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

LiDAR Surveys and Flood Mapping of Himogaan River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
University of the Philippines Cebu

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For questions/queries regarding this report, contact:

Jonnifer Sinogaya, PhD.
Project Leader, Phil-LiDAR 1 Program
University of the Philippines Cebu
Cebu City, Cebu, Philippines 6000
E-mail: jrsinogaya@yahoo.com

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

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CHAPTER 1: OVERVIEW OF THE PROGRAM AND HIMOGAAN RIVER

Enrico C. Paringit, Dr. Eng. and Jonnifer Sinogaya, PhD.

1.1 Background of the Phil-LiDAR 1 Program

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

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

1.1 Himogaan River Basin

Himogaan River Basin is located in the province of Negros Occidental located at the north of Negros Island. The watershed is traversed by Himogaan River that serves as the main stream of base flow and direct runoff of water within the basin. The location of the Himogaan River Basin is as shown in Figure 1.

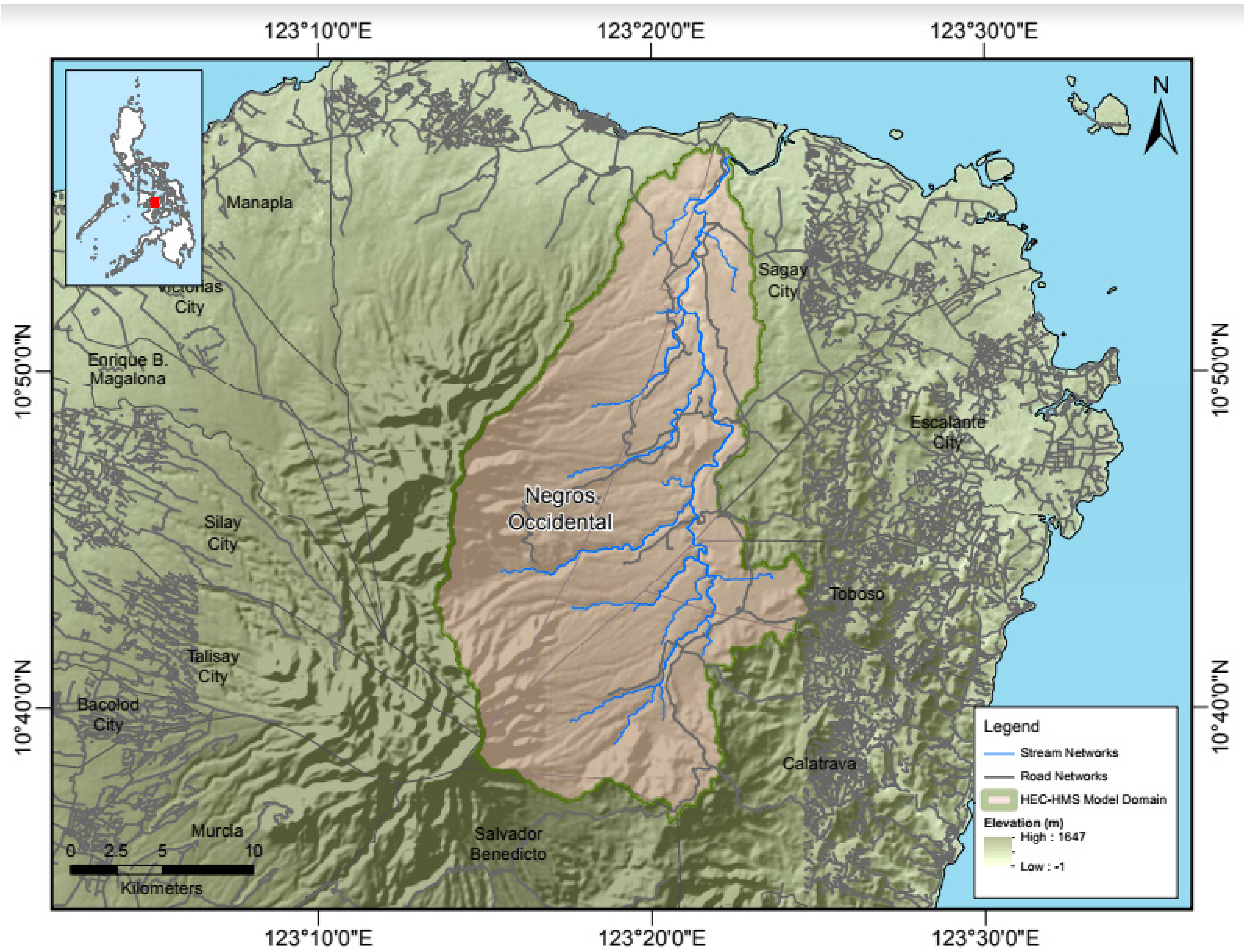


Figure 1. Map of the Himogaan river basin (in brown)

The Himogaan River Basin is located in the province of Negros Occidental located at the north of Negros Island. The floodplain and drainage area of 126.41 km2 and 108.31 km2 respectively covers Sagay City and Cadiz City. The DENR RBCO identified it to have an estimated 543 million cubic meter annual run-off with an average terrain elevation above sea level -99 meters.

Its main stem, Himogaan river is part of the river systems in Visayas Region.According to the 2010 census of National Statistics Office, there is a total of 45,991 people residing in the immediate vicinity of the river which is distributed among four (4) barangays, namely: Himogaan Baybay, Tigalawan, Cabahug and Paraiso. Its primary economic activities include sugar cane planting and other related activities to sugar cane production and distribution and fishing in coastal areas. The river also serves as a tourist spot because of its navigable length and depth. The recent flooding events were due to the presence of active low pressure areas that occurred in the whole Western Visayas causing intermittent rains. In 2011, the worst hit was in Sagay City where the floods displaced more than 1, 000 families after the Himogaan River overflowed due to incessant rains. The river once again overflowed in 2012 submerging several houses in Barangay Paraiso

The floodplain is 100% covered with LiDAR data which compromises 5 blocks. The LiDAR data was calibrated then mosaicked with an RMSE of 0.09 and then bathy burned. The bathy survey conducted reached a total length of 15.68 km starting from Fabrica, Sagay City up to the river mouth with 13533 points surveyed. There are 11473 buildings, 317.58km roads, 277 waterbodies and 13 bridges digitized based from the LiDAR data. Feature Extraction Attribution was conducted and among the building features, 11123 of them are Residential, 158 are schools and 5 are Medical Institutions.

The flood hazard map produced covers the 22.18 km2, 25.38 km2, 28 km2 for the 5-year, 25-year, and 100 year rainfall return period in Cadiz City which affects 4 barangays and in Sagay City which affects 8 barangays. A flood depth validation was conducted using 271 randomly generated points which is spread throughout the 6 ranges namely 0m-0.2m, 0.21m-0.5m, 0.51m-1m, 1.01m-2m, 2.10m-5m, 5m+ depth using the 25-yr rainfall flood depth map. It yielded a 0.403m RMSE.

A rating curve was developed at Himogaan Bridge, Sagay City, Negros Occidental, which shows the relationship between the observed water levels at Himogaan Bridge and outflow of the watershed at this location. This rating curve equation, expressed as Q = 66.291e0.5476x, was used to compute the river outflow at Himogaan Bridge for the calibration of the HEC-HMS model. The resulting outflow was used to simulate the flooded areas using HEC-RAS. The simulated model will be an integral part in determining the real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website.

CHAPTER 2: LIDAR ACQUISITION IN HIMOGAAN FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Gracia Acuña, Engr. Gerome Hipolito, Ms. Jasmine T. Alviar, and Mr. Darryl M. Austria

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Himogaan floodplain in Negros Occidental. These missions were planned for 14 lines and ran for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR system are found in Table 1 and Table 2. Figure 2 shows the flight plan for Himogaan floodplain.

Table 1. Flight planning parameters for Aquarius LiDAR system

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK44 A	600	30	36	70	50	120	5
BLK44 E	600	30	36	70	50	120	5
BLK 44 E_ additional	600	30	36	70	50	120	5
BLK44 D	600	30	36	70	50	120	5

Table 2. Flight planning parameters for Pegasus 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)
BLK44 D	1000	30	50	200	30	130	5
BLK44 E	1000	30	50	200	30	130	5
BLK44 F	1000	30	50	200	30	130	5
BLK44 G	1000	30	50	200	30	130	5
Bantayan Island	1200	30	50	200	30	130	5

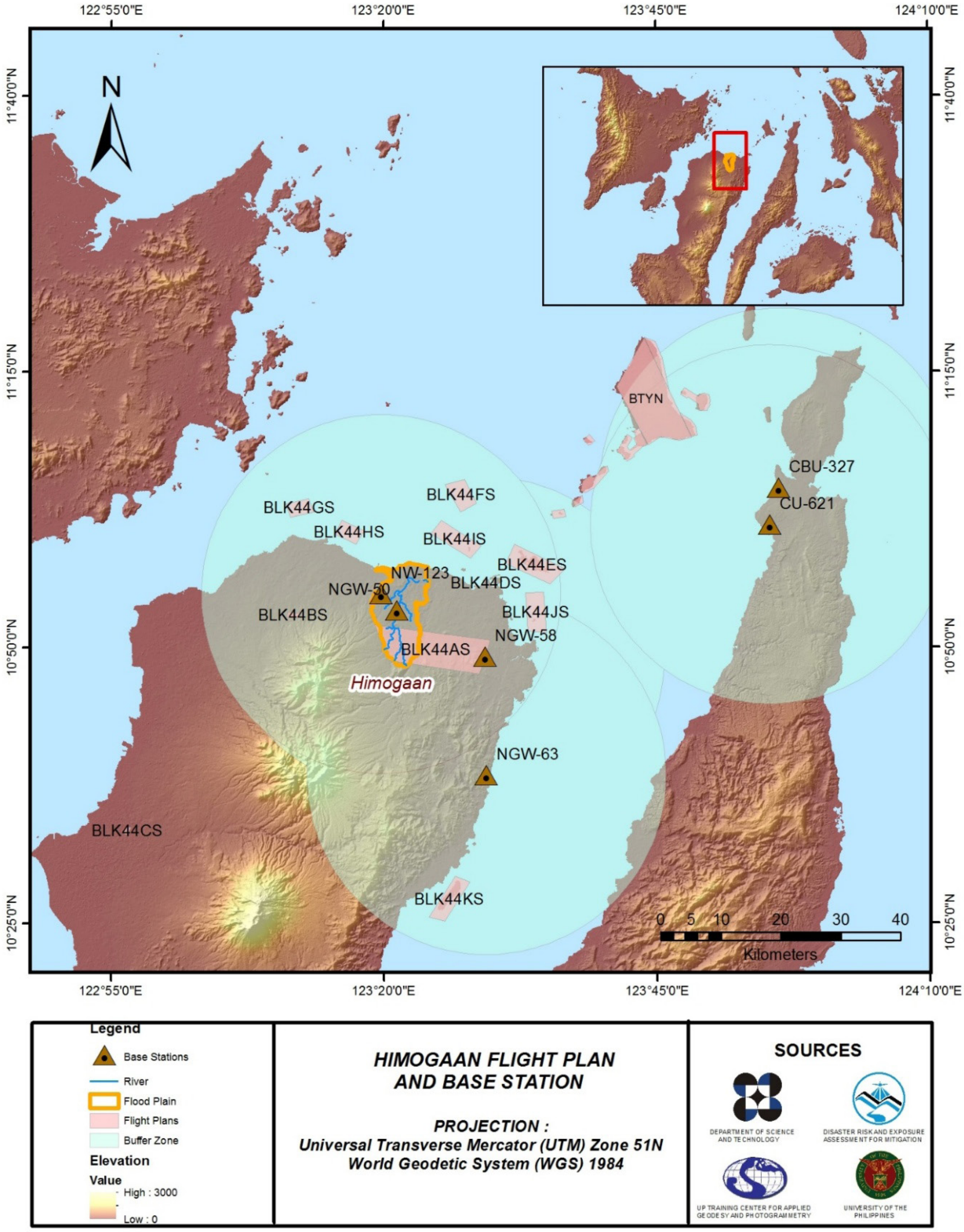


Figure 2. Flight plan and base stations used for Himogaan floodplain.

2.2 Ground Base Station

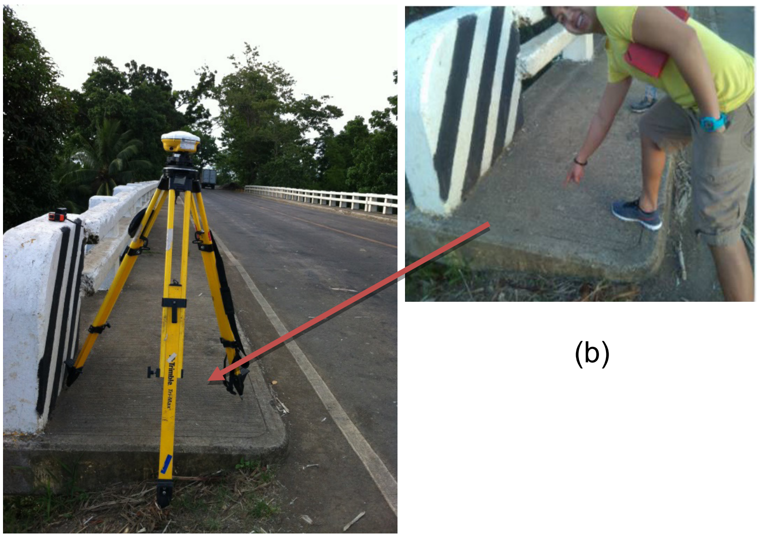
The project team was able to recover four(4) NAMRIA reference points: NGW-50, NGW-58, NGW-63, and CBU-327,which are of second (2^{nd}) order accuracy. The team also recovered two (2) benchmarks NW-123 and CU-621. These benchmarks were used as vertical reference points and were also established as ground control points. The certification for the NAMRIA reference points and benchmarks 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 (April to July 2014 and April 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 Himogaan floodplain are shown in Figure 2.

Figure 3 to Figure 8 shows the recovered NAMRIA control station within the area. In addition, Table 3 to Table 8 show the details about the following NAMRIA control stations and established points, while Table 9 shows the list of all ground control points occupied during the acquisition with the corresponding dates of utilization.

Figure 3. GPS set-up over NGW-50 in Sagay, Negros Occidental (a) NAMRIA reference point NGW-50 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point NGW-50 used as base station for the LiDAR Acquisition.

Station Name	NGW-50	
Order of Accuracy	2nd	
Relative Error (Horizontal Positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 53’ 26.84456” 123° 21’ 06.66798” 15.386 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting	538465.927 m
	Northing	1204272.594 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 53’ 26.84456” North 123° 21’ 06.66798” East 15.386 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting	538452.463 meters
	Northing	1203851.077 meters



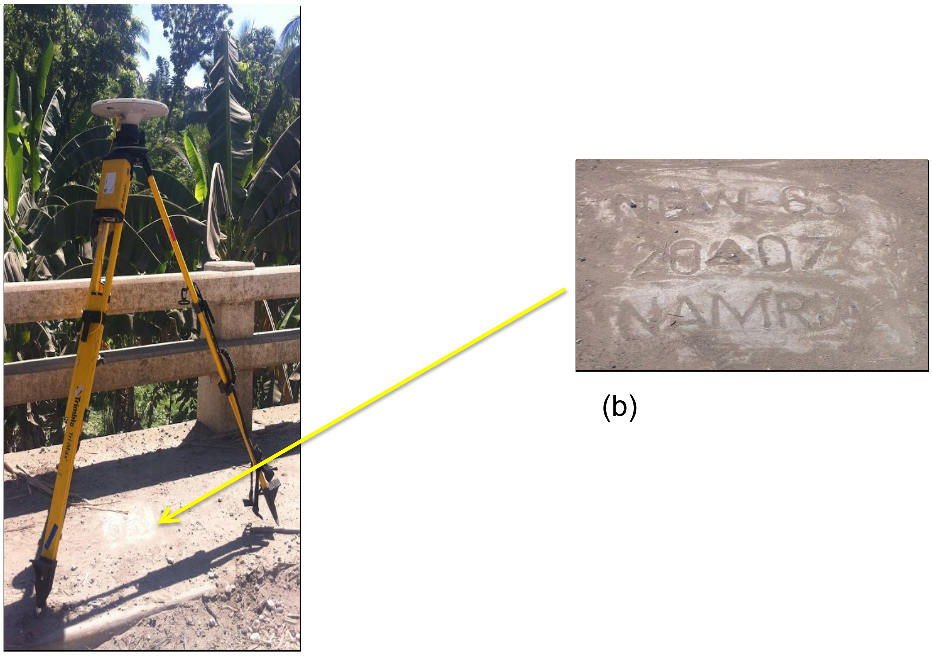
(b)

(a)

Figure 4. GPS set-up over NGW-58 in Brgy. Jonobjonob, Sitio Labarca, Escalante, Negros Occidental. It is on top of embedded benchmark NW-100.

Table 4. Details of the recovered NAMRIA horizontal control point NGW-58 used as base station for the LiDAR Acquisition.

Station Name	NGW-58	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 49’ 16.43235” 123° 29’ 11.51295” 8.72200 m
Grid Coordinates, PTM	Easting Northing	553202.195 m 1196599.363 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 49’ 12.14178” 123° 29’ 16.71871” 68.25600 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	553,183.57 1,196,180.53

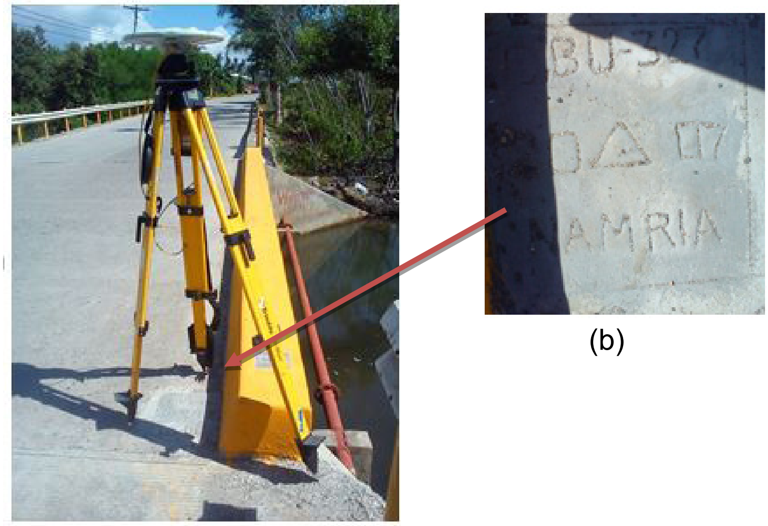


(a) (b)

Figure 5. GPS set-up over NGW-63 in Brgy. Lemery, Calatrava, Negros Occidental and NAMRIA reference point NGW-63 (b) as recovered by the field team.

Table 5. Details of the recovered NAMRIA horizontal control point NGW-63 used as base station for the LiDAR Acquisition.

Station Name	NGW-63	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 38’ 30.18023” 123° 29’ 18.57332” 10.15500 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	553448.18 m 1176744.618 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 38’ 25.93535” 123° 29’ 23.79491” 70.11800 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	553429.47 m 1176332.74 m

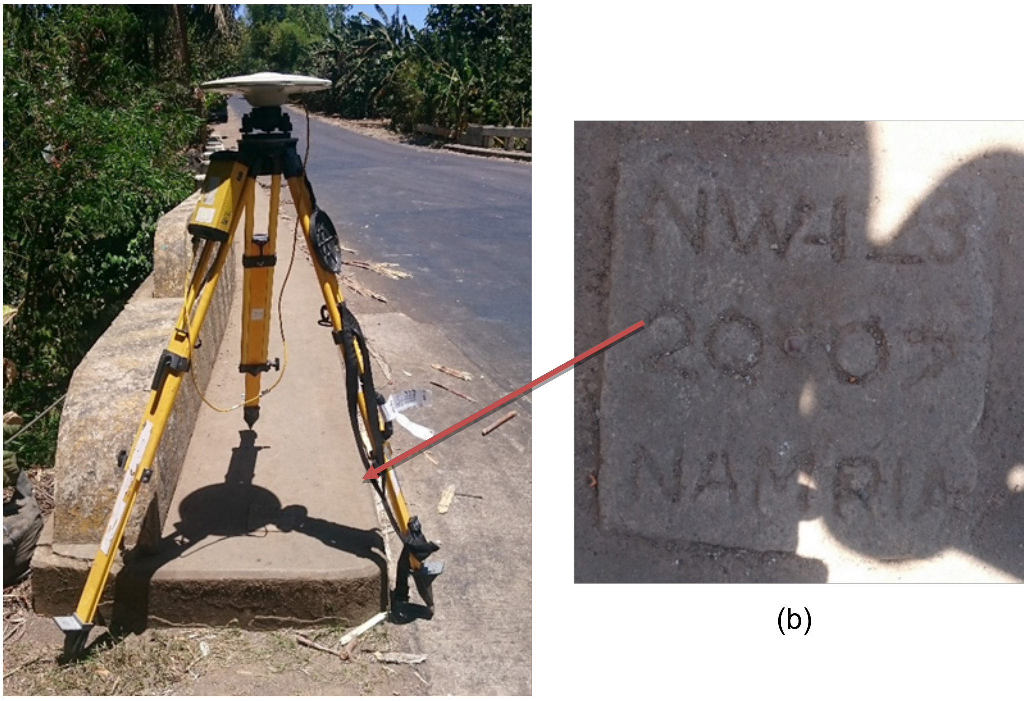


(a)

Figure 6. GPS set-up over CBU-327 in Barangay Poblacion, San Remigio, Cebu, on the bridge adjacent to San Remigio Public Cemetery, and NAMRIA reference point CBU-327 (b) as recovered by the field team.

Table 6. Details of the recovered NAMRIA horizontal control point CBU-327 used as base station for the LiDAR acquisition.

Station Name	CBU-327	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11° 4' 30.20546" 123° 56' 10.33433" 3.541 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	602289.857 m 1224791.193 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 4' 25.88934" 123° 56' 15.51412" 63.574 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	602254.06 m 1224362.49 m



(b)

(a)

Figure 7. GPS set-up over NW-123 in Cadiz, Negros Occidental going to San Carlos, along the national road (a) and NAMRIA reference point NW-123 (b) as recovered by the field team.

Table 7. Details of the recovered NAMRIA bench mark point NW-123 with processed coordinates used as base station for the LiDAR Acquisition.

Station Name	NW-123	
Order of Accuracy	2nd	
Relative Error (Horizontal Positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 54' 55.44193" 123° 19' 39.85851" 29.402 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 54' 51.11386" North 123° 19' 45.05716" East 88.320 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	535814.201 meters 1206569.167 meters

(a)

(b)

Figure 8. GPS set-up over CU-621A in Barangay Tambongan, San Remigio, Cebu (a) as CU-621 (b) as recovered by the field team.

Table 8. Details of the recovered NAMRIA benchmark point CU-621 with processed coordinates used as base station for the LiDAR acquisition.

Station Name	CU-621A	
Order of Accuracy	2nd	
Relative Error (Horizontal Positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11° 01' 11.40721" 123° 55' 20.28470" 15.65695 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 01' 07.10388" North 123° 55' 25.46947" East 75.791 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	600754.2895 meters 1218251.478 meters

Table 9. Ground control points used during LiDAR Data Acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
May 1, 2014	1411P	1BLK44D121A	NGW-50 and NGW-58
May 6, 2014	1431P	1BLK44GHS126A	NGW-58 and NGW-63
May 6, 2014	1433P	1BLK44FGS126B	NGW-58 and NGW-63
May 7, 2014	1435P	1BLK44DS127A	NGW-58 and NGW-63
July 23, 2014	1745P	1BTYN204A	CBU-327 and CU-621A
April 22, 2016	8453AC	3BLK44AS113A	NGW-50 and NW-123
April 23, 2016	8455AC	3BLK44AS114A	NGW-50 and NW-123
April 24, 2016	8457AC	3BLK44EDS115A	NGW-50 and NW-123

2.3 Flight Missions

Eight (8) missions were conducted to complete LiDAR data acquisition in Himogaan floodplain, for a total of 33 hours and 3 minutes (33+3) of flying time for RP-C9022 and RP-C9322. All missions were acquired using the Aquarius and Pegasus LiDAR systems. Table 10 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 11 presents the actual parameters used during the LiDAR data acquisition.

Table 10. Flight missions for LiDAR data acquisition in Himogaan 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 1, 2014	1411P	584.55	358.76	60.75	298.01	519	3	47
May 6, 2014	1431P	501.27	217.96	0	217.96	727	4	21
May 6, 2014	1433P	341.79	199.15	4.65	194.5	973	4	29
May 7, 2014	1435P	843.06	303.80	27.01	276.79	NA	4	53
July 23, 2014	1745P	153.44	180.65	0	180.65	762	3	36
April 22, 2016	8453AC	108.13	103.85	30.64	73.21	NA	4	11
April 23, 2016	8455AC	35.96	60.01	11.51	48.5	NA	3	53
April 24, 2016	8457AC	53.08	64.14	3.65	60.49	NA	3	53
Total		2621.28	1488.32	138.21	1350.11	2981	33	3

Table 11. 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)
1411P	1200	25	50	200	30	130	5
1431P	800	25	50	200	30	130	5
1433P	800	25	50	200	30	130	5
1435P	800	25	50	200	30	130	5
1745P	1200	30	50	200	30	130	5
8453AC	500	30	36	50	45	125	5
8455AC	500	30	36	50	45	125	5
8457AC	500	60	40	50	40	125	5

2.4 Survey Coverage

Himogaan floodplain is located in the province of Negros Occidental with majority of the floodplain situated within the cities of Sagay and Cadiz. Sagay and Escalante in Negros Occidental, and Bantayan and Madridejos in Cebu are mostly covered by the survey. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 12. The actual coverage of the LiDAR acquisition for Himogaan floodplain is presented in Figure 9.

Table 12. List of cities and municipalities covered during Himogaan floodplain survey

Province	Municipality/City	Area of Municipality/City	Total Area Surveyed	Percentage of Area Surveyed (%)
Negros Occidental	Sagay	304.62	283.92	**93.2**
	Cadiz	516.18	246.32	**47.72**
	Escalante	193.4	155.38	**80.34**
	Calatrava	344.54	139.66	**40.54**
	Toboso	118.52	79.12	**66.76**
	San Carlos	408.97	33.06	**8.08**
	Manapla	99.18	4.56	**4.6**
Cebu	Bantayan	82.8	74.6	**90.1**
	Madridejos	24.33	24.31	**99.92**
	Santa Fe	32.23	22.85	**70.9**

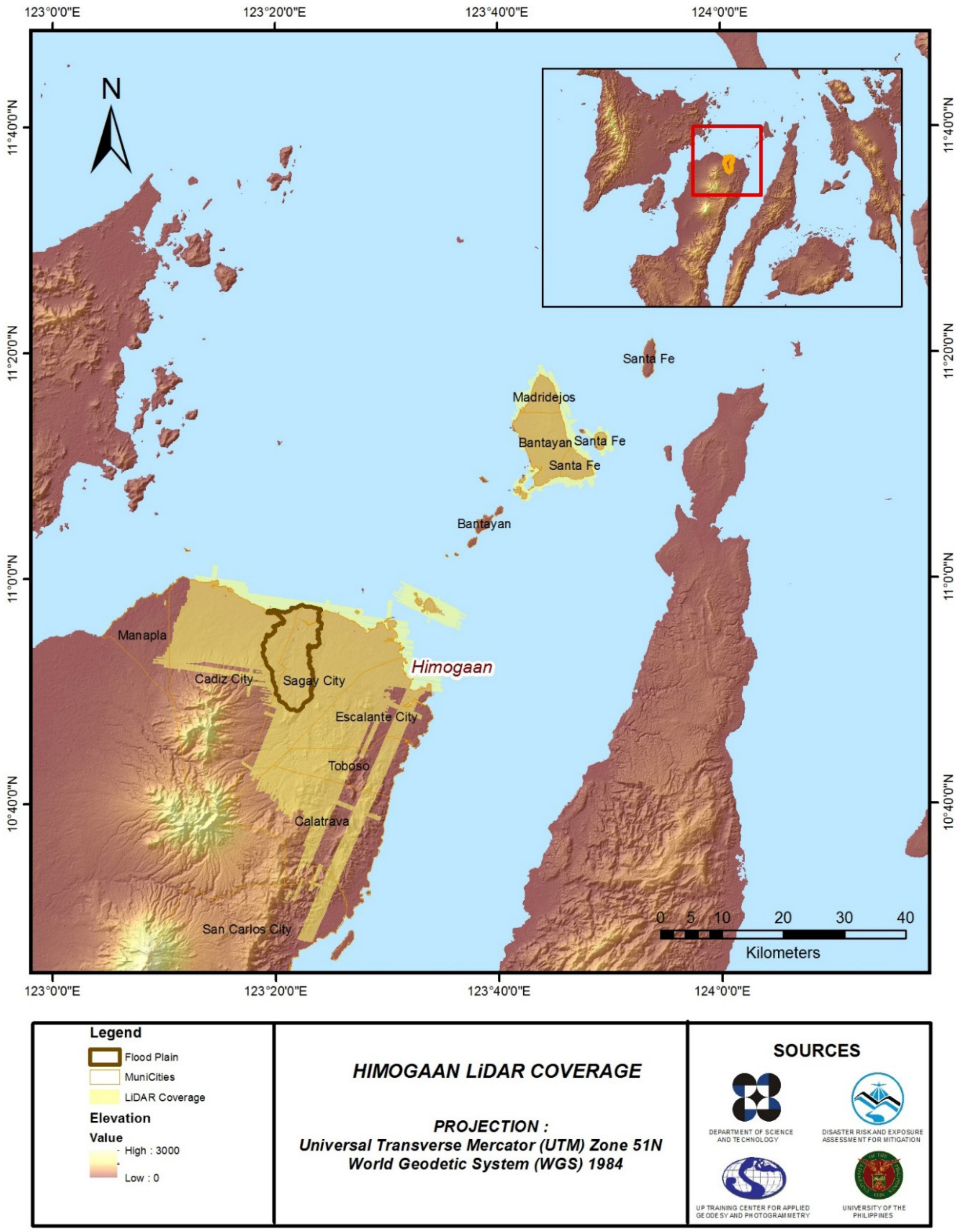


Figure 9. Actual LiDAR data acquisition for Himogaan floodplain.

CHAPTER 3: LIDAR DATA PROCESSING FOR HIMOGAAN FLOODPLAIN

Engr. Ma. Rosario Concepcion O. Ang, Engr. John Louie D. Fabila, Engr. Sarah Jane D. Samalburo , Engr. Gladys Mae Apat , Engr. Joida F. Prieto , Engr. Ma. Ailyn L. Olanda, Engr. Justine Y. Francisco, Eng. Czarina Jean P. Añonuevo , Franklin D. Maraya, and Chester B. de Guzman

3.1 Overview of LiDAR Data Pre-Processing

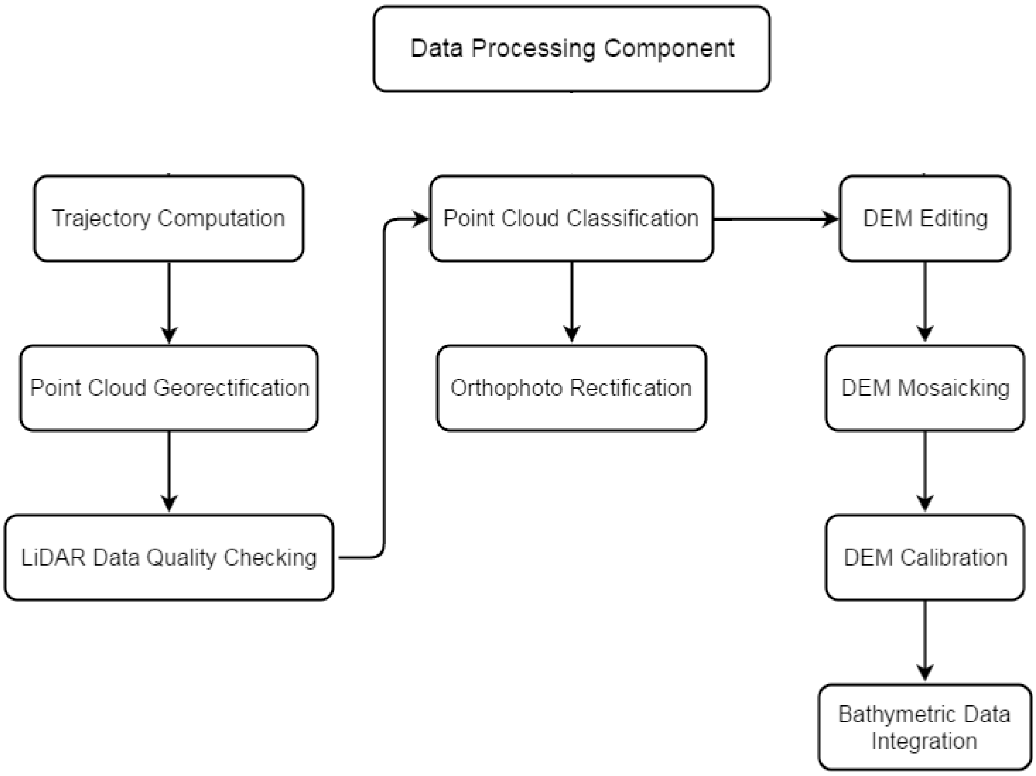


Figure 10. Schematic Diagram for Data Pre-Processing Component

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 trajectoryis 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 georectifiedLiDAR 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 10.

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Himogaan floodplain can be found in Annex 5. Missions flown during the first survey conducted on May 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system while missions acquired during the second survey on May2016 were flown using the Aquarius system over Sagay, Negros Occidental. The Data Acquisition Component (DAC) transferred a total of 135.84 Gigabytes of Range data, 1.73 Gigabytes of POS data, 326.78 Megabytes of GPS base station data, and 219.9 Gigabytes of raw image data to the data server on May 19, 2014 for the first survey and May 18, 2016 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Himogaan was fully transferred on May 20, 2016, as indicated on the Data Transfer Sheets for Himogaan floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 1431P, one of the Himogaan flights, which is the North, East, and Down position RMSE values are shown in Figure 11. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on May 06, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

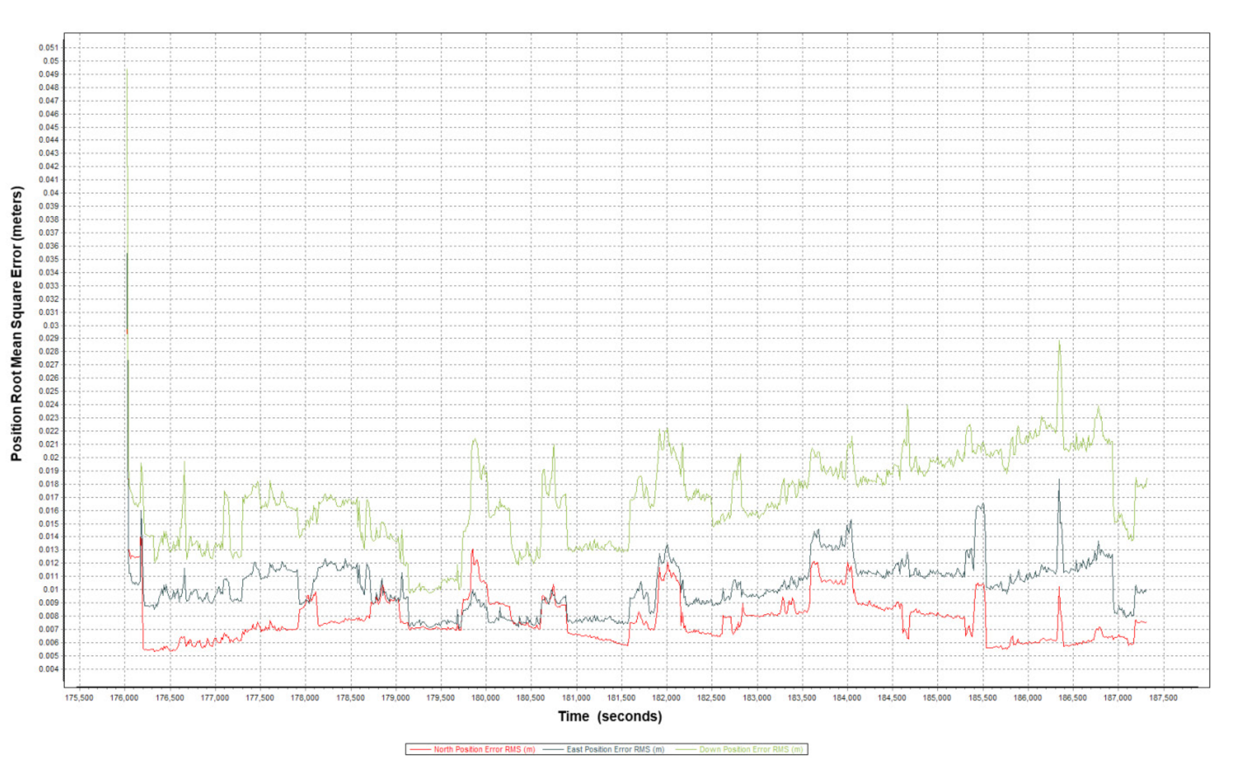


Figure 11. Smoothed Performance Metrics of a Himogaan Flight 1431P.

The time of flight was from 176000 seconds to 187500 seconds, which corresponds to morning of May 06, 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 1.30 centimeters, the East position RMSE peaks at 1. 80 centimeters, and the Down position RMSE peaks at 2.90 centimeters, which are within the prescribed accuracies described in the methodology.

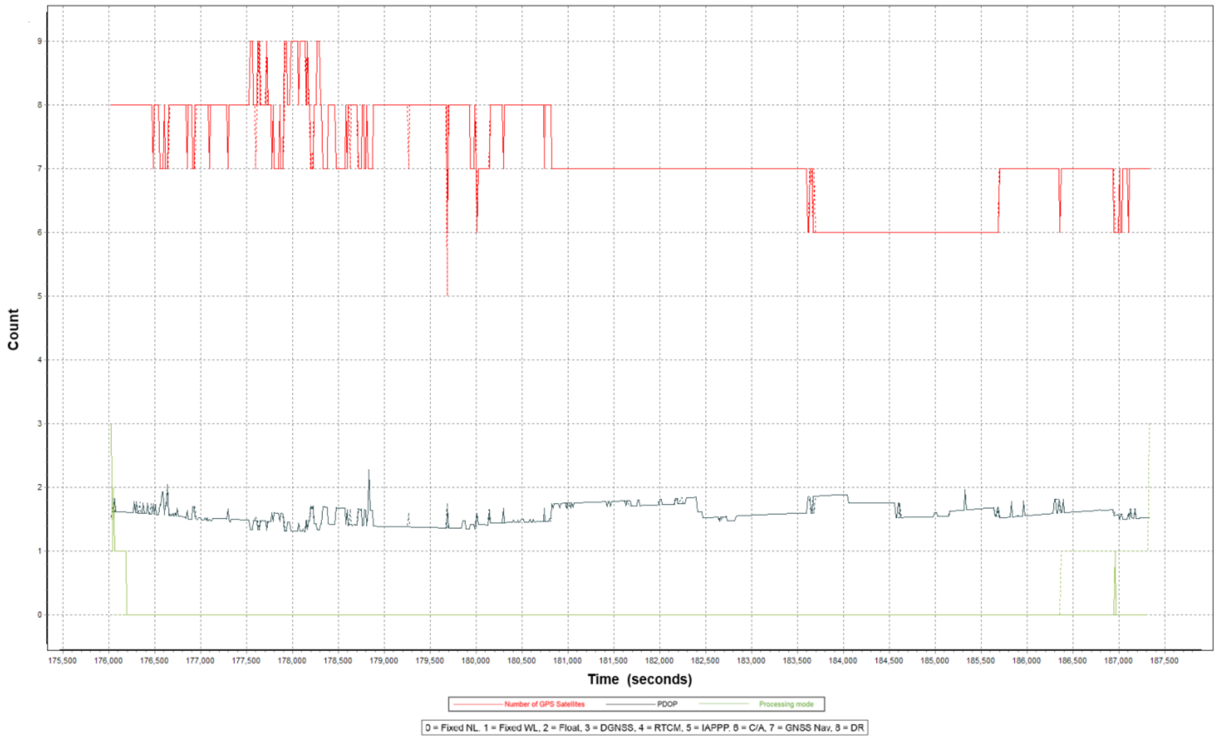


Figure 12. Solution Status Parameters of Himogaan Flight 1431P.

The Solution Status parameters of flight 1431P, one of the Himogaan flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 12. The graphs indicate that the number of satellites during the acquisition did not go down to 5. Majority of the time, the number of satellites tracked was between 5 and 9. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 1 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Himogaan flights is shown in Figure 13.

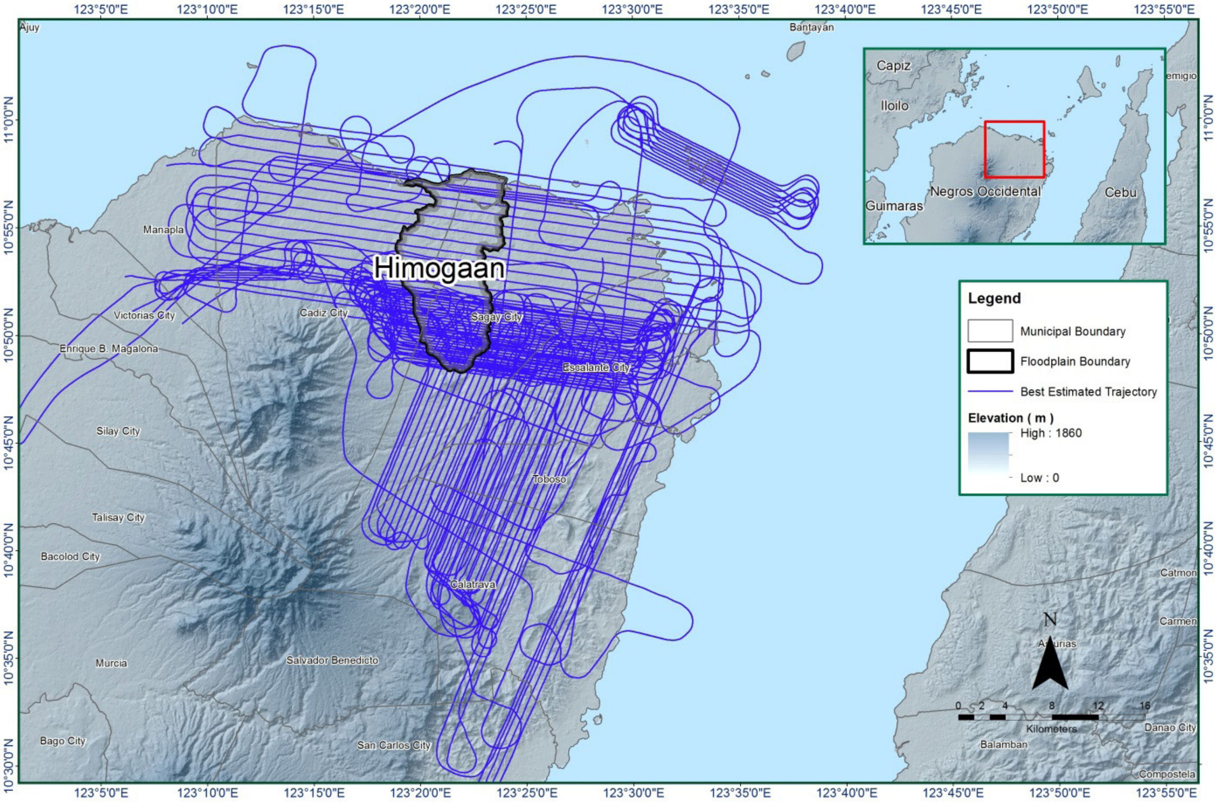


Figure 13. Best Estimated Trajectory for Himogaan floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 115 flight lines, the flight lines from Aquarius system contain one channel, while the flight lines from the Pegasus system contain two channels. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Himogaan floodplain are given in Table 13.

Table 13. Self-Calibration Results values for Himogaan flights.

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

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

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Himogaan Floodplain is shown in Figure 14. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

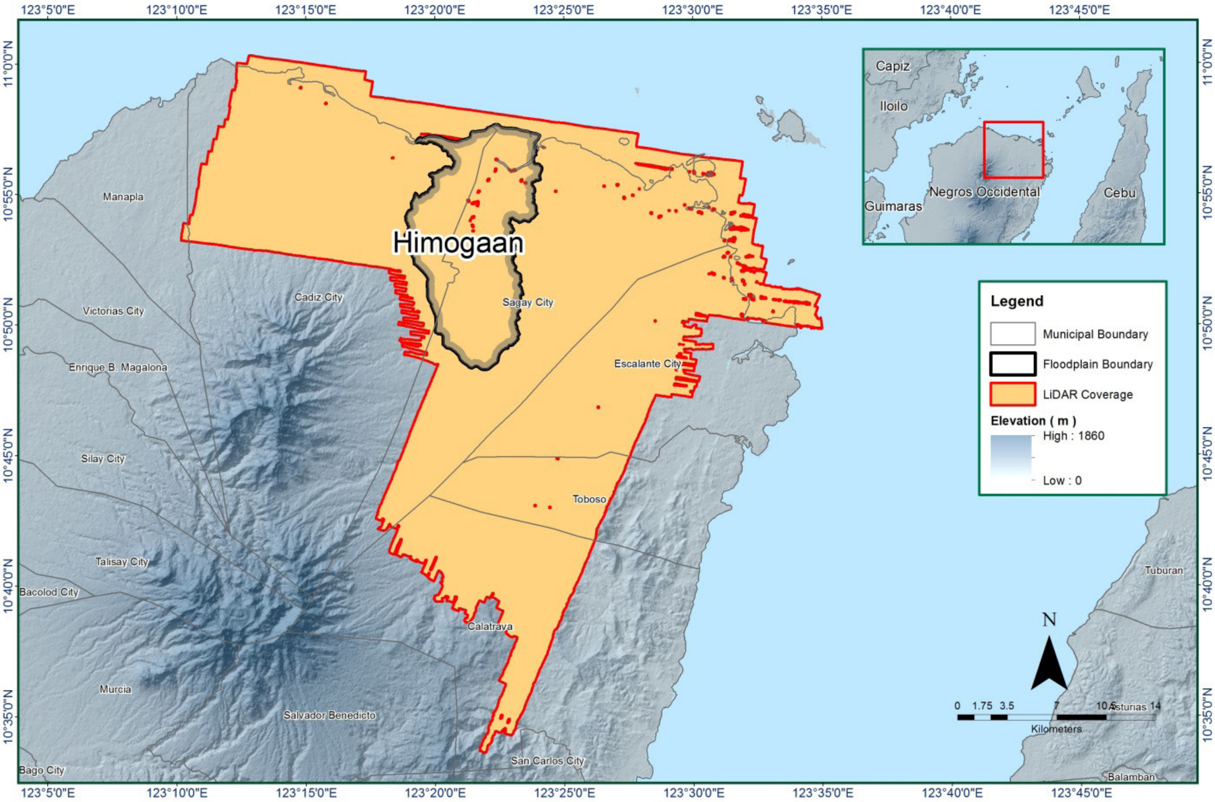


Figure 14. Boundary of the processed LiDAR data over Himogaan Floodplain

The total area covered by the Himogaan missions is 936.05 sq.km that is comprised of seven (7) flight acquisitions grouped and merged into five (5) blocks as shown in Table 14.

Table 14. List of LiDAR blocks for Himogaan floodplain.

LiDAR Blocks	Flight Numbers	Area (sq.km)
Negros_Blk44D	1411P 1435P	475.2
Negros_Blk44FG	1431P 1431P	283.7
Bacolod_Blk44E	8453AC	101.6
Bacolod_Blk44E_additional	8455AC	54.26
Bacolod_Blk44D	8457AC	15.29
TOTAL		**930.05 sq.km**

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 15. Since 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. On the other hand, the Pegasus system employs two channels, the average value of 2 (blue) for areas where there is limited overlap, and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines.

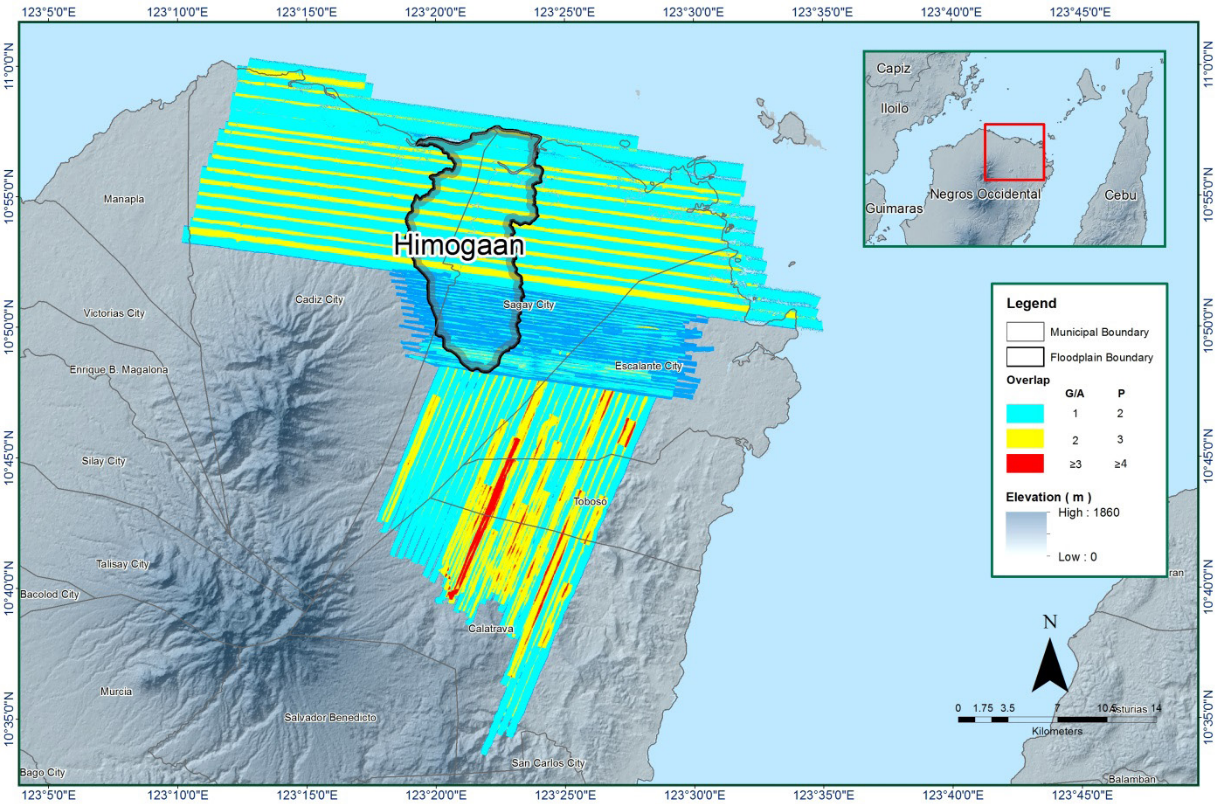


Figure 15. Image of data overlap for Himogaan floodplain.

The overlap statistics per block for the Himogaan floodplain can be found in Annex 8. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 27.44% and 47.40% respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 16. It was determined that all LiDAR data for Himogaan floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.74 points per square meter.

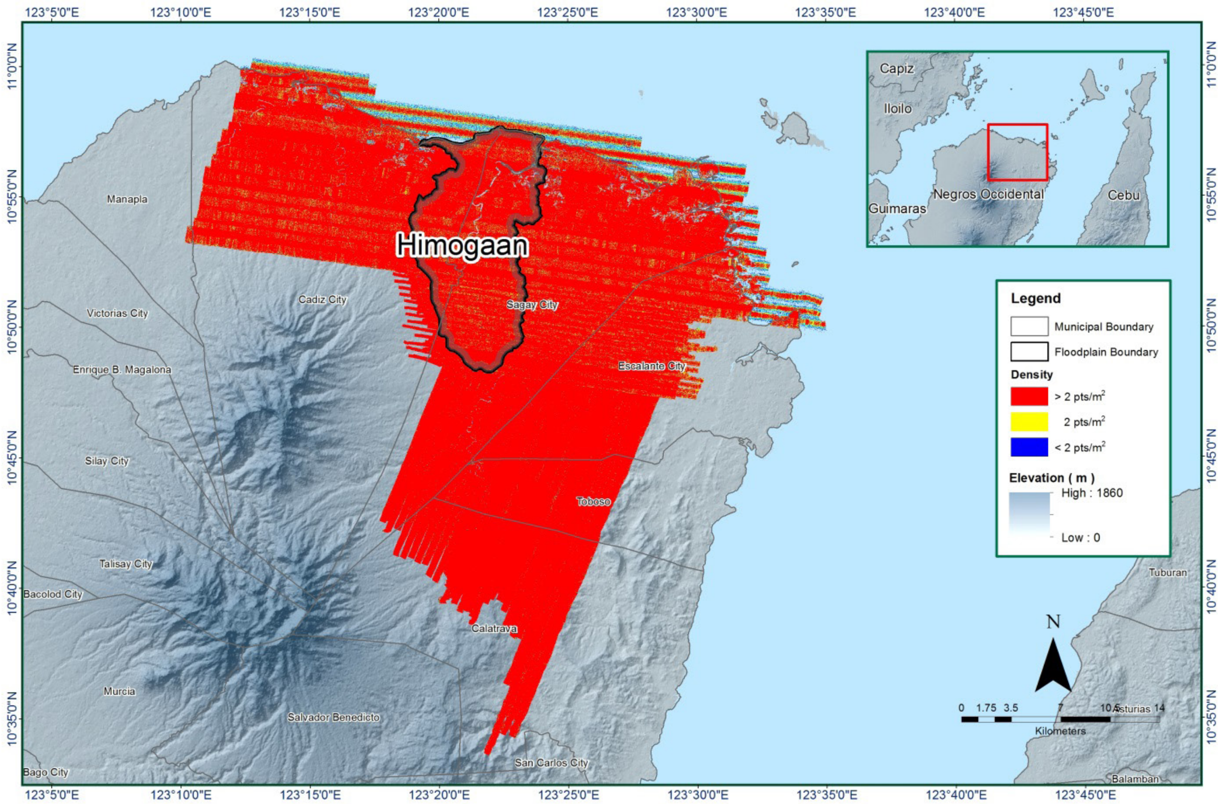


Figure 16. Pulse density map of merged LiDAR data for Himogaan floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 17. The default color range is from blue to red, where bright blue areas correspond to portions where elevations of a previous flight line, identified by its acquisition time,are higher by more than 0.20m relative to elevations of its adjacent flight line. Bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20m relative to elevations of its adjacent flight line. Areas with bright red or bright blue need to be investigated further using Quick Terrain Modeler software.

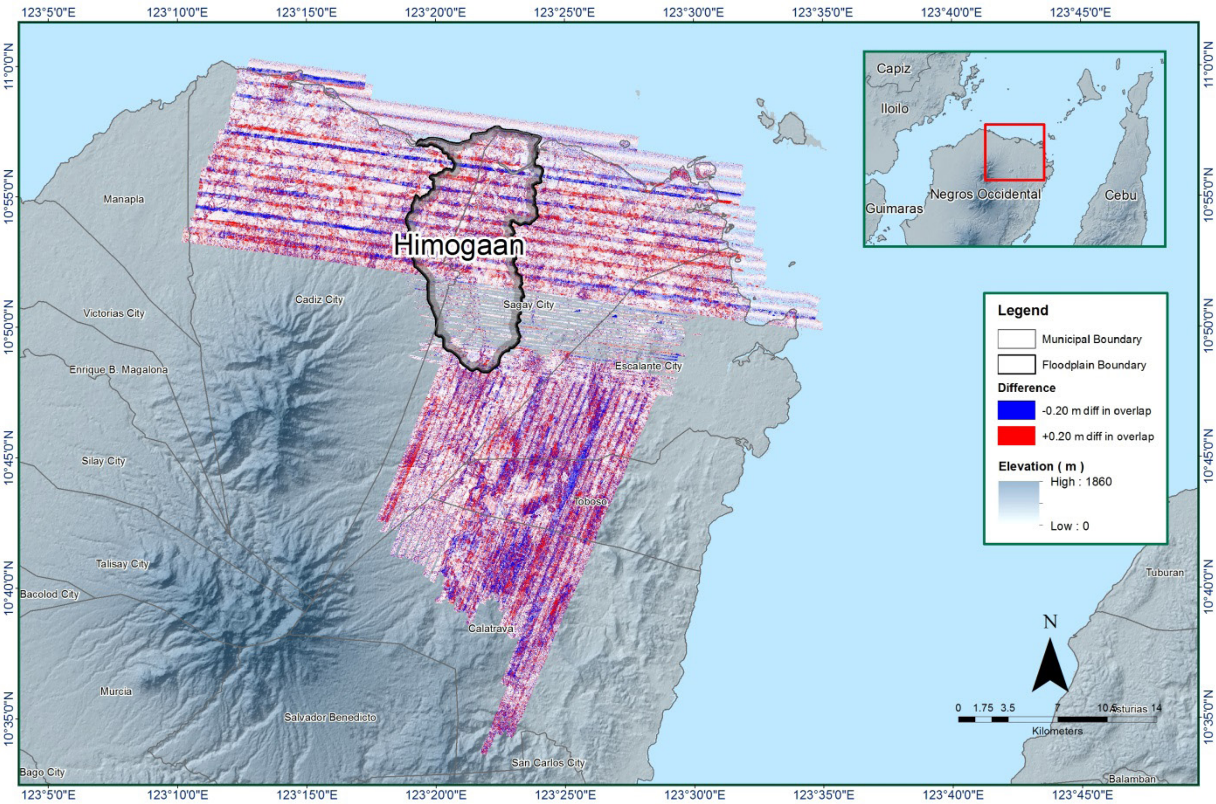


Figure 17. Elevation difference map between flight lines for Himogaan floodplain.

