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

LiDAR Surveys and Flood Mapping of Imbang River

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

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LIST OF ACRONYMS AND ABBREVIATIONS

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

CHAPTER 1: OVERVIEW OF THE PROGRAM AND IMBANG RIVER

Enrico C. Paringit, Dr. Eng. and Jonnifer R. 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 in 2014 entitled "Nationwide Hazard Mapping using LiDAR" or Phil-LiDAR 1, supported by the Department of Science and Technology (DOST) Grants-in-Aid (GiA) Program. The program was primarily aimed at acquiring a national elevation and resource dataset at sufficient resolution to produce information necessary to support the different phases of disaster management. Particularly, it targeted to operationalize the development of flood hazard models that would produce updated and detailed flood hazard maps for the major river systems in the country.

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

The implementing partner university for the Phil-LiDAR 1 Program is the University of the Philippines Cebu (UPC). UPC is in charge of processing LiDAR data and conducting data validation reconnaissance, cross section, bathymetric survey, validation, river flow measurements, flood height and extent data gathering, flood modeling, and flood map generation for the 22 river basins in the Western Visayas Region. The university is located in Cebu City in the province of Cebu.

1.2 Imbang River Basin

Imbang River Basin is located in the province of Negros Occidental located at the midwest of Negros Island. The floodplain and drainage area of 163.02 km2 and 144.762 km2 respectively covers the cities of Silay and Talisay. The DENR River Basin Control Office (RBCO) identified it to be as one of the 140 critical watersheds in the Philippines, having an estimated 191 million cubic meter annual run-off. The floodplain is 100% covered with LiDAR data which compromises 3 blocks. The LiDAR data was calibrated then mosaicked with an RMSE of -0.07 and then bathy burned. The bathy survey conducted reached a total length of 14.16 km starting from E. Lopez, Silay City up to the river mouth with 10917 points surveyed. There are 23099 buildings, 439.48 roads, 859 waterbodies and 24 bridges digitized based from the LiDAR data. Feature Extraction Attribution was conducted and among the building features, 22364 of them are Residential, 260 are schools and 10 are Medical Institutions.

Its main stem, Imbang River, is among the twenty-four (24) river system in Eastern Visayas Region. There is a total of 30,223 people living in the nearby barangays of the upstream and downstream portions of Imbang River according to the 2010 census conducted by the NSO. Sugar is the primary agricultural product in the city, with sugarcane plantations occupying most of the lands. The river is close to Hacienda Calasa, one of the oldest sugarcane plantations in Negros Occidental. On the other hand, coastal areas are mainly used as fishing grounds.

The flood hazard map produced covers the 60.40km2, 97.24km2, 115.17km2 for the 5-year, 25-year, and 100 year rainfall return period inSilay City which affects 15 barangays, inEB Magalona which affects 21 barangays, inManapla which affects 1 barangay, inVictorias City which affects 24 barangays and inTalisay City which affects 1 barangay.A flood depth validation was conducted using 270 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 a0.830m RMSE.

A rating curve was developed at La Purisima Bridge, Silay City, Negros Occidental, which shows the relationship between the observed water levels at La Purisima Bridgeand outflow of the watershed at this location. This rating curve equation, expressed as $Q = 0.004e^{0.7057x}$, was used to compute the river outflow at La Purisima Bridgefor 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.

On September 2011, the flashflood in Negros Occidental caused by Typhoon Pedring claimed the lives of two (2) persons who died of drowning at Imbang River in Hacienda Makina, Brgy. Rizal, Silay City while strong winds destroyed seven houses. Tropical Storm Basyang hit Negros Occidental on February 2014, which forced thousands of families affected by floods to reside at evacuation centers. In Silay City, 738 families were affected, while two (2) houses were reported destroyed and 55 were damaged.

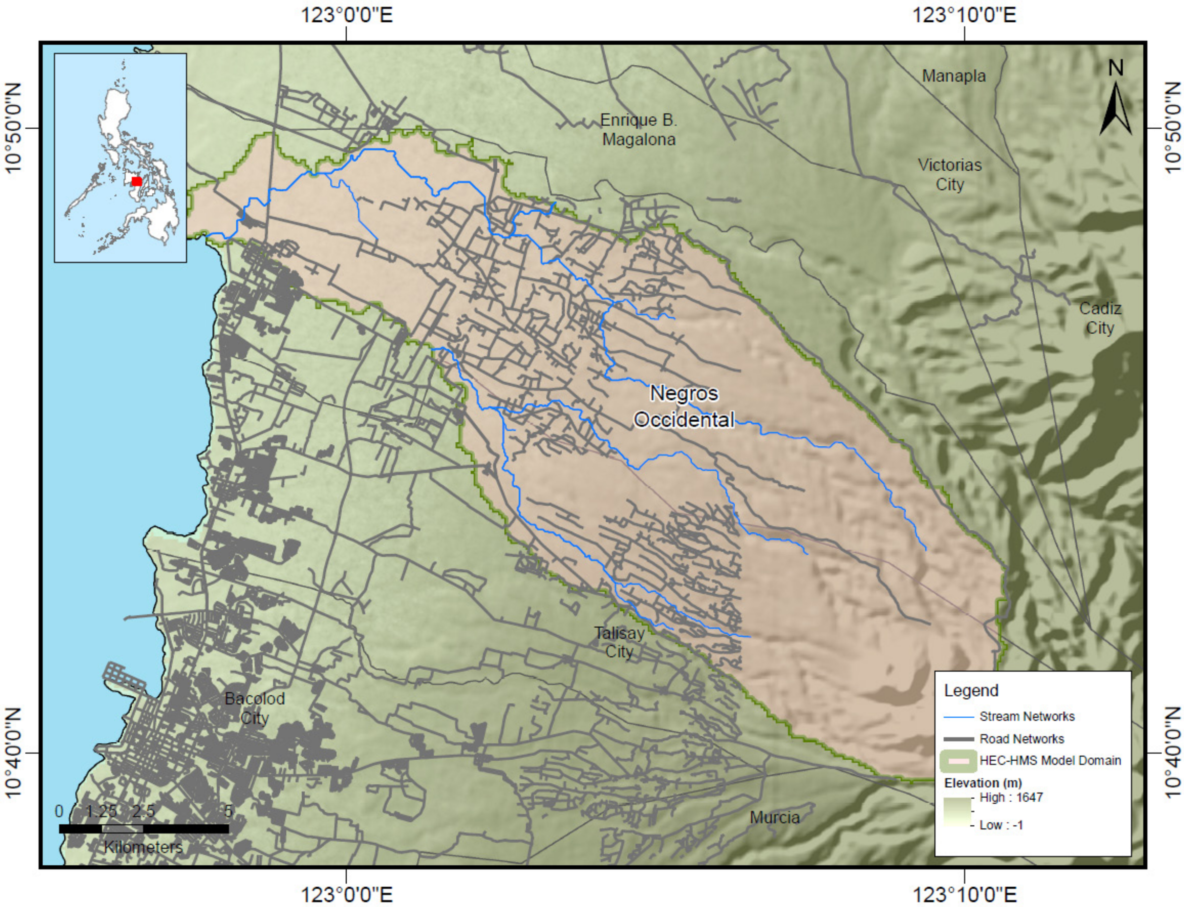


Figure 1. Map of Imbang River Basin (in brown)

CHAPTER 2: LIDAR ACQUISITION IN IMBANG 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 Imbangfloodplain in Negros Occidental. These missions wereplanned for17lines and ran for at most fourand a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR system used in the LiDAR system are found inTable 1.Figure 2 shows the flight plan for Imbangfloodplain.

Table 1. 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)
BLK44AB	1000	30	50	200	30	130	5
BLK44C	1000	30	50	200	30	130	5
BLK44A	1000	30	50	200	30	130	5

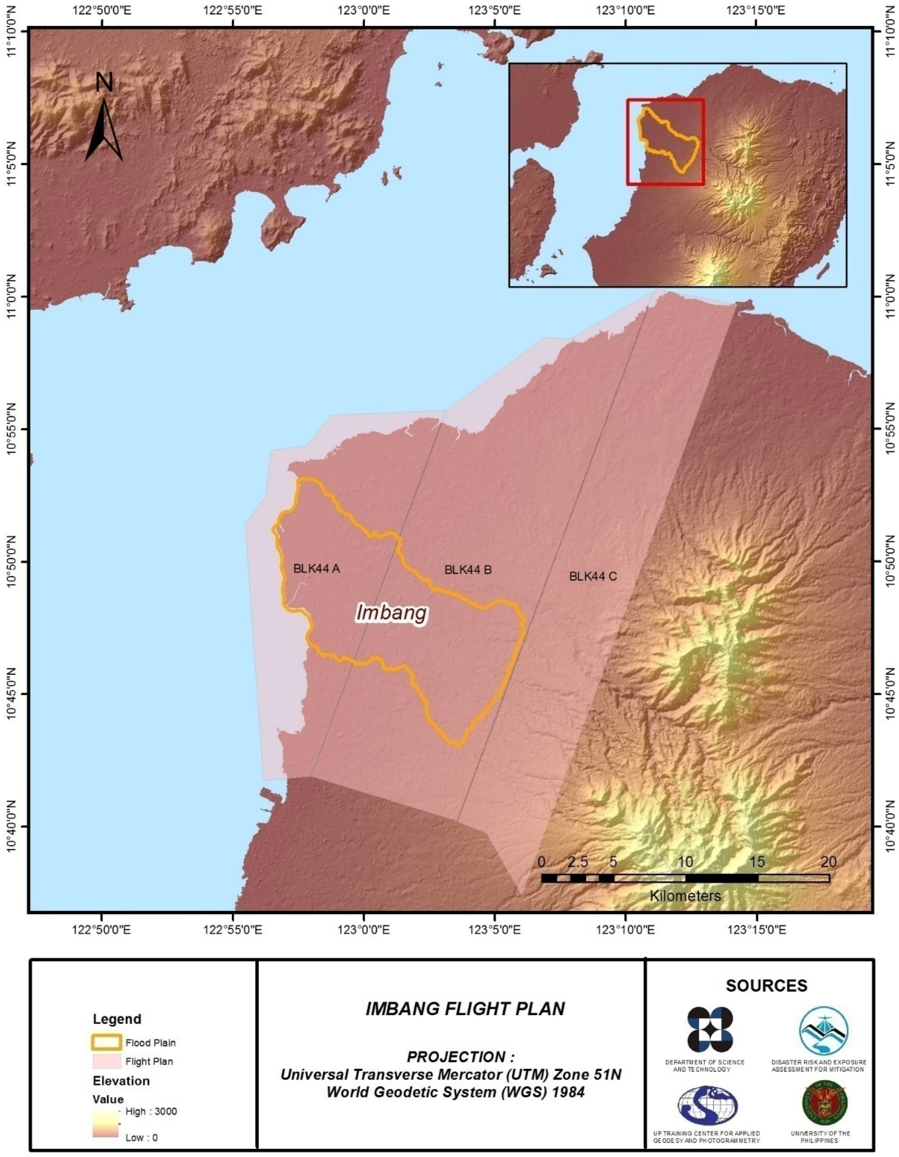


Figure 2. Flight plan used to for Imbang floodplain

2.2 Ground Base Station

The project team was able to recover two (2) NAMRIA ground control points,NGW-55 and NGW-80, which are of second (2nd) order accuracy, and one (1) NAMRIA benchmark, NW-207, which is of first (1st) order accuracy.NW-207 was used as vertical reference point and was also established as ground control point. The certification for the NAMRIA reference points are found in Annex C while the baseline processing report for the NW-207is found in Annex D. These ground control points were used as base stations during flight operations for the entire duration of the survey (April 26, 2014 and October 2, 2015). Base stations were observed using dual frequency GPS receivers, Trimble SPS 852 and SPS 882. Flight plans and location of base stations used during the aerial LiDAR data acquisition in Imbang floodplain are shown in Figure 3.

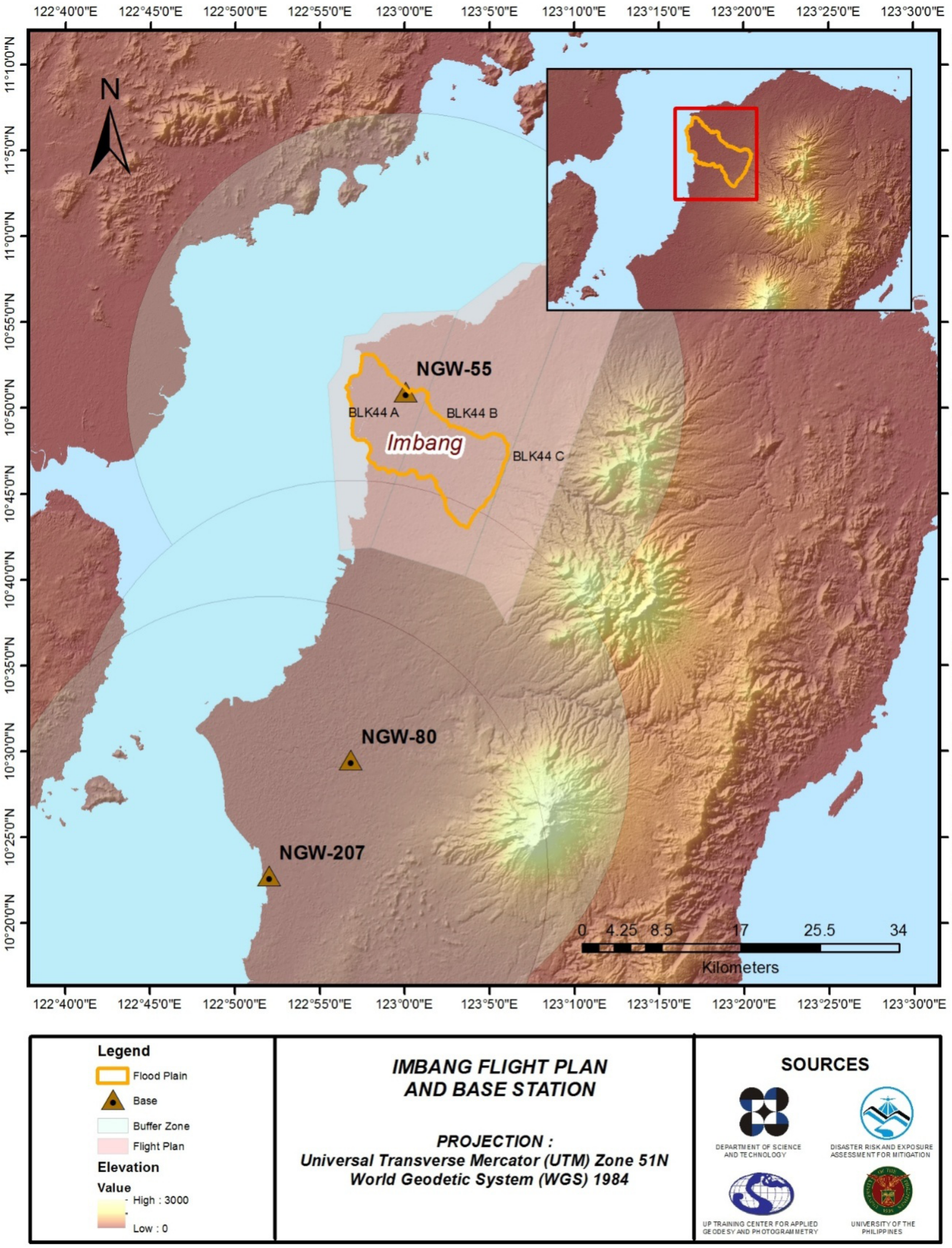


Figure 3. Flight plans and base station for Imbang floodplain

Figure 4 to 6 shows the recovered NAMRIA reference points within the area.In addition,Table 2to 4 show the details about the recovered NAMRIA reference points, Table 5 shows the list of all ground control points occupied during the acquisition together with the corresponding survey dates.

(a) (b)

Figure 4. GPS set-up (a) over NGW-55, positioned about 9 km from the junction of national highway and the road heading to sugar central, located at Brgy. Tanza, E.B. Magalona, Negros Occidental, and NAMRIA reference point NGW-55 (b) as recovered by the field team.

Table 2. Details of the recovered NAMRIA horizontal control point NGW-55 used as base station for the LiDAR data acquisition.

Station Name	NGW-55	
Order of Accuracy	2rd	
Relative Error (horizontal positioning)	1 : 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 51’ 0.88734” North 122° 59’ 57.75865” East 12.016 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	1199766.082 meters 499931.926 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 50’ 56.54743” North 123° 0’ 2.96548” East 70.280 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	499931.95 meters 1199346.14 meters

(a)

(b)

Figure 5. GPS set-up (a) over NGW-80 located at the sidewalk of Quezon Bridge in Brgy. Ma-ao, Negros Occidental, and NAMRIA reference point NGW-80 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point NGW-80 used as base station for the LiDAR data acquisition.

Station Name	NGW-80	
Order of Accuracy	2rd	
Relative Error (horizontal positioning)	1 : 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 29’ 35.8609” North 122° 56’ 43.79550” East 30.72 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	494033.975 meters 1160287 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 29’ 31.60669” North 122° 56’ 49.03425” East 89.691 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	494036.06 meters 1159881.54 meters

(a) (b)

Figure 6. GPS set-up (a) over NW-207, positioned on concrete sidewalk at Ponteverda Bridge, located in Brgy. San Juan, Ponteverda, Negros Occidental, and NAMRIA benchmark NW-207 (b) as recovered by the field team.

Table 4. Details of the recovered NAMRIA vertical reference pointNW-207 used as base station for the LiDAR data acquisition.

Station Name	NW-207	
Order of Accuracy	2rd	
Relative Error (horizontal positioning)	1 : 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 22' 49.75933" North 122° 51' 55.33813" East 30.720 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 22' 45.52680" 122° 52' 0.58746" 67.481 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	485262.641 meters 1147412.335 meters

Table 5. Ground control points used during LiDAR data acquisiton

Date Surveyed	Flight Number	Mission Name	Ground Control Points
April 26, 2014	1391P	1BLK44CB115A	NGW-55
April 26, 2014	1393P	1BLK44AB115B	NGW-55
October 2, 2015	10007	1BLK44LMSCALIB275A	NGW-80 and NW-207

2.3 Flight Missions

Three (3) missions were conducted to complete LiDAR data acquisition in Imbang Floodplain, for a total of thirteen hours and nine minutes (13+9) of flying time for RP-C9022 and RP-C9522. All missions were acquired using the Pegasus LiDAR system. Table 6shows the total area of actual coverage per mission with the corresponding flight duration, while Table 7 presents the actual parameters used during the LiDAR data acquisition.

Table 6. Flight missions for LiDAR data acquisition in Imbangfloodplain

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
April 26, 2014	1391P	176.78	325.12	37.47	287.66	0	4	23
April 26, 2014	1393P	474.56	426.54	114.26	312.33	0	4	23
October 2, 2015	10007P	210.54	90.18	0	90.18	1	4	23
TOTAL		651.34	751.66	151.73	690.17	1	13	9

Table 7. 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)
1391P	1000	30	50	200	30	130	5
1393P	1200	15	50	200	30	130	5
10007P	1000	30	50	200	30	130	5

2.4 Survey Coverage

Imbang floodplain is located in the province of Negros Occidental with majority of the floodplain situated within the city of Silay. The municipality of Enrique B. Magalona and Talisay City 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 8. The actual coverage of the LiDAR acquisition for Malagofloodplain is presented in Figure 7.

Table 8. List of municipalities and cities surveyed during Imbang floodplain LiDAR survey

Province	Municipality/City	Area of Municipality/ City(km^2)	Total Area Surveyed(km^2)	Percentage of Area Surveyed
Negros Occidental	Manapla	99.18	92.24	93%
	Enrique B. Magalona	140.32	116.97	83%
	Victorias City	103.55	78.26	76%
	Silay City	196.52	147.32	75%
	Talisay City	199.01	108.56	55%
	Valladolid	40.37	18.72	46%
	Bacolod City	152.24	52.12	34%
	Pulupandan	16.13	3.09	19%
	Bago	350.91	24.00	7%
	Cadiz City	516.18	33.42	6%
	Murcia	364.20	3.15	1%

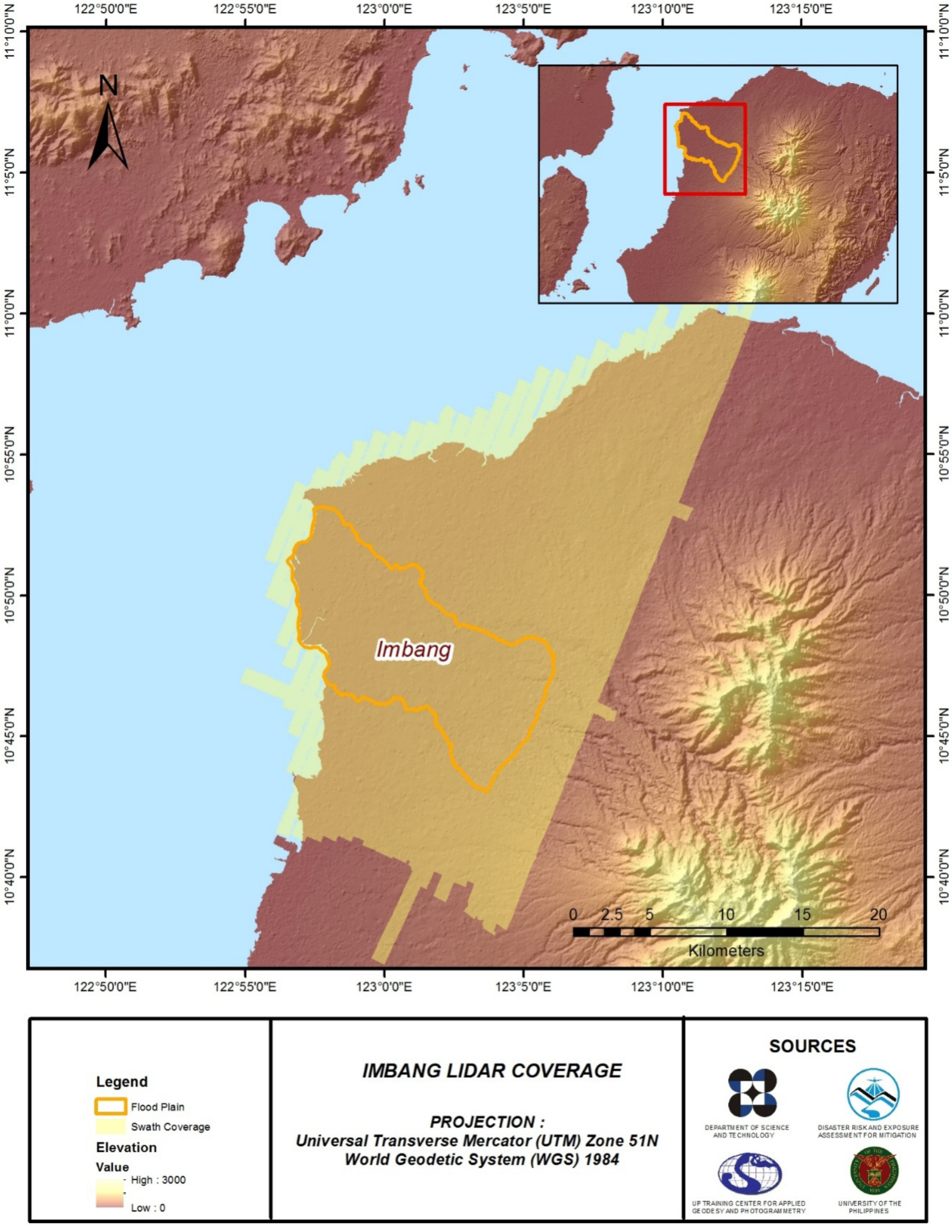


Figure 7. Actual LiDAR survey coverage for Imbang floodplain

CHAPTER 3: LIDAR DATA PROCESSING FOR IMBANG 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

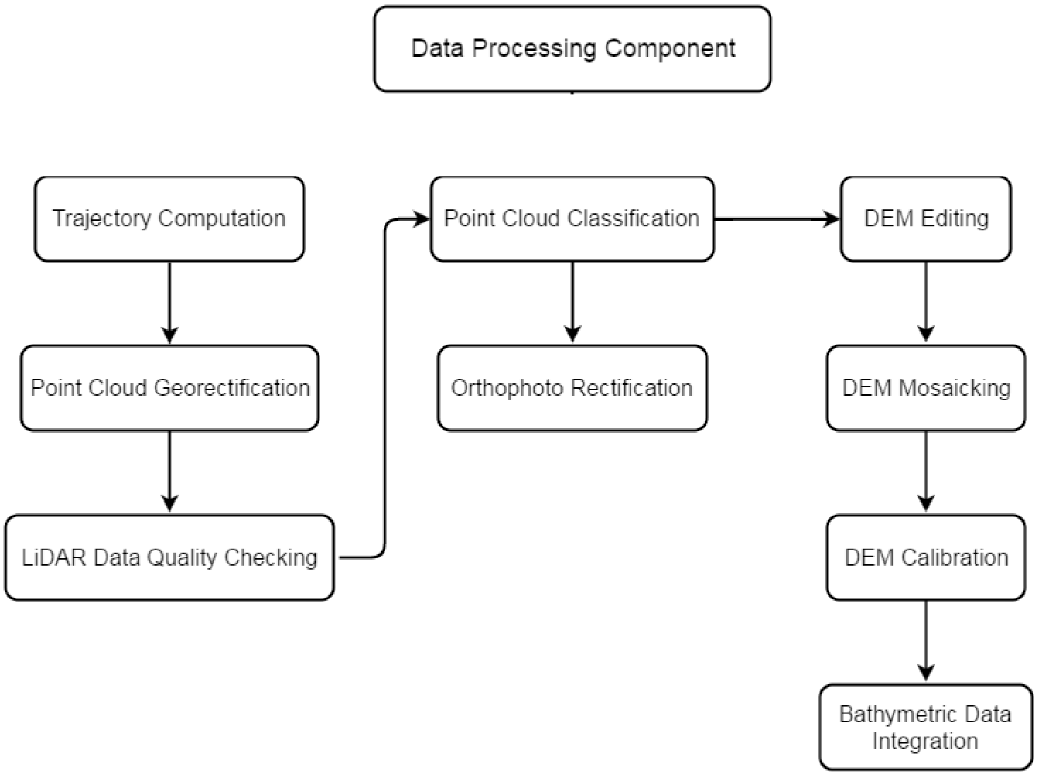


Figure 8. Schematic Diagram for Data Pre-Processing Component

3.1 Overview of the LiDAR Data Pre-Processing

The data transmitted by the Data Acquisition Component are checked for completeness based on the list of raw files required to proceed with the pre-processing of the LiDAR data. Upon acceptance of the LiDAR field data, georeferencing of the flight trajectories 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 8.

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Imbang floodplain can be found in Annex A-5. Missions flown for all the surveys conducted used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system over Negros Occidental. The Data Acquisition Component (DAC) transferred a total of 80.9 Gigabytes of Range data, 0.78 Gigabytes of POS data, 30.31 Megabytes of GPS base station data, and

150.46 Gigabytes of raw image data to the data server on April 26, 2014 for the first survey and October2, 2015 for the last survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Imbang was fully transferred on November03, 2015, as indicated on the Data Transfer Sheets for Imbang floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 1393P, one of the Imbang flights, which is the North, East, and Down position RMSE values are shown in Figure 9. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on April 27, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

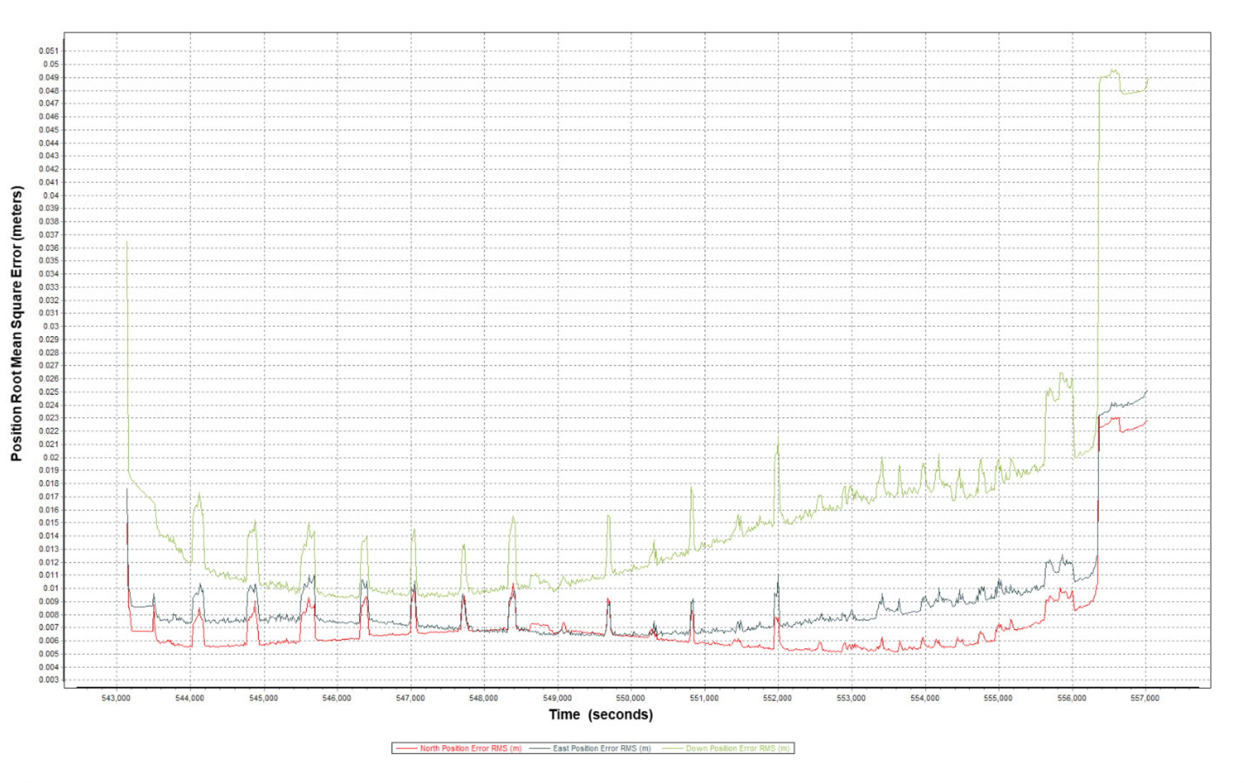


Figure 9. Smoothed Performance Metrics of Imbang Flight 1393P.

The time of flight was from 543000 seconds to 557000 seconds, which corresponds to afternoon of April 27, 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 9 shows that the North position RMSE peaks at 1.10 centimeters, the East position RMSE peaks at 1.30 centimeters, and the Down position RMSE peaks at 2.70 centimeters, which are within the prescribed accuracies described in the methodology.

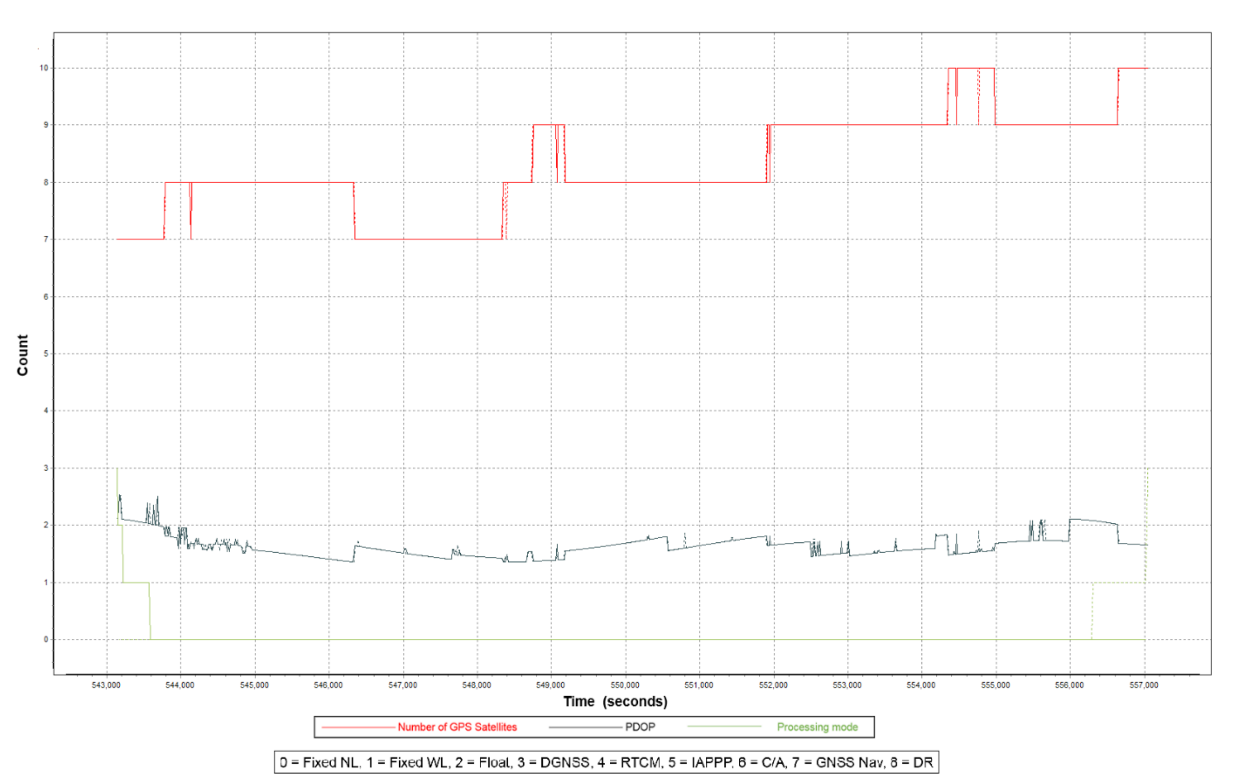


Figure 10. Solution Status Parameters of Imbang Flight 1393P.

The Solution Status parameters of flight 1393P, one of the Imbang flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 10. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Majority of the time, the number of satellites tracked was between 7 and 10. 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 Imbang flights is shown in Figure 11.

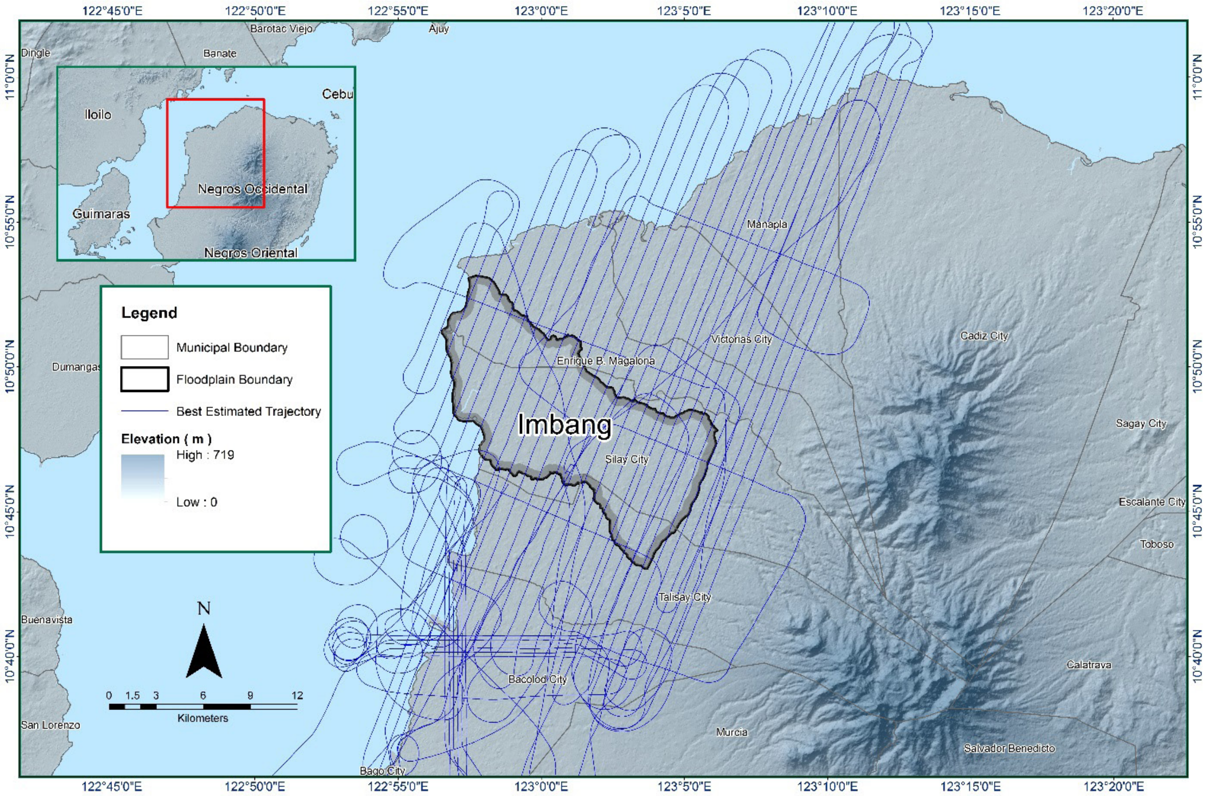


Figure 11. Best Estimated Trajectory for Imbang Floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 35 flight lines, with each flight line containing two channels, since the Pegasus system contains two channels. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Imbang floodplain are given in Table 9.

Table 9. Self-Calibration Results values for Imbang flights.

Parameter	Acceptable Value	Computed Value
Boresight Correction stdev	(<0.001degrees)	0.000499
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.000966
GPS Position Z-correction stdev	(<0.01meters)	0.0085

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

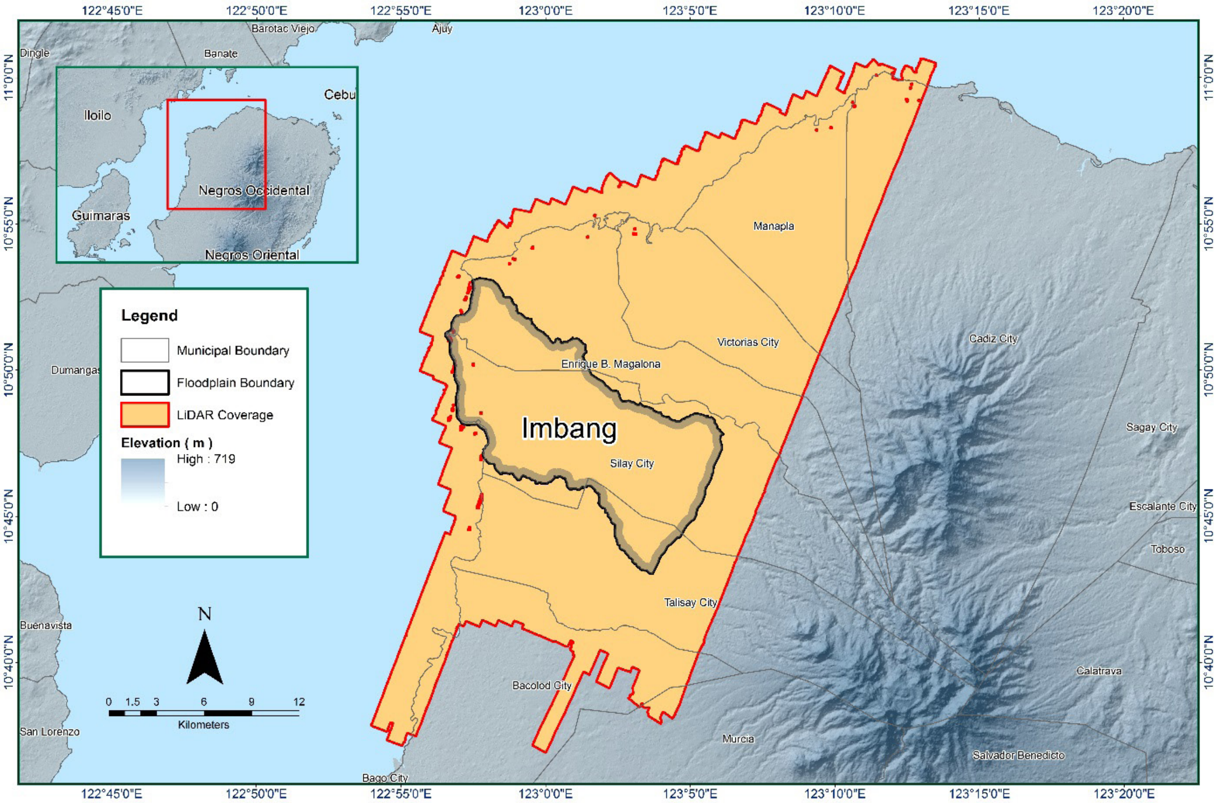


Figure 12. Boundary of the processed LiDAR data over Imbang Floodplain

The total area covered by the Imbang missions is 774.14 sq.km that is comprised of three (3) flight acquisitions grouped and merged into three (3) blocks as shown in Table 10.

Table 10. List of LiDAR blocks for Imbang floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Negros_Blk44AB	1393P	416.93
Negros_Blk44C	1391P	320.38
NegrosOccidental_reflights_Blk44A	10007P	36.83
TOTAL		**774.14 sq.km**

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 13. Since the Pegasus system employs two channels, we would expect an 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.

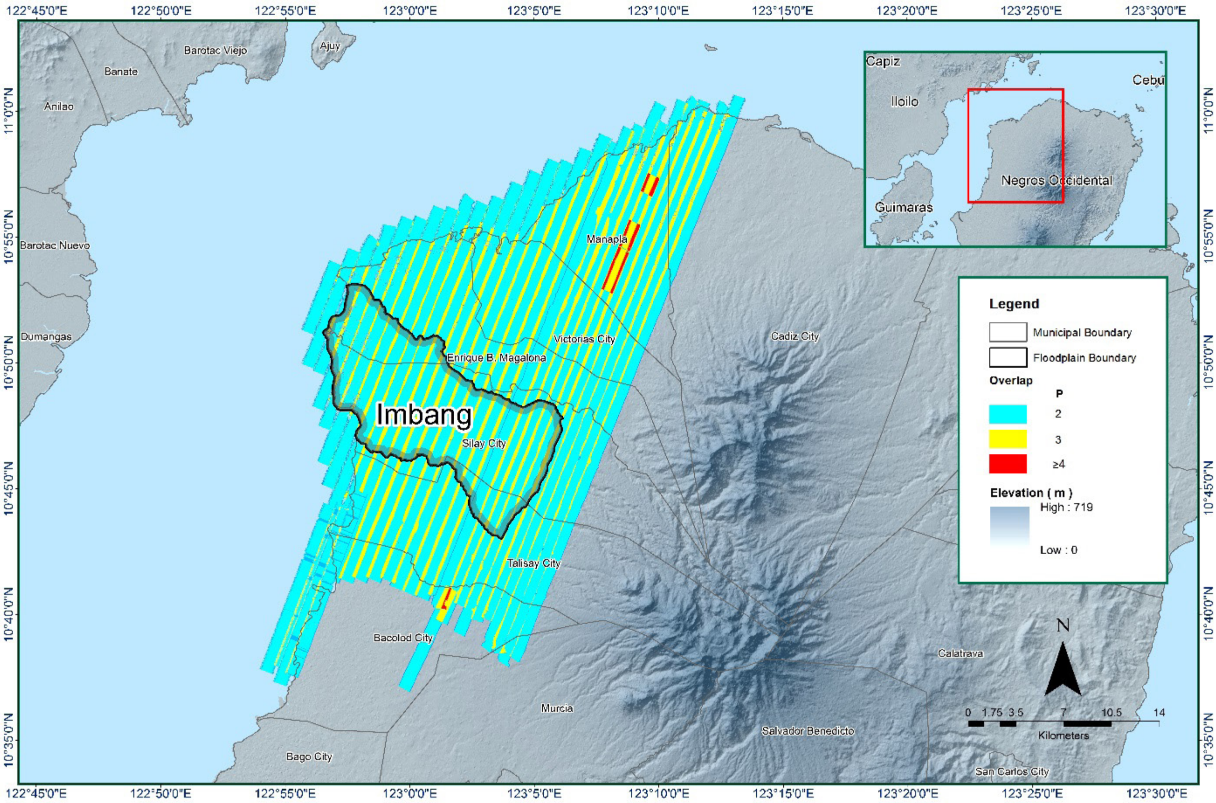


Figure 13. Image of data overlap for Imbang floodplain.

The overlap statistics per block for the Imbang 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 10.94% and 26.54% respectively.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 14. It was determined that all LiDAR data for Imbang floodplain satisfy the point density requirement, and the average density for the entire survey area is 1.77points per square meter.

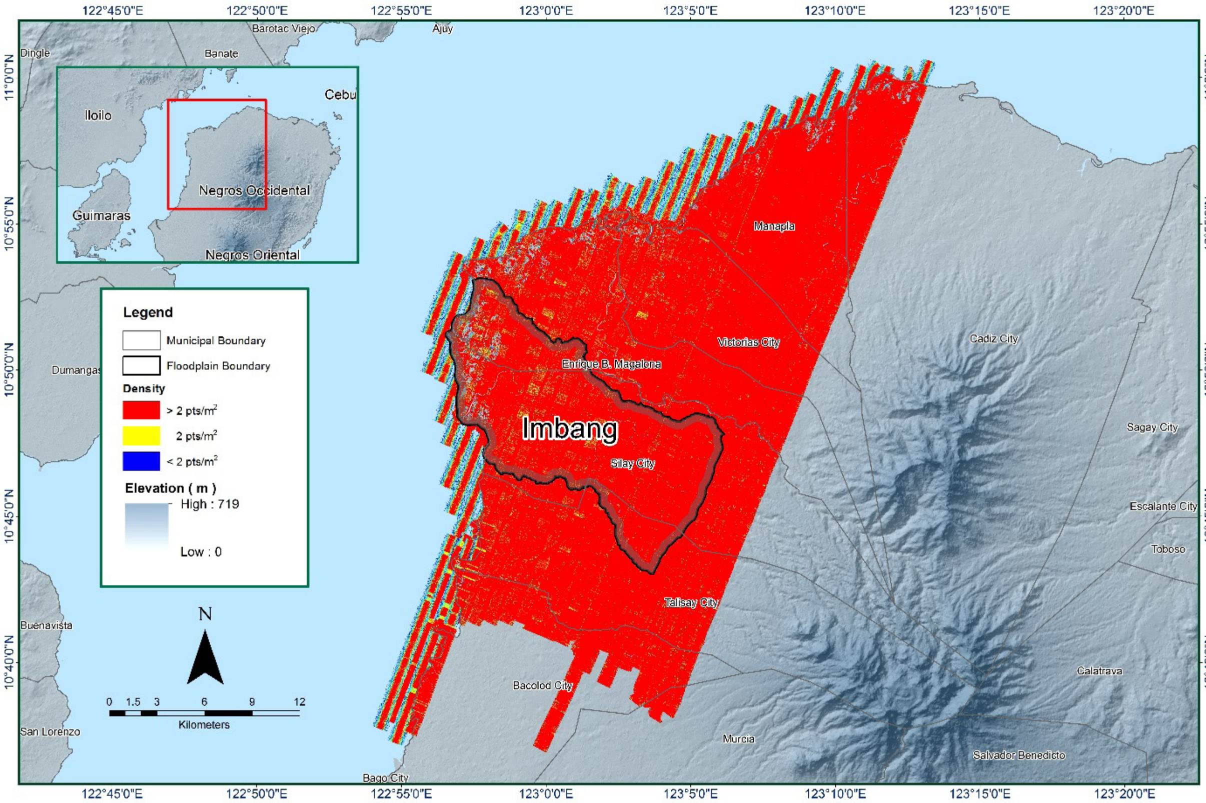


Figure 14. Pulse Density map of merged LiDAR data for Imbang floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 15. The default color range is from blue to red, where bright blue areas correspond to portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.20m 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.

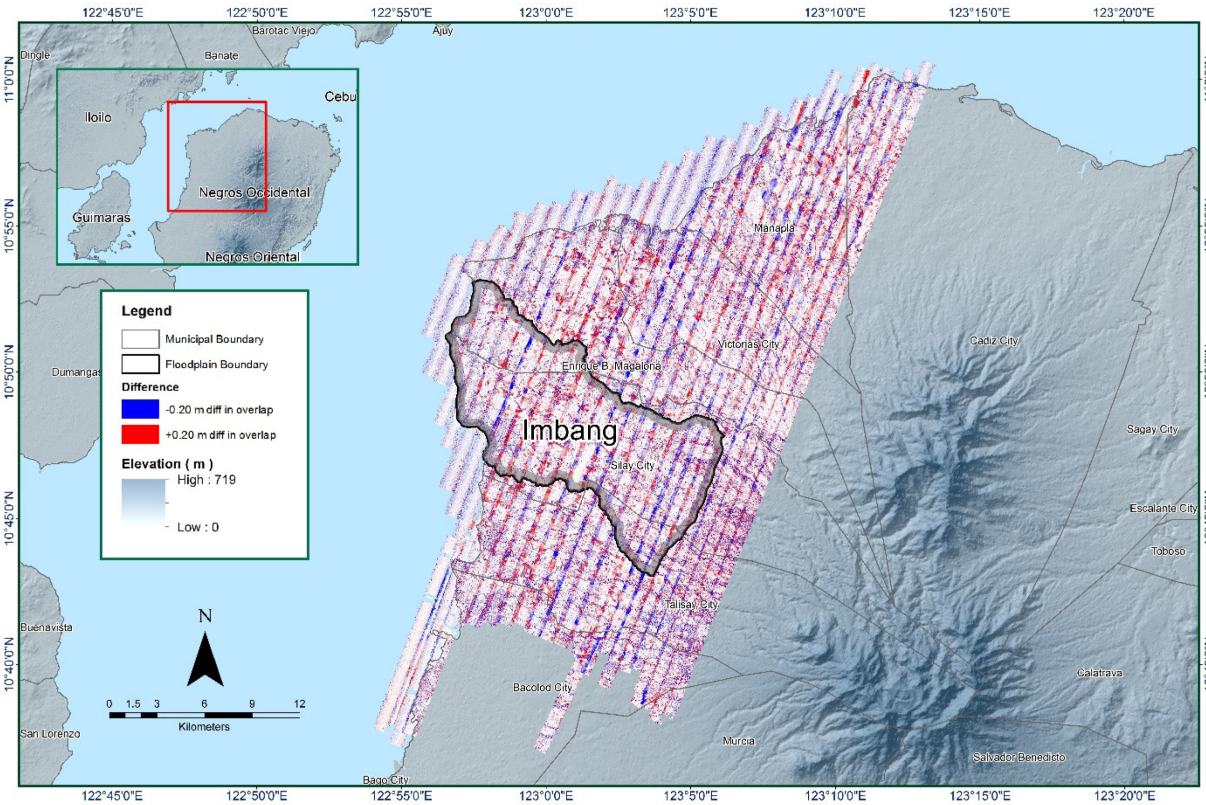


Figure 15. Elevation difference map between flight lines for Imbang floodplain.

A screen capture of the processed LAS data from Imbang flight 1393P loaded in QT Modeler is shown in Figure 16. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

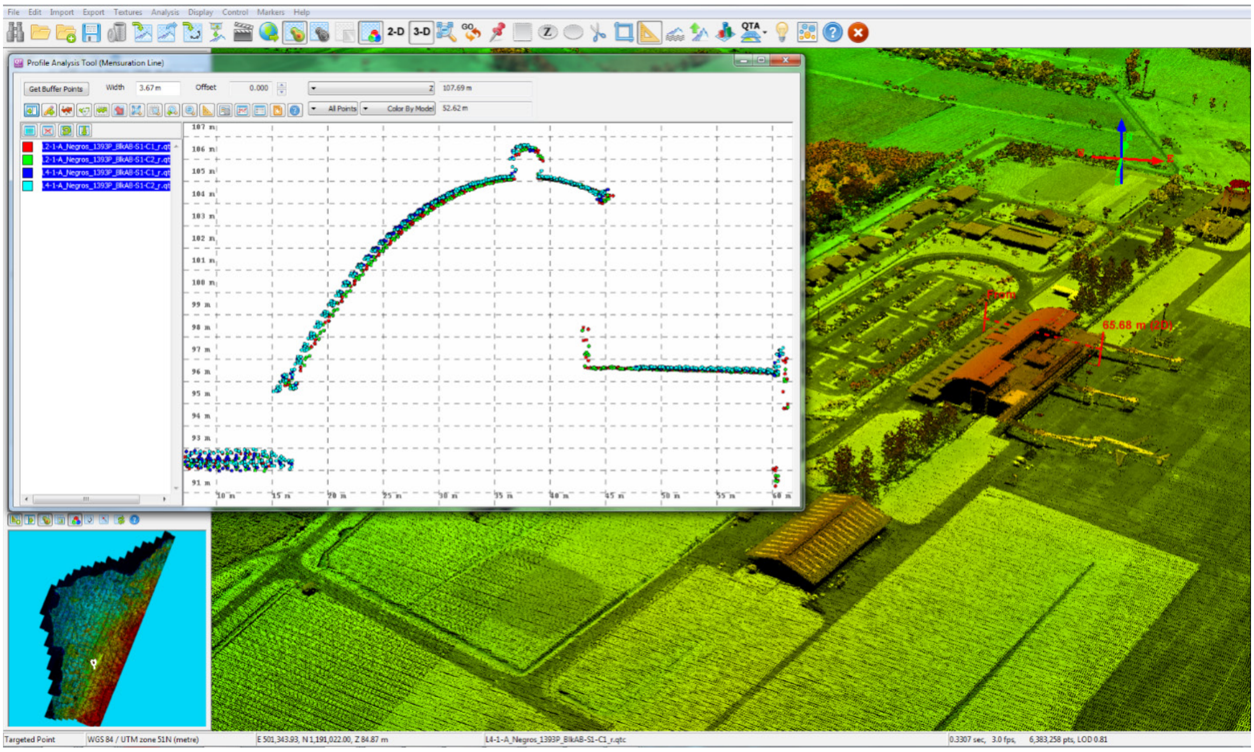


Figure 16. Quality checking for Imbang flight 1393P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 11. Imbang classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	735,992,105
Low Vegetation	626,681,839
Medium Vegetation	762,842,520
High Vegetation	175,462,702
Building	207,909,147

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Imbang floodplain is shown in Figure 17. A total of 958 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 11. The point cloud has a maximum and minimum height of 395.70 meters and 49.66 meters respectively.

