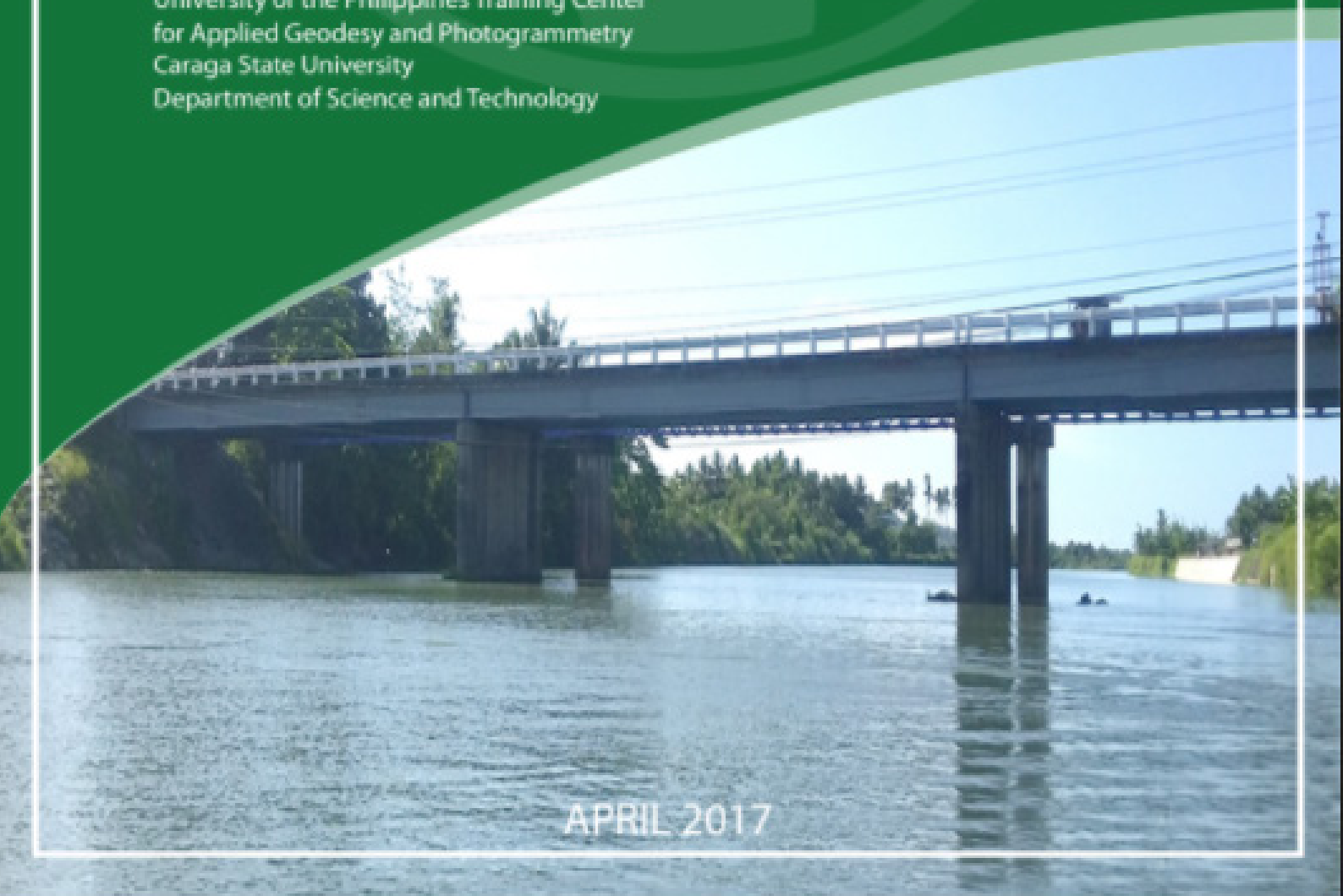
Hazard Mapping of the Philippines Using LIDAR (Phil-LIDAR 1)

LiDAR Surveys and Flood Mapping of Surigao River

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



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

CHAPTER 1: OVERVIEW OF THE PROGRAM AND SURIGAO RIVER

Engr. Meriam M. Santillan and Enrico C. Paringit, Dr. Eng.

1.1 Background of the Phil-LIDAR 1 Program

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

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 Surigao River Basin

Surigao River Basin is located in the Province of Surigao del Norte in the eastern portion of Mindanao, Philippines. It lies generally between 125**°26**' to 125°33' east longitude and 9**°36**' to 9**°48**' north latitude. It includes a major part of Surigao City and Municipality of Sison, Surigao del Norte. The basin covers an area of approximately 188 square kilometers, and is about 24 kilometers from north to south and averages about 8 kilometers from west to east.

The Surigao River is the principal drainageway of the basin. It originates in Barangay Silop, Municipality of Mainit, Surigao del Norte and traverses the entire length of the basin in a northerly direction and then discharges into Bilang-bilang Bay in Barangay Sabang, Surigao City. The river channel is narrow and navigable by motor boats up to about 5 kilometers from the outlet to upstream. Several tributaries such as Bonifacio River in Barangay Bonifacio and Trinidad River in Barangay Trinidad, Surigao City, Surigao del Norte which originates from the west has contributed directly to Surigao River.

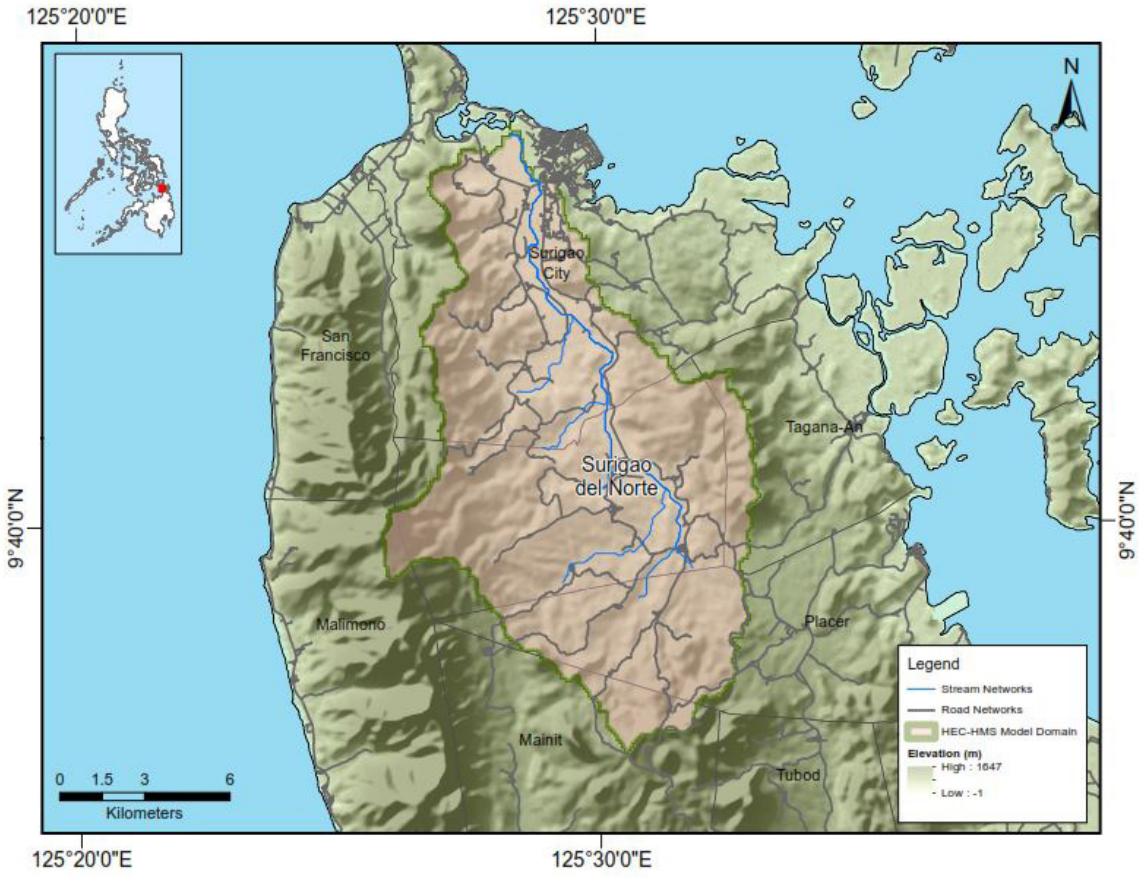


Figure 1. Map of Surigao River Basin (in brown).

The climate in Surigao River Basin is tropical, and classified as Af by the Köppen-Geiger system. The wet season of the basin fall between the months of November until March and dry season starts between April to September. Rainfall is significant, with precipitation even during the driest month. The temperature averages 27.0 °C and about 3582 mm of precipitation falls annually[1].

The basin's highest point is at 818 meters above mean sea level situated along the mountain ridges of the Barangay Jubgan, Municipality of San Francisco, Surigao del Norte[2]. The most abundant soil type in the basin based on maps published by the Department of Agriculture is clay loam which accounts for 68% of the basin's land area. The basin is mostly covered by brush land and cultivated areas leaving the built-up areas only covering 1% of the basin.

Built-up areas and communities in the basin are concentrated in Surigao City in the northeastern part of the basin. The city is blessed with abundant mineral reserves, fisheries, and aquatic resources as well as tracts of fertile arable lands, which are the prime sources of its people's livelihood. Its location along the coast offers a wide array of white sand or black pebbled beaches. Surigao City's population as of the year 2000 census was 118,534, growing at a rate of 2.56%[3].

Its land use is classified into two uses based on DENR's data, namely: Alienable and Disposable lands (A&D) of 14,883 hectares or 57% and Forest Land of 11,234 hectares or 43%. Forestland is divided in two categories; Production Forest of 11,091.388 hectares which is located at Barangays Day-asan, San Isidro and Nabago and Protection Forest of 142.612 hectares.

There are two headwaters of the watershed, namely: Parang-Parang and Lumaban areas. The first

1 https://en.climate-data.org/region/1904/

2 The NAMRIA. Retrieved from http://www.namria.gov.ph/4120-IIITubod.html

3 The Department of Tourism. Region XIII (CARAGA), Surigao City. Retrieved from http://www.tourism.gov.ph/SitePages/InteractiveSitesPage.aspx?siteID=75

headwater covers a total area of 69.60 hectares at Parang-Parang, Mabini. The whole area is proclaimed protected area under Presidential Proclamation No. 365. The other watershed is located at Sitio Lumaban-Balibayon, Barangay Rizal with an area of 73.012 hectares[4].

In November 4, 2016 the weather bureau reported that the low pressure area is spotted in the vicinity of Sorsogon City (13.0°N, 124.2°E) embedded along the Intertropical Convergence Zone (ITCZ) affecting Southern Luzon, Visayas and Mindanao. Surigao City experienced flash floods brought by a heavy downpour and floodwaters rose ankle to knee-deep along within streets of the City particularly in Navarro, Borromeo San Nicolas, Diez, Sarvida, Roxas and Narcisco and Kilometer 1, National Highway, Gemina Vasques streets were impassable as floodwaters rose from knee to waist-deep. The rain gauge in the city recorded 15 millimeter per hour as of 4 PM, prompting them to declare an alert level 1. At 6PM, the alert level rose to number 2 as the rain gauge measured. 26.7 millimeter per hour with a total of 82 millimeter from 3 PM to 6PM[5]. Fortunately, there are no reported casualties and damages after the said flooding occurred.

4 City Government of Surigao, (*2015) Surigao City Ecological Profile (formerly Socio-Economic Profile).* Retrieved from http://www.surigaocity.gov.ph/document/socio-economic-profile

5 Catoto, R. (2016, November 05). Flash flood hits Surigao City. Retrieved July 04, 2017, from http://www.mindanews.com/top-stories/2016/11/flash-flood-hits-surigao-city/

CHAPTER 2: LIDAR DATA ACQUISITION OF THE SURIGAO FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Gracia Acuña, Engr. Gerome Hipolito, Engr. Christopher L. Joaquin and Ms. Mary Catherine Elizabeth M. Baliguas

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 Surigao floodplain, the Data Acquisition Component (DAC) created flight plans within the delineated priority area for Surigao Floodplain in Surigao del Norte. These flight missions were planned for 11 lines and ran for at most four and a half hours (4.5) including take-off, landing and turning time. The flight planning parameters for the LiDAR system are outlined in Table 1and Table 2. Figure 2 and Figure 3 shows the flight plan for Surigao floodplain survey.

Table 1. Flight planning parameters for the Gemini LiDAR system.

Block Name	Flying Height (m AGL)	Over-lap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK 59C	700/ 1300	30	50/22	167/100	40	130/125	5
BLK 59E	1300	30	22	100	50	125	5
BLK 59ES	1000	30	40	100	50	120	5
BLK 59F	900/1000/1200	30	40	125/100	50	120	5
BLK 59G	1000/900/750/600	30	40	125/167	50	120/130	5
BLK 60D	1200/1000	30	40	100	45	120	5

Table 2. Flight planning parameters for Aquarius LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK 59A	500	30	36	50	45	120	5
BLK 59B	500	30	36	50	45	120	5
BLK 59C	500	30	36	50	45	120	5
BLK 59G	600	30	36	50	45	120	5
BLK 59F	600	30	36	50	45	120	5

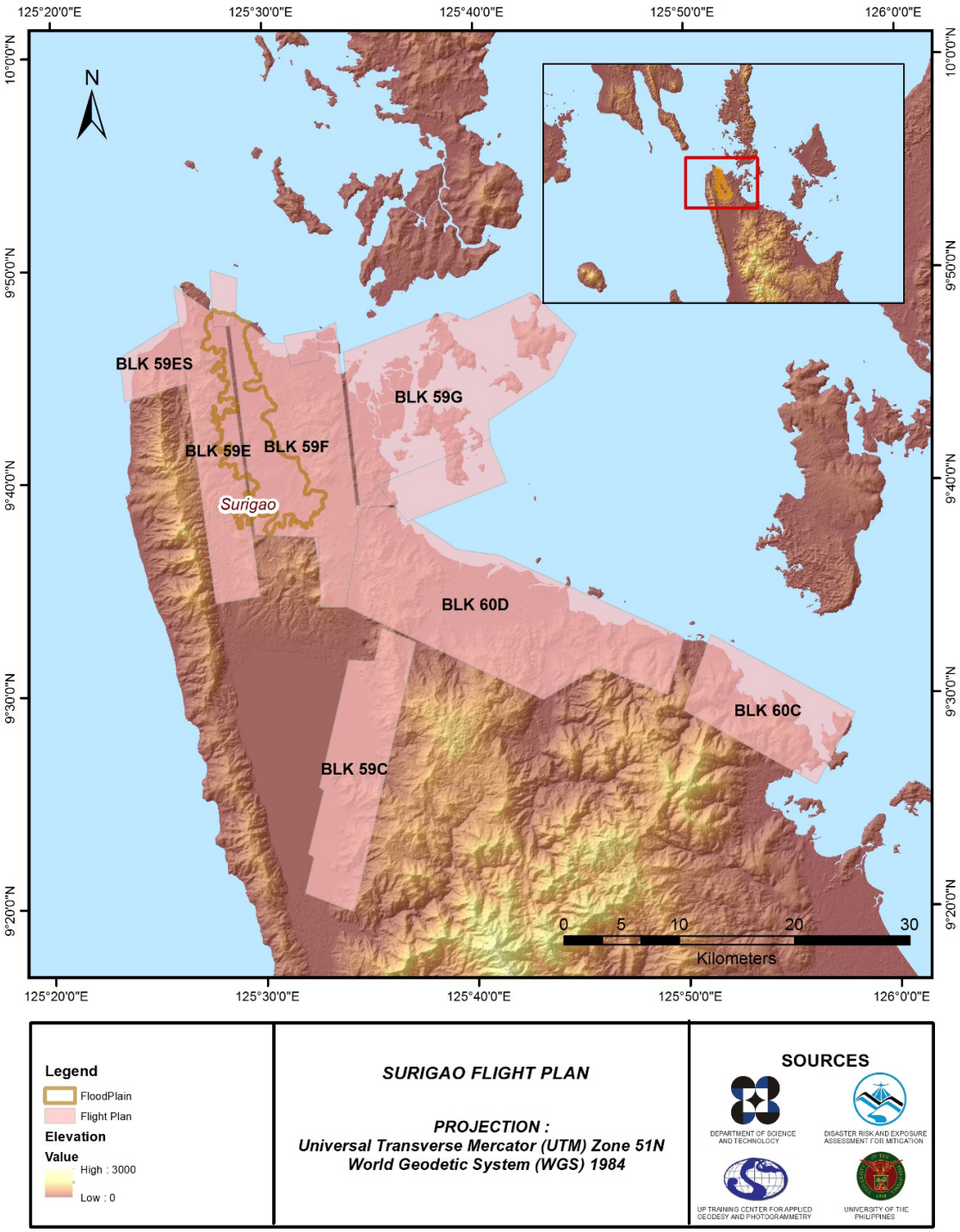


Figure 2. Flight plans and base stations used for Surigao floodplain using Gemini LiDAR system.

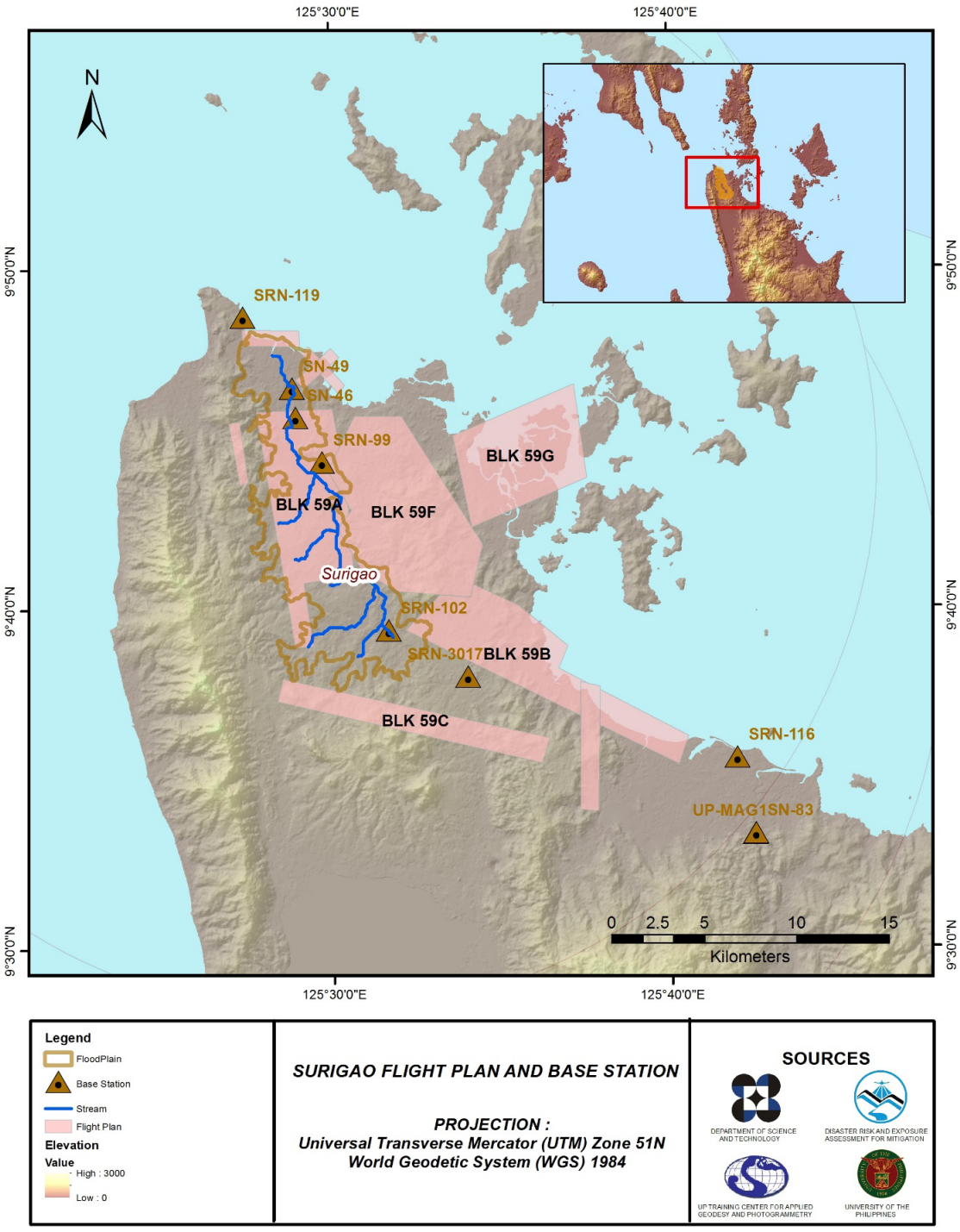


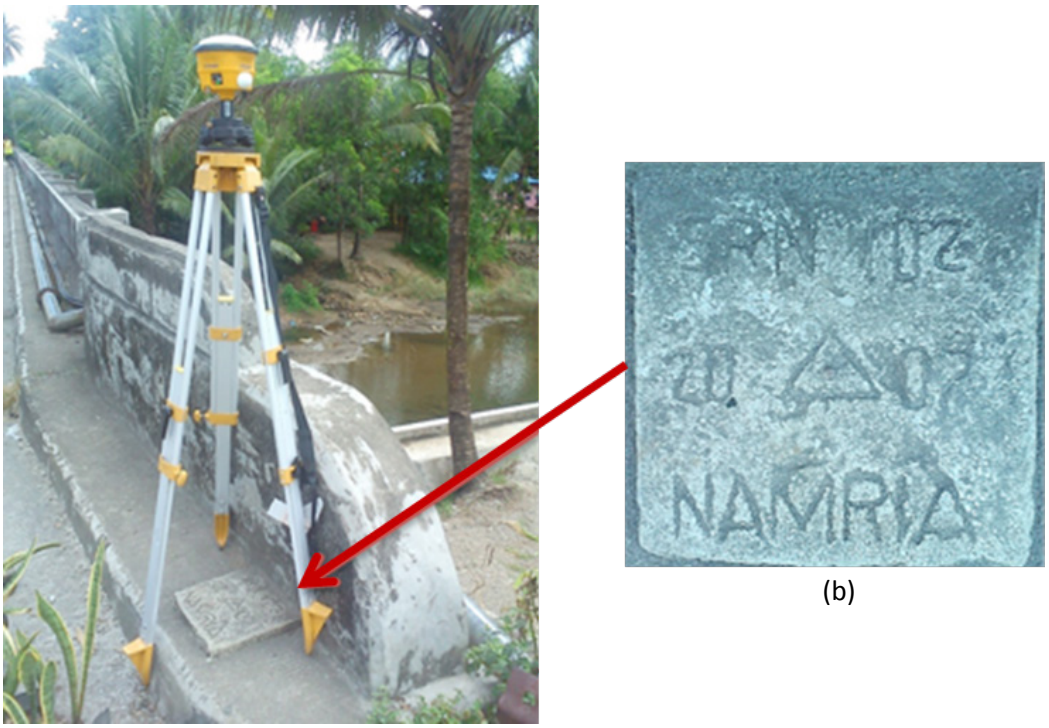
Figure 3. Flight plans and base stations used for Surigao floodplain using Aquarius LiDAR system.

2.2 Ground Base Stations

The project team was able to recover four (4) NAMRIA horizontal ground control points: SRN-99, SRN-102, SRN-116 and SRN-119 which are all of second (2nd) order accuracy. The project team also re-processed ground control points: SRN-3181 and SRN-3017; and established one (1) ground control point: UP-MAG1. Two (2) NAMRIA benchmarks were recovered, SN-46 and SN-49 which are of second (2nd) order accuracy. These benchmarks were used as vertical reference point and were also established as ground control points.

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 May 30 to June 9, 2014; September 20-21, 2014; and May 8-13, 2016. 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 Surigao floodplain are shown in Figure 2 and Figure 3.

The succeeding sections depict the sets of reference points, control stations and established points, and the ground control points for the entire Surigao Floodplain LiDAR Survey. Figure 4 to Figure 7 show the recovered NAMRIA reference points and established point within the area of the floodplain, while Table 3 to Table 11 show the details about the following NAMRIA control stations and established points. Table 12, on the other hand, shows the list of all ground control points occupied during the acquisition together with the corresponding dates of utilization.



(a) (b)

Figure 4. GPS set-up over SRN-102 located at the first approach of Patag Bridge, Municipality of Sison, Surigao del Norte (a) and NAMRIA reference point SRN-102 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point SRN-102 used as base station for the LiDAR acquisition.

Station Name	SRN-102	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9° 39' 24.81730" North 125° 31' 35.42419" East 35.04700 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	1067829.026 meters 557783.962 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9° 39' 21.00341" North 125° 31' 40.71501" East 102.29400 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS1992)	Easting Northing	777426.956 meters 1068387.750 meters

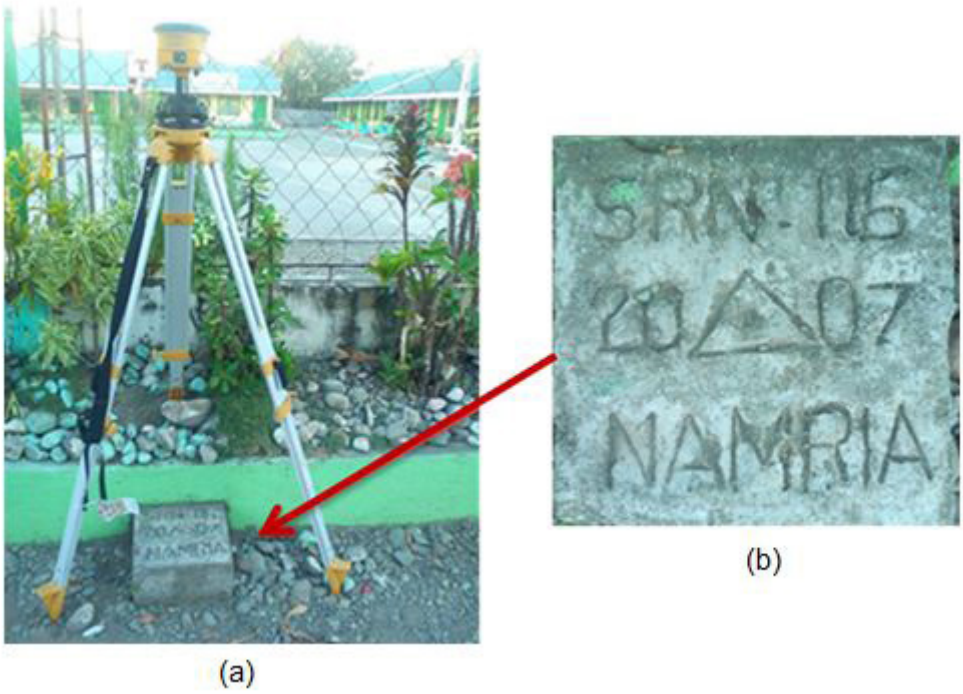


Figure 5. GPS set-up over SRN-116 located in front and near the fence of Ipil Primary School, Gigaquit, Surigao del Norte (a) and NAMRIA reference point SRN-116 (b) as recovered by the field team.

Table 4. Details of the recovered NAMRIA horizontal control point SRN-116 used as base station for the LiDAR acquisition.

Station Name	SRN-116	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9° 35' 38.35819" North 125° 41' 52.08650" East 2.65000 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	576598.493 meters 1060905.34 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9° 35' 34.57572" North 125° 41' 57.38121" East 70.45900 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS1992)	Easting Northing	796293.133 meters 1061570.526 meters

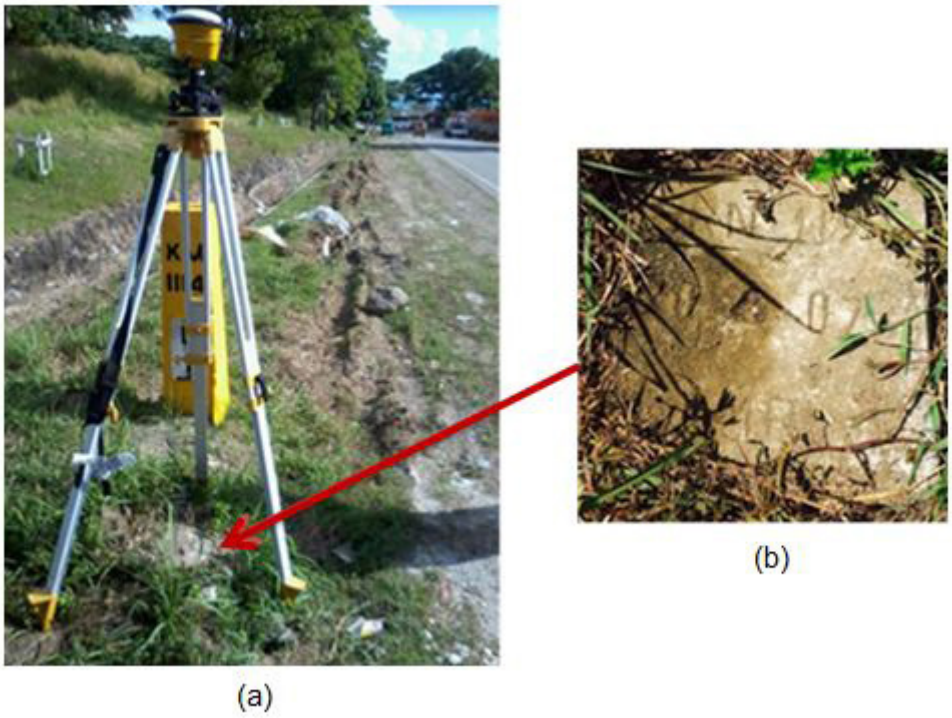


Figure 6. GPS set-up over SRN-119 located beside Kilometer Post 1114 along the National Highway, Surigao City, Surigao del Norte (a) and NAMRIA reference point SRN-119 (b) as recovered by the field team.

Table 5. Details of the recovered NAMRIA horizontal control point SRN-119 used as base station for the LiDAR acquisition.

Station Name	SRN-119	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9° 48' 39.53835" North 125° 27' 19.47825" East 26.17900 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	549958.116 meters 1084859.315 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9° 48' 35.66803" North 125° 27' 24.75607" East 92.90500 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS1992)	Easting Northing	769495.998 meters 1085380.264 meters

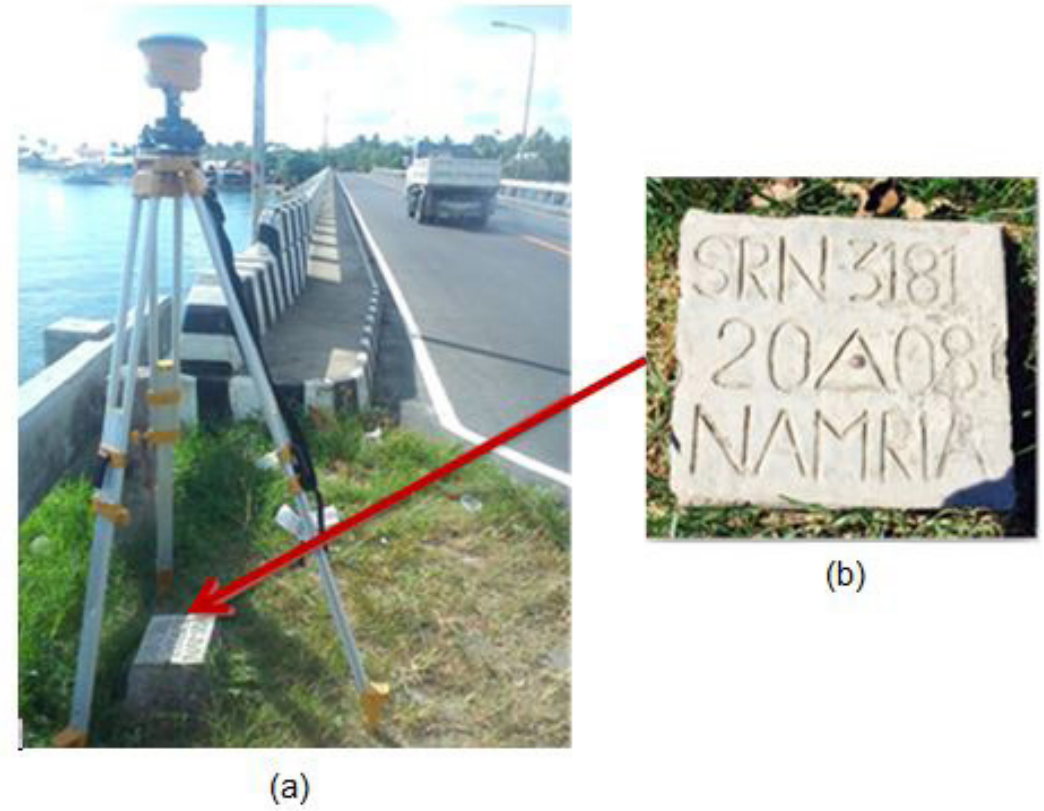


Figure 7. GPS set-up over SRN-3181 located near the edge of Sabang Bridge, Surigao City, Surigao del Norte (a) and NAMRIA reference point SRN-3181 (b) as recovered by the field team.

Table 6. Details of the recovered NAMRIA horizontal control point SRN-3181 used as base station for the LiDAR acquisition.

Station Name	SRN-3181	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9° 47'54.85423" North 125° 28' 17.37359" East 4.873 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9° 47' 50.99862" North 125° 28' 22.65237" East 71.666 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS1992)	Easting Northing	771112.645meters 1084069.428meters

Table 7. Details of the recovered NAMRIA horizontal control point SRN-3017 used as base station for the LiDAR acquisition.

Station Name	SRN-3017	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9° 37'58.98617" North 125° 34' 00.72582" East 151.234 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9° 38' 02.79068" North 125° 33' 55.43339" East 83.340 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS1992)	Easting Northing	781557.728meters 1065947.166meters

Table 8. Details of the recovered NAMRIA vertical control point SN-46 used as base station for the LiDAR acquisition with established coordinates.

Station Name	SN-46	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9° 45' 41.79368" North 125° 28' 52.27552" East 6.010 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9° 45' 37.94854" North 125° 28' 57.55750" East 72.910 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS1992)	Easting Northing	772206.8798meters 1065947.166meters

Table 9. Details of the recovered NAMRIA vertical control point SN-49 used as base station for the LiDAR acquisition with established coordinates.

Station Name	SN-49	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9° 46' 29.35520" North 125° 28' 51.39573" East 73.947 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9° 46' 29.35520" North 125° 28' 51.393573" East 73.947 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS1992)	Easting Northing	772166.046meters 1081516.934meters

Table 10. Details of the recovered NAMRIA vertical control point SN-83 used as base station for the LiDAR acquisition with established coordinates.

Station Name	SN-83	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9° 33' 23.94445" North 125° 42' 24.18740" East 12.853 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9° 33' 20.17252" North 125° 42' 29.48535" East 80.767 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS1992)	Easting Northing	797146.192meters 1057494.439meters

Table 11. Details of the established control point UP-MAG1 used as base station for the LiDAR acquisition.

Station Name	UP-MAG1	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9° 33' 23.85603" North 125° 42' 23.93365" East 12.425 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9° 33' 20.08411" North 125° 42' 29.23160" East 80.339 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS1992)	Easting Northing	797146.192meters 1057494.439meters

Table 12. Ground control points used during the LiDAR data acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
May 30, 2014	7280GC	2BLK59FG150A	SRN-119 and SRN-3181
May 30, 2014	7281GC	2BLK59F150B	SRN-119 and SRN-3181
May 31, 2014	7282GC	2BLK59EFS151A	SRN-119 and SRN-3181
May 31, 2014	7283GC	2BLK59GS151B	SRN-119 and SRN-3181
June 1, 2014	7284GC	2BLK59GS152A	SRN-119 and SRN-3181
June 3, 2014	7288GC	2BLK59C+ BLK60D154A	SRN-102 and SRN-3017
June 5, 2014	7292GC	2BLK60DS156A	SRN-102 and SRN-3017
June 5, 2014	7293GC	2BLK59GS156B	SRN-102 and SRN-3017

June 6, 2014	7295GC	2BLK59GS+FV157B	SRN-119 and SRN-3181
June 7, 2014	7296GC	2BLK60CDS158A	SRN-116 and SRN-3017
June 7, 2014	7297GC	2BLK59ES158B	SRN-119 and SRN-3181
June 9, 2014	7300GC	2BLK59FG+BLK60DCV160A	SRN-116 and SRN-3017
September 20, 2014	1970A	3BLK59S263A	SRN-119 and SN-49
September 21, 2014	1974A	3BLK59S264A	SRN-102 and SN-49
May 8, 2016	8481AC	3BLK59AB129A	SN-83 and UP-MAG1
May 10, 2016	8485AC	3BLK59BC131A	SRN-116 and SN-83
May 13, 2016	8491AC	3CALIB134A & 3BLK59C134A	SRN-99 and SN-46

2.3 Flight Missions

A total of seventeen (17) missions were conducted to complete the LiDAR data acquisition in Surigao floodplain, for a total of fifty-four and one minute (54+1) of flying time for RP-C9122 and RP-9322 (See Annex 6). All missions were acquired using Gemini and Aquarius system. As shown below, the total area of actual coverage per mission and the corresponding flying hours are depicted in Table 13, while the actual parameters used during the LiDAR data acquisition are presented in Table 14.

Table 13. Flight missions for LiDAR data acquisition in Surigao 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
May 30, 2014	7280GC	48.26	60.27	32.85	27.42	0	2	23
May 30, 2014	7281GC	74.27	102.19	1.96	100.23	0	2	29
May 31, 2014	7282GC	279.1	184.5	46.67	137.83	0	4	17
May 31, 2014	7283GC	231.9	91.98	0	91.98	0	2	23
June 1, 2014	7284GC	231.9	36.84	0	36.84	0	2	35
June 3, 2014	7288GC	388.35	241.74	1.18	240.56	0	4	23
June 5, 2014	7292GC	272.32	167.59	0.95	166.64	0	3	59
June 5, 2014	7293GC	231.9	242.05	3.26	238.79	0	2	11
June 6, 2014	7295GC	56.08	98.83	5.85	92.98	0	2	11
June 7, 2014	7296GC	126.2	188.31	6.33	181.98	0	4	29
June 7, 2014	7297GC	28.15	40.13	0	40.13	0	1	53

June 9, 2014	7300GC	54.23	136.23	11.55	124.68	0	3	41
Sept. 20, 2014	1970A	34.45	49.31	0	49.31	0	2	41
Sept. 21, 2014	1974A	54.13	61.79	3.28	58.51	0	3	11
May 8, 2016	8481AC	83.6	85.71	44.09	41.62	0	4	17
May 10, 2016	8485AC	62.22	67.12	0.85	66.27	0	3	47
May 13, 2016	8491AC	25.91	39.25	3.53	35.72	0	3	11
TOTAL		2282.97	1893.84	162.35	1731.49	0	54	1

Table 14. Actual parameters used during LiDAR data acquisition.

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (khz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
7280GC	1000, 900	30	40, 50	100, 125	50, 40	120	5
7281GC	1000, 900	30	40, 50	100, 125	50, 40	110	5
7282GC	1300	30	22	70	50	120	5
7283GC	1300	30	50	142,100	40	120	5
7284GC	750	30	60	125	30	120	5
7288GC	1300	30	22	70	50	120	5
7292GC	1300	30	22	70	50	115	5
7293GC	750	30	60	125	32	115	5
7295GC	750	30	60	125	32	115	5
7296GC	1000	30	40	70	40	115	5
7297GC	1000	30	40	100	50	115	5
7300GC	1000	30	40	100	50	115	5
1970A	600	30	36	50	45	120	5
1974A	600	30	36	50	45	115	5
8481AC	600	30	36	50	45	120	5
8485AC	500	30	36	50	45	120	5
8491AC	500	30	36	50	45	120	5

2.4 Survey Coverage

This certain LiDAR acquisition survey covered the Surigao floodplain (See Annex 7). It is located in the province of Surigao del Norte with majority of the floodplain situated within Surigao City and municipality of Sison.Municipalities of Tagana-An and Places are completely covered during the survey. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 15. Figure 8, on the other hand, shows the actual coverage of the LiDAR acquisition for theSurigao floodplain.

Table 15. List of municipalities and cities surveyed during Surigao floodplain LiDAR survey.

Province	Municipality/City	Area of Municipality/City (km^2)	Total Area Surveyed (km^2)	Percentage of Area Surveyed
Agusan del Norte	Mainit Lake	69.28	21.59	31.17%
	Kitcharao	122.41	26.99	22.05%
	Jabonga	269.89	19.35	7.17%
Surigao del Norte	Tagana-An	81.99	81.98	99.99%
	Placer	88.79	88.62	99.81%
	Bacuag	63.68	57.67	90.57%
	Sison	68.78	61.06	88.78%
	Tubod	37.53	23.55	62.75%
	Surigao City	240.67	148.37	61.65%
	Alegria	79.04	43.93	55.58%
	Claver	337.34	150.05	44.48%
	San Francisco	45.62	18.05	39.57%
	Gigaquit	119.02	41.17	34.59%
	Mainit	114.07	35.67	31.27%
	Mainit Lake	72.60	4.98	6.86%
Surigao del Sur	Carrascal	317.34	26.64	8.40%
Total		2128.05	849.71	49.04%

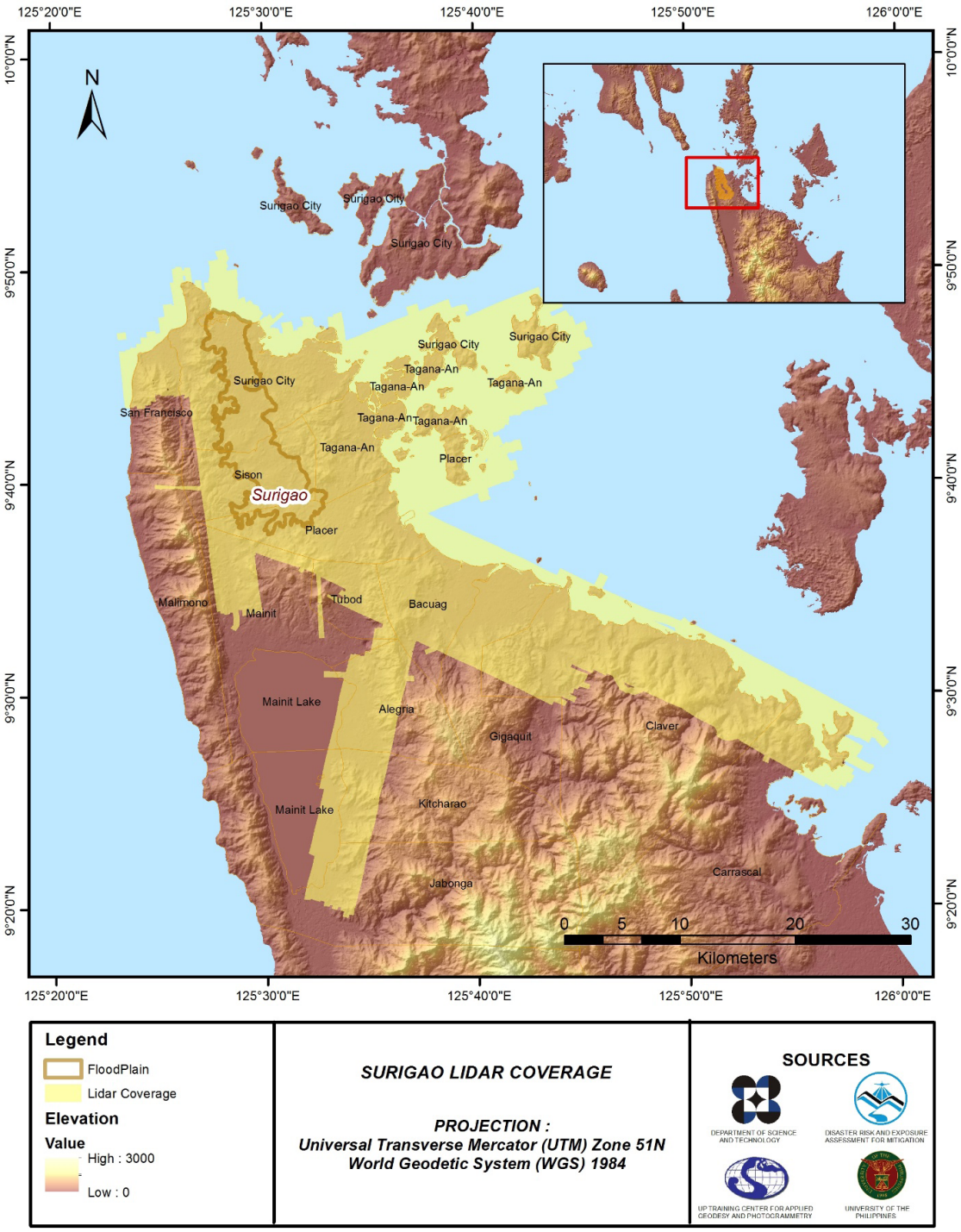


Figure 8. Actual LiDAR survey coverage for Surigao floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE SURIGAO 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 9.

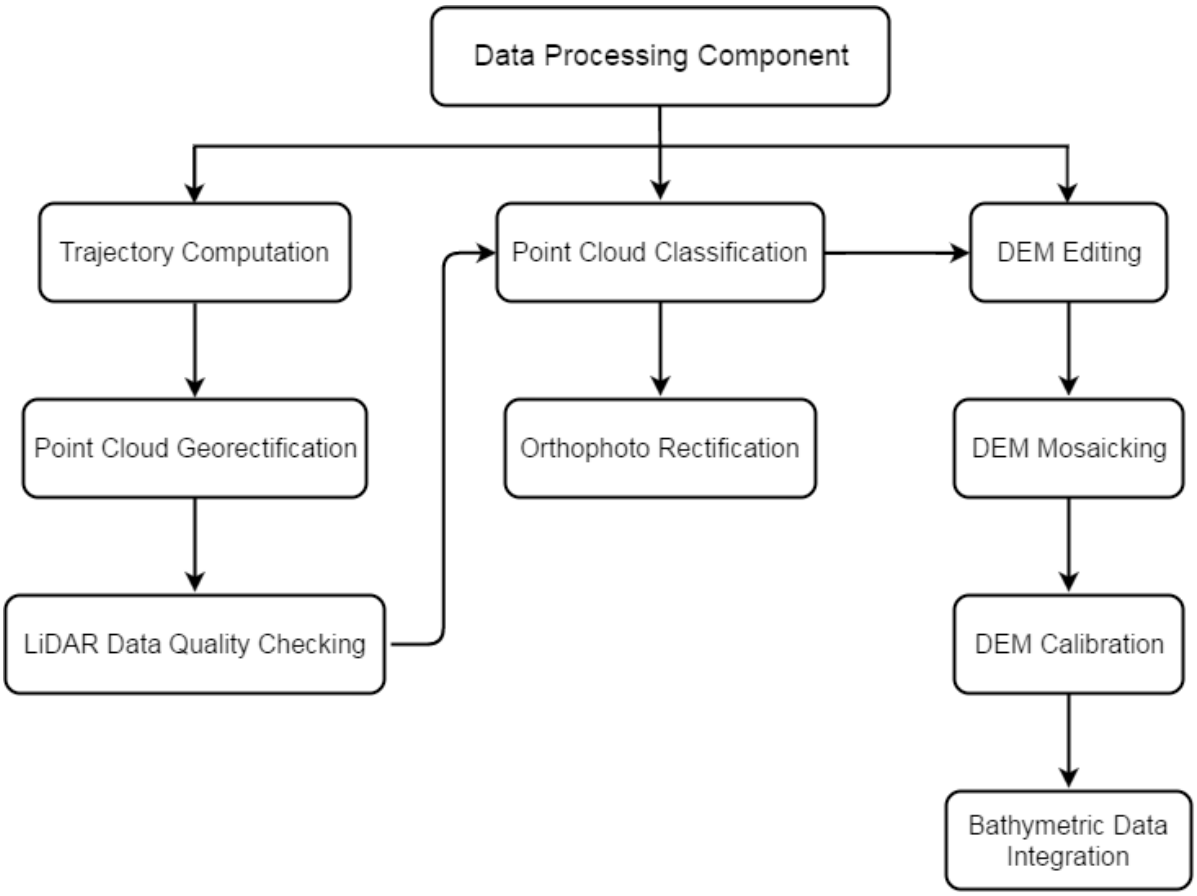

Figure 9. Schematic diagram for the data pre-processing.

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions of the Surigao 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 Norte.

The Data Acquisition Component (DAC) transferred a total of 208.81 Gigabytes of Range data, 3.16 Gigabytes of POS data, 334.61 Megabytes of GPS base station data, and 120.3 Gigabytes of raw image data to the data server on June 20, 2014 for the first survey and October 30, 2014 for the second survey, which was verified for accuracy and completeness by the DPPC. The whole dataset for the Surigao Floodplain was fully transferred on August 31, 2014, as indicated on the Data Transfer Sheets for the Surigao floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for Flight 7281GC, one of the Surigao flights, which is the North, East, and Down position RMSE values are shown in Figure 10. 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 May 30, 2014, 00:00AM. The y-axis, on the other hand, represents the RMSE value for that particular position.

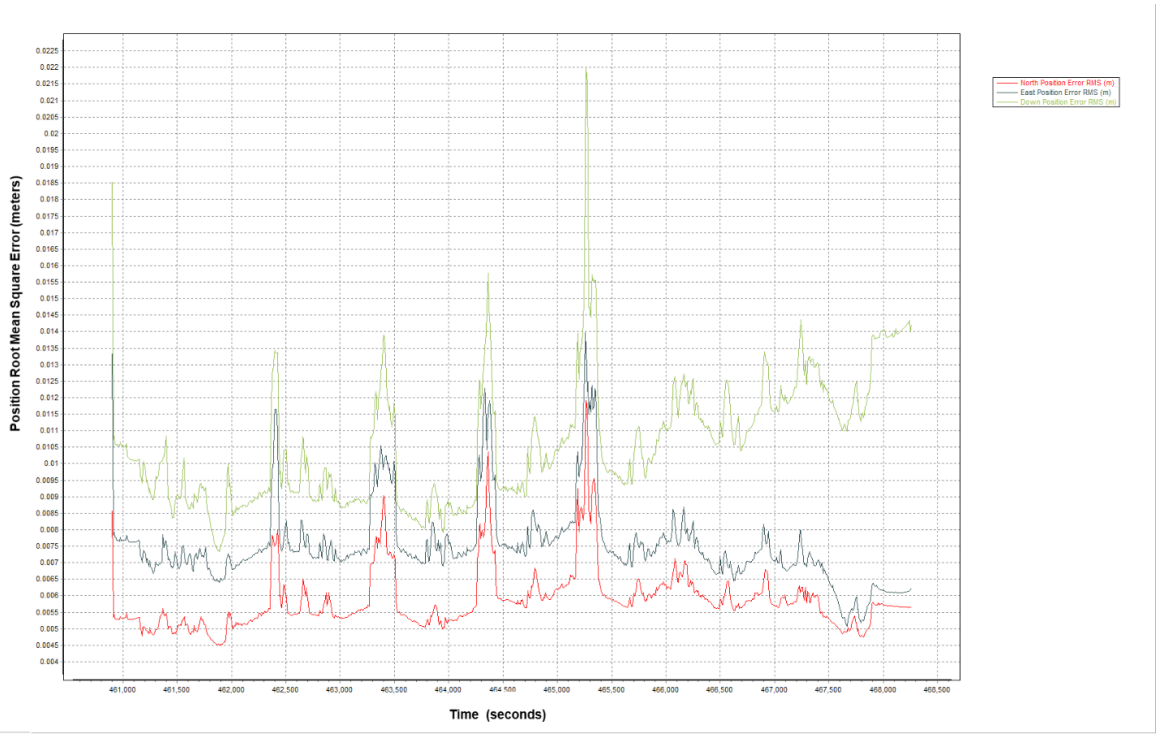

Figure 10. Smoothed Performance Metric Parameters of Surigao Flight 7281GC.

The time of flight was from 461000 seconds to 468500 seconds, which corresponds to afternoon of May 30, 2014. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft.

Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 11 shows that the North position RMSE peaks at 1.20 centimeters, the East position RMSE peaks at 1.35 centimeters, and the Down position RMSE peaks at 2.20 centimeters, which are within the prescribed accuracies described in the methodology.

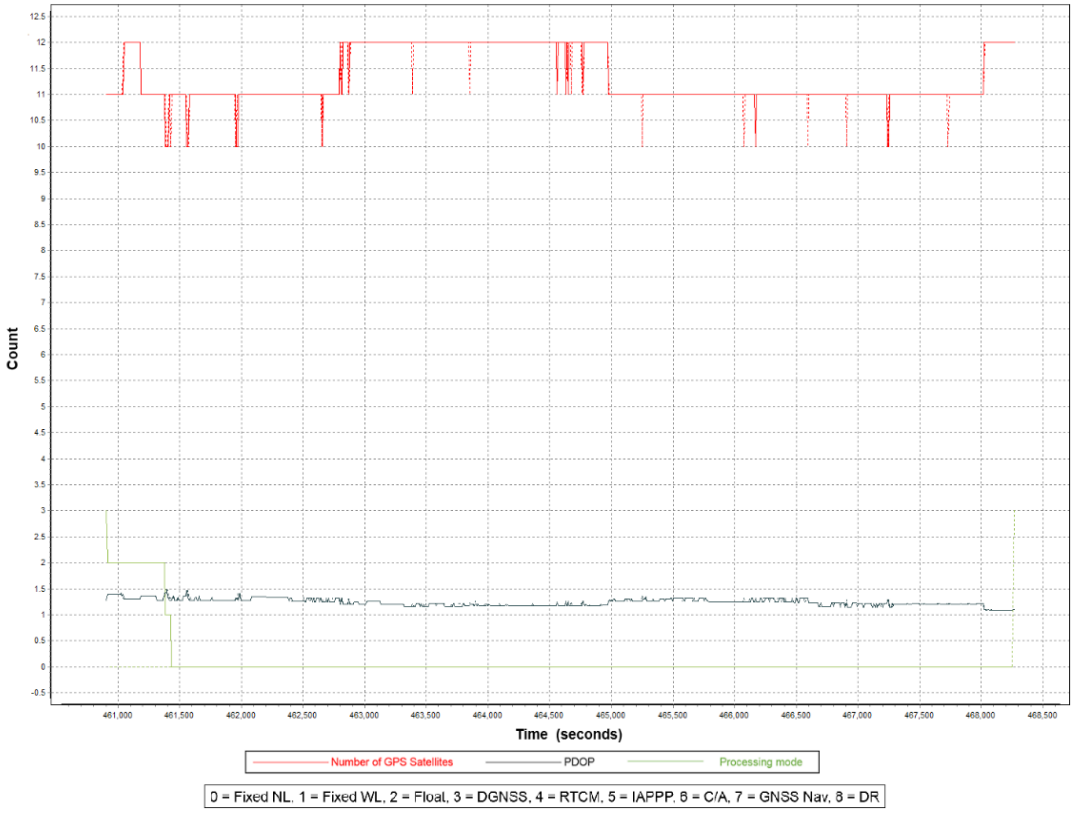

Figure 11. Solution Status Parameters of Surigao Flight 7281GC.

The Solution Status parameters, which indicate the number of GPS satellites; Positional Dilution of Precision (PDOP); and the GPS processing mode used for Surigao Flight 7281GC are shown in Figure 11. For the Solution Status parameters, the figure above signifies that the number of satellites utilized and tracked during the acquisition were between 10 and 12, not going lower than 10. 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 for majority of the surveywith some peaks up to 1 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane Mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for 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 Surigao flights is shown in Figure 12.

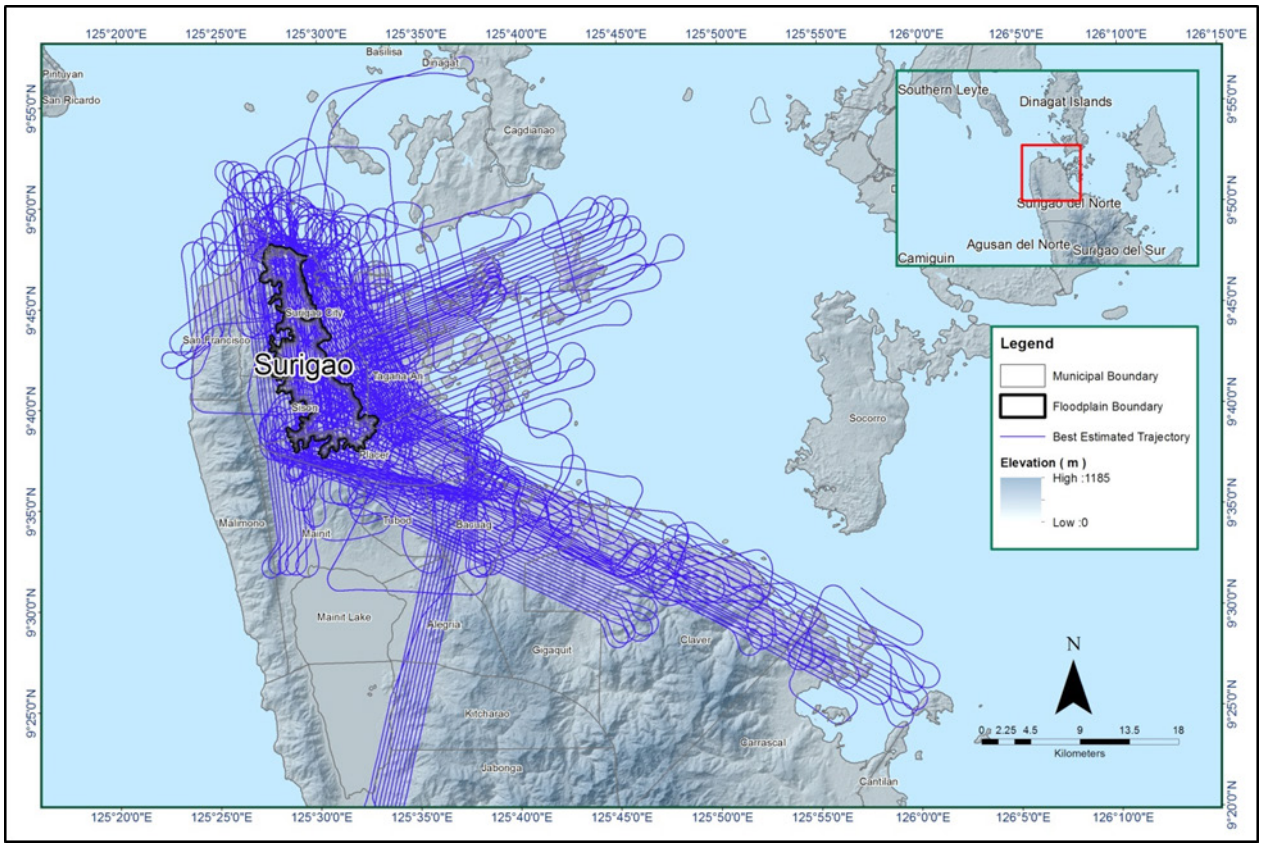

Figure 12. Best Estimated Trajectory of the LiDAR missions conducted over the Surigao Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS contains 244 flight lines, with each flight line contains one channel, since the Gemini and Aquarius system contains only one channel only. The summary of the self-calibration results obtained from LiDAR processing in the LiDAR Mapping Suite (LMS) software for all flights over the Surigao floodplain are given in Table 16.

Table 16. Self-calibration Results values for Surigaoflights.

Parameter	Acceptable Value	Computed Value
Boresight Correction stdev)	<0.001degrees	0.000221
IMU Attitude Correction Roll and Pitch Corrections stdev)	<0.001degrees	0.004631
GPS Position Z-correction stdev)	<0.01meters	0.0213

The optimum accuracy values for all Surigao 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 Surigao Floodplain is shown inFigure 13. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

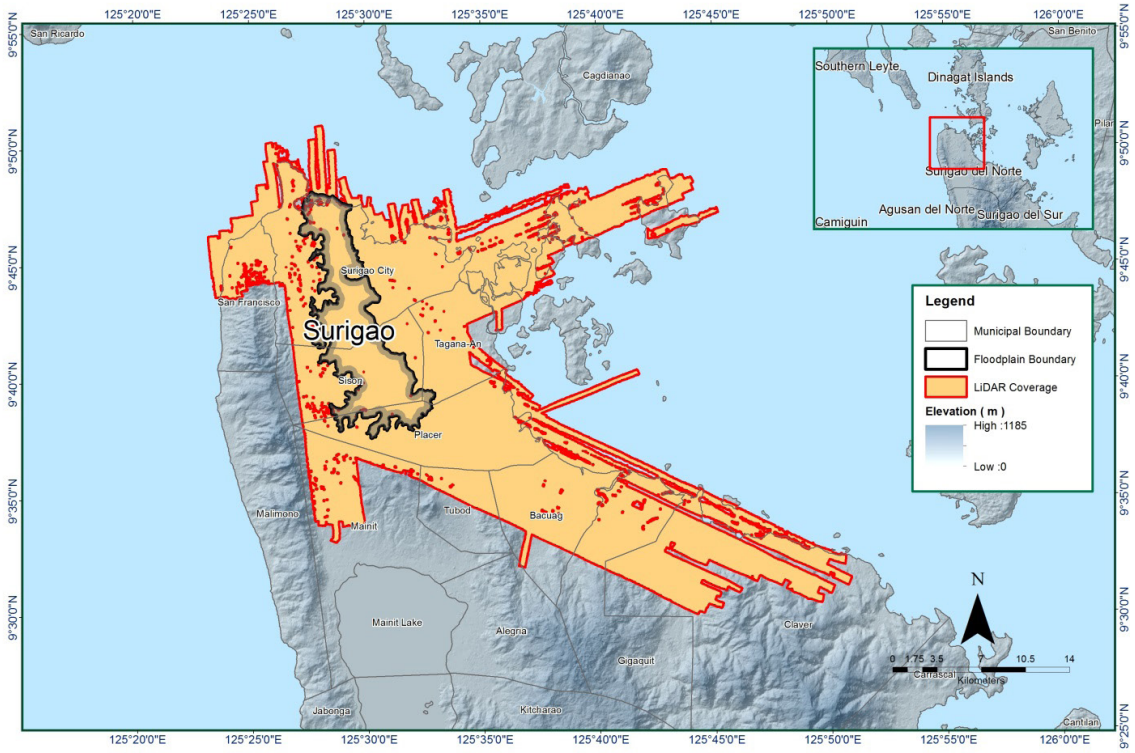

Figure 13. Boundaries of the processed LiDAR data over the Surigao Floodplain.

A total area of 1,000.15 square kilometers (sq. kms.) were covered by the Surigao flight missions as a result of eighteen (18) flight acquisitions, which were grouped and merged into fifteen (15) blocks accordingly, as portrayed in Table 17.

Table 17. List of LiDAR blocks for the Surigao floodplain.

LiDAR Blocks	Flight Numbers	Area (sq.km)
Siargao_Blk59S	59S	16.23
Surigao_reflights_Blk59D	8491AC	24.79
Surigao_reflights_Blk60D	8481AC	63.79
	8485AC	
Surigao_reflights_Blk59E	8481AC	57.89
Surigao_reflights_Blk59E_supplement	8491AC	8.89
SurigaodelNorte_Blk59D_supplement	7300GC	32.70
SurigaodelNorte_Blk59E	7282GC	106.74
SurigaodelNorte_Blk59F_supplement	1974A	60.71
SurigaodelNorte_Blk59E_extension	7282GC	45.14
SurigaodelNorte_Blk59F_additional	7300GC	10.47
SurigaodelNorte_Blk59F	7280GC	185.55
	7281GC	
	7282GC	
	7295GC	
SurigaodelNorte_Blk60D	7288GC	258.00
	7292GC	
	7296GC	
SurigaodelNorte_Blk59G_addtional	7300GC	6.62
SurigaodelNorte_Blk59G_supplement	1970A	46.40
SurigaodelNorte_Blk59G	7280GC	76.23
	7281GC	
	7283GC	
	7284GC	
	7295GC	
	7293GC	
TOTAL		**1000.15 sq. km.**

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown inFigure 14. 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.

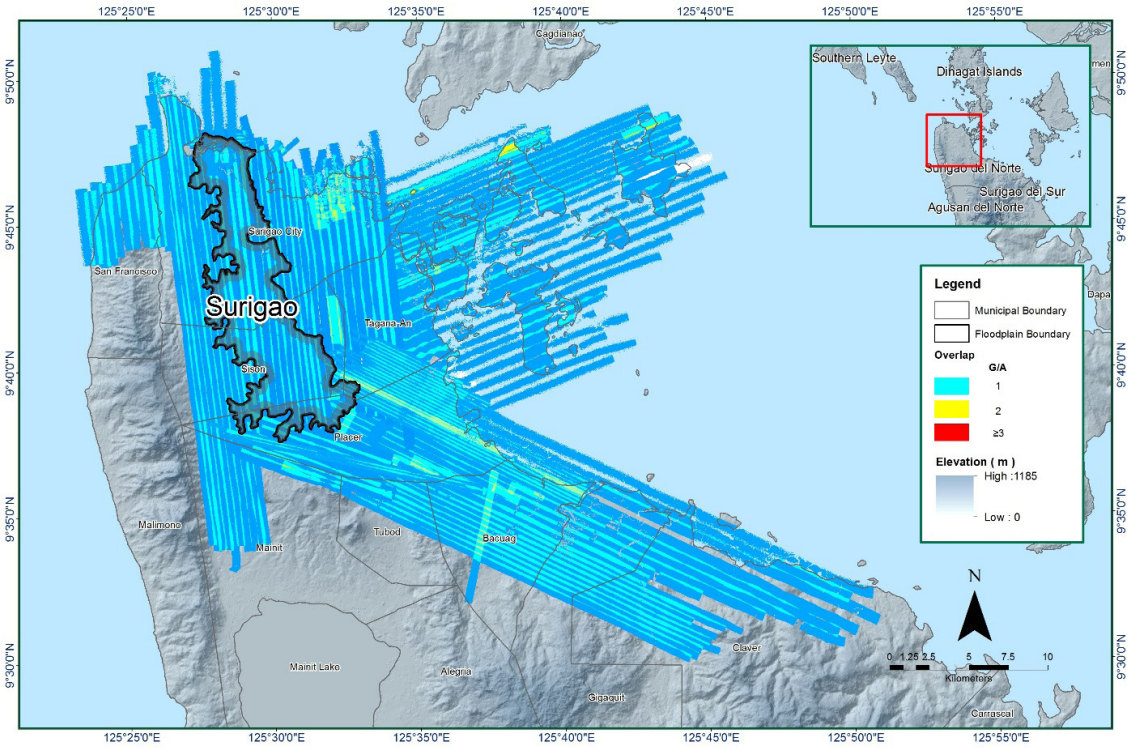

Figure 14. Image of data overlap for Surigao floodplain.

The overlap statistics per block for the Surigao 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 25.16% and 44.61%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 15. As seen in the figure below, it was determined that all LiDAR data for the Surigao Floodplain Survey satisfy the point density requirement, as the average density for the entire survey area is 3.12 points per square meter.

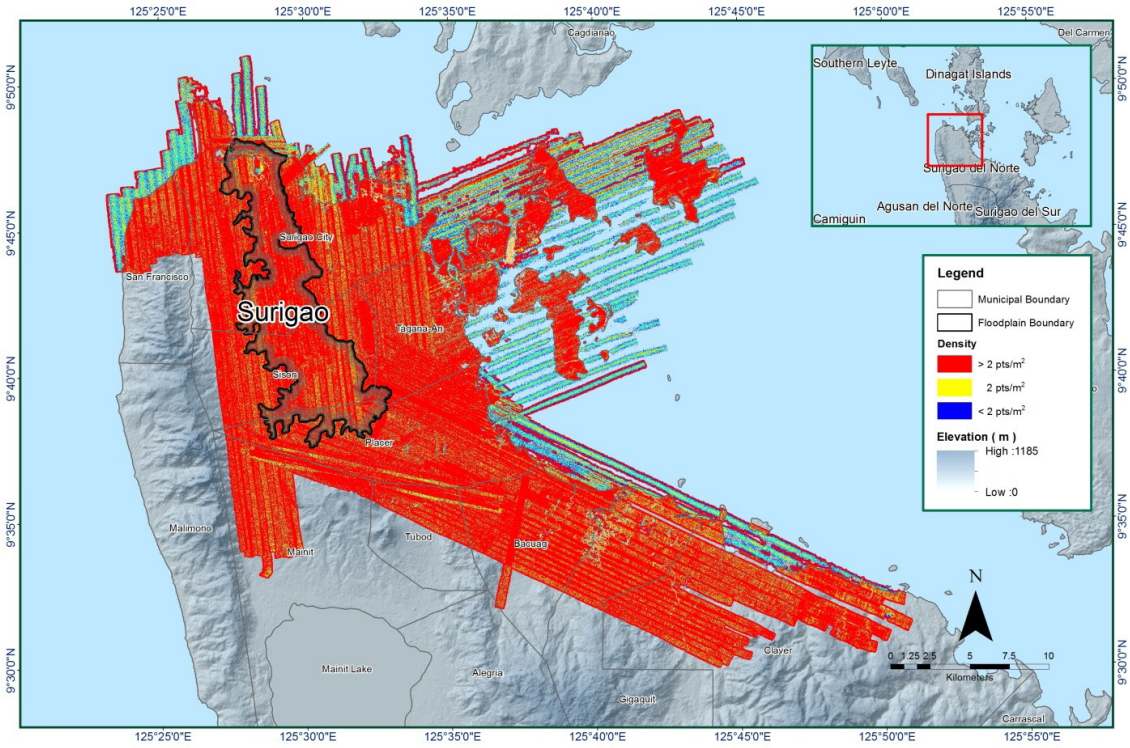

Figure 15. Pulse density map of the merged LiDAR data for Surigao floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 16. 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.

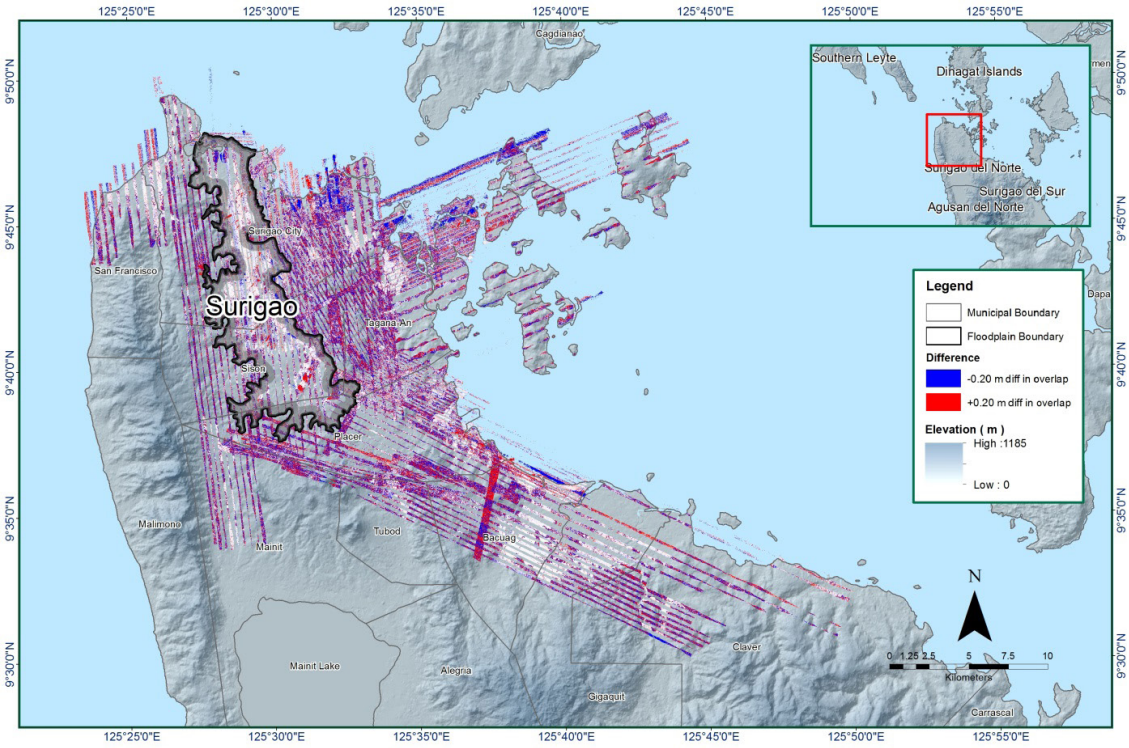

Figure 16. Elevation difference Map between flight lines for the Surigao Floodplain Survey.

A screen-capture of the processed LAS data from Surigao flight 7281GC loaded in QT Modeler is shown in Figure 17. 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.

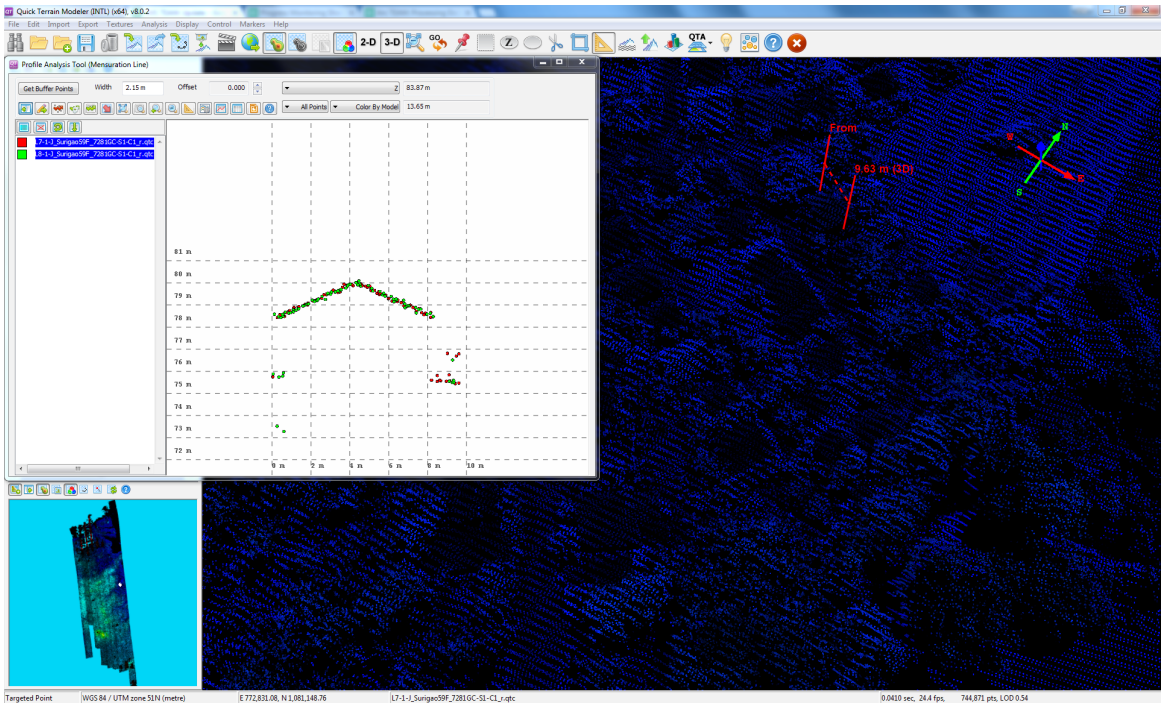

Figure 17. Quality checking for Surigao flight 7281GC using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 18. Surigao classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	371,763,853
Low Vegetation	309,730,966
Medium Vegetation	482,472,574
High Vegetation	1,521,856,344
Building	49,959,159

The tile system that TerraScan employed for the LiDAR data as well as the final classification image for a block of the Surigao floodplain is shown in Figure 18. A total of 1,596 tiles with 1 km. X 1 km. (one kilometer by one kilometer) size were produced. Correspondingly, Table 18summarizes the number of points classified to the pertinent categories. The point cloud has a maximum and minimum height of 962.45 meters and 12.81 meters respectively.

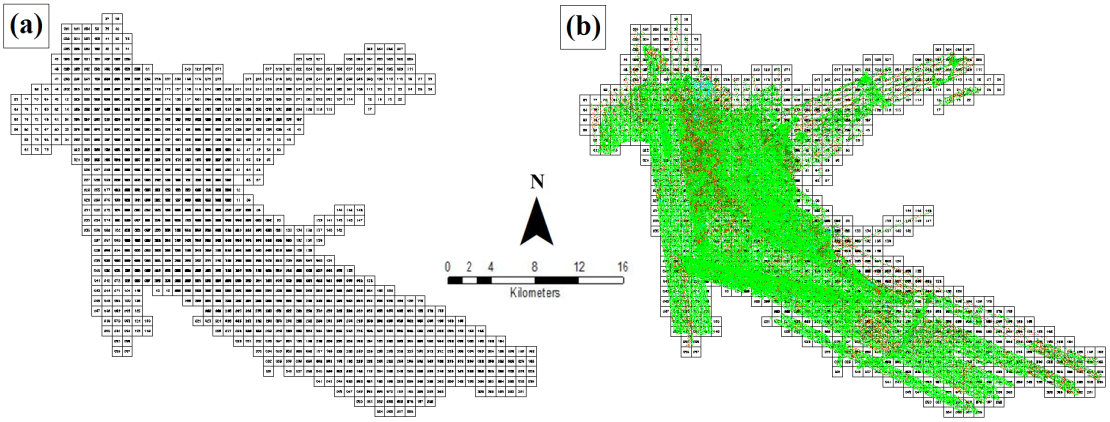

Figure 18. Tiles for Surigao floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 19. 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.

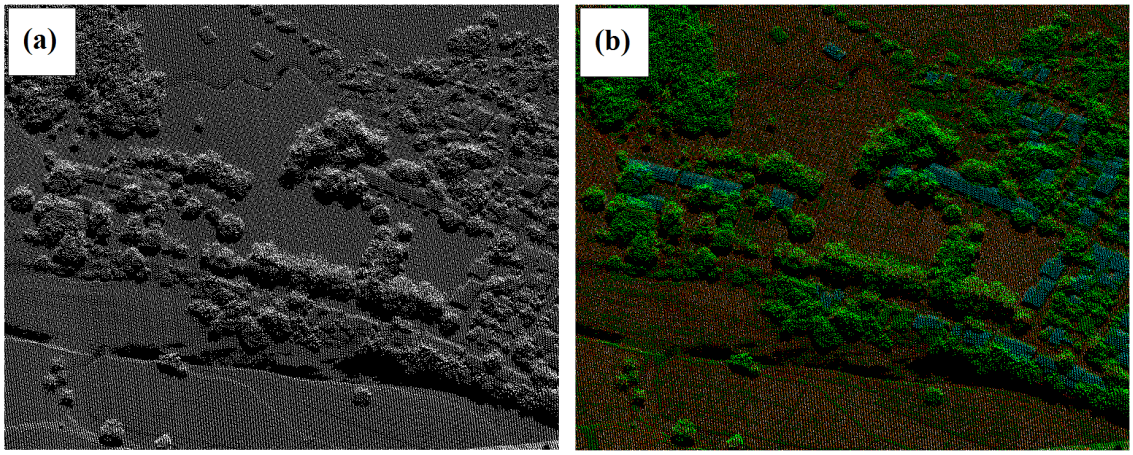

Figure 19. Point cloud before (a) and after (b) classification.

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

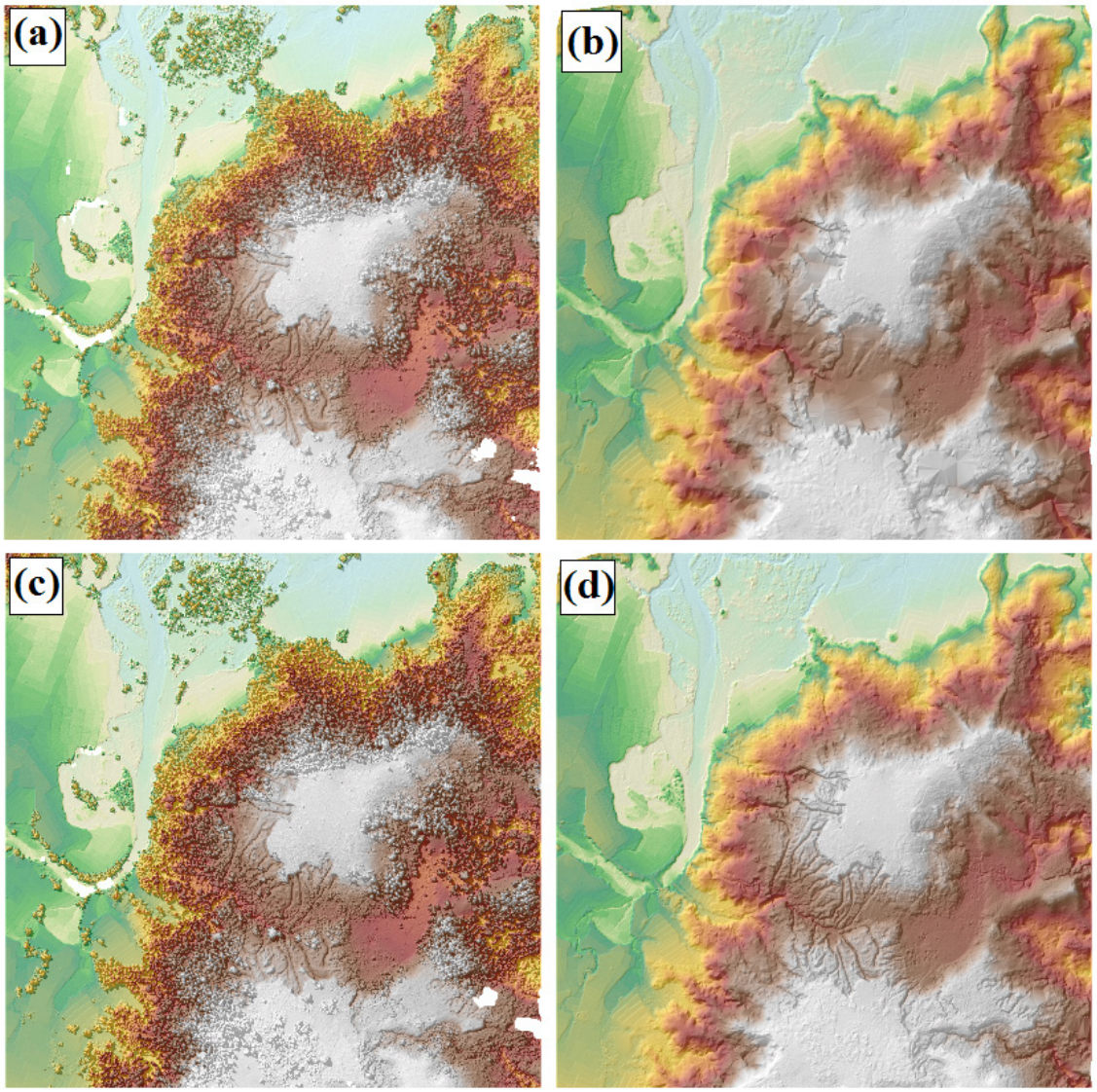

Figure 20. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Surigao floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

There are no available orthophotographs for the Surigao floodplain.

3.8 DEM Editing and Hydro-Correction

Fifteen (15) mission blocks were processed for the Surigao Floodplain Survey. These blocks are composed of Surigao del Norte blocks with a total area of 1,000.15square kilometers. Table 19shows the name and corresponding area of each block in square kilometers.

Table 19. LiDAR blocks with its corresponding areas.

LiDAR Blocks	Area (sq. km.)
Siargao_Blk59S	16.23
Surigao_reflights_Blk59D	24.79
Surigao_reflights_Blk60D	63.79
Surigao_reflights_Blk59E	57.89
Surigao_reflights_Blk59E_supplement	8.89
SurigaodelNorte_Blk59D_supplement	32.70
SurigaodelNorte_Blk59E	106.74
SurigaodelNorte_Blk59F_supplement	60.71
SurigaodelNorte_Blk59E_extension	45.14
SurigaodelNorte_Blk59F_additional	10.47
SurigaodelNorte_Blk59F	185.55
SurigaodelNorte_Blk60D	258.00
SurigaodelNorte_Blk59G_addtional	6.62
SurigaodelNorte_Blk59G_supplement	46.40
SurigaodelNorte_Blk59G	76.23
TOTAL	1,000.15 sq.km

Figure 21 shows portions of a DTM before and after manual editing. As evident in the figure, the hilly portion (Figure 21a) was misclassified and removed during the classification process. To complete the surface, the hilly portion (Figure 21b) was retrieved and reclassified through manual editing to allow the correct water flow. Likewise, the bridge (Figure 21c) has obstructed the flow of water along the river. To correct the river hydrologically, the bridge was removed through manual editing (Figure 21d). Another example is a building that is still present in the DTM after classification (Figure 21e) and has to be removed through manual editing (Figure 21f).

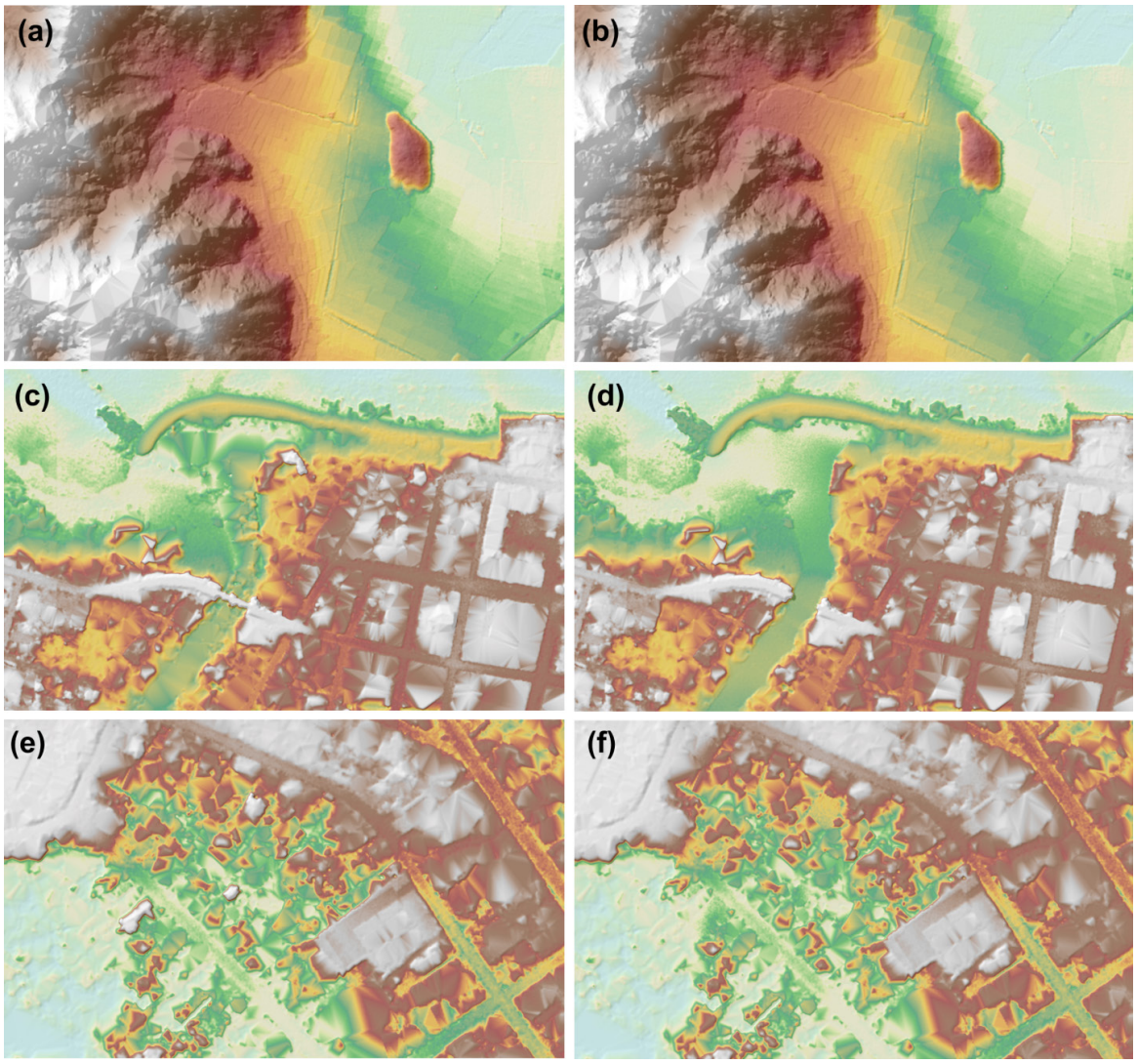

Figure 21. Portions in the DTM of the Surigao Floodplain – hilly portion before (a) and after (b) data retrieval; a bridge before (c) and after (d) manual editing; and a building before (e) and after (f) manual editing.

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 20shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Surigao Floodplain is shown in Figure 22. It can be seen that the entire Surigao floodplain is 99.92% covered by LiDAR data.

Table 20. Shift values of each LiDAR block of Surigao Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Siargao_Blk59S	0.00	0.00	0.53
Surigao_reflights_Blk59D	0.00	0.00	0.89
Surigao_reflights_Blk60D	0.00	0.00	0.63
Surigao_reflights_Blk59E	0.00	0.00	-5.95
Surigao_reflights_Blk59E_supplement	0.00	0.00	0.80
SurigaodelNorte_Blk59D_supplement	0.00	0.00	0.01
SurigaodelNorte_Blk59E	27.60	1.08	0.34
SurigaodelNorte_Blk59F_supplement	0.00	0.00	0.32
SurigaodelNorte_Blk59E_extension	0.00	0.00	0.23
SurigaodelNorte_Blk59F_additional	0.00	0.00	-0.02
SurigaodelNorte_Blk60D	0.00	0.00	-0.70
SurigaodelNorte_Blk59G_addtional	0.00	0.00	0.07
SurigaodelNorte_Blk59G_supplement	0.00	0.00	0.37
SurigaodelNorte_Blk59G	0.00	0.00	-0.09

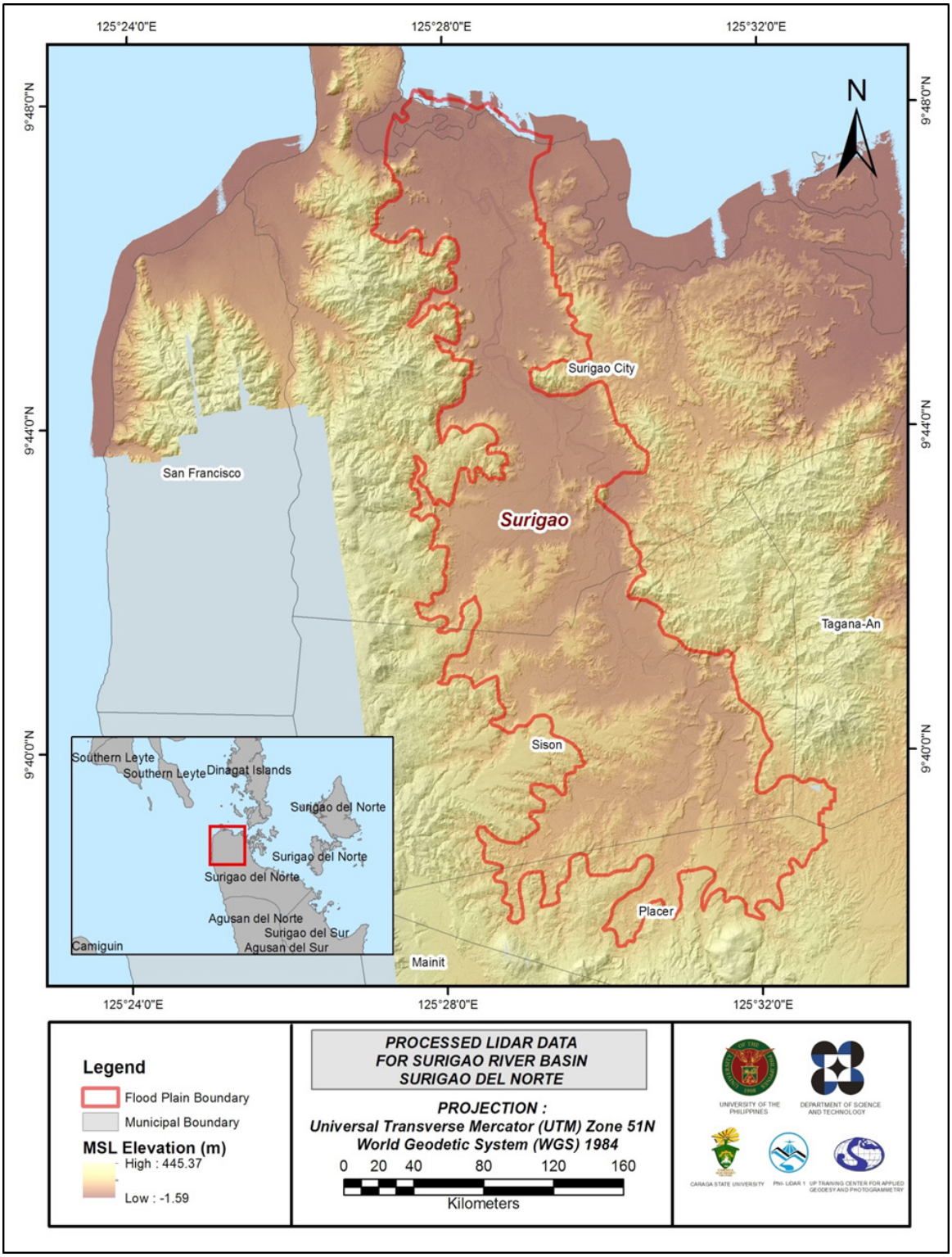

Figure 22. Map of processed LiDAR data for the Surigao Floodplain.

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 Surigao to collect points with which the LiDAR dataset is validated is shown in Figure 23, with the validation survey points highlighted in green. A total of 7,463 survey points were gathered for the Surigao floodplain. Random selection of 80% of the survey points, resulting to 5,970 points, was used for calibration.

A good correlation between the uncalibrated mosaicked LiDAR DTM and the ground survey elevation values is shown in Figure 24. 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 0.22 meters, with a standard deviation of 0.19 meters. The calibration of the SurigaoLiDAR data was accomplished by adding the height difference value of 0.22 meters to the Surigao mosaicked LiDAR data. Table 21shows the statistical values of the compared elevation values between the Surigao LiDAR data and the calibration data.

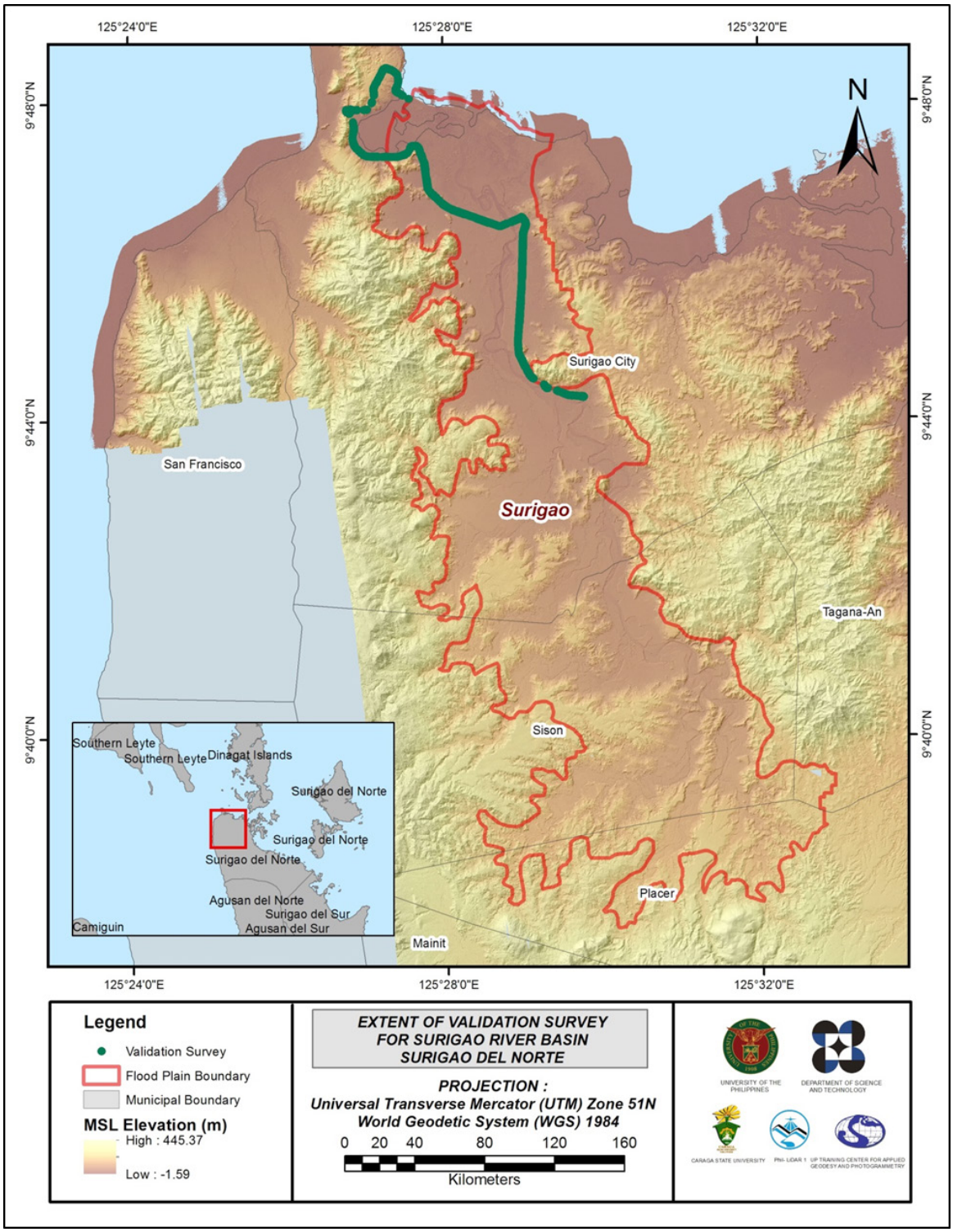

Figure 23. Map of Surigao Floodplain with validation survey points in green.

