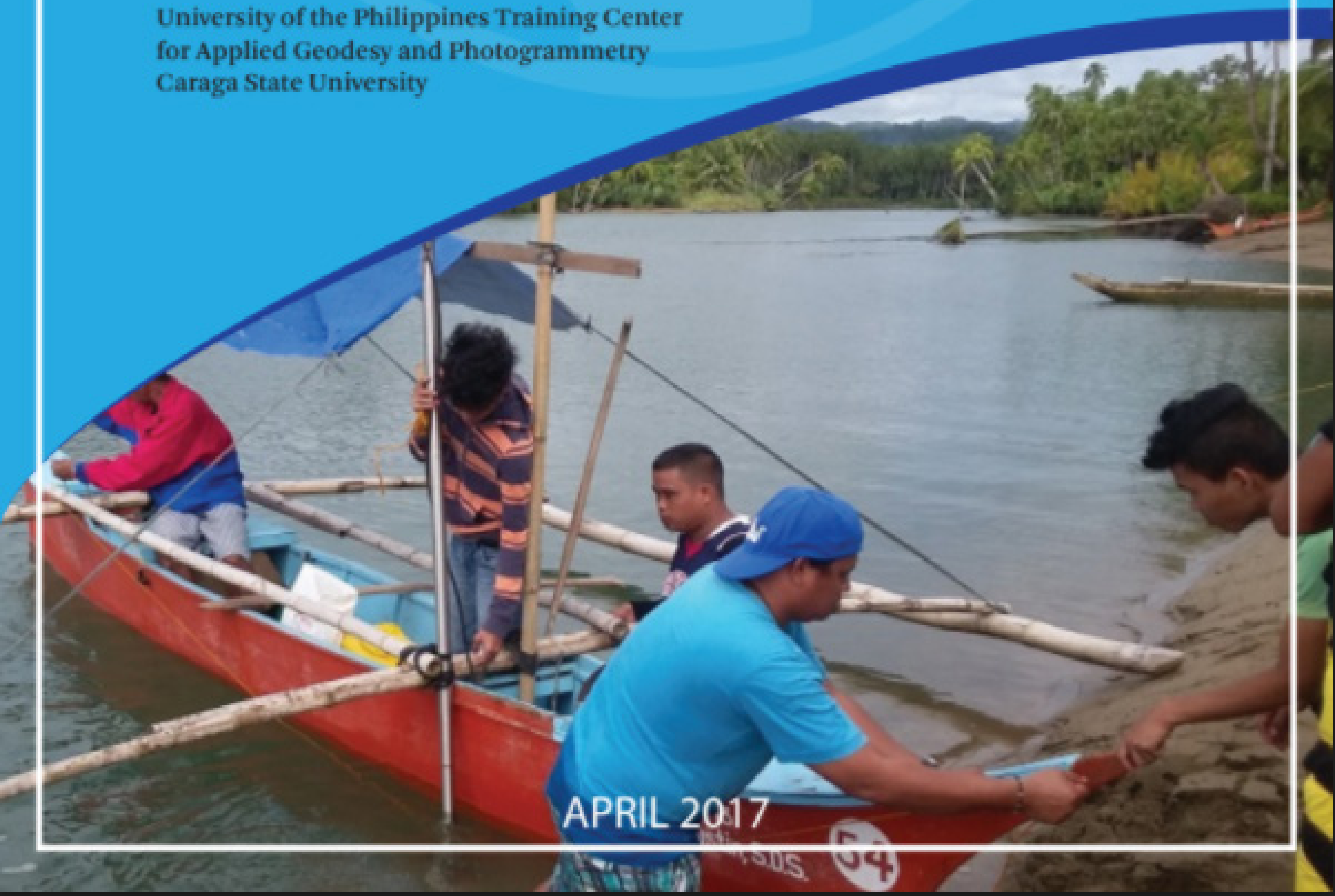
HAZARD MAPPING OF THE PHILIPPINES USING LIDAR (PHIL-LIDAR I)

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

CHAPTER 1: OVERVIEW OF THE PROGRAM AND HUBO-OTIEZA RIVER

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1.1 Background of the Phil-LIDAR 1 Program

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

Also, the program was aimed at producing an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through DOST. The methods applied in this report are thoroughly described in a separate publication entitled "FLOOD MAPPING OF RIVERS IN THE PHILIPPINES USING AIRBORNE LIDAR: METHODS (Paringit, et. al. 2017) available separately.

The implementing partner university for the Phil-LiDAR 1 Program is the 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 Hubo-Otieza River Basin

Hubo-Otieza River Basin is located in the Province of Surigao del Sur in the eastern portion of Mindanao, Philippines. It lies generally between 125**°59›** to 126°14’ east longitude and 8**°40› to** 8**°49› north latitude**. It includes a major part of the Municipalities of San Agustin, San Miguel, and Lianga, and small areas of the Municipality of Marihatag. The basin covers an area of approximately 213 square kilometers, and is about 17 kilometers long and averages about 29 kilometers in width.

The Hubo River is the principal drainageway of the basin. It originates in the Municipality of San Miguel and traverses the entire length of the basin in a southeastern direction and discharges into San Agustin bay. The river channel near the outlet is wide and is navigable by motor boats up to 2 kilometers going upstream. The only tributary that contributes directly to Hubo River is the Buatong River, located at Barangay Buatong, San Agustin, Surigao del Sur, originating from the south portion of the basin.

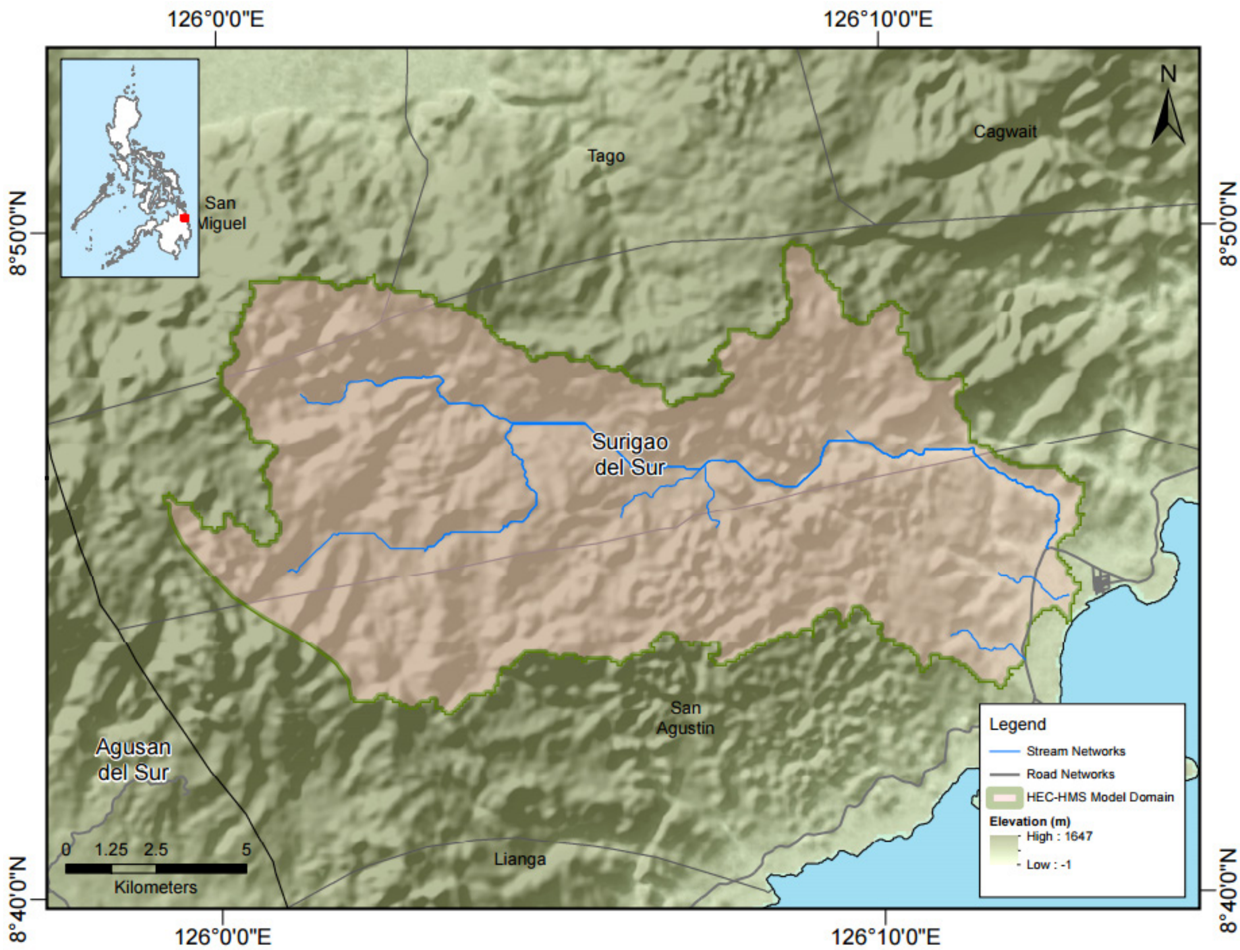

Figure 1. Map of Hubo-Otieza River Basin (in brown)

The climate of the basin is Type II, which is characterized by no dry season but with a very pronounced precipitation period generally during November to January. The seasonal precipitation distribution, which is similar to that of the nearby Agusan River Basin, is caused primarily by the three main seasonal winds that pass through it. The northeast monsoon passes during the period from October to January, the trade wind with an east to southeast direction from February to April, and the southwest monsoon for the rest of the year[1].

The basin's highest point is 907 meters above mean sea level situated at the mountain ridges along Barangay Bolhoon, San Miguel, Surigao Del Sur[2]. The most abundant soil type in the basin based on maps published by the Department of Agriculture was clay which accounts for 75% of the basin's land area. The basin is mostly covered by open canopy forests and brush land leaving the built-up areas only covering less than 1 % of the basin.

Built-up areas and communities in the basin are concentrated in the Municipality of San Agustin particularly in Barangay Santo Niño, Hornasan, and Gata. According to the 2015 census, the Municipality of San Agustin has a population of 22,779 people[3]. The people's source of drinking water is from Lianga Water District, which came from the basin's upstream watersheds. The Hubo Bridge, which plies the Surigao-Davao Coastal Road, connects the municipality and other localities in the south to Marihatag, Surigao Del Sur in the north.

The local language of the municipality is Cebuano. The people's main sources of living are fishing, rice cropping, and tourism. One of the reasons why the Municipality of San Agustin became popular was because of their eco-tourism. The municipality boasts of a group of islands which is gaining potential to be world-renowned destination. The Britannia group of islands has 24 Islands and Islets so beautifully scattered in the waters reaching Lianga Bay[4].

The Municipality of San Agustin is one of localities affected during the onslaught of Tropical Storm "Agaton" in January 2014. It can be recalled that "Agaton" was the first Tropical Storm that affected the country. It was a low pressure area and developed into a Tropical Depression 130 kilometer northeast of Guiian, Eastern Samar in the morning of 17 January 2014, and it moved westward slowly at 5 kilometers per hour closer to the provinces of Surigao del Norte and Surigao del Sur[5]. The slow movement of "Agaton" and the continuous rain and strong winds it brought along has caused flooding and landslides not only in the municipality but also in other localities in Mindanao.

1 US Department of Interior, 1966. A Report on the Agusan River Basin, Mindanao, Philippines. Bureau of Reclamation, US Department of Interior.

2 NAMRIA. (n.d.). Retrieved June 29, 2017, from http://www.namria.gov.ph/topo50Index.aspx

3 (2017, May 27). Retrieved July 4, 2017, from (2017, May 27). Retrieved from https://en.wikipedia.org/wiki/San_Agustin,_Surigao_del_Sur

4 Natividad, B. (2014, February 4). Discovering Surigao del Sur's Hidden Beauty. Retrieved from http://ati.da.gov.ph/ati2/blog/benedict-natividad/2014/discovering-surigao-del-sur%E2%80%99s-hidden-beauty

5 Final Report, re: Effects of Tropical Depression "AGATON" (Rep.). (2014, January). Retrieved http://ndrrmc.gov.ph/attachments/article/2783/FINAL_REPORT_re_Effects_of_Tropical_Depression_AGATON_17_-_20JAN2014.pdf

CHAPTER 2: LIDAR DATA ACQUISITION OF THE HUBO-OTIEZA 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).

2.1 Flight Plans

To initiate the LiDAR acquisition survey of the Hubo-Otieza floodplain, the Data Acquisition Component (DAC) created flight plans within the delineated priority area for Hubo-Otieza Floodplain in Surigao del Sur. These flight missions were planned for 16 lines and ran for at most four and a half hours including take-off, landing and turning time. The flight planning parameters for the LiDAR system are outlined in Table 1. Figure 2 shows the flight plan for Hubo-Otieza floodplain survey.

Table 1. Flight planning parameters for the 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)
BLK61E	600	60	36	50	45	120	5
BLK61I	600	60	36	50	45	120	5
BLK65A	600	60	36	50	45	120	5
BLK65B	600	60	36	50	45	120	5
BLK65C	600	60	36	50	45	120	5
	600	60	36	50	45	120	5
BLK65D	600	40,60	36	50	45	120	5
BLK65E	600	40,60	36	50	45	120	5
BLK65F	600	40,60	36	50	45	120	5
BLK65G	600	40,60	36	50	45	120	5

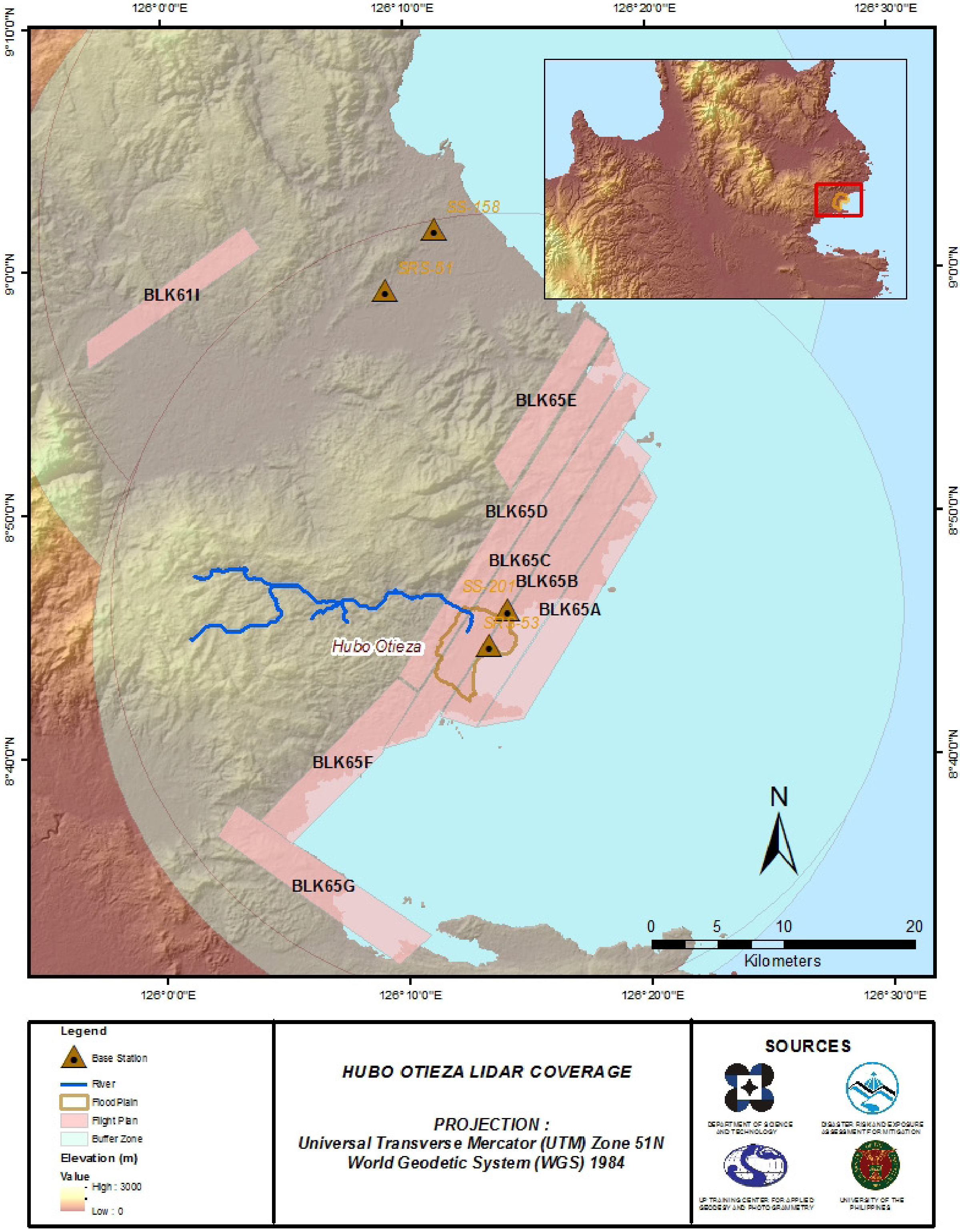

Figure 2. Flight Plan and base stations used for the Hubo-Otieza Floodplain survey using Aquarius sensor.

2.2 Ground Base Stations

The field team was able to recover two (2) NAMRIA ground control points: SRS-51 and SRS-53, and two (2) NAMRIA benchmarks SS-201 and SS-158, which are all of second (2^{nd}) order accuracy.

The certifications for the base stations are found in Annex 2 while the baseline processing reports for the established control points are found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey from July 3 to August 1, 2014. Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and SPS 985. Flight plans and location of base stations used during the aerial LiDAR acquisition in Hubo-Otieza floodplain are shown in Figure 2.

The succeeding sections depict the sets of reference points, control stations and established points, and the ground control points for the entire Hubo-Otieza Floodplain LiDAR Survey. Figure 3 to Figure 6 show the recovered NAMRIA reference points and established point within the area of the floodplain, while Table 2 to Table 5 show the details about the following NAMRIA control stations and established points. Table 6, on the other hand, shows the list of all ground control points occupied during the acquisition together with the corresponding dates of utilization.

Figure 3. GPS set-up over SRS-51 recovered inside the compound of the barangay hall, beside the basketball court in Brgy. Bajao, Tandag, Surigao del Sur (a) and NAMRIA reference point SMR-33 (b) as recovered by the field team.

Table 2. 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	8° 59’ 14.14996”
	Longitude	126° 9’ 6.83415”
	Ellipsoidal Height	3.97000 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting	406741.509 meters
	Northing	99387.182 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	8°59’ 10.56678” North
	Longitude	126° 9’ 12.17833” East
	Ellipsoidal Height	74.22300 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS92)	Easting	186815.64 meters
	Northing	994598.26 meters

Figure 4. GPS set-up over SRS-53 located in the NE corner of the flagpole of San Agustin Central Elementary School in Brgy. San Agustin, Surigao del Sur (a) and NAMRIA reference point SMR-53 (b) as recovered by the field team..

Table 3. Details of the recovered NAMRIA horizontal control point SGS-53 used as base station for the LiDAR acquisition.

Station Name	SRS-53	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	8° 44’ 37.87784”
	Longitude	126° 13’ 16.64511”
	Ellipsoidal Height	-1.34900 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting	414316.026 meters
	Northing	966899.682 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	8° 44’ 34.36515” North
	Longitude	126° 13’ 22.01039” East
	Ellipsoidal Height	69.59300 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	194250.44 meters
	Northing	967600.49 meters

Figure 5. GPS set-up over SS-158 located at Batang Bridge in Brgy. Dayo-an, Surigao del Sur (a) and NAMRIA reference point SM-286 (b) as recovered by the field team.

Table 4. 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)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	9°01’43.29494”
	Longitude	126°11’10.19014”
	Ellipsoidal Height	1.842 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting	850353.357 meters
	Northing	999491.438 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	9°01’39.70405” North
	Longitude	126°11’15.53082” East
	Ellipsoidal Height	76.97 meters

Figure 6. GPS set-up over SS-201 located in Sto. Nino Bridge in San Agustin, Surigao del Sur (a) and NAMRIA reference point SM-201 (b) as recovered by the field team.

Table 5. Details of the recovered NAMRIA vertical control point SS-201 used as base station for the LiDAR acquisition with established coordinates.

Station Name	SS-201	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	8°46'03.02195"
	Longitude	126°14'07.03352"
	Ellipsoidal Height	72.180 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting	856009.096 meters
	Northing	970681.752 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	8°46'03.02195"
	Longitude	126°14'07.03352"
	Ellipsoidal Height	72.180 meter3

Table 6. Ground control points used during the LiDAR data acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
12 July 2014	1690A	3BLK61IS193A, 3BLK65E193A	SS-158 and SRS-51
13 July 2014	1694A	3BLK65ESD194A	SS-201 and SRS-53
14 July 2014	1698A	3BLK65C195A	SS-201 and SRS-53
15 July 2014	1702A	3BLK65BCSDS196A	SS-201 and SRS-53
16 July 2014	1706A	3BLK65BSA197A	SS-201 and SRS-53
18 July 2014	1714A	3BLK65FG199A	SS-201 and SRS-53
21 July 2014	1726A	3BLK65ASBSCS202A	SS-201 and SRS-53
23 July 2014	1734A	3BLK65FSGS204A	SS-201, SRS-53, SS-158 and SRS-51

2.3 Flight Missions

A total of eight (8) missions were conducted to complete the LiDAR data acquisition in Hubo-Otieza floodplain, for a total of thirty-two hours and twenty-eight minutes (32+28) of flying time for RP-C9122 (See Annex 6). All missions were acquired using the Aquarius system. As shown below, the total area of actual coverage per mission and the corresponding flying hours are depicted in Table 7, while the actual parameters used during the LiDAR data acquisition are presented in Table 8.

Table 7. Flight missions for the LiDAR data acquisition of the Hubo-Otieza 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
12 July 2014	1690A	32.97	60.54	NA	60.54	NA	4	23
13 July 2014	1694A	86	80.1	1.05	79.05	1034	4	23
14 July 2014	1698A	72	65.4	10.52	54.88	731	4	23
15 July 2014	1702A	230.252	65.1	12	53.1	723	3	23
16 July 2014	1706A	83.277	92.1	3.90	88.2	1015	4	23
18 July 2014	1714A	171.157	85.5	NA	85.5	1515	4	23
21 July 2014	1726A	143.164	96.99	5.95	91.04	990	4	17
23 July 2014	1734A	56.17	27.6	NA	27.6	591	2	53
TOTAL		874.99	573.33	33.42	539.91	6599	32	28

Table 8. Actual parameters used during the LiDAR data acquisition of the Hubo-Otieza Floodplain.

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (khz)	Scan Frequency (Hz)	Average Speed **(kts)**	**Average Turn Time (Minutes)**
1690A	600	60	36	50	45	120	5
1694A	600	40	36	50	45	120	5
1698A	600	60	36	50	45	120	5
1702A	600	60	36	50	45	120	5
1706A	600	60	36	50	45	120	5
1714A	600	40,60	36	50	45	120	5
1726A	600	60	36	50	45	120	5
1734A	600	60	36	50	45	120	5

2.4 Survey Coverage

This certain LiDAR acquisition survey covered the Hubo-Otieza floodplain (See Annex 7). It is located in the province of Surigao del Sur with majority of the floodplain situated within the municipality of San Miguel. The municipalitiy of Cagwait is partially covered by the survey. The list of municipalities and cities surveyed with at least one (1) square kilometer coverage is shown in Table 9. Figure 7, on the other hand, shows the actual coverage of the LiDAR acquisition for the Hubo-Otieza floodplain.

Table 9. The list of municipalities and cities surveyed of the Hubo-Otieza Floodplain LiDAR acquisition.

Province	Municipality/City	Area of Municipality/ City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Surigao del Sur	Cagwait	200.13	83.1	42%
	Lianga	141.51	52.27	37%
	San Agustin	232	82	35%
	Marihatag	272.4	78.16	29%
	Bayabas	48.26	11.22	23%
	San Miguel	410.02	28.42	7%
	Barobo	194.07	6.45	3%
	Tandag	392.39	3.73	1%
Total		1,890.78	345.35	18.26%

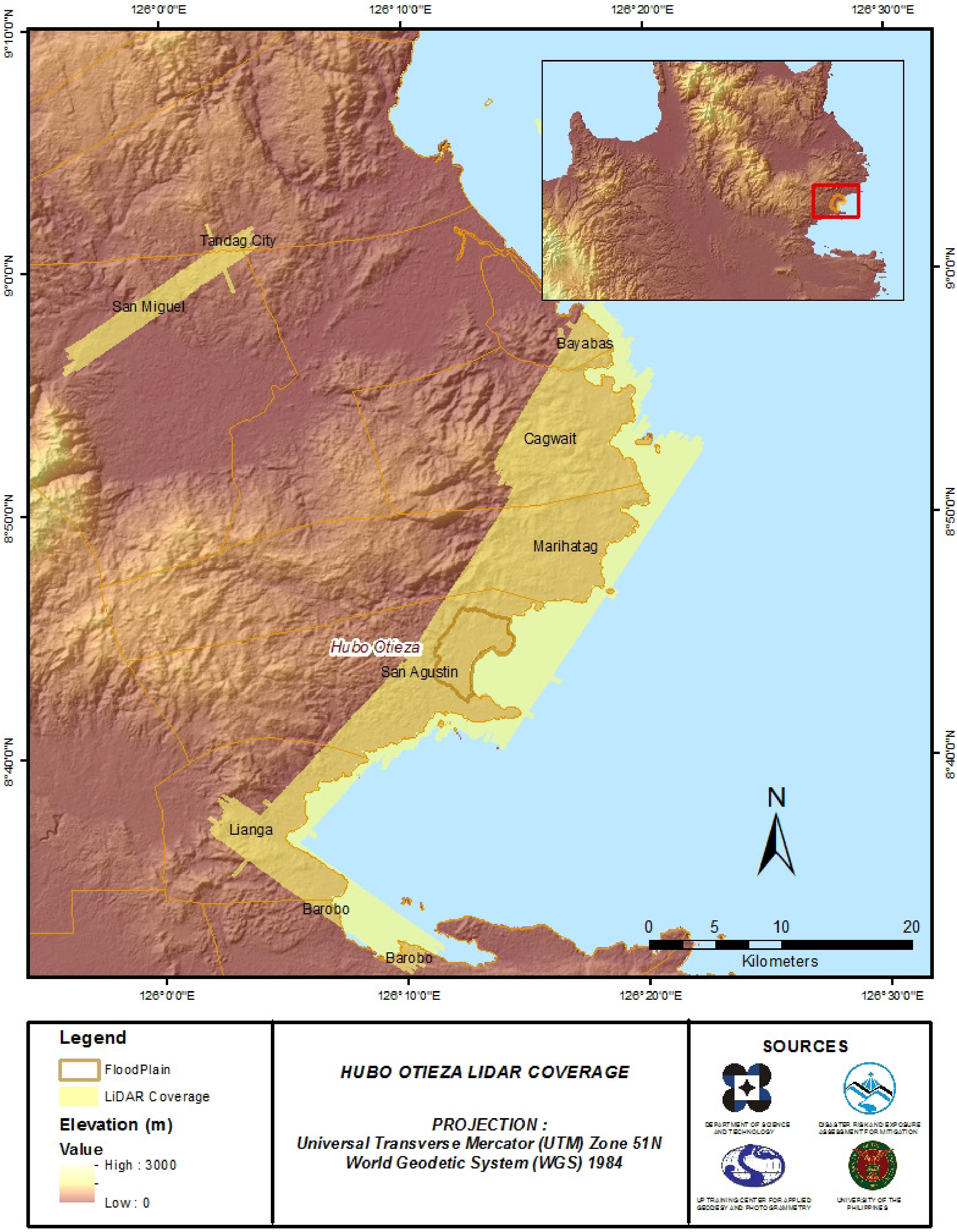

Figure 7. Actual LiDAR survey coverage of the Hubo-Otieza Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE HUBO-OTIEZA FLOODPLAIN

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

3.1 Overview of the LIDAR Data Pre-Processing

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

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

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

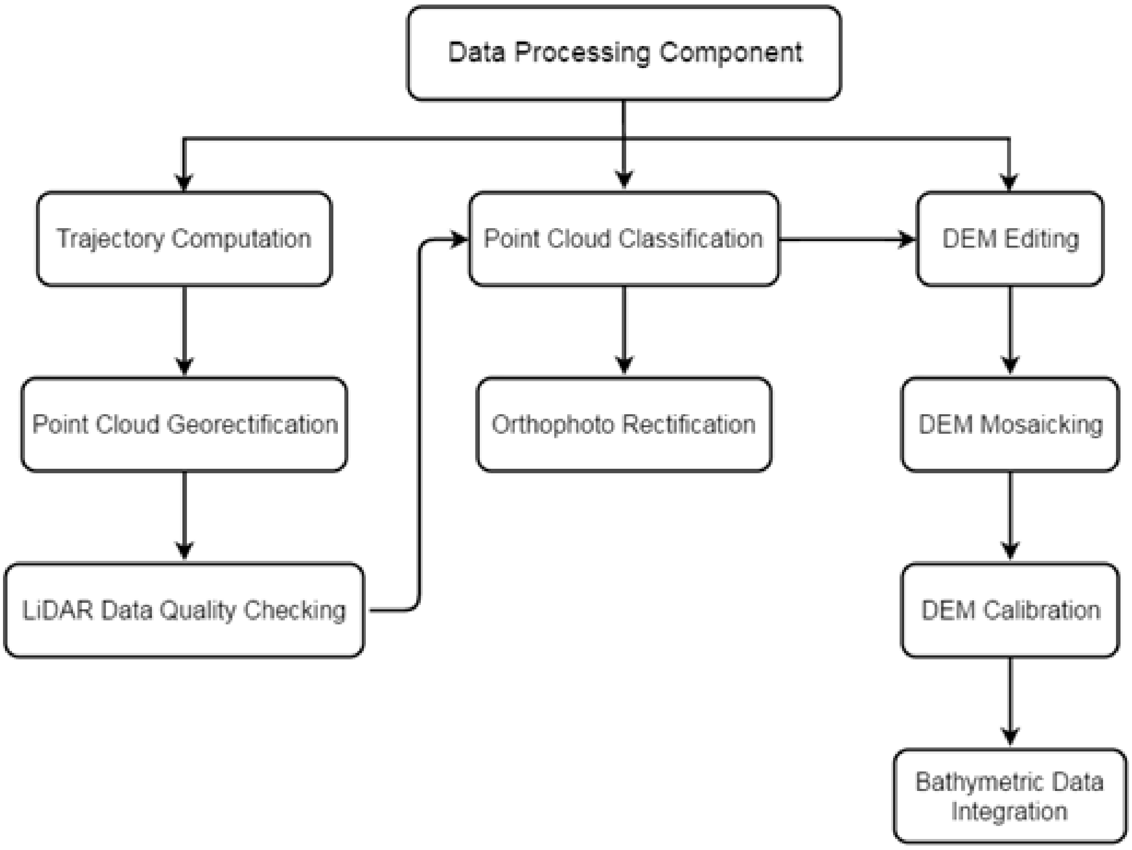

Figure 8. Schematic diagram for the data pre-processing.

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions of the Hubo-Otieza Floodplain can be found in Annex 5. The missions flown during the conduct of the first survey in July 2014 utilized the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Aquarius system over Surigao del Sur.

The Data Acquisition Component (DAC) transferred a total of 89.18 Gigabytes of Range data, 1.814 Gigabytes of POS data, 84.82 Megabytes of GPS base station data, and 419.7 Gigabytes of raw image data to the data server on July 23, 2014 for the survey, which was verified for accuracy and completeness by the DPPC. The whole dataset for the Hubo-Otieza Floodplain was fully transferred on August 5, 2016, as indicated on the Data Transfer Sheets for the Hubo-Otieza floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for Flight 1702A, one of the Hubo-Otieza flights, which is the North, East, and Down position RMSE values are shown in Figure 9. The x-axis corresponds to the time of the flight, which was measured by the number of seconds from the midnight of the start of the GPS week, which fell on the date and time of July 15, 2014, 00:00AM. The y-axis, on the other hand, represents the RMSE value for that particular position.

Figure 9. Smoothed Performance Metric Parameters of Hubo-Otieza Flight 1702A.

The time of flight was from 188,000 seconds to 196,200 seconds, which corresponds to morning of July 15, 2014. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft.

Redundant measurements from the POS system quickly minimize 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 1.80 centimeters, the East position RMSE peaks at 3.00 centimeters, and the Down position RMSE peaks at 4.00 centimeters, which are within the prescribed accuracies described in the methodology.

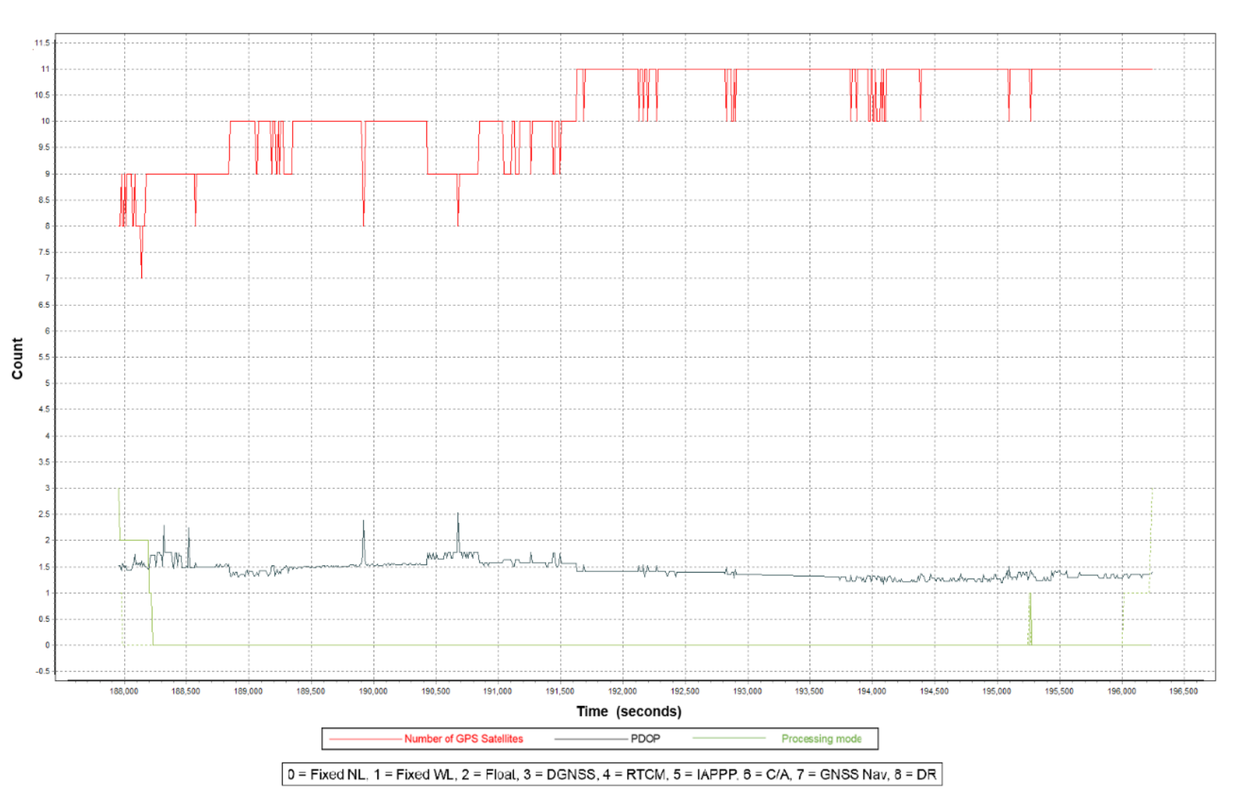

Figure 10. Solution Status Parameters of Hubo-Otieza Flight 1702A.

The Solution Status parameters, which indicate the number of GPS satellites; Positional Dilution of Precision (PDOP); and the GPS processing mode used for Hubo-Otieza Flight 1702A are shown in Figure 10. For the Solution Status parameters, the figure above signifies that the number of satellites utilized and tracked during the acquisition were between 7 and 11, not going lower than 6. Similarly, the PDOP value did not go above the value of 3, which indicates optimal GPS geometry. The processing mode also stayed at the value of 0 for the majority of the survey stayed at the value of 0. The value of 0 corresponds to a Fixed, Narrow-Lane Mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for the POSPAC MMS. Fundamentally, 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 Hubo-Otieza flights is shown in Figure 11.

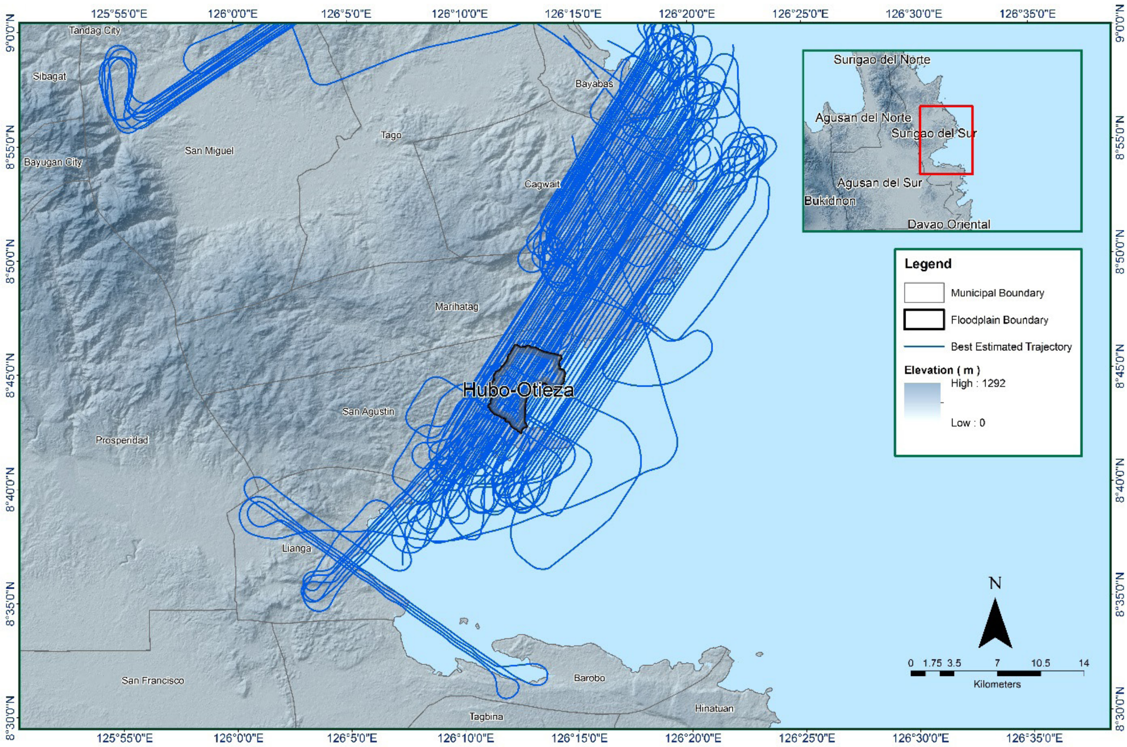

Figure 11. Best Estimated Trajectory of the LiDAR missions conducted over the Hubo-Otieza Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS contains 111 flight lines, with each flight line contains one channel, since the Aquarius system contains only one channel. The summary of the self-calibration results obtained from LiDAR processing in the LiDAR Mapping Suite (LMS) software for all flights over the Hubo-Otieza floodplain are given in Table 10.

Table 10. Self-calibration Results values for Hubo-Otieza flights.

Parameter	Acceptable Value	Computed Value
Boresight Correction stdev)	<0.001degrees	0.000218
IMU Attitude Correction Roll and Pitch Corrections stdev)	<0.001degrees	0.000903
GPS Position Z-correction stdev)	<0.01meters	0.0027

The optimum accuracy values for all Hubo-Otieza flights were also calculated, which are based on the computed standard deviations of the corrections of the orientation parameters. The standard deviation values for individual blocks are presented in the Mission Summary Reports (Annex 8).

3.5 LiDAR Quality Checking

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

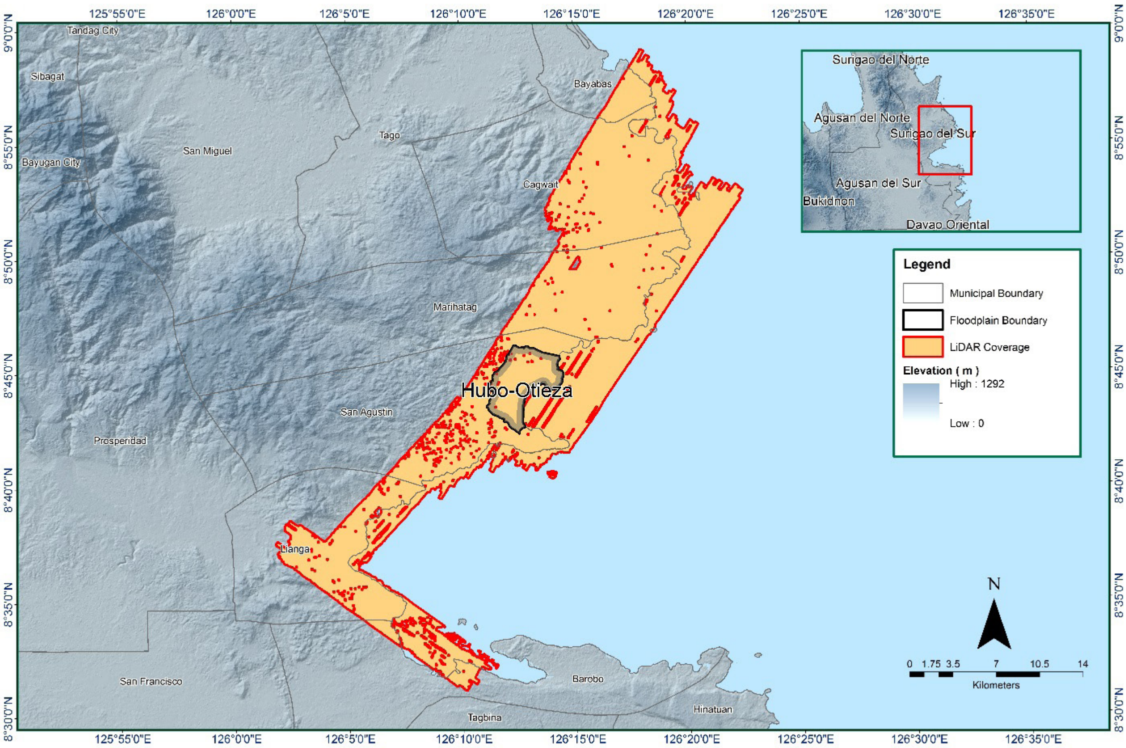

Figure 12. Boundaries of the processed LiDAR data over the Hubo-Otieza Floodplain.

A total area of 474.28 square kilometers (sq. kms.) were covered by the Hubo-Otieza flight missions as a result of eight (8) flight acquisitions, which were grouped and merged into four (4) blocks accordingly, as portrayed in Table 11.

Table 11. List of LiDAR blocks for the Hubo-Otieza floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
SurigaodelSur_Blk65AB	1706A	159.52
SurigaodelSur_Blk65CD	1702A	110.55
	1698A	
SurigaodelSur_Blk65E	1726A	92.15
	1690A	
SurigaodelSur_Blk65FG	1694A	112.06
	1714A	
TOTAL		472.09 sq.km

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 13. Since the Aquarius system employs one channel, we would expect an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines.

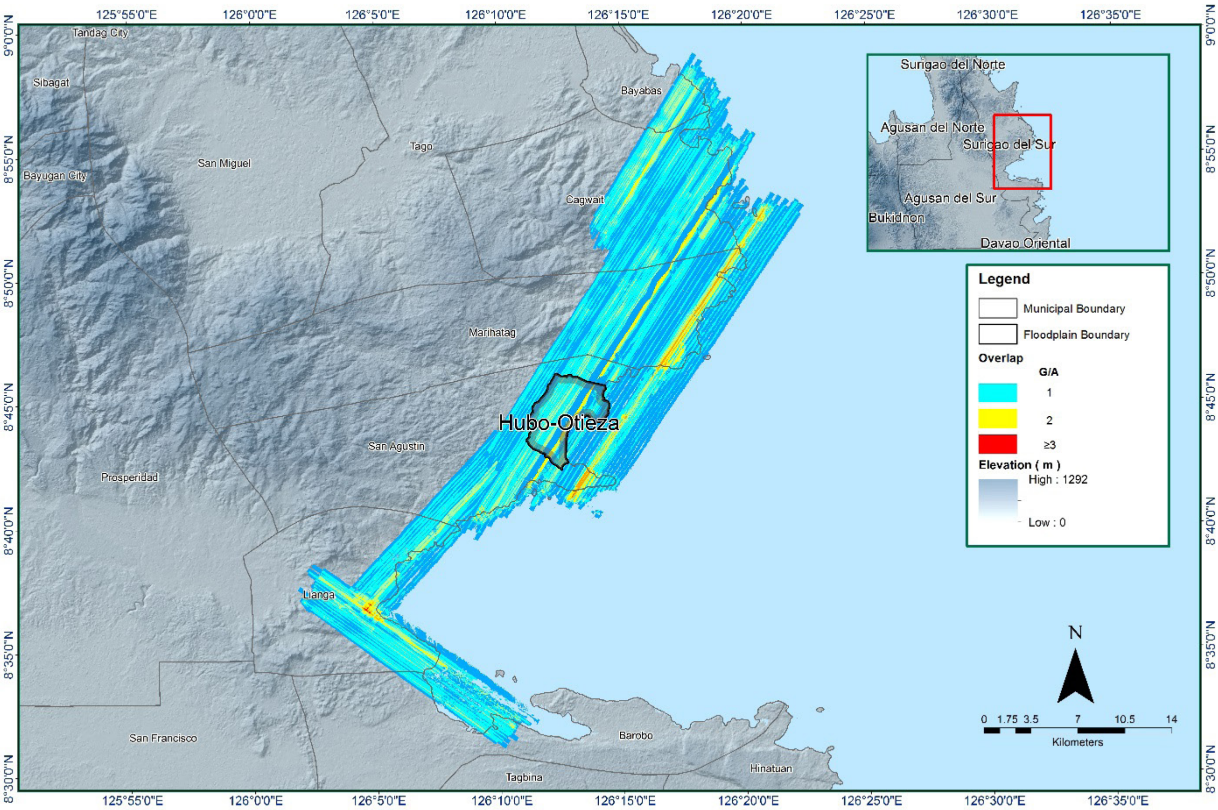

Figure 13. Image of data overlap for Hubo-Otieza floodplain.

The overlap statistics per block for the Hubo-Otieza floodplain can be found in the Mission Summary Reports (Annex 8). One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 42.61% and 77.15% 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 two (2) points per square meter criterion is shown in Figure 14. As seen in the figure below, it was determined that all LiDAR data for the Hubo-Otieza Floodplain Survey satisfy the point density requirement, as the average density for the entire survey area is 3.78 points per square meter.

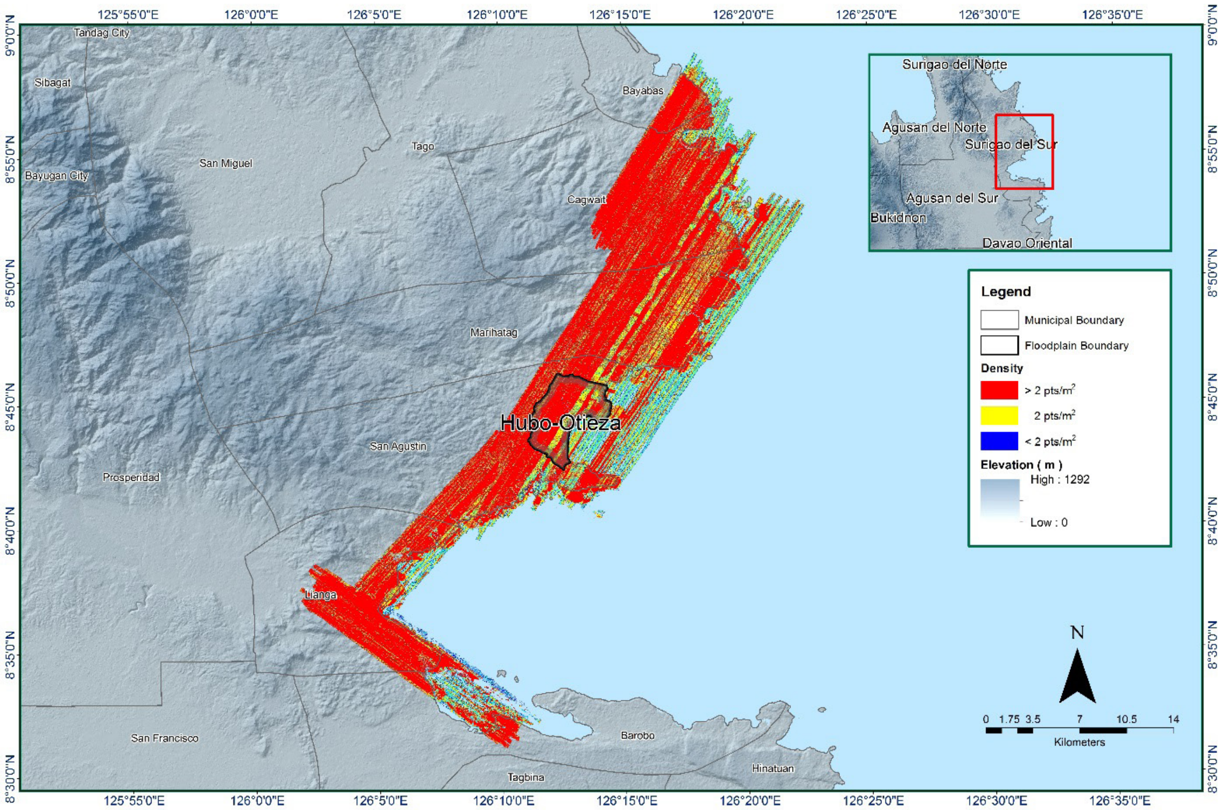

Figure 14. Pulse density map of the merged LiDAR data for Hubo-Otieza floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 15. The default color range is blue to red, where bright blue areas correspond to portions where elevations of a previous flight line are higher by more than 0.20m, as identified by its acquisition time; which is relative to the elevations of its adjacent flight line. Similarly, bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20m, relative to the elevations of its adjacent flight line. Areas highlighted in bright red or bright blue necessitate further investigation using the Quick Terrain Modeler software.

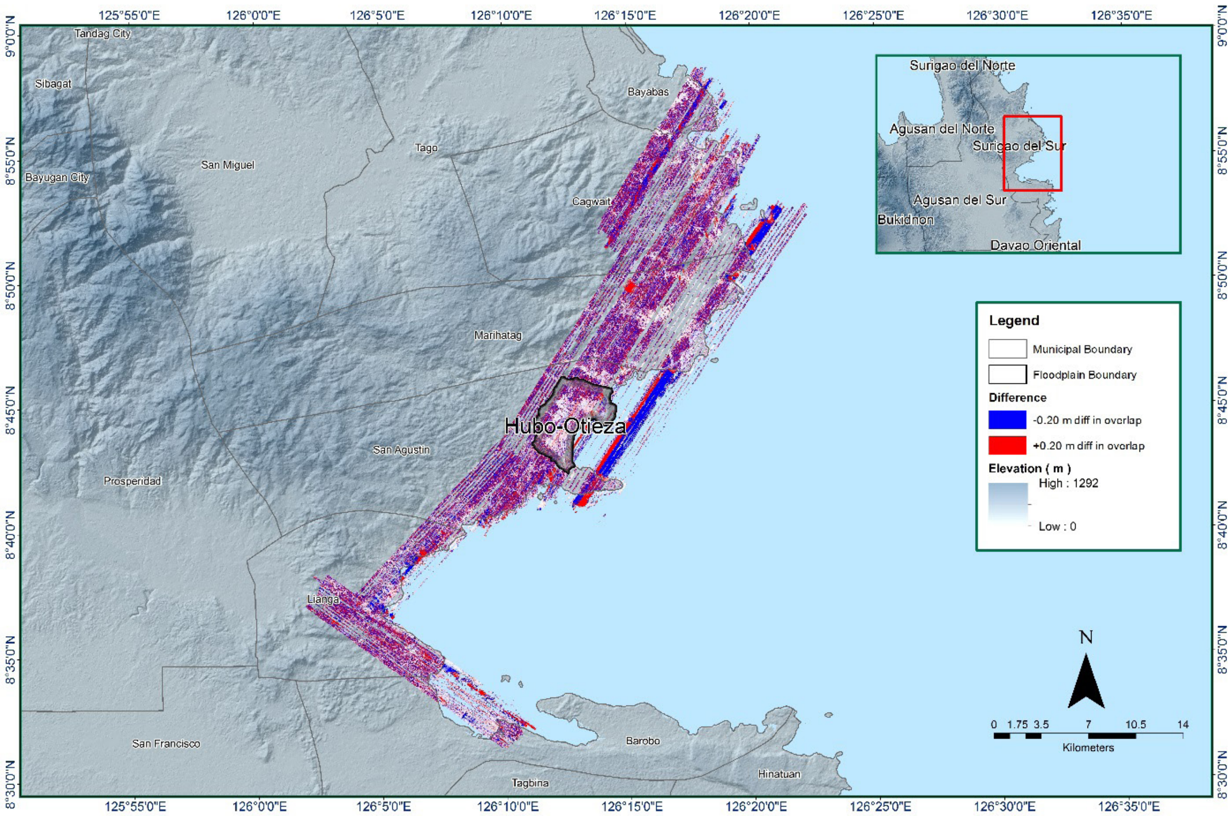

Figure 15. Elevation difference Map between flight lines for the Hubo-Otieza Floodplain Survey.

A screen-capture of the processed LAS data from Hubo-Otieza flight 1702A loaded in QT Modeler is shown in Figure 16. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data generated satisfactory results. No reprocessing was done for this LiDAR dataset.

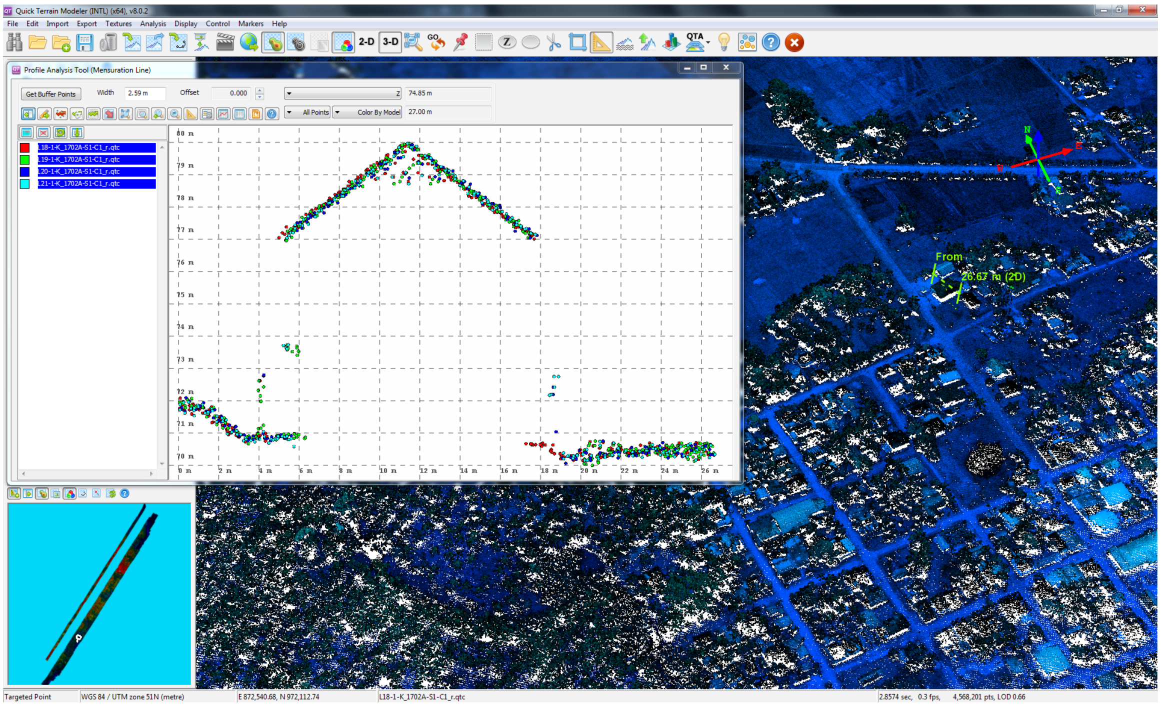

Figure 16. Quality checking for Hubo-Otieza flight 1702A using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 12. Hubo-Otieza classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	178,475,094
Low Vegetation	187,594,122
Medium Vegetation	317,240,334
High Vegetation	638,889,274
Building	23,295,587

The tile system that TerraScan employed for the LiDAR data as well as the final classification image for a block of the Hubo-Otieza floodplain is shown in Figure 17. A total of 725 tiles with 1 km. X 1 km. (one kilometer by one kilometer) size were produced. Correspondingly, Table 12 summarizes the number of points classified to the pertinent categories. The point cloud has a maximum and minimum height of 471.84 meters and 40.03 meters respectively.

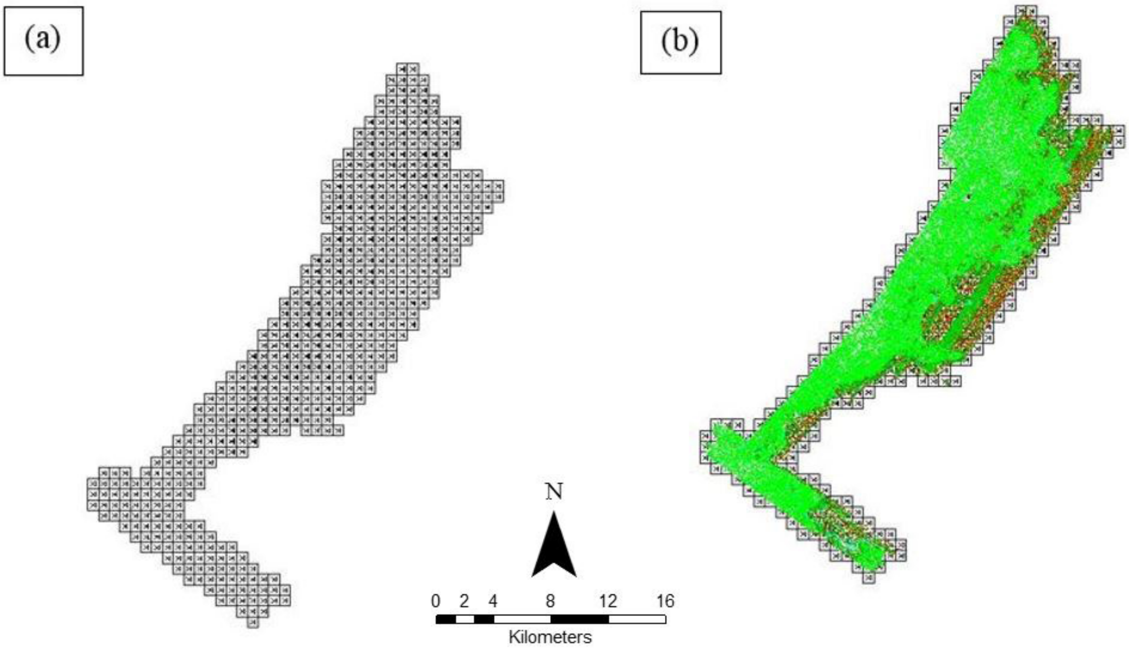

Figure 17. Tiles for Hubo-Otieza floodplain (a) and classification results (b) in TerraScan.

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

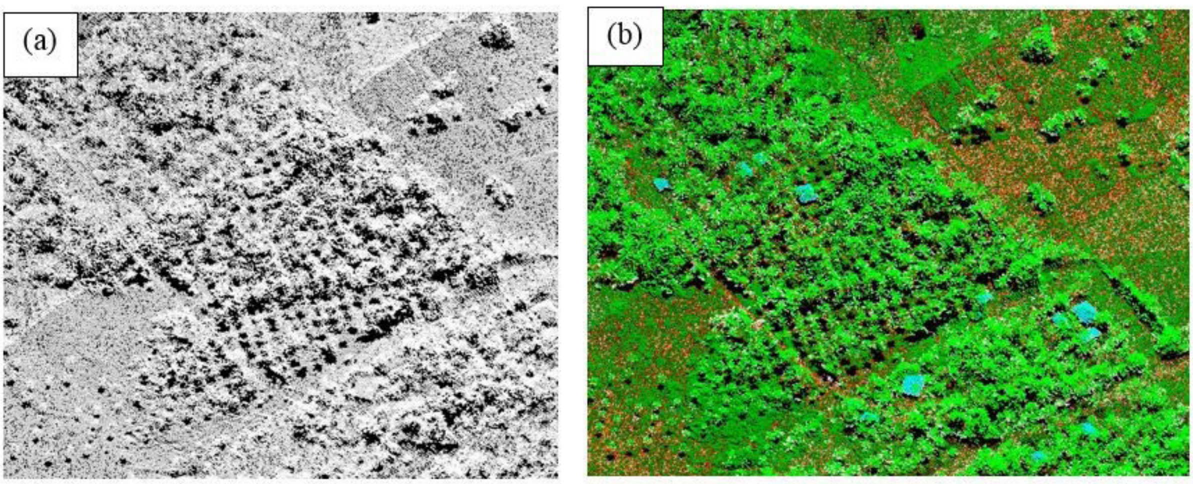

Figure 18. Point cloud before (a) and after (b) classification.

The production of the last return (V_ASCII) and secondary (T_ ASCII) DTM as well as the first (S_ ASCII) and last (D_ ASCII) return DSM of the area in top view display are show 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.

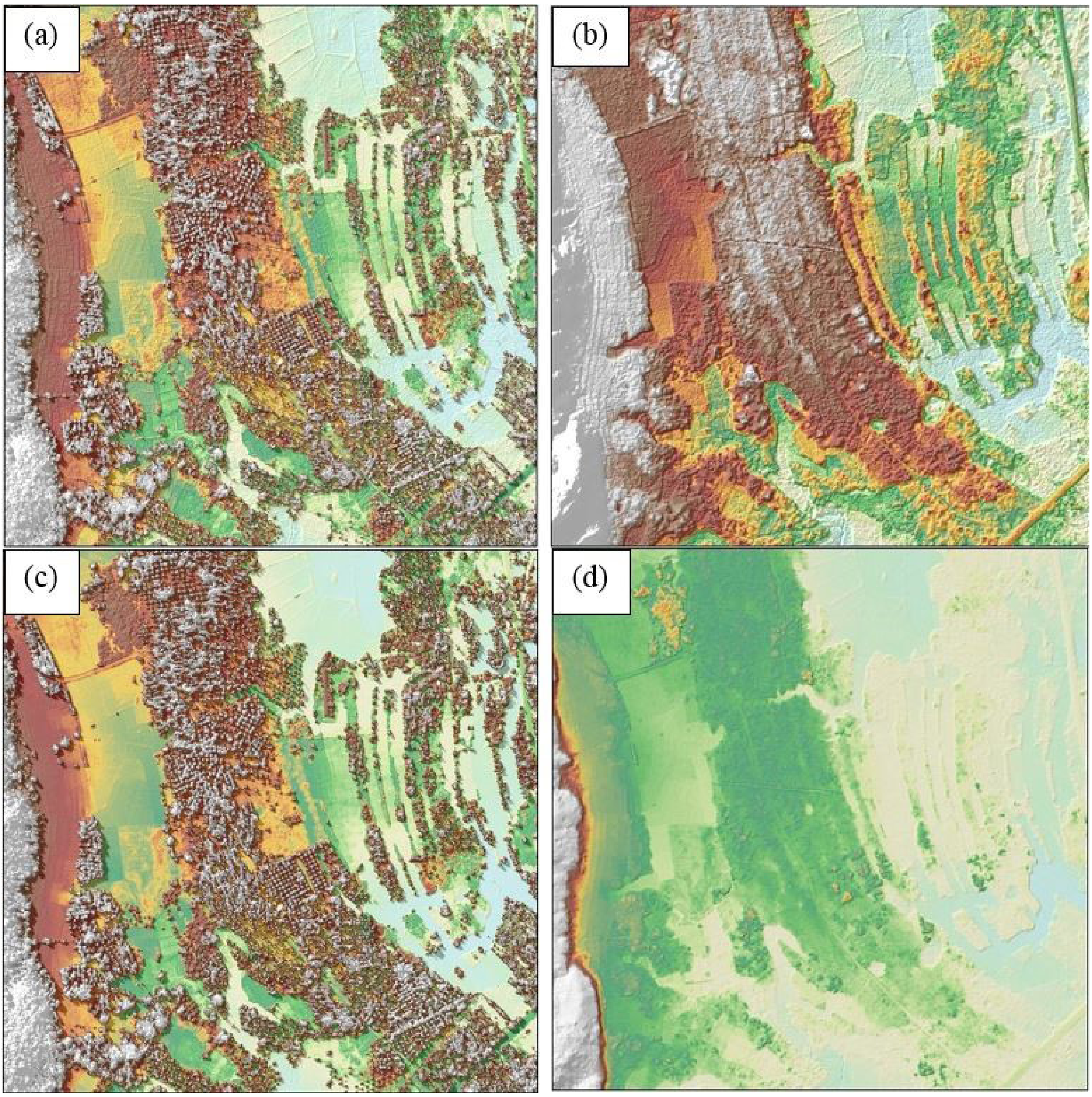

Figure 19. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Hubo-Otieza floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 725 1km by 1km tiles area covered by the Hubo-Otieza floodplain is shown in Figure 20. After the tie point selection to fix photo misalignments, color points were added to smooth out visual inconsistencies along the seam lines where photos overlap. The Hubo-Otieza floodplain attained a total of 437 sq. kms. in orthophotograph coverage comprised of 6,053 images. A zoomed-in version of sample orthophotographs named in reference to its tile number is shown in Figure 21.

