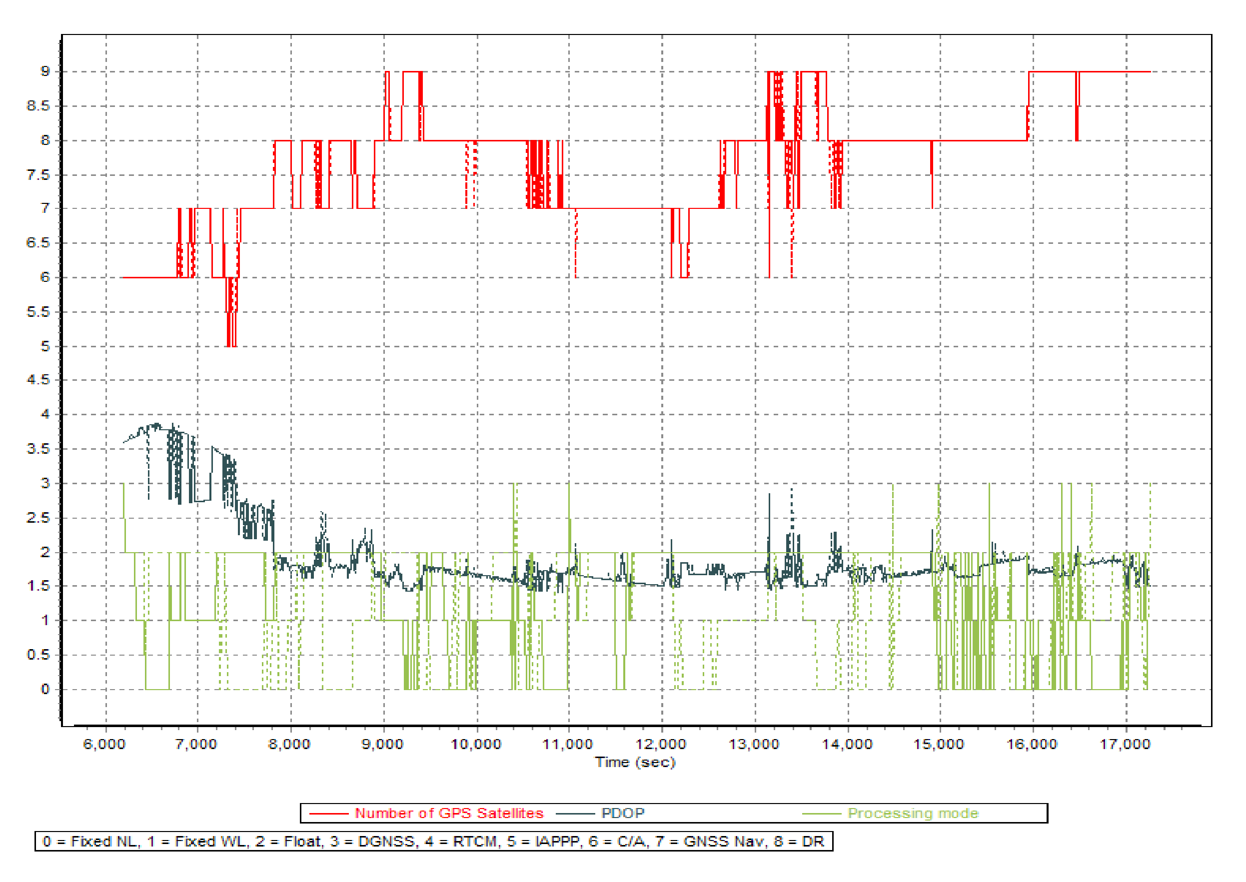


Figure 1.3.1 Solution Status

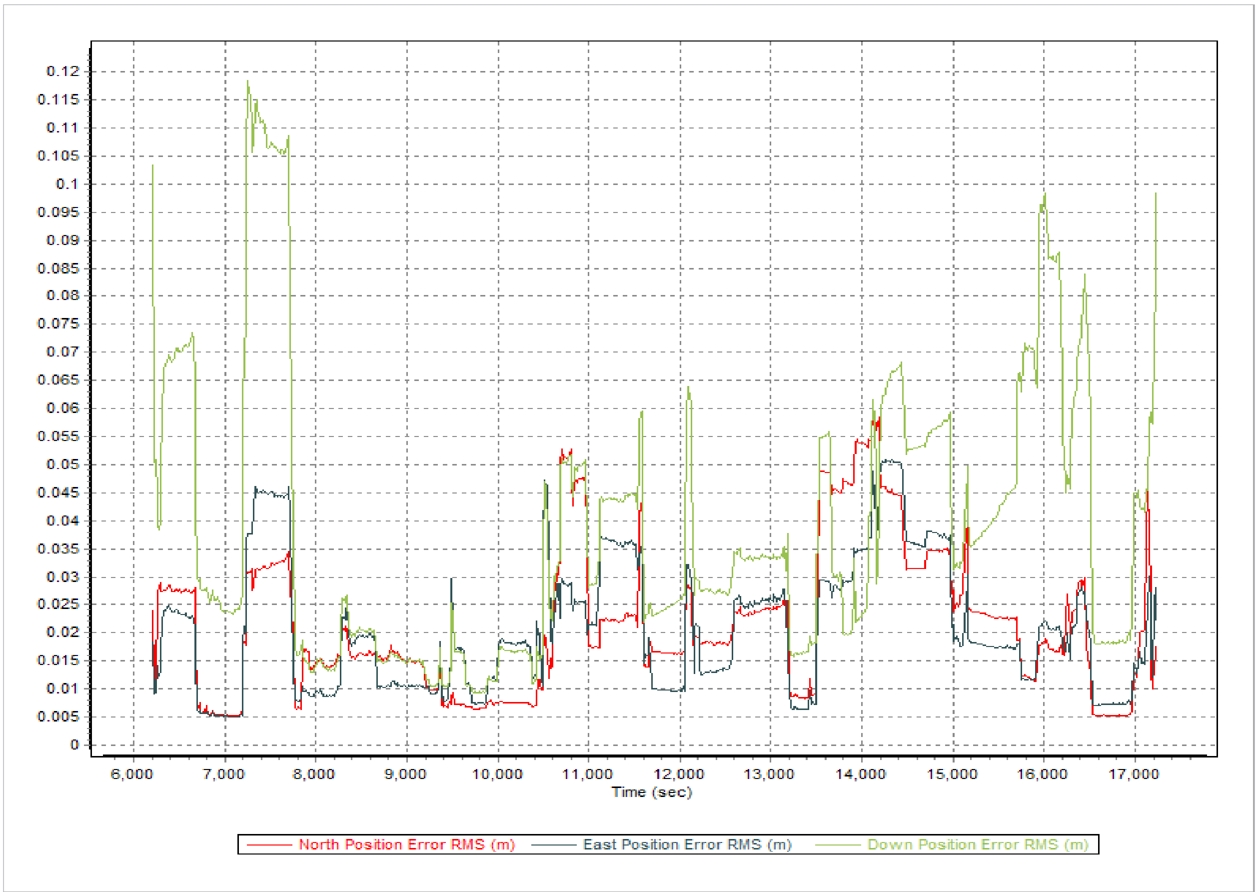


Figure 1.3.2 Smoothed Performance Metric Parameters

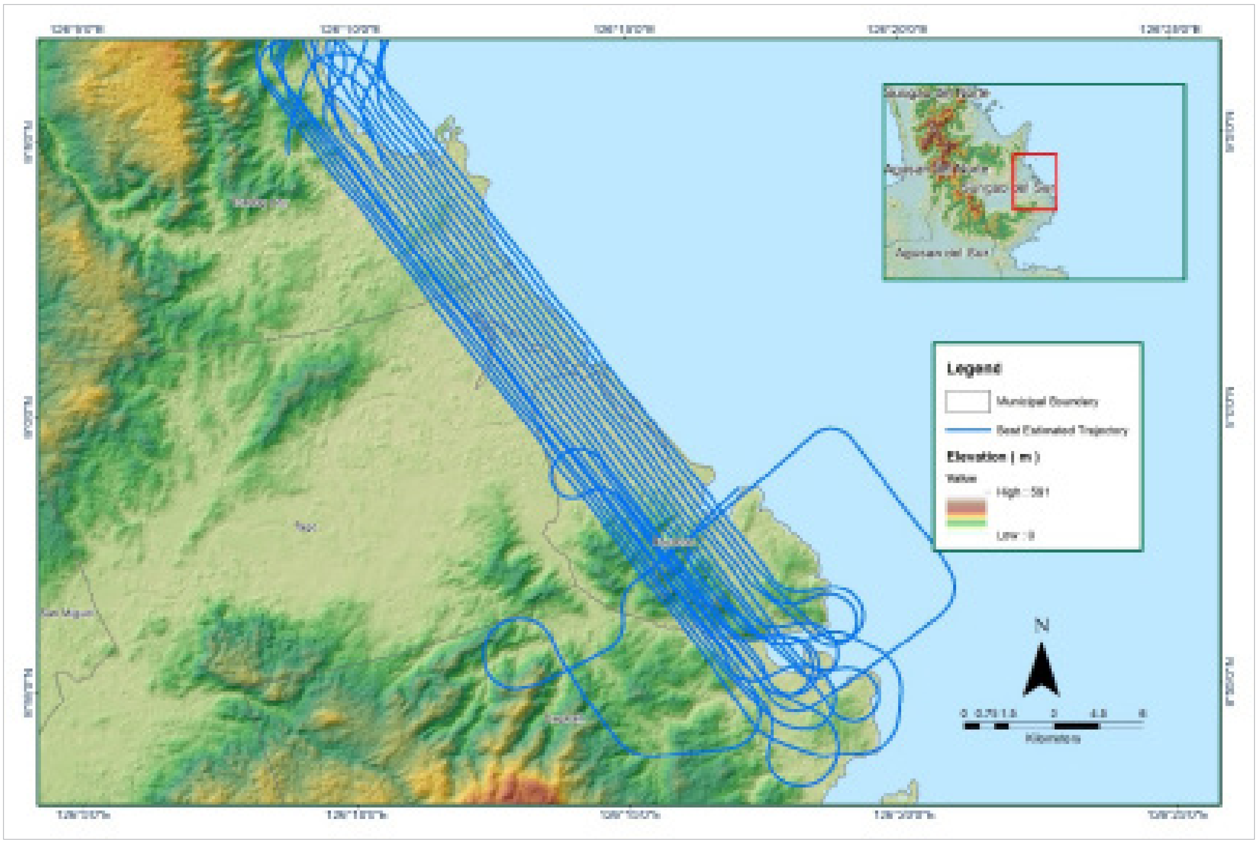


Figure 1.3.3 Best Estimated Trajectory

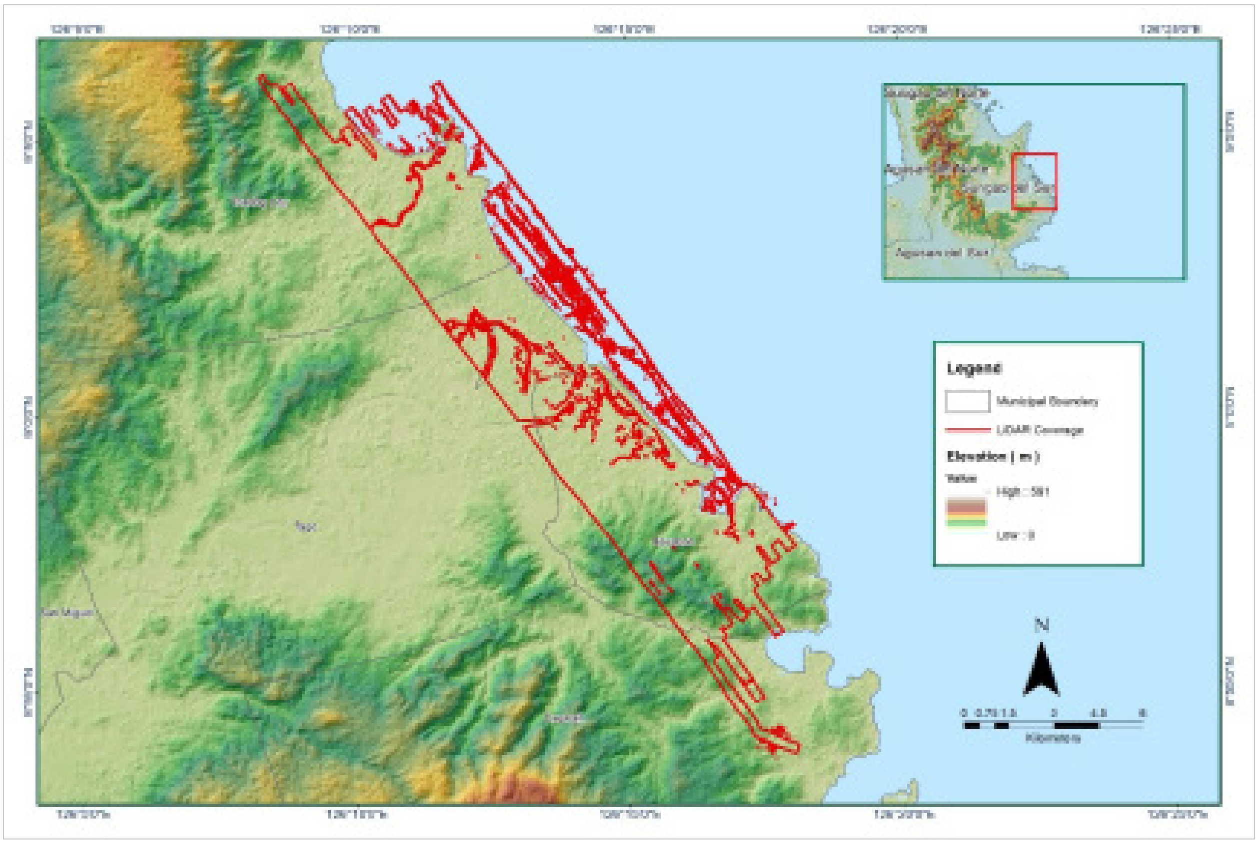


Figure 1.3.4 Coverage of LiDAR data

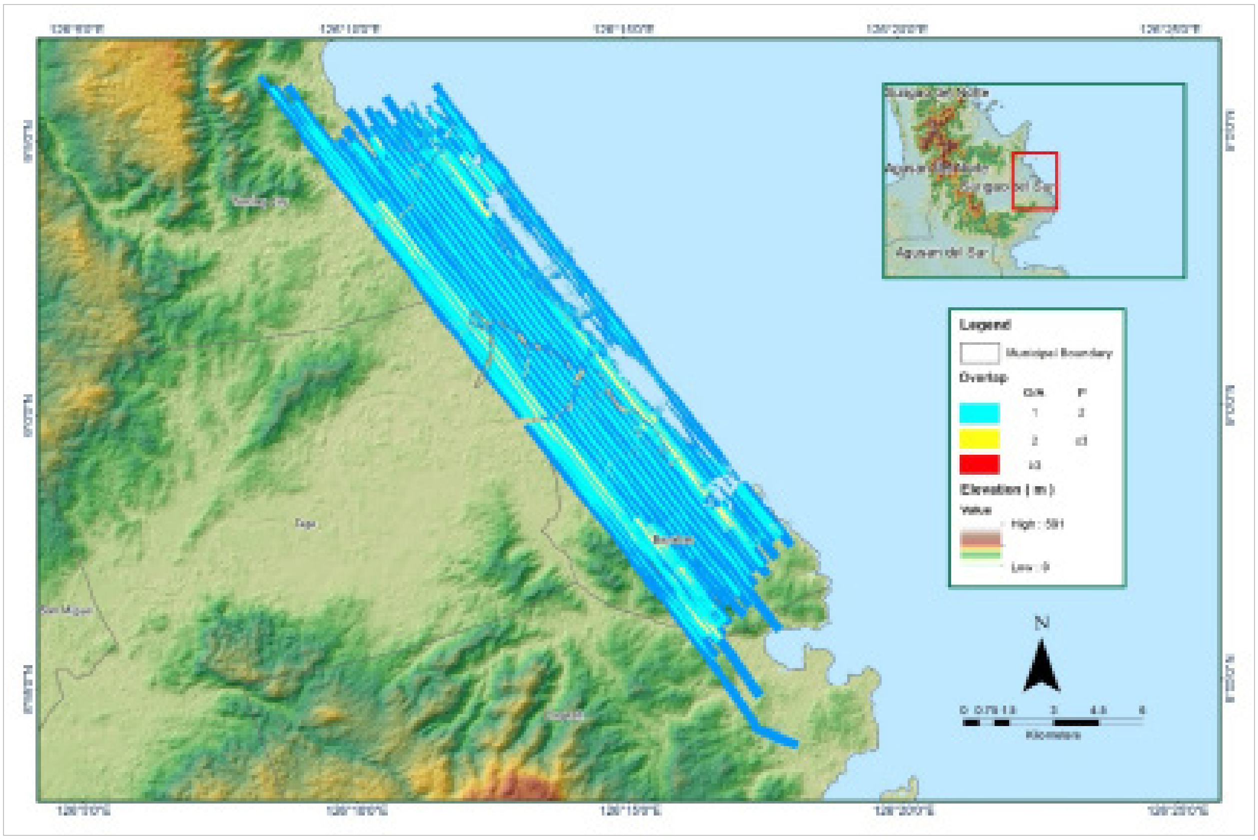


Figure 1.3.5 Image of data overlap

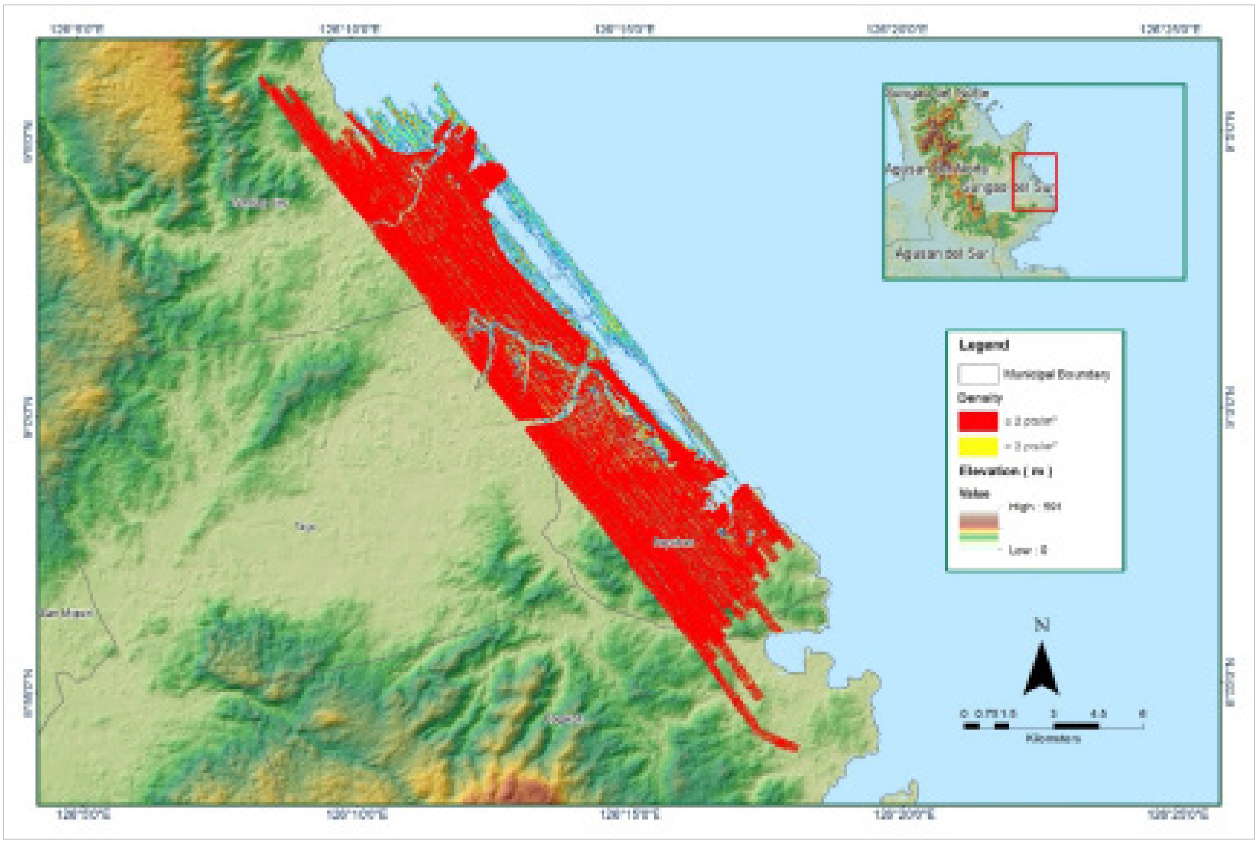


Figure 1.3.6 Density map of merged LiDAR data

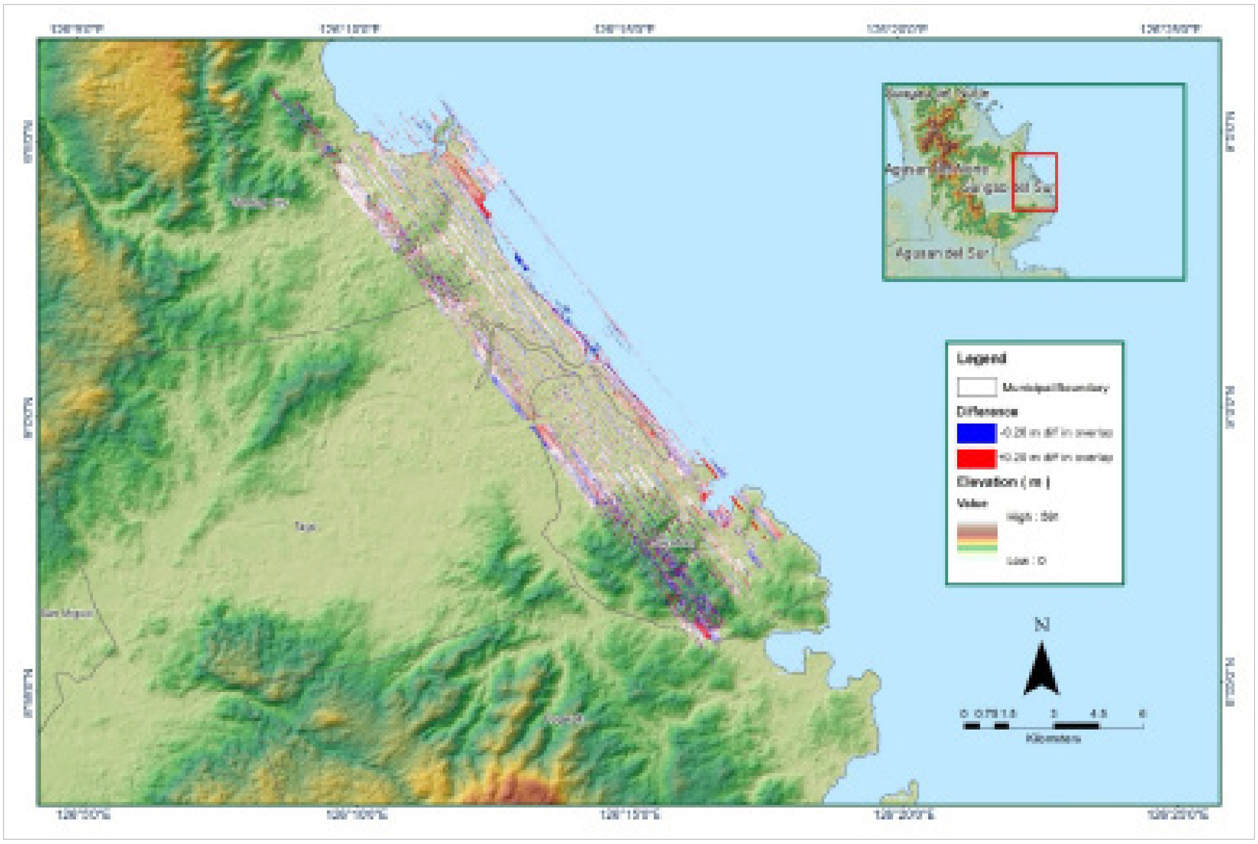


Figure 1.3.7 Elevation difference between flight lines

Flight Area	Tandag (Surigao Del SurSurigao del Sur)
Mission Name	Block 61N
Inclusive Flights	1758A, 1762A & 1766A
Range data size	34.25 GB
POS	712 MB
Base data size	34.11
Image	166.80 MB
Transfer date	August 14, 2014 & September 1, 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)	2.10
RMSE for East Position (<4.0 cm)	2.25
RMSE for Down Position (<8.0 cm)	3.20
Boresight correction stdev (<0.001deg)	0.000322
IMU attitude correction stdev (<0.001deg)	0.007229
GPS position stdev (<0.01m)	0.0142
Minimum % overlap (>25)	59.67
Ave point cloud density per sq.m. (>2.0)	4.30
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	176
Maximum Height	603.04 m
Minimum Height	68.14 m
Classification (# of points)	
Ground	90,724,477
Low vegetation	90,541,962
Medium vegetation	159,165,712
High vegetation	272,112,461
Building	13,596,437
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Engr. Harmond Santos, Engr. Elainne Lopez, Engr. Czarina Añonuevo