A screen capture of the processed LAS data from a Himogaan flight 1431P loaded in QT Modeler is shown in Figure 18. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed yellow line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

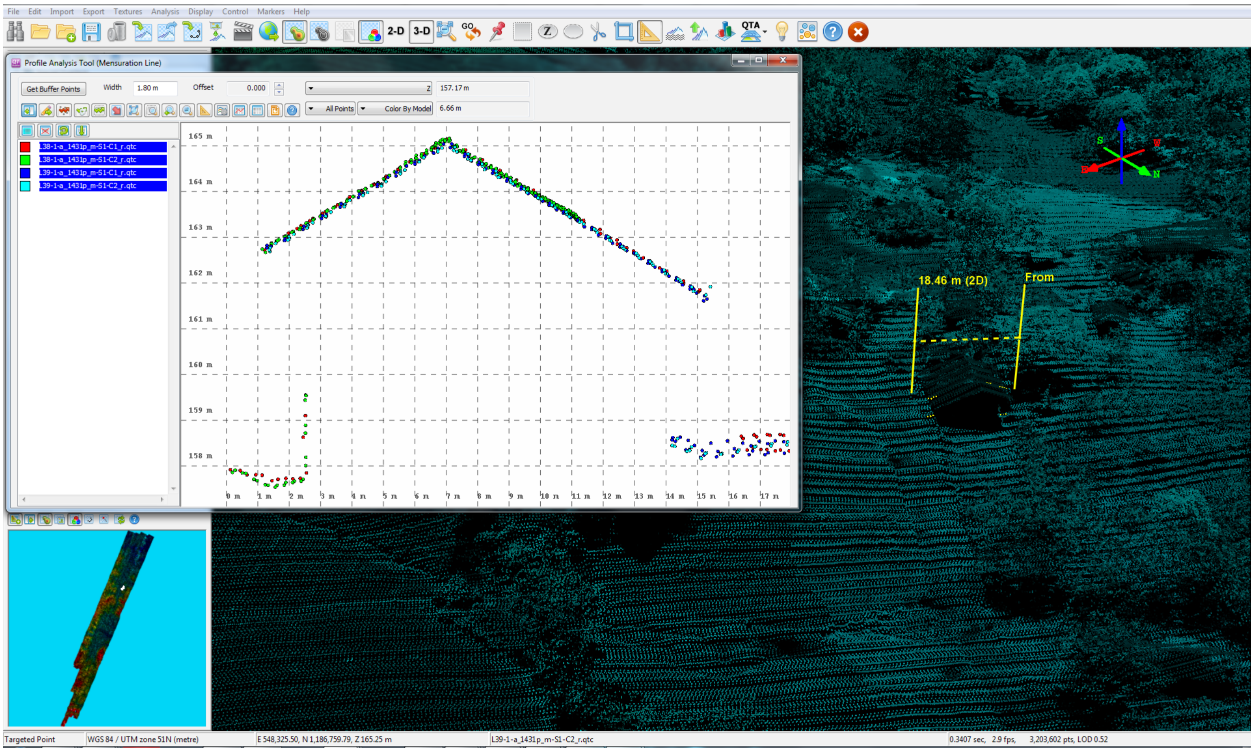


Figure 18. Quality checking for a Himogaan flight 1431P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 15. Himogaan classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	1,160,881,260
Low Vegetation	1,145,108,649
Medium Vegetation	1,776,503,683
High Vegetation	544,946,392
Building	33,829,606

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Himogaan floodplain is shown in Figure 21. A total of 1,456 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 15. The point cloud has a maximum and minimum height of 584.11 meters and 50.48 meters respectively.

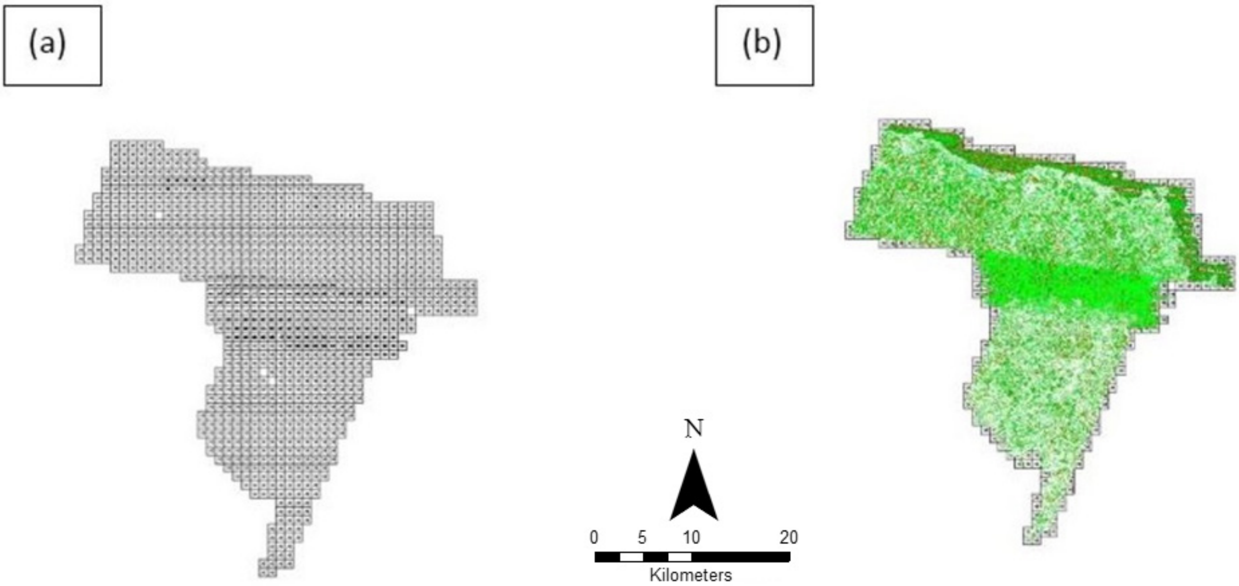


Figure 19. Tiles for Himogaan floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 20. The ground points are in orange, the vegetation is in different shades of green, and the buildings are in cyan. It can be seen that residential structures adjacent or even below canopy are classified correctly, due to the density of the LiDAR data.

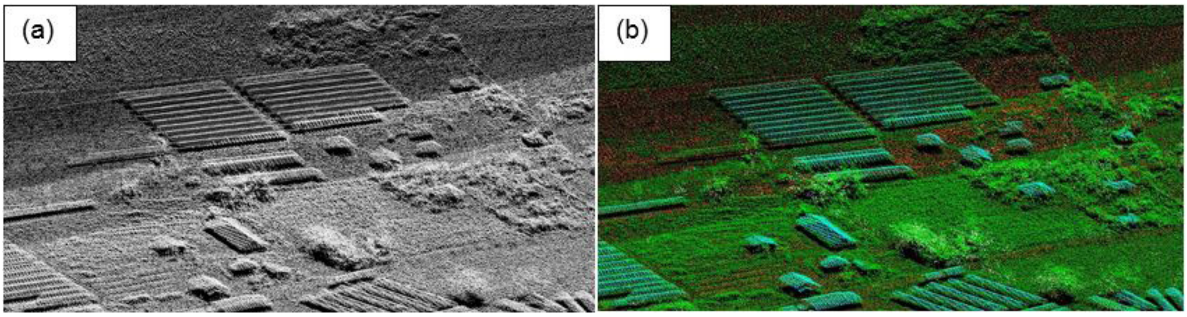


Figure 20. Point cloud before (a) and after (b) classification.

The production of last return (V_ASCII) and the secondary (T_ ASCII) DTM, first (S_ ASCII) and last (D_ ASCII) return DSM of the area in top view display are shown in Figure 23. It shows that DTMs are the representation of the bare earth while on the DSMs, all features are present such as buildings and vegetation.

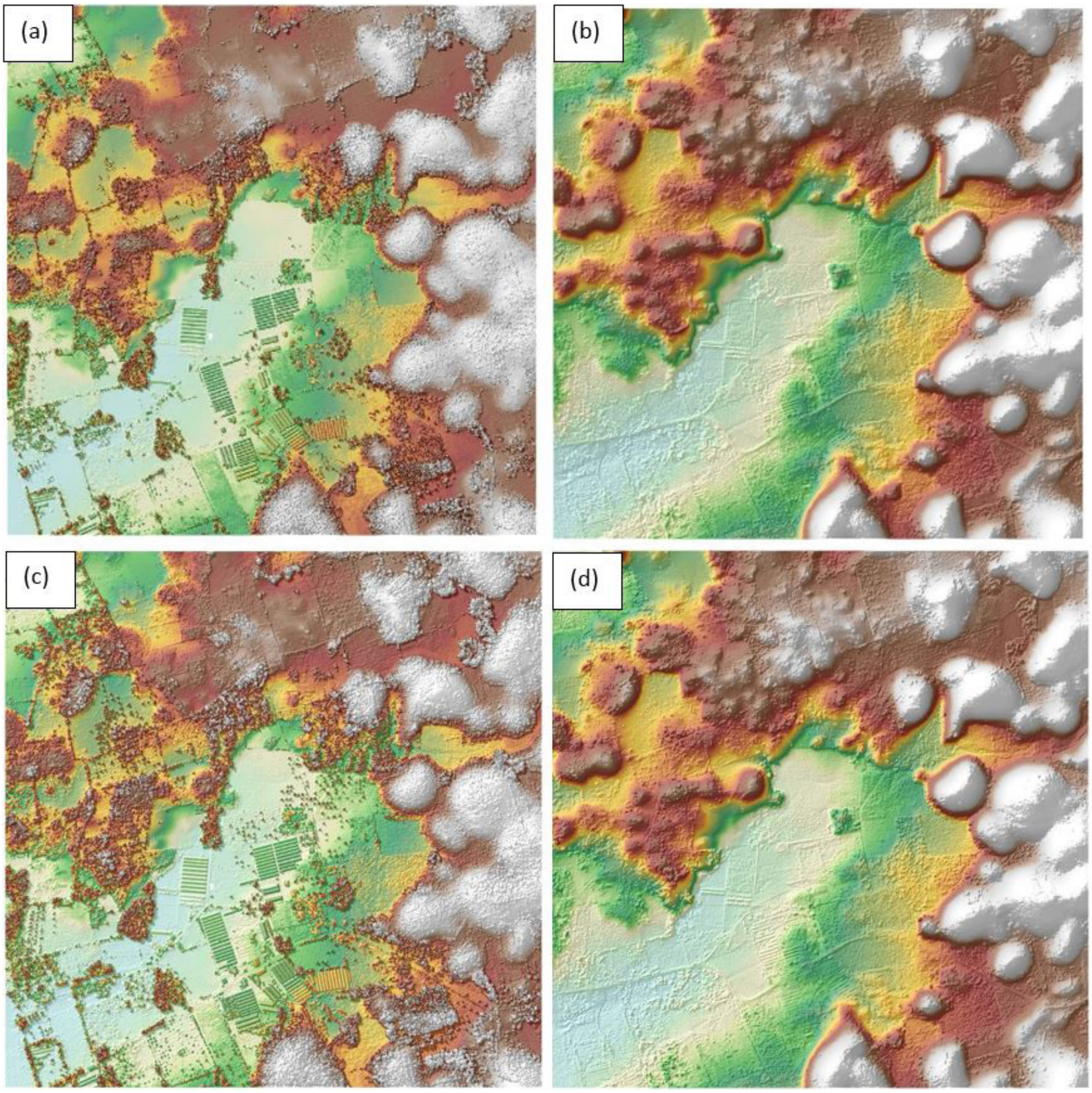


Figure 21. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Himogaan floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 685 1km by 1km tiles area covered by Himogaan floodplain is shown in Figure 22. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Himogaan floodplain has a total of 528.31 sq.km orthophotogaph coverage comprised of 1,248 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 23.

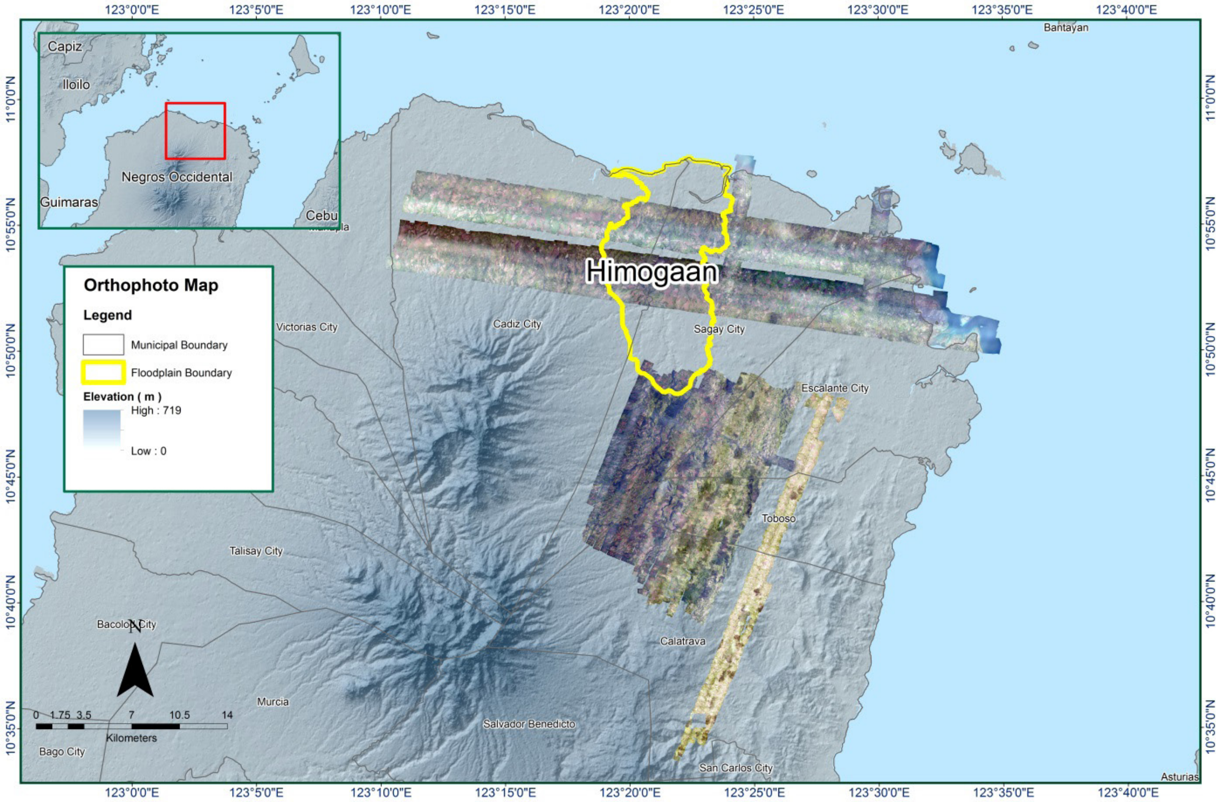


Figure 22. Himogaan floodplain with available orthophotographs.

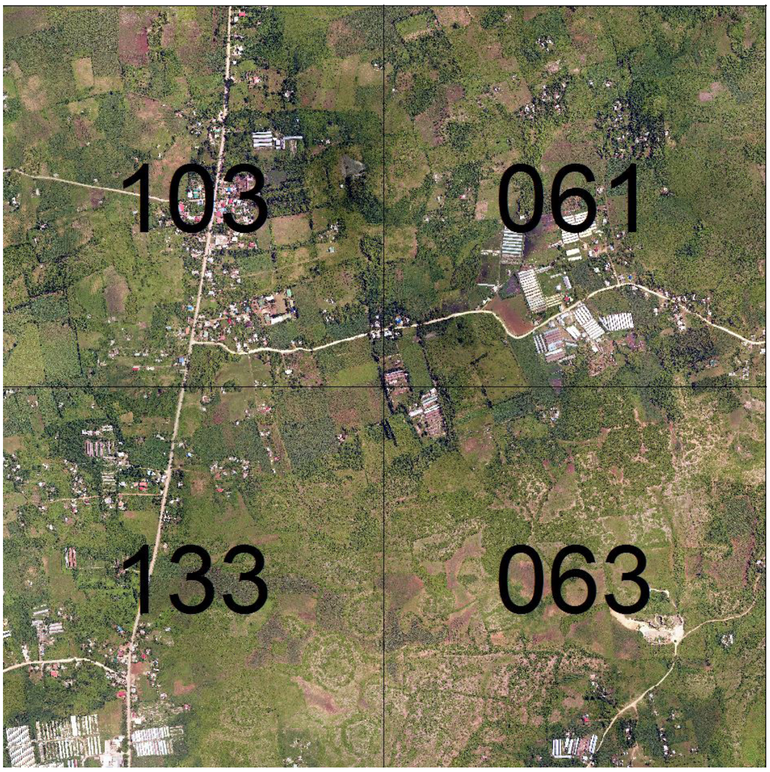


Figure 23. Sample orthophotograph tiles for Himogaan floodplain.

3.8 DEM Editing and Hydro-Correction

Five (5) mission blocks were processed for Himogaan flood plain. These blocks are composed of Negros and Bacolod blocks with a total area of 930.05 square kilometers. Table 16 shows the name and corresponding area of each block in square kilometers.

Table 16. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq.km)
Negros_Blk44D	475.20
Negros_Blk44FG	283.70
Bacolod_Blk44D	15.29
Bacolod_Blk44E	101.6
Bacolod_Blk44E_additional	54.26
TOTAL	**930.05 sq.km**

Portions of DTM before and after manual editing are shown in Figure 24. It shows that the paddy field (Figure 24a) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 24b). The bridges (Figure 24c) would be an impedance to the flow of water along the river and have to be removed (Figure 24d) in order to hydrologically correct the river. Another example is a road that has been misclassified (Figure 24e) and has to be retrieved through manual editing (Figure 24f).

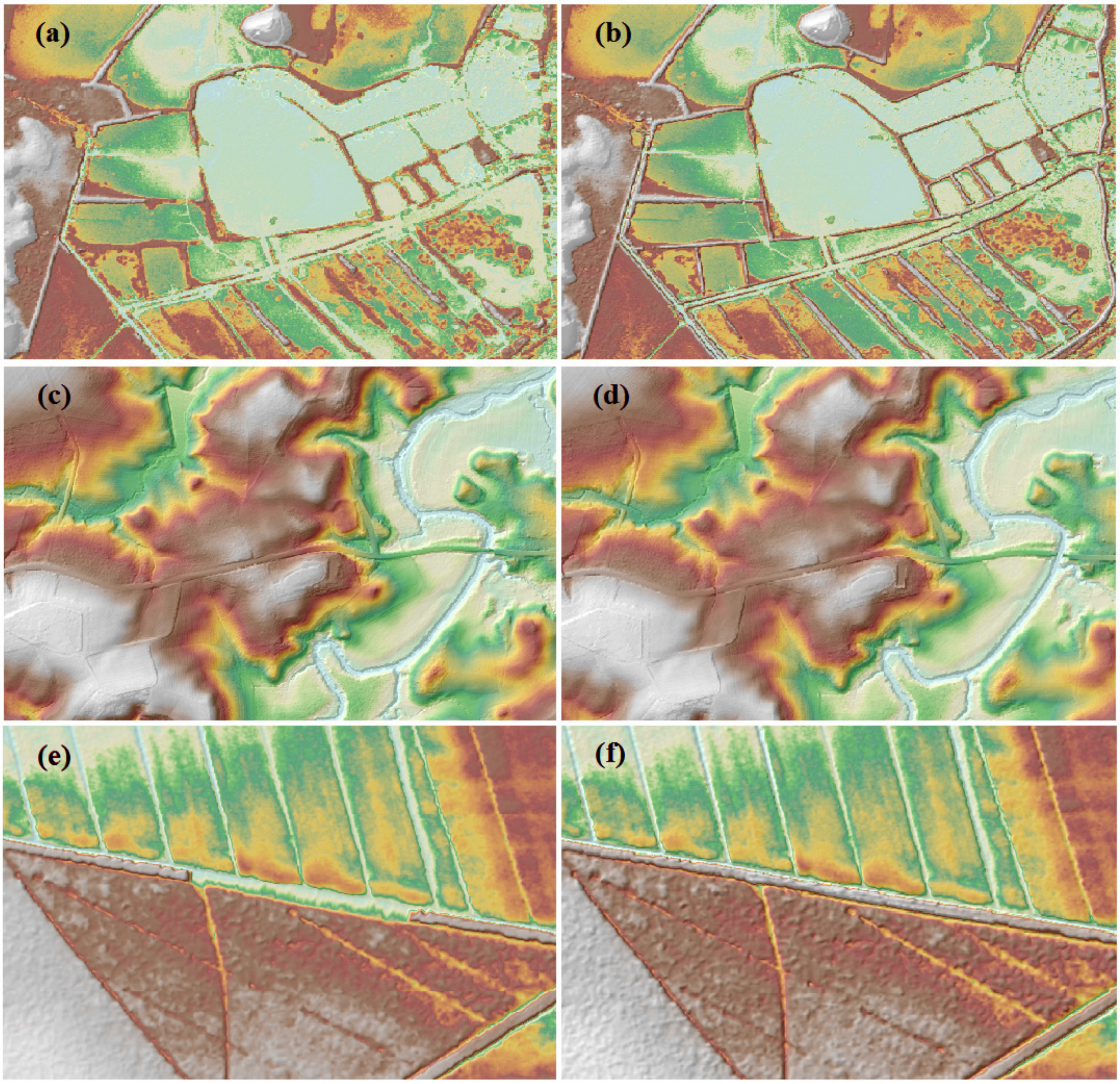


Figure 24. Portions in the DTM of Himogaan Floodplain – a paddy field before (a) and after (b) data retrieval; bridges before (c) and after (d) manual editing; and a road before (e) and after (f) data retrieval

3.9 Mosaicking of Blocks

Negros_Blk44AB was used as the reference block at the start of mosaicking because it was referred to a base station with an acceptable order of accuracy. Table 17 shows the area of each LiDAR block and the shift values applied during mosaicking.

Mosaicked LiDAR DTM for Himogaan floodplain is shown in Figure 25. It can be seen that the entire Himogaan floodplain is 100% covered by LiDAR data.

Table 17. Shift Values of each LiDAR Block of Himogaan floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Negros_Blk44D	0.00	0.00	0.66
Negros_Blk44FG	0.00	0.00	0.57
Bacolod_Blk44D	0.00	0.00	1.66
Bacolod_Blk44E	0.00	0.00	1.39
Bacolod_Blk44E_additional	0.00	0.00	1.45

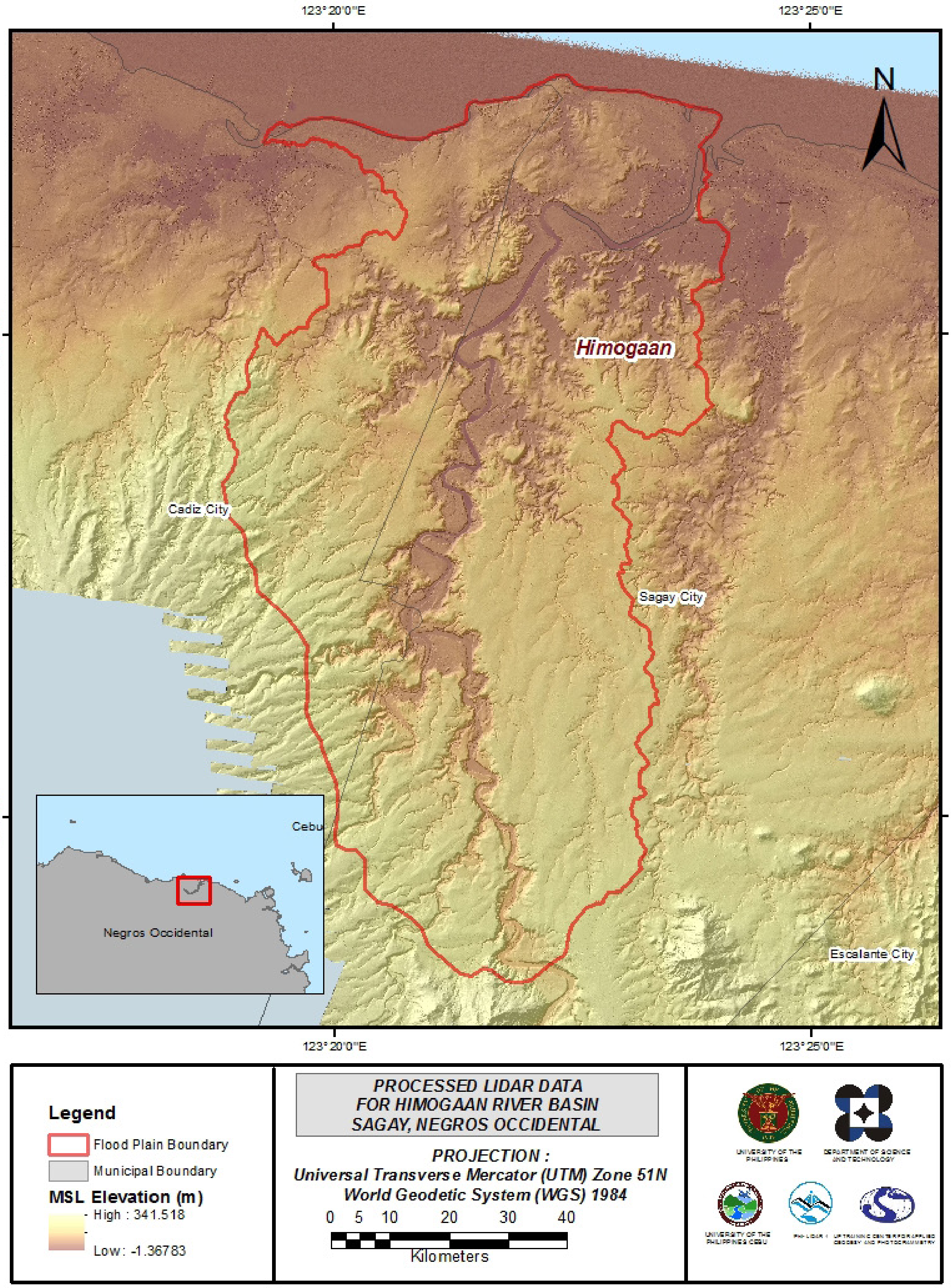


Figure 25. Map of Processed LiDAR Data for Himogaan Floodplain.

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in the Negros Island to collect points with which the LiDAR dataset is validated is shown in Figure 26. A total of 39,705 points were gathered for all the floodplains within the Negros Island wherein the Himogaan is located. Random selection of 80% of the survey points, resulting to 31,385 points, were used for calibration.

A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure 27. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration elevation values is 0.94 meters with a standard deviation of 0.15 meters. Calibration of Himogaan LiDAR data was done by subtracting the height difference value, 0.94 meters, to the mosaicked LiDAR data for Himogaan. Table 18 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

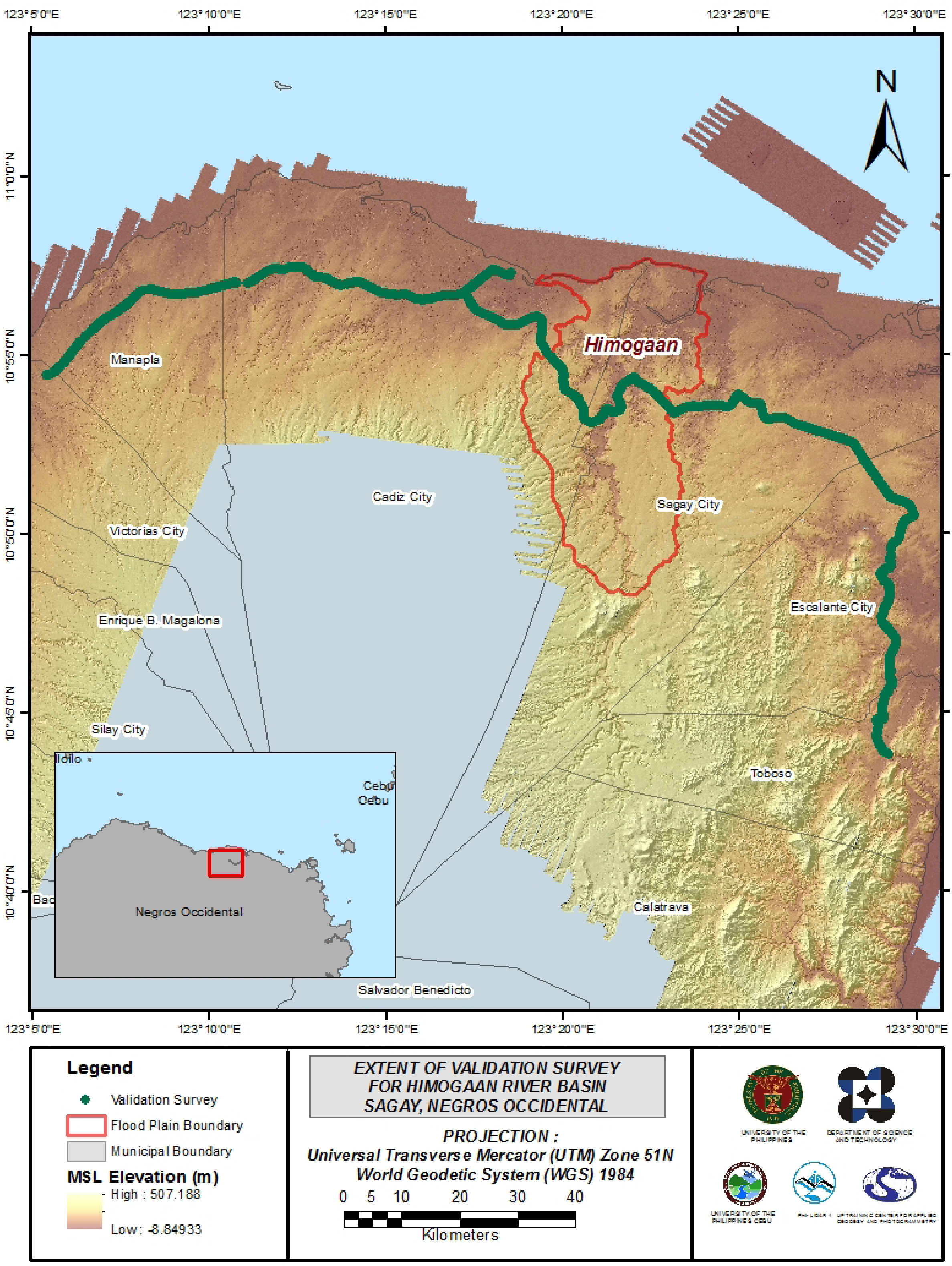


Figure 26. Map of Himogaan Flood Plain with validation survey points in green.

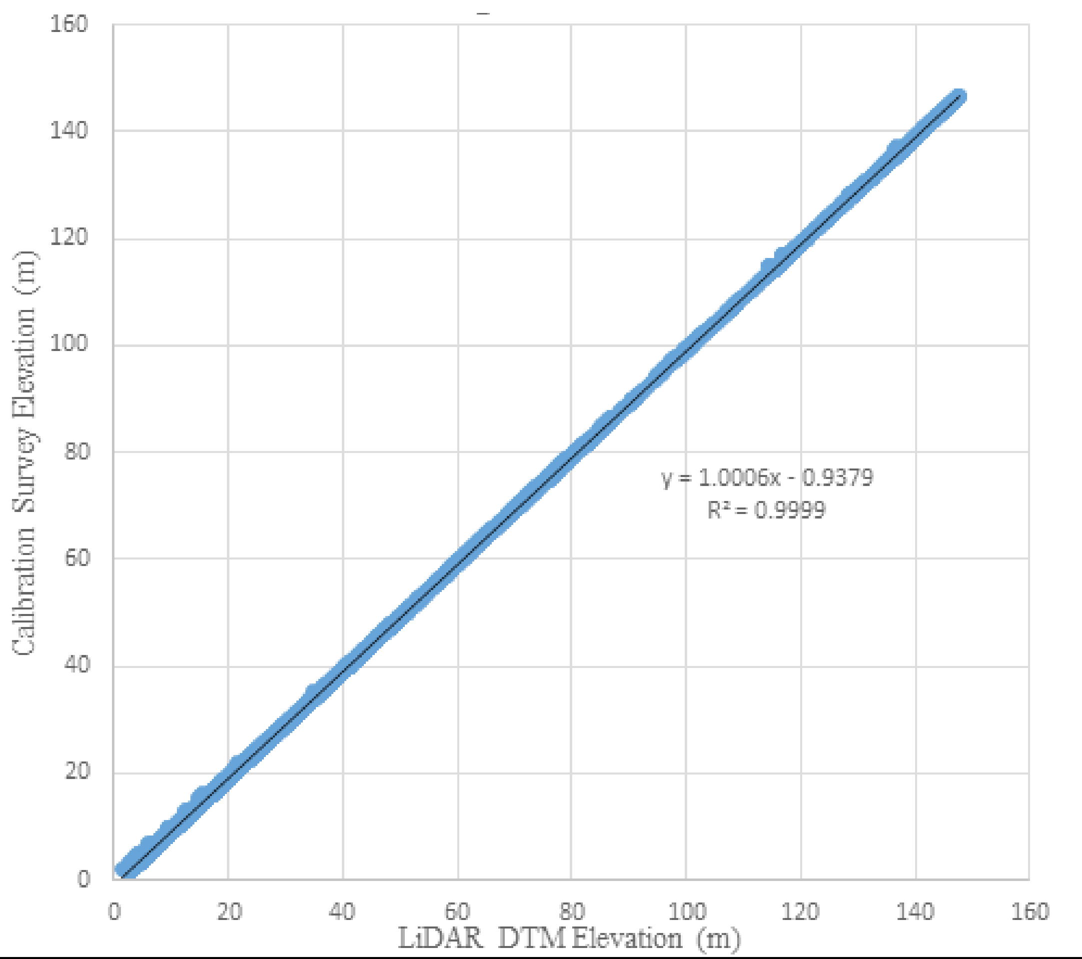


Figure 27. Correlation plot between calibration survey points and LiDAR data.

Table 18. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	0.94
Standard Deviation	0.15
Average	-0.93
Minimum	-1.21
Maximum	0.89

A total of 270 survey points that are within Himogaan flood plain were used for the validation of the calibrated Himogaan DTM. A good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM is shown in Figure 28. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.08 meters with a standard deviation of 0.08 meters, as shown in Table 19.

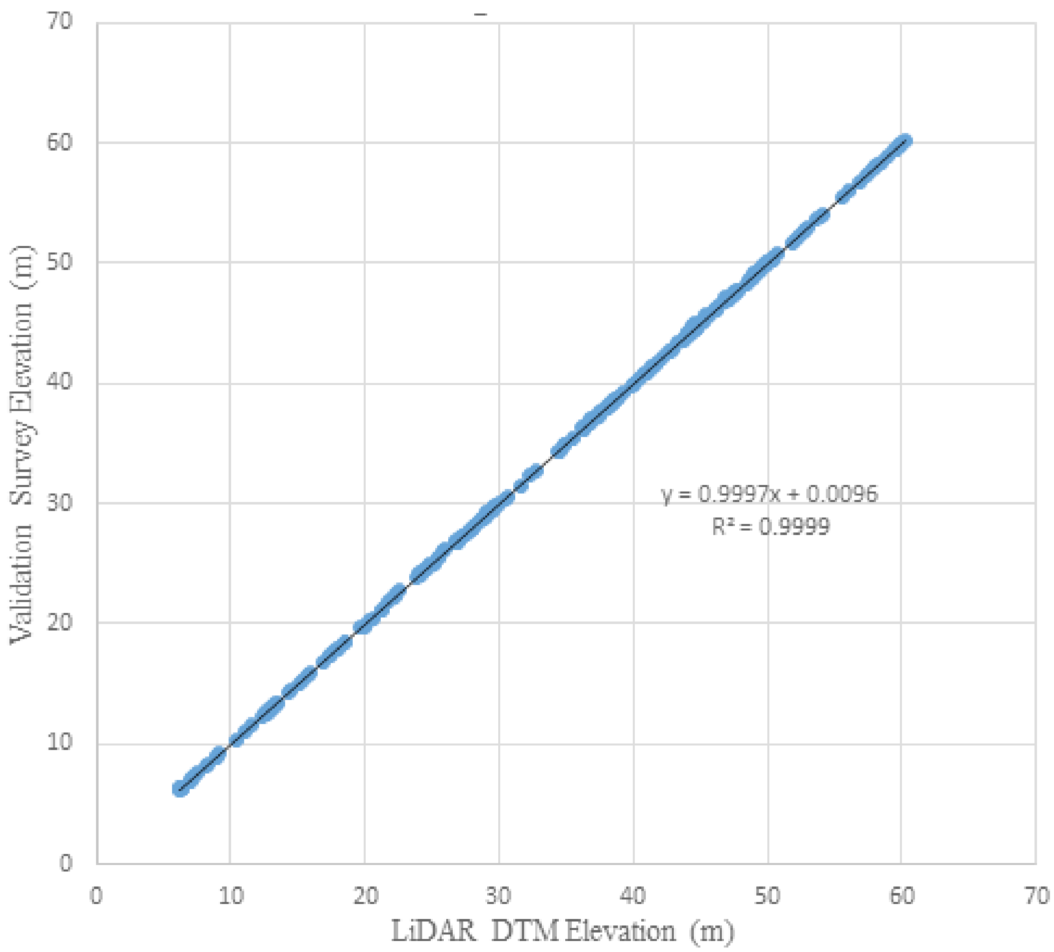


Figure 28. Correlation plot between validation survey points and LiDAR data.

Table 19. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.08
Standard Deviation	0.08
Average	-0.001
Minimum	-0.18
Maximum	0.31

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data was available for Himogaan with 13,533 bathymetric survey points. The resulting raster surface produced was done by Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.07 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Himogaan integrated with the processed LiDAR DEM is shown in Figure 29.

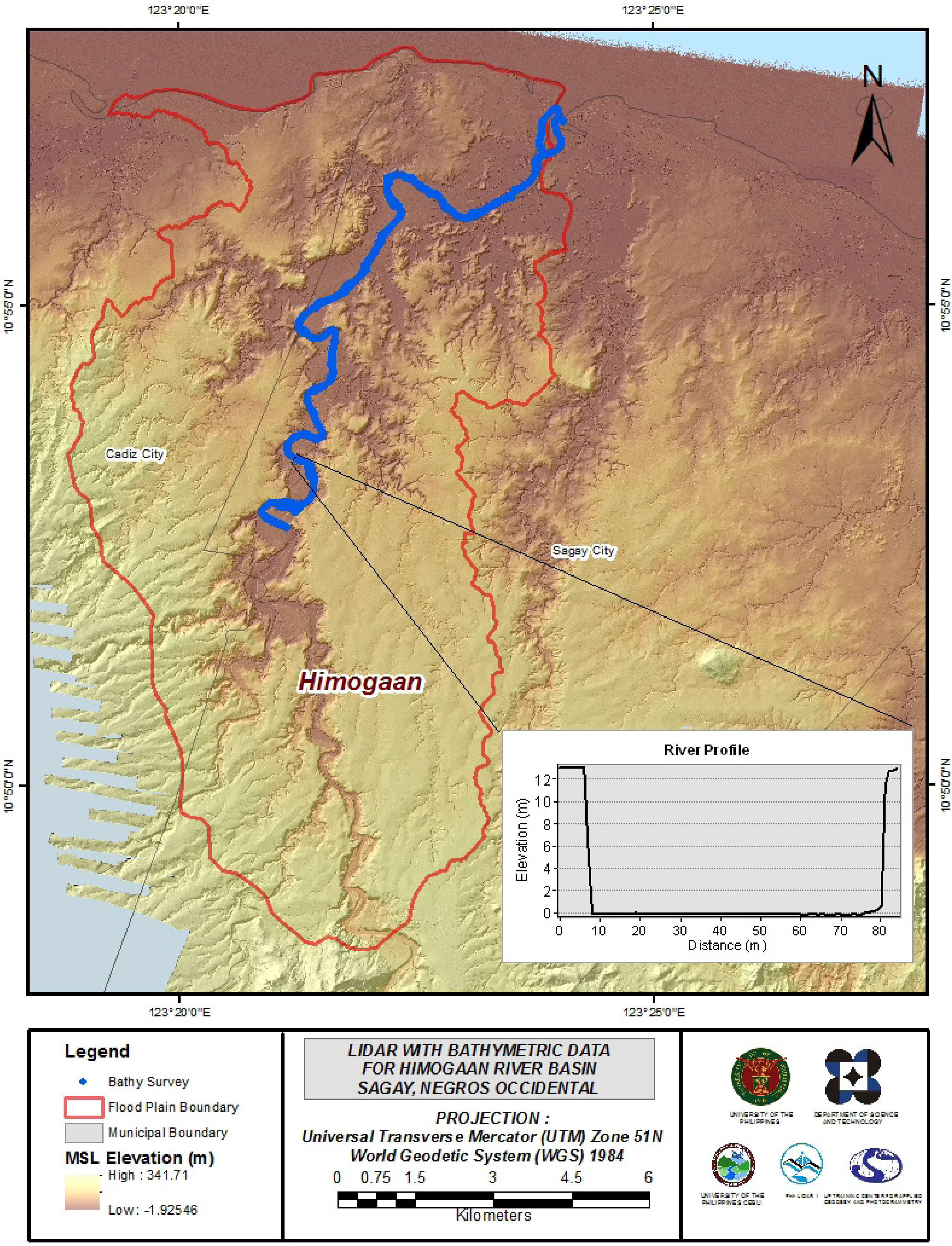


Figure 29. Map of Himogaan Flood Plain with bathymetric survey points shown in blue.

3.12 Feature Extraction

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

3.12.1 Quality Checking of Digitized Features' Boundary

Himogaan floodplain, including its 200 m buffer, has a total area of 120.29sq km. For this area, a total of 5.0 sq km, corresponding to a total of 1389 building features, are considered for QC. Figure 30 shows the QC blocks for Himogaan floodplain.

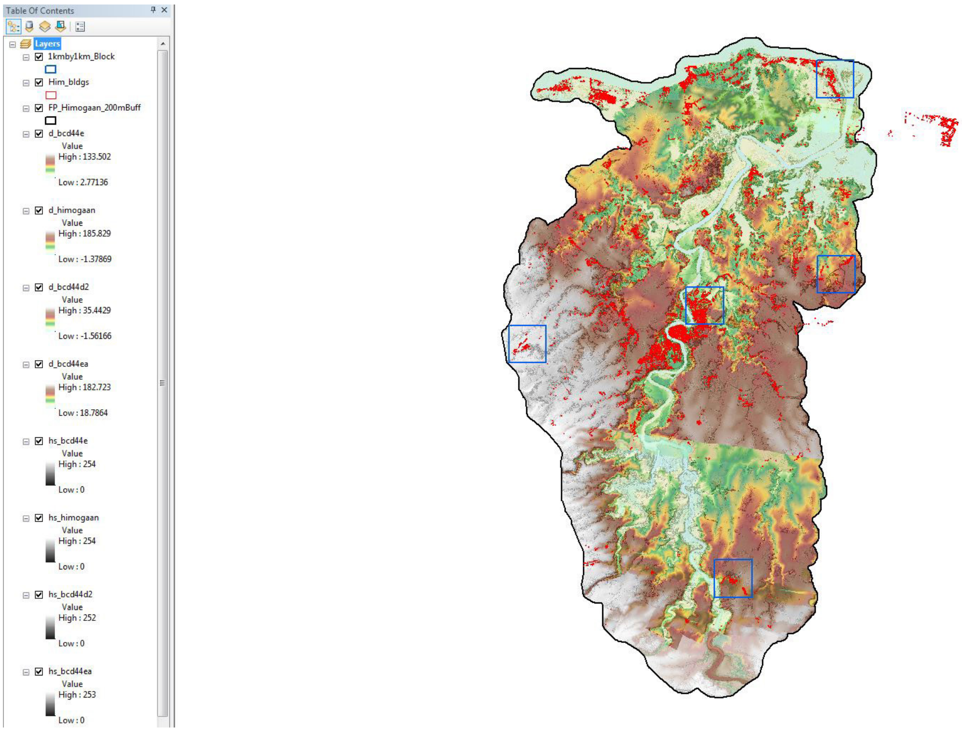


Figure 30. QC blocks for Himogaan building features.

Quality checking of Himogaan building features resulted in the ratings shown in Table 20.

Table 20. Quality Checking Ratings for Himogaan Building Features.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Himogaan	100.00	100.00	97.98	PASSED

3.12.2 Height Extraction

Height extraction was done for 12,011 building features in Himogaan floodplain. Of these building features, 538 was filtered out after height extraction, resulting to 11473 buildings with height attributes. The lowest building height is at 2.0 m, while the highest building is at 17.05 m.

3.12.3 Feature Attribution

The feature attribution survey was conducted through a participatory community-based mapping in coordination with the Local Government Units of the Municipality/City. The research associates of Phil-LiDAR 1 team visited local barangay units and interviewed key local personnel and officials who possessed expert knowledge of their local environments to identify and map out features.

Maps were displayed on a laptop and were presented to the interviewees for identification. The displayed map include the orthophotographs, Digital Surface Models, existing landmarks, and extracted feature shapefiles. Physical surveys of the barangay were also done by the Phil-LiDAR 1 team every after interview for validation. The number of days by which the survey was conducted was dependent on the number of features and number of barangays included in the flood plain of the river basin.

Table 21 summarizes the number of building features per type. On the other hand, Table 22 shows the total length of each road type, while Table 23 shows the number of water features extracted per type.

Table 21. Building Features Extracted for Himogaan Floodplain.

Facility Type	No. of Features
Residential	11,123
School	158
Market	3
Agricultural/Agro-Industrial Facilities	11
Medical Institutions	5
Barangay Hall	6
Military Institution	0
Sports Center/Gymnasium/Covered Court	5
Telecommunication Facilities	4
Transport Terminal	3
Warehouse	1
Power Plant/Substation	0
NGO/CSO Offices	1
Police Station	0
Water Supply/Sewerage	0
Religious Institutions	26
Bank	1
Factory	56
Gas Station	1
Fire Station	0
Other Government Offices	13
Other Commercial Establishments	54
N/A	2
Total	**11,473**

Table 22. Total Length of Extracted Roads for Himogaan Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Himogaan	385.87	0.00	0.00	16.33	11.12	**413.32**

Table 23. Number of Extracted Water Bodies for Himogaan Floodplain.

Floodplain	Water Body Type					Total
	Rivers/ Streams	Lakes/ Ponds	Sea	Dam	Fish Pen	
Himogaan	20	0	0	0	257	**277**

A total of 13 bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

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

Figure 31 shows the Digital Surface Model (DSM) ofHimogaan floodplain overlaid with its ground features.

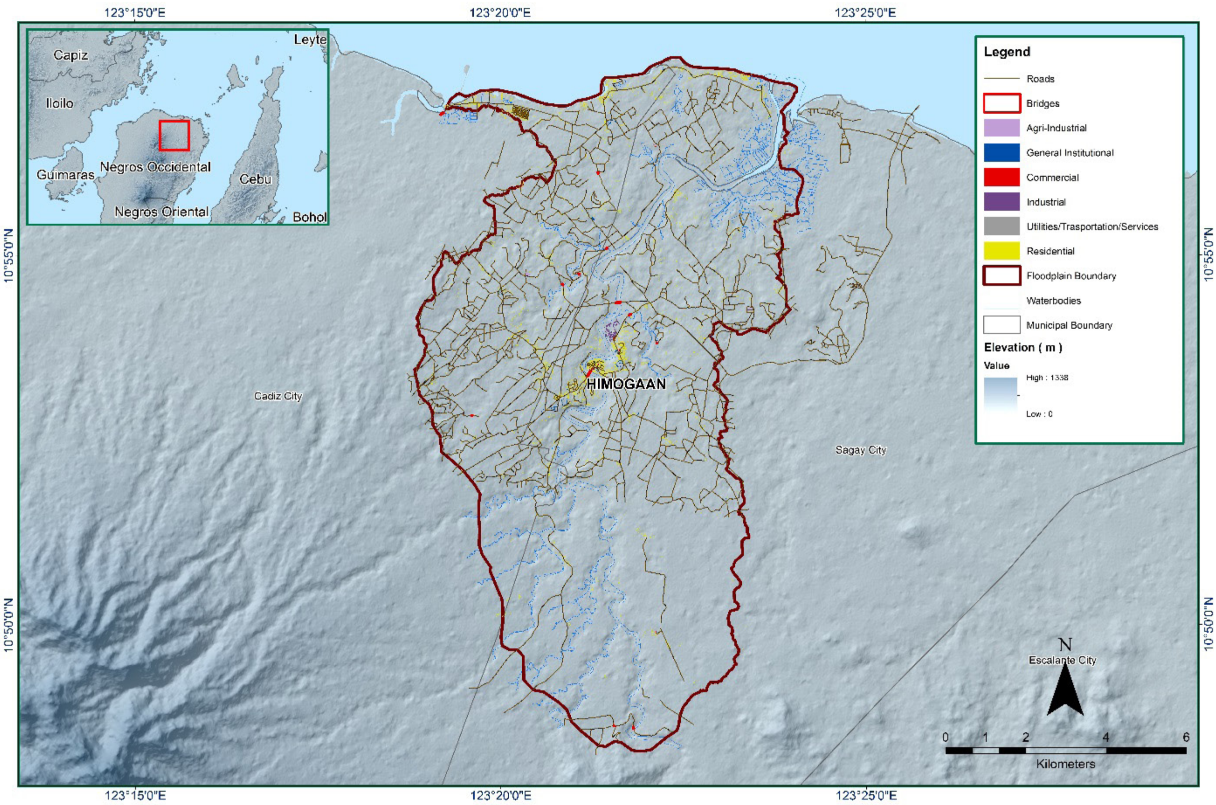


Figure 31. Extracted features for Himogaan floodplain.

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

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

4.1 Summary of Activities

The Data Validation and Bathymetry Component (DVBC) conducted a field survey in Himogaan River from December 6 to 18, 2014 with the following scope of work: reconnaissance survey to determine the viability of traversing the planned routes for bathymetric survey; courtesy call to the barangays near the survey area for information dissemination of the team's activities and to ask for a boat and a local aide's assistance; control survey for the establishment of a control point; cross-section survey, bridge as-built and water level marking in MSL of Himogaan Bridge piers; ground validation data acquisition survey of about 106.70 km; and bathymetric survey from Brgy. Paraiso, Sagay City down to the mouth of the river in Brgy. Himogaan Baybay, Sagay City, with an estimated length of 18 km using an Ohmex™ Single Beam Echo Sounder integrated with a roving GNSS receiver, Trimble® SPS 882 utilizing GNSS PPK survey technique. The survey extent of the Himogaan river basin is shown in Figure 32.

Figure 32. Himogaan survey extent

4.2 Control Survey

The GNSS network used for Himogaan River survey is composed of a single loop established on September 9, 2014 occupying the following reference points: NGW-50, a second order GCP in Brgy. Paraiso, Sagay City; and NW-100, a first order BM in Brgy. Jonobjonob, Escalante City, Negros Occidental.

The point NW-130, a NAMRIA established control point, along the approach of Trozo Bridge in Brgy. Daga, Cadiz City, was also occupied to use by the DVBC survey team as marker during the survey.

An offset of 0.0188 m between geoid (EGM2008) and MSL values of the benchmark NW-100 from September 10 to 24, 2014 was applied for referring the elevation of the control points to MSL because the direct processing to BMOrtho will give a low accuracy level.

The summary of reference and control points is shown in Table 24, while the GNSS network established is illustrated in Figure 33.

Figure 33. GNSS Network of Himogaan River Field Survey

Table 24. List of references and control points occupied in Himogaan River survey (Source: NAMRIA; UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (m)	MSL Elevation (m)	Date Estab-lished
NGW-50	2nd order, GCP	10°53'22.52478"	123°21'11.86863"	74.422	13.0512	2013
NW-100	1st order, BM	-	-	68.325	7.2272	2007
NW-130	Used as Marker	-	-	-	-	2017

The GNSS set-ups on recovered reference points and established control points in Himogaan River are shown in Figure 34 to Figure 36.

Figure 34. GNSS base receiver setup, Trimble® SPS 852, at NGW-50 in Himogaan Bridge, Brgy. Paraiso, Sagay City, Negros Occidental

Figure 35. GNSS base receiver setup, Trimble® SPS 852, at NW-100 in Danao Bridge, Brgy. Jonobjonob, Escalante City, Negros Occidental

Figure 36. GNSS base receiver setup, Trimble® SPS 852, over NW-130 in Troso Bridge, Brgy. Daga, Cadiz City, Negros Occidental

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 case where one or more baselines did not meet all of these criteria, masking is performed. Masking is done by removing/masking portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. The Baseline processing result of control points in Himogaan River Basin is summarized in Table 25, as generated by TBC software.

Table 25. Baseline Processing Report for Himogaan River 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

4.4 Network Adjustment

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

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

Where:

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

for each control point. See the Network Adjustment Report shown in Table 26 to Table 29 for complete details.

The three control points, NGW-50, NW-100, and NW-130 were occupied and observed simultaneously to form a GNSS loop. Coordinates and elevation value of NGW-50 were held fixed during the processing of the control points as presented in Table 26. Computed elevation offset of NW-100 were applied after the processing. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 26. Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
NGW 50	Global	Fixed	Fixed	Fixed	
Fixed = 0.000001 (Meter)					

The list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 27. The fixed control NGW-50 has no values for and elevation error yet.

Table 27. Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
NGW 50	538610.026	?	1203793.905	?	13.070	?	LLh
NW 100	553341.183	0.013	1196123.819	0.007	7.170	0.020	
NW 130	529529.956	0.017	1209636.397	0.008	10.639	0.024	

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

NGW-50

horizontal accuracy = Fixed
vertical accuracy = Fixed

NW-100

horizontal accuracy = $\sqrt{((1.3)^2 + (0.7)^2}$
= $\sqrt{(1.69 + 0.49)}$
= 1.48 < 20 cm
vertical accuracy = 2.0 cm < 10 cm

NW-130

horizontal accuracy = $\sqrt{((1.7)^2 + (0.8)^2}$
= $\sqrt{(2.89 + 0.64)}$
= 1.88 < 20 cm
vertical accuracy = 2.4 cm < 10 cm

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

Table 28. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
NGW 50	N10°53'22.52478"	E123°21'11.86863"	74.422	?	LLh
NW 130	N10°56'33.04992"	E123°16'12.93293"	71.819	0.024	
NW 100	N10°49'12.14033"	E123°29'16.71793"	68.325	0.020	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table C-5. Based on the result of the computation, the equation is satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table 29.

Table 29. Reference and control points used and its location
(Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing	Easting	MSL Elevation (m)
NGW-50	2nd order, GCP	10°53'22.52478"	123°21'11.86863"	74.422	1203793.905	538610.026	13.051
NW-100	1st order BM	10°49'12.14033"	123°29'16.71793"	68.325	1196123.819	553341.183	7.227
NW-130	Used as Marker	10°56'33.04992"	123°16'12.93293"	71.819	1209636.397	529529.956	10.643

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

Cross-section and bridge as-built surveys were conducted on September 12 and 22, 2014 along the downstream part of Himogaan bridge in Brgy. Paraiso, Sagay Cityusing a GNSS receiver Trimble® SPS 882 and an Ohmex™ Single Beam Echo Sounder utilizing GNSS PPK survey technique as shown in Figure 37.

Figure 37. (A) Cross-Section Survey and (B) Bridge As-Built survey at Himogaan Bridge in Sagay City

The cross-sectional line of Himogaan Bridge is about 83.28 m with 86 points acquired using NGW-50 as GNSS base station. Figure 38 to Figure 40 show the location map, cross-section diagram, and bridge as-built form of Himogaan Bridge.