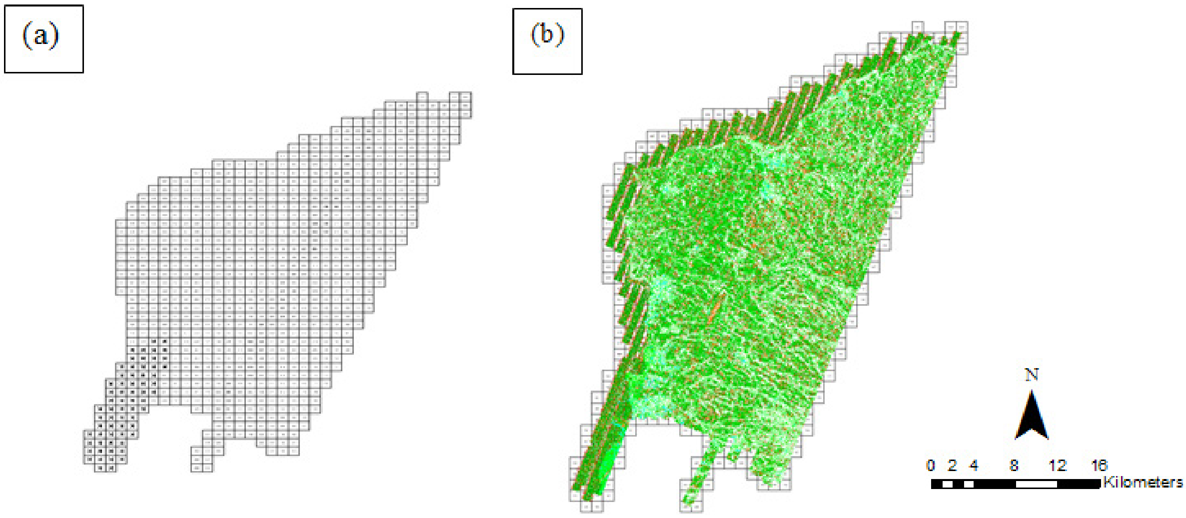


Figure 17. Tiles for Imbang floodplain (a) and classification results (b) in TerraScan.

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

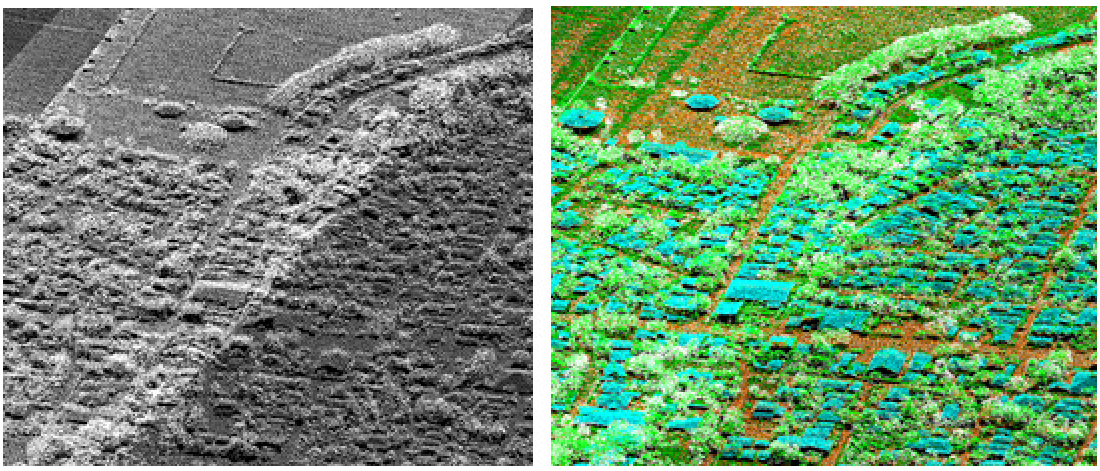


Figure 18. Point cloud before (a) and after (b) classification.

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

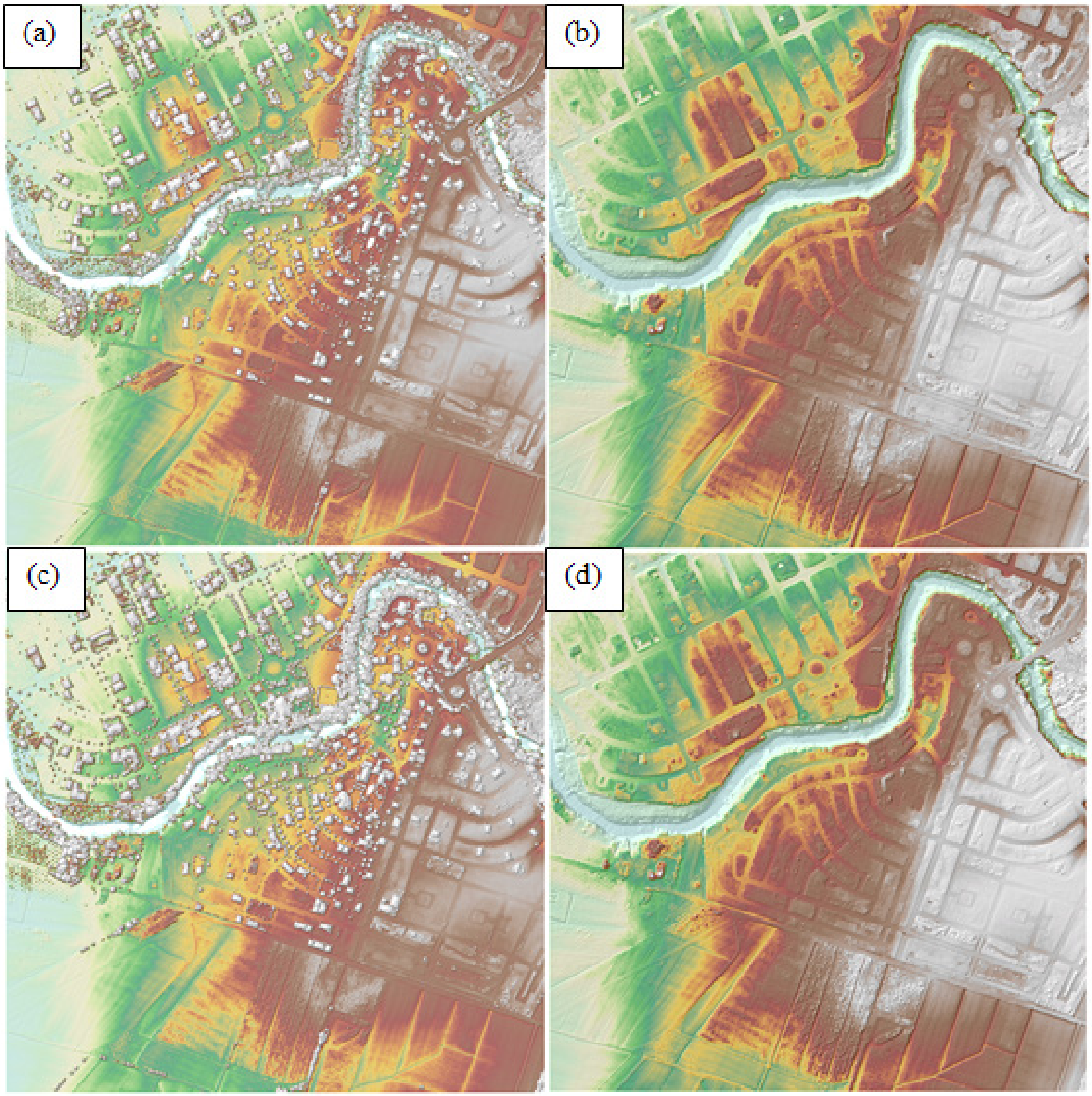


Figure 19. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Imbang floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 899 1km by 1km tiles area covered by Imbang floodplain is shown in Figure 20. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Imbang floodplain has a total of 720.24 sq.km orthophotograph coverage comprised of 1,482 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 21.

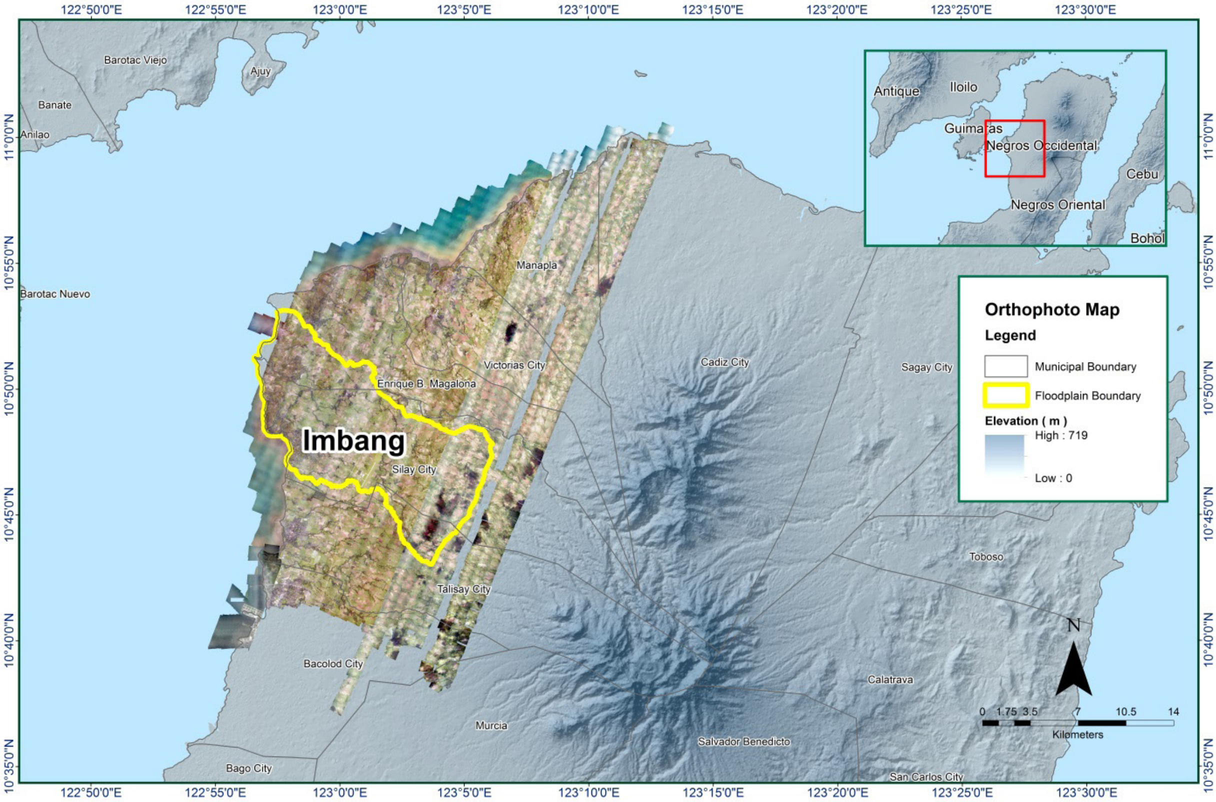


Figure 20. Imbang floodplain with available orthophotographs.

Figure 21. Sample orthophotograph tiles for Imbang floodplain.

3.8 DEM Editing and Hydro-Correction

Three (3) mission blocks were processed for Imbang flood plain. These blocks are composed of Negros and Negros Occidental reflightsblocks with a total area of 774.14 square kilometers. Table 12 shows the name and corresponding area of each block in square kilometers.

Table 12. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq.km)
Negros_Blk44AB	416.93
Negros_Blk44C	320.38
NegrosOccidental_reflights_Blk44A	36.83
TOTAL	**774.14 sq.km**

Portions of DTM before and after manual editing are shown in Figure 22. It shows that the paddy field(Figure 22a) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 22b). The bridges (Figure 22c) would be an impedance to the flow of water along the river and have to be removed (Figure 22d) in order to hydrologically correct the river.Another example is a road that has been misclassified (Figure 22e) and has to be retrieved through manual editing (Figure 22f).

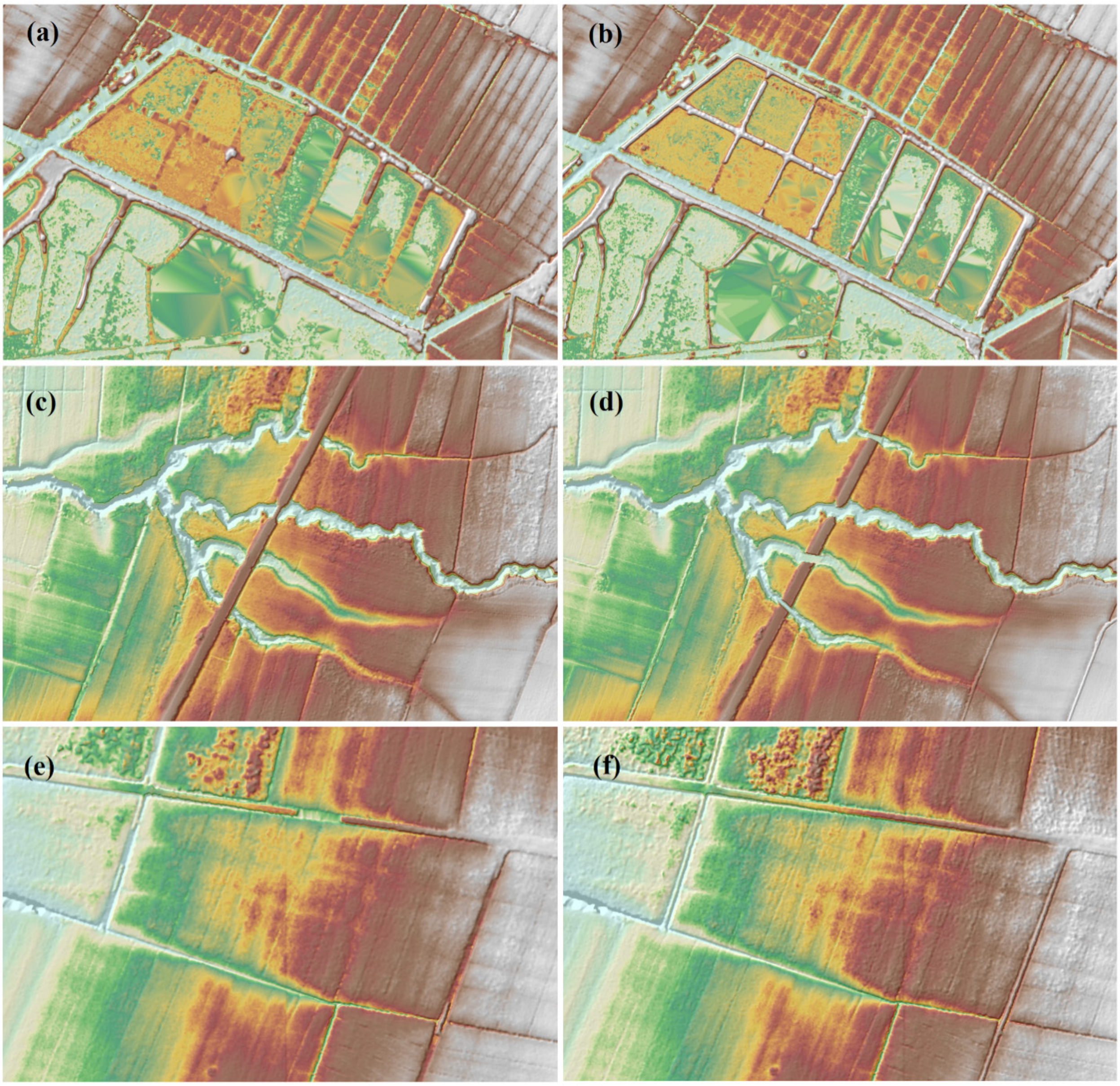


Figure 22. Portions in the DTM of Imbang floodplain – a paddy field before (a) and after (b) data retrieval; bridges before (c) and after (d) manual editing; and a road before (e) and after (f) data retrieval.

3.9 Mosaicking of Blocks

Negros_Blk44AB was used as the reference block at the start of mosaicking because it covers seventy-eight percent (78%) of the total area of Imbang floodplain. Table 13 shows the area of each LiDAR block and the shift values applied during mosaicking.

Mosaicked LiDAR DTM for Imbang floodplain is shown in Figure 23. It can be seen that the entire Imbang floodplain is 100% covered by LiDAR data.

Table 13. Shift Values of each LiDAR Block of Imbang floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Negros_Blk44AB	0.00	0.00	0.00
Negros_Blk44C	0.00	0.00	0.15
NegrosOccidental_reflights_Blk44A	0.00	0.00	0.20

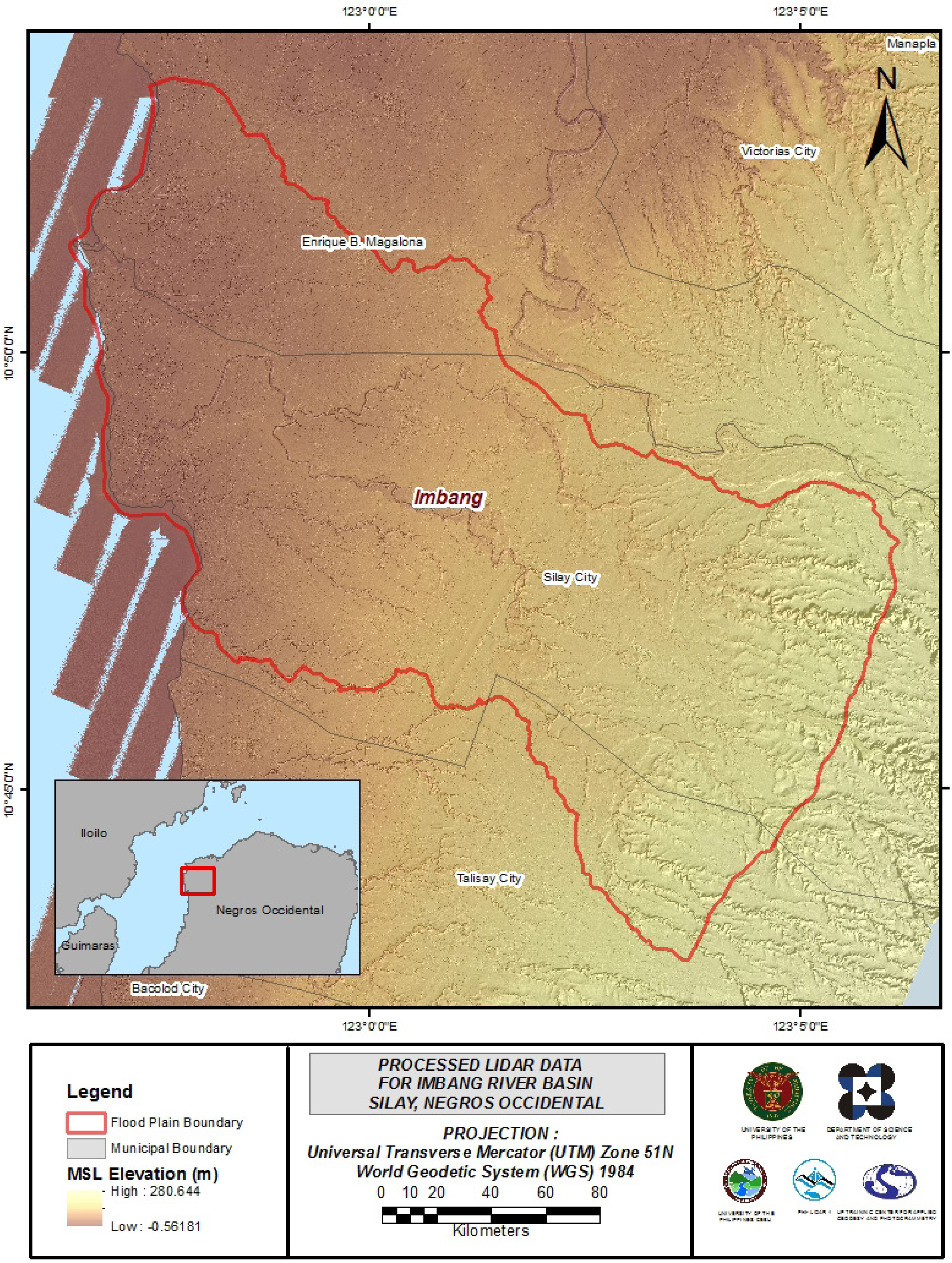


Figure 23. Map of Processed LiDAR Data for Imbang Flood Plain.

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in the Negros Island to collect points with which the LiDAR dataset is validated is shown in Figure 24. A total of 39,705 points were gathered for all the floodplains within the Negros Island wherein the Imbang 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 25. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration elevation values is 0.94 meters with a standard deviation of 0.15 meters. Calibration of Imbang LiDAR data was done by subtracting the height difference value, 0.94 meters, to the mosaicked LiDAR data for Imbang. Table 14 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

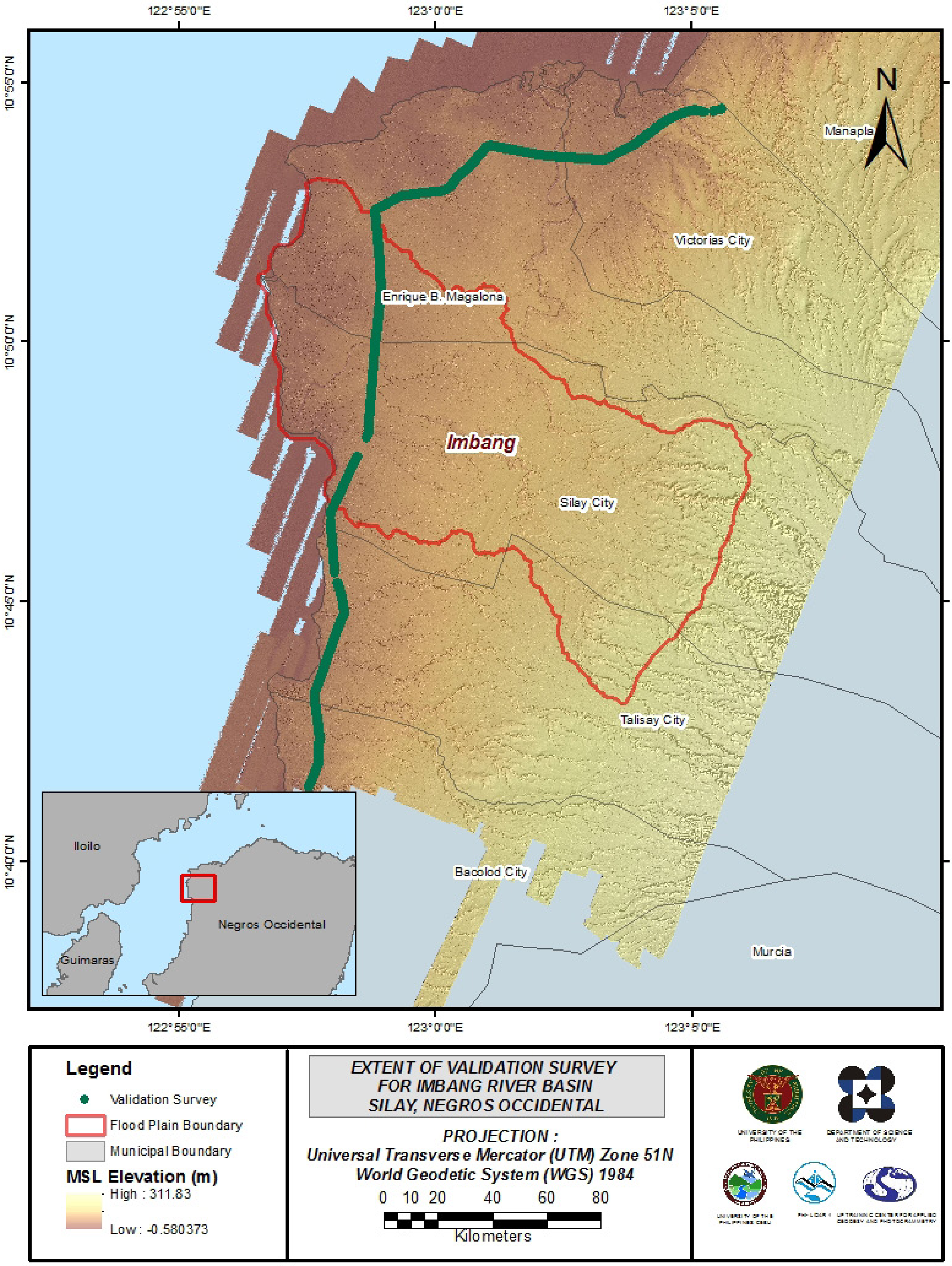


Figure 24. Map of Imbang Flood Plain with validation survey points in green.

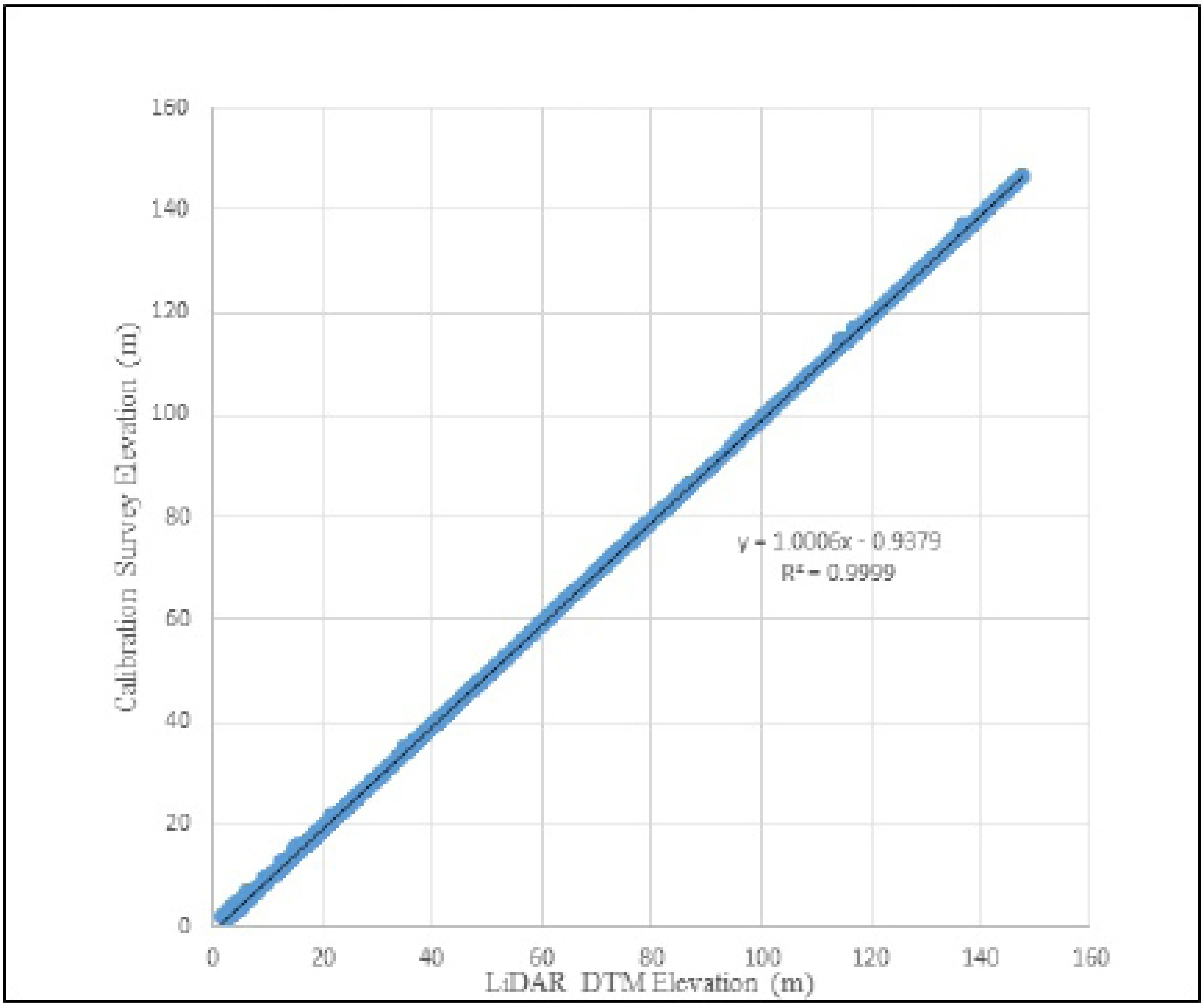


Figure 25. Correlation plot between calibration survey points and LiDAR data.

Table 14. Calibration Statistical Measures.

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

A total of 214 survey points that are within Imbang flood plain were used for the validation of the calibrated Imbang DTM. A good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM is shown in Figure 26. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.08 meters with a standard deviation of 0.07 meters, as shown in Table 15.

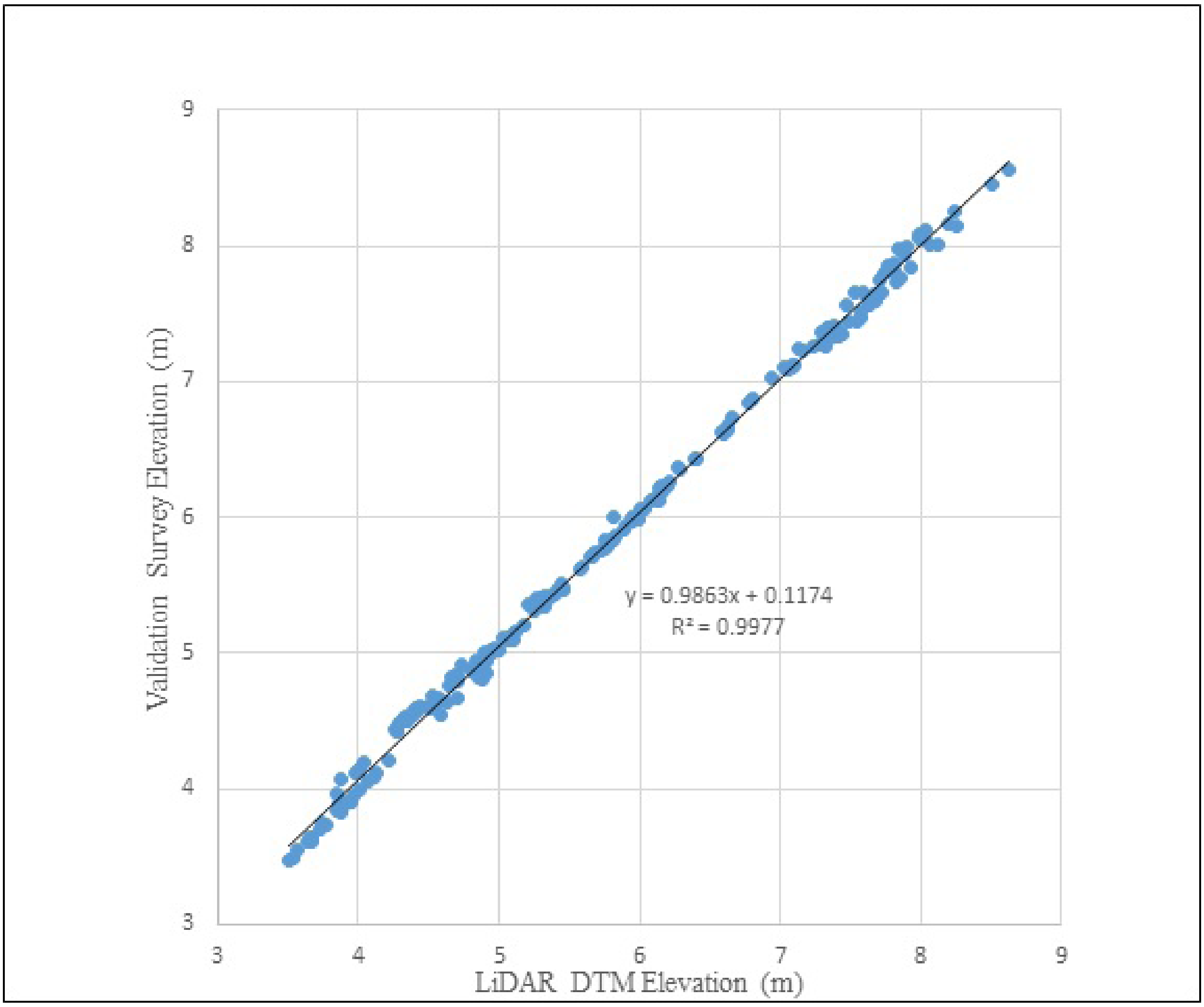


Figure 26. Correlation plot between validation survey points and LiDAR data.

Table 15. Validation Statistical Measures.

Calibration Statistical Measures	Value (m)
RMSE	0.08
Standard Deviation	0.07
Average	0.04
Minimum	-0.10
Maximum	0.20

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data was available for Imbang with 10917 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 Imbang integrated with the processed LiDAR DEM is shown in Figure 27.

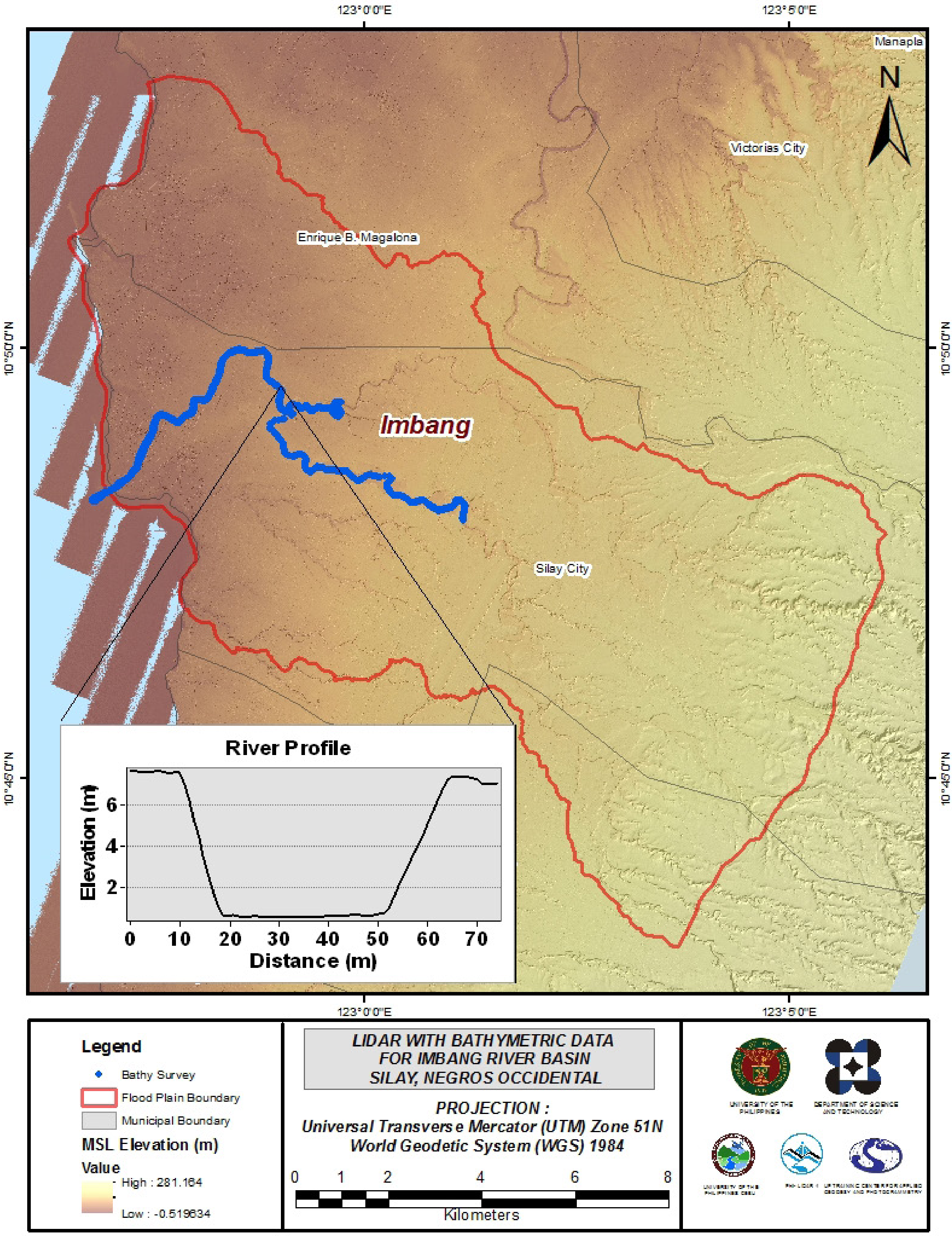


Figure 27. Map of Imbang Flood Plain with bathymetric survey points shown in blue.

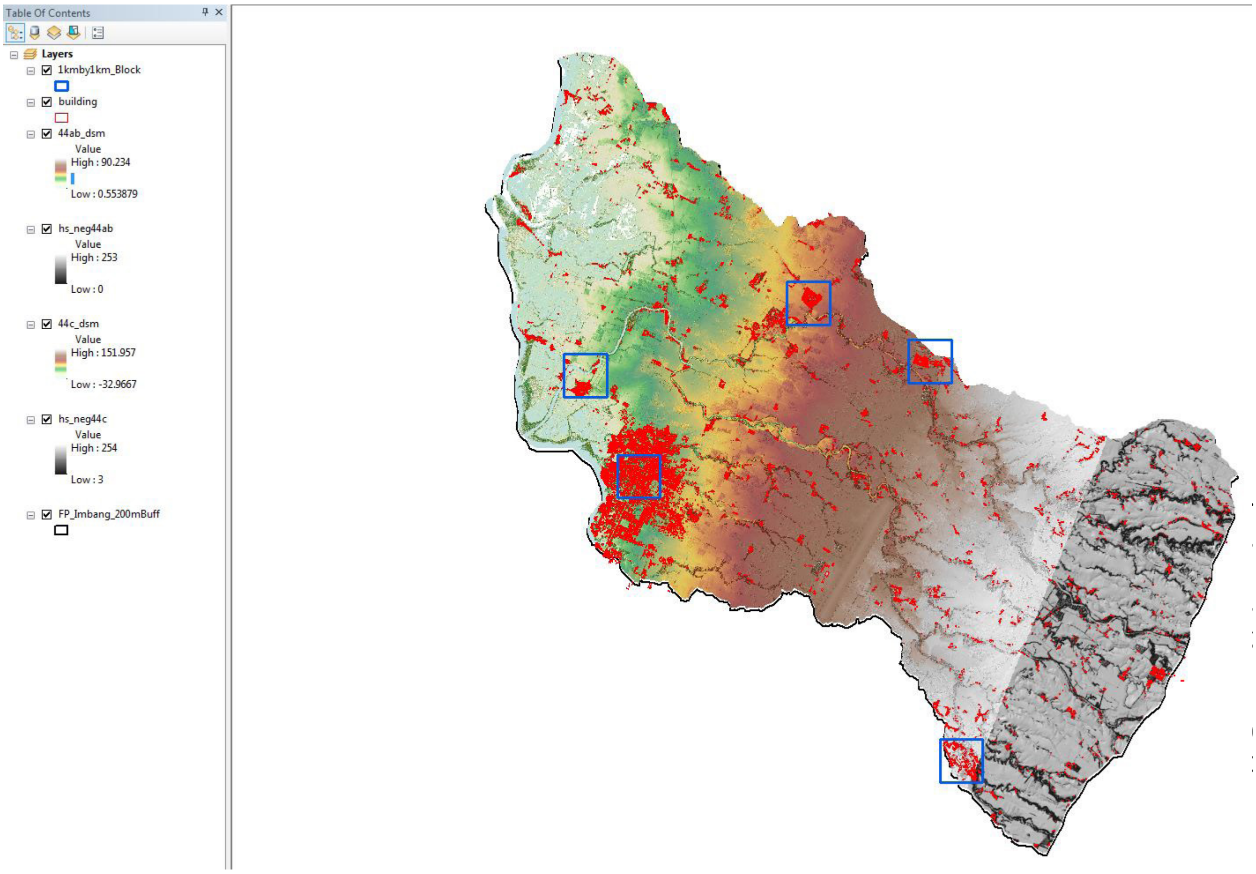


Figure 28. QC blocks for Imbang building features

Quality checking of Imbang building features resulted in the ratings shown in Table 16.

Table 16. Quality Checking Ratings for Imbang Building Features.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Imbang	100.00	100.00	99.71	PASSED

3.12.2 Height Extraction

Height extraction was done for 5,690 building features in Imbang floodplain. Of these building features, none was filtered out after height extraction, resulting to 5,690 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 8.74 m.

3.12.3 Feature Attribution

The digitized features were marked and coded in the field using handheld GPS receivers. The attributes of non-residential buildings were first identified; all other buildings were then coded as residential. An nDSM was generated using the LiDAR DEMs to extract the heights of the buildings. A minimum height of 2 meters was used to filter out the terrain features that were digitized as buildings. Buildings that were not yet constructed during the time of LiDAR acquisition were noted as new buildings in the attribute table.

Table 17 summarizes the number of building features per type. On the other hand, Table 18 shows the total length of each road type, while Table 19 shows the number of water features extracted per type.

Table 17. Building Features Extracted for Imbang Floodplain.

Facility Type	No. of Features
Residential	5,486
School	83
Market	1
Agricultural/Agro-Industrial Facilities	16
Medical Institutions	2
Barangay Hall	9
Military Institution	14
Sports Center/Gymnasium/Covered Court	10
Telecommunication Facilities	1
Transport Terminal	0
Warehouse	4
Power Plant/Substation	3
NGO/CSO Offices	0
Police Station	0
Water Supply/Sewerage	0
Religious Institutions	18
Bank	0
Factory	0
Gas Station	1
Fire Station	0
Other Government Offices	21
Other Commercial Establishments	21
Total	**5,690**

Table 18. Total Length of Extracted Roads for Imbang Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Imbang	22.95	13.63	0.00	19.77	0.00	**56.35**

Table 19. Number of Extracted Water Bodies for Imbang Floodplain.

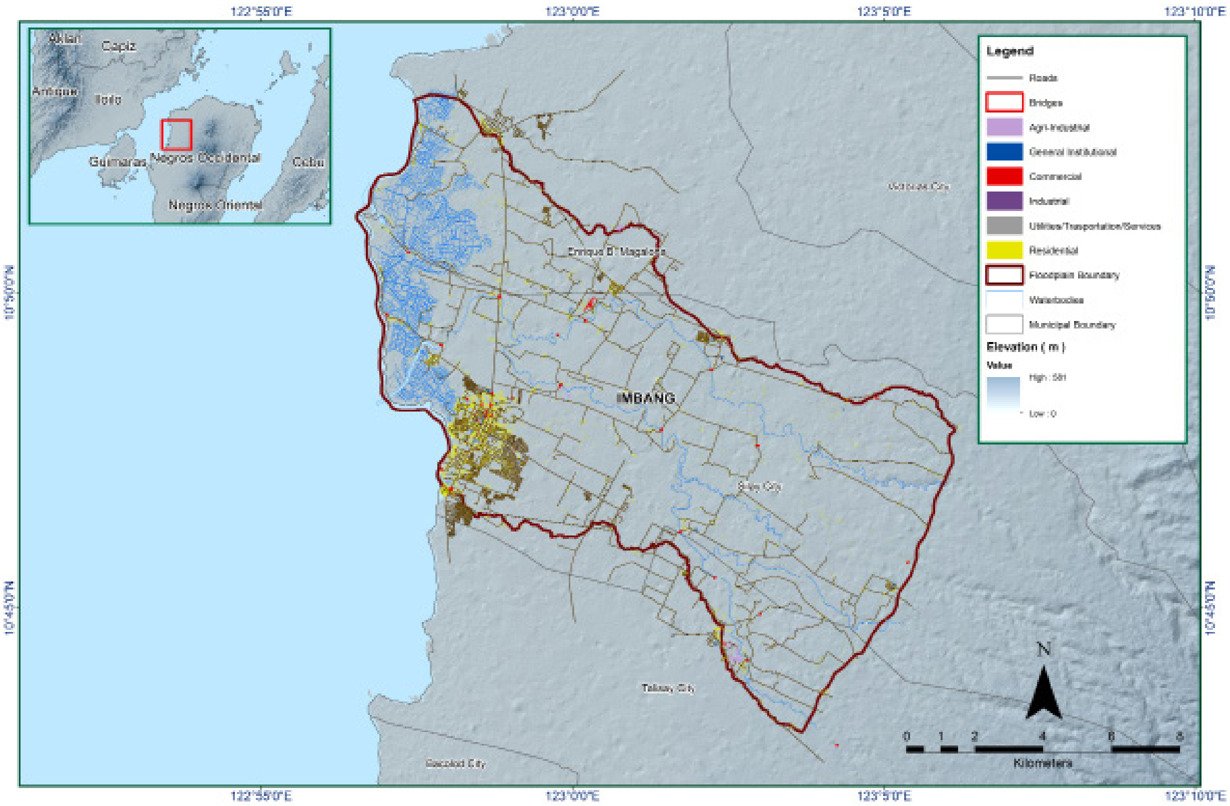
Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Imbang	157	49	0	0	0	**206**

A total of 44 bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

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

Figure 29 shows the Digital Surface Model (DSM) ofImbang floodplain overlaid with its ground features.



CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS OF THE IMBANG 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 two (2) field surveys in Imbang River. The first one was conducted from September 10 to 24, 2014 with following scope of work: control survey for the establishment of a control point; cross-section and bridge as-built and water level marking in MSL of Imbang Bridge piers; and ground validation data acquisition of about 35.18 km. The second survey was conducted from December 4 to 16, 2014 for the bathymetric survey from Brgy. Lantay and Eustaquio Lopez, Silay City down to the mouth of the river in Brgy. Lantad, Silay City, with an estimated length of 13 km using an Ohmex™ Single Beam Echo Sounder integrated with a roving GNSS receiver, Trimble® SPS 882 utilizing GNSS PPK survey technique (see Figure 30).

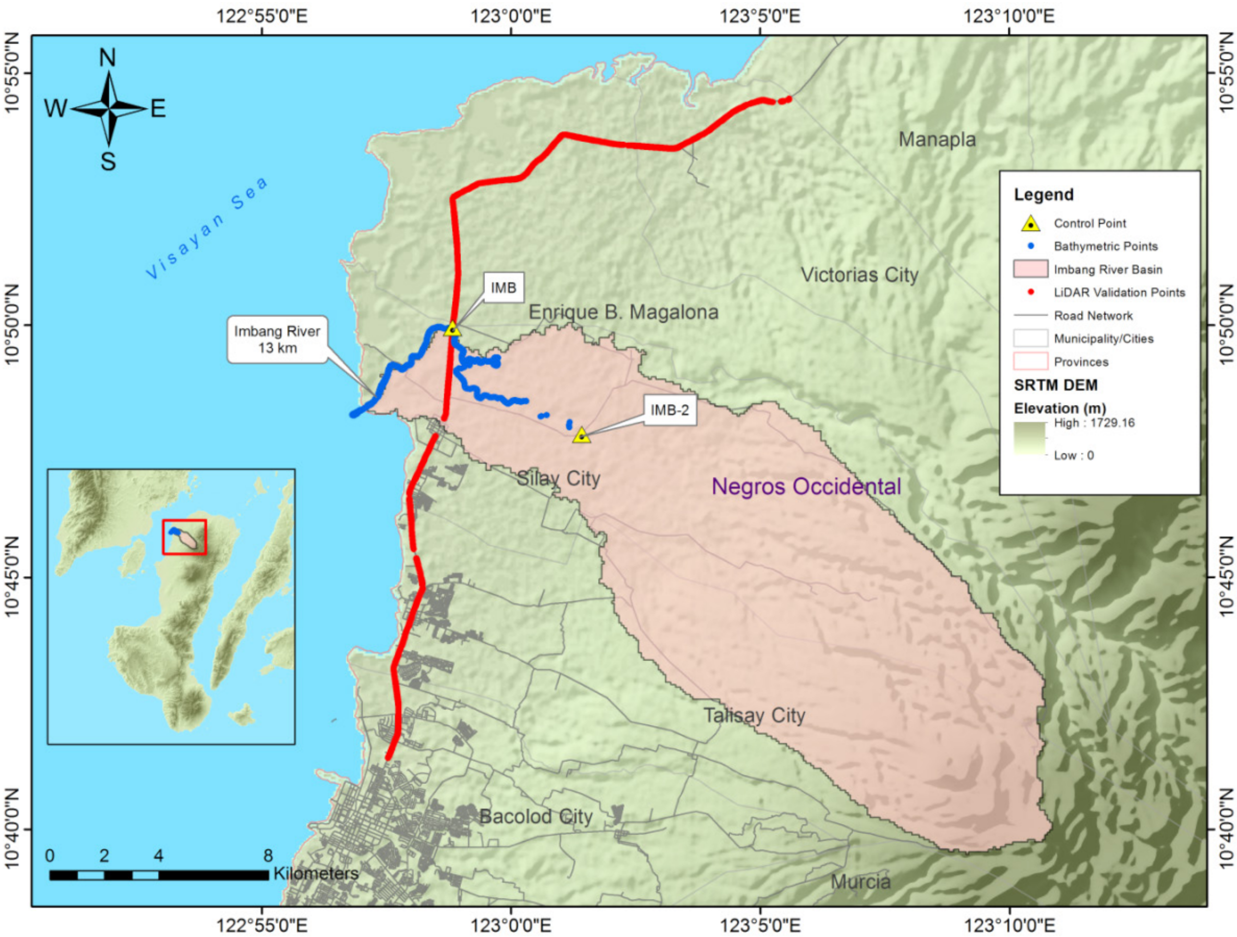


Figure 30. Imbang River survey extent

4.2 Control Survey

The GNSS network used for Imbang River survey is composed of a single loop and two baselines established on September 9 and 14, 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.

Two (2) control points were established along approach of bridges namely: IMB at Imbang Bridge, in Brgy. Lantad, Silay City; and MLG at Malogo Bridge in Brgy. Alicante, Victorias City. The point NW-130, a NAMRIA established control point, along the approach of Trozo Bridge in Brgy. Daga, Cadiz City, was also 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.

The summary of reference and control points is shown in Table 20, while the GNSS network established is illustrated in Figure 31.

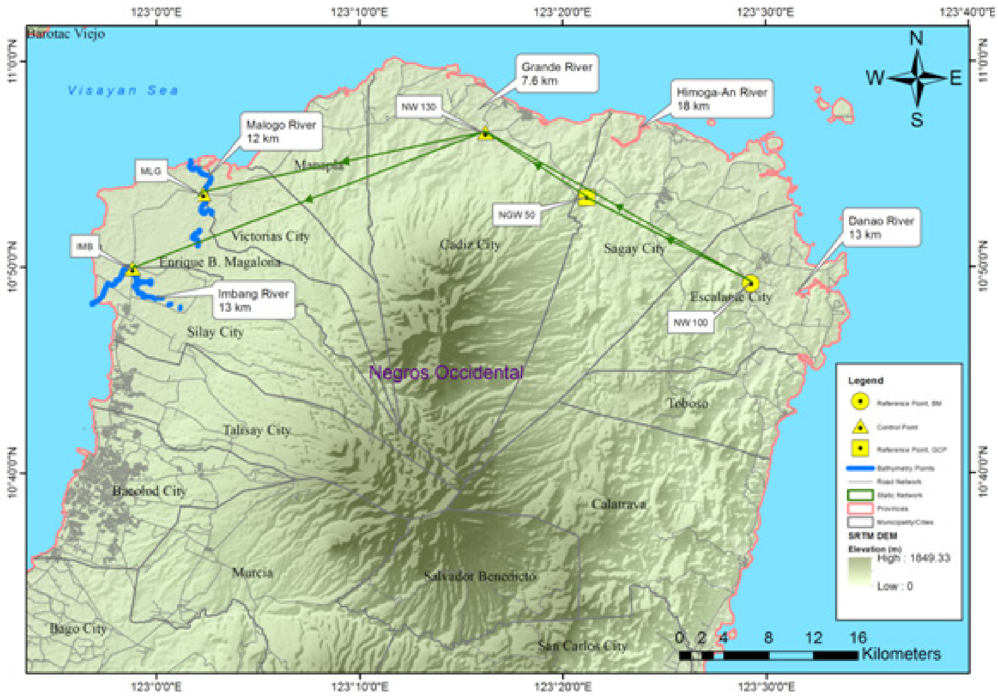


Figure 31. GNSS network of Imbang River field survey

Table 20. References and Control Pointsoccupied in Negros Occidental survey (Source: NAMRIA; UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (m)	MSL Elevation (m)	Date Established
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
IMB	UP Established	-	-	-	-	9-13-2014
MLG	UP established	-	-	-	-	9-13-2014

The GNSS set-ups on recovered reference points and established control points in Imbang River are shown in Figure 32to Figure 36.

Figure 32. GNSS base receiver setup, Trimble® SPS 852, at NGW-50 in Himoga-An Bridge, Brgy. Paraiso, Sagay City, Negros Occidental

Figure 33. GNSS base receiver setup, Trimble® SPS 852, at NW-100 in Danao Bridge,Brgy. Jonobjonob, Escalante City, Negros Occidental

Figure 34. GNSS base receiver setup, Trimble® SPS 852, over NW-130 in Troso Bridge, Brgy. Daga, Cadiz City, Negros Occidental

Figure 35. GNSS base receiver setup, Trimble® SPS 852, at IMB in Imbang Bridge, Brgy. Lantad, Silay City, Negros Occidental

Figure 36. GNSS base receiver setup, Trimble® SPS 852, at MLG in Malogo Bridge,Brgy. Alicante, Victorias 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 Imbang River Basin is summarized in Table 21 as generated by TBC software.

Table 21. Baseline Processing Report for Imbang 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:

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

Where:

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

for each control point.

The control points, NGW-50, NW-100, and NW-130 were occupied and observed simultaneously to form a GNSS loop. Coordinates of NGW-50; and elevation value of NW-100 were held fixed during the processing of the control points as presented in Table 22. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 22. 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 23. The fixed control NGW-50 has no values for and elevation error yet.

Table 23. Adjusted Grid Coordinates

Point ID	Easting	Easting Error	Northing	Northing Error	Elevation	Elevation Error	Constraint
	(Meter)	(Meter)	(Meter)	(Meter)	(Meter)	(Meter)	
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, $\sqrt{((x_e)^2 + (y_e)^2)} < 20cm$ for horizontal and $z_e < 10\ cm$ 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 24. 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 24. 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 25.