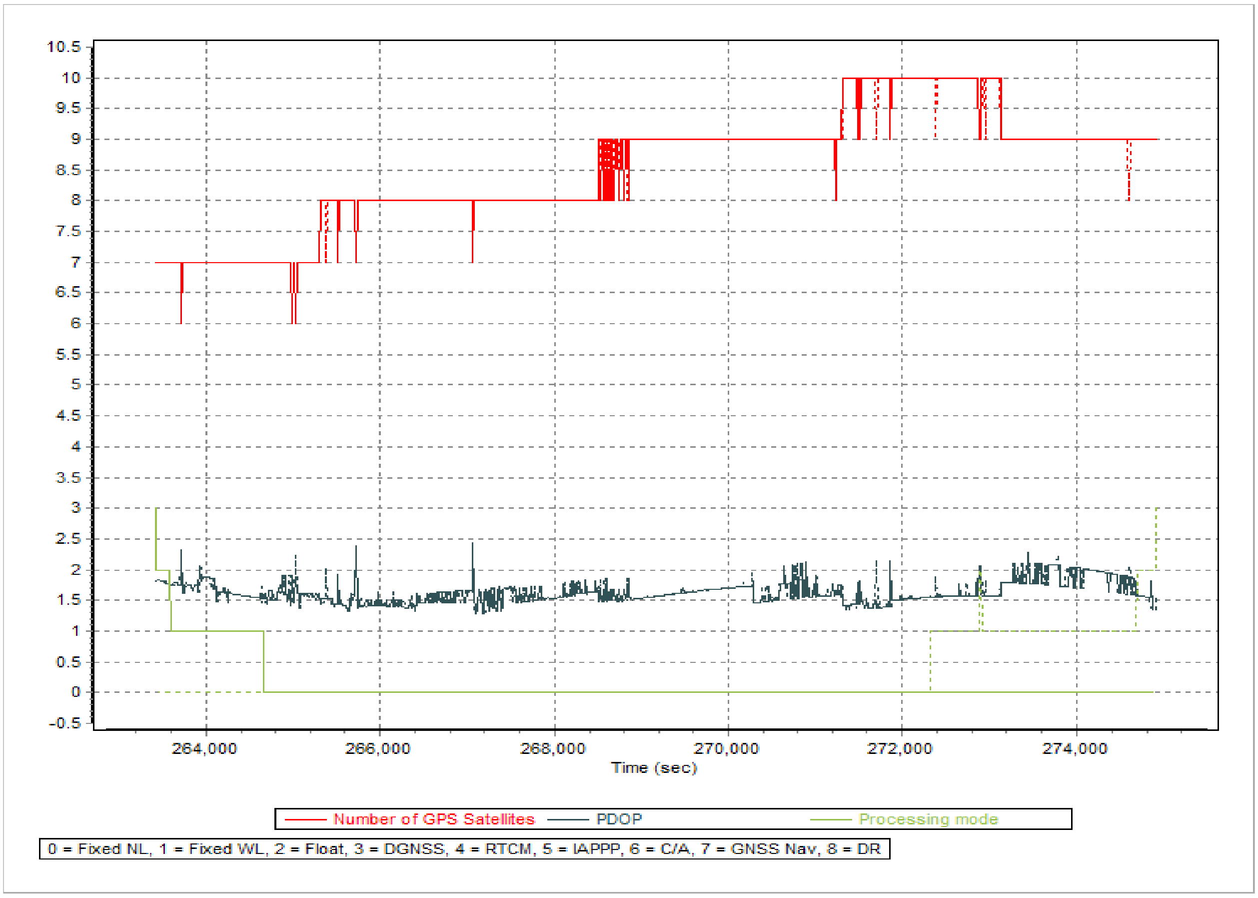


Figure 1.4.1 Solution Status

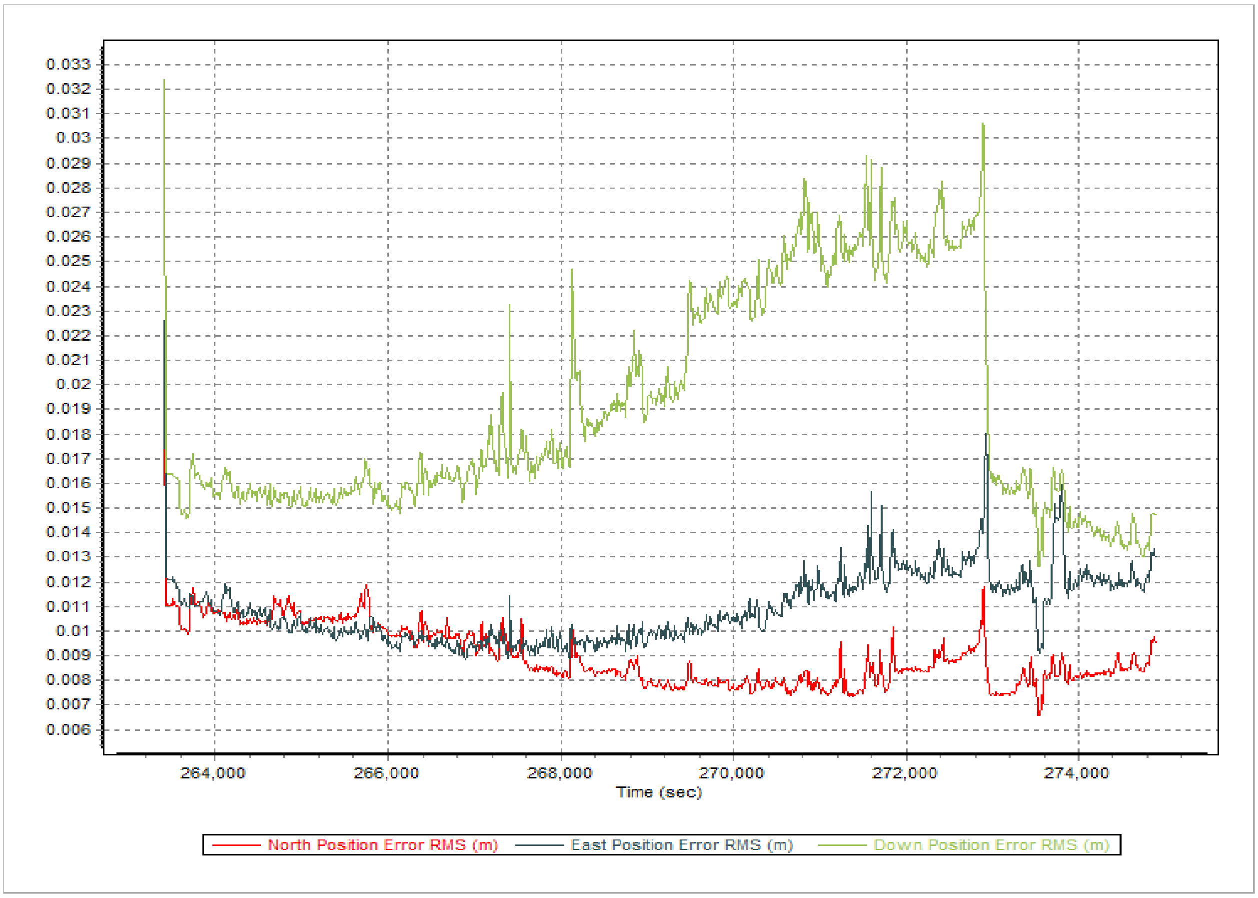


Figure 1.4.2 Smoothed Performance Metric Parameters

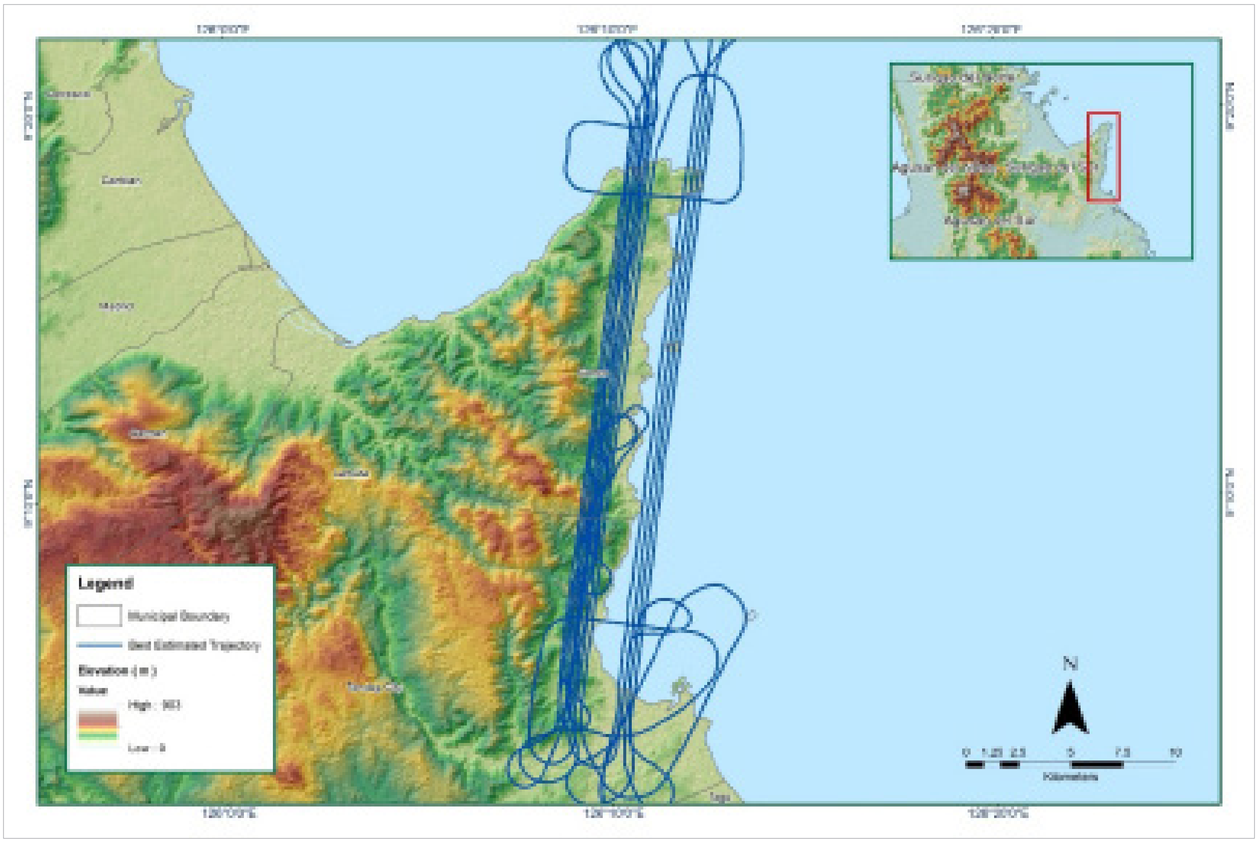


Figure 1.4.3 Best Estimated Trajectory

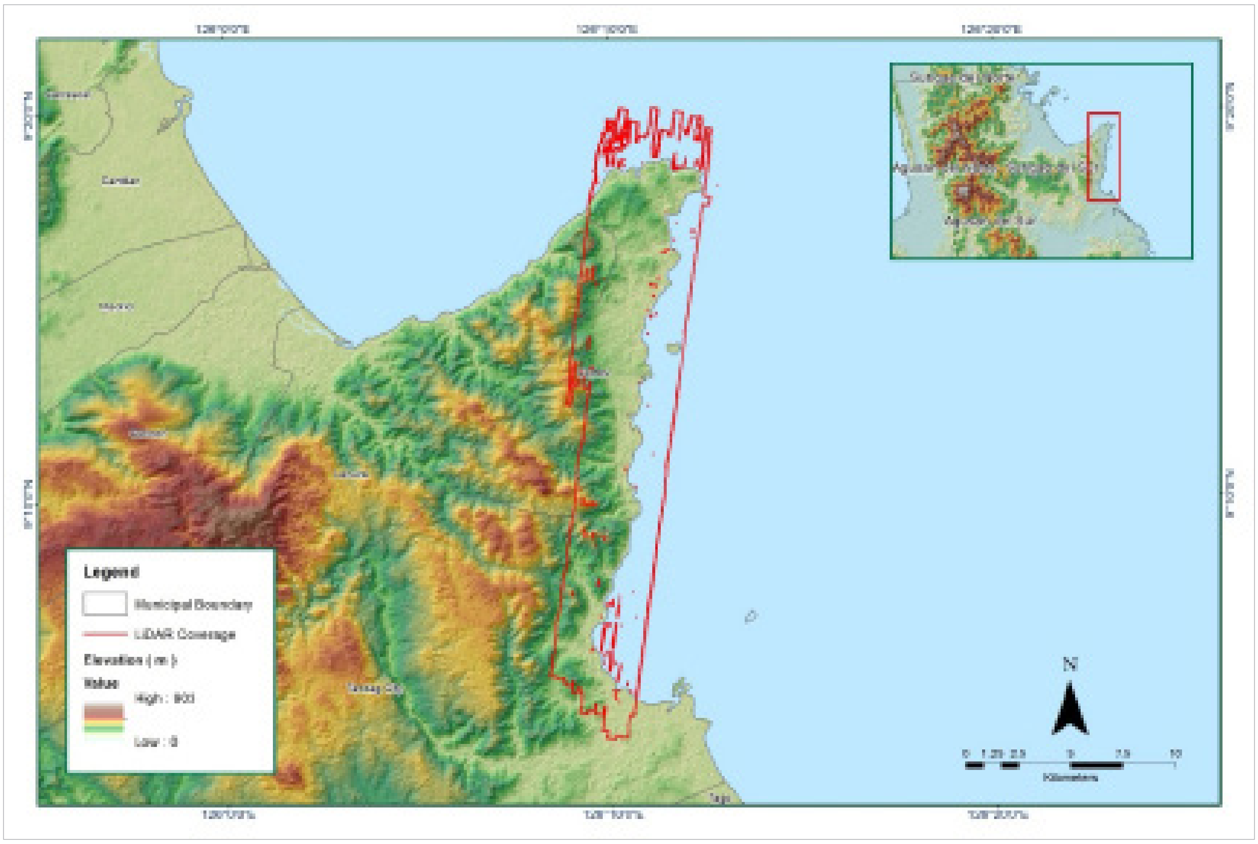


Figure 1.4.4 Coverage of LiDAR data

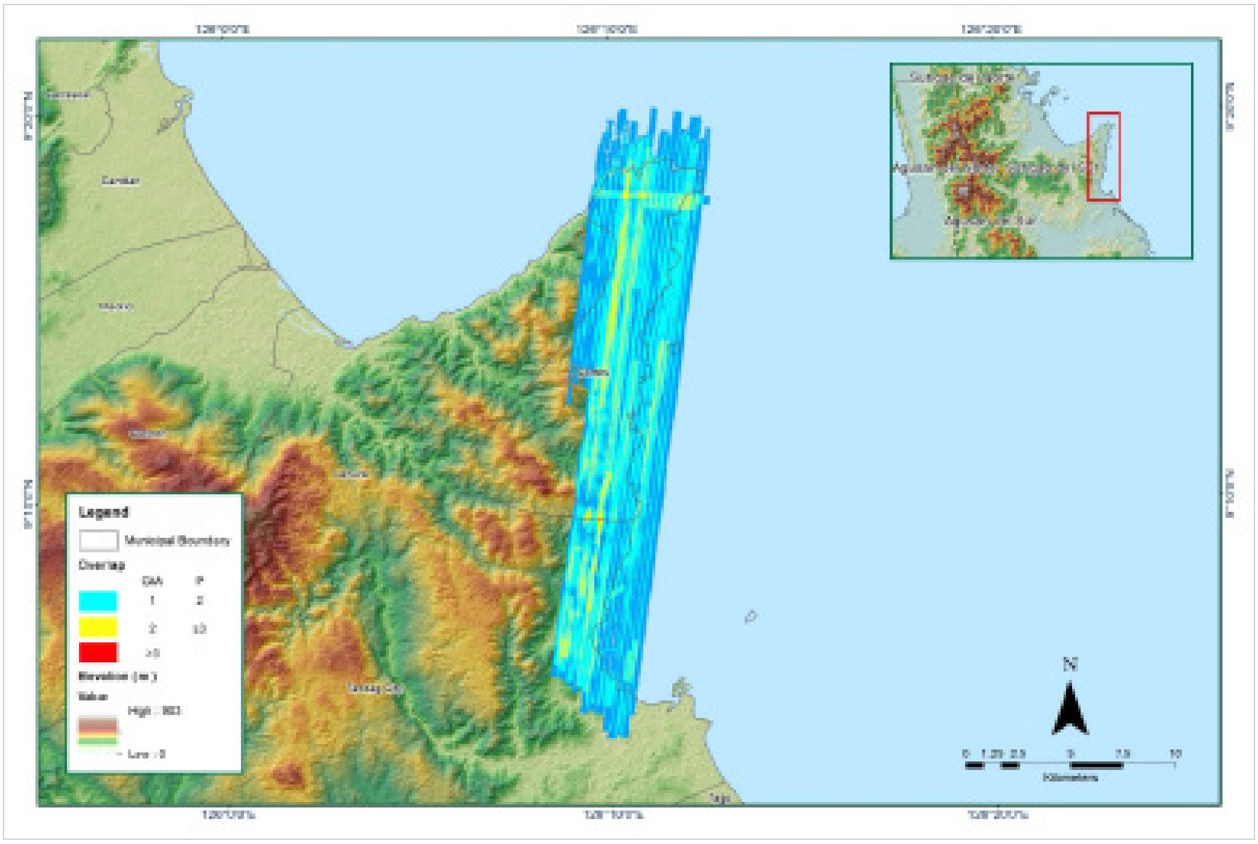


Figure 1.4.5 Image of data overlap

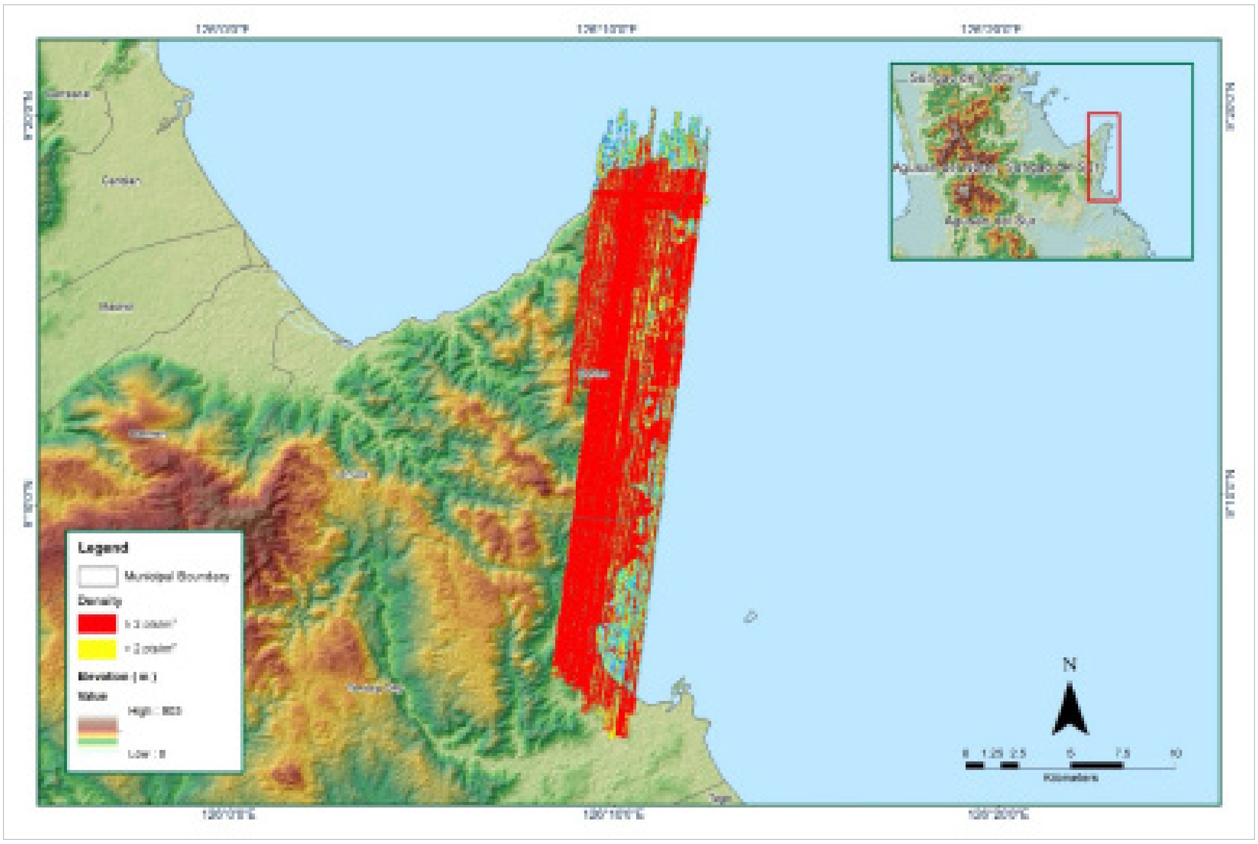


Figure 1.4.6 Density map of merged LiDAR data

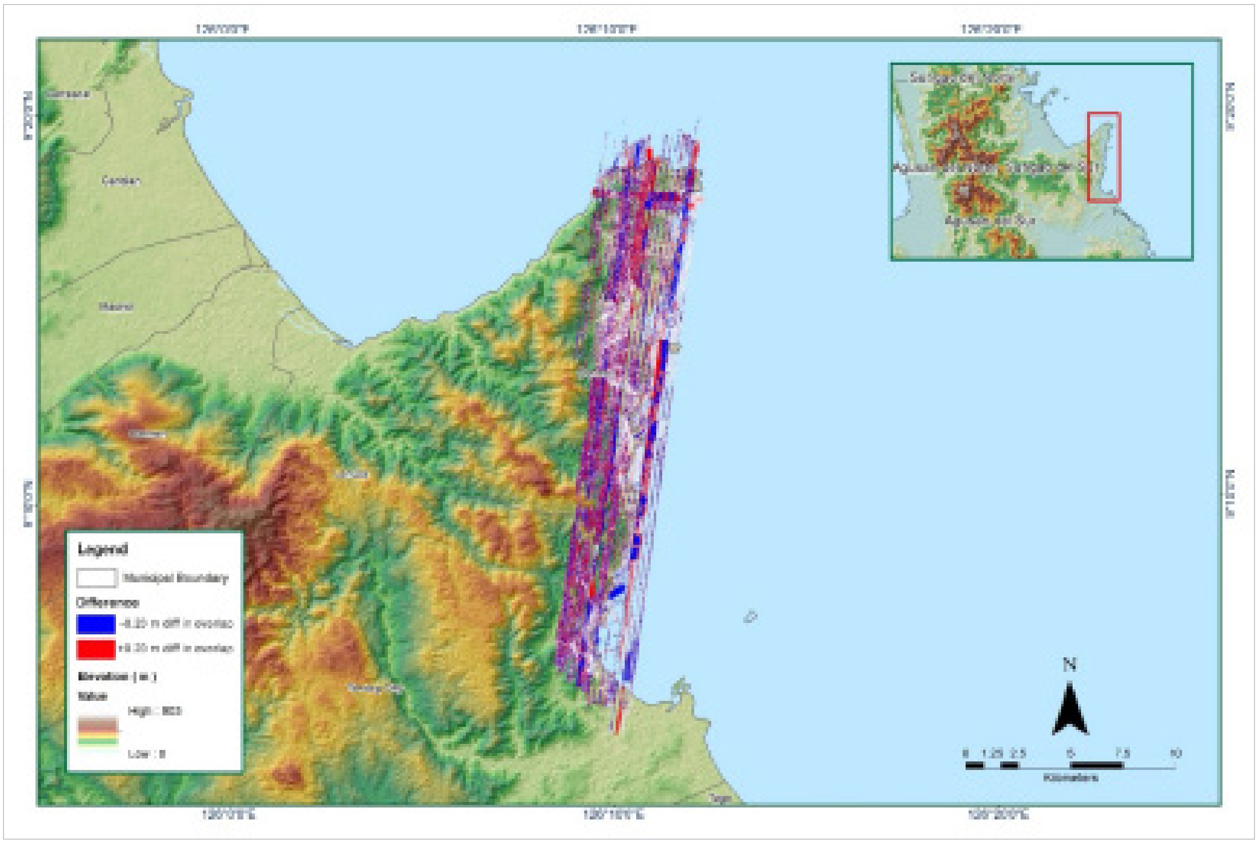


Figure 1.4.7 Elevation difference between flight lines

Flight Area	Tandag
Mission Name	Blk61B
Inclusive Flights	23608P
Range data size	5.39 GB
Base data size	369 MB
POS	114 MB
Image	NA
Transfer date	January 3, 2017
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.74
RMSE for East Position (<4.0 cm)	1.57
RMSE for Down Position (<8.0 cm)	2.3
Boresight correction stdev (<0.001deg)	0.001805
IMU attitude correction stdev (<0.001deg)	0.008304
GPS position stdev (<0.01m)	0.0188
Minimum % overlap (>25)	13.08
Ave point cloud density per sq.m. (>2.0)	2.48
Elevation difference between strips (<0.20 m)	YES
Number of 1km x 1km blocks	82
Maximum Height	359.17 m
Minimum Height	55.59 m
Classification (# of points)	
Ground	39,289,646
Low vegetation	15,975,656
Medium vegetation	20,509,343
High vegetation	83,429,502
Building	846,925
Ortophoto	No
Processed by	Engr. Jennifer Saguran, Engr. Harmond Santos, Engr. Gladys Mae Apat