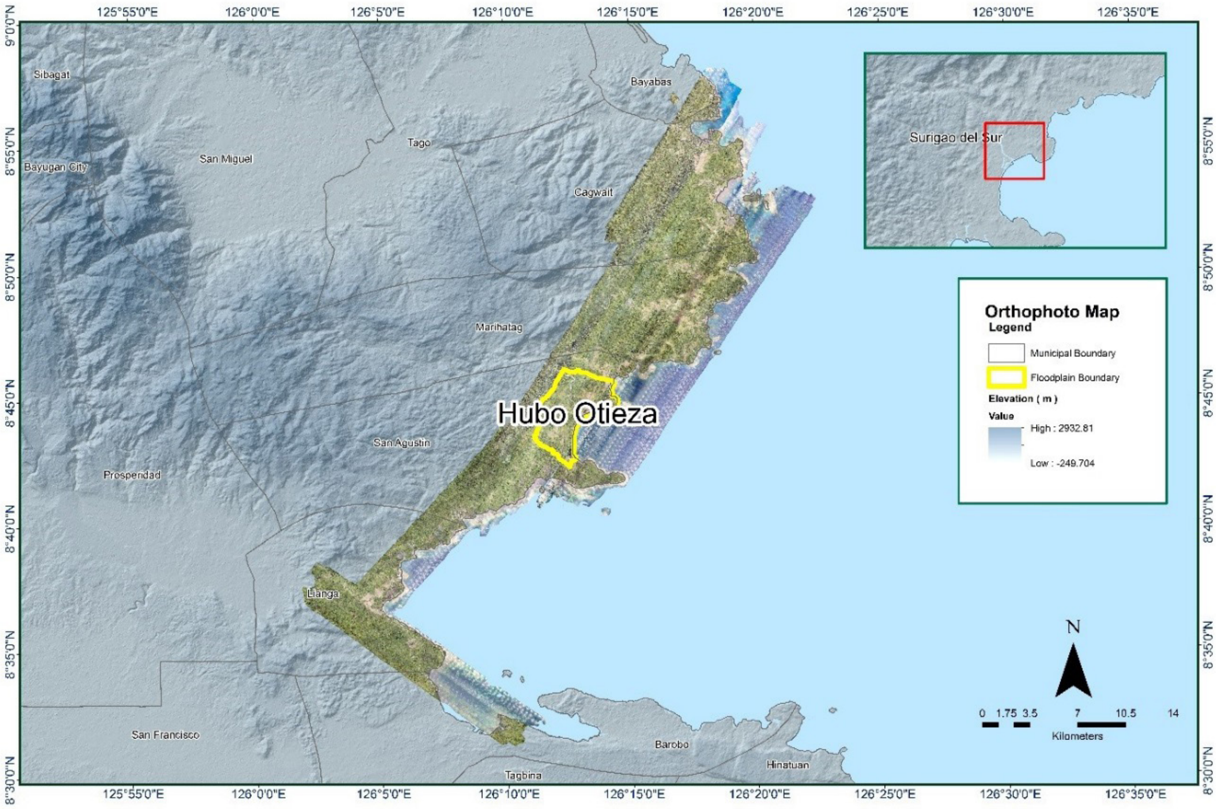

Figure 20. Hubo-Otieza Floodplain with the available orthophotographs.

Figure 21. Sample orthophotograph tiles for the Hubo-Otieza Floodplain.

3.8 DEM Editing and Hydro-Correction

Four (4) mission blocks were processed for the Hubo-Otieza Floodplain Survey. These blocks are composed of Surigao del Sur blocks with a total area of 474.28 square kilometers. Table 13shows the name and corresponding area of each block in square kilometers.

Table 13. LiDAR blocks with its corresponding areas.

LiDAR Blocks	Area (sq. km.)
SurigaodelSur_Blk65AB	159.52
SurigaodelSur_Blk65CD	110.55
SurigaodelSur_Blk65E	92.15
SurigaodelSur_Blk65FG	112.06
TOTAL	474.28 sq.km

Figure 22 shows portions of a DTM before and after manual editing. As evident in the figure, the hilly portion (Figure 22a) was misclassified and removed during the classification process. To complete the surface, the hilly portion (Figure 22b) was retrieved and reclassified through manual editing to allow the correct water flow. Likewise, the bridge (Figure 22c) has obstructed the flow of water along the river. To correct the river hydrologically, the bridge was removed through manual editing (Figure 22d).

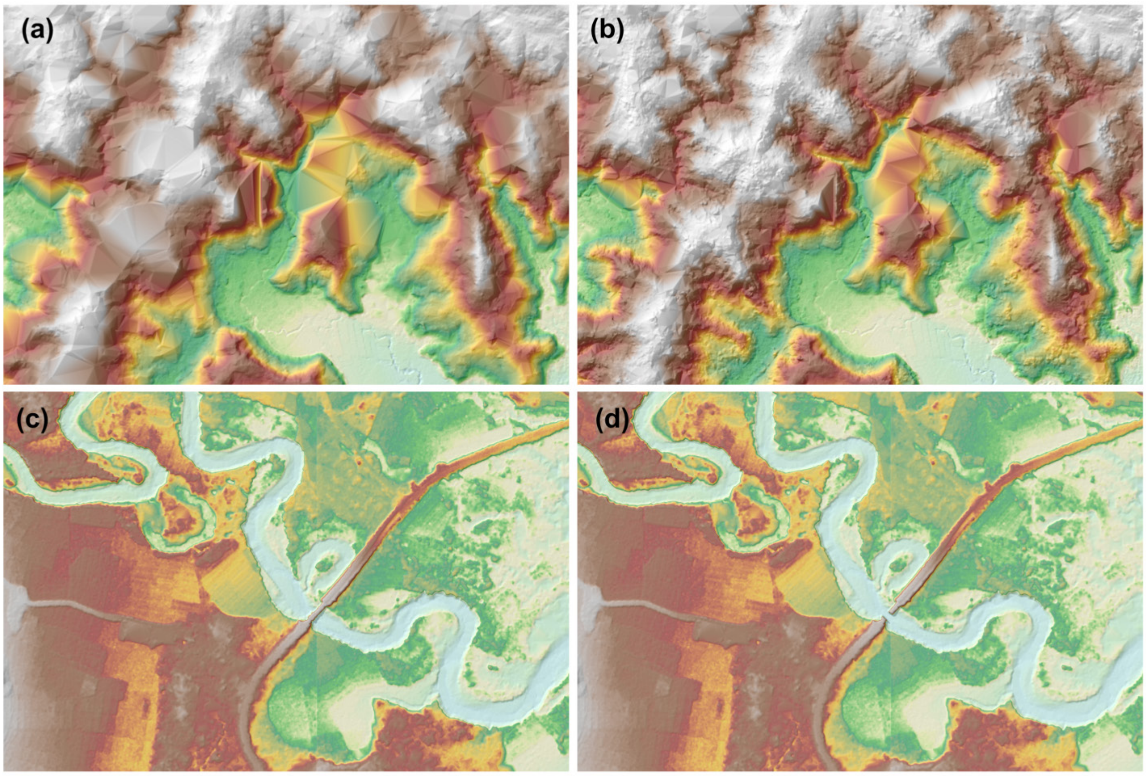

Figure 22. Portions in the DTM of the Hubo-Otieza Floodplain – hilly portion before (a) and after (b) data retrieval; a bridge before (c) and after (d) manual editing.

3.9 Mosaicking of Blocks

SurigaodelSur_Blk65AB 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. Table 14 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Hubo-Otieza Floodplain is shown in Figure 23. It can be seen that the entire Hubo-Otieza floodplain is 99.92% covered by LiDAR data.

Table 14. Shift values of each LiDAR block of Hubo-Otieza Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
SurigaodelSur_Blk65CD	0.00	0.00	0.08
SurigaodelSur_Blk65E	0.00	0.00	0.13
SurigaodelSur_Blk65FG	0.00	0.00	1.49

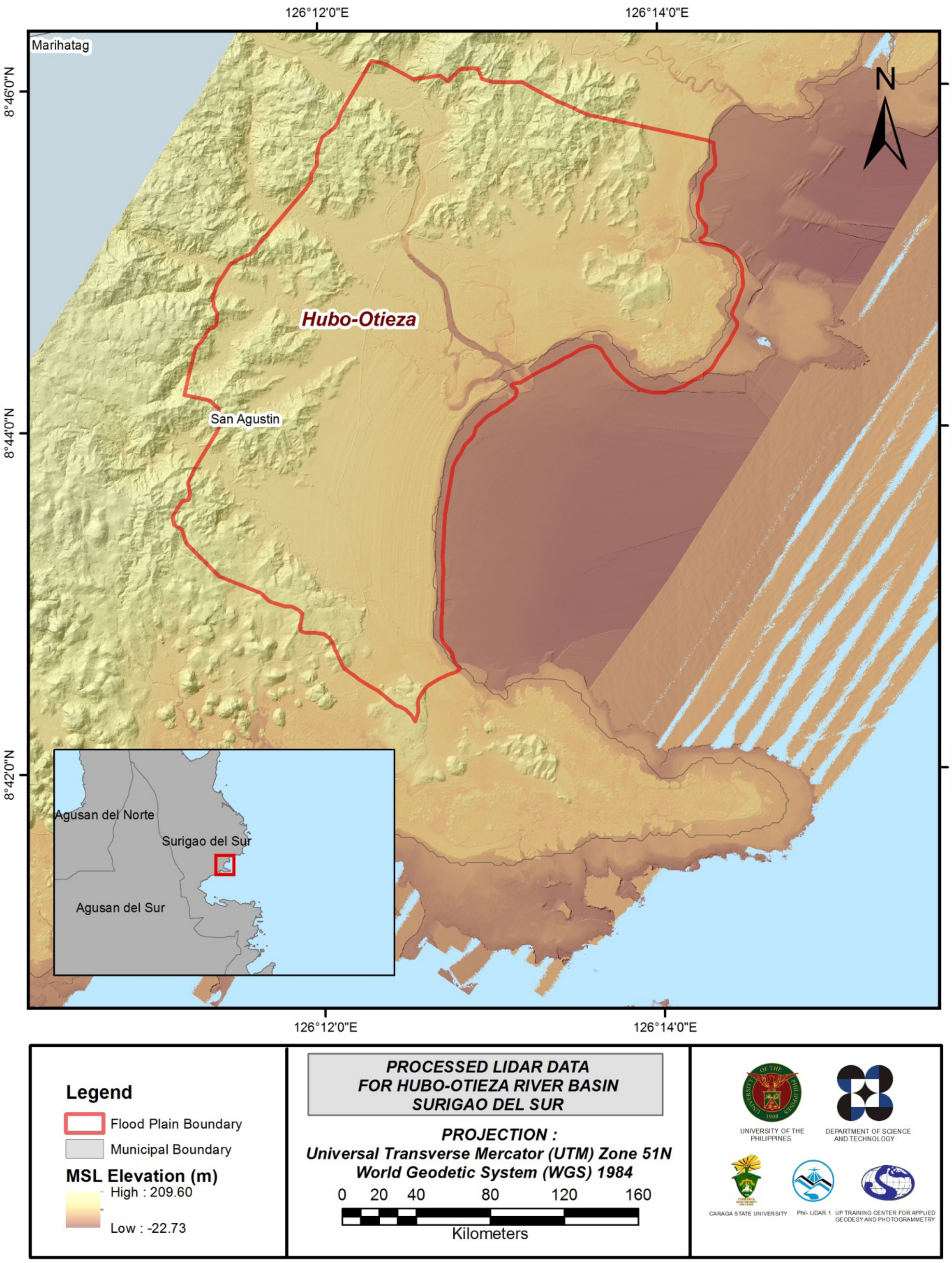

Figure 23. Map of processed LiDAR data for the Hubo-Otieza Floodplain.

3.10 Calibration and Validation of Mosaicked LiDAR DEM

The extent of the validation survey done by the CSU's Field Survey Team (FST) in coordination with the Data Validation and Bathymetry Component (DVBC) in Hubo-Otieza to collect points with which the LiDAR dataset is validated is shown in Figure 24, with the validation survey points highlighted in green. A total of 5,642 survey points were gathered for the Hubo-Otieza floodplain. Random selection of 80% of the survey points, resulting to 4,850 points, was used for calibration.

A good correlation between the uncalibrated mosaicked LiDAR DTM 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 the data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration points is 0.42 meters, with a standard deviation of 0.20 meters. The calibration of the Hubo-Otieza LiDAR data was accomplished by adding the height difference value of 0.42 meters to the Hubo-Otieza mosaicked LiDAR data. Table 15 shows the statistical values of the compared elevation values between the Hubo-Otieza LiDAR data and the calibration data.

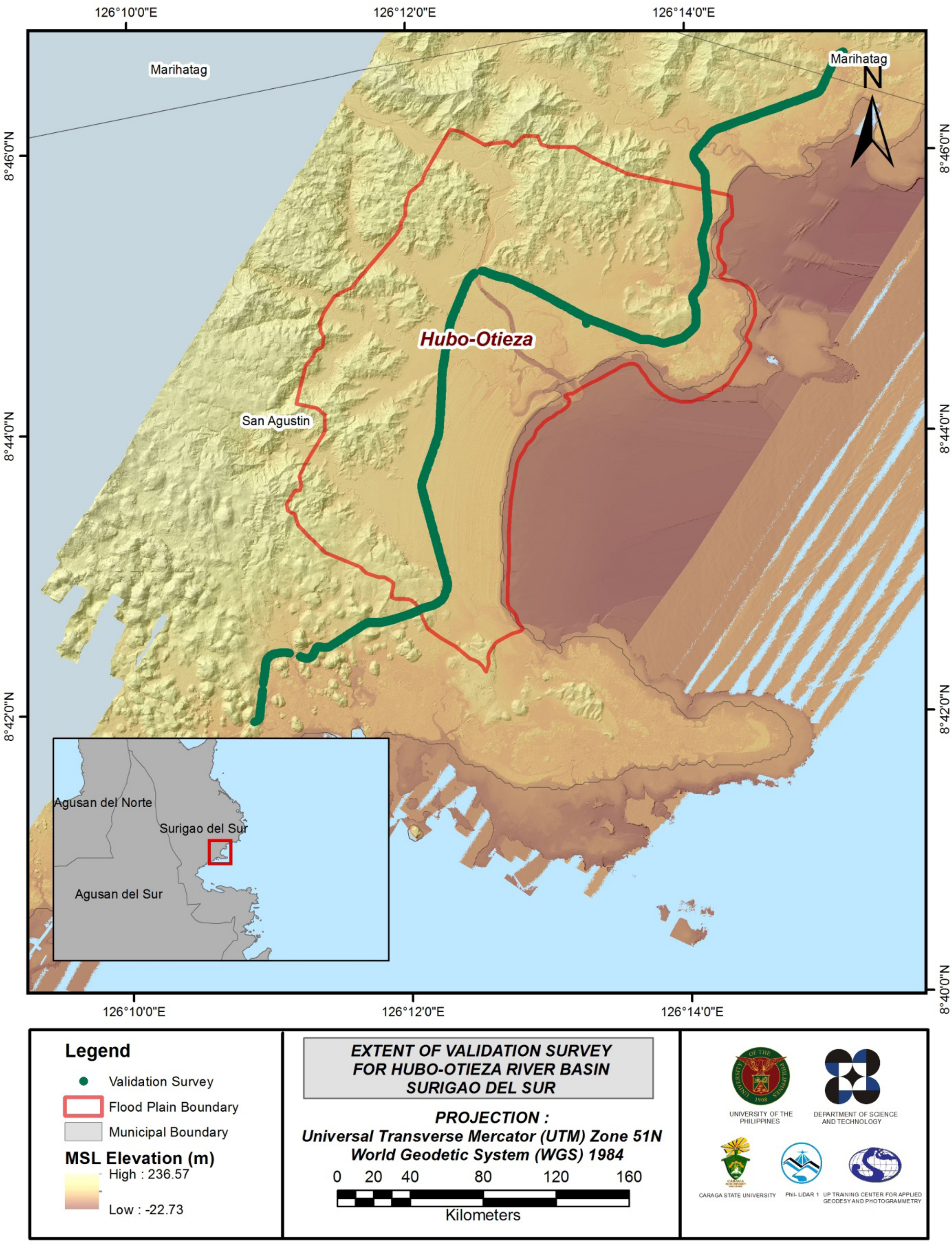

Figure 24. Map of Hubo-Otieza Floodplain with validation survey points in green

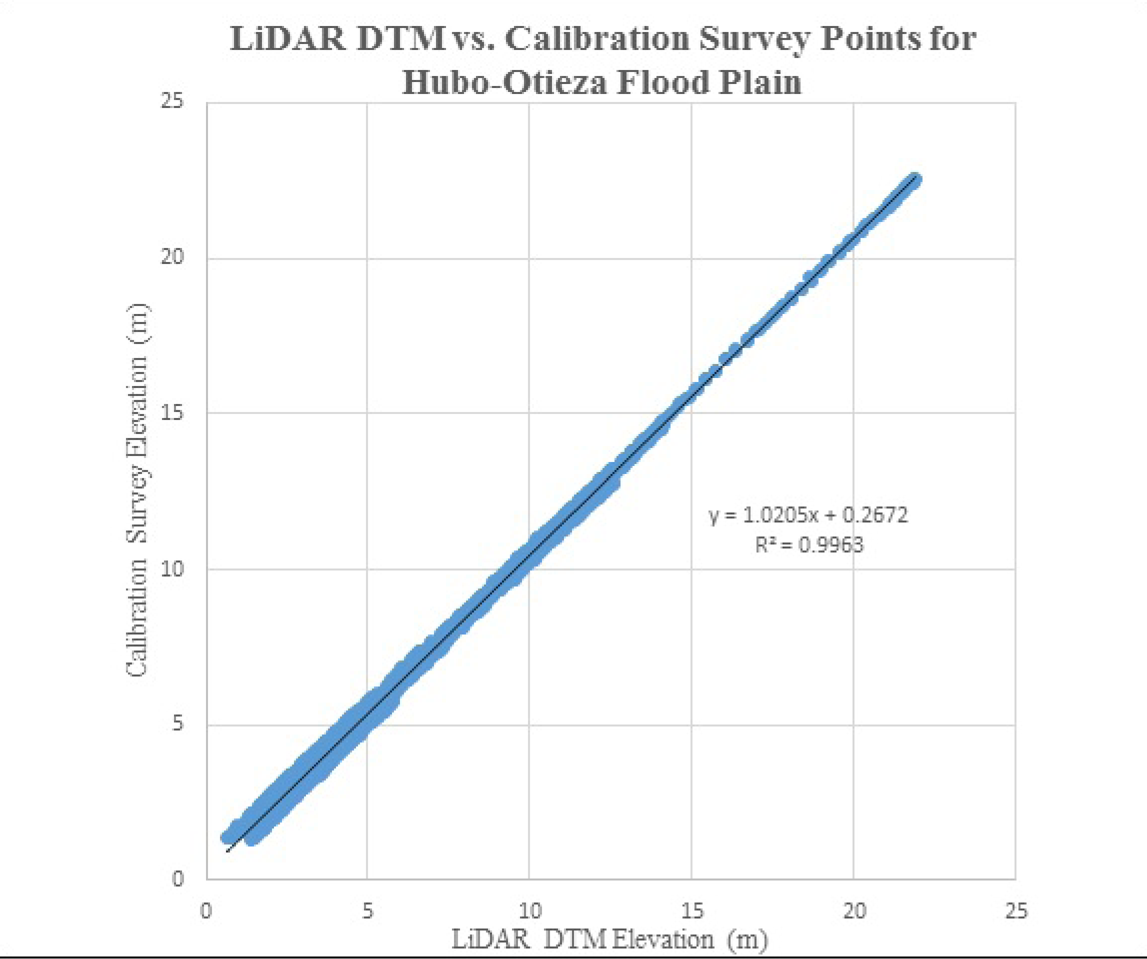

Figure 25. Correlation plot between calibration survey points and LiDAR data.

Table 15. Calibration Statistical Measures

Calibration Statistical Measures	Value (meters)
Height Difference	0.42
Standard Deviation	0.20
Average	0.37
Minimum	-0.02
Maximum	0.76

A total of 1,213 survey points lie within the Hubo-Otieza Floodplain; all of which were used to validate the calibrated Hubo-Otieza DTM. A good correlation between the calibrated mosaicked LiDAR elevation and the ground survey elevation values, which point toward the quality of the LiDAR DTM is shown in Figure 26. The computed RMSE value between the calibrated LiDAR DTM and the validation elevation values is at 0.20 meters with a standard deviation of 0.19 meters, as shown in Table 16.

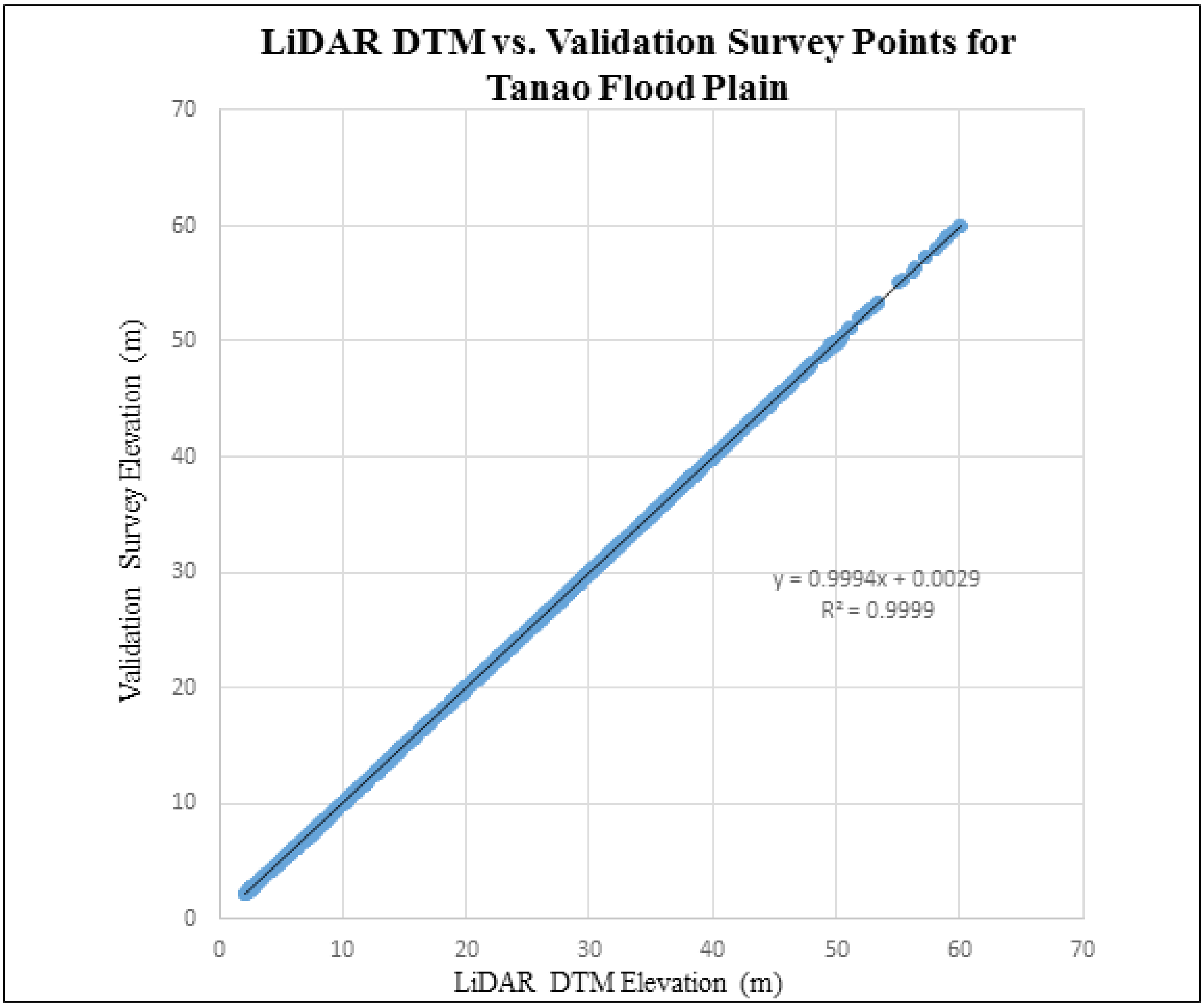

Figure 26. Correlation plot between the validation survey points and the LiDAR data.

Table 16. Validation Statistical Measures

Validation Statistical Measures	Value (meters)
RMSE	0.07
Standard Deviation	0.07
Average	0.01
Minimum	-0.16
Maximum	0.19

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and zigzag data were available for Hubo-Otieza with a total of 29,806 bathymetric survey points. The resulting raster surface produced was done by Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.46 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 Hubo-Otieza integrated with the processed LiDAR DEM is shown in Figure 27.

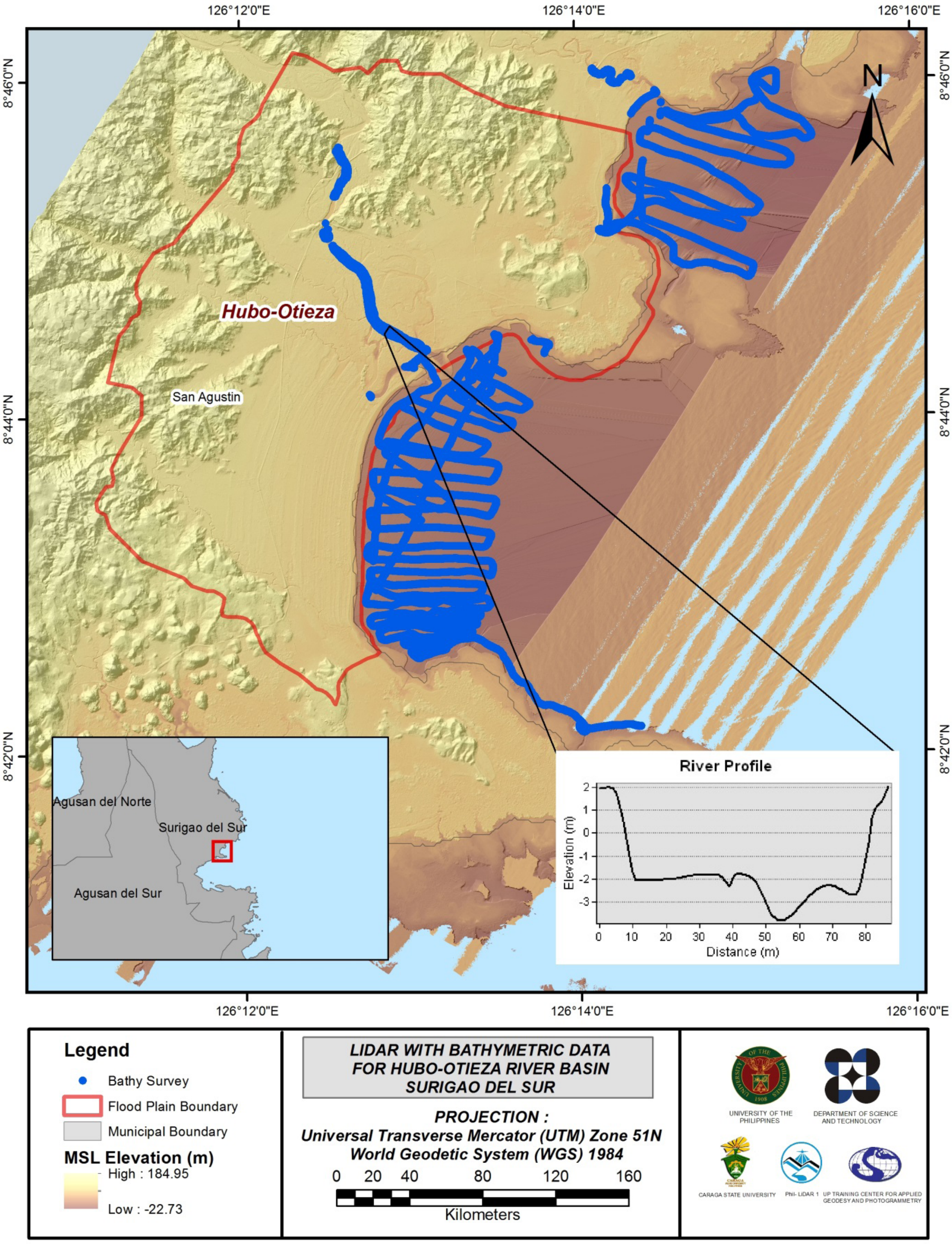

Figure 27. Map of Hubo-Otieza floodplain with bathymetric survey points in blue.

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 a 200-meter buffer zone. Mosaicked LiDAR DEMs with a 1-m resolution were used to delineate footprints of building features, which comprised 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 the routing of disaster response efforts. These features are represented by network of road centerlines.

3.12.1 Quality Checking of Digitized Features' Boundary

Hubo-Otieza floodplain, including its 200-m buffer, has a total area of 27.61 sq km. For this area, a total of 5.0 sq. km., corresponding to a total of 1,477 building features, were considered for QC. Figure 28 shows the QC blocks for the Hubo-Otieza floodplain.

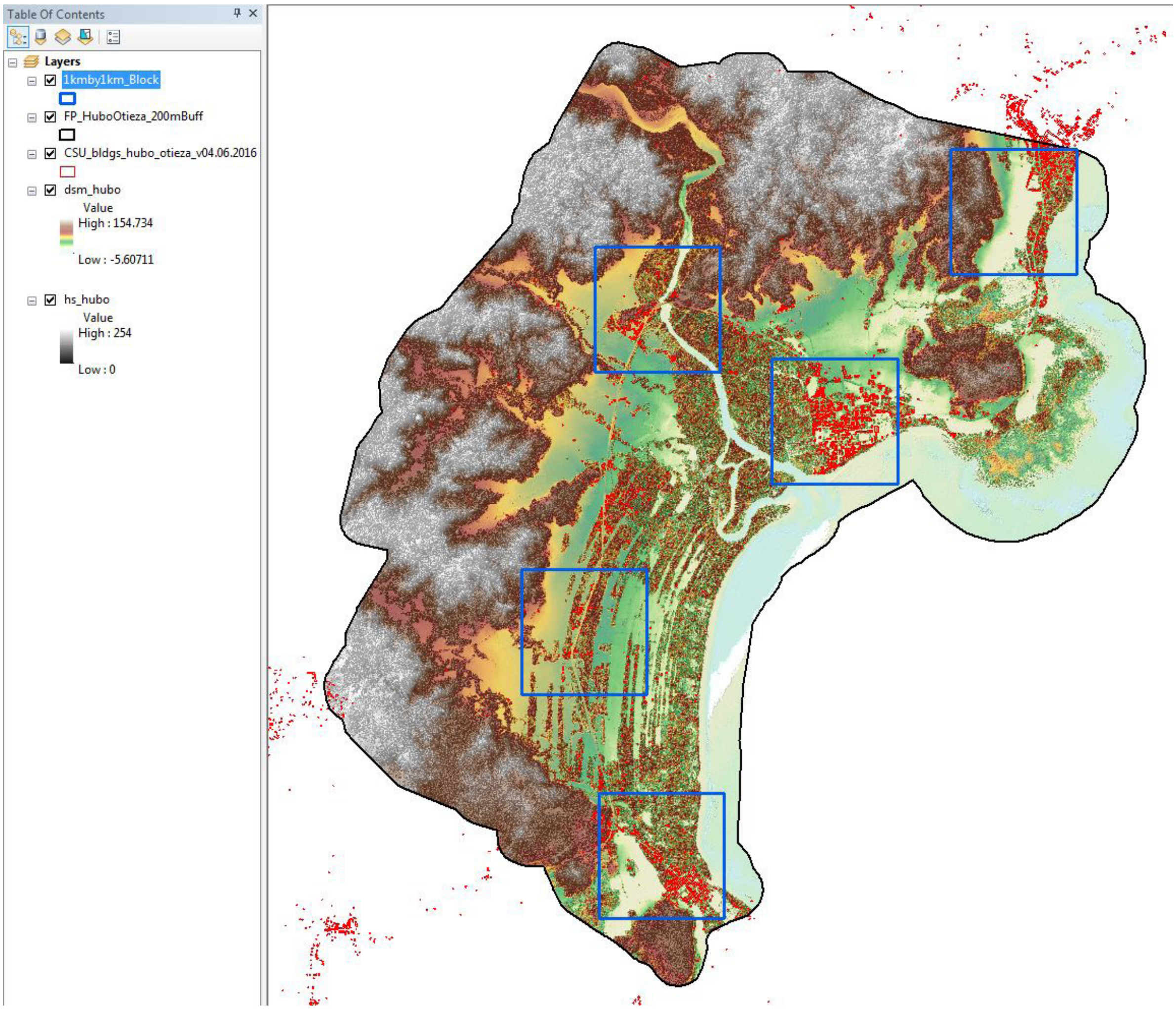

Figure 28. Blocks (in blue) of Hubo-Otieza building features that were subjected to QC.

Quality checking of Hubo-Otieza building features resulted in the ratings shown in Table 17.

Table 17. Details of the quality checking ratings for the building features extracted for the Hubo-Otieza River Basin

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Hubo-Otieza	95.94	99.26	90.25	PASSED

3.12.2 Height Extraction

Height extraction was done for 4,300 building features in Hubo-Otieza floodplain. Of these building features, 335 buildings were filtered out after height extraction, resulting to 3,965 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 6.85 meters.

3.12.3 Feature Attribution

Field surveys, familiarity with the area, and free online web maps such as Wikimapia (http://wikimapia.org/) and Google Map (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, while Table 19 shows the total length of each road type. Table 20, on the other hand, shows the number of water features extracted per type.

Table 18. Building features extracted for Hubo-Otieza Floodplain.

Facility Type	No. of Features
Residential	3,872
School	75
Market	0
Agricultural/Agro-Industrial Facilities	0
Medical Institutions	0
Barangay Hall	0
Military Institution	0
Sports Center/Gymnasium/Covered Court	5
Telecommunication Facilities	0
Transport Terminal	0
Warehouse	0
Power Plant/Substation	0
NGO/CSO Offices	0
Police Station	0
Water Supply/Sewerage	0
Religious Institutions	2
Bank	0
Factory	0
Gas Station	0
Fire Station	0
Other Government Offices	10
Other Commercial Establishments	1
Total	**3,965**

Table 19. Total length of extracted roads for Hubo-Otieza Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Hubo-Otieza	7.17	12.47	29.48	19.46	0	**68.58**

Table 20. Number of extracted water bodies for Hubo-Otieza Floodplain.

Floodplain	Water Body Type					Total
	Rivers/ Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Hubo-Otieza	35	0	0	0	0	**35**

A total of 13 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 given the complete required attributes. Respectively, all these output features comprise the flood hazard exposure database for the floodplain. The final quality checking completes the feature extraction phase of the project.

Figure 29 shows the completed Digital Surface Model (DSM) of the Hubo-Otieza floodplain overlaid with its ground features.

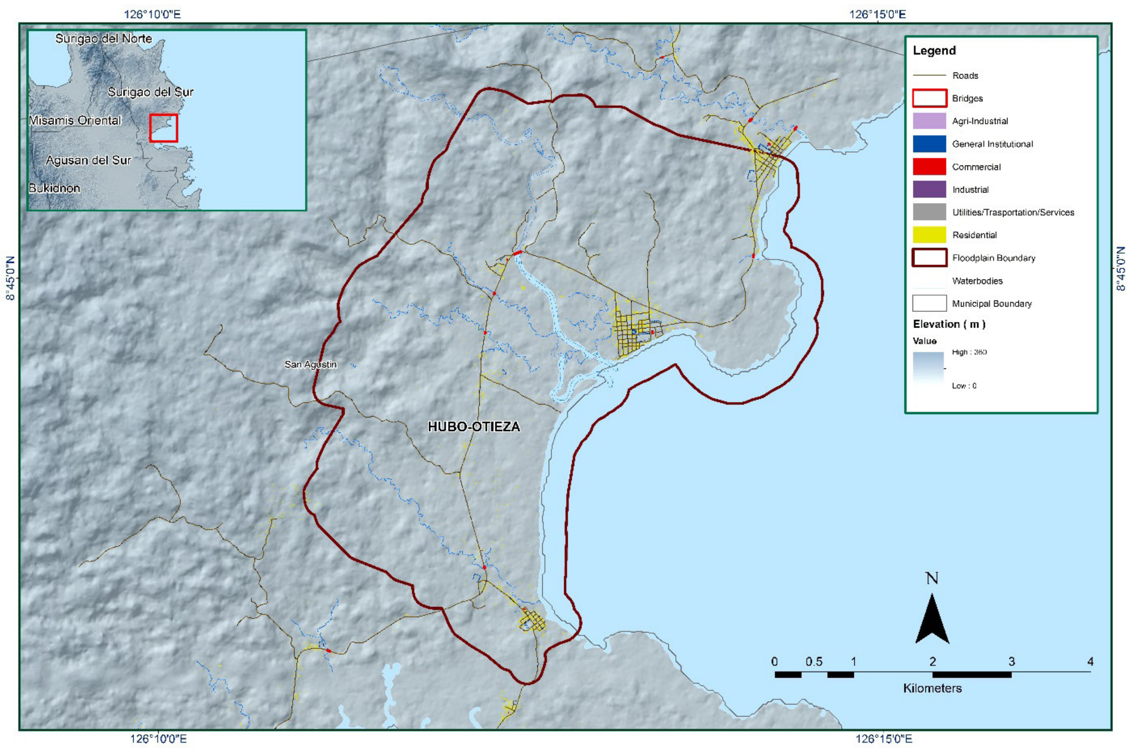

Figure 29. Extracted features of the Hubo-Otieza Floodplain.

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS OF THE HUBO-OTIEZA RIVER BASIN

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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).

4.1 Summary of Activities

Caraga State University (CSU) conducted a field survey in Hubo Otieza River on March 8-11, 2016 with the following scope of work: reconnaissance; control survey; cross-section survey of selected riverbed in Brgy. Otieza, Municipality of San Agustin; validation points acquisition of about 16.10 km covering the Hubo Otieza River Basin from Barangay Amontay, municipality of Marihatag down to Barangay Salvacion, municipality of San Agustin and bathymetric surveyfrom its upstream in Brgy. Otieza, Municipality of San Agustin down to the mouth of the river located in th Brgy. Buhisan, San Agustin, with an approximate length of 2 km using Ohmex™ single beam echo sounder and South® S86T in GNSS RTK survey technique (Figure 30).

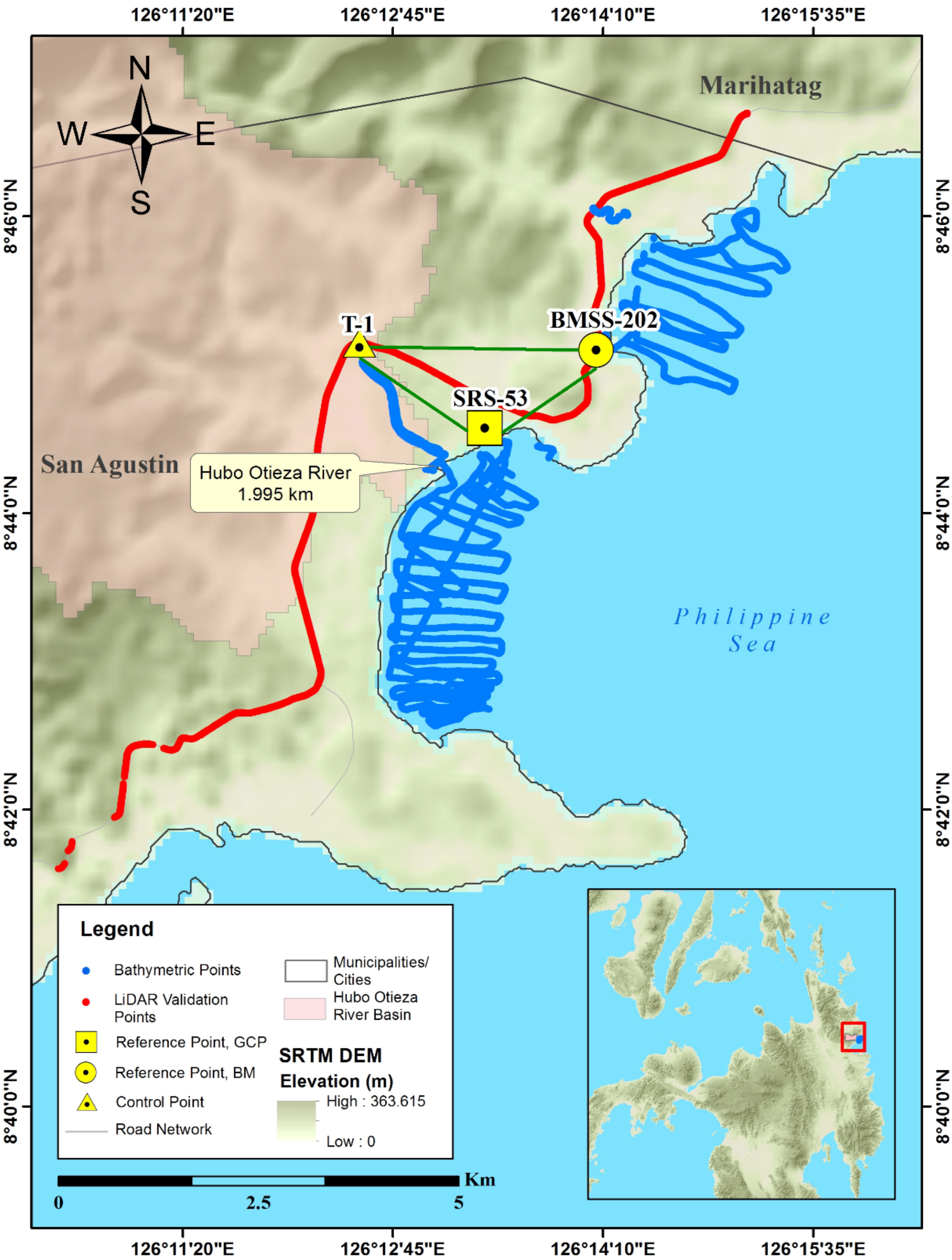


Figure 30. Extent of the bathymetric survey (in blue line) in Hubo-Otieza Riverand the LiDAR data validation survey (in red).

4.2 Control Survey

The GNSS network used for Hubo-Otieza River survey is composed of a single loop established on March 8, 2016 occupying the following reference points: SRS-53, a second order GCP in Brgy. Poblacion, Municipality of San Agustin, Surigao Del Sur; and SS-202, a first order BM in Brgy. Otieza, Municipality of San Agustin, Surigao Del Sur.

A control point was established along approach of Buhisan Bridge namely, T-1 in Brgy. Otieza, Municipality of San Agustin, Surgao Del Sur.

Table 21 depicts the summary of reference and control points utilized, with their corresponding locations, while Figure 31 shows the GNSS network established in the Hubo-Otieza River Survey.

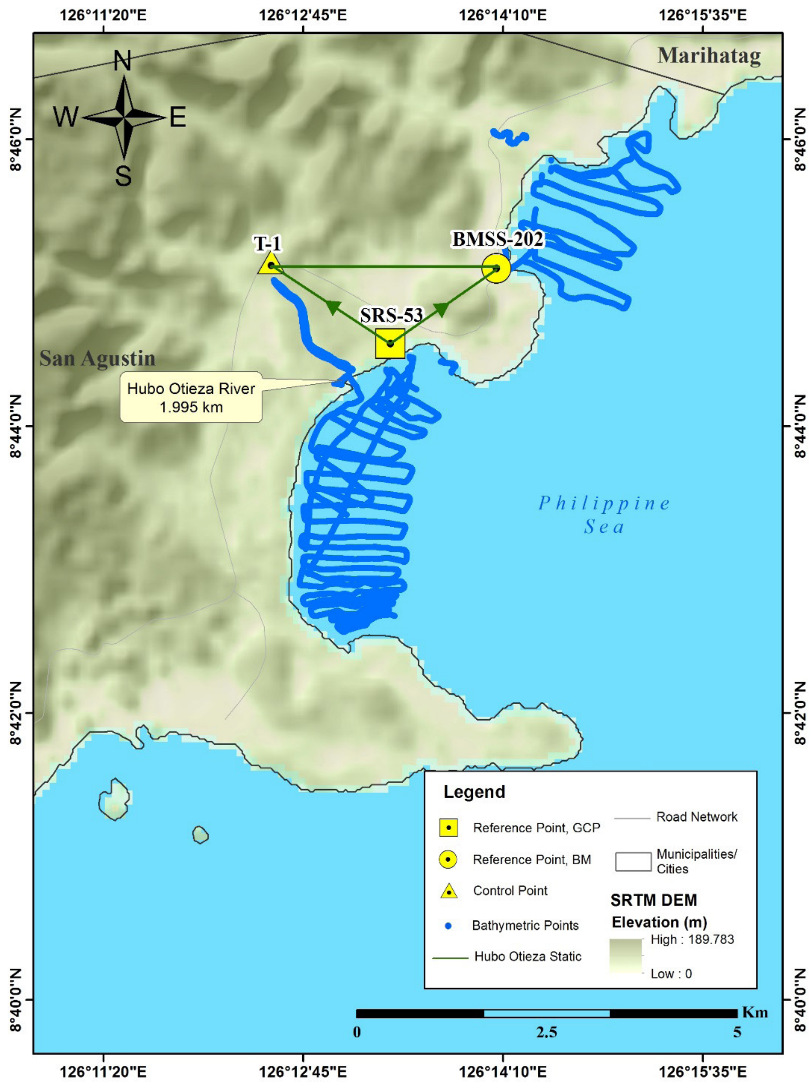


Figure 31. The GNSS Network established in the Hubo-Otieza River Survey.

Table 21. References used and control points established in the Hubo-Otieza River Survey
(Source: NAMRIA, UP-TCAGP).

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (Meter)	Elevation in MSL (Meter)	Date Established
SRS-53	2nd order, GCP	8°44’34.36515”	126°13’22.01039”	69.5930	-	2007
SS-202	1st order, BM	-	-	71.8140	4.4349	2007
T-1	UP established	-	-	-	-	Mar 8, 2016

Figure 32 to Figure 34 depict the setup of the GNSS on recovered reference points and established control points in the Hubo-Otieza River.

Figure 32. The GNSS base receiver setup, South® S86T, at SRS-53 in San Agustin Central Elementary School in Surigao Del Sur

Figure 33. GNSS base receiver setup, Trimble® SPS 852, at SS-202 in Brgy. Otieza, Municipality of San Agustin, Surogao Del Sur

Figure 34. GNSS base receiver setup, South® S86T, on T-1 along approach of Buhisan Brige in Brgy. Otieza, Municipality of San Agustin, Surigao Del Sur

4.3 Baseline Processing

The GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement respectively. In cases where one or more baselines did not meet all of these criteria, masking was performed. Masking is the removal or covering of portions of the baseline data using the same processing software. The data is then repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, a resurvey is initiated. Table 22 presents the baseline processing results of control points in the Hubo-Otieza River Basin, as generated by the TBC software.

Table 22. The Baseline processing report for the Hubo-Otieza River GNSS static observation survey.

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
NGW 50 --- NW 130 (B4)	09-11-2014	Fixed	0.005	0.008	302°49’33”	10801.487	-2.613
NW 130 --- NW 100 (B5)	9-11-2014	Fixed	0.185	0.037	119°37’31”	27388.571	-3.542
NGW 50 --- NW 100 (B6)	9-11-2014	Fixed	0.004	0.006	117°34’16”	16614.558	-6.178

As shown in Table 22, a total of three (3) baselines were processed with the coordinates of NGW-50, and the elevation value of reference points NW-100 held fixed; it is apparent that all baselines passed the required accuracy.

4.4 Network Adjustment

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

$$<20cm \text{ and } z_e < 10 \text{ cm}$$

where:

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

For complete details, see the Network Adjustment Report shown in Table 23 to Table 26.

The three (3) control points: SRS-53, SS-202 and T-1 were occupied and observed simultaneously to form a GNSS loop. Coordinates of SRS-53; and elevation value of SS-202 were held fixed during the processing of the control points as presented in Table 23. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

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

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
SRS-53	Global	Fixed	Fixed	Fixed	
Fixed = 0.000001 (Meter)					

Likewise, the list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 24. The fixed control SRS-53 has no values for grid and elevation errors.

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

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
SRS-53	854654.8704	?	967943.1202	?	1.5852	?	LLh
SS-202 856028.3255 0.001 968922.9885 0.001 4.0037						0.003	
T-1	853094.4845	0.001	968990.0325	0.001	8.4613	0.003	

The results of the computation for accuracy are as follows:

SRS-53
horizontal accuracy = Fixed
vertical accuracy = Fixed

SS-202
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

T-1
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 25. Adjusted geodetic coordinates for control points used in the Hubo-Otieza River Flood Plain validation.

Point ID	Latitude	Longitude	Ellipsoid Height (Meter)	Height Error (Meter)	Constraint
SRS-53	8°44'34.36515"	126°13'22.01039"	69.5930	?	LLh
SS-202	8°45'05.83828"	126°14'07.16714"	71.8140	0.003	
T-1	°45'08.83497"	126°12'31.31142"	76.6740	0.003	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 25. Based on the results of the computation, the accuracy conditions are satisfied; hence, the required accuracy for the program was met. The computed coordinates of the reference and control points utilized in the Hubo-Otieza River GNSS Static Survey are seen in Table 26.

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

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
SRS-53	2nd order, GCP	8°44'34.36515"	126°13'22.01039"	69.5930	967943.1202	854654.8704	2.0159
SS-202	1st order BM	8°45'05.83828"	126°14'07.16714"	71.8140	968922.9885	856028.3255	4.4349
T-1	UP Estab-lished	8°45'08.83497"	126°12'31.31142"	76.6740	968990.0325	853094.4845	8.8919

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

The bridge cross-section and as-built surveys were conducted on March 2016 in Buhisan Bridge, Brgy. Otieza, Municipality of San Agustin using the GNSS receiver South® S86T utilizing GNSS RTK survey technique.

The cross-sectional line of Hubo-Otieza Bridge is about 374.80 meters with eighty-nine (89) points acquired using T-1 as GNSS base station. The cross-section diagram and the location map are shown in Figure 35 and Figure 36.

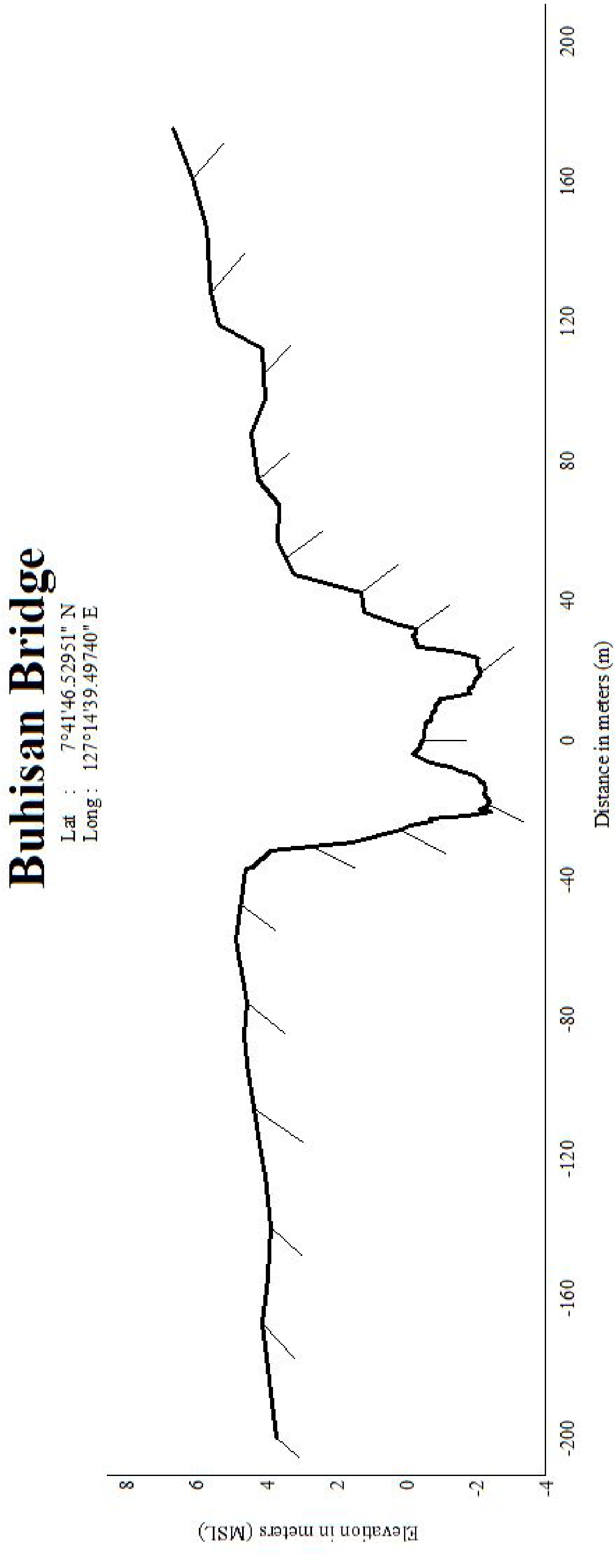


Figure 35. The Hubo-Otieza cross-section survey in Buhisan Bridge drawn to scale

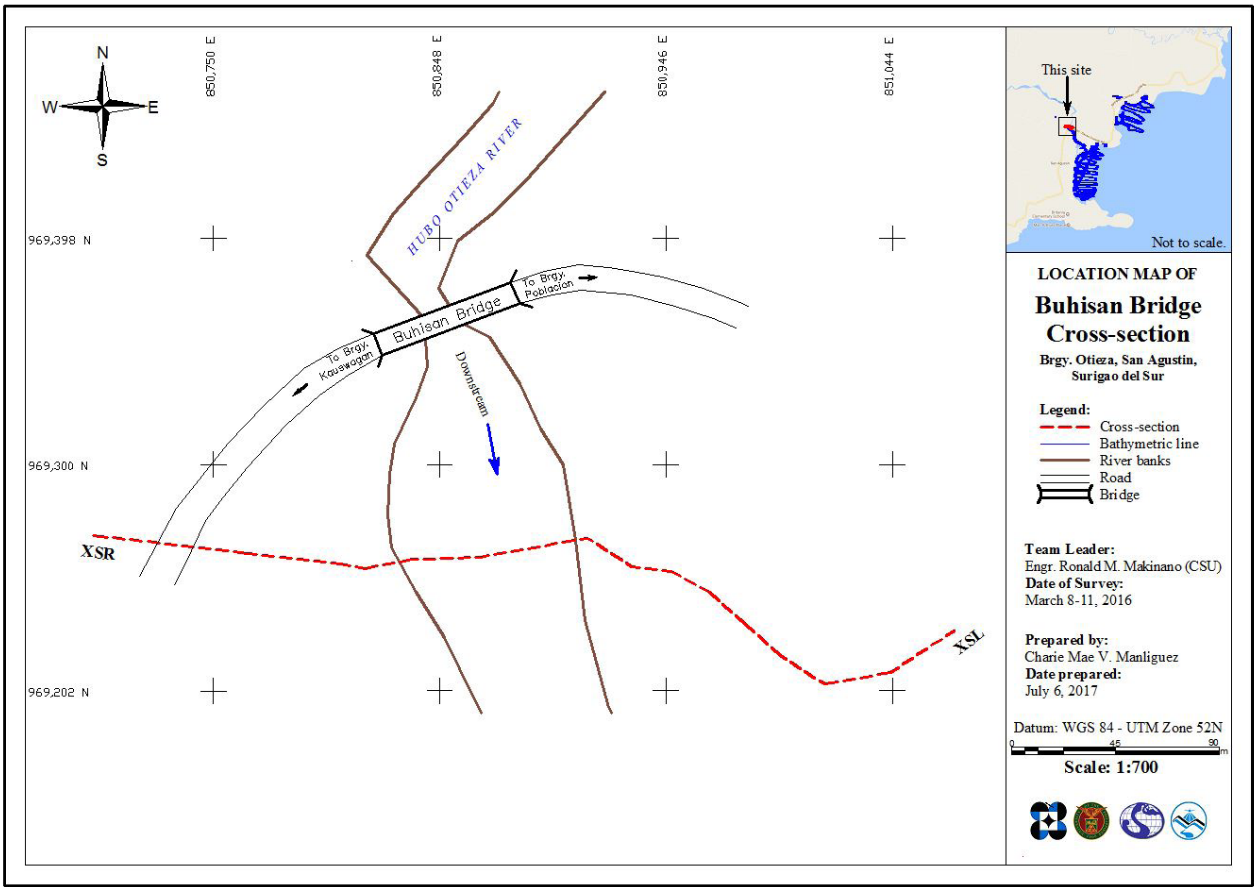


Figure 36. Location map of the Hubo-Otieza cross-section survey in Buhisan Bridge.

4.6 Validation Points Acquisition Survey

The validation points acquisition survey was conducted on March 8, 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 will 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.

Figure 37. GNSS Receiver South® S86T installed on a vehicle for Ground Validation Survey

The GNSS base station was set-up over T-1 gathered validation points from Brgy. Amontay, Municipality of Maruhatag; down to Brgy. Salvacion, Municipality of San Agustin. The ground validation line is approximately 16.10 km in length with 6,063 points.

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.

The ground validation line is approximately 60 km in length and with overall gathered points of 24,810. Figure 38 shows the validation points acquisition survey coverage as well as the LiDAR bathymetric data validation survey result.

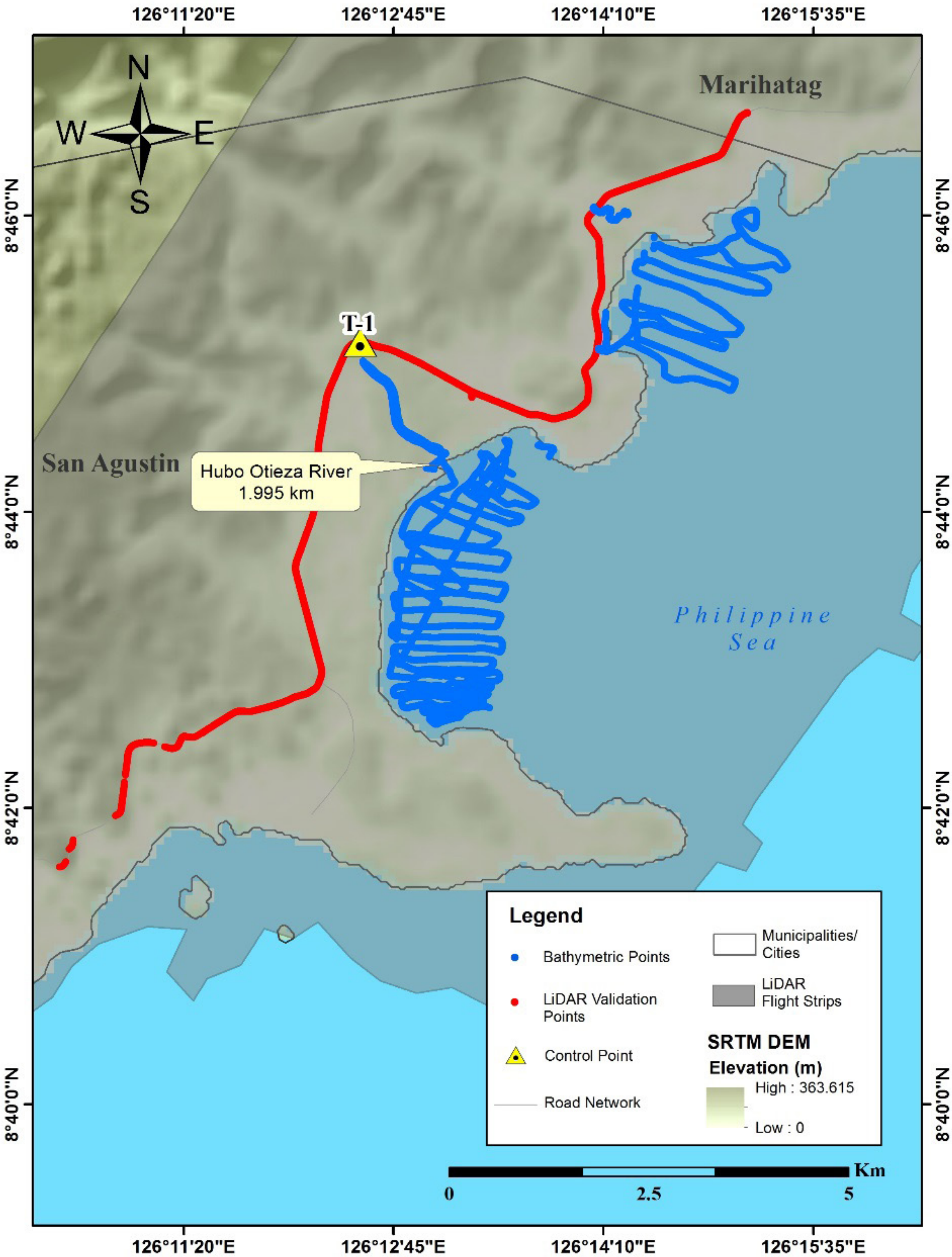


Figure 38. The extent of the LiDAR ground validation survey (in red) for Hubo-Otieza River Basin

4.7 River Bathymetric Survey

On March 8, 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. Otieza, Municipality of San Agustin with coordinates 8˚45'01.10839" 126˚12'32.65514", down to the mouth of the river in Brgy. Buhisan, Also in San Agustin with coordinates 8˚44'12.76927" 126˚13'09.34517".

Figure 39. Set up of the bathymetric survey in Hubo-Otiexa River

The entire bathymetric data coverage for Hubo-Otieza River is illustrated in the map in Figure 40. The bathymetric line is approximately 2 km in length with 4,718 bathymetric points acquired using T-1 as GNSS base station covering Brgy. Otieza, Kauswagan, Poblacion and Buhisan, Municipality of San Agustin. A CAD diagram was also produced to illustrate the Hubo-Otieza riverbed profile as shown in Figure 41. The lowest elevation was recorded at -5.274 m (below MSL), while the highest elevation observed was -1.325 m in MSL both recorded in Brgy. Kauswagan. Additional LiDAR bathymetric data validation survey was executed covering the shoreline of San Agustin in Tandag as shown in Figure 40.

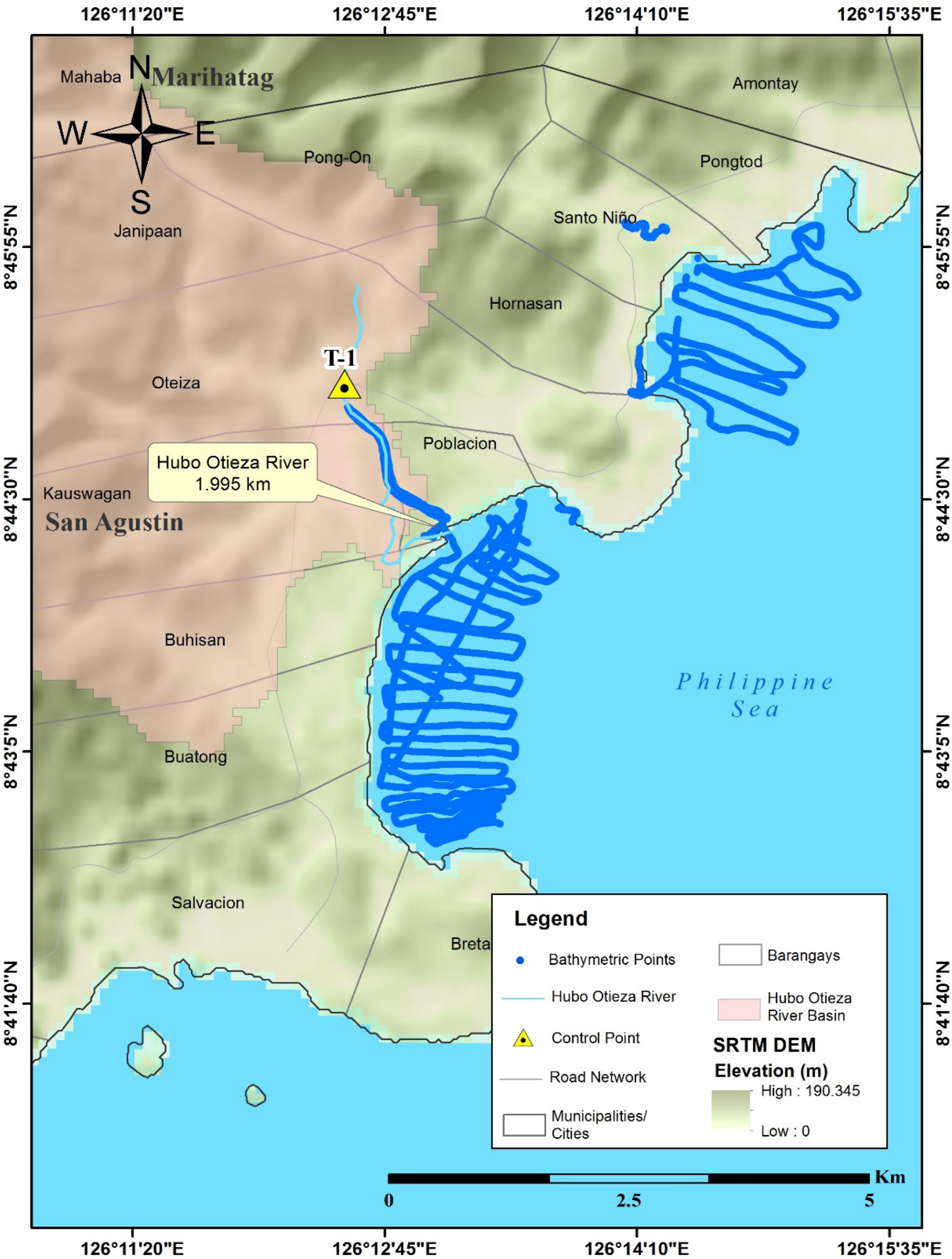


Figure 40. The extent of the Hubo-Otieza River Bathymetry Survey and the LiDAR bathymetric data validation points.