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

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	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
IMB	UP Established	10°49'57.92767"	122°58'49.65411"	68.641	1197487.542	497864.124	8.554
MLG	UP Established	10°53'34.18449"	123°02'17.25034"	70.160	1204129.792	504166.429	9.825

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

Cross-section and bridge as-built surveys were conducted on September 15, 2014 along the upstream side of Imbang Bridge Brgy. Lantay and E. Lopez, Silay City using GNSS receiver Trimble® SPS 882 utilizing GNSS PPK survey technique as shown in Figure 37.

Figure 37. Cross-section survey at Imbang Bridge, Brgy Lantay and E. Lopez, Silay City

The cross-section line is about 94.81 m with 70 points acquired using IMB as the GNSS base station. Figure 38 and Figure 39 show the summary of gathered cross-section and as-built data.

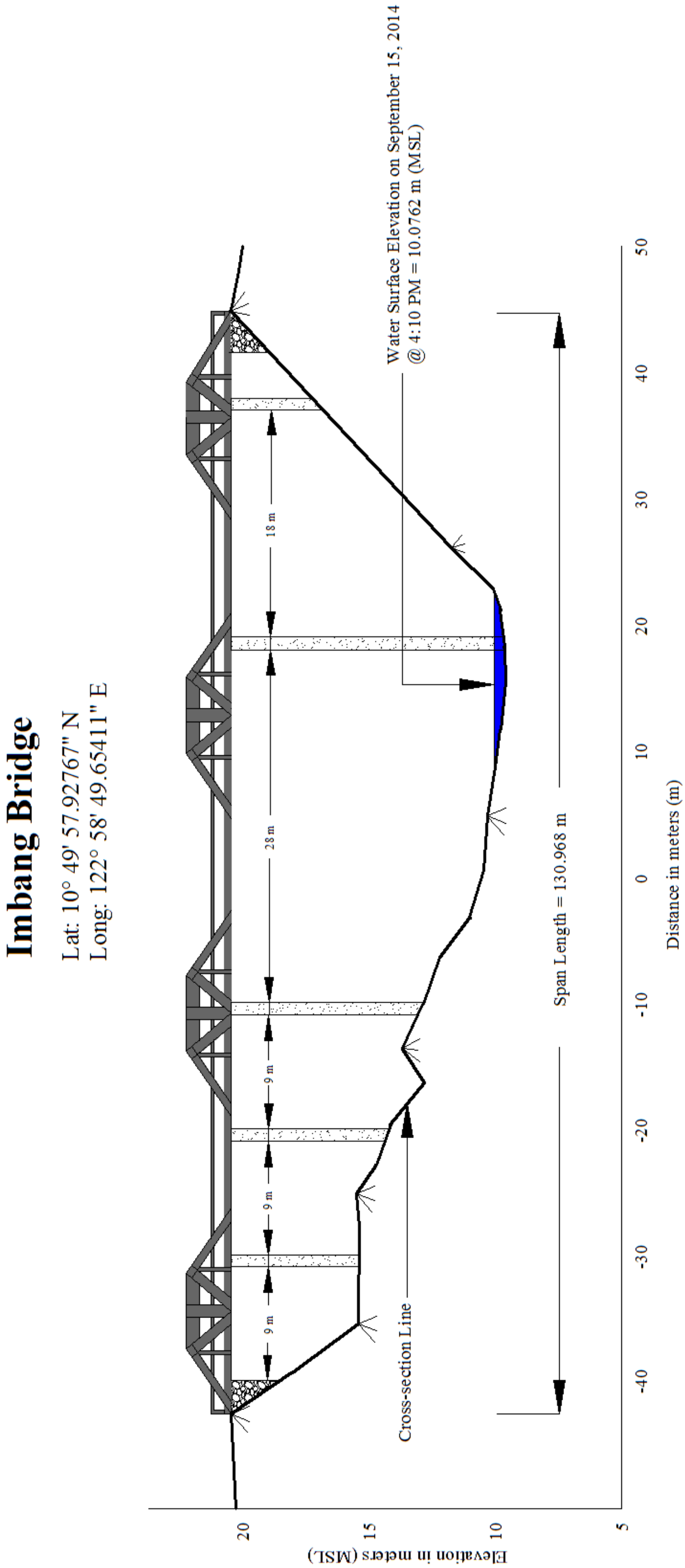


Figure 38. Imbang Bridge cross-section diagram

Bridge Data Form

Bridge Name: Imbang Bridge **Date:** September 15, 2014

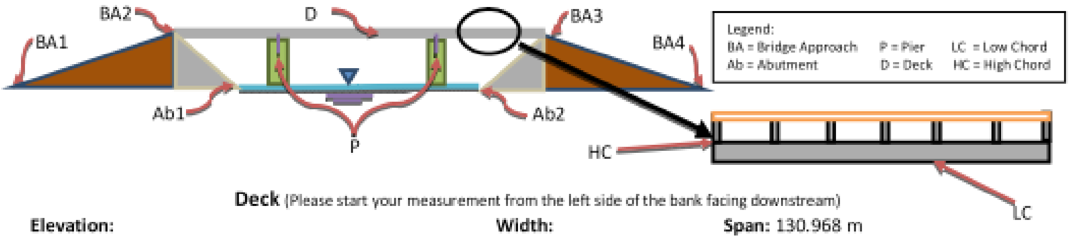
River Name: Imbang River **Time:** 2: 00 PM

Location (Brgy, City,Region): Silay City, Negros Occidental

Survey Team: Negros Occidental Survey Team

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

Latitude: 10d49'57.92767"N **Longitude:** 122d58'49.65411" E



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

Elevation: **Width:** **Span:** 130.968 m

	Station	High Chord Elevation	Low Chord Elevation
1		-	-
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	**n/a**	n/a	**BA3**	87.3 m	20.4442 m
BA2	0	20.4652 m	**BA4**	94.81	20.2562

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	84.01 m	18.0362 m

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

Shape: rectangular **Number of Piers:** 6 **Height of column footing:** ______________

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	10.37	20.1182	
Pier 2	28.73	20.3052	
Pier 3	56.67	20.1662	
Pier 4	66.29	20.2092	
Pier 5	75.22	20.1952	
Pier 6	84.61	20.4192	

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

Figure 39. Imbang Bridge Data Form

The water surface elevation of Imbang Bridge on the left and right banks was acquired using GNSS receiver Trimble® SPS 882 in GNSS PPK survey technique on September 15, 2014 at 4:10 PM. With a value of 10.0762 m above MSL. This was translated into the piers of Imbang Bridge to serve as a reference for flow data gathering and depth gauge deployment of UP Cebu PHIL-LIDAR 1 as shown in Figure 40.

Figure 40. Water level marking at the center pier (facing upstream) of Imbang Bridge

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on September 15, 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 41. It was secured with a steel rod and tied with cable ties to ensure that it was horizontally and vertically balanced. The antenna height of 1.906 meters was measured from the ground up to bottom of the notch of the GNSS rover receiver. Points were gathered along concrete roads of Osmeña Avenue national highway in Victorias City to Rizal Street in Bacolod City and observing a vehicle speed of 10 to 20 kph across the flight strips of the Data Acquisition Component (DAC).

The GNSS base station was set-up over IMB in Imbang Bridge and gathered validation points from Brgy. VI Manapla to Bacolod City. The ground validation line is approximately 35.18 km in length and with 3,955 points. The map on Figure 42shows the coverage of the ground validation survey.

Figure 41. (A) GNSS Receiver Trimble® SPS 882 installation (B) Final set up of GNSS Receiver and (C) Base setup at IMB in Imbang Bridge, Silay City

Figure 42. Validation Points Acquisition survey from Brgy. VI Manapla to Bacolod City

4.7 Bathymetric Survey

Bathymetric survey was executed on December 4 and 5, 2014 using Ohmex™ Single Beam Echo Sounder integrated with a roving GNSS receiver, Trimble® SPS 882 installed on a boat utilizing PPK survey technique as shown in Figure 43. The survey began at the upstream part in Brgy. 6 Poblacion, Silay City with coordinates 10°49'21.32850"122°59'44.51571", down to the mouth of the river in Brgy. Lantad, Silay City with coordinates 10°48'12.44093"122°56'50.03108".

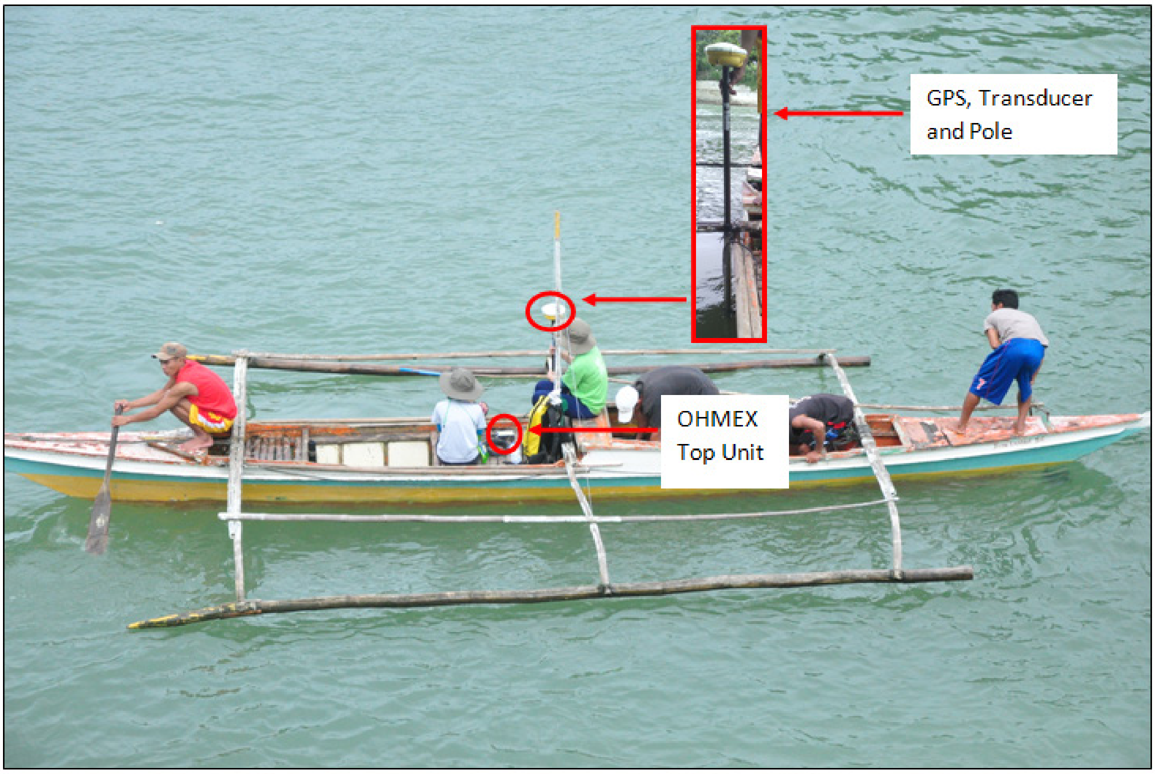


Figure 43. Set up of bathymetric survey for Imbang River Survey

Manual bathymetric survey was performed on December 21, 2014 using Trimble®SPS 882 in NSS PPK survey technique as shown in Figure 44. The survey began in the upstream of the second tributary if Imbang River in Brgy. E. Lopez, Silay City with coordinates 10°48'11.71977"123°00'36.33447", traversed downstream by foot and ended in Brgy. VI Poblacion, Silay City with coordinates 10°49'14.44539"122°59'07.26222". The control point IMB was used as the GNSS base station all throughout the survey.

Figure 44. Manual bathymetry survey from Brgy. Eustaquio Lopez to Brgy. VI Poblacion

Bathymetric line is approximately 13 km in length with 9,897 points from Brgy. Lantay and E. Lopez, Silay City down to Brgy. Lantad, Silay City as shown in Figure 45. A CAD drawing of the centerline riverbed profile was also produced as shown in Figure 46. The lowest elevation was -5.67 m below MSL, was recorded at approximately 2,500 meters downstream of Imbang Bridge in Bacolod-Silay Highway, while the highest elevation was 7.782 m in MSL located in Brgy. E. Lopez, Silay City. The gaps in between bathymetric points were due to poor satellite signal.

Figure 45. Bathymetric points gathered along Imbang River

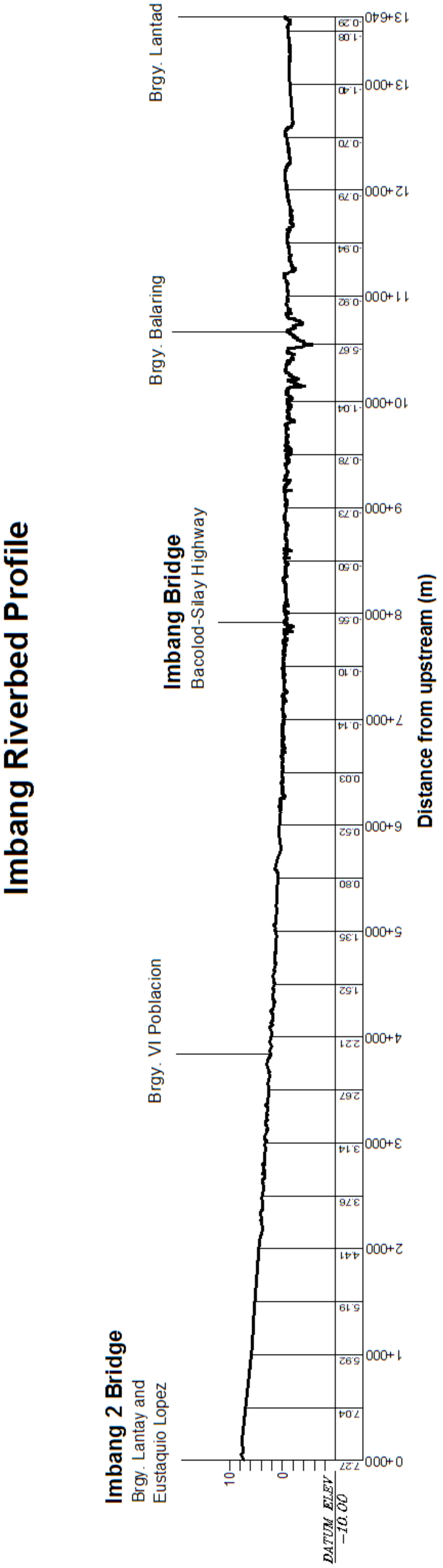


Figure 46. Riverbed profile of Imbang River

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 components and data that affect the hydrologic cycle of the Imbang river basin were monitored, collected, and analyzed. These include the rainfall, water level, and flow in a certain period of time.

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. E Lopez, Silay City, Negros Occidental (Figure 47). The precipitation data collection started from July 2, 2015 at 11:00 PM to July 4, 2015 at 11:15with a recording interval of 15 minutes.

The total precipitation for this event in BrgyE Lopez ARG was 24 mm. It has a peak rainfall of 4 mm. on July3, 2015 at 2:15in the afternoon. The lag time between the peak rainfall and discharge is 11 hours and 40 minutes.

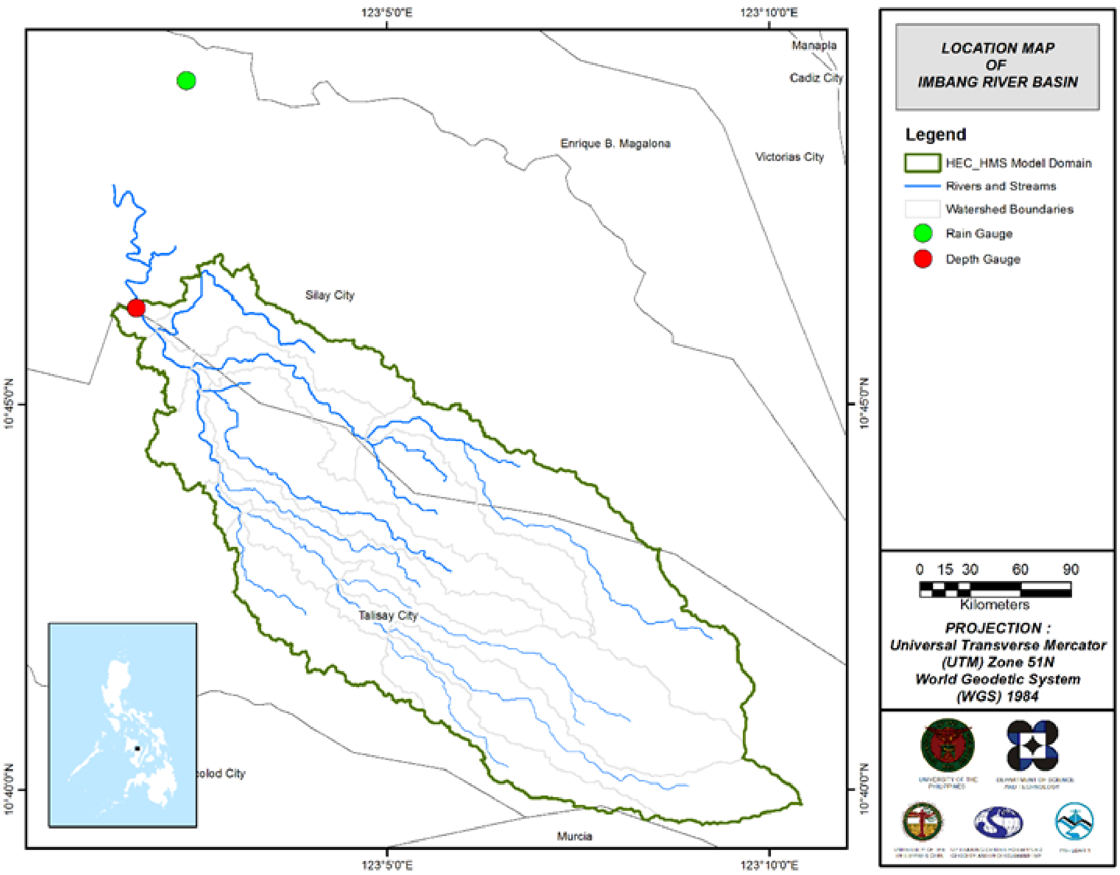


Figure 47. The location map of Imbang HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was computed using the prevailing cross-section (Figure 48) atLa Purisima Bridge, Silay City, Negros Occidental(10°47’49.33”N, 123° 1’25.14”E). It gives the relationship between the observed water levels at La Purisima Bridge and outflow of the watershed at this location.

For La Purisima Bridge (Imbang Bridge), the rating curve is expressed as $Q = 0.004e^{0.7057x}$ as shown in Figure 49.

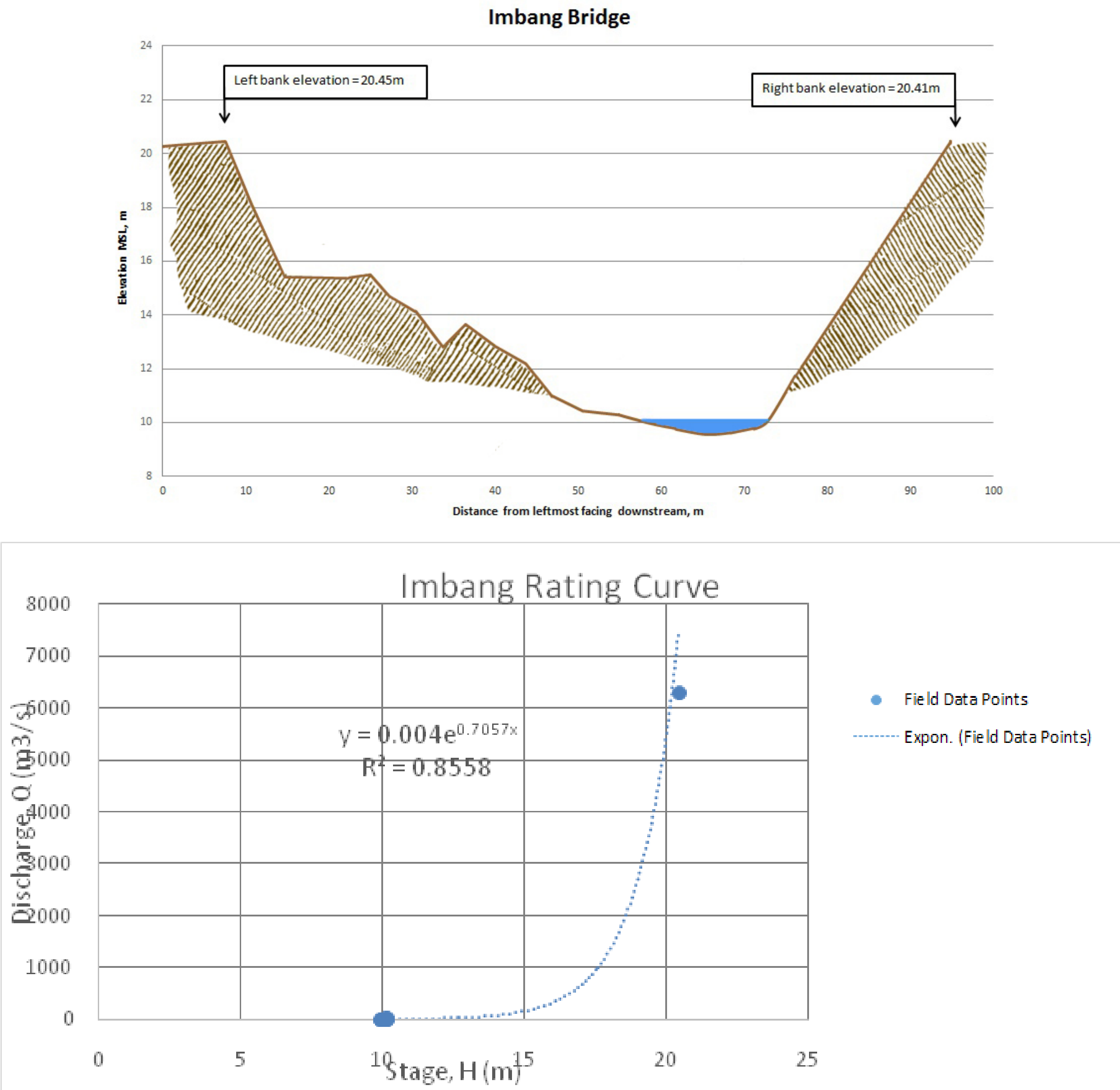


Figure 49. Rating Curve at La Purisima Bridge, E. Lopez, Silay City

This rating curve equation was used to compute the river outflow at La Purisima Bridge for the calibration of the HEC-HMS model shown in Figure 50. The total rainfall for this event is 24mm Peak discharge is 102.5m^{3}second at 12:00 noon, July 30, 2016.

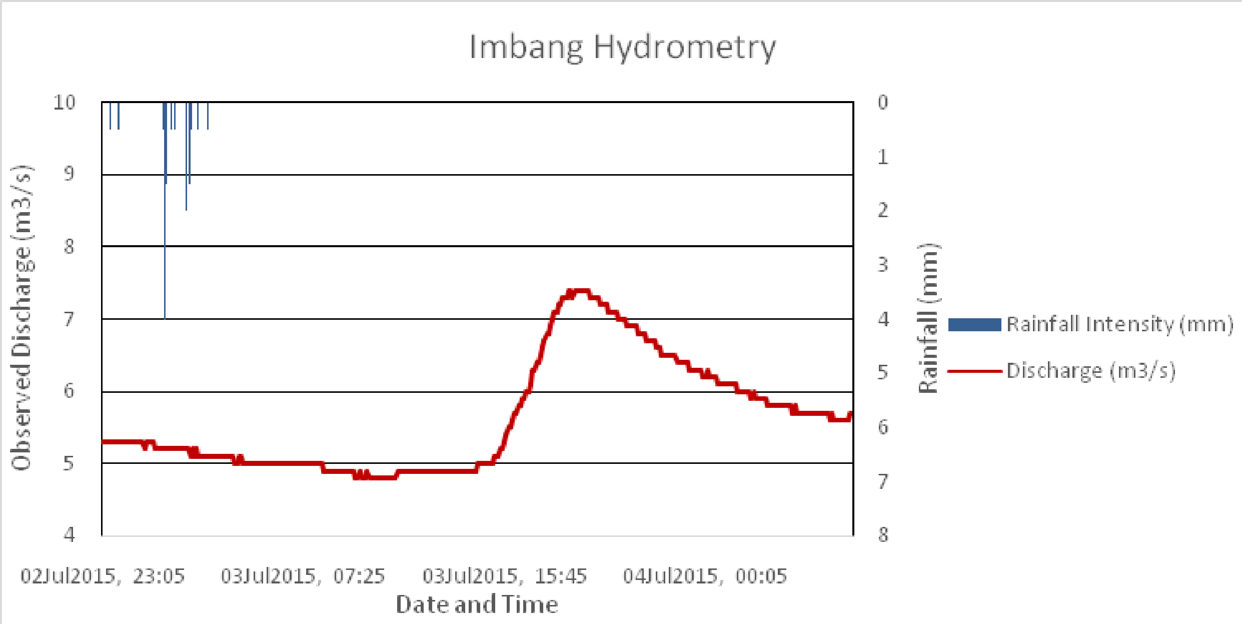


Figure 50. Rainfall and outflow data at Imbang used for modeling

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 Imbang watershed. The extreme values for this watershed were computed based on a 59-year record.

Table 26. 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

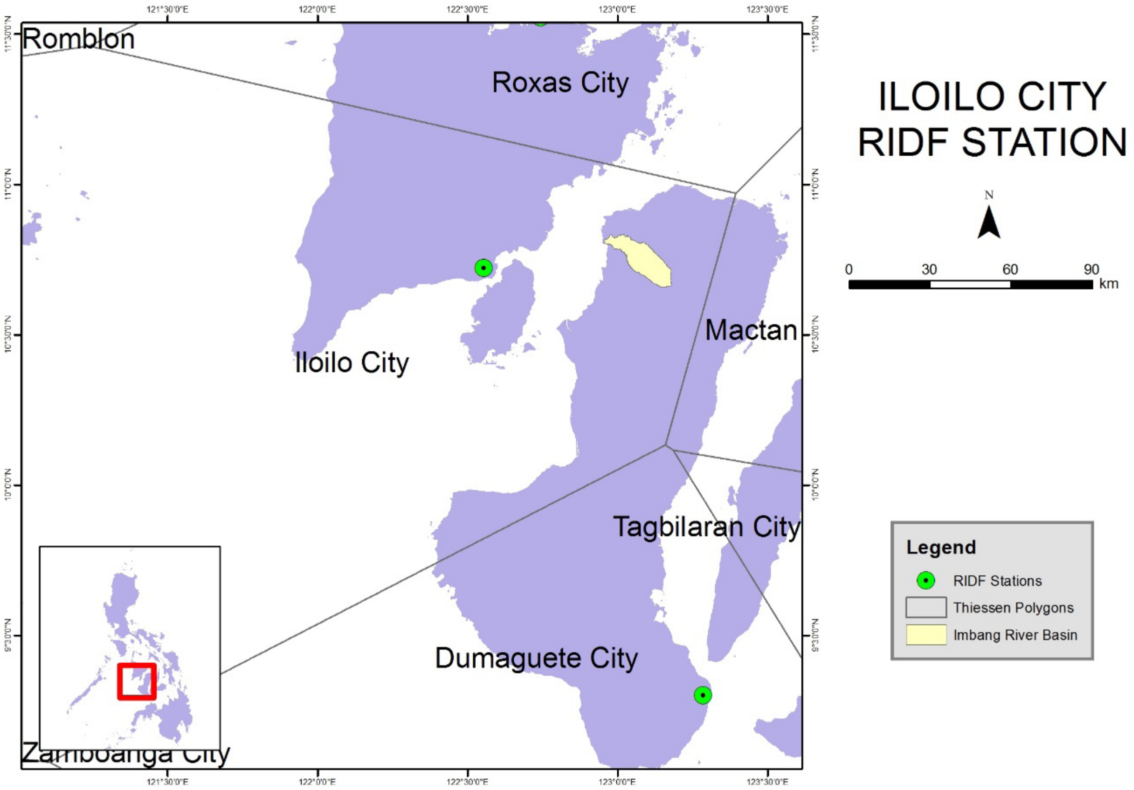


Figure 51. Location of Iloilo RIDF station relative to Imbang River Basin

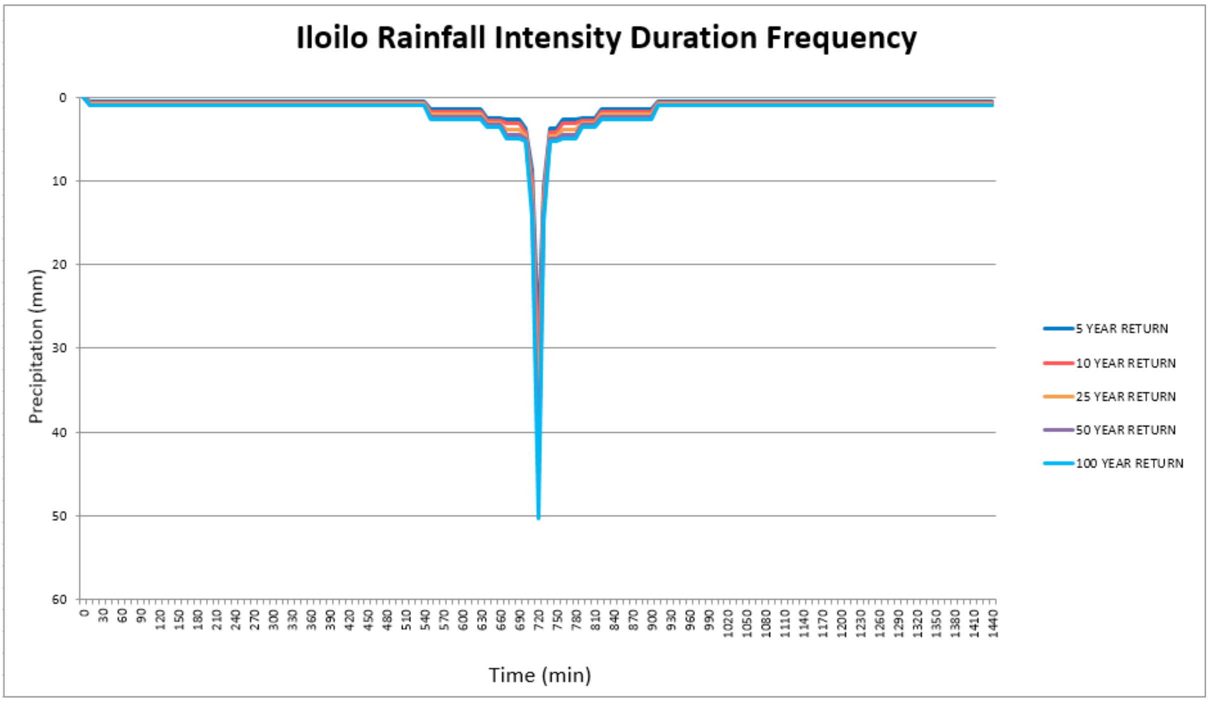


Figure 52. Synthetic storm generated for a 24-hr period rainfall for various return periods

5.3 HMS Model

The soil dataset was generated in 2004 by the Bureau of Soil and Water Management; 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 Imbang River Basin are shown in Figures 53 and 54, respectively.

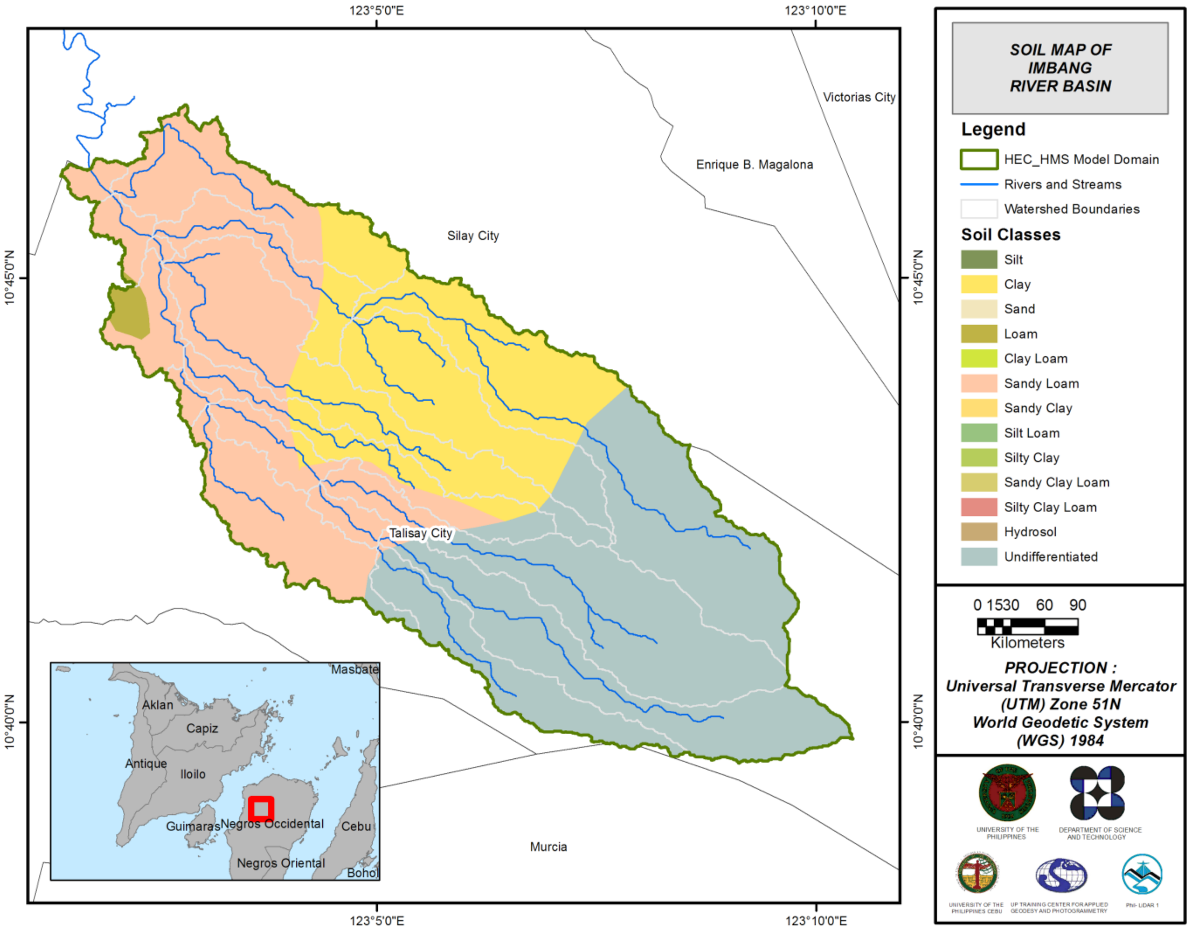


Figure 53. The soil map of the Imbang River Basin

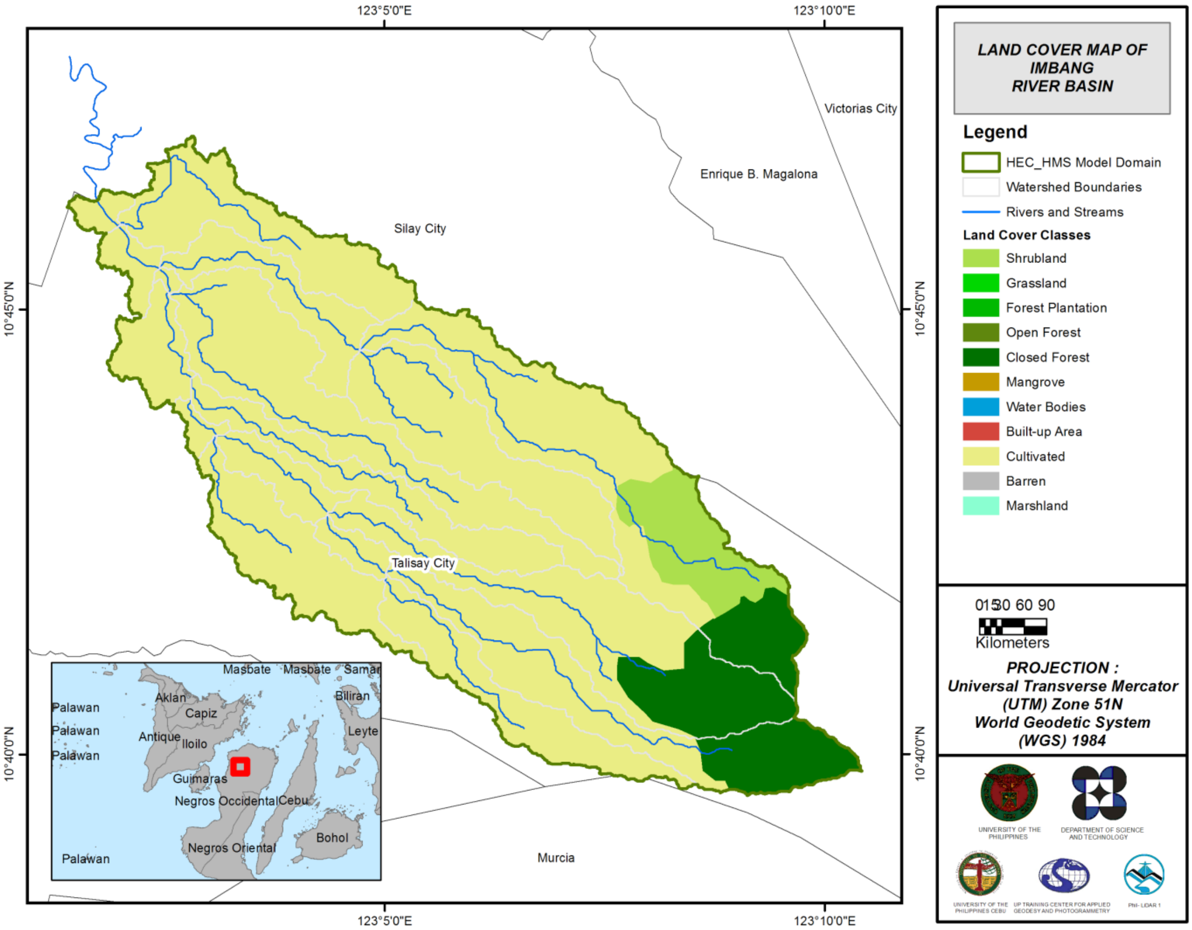


Figure 54. The land cover map of the Imbang River Basin

For Imbang, four soil classes were identified. These are loam, sandy loam, clay, and undifferentiated soil. Moreover, three land cover classes were identified. Namely, shrubland, closed forest, and cultivated areas.

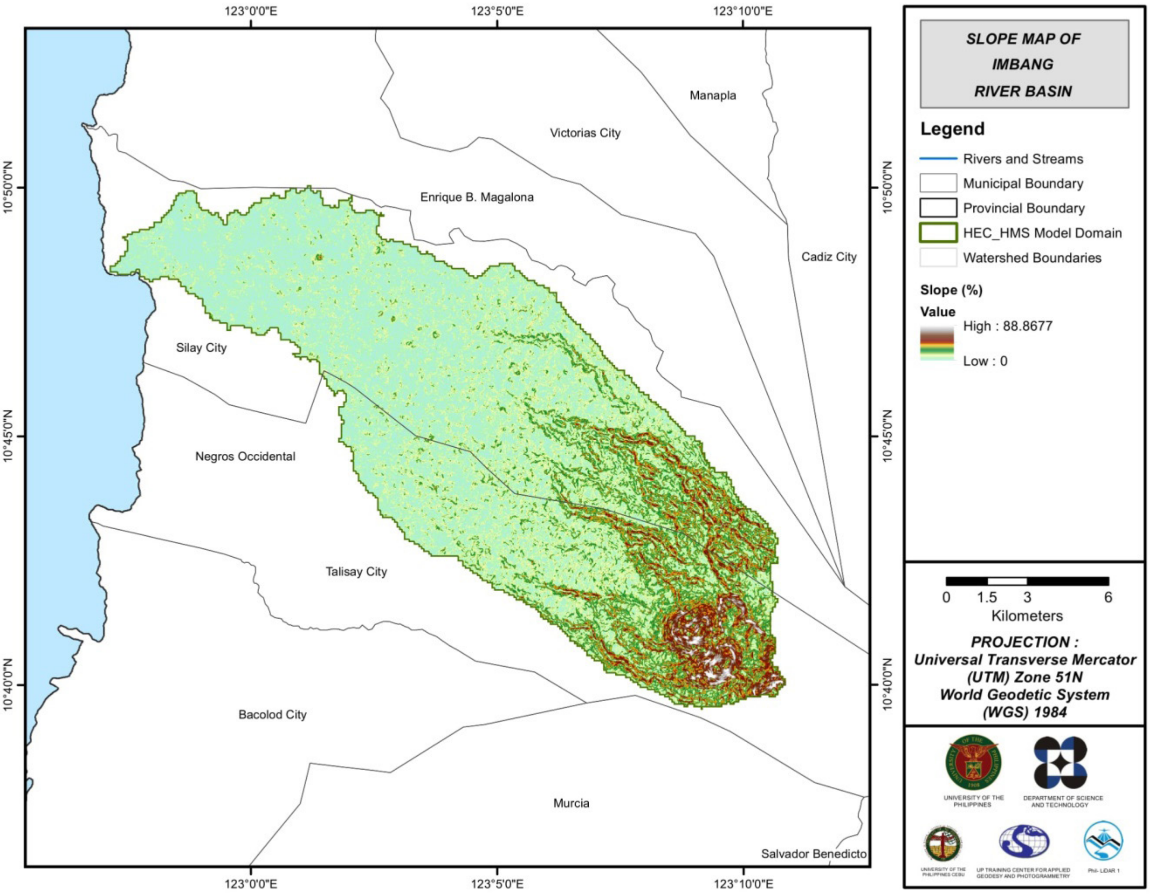


Figure 55. Slope map of the Imbang River Basin

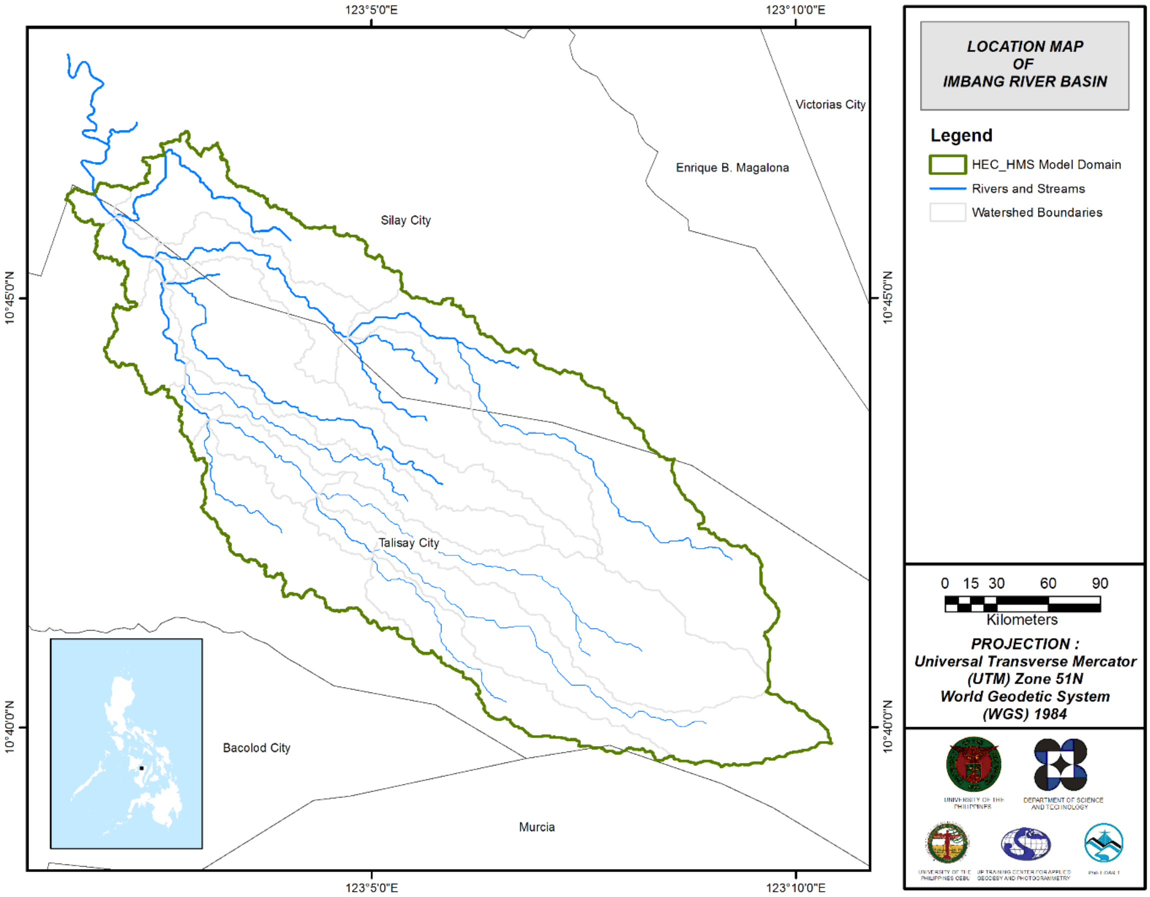


Figure 56. Stream delineation map of Imbang river basin

Using the SAR-based DEM, the Imbang basin was delineated and further subdivided into subbasins. The model consists of 27 sub basins, 13 reaches, and 12 junctions as shown in Figure 57. The main outlet is at La Purisima Bridge.

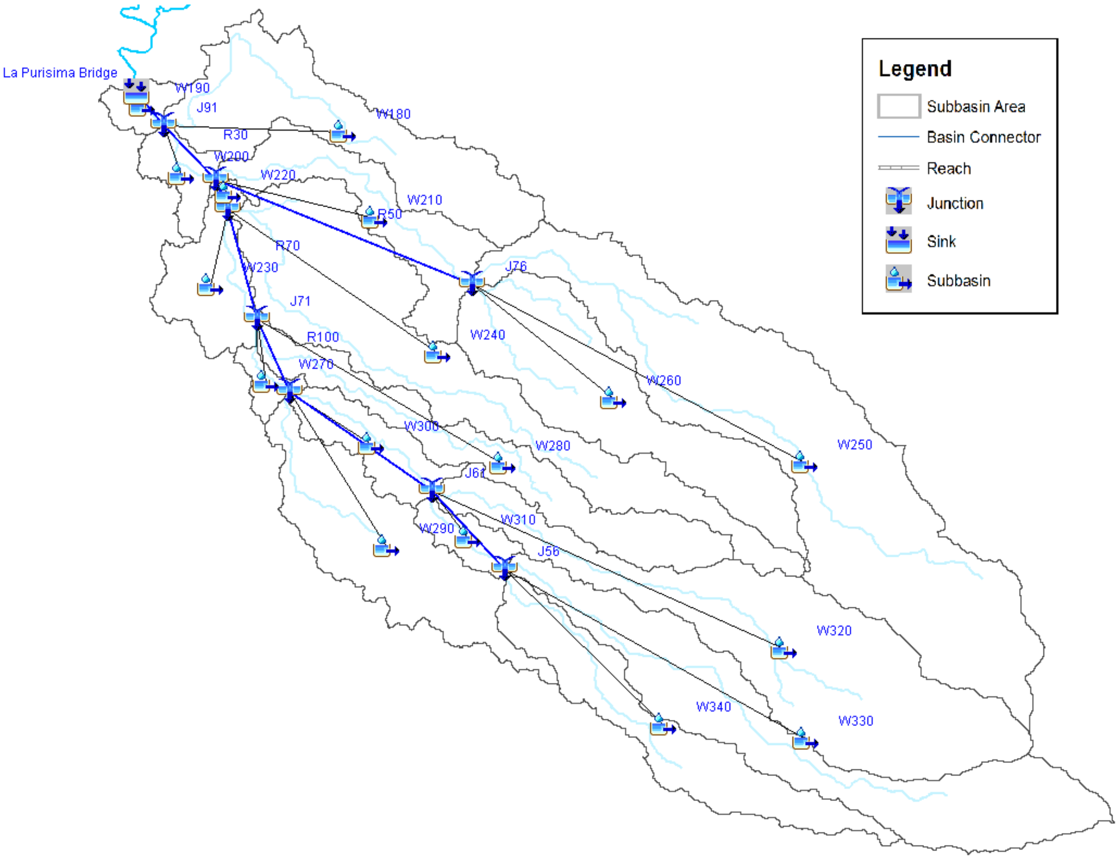


Figure 57. The Imbang river basin model generated using HEC-HMS

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.

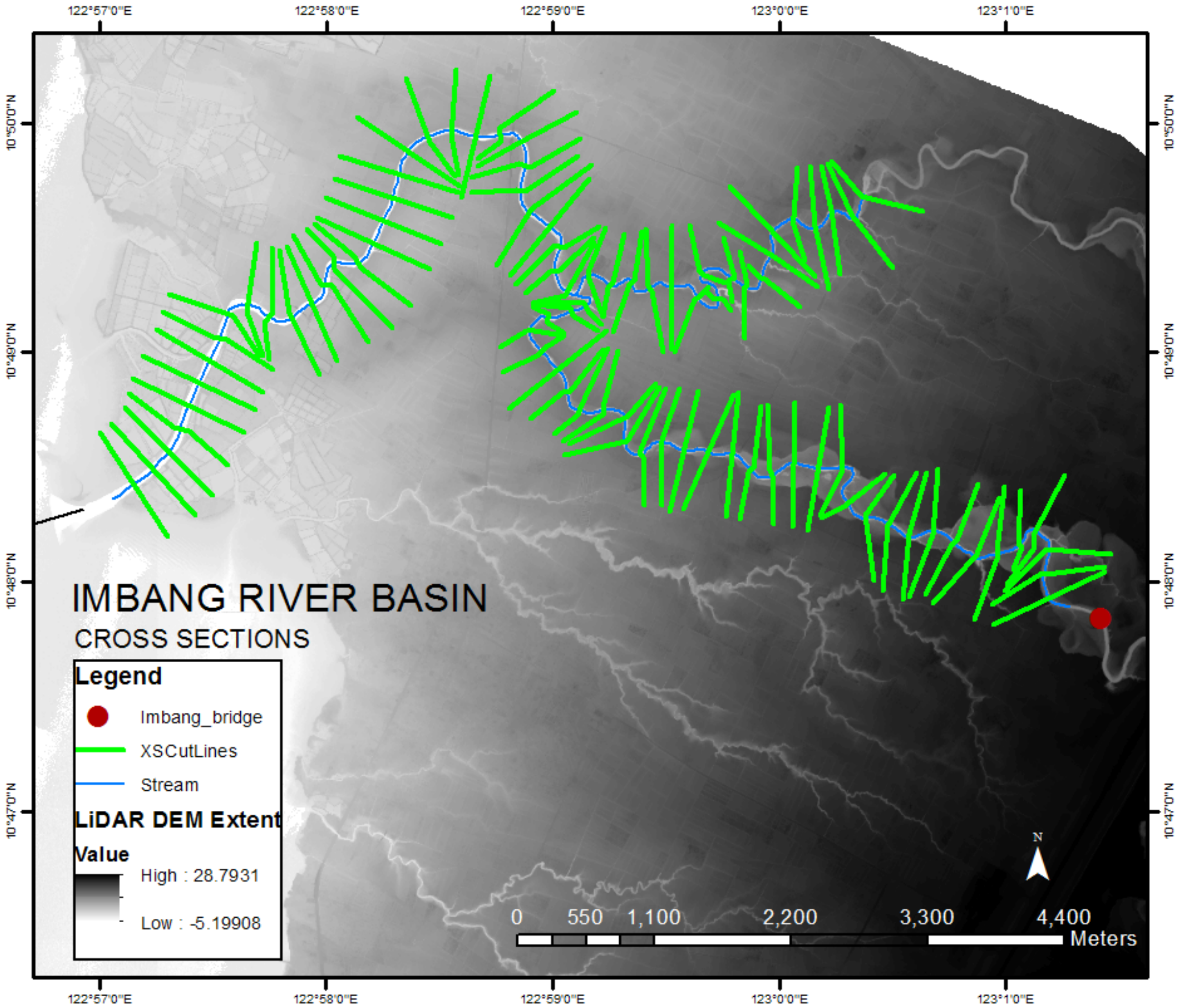


Figure 58. River cross-section of Imbang River generated through Arcmap HEC GeoRAS tool

5.5 Flo 2 D 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.

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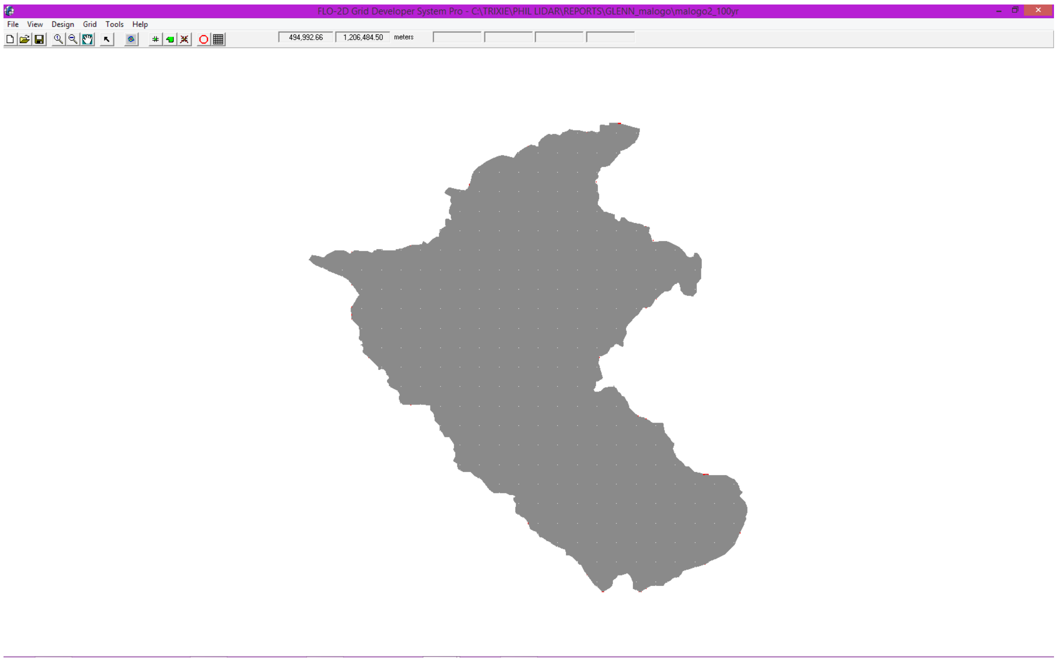


Figure 59. Screenshot of subcatchment with the computational area to be modeled in FLO-2D Grid Developer System Pro(FLO-2D GDS Pro)

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 27.58203 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.