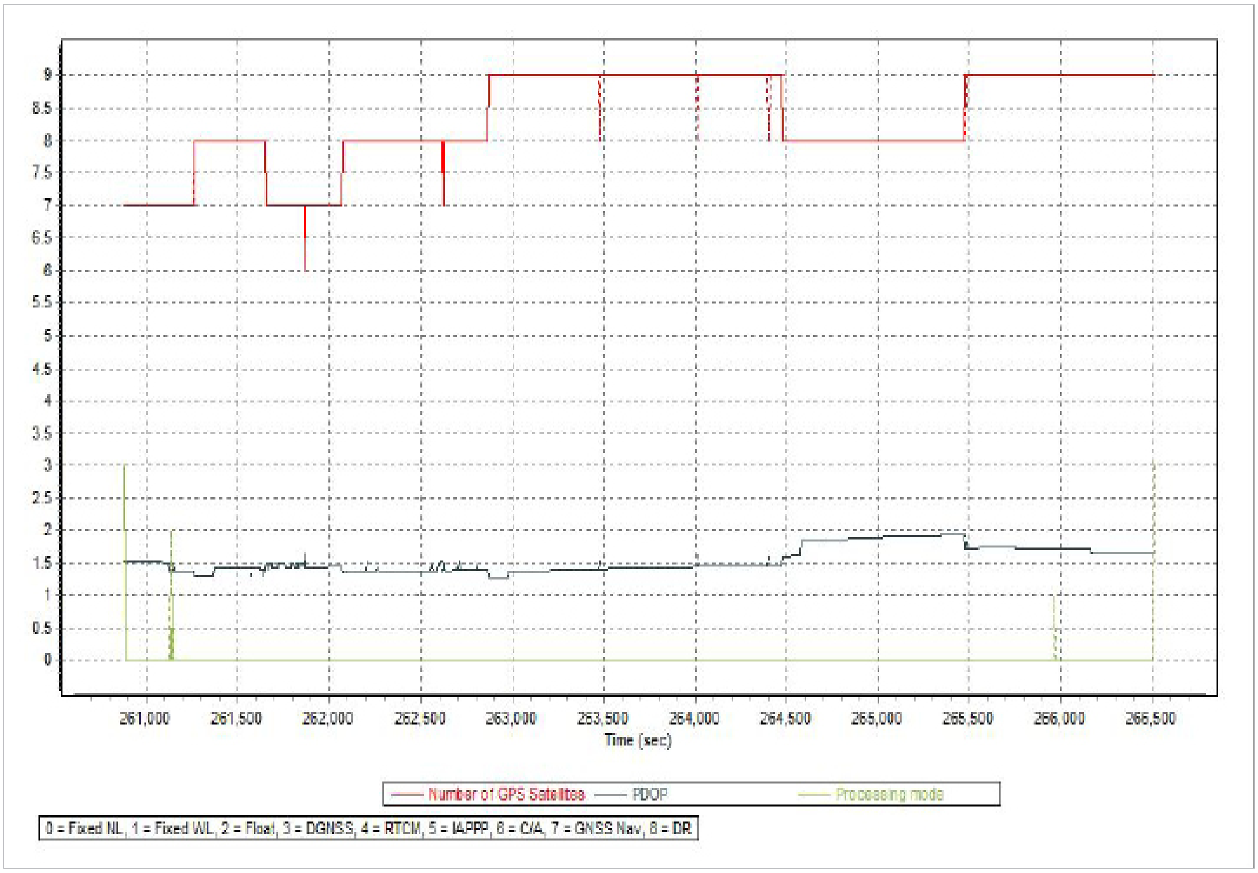


Figure 1.5.1. Solution Status

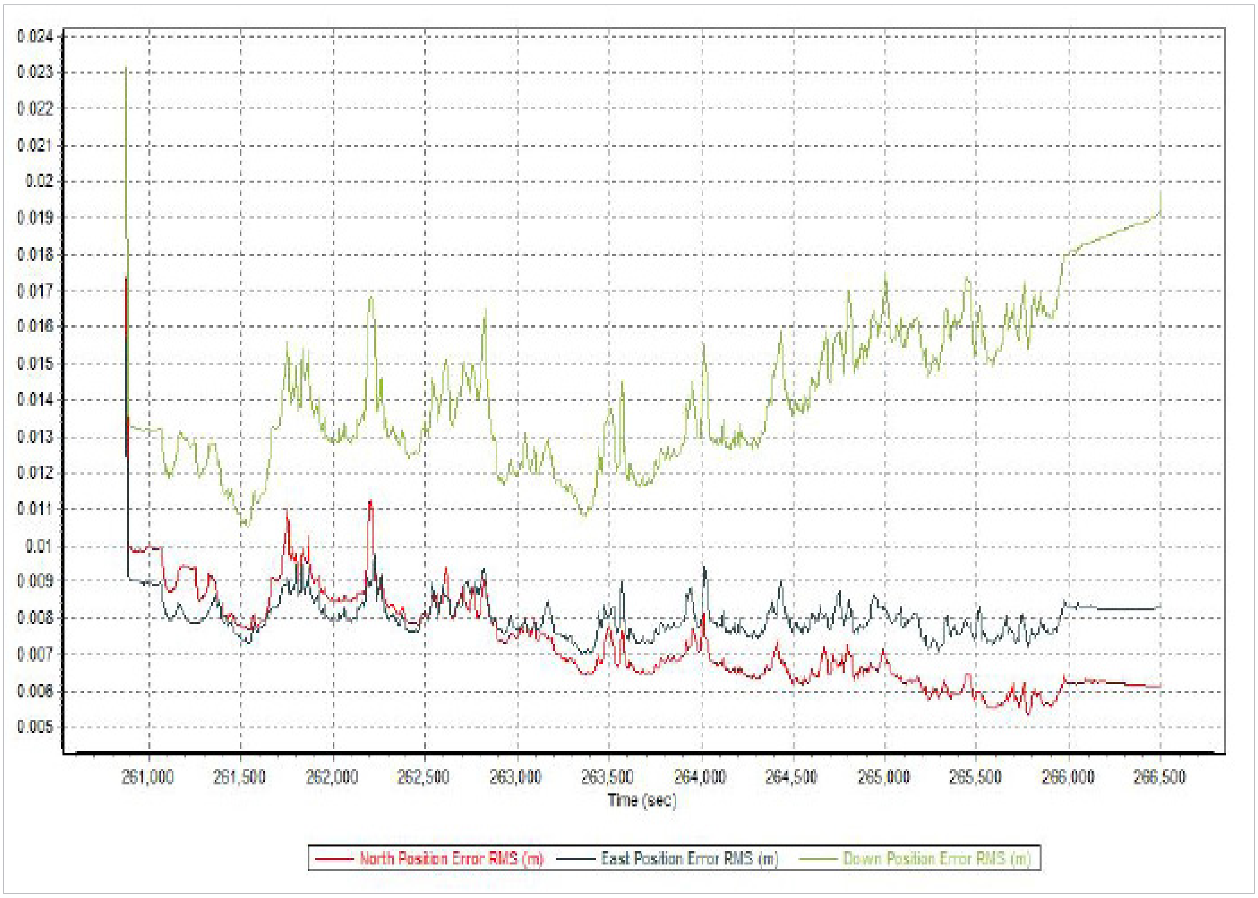


Figure 1.5.2. Smoothed Performance Metric Parameters

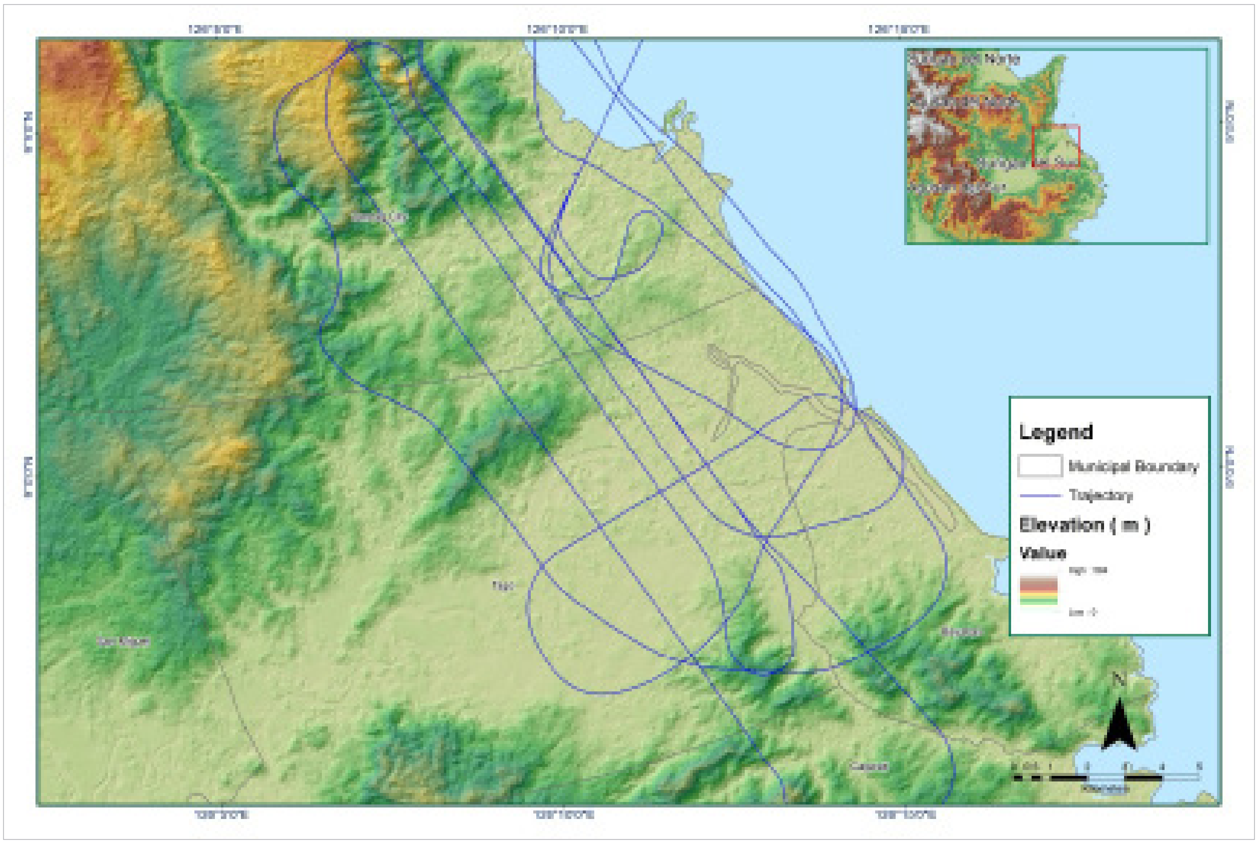


Figure 1.5.3 Best Estimated Trajectory

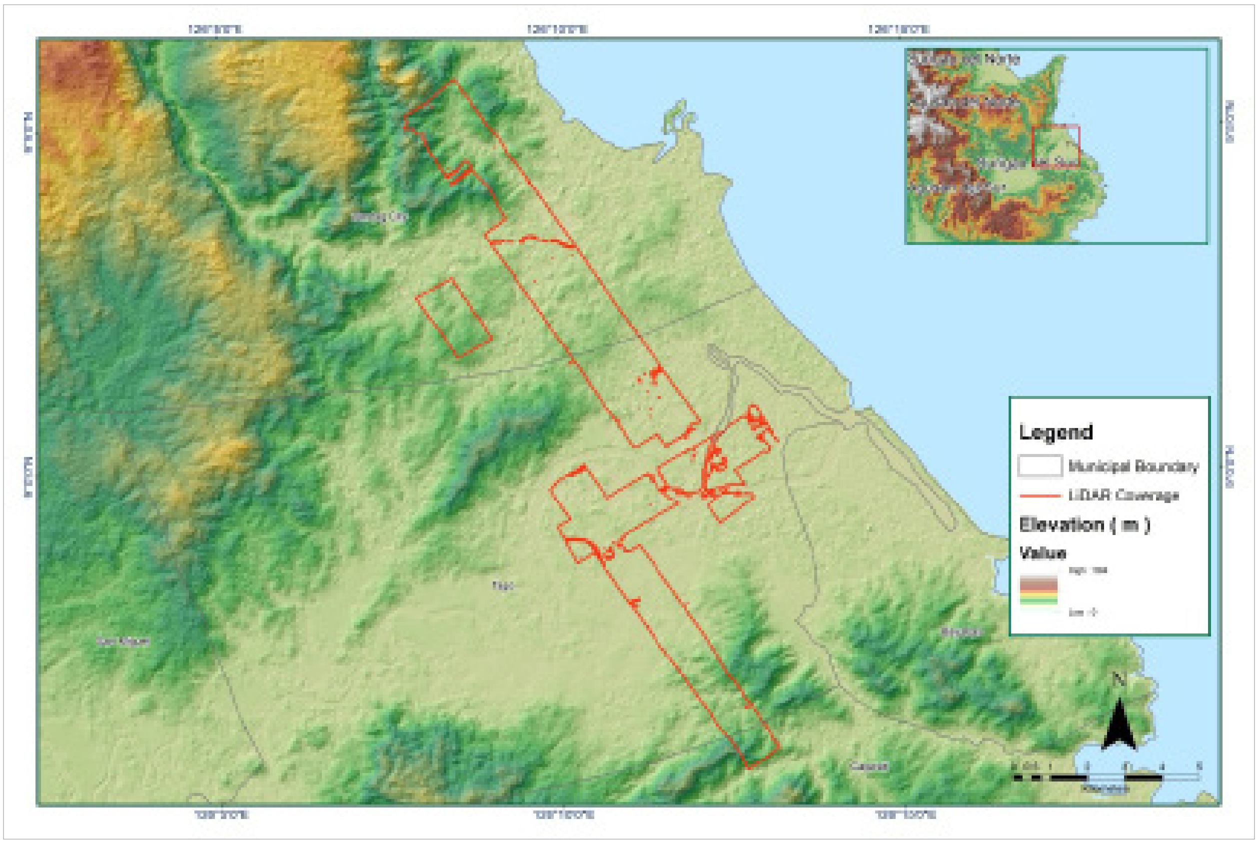


Figure 1.5.4 Coverage of LiDAR data

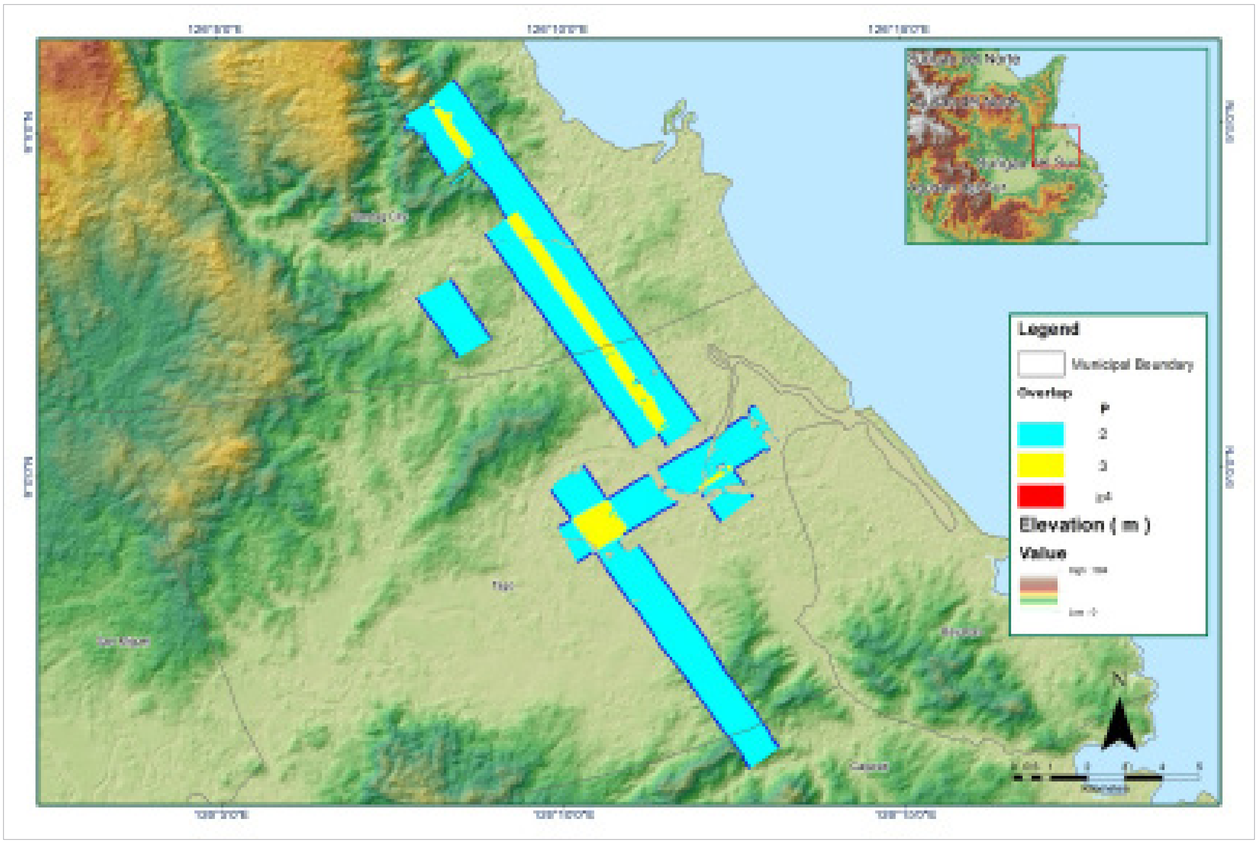


Figure 1.5.5 Image of data overlap

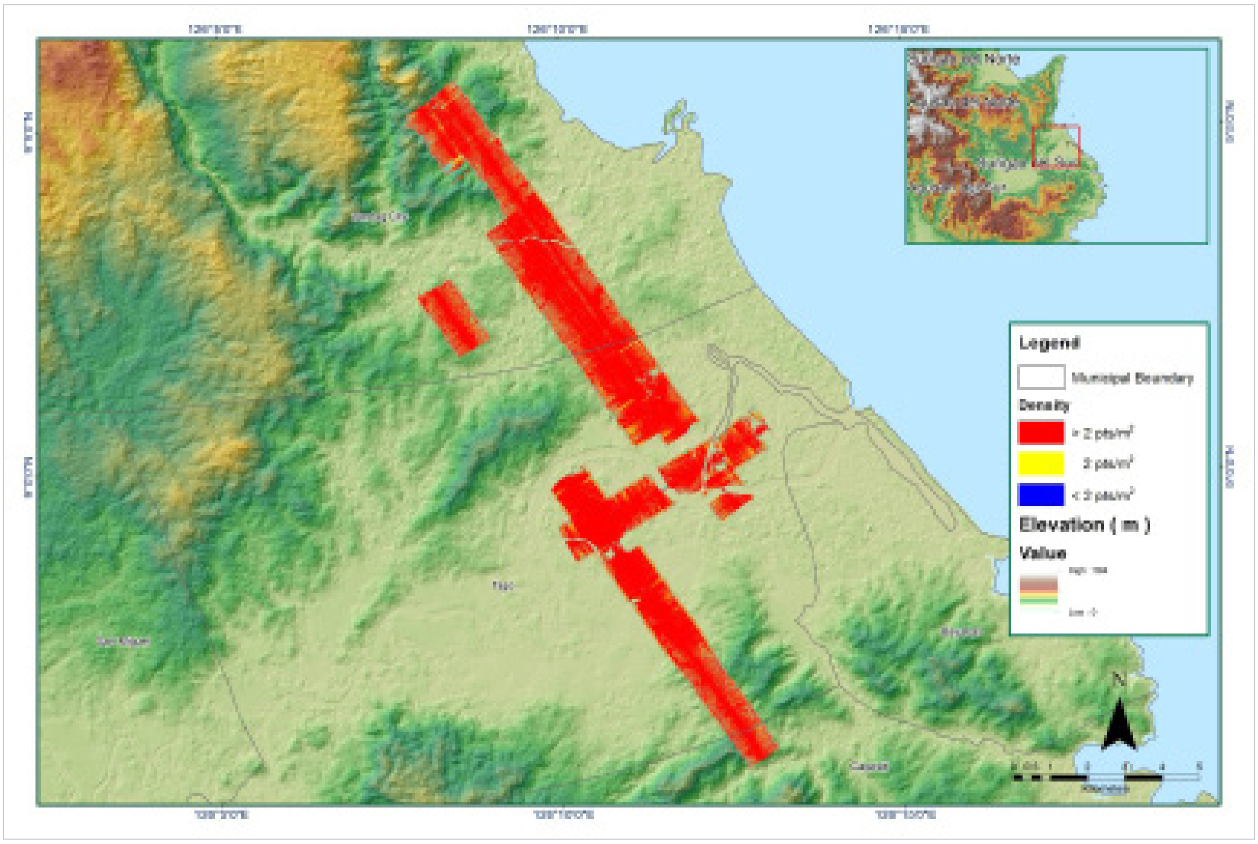


Figure 1.5.6 Density Map of merged LiDAR data

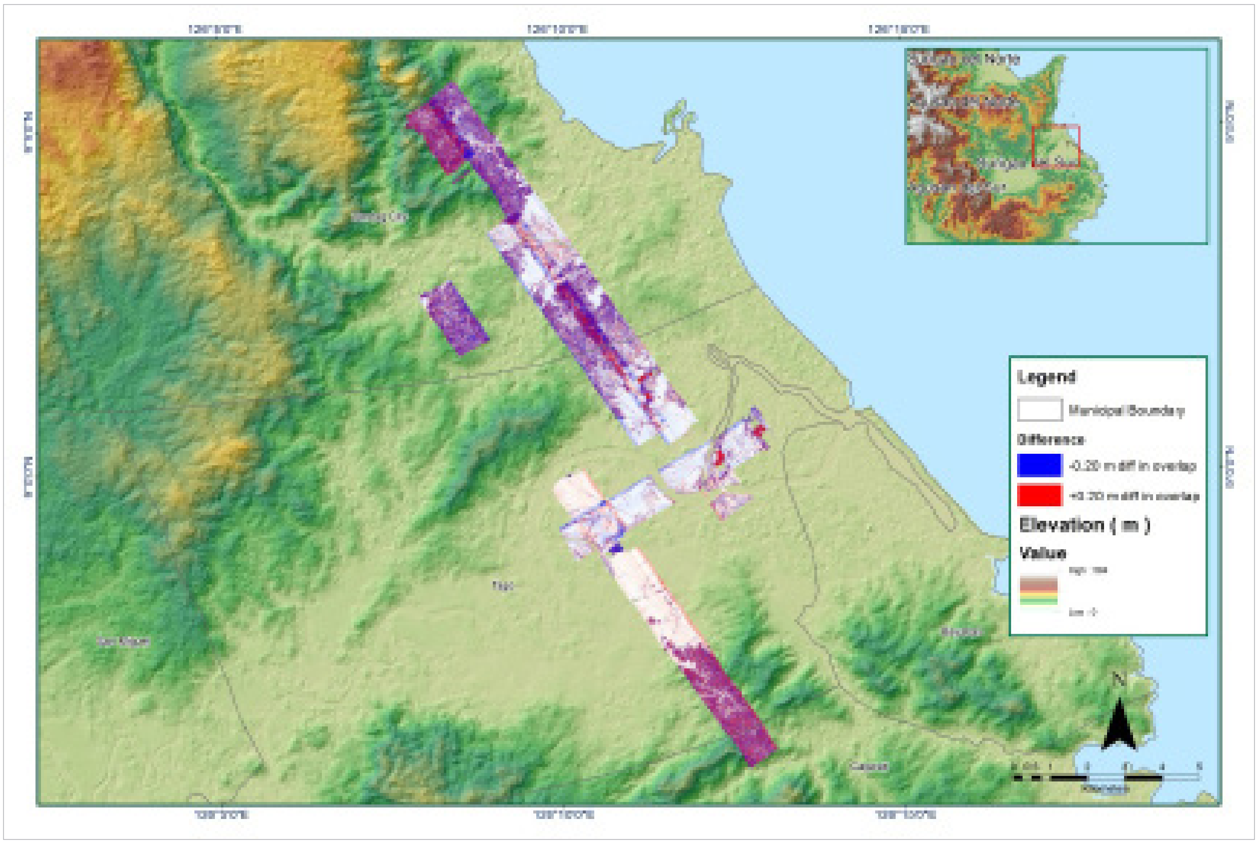


Figure 1.5.7 Elevation Difference Between flight lines

Flight Area	Tandag
Mission Name	Blk61C
Inclusive Flights	23610P
Range data size	13.7 GB
Base data size	369 MB
POS	480 MB
Image	NA
Transfer date	January 3, 2017
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.27
RMSE for East Position (<4.0 cm)	1.25
RMSE for Down Position (<8.0 cm)	3.3
Boresight correction stdev (<0.001deg)	0.000257
IMU attitude correction stdev (<0.001deg)	0.000441
GPS position stdev (<0.01m)	0.0072
Minimum % overlap (>25)	31.42
Ave point cloud density per sq.m. (>2.0)	3.87
Elevation difference between strips (<0.20 m)	YES
Number of 1km x 1km blocks	179
Maximum Height	834.4 m
Minimum Height	57.55 m
Classification (# of points)	
Ground	139,523,754
Low vegetation	71,702,105
Medium vegetation	116,146,930
High vegetation	188,868,056
Building	1,173,534
Ortophoto	No
Processed by	Engr. Analyn Naldo, Engr. Harmond Santos, Engr. Gladys Mae Apat