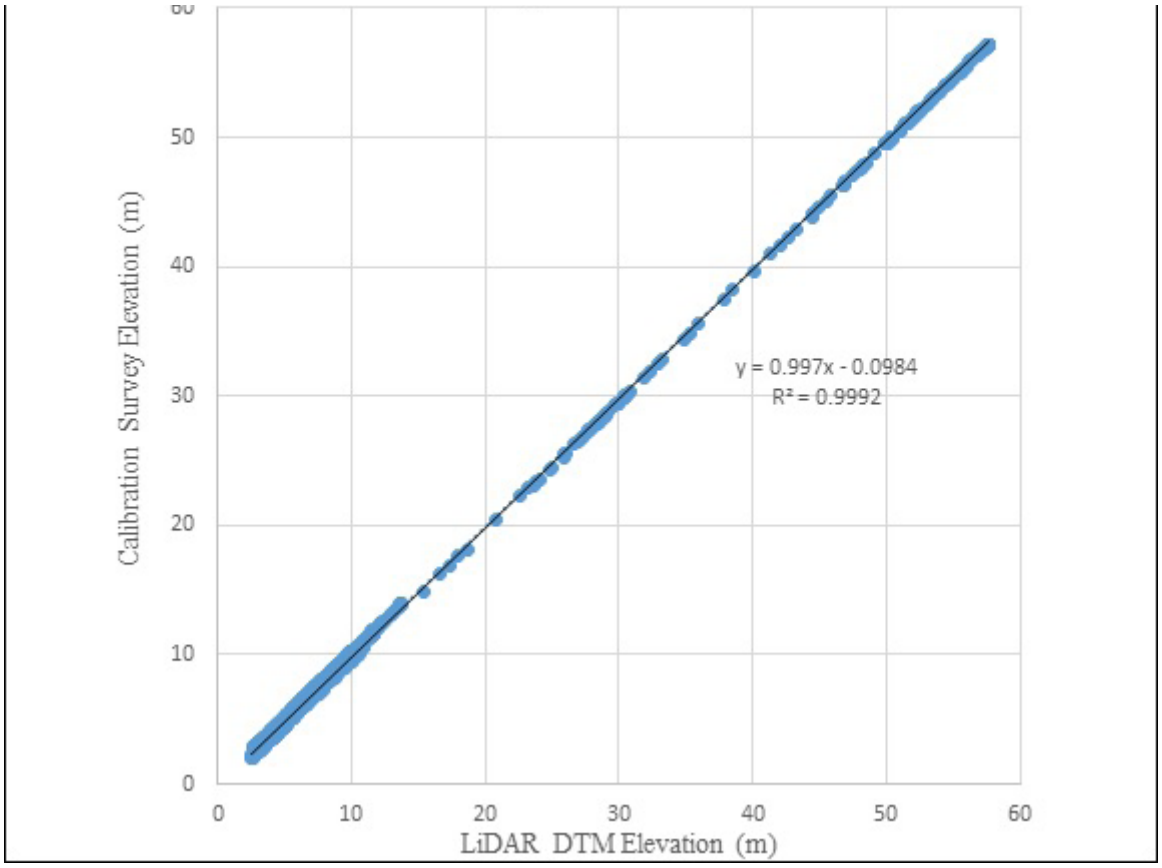

Figure 24. Correlation plot between calibration survey points and LiDAR data.

Table 21. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	0.22
Standard Deviation	0.19
Average	-0.12
Minimum	-0.50
Maximum	0.27

A total of 604 survey points lie within the Surigao Floodplain; all of which were used to validate the calibrated Surigao 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 inFigure 25. The computed RMSE value between the calibrated LiDAR DTM and the validation elevation values is at 0.23 meters with a standard deviation of 0.22 meters, as shown inTable 22.

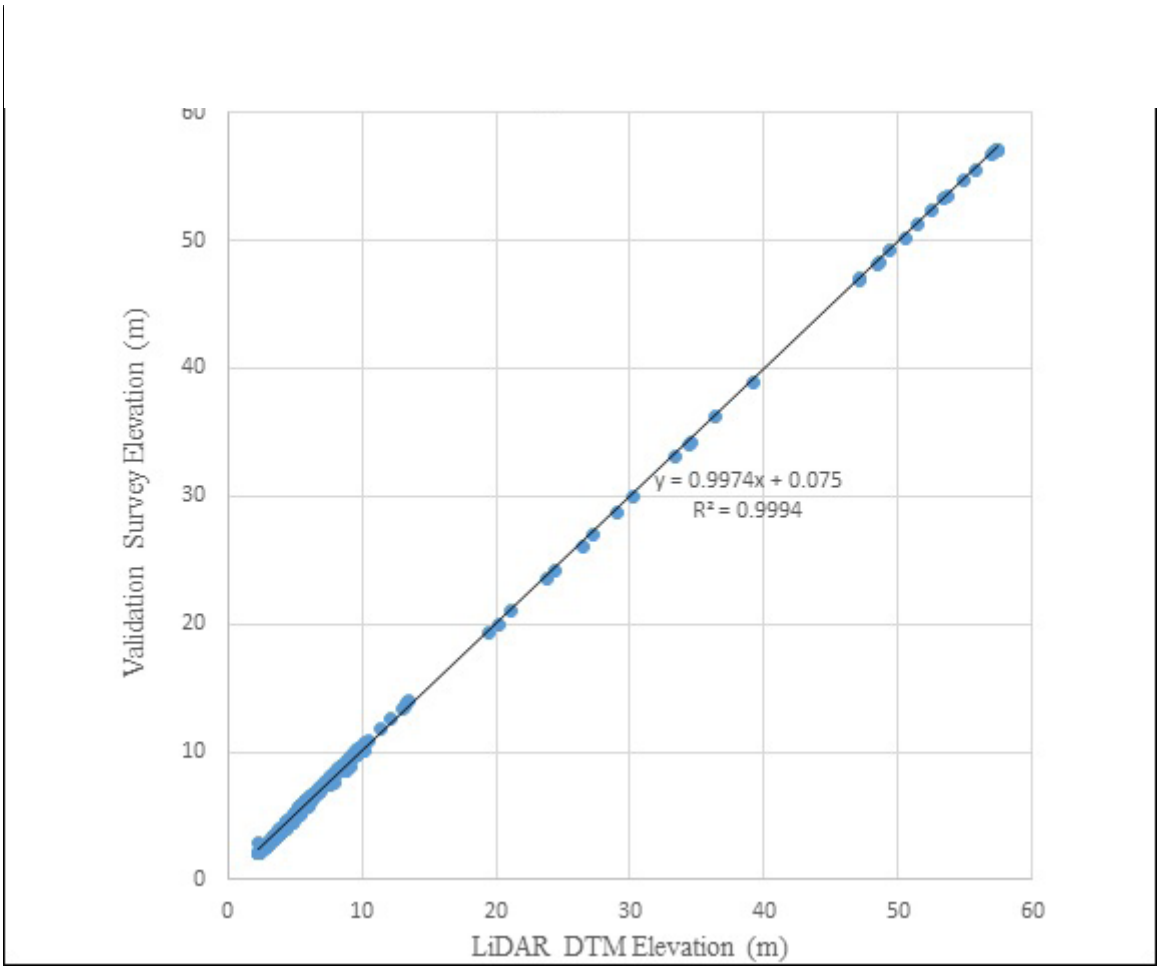

Figure 25. Correlation plot between the validation survey points and the LiDAR data.

Table 22. Validation Statistical Measures

Validation Statistical Measures	Value (meters)
RMSE	0.23
Standard Deviation	0.22
Average	0.05
Minimum	-0.39
Maximum	0.50

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and zigzag data were available for Surigao with a total of 72,241 bathymetric survey points. The resulting raster surface produced was done by Kernel Interpolation with Barriers interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.19 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 Surigao integrated with the processed LiDAR DEM is shown in Figure 26.

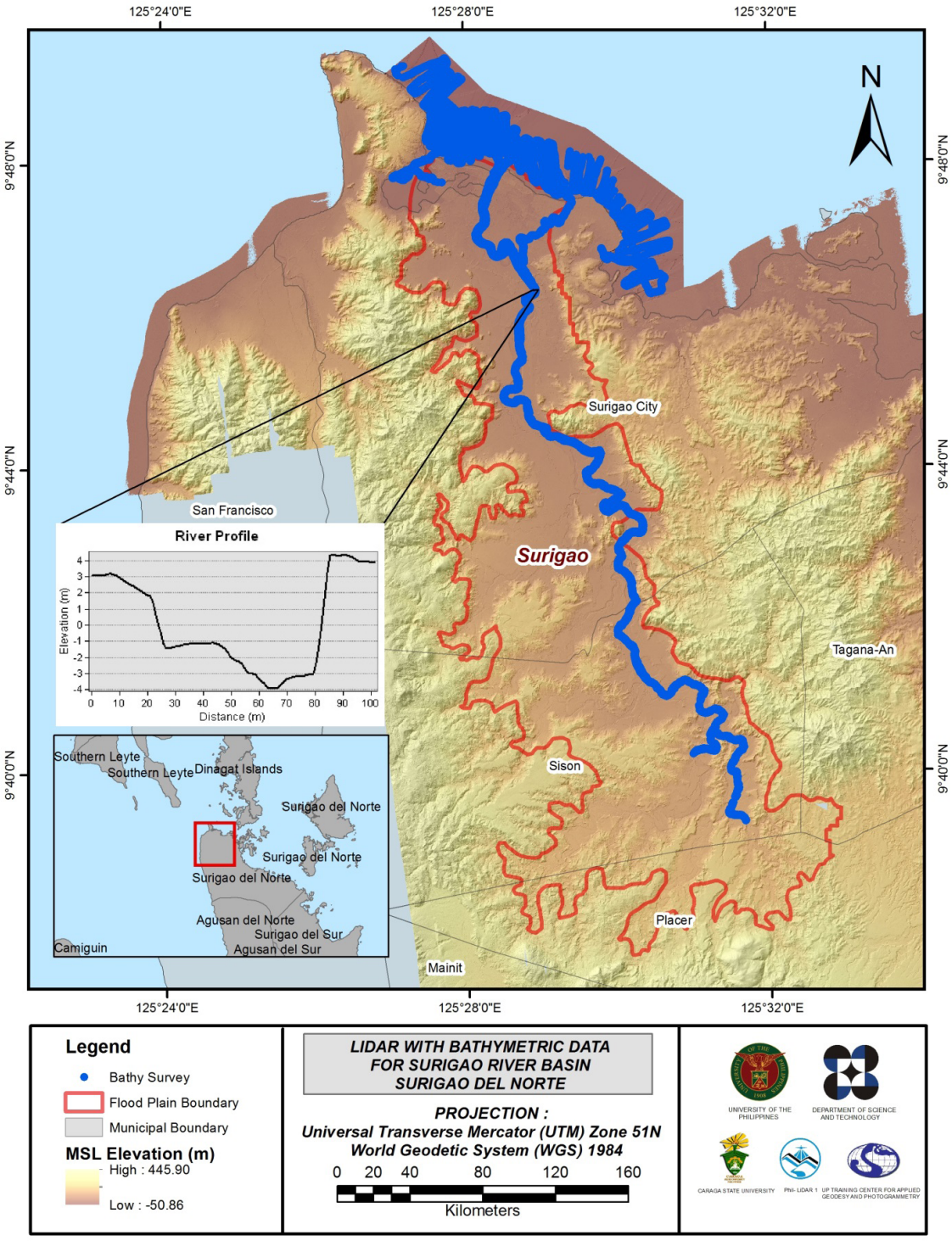

Figure 26. Map of Surigao floodplain with bathymetric survey points in blue.

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 (QC) of Digitized Features' Boundary

Surigao floodplain, including its 200-m buffer, has a total area of 96.98 sq km. For this area, a total of 5.0 sq. km., corresponding to a total of 2,230 building features, were considered for QC. Figure 27 shows the QC blocks for the Surigao floodplain.

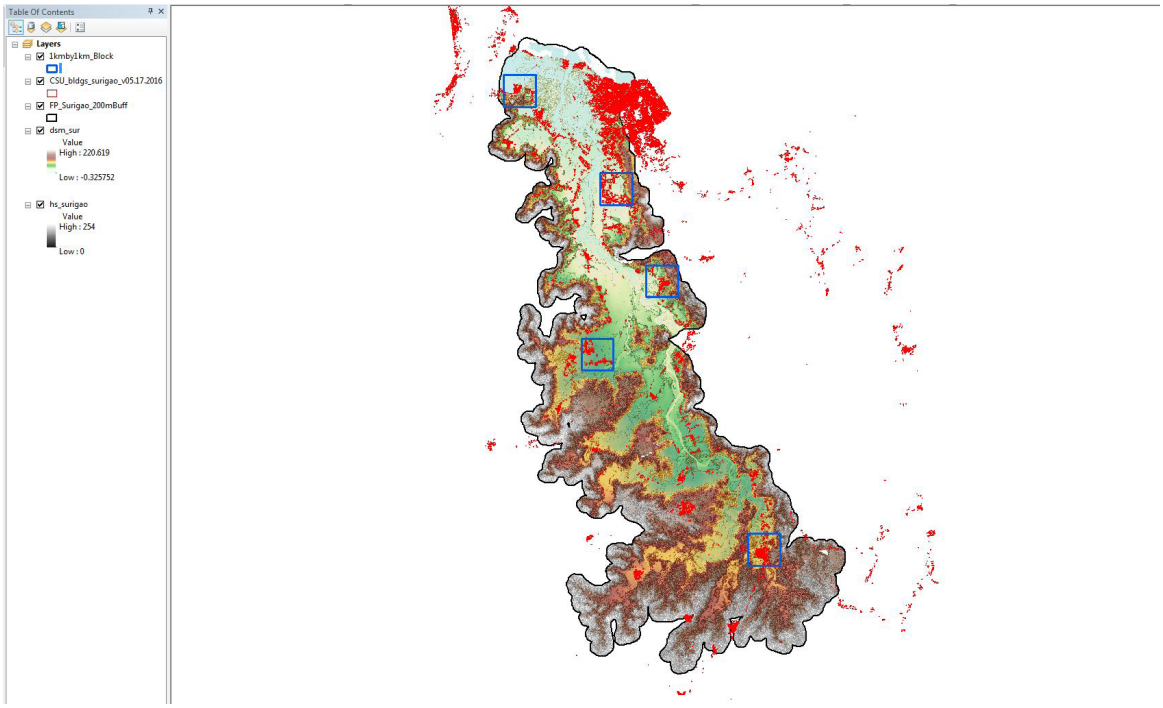

Figure 27. Blocks (in blue) of Surigao building features that were subjected to QC.

Quality checking of Surigao building features resulted in the ratings shown inTable 23.

Table 23. Details of the quality checking ratings for the building features extracted for the Surigao River Basin

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Surigao	99.40	99.66	95.43	PASSED

3.12.2 Height Extraction

Height extraction was done for 29,413 building features in Surigao floodplain. Of these building features, 852 buildings were filtered out after height extraction, resulting to 28,561 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 12.01 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 24 summarizes the number of building features per type, while Table 19 shows the total length of each road type. Table 25, on the other hand, shows the number of water features extracted per type.

Table 24. Building features extracted for Surigao Floodplain.

Facility Type	No. of Features
Residential	28,028
School	283
Market	2
Agricultural/Agro-Industrial Facilities	0
Medical Institutions	22
Barangay Hall	5
Military Institution	0
Sports Center/Gymnasium/Covered Court	22
Telecommunication Facilities	3
Transport Terminal	7
Warehouse	0
Power Plant/Substation	2
NGO/CSO Offices	0
Police Station	10
Water Supply/Sewerage	0
Religious Institutions	12
Bank	9
Factory	18
Gas Station	17
Fire Station	0
Other Government Offices	45
Other Commercial Establishments	76
Total	**28,561**

Table 25. Total length of extracted roads for Surigao Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Surigao	70.32	52.54	159.62	49.19	0.00	**331.67**

Table 26. Number of extracted water bodies forSurigao Floodplain.

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Surigao	54	63	2	0	0	**119**

A total of 56 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 28 shows the completed Digital Surface Model (DSM) of the Surigao floodplain overlaid with its ground features.

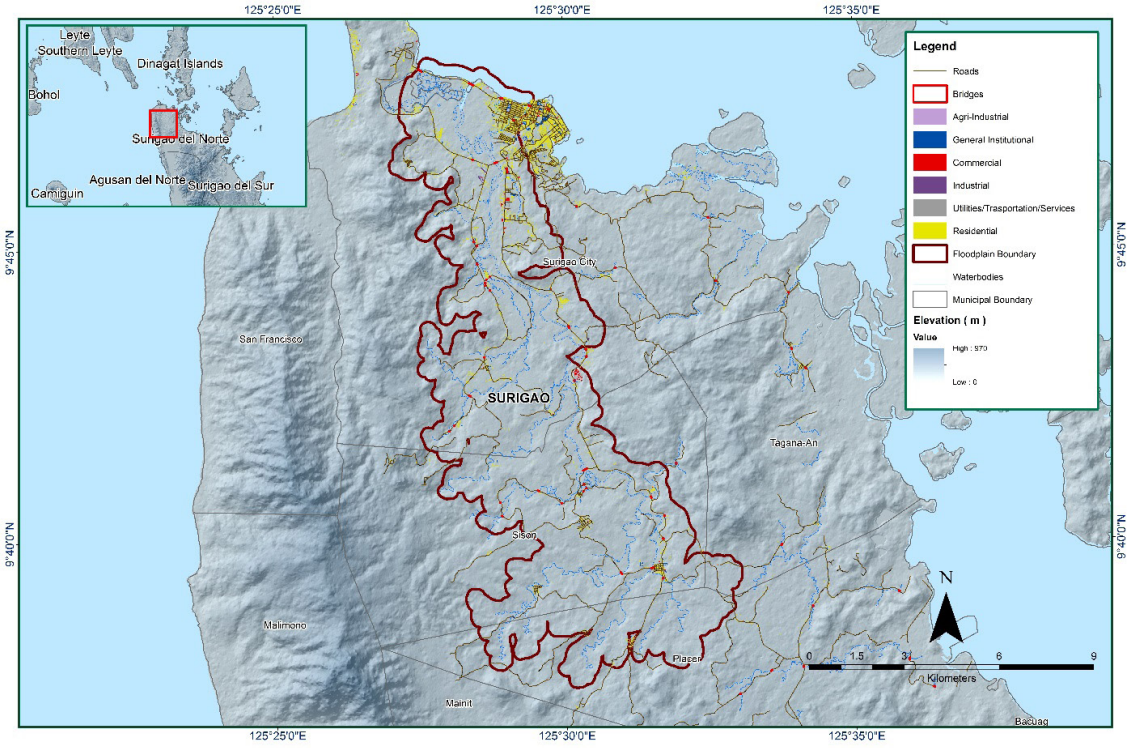

Figure 28. Extracted features of the Surigao Floodplain.

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS OF THE SURIGAO 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 Surigao River on March 14 to June 14, 2016with the following scope of work: reconnaissance; control survey; cross-section survey of selected riverbed in Kinabutan Bridge, Municipality in Brgy. Poblacion, Surigao City, Surigao del Norte; validation points acquisition covering the Surigao River Basin using South™ S86T GNSS and bathymetric surveystarting from the mouth of the river in Brgy. Taft, Surigao City, Surigao del Norte going upstream In Brgy. Mat-I, Surigao City, Surigao del Norte, using South™ SDE-28S echo sounder.(Figure 29).

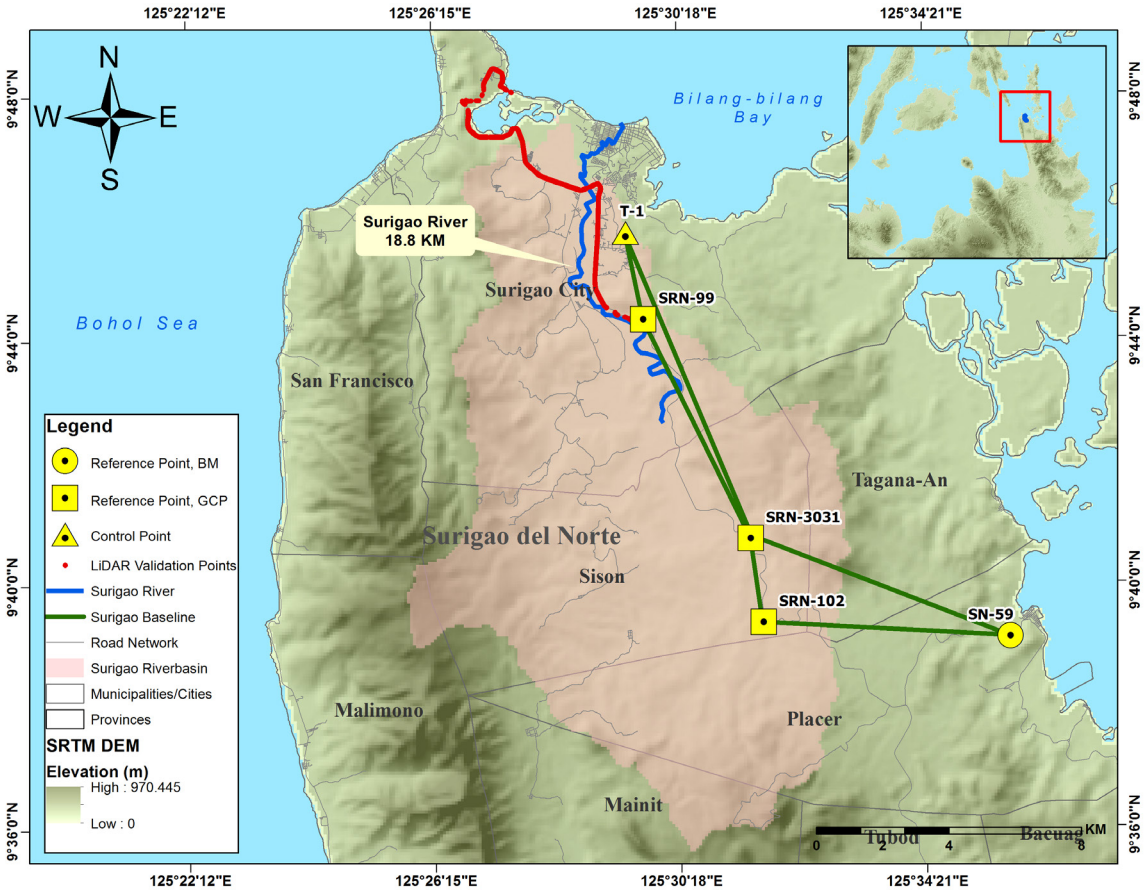


Figure 29. Surigao River Survey Extent

4.2 Control Survey

The GNSS network used for Surigao River survey is composed of two (2) loops established on March 28, 2016 to April 2, 2016 occupying the following reference points: SRN-3031, a second order GCP in Brgy. Mabuhay, Municipality of Sison, Surigao del Norte; and SRN-99, a second-order GCP in Brgy. Bonifacio Surigao City, Surigao del Norte, and SN-59,a first order BM in Brgy. Magsaysay, Municipality of Placer, Surigao del Norte.

A control point was established in the area by CSU was also occupied T-1 located in Brgy. Luna, Surigao City, Province of Surigao del Norte.

Table 27 depicts the summary of reference and control points utilized, with their corresponding locations, while Figure 30shows the GNSS network established in the Surigao River Survey.

Table 27. List of reference and control points used during the survey in Surigao River (Source: NAMRIA, UP-TCAGP).

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoid Height (m)	Elevation(MSL) (m)	Date of Establishment
SRN-3031	2nd order, GCP	9°40'43.37137"N	125°31'28.60503"E	91.423/ 91.374	23.778	2007
SRN-102	2nd order, GCP	9°39'21.00341"N	125°31'40.71501"E	102.294	34.514	2007
SRN-99	2nd order, GCP	9° 44' 19.11233"N	125° 29' 43.66472"E	78.829	11.729	2007
SN-59	1st order, BM	9°39'06.01302"N	125°35'44.75667"E	73.390	5.127	2009
T-1	Established	9°45'44.30089"N	125°29'26.41096"E	128.503	61.540	March 16, 2016

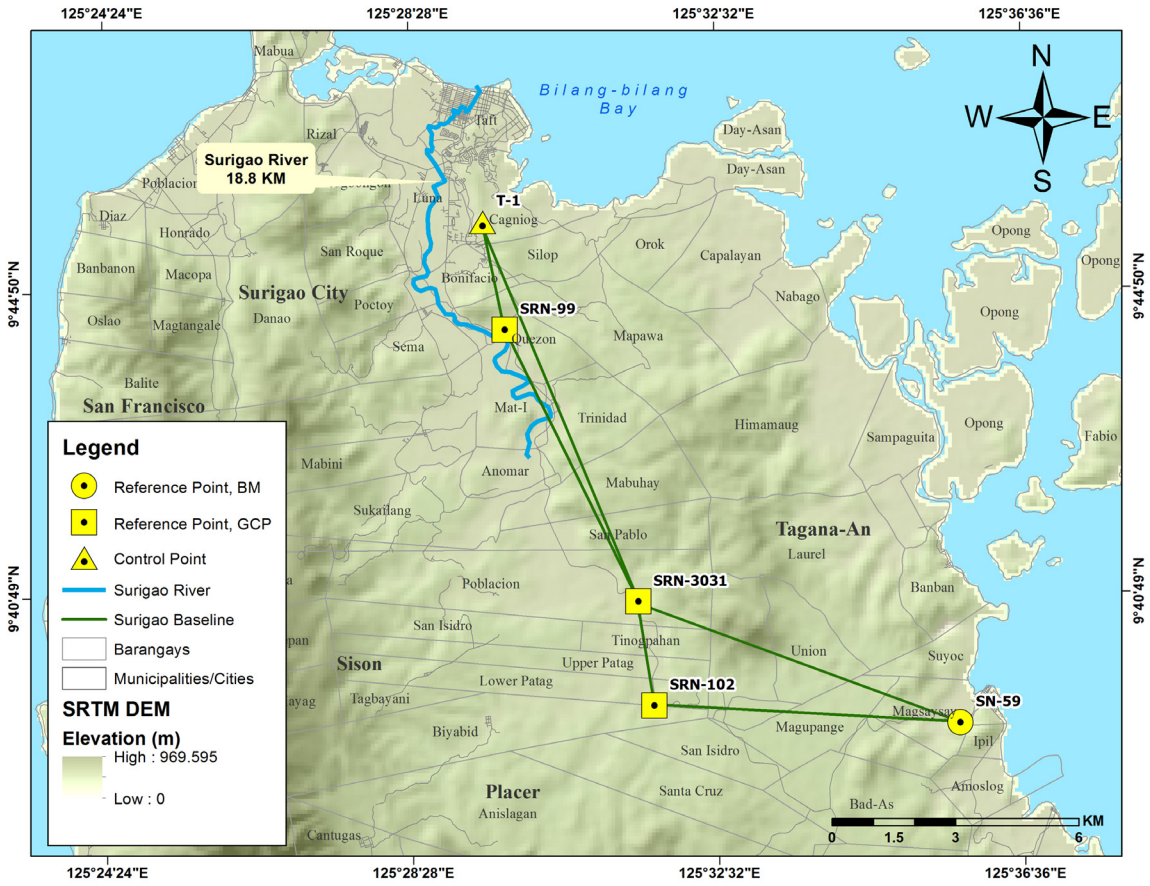


Figure 30. Surigao River Basin Control Survey Extent.

Figure 31 to Figure 35 depict the setup of the GNSS on recovered reference points and established control points in the Surigao River.

Figure 31. GNSS receiver set up, South® S86T, at SRN-102, located at the approach of Bridge in Brgy. Poblacion, Sison, Province of Surigao del Norte.

Figure 32. GNSS receiver set up, South® S86T, at SRN-3031, located at the approach of Mabuhay Bridge in Brgy. Mabuhay, Sison, Province of Surigao del Norte.

Figure 33. GNSS receiver set up, South® S86T, at SRN-99, located inside Bonifacio Elementary School in Brgy. Bonifacio, Surigao City, Province of Surigao del Norte.

Figure 34. GNSS base set up, South® S86T, at SN-59, located at the approach of Mapaso Bridge in Brgy. Magsaysay, Placer, Province of Surigao del Norte.

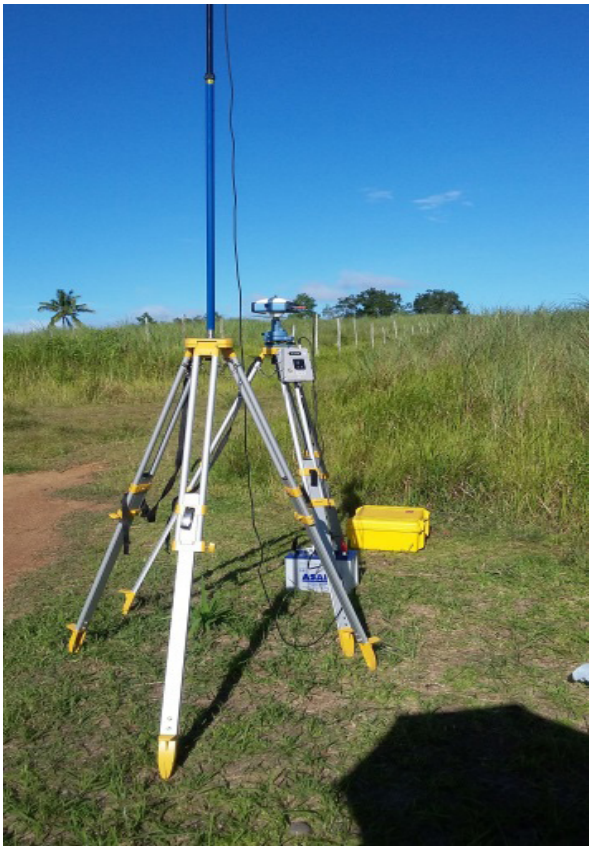


Figure 35. GNSS receiver set up, South® S86T, at T-1, located in Brgy. Luna, Surigao City, Province of Surigao del Norte.

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 28 presents the baseline processing results of control points in the Surigao River Basin, as generated by the TBC software.

Table 28. The Baseline processing report for the Surigao 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:

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

where:

x_e is the Easting Error,

y_e is the Northing Error, and

z_e is the Elevation Error

For complete details, see the Network Adjustment Report shown in Table 29 toTable 32.

The four (4) control points, SRN-99, SN-1064-A, UP-SUR-1, and UP-SUR-2 were occupied and observed simultaneously to form a GNSS loop. The coordinates and ellipsoidal height of SRN-99 were held fixed during the processing of the control points as presented in Table 29. Through this reference point, the coordinates and ellipsoidal height of the unknown control points will be computed.

Table 29. Constraints applied to the adjustment of the control points.

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
SRN-99	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 30.

Table 30. Adjusted grid coordinates for the control points used in the Surigao River flood plain survey.

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
SRN-102	777426.9597	?	1068387.750	?	34.484	?	LLh
SRN-3031	777038.824	0.001	1070916.993	0.001	23.7485	0.003	
SN-59	784874.625	0.002	1067982.791	0.002	5.098	0.005	
Point ID	**Easting (Meter)**	**Easting Error (Meter)**	**Northing (Meter)**	**Northing Error (Meter)**	**Elevation (Meter)**	**Elevation Error (Meter)**	**Constraint**
T-1	773243.922	0.001	1070916.982	0.001	23.699	0.002	
SRN-99	773789.360	?	1077525.117	?	11.670	?	LLh
SRN-3031	777038.817	0.001	1070916.981	0.001	23.7485	0.002	

The results of the computation for accuracy are as follows:

a. SN-59

horizontal accuracy = $\sqrt{((0.2)^2 + (0.2)^2}$
= $\sqrt{}$ (0.4+ 0.4)
= 0.8< 20 cm
vertical accuracy = 0.5< 10 cm

b. SRN-102

horizontal accuracy = Fixed
vertical accuracy = Fixed

c. SRN-3031

horizontal accuracy = $\sqrt{((0.1)^2 + (0.1)^2}$
= $\sqrt{}$ (0.1 + 0.1)
= 1.00< 20 cm
vertical accuracy = 0.3< 10 cm

horizontal accuracy = $\sqrt{((0.1)^2 + (0.1)^2}$
= $\sqrt{}$ (0.1 + 0.1)
= 1.00< 20 cm
vertical accuracy = 0.2< 10 cm

d. SRN-99

horizontal accuracy = Fixed
vertical accuracy = Fixed

e. T-1

horizontal accuracy = $\sqrt{((0.1)^2 + (0.1)^2}$
= $\sqrt{}$ (0.1 + 0.1)
= 0.2< 20 cm
vertical accuracy = 0.2< 10 cm

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

Table 31. Adjusted geodetic coordinates for control points used in the Surigao River Flood Plain validation.

Point ID	Latitude	Longitude	Ellipsoid Height (Meter)	Height Error (Meter)	Constraint
SRN-102	N9°39'21.00341"	E125°31'40.71501"	102.294	?	LLh
SRN-3031	N9°40'43.37137"	E125°31'28.60503"	91.423	0.003	
SN-59	N9°39'06.01302"	E125°35'44.75667"	73.390	0.005	
T-1	N9°45'44.30089"	E125°29'43.66472"	128.503	0.002	
SRN-99	N9°44'19.11233"	E125°29'43.66472"	78.829	?	LLh
SRN-3031	N9°40'43.37100"	E125°31'28.60480"	91.374	0.002	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown inTable 31. 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 Surigao River GNSS Static Survey are seen in Table 32.

Table 32. The reference and control points utilized in the Surigao 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)
SRN-102	2nd order, GCP	9°39'21.00341" N	125°31'40.71501" E	102.294	1068387.750	777426.960	34.514
SRN-3031	2nd order, GCP	9°40'43.37137" N	125°31'28.60503" E	91.423	1070916.993	777038.824	23.778
SRN-99	2nd order, GCP	9°44'19.11233" N	125°29'43.66472" E	78.829	1077525.117	773243.922	11.729
SN-59	1st order, BM	9°39'06.01302" N	125°35'44.75667" E	73.390	1067982.791	784874.625	5.127
T-1	Established	9°45'44.30089" N	125°29'26.41096" E	128.503	1080139.869	773243.922	61.511

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

The bridge cross-section and as-built surveys were conducted on April 9, 2016 at the upstream side of Kinabutan Bridge, Brgy. Poblaicion, Municipality of Sison using the GNSS receiver South® S86T utilizing GNSS RTK survey technique, (Figure 36 and Figure 37).

Figure 36. Kinabutan Bridge facing downstream

Figure 37. Cross-section survey conducted at Kinabutan Bridge.

The length of the cross-sectional line surveyed atKinabutan Bridge is about 192.410 meters (Figure 36) with forty-one (41) points acquired using the control points UP_SUR-1 and UP_SUR-2 that ABSD established as the GNSS base stations. The location map, cross-section diagram, and the accomplished bridge data fromare shown in Figure 38, 39 and 40, respectively.

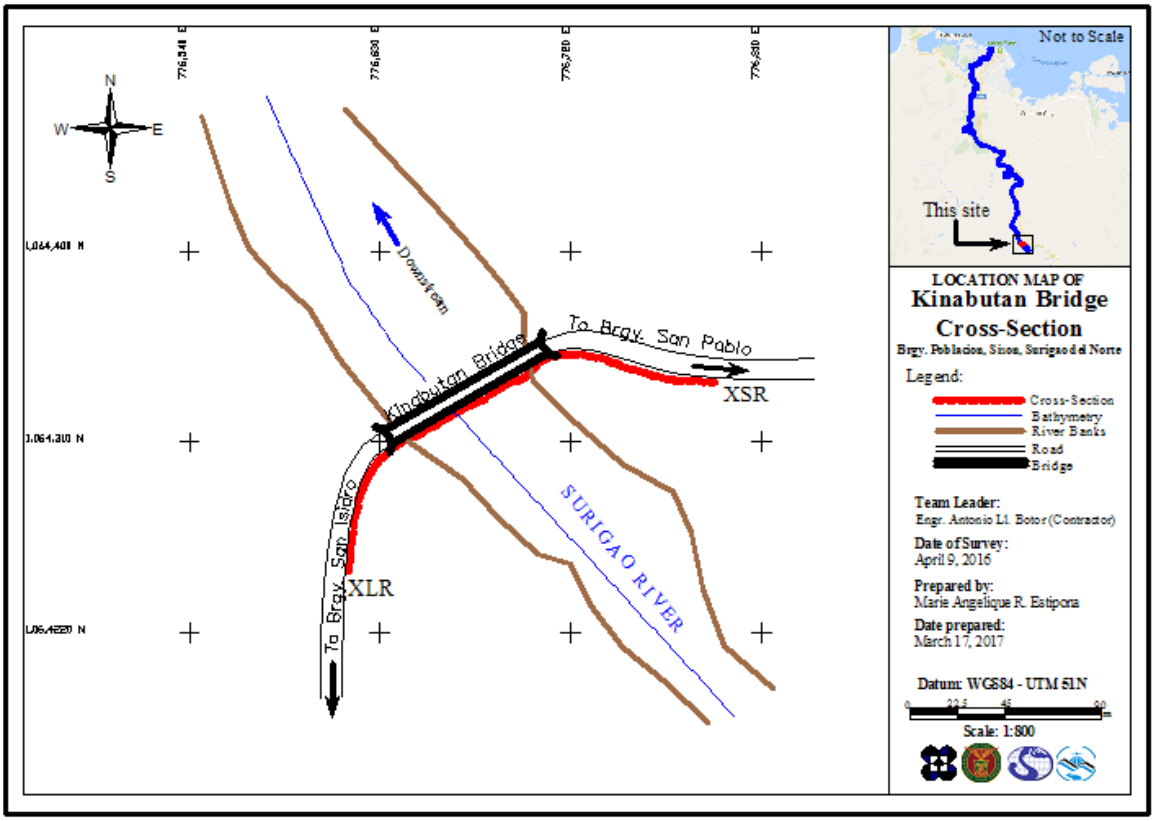


Figure 38. Location map of the Kinabutan Bridge cross section.

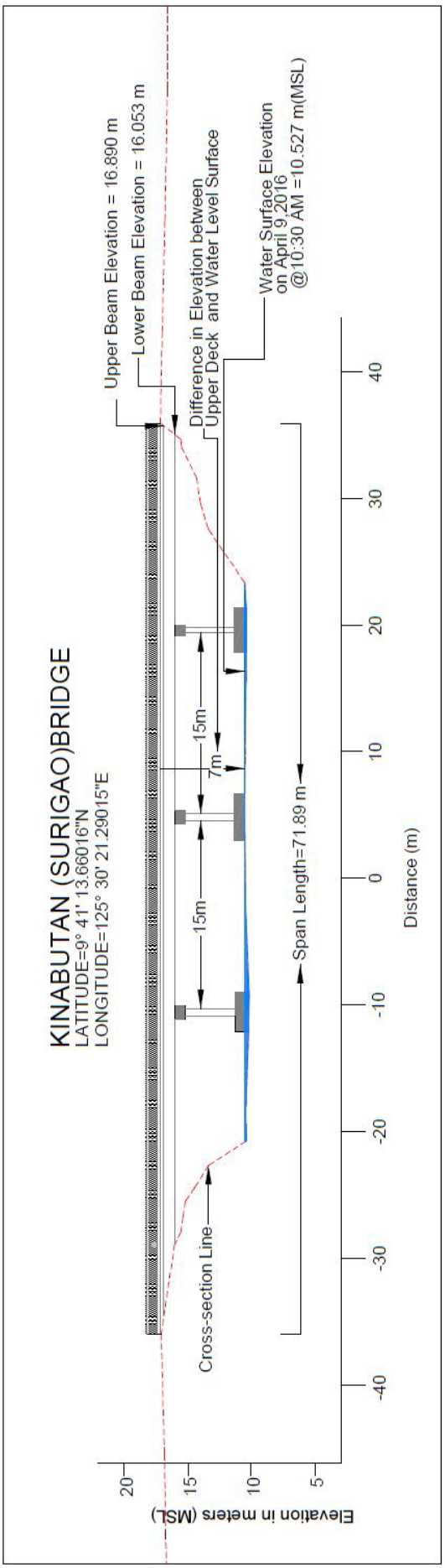


Figure 39. The Surigao cross-section survey in Kinabutan Bridge drawn to scale.

Bridge Data Form

Bridge Name: Kinabutan Bridge

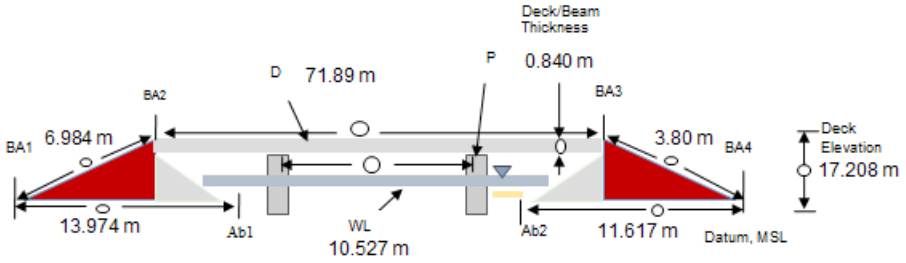
River Name: Surigao River
Location (Brgy, City, Region): Brgy. Poblacion, Sison, Surigao del Norte

Survey Team:
Date and Time: April 9, 2016, 10.30 am

Flow Condition: low ✔ normal high

Weather Condition: ✔ fair rainy

Cross-sectional View (not to scale)



Legend:
BA = Bridge Approach
P = Pier
Ab = Abutment
D = Deck
WL = Water Level/Surface
MSL = Mean Sea Level
◯ = Measurement Value

Line Segment	Measurement (m)	Remarks
1. BA1-BA2	6.984 m	
2. BA2-BA3	71.890 m	
3. BA3-BA4	7.169 m	
4. BA1-Ab1	13.974 m	
5. Ab2-BA4	11.617 m	
6. Deck/beam thickness	0.840 m	
7. Deck elevation	17.208 m	

Note: Observer should be facing downstream

Figure 40. Kinabutan Bridge Data Sheet.

The water surface elevation of Surigao River was determined by a Horizon® Total Station on April 9, 2016 at 10:30 AM at Kinabutan Bridge area with a value of 10.527 m in MSL as shown inFigure 39. This was translated into marking on the bridge's pier as shown in Figure 41. The marking will serve as reference for flow data gathering and depth gauge deployment of the partner SUC responsible for Surigao River, Caraga State University.

Figure 41. Water-level markings on Kinabutan Bridge.

4.6 Validation Points Acquisition Survey

The validation points acquisition survey was conducted from June 13 to 14, 2016 using a survey GNSS rover receiver South® S86T mounted on a range pole, which was attached in front of the vehicle as shown inFigure 42. It was secured with a bipod and ropes to ensure that it was horizontally and vertically balanced. The antenna height was 2.950 m and measured from the ground up to the bottom of the quick release of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with T-1 occupied as the GNSS base station in the conduct of the survey.

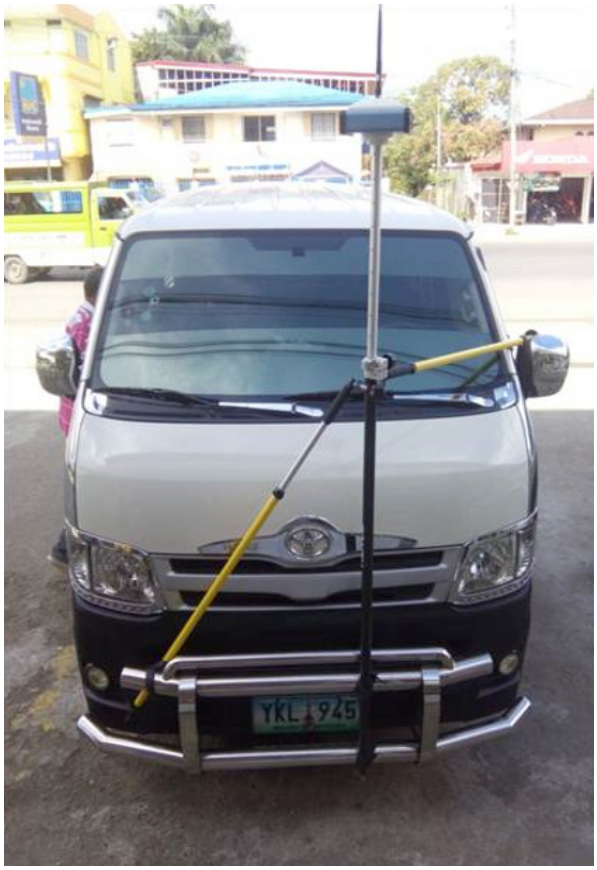


Figure 42. GNSS Receiver South® S86T installed on a vehicle for Ground Validation Survey.

The GNSS base station was set-up over T-1 gathered validation points from Brgy. Lipata, Surigao City, Surigao del Sur going southeast along the national highway covering nine (9) barangays, ending in Brgy. Quezon, Surigao City Surigao del Norte. A total of 3,619 points were gathered with approximate length of 9.30 kmusing T-1 as GNSS base station for the entire extent validation points acquisition survey, as illustrated in the map in Figure 43.

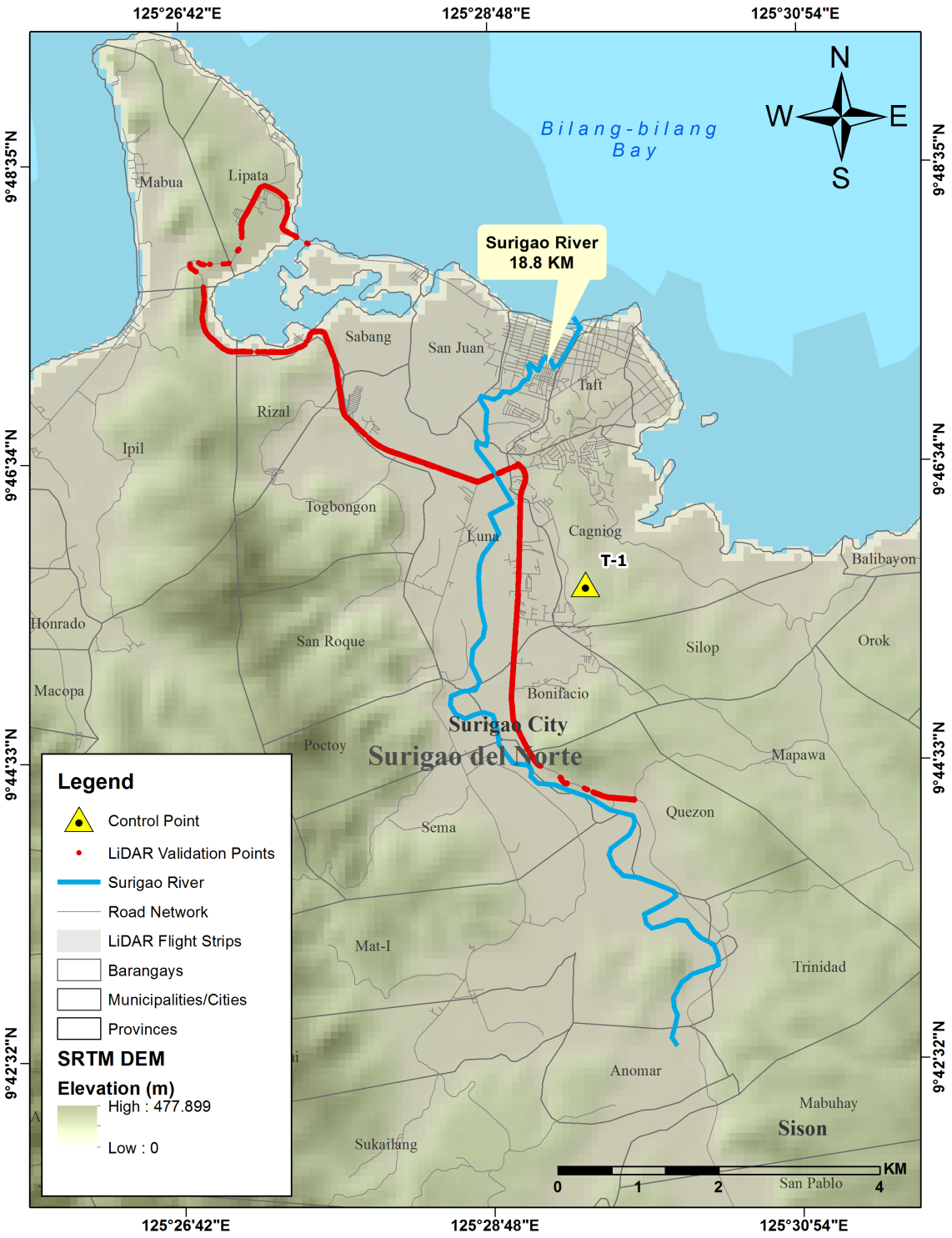


Figure 43. The extent of the LiDAR ground validation survey (in red) for Surigao River Basin.

4.7 River Bathymetric Survey

A bathymetric survey was performed on May 31, 2016 to June 4, 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 44.

Figure 44. Set up of the bathymetric survey in Surigao River

The survey started in Brgy. Taft, City of Surigao, Surigao del Norte with coordinates 9°47'45.72"N, 125°29'6.32"E and ended in Brgy. Mat-I, City of Surigao as well, with coordinates 9°72'42.21"N, 125°49'91.15"E. The control point T-1 was used as GNSS base stations all throughout the bathymetricsurvey.

Overall, the extent of the bathymetric survey for the Surigao River is shown in Figure 45. To further illustrate this, a CAD drawing of the riverbed profile of the Surigao River was produced as seen in Figure 46.

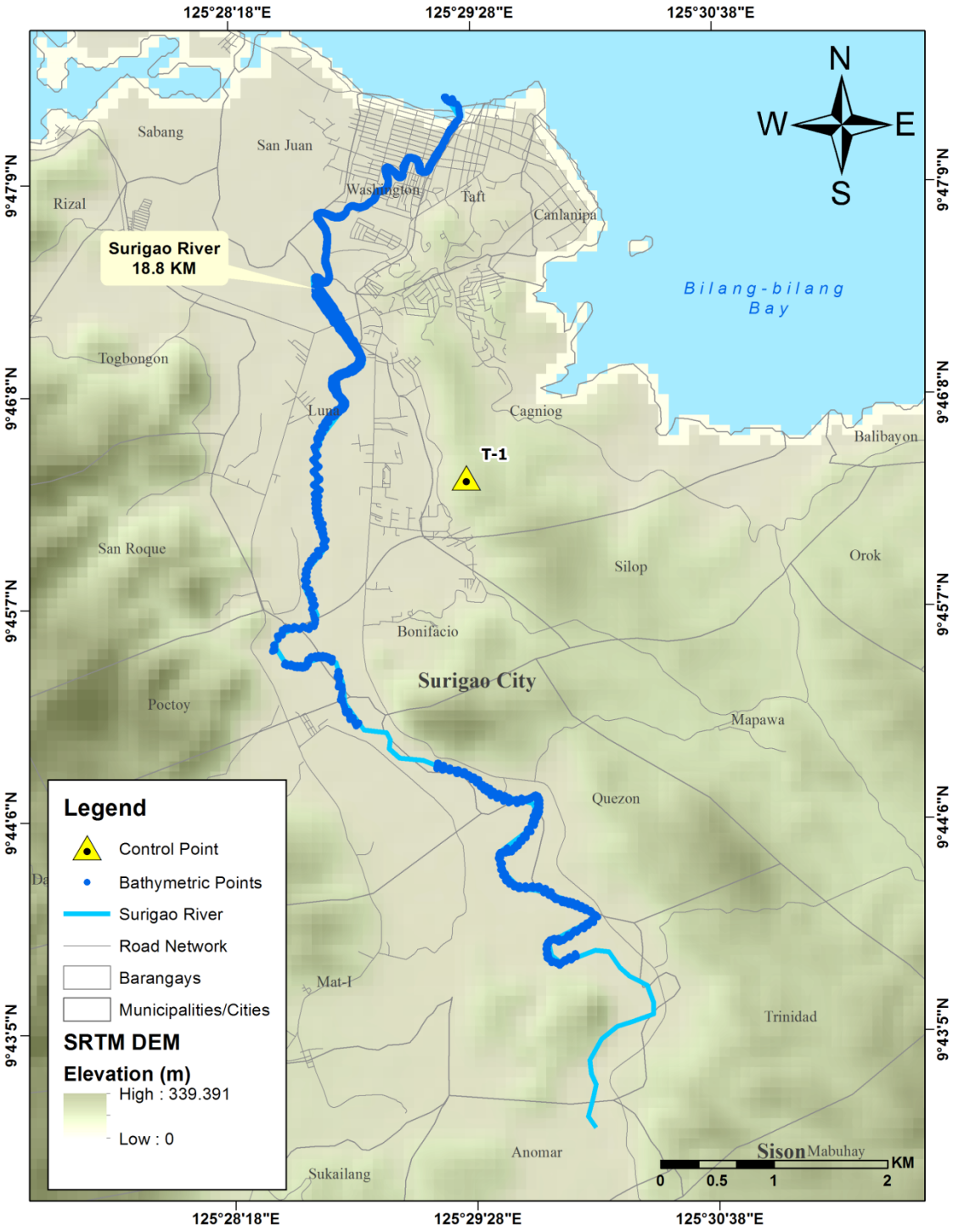


Figure 45. The extent of the Surigao River Bathymetry Survey.

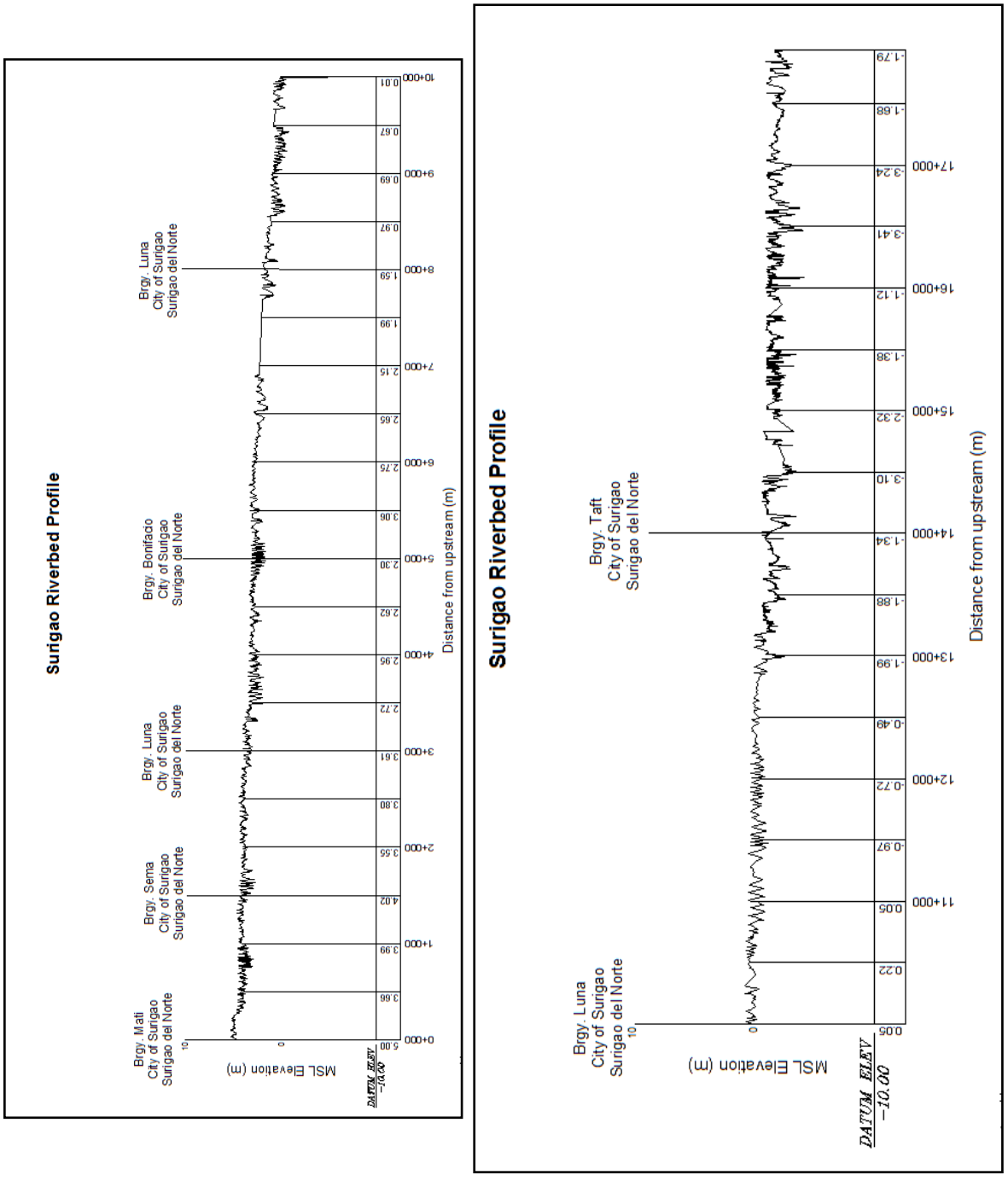


Figure 46. The Surigao Riverbed Profile.

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. The ARG was installed at the compound of Mat-I National High School in Surigao City as illustrated inFigure 47. The precipitation data collection started from May 15, 2016 at 3:40 PM to May 17, 2016 at 0:00 AM.

The total precipitation for this event in Mat-i ARG was 30.48 mm. It has a peak rainfall of 9.906 mm on May 15, 2016 at 08:15 in the evening. The lag time between the peak rainfall and discharge at Anomar Bridge is 3 hours and 25 minutes.

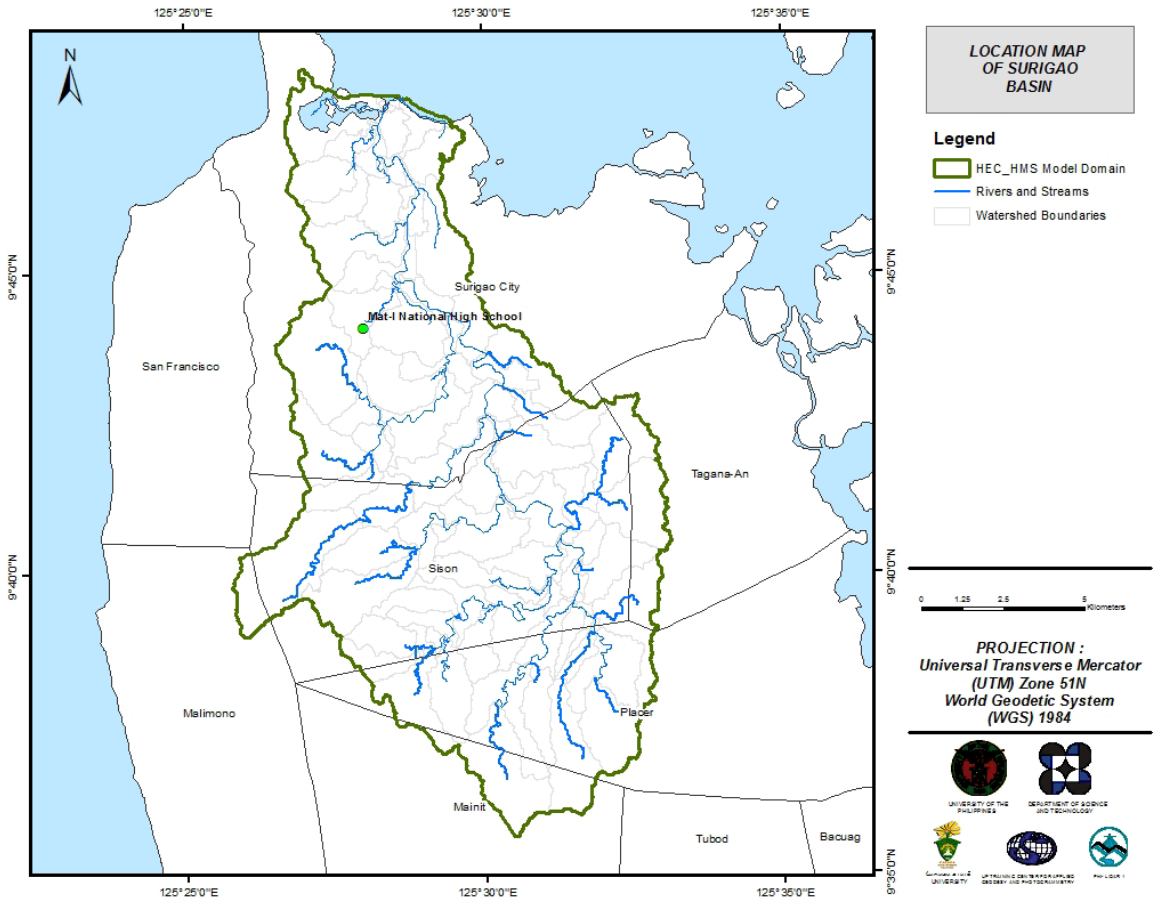


Figure 47. Location Map of the Surigao HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Anomar Bridge, Surigao City, Surigao del Norte (9°41'13.60"N, 125°30'20.93"E) to establish the relationship between the observed water levels (H) at Anomar Bridge and outflow (Q) of the watershed at this location.

For Anomar Bridge, the rating curve is expressed as $Q = 23.455H^2 + 478.64H + 2442.1$as shown inFigure 48.

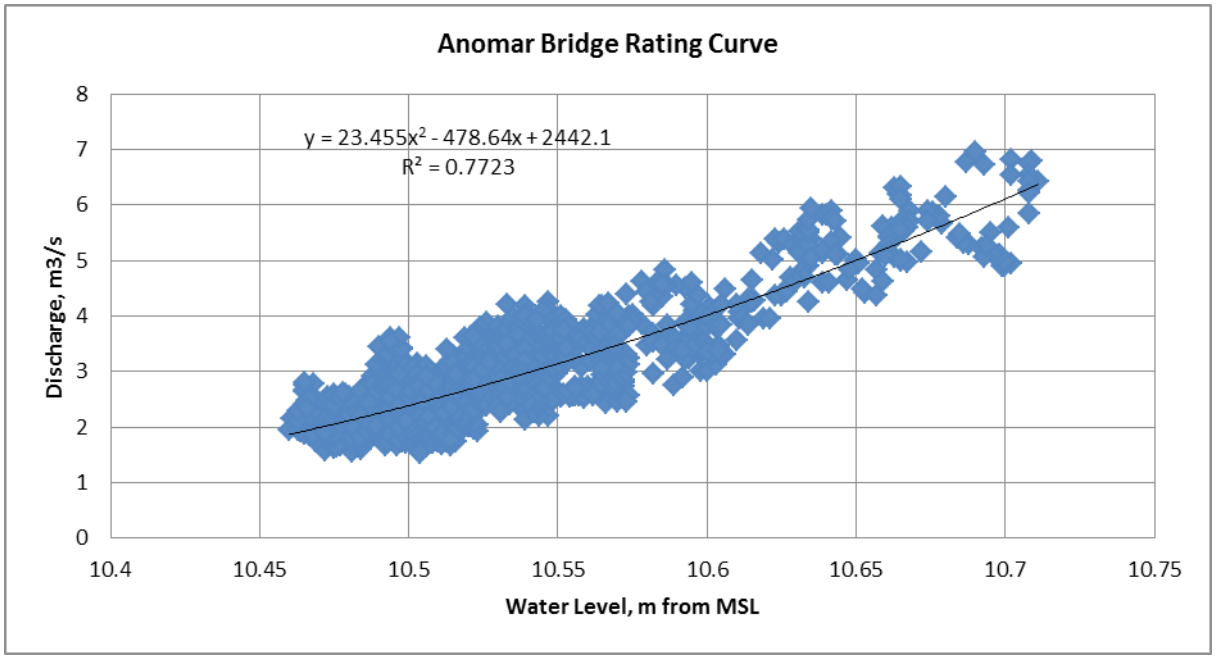


Figure 48. The rating curve at Anomae Bridge, Surigao City, Surigao del Norte.

This rating curve equation was used to compute the river outflow at Anomar Bridge for the calibration of the HEC-HMS model shown in Figure 47. The peak discharge is 3.04 m^3/s at 5:40 in the morning, May 16, 2016.

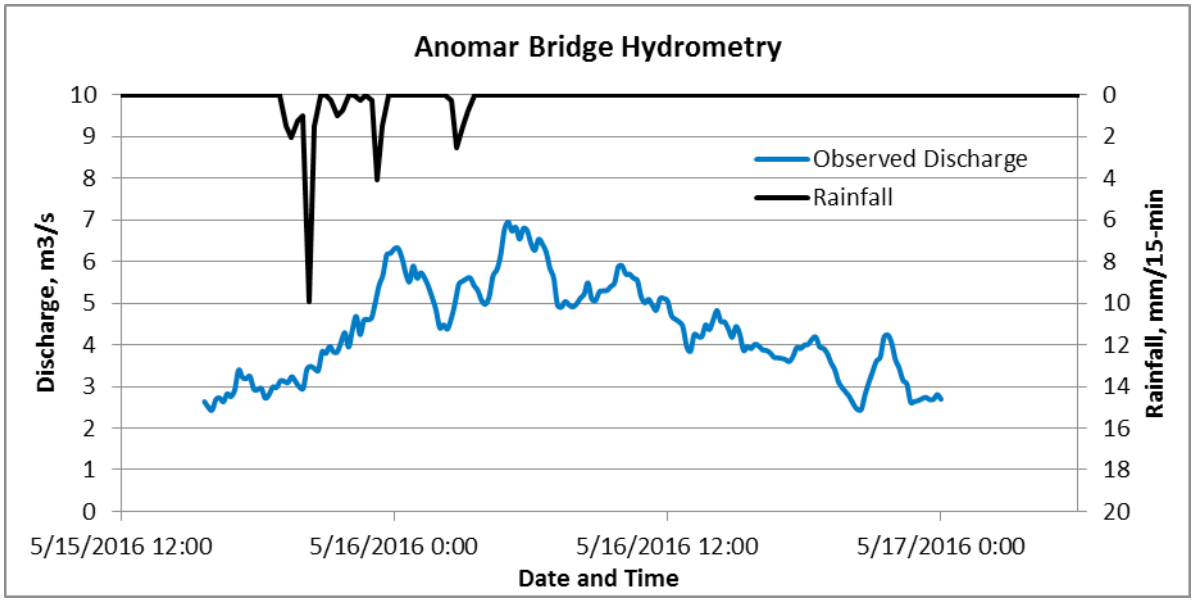


Figure 49. Rainfall at Mat-I National High School and outflow data at the Anomar Bridge of the Surigao River Basin, which was used for modeling.

5.2 RIDF Station

PAGASA computed the Rainfall Intensity Duration Frequency (RIDF) values for the Surigao 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 Surigao watershed. The extreme values for this watershed were computed based on a 46-year record.

Table 33. RIDF values for the Surigao River Basin based on average RIDF data of Surigao station, as computed by PAGASA.

COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION									
T (yrs)	**10 mins**	**20 mins**	**30 mins**	**1 hr**	**2 hrs**	**3 hrs**	**6 hrs**	**12 hrs**	**24 hrs**
5	34.34	53	66.1	88.3	125.8	150.9	199.2	246.3	286.5
10	42.3	64.7	80.7	107.7	155	186.5	245.8	305.1	351.2
25	52.2	79.6	99.1	132.2	191.8	231.4	304.7	379.5	433
50	59.6	90.6	112.7	150.3	219.1	264.8	348.4	434.6	493.7
100	66.9	101.6	126.3	168.3	246.2	297.9	391.8	489.4	553.9

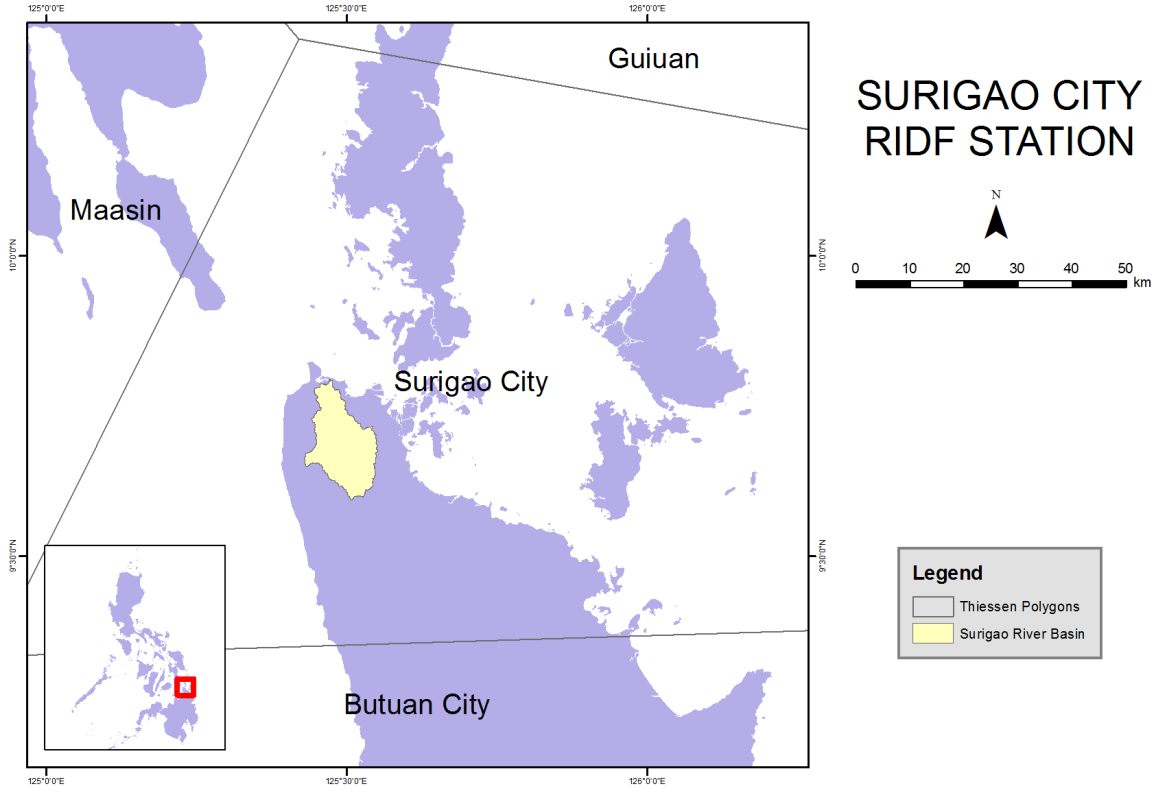


Figure 50. The location of the Surigao RIDF station relative to the Surigao River Basin.

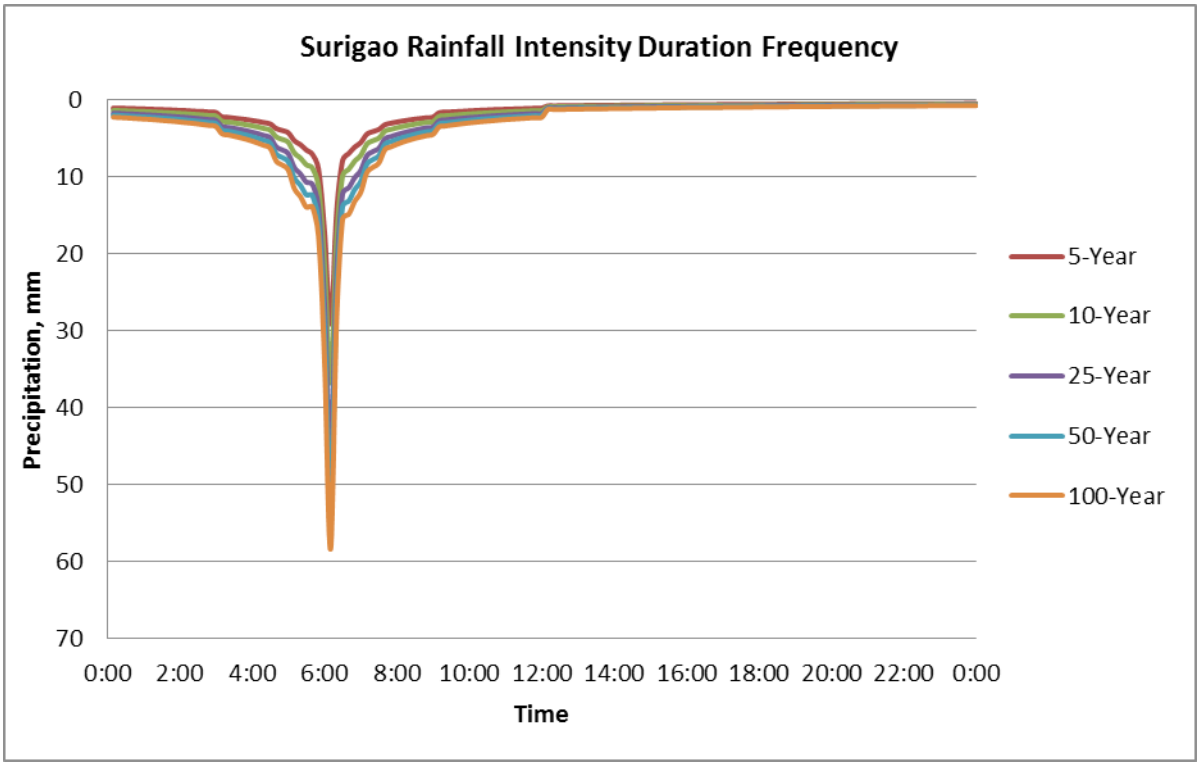


Figure 51. The synthetic storm generated for a 24-hour period rainfall for various return periods

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 Surigao River Basin are shown in Figure 52 and Figure 53 respectively.

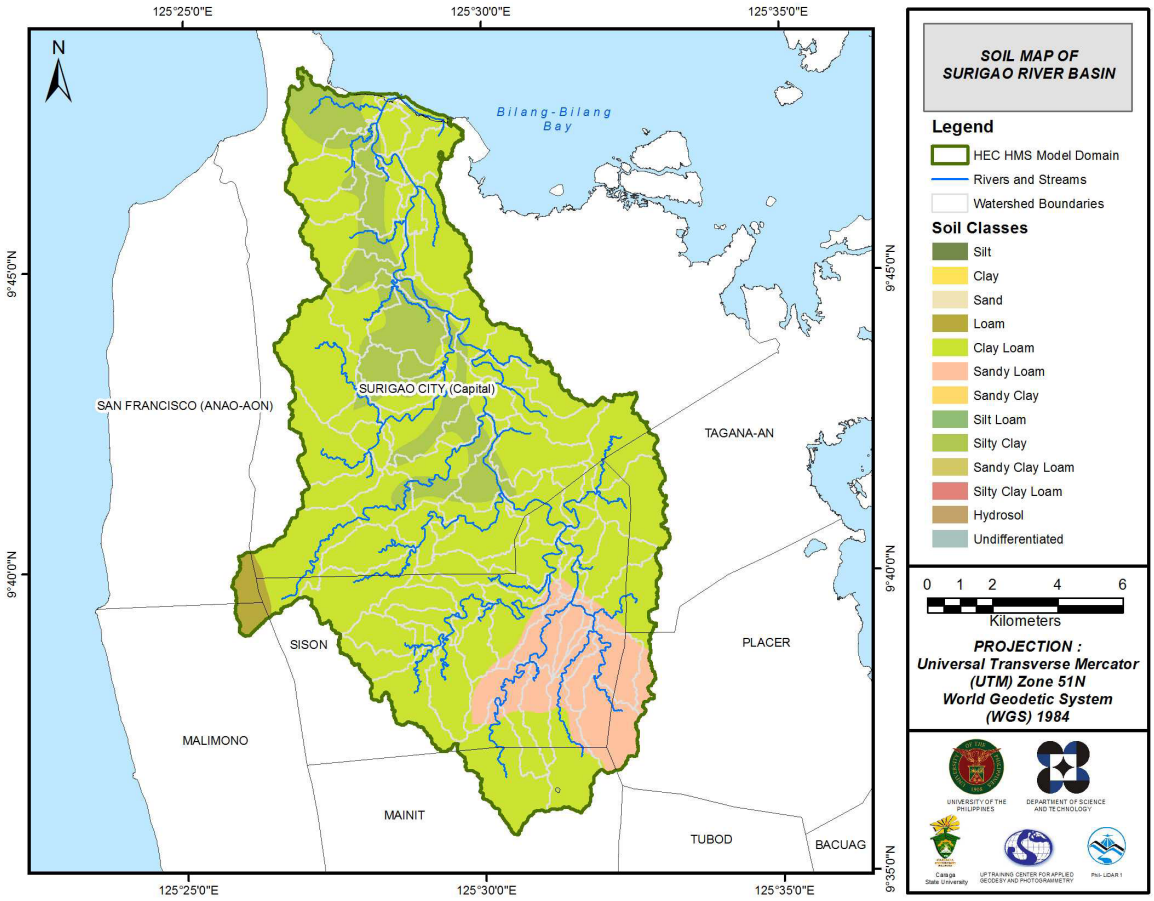


Figure 52. Soil Map of Surigao River Basin.

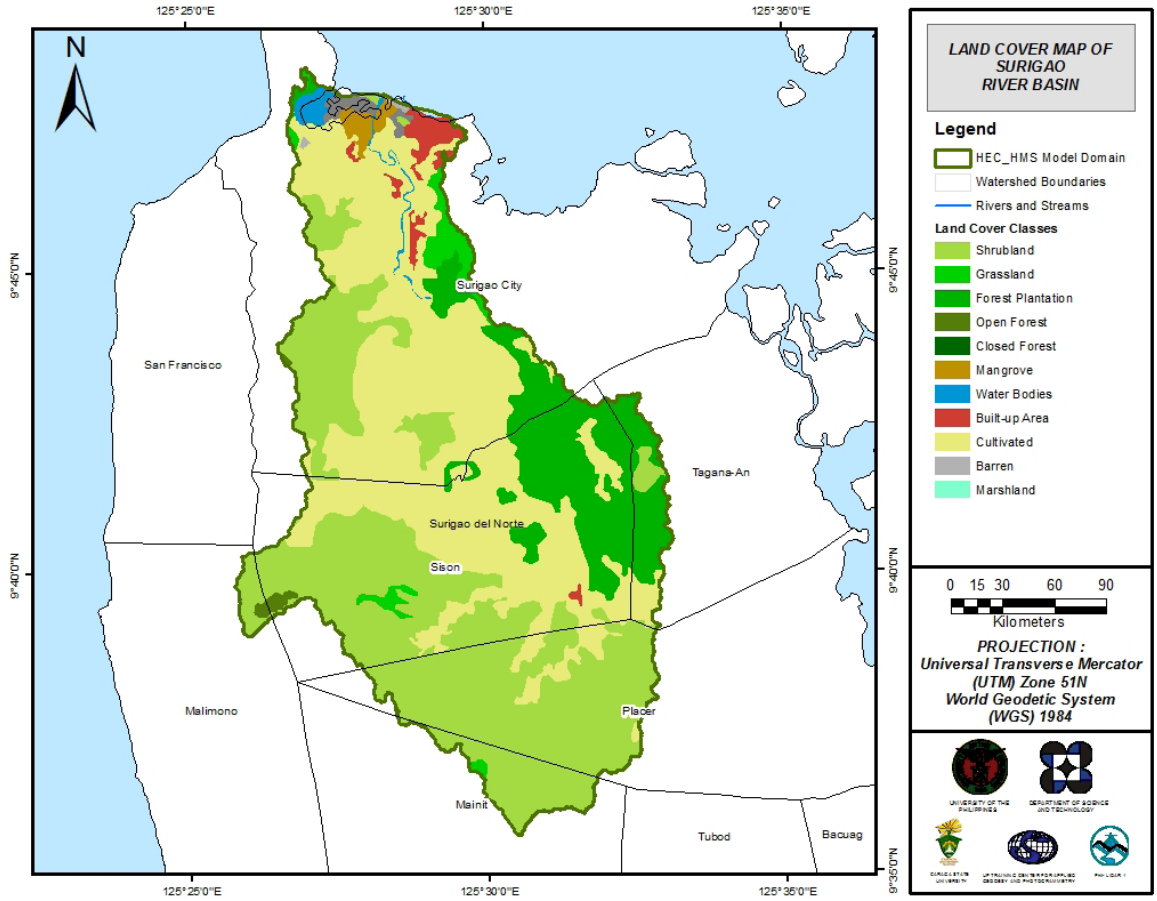


Figure 53. Land Cover Map of Surigao River Basin.

For Surigao, four soil classes were identified. These are are sand, loam, clay loam and silt loam. Moreover, seven land cover classes were identified. These are forest plantation, grassland, shrubland, cultivated lands, mangrove, built-up and inland water bodies.

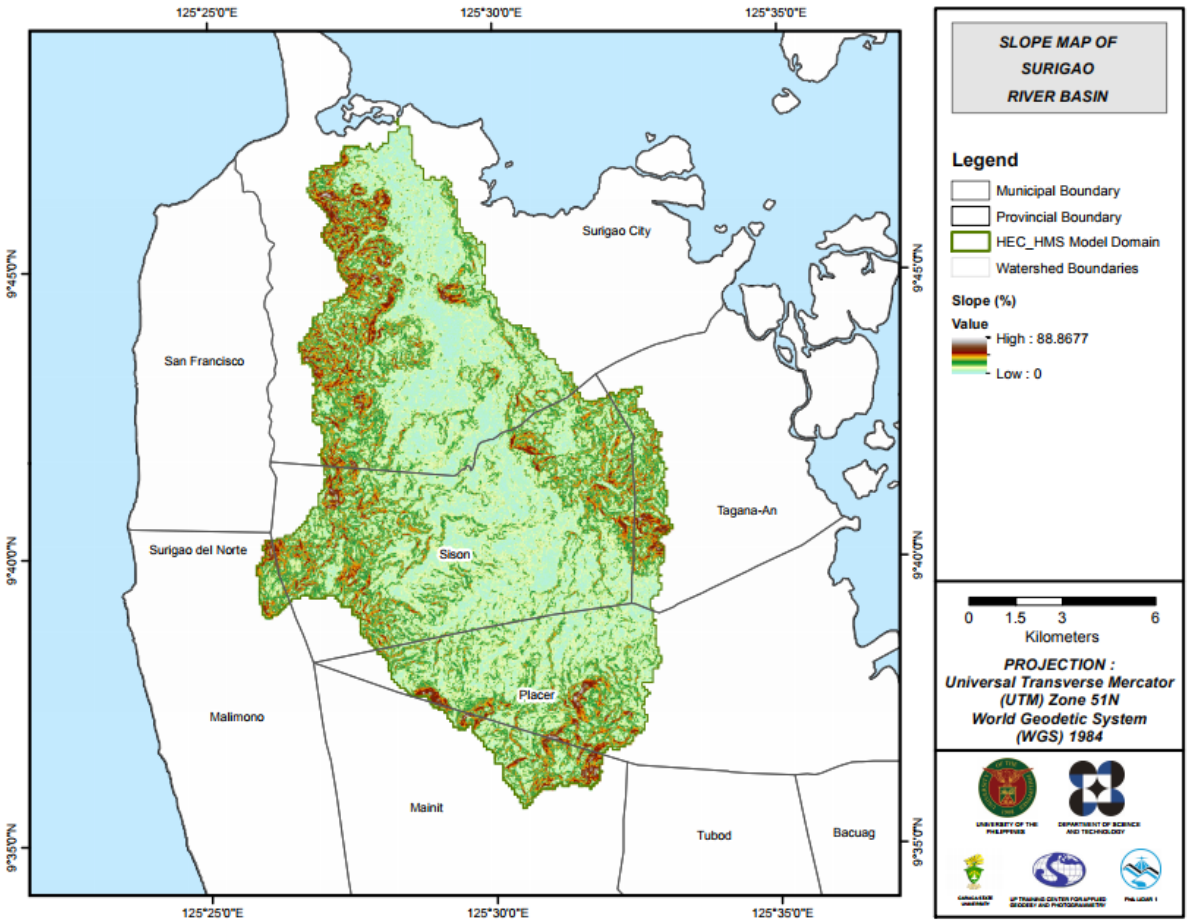


Figure 54. Slope Map of the Surigao River Basin.

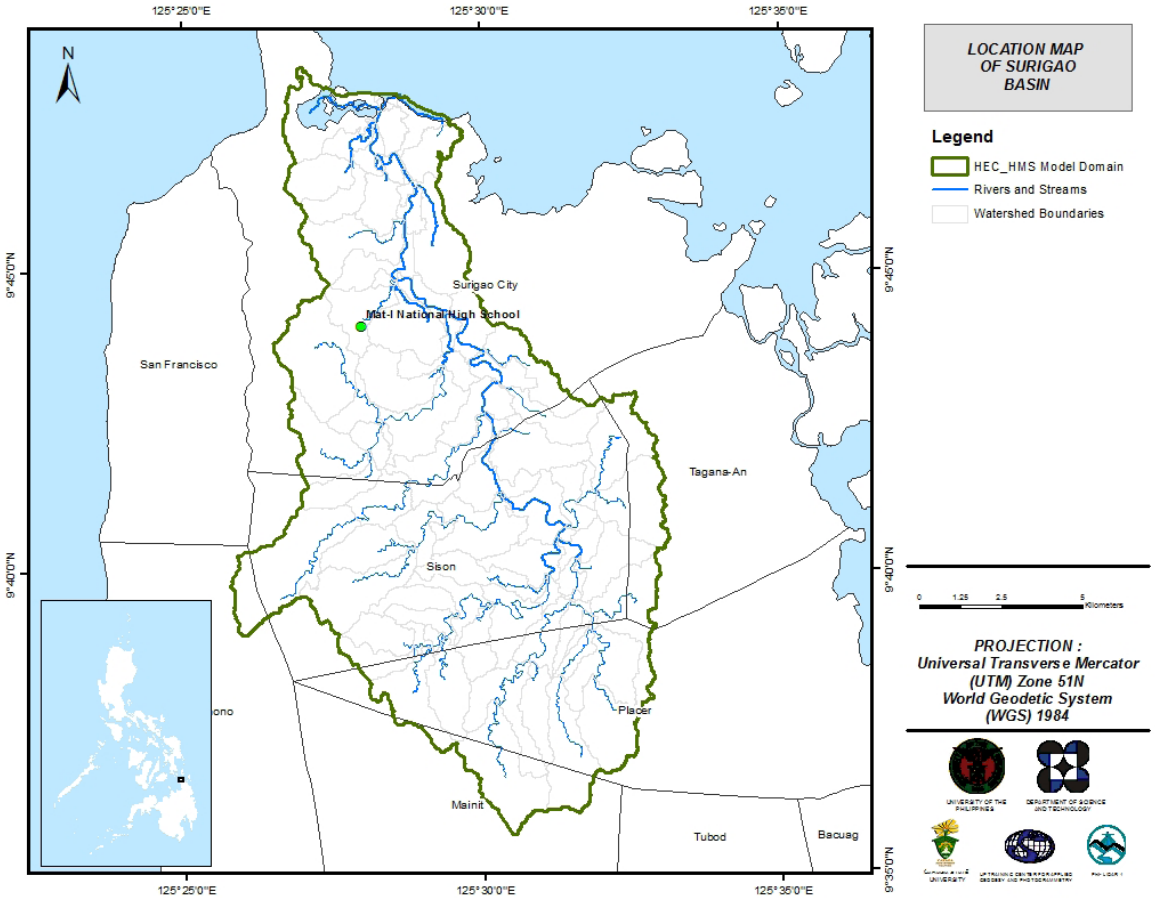


Figure 55. Stream Delineation Map of Surigao River Basin

Using the SAR-based DEM, the Surigao basin was delineated and further subdivided into subbasins. The model consists of 136 sub basins, 80 reaches, 79 junctions, and 1 diversion as shown inFigure 56. The main outlet is at Anomar Bridge.

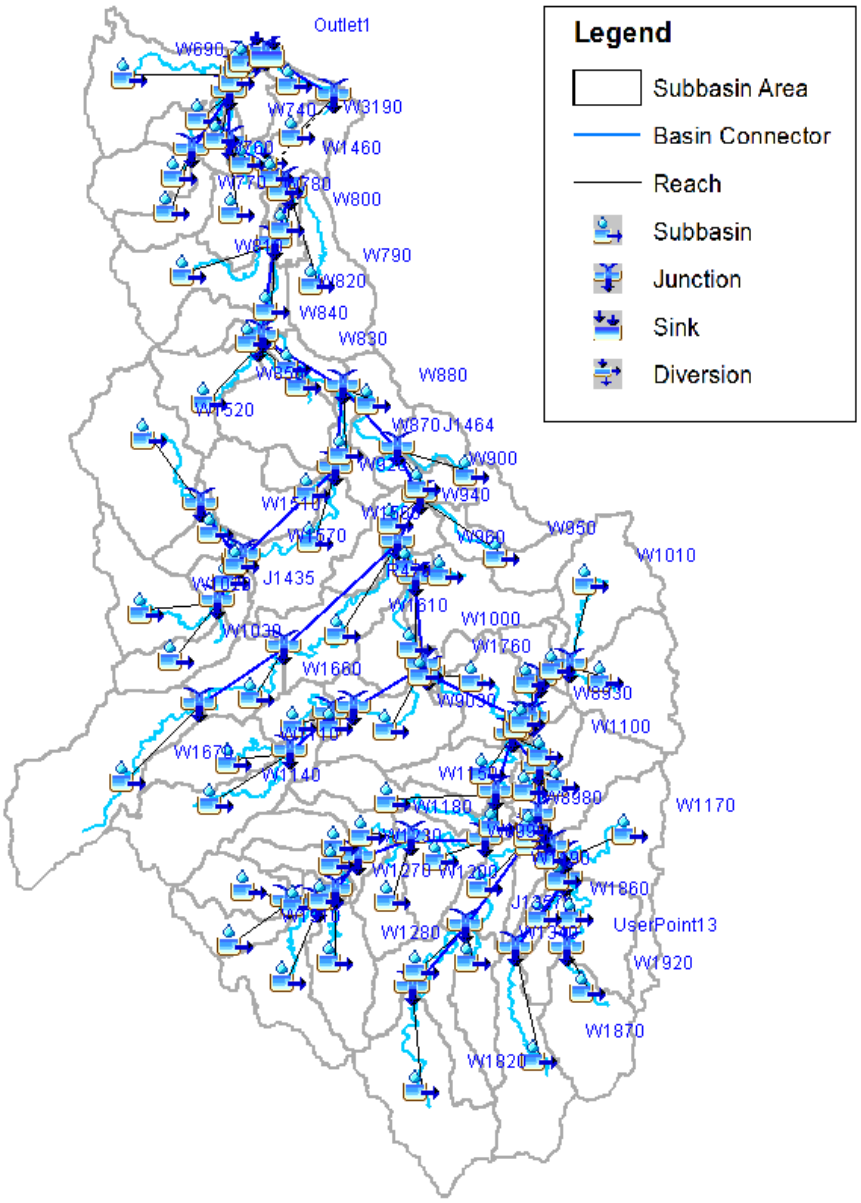


Figure 56. Surigao river basin model generated in HEC-HMS.

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 57).

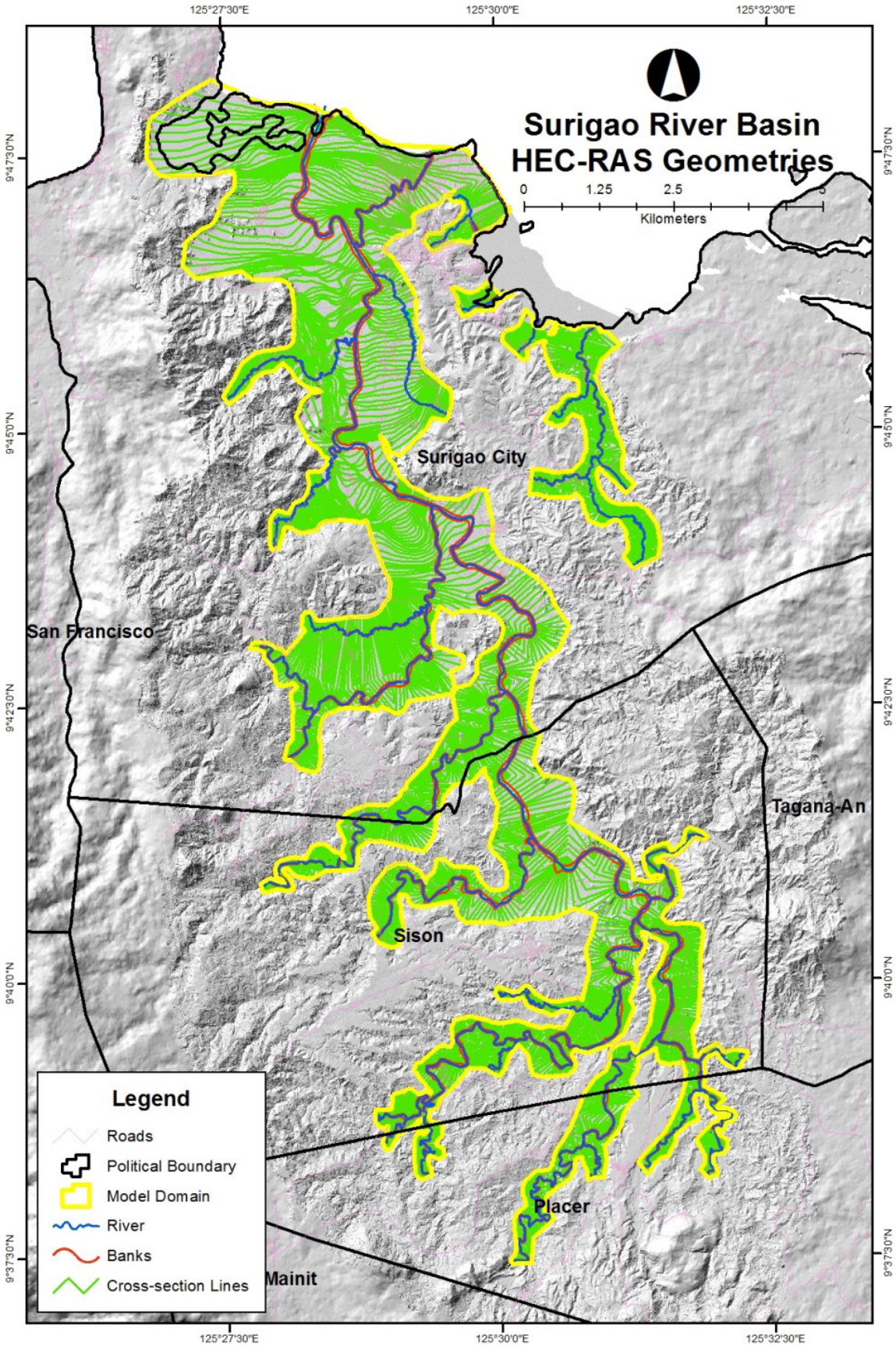


Figure 57. River cross-section of the Surigao River through the ArcMap HEC GeoRas tool

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.