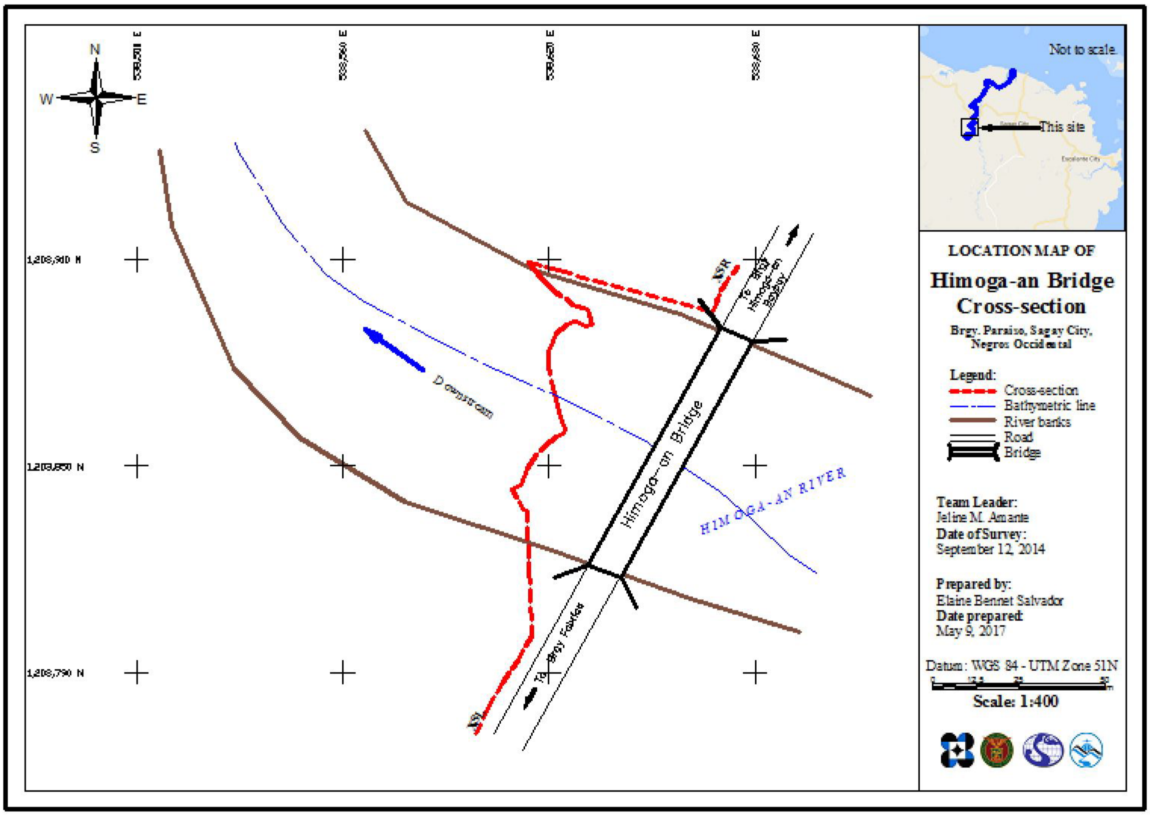


Figure 38. Location map of Himogaan bridge cross-section

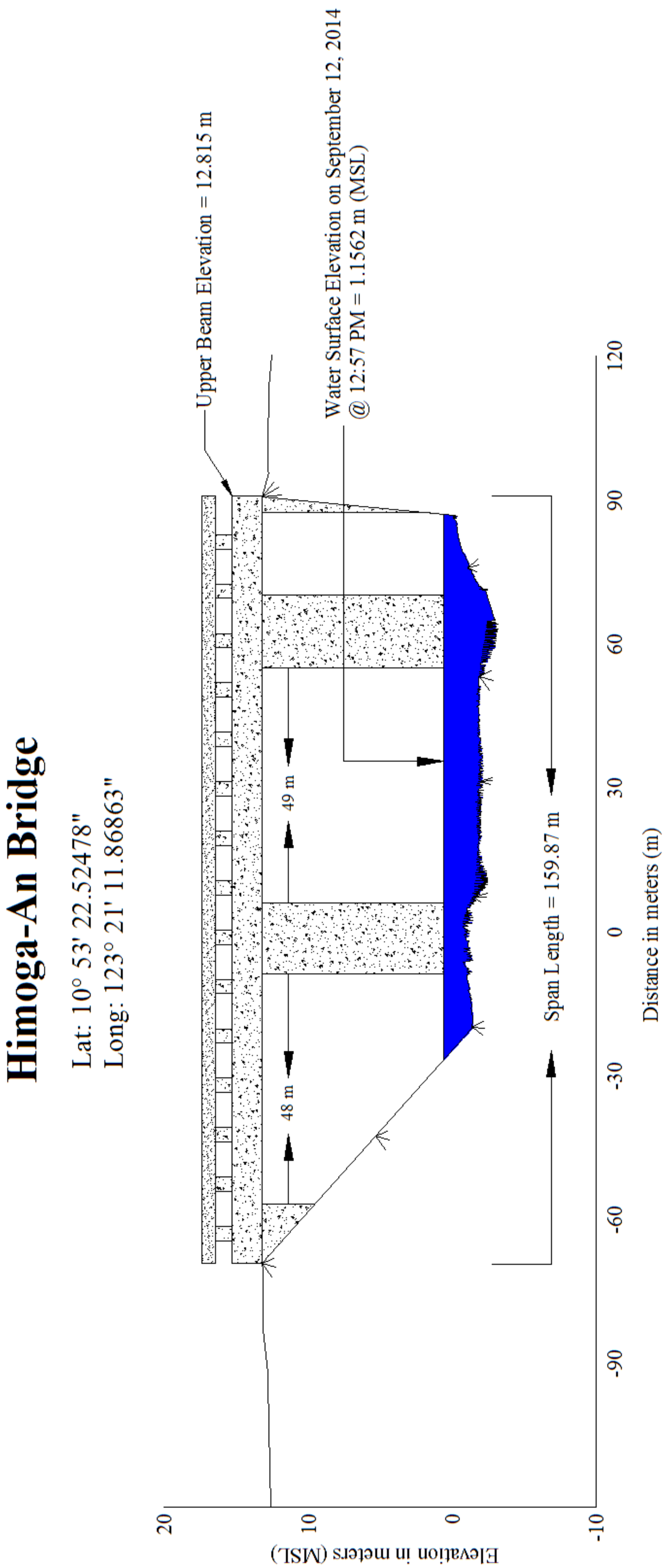


Figure 39. Himogaan bridge cross-section diagram

Bridge Data Form

Bridge Name: Himoga-An Bridge **Date:** September 12 & 22, 2014

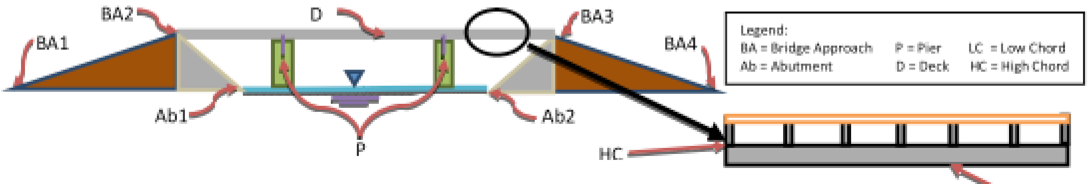
River Name: Himoga-An River **Time:** 12:30 PM

Location (Brgy, City,Region): Brgy. Fabrica, Sagay City, Negros Occidental

Survey Team: Negros Occidental Survey Team

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

Latitude: 10d53'22.52478"N **Longitude:** 123d21'11.86863" E



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

Elevation: 8.9883 m **Width:** 9.486 m **Span (BA3-BA2):** 159.87 m

	Station	High Chord Elevation	Low Chord Elevation
1	-	12.815 m	-
2			
3			
4			
5			

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	12.6142m	**BA3**	122.78 m	13.1482 m
BA2	15.23 m	13.1552 m	**BA4**	155.607 m	12.6142 m

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

	Station (Distance from BA1)	Elevation
Ab1	n/a	n/a
Ab2	n/a	n/a

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

Shape: rectangular **Number of Piers:** 2 **Height of column footing:** _______________

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	23.5648	13.2112 m	
Pier 2	73.02	13.2852	
Pier 3	121.73	13.1932	
Pier 4			
Pier 5			
Pier 6			

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

Figure 40. Himogaan Bridge Data Form

The water surface elevation of Himogaan River on the left and right banks was acquired using GNSS receiver Trimble® SPS 882 in GNSS PPK survey technique on September 12, 2014 at 12:57 PM. The resulting water surface elevation data is 1.1562 m above MSL, translated and marked at the pier of Himogaan Bridge as shown in Figure 41. The markings on the bridge piers shall serve as a reference for flow data gathering and depth gauge deployment of UP Cebu PHIL-LIDAR 1.

Figure 41. Water Level Mark at the pier of Himogaan Bridge

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on September 12 and 13, 2014 using a survey GNSS rover receiver Trimble® SPS 882 mounted on a pole, which was attached in front of the vehicle as shown in Figure 42. It was secured with a steel rod and tied with cable ties to ensure that it was horizontally and vertically balanced. The antenna height was measured from the ground up to the bottom of the notch of the GNSS rover receiver with a value of 2.10 m.

The ground validation line is approximately 106.70 km in length and with a total of 8,887 gathered points acquired using NGW-50 and NW-130 as GNSS base station. The survey covered four Cities, namely: Escalante, Sagay, Cadiz and Victorias. Figure 43 shows the ground validation survey result.

Figure 42. (A) Occupied base station, NGW-50 in Himogaan Bridge, Sagay City and (B) Installation of GNSS Receiver Trimble® SPS 882 in front of a van

Figure 43. LiDAR ground validation survey from Brgy. Poblacion Toboso to Brgy. VI Manapla

4.7 Bathymetric Survey

Bathymetric survey was conducted on December 9, 2014 and December 14, 2014 using an Ohmex™ Single Beam Echo Sounder integrated with a roving GNSS receiver, Trimble® SPS 882, installed on a boat was utilizing PPK survey technique as shown in Figure 44. The survey began in the upstream part of the river in Brgy. Parais, Sagay City with coordinates 10°52'41.10112"123°21'07.23521", down to the mouth of the river in Brgy. Himogaan Baybay, Sagay City with coordinates 10°56'54.14218"123°24'03.54658". The reference point NGW-50, located at Himogaan Bridge in Brgy. Fabrica, Sagay City, served as the base station in conducting the bathymetric survey.

Figure 44. Set up on a paddle boat for the Bathymetric Survey at the Himogaan River upstream

Bathymetric line measured is approximately 18 km in length with a total of 34,313 points acquired using NGW-50 covering Brgy. Himogaan Baybay and Paraiso as shown in Figure 45. A CAD drawing was also produced to illustrate the Himogaan riverbed profile. As shown in Figure 46 and Figure 47, the lowest elevation was recorded at -11.997 m in MSL, approximately 2,000 m from Himogan Bridge and about 1,000 m from Himogaan to Bridge, while the highest elevation observed was 0.519 m in MSL located in Brgy. Paraiso, Sagay City.

Figure 45. Bathymetric points gathered from Himogaan River

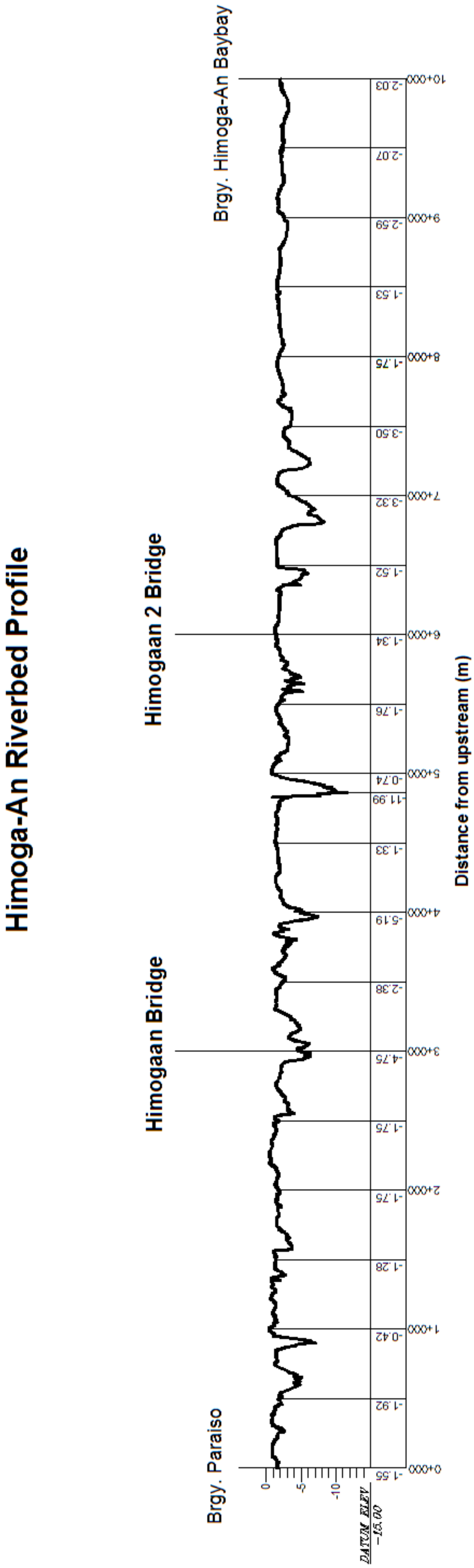


Figure 46. Riverbed profile of Himogaan River

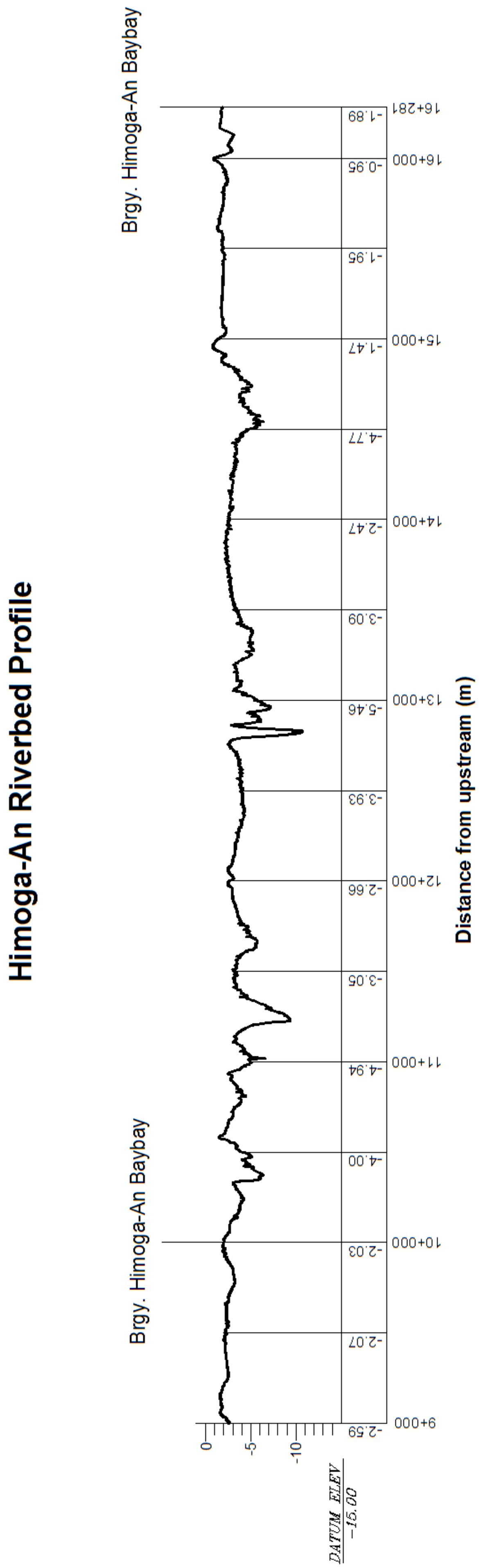


Figure 47. Riverbed profile of Himogaan River

CHAPTER 5: FLOOD MODELING AND MAPPING

Dr. Alfredo Mahar Lagmay, Christopher Uichanco, Sylvia Sueno, Marc Moises, Hale Ines, Miguel del Rosario, Kenneth Punay, Neil Tingin, Narvin Clyd Tan, and Marvin Arias

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

Precipitation data was taken from an automatic rain gauge (ARG) deployed by the UP Cebu Flood Modeling Component (FMC) team. The ARG was installed at Brgy. Puey, Sagay City, Negros Occidental (Figure 50). The precipitation data collection started from July 29, 2016 at 2:20 PM to July 30, 2016 at 12:10 with 10 minutes recording interval.

The total precipitation for this event in Brgy Puey ARG was 43.8 mm. It has a peak rainfall of 2.88 mm. on January 9, 2017 at 9:25 in the evening. The lag time between the peak rainfall and discharge is 7 hours and 35 minutes.

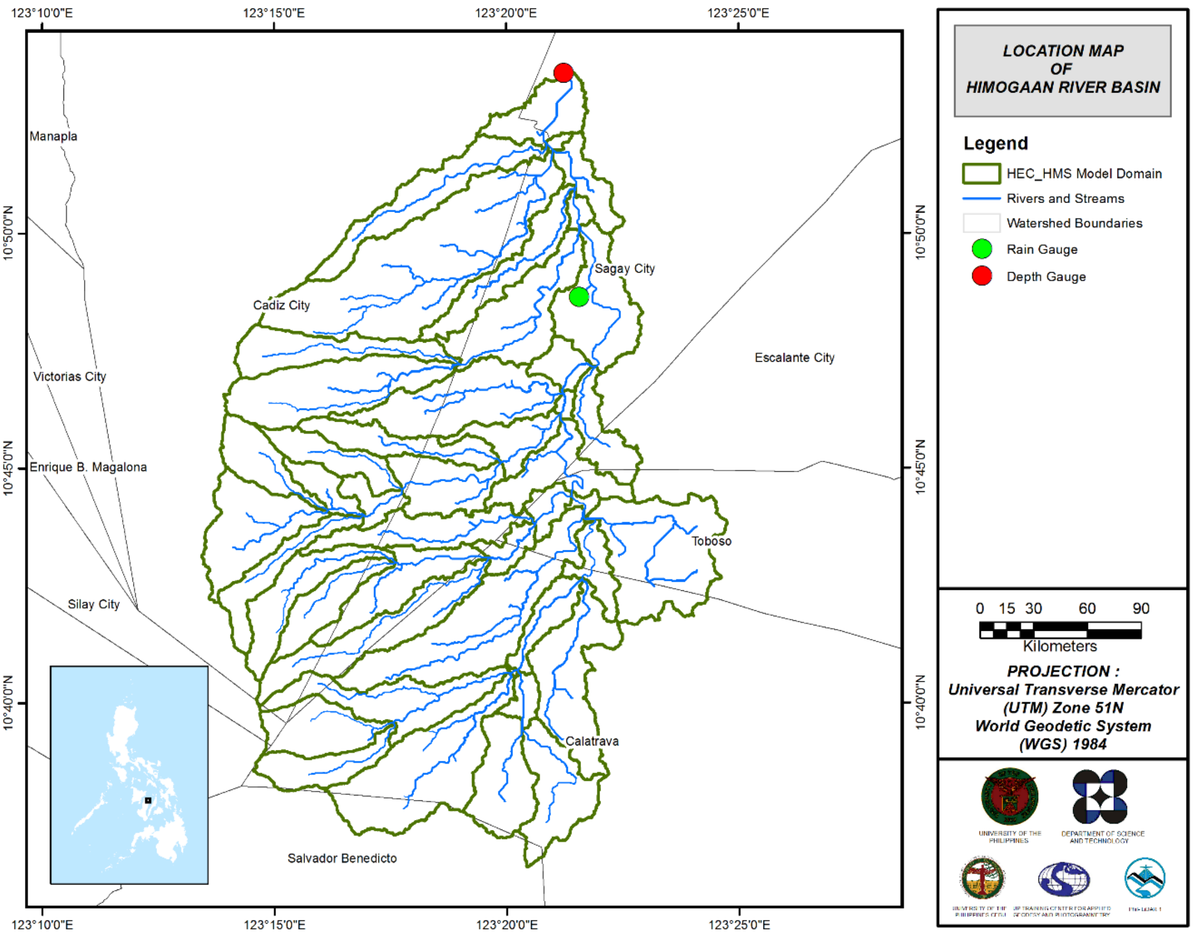


Figure 48. Location map of Himogaan HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Himogaan Bridge, Sagay City, Negros Occidental (10°53’25.0”N 123°21’12.9”E). It gives the relationship between the observed water levels at Himogaan Bridge and outflow of the watershed at this location.

For Himogaan Bridge, the rating curve is expressed as Q = 162.07x–129.63 as shown in Figure 50.

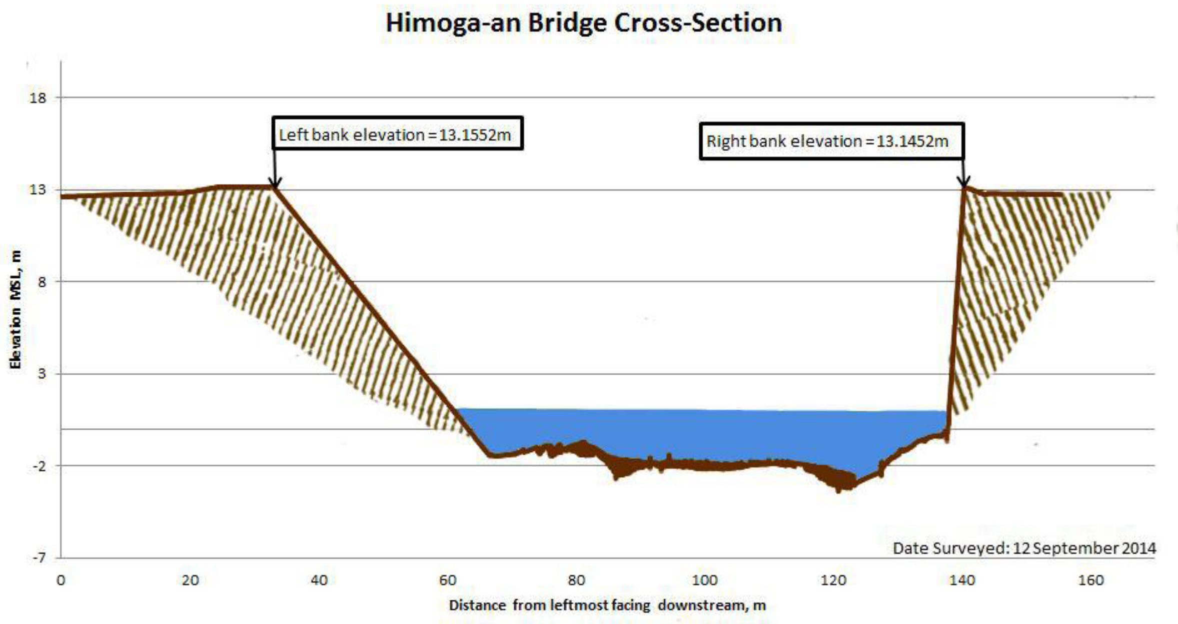


Figure 49. Cross-Section Plot of Himogaan Bridge

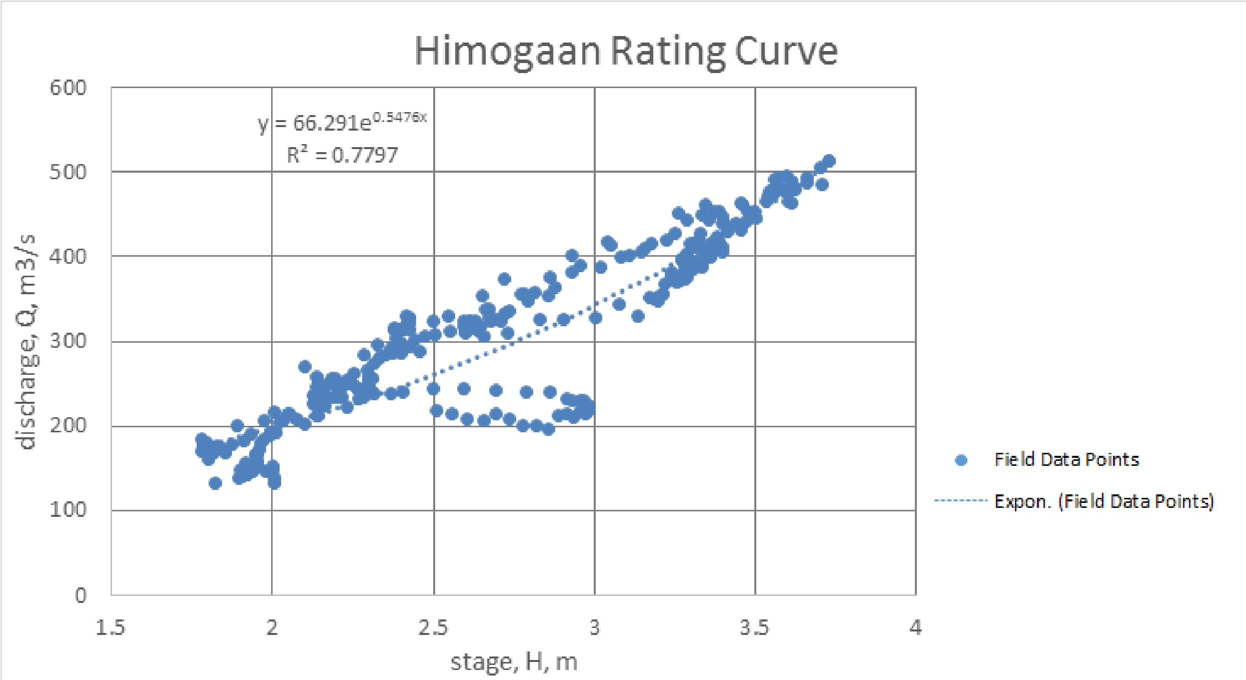


Figure 50. Rating Curve at Himogaan Bridge, Paraiso, Sagay City

This rating curve equation was used to compute the river outflow at Himogaan Bridge for the calibration of the HEC-HMS model shown in Figure 51. Peak discharge is 461.1 cubic meters per second at 5:00 PM, January 9, 2017.

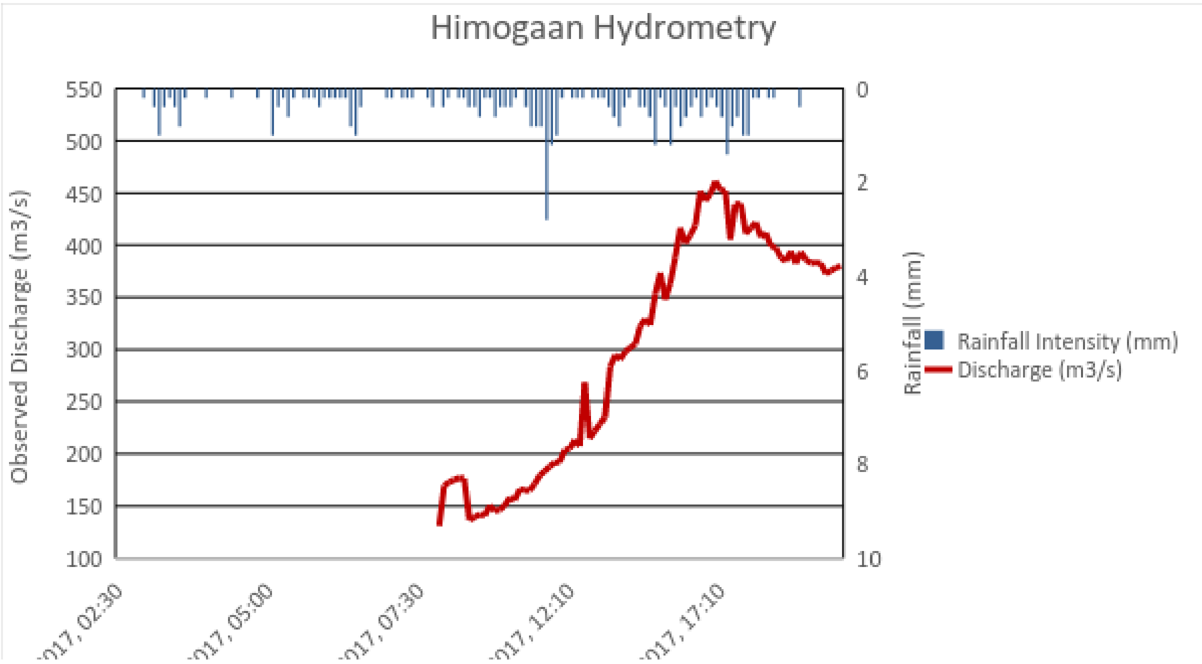


Figure 51. Rainfall and outflow data at Himogaan used for modeling

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Iloilo Rain Gauge. The RIDF rainfall amount for 24 hours was converted to a synthetic storm by interpolating and re-arranging the value in such a way certain peak value will be attained at a certain time. This station chosen based on its proximity to the Himogaan watershed. The extreme values for this watershed were computed based on a 59-year record.

Table 30. RIDF values for Iloilo Rain Gauge computed by PAGASA

COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION									
T (yrs)	10 mins	20 mins	30 mins	1 hr	2 hrs	3 hrs	6 hrs	12 hrs	24 hrs
5	28.7	39.4	48	59.4	74.9	90	114.7	131.7	165.2
10	33.9	45.6	55.6	68.1	85	103.6	133.6	155.4	198.9
25	40.5	53.5	65.3	79.2	97.6	120.8	157.6	185.3	241.5
50	45.4	59.4	72.4	87.3	107	133.5	175.3	207.4	273.1
100	50.3	65.2	79.5	95.4	116.4	146.2	193	229.4	304.5

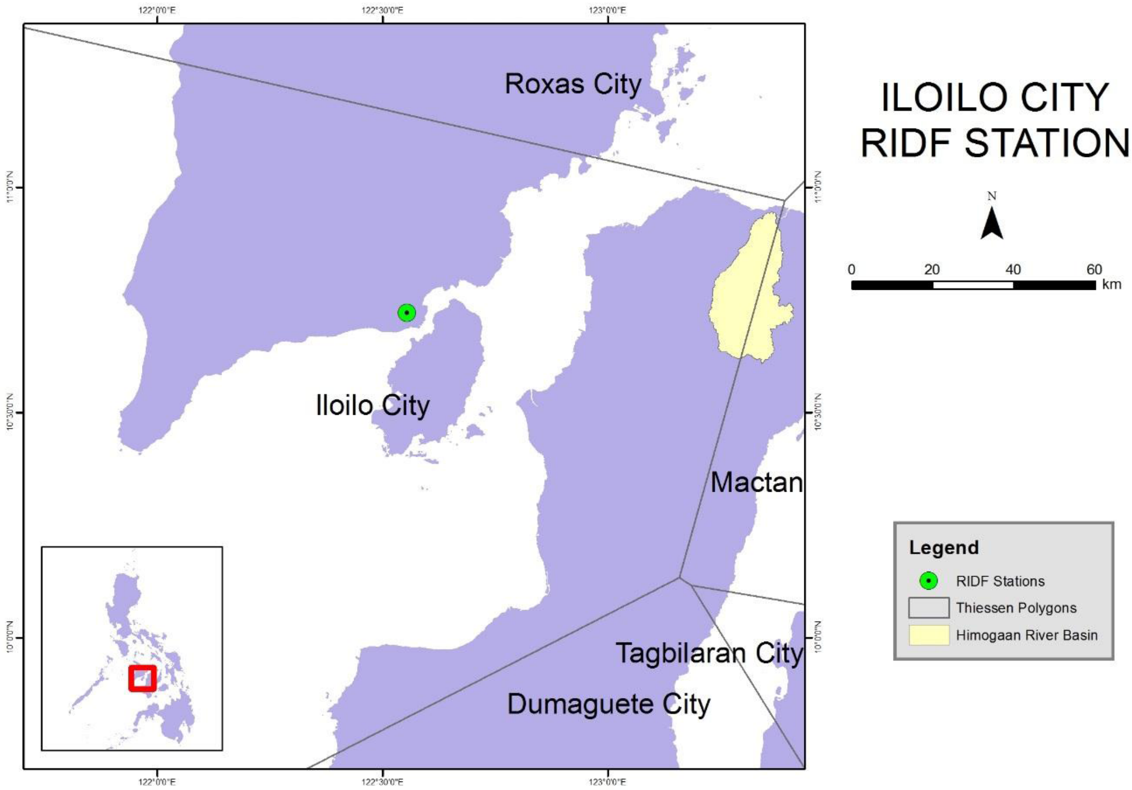


Figure 52. Location of Iloilo RIDF station relative to Himogaan River Basin

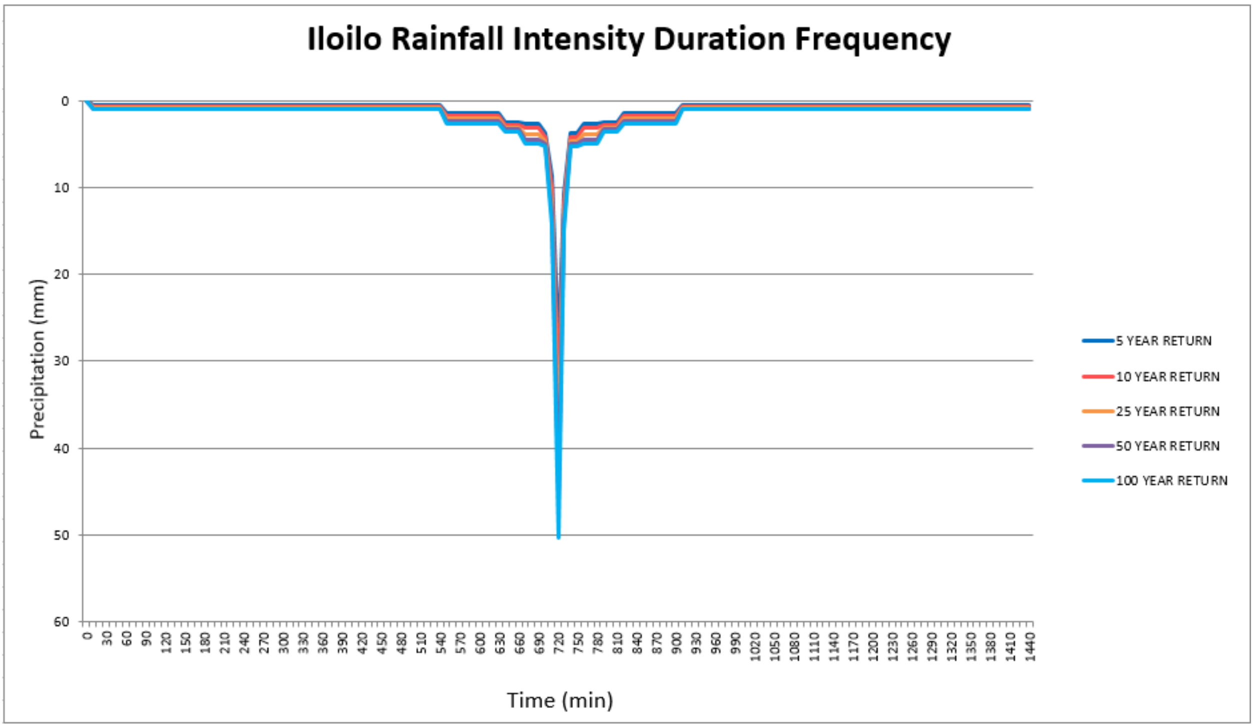


Figure 53. Synthetic storm generated for a 24-hr period rainfall for various return periods

5.3 HMS Model

The soil dataset was generated in 2004 by the Bureau of Soils; this is under the Department of Agriculture. The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Himogaan River Basin are shown in Figures 54 and 55, respectively.

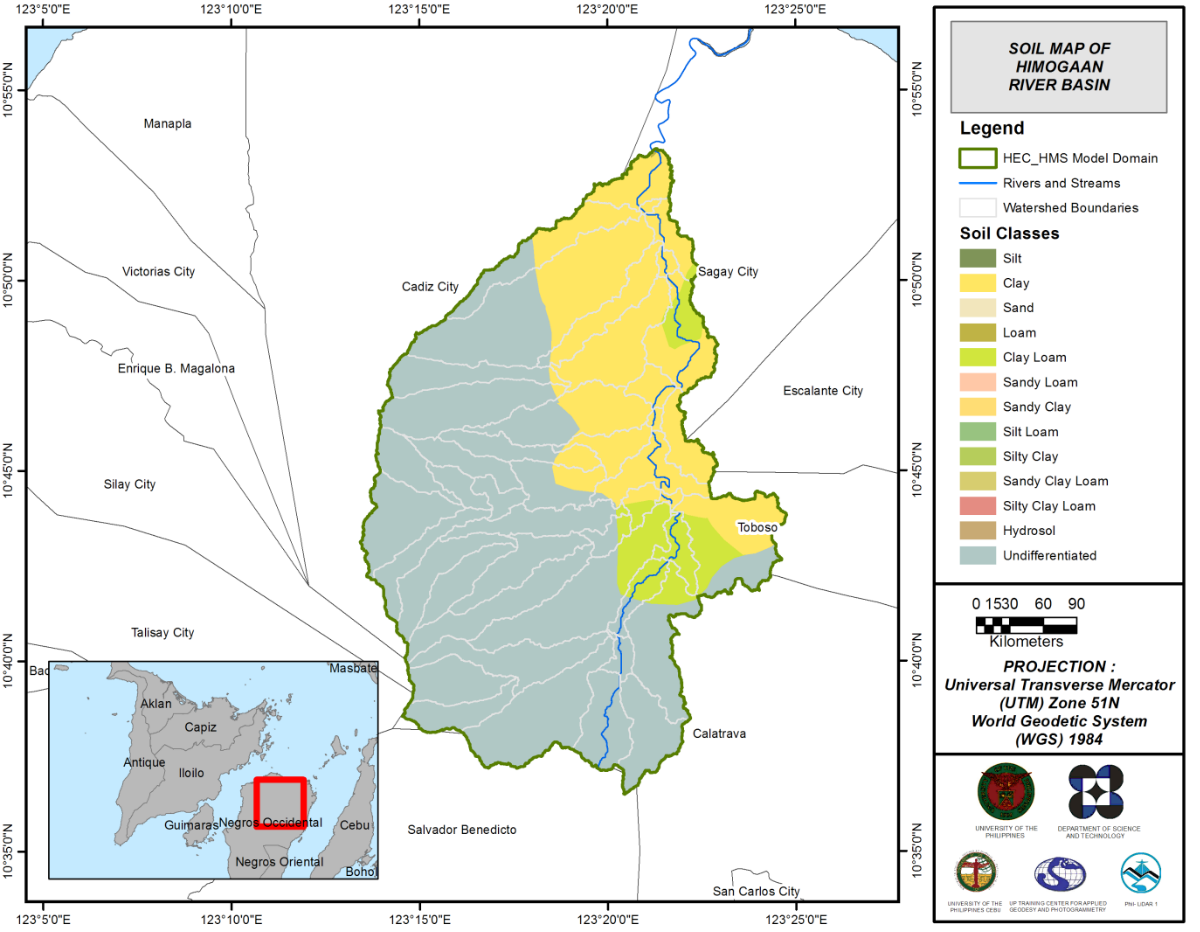


Figure 54. Soil map of Himogaan River Basin

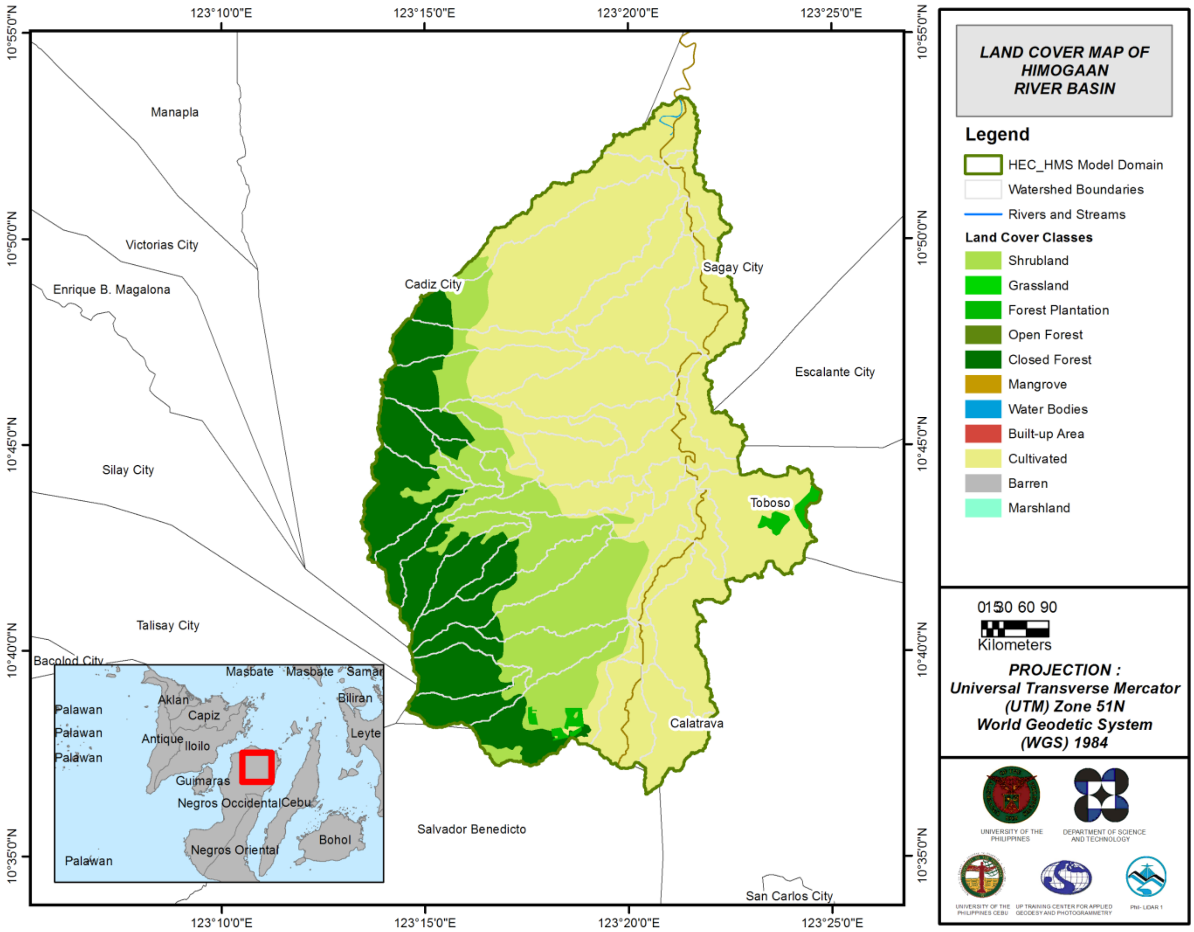


Figure 55. Land cover map of Himogaan River Basin

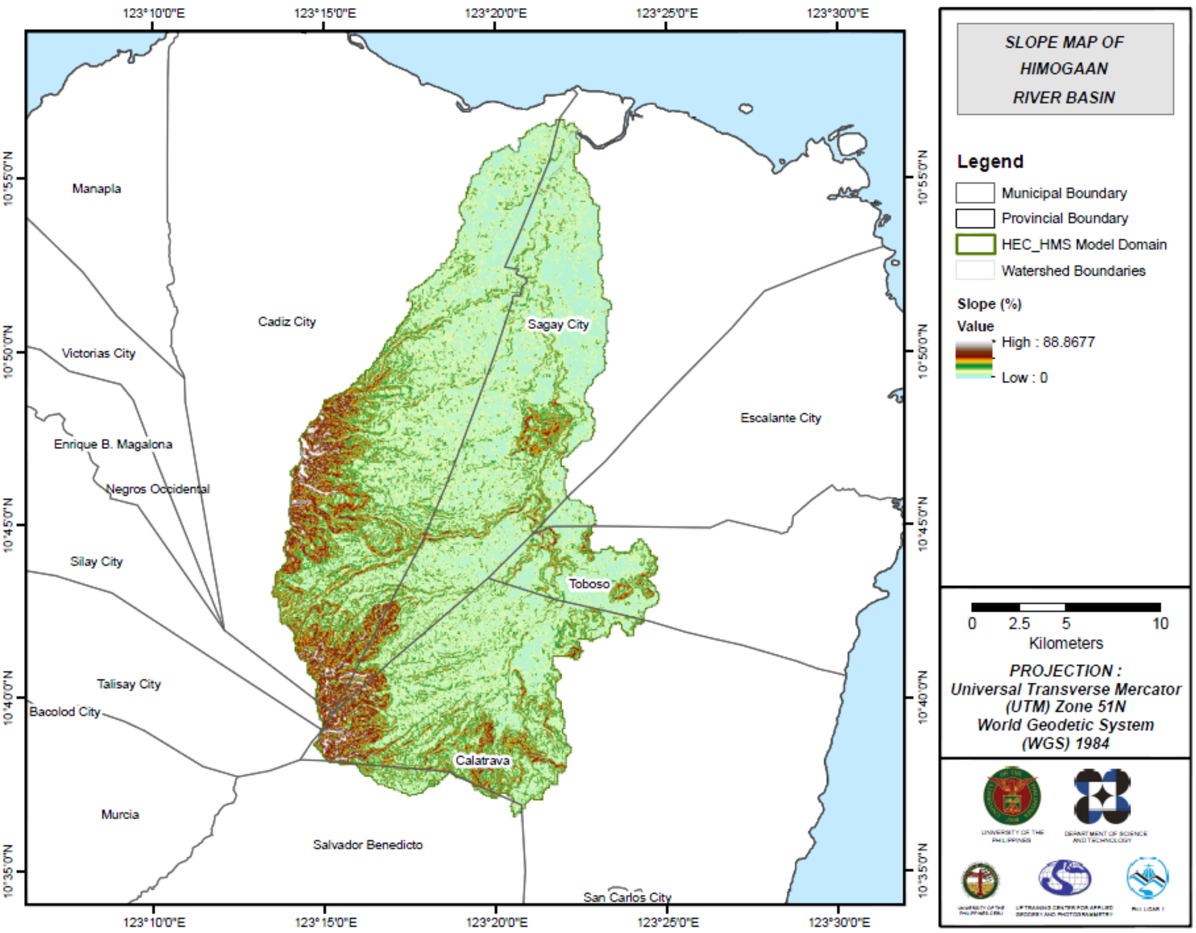


Figure 56. Slope Map of Himogaan River Basin

Using the SAR-based DEM, the Himogaan basin was delineated and further subdivided into subbasins. The model consists of 47 sub basins, 23 reaches, and 23 junctions as shown in Figure 57. The main outlet is at Himogaan Bridge.

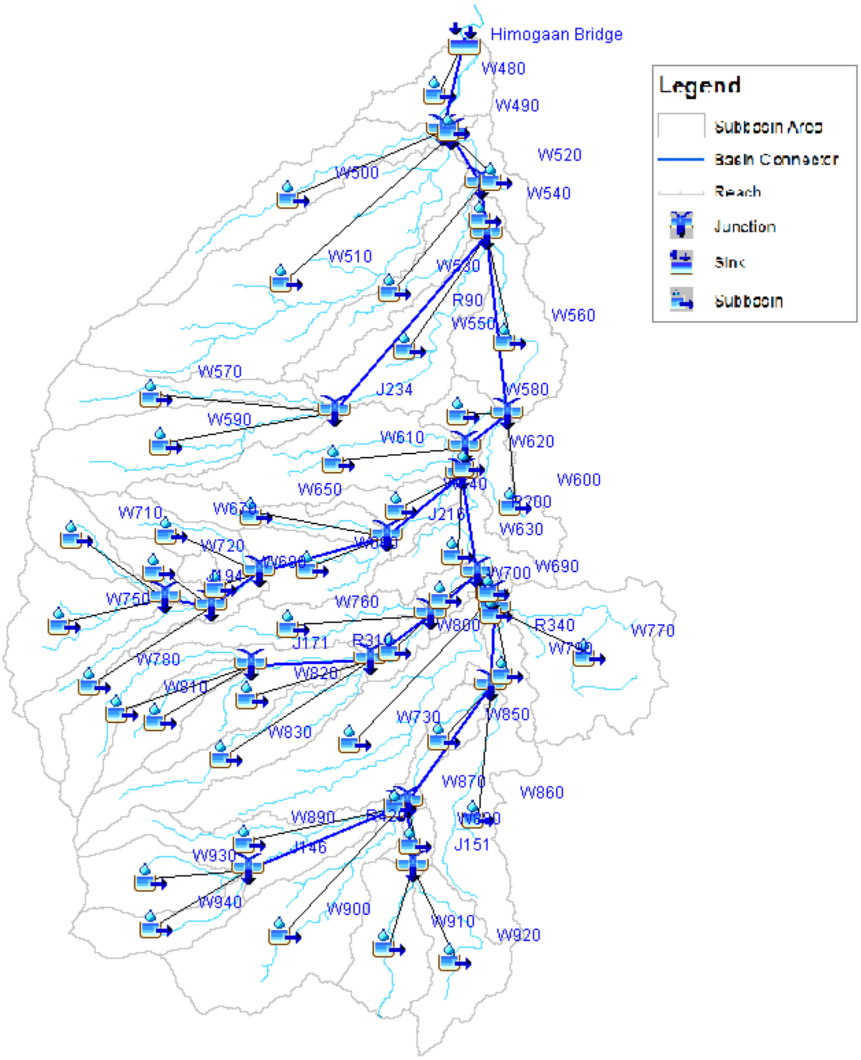


Figure 57. The Himogaan River Basin model generated using HEC-HMS

5.4 Cross-section Data

Riverbed cross-sections of the watershed are crucial in the HEC-RAS model setup. The cross-section data for the HEC-RAS model was derived using the LiDAR DEM data. It was defined using the Arc GeoRAS tool and was post-processed in ArcGIS.

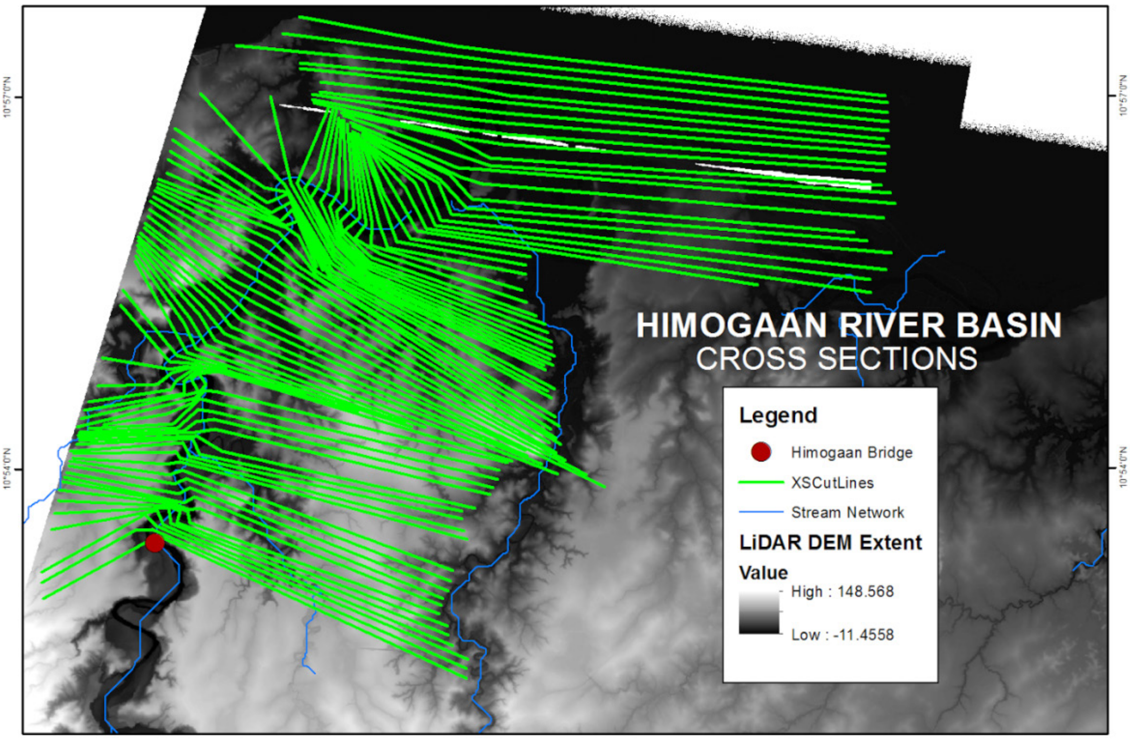


Figure 58. River cross-section of Himogaan River generated through Arcmap HEC GeoRAS tool

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

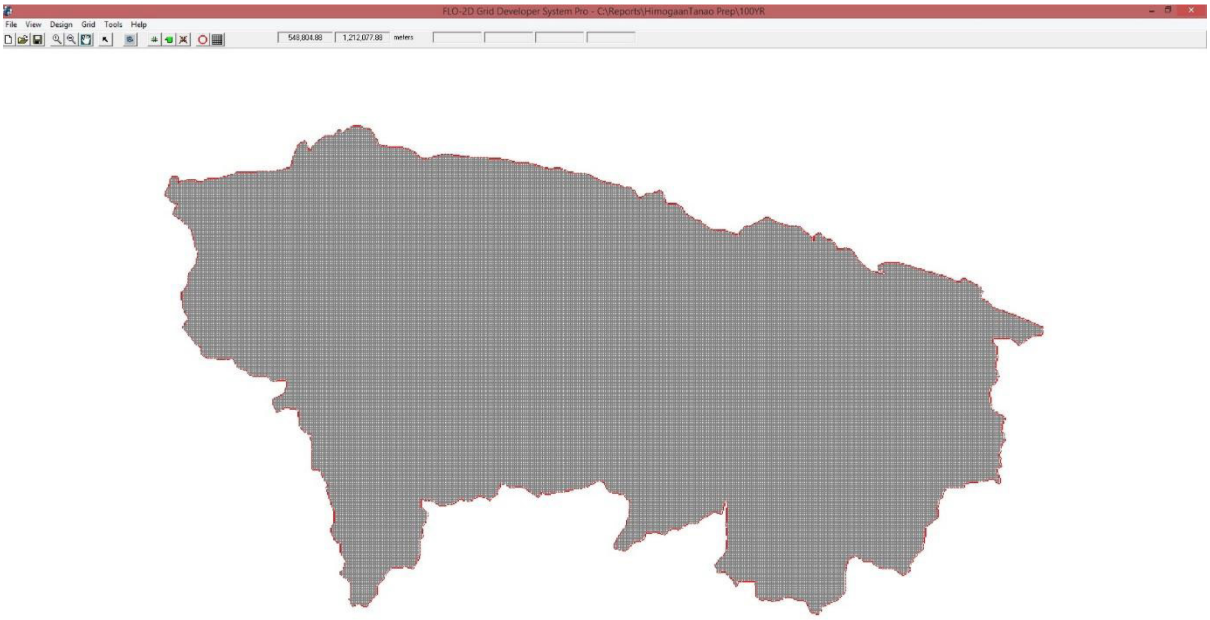


Figure 59. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 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 m2/s. The generated hazard maps for Himogaan are in Figure 70, 72, and 74, respectively.

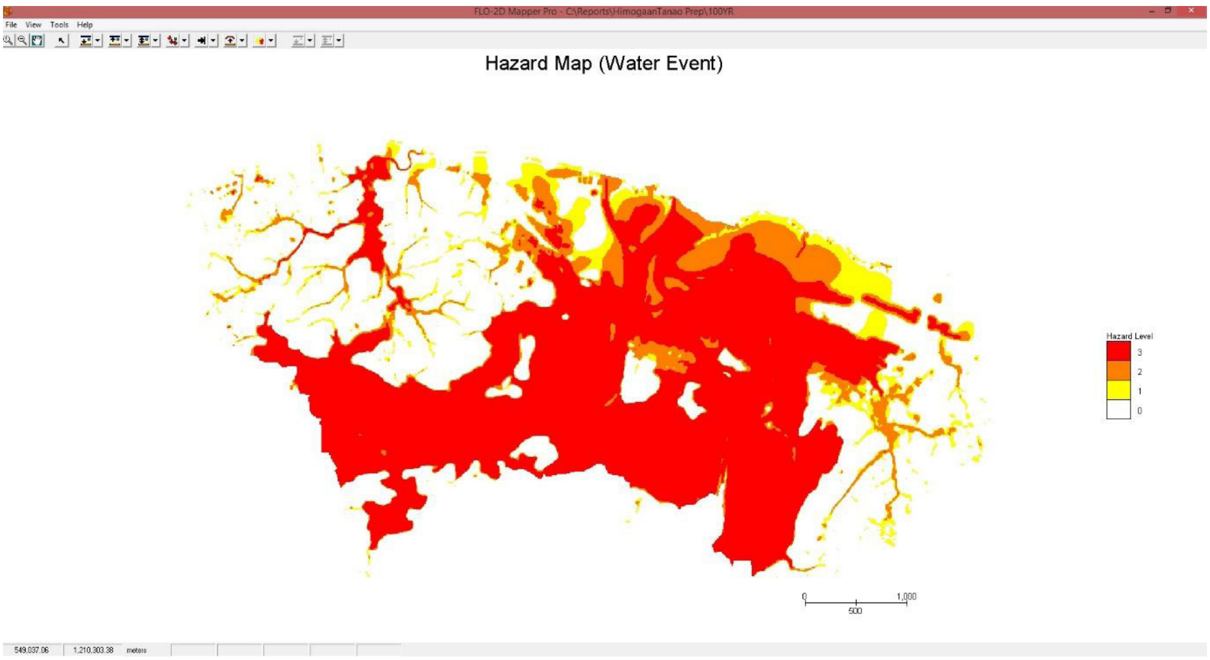


Figure 60. Generated 100-year rain return hazard map from FLO-2D Mapper

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 Himogaan are in Figure 71, 73, and 75, respectively.