Figure 1.6.1. Solution Status

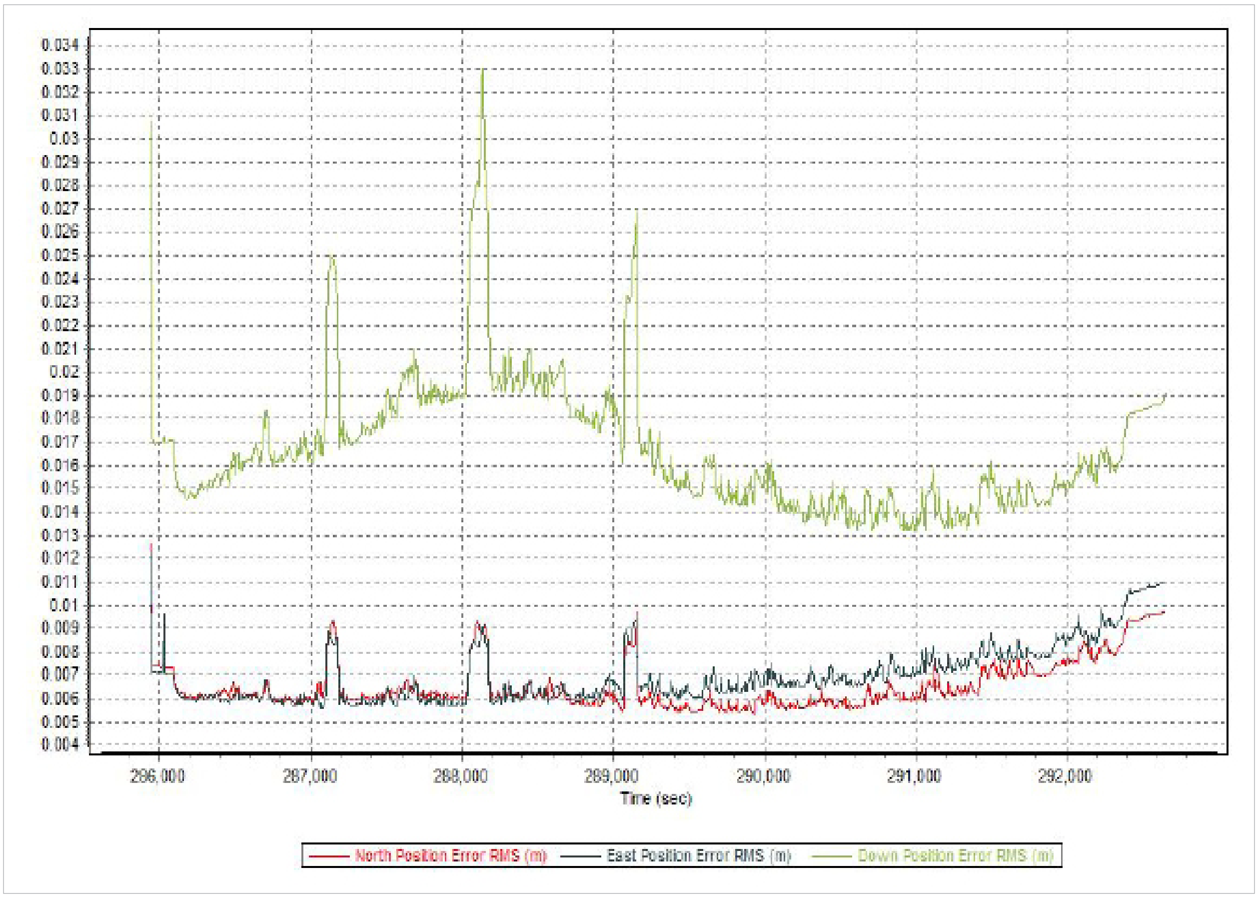


Figure 1.6.2. Smoothed Performance Metric Parameters

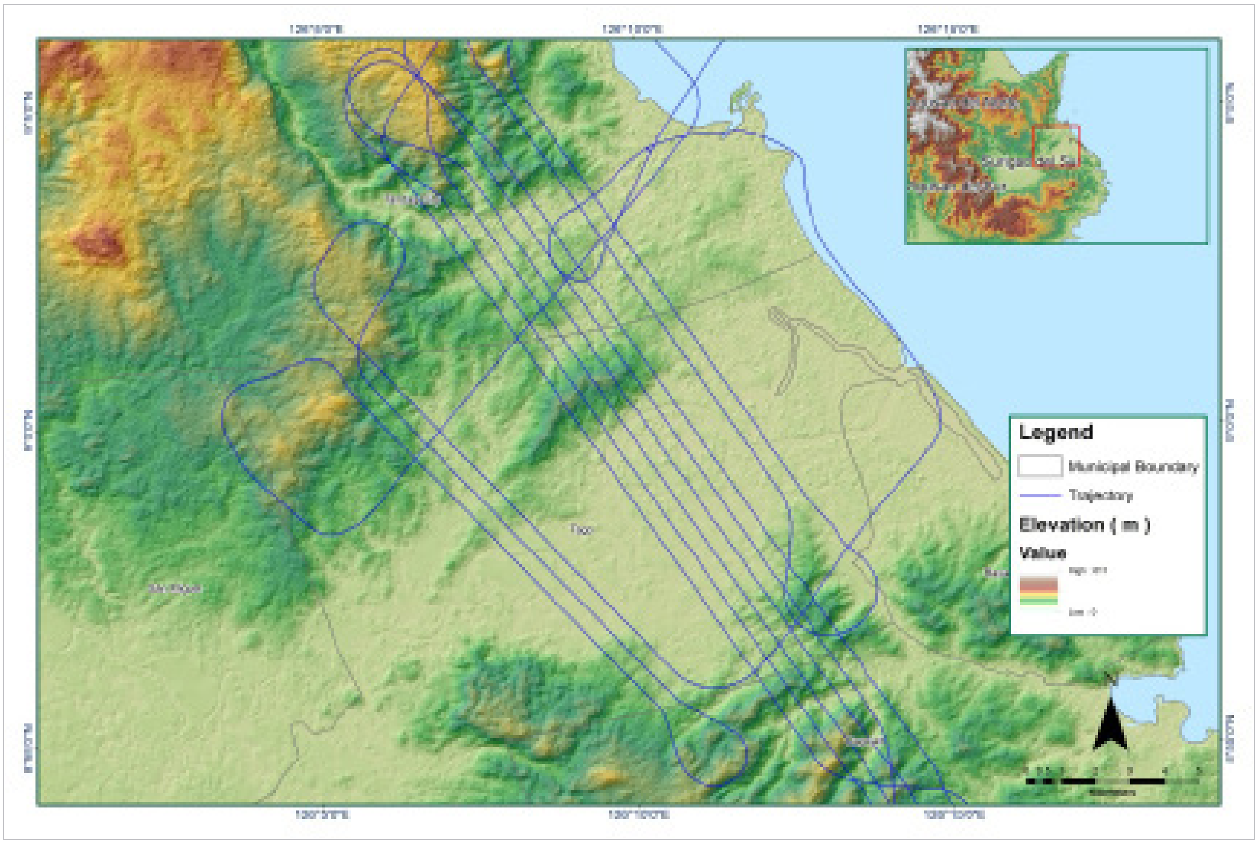


Figure 1.6.3 Best Estimated Trajectory

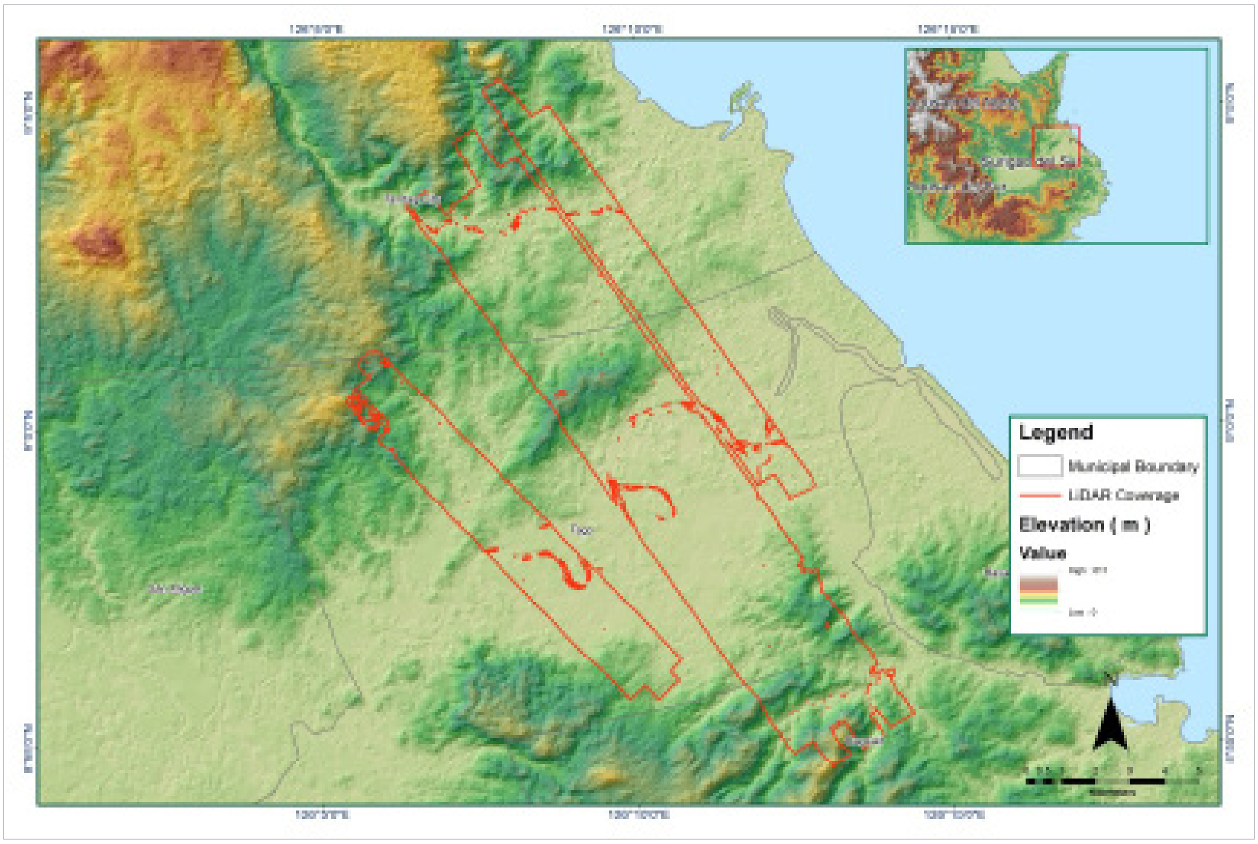


Figure 1.6.4 Coverage of LiDAR data

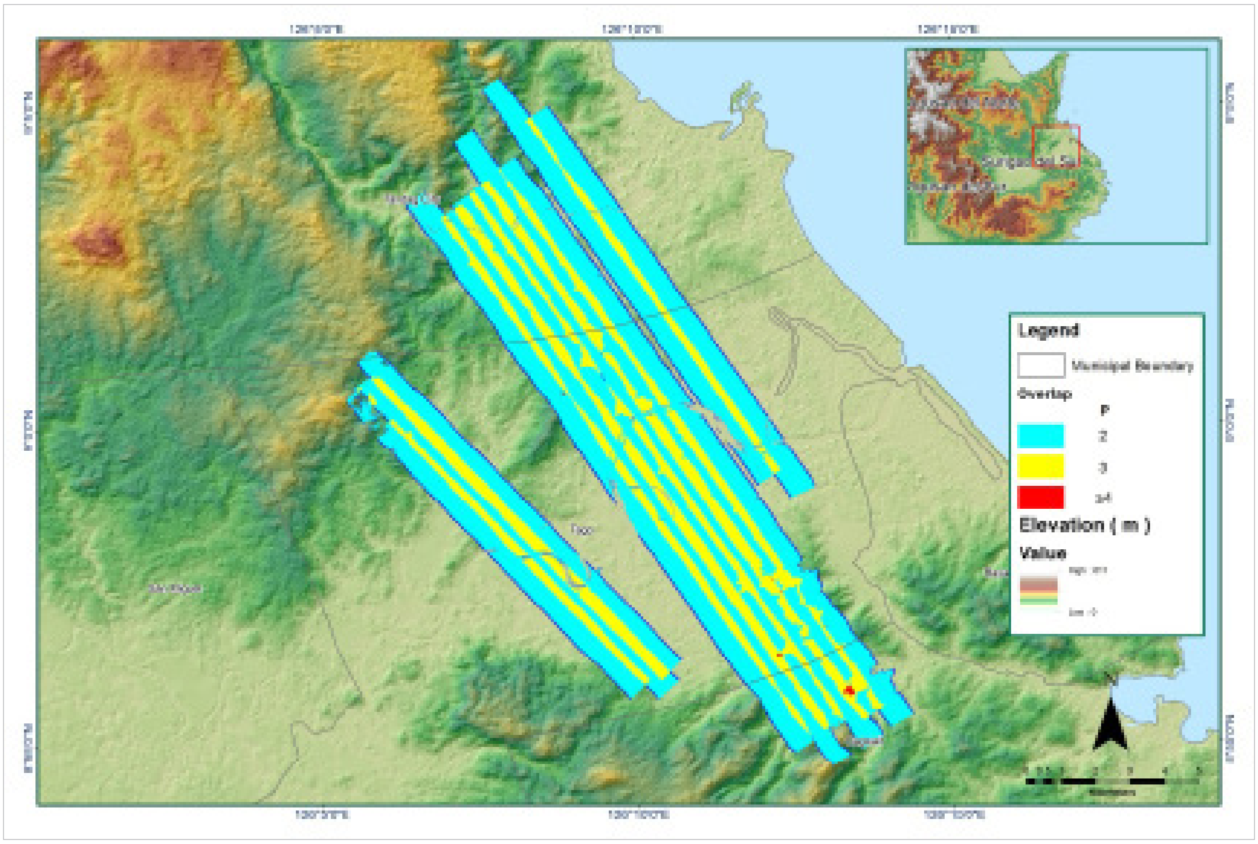


Figure 1.6.5 Image of data overlap

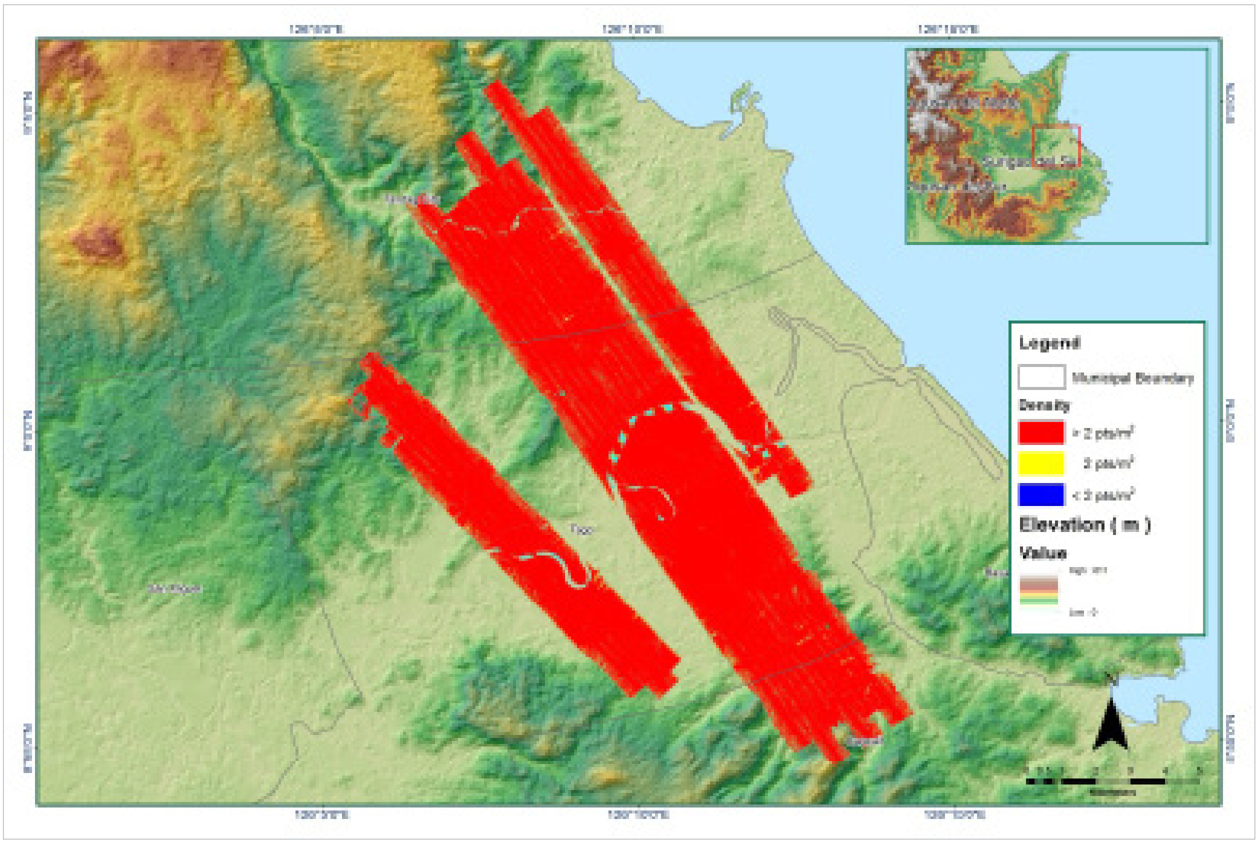


Figure 1.6.6 Density Map of merged LiDAR data

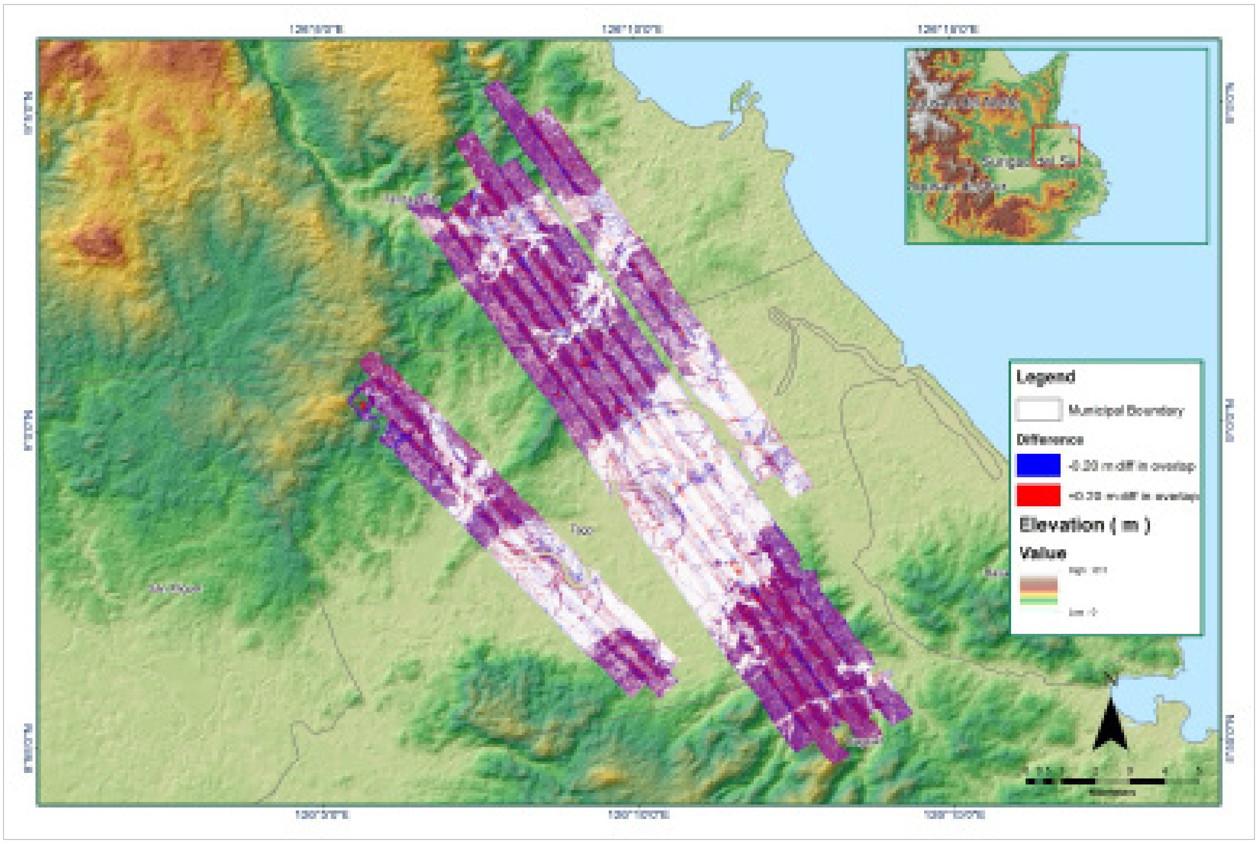


Figure 1.6.7 Elevation Difference Between flight lines

Flight Area	**Tandag**
Mission Name	Blk61G
Inclusive Flights	23640P
Range data size	13.7 GB
Base data size	273 MB
POS	163 MB
Image	NA
Transfer date	January 6, 2017
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.60
RMSE for East Position (<4.0 cm)	1.60
RMSE for Down Position (<8.0 cm)	3.50
Boresight correction stdev (<0.001deg)	0.000861
IMU attitude correction stdev (<0.001deg)	0.010847
GPS position stdev (<0.01m)	0.220
Minimum % overlap (>25)	27.30
Ave point cloud density per sq.m. (>2.0)	3.92
Elevation difference between strips (<0.20 m)	YES
Number of 1km x 1km blocks	136
Maximum Height	741.75 m
Minimum Height	66.62 m
Classification (# of points)	
Ground	7,1196,900
Low vegetation	67,519,269
Medium vegetation	74,694,951
High vegetation	182,678,627
Building	68,16,726
Ortophoto	No
Processed by	Engr. Jennifer Saguran, Engr. Harmond Santos, Engr. Gladys Mae Apat