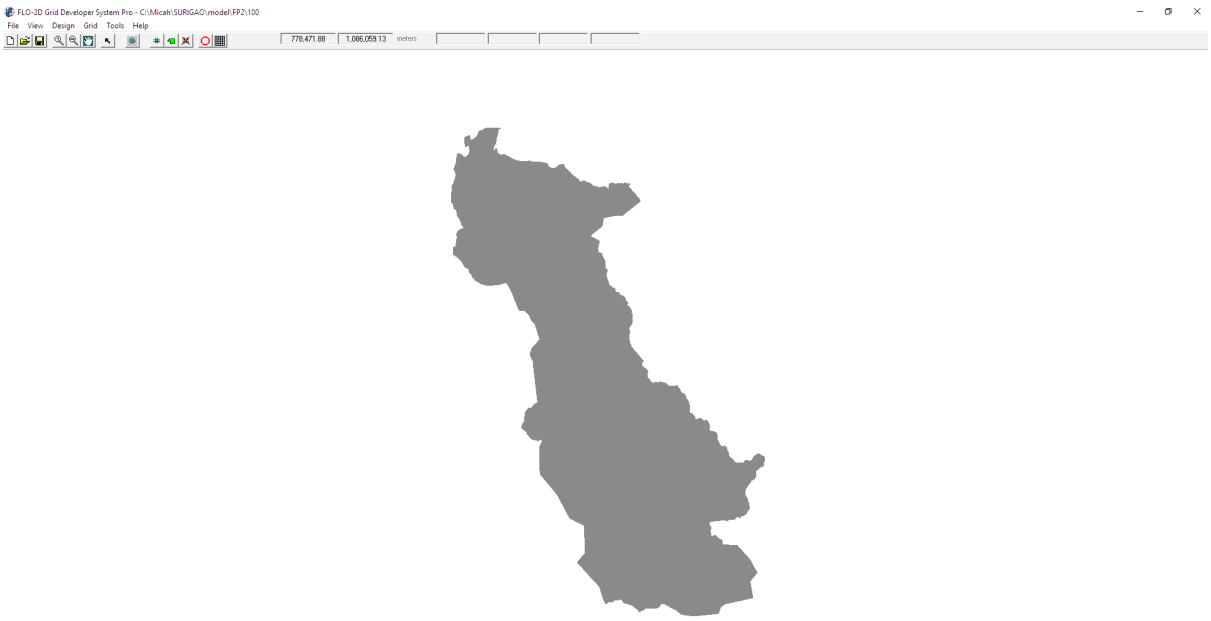


Figure 58. A screenshot of the river sub-catchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro).

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 Surigao are inFigure 62, 64 and 66.

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 Surigao are inFigure 63, 65, and 67.

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 Surigao HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 59 shows the comparison between the two discharge data.

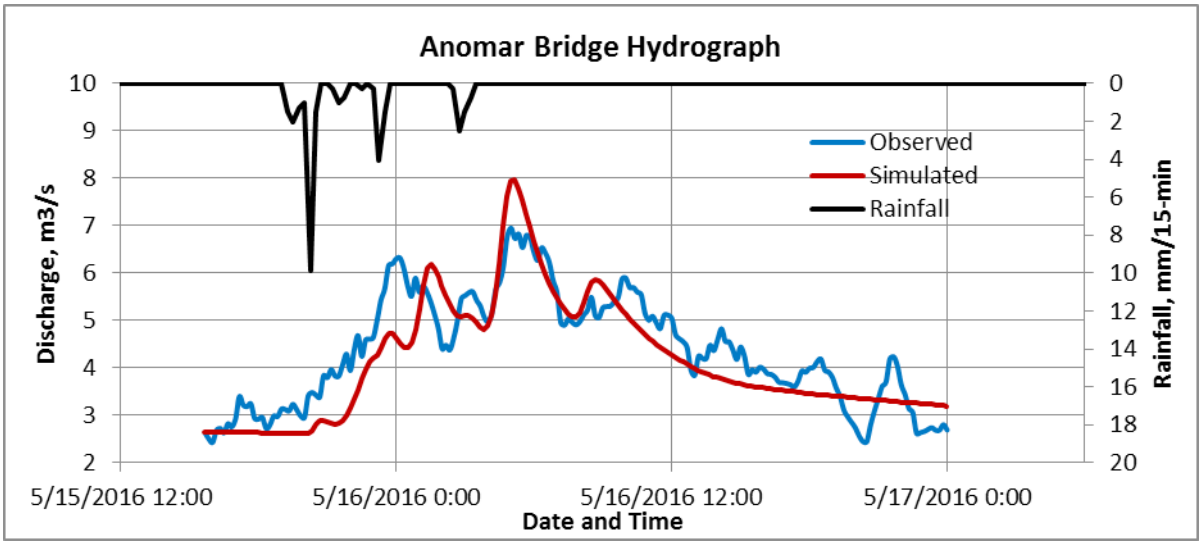


Figure 59. Outflow Hydrograph of Anomar Bridge produced by the HEC-HMS model compared with observed outflow

Table 34 shows the adjusted ranges of values of the parameters used in calibrating the model.

Table 34. Range of calibrated values for the Surigao River Basin.

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0-99.98
			Curve Number	33-84.9
			Impervious (%)	0-61.99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.078-1.74
			Storage Coefficient (hr)	0.27-6.10
	Baseflow	Recession	Recession Constant	0.75
			Ratio to Peak	0.3
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.025

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 0 mm to 100 mm means that there is high amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 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 Surigao, 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 0.78 hours to 1.74 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 0.75 indicates that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.3 indicates a steeper receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.025 corresponds to the common roughness in the Surigao watershed, which is determined to be cultivated with mature field crops (Brunner, 2010).

Table 35. Summary of the Efficiency Test of the Hubo-Otieza HMS Model

Accuracy measure	Value
RMSE	0.6
r^2	0.7733
NSE	0.70
PBIAS	5.14
RSR	0.55

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 0.6 (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 0.7733.

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 0.70.

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 5.14.

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 0.55.

5.7 Calculated Outflow hydrographys and Discharge Values for different Rainfall Return Periods

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph (Figure 60) shows the Surigao outflow using the Surigao 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.

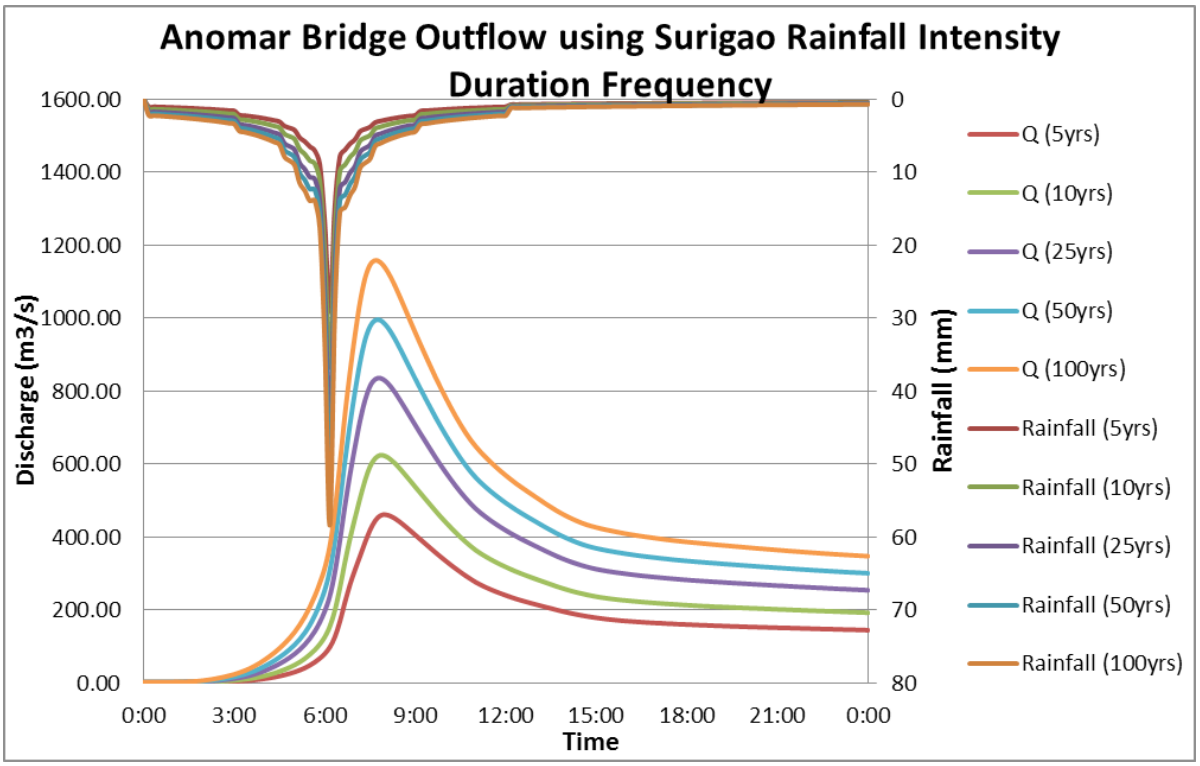


Figure 60. The Outflow hydrograph at the Anomar Bridge, generated using the Surigao RIDF simulated in HEC-HMS.

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Anomar Bridge discharge using the Surigao Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown inTable 36.

Table 36. The peak values of the Surigao HEC-HMS Model outflow at Anomar Bridge using the Surigao RIDF.

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m^3/s)	Time to Peak
5-Year	286.50	29.09	461.71	2 hours
10-Year	351.20	36.74	624.59	1 hours 50 minutes
25-Year	433.00	45.66	835.97	1 hours 50 minutes

50-Year	493.70	52.03	994.68	1 hours 50 minutes
100-Year	553.90	58.35	1,158.35	1 hours 40 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 61 shows a generated sample map of the Surigao River using the calibrated HMS base flow of Typhoon Agaton.

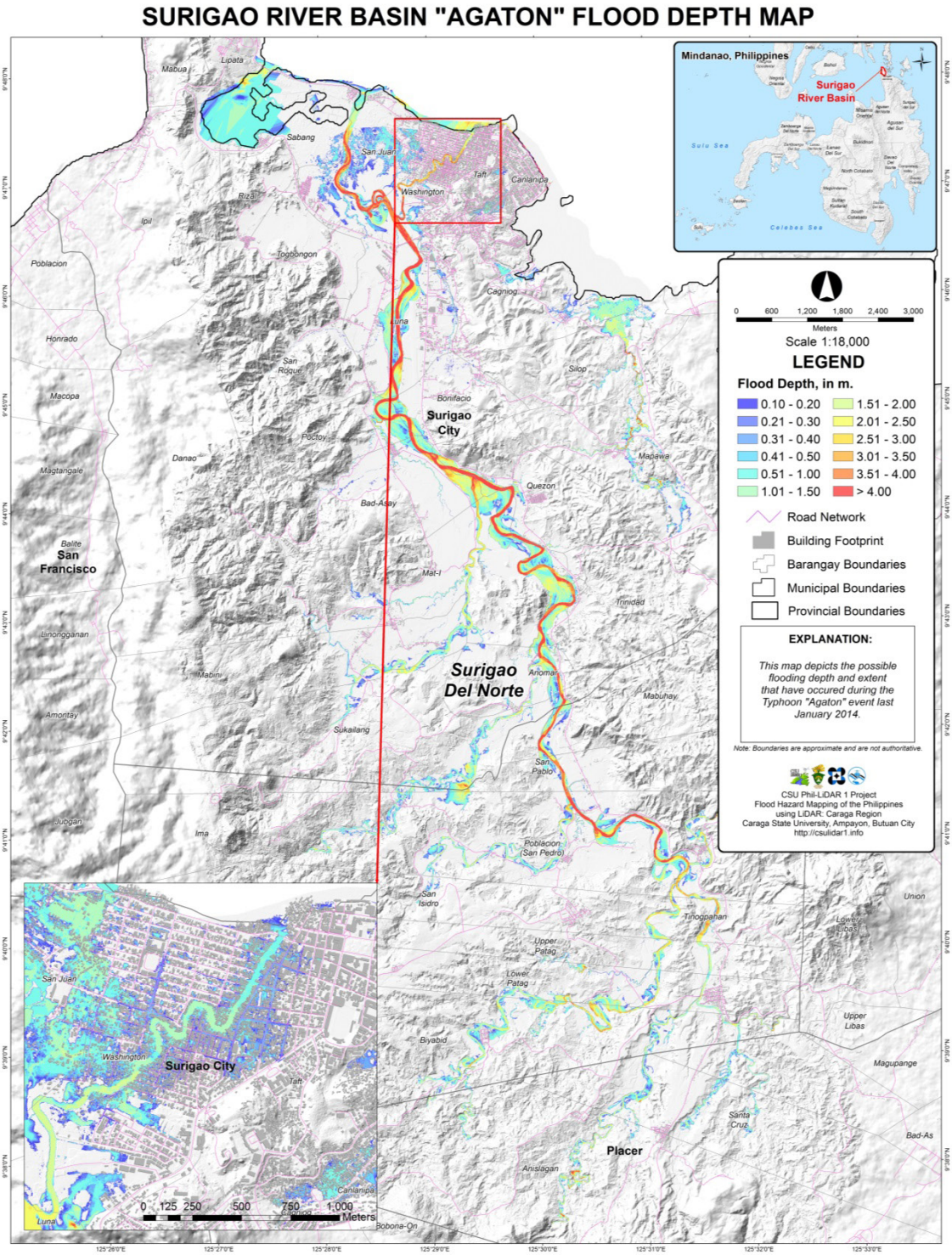


Figure 61. Sample output map of the Surigao RAS Model.

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figure 62to Figure 67shows the 5-, 25-, and 100-year rain return scenarios of the Surigao floodplain. The floodplain, with an area of 172.14 sq. km., covers four municipalites namely Placer, Sison, Surigao City and Tagana-an.Table 37 shows the percentage of area affected by flooding per municipality.

Table 37. Municipalities affected in Surigao floodplain.

Municipality	Total Area	Area Flooded	% Flooded
Placer	88.79432	14.92593	16.81%
Sison	68.78138	48.6008	70.66%
Surigao City	240.6701	99.19355	41.22%

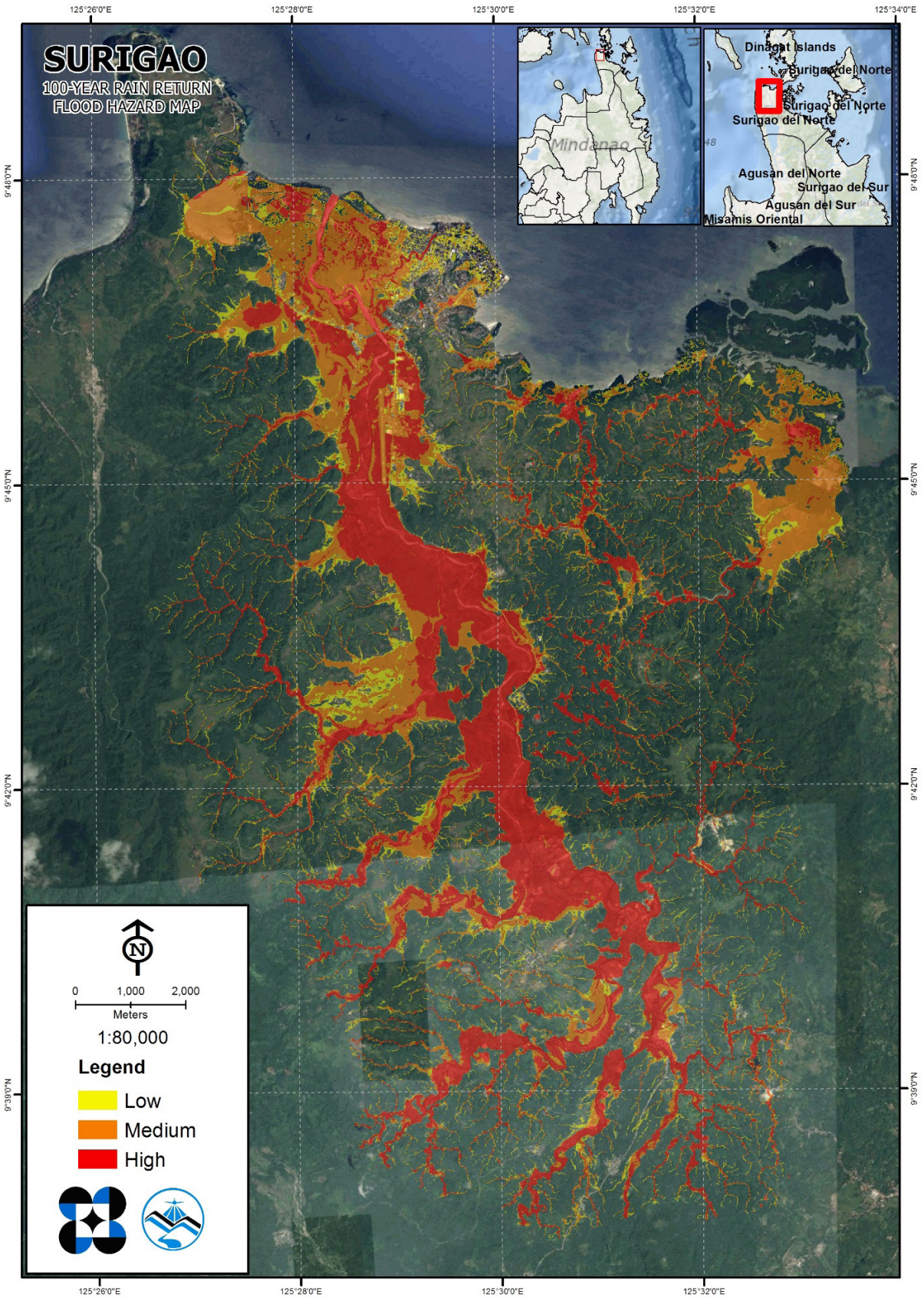


Figure 62. A 100-year Flood Hazard Map for Surigao Floodplain overlaid on Google Earth imagery.

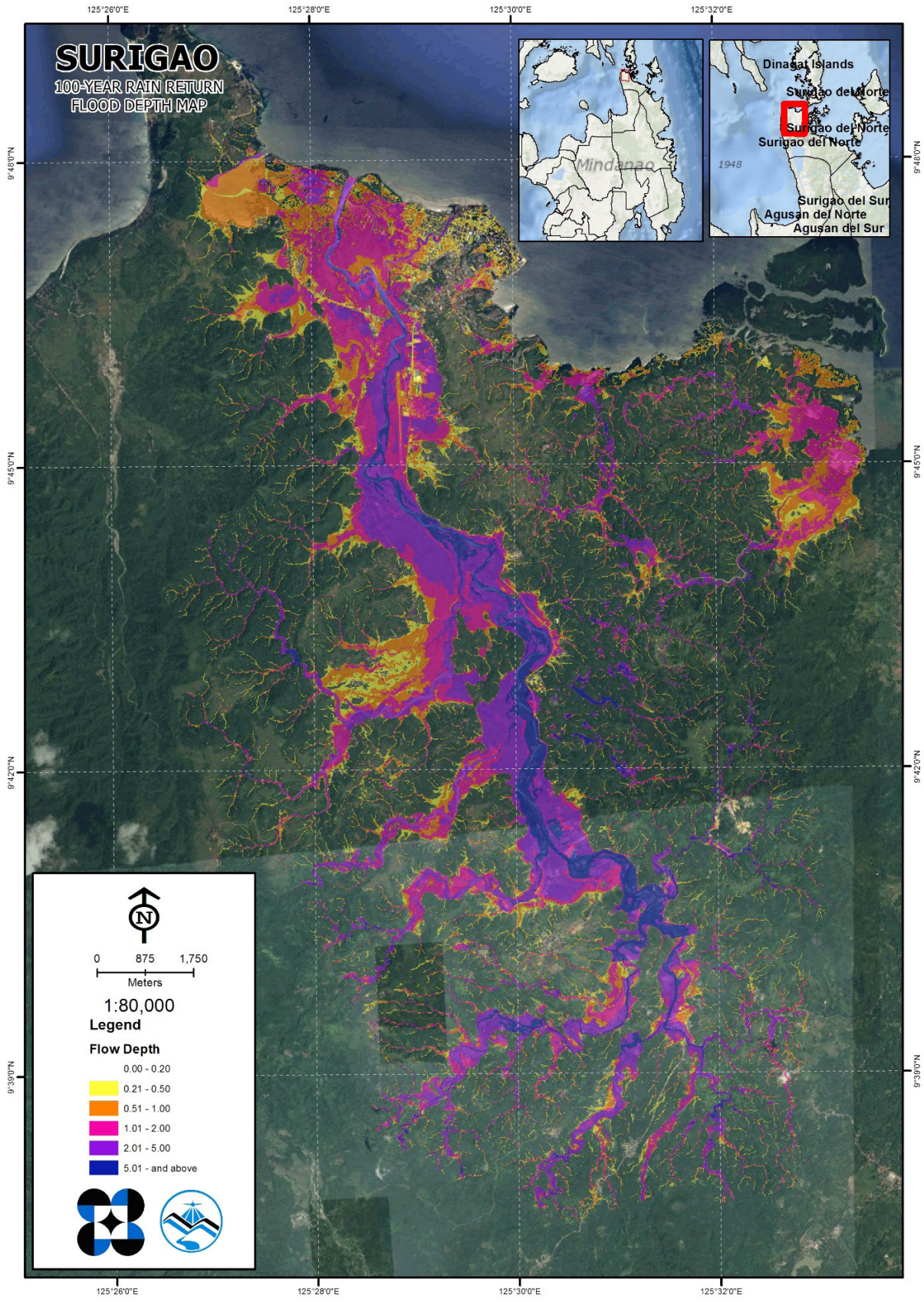


Figure 63. A 100-year Flow Depth Map for Surigao Floodplain overlaid on Google Earth imagery.

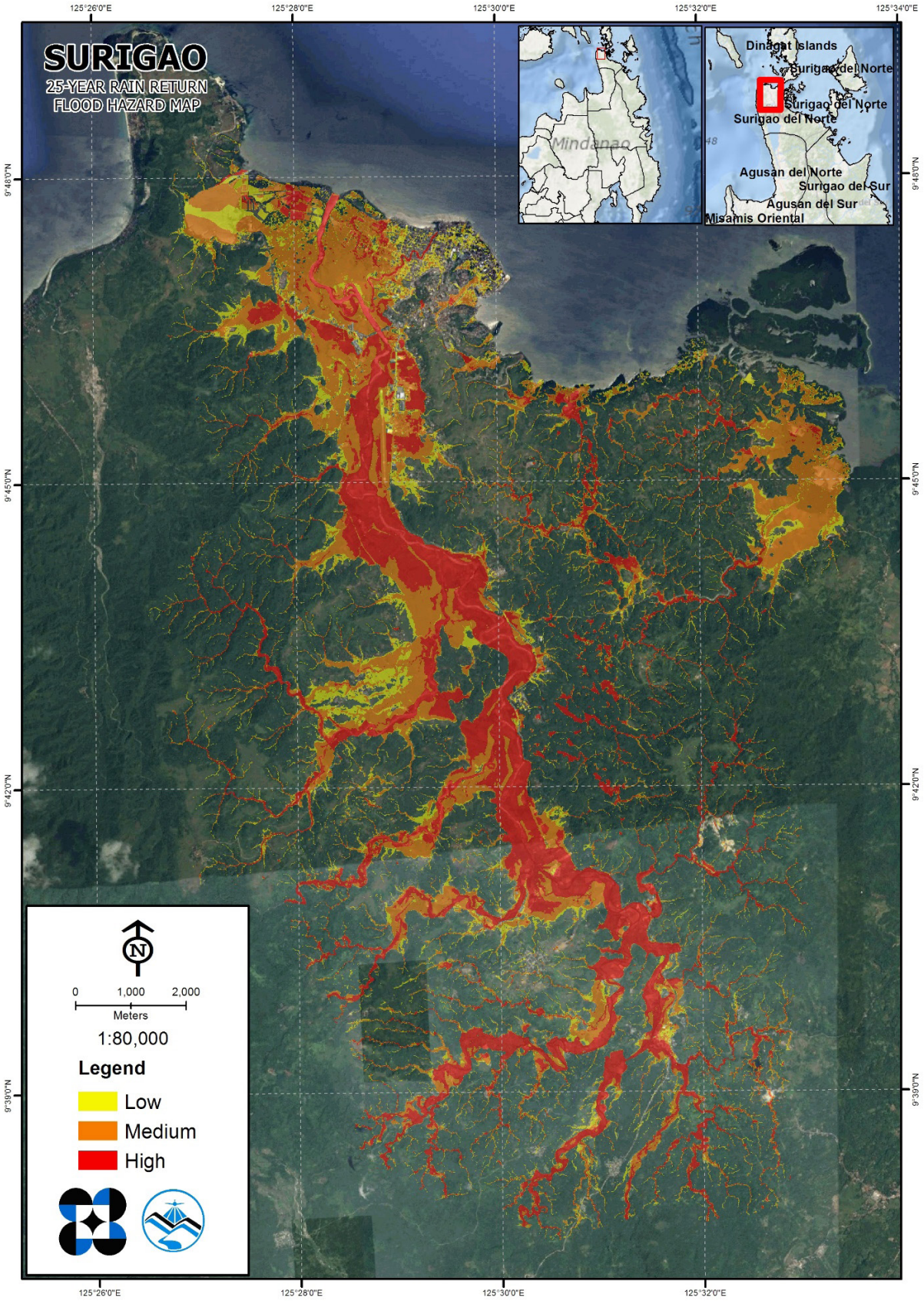


Figure 64. A 25-year Flood Hazard Map for Surigao Floodplain overlaid on Google Earth imagery.

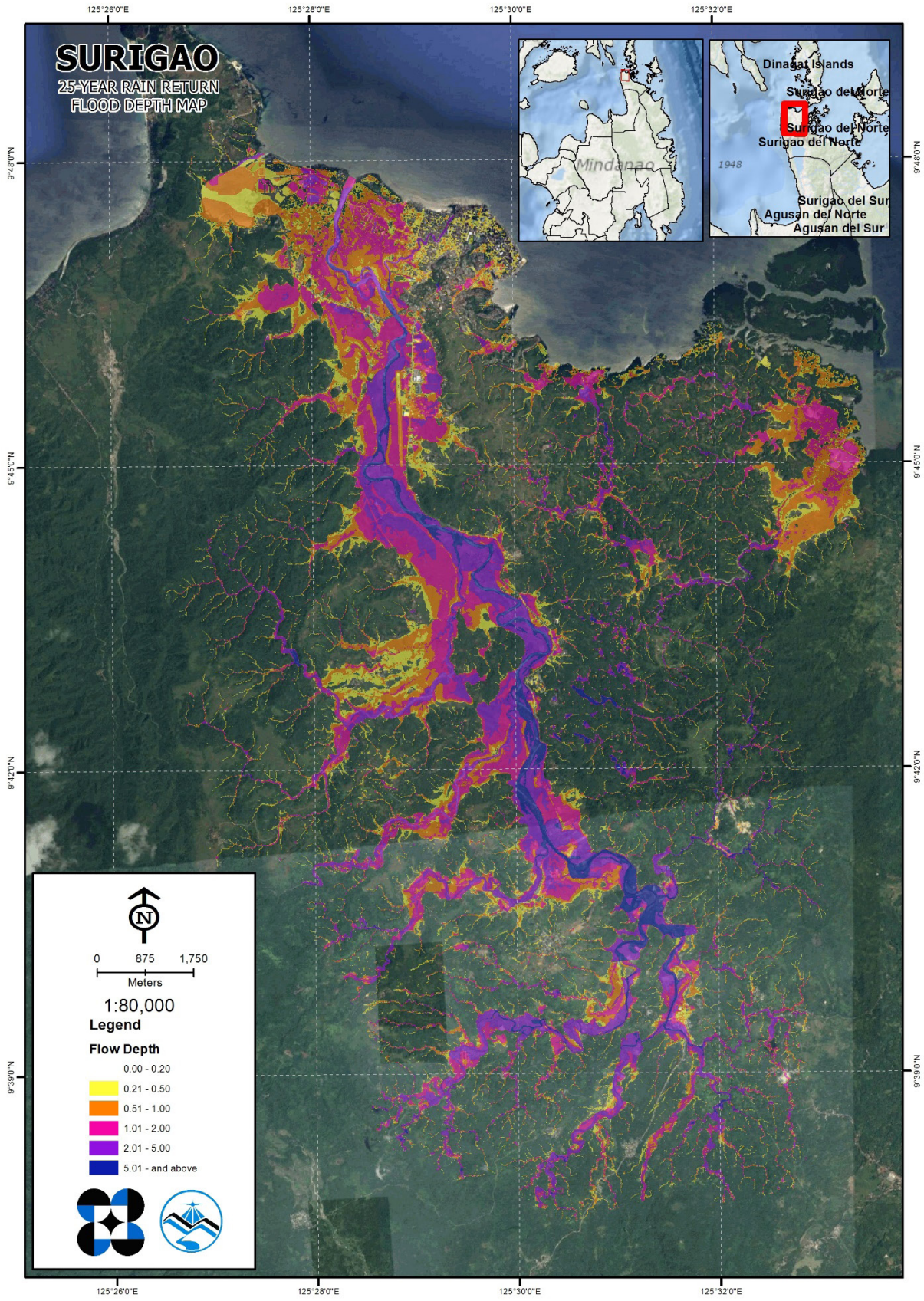


Figure 65. A 25-year Flow Depth Map for Surigao Floodplain overlaid on Google Earth imagery.

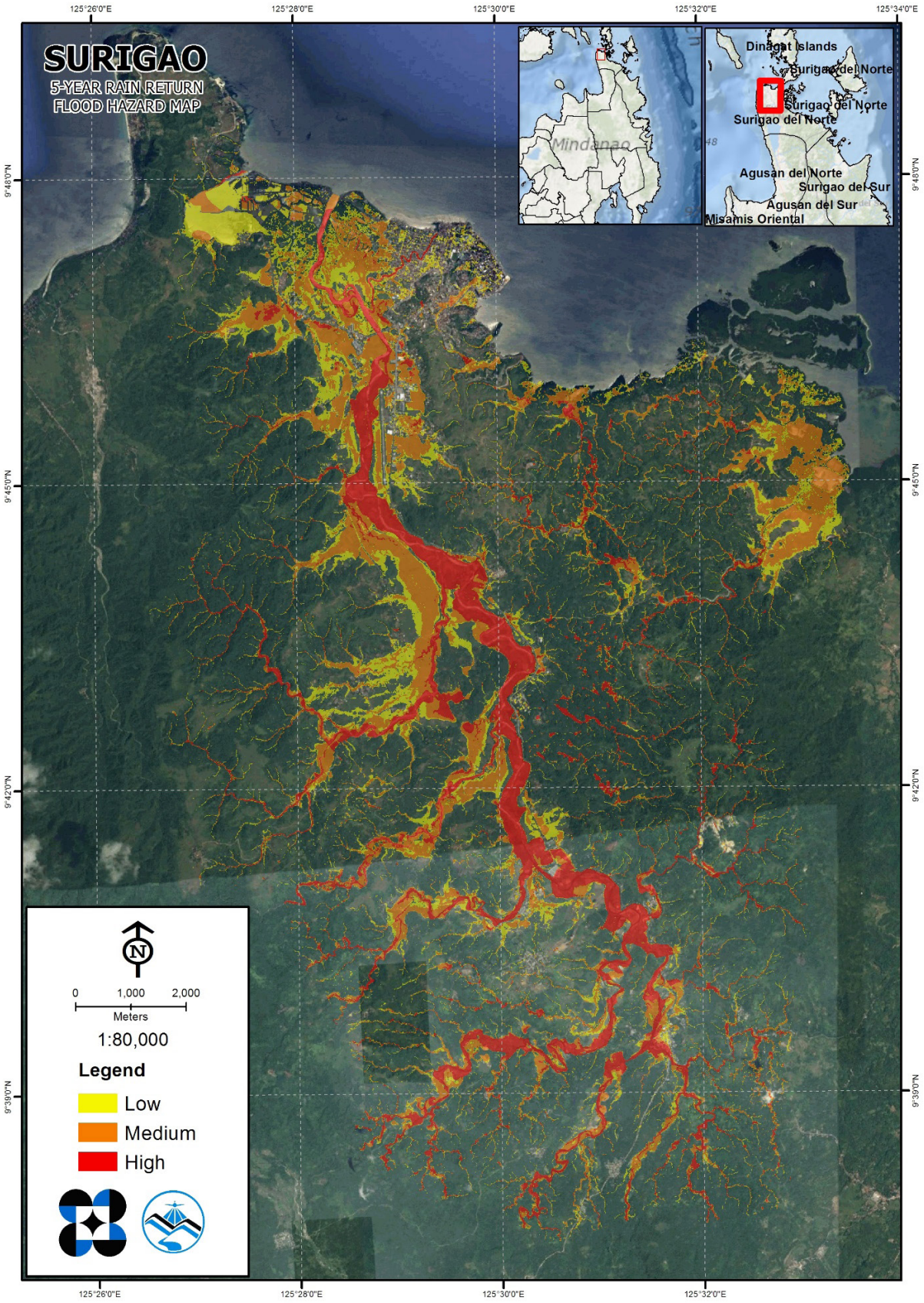


Figure 66. A 5-year Flood Hazard Map for Surigao Floodplain overlaid on Google Earth imagery.

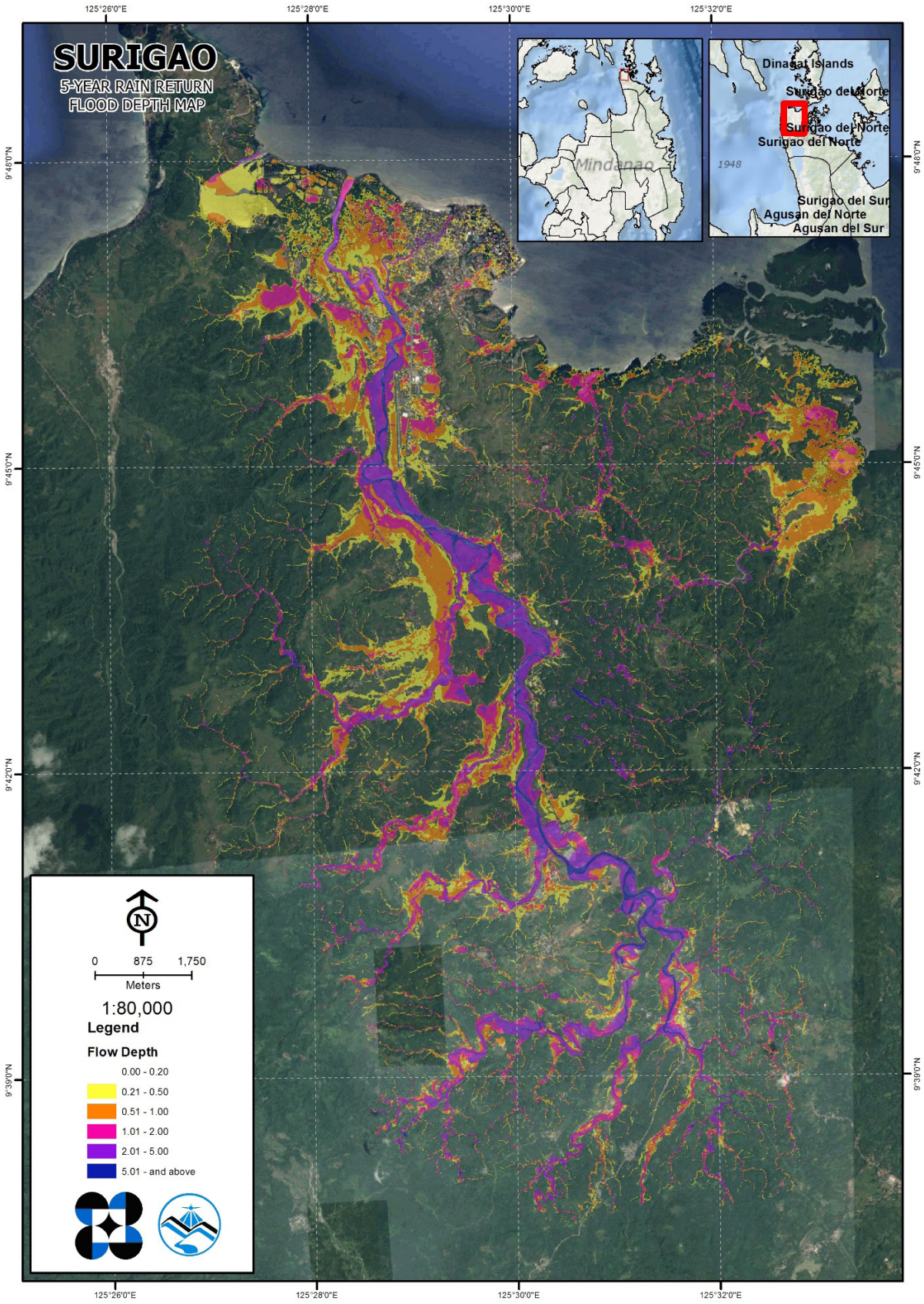


Figure 67. A 5-year Flood Depth Map for Surigao Floodplain overlaid on Google Earth imagery.

5.10 Inventory of Areas Exposed to Flooding of Affected Areas

Listed below are the affected barangays in the Surigao River Basin, grouped accordingly by municipality. For the said basin, four (4) municipalities consisting of 45 barangays are expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 14.13% of the municipality of Placer with an area of 288.73 sq. km.will experience flood levels of less 0.20 meters. 0.69% of the area will experience flood levels of 0.21 to 0.50 meters while 0.68%, 0.80%, 0.50%, and 0.01% 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 38are the affected areas in Placer in square kilometers by flood depth per barangay. Annex 12 and Annex 13 shows the educational and health institutions exposed to flooding, respectively.

Table 38. Affected Areas in Placer, Surigao del Norte during 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	**Areas of affected Barangays in Placer (in sq.km.)**			
	Anislagan	Magupange	San Isidro	Santa Cruz
0.03-0.20	5.75	0.079	2.04	4.67
0.21-0.50	0.27	0.0044	0.11	0.23
0.51-1.00	0.25	0.0052	0.1	0.25
1.01-2.00	0.28	0.0055	0.11	0.31
2.01-5.00	0.23	0.0024	0.085	0.13
> 5.00	0.0063	0	0.0036	0.0018

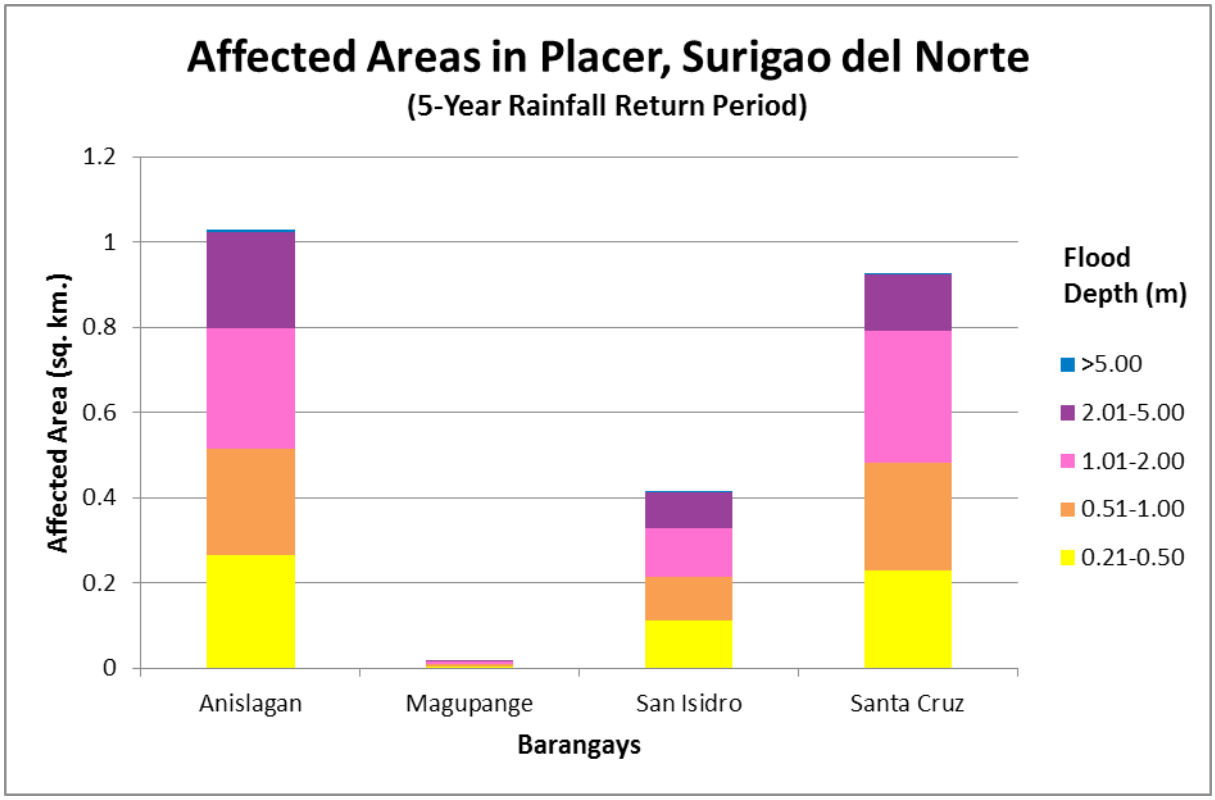


Figure 68. Affected Areas in Placer, Surigao del Norte during 5-Year Rainfall Return Period.

For the municipality of Sison with an area of 68.78 sq. km., 97.21% will experience flood levels of less than 0.20 meters. 3.69% of the area will experience flood levels of 0.21 to 0.50 meters while 3.37%, 3.63%, 4.43%, and 0.89% 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 39 are the affected areas in Sison in square kilometers by flood depth per barangay.

Table 39. Affected Areas in Sison, Surigao del Norte during 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Areas of affected Barangays in Sison									
	Biyabid	Ima	Lower Patag	Mabuhay	Poblacion	San Isidro	San Pablo	Tagbayani	Tinogpahan	Upper Patag
0.03-0.20	4.83	0.51	3.7	5.2	10.13	3.39	4.4	0.43	1.67	32.6
0.21-0.50	0.33	0.016	0.27	0.22	0.86	0.17	0.34	0.014	0.1	0.22
0.51-1.00	0.44	0.0071	0.24	0.17	0.8	0.13	0.21	0.013	0.12	0.19
1.01-2.00	0.63	0.004	0.32	0.14	0.76	0.13	0.13	0.0098	0.17	0.2
2.01-5.00	0.58	0.00046	0.38	0.32	1.18	0.07	0.24	0.0066	0.16	0.11
> 5.00	0.016	0	0.039	0.073	0.33	0.0011	0.041	0.0001	0.084	0.029

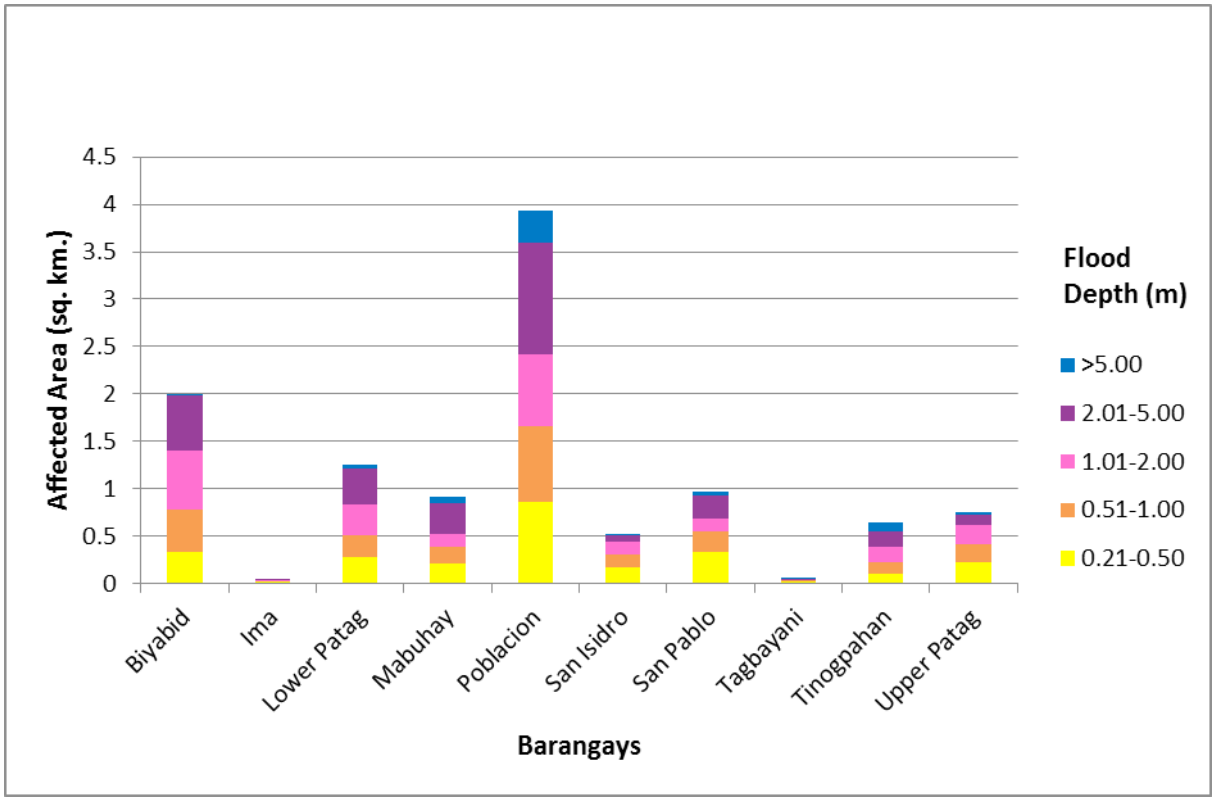


Figure 69. Affected Areas in Sison, Surigao del Norte during 5-Year Rainfall Return Period.

For Surigao City with an area of 240.67 sq. km., 29.53% will experience flood levels of less than 0.20 meters. 3.91% of the area will experience flood levels of 0.21 to 0.50 meters while 3.75%, 2.13%, 1.58%, and 0.30% 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 40are the affected areas in Marihatag in square kilometers by flood depth per barangay.

Table 40. Affected Areas in Surigao City, Surigao del Norte during 5-Year Rainfall Return Period.

Affected area	Areas of affected Barangays in Surigao City										
(sq. km.) by flood depth (in m.)	Anomar	Balibayon	Bonifacio	Cabongbongan	Cagniog	Canlanipa	Capalayan	Danao	Day-Asan	Ipil	Lipata
0.03-0.20	1.24	1.02	1.31	1.55	3.77	0.45	3.5	2.81	0.093	1.41	0.77
0.21-0.50	0.14	0.1	0.33	0.42	0.29	0.12	0.74	0.078	0.014	0.1	0.056
0.51-1.00	0.21	0.051	0.22	0.64	0.3	0.035	1.08	0.048	0.004	0.02	0.019
1.01-2.00	0.28	0.027	0.083	0.033	0.26	0.0057	0.28	0.053	0	0.0035	0.013
2.01-5.00	0.23	0.0049	0.098	0.014	0.0074	0	0.021	0.036	0	0.00074	0.0058
> 5.00	0.041	0	0.028	0	0	0	0.00059	0.0014	0	0	0

Affected area											
(sq. km.) by flood depth (in m.)	Luna	Mabini	Mabua	Mapa-wa	Mat-I	Nabago	Orok	Poctoy	Quezon	Rizal	
0.03-0.20	1.45	3.04	0.23	8.17	6.28	0.096	2.65	2.03	2.89	1.36	
0.21-0.50	1.05	0.5	0.013	0.45	0.97	0.1	0.1	0.12	0.16	0.17	
0.51-1.00	1.13	0.32	0.0067	0.4	0.86	0.29	0.1	0.12	0.11	0.1	
1.01-2.00	0.72	0.26	0.008	0.4	0.53	0.065	0.12	0.088	0.13	0.012	
2.01-5.00	0.56	0.23	0.000063	0.23	1.08	0	0.022	0.24	0.17	0.0004	
> 5.00	0.19	0	0	0.0012	0.19	0	0.000013	0.042	0.085	0	

Affected area											
(sq. km.) by flood depth (in m.)	Sabang	San Juan	San Roque	Sema	Silop	Sukailang	Taft	Togbongon	Trinidad	Washington	
0.03-0.20	1.05	0.49	3.23	2.76	2.96	6.1	1.07	2.39	4.11	0.78	
0.21-0.50	0.51	0.5	0.16	0.46	0.19	0.54	0.21	0.41	0.17	0.25	
0.51-1.00	0.16	0.57	0.15	0.74	0.13	0.58	0.043	0.32	0.12	0.14	
1.01-2.00	0.034	0.2	0.097	0.28	0.14	0.45	0.0089	0.34	0.14	0.076	
2.01-5.00	0.03	0.093	0.02	0.24	0.029	0.22	0.003	0.0047	0.15	0.066	
> 5.00	0	0.0034	0.0004	0.079	0.0059	0.017	0.0011	0	0.044	0.0025	

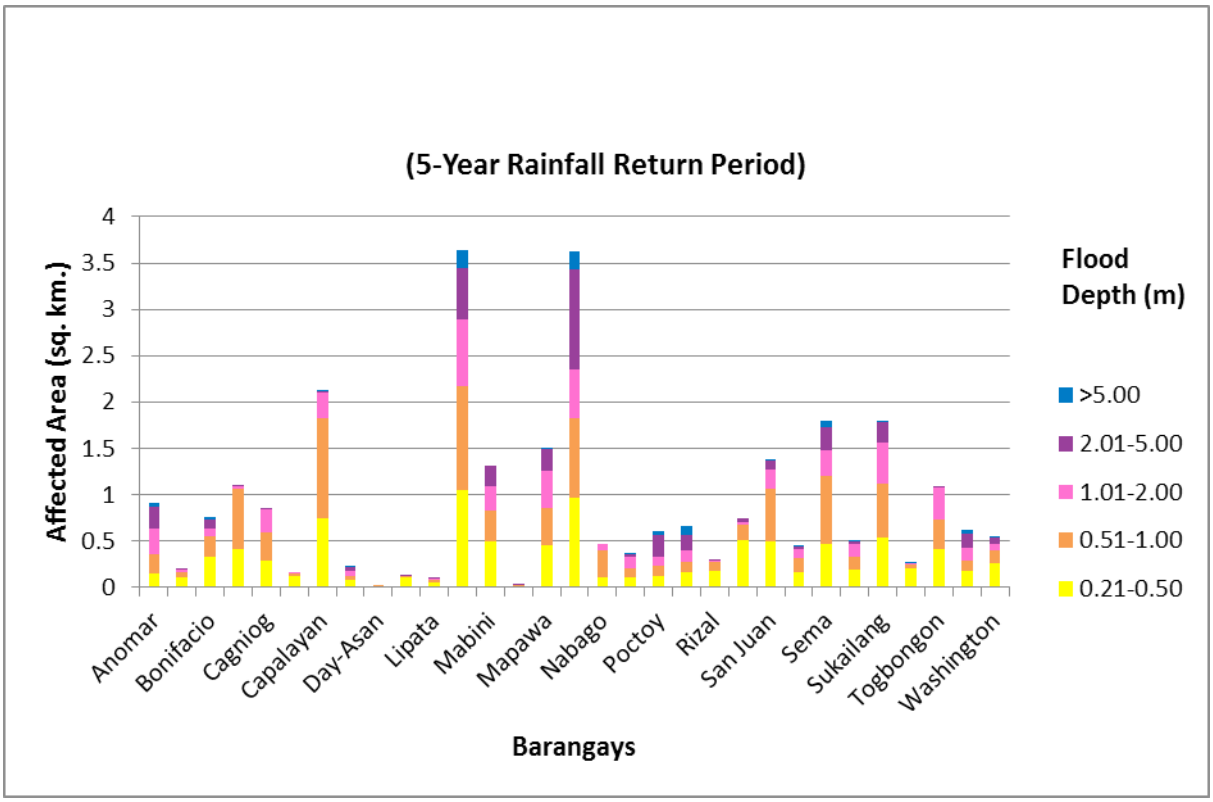


Figure 70. Affected Areas in Surigao City, Surigao del Norte during 5-Year Rainfall Return Period.

For the municipality of Tagana-an with an area of 81.99 sq. km., 8.20% will experience flood levels of less 0.20 meters. 0.25% of the area will experience flood levels of 0.21 to 0.50 meters while 0.18%, 0.18%, 0.11%, and 0.01% 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 41are the affected areas in square kilometers by flood depth per barangay.

Table 41. Affected Areas in Tagana-an, Surigao del Norte during 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Areas of affected Barangays in Tagana-an			
	Himamaug	Laurel	Lower Libas	Upper Libas
0.03-0.20	2.53	1.71	2.78	0.26
0.21-0.50	0.069	0.049	0.084	0.021
0.51-1.00	0.044	0.026	0.073	0.02
1.01-2.00	0.04	0.022	0.081	0.015
2.01-5.00	0.034	0.017	0.048	0.0022
> 5.00	0.0062	0.0027	0.0021	0

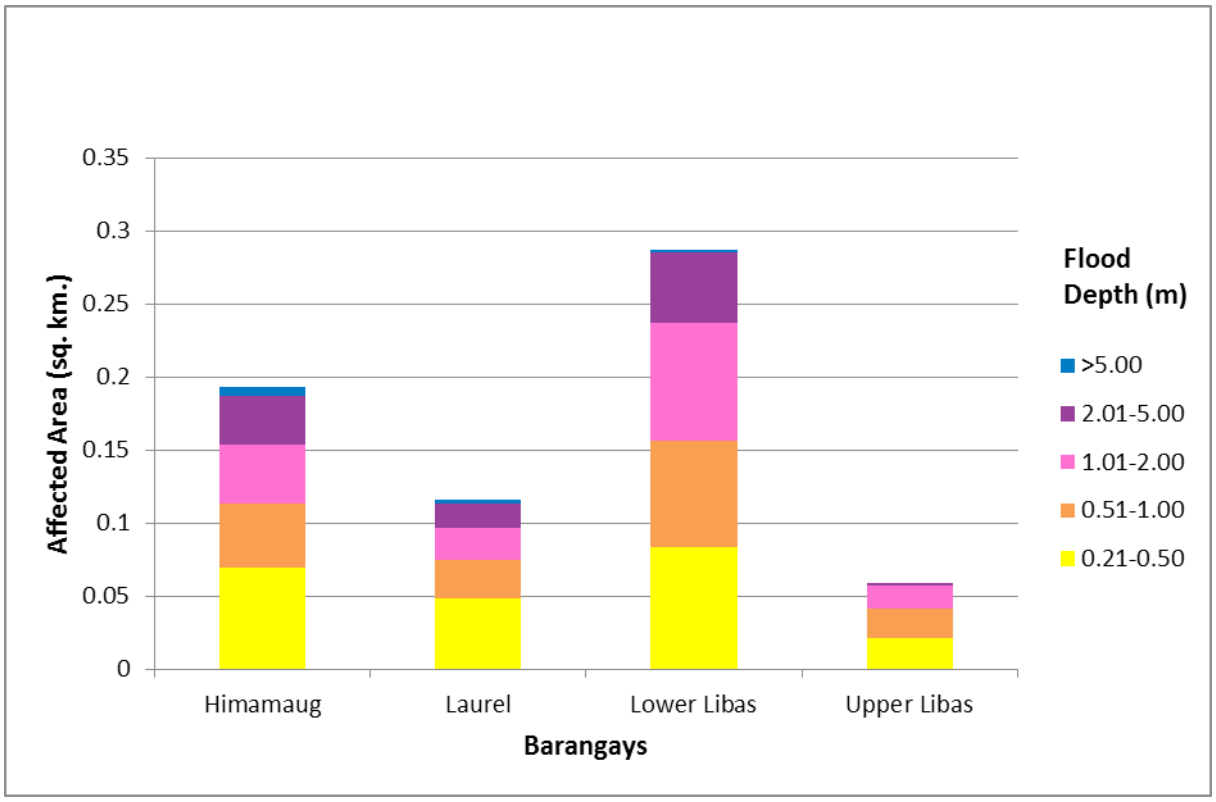


Figure 71. Affected Areas in Tagana-an, Surigao del Norte during 5-Year Rainfall Return Period.

For the 25-year return period, 13.60% of the municipality of Placer with an area of 88.73 sq. km. will experience flood levels of less 0.20 meters. 0.77% of the area will experience flood levels of 0.21 to 0.50 meters while 0.64%, 0.86%, 0.88%, and 0.04% 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 42 are the affected areas in Placer in square kilometers by flood depth per barangay.

Table 42. Affected Areas in Placer, Surigao del Norte during 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Areas of affected Barangays in Placer (in sq.km.)			
	Anislagan	Magupange	San Isidro	Santa Cruz
0.03-0.20	5.56	0.076	1.95	4.48
0.21-0.50	0.29	0.0038	0.11	0.28
0.51-1.00	0.24	0.0051	0.11	0.21
1.01-2.00	0.31	0.0068	0.13	0.32
2.01-5.00	0.35	0.0044	0.13	0.3
> 5.00	0.018	0	0.015	0.0057

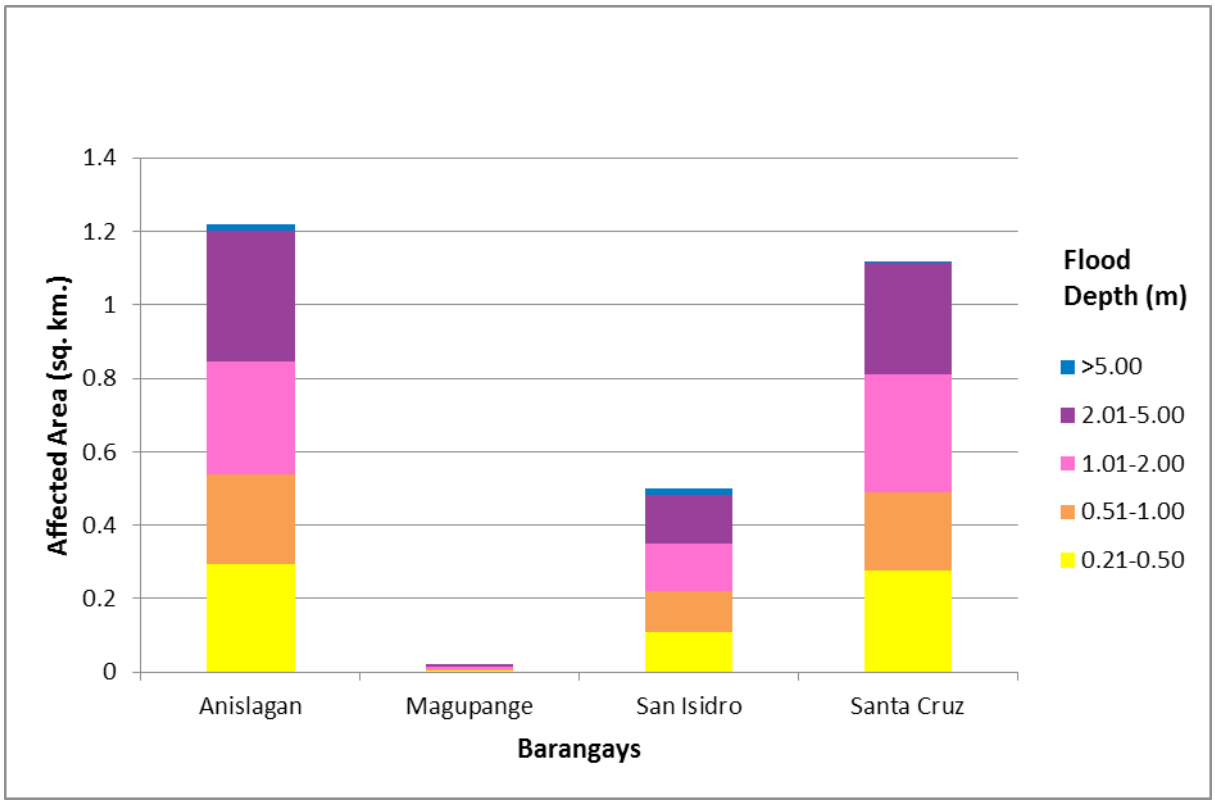


Figure 72. Affected Areas in Placer, Surigao del Norte during 25-Year Rainfall Return Period.

For the municipality of Sison with an area of 68.78 sq. km., 50.95% will experience flood levels of less than 0.20 meters. 3.09% of the area will experience flood levels of 0.21 to 0.50 meters while 3.49%, 4.94%, 6.00%, and 2.17% 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 43 are the affected areas in Sison in square kilometers by flood depth per barangay.

Table 43. Affected Areas in Sison, Surigao del Norte during 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)			Areas of affected Barangays in Sison							
	Biyabid	Ima	Lower Patag	Mabuhay	Poblacion	San Isidro	San Pablo	Tagbayani	Tinogpahan	Upper Patag
0.03-0.20	4.57	0.5	3.41	4.99	9.08	3.29	4.15	0.43	1.51	3.11
0.21-0.50	0.26	0.02	0.27	0.17	0.68	0.18	0.22	0.012	0.095	0.22
0.51-1.00	0.33	0.0086	0.32	0.15	0.9	0.14	0.19	0.014	0.1	0.25
1.01-2.00	0.65	0.0061	0.36	0.27	1.18	0.16	0.4	0.014	0.14	0.22
2.01-5.00	0.96	0.00058	0.53	0.32	1.46	0.11	0.26	0.0088	0.27	0.21
> 5.00	0.065	0	0.071	0.21	0.77	0.0065	0.13	0.0002	0.19	0.048

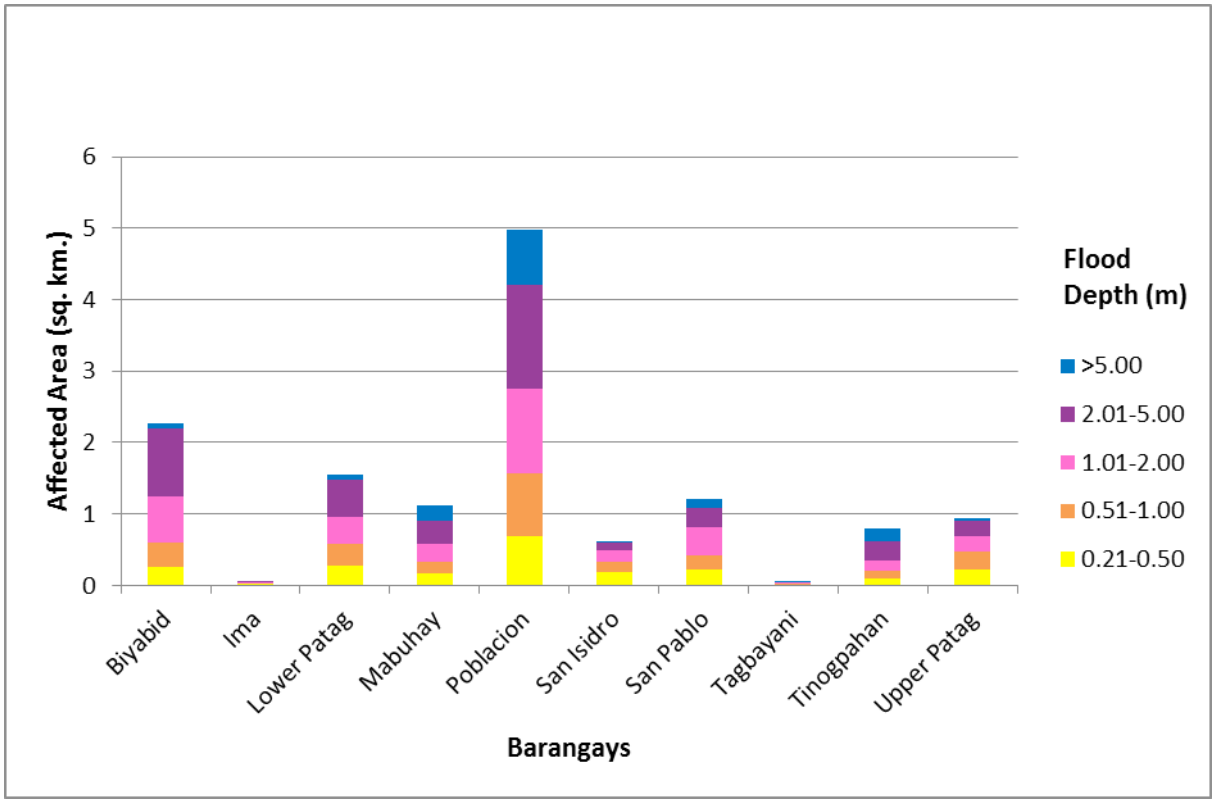


Figure 73. Affected Areas in Sison, Surigao del Norte during 25-Year Rainfall Return Period.

For Surigao City with an area of 240.67 sq. km., 26.99% will experience flood levels of less than 0.20 meters. 3.08% of the area will experience flood levels of 0.21 to 0.50 meters while 4.05%, 4.17%, 2.42%, and 0.53% 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 44are the affected areas in Surigao City in square kilometers by flood depth per barangay.

Table 44. Affected Areas in Surigao City, Surigao del Norte during 25-Year Rainfall Return Period.

Affected area	Areas of affected Barangays in Surigao City										
(sq. km.) by flood depth (in m.)	Anomar	Balibayon	Bonifacio	Cabongbongan	Cagniog	Canlanipa	Capalayan	Danao	Day-Asan	Ipil	Lipata
0.03-0.20	0.99	0.97	1.14	1.41	3.61	0.39	3.25	2.76	0.086	1.37	0.75
0.21-0.50	0.066	0.12	0.25	0.3	0.27	0.15	0.47	0.095	0.017	0.094	0.062
0.51-1.00	0.12	0.073	0.19	0.75	0.32	0.055	1.15	0.051	0.0076	0.059	0.034
1.01-2.00	0.35	0.032	0.34	0.17	0.35	0.014	0.71	0.058	0	0.005	0.014
2.01-5.00	0.46	0.014	0.1	0.019	0.074	0	0.053	0.057	0	0.0015	0.0085
> 5.00	0.16	0	0.039	0	0	0	0.0011	0.002	0	0	0

Affected area											
(sq. km.) by flood depth (in m.)	Luna	Mabini	Mabua	Mapa-wa	Mat-I	Nabago	Orok	Poctoy	Quezon	Rizal	
0.03-0.20	1.45	3.04	0.23	8.17	6.28	0.096	2.65	2.03	2.89	1.36	
0.21-0.50	1.05	0.5	0.013	0.45	0.97	0.1	0.1	0.12	0.16	0.17	
0.51-1.00	1.13	0.32	0.0067	0.4	0.86	0.29	0.1	0.12	0.11	0.1	
1.01-2.00	0.72	0.26	0.008	0.4	0.53	0.065	0.12	0.088	0.13	0.012	
2.01-5.00	0.56	0.23	0.000063	0.23	1.08	0	0.022	0.24	0.17	0.0004	
> 5.00	0.19	0	0	0.0012	0.19	0	0.000013	0.042	0.085	0	

Affected area											
(sq. km.) by flood depth (in m.)	Sabang	San Juan	San Roque	Sema	Silop	Sukailang	Taft	Togbongon	Trinidad	Washington	
0.03-0.20	0.5	0.19	3.16	2.52	2.87	5.8	0.97	2.25	3.92	0.52	
0.21-0.50	0.4	0.18	0.17	0.24	0.2	0.48	0.27	0.28	0.2	0.3	
0.51-1.00	0.6	0.63	0.15	0.28	0.15	0.52	0.073	0.37	0.14	0.27	
1.01-2.00	0.21	0.72	0.15	0.79	0.15	0.69	0.017	0.54	0.17	0.15	
2.01-5.00	0.066	0.11	0.034	0.62	0.082	0.36	0.0038	0.033	0.22	0.081	
> 5.00	0	0.023	0.00065	0.13	0.0098	0.051	0.0027	0.0002	0.092	0.0045	

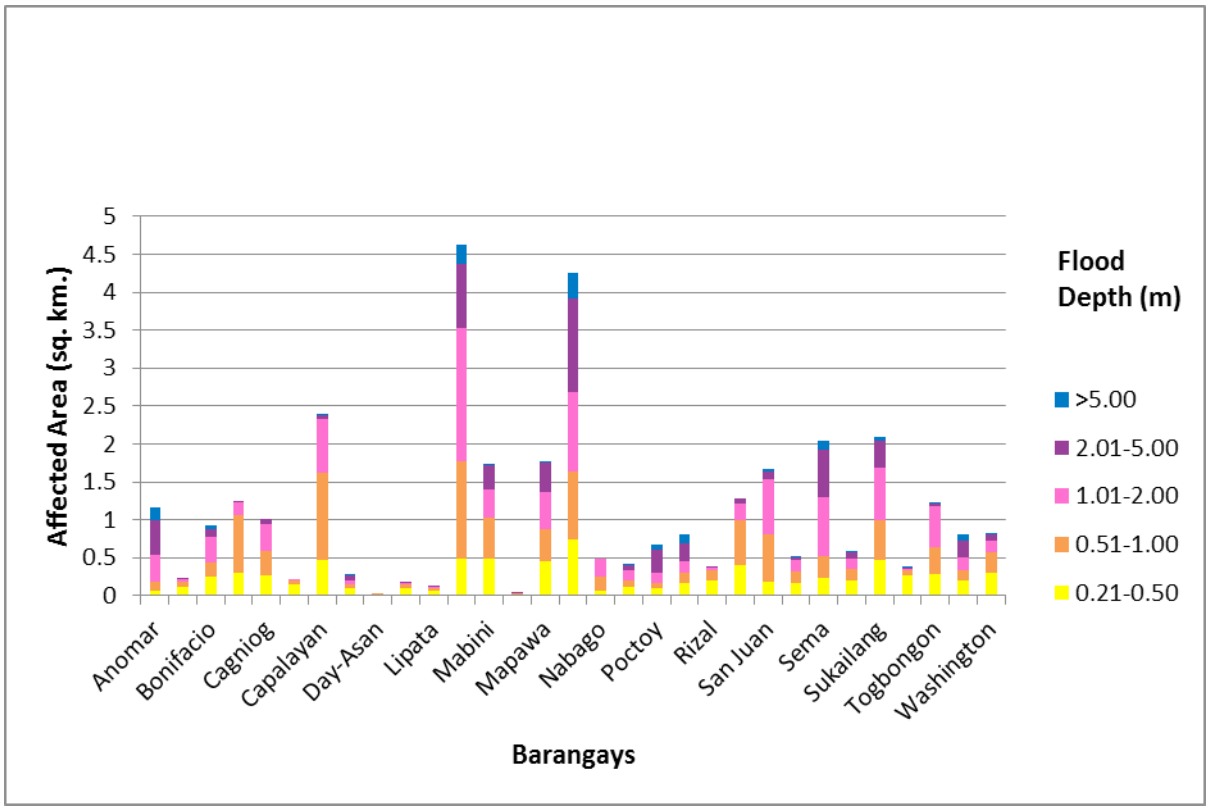


Figure 74. Affected Areas in Surigao City, Surigao del Norte during 25-Year Rainfall Return Period.

For the municipality of Tagana-an with an area of 81.99 sq. km., 8.05% will experience flood levels of less 0.20 meters. 0.29% of the area will experience flood levels of 0.21 to 0.50 meters while 0.20%, 0.21%, 0.18%, and 0.02% 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 45are the affected areas in square kilometers by flood depth per barangay.

Table 45. Affected Areas in Tagana-an, Surigao del Norte during 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Areas of affected Barangays in Tagana-an			
	Himamaug	Laurel	Lower Libas	Upper Libas
0.03-0.20	2.49	1.68	2.72	0.24
0.21-0.50	0.079	0.061	0.096	0.024
0.51-1.00	0.05	0.029	0.072	0.023
1.01-2.00	0.047	0.027	0.089	0.02
2.01-5.00	0.046	0.021	0.086	0.0055
> 5.00	0.0093	0.004	0.0044	0

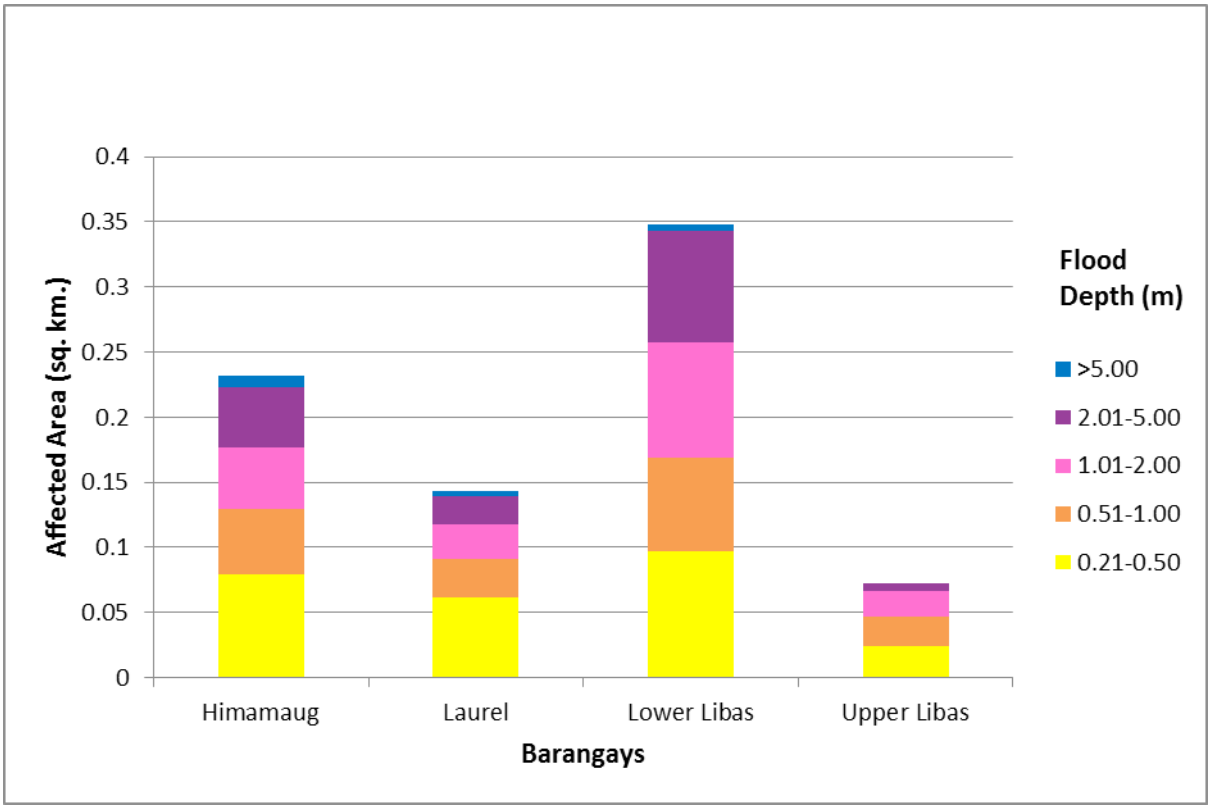


Figure 75. Affected Areas in Tagana-an, Surigao del Norte during 25-Year Rainfall Return Period.

For the 100-year return period, 13.26% of the municipality of Placer with an area of 88.73 sq. km. will experience flood levels of less 0.20 meters.0.79% of the area will experience flood levels of 0.21 to 0.50 meters while 0.65%, 0.89%, 1.14%, and 0.10% 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 46 are the affected areas in Placer in square kilometers by flood depth per barangay.

Table 46. Affected Areas in Placer, Surigao del Norte during 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Areas of affected Barangays in Placer (in sq.km.)			
	Anislagan	Magupange	San Isidro	Santa Cruz
0.03-0.20	5.44	0.075	1.9	4.35
0.21-0.50	0.31	0.0044	0.11	0.28
0.51-1.00	0.24	0.0047	0.1	0.23
1.01-2.00	0.31	0.0072	0.16	0.31
2.01-5.00	0.44	0.0055	0.16	0.41
> 5.00	0.038	0	0.028	0.02

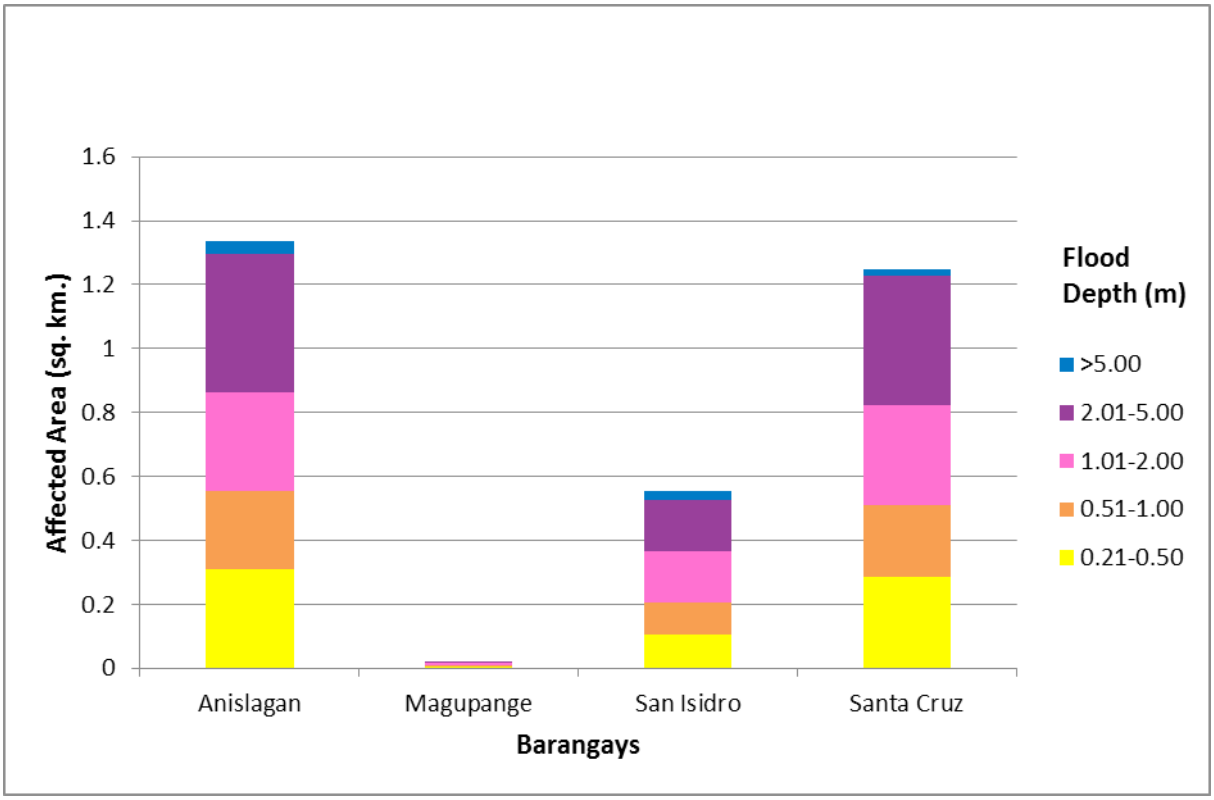


Figure 76. Affected Areas in Placer, Surigao del Norte during 100-Year Rainfall Return Period.

For the municipality of Sison with an area of 68.78 sq. km., 49.46% will experience flood levels of less than 0.20 meters. 2.92% of the area will experience flood levels of 0.21 to 0.50 meters while 2.76%, 4.64%, 7.62%, and 3.29% 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 47are the affected areas in Sison in square kilometers by flood depth per barangay.

Table 47. Affected Areas in Sison, Surigao del Norte during 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Areas of affected Barangays in Sison							
	Biyabid	Ima	Lower Patag	Mabuhay	Poblacion	San Isidro	San Pablo	Tagbayani
0.03-0.20	4.41	0.5	3.29	4.9	8.72	3.23	4.07	0.42
0.21-0.50	0.25	0.021	0.22	0.18	0.62	0.19	0.22	0.014
0.51-1.00	0.28	0.011	0.3	0.13	0.53	0.15	0.16	0.012
1.01-2.00	0.57	0.0068	0.45	0.15	1.2	0.16	0.22	0.017
2.01-5.00	1.15	0.00098	0.59	0.42	1.89	0.15	0.47	0.011
> 5.00	0.17	0	0.11	0.34	1.1	0.014	0.23	0.0003

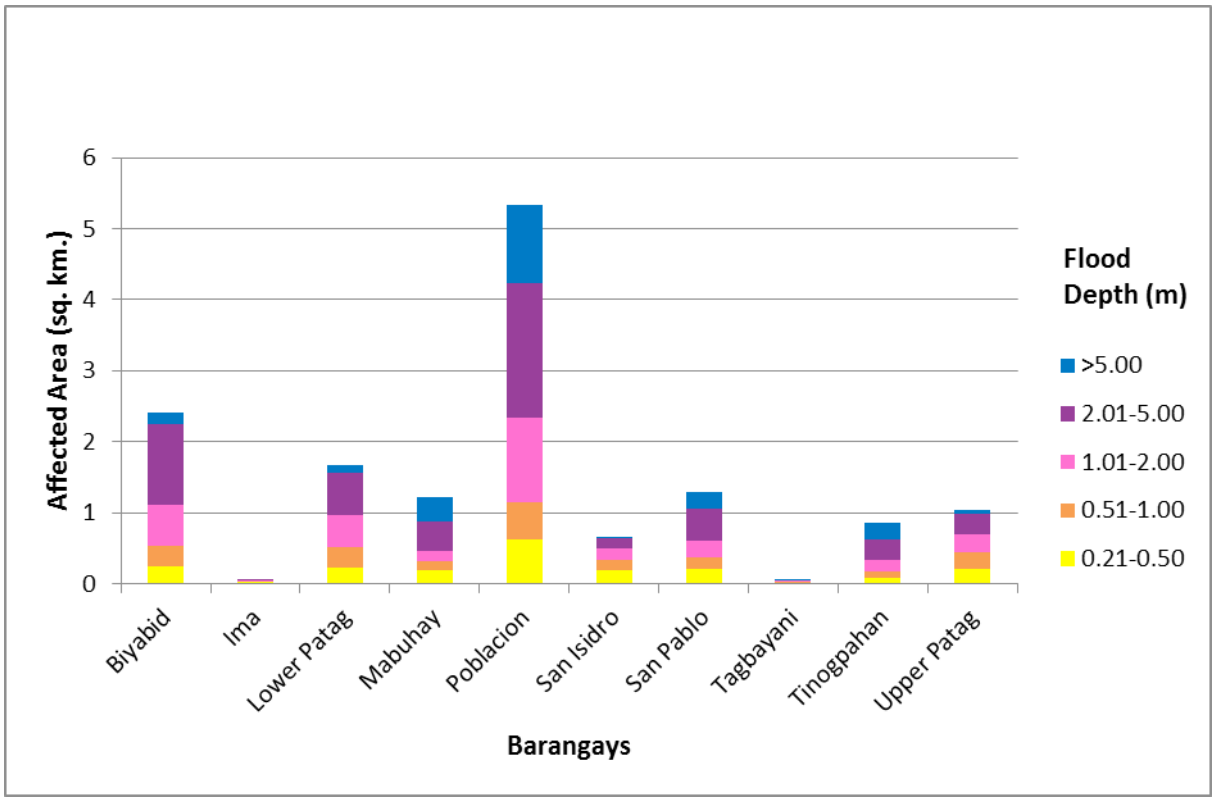


Figure 77. Affected Areas in Sison, Surigao del Norte during 100-Year Rainfall Return Period.

For Surigao City with an area of 240.67 sq. km., 26.01% will experience flood levels of less than 0.20 meters. 2.66% of the area will experience flood levels of 0.21 to 0.50 meters while 3.59%, 4.79%, 3.31%, and 0.83% 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 48are the affected areas in Surigao City in square kilometers by flood depth per barangay.

Table 48. Affected Areas in Surigao City, Surigao del Norte during 100-Year Rainfall Return Period.

Affected area	Areas of affected Barangays in Surigao City										
(sq. km.) by flood depth (in m.)	Anomar	Balibayon	Bonifacio	Cabongbongan	Cagniog	Canlanipa	Capalayan	Danao	Day-Asan	Ipil	Lipata
0.03-0.20	0.94	0.95	1.08	1.34	3.54	0.36	3.13	2.73	0.084	1.35	0.73
0.21-0.50	0.051	0.11	0.22	0.26	0.26	0.16	0.38	0.1	0.017	0.1	0.069
0.51-1.00	0.05	0.091	0.19	0.57	0.32	0.068	0.96	0.055	0.0095	0.072	0.04
1.01-2.00	0.14	0.031	0.34	0.46	0.4	0.02	1.08	0.058	0.0001	0.006	0.016
2.01-5.00	0.73	0.022	0.17	0.022	0.11	0	0.066	0.072	0	0.002	0.0095
> 5.00	0.24	0	0.051	0	0	0	0.0015	0.0038	0	0	0.0002

Affected area											
(sq. km.) by flood depth (in m.)	Luna	Mabini	Mabua	Mapawa	Mat-I	Nabago	Orok	Poctoy	Quezon	Rizal	
0.03-0.20	0.26	2.44	0.22	7.72	5.45	0.055	2.56	1.94	2.66	1.25	
0.21-0.50	0.31	0.45	0.017	0.45	0.52	0.041	0.11	0.1	0.16	0.19	
0.51-1.00	0.86	0.55	0.0095	0.43	0.78	0.16	0.093	0.063	0.11	0.14	
1.01-2.00	2.22	0.52	0.012	0.52	1.1	0.31	0.14	0.089	0.17	0.07	
2.01-5.00	1.15	0.38	0.00028	0.51	1.4	0	0.1	0.35	0.28	0.0021	
> 5.00	0.3	0.0044	0	0.021	0.65	0	0.0003	0.093	0.16	0	

Affected area											
(sq. km.) by flood depth (in m.)	Sabang	San Juan	San Roque	Sema	Silop	Sukailang	Taft	Togbongon	Trinidad	Washington	
0.03-0.20	0.39	0.14	3.1	2.45	2.82	5.65	0.92	2.19	3.78	0.37	
0.21-0.50	0.2	0.097	0.18	0.21	0.19	0.46	0.29	0.25	0.2	0.25	
0.51-1.00	0.7	0.39	0.15	0.22	0.16	0.47	0.099	0.31	0.16	0.36	
1.01-2.00	0.4	1.04	0.18	0.33	0.15	0.7	0.021	0.58	0.19	0.24	
2.01-5.00	0.094	0.14	0.052	1.14	0.11	0.55	0.0049	0.14	0.27	0.093	
> 5.00	0.0024	0.048	0.00067	0.21	0.012	0.07	0.0029	0.0002	0.13	0.0059	

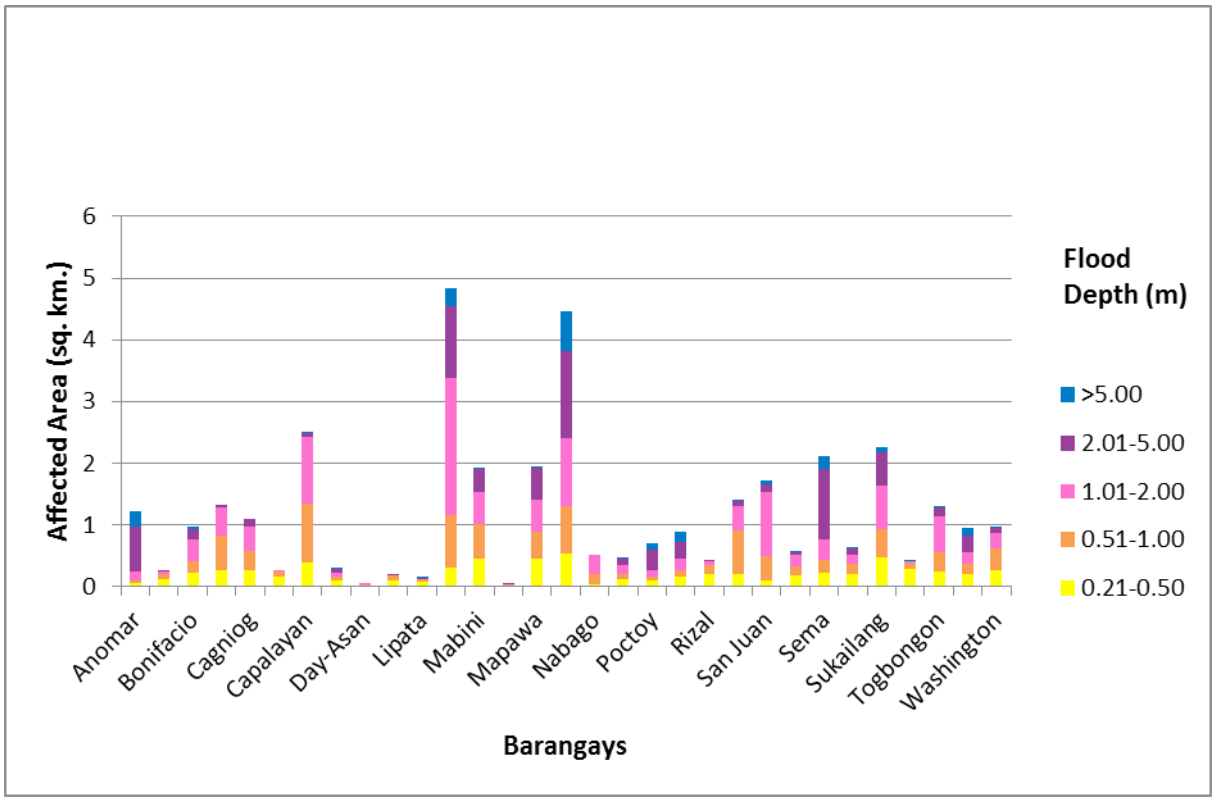


Figure 78. Affected Areas in Surigao City, Surigao del Norte during 100-Year Rainfall Return Period.

For the municipality of Tagana-an with an area of 81.99 sq. km., 7.95% will experience flood levels of less 0.20 meters. 0.32% of the area will experience flood levels of 0.21 to 0.50 meters while 0.21%, 0.22%, 0.22%, and 0.03% 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 49are the affected areas in square kilometers by flood depth per barangay.

Table 49. Affected Areas in Tagana-an, Surigao del Norte during 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Areas of affected Barangays in Tagana-an			
	Himamaug	Laurel	Lower Libas	Upper Libas
0.03-0.20	2.47	1.67	2.68	0.24
0.21-0.50	0.084	0.067	0.11	0.022
0.51-1.00	0.053	0.034	0.074	0.026
1.01-2.00	0.051	0.03	0.091	0.023
2.01-5.00	0.053	0.025	0.11	0.0072
> 5.00	0.012	0.0045	0.0062	0

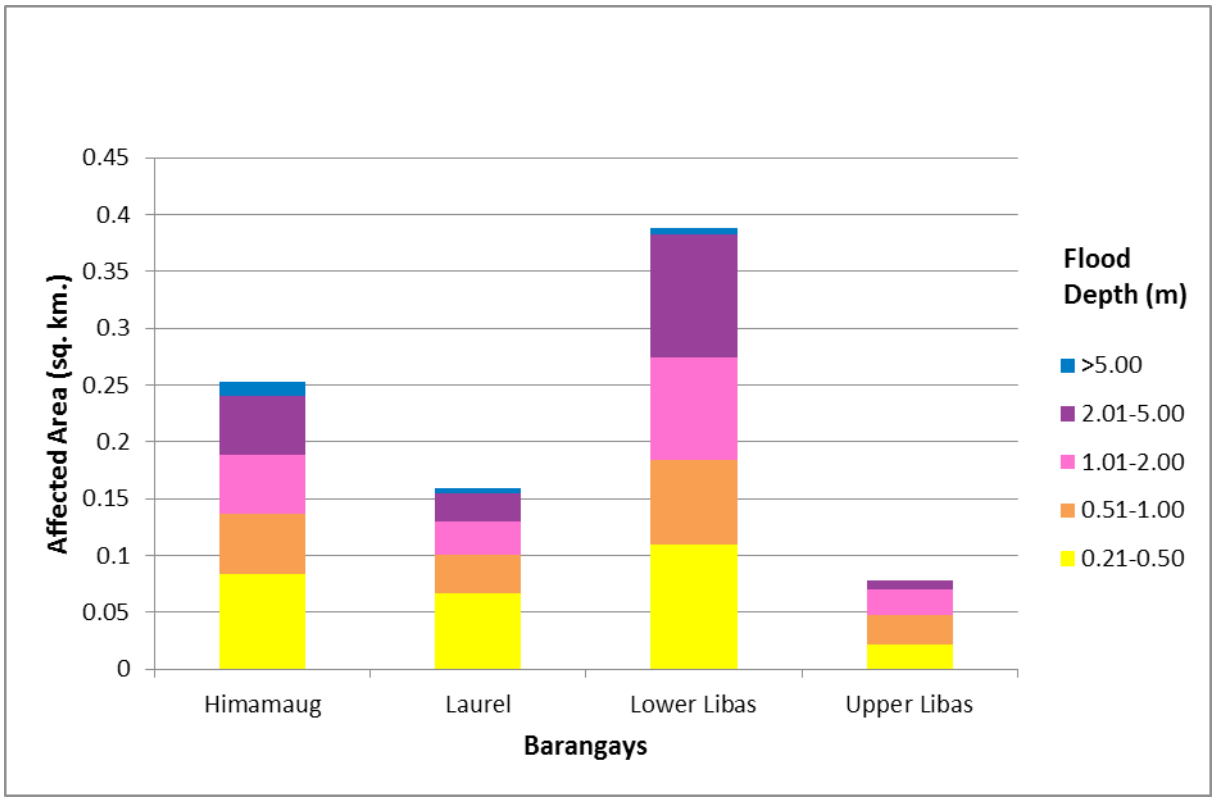


Figure 79. Affected Areas in Tagana-an, Surigao del Norte during 100-Year Rainfall Return Period.

Among the barangays in the municipality of Placer, Anislaganis is projected to have the highest percentage of area that will experience flood levels at 8%. Meanwhile, Santa Cruz posted the second highest percentage of area that may be affected by flood depths at 6%.

Among the barangays in the municipality of Sison, Poblacion is projected to have the highest percentage of area that will experience flood levels at 20%. Meanwhile, Biyabid posted the second highest percentage of area that may be affected by flood depths at 10%.

Among the barangays in the municipality of Surigao City, Mat-I is projected to have the highest percentage of area that will experience flood levels at 4.11%. Meanwhile, Mapawa posted the second highest percentage of area that may be affected by flood depths at 4.01%.

Among the barangays in the municipality of Tagana-An, Lower Libas is projected to have the highest percentage of area that will experience flood levels at 4%. Meanwhile, Himamaug posted the second highest percentage of area that may be affected by flood depths at 3%.

Moreover, the generated flood hazard maps for the Surigao 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 50. 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	13.5	10.72	9.31
Medium	17.68	22.16	21.36
High	12.16	19.95	25.95

Of the 52 identified Education Institute in Surigao Flood plain, four (4) schools were discovered exposed to Low-level flooding during a 5-year scenario, while eight (8) schools were found exposed to Medium-level flooding in the same scenario; and one for High-level flooding.

In the 25-year scenario, eleven (11) schools were found exposed to Low-level flooding, while twelve (12) schools were discovered exposed to Medium-level flooding; three (3) for High-level flooding.

For the 100-year scenario, eleven (11) school was discovered exposed to Low-level flooding, while thirteen (13) schools were exposed to Medium-level flooding. In the same scenario, seven (7) schools were found exposed to High-level flooding.

Apart from this, five (5) Medical Institutions were identified in the Surigao Floodplain; one (1) was exposed to Low-level flooding in a 5 year scenario. Three (3) were exposed to Low level flooding in a 25-year scenario. Two (2) were exposed to Low-level flooding in a 100-year scenario, one 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 80.

The flood validation consists of 597 points randomly selected all over the Surigao flood plain Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 0.92 m. Table 51shows a contingency matrix of the comparison. The validation points are found in Annex 11.

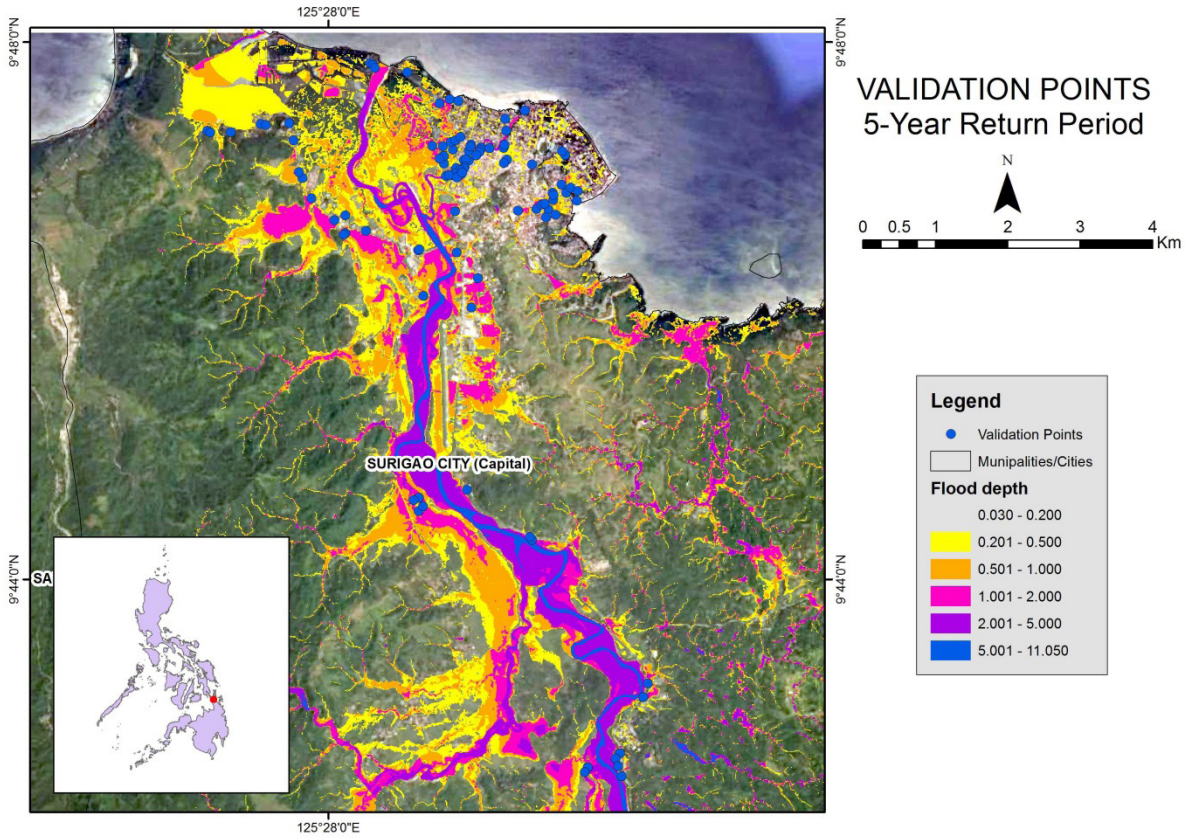


Figure 80. Validation Points for a 5-year Flood Depth Map of the Surigao Floodplain.