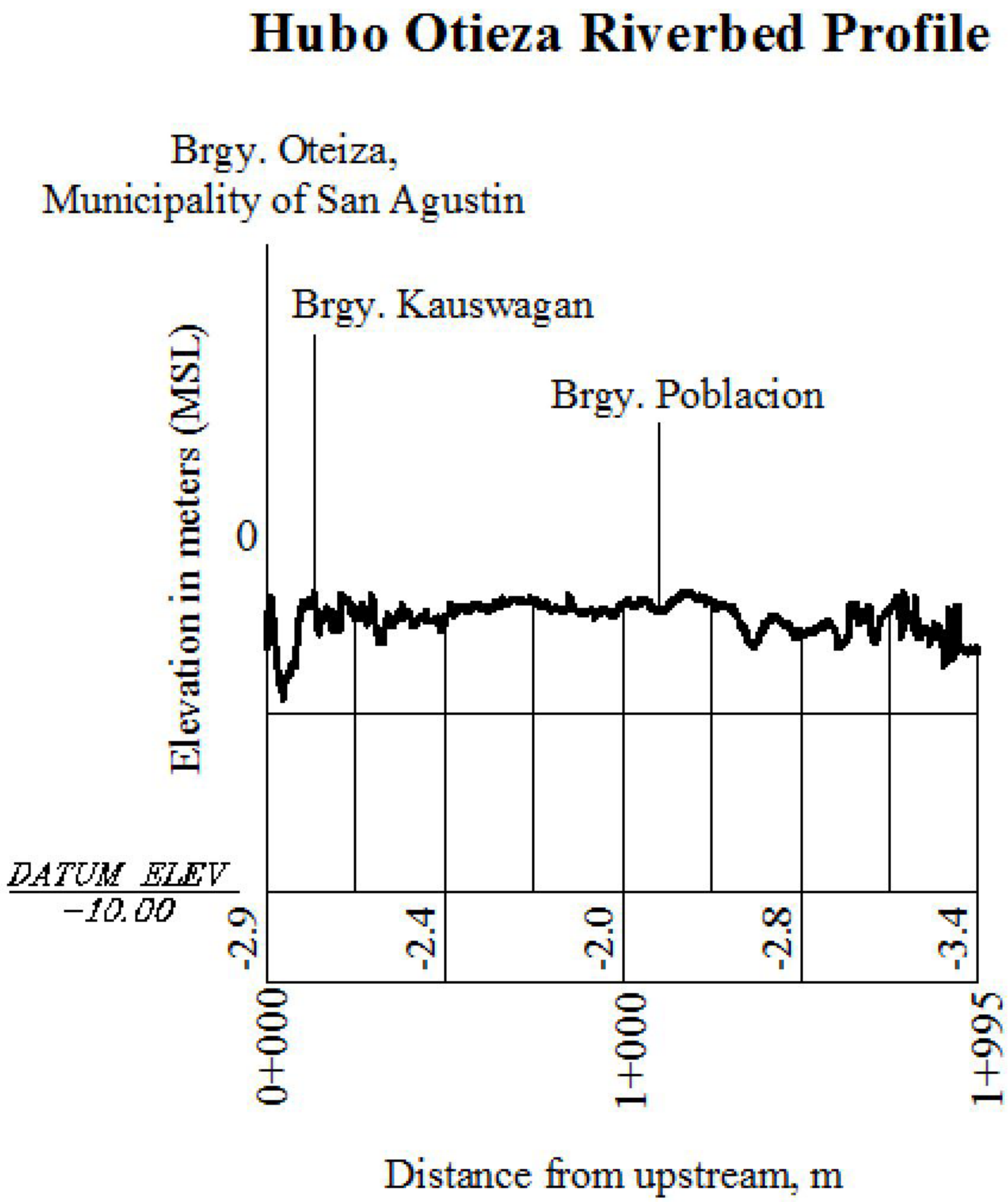


Figure 41. The HUbo-Otieza River Bed Profile

CHAPTER 5: FLOOD MODELING AND MAPPING

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

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).

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

All components and data, such as rainfall, water level, and flow in a certain period of time, which may affect the hydrologic cycle of the Hubo-Otieza River Basin were monitored, collected, and analyzed.

5.1.2 Precipitation

Precipitation data was taken from an automatic rain gauge (ARG) installed by the Department of Science and Technology – Advanced Science and Technology Institute as illustrated in Figure 42. The precipitation data collection started from November 16, 2015 at 0:00 AM to Nove,ber 19, 2015 at 10:00 AM.

The total precipitation for this event in Tina ARG was 65.2 mm. It has a peak rainfall of 4 mm. on November 18, 2015 at 08:45 in the morning. The lag time between the peak rainfall and discharge at Buhisan Bridge is 8 hours and 35 minutes.

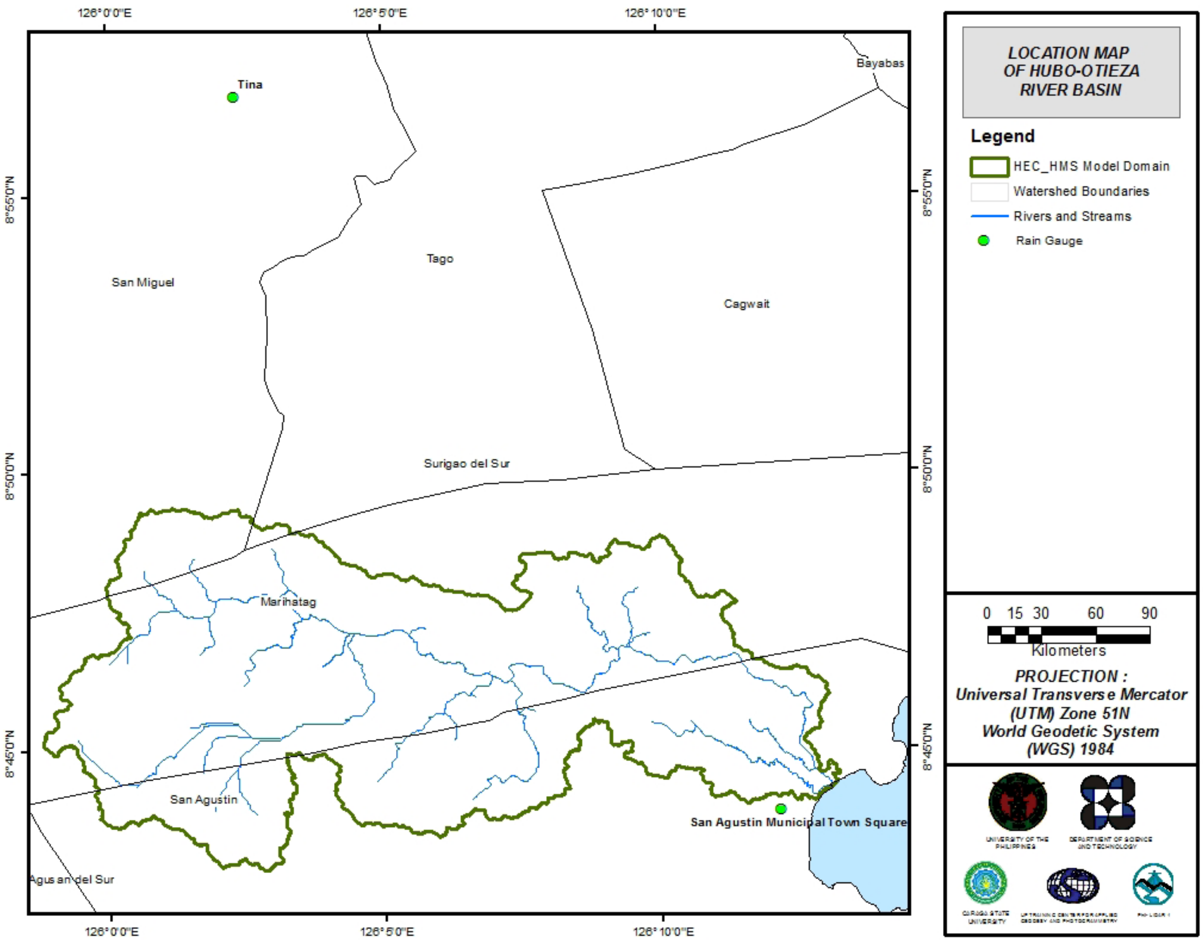


Figure 42. Location Map of the Hubo-Otieza HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Buhisan Bridge, San Agustin, Surigao del Sur (8°45'7.38"N, 126°12'29.83"E) to establish the relationship between the observed water levels (H) at Buhisan Bridge and outflow (Q) of the watershed at this location.

For Buhisan Bridge, the rating curve is expressed as Q = 92.433H + 45.757 as shown in Figure 44.

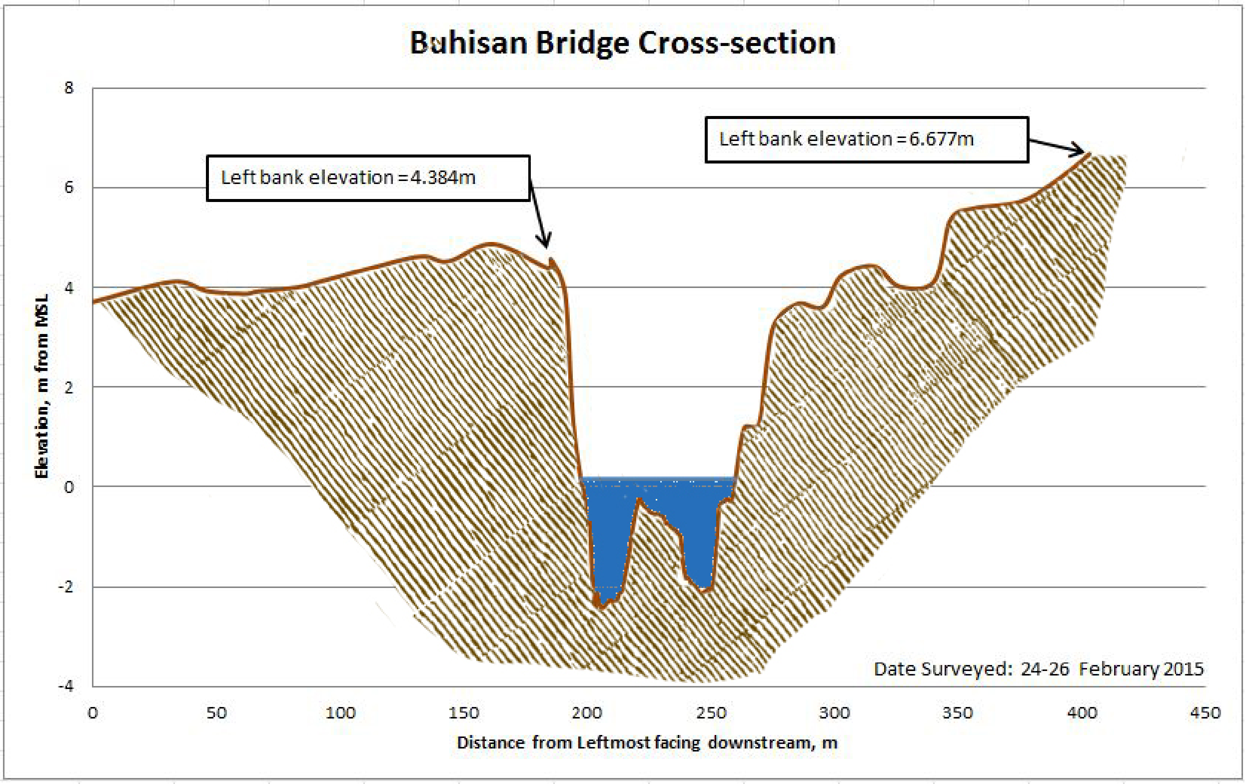


Figure 43. The cross-section plot of the Buhisan Bridge.

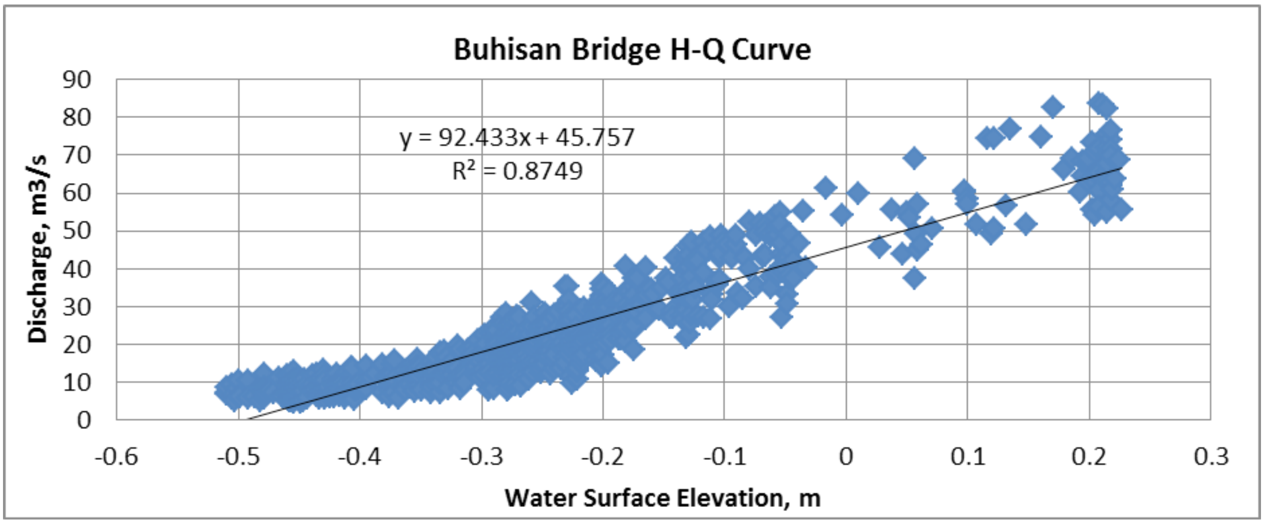


Figure 44. The rating curve at Buhisan Bridge, San Agustin, Surigao del Sur.

This rating curve equation was used to compute the river outflow at Buhisan Bridge for the calibration of the HEC-HMS model shown in Figure 45. The peak discharge is 73.97 m^3/s at 5:00 in the morning, November 19, 2015.

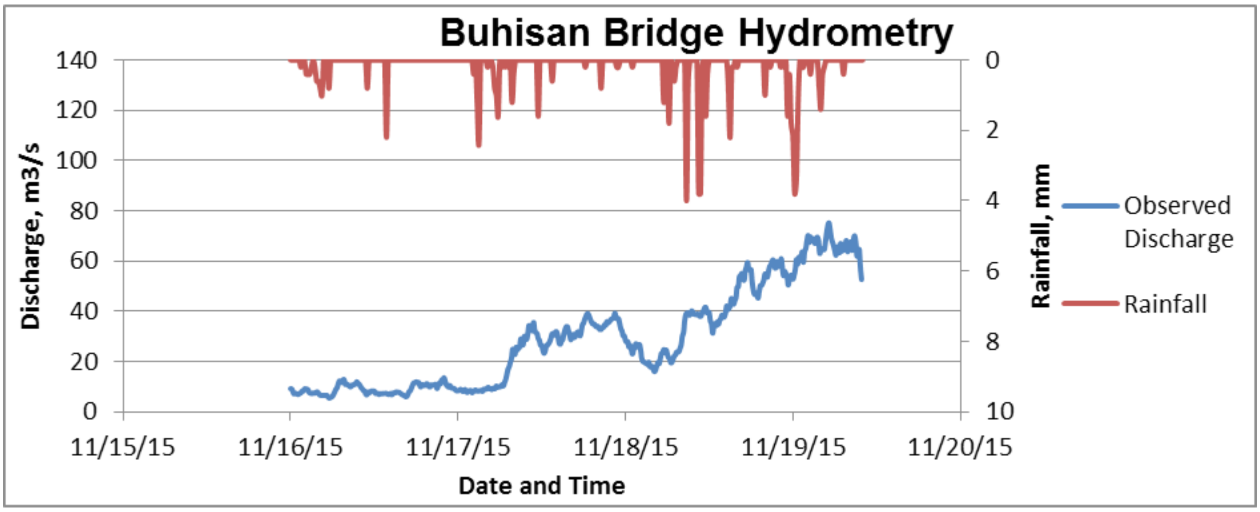


Figure 45. Rainfall at Tina ARG and outflow data at the Buhisan Bridge of the Hubo-Otieza River Basin, which was used for modeling.

5.2 RIDF Station

PAGASA computed the Rainfall Intensity Duration Frequency (RIDF) values for the Iloilo Rain Gauge (Table 27). The RIDF rainfall amount for 24 hours was converted into a synthetic storm by interpolating and re-arranging the values in such a way that certain peak values will be attained at a certain time (Figure 46). This station was selected based on its proximity to the Hubo-Otieza watershed. The extreme values for this watershed were computed based on a 42-year record.

Table 27. RIDF values for the Hubo-Otieza River Basin based on average RIDF data of Hinatuan station, as computed by PAGASA

COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION									
T (yrs)	5 mins	10 mins	15 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

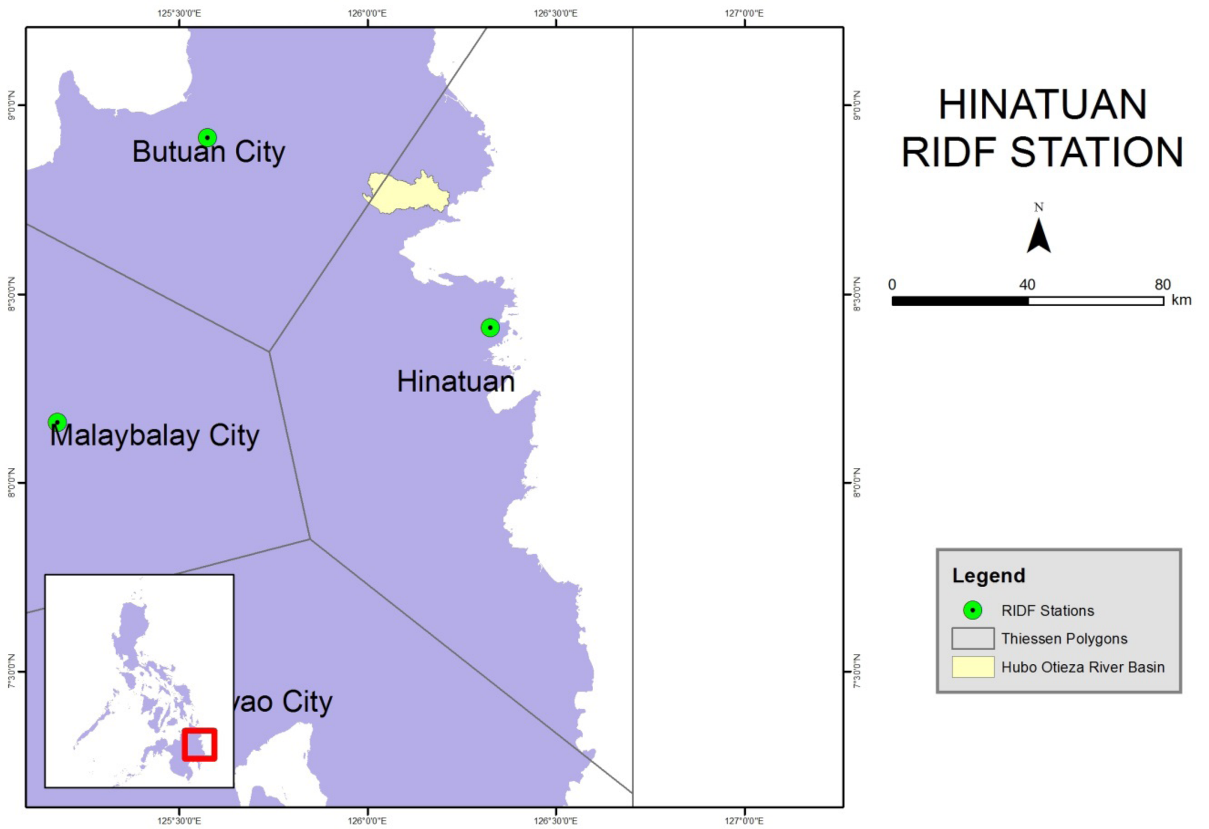


Figure 46. The location of the Hinatuan RIDF station relative to the Hubo-Otieza River Basin.

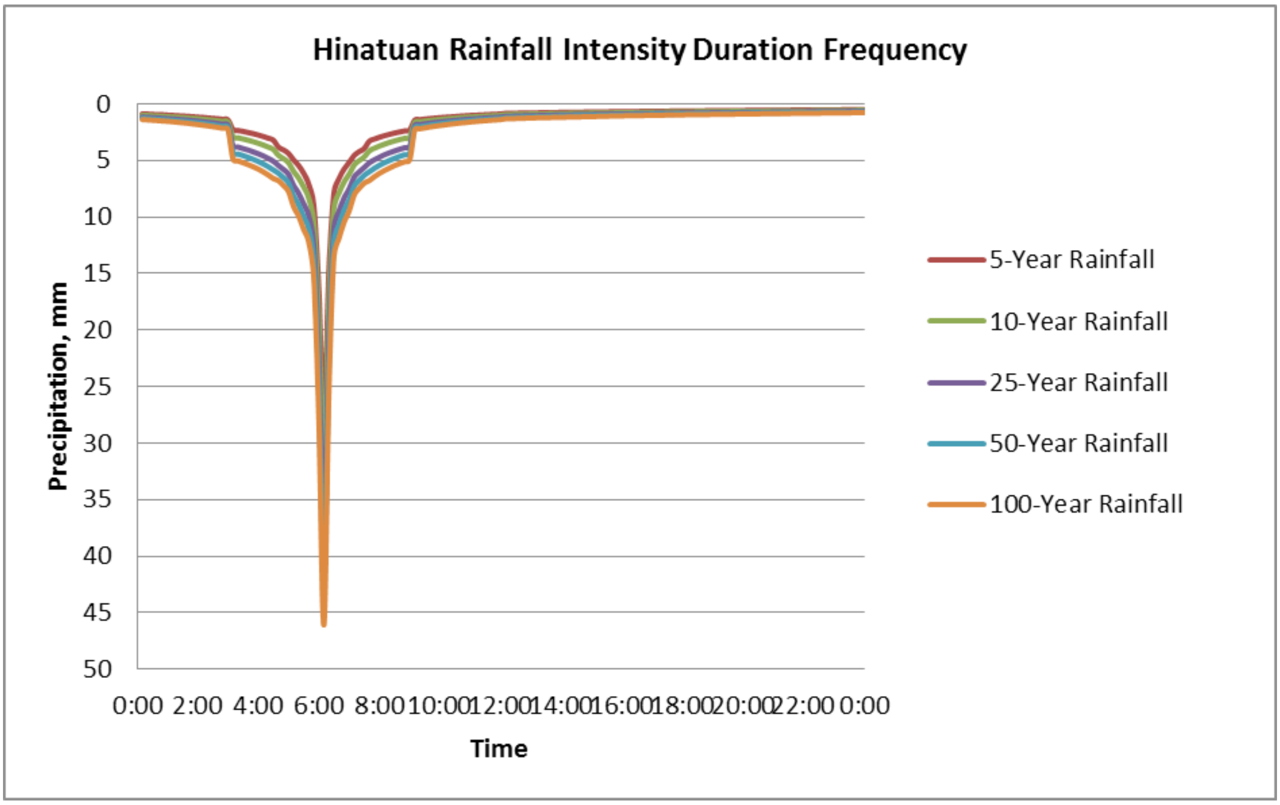


Figure 47. The synthetic storm generated for a 24-hour period rainfall for various return periods

5.3 HMS Model

These soil dataset was taken on 2004 from the Bureau of Soils and Water Management (BSWM). It is under the Department of Agriculture (DA). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Hubo-Otieza River Basin are shown in Figure 48 and Figure 49 respectively.

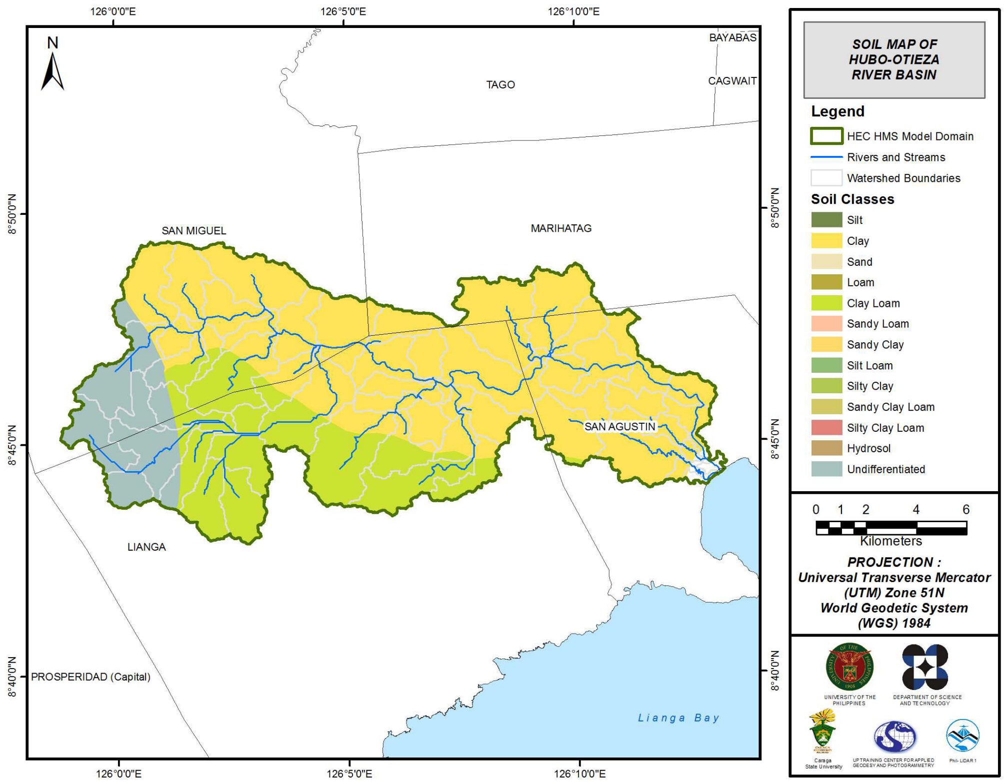


Figure 48. Soil Map of Hubo-Otieza River Basin.

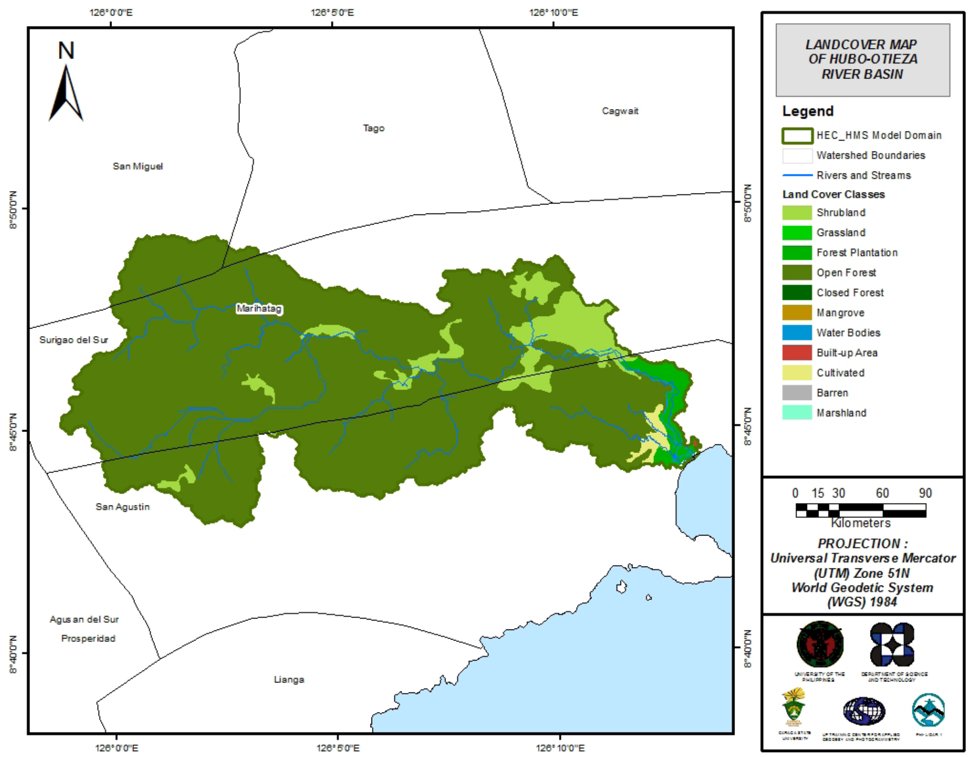


Figure 49. Land Cover Map of Hubo-Otieza River Basin.

For Hubo-Otieza, four soil classes were identified. These are are clay loam, clay, and undifferentiated soil. Moreover, three land cover classes were identified. These are brushland, open canopy forest and cultivated lands.

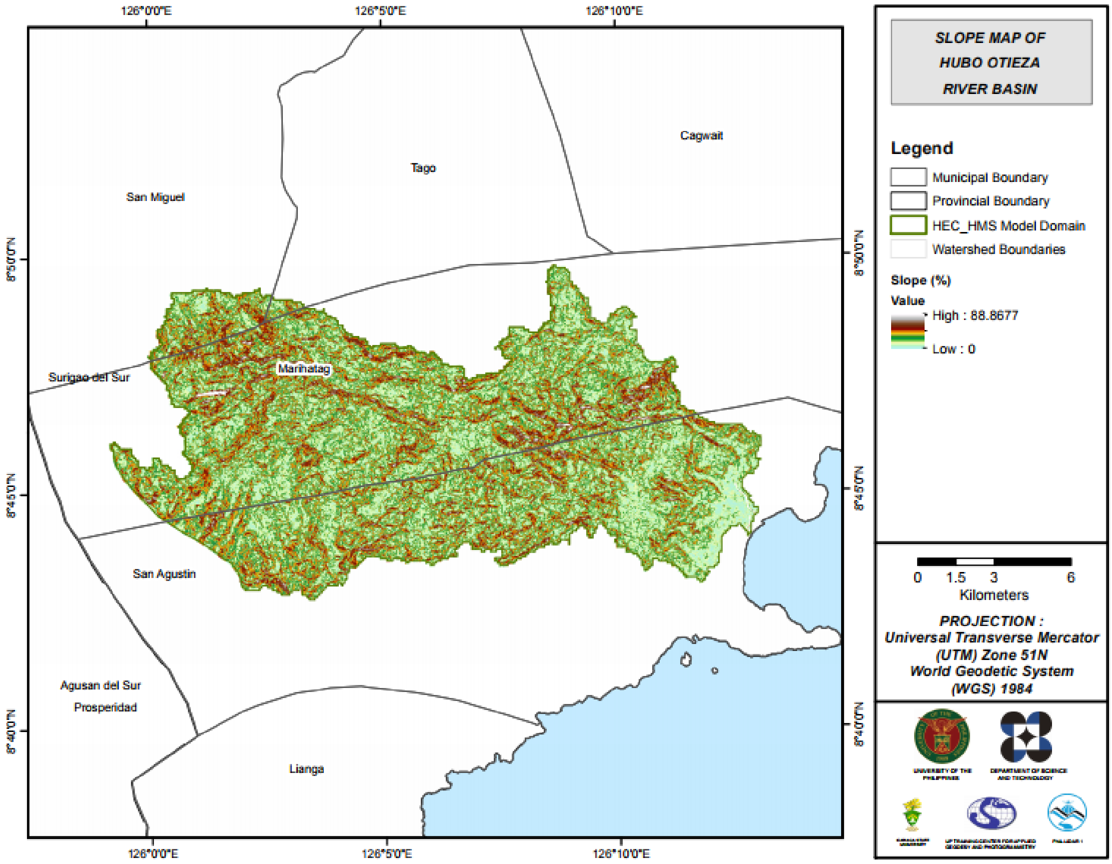


Figure 50. Slope Map of the Hubo-Otieza River Basin.

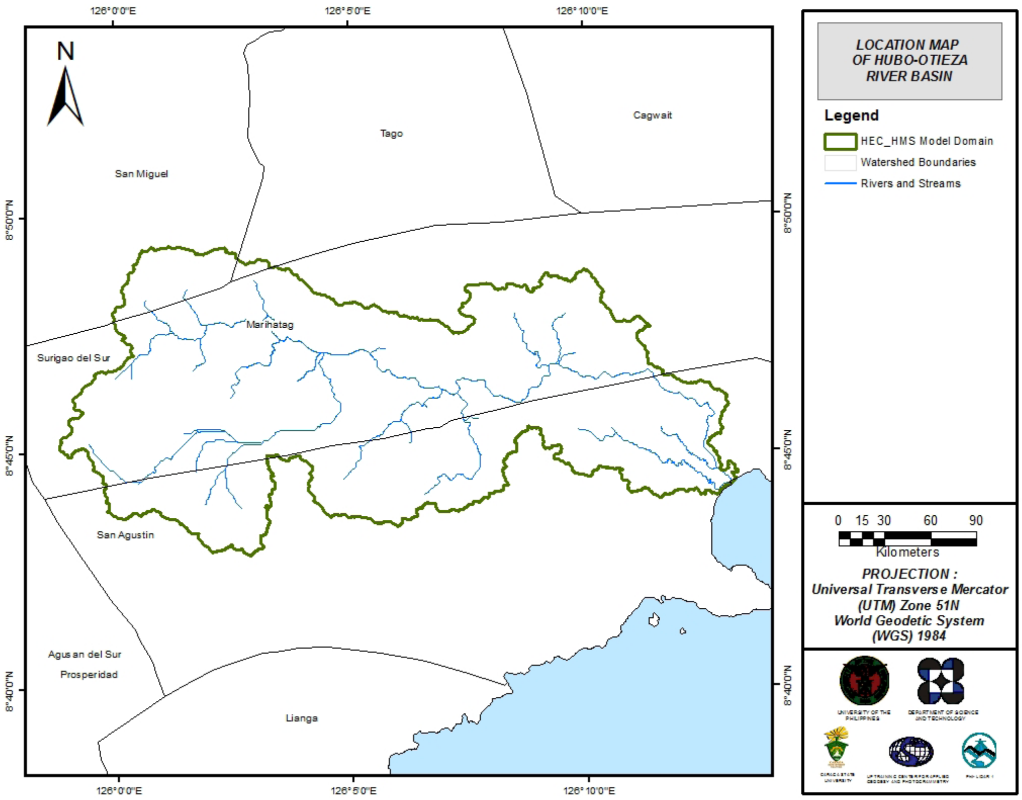


Figure 51. Stream Delineation Map of Hubo-Otieza River Basin

Using the SAR-based DEM and the resampled 10-meter resolution LiDAR DTM, the Hubo-Otieza basin was delineated and further subdivided into subbasins. The model consists of 66 sub basins, 41 reaches, 38 junctions, and 2 diversions as shown in Figure 52. The main outlet is at Buhisan Bridge.

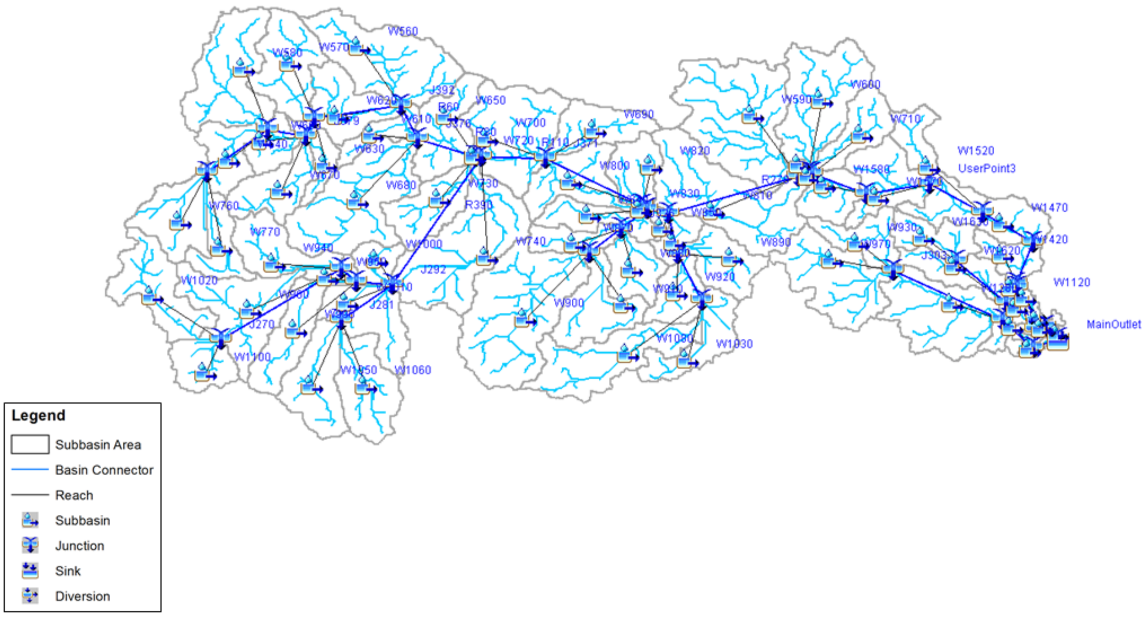


Figure 52. Hubo-Otieza river basin model generated in HEC-HMS.

5.4 Cross-section Data

The riverbed cross-sections of the watershed were necessary in the HEC-RAS model setup. The cross-section data for the HEC-RAS model was derived from the LiDAR DEM data, which was defined using the Arc GeoRAS tool and was post-processed in ArcGIS (Figure 53).

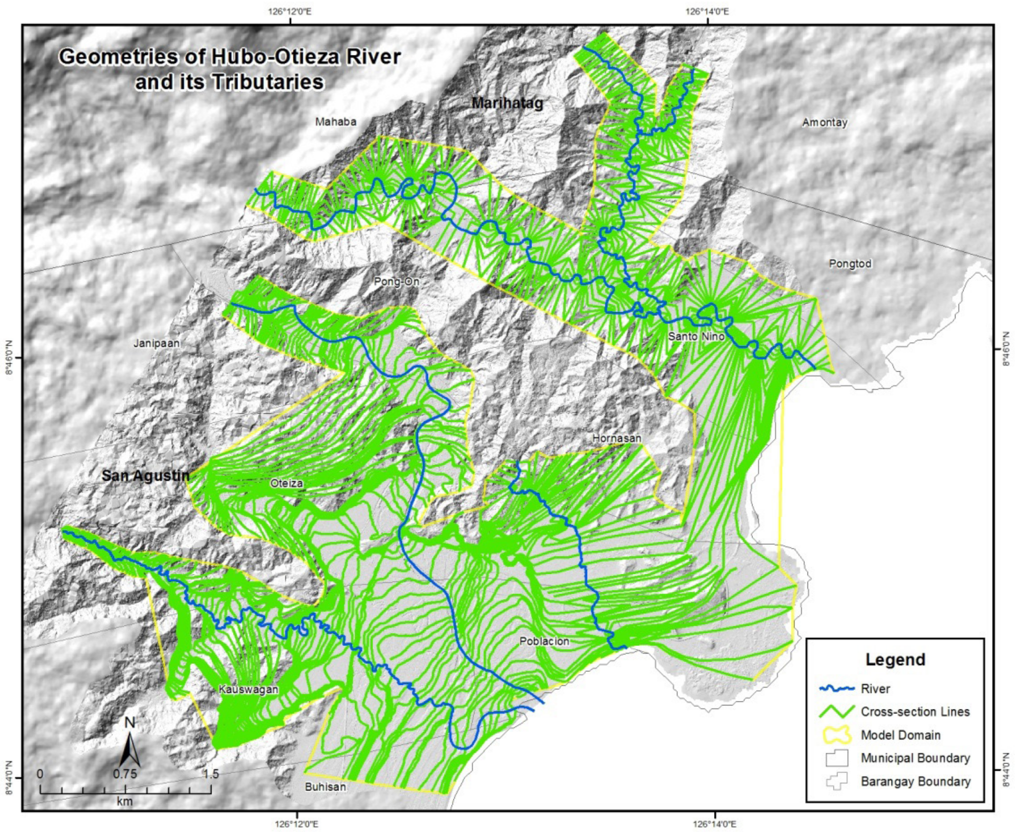


Figure 53. River cross-section of the Hubo-Otieza River through the ArcMap HEC GeoRas tool

5.5 Flo 2D Model

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

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

Figure 54. A screenshot of the river sub-catchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro)

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 22.20007 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m^2/s. The generated hazard maps for Hubo-Otieza are in Figure 58, 60 and 62.

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 22958400.00 m2. The generated flood depth maps for Hubo-Otieza are in Figure 59, 61, and 63.

There is a total of 61783670.89 m^3 of water entering the model. Of this amount, 6072171.66 m^3 is due to rainfall while 55711499.22 m^3 is inflow from other areas outside the model 4363573.50 m^3 of this water is lost to infiltration and interception, while 33831397.31 m^3 is stored by the flood plain. The rest, amounting up to 23588699.98 m^3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Hubo-Otieza HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 55 shows the comparison between the two discharge data.

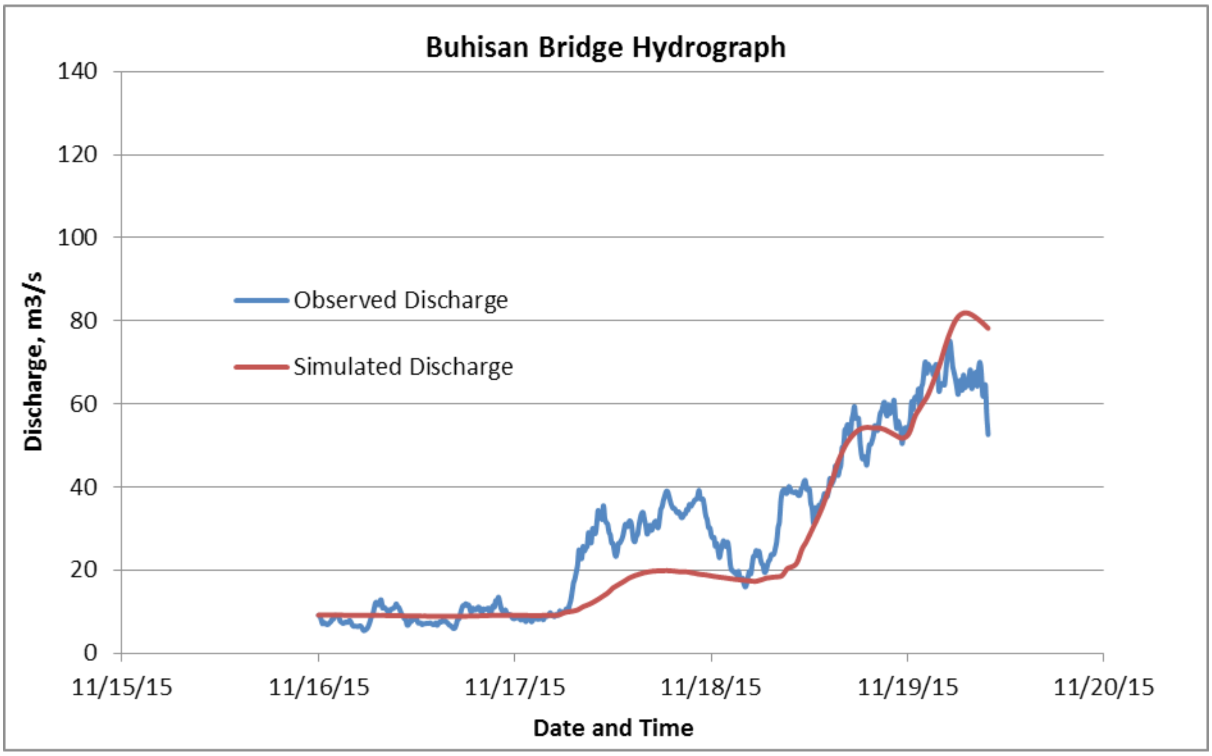


Figure 55. Outflow Hydrograph of Buhisan Bridge produced by the HEC-HMS model compared with observed outflow

Table 28 shows the adjusted ranges of values of the parameters used in calibrating the model.

Table 28. Range of calibrated values for the Hubo-Otieza River Basin.

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	2.67-10.54
			Curve Number	35.2-95.64
			Impervious (%)	0-14.43
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.20-2.78
			Storage Coefficient (hr)	1.16-6.95
	Baseflow	Recession	Recession Constant	0.8
			Ratio to Peak	0
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.15

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 2.67 mm to 10.54 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 65 to 90 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For Hubo-Otieza, the low values indicate high runoffs from less vegetated areas.

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0 hours to 6 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.9 indicates that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.8 indicates a gentler receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.15 corresponds to the common roughness in the Hubo-Otieza watershed, which is determined to be smooth waterways (Brunner, 2010).

Table 29. Summary of the Efficiency Test of the Hubo-Otieza HMS Model

Accuracy measure	Value
RMSE	8.8
r2	0.8617
NSE	0.81
PBIAS	11.83
RSR	0.44

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 8.8 (m^3/s).

The Pearson correlation coefficient (r^2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.8617.

The Nash-Sutcliffe (E) method was also used to assess the predictive power of the model. Here the optimal value is 1. The model attained an efficiency coefficient of 0.81.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is 11.83.

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 0.44.

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 56) shows the Hubo-Otieza outflow using the Hinatuan Rainfall Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) data. The simulation results reveal increasing outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

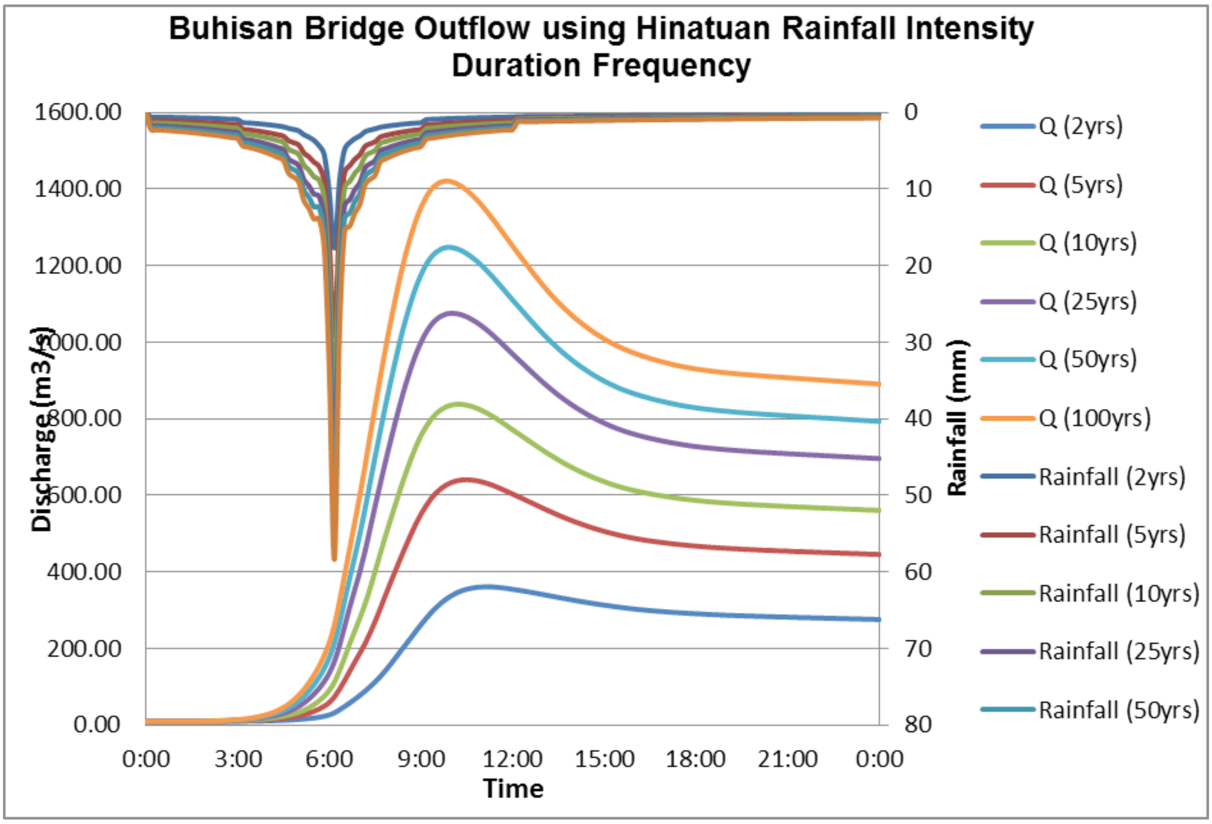


Figure 56. The Outflow hydrograph at the Hinatuan Station, generated using the Hinatuan RIDF simulated in HEC-HMS.

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

Table 30. The peak values of the Hubo-Otieza HEC-HMS Model outflow at Buhisan Bridge using the Hinatuan RIDF.

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	286.50	29.09	640.95	4 hours and 30 minutes
10-Year	351.20	36.74	838.19	4 hours and 10 minutes
25-Year	433.00	45.66	1,075.93	4 hours and 0 minute
50-Year	493.70	52.03	1,247.77	3 hours and 50 minutes
100-Year	553.90	58.35	1,421.47	3 hours and 50 minutes

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. Figure 57 shows a generated sample map of the Hubo-Otieza River using the calibrated HMS base flow of Typhoon Agaton.

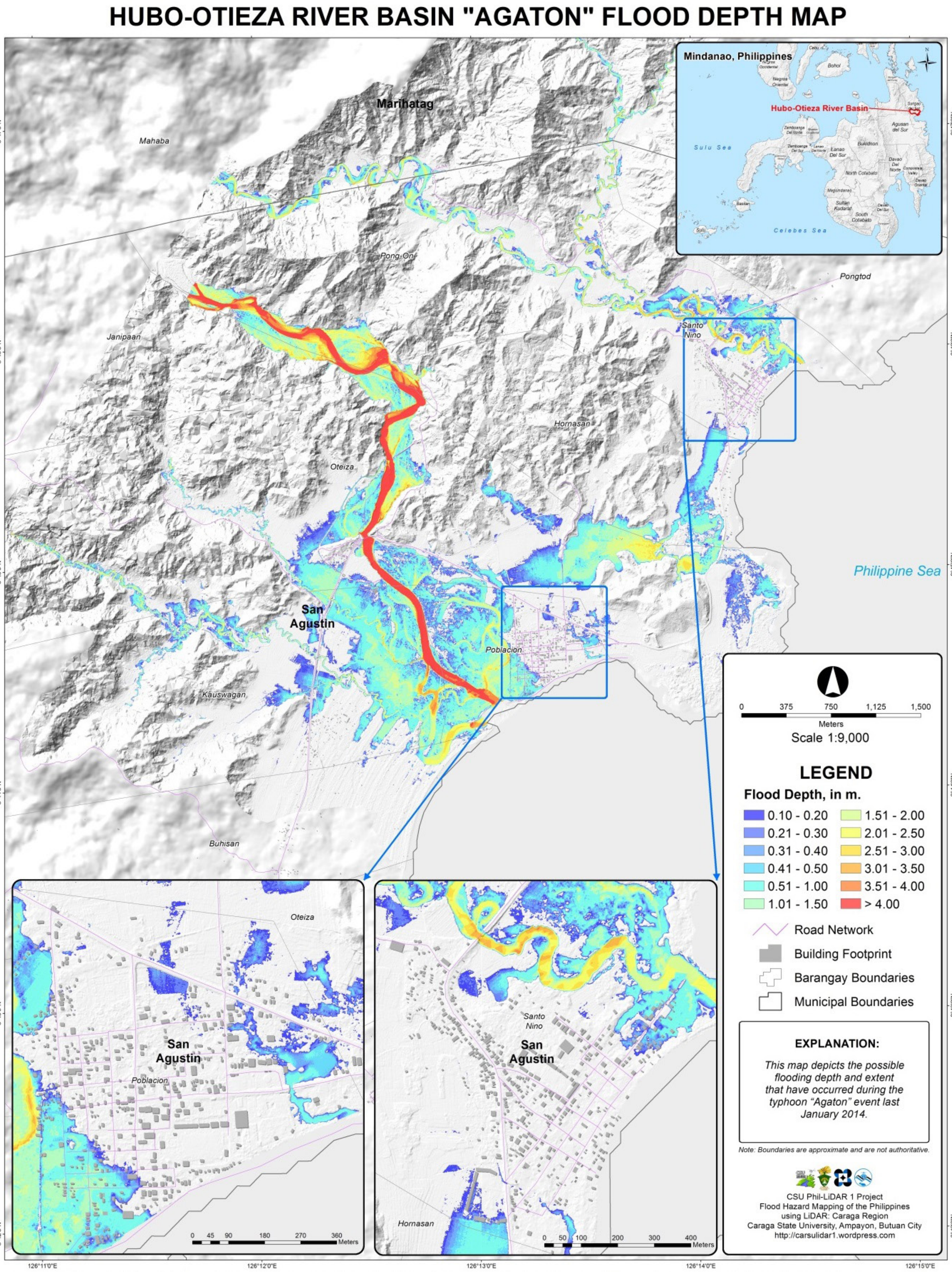


Figure 57. Sample output map of the Hubo-Otieza RAS Model.

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figure 58 to Figure 63 shows the 5-, 25-, and 100-year rain return scenarios of the Hubo-Otieza floodplain. The floodplain, with an area of 50.81 sq. km., covers two municipalities namely Marihatag and San Agustin. Table 31 shows the percentage of area affected by flooding per municipality.

Table 31. Municipalities affected in Hubo-Otieza floodplain.

Municipality	Total Area	Area Flooded	% Flooded
Marihatag	272.40	0.61	0.22%
San Agustin	231.99	50.03	21.57%

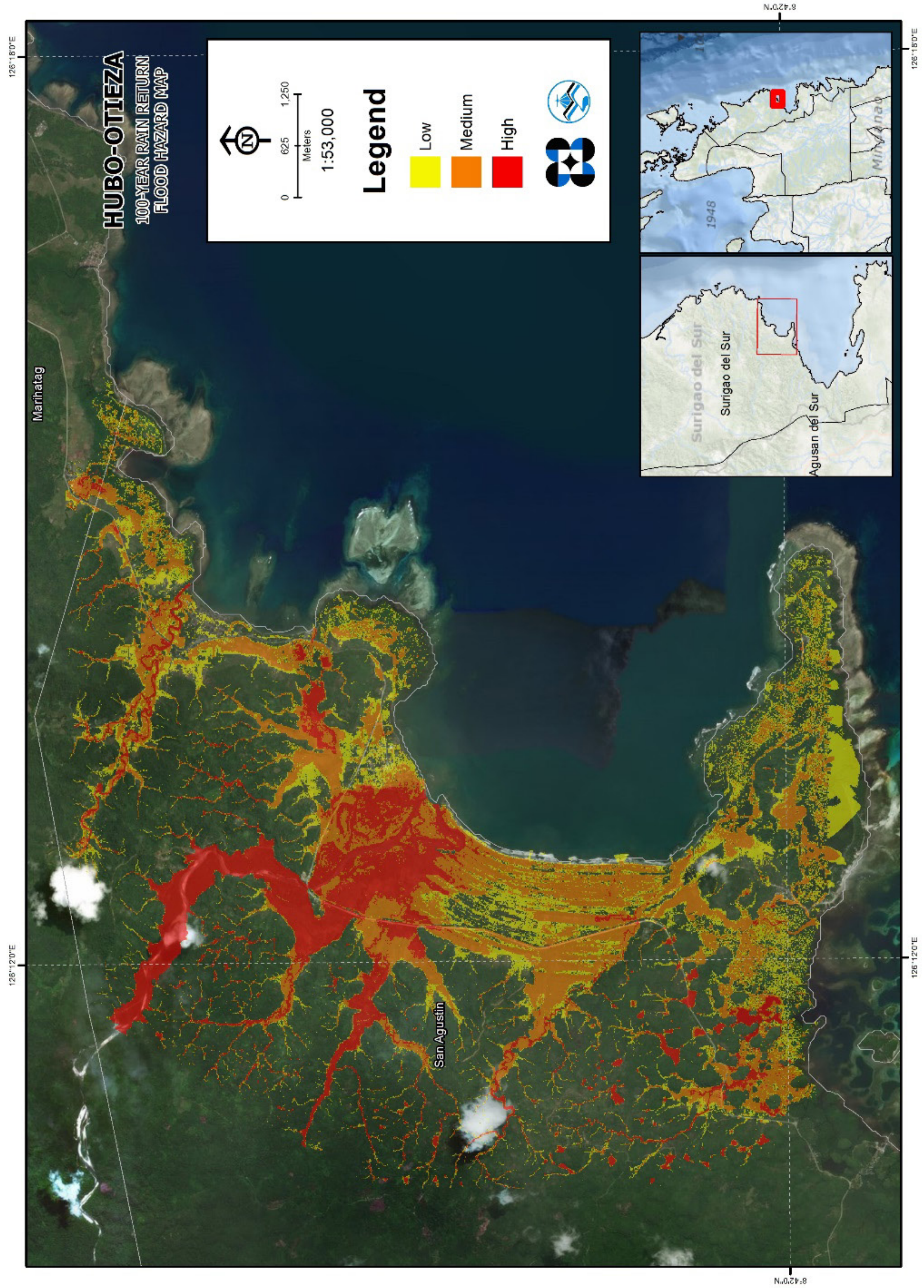


Figure 58. A 100-year Flood Hazard Map for Hubo-Otieza Floodplain overlaid on Google Earth imagery.

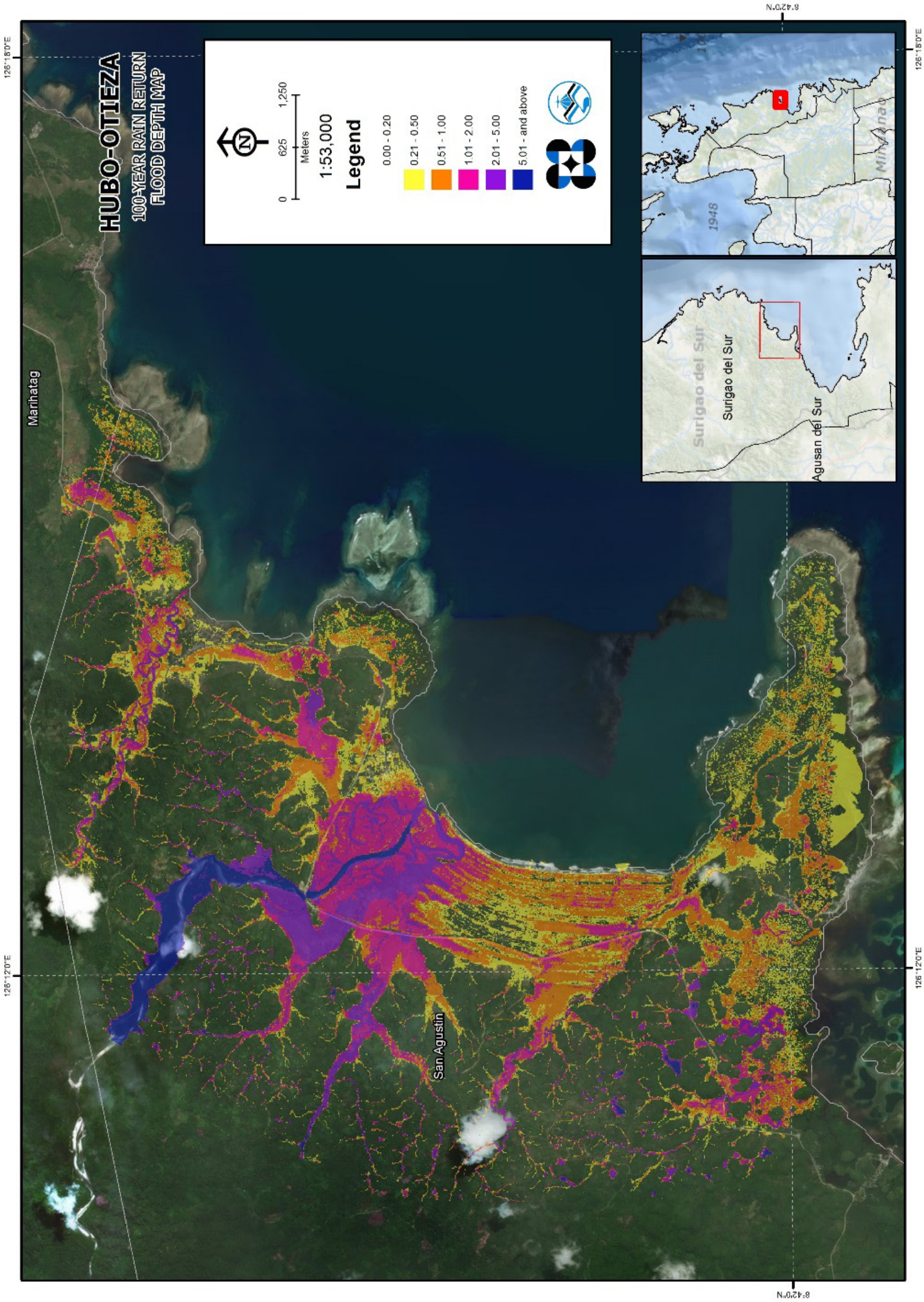


Figure 59. A 100-year Flow Depth Map for Hubo-Otieza Floodplain overlaid on Google Earth imagery.

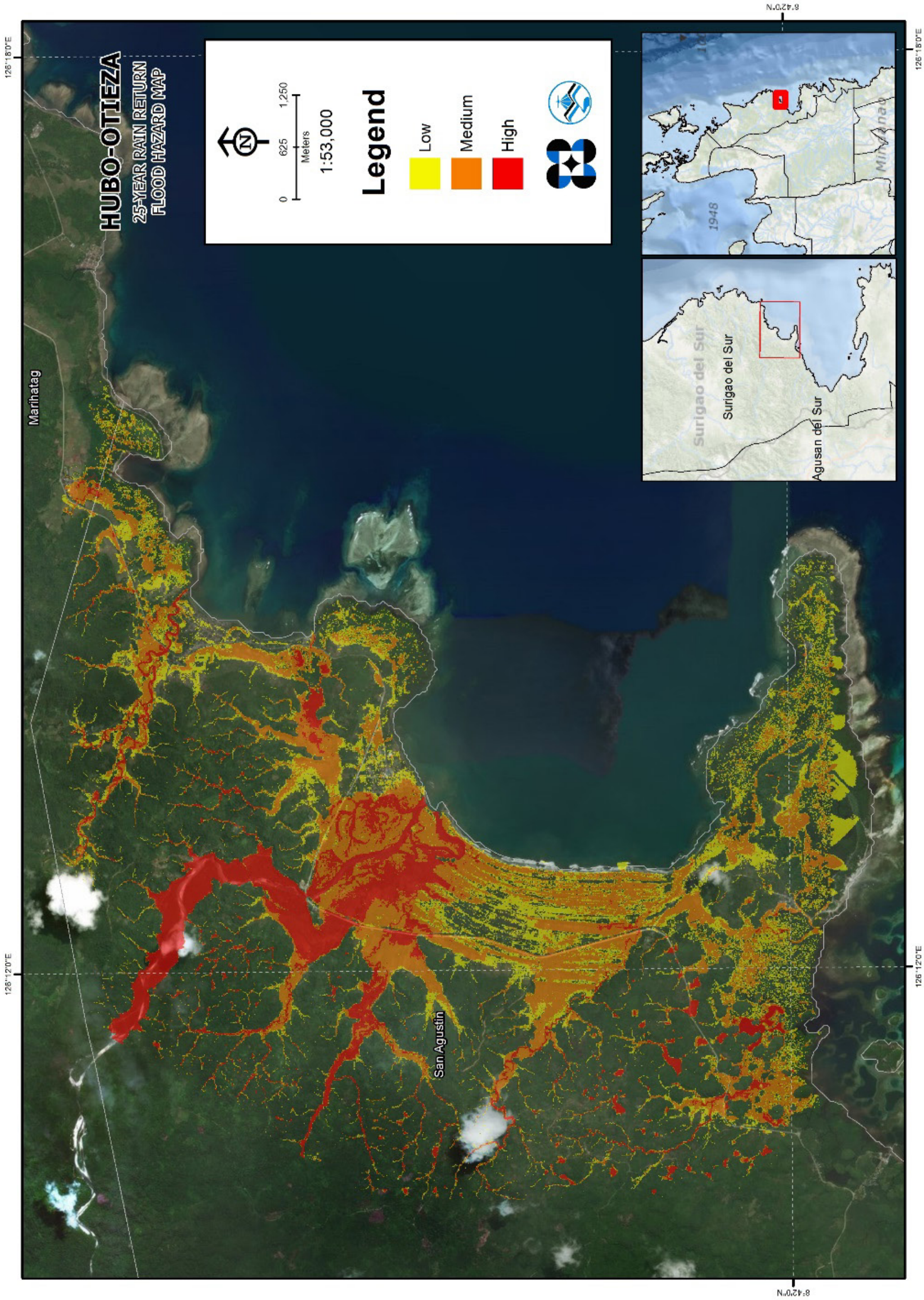


Figure 60. A 25-year Flood Hazard Map for Hubo-Otieza Floodplain overlaid on Google Earth imagery.