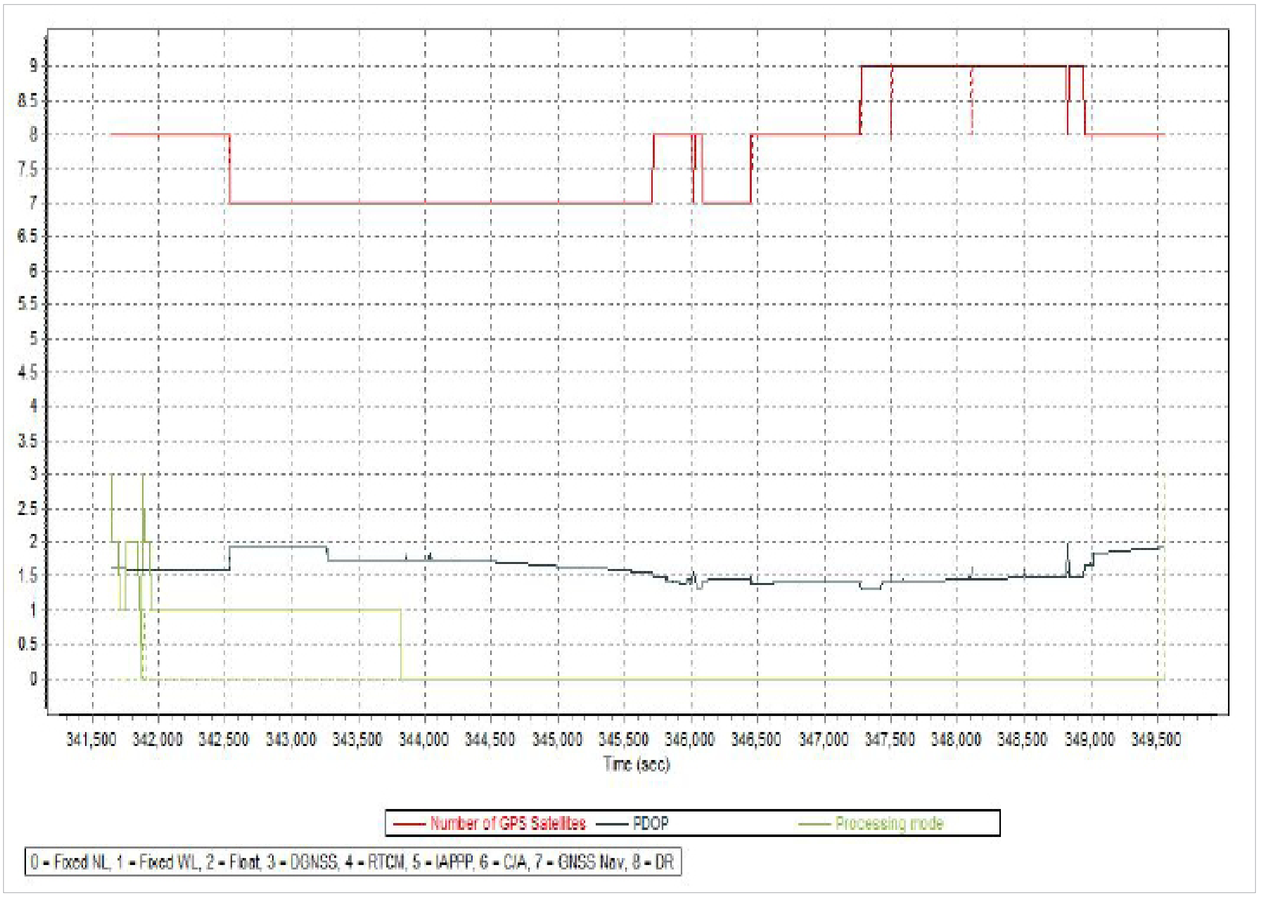


Figure 1.7.1. Solution Status

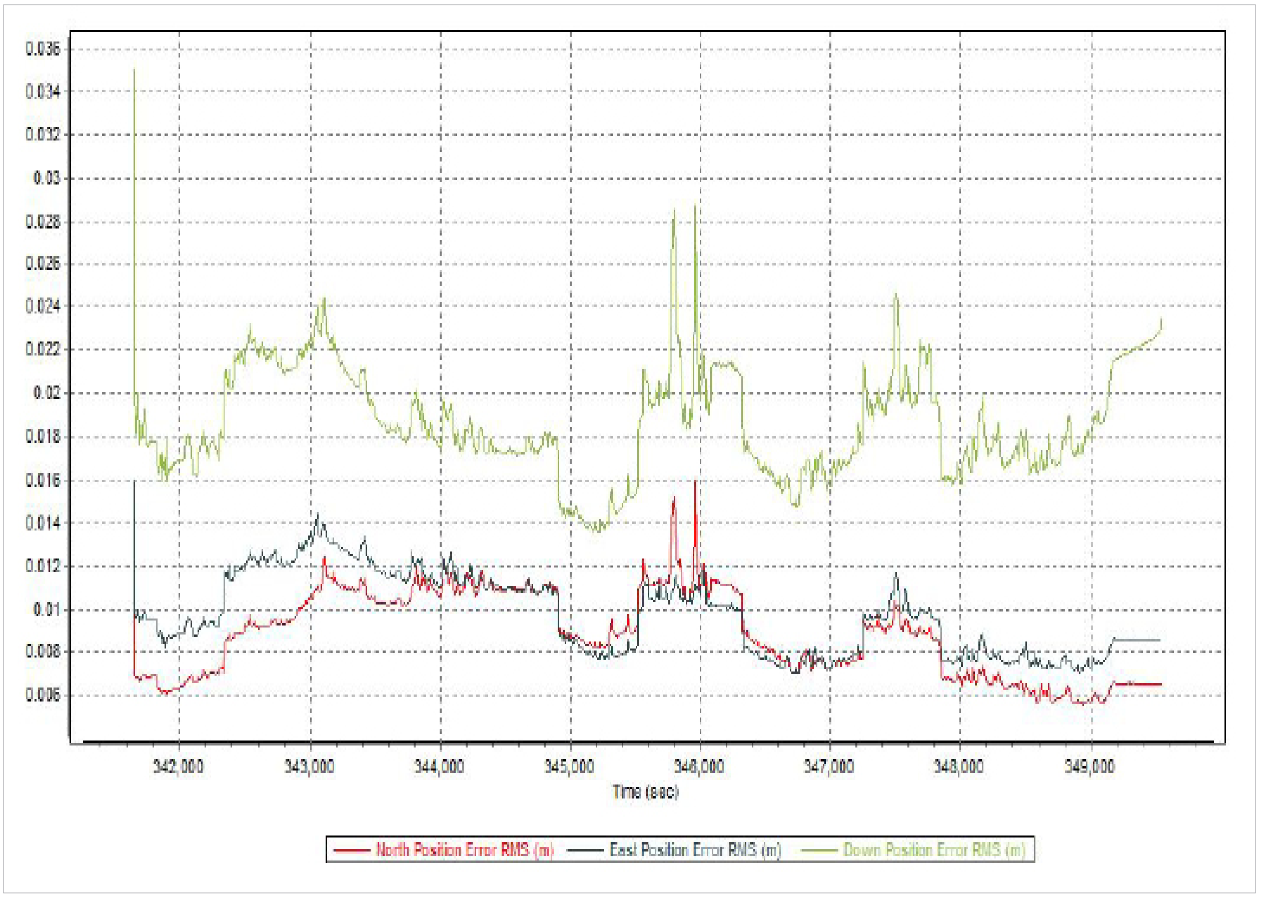


Figure 1.7.2. Smoothed Performance Metric Parameters

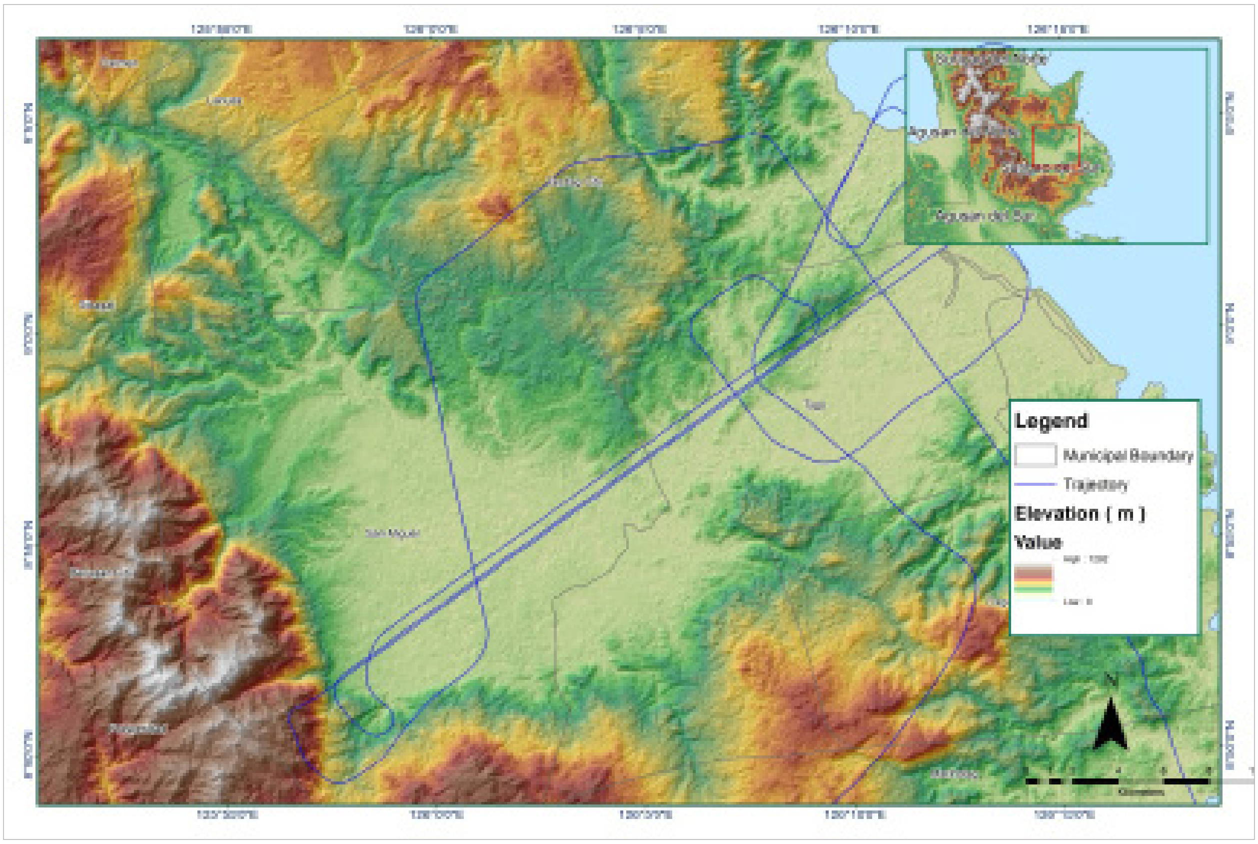


Figure 1.7.3 Best Estimated Trajectory

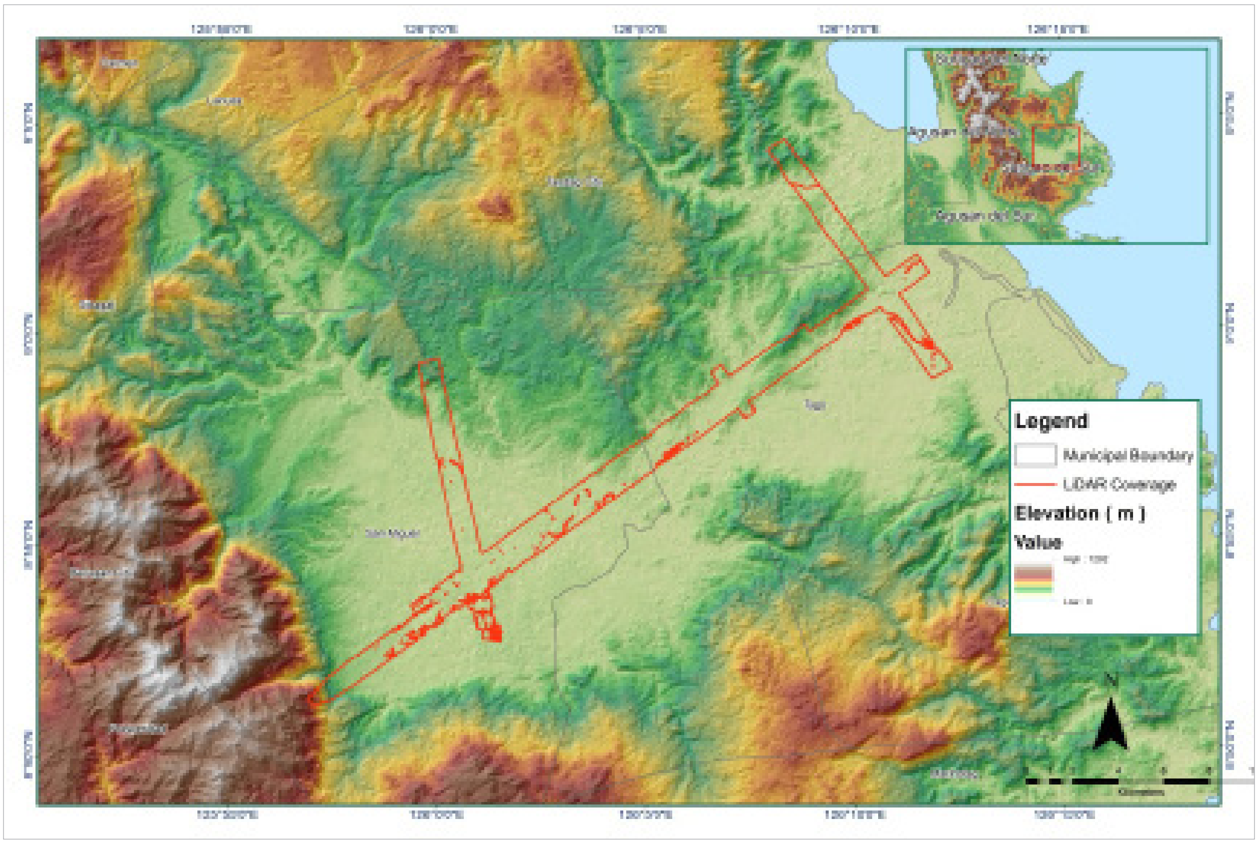


Figure 1.7.4 Coverage of LiDAR data

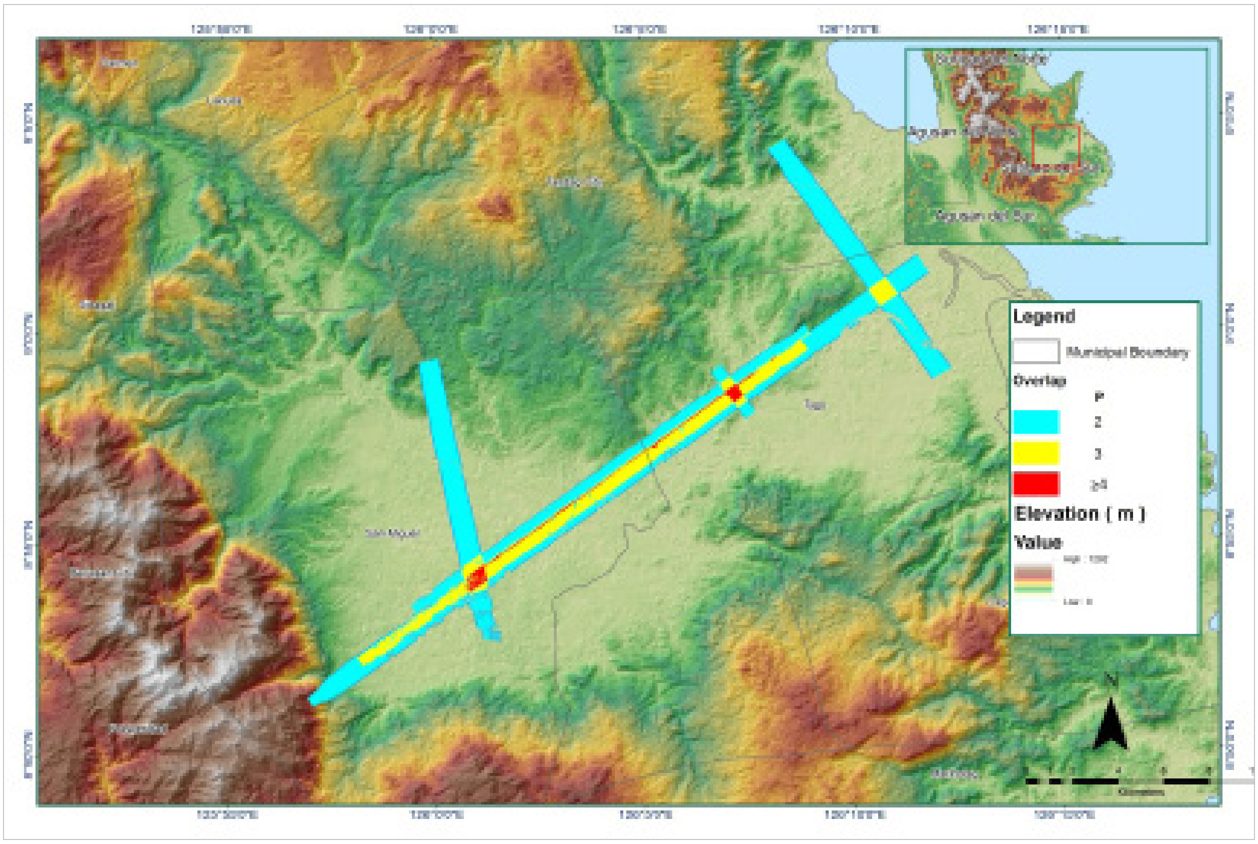


Figure 1.7.5 Image of data overlap

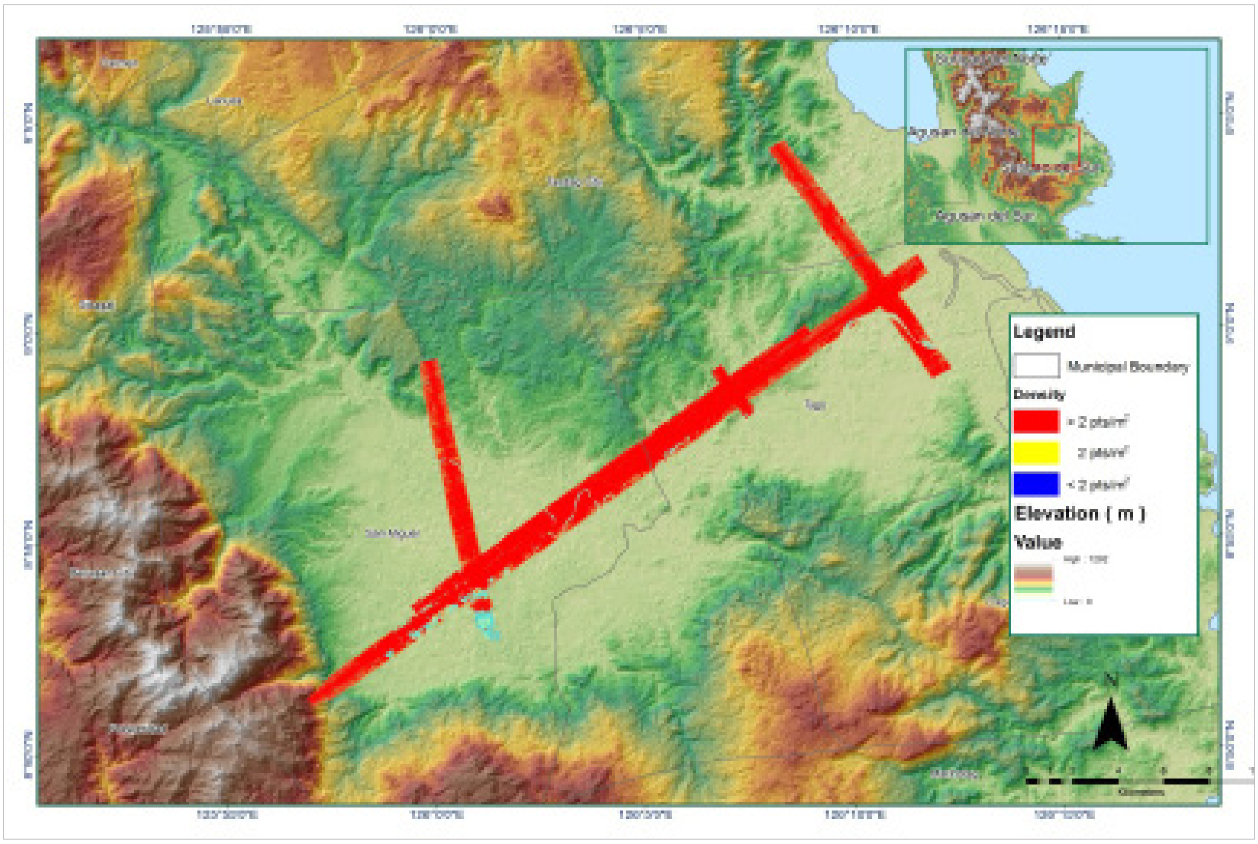


Figure 1.7.6 Density Map of merged LiDAR data

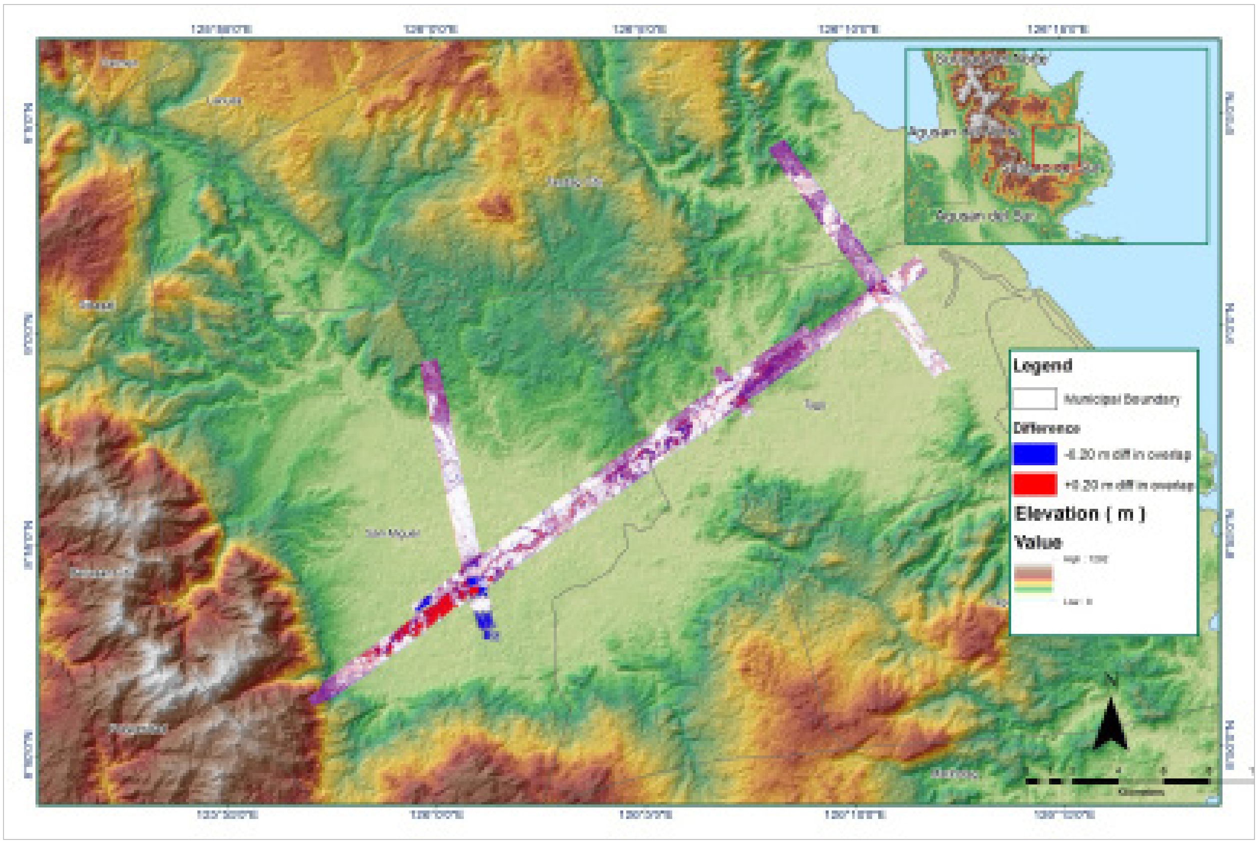


Figure 1.7.7 Elevation Difference Between flight lines

Flight Area	Tandag
Mission Name	Blk61F
Inclusive Flights	23612P
Range data size	15.4 GB
Base data size	294 MB
POS	186 MB
Image	NA
Transfer date	January 3, 2017
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.83
RMSE for East Position (<4.0 cm)	1.33
RMSE for Down Position (<8.0 cm)	3.33
Boresight correction stdev (<0.001deg)	0.000499
IMU attitude correction stdev (<0.001deg)	0.000586
GPS position stdev (<0.01m)	0.0016
Minimum % overlap (>25)	32.64
Ave point cloud density per sq.m. (>2.0)	2.87
Elevation difference between strips (<0.20 m)	YES
Number of 1km x 1km blocks	275
Maximum Height	504.73 m
Minimum Height	41.36 m
Classification (# of points)	
Ground	189,502,075
Low vegetation	100,021,927
Medium vegetation	122,781,681
High vegetation	418,418,194
Building	10,898,125
Ortophoto	No
Processed by	Engr. Jennifer Saguran, Engr. Harmond Santos, Engr. Gladys Mae Apat