Table 51. Actual Flood Depth versus Simulated Flood Depth at different levels in the Surigao River Basin.

SURIGAO 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	170	67	70	68	21	0	396
	0.21-0.50	18	17	18	15	13	0	81
	0.51-1.00	16	14	21	15	3	0	69
	1.01-2.00	2	0	20	20	9	0	51
	2.01-5.00	0	0	0	0	0	0	0
	> 5.00	0	0	0	0	0	0	0
	Total	206	98	129	118	46	0	597

On the whole, the overall accuracy generated by the flood model is estimated at 38.19%, with 228 points correctly matching the actual flood depths. In addition, there were 161 points estimated one level above and below the correct flood depths while there were 104 points estimated two levels above and below, and 125 points three or more levels above and below the correct flood. A total of 299 points were overestimated while a total of 70 points were underestimated in the modelled flood depths of Surigao. Table 52depicts the summary of the Accuracy Assessment in the Surigao River Basin Flood Depth Map.

Table 52. Summary of the Accuracy Assessment in the Surigao River Basin Survey.

	No. of Points	%
Correct	228	38.19
Overestimated	299	50.08
Underestimated	70	11.73
Total	597	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.

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Brunner, G. H. 2010a. HEC-RAS River Analysis System Hydraulic Reference Manual. Davis, CA: U.S. Army Corps of Engineers, Institute for Water Resources, Hydrologic Engineering Center.

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

Paringit E.C, Balicanta L.P., Ang, M.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 Surigao Floodplain Survey

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

1. 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

2. 2. GEMINI SENSOR

Figure A-1.2. Gemini Sensor

Table A-1.2. Parameters and Specifications of Gemini Sensor

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

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

1. SRN-99

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

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

May 17, 2016

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 NORTE**
Station Name: **SRN-99**
Order: **2nd**
Island: **MINDANAO**
Barangay: **BONIFACIO**
Municipality: **SURIGAO CITY (CAPITAL)**
MSL Elevation:

PRS92 Coordinates

Latitude: **9° 44' 22.95065"** Longitude: **125° 29' 38.38093"** Ellipsoidal Hgt: **11.84800 m.**

WGS84 Coordinates

Latitude: **9° 44' 19.11233"** Longitude: **125° 29' 43.66472"** Ellipsoidal Hgt: **78.82900 m.**

PTM / PRS92 Coordinates

Northing: **1076982.803 m.** Easting: **554202.388 m.** Zone: **5**

UTM / PRS92 Coordinates

Northing: **1,077,574.28** Easting: **773,630.64** Zone: **51**

Location Description

SRN-99
The station is located inside Bonifacio Elementary School compound on the concrete ground beside a concrete foundation 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 SRN-99 2007 NAMRIA.

Requesting Party: **UP-DREAM**
Purpose: **Reference**
OR Number: **8090370 I**
T.N.: **2016-1111**

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

9905172016095849

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
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ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.1. SRN-99

2. SRN-102

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

June 06, 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 NORTE**
Station Name: **SRN-102**
Order: **2nd**

Island: **MINDANAO**
Municipality: **SISON**
Barangay: **POBLACION (SAN PEDRO)**

PRS92 Coordinates

Latitude: **9° 39' 24.81730"** Longitude: **125° 31' 35.42419"** Ellipsoidal Hgt: **35.04700 m.**

WGS84 Coordinates

Latitude: **9° 39' 21.00341"** Longitude: **125° 31' 40.71501"** Ellipsoidal Hgt: **102.29400 m.**

PTM Coordinates

Northing: **1067829.026 m.** Easting: **557783.962 m.** Zone: **5**

UTM Coordinates

Northing: Easting: Zone:

Location Description

SRN-102
From Brgy. Bad-as junction landmark travel towards municipality of Sison for 7.1 km NE, turn left in the first municipality of Sison for 50 m to the barangay hall landmark then turn left by 300 m up to Patag bridge where SRN-102 monument is located. Mark is the head of a 3" copper nail set at the center of cement block embedded on the ground inscribe with SRN-102 2007 NAMRIA.

Requesting Party: **UP-TCAGP**
Pupose: **Reference**
OR Number: **8796290 A**
T.N.: **2014-1299**

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

9906062014164418

CIP/4701/12/09/814

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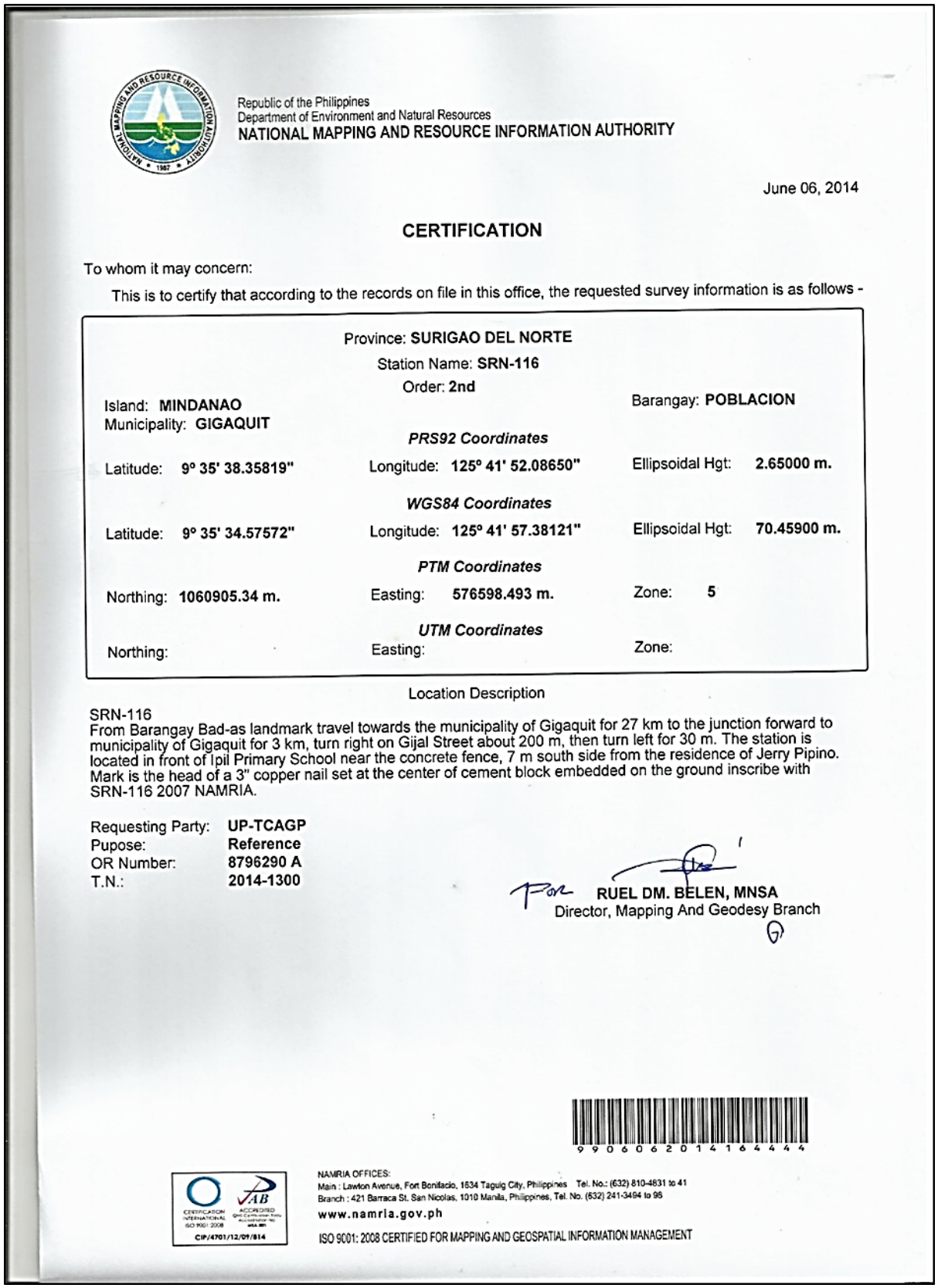
Figure A-2.2. SRN-102

3. SRN-116



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

June 06, 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 NORTE**
Station Name: **SRN-116**
Order: **2nd**

Island: **MINDANAO**
Municipality: **GIGAQUIT**
Barangay: **POBLACION**

PRS92 Coordinates

Latitude: **9° 35' 38.35819"** Longitude: **125° 41' 52.08650"** Ellipsoidal Hgt: **2.65000 m.**

WGS84 Coordinates

Latitude: **9° 35' 34.57572"** Longitude: **125° 41' 57.38121"** Ellipsoidal Hgt: **70.45900 m.**

PTM Coordinates

Northing: **1060905.34 m.** Easting: **576598.493 m.** Zone: **5**

UTM Coordinates

Northing: Easting: Zone:

Location Description

SRN-116
From Barangay Bad-as landmark travel towards the municipality of Gigaquit for 27 km to the junction forward to municipality of Gigaquit for 3 km, turn right on Gijal Street about 200 m, then turn left for 30 m. The station is located in front of Ipil Primary School near the concrete fence, 7 m south side from the residence of Jerry Pipino. Mark is the head of a 3" copper nail set at the center of cement block embedded on the ground inscribe with SRN-116 2007 NAMRIA.

Requesting Party: **UP-TCAGP**
Pupose: **Reference**
OR Number: **8796290 A**
T.N.: **2014-1300**

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

9906062014164444

CIP/4701/12/09/814

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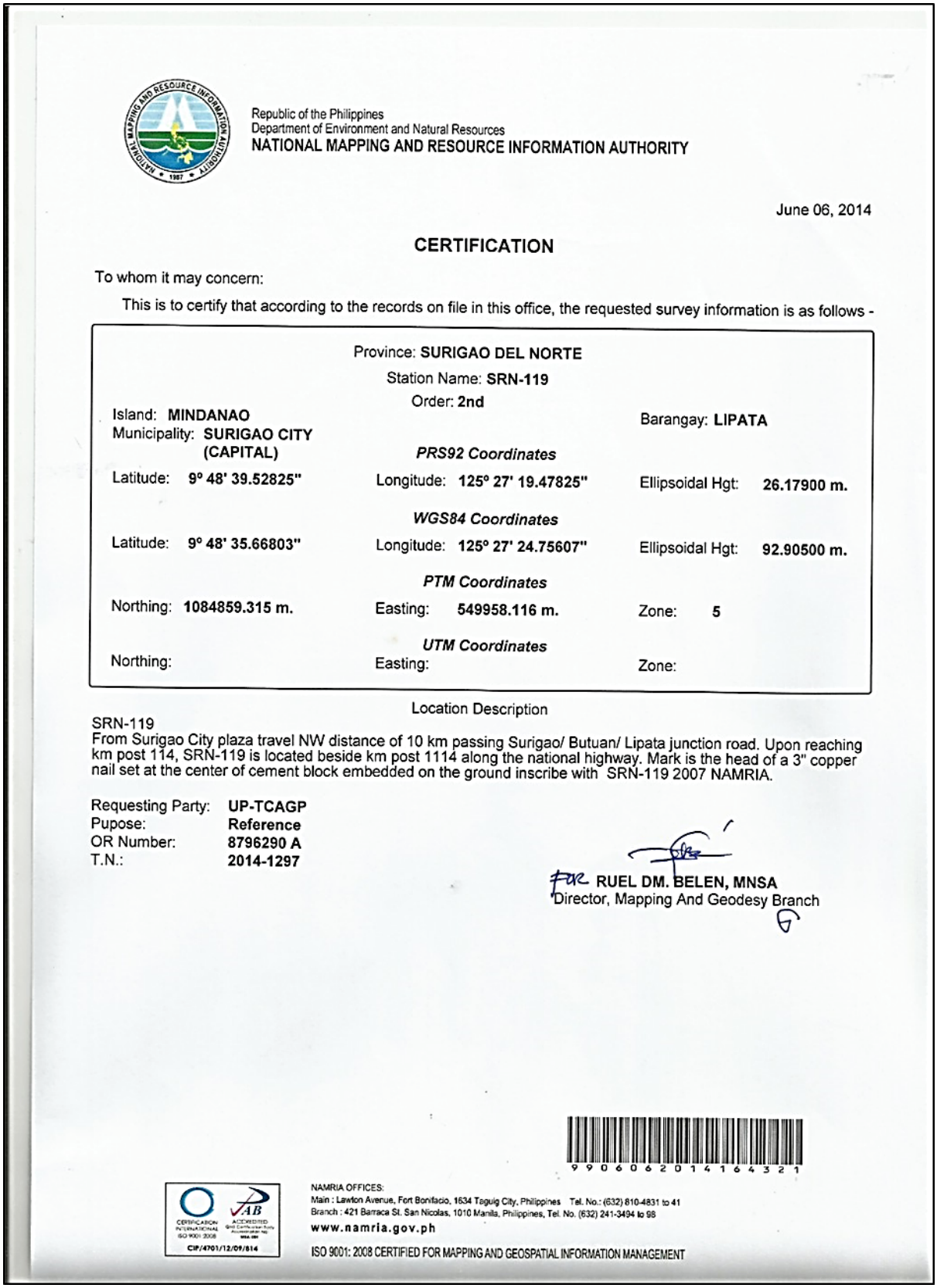
Figure A-2.3. SRN-116

4. SRN-119



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

June 06, 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 NORTE**
Station Name: **SRN-119**
Order: **2nd**

Island: **MINDANAO**
Municipality: **SURIGAO CITY (CAPITAL)**
Barangay: **LIPATA**

PRS92 Coordinates

Latitude: **9° 48' 39.52825"** Longitude: **125° 27' 19.47825"** Ellipsoidal Hgt: **26.17900 m.**

WGS84 Coordinates

Latitude: **9° 48' 35.66803"** Longitude: **125° 27' 24.75607"** Ellipsoidal Hgt: **92.90500 m.**

PTM Coordinates

Northing: **1084859.315 m.** Easting: **549958.116 m.** Zone: **5**

UTM Coordinates

Northing: Easting: Zone:

Location Description

SRN-119
From Surigao City plaza travel NW distance of 10 km passing Surigao/ Butuan/ Lipata junction road. Upon reaching km post 114, SRN-119 is located beside km post 1114 along the national highway. Mark is the head of a 3" copper nail set at the center of cement block embedded on the ground inscribe with SRN-119 2007 NAMRIA.

Requesting Party: **UP-TCAGP**
Pupose: **Reference**
OR Number: **8796290 A**
T.N.: **2014-1297**

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

9906062014164321

CIP/4701/12/09/814

NAMRIA OFFICES:
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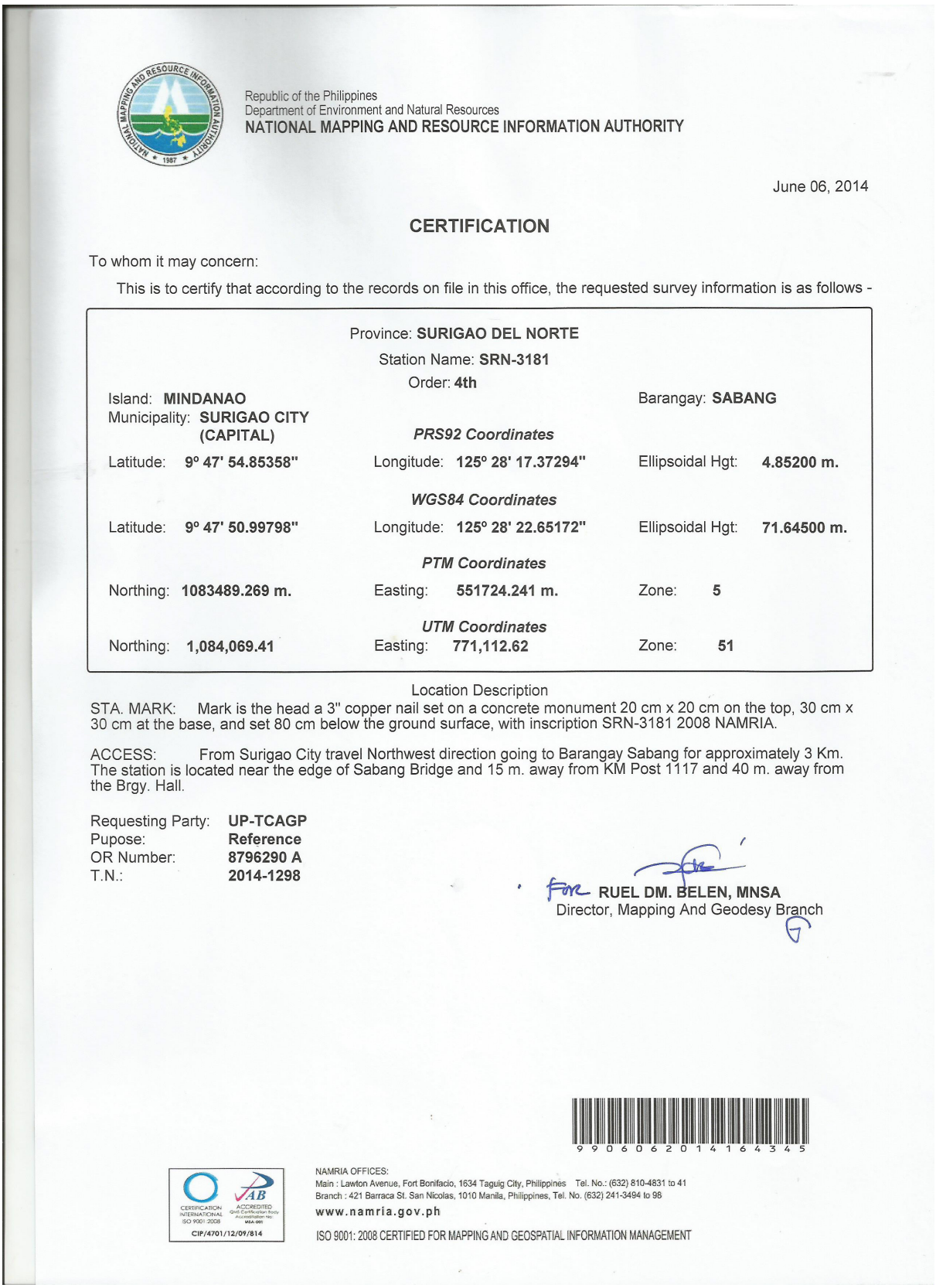
Figure A-2.4. SRN-119

5. SRN-3181



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

June 06, 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 NORTE**
Station Name: **SRN-3181**
Order: **4th**

Island: **MINDANAO**
Municipality: **SURIGAO CITY (CAPITAL)**
Barangay: **SABANG**

PRS92 Coordinates

Latitude: **9° 47' 54.85358"** Longitude: **125° 28' 17.37294"** Ellipsoidal Hgt: **4.85200 m.**

WGS84 Coordinates

Latitude: **9° 47' 50.99798"** Longitude: **125° 28' 22.65172"** Ellipsoidal Hgt: **71.64500 m.**

PTM Coordinates

Northing: **1083489.269 m.** Easting: **551724.241 m.** Zone: **5**

UTM Coordinates

Northing: **1,084,069.41** Easting: **771,112.62** Zone: **51**

Location Description

STA. MARK: Mark is the head a 3" copper nail set on a concrete monument 20 cm x 20 cm on the top, 30 cm x 30 cm at the base, and set 80 cm below the ground surface, with inscription SRN-3181 2008 NAMRIA.

ACCESS: From Surigao City travel Northwest direction going to Barangay Sabang for approximately 3 Km. The station is located near the edge of Sabang Bridge and 15 m. away from KM Post 1117 and 40 m. away from the Brgy. Hall.

Requesting Party: **UP-TCAGP**
Pupose: **Reference**
OR Number: **8796290 A**
T.N.: **2014-1298**

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

9 9 0 6 0 6 2 0 1 4 1 6 4 3 4 5

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Figure A-2.5. SRN-3181

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

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

1. SRN-3017

Table A-3.1. SRN-3017

Vector Components (Mark to Mark)

From:	SRN-102				
Grid		Local		Global	
Easting	777268.020 m	Latitude	N9°39'24.81730"	Latitude	N9°39'21.00341"
Northing	1068436.715 m	Longitude	E125°31'35.42419"	Longitude	E125°31'40.71501"
Elevation	34.474 m	Height	35.047 m	Height	102.294 m

To:	SRN-3017				
Grid		Local		Global	
Easting	781557.728 m	Latitude	N9°38'02.79068"	Latitude	N9°37'58.98617"
Northing	1065947.166 m	Longitude	E125°33'55.43339"	Longitude	E125°34'00.72582"
Elevation	83.010 m	Height	83.840 m	Height	151.234 m

Vector					
ΔEasting	4289.708 m	NS Fwd Azimuth	120°33'09"	ΔX	-3746.670 m
ΔNorthing	-2489.549 m	Ellipsoid Dist.	4956.976 m	ΔY	-2098.984 m
ΔElevation	48.536 m	ΔHeight	48.793 m	ΔZ	-2476.112 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 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	0.007 m	σ ΔHeight	0.007 m	σ ΔZ	0.002 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000148483		
Y	-0.0000181777	0.0000280552	
Z	-0.0000049611	0.0000061693	0.0000027000

2. SRN-3181

Table A-3.2. SRN-3181

Vector Components (Mark to Mark)

From:	SRN-119				
Grid		Local		Global	
Easting	769337.455 m	Latitude	N9°48'39.52825"	Latitude	N9°48'35.66803"
Northing	1085429.633 m	Longitude	E125°27'19.47825"	Longitude	E125°27'24.75607"
Elevation	26.269 m	Height	26.179 m	Height	92.905 m

To:	SRN-3181				
Grid		Local		Global	
Easting	771112.645 m	Latitude	N9°47'54.85423"	Latitude	N9°47'50.99862"
Northing	1084069.428 m	Longitude	E125°28'17.37359"	Longitude	E125°28'22.65237"
Elevation	4.909 m	Height	4.873 m	Height	71.666 m

Vector					
ΔEasting	1775.189 m	NS Fwd Azimuth	127°52'44"	ΔX	-1560.436 m
ΔNorthing	-1360.205 m	Ellipsoid Dist.	2235.267 m	ΔY	-850.381 m
ΔElevation	-21.360 m	ΔHeight	-21.306 m	ΔZ	-1356.016 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.002 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.003 m
σ ΔElevation	0.004 m	σ ΔHeight	0.004 m	σ ΔZ	0.001 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000056987		
Y	-0.0000068866	0.0000106715	
Z	-0.0000018066	0.0000025153	0.0000010408

3. SN-46

Table A-3.3. SN-46

Vector Components (Mark to Mark)

From:	SN-46				
Grid		Local		Global	
Easting	772206.879 m	Latitude	N9°45'41.79368"	Latitude	N9°45'37.94854"
Northing	1079987.356 m	Longitude	E125°28'52.27552"	Longitude	E125°28'57.55750"
Elevation	5.970 m	Height	6.010 m	Height	72.910 m

To:	SRN-99				
Grid		Local		Global	
Easting	773633.477 m	Latitude	N9°44'23.13724"	Latitude	N9°44'19.29891"
Northing	1077580.038 m	Longitude	E125°29'38.47543"	Longitude	E125°29'43.75922"
Elevation	11.297 m	Height	11.444 m	Height	78.425 m

Vector					
ΔEasting	1426.598 m	NS Fwd Azimuth	149°46'09"	ΔX	-1387.291 m
ΔNorthing	-2407.318 m	Ellipsoid Dist.	2796.818 m	ΔY	-479.896 m
ΔElevation	5.328 m	ΔHeight	5.434 m	ΔZ	-2380.620 m

Standard Errors

Vector errors:					
σ ΔEasting	0.011 m	σ NS fwd Azimuth	0°00'01"	σ ΔX	0.034 m
σ ΔNorthing	0.006 m	σ Ellipsoid Dist.	0.007 m	σ ΔY	0.061 m
σ ΔElevation	0.070 m	σ ΔHeight	0.070 m	σ ΔZ	0.013 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0011656374		
Y	-0.0020215143	0.0037052522	
Z	-0.0003898496	0.0007039704	0.0001667969

4. SN-49

Table A-3.4. SN-49

SRN-119 - SN-49 (3:41:03 PM-6:20:14 PM) (S1)

Baseline observation:	SRN-119 --- SN-49 (B1)
Processed:	6/17/2014 4:40:09 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.005 m
Vertical precision:	0.017 m
RMS:	0.003 m
Maximum PDOP:	2.990
Ephemeris used:	Broadcast
Antenna model:	Trimble Relative
Processing start time:	6/1/2014 3:41:04 PM (Local: UTC+8hr)
Processing stop time:	6/1/2014 6:20:14 PM (Local: UTC+8hr)
Processing duration:	02:39:10
Processing interval:	5 seconds

Vector Components (Mark to Mark)

From:	SRN-119				
Grid		Local		Global	
Easting	769496.002 m	Latitude	N9°48'35.66803"	Latitude	N9°48'35.66803"
Northing	1085380.264 m	Longitude	E125°27'24.75607"	Longitude	E125°27'24.75607"
Elevation	26.269 m	Height	92.905 m	Height	92.905 m

To:	SN-49				
Grid		Local		Global	
Easting	772166.046 m	Latitude	N9°46'29.35520"	Latitude	N9°46'29.35520"
Northing	1081516.934 m	Longitude	E125°28'51.39573"	Longitude	E125°28'51.39573"
Elevation	7.073 m	Height	73.947 m	Height	73.947 m

Vector					
ΔEasting	2670.045 m	NS Fwd Azimuth	145°46'08"	ΔX	-2522.533 m
ΔNorthing	-3863.330 m	Ellipsoid Dist.	4693.834 m	ΔY	-1009.732 m
ΔElevation	-19.197 m	ΔHeight	-18.958 m	ΔZ	-3827.569 m

5. SN-83

Table A-3.5. SN-83

Vector Components (Mark to Mark)

From:	SRN-116				
Grid		Local		Global	
Easting	796134.205 m	Latitude	N9°35'38.35818"	Latitude	N9°35'34.57572"
Northing	1061618.891 m	Longitude	E125°41'52.08650"	Longitude	E125°41'57.38121"
Elevation	1.587 m	Height	2.650 m	Height	70.459 m

To:	BMSN-83				
Grid		Local		Global	
Easting	797146.192 m	Latitude	N9°33'23.94445"	Latitude	N9°33'20.17252"
Northing	1057494.439 m	Longitude	E125°42'24.18740"	Longitude	E125°42'29.48535"
Elevation	11.642 m	Height	12.853 m	Height	80.767 m

Vector					
ΔEasting	1011.987 m	NS Fwd Azimuth	166°39'47"	ΔX	-1201.753 m
ΔNorthing	-4124.452 m	Ellipsoid Dist.	4243.865 m	ΔY	-5.351 m
ΔElevation	10.055 m	ΔHeight	10.203 m	ΔZ	-4070.167 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.005 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.007 m
σ ΔElevation	0.008 m	σ ΔHeight	0.008 m	σ ΔZ	0.002 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000206996		
Y	-0.0000299621	0.0000490818	
Z	-0.0000060059	0.0000095068	0.0000029816

6. UP-MAG1

Table A-3.6. UP-MAG1

BMSN-83 - UPMAG-01 (8:14:44 AM-12:32:05 PM) (S1)

Baseline observation:	BMSN-83 --- UPMAG-01 (B1)
Processed:	6/8/2016 6:10:34 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.001 m
Vertical precision:	0.002 m
RMS:	0.000 m
Maximum PDOP:	2.730
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	5/11/2016 8:14:44 AM (Local: UTC+8hr)
Processing stop time:	5/11/2016 12:32:05 PM (Local: UTC+8hr)
Processing duration:	04:17:21
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	BMSN-83				
Grid		Local		Global	
Easting	797146.192 m	Latitude	N9°33'23.94445"	Latitude	N9°33'20.17252"
Northing	1057494.439 m	Longitude	E125°42'24.18740"	Longitude	E125°42'29.48535"
Elevation	11.642 m	Height	12.853 m	Height	80.767 m

To:	UPMAG-01				
Grid		Local		Global	
Easting	797138.469 m	Latitude	N9°33'23.85603"	Latitude	N9°33'20.08411"
Northing	1057491.660 m	Longitude	E125°42'23.93365"	Longitude	E125°42'29.23160"
Elevation	11.213 m	Height	12.425 m	Height	80.339 m

Vector					
ΔEasting	-7.722 m	NS Fwd Azimuth	250°39'29"	ΔX	6.267 m
ΔNorthing	-2.779 m	Ellipsoid Dist.	8.201 m	ΔY	4.540 m
ΔElevation	-0.429 m	ΔHeight	-0.428 m	ΔZ	-2.750 m

Standard Errors

Vector errors:					
σ ΔEasting	0.000 m	σ NS fwd Azimuth	0°00'08"	σ ΔX	0.000 m
σ ΔNorthing	0.000 m	σ Ellipsoid Dist.	0.000 m	σ ΔY	0.001 m
σ ΔElevation	0.001 m	σ ΔHeight	0.001 m	σ ΔZ	0.000 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000002129		
Y	-0.0000002275	0.0000006674	
Z	-0.0000000534	0.0000001270	0.0000001093

Annex 4. The LiDAR Survey Team Composition

Table A-4.1. The LiDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader - I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
	Data Component Project Leader – I	ENGR. LOUIE P. BALICANTA	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	UP-TCAGP
		LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Supervising SRS	LOVELYN ASUNCION	UP-TCAGP
	SSRS	JASMINE ALVIAR	UP-TCAGP
	SSRS	PAULINE JOANNE ARCEO	UP-TCAGP
	RA	ENGR. LARAH KRISELLE PARAGAS	UP-TCAGP
	RA	FOR. MA. VERLINA TONGA	UP-TCAGP
	RA	ENGR. DAN CHRISTOPHER ALDOVINO	UP-TCAGP
	RA	ENGR. RENAN PUNTO	UP-TCAGP
	RA	MARY CATHERINE BALIGUAS	UP-TCAGP
	RA	MILLIE SHANE REYES	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	ENGR. KENNETH QUISADO	UP-TCAGP
	RA	ENGR. JOHN ELY MANALOTO	UP-TCAGP
	RA	ENGR. GEF SORIANO	UP-TCAGP
LiDAR Operation	Airborne Security	SSG. MIKE DIAPANA	PHILIPPINE AIR FORCE (PAF)
		SSG. JOHN ERIC CACANINDIN	PAF
		SSG. CHA NAVARRO	PAF
	Pilot	CAPT. RAUL CZ SAMAR II	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. JOHN BRYAN DONGUINES	AAC
		CAPT. JEFF JEREMY ALAJAR	AAC
		CAPT. MARK GARCHITORENA	AAC
		CAPT. RANDY LAGCO	AAC
		CAPT. JERICHO JECIEL	AAC

Table A-4.1. The LiDAR Survey Team Composition

Annex 5. Data Transfer Sheet for Surigao Floodplain

Table A-5.1 Data Transfer Sheet for Surigao Floodplain

DATA TRANSFER SHEET
06/16/2014(Surigao)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
5/30/2014	7280GC	2BLK59FG150A	Gemini	na	82.6	236	100	na	na	8.34	NA	3.96	1KB	1KB	8	9.91	Z:\Airborne_Raw\7280GC
5/30/2014	7281GC	2BLK59F150B	Gemini	na	143	259	139	na	na	10.4	NA	4.42	1KB	1KB	9.16	NA	Z:\Airborne_Raw\7281GC
5/31/2014	7282GC	2BLK59EFS151A	Gemini	na	557	560	245	na	na	20.3	NA	2.86	1KB	1KB	7.14	NA	Z:\Airborne_Raw\7282GC
5/31/2014	7283GC	2BLK59GS151B	Gemini	na	150	334	133	na	na	12.3	NA	4.36	1KB	1KB	9.54	25.9	Z:\Airborne_Raw\7283GC
6/1/2014	7284GC	2BLK59GS152A	Gemini	na	23.3	188	117	na	na	6.03	NA	4.98	1KB	1KB	3.99	NA	Z:\Airborne_Raw\7284GC
6/2/2014	7286GC	2BLK59CD153A	Gemini	na	235	375	214	na	na	13.8	NA	4.32	1KB	1KB	10	NA	Z:\Airborne_Raw\7286GC
6/3/2014	7288GC	2BLK59C+BLK60D154A	Gemini	na	417	540	261	na	na	22.2	NA	4.6	1KB	1KB	7.4	9.44	Z:\Airborne_Raw\7288GC

Received from
Name C. SORIANO
Position
Signature

Received by
Name JOIDA S. PRIETO
Position SSRS
Signature 6/16/14

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

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DATA TRANSFER SHEET
06/20/2014(Surigao)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
5-Jun-14	7292GC	2BLK60DS156A	Gemini	na	352	483	230	na	na	19.1	NA	1.09	1KB	1KB	16	29	Z:\Airborne_Raw\7292GC
5-Jun-14	7293GC	2BLK59GS156B	Gemini	na	312	291	122	na	na	12.4	NA	4.07	1KB	1KB	4	NA	Z:\Airborne_Raw\7293GC
6-Jun-14	7294GC	2BLK59AB157A	Gemini	na	345	595	260	na	na	6.18	NA	8.24	1KB	1KB	6	15	Z:\Airborne_Raw\7294GC
6-Jun-14	7295GC	2BLK59GS+FV157B	Gemini	na	32.7	275	123	na	na	9.98	NA	8.24	1KB	1KB	13	na	Z:\Airborne_Raw\7295GC
7-Jun-14	7296GC	2BLK60CDS158A	Gemini	na	95.8	557	257	na	na	20.9	NA	8.45	1KB	1KB	10	NA	Z:\Airborne_Raw\7296GC
7-Jun-14	7297GC	2BLK59ES158B	Gemini	na	61.2	149	99.9	na	na	5.1	NA	8.45	1KB	1KB	22	14	Z:\Airborne_Raw\7297GC
8-Jun-14	7298GC	2BLK59ASDS159A	Gemini	na	73.6	463	204	na	na	17.9	NA	8.52	1KB	1KB	10	17	Z:\Airborne_Raw\7298GC
9-Jun-14	7300GC	2BLK59FG+BLK60DCV160A	Gemini	na	258	468	216	na	na	15.4	NA	4.78	1KB	1KB	18	na	Z:\Airborne_Raw\7300GC

Received from

Name C. Jaramillo
Position RA
Signature

Received by

Name JOIDA E. PRIETO
Position SSRS
Signature 6/20/2014

14-45

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

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

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
14-Sep	1946A	3BLK59BS257A	Aquarius	na	844	0.98	170	na	na	8.45	na	9.26	1KB	1KB	5/6	na	Z:\DAC\RAW DATA
15-Sep	1950A	3BLK59D258A	Aquarius	na	286	577	209	na	na	11.2	na	9.14	1KB	1KB	7	na	Z:\DAC\RAW DATA
19-Sep	1966A	3BLK59C262A	Aquarius	na	1167	2.14	214	na	na	12	na	10.3	1KB	1KB	10	na	Z:\DAC\RAW DATA
19-Sep	1968A	3BLK59D262B	Aquarius	na	231	1.99	137	na	na	6.56	na	10.3	1KB	1KB	10/7	na	Z:\DAC\RAW DATA
20-Sep	1970A	3BLK59S263A	Aquarius	na	341	2.98	153	na	na	6.25	na	9.05	1KB	1KB	11	na	Z:\DAC\RAW DATA
21-Sep	1974A	3BLK59S264A	Aquarius	na	204	867	182	na	na	8.2	na	13.4	1KB	1KB	8	na	Z:\DAC\RAW DATA
23-Sep	1982A	3BLK59DS266A	Aquarius	na	149	324	142	na	na	6.44	na	8.44	1KB	1KB	10	na	Z:\DAC\RAW DATA
24-Sep	1986A	3BLK59E267A	Aquarius	na	332	643	220	na	na	13.5	na	22.7	1KB	1KB	14.8	na	Z:\DAC\RAW DATA
24-Sep	1988A	3BLK59ES267B	Aquarius	na	630	0.98	186	na	na	11.6	na	22.7	1KB	1KB	7	na	Z:\DAC\RAW DATA
27-Sep	1998A	3BLK59F270A	Aquarius	na	537/119	1.3	278	na	na	15.7	na	12.4	1KB	1KB	12/18	na	Z:\DAC\RAW DATA
28-Sep	2002A	3BLK59FDS271A	Aquarius	na	226	619	207	na	na	11.7	na	9.74	1KB	1KB	10/18	na	Z:\DAC\RAW DATA
11-Oct	2054A	3BLK59S284A	Aquarius	na	na	466	212	na	na	6.7	na	8.54	1KB	1KB	10/20/21	na	Z:\DAC\RAW DATA
12-Oct	2060A	3BLK59FS285B	Aquarius	na	40	1.33	120	na	na	2.36	na	13.7	1KB	1KB	21/24	na	Z:\DAC\RAW DATA
18-Oct	2082A	3BLK59S291A	Aquarius	na	431	724	152	na	na	4.73	na	6.1	1KB	1KB	na	na	Z:\DAC\RAW DATA
20-Oct	2090A	3BLK59DS293A	Aquarius	na	89	240	117	na	na	5.04	na	5.43	1KB	1KB	11	na	Z:\DAC\RAW DATA
21-Oct	2094A	3BLK63R294A	Aquarius	na	193	691	205	na	na	8.75	na	10.4	1KB	1KB	5/6	na	Z:\DAC\RAW DATA
21-Oct	2096A	3BLK63R294B	Aquarius	na	405	875	190	na	na	8.84	na	9.64	1KB	1KB	5/6	na	Z:\DAC\RAW DATA
22-Oct	2098A	3BLK59S295A	Aquarius	na	na	329	106	na	na	2.48	na	8.9	1KB	1KB	15/23	na	Z:\DAC\RAW DATA

Received from

Name C. JOAQUIN
Position FA
Signature

Received by

Name JOIDA F. PRIETO
Position SUPSRS
Signature 10/31/2014

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

DATA TRANSFER SHEET
20/06/2016 SURIGAO DEL NORTE AND DINAGAT

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
5/8/2016	8481AC	3BLK59AB129A	AQUARIUS	NA	268	683	253	42.9	31.8/6.19	11.7	163	76.5	1KB	1KB	17/187	NA	Z:\DAC\RAWDATA
5/10/2016	8485AC	3BLK59BC131A	AQUARIUS	NA	250	659	231	39.8	92.4/181/0	10.6	183	74.9	1KB	1KB	15.3/170	42.9	Z:\DAC\RAWDATA
5/11/2016	8487AC	3BLK60AB132A	AQUARIUS	NA	311	1.01	270	77.2	199/120	13.5	147	125	1KB	1KB	16.3/219	NA	Z:\DAC\RAWDATA
5/11/2016	8488AC	3BLK60D132B	AQUARIUS	NA	108	1.01	144	30.1	199/120	5.13	76.8	125	1KB	1KB	13/75.2	NA	Z:\DAC\RAWDATA
5/12/2016	8489AC	3BLK60EF133A	AQUARIUS	NA	210	585	256	75.5	164/172	9.49	152	91.3	1KB	1KB	13/75.2	NA	Z:\DAC\RAWDATA
5/12/2016	8490AC	3BLK60CEsG133B	AQUARIUS	NA	318	948	146	23.2	164/172	5.19	NA	91.3	1KB	1KB	13	NA	Z:\DAC\RAWDATA
5/13/2016	8491AC	3CALIB134A & 3BLK59C134A	AQUARIUS	NA	156	734	190	37.6	384/554	7.13	113	91.6	1KB	1KB	14.1/107	NA	Z:\DAC\RAWDATA
5/13/2016	8492AC	3BLK60CS134B	AQUARIUS	NA	306	268	146	NA	NA	4.79	74.7	91.6	1KB	1KB	13/143	NA	Z:\DAC\RAWDATA
5/14/2016	8493AC	3DNGB135A	AQUARIUS	NA	43.6	156	74.8	12.9	64.9	2.24	13.5	28.4	1KB	1KB	4.38/29.4	NA	Z:\DAC\RAWDATA
5/16/2016	8497AC	3DNGABSC137A	AQUARIUS	NA	216	604	240	51.4	183	9.66	NA	75.7	1KB	1KB	6.87/144	NA	Z:\DAC\RAWDATA
5/17/2016	8499AC	3DNGE138A	AQUARIUS	NA	210	611	236	NA	NA	9.44	NA	3	1KB	1KB	4.59/145	14.5	Z:\DAC\RAWDATA
5/18/2016	8501AC	3BLK60AS139A	AQUARIUS	NA	59.6	173	113	11	76.2	3.09	NA	47.6	1KB	1KB	40.6	NA	Z:\DAC\RAWDATA

Name DARRYL M. AUSTRIA
Position R.A.
Signature

Name AC Bongat
Position SSRS
Signature

OK!
- Sheila

16-38

Figure A-5.4. Transfer Sheet for Surigao Floodplain - D

Annex 6. Flight logs for the flight missions

1. Flight Log for 7280GC Mission

Table A-6.1. Flight logs for the flight missions

DREAM Data Acquisition Flight Log

Flight Log No.: 7280

1 LIDAR Operator: LK Paragas	2 ALTM Model: Gemf	3 Mission Name: 2BLK59FF50A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C7322
7 Pilot: R.Samar II	8 Co-Pilot: ASJ	9 Route:			
10 Date: 5-30-14	12 Airport of Departure (Airport, City/Province): RPMS		12 Airport of Arrival (Airport, City/Province): RPMS		
13 Engine On: 5 f 47	14 Engine Off: 8 f 10	15 Total Engine Time: 2 f 23	16 Take off:	17 Landing:	18 Total Flight Time:

19 Weather

20 Remarks:

Surveyed 5 lines in Area F & G
Flight aborted due to low cloud ceiling

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
G. HIPOLITO		D. SAMIANO	LK Paragas
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 7280GC

2. Flight Log for 7281GC Mission

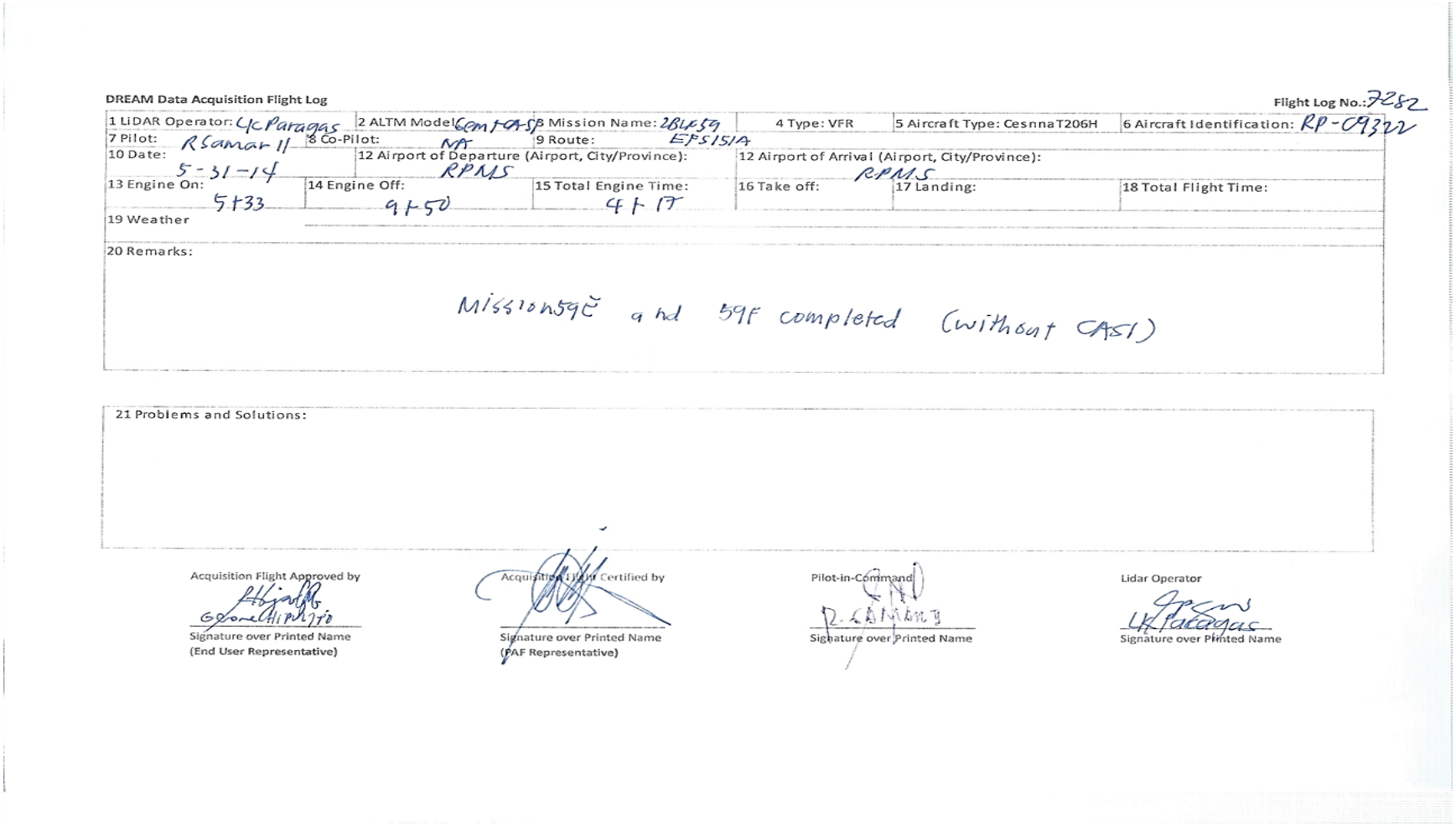
DREAM Data Acquisition Flight Log — Flight Log No. 7281

1 LiDAR Operator: MV Tonga	2 ALTM Model: Gemini CASI	3 Mission Name: 2BLK59B/59C	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9322
7 Pilot: R-Samar II	8 Co-Pilot:	9 Route:			
10 Date: 5-30-14	12 Airport of Departure (Airport, City/Province): RPMS		12 Airport of Arrival (Airport, City/Province): RPMS		
13 Engine On: 15+45	14 Engine Off: 18+14	15 Total Engine Time: 2+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Surveyed lines in Area F (Without CASI)					
21 Problems and Solutions:					

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
G. HIPOLITO		D. CAMAING	MV TONGA
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.2. Flight Log for Mission 7281GC

3. Flight Log for 7282GC Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 7282

1 LiDAR Operator: LK Paragas	2 ALTM Model: Gemini 58	3 Mission Name: 28Apr59	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9322
7 Pilot: R Samar II	8 Co-Pilot: NA	9 Route: EFS151A			
10 Date: 5-31-14	12 Airport of Departure (Airport, City/Province): RPMS		12 Airport of Arrival (Airport, City/Province): RPMS		
13 Engine On: 5+33	14 Engine Off: 9+50	15 Total Engine Time: 4+17	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Mission 59C and 59F completed (without CASI)					
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
R. SAMAR II
Signature over Printed Name

Lidar Operator
LK Paragas
Signature over Printed Name

Figure A-6.3. Flight Log for Mission 7282GC

4. Flight Log for 7283GC Mission

DREAM Data Acquisition Flight Log Flight Log No.: 7283

1 LiDAR Operator: MV Tonga	2 ALTM Model: Gemini SI	3 Mission Name: 2BLK596515IB	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RP-C9322
7 Pilot: R. Gamarra	8 Co-Pilot: NA	9 Route:			
10 Date: 5-31-14	12 Airport of Departure (Airport, City/Province): RPMS	12 Airport of Arrival (Airport, City/Province): RPMS			
13 Engine On: 15:57	14 Engine Off: 18:20	15 Total Engine Time: 2:23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Surveyed lines in 596 (without CASI)					
21 Problems and Solutions:					

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

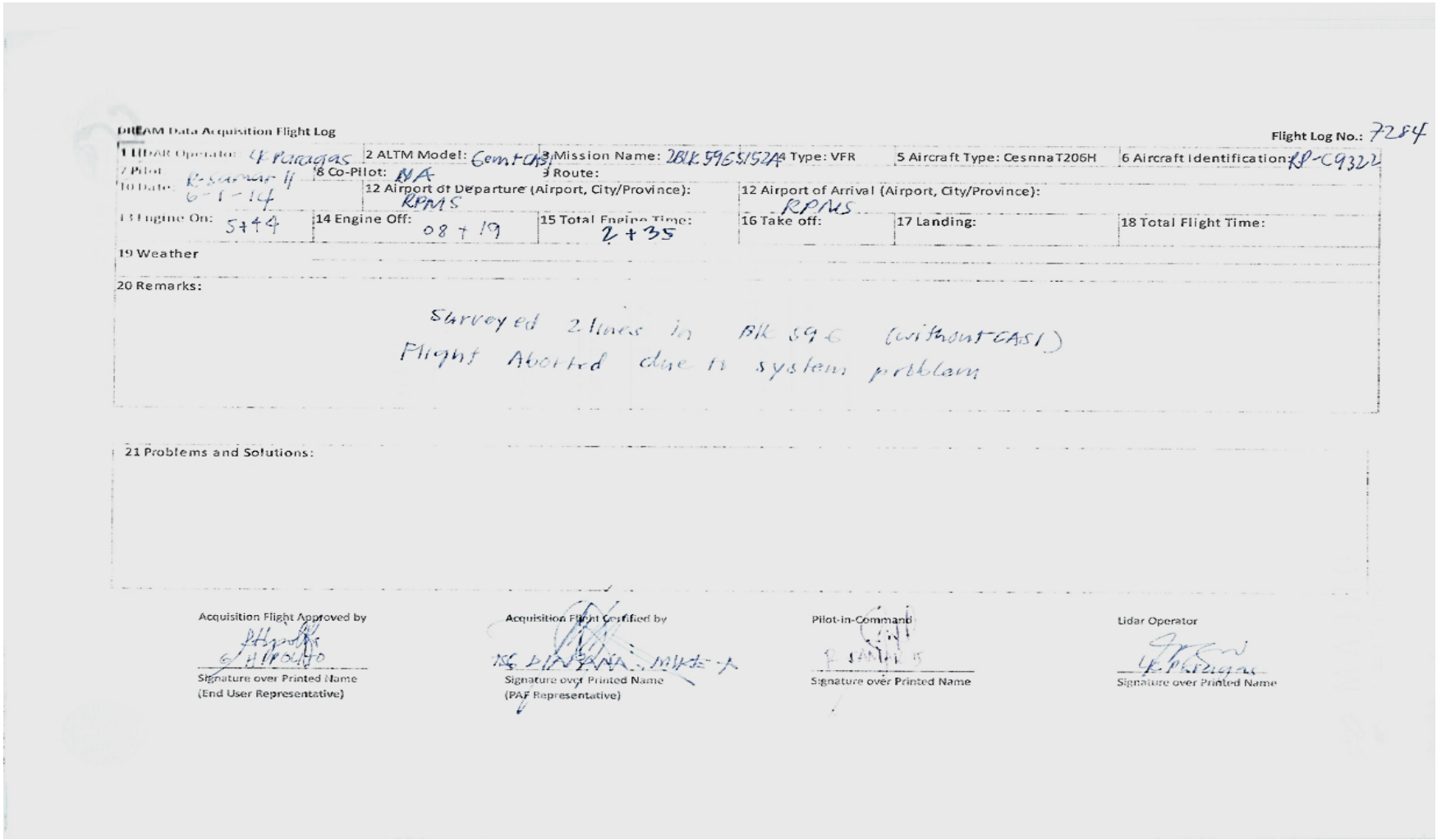
Acquisition Flight Certified by
Signature over Printed Name
(PAF Representative)

Pilot-in-Command
R. Gamarra
Signature over Printed Name

Lidar Operator
MV Tonga
Signature over Printed Name

Figure A-6.4. Flight Log for Mission 7283GC

5. Flight log for 7284GC Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 7284

1 DREAM Operator: 4 Paragas	2 ALTM Model: Gemini	3 Mission Name: Blk59G5152A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9322
7 Pilot: Rosamar H	8 Co-Pilot: NA	9 Route:			
10 Date: 6-1-14	11 Airport of Departure (Airport, City/Province): RPMS		12 Airport of Arrival (Airport, City/Province): RPMS		
13 Engine On: 5+44	14 Engine Off: 08+19	15 Total Engine Time: 2+35	16 Take off:	17 Landing:	18 Total Flight Time:

19 Weather

20 Remarks:

Surveyed 2 lines in Blk 59G (without GAS1)
Flight Aborted due to system problem

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-6.5. Flight Log for Mission 7284GC

6. Flight Log for 7288GC Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 7288

1 LiDAR Operator: MV Tonga	2 ALTM Model: Gemini CAS1	3 Mission Name: 2BLK59C600	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9322
7 Pilot: R-Samar II	8 Co-Pilot: B-Dongguines	9 Route: 154A			
10 Date: 6-3-14	12 Airport of Departure (Airport, City/Province): RPMS		12 Airport of Arrival (Airport, City/Province): RPMS		
13 Engine On: 5 f 13	14 Engine Off: 9 f 36	15 Total Engine Time: 4 f 23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Mission 59C completed and surveyed lines in COD without CASI

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-6.6. Flight Log for Mission 7288GC

7. Flight log for 7292GC Mission

DREAM Data Acquisition Flight Log Flight Log No.: 7292

1 LiDAR Operator: MV Tonga	2 ALTM Model Gemini SN1	3 Mission Name: 2BLK60DS	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RPC9322
7 Pilot: R. Samar II	8 Co-Pilot: R. Donguites	9 Route: 156A			
10 Date: 6-5-14	12 Airport of Departure (Airport, City/Province): RPMS	12 Airport of Arrival (Airport, City/Province): RPMS			
13 Engine On: 6:46	14 Engine Off: 10:45	15 Total Engine Time: 3:59	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Mission 60D completed (without CASI)					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
G. HIPOLITO		R. SAMAR II	MV Tonga
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.7. Flight Log for Mission 7292GC

8. Flight log for 7293GC Mission

DREAM Data Acquisition Flight Log — Flight Log No.: 7293

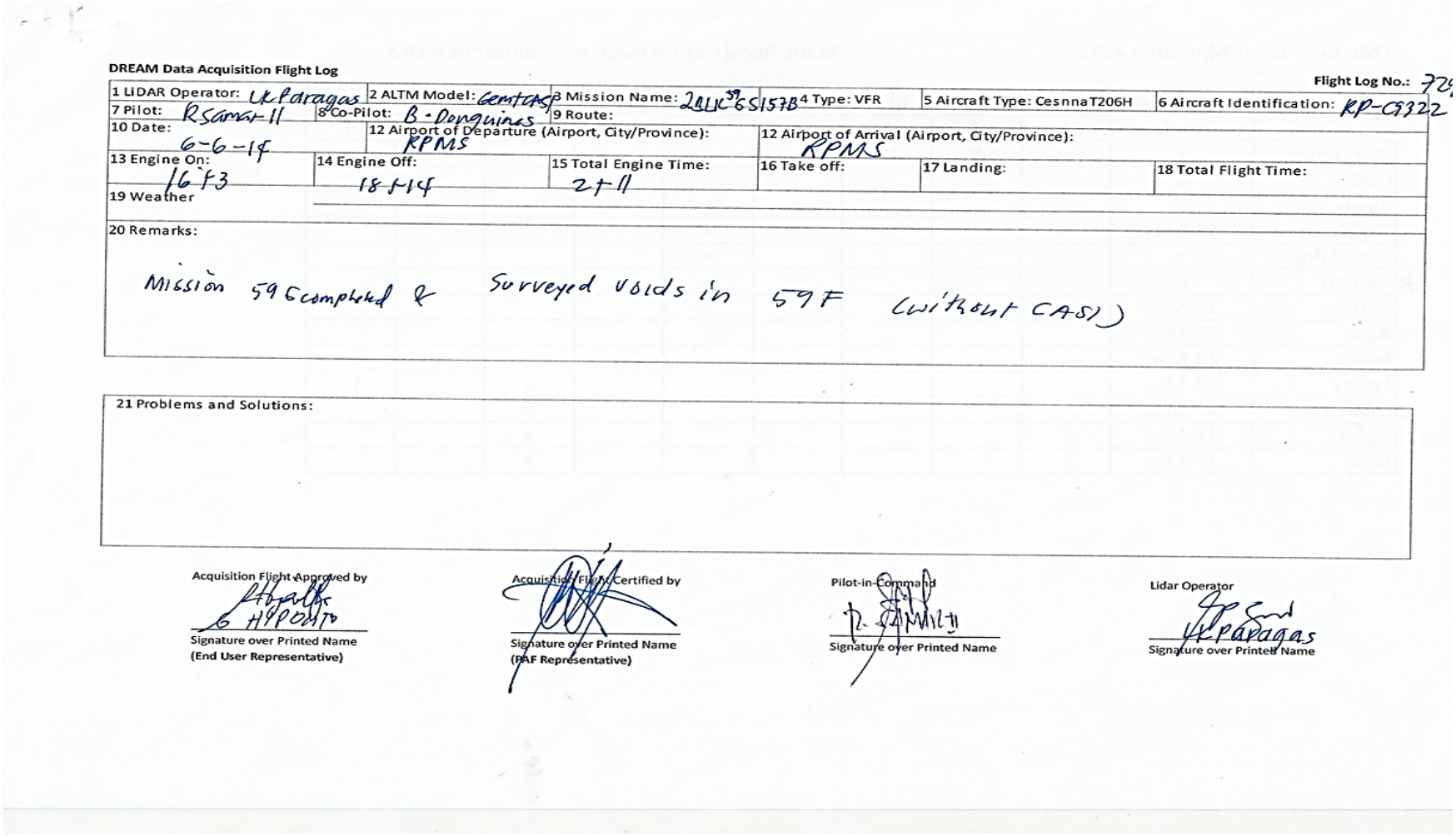
1 LiDAR Operator: UC Paragas	2 ALTM Model: Gemini	3 Mission Name: 2BLK59G5	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9322
7 Pilot: R. Sanchez II	8 Co-Pilot: B. Dongcines	9 Route: 156B			
10 Date: 6-5-14	12 Airport of Departure (Airport, City/Province): RPMS	12 Airport of Arrival (Airport, City/Province): RPMS			
13 Engine On: 16 +8	14 Engine Off: 18 +19	15 Total Engine Time: 2 +11	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: surveyed 8 lines in 59D (without CASI)					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
G. HIPOLITO		R. SANCHEZ II	UC Paragas
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 7293GC

9. Flight log for 7295GC Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 72

1 LiDAR Operator: LR Paragas	2 ALTM Model: Gemini A3	3 Mission Name: 2ALK 7295157B	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RP-C9322
7 Pilot: R Samar II	8 Co-Pilot: B - Dongquines	9 Route:			
10 Date: 6-6-14	12 Airport of Departure (Airport, City/Province): RPMS	12 Airport of Arrival (Airport, City/Province): RPMS			
13 Engine On: 16+3	14 Engine Off: 18+14	15 Total Engine Time: 2+11	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Mission 59G completed & Surveyed voids in 59F (without CASI)

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
G HIPOLITO		R SAMAR II	LR Paragas
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.9. Flight Log for Mission 7295GC

10. Flight log for 7296GC Mission

Flight Log No.: 729

DREAM Data Acquisition Flight Log

1 LiDAR Operator: LK Paragas	2 ALTM Model: Gemini CAS1	3 Mission Name: 28LK60C05	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9322
7 Pilot: R.Sanar II	8 Co-Pilot: B. Donguines	9 Route: 158A			
10 Date: 6-7-14	12 Airport of Departure (Airport, City/Province): RPMS	12 Airport of Arrival (Airport, City/Province): RPMS			
13 Engine On: 5 + 39	14 Engine Off: 10 + 8	15 Total Engine Time: 4+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Mission 60C completed & surveyed voids in 60D

(without CAS1)

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
G. HIPOLITO		R. SANAR II	LK Paragas
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.10. Flight Log for Mission 7296GC

11. Flight log for 7297GC Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 7297

1 LiDAR Operator: MV Tonga	2 ALTM Model: Gemini	3 Mission Name: 2BLK59V	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9722
7 Pilot: R-Samar II	8 Co-Pilot: B-Dasquiños	9 Route: 158B			
10 Date: 6-7-14	12 Airport of Departure (Airport, City/Province): RPMS	12 Airport of Arrival (Airport, City/Province): RPMS			
13 Engine On: 15+52	14 Engine Off: 17+45	15 Total Engine Time: 1+53	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Surveyed voids in 59V without CASI

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
		R-Samar II	MV Tonga

Figure A-6.11. Flight Log for Mission 7297GC

12. Flight log for 7200GC Mission

DREAM Data Acquisition Flight Log Flight Log No.: 730

1 LiDAR Operator: UC Paracgas	2 ALTM Model: Gemini CAS	3 Mission Name: 2014C5960V	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9522
7 Pilot: R.Samar-if	8 Co-Pilot: B-Dongiines	9 Route: 160A			
10 Date: 6-9-14	12 Airport of Departure (Airport, City/Province): RPMS	12 Airport of Arrival (Airport, City/Province): RPMS			
13 Engine On: 5+28	14 Engine Off: 9+9	15 Total Engine Time: 3+41	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Fair					

20 Remarks:

Surveyed voids in Blk 59 & 60
(without CASI)

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)	R. Samar-if Signature over Printed Name	UC Paracgas Signature over Printed Name

Figure A-6.12. Flight Log for Mission 7300GC

13. Flight log for 1970A Mission

PHIL-LiDAR 1 Data Acquisition Flight Log — **Flight Log No.:** 1979

1 LiDAR Operator: DC Aldovino	2 ALTM Model: Aquarius	3 Mission Name: 3BUS9R2AA	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9722
7 Pilot: J. Alajar	8 Co-Pilot: M. Garcelitorres	9 Route: SUG – SUG			
10 Date: Sept 21, 2014	12 Airport of Departure (Airport, City/Province): Surigao		12 Airport of Arrival (Airport, City/Province): Surigao		
13 Engine On: 1019A	14 Engine Off: 1330A	15 Total Engine Time: 3+11	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: partly cloudy					
20 Remarks: Filed up 8 amps in Surigao del Norte					
21 Problems and Solutions:					

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

Figure A-6.13. Flight Log for Mission 1970A

14. Flight log for 1974A Mission

PHIL-LiDAR 1 Data Acquisition Flight Log — **Flight Log No.:** 1970

1 LiDAR Operator: E. Punto	2 ALTM Model: Aquarius	3 Mission Name: 3BLK55B2643A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9122
7 Pilot: J. Alajar	8 Co-Pilot: M. Garduitorma	9 Route: Surigao – Surigao			
10 Date: Sept 20, 2014	12 Airport of Departure (Airport, City/Province): Surigao		12 Airport of Arrival (Airport, City/Province): Surigao		
13 Engine On: 1100 H	14 Engine Off: 1341 H	15 Total Engine Time: 2+41	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	partly cloudy				
20 Remarks: Surveyed gaps in Surigao del Norte					
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-6.14. Flight Log for Mission 1974A

15. Flight log for 8481AC Mission

D R E A M | Data Acquisition Flight Log — **Flight Log No.:** 8481Ac

1 LiDAR Operator: MCE BALICUAS	2 ALTM Model: PEGASUS (AQUATICAS)	3 Mission Name: 2BLK59AB1291	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9322
7 Pilot: R. LAGCO	8 Co-Pilot: J. JECIEL	9 Route:			
10 Date: May 8, 2016	12 Airport of Departure (Airport, City/Province): SURIGAO	12 Airport of Arrival (Airport, City/Province): SURIGAO			
13 Engine On: 0946	14 Engine Off: 1357	15 Total Engine Time: 4+17	16 Take off: 0935	17 Landing: 1352	18 Total Flight Time: 4+07
19 Weather: Rainy / Cloudy					

20 Flight Classification

20.a Billable	20.b Non Billable	20.c Others
☑ Acquisition Flight	○ Aircraft Test Flight	○ LiDAR System Maintenance
○ Ferry Flight	○ AAC Admin Flight	○ Aircraft Maintenance
○ System Test Flight	○ Others: _____	○ DREAM Admin Activities
○ Calibration Flight		

21 Remarks: Surveyed BLK59A & BLK59B

22 Problems and Solutions

- ○ Weather Problem
- ○ System Problem
- ○ Aircraft Problem
- ○ Pilot Problem
- ○ Others: _____

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Technician
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	MCE BALICUAS Signature over Printed Name	Signature over Printed Name

Figure A-6.15. Flight Log for Mission 8481AC

16. Flight log for 8485AC Mission

Data Acquisition Flight Log

Flight Log No.: 8485AC

1 LiDAR Operator: MS Reyes	2 ALTM Model: Aqua Teasi	3 Mission Name: 3BLK59B13	A 4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9322
7 Pilot: R. LAGCO	8 Co-Pilot: J. Jecicl	9 Route:			
10 Date: May 10, 2016	12 Airport of Departure (Airport, City/Province): SURIGAO		12 Airport of Arrival (Airport, City/Province): SURIGAO		
13 Engine On: 0820	14 Engine Off: 1207	15 Total Engine Time: 3+47	16 Take off: 0825	17 Landing: 1202	18 Total Flight Time: 3+37
19 Weather	Partly cloudy				

20 Flight Classification

20.a Billable	20.b Non Billable	20.c Others
☑ Acquisition Flight	○ Aircraft Test Flight	○ LiDAR System Maintenance
○ Ferry Flight	○ AAC Admin Flight	○ Aircraft Maintenance
○ System Test Flight	○ Others: _____	○ Phil-LiDAR Admin Activities
○ Calibration Flight		

21 Remarks: Supplementary flight for BLK59B

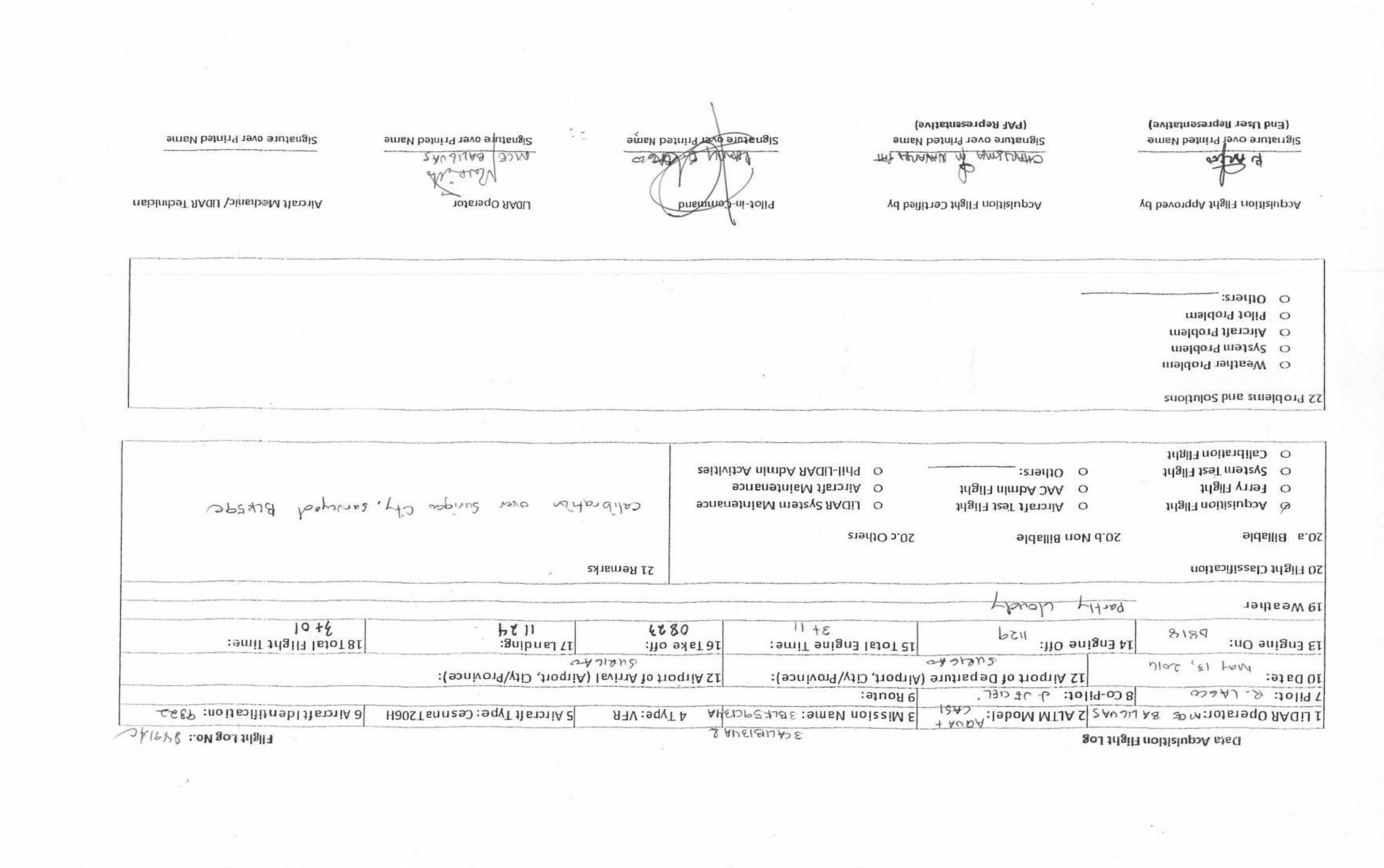
22 Problems and Solutions

- ○ Weather Problem
- ○ System Problem
- ○ Aircraft Problem
- ○ Pilot Problem
- ○ Others: _____

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Technician
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.16. Flight Log for Mission 8485AC

17. Flight log for 8491AC Mission



Data Acquisition Flight Log — Flight Log No.: 8491AC

1 LiDAR Operator: MCE BALICUAS	2 ALTM Model: AQUA + CASI	3 Mission Name: 3BLK59C134A 3CALIB134A2	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: R. LAGCO	8 Co-Pilot: J. JT GIEL	9 Route:			
10 Date: May 13, 2016	12 Airport of Departure (Airport, City/Province): SURIGAO		12 Airport of Arrival (Airport, City/Province): SURIGAO		
13 Engine On: 0818	14 Engine Off: 1129	15 Total Engine Time: 3+11	16 Take off: 0823	17 Landing: 1124	18 Total Flight Time: 3+01
19 Weather: Partly cloudy					

20 Flight Classification

20.a Billable
- ✓ Acquisition Flight
- o Ferry Flight
- o System Test Flight
- o Calibration Flight

20.b Non Billable
- o Aircraft Test Flight
- o AAC Admin Flight
- o Others: ____

20.c Others
- o LiDAR System Maintenance
- o Aircraft Maintenance
- o Phil-LiDAR Admin Activities

21 Remarks

calibration over Surigao City, surveyed BLK59C

22 Problems and Solutions
- o Weather Problem
- o System Problem
- o Aircraft Problem
- o Pilot Problem
- o Others: ____

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 — MCE BALICUAS — Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician — Signature over Printed Name

Figure A-6.17. Flight Log for Mission 8491AC

Annex 7. Flight status reports

Surigao Mission

May 30 to June 9, 2014, September 20 to 21, 2014, and May 8 to 13, 2016

Table A-7.1. Flight Status Report

FLIGHT NO.	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
7280GC	BLK59F, BLK59G	2BLK59FG150A	L. PARAGAS	May 30, 2014	Covered 4 strips of area F then moved to area G due to the build-up of clouds. However two lines were just surveyed because of the 100% dropouts experienced in the 3rd strip.
7281GC	BLK59F	2BLK59F150B	MV. TONGA	May 30, 2014	Bad swath in line 3 so the operator decided to change the flight plan parameters. Nonetheless, still covered 10 strips of area F including line 3.
7282GC	BLK59E, BLK59F	2BLK59EFS151A	L.PARAGAS	May 31, 2014	Completed area E and 8 strips of area F.
7283GC	BLK59G	2BLK59GS151B	MV. TONGA	May 31, 2014	Covered 10 strips of area G.
7284GC	BLK59G	2BLK59GS152A	L. PARAGAS	June 1, 2014	Experienced dropouts after 2 lines of area G.
7288GC	BLK59C, BLK60D	2BLK59C+BLK60D154A	MV. TONGA	June 3, 2014	Completed area C, but there are gaps due to high terrain, also covered 7 strips of area BLK60D.
7292GC	Blk60D	2BLK60DS156A	MV. TONGA	June 5, 2014	Covered 17 lines, some lines were shortened due to low cloud ceiling
7293GC	BLK59G	2BLK59GS156B	L. PARAGAS	June 5, 2014	Continuation of BLKG, was able to cover 9 strips
7295GC	BLK59G and BLKF	2BLK59GS+FV157B	L. PARAGAS	June 6, 2014	Covered the remaining strips of area G as well as voids and gaps in area E & F.
7296GC	BLK60C and BLK60D	2BLK60CDS158A	L. PARAGAS	June 7, 2014	Completed area C, however there are some possible voids due to clouds and high terrain. Also covered gaps in area D.
7297GC	BLK59E	2BLK59ES158B	MV. TONGA	June 7, 2014	Mission completed
7300GC	BLK59F, BLK59G, BLK60C, and BLK60D	2BLK59FG+BLK60DCV160A	L. PARAGAS	June 9, 2014	Covered all the voids and gaps in BLKS59 F, G, & BLKS60 C & D.

1970A	BLK59G	3BLK59S263A	R. Punto	September 20, 2014	Filled in gaps in BLK 59 (mainland) from the previous LiDAR (Gemini) survey
1974A	BLK59F	3BLK59S264A	DC Aldovino	September 21, 2014	Filled in gaps in BLK 59 (mainland) from the previous LiDAR (Gemini) survey
8481AC	BLK59A and BLK59B	3BLK59AB129A	MCE Baliguas	May 8, 2016	Surveyed Blk59A And Blk59B
8485AC	BLK59B and BLK59C	3BLK59BC131A	MS Reyes	May 10, 2016	Surveyed Supplementary Flights For 59b
8491AC	BLK59C	3CALIB134A & 3BLK59C134A	MCE Baliguas	May 13, 2016	Calibration Over Surigao City; Surveyed Blk59C And Voids Over Surigao Floodplain

SWATH PER FLIGHT MISSION

Flight No. : 7280GC
Area: BLK 59F, 59G
Mission Name:2BLK59FG150A
Parameters:
Altitude: 1000, 900
Scan Frequency: 50, 40
Scan Angle: 40, 50
Overlap: 30

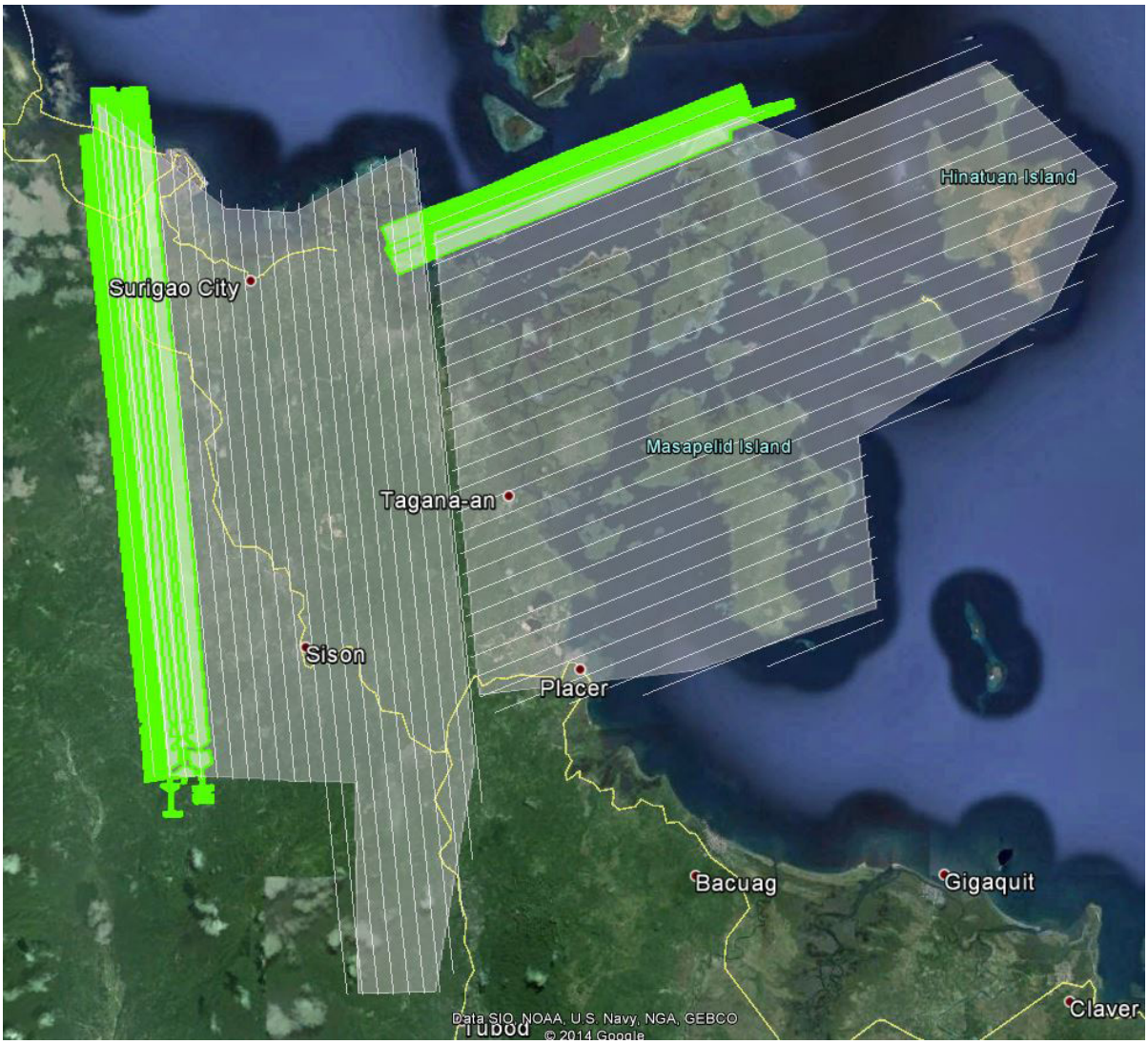


Figure A-7.1. Swath for Flight No. 7280GC

Flight No. : 7281GC
Area: BLK 59F
Mission Name:2BLK59F150B
Parameters:
Altitude: 1000, 900
Scan Frequency: 50, 40
Scan Angle: 40, 50
Overlap: 30

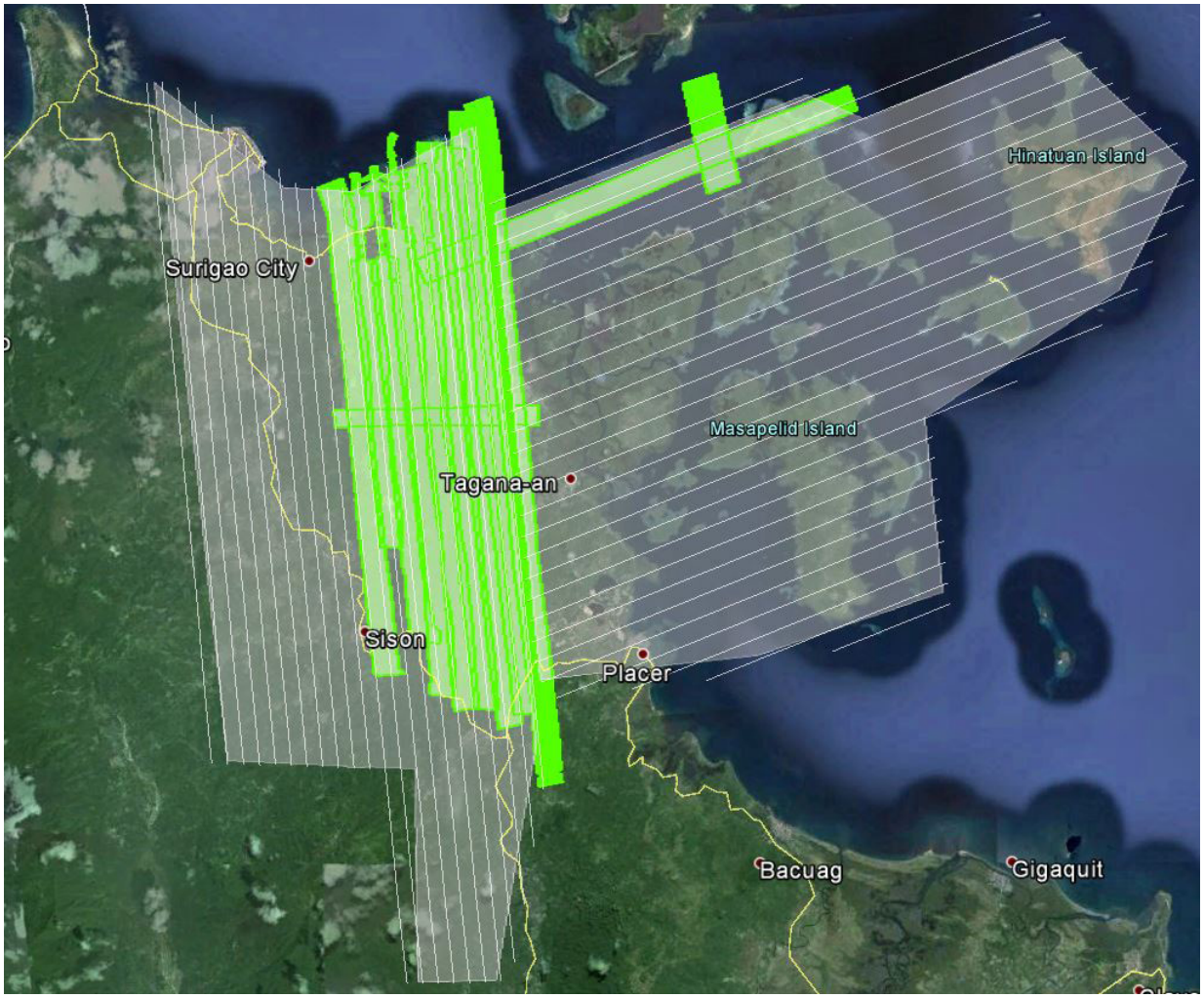


Figure A-7.2. Swath for Flight No. 7281GC

Flight No. : 7282GC
Area: BLK 59E, 59F
Mission Name:2BLK59EFS151A
Parameters:
Altitude: 1300
Scan Frequency: 50
Scan Angle: 22
Overlap: 30

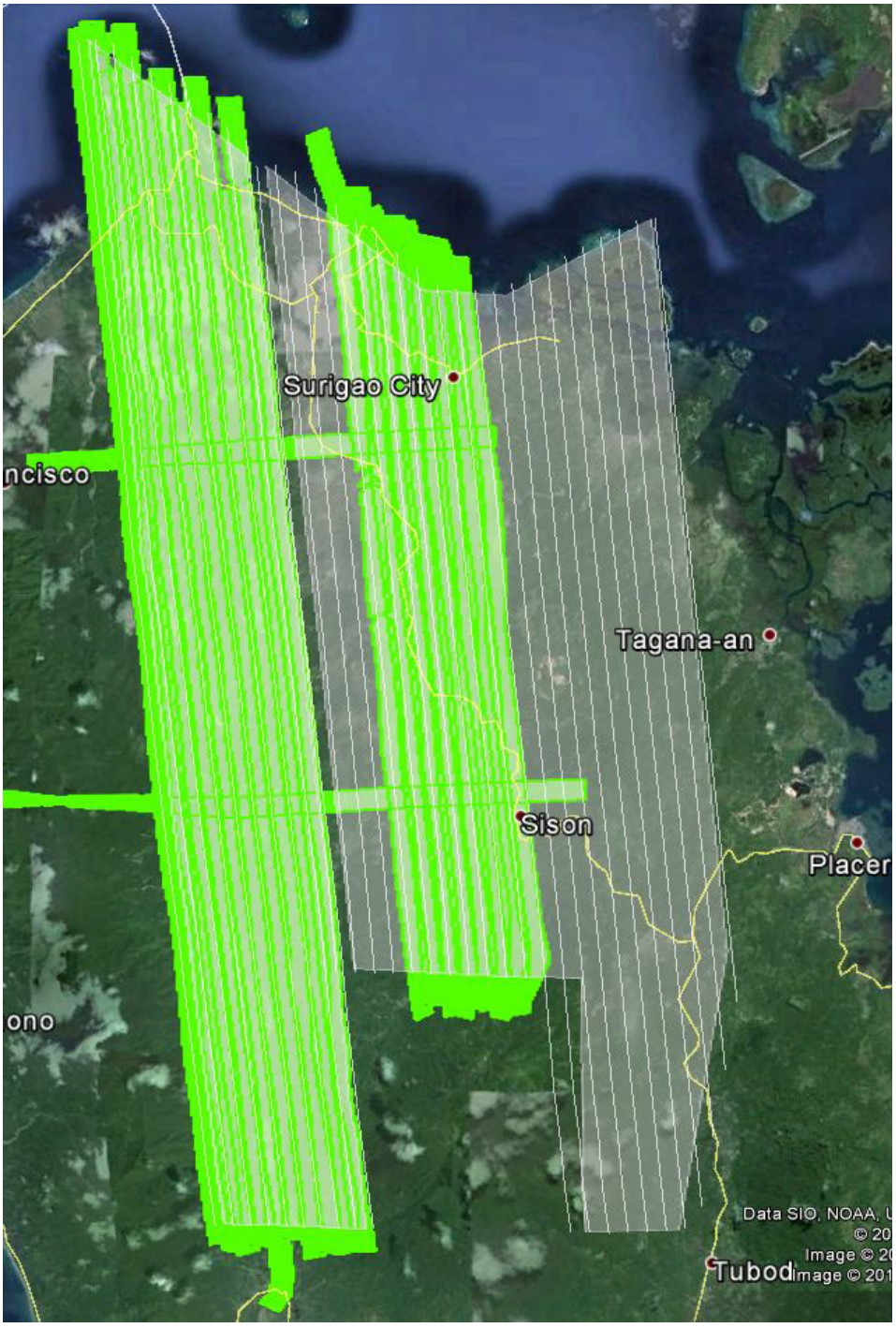


Figure A-7.3. Swath for Flight No. 7282GC

Flight No. : 7283GC
Area: BLK 59G
Mission Name:2BLK59GS151B
Parameters:
Altitude: 1300
Scan Frequency: 40
Scan Angle: 50
Overlap: 30

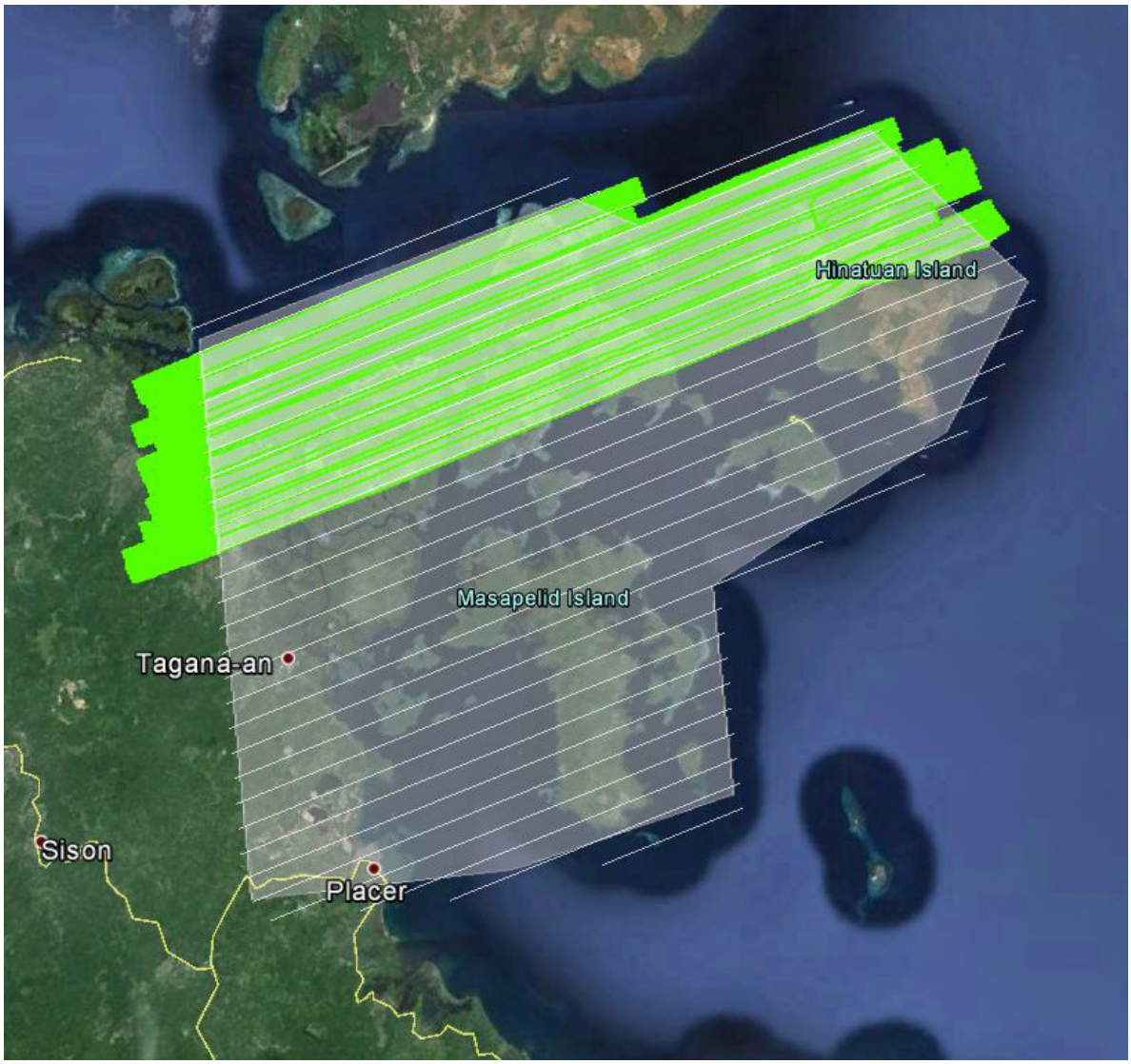


Figure A-7.4. Swath for Flight No. 7283GC

Flight No. : 7284GC
Area: BLK 59G
Mission Name:2BLK59GS152A
Parameters:
Altitude: 750
Scan Frequency: 30
Scan Angle: 60
Overlap: 30

Figure A-7.5. Swath for Flight No. 7284GC

Flight No. : 7288GC
Area: BLK59C, BLK60D
Mission Name:2BLK59C+BLK60D154A
Parameters:
Altitude: 1300
Scan Frequency: 50
Scan Angle: 22
Overlap: 30

Figure A-7.6. Swath for Flight No. 7288GC

Flight No. : 7292GC
Area: Blk60D
Mission Name:2BLK60DS156A
Parameters:
Altitude: 1300
Scan Frequency: 30
Scan Angle: 22
Overlap: 30

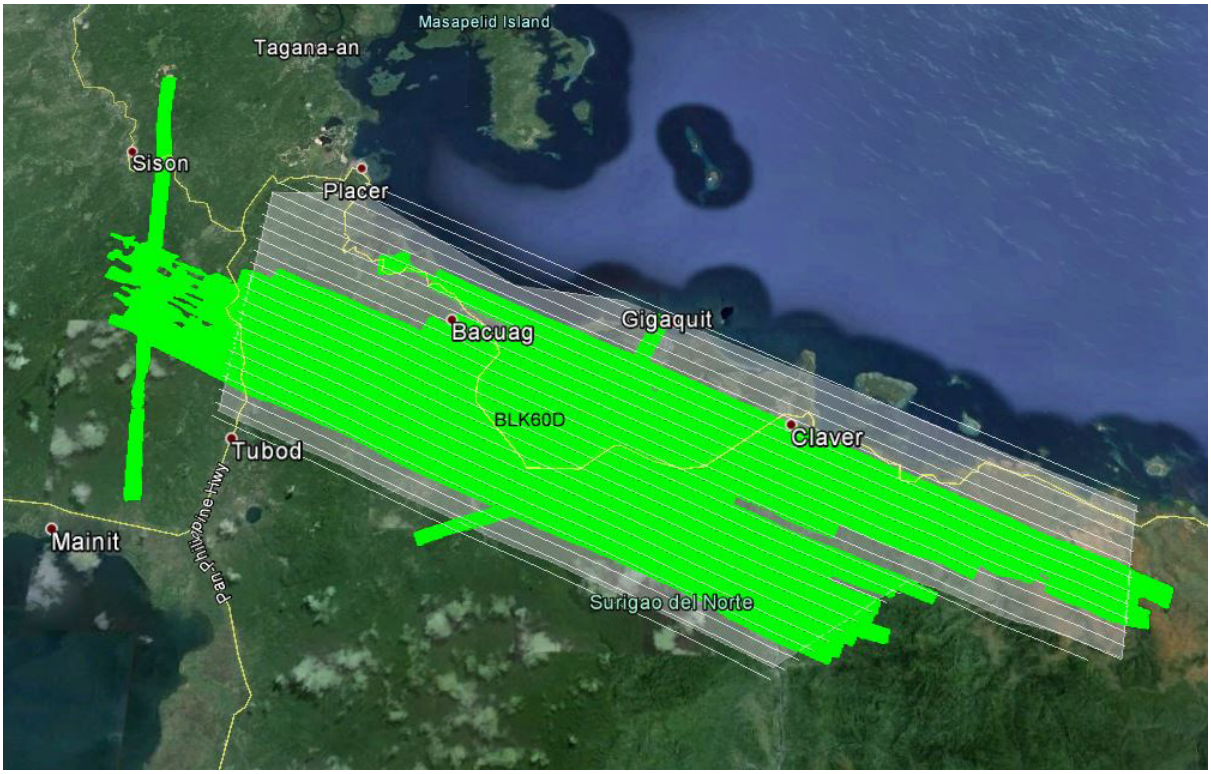


Figure A-7.7. Swath for Flight No. 7292GC

Flight No. : 7293GC
Area: BLK59G
Mission Name:2BLK59GS156B
Parameters:
Altitude: 750
Scan Frequency: 32
Scan Angle: 60
Overlap: 30

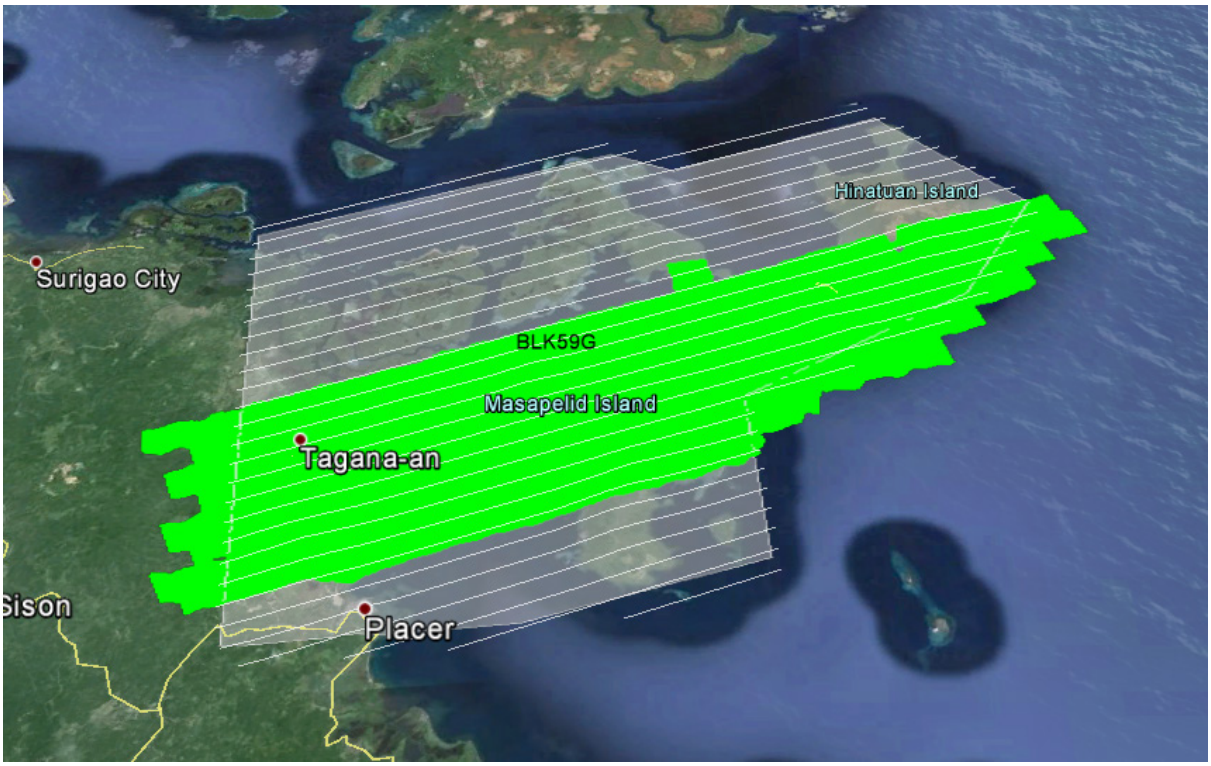


Figure A-7.8. Swath for Flight No. 7293GC

Flight No. : 7295GC
Area: BLK59G and BLKF
Mission Name:2BLK59GS+FV157B
Parameters:
Altitude: 750
Scan Frequency: 32
Scan Angle: 60
Overlap: 30