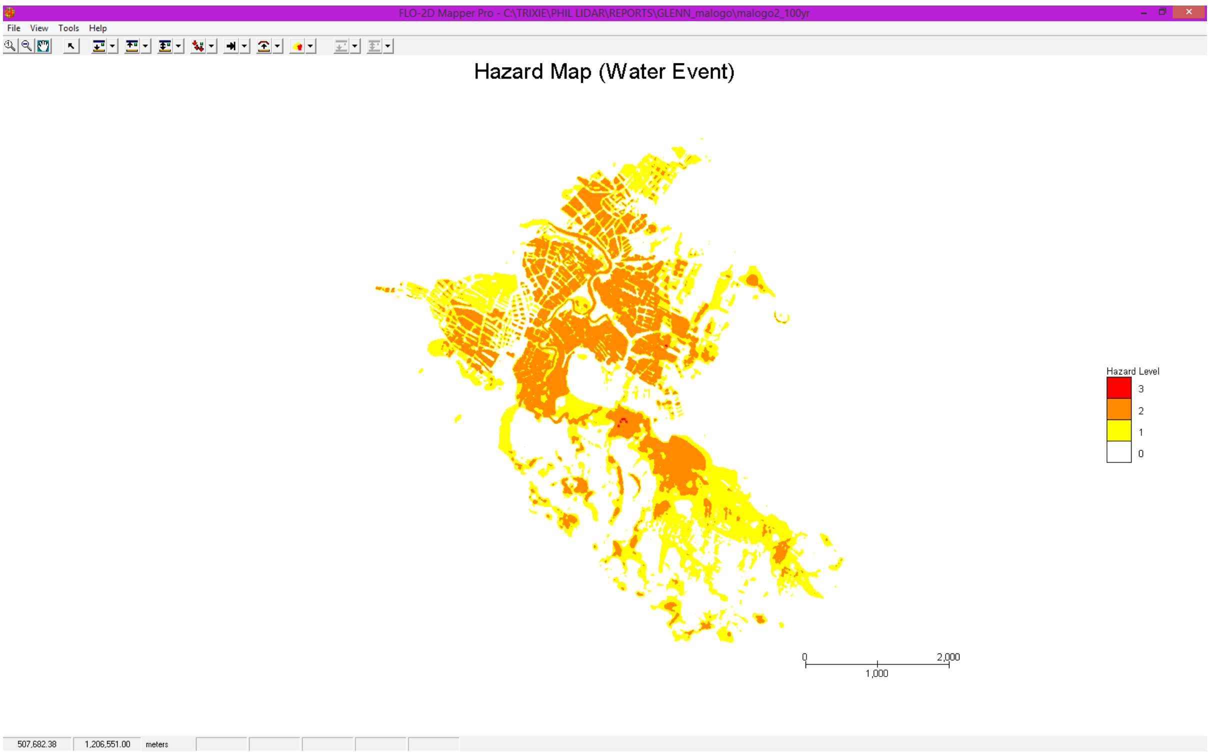


Figure 60. Generated 100-year rain return hazard map from FLO-2D Mapper

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 21957300.00 m2.

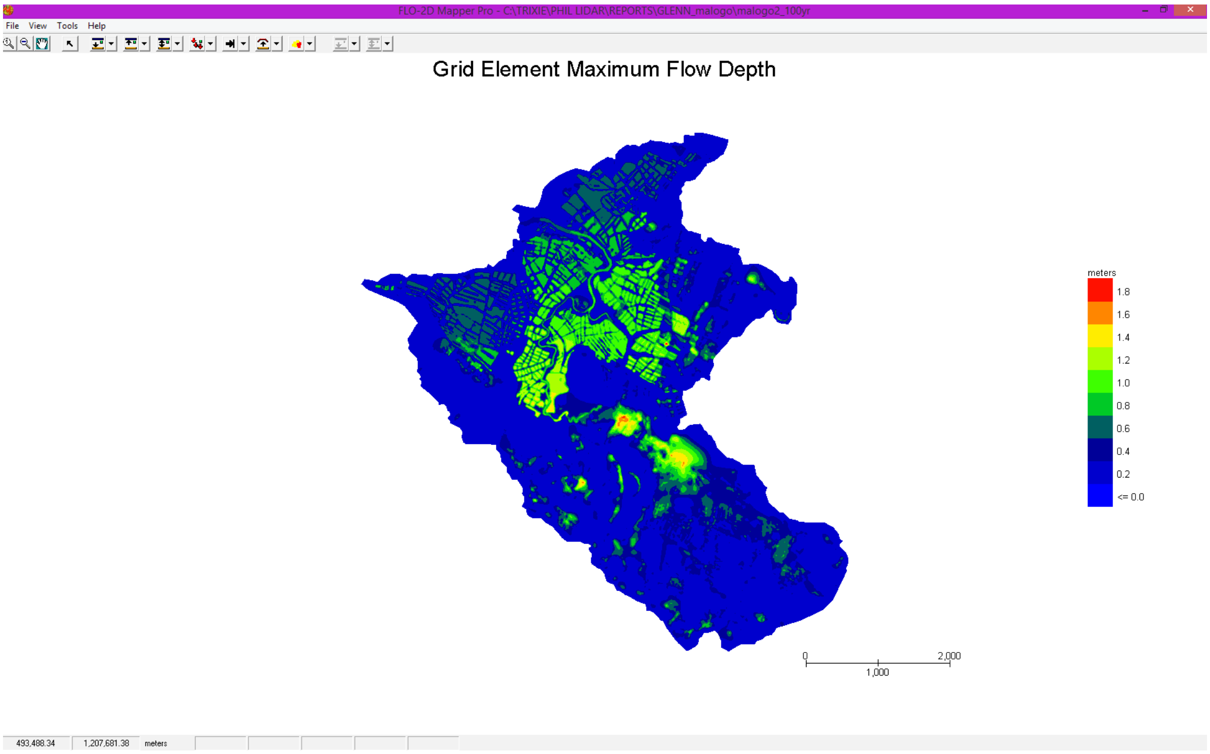


Figure 61. Generated 100-year rain return flow depth map from FLO-2D Mapper

There is a total of 44530945.60 m3 of water entering the model. Of this amount, 6644245.62 m3 is due to rainfall while 37886699.99 m3 is inflow from other areas outside the model. 3295583.50 m3 of this water is lost to infiltration and interception, while 9121167.79 m3 is stored by the flood plain. The rest, amounting up to 32114193.48 m3, is outflow.

5.6 Results of HMS Calibration

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

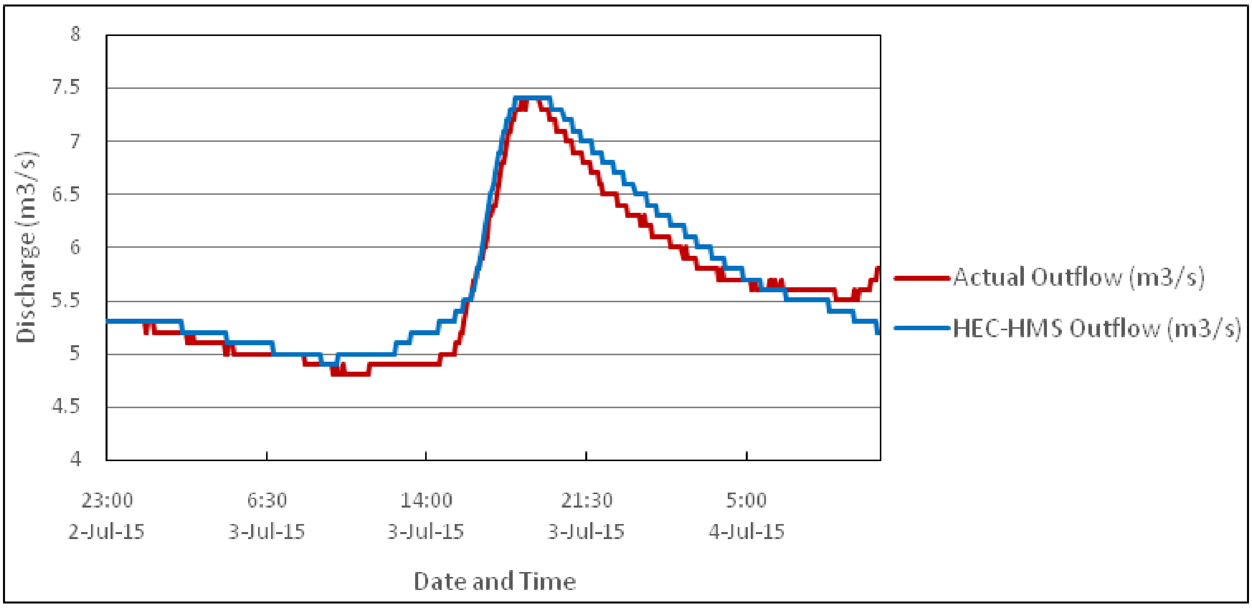


Figure 62. Outflow Hydrograph of Imbang produced by the HEC-HMS model compared with observed outflow

Enumerated in Table 27 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 27. Range of Calibrated Values for Imbang

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	5.8-13.3
			Curve Number	37.2-75.1
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	2.8-5
			Storage Coefficient (hr)	2.2-23
	Baseflow	Recession	Recession Constant	1
			Ratio to Peak	0.5
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.012-0.15

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 5.8mm to 13.3mm 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 37.2 to 75.1 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For Imbang, the basin mostly consists of closed canopy, brushland and cultivated areas and the soil consists of clay, sandy loam, loam, and mountainous 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 2.8 hours to 5 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 1 indicates that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.5 indicates a gradual receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.012 to 0.15 corresponds to the common roughness of Philippine watersheds. Imbang river basin is determined to have mangrove forests with heavy stand trees (Brunner, 2010).

Table 28. Summary of the Efficiency Test of Imbang HMS Model

RMS Error	0.2
r^2	0.9801
NSE	0.94
RSR	0.24
PBIAS	-1.60

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 0.2 (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 0.9801.

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 0.94.

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 -1.6.

The Observation Standard Deviation Ratio, RSR, is an error index. A perfect model attains a value of 0 when the error in the units of the valuable a quantified. The model has an RSR value of 0.24.

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 Imbang 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 from 165.2m^3 in a 5-year return period to 304.5m^3 for a 100-year return period.

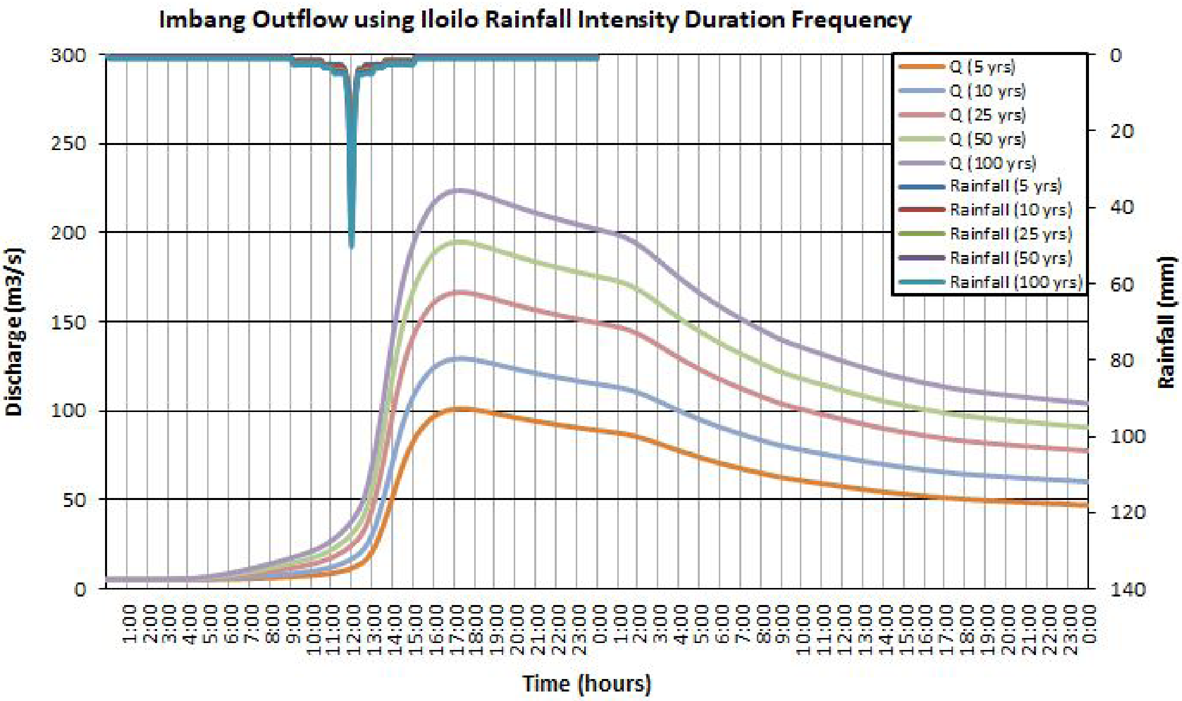


Figure 63. Outflow hydrograph at Imbang Station generated using Iloilo RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Imbang discharge using the Iloilo Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 29.

Table 29. Peak values of the Imbang HEC-HMS Model outflow using the Imbang RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m ^{3}/s)	Time to Peak
5-Year	165.2	28.7	101.2	5 hours, 30 minutes
10-Year	198.9	33.9	129.4	5 hours, 30 minutes
25-Year	241.5	40.5	166.6	5 hours, 20 minutes
50-Year	273.1	45.4	194.9	5 hours, 20 minutes
100-Year	304.5	50.3	223.8	5 hours, 20 minutes

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. For this publication, only a sample output map river was to be shown, since only the UPC-FMC base flow was calibrated. The sample generated map of Imbang River using the calibrated HMS base flow is shown in Figure 64.

Figure 64. Sample output of Imbang RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figure 65 to Figure 70 shows the 5-, 25-, and 100-year rain return scenarios of the Imbang-Malogo floodplain. The floodplain, with an area of 535.61sq.km., covers eight municipalities namely, Cadiz City, Calatrava, Enrique B. Magalona, Manapla, Salvador Benedicto, Silay City, Talisay City, and Victorias City.

Table 30. Municipalities affected in the Imbang-Malogo Floodplain

Municipality	Total Area	Area Flooded	% Flooded
Cadiz City	516.184	40.44	7.84
Calatrava	344.54	0.044	0.013
Enrique B. Magalona	140.32	132.52	34.44
Manapla	99.18	0.99	1.002
Salvador Benedicto	182.22	0.42	0.23
Silay City	196.525	181.41	92.31
Talisay City	199.01	100.21	50.35
Victorias City	103.55	79.53	76.8

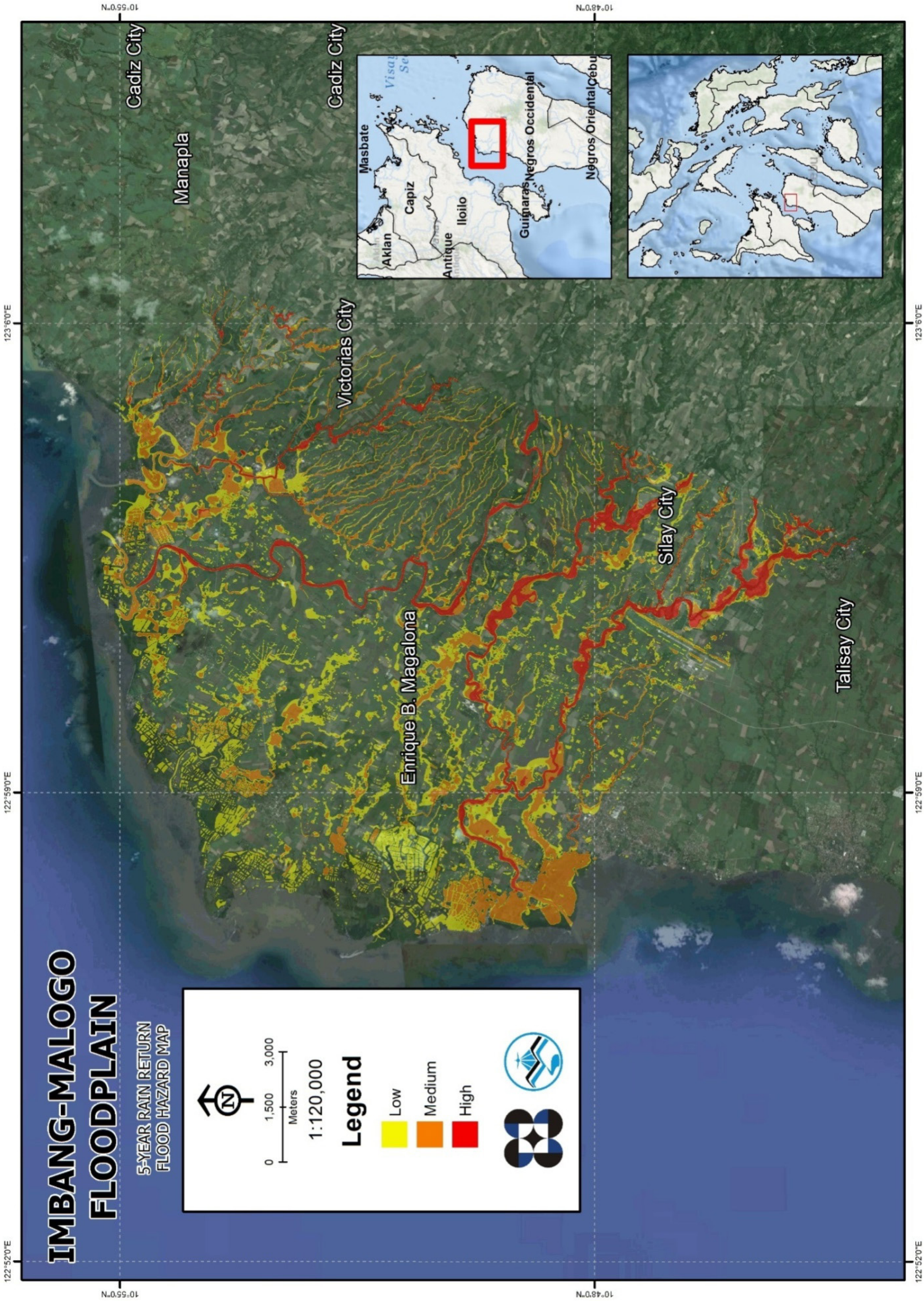


Figure 65. 100-year Flood Hazard Map for Malogo-Imbang Floodplainoverlaid on Google Earth imagery

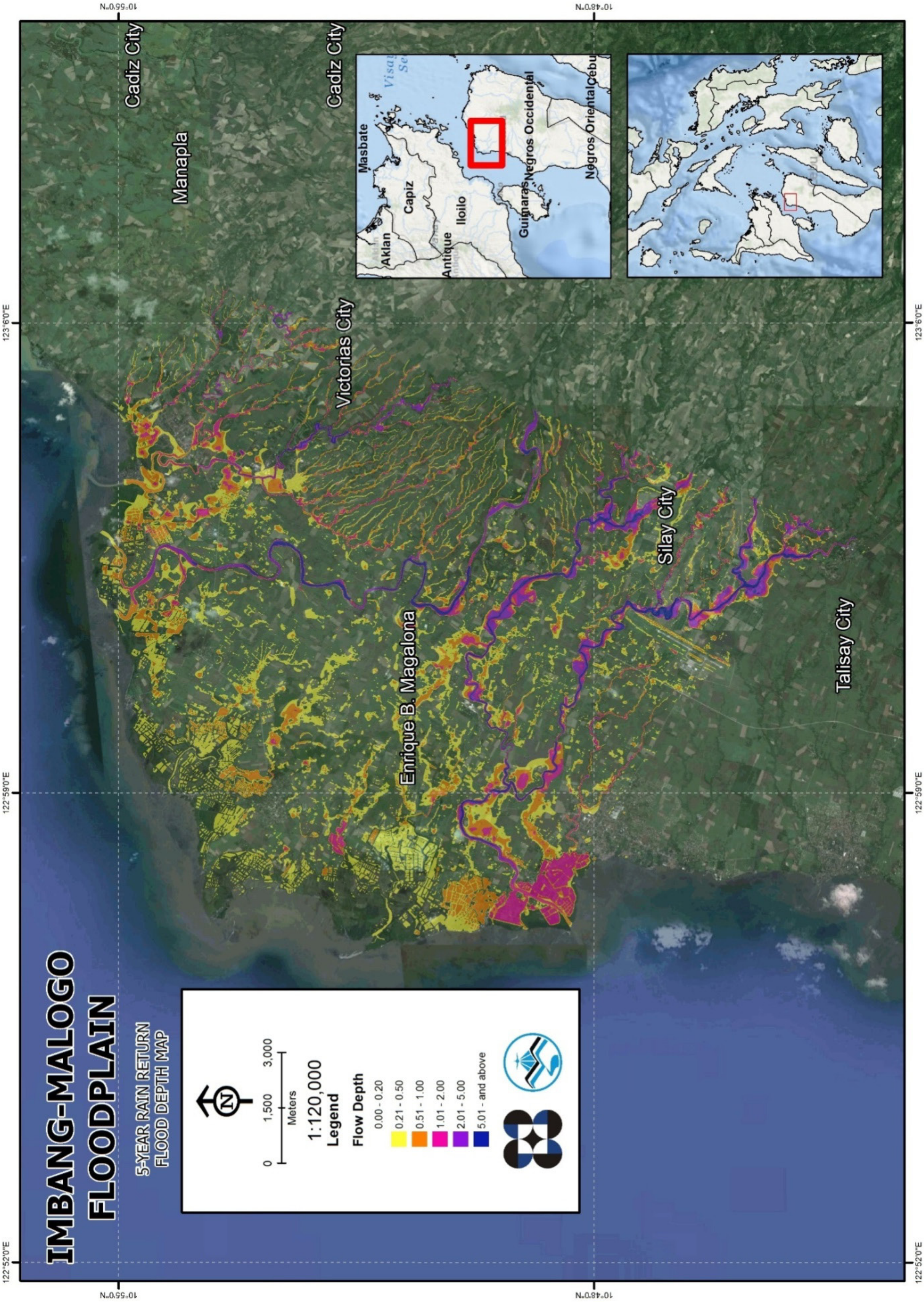


Figure 66. 100-year Flow Depth Map for Malogo-Imbang Floodplainoverlaid on Google Earth imagery

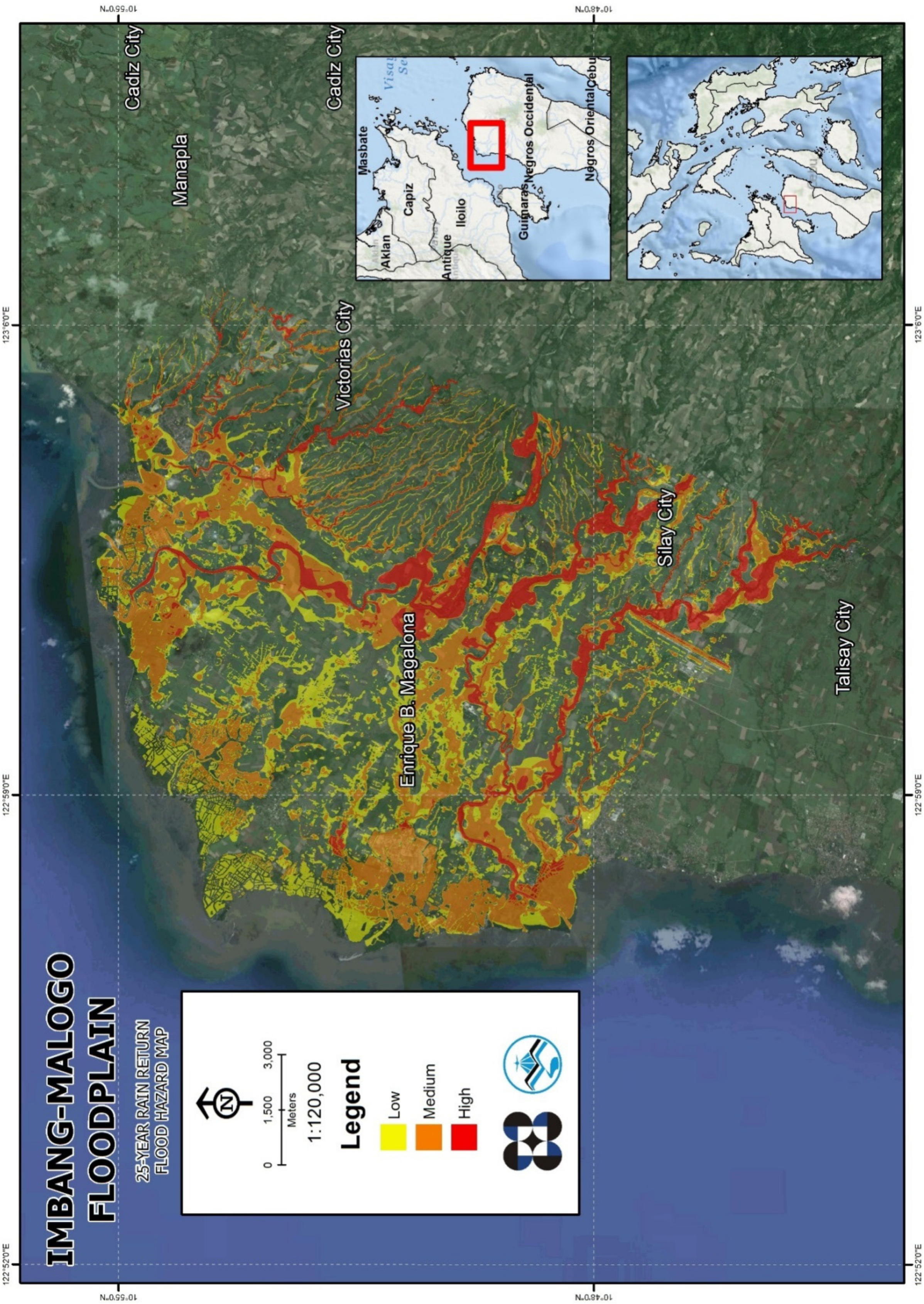


Figure 67. 25-year Flood Hazard Map for Malogo-Imbang Floodplainoverlaid on Google Earth imagery

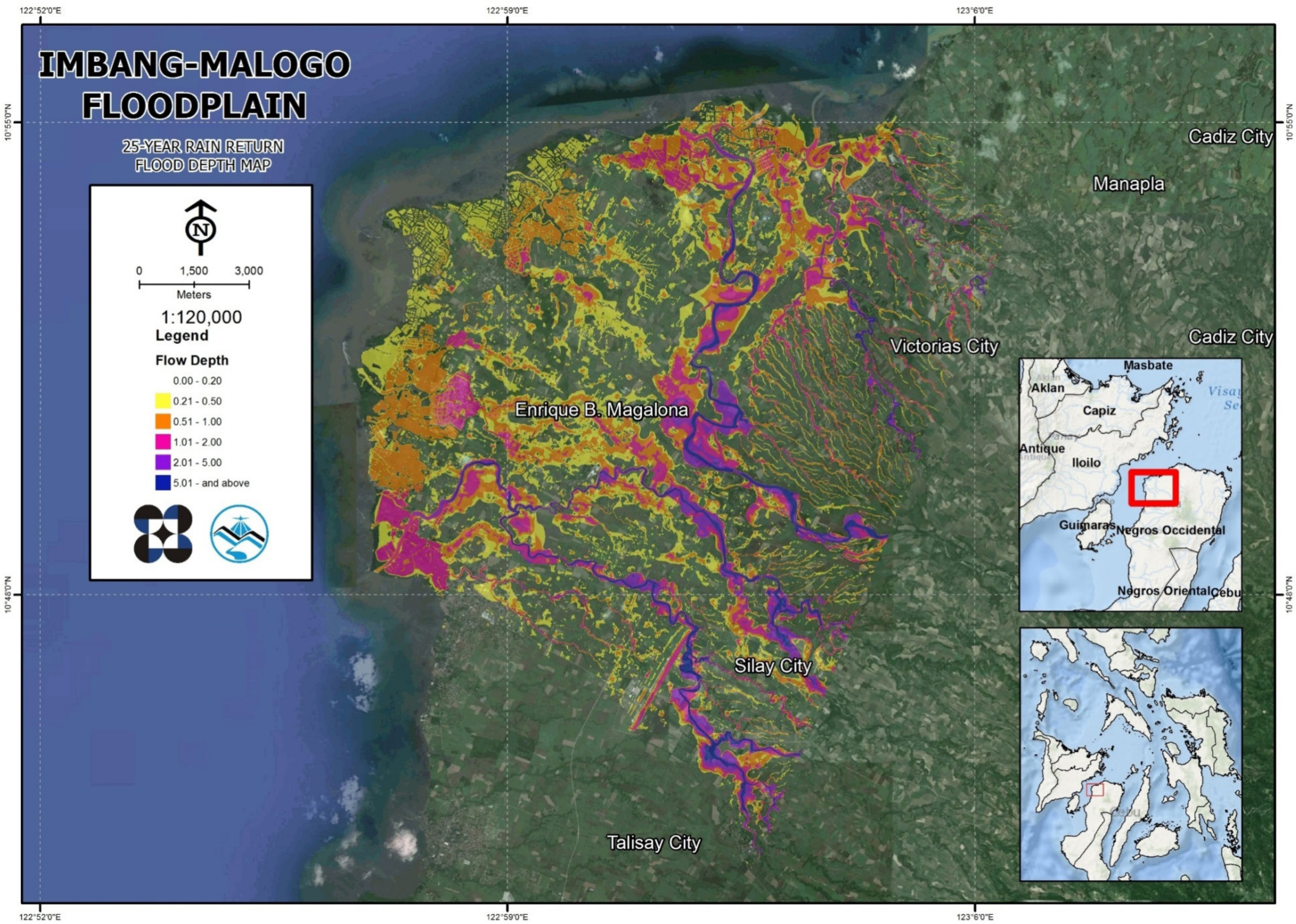


Figure 68. 25-year Flow Depth Map for Malogo-Imbang Floodplainoverlaid on Google Earth imagery

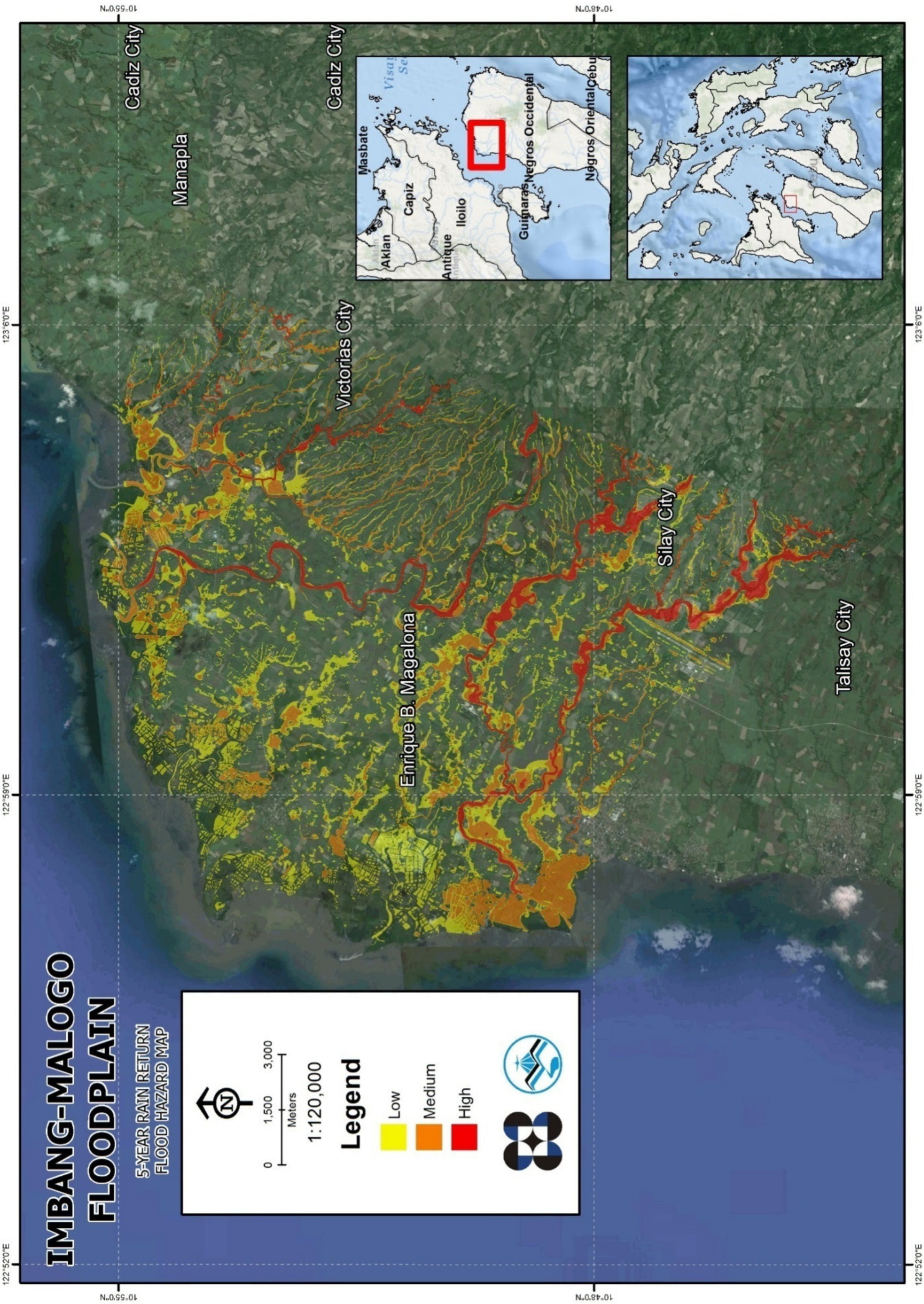


Figure 69. 5-year Flood Hazard Map for Malogo-Imbang Floodplainoverlaid on Google Earth imagery

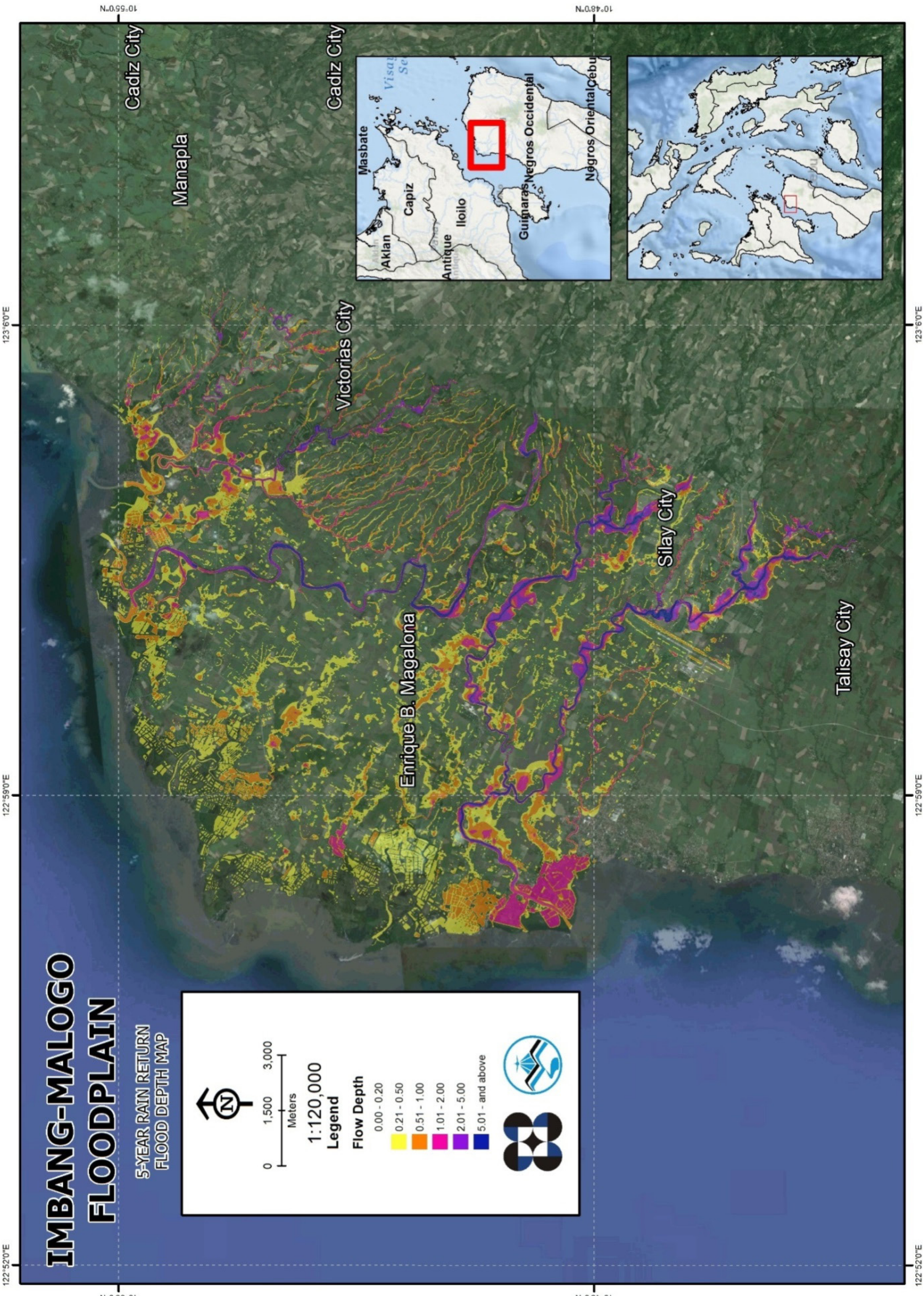


Figure 70. 5-year Flood Depth Map for Malogo-Imbang Floodplainoverlaid on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding of Affected Areas

Affected barangays in the Imbang (Imbang-Malogo) river basin, grouped by municipality, are listed below. For the said basin, eight municipalities consisting of 75 barangays are expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 7.46% of the city of Cadiz with an area of 516.184 sq. km. will experience flood levels of less 0.20 meters. 0.16% of the area will experience flood levels of 0.21 to 0.50 meters while 0.074%, 0.054%, 0.05%, and 0.041% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, greater than 5 meters respectively. Listed in Table 31 are the affected areas in square kilometres by flood depth per barangay.

Table 31. 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.)
	Celestino Villacin
0.03-0.20	38.51
0.21-0.50	0.81
0.51-1.00	0.38
1.01-2.00	0.28
2.01-5.00	0.25
> 5.00	0.21

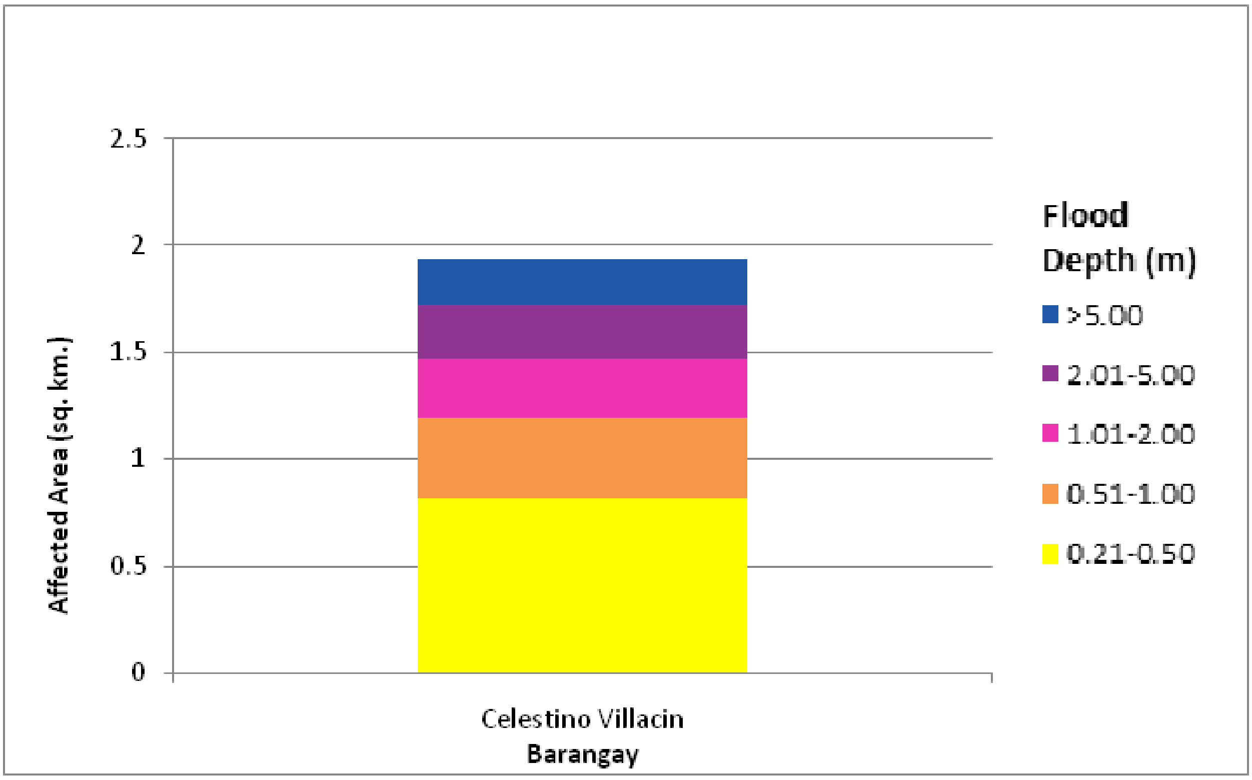


Figure. 71. Affected Areas in Cadiz City, Negros Occidental during 5-Year Rainfall Return Period

For the municipality of Calatrava, with an area of 344.54 sq. km., 0.013% will experience flood levels of less 0.20 meters. 0.000014% of the area will experience flood levels of 0.21 to 0.50 meters.

Table 32. Affected Areas in Calatrava, Negros Occidental during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calatrava (in sq. km.)
	Lalong
0.03-0.20	0.04
0.21-0.50	0
0.51-1.00	0
1.01-2.00	0
2.01-5.00	0
> 5.00	0

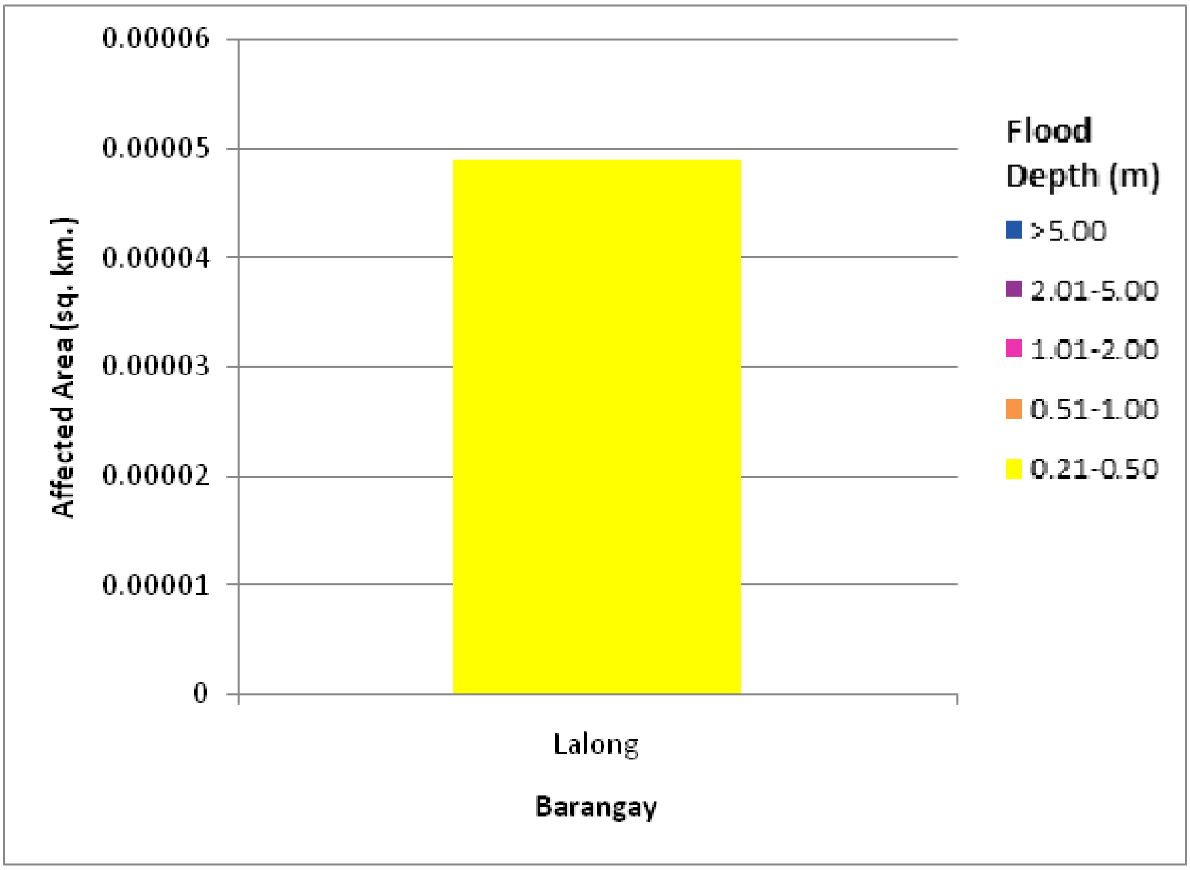


Figure 72. Affected Areas in Calatrava, Negros Occidental during 5-Year Rainfall Return Period

For the municipality of Enrique B. Magalona, with an area of 140.2 sq. km., 75.86% will experience flood levels of less 0.20 meters. 11.99% of the area will experience flood levels of 0.21 to 0.50 meters while 3.774%, 1.275%, 0.9416%, 0.596% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, 2.01 to 5 meters, greater than 5 meters respectively. Listed in Table 33 are the affected areas in square kilometres by flood depth per barangay.

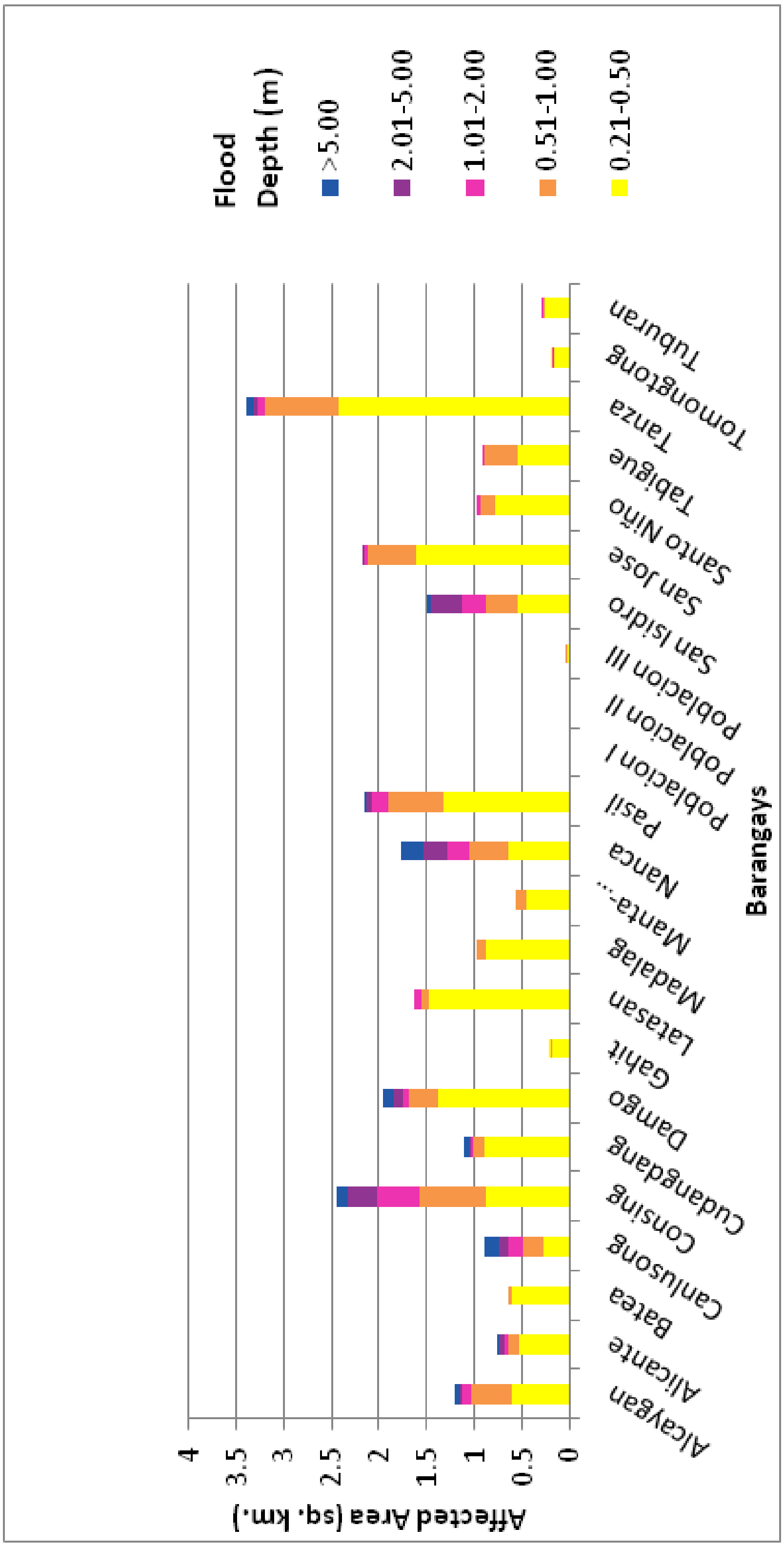


Figure 73. Affected Areas in Enrique B. Magalona, Negros Occidental during 5-Year Rainfall Return Period

Table 33. Affected Areas in Enrique B. Magalona, Negros Occidental during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Enrique B. Magalona (in sq. km.)											
	Alcay-gan	Alicante	Batea	Canlusong	Consing	Cudang-dang	Damgo	Gahit	Latasan	Madalag	Manta-An-gan	Nanca
0.03-0.20	6.66	3.38	1.56	9.44	15.99	5.03	7.69	0.75	4.39	2.28	2.49	5.37
0.21-0.50	0.63	0.54	0.61	0.29	0.89	0.92	1.39	0.21	1.48	0.89	0.47	0.66
0.51-1.00	0.41	0.13	0.05	0.22	0.7	0.11	0.31	0	0.07	0.09	0.1	0.4
1.01-2.00	0.11	0.04	0	0.15	0.44	0.01	0.05	0	0.09	0	0	0.24
2.01-5.00	0.02	0.06	0	0.1	0.31	0.03	0.12	0	0	0	0	0.25
> 5.00	0.06	0.01	0	0.14	0.11	0.05	0.11	0	0	0	0	0.24
	Pasil	Poblacion I	Poblacion II	Poblacion III	San Isidro	San Jose	Santo Niño	Tabigue	Tanza	Tomong-tong	Tuburan	
0.03-0.20	2.69	0.46	0.17	0.72	11.98	5.02	4.86	1.63	11.01	1.87	1.02	
0.21-0.50	1.34	0.01	0	0.04	0.56	1.63	0.8	0.56	2.44	0.19	0.27	
0.51-1.00	0.57	0	0	0.02	0.32	0.5	0.14	0.34	0.76	0.01	0.03	
1.01-2.00	0.18	0	0	0	0.25	0.07	0.05	0.02	0.09	0	0.01	
2.01-5.00	0.08	0	0	0	0.33	0	0	0	0.03	0	0	
> 5.00	0	0	0	0	0.03	0	0	0	0.08	0	0	

For the municipality of Manapla, with an area of 99.18 sq. km., 80% will experience flood levels of less 0.20 meters. 0.125% of the area will experience flood levels of 0.21 to 0.50 meters while 0.52%, 0.018%, 0.0029%of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters respectively. Listed in Table 34 are the affected areas in square kilometres by flood depth per barangay.