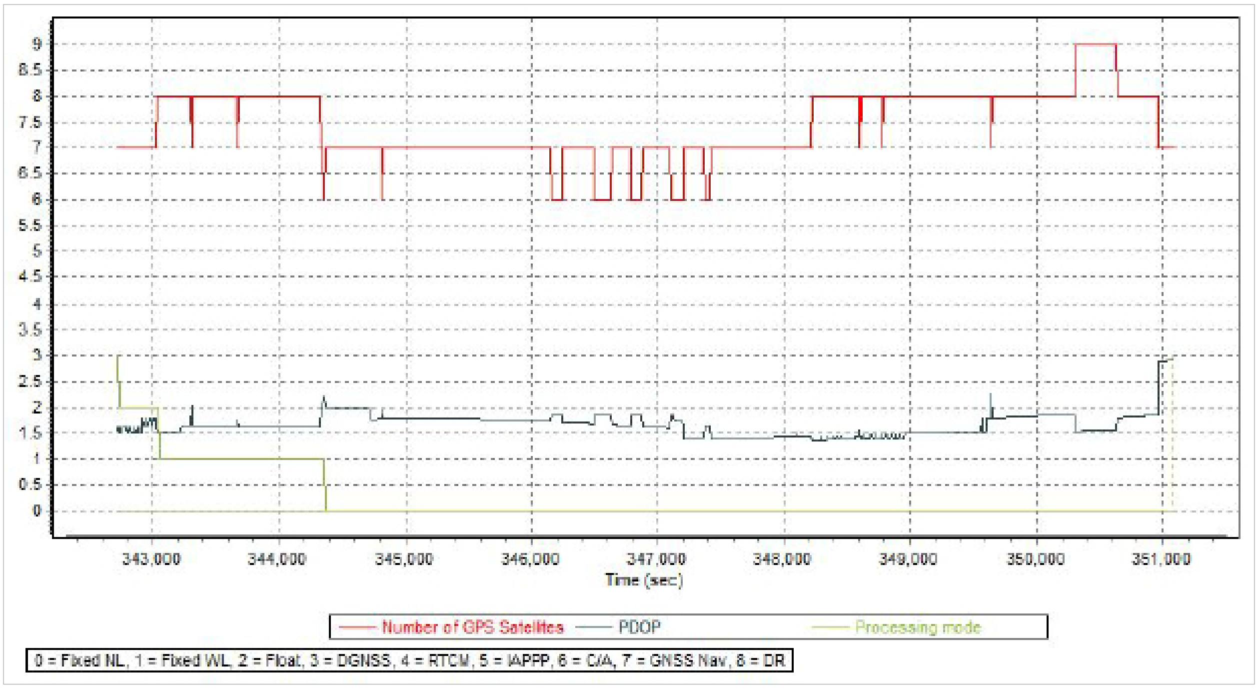


Figure 1.8.1. Solution Status

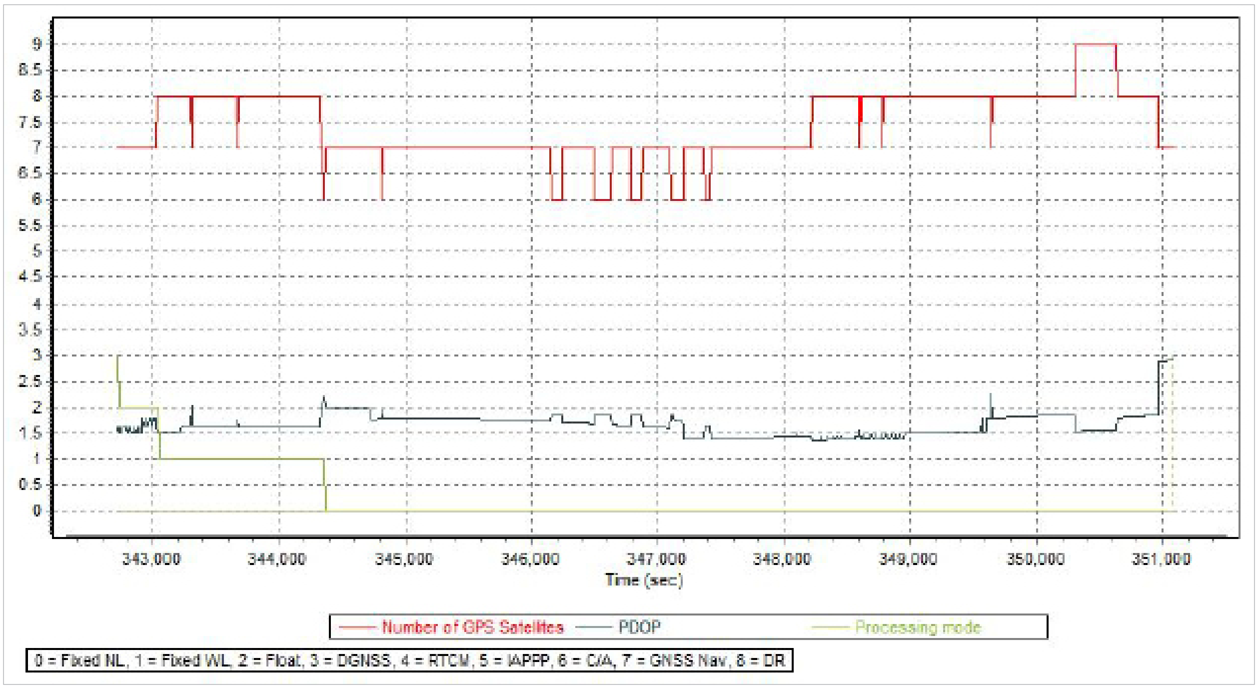


Figure 1.8.2. Smoothed Performance Metric Parameters

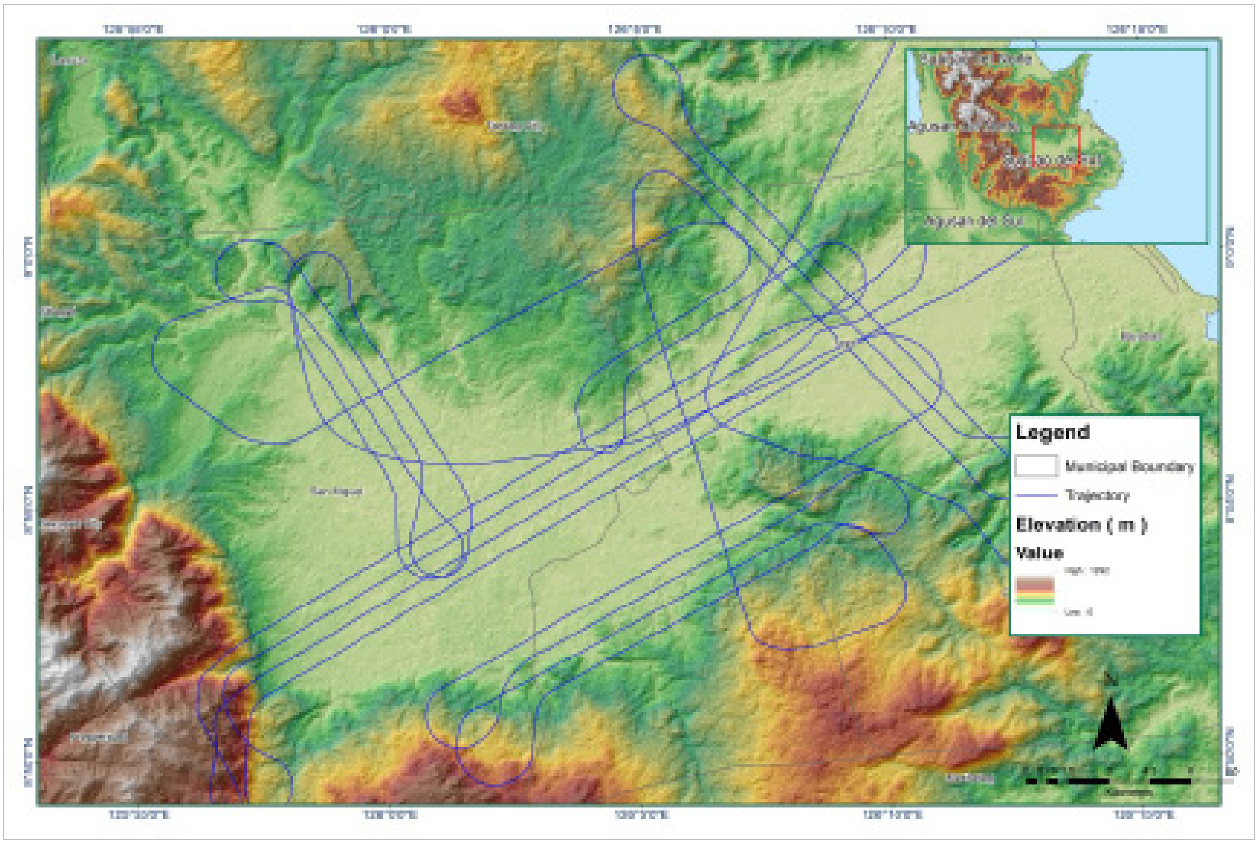


Figure 1.8.3 Best Estimated Trajectory

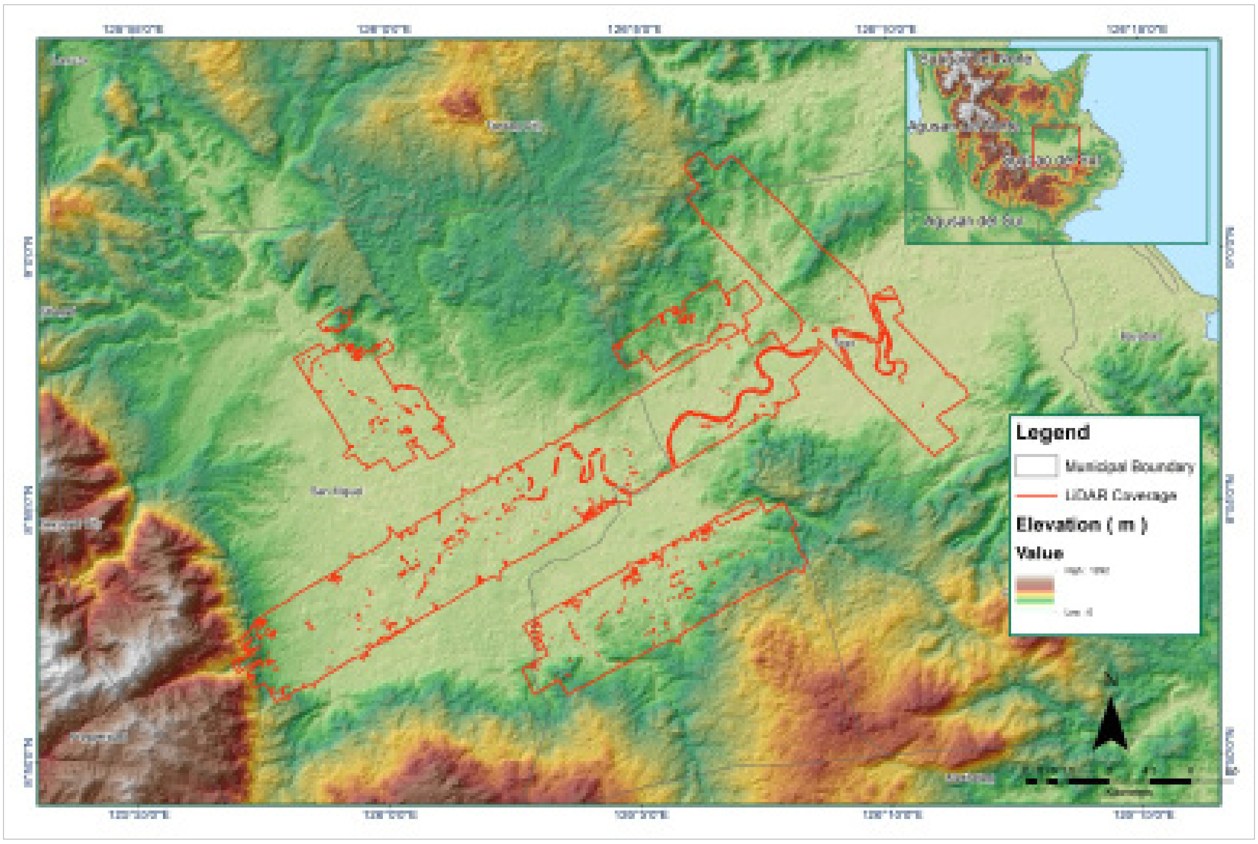


Figure 1.8.4 Coverage of LiDAR data

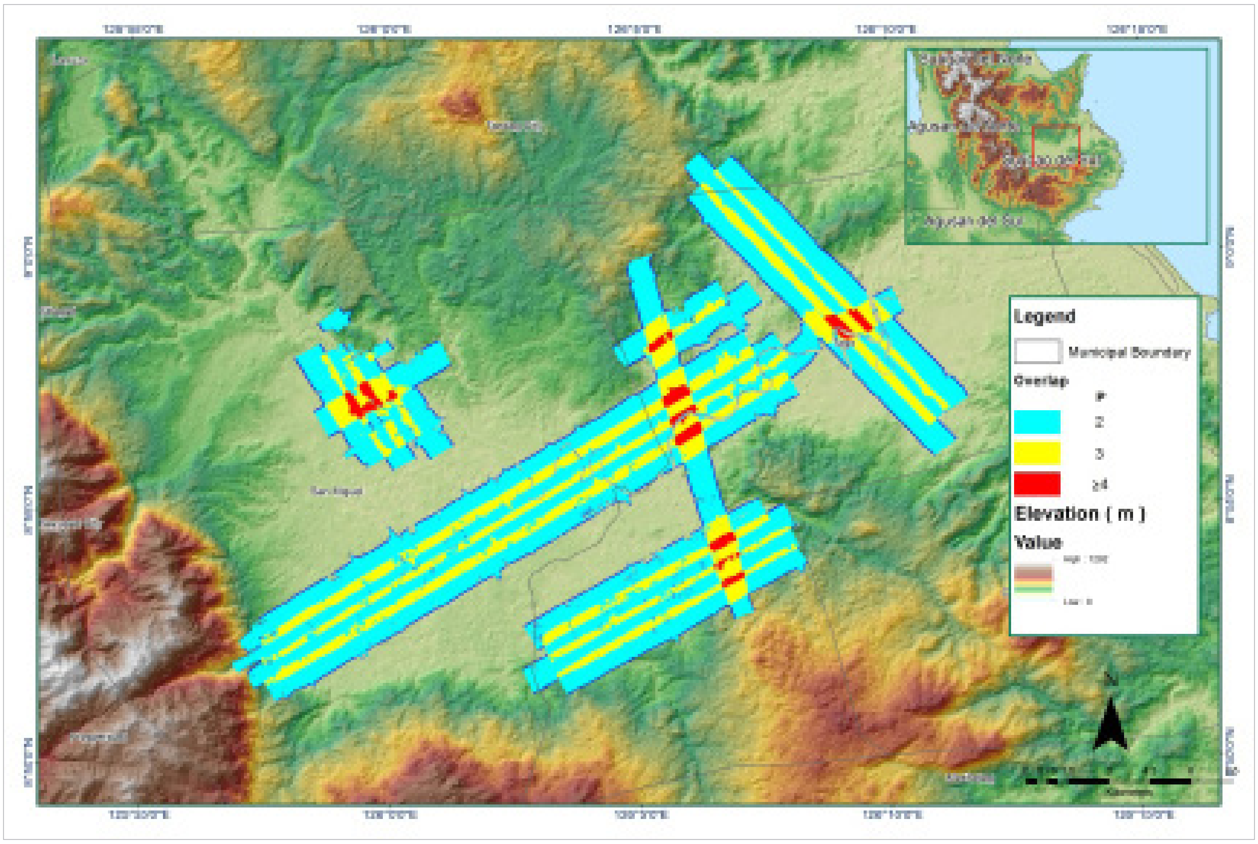


Figure 1.8.5 Image of data overlap

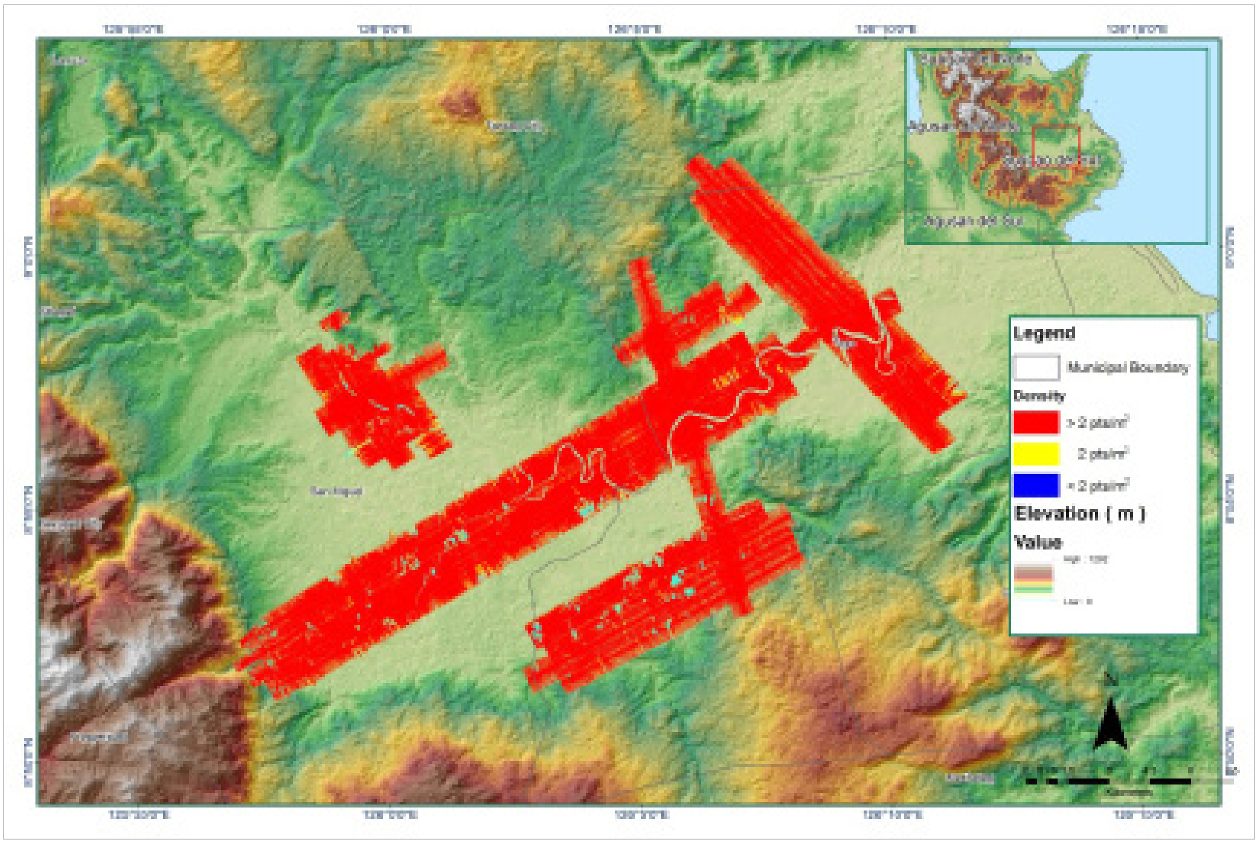


Figure 1.8.6 Density Map of merged LiDAR data

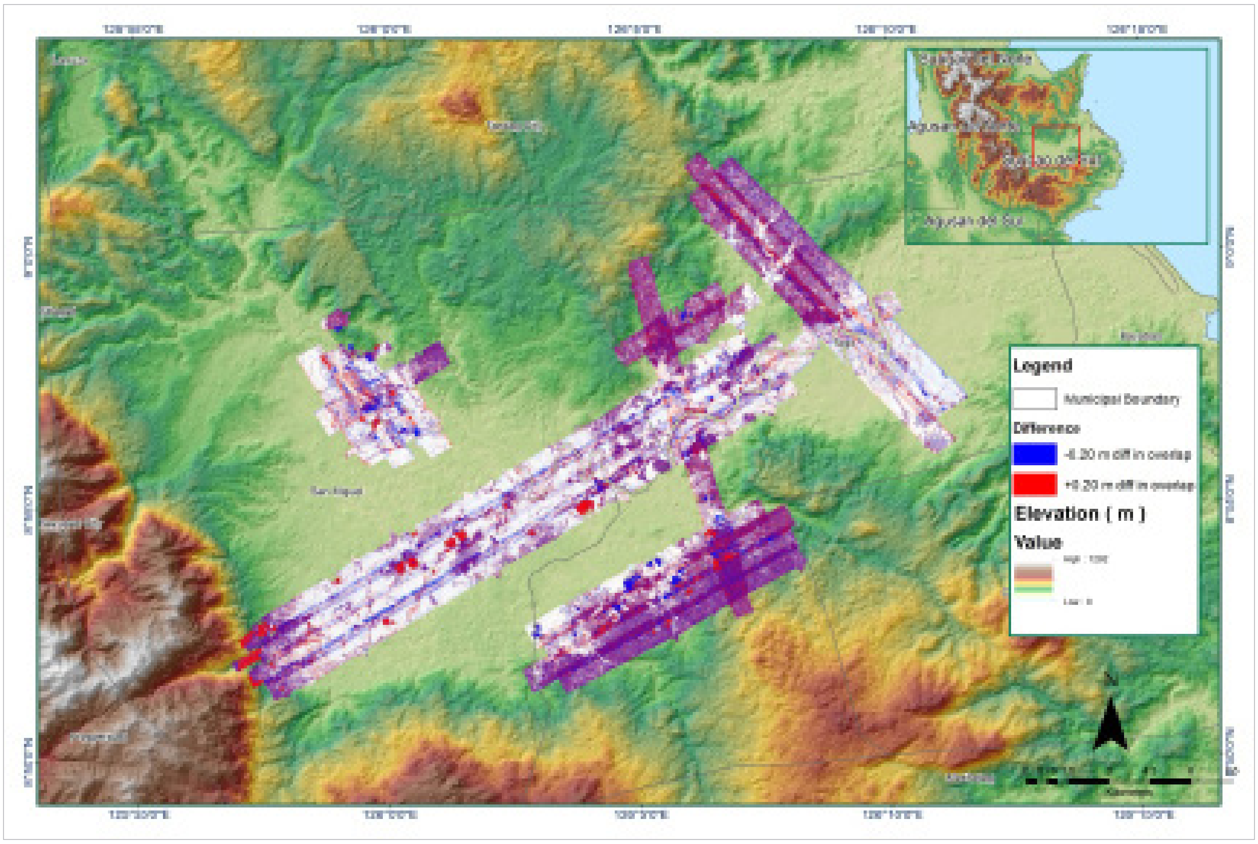


Figure 1.8.7 Elevation Difference Between flight lines

ANNEX 9. Tandag Model Basin Parameters

Table A-9.1. Tandag Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (m^3/s)	Recession Constant	Threshold Type	Ratio to Peak
W1010	5.87	89.64	61.03	1.1697	2.3394	Discharge	0.80	1	Ratio to Peak	0.0500
W1020	10.39	83.01	17.37	1.9670	3.9340	Discharge	0.18	1	Ratio to Peak	0.0500
W480	3.59	89.08	0.55	0.8351	3.8814	Discharge	1.07	1	Ratio to Peak	0.0500
W490	9.14	89.08	0.00	0.8346	3.7345	Discharge	0.35	1	Ratio to Peak	0.0500
W500	4.54	89.64	0.00	1.2594	5.6258	Discharge	0.31	1	Ratio to Peak	0.0500
W510	8.71	89.64	0.00	2.0078	2.7080	Discharge	0.61	1	Ratio to Peak	0.0500
W520	3.61	89.64	0.00	1.1087	7.4965	Discharge	0.37	1	Ratio to Peak	0.0500
W530	4.32	89.64	0.00	0.9865	6.4908	Discharge	0.46	1	Ratio to Peak	0.0500
W540	5.90	89.64	0.00	0.1944	2.0398	Discharge	0.09	1	Ratio to Peak	0.0500
W550	3.51	88.51	0.00	2.1959	6.5354	Discharge	1.21	1	Ratio to Peak	0.0500
W560	4.90	90.75	0.00	0.1789	0.1963	Discharge	0.05	1	Ratio to Peak	0.0758
W570	4.47	91.29	0.00	0.1865	0.1692	Discharge	0.09	1	Ratio to Peak	0.0509
W580	3.36	89.64	0.00	1.3334	7.8893	Discharge	0.84	1	Ratio to Peak	0.0500
W590	7.17	89.08	0.00	0.3164	2.2259	Discharge	0.37	1	Ratio to Peak	0.0500
W600	8.60	89.64	0.00	0.1845	2.9010	Discharge	0.48	1	Ratio to Peak	0.0500
W610	6.09	89.08	0.00	1.0172	3.0550	Discharge	0.27	1	Ratio to Peak	0.0500
W620	20.61	89.08	0.00	0.9354	2.7983	Discharge	0.53	1	Ratio to Peak	0.0500
W630	9.38	89.08	0.00	0.8384	0.7116	Discharge	0.12	1	Ratio to Peak	0.0500
W640	4.46	88.51	0.00	2.0803	2.8693	Discharge	0.41	1	Ratio to Peak	0.0500
W650	3.68	89.64	0.00	0.1983	0.1685	Discharge	0.06	1	Ratio to Peak	0.0506
W660	4.46	88.51	0.00	2.0949	2.8910	Discharge	0.34	1	Ratio to Peak	0.0500

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (m^3/s)	Recession Constant	Threshold Type	Ratio to Peak
W670	5.83	89.64	0.00	0.3539	5.6232	Discharge	0.63	1	Ratio to Peak	0.0500
W680	2.80	89.08	0.21	2.1399	4.8641	Discharge	1.23	1	Ratio to Peak	0.0500
W690	12.62	89.08	0.00	0.4453	0.3493	Discharge	0.02	1	Ratio to Peak	0.0500
W700	4.09	89.08	0.00	1.0065	6.5147	Discharge	0.71	1	Ratio to Peak	0.0500
W710	4.09	89.08	0.00	1.1016	3.2688	Discharge	0.26	1	Ratio to Peak	0.0500
W720	2.95	88.51	0.00	0.8224	3.6495	Discharge	0.33	1	Ratio to Peak	0.0500
W730	6.25	89.64	0.00	2.7890	3.8773	Discharge	1.63	1	Ratio to Peak	0.0500
W740	7.54	88.51	0.00	0.8740	2.8467	Discharge	0.73	1	Ratio to Peak	0.0500
W750	9.85	89.64	0.00	0.9873	4.4237	Discharge	0.98	1	Ratio to Peak	0.0500
W760	4.13	89.08	0.00	1.7309	3.4661	Discharge	0.96	1	Ratio to Peak	0.0500
W780	3.79	89.64	0.00	1.0073	2.9977	Discharge	0.92	1	Ratio to Peak	0.0500
W790	3.83	89.08	0.00	1.1403	7.5984	Discharge	0.31	1	Ratio to Peak	0.0500
W800	2.01	90.20	0.00	1.3143	8.5672	Discharge	0.68	1	Ratio to Peak	0.0500
W810	6.60	88.51	0.00	0.4993	0.9986	Discharge	0.31	1	Ratio to Peak	0.0500
W830	7.36	87.34	1.59	1.6782	3.3564	Discharge	0.35	1	Ratio to Peak	0.0500
W840	8.17	86.15	1.15	1.1995	2.3990	Discharge	0.69	1	Ratio to Peak	0.0500
W850	1.14	89.64	0.00	0.7564	3.2781	Discharge	0.33	1	Ratio to Peak	0.0500
W860	6.60	88.51	1.38	1.4489	2.8978	Discharge	0.36	1	Ratio to Peak	0.0500
W870	4.21	92.35	2.20	0.9039	1.8078	Discharge	0.01	1	Ratio to Peak	0.0500
W880	1.01	89.08	0.00	2.3497	0.7117	Discharge	0.37	1	Ratio to Peak	0.0500
W890	4.68	90.75	0.00	0.1717	0.3829	Discharge	0.09	1	Ratio to Peak	0.0500
W900	9.33	89.08	0.48	2.7872	5.5737	Discharge	0.80	1	Ratio to Peak	0.0500

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction	**Curve Number**	**Impervious (%)**	**Time of Concentration (HR)**	**Storage Coefficient (HR)**	**Initial Type**	**Initial Discharge (m^3/s)**	**Recession Constant**	**Threshold Type**	**Ratio to Peak**
W910	5.18	90.75	0.04	0.9628	1.9256	Discharge	0.34	1	Ratio to Peak	0.0500
W920	5.52	90.20	0.00	0.9270	1.8540	Discharge	0.37	1	Ratio to Peak	0.0500
W930	4.85	91.29	0.36	0.9927	1.9853	Discharge	0.09	1	Ratio to Peak	0.0500
W940	5.18	90.75	0.00	0.7533	1.5066	Discharge	0.28	1	Ratio to Peak	0.0500
W960	5.18	90.75	1.25	0.5129	1.0258	Discharge	0.26	1	Ratio to Peak	0.0500
W970	5.09	90.20	2.30	0.3026	0.1723	Discharge	0.01	1	Ratio to Peak	0.0510

ANNEX 10. Tandag Model Reach Parameters

Table A-10.1 Tandag Model Reach Parameters

Table A-10.1. Hinatuan Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing					
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width
R230	Automatic Fixed Interval	8325.60	0.0231	0.05	Rectangle	13.77
R190	Automatic Fixed Interval	570.71	0.0127	0.05	Rectangle	13.77
R180	Automatic Fixed Interval	1538.50	0.0440	0.05	Rectangle	13.77
R220	Automatic Fixed Interval	1327.40	0.0230	0.05	Rectangle	22.00
R200	Automatic Fixed Interval	7381.00	0.0129	0.05	Rectangle	39.76
R60	Automatic Fixed Interval	3393.90	0.0617	0.05	Rectangle	37.59
R70	Automatic Fixed Interval	1067.30	0.0049	0.05	Rectangle	35.76
R50	Automatic Fixed Interval	1121.50	0.0884	0.05	Rectangle	13.77
R80	Automatic Fixed Interval	936.40	0.0061	0.05	Rectangle	49.14
R150	Automatic Fixed Interval	2124.10	0.0125	0.05	Rectangle	51.60
R160	Automatic Fixed Interval	807.70	0.0716	0.05	Rectangle	13.77
R250	Automatic Fixed Interval	2674.20	0.0004	0.05	Rectangle	82.63
R270	Automatic Fixed Interval	3666.10	0.0004	0.05	Rectangle	59.18
R300	Automatic Fixed Interval	3516.50	0.0118	0.05	Rectangle	87.34
R340	Automatic Fixed Interval	3072.20	0.0089	0.05	Rectangle	98.61
R410	Automatic Fixed Interval	2753.30	0.0053	0.05	Rectangle	74.62
R420	Automatic Fixed Interval	1091.50	0.0004	0.05	Rectangle	108.06
R1080	Automatic Fixed Interval	198.99	0.0272	0.05	Rectangle	183.07
R400	Automatic Fixed Interval	1281.50	0.0026	0.05	Rectangle	157.49
R350	Automatic Fixed Interval	4585.80	0.0004	0.05	Rectangle	71.07
R470	Automatic Fixed Interval	2133.80	0.0026	0.05	Rectangle	18.01
R440	Automatic Fixed Interval	3930.90	0.0013	0.05	Rectangle	23.65
R320	Automatic Fixed Interval	318.99	0.0088	0.05	Rectangle	84.44
R330	Automatic Fixed Interval	3659.60	0.0031	0.05	Rectangle	98.56
R290	Automatic Fixed Interval	369.91	0.0004	0.05	Rectangle	87.34