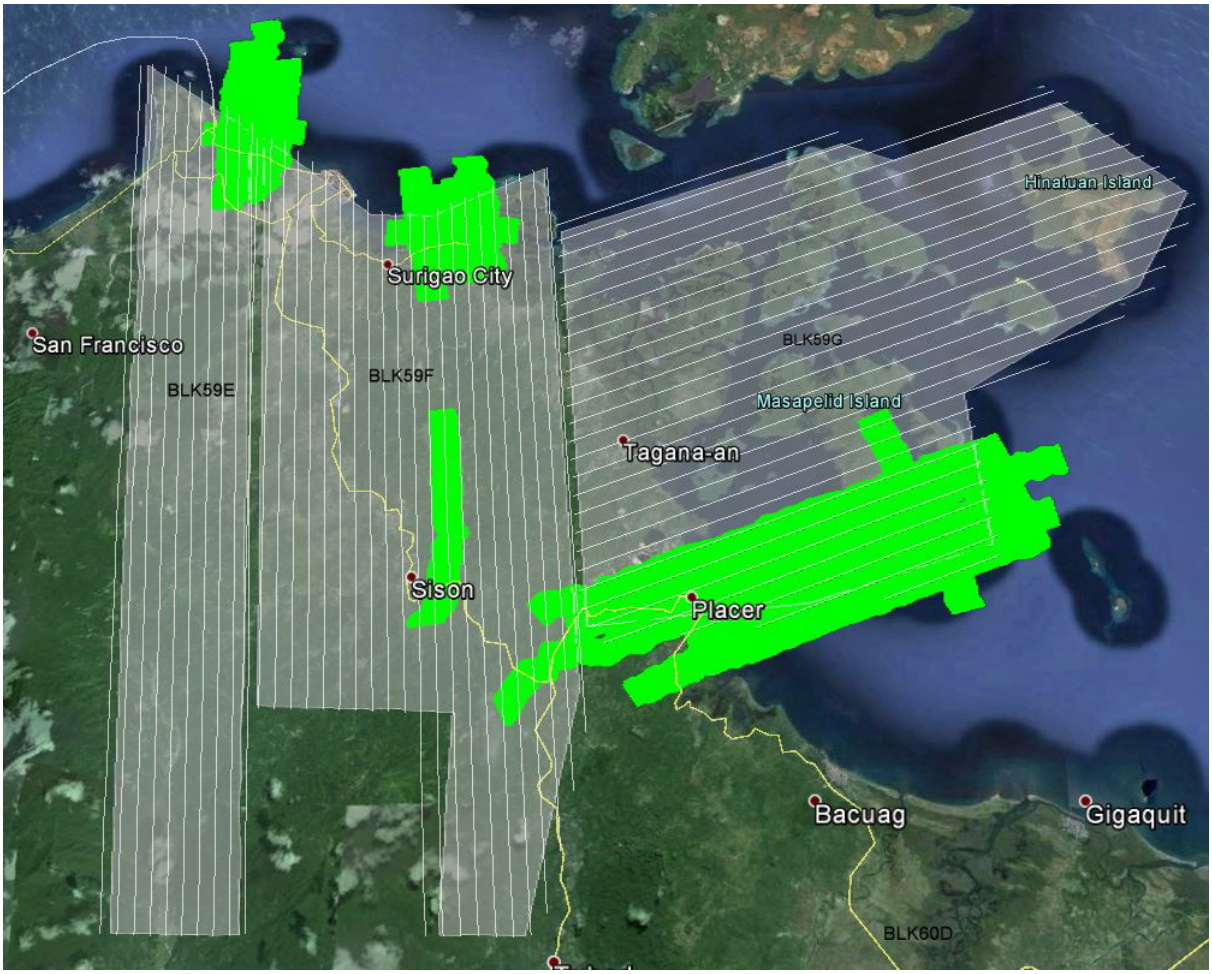


Figure A-7.9. Swath for Flight No. 7295GC

Flight No. : 7296GC
Area: BLK60C and BLK60D
Mission Name:2BLK60CDS158A
Parameters:
Altitude: 1000
Scan Frequency: 40
Scan Angle: 40
Overlap: 30

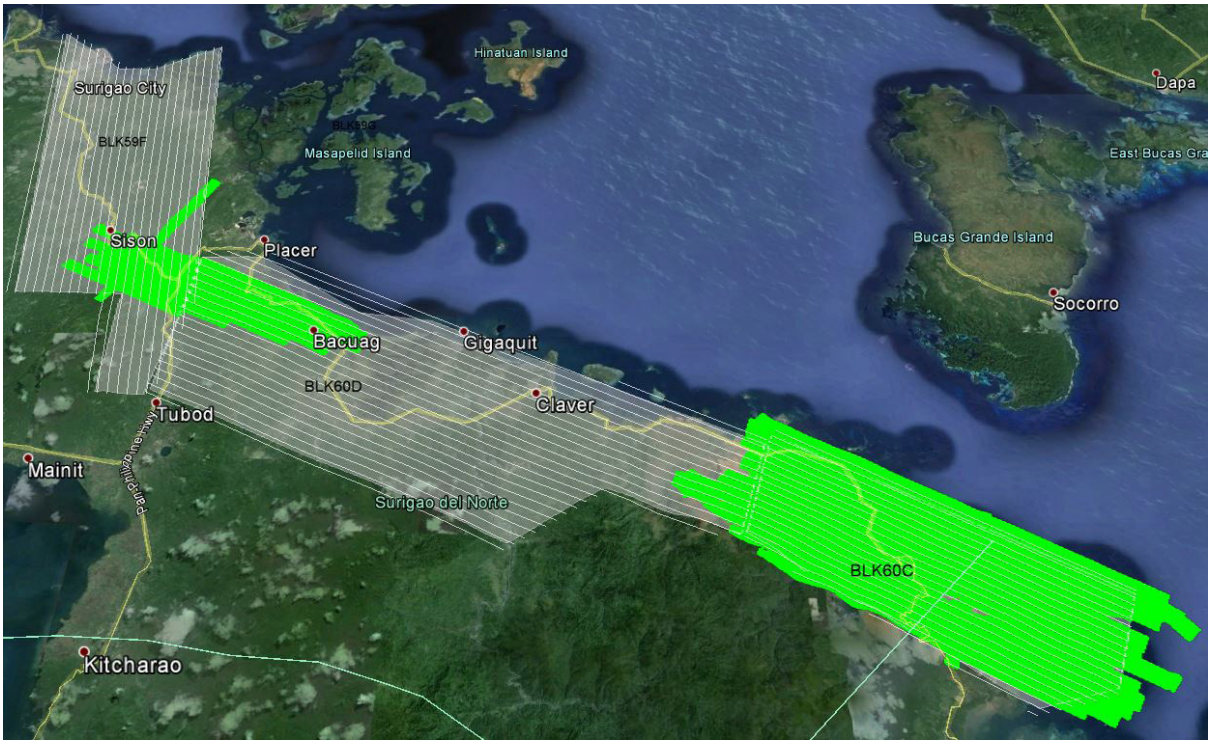


Figure A-7.10. Swath for Flight No. 7296GC

Flight No. : 7297GC
Area: BLK59E
Mission Name:2BLK59ES158B
Parameters:
Altitude: 1000
Scan Frequency: 50
Scan Angle: 40
Overlap: 30

Figure A-7.11. Swath for Flight No. 7297GC

Flight No. : 7300GC
Area: BLK59F, BLK59G, BLK60C, and BLK60D
Mission Name:2BLK59FG+BLK60DCV160A
Parameters:
Altitude: 1000
Scan Frequency: 50
Scan Angle: 40
Overlap: 30

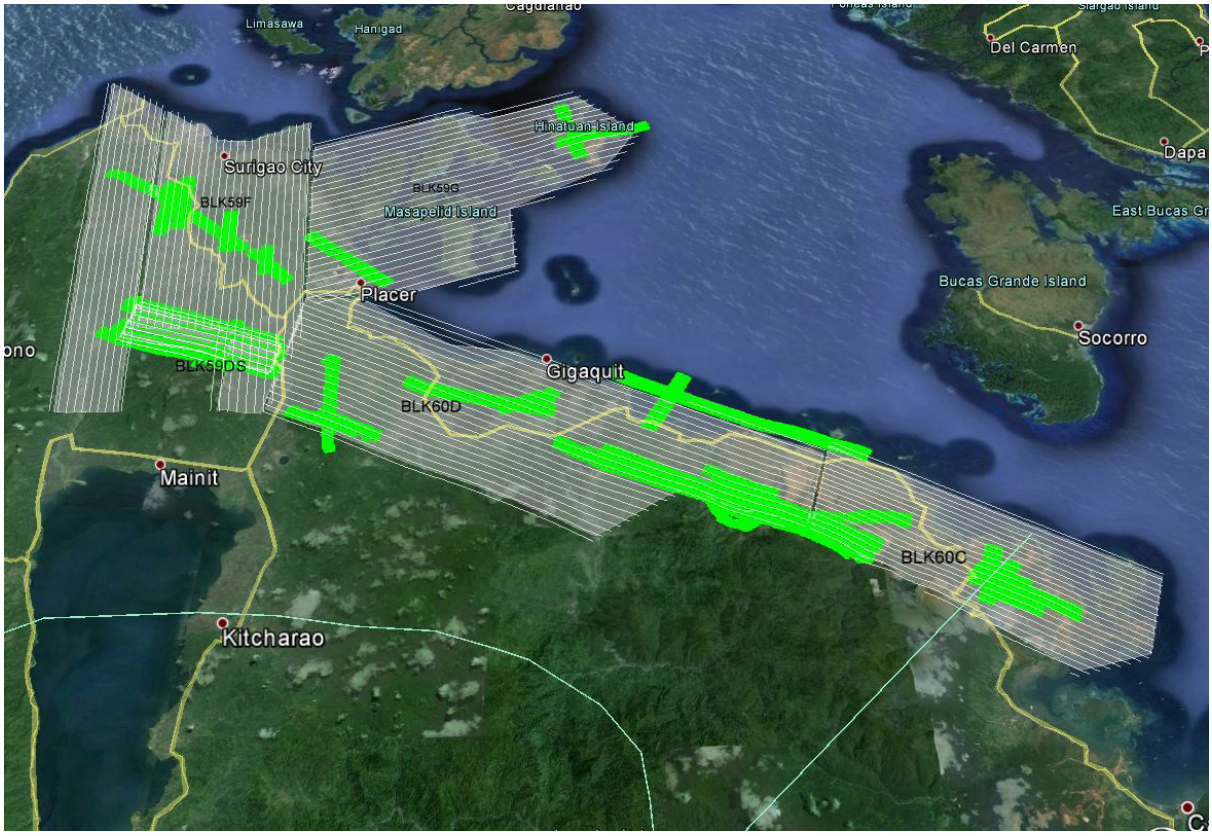


Figure A-7.12. Swath for Flight No. 7300GC

Flight No. : 1970A
Area: BLK59G
Mission Name:3BLK59S263A
Parameters:
Altitude: 600
Scan Frequency: 45
Scan Angle: 36
Overlap: 30

Figure A-7.13. Swath for Flight No. 1970A

Flight No. : 1974A
Area: BLK59F
Mission Name:3BLK59S264A
Parameters:
Altitude: 600
Scan Frequency: 45
Scan Angle: 36
Overlap: 30

Figure A-7.14. Swath for Flight No. 1974A

Flight No. : 8481AC
Area: BLK59A and BLK59B
Mission Name:3BLK59AB129A
Parameters:
Altitude: 600
Scan Frequency: 45
Scan Angle: 36
Overlap: 30

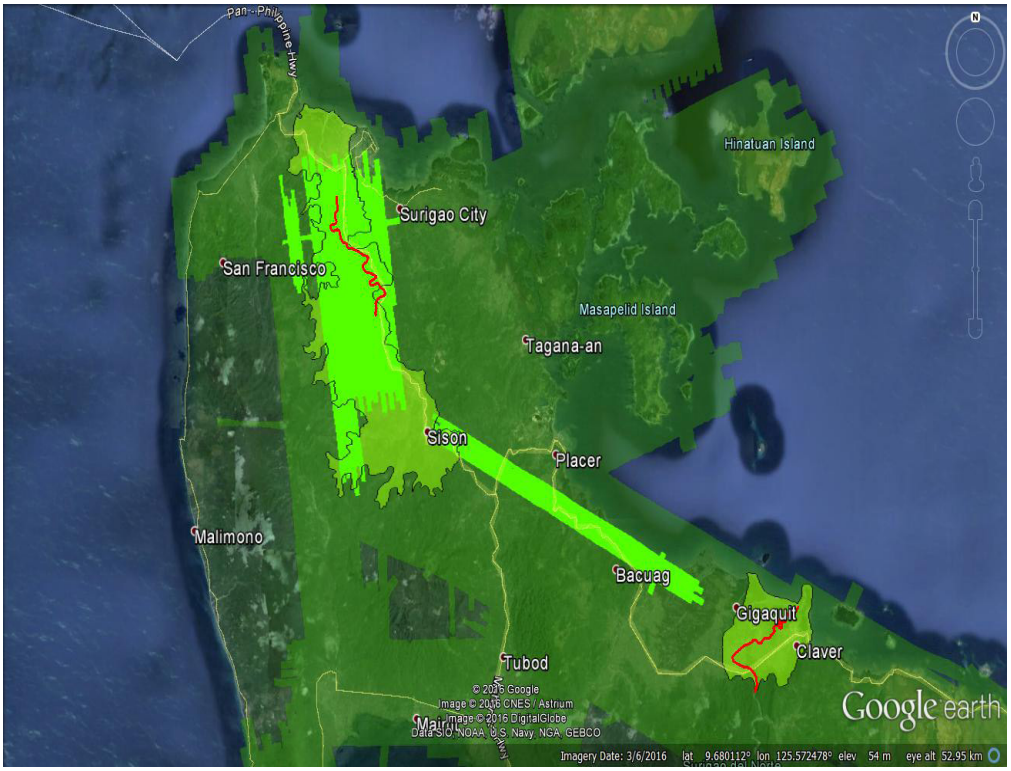


Figure A-7.15. Swath for Flight No. 8481AC

Flight No. : 8485AC
Area: BLK59B and BLK59C
Mission Name:3BLK59BC131A
Parameters:
Altitude: 600
Scan Frequency: 45
Scan Angle: 36
Overlap: 30

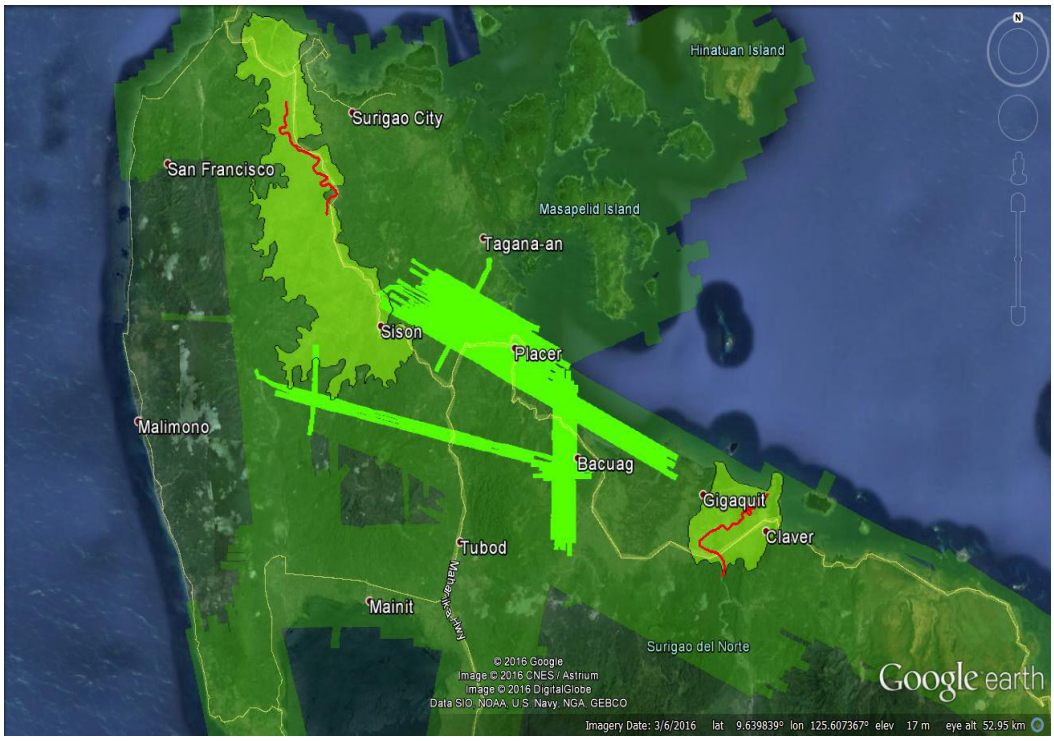


Figure A-7.16. Swath for Flight No. 8485AC

Flight No. : 8491AC
Area: BLK59C
Mission Name:3CALIB134A & 3BLK59C134A
Parameters:
Altitude: 600
Scan Frequency: 45
Scan Angle: 36
Overlap: 30

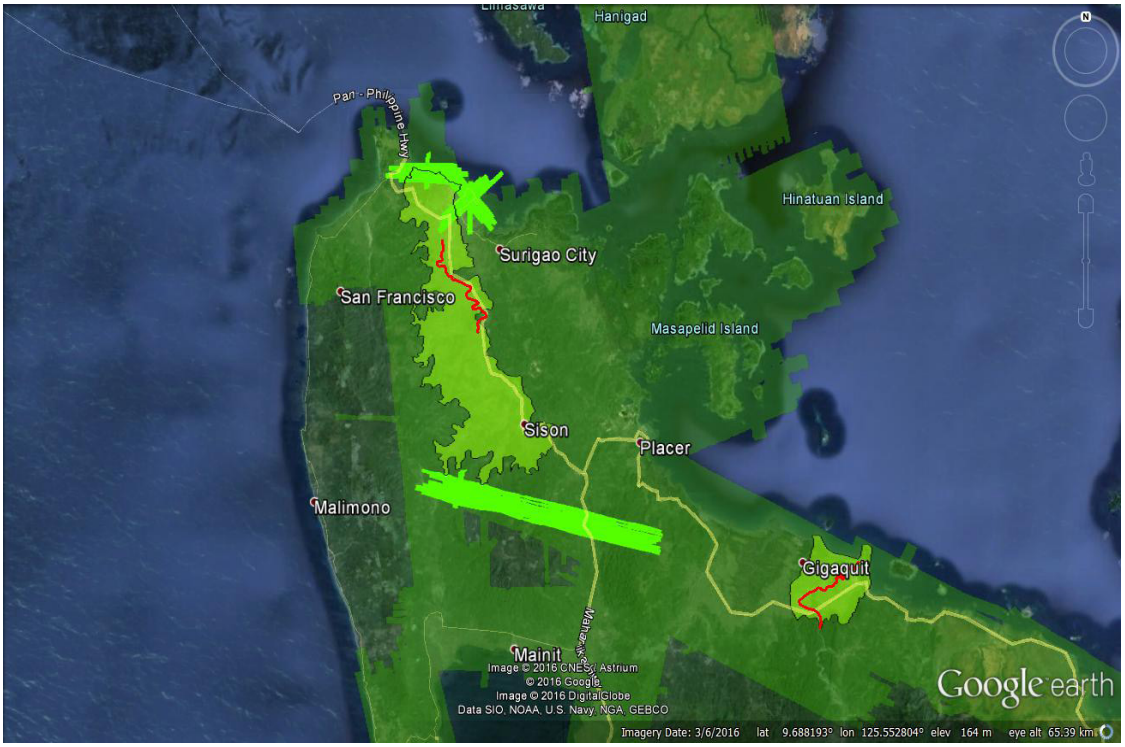


Figure A-7.17. Swath for Flight No. 8491AC

Annex 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Blk59S

Flight Area	Surigao City
Mission Name	Block59S (Siargao)
Inclusive Flights	2098A
Range data size	2.48 GB
Base data size	106 MB
POS	8.9 MB
Image	NA
Transfer date	October 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)	1.55
RMSE for East Position (<4.0 cm)	1.50
RMSE for Down Position (<8.0 cm)	2.60
Boresight correction stdev (<0.001deg)	0.000419
IMU attitude correction stdev (<0.001deg)	0.079240
GPS position stdev (<0.01m)	0.0046
Minimum % overlap (>25)	25.16
Ave point cloud density per sq.m. (>2.0)	2.64
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	61
Maximum Height	395.70 m
Minimum Height	61.78 m
Classification (# of points)	
Ground	7,605,135
Low vegetation	6,863,127
Medium vegetation	8,127,697
High vegetation	11,046,719
Building	1,042,530
Orthophoto	No
Processed by	Engr. Irish Cortez, Engr. Chelou Prado, Engr. Melissa Fernandez

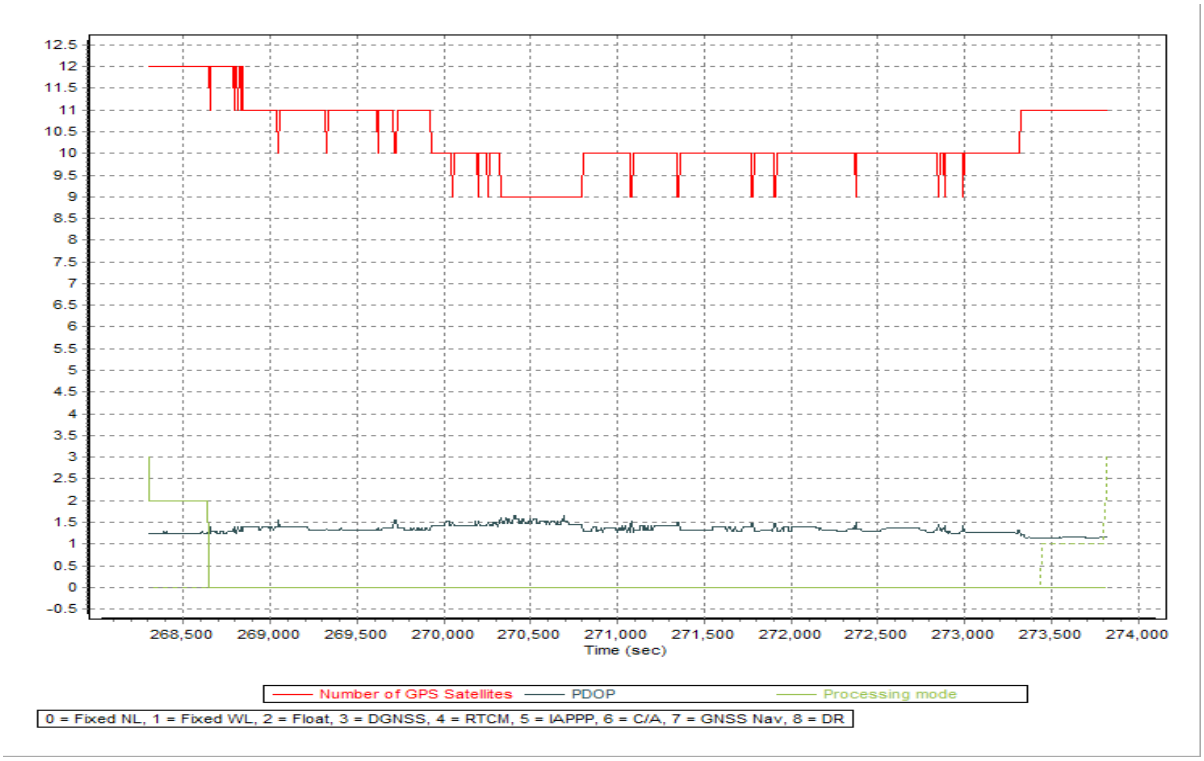


Figure A-8.1 Solution Status

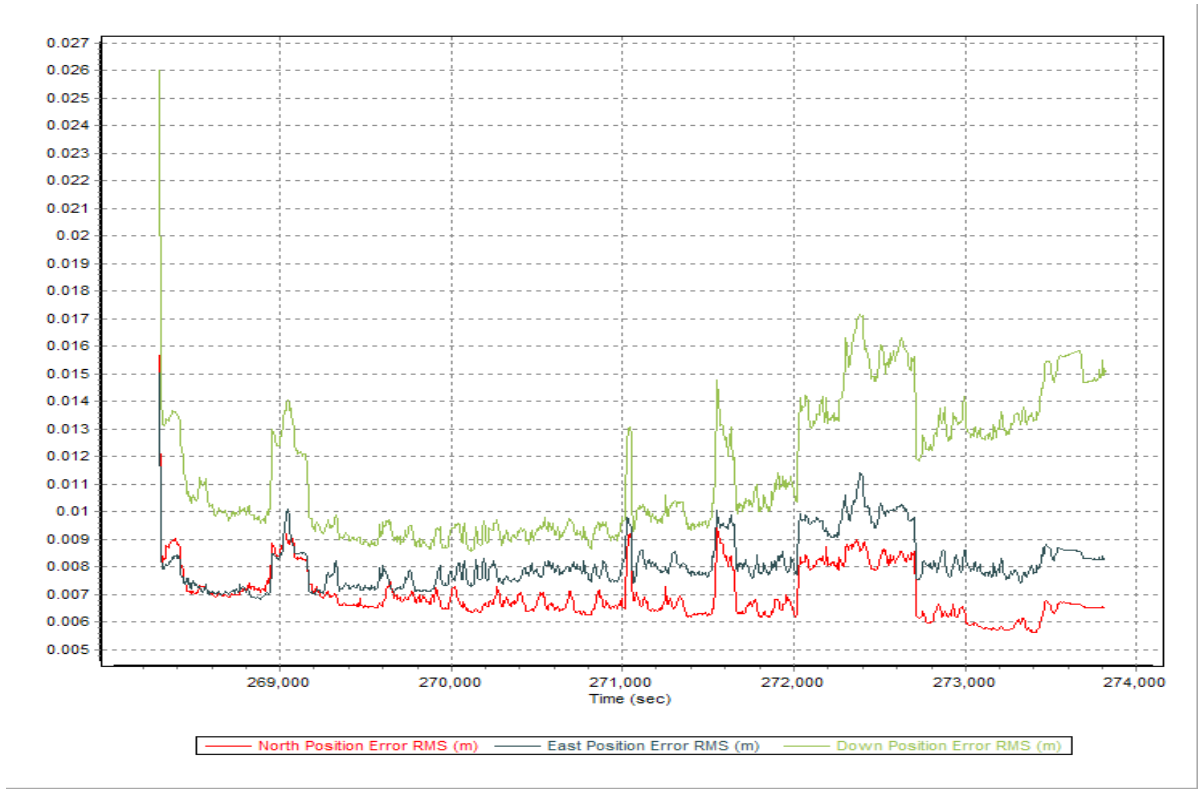


Figure A-8.2 Smoothed Performance Metric Parameters

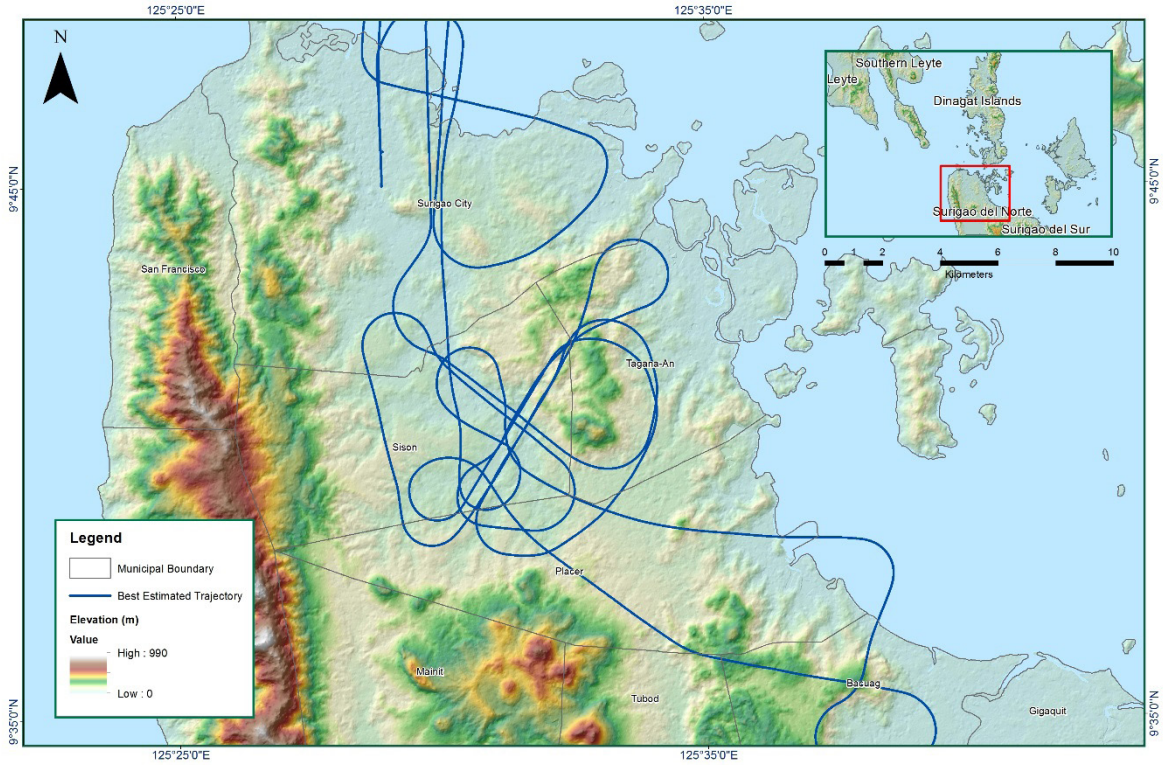


Figure A-8.3 Best Estimated Trajectory

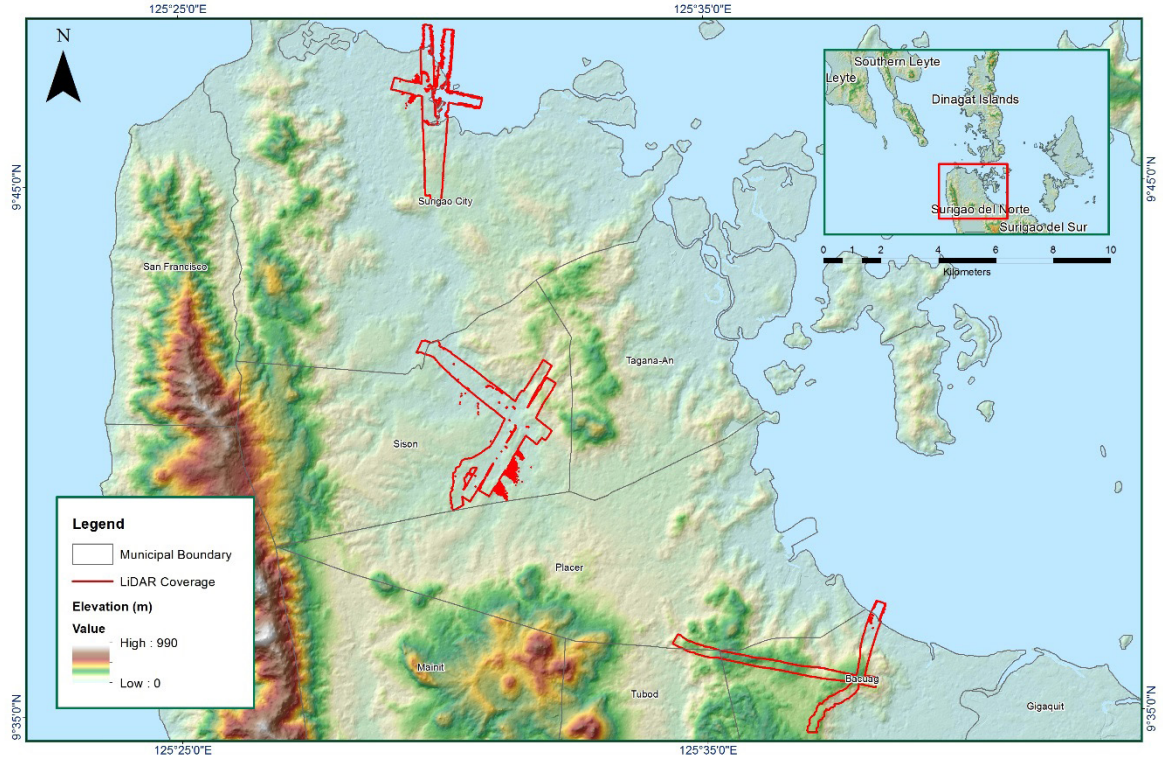


Figure A-8.4 Coverage of LiDAR data

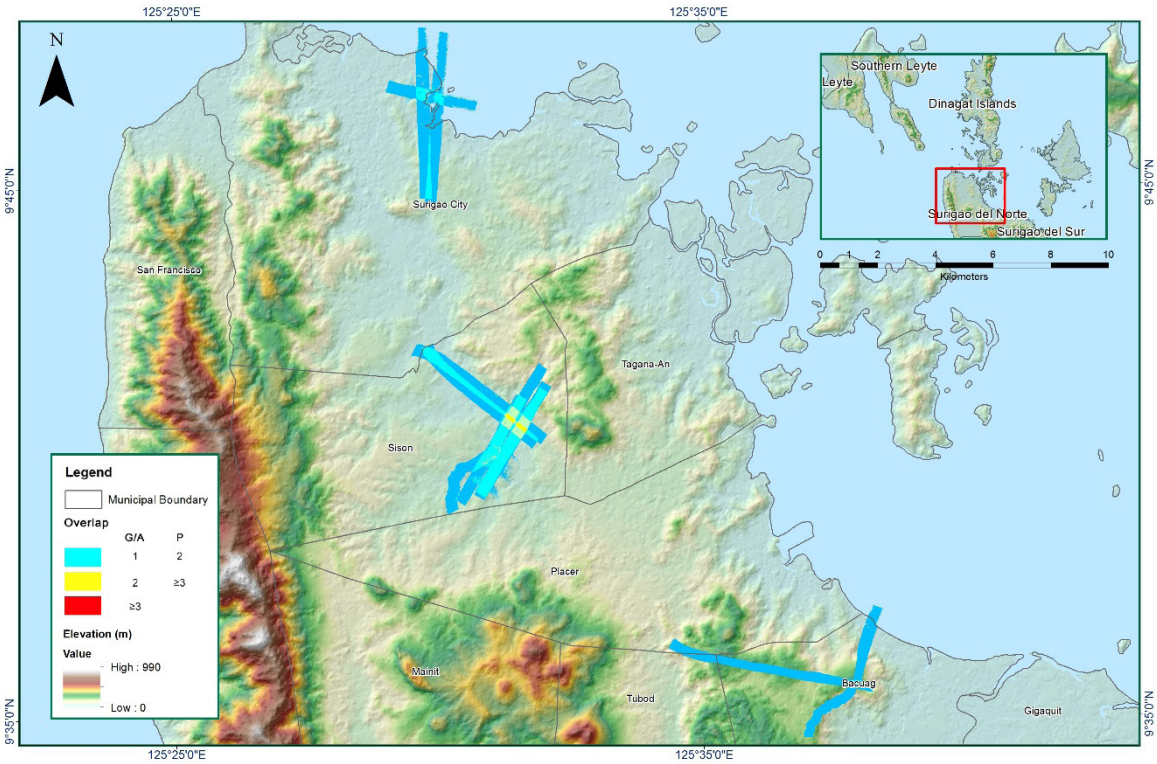


Figure A-8.5 Image of data overlap

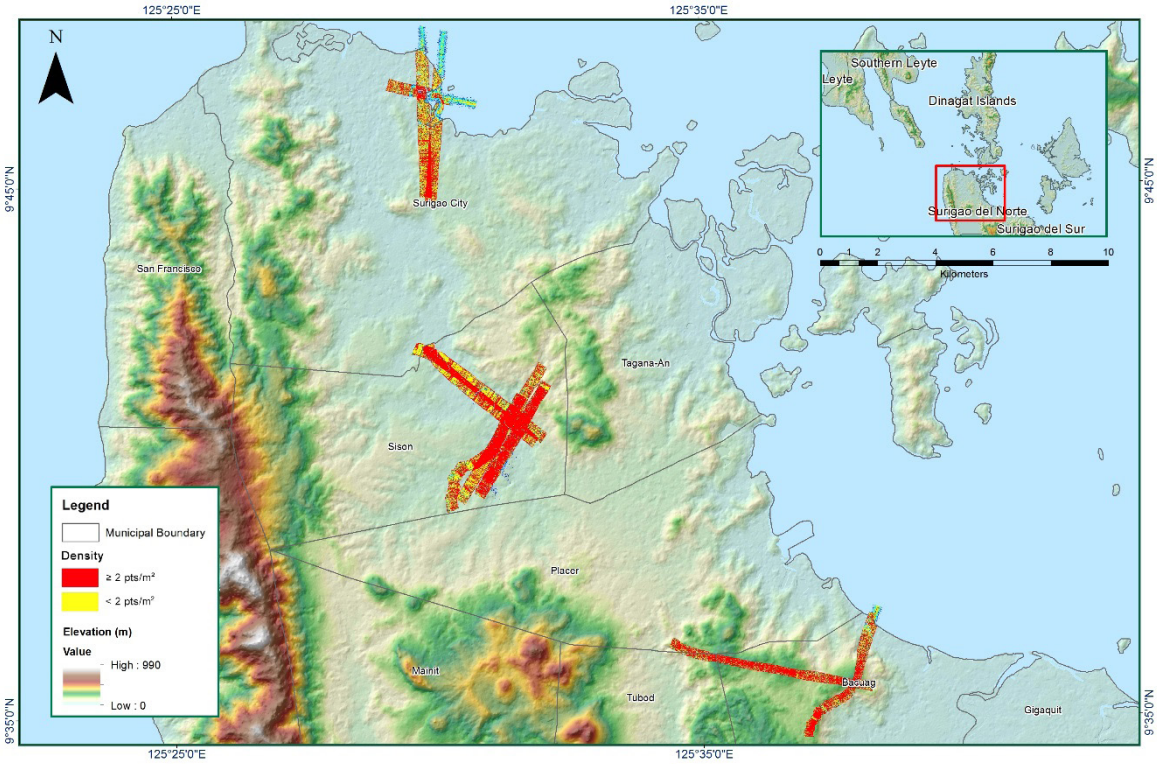


Figure A-8.6 Density map of merged LiDAR data

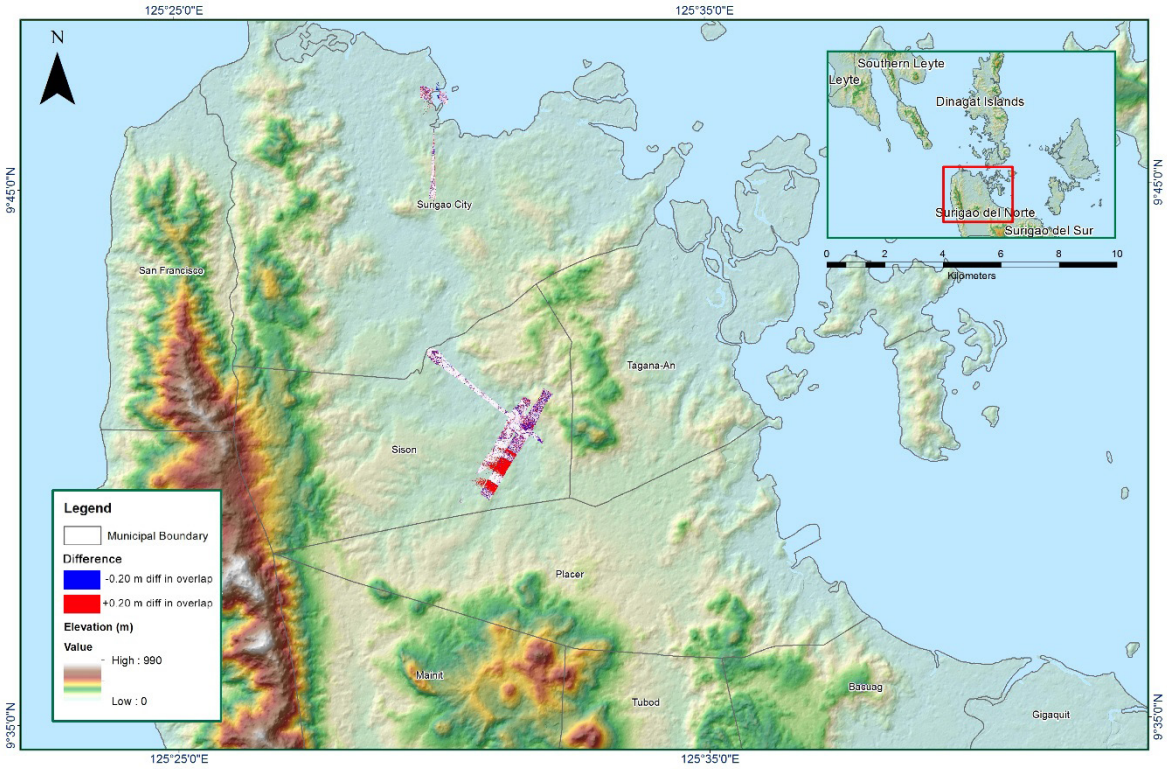


Figure A-8.7 Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Blk59D

Flight Area	Surigao Reflights
Mission Name	Block 59D
Inclusive Flights	8491AC
Range data size	7.13 GB
Base data size	190 MB
POS	91.6 MB
Image	37.6 GB
Transfer date	June 23, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.171
RMSE for East Position (<4.0 cm)	1.716
RMSE for Down Position (<8.0 cm)	2.678
Boresight correction stdev (<0.001deg)	0.000549
IMU attitude correction stdev (<0.001deg)	0.001578
GPS position stdev (<0.01m)	0.0031
Minimum % overlap (>25)	36.50
Ave point cloud density per sq.m. (>2.0)	4.98
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	47
Maximum Height	634.76 m
Minimum Height	129.84 m
Classification (# of points)	
Ground	18,464,024
Low vegetation	3,689,212
Medium vegetation	14,494,998
High vegetation	82,150,578
Building	1,644,409
Orthophoto	No

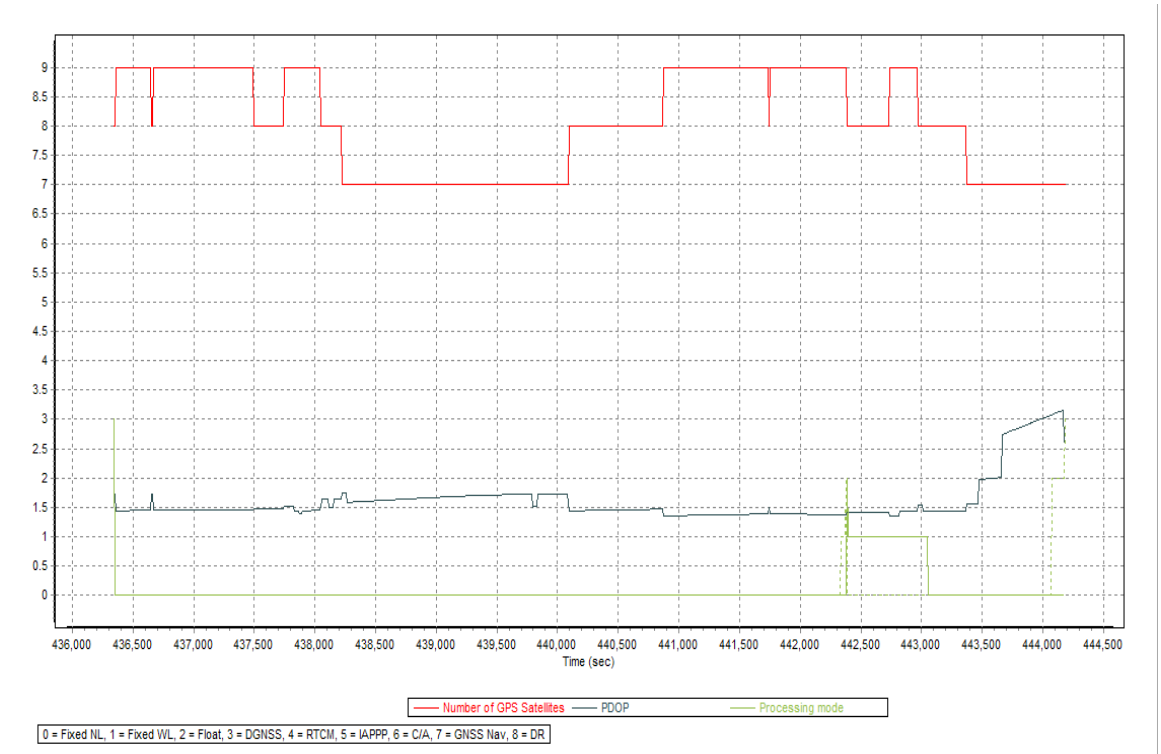


Figure A-8.8 Solution Status

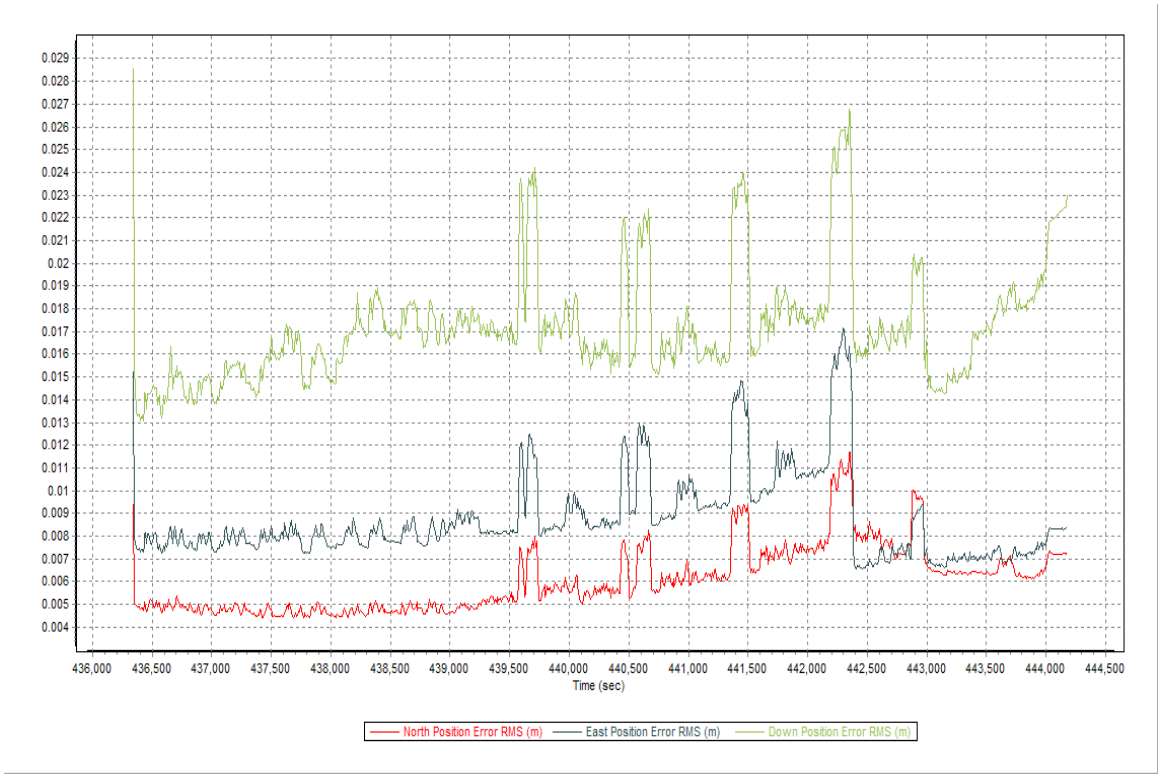


Figure A-8.9 Smoothed Performance Metric Parameters

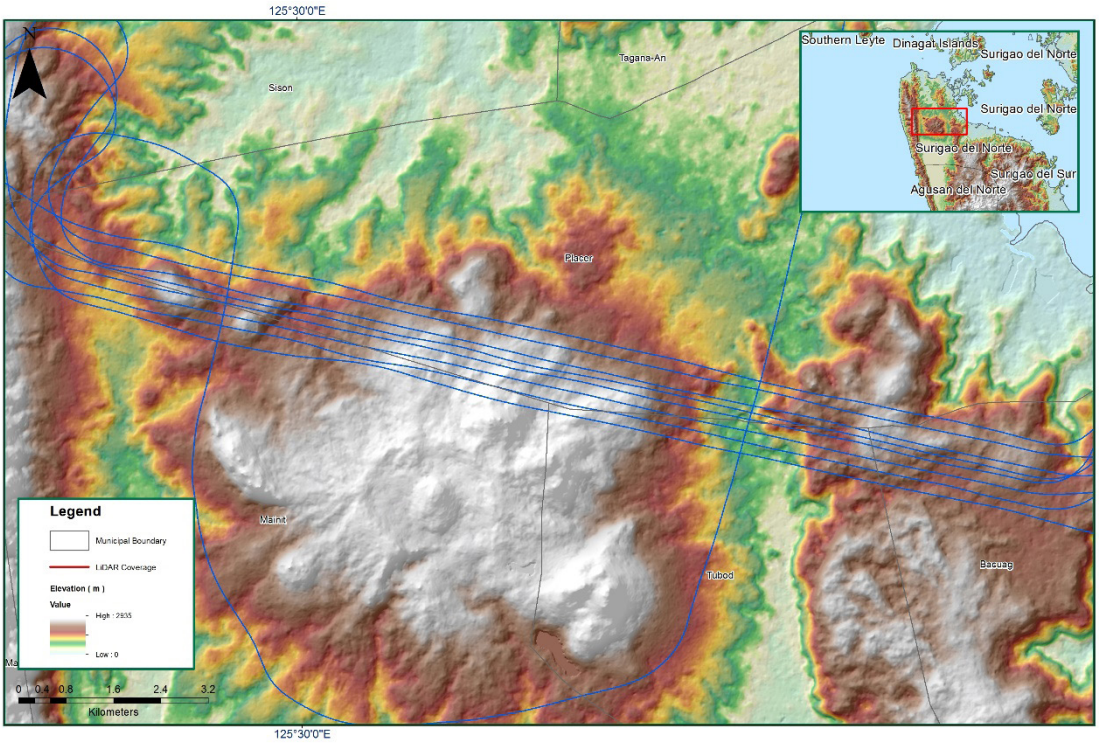


Figure A-8.10 Best Estimated Trajectory

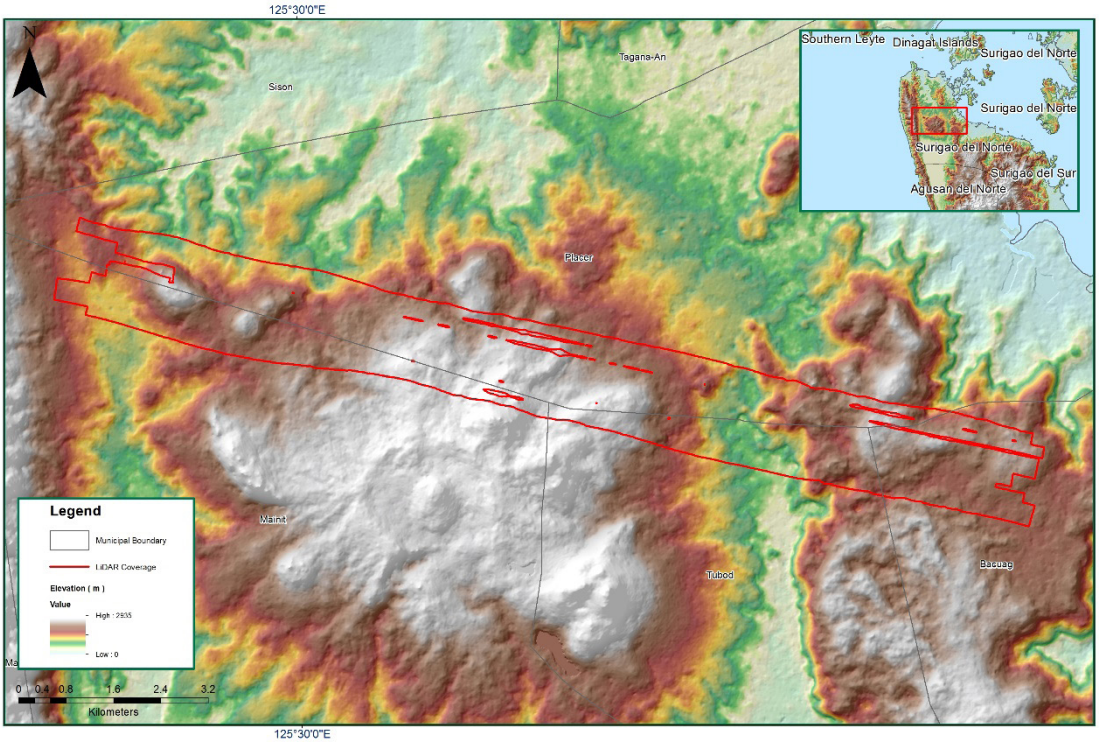


Figure A-8.11 Coverage of LiDAR data

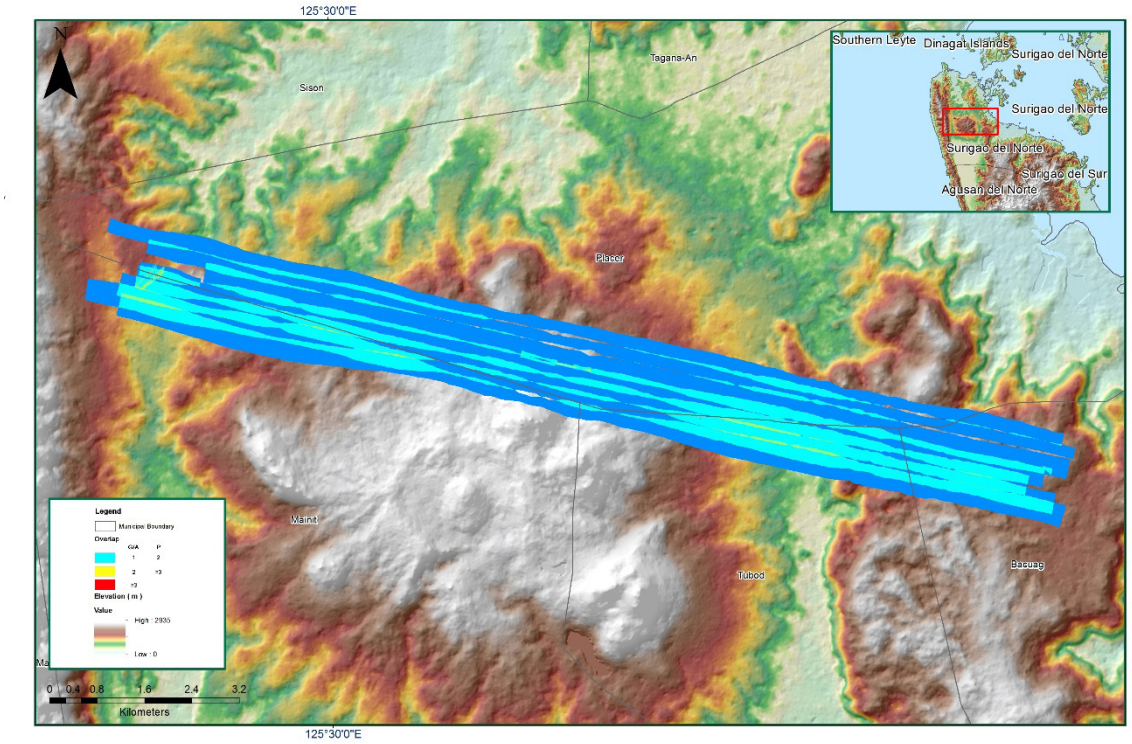


Figure A-8.12 Image of data overlap

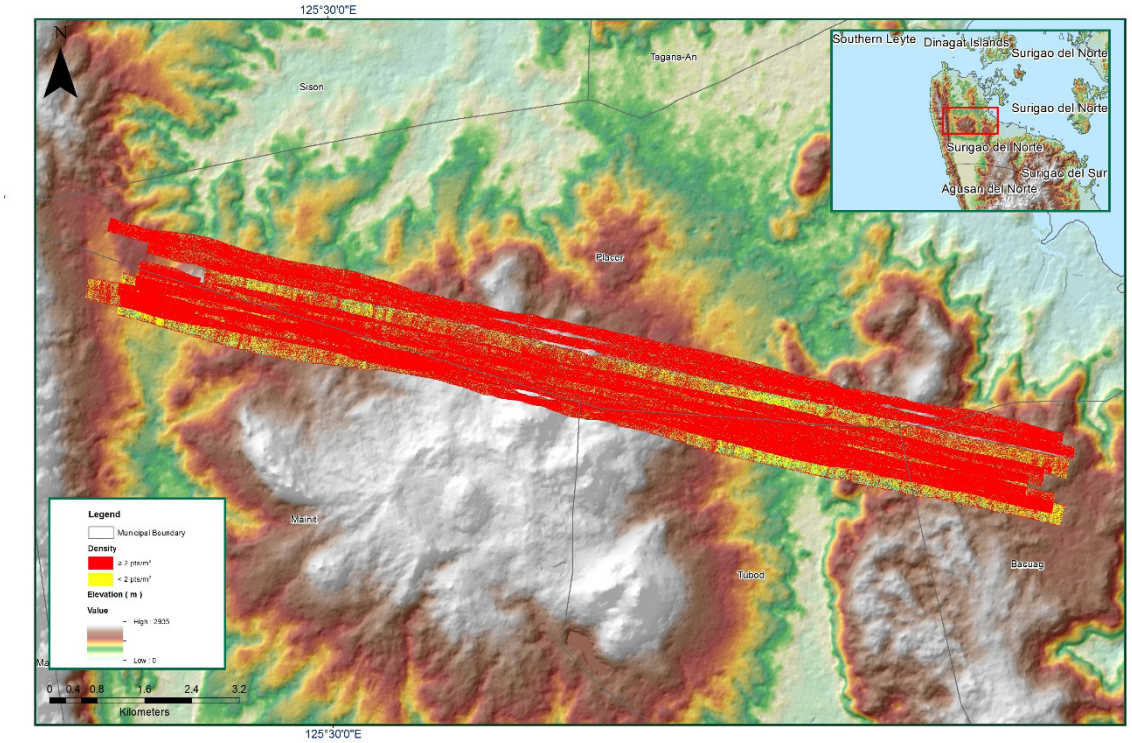


Figure A-8.13 Density map of merged LiDAR data

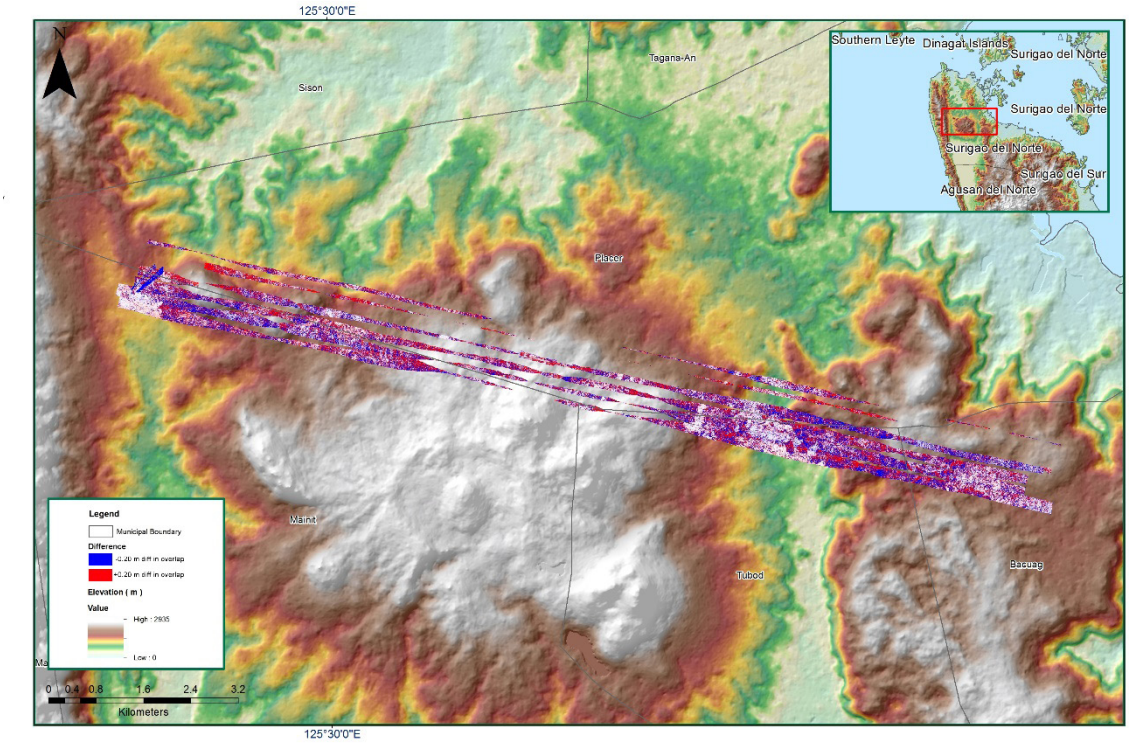


Figure A-8.14 Elevation difference between flight lines

Table A-8.3. Mission Summary Report for Mission Blk59E

Flight Area	Surigao Refilghts
Mission Name	Block 59E
Inclusive Flights	8481AC
Range data size	11.7 GB
Base data size	253 MB
POS	76.5 MB
Image	42.9 GB
Transfer date	June 23, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.104
RMSE for East Position (<4.0 cm)	1.494
RMSE for Down Position (<8.0 cm)	0.626
Boresight correction stdev (<0.001deg)	N/A
IMU attitude correction stdev (<0.001deg)	N/A
GPS position stdev (<0.01m)	N/A
Minimum % overlap (>25)	36.82
Ave point cloud density per sq.m. (>2.0)	3.95
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	96
Maximum Height	445.06 m
Minimum Height	69.68 m
Classification (# of points)	
Ground	49,264,873
Low vegetation	38,623,583
Medium vegetation	39,611,507
High vegetation	90,500,735
Building	4,519,852
Orthophoto	No

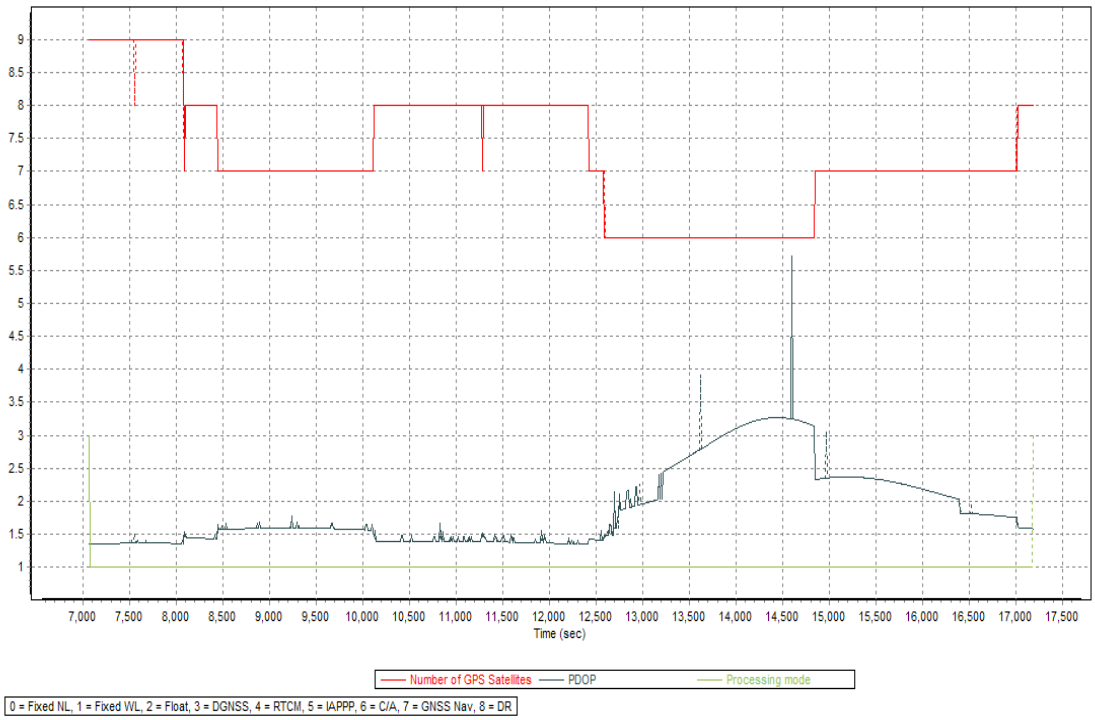


Figure A-8.15 Solution Status

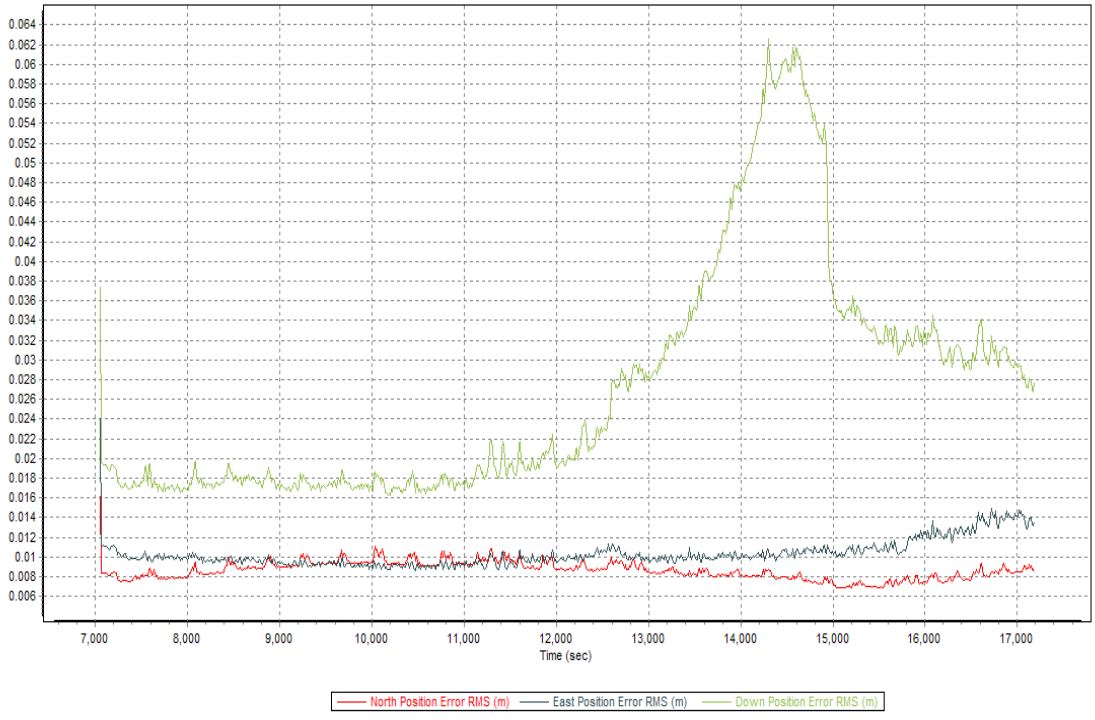


Figure A-8.16 Smoothed Performance Metric Parameters

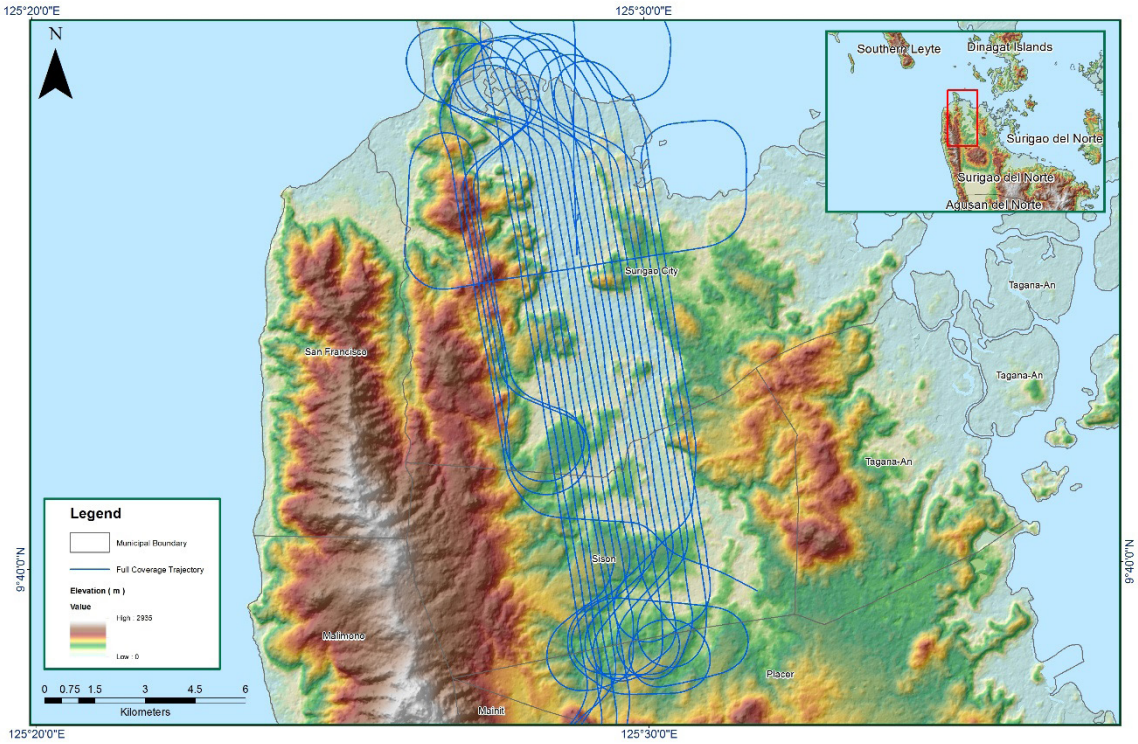


Figure A-8.17 Best Estimated Trajectory

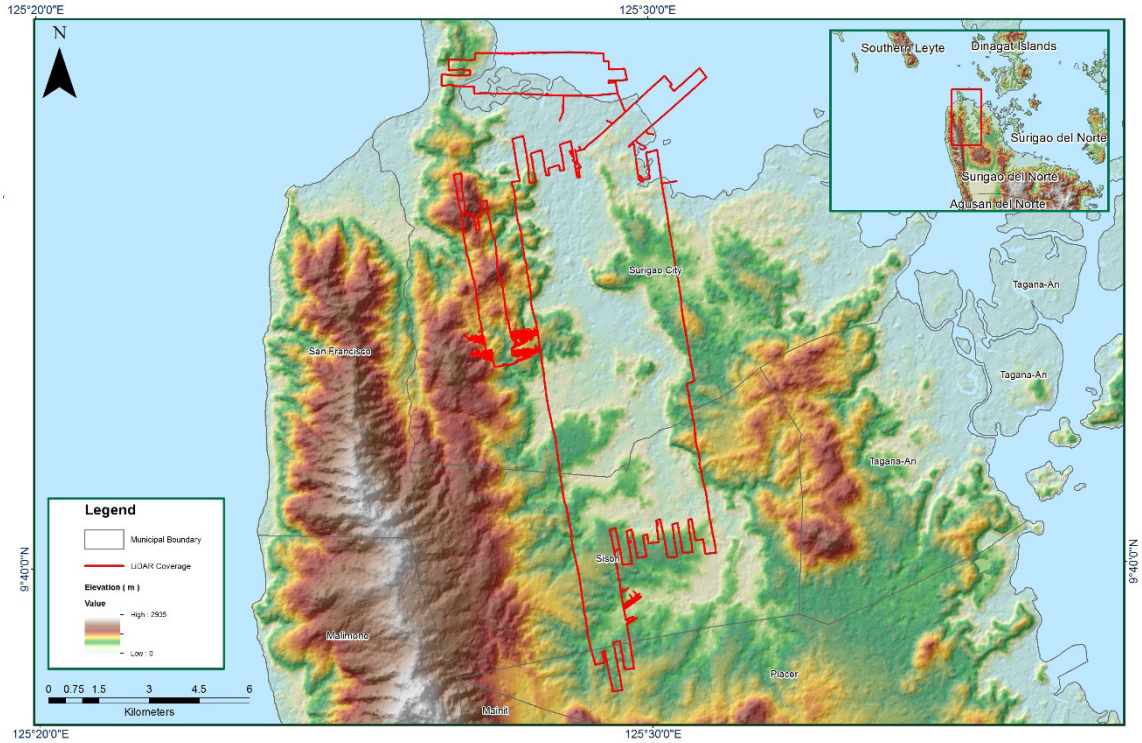


Figure A-8.18 Coverage of LiDAR data

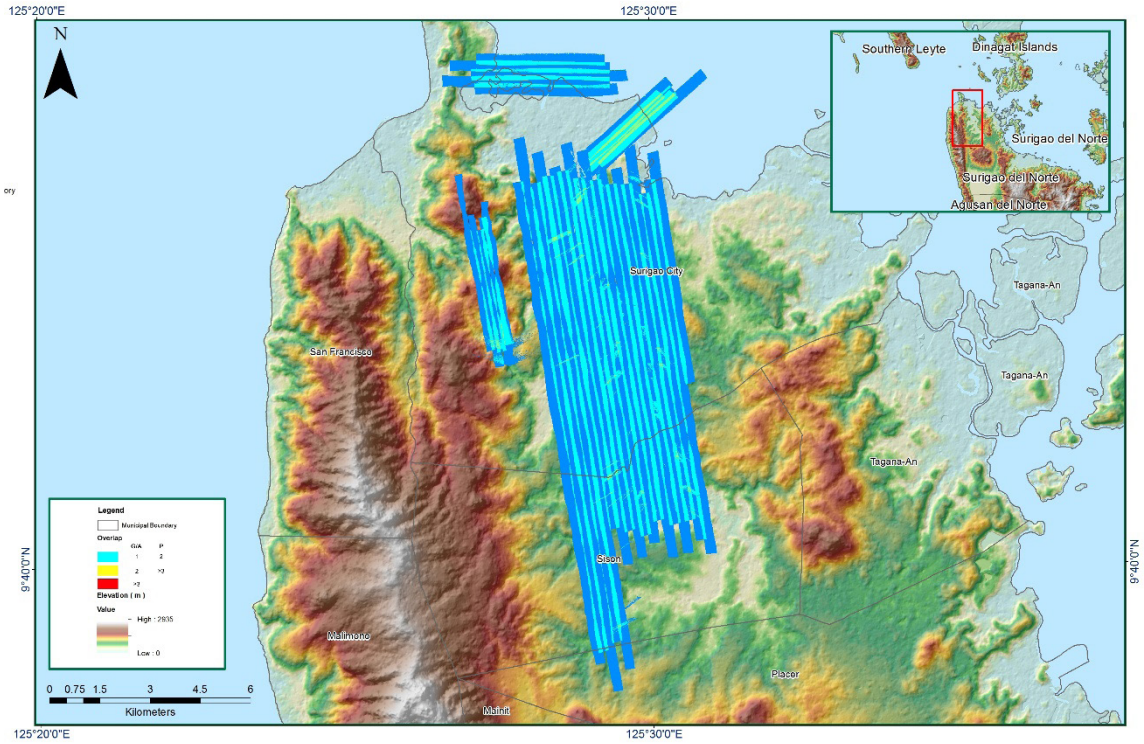


Figure A-8.19 Image of data overlap

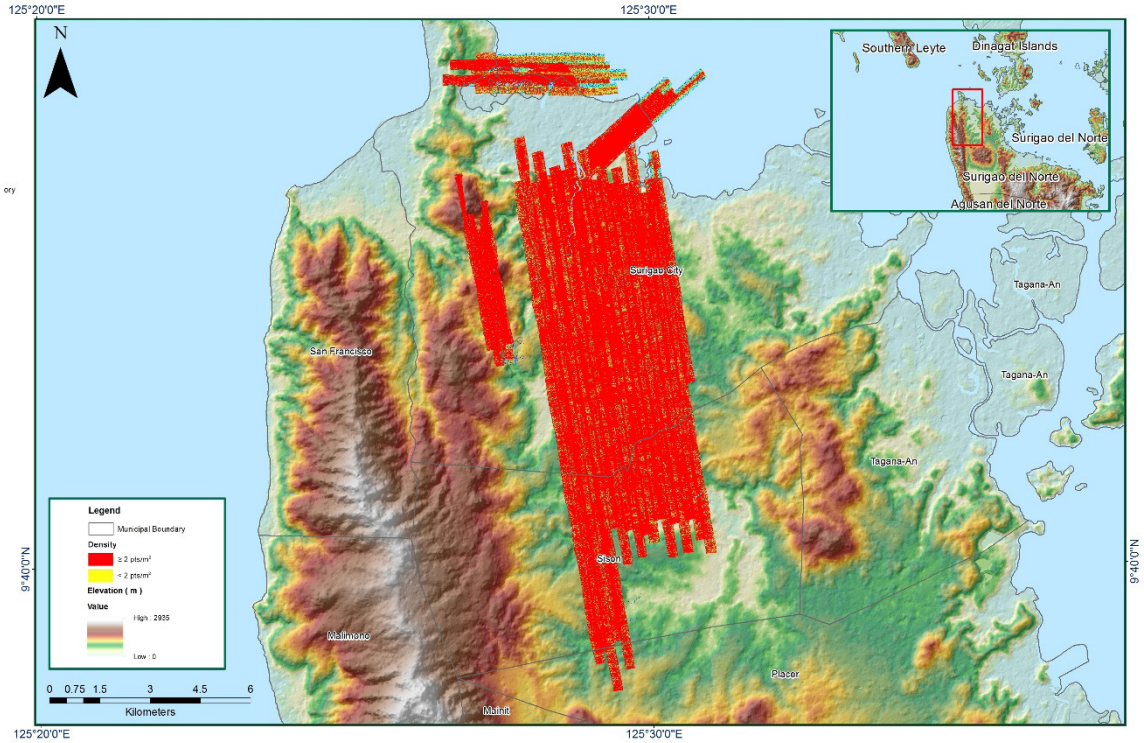


Figure A-8.20 Density map of merged LiDAR data

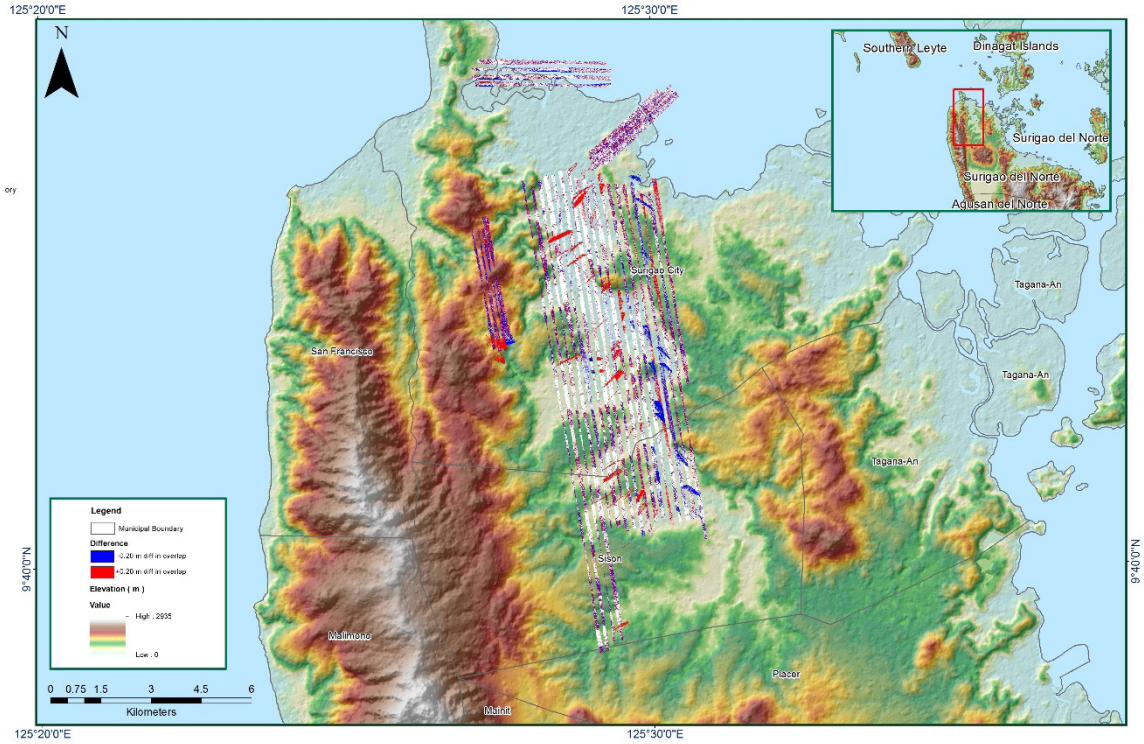


Figure A-8.21 Elevation difference between flight lines

Table A-8.4. Mission Summary Report for Mission Blk59E_supplement

Flight Area	Surigao Reflights
Mission Name	Block 59E_supplement
Inclusive Flights	8491AC
Range data size	7.13 GB
Base data size	190 MB
POS	91.6 MB
Image	37.6 GB
Transfer date	June 23, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	3.97
RMSE for East Position (<4.0 cm)	5.04
RMSE for Down Position (<8.0 cm)	6.44
Boresight correction stdev (<0.001deg)	0.000549
IMU attitude correction stdev (<0.001deg)	0.001578
GPS position stdev (<0.01m)	0.0031
Minimum % overlap (>25)	41.54
Ave point cloud density per sq.m. (>2.0)	3.15
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	23
Maximum Height	59.32 m
Minimum Height	198.04 m
Classification (# of points)	
Ground	5,094,893
Low vegetation	4,668,230
Medium vegetation	5,179,248
High vegetation	3,470,232
Building	3,048,257
Orthophoto	Yes

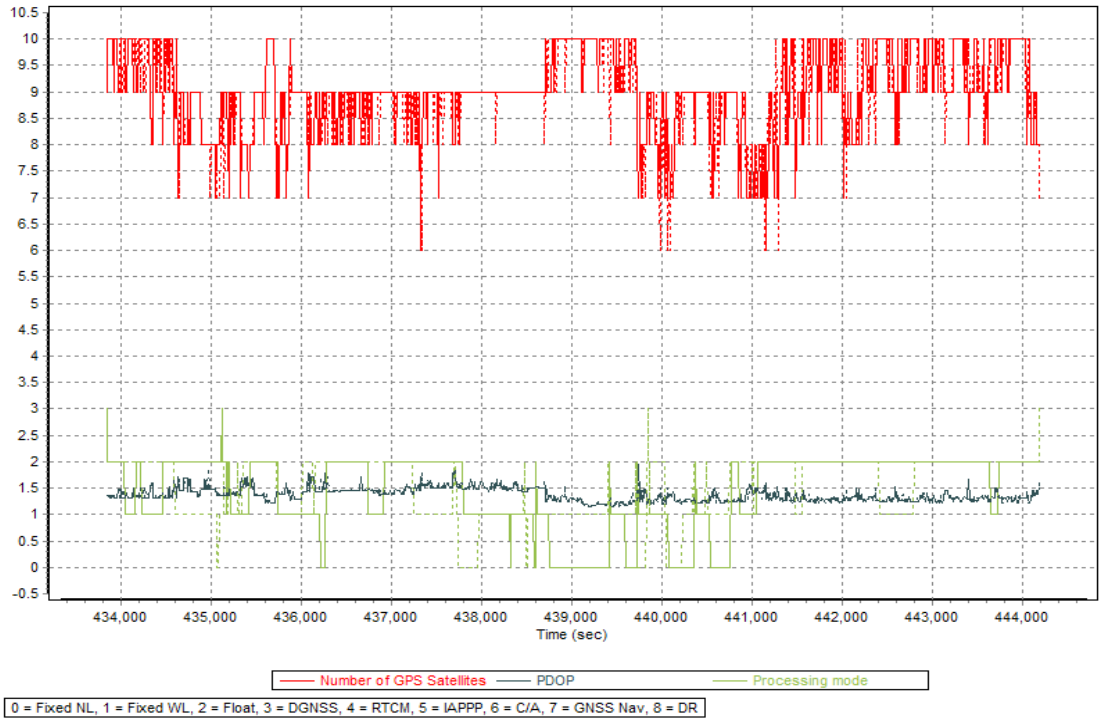


Figure A-8.22 Solution Status

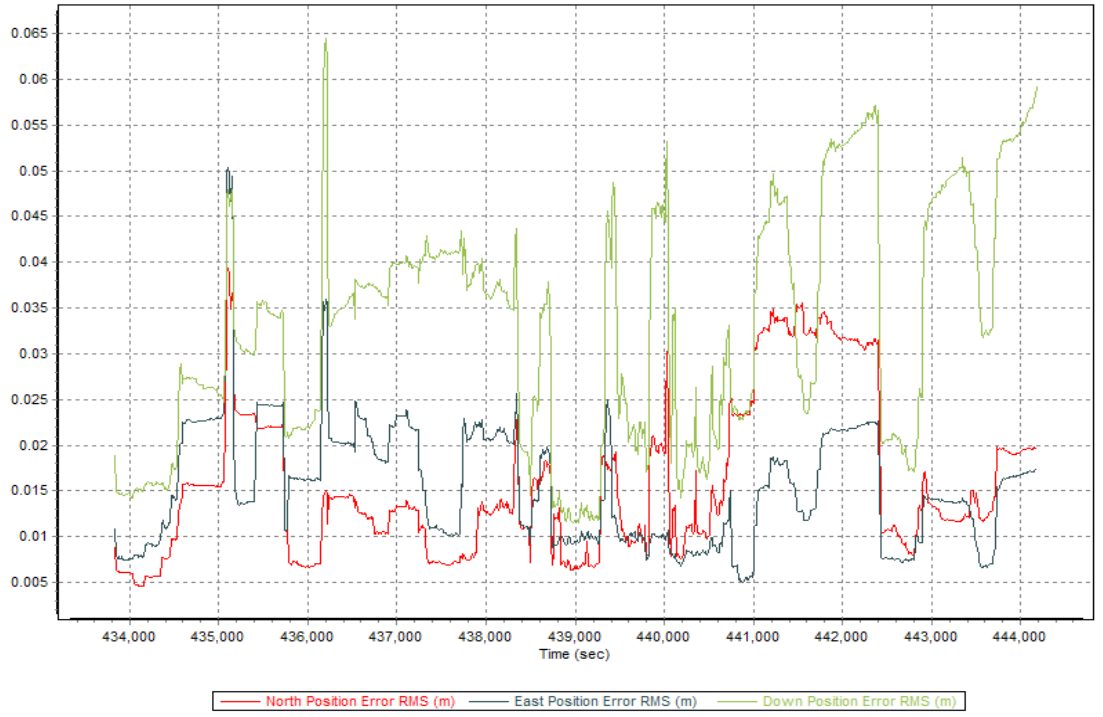


Figure A-8.23 Smoothed Performance Metric Parameters

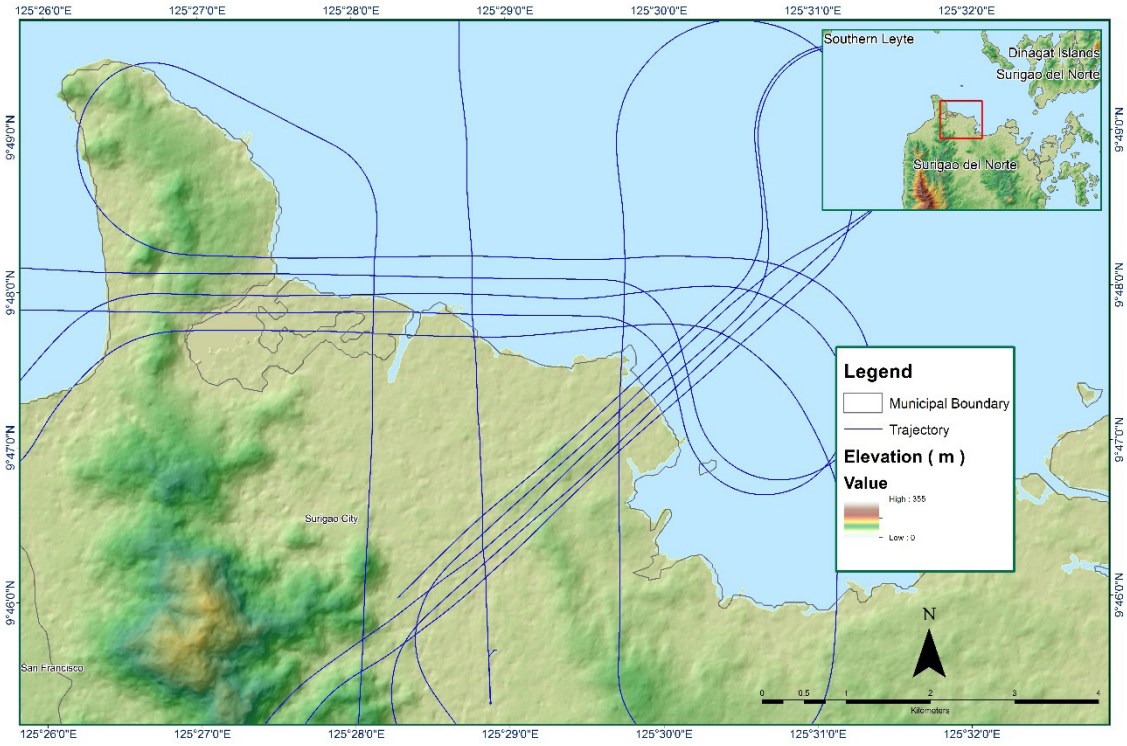


Figure A-8.24 Best Estimated Trajectory

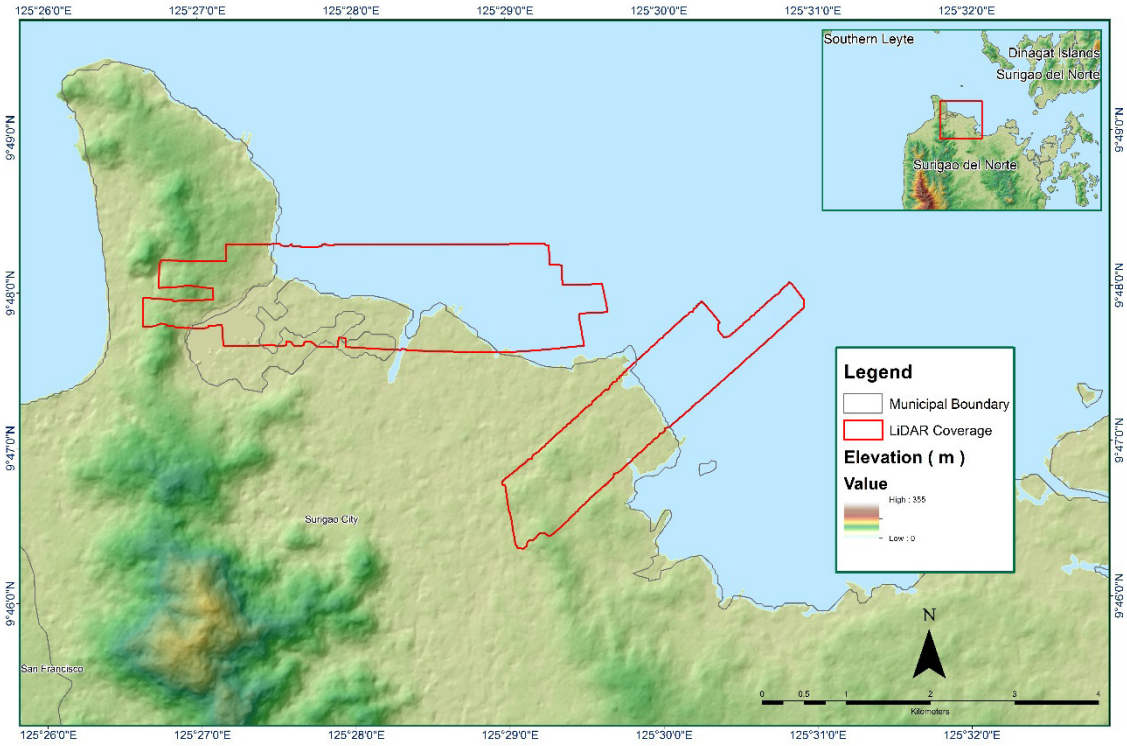


Figure A-8.25 Coverage of LiDAR data

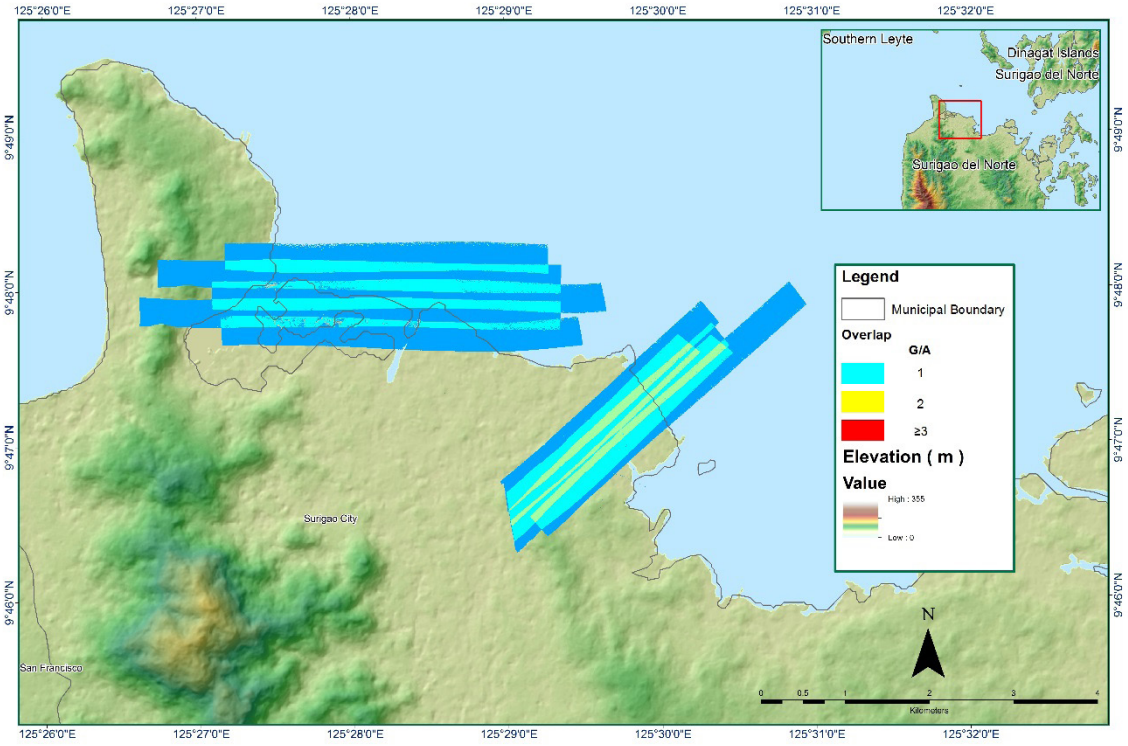


Figure A-8.26 Image of data overlap

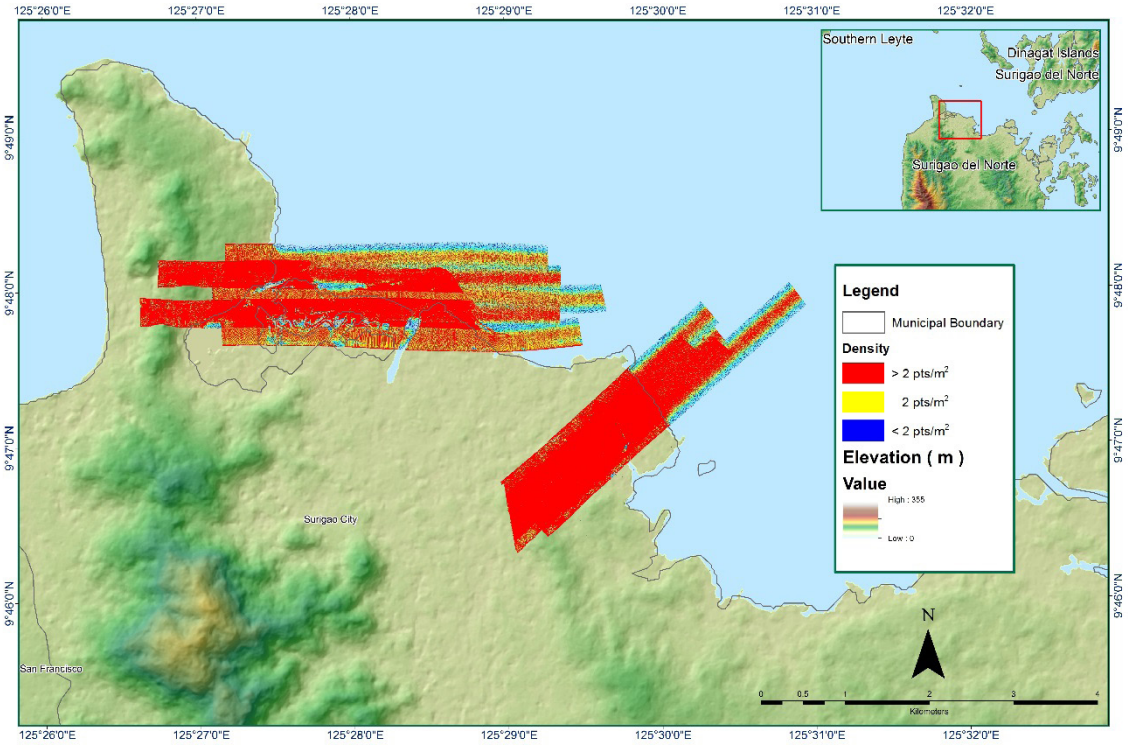


Figure A-8.27 Density map of merged LiDAR data

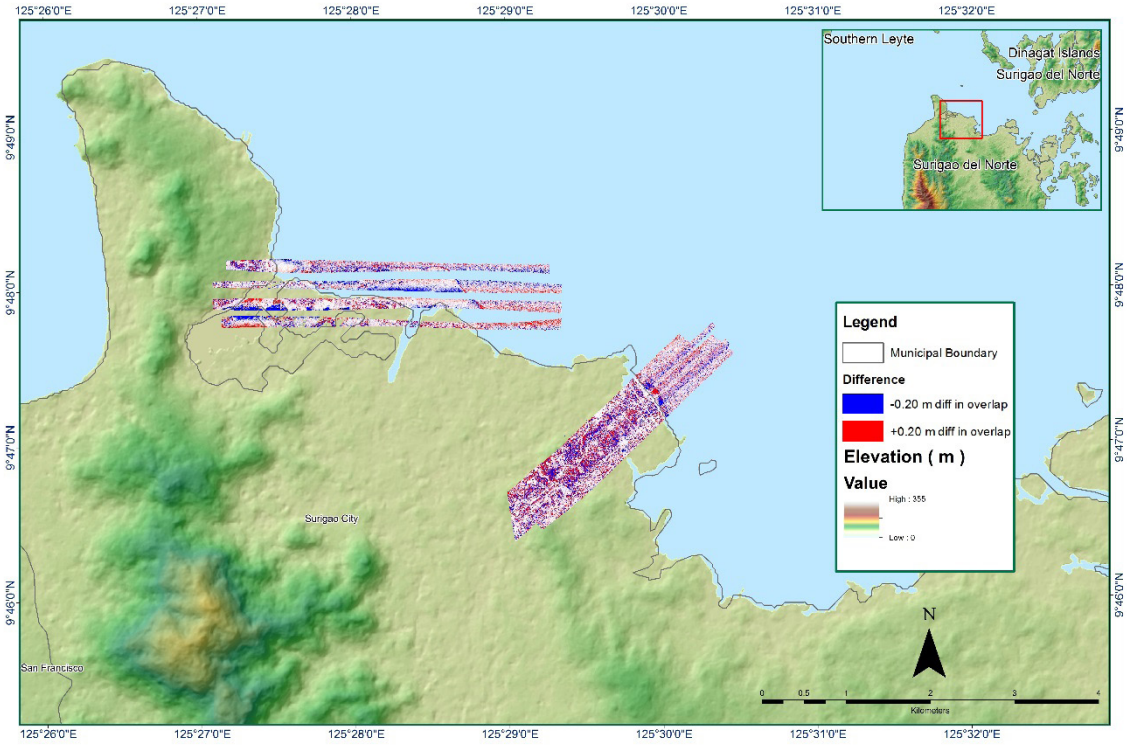


Figure A-8.28 Elevation difference between flight lines

Table A-8.5. Mission Summary Report for Mission Blk60D

Flight Area	Surigao Reflights
Mission Name	Block60D
Inclusive Flights	8485AC
Range data size	10.6 GB
Base data size	231 MB
POS	74.9 MB
Image	39.8 GB
Transfer date	June 23, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.184
RMSE for East Position (<4.0 cm)	1.387
RMSE for Down Position (<8.0 cm)	4.314
Boresight correction stdev (<0.001deg)	0.000865
IMU attitude correction stdev (<0.001deg)	0.001788
GPS position stdev (<0.01m)	0.0087
Minimum % overlap (>25)	29.98
Ave point cloud density per sq.m. (>2.0)	4.37
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	130
Maximum Height	488.63 m
Minimum Height	62.35 m
Classification (# of points)	
Ground	31,021,122
Low vegetation	28,360,664
Medium vegetation	49,944,879
High vegetation	145,523,337
Building	5,143,740
Ortophoto	No