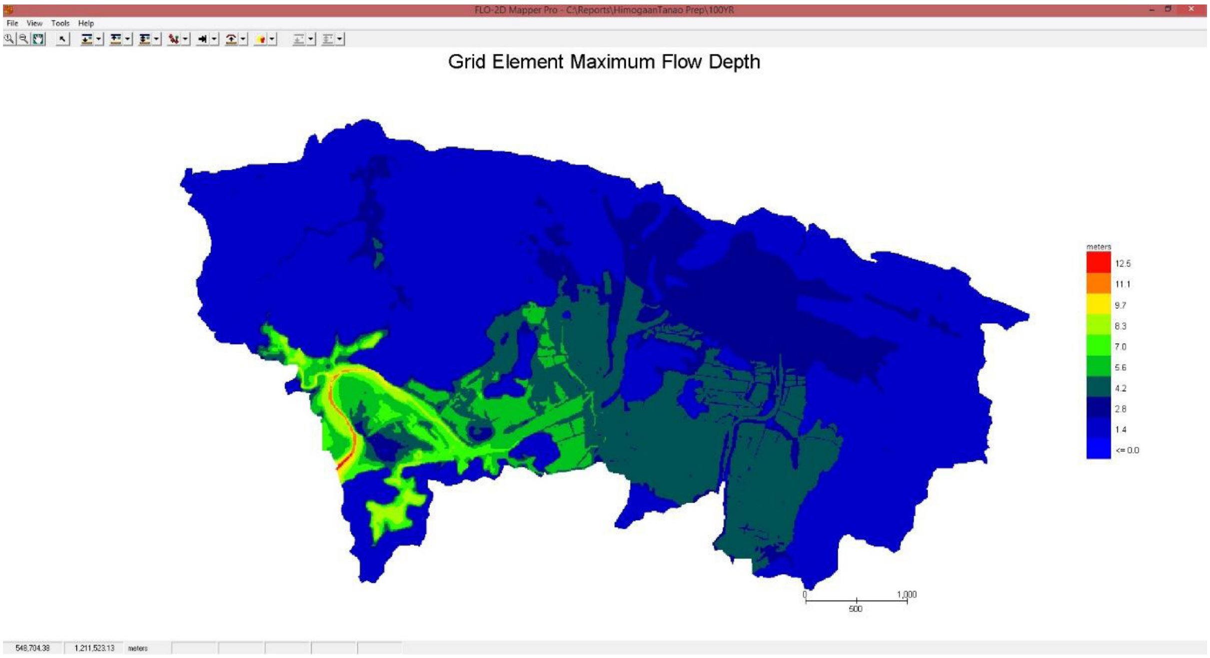


Figure 61. Generated 100-year rain return flow depth map from FLO-2D Mapper

There is a total of 61783670.89 m3 of water entering the model. Of this amount, 6072171.66 m3 is due to rainfall while 55711499.22 m3 is inflow from other areas outside the model 4363573.50 m3 of this water is lost to infiltration and interception, while 33831397.31 m3 is stored by the flood plain. The rest, amounting up to 23588699.98 m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Silaga HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 62 shows the comparison between the two discharge data.

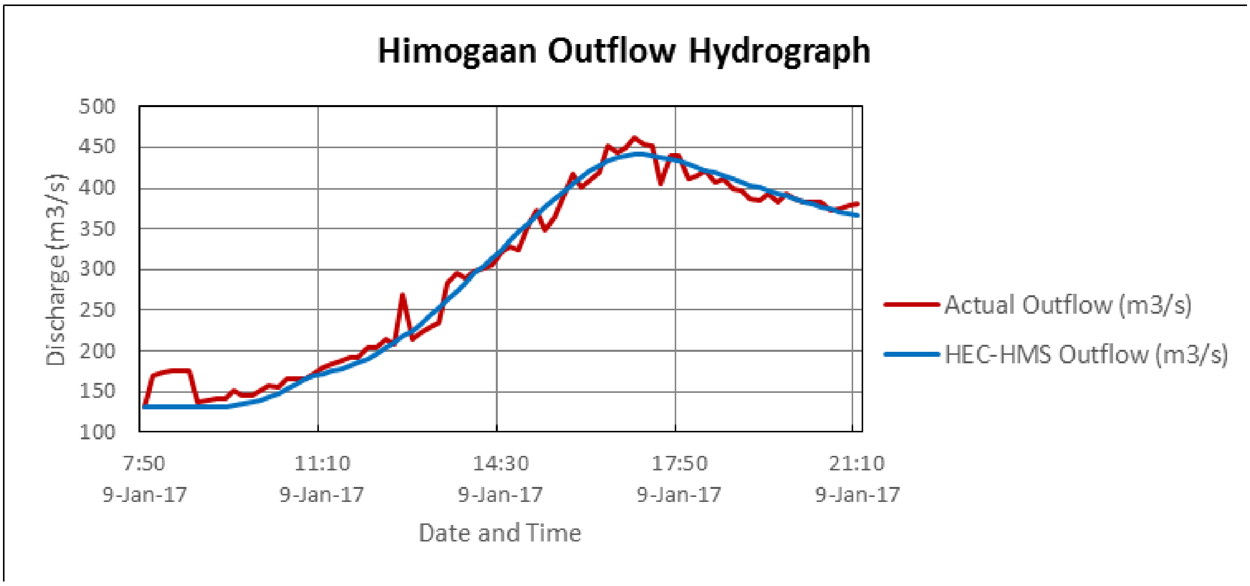


Figure 62. Outflow Hydrograph of Himogaan produced by the HEC-HMS model compared with observed outflow

Enumerated in Table 31 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 31. Range of Calibrated Values for Himogaan River Basin

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.015-0.13
			Curve Number	39.3-99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.25-9
			Storage Coefficient (hr)	0.11-5.52
	Baseflow	Recession	Recession Constant	0.9
			Ratio to Peak	0.65
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.0001

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 0.015 mm to 0.13 mm means that there is minimal to average amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 65 to 90 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area. For Himogaan, the basin mostly consists of brushlands and urban area, and the soil consists of clay, clay loam, and mountain soil.

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 0.25 hours to 9 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.9 indicates that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.65 indicates a steeper receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.0001 corresponds to the common roughness of Philippine watersheds. Himogaan river basin is determined to be cultivated with mature field crops.

Table 32. Summary of the Efficiency Test of Himogaan HMS Model

Accuracy Measure	Value
RMS Error	16.7
r^2	0.9917
NSE	0.98
RSR	0.15
PBIAS	1.35

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 16.7 (m3/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 0.9917.

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 0.98.

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 0.15.

The Observation Standard Deviation Ratio, RSR, is an error index. A perfect model attains a value of 0 when the error in the units of the valuable a quantified. The model has an RSR value of 1.35.

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 63) shows the Himogaan outflow using the Iloilo Rainfall Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAG-ASA) data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

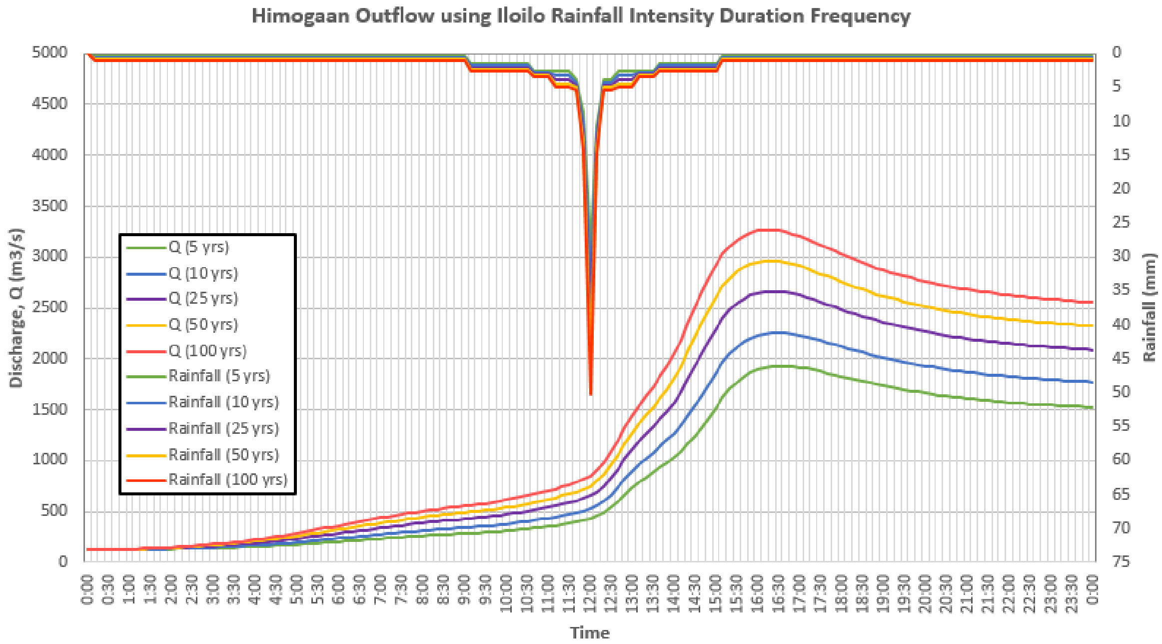


Figure 63. Outflow hydrograph at Himogaan Station generated using Iloilo RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Himogaan discharge using the Iloilo Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 33.

Table 33. Peak values of the Himogaan HEC-HMS Model outflow using the Iloilo RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m^3/s)	Time to Peak
5-Year	165.2	28.7	1931.5	4 hours, 30 minutes
10-Year	198.9	33.9	2255.2	4 hours, 30 minutes
25-Year	241.5	40.5	2663.7	4 hours, 20 minutes
50-Year	273.1	45.4	2964.2	4 hours, 20 minutes
100-Year	304.5	50.3	3264.3	4 hours, 10 minutes

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

The river discharges entering the floodplain are shown in Figure 64 to Figure 68 and the peak values are summarized in Table 34 to Table 37.

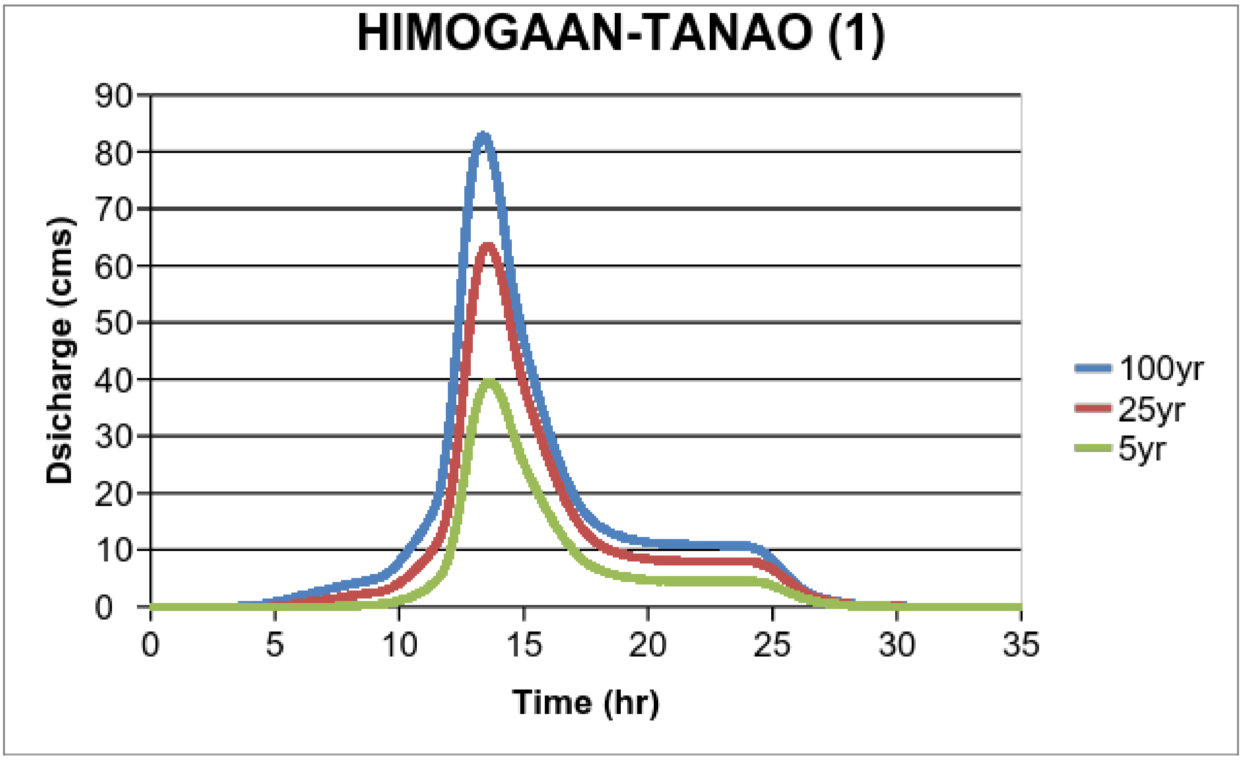


Figure 64. Himogaan and Tanao river (1) generated discharge using 5-, 25-, and 100-year Iloilo and Mactan stations' rainfall intensity-duration-frequency (RIDF) in HEC-HMS

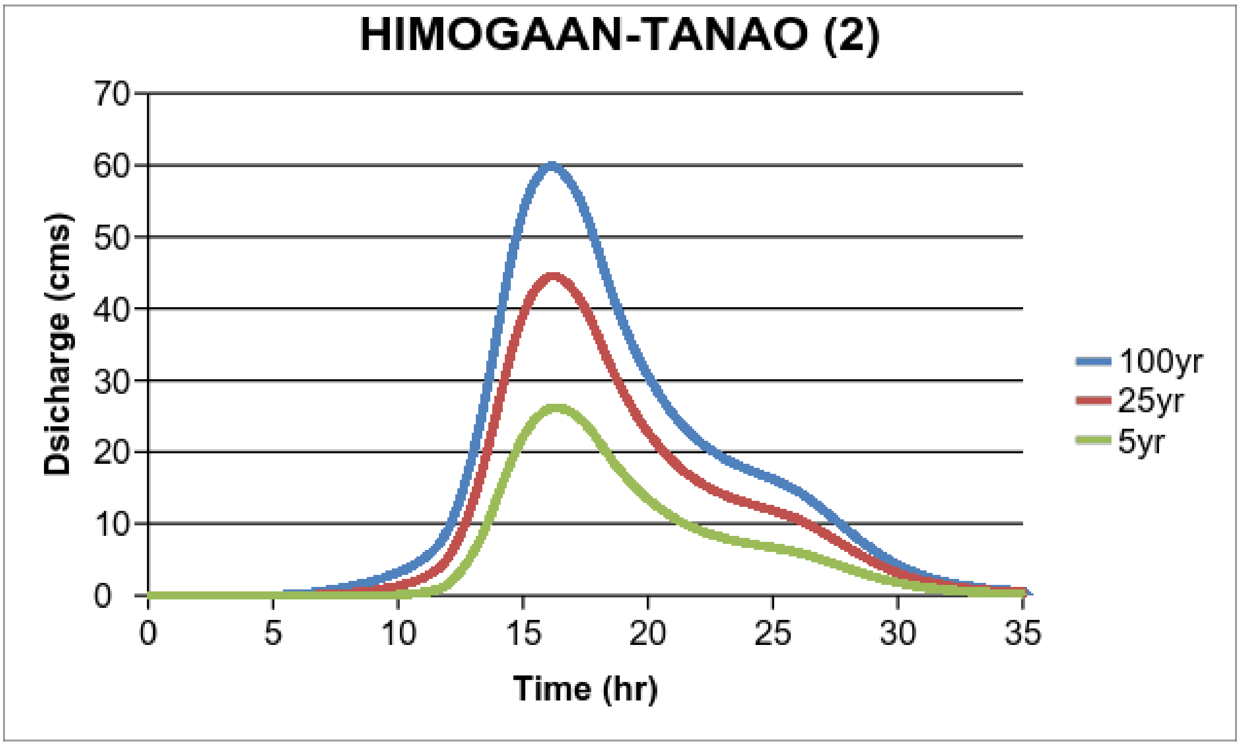


Figure 65. Himogaan and Tanao river (2) generated discharge using 5-, 25-, and 100-year Iloilo and Mactan stations' rainfall intensity-duration-frequency (RIDF) in HEC-HMS

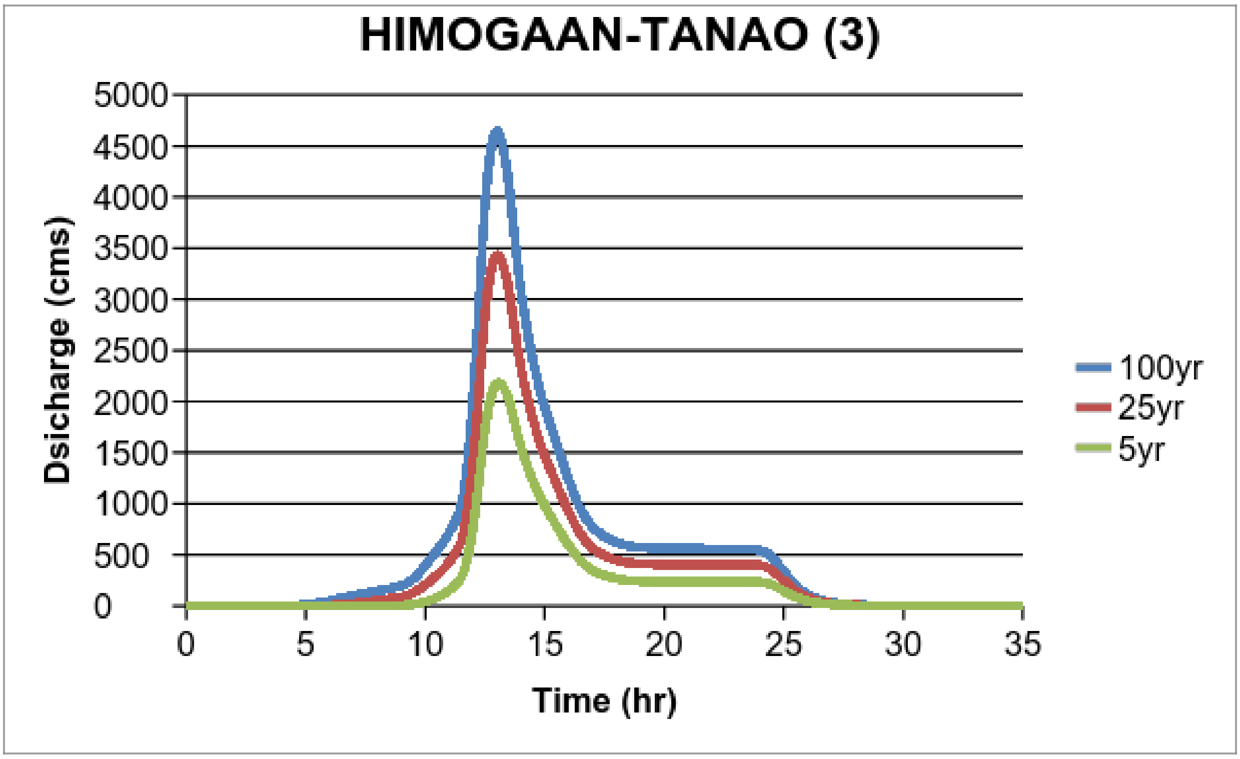


Figure 66. Himogaan and Tanao river (3) generated discharge using 5-, 25-, and 100-year Iloilo and Mactan stations' rainfall intensity-duration-frequency (RIDF) in HEC-HMS

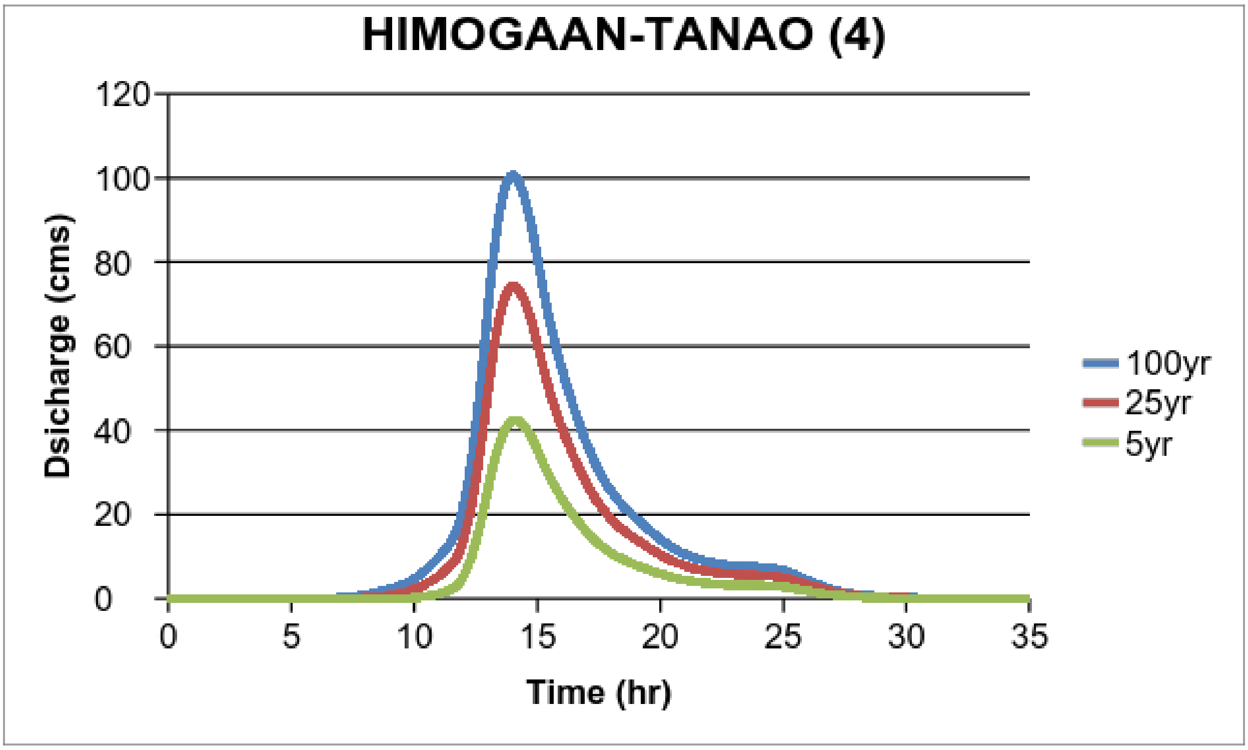


Figure 67. Himogaan and Tanao river (4) generated discharge using 5-, 25-, and 100-year Iloilo and Mactan stations' rainfall intensity-duration-frequency (RIDF) in HEC-HMS

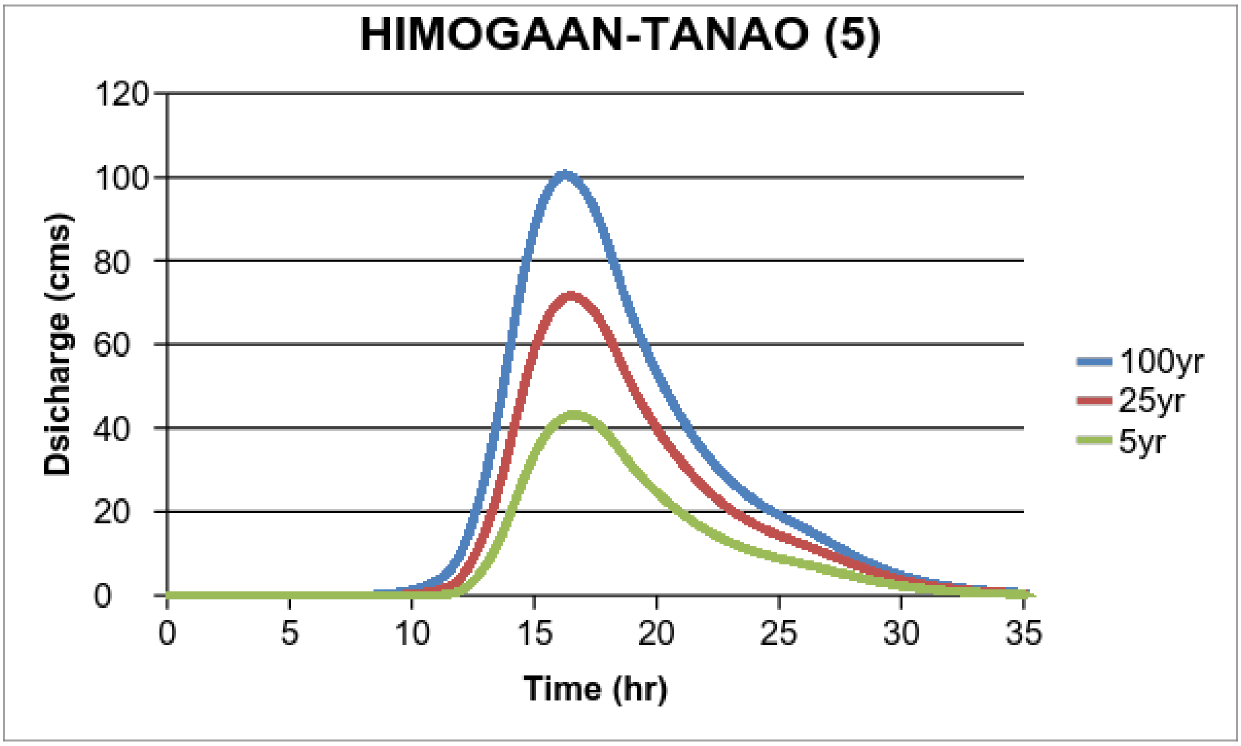


Figure 68. Himogaan and Tanao river (5) generated discharge using 5-, 25-, and 100-year Iloilo and Mactan stations' rainfall intensity-duration-frequency (RIDF) in HEC-HMS

Table 34. Summary of Himogaan and Tanao river (1) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	82.8	13 hours, 20 minutes
25-Year	63.4	13 hours, 30 minutes
5-Year	39.5	13 hours, 30 minutes

Table 35. Summary of Himogaan and Tanao river (2) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	60.0	16 hours, 10 minutes
25-Year	44.6	16 hours, 10 minutes
5-Year	26.2	16 hours, 10 minutes

Table 36. Summary of Himogaan and Tanao river (3) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	4646.0	13 hours
25-Year	3430.0	13 hours
5-Year	2176.8	13 hours

Table 37. Summary of Himogaan and Tanao river (4) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	100.7	14 hours
25-Year	74.3	14 hours
5-Year	42.3	14 hours

Table 38. Summary of Himogaan and Tanao river (5) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	100.5	16 hours, 20 minutes
25-Year	71.6	16 hours, 30 minutes
5-Year	43.1	16 hours, 30 minutes

The comparison of the discharge results using Dr. Horritt's recommended hydrological method against the bankful and specific discharge estimates is shown in Table 39.

Table 39. Validation of river discharge estimates

Discharge Point	$Q_{MED(SCS)}$, cms	$Q_{BANKFUL}$, cms	$Q_{MED(SPEC)}$, cms	VALIDATION	
				Bankful Discharge	Specific Discharge
Himogaan-Tanao (1)	34.760	51.930	34.649	Pass	Pass
Himogaan-Tanao (2)	23.056	29.710	75.694	Pass	Fail
Himogaan-Tanao (3)	1915.584	3471.490	529.417	Pass	Fail
Himogaan-Tanao (4)	37.224	58.830	45.224	Pass	Pass
Himogaan-Tanao (5)	37.928	66.320	118.887	Pass	Fail

All five values from the HEC-HMS river discharge estimates were able to satisfy at least one of the conditions for validation using the bankful and specific discharge methods. The calculated values are based on theory but are supported using other discharge computation methods so they were good to use flood modeling. However, these values will need further investigation for the purpose of validation. It is therefore recommended to obtain actual values of the river discharges for higher-accuracy modeling.

5.8 River Analysis (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. The sample generated map of Himogaan River using the calibrated HMS event flow is shown in Figure 69.

Figure 69. Sample output of Himogaan RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figure 70 to Figure 75 shows the 5-, 25-, and 100-year rain return scenarios of the Himogaan floodplain.

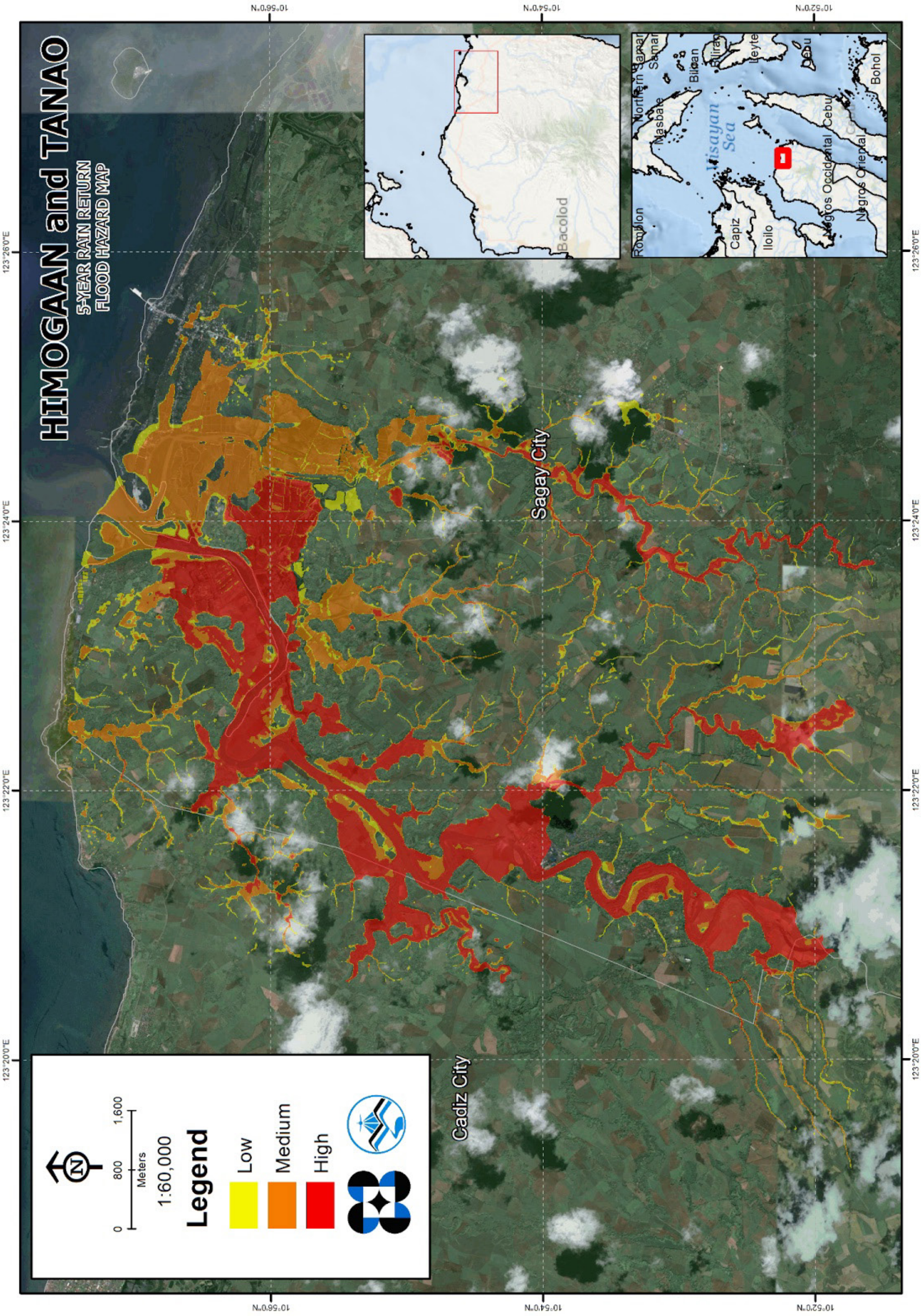


Figure 70. 5-year Flood Hazard Map for Himogaan Floodplain

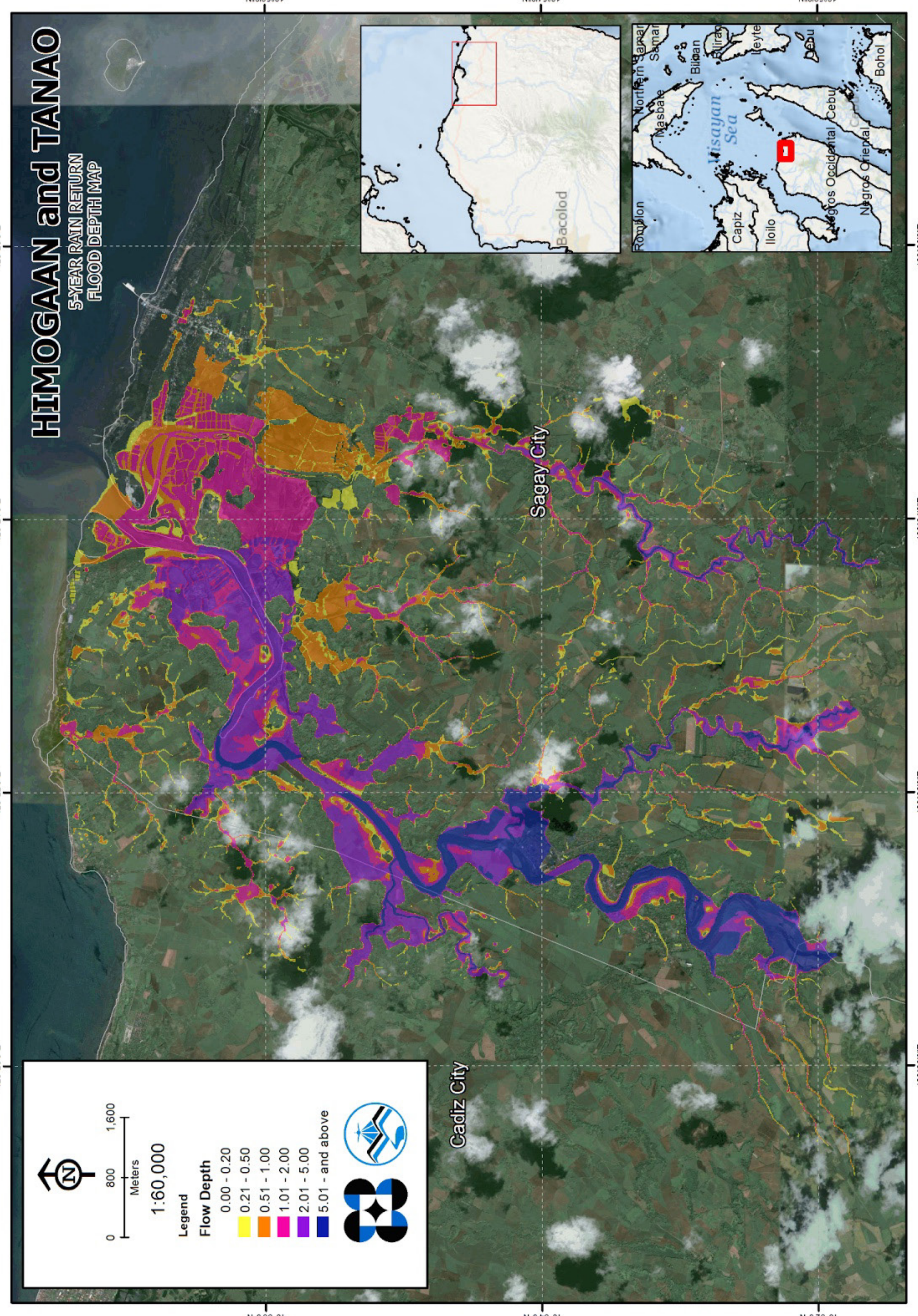


Figure 71. 5-year Flood Depth Map for Himogaan Floodplain

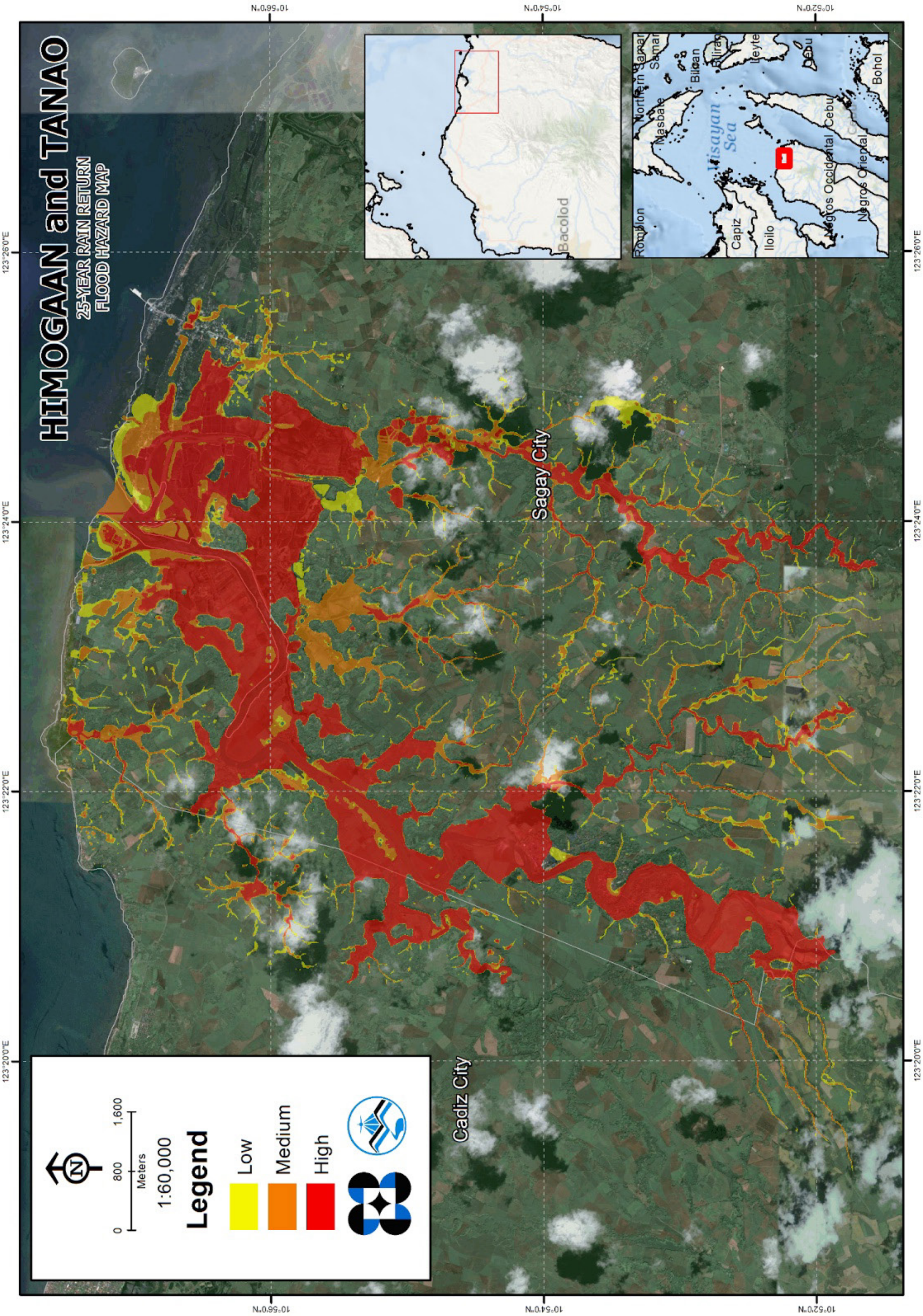


Figure 72. 25-year Flood Hazard Map for Himogaan Floodplain

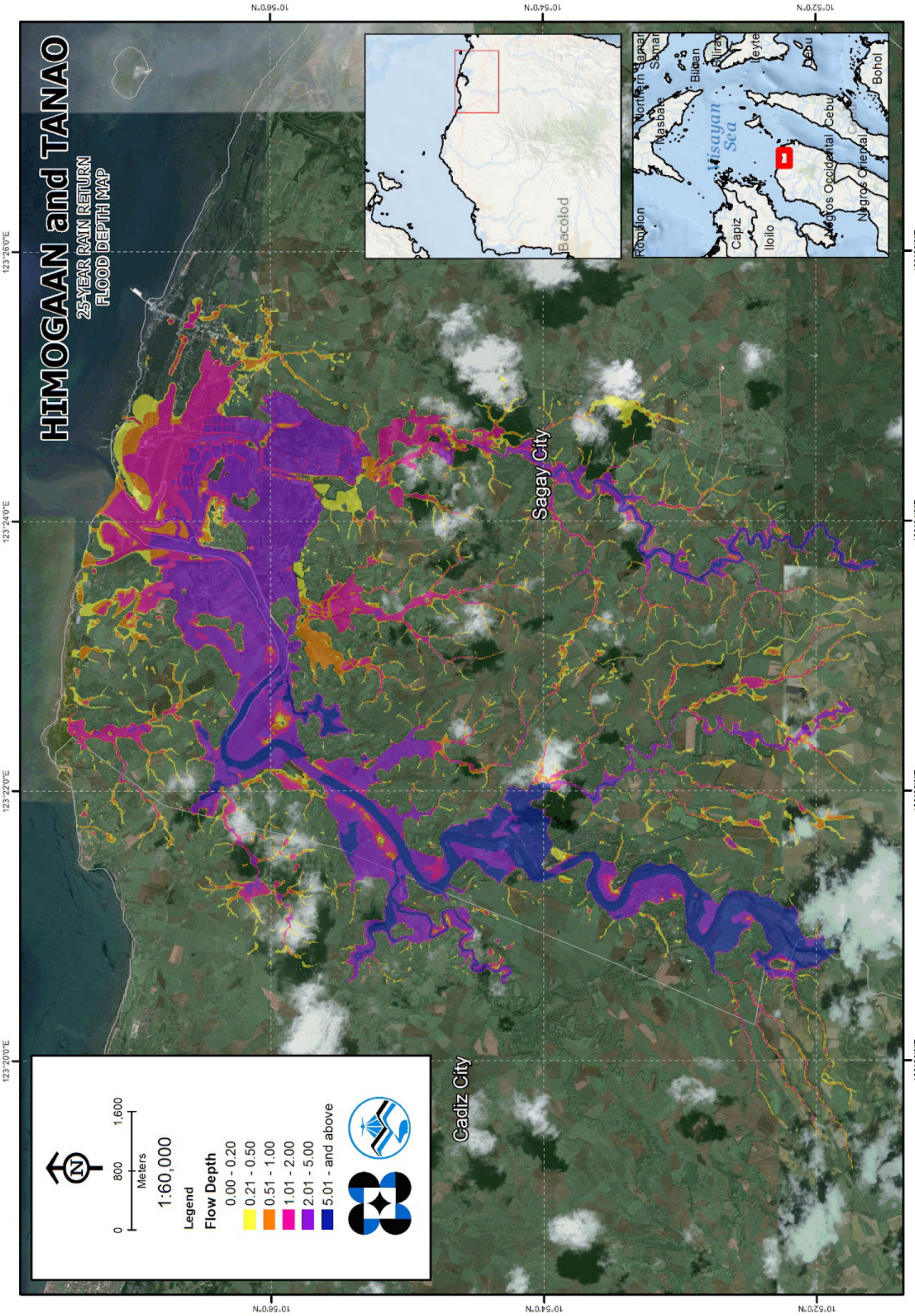


Figure 73. 25-year Flow Depth Map for Himogaan Floodplain

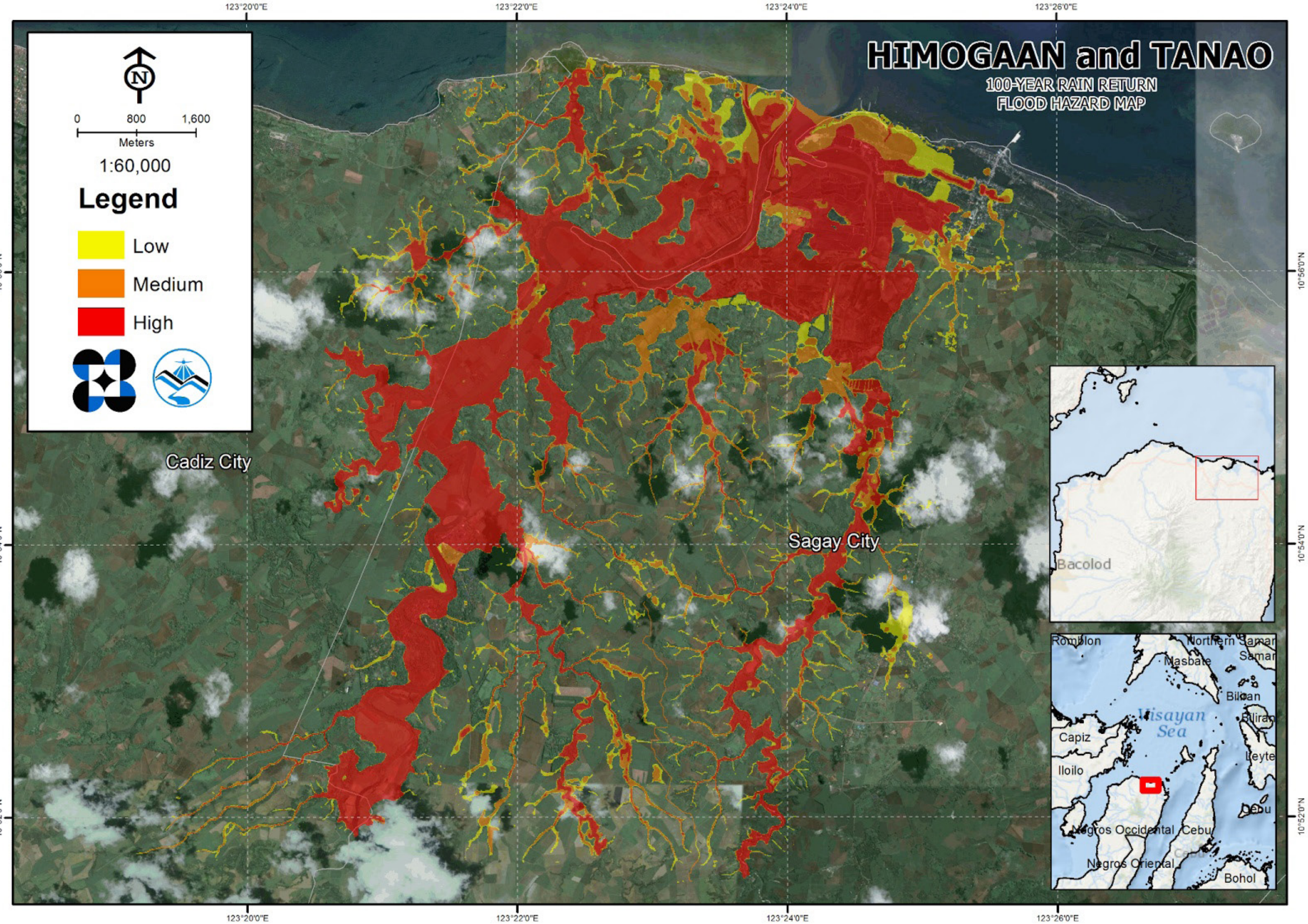


Figure 74. 100-year Flood Hazard Map for Himogaan Floodplain

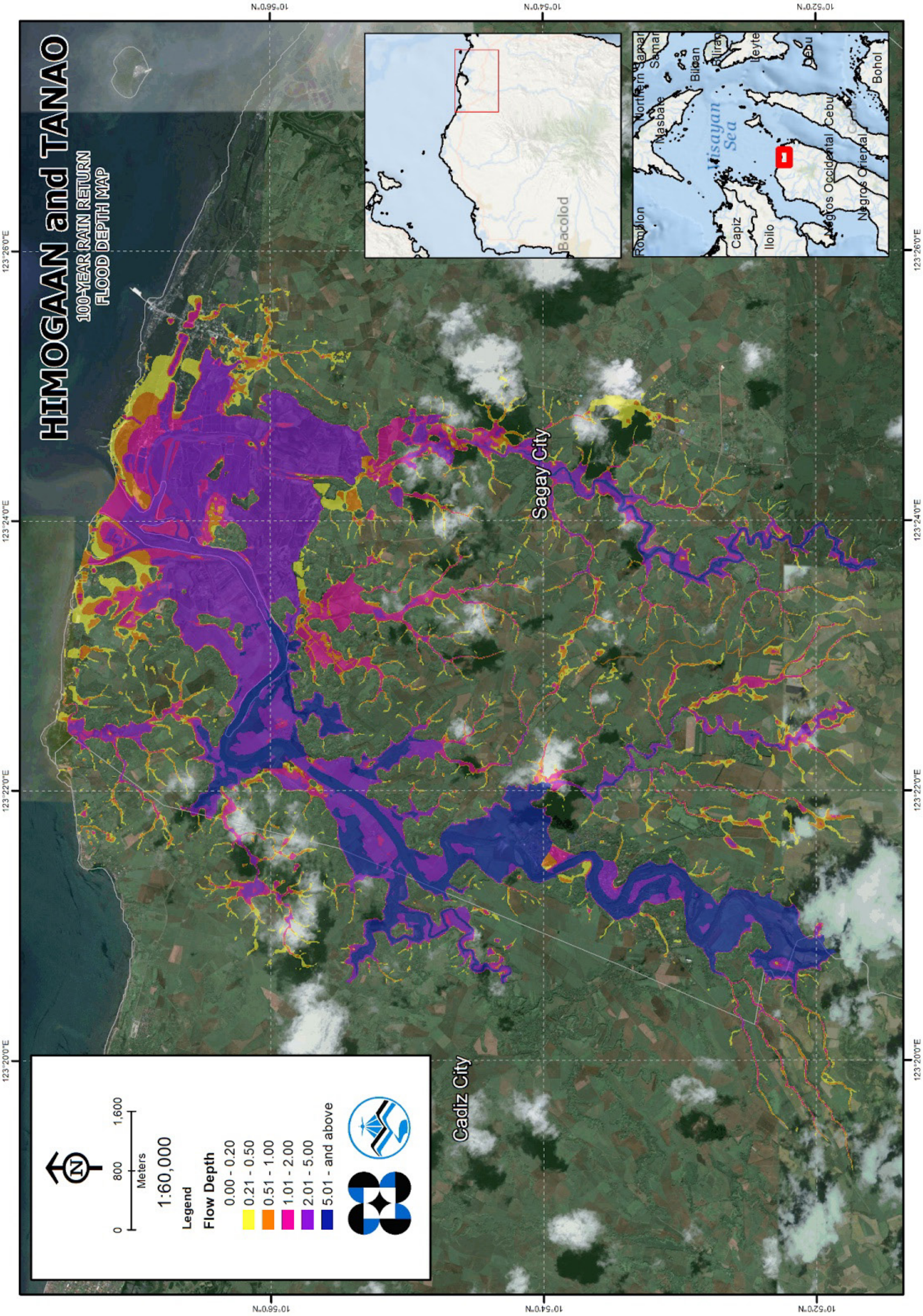


Figure 75. 100-year Flow Depth Map for Himogaan Floodplain

5.10 Inventory of Areas Exposed to Flooding of Affected Areas

Affected barangays in Himogaan river basin, grouped by municipality, are listed below. For the said basin, two municipalities consisting of 12 barangays are expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 1.88% of the city of Cadiz with an area of 516.18 sq. km. will experience flood levels of less 0.20 meters. 0.07% of the area will experience flood levels of 0.21 to 0.50 meters while 0.06%, 0.06%, 0.12%, 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 40 are the affected areas in square kilometres by flood depth per barangay.

Table 40. Affected Areas in Cadiz City, Negros Occidental during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Cadiz City (in sq. km.)			
	Banquerohan	Cabahug	Magsaysay	Tiglawigan
0.03-0.20	0.55	2.42	2.91	3.8
00.21-0.50	0.02	0.07	0.09	0.20
0.51-1.00	0	0.08	0.1	0.14
1.01-2.00	0	0.15	0.06	0.12
2.01-5.00	0	0.59	0.03	0.01
> 5.00	0	0.09	0.11	0

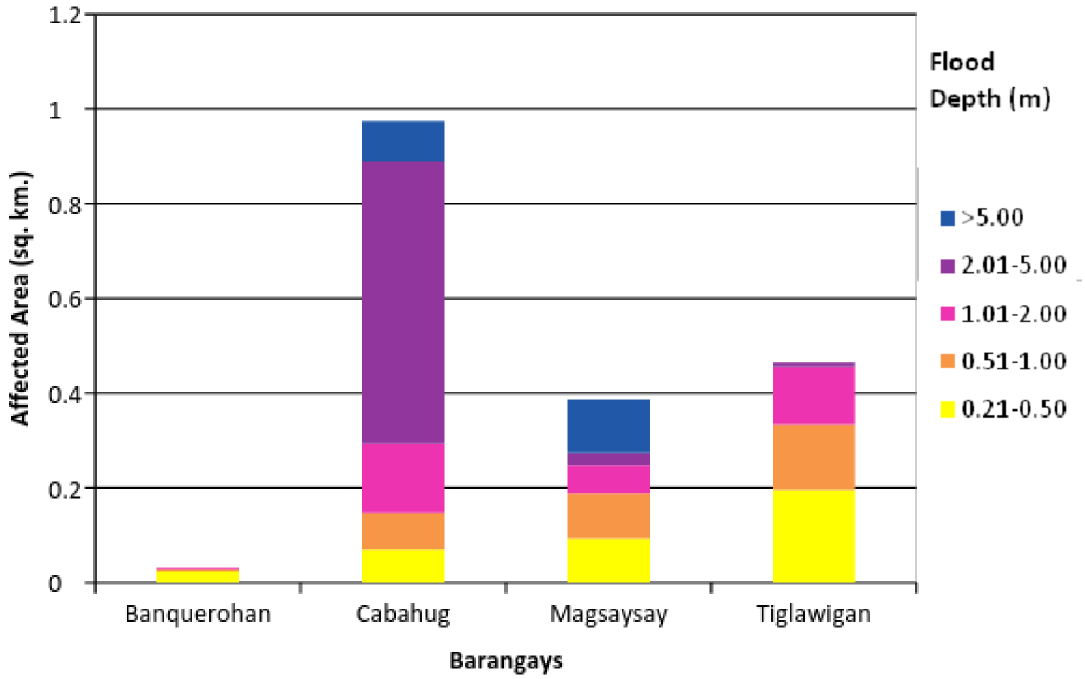


Figure 76. Affected Areas in Cadiz City, Negros Occidental during 5-Year Rainfall Return Period

For the city of Sagay, with an area of 304.62 sq. km., 16.36% will experience flood levels of less 0.20 meters. 1% of the area will experience flood levels of 0.21 to 0.50 meters while 1.57%, 1.72%, 1.49%, and 0.82% 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 41 are the affected areas in square kilometres by flood depth per barangay.

Table 41. Affected Areas in Sagay City, Negros Occidental during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sagay City (in sq. km.)							
	Fabrica	Himogaan Baybay	Malubon	Old Sagay	Paraiso	Poblacion I	Poblacion II	Taba-Ao
0.03-0.20	1.28	17.44	4.002	4.24	10.4	0.75	10.34	1.38
0.21-0.50	0.041	1.25	0.17	0.49	0.48	0.081	0.47	0.062
0.51-1.00	0.035	1.77	0.14	1.98	0.4	0.011	0.41	0.042
1.01-2.00	0.052	2.95	0.14	1.26	0.37	0.0011	0.46	0.016
2.01-5.00	0.11	3.49	0.22	0	0.37	0	0.35	0
> 5.00	0.27	1.3	0.25	0	0.56	0	0.13	0

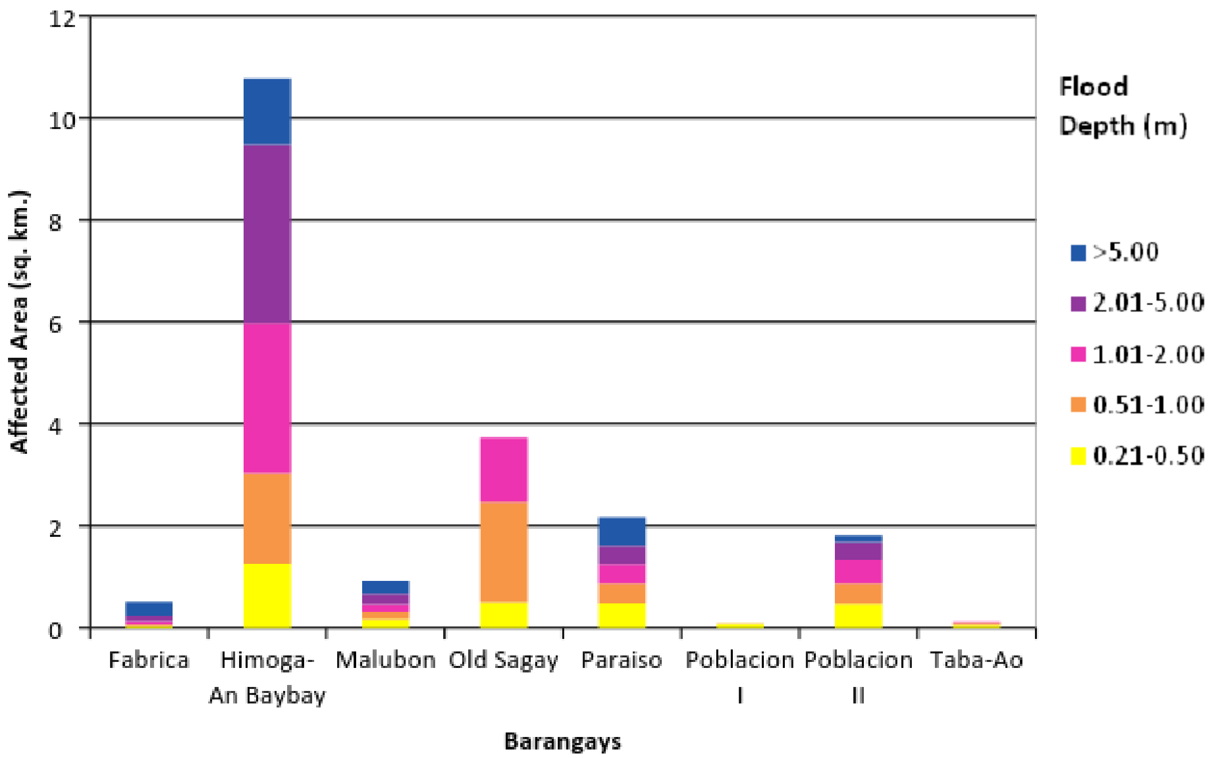


Figure 77. Affected Areas in Sagay City, Negros Occidental during 5-Year Rainfall Return Period

For the 25-year return period, 1.81% of the city of Cadiz with an area of 516.18 sq. km. will experience flood levels of less 0.20 meters. 0.08% of the area will experience flood levels of 0.21 to 0.50 meters while 0.07%, 0.07%, 0.13%, and 0.07% 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 square kilometres by flood depth per barangay.