Table 34. Affected Areas in Manapla, Negros Occidental during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Manapla (in sq. km.)
	Tortosa
0.03-0.20	0.8
0.21-0.50	0.12
0.51-1.00	0.05
1.01-2.00	0.02
2.01-5.00	0
> 5.00	0

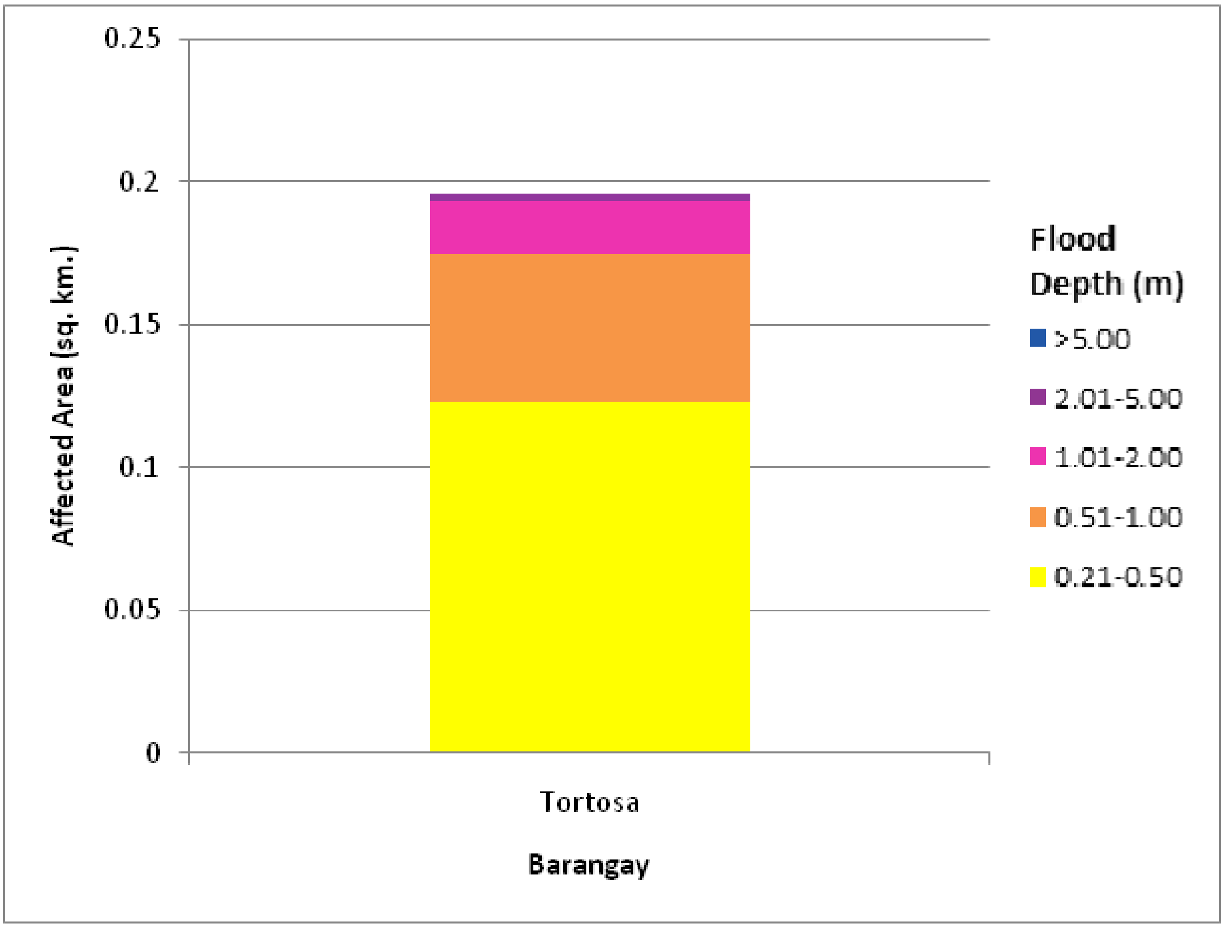


Figure 74. Affected Areas in Manapla, Negros Occidental during 5-Year Rainfall Return Period

For the municipality of Salvador Benedicto, with an area of 182.22 sq. km., 0.23% will experience flood levels of less 0.20 meters and 0.000019% of the area will experience flood levels of 0.21 to 0.50 meters. Listed in Table 35 are the affected areas in square kilometres by flood depth per barangay.

Table 35. Affected Areas in Salvador Benedicto, Negros Occidental during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Salvador Benedicto (in sq. km.)	
	Igmay-an	Pandanan
0.03-0.20	0.32	0.1
0.21-0.50	0	0
0.51-1.00	0	0
1.01-2.00	0	0
2.01-5.00	0	0
> 5.00	0	0

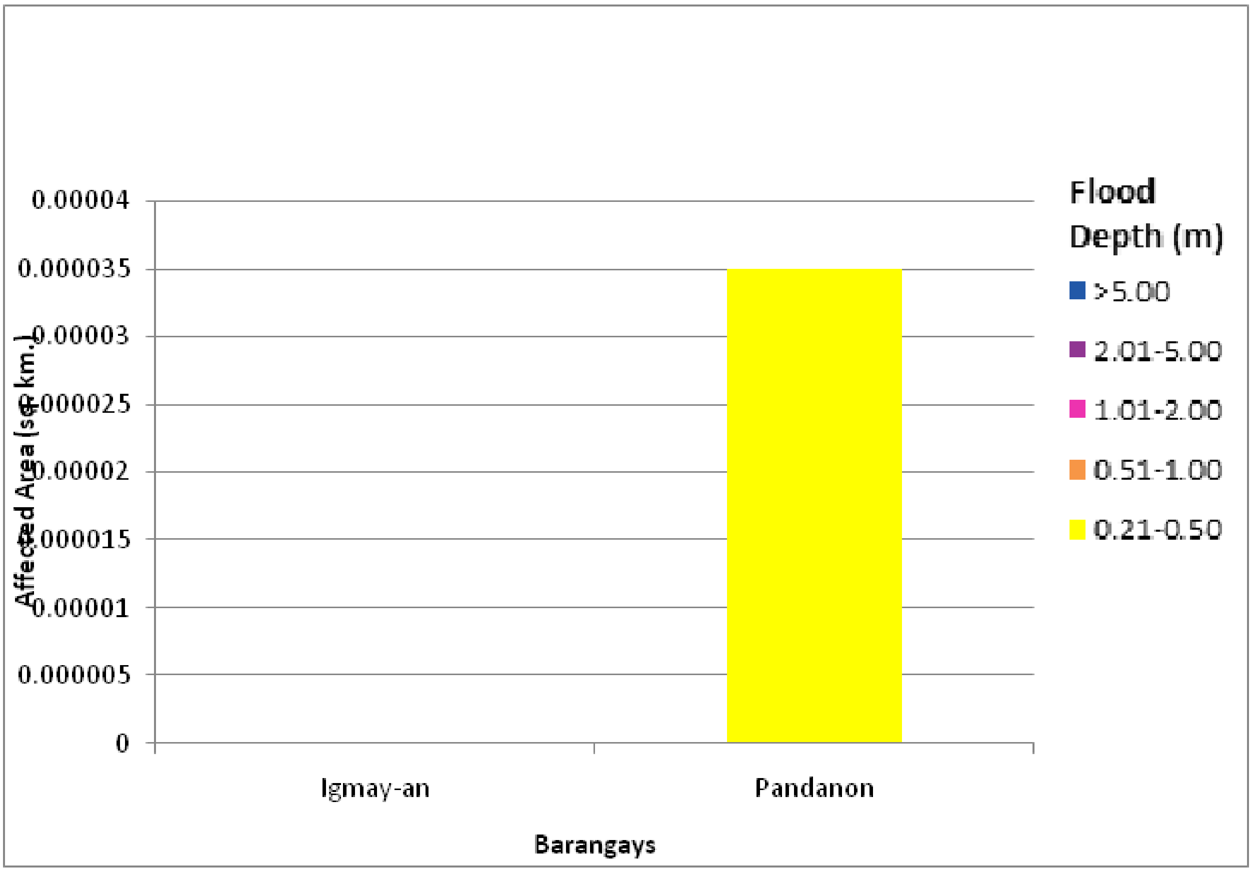


Figure 75. Affected Areas in Salvador Benedicto, Negros Occidental during 5-Year Rainfall Return Period

For the city of Silay, with an area of 199.01 sq. km., 74.2% will experience flood levels of less 0.20 meters. 6.4% of the area will experience flood levels of 0.21 to 0.50 meters while 4.3%, 3.55%, 2.47%, and 1.28% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, 2.01 to 5 meters, greater than 5 meters respectively. Listed in Table 36 are the affected areas in square kilometres by flood depth per barangay.

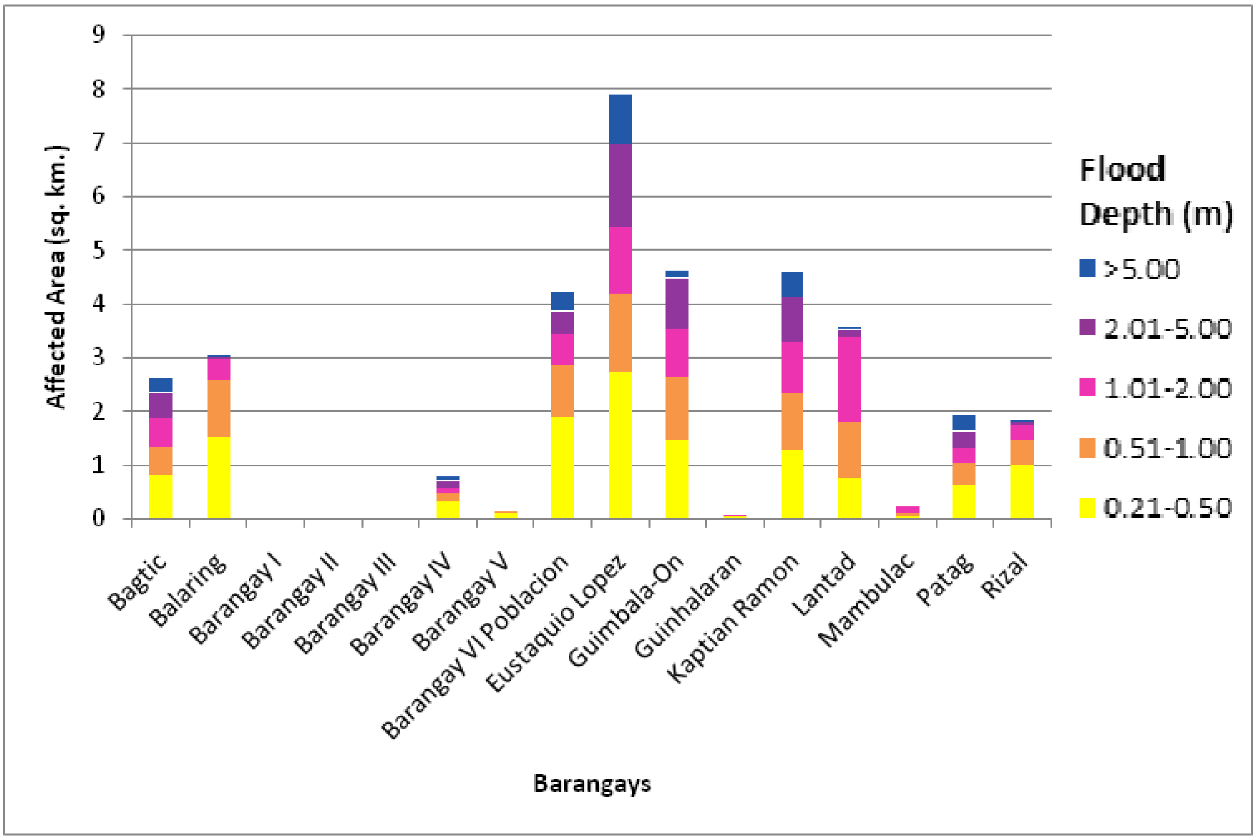


Figure 76. Affected Areas in Silay City, Negros Occidental during 5-Year Rainfall Return Period

Table 36. Affected Areas in Silay City, Negros Occidental during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Silay City (in sq. km.)							
	Bagtic	Balaring	Brgy. I	Brgy. II	Brgy. III	Brgy. IV	Brgy. V	Brgy. VI Poblacion
0.03-0.20	9.42	3.47	0.17	0.22	0.27	3.41	1.26	7.65
0.21-0.50	0.82	1.54	0.02	0.01	0	0.33	0.1	1.9
0.51-1.00	0.53	1.06	0	0	0	0.15	0.03	0.98
1.01-2.00	0.53	0.42	0	0	0	0.11	0	0.58
2.01-5.00	0.47	0.01	0	0	0	0.13	0	0.42
> 5.00	0.25	0	0	0	0	0.06	0	0.33
	Eustaquio Lopez	Guimbala-On	Guinhalaran	Kaptian Ramon	Lantad	Mambulac	Patag	Rizal
0.03-0.20	20.12	30.61	0.49	29.55	2.61	0.5	30.31	5.77
0.21-0.50	2.73	1.48	0.06	1.29	0.75	0.05	0.65	1.02
0.51-1.00	1.47	1.16	0.03	1.07	1.07	0.08	0.39	0.48
1.01-2.00	1.25	0.91	0.01	0.94	1.57	0.11	0.29	0.27
2.01-5.00	1.55	0.93	0	0.84	0.14	0	0.33	0.05
> 5.00	0.94	0.14	0	0.45	0.04	0	0.28	0.02

For the city of Talisay, with an area of 199.01 sq. km., 46% will experience flood levels of less 0.20 meters. 1.3% of the area will experience flood levels of 0.21 to 0.50 meters while 0.85%, 0.72%, 0.76%, and 0.2% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, 2.01 to 5 meters, greater than 5 meters respectively. Listed in Table 37 are the affected areas in square kilometres by flood depth per barangay.

Table 37. Affected Areas in Talisay City, Negros Occidental during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Talisay City (in sq. km.)				
	Cabatangan	Dos Hermanas	Katilingban	Matab-Ang	San Fernando
0.03-0.20	15.76	9.46	16.02	0.01	51.41
0.21-0.50	0.36	0.53	0.48	0	1.14
0.51-1.00	0.19	0.51	0.4	0	0.6
1.01-2.00	0.16	0.47	0.35	0	0.46
2.01-5.00	0.11	0.66	0.21	0	0.52
> 5.00	0.01	0.25	0.01	0	0.14

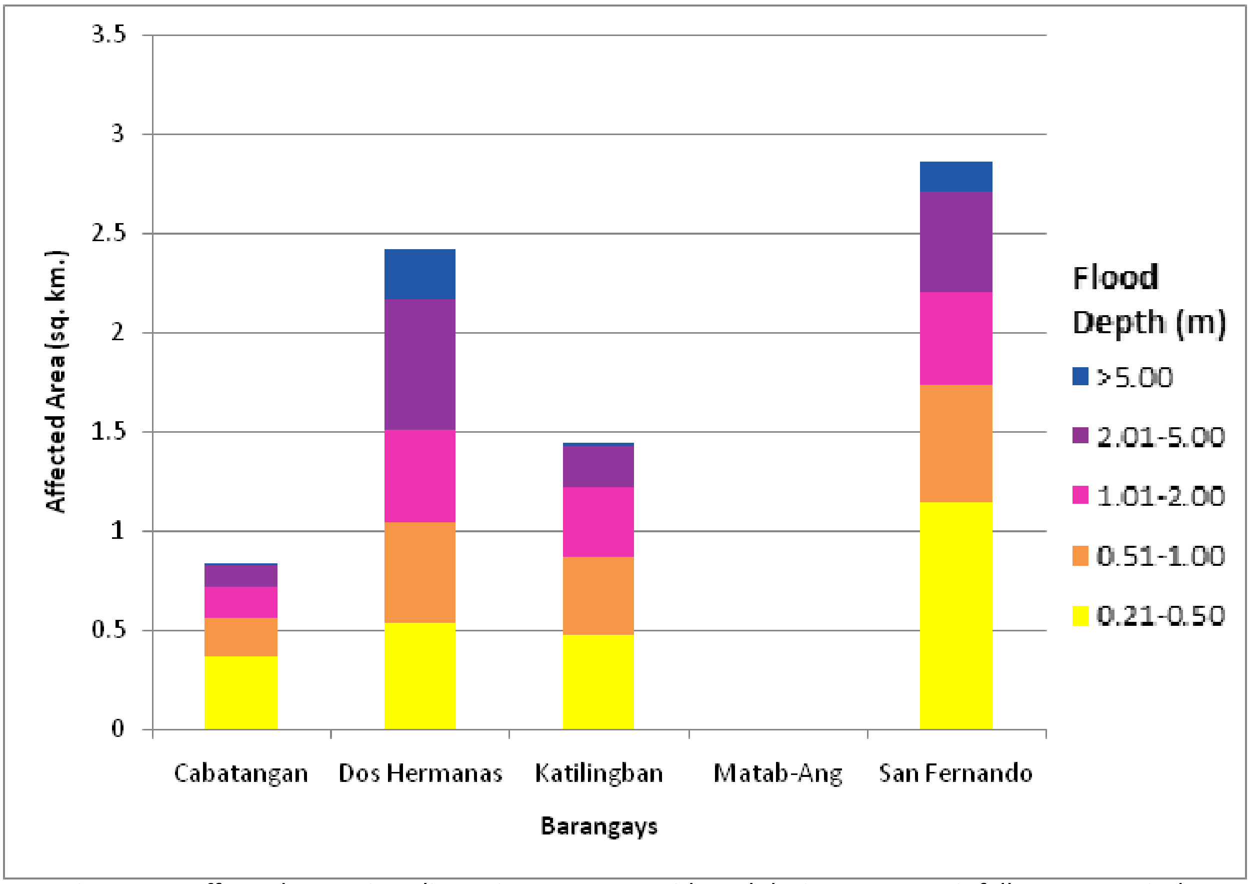


Figure 77. Affected Areas in Talisay City, Negros Occidental during 5-Year Rainfall Return Period

For the city of Victorias, with an area of 199.01 sq. km., 63% will experience flood levels of less 0.20 meters. 6% of the area will experience flood levels of 0.21 to 0.50 meters while 4.45%, 2.3%, 0.8%, and 0.2% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, 2.01 to 5 meters, greater than 5 meters respectively. Listed in Table 38 are the affected areas in square kilometres by flood depth per barangay.

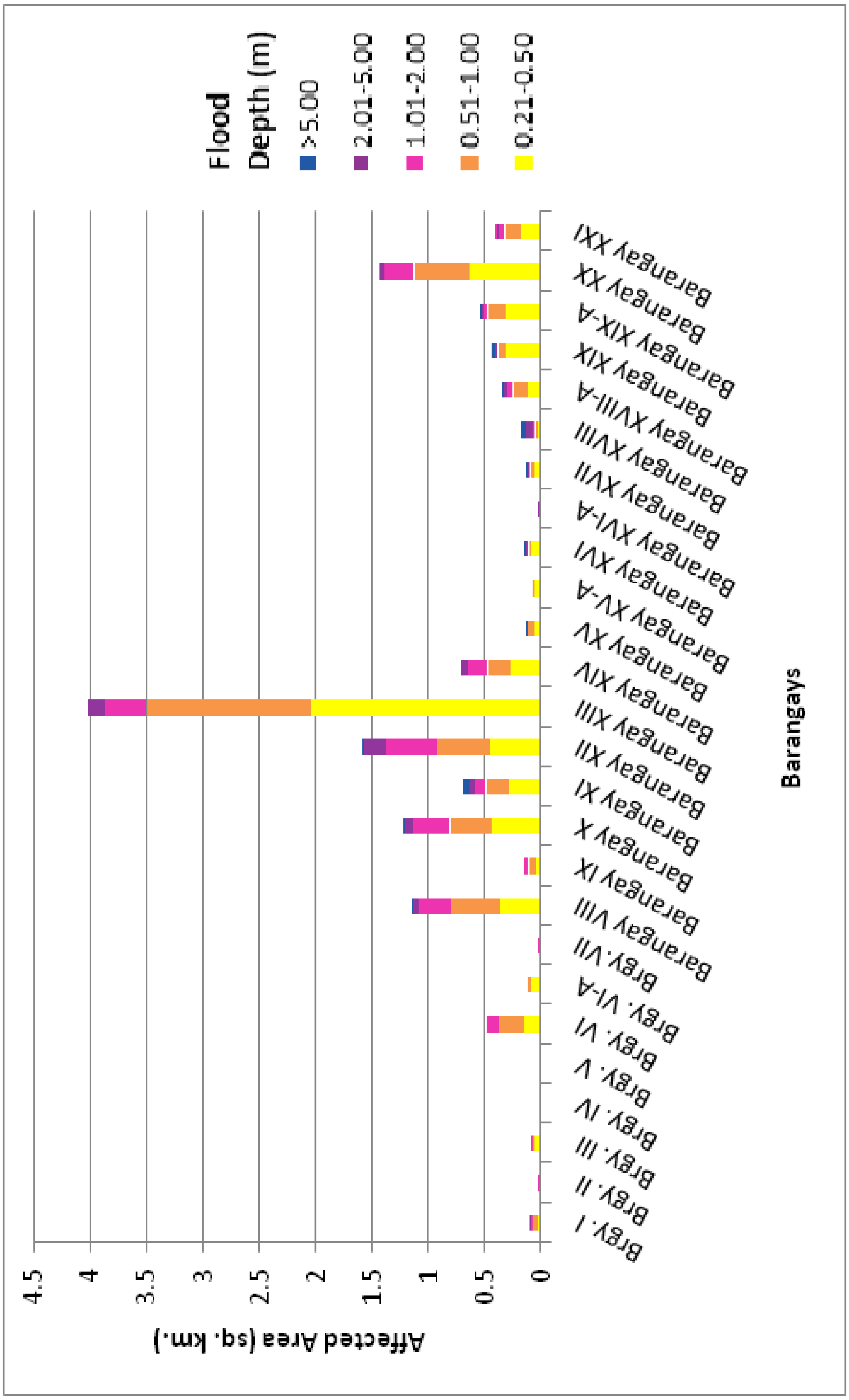


Figure 78. Affected Areas in Victorias City, Negros Occidental during 5-Year Rainfall Return Period

Table 38. Affected Areas in Victorias City, Negros Occidental during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Victorias City (in sq. km.)									
	Brgy. I	Brgy. II	Brgy. III	Brgy. IV	Brgy. V	Brgy. VI	Brgy. VI-A	Brgy.VII	Brgy. VIII	Brgy. IX
0.03-0.20	0.12	0.04	0.08	0.12	0.3	0.31	1.26	0.08	8.22	0.21
0.21-0.50	0.04	0	0.06	0	0	0.15	0.1	0.01	0.37	0.05
0.51-1.00	0.04	0.01	0.01	0	0	0.22	0.03	0.01	0.43	0.06
1.01-2.00	0.03	0	0	0	0	0.11	0	0.01	0.29	0.03
2.01-5.00	0	0	0	0	0	0	0	0	0.06	0
> 5.00	0	0	0	0	0	0	0	0	0	0
	Brgy. X	Brgy. XI	Brgy. XII	Brgy. XIII	Brgy. XIV	Brgy. XV	Brgy. XV-A	Brgy. XVI	Brgy. XVI-A	Brgy. XVII
0.03-0.20	9.36	10.7	7.2	6.61	5.73	0.21	0.62	0.18	0	0.58
0.21-0.50	0.44	0.28	0.45	2.05	0.28	0.07	0.07	0.1	0.01	0.06
0.51-1.00	0.37	0.21	0.47	1.46	0.19	0.05	0.01	0.01	0	0.04
1.01-2.00	0.32	0.1	0.46	0.38	0.18	0.01	0	0.01	0	0.01
2.01-5.00	0.1	0.04	0.19	0.15	0.06	0.01	0	0.03	0.01	0.01
> 5.00	0	0.06	0.02	0	0	0	0	0.01	0	0.01
	Brgy. XVIII	Brgy.XVIII-A	Brgy. XIX	Brgy. XIX-A	Brgy. XX	Brgy. XXI				
0.03-0.20	0.33	2.89	1.96	0.39	5.51	2.21				
0.21-0.50	0.03	0.13	0.33	0.32	0.64	0.18				
0.51-1.00	0.02	0.12	0.06	0.15	0.49	0.14				
1.01-2.00	0.03	0.05	0.01	0.04	0.27	0.07				
2.01-5.00	0.06	0.03	0.02	0.02	0.04	0				
> 5.00	0.05	0.01	0.02	0	0	0				

For the 25-year return period, 7.38% of the city of Cadiz with an area of 516.184 sq. km. will experience flood levels of less 0.20 meters. 0.19% of the area will experience flood levels of 0.21 to 0.50 meters while 0.08%, 0.06%, 0.059%, and 0.057% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, greater than 5 meters respectively. Listed in Table 39 are the affected areas in square kilometres by flood depth per barangay.

Table 39. 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.)
	Celestino Villacin
0.03-0.20	38.08
0.21-0.50	0.99
0.51-1.00	0.46
1.01-2.00	0.32
2.01-5.00	0.3
> 5.00	0.3

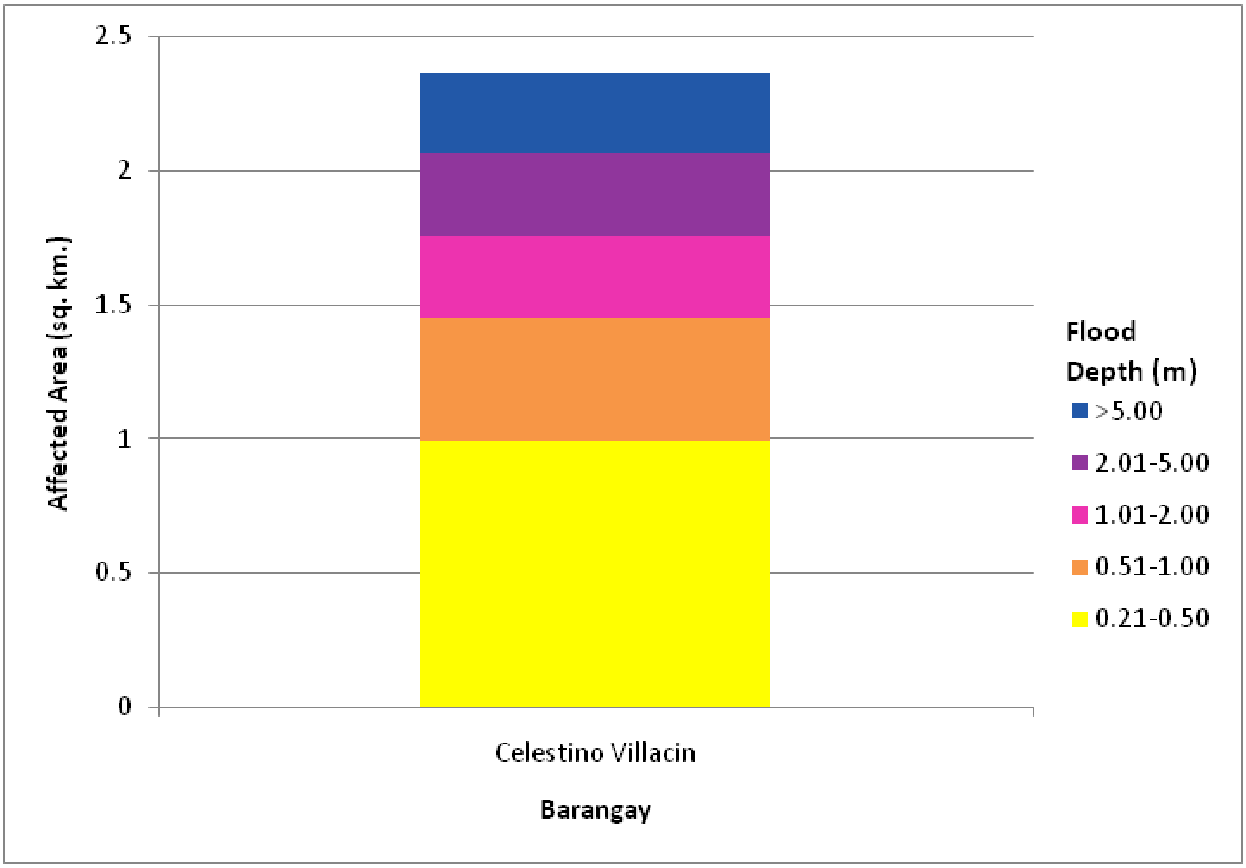


Figure 79. Affected Areas in Cadiz City, Negros Occidental during 25-Year Rainfall Return Period

For the municipality of Calatrava, with an area of 344.54 sq. km., 0.013% will experience flood levels of less 0.20 meters. 0.000014% of the area will experience flood levels of 0.21 to 0.50 meters.

Table 40. Affected Areas in Calatrava, Negros Occidental during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calatrava (in sq. km.)
	Lalong
0.03-0.20	0.04
0.21-0.50	0
0.51-1.00	0
1.01-2.00	0
2.01-5.00	0
> 5.00	0

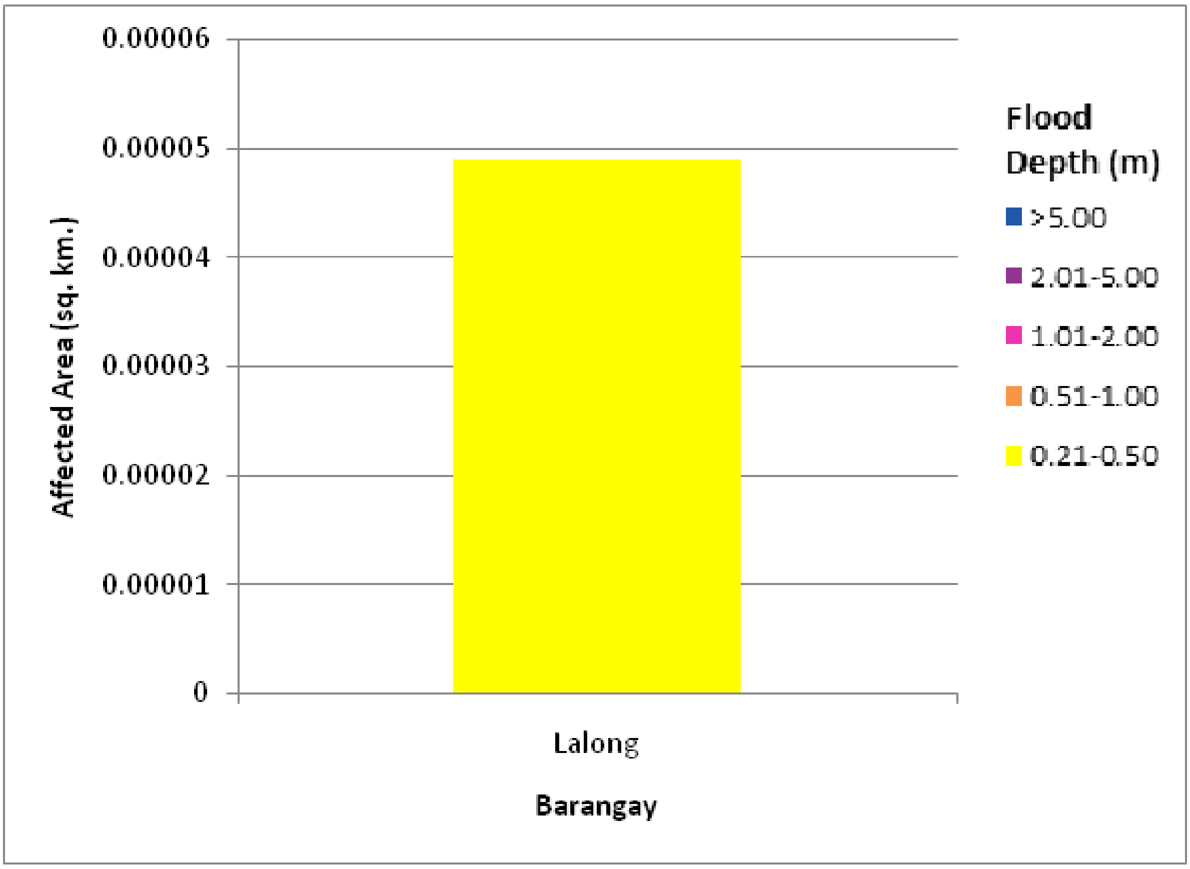


Figure 80. Affected Areas in Calatrava, Negros Occidental during 25-Year Rainfall Return Period

For the municipality of Enrique B. Magalona, with an area of 140.2 sq. km., 60.41% will experience flood levels of less 0.20 meters. 14.84% of the area will experience flood levels of 0.21 to 0.50 meters while 10.9%, 5.14%, 2.07%, 1.06% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, 2.01 to 5 meters, greater than 5 meters respectively. Listed in Table 41 are the affected areas in square kilometres by flood depth per barangay.

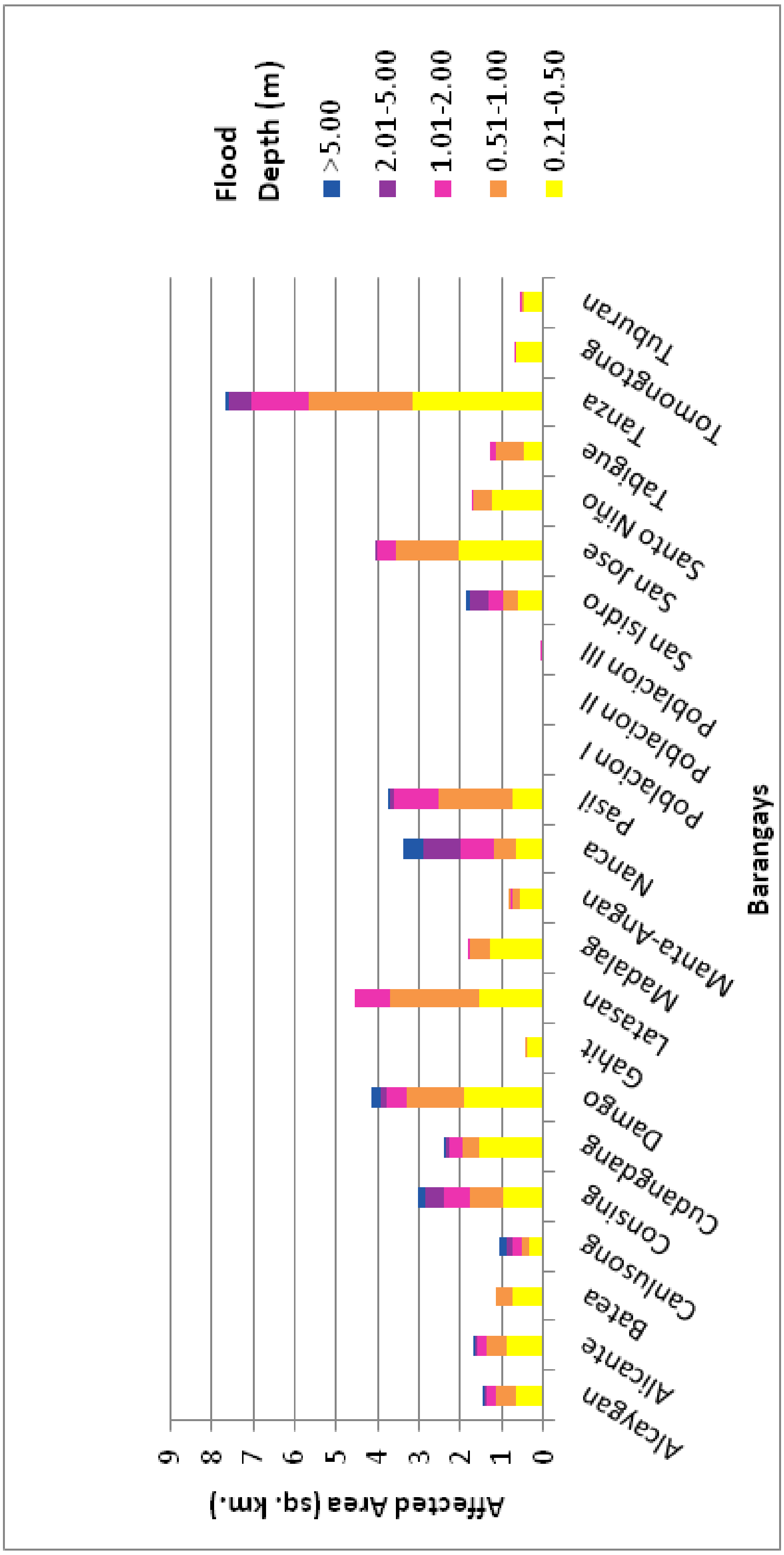


Figure 81. Affected Areas in Enrique B. Magalona, Negros Occidental during 25-Year Rainfall Return Period

Table 41. Affected Areas in Enrique B. Magalona, Negros Occidental during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Enrique B. Magalona (in sq. km.)											
	Alcaygan	Alicante	Batea	Canlusong	Consing	Cudang-dang	Damgo	Gahit	Latasan	Madalag	Manta-Angan	Nanca
0.03-0.20	6.39	2.45	1.1	9.26	15.42	3.72	5.51	0.54	1.48	1.46	2.24	3.77
0.21-0.50	0.64	0.88	0.75	0.31	0.95	1.53	1.91	0.38	1.51	1.28	0.56	0.66
0.51-1.00	0.52	0.51	0.37	0.23	0.82	0.43	1.37	0.04	2.19	0.52	0.24	0.54
1.01-2.00	0.22	0.19	0	0.22	0.64	0.32	0.48	0	0.85	0.01	0.02	0.78
2.01-5.00	0.04	0.06	0	0.13	0.43	0.07	0.16	0	0	0	0	0.91
> 5.00	0.07	0.05	0	0.18	0.19	0.08	0.22	0	0	0	0	0.48
	Pasil	Poblacion I	Poblacion II	Poblacion III	San Isidro	San Jose	Santo Niño	Tabigue	Tanza	Tomong-tong	Tuburan	
0.03-0.20	1.12	0.45	0.15	0.69	11.59	3.17	4.11	1.25	6.75	1.38	0.76	
0.21-0.50	0.74	0.02	0.02	0.06	0.61	2.02	1.23	0.46	3.14	0.68	0.48	
0.51-1.00	1.81	0	0	0.02	0.39	1.56	0.45	0.7	2.51	0.02	0.07	
1.01-2.00	1.08	0	0	0.01	0.33	0.46	0.07	0.15	1.38	0	0.01	
2.01-5.00	0.11	0	0	0	0.45	0	0	0	0.53	0	0	
> 5.00	0.01	0	0	0	0.1	0	0	0	0.11	0	0	

For the municipality of Manapla, with an area of 99.18 sq. km., 73% will experience flood levels of less 0.20 meters. 0.12% of the area will experience flood levels of 0.21 to 0.50 meters while 0.12%, 0.024%, 0.005%of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters respectively. Listed in Table 42 are the affected areas in square kilometres by flood depth per barangay.

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

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Manapla (in sq. km.)
	Tortosa
0.03-0.20	0.73
0.21-0.50	0.12
0.51-1.00	0.12
1.01-2.00	0.02
2.01-5.00	0.01
> 5.00	0

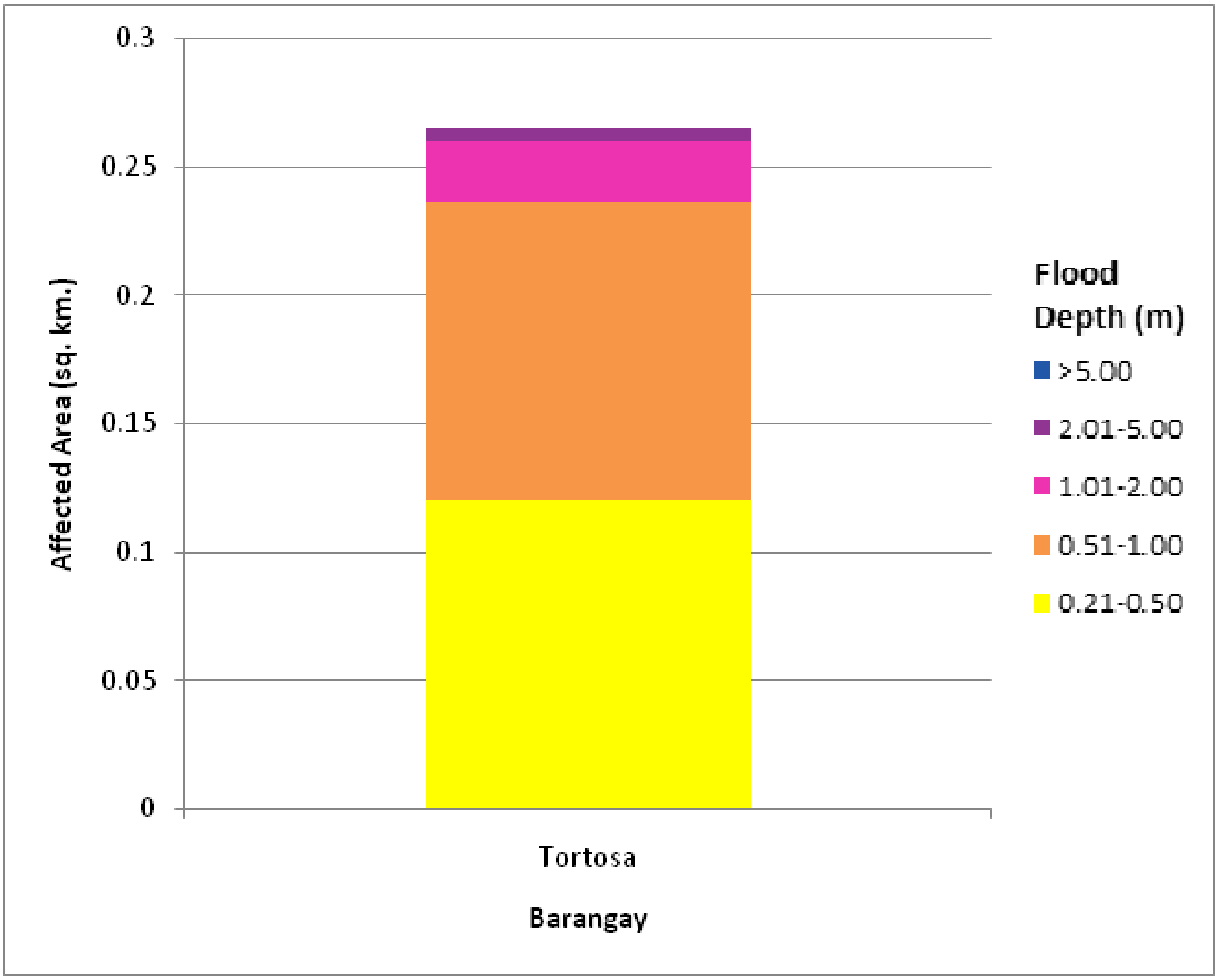


Figure 82. Affected Areas in Manapla, Negros Occidental during 25-Year Rainfall Return Period

For the municipality of Salvador Benedicto, with an area of 182.22 sq. km., 0.23% will experience flood levels of less 0.20 meters and 0.000019% of the area will experience flood levels of 0.21 to 0.50 meters. Listed in Table 43 are the affected areas in square kilometres by flood depth per barangay.

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

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Salvador Benedicto (in sq. km.)	
	Igmay-an	Pandanan
0.03-0.20	0.32	0.1
0.21-0.50	0	0
0.51-1.00	0	0
1.01-2.00	0	0
2.01-5.00	0	0
> 5.00	0	0

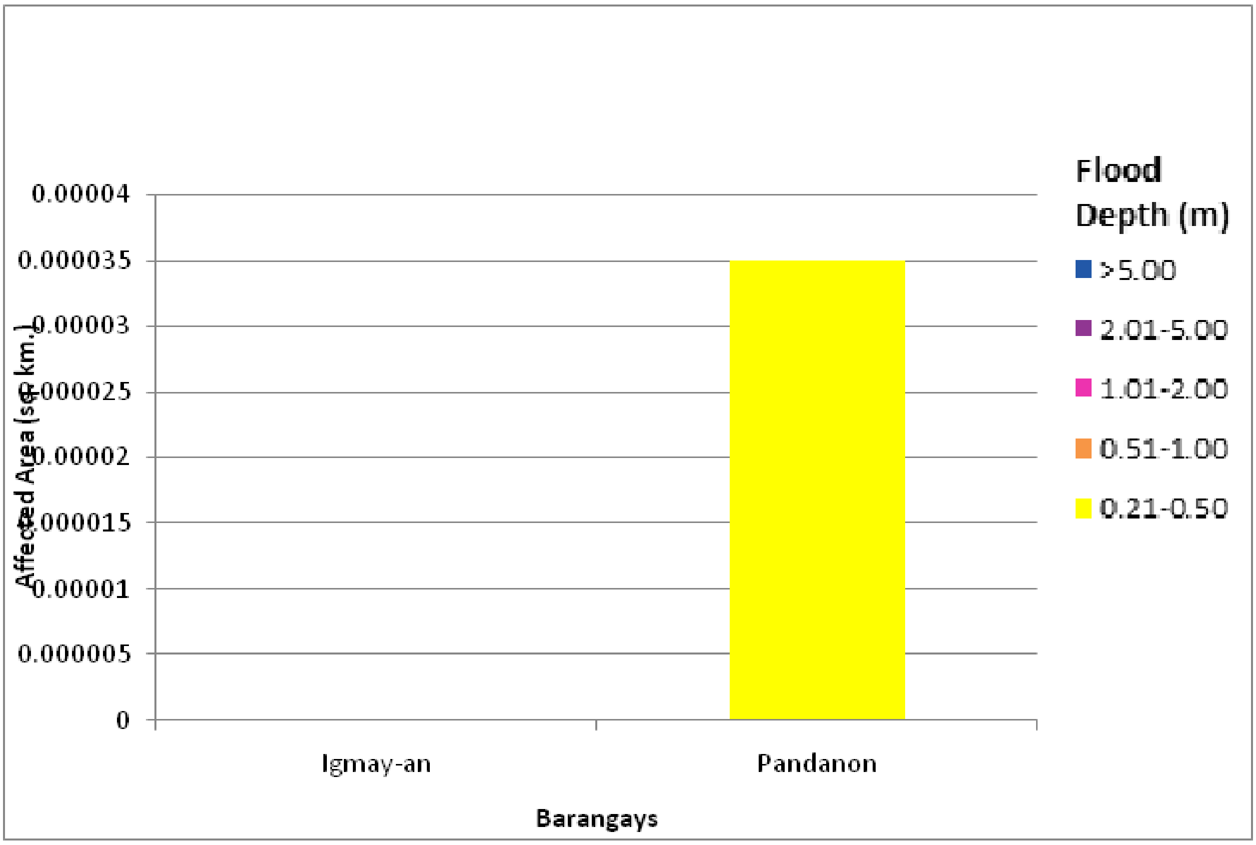


Figure 83. Affected Areas in Salvador Benedicto, Negros Occidental during 25-Year Rainfall Return Period

For the city of Silay, with an area of 199.01 sq. km., 67.93% will experience flood levels of less 0.20 meters. 7.4% of the area will experience flood levels of 0.21 to 0.50 meters while 6.3%, 5.3%, 3.48%, and 1.82% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, 2.01 to 5 meters, greater than 5 meters respectively. Listed in Table 44 are the affected areas in square kilometres by flood depth per barangay.

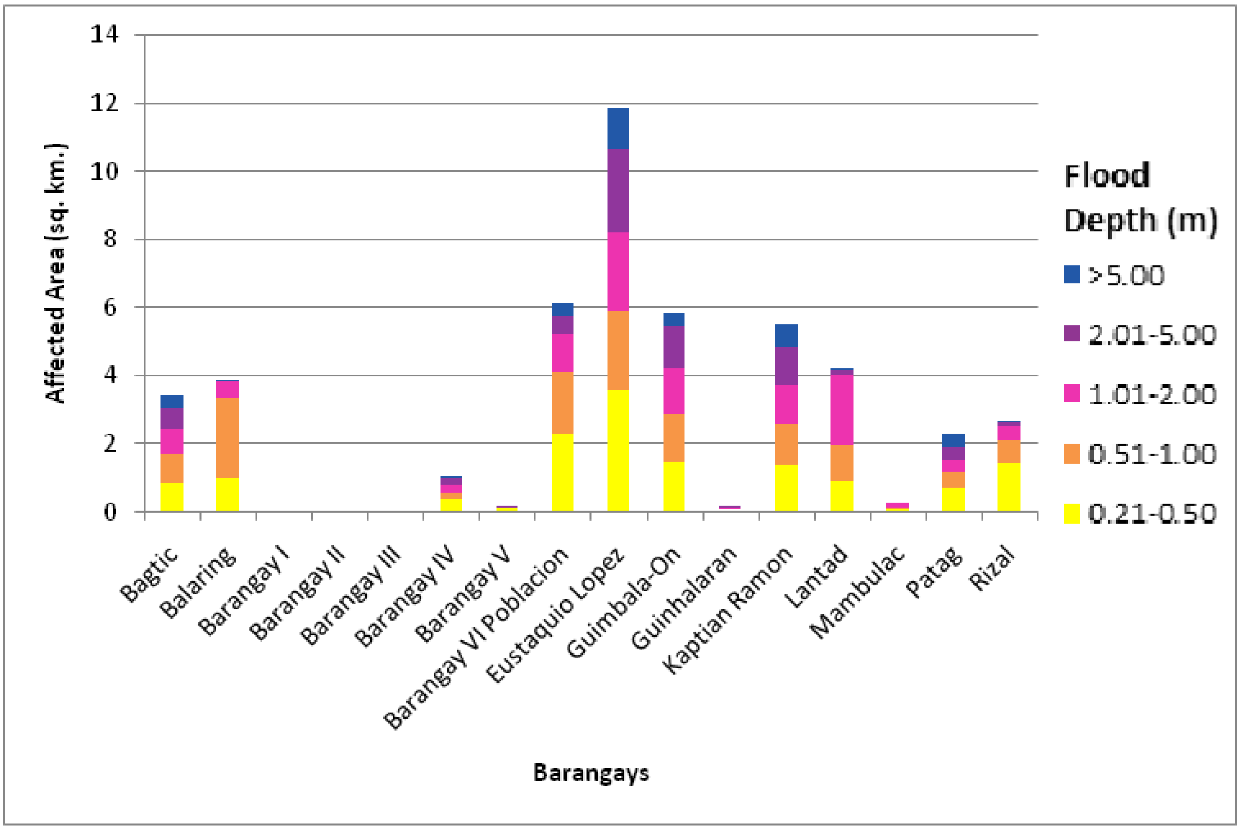


Figure 84. Affected Areas in Silay City, Negros Occidental during 25-Year Rainfall Return Period

Table 44. Affected Areas in Silay City, Negros Occidental during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Silay City (in sq. km.)							
	Bagtic	Balaring	Brgy. I	Brgy. II	Brgy. III	Brgy. IV	Brgy. V	Brgy. VI Poblacion
0.03-0.20	8.56	2.61	0.15	0.17	0.27	3.11	1.18	5.72
0.21-0.50	0.86	1.02	0.04	0.06	0	0.4	0.13	2.31
0.51-1.00	0.87	2.36	0.01	0	0	0.19	0.05	1.82
1.01-2.00	0.72	0.49	0	0	0	0.21	0.02	1.11
2.01-5.00	0.62	0.02	0	0	0	0.19	0	0.52
> 5.00	0.38	0	0	0	0	0.08	0	0.37
	Eustaquio Lopez	Guimbala-On	Guinhalaran	Kaptian Ramon	Lantad	Mambulac	Patag	Rizal
0.03-0.20	16.15	29.36	0.4	28.62	1.91	0.44	29.92	4.9
0.21-0.50	3.61	1.5	0.07	1.38	0.9	0.09	0.74	1.43
0.51-1.00	2.3	1.38	0.05	1.23	1.07	0.06	0.45	0.7
1.01-2.00	2.33	1.34	0.05	1.13	2.09	0.14	0.34	0.43
2.01-5.00	2.44	1.25	0.01	1.13	0.15	0	0.39	0.12
> 5.00	1.21	0.41	0	0.66	0.05	0	0.4	0.02

For the city of Talisay, with an area of 199.01 sq. km., 45.6% will experience flood levels of less 0.20 meters. 1.46% of the area will experience flood levels of 0.21 to 0.50 meters while 1.02%, 0.9%, 1.03%, and 0.35% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, 2.01 to 5 meters, greater 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 Talisay City, Negros Occidental during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Talisay City (in sq. km.)				
	Cabatangan	Dos Hermanas	Katilingban	Matab-Ang	San Fernando
0.03-0.20	15.59	8.62	15.75	0.01	50.77
0.21-0.50	0.43	0.58	0.52	0	1.37
0.51-1.00	0.21	0.71	0.42	0	0.7
1.01-2.00	0.18	0.68	0.4	0	0.53
2.01-5.00	0.17	0.91	0.33	0	0.64
> 5.00	0.02	0.39	0.03	0	0.26

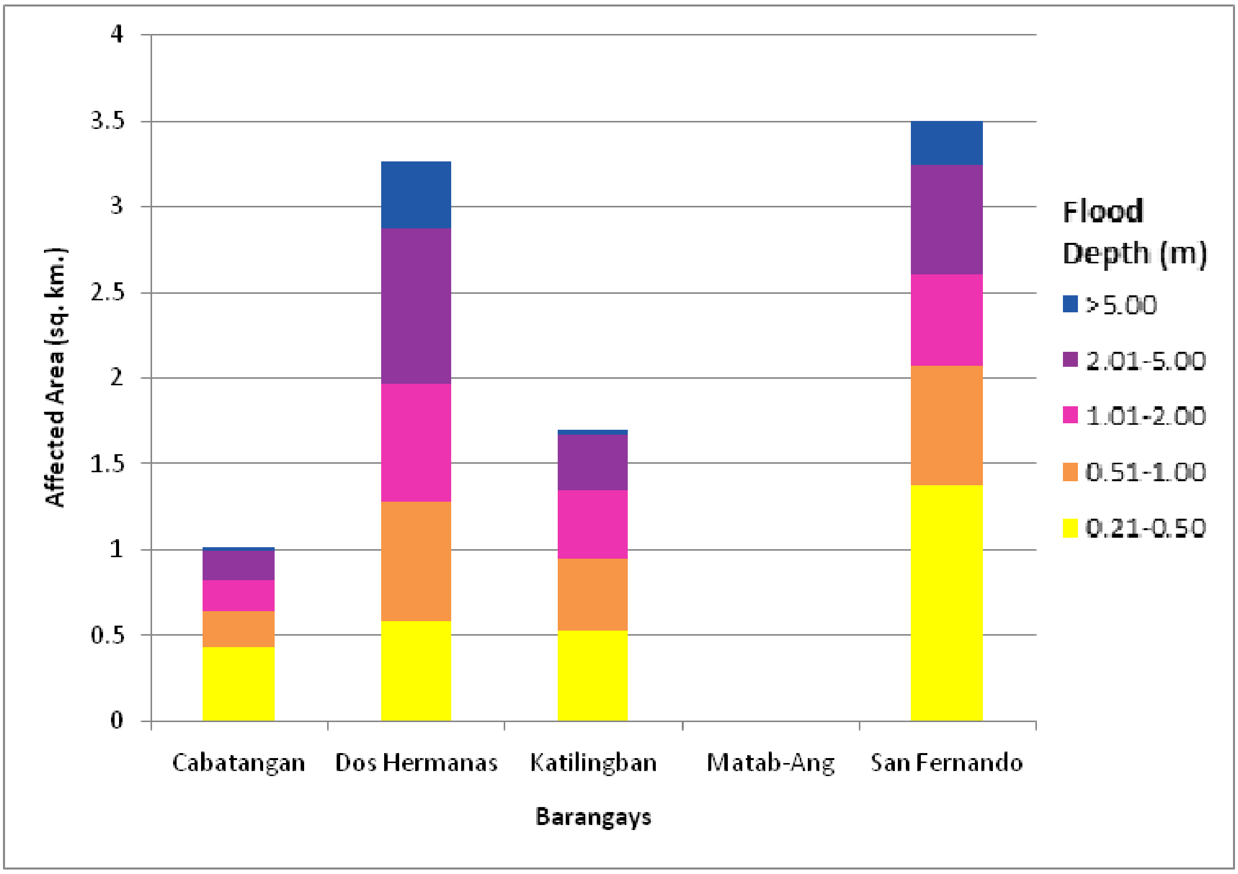


Figure 85. Affected Areas in Talisay City, Negros Occidental during 5-Year Rainfall Return Period

For the city of Victorias, with an area of 199.01 sq. km., 56.87% will experience flood levels of less 0.20 meters. 6% of the area will experience flood levels of 0.21 to 0.50 meters while 6.88%, 4.3%, 1.3%, and 0.33% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, 2.01 to 5 meters, greater than 5 meters respectively. Listed in Table 46 are the affected areas in square kilometres by flood depth per barangay.