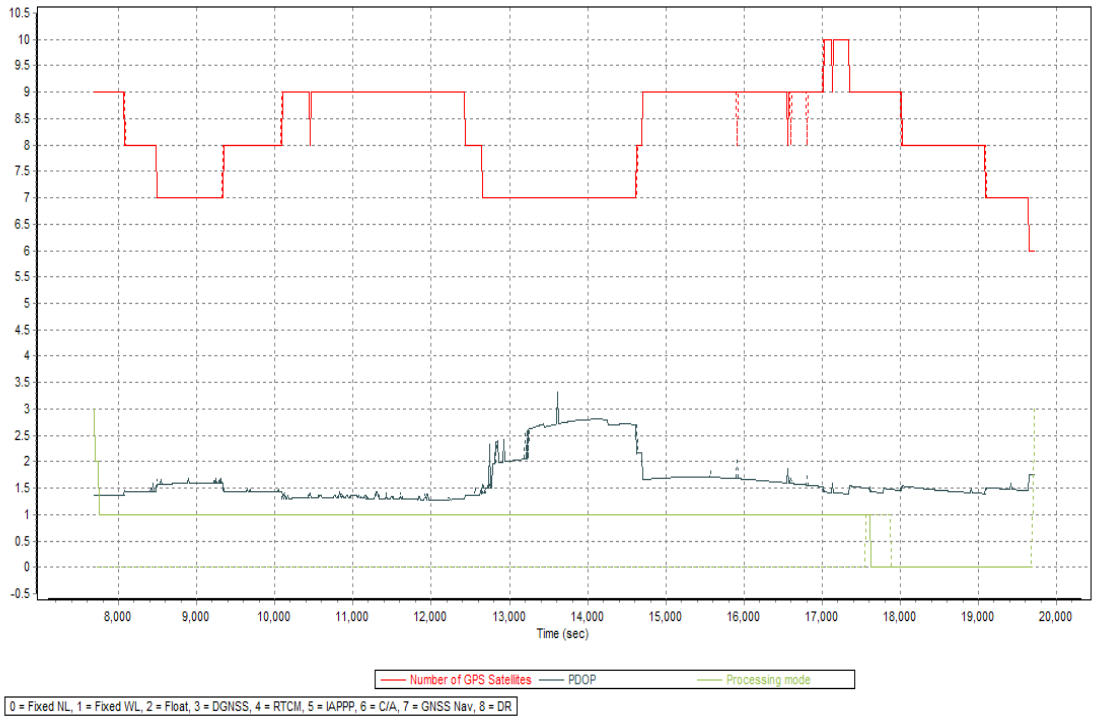


Figure A-8.29 Solution Status

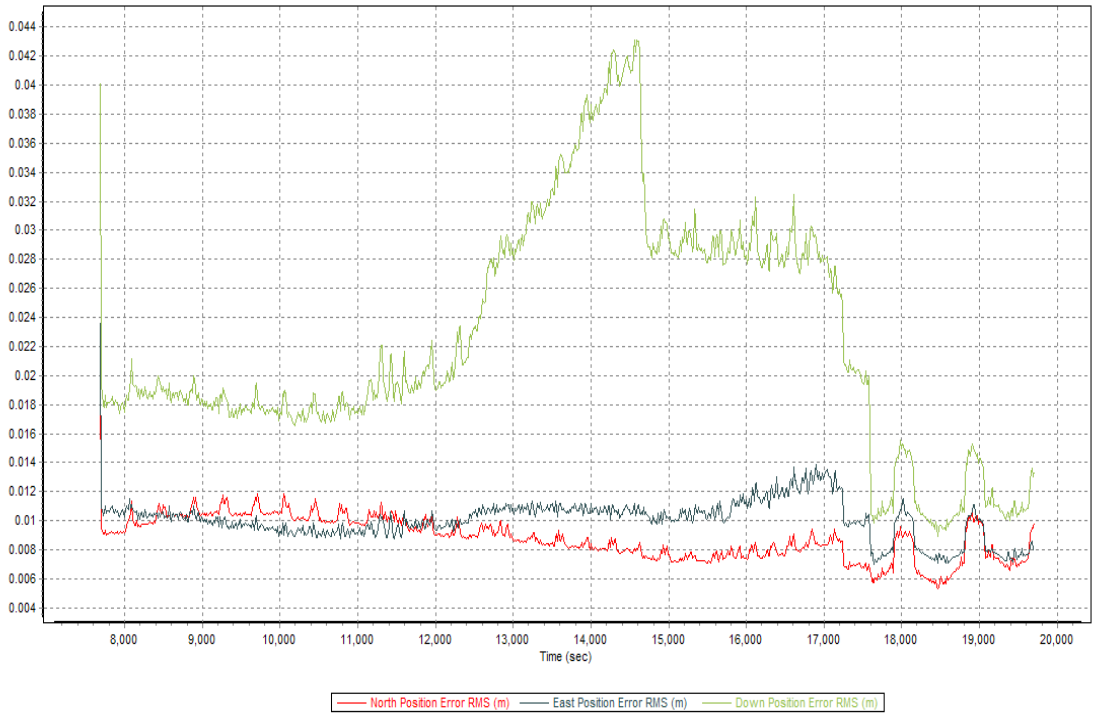


Figure A-8.30 Smoothed Performance Metric Parameters

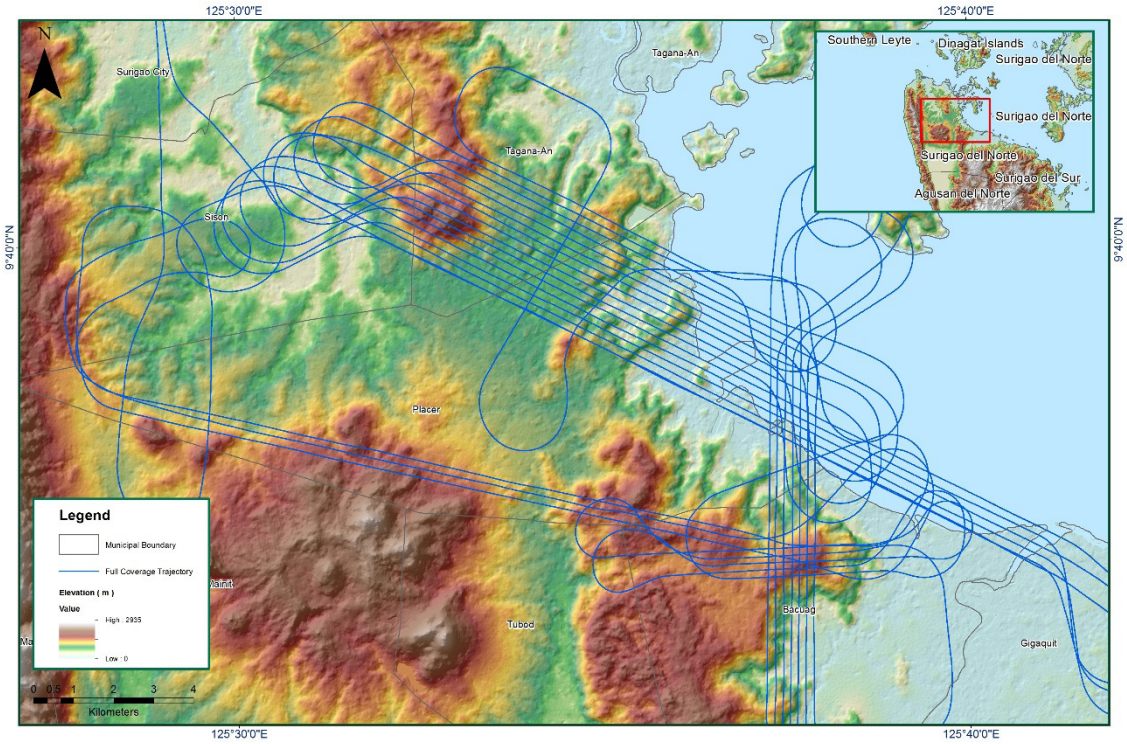


Figure A-8.31 Best Estimated Trajectory

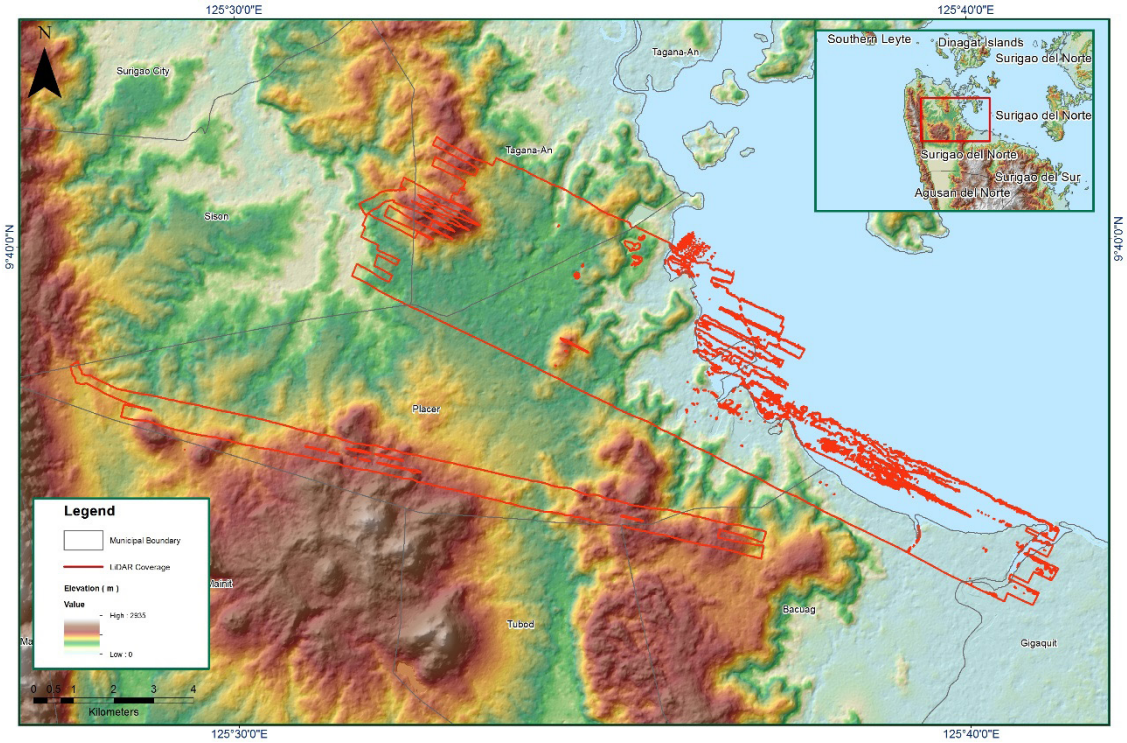


Figure A-8.32 Coverage of LiDAR data

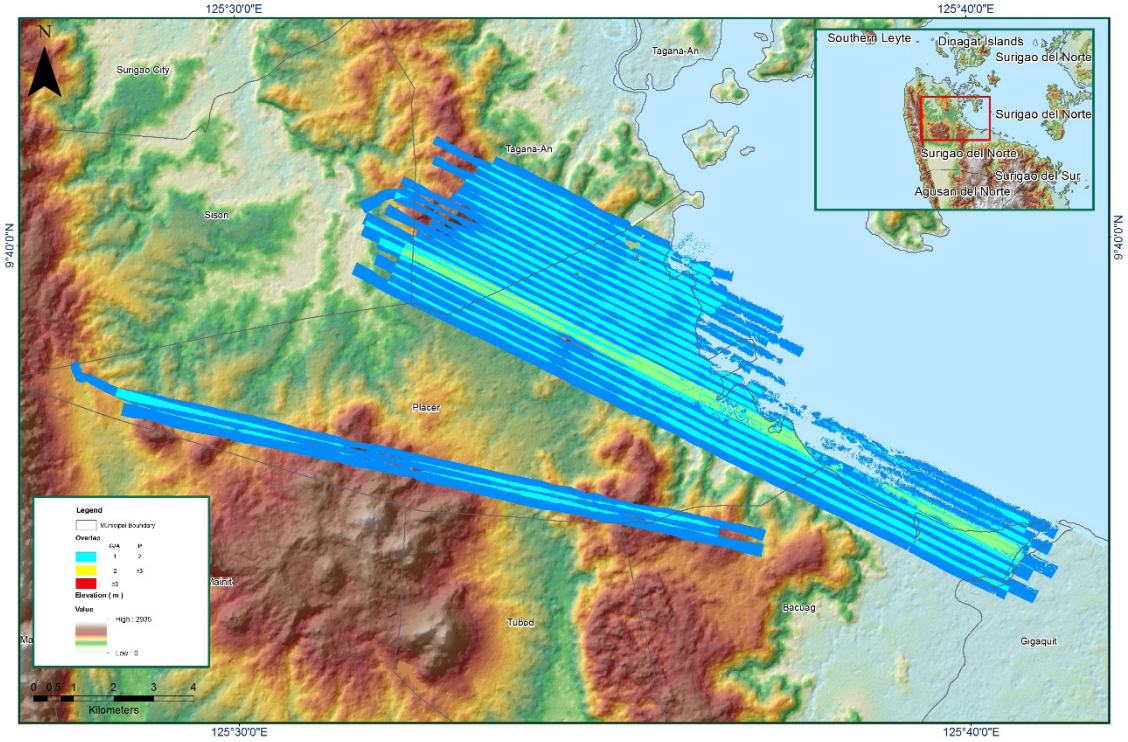


Figure A-8.33 Image of data overlap

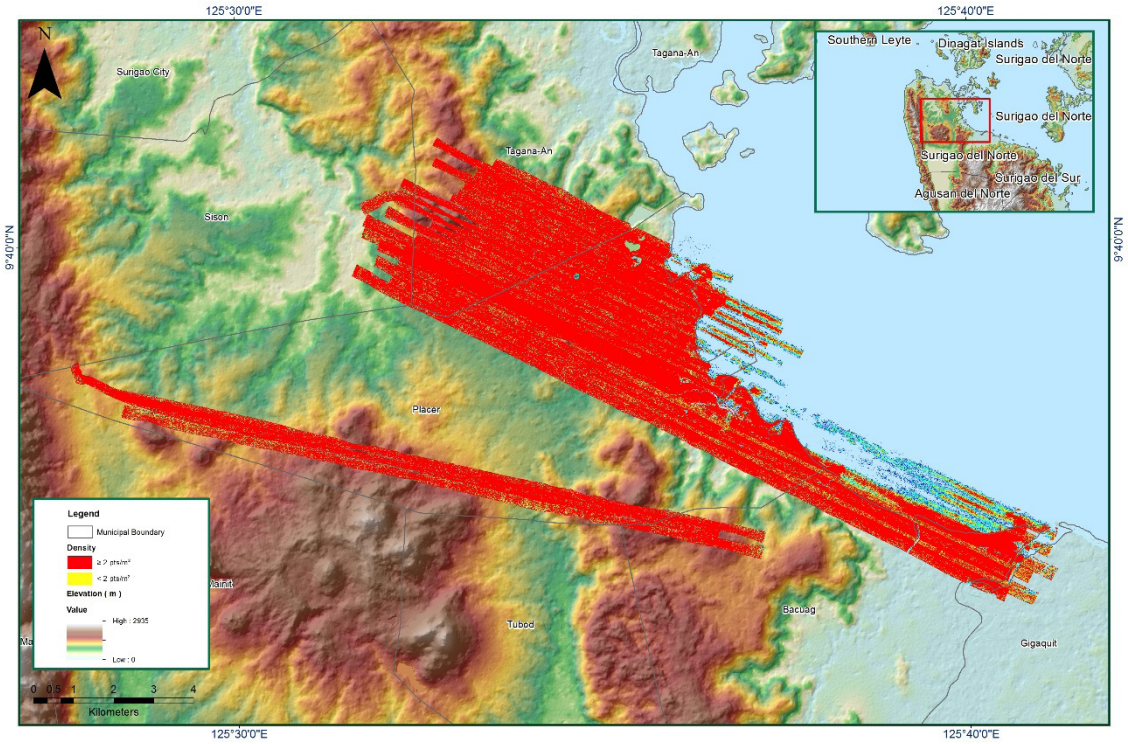


Figure A-8.34 Density Map of merged LiDAR data

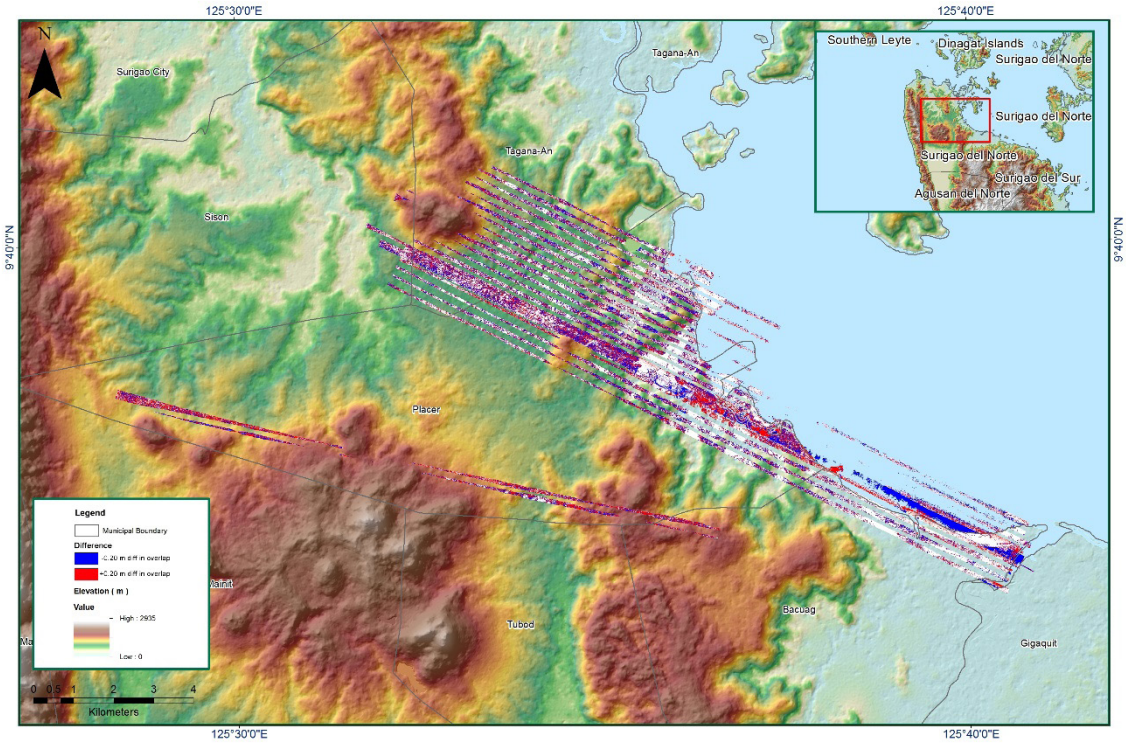


Figure A-8.35 Elevation Difference Between flight lines

Table A-8.6. Mission Summary Report for Mission Blk59E Extension

Flight Area	Surigao City
Mission Name	Block59E Extension (Surigao del Norte)
Inclusive Flights	7297GC
Range data size	5.10 GB
POS	99.90 MB
Image	N/A
Transfer date	June 20, 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)	1.35
RMSE for East Position (<4.0 cm)	1.60
RMSE for Down Position (<8.0 cm)	2.00
Boresight correction stdev (<0.001deg)	0.000918
IMU attitude correction stdev (<0.001deg)	0.006393
GPS position stdev (<0.01m)	0.0197
Minimum % overlap (>25)	24.55%
Ave point cloud density per sq.m. (>2.0)	2.29
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	86
Maximum Height	506.39 m
Minimum Height	64.34 m
Classification (# of points)	
Ground	12,907,328
Low vegetation	12,100,037
Medium vegetation	19,316,964
High vegetation	46,151,428
Building	811,299
Ortophoto	No

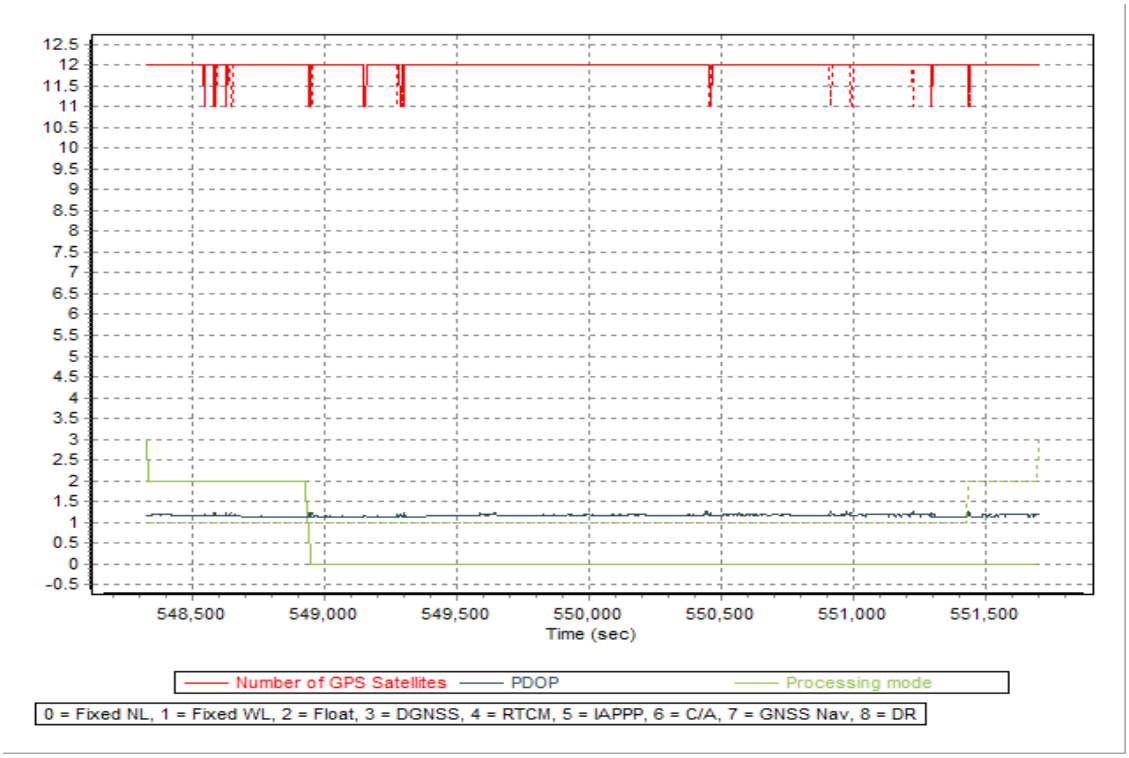


Figure A-8.36 Solution Status

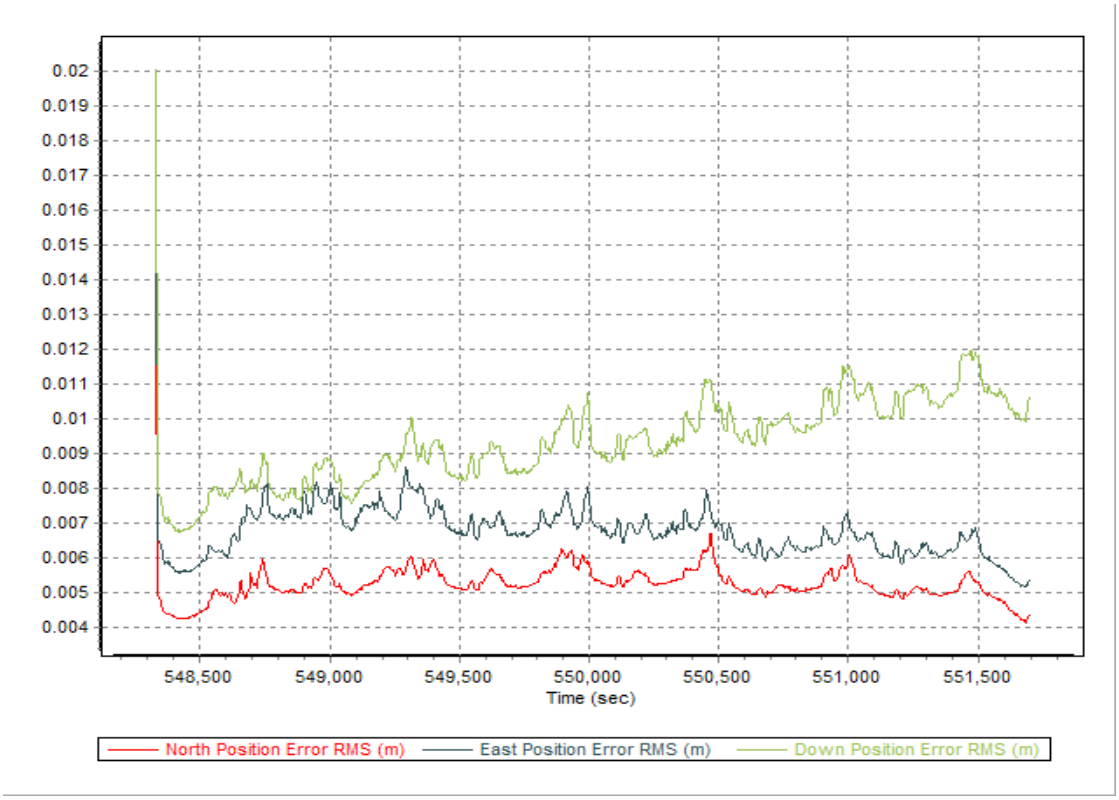


Figure A-8.37 Smoothed Performance Metric Parameters

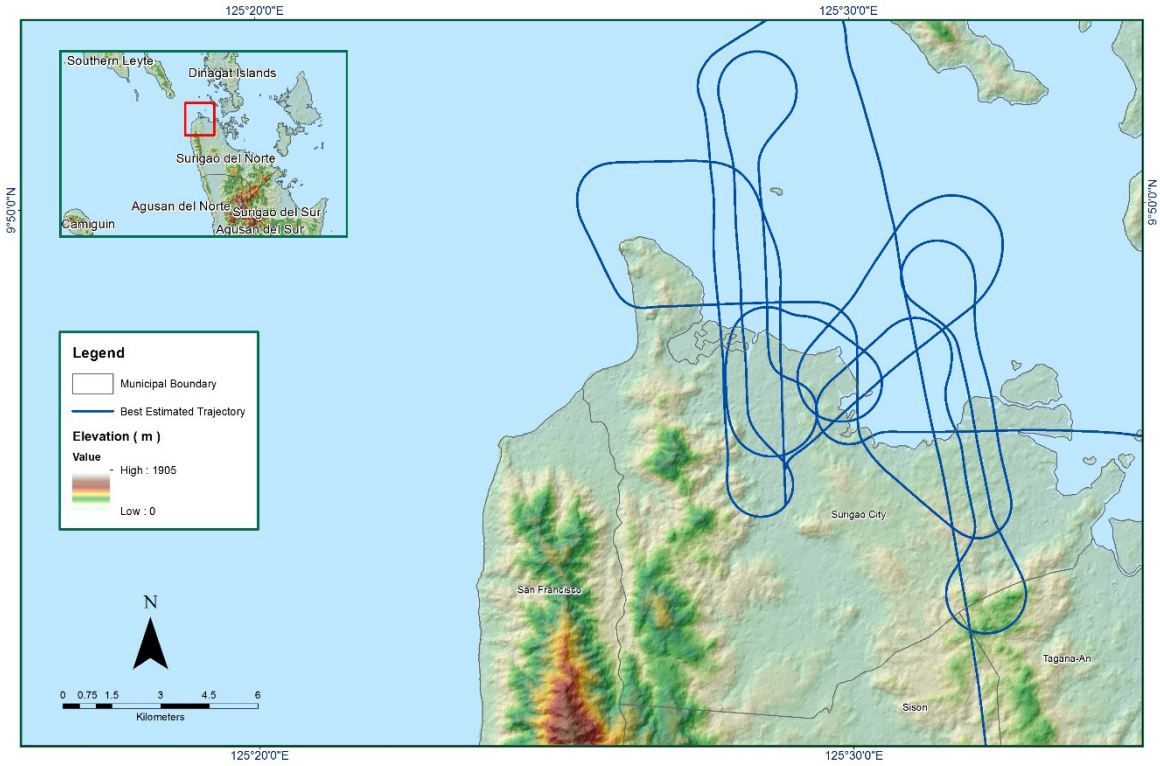


Figure A-8.38 Best Estimated Trajectory

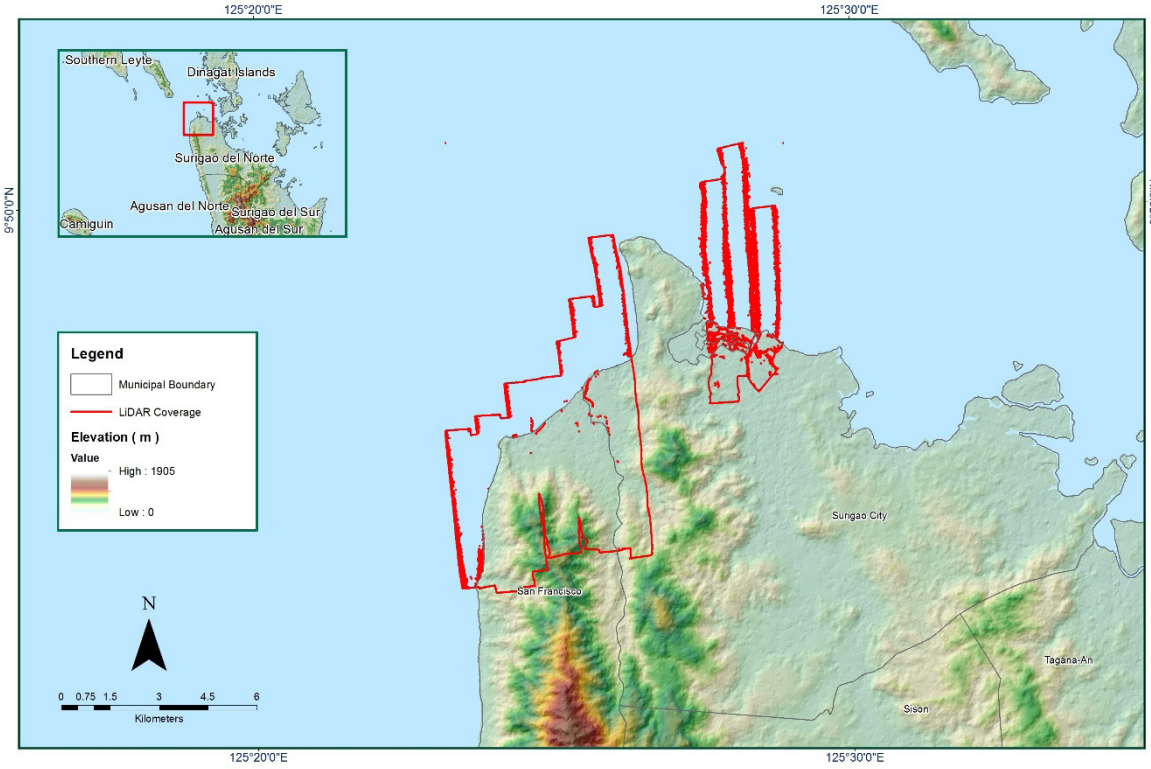


Figure A-8.39 Coverage of LiDAR data

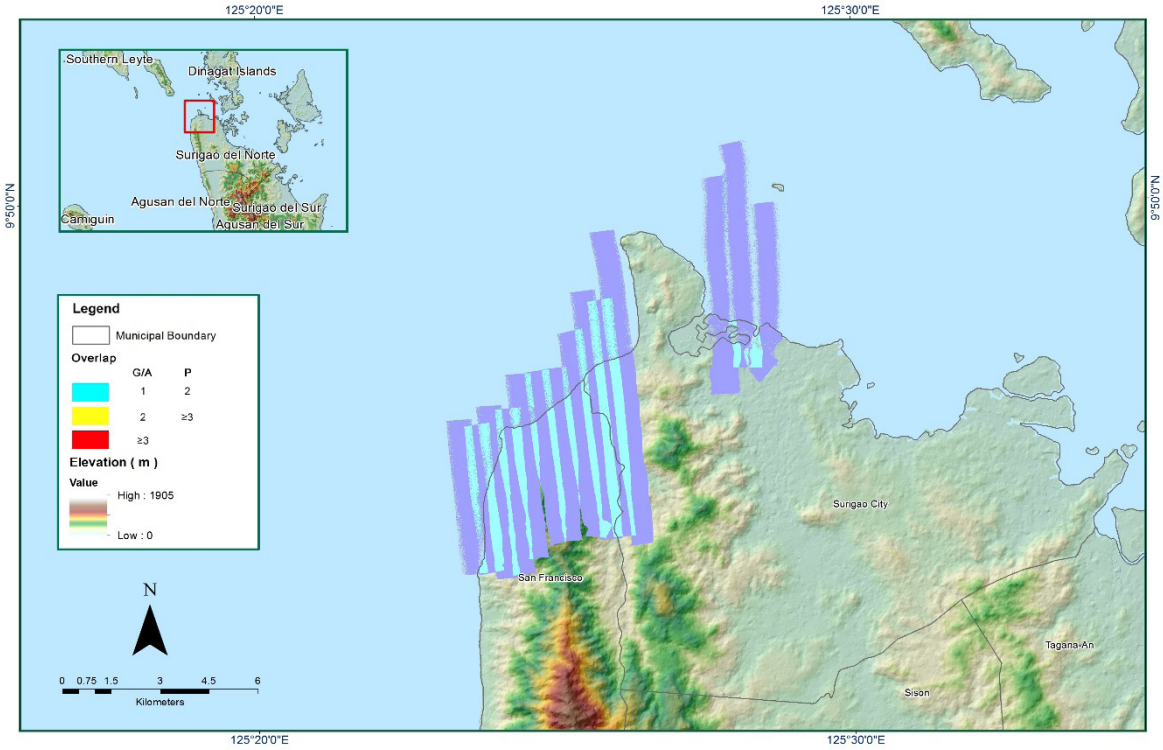


Figure A-8.40 Image of data overlap

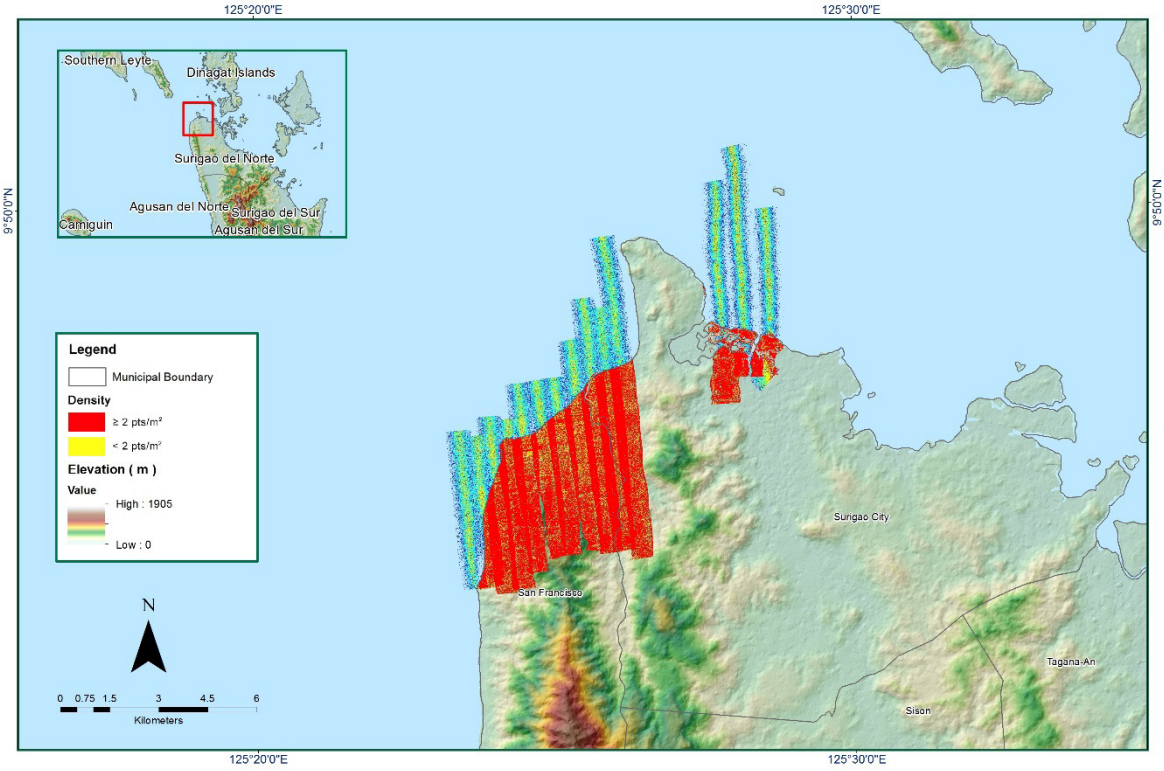


Figure A-8.41 Density Map of merged LiDAR data

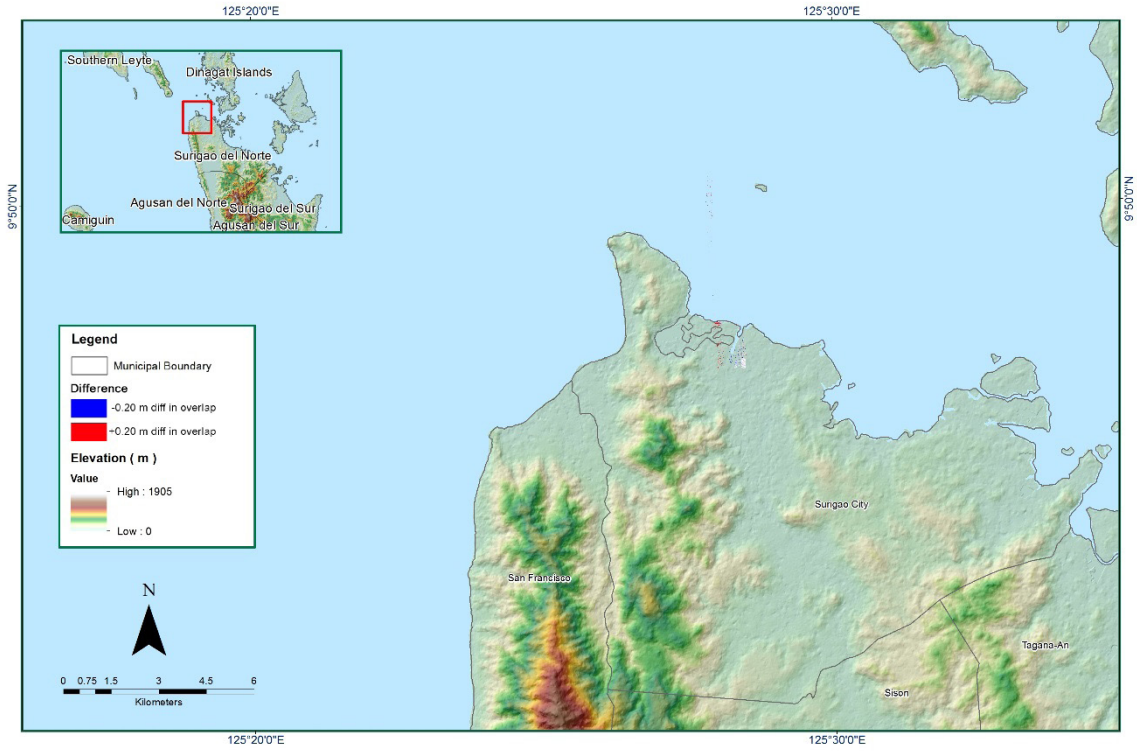


Figure A-8.42 Elevation Difference Between flight lines

Table A-8.7. Mission Summary Report for Mission Blk59E

Flight Area	Surigao City
Mission Name	Block59E (Surigao del Norte)
Inclusive Flights	7282GC
Range data size	20.3 GB
POS	245 MB
Image	N/A
Transfer date	June 16, 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)	1.55
RMSE for East Position (<4.0 cm)	1.45
RMSE for Down Position (<8.0 cm)	2.90
Boresight correction stdev (<0.001deg)	0.000364
IMU attitude correction stdev (<0.001deg)	0.001015
GPS position stdev (<0.01m)	0.0090
Minimum % overlap (>25)	28.75%
Ave point cloud density per sq.m. (>2.0)	3.30
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	158
Maximum Height	605.88 m
Minimum Height	66.08 m
Classification (# of points)	
Ground	30,245,503
Low vegetation	21,922,117
Medium vegetation	44,703,172
High vegetation	207,060,326
Building	7,854,568
Ortophoto	No

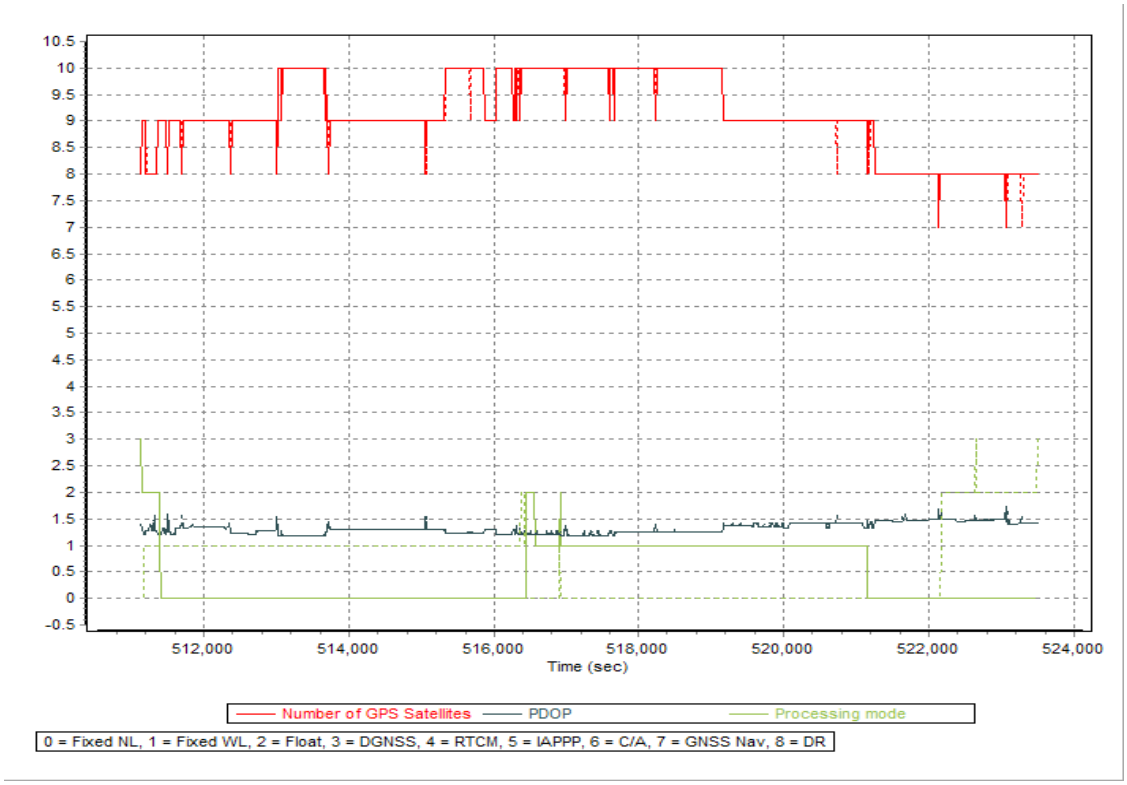


Figure A-8.43 Solution Status

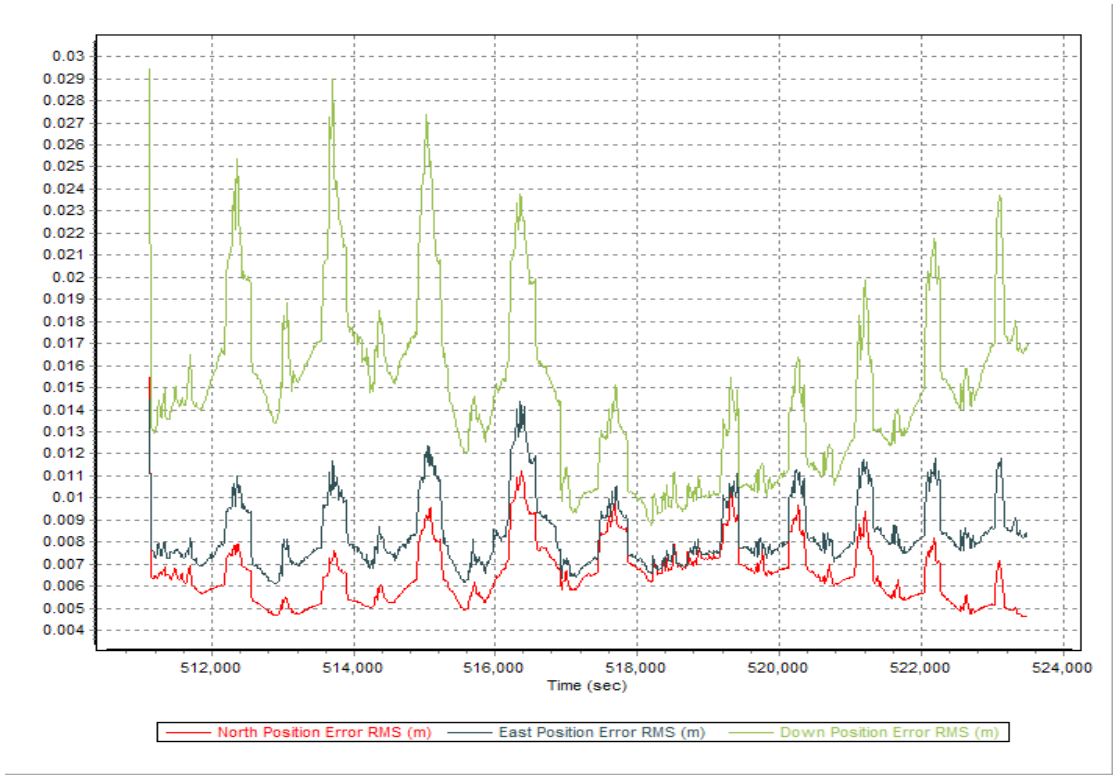


Figure A-8.44 Smoothed Performance Metric Parameters

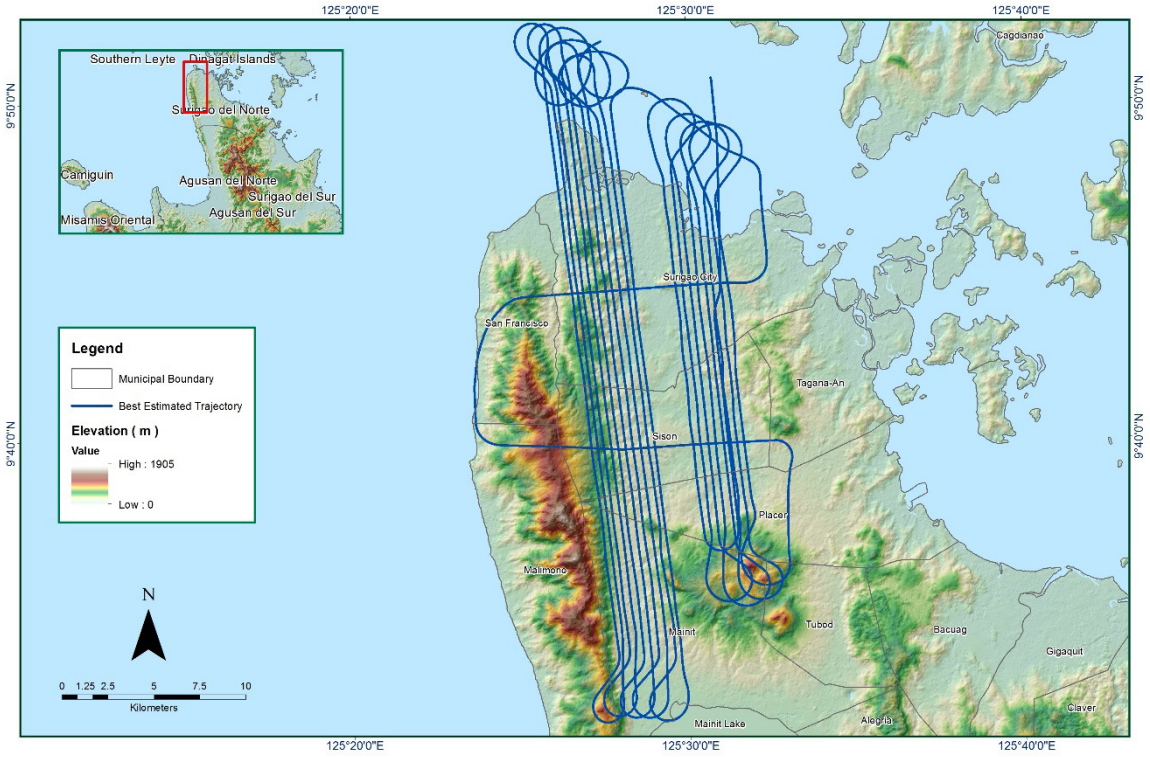


Figure A-8.45 Best Estimated Trajectory

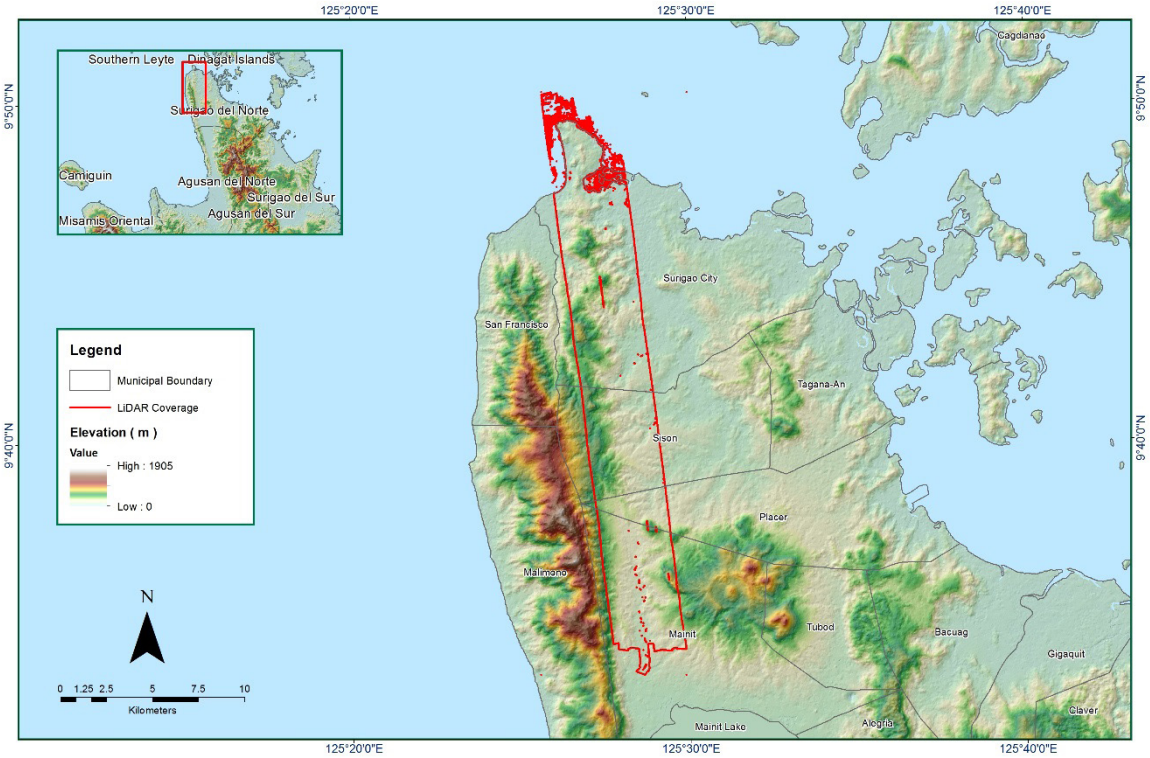


Figure A-8.46 Coverage of LiDAR data

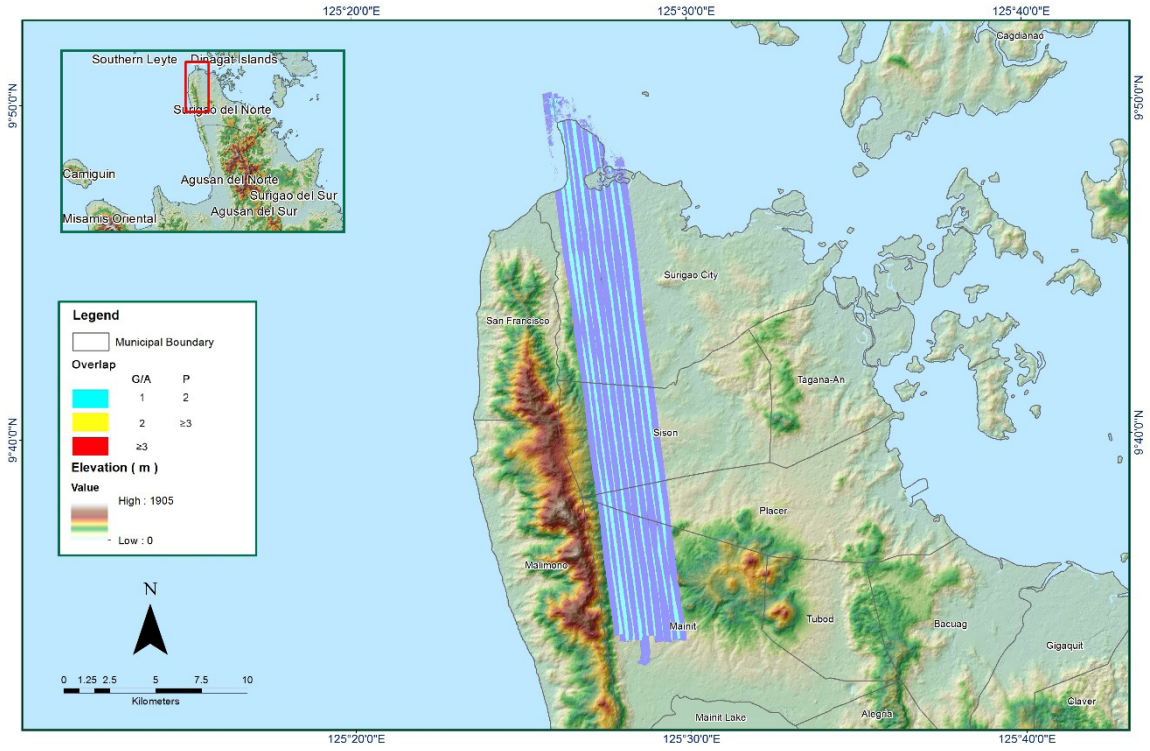


Figure A-8.47 Image of data overlap

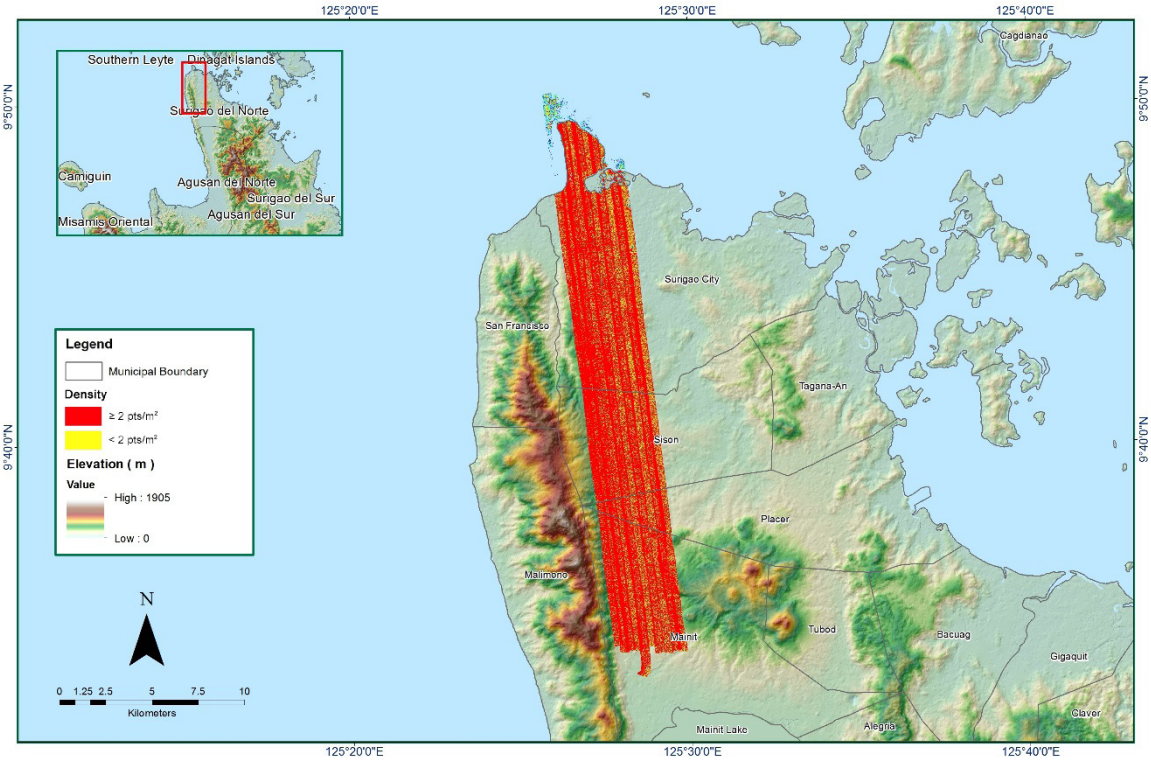


Figure A-8.48 Density Map of merged LiDAR data

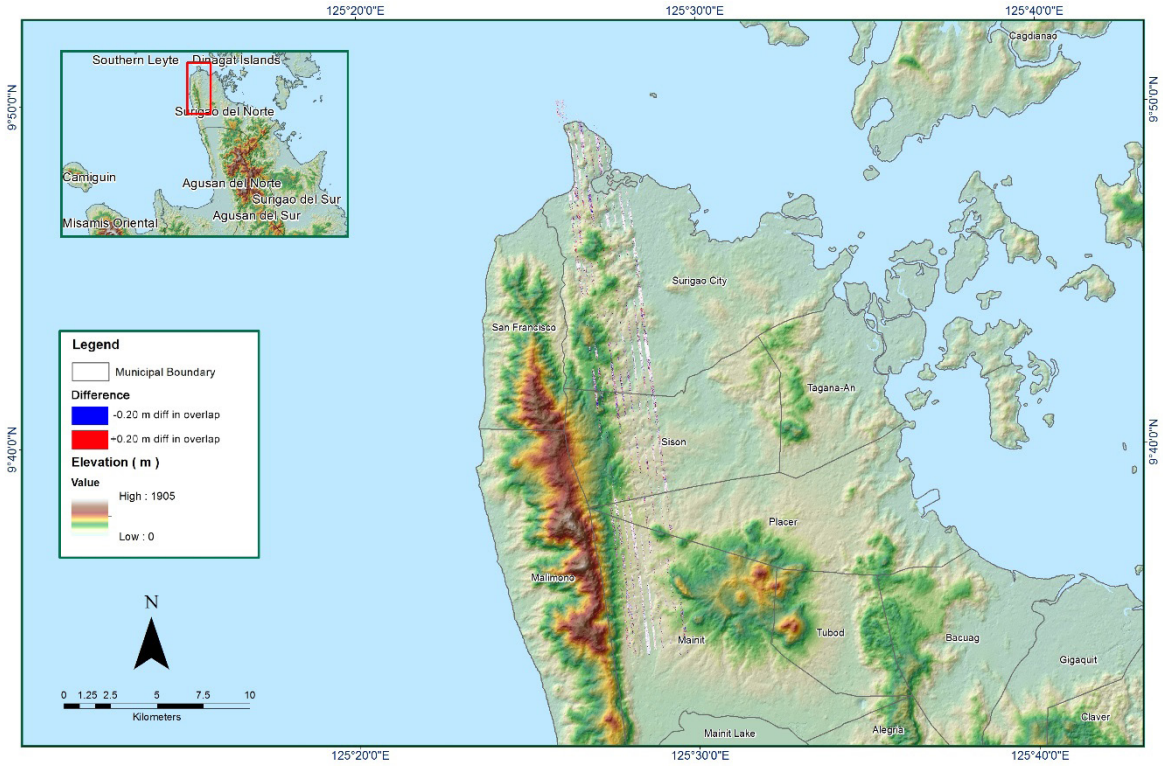


Figure A-8.49 Elevation Difference Between flight lines

Table A-8.8. Mission Summary Report for Mission Blk59F

Flight Area	Surigao City
Mission Name	Block59F (Siargao del Norte)
Inclusive Flights	7280GC, 7281GC, 7282GC & 7295GC
Range data size	49.02 GB
POS	607 MB
Image	N/A
Transfer date	June 16, 2014 & July 2, 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)	1.20
RMSE for East Position (<4.0 cm)	1.35
RMSE for Down Position (<8.0 cm)	2.20
Boresight correction stdev (<0.001deg)	0.000221
IMU attitude correction stdev (<0.001deg)	0.004631
GPS position stdev (<0.01m)	0.0213
Minimum % overlap (>25)	29.74%
Ave point cloud density per sq.m. (>2.0)	3.35
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	240
Maximum Height	485.19 m
Minimum Height	64.94 m
Classification (# of points)	
Ground	65,163,092
Low vegetation	60,609,277
Medium vegetation	95,375,302
High vegetation	275,896,683
Building	10,268,914
Orthophoto	No

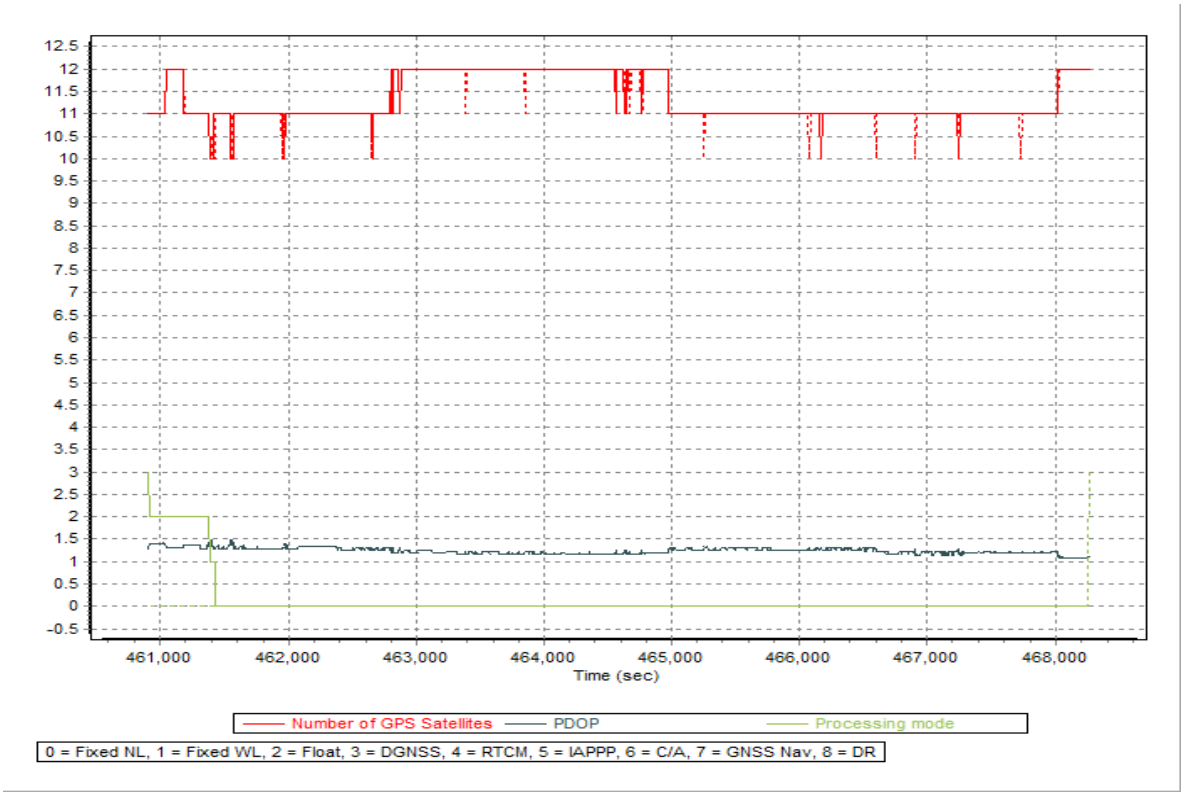


Figure A-8.50 Solution Status

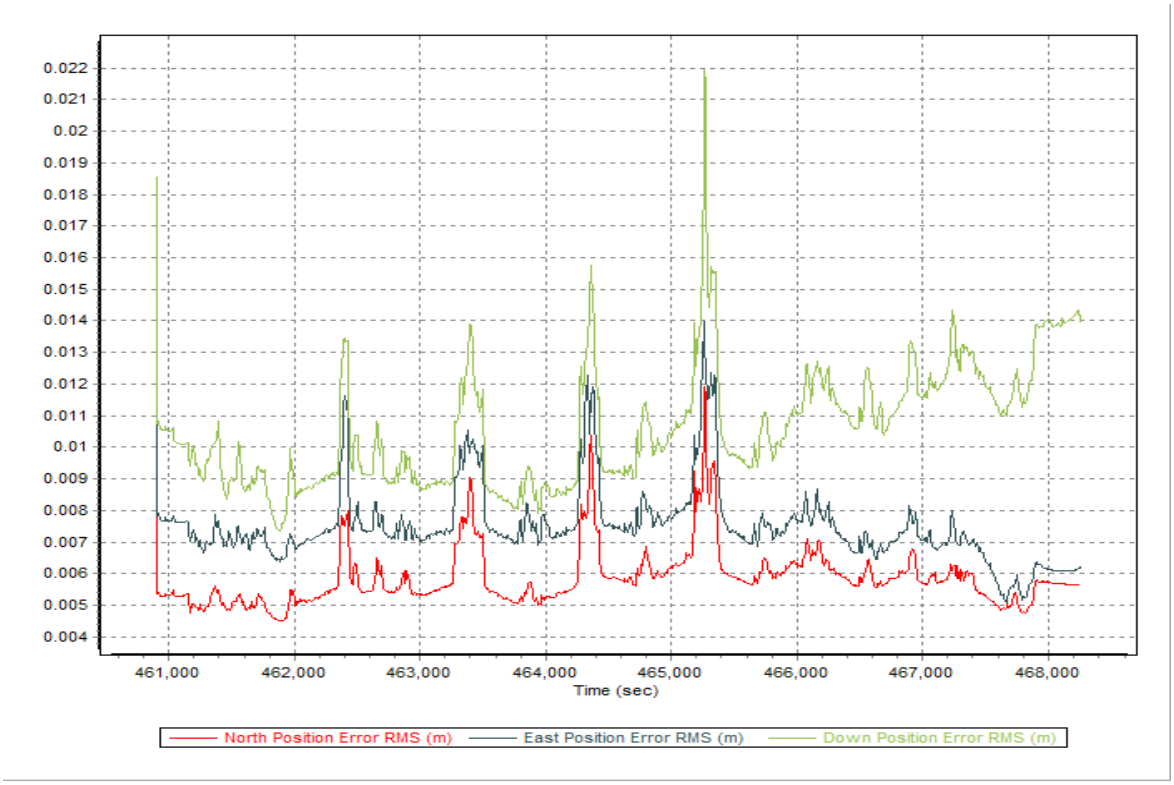


Figure A-8.51 Smoothed Performance Metric Parameters

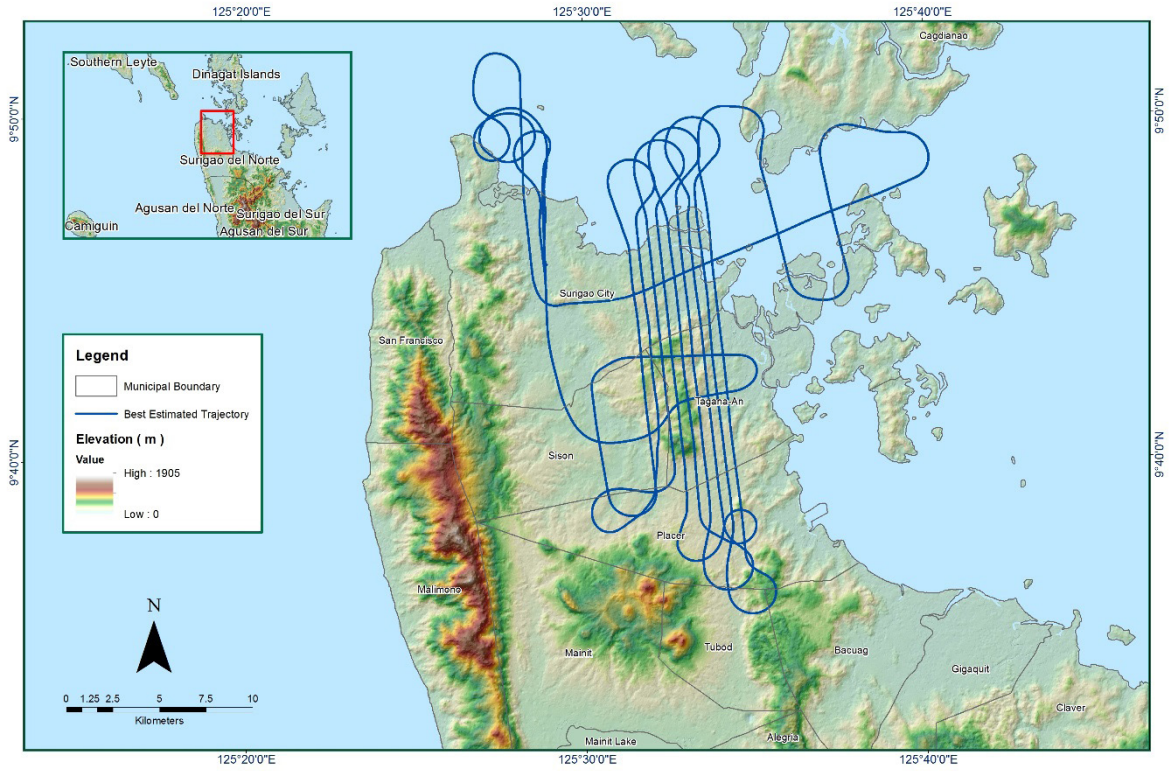


Figure A-8.52 Best Estimated Trajectory

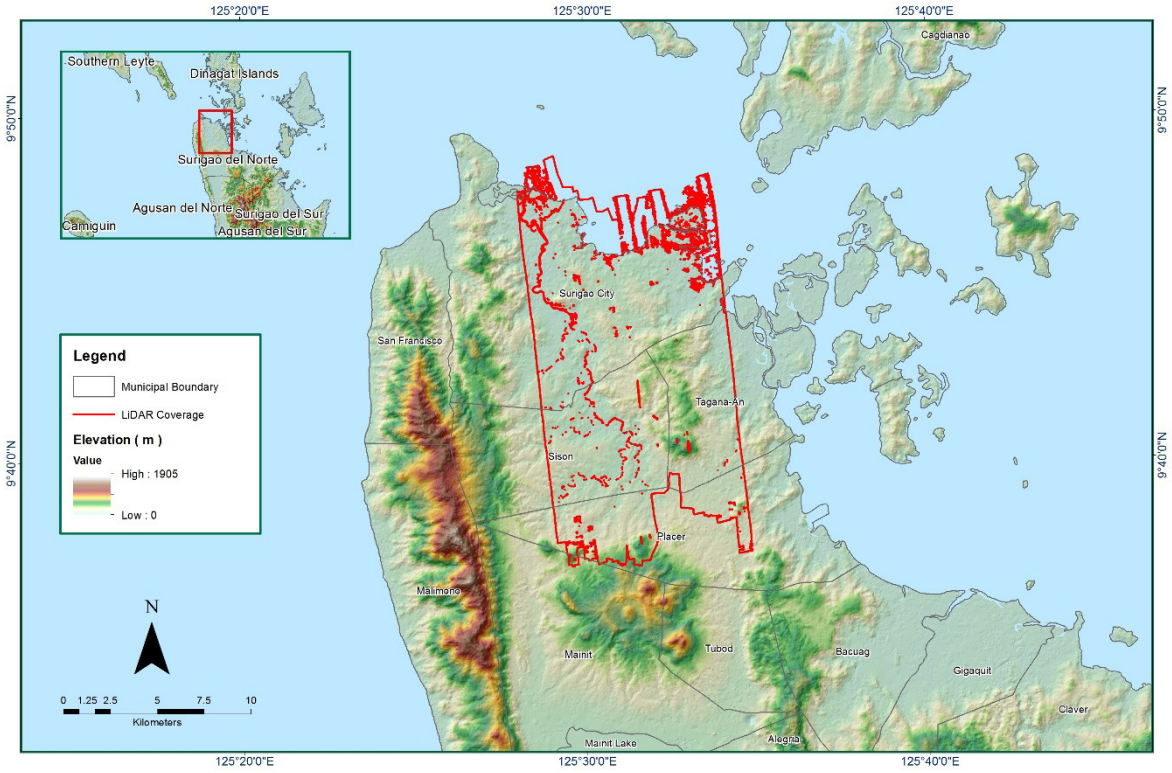


Figure A-8.53 Coverage of LiDAR data

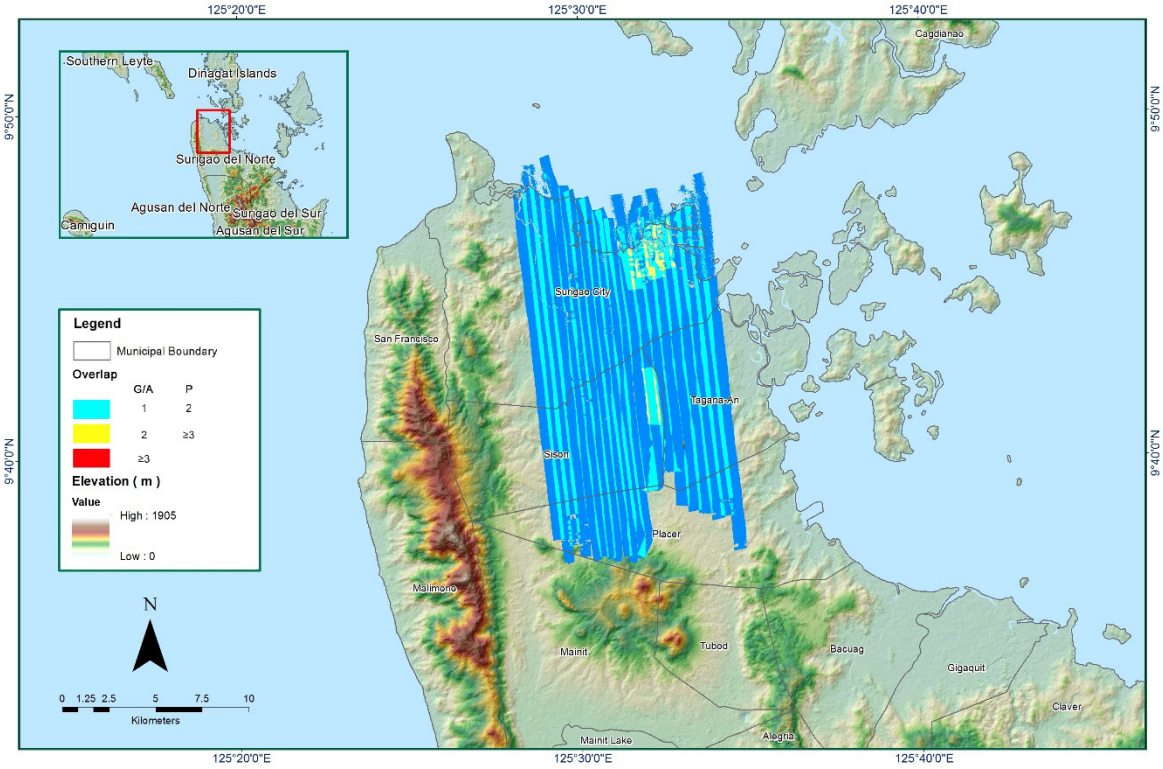


Figure A-8.54 Image of data overlap

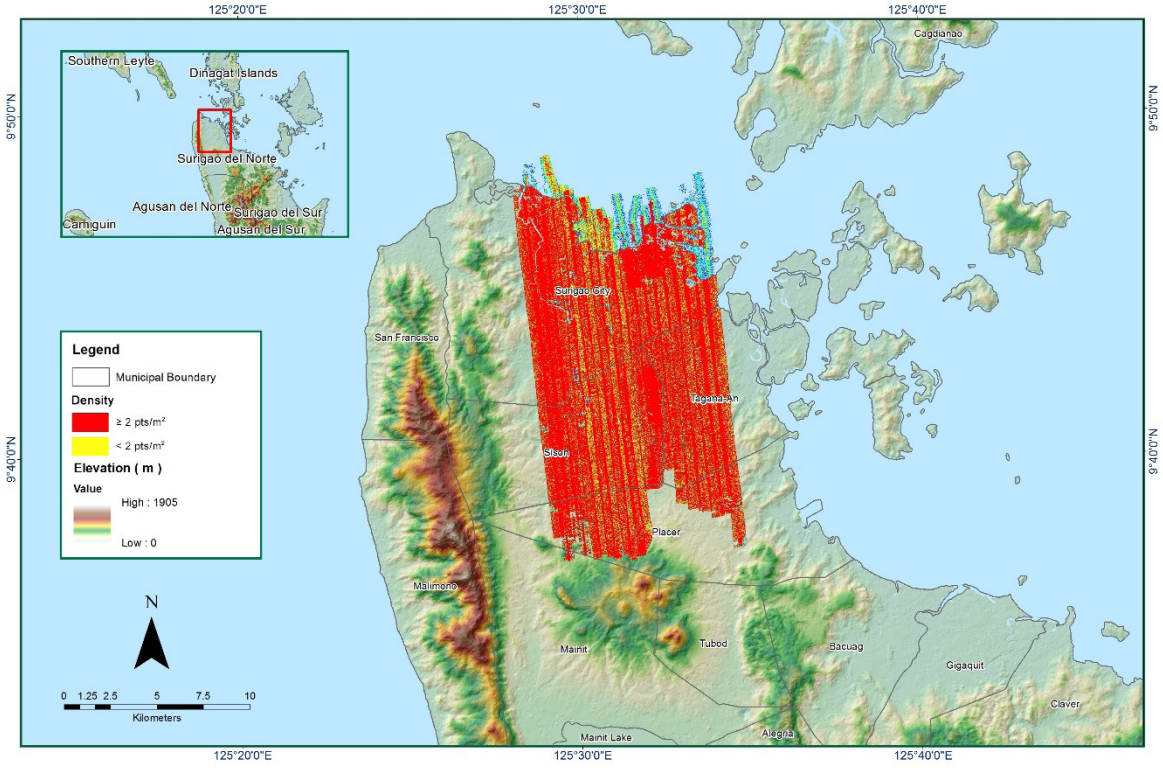


Figure A-8.55 Density map of merged LiDAR data

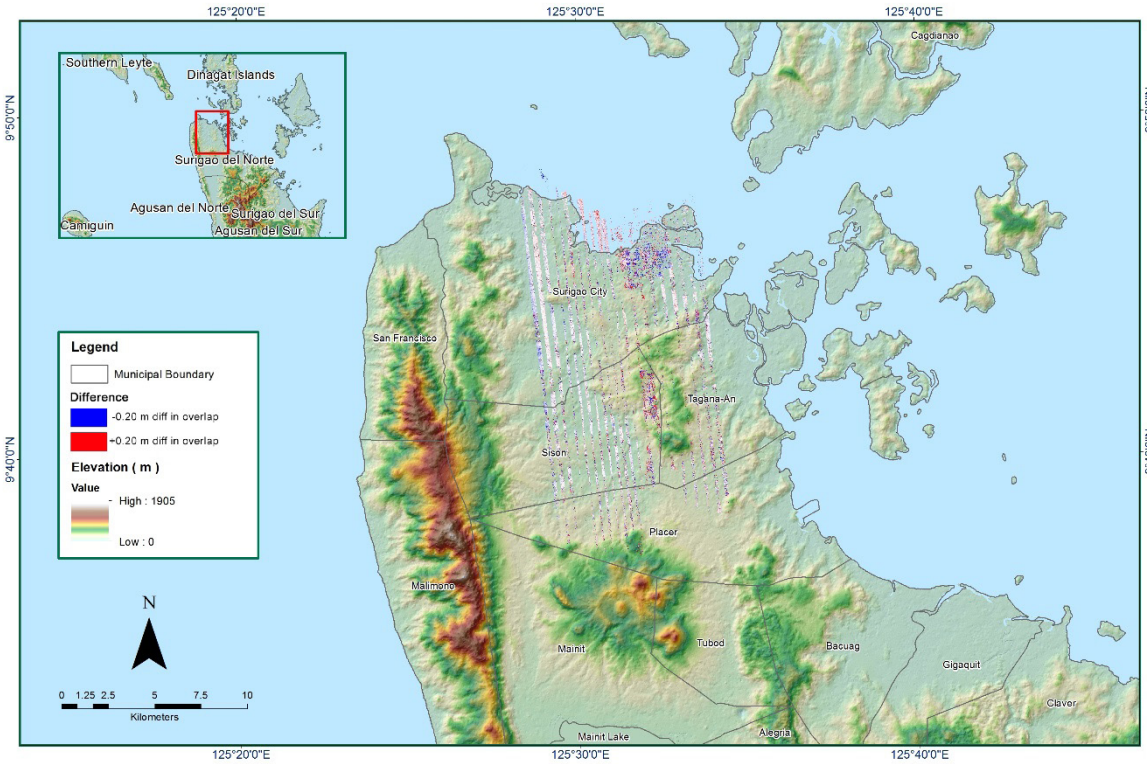


Figure A-8.56Elevation difference between flight lines

Table A-8.9. Mission Summary Report for Mission Blk59F Additional

Flight Area	Surigao City
Mission Name	Block59F Additional (Surigao del Norte)
Inclusive Flights	7300GC
Range data size	15.40 GB
POS	216 MB
Image	N/A
Transfer date	June 20, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.55
RMSE for East Position (<4.0 cm)	2.10
RMSE for Down Position (<8.0 cm)	5.40
Boresight correction stdev (<0.001deg)	0.000347
IMU attitude correction stdev (<0.001deg)	0.000869
GPS position stdev (<0.01m)	0.0101
Minimum % overlap (>25)	0%
Ave point cloud density per sq.m. (>2.0)	2.41
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	33
Maximum Height	489.7 m
Minimum Height	69.98 m
Classification (# of points)	
Ground	4,118,552
Low vegetation	3,977,081
Medium vegetation	2,911,454
High vegetation	11,656,876
Building	132,861
Orthophoto	No