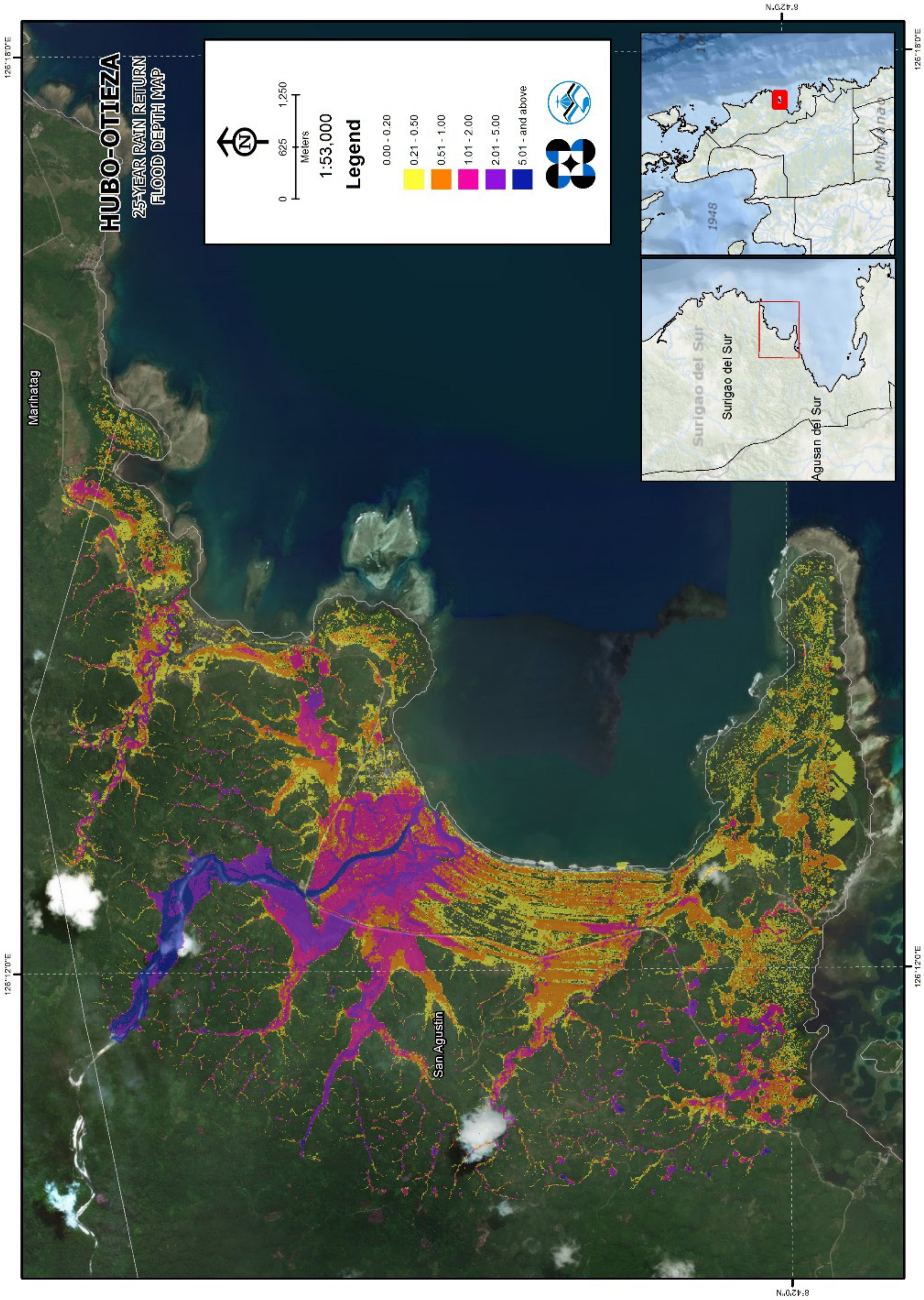


Figure 61. A 25-year Flow Depth Map for Hubo-Otieza Floodplain overlaid on Google Earth imagery.

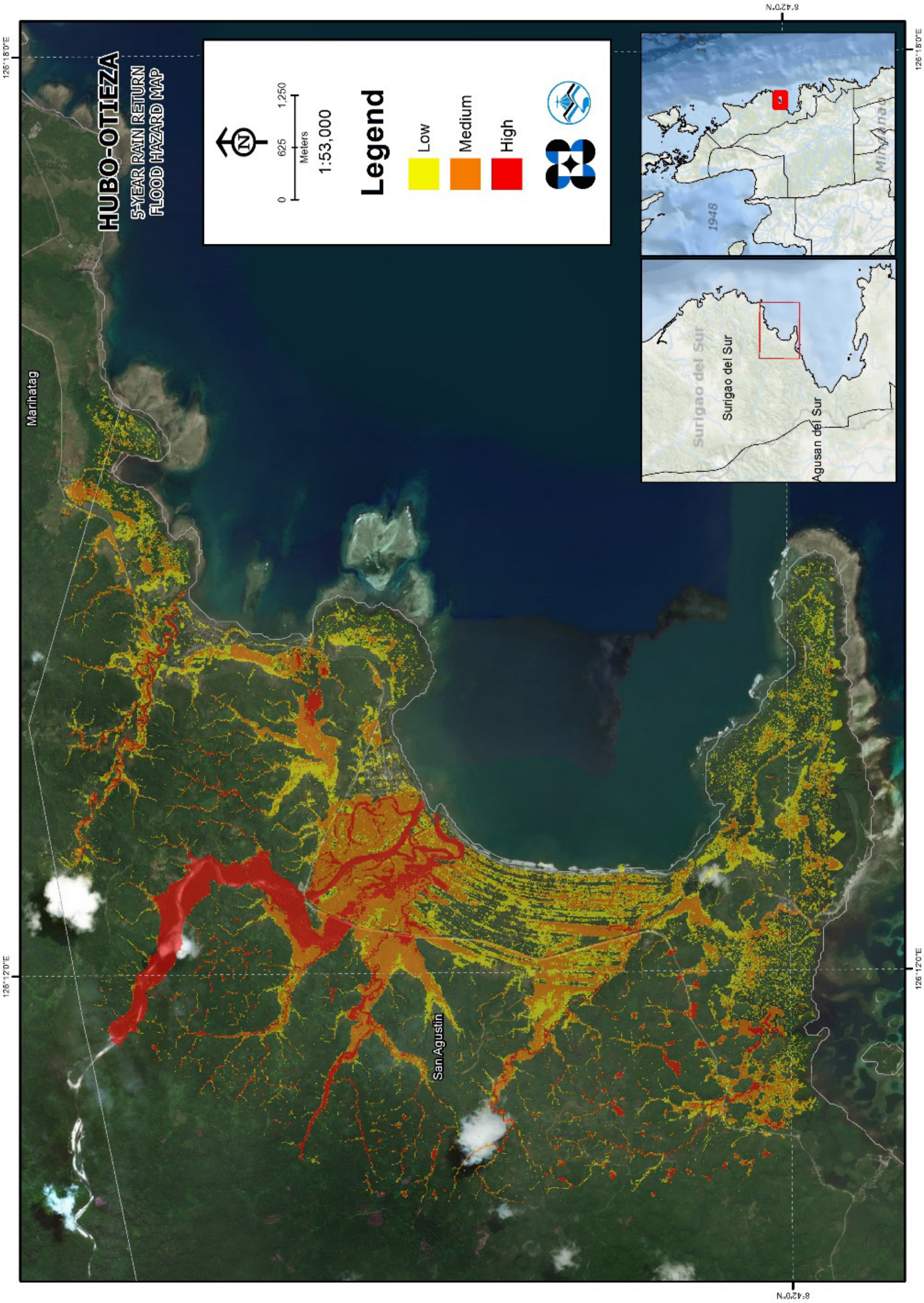


Figure 62. A 5-year Flood Hazard Map for Hubo-Otieza Floodplain overlaid on Google Earth imagery.

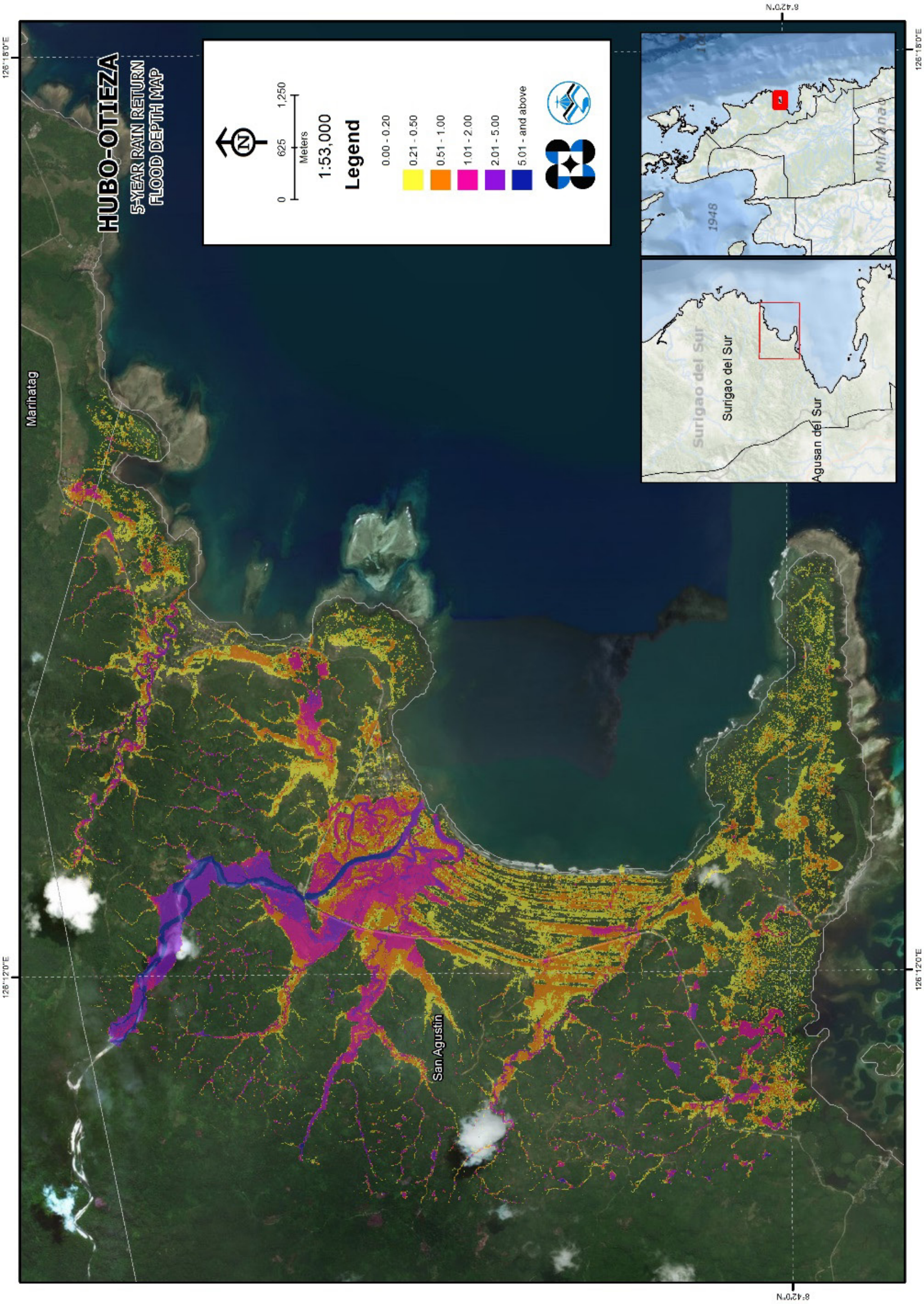


Figure 63. A 5-year Flood Depth Map for Hubo-Otieza Floodplain overlaid on Google Earth imagery.

5.10 Inventory of Areas Exposed to Flooding

Listed below are the affected barangays in the Hubo-Otieza River Basin, grouped accordingly by municipality. For the said basin, two (2) municipalities consisting of 12 barangays are expected to experience flooding when subjected to 5-yr rainfall return period.

For the municipality of Marihatag with an area of 272.4 sq. km., 0.16% will experience flood levels of less 0.20 meters. 0.03% of the area will experience flood levels of 0.21 to 0.50 meters while 0.02%, 0.01%, 0.00%, and 0.00% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 32 are the affected areas in Marihatag in square kilometers by flood depth per barangay. Annex 12 shows the educational institutions exposed to flooding.

Table 32. Affected Areas in the municipality of Marihatag, Surigao del Sur during 5-Year Rainfall Return Period.

Affected Area (sq. km.)	Affected Barangays in Marihatag			
	Banquerohan	Cabahug	Magsaysay	Tiglawigan
0.03-0.20	0.553186	2.42144	2.90551	3.80156
0.21-0.50	0.024227	0.070052	0.092574	0.195424
0.51-1.00	0.004834	0.077707	0.09597	0.138611
1.01-2.00	0.002354	0.145686	0.059252	0.121554
2.01-5.00	0	0.594736	0.025961	0.0092
> 5.00	0	0.085987	0.113777	0

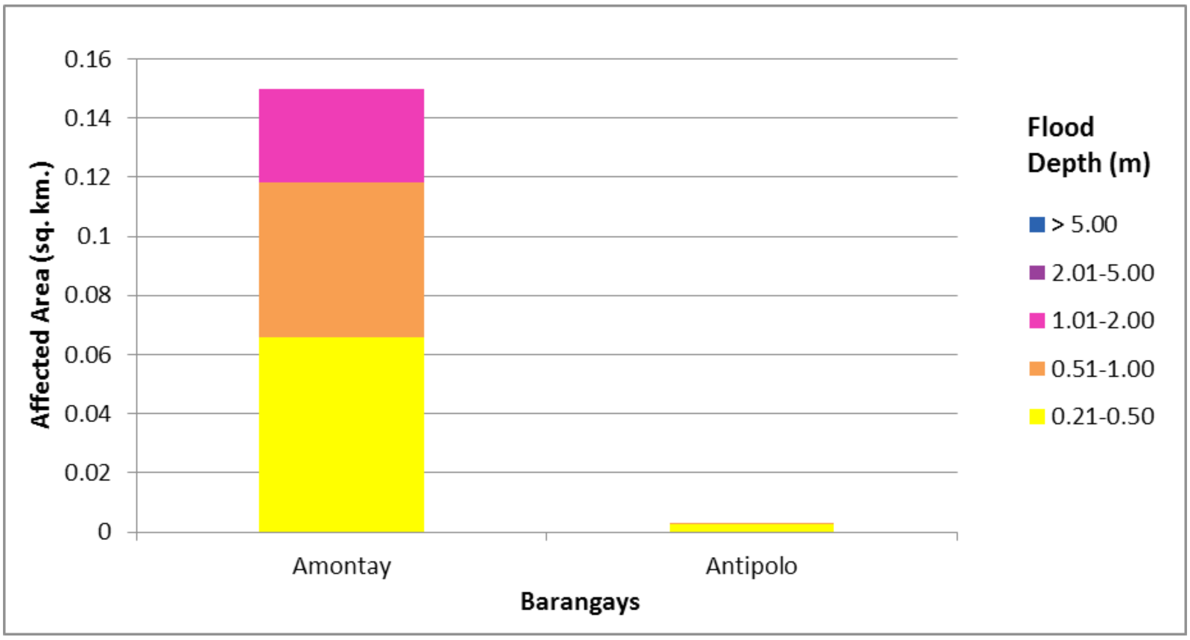


Figure 64. Affected Areas in Marihatag, Surigao del Sur during 5-Year Rainfall Return Period.

For the municipality of San Agustin with an area of 231.99 sq. km., 15.32% will experience flood levels of less than 0.20 meters. 2.43% of the area will experience flood levels of 0.21 to 0.50 meters while 1.83%, 1.15%, 0.68%, and 0.16% 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 33 are the affected areas in San Agustin in square kilometers by flood depth per barangay.

Table 33. Affected Areas in San Agustin, Surigao del Sur during 5-Year Rainfall Return Period.

Affected Area (sq. km.)	Affected Barangays in San Agustin							
	Fabrica	Himoga-An Baybay	Malubon	Old Sagay	Paraiso	Poblacion I	Poblacion II	Taba-Ao
0.03-0.20	1.28123	17.4411	4.00184	4.23811	10.399	0.752548	10.338	1.37576
0.21-0.50	0.041184	1.25263	0.172558	0.494869	0.483667	0.080614	0.467005	0.062326
0.51-1.00	0.034743	1.77435	0.141726	1.97894	0.39593	0.010942	0.406476	0.042474
1.01-2.00	0.052088	2.95322	0.139992	1.26489	0.369743	0.0011	0.461043	0.0161
2.01-5.00	0.111037	3.49429	0.217296	0	0.367735	0	0.348436	0
> 5.00	0.267273	1.29844	0.253985	0	0.557231	0	0.130473	0

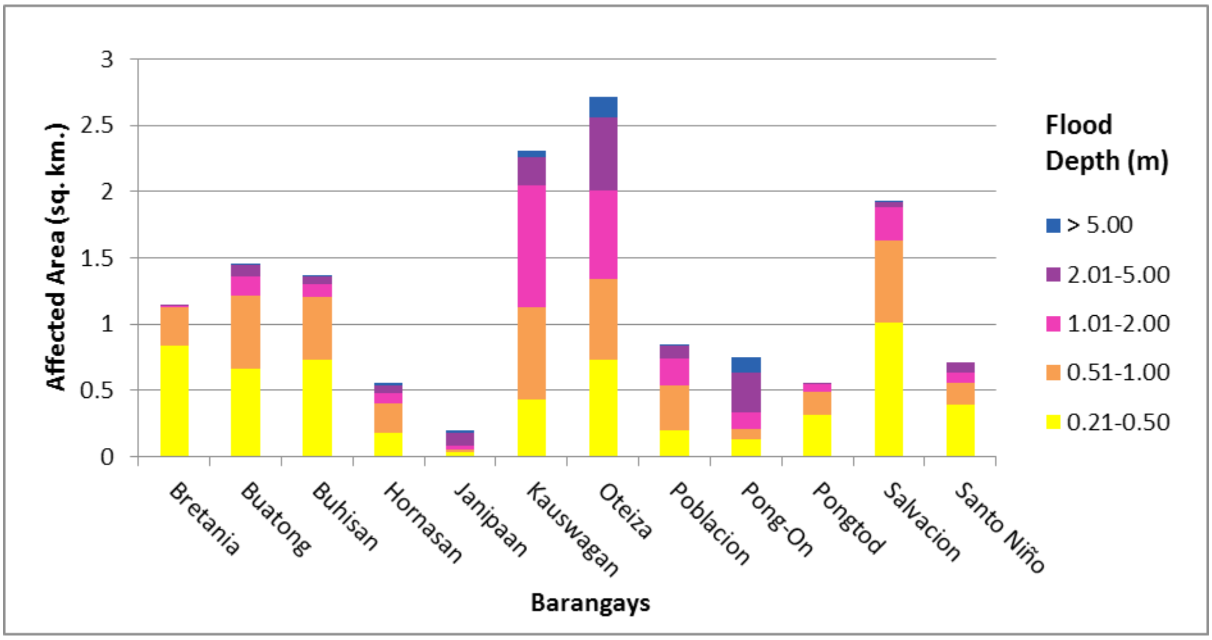


Figure 65. Affected Areas in San Agustin, Surigao del Sur during 5-Year Rainfall Return Period.

For the municipality of Marihatag with an area of 272.4 sq. km., 0.16% will experience flood levels of less than 0.20 meters. 0.03% of the area will experience flood levels of 0.21 to 0.50 meters while 0.02%, 0.02%, 0.00%, and 0.00% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 34 are the affected areas in Marihatag in square kilometers by flood depth per barangay.

Table 34. Affected Areas in Marihatag, Surigao del Sur during 25-Year Rainfall Return Period.

Affected Area (sq. km.)	Affected Barangays in Marihatag			
	Banquerohan	Cabahug	Magsaysay	Tiglawigan
0.03-0.20	0.53731	2.31768	2.84071	3.68507
0.21-0.50	0.036587	0.076458	0.096359	0.222521
0.51-1.00	0.005519	0.069675	0.100343	0.163786
1.01-2.00	0.005185	0.124283	0.073332	0.146299
2.01-5.00	0	0.579794	0.048736	0.048594
> 5.00	0	0.227716	0.133562	0

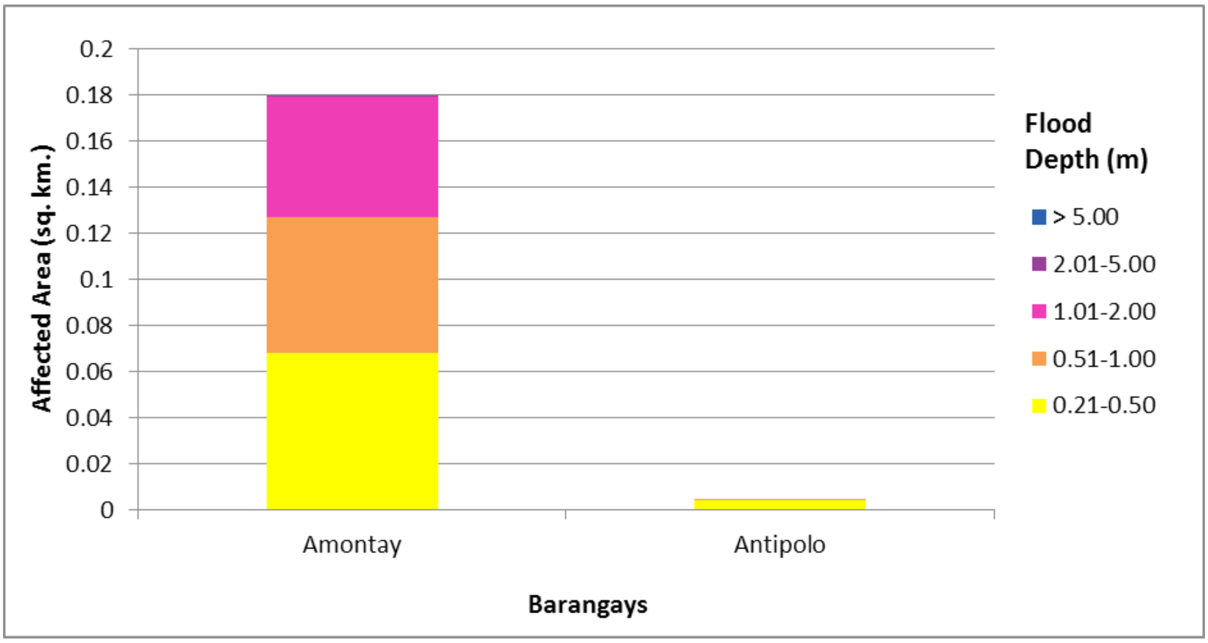


Figure 66. Affected Areas in Marihatag, Surigao del Sur during 25-Year Rainfall Return Period.

For the municipality of San Agustin with an area of 231.99 sq. km., 14.07% will experience flood levels of less 0.20 meters. 2.44% of the area will experience flood levels of 0.21 to 0.50 meters while 2.27%, 1.56%, 0.89%, and 0.33% 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 are the affected areas in square kilometers by flood depth per barangay.

Table 35. Affected Areas in San Agustin, Surigao del Sur during 25-Year Rainfall Return Period.

Affected Area (sq. km.)	Affected Barangays in San Agustin							
	Fabrica	Himoga-An Baybay	Malubon	Old Sagay	Paraiso	Poblacion I	Poblacion II	Taba-Ao
0.03-0.20	1.28123	17.4411	4.00184	4.23811	10.399	0.752548	10.338	1.37576
0.21-0.50	0.041184	1.25263	0.172558	0.494869	0.483667	0.080614	0.467005	0.062326
0.51-1.00	0.034743	1.77435	0.141726	1.97894	0.39593	0.010942	0.406476	0.042474
1.01-2.00	0.052088	2.95322	0.139992	1.26489	0.369743	0.0011	0.461043	0.0161
2.01-5.00	0.111037	3.49429	0.217296	0	0.367735	0	0.348436	0
> 5.00	0.267273	1.29844	0.253985	0	0.557231	0	0.130473	0

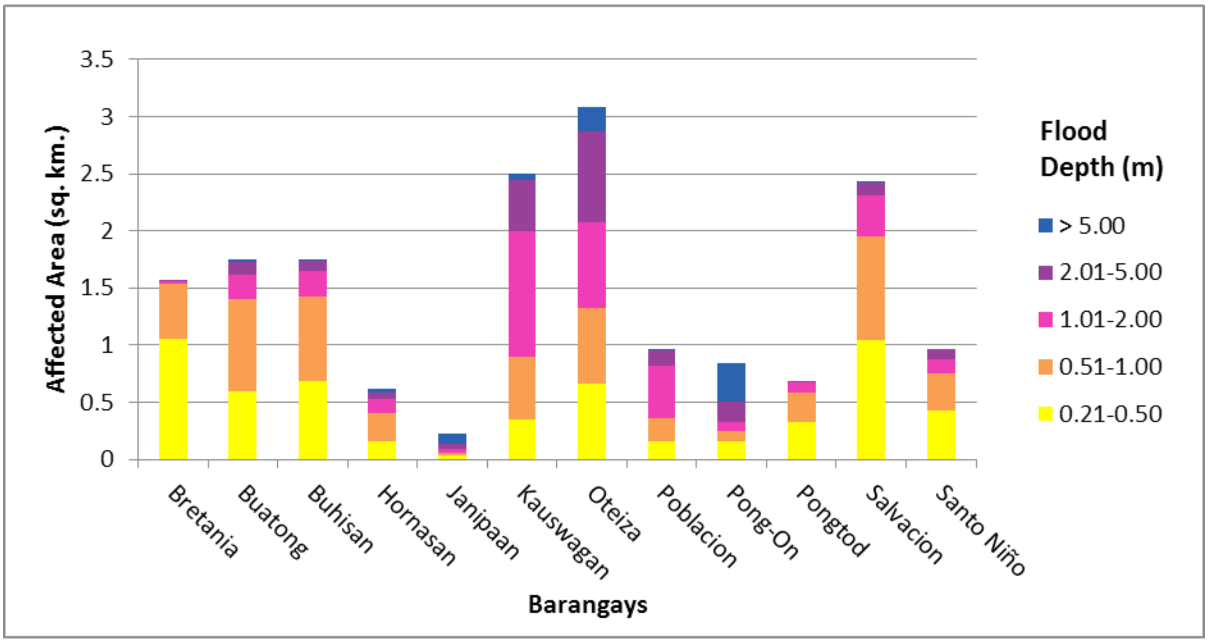


Figure 67. Affected Areas in San Agustin, Surigao del Sur during 25-Year Rainfall Return Period.

For the municipality of Marihatag with an area of 272.4 sq. km., 0.15% will experience flood levels of less 0.20 meters. 0.03% of the area will experience flood levels of 0.21 to 0.50 meters while 0.03%, 0.02%, 0.00%, and 0.00% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 36 are the affected areas in square kilometers by flood depth per barangay.

Table 36. Affected Areas in Marihatag, Surigao del Sur during 100-Year Rainfall Return Period.

Affected Area (sq. km.)	Affected Barangays in Marihatag			
	Banquerohan	Cabahug	Magsaysay	Tiglawigan
0.03-0.20	0.522408	2.21632	2.78338	3.59777
0.21-0.50	0.047504	0.078624	0.09941	0.247649
0.51-1.00	0.007404	0.063713	0.09635	0.177258
1.01-2.00	0.00574	0.098005	0.088077	0.157249
2.01-5.00	0.001544	0.3853	0.047409	0.087343
> 5.00	0	0.553649	0.178415	0

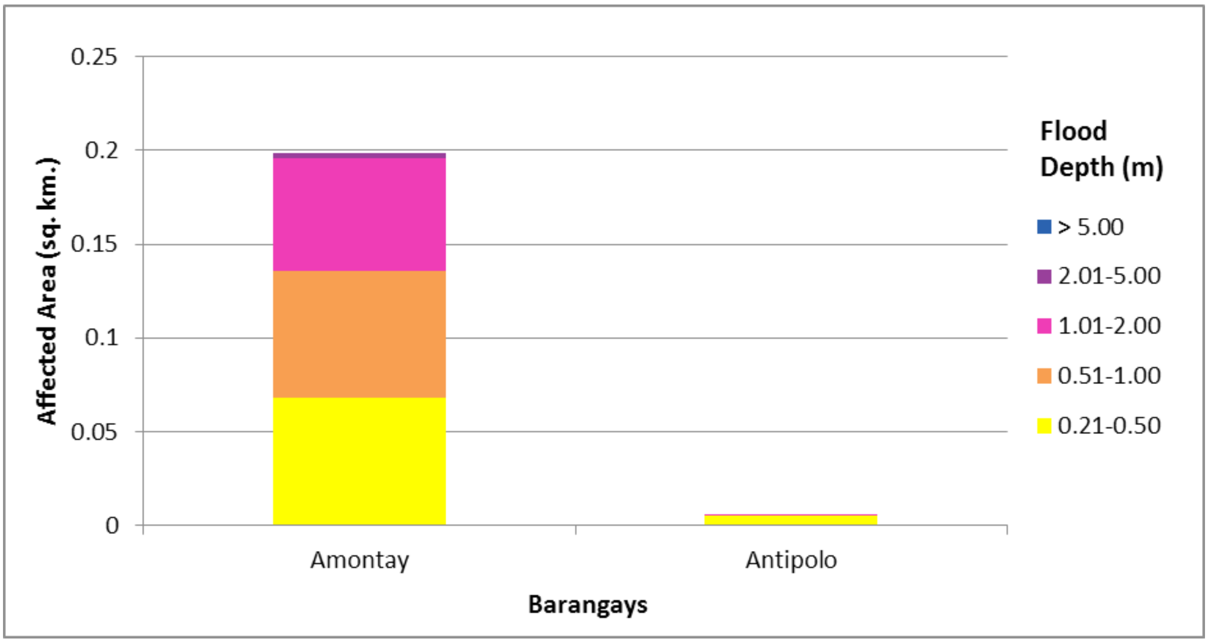


Figure 68. Affected Areas in Marihatag, Surigao del Sur during 100-Year Rainfall Return Period.

For the municipality of San Agustin with an area of 231.99 sq. km., 13.34% will experience flood levels of less 0.20 meters. 2.48% of the area will experience flood levels of 0.21 to 0.50 meters while 2.46%, 1.77%, 1.06%, and 0.45% 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 37 are the affected areas in square kilometers by flood depth per barangay.

Table 37. Affected Areas in San Agustin, Surigao del Sur during 100-Year Rainfall Return Period.

Affected Area (sq. km.)	Affected Barangays in San Agustin							
	Fabrica	Himoga-An Baybay	Malubon	Old Sagay	Paraiso	Poblacion I	Poblacion II	Taba-Ao
0.03-0.20	1.28123	17.4411	4.00184	4.23811	10.399	0.752548	10.338	1.37576
0.21-0.50	0.041184	1.25263	0.172558	0.494869	0.483667	0.080614	0.467005	0.062326
0.51-1.00	0.034743	1.77435	0.141726	1.97894	0.39593	0.010942	0.406476	0.042474
1.01-2.00	0.052088	2.95322	0.139992	1.26489	0.369743	0.0011	0.461043	0.0161
2.01-5.00	0.111037	3.49429	0.217296	0	0.367735	0	0.348436	0
> 5.00	0.267273	1.29844	0.253985	0	0.557231	0	0.130473	0

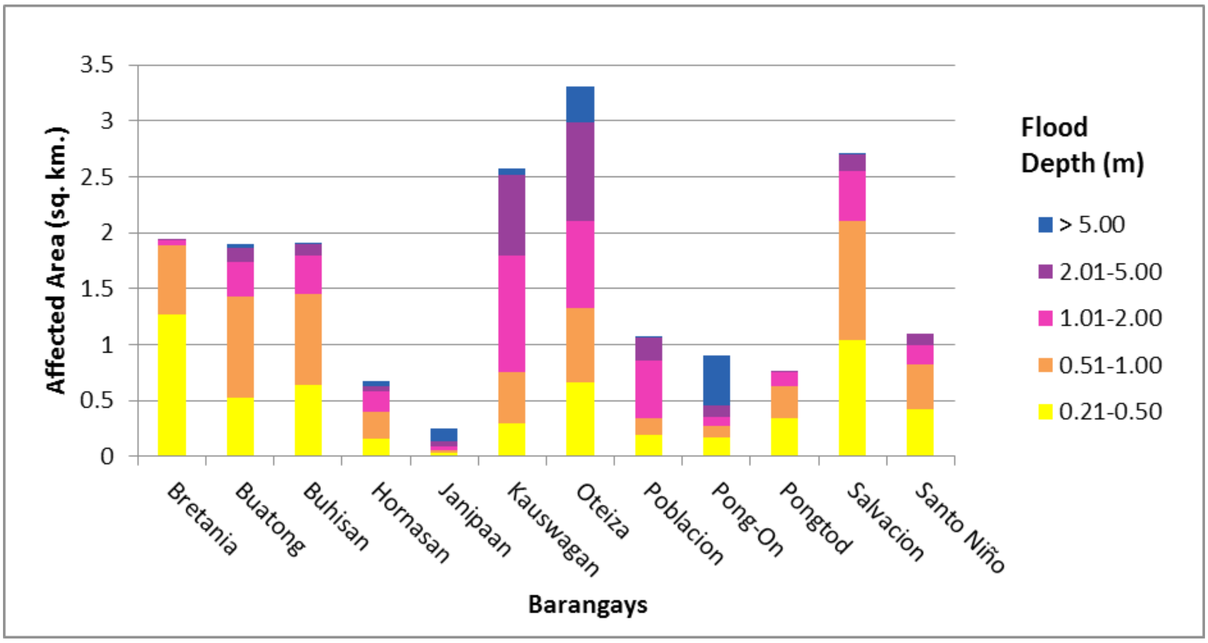


Figure 69. Affected Areas in San Agustin, Surigao del Sur during 100-Year Rainfall Return Period.

Among the barangays in the municipality of Marihatag, Amontay is projected to have the highest percentage of area that will experience flood levels at 0.21%. Meanwhile, Antipolo posted the second highest percentage of area that may be affected by flood depths at 0.01%

Among the barangays in the municipality of in San Agustin, Surigao del Sur, Otieza is projected to have the highest percentage of area that will experience flood levels at 4%. Meanwhile, Kauswagan posted the second highest percentage of area that may be affected by flood depths at 3%.

Moreover, the generated flood hazard maps for the Hubo-Otieza 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 38. Area covered by each warning level with respect to the rainfall scenarios

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	5.80	5.83	5.93
Medium	6.14	7.72	8.45
High	2.96	4.26	5.18

Of the 13 identified education institutions in Hubo-Otieza flood plain, five (5) schools were discovered exposed Low-level flooding during a 5-year scenario, while two (2) schools were found exposed to Medium-level flooding in the same scenario.

In the 25-year scenario, two (2) schools were found exposed to the Low-level flooding, while seven (7) schools were exposed to Medium-level flooding.

For the 100-year scenario, three (3) schools were discovered exposed Low-level flooding, while seven (7) schools were exposed to Medium-level flooding.

5.11 Flood Validation

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

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

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

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 the results of the flood map. The points in the flood map versus its corresponding validation depths are shown in Figure 70.

The flood validation consists of 618 points randomly selected all over the Hubo-Otieza flood plain Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 1.03 m. Table 39 shows a contingency matrix of the comparison. The validation points are found in Annex 11.

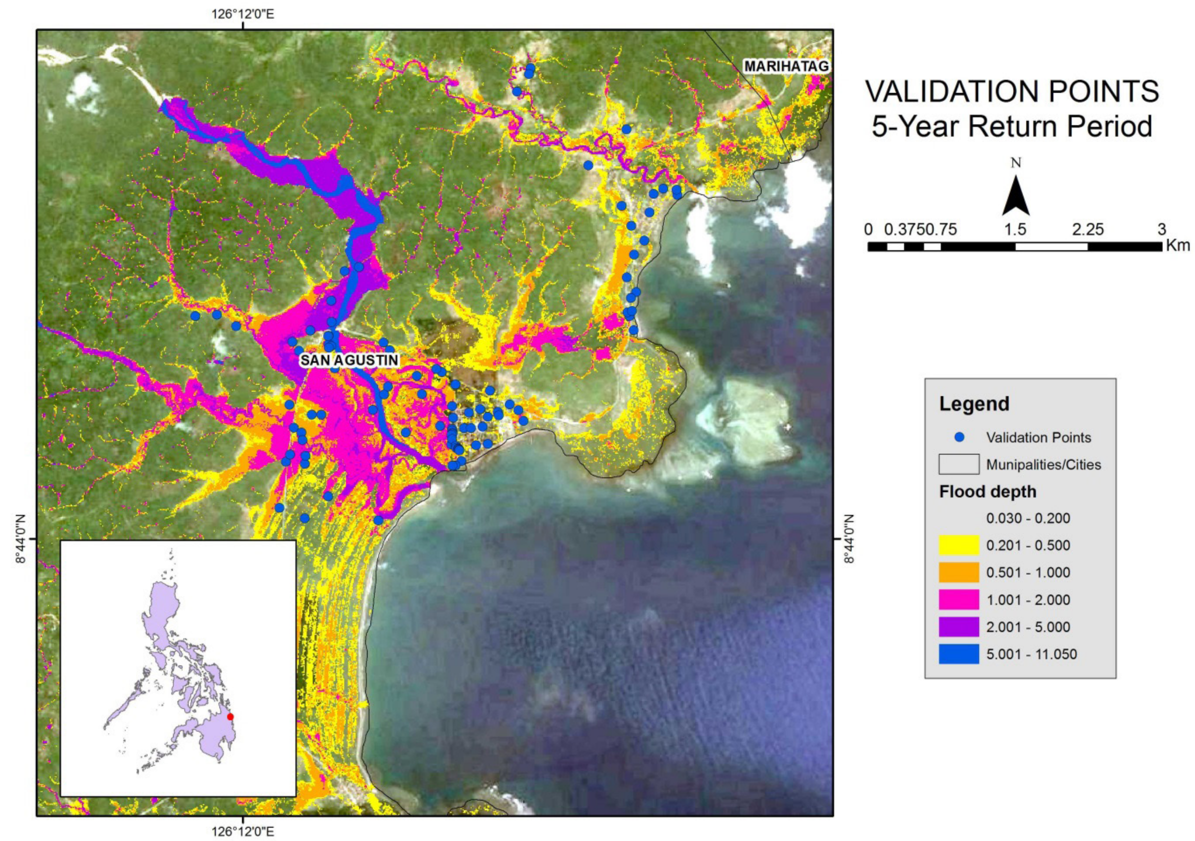


Figure 70. Validation Points for a 5-year Flood Depth Map of the Hubo-Otieza Floodplain.

Table 39. Actual Flood Depth versus Simulated Flood Depth at different levels in the Hubo-Otieza River Basin.

HUBO-OTIEZA BASIN 0-0.20		Modeled Flood Depth (m)						
		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	161	44	54	49	16	0	324
	0.21-0.50	32	26	32	47	13	0	150
	0.51-1.00	10	6	18	44	15	0	93
	1.01-2.00	11	10	10	12	8	0	51
	2.01-5.00	0	0	0	0	0	6	0
	> 5.00	0	0	0	0	0	0	0
	Total	214	86	114	152	52	0	618

On the whole, the overall accuracy generated by the flood model is estimated at 35.11%, with 217 points correctly matching the actual flood depths. In addition, there were 176 points estimated one level above and below the correct flood depths while there were 136 points estimated two levels above and below, and 89 points three or more levels above and below the correct flood. A total of 322 points were overestimated while a total of 79 points were underestimated in the modelled flood depths of Hubo-Otieza. Table 40 depicts the summary of the Accuracy Assessment in the Himogaan-Hubo-Otieza River Basin Flood Depth Map.

Table 40. Summary of the Accuracy Assessment in the Himogaan-Hubo-Otieza River Basin Survey.

	No. of Points	%
Correct	217	35.11
Overestimated	322	52.10
Underestimated	79	12.78
Total	618	100.00

REFERENCES

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

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

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

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

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

UP TCAGP 2016, Acceptance and Evaluation of Synthetic Aperture Radar Digital Surface Model (SAR DSM) and Ground Control Points (GCP). Quezon City, Philippines: UP Training Center for Applied Geodesy and Photogrammetry.

ANNEXES

Annex 1. Technical Specifications of the LIDAR Sensors used in the Hubo-Otieza Floodplain Survey

AQUARIUS SENSOR

Figure A-1.1. Aquarius Sensor

Table A-1.1. Parameters and Specifications of Aquarius Sensor

Parameter	Specification
Operational altitude	300-600 m AGL
Laser pulse repetition rate	33, 50. 70 kHz
Scan rate	0-70 Hz
Scan half-angle	0 to ± 25 ˚
Laser footprint on water surface	30-60 cm
Depth range	0 to > 10 m (for k < 0.1/m)
Topographic mode	
Operational 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 Certificate 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: **994,598.26**	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

9907112014145938

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

CIP/4701/12/09/814

Figure A-2.1. SRS-51

SRS_53

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-53**
Order: **2nd**

Island: **MINDANAO**		Barangay: **POBLACION**
Municipality: **SAN AGUSTIN**		MSL Elevation:
	PRS92 Coordinates	
Latitude: **8° 44' 37.87784"**	Longitude: **126° 13' 16.64511"**	Ellipsoidal Hgt: **-1.34900 m.**
	WGS84 Coordinates	
Latitude: **8° 44' 34.36515"**	Longitude: **126° 13' 22.01039"**	Ellipsoidal Hgt: **69.59300 m.**
	PTM / PRS92 Coordinates	
Northing: **966899.682 m.**	Easting: **414316.026 m.**	Zone: **5**
	UTM / PRS92 Coordinates	
Northing: **967,600.49**	Easting: **194,250.44**	Zone: **52**

Location Description

SRS-53
From Tandag City travel for 68 km south to municipality of San Agustin; then turn left on the national road about 70 m leading to San Agustin school. Station is located inside the compound of San Agustin Central Elementary School; 82 m from stage on the NE corner of the flagpole. Mark is the head of a 3: copper nail set at the center of cement block embedded on the ground with inscriptions SRS-53 2007 NAMRIA.

Requesting Party: **UP TCAGP / Engr. Christopher Cruz**
Pupose: **Reference**
OR Number: **8796507 A**
T.N.: **2014-1593**

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

9 9 0 7 1 1 2 0 1 4 1 4 5 9 2 1

CERTIFICATION INTERNATIONAL ISO 9001:2008 ACCREDITED
CIP/4701/12/09/814

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.2. SRS-53

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

SS-158

Table A-3.1. 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

2. SS-201

Table A-3.1. SS-201

Project Information		Coordinate System	
Name:		Name:	UTM
Size:		Datum:	WGS 1984
Modified:	10/12/2012 4:40:11 PM (UTC:-6)	Zone:	51 North (123E)
Time zone:	Mountain Standard Time	Geoid:	EGM96 (Global)
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)
SRS53 --- BMSS201 (B1)	SRS53	BMSS201	Fixed	0.004	0.012	26°48'11"	3051.616	2.587
SRS53 --- BMSS201 (B2)	SRS53	BMSS201	Fixed	0.003	0.010	26°48'11"	3051.616	2.570
SRS53 --- BMSS201 (B3)	SRS53	BMSS201	Fixed	0.005	0.012	26°48'11"	3051.606	3.061

Acceptance Summary

Processed	Passed	Flag	Fail
3	3	0	0

SRS53 - BMSS201 (11:01:12 AM-3:26:18 PM) (S1)

Baseline observation:	SRS53 --- BMSS201 (B1)
Processed:	8/2/2014 3:33:43 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:	2.308
Ephemeris used:	Broadcast
Antenna model:	Trimble Relative
Processing start time:	7/16/2014 11:01:27 AM (Local: UTC+8hr)
Processing stop time:	7/16/2014 3:26:18 PM (Local: UTC+8hr)
Processing duration:	04:24:51
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	SRS53				
Grid		Local		Global	
Easting	854654.870 m	Latitude	N8°44'34.36515"	Latitude	N8°44'34.36515"
Northing	967943.120 m	Longitude	E126°13'22.01039"	Longitude	E126°13'22.01039"
Elevation	3.274 m	Height	69.593 m	Height	69.593 m

To:	BMSS201				
Grid		Local		Global	
Easting	856009.096 m	Latitude	N8°46'03.02195"	Latitude	N8°46'03.02195"
Northing	970681.752 m	Longitude	E126°14'07.03352"	Longitude	E126°14'07.03352"
Elevation	6.020 m	Height	72.180 m	Height	72.180 m

Vector					
ΔEasting	1354.226 m	NS Fwd Azimuth	26°48'11"	ΔX	-866.534 m
ΔNorthing	2738.632 m	Ellipsoid Dist.	3051.616 m	ΔY	-1145.673 m
ΔElevation	2.746 m	ΔHeight	2.587 m	ΔZ	2692.420 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.	0.001 m	σ ΔY	0.005 m
σ ΔElevation	0.006 m	σ ΔHeight	0.006 m	σ ΔZ	0.002 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000139315		
Y	-0.0000161276	0.0000265278	
Z	-0.0000041845	0.0000058211	0.0000027776

Occupations

	From	To
Point ID:	SRS53	BMSS201
Data file:	C:\Users\DAC\Documents\Business Center - HCE\Unnamed(1)\SRS53 (Modular) 7-16-14 [1.775m].T02	C:\Users\DAC\Documents\Business Center - HCE\Unnamed(1)\BMSS201 (Rover0 7-16-14 [1.755m].T02
Receiver type:	SPS852	SPS985
Receiver serial number:	5203K81512	5245F15374
Antenna type:	Zephyr Geodetic 2	SPS985 Internal
Antenna serial number:	--------	--------
Antenna height (measured):	1.775 m	1.755 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 PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader –I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
		ENGR. LOUIE P. BALICANTA	
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist	ENGR. LOVELYN ASUNCION	UP-TCAGP
		LOVELY GRACIA ACUNA	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Research Associate (RA)	MARY CATHERINE ELIZABETH BALIGUAS	UP-TCAGP
	RA	MA. REMEDIOS VILLANUEVA	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	JONATHAN ALMALVEZ	UP-TCAGP
LiDAR Operation	Airborne Security	TSG. MICHAEL BERONILLA	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. JEFFREY JEREMY ALAJAR	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. NEIL ACHILLES AGAWIN	AAC
		CAPT. ANGELO GARCHITORENA	AAC

Annex 5. Data Transfer Sheet for Hubo-Otieza Floodplain

DATA TRANSFER SHEET
08/04/2014(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	
7/10/2014	1682A	3BLK61GSE191A	Aquarius	NA	666	1.05	210	81.2	312	12	NA	14.1	1KB	1KB	3	8	Z:\Airborne_Raw
7/10/2014	1684A	3BLK61E191B	Aquarius	NA	415	687	152	25.7/10	237/101	7.55	NA	14.1	1KB	1KB	4	NA	Z:\Airborne_Raw
7/11/2014	1686A	3BLK61ESHI192A	Aquarius	NA	134/430	1.33	266	73	308	12.9	NA	8.12	1KB	1KB	4/3/3	9	Z:\Airborne_Raw
7/12/2014	1690A	3BLK61IS193A & 3BLK65E193A	Aquarius	NA	154/113	512	248	NA	NA	11	NA	9.69	1KB	1KB	10/3	154/113/7	Z:\Airborne_Raw
7/13/2014	1694A	3BLK65ESD194A	Aquarius	NA	615	0.98	258	69.7	522	11.7	NA	10.6	1KB	1KB	5	12	Z:\Airborne_Raw
7/14/2014	1698A	3BLK65C195A	Aquarius	NA	520	799	184	48.5	369	11.6	NA	7.55	1KB	1KB	3	520	Z:\Airborne_Raw

Received from

Name TIN ANDAYA
Position RA
Signature

Received by

Name JOIDA F. PRIETO
Position SSRS
Signature 8/5/14

Figure A-5.1. Transfer Sheet for Hubo-Otieza Floodplain - A

DATA TRANSFER SHEET
07/30/2014(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	
Jul 29, 2014	7038GC	2NEJFG029A	Gemini	NA	82	173	204	NA	NA	8.65	NA	3.77	1KB	1KB	4/4	82	Z:\Airborne_Raw
7/15/2014	1702A	3BLK65BCSDS196A	Aquarius	NA	173	766	193	49.9	357	10.6	NA	8.44	1KB	1KB	3/3/10/6	9/16/2012	Z:\Airborne_Raw
7/16/2014	1706A	3BLK65BSA197A	Aquarius	NA	279	1	253	67.5	495	12.2	NA	8.55	1KB	1KB	3/5	382/629	Z:\Airborne_Raw
7/18/2014	1714A	3BLK65FG199A	Aquarius	NA	704	1.29	263	74.5	581	13.1	NA	8.09	1KB	1KB	3/3/5/5	10/11	Z:\Airborne_Raw
7/21/2014	1726A	3BLK65ASBSCS202A	Aquarius	NA	117	2.6	238	69.2	509	12	NA	16.9	1KB	1KB	5/6/6/3	117/9/1691/173/117/173/535/112	Z:\Airborne_Raw
7/21/2014	1728A	3BLK65H202B	Aquarius	NA	145	254	114	10.2	109	3.14	NA	16.9	1KB	1KB	3	145	Z:\Airborne_Raw
7/22/2014	1730A	3BLK65HS203A	Aquarius	NA	351	646	202	43.5	201	7.64	NA	14	1KB	1KB	3	NA	Z:\Airborne_Raw
7/22/2014	1732A	3LMSCALIB203B & 2BLK61J203B	Aquarius	NA	110/6	334	137	15	131	4.21	NA	14	1KB	1KB	6/4	110/6	Z:\Airborne_Raw
7/23/2014	1734A	3BLK65FSGS204A	Aquarius	NA	219/141/141	603	177	40.4	295	6.98	NA	15	1KB	1KB	5/5	11-Sep	Z:\Airborne_Raw
7/23/2014	1736A	3BLK61JS204B	Aquarius	NA	225	397	165	14.7	147	5.77	NA	15	1KB	1KB	6	225	Z:\Airborne_Raw

Received from

Name TIN ANDAYA
Position RA
Signature

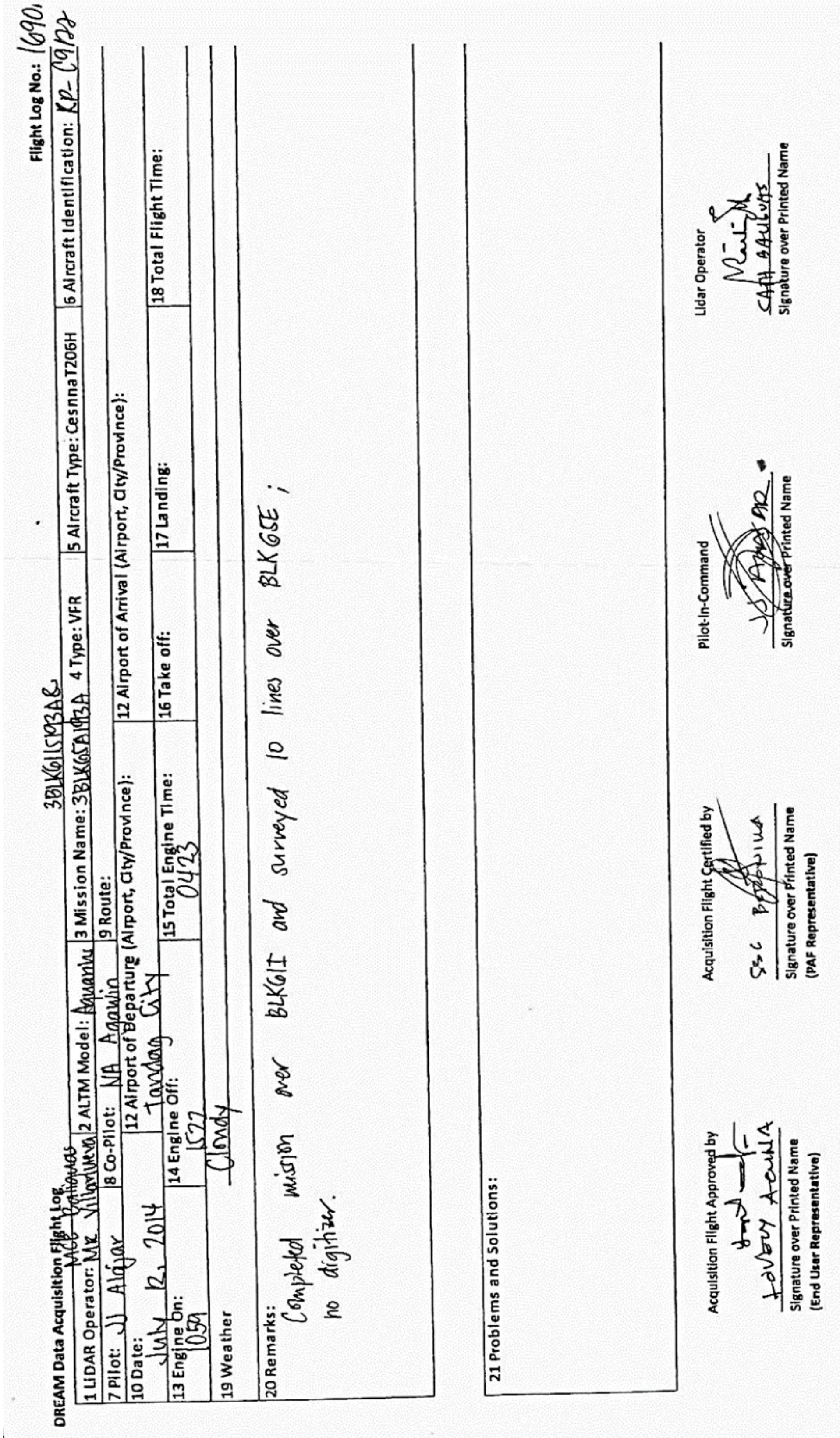
Received by

Name JOIDA PRIETO
Position SSRS
Signature 7/31/14

Figure A-5.2. Transfer Sheet for Hubo-Otieza Floodplain - B

Annex 6. Flight logs for the flight missions

Flight Log for 1690A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1690A

1 LIDAR Operator: MCE Balinas / MR Villanueva	2 ALTM Model: Aquarius	3 Mission Name: 3BLK61S193AB / 3BLK61S193A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9122
7 Pilot: JJ Alajar	8 Co-Pilot: NA Aquino	9 Route:			
10 Date: July 12, 2014	12 Airport of Departure (Airport, City/Province): Tarlac City	12 Airport of Arrival (Airport, City/Province):			
13 Engine On: 1054	14 Engine Off: 1527	15 Total Engine Time: 0423	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Cloudy					

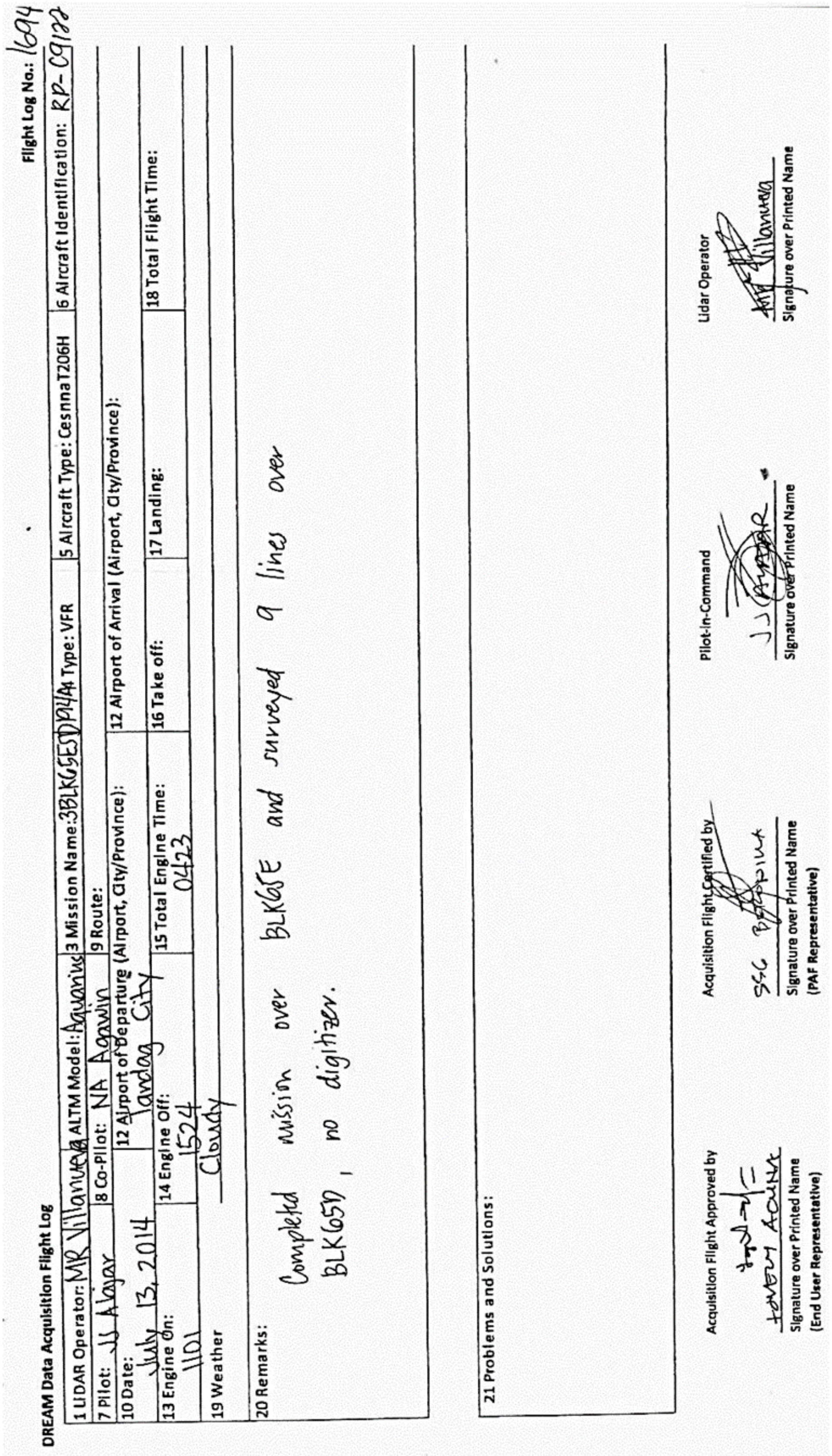
20 Remarks:
Completed mission over BLK61I and surveyed 10 lines over BLK61E ; no digitizer.

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)	Signature over Printed Name	Signature over Printed Name

Figure A-6.1. Flight Log for Mission 1690A

Flight Log for 1694A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1694

1 LIDAR Operator: MR Villanueva	2 ALTM Model: Aquarius	3 Mission Name: 3BLK65ESD194A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9122
7 Pilot: JJ Alajar	8 Co-Pilot: NA Agawin	9 Route:			
10 Date: July 13, 2014	12 Airport of Departure (Airport, City/Province): Tandag City	12 Airport of Arrival (Airport, City/Province):			
13 Engine On: 1101	14 Engine Off: 1524	15 Total Engine Time: 0423	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Cloudy					

20 Remarks:

Completed mission over BLK65E and surveyed 9 lines over BLK65D, no digitizer.

21 Problems and Solutions:

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

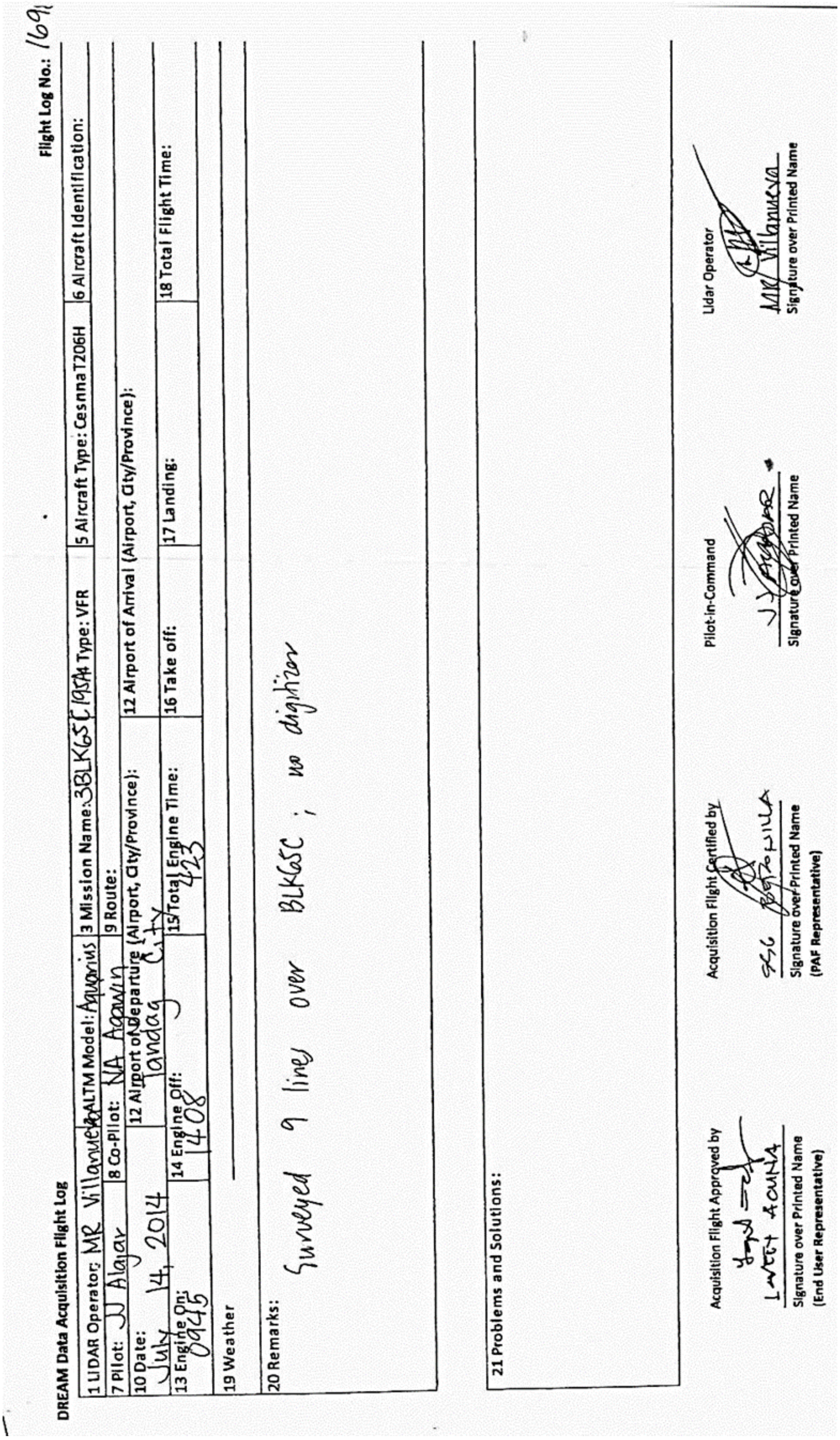
Acquisition Flight Certified by
SSG
Signature over Printed Name
(PAF Representative)

Pilot-in-Command
JJ Alajar
Signature over Printed Name

Lidar Operator
MR Villanueva
Signature over Printed Name

Figure A-6.2. Flight Log for Mission 1694A

Flight Log for 1698A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 169

1 LIDAR Operator: MR Villanueva	2 ALTM Model: Aquarius	3 Mission Name: 3BLK65C195A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification:
7 Pilot: JJ Alagar	8 Co-Pilot: NA Agawin	9 Route:			
10 Date: July 14, 2014	12 Airport of Departure (Airport, City/Province): Tandag City		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0945	14 Engine Off: 1408	15 Total Engine Time: 423	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Surveyed 9 lines over BLK65C; 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
Signature over Printed Name

Lidar Operator
MR Villanueva
Signature over Printed Name

Figure A-6.3. Flight Log for Mission 1698A

Flight Log for 1702A Mission

DREAM Data Acquisition Flight Log — Flight Log No.: 170

1 LIDAR Operator: MCE Baligues	2 ALTM Model: Aquarius	3 Mission Name: 3BLK65BCSD196A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification:
7 Pilot: JJ Alajar	8 Co-Pilot: NA Agawin	9 Route:			
10 Date: July 15, 2014	12 Airport of Departure (Airport, City/Province): Tandag City		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1139	14 Engine Off: 1502	15 Total Engine Time: 0323	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Cloudy					

20 Remarks:

Finished area of BLK65C and surveyed 3 lines over BLK65B. Covered gaps over BLK65D; no digitizer.

21 Problems and Solutions:

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

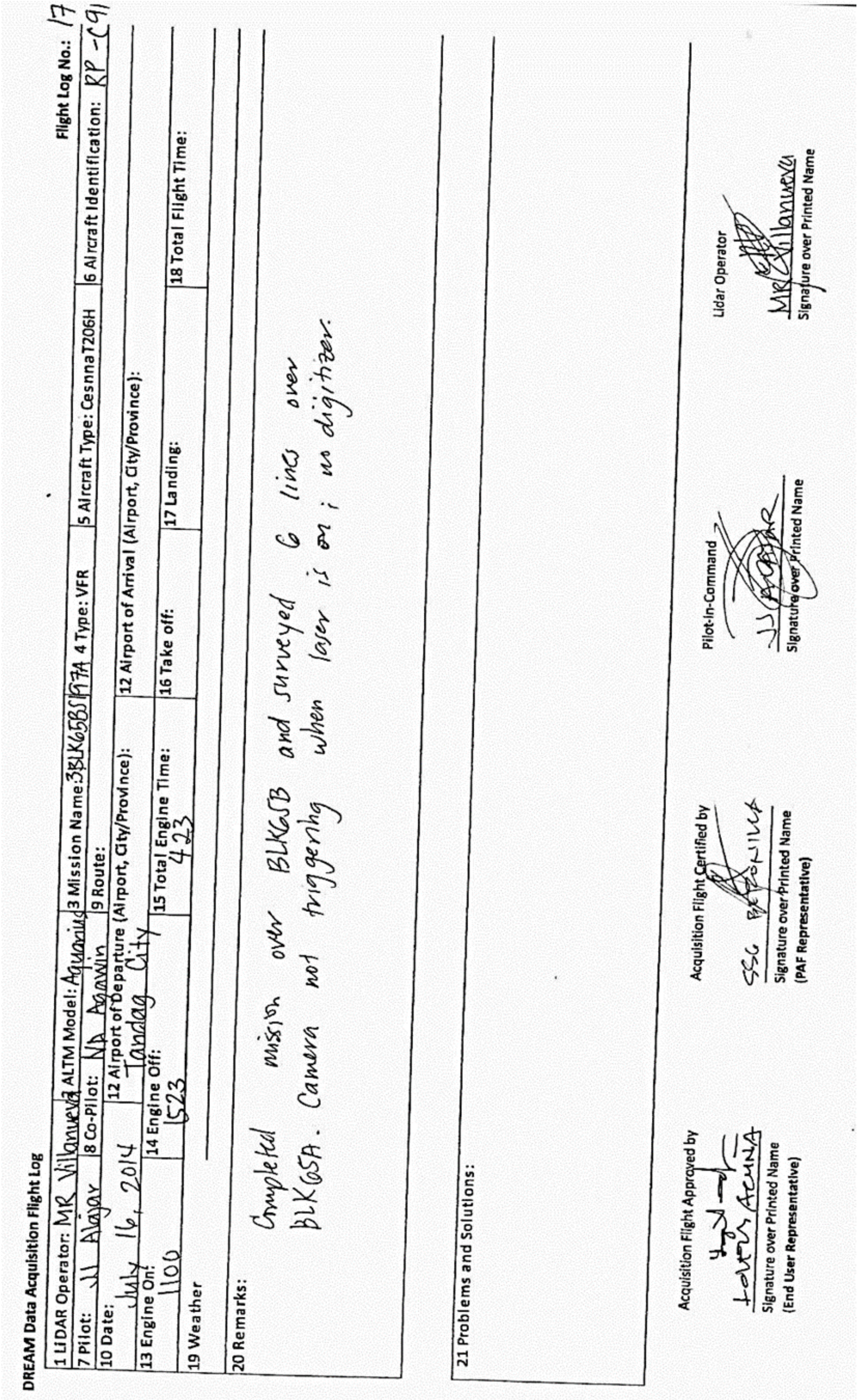
Acquisition Flight Certified by — Signature over Printed Name (PAF Representative)

Pilot-in-Command — Signature over Printed Name

Lidar Operator — Signature over Printed Name

Figure A-6.4. Flight Log for Mission 1702A

Flight log for 1706A Mission



DREAM Data Acquisition Flight Log

1 LIDAR Operator: MR Villanueva	2 ALTM Model: Aquarius	3 Mission Name: 3BLK65BS197A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9
7 Pilot: JJ Alajar	8 Co-Pilot: NA Agawin	9 Route:			Flight Log No.: 17
10 Date: July 16, 2014	12 Airport of Departure (Airport, City/Province): Tandag City		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1100	14 Engine Off: 1523	15 Total Engine Time: 423	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Completed mission over BLK65B and surveyed 6 lines over BLK65A. Camera not triggering when laser is on; no digitizer.