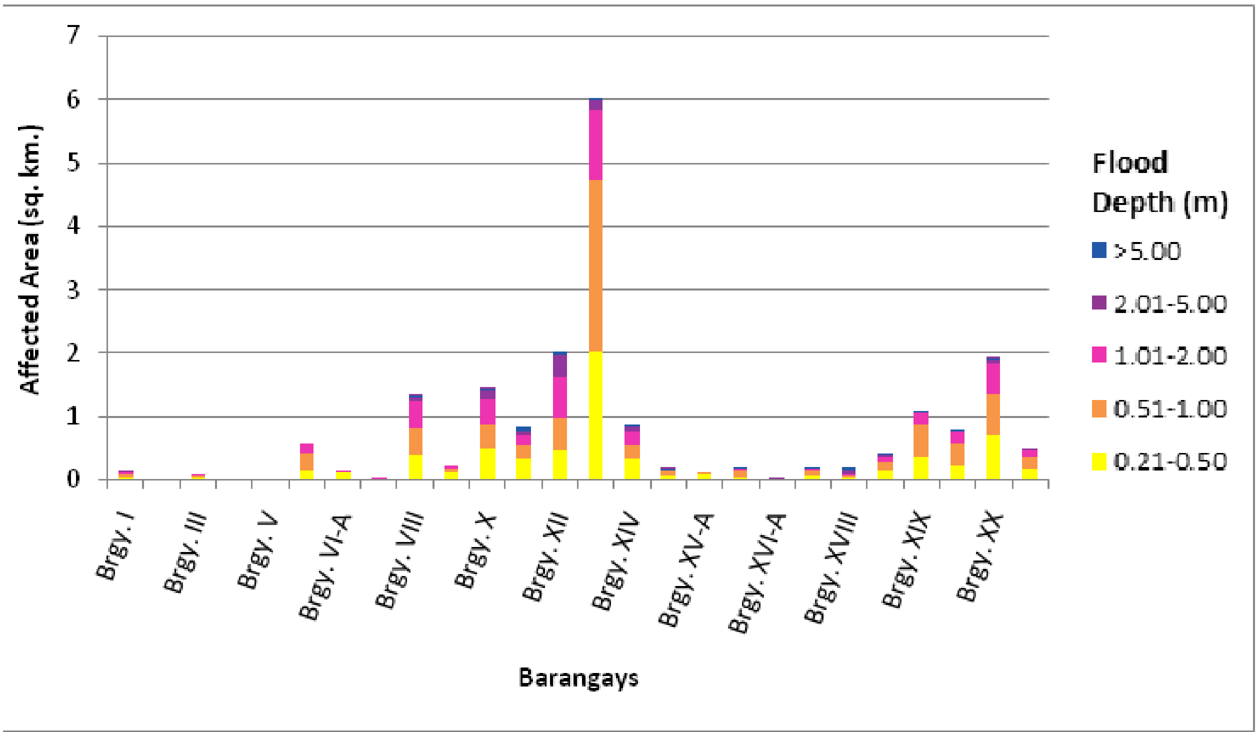


Figure 86. Affected Areas in Victorias City, Negros Occidental during 25-Year Rainfall Return Period

Table 46. Affected Areas in Victorias City, Negros Occidental during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Victorias City (in sq. km.)									
	Brgy. I	Brgy. II	Brgy. III	Brgy. IV	Brgy. V	Brgy. VI	Brgy. VI-A	Brgy.VII	Brgy. VIII	Brgy. IX
0.03-0.20	0.09	0.04	0.06	0.11	0.3	0.22	0.2	0.08	8.03	0.13
0.21-0.50	0.04	0	0.04	0.01	0.01	0.14	0.11	0.01	0.38	0.11
0.51-1.00	0.05	0.01	0.06	0	0	0.26	0.03	0.01	0.43	0.06
1.01-2.00	0.04	0.01	0	0	0	0.17	0	0.01	0.44	0.05
2.01-5.00	0	0	0	0	0	0	0	0	0.1	0
> 5.00	0	0	0	0	0	0	0	0	0.01	0
	Brgy. X	Brgy. XI	Brgy. XII	Brgy. XIII	Brgy. XIV	Brgy. XV	Brgy. XV-A	Brgy. XVI	Brgy. XVI-A	Brgy. XVII
0.03-0.20	9.14	10.55	6.75	4.61	5.56	0.16	0.58	0.13	0	0.51
0.21-0.50	0.48	0.32	0.48	2.02	0.32	0.05	0.11	0.04	0	0.06
0.51-1.00	0.39	0.23	0.51	2.71	0.23	0.1	0.02	0.09	0.01	0.09
1.01-2.00	0.39	0.17	0.64	1.11	0.2	0.03	0	0.03	0	0.03
2.01-5.00	0.18	0.07	0.35	0.18	0.13	0.01	0	0.03	0.01	0.02
> 5.00	0	0.08	0.07	0.01	0	0	0	0.01	0	0.02
	Brgy. XVIII	Brgy.XVIII-A	Brgy. XIX	Brgy. XIX-A	Brgy. XX	Brgy. XXI				
0.03-0.20	0.3	2.81	1.28	0.13	5	2.11				
0.21-0.50	0.03	0.14	0.35	0.23	0.7	0.18				
0.51-1.00	0.02	0.13	0.51	0.34	0.65	0.19				
1.01-2.00	0.03	0.09	0.19	0.19	0.49	0.11				
2.01-5.00	0.06	0.03	0.01	0.04	0.1	0.02				
> 5.00	0.07	0.02	0.04	0.01	0	0				

For the 100-year return period, 7.3% of the city of Cadiz with an area of 516.184 sq. km. will experience flood levels of less 0.20 meters. 0.22% of the area will experience flood levels of 0.21 to 0.50 meters while 0.1%, 0.065%, 0.066%, and 0.071% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, greater than 5 meters respectively. Listed in Table 47 are the affected areas in square kilometres by flood depth per barangay.

Table 47. 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.)
	Celestino Villacin
0.03-0.20	37.78
0.21-0.50	1.12
0.51-1.00	0.5
1.01-2.00	0.34
2.01-5.00	0.34
> 5.00	0.37

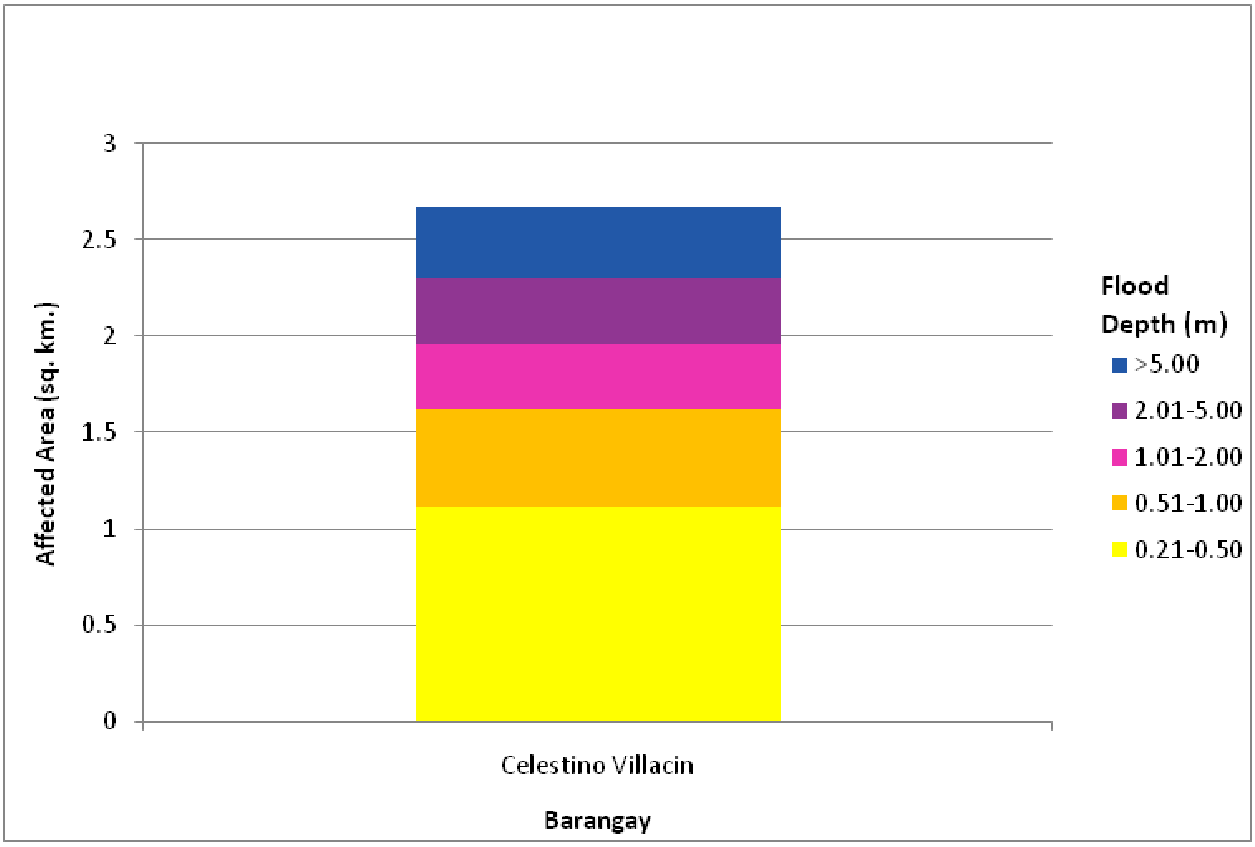


Figure 87. Affected Areas in Cadiz City, Negros Occidental during 100-Year Rainfall Return Period

For the municipality of Calatrava, with an area of 344.54 sq. km., 0.013% will experience flood levels of less 0.20 meters. 0.000014% of the area will experience flood levels of 0.21 to 0.50 meters.

Table 48. Affected Areas in Calatrava, Negros Occidental during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calatrava (in sq. km.)
	Lalong
0.03-0.20	0.04
0.21-0.50	0
0.51-1.00	0
1.01-2.00	0
2.01-5.00	0
> 5.00	0

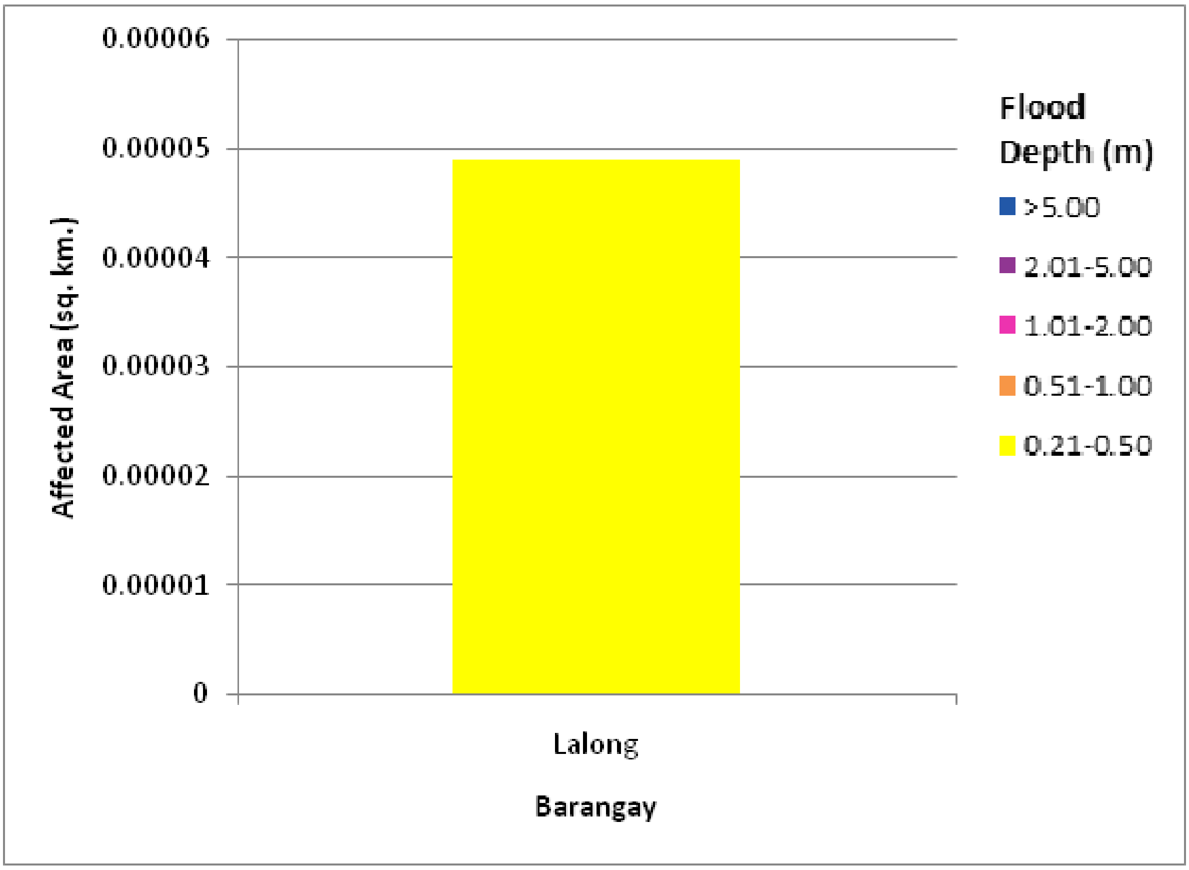


Figure 88. Affected Areas in Calatrava, Negros Occidental during 100-Year Rainfall Return Period

For the municipality of Enrique B. Magalona, with an area of 140.2 sq. km., 54.35% will experience flood levels of less 0.20 meters. 14.15% of the area will experience flood levels of 0.21 to 0.50 meters while 13.23%, 8.19%, 3.15%, 1.37% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, 2.01 to 5 meters, greater than 5 meters respectively. Listed in Table 49 are the affected areas in square kilometres by flood depth per barangay.

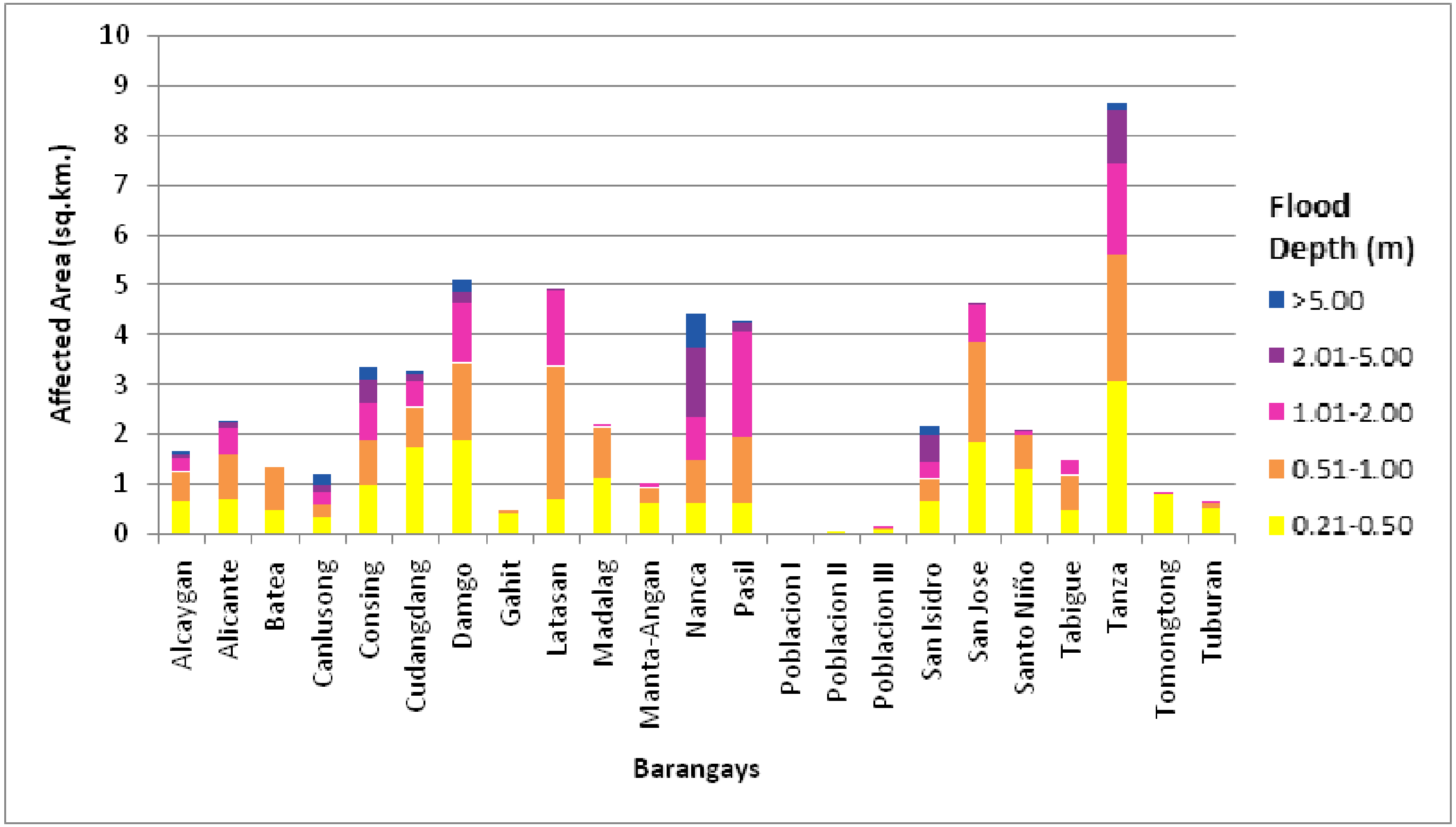


Figure 89. Affected Areas in Enrique B. Magalona, Negros Occidental during 100-Year Rainfall Return Period

Table 49. Affected Areas in Enrique B. Magalona, Negros Occidental during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Enrique B. Magalona (in sq. km.)											
	Alcaygan	Alicante	Batea	Canlusong	Consing	Cudang-dang	Damgo	Gahit	Latasan	Madalag	Man-ta-Angan	Nanca
0.03-0.20	6.23	1.88	0.87	9.14	15.11	2.85	4.55	0.48	1.12	1.06	2.04	2.72
0.21-0.50	0.65	0.69	0.5	0.33	1.01	1.74	1.89	0.4	0.7	1.15	0.64	0.62
0.51-1.00	0.59	0.89	0.85	0.25	0.87	0.8	1.54	0.08	2.66	1.01	0.28	0.87
1.01-2.00	0.28	0.53	0	0.25	0.75	0.5	1.19	0	1.54	0.06	0.1	0.86
2.01-5.00	0.06	0.11	0	0.15	0.49	0.17	0.24	0	0	0	0	1.37
> 5.00	0.07	0.05	0	0.22	0.23	0.08	0.24	0	0	0	0	0.7
	Pasil	Pobla-cion I	Pobla-cion II	Poblacion III	San Isidro	San Jose	Santo Niño	Tabigue	Tanza	Tomong-tong	Tuburan	
0.03-0.20	0.59	0.44	0.12	0.63	11.32	2.59	3.79	1.07	5.76	1.24	0.66	
0.21-0.50	0.62	0.02	0.05	0.12	0.67	1.84	1.33	0.48	3.07	0.81	0.53	
0.51-1.00	1.33	0	0	0.02	0.44	2.01	0.66	0.7	2.55	0.02	0.13	
1.01-2.00	2.12	0	0	0.02	0.34	0.73	0.08	0.3	1.84	0	0.01	
2.01-5.00	0.19	0	0	0	0.53	0.04	0	0	1.07	0	0	
> 5.00	0.01	0	0	0	0.18	0	0	0	0.13	0	0	

For the municipality of Manapla, with an area of 99.18 sq. km., 70% will experience flood levels of less 0.20 meters. 0.125% of the area will experience flood levels of 0.21 to 0.50 meters while 0.14%, 0.03%, 0.007%of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters respectively. Listed in Table 50 are the affected areas in square kilometres by flood depth per barangay.

Table 50. Affected Areas in Manapla, Negros Occidental during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Manapla (in sq. km.)
	Tortosa
0.03-0.20	0.69
0.21-0.50	0.12
0.51-1.00	0.14
1.01-2.00	0.03
2.01-5.00	0.01
> 5.00	0

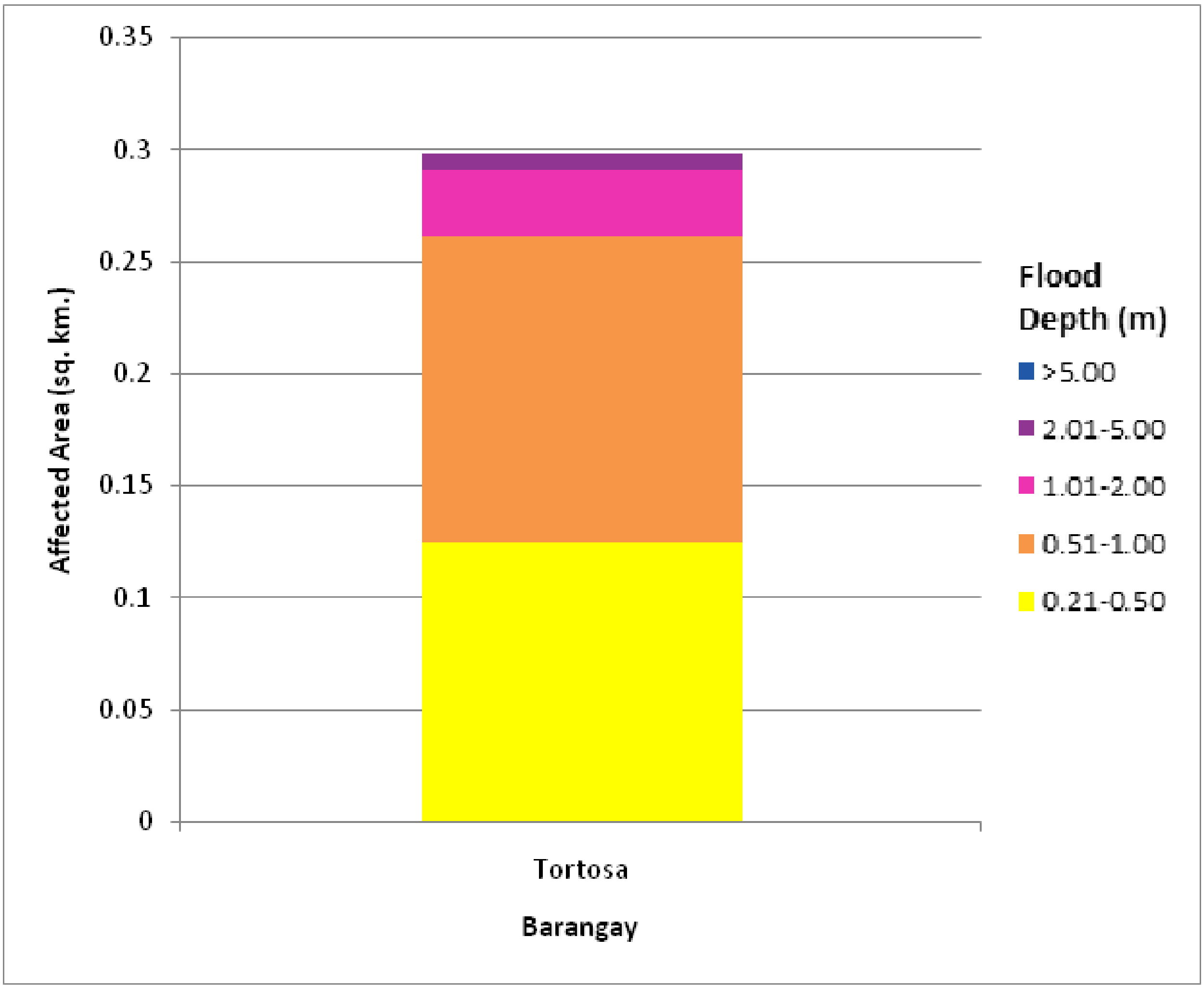


Figure 90. Affected Areas in Manapla, Negros Occidental during 100-Year Rainfall Return Period

For the municipality of Salvador Benedicto, with an area of 182.22 sq. km., 0.23% will experience flood levels of less 0.20 meters and 0.00009% of the area will experience flood levels of 0.21 to 0.50 meters. Listed in Table 51 are the affected areas in square kilometres by flood depth per barangay.

Table 51. Affected Areas in Salvador Benedicto, Negros Occidental during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Salvador Benedicto (in sq. km.)	
	Igmay-an	Pandanan
0.03-0.20	0.32	0.1
0.21-0.50	0	0
0.51-1.00	0	0
1.01-2.00	0	0
2.01-5.00	0	0
> 5.00	0	0

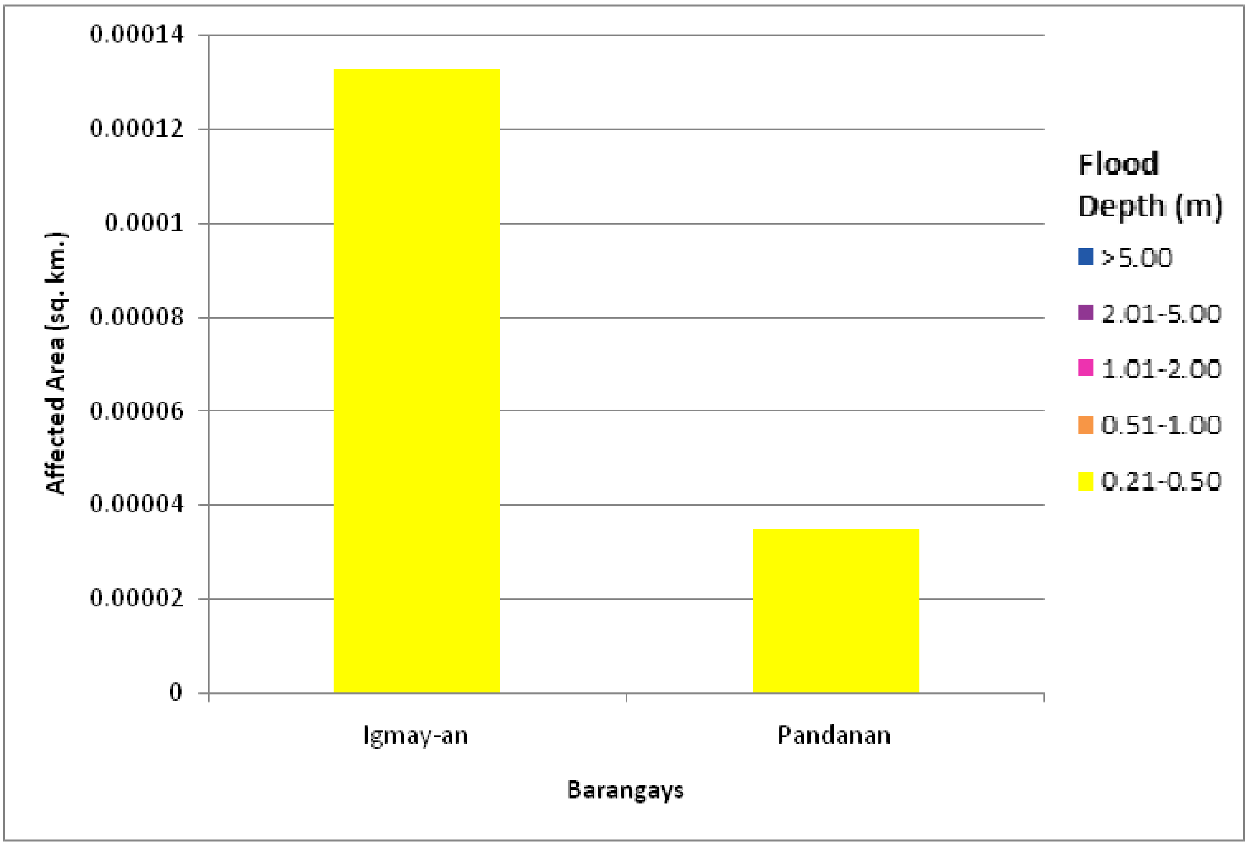


Figure 91. Affected Areas in Salvador Benedicto, Negros Occidental during 25-Year Rainfall Return Period

For the city of Silay, with an area of 199.01 sq. km., 64.77% will experience flood levels of less 0.20 meters. 7.9% of the area will experience flood levels of 0.21 to 0.50 meters while 6.9%, 6.43%, 4.14%, and 2.12% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, 2.01 to 5 meters, greater than 5 meters respectively. Listed in Table 52 are the affected areas in square kilometres by flood depth per barangay.

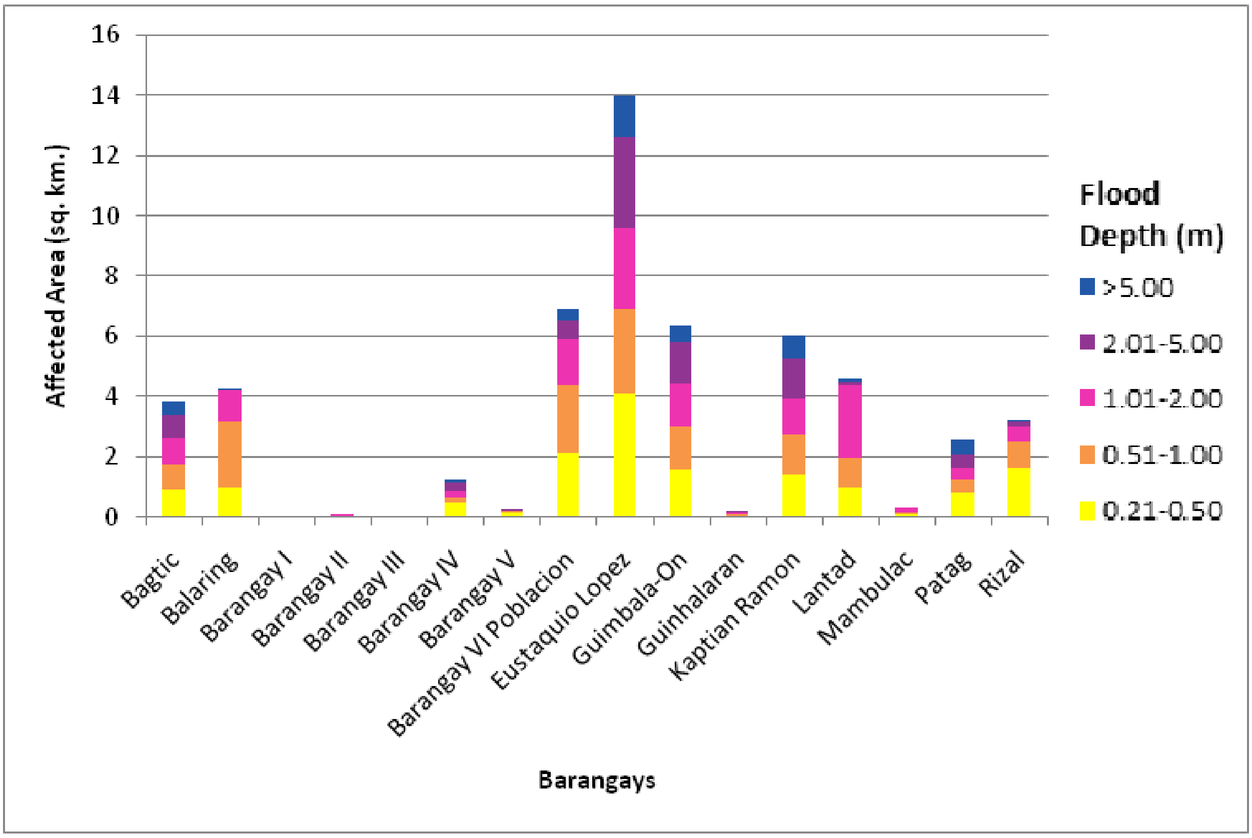


Figure 92. Affected Areas in Silay City, Negros Occidental during 100-Year Rainfall Return Period

Table 52. Affected Areas in Silay City, Negros Occidental during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Silay City (in sq. km.)							
	Bagtic	Balaring	Brgy. I	Brgy. II	Brgy. III	Brgy. IV	Brgy. V	Brgy. VI Poblacion
0.03-0.20	8.19	2.23	0.14	0.1	0.27	2.94	1.12	4.91
0.21-0.50	0.91	0.97	0.05	0.13	0	0.49	0.15	2.16
0.51-1.00	0.88	2.22	0.01	0	0	0.18	0.05	2.23
1.01-2.00	0.86	1.07	0	0	0	0.24	0.05	1.55
2.01-5.00	0.75	0.02	0	0	0	0.24	0.01	0.61
> 5.00	0.44	0	0	0	0	0.09	0	0.4
	Eustaquio Lopez	Guimbala-On	Guinhalaran	Kaptian Ramon	Lantad	Mambulac	Patag	Rizal
0.03-0.20	14.05	28.85	0.36	28.11	1.58	0.42	29.66	4.37
0.21-0.50	4.12	1.57	0.07	1.41	0.97	0.11	0.81	1.64
0.51-1.00	2.79	1.46	0.06	1.32	0.98	0.06	0.48	0.9
1.01-2.00	2.7	1.44	0.06	1.24	2.42	0.15	0.38	0.49
2.01-5.00	3.02	1.38	0.03	1.32	0.16	0	0.41	0.18
> 5.00	1.37	0.53	0	0.75	0.06	0	0.49	0.02

For the city of Talisay, with an area of 199.01 sq. km., 45.1% will experience flood levels of less 0.20 meters. 1.58% of the area will experience flood levels of 0.21 to 0.50 meters while 1.08%, 1.02%, 1.18%, and 0.44% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, 2.01 to 5 meters, greater than 5 meters respectively. Listed in Table 53 are the affected areas in square kilometres by flood depth per barangay.

Table 53. Affected Areas in Talisay City, Negros Occidental during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Talisay City (in sq. km.)				
	Cabatangan	Dos Hermanas	Katilingban	Matab-Ang	San Fernando
0.03-0.20	15.46	8.31	15.57	0.01	50.33
0.21-0.50	0.49	0.58	0.56	0	1.51
0.51-1.00	0.23	0.7	0.44	0	0.78
1.01-2.00	0.2	0.8	0.44	0	0.59
2.01-5.00	0.2	1.04	0.41	0	0.71
> 5.00	0.03	0.45	0.05	0	0.35

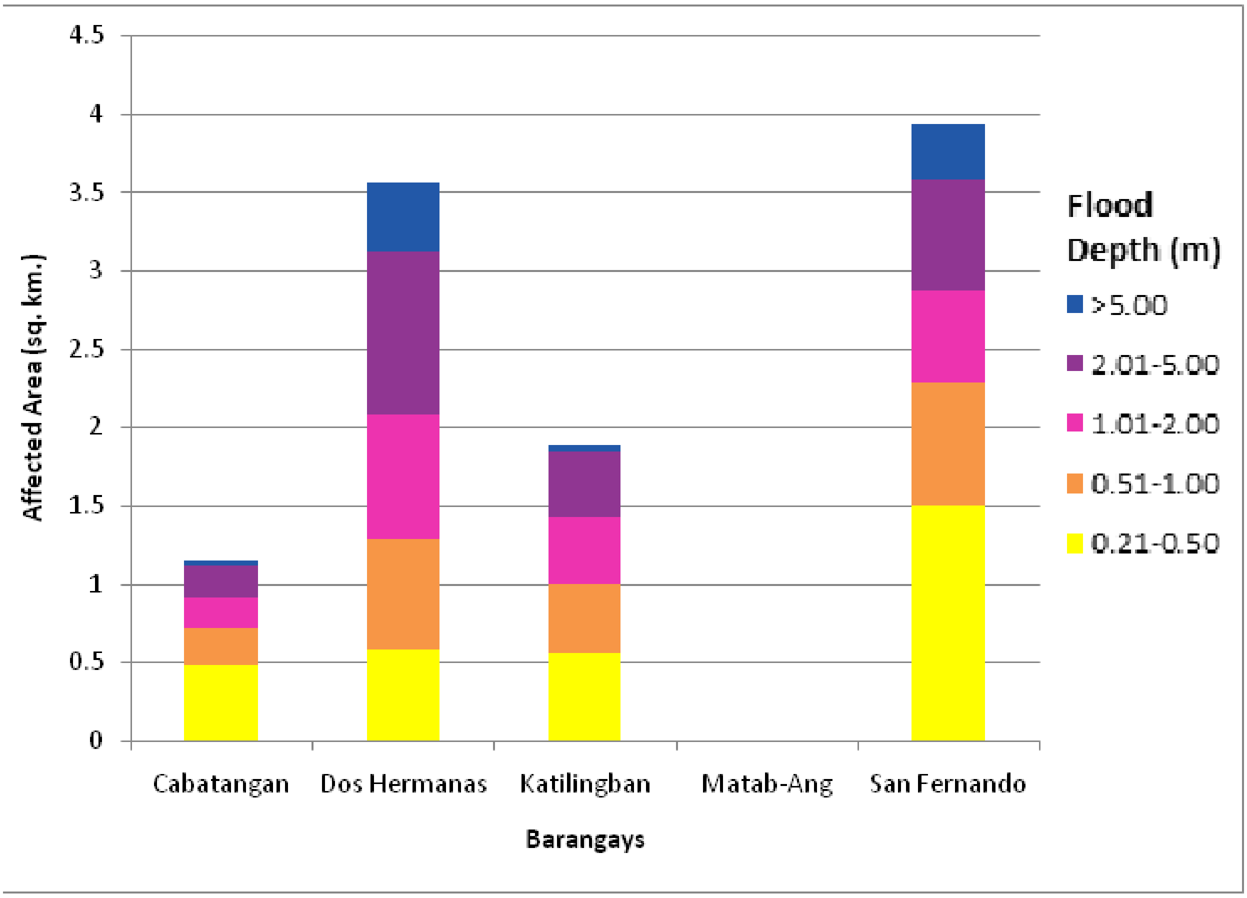


Figure 93. Affected Areas in Talisay City, Negros Occidental during 100-Year Rainfall Return Period

For the city of Victorias, with an area of 199.01 sq. km., 52.42% will experience flood levels of less 0.20 meters. 5.89% of the area will experience flood levels of 0.21 to 0.50 meters while 4.21%, 7.28%, 2.45%, and 0.53% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, 2.01 to 5 meters, greater than 5 meters respectively. Listed in Table 54 are the affected areas in square kilometres by flood depth per barangay.

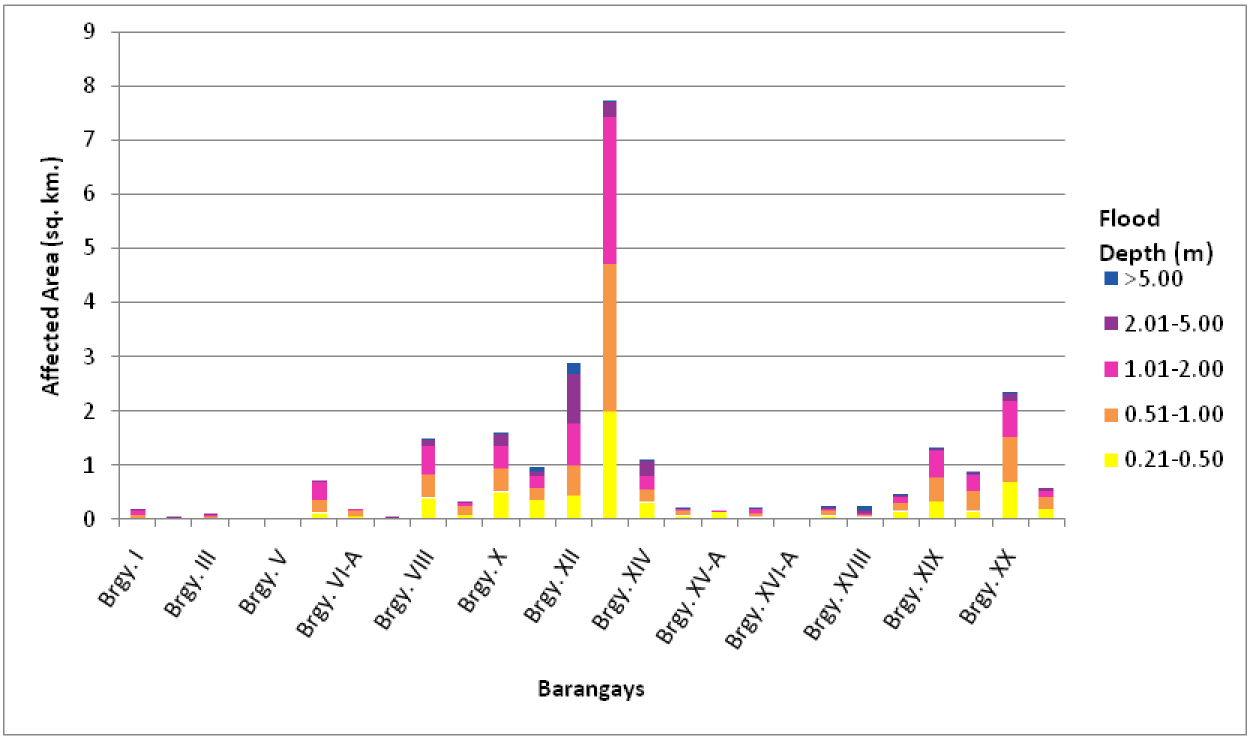


Figure 94. Affected Areas in VictoriasCity, Negros Occidental during 100-Year Rainfall Return Period

Table 54. Affected Areas in Victorias City, Negros Occidental during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Victorias City (in sq. km.)									
	Brgy. I	Brgy. II	Brgy. III	Brgy. IV	Brgy. V	Brgy. VI	Brgy. VI-A	Brgy.VII	Brgy. VIII	Brgy. IX
0.03-0.20	0.03	0.03	0.05	0.1	0.29	0.07	0.15	0.06	7.89	0.03
0.21-0.50	0.02	0	0	0.01	0.01	0.12	0.05	0.01	0.39	0.08
0.51-1.00	0.06	0	0.04	0.01	0	0.22	0.11	0.01	0.42	0.15
1.01-2.00	0.08	0.01	0.06	0.01	0	0.35	0.02	0.01	0.53	0.09
2.01-5.00	0.03	0.01	0	0.01	0	0.03	0	0.02	0.14	0
> 5.00	0	0	0	0	0	0	0	0	0.01	0
	Brgy. X	Brgy. XI	Brgy. XII	Brgy. XIII	Brgy. XIV	Brgy. XV	Brgy. XV-A	Brgy. XVI	Brgy. XVI-A	Brgy. XVII
0.03-0.20	8.98	10.43	5.9	2.89	5.32	0.13	0.54	0.11	0	0.47
0.21-0.50	0.5	0.35	0.43	1.99	0.32	0.05	0.13	0.04	0	0.06
0.51-1.00	0.42	0.23	0.55	2.72	0.23	0.09	0.03	0.06	0.01	0.1
1.01-2.00	0.44	0.21	0.79	2.74	0.26	0.06	0	0.08	0.01	0.05
2.01-5.00	0.25	0.09	0.92	0.28	0.29	0.01	0	0.03	0.01	0.02
> 5.00	0	0.09	0.21	0.01	0.03	0	0	0.01	0	0.02
	Brgy. XVIII	Brgy.XVIII-A	Brgy. XIX	Brgy. XIX-A	Brgy. XX	Brgy. XXI				
0.03-0.20	0.28	2.77	1.05	0.06	4.6	2.05				
0.21-0.50	0.03	0.15	0.32	0.14	0.68	0.19				
0.51-1.00	0.03	0.13	0.45	0.38	0.82	0.21				
1.01-2.00	0.03	0.12	0.5	0.29	0.67	0.14				
2.01-5.00	0.07	0.04	0.02	0.05	0.17	0.03				
> 5.00	0.08	0.03	0.04	0.01	0.01	0				

Among the barangays in the city of Cadiz, CelestinoVillacin is projected to have the highest percentage of area that will experience flood levels at 7.84%.

Among the barangays in the municipality of Calatrava, Lalong is projected to have the highest percentage of area that will experience flood levels at 0.013%.

Among the barangays in the municipality of Enrique B. Magalona, Consing is projected to have the highest percentage of area that will experience flood levels of at 13.14%. Meanwhile, Tanza posted the second highest percentage of area that may be affected by flood depths of at 10.28%.

Among the barangays in the municipality of Manapla, Tortosa is projected to have the highest percentage of area that will experience flood levels at 1%.

Among the barangays in the municipality of Salvador Benedicto, Igmay-an is projected to have the highest percentage of area that will experience flood levels at 0.17%. Meanwhile, Pandanan posted the second highest percentage of area that may be affected by flood depths at 0.06%.

Among the barangays in the city of Silay, Guimbala-On is projected to have the highest percentage of area that will experience flood levels at 17.38%. Meanwhile, Patag posted the second highest percentage of area that may be affected by flood depths at 16.40%.

Among the barangays in the city of Talisay, San Fernando is projected to have the highest percentage of area that will experience flood levels of at 27.27%. Meanwhile, Cabatangan posted the percentage of area that may be affected by flood depths of at 8.34%.

Among the barangays in the city of Victorias, Barangay XI is projected to have the highest percentage of area that will experience flood levels at 11.01%. Meanwhile, Barangay X posted the second highest percentage of area that may be affected by flood depths of at 10.23%.

Moreover, the generated flood hazard maps for the Imbang 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 55. 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	38.95	45.073	45.30
Medium	28.57	53.42	64.032
High	20.94	31.72	41.70
Total	**88.46**	**130.21**	**151.025**

Of the 39 identified Education Institute in Imbang (Imbang-Malogo) Flood plain, 3 schools were assessed to be exposed to the Low level flooding during a 5 year scenario while 1 school was assessed to be exposed to medium level flooding in the same scenario. In the 25 year scenario, 9 schools were assessed to be exposed to the Low level flooding while 3 schools was assessed to be exposed to medium level flooding. For the 100 year scenario, 11 schools were assessed for Low level flooding, and 2 schools for Medium level flooding

Nine (9) Medical Institutions were identified in the Imbang (Imbang-MalogoFloodplain,nonewere assessed to be exposed to the Low level flooding during a 5 year scenario. In the 25 year scenario, 1 was assessed to be exposed to the Low level flooding. For the 100 year scenario, 1 was assessed to be exposed to Low level flooding.

5.11 Flood Validation

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

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

The validation personnel went to the specified points identified in a river basin and gathered data regarding the actual flood level in each location. Data gathering was done through a local DRRM office to obtain maps or situation reports about the past flooding events or 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 points in the flood map versus its corresponding validation depths are shown in Figure 94.

The flood validation consisted of 232 points randomly selected all over the Malogo-Imbang floodplain. Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 0.83m. Table 56 shows a contingency matrix of the comparison.

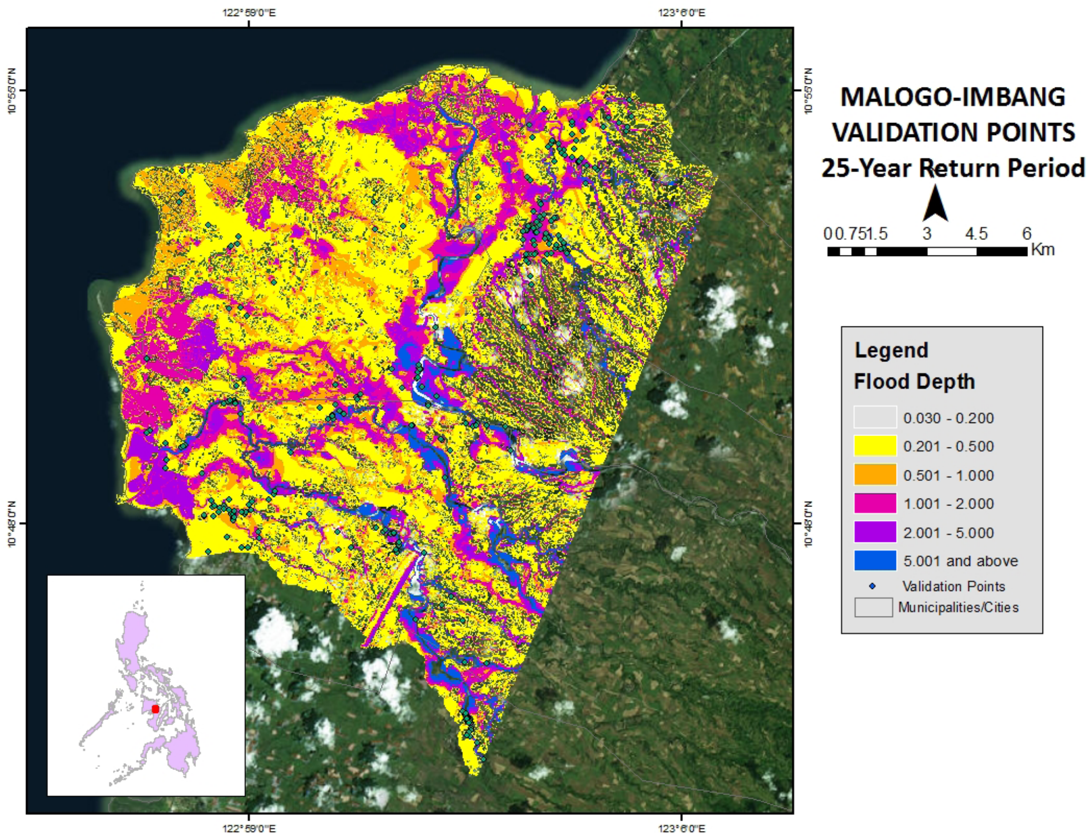


Figure 95. Validation points for 25-year Flood Depth Map of Malogo-Imbang Floodplain

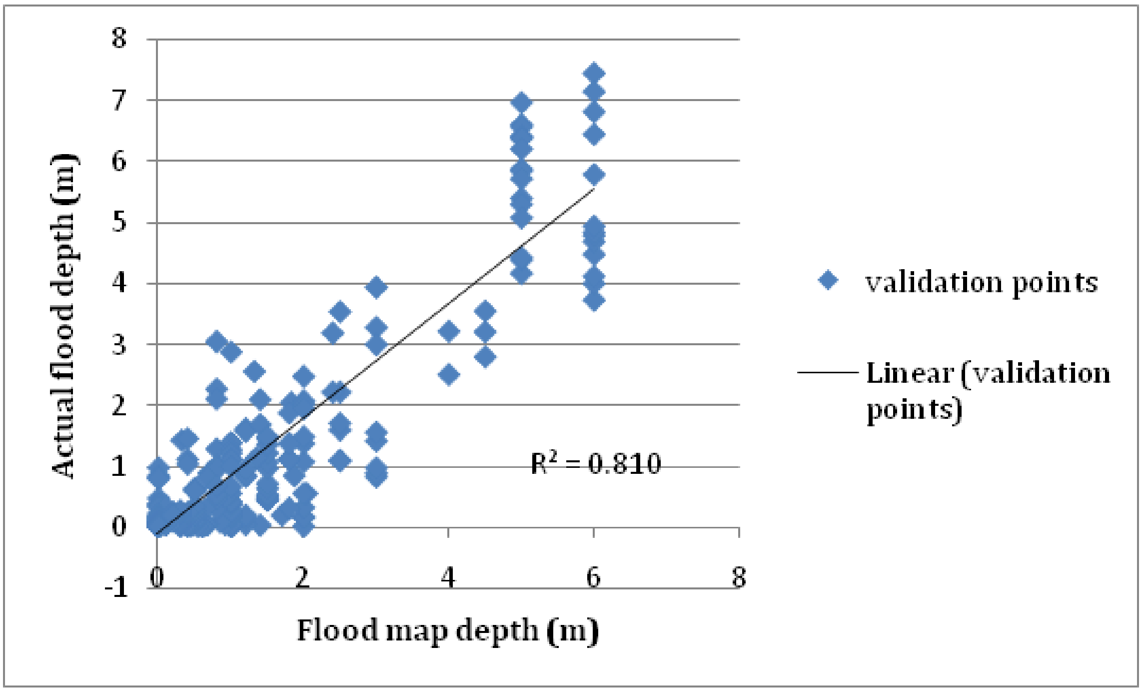


Figure 96. Flood map depth vs actual flood depth

Table 56. Actual Flood Depth vs Simulated Flood Depth in the Malogo-Imbang River Basin

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	39	9	4	0	0	0	52
0.21-0.50	16	9	4	4	0	0	33
0.51-1.00	16	9	8	9	4	0	46
1.01-2.00	6	7	11	17	6	0	47
2.01-5.00	0	0	4	6	15	13	38
> 5.00	0	0	0	0	11	5	16
Total	77	34	31	36	36	18	232

The overall accuracy generated by the flood model is estimated at 40.09%, with 93 points correctly matching the actual flood depths. In addition, there were 94 points estimated one level above and below the correct flood depths while there were 39 points and 6 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 53 points were overestimated while a total of 86 points were underestimated in the modelled flood depths of Malogo-Imbang. Table 57 depicts the summary of the Accuracy Assessment in the Malogo-Imbang River Basin Survey.