Table 42. Affected Areas in Cadiz City, Negros Occidental during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Cadiz City (in sq. km.)			
	Banquerohan	Cabahug	Magsaysay	Tiglawigan
0.03-0.20	0.54	2.32	2.84	3.69
0.21-0.50	0.04	0.08	0.1	0.22
0.51-1.00	0.01	0.07	0.1	0.16
1.01-2.00	0.01	0.12	0.07	0.15
2.01-5.00	0	0.58	0.05	0.05
> 5.00	0	0.23	0.13	0

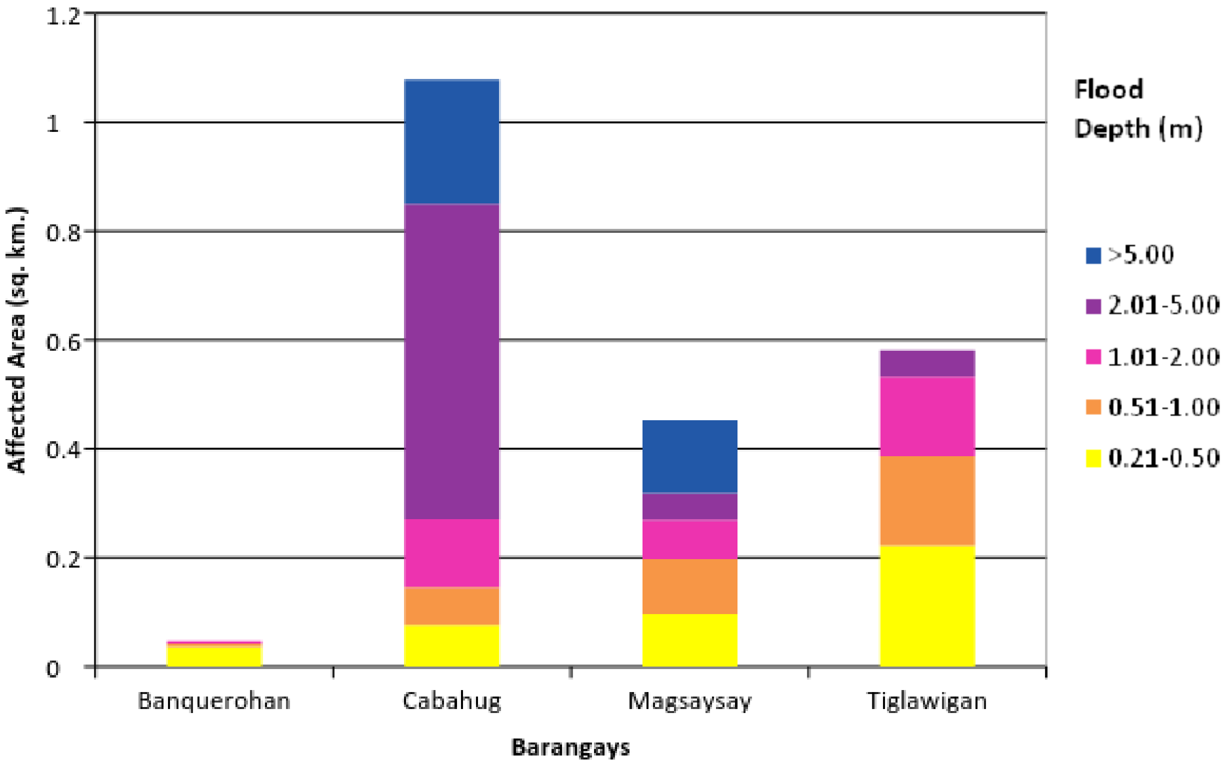


Figure 78. Affected Areas in Cadiz City, Negros Occidental during 25-Year Rainfall Return Period

For the city of Sagay, with an area of 304.62 sq. km., 15.41% will experience flood levels of less 0.20 meters. 1.1% of the area will experience flood levels of 0.21 to 0.50 meters while 1%, 1.7%, 2.7%, and 1.01% 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 43 are the affected areas in square kilometres by flood depth per barangay.

Table 43. Affected Areas in Sagay City, Negros Occidental during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Cadiz City (in sq. km.)							
	Fabrica	Himogaan Baybay	Malubon	Old Sagay	Paraiso	Poblacion I	Poblacion II	Taba-Ao
0.03-0.20	1.22	16.18	4.04	3.41	10.26	0.66	9.84	1.32
0.21-0.50	0.043	1.24	0.23	0.58	0.53	0.16	0.50	0.082
0.51-1.00	0.03	1.42	0.17	0.55	0.4	0.018	0.41	0.054
1.01-2.00	0.049	2.21	0.11	1.86	0.35	0.0019	0.56	0.036
2.01-5.00	0.11	5.30	0.11	1.58	0.54	0	0.58	0
> 5.00	0.34	1.87	0.26	0	0.49	0	0.26	0

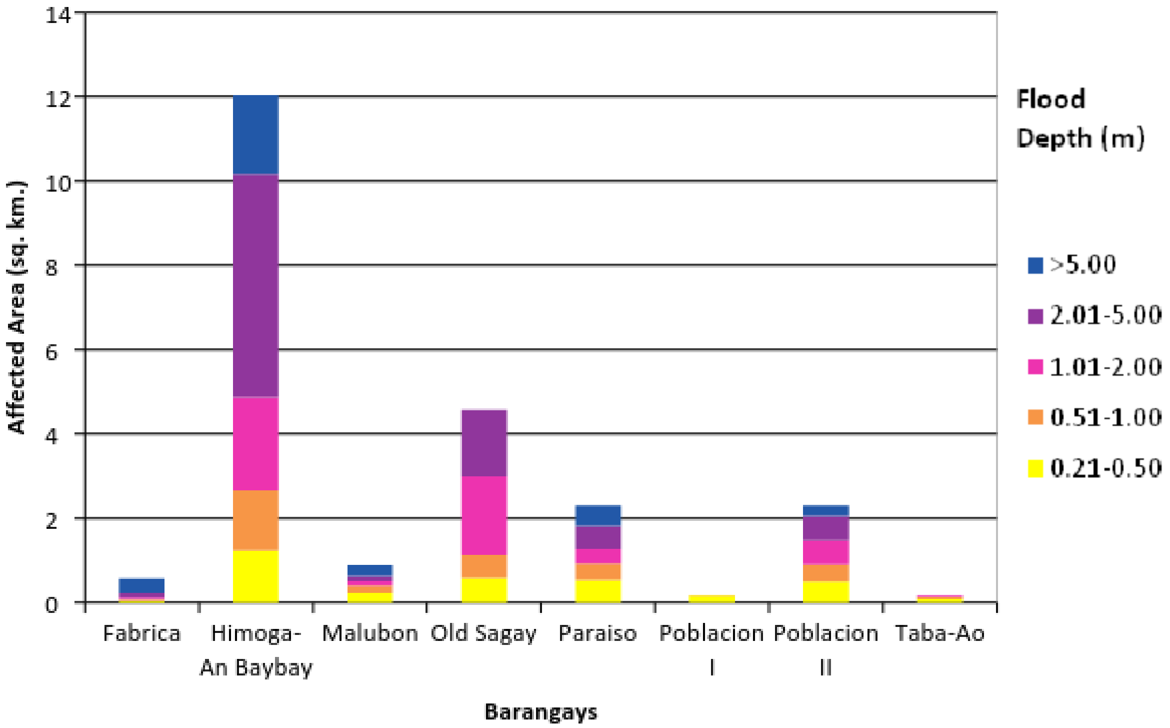


Figure 79. Affected Areas in Sagay City, Negros Occidental during 25-Year Rainfall Return Period

For the 100-year return period, 1.77% of the city of Cadiz with an area of 516.18 sq. km. will experience flood levels of less 0.20 meters. 0.09% of the area will experience flood levels of 0.21 to 0.50 meters while 0.07%, 0.07%, 0.1%, and 0.14% 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 44 are the affected areas in square kilometres by flood depth per barangay.

Table 44. Affected Areas in Cadiz City, Negros Occidental during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Cadiz City (in sq. km.)			
	Banquerohan	Cabahug	Magsaysay	Tiglawigan
0.03-0.20	0.52	2.22	2.78	3.6
0.21-0.50	0.05	0.08	0.1	0.25
0.51-1.00	0.01	0.06	0.1	0.18
1.01-2.00	0.01	0.1	0.09	0.16
2.01-5.00	0	0.39	0.05	0.09
> 5.00	0	0.55	0.18	0

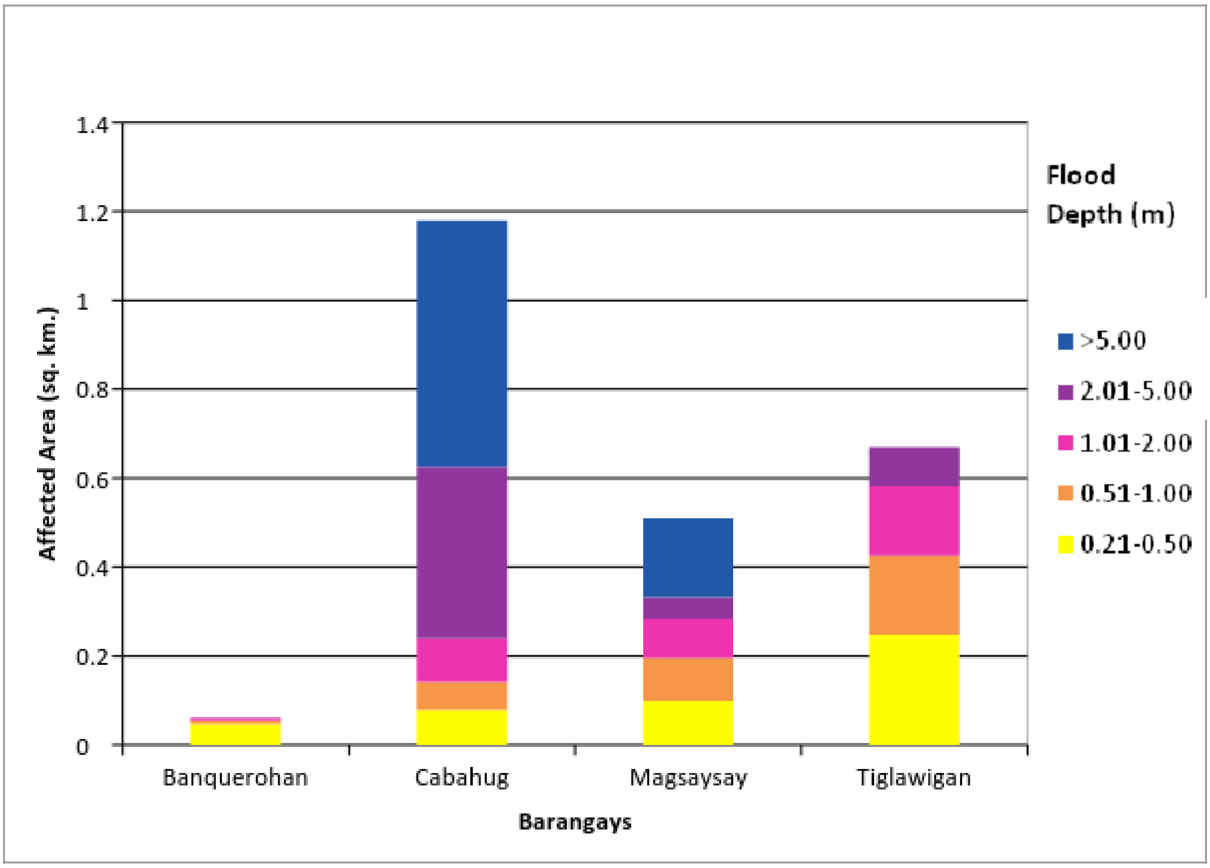


Figure 80. Affected Areas in Cadiz City, Negros Occidental during 100-Year Rainfall Return Period

For the city of Sagay, with an area of 304.62 sq. km., 14.65% will experience flood levels of less 0.20 meters. 1.15% of the area will experience flood levels of 0.21 to 0.50 meters while 1%, 1.35%, 3.24%, and 1.6% 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 45 are the affected areas in square kilometres by flood depth per barangay.

Table 45. Affected Areas in Sagay City, Negros Occidental during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Cadiz City (in sq. km.)							
	Fabrica	Himogaan Baybay	Malubon	Old Sagay	Paraiso	Poblacion I	Poblacion II	Taba-Ao
0.03-0.20	1.18	15.11	3.91	2.88	10.06	0.62	9.58	1.28
0.21-0.50	0.043	1.24	0.24	0.64	0.55	0.2	0.49	0.1
0.51-1.00	0.024	1.22	0.18	0.64	0.44	0.024	0.4	0.061
1.01-2.00	0.04	2.03	0.15	0.92	0.36	0.0027	0.55	0.046
2.01-5.00	0.076	5.53	0.14	2.91	0.45	0	0.78	0.0034
> 5.00	0.43	3.09	0.31	0	0.72	0	0.35	0

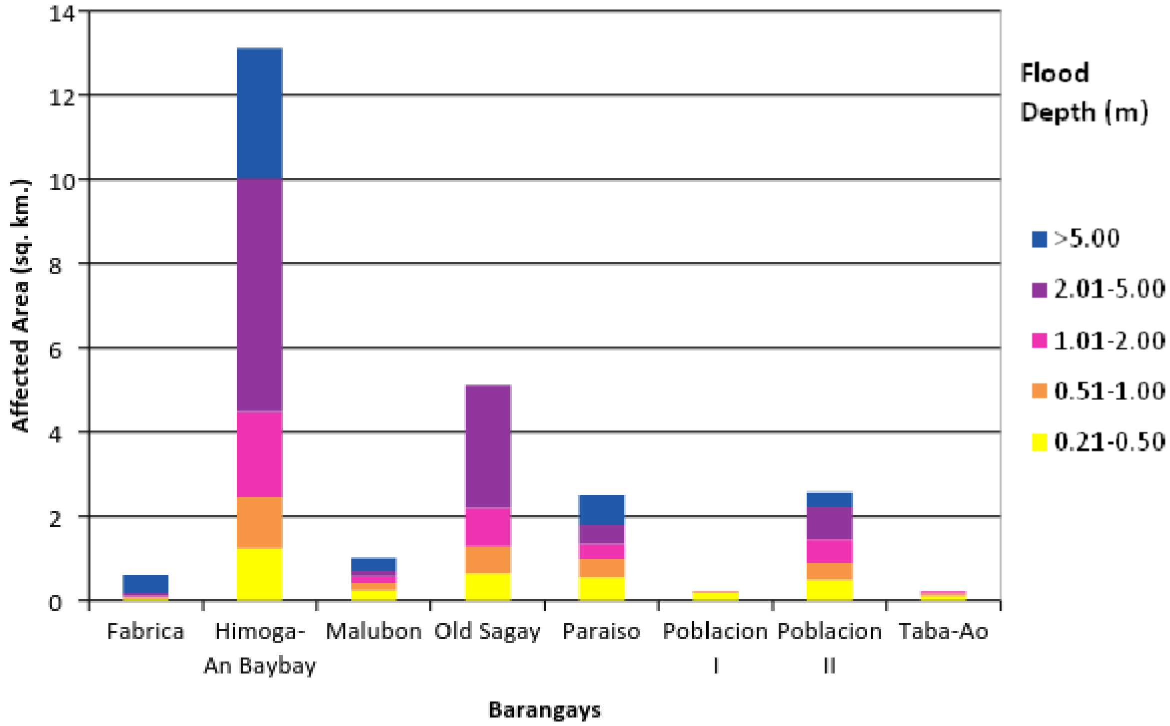


Figure 81. Affected Areas in Sagay City, Negros Occidental during 100-Year Rainfall Return Period

Among the barangays in the city of Cadiz, Tiglawigan is projected to have the highest percentage of area that will experience flood levels at 4.27%. Meanwhile, Cabahug posted the second highest percentage of area that may be affected by flood depths at 3.4%.

Among the barangays in the city of Sagay, Himogaan Baybay is projected to have the highest percentage of area that will experience flood levels at 28.21%. Meanwhile, Paraiso posted the second highest percentage of area that may be affected by flood depths at 12.57%.

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

Table 46. Area covered by each warning level with respect to the rainfall scenario

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	3.56	3.92	4.12
Medium	8.83	16.22	5.91
High	10.65	16.22	18.89
Total	**23.04**	**36.36**	**28.92**

Of the twenty (20) identified Education Institute in Himogaan-Tanao Flood plain, 1 school was assessed to be exposed to the medium level flooding during a 25 year scenario while 2 schools were assessed to be exposed to high level flooding in the same scenario. In the 100 year scenario, 3 schools were assessed to be exposed to the high level flooding scenario.

Two (2) Medical Institutions were identified in Himogaan-Tanao Floodplain, only 1 was assessed to be exposed to high level flooding in two different scenarios, medium and high, in Barangay Himogaan Baybay.

5.11 Flood Validation

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

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

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

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

The flood validation consisted of 245 points randomly selected all over Himogaan floodplain. It has an RMSE value of 2.959962.

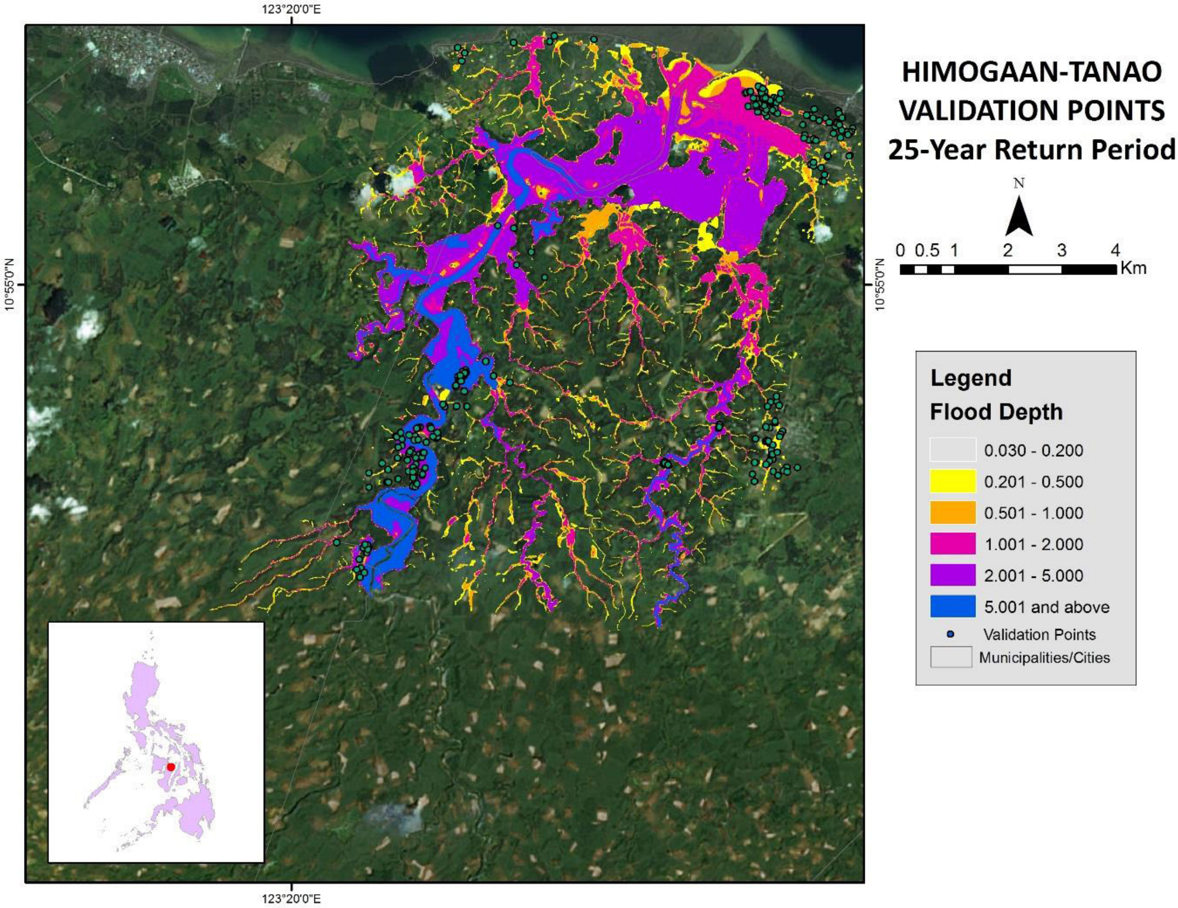


Figure 82. Validation points for 5-year Flood Depth Map of Himogaan Floodplain

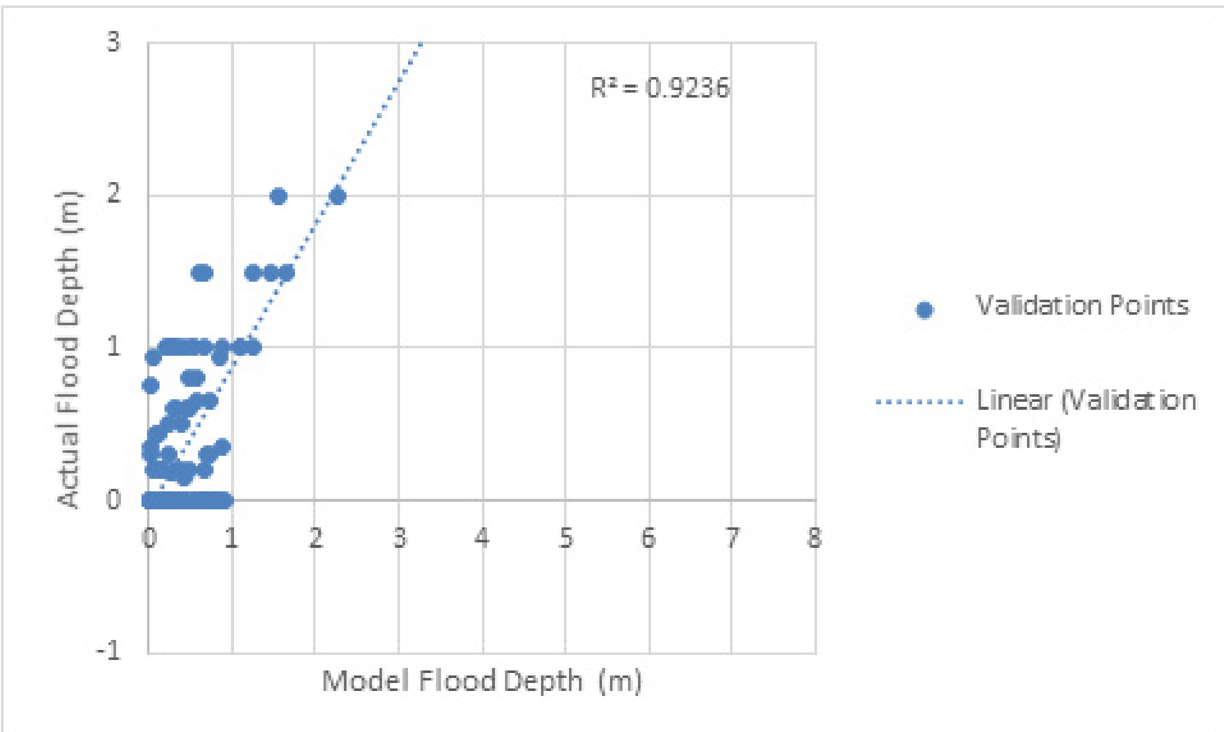


Figure 83. Flood map depth vs. actual flood depth

Table 47. Actual Flood Depth vs Simulated Flood Depth in Himogaan

Actual Flood Depth (m)	Modeled Flood Depth (m)						
	0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
0-0.20	75	5	10	10	15	5	120
0.21-0.50	12	3	4	3	2		24
0.51-1.00	15	1	12	6	1		35
1.01-2.00	7	1	7	7	3		25
2.01-5.00	5	2	5	0	4	4	20
> 5.00	1	0	0	3	10	7	21
Total	115	12	38	29	35	16	245

The overall accuracy generated by the flood model is estimated at 44.08%, with 108 points correctly matching the actual flood depths. In addition, there were 52 points estimated one level above and below the correct flood depths while there were 38 points and 21 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 68 points were overestimated while a total of 69 points were underestimated in the modelled flood depths of Himogaan-Tanao.

Table 48. Summary of Accuracy Assessment in the Himogaan River Basin Survey

	No. of Points	%
Correct	108	44.08
Overestimated	68	27.76
Underestimated	69	28.16
Total	245	100

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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.

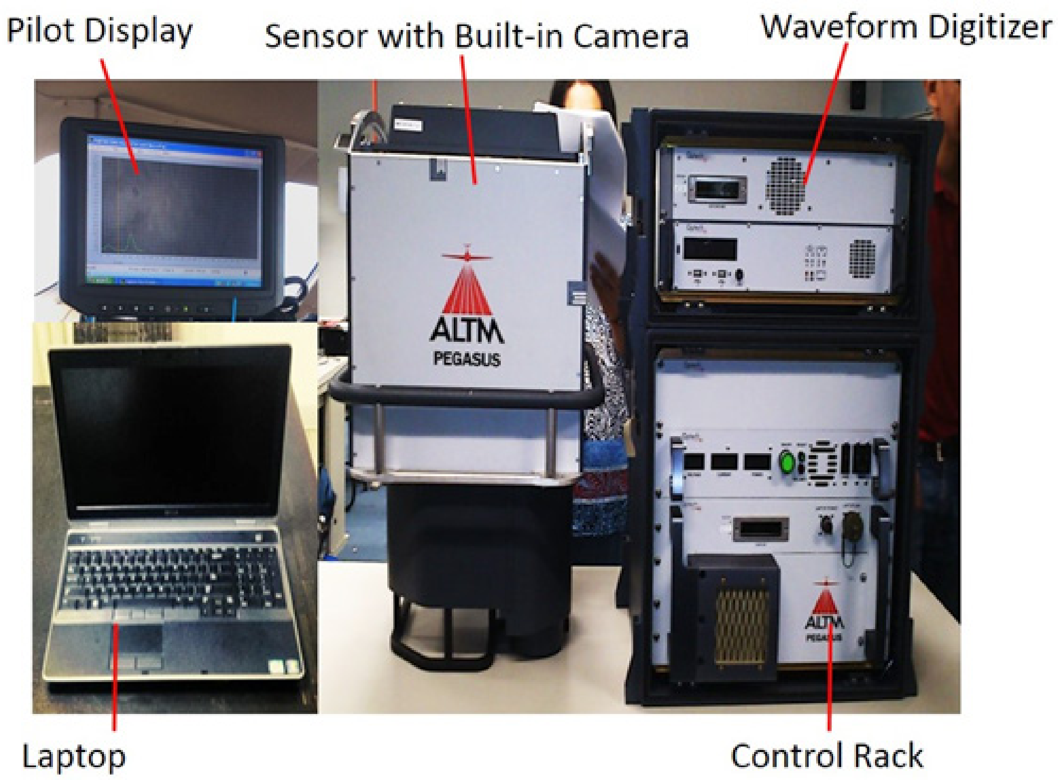
Sarmiento C., Paringit E.C., et al. 2014. DREAM Data Acquisition Component Manual. Quezon City, Philippines: UP Training Center for Applied Geodesy and Photogrammetry.

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

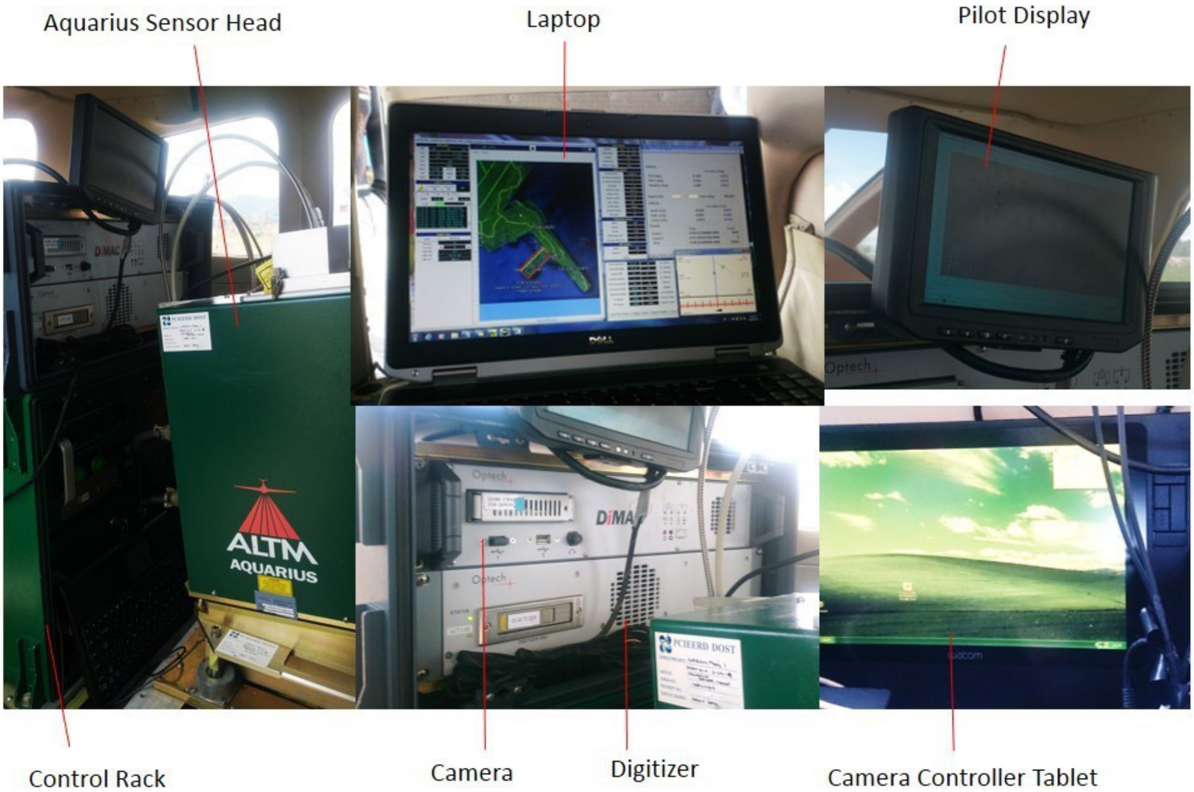
Annex 1. Optech Technical Specifications

1. Pegasus Sensor



Parameter	Specification
Operational envelope (1,2,3,4)	150-5000 m AGL, nominal
Laser wavelength	1064 nm
Horizontal accuracy (2)	1/5,500 x altitude, 1σ
Elevation accuracy (2)	< 5-20 cm, 1σ
Effective laser repetition rate	Programmable, 100-500 kHz
Position and orientation system	POS AV ™AP50 (OEM)
Scan width (FOV)	Programmable, 0-75 ˚
Scan frequency (5)	Programmable, 0-140 Hz (effective)
Sensor scan product	800 maximum
Beam divergence	0.25 mrad (1/e)
Roll compensation	Programmable, ±37˚ (FOV dependent)
Vertical target separation distance	<0.7 m
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)
Image capture	5 MP interline camera (standard); 60 MP full frame (optional)
Full waveform capture	12-bit Optech IWD-2 Intelligent Waveform Digitizer
Data storage	Removable solid state disk SSD (SATA II)
Power requirements	28 V, 800 W, 30 A
Dimensions and weight	Sensor: 630 x 540 x 450 mm; 65 kg;
	Control rack: 650 x 590 x 490 mm; 46 kg
Operating Temperature	-10°C to +35°C
Relative humidity	0-95% non-condensing

2. 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

3. ITRES TECHNICAL SPECIFICATIONS OF CASI

Sensor Type	
VNIR Push-broom Sensor	
(Compact Airborne Spectrographic Imager)	
Performance	
Spectral Range (Continuous Coverage)	380-1050 nm
# Spectral Channels	Up to 288
#Across-Track Pixels	1500
Total Field of View	40 deg
IFOV	0.49 mRad
t/#	t/3.5
Spectral Width Sampling Row	2.4 nm
Spectral Resolution (FWHM)	<3.5 nm
Pixel Size	20x20 microns
Dynamic Range	14-bits (16384:1)
Sustained Date Rate (Mpix/Second)	9.6 Mpix/Sec
Spectral Smile/Keystone Distortion	±0.35 pixels
Peak Signal Noise Ration	SNR models for various radiance conditions are available
Relative humidity	0-95% no-condensing

Annex 2. NAMRIA Certificates of Reference Points Used

NGW-50

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

May 09, 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: **NEGROS OCCIDENTAL**
Station Name: **NGW-50**
Order: **2nd**

Island: **VISAYAS**
Municipality: **SAGAY**
Barangay: **FABRICA**

PRS92 Coordinates

Latitude: **10° 53' 26.84456"**	Longitude: **123° 21' 6.66799"**	Ellipsoidal Hgt: **15.38600 m.**

WGS84 Coordinates

Latitude: **10° 53' 22.52478"**	Longitude: **123° 21' 11.86863"**	Ellipsoidal Hgt: **74.42200 m.**

PTM Coordinates

Northing: **1204272.594 m.**	Easting: **538465.927 m.**	Zone: **4**

UTM Coordinates

Northing: **1,203,851.08**	Easting: **538,452.46**	Zone: **51**

Location Description

NGW-50
The station is on the NW sidewalk of Himoga-an bridge at km. 73+545 along the Sagay-Bacolod national highway. Mark is the head of a 4" copper nail drilled and grouted at the center of a 30 x 30 cm. cement putty embedded on top of the concrete sidewalk with inscriptions "NGW-50; 2007; NAMRIA".

Requesting Party: **UP DREAM**
Pupose: **Reference**
OR Number: **8796117 A**
T.N.: **2014-1064**

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

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

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

NGW-58

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

May 09, 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: **NEGROS OCCIDENTAL**
Station Name: **NGW-58**
Order: **2nd**

Island: **VISAYAS**		Barangay: **ONOBONOB, SITIO LABARCA**
Municipality: **ESCALANTE**		
	PRS92 Coordinates	
Latitude: **10° 49' 16.43235"**	Longitude: **123° 29' 11.51295"**	Ellipsoidal Hgt: **8.72200 m.**
	WGS84 Coordinates	
Latitude: **10° 49' 12.14178"**	Longitude: **123° 29' 16.71871"**	Ellipsoidal Hgt: **68.25600 m.**
	PTM Coordinates	
Northing: **1196599.363 m.**	Easting: **553202.195 m.**	Zone: **4**
	UTM Coordinates	
Northing: **1,196,180.53**	Easting: **553,183.57**	Zone: **51**

Location Description

NGW-58
The station is on the NE sidewalk of Danao bridge. It is about 2.4 km. from Escalante City proper. Mark is the head of a 4" copper nail flushed at the center of an existing benchmark embedded on the concrete sidewalk with inscriptions "NW-100; 2007; NAMRIA".

Requesting Party: **UP DREAM**
Pupose: **Reference**
OR Number: **8796117 A**
T.N.: **2014-1066**

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

9905092014100606

CIP/4701/12/09/814

NAMRIA OFFICES:
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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

NGW-63

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

May 09, 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: **NEGROS OCCIDENTAL**

Station Name: **NGW-63**

Order: **2nd**

Island: **VISAYAS**		Barangay: **LEMERY**
Municipality: **CALATRAVA**		
	PRS92 Coordinates	
Latitude: **10° 38' 30.18023"**	Longitude: **123° 29' 18.57332"**	Ellipsoidal Hgt: **10.15500 m.**
	WGS84 Coordinates	
Latitude: **10° 38' 25.93535"**	Longitude: **123° 29' 23.79491"**	Ellipsoidal Hgt: **70.11800 m.**
	PTM Coordinates	
Northing: **1176744.618 m.**	Easting: **553448.18 m.**	Zone: **4**
	UTM Coordinates	
Northing: **1,176,332.74**	Easting: **553,429.47**	Zone: **51**

Location Description

NGW-63
The station is on the NE end of the sidewalk. It is located at Daan-Lunsod bridge at km.124+077 along San Carlos-Bacolod national highway. The station is about 10.1 km. from Calatrava town proper. Mark is the head of a 4" copper nail drilled and grouted at the center of a 30 x 30 cm. cement putty embedded on top of the concrete sidewalk with inscriptions "NGW-63; 2007; NAMRIA".

Requesting Party: **UP DREAM**
Pupose: **Reference**
OR Number: **8796117 A**
T.N.: **2014-1067**

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

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

CIP/4701/12/09/814

NAMRIA OFFICES:
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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

CBU-327

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

July 25, 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: **CEBU**
Station Name: **CBU-327**
Order: **2nd**

Island: **VISAYAS**		Barangay: **POBLACION**
Municipality: **SAN REMIGIO**		MSL Elevation:
	PRS92 Coordinates	
Latitude: **11° 4' 30.20546"**	Longitude: **123° 56' 10.33433"**	Ellipsoidal Hgt: **3.54100 m.**
	WGS84 Coordinates	
Latitude: **11° 4' 25.88934"**	Longitude: **123° 56' 15.51412"**	Ellipsoidal Hgt: **63.57400 m.**
	PTM / PRS92 Coordinates	
Northing: **1224791.193 m.**	Easting: **602289.857 m.**	Zone: **4**
	UTM / PRS92 Coordinates	
Northing: **1,224,362.49**	Easting: **602,254.06**	Zone: **51**

Location Description

CBU-327

Station is located at San Remegio. It is situated on the bridge adjacent to San Remegio Public Cemetery.

Mark is the head of a 3 in. copper nail embedded and centered on a 30 cm x 30 cm x 1.20 cm concrete monument, protruding about 20 cm above the ground with inscriptions, "CBU-327, 2007, NAMRIA".

Requesting Party: **UP-TCAGP / Engr. Christopher Cruz**
Pupose: **Reference**
OR Number: **8799582 A**
T.N.: **2014-1733**

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

9907252014131911

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

CIP/4701/12/09/814

Annex 3. Baseline Processing Reports

NW-123

Vector Components (Mark to Mark)

From:	NGW-50				
Grid		Local		Global	
Easting	538452.463 m	Latitude	N10°53'26.84456"	Latitude	N10°53'22.52478"
Northing	1203851.077 m	Longitude	E123°21'06.66798"	Longitude	E123°21'11.86863"
Elevation	13.070 m	Height	15.386 m	Height	74.422 m

To:	NW-123				
Grid		Local		Global	
Easting	535814.193 m	Latitude	N10°54'55.44186"	Latitude	N10°54'51.11379"
Northing	1206569.165 m	Longitude	E123°19'39.85826"	Longitude	E123°19'45.05691"
Elevation	26.999 m	Height	29.378 m	Height	88.296 m

Vector					
ΔEasting	-2638.270 m	NS Fwd Azimuth	315°55'13"	ΔX	2477.863 m
ΔNorthing	2718.087 m	Ellipsoid Dist.	3789.388 m	ΔY	1030.277 m
ΔElevation	13.929 m	ΔHeight	13.992 m	ΔZ	2675.529 m

Standard Errors

Vector errors:					
σ ΔEasting	0.009 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.017 m
σ ΔNorthing	0.003 m	σ Ellipsoid Dist.	0.006 m	σ ΔY	0.024 m
σ ΔElevation	0.029 m	σ ΔHeight	0.029 m	σ ΔZ	0.007 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0002973675		
Y	-0.0003341330	0.0005735969	
Z	-0.0000950547	0.0001441364	0.0000468436

2

CU-621A

Vector Components (Mark to Mark)

From:	CBU-327				
Grid		Local		Global	
Easting	602254.054 m	Latitude	N11°04'30.20546"	Latitude	N11°04'25.88935"
Northing	1224362.494 m	Longitude	E123°56'10.33433"	Longitude	E123°56'15.51412"
Elevation	2.863 m	Height	3.541 m	Height	63.573 m

To:	CU-621A				
Grid		Local		Global	
Easting	600754.296 m	Latitude	N11°01'11.40740"	Latitude	N11°01'07.10407"
Northing	1218251.484 m	Longitude	E123°55'20.28492"	Longitude	E123°55'25.46968"
Elevation	15.098 m	Height	15.654 m	Height	75.785 m

Vector					
ΔEasting	-1499.757 m	NS Fwd Azimuth	193°58'06"	ΔX	600.402 m
ΔNorthing	-6111.011 m	Ellipsoid Dist.	6294.070 m	ΔY	1828.859 m
ΔElevation	12.235 m	ΔHeight	12.113 m	ΔZ	-5992.519 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.004 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.006 m
σ ΔElevation	0.007 m	σ ΔHeight	0.007 m	σ ΔZ	0.002 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000156253		
Y	-0.0000207517	0.0000355938	
Z	-0.0000049255	0.0000086616	0.0000031280

2

Annex 4. The Survey Team

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
		ENGR. LOUIE P. BALICANTA	
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	Senior Science Research Specialist (SSRS)	JASMINE ALVIAR	UP-TCAGP
		CHRISTOPHER JOAQUIN	
	Research Associate (RA)	DC ALDOVINO	UP-TCAGP
		RENAN PUNTO	
	RA	MA. VERLINA TONGA,	UP-TCAGP
		JONALYN GONZALES	
Ground Survey, Data Download and Transfer	RA	LANCE CINCO	UP-TCAGP
		KENNETH QUISADO	
LiDAR Operation	Airborne Security	SSG. DAVE GUMBAN	PILIPPINE AIR FORCE (PAF)
		SSG. LEE JAY PUNZALAN	
	Pilot	CAPT. JEFFREY JEREMY ALAJAR;	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. RANDY LAGCO	
		CAPT. BRYAN DONGUINES	AAC
		CAPT. JERICHO JECIEL	

Annex 5. Data Transfer Sheet for Himogaan Floodplain

DATA TRANSFER SHEET
5/19/2014(Bacolod Ready)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
4/29/2014	1403P	1BLK44DE119A	PEGASUS	2.89GB	2078KB	13.3	550	54.5	431	57.1	NA	7.14MB	1KB	1KB	92/75/52/56	NA	Z:\Airborne_Raw\1403P
5/1/2014	1411P	1BLK44D121A	PEGASUS	NA	88KB	10.9	221	31.5	264	26.5	NA	6.74MB	1KB	1KB	82/69/56	NA	Z:\Airborne_Raw\1411P
5/2/2014	1415P	1BLK44H122A	PEGASUS	3.27GB	2121KB	14.1	266	40.3	346	32.8	NA	7.32MB	1KB	1KB	37/38/46	NA	Z:\Airborne_Raw\1415P
5/5/2014	1427P	1BLK45E125A	PEGASUS	2.73GB	661KB	10.6	219	NA	NA	25.7	NA	6.12	1KB	1KB	30.9	NA	Z:\Airborne_Raw\1427P
5/6/2014	1431P	1BLK44GHS126A	PEGASUS	3.11	1612KB	13	254	51.3	370	29.2	NA	14.4	1KB	1KB	144/137/110	NA	Z:\Airborne_Raw\1431P
5/6/2014	1433P	1BLK44FGS126B	PEGASUS	3.04	1652	12.8	271	59	495	27.8	NA	14.4	1KB	1KB	144/137/110	NA	Z:\Airborne_Raw\1433P
5/7/2014	1435P	1BLK44DS127A	PEGASUS	2.94	712	14	285	NA	NA	19.6	NA	7.14	1KB	1KB	114	NA	Z:\Airborne_Raw\1435P
5/10/2014	1447P	1BLK45FG130A	PEGASUS	3.45	1382	14.4	294	NA	NA	32.3	NA	6.21	1KB	1KB	43	NA	Z:\Airborne_Raw\1447P
5/11/2014	1451P	1BLK45S132A	PEGASUS	2.42	500	11.5	243	NA	NA	27.2	NA	11.4	1KB	1KB	53	NA	Z:\Airborne_Raw\1451P
5/11/2014	1453P	1BLK45DFGS133A	PEGASUS	1.8	581	7.34	170	21.5	171	16.6	NA	11.4	1KB	1KB	49.3	NA	Z:\Airborne_Raw\1453P
5/12/2014	1455P	1IHLS134A	PEGASUS	3.05	530	13.2	298	NA	NA	26.3	NA	8.9	1KB	1KB	81/82/33/23	NA	Z:\Airborne_Raw\1455P
5/13/2014	1459P	1IHLS136A	PEGASUS	3.23	577	14.6	287	NA	NA	31.1	NA	7.18	1KB	1KB	88	NA	Z:\Airborne_Raw\1459P
5/14/2014	1463P	1IHLX137A	PEGASUS	782MB	249	5.69	148	NA	NA	8.26	NA	6.42	1KB	1KB	119	NA	Z:\Airborne_Raw\1463P

Received from
Name [illegible]
Position RA
Signature

Received by
Name JOIDA F. PRIETO
Position SSRS
Signature 5/26/2014

DATA TRANSFER SHEET
BACOLOD 5/18/2016

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	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	
April 22,2016	8453AC	3BLK44AS113A	AQUA/CASI	NA	343	769	246	NA	NA	13.9	101	99.1	1KB	1KB	6	14	Z:\DAC\RAW DATA
April 23,2016	8455AC	3BLK44AS114A	AQUA/CASI	NA	247	663	233	38.5	43	10.2	85.3	91	1KB	1KB	20	30	Z:\DAC\RAW DATA
April 24,2016	8457AC	3BLK44EDS115A	AQUA/CASI	NA	197	544	222	39.6	221	8.64	66.9	94	1KB	1KB	40	22	Z:\DAC\RAW DATA
April 25,2016	8459AC	3BLK44IJS116A	AQUA/CASI	NA	240	603	262	43.4	248	10.3	66.5	100	1KB	1KB	18	38	Z:\DAC\RAW DATA
April 26,2016	8462AC	3BLK46AS117B	AQUA/CASI	NA	194	502	229	37.4	187	8.59	67.4	107	1KB	1KB	8	20	Z:\DAC\RAW DATA
April 27,2016	8464AC	3BLK46AS118B	AQUA/CASI	NA	81	209	143	9.78	3.23	4	23.9	158	1KB	1KB	8	20	Z:\DAC\RAW DATA
May 1,2016	8471AC	3BLK44FGHS122A	AQUA/CASI	NA	191	541	241	45.3	263	8.33	139	90.5	1KB	1KB	10	22	Z:\DAC\RAW DATA
May 2,2016	8473AC	3BLK46AS123A	AQUA/CASI	NA	88	320	206	5.45	3.7	4.59	55.3	64.6	1KB	NA	16	22	Z:\DAC\RAW DATA

Received from

Name R. PUNTO
Position RA
Signature

Received by

Name AC Bongat
Position SSRS
Signature 5/20/16

DATA TRANSFER SHEET
08/01/2014(CEBU ready)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
7/18/2014	1725P	1BLK47B199A	Pegasus	2.62	1.67	13.8	232	45.1	315	26	117	5.03	1KB	1KB	51	NA	Z:\Airborne_Raw
7/22/2014	1741P	1BLK36H203A	Pegasus	2.24	1.5	12.1	250	40.4	288	23.3	69.3	10.4	1KB	1KB	55/53	NA	Z:\Airborne_Raw
7/22/2014	1743P	1BLK36H203B	Pegasus	1.93	1.15	7.95	170	29.6	243	18.5	124	10.4	1KB	1KB	55	NA	Z:\Airborne_Raw
7/23/2014	1747P	1BLK36A204B	Pegasus	NA	1.82	12.8	227	48.4	385	27.5	NA	9.78	1KB	1KB	38/30	NA	Z:\Airborne_Raw
7/24/2014	1749P	1BLK36AS205A	Pegasus	NA	708	7.24	192	13.8	114	10.9	NA	3.45	1KB	1KB	37	NA	Z:\Airborne_Raw

Received from

Name TIN ANDAYA
Position RA
Signature

Received by

Name JOIDA F. PRIETO
Position SSRS
Signature 8/4/2014

Annex 6. Flight Logs

Flight Log for 1411P Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1411P

1 LiDAR Operator: D. Aldovino	2 ALTM Model: Pegasus	3 Mission Name: 1BLK44D121A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: J. Alajar	8 Co-Pilot: B. Donguines	9 Route: Bacolod			
10 Date: May 1, 2014	12 Airport of Departure (Airport, City/Province): Bacolod		12 Airport of Arrival (Airport, City/Province): Bacolod		
13 Engine On: 1505 H	14 Engine Off: 1852 H	15 Total Engine Time: 3+47	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Partly cloudy					

20 Remarks:

Mission successful at 1200 m; surveyed BLK 44D and parts of BLK 44E

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
J. Alviar	Dave Gumban	J J Alajar	D. Aldovino
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Flight Log for 1431P Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1431P

1 LiDAR Operator: D. ALDOVINO	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK44GHS126A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: J. ALAJAR	8 Co-Pilot: B. DONGUINES	9 Route: NEGROS OCC.			
10 Date: MAY 6, 2014	12 Airport of Departure (Airport, City/Province): BACOLOD		12 Airport of Arrival (Airport, City/Province): BACOLOD		
13 Engine On: 8+10	14 Engine Off: 12+51	15 Total Engine Time: 4+41	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: very cloudy					
20 Remarks: Mission successful @ 800 m; filled gaps in BLK44H + BLK44G					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Jasmine Alviar	Dave Bumban	J. ALAJAR	DAN ALDOVINO
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Flight Log for 1433P Mission

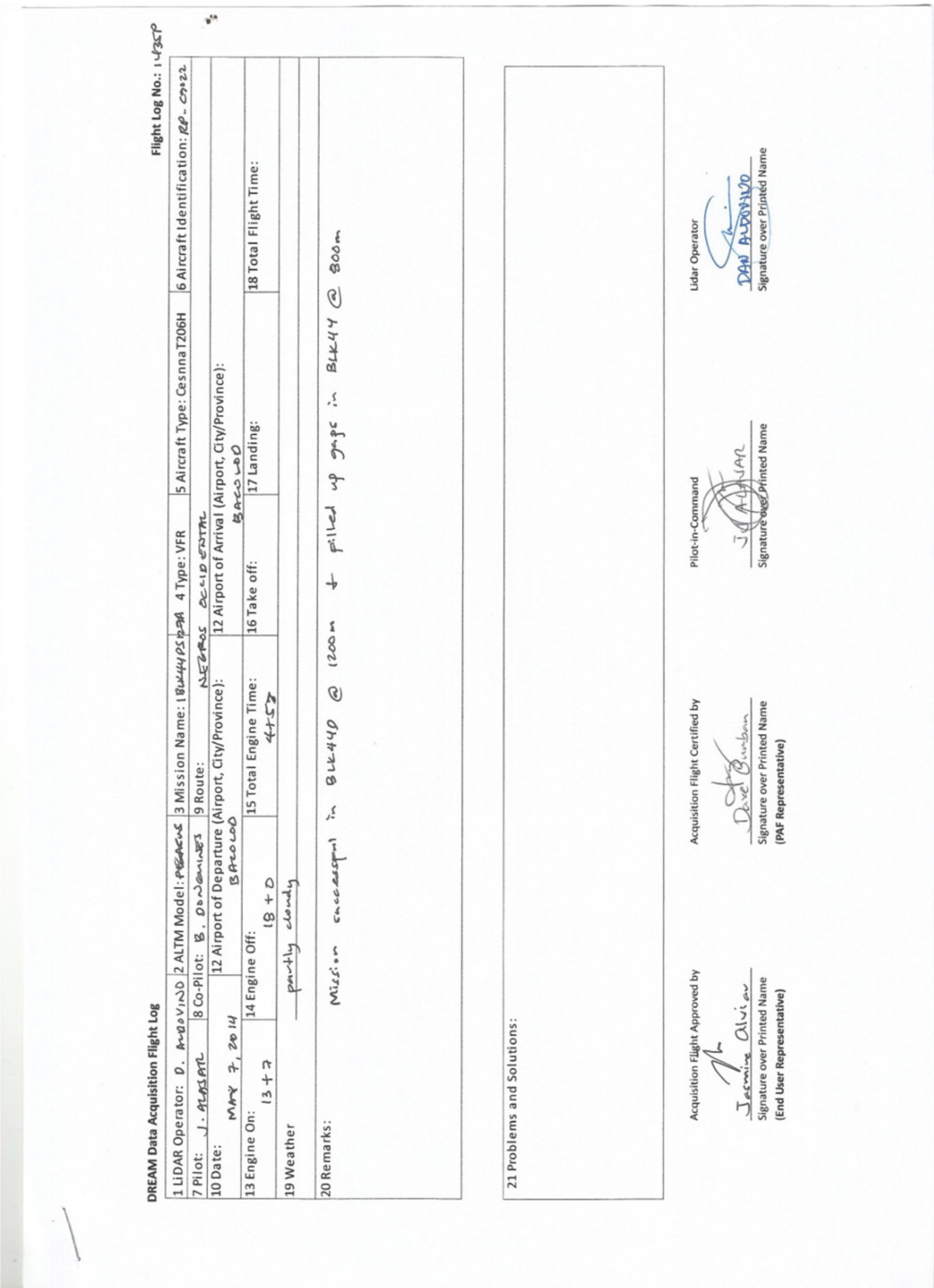
DREAM Data Acquisition Flight Log — **Flight Log No.:** 1433P

1 LiDAR Operator: R. PUNTO	2 ALTM Model: PEGASUS	3 Mission Name: [illegible]	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9022
7 Pilot: J. ALAJAR	8 Co-Pilot: B. DONGUINES	9 Route: NEGROS OCC.			
10 Date: MAY 6, 2014	12 Airport of Departure (Airport, City/Province): BACOLOD		12 Airport of Arrival (Airport, City/Province): BACOLOD		
13 Engine On: 14+4	14 Engine Off: 18+33	15 Total Engine Time: 4+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: very cloudy					
20 Remarks: Mission successful @ 800 m; gaps due to diminished overlap, high terrain, low cloud ceiling					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Jasmine Alviar	Dave Gumban	J. ALAJAR	R. PUNTO
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Flight log for 1435P Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1435P

1 LiDAR Operator: D. ALDOVINO	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK44PS127A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: J. ALAJAR	8 Co-Pilot: B. DONGUINES	9 Route: NEGROS OCCIDENTAL			
10 Date: MAY 7, 2014	12 Airport of Departure (Airport, City/Province): BACOLOD		12 Airport of Arrival (Airport, City/Province): BACOLOD		
13 Engine On: 13+7	14 Engine Off: 18+0	15 Total Engine Time: 4+53	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	partly cloudy				

20 Remarks:

Mission successful in BLK44D @ 1200m + filled up gaps in BLK44 @ 800m

21 Problems and Solutions:

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

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

Pilot-in-Command
J. ALAJAR
Signature over Printed Name

Lidar Operator
DAN ALDOVINO
Signature over Printed Name

Flight Log for 1745P Mission

DREAM Data Acquisition Flight Log

Lidar Operator: I. Roxas	ALTM Model: Peg	Type: VFR	Mission Name:		Flight Log No.: 17[illegible]
Pilot: C. Alfonso	Co-Pilot: F. Deocampo	Route: Cebu		Aircraft Type: CesnnaT206H	Aircraft Identification: RP-C902[illegible]
Date: July 23, 2014	PRF: kHz	Scan Freq: Hz	1/2 Scan Angle:	Airport of Departure: Cebu	Airport of Arrival: Cebu
Set of Hard Drive A B			Approx. Swath:	Eyesafe: m	
	Mission Folder Name:			Camera Mission Folder Name	
Weather:			Ground Base Station	Ground Surveyor	

LINE #:	Speed Kts	Rng/Ht m AGL	GPS Status SVS	GPS Status PDOP	Comments
Primary POS					
					Mission successful at 1200m flying height; Completed Bantayan Island.
					Please refer to electronic oplog

Problems and Solutions

RECEIVED FROM:
NAME: ______
POSITION: ______

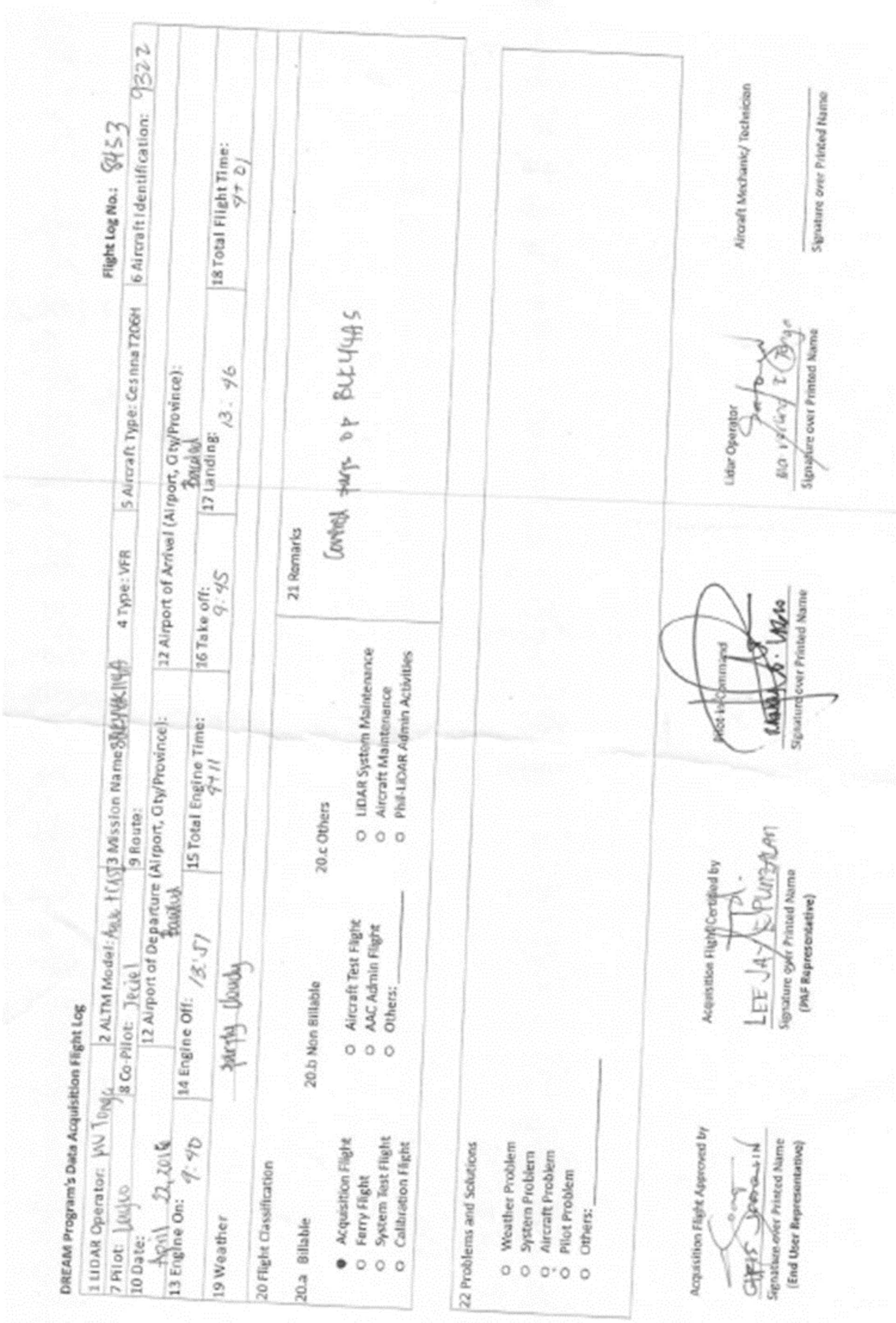
SIGNATURE: ______
DATE TRANSFERRED: ______