21 Problems and Solutions:

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

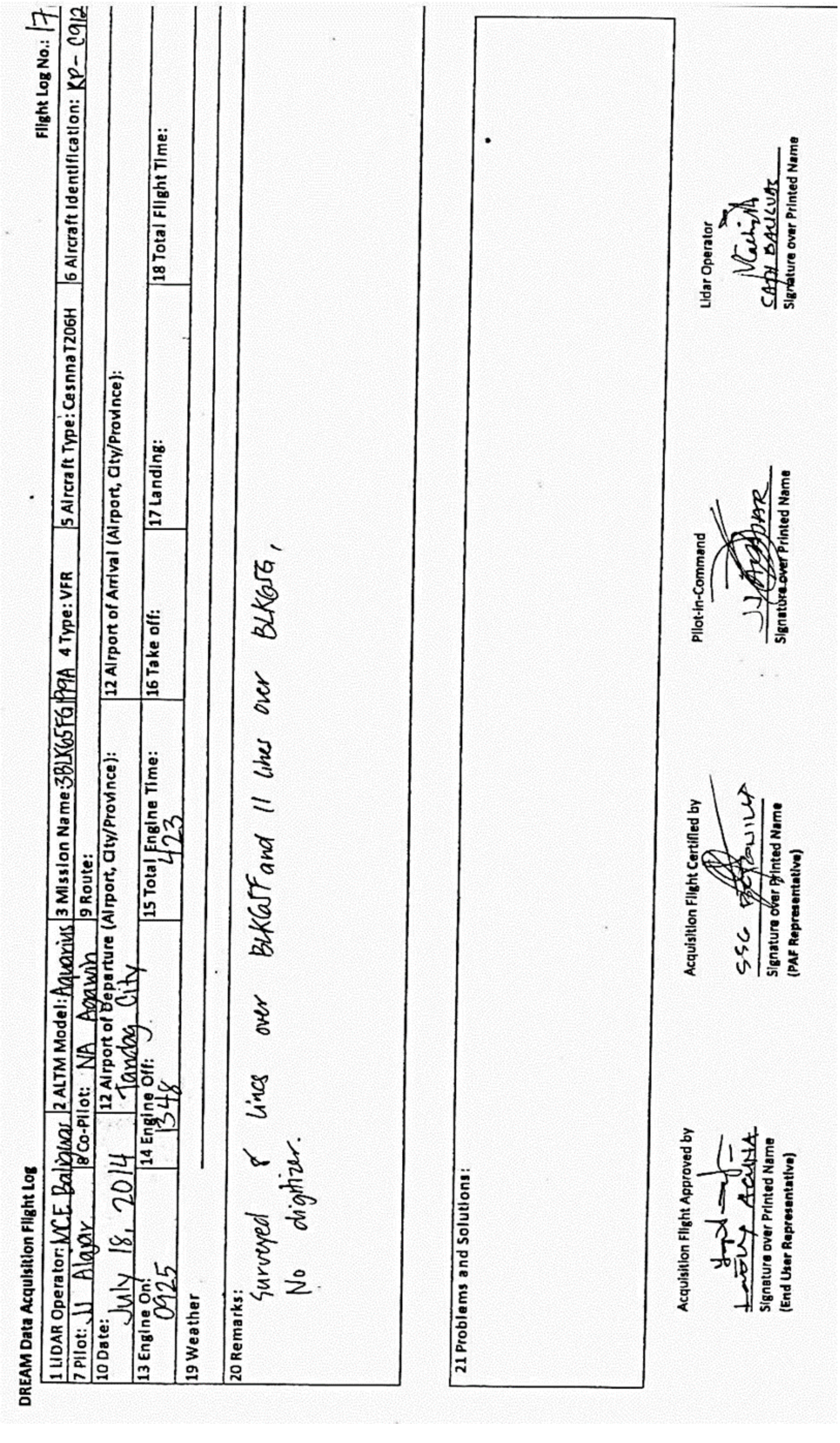
Acquisition Flight Certified by
SSG Peronilla
Signature over Printed Name
(PAF Representative)

Pilot-in-Command
JJ Alajar
Signature over Printed Name

Lidar Operator
MR Villanueva
Signature over Printed Name

Figure A-6.5. Flight Log for Mission 1706A

Flight Log for 1714A Mission



DREAM Data Acquisition Flight Log — Flight Log No.: 17

1 LIDAR Operator: VCE Balguar	2 ALTM Model: Aquarius	3 Mission Name: 3BLK65FG199A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9122
7 Pilot: JJ Alajar	8 Co-Pilot: NA	9 Route: Aquawin			
10 Date: July 18, 2014	12 Airport of Departure (Airport, City/Province): Tandag City		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0925	14 Engine Off: 1348	15 Total Engine Time: 4+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Surveyed 8 lines over BLK65F and 11 lines over BLK65G, No digitizer.

21 Problems and Solutions:

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

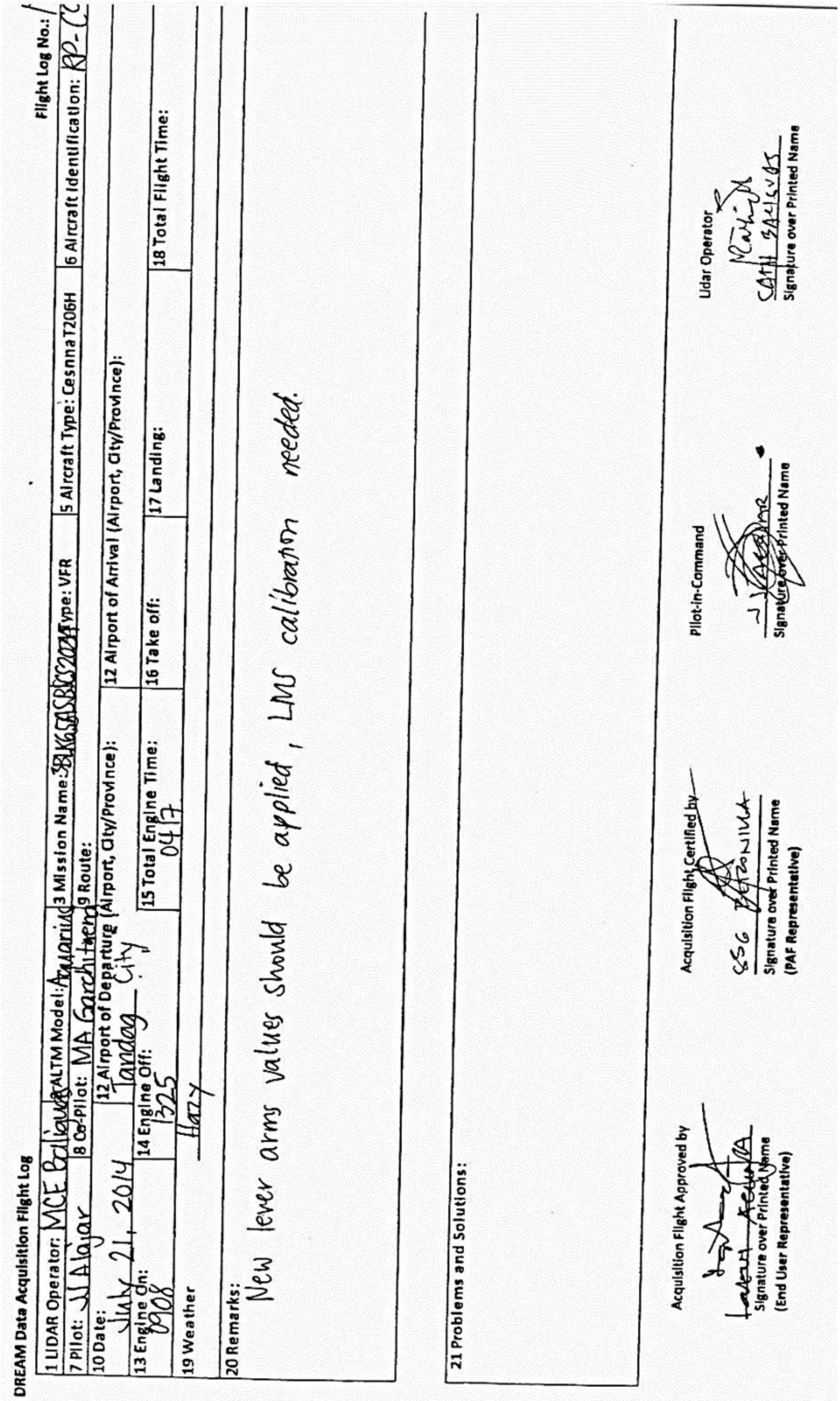
Acquisition Flight Certified by — SSC — Signature over Printed Name (PAF Representative)

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

Lidar Operator — Signature over Printed Name

Figure A-6.6. Flight Log for Mission 1714A

Flight log for 1726A Mission



DREAM Data Acquisition Flight Log

Flight Log No.:

1 LIDAR Operator: MCE Balicuat | 2 ALTM Model: Aquarius | 3 Mission Name: 3BLK63ASBKS202A | 4 Type: VFR | 5 Aircraft Type: Cesnna T206H | 6 Aircraft Identification: RP-C

7 Pilot: JJ Alajar | 8 Co-Pilot: MA Garchitorena | 9 Route:

10 Date: July 21, 2014 | 12 Airport of Departure (Airport, City/Province): Tandag City | 12 Airport of Arrival (Airport, City/Province):

13 Engine On: 0908 | 14 Engine Off: 1325 | 15 Total Engine Time: 0417 | 16 Take off: | 17 Landing: | 18 Total Flight Time:

19 Weather: Hazy

20 Remarks:

New lever arms values should be applied, LMS calibration needed.

21 Problems and Solutions:

Acquisition Flight Approved by

Signature over Printed Name

(End User Representative)

Acquisition Flight Certified by

SSG [illegible]

Signature over Printed Name

(PAF Representative)

Pilot-in-Command

Signature over Printed Name

Lidar Operator

Signature over Printed Name

Figure A-6.7. Flight Log for Mission 1726A

Flight log for 1734A Mission

DREAM Data Acquisition Flight Log — Flight Log No.:

1 LiDAR Operator: MCE Baliguas	2 ALTM Model: Aquarius	3 Mission Name: 3BLK65FG204A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9
7 Pilot: JJ Alajar	8 Co-Pilot: MA Garchitorena	9 Route:			
10 Date: July 23, 2014	12 Airport of Departure (Airport, City/Province): Tandag Airport		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0935	14 Engine Off: 1206	15 Total Engine Time: 0311	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Partly cloudy					
20 Remarks: Completed mission over BLK65F and BLK65G					
21 Problems and Solutions:					

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

Figure A-6.8. Flight Log for Mission 1734A

Annex 7. Flight status reports

Surigao del Sur Mission
July 3 to August 1, 2014

Table A-7.1. Flight Status Report

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1690	BLK61I, BLK65E	3BLK61IS193A, 3BLK65E193A	MCE BALIGUAS, MR VILLANUEVA	12 July 14	Completed mission over BLK61I. Surveyed 10 lines over BLKK65E
1694	BLK61E, BLK61D	3BLK65ESD194A	MR VILLANUEVA	13 July 14	Completed mission over BLK65E. Surveyed 9 lines over BLK65D
1698	BLK65C	3BLK65C195A	MR VILLANUEVA	14 July 14	Surveyed 9 lines over BLK65C; no digitizer
1702	BLK65B, BLK65C, BLK65D	3BLK65BCSDS196A	MCE BALIGUAS	15 July 14	Finished area of BLK65C and surveyed 3 lines over BLK65B. Covered gaps over BLK65D; no digitizer
1706	BLK65B, BLK65A	3BLK65BSA197A	MR VILLANUEVA	16 July 14	Completed mission over BLK65B and surveyed 6 lines over BLK65A. Camera not triggering when laser is on; no digitizer
1714	BLK65F, BLK65G	3BLK65FG199A	MCE BALIGUAS	18 July 14	Surveyed 8 lines over BLK65F and 11 lines over BLK65G; no digitizer
1726	BLK65A, BLK65B, BLK65C	3BLK65ASBSCS202A	MCE BALIGUAS	21 July 14	New Lever Arms values should be applied, LMS calibration needed
1734	BLK65F, BLK65G	3BLK65FSGS204A	MCE BALIGUAS	23 July 14	Completed mission over BLK65F and BLK65G

SWATH PER FLIGHT MISSION

Flight No.: 1690
Area: BLK61I, BLK65E
Mission Name: 3BLK61ISE193A, 3BLK65E193A
Parameters:Alt:600 Scan Freq:40 kHz Scan Angle: 25 deg
Total Area Surveyed: 57.5 sq km

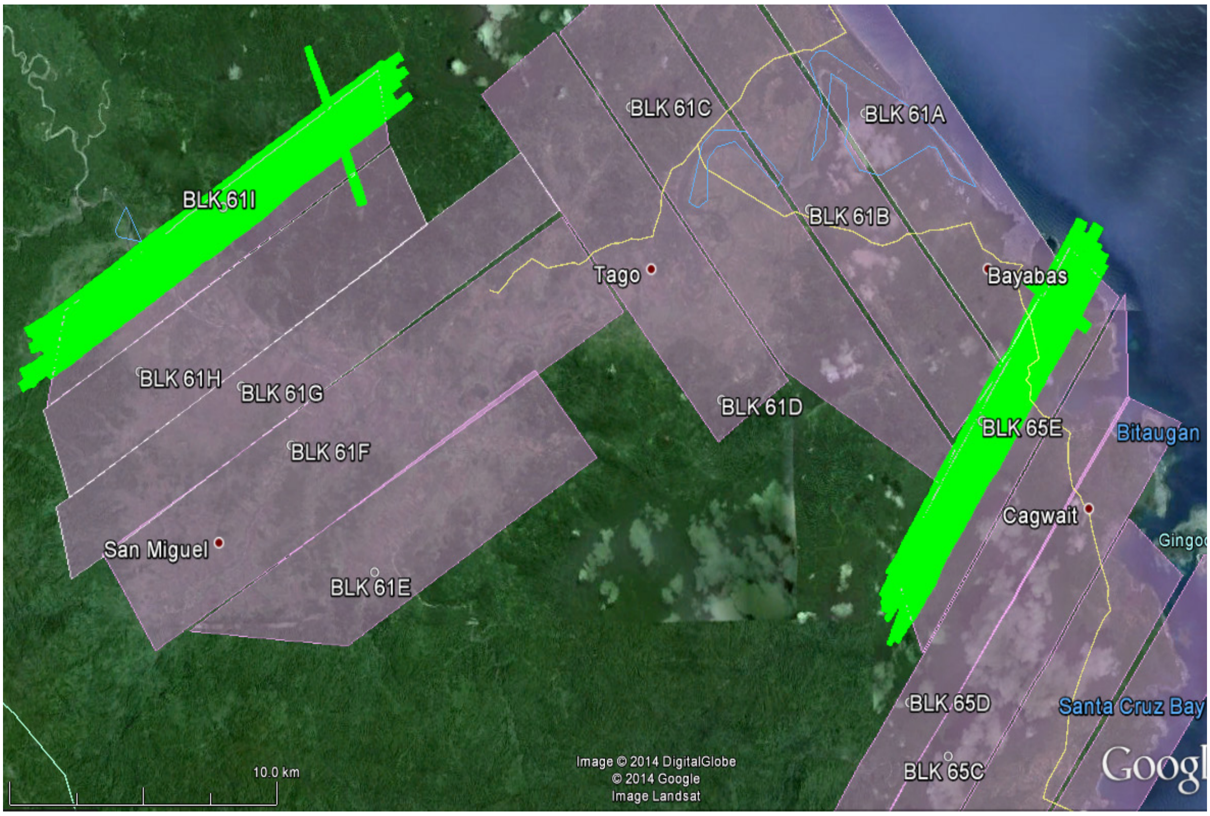


Figure A-7.1. Swath for Flight No. 1690A

Flight No.: 1694
Area: BLK65E, BLK65D
Mission Name: 3BLK65ESD194A
Parameters: Alt:600 Scan Freq:40 kHz Scan Angle: 25 deg
Total Area Surveyed: 80.1 sq km

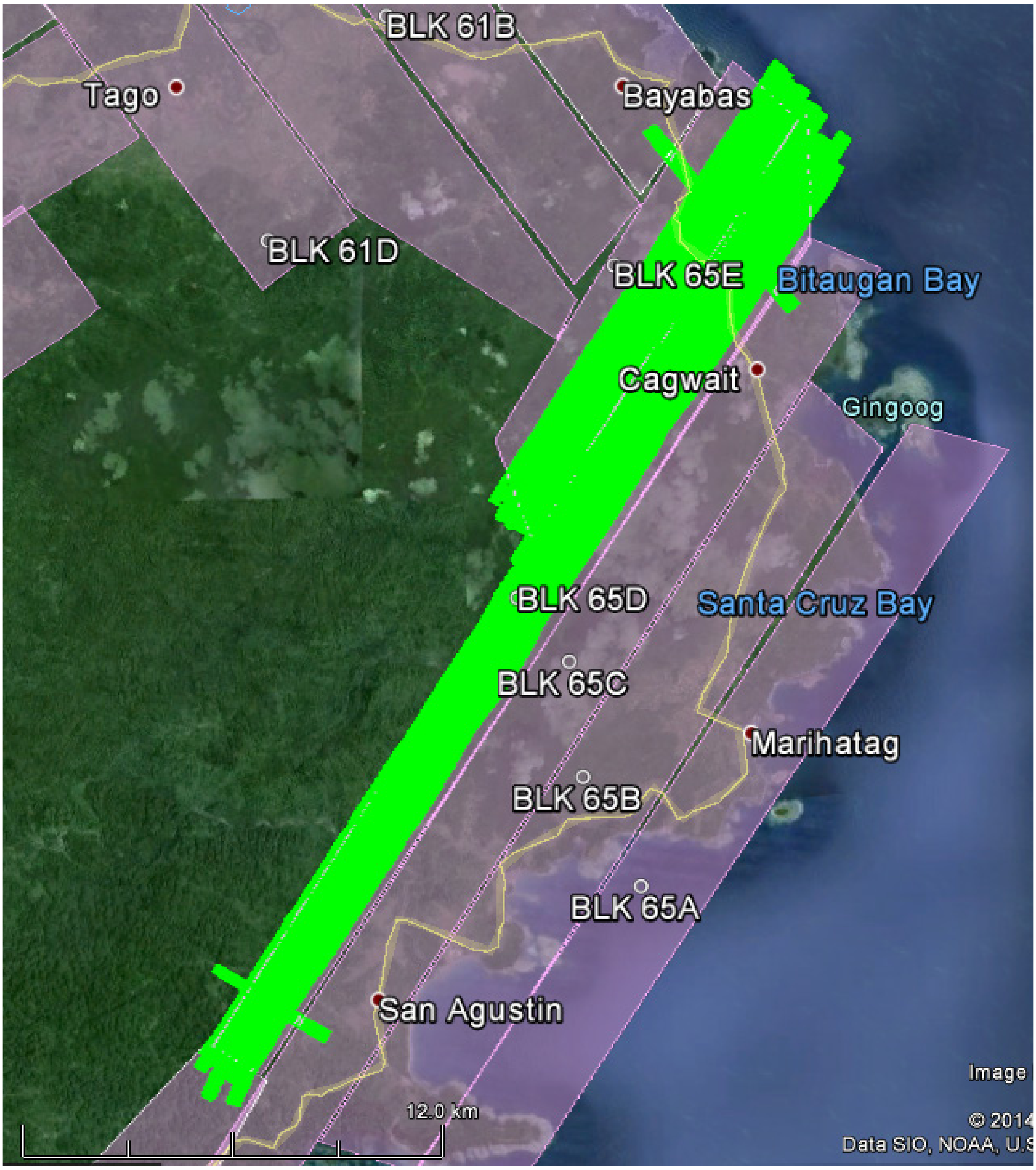


Figure A-7.2. Swath for Flight No. 1694A

Flight No.: 1698
Area: BLK65C
Mission Name: 3BLK65C195A
Parameters: Alt:600 Scan Freq:40 kHz Scan Angle: 25 deg
Total Surveyed Area: 65.4 sq km

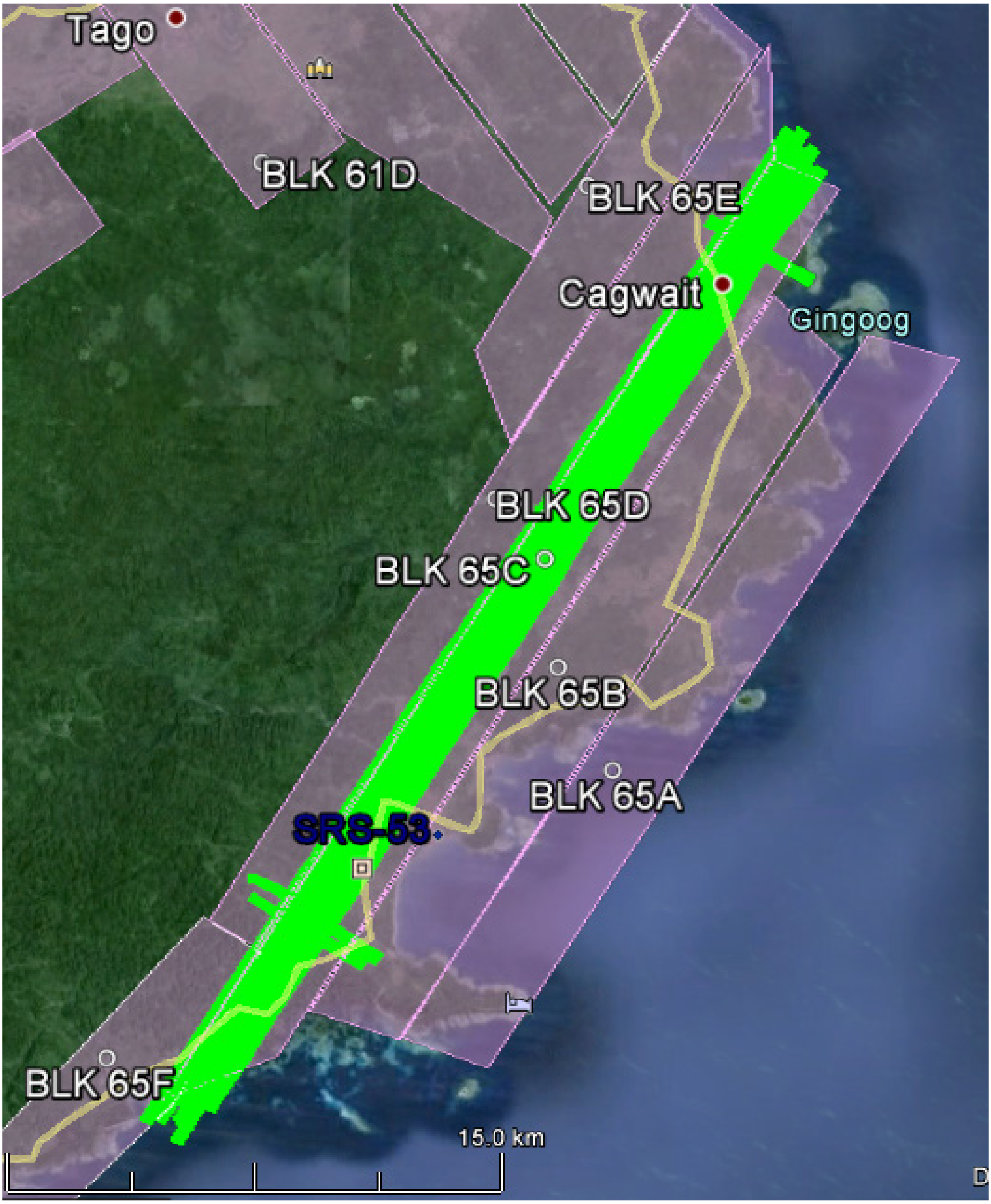


Figure A-7.3. Swath for Flight No. 1698A

Flight No.: 1702
Area: BLK65B, BLK65C, BLK65D
Mission Name: 3BLK65BCSDS196A
Parameters: Alt:600 Scan Freq:40 kHz Scan Angle: 25 deg
Total Surveyed Area: 65.1 sq km

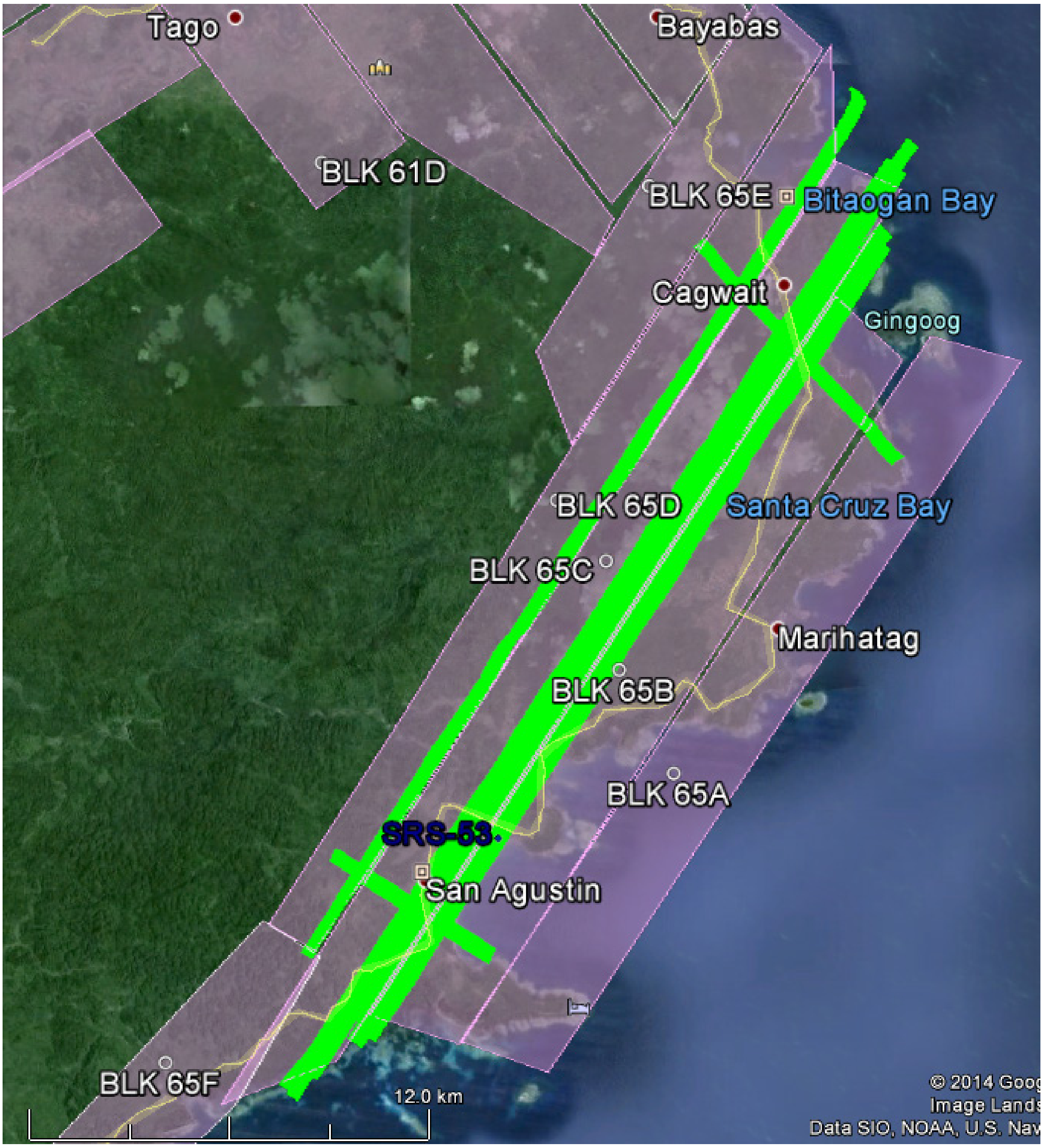


Figure A-7.4. Swath for Flight No. 1702A

Flight No.: 1706
Area: BLK65A, BLK65B
Mission Name: 3BLK65ABS197A
Parameters: Alt:600 Scan Freq:40 kHz Scan Angle: 25 deg
Total Area Surveyed: 92.1 sq km

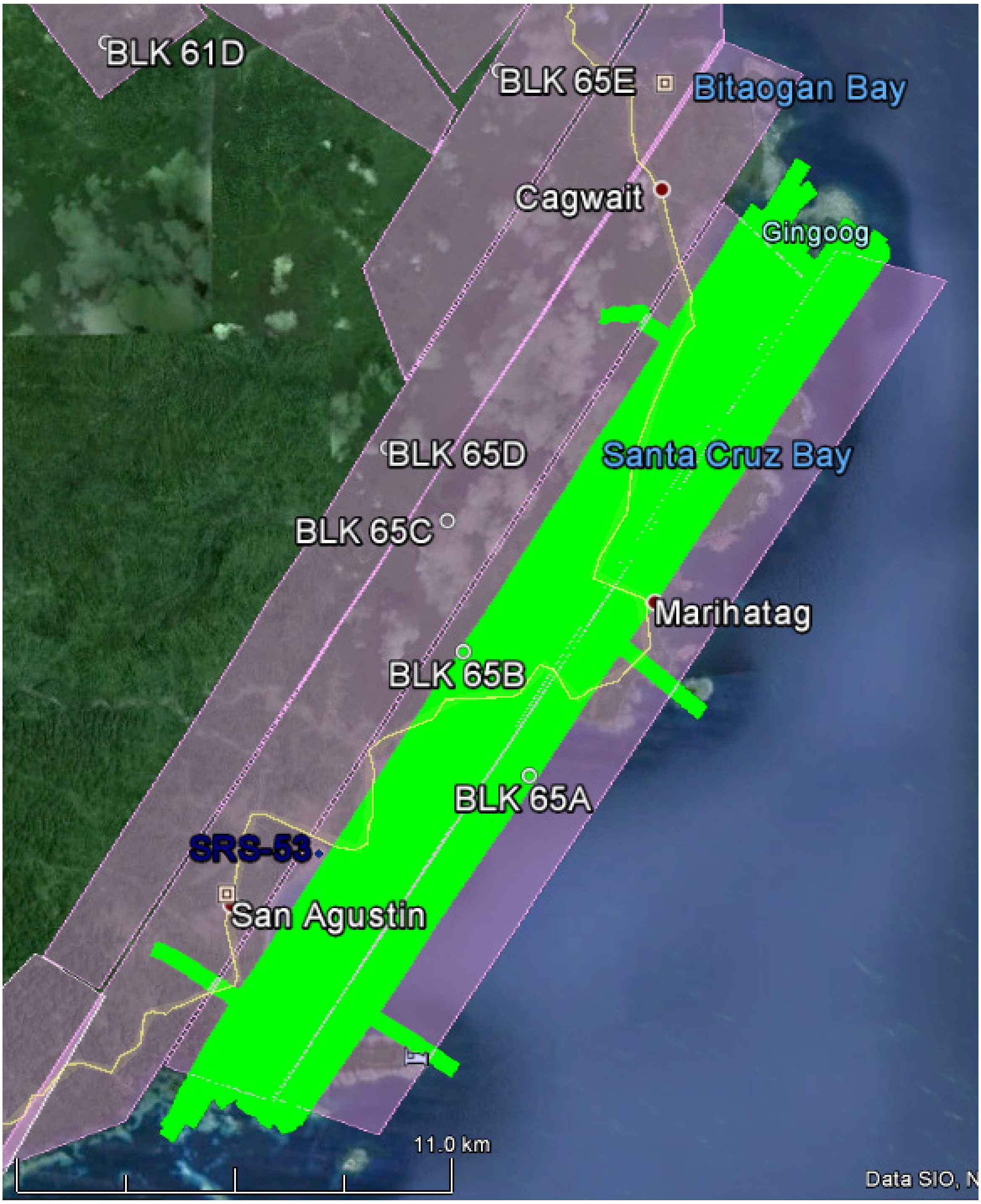


Figure A-7.5. Swath for Flight No. 1706A

Flight No.: 1714
Area: BLK65EF, BLK65G
Mission Name: 3BLK65FG199A
Parameters: Alt:600 Scan Freq:40 kHz Scan Angle: 25 deg
Total Area Surveyed: 85.5 sq km

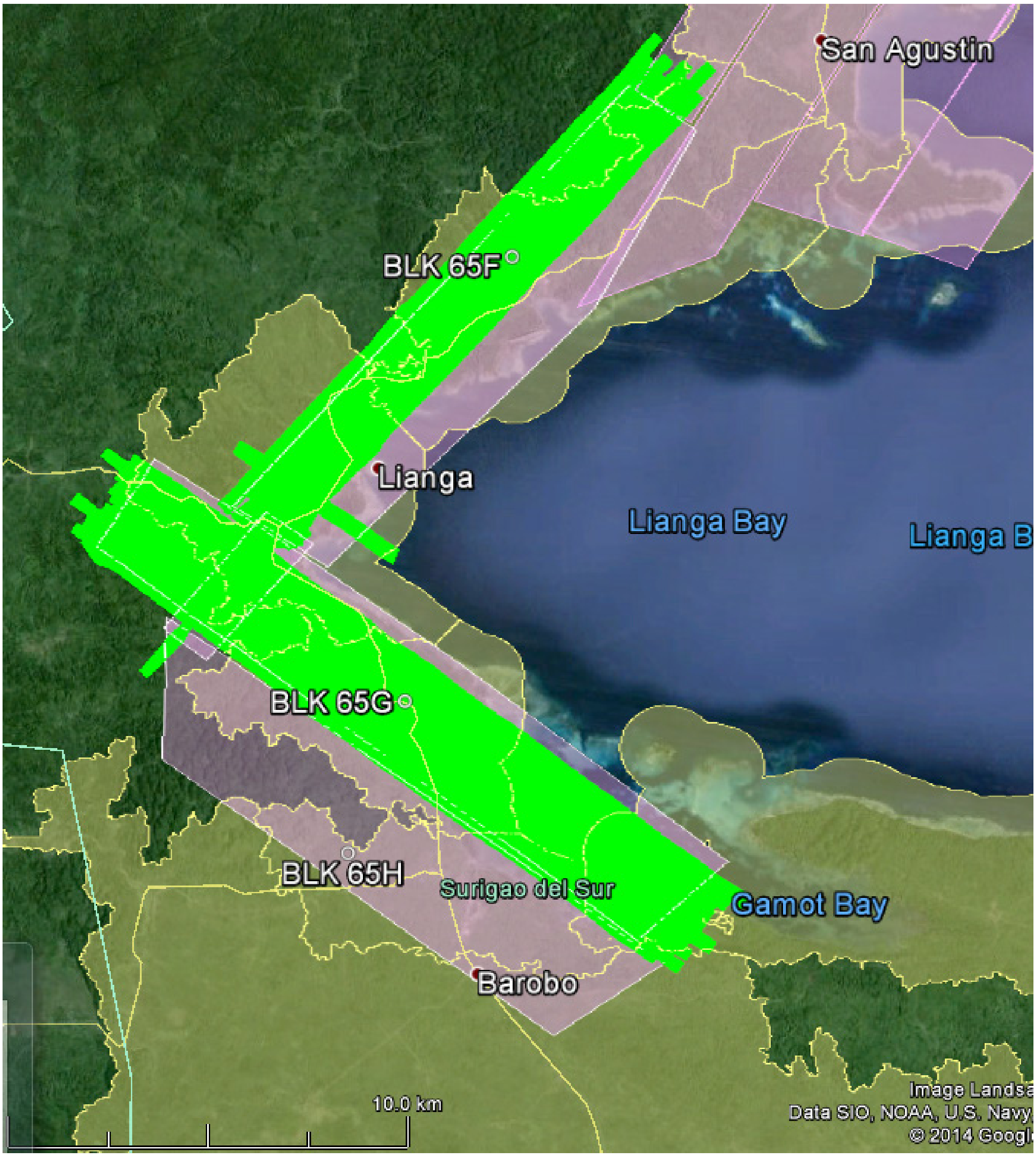


Figure A-7.6. Swath for Flight No. 1714A

Flight No.: 1726
Area: BLK65A, BLK65B, BLK65C
Mission Name: 3BLK65ASBSCS202A
Parameters: Alt:600 Scan Freq:40 kHz Scan Angle: 25 deg
Total Area Surveyed: 96.99 sq km

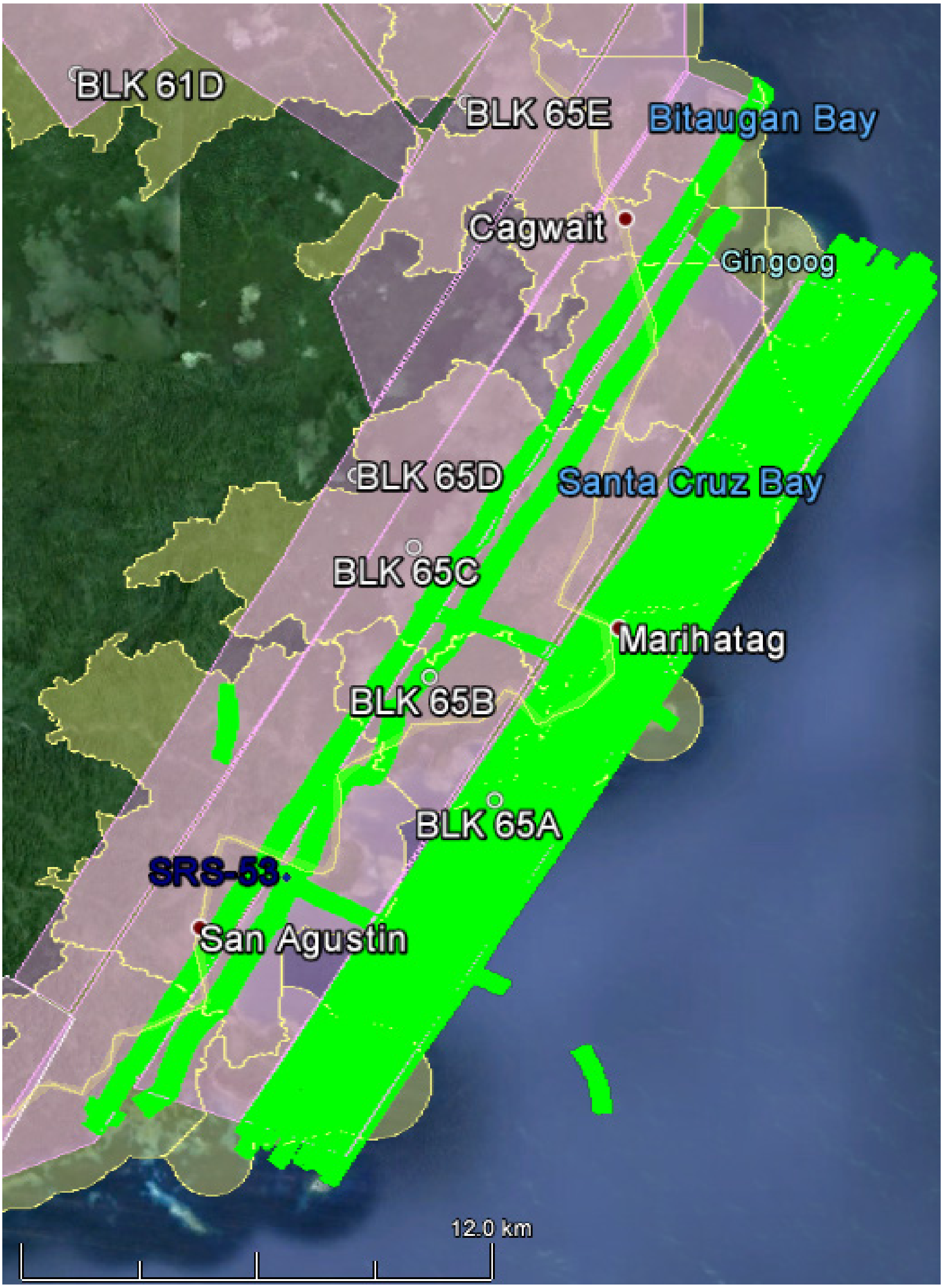


Figure A-7.7. Swath for Flight No. 1726A

Flight No. : 1734
Area: BLK65F, BLK65G
Mission Name: 3BLK65FSGS204A
Parameters: Alt:600 Scan Freq:40 kHz Scan Angle: 25 deg
Total Area Surveyed: 49.7 sq km

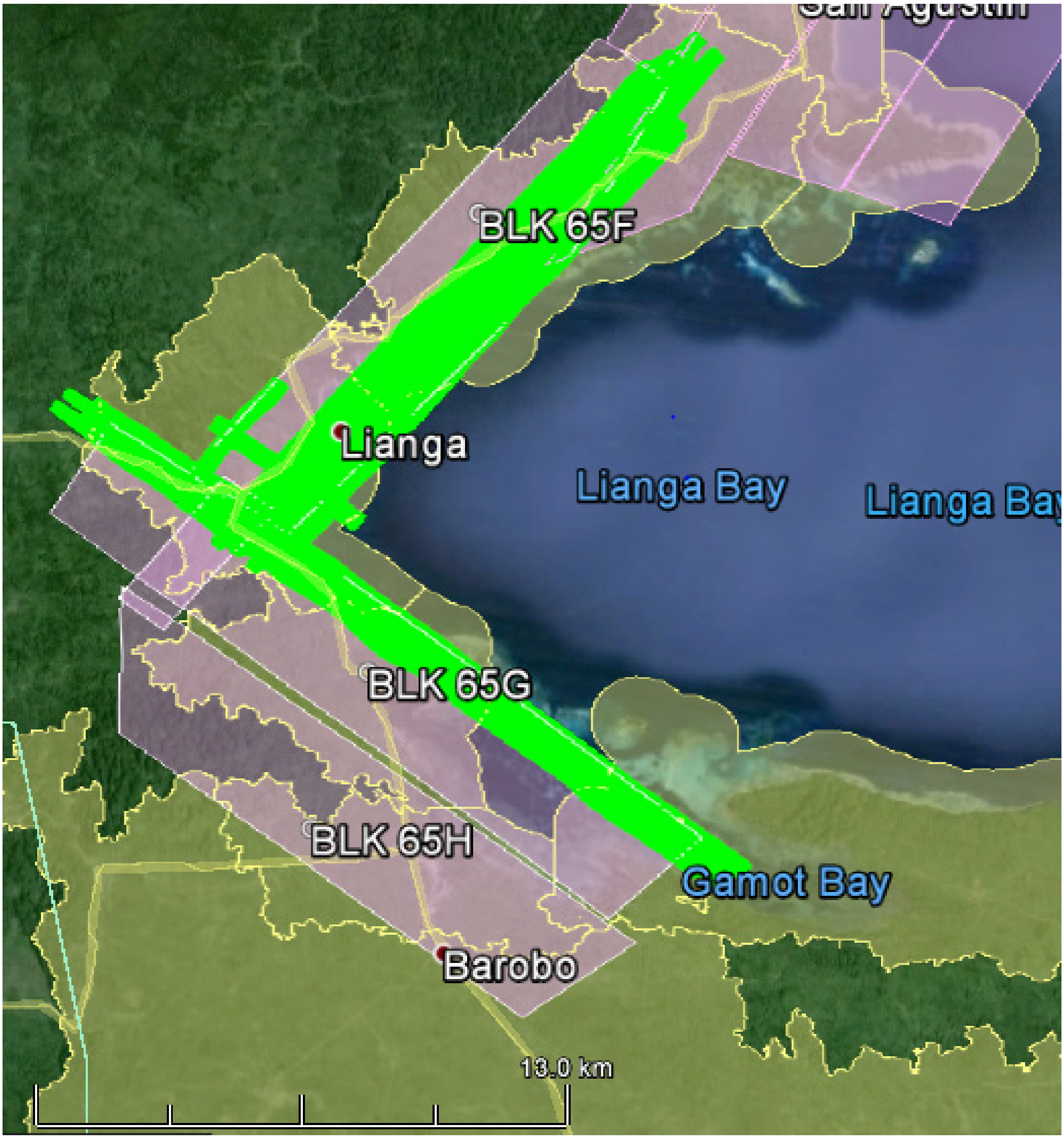


Figure A-7.8. Swath for Flight No. 1734A

Annex 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Blk65CD

Flight Area	Tandag (Surigao Del Sur)
Mission Name	Block 65CD
Inclusive Flights	1698A & 1702A
Range data size	22.20 GB
Base data size	15.99 MB
POS	377 MB
Image	98.40 MB
Transfer date	August 5, 2014 & July 31, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.85
RMSE for East Position (<4.0 cm)	3.10
RMSE for Down Position (<8.0 cm)	4.00
Boresight correction stdev (<0.001deg)	0.000440
IMU attitude correction stdev (<0.001deg)	0.004612
GPS position stdev (<0.01m)	0.0097
Minimum % overlap (>25)	77.15
Ave point cloud density per sq.m. (>2.0)	4.52
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	170
Maximum Height	371.95 m
Minimum Height	47.81 m
Classification (# of points)	
Ground	43,795,160
Low vegetation	57,597,183
Medium vegetation	98,661,251
High vegetation	185,453,527
Building	5,549,843
Orthophoto	Yes
Processed by	Engr. Kenneth Solidum, Engr. Harmond Santos

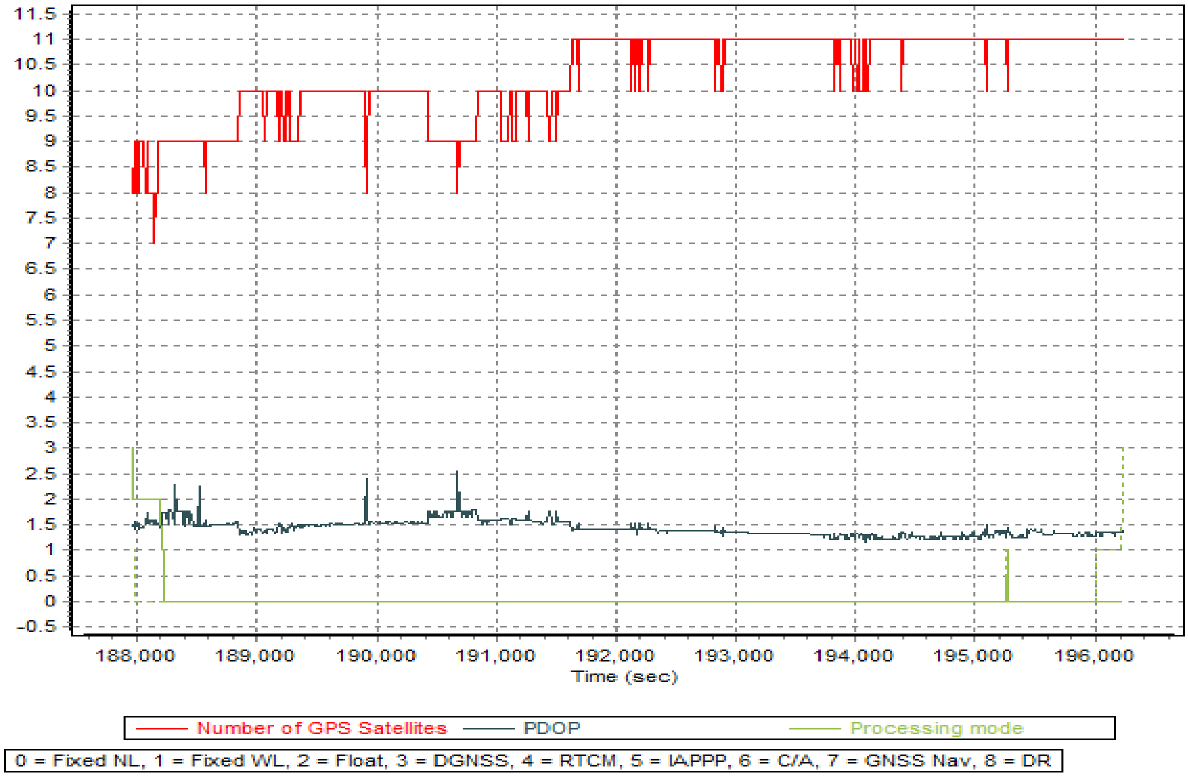


Figure A-8.1 Solution Status

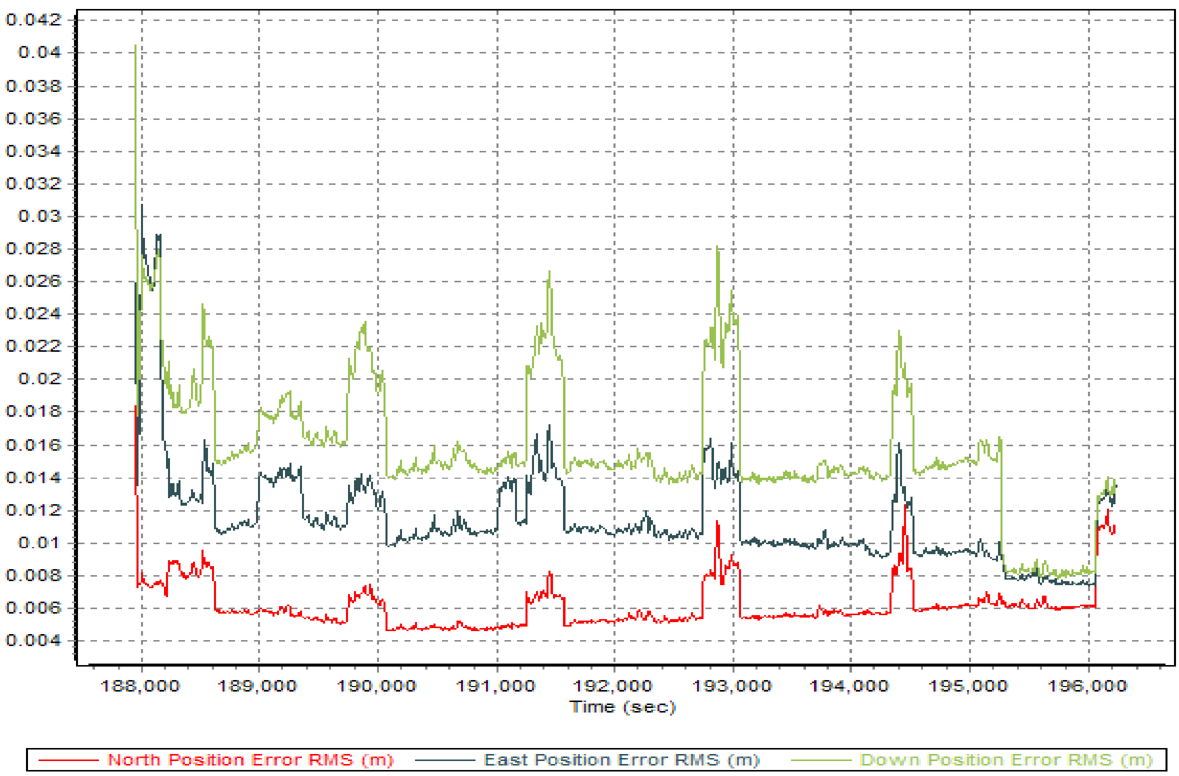


Figure A-8.2 Smoothed Performance Metric Parameters

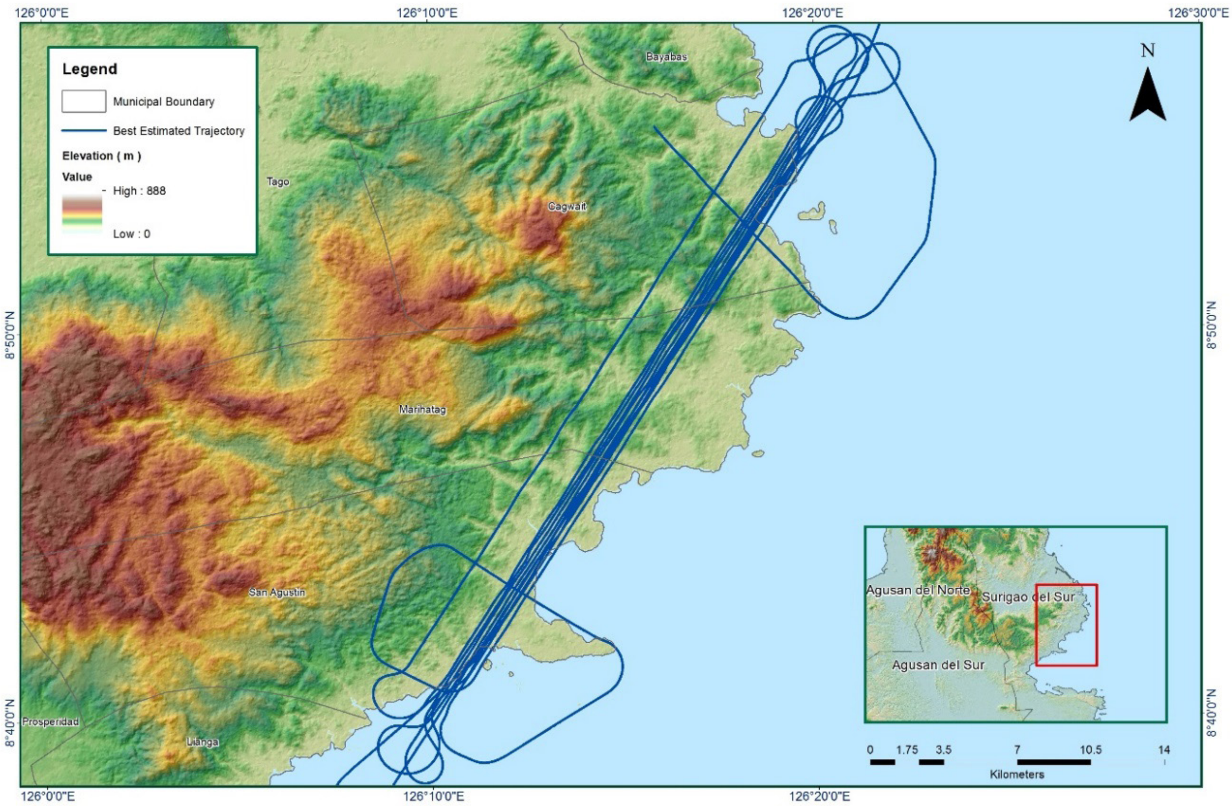


Figure A-8.3 Best Estimated Trajectory

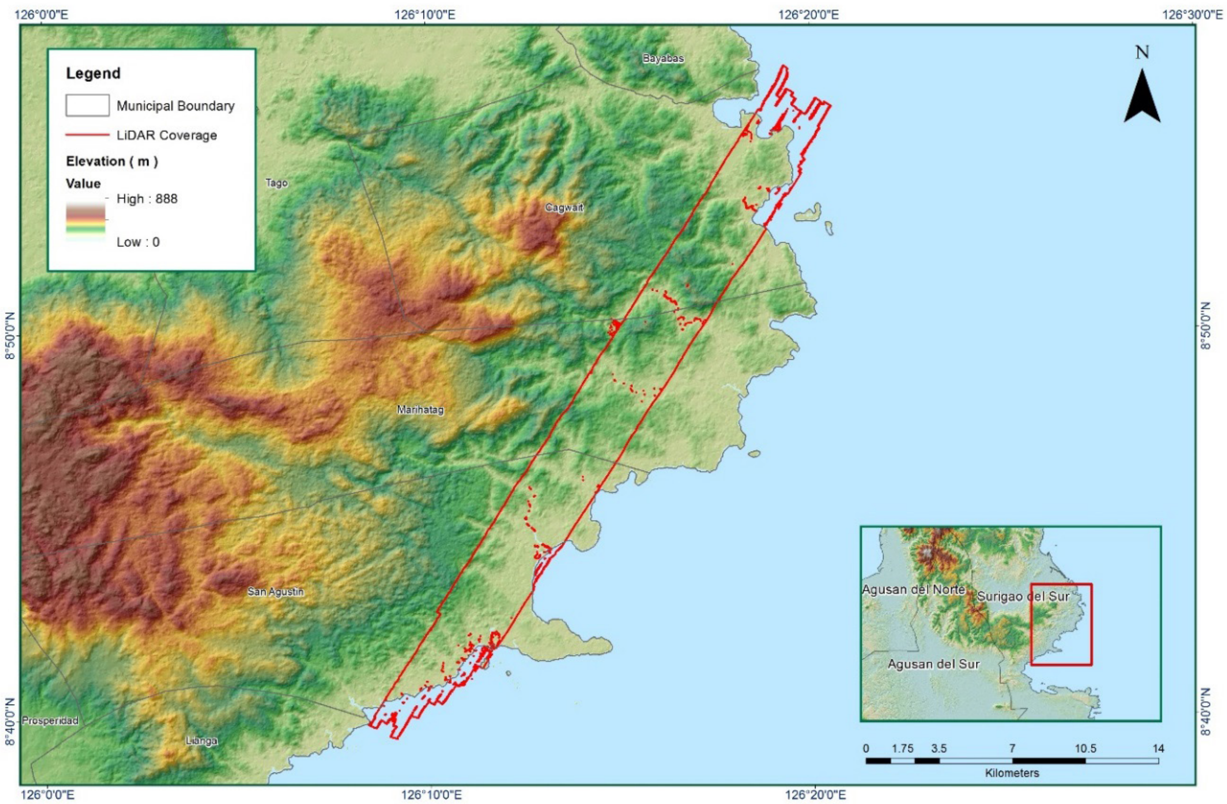


Figure A-8.4 Coverage of LiDAR data

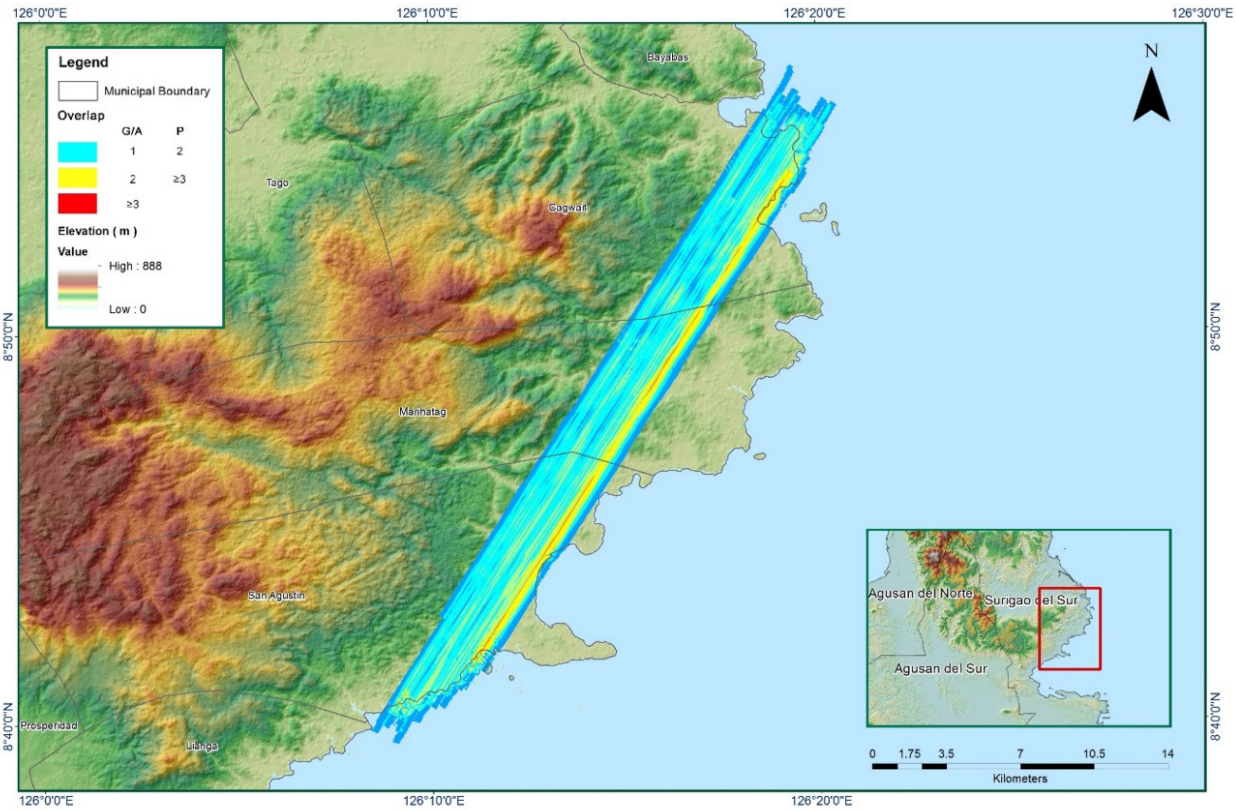


Figure A-8.5 Image of data overlap

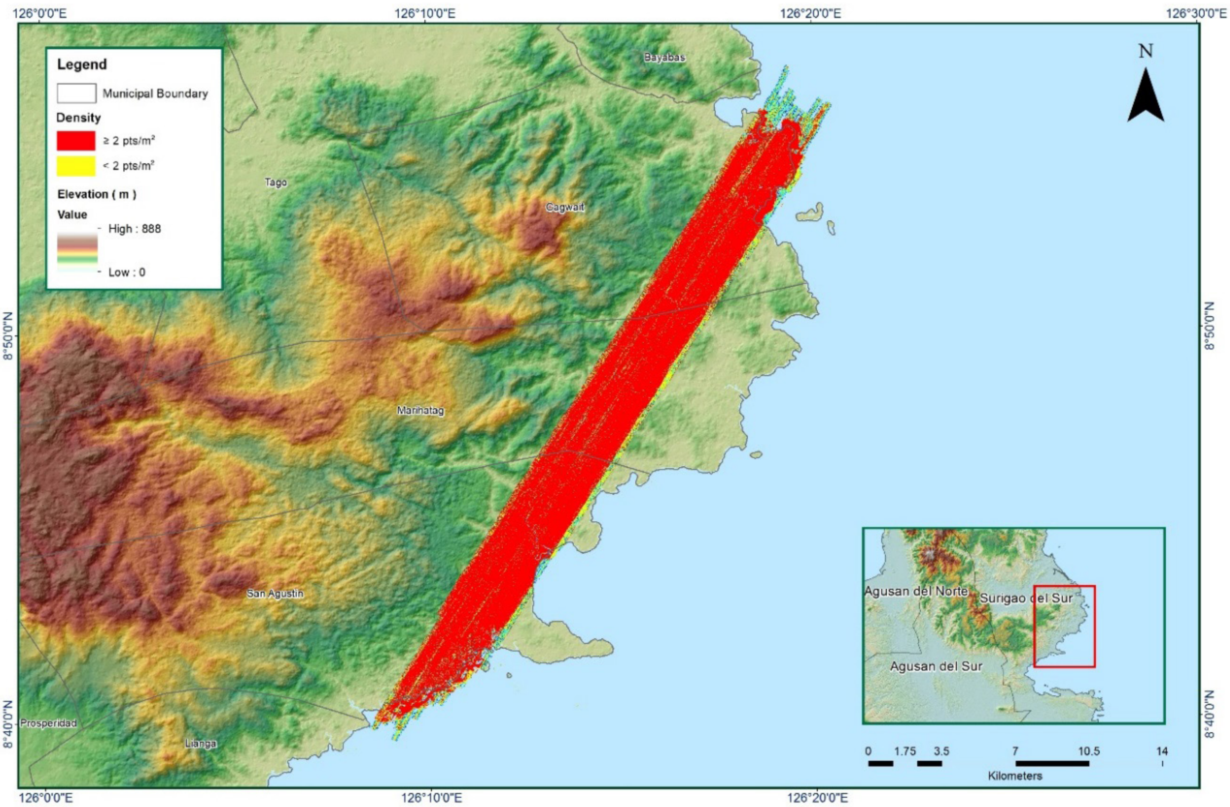


Figure A-8.6 Density map of merged LiDAR data

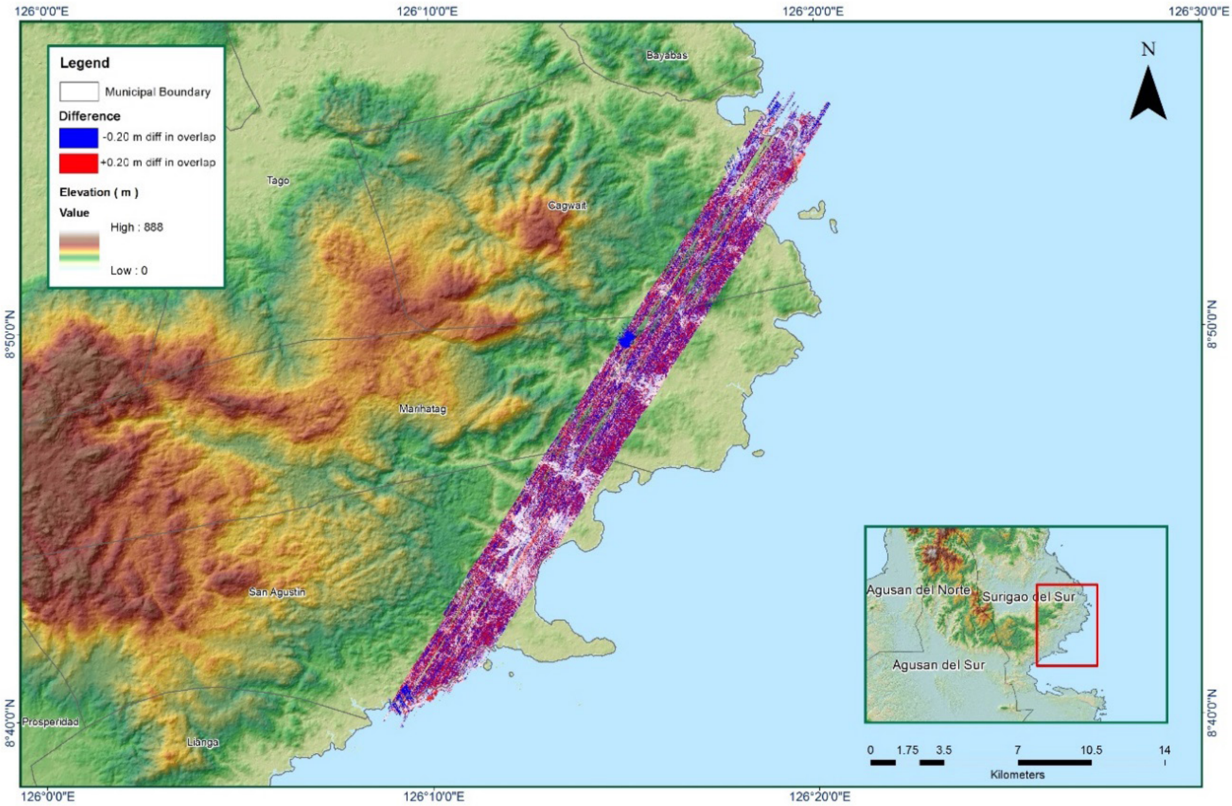


Figure A-8.7 Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Blk65AB

Flight Area	Tandag (Surigao Del Sur)
Mission Name	Block 65AB
Inclusive Flights	1706A & 1726A
Range data size	24.20 GB
Base data size	25.45 MB
POS	491MB
Image	136.70 MB
Transfer date	July 31, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.10
RMSE for East Position (<4.0 cm)	2.70
RMSE for Down Position (<8.0 cm)	3.50
Boresight correction stdev (<0.001deg)	0.000728
IMU attitude correction stdev (<0.001deg)	0.010218
GPS position stdev (<0.01m)	0.0082
Minimum % overlap (>25)	42.61
Ave point cloud density per sq.m. (>2.0)	2.54
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	233
Maximum Height	357.22 m
Minimum Height	40.03 m
Classification (# of points)	
Ground	67,240,480
Low vegetation	68,127,741
Medium vegetation	81,511,695
High vegetation	76,902,555
Building	3,337,429
Orthophoto	Yes
Processed by	Engr. Kenneth Solidum, Engr. Analyn Naldo Engr. Chelou Prado, Engr. Gladys Apat