ANNEX 11. Tandag Field Validation Points

Table A-11.1 Tandag Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
1	9.063987	126.2009	0.326	1.5	1.174	Agaton / 2014-Jan	5-Year
2	9.049307	126.2006	0	0.27	0.27	Agaton / 2014-Jan	5-Year
3	9.068336	126.2036	0	0	0	Agaton / 2014-Jan	5-Year
4	9.069815	126.2021	0	0	0	Agaton / 2014-Jan	5-Year
5	9.066068	126.1675	0.669	0.2	-0.469	Agaton / 2014-Jan	5-Year
6	9.061583	126.1622	0.67	0.32	-0.35	Agaton / 2014-Jan	5-Year
7	9.079567	126.192	0	0	0	Agaton / 2014-Jan	5-Year
8	9.078393	126.1917	0	0	0	Agaton / 2014-Jan	5-Year
9	9.077577	126.1907	0.139	0	-0.139	Agaton / 2014-Jan	5-Year
10	9.077392	126.1904	0	0	0	Agaton / 2014-Jan	5-Year
11	9.076997	126.19	0	0.46	0.46	Agaton / 2014-Jan	5-Year
12	9.076532	126.1887	0	0	0	Agaton / 2014-Jan	5-Year
13	9.07654	126.1883	0.238	0.46	0.222	Agaton / 2014-Jan	5-Year
14	9.077234	126.1879	0	0	0	Agaton / 2014-Jan	5-Year
15	9.07792	126.1864	0	0	0	Agaton / 2014-Jan	5-Year
16	9.066128	126.1817	0	0.8	0.8	Agaton / 2014-Jan	5-Year
17	9.071123	126.1812	1.283	0.35	-0.933	Agaton / 2014-Jan	5-Year
18	9.070238	126.1792	0.745	0	-0.745	Agaton / 2014-Jan	5-Year
19	9.058541	126.1723	0.845	0	-0.845	Agaton / 2014-Jan	5-Year
20	9.057149	126.1708	0.474	1.6	1.126	Agaton / 2014-Jan	5-Year
21	9.060011	126.1732	1.49	1.04	-0.45	Agaton / 2014-Jan	5-Year
22	9.061051	126.1753	0	0	0	Agaton / 2014-Jan	5-Year
23	9.061068	126.1759	0.705	0	-0.705	Agaton / 2014-Jan	5-Year
24	9.062307	126.1784	1.094	0.93	-0.164	Agaton / 2014-Jan	5-Year
25	9.062941	126.184	1.289	0	-1.289	Agaton / 2014-Jan	5-Year
26	9.060587	126.181	0	0	0	Agaton / 2014-Jan	5-Year
27	9.065022	126.1806	1.667	0	-1.667	Agaton / 2014-Jan	5-Year
28	9.066128	126.1817	0	0	0	Agaton / 2014-Jan	5-Year
29	9.066885	126.182	0.608	0.2	-0.408	Agaton / 2014-Jan	5-Year
30	9.083983	126.1687	1.937	0.7	-1.237	Agaton / 2014-Jan	5-Year
31	9.08301	126.1703	0.136	0	-0.136	Agaton / 2014-Jan	5-Year
32	9.076951	126.171	1.809	0.77	-1.039	Agaton / 2014-Jan	5-Year
33	9.074975	126.1699	0.162	0	-0.162	Agaton / 2014-Jan	5-Year
34	9.070035	126.2014	0	0.98	0.98	Agaton / 2014-Jan	5-Year
35	9.064606	126.2013	0	0	0	Agaton / 2014-Jan	5-Year
36	9.065761	126.2011	0.875	1.39	0.515	Agaton / 2014-Jan	5-Year
37	9.066385	126.201	0	0.88	0.88	Agaton / 2014-Jan	5-Year
38	9.06704	126.2014	0	1	1	Agaton / 2014-Jan	5-Year
39	9.070272	126.1991	0.434	0.56	0.126	Agaton / 2014-Jan	5-Year
40	9.070035	126.1999	0	0	0	Agaton / 2014-Jan	5-Year
41	9.069177	0	0	0.15	0.15	Agaton / 2014-Jan	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
42	9.069086	126.1979	0.255	1.2	0.945	Agaton / 2014-Jan	5-Year
43	9.069416	126.1977	0.732	1.3	0.568	Agaton / 2014-Jan	5-Year
44	9.076309	126.1942	0.139	1	0.861	Agaton / 2014-Jan	5-Year
45	9.074237	126.1961	1.974	1.5	-0.474	Agaton / 2014-Jan	5-Year
46	9.073961	126.1967	0.156	1.45	1.294	Agaton / 2014-Jan	5-Year
47	9.073706	126.1968	0.164	1.78	1.616	Agaton / 2014-Jan	5-Year
48	9.073597	126.1972	0	0.41	0.41	Agaton / 2014-Jan	5-Year
49	9.073183	126.1971	0	0.84	0.84	Agaton / 2014-Jan	5-Year
50	9.073498	126.1986	0.174	0.43	0.256	Agaton / 2014-Jan	5-Year
51	9.073604	126.1992	0.288	0.5	0.212	Agaton / 2014-Jan	5-Year
52	9.075818	126.1989	0.58	0	-0.58	Agaton / 2014-Jan	5-Year
53	9.077004	126.2005	0.143	0.05	-0.093	Agaton / 2014-Jan	5-Year
54	9.078393	126.1999	0.167	0.2	0.033	Agaton / 2014-Jan	5-Year
55	9.080361	126.1982	0	0	0	Agaton / 2014-Jan	5-Year
56	9.082364	126.1952	0	1.3	1.3	Agaton / 2014-Jan	5-Year
57	9.082775	126.1983	0	0.48	0.48	Agaton / 2014-Jan	5-Year
58	9.082473	126.1954	0	0.59	0.59	Agaton / 2014-Jan	5-Year
59	9.073193	126.183	0.164	0.32	0.156	Agaton / 2014-Jan	5-Year
60	9.074421	126.1826	0.808	0.31	-0.498	Agaton / 2014-Jan	5-Year
61	9.074508	126.1834	0.238	0.32	0.082	Agaton / 2014-Jan	5-Year
62	9.068546	126.1894	0	0	0	Agaton / 2014-Jan	5-Year
63	9.054802	126.181	0.184	1.01	0.826	Agaton / 2014-Jan	5-Year
64	9.05447	126.1752	0.436	0	-0.436	Agaton / 2014-Jan	5-Year
65	9.052876	126.1798	0	0	0	Agaton / 2014-Jan	5-Year
66	9.046969	126.1624	2.195	0	-2.195	Agaton / 2014-Jan	5-Year
67	9.044089	126.1596	1.599	1.01	-0.589	Agaton / 2014-Jan	5-Year
68	9.051277	126.1641	1.833	0.71	-1.123	Agaton / 2014-Jan	5-Year
69	9.057837	126.1656	0.536	0.1	-0.436	Agaton / 2014-Jan	5-Year
70	9.060935	126.1642	0.636	0	-0.636	Agaton / 2014-Jan	5-Year
71	9.0603	126.1625	0.474	0	-0.474	Agaton / 2014-Jan	5-Year
72	9.061064	126.1598	1.408	0	-1.408	Agaton / 2014-Jan	5-Year
73	9.061031	126.1572	1.982	0	-1.982	Agaton / 2014-Jan	5-Year
74	9.081851	126.1727	0	0	0	Agaton / 2014-Jan	5-Year
75	9.069461	126.1693	0.739	0.62	-0.119	Agaton / 2014-Jan	5-Year
76	9.075662	126.1669	0.811	0.36	-0.451	Agaton / 2014-Jan	5-Year
77	9.074536	126.168	0	0	0	Agaton / 2014-Jan	5-Year
78	9.059081	126.1655	0.66	0	-0.66	Agaton / 2014-Jan	5-Year
79	9.056679	126.1674	0.52	0	-0.52	Agaton / 2014-Jan	5-Year
80	9.075684	126.1968	0	0	0	Agaton / 2014-Jan	5-Year
81	9.073387	126.1932	0.194	0	-0.194	Agaton / 2014-Jan	5-Year
82	9.072885	126.1914	0.188	0	-0.188	Agaton / 2014-Jan	5-Year
83	9.073878	126.1924	0	0	0	Agaton / 2014-Jan	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
84	9.073783	126.1942	0.095	0.04	-0.055	Agaton / 2014-Jan	5-Year
85	9.071671	126.193	0.121	0	-0.121	Agaton / 2014-Jan	5-Year
86	9.076604	126.1933	0	0	0	Agaton / 2014-Jan	5-Year
87	9.076448	126.1931	0	0	0	Agaton / 2014-Jan	5-Year
88	9.07622	126.193	2.137	1.1	-1.037	Agaton / 2014-Jan	5-Year
89	9.075664	126.1956	0	0	0	Agaton / 2014-Jan	5-Year
90	9.075372	126.1955	0	0.3	0.3	Agaton / 2014-Jan	5-Year
91	9.077281	126.1934	0	0	0	Agaton / 2014-Jan	5-Year
92	9.077661	126.1938	0	0.15	0.15	Agaton / 2014-Jan	5-Year
93	9.079365	126.1507	2.455	1.7	-0.755	Agaton / 2014-Jan	5-Year
94	9.079083	126.1518	1.364	0.62	-0.744	Agaton / 2014-Jan	5-Year
95	9.07683	126.1665	1.056	0.37	-0.686	Agaton / 2014-Jan	5-Year
96	9.071464	126.1647	0.294	0	-0.294	Agaton / 2014-Jan	5-Year
97	9.069887	126.1684	0.203	0	-0.203	Agaton / 2014-Jan	5-Year
98	9.080512	126.1958	0	1.42	1.42	Agaton / 2014-Jan	5-Year
99	9.079287	126.1955	0	0.51	0.51	Agaton / 2014-Jan	5-Year
100	9.079465	126.1513	2.161	0.41	-1.751	Agaton / 2014-Jan	5-Year
101	9.079685	126.1512	0	0.64	0.64	Agaton / 2014-Jan	5-Year
102	9.063987	126.2009	0.44	1.94	1.06	Seniang / 2014-Dec	5-Year
103	9.049307	126.2006	0	0.49	0.27	Seniang / 2014-Dec	5-Year
104	9.068336	126.2036	0	0	0	Seniang / 2014-Dec	5-Year
105	9.069815	126.2021	0.104	0	-0.104	Seniang / 2014-Dec	5-Year
106	9.066068	126.1675	1.271	0.37	-1.071	Seniang / 2014-Dec	5-Year
107	9.061583	126.1622	1.024	0.32	-0.704	Seniang / 2014-Dec	5-Year
108	9.079567	126.192	0	0	0	Seniang / 2014-Dec	5-Year
109	9.078393	126.1917	0	0	0	Seniang / 2014-Dec	5-Year
110	9.077577	126.1907	0.207	0.61	-0.207	Seniang / 2014-Dec	5-Year
111	9.077392	126.1904	0	0.61	0	Seniang / 2014-Dec	5-Year
112	9.076997	126.19	0	0.85	0.46	Seniang / 2014-Dec	5-Year
113	9.076532	126.1887	0.582	0.46	-0.582	Seniang / 2014-Dec	5-Year
114	9.07654	126.1883	1.226	0.63	-0.766	Seniang / 2014-Dec	5-Year
115	9.077234	126.1879	0.95	0	-0.95	Seniang / 2014-Dec	5-Year
116	9.07792	126.1864	0	0	0	Seniang / 2014-Dec	5-Year
117	9.066128	126.1817	0.534	0.86	0.266	Seniang / 2014-Dec	5-Year
118	9.071123	126.1812	1.89	1.37	-1.54	Seniang / 2014-Dec	5-Year
119	9.070238	126.1792	1.391	0.36	-1.391	Seniang / 2014-Dec	5-Year
120	9.058541	126.1723	1.427	0	-1.427	Seniang / 2014-Dec	5-Year
121	9.057149	126.1708	0.994	1.91	0.606	Seniang / 2014-Dec	5-Year
122	9.060011	126.1732	2.059	0.7	-1.019	Seniang / 2014-Dec	5-Year
123	9.061051	126.1753	0	0	0	Seniang / 2014-Dec	5-Year
124	9.061068	126.1759	1.145	0	-1.145	Seniang / 2014-Dec	5-Year
125	9.062307	126.1784	1.588	0.67	-0.658	Seniang / 2014-Dec	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
126	9.062941	126.184	1.87	0.87	-1.87	Seniang / 2014-Dec	5-Year
127	9.060587	126.181	0.632	0.33	-0.632	Seniang / 2014-Dec	5-Year
128	9.065022	126.1806	2.236	1.51	-2.236	Seniang / 2014-Dec	5-Year
129	9.066128	126.1817	0.534	0	-0.534	Seniang / 2014-Dec	5-Year
130	9.066885	126.182	1.179	0.46	-0.979	Seniang / 2014-Dec	5-Year
131	9.083983	126.1687	2.411	0.85	-1.711	Seniang / 2014-Dec	5-Year
132	9.08301	126.1703	0.657	0.54	-0.657	Seniang / 2014-Dec	5-Year
133	9.076951	126.171	2.52	0.53	-1.75	Seniang / 2014-Dec	5-Year
134	9.074975	126.1699	0.987	0.22	-0.987	Seniang / 2014-Dec	5-Year
135	9.070035	126.2014	0.097	0.85	0.883	Seniang / 2014-Dec	5-Year
136	9.064606	126.2013	0	0	0	Seniang / 2014-Dec	5-Year
137	9.065761	126.2011	1.16	1.39	0.23	Seniang / 2014-Dec	5-Year
138	9.066385	126.201	0	0.87	0.88	Seniang / 2014-Dec	5-Year
139	9.06704	126.2014	0.346	1	0.654	Seniang / 2014-Dec	5-Year
140	9.070272	126.1991	0.669	0.47	-0.109	Seniang / 2014-Dec	5-Year
141	9.070035	126.1999	0	0	0	Seniang / 2014-Dec	5-Year
142	9.069177	0	0	0.15	0.15	Seniang / 2014-Dec	5-Year
143	9.069086	126.1979	0.491	1.2	0.709	Seniang / 2014-Dec	5-Year
144	9.069416	126.1977	0.966	1.3	0.334	Seniang / 2014-Dec	5-Year
145	9.076309	126.1942	0.162	1.2	0.838	Seniang / 2014-Dec	5-Year
146	9.074237	126.1961	2.517	1.63	-1.017	Seniang / 2014-Dec	5-Year
147	9.073961	126.1967	0.597	1.4	0.853	Seniang / 2014-Dec	5-Year
148	9.073706	126.1968	0.623	1.1	1.157	Seniang / 2014-Dec	5-Year
149	9.073597	126.1972	0	0.59	0.41	Seniang / 2014-Dec	5-Year
150	9.073183	126.1971	0.364	1.44	0.476	Seniang / 2014-Dec	5-Year
151	9.073498	126.1986	0.477	0.95	-0.047	Seniang / 2014-Dec	5-Year
152	9.073604	126.1992	0.592	0.23	-0.092	Seniang / 2014-Dec	5-Year
153	9.075818	126.1989	0.661	0	-0.661	Seniang / 2014-Dec	5-Year
154	9.077004	126.2005	0.179	0.05	-0.129	Seniang / 2014-Dec	5-Year
155	9.078393	126.1999	0.185	0.2	0.015	Seniang / 2014-Dec	5-Year
156	9.080361	126.1982	0	0	0	Seniang / 2014-Dec	5-Year
157	9.082364	126.1952	0	1.3	1.3	Seniang / 2014-Dec	5-Year
158	9.082775	126.1983	0	0.48	0.48	Seniang / 2014-Dec	5-Year
159	9.082473	126.1954	0	0.59	0.59	Seniang / 2014-Dec	5-Year
160	9.073193	126.183	0.635	0.49	-0.315	Seniang / 2014-Dec	5-Year
161	9.074421	126.1826	1.261	0.4	-0.951	Seniang / 2014-Dec	5-Year
162	9.074508	126.1834	0.643	0.57	-0.323	Seniang / 2014-Dec	5-Year
163	9.068546	126.1894	0	0	0	Seniang / 2014-Dec	5-Year
164	9.054802	126.181	0.242	1.06	0.768	Seniang / 2014-Dec	5-Year
165	9.05447	126.1752	1.012	0	-1.012	Seniang / 2014-Dec	5-Year
166	9.052876	126.1798	0	0	0	Seniang / 2014-Dec	5-Year
167	9.046969	126.1624	2.7	0.12	-2.7	Seniang / 2014-Dec	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
168	9.044089	126.1596	2.112	0.56	-1.102	Seniang / 2014-Dec	5-Year
169	9.051277	126.1641	2.326	1.28	-1.616	Seniang / 2014-Dec	5-Year
170	9.057837	126.1656	0.871	0.16	-0.771	Seniang / 2014-Dec	5-Year
171	9.060935	126.1642	1.142	0	-1.142	Seniang / 2014-Dec	5-Year
172	9.0603	126.1625	0.91	0	-0.91	Seniang / 2014-Dec	5-Year
173	9.061064	126.1598	1.943	26	-1.943	Seniang / 2014-Dec	5-Year
174	9.061031	126.1572	2.568	0.52	-2.568	Seniang / 2014-Dec	5-Year
175	9.081851	126.1727	0	0	0	Seniang / 2014-Dec	5-Year
176	9.069461	126.1693	1.187	0.62	-0.567	Seniang / 2014-Dec	5-Year
177	9.075662	126.1669	1.557	0.36	-1.197	Seniang / 2014-Dec	5-Year
178	9.074536	126.168	0.392	0	-0.392	Seniang / 2014-Dec	5-Year
179	9.059081	126.1655	1.025	0	-1.025	Seniang / 2014-Dec	5-Year
180	9.056679	126.1674	0.867	0.47	-0.867	Seniang / 2014-Dec	5-Year
181	9.075684	126.1968	0	0.1	0	Seniang / 2014-Dec	5-Year
182	9.073387	126.1932	0.235	0	-0.235	Seniang / 2014-Dec	5-Year
183	9.072885	126.1914	0.22	0	-0.22	Seniang / 2014-Dec	5-Year
184	9.073878	126.1924	0	0	0	Seniang / 2014-Dec	5-Year
185	9.073783	126.1942	0.116	0.08	-0.076	Seniang / 2014-Dec	5-Year
186	9.071671	126.193	0.141	0	-0.141	Seniang / 2014-Dec	5-Year
187	9.076604	126.1933	0	0	0	Seniang / 2014-Dec	5-Year
188	9.076448	126.1931	0	0	0	Seniang / 2014-Dec	5-Year
189	9.07622	126.193	2.881	1.1	-1.781	Seniang / 2014-Dec	5-Year
190	9.075664	126.1956	0	1.52	0	Seniang / 2014-Dec	5-Year
191	9.075372	126.1955	0	0.3	0.3	Seniang / 2014-Dec	5-Year
192	9.077281	126.1934	0	0	0	Seniang / 2014-Dec	5-Year
193	9.077661	126.1938	0	0.37	0.15	Seniang / 2014-Dec	5-Year
194	9.079365	126.1507	2.877	1.23	-1.177	Seniang / 2014-Dec	5-Year
195	9.079083	126.1518	1.8	0.62	-1.18	Seniang / 2014-Dec	5-Year
196	9.07683	126.1665	1.769	0.37	-1.399	Seniang / 2014-Dec	5-Year
197	9.071464	126.1647	0.316	0.61	-0.316	Seniang / 2014-Dec	5-Year
198	9.069887	126.1684	0.687	0.72	-0.687	Seniang / 2014-Dec	5-Year
199	9.080512	126.1958	0	1.13	1.42	Seniang / 2014-Dec	5-Year
200	9.079287	126.1955	0	0.2	0.51	Seniang / 2014-Dec	5-Year
201	9.079465	126.1513	2.597	0.6	-2.187	Seniang / 2014-Dec	5-Year
202	9.079685	126.1512	0	0.8	0.64	Seniang / 2014-Dec	5-Year
203	9.063987	126.2009	0.525	1.5	0.975	Agaton / 2014-Jan	25-Year
204	9.049307	126.2006	0	0.27	0.27	Agaton / 2014-Jan	25-Year
205	9.068336	126.2036	0	0	0	Agaton / 2014-Jan	25-Year
206	9.069815	126.2021	0.12	0	-0.12	Agaton / 2014-Jan	25-Year
207	9.066068	126.1675	1.67	0.2	-1.47	Agaton / 2014-Jan	25-Year
208	9.061583	126.1622	1.319	0.32	-0.999	Agaton / 2014-Jan	25-Year
209	9.079567	126.192	0	0	0	Agaton / 2014-Jan	25-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
210	9.078393	126.1917	0	0	0	Agaton / 2014-Jan	25-Year
211	9.077577	126.1907	0.382	0	-0.382	Agaton / 2014-Jan	25-Year
212	9.077392	126.1904	0.18	0	-0.18	Agaton / 2014-Jan	25-Year
213	9.076997	126.19	0.121	0.46	0.339	Agaton / 2014-Jan	25-Year
214	9.076532	126.1887	0.97	0	-0.97	Agaton / 2014-Jan	25-Year
215	9.07654	126.1883	1.644	0.46	-1.184	Agaton / 2014-Jan	25-Year
216	9.077234	126.1879	1.377	0	-1.377	Agaton / 2014-Jan	25-Year
217	9.07792	126.1864	0	0	0	Agaton / 2014-Jan	25-Year
218	9.066128	126.1817	0.899	0.8	-0.099	Agaton / 2014-Jan	25-Year
219	9.071123	126.1812	2.292	0.35	-1.942	Agaton / 2014-Jan	25-Year
220	9.070238	126.1792	1.813	0	-1.813	Agaton / 2014-Jan	25-Year
221	9.058541	126.1723	1.83	0	-1.83	Agaton / 2014-Jan	25-Year
222	9.057149	126.1708	1.394	1.6	0.206	Agaton / 2014-Jan	25-Year
223	9.060011	126.1732	2.443	1.04	-1.403	Agaton / 2014-Jan	25-Year
224	9.061051	126.1753	0	0	0	Agaton / 2014-Jan	25-Year
225	9.061068	126.1759	1.467	0	-1.467	Agaton / 2014-Jan	25-Year
226	9.062307	126.1784	1.966	0.93	-1.036	Agaton / 2014-Jan	25-Year
227	9.062941	126.184	2.266	0	-2.266	Agaton / 2014-Jan	25-Year
228	9.060587	126.181	0.986	0	-0.986	Agaton / 2014-Jan	25-Year
229	9.065022	126.1806	2.617	0	-2.617	Agaton / 2014-Jan	25-Year
230	9.066128	126.1817	0.899	0	-0.899	Agaton / 2014-Jan	25-Year
231	9.066885	126.182	1.551	0.2	-1.351	Agaton / 2014-Jan	25-Year
232	9.083983	126.1687	2.705	0.7	-2.005	Agaton / 2014-Jan	25-Year
233	9.08301	126.1703	0.97	0	-0.97	Agaton / 2014-Jan	25-Year
234	9.076951	126.171	2.951	0.77	-2.181	Agaton / 2014-Jan	25-Year
235	9.074975	126.1699	1.496	0	-1.496	Agaton / 2014-Jan	25-Year
236	9.070035	126.2014	0.112	0.98	0.868	Agaton / 2014-Jan	25-Year
237	9.064606	126.2013	0	0	0	Agaton / 2014-Jan	25-Year
238	9.065761	126.2011	1.278	1.39	0.112	Agaton / 2014-Jan	25-Year
239	9.066385	126.201	0	0.88	0.88	Agaton / 2014-Jan	25-Year
240	9.06704	126.2014	0.466	1	0.534	Agaton / 2014-Jan	25-Year
241	9.070272	126.1991	0.82	0.56	-0.26	Agaton / 2014-Jan	25-Year
242	9.070035	126.1999	0	0	0	Agaton / 2014-Jan	25-Year
243	9.069177	0	0	0.15	0.15	Agaton / 2014-Jan	25-Year
244	9.069086	126.1979	0.641	1.2	0.559	Agaton / 2014-Jan	25-Year
245	9.069416	126.1977	1.119	1.3	0.181	Agaton / 2014-Jan	25-Year
246	9.076309	126.1942	0.438	1	0.562	Agaton / 2014-Jan	25-Year
247	9.074237	126.1961	2.82	1.5	-1.32	Agaton / 2014-Jan	25-Year
248	9.073961	126.1967	0.905	1.45	0.545	Agaton / 2014-Jan	25-Year
249	9.073706	126.1968	0.933	1.78	0.847	Agaton / 2014-Jan	25-Year
250	9.073597	126.1972	0.243	0.41	0.167	Agaton / 2014-Jan	25-Year
251	9.073183	126.1971	0.674	0.84	0.166	Agaton / 2014-Jan	25-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
252	9.073498	126.1986	0.61	0.43	-0.18	Agaton / 2014-Jan	25-Year
253	9.073604	126.1992	0.725	0.5	-0.225	Agaton / 2014-Jan	25-Year
254	9.075818	126.1989	0.703	0	-0.703	Agaton / 2014-Jan	25-Year
255	9.077004	126.2005	0.2	0.05	-0.15	Agaton / 2014-Jan	25-Year
256	9.078393	126.1999	0.219	0.2	-0.019	Agaton / 2014-Jan	25-Year
257	9.080361	126.1982	0	0	0	Agaton / 2014-Jan	25-Year
258	9.082364	126.1952	0	1.3	1.3	Agaton / 2014-Jan	25-Year
259	9.082775	126.1983	0	0.48	0.48	Agaton / 2014-Jan	25-Year
260	9.082473	126.1954	0	0.59	0.59	Agaton / 2014-Jan	25-Year
261	9.073193	126.183	0.984	0.32	-0.664	Agaton / 2014-Jan	25-Year
262	9.074421	126.1826	1.586	0.31	-1.276	Agaton / 2014-Jan	25-Year
263	9.074508	126.1834	0.939	0.32	-0.619	Agaton / 2014-Jan	25-Year
264	9.068546	126.1894	0	0	0	Agaton / 2014-Jan	25-Year
265	9.054802	126.181	0.28	1.01	0.73	Agaton / 2014-Jan	25-Year
266	9.05447	126.1752	1.405	0	-1.405	Agaton / 2014-Jan	25-Year
267	9.052876	126.1798	0	0	0	Agaton / 2014-Jan	25-Year
268	9.046969	126.1624	3.046	0	-3.046	Agaton / 2014-Jan	25-Year
269	9.044089	126.1596	2.462	1.01	-1.452	Agaton / 2014-Jan	25-Year
270	9.051277	126.1641	2.67	0.71	-1.96	Agaton / 2014-Jan	25-Year
271	9.057837	126.1656	1.131	0.1	-1.031	Agaton / 2014-Jan	25-Year
272	9.060935	126.1642	1.566	0	-1.566	Agaton / 2014-Jan	25-Year
273	9.0603	126.1625	1.194	0	-1.194	Agaton / 2014-Jan	25-Year
274	9.061064	126.1598	2.346	0	-2.346	Agaton / 2014-Jan	25-Year
275	9.061031	126.1572	2.992	0	-2.992	Agaton / 2014-Jan	25-Year
276	9.081851	126.1727	0	0	0	Agaton / 2014-Jan	25-Year
277	9.069461	126.1693	1.562	0.62	-0.942	Agaton / 2014-Jan	25-Year
278	9.075662	126.1669	2.02	0.36	-1.66	Agaton / 2014-Jan	25-Year
279	9.074536	126.168	0.89	0	-0.89	Agaton / 2014-Jan	25-Year
280	9.059081	126.1655	1.403	0	-1.403	Agaton / 2014-Jan	25-Year
281	9.056679	126.1674	1.218	0	-1.218	Agaton / 2014-Jan	25-Year
282	9.075684	126.1968	0	0	0	Agaton / 2014-Jan	25-Year
283	9.073387	126.1932	0.266	0	-0.266	Agaton / 2014-Jan	25-Year
284	9.072885	126.1914	0.249	0	-0.249	Agaton / 2014-Jan	25-Year
285	9.073878	126.1924	0	0	0	Agaton / 2014-Jan	25-Year
286	9.073783	126.1942	0.132	0.04	-0.092	Agaton / 2014-Jan	25-Year
287	9.071671	126.193	0.159	0	-0.159	Agaton / 2014-Jan	25-Year
288	9.076604	126.1933	0	0	0	Agaton / 2014-Jan	25-Year
289	9.076448	126.1931	0	0	0	Agaton / 2014-Jan	25-Year
290	9.07622	126.193	3.35	1.1	-2.25	Agaton / 2014-Jan	25-Year
291	9.075664	126.1956	0.194	0	-0.194	Agaton / 2014-Jan	25-Year
292	9.075372	126.1955	0	0.3	0.3	Agaton / 2014-Jan	25-Year
293	9.077281	126.1934	0	0	0	Agaton / 2014-Jan	25-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
294	9.077661	126.1938	0	0.15	0.15	Agaton / 2014-Jan	25-Year
295	9.079365	126.1507	3.216	1.7	-1.516	Agaton / 2014-Jan	25-Year
296	9.079083	126.1518	2.128	0.62	-1.508	Agaton / 2014-Jan	25-Year
297	9.07683	126.1665	2.2	0.37	-1.83	Agaton / 2014-Jan	25-Year
298	9.071464	126.1647	0.549	0	-0.549	Agaton / 2014-Jan	25-Year
299	9.069887	126.1684	1.094	0	-1.094	Agaton / 2014-Jan	25-Year
300	9.080512	126.1958	0	1.42	1.42	Agaton / 2014-Jan	25-Year
301	9.079287	126.1955	0	0.51	0.51	Agaton / 2014-Jan	25-Year
302	9.079465	126.1513	2.928	0.41	-2.518	Agaton / 2014-Jan	25-Year
303	9.079685	126.1512	0.269	0.64	0.371	Agaton / 2014-Jan	25-Year
304	9.063987	126.2009	0.326	1.94	1.614	Seniang / 2014-Dec	25-Year
305	9.049307	126.2006	0	0.49	0.49	Seniang / 2014-Dec	25-Year
306	9.068336	126.2036	0	0	0	Seniang / 2014-Dec	25-Year
307	9.069815	126.2021	0	0	0	Seniang / 2014-Dec	25-Year
308	9.066068	126.1675	0.669	0.37	-0.299	Seniang / 2014-Dec	25-Year
309	9.061583	126.1622	0.67	0.32	-0.35	Seniang / 2014-Dec	25-Year
310	9.079567	126.192	0	0	0	Seniang / 2014-Dec	25-Year
311	9.078393	126.1917	0	0	0	Seniang / 2014-Dec	25-Year
312	9.077577	126.1907	0.139	0.61	0.471	Seniang / 2014-Dec	25-Year
313	9.077392	126.1904	0	0.61	0.61	Seniang / 2014-Dec	25-Year
314	9.076997	126.19	0	0.85	0.85	Seniang / 2014-Dec	25-Year
315	9.076532	126.1887	0	0.46	0.46	Seniang / 2014-Dec	25-Year
316	9.07654	126.1883	0.238	0.63	0.392	Seniang / 2014-Dec	25-Year
317	9.077234	126.1879	0	0	0	Seniang / 2014-Dec	25-Year
318	9.07792	126.1864	0	0	0	Seniang / 2014-Dec	25-Year
319	9.066128	126.1817	0	0.86	0.86	Seniang / 2014-Dec	25-Year
320	9.071123	126.1812	1.283	1.37	0.087	Seniang / 2014-Dec	25-Year
321	9.070238	126.1792	0.745	0.36	-0.385	Seniang / 2014-Dec	25-Year
322	9.058541	126.1723	0.845	0	-0.845	Seniang / 2014-Dec	25-Year
323	9.057149	126.1708	0.474	1.91	1.436	Seniang / 2014-Dec	25-Year
324	9.060011	126.1732	1.49	0.7	-0.79	Seniang / 2014-Dec	25-Year
325	9.061051	126.1753	0	0	0	Seniang / 2014-Dec	25-Year
326	9.061068	126.1759	0.705	0	-0.705	Seniang / 2014-Dec	25-Year
327	9.062307	126.1784	1.094	0.67	-0.424	Seniang / 2014-Dec	25-Year
328	9.062941	126.184	1.289	0.87	-0.419	Seniang / 2014-Dec	25-Year
329	9.060587	126.181	0	0.33	0.33	Seniang / 2014-Dec	25-Year
330	9.065022	126.1806	1.667	1.51	-0.157	Seniang / 2014-Dec	25-Year
331	9.066128	126.1817	0	0	0	Seniang / 2014-Dec	25-Year
332	9.066885	126.182	0.608	0.46	-0.148	Seniang / 2014-Dec	25-Year
333	9.083983	126.1687	1.937	0.85	-1.087	Seniang / 2014-Dec	25-Year
334	9.08301	126.1703	0.136	0.54	0.404	Seniang / 2014-Dec	25-Year
335	9.076951	126.171	1.809	0.53	-1.279	Seniang / 2014-Dec	25-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
336	9.074975	126.1699	0.162	0.22	0.058	Seniang / 2014-Dec	25-Year
337	9.070035	126.2014	0	0.85	0.85	Seniang / 2014-Dec	25-Year
338	9.064606	126.2013	0	0	0	Seniang / 2014-Dec	25-Year
339	9.065761	126.2011	0.875	1.39	0.515	Seniang / 2014-Dec	25-Year
340	9.066385	126.201	0	0.87	0.87	Seniang / 2014-Dec	25-Year
341	9.06704	126.2014	0	1	1	Seniang / 2014-Dec	25-Year
342	9.070272	126.1991	0.434	0.47	0.036	Seniang / 2014-Dec	25-Year
343	9.070035	126.1999	0	0	0	Seniang / 2014-Dec	25-Year
344	9.069177	0	0	0.15	0.15	Seniang / 2014-Dec	25-Year
345	9.069086	126.1979	0.255	1.2	0.945	Seniang / 2014-Dec	25-Year
346	9.069416	126.1977	0.732	1.3	0.568	Seniang / 2014-Dec	25-Year
347	9.076309	126.1942	0.139	1.2	1.061	Seniang / 2014-Dec	25-Year
348	9.074237	126.1961	1.974	1.63	-0.344	Seniang / 2014-Dec	25-Year
349	9.073961	126.1967	0.156	1.4	1.244	Seniang / 2014-Dec	25-Year
350	9.073706	126.1968	0.164	1.1	0.936	Seniang / 2014-Dec	25-Year
351	9.073597	126.1972	0	0.59	0.59	Seniang / 2014-Dec	25-Year
352	9.073183	126.1971	0	1.44	1.44	Seniang / 2014-Dec	25-Year
353	9.073498	126.1986	0.174	0.95	0.776	Seniang / 2014-Dec	25-Year
354	9.073604	126.1992	0.288	0.23	-0.058	Seniang / 2014-Dec	25-Year
355	9.075818	126.1989	0.58	0	-0.58	Seniang / 2014-Dec	25-Year
356	9.077004	126.2005	0.143	0.05	-0.093	Seniang / 2014-Dec	25-Year
357	9.078393	126.1999	0.167	0.2	0.033	Seniang / 2014-Dec	25-Year
358	9.080361	126.1982	0	0	0	Seniang / 2014-Dec	25-Year
359	9.082364	126.1952	0	1.3	1.3	Seniang / 2014-Dec	25-Year
360	9.082775	126.1983	0	0.48	0.48	Seniang / 2014-Dec	25-Year
361	9.082473	126.1954	0	0.59	0.59	Seniang / 2014-Dec	25-Year
362	9.073193	126.183	0.164	0.49	0.326	Seniang / 2014-Dec	25-Year
363	9.074421	126.1826	0.808	0.4	-0.408	Seniang / 2014-Dec	25-Year
364	9.074508	126.1834	0.238	0.57	0.332	Seniang / 2014-Dec	25-Year
365	9.068546	126.1894	0	0	0	Seniang / 2014-Dec	25-Year
366	9.054802	126.181	0.184	1.06	0.876	Seniang / 2014-Dec	25-Year
367	9.05447	126.1752	0.436	0	-0.436	Seniang / 2014-Dec	25-Year
368	9.052876	126.1798	0	0	0	Seniang / 2014-Dec	25-Year
369	9.046969	126.1624	2.195	0.12	-2.075	Seniang / 2014-Dec	25-Year
370	9.044089	126.1596	1.599	0.56	-1.039	Seniang / 2014-Dec	25-Year
371	9.051277	126.1641	1.833	1.28	-0.553	Seniang / 2014-Dec	25-Year
372	9.057837	126.1656	0.536	0.16	-0.376	Seniang / 2014-Dec	25-Year
373	9.060935	126.1642	0.636	0	-0.636	Seniang / 2014-Dec	25-Year
374	9.0603	126.1625	0.474	0	-0.474	Seniang / 2014-Dec	25-Year
375	9.061064	126.1598	1.408	26	24.592	Seniang / 2014-Dec	25-Year
376	9.061031	126.1572	1.982	0.52	-1.462	Seniang / 2014-Dec	25-Year
377	9.081851	126.1727	0	0	0	Seniang / 2014-Dec	25-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
378	9.069461	126.1693	0.739	0.62	-0.119	Seniang / 2014-Dec	25-Year
379	9.075662	126.1669	0.811	0.36	-0.451	Seniang / 2014-Dec	25-Year
380	9.074536	126.168	0	0	0	Seniang / 2014-Dec	25-Year
381	9.059081	126.1655	0.66	0	-0.66	Seniang / 2014-Dec	25-Year
382	9.056679	126.1674	0.52	0.47	-0.05	Seniang / 2014-Dec	25-Year
383	9.075684	126.1968	0	0.1	0.1	Seniang / 2014-Dec	25-Year
384	9.073387	126.1932	0.194	0	-0.194	Seniang / 2014-Dec	25-Year
385	9.072885	126.1914	0.188	0	-0.188	Seniang / 2014-Dec	25-Year
386	9.073878	126.1924	0	0	0	Seniang / 2014-Dec	25-Year
387	9.073783	126.1942	0.095	0.08	-0.015	Seniang / 2014-Dec	25-Year
388	9.071671	126.193	0.121	0	-0.121	Seniang / 2014-Dec	25-Year
389	9.076604	126.1933	0	0	0	Seniang / 2014-Dec	25-Year
390	9.076448	126.1931	0	0	0	Seniang / 2014-Dec	25-Year
391	9.07622	126.193	2.137	1.1	-1.037	Seniang / 2014-Dec	25-Year
392	9.075664	126.1956	0	1.52	1.52	Seniang / 2014-Dec	25-Year
393	9.075372	126.1955	0	0.3	0.3	Seniang / 2014-Dec	25-Year
394	9.077281	126.1934	0	0	0	Seniang / 2014-Dec	25-Year
395	9.077661	126.1938	0	0.37	0.37	Seniang / 2014-Dec	25-Year
396	9.079365	126.1507	2.455	1.23	-1.225	Seniang / 2014-Dec	25-Year
397	9.079083	126.1518	1.364	0.62	-0.744	Seniang / 2014-Dec	25-Year
398	9.07683	126.1665	1.056	0.37	-0.686	Seniang / 2014-Dec	25-Year
399	9.071464	126.1647	0.294	0.61	0.316	Seniang / 2014-Dec	25-Year
400	9.069887	126.1684	0.203	0.72	0.517	Seniang / 2014-Dec	25-Year
401	9.080512	126.1958	0	1.13	1.13	Seniang / 2014-Dec	25-Year
402	9.079287	126.1955	0	0.2	0.2	Seniang / 2014-Dec	25-Year
403	9.079465	126.1513	2.161	0.6	-1.561	Seniang / 2014-Dec	25-Year
404	9.079685	126.1512	0	0.8	0.8	Seniang / 2014-Dec	25-Year
405	9.063987	126.2009	0.44	1.5	1.5	Agaton / 2014-Jan	100-Year
406	9.049307	126.2006	0	0.27	0.49	Agaton / 2014-Jan	100-Year
407	9.068336	126.2036	0	0	0	Agaton / 2014-Jan	100-Year
408	9.069815	126.2021	0.104	0	-0.104	Agaton / 2014-Jan	100-Year
409	9.066068	126.1675	1.271	0.2	-0.901	Agaton / 2014-Jan	100-Year
410	9.061583	126.1622	1.024	0.32	-0.704	Agaton / 2014-Jan	100-Year
411	9.079567	126.192	0	0	0	Agaton / 2014-Jan	100-Year
412	9.078393	126.1917	0	0	0	Agaton / 2014-Jan	100-Year
413	9.077577	126.1907	0.207	0	0.403	Agaton / 2014-Jan	100-Year
414	9.077392	126.1904	0	0	0.61	Agaton / 2014-Jan	100-Year
415	9.076997	126.19	0	0.46	0.85	Agaton / 2014-Jan	100-Year
416	9.076532	126.1887	0.582	0	-0.122	Agaton / 2014-Jan	100-Year
417	9.07654	126.1883	1.226	0.46	-0.596	Agaton / 2014-Jan	100-Year
418	9.077234	126.1879	0.95	0	-0.95	Agaton / 2014-Jan	100-Year
419	9.07792	126.1864	0	0	0	Agaton / 2014-Jan	100-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
420	9.066128	126.1817	0.534	0.8	0.326	Agaton / 2014-Jan	100-Year
421	9.071123	126.1812	1.89	0.35	-0.52	Agaton / 2014-Jan	100-Year
422	9.070238	126.1792	1.391	0	-1.031	Agaton / 2014-Jan	100-Year
423	9.058541	126.1723	1.427	0	-1.427	Agaton / 2014-Jan	100-Year
424	9.057149	126.1708	0.994	1.6	0.916	Agaton / 2014-Jan	100-Year
425	9.060011	126.1732	2.059	1.04	-1.359	Agaton / 2014-Jan	100-Year
426	9.061051	126.1753	0	0	0	Agaton / 2014-Jan	100-Year
427	9.061068	126.1759	1.145	0	-1.145	Agaton / 2014-Jan	100-Year
428	9.062307	126.1784	1.588	0.93	-0.918	Agaton / 2014-Jan	100-Year
429	9.062941	126.184	1.87	0	-1	Agaton / 2014-Jan	100-Year
430	9.060587	126.181	0.632	0	-0.302	Agaton / 2014-Jan	100-Year
431	9.065022	126.1806	2.236	0	-0.726	Agaton / 2014-Jan	100-Year
432	9.066128	126.1817	0.534	0	-0.534	Agaton / 2014-Jan	100-Year
433	9.066885	126.182	1.179	0.2	-0.719	Agaton / 2014-Jan	100-Year
434	9.083983	126.1687	2.411	0.7	-1.561	Agaton / 2014-Jan	100-Year
435	9.08301	126.1703	0.657	0	-0.117	Agaton / 2014-Jan	100-Year
436	9.076951	126.171	2.52	0.77	-1.99	Agaton / 2014-Jan	100-Year
437	9.074975	126.1699	0.987	0	-0.767	Agaton / 2014-Jan	100-Year
438	9.070035	126.2014	0.097	0.98	0.753	Agaton / 2014-Jan	100-Year
439	9.064606	126.2013	0	0	0	Agaton / 2014-Jan	100-Year
440	9.065761	126.2011	1.16	1.39	0.23	Agaton / 2014-Jan	100-Year
441	9.066385	126.201	0	0.88	0.87	Agaton / 2014-Jan	100-Year
442	9.06704	126.2014	0.346	1	0.654	Agaton / 2014-Jan	100-Year
443	9.070272	126.1991	0.669	0.56	-0.199	Agaton / 2014-Jan	100-Year
444	9.070035	126.1999	0	0	0	Agaton / 2014-Jan	100-Year
445	9.069177	0	0	0.15	0.15	Agaton / 2014-Jan	100-Year
446	9.069086	126.1979	0.491	1.2	0.709	Agaton / 2014-Jan	100-Year
447	9.069416	126.1977	0.966	1.3	0.334	Agaton / 2014-Jan	100-Year
448	9.076309	126.1942	0.162	1	1.038	Agaton / 2014-Jan	100-Year
449	9.074237	126.1961	2.517	1.5	-0.887	Agaton / 2014-Jan	100-Year
450	9.073961	126.1967	0.597	1.45	0.803	Agaton / 2014-Jan	100-Year
451	9.073706	126.1968	0.623	1.78	0.477	Agaton / 2014-Jan	100-Year
452	9.073597	126.1972	0	0.41	0.59	Agaton / 2014-Jan	100-Year
453	9.073183	126.1971	0.364	0.84	1.076	Agaton / 2014-Jan	100-Year
454	9.073498	126.1986	0.477	0.43	0.473	Agaton / 2014-Jan	100-Year
455	9.073604	126.1992	0.592	0.5	-0.362	Agaton / 2014-Jan	100-Year
456	9.075818	126.1989	0.661	0	-0.661	Agaton / 2014-Jan	100-Year
457	9.077004	126.2005	0.179	0.05	-0.129	Agaton / 2014-Jan	100-Year
458	9.078393	126.1999	0.185	0.2	0.015	Agaton / 2014-Jan	100-Year
459	9.080361	126.1982	0	0	0	Agaton / 2014-Jan	100-Year
460	9.082364	126.1952	0	1.3	1.3	Agaton / 2014-Jan	100-Year
461	9.082775	126.1983	0	0.48	0.48	Agaton / 2014-Jan	100-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
462	9.082473	126.1954	0	0.59	0.59	Agaton / 2014-Jan	100-Year
463	9.073193	126.183	0.635	0.32	-0.145	Agaton / 2014-Jan	100-Year
464	9.074421	126.1826	1.261	0.31	-0.861	Agaton / 2014-Jan	100-Year
465	9.074508	126.1834	0.643	0.32	-0.073	Agaton / 2014-Jan	100-Year
466	9.068546	126.1894	0	0	0	Agaton / 2014-Jan	100-Year
467	9.054802	126.181	0.242	1.01	0.818	Agaton / 2014-Jan	100-Year
468	9.05447	126.1752	1.012	0	-1.012	Agaton / 2014-Jan	100-Year
469	9.052876	126.1798	0	0	0	Agaton / 2014-Jan	100-Year
470	9.046969	126.1624	2.7	0	-2.58	Agaton / 2014-Jan	100-Year
471	9.044089	126.1596	2.112	1.01	-1.552	Agaton / 2014-Jan	100-Year
472	9.051277	126.1641	2.326	0.71	-1.046	Agaton / 2014-Jan	100-Year
473	9.057837	126.1656	0.871	0.1	-0.711	Agaton / 2014-Jan	100-Year
474	9.060935	126.1642	1.142	0	-1.142	Agaton / 2014-Jan	100-Year
475	9.0603	126.1625	0.91	0	-0.91	Agaton / 2014-Jan	100-Year
476	9.061064	126.1598	1.943	0	24.057	Agaton / 2014-Jan	100-Year
477	9.061031	126.1572	2.568	0	-2.048	Agaton / 2014-Jan	100-Year
478	9.081851	126.1727	0	0	0	Agaton / 2014-Jan	100-Year
479	9.069461	126.1693	1.187	0.62	-0.567	Agaton / 2014-Jan	100-Year
480	9.075662	126.1669	1.557	0.36	-1.197	Agaton / 2014-Jan	100-Year
481	9.074536	126.168	0.392	0	-0.392	Agaton / 2014-Jan	100-Year
482	9.059081	126.1655	1.025	0	-1.025	Agaton / 2014-Jan	100-Year
483	9.056679	126.1674	0.867	0	-0.397	Agaton / 2014-Jan	100-Year
484	9.075684	126.1968	0	0	0.1	Agaton / 2014-Jan	100-Year
485	9.073387	126.1932	0.235	0	-0.235	Agaton / 2014-Jan	100-Year
486	9.072885	126.1914	0.22	0	-0.22	Agaton / 2014-Jan	100-Year
487	9.073878	126.1924	0	0	0	Agaton / 2014-Jan	100-Year
488	9.073783	126.1942	0.116	0.04	-0.036	Agaton / 2014-Jan	100-Year
489	9.071671	126.193	0.141	0	-0.141	Agaton / 2014-Jan	100-Year
490	9.076604	126.1933	0	0	0	Agaton / 2014-Jan	100-Year
491	9.076448	126.1931	0	0	0	Agaton / 2014-Jan	100-Year
492	9.07622	126.193	2.881	1.1	-1.781	Agaton / 2014-Jan	100-Year
493	9.075664	126.1956	0	0	1.52	Agaton / 2014-Jan	100-Year
494	9.075372	126.1955	0	0.3	0.3	Agaton / 2014-Jan	100-Year
495	9.077281	126.1934	0	0	0	Agaton / 2014-Jan	100-Year
496	9.077661	126.1938	0	0.15	0.37	Agaton / 2014-Jan	100-Year
497	9.079365	126.1507	2.877	1.7	-1.647	Agaton / 2014-Jan	100-Year
498	9.079083	126.1518	1.8	0.62	-1.18	Agaton / 2014-Jan	100-Year
499	9.07683	126.1665	1.769	0.37	-1.399	Agaton / 2014-Jan	100-Year
500	9.071464	126.1647	0.316	0	0.294	Agaton / 2014-Jan	100-Year
501	9.069887	126.1684	0.687	0	0.033	Agaton / 2014-Jan	100-Year
502	9.080512	126.1958	0	1.42	1.13	Agaton / 2014-Jan	100-Year
503	9.079287	126.1955	0	0.51	0.2	Agaton / 2014-Jan	100-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
504	9.079465	126.1513	2.597	0.41	-1.997	Agaton / 2014-Jan	100-Year
505	9.079685	126.1512	0	0.64	0.8	Agaton / 2014-Jan	100-Year
506	9.063987	126.2009	0.525	1.94	1.415	Seniang / 2014-Dec	100-Year
507	9.049307	126.2006	0	0.49	0.49	Seniang / 2014-Dec	100-Year
508	9.068336	126.2036	0	0	0	Seniang / 2014-Dec	100-Year
509	9.069815	126.2021	0.12	0	-0.12	Seniang / 2014-Dec	100-Year
510	9.066068	126.1675	1.67	0.37	-1.3	Seniang / 2014-Dec	100-Year
511	9.061583	126.1622	1.319	0.32	-0.999	Seniang / 2014-Dec	100-Year
512	9.079567	126.192	0	0	0	Seniang / 2014-Dec	100-Year
513	9.078393	126.1917	0	0	0	Seniang / 2014-Dec	100-Year
514	9.077577	126.1907	0.382	0.61	0.228	Seniang / 2014-Dec	100-Year
515	9.077392	126.1904	0.18	0.61	0.43	Seniang / 2014-Dec	100-Year
516	9.076997	126.19	0.121	0.85	0.729	Seniang / 2014-Dec	100-Year
517	9.076532	126.1887	0.97	0.46	-0.51	Seniang / 2014-Dec	100-Year
518	9.07654	126.1883	1.644	0.63	-1.014	Seniang / 2014-Dec	100-Year
519	9.077234	126.1879	1.377	0	-1.377	Seniang / 2014-Dec	100-Year
520	9.07792	126.1864	0	0	0	Seniang / 2014-Dec	100-Year
521	9.066128	126.1817	0.899	0.86	-0.039	Seniang / 2014-Dec	100-Year
522	9.071123	126.1812	2.292	1.37	-0.922	Seniang / 2014-Dec	100-Year
523	9.070238	126.1792	1.813	0.36	-1.453	Seniang / 2014-Dec	100-Year
524	9.058541	126.1723	1.83	0	-1.83	Seniang / 2014-Dec	100-Year
525	9.057149	126.1708	1.394	1.91	0.516	Seniang / 2014-Dec	100-Year
526	9.060011	126.1732	2.443	0.7	-1.743	Seniang / 2014-Dec	100-Year
527	9.061051	126.1753	0	0	0	Seniang / 2014-Dec	100-Year
528	9.061068	126.1759	1.467	0	-1.467	Seniang / 2014-Dec	100-Year
529	9.062307	126.1784	1.966	0.67	-1.296	Seniang / 2014-Dec	100-Year
530	9.062941	126.184	2.266	0.87	-1.396	Seniang / 2014-Dec	100-Year
531	9.060587	126.181	0.986	0.33	-0.656	Seniang / 2014-Dec	100-Year
532	9.065022	126.1806	2.617	1.51	-1.107	Seniang / 2014-Dec	100-Year
533	9.066128	126.1817	0.899	0	-0.899	Seniang / 2014-Dec	100-Year
534	9.066885	126.182	1.551	0.46	-1.091	Seniang / 2014-Dec	100-Year
535	9.083983	126.1687	2.705	0.85	-1.855	Seniang / 2014-Dec	100-Year
536	9.08301	126.1703	0.97	0.54	-0.43	Seniang / 2014-Dec	100-Year
537	9.076951	126.171	2.951	0.53	-2.421	Seniang / 2014-Dec	100-Year
538	9.074975	126.1699	1.496	0.22	-1.276	Seniang / 2014-Dec	100-Year
539	9.070035	126.2014	0.112	0.85	0.738	Seniang / 2014-Dec	100-Year
540	9.064606	126.2013	0	0	0	Seniang / 2014-Dec	100-Year
541	9.065761	126.2011	1.278	1.39	0.112	Seniang / 2014-Dec	100-Year
542	9.066385	126.201	0	0.87	0.87	Seniang / 2014-Dec	100-Year
543	9.06704	126.2014	0.466	1	0.534	Seniang / 2014-Dec	100-Year
544	9.070272	126.1991	0.82	0.47	-0.35	Seniang / 2014-Dec	100-Year
545	9.070035	126.1999	0	0	0	Seniang / 2014-Dec	100-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
546	9.069177	0	0	0.15	0.15	Seniang / 2014-Dec	100-Year
547	9.069086	126.1979	0.641	1.2	0.559	Seniang / 2014-Dec	100-Year
548	9.069416	126.1977	1.119	1.3	0.181	Seniang / 2014-Dec	100-Year
549	9.076309	126.1942	0.438	1.2	0.762	Seniang / 2014-Dec	100-Year
550	9.074237	126.1961	2.82	1.63	-1.19	Seniang / 2014-Dec	100-Year
551	9.073961	126.1967	0.905	1.4	0.495	Seniang / 2014-Dec	100-Year
552	9.073706	126.1968	0.933	1.1	0.167	Seniang / 2014-Dec	100-Year
553	9.073597	126.1972	0.243	0.59	0.347	Seniang / 2014-Dec	100-Year
554	9.073183	126.1971	0.674	1.44	0.766	Seniang / 2014-Dec	100-Year
555	9.073498	126.1986	0.61	0.95	0.34	Seniang / 2014-Dec	100-Year
556	9.073604	126.1992	0.725	0.23	-0.495	Seniang / 2014-Dec	100-Year
557	9.075818	126.1989	0.703	0	-0.703	Seniang / 2014-Dec	100-Year
558	9.077004	126.2005	0.2	0.05	-0.15	Seniang / 2014-Dec	100-Year
559	9.078393	126.1999	0.219	0.2	-0.019	Seniang / 2014-Dec	100-Year
560	9.080361	126.1982	0	0	0	Seniang / 2014-Dec	100-Year
561	9.082364	126.1952	0	1.3	1.3	Seniang / 2014-Dec	100-Year
562	9.082775	126.1983	0	0.48	0.48	Seniang / 2014-Dec	100-Year
563	9.082473	126.1954	0	0.59	0.59	Seniang / 2014-Dec	100-Year
564	9.073193	126.183	0.984	0.49	-0.494	Seniang / 2014-Dec	100-Year
565	9.074421	126.1826	1.586	0.4	-1.186	Seniang / 2014-Dec	100-Year
566	9.074508	126.1834	0.939	0.57	-0.369	Seniang / 2014-Dec	100-Year
567	9.068546	126.1894	0	0	0	Seniang / 2014-Dec	100-Year
568	9.054802	126.181	0.28	1.06	0.78	Seniang / 2014-Dec	100-Year
569	9.05447	126.1752	1.405	0	-1.405	Seniang / 2014-Dec	100-Year
570	9.052876	126.1798	0	0	0	Seniang / 2014-Dec	100-Year
571	9.046969	126.1624	3.046	0.12	-2.926	Seniang / 2014-Dec	100-Year
572	9.044089	126.1596	2.462	0.56	-1.902	Seniang / 2014-Dec	100-Year
573	9.051277	126.1641	2.67	1.28	-1.39	Seniang / 2014-Dec	100-Year
574	9.057837	126.1656	1.131	0.16	-0.971	Seniang / 2014-Dec	100-Year
575	9.060935	126.1642	1.566	0	-1.566	Seniang / 2014-Dec	100-Year
576	9.0603	126.1625	1.194	0	-1.194	Seniang / 2014-Dec	100-Year
577	9.061064	126.1598	2.346	26	23.654	Seniang / 2014-Dec	100-Year
578	9.061031	126.1572	2.992	0.52	-2.472	Seniang / 2014-Dec	100-Year
579	9.081851	126.1727	0	0	0	Seniang / 2014-Dec	100-Year
580	9.069461	126.1693	1.562	0.62	-0.942	Seniang / 2014-Dec	100-Year
581	9.075662	126.1669	2.02	0.36	-1.66	Seniang / 2014-Dec	100-Year
582	9.074536	126.168	0.89	0	-0.89	Seniang / 2014-Dec	100-Year
583	9.059081	126.1655	1.403	0	-1.403	Seniang / 2014-Dec	100-Year
584	9.056679	126.1674	1.218	0.47	-0.748	Seniang / 2014-Dec	100-Year
585	9.075684	126.1968	0	0.1	0.1	Seniang / 2014-Dec	100-Year
586	9.073387	126.1932	0.266	0	-0.266	Seniang / 2014-Dec	100-Year
587	9.072885	126.1914	0.249	0	-0.249	Seniang / 2014-Dec	100-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
588	9.073878	126.1924	0	0	0	Seniang / 2014-Dec	100-Year
589	9.073783	126.1942	0.132	0.08	-0.052	Seniang / 2014-Dec	100-Year
590	9.071671	126.193	0.159	0	-0.159	Seniang / 2014-Dec	100-Year
591	9.076604	126.1933	0	0	0	Seniang / 2014-Dec	100-Year
592	9.076448	126.1931	0	0	0	Seniang / 2014-Dec	100-Year
593	9.07622	126.193	3.35	1.1	-2.25	Seniang / 2014-Dec	100-Year
594	9.075664	126.1956	0.194	1.52	1.326	Seniang / 2014-Dec	100-Year
595	9.075372	126.1955	0	0.3	0.3	Seniang / 2014-Dec	100-Year
596	9.077281	126.1934	0	0	0	Seniang / 2014-Dec	100-Year
597	9.077661	126.1938	0	0.37	0.37	Seniang / 2014-Dec	100-Year
598	9.079365	126.1507	3.216	1.23	-1.986	Seniang / 2014-Dec	100-Year
599	9.079083	126.1518	2.128	0.62	-1.508	Seniang / 2014-Dec	100-Year
600	9.07683	126.1665	2.2	0.37	-1.83	Seniang / 2014-Dec	100-Year
601	9.071464	126.1647	0.549	0.61	0.061	Seniang / 2014-Dec	100-Year
602	9.069887	126.1684	1.094	0.72	-0.374	Seniang / 2014-Dec	100-Year
603	9.080512	126.1958	0	1.13	1.13	Seniang / 2014-Dec	100-Year
604	9.079287	126.1955	0	0.2	0.2	Seniang / 2014-Dec	100-Year
605	9.079465	126.1513	2.928	0.6	-2.328	Seniang / 2014-Dec	100-Year
606	9.079685	126.1512	0.269	0.8	0.531	Seniang / 2014-Dec	100-Year