RECEIVED BY:
NAME: ______
POSITION: ______

SIGNATURE: ______
DATE TRANSFERRED: ______

DREAM Disaster Risk Exposure and Assessment for Mitigation

Flight Log for 8453AC Mission



DREAM Program's Data Acquisition Flight Log

Flight Log No.: 8453

1 LIDAR Operator: JW Tongga
2 ALTM Model: Pegasus
3 Mission Name: 3BLK41I112A
4 Type: VFR
5 Aircraft Type: Cessna T206H
6 Aircraft Identification: 9322

7 Pilot: Lalaguo
8 Co-Pilot: Jaciel
9 Route:

10 Date: April 22, 2016
12 Airport of Departure (Airport, City/Province): Bacolod
12 Airport of Arrival (Airport, City/Province): Bacolod

13 Engine On: 9:40
14 Engine Off: 13:51
15 Total Engine Time: 4+11
16 Take off: 9:45
17 Landing: 13:46
18 Total Flight Time: 4+01

19 Weather: partly cloudy

20 Flight Classification

20.a Billable
- ● Acquisition Flight
- ○ Ferry Flight
- ○ System Test Flight
- ○ Calibration Flight

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

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

21 Remarks

Covered parts of BLK41AS

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

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

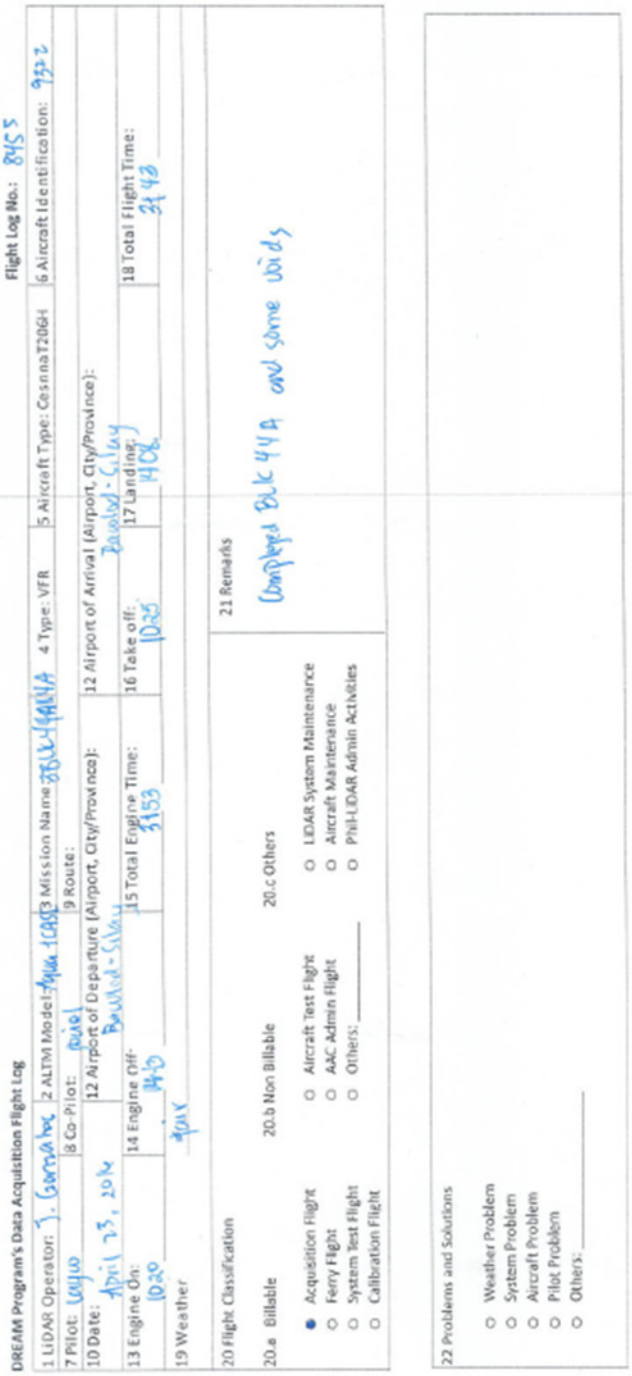
Acquisition Flight Certified by: LEE JAY PUNZALAN, Signature over Printed Name (PAF Representative)

Pilot-in-Command: Signature over Printed Name

Lidar Operator: Signature over Printed Name

Aircraft Mechanic/ Technician: Signature over Printed Name

Flight Log for 8455AC Mission



DREAM Program's Data Acquisition Flight Log

Flight Log No.: 8455

1 LiDAR Operator: J. Gonzales	2 ALTM Model: Aqua 1CASI	3 Mission Name: 3BLK44A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: Layug	8 Co-Pilot: Puiol	9 Route:			
10 Date: April 23, 2016	12 Airport of Departure (Airport, City/Province): Bacolod-Silay		12 Airport of Arrival (Airport, City/Province): Bacolod-Silay		
13 Engine On: 1020	14 Engine Off: 1413	15 Total Engine Time: 3153	16 Take off: 1025	17 Landing: 1408	18 Total Flight Time: 3+43
19 Weather: fair					

20 Flight Classification

20.a Billable
- ● Acquisition Flight
- ○ Ferry Flight
- ○ System Test Flight
- ○ Calibration Flight

20.b Non Billable
- ○ Aircraft Test Flight
- ○ AAC Admin Flight
- ○ Others: ____________

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

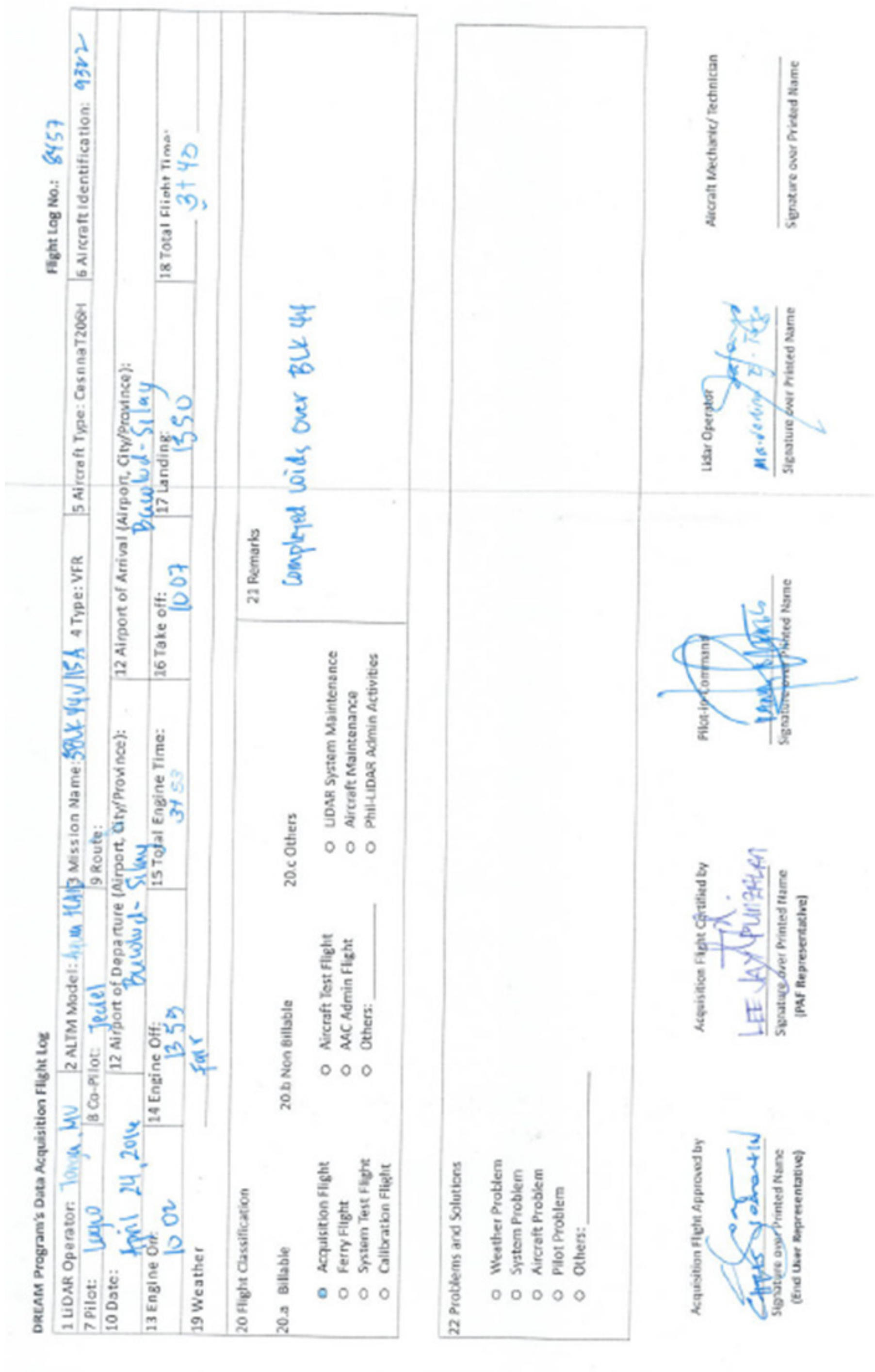
21 Remarks

Completed BLK 44A and some voids

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/ Technician
[signature]	LEE JAY A. PUNZALAN [signature]		[signature]	
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

Flight Log for 8457AC Mission



DREAM Program's Data Acquisition Flight Log

Flight Log No.: 8457

1 LiDAR Operator: Tong-a, MV	2 ALTM Model: [illegible]	3 Mission Name: [illegible]	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9322
7 Pilot: Lugo	8 Co-Pilot: Jedel	9 Route:			
10 Date: April 24, 2016	12 Airport of Departure (Airport, City/Province): Bulwid-Silay		12 Airport of Arrival (Airport, City/Province): Bulwid-Silay		
13 Engine On: 1002	14 Engine Off: 1355	15 Total Engine Time: 3+53	16 Take off: 1007	17 Landing: 1350	18 Total Flight Time: 3+43
19 Weather: Fair					

20 Flight Classification

20.a Billable
- ● Acquisition Flight
- ○ Ferry Flight
- ○ System Test Flight
- ○ Calibration Flight

20.b Non Billable
- ○ Aircraft Test Flight
- ○ AAC Admin Flight
- ○ Others: ______

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

21 Remarks

Completed voids over BLK 44

22 Problems and Solutions
- ○ Weather Problem
- ○ System Problem
- ○ Aircraft Problem
- ○ Pilot Problem
- ○ Others: ______

Acquisition Flight Approved by: [illegible] — Signature over Printed Name (End User Representative)

Acquisition Flight Certified by: Lee Jay Punzalan — Signature over Printed Name (PAF Representative)

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

Lidar Operator: Ma-Verlyn B. Tong-a — Signature over Printed Name

Aircraft Mechanic/ Technician — Signature over Printed Name

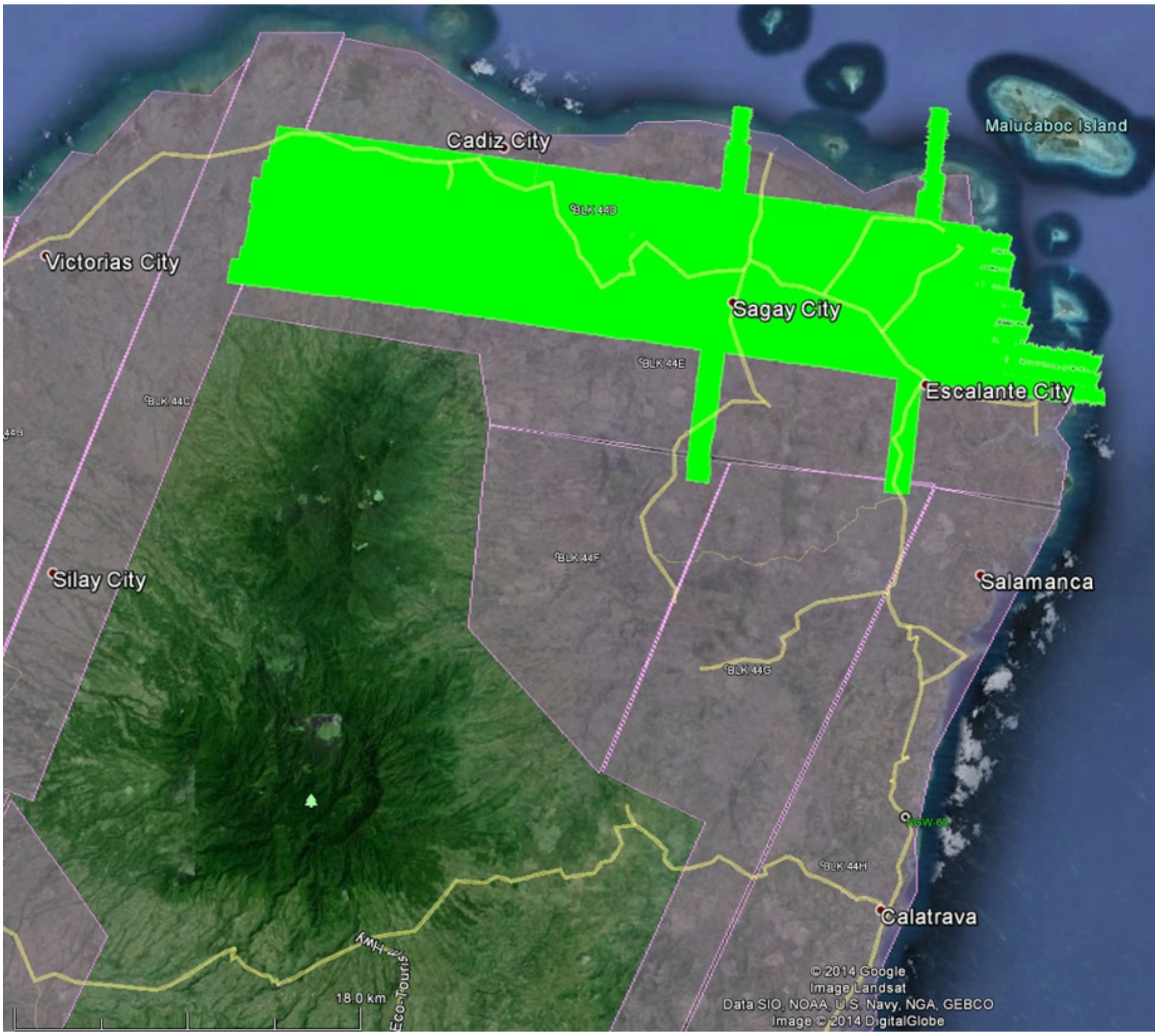
Annex 7. Flight Status

FLIGHT STATUS REPORT
HIMOGAAN
April to May 2014 and 2016

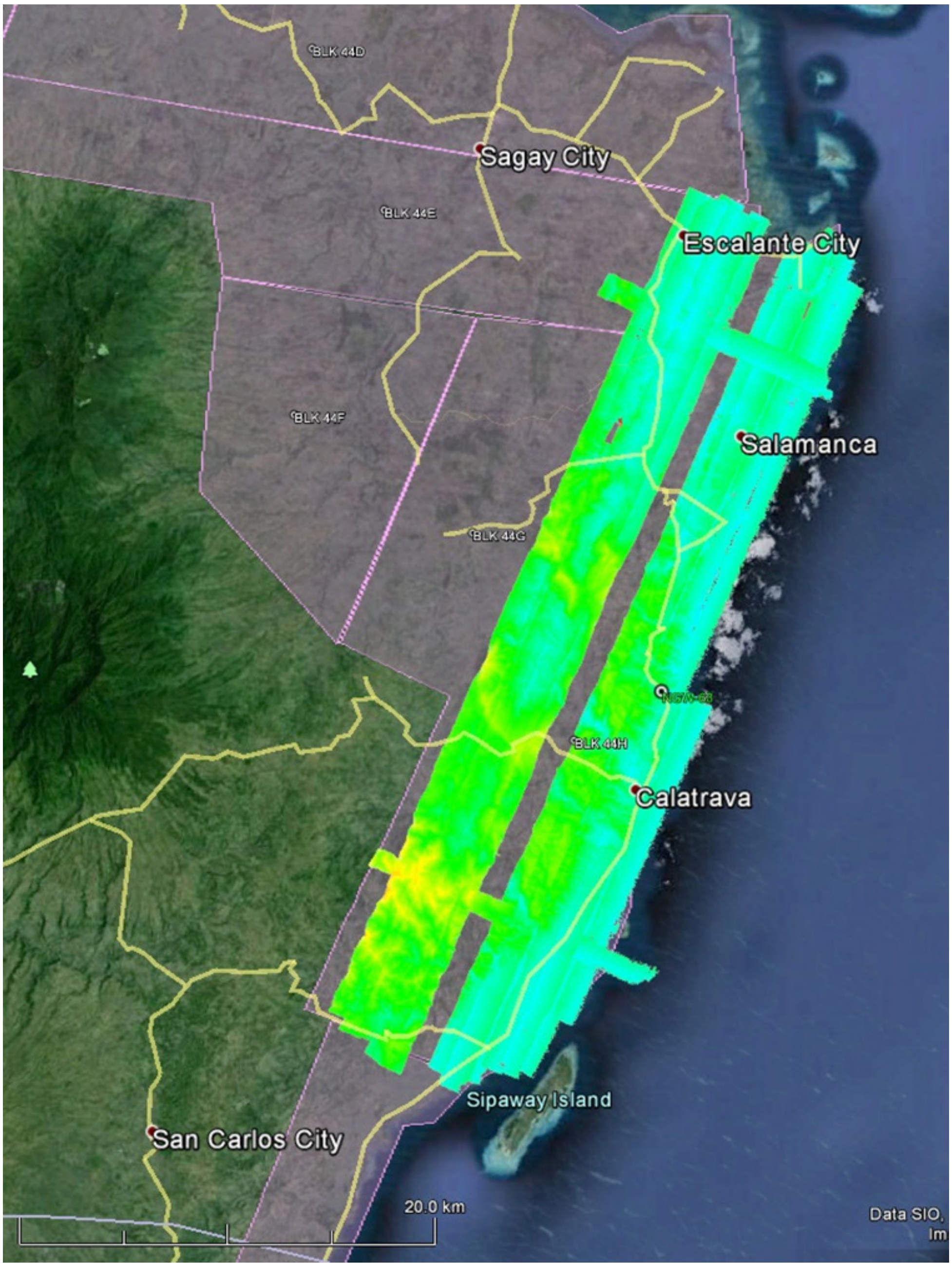
FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1411P	BLK 44DE	1BLK44D121A	D. Aldovino	May 1, 2014	Mission successful at 1200m; surveyed BLK 44D and parts of BLK 44E
1431P	BLK 44G, BLK 44H, BLK 44F	1BLK44GHS126A	D. Aldovino	May 6, 2014	Mission successful at 800m; filled gaps in BLK 44H and BLK 44G and some parts of BLK 44F
1433P	BLK 44G, BLK 44F	1BLK44FGS126B	R. Punto	May 6, 2014	Mission successful at 800m; filled gaps in BLK 44H; gaps due to diminished overlap (high terrain, low cloud ceiling)
1435P	BLK 44D, 44E, 44F, 44G	1BLk44DS127A	D. Aldovino	May 7, 2014	Mission successful in BLK 44D at 1200m and filled up gaps in BLK 44 at 800m.
1745P	Bantayan Island	1BTYN204A	G. Sinadjan	July 23, 2016	Surveyed Bantayan at 1200m
8453AC	BLK44As Himogaan, Himogaan FP	3BLK44AS113A	V. TONGA	APR 22, 2016	SURVEYED PARTS OF BLK44AS
8455AC	BLK44As Himogaan, Himogaan FP	3BLK44As114A	J. GONZALES	APR 23, 2016	SURVEYED REST OF BLK44AS
8457AC	BLK44IS, BLK44JS	3BLK44IJS116A	J. GONZALES	APR 25	SURVEYED BLK44IS AND BLK-44JS

LAS/SWATH BOUNDARIES PER MISSION FLIGHT

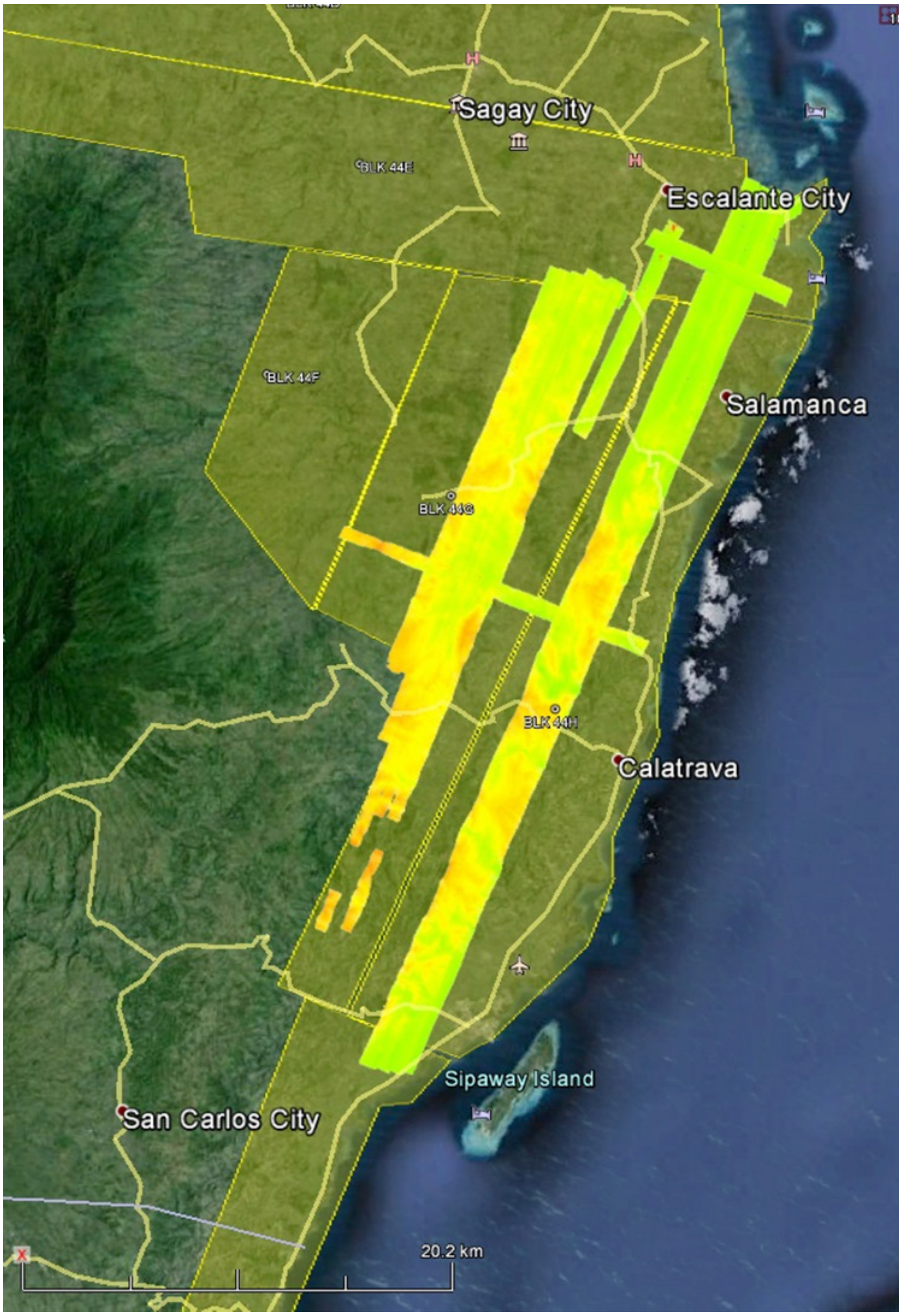
Flight No. : 1411P
Area: BLK 44DE
Mission Name: 1BLK44D121A
Area Surveyed: 356.01 sq.km.



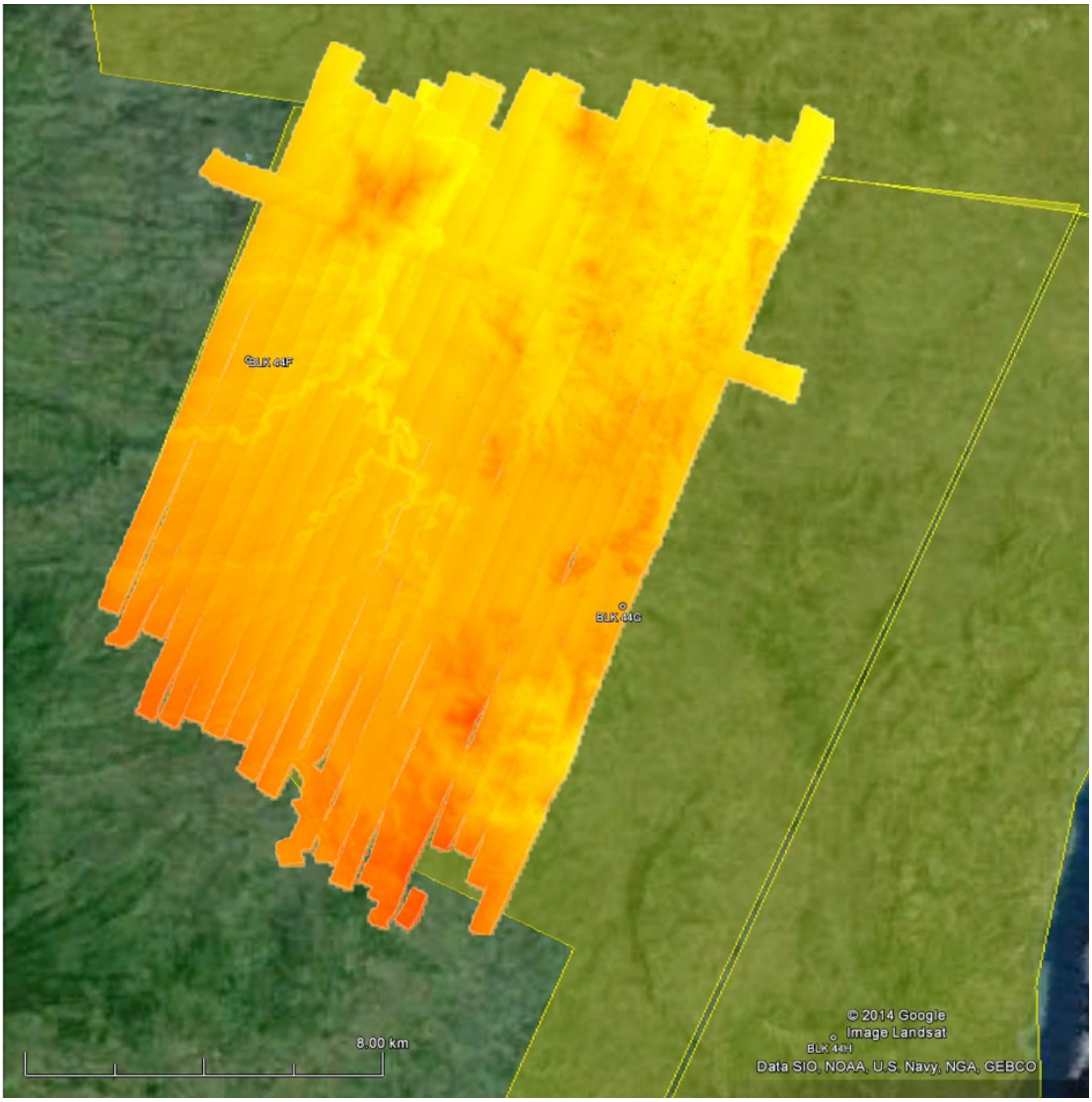
Flight No. : 1415P
Area: BLK 44H
Mission Name: 1BLK44H122A
Area Surveyed: 371.6 sq.km



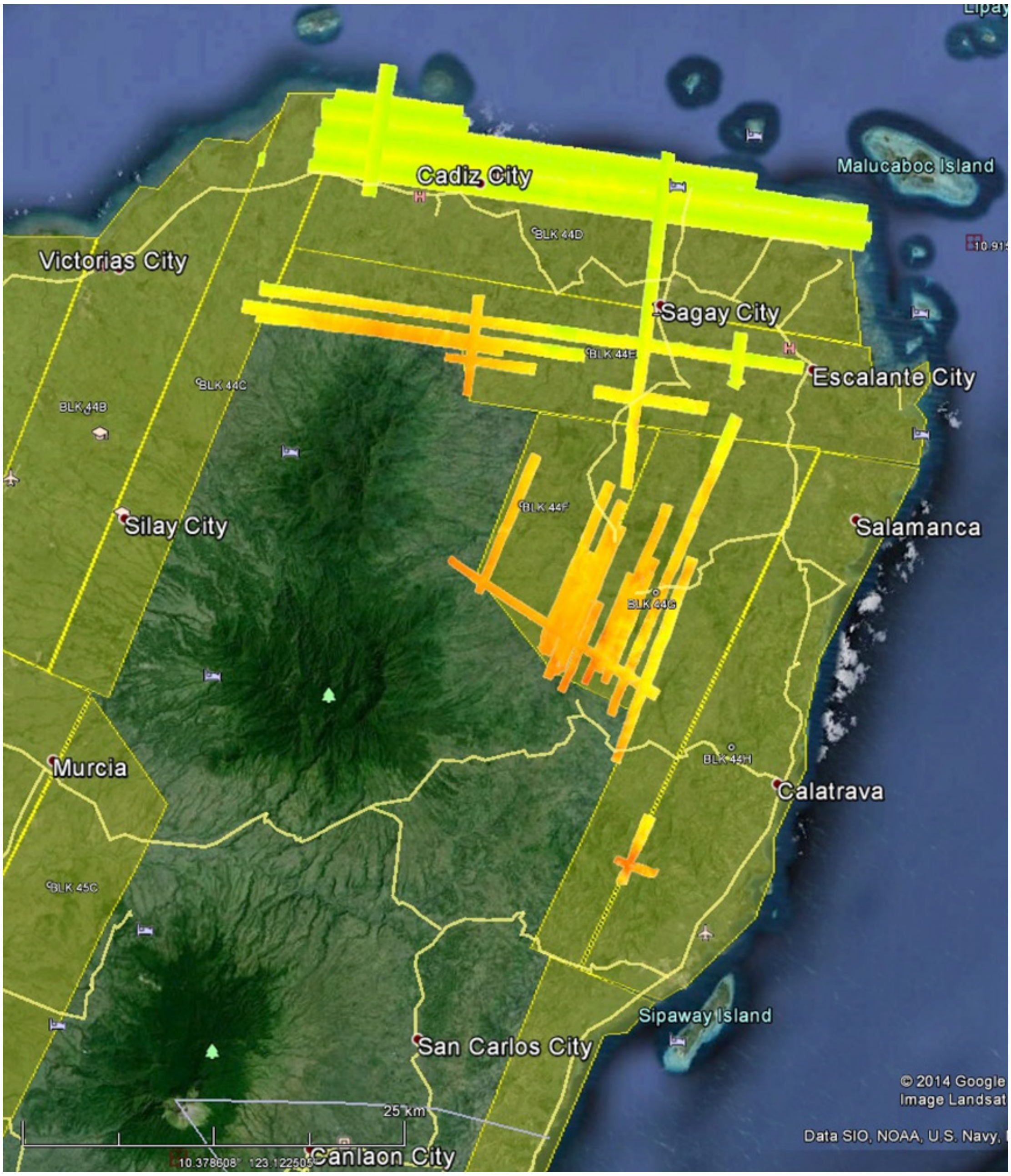
Flight No. : 1431P
Area: BLK 44G, 44H, 44F
Mission Name: 1BLK44GHS126A
Area Surveyed: 230.5 sq.km



Flight No. : 1433P
Area: BLK 44G, 44F
Mission Name: 1BLKFGS126B
Area Surveyed: 204.44 sq.km.



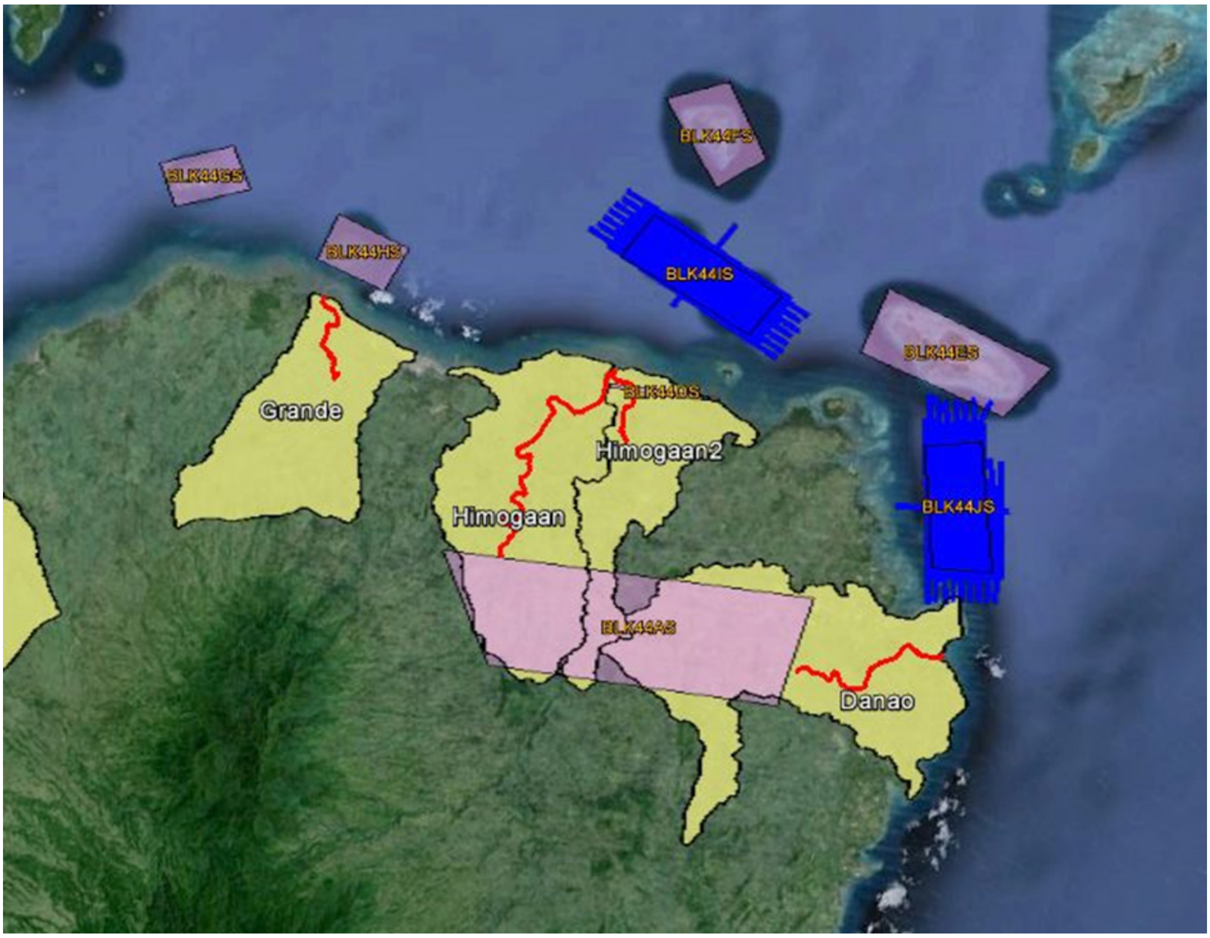
Flight No. : 1435P
Area: BLK 44D, 44E, 44F, 44G
Mission Name: 1BLK44DS127A
Area Surveyed: 139.55 sq.km new area; 131.307 gap filling



Flight No. : 8453AC
Area: BLK44AS
Mission Name: 3BLK44As113A
Parameters: Altitude: 500m; Scan Frequency: 45; Scan Angle: 18; Overlap: 30 %; PRF: 50kHz
Total Area Surveyed: 98.3 sq km

Flight No. : 8455AC
Area: BLK44AS
Mission Name: 3BLK44AS114A
Parameters: Altitude: 500m; Scan Frequency: 45; Scan Angle: 18; Overlap: 30 %; PRF: 50kHz
Total Area Surveyed: 35 sq km

Flight No. :	8459AC
Area:	BLK44IS, BLK44JS
Mission Name:	3BLK44IJS116A
Parameters:	Altitude: 500m; Scan Frequency: 45; Scan Angle: 18; Overlap: 50 %; PRF: 50kHz
Total Area Surveyed:	70 sq km



Annex 8. Mission Summary Report

Flight Area	Negros
Mission Name	**Blk44D**
Inclusive Flights	1411P, 1435P
Range data size	75.2 GB
POS	728 MB
Base data size	13.88 MB
Image	31.5 GB
Transfer date	May 26, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.04
RMSE for East Position (<4.0 cm)	1.26
RMSE for Down Position (<8.0 cm)	2.51
Boresight correction stdev (<0.001deg)	0.000446
IMU attitude correction stdev (<0.001deg)	0.005774
GPS position stdev (<0.01m)	0.0134
Minimum % overlap (>25)	27.44%
Ave point cloud density per sq.m. (>2.0)	3.51
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	552
Maximum Height	395.70 m
Minimum Height	50.84 m
Classification (# of points)	
Ground	387,844,370
Low vegetation	324,638,606
Medium vegetation	458,253,579
High vegetation	120,361,293
Building	9,453,151
Orthophoto	Yes
Processed by	Engr. Jommer Medina, Engr. Carlyn Ann Ibañez, Engr. Melanie Hingpit, Engr. Gladys Mae Apat

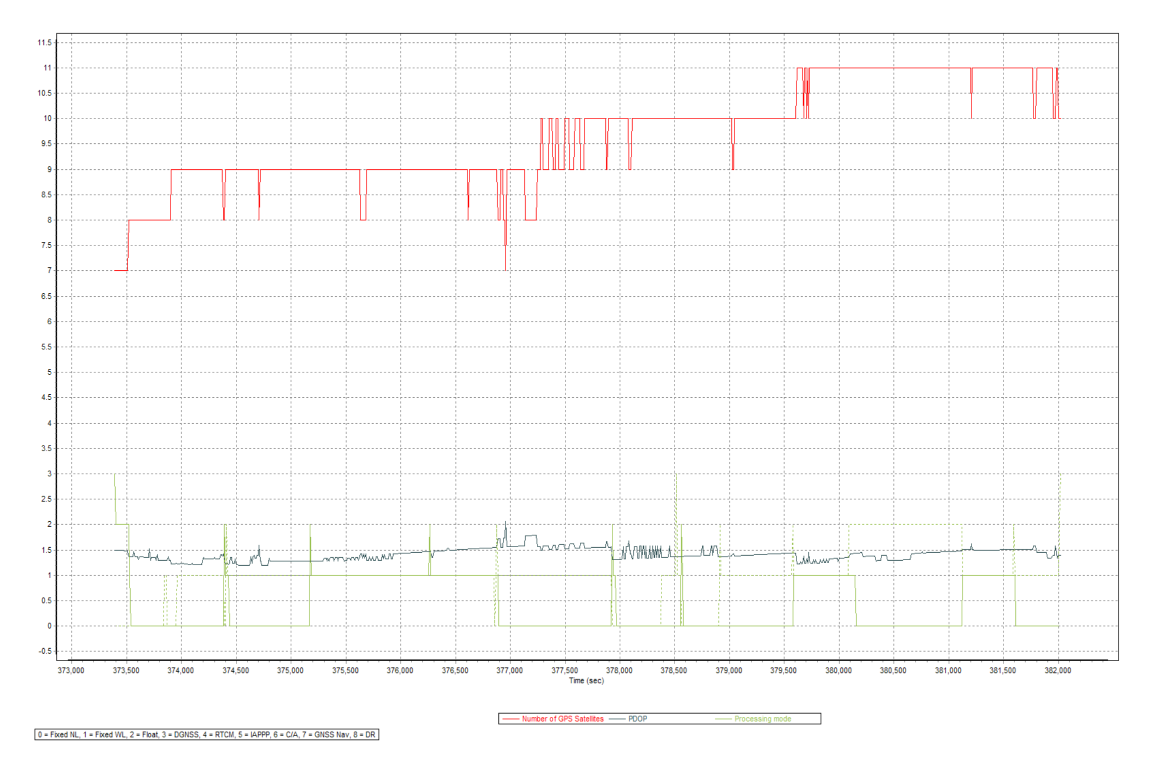


Figure 1.1.1 Solution Status

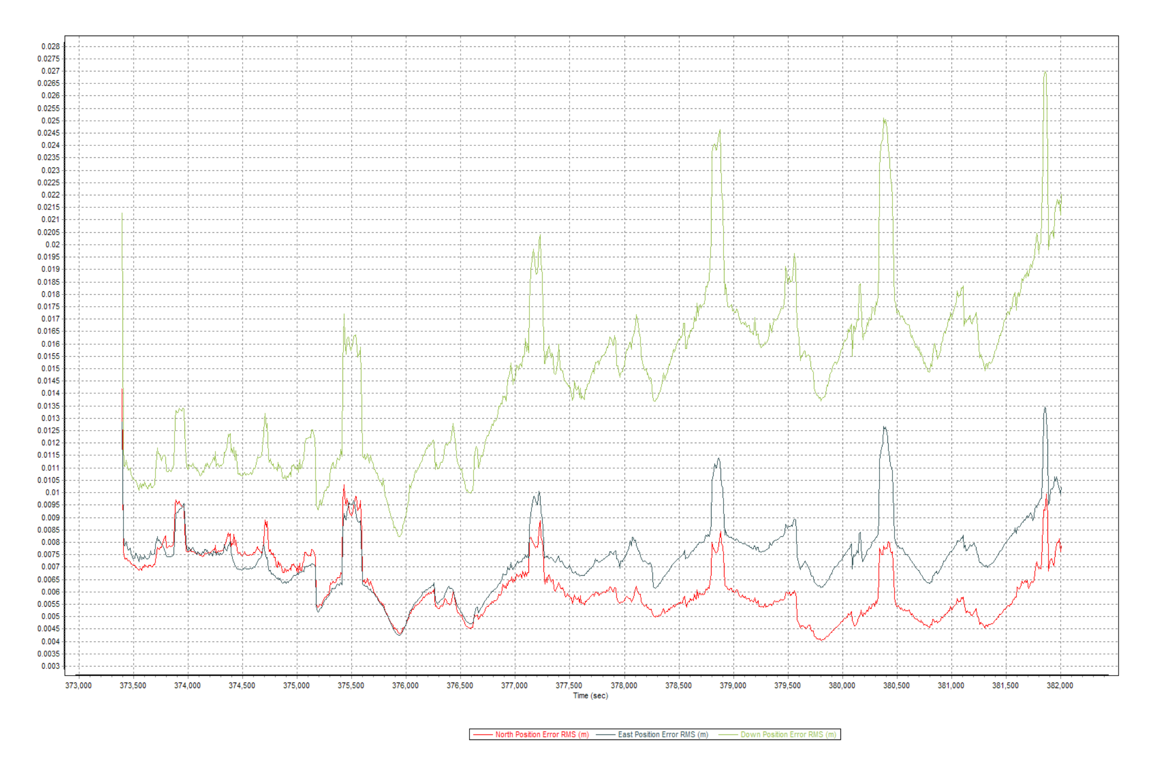


Figure 1.1.2 Smoothed Performance Metric Parameters

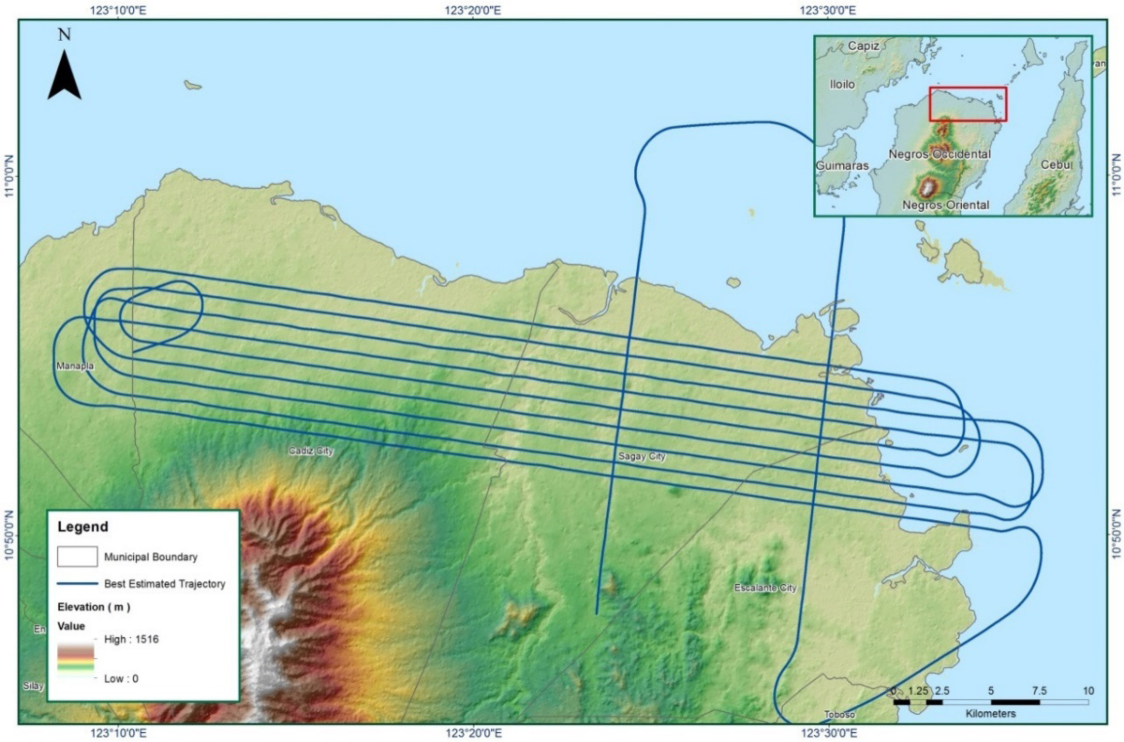


Figure 1.1.3 Best Estimated Trajectory

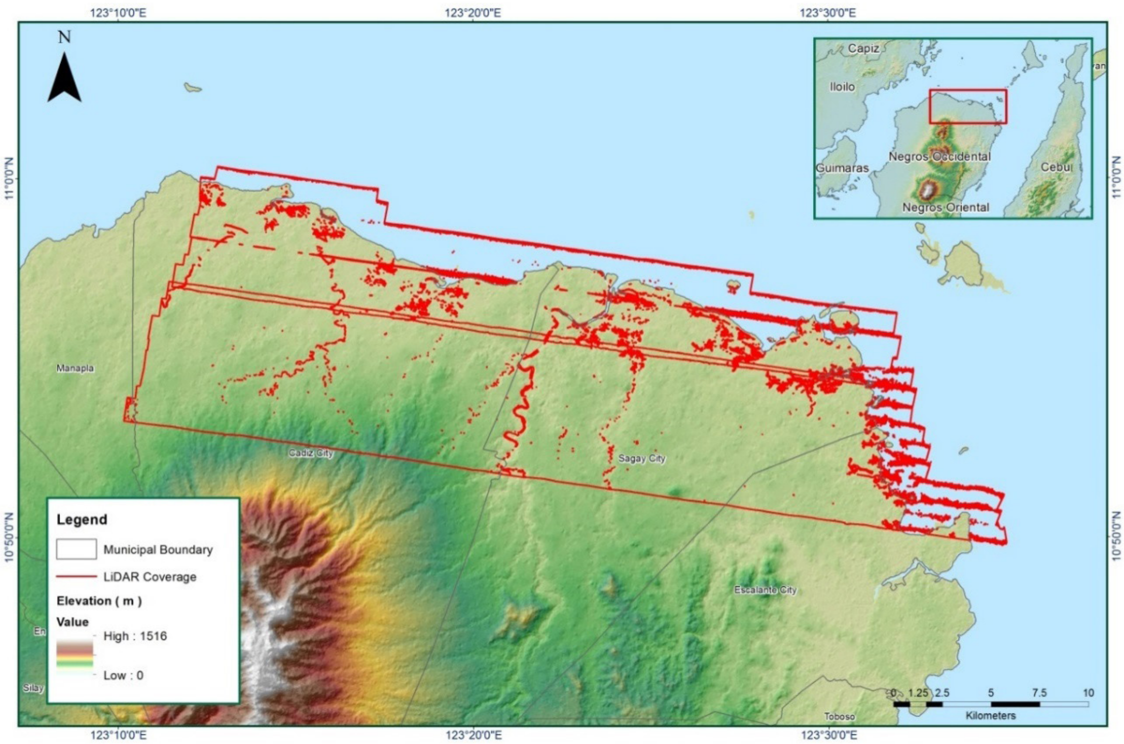


Figure 1.1.4 Coverage of LiDAR data

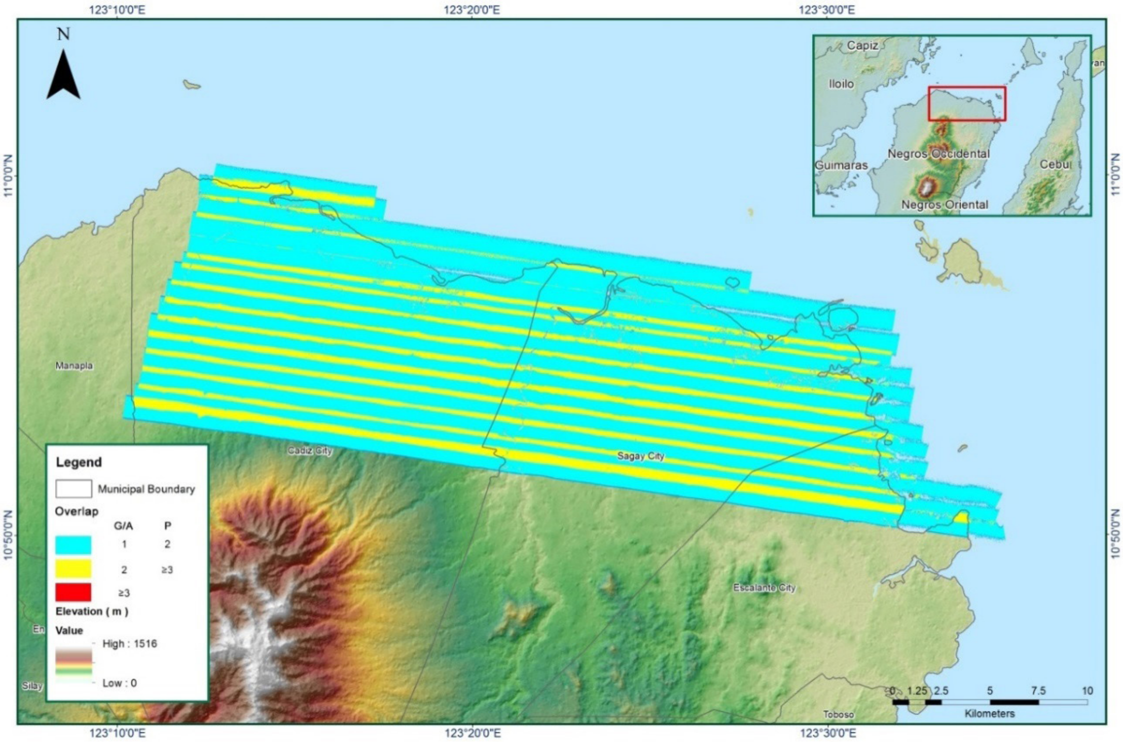


Figure 1.1.5 Image of data overlap

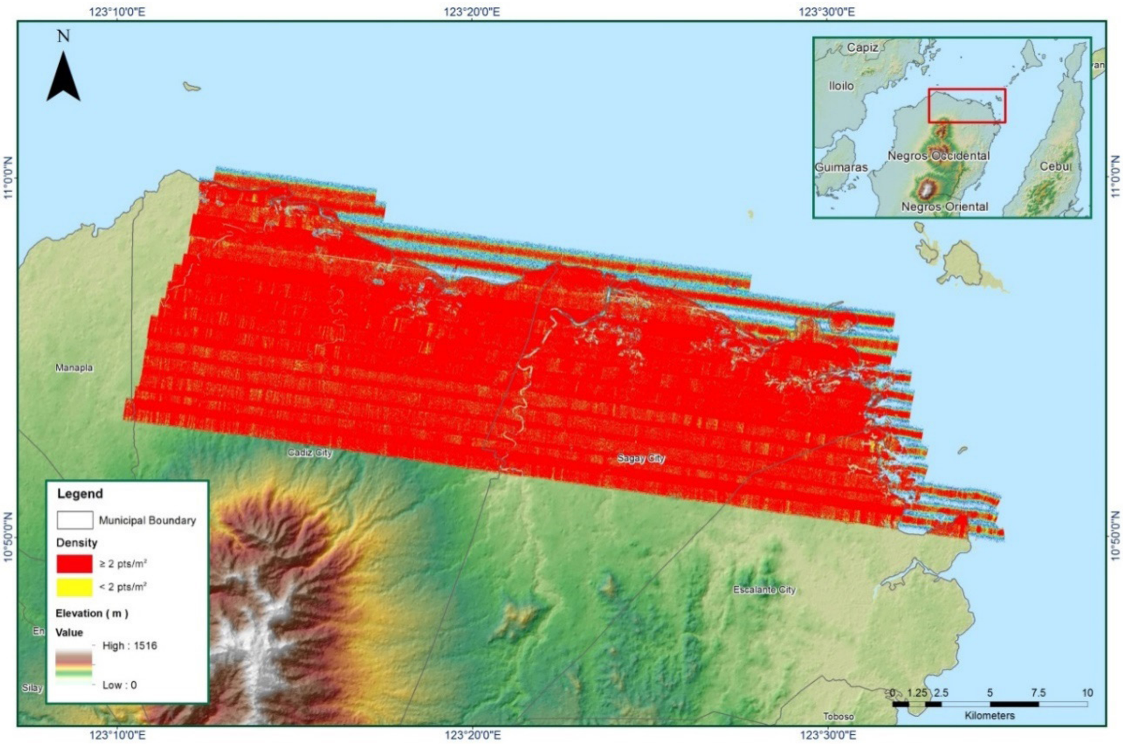


Figure 1.1.6 Density map of merged LiDAR data

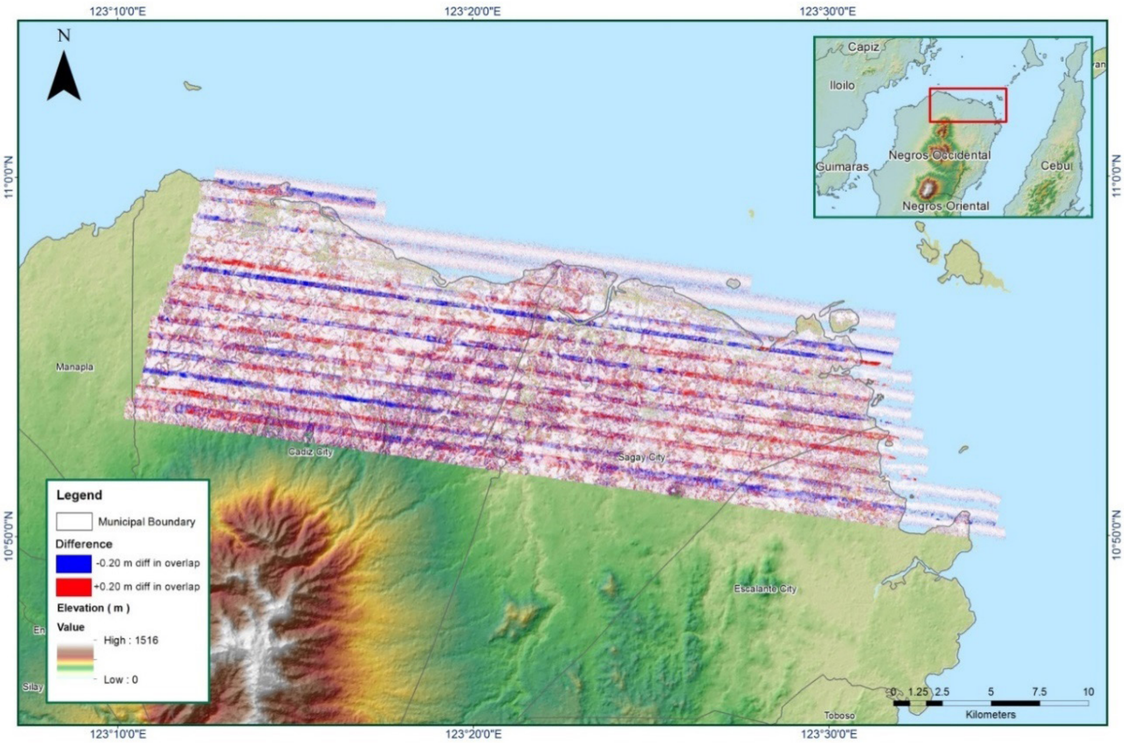


Figure 1.1.7 Elevation difference between flight lines

Flight Area	Negros
Mission Name	**Blk44FG**
Inclusive Flights	1431P, 1433P, 1435P
Range data size	105.7 GB
POS	810 MB
Base data size	35.94 MB
Image	110.3 GB
Transfer date	May 26, 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)	1.24
RMSE for East Position (<4.0 cm)	1.41
RMSE for Down Position (<8.0 cm)	2.62
Boresight correction stdev (<0.001deg)	0.000248
IMU attitude correction stdev (<0.001deg)	0.001112
GPS position stdev (<0.01m)	0.0062
Minimum % overlap (>25)	43.01%
Ave point cloud density per sq.m. (>2.0)	9.26
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	347
Maximum Height	584.11 m
Minimum Height	72.76 m
Classification (# of points)	
Ground	445,025,694
Low vegetation	463,475,098
Medium vegetation	838,129,177
High vegetation	234,468,284
Building	6,471,602
Orthophoto	Yes
Processed by	Engr. Carlyn Ann Ibañez, Engr. Christy Lubiano, Engr. Gladys Mae Apat