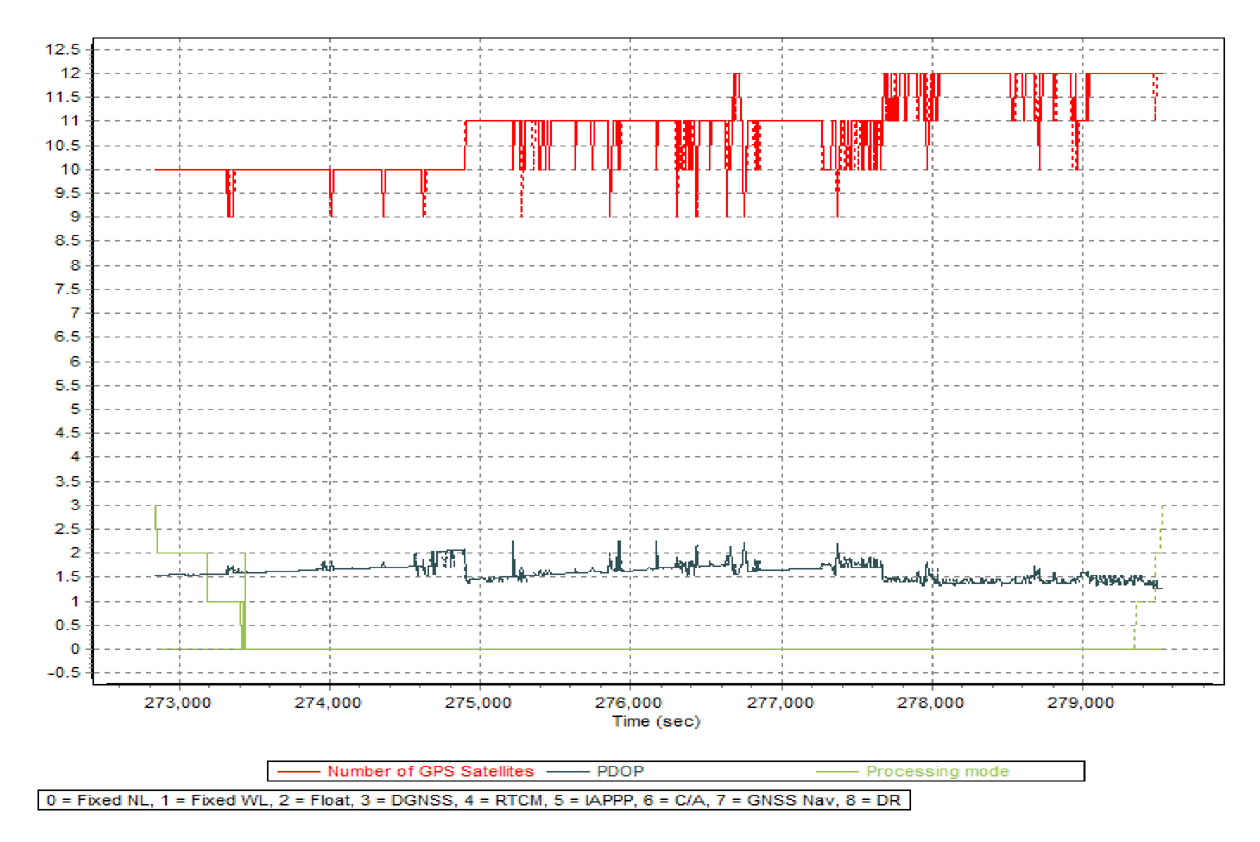


Figure A-8.8 Solution Status

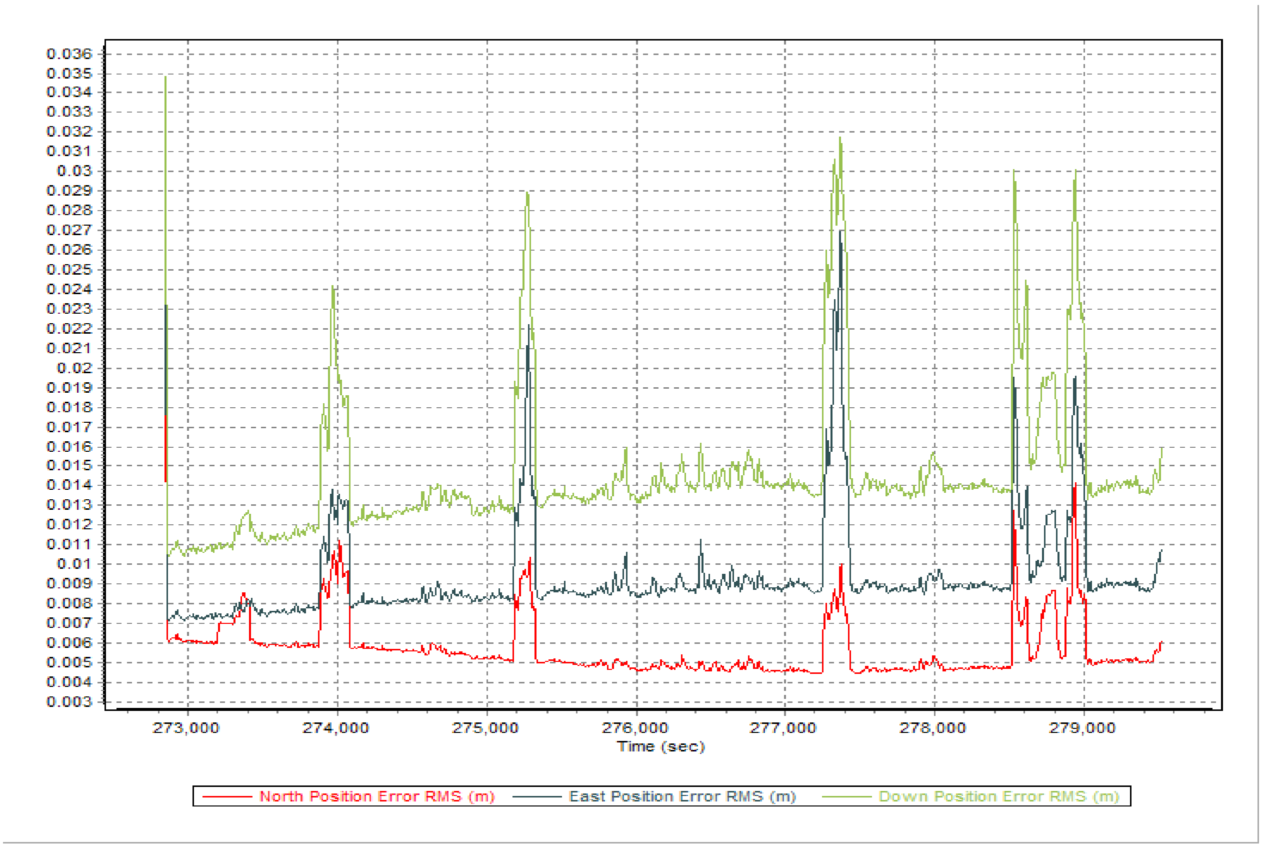


Figure A-8.9 Smoothed Performance Metric Parameters

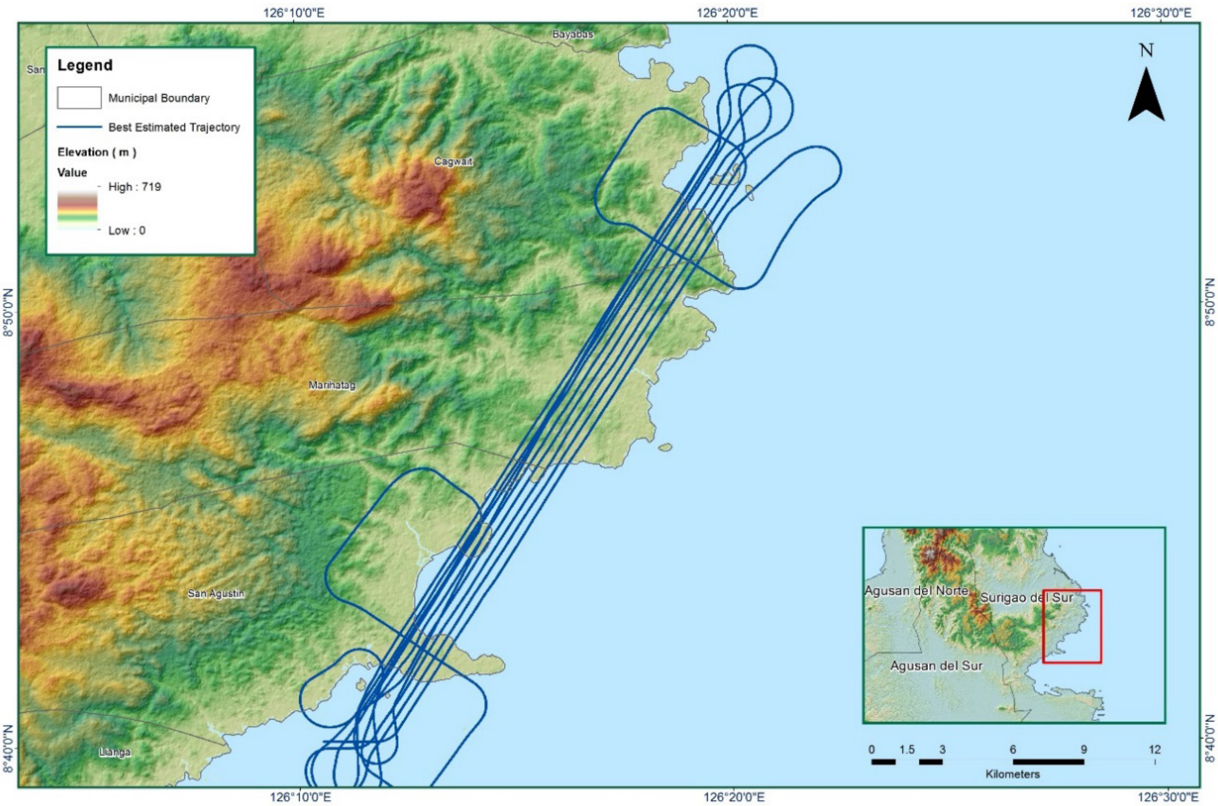


Figure A-8.10 Best Estimated Trajectory

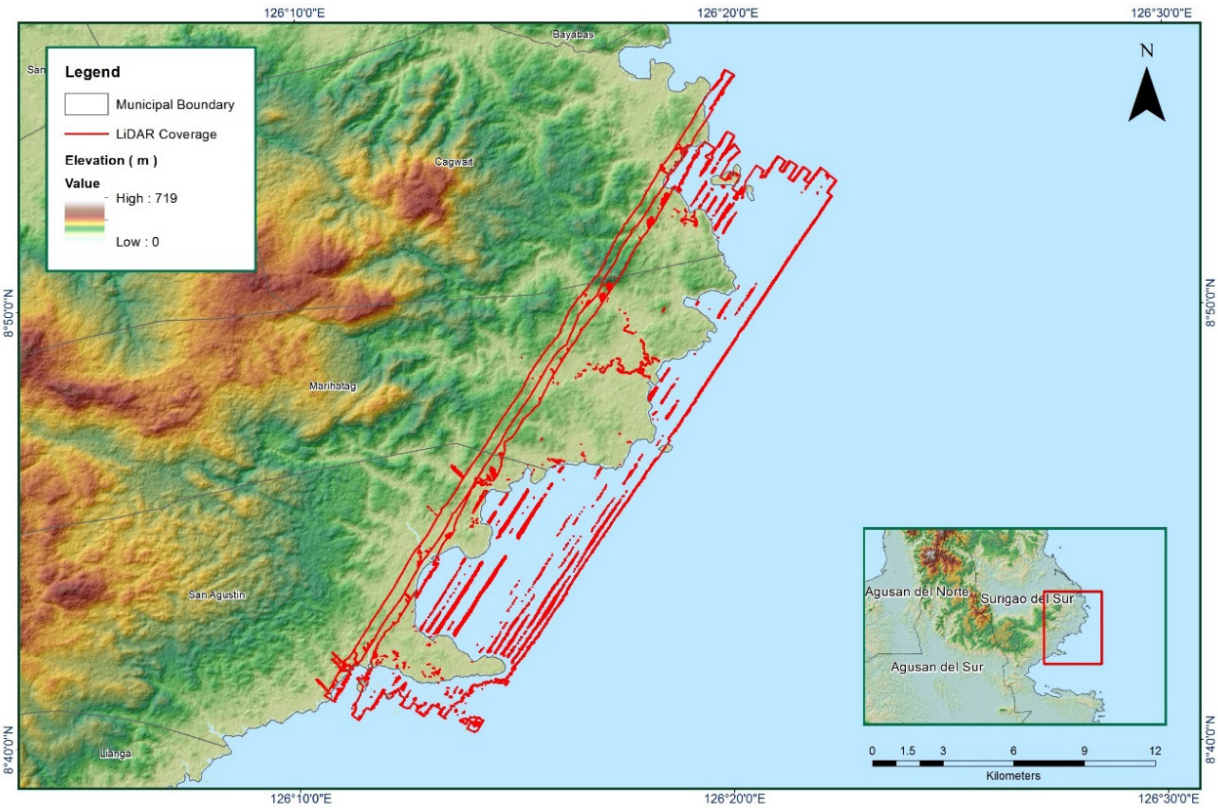


Figure A-8.11 Coverage of LiDAR data

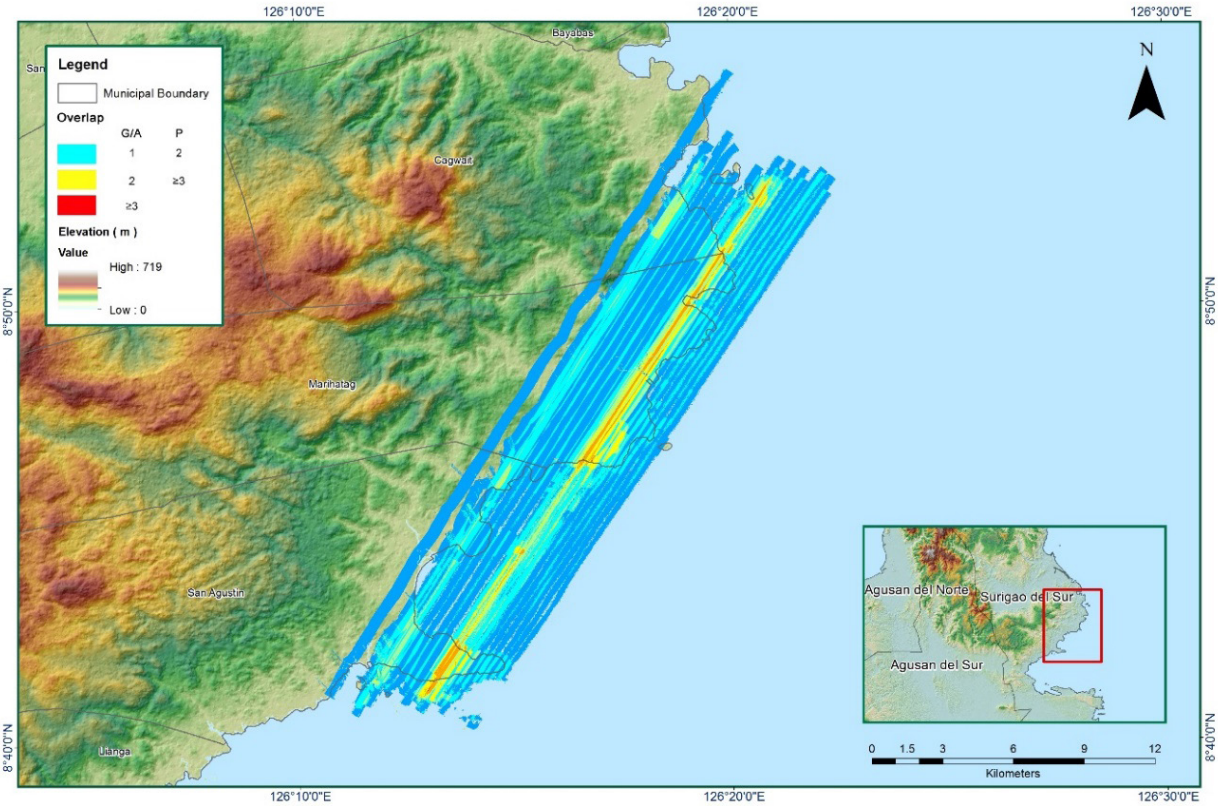


Figure A-8.12 Image of data overlap

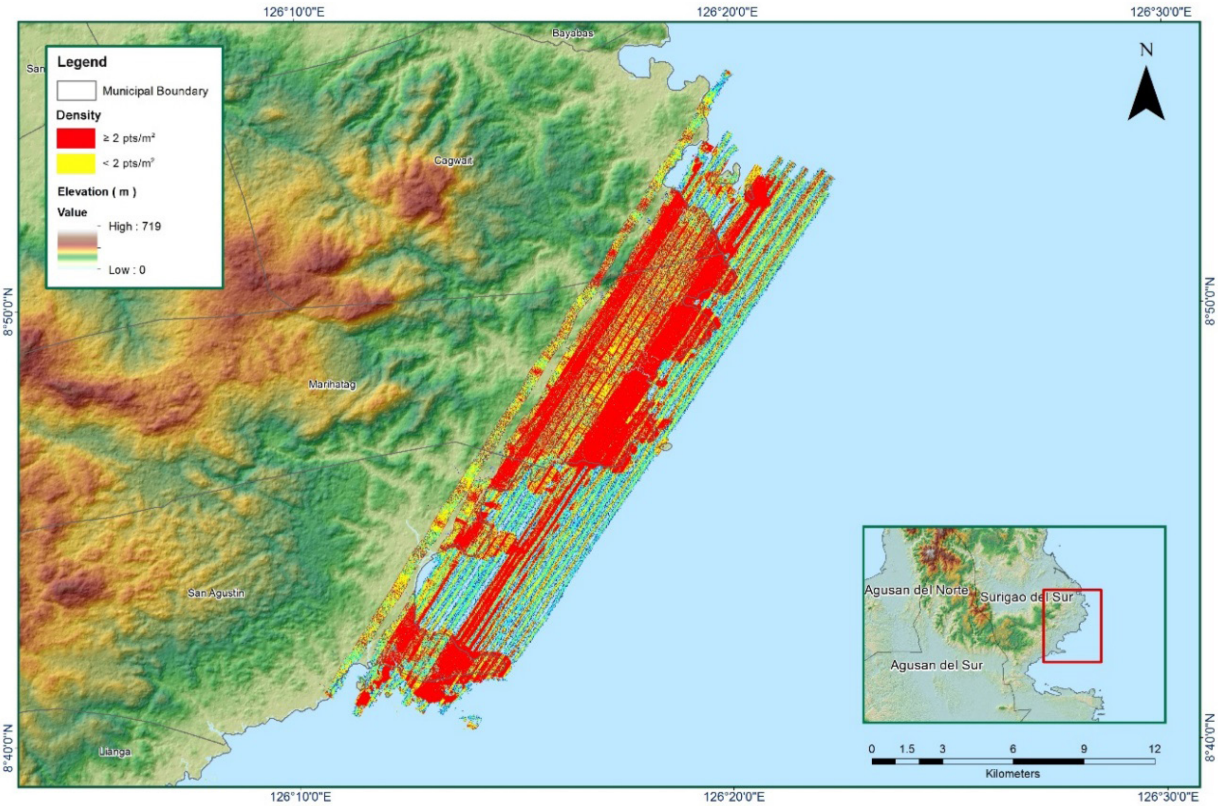


Figure A-8.13 Density map of merged LiDAR data

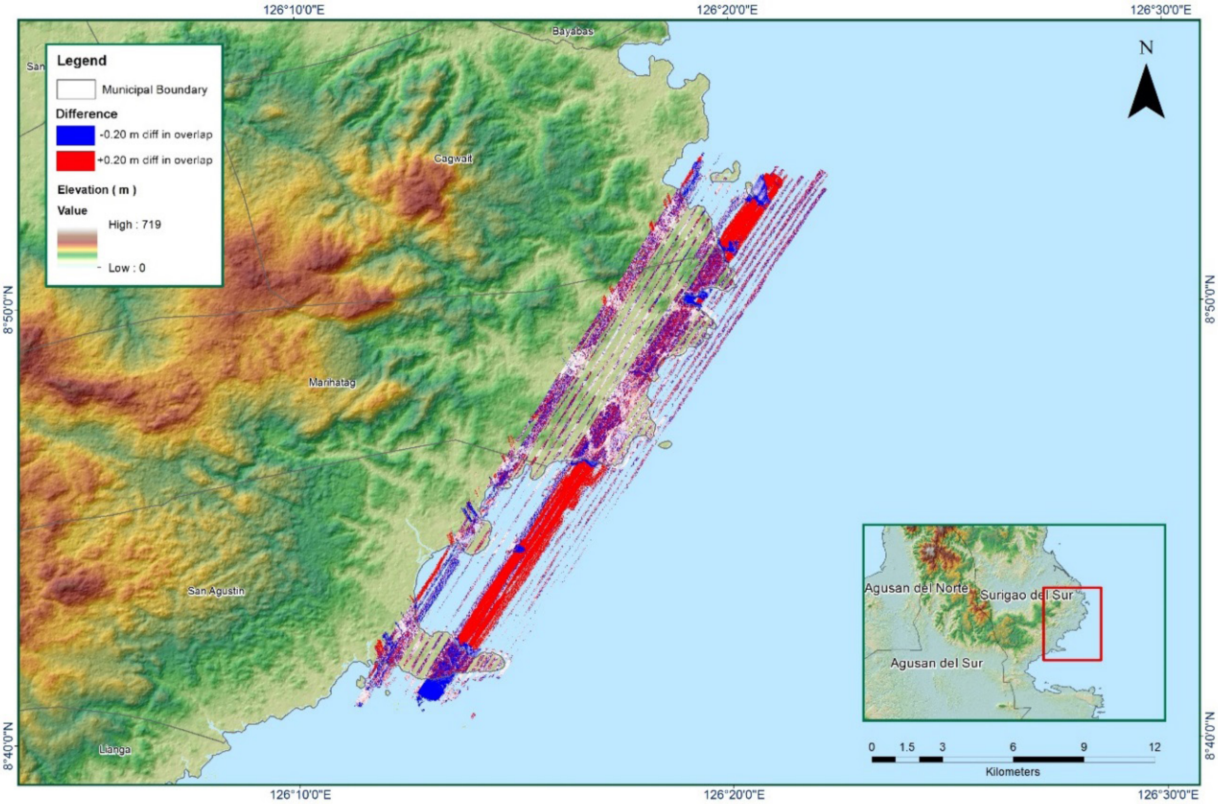


Figure A-8.14 Elevation difference between flight lines

Table A-8.3. Mission Summary Report for Mission Blk65E

Flight Area	Tandag (Surigao Del Sur)
Mission Name	Block 65E
Inclusive Flights	1690A & 1694A
Range data size	22.70 GB
Base data size	20.29 MB
POS	506 MB
Image	69.70 MB
Transfer date	August 5, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.75
RMSE for East Position (<4.0 cm)	2.00
RMSE for Down Position (<8.0 cm)	3.33
Boresight correction stdev (<0.001deg)	0.000428
IMU attitude correction stdev (<0.001deg)	0.002691
GPS position stdev (<0.01m)	0.0091
Minimum % overlap (>25)	55.88
Ave point cloud density per sq.m. (>2.0)	4.61
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	142
Maximum Height	471.84 m
Minimum Height	53.27 m
Classification (# of points)	
Ground	28,059,412
Low vegetation	26,073,517
Medium vegetation	70,629,052
High vegetation	207,464,655
Building	5,418,951
Orthophoto	Yes
Processed by	Engr. Kenneth Solidum, Engr. Melanie Hingpit, Engr. Melissa Fernandez

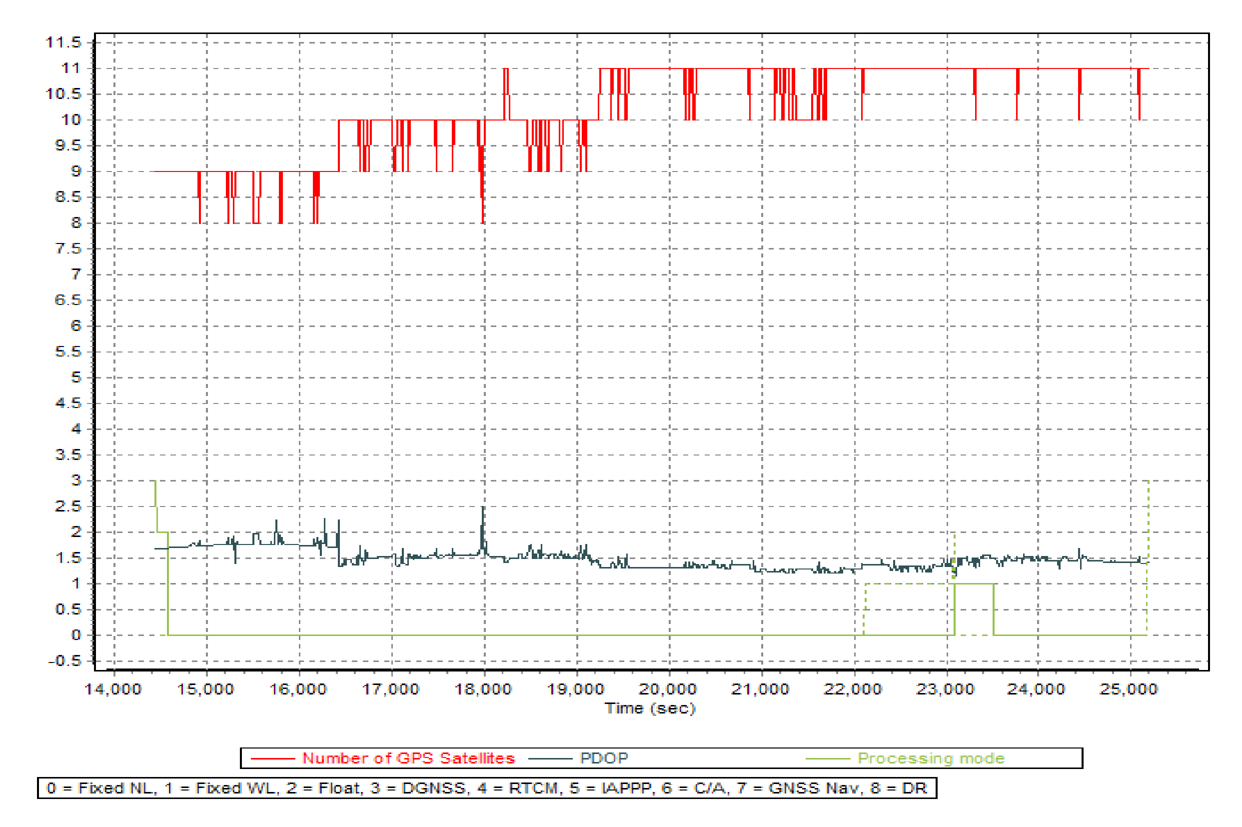


Figure A-8.15 Solution Status

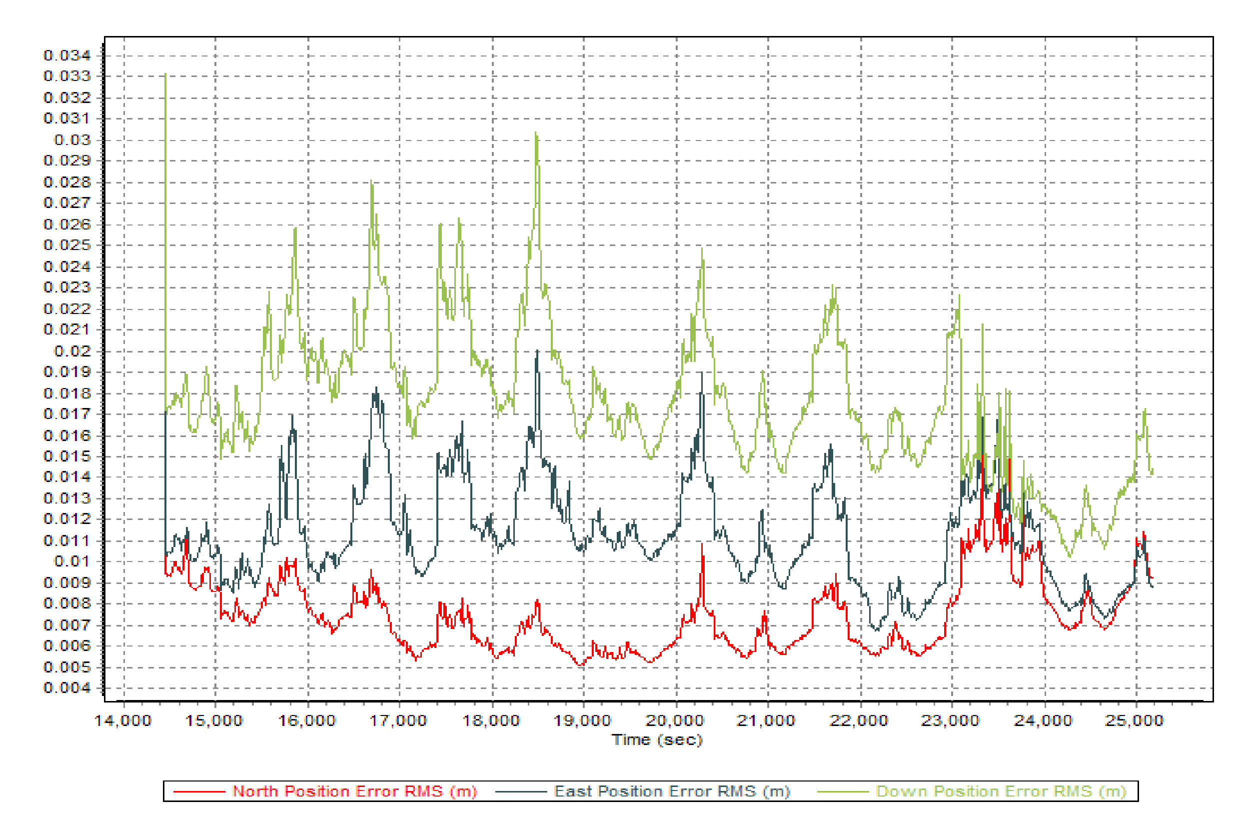


Figure A-8.16 Smoothed Performance Metric Parameters

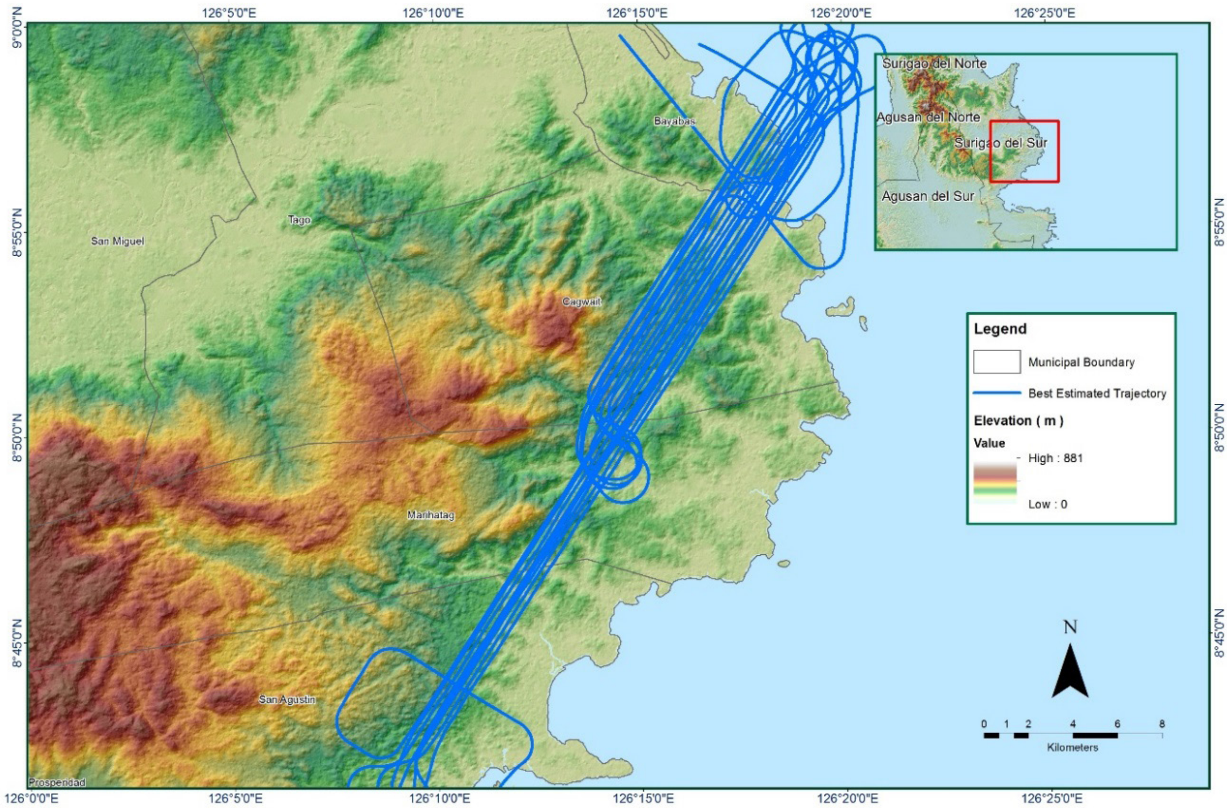


Figure A-8.17 Best Estimated Trajectory

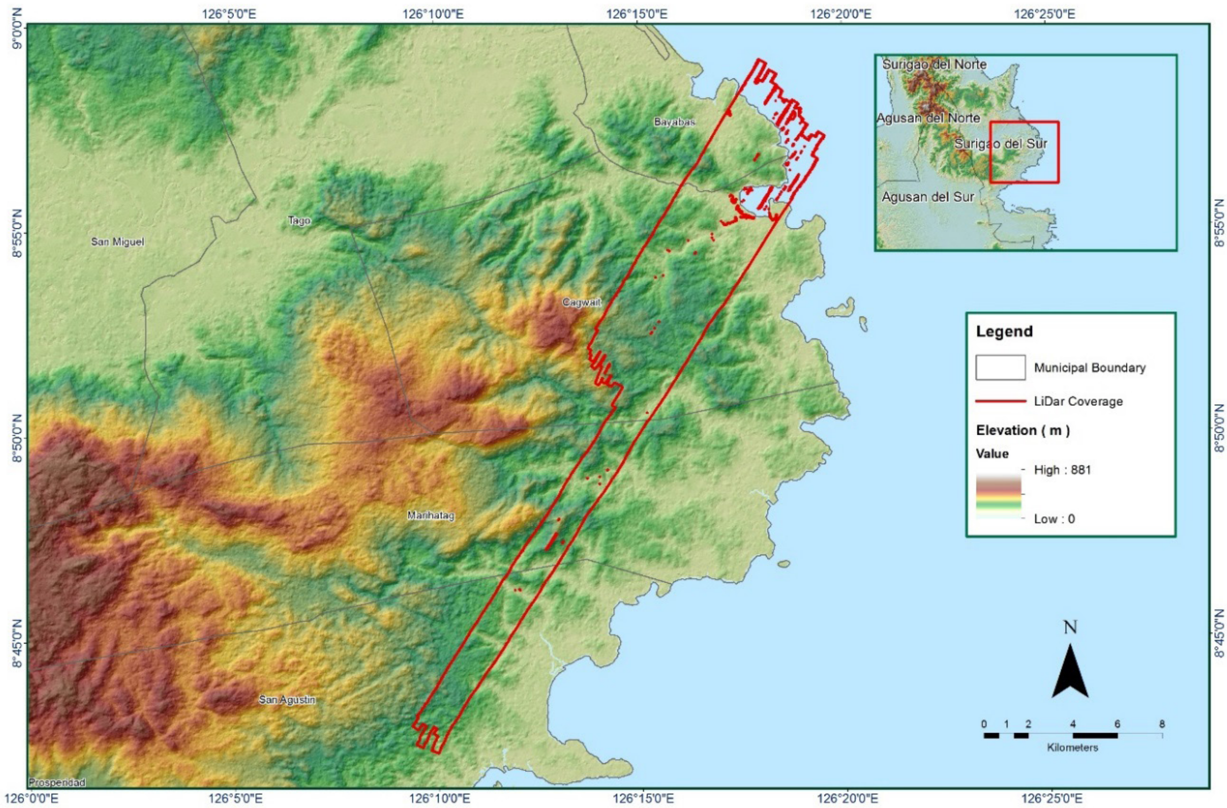


Figure A-8.18 Coverage of LiDAR data

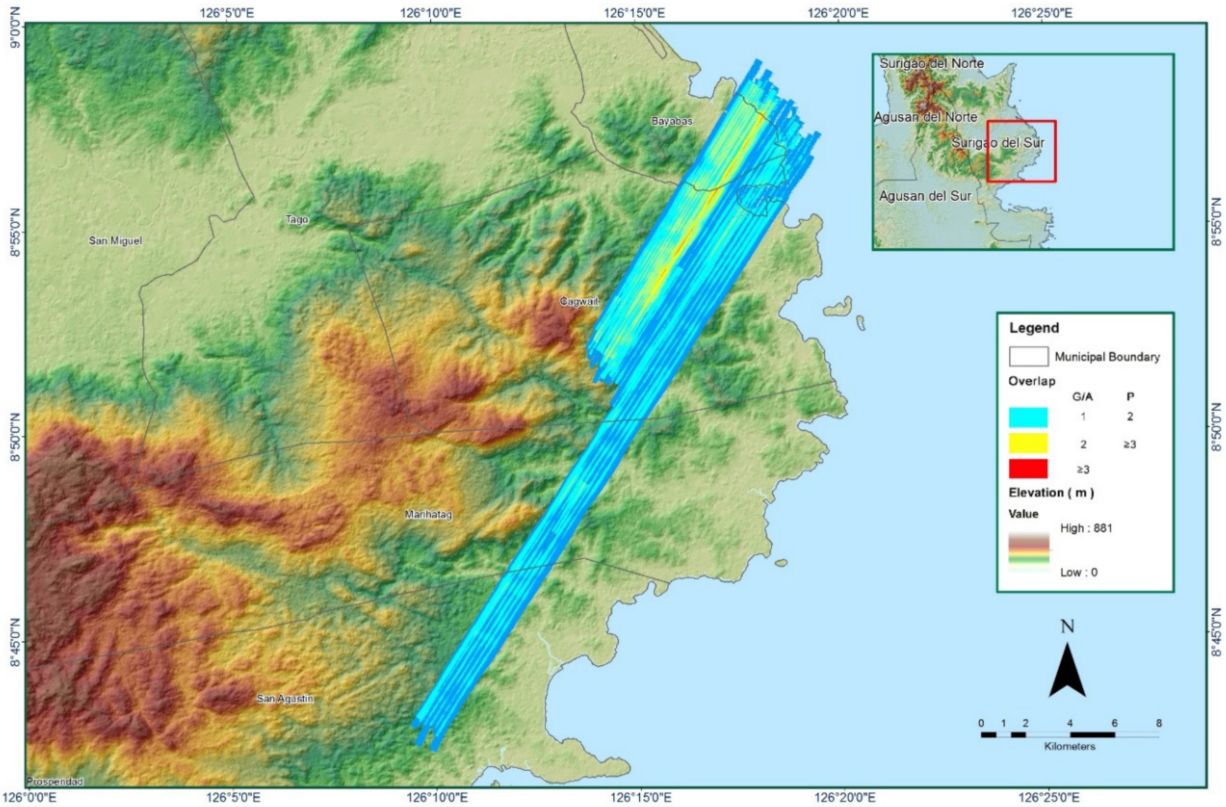


Figure A-8.19 Image of data overlap

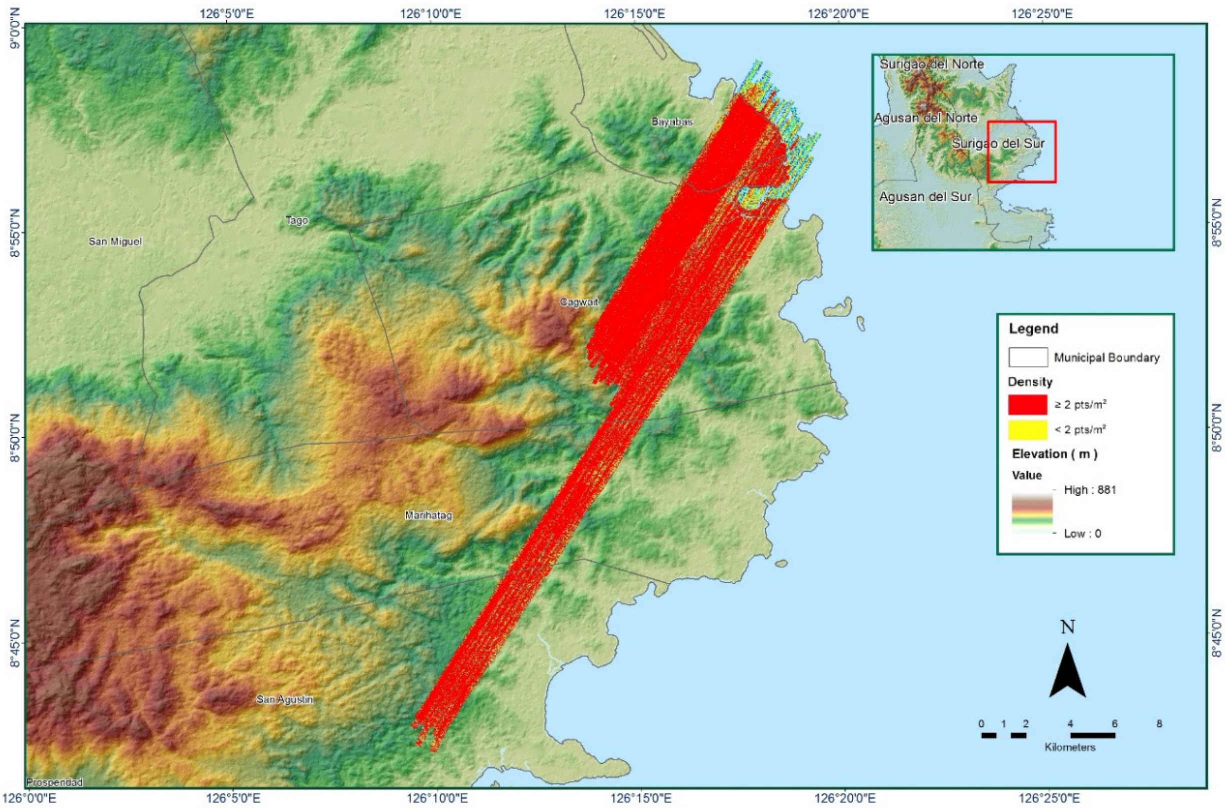


Figure A-8.20 Density map of merged LiDAR data

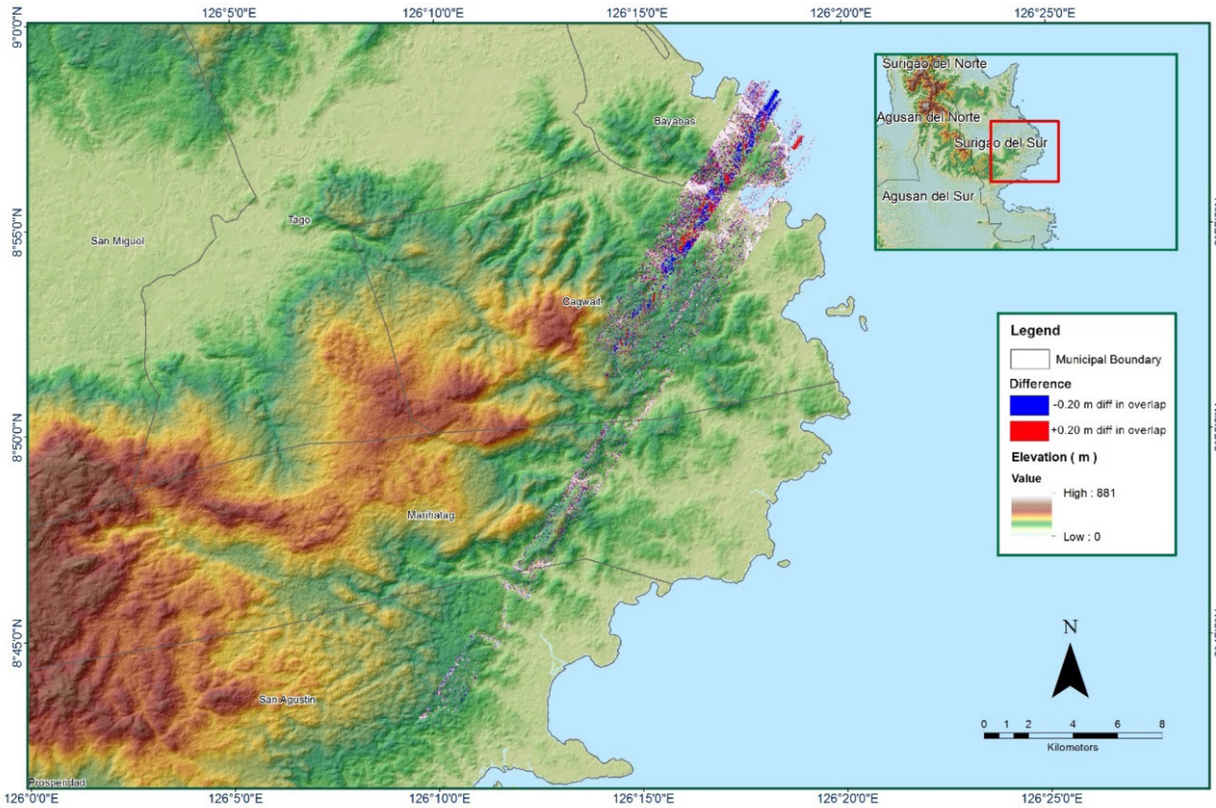


Figure A-8.21 Elevation difference between flight lines

Table A-8.4. Mission Summary Report for Mission Blk65FG

Flight Area	Tandag (Surigao Del Sur)
Mission Name	Block 65FG
Inclusive Flights	1714A & 1734A
Range data size	20.08 GB
Base data size	23.09 MB
POS	440 MB
Image	114.90 MB
Transfer date	July 31, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.95
RMSE for East Position (<4.0 cm)	2.10
RMSE for Down Position (<8.0 cm)	3.40
Boresight correction stdev (<0.001deg)	0.000467
IMU attitude correction stdev (<0.001deg)	0.001135
GPS position stdev (<0.01m)	0.0072
Minimum % overlap (>25)	59.75
Ave point cloud density per sq.m. (>2.0)	3.58
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	179
Maximum Height	388.37 m
Minimum Height	45.74 m
Classification (# of points)	
Ground	35,792,604
Low vegetation	37,451,825
Medium vegetation	74,379,583
High vegetation	155,910,057
Building	6,109,884
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Engr. Edgar Gubatanga, Jr., Jovy Narisma

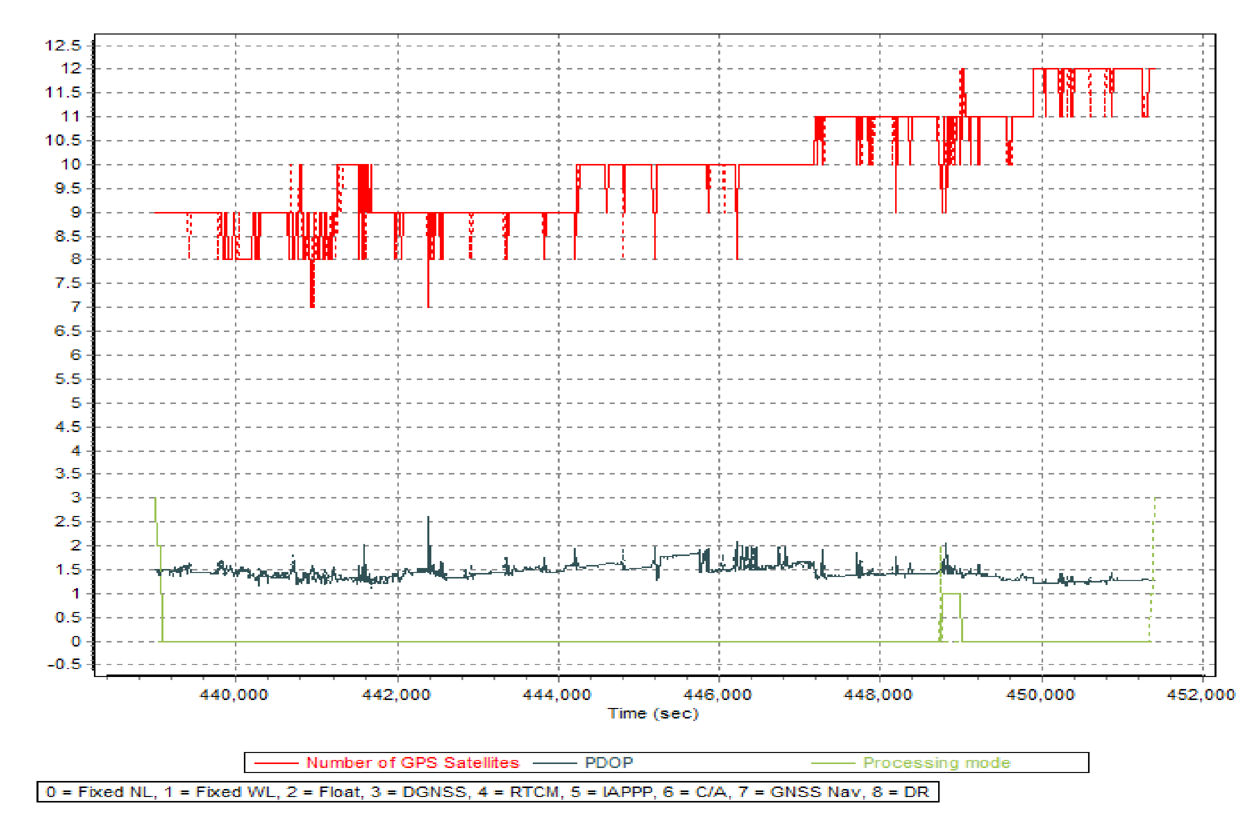


Figure A-8.22 Solution Status

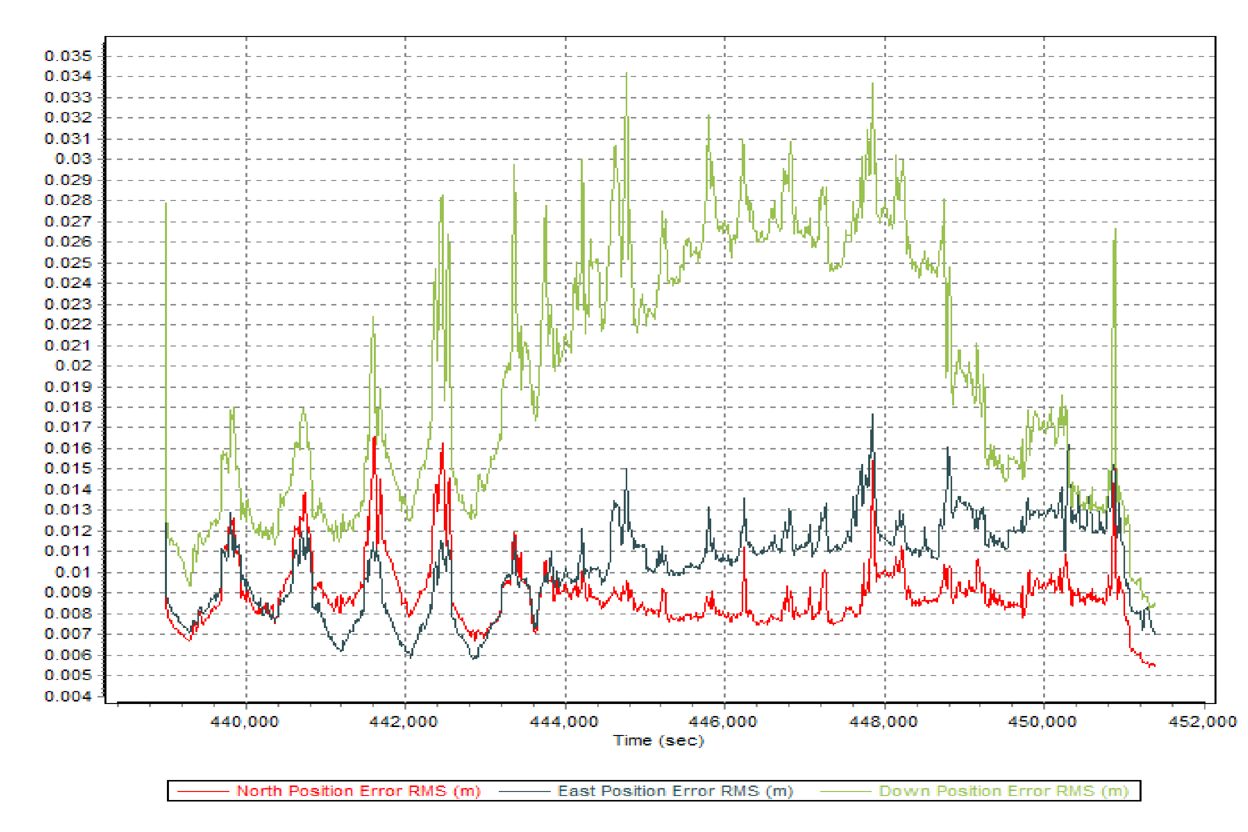


Figure A-8.23 Smoothed Performance Metric Parameters

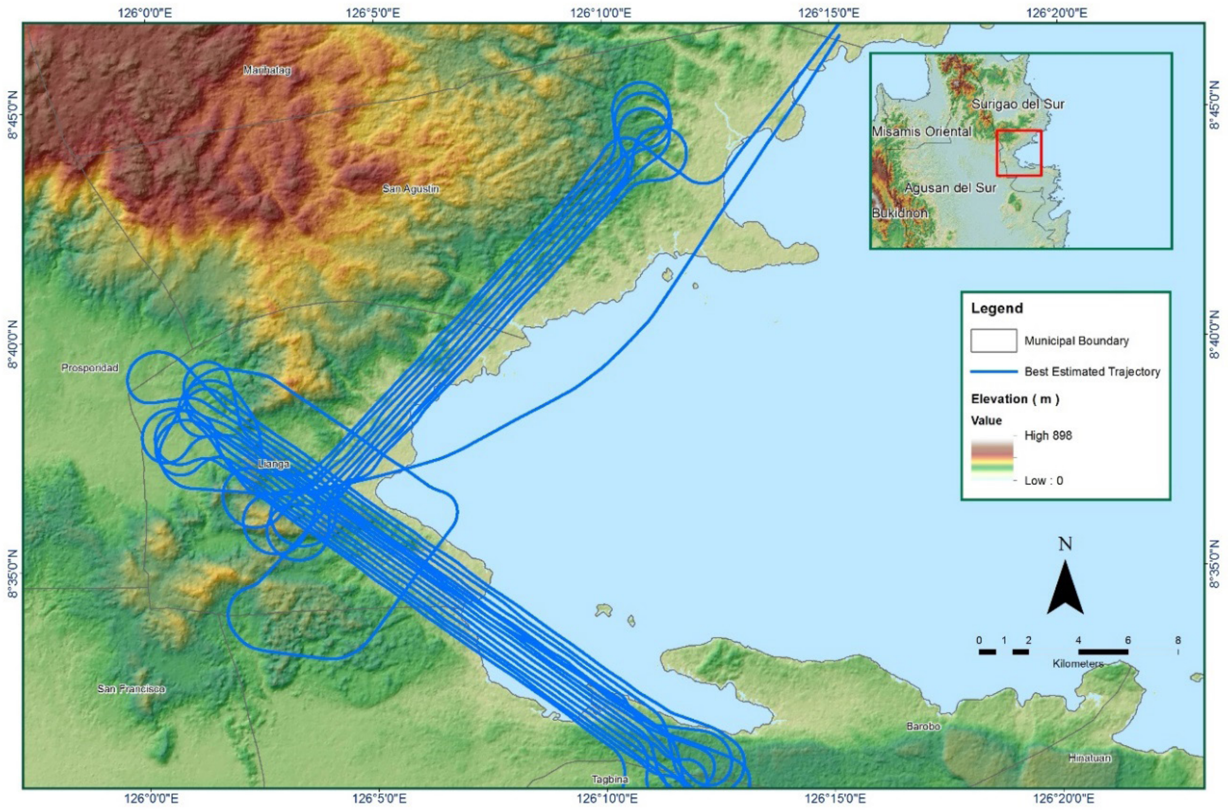


Figure A-8.24 Best Estimated Trajectory

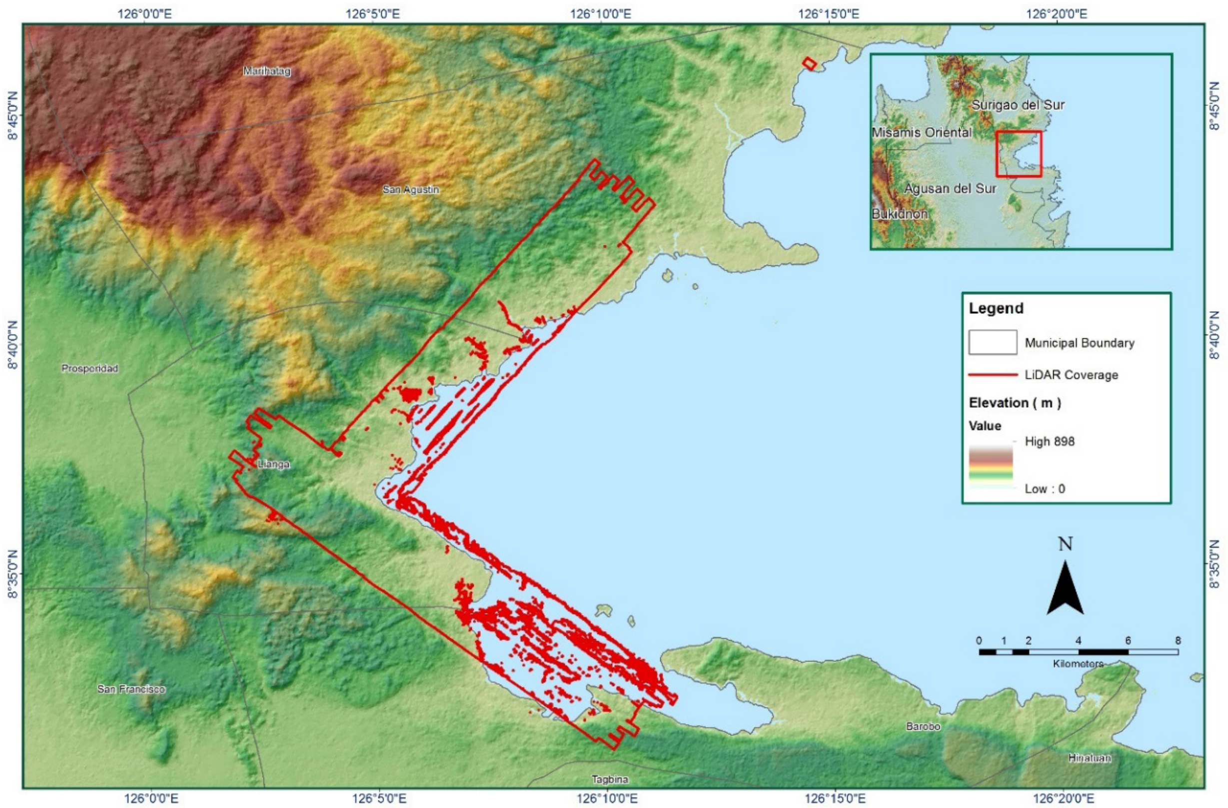


Figure A-8.25 Coverage of LiDAR data

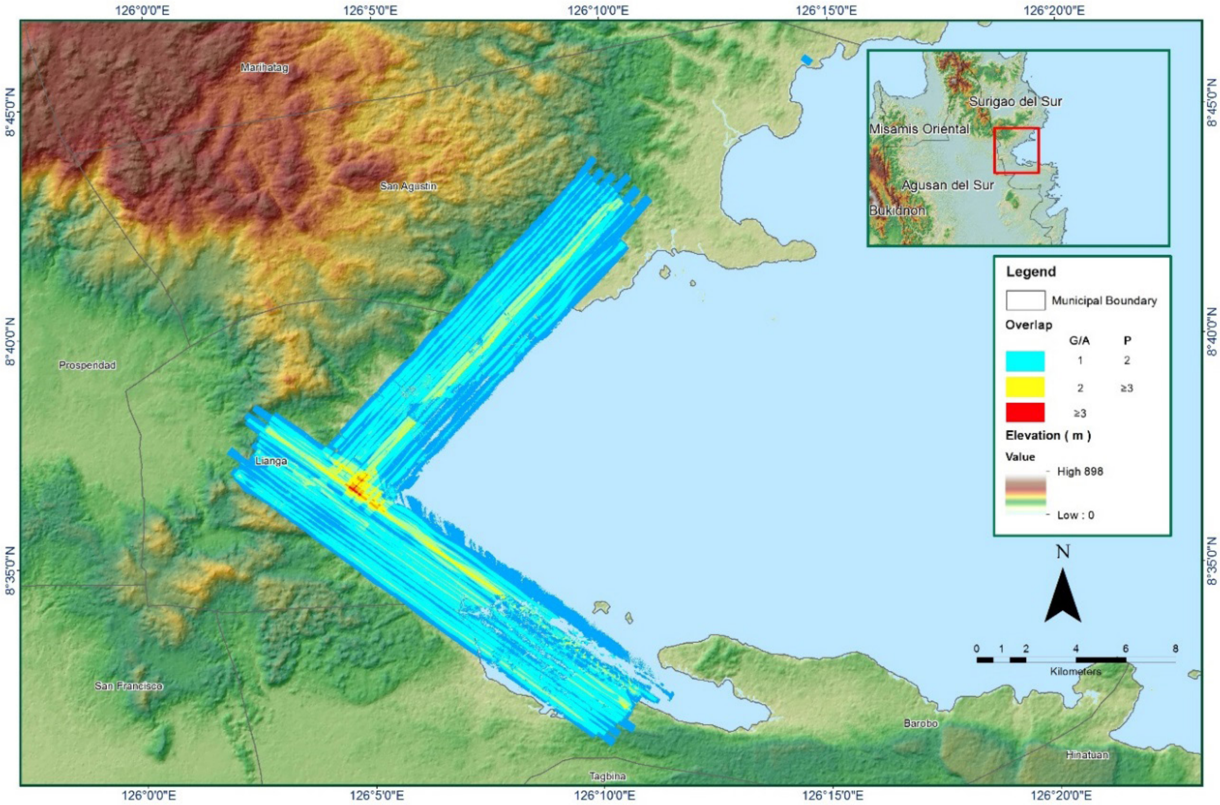


Figure A-8.26 Image of data overlap

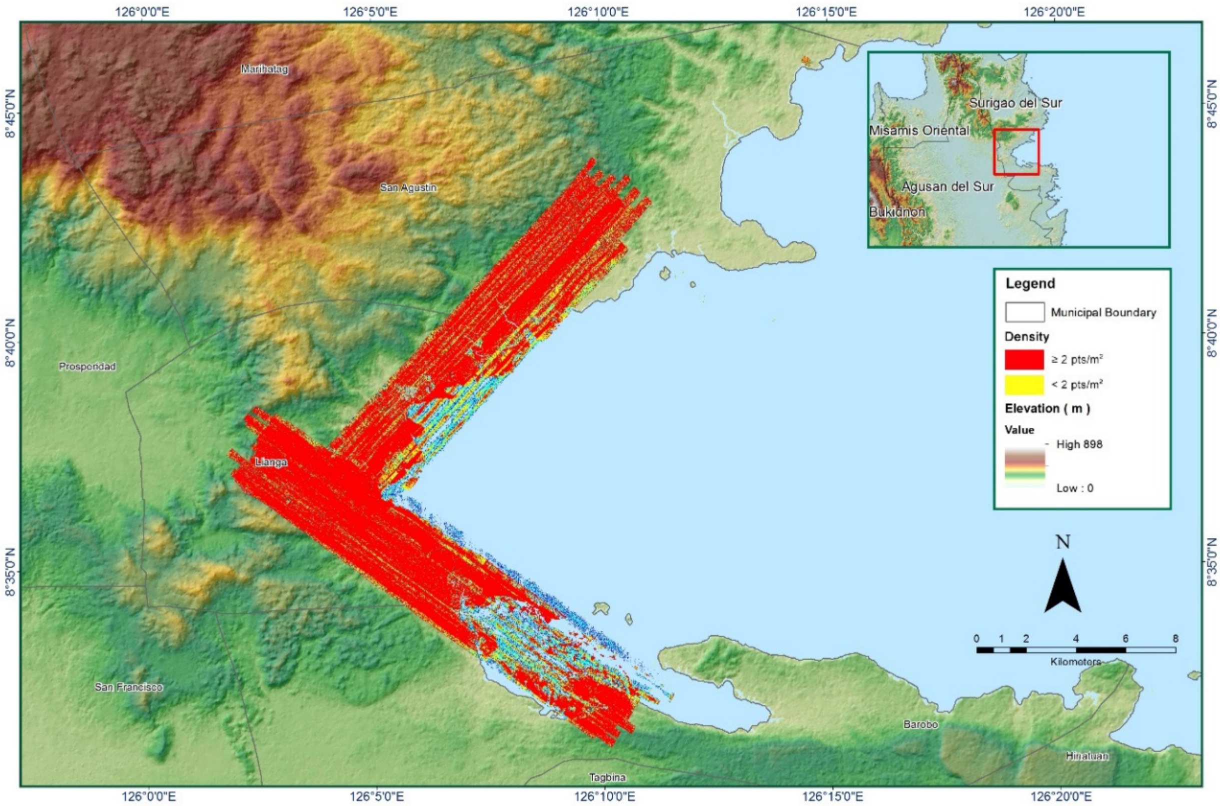


Figure A-8.27 Density map of merged LiDAR data

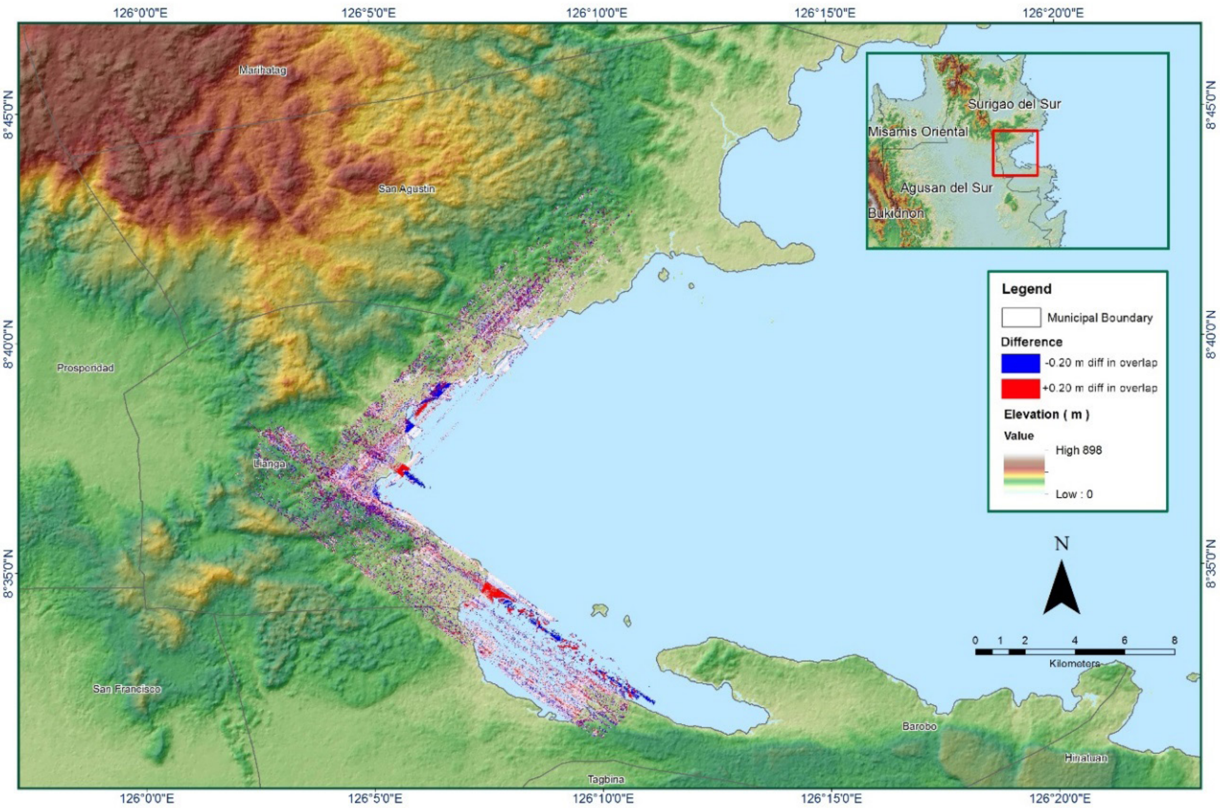


Figure A-8.28 Elevation difference between flight lines

Table A-8.5. Mission Summary Report for Mission Blk65E

Flight Area	Tandag
Mission Name	Blk65E
Inclusive Flights	23616P
Range data size	6.16 GB
Base data size	354 MB
POS	142 MB
Image	NA
Transfer date	January 3, 2017
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.50
RMSE for East Position (<4.0 cm)	3.96
RMSE for Down Position (<8.0 cm)	7.06
Boresight correction stdev (<0.001deg)	0.000429
IMU attitude correction stdev (<0.001deg)	0.000528
GPS position stdev (<0.01m)	0.0093
Minimum % overlap (>25)	3.45
Ave point cloud density per sq.m. (>2.0)	2.14
Elevation difference between strips (<0.20 m)	YES
Number of 1km x 1km blocks	60
Maximum Height	230.72 m
Minimum Height	64.93 m
Classification (# of points)	
Ground	22,379,198
Low vegetation	16,075,670
Medium vegetation	21,650,971
High vegetation	61,848,018
Building	1,405,453
Ortophoto	No
Processed by	