ANNEX 12. Educational Institutions Affected by Flooding in Tandag Floodplain

Table A-12.1. Educational Institutions Affected by Flooding in Tandan Floodplain

Surigao del SurSurigao del Sur				
Tandag City				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Awasian Elementary School	Awasian	Medium	Medium	Medium
Sain Peregrine Learning Center	Bagong Lungsod			
Tandag Central Elementary School	Bagong Lungsod	Low	Low	Low
Bioto Elementary School	Bioto	Medium	Medium	Medium
Bongtud Elementary School	Bongtod Poblacion			
St. Theresa College	Bongtod Poblacion			
Bongtud Elementary School	Dagocdoc			
St. Theresa College	Dagocdoc			
Telaje Elementary School	Dagocdoc			
San Isidro Elementary School	Maticdum			
Quezon Elementary School	Quezon	Medium	Medium	Medium
Tandag National Science High School	Quezon	Medium	Medium	Medium
Vicente Pimentel National High School	Quezon	Medium	Medium	Medium
Engr. Nestor Ty Memorial Elementary School	San Agustin Sur			
ANNEX Engr. Nestor Ty Memorial Elementary School	San Agustin Sur			
San Isidro Elementary School	San Isidro	High	High	High
San Jose Elementary School	San Jose			
Jacinto P. Elpa National High School	Telaje	Low	Low	Low
Quintos Elementary School	Telaje			
Saint Thomas Mentoring Center	Telaje			
Tandag Christian School	Telaje			
Telaje Elementary School	Telaje			

ANNEX 13. Health Institutions Affected by Flooding in Tandag Floodplain

Table A-13.1. Health Institutions Affected by Flooding in Tandag Floodplain

Surigao del SurSurigao del Sur				
Tandag City				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Pama Polyclinic	Bagong Lungsod			
Adela Serra Ty Memorial Medical Center	Telaje			