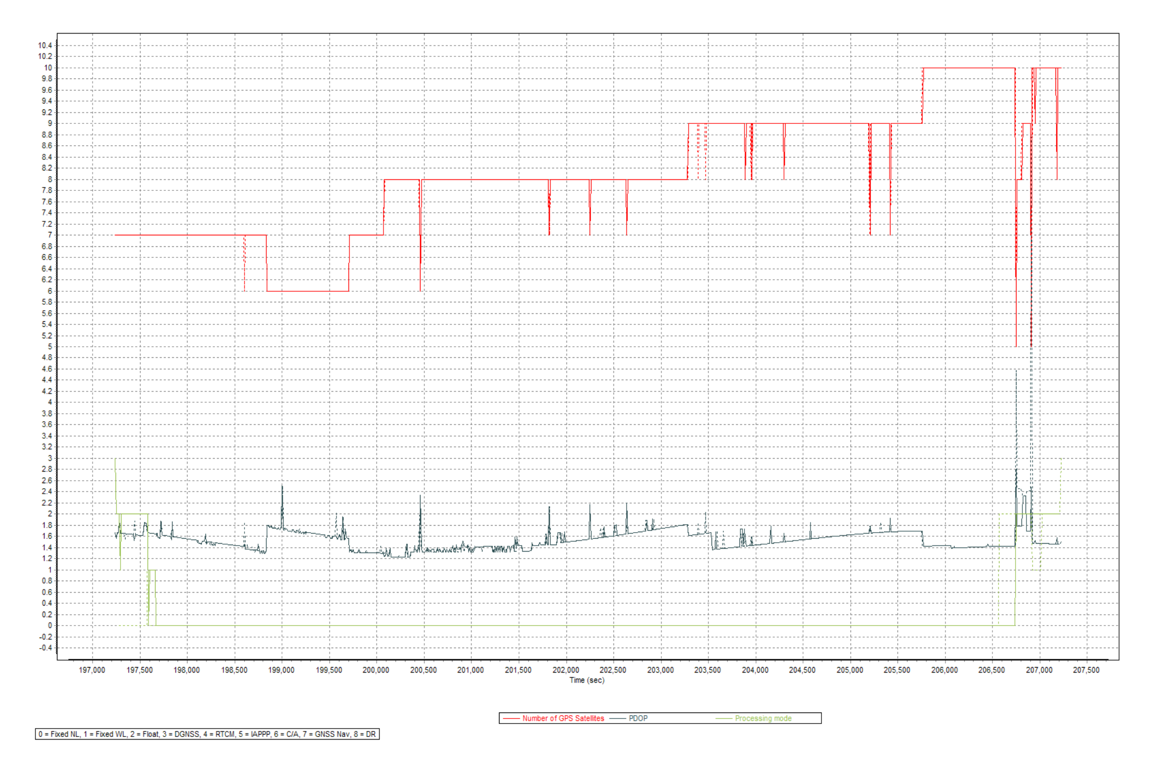


Figure 1.2.1 Solution Status

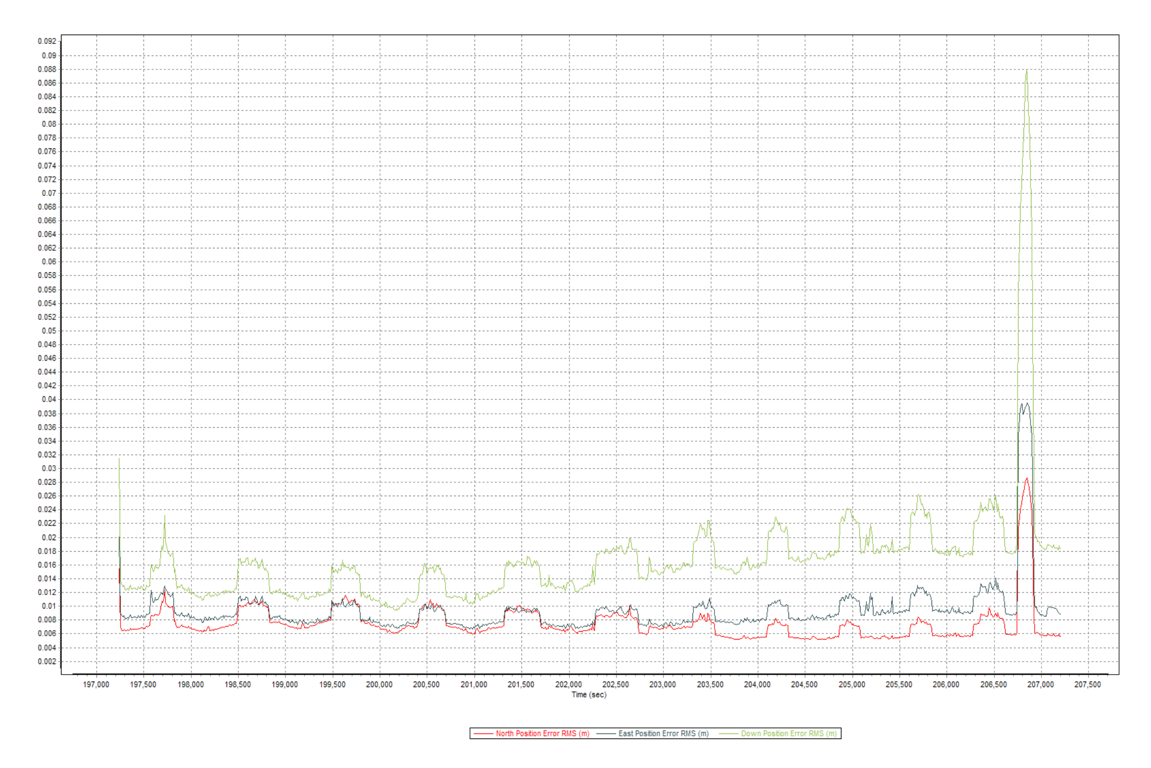


Figure 1.2.2 Smoothed Performance Metric Parameters

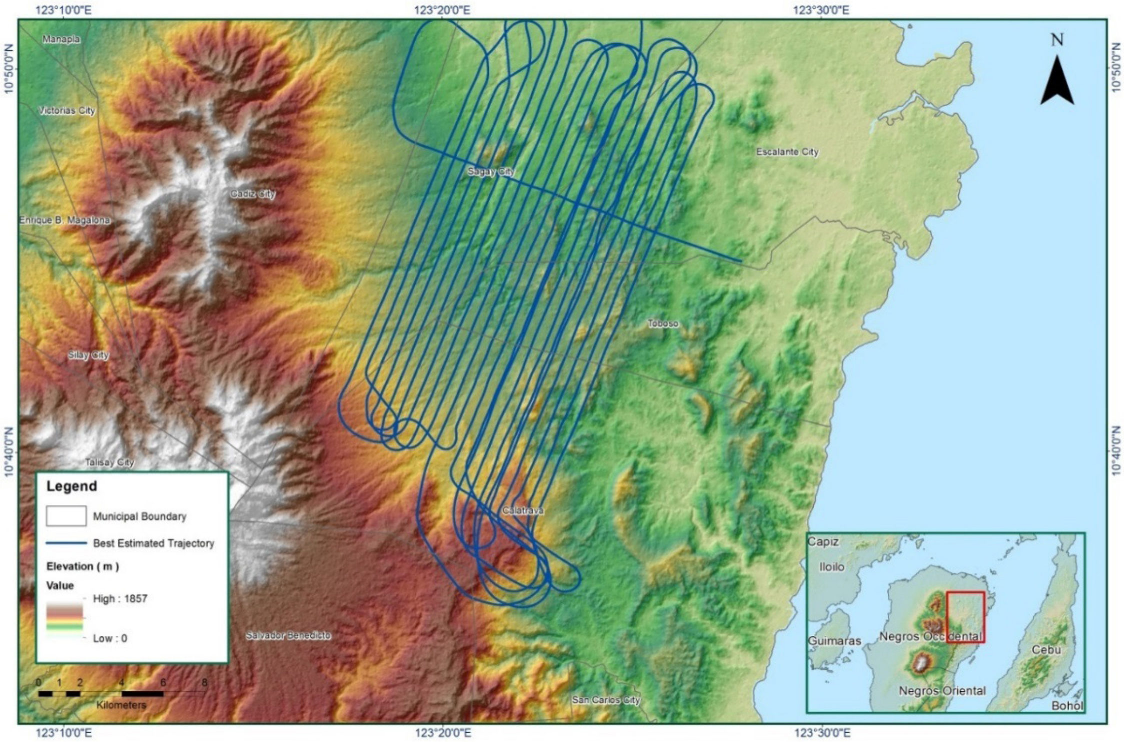


Figure 1.2.3 Best Estimated Trajectory

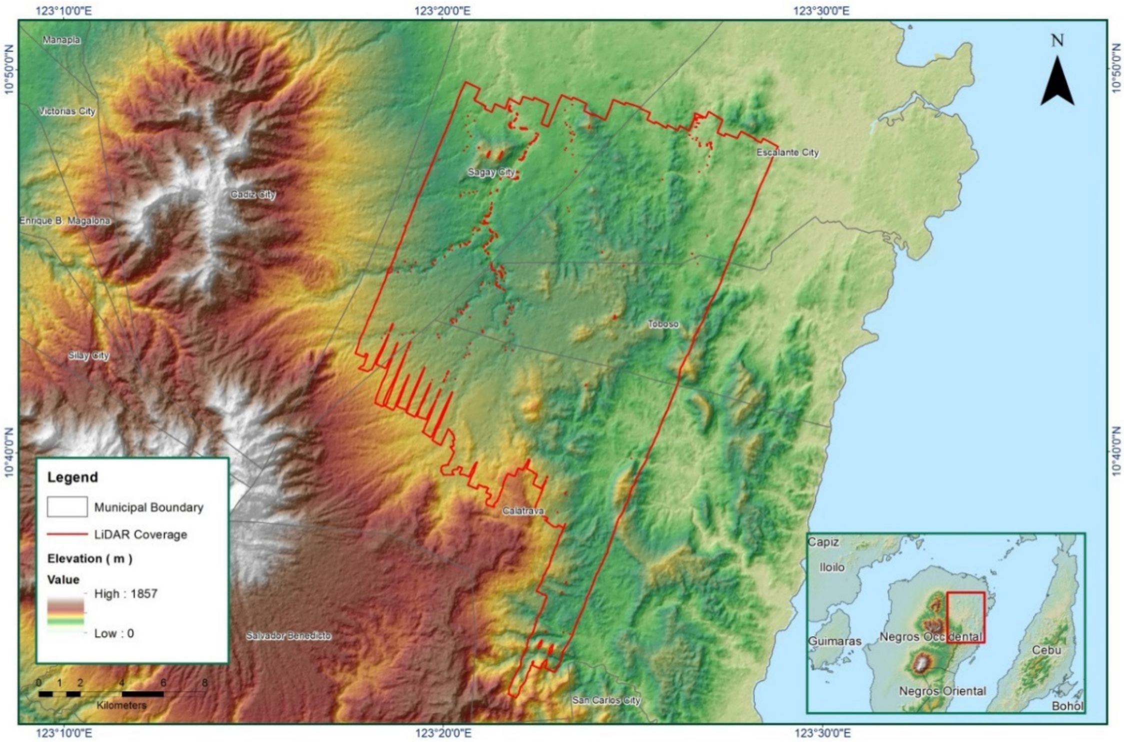


Figure 1.2.4 Coverage of LiDAR data

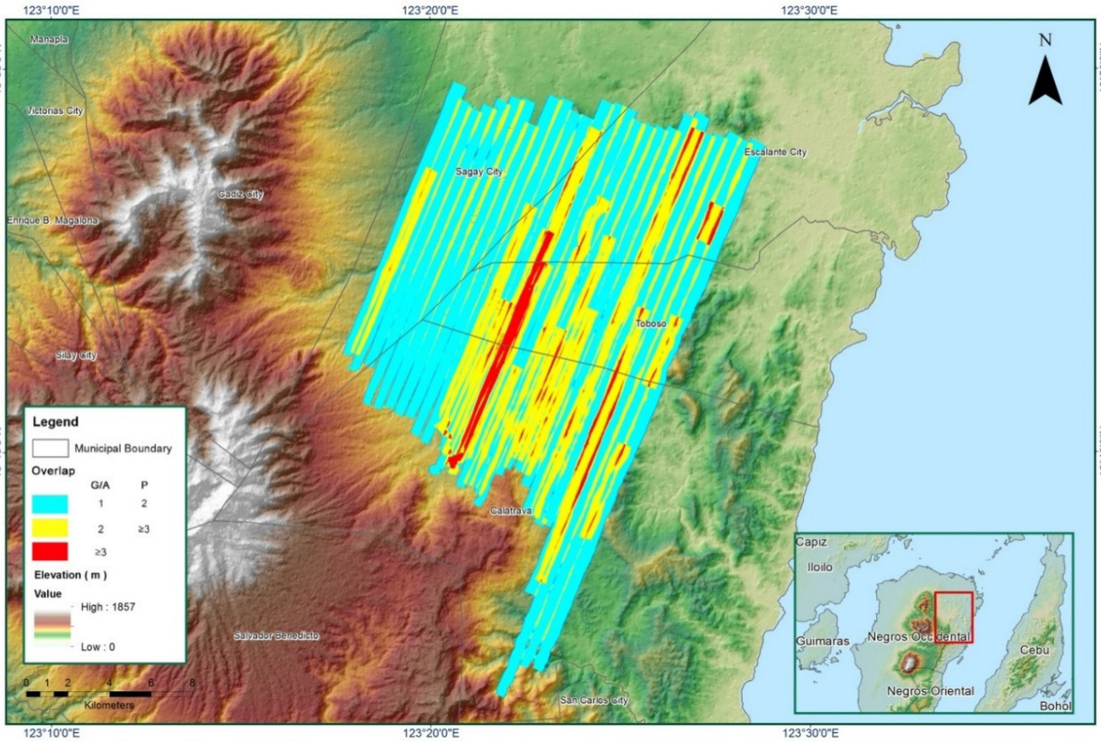


Figure 1.2.5 Image of data overlap

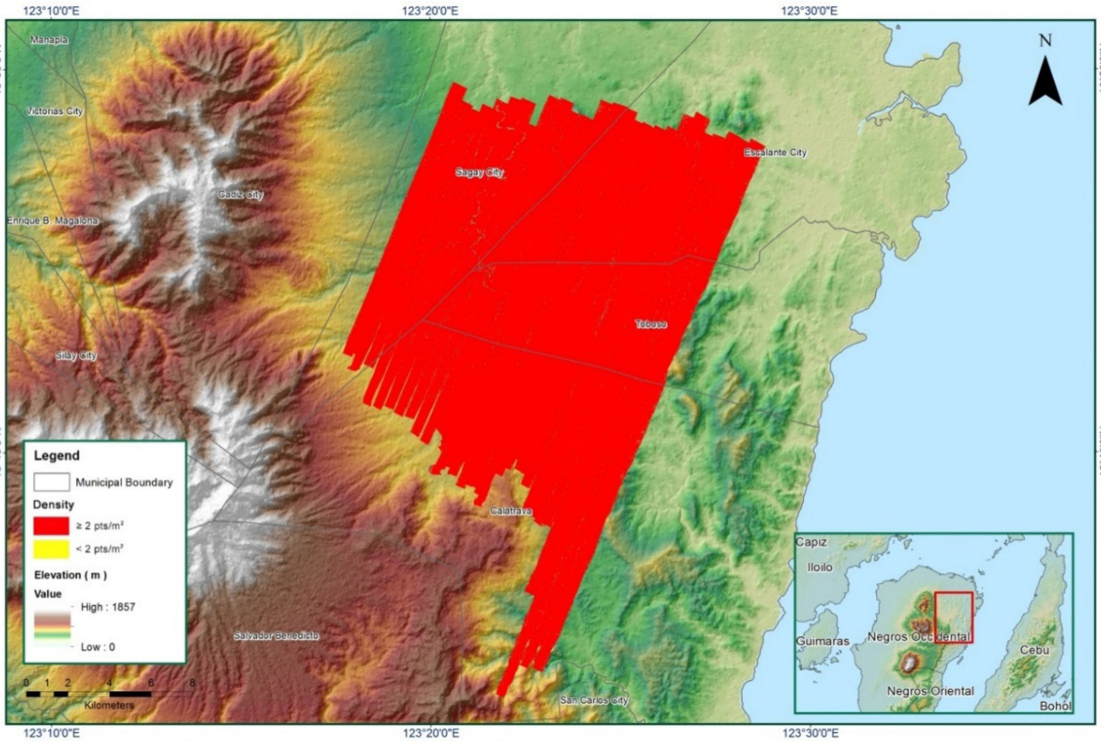


Figure 1.2.6 Density map of merged LiDAR data

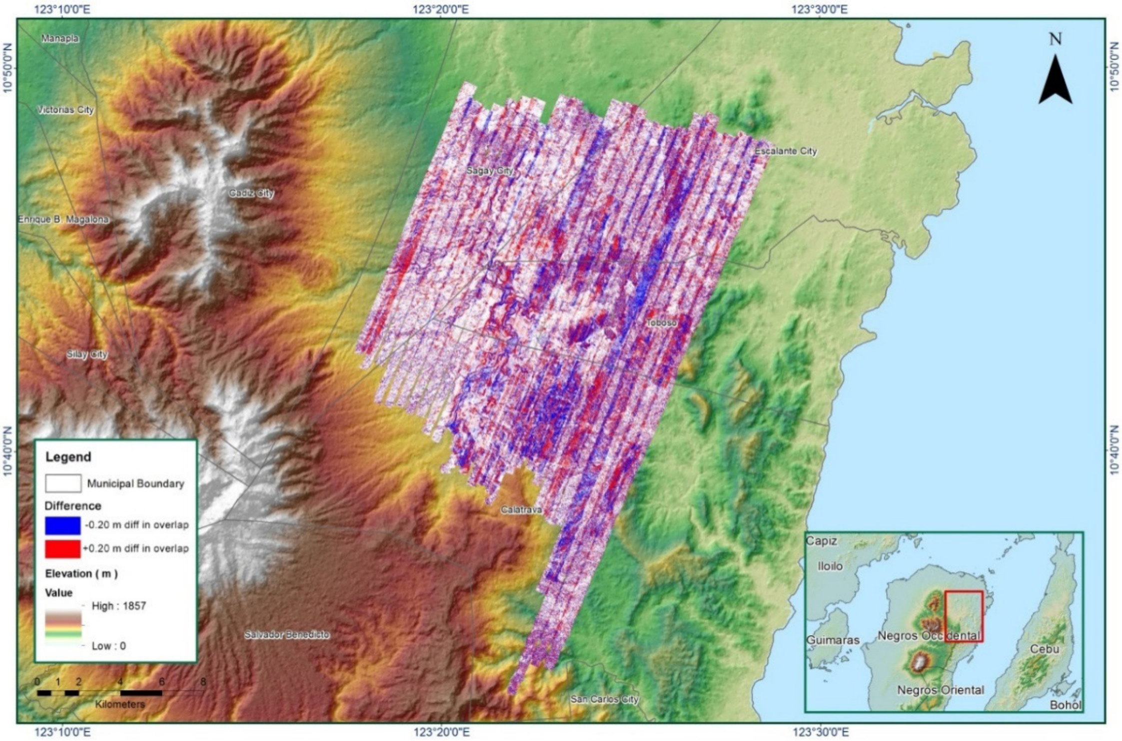


Figure 1.2.7 Elevation difference between flight lines

Flight Area	Bacolod
Mission Name	**Block 44E**
Inclusive Flights	8453AC
Range data size	13.9 GB
POS data size	246 MB
Base data size	99.1 MB
Image	n/a
Transfer date	May 20, 2016
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.002
RMSE for East Position (<4.0 cm)	1.603
RMSE for Down Position (<8.0 cm)	5.037
Boresight correction stdev (<0.001deg)	0.000258
IMU attitude correction stdev (<0.001deg)	0.000791
GPS position stdev (<0.01m)	0.0016
Minimum % overlap (>25)	30.04
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	139
Maximum Height	578.38
Minimum Height	60.03
Classification (# of points)	
Ground	93,527,454
Low vegetation	98,324,857
Medium vegetation	111,788,117
High vegetation	66,668,017
Building	3,363,991
Orthophoto	
Processed by	Engr. Sheila-Maye Santillan, Engr. Merven Natino, Engr. Elainne Lopez

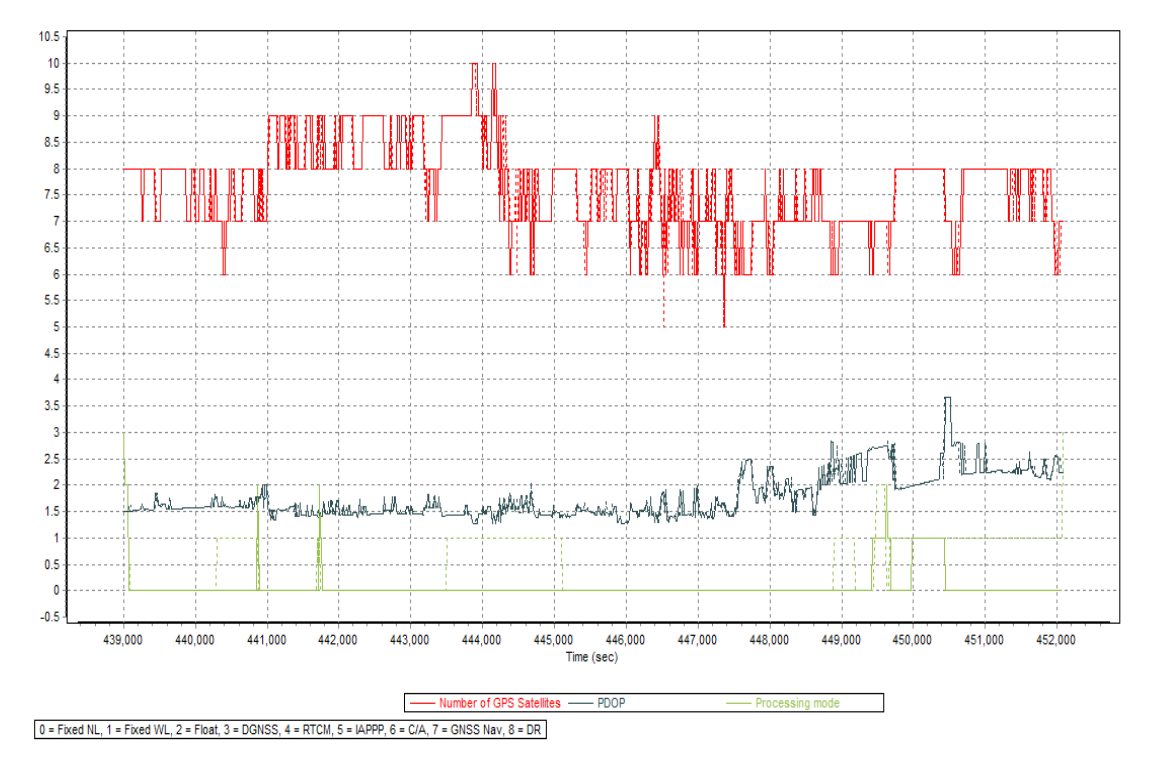


Figure 1.3.1 Solution Status

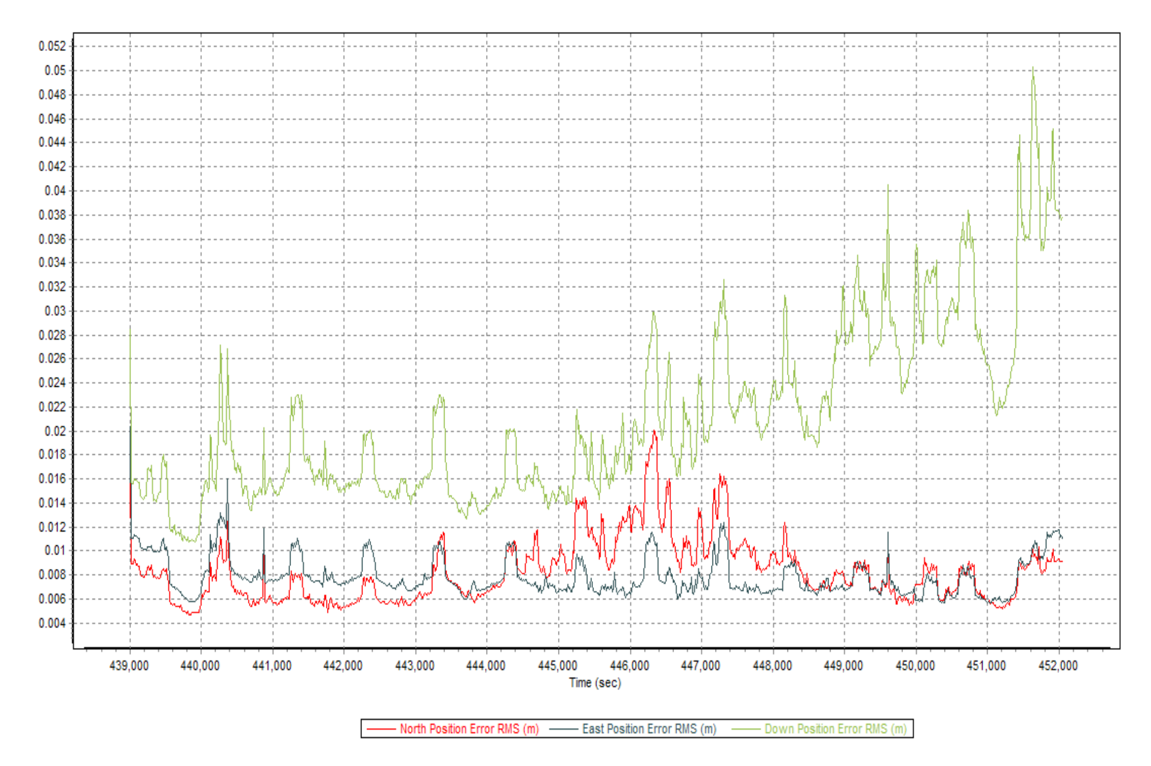


Figure 1.3.2 Smoothed Performance Metric Parameters

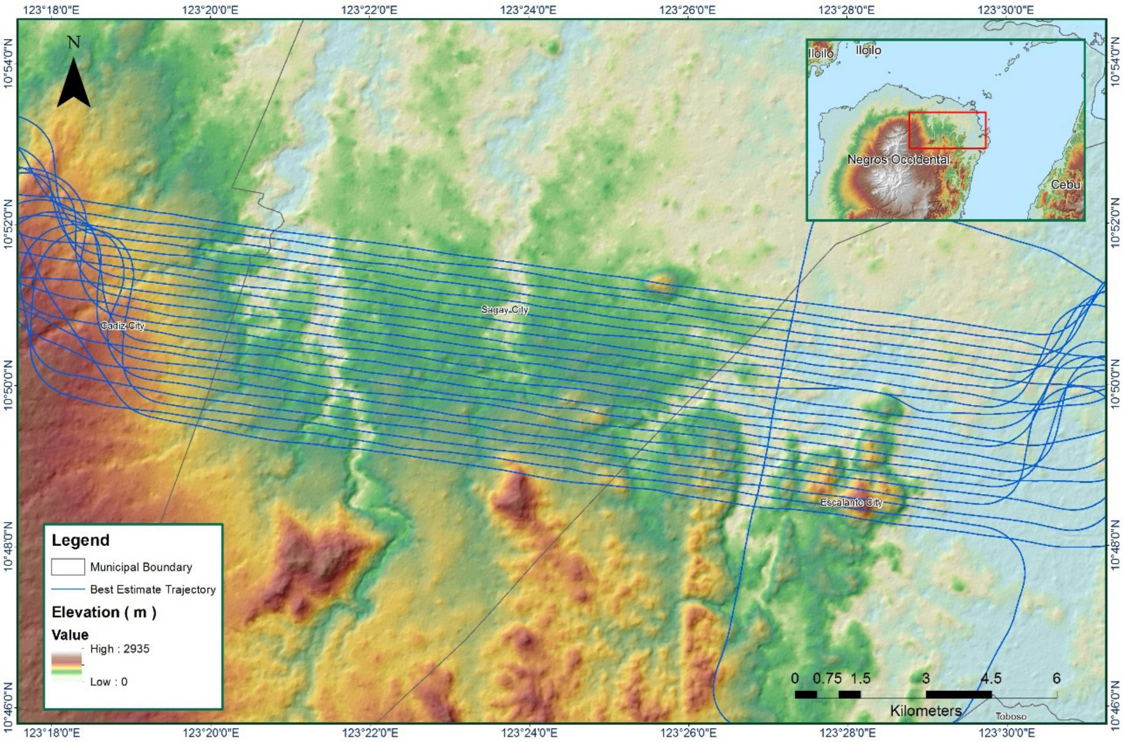


Figure 1.3.3 Best Estimated Trajectory

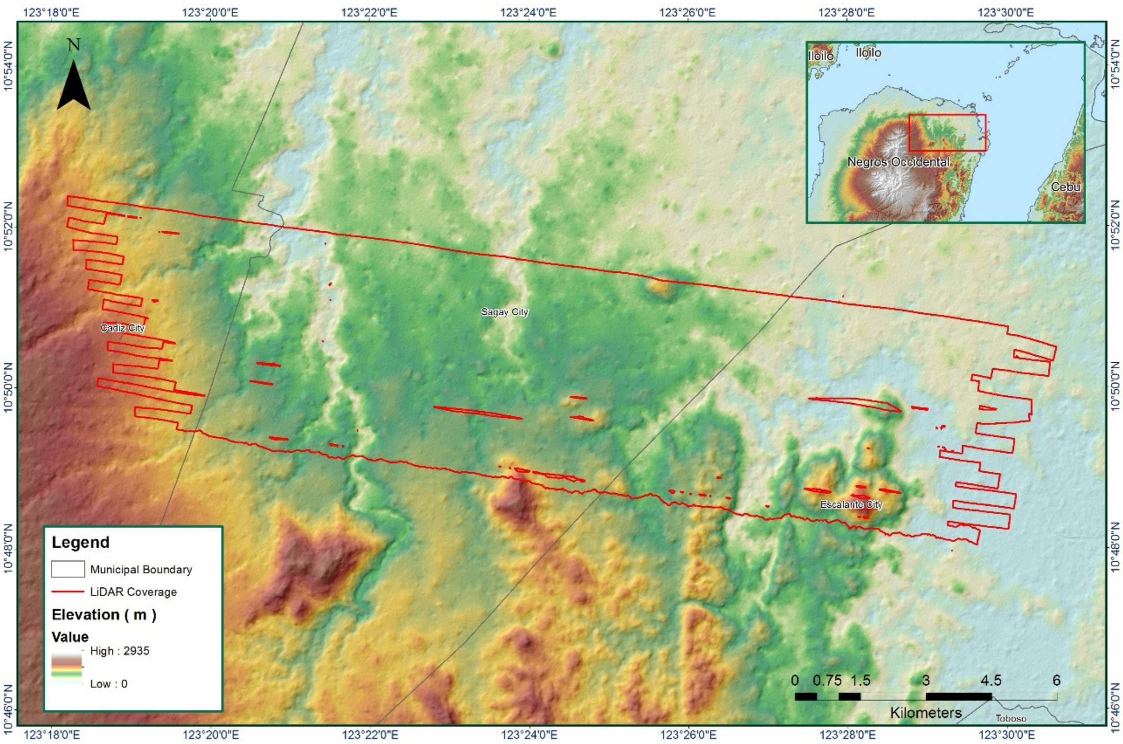


Figure 1.3.4 Coverage of LiDAR Data

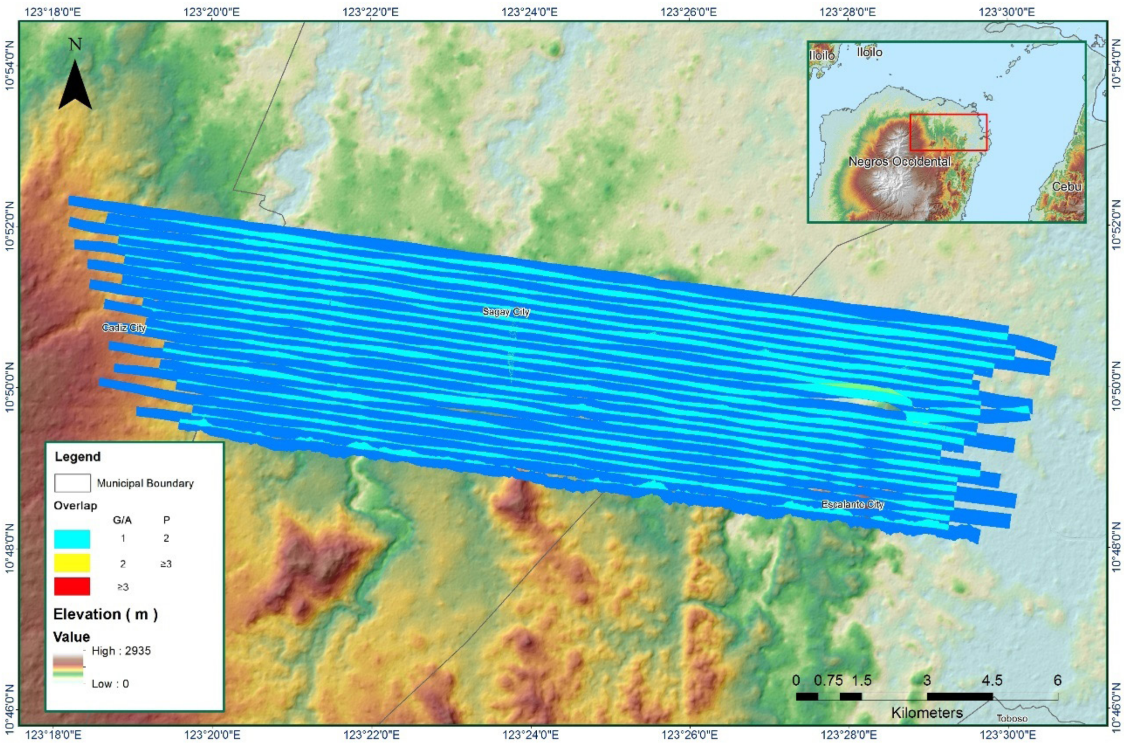


Figure 1.3.5 Image of data overlap

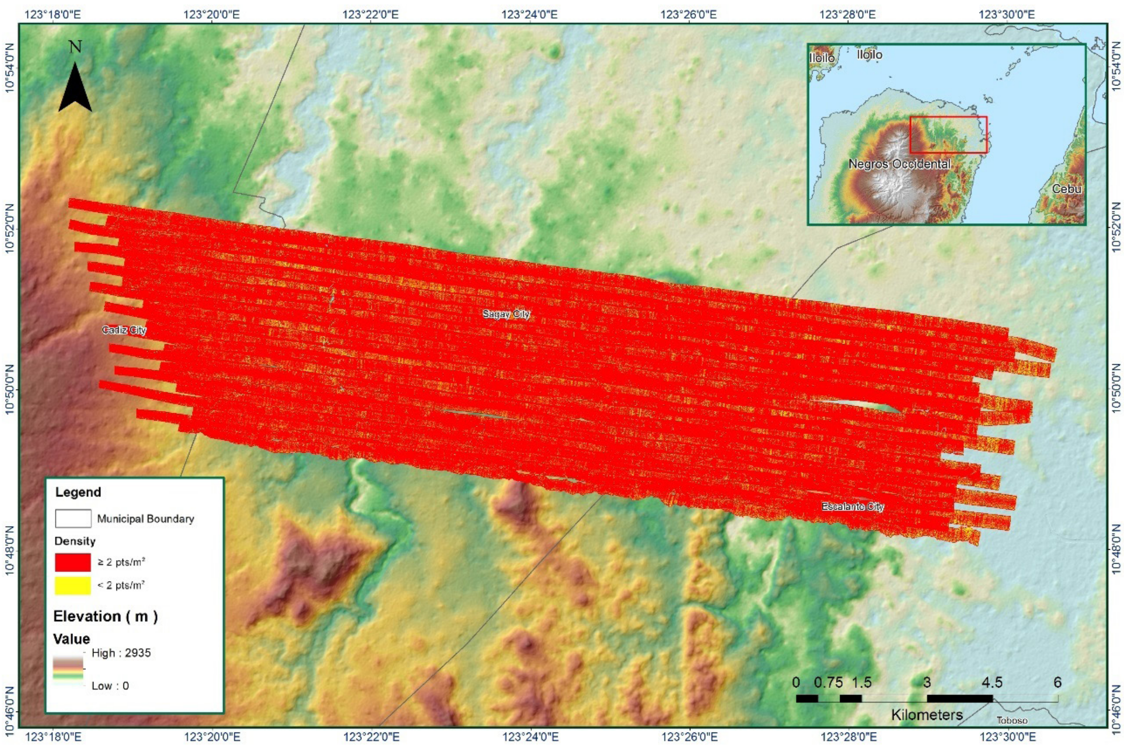


Figure 1.3.6. Density map of merged LiDAR data

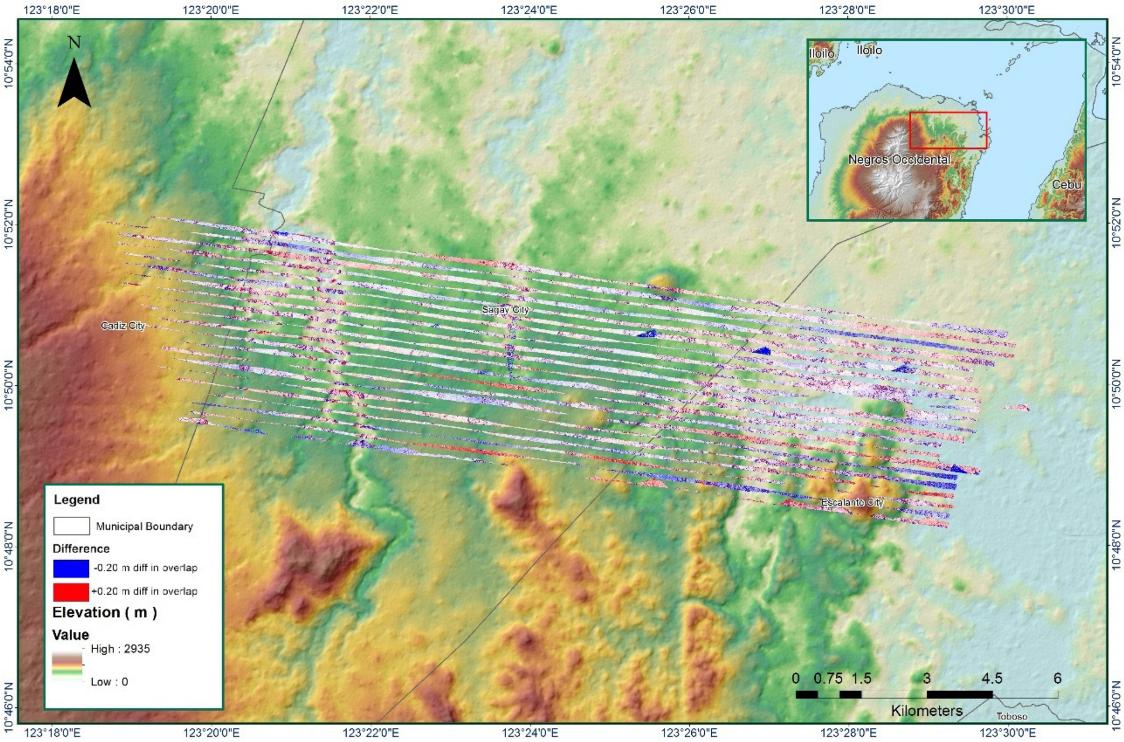


Figure 1.3.7. Elevation difference between flight lines

Flight Area	Bacolod
Mission Name	**Block 44E additional**
Inclusive Flights	8455AC
Range data size	10.2 GB
POS data size	233 MB
Base data size	91 MB
Image	38.5 GB
Transfer date	May 20, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.245
RMSE for East Position (<4.0 cm)	1.87
RMSE for Down Position (<8.0 cm)	4.065
Boresight correction stdev (<0.001deg)	0.000218
IMU attitude correction stdev (<0.001deg)	0.004166
GPS position stdev (<0.01m)	0.0027
Minimum % overlap (>25)	41.20
Ave point cloud density per sq.m. (>2.0)	4.92
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	120
Maximum Height	387.49
Minimum Height	59.77
Classification (# of points)	
Ground	53,625,771
Low vegetation	63,815,686
Medium vegetation	72,382,824
High vegetation	55,860,054
Building	2,859,236
Orthophoto	None
Processed by	Engr. Sheila-Maye Santillan, Engr. Edgardo Gubatanga, Jr., Engr. Melissa Fernandez

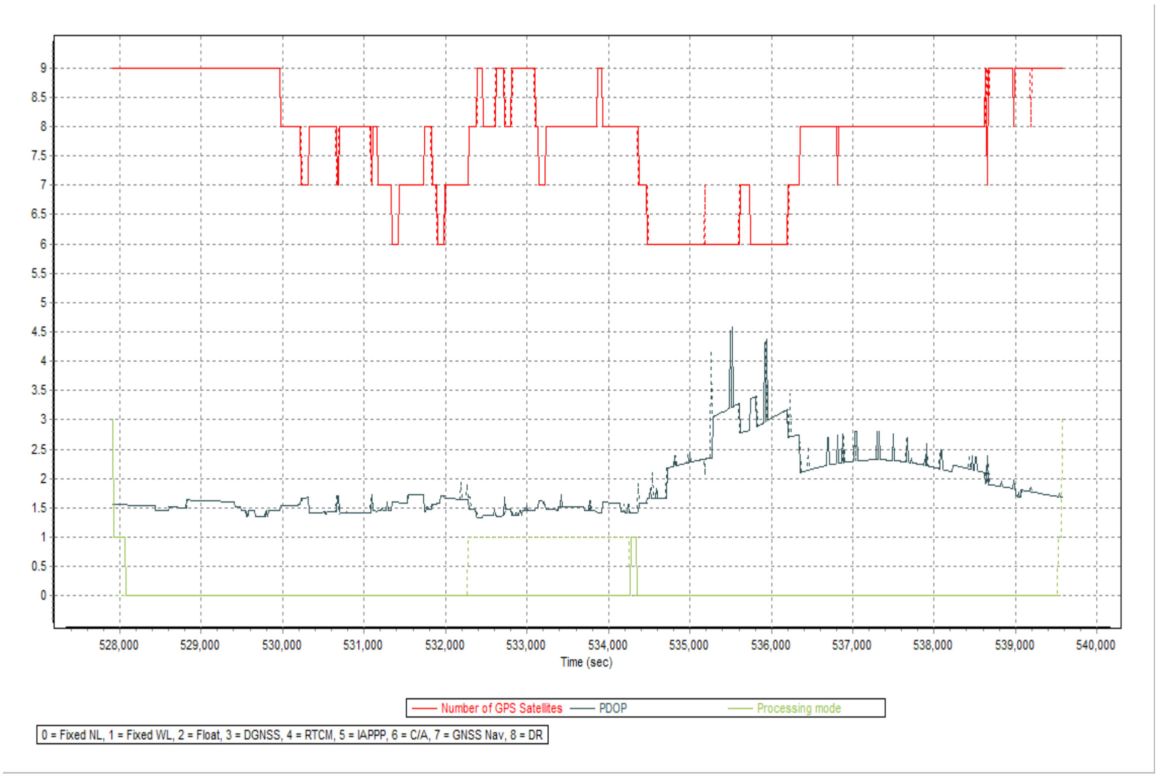


Figure 1.4.1 Solution Status

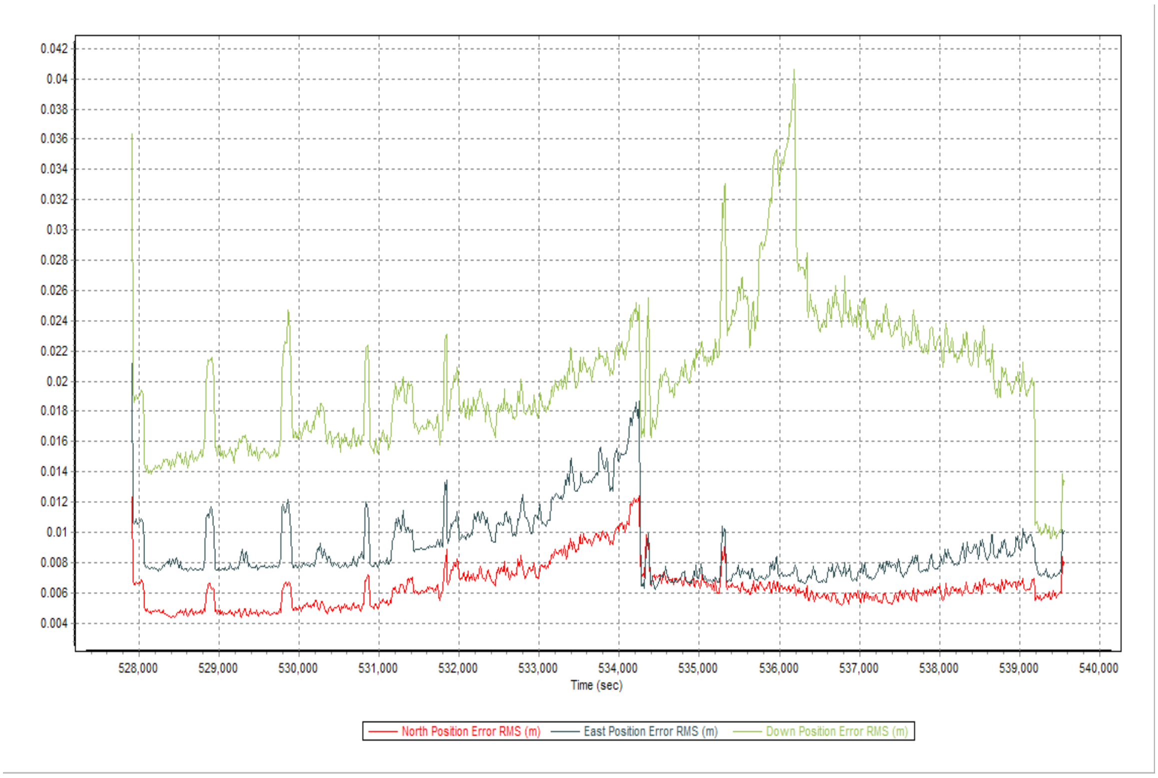


Figure 1.4.2 Smoothed Performance Metric Parameters

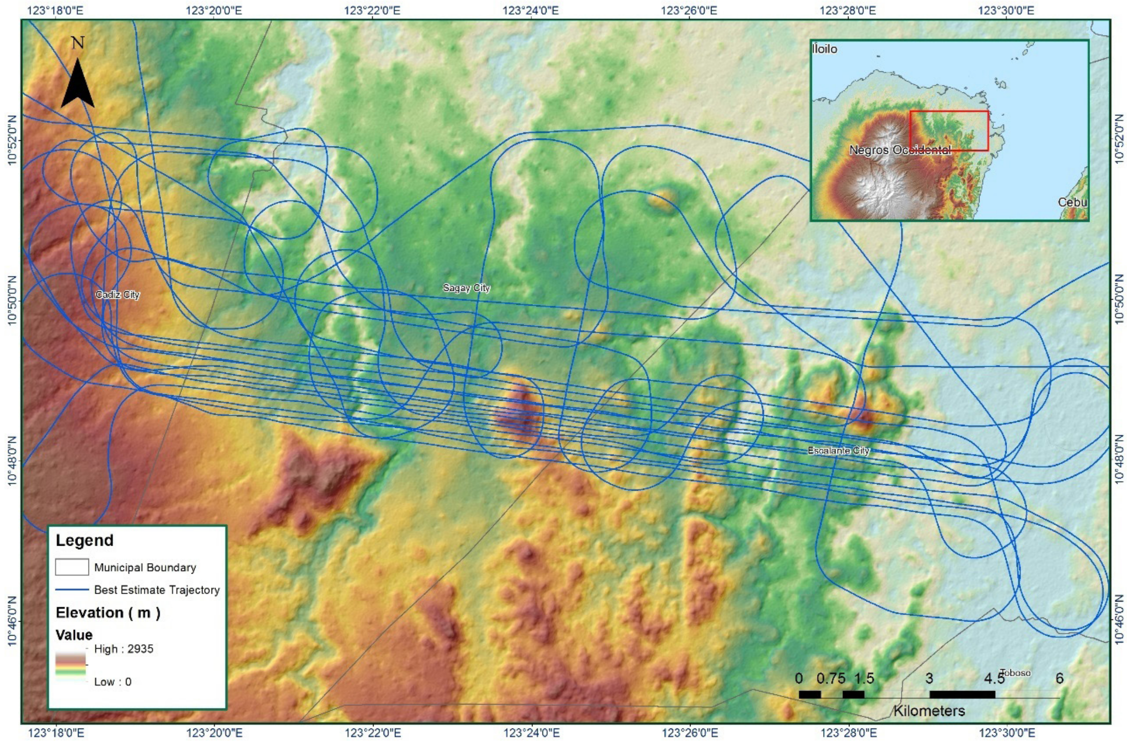


Figure 1.4.3 Best Estimated Trajectory

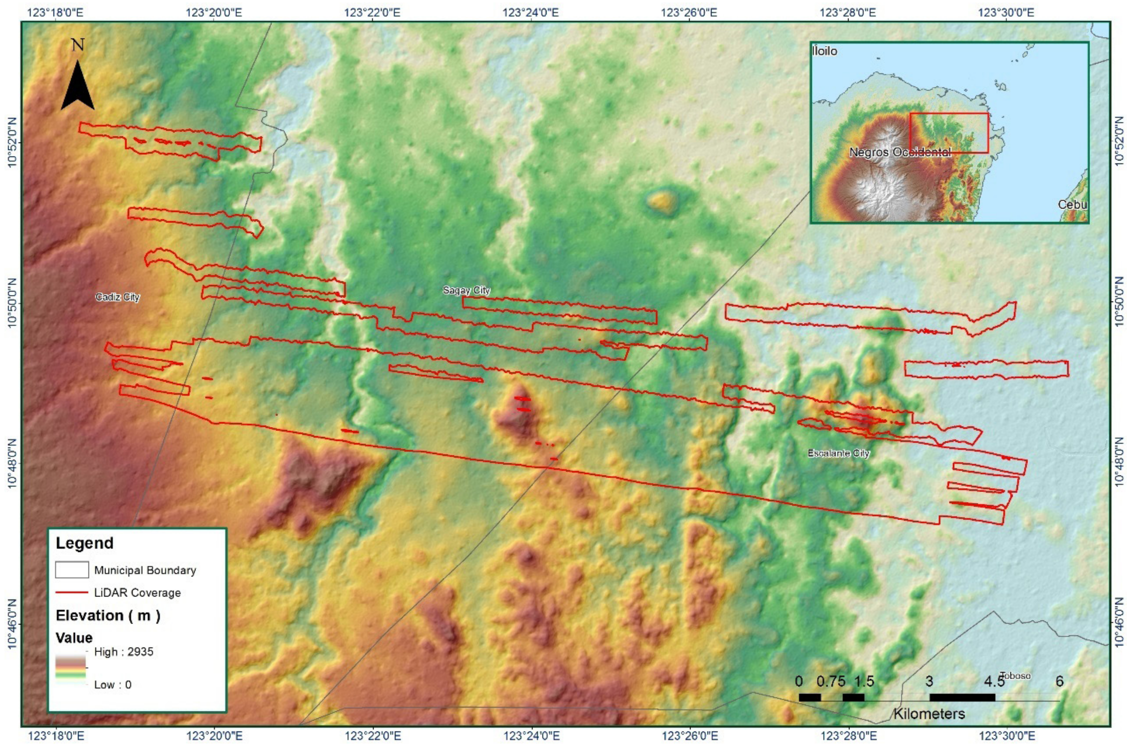


Figure 1.4.4 Coverage of LiDAR Data

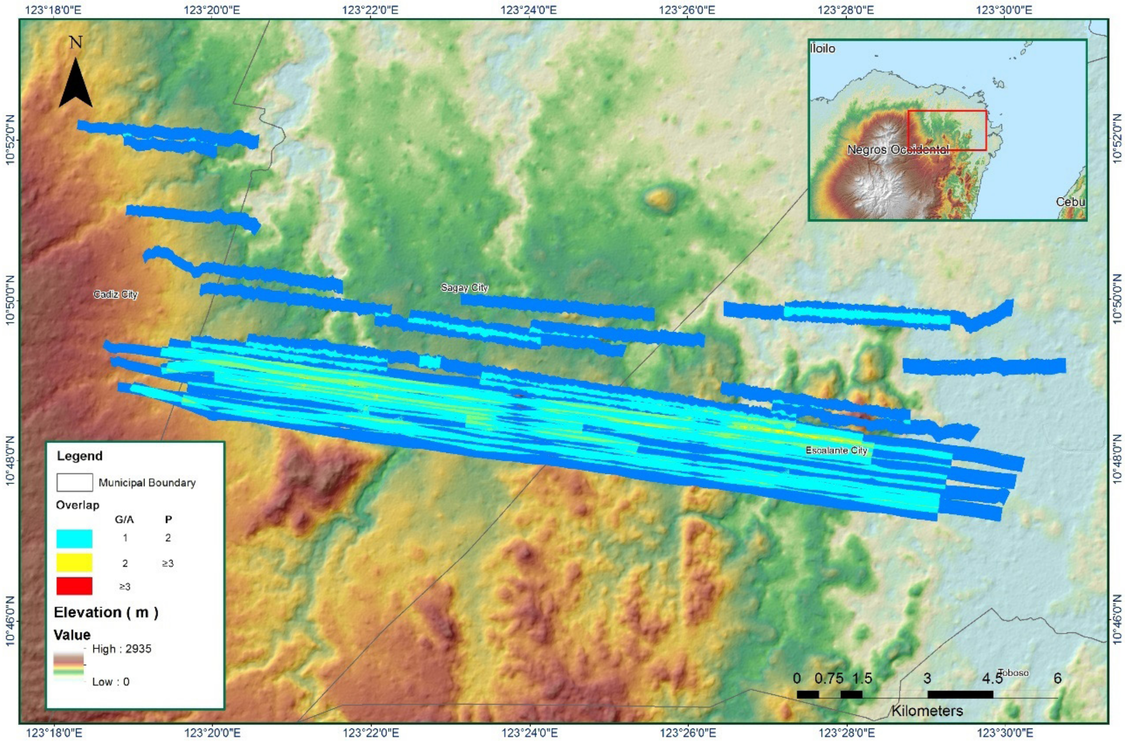


Figure 1.4.5 Image of data overlap

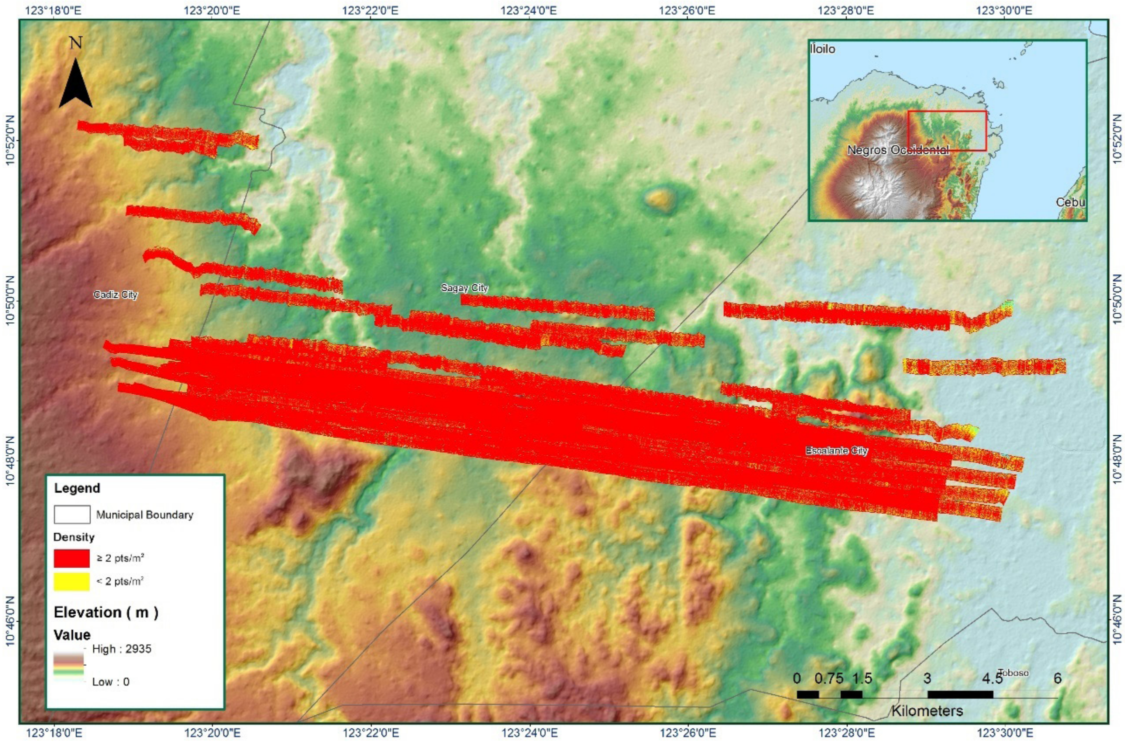


Figure 1.4.6 Density map of merged LiDAR data

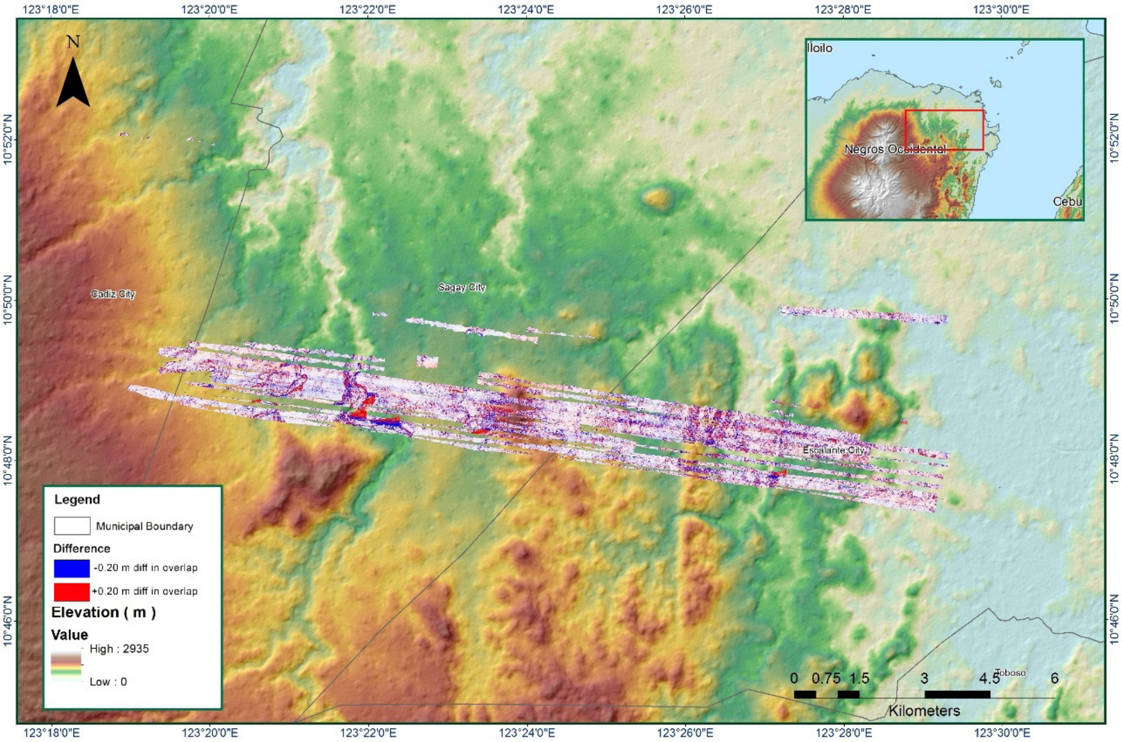


Figure 1.4.7 Elevation difference between flight lines

Flight Area	**Bacolod**
Mission Name	**Block 44D**
Inclusive Flights	8457AC
Range data size	8.64 GB
POS data size	222 MB
Base data size	94 MB
Image	39.6
Transfer date	May 20, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.2
RMSE for East Position (<4.0 cm)	1.204
RMSE for Down Position (<8.0 cm)	5.78
Boresight correction stdev (<0.001deg)	0.000478
IMU attitude correction stdev (<0.001deg)	0.000940
GPS position stdev (<0.01m)	0.0025
Minimum % overlap (>25)	30.10
Ave point cloud density per sq.m. (>2.0)	3.33
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	48
Maximum Height	106.51
Minimum Height	57.85
Classification (# of points)	
Ground	11,374,042
Low vegetation	10,746,942
Medium vegetation	12,511,682
High vegetation	8,971,525
Building	2,031,597
Orthophoto	None
Processed by	Engr. Irish Cortez, Engr. Melanie Hingpit, Engr. Monalyne Rabino