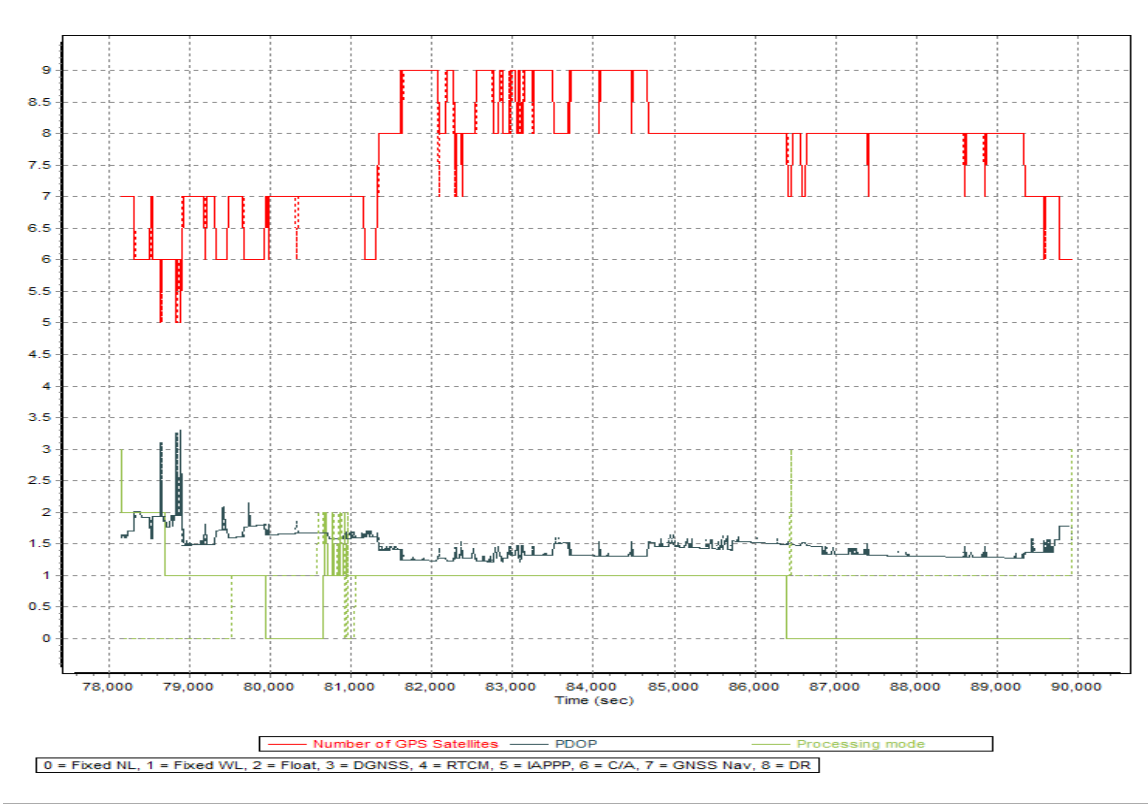


Figure A-8.57 Solution Status

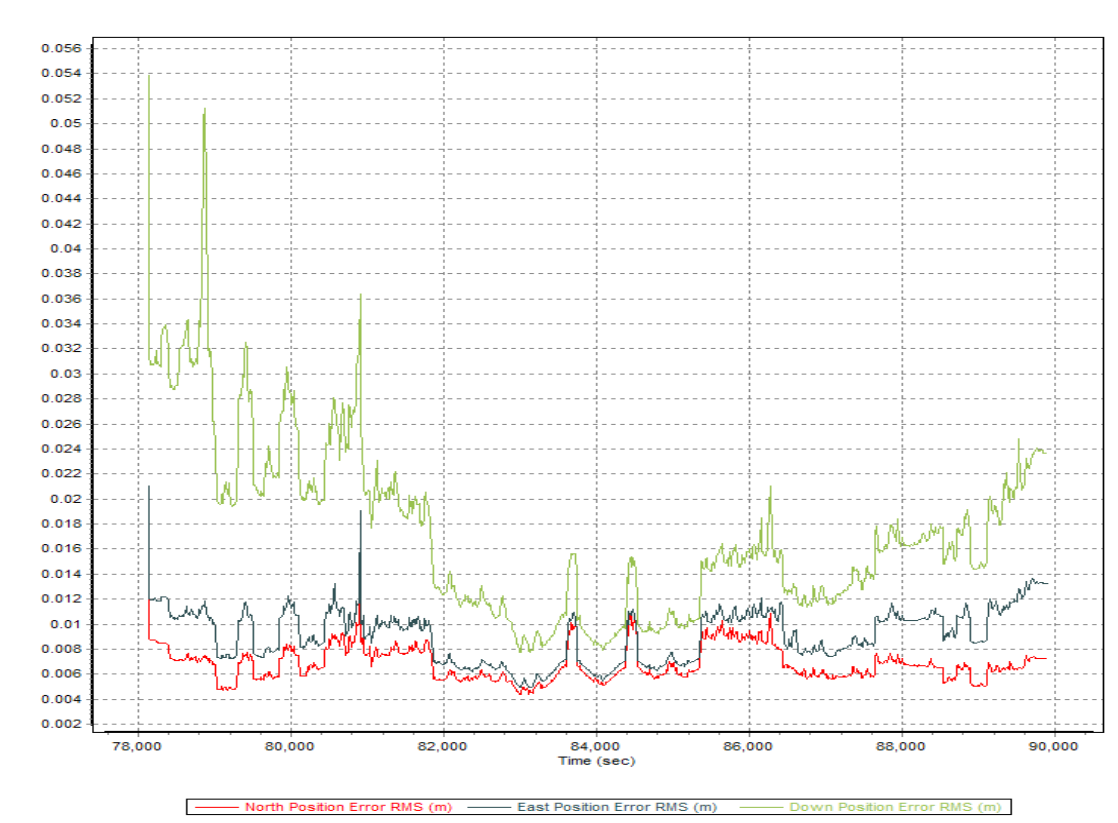


Figure A-8.58 Smoothed Performance Metric Parameters

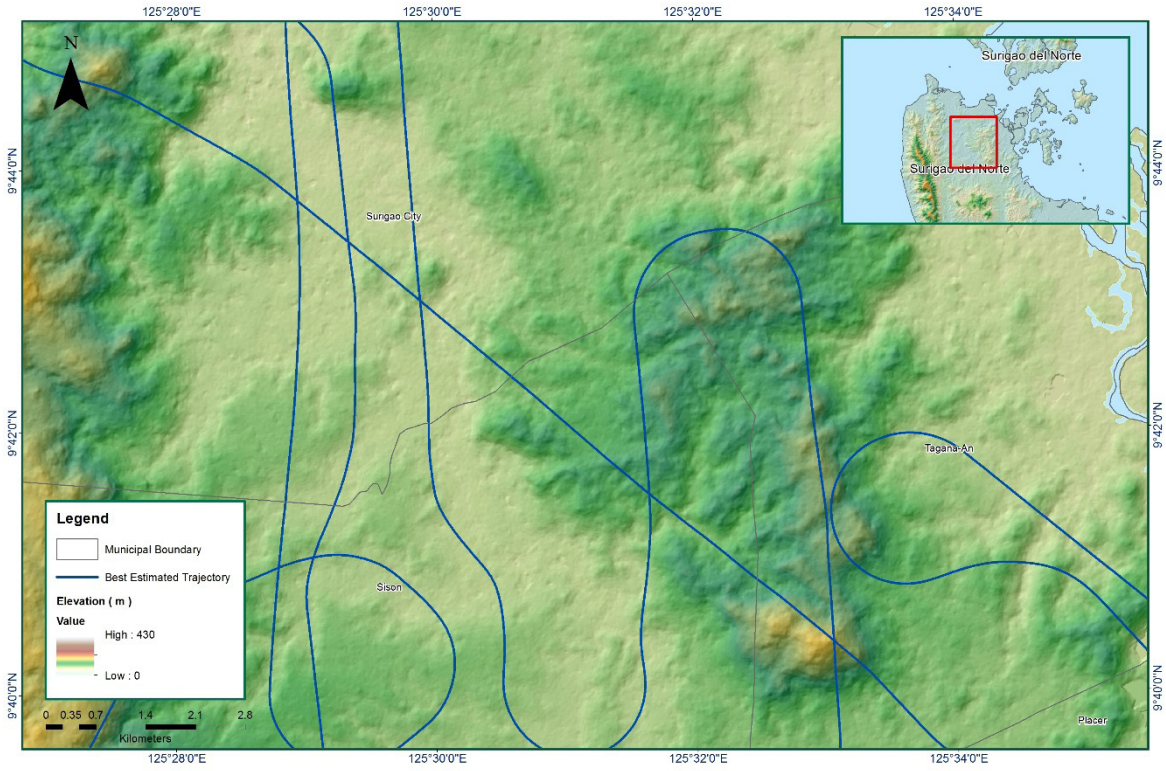


Figure A-8.59 Best Estimated Trajectory

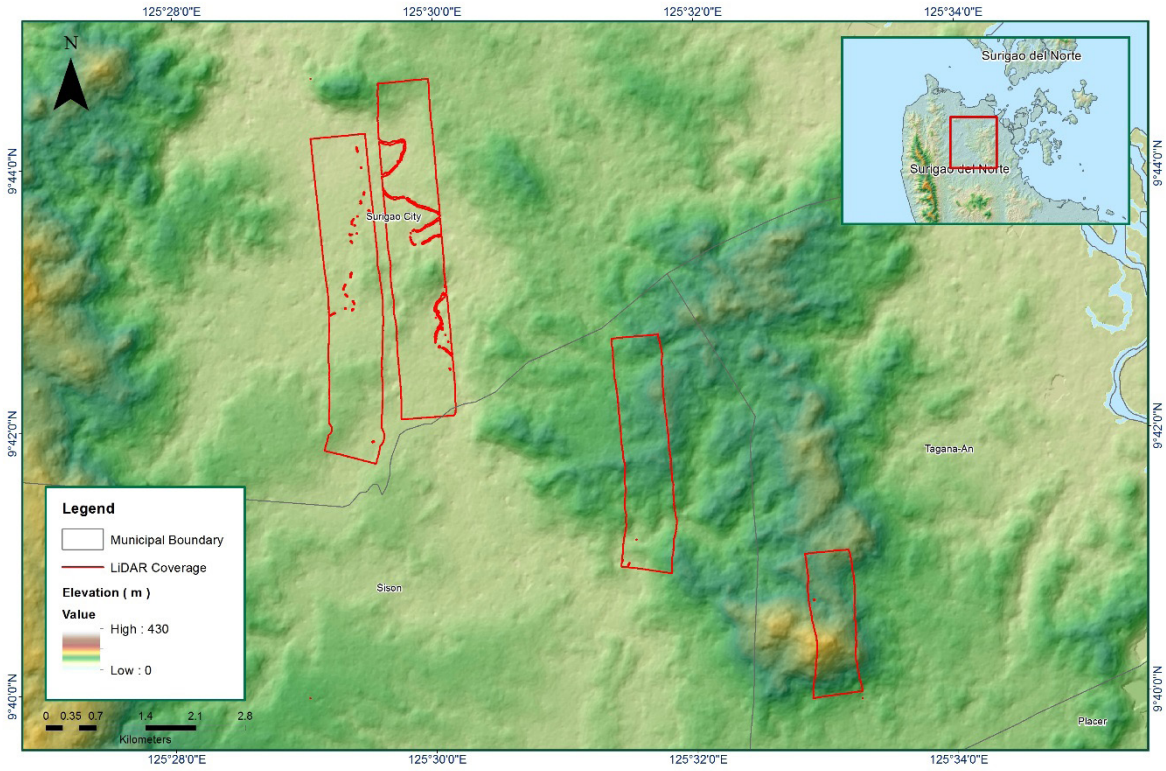


Figure A-8.60 Coverage of LiDAR data

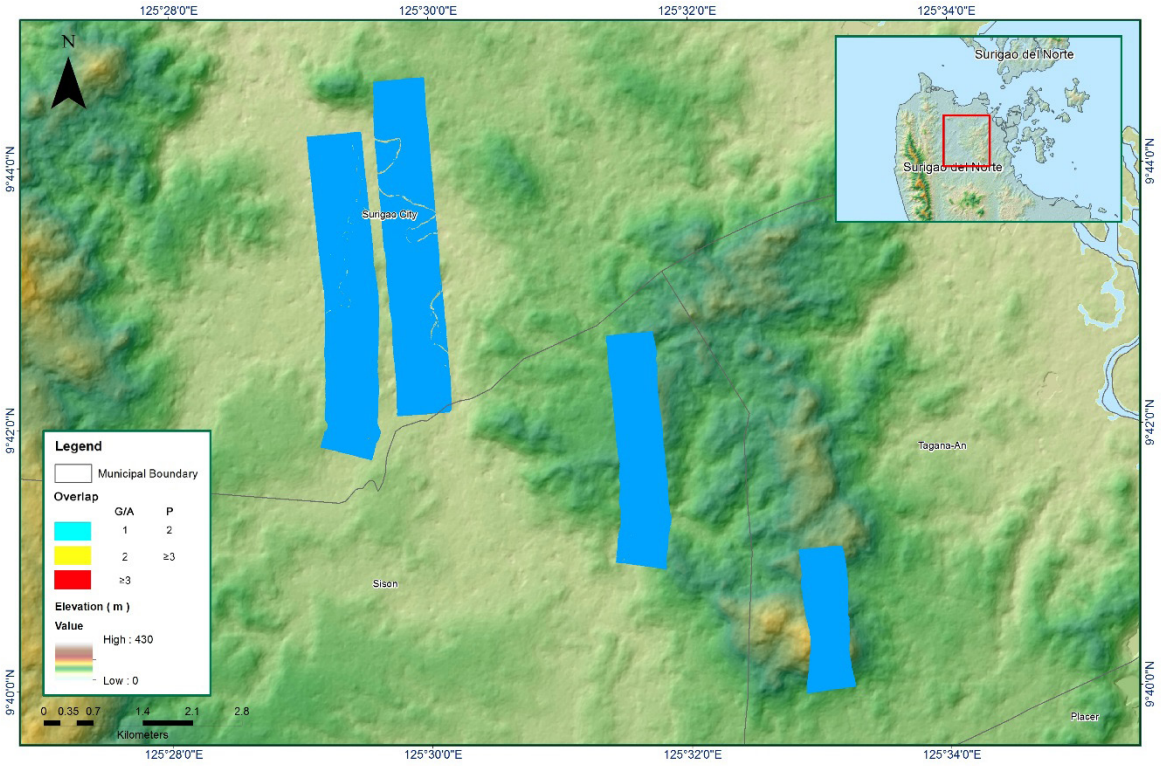


Figure A-8.61 Image of data overlap

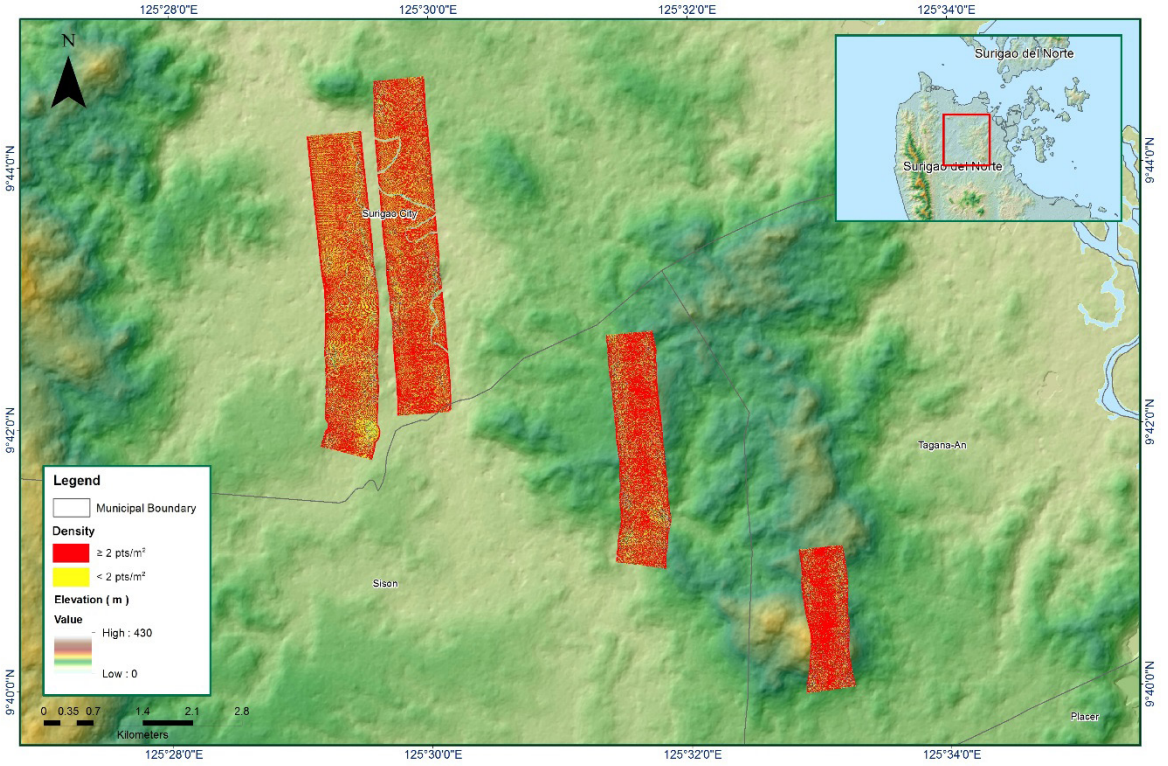


Figure A-8.62 Density map of merged LiDAR data

Table A-8.10. Mission Summary Report for Mission Blk59F Supplement

Flight Area	Surigao City
Mission Name	Block59F Supplement
Inclusive Flights	1974A
Range data size	8.20 GB
POS	182 MB
Image	NA
Transfer date	October 31, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.30
RMSE for East Position (<4.0 cm)	3.40
RMSE for Down Position (<8.0 cm)	5.60
Boresight correction stdev (<0.001deg)	0.000259
IMU attitude correction stdev (<0.001deg)	0.015740
GPS position stdev (<0.01m)	0.0041
Minimum % overlap (>25)	44.61%
Ave point cloud density per sq.m. (>2.0)	3.46
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	88
Maximum Height	491.32 m
Minimum Height	61.97 m
Classification (# of points)	
Ground	18,621,501
Low vegetation	14,653,423
Medium vegetation	38,755,029
High vegetation	94,542,606
Building	2,540,120
Orthophoto	No

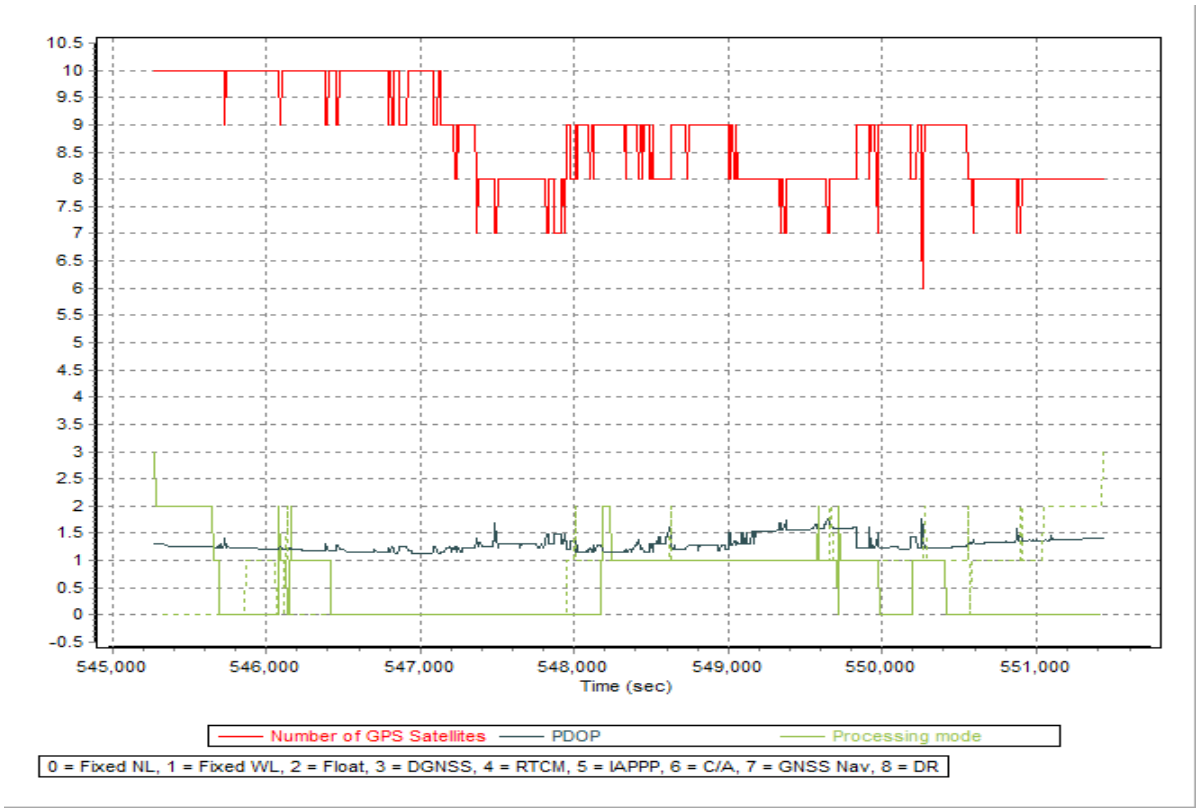


Figure A-8.63 Solution Status

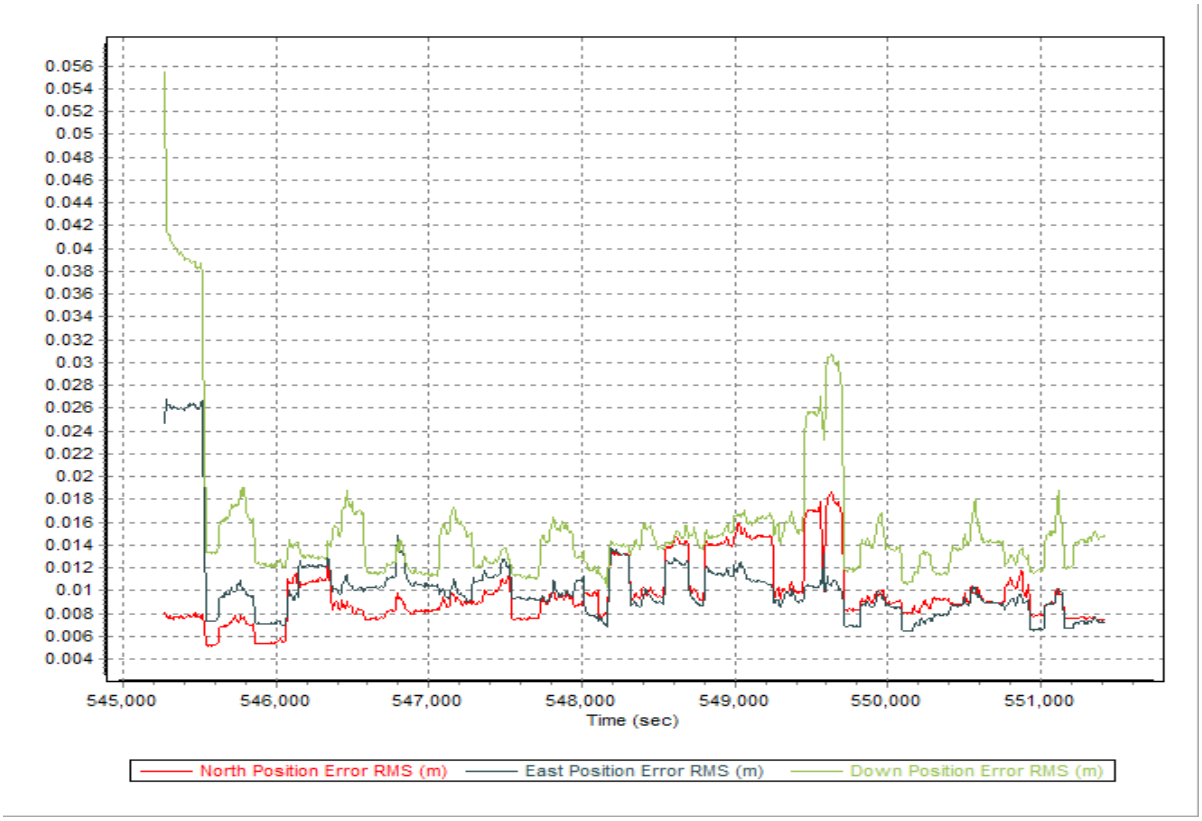


Figure A-8.64 Smoothed Performance Metric Parameters

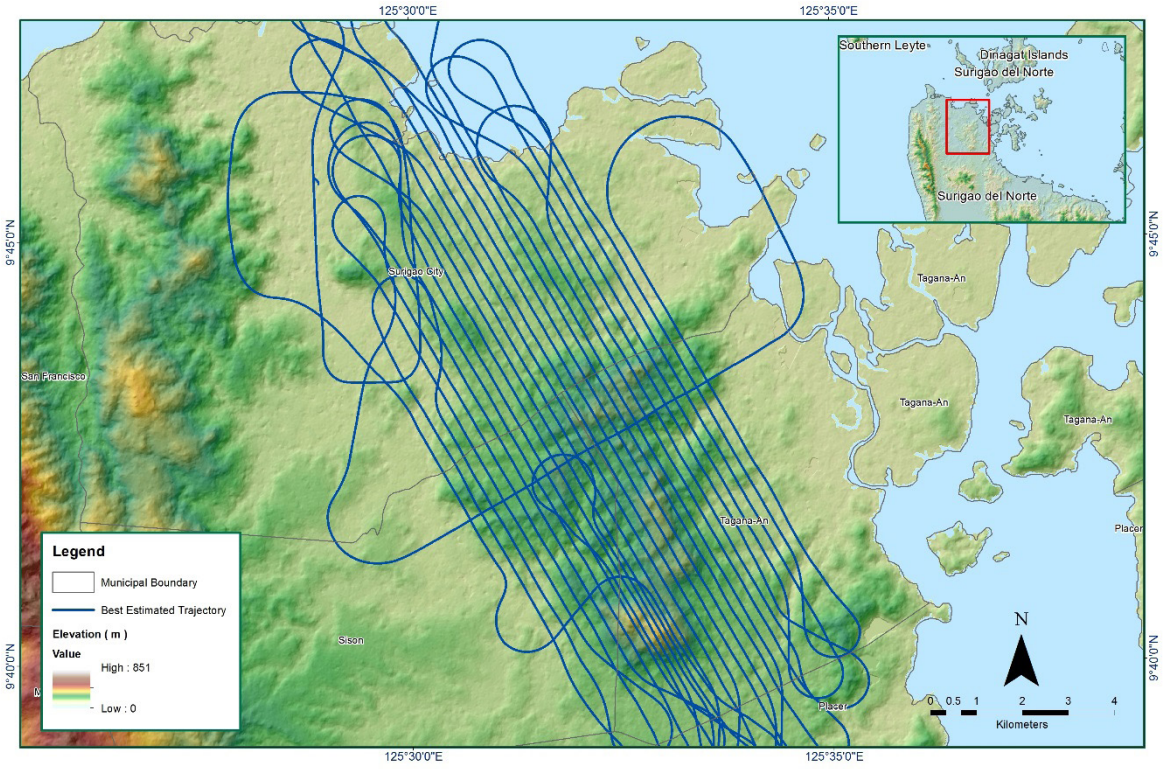


Figure A-8.65 Best Estimated Trajectory

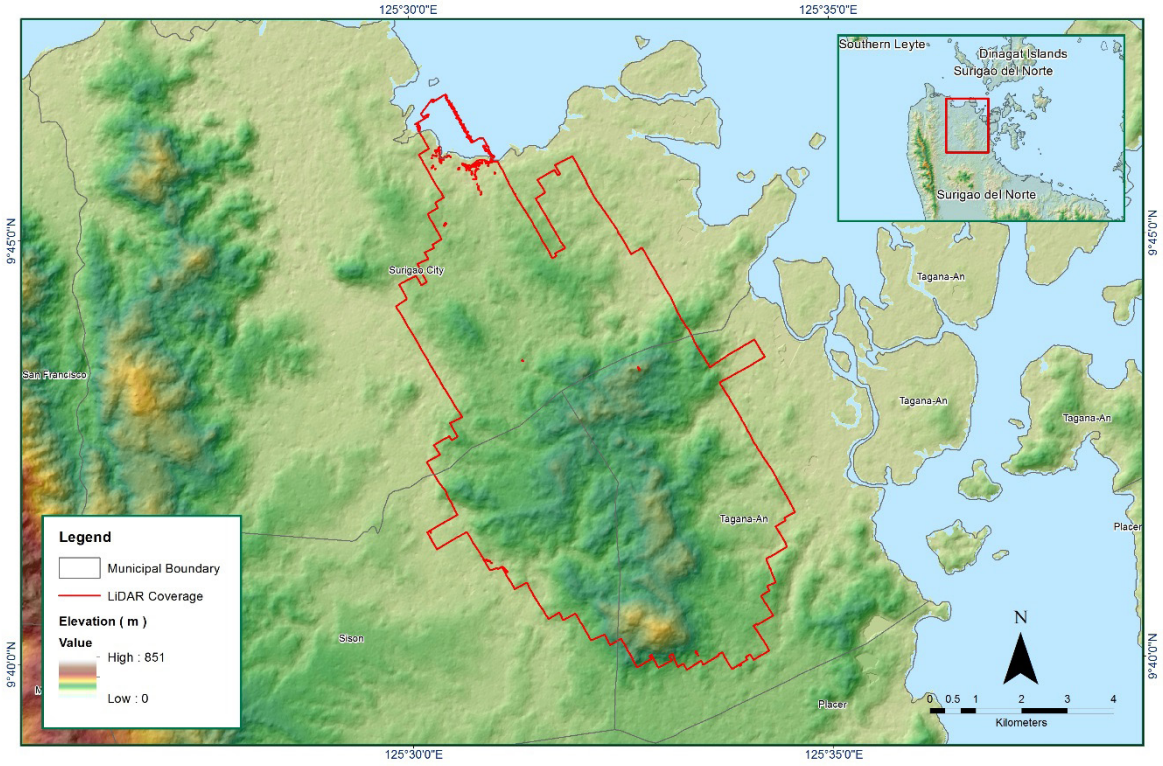


Figure A-8.66 Coverage of LiDAR data

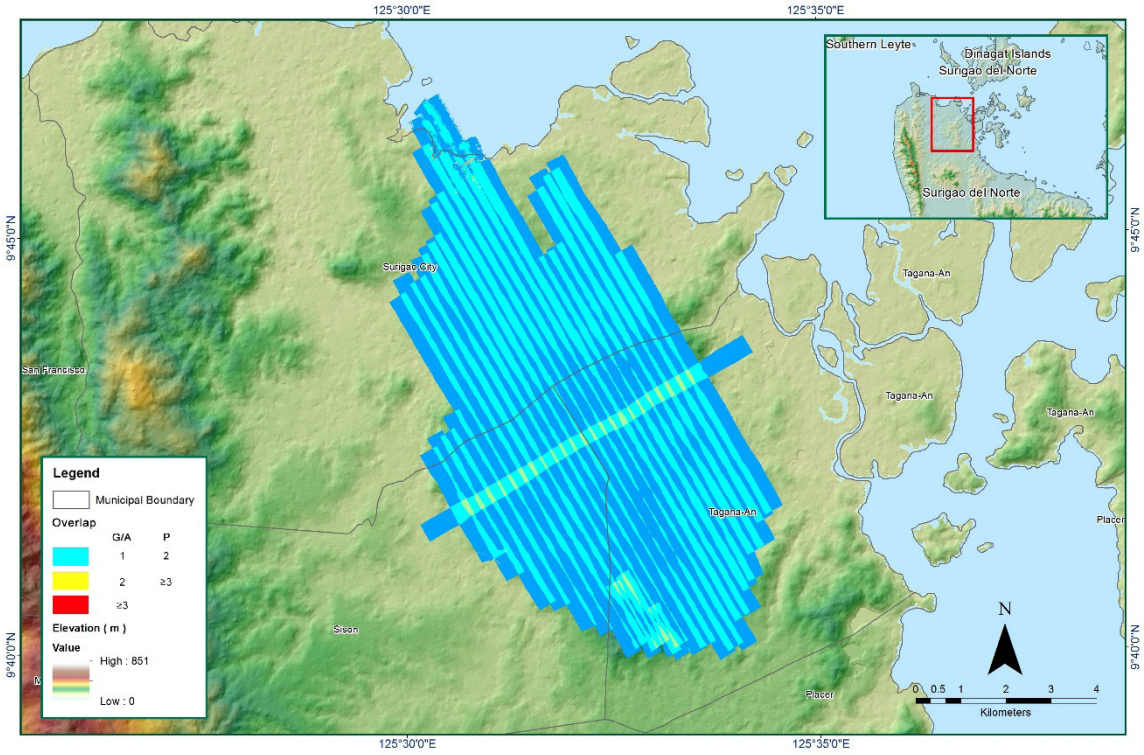


Figure A-8.67 Image of data overlap

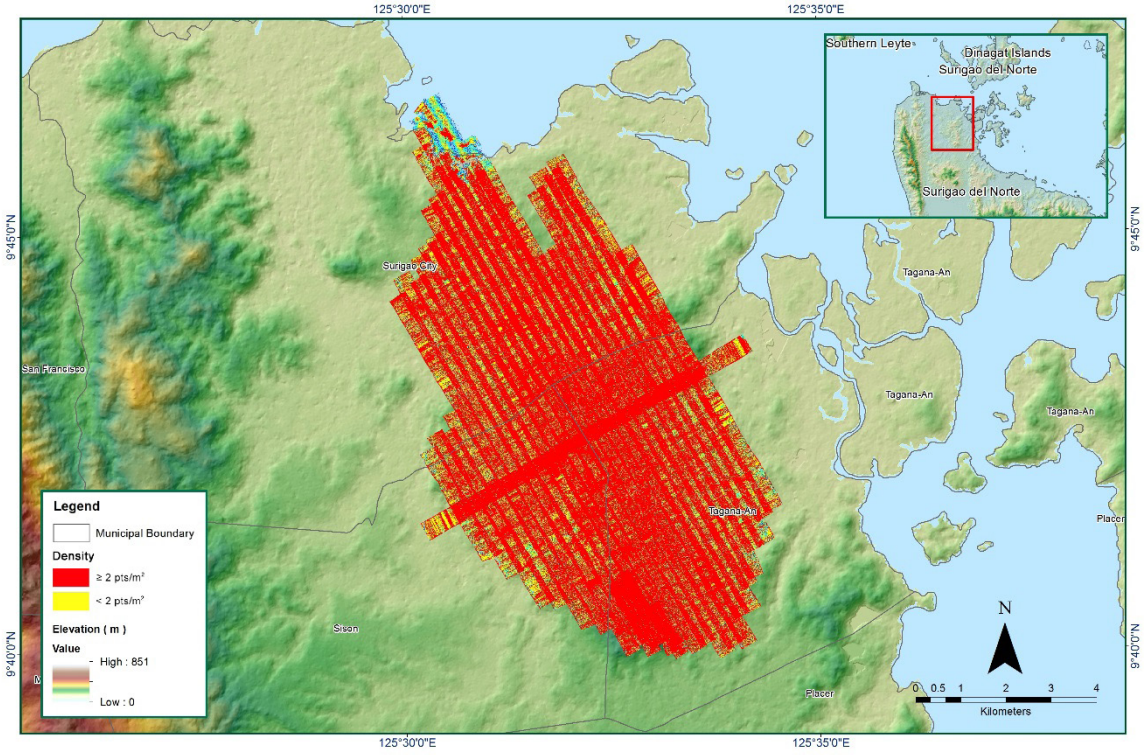


Figure A-8.68 Density map of merged LiDAR data

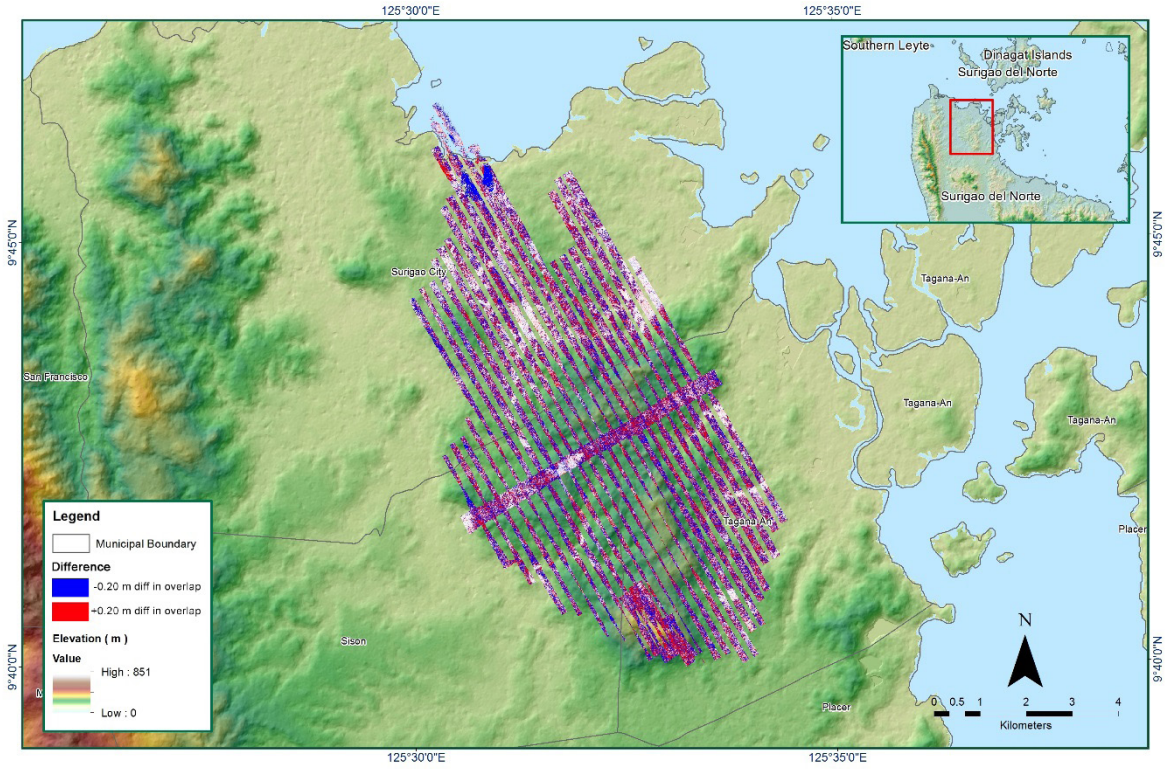


Figure A-8.69Elevation difference between flight lines

Table A-8.11. Mission Summary Report for Mission Blk59G

Flight Area	Surigao City
Mission Name	Block 59G (Surigao del Norte)
Inclusive Flights	7280GC, 7281GC, 7283GC, 7284GC, 7293GC & 7295GC
Range data size	59.45 GB
POS	734 MB
Image	N/A
Transfer date	June 16, 2014 & July 2, 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)	1.05
RMSE for East Position (<4.0 cm)	1.39
RMSE for Down Position (<8.0 cm)	2.05
Boresight correction stdev (<0.001deg)	0.000524
IMU attitude correction stdev (<0.001deg)	--
GPS position stdev (<0.01m)	0.0237
Minimum % overlap (>25)	14.30%
Ave point cloud density per sq.m. (>2.0)	2.28
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	75
Maximum Height	338.36 m
Minimum Height	52.55 m
Classification (# of points)	
Ground	10,543,342
Low vegetation	9,880,482
Medium vegetation	21,037,382
High vegetation	10,479,343
Building	299,468
Orthophoto	No

Figure A-8.70 Solution Status

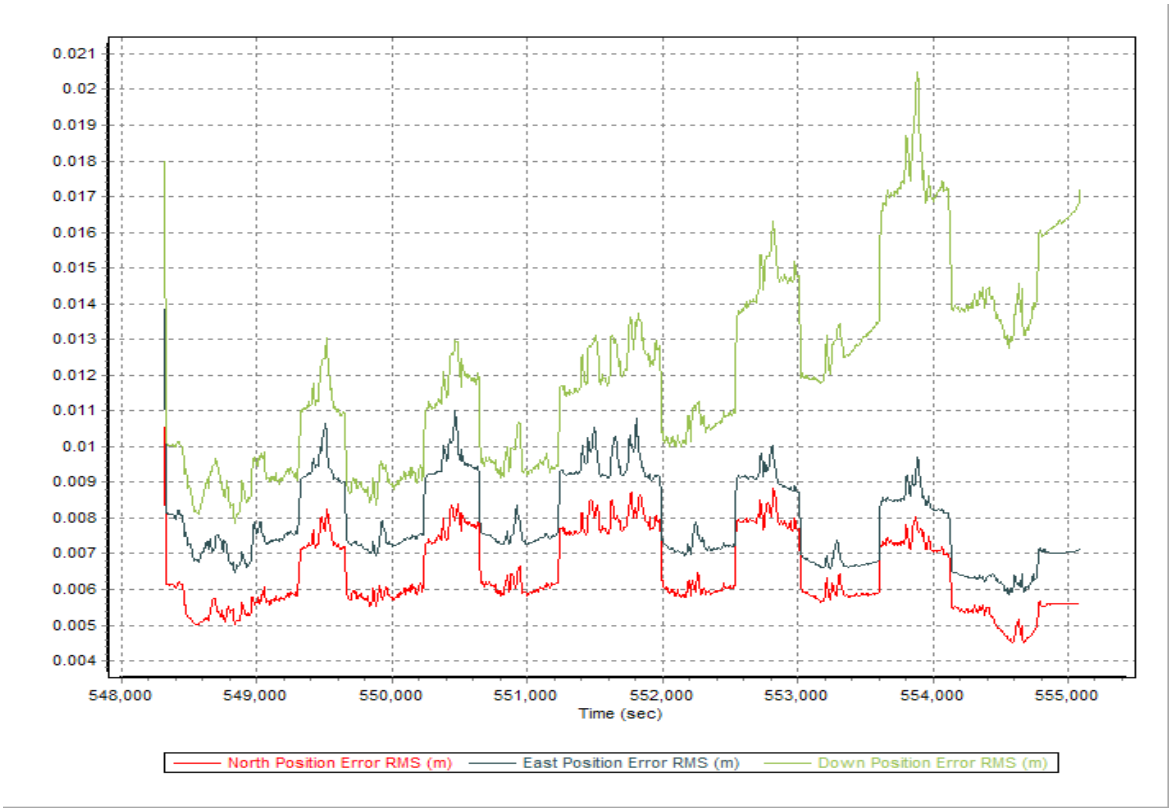


Figure A-8.71 Smoothed Performance Metric Parameters

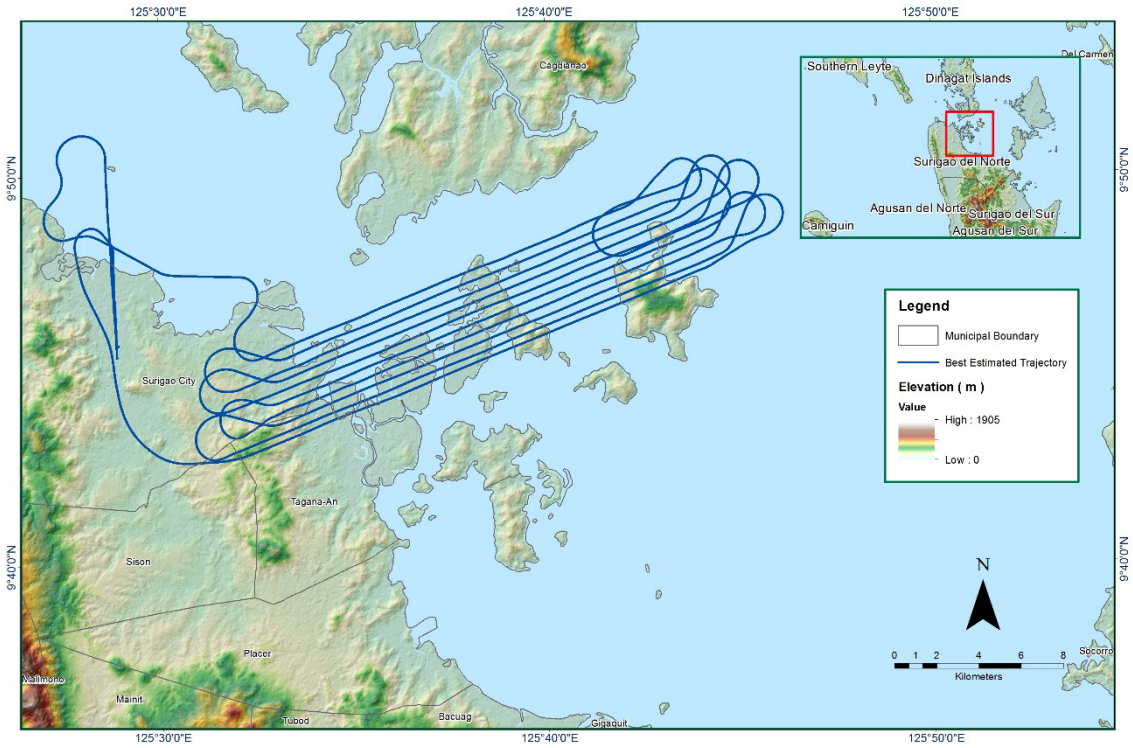


Figure A-8.72 Best Estimated Trajectory

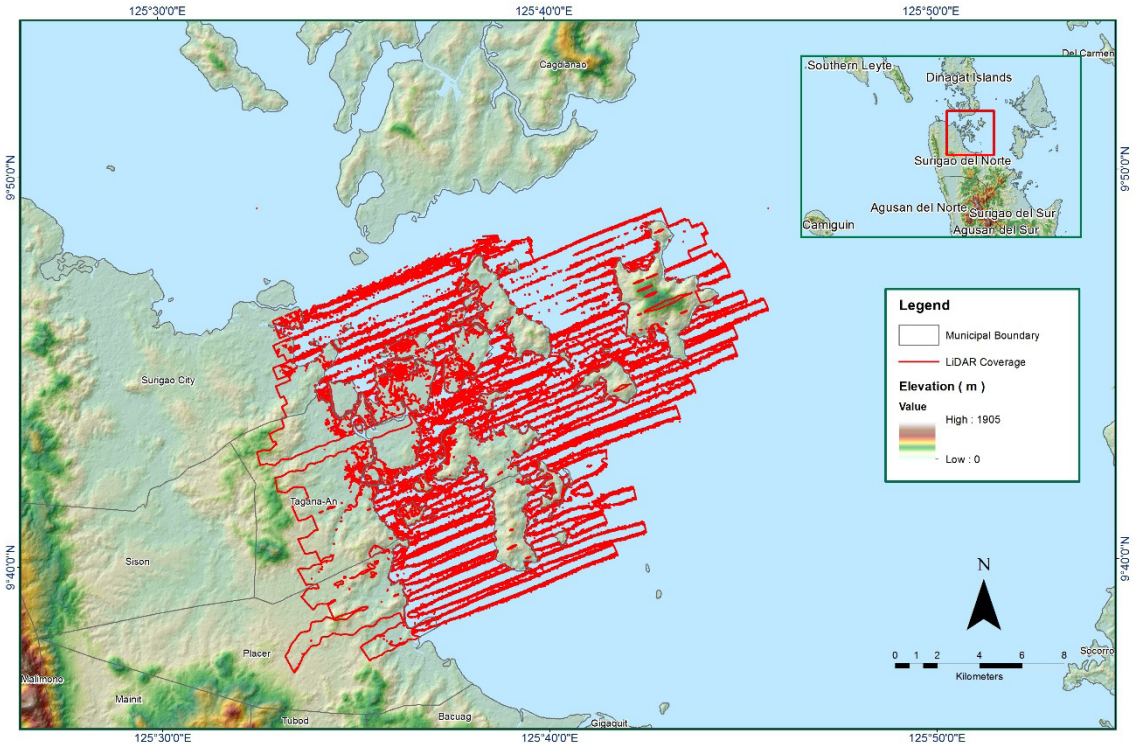


Figure A-8.73 Coverage of LiDAR data

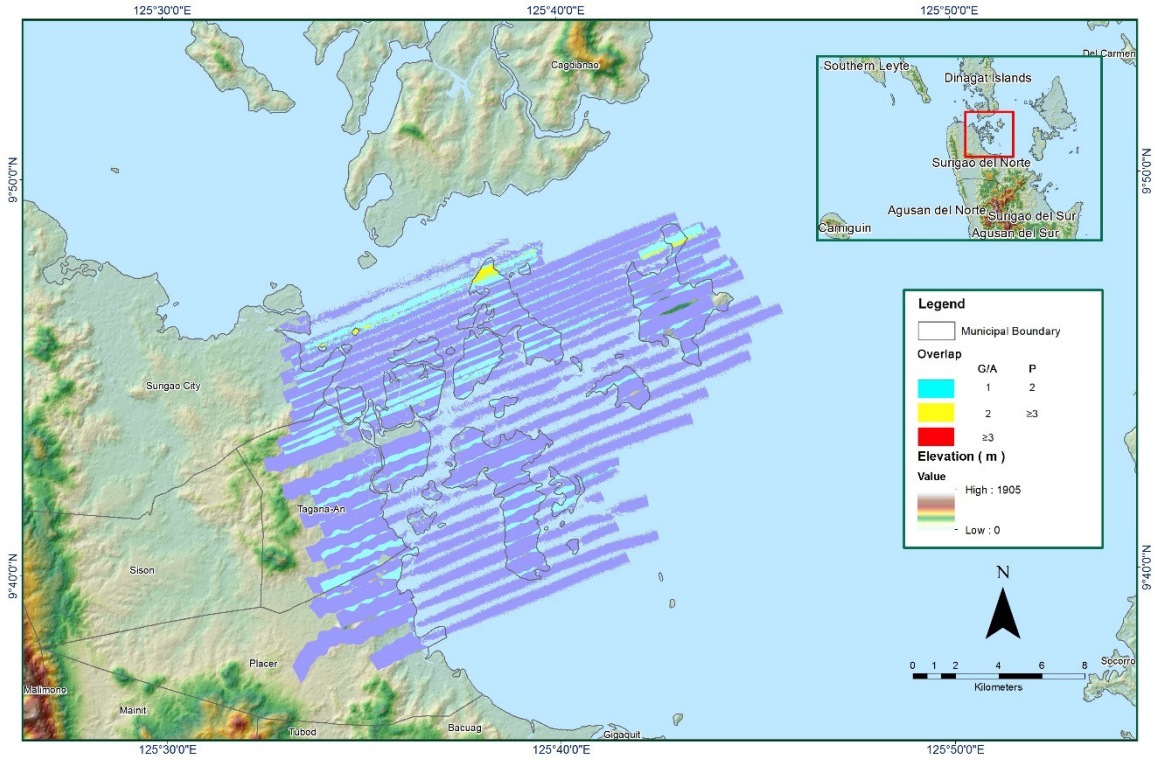


Figure A-8.74 Image of data overlap

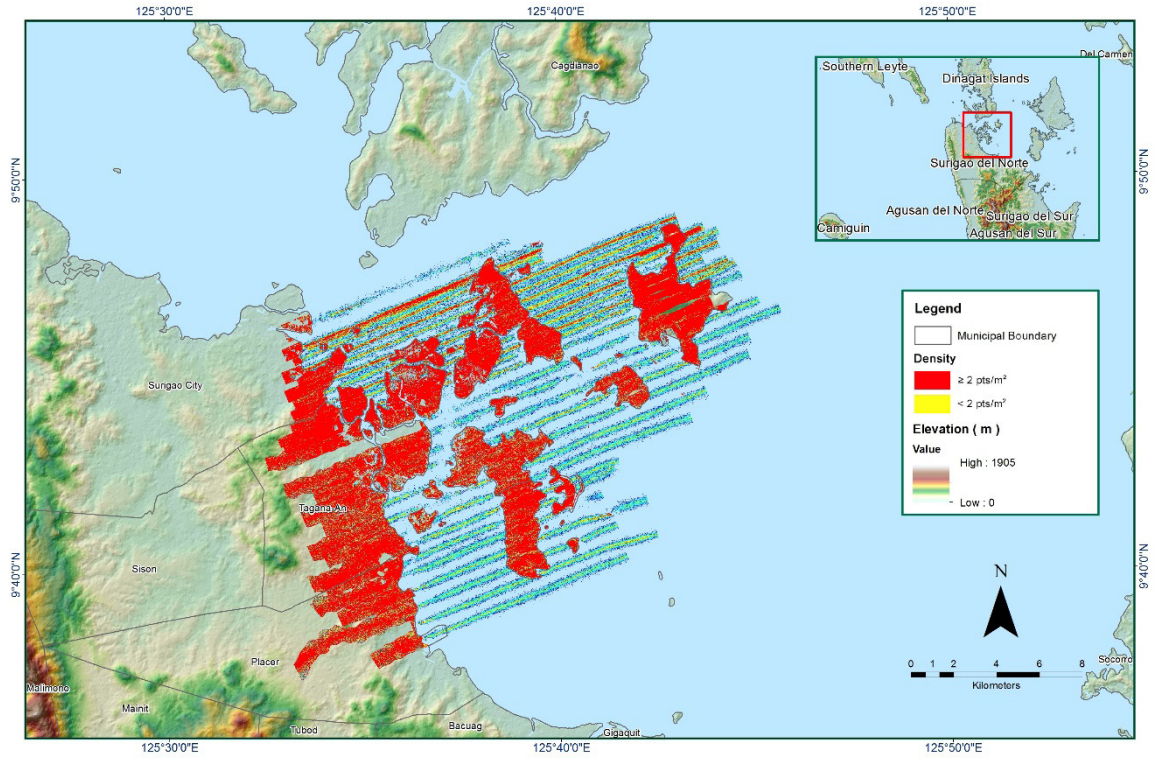


Figure A-8.75 Density map of merged LiDAR data

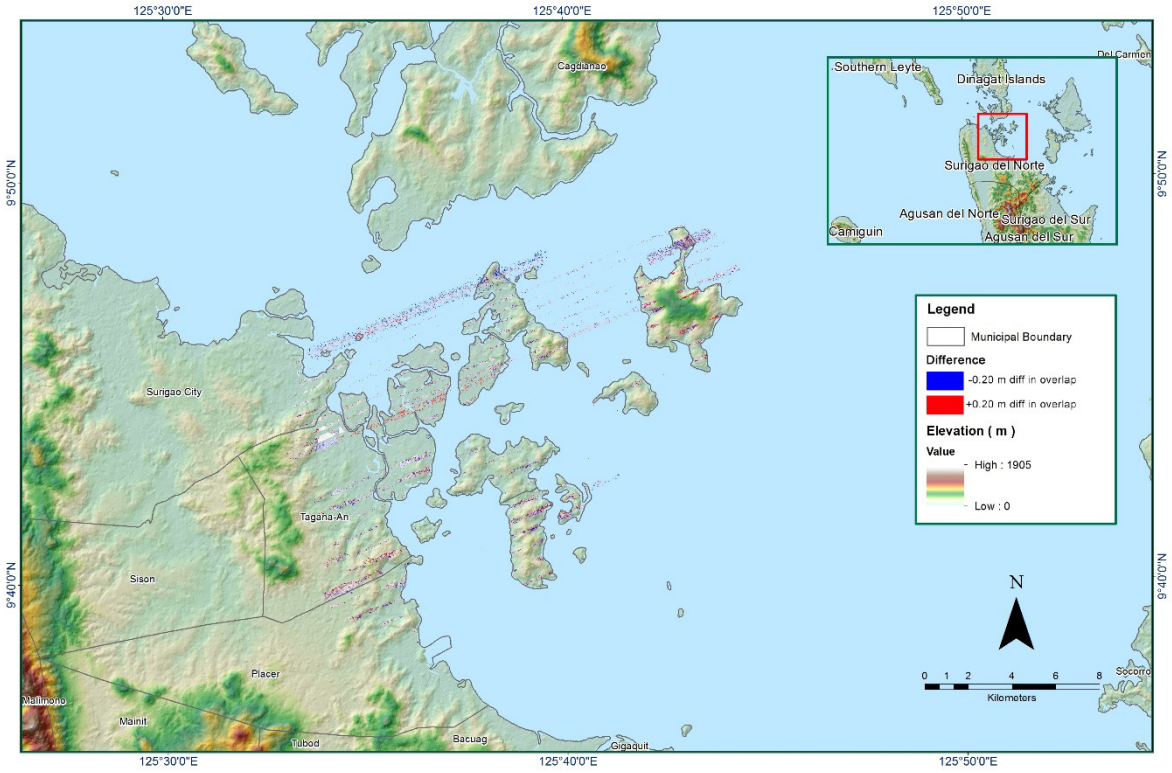


Figure A-8.76Elevation difference between flight lines

Table A-8.12. Mission Summary Report for Mission Blk59G Additional

Flight Area	Surigao City
Mission Name	Block 59G Additional (Surigao del Norte)
Inclusive Flights	7300GC
Range data size	15.40 GB
POS	216 MB
Image	N/A
Transfer date	June 20, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.55
RMSE for East Position (<4.0 cm)	2.10
RMSE for Down Position (<8.0 cm)	5.40
Boresight correction stdev (<0.001deg)	0.000347
IMU attitude correction stdev (<0.001deg)	0.000869
GPS position stdev (<0.01m)	0.0101
Minimum % overlap (>25)	0%
Ave point cloud density per sq.m. (>2.0)	2.22
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	97
Maximum Height	717.62 m
Minimum Height	12.81 m
Classification (# of points)	
Ground	30,347,129
Low vegetation	27,925,435
Medium vegetation	21,100,846
High vegetation	112,876,806
Building	3,092,248
Ortophoto	No

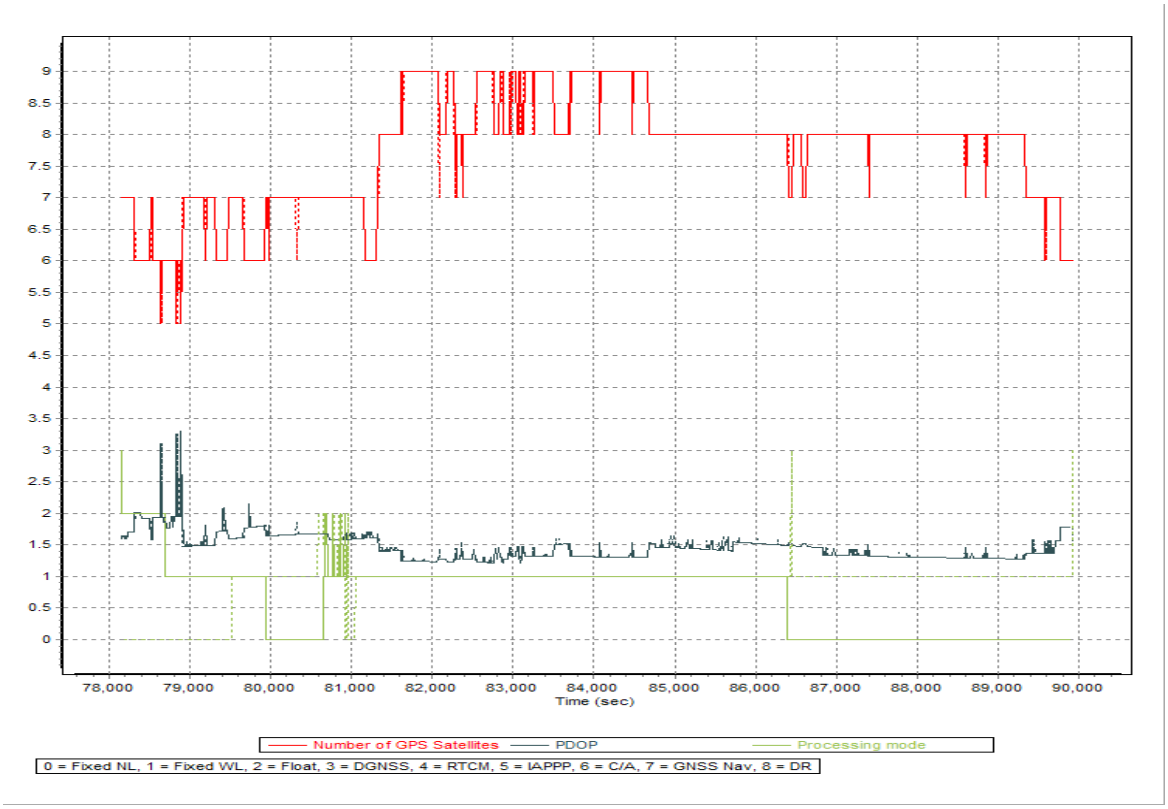


Figure A-8.77 Solution Status

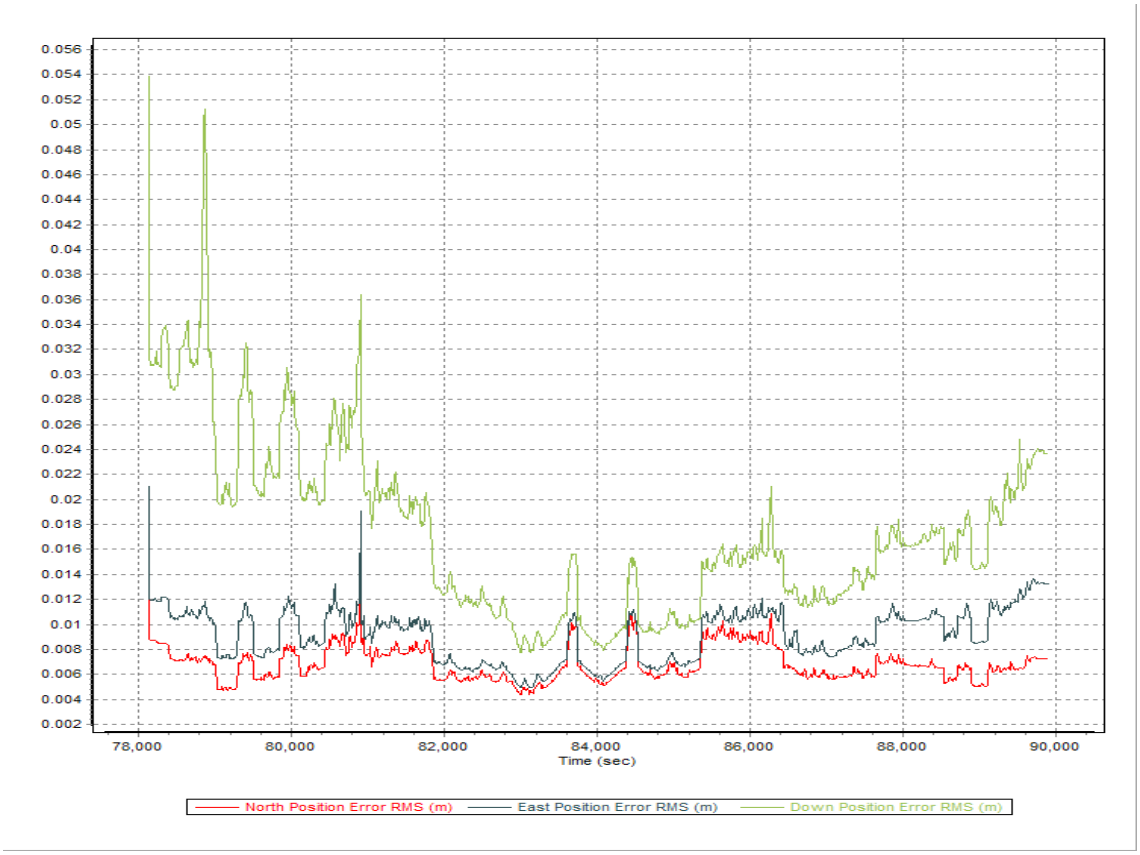


Figure A-8.78 Smoothed Performance Metric Parameters

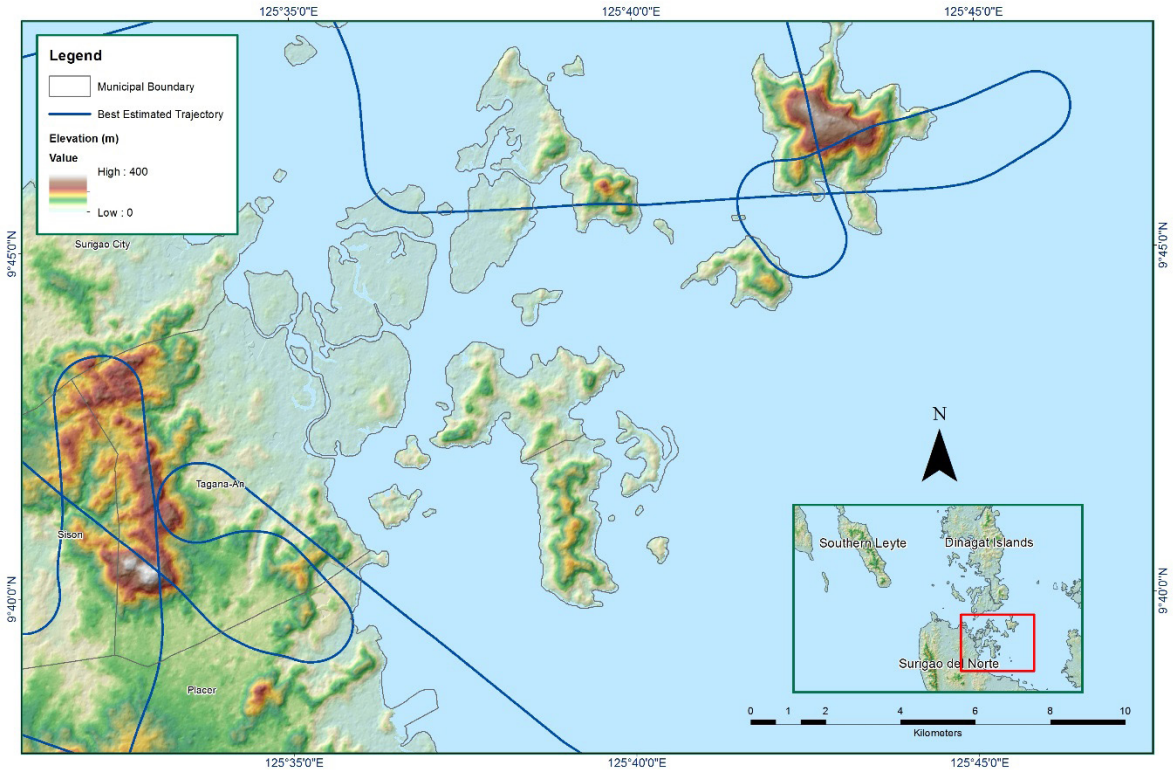


Figure A-8.79 Best Estimated Trajectory

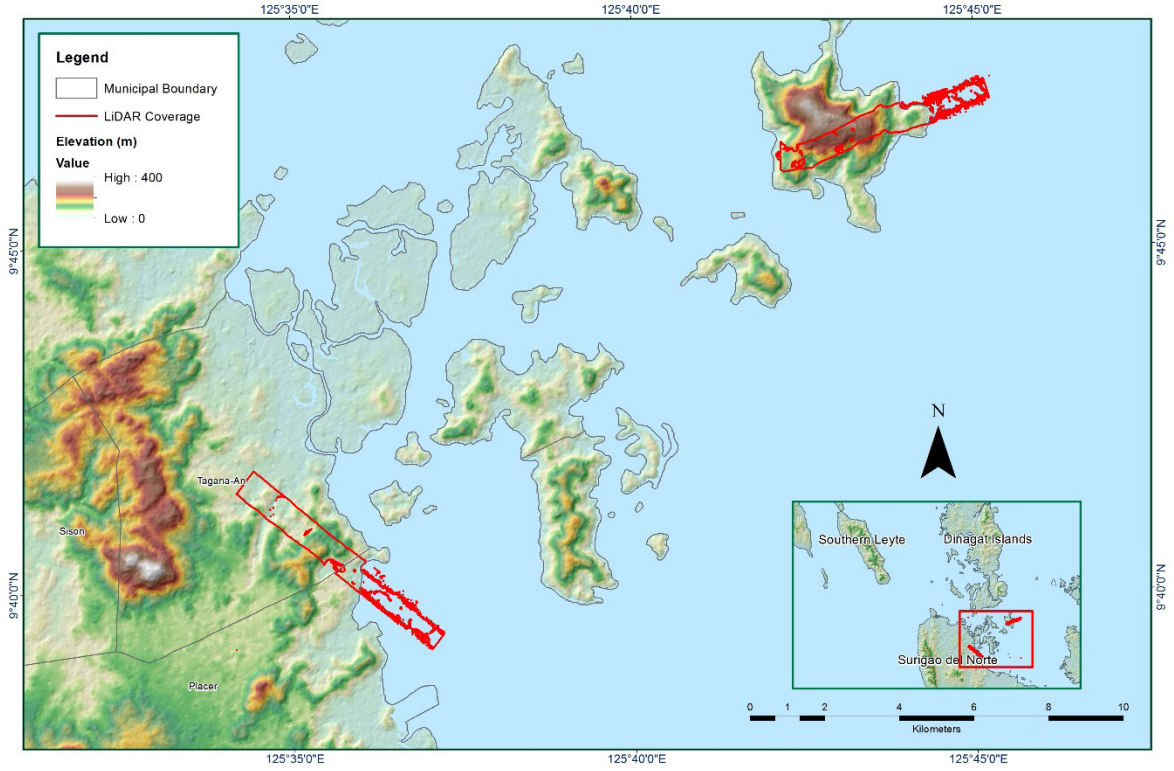


Figure A-8.80 Coverage of LiDAR data

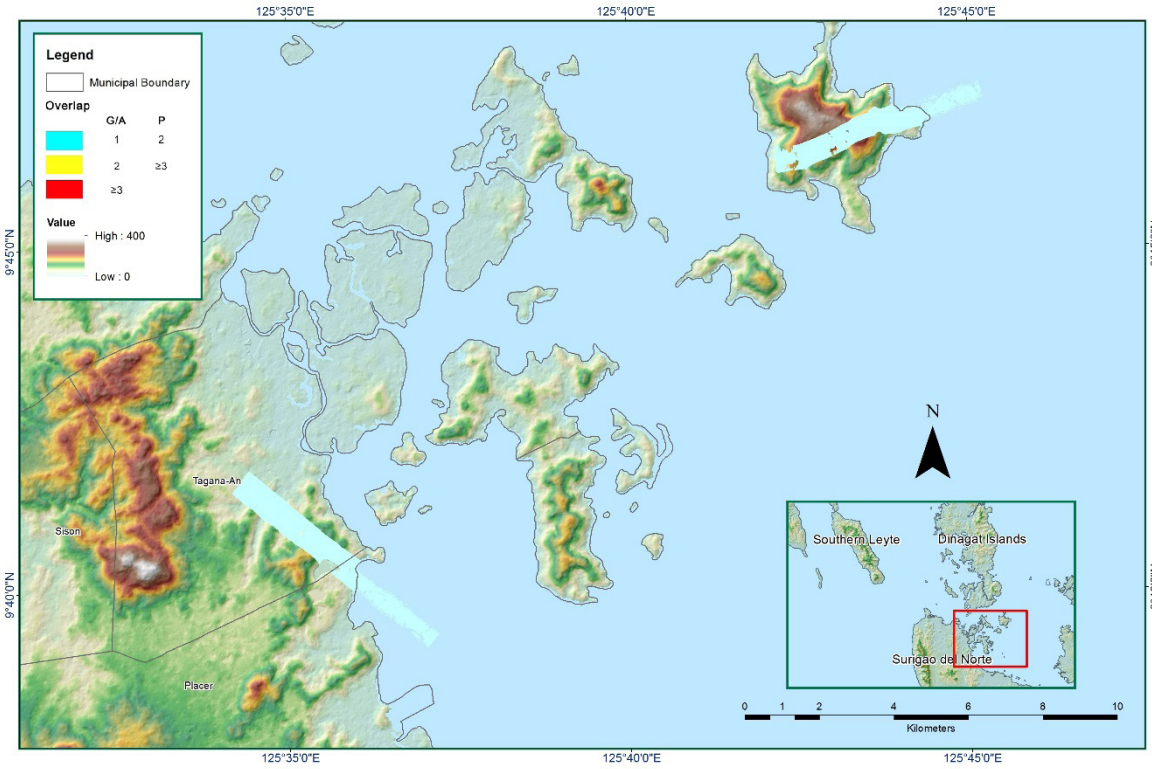


Figure A-8.81 Image of data overlap

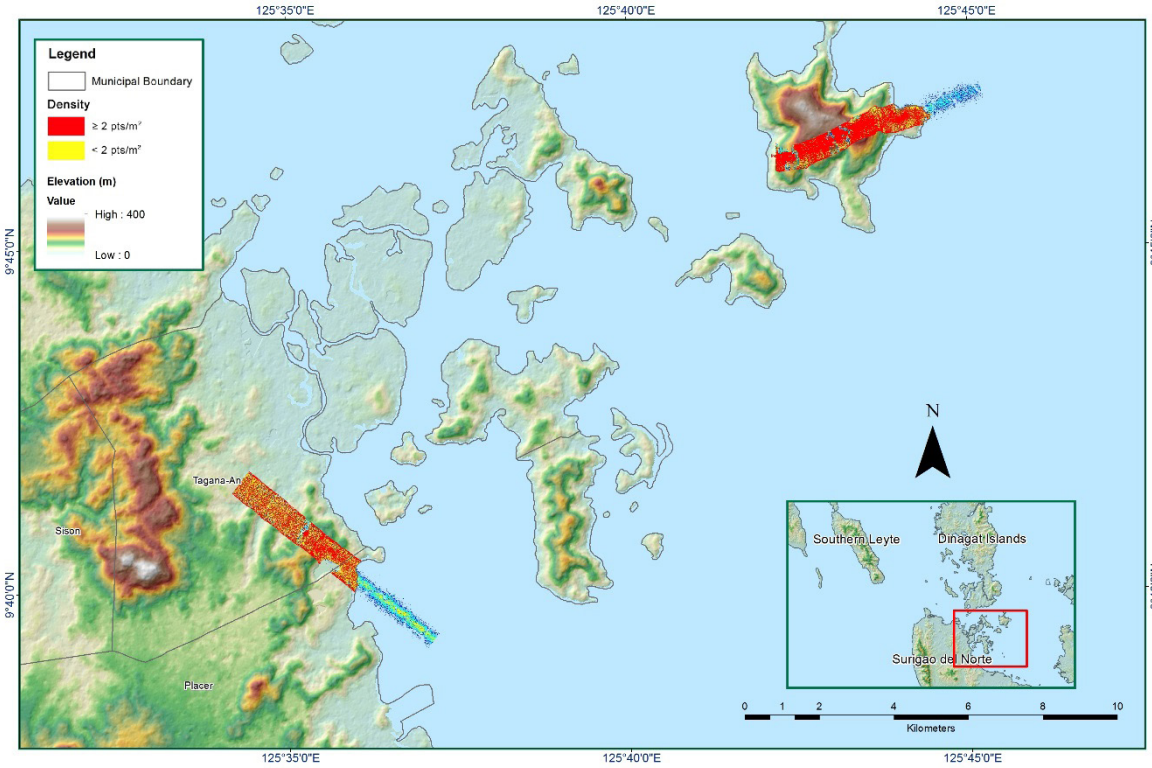


Figure A-8.82 Density Map of merged LiDAR data

Table A-8.13. Mission Summary Report for Mission Blk59G Supplement

Flight Area	Surigao City
Mission Name	Block59G Supplement
Inclusive Flights	1970A
Range data size	6.25 GB
Base data size	9.05 MB
POS	153 MB
Image	NA
Transfer date	October 31, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.17
RMSE for East Position (<4.0 cm)	1.45
RMSE for Down Position (<8.0 cm)	2.22
Boresight correction stdev (<0.001deg)	0.000611
IMU attitude correction stdev (<0.001deg)	0.001589
GPS position stdev (<0.01m)	0.0035
Minimum % overlap (>25)	42.17
Ave point cloud density per sq.m. (>2.0)	2.13
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	75
Maximum Height	338.86 m
Minimum Height	52.55 m
Classification (# of points)	
Ground	10543342
Low vegetation	9880482
Medium vegetation	21037382
High vegetation	10479343
Building	299468
Ortophoto	No

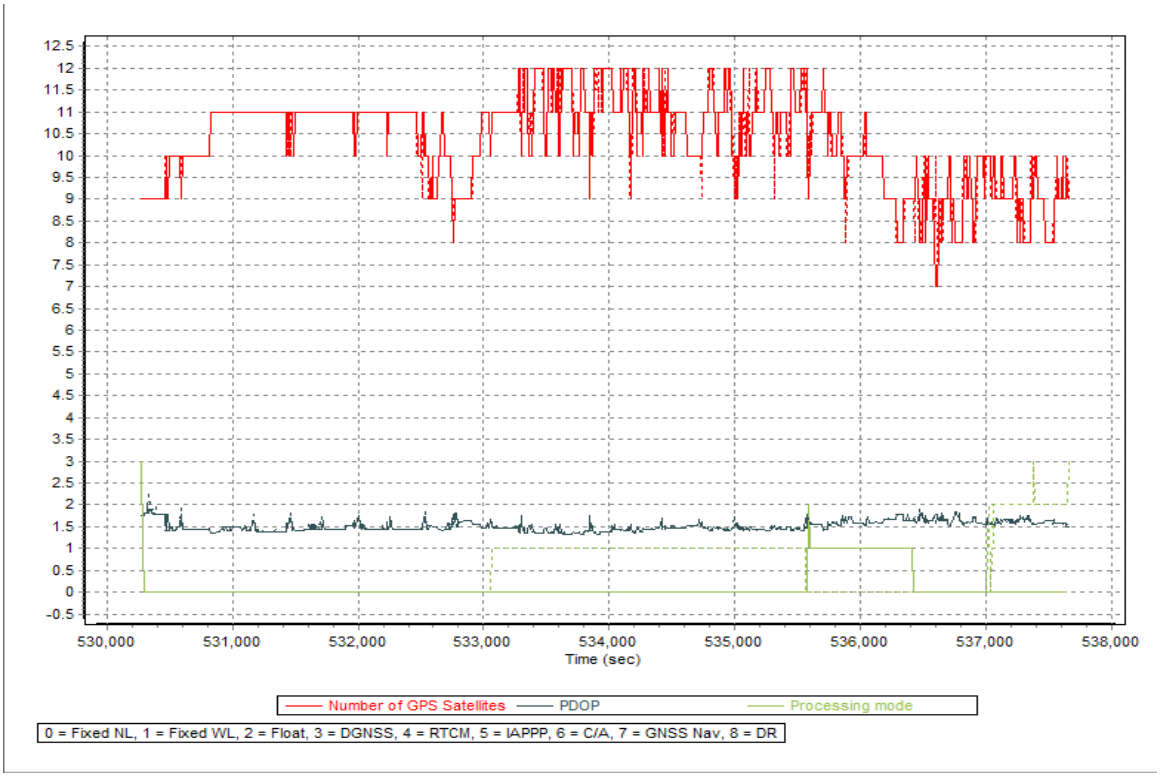


Figure A-8.83 Solution Status

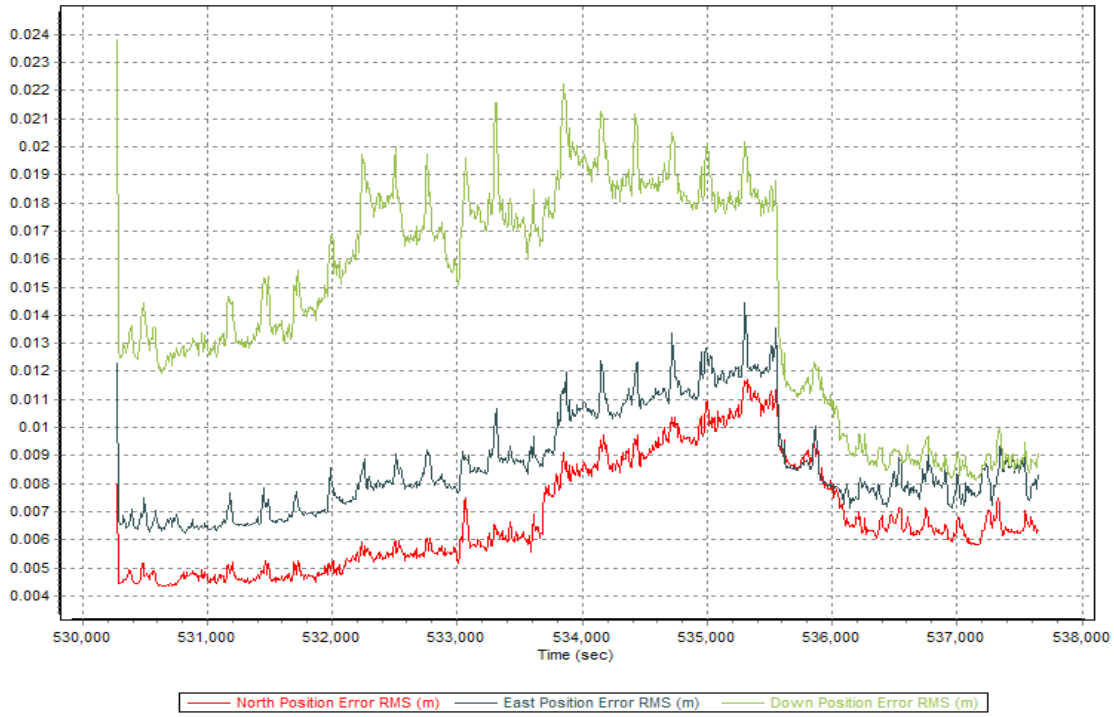


Figure A-8.84 Smoothed Performance Metric Parameters

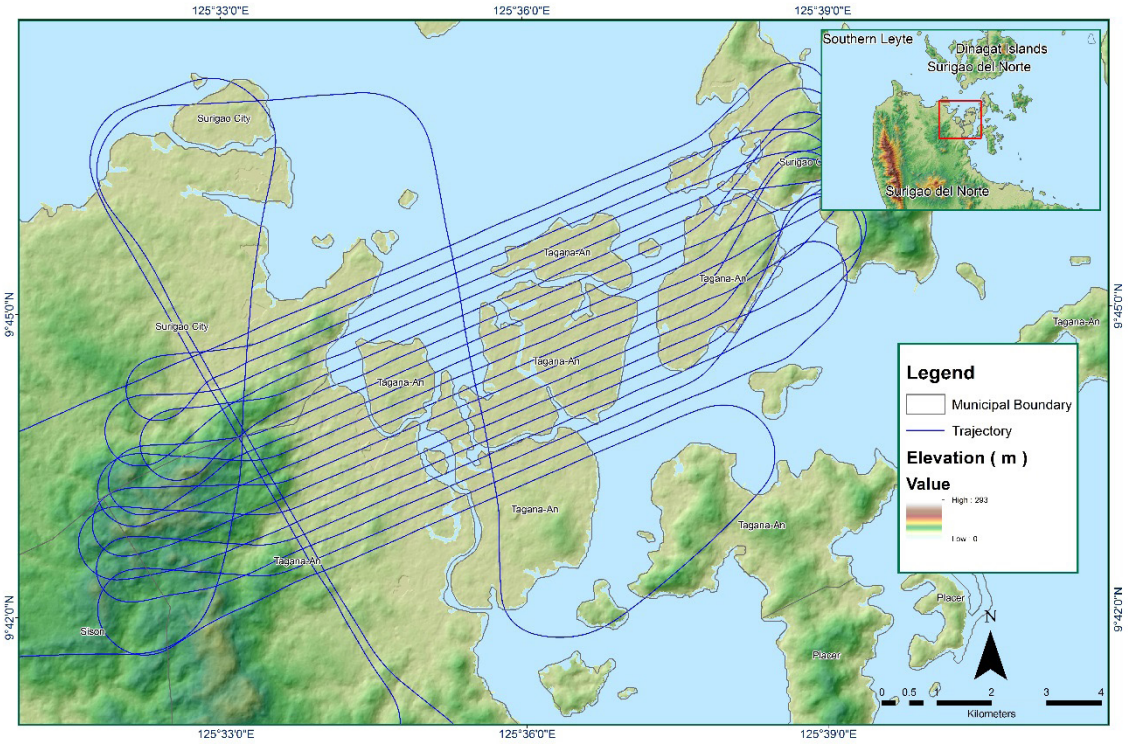


Figure A-8.85 Best Estimated Trajectory

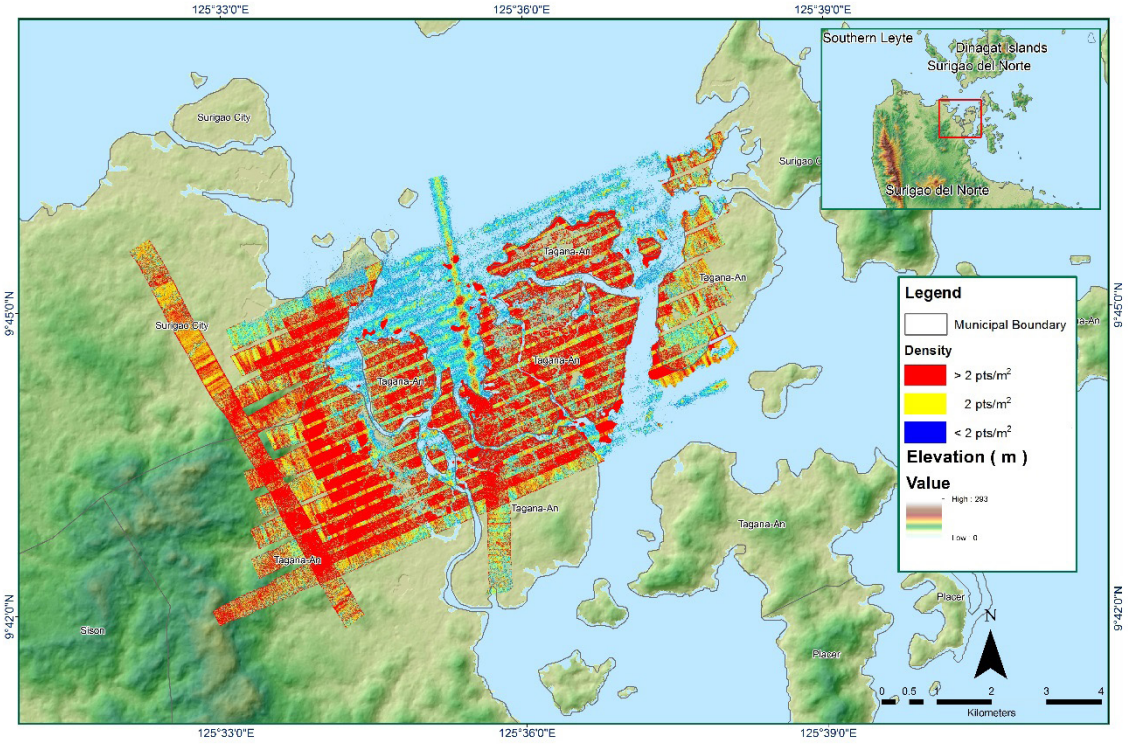


Figure A-8.86 Coverage of LiDAR data

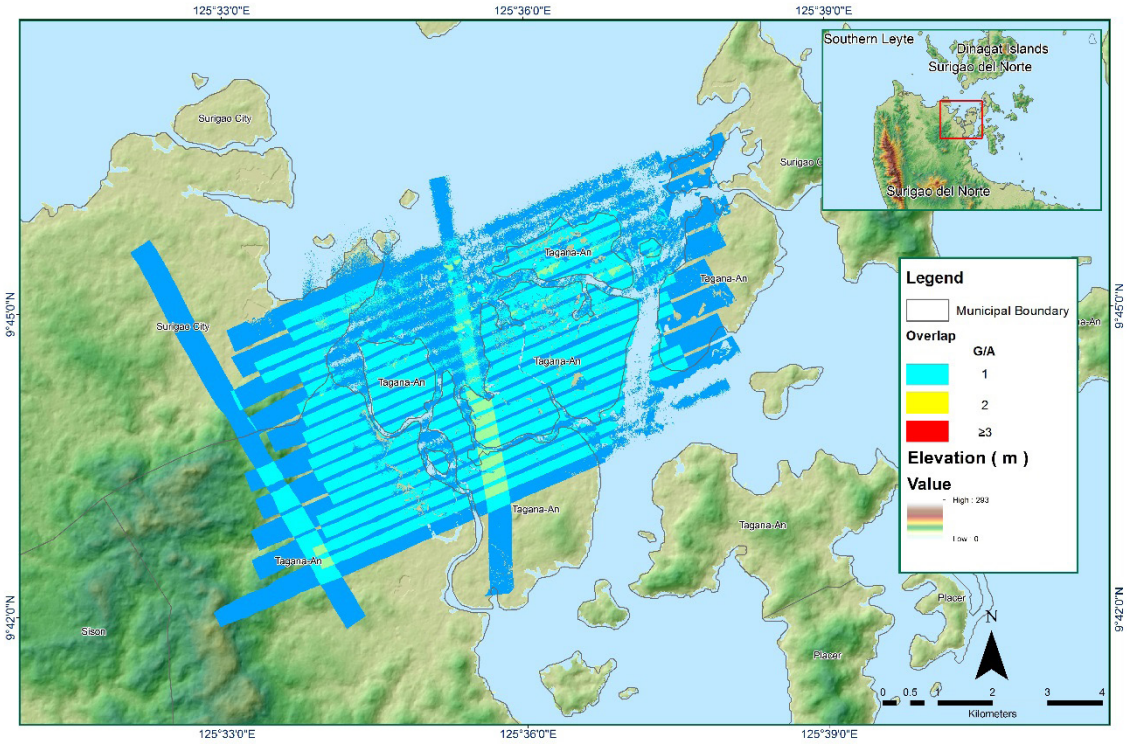


Figure A-8.87 Image of data overlap

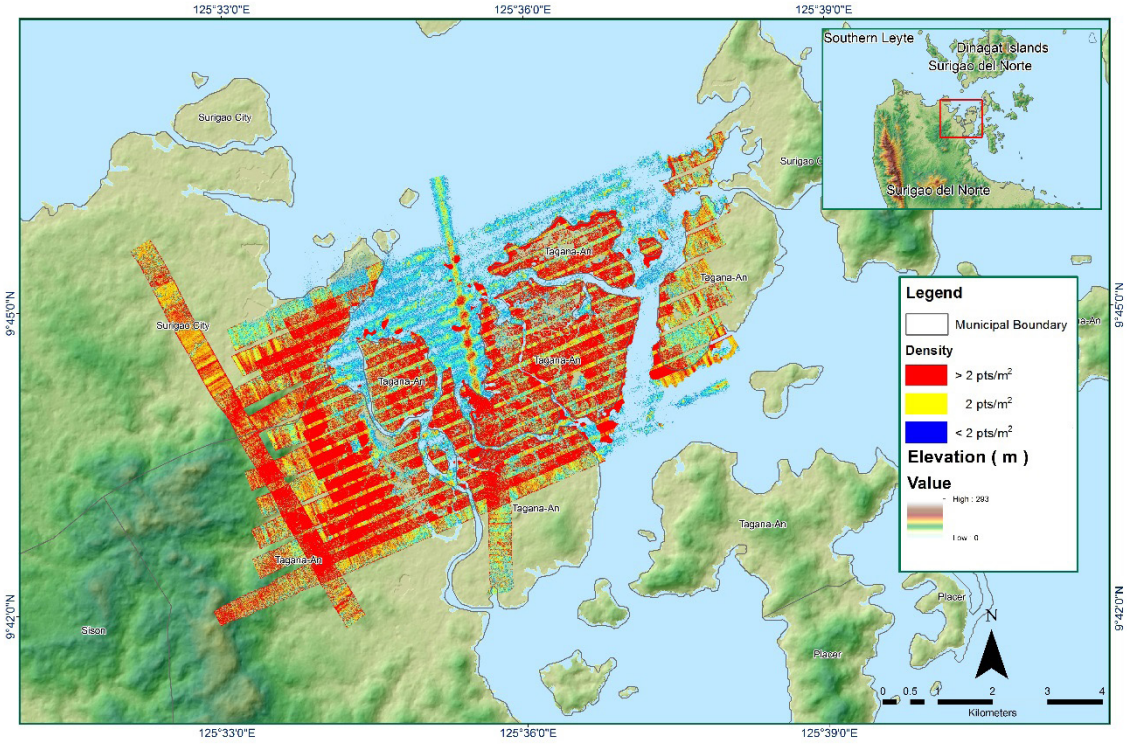


Figure A-8.88 Density Map of merged LiDAR data

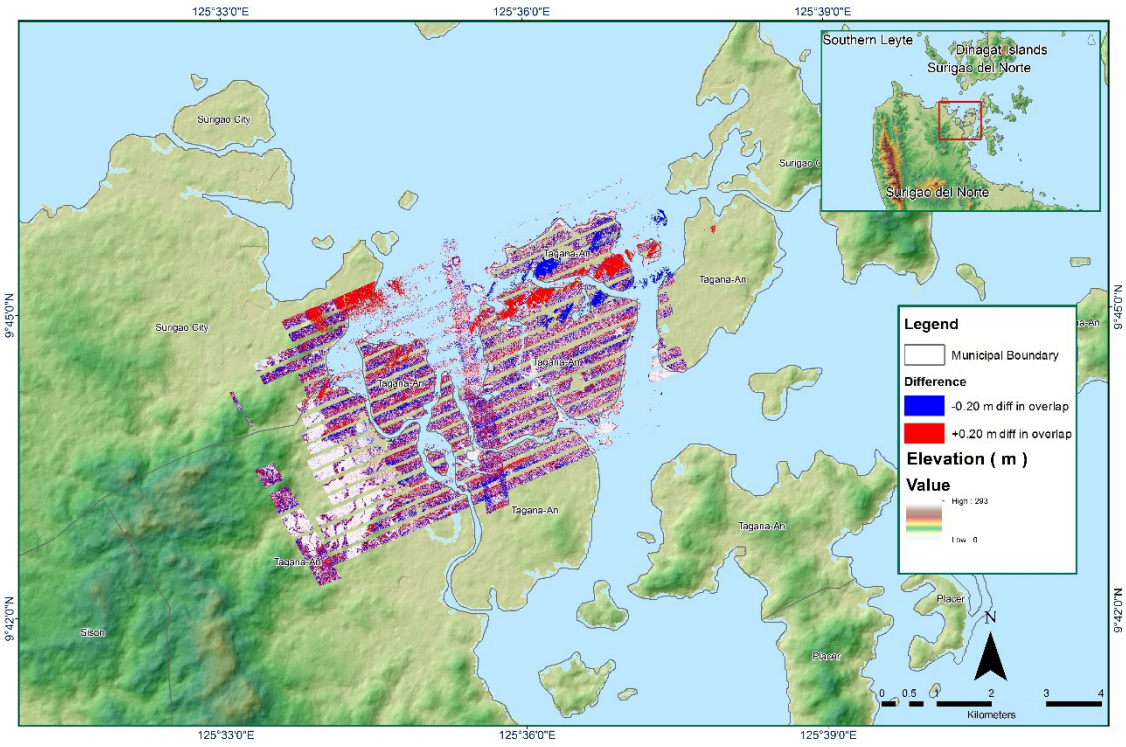


Figure A-8.89 Elevation Difference Between flight lines

Table A-8.14. Mission Summary Report for Mission Blk59D Supplement

Flight Area	Surigao City
Mission Name	Block 59D Supplement (Surigao del Norte)
Inclusive Flights	7300GC
Range data size	15.40 GB
POS	216 MB
Image	N/A
Transfer date	June 20, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.55
RMSE for East Position (<4.0 cm)	2.10
RMSE for Down Position (<8.0 cm)	5.40
Boresight correction stdev (<0.001deg)	0.000347
IMU attitude correction stdev (<0.001deg)	0.000869
GPS position stdev (<0.01m)	0.0101
Minimum % overlap (>25)	28.38%
Ave point cloud density per sq.m. (>2.0)	3.85
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	53
Maximum Height	747.46
Minimum Height	107.99
Classification (# of points)	
Ground	6,167,045
Low vegetation	4,538,106
Medium vegetation	12,863,701
High vegetation	86,839,609
Building	1,121,284
Ortophoto	No