Table 57. Summary of Accuracy Assessment in the Malogo-Imbang River Basin Survey

	No. of Points	%
Correct	93	**40.09**
Overestimated	53	**22.84**
Underestimated	86	**37.07**
Total	232	**100.00**

REFERENCES

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

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

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

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

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

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

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

ANNEXES

Annex 1. OPTECH Technical Specification of the 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

1 Target reflectivity ≥20%

2 Dependent on selected operational parameters using nominal FOV of up to 40° in standard atmospheric conditions with 24-km visibility

3 Angle of incidence ≤20°

4 Target size ≥ laser footprint5 Dependent on system configuration

Annex 2. NAMRIA Certificates of Reference Points Used

NGW-55

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

May 14, 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-55**	
Island: **VISAYAS**	Order: **2nd**	Barangay: **TANZA**
Municipality: **E.B. MAGALONA**		
	PRS92 Coordinates	
Latitude: **10° 51' 0.88734"**	Longitude: **122° 59' 57.75865"**	Ellipsoidal Hgt: **12.01600 m.**
	WGS84 Coordinates	
Latitude: **10° 50' 56.54743"**	Longitude: **123° 0' 2.96548"**	Ellipsoidal Hgt: **70.28000 m.**
	PTM Coordinates	
Northing: **1199766.082 m.**	Easting: **499931.926 m.**	Zone: **4**
	UTM Coordinates	
Northing: **1,199,346.14**	Easting: **499,931.95**	Zone: **51**

Location Description

NGW-55
The station is on the SW side of the road heading to sugar central. It is about 9.0 km. from the junction of national highway and the road heading to sugar central. 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 headwall with inscriptions "NGW-55; 2007; NAMRIA".

Requesting Party:	**UP-DREAM**
Pupose:	**Reference**
OR Number:	**8796150 A**
T.N.:	**2014-1106**

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

NGW-80

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

April 23, 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-80**
Order: **2nd**

Island: **VISAYAS**
Municipality: **BAGO**
Barangay: **MA-AO**

PRS92 Coordinates

Latitude:	**10° 29' 35.86090"**	Longitude:	**122° 56' 43.79550"**	Ellipsoidal Hgt:	**30.72000 m.**

WGS84 Coordinates

Latitude:	**10° 29' 31.60669"**	Longitude:	**122° 56' 49.03425"**	Ellipsoidal Hgt:	**89.69100 m.**

PTM Coordinates

Northing:	**1160287.663 m.**	Easting:	**494033.975 m.**	Zone:	**4**

UTM Coordinates

Northing:	**1,159,881.54**	Easting:	**494,036.06**	Zone:	**51**

Location Description

NGW-80
From Ma-ao Provincial Road, turn right on the road heading to Sum-ag. The Quezon Bridge is at Km 33+188. Mark is the head of a 4" copper nail drilled and grouted at the center of a 30 x 30 cm. cement putty with inscriptions "NGW-80; 2007; NAMRIA". The station is on the SW sidewalk of the Quezon Bridge.

Requesting Party: **Engr. Christopher Cruz/ UP-DREAM**
Pupose: **Reference**
OR Number: **8796021 A**
T.N.: **2014-921**

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

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

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

NW-207

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

October 12, 2015

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: **NW-207**	
Island: **VISAYAS**	Municipality: **PONTEVEDRA**	Barangay: **SAN JUAN**
Elevation: **5.5545 +/- 0.04 m.**	Order: **1st Order**	Datum: **Mean Sea Level**
Latitude: **10° 22' 45.59000"**	Longitude: **122° 52' 0.60000"**	

Location Description

NW-207 is in the province of Negros Occidental, Municipality of Pontevedra, Barangay San Juan, Purok Ipil-ipil along San Enrique - Pontevedra highway.

Station is located on concrete sidewalk, Northwest end of Pontevedra bridge, 0.20 meter above the ground, 5 meters West of the road centerline, 60 meters South of KM Post 42.

Mark is the head of a 4" long copper nail set on a drilled hole and flushed to a 6" x 6" cement putty with inscription "NW-207, 2007, NAMRIA"

Requesting Party: **Christopher Cruz/ UP DREAM**
Purpose: **Reference**
OR Number: **8088299 I**
T.N.: **2015-3188**

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

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

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Annex 3. Baseline Processing Report of Reference Point Used

NW-207

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
NW-207 --- NGW-80 (B1)	NGW-80	NW-207	Fixed	0.005	0.023	215°07'14"	15252.524	-22.274

Acceptance Summary

Processed	Passed	Flag	Fail
1	1	0	0

Vector Components (Mark to Mark)

From:	NGW-80				
Grid		Local		Global	
Easting	494036.064 m	Latitude	N10°29'35.86090"	Latitude	N10°29'31.60669"
Northing	1159881.542 m	Longitude	E122°56'43.79550"	Longitude	E122°56'49.03425"
Elevation	28.344 m	Height	30.720 m	Height	89.691 m

To:	NW-207				
Grid		Local		Global	
Easting	485262.641 m	Latitude	N10°22'49.75933"	Latitude	N10°22'45.52680"
Northing	1147412.335 m	Longitude	E122°51'55.33813"	Longitude	E122°52'00.58746"
Elevation	6.192 m	Height	8.446 m	Height	67.481 m

Vector					
ΔEasting	-8773.423 m	NS Fwd Azimuth	215°07'14"	ΔX	6149.399 m
ΔNorthing	-12469.207 m	Ellipsoid Dist.	15252.524 m	ΔY	6645.152 m
ΔElevation	-22.151 m	ΔHeight	-22.274 m	ΔZ	-12274.675 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.007 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.010 m
σ ΔElevation	0.012 m	σ ΔHeight	0.012 m	σ ΔZ	0.003 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000439058		
Y	-0.0000605482	0.0000950520	
Z	-0.0000146573	0.0000233128	0.0000070809

Annex 4. The LiDAR Survey Team Composition

Data Acquisition Component Sub -Team	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. CZAR JAKIRI S. SARMIENTO	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	UP-TCAGP
		LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	JASMINE ALVIAR	UP-TCAGP
		PAULINE JOANNE ARCEO	UP-TCAGP
	Research Associate (RA)	RENAN PUNTO	UP-TCAGP
	RA	DAN ALDOVINO	UP-TCAGP
	RA	MILLIE SHANE REYES	UP-TCAGP
	RA	JONALYN GONZALES	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	RENAN PUNTO	UP-TCAGP
	RA	FRANK NICOLAS ILEJAY	UP-TCAGP
LiDAR Operation	Airborne Security	SSG. DAVE GUMBAN	PHILIPPINE AIR FORCE (PAF)
		SSG. KRISTOF LACANLALE	PAF
	Pilot	CAPT. JEFFREY ALAJAR	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. BRYAN DONGUINES	AAC
		CAPT. CESAR SHERWIN ALFONSO III	AAC
		CAPT. RANDY LAGCO	AAC

Annex 5. Data Transfer Sheets for Imbang Floodplain

DATA TRANSFER SHEET
5/5/2014(Bacolod ~~Pending~~) Ready

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES	MISSION LOG FILE	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
Apr 21, 2014	1371P	1BLK45DE110A	PEGASUS	1.83GB	300KB	7.87MB	165MB	43.7GB	336KB	16.9GB	N/A	14.8MB	103B	0B	53.3KB/48.8KB/ 39.9KB/53.3KB/	1.67KB	Z:\Airborne_Raw\1371P
Apr 21, 2014	1373P	1BLK45B110B	PEGASUS	1.93GB	1.42MB	7.76MB	149MB	23.2GB	221KB	17.2GB	N/A	14.8MB	103B	230B	39.9KB	1.67KB	Z:\Airborne_Raw\1373P
Apr 22, 2014	1375P	1BLK45B111A	PEGASUS	3.72GB	1.65MB	13.9MB	264MB	46.0GB	366KB	34.9GB	N/A	13.6MB	103B	527B	28.3KB/37.8KB/ 41.0KB	1.67KB	Z:\Airborne_Raw\1375P
Apr 22, 2014	1377P	1BLK45C111B	PEGASUS	1.73GB	1.06MB	7.10MB	154MB	17.5GB	4.19KB/ 164KB	15.6GB	N/A	13.6MB	103B	250B	3.44KB/49.6KB	1.67KB	Z:\Airborne_Raw\1377P
Apr 25, 2014	1387P	1BLK45AC114A	PEGASUS	2.59GB	672KB	13.2MB	275MB	44.2GB	350KB	27.3GB	N/A	7.15MB	103B	457B	73.5KB/62.3KB/ 57.8KB	1.67KB	Z:\Airborne_Raw\1387P
Apr 26, 2014	1391P	1BLK44CB115A	PEGASUS	3.40GB	1.51MB	12.6MB	257MB	52.0GB	159KB/ 168KB	30.7GB	N/A	12.3MB	152B	460B	51KB/48.8KB/7. 25KB/63.8KB/3.	2.01KB	Z:\Airborne_Raw\1391P
Apr 27, 2014	1393P	1BLK44AB115B	PEGASUS	2.92GB	2.91MB	13.3MB	264MB	45.0GB	356KB	30.6GB	N/A	12.3MB	152B	666B	51.3KB/49.1KB	2.01KB	Z:\Airborne_Raw\1393P

Received from

Name GRACE B. SINADJAN
Position RA
Signature

Received by

Name Benjamin Magallon
Position
Signature

5/26/2014

DATA TRANSFER SHEET
Bacolod Reflights 10/22/15

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	
02-Oct-15	10007P	1BLK44LMSCALIB275A	PEGASUS	1.07	628/720	9.21	263	30/14.2/9.26	128/237/17/6	10.6	NA	8.71	1KB	1KB	36/31/27/32	NA	Z:\DAC\RAW DATA
2-Oct-15	10008P	1BLK45BLK46276A	PEGASUS	206	258	2.5	95.1	5.7	48	36	NA	9.98	1KB	1KB	109/92/83	NA	Z:\DAC\RAW DATA
3-Oct-15	10009P	1BLK45BLK46276B	PEGASUS	858	1.04	6.29	193	2.2/9.2/10.3	18/70/1/7	11.7	NA	10	1KB	1KB	109/92/83	NA	Z:\DAC\RAW DATA

Received from

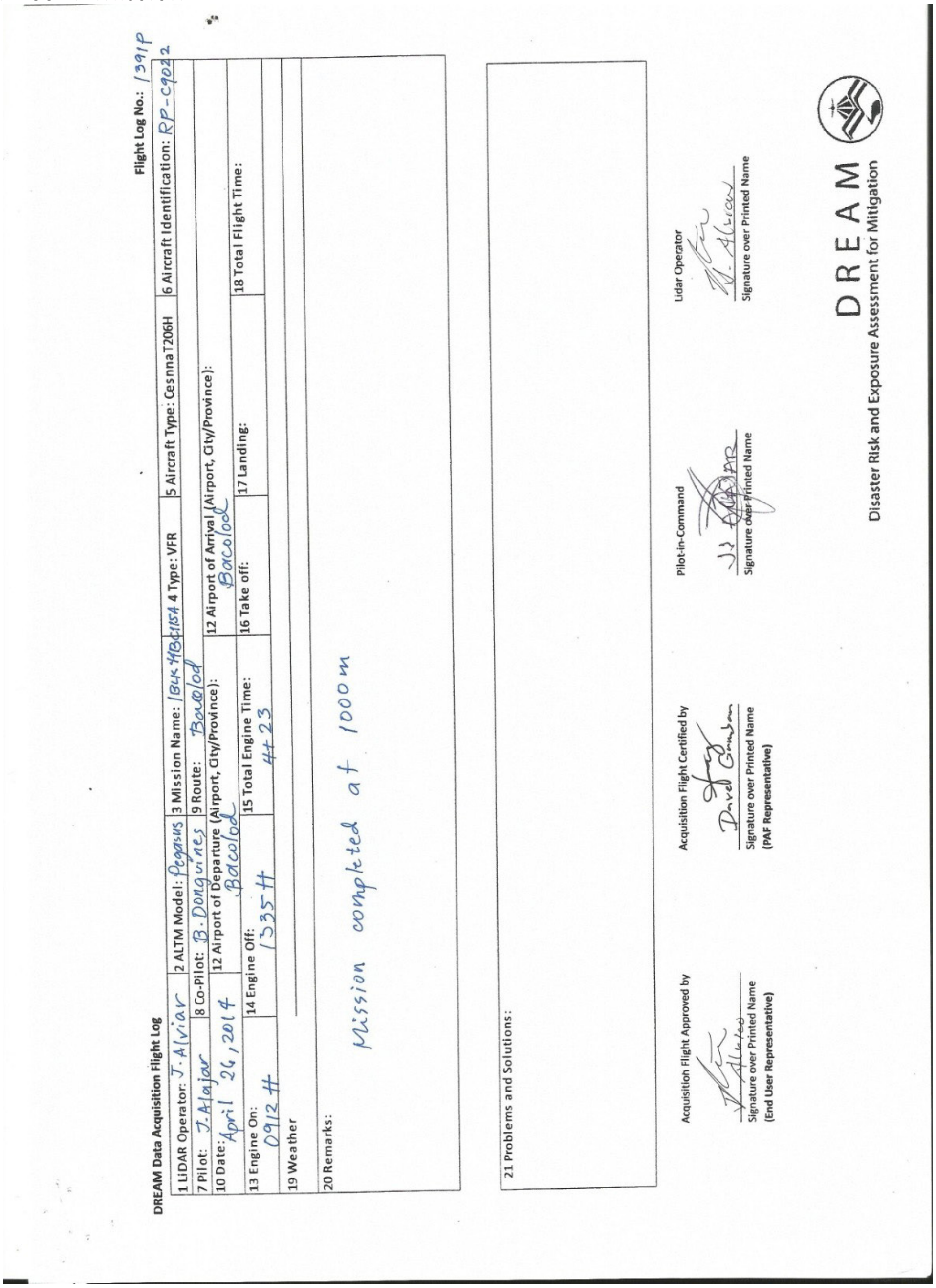
Name C JOAQUIN
Position RA
Signature

Received by

Name JOIDA F. PRIETO
Position SUPSRS
Signature 11/03/15

Annex 6. Flight Logs

Flight Log for 1391P Mission



Flight Log No.: 1391P

DREAM Data Acquisition Flight Log

1 LIDAR Operator: J. Alviar	2 ALTM Model: Pegasus	3 Mission Name: 1BLK41BC154	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9022
7 Pilot: J. Alajar	8 Co-Pilot: B. Donguines	9 Route: Bacolod			
10 Date: April 26, 2014	12 Airport of Departure (Airport, City/Province): Bacolod		12 Airport of Arrival (Airport, City/Province): Bacolod		
13 Engine On: 0912 H	14 Engine Off: 1335 H	15 Total Engine Time: 4+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Mission completed at 1000m

21 Problems and Solutions:

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

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

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

Lidar Operator — J. Alviar — Signature over Printed Name

DREAM

Disaster Risk and Exposure Assessment for Mitigation

Flight Log for 1393P Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1393P

1 LiDAR Operator: D. Aldovino	2 ALTM Model: Pegasus	3 Mission Name: 1BLK44AB115B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RPC9022
7 Pilot: J. Alajar	8 Co-Pilot: B. Donguines	9 Route: Bacolod			
10 Date: April 24, 2014	12 Airport of Departure (Airport, City/Province): Bacolod		12 Airport of Arrival (Airport, City/Province): Bacolod		
13 Engine On: 1432H	14 Engine Off: 1855H	15 Total Engine Time: 4+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Mission completed at 1200 m					

21 Problems and Solutions:

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

DREAM

Disaster Risk and Exposure Assessment for Mitigation

Flight Log for 10007P Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1393P

1 LiDAR Operator: D. Aldovino	2 ALTM Model: Pegasus	3 Mission Name: 1BLK44AB115B	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: April 24, 2014	12 Airport of Departure (Airport, City/Province): Bacolod		12 Airport of Arrival (Airport, City/Province): Bacolod		
13 Engine On: 1432 H	14 Engine Off: 1855 H	15 Total Engine Time: 4+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Mission completed at 1200 m					

21 Problems and Solutions:

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

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Annex 7. Flight Status

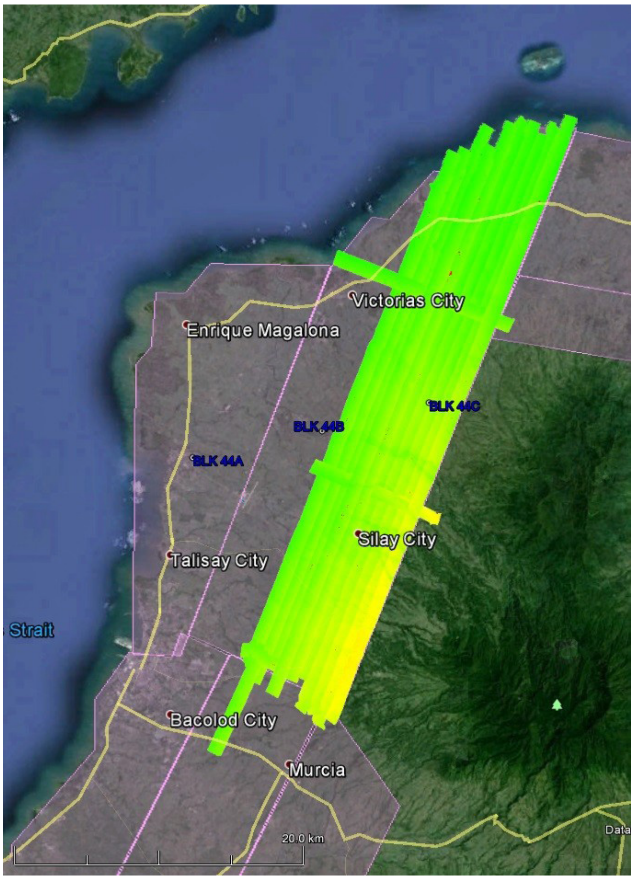
FLIGHT STATUS REPORT
NEGROS OCCIDENTAL
April 6, 2014 and October 2, 2015

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1391P	BLK44CB	1BLK44CB115A	J. Alviar	Apr 26, 2014	Mission completed at 1000m; surveyed BLK 44C and parts of BLK 44B
1393P	BLK44AB	1BLK44AB115B	D. Aldovino	Apr 26, 2014	Mission completed at 1200m, covered BLK 44A and remaining areas of BLK 44B
10007P	BLK44A	1BLK44LMSCALIB275A	J. Gonzales and M. Reyes	Oct. 2, 2015	Mission successful; Conducted LMS and Camera Calibration and Surveyed BLK44

LASBOUNDARIES PER FLIGHT

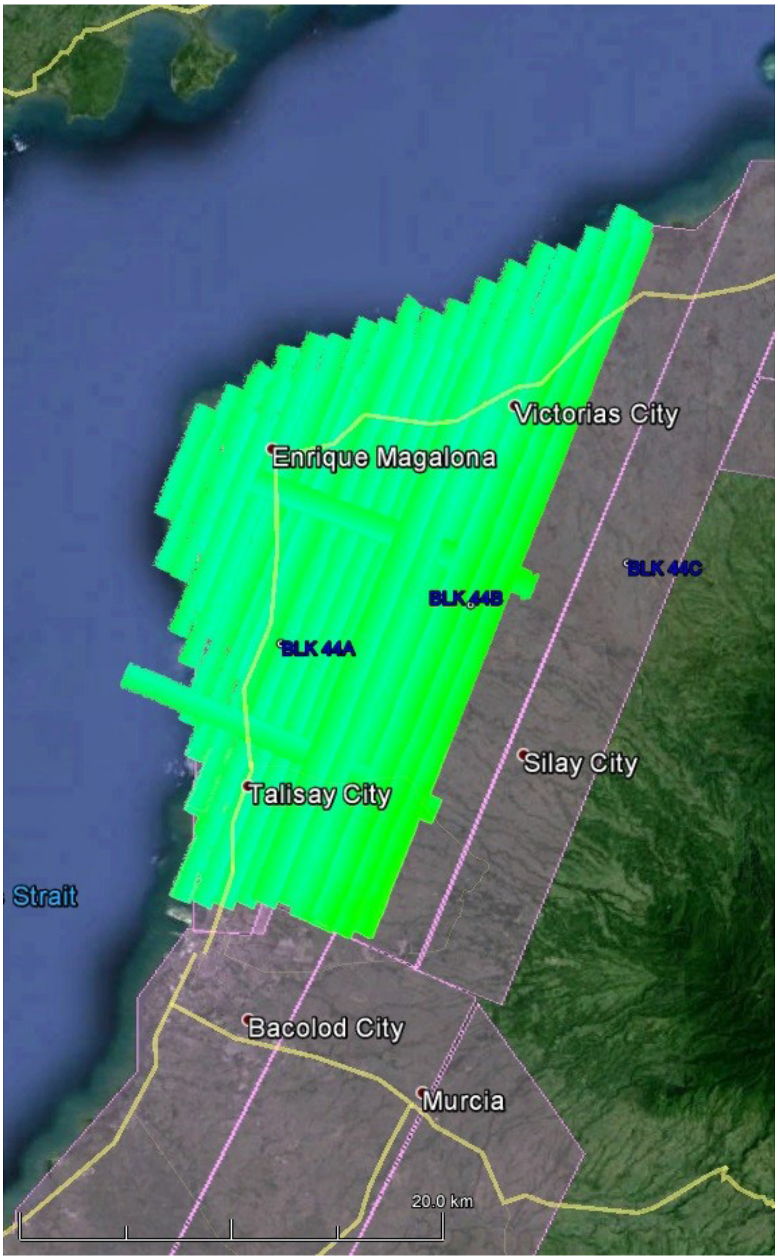
Flight No.: 1391P
Area: BLK44B & 44C
Mission Name: 1BLK44BC115A
Parameters: Altitude: 1000; Scan Frequency: 30; Scan Angle: 25; Overlap: 30%

LAS

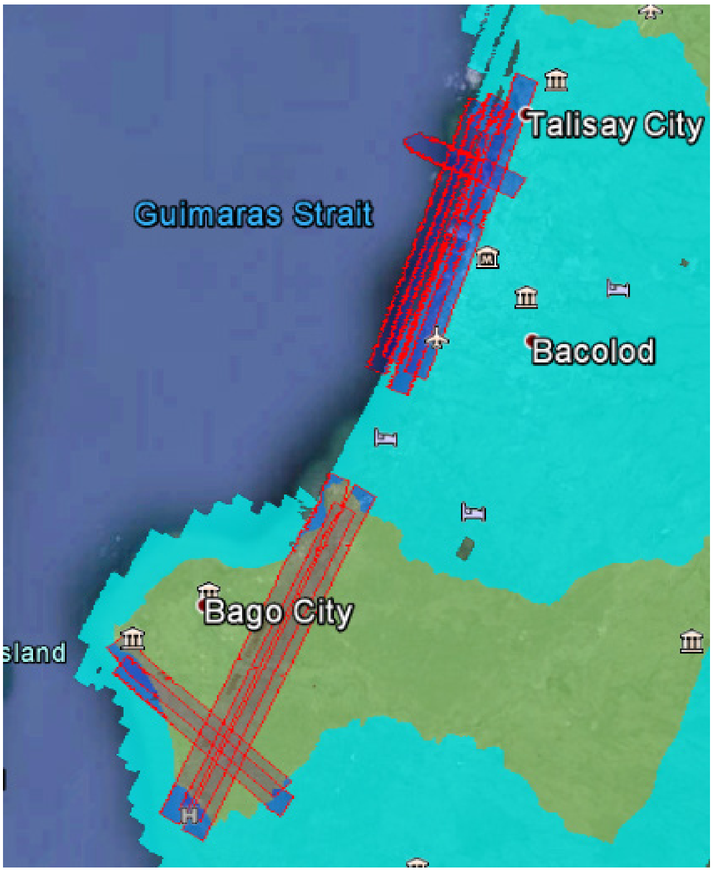


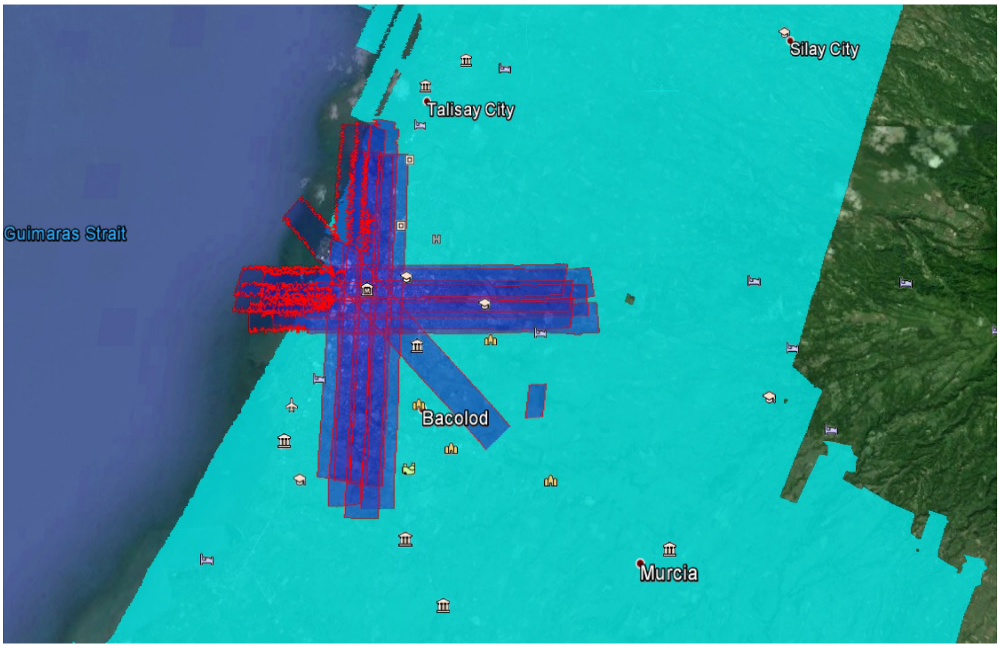
Flight No.: 1393P
Area: BLK 44A & 44B
Mission Name: 1BLK44AB115B
Parameters: Altitude: 1200; Scan Frequency: 30; Scan Angle: 25; Overlap: 15%

LAS



Flight No.: 10007P
Area: BLK 44A
Mission Name: 1BLK44LMSCALIB275A
Parameters: Altitude: 1000; Scan Frequency: 30; Scan Angle: 25; Overlap: 30%





Annex 8. Mission Summary Report

Flight Area	Negros
Mission Name	**Blk44AB**
Inclusive Flights	1393P
Range data size	30.6 GB
POS data size	264 MB
Image	45 GB
Base data size	12.3 MB
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)	1.05
RMSE for East Position (<4.0 cm)	1.1
RMSE for Down Position (<8.0 cm)	2.16
Boresight correction stdev (<0.001deg)	0.000499
IMU attitude correction stdev (<0.001deg)	0.011782
GPS position stdev (<0.01m)	0.0166
Minimum % overlap (>25)	21.28%
Ave point cloud density per sq.m. (>2.0)	3.09
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	494
Maximum Height	194.95 m
Minimum Height	59.93
Classification (# of points)	
Ground	352,505,220
Low vegetation	270,993,261
Medium vegetation	316,234,276
High vegetation	70,400,719
Building	19,489,857
Orthophoto	Yes
Processed by	Engr. Analyn Naldo, Engr. Harmond Santos, Engr. Gladys Mae Apat

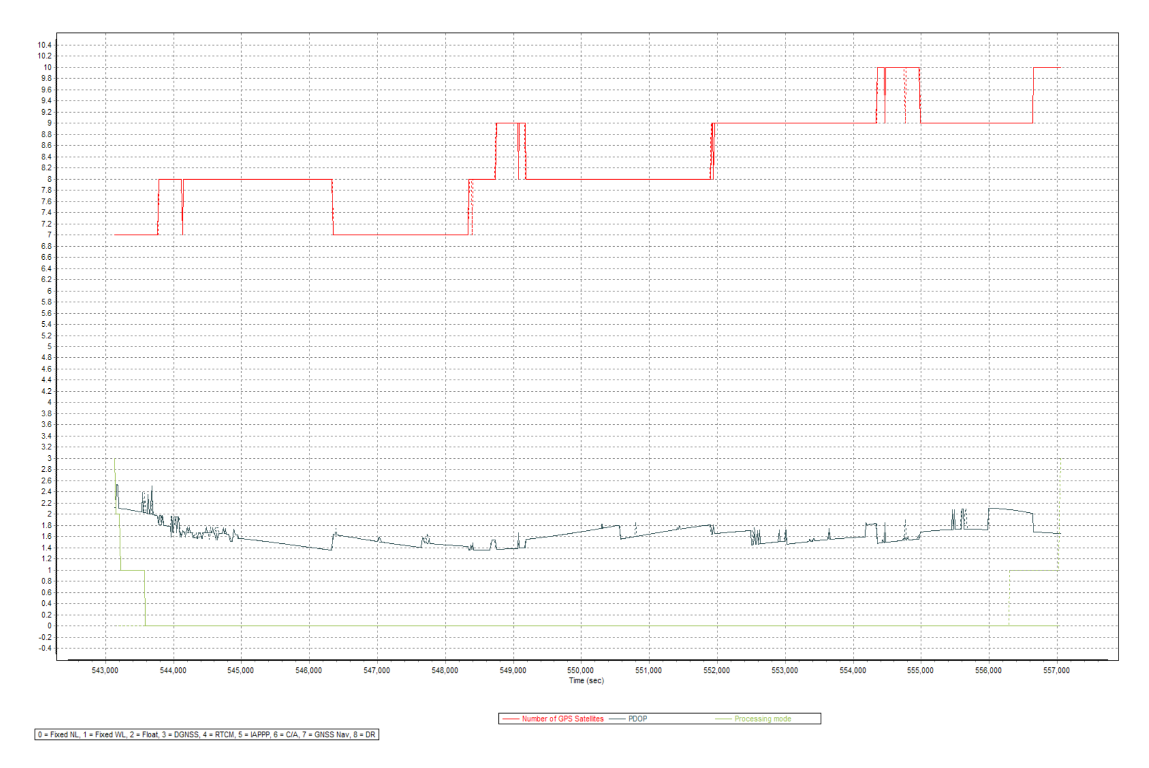


Figure 1.1.1 Solution Status

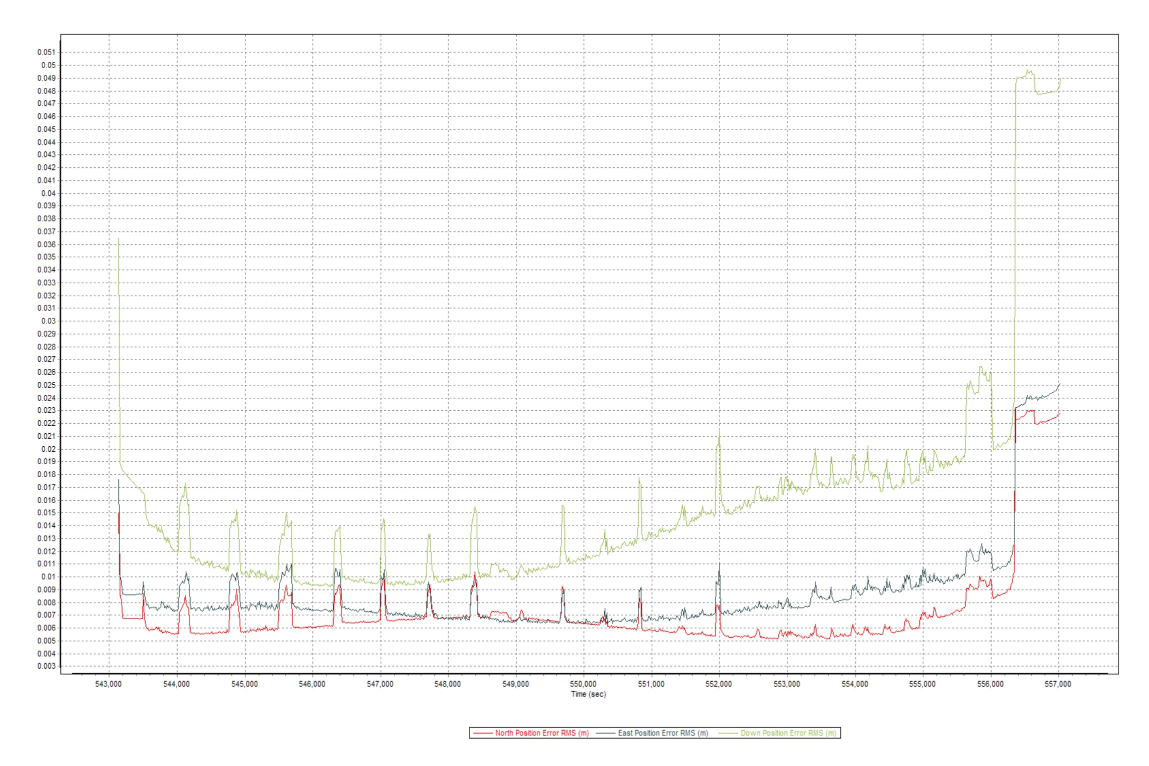


Figure 1.1.2 Smoothed Performance Metric Parameters

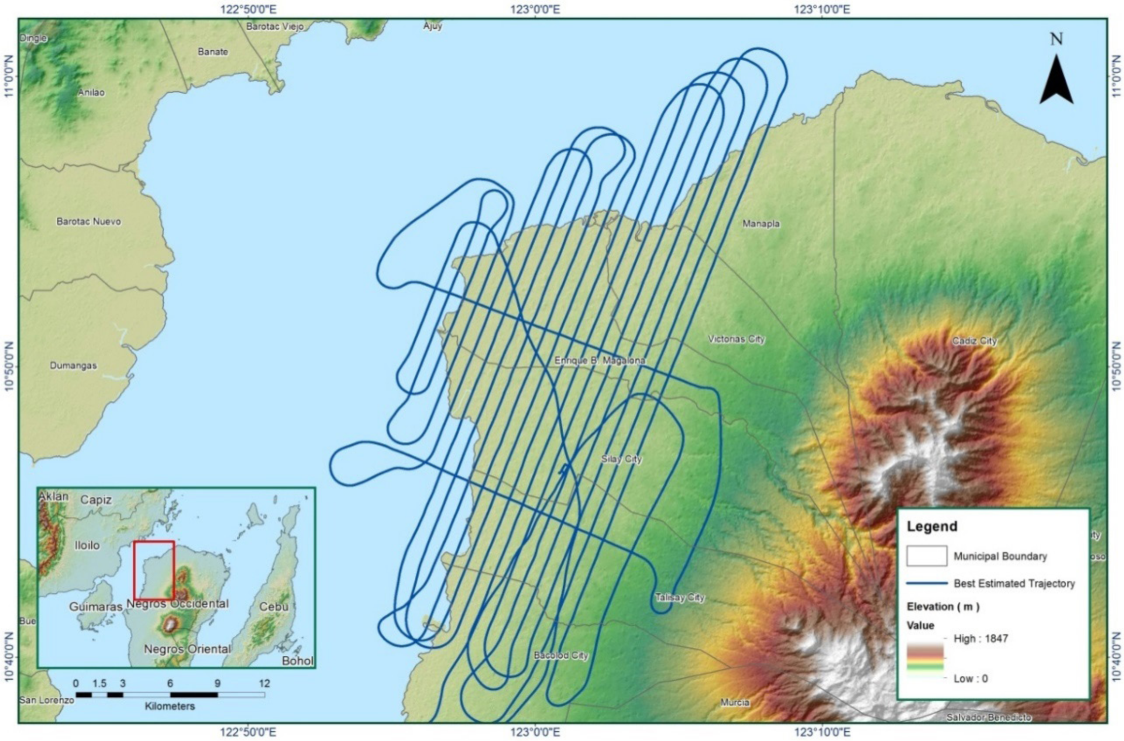


Figure 1.1.3 Best Estimated Trajectory

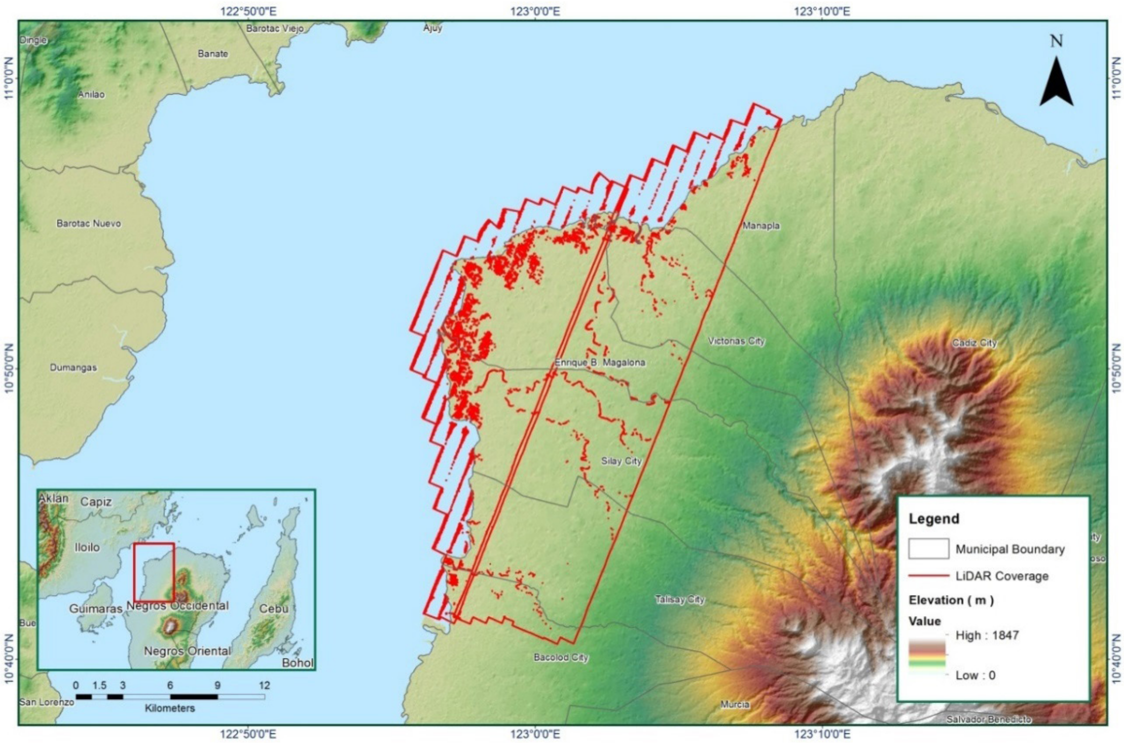


Figure 1.1.4 Coverage of LIDAR data

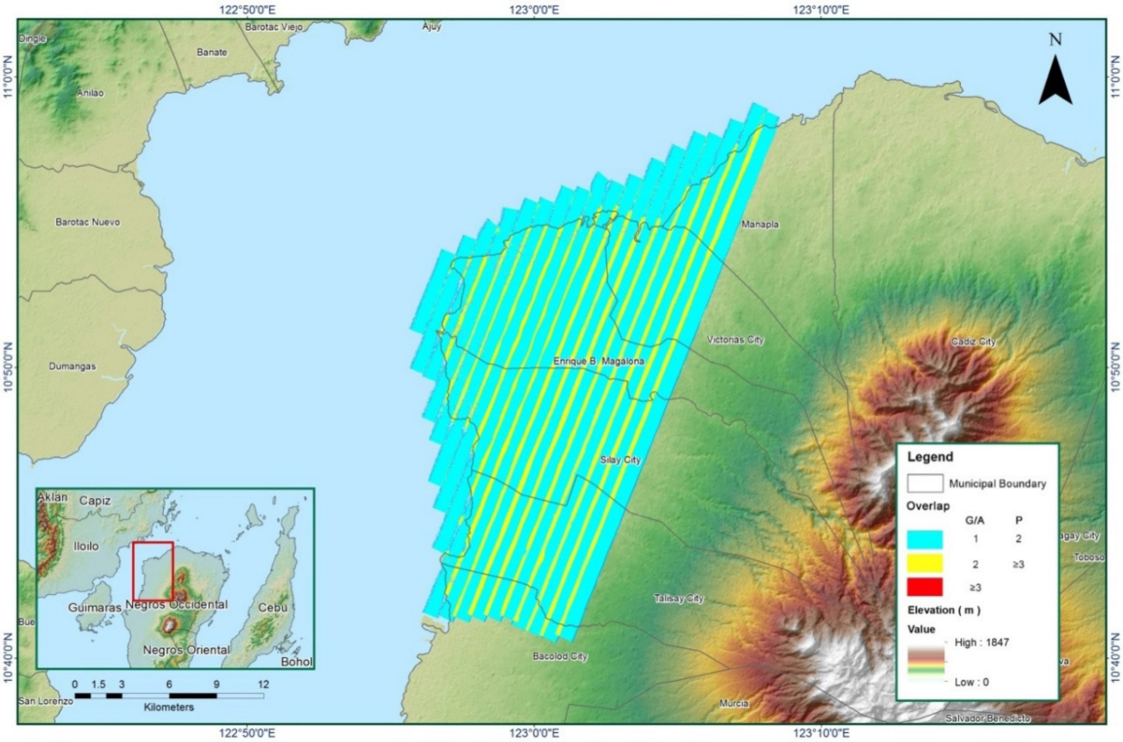


Figure 1.1.5 Image of Data Overlap

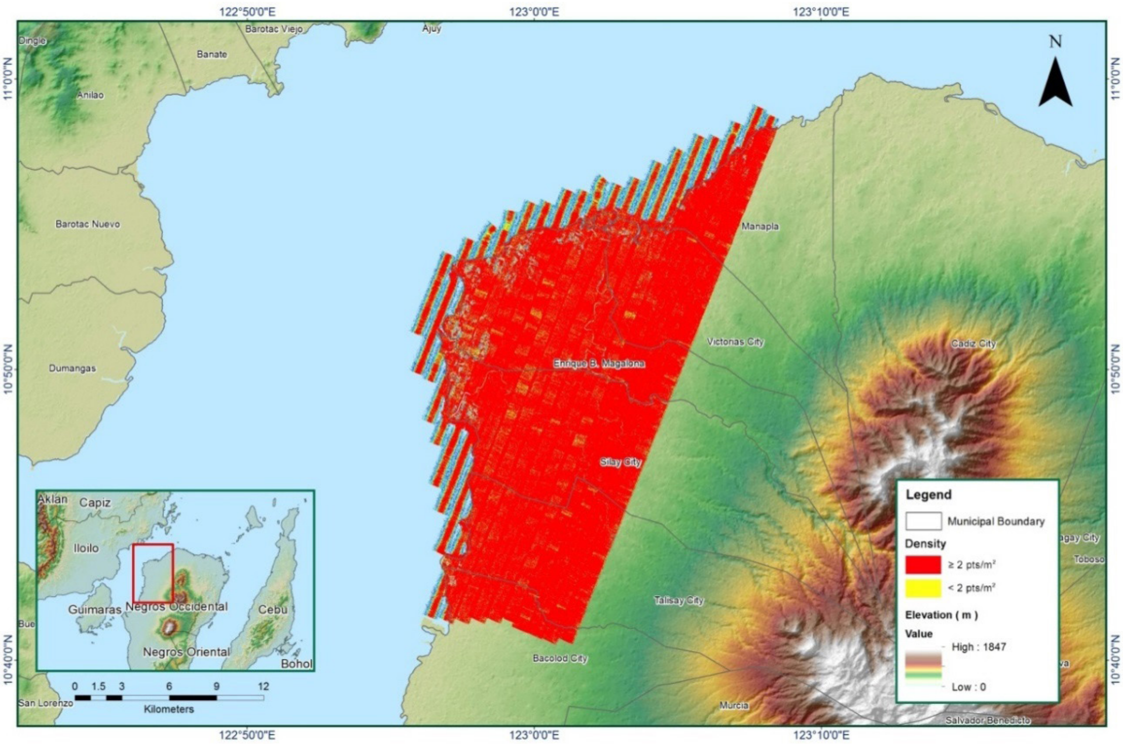


Figure 1.1.6 Density map of merged LIDAR data

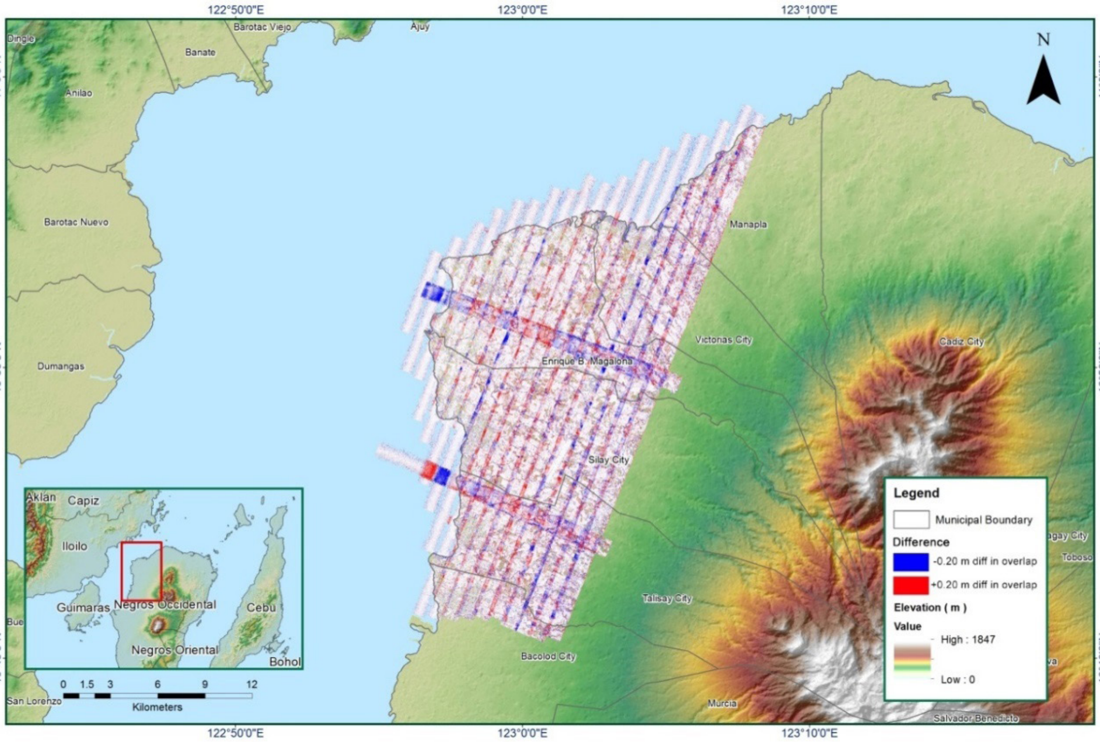


Figure 1.1.7 Elevation difference between flight lines

Flight Area	Negros
Mission Name	**Blk44C**
Inclusive Flights	1391P
Range data size	30.7 GB
POS data size	257 MB
Image	52 GB
Base data size	12.3 MB
Transfer date	May 26, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.16
RMSE for East Position (<4.0 cm)	1.54
RMSE for Down Position (<8.0 cm)	2.73
Boresight correction stdev (<0.001deg)	0.000312
IMU attitude correction stdev (<0.001deg)	0.001371
GPS position stdev (<0.01m)	0.006
Minimum % overlap (>25)	26.54%
Ave point cloud density per sq.m. (>2.0)	4.79
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	399
Maximum Height	395.70 m
Minimum Height	61.24 m
Classification (# of points)	
Ground	350,273,998
Low vegetation	332,575,391
Medium vegetation	433,345,906
High vegetation	91,636,263
Building	7,157,778
Orthophoto	Yes
Processed by	Engr. Analyn Naldo, Engr. Harmond Santos, Engr. Gladys Mae Apat