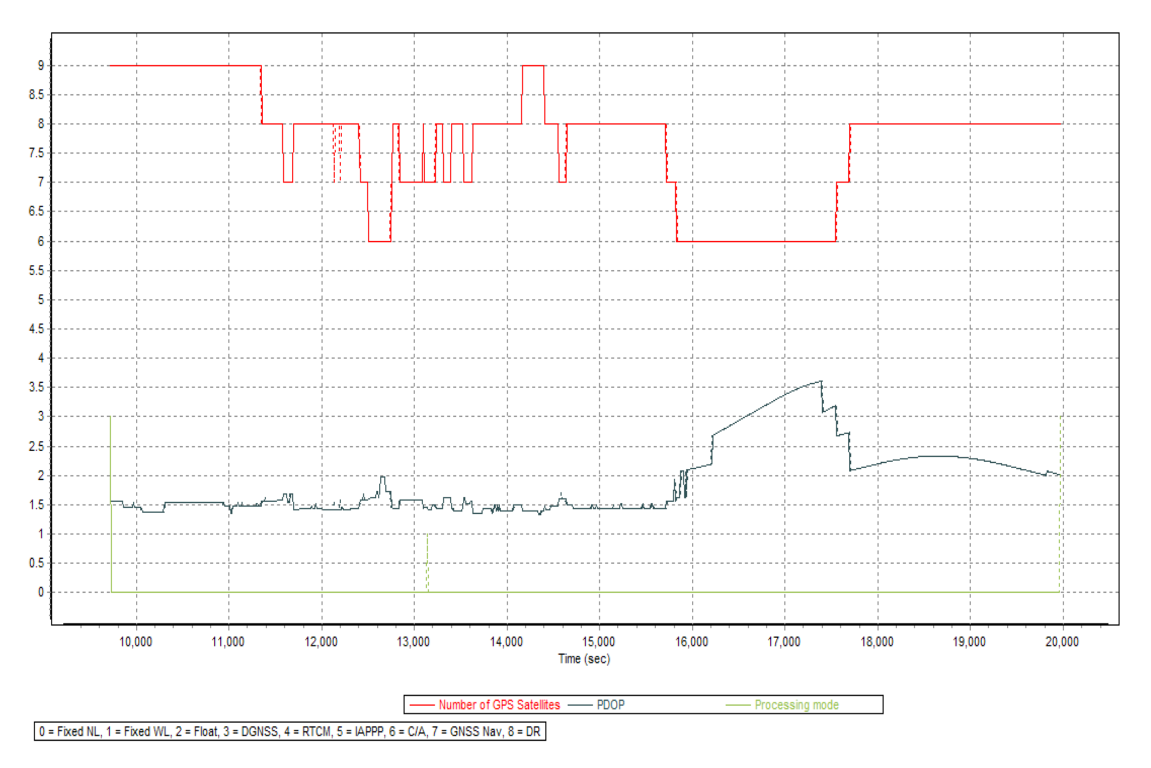


Figure 1.5.1 Solution Status

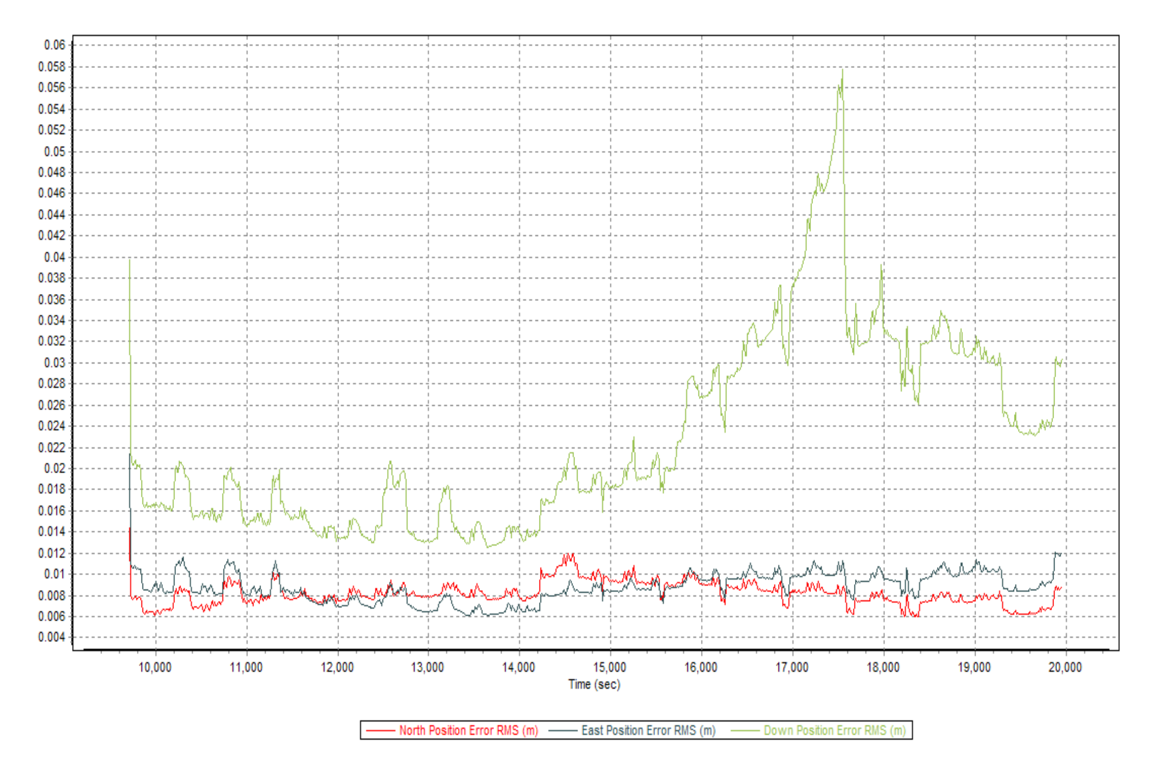


Figure 1.5.2 Smoothed Performance Metric Parameters

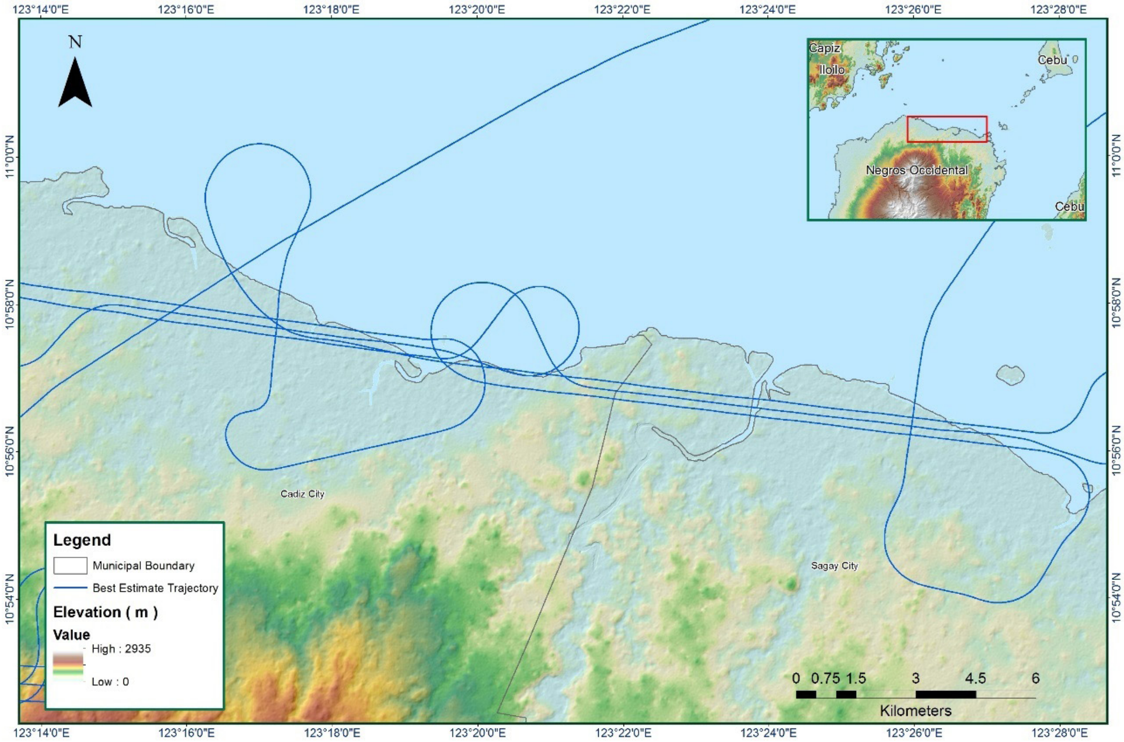


Figure 1.5.3 Best Estimated Trajectory

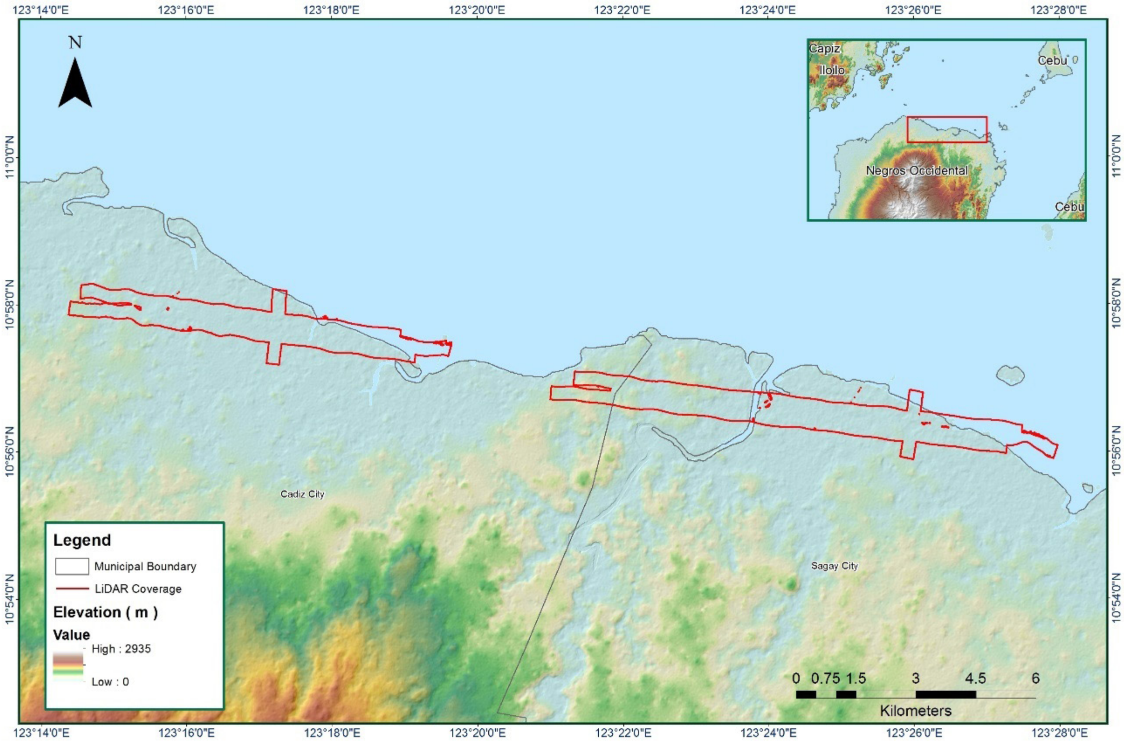


Figure 1.5.4 Coverage of LiDAR Data

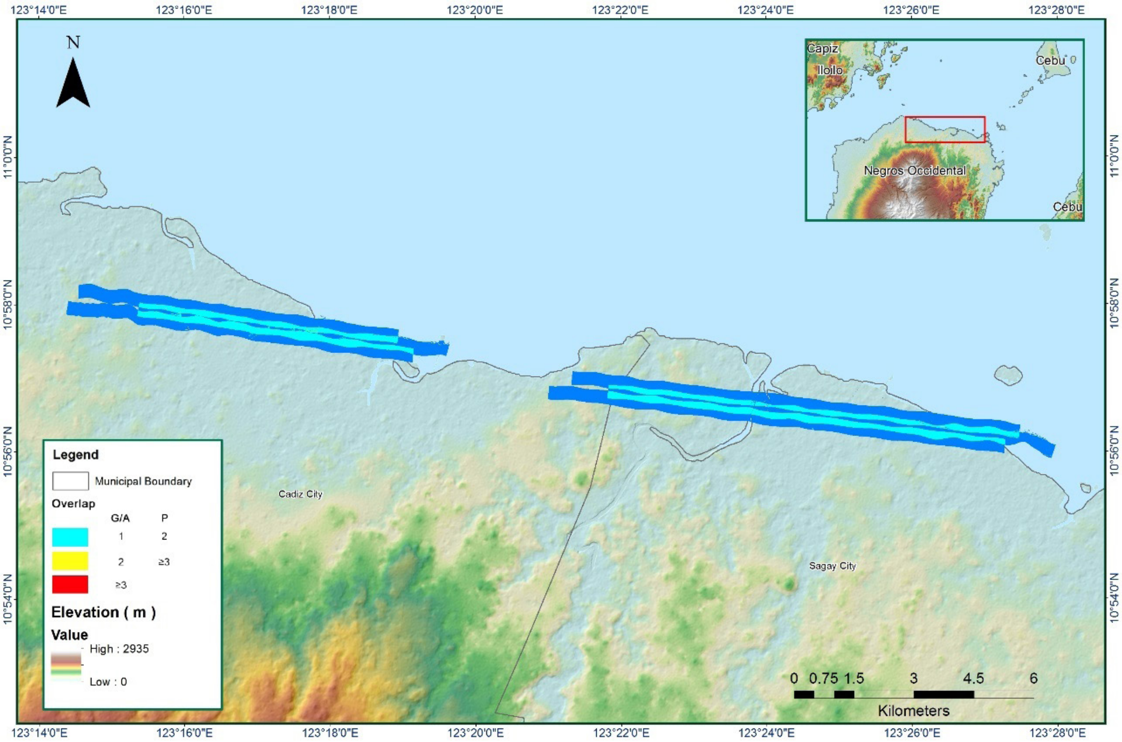


Figure 1.5.5 Image of data overlap

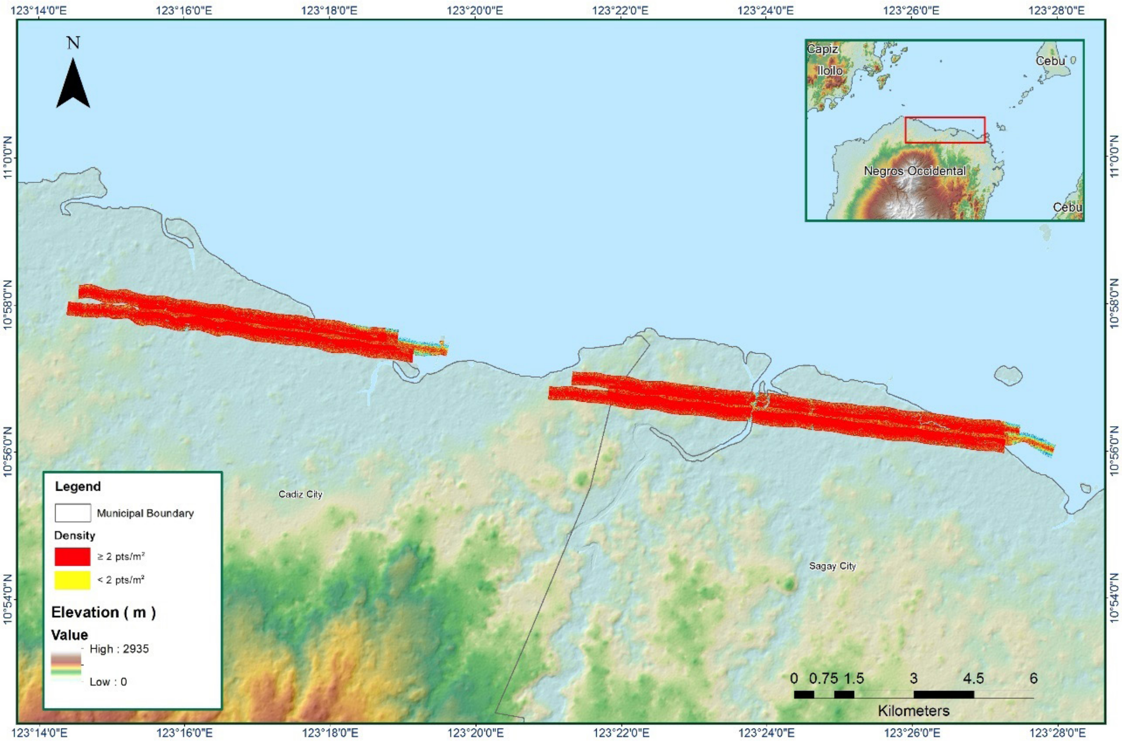


Figure 1.5.6 Density map of merged LiDAR data

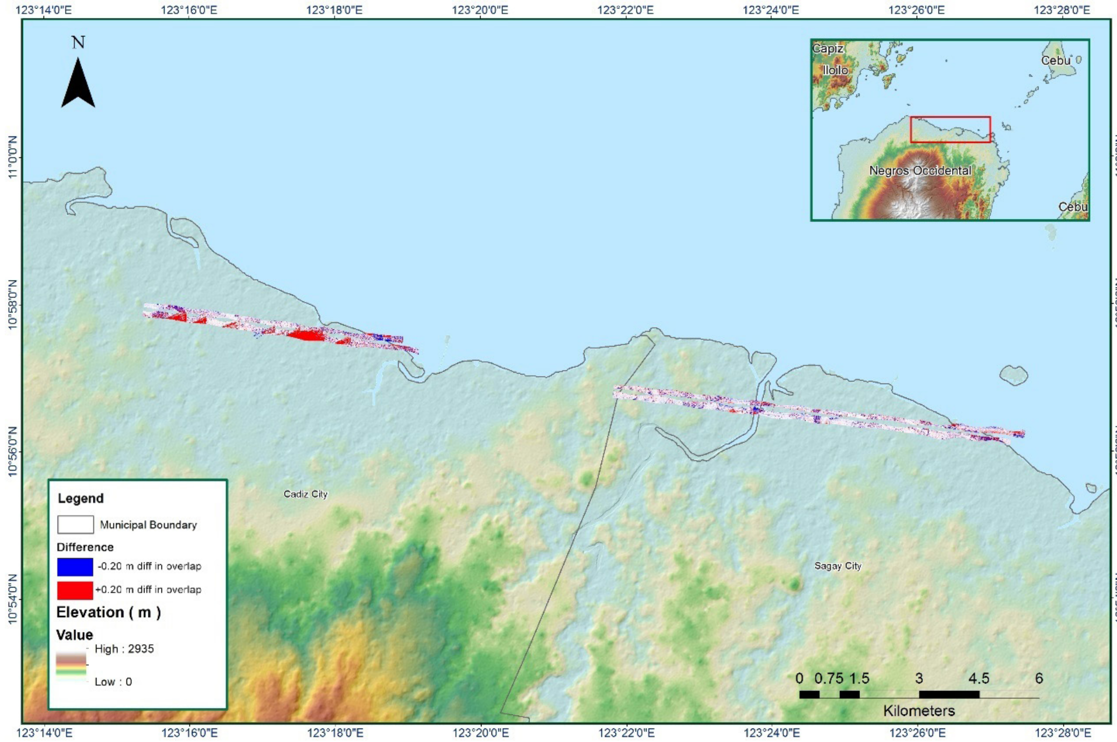


Figure 1.5.7 Elevation difference between flight lines

Annex 9. Himogaan Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Imper-vious (%)	Time of Concen-tration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Thres-hold Type	Ratio to Peak
W480	0.0154555	87.646	0	2.5545	0.57503	Discharge	2.3002	0.9	Ratio to Peak	0.65
W490	0.0155	99	0	0.28756	0.13161	Discharge	0.0775488	0.9	Ratio to Peak	0.65
W500	0.0287197	97.02	0	0.97479	0.70325	Discharge	3.8044	0.9	Ratio to Peak	0.65
W510	0.0352893	95.818	0	2.7907	3.1251	Discharge	12.709	0.9	Ratio to Peak	0.65
W520	0.0155	97.223	0	1.1124	0.59151	Discharge	1.4654	0.9	Ratio to Peak	0.65
W530	0.0163968	99	0	0.32619	1.691	Discharge	2.73	0.9	Ratio to Peak	0.65
W540	0.0155	99	0	1.7611	0.25233	Discharge	0.3769	0.9	Ratio to Peak	0.65
W550	0.0155	96.706	0	6.0123	0.84027	Discharge	4.4211	0.9	Ratio to Peak	0.65
W560	0.0155	98.832	0	8.9884	4.3865	Discharge	3.9555	0.9	Ratio to Peak	0.65
W570	0.0713777	98.93	0	1.6718	2.7261	Discharge	3.0008	0.9	Ratio to Peak	0.65
W580	0.0155	99	0	1.9047	0.18564	Discharge	1.0173	0.9	Ratio to Peak	0.65
W590	0.0703753	97.333	0	3.4106	2.6333	Discharge	5.3266	0.9	Ratio to Peak	0.65
W600	0.0155	96.524	0	0.92465	0.6831	Discharge	1.8902	0.9	Ratio to Peak	0.65
W610	0.024235	99	0	3.5644	2.1354	Discharge	5.1452	0.9	Ratio to Peak	0.65
W620	0.0155	99	0	0.42111	0.13112	Discharge	0.23029	0.9	Ratio to Peak	0.65
W630	0.0164458	98.772	0	2.9141	4.7521	Discharge	2.7996	0.9	Ratio to Peak	0.65
W640	0.0162888	95.559	0	4.8695	0.45582	Discharge	1.6831	0.9	Ratio to Peak	0.65
W650	0.047173	99	0	6.9047	5.007	Discharge	2.3262	0.9	Ratio to Peak	0.65
W660	0.0291891	98.627	0	0.95434	2.2699	Discharge	2.6923	0.9	Ratio to Peak	0.65
W670	0.10276	99	0	1.4469	3.4549	Discharge	1.9621	0.9	Ratio to Peak	0.65
W680	0.0959578	99	0	2.3461	2.5326	Discharge	0.93965	0.9	Ratio to Peak	0.65
W690	0.0155	99	0	0.79966	0.16841	Discharge	0.23682	0.9	Ratio to Peak	0.65
W700	0.0155	99	0	4.3371	0.40598	Discharge	0.81368	0.9	Ratio to Peak	0.65
W710	0.1069	39.382	0	0.75308	1.1763	Discharge	2.029	0.9	Ratio to Peak	0.65
W720	0.12166	99	0	2.757	3.4313	Discharge	1.0656	0.9	Ratio to Peak	0.65

W730	0.0879324	95.136	0	7.3207	4.4558	Discharge	7.4228	0.9	Ratio to Peak	0.65
W740	0.0155	99	0	0.30291	0.13864	Discharge	0.0195923	0.9	Ratio to Peak	0.65
W750	0.10871	98.803	0	3.0488	2.7393	Discharge	4.1024	0.9	Ratio to Peak	0.65
W760	0.0702108	97.875	0	2.6593	5.5169	Discharge	3.0597	0.9	Ratio to Peak	0.65
W770	0.020799	97.629	0	5.1042	3.7924	Discharge	6.3949	0.9	Ratio to Peak	0.65
W780	0.1086274	89.132	0	3.9132	3.2164	Discharge	2.0837	0.9	Ratio to Peak	0.65
W790	0.0155	92.778	0	3.1321	0.43765	Discharge	1.3435	0.9	Ratio to Peak	0.65
W800	0.0442372	98.366	0	1.622	2.6305	Discharge	0.88101	0.9	Ratio to Peak	0.65
W810	0.11456	86.601	0	4.1672	3.0198	Discharge	2.904	0.9	Ratio to Peak	0.65
W820	0.1123537	90.014	0	2.2041	3.0171	Discharge	2.9869	0.9	Ratio to Peak	0.65
W830	0.12007	85.877	0	5.3931	3.5726	Discharge	4.1331	0.9	Ratio to Peak	0.65
W840	0.11091	86.797	0	1.4123	3.381	Discharge	2.1194	0.9	Ratio to Peak	0.65
W850	0.0233456	98.206	0	1.5914	2.5931	Discharge	1.4292	0.9	Ratio to Peak	0.65
W860	0.0318954	97.968	0	5.1739	5.0626	Discharge	4.5768	0.9	Ratio to Peak	0.65
W870	0.0814581	98.06	0	0.25325	0.11769	Discharge	0.0353209	0.9	Ratio to Peak	0.65
W880	0.0416304	99	0	1.1217	0.74072	Discharge	0.6844	0.9	Ratio to Peak	0.65
W890	0.12579	90.296	0	1.5162	3.8026	Discharge	3.8858	0.9	Ratio to Peak	0.65
W900	0.11233	88.133	0	4.3775	2.8863	Discharge	6.5112	0.9	Ratio to Peak	0.65
W910	0.0369628	99	0	0.53179	2.9682	Discharge	3.1206	0.9	Ratio to Peak	0.65
W920	0.0355	95.954	0	3.0783	2.4949	Discharge	3.296	0.9	Ratio to Peak	0.65
W930	0.10578	88.647	0	1.1596	1.7502	Discharge	2.7609	0.9	Ratio to Peak	0.65
W940	0.1073651	99	0	1.1331	1.8853	Discharge	2.0504261	0.9	Ratio to Peak	0.65

Annex 10. Himogaan Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R10	Automatic Fixed Interval	5818.97	0.001019	0.0409744	Trapezoid	75.48	1
R20	Automatic Fixed Interval	333.848	0.004958	0.0407784	Trapezoid	75.48	1
R30	Automatic Fixed Interval	2326.81	0.007981	0.0403754	Trapezoid	75.48	1
R50	Automatic Fixed Interval	1731.25	0.006182	0.0608454	Trapezoid	75.48	1
R90	Automatic Fixed Interval	9737.03	0.020112	0.0908368	Trapezoid	75.48	1
R100	Automatic Fixed Interval	7596.37	0.005574	0.0883801	Trapezoid	75.48	1
R120	Automatic Fixed Interval	2097.94	0.006663	0.0891	Trapezoid	75.48	1
R150	Automatic Fixed Interval	962.548	0.008648	0.0906639	Trapezoid	75.48	1
R170	Automatic Fixed Interval	3644.34	0.015614	0.14234	Trapezoid	75.48	1
R190	Automatic Fixed Interval	5164.87	0.020032	0.0874535	Trapezoid	75.48	1
R200	Automatic Fixed Interval	5198.72	0.011111	0.0588148	Trapezoid	75.48	1
R210	Automatic Fixed Interval	1087.4	0.003816	0.0602832	Trapezoid	75.48	1
R230	Automatic Fixed Interval	1713.68	0.041131	0.0884677	Trapezoid	75.48	1
R240	Automatic Fixed Interval	2103.09	0.031525	0.0600594	Trapezoid	75.48	1
R250	Automatic Fixed Interval	442.426	0.015362	0.0592017	Trapezoid	75.48	1
R260	Automatic Fixed Interval	2612.79	0.008366	0.0395608	Trapezoid	75.48	1
R300	Automatic Fixed Interval	3028.36	0.021735	0.0403847	Trapezoid	75.48	1
R310	Automatic Fixed Interval	4148.65	0.020545	0.0401911	Trapezoid	75.48	1
R340	Automatic Fixed Interval	3660.9	0.01293	0.0591948	Trapezoid	75.48	1
R380	Automatic Fixed Interval	5135	0.019052	0.0350633	Trapezoid	75.48	1
R390	Automatic Fixed Interval	279.706	0.038434	0.0393473	Trapezoid	75.48	1
R410	Automatic Fixed Interval	2198.82	0.015092	0.0599762	Trapezoid	75.48	1
R420	Automatic Fixed Interval	6037.01	0.035476	0.0402832	Trapezoid	75.48	1

Annex 11. Himogaan-Tanao Field Validation

Point Number	Validation Coordinates		Model var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
1	10.89304	123.4049171	3.49	5	2.2801	Undang/November 5-7, 1985	100-Year
2	10.88665	123.3956462	1.08	5	15.3664	Undang/November 5-7, 1986	100-Year
3	10.88706	123.3956749	0.95	5	16.4025	Undang/November 5-7, 1987	100-Year
4	10.88671	123.3956508	3.17	5	3.3489	Undang/November 5-7, 1988	100-Year
5	10.88675	123.3961603	0.00	3	9	Ruping/November 13-18, 1990	100-Year
6	10.89284	123.4048072	4.03	5	0.9409	Undang/November 5-7, 1989	100-Year
7	10.8866	123.3956406	1.97	5	9.1809	Undang/November 5-7, 1990	100-Year
8	10.88644	123.3964139	0.30	5	22.09	Undang/November 5-7, 1991	100-Year
9	10.88685	123.3961504	1.78	3	1.4884	Ruping/November 13-18, 1991	100-Year
10	10.89264	123.4047981	0.05	5	24.5025	Undang/November 5-7, 1992	100-Year
11	10.88679	123.395619	0.24	5	22.6576	Undang/November 5-7, 1993	100-Year
12	10.88678	123.395511	1.84	5	9.9856	Undang/November 5-7, 1994	100-Year
13	10.88679	123.3957428	1.98	3	1.0404	Ruping/November 13-18, 1992	100-Year
14	10.89333	123.4049507	1.62	3	1.9044	Ruping/November 13-18, 1993	100-Year
15	10.89323	123.4049247	0.03	3	8.8209	Ruping/November 13-18, 1994	100-Year
16	10.89268	123.4047117	0.39	3	6.8121	Ruping/November 13-18, 1995	100-Year
17	10.89289	123.4048491	0.59	5	19.4481	Undang/November 5-7, 1995	100-Year
18	10.88686	123.3957575	0.26	5	22.4676	Undang/November 5-7, 1996	100-Year
19	10.88656	123.3963104	0.74	5	18.1476	Undang/November 5-7, 1997	100-Year
20	10.88494	123.4104032	0.59	0.75	0.0256	Yolanda/ November 2-11, 2013	5-Year
21	10.89096	123.357543	0.6	3	5.76	Yolanda/ November 2-11, 2013	5-Year
22	10.88607	123.4179368	1.39	0	1.9321		5-Year
23	10.89276	123.4133247	2.46	0	6.0516		5-Year
24	10.8828	123.3463334	0.00	0	0		5-Year
25	10.89703	123.4134465	2.17	0	4.7089		5-Year
26	10.89627	123.3590016	0.03	0	0.0009		5-Year
27	10.8868	123.3485264	0.00	0	0		5-Year
28	10.88362	123.3492893	0.00	0	0		5-Year
29	10.89705	123.4145236	0.00	0.2	0.04	Yolanda/ November 2-11, 2013	5-Year
30	10.88689	123.4107982	0.23	0	0.0529	Yolanda/ November 2-11, 2013	5-Year
31	10.88372	123.4107134	10.23	0	104.6529		5-Year
32	10.88471	123.4146668	5.62	0	31.5844		5-Year
33	10.88612	123.4161576	5.67	0	32.1489		5-Year
34	10.89088	123.4108827	0.14	0	0.0196		5-Year
35	10.88573	123.3495022	5.37	0	28.8369		5-Year
36	10.89633	123.3609441	0.04	0	0.0016		5-Year
37	10.89118	123.3577763	1.08	3	3.6864	Yolanda/ November 2-11, 2013	5-Year
38	10.89884	123.3622023	0.03	0	0.0009		5-Year
39	10.89628	123.3627223	0.06	0	0.0036		5-Year
40	10.89005	123.4133036	5.23	0.3	24.3049	Yolanda/ November 2-11, 2013	5-Year
41	10.94794	123.4139833	0.05	0	0.0025		5-Year
42	10.88898	123.4135544	0.00	0	0		5-Year
43	10.93673	123.4201519	0.76	0.6	0.0256	Marce/November 24 -28, 2016	5-Year
44	10.89043	123.4125809	6.5	0.2	39.69	Yolanda/ November 2-11, 2013	5-Year
45	10.89063	123.4128556	5.71	0.2	30.3601	Yolanda/ November 2-11, 2013	5-Year

46	10.88668	123.4128659	2.58	0	6.6564		5-Year
47	10.89215	123.4154028	4.75	0	22.5625		5-Year
48	10.93655	123.4206146	0.03	0.6	0.3249	Marce/November 24 -28, 2016	5-Year
49	10.88829	123.4136962	5.62	0	31.5844		5-Year
50	10.89798	123.4144229	5.71	0.2	30.3601	Yolanda/ November 2-11, 2013	5-Year
51	10.89053	123.4130661	6.06	0.2	34.3396	Yolanda/ November 2-11, 2013	5-Year
52	10.93826	123.4266992	0.14	0	0.0196		5-Year
53	10.88767	123.3510572	0.03	0.5	0.2209	Yolanda/ November 2-11, 2013	5-Year
54	10.94281	123.4271363	0.03	1	0.9409	Marce/November 24 -28, 2016	5-Year
55	10.94779	123.4144961	0.54	0	0.2916		5-Year
56	10.89166	123.4150796	1.37	0	1.8769		5-Year
57	10.88746	123.4138217	4.44	0	19.7136		5-Year
58	10.88362	123.3495837	0.00	0	0		5-Year
59	10.88819	123.4135659	4.95	0	24.5025		5-Year
60	10.94931	123.4117194	0.1	1	0.81	Yolanda/ November 2-11, 2013	5-Year
61	10.94866	123.415151	0.72	0	0.5184		5-Year
62	10.94504	123.419977	0.03	0.3	0.0729	Yolanda/ November 2-11, 2013	5-Year
63	10.89353	123.4142786	0.03	0	0.0009		5-Year
64	10.88829	123.4137663	2.73	0	7.4529		5-Year
65	10.94956	123.4118795	0.05	1.5	2.1025	Yolanda/ November 2-11, 2013	5-Year
66	10.94901	123.4124439	0.03	1	0.9409	Yolanda/ November 2-11, 2013	5-Year
67	10.88985	123.4138047	0.00	0.5	0.25	Yolanda/ November 2-11, 2013	5-Year
68	10.89388	123.4141792	5.12	0	26.2144		5-Year
69	10.94486	123.4127808	0.1	2	3.61	Yolanda/ November 2-11, 2013	5-Year
70	10.9471	123.4128954	0.21	1	0.6241	Yolanda/ November 2-11, 2013	5-Year
71	10.94125	123.4250748	0.03	0	0.0009		5-Year
72	10.93804	123.4228981	0.03	0.8	0.5929	Marce/November 24 -28, 2016	5-Year
73	10.89136	123.3540596	0.03	2.5	6.1009	Senyang/December 28-30, 2014	5-Year
74	10.94379	123.4243637	0.03	1	0.9409	Marce/November 24 -28, 2016	5-Year
75	10.94798	123.4126136	0.00	1.5	2.25	Yolanda/ November 2-11, 2013	5-Year
76	10.94448	123.4226574	0.12	1	0.7744	Yolanda/ November 2-11, 2013	5-Year
77	10.94873	123.411936	0.56	0	0.3136		5-Year
78	10.94538	123.4124247	0.37	0.35	0.0004	Yolanda/ November 2-11, 2013	5-Year
79	10.89627	123.4128828	0.03	0	0.0009		5-Year
80	10.94769	123.4121133	0.16	1.5	1.7956	Yolanda/ November 2-11, 2013	5-Year
81	10.88862	123.4145798	3.45	0.15	10.89	Yolanda/ November 2-11, 2013	5-Year
82	10.93814	123.4265406	0.09	0	0.0081		5-Year
83	10.88516	123.3463296	0.00	0	0		5-Year
84	10.93711	123.4205947	0.55	0.6	0.0025	Marce/November 24 -28, 2016	5-Year
85	10.93403	123.4220335	0.04	0.65	0.3721	Yolanda/ November 2-11, 2013	5-Year
86	10.93393	123.4223241	1.18	0.65	0.2809	Yolanda/ November 2-11, 2013	5-Year
87	10.94984	123.411379	0.05	1	0.9025	Yolanda/ November 2-11, 2013	5-Year
88	10.88415	123.3511928	0.00	0	0		5-Year
89	10.9476	123.413034	0.03	1.5	2.1609	Yolanda/ November 2-11, 2013	5-Year
90	10.88392	123.353926	0.67	1.5	0.6889	Ruby/December 6-7, 2014	5-Year
91	10.93823	123.4230217	0.03	0.8	0.5929	Marce/November 24 -28, 2016	5-Year
92	10.94181	123.4262827	0.09	1	0.8281	Yolanda/ November 2-11, 2013	5-Year
93	10.94222	123.4269669	0.03	1	0.9409	Marce/November 24 -28, 2016	5-Year
94	10.94785	123.4121691	0.25	1.5	1.5625	Yolanda/ November 2-11, 2013	5-Year
95	10.94717	123.4133356	0.04	0	0.0016		5-Year

96	10.94743	123.4133695	0.31	0	0.0961		5-Year
97	10.94449	123.4205476	0.00	0.3	0.09	Yolanda/ November 2-11, 2013	5-Year
98	10.8908	123.3542476	4.66	2	7.075599	Ruping/November 13-18, 1996	100-Year
99	10.94782	123.4125584	0.24	0	0.0576		5-Year
100	10.94669	123.4109516	0.30	2	2.89	Sig #3/November 5-7, 1984	5-Year
101	10.94582	123.4137397	0.03	0	0.0009		5-Year
102	10.94898	123.4101126	0.03	0	0.0009		5-Year
103	10.94556	123.414017	0.06	0	0.0036		5-Year
104	10.94657	123.4102076	0.67	0	0.4489		5-Year
105	10.94168	123.4191304	0.26	2	3.0276	Yolanda/ November 2-11, 2013	5-Year
106	10.94083	123.4202902	0.47	2	2.3409	Yolanda/ November 2-11, 2013	5-Year
107	10.89189	123.3577537	1.21	3	3.2041	Yolanda/ November 2-11, 2013	5-Year
108	10.9455	123.4114517	0.64	0	0.4096		5-Year
109	10.94693	123.4125658	1.12	0	1.2544		5-Year
110	10.94939	123.4121342	0.68	1	0.1024	Yolanda/ November 2-11, 2013	5-Year
111	10.94532	123.4145939	0.03	0	0.0009		5-Year
112	10.94217	123.4266381	0.03	1	0.9409	Yolanda/ November 2-11, 2013	5-Year
113	10.94568	123.4247056	0.03	1	0.9409	Marce/November 24 -28, 2016	5-Year
114	10.88547	123.3529407	0.00	0	0		5-Year
115	10.94778	123.4110035	0.03	0.6	0.3249	Yolanda/ November 2-11, 2013	5-Year
116	10.94503	123.4194403	0.47	0.3	0.0289	Yolanda/ November 2-11, 2013	5-Year
117	10.94869	123.4091837	1.09	0	1.1881		5-Year
118	10.9408	123.4198035	0.03	2	3.8809	Yolanda/ November 2-11, 2013	5-Year
119	10.94689	123.4135927	0.03	1	0.9409	Yolanda/ November 2-11, 2013	5-Year
120	10.9431	123.4242639	0.76	1	0.0576	Marce/November 24 -28, 2016	5-Year
121	10.94663	123.4141144	1.23	1	0.0529	Yolanda/ November 2-11, 2013	5-Year
122	10.88535	123.3536215	0.00	0	0		5-Year
123	10.94103	123.4205604	0.85	2	1.3225	Yolanda/ November 2-11, 2013	5-Year
124	10.94587	123.4126984	0.03	0.35	0.1024	Yolanda/ November 2-11, 2013	5-Year
125	10.88297	123.3536586	3.19	1.5	2.8561	Ruby/December 6-7, 2014	5-Year
126	10.9455	123.4112715	0.51	0	0.2601		5-Year
127	10.947	123.4134435	0.73	1	0.0729	Yolanda/ November 2-11, 2013	5-Year
128	10.94695	123.4143944	0.8	1	0.04	Yolanda/ November 2-11, 2013	5-Year
129	10.94077	123.4209853	0.97	2	1.0609	Yolanda/ November 2-11, 2013	5-Year
130	10.89127	123.3507638	0.06	0	0.0036	Frank/June 18-23, 2008	100-Year
131	10.94646	123.409658	1.09	0	1.1881		5-Year
132	10.94662	123.4123274	0.84	0	0.7056		5-Year
133	10.94694	123.4114504	1.08	1.5	0.1764	Yolanda/ November 2-11, 2013	5-Year
134	10.94881	123.4094301	0.67	0	0.4489		5-Year
135	10.94613	123.4142009	0.97	1	0.0009	Yolanda/ November 2-11, 2013	5-Year
136	10.94109	123.4190218	0.89	2	1.2321	Yolanda/ November 2-11, 2013	5-Year
137	10.89125	123.3570098	3.07	3	0.0049	Yolanda/ November 2-11, 2013	5-Year
138	10.8848	123.3539152	0.51	1.5	0.9801	Ruby/December 6-7, 2014	5-Year
139	10.88527	123.3551674	0.47	0	0.2209		5-Year
140	10.8866	123.354211	1.36	0	1.8496		5-Year
141	10.89279	123.3549387	0.03	0.2	0.0289	Yolanda/ November 2-11, 2013	5-Year
142	10.88906	123.3534196	1.37	0	1.8769		5-Year
143	10.88613	123.3536963	0.11	0	0.0121		5-Year
144	10.88834	123.3536729	3.16	0	9.985601		5-Year
145	10.89299	123.3564838	0.05	0.2	0.0225	Yolanda/ November 2-11, 2013	5-Year

146	10.88535	123.3545947	0.00	0.3	0.09	Ondoy/September 24-30, 2009	5-Year
147	10.89117	123.3509395	0.04	0	0.0016	Frank/June 18-23, 2008	100-Year
148	10.88769	123.3547796	1.69	2	0.0961		5-Year
149	10.89275	123.3545688	0.04	0.2	0.0256	Yolanda/ November 2-11, 2013	5-Year
150	10.8828	123.3540693	0.92	1.5	0.3364	Ruby/December 6-7, 2014	5-Year
151	10.87203	123.3459072	0.21	5	22.9441	Yolanda/ November 2-11, 2013	5-Year
152	10.88474	123.3552168	2.02	0	4.0804		5-Year
153	10.88795	123.3549578	1.48	0	2.1904		5-Year
154	10.88947	123.3511989	0.13	8	61.9369	Ruping/November 13-18, 1997	100-Year
155	10.88835	123.3529977	1.87	0	3.4969		5-Year
156	10.8897	123.3518951	0.65	6.00	28.6225	Yolanda/ November 2-11, 2013	5-Year
157	10.88832	123.3548094	1.78	0	3.1684		5-Year
158	10.88597	123.3557111	1.73	5	10.6929	Luding/August 8 – August 18, 1963	5-Year
159	10.87262	123.345349	0.21	0.6	0.1521	Ruby/December 6-7, 2014	5-Year
160	10.88441	123.3536771	1.05	1.5	0.2025	Ruby/December 6-7, 2014	5-Year
161	10.87179	123.3459513	0.03	5	24.7009	Yolanda/ November 2-11, 2013	5-Year
162	10.88495	123.3553053	0.88	0	0.7744		5-Year
163	10.89071	123.3538806	0.59	2.50	3.6481	Yolanda/ November 2-11, 2013	5-Year
164	10.88782	123.3552082	4.02	0	16.1604		5-Year
165	10.88772	123.3541393	0.00	2	4	Yolanda/ November 2-11, 2013	5-Year
166	10.88548	123.3540685	0.08	0.3	0.0484	Ondoy/September 24-30, 2009	5-Year
167	10.88856	123.3552818	3.04	0	9.2416		5-Year
168	10.89271	123.3566393	0.06	0.2	0.0196	Yolanda/ November 2-11, 2013	5-Year
169	10.88339	123.3543612	0.03	1.5	2.1609	Ruby/December 6-7, 2014	5-Year
170	10.89154	123.3530177	0.05	4	15.6025	Yolanda/ November 2-11, 2013	5-Year
171	10.89266	123.3543278	0.04	0.2	0.0256	Yolanda/ November 2-11, 2013	5-Year
172	10.88496	123.3553005	0.00	0	0		5-Year
173	10.86769	123.3447925	3.34	1.50	3.3856	Marce/November 24 -28, 2016	5-Year
174	10.90128	123.3612056	0.32	5	21.9024	Sendong/December 28, 2011	5-Year
175	10.90067	123.3612542	0.03	5	24.7009	Sendong/December 28, 2011	5-Year
176	10.9024	123.3624837	0.21	8	60.6841	Zoraida/November 11-15, 1013	5-Year
177	10.88853	123.3555433	1.78	0	3.1684		5-Year
178	10.90054	123.3615289	0.05	5	24.5025	Sendong/40905	5-Year
179	10.90149	123.3621954	0.03	8	63.5209	Zoraida/November 11-15, 1013	5-Year
180	10.8727	123.3463318	0.05	5	24.5025	Yolanda/ November 2-11, 2013	5-Year
181	10.90195	123.3626131	0.25	8	60.0625	Zoraida/November 11-15, 1013	5-Year
182	10.89962	123.3607491	0.06	2	3.7636	Ruby/December 6-7, 2014	5-Year
183	10.89979	123.3608398	0.16	2	3.3856	Ruby/December 6-7, 2014	5-Year
184	10.90154	123.3618846	0.04	8	63.3616	Zoraida/November 11-15, 1013	5-Year
185	10.87314	123.3461015	0.23	5	22.7529	Yolanda/ November 2-11, 2013	5-Year
186	10.90215	123.3620047	0.15	8	61.6225	Zoraida/November 11-15, 1013	5-Year
187	10.90189	123.3622862	0.13	8	61.9369	Zoraida/November 11-15, 1013	5-Year
188	10.86925	123.3449526	7.28	1.50	33.4084	Marce/November 24 -28, 2016	5-Year
189	10.89191	123.3516445	0.46	2	2.3716	Ruping/November 13-18, 1998	100-Year
190	10.90145	123.361588	0.00	8	64	Zoraida/November 11-15, 1013	5-Year
191	10.87239	123.3461403	0.09	5	24.1081	Yolanda/ November 2-11, 2013	5-Year
192	10.87319	123.3456494	0.03	0.6	0.3249	Ruby/December 6-7, 2014	5-Year
193	10.90047	123.3616751	0.08	5	24.2064	Sendong/December 8, 2011	5-Year
194	10.90143	123.3671474	0.13	7	47.1969	Yolanda/ November 2-11, 2013	5-Year
195	10.86851	123.3455463	5.33	1.50	14.6689	Marce/November 24 -28, 2016	5-Year

196	10.90385	123.3658228	0.03	7	48.5809	Yolanda/ November 2-11, 2013	5-Year
197	10.89079	123.3518837	0.08	0	0.0064		5-Year
198	10.88872	123.3531789	2.28	0	5.1984		5-Year
199	10.92649	123.3678583	0.61	1	0.1521		5-Year
200	10.89668	123.358702	0.19	0	0.0361		5-Year
201	10.86897	123.344254	0.00	0	0		5-Year
202	10.94411	123.4215309	0.39	0	0.1521		5-Year
203	10.89078	123.3545456	6.15	1.68	19.9809		5-Year
204	10.87069	123.3446994	0.22	0	0.0484		5-Year
205	10.89266	123.3566754	0.09	6	34.9281		5-Year
206	10.9199	123.3710044	0.03	1	0.9409		5-Year
207	10.94221	123.4260776	0.07	0.94	0.7569	Yolanda/ November 2-11, 2013	5-Year
208	10.94244	123.4253684	0.05	0	0.0025		5-Year
209	10.94783	123.4105409	0.74	0	0.5476		5-Year
210	10.94529	123.4248301	0.03	0	0.0009		5-Year
211	10.95827	123.377296	0.17	0	0.0289		5-Year
212	10.94357	123.4245559	0.03	0	0.0009		5-Year
213	10.94642	123.4110986	0.00	0	0		5-Year
214	10.94901	123.4099329	1.08	0	1.1664		5-Year
215	10.95403	123.3618145	4.70	0	22.09		5-Year
216	10.88718	123.4132905	6.36	0	40.4496		5-Year
217	10.94763	123.4148646	0.03	1	0.9409	Yolanda/ November 2-11, 2013	5-Year
218	10.93618	123.4218418	2.02	0.18	3.3856	Yolanda/ November 2-11, 2013	5-Year
219	10.95537	123.3622837	0.00	1	1	Ruby/December 6-7, 2014	5-Year
220	10.90032	123.3698211	0.13	1.5	1.8769		5-Year
221	10.87358	123.3409052	1.26	0	1.5876		5-Year
222	10.88663	123.4126754	3.85	0	14.8225		5-Year
223	10.88559	123.4155922	9.91	0	98.2081		5-Year
224	10.89121	123.4149052	7.35	0	54.0225		5-Year
225	10.94175	123.4263453	0.09	0	0.0081	Yolanda/ November 2-11, 2013	5-Year
226	10.94381	123.4232168	0.04	0	0.0016		5-Year
227	10.93502	123.4224829	0.75	1.22	0.2209	Yolanda/ November 2-11, 2013	5-Year
228	10.94338	123.4248985	0.03	0	0.0009		5-Year
229	10.95766	123.3838976	0.04	0.43	0.1521	Yolanda/ November 2-11, 2013	5-Year
230	10.9434	123.4187944	1.05	0.43	0.3844	Yolanda/ November 2-11, 2013	5-Year
231	10.89648	123.4148746	2.44	0	5.9536		5-Year
232	10.95714	123.3704565	0.00	0	0		5-Year
233	10.95632	123.3611062	2.73	0	7.4529		5-Year
234	10.89286	123.4126843	1.00	0	1		5-Year
235	10.9419	123.4239126	0.06	0.94	0.7744		5-Year
236	10.95734	123.37657	0.00	0	0		5-Year
237	10.88541	123.416213	4.13	0	17.0569		5-Year
238	10.94599	123.4206997	1.10	0	1.21		5-Year
239	10.88727	123.3527191	0.03	0	0.0009		5-Year
240	10.89034	123.3559081	0.08	0	0.0064		5-Year
241	10.88543	123.4139001	0.06	0	0.0036		5-Year
242	10.94451	123.4253982	0.03	0	0.0009		5-Year
243	10.92607	123.370525	0.03	1	0.9409		5-Year
244	10.92209	123.3734647	0.08	1	0.8464		5-Year
245	10.91786	123.375687	0.73	1	0.0729		5-Year

Annex 12. Educational Institutions Affected in Himogaan-Tanao Floodplain

Negros Occidental				
Sagay City				
Barangay	Building Name	Rainfall Scenario		
		5-year	25-year	100-year
Fabrica	Faraon Institute			
Fabrica	Gil Lopez Elementary School			
Fabrica	TLRC Building			
Himogaan Baybay	Fabrica Elementary School			
Himogaan Baybay	Himogaan Integrated School			
Himogaan Baybay	Holy Family School			
Himogaan Baybay	Josebio Gonzaga Elementary School		High	High
Himogaan Baybay	Paraiso Day Care		High	High
Malubon	Filomeno Pascual Elementary School		Medium	High
Malubon	Uychiat Elementary School			
Paraiso	Eusebio Lopez Integrated School			
Paraiso	Josebio Lopez Gonzaga Memorial Extension			
Paraiso	Ricardo Gamboa Elementary School			

Annex 13. Medical Institutions Affected in Himogaan-Tanao Floodplain

Negros Occidental				
Sagay City				
Barangay	Building Name	Rainfall Scenario		
		5-year	25-year	100-year
Himogaan Baybay	Paraiso Health Center		High	High

Annex 14. UPC Phil-LiDAR 1 Team Composition

Project Leader
Jonnifer R. Sinogaya, PhD.

Chief Science Research Specialist
Chito Patiño

Senior Science Research Specialists
Christine Coca
Jared Kislev Vicentillo

Research Associates
Isabella Pauline Quijano
Jarlou Valenzuela
Rey Sidney Carredo
Mary Blaise Obaob
Rani Dawn Olavides
Sabrina Maluya
Naressa Belle Saripada
Jao Hallen Bañados
Michael Angelo Palomar
Glory Ann Jotea