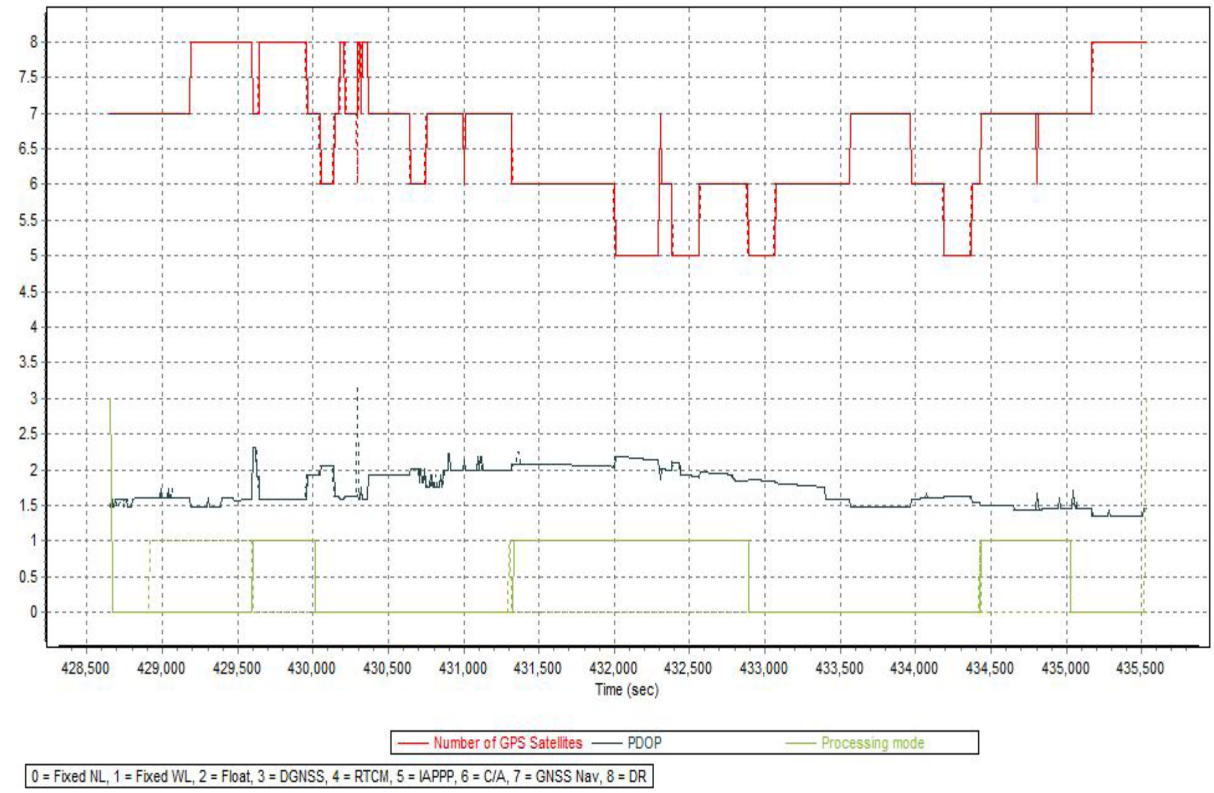


Figure A-8.29. Solution Status

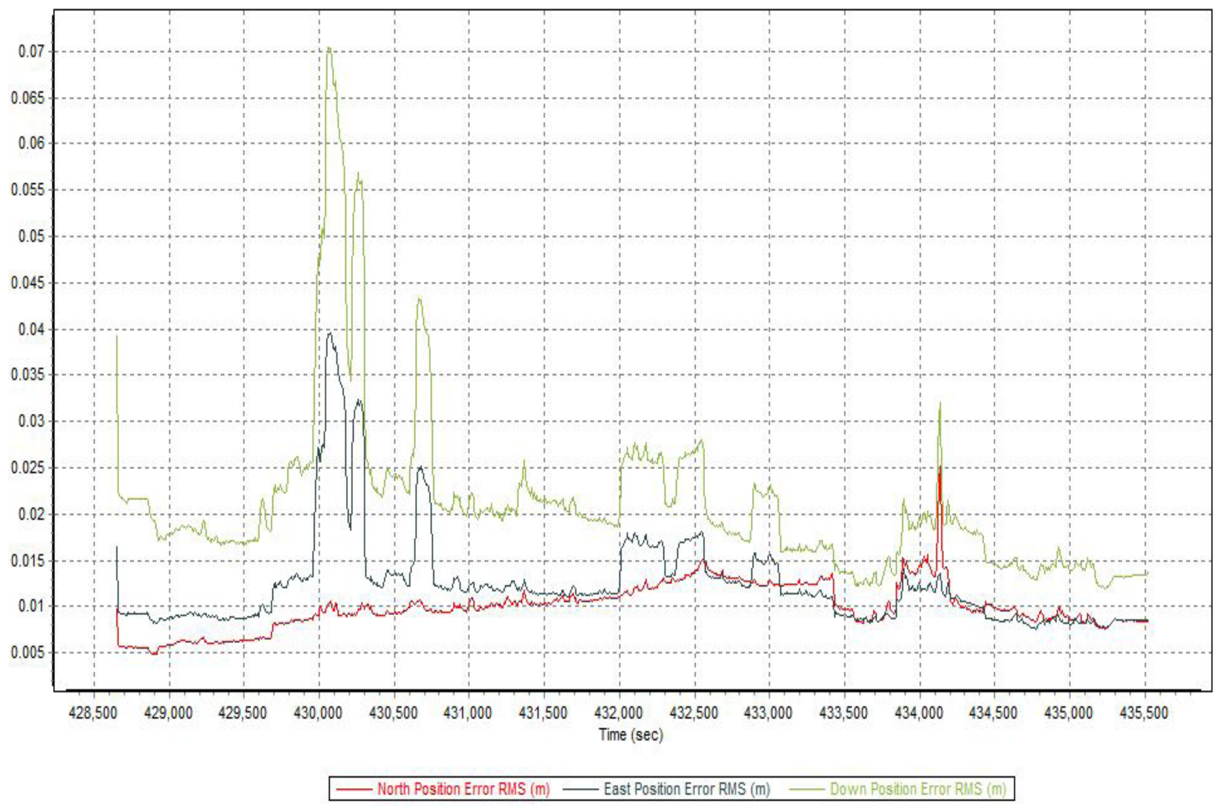


Figure A-8.30. Smoothed Performance Metric Parameters

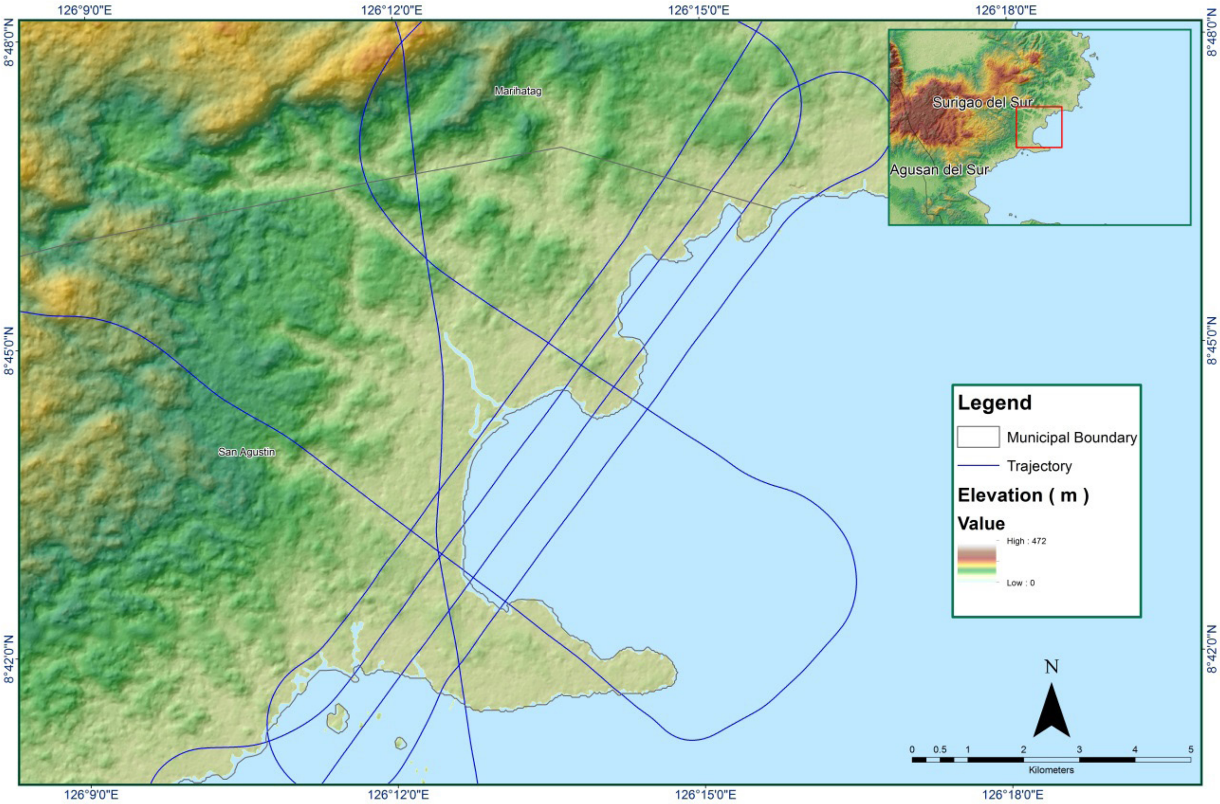


Figure A-8.31 Best Estimated Trajectory

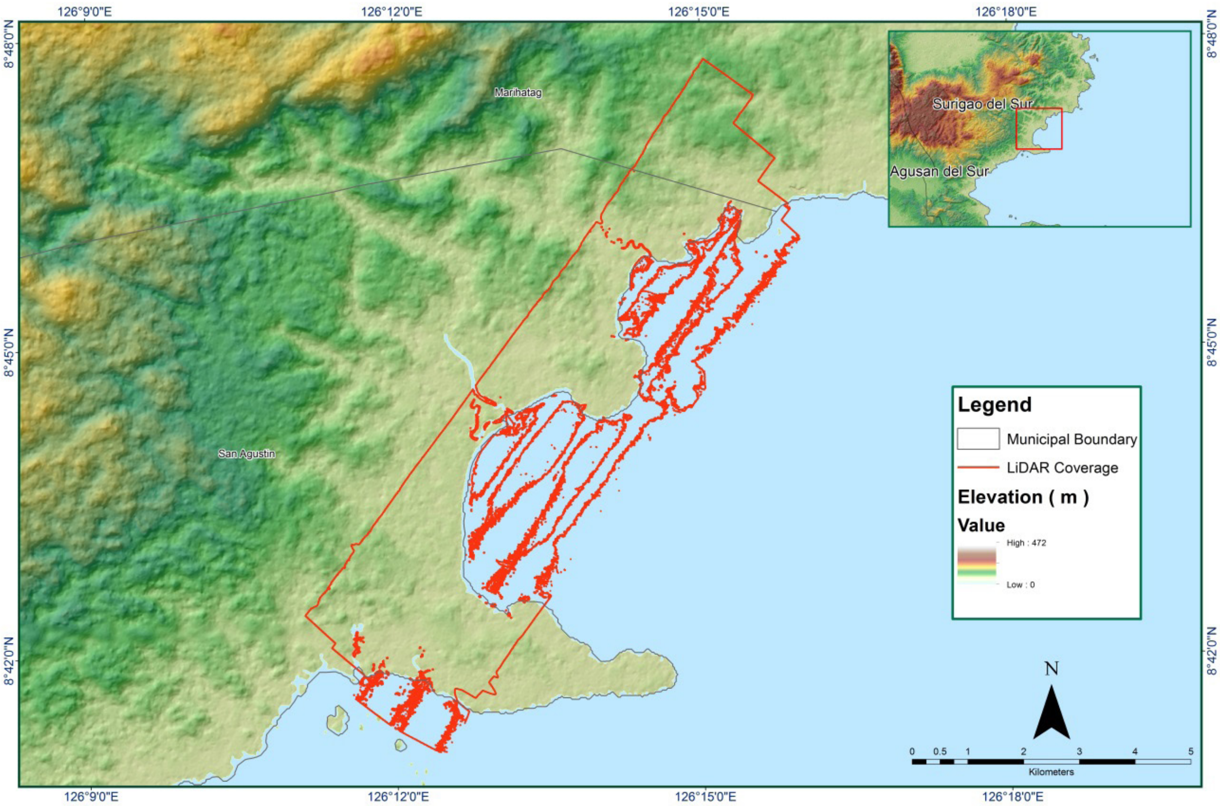


Figure A-8.32 Coverage of LiDAR data

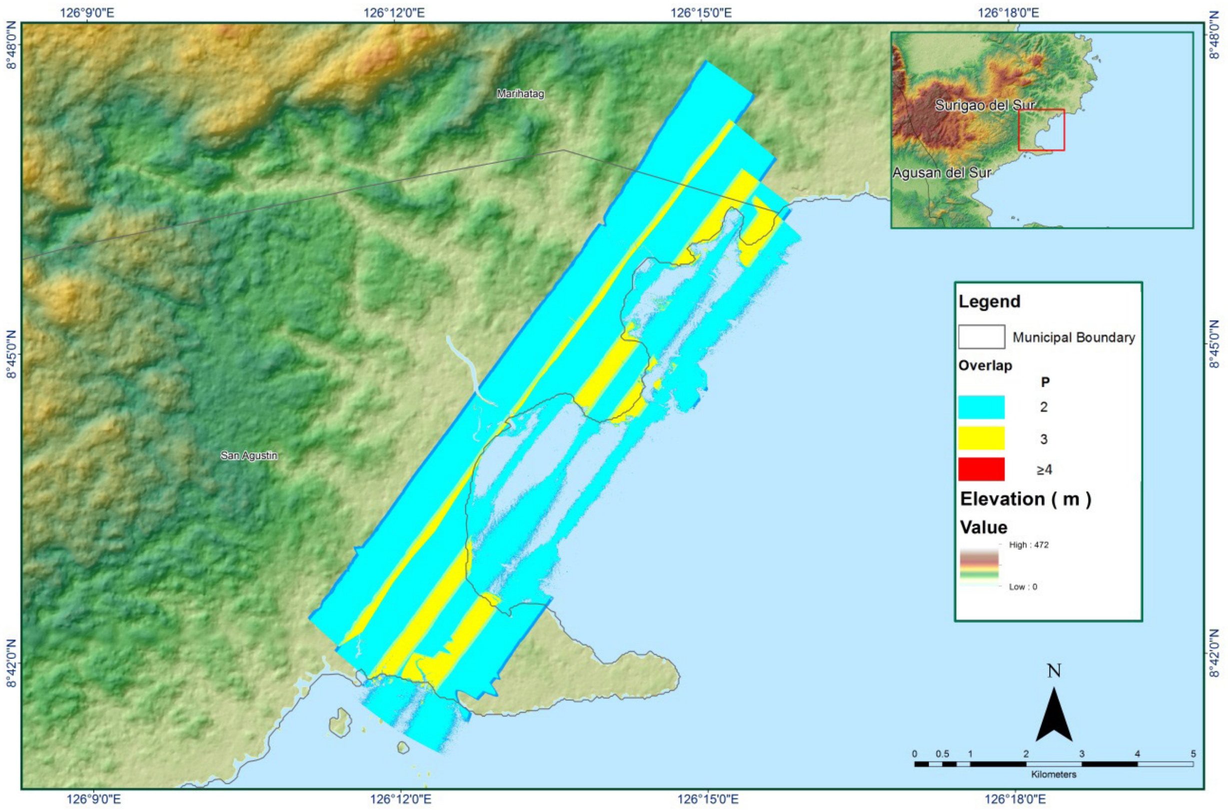


Figure A-8.33 Image of data overlap

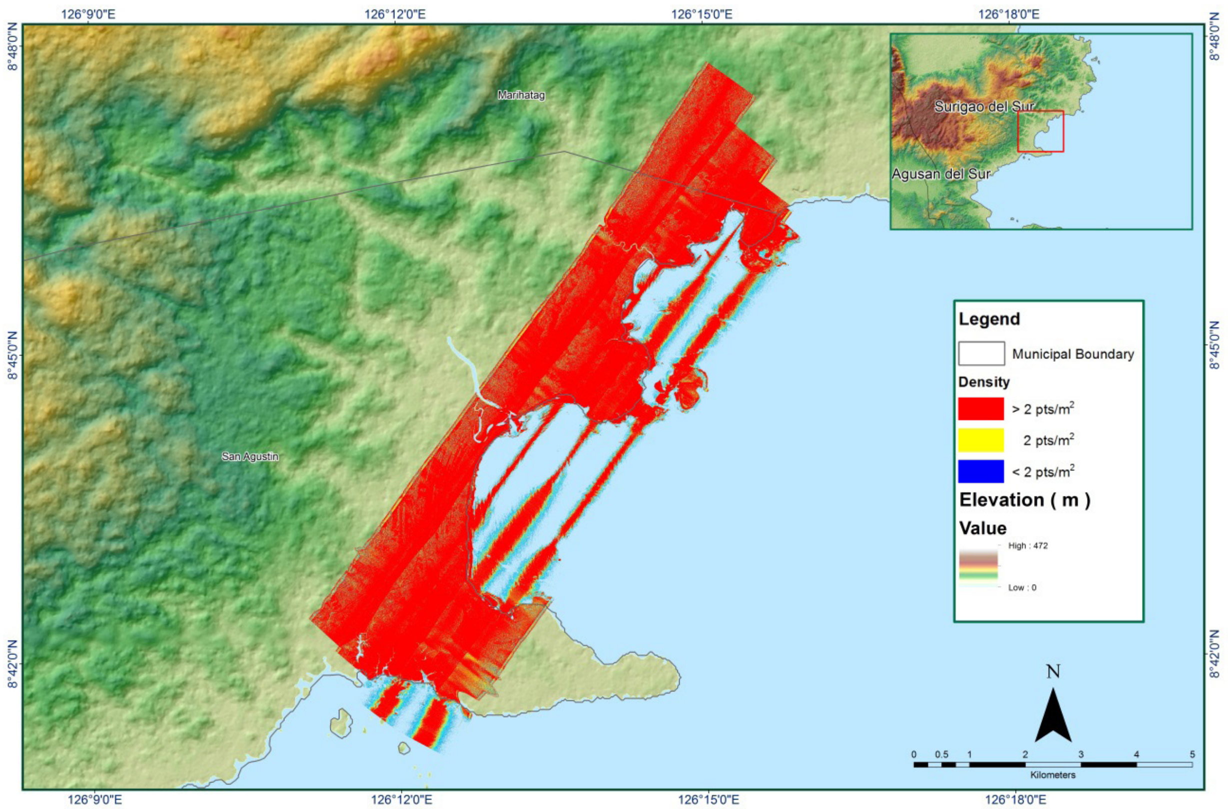


Figure A-8.34 Density Map of merged LiDAR data

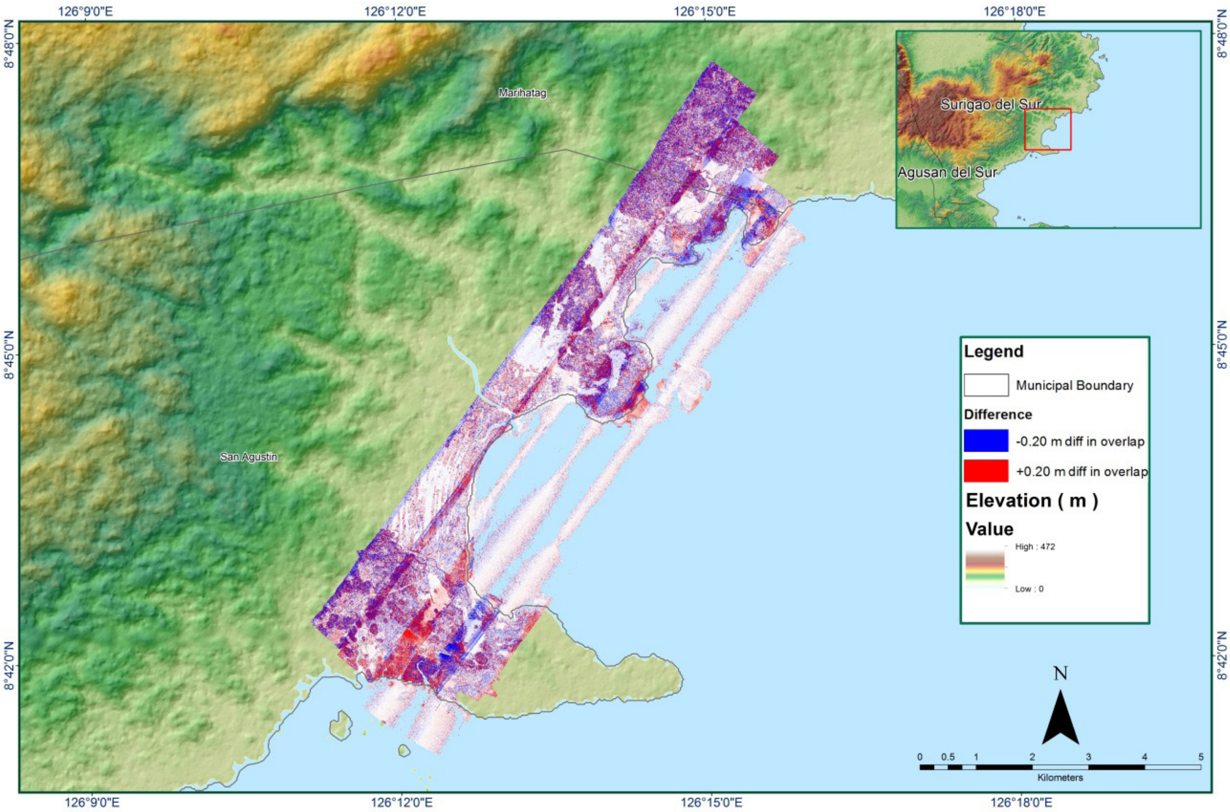


Figure A-8.35 Elevation Difference Between flight lines

Table A-8.6. Mission Summary Report for Mission Blk65F

Flight Area	Tandag
Mission Name	Blk65F
Inclusive Flights	23620P
Range data size	15.2 GB
Base data size	315 MB
POS	202 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)	1.80
RMSE for East Position (<4.0 cm)	1.95
RMSE for Down Position (<8.0 cm)	3.27
Boresight correction stdev (<0.001deg)	0.001319
IMU attitude correction stdev (<0.001deg)	0.001098
GPS position stdev (<0.01m)	0.0130
Minimum % overlap (>25)	0.55
Ave point cloud density per sq.m. (>2.0)	1.82
Elevation difference between strips (<0.20 m)	YES
Number of 1km x 1km blocks	38
Maximum Height	152.61 m
Minimum Height	66.5 m
Classification (# of points)	
Ground	12,528,426
Low vegetation	11,331,749
Medium vegetation	9,431,920
High vegetation	20,774,167
Building	587,718
Ortophoto	No
Processed by	

Figure A-8.36. Solution Status

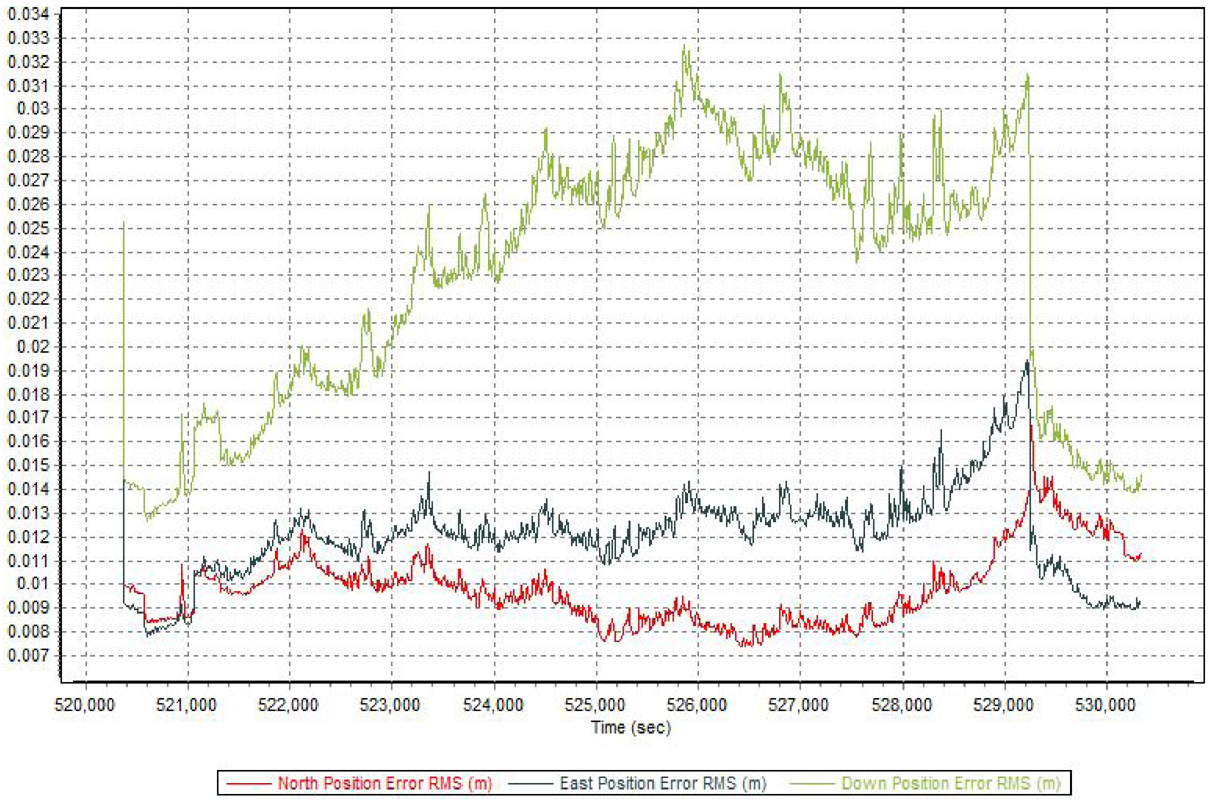


Figure A-8.37. Smoothed Performance Metric Parameters

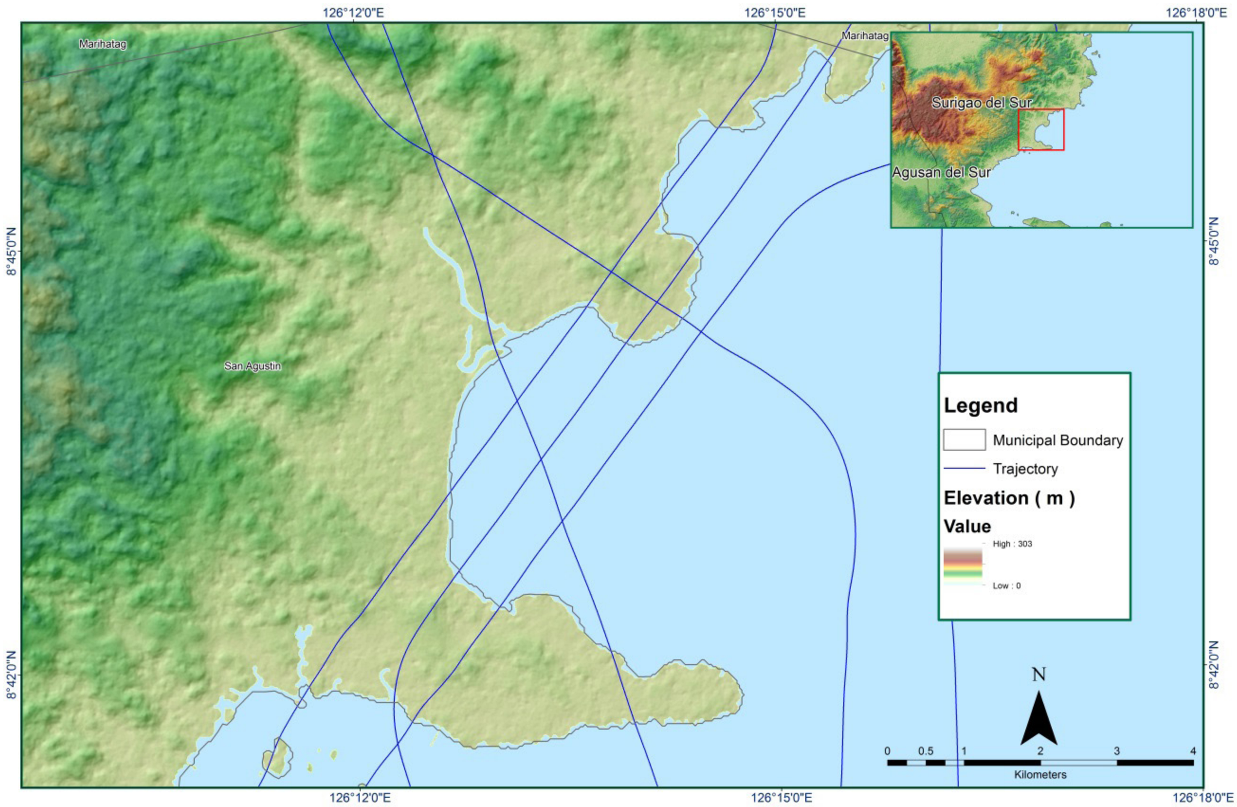


Figure A-8.38 Best Estimated Trajectory

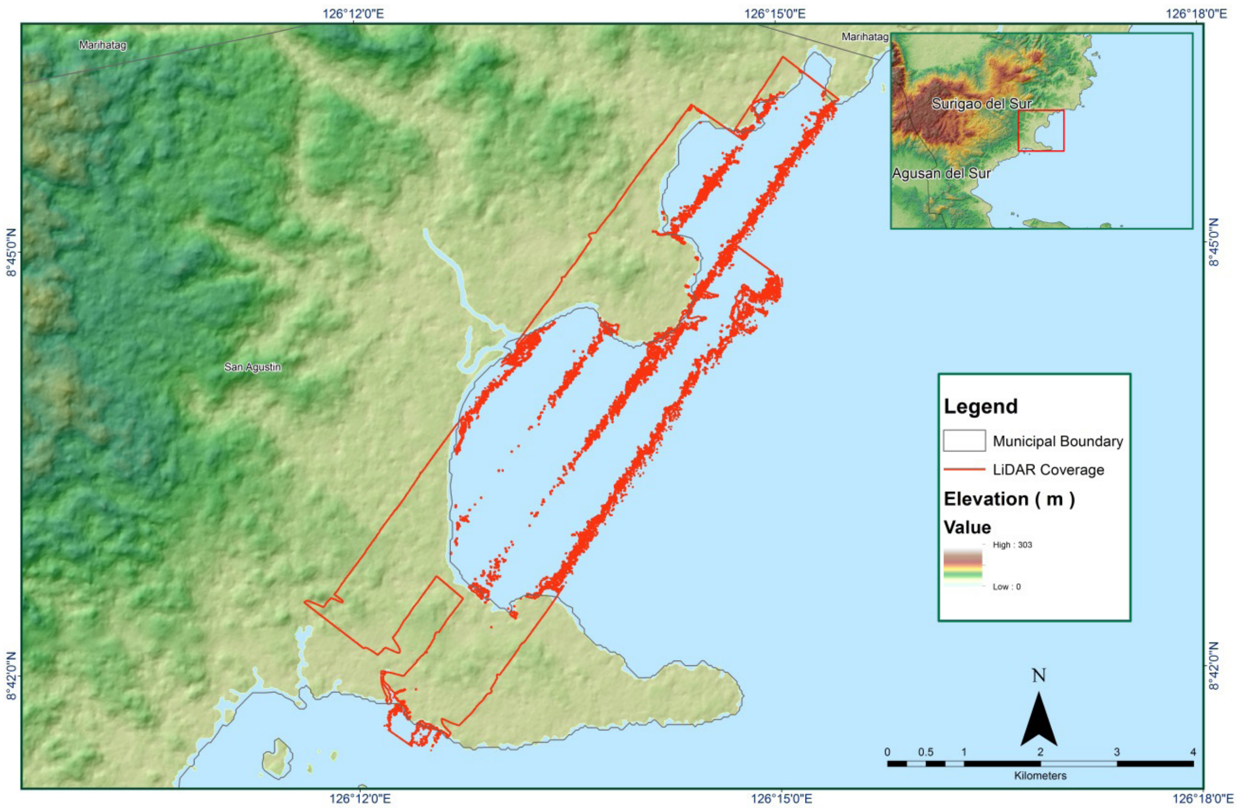


Figure A-8.39 Coverage of LiDAR data

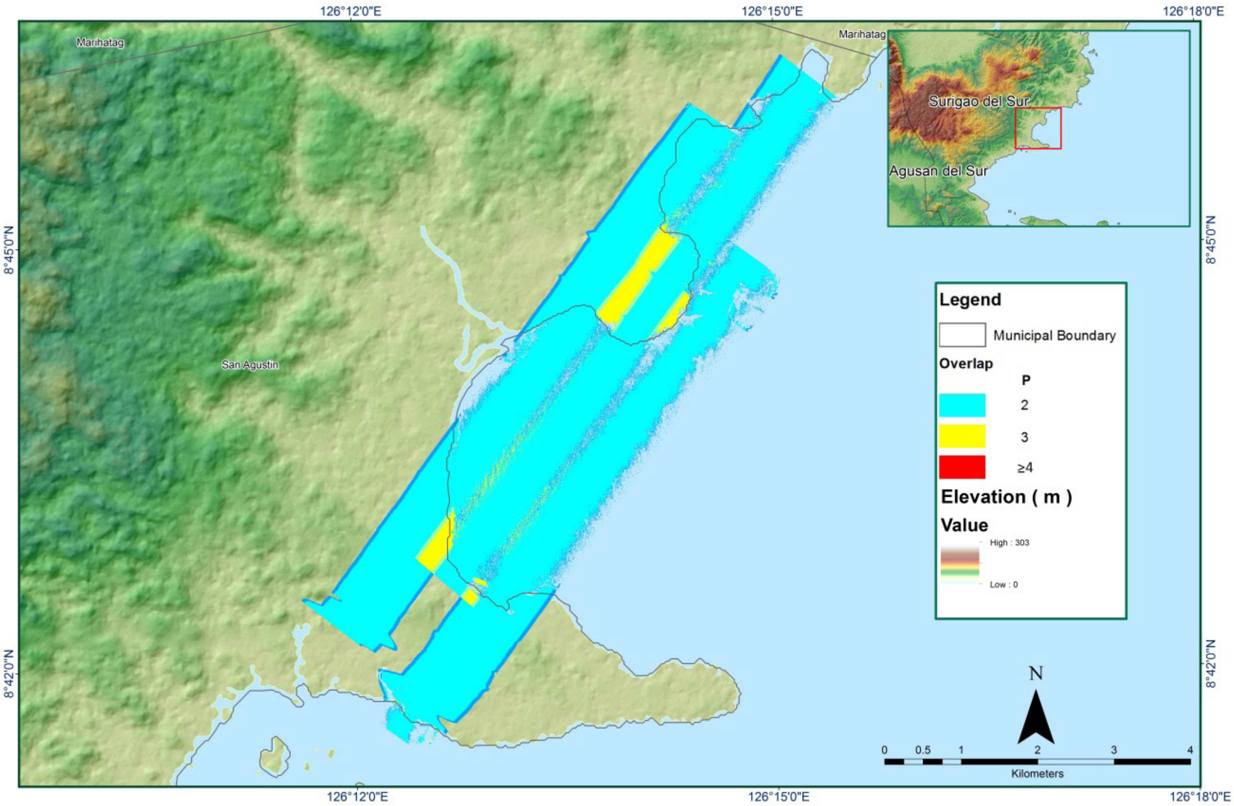


Figure A-8.40 Image of data overlap

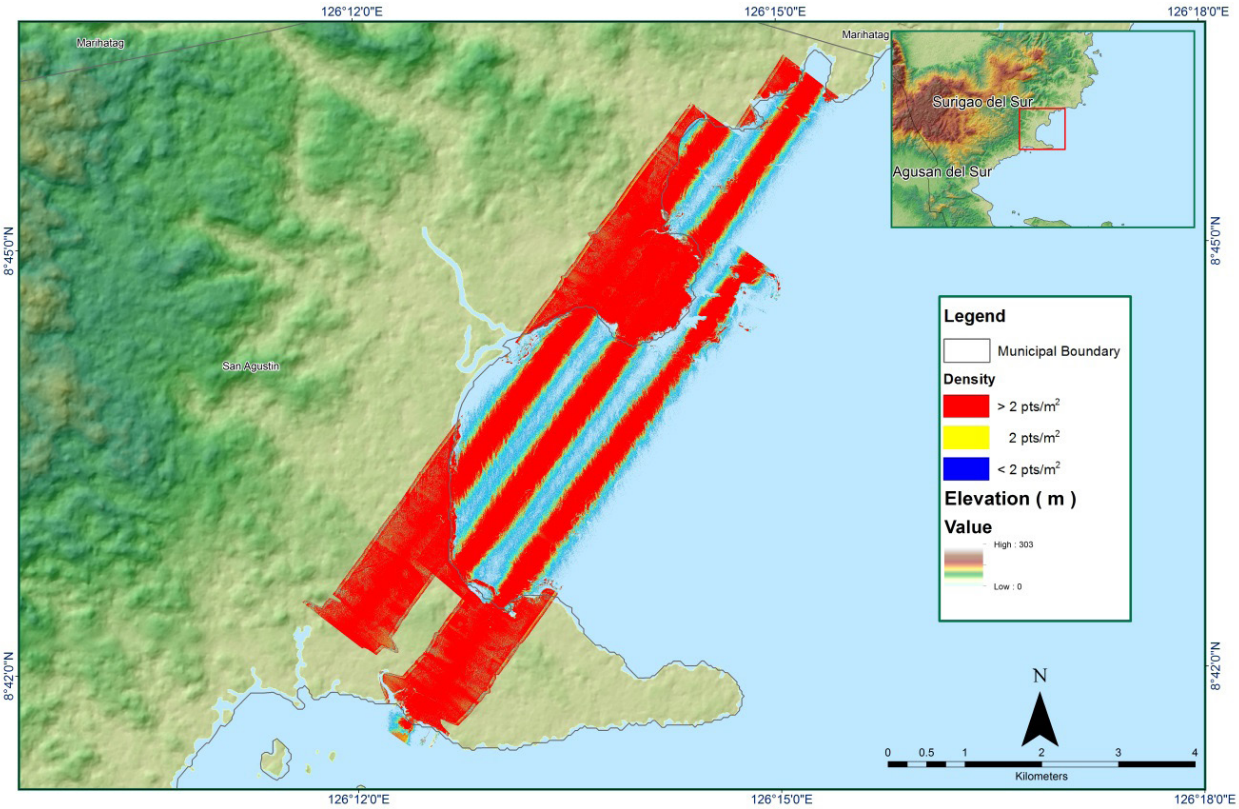


Figure A-8.41 Density Map of merged LiDAR data

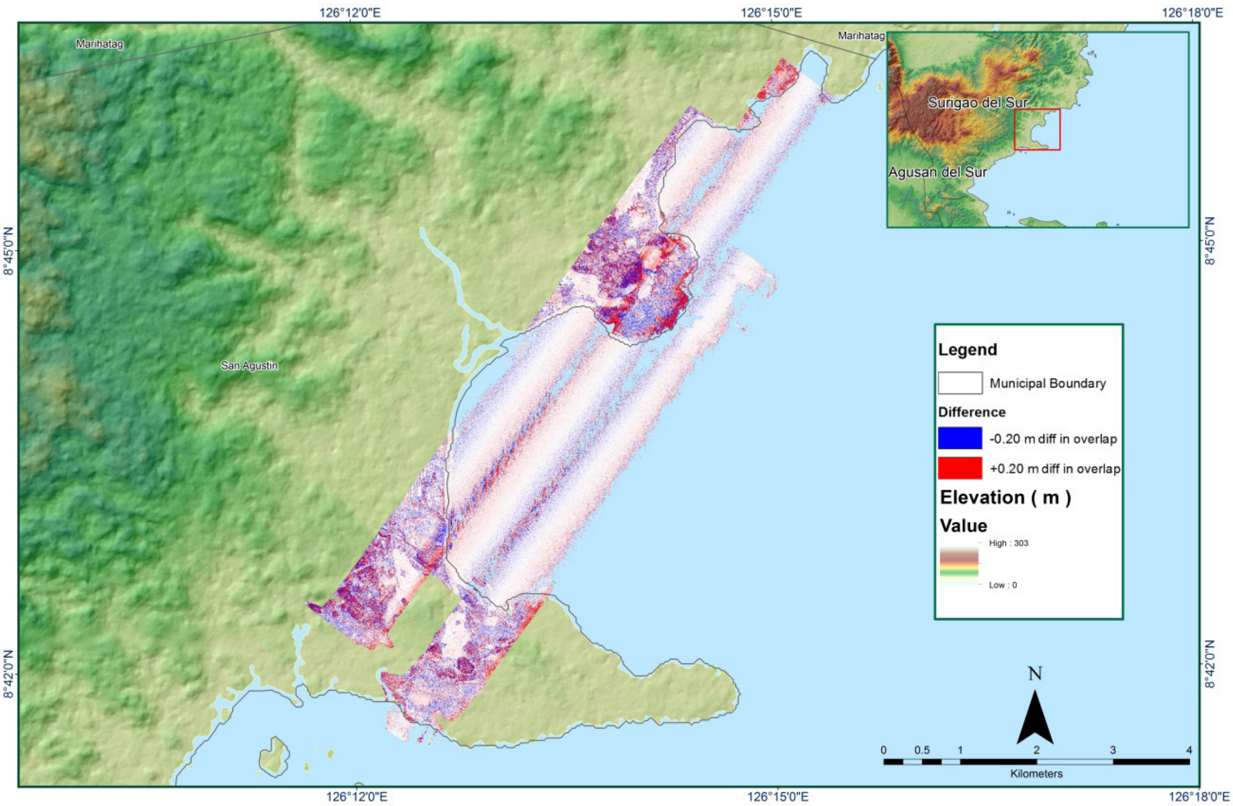


Figure A-8.42 Elevation Difference Between flight lines

Table A-8.7. Mission Summary Report for Mission Blk65F_additional

Flight Area	Tandag
Mission Name	Blk65F_additional
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)	1.59
RMSE for East Position (<4.0 cm)	1.59
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)	0.0220
Minimum % overlap (>25)	NA
Ave point cloud density per sq.m. (>2.0)	2.68
Elevation difference between strips (<0.20 m)	YES
Number of 1km x 1km blocks	24
Maximum Height	184.49 m
Minimum Height	57.69 m
Classification (# of points)	
Ground	3,462,027
Low vegetation	1,390,696
Medium vegetation	6,281,842
High vegetation	5,002,447
Building	99,942
Ortophoto	No
Processed by	

Figure A-8.43. Solution Status

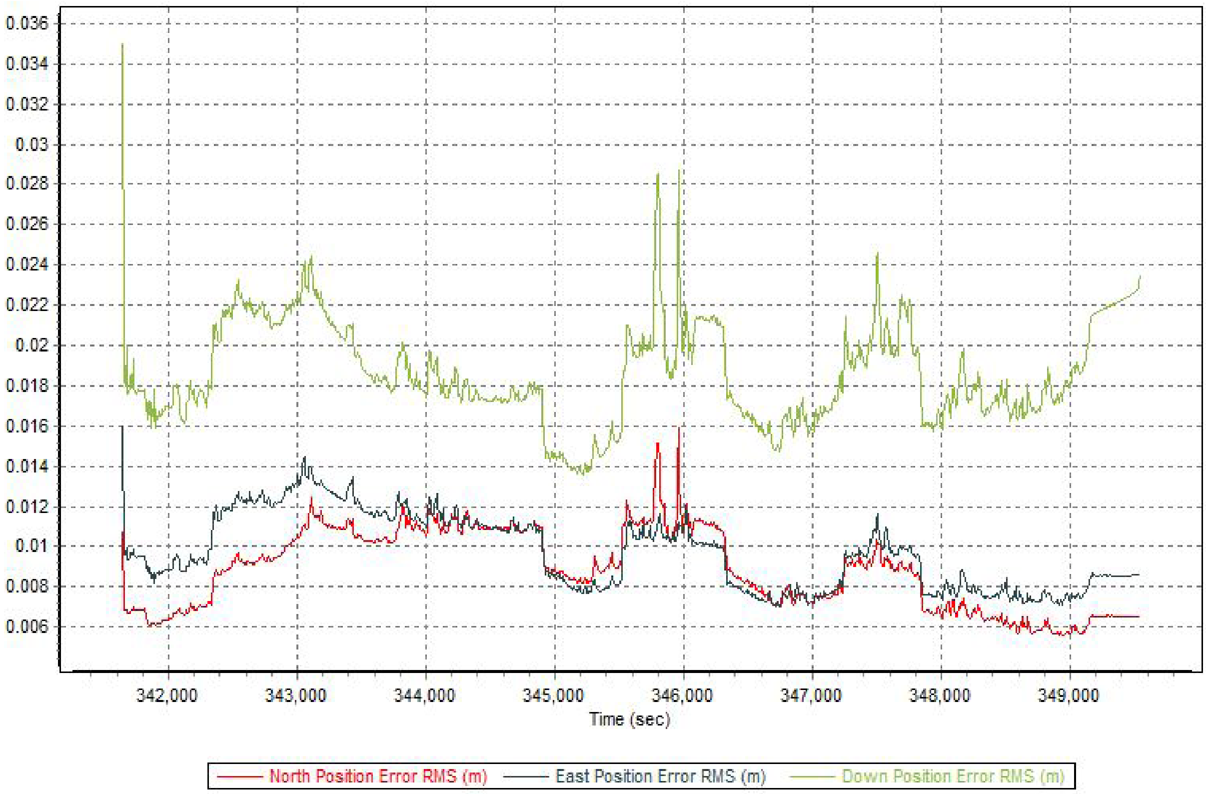


Figure A-8.44. Smoothed Performance Metric Parameters

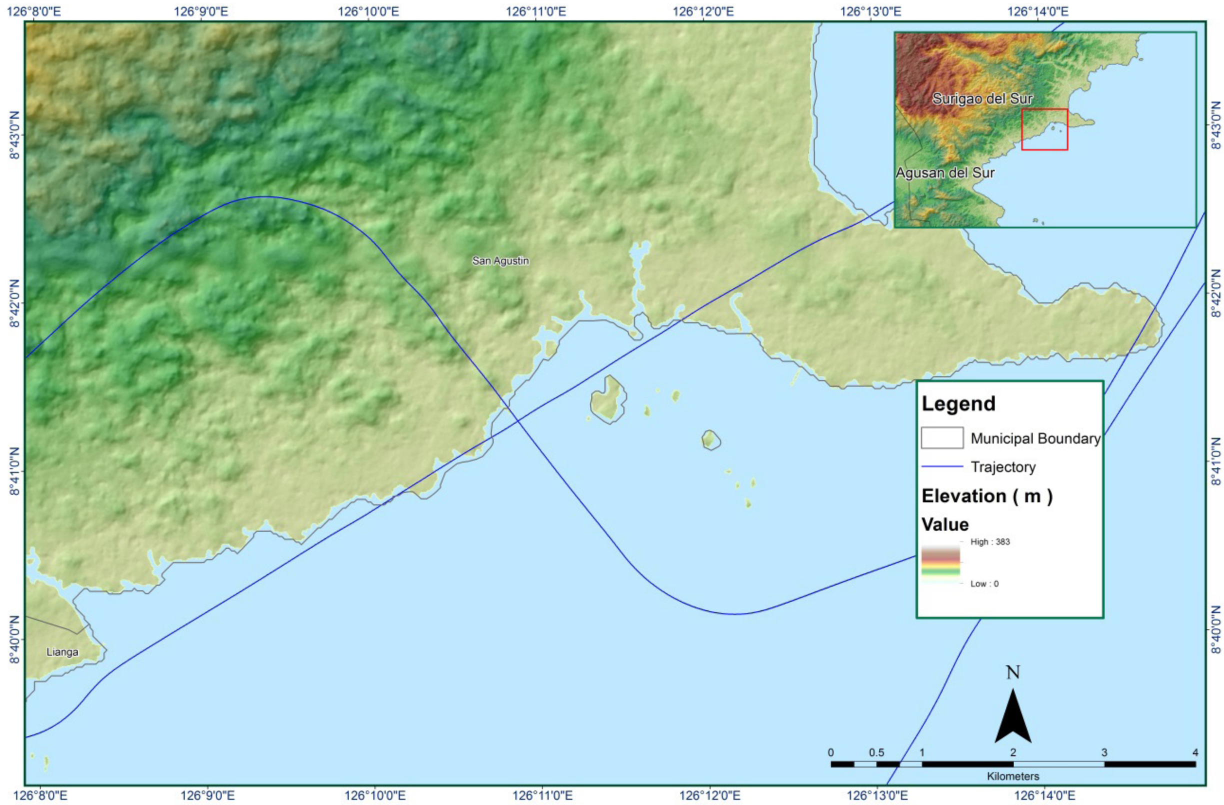


Figure A-8.45 Best Estimated Trajectory

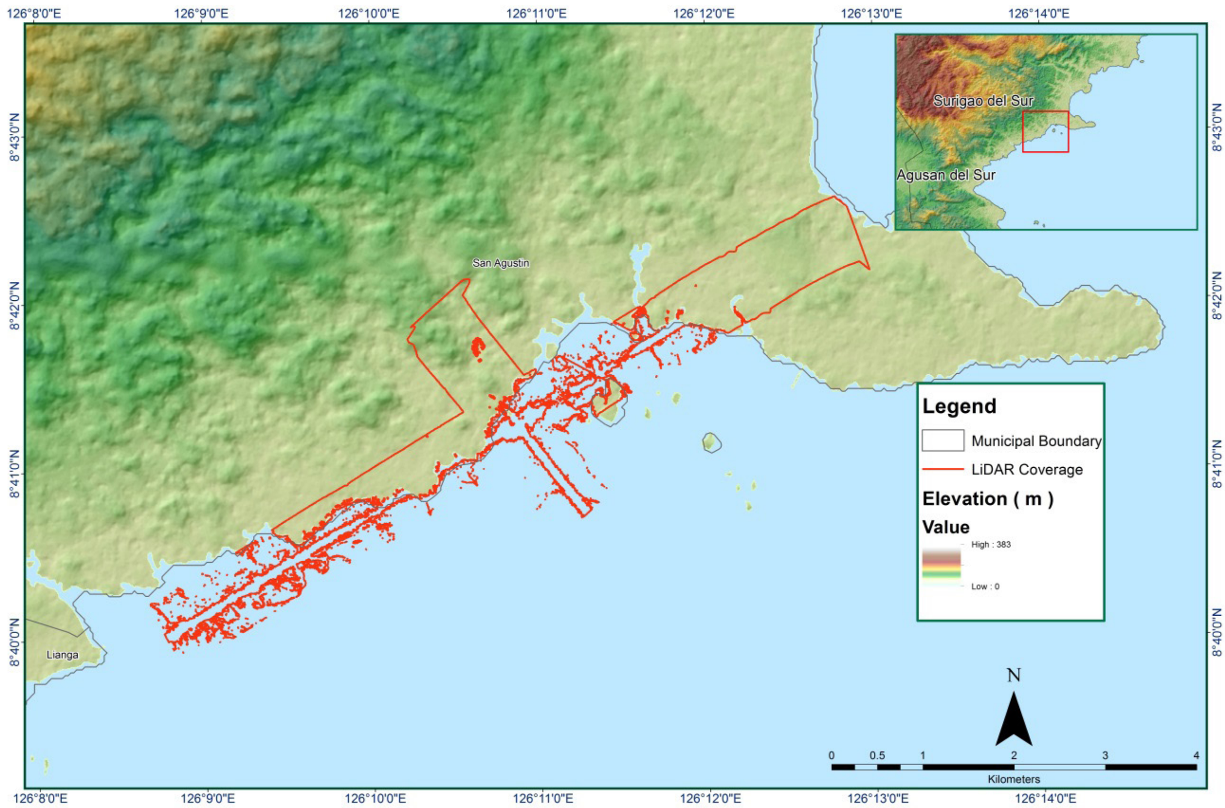


Figure A-8.46 Coverage of LiDAR data

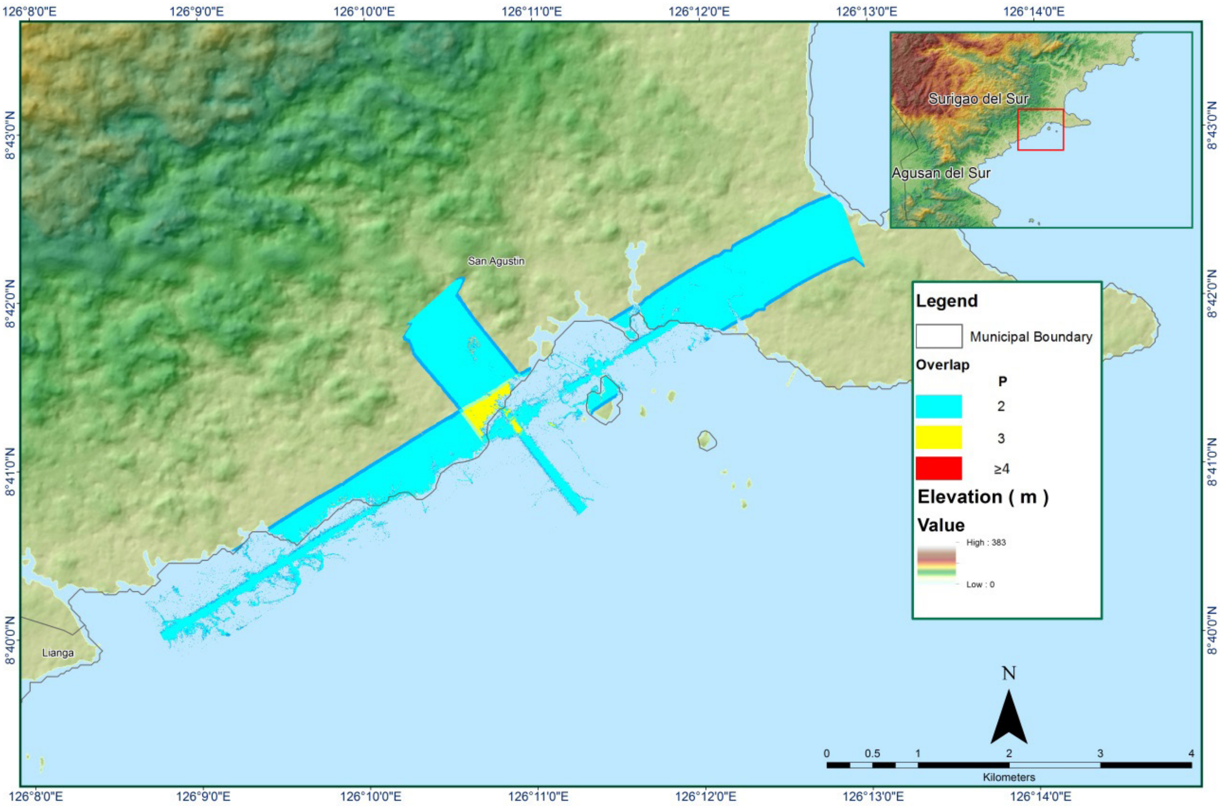


Figure A-8.47 Image of data overlap

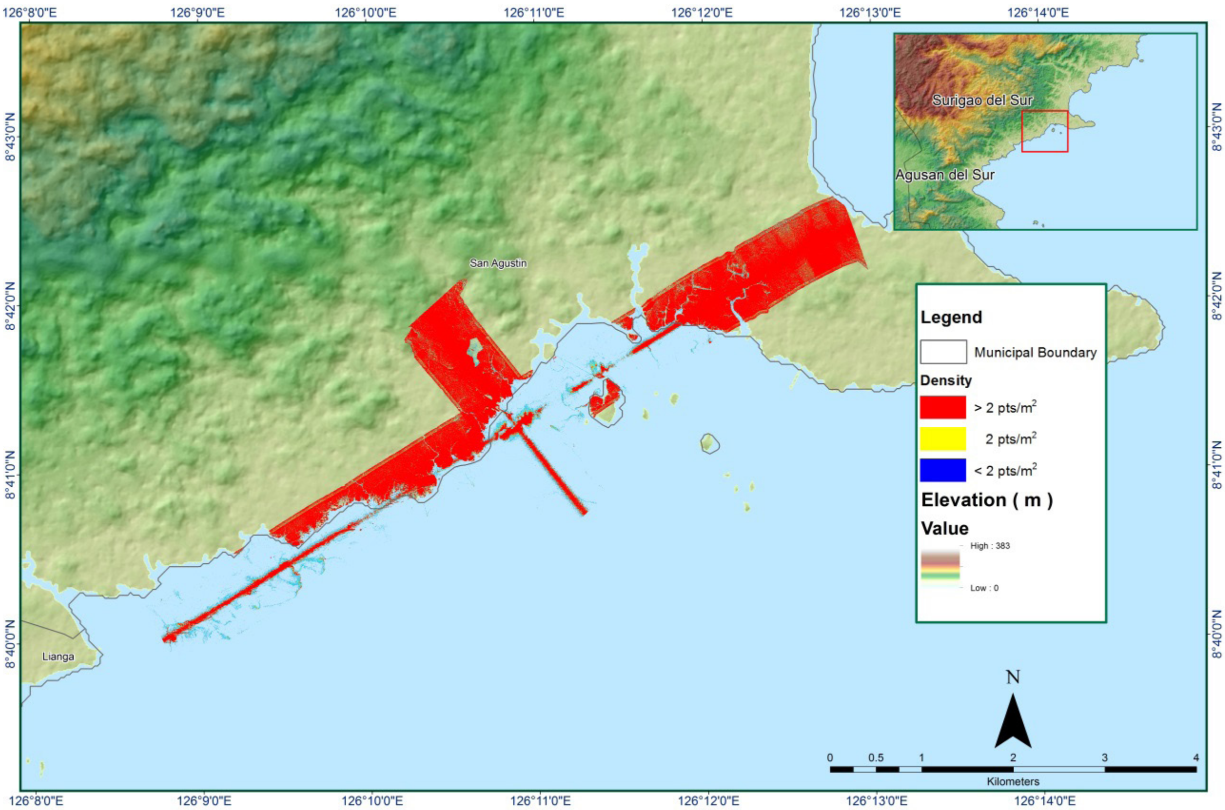


Figure A-8.48 Density Map of merged LiDAR data

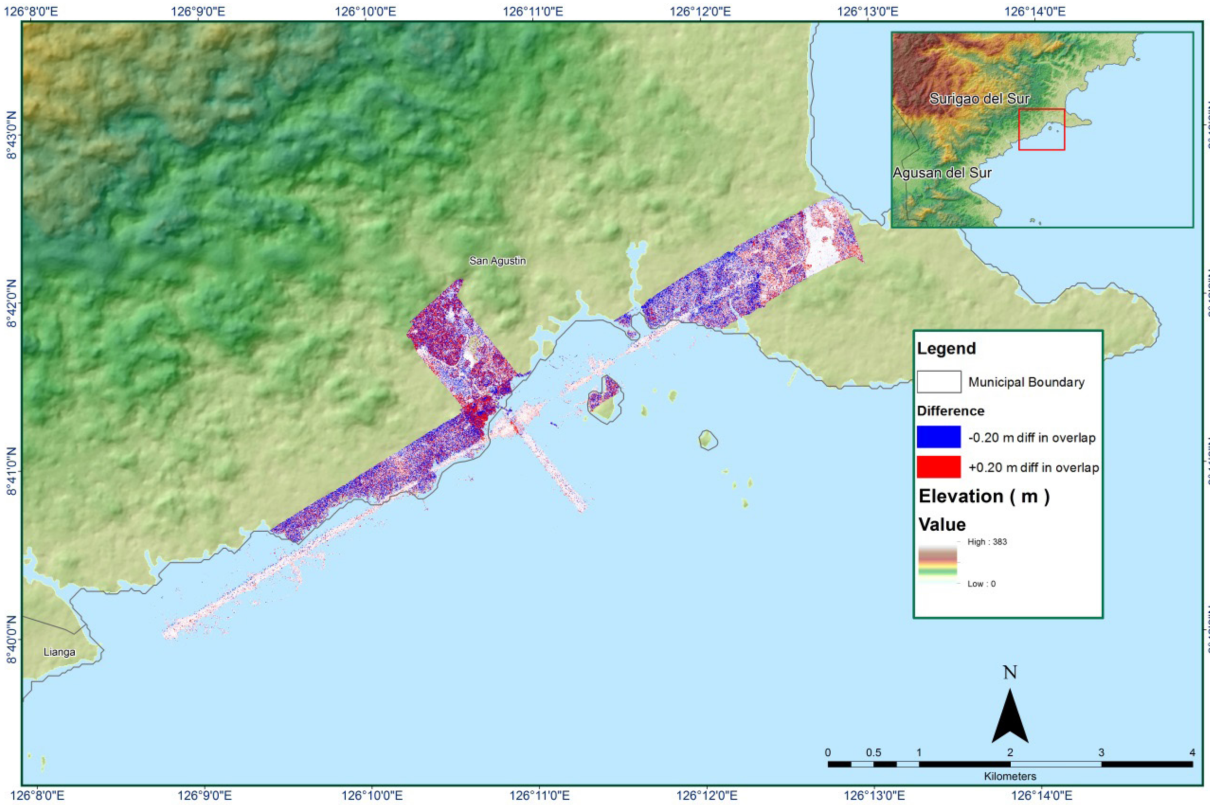


Figure A-8.49 Elevation Difference Between flight lines

Annex 9. Hubo-Otieza Model Basin Parameters

Table A-9.1. Hubo-Otieza 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 (m3/s)	Recession Constant	Threshold Type	Ratio to Peak
W760	5.65	35.56	0.00	0.7340	4.6486	Discharge	0.0016	0.8	Ratio to Peak	0.5
W770	5.76	45.75	0.00	0.6336	4.0141	Discharge	0.0836	0.8	Ratio to Peak	0.5
W580	8.47	38.85	0.00	1.3212	5.7644	Discharge	0.1082	0.8	Ratio to Peak	0.5
W640	5.76	58.29	0.00	0.3322	3.0055	Discharge	0.1981	0.8	Ratio to Peak	0.5
W670	5.76	35.28	0.00	0.5113	3.2016	Discharge	0.1791	0.8	Ratio to Peak	0.5
W660	5.76	94.55	0.00	0.2836	2.7137	Discharge	0.1127	0.8	Ratio to Peak	0.5
W570	2.67	77.79	0.00	0.4902	3.0579	Discharge	0.0012	0.8	Ratio to Peak	0.5
W630	3.92	58.29	0.00	0.2986	3.9658	Discharge	0.1316	0.8	Ratio to Peak	0.5
W560	8.47	95.64	0.00	0.8184	3.8907	Discharge	0.0117	0.8	Ratio to Peak	0.5
W620	5.76	95.64	0.00	0.3359	4.5140	Discharge	0.3133	0.8	Ratio to Peak	0.5
W680	3.93	35.26	0.00	0.8372	5.3500	Discharge	0.4152	0.8	Ratio to Peak	0.5
W610	5.76	36.28	0.00	0.2753	2.4348	Discharge	0.4573	0.8	Ratio to Peak	0.5
W650	5.77	95.64	0.00	0.3214	4.3009	Discharge	0.0598	0.8	Ratio to Peak	0.5
W730	2.70	94.28	0.00	0.3647	3.3147	Discharge	0.0197	0.8	Ratio to Peak	0.5
W1020	8.47	35.28	0.00	1.3132	5.7040	Discharge	0.1175	0.8	Ratio to Peak	0.5
W1100	3.92	94.46	0.00	0.4429	2.7574	Discharge	0.0037	0.8	Ratio to Peak	0.5
W960	5.76	95.64	0.00	1.5238	4.4536	Discharge	0.1181	0.8	Ratio to Peak	0.5
W940	8.47	78.40	0.00	1.7236	3.3889	Discharge	0.1892	0.8	Ratio to Peak	0.5
W990	5.84	54.88	0.00	1.3340	5.7950	Discharge	0.3129	0.8	Ratio to Peak	0.5
W950	8.26	49.65	0.00	0.8963	1.7443	Discharge	0.1468	0.8	Ratio to Peak	0.5
W1060	5.76	36.28	0.00	0.3464	3.1454	Discharge	0.4137	0.8	Ratio to Peak	0.5
W1050	3.94	58.38	0.00	0.3590	3.2618	Discharge	0.0012	0.8	Ratio to Peak	0.5