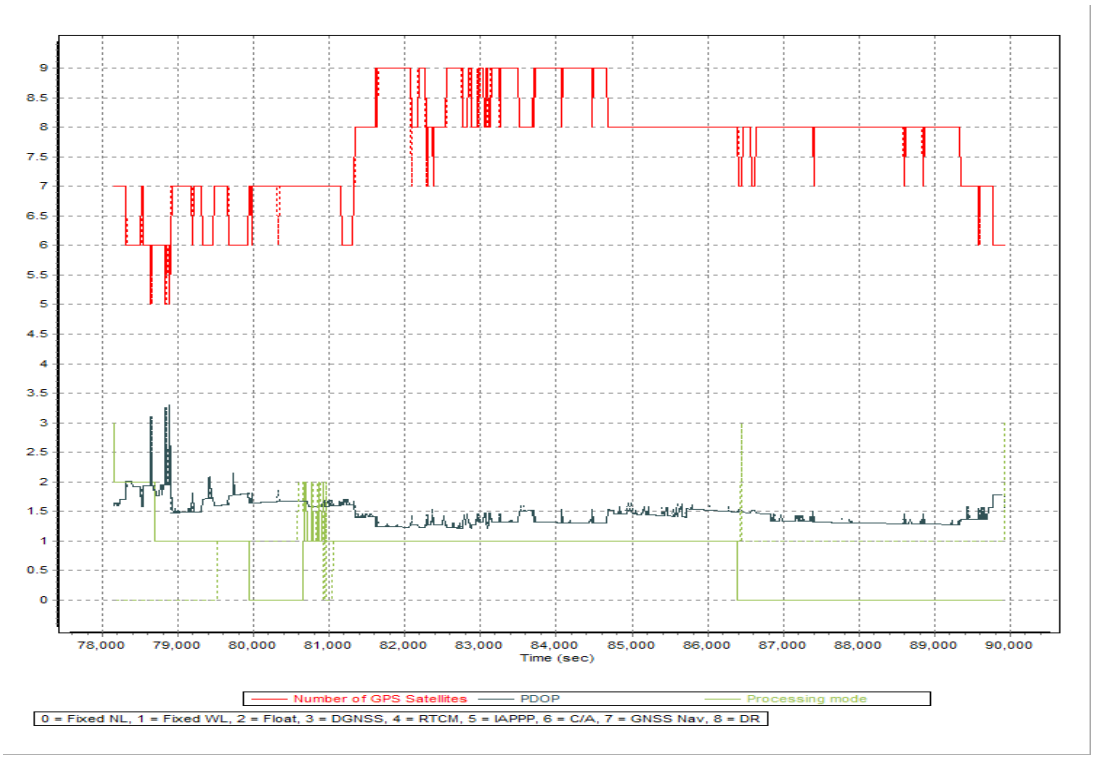


Figure A-8.90 Solution Status

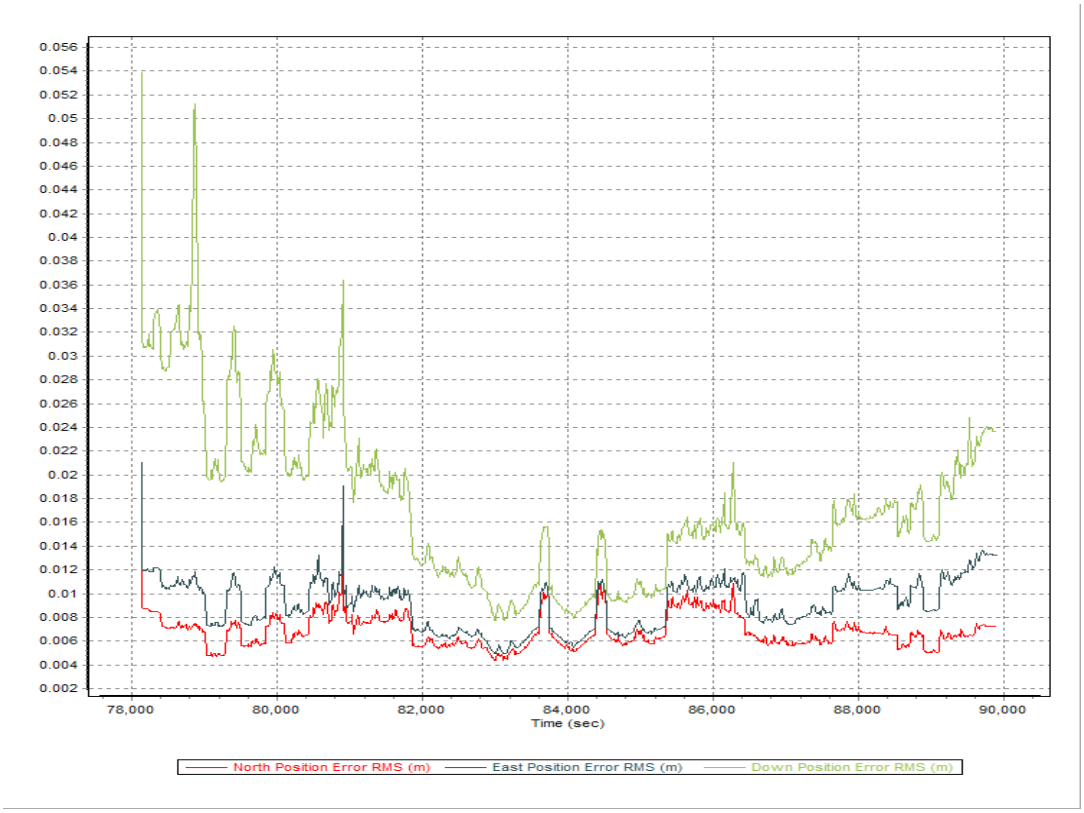


Figure A-8.91 Smoothed Performance Metric Parameters

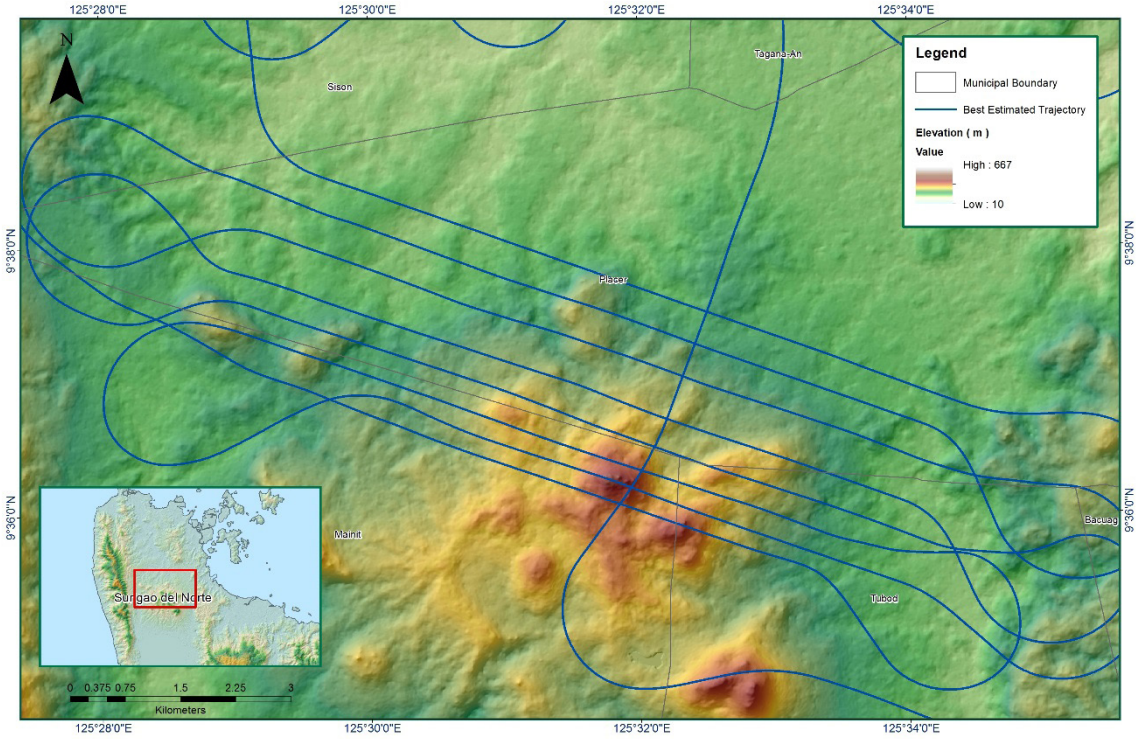


Figure A-8.92 Best Estimated Trajectory

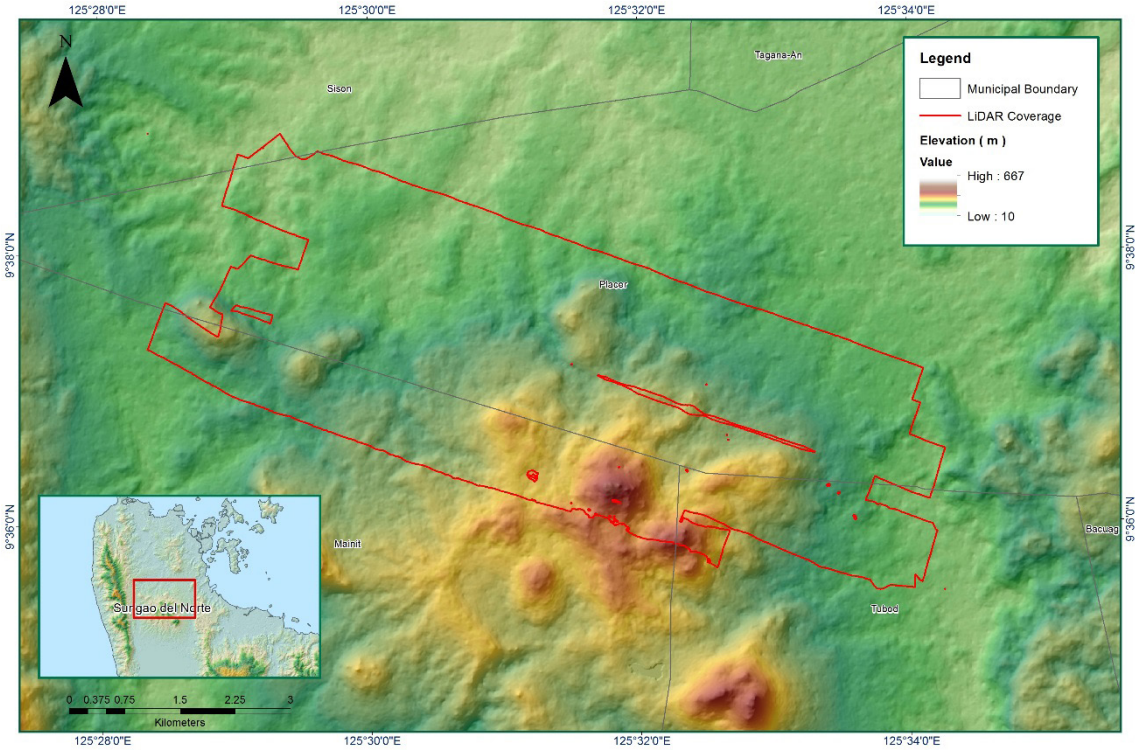


Figure A-8.93 Coverage of LiDAR data

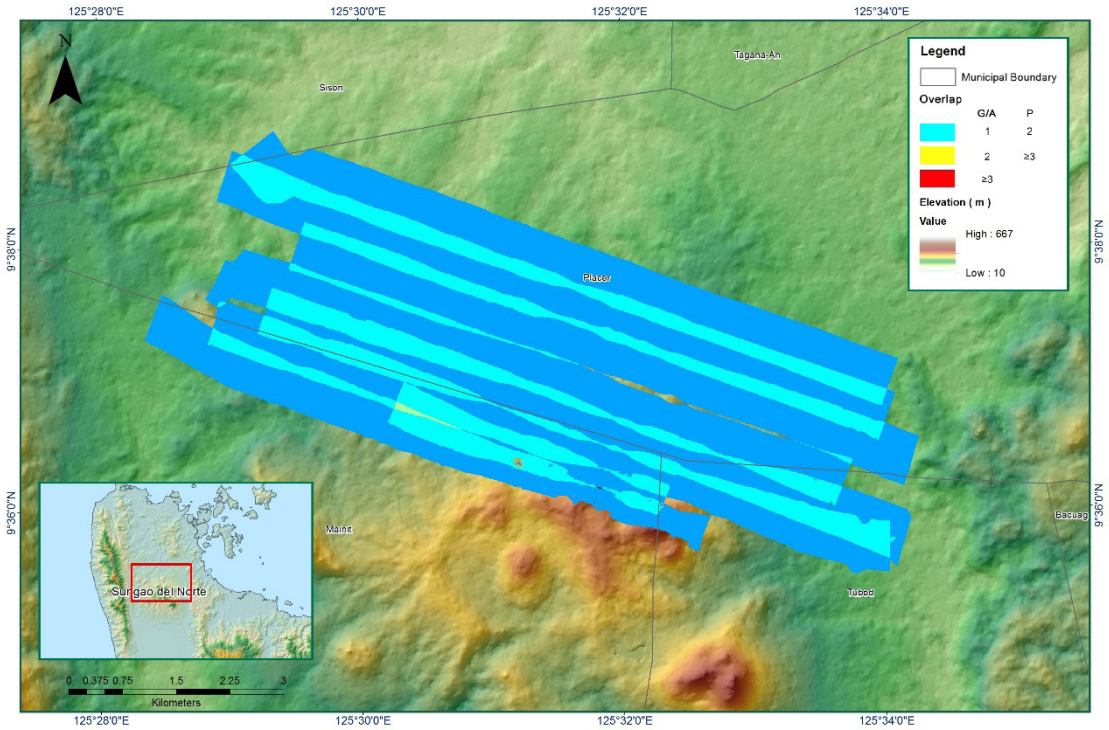


Figure A-8.94 Image of data overlap

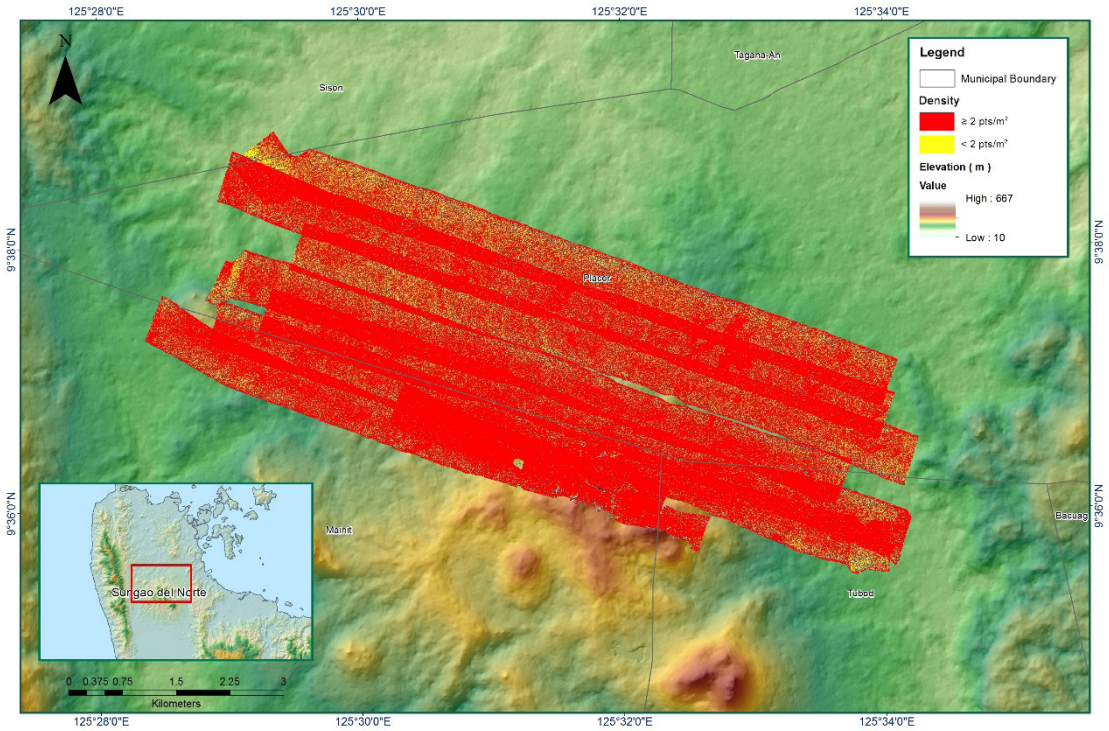


Figure A-8.95 Density Map of merged LiDAR data

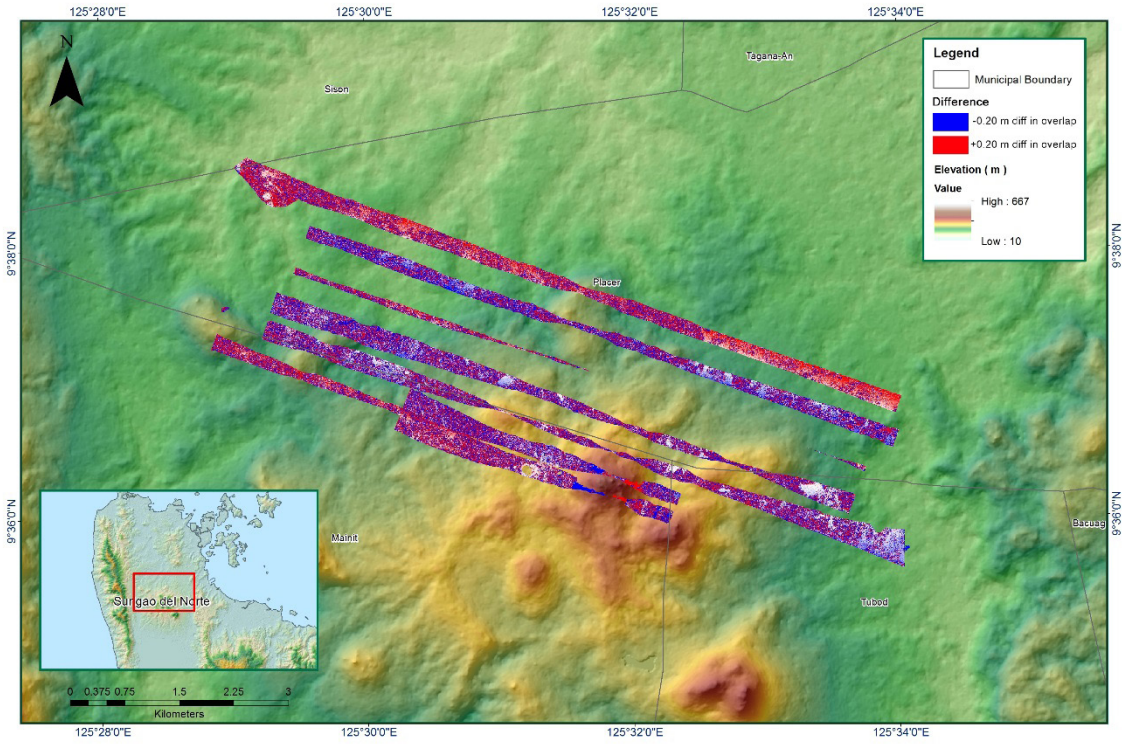


Figure A-8.96 Elevation Difference Between flight lines

Table A-8.15. Mission Summary Report for Mission Blk59D Supplement

Flight Area	Surigao City
Mission Name	Block 60D (Surigao del Norte)
Inclusive Flights	7288GC, 7292GC & 7296GC
Range data size	62.20 GB
POS	748 MB
Image	N/A
Transfer date	June 16 & 20, 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)	1.10
RMSE for East Position (<4.0 cm)	1.50
RMSE for Down Position (<8.0 cm)	3.00
Boresight correction stdev (<0.001deg)	0.000262
IMU attitude correction stdev (<0.001deg)	0.001423
GPS position stdev (<0.01m)	0.0029
Minimum % overlap (>25)	30.61%
Ave point cloud density per sq.m. (>2.0)	3.49
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	387
Maximum Height	962.45 m
Minimum Height	68.11 m
Classification (# of points)	
Ground	77,824,017
Low vegetation	66,577,816
Medium vegetation	100,876,714
High vegetation	420,021,332
Building	9,261,425
Ortophoto	No

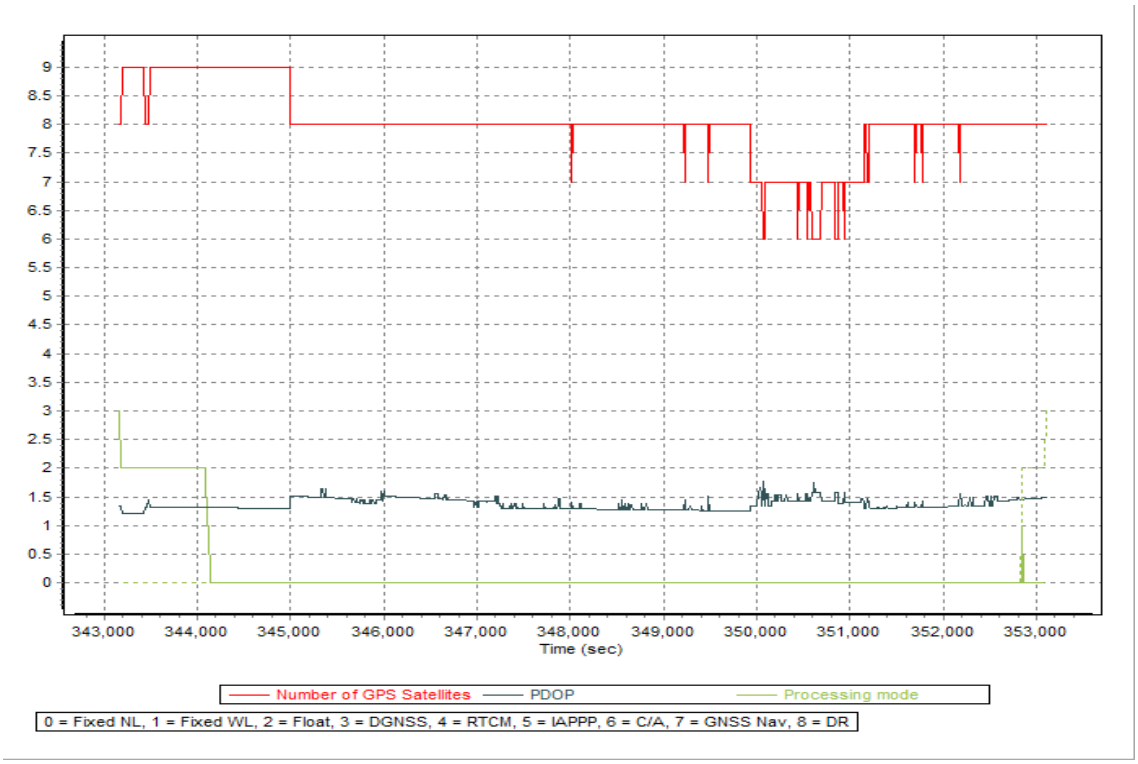


Figure A-8.97 Solution Status

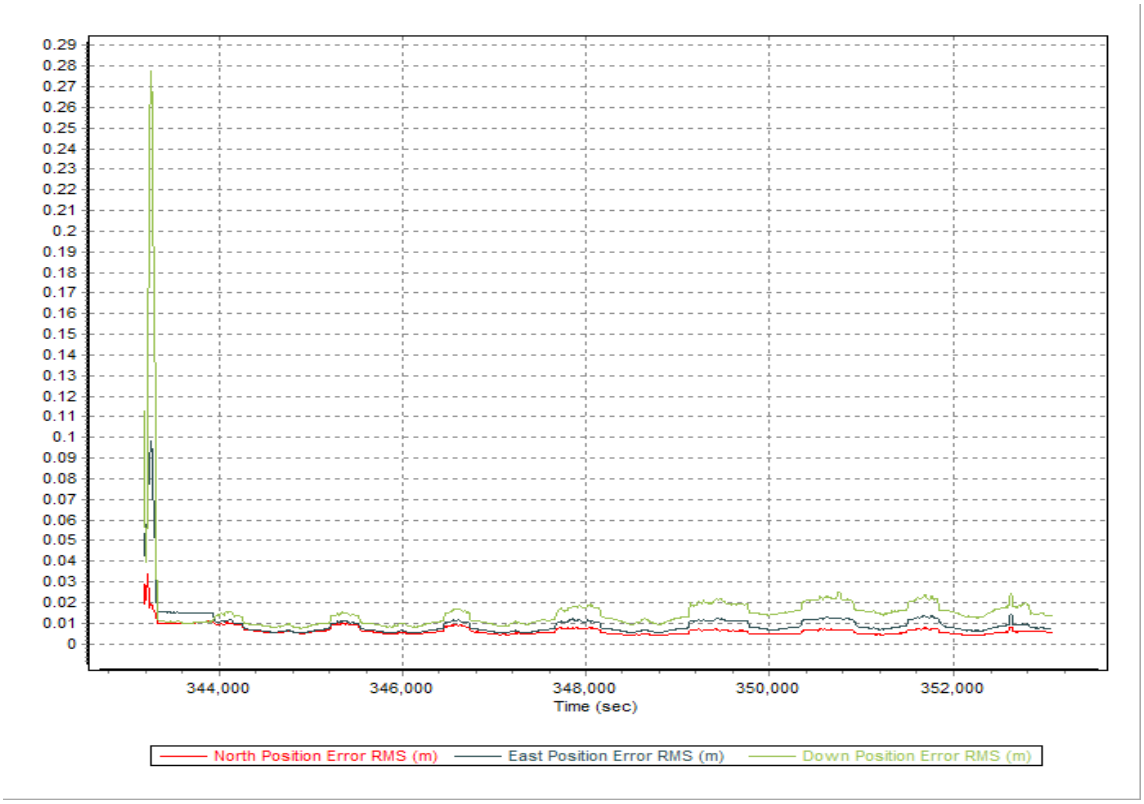


Figure A-8.98 Smoothed Performance Metric Parameters

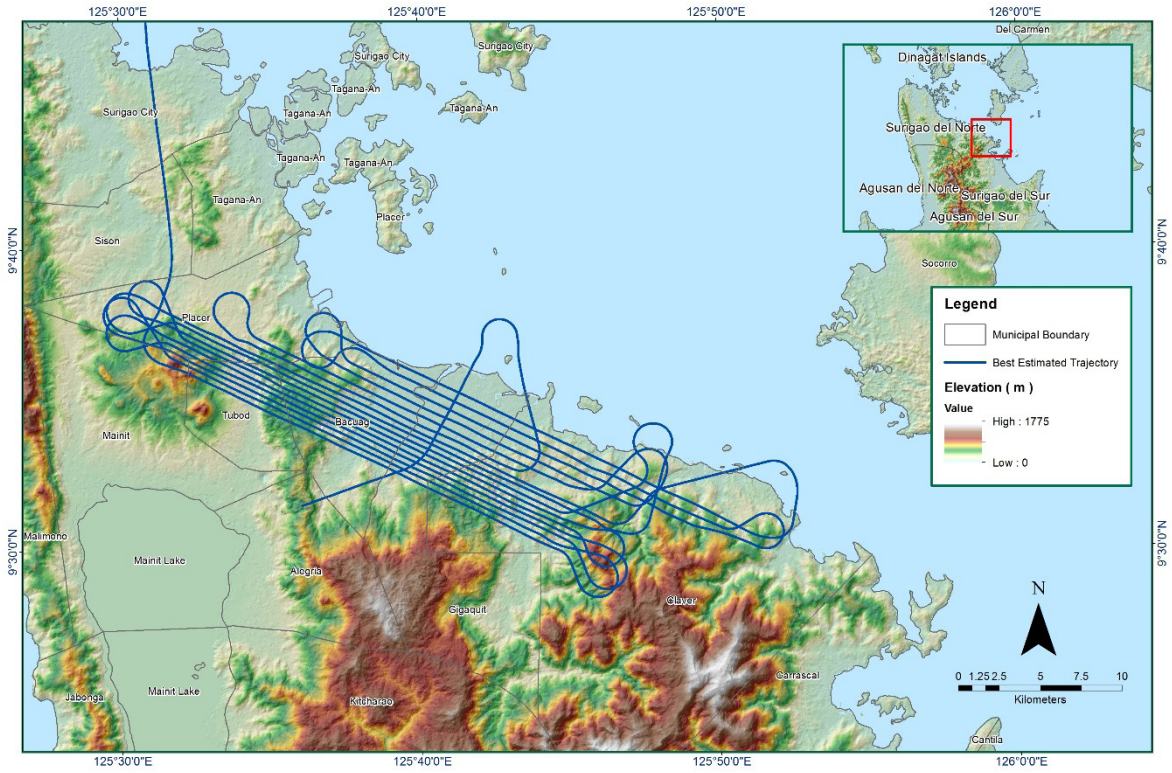


Figure A-8.99 Best Estimated Trajectory

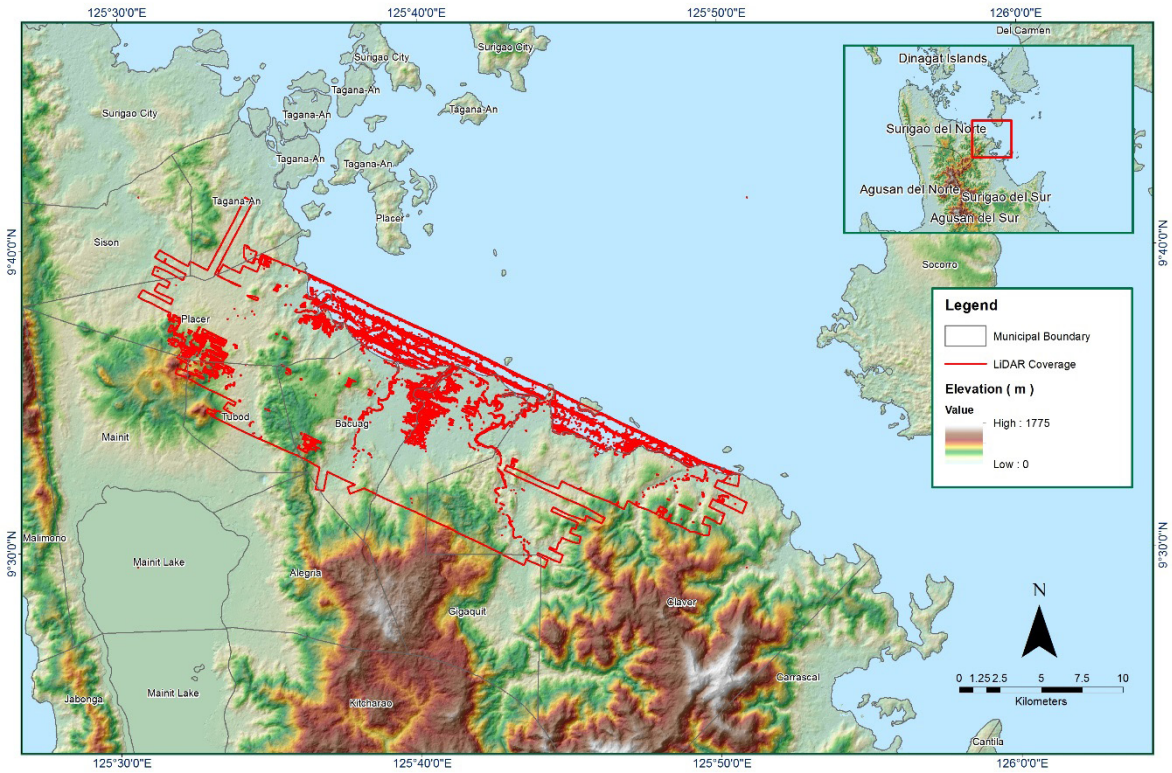


Figure A-8.100 Coverage of LiDAR data

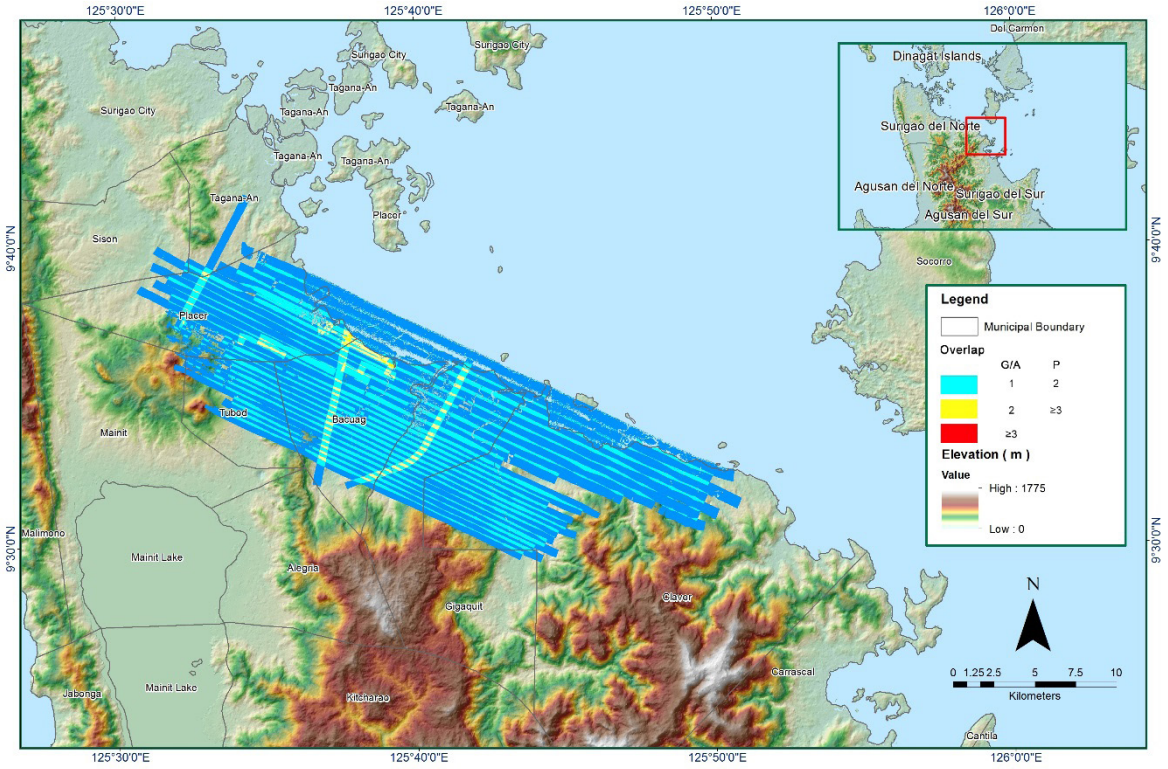


Figure A-8.101 Image of data overlap

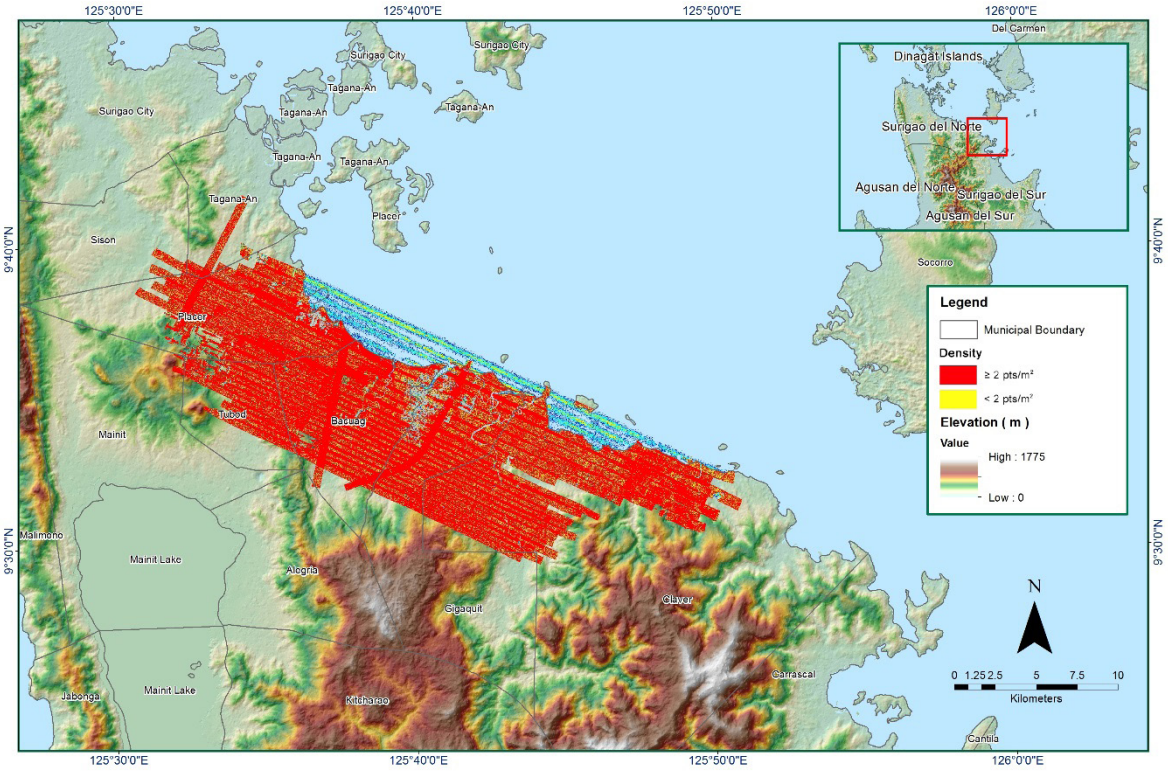


Figure A-8.102 Density Map of merged LiDAR data

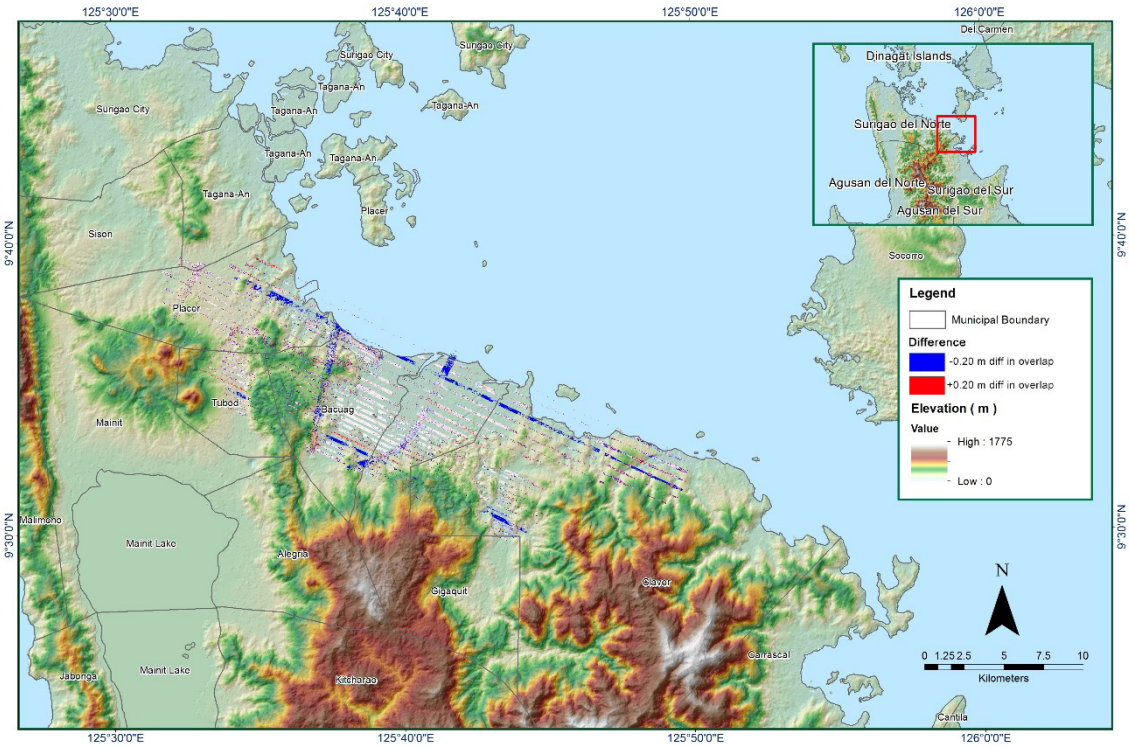


Figure A-8.103 Elevation Difference Between flight lines

Annex 9. Surigao Model Basin Parameters

Table A-9.1. Surigao 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
W1000	7.90	77.89	0.00	0.5699	1.9947	Discharge	0.0871	0.75	Ratio to Peak	0.30
W1010	10.49	74.59	0.00	0.4225	1.4788	Discharge	0.1381	0.75	Ratio to Peak	0.30
W1020	10.44	74.66	0.00	0.5052	1.7681	Discharge	0.1318	0.75	Ratio to Peak	0.30
W1030	6.95	79.17	0.00	0.3247	1.1365	Discharge	0.0675	0.75	Ratio to Peak	0.30
W1040	11.63	73.23	0.00	0.3820	1.3370	Discharge	0.1503	0.75	Ratio to Peak	0.30
W1080	7.20	78.83	0.00	0.1969	0.6892	Discharge	0.0063	0.75	Ratio to Peak	0.30
W1090	7.52	78.39	0.00	0.5743	2.0101	Discharge	0.0784	0.75	Ratio to Peak	0.30
W1100	9.61	75.68	0.00	0.2898	1.0141	Discharge	0.0416	0.75	Ratio to Peak	0.30
W1110	15.12	69.36	0.00	0.5642	1.9746	Discharge	0.0985	0.75	Ratio to Peak	0.30
W1130	10.65	74.40	0.00	0.4046	1.4162	Discharge	0.0970	0.75	Ratio to Peak	0.30
W1140	14.77	69.72	0.00	0.6851	2.3979	Discharge	0.1576	0.75	Ratio to Peak	0.30
W1150	9.68	75.60	0.00	0.8660	3.0308	Discharge	0.0918	0.75	Ratio to Peak	0.30
W1170	19.95	64.62	0.00	1.1945	4.1809	Discharge	0.1614	0.75	Ratio to Peak	0.30
W1180	13.25	71.38	0.00	0.6713	2.3496	Discharge	0.0610	0.75	Ratio to Peak	0.30
W1190	53.25	43.94	0.00	1.6008	5.6027	Discharge	0.0697	0.75	Ratio to Peak	0.30
W1200	16.35	68.09	0.00	0.6190	2.1666	Discharge	0.0650	0.75	Ratio to Peak	0.30
W1220	13.11	71.54	0.00	0.6075	2.1263	Discharge	0.0559	0.75	Ratio to Peak	0.30
W1230	12.30	72.45	0.00	0.4329	1.5150	Discharge	0.0434	0.75	Ratio to Peak	0.30
W1240	37.36	51.86	0.00	0.7487	2.6203	Discharge	0.0105	0.75	Ratio to Peak	0.30
W1270	8.47	77.14	0.00	0.2131	0.7459	Discharge	0.0111	0.75	Ratio to Peak	0.30
W1280	15.09	69.39	0.00	0.7029	2.4601	Discharge	0.1049	0.75	Ratio to Peak	0.30
W1290	14.96	69.53	0.00	0.3697	1.2938	Discharge	0.0684	0.75	Ratio to Peak	0.30
W1300	10.09	75.09	0.00	0.2465	0.8626	Discharge	0.0140	0.75	Ratio to Peak	0.30

W1310	15.11	69.37	0.00	0.5400	1.8899	Discharge	0.0569	0.75	Ratio to Peak	0.30
W1320	15.10	69.38	0.00	0.6338	2.2181	Discharge	0.1204	0.75	Ratio to Peak	0.30
W1340	33.68	54.12	0.00	0.9452	3.3080	Discharge	0.0727	0.75	Ratio to Peak	0.30
W1410	5.82	80.74	6.30	0.5337	1.8679	Discharge	0.0183	0.75	Ratio to Peak	0.30
W1460	5.96	80.55	0.00	0.2210	0.7733	Discharge	0.0035	0.75	Ratio to Peak	0.30
W1470	6.06	80.41	0.04	0.4485	1.5697	Discharge	0.0091	0.75	Ratio to Peak	0.30
W1510	9.65	75.63	0.00	0.3048	1.0666	Discharge	0.0469	0.75	Ratio to Peak	0.30
W1520	14.74	69.76	0.00	0.5368	1.8787	Discharge	0.2250	0.75	Ratio to Peak	0.30
W1560	9.63	75.66	0.00	0.8135	2.8474	Discharge	0.1311	0.75	Ratio to Peak	0.30
W1570	6.93	79.19	0.00	0.1867	0.6535	Discharge	0.0053	0.75	Ratio to Peak	0.30
W1610	7.56	78.35	0.00	0.8694	3.0430	Discharge	0.1310	0.75	Ratio to Peak	0.30
W1660	8.29	77.37	0.00	0.4284	1.4994	Discharge	0.0828	0.75	Ratio to Peak	0.30
W1670	18.72	65.77	0.00	0.9066	3.1730	Discharge	0.2703	0.75	Ratio to Peak	0.30
W1720	8.76	76.77	0.00	0.4000	1.4001	Discharge	0.0612	0.75	Ratio to Peak	0.30
W1760	10.92	74.08	0.00	0.0801	0.2803	Discharge	0.0007	0.75	Ratio to Peak	0.30
W1770	8.71	76.82	0.00	0.4431	1.5507	Discharge	0.0911	0.75	Ratio to Peak	0.30
W1810	43.96	48.25	0.00	1.6316	5.7107	Discharge	0.1302	0.75	Ratio to Peak	0.30
W1820	16.82	67.61	0.00	0.7828	2.7398	Discharge	0.2006	0.75	Ratio to Peak	0.30
W1860	43.39	48.54	0.00	0.9703	3.3961	Discharge	0.0289	0.75	Ratio to Peak	0.30
W1870	24.09	61.05	0.00	0.8155	2.8544	Discharge	0.1539	0.75	Ratio to Peak	0.30
W1910	85.05	33.65	0.00	1.7437	6.1028	Discharge	0.1280	0.75	Ratio to Peak	0.30
W1920	87.76	33.00	0.00	1.6546	5.7912	Discharge	0.1327	0.75	Ratio to Peak	0.30
W1970	10.59	74.48	0.00	0.2220	0.7771	Discharge	0.0192	0.75	Ratio to Peak	0.30
W2010	49.77	45.46	1.76	1.4583	5.1039	Discharge	0.0357	0.75	Ratio to Peak	0.30
W2020	32.84	54.66	0.00	0.3270	1.1446	Discharge	0.0050	0.75	Ratio to Peak	0.30
W2060	10.68	74.36	6.18	0.3142	1.0997	Discharge	0.0234	0.75	Ratio to Peak	0.30
W2110	15.89	68.56	60.84	0.2644	0.9252	Discharge	0.0044	0.75	Ratio to Peak	0.30
W2120	19.48	65.06	42.86	0.1002	0.3508	Discharge	0.0005	0.75	Ratio to Peak	0.30
W3130	3.05	84.90	0.00	0.3790	1.3265	Discharge	0.0066	0.75	Ratio to Peak	0.30
W3140	10.82	74.20	0.00	0.2977	1.0420	Discharge	0.0046	0.75	Ratio to Peak	0.30

W3180	3.43	84.31	61.99	0.7548	2.6416	Discharge	0.0439	0.75	Ratio to Peak	0.30
W3190	5.12	81.76	59.39	0.5906	2.0670	Discharge	0.0666	0.75	Ratio to Peak	0.30
W690	5.50	81.21	0.00	0.6374	2.2310	Discharge	0.1677	0.75	Ratio to Peak	0.30
W720	6.09	80.37	8.72	0.8621	3.0172	Discharge	0.0368	0.75	Ratio to Peak	0.30
W730	8.76	76.76	9.27	0.4675	1.6364	Discharge	0.0376	0.75	Ratio to Peak	0.30
W740	7.47	78.46	2.49	0.8944	3.1303	Discharge	0.0267	0.75	Ratio to Peak	0.30
W760	7.29	78.71	0.03	0.2617	0.9160	Discharge	0.0840	0.75	Ratio to Peak	0.30
W770	9.99	75.21	0.25	0.2913	1.0196	Discharge	0.0608	0.75	Ratio to Peak	0.30
W780	6.65	79.59	6.89	0.5314	1.8600	Discharge	0.0692	0.75	Ratio to Peak	0.30
W790	9.25	76.14	1.24	0.6689	2.3410	Discharge	0.1472	0.75	Ratio to Peak	0.30
W800	5.87	80.68	24.59	0.5758	2.0152	Discharge	0.0277	0.75	Ratio to Peak	0.30
W810	9.15	76.26	0.00	0.4072	1.4251	Discharge	0.1351	0.75	Ratio to Peak	0.30
W820	7.02	79.08	10.31	0.3929	1.3752	Discharge	0.0756	0.75	Ratio to Peak	0.30
W830	8.34	77.31	0.00	0.3720	1.3019	Discharge	0.0398	0.75	Ratio to Peak	0.30
W840	9.80	75.44	0.00	0.1607	0.5626	Discharge	0.0098	0.75	Ratio to Peak	0.30
W850	11.92	72.90	0.00	0.4090	1.4315	Discharge	0.0938	0.75	Ratio to Peak	0.30
W860	8.33	77.32	0.00	0.6109	2.1382	Discharge	0.1217	0.75	Ratio to Peak	0.30
W870	6.93	79.20	0.00	0.5213	1.8247	Discharge	0.0700	0.75	Ratio to Peak	0.30
W880	7.90	77.88	0.00	0.4223	1.4780	Discharge	0.0701	0.75	Ratio to Peak	0.30
W8930	7.64	78.23	0.00	0.0788	0.2757	Discharge	0.0008	0.75	Ratio to Peak	0.30
W8940	10.67	74.38	0.00	0.3615	1.2651	Discharge	0.0561	0.75	Ratio to Peak	0.30
W8980	24.19	60.97	0.00	0.4114	1.4397	Discharge	0.0150	0.75	Ratio to Peak	0.30
W8990	17.54	66.90	0.00	0.9926	3.4739	Discharge	0.0961	0.75	Ratio to Peak	0.30
W900	8.00	77.76	0.00	0.4098	1.4343	Discharge	0.0473	0.75	Ratio to Peak	0.30
W9030	7.27	78.74	0.00	0.5586	1.9550	Discharge	0.1345	0.75	Ratio to Peak	0.30
W9040	6.93	79.20	0.00	0.1766	0.6180	Discharge	0.0116	0.75	Ratio to Peak	0.30
W910	9.95	75.25	0.00	0.4980	1.7429	Discharge	0.1075	0.75	Ratio to Peak	0.30
W920	6.93	79.20	0.00	0.5307	1.8575	Discharge	0.1126	0.75	Ratio to Peak	0.30
W940	7.70	78.16	0.00	0.4982	1.7437	Discharge	0.0837	0.75	Ratio to Peak	0.30
W950	10.45	74.65	0.00	0.4422	1.5475	Discharge	0.0870	0.75	Ratio to Peak	0.30

W960	7.58	78.31	0.00	0.1758	0.6151	Discharge	0.0091	0.75	Ratio to Peak	0.30
W980	7.54	78.37	0.00	0.2382	0.8338	Discharge	0.0389	0.75	Ratio to Peak	0.30
W990	9.96	75.25	0.00	0.4620	1.6169	Discharge	0.1280	0.75	Ratio to Peak	0.30

Annex 10. Surigao Model Reach Parameters

Table A-10.1. Surigao Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing					
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width
R10	Automatic Fixed Interval	121.57	0.000177	0.025	Rectangle	3.90
R110	Automatic Fixed Interval	1584.40	0.000177	0.025	Rectangle	63.02
R120	Automatic Fixed Interval	1330.20	0.000177	0.025	Rectangle	60.85
R1430	Automatic Fixed Interval	493.55	0.000203	0.025	Rectangle	100.05
R1480	Automatic Fixed Interval	209.71	0.000177	0.025	Rectangle	85.44
R150	Automatic Fixed Interval	2331.00	0.000297	0.025	Rectangle	55.24
R1580	Automatic Fixed Interval	104.85	0.002051	0.025	Rectangle	32.06
R160	Automatic Fixed Interval	476.98	0.007321	0.025	Rectangle	21.67
R1640	Automatic Fixed Interval	3762.30	0.010436	0.025	Rectangle	21.44
R170	Automatic Fixed Interval	2355.80	0.000843	0.025	Rectangle	47.75
R1730	Automatic Fixed Interval	2362.80	0.005909	0.025	Rectangle	24.77
R1790	Automatic Fixed Interval	3154.30	0.001262	0.025	Rectangle	63.95
R1980	Automatic Fixed Interval	889.12	0.031933	0.025	Rectangle	16.99
R20	Automatic Fixed Interval	445.56	0.000177	0.025	Rectangle	3.90
R200	Automatic Fixed Interval	2562.50	0.000454	0.025	Rectangle	44.28
R2030	Automatic Fixed Interval	379.71	0.007975	0.025	Rectangle	39.74
R2080	Automatic Fixed Interval	355.56	0.004022	0.025	Rectangle	38.79
R210	Automatic Fixed Interval	2310.70	0.001743	0.025	Rectangle	42.41
R2130	Automatic Fixed Interval	52.43	0.006881	0.025	Rectangle	36.60
R240	Automatic Fixed Interval	2196.20	0.001151	0.025	Rectangle	41.61
R250	Automatic Fixed Interval	1382.00	0.001029	0.025	Rectangle	59.58
R270	Automatic Fixed Interval	2048.90	0.008748	0.025	Rectangle	27.59
R280	Automatic Fixed Interval	3990.00	0.003174	0.025	Rectangle	47.28
R290	Automatic Fixed Interval	894.26	0.000403	0.025	Rectangle	61.66
R310	Automatic Fixed Interval	1126.40	0.006687	0.025	Rectangle	27.68
R3150	Automatic Fixed Interval	362.13	0.001424	0.025	Rectangle	159.95
R340	Automatic Fixed Interval	2163.50	0.001012	0.025	Rectangle	64.92
R370	Automatic Fixed Interval	191.42	0.002024	0.025	Rectangle	50.43
R380	Automatic Fixed Interval	210.71	0.011796	0.025	Rectangle	26.53
R390	Automatic Fixed Interval	434.56	0.001830	0.025	Rectangle	63.71
R40	Automatic Fixed Interval	456.27	0.000177	0.025	Rectangle	96.52
R400	Automatic Fixed Interval	3103.90	0.003913	0.025	Rectangle	64.92
R420	Automatic Fixed Interval	1330.50	0.001548	0.025	Rectangle	44.81
R440	Automatic Fixed Interval	2219.70	0.002115	0.025	Rectangle	41.88
R470	Automatic Fixed Interval	5150.40	0.003591	0.025	Rectangle	30.18
R480	Automatic Fixed Interval	1186.70	0.004395	0.025	Rectangle	65.43
R490	Automatic Fixed Interval	645.27	0.006077	0.025	Rectangle	35.26
R50	Automatic Fixed Interval	1787.50	0.000177	0.025	Rectangle	3.90
R510	Automatic Fixed Interval	2372.10	0.002562	0.025	Rectangle	37.40
R530	Automatic Fixed Interval	1084.30	0.002507	0.025	Rectangle	41.88

R550	Automatic Fixed Interval	467.28	0.007050	0.025	Rectangle	39.97
R560	Automatic Fixed Interval	1463.40	0.002563	0.025	Rectangle	3.90
R570	Automatic Fixed Interval	934.97	0.004852	0.025	Rectangle	24.90
R580	Automatic Fixed Interval	803.55	0.009418	0.025	Rectangle	24.90
R60	Automatic Fixed Interval	1167.40	0.000177	0.025	Rectangle	76.12
R610	Automatic Fixed Interval	3467.50	0.005793	0.025	Rectangle	22.49
R650	Automatic Fixed Interval	2801.10	0.007863	0.025	Rectangle	22.39
R660	Automatic Fixed Interval	2282.80	0.016925	0.025	Rectangle	39.97
R670	Automatic Fixed Interval	3658.50	0.007473	0.025	Rectangle	19.71
R70	Automatic Fixed Interval	2570.40	0.000961	0.025	Rectangle	7.39
R8960	Automatic Fixed Interval	1834.80	0.008986	0.025	Rectangle	26.53
R9010	Automatic Fixed Interval	3296.80	0.002251	0.025	Rectangle	41.88
R9050	Automatic Fixed Interval	650.83	0.003949	0.025	Rectangle	64.92

Annex 11. Surigao Field Validation Points

Table A-11.1. SurigaoField Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event /Date	Rain Return / Scenario
	Lat	Long					
1	9.783444	125.4821	0.577	0	-0.577	Agaton	5-year
2	9.783361	125.4813	0	0	0	Agaton	5-year
3	9.784917	125.481	0.526	0	-0.526	Agaton	5-year
4	9.785306	125.4841	3.388	0.3	-3.088	Agaton	5-year
5	9.785333	125.4835	0.339	0.47	0.131	Agaton	5-year
6	9.7855	125.4837	0	0	0	Agaton	5-year
7	9.784528	125.4836	0.808	0	-0.808	Agaton	5-year
8	9.784306	125.4834	1.043	0.42	-0.623	Agaton	5-year
9	9.786889	125.4856	0	0.24	0.24	Agaton	5-year
10	9.786667	125.4855	0.399	0.15	-0.249	Agaton	5-year
11	9.787278	125.4844	0	0.3	0.3	Agaton	5-year
12	9.7865	125.4841	0	0.49	0.49	Agaton	5-year
13	9.787028	125.4843	2.966	0	-2.966	Agaton	5-year
14	9.784361	125.4825	0.208	0	-0.208	Agaton	5-year
15	9.784083	125.483	0.585	1.1	0.515	Agaton	5-year
16	9.781306	125.4945	0.545	0.7	0.155	Agaton	5-year
17	9.783667	125.4824	0	0	0	Agaton	5-year
18	9.7835	125.4816	0.586	0.63	0.044	Agaton	5-year
19	9.785861	125.481	0.636	0.56	-0.076	Agaton	5-year
20	9.785556	125.4804	0.996	1.05	0.054	Agaton	5-year
21	9.7915	125.491	0	0.05	0.05	Agaton	5-year
22	9.783583	125.4831	0	1.1	1.1	Agaton	5-year
23	9.783194	125.4826	0.549	1.18	0.631	Agaton	5-year
24	9.786806	125.4866	0	0	0	Agaton	5-year
25	9.786361	125.4854	3.598	1.5	-2.098	Agaton	5-year
26	9.785917	125.485	0	0.3	0.3	Agaton	5-year
27	9.783806	125.4832	0.86	0	-0.86	Agaton	5-year
28	9.787111	125.4795	0	0.18	0.18	Agaton	5-year
29	9.787083	125.4809	0.366	0.69	0.324	Agaton	5-year
30	9.786639	125.4821	0.324	0.65	0.326	Agaton	5-year
31	9.781306	125.4962	0.254	0.2	-0.054	Agaton	5-year
32	9.781917	125.4967	0	0	0	Agaton	5-year
33	9.7815	125.4976	0.404	0	-0.404	Agaton	5-year
34	9.785972	125.4961	0.24	0	-0.24	Agaton	5-year
35	9.784833	125.4919	0	0	0	Agaton	5-year
36	9.786417	125.4956	0	0	0	Agaton	5-year
37	9.780389	125.4945	0.195	0.14	-0.055	Agaton	5-year
38	9.779222	125.4939	0.213	0.9	0.687	Agaton	5-year
39	9.779083	125.4902	0	0	0	Agaton	5-year
40	9.776556	125.4713	0	0.8	0.8	Agaton	5-year

41	9.787806	125.4623	0.122	0.51	0.388	Agaton	5-year
42	9.789833	125.4583	0.107	0	-0.107	Agaton	5-year
43	9.788972	125.4516	0	0	0	Agaton	5-year
44	9.783139	125.4634	0.689	0	-0.689	Agaton	5-year
45	9.783833	125.463	0	0.6	0.6	Agaton	5-year
46	9.796278	125.4764	0	0	0	Agaton	5-year
47	9.792389	125.4804	0.556	0	-0.556	Agaton	5-year
48	9.782333	125.4956	0.998	0	-0.998	Agaton	5-year
49	9.781	125.4946	0.413	0.41	-0.003	Agaton	5-year
50	9.778556	125.4949	0	0	0	Agaton	5-year
51	9.780306	125.4975	0	0	0	Agaton	5-year
52	9.792917	125.4817	0	0	0	Agaton	5-year
53	9.792694	125.4828	0	0	0	Agaton	5-year
54	9.797361	125.4719	0	0	0	Agaton	5-year
55	9.797167	125.4722	0	0	0	Agaton	5-year
56	9.796806	125.4724	0	0.34	0.34	Agaton	5-year
57	9.779306	125.4924	1.582	0	-1.582	Agaton	5-year
58	9.778222	125.4936	0	0	0	Agaton	5-year
59	9.779833	125.4931	1.019	0.8	-0.219	Agaton	5-year
60	9.779917	125.4935	0.509	0	-0.509	Agaton	5-year
61	9.785417	125.4888	0.49	0.05	-0.44	Agaton	5-year
62	9.784972	125.4884	0.357	0.2	-0.157	Agaton	5-year
63	9.789	125.4887	0	0	0	Agaton	5-year
64	9.790472	125.4886	0.488	0.3	-0.188	Agaton	5-year
65	9.773889	125.4826	1.494	0.3	-1.194	Agaton	5-year
66	9.779	125.4824	0.868	0	-0.868	Agaton	5-year
67	9.786861	125.4884	0.204	0	-0.204	Agaton	5-year
68	9.78725	125.4885	0.23	0.16	-0.07	Agaton	5-year
69	9.787583	125.4818	0.83	1.11	0.28	Agaton	5-year
70	9.787806	125.4824	0.444	0	-0.444	Agaton	5-year
71	9.788222	125.483	0.571	1.1	0.529	Agaton	5-year
72	9.770694	125.4852	0.599	0	-0.599	Agaton	5-year
73	9.767056	125.4844	0.824	0	-0.824	Agaton	5-year
74	9.7685	125.4784	0.499	0.5	0.001	Agaton	5-year
75	9.788806	125.4546	0.137	0	-0.137	Agaton	5-year
76	9.788778	125.452	0	0	0	Agaton	5-year
77	9.789722	125.4589	0	0	0	Agaton	5-year
78	9.789917	125.4618	0	0	0	Agaton	5-year
79	9.774167	125.4778	0	0	0	Agaton	5-year
80	9.774278	125.4779	0	0.5	0.5	Agaton	5-year
81	9.776278	125.4687	0.644	0	-0.644	Agaton	5-year
82	9.776111	125.4685	0.284	0	-0.284	Agaton	5-year
83	9.7785	125.4687	0	0	0	Agaton	5-year
84	9.777889	125.4674	0	0	0	Agaton	5-year
85	9.780611	125.4645	0.186	0	-0.186	Agaton	5-year
86	9.738222	125.4919	0.674	0	-0.674	Agaton	5-year

87	9.738611	125.4916	1.701	0.37	-1.331	Agaton	5-year
88	9.744444	125.4838	0	0	0	Agaton	5-year
89	9.743444	125.4779	2.16	1.23	-0.93	Agaton	5-year
90	9.743139	125.4772	0.707	0	-0.707	Agaton	5-year
91	9.741778	125.4778	0.482	0	-0.482	Agaton	5-year
92	9.742389	125.4784	1.772	0.67	-1.102	Agaton	5-year
93	9.708889	125.5031	0	0	0	Agaton	5-year
94	9.71175	125.5028	0	0	0	Agaton	5-year
95	9.711111	125.5023	0	0	0	Agaton	5-year
96	9.710139	125.5026	0	0	0	Agaton	5-year
97	9.709972	125.4988	0	0	0	Agaton	5-year
98	9.709389	125.4985	0	0	0	Agaton	5-year
99	9.718722	125.5058	0	0	0	Agaton	5-year
100	9.720389	125.5063	0	0	0	Agaton	5-year
101	9.783361	125.4813	0	0.69	0	Seniang	5-year
102	9.784917	125.481	0.526	0	-0.026	Seniang	5-year
103	9.785306	125.4841	3.388	0.5	-2.588	Seniang	5-year
104	9.785333	125.4835	0.339	0.8	-0.339	Seniang	5-year
105	9.7855	125.4837	0	0	0.48	Seniang	5-year
106	9.784528	125.4836	0.808	0.48	-0.388	Seniang	5-year
107	9.784306	125.4834	1.043	0.42	-0.803	Seniang	5-year
108	9.786889	125.4856	0	0.24	0	Seniang	5-year
109	9.786667	125.4855	0.399	0	0.001	Seniang	5-year
110	9.787278	125.4844	0	0.4	0.73	Seniang	5-year
111	9.7865	125.4841	0	0.73	0	Seniang	5-year
112	9.787028	125.4843	2.966	0	-1.986	Seniang	5-year
113	9.784361	125.4825	0.208	0.98	0.892	Seniang	5-year
114	9.784083	125.483	0.585	1.1	0.865	Seniang	5-year
115	9.781306	125.4945	0.545	1.45	-0.545	Seniang	5-year
116	9.783667	125.4824	0	0	0.63	Seniang	5-year
117	9.7835	125.4816	0.586	0.63	1.314	Seniang	5-year
118	9.785861	125.481	0.636	1.9	0.464	Seniang	5-year
119	9.785556	125.4804	0.996	1.1	-0.946	Seniang	5-year
120	9.7915	125.491	0	0.05	1.1	Seniang	5-year
121	9.783583	125.4831	0	1.1	1.18	Seniang	5-year
122	9.783194	125.4826	0.549	1.18	-0.549	Seniang	5-year
123	9.786806	125.4866	0	0	1.8	Seniang	5-year
124	9.786361	125.4854	3.598	1.8	-2.998	Seniang	5-year
125	9.785917	125.485	0	0.6	0	Seniang	5-year
126	9.783806	125.4832	0.86	0	0.06	Seniang	5-year
127	9.787111	125.4795	0	0.92	0.69	Seniang	5-year
128	9.787083	125.4809	0.366	0.69	-0.366	Seniang	5-year
129	9.786639	125.4821	0.324	0	-0.124	Seniang	5-year
130	9.781306	125.4962	0.254	0.2	-0.254	Seniang	5-year
131	9.781917	125.4967	0	0	0	Seniang	5-year
132	9.7815	125.4976	0.404	0	-0.404	Seniang	5-year

133	9.785972	125.4961	0.24	0	-0.24	Seniang	5-year
134	9.784833	125.4919	0	0	0	Seniang	5-year
135	9.786417	125.4956	0	0	0	Seniang	5-year
136	9.780389	125.4945	0.195	0	-0.195	Seniang	5-year
137	9.779222	125.4939	0.213	0	-0.213	Seniang	5-year
138	9.779083	125.4902	0	0	0	Seniang	5-year
139	9.776556	125.4713	0	0	0.51	Seniang	5-year
140	9.787806	125.4623	0.122	0.51	-0.122	Seniang	5-year
141	9.789833	125.4583	0.107	0	-0.107	Seniang	5-year
142	9.788972	125.4516	0	0	0	Seniang	5-year
143	9.783139	125.4634	0.689	0	-0.089	Seniang	5-year
144	9.783833	125.463	0	0.6	0.25	Seniang	5-year
145	9.796278	125.4764	0	0.25	0	Seniang	5-year
146	9.792389	125.4804	0.556	0	-0.406	Seniang	5-year
147	9.782333	125.4956	0.998	0.15	-0.588	Seniang	5-year
148	9.781	125.4946	0.413	0.41	-0.413	Seniang	5-year
149	9.778556	125.4949	0	0	0	Seniang	5-year
150	9.780306	125.4975	0	0	0.35	Seniang	5-year
151	9.792917	125.4817	0	0.35	0	Seniang	5-year
152	9.792694	125.4828	0	0	0	Seniang	5-year
153	9.797361	125.4719	0	0	0	Seniang	5-year
154	9.797167	125.4722	0	0	0.1	Seniang	5-year
155	9.796806	125.4724	0	0.1	0	Seniang	5-year
156	9.779306	125.4924	1.582	0	-1.582	Seniang	5-year
157	9.778222	125.4936	0	0	0.8	Seniang	5-year
158	9.779833	125.4931	1.019	0.8	-1.019	Seniang	5-year
159	9.779917	125.4935	0.509	0	-0.459	Seniang	5-year
160	9.785417	125.4888	0.49	0.05	-0.09	Seniang	5-year
161	9.784972	125.4884	0.357	0.4	-0.357	Seniang	5-year
162	9.789	125.4887	0	0	0.3	Seniang	5-year
163	9.790472	125.4886	0.488	0.3	-0.488	Seniang	5-year
164	9.773889	125.4826	1.494	0	-1.494	Seniang	5-year
165	9.779	125.4824	0.868	0	-0.868	Seniang	5-year
166	9.786861	125.4884	0.204	0	0.256	Seniang	5-year
167	9.78725	125.4885	0.23	0.46	0.88	Seniang	5-year
168	9.787583	125.4818	0.83	1.11	-0.83	Seniang	5-year
169	9.787806	125.4824	0.444	0	0.656	Seniang	5-year
170	9.788222	125.483	0.571	1.1	-0.571	Seniang	5-year
171	9.770694	125.4852	0.599	0	0.041	Seniang	5-year
172	9.767056	125.4844	0.824	0.64	-0.824	Seniang	5-year
173	9.7685	125.4784	0.499	0	-0.499	Seniang	5-year
174	9.788806	125.4546	0.137	0	-0.137	Seniang	5-year
175	9.788778	125.452	0	0	0	Seniang	5-year
176	9.789722	125.4589	0	0	0	Seniang	5-year
177	9.789917	125.4618	0	0	0	Seniang	5-year
178	9.774167	125.4778	0	0	0	Seniang	5-year

179	9.774278	125.4779	0	0	0	Seniang	5-year
180	9.776278	125.4687	0.644	0	-0.644	Seniang	5-year
181	9.776111	125.4685	0.284	0	-0.284	Seniang	5-year
182	9.7785	125.4687	0	0	0	Seniang	5-year
183	9.777889	125.4674	0	0	0	Seniang	5-year
184	9.780611	125.4645	0.186	0	-0.186	Seniang	5-year
185	9.738222	125.4919	0.674	0	-0.674	Seniang	5-year
186	9.738611	125.4916	1.701	0	-1.701	Seniang	5-year
187	9.744444	125.4838	0	0	0.5	Seniang	5-year
188	9.743444	125.4779	2.16	0.5	-1.73	Seniang	5-year
189	9.743139	125.4772	0.707	0.43	-0.707	Seniang	5-year
190	9.741778	125.4778	0.482	0	-0.482	Seniang	5-year
191	9.742389	125.4784	1.772	0	-1.772	Seniang	5-year
192	9.708889	125.5031	0	0	0	Seniang	5-year
193	9.71175	125.5028	0	0	0	Seniang	5-year
194	9.711111	125.5023	0	0	0	Seniang	5-year
195	9.710139	125.5026	0	0	0	Seniang	5-year
196	9.709972	125.4988	0	0	0	Seniang	5-year
197	9.709389	125.4985	0	0	0	Seniang	5-year
198	9.718722	125.5058	0	0	0	Seniang	5-year
199	9.720389	125.5063	0	0	0	Seniang	5-year
200	9.783444	125.4821	1.031	0	-1.031	Agaton	25-year
201	9.783361	125.4813	0.373	0	-0.373	Agaton	25-year
202	9.784917	125.481	0.989	0	-0.989	Agaton	25-year
203	9.785306	125.4841	3.888	0.3	-3.588	Agaton	25-year
204	9.785333	125.4835	0.835	0.47	-0.365	Agaton	25-year
205	9.7855	125.4837	0.539	0	-0.539	Agaton	25-year
206	9.784528	125.4836	1.284	0	-1.284	Agaton	25-year
207	9.784306	125.4834	1.515	0.42	-1.095	Agaton	25-year
208	9.786889	125.4856	0	0.24	0.24	Agaton	25-year
209	9.786667	125.4855	1.057	0.15	-0.907	Agaton	25-year
210	9.787278	125.4844	0.299	0.3	0.001	Agaton	25-year
211	9.7865	125.4841	0.265	0.49	0.225	Agaton	25-year
212	9.787028	125.4843	3.591	0	-3.591	Agaton	25-year
213	9.784361	125.4825	0.659	0	-0.659	Agaton	25-year
214	9.784083	125.483	1.061	1.1	0.039	Agaton	25-year
215	9.781306	125.4945	0.66	0.7	0.04	Agaton	25-year
216	9.783667	125.4824	0.438	0	-0.438	Agaton	25-year
217	9.7835	125.4816	0.996	0.63	-0.366	Agaton	25-year
218	9.785861	125.481	1.078	0.56	-0.518	Agaton	25-year
219	9.785556	125.4804	1.454	1.05	-0.404	Agaton	25-year
220	9.7915	125.491	0	0.05	0.05	Agaton	25-year
221	9.783583	125.4831	0.506	1.1	0.594	Agaton	25-year
222	9.783194	125.4826	1.033	1.18	0.147	Agaton	25-year
223	9.786806	125.4866	0	0	0	Agaton	25-year
224	9.786361	125.4854	4.254	1.5	-2.754	Agaton	25-year

225	9.785917	125.485	0.497	0.3	-0.197	Agaton	25-year
226	9.783806	125.4832	1.336	0	-1.336	Agaton	25-year
227	9.787111	125.4795	0.499	0.18	-0.319	Agaton	25-year
228	9.787083	125.4809	0.774	0.69	-0.084	Agaton	25-year
229	9.786639	125.4821	0.718	0.65	-0.068	Agaton	25-year
230	9.781306	125.4962	0.419	0.2	-0.219	Agaton	25-year
231	9.781917	125.4967	0.151	0	-0.151	Agaton	25-year
232	9.7815	125.4976	0.502	0	-0.502	Agaton	25-year
233	9.785972	125.4961	0.283	0	-0.283	Agaton	25-year
234	9.784833	125.4919	0	0	0	Agaton	25-year
235	9.786417	125.4956	0	0	0	Agaton	25-year
236	9.780389	125.4945	0.422	0.14	-0.282	Agaton	25-year
237	9.779222	125.4939	0.423	0.9	0.477	Agaton	25-year
238	9.779083	125.4902	0	0	0	Agaton	25-year
239	9.776556	125.4713	0.122	0.8	0.678	Agaton	25-year
240	9.787806	125.4623	0.2	0.51	0.31	Agaton	25-year
241	9.789833	125.4583	0.142	0	-0.142	Agaton	25-year
242	9.788972	125.4516	0	0	0	Agaton	25-year
243	9.783139	125.4634	0.802	0	-0.802	Agaton	25-year
244	9.783833	125.463	0	0.6	0.6	Agaton	25-year
245	9.796278	125.4764	0.13	0	-0.13	Agaton	25-year
246	9.792389	125.4804	1.167	0	-1.167	Agaton	25-year
247	9.782333	125.4956	1.112	0	-1.112	Agaton	25-year
248	9.781	125.4946	0.525	0.41	-0.115	Agaton	25-year
249	9.778556	125.4949	0	0	0	Agaton	25-year
250	9.780306	125.4975	0	0	0	Agaton	25-year
251	9.792917	125.4817	0.641	0	-0.641	Agaton	25-year
252	9.792694	125.4828	0	0	0	Agaton	25-year
253	9.797361	125.4719	0	0	0	Agaton	25-year
254	9.797167	125.4722	0	0	0	Agaton	25-year
255	9.796806	125.4724	0	0.34	0.34	Agaton	25-year
256	9.779306	125.4924	1.789	0	-1.789	Agaton	25-year
257	9.778222	125.4936	0	0	0	Agaton	25-year
258	9.779833	125.4931	1.206	0.8	-0.406	Agaton	25-year
259	9.779917	125.4935	0.684	0	-0.684	Agaton	25-year
260	9.785417	125.4888	0.581	0.05	-0.531	Agaton	25-year
261	9.784972	125.4884	0.45	0.2	-0.25	Agaton	25-year
262	9.789	125.4887	0	0	0	Agaton	25-year
263	9.790472	125.4886	0.564	0.3	-0.264	Agaton	25-year
264	9.773889	125.4826	1.991	0.3	-1.691	Agaton	25-year
265	9.779	125.4824	1.181	0	-1.181	Agaton	25-year
266	9.786861	125.4884	0.277	0	-0.277	Agaton	25-year
267	9.78725	125.4885	0.297	0.16	-0.137	Agaton	25-year
268	9.787583	125.4818	1.215	1.11	-0.105	Agaton	25-year
269	9.787806	125.4824	0.816	0	-0.816	Agaton	25-year
270	9.788222	125.483	0.986	1.1	0.114	Agaton	25-year

271	9.770694	125.4852	1.53	0	-1.53	Agaton	25-year
272	9.767056	125.4844	1.878	0	-1.878	Agaton	25-year
273	9.7685	125.4784	1.033	0.5	-0.533	Agaton	25-year
274	9.788806	125.4546	0.214	0	-0.214	Agaton	25-year
275	9.788778	125.452	0.109	0	-0.109	Agaton	25-year
276	9.789722	125.4589	0	0	0	Agaton	25-year
277	9.789917	125.4618	0	0	0	Agaton	25-year
278	9.774167	125.4778	0	0	0	Agaton	25-year
279	9.774278	125.4779	0	0.5	0.5	Agaton	25-year
280	9.776278	125.4687	1.207	0	-1.207	Agaton	25-year
281	9.776111	125.4685	0.848	0	-0.848	Agaton	25-year
282	9.7785	125.4687	0.217	0	-0.217	Agaton	25-year
283	9.777889	125.4674	0.109	0	-0.109	Agaton	25-year
284	9.780611	125.4645	0.35	0	-0.35	Agaton	25-year
285	9.738222	125.4919	1.588	0	-1.588	Agaton	25-year
286	9.738611	125.4916	2.626	0.37	-2.256	Agaton	25-year
287	9.744444	125.4838	0	0	0	Agaton	25-year
288	9.743444	125.4779	3.385	1.23	-2.155	Agaton	25-year
289	9.743139	125.4772	1.929	0	-1.929	Agaton	25-year
290	9.741778	125.4778	1.713	0	-1.713	Agaton	25-year
291	9.742389	125.4784	3.035	0.67	-2.365	Agaton	25-year
292	9.708889	125.5031	0	0	0	Agaton	25-year
293	9.71175	125.5028	0.391	0	-0.391	Agaton	25-year
294	9.711111	125.5023	0.628	0	-0.628	Agaton	25-year
295	9.710139	125.5026	0.636	0	-0.636	Agaton	25-year
296	9.709972	125.4988	1.357	0	-1.357	Agaton	25-year
297	9.709389	125.4985	1.029	0	-1.029	Agaton	25-year
298	9.718722	125.5058	0.213	0	-0.213	Agaton	25-year
299	9.720389	125.5063	0.156	0	-0.156	Agaton	25-year
300	9.783361	125.4813	0.373	0.69	-0.373	Seniang	25-year
301	9.784917	125.481	0.989	0	-0.489	Seniang	25-year
302	9.785306	125.4841	3.888	0.5	-3.088	Seniang	25-year
303	9.785333	125.4835	0.835	0.8	-0.835	Seniang	25-year
304	9.7855	125.4837	0.539	0	-0.059	Seniang	25-year
305	9.784528	125.4836	1.284	0.48	-0.864	Seniang	25-year
306	9.784306	125.4834	1.515	0.42	-1.275	Seniang	25-year
307	9.786889	125.4856	0	0.24	0	Seniang	25-year
308	9.786667	125.4855	1.057	0	-0.657	Seniang	25-year
309	9.787278	125.4844	0.299	0.4	0.431	Seniang	25-year
310	9.7865	125.4841	0.265	0.73	-0.265	Seniang	25-year
311	9.787028	125.4843	3.591	0	-2.611	Seniang	25-year
312	9.784361	125.4825	0.659	0.98	0.441	Seniang	25-year
313	9.784083	125.483	1.061	1.1	0.389	Seniang	25-year
314	9.781306	125.4945	0.66	1.45	-0.66	Seniang	25-year
315	9.783667	125.4824	0.438	0	0.192	Seniang	25-year
316	9.7835	125.4816	0.996	0.63	0.904	Seniang	25-year

317	9.785861	125.481	1.078	1.9	0.022	Seniang	25-year
318	9.785556	125.4804	1.454	1.1	-1.404	Seniang	25-year
319	9.7915	125.491	0	0.05	1.1	Seniang	25-year
320	9.783583	125.4831	0.506	1.1	0.674	Seniang	25-year
321	9.783194	125.4826	1.033	1.18	-1.033	Seniang	25-year
322	9.786806	125.4866	0	0	1.8	Seniang	25-year
323	9.786361	125.4854	4.254	1.8	-3.654	Seniang	25-year
324	9.785917	125.485	0.497	0.6	-0.497	Seniang	25-year
325	9.783806	125.4832	1.336	0	-0.416	Seniang	25-year
326	9.787111	125.4795	0.499	0.92	0.191	Seniang	25-year
327	9.787083	125.4809	0.774	0.69	-0.774	Seniang	25-year
328	9.786639	125.4821	0.718	0	-0.518	Seniang	25-year
329	9.781306	125.4962	0.419	0.2	-0.419	Seniang	25-year
330	9.781917	125.4967	0.151	0	-0.151	Seniang	25-year
331	9.7815	125.4976	0.502	0	-0.502	Seniang	25-year
332	9.785972	125.4961	0.283	0	-0.283	Seniang	25-year
333	9.784833	125.4919	0	0	0	Seniang	25-year
334	9.786417	125.4956	0	0	0	Seniang	25-year
335	9.780389	125.4945	0.422	0	-0.422	Seniang	25-year
336	9.779222	125.4939	0.423	0	-0.423	Seniang	25-year
337	9.779083	125.4902	0	0	0	Seniang	25-year
338	9.776556	125.4713	0.122	0	0.388	Seniang	25-year
339	9.787806	125.4623	0.2	0.51	-0.2	Seniang	25-year
340	9.789833	125.4583	0.142	0	-0.142	Seniang	25-year
341	9.788972	125.4516	0	0	0	Seniang	25-year
342	9.783139	125.4634	0.802	0	-0.202	Seniang	25-year
343	9.783833	125.463	0	0.6	0.25	Seniang	25-year
344	9.796278	125.4764	0.13	0.25	-0.13	Seniang	25-year
345	9.792389	125.4804	1.167	0	-1.017	Seniang	25-year
346	9.782333	125.4956	1.112	0.15	-0.702	Seniang	25-year
347	9.781	125.4946	0.525	0.41	-0.525	Seniang	25-year
348	9.778556	125.4949	0	0	0	Seniang	25-year
349	9.780306	125.4975	0	0	0.35	Seniang	25-year
350	9.792917	125.4817	0.641	0.35	-0.641	Seniang	25-year
351	9.792694	125.4828	0	0	0	Seniang	25-year
352	9.797361	125.4719	0	0	0	Seniang	25-year
353	9.797167	125.4722	0	0	0.1	Seniang	25-year
354	9.796806	125.4724	0	0.1	0	Seniang	25-year
355	9.779306	125.4924	1.789	0	-1.789	Seniang	25-year
356	9.778222	125.4936	0	0	0.8	Seniang	25-year
357	9.779833	125.4931	1.206	0.8	-1.206	Seniang	25-year
358	9.779917	125.4935	0.684	0	-0.634	Seniang	25-year
359	9.785417	125.4888	0.581	0.05	-0.181	Seniang	25-year
360	9.784972	125.4884	0.45	0.4	-0.45	Seniang	25-year
361	9.789	125.4887	0	0	0.3	Seniang	25-year
362	9.790472	125.4886	0.564	0.3	-0.564	Seniang	25-year

363	9.773889	125.4826	1.991	0	-1.991	Seniang	25-year
364	9.779	125.4824	1.181	0	-1.181	Seniang	25-year
365	9.786861	125.4884	0.277	0	0.183	Seniang	25-year
366	9.78725	125.4885	0.297	0.46	0.813	Seniang	25-year
367	9.787583	125.4818	1.215	1.11	-1.215	Seniang	25-year
368	9.787806	125.4824	0.816	0	0.284	Seniang	25-year
369	9.788222	125.483	0.986	1.1	-0.986	Seniang	25-year
370	9.770694	125.4852	1.53	0	-0.89	Seniang	25-year
371	9.767056	125.4844	1.878	0.64	-1.878	Seniang	25-year
372	9.7685	125.4784	1.033	0	-1.033	Seniang	25-year
373	9.788806	125.4546	0.214	0	-0.214	Seniang	25-year
374	9.788778	125.452	0.109	0	-0.109	Seniang	25-year
375	9.789722	125.4589	0	0	0	Seniang	25-year
376	9.789917	125.4618	0	0	0	Seniang	25-year
377	9.774167	125.4778	0	0	0	Seniang	25-year
378	9.774278	125.4779	0	0	0	Seniang	25-year
379	9.776278	125.4687	1.207	0	-1.207	Seniang	25-year
380	9.776111	125.4685	0.848	0	-0.848	Seniang	25-year
381	9.7785	125.4687	0.217	0	-0.217	Seniang	25-year
382	9.777889	125.4674	0.109	0	-0.109	Seniang	25-year
383	9.780611	125.4645	0.35	0	-0.35	Seniang	25-year
384	9.738222	125.4919	1.588	0	-1.588	Seniang	25-year
385	9.738611	125.4916	2.626	0	-2.626	Seniang	25-year
386	9.744444	125.4838	0	0	0.5	Seniang	25-year
387	9.743444	125.4779	3.385	0.5	-2.955	Seniang	25-year
388	9.743139	125.4772	1.929	0.43	-1.929	Seniang	25-year
389	9.741778	125.4778	1.713	0	-1.713	Seniang	25-year
390	9.742389	125.4784	3.035	0	-3.035	Seniang	25-year
391	9.708889	125.5031	0	0	0	Seniang	25-year
392	9.71175	125.5028	0.391	0	-0.391	Seniang	25-year
393	9.711111	125.5023	0.628	0	-0.628	Seniang	25-year
394	9.710139	125.5026	0.636	0	-0.636	Seniang	25-year
395	9.709972	125.4988	1.357	0	-1.357	Seniang	25-year
396	9.709389	125.4985	1.029	0	-1.029	Seniang	25-year
397	9.718722	125.5058	0.213	0	-0.213	Seniang	25-year
398	9.720389	125.5063	0.156	0	-0.156	Seniang	25-year
399	9.783444	125.4821	1.306	0	-1.306	Agaton	100-year
400	9.783361	125.4813	0.623	0	-0.623	Agaton	100-year
401	9.784917	125.481	1.271	0	-1.271	Agaton	100-year
402	9.785306	125.4841	4.184	0.3	-3.884	Agaton	100-year
403	9.785333	125.4835	1.128	0.47	-0.658	Agaton	100-year
404	9.7855	125.4837	0.835	0	-0.835	Agaton	100-year
405	9.784528	125.4836	1.571	0	-1.571	Agaton	100-year
406	9.784306	125.4834	1.801	0.42	-1.381	Agaton	100-year
407	9.786889	125.4856	0.355	0.24	-0.115	Agaton	100-year
408	9.786667	125.4855	1.548	0.15	-1.398	Agaton	100-year

409	9.787278	125.4844	0.712	0.3	-0.412	Agaton	100-year
410	9.7865	125.4841	0.625	0.49	-0.135	Agaton	100-year
411	9.787028	125.4843	3.994	0	-3.994	Agaton	100-year
412	9.784361	125.4825	0.934	0	-0.934	Agaton	100-year
413	9.784083	125.483	1.345	1.1	-0.245	Agaton	100-year
414	9.781306	125.4945	0.726	0.7	-0.026	Agaton	100-year
415	9.783667	125.4824	0.715	0	-0.715	Agaton	100-year
416	9.7835	125.4816	1.257	0.63	-0.627	Agaton	100-year
417	9.785861	125.481	1.35	0.56	-0.79	Agaton	100-year
418	9.785556	125.4804	1.73	1.05	-0.68	Agaton	100-year
419	9.7915	125.491	0	0.05	0.05	Agaton	100-year
420	9.783583	125.4831	0.79	1.1	0.31	Agaton	100-year
421	9.783194	125.4826	1.321	1.18	-0.141	Agaton	100-year
422	9.786806	125.4866	0.164	0	-0.164	Agaton	100-year
423	9.786361	125.4854	4.712	1.5	-3.212	Agaton	100-year
424	9.785917	125.485	0.869	0.3	-0.569	Agaton	100-year
425	9.783806	125.4832	1.622	0	-1.622	Agaton	100-year
426	9.787111	125.4795	0.761	0.18	-0.581	Agaton	100-year
427	9.787083	125.4809	1.036	0.69	-0.346	Agaton	100-year
428	9.786639	125.4821	0.983	0.65	-0.333	Agaton	100-year
429	9.781306	125.4962	0.499	0.2	-0.299	Agaton	100-year
430	9.781917	125.4967	0.201	0	-0.201	Agaton	100-year
431	9.7815	125.4976	0.564	0	-0.564	Agaton	100-year
432	9.785972	125.4961	0.313	0	-0.313	Agaton	100-year
433	9.784833	125.4919	0	0	0	Agaton	100-year
434	9.786417	125.4956	0	0	0	Agaton	100-year
435	9.780389	125.4945	0.555	0.14	-0.415	Agaton	100-year
436	9.779222	125.4939	0.578	0.9	0.322	Agaton	100-year
437	9.779083	125.4902	0	0	0	Agaton	100-year
438	9.776556	125.4713	0.292	0.8	0.508	Agaton	100-year
439	9.787806	125.4623	0.249	0.51	0.261	Agaton	100-year
440	9.789833	125.4583	0.177	0	-0.177	Agaton	100-year
441	9.788972	125.4516	0	0	0	Agaton	100-year
442	9.783139	125.4634	0.861	0	-0.861	Agaton	100-year
443	9.783833	125.463	0	0.6	0.6	Agaton	100-year
444	9.796278	125.4764	0.168	0	-0.168	Agaton	100-year
445	9.792389	125.4804	1.414	0	-1.414	Agaton	100-year
446	9.782333	125.4956	1.182	0	-1.182	Agaton	100-year
447	9.781	125.4946	0.586	0.41	-0.176	Agaton	100-year
448	9.778556	125.4949	0	0	0	Agaton	100-year
449	9.780306	125.4975	0	0	0	Agaton	100-year
450	9.792917	125.4817	0.877	0	-0.877	Agaton	100-year
451	9.792694	125.4828	0	0	0	Agaton	100-year
452	9.797361	125.4719	0	0	0	Agaton	100-year
453	9.797167	125.4722	0	0	0	Agaton	100-year
454	9.796806	125.4724	0	0.34	0.34	Agaton	100-year

455	9.779306	125.4924	1.892	0	-1.892	Agaton	100-year
456	9.778222	125.4936	0	0	0	Agaton	100-year
457	9.779833	125.4931	1.29	0.8	-0.49	Agaton	100-year
458	9.779917	125.4935	0.766	0	-0.766	Agaton	100-year
459	9.785417	125.4888	0.641	0.05	-0.591	Agaton	100-year
460	9.784972	125.4884	0.508	0.2	-0.308	Agaton	100-year
461	9.789	125.4887	0	0	0	Agaton	100-year
462	9.790472	125.4886	0.597	0.3	-0.297	Agaton	100-year
463	9.773889	125.4826	2.292	0.3	-1.992	Agaton	100-year
464	9.779	125.4824	1.355	0	-1.355	Agaton	100-year
465	9.786861	125.4884	0.321	0	-0.321	Agaton	100-year
466	9.78725	125.4885	0.337	0.16	-0.177	Agaton	100-year
467	9.787583	125.4818	1.468	1.11	-0.358	Agaton	100-year
468	9.787806	125.4824	1.063	0	-1.063	Agaton	100-year
469	9.788222	125.483	1.24	1.1	-0.14	Agaton	100-year
470	9.770694	125.4852	1.678	0	-1.678	Agaton	100-year
471	9.767056	125.4844	2.082	0	-2.082	Agaton	100-year
472	9.7685	125.4784	1.332	0.5	-0.832	Agaton	100-year
473	9.788806	125.4546	0.257	0	-0.257	Agaton	100-year
474	9.788778	125.452	0.138	0	-0.138	Agaton	100-year
475	9.789722	125.4589	0	0	0	Agaton	100-year
476	9.789917	125.4618	0	0	0	Agaton	100-year
477	9.774167	125.4778	0	0	0	Agaton	100-year
478	9.774278	125.4779	0	0.5	0.5	Agaton	100-year
479	9.776278	125.4687	1.4	0	-1.4	Agaton	100-year
480	9.776111	125.4685	1.047	0	-1.047	Agaton	100-year
481	9.7785	125.4687	0.569	0	-0.569	Agaton	100-year
482	9.777889	125.4674	0.237	0	-0.237	Agaton	100-year
483	9.780611	125.4645	0.459	0	-0.459	Agaton	100-year
484	9.738222	125.4919	2.316	0	-2.316	Agaton	100-year
485	9.738611	125.4916	3.35	0.37	-2.98	Agaton	100-year
486	9.744444	125.4838	0.236	0	-0.236	Agaton	100-year
487	9.743444	125.4779	3.973	1.23	-2.743	Agaton	100-year
488	9.743139	125.4772	2.522	0	-2.522	Agaton	100-year
489	9.741778	125.4778	2.329	0	-2.329	Agaton	100-year
490	9.742389	125.4784	3.643	0.67	-2.973	Agaton	100-year
491	9.708889	125.5031	0.428	0	-0.428	Agaton	100-year
492	9.71175	125.5028	1.539	0	-1.539	Agaton	100-year
493	9.711111	125.5023	1.797	0	-1.797	Agaton	100-year
494	9.710139	125.5026	1.665	0	-1.665	Agaton	100-year
495	9.709972	125.4988	2.466	0	-2.466	Agaton	100-year
496	9.709389	125.4985	2.163	0	-2.163	Agaton	100-year
497	9.718722	125.5058	1.041	0	-1.041	Agaton	100-year
498	9.720389	125.5063	0.805	0	-0.805	Agaton	100-year
499	9.783361	125.4813	0.623	0.69	-0.623	Seniang	100-year
500	9.784917	125.481	1.271	0	-0.771	Seniang	100-year

501	9.785306	125.4841	4.184	0.5	-3.384	Seniang	100-year
502	9.785333	125.4835	1.128	0.8	-1.128	Seniang	100-year
503	9.7855	125.4837	0.835	0	-0.355	Seniang	100-year
504	9.784528	125.4836	1.571	0.48	-1.151	Seniang	100-year
505	9.784306	125.4834	1.801	0.42	-1.561	Seniang	100-year
506	9.786889	125.4856	0.355	0.24	-0.355	Seniang	100-year
507	9.786667	125.4855	1.548	0	-1.148	Seniang	100-year
508	9.787278	125.4844	0.712	0.4	0.018	Seniang	100-year
509	9.7865	125.4841	0.625	0.73	-0.625	Seniang	100-year
510	9.787028	125.4843	3.994	0	-3.014	Seniang	100-year
511	9.784361	125.4825	0.934	0.98	0.166	Seniang	100-year
512	9.784083	125.483	1.345	1.1	0.105	Seniang	100-year
513	9.781306	125.4945	0.726	1.45	-0.726	Seniang	100-year
514	9.783667	125.4824	0.715	0	-0.085	Seniang	100-year
515	9.7835	125.4816	1.257	0.63	0.643	Seniang	100-year
516	9.785861	125.481	1.35	1.9	-0.25	Seniang	100-year
517	9.785556	125.4804	1.73	1.1	-1.68	Seniang	100-year
518	9.7915	125.491	0	0.05	1.1	Seniang	100-year
519	9.783583	125.4831	0.79	1.1	0.39	Seniang	100-year
520	9.783194	125.4826	1.321	1.18	-1.321	Seniang	100-year
521	9.786806	125.4866	0.164	0	1.636	Seniang	100-year
522	9.786361	125.4854	4.712	1.8	-4.112	Seniang	100-year
523	9.785917	125.485	0.869	0.6	-0.869	Seniang	100-year
524	9.783806	125.4832	1.622	0	-0.702	Seniang	100-year
525	9.787111	125.4795	0.761	0.92	-0.071	Seniang	100-year
526	9.787083	125.4809	1.036	0.69	-1.036	Seniang	100-year
527	9.786639	125.4821	0.983	0	-0.783	Seniang	100-year
528	9.781306	125.4962	0.499	0.2	-0.499	Seniang	100-year
529	9.781917	125.4967	0.201	0	-0.201	Seniang	100-year
530	9.7815	125.4976	0.564	0	-0.564	Seniang	100-year
531	9.785972	125.4961	0.313	0	-0.313	Seniang	100-year
532	9.784833	125.4919	0	0	0	Seniang	100-year
533	9.786417	125.4956	0	0	0	Seniang	100-year
534	9.780389	125.4945	0.555	0	-0.555	Seniang	100-year
535	9.779222	125.4939	0.578	0	-0.578	Seniang	100-year
536	9.779083	125.4902	0	0	0	Seniang	100-year
537	9.776556	125.4713	0.292	0	0.218	Seniang	100-year
538	9.787806	125.4623	0.249	0.51	-0.249	Seniang	100-year
539	9.789833	125.4583	0.177	0	-0.177	Seniang	100-year
540	9.788972	125.4516	0	0	0	Seniang	100-year
541	9.783139	125.4634	0.861	0	-0.261	Seniang	100-year
542	9.783833	125.463	0	0.6	0.25	Seniang	100-year
543	9.796278	125.4764	0.168	0.25	-0.168	Seniang	100-year
544	9.792389	125.4804	1.414	0	-1.264	Seniang	100-year
545	9.782333	125.4956	1.182	0.15	-0.772	Seniang	100-year
546	9.781	125.4946	0.586	0.41	-0.586	Seniang	100-year

547	9.778556	125.4949	0	0	0	Seniang	100-year
548	9.780306	125.4975	0	0	0.35	Seniang	100-year
549	9.792917	125.4817	0.877	0.35	-0.877	Seniang	100-year
550	9.792694	125.4828	0	0	0	Seniang	100-year
551	9.797361	125.4719	0	0	0	Seniang	100-year
552	9.797167	125.4722	0	0	0.1	Seniang	100-year
553	9.796806	125.4724	0	0.1	0	Seniang	100-year
554	9.779306	125.4924	1.892	0	-1.892	Seniang	100-year
555	9.778222	125.4936	0	0	0.8	Seniang	100-year
556	9.779833	125.4931	1.29	0.8	-1.29	Seniang	100-year
557	9.779917	125.4935	0.766	0	-0.716	Seniang	100-year
558	9.785417	125.4888	0.641	0.05	-0.241	Seniang	100-year
559	9.784972	125.4884	0.508	0.4	-0.508	Seniang	100-year
560	9.789	125.4887	0	0	0.3	Seniang	100-year
561	9.790472	125.4886	0.597	0.3	-0.597	Seniang	100-year
562	9.773889	125.4826	2.292	0	-2.292	Seniang	100-year
563	9.779	125.4824	1.355	0	-1.355	Seniang	100-year
564	9.786861	125.4884	0.321	0	0.139	Seniang	100-year
565	9.78725	125.4885	0.337	0.46	0.773	Seniang	100-year
566	9.787583	125.4818	1.468	1.11	-1.468	Seniang	100-year
567	9.787806	125.4824	1.063	0	0.037	Seniang	100-year
568	9.788222	125.483	1.24	1.1	-1.24	Seniang	100-year
569	9.770694	125.4852	1.678	0	-1.038	Seniang	100-year
570	9.767056	125.4844	2.082	0.64	-2.082	Seniang	100-year
571	9.7685	125.4784	1.332	0	-1.332	Seniang	100-year
572	9.788806	125.4546	0.257	0	-0.257	Seniang	100-year
573	9.788778	125.452	0.138	0	-0.138	Seniang	100-year
574	9.789722	125.4589	0	0	0	Seniang	100-year
575	9.789917	125.4618	0	0	0	Seniang	100-year
576	9.774167	125.4778	0	0	0	Seniang	100-year
577	9.774278	125.4779	0	0	0	Seniang	100-year
578	9.776278	125.4687	1.4	0	-1.4	Seniang	100-year
579	9.776111	125.4685	1.047	0	-1.047	Seniang	100-year
580	9.7785	125.4687	0.569	0	-0.569	Seniang	100-year
581	9.777889	125.4674	0.237	0	-0.237	Seniang	100-year
582	9.780611	125.4645	0.459	0	-0.459	Seniang	100-year
583	9.738222	125.4919	2.316	0	-2.316	Seniang	100-year
584	9.738611	125.4916	3.35	0	-3.35	Seniang	100-year
585	9.744444	125.4838	0.236	0	0.264	Seniang	100-year
586	9.743444	125.4779	3.973	0.5	-3.543	Seniang	100-year
587	9.743139	125.4772	2.522	0.43	-2.522	Seniang	100-year
588	9.741778	125.4778	2.329	0	-2.329	Seniang	100-year
589	9.742389	125.4784	3.643	0	-3.643	Seniang	100-year
590	9.708889	125.5031	0.428	0	-0.428	Seniang	100-year
591	9.71175	125.5028	1.539	0	-1.539	Seniang	100-year
592	9.711111	125.5023	1.797	0	-1.797	Seniang	100-year

593	9.710139	125.5026	1.665	0	-1.665	Seniang	100-year
594	9.709972	125.4988	2.466	0	-2.466	Seniang	100-year
595	9.709389	125.4985	2.163	0	-2.163	Seniang	100-year
596	9.718722	125.5058	1.041	0	-1.041	Seniang	100-year
597	9.720389	125.5063	0.805	0	-0.805	Seniang	100-year

Annex 12. Educational Institutions affected by flooding in Surigao Flood Plain

Table A-12.1. Educational Institutions in Placer, Surigao del Norte affected by flooding in Surigao Flood Plain

Surigao del Norte				
Placer				
Barangay	Building Name	Rainfall Scenario		
		5-year	25-year	100-year
Anislagan	Dakung Patag National High School			
Anislagan	Hinapayaw Elementary School			
Anislagan	Upper Patag Elementary School			
Santa Cruz	Dakung Patag Elementary School			

Table A-12.2. Educational Institutions in Sison, Surigao del Norte affected by flooding in Surigao Flood Plain

Surigao del Norte				
Sison				
Barangay	Building Name	Rainfall Scenario		
		5-year	25-year	100-year
Lower Patag	Ima Elementary School			
Lower Patag	Sison Central Elementary School	MEDIUM	MEDIUM	MEDIUM
Lower Patag	Sison National High School			
Poblacion	Anomar National High School		MEDIUM	HIGH
Poblacion	E. Siscon Pre School	HIGH	HIGH	HIGH
Poblacion	Enrico Borja Elementary School		MEDIUM	HIGH
Poblacion	Mabuhay Elementary School	MEDIUM	HIGH	HIGH
Poblacion	Mayag Elementary School		MEDIUM	HIGH
Poblacion	Tugonan Elementary School			
San Isidro	Sukailang Elementary School			
San Pablo	Enrico Borja Elementary School		MEDIUM	HIGH

Table A-12.3. Educational Institutions in Surigao City, Surigao del Norte affected by flooding in Surigao Flood Plain

Surigao del Norte				
Surigao City				
Barangay	Building Name	Rainfall Scenario		
		5-year	25-year	100-year
Cabongbongan	Capalayan Elementary School		LOW	LOW
Cabongbongan	Capalayan National High School		LOW	MEDIUM
Cagniog	Canlapina Elementary School			
Cagniog	Melquiades N. Cagasan Memorial Elementary School	MEDIUM	MEDIUM	MEDIUM

Cagniog	Ouano Elementary School			
Canlanipa	M.E.M.C.E.S	LOW	LOW	LOW
Canlanipa	Navarro Memorial Elementary School			
Canlanipa	Surigao Central Elementary School			
Canlanipa	Surigao City Pilot School			
Canlanipa	Taft National High School - Annex		LOW	MEDIUM
Capalayan	Orok Elementary School	MEDIUM	MEDIUM	MEDIUM
Lipata	Lipata National High School			
Luna	B. Vasquez Community Elementary School	MEDIUM	MEDIUM	MEDIUM
Luna	San Roque Elementary School			LOW
Luna	St. Paul University (High School)		MEDIUM	MEDIUM
Mabini	Mat-i Elementary School			
Mat-I	Mat-i Elementary School		LOW	LOW
Mat-I	Mat-i National High School		LOW	LOW
Poctoy	J.R. Clavero Memorial Elementary School	MEDIUM	HIGH	HIGH
Quezon	Bonifacio Elementary School			LOW
San Juan	Caraga Regional Science High School		LOW	MEDIUM
San Roque	Josefa E. Fernandez Elemntary School	MEDIUM	MEDIUM	MEDIUM
Sema	Serna Elementary School			
Sukailang	Calderon Village Elementary School			
Taft	C.V. Diez Memorial Central Elementary School	MEDIUM	MEDIUM	MEDIUM
Taft	Saint Paul University		LOW	LOW
Taft	Special Science Elementary School	LOW	LOW	MEDIUM
Taft	St. Ignatius Loyola Computer College			
Taft	STI		LOW	LOW
Taft	Surigao Central Elementary School			LOW
Taft	Surigao City Pilot School			
Taft	Surigao del Norte National High School			
Taft	Surigao State College of Technology			LOW
Trinidad	Quezon Elementary School			
Washington	Surigao City National High School	LOW	LOW	MEDIUM
Washington	Surigao Education Center			LOW
Washington	Surigao West Central Elemnetary School	LOW	MEDIUM	MEDIUM

Annex 13. Health Institutions affected by flooding in Surigao Floodplain

Table A-13.1. Health Institutions in Surigao City, Surigao del Norte affected by flooding in Surigao Flood Plain

Surigao del Norte				
Surigao City				
Barangay	Building Name	Rainfall Scenario		
		5-year	25-year	100-year
Taft	Brgy. Washington District Health Center			
Taft	CARAGA Hospital		LOW	LOW
Taft	Surigao Medical Center			
Washington	Miranda Family Hospital	LOW	LOW	MEDIUM
Washington	Surigao Medical Center		LOW	LOW