Figure 1.2.1 Solution Status

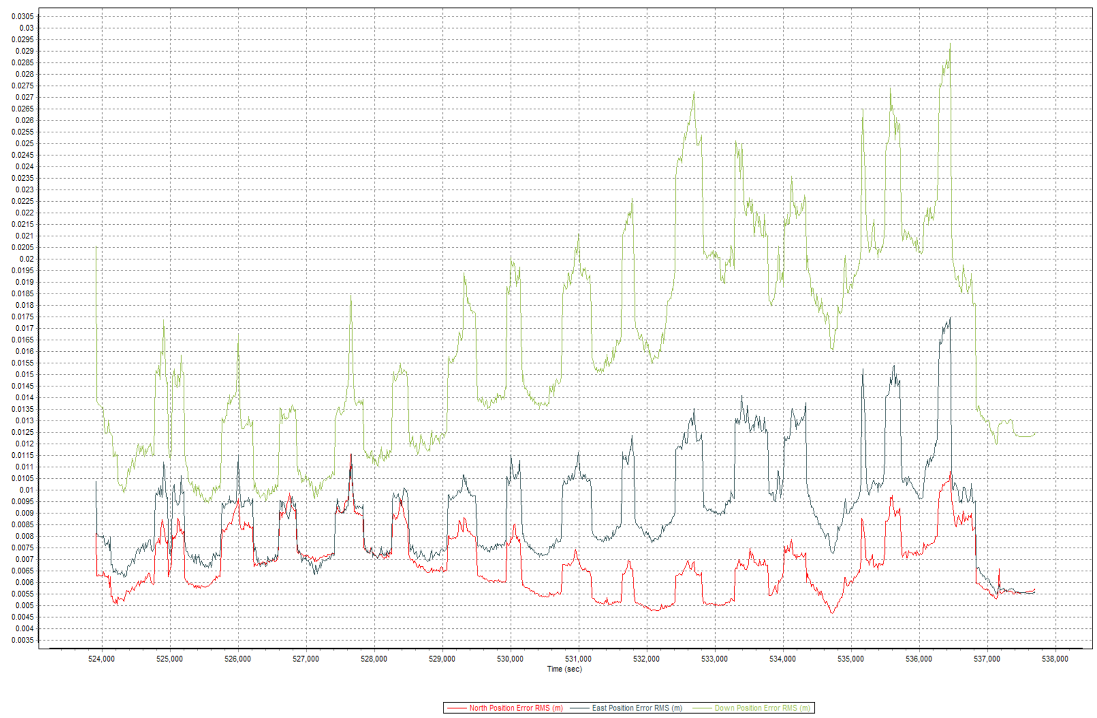


Figure 1.2.2 Smoothed Performance Metric Parameters

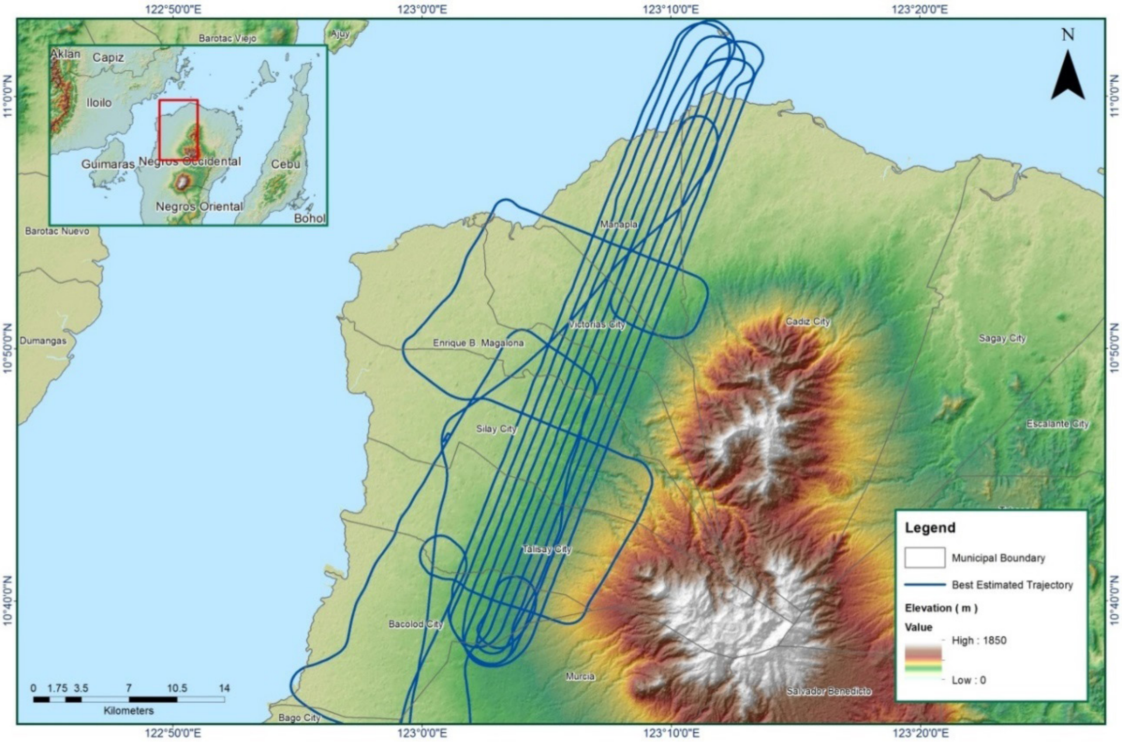


Figure 1.2.3 Best Estimated Trajectory

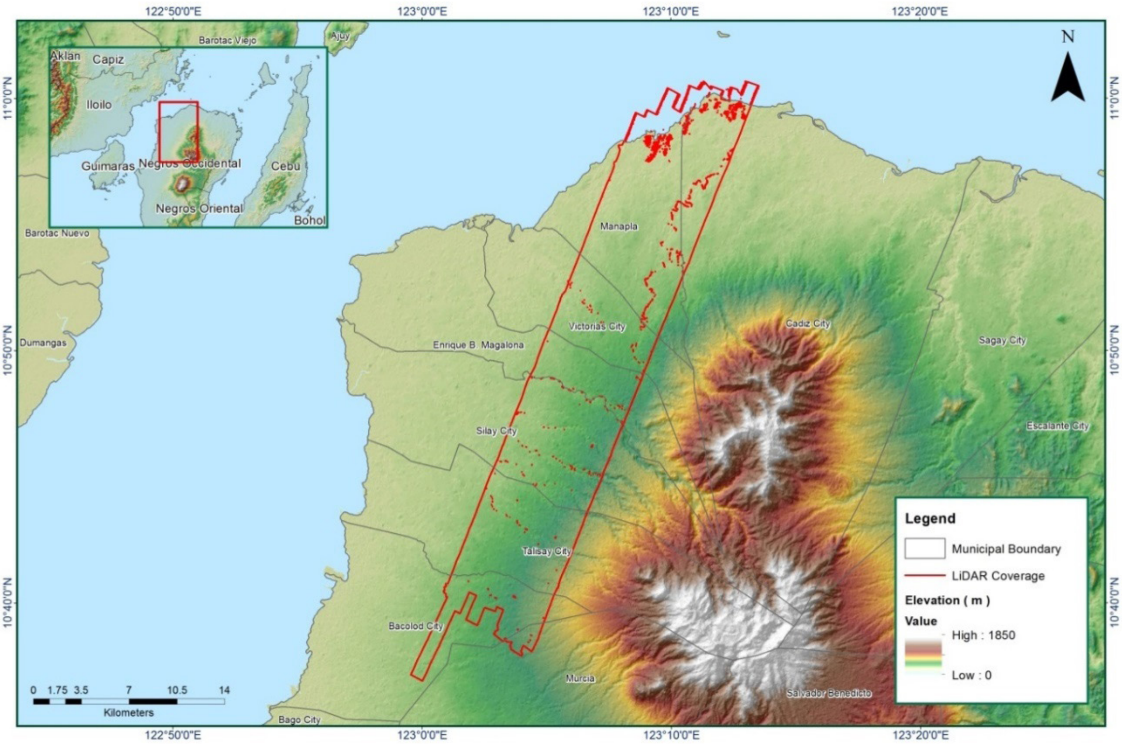


Figure 1.2.4 Coverage of LIDAR data

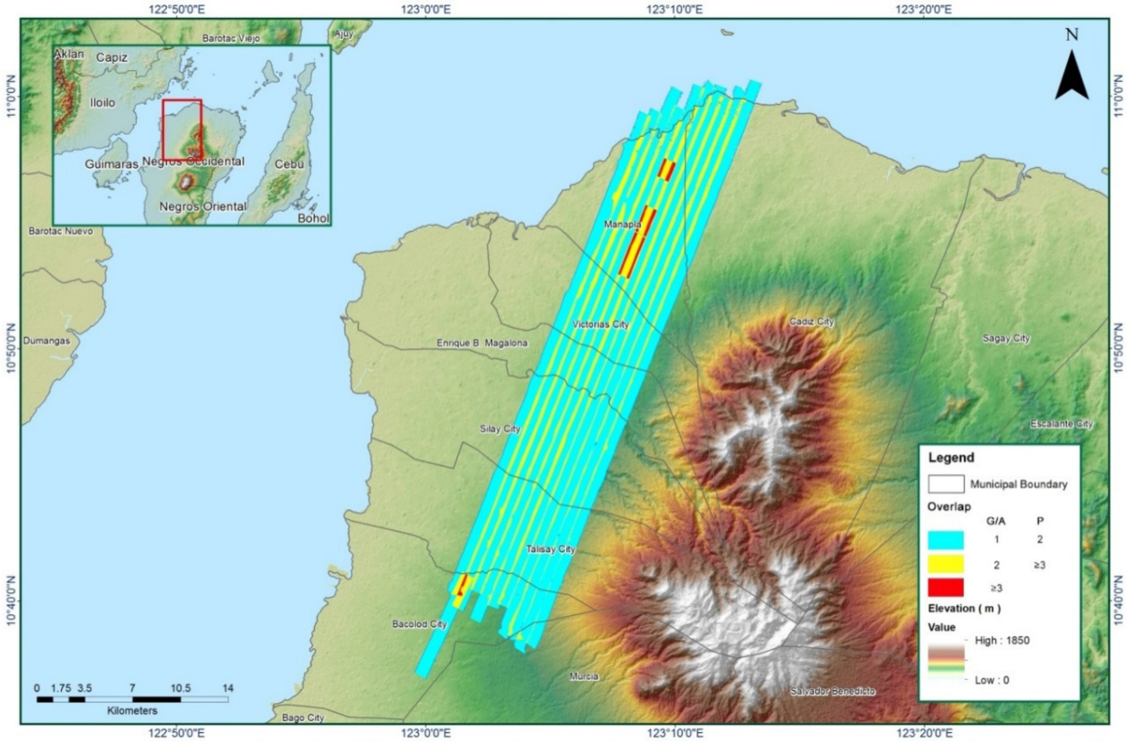


Figure 1.2.5 Image of Data Overlap

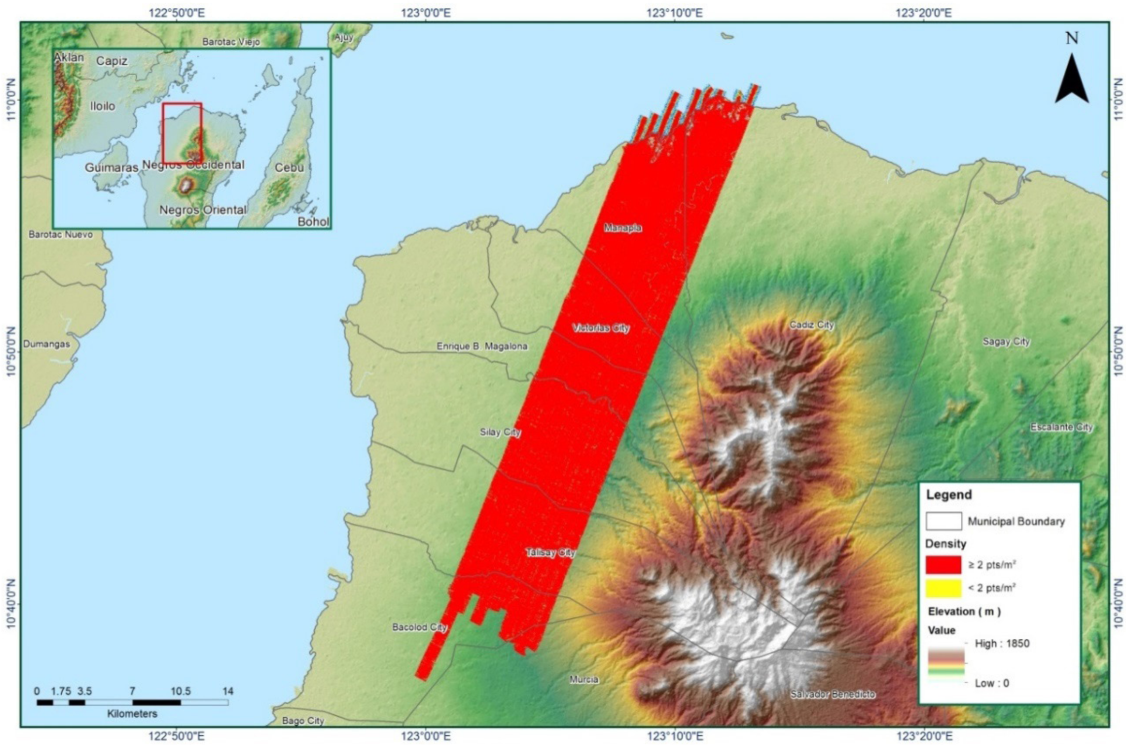


Figure 1.2.6 Density map of merged LIDAR data

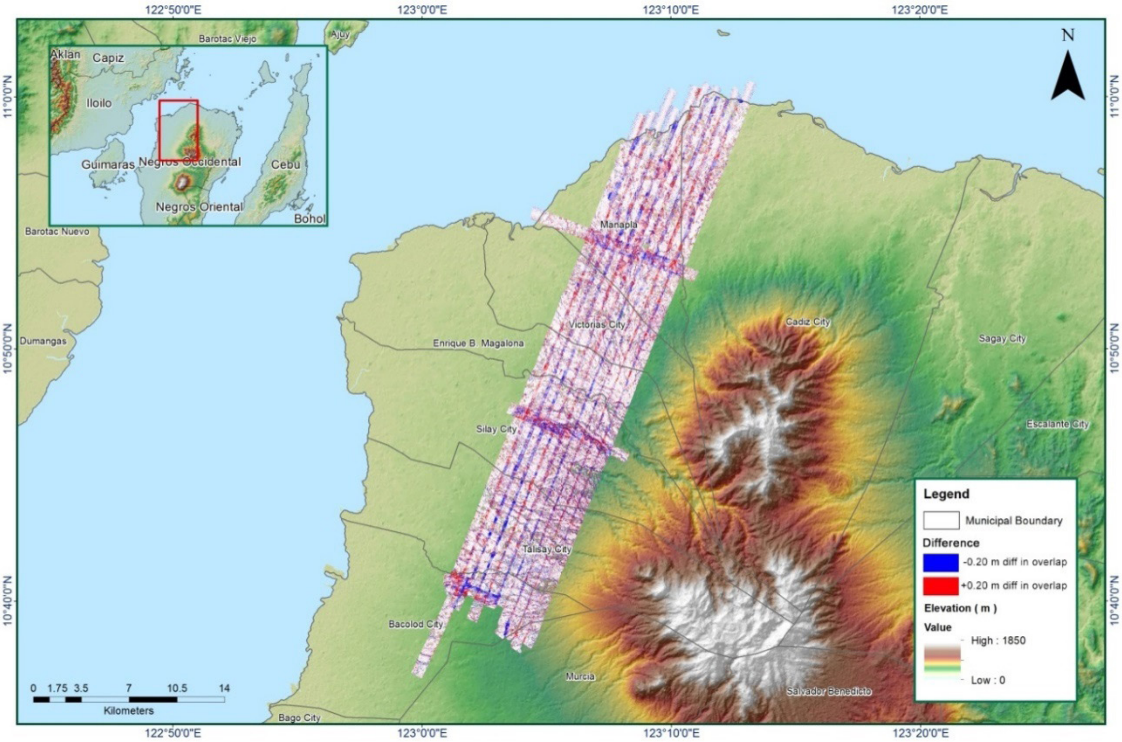


Figure 1.2.7 Elevation difference between flight lines

Flight Area	Negros Occidental Reflights
Mission Name	**Blk44A**
Inclusive Flights	10007P
Range data size	19.6 GB
Base data size	5.71 MB
POS	263 MB
Image	53.26 GB
Transfer date	November 3, 2015
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.97
RMSE for East Position (<4.0 cm)	1.41
RMSE for Down Position (<8.0 cm)	5.68
Boresight correction stdev (<0.001deg)	0.000210
IMU attitude correction stdev (<0.001deg)	0.000353
GPS position stdev (<0.01m)	0.0011
Minimum % overlap (>25)	10.94
Ave point cloud density per sq.m. (>2.0)	1.38
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	65
Maximum Height	149.14
Minimum Height	49.66
Classification (# of points)	
Ground	33,212,887
Low vegetation	23,113,187
Medium vegetation	13,262,338
High vegetation	13,425,720
Building	5,852,512
Orthophoto	yes
Processed by	Engr. Irish Cortez, Engr. Jovelle Anjeanette Canlas, Engr. Mark Sueden Lyle Magtalas

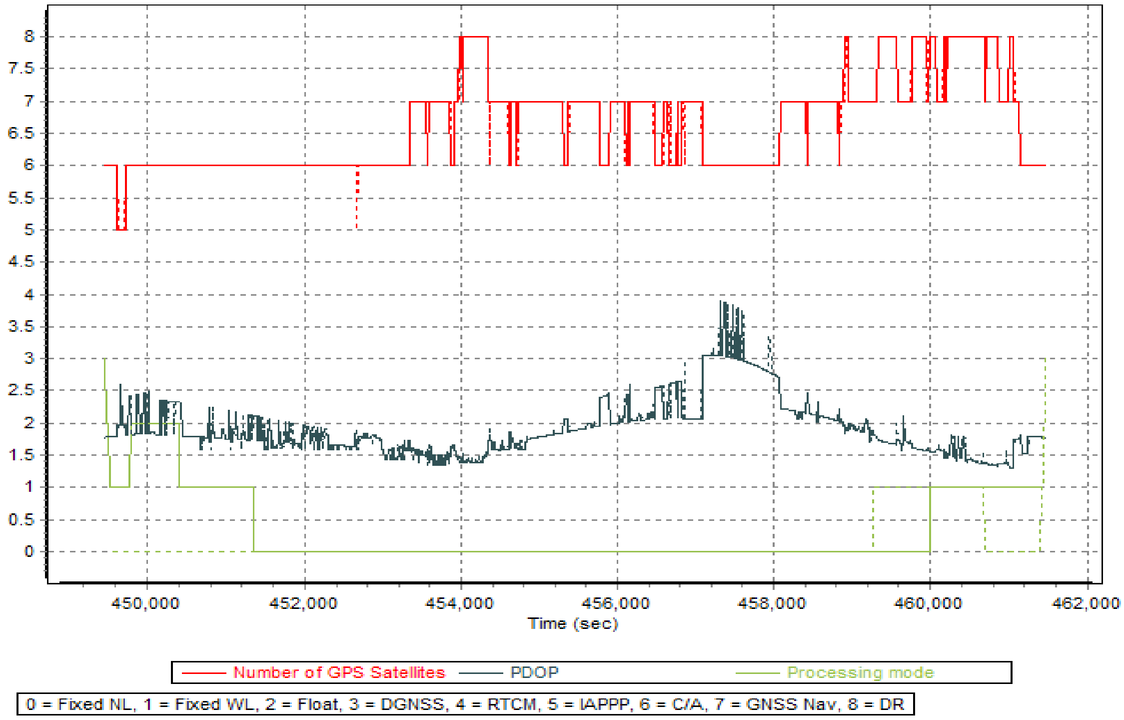


Figure 1.3.1. Solution Status

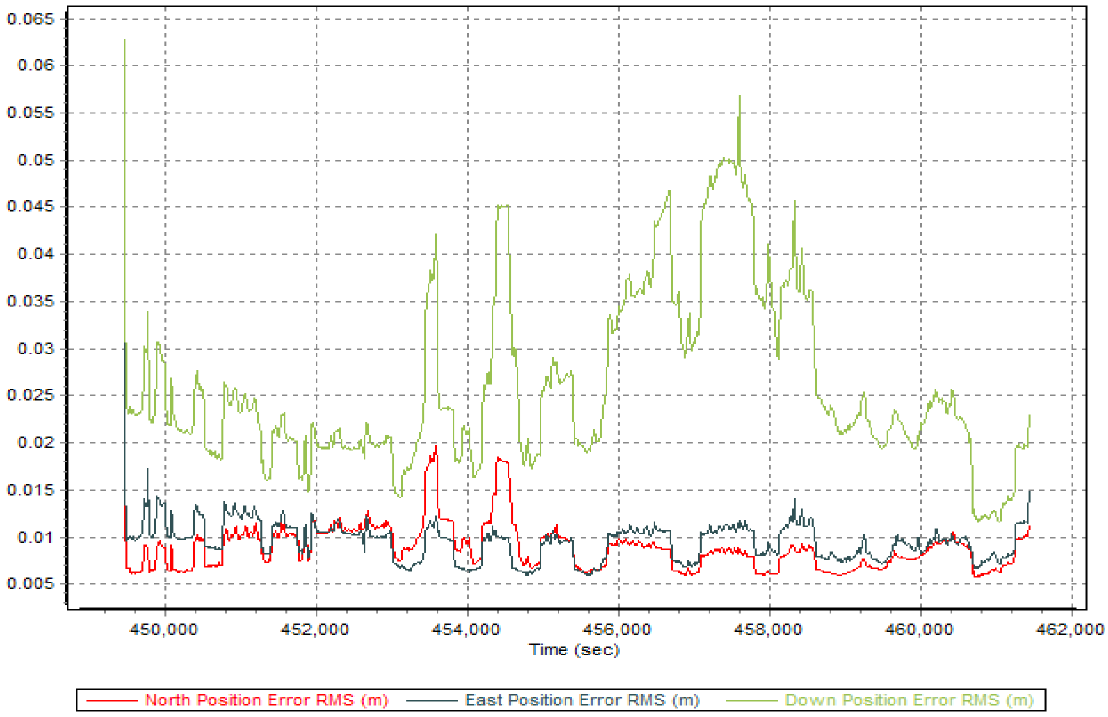


Figure 1.3.2. Smoothed Performance Metric Parameters

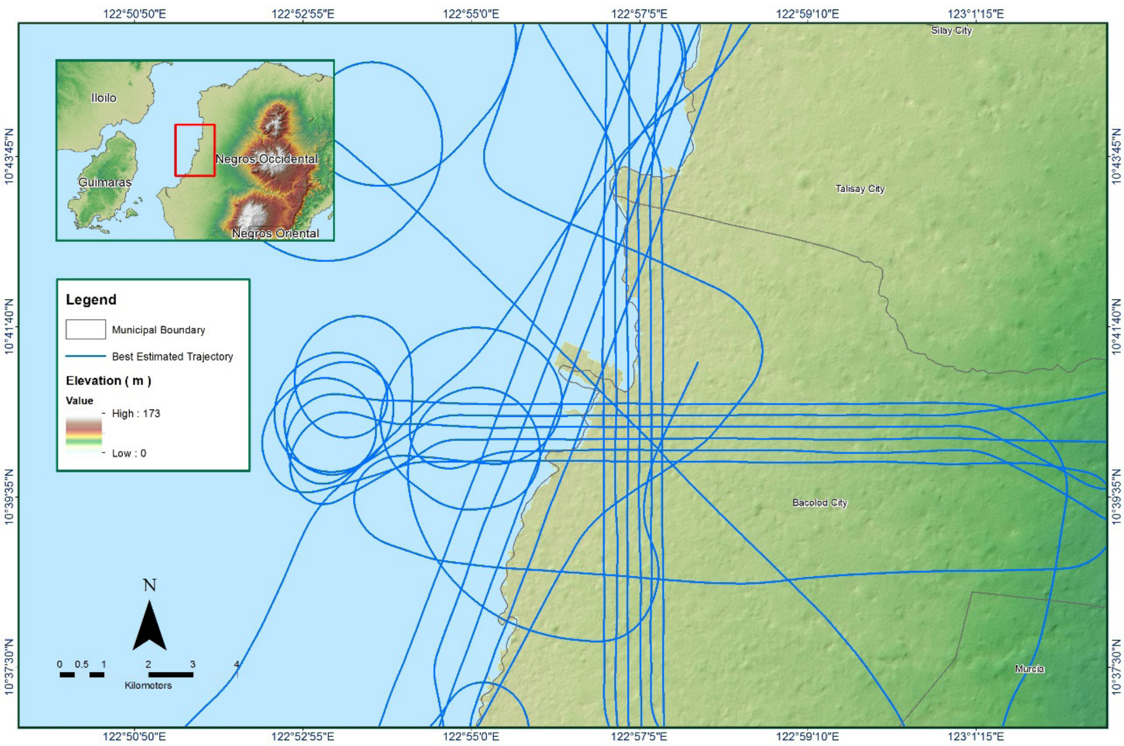


Figure 1.3.3. Best estimate trajectory

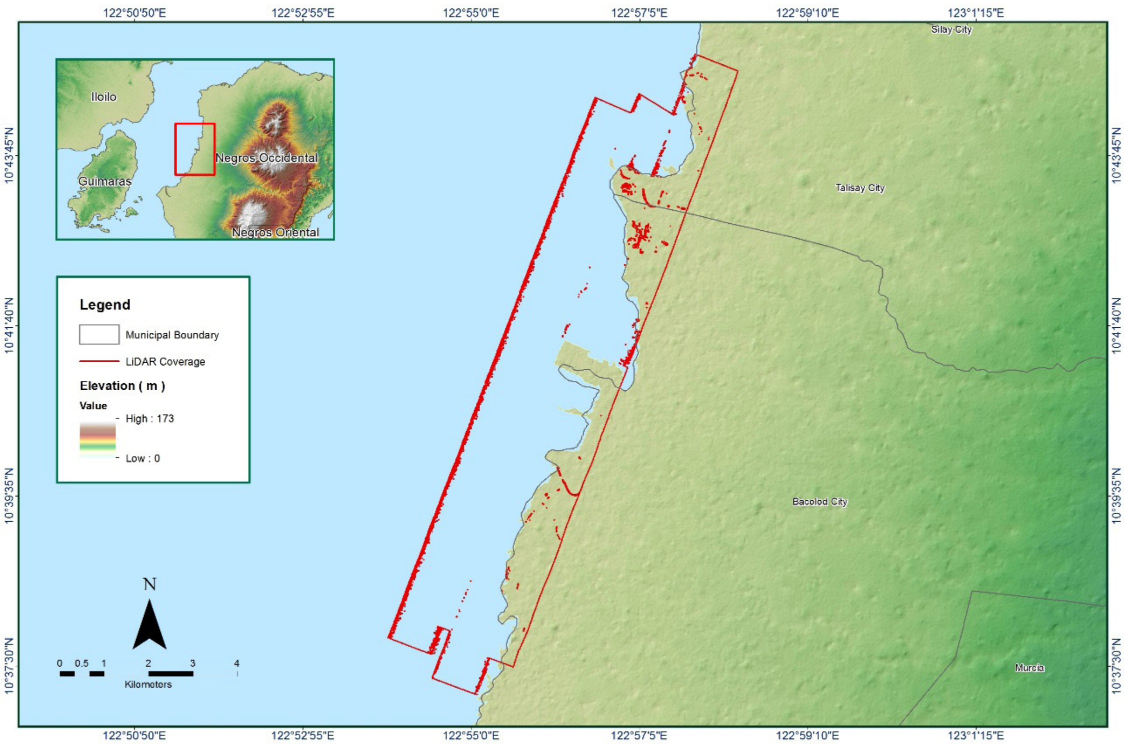


Figure 1.3.4. Coverage of LiDAR data

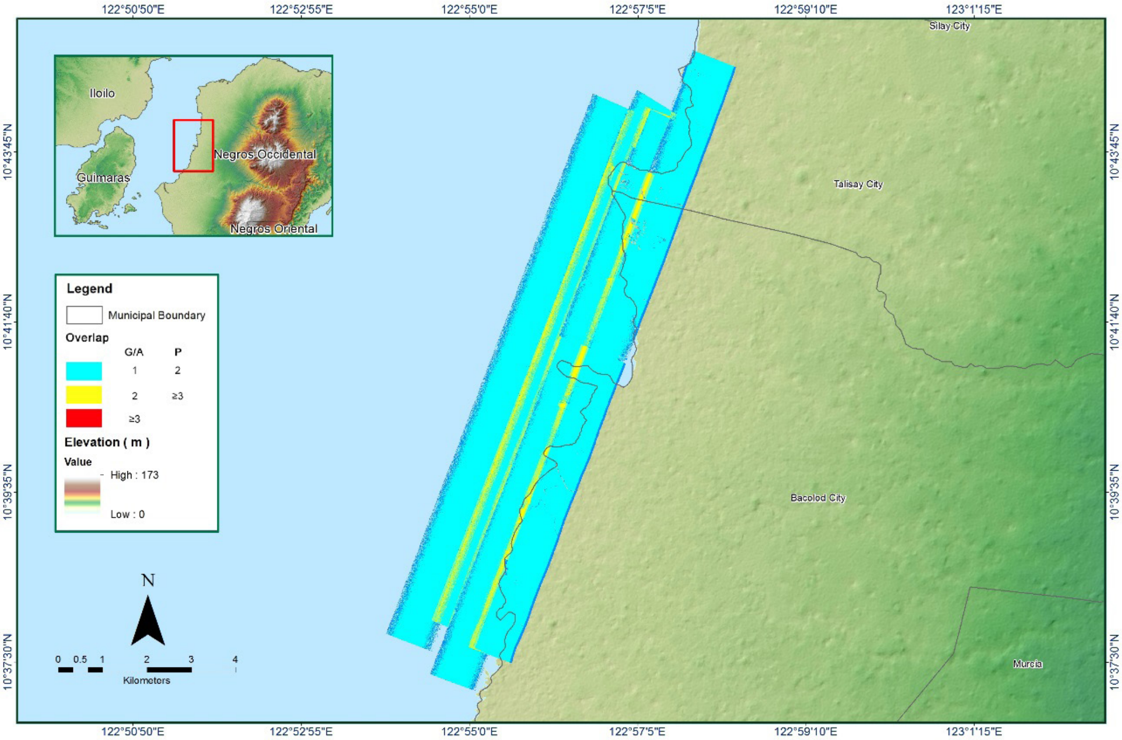


Figure 1.3.5. Image of data overlaps

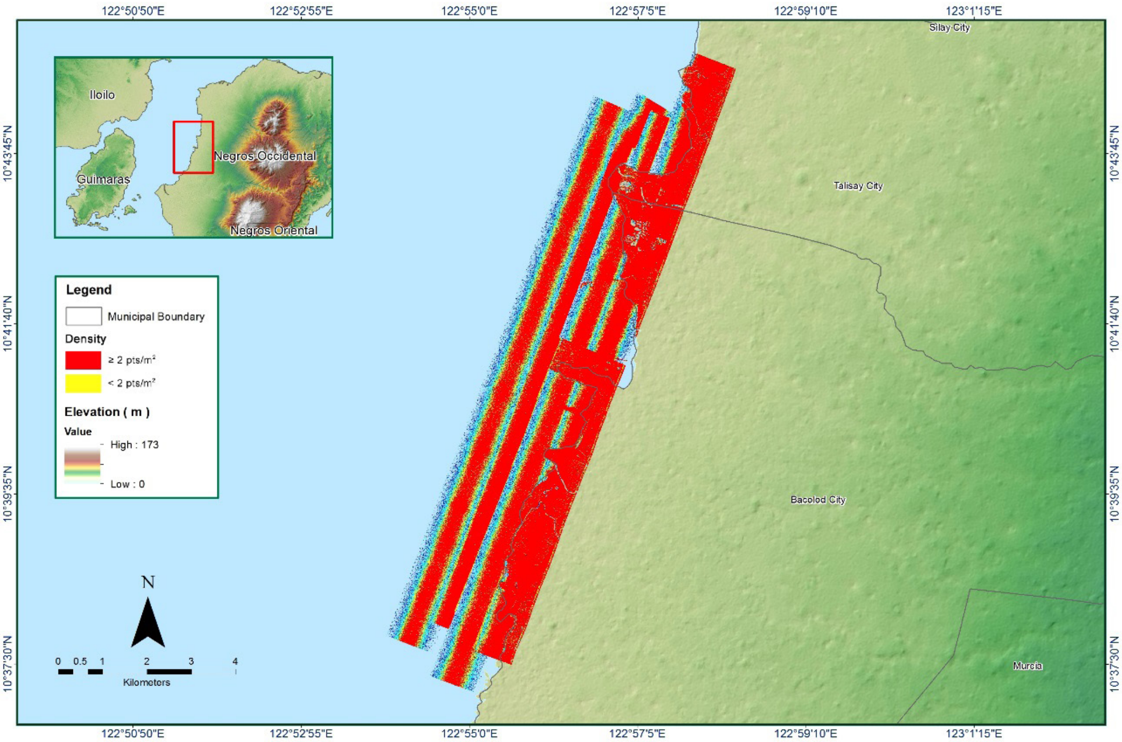


Figure 1.3.6. Density of merged LiDAR data

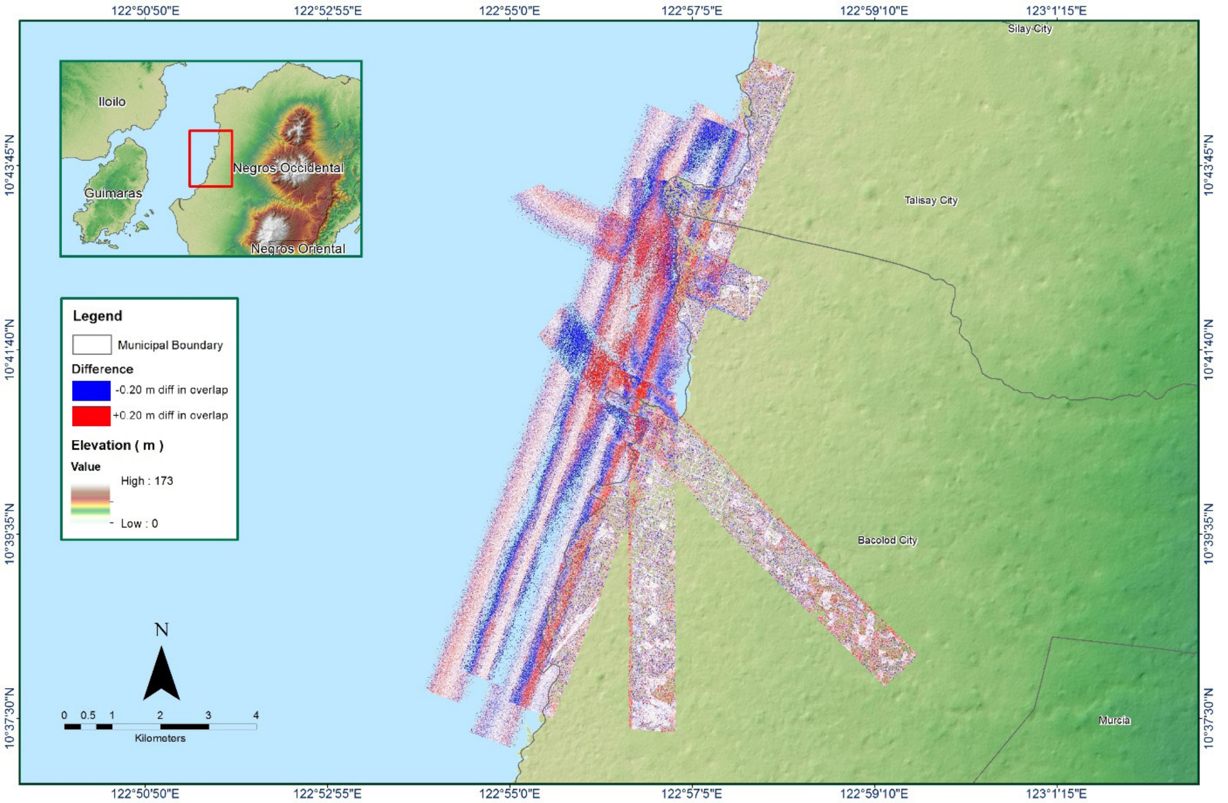


Figure 1.3.7. Elevation difference between flight lines

Annex 9. Imbang Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W280	10.3125	60.3	0	5.814291	34.1601228	Discharge	0.20461	0.8	Ratio to Peak	0.5
W290	10.3125	60.3	0	3.986763	23.4230292	Discharge	0.12486	0.8	Ratio to Peak	0.5
W300	10.3125	60.3	0	3.365803	19.7747712	Discharge	0.11274	0.8	Ratio to Peak	0.5
W310	7.8486	65.476256	0	5.722082	33.6183732	Discharge	0.37314	0.8	Ratio to Peak	0.5
W320	10.184	60.565669	0	2.414159	14.1836652	Discharge	0.0632458	0.8	Ratio to Peak	0.5
W330	7.1804172	67.031172	0	3.78945	22.2637788	Discharge	0.21176	0.8	Ratio to Peak	0.5
W340	10.3125	60.3	0	1.053216	6.1878564	Discharge	0.0095517	0.8	Ratio to Peak	0.5
W350	10.2385338	60.459645	0	2.909614	17.094564	Discharge	0.12238	0.8	Ratio to Peak	0.5
W360	8.9909952	62.97837	0	3.229268	18.9725976	Discharge	0.1324	0.8	Ratio to Peak	0.5
W370	10.3125	60.3	0	0.533818	3.1362912	Discharge	0.0035819	0.8	Ratio to Peak	0.5
W380	5.588	71.052593	0	3.902919	22.930434	Discharge	0.44892	0.8	Ratio to Peak	0.5
W390	2.5575	80.1	0	1.654814	9.7223652	Discharge	0.11017	0.8	Ratio to Peak	0.5
W400	3.3122	77.715878	0	2.467311	14.4959472	Discharge	0.1951	0.8	Ratio to Peak	0.5
W410	2.5575	80.1	0	0.783579	4.6036836	Discharge	0.024797	0.8	Ratio to Peak	0.5
W420	3.0863052	78.446235	0	1.554299	9.1318212	Discharge	0.17721	0.8	Ratio to Peak	0.5
W430	10.3125	60.3	0	1.724801	10.13355	Discharge	0.0294101	0.8	Ratio to Peak	0.5
W440	5.8257771	70.421779	0	3.54917	20.852082	Discharge	0.26979	0.8	Ratio to Peak	0.5
W280	10.3125	60.3	0	5.814291	34.1601228	Discharge	0.20461	0.8	Ratio to Peak	0.5
W290	10.3125	60.3	0	3.986763	23.4230292	Discharge	0.12486	0.8	Ratio to Peak	0.5
W300	10.3125	60.3	0	3.365803	19.7747712	Discharge	0.11274	0.8	Ratio to Peak	0.5
W450	2.7955	79.406797	0	2.048954	12.0380148	Discharge	0.1875	0.8	Ratio to Peak	0.5
W460	9.1593348	62.62632	0	2.350996	13.81257	Discharge	0.11153	0.8	Ratio to Peak	0.5
W470	10.3125	60.3	0	1.533188	9.0077868	Discharge	0.0523619	0.8	Ratio to Peak	0.5
W480	6.854199	67.817484	0	2.377449	13.9679892	Discharge	0.37609	0.8	Ratio to Peak	0.5

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W490	10.0149753	60.896076	0	4.107688	24.1334892	Discharge	0.32277	0.8	Ratio to Peak	0.5
W500	11.149	58.744177	0	3.637777	21.3726708	Discharge	0.6231	0.8	Ratio to Peak	0.5
W510	8.9942	62.971628	0	3.127163	18.372708	Discharge	0.50428	0.8	Ratio to Peak	0.5
W520	5.9368551	70.130895	0	2.356525	13.8450564	Discharge	0.27567	0.8	Ratio to Peak	0.5
W530	12.0373968	57.16317	0	1.568207	9.2135304	Discharge	0.11785	0.8	Ratio to Peak	0.5
W540	13.6618515	54.480689	0	1.548919	9.1002132	Discharge	0.15163	0.8	Ratio to Peak	0.5

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W180	9.7329	45.526	0	2.8272	9.5043	Discharge	0.40373	1	Ratio to Peak	0.5
W190	12.742	41.788	0	2.8272	6.1071	Discharge	0.0408069	1	Ratio to Peak	0.5
W200	12.574	42.832	0	2.8272	6.7238	Discharge	0.0682304	1	Ratio to Peak	0.5
W210	13.201	47.431	0	2.8272	6.2619	Discharge	0.22908	1	Ratio to Peak	0.5
W220	12.742	42.641	0	2.8272	3.1993	Discharge	0.0106021	1	Ratio to Peak	0.5
W230	11.116	44.518	0	2.8272	12.178	Discharge	0.14318	1	Ratio to Peak	0.5
W240	8.0376	48.778	0	2.8272	10.995	Discharge	0.62209	1	Ratio to Peak	0.5
W250	9.6207	53.263	0	2.8272	5.6223	Discharge	0.98515	1	Ratio to Peak	0.5
W260	5.8643	45.432	0	2.8272	22.947	Discharge	0.44081	1	Ratio to Peak	0.5
W270	12.727	75.057	0	2.8272	6.4225	Discharge	0.0318223	1	Ratio to Peak	0.5
W280	7.238	49.784	0	2.8272	5.8731	Discharge	0.29192	1	Ratio to Peak	0.5
W290	12.346	37.238	0	2.8272	15.305	Discharge	0.34924	1	Ratio to Peak	0.5
W300	11.299	69.758	0	2.8272	5.8035	Discharge	0.12068	1	Ratio to Peak	0.5
W310	12.059	66.599	0	2.8272	3.5492	Discharge	0.0566567	1	Ratio to Peak	0.5
W320	11.215	44.763	0	2.8272	2.3693	Discharge	0.69853	1	Ratio to Peak	0.5
W330	11.034	45.55	0	2.8272	2.2713	Discharge	0.54564	1	Ratio to Peak	0.5
W340	7.3148	51.82	0	4.91	13.04	Discharge	0.29828	1	Ratio to Peak	0.5

Annex 10. Imbang Model Reach Parameters

Reach Number	MuskingumCunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R10	Automatic Fixed Interval	985	0.000711	0.0129883	Trapezoid	20.54	1
R30	Automatic Fixed Interval	1794.14	0.004886	0.0191791	Trapezoid	20.54	1
R40	Automatic Fixed Interval	754.142	0.000822	0.0283251	Trapezoid	20.54	1
R50	Automatic Fixed Interval	6023.7	0.010371	0.064359	Trapezoid	20.54	1
R70	Automatic Fixed Interval	2567.11	0.010169	0.0426587	Trapezoid	20.54	1
R100	Automatic Fixed Interval	1574.68	0.010326	0.0628311	Trapezoid	20.54	1
R110	Automatic Fixed Interval	3249.19	0.017365	0.0413884	Trapezoid	20.54	1
R140	Automatic Fixed Interval	2036.52	0.027183	0.14026	Trapezoid	20.54	1

Annex 11. Malogo-Imbang Field Validation

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/ Date	Rain Return/ Scenario
	Lat	Long					
0	10.874581	122.978083	0.31	0.2	0.012		
1	10.886806	123.061748	0.3	0	0.09		
2	10.831938	123.006666	0.07	0.3	0.053	Ondoy	5-Year
3	10.801434	122.978958	0.24	0.5	0.068	Yolanda	5-Year
4	10.905725	123.085109	0.03	0.3	0.073	Yolanda	5-Year
5	10.802418	122.982114	0.38	0.19	0.036	Frank	5-Year
6	10.833958	123.012430	0.11	0.3	0.036	Ondoy	5-Year
7	10.834760	123.013500	0.03	0.3	0.073	Ondoy	5-Year
8	10.802543	122.978385	0.23	0.5	0.073	Yolanda	5-Year
9	10.870298	123.058635	0.07	0.2	0.017		
10	10.805041	122.983177	0.3	0	0.09		
11	10.872569	123.063731	0.17	0	0.029		
12	10.858180	122.981078	0.24	0.2	0.002	Yolanda	5-Year
13	10.804439	122.973399	0.07	0	0.005		
14	10.893419	123.058590	0.1	0.3	0.04	Yolanda	5-Year
15	10.876223	123.060129	0.14	0	0.02		
16	10.877563	123.063463	0.29	0.3	0		
17	10.797742	122.985954	0.27	0.3	0.001		
18	10.796024	122.985973	0.24	0.3	0.004		
19	10.892683	123.059338	0.13	0.3	0.029	Yolanda	5-Year
20	10.909637	123.080432	0.03	0	0.001		
21	10.793413	122.983148	0.21	0.3	0.008		
22	10.857991	122.977970	0.3	0.2	0.01	Yolanda	5-Year
23	10.802467	122.979111	0.35	2	2.723	Uring	5-Year
24	10.874292	123.066013	0.06	0	0.004		
25	10.800864	122.978968	0.58	0.5	0.006	Yolanda	5-Year
26	10.905975	123.073438	1.06	0.22	0.706	Frank	100-Year
27	10.903209	123.071696	0.4	0	0.16		
28	10.819649	123.037728	0.44	0	0.194		
29	10.889418	122.965447	0.03	0.4	0.137		
30	10.888859	122.964993	0.18	0.4	0.048		
31	10.900886	123.068373	0.51	2	2.22	Seniang	5-Year
32	10.872684	123.058833	1.02	1.2	0.032	Rosing	5-Year
33	10.837002	122.979905	0.15	0.8	0.423		
34	10.872698	123.063797	2.07	0	4.285		
35	10.914410	123.085986	3.19	1.5	2.856	Yolanda	5-Year
36	10.748367	123.041491	1.32	0.4	0.846	Ruping	5-Year
37	10.880037	123.060877	0.91	0.8	0.012	Rosing	5-Year
38	10.872776	123.060720	0.89	1.2	0.096	Rosing	5-Year
39	10.872822	123.064840	0.05	0	0.003		
40	10.907443	123.070540	1.21	0.09	1.254	Frank	5-Year
41	10.883281	123.063011	0.06	1.5	2.074	Rosing	5-Year

42	10.870380	123.063558	1.49	0.7	0.624	Rosing	5-Year
43	10.838854	122.981991	1.93	0.8	1.277		
44	10.903113	123.065461	0.46	0.8	0.116	Yolanda	5-Year
45	10.881575	123.065084	1.43	1.5	0.005	Rosing	5-Year
46	10.891877	123.074221	0.33	2	2.789	Ruping	5-Year
47	10.801880	122.97107	0.71	0	0.504		
48	10.906921	123.085458	0.03	1.5	2.161	Yolanda	5-Year
49	10.820396	122.964973	1.06	0.4	0.436	Yolanda	5-Year
50	10.898672	123.070463	1.05	2	0.903	Ruping	5-Year
51	10.901158	123.067217	0.03	0.8	0.593	Seniang	5-Year
52	10.829199	123.005950	0.06	0.5	0.194		
53	10.803154	122.981493	0.92	0.06	0.74	Frank	100-Year
54	10.880416	123.059597	0.03	1	0.941	Rosing	5-Year
55	10.828212	123.004701	0.06	0.5	0.194		
56	10.804824	122.974034	0.9	1	0.01	Ruping	5-Year
57	10.872730	123.058105	0.97	1.2	0.053	Rosing	5-Year
58	10.822419	123.035397	0.52	1	0.23	Ondoy	5-Year
59	10.880166	123.059274	0.05	1	0.903	Rosing	5-Year
60	10.909821	123.086730	0.8	1.5	0.49	Yolanda	5-Year
61	10.813411	122.970690	3.21	0.5	7.344	Yolanda	5-Year
62	10.821215	122.966014	1.74	1.5	0.058	Yolanda	5-Year
63	10.820738	122.965538	0.47	1.5	1.061	Yolanda	5-Year
64	10.803102	122.982312	0.89	0.5	0.152	Frank	5-Year
65	10.886085	123.062013	0.03	2	3.881	Rosing	5-Year
66	10.896469	123.074646	0.04	4	15.682		
67	10.897500	123.072407	1.06	4	8.644		
68	10.812406	123.036194	0.64	1	0.13		
69	10.803436	122.979345	0.72	4	10.758	Yolanda	5-Year
70	10.879142	123.058398	0.67	1.2	0.281	Rosing	5-Year
71	10.902383	123.064953	1.09	2.5	1.988	Yolanda	5-Year
72	10.882240	123.062421	1.49	1.5	0	Rosing	5-Year
73	10.878475	123.060758	2.61	0.4	4.884	Rosing	5-Year
74	10.897734	123.072374	0.95	4	9.303		
75	10.882443	123.066312	1.32	1.5	0.032	Rosing	5-Year
76	10.880485	123.061902	1.65	2	0.123	Rosing	5-Year
77	10.902586	123.066947	0.04	2.5	6.052	Yolanda	5-Year
78	10.826990	123.041884	0.03	1	0.941	Yolanda	5-Year
79	10.827034	123.044998	0.05	1	0.903	Yolanda	5-Year
80	10.882401	123.065904	2.07	1.5	0.325	Rosing	5-Year
81	10.897657	123.072499	0.83	4	10.049		
82	10.807928	122.989912	0.04	0.4	0.13	Yolanda	5-Year
83	10.797101	123.021483	0.31	0.5	0.036	Yolanda	5-Year
84	10.840902	123.028981	0.66	3	5.476	Yolanda	5-Year
85	10.749377	123.041147	0.28	0.5	0.048	Yolanda	5-Year
86	10.870995	123.058319	1.65	2	0.123	Rosing	5-Year
87	10.879216	123.058235	1.56	1.2	0.13	Rosing	5-Year

88	10.805906	122.983998	0.12	0.4	0.078	Yolanda	5-Year
89	10.808594	122.990384	0.03	0.4	0.137	Yolanda	5-Year
90	10.882748	123.061871	0.87	2	1.277	Rosing	5-Year
91	10.878945	123.057272	1.73	5	10.693	Rosing	5-Year
92	10.895426	123.077324	2.23	4	3.133		
93	10.803099	122.981455	3.22	0.53	7.236	Frank	5-Year
94	10.744704	123.043396	0.36	2.5	4.58	Yolanda	5-Year
95	10.833155	122.979441	2.16	0.8	1.85	Ruping	5-Year
96	10.746931	123.041978	0.05	3	8.703	Yolanda	5-Year
97	10.842022	123.029220	2.19	3	0.656	Yolanda	5-Year
98	10.877468	123.064150	2.28	4.5	4.928	Rosing	5-Year
99	10.747132	123.042936	0.03	3	8.821	Yolanda	5-Year
100	10.832435	123.031862	1.96	3	1.082	Yolanda	5-Year
101	10.742809	123.042476	0.6	2	1.96	Yolanda	5-Year
102	10.832992	122.977699	3.77	0.8	8.821	Ruping	5-Year
103	10.804093	122.975445	4.65	4	0.423	Yolanda	5-Year
104	10.881256	123.060968	2.26	4	3.028	Rosing	5-Year
105	10.744044	123.042874	0.15	2.5	5.523	Yolanda	5-Year
106	10.881438	123.061009	1.04	4	8.762	Rosing	5-Year
107	10.774040	123.028298	4.01	6	3.96		
108	10.746742	123.04247	5.36	3	5.57	Yolanda	5-Year
109	10.833170	122.978247	6.72	0.8	35.046	Ruping	5-Year
110	10.876590	123.057331	2.5	5	6.25	Rosing	5-Year
111	10.878698	123.057398	2.58	5	5.856	Rosing	5-Year
112	10.762126	123.047387	2.19	6	14.516		
113	10.747764	123.042395	0.7	3	5.29	Yolanda	5-Year
114	10.873440	123.069387	4.05	5	0.903	Rosing	5-Year
115	10.842056	123.029225	3.28	3	0.078	Yolanda	5-Year
116	10.742452	123.042932	0.75	2	1.563	Yolanda	5-Year
117	10.797290	123.022306	1.35	1	0.123	Yolanda	5-Year
118	10.878312	123.063579	14.62	4.5	102.414	Rosing	5-Year
119	10.797812	123.019746	0.03	1	0.941	Yolanda	5-Year
120	10.797397	123.022308	0.03	1	0.941	Yolanda	5-Year
121	10.743987	123.043046	1.04	2.5	2.132	Yolanda	5-Year
122	10.743276	123.042561	0.43	2	2.465	Yolanda	5-Year
123	10.831856	123.031836	0.16	3	8.066	Yolanda	5-Year
124	10.744257	123.043151	0.13	2.5	5.617	Yolanda	5-Year
125	10.806267	122.973150	9.04	4	25.402	Yolanda	5-Year
126	10.826353	123.047530	0.33	4	13.469	Yolanda	5-Year
127	10.819763	123.053930	0.03	4	15.761	Yolanda	5-Year
128	10.836879	123.030154	8.33	3	28.409	Yolanda	5-Year
129	10.762431	123.041437	1.85	6	17.223		
130	10.834339	123.033879	0.03	3	8.821	Yolanda	5-Year
131	10.873216	123.069307	17.02	5	144.48	Rosing	5-Year
132	10.873741	123.068664	6.01	5	1.02	Rosing	5-Year
133	10.798299	123.020121	6.82	6	0.672	Yolanda	5-Year

134	10.875795	123.068458	6.65	5	2.723	Rosing	5-Year
135	10.875560	123.068444	11.1	5	37.21	Rosing	5-Year
136	10.841618	123.029621	1.47	6	20.521	Yolanda	5-Year
137	10.746953	123.042513	0.04	5	24.602	Yolanda	5-Year
138	10.748219	123.042167	0.27	5	22.373	Yolanda	5-Year
139	10.873692	123.068593	5.75	5	0.563	Rosing	5-Year
140	10.877576	123.066906	4.09	5	0.828	Rosing	5-Year
141	10.748187	123.041852	2.29	5	7.344	Yolanda	5-Year
142	10.747476	123.042308	0.55	5	19.803	Yolanda	5-Year
143	10.826214	123.052502	9.44	6	11.834	Yolanda	5-Year
144	10.746417	123.043080	0.03	6	35.641	Yolanda	5-Year
145	10.832692	122.979678	0.03	6	35.641	Ruping	5-Year
146	10.832485	122.976493	0.03	6	35.641	Ruping	5-Year
147	10.746226	123.043073	0.14	6	34.34	Yolanda	5-Year
148	10.832371	122.979626	5.09	6	0.828	Ruping	5-Year
149	10.841689	123.029606	3.58	6	5.856	Yolanda	5-Year
150	10.746066	123.043139	0.04	6	35.522	Yolanda	5-Year
151	10.839335	123.028978	0.04	4.5	19.892	Yolanda	5-Year
152	10.747165	123.042488	7.86	5	8.18	Yolanda	5-Year
153	10.832476	122.976563	2.57	6	11.765	Ruping	5-Year
154	10.828020	123.006029	0.05	6	35.403	Yolanda	5-Year
155	10.876513	123.064803	0.03	5	24.701	Rosing	5-Year
156	10.747269	123.042223	0.03	5	24.701	Yolanda	5-Year
157	10.877032	123.064007	1.34	5	13.396	Rosing	5-Year
158	10.875852	123.068354	1.23	5	14.213	Rosing	5-Year
159	10.876588	123.067500	2.1	5	8.41	Rosing	5-Year
160	10.746347	123.042981	1.97	6	16.241	Yolanda	5-Year
161	10.748710	123.041867	1.76	5	10.498	Yolanda	5-Year
162	10.792022	123.030493	0.4	6	31.36	Yolanda	5-Year
163	10.872895	123.069108	2.87	5	4.537	Rosing	5-Year
164	10.793991	123.023866	1.05	6	24.503	Yolanda	5-Year
165	10.780159	123.037834	0.77	0	0.593		
166	10.777876	123.035387	0.39	0	0.152		
167	10.886712	122.964304	0.03	0	0.001		
168	10.792815	123.007647	0.03	0	0.001		
169	10.747313	123.042309	0.07	3	8.585	Ruping	5-Year
170	10.746919	123.042456	0.06	3	8.644	Ruping	5-Year
171	10.736306	123.046641	0.06	0	0.004		
172	10.795012	123.023847	0.04	2	3.842	Ruping	5-Year
173	10.852872	123.033817	0.03	1.5	2.161	Yolanda	5-Year
174	10.746474	123.043036	1.54	1	0.292	Ruping	5-Year
175	10.874399	123.068412	0.22	1	0.608	Yolanda	100-Year
176	10.829581	122.980926	0.52	0.8	0.078	Seniang	5-Year
177	10.798241	123.020102	0.06	3	8.644	Yolanda	5-Year
178	10.747226	123.042048	1.15	1	0.023	Ruping	5-Year
179	10.743675	123.042639	0.46	0	0.212		

180	10.838975	123.028649	0.66	2.4	3.028	Yolanda	5-Year
181	10.818986	122.994633	0.05	0	0.003		
182	10.798793	123.017762	1.89	0	3.572		
183	10.836705	123.024631	0.21	0.6	0.152	Yolanda	5-Year
184	10.826284	123.043919	0.47	0	0.221		
185	10.899996	123.067756	1.77	3	1.513	Ruping	5-Year
186	10.803558	122.983947	0.52	3	6.15		
187	10.746305	123.042841	1.17	1	0.029	Ruping	5-Year
188	10.830458	123.007860	0.1	1.32	1.488	Yolanda	5-Year
189	10.742727	123.042220	0.24	0	0.058		
190	10.804837	122.976479	0.63	1.4	0.593		
191	10.839530	123.029047	0.16	2.4	5.018	Yolanda	5-Year
192	10.826385	123.044563	0.35	3	7.023	Seniang	5-Year
193	10.842703	123.029258	0.03	1.4	1.877	Pepang	5-Year
194	10.897611	123.072551	0.07	1.8	2.993	Ruping	5-Year
195	10.803731	122.977827	0.22	0.32	0.01		
196	10.829633	123.008785	0.03	1.83	3.24	Yolanda	5-Year
197	10.791955	123.023411	0.45	0	0.203		
198	10.866694	123.059372	1.17	1	0.029	Ondoy	5-Year
199	10.888195	123.045361	0.51	0.45	0.004	Ruping	5-Year
200	10.853015	123.057287	0.03	0	0.001		
201	10.802477	122.999631	0.05	0	0.003		
202	10.773716	123.041137	0.27	0	0.073		
203	10.793059	123.022972	0.26	0	0.068		
204	10.817254	122.961133	0.03	0.82	0.624	Yolanda	5-Year
205	10.878505	123.060876	0.05	4	15.603		
206	10.814915	122.960863	0.24	0.67	0.185	Yolanda	5-Year
207	10.879782	123.060221	0.07	1.5	2.045	Yolanda	5-Year
208	10.89842	123.073003	0.13	1.2	1.145	Ruping	5-Year
209	10.824926	122.956644	0.07	0	0.005		
210	10.880147	123.058738	0.03	1.5	2.161	Yolanda	5-Year
211	10.872564	123.059530	0.04	1.5	2.132		
212	10.806583	122.977833	0.24	1.87	2.657		
213	10.841633	123.021842	0.33	0.45	0.014	Ruping	5-Year
214	10.740929	123.044889	0.03	0	0.001		
215	10.822858	123.035063	0.25	0.92	0.449	Yolanda	5-Year
216	10.907518	123.058912	0.03	1	0.941		
217	10.908937	123.075239	0.03	1	0.941	Yolanda	5-Year
218	10.908240	123.070592	0.03	0	0.001		
219	10.824557	122.955829	0.18	0	0.032		
220	10.826400	123.027482	0.27	0.5	0.053	Ruping	5-Year
221	10.903403	123.065113	0.07	1	0.865		
222	10.826336	123.027204	0.03	1.35	1.742	Yolanda	5-Year
223	10.880111	123.024995	0.1	0	0.01		
224	10.879256	123.017315	0.03	0	0.001		
225	10.886818	123.017198	0.13	0	0.017		

226	10.797822	123.007088	0.03	0	0.001		
227	10.837470	123.006690	0.06	0.64	0.336		
228	10.884136	123.060048	0.08	0	0.006		
229	10.872494	123.060409	0.06	0.1	0.002		
230	10.908128	123.083348	0.06	1	0.884	Lando	5-Year
231	10.901643	123.064081	0.06	2.75	7.236	Seniang	5-Year

Annex 12. Educational Institutions Affected in Malogo-Imbang Flood Plain

Negros Occidental				
Enrique B. Magalona				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Brgy. Day Care Center	Latasan			
Latasan Elem. School	Latasan			
Poblacion1 Day Care Centere	Poblacion I			
Jose D. Cuaycong Elementary School	San Jose	Medium	Medium	Medium
Learn and Shine Academy	San Jose			Low
Barangay Daycare	Santo Niño			
Don H. Maravilla Memorial School	Santo Niño	Low	Low	Low
Rita Lovino Elem. School	Tuburan			

Silay City				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Bagtic Elem. School	Bagtic			
SerafinGamboaElemtary School	Bagtic			
Balaring Elementary School	Balaring			
Bongol Elementary School	Balaring			
Mambag-id Elementary School	Balaring			
Silay North Elementary School	Barangay I		Low	Low
Silay South Elementary School	Barangay I			
San Diego alcala Parish School	Barangay II		Low	Low
Silay Institute	Barangay II			Low
Silay North Elementary School	Barangay II			Low
Silay South Elementary School	Barangay II		Low	Low
Mambulac Elementary School	Barangay III			
Silay South Elementary School	Barangay III			
Silay Institute	Barangay IV			
Silay North Elementary School	