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 (m3/s)	Recession Constant	Threshold Type	Ratio to Peak
W1010	5.76	41.95	0.00	0.3096	2.7731	Discharge	0.1657	0.8	Ratio to Peak	0.5
W1000	5.76	94.21	0.00	0.3461	2.1095	Discharge	0.1920	0.8	Ratio to Peak	0.5
W740	5.78	92.60	0.00	2.7846	5.4939	Discharge	0.3885	0.8	Ratio to Peak	0.5
W720	5.84	95.64	0.00	0.1995	2.5812	Discharge	0.0774	0.8	Ratio to Peak	0.5
W700	5.85	92.64	0.00	0.3926	5.2689	Discharge	0.1745	0.8	Ratio to Peak	0.5
W690	3.92	55.89	0.00	0.4713	4.7438	Discharge	0.3505	0.8	Ratio to Peak	0.5
W800	5.77	95.64	0.00	0.3724	5.7114	Discharge	0.0765	0.8	Ratio to Peak	0.5
W820	5.84	95.64	0.00	0.2645	2.1829	Discharge	0.2224	0.8	Ratio to Peak	0.5
W900	8.47	95.64	0.00	0.6503	6.9514	Discharge	0.1569	0.8	Ratio to Peak	0.5
W910	8.47	71.69	0.00	0.8164	3.4913	Discharge	0.0859	0.8	Ratio to Peak	0.5
W880	3.93	94.24	0.00	0.2435	2.3969	Discharge	0.1277	0.8	Ratio to Peak	0.5
W870	2.70	35.20	0.00	0.4092	3.8887	Discharge	0.3073	0.8	Ratio to Peak	0.5
W840	5.89	95.64	0.00	0.3832	3.5523	Discharge	0.1157	0.8	Ratio to Peak	0.5
W830	6.39	95.30	0.00	0.1995	1.5612	Discharge	0.1847	0.8	Ratio to Peak	0.5
W1080	3.92	95.64	0.00	0.8150	5.1598	Discharge	0.1916	0.8	Ratio to Peak	0.5
W1030	4.03	94.20	0.00	0.3214	2.8440	Discharge	0.0749	0.8	Ratio to Peak	0.5
W890	5.76	44.93	0.00	0.2969	3.9445	Discharge	0.1761	0.8	Ratio to Peak	0.5
W920	8.47	52.63	0.00	0.2556	3.6087	Discharge	0.0330	0.8	Ratio to Peak	0.5
W860	5.76	49.82	0.00	0.2849	1.8357	Discharge	0.2822	0.8	Ratio to Peak	0.5
W850	5.89	49.33	0.00	0.2012	2.5812	Discharge	0.1575	0.8	Ratio to Peak	0.5
W590	5.77	94.28	0.00	0.2759	3.2882	Discharge	0.1176	0.8	Ratio to Peak	0.5
W810	5.91	94.28	0.00	0.2919	4.1028	Discharge	0.2231	0.8	Ratio to Peak	0.5
W600	6.05	95.47	0.00	0.2917	4.4397	Discharge	0.2073	0.8	Ratio to Peak	0.5
W750	6.16	47.96	0.00	0.2012	1.7325	Discharge	0.2071	0.8	Ratio to Peak	0.5

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 (m3/s)	Recession Constant	Threshold Type	Ratio to Peak
W710	6.41	52.46	0.00	0.4074	3.8117	Discharge	0.1242	0.8	Ratio to Peak	0.5
W780	6.42	95.30	0.00	0.1995	1.1645	Discharge	0.0851	0.8	Ratio to Peak	0.5
W1580	6.05	95.47	0.00	0.2565	2.2067	Discharge	0.1903	0.8	Ratio to Peak	0.5
W1570	9.04	47.96	0.00	0.2259	2.5457	Discharge	0.4950	0.8	Ratio to Peak	0.5
W1520	5.96	94.20	0.00	0.3831	3.5508	Discharge	0.1168	0.8	Ratio to Peak	0.5
W1470	10.37	94.92	0.00	0.2773	2.0714	Discharge	0.1468	0.8	Ratio to Peak	0.5
W1420	10.54	94.92	0.00	0.2437	2.5400	Discharge	0.2894	0.8	Ratio to Peak	0.5
W1170	4.22	78.13	0.00	0.2870	2.4885	Discharge	0.0000	0.8	Ratio to Peak	0.5
W1630	6.02	72.62	0.00	0.4245	3.6815	Discharge	0.0000	0.8	Ratio to Peak	0.5
W1620	5.46	74.46	0.00	0.6298	5.4617	Discharge	0.0000	0.8	Ratio to Peak	0.5
W1220	3.78	79.05	0.00	0.4137	3.5877	Discharge	0.0000	0.8	Ratio to Peak	0.5
W1120	4.47	77.21	0.00	0.2870	2.4885	Discharge	0.0000	0.8	Ratio to Peak	0.5
W1380	4.18	78.13	0.00	0.2870	2.4885	Discharge	0.0000	0.8	Ratio to Peak	0.5
W970	6.03	72.62	0.00	0.5812	5.0400	Discharge	0.0000	0.8	Ratio to Peak	0.5
W930	6.16	72.62	0.00	0.5632	4.8839	Discharge	0.0000	0.8	Ratio to Peak	0.5
W1280	5.74	73.54	0.00	0.6862	5.9504	Discharge	0.0000	0.8	Ratio to Peak	0.5
W1330	4.03	78.13	0.00	0.5340	4.6306	Discharge	0.0000	0.8	Ratio to Peak	0.5
W1370	3.78	79.05	14.43	0.2870	2.4885	Discharge	0.0000	0.8	Ratio to Peak	0.5
W1320	4.61	76.30	0.00	0.3615	3.1350	Discharge	0.0000	0.8	Ratio to Peak	0.5
W1090	3.78	79.05	0.00	0.2870	2.4885	Discharge	0.0000	0.8	Ratio to Peak	0.5

Annex 10. Hubo-Otieza Model Reach Parameters

Table A-10.1. Hubo-Otieza Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing					
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width
R120	Automatic Fixed Interval	2517.90	0.0682	0.15	Rectangle	13.73
R70	Automatic Fixed Interval	1272.50	0.0583	0.15	Rectangle	13.73
R50	Automatic Fixed Interval	593.55	0.0278	0.15	Rectangle	13.73
R30	Automatic Fixed Interval	3115.40	0.0225	0.15	Rectangle	13.73
R60	Automatic Fixed Interval	1379.20	0.0117	0.15	Rectangle	13.73
R80	Automatic Fixed Interval	2059.90	0.0180	0.15	Rectangle	13.73
R90	Automatic Fixed Interval	150.00	0.1032	0.15	Rectangle	13.73
R500	Automatic Fixed Interval	4538.00	0.0248	0.15	Rectangle	13.73
R360	Automatic Fixed Interval	567.40	0.0003	0.15	Rectangle	13.73
R380	Automatic Fixed Interval	1053.10	0.0003	0.15	Rectangle	13.73
R420	Automatic Fixed Interval	2003.40	0.0003	0.15	Rectangle	13.73
R390	Automatic Fixed Interval	6776.40	0.0375	0.15	Rectangle	13.73
R110	Automatic Fixed Interval	2091.80	0.0209	0.15	Rectangle	26.46
R230	Automatic Fixed Interval	3863.20	0.0041	0.15	Rectangle	22.06
R240	Automatic Fixed Interval	191.42	0.0312	0.15	Rectangle	39.26
R300	Automatic Fixed Interval	1516.10	0.0458	0.15	Rectangle	13.73
R280	Automatic Fixed Interval	1120.50	0.0402	0.15	Rectangle	31.13
R250	Automatic Fixed Interval	685.98	0.0033	0.15	Rectangle	32.17
R400	Automatic Fixed Interval	1752.70	0.0411	0.15	Rectangle	13.73
R310	Automatic Fixed Interval	1419.90	0.0292	0.15	Rectangle	13.73
R270	Automatic Fixed Interval	5971.90	0.0140	0.15	Rectangle	38.30
R160	Automatic Fixed Interval	361.42	0.1504	0.15	Rectangle	35.49

Reach Number	Muskingum Cunge Channel Routing					
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width
R140	Automatic Fixed Interval	104.14	0.0433	0.15	Rectangle	38.72
R1590	Automatic Fixed Interval	1746.80	0.0003	0.15	Rectangle	32.18
R1550	Automatic Fixed Interval	2178.70	0.0377	0.15	Rectangle	49.94
R1500	Automatic Fixed Interval	2028.90	0.0011	0.15	Rectangle	50.44
R1450	Automatic Fixed Interval	1999.40	0.0003	0.15	Rectangle	93.28
R1200	Automatic Fixed Interval	1472.30	0.0218	0.15	Rectangle	49.44
R1150	Automatic Fixed Interval	104.14	0.0003	0.15	Rectangle	36.72
R430	Automatic Fixed Interval	1127.80	0.0003	0.15	Rectangle	52.94
R1250	Automatic Fixed Interval	2301.10	0.0134	0.15	Rectangle	21.48
R440	Automatic Fixed Interval	1343.00	0.0114	0.15	Rectangle	18.27
R1390	Automatic Fixed Interval	310.42	0.0003	0.15	Rectangle	49.76
D2-J2	Automatic Fixed Interval	241.80	0.0003	0.15	Rectangle	33.00
R480	Automatic Fixed Interval	530.12	0.0003	0.15	Rectangle	46.64
R1300	Automatic Fixed Interval	4826.00	0.0249	0.15	Rectangle	16.20
R1350	Automatic Fixed Interval	1974.80	0.0066	0.15	Rectangle	15.22
D1-D2	Automatic Fixed Interval	467.32	0.0003	0.15	Rectangle	29.23
D2-J1	Automatic Fixed Interval	508.69	0.0003	0.15	Rectangle	42.88
R520	Automatic Fixed Interval	882.55	0.0003	0.15	Rectangle	61.35
R470	Automatic Fixed Interval	7.07	0.0003	0.15	Rectangle	13.73

Annex 11. Hubo-Otieza Field Validation Points

Table A-11.1. Hubo-Otieza Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/ Date	Rain Return /Scenario
	Lat	Long					
1	8.776507	126.2264	0.87	0.29	-0.580	Agaton	5-year
2	8.775968	126.2262	0.03	0	-0.030	Agaton	5-year
3	8.77436	126.2251	0.05	1.3	1.250	Agaton	5-year
4	8.770921	126.2352	0.03	0	-0.030	Agaton	5-year
5	8.767604	126.2317	0.03	0	-0.030	Agaton	5-year
6	8.76388	126.2348	0.33	0.28	-0.050	Agaton	5-year
7	8.762055	126.2356	0.26	0	-0.260	Agaton	5-year
8	8.764906	126.2399	0.28	0	-0.280	Agaton	5-year
9	8.76535	126.2398	0.03	0.9	0.870	Agaton	5-year
10	8.765457	126.2386	0.03	0	-0.030	Agaton	5-year
11	8.764992	126.2377	0.04	0	-0.040	Agaton	5-year
12	8.76328	126.2373	0.03	0	-0.030	Agaton	5-year
13	8.76071	126.2368	0.03	0.37	0.340	Agaton	5-year
14	8.759407	126.2359	0.16	0.46	0.300	Agaton	5-year
15	8.757313	126.2352	0.03	0	-0.030	Agaton	5-year
16	8.755963	126.2361	0.03	0	-0.030	Agaton	5-year
17	8.755439	126.2356	0.03	0	-0.030	Agaton	5-year
18	8.754129	126.2355	0.03	0	-0.030	Agaton	5-year
19	8.75376	126.2355	0.03	0	-0.030	Agaton	5-year
20	8.744157	126.2258	0.87	0	-0.870	Agaton	5-year
21	8.74513	126.2253	0.37	0	-0.370	Agaton	5-year
22	8.745666	126.2245	0.13	0	-0.130	Agaton	5-year
23	8.730472	126.2027	0.03	0.4	0.370	Agaton	5-year
24	8.736173	126.2033	0.11	0.38	0.270	Agaton	5-year
25	8.737224	126.2078	0.59	0.56	-0.030	Agaton	5-year
26	8.740406	126.2039	1.35	1.04	-0.310	Agaton	5-year
27	8.741071	126.2043	1.9	0.6	-1.300	Agaton	5-year
28	8.745631	126.2043	0.65	0.38	-0.270	Agaton	5-year
29	8.74472	126.2063	0.39	0.45	0.060	Agaton	5-year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/ Date	Rain Return /Scenario
	Lat	Long					
30	8.744733	126.2072	0.6	0	-0.600	Agaton	5-year
31	8.750033	126.2065	1.25	0	-1.250	Agaton	5-year
32	8.749937	126.206	1.78	0.4	-1.380	Agaton	5-year
33	8.750581	126.2051	1.43	0	-1.430	Agaton	5-year
34	8.751412	126.2045	1.36	0	-1.360	Agaton	5-year
35	8.748971	126.2084	0.72	0	-0.720	Agaton	5-year
36	8.745151	126.2119	1.31	0.8	-0.510	Agaton	5-year
37	8.751181	126.2079	2.26	0.1	-2.160	Agaton	5-year
38	8.751013	126.2081	0.25	0	-0.250	Agaton	5-year
39	8.750864	126.2079	0.65	0	-0.650	Agaton	5-year
40	8.752457	126.2062	2.01	0.39	-1.620	Agaton	5-year
41	8.75198	126.2078	0.03	0	-0.030	Agaton	5-year
42	8.754105	126.2353	0.04	0	-0.040	Agaton	5-year
43	8.75424	126.2357	0.19	0	-0.190	Agaton	5-year
44	8.75247	126.2359	0.03	0	-0.030	Agaton	5-year
45	8.746925	126.2227	0.03	0	-0.030	Agaton	5-year
46	8.748631	126.2182	0.56	0.43	-0.130	Agaton	5-year
47	8.747502	126.2195	0.06	0	-0.060	Agaton	5-year
48	8.745514	126.2192	1.11	0	-1.110	Agaton	5-year
49	8.74444	126.2193	0.03	0	-0.030	Agaton	5-year
50	8.743692	126.2181	1	0	-1.000	Agaton	5-year
51	8.743427	126.2192	0.72	0	-0.720	Agaton	5-year
52	8.743222	126.2192	0.26	0.3	0.040	Agaton	5-year
53	8.743271	126.2192	1.66	0.3	-1.360	Agaton	5-year
54	8.743055	126.2192	0.18	0	-0.180	Agaton	5-year
55	8.74297	126.2192	0.04	0	-0.040	Agaton	5-year
56	8.742873	126.2191	1.08	0.4	-0.680	Agaton	5-year
57	8.742063	126.2192	0.97	0.2	-0.770	Agaton	5-year
58	8.741983	126.2191	0.97	0	-0.970	Agaton	5-year
59	8.74249	126.2192	0.21	0	-0.210	Agaton	5-year
60	8.741854	126.2195	0.29	0	-0.290	Agaton	5-year
61	8.741663	126.2196	0.66	0	-0.660	Agaton	5-year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/ Date	Rain Return /Scenario
	Lat	Long					
62	8.741593	126.2198	0.37	0	-0.370	Agaton	5-year
63	8.74157	126.2198	0.37	0	-0.370	Agaton	5-year
64	8.74151	126.2198	0.56	0	-0.560	Agaton	5-year
65	8.741462	126.2198	0.56	0	-0.560	Agaton	5-year
66	8.740465	126.22	0.21	0	-0.210	Agaton	5-year
67	8.740049	126.2195	0.78	0.33	-0.450	Agaton	5-year
68	8.740067	126.2192	0.19	0.12	-0.070	Agaton	5-year
69	8.741927	126.2214	0.09	0.1	0.010	Agaton	5-year
70	8.742034	126.2225	0.03	0	-0.030	Agaton	5-year
71	8.743613	126.222	0.03	0	-0.030	Agaton	5-year
72	8.744547	126.2225	0.07	0	-0.070	Agaton	5-year
73	8.7435	126.2203	0.03	0	-0.030	Agaton	5-year
74	8.743482	126.2209	0.04	0	-0.040	Agaton	5-year
75	8.744899	126.2207	0.06	0	-0.060	Agaton	5-year
76	8.745229	126.2218	0.03	0	-0.030	Agaton	5-year
77	8.744982	126.2234	0.04	0	-0.040	Agaton	5-year
78	8.744664	126.2235	0.05	0	-0.050	Agaton	5-year
79	8.7552	126.2081	2.12	0.4	-1.720	Agaton	5-year
80	8.757898	126.2093	0.75	0	-0.750	Agaton	5-year
81	8.758266	126.2107	2.79	0	-2.790	Agaton	5-year
82	8.752845	126.1994	0.03	0	-0.030	Agaton	5-year
83	8.753899	126.1976	0.06	0	-0.060	Agaton	5-year
84	8.753772	126.1956	0.06	0.4	0.340	Agaton	5-year
85	8.732091	126.203	0.6	0.2	-0.400	Agaton	5-year
86	8.735219	126.2057	0.16	0	-0.160	Agaton	5-year
87	8.73502	126.2124	0.45	0.48	0.030	Agaton	5-year
88	8.751938	126.2078	0.03	0.1	0.070	Agaton	5-year
89	8.753221	126.2081	2.99	0.4	-2.590	Agaton	5-year
90	8.751355	126.2129	0.28	0.1	-0.180	Agaton	5-year
91	8.750653	126.2135	0.96	0.3	-0.660	Agaton	5-year
92	8.748923	126.2177	0.86	0.9	0.040	Agaton	5-year
93	8.748922	126.2185	1.01	0.59	-0.420	Agaton	5-year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/ Date	Rain Return /Scenario
	Lat	Long					
94	8.748272	126.2159	0.35	0.4	0.050	Agaton	5-year
95	8.746614	126.2164	0.83	0.1	-0.730	Agaton	5-year
96	8.7431	126.215	0.61	0.54	-0.070	Agaton	5-year
97	8.746587	126.213	0.78	0.32	-0.460	Agaton	5-year
98	8.747305	126.2133	0.78	0.3	-0.480	Agaton	5-year
99	8.743521	126.2047	0.03	1.53	1.500	Agaton	5-year
100	8.743094	126.2053	0.5	0.4	-0.100	Agaton	5-year
101	8.742383	126.2055	0.96	0.42	-0.540	Agaton	5-year
102	8.740219	126.2057	0.29	0	-0.290	Agaton	5-year
103	8.740944	126.2057	1	0.1	-0.900	Agaton	5-year
104	8.776507	126.2264	0.87	0.5	-0.370	Seniang	5-year
105	8.775968	126.2262	0.03	0	-0.030	Seniang	5-year
106	8.77436	126.2251	0.05	1.3	1.250	Seniang	5-year
107	8.770921	126.2352	0.03	0.18	0.150	Seniang	5-year
108	8.767604	126.2317	0.03	0	-0.030	Seniang	5-year
109	8.76388	126.2348	0.33	0.28	-0.050	Seniang	5-year
110	8.762055	126.2356	0.26	0.28	0.020	Seniang	5-year
111	8.764906	126.2399	0.28	1.48	1.200	Seniang	5-year
112	8.76535	126.2398	0.03	1.37	1.340	Seniang	5-year
113	8.765457	126.2386	0.03	0.68	0.650	Seniang	5-year
114	8.764992	126.2377	0.04	0.18	0.140	Seniang	5-year
115	8.76328	126.2373	0.03	0	-0.030	Seniang	5-year
116	8.76071	126.2368	0.03	0.28	0.250	Seniang	5-year
117	8.759407	126.2359	0.16	0.68	0.520	Seniang	5-year
118	8.757313	126.2352	0.03	0	-0.030	Seniang	5-year
119	8.755963	126.2361	0.03	0.17	0.140	Seniang	5-year
120	8.755439	126.2356	0.03	0	-0.030	Seniang	5-year
121	8.754129	126.2355	0.03	0.12	0.090	Seniang	5-year
122	8.75376	126.2355	0.03	0	-0.030	Seniang	5-year
123	8.744157	126.2258	0.87	0.45	-0.420	Seniang	5-year
124	8.74513	126.2253	0.37	0	-0.370	Seniang	5-year
125	8.745666	126.2245	0.13	0.29	0.160	Seniang	5-year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/ Date	Rain Return /Scenario
	Lat	Long					
126	8.730472	126.2027	0.03	0	-0.030	Seniang	5-year
127	8.736173	126.2033	0.11	0	-0.110	Seniang	5-year
128	8.737224	126.2078	0.59	0.56	-0.030	Seniang	5-year
129	8.740406	126.2039	1.35	1.04	-0.310	Seniang	5-year
130	8.741071	126.2043	1.9	1.05	-0.850	Seniang	5-year
131	8.745631	126.2043	0.65	0.38	-0.270	Seniang	5-year
132	8.74472	126.2063	0.39	0.45	0.060	Seniang	5-year
133	8.744733	126.2072	0.6	0	-0.600	Seniang	5-year
134	8.750033	126.2065	1.25	0.75	-0.500	Seniang	5-year
135	8.749937	126.206	1.78	0.6	-1.180	Seniang	5-year
136	8.750581	126.2051	1.43	0.67	-0.760	Seniang	5-year
137	8.751412	126.2045	1.36	0	-1.360	Seniang	5-year
138	8.748971	126.2084	0.72	0	-0.720	Seniang	5-year
139	8.745151	126.2119	1.31	0.97	-0.340	Seniang	5-year
140	8.751181	126.2079	2.26	0.1	-2.160	Seniang	5-year
141	8.751013	126.2081	0.25	0	-0.250	Seniang	5-year
142	8.750864	126.2079	0.65	0	-0.650	Seniang	5-year
143	8.752457	126.2062	2.01	0.7	-1.310	Seniang	5-year
144	8.75198	126.2078	0.03	0	-0.030	Seniang	5-year
145	8.754105	126.2353	0.04	0	-0.040	Seniang	5-year
146	8.75424	126.2357	0.19	0	-0.190	Seniang	5-year
147	8.75247	126.2359	0.03	0	-0.030	Seniang	5-year
148	8.746925	126.2227	0.03	0	-0.030	Seniang	5-year
149	8.748631	126.2182	0.56	0.89	0.330	Seniang	5-year
150	8.747502	126.2195	0.06	0	-0.060	Seniang	5-year
151	8.745514	126.2192	1.11	0.37	-0.740	Seniang	5-year
152	8.74444	126.2193	0.03	0	-0.030	Seniang	5-year
153	8.743692	126.2181	1	0	-1.000	Seniang	5-year
154	8.743427	126.2192	0.72	1.05	0.330	Seniang	5-year
155	8.743222	126.2192	0.26	1.17	0.910	Seniang	5-year
156	8.743271	126.2192	1.66	0.7	-0.960	Seniang	5-year
157	8.743055	126.2192	0.18	1.2	1.020	Seniang	5-year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/ Date	Rain Return /Scenario
	Lat	Long					
158	8.74297	126.2192	0.04	1.23	1.190	Seniang	5-year
159	8.742873	126.2191	1.08	0.8	-0.280	Seniang	5-year
160	8.742063	126.2192	0.97	1.03	0.060	Seniang	5-year
161	8.741983	126.2191	0.97	0.92	-0.050	Seniang	5-year
162	8.74249	126.2192	0.21	1.05	0.840	Seniang	5-year
163	8.741854	126.2195	0.29	0.52	0.230	Seniang	5-year
164	8.741663	126.2196	0.66	0.48	-0.180	Seniang	5-year
165	8.741593	126.2198	0.37	0.15	-0.220	Seniang	5-year
166	8.74157	126.2198	0.37	0.15	-0.220	Seniang	5-year
167	8.74151	126.2198	0.56	0.41	-0.150	Seniang	5-year
168	8.741462	126.2198	0.56	0.3	-0.260	Seniang	5-year
169	8.740465	126.22	0.21	0	-0.210	Seniang	5-year
170	8.740049	126.2195	0.78	0.33	-0.450	Seniang	5-year
171	8.740067	126.2192	0.19	0.43	0.240	Seniang	5-year
172	8.741927	126.2214	0.09	0.1	0.010	Seniang	5-year
173	8.742034	126.2225	0.03	0.3	0.270	Seniang	5-year
174	8.743613	126.222	0.03	0	-0.030	Seniang	5-year
175	8.744547	126.2225	0.07	0.35	0.280	Seniang	5-year
176	8.7435	126.2203	0.03	0.26	0.230	Seniang	5-year
177	8.743482	126.2209	0.04	0	-0.040	Seniang	5-year
178	8.744899	126.2207	0.06	0.3	0.240	Seniang	5-year
179	8.745229	126.2218	0.03	0	-0.030	Seniang	5-year
180	8.744982	126.2234	0.04	0	-0.040	Seniang	5-year
181	8.744664	126.2235	0.05	0.07	0.020	Seniang	5-year
182	8.7552	126.2081	2.12	1.4	-0.720	Seniang	5-year
183	8.757898	126.2093	0.75	0	-0.750	Seniang	5-year
184	8.758266	126.2107	2.79	0.52	-2.270	Seniang	5-year
185	8.752845	126.1994	0.03	0	-0.030	Seniang	5-year
186	8.753899	126.1976	0.06	0.5	0.440	Seniang	5-year
187	8.753772	126.1956	0.06	1	0.940	Seniang	5-year
188	8.732091	126.203	0.6	0.4	-0.200	Seniang	5-year
189	8.735219	126.2057	0.16	0.3	0.140	Seniang	5-year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/ Date	Rain Return /Scenario
	Lat	Long					
190	8.73502	126.2124	0.45	0.56	0.110	Seniang	5-year
191	8.751938	126.2078	0.03	0.1	0.070	Seniang	5-year
192	8.753221	126.2081	2.99	1.15	-1.840	Seniang	5-year
193	8.751355	126.2129	0.28	0.26	-0.020	Seniang	5-year
194	8.750653	126.2135	0.96	0.48	-0.480	Seniang	5-year
195	8.748923	126.2177	0.86	0.9	0.040	Seniang	5-year
196	8.748922	126.2185	1.01	0.79	-0.220	Seniang	5-year
197	8.748272	126.2159	0.35	0.59	0.240	Seniang	5-year
198	8.746614	126.2164	0.83	0.4	-0.430	Seniang	5-year
199	8.7431	126.215	0.61	0.89	0.280	Seniang	5-year
200	8.746587	126.213	0.78	0.55	-0.230	Seniang	5-year
201	8.747305	126.2133	0.78	0.65	-0.130	Seniang	5-year
202	8.743521	126.2047	0.03	1.53	1.500	Seniang	5-year
203	8.743094	126.2053	0.5	0.58	0.080	Seniang	5-year
204	8.742383	126.2055	0.96	0.76	-0.200	Seniang	5-year
205	8.740219	126.2057	0.29	0	-0.290	Seniang	5-year
206	8.740944	126.2057	1	0.4	-0.600	Seniang	5-year
207	8.776507	126.2264	1.08	0.29	-0.79	Agaton	25-year
208	8.775968	126.2262	0.03	0	-0.03	Agaton	25-year
209	8.77436	126.2251	0.34	1.3	0.96	Agaton	25-year
210	8.770921	126.2352	0.03	0	-0.03	Agaton	25-year
211	8.767604	126.2317	0.03	0	-0.03	Agaton	25-year
212	8.76388	126.2348	0.43	0.28	-0.15	Agaton	25-year
213	8.762055	126.2356	0.35	0	-0.35	Agaton	25-year
214	8.764906	126.2399	0.35	0	-0.35	Agaton	25-year
215	8.76535	126.2398	0.03	0.9	0.87	Agaton	25-year
216	8.765457	126.2386	0.04	0	-0.04	Agaton	25-year
217	8.764992	126.2377	0.05	0	-0.05	Agaton	25-year
218	8.76328	126.2373	0.04	0	-0.04	Agaton	25-year
219	8.76071	126.2368	0.03	0.37	0.34	Agaton	25-year
220	8.759407	126.2359	0.34	0.46	0.12	Agaton	25-year
221	8.757313	126.2352	0.03	0	-0.03	Agaton	25-year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/ Date	Rain Return /Scenario
	Lat	Long					
222	8.755963	126.2361	0.03	0	-0.03	Agaton	25-year
223	8.755439	126.2356	0.03	0	-0.03	Agaton	25-year
224	8.754129	126.2355	0.03	0	-0.03	Agaton	25-year
225	8.75376	126.2355	0.09	0	-0.09	Agaton	25-year
226	8.744157	126.2258	1.06	0	-1.06	Agaton	25-year
227	8.74513	126.2253	0.55	0	-0.55	Agaton	25-year
228	8.745666	126.2245	0.24	0	-0.24	Agaton	25-year
229	8.730472	126.2027	0.03	0.4	0.37	Agaton	25-year
230	8.736173	126.2033	0.33	0.38	0.05	Agaton	25-year
231	8.737224	126.2078	0.93	0.56	-0.37	Agaton	25-year
232	8.740406	126.2039	1.52	1.04	-0.48	Agaton	25-year
233	8.741071	126.2043	2.17	0.6	-1.57	Agaton	25-year
234	8.745631	126.2043	0.87	0.38	-0.49	Agaton	25-year
235	8.74472	126.2063	0.79	0.45	-0.34	Agaton	25-year
236	8.744733	126.2072	1.1	0	-1.1	Agaton	25-year
237	8.750033	126.2065	1.61	0	-1.61	Agaton	25-year
238	8.749937	126.206	2.19	0.4	-1.79	Agaton	25-year
239	8.750581	126.2051	1.98	0	-1.98	Agaton	25-year
240	8.751412	126.2045	2.03	0	-2.03	Agaton	25-year
241	8.748971	126.2084	1.25	0	-1.25	Agaton	25-year
242	8.745151	126.2119	1.74	0.8	-0.94	Agaton	25-year
243	8.751181	126.2079	2.64	0.1	-2.54	Agaton	25-year
244	8.751013	126.2081	0.61	0	-0.61	Agaton	25-year
245	8.750864	126.2079	1	0	-1	Agaton	25-year
246	8.752457	126.2062	2.73	0.39	-2.34	Agaton	25-year
247	8.75198	126.2078	0.06	0	-0.06	Agaton	25-year
248	8.754105	126.2353	0.05	0	-0.05	Agaton	25-year
249	8.75424	126.2357	0.22	0	-0.22	Agaton	25-year
250	8.75247	126.2359	0.03	0	-0.03	Agaton	25-year
251	8.746925	126.2227	0.03	0	-0.03	Agaton	25-year
252	8.748631	126.2182	0.85	0.43	-0.42	Agaton	25-year
253	8.747502	126.2195	0.06	0	-0.06	Agaton	25-year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/ Date	Rain Return /Scenario
	Lat	Long					
254	8.745514	126.2192	1.59	0	-1.59	Agaton	25-year
255	8.74444	126.2193	0.03	0	-0.03	Agaton	25-year
256	8.743692	126.2181	1.53	0	-1.53	Agaton	25-year
257	8.743427	126.2192	1.23	0	-1.23	Agaton	25-year
258	8.743222	126.2192	0.78	0.3	-0.48	Agaton	25-year
259	8.743271	126.2192	2.17	0.3	-1.87	Agaton	25-year
260	8.743055	126.2192	0.69	0	-0.69	Agaton	25-year
261	8.74297	126.2192	0.54	0	-0.54	Agaton	25-year
262	8.742873	126.2191	1.57	0.4	-1.17	Agaton	25-year
263	8.742063	126.2192	1.44	0.2	-1.24	Agaton	25-year
264	8.741983	126.2191	1.44	0	-1.44	Agaton	25-year
265	8.74249	126.2192	0.69	0	-0.69	Agaton	25-year
266	8.741854	126.2195	0.75	0	-0.75	Agaton	25-year
267	8.741663	126.2196	1.14	0	-1.14	Agaton	25-year
268	8.741593	126.2198	0.84	0	-0.84	Agaton	25-year
269	8.74157	126.2198	0.84	0	-0.84	Agaton	25-year
270	8.74151	126.2198	1.02	0	-1.02	Agaton	25-year
271	8.741462	126.2198	1.02	0	-1.02	Agaton	25-year
272	8.740465	126.22	0.66	0	-0.66	Agaton	25-year
273	8.740049	126.2195	1.18	0.33	-0.85	Agaton	25-year
274	8.740067	126.2192	0.6	0.12	-0.48	Agaton	25-year
275	8.741927	126.2214	0.27	0.1	-0.17	Agaton	25-year
276	8.742034	126.2225	0.03	0	-0.03	Agaton	25-year
277	8.743613	126.222	0.03	0	-0.03	Agaton	25-year
278	8.744547	126.2225	0.13	0	-0.13	Agaton	25-year
279	8.7435	126.2203	0.14	0	-0.14	Agaton	25-year
280	8.743482	126.2209	0.09	0	-0.09	Agaton	25-year
281	8.744899	126.2207	0.07	0	-0.07	Agaton	25-year
282	8.745229	126.2218	0.03	0	-0.03	Agaton	25-year
283	8.744982	126.2234	0.07	0	-0.07	Agaton	25-year
284	8.744664	126.2235	0.08	0	-0.08	Agaton	25-year
285	8.7552	126.2081	2.92	0.4	-2.52	Agaton	25-year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/ Date	Rain Return /Scenario
	Lat	Long					
286	8.757898	126.2093	1.75	0	-1.75	Agaton	25-year
287	8.758266	126.2107	4.01	0	-4.01	Agaton	25-year
288	8.752845	126.1994	0.03	0	-0.03	Agaton	25-year
289	8.753899	126.1976	0.07	0	-0.07	Agaton	25-year
290	8.753772	126.1956	0.07	0.4	0.33	Agaton	25-year
291	8.732091	126.203	0.73	0.2	-0.53	Agaton	25-year
292	8.735219	126.2057	0.19	0	-0.19	Agaton	25-year
293	8.73502	126.2124	1.05	0.48	-0.57	Agaton	25-year
294	8.751938	126.2078	0.06	0.1	0.04	Agaton	25-year
295	8.753221	126.2081	3.78	0.4	-3.38	Agaton	25-year
296	8.751355	126.2129	0.36	0.1	-0.26	Agaton	25-year
297	8.750653	126.2135	1.22	0.3	-0.92	Agaton	25-year
298	8.748923	126.2177	1.16	0.9	-0.26	Agaton	25-year
299	8.748922	126.2185	1.29	0.59	-0.7	Agaton	25-year
300	8.748272	126.2159	0.75	0.4	-0.35	Agaton	25-year
301	8.746614	126.2164	1.31	0.1	-1.21	Agaton	25-year
302	8.7431	126.215	1.13	0.54	-0.59	Agaton	25-year
303	8.746587	126.213	1.12	0.32	-0.8	Agaton	25-year
304	8.747305	126.2133	1.11	0.3	-0.81	Agaton	25-year
305	8.743521	126.2047	0.08	1.53	1.45	Agaton	25-year
306	8.743094	126.2053	0.71	0.4	-0.31	Agaton	25-year
307	8.742383	126.2055	1.18	0.42	-0.76	Agaton	25-year
308	8.740219	126.2057	0.52	0	-0.52	Agaton	25-year
309	8.740944	126.2057	1.21	0.1	-1.11	Agaton	25-year
310	8.776507	126.2264	1.08	0.500	-0.58	Seniang	25-year
311	8.775968	126.2262	0.03	0.000	-0.03	Seniang	25-year
312	8.77436	126.2251	0.34	1.300	0.96	Seniang	25-year
313	8.770921	126.2352	0.03	0.180	0.15	Seniang	25-year
314	8.767604	126.2317	0.03	0.000	-0.03	Seniang	25-year
315	8.76388	126.2348	0.43	0.280	-0.15	Seniang	25-year
316	8.762055	126.2356	0.35	0.280	-0.07	Seniang	25-year
317	8.764906	126.2399	0.35	1.480	1.13	Seniang	25-year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/ Date	Rain Return /Scenario
	Lat	Long					
318	8.76535	126.2398	0.03	1.370	1.34	Seniang	25-year
319	8.765457	126.2386	0.04	0.680	0.64	Seniang	25-year
320	8.764992	126.2377	0.05	0.180	0.13	Seniang	25-year
321	8.76328	126.2373	0.04	0.000	-0.04	Seniang	25-year
322	8.76071	126.2368	0.03	0.280	0.25	Seniang	25-year
323	8.759407	126.2359	0.34	0.680	0.34	Seniang	25-year
324	8.757313	126.2352	0.03	0.000	-0.03	Seniang	25-year
325	8.755963	126.2361	0.03	0.170	0.14	Seniang	25-year
326	8.755439	126.2356	0.03	0.000	-0.03	Seniang	25-year
327	8.754129	126.2355	0.03	0.120	0.09	Seniang	25-year
328	8.75376	126.2355	0.09	0.000	-0.09	Seniang	25-year
329	8.744157	126.2258	1.06	0.450	-0.61	Seniang	25-year
330	8.74513	126.2253	0.55	0.000	-0.55	Seniang	25-year
331	8.745666	126.2245	0.24	0.290	0.05	Seniang	25-year
332	8.730472	126.2027	0.03	0.000	-0.03	Seniang	25-year
333	8.736173	126.2033	0.33	0.000	-0.33	Seniang	25-year
334	8.737224	126.2078	0.93	0.560	-0.37	Seniang	25-year
335	8.740406	126.2039	1.52	1.040	-0.48	Seniang	25-year
336	8.741071	126.2043	2.17	1.05	-1.12	Seniang	25-year
337	8.745631	126.2043	0.87	0.38	-0.49	Seniang	25-year
338	8.74472	126.2063	0.79	0.45	-0.34	Seniang	25-year
339	8.744733	126.2072	1.1	0	-1.1	Seniang	25-year
340	8.750033	126.2065	1.61	0.75	-0.86	Seniang	25-year
341	8.749937	126.206	2.19	0.6	-1.59	Seniang	25-year
342	8.750581	126.2051	1.98	0.67	-1.31	Seniang	25-year
343	8.751412	126.2045	2.03	0	-2.03	Seniang	25-year
344	8.748971	126.2084	1.25	0	-1.25	Seniang	25-year
345	8.745151	126.2119	1.74	0.97	-0.77	Seniang	25-year
346	8.751181	126.2079	2.64	0.1	-2.54	Seniang	25-year
347	8.751013	126.2081	0.61	0	-0.61	Seniang	25-year
348	8.750864	126.2079	1	0	-1	Seniang	25-year
349	8.752457	126.2062	2.73	0.7	-2.03	Seniang	25-year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/ Date	Rain Return /Scenario
	Lat	Long					
350	8.75198	126.2078	0.06	0	-0.06	Seniang	25-year
351	8.754105	126.2353	0.05	0	-0.05	Seniang	25-year
352	8.75424	126.2357	0.22	0	-0.22	Seniang	25-year
353	8.75247	126.2359	0.03	0	-0.03	Seniang	25-year
354	8.746925	126.2227	0.03	0	-0.03	Seniang	25-year
355	8.748631	126.2182	0.85	0.89	0.04	Seniang	25-year
356	8.747502	126.2195	0.06	0	-0.06	Seniang	25-year
357	8.745514	126.2192	1.59	0.37	-1.22	Seniang	25-year
358	8.74444	126.2193	0.03	0	-0.03	Seniang	25-year
359	8.743692	126.2181	1.53	0	-1.53	Seniang	25-year
360	8.743427	126.2192	1.23	1.05	-0.18	Seniang	25-year
361	8.743222	126.2192	0.78	1.17	0.39	Seniang	25-year
362	8.743271	126.2192	2.17	0.7	-1.47	Seniang	25-year
363	8.743055	126.2192	0.69	1.2	0.51	Seniang	25-year
364	8.74297	126.2192	0.54	1.23	0.69	Seniang	25-year
365	8.742873	126.2191	1.57	0.8	-0.77	Seniang	25-year
366	8.742063	126.2192	1.44	1.03	-0.41	Seniang	25-year
367	8.741983	126.2191	1.44	0.92	-0.52	Seniang	25-year
368	8.74249	126.2192	0.69	1.05	0.36	Seniang	25-year
369	8.741854	126.2195	0.75	0.52	-0.23	Seniang	25-year
370	8.741663	126.2196	1.14	0.48	-0.66	Seniang	25-year
371	8.741593	126.2198	0.84	0.15	-0.69	Seniang	25-year
372	8.74157	126.2198	0.84	0.15	-0.69	Seniang	25-year
373	8.74151	126.2198	1.02	0.41	-0.61	Seniang	25-year
374	8.741462	126.2198	1.02	0.3	-0.72	Seniang	25-year
375	8.740465	126.22	0.66	0	-0.66	Seniang	25-year
376	8.740049	126.2195	1.18	0.33	-0.85	Seniang	25-year
377	8.740067	126.2192	0.6	0.43	-0.17	Seniang	25-year
378	8.741927	126.2214	0.27	0.1	-0.17	Seniang	25-year
379	8.742034	126.2225	0.03	0.3	0.27	Seniang	25-year
380	8.743613	126.222	0.03	0	-0.03	Seniang	25-year
381	8.744547	126.2225	0.13	0.35	0.22	Seniang	25-year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/ Date	Rain Return /Scenario
	Lat	Long					
382	8.7435	126.2203	0.14	0.26	0.12	Seniang	25-year
383	8.743482	126.2209	0.09	0	-0.09	Seniang	25-year
384	8.744899	126.2207	0.07	0.3	0.23	Seniang	25-year
385	8.745229	126.2218	0.03	0	-0.03	Seniang	25-year
386	8.744982	126.2234	0.07	0	-0.07	Seniang	25-year
387	8.744664	126.2235	0.08	0.07	-0.01	Seniang	25-year
388	8.7552	126.2081	2.92	1.4	-1.52	Seniang	25-year
389	8.757898	126.2093	1.75	0	-1.75	Seniang	25-year
390	8.758266	126.2107	4.01	0.52	-3.49	Seniang	25-year
391	8.752845	126.1994	0.03	0	-0.03	Seniang	25-year
392	8.753899	126.1976	0.07	0.5	0.43	Seniang	25-year
393	8.753772	126.1956	0.07	1	0.93	Seniang	25-year
394	8.732091	126.203	0.73	0.4	-0.33	Seniang	25-year
395	8.735219	126.2057	0.19	0.3	0.11	Seniang	25-year
396	8.73502	126.2124	1.05	0.56	-0.49	Seniang	25-year
397	8.751938	126.2078	0.06	0.1	0.04	Seniang	25-year
398	8.753221	126.2081	3.78	1.15	-2.63	Seniang	25-year
399	8.751355	126.2129	0.36	0.26	-0.1	Seniang	25-year
400	8.750653	126.2135	1.22	0.48	-0.74	Seniang	25-year
401	8.748923	126.2177	1.16	0.9	-0.26	Seniang	25-year
402	8.748922	126.2185	1.29	0.79	-0.5	Seniang	25-year
403	8.748272	126.2159	0.75	0.59	-0.16	Seniang	25-year
404	8.746614	126.2164	1.31	0.4	-0.91	Seniang	25-year
405	8.7431	126.215	1.13	0.89	-0.24	Seniang	25-year
406	8.746587	126.213	1.12	0.55	-0.57	Seniang	25-year
407	8.747305	126.2133	1.11	0.65	-0.46	Seniang	25-year
408	8.743521	126.2047	0.08	1.53	1.45	Seniang	25-year
409	8.743094	126.2053	0.71	0.58	-0.13	Seniang	25-year
410	8.742383	126.2055	1.18	0.76	-0.42	Seniang	25-year
411	8.740219	126.2057	0.52	0	-0.52	Seniang	25-year
412	8.740944	126.2057	1.21	0.4	-0.81	Seniang	25-year
413	8.776507	126.2264	1.18	0.29	-0.89	Agaton	100-year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/ Date	Rain Return /Scenario
	Lat	Long					
414	8.775968	126.2262	0.03	0	-0.03	Agaton	100-year
415	8.77436	126.2251	0.47	1.3	0.83	Agaton	100-year
416	8.770921	126.2352	0.04	0	-0.04	Agaton	100-year
417	8.767604	126.2317	0.03	0	-0.03	Agaton	100-year
418	8.76388	126.2348	0.49	0.28	-0.21	Agaton	100-year
419	8.762055	126.2356	0.41	0	-0.41	Agaton	100-year
420	8.764906	126.2399	0.56	0	-0.56	Agaton	100-year
421	8.76535	126.2398	0.03	0.9	0.87	Agaton	100-year
422	8.765457	126.2386	0.1	0	-0.1	Agaton	100-year
423	8.764992	126.2377	0.06	0	-0.06	Agaton	100-year
424	8.76328	126.2373	0.04	0	-0.04	Agaton	100-year
425	8.76071	126.2368	0.03	0.37	0.34	Agaton	100-year
426	8.759407	126.2359	0.45	0.46	0.01	Agaton	100-year
427	8.757313	126.2352	0.03	0	-0.03	Agaton	100-year
428	8.755963	126.2361	0.03	0	-0.03	Agaton	100-year
429	8.755439	126.2356	0.03	0	-0.03	Agaton	100-year
430	8.754129	126.2355	0.03	0	-0.03	Agaton	100-year
431	8.75376	126.2355	0.19	0	-0.19	Agaton	100-year
432	8.744157	126.2258	1.21	0	-1.21	Agaton	100-year
433	8.74513	126.2253	0.71	0	-0.71	Agaton	100-year
434	8.745666	126.2245	0.5	0	-0.5	Agaton	100-year
435	8.730472	126.2027	0.03	0.4	0.37	Agaton	100-year
436	8.736173	126.2033	0.49	0.38	-0.11	Agaton	100-year
437	8.737224	126.2078	1.16	0.56	-0.6	Agaton	100-year
438	8.740406	126.2039	1.64	1.04	-0.6	Agaton	100-year
439	8.741071	126.2043	2.35	0.6	-1.75	Agaton	100-year
440	8.745631	126.2043	1.07	0.38	-0.69	Agaton	100-year
441	8.74472	126.2063	1.06	0.45	-0.61	Agaton	100-year
442	8.744733	126.2072	1.41	0	-1.41	Agaton	100-year
443	8.750033	126.2065	1.88	0	-1.88	Agaton	100-year
444	8.749937	126.206	2.49	0.4	-2.09	Agaton	100-year
445	8.750581	126.2051	2.35	0	-2.35	Agaton	100-year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/ Date	Rain Return /Scenario
	Lat	Long					
446	8.751412	126.2045	2.47	0	-2.47	Agaton	100-year
447	8.748971	126.2084	1.6	0	-1.6	Agaton	100-year
448	8.745151	126.2119	2.03	0.8	-1.23	Agaton	100-year
449	8.751181	126.2079	2.97	0.1	-2.87	Agaton	100-year
450	8.751013	126.2081	0.94	0	-0.94	Agaton	100-year
451	8.750864	126.2079	1.32	0	-1.32	Agaton	100-year
452	8.752457	126.2062	3.21	0.39	-2.82	Agaton	100-year
453	8.75198	126.2078	0.47	0	-0.47	Agaton	100-year
454	8.754105	126.2353	0.15	0	-0.15	Agaton	100-year
455	8.75424	126.2357	0.23	0	-0.23	Agaton	100-year
456	8.75247	126.2359	0.03	0	-0.03	Agaton	100-year
457	8.746925	126.2227	0.03	0	-0.03	Agaton	100-year
458	8.748631	126.2182	1.12	0.43	-0.69	Agaton	100-year
459	8.747502	126.2195	0.14	0	-0.14	Agaton	100-year
460	8.745514	126.2192	1.88	0	-1.88	Agaton	100-year
461	8.74444	126.2193	0.33	0	-0.33	Agaton	100-year
462	8.743692	126.2181	1.83	0	-1.83	Agaton	100-year
463	8.743427	126.2192	1.51	0	-1.51	Agaton	100-year
464	8.743222	126.2192	1.05	0.3	-0.75	Agaton	100-year
465	8.743271	126.2192	2.45	0.3	-2.15	Agaton	100-year
466	8.743055	126.2192	0.96	0	-0.96	Agaton	100-year
467	8.74297	126.2192	0.82	0	-0.82	Agaton	100-year
468	8.742873	126.2191	1.85	0.4	-1.45	Agaton	100-year
469	8.742063	126.2192	1.71	0.2	-1.51	Agaton	100-year
470	8.741983	126.2191	1.71	0	-1.71	Agaton	100-year
471	8.74249	126.2192	0.97	0	-0.97	Agaton	100-year
472	8.741854	126.2195	1.02	0	-1.02	Agaton	100-year
473	8.741663	126.2196	1.41	0	-1.41	Agaton	100-year
474	8.741593	126.2198	1.1	0	-1.1	Agaton	100-year
475	8.74157	126.2198	1.1	0	-1.1	Agaton	100-year
476	8.74151	126.2198	1.27	0	-1.27	Agaton	100-year
477	8.741462	126.2198	1.27	0	-1.27	Agaton	100-year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/ Date	Rain Return /Scenario
	Lat	Long					
478	8.740465	126.22	0.88	0	-0.88	Agaton	100-year
479	8.740049	126.2195	1.37	0.33	-1.04	Agaton	100-year
480	8.740067	126.2192	0.8	0.12	-0.68	Agaton	100-year
481	8.741927	126.2214	0.5	0.1	-0.4	Agaton	100-year
482	8.742034	126.2225	0.11	0	-0.11	Agaton	100-year
483	8.743613	126.222	0.04	0	-0.04	Agaton	100-year
484	8.744547	126.2225	0.16	0	-0.16	Agaton	100-year
485	8.7435	126.2203	0.41	0	-0.41	Agaton	100-year
486	8.743482	126.2209	0.35	0	-0.35	Agaton	100-year
487	8.744899	126.2207	0.18	0	-0.18	Agaton	100-year
488	8.745229	126.2218	0.03	0	-0.03	Agaton	100-year
489	8.744982	126.2234	0.08	0	-0.08	Agaton	100-year
490	8.744664	126.2235	0.17	0	-0.17	Agaton	100-year
491	8.7552	126.2081	3.45	0.4	-3.05	Agaton	100-year
492	8.757898	126.2093	2.43	0	-2.43	Agaton	100-year
493	8.758266	126.2107	4.74	0	-4.74	Agaton	100-year
494	8.752845	126.1994	0.03	0	-0.03	Agaton	100-year
495	8.753899	126.1976	0.07	0	-0.07	Agaton	100-year
496	8.753772	126.1956	0.09	0.4	0.31	Agaton	100-year
497	8.732091	126.203	0.79	0.2	-0.59	Agaton	100-year
498	8.735219	126.2057	0.21	0	-0.21	Agaton	100-year
499	8.73502	126.2124	1.3	0.48	-0.82	Agaton	100-year
500	8.751938	126.2078	0.47	0.1	-0.37	Agaton	100-year
501	8.753221	126.2081	4.28	0.4	-3.88	Agaton	100-year
502	8.751355	126.2129	0.41	0.1	-0.31	Agaton	100-year
503	8.750653	126.2135	1.43	0.3	-1.13	Agaton	100-year
504	8.748923	126.2177	1.44	0.9	-0.54	Agaton	100-year
505	8.748922	126.2185	1.56	0.59	-0.97	Agaton	100-year
506	8.748272	126.2159	1.06	0.4	-0.66	Agaton	100-year
507	8.746614	126.2164	1.63	0.1	-1.53	Agaton	100-year
508	8.7431	126.215	1.43	0.54	-0.89	Agaton	100-year
509	8.746587	126.213	1.39	0.32	-1.07	Agaton	100-year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/ Date	Rain Return /Scenario
	Lat	Long					
510	8.747305	126.2133	1.37	0.3	-1.07	Agaton	100-year
511	8.743521	126.2047	0.23	1.53	1.3	Agaton	100-year
512	8.743094	126.2053	0.93	0.4	-0.53	Agaton	100-year
513	8.742383	126.2055	1.33	0.42	-0.91	Agaton	100-year
514	8.740219	126.2057	0.67	0	-0.67	Agaton	100-year
515	8.740944	126.2057	1.37	0.1	-1.27	Agaton	100-year
516	8.776507	126.2264	1.18	0.5	-0.68	Seniang	100-year
517	8.775968	126.2262	0.03	0	-0.03	Seniang	100-year
518	8.77436	126.2251	0.47	1.3	0.83	Seniang	100-year
519	8.770921	126.2352	0.04	0.18	0.14	Seniang	100-year
520	8.767604	126.2317	0.03	0	-0.03	Seniang	100-year
521	8.76388	126.2348	0.49	0.28	-0.21	Seniang	100-year
522	8.762055	126.2356	0.41	0.28	-0.13	Seniang	100-year
523	8.764906	126.2399	0.56	1.48	0.92	Seniang	100-year
524	8.76535	126.2398	0.03	1.37	1.34	Seniang	100-year
525	8.765457	126.2386	0.1	0.68	0.58	Seniang	100-year
526	8.764992	126.2377	0.06	0.18	0.12	Seniang	100-year
527	8.76328	126.2373	0.04	0	-0.04	Seniang	100-year
528	8.76071	126.2368	0.03	0.28	0.25	Seniang	100-year
529	8.759407	126.2359	0.45	0.68	0.23	Seniang	100-year
530	8.757313	126.2352	0.03	0	-0.03	Seniang	100-year
531	8.755963	126.2361	0.03	0.17	0.14	Seniang	100-year
532	8.755439	126.2356	0.03	0	-0.03	Seniang	100-year
533	8.754129	126.2355	0.03	0.12	0.09	Seniang	100-year
534	8.75376	126.2355	0.19	0	-0.19	Seniang	100-year
535	8.744157	126.2258	1.21	0.45	-0.76	Seniang	100-year
536	8.74513	126.2253	0.71	0	-0.71	Seniang	100-year
537	8.745666	126.2245	0.5	0.29	-0.21	Seniang	100-year
538	8.730472	126.2027	0.03	0	-0.03	Seniang	100-year
539	8.736173	126.2033	0.49	0	-0.49	Seniang	100-year
540	8.737224	126.2078	1.16	0.56	-0.6	Seniang	100-year
541	8.740406	126.2039	1.64	1.04	-0.6	Seniang	100-year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/ Date	Rain Return /Scenario
	Lat	Long					
542	8.741071	126.2043	2.35	1.05	-1.3	Seniang	100-year
543	8.745631	126.2043	1.07	0.38	-0.69	Seniang	100-year
544	8.74472	126.2063	1.06	0.45	-0.61	Seniang	100-year
545	8.744733	126.2072	1.41	0	-1.41	Seniang	100-year
546	8.750033	126.2065	1.88	0.75	-1.13	Seniang	100-year
547	8.749937	126.206	2.49	0.6	-1.89	Seniang	100-year
548	8.750581	126.2051	2.35	0.67	-1.68	Seniang	100-year
549	8.751412	126.2045	2.47	0	-2.47	Seniang	100-year
550	8.748971	126.2084	1.6	0	-1.6	Seniang	100-year
551	8.745151	126.2119	2.03	0.97	-1.06	Seniang	100-year
552	8.751181	126.2079	2.97	0.1	-2.87	Seniang	100-year
553	8.751013	126.2081	0.94	0	-0.94	Seniang	100-year
554	8.750864	126.2079	1.32	0	-1.32	Seniang	100-year
555	8.752457	126.2062	3.21	0.7	-2.51	Seniang	100-year
556	8.75198	126.2078	0.47	0	-0.47	Seniang	100-year
557	8.754105	126.2353	0.15	0	-0.15	Seniang	100-year
558	8.75424	126.2357	0.23	0	-0.23	Seniang	100-year
559	8.75247	126.2359	0.03	0	-0.03	Seniang	100-year
560	8.746925	126.2227	0.03	0	-0.03	Seniang	100-year
561	8.748631	126.2182	1.12	0.89	-0.23	Seniang	100-year
562	8.747502	126.2195	0.14	0	-0.14	Seniang	100-year
563	8.745514	126.2192	1.88	0.37	-1.51	Seniang	100-year
564	8.74444	126.2193	0.33	0	-0.33	Seniang	100-year
565	8.743692	126.2181	1.83	0	-1.83	Seniang	100-year
566	8.743427	126.2192	1.51	1.05	-0.46	Seniang	100-year
567	8.743222	126.2192	1.05	1.17	0.12	Seniang	100-year
568	8.743271	126.2192	2.45	0.7	-1.75	Seniang	100-year
569	8.743055	126.2192	0.96	1.2	0.24	Seniang	100-year
570	8.74297	126.2192	0.82	1.23	0.41	Seniang	100-year
571	8.742873	126.2191	1.85	0.8	-1.05	Seniang	100-year
572	8.742063	126.2192	1.71	1.03	-0.68	Seniang	100-year
573	8.741983	126.2191	1.71	0.92	-0.79	Seniang	100-year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/ Date	Rain Return /Scenario
	Lat	Long					
574	8.74249	126.2192	0.97	1.05	0.08	Seniang	100-year
575	8.741854	126.2195	1.02	0.52	-0.5	Seniang	100-year
576	8.741663	126.2196	1.41	0.48	-0.93	Seniang	100-year
577	8.741593	126.2198	1.1	0.15	-0.95	Seniang	100-year
578	8.74157	126.2198	1.1	0.15	-0.95	Seniang	100-year
579	8.74151	126.2198	1.27	0.41	-0.86	Seniang	100-year
580	8.741462	126.2198	1.27	0.3	-0.97	Seniang	100-year
581	8.740465	126.22	0.88	0	-0.88	Seniang	100-year
582	8.740049	126.2195	1.37	0.33	-1.04	Seniang	100-year
583	8.740067	126.2192	0.8	0.43	-0.37	Seniang	100-year
584	8.741927	126.2214	0.5	0.1	-0.4	Seniang	100-year
585	8.742034	126.2225	0.11	0.3	0.19	Seniang	100-year
586	8.743613	126.222	0.04	0	-0.04	Seniang	100-year
587	8.744547	126.2225	0.16	0.35	0.19	Seniang	100-year
588	8.7435	126.2203	0.41	0.26	-0.15	Seniang	100-year
589	8.743482	126.2209	0.35	0	-0.35	Seniang	100-year
590	8.744899	126.2207	0.18	0.3	0.12	Seniang	100-year
591	8.745229	126.2218	0.03	0	-0.03	Seniang	100-year
592	8.744982	126.2234	0.08	0	-0.08	Seniang	100-year
593	8.744664	126.2235	0.17	0.07	-0.1	Seniang	100-year
594	8.7552	126.2081	3.45	1.4	-2.05	Seniang	100-year
595	8.757898	126.2093	2.43	0	-2.43	Seniang	100-year
596	8.758266	126.2107	4.74	0.52	-4.22	Seniang	100-year
597	8.752845	126.1994	0.03	0	-0.03	Seniang	100-year
598	8.753899	126.1976	0.07	0.5	0.43	Seniang	100-year
599	8.753772	126.1956	0.09	1	0.91	Seniang	100-year
600	8.732091	126.203	0.79	0.4	-0.39	Seniang	100-year
601	8.735219	126.2057	0.21	0.3	0.09	Seniang	100-year
602	8.73502	126.2124	1.3	0.56	-0.74	Seniang	100-year
603	8.751938	126.2078	0.47	0.1	-0.37	Seniang	100-year
604	8.753221	126.2081	4.28	1.15	-3.13	Seniang	100-year
605	8.751355	126.2129	0.41	0.26	-0.15	Seniang	100-year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/ Date	Rain Return /Scenario
	Lat	Long					
606	8.750653	126.2135	1.43	0.48	-0.95	Seniang	100-year
607	8.748923	126.2177	1.44	0.9	-0.54	Seniang	100-year
608	8.748922	126.2185	1.56	0.79	-0.77	Seniang	100-year
609	8.748272	126.2159	1.06	0.59	-0.47	Seniang	100-year
610	8.746614	126.2164	1.63	0.4	-1.23	Seniang	100-year
611	8.7431	126.215	1.43	0.89	-0.54	Seniang	100-year
612	8.746587	126.213	1.39	0.55	-0.84	Seniang	100-year
613	8.747305	126.2133	1.37	0.65	-0.72	Seniang	100-year
614	8.743521	126.2047	0.23	1.53	1.3	Seniang	100-year
615	8.743094	126.2053	0.93	0.58	-0.35	Seniang	100-year
616	8.742383	126.2055	1.33	0.76	-0.57	Seniang	100-year
617	8.740219	126.2057	0.67	0	-0.67	Seniang	100-year
618	8.740944	126.2057	1.37	0.4	-0.97	Seniang	100-year

Annex 12. Educational Institutions Affected by flooding in Hubo-Otieza Flood Plain

Table A-12.1. Educational Institutions in San Agustin, Surigao del Sur affected by flooding in Hubo-Otieza Floodplain

Surigao del Sur				
Municipality of San Agustin				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Salvacion National High School	Buatong	0	0	0
Hornasan Elementary School	Hornasan	2	2	2
Kauswagan Elementary School	Kauswagan	1	2	2
Otieza Elementary School	Oteiza	0	0	0
San Agustin Central Elementary School	Poblacion	0	0	1
Britania Elementary School	Salvacion	0	0	0
Campanubay Elementary School	Salvacion	1	2	2
Salvacion Elementary School	Salvacion	0	1	1
Pong-on Elementary School	Santo Niño	0	0	0
Santo Niño National High School	Santo Niño	1	2	2
Santo Niño National High School	Santo Niño	1	2	2
Santo Niño National High School	Santo Niño	1	2	2
Santo Niño Elementary School	Santo Niño	0	1	1
Santo Niño National High School	Santo Niño	2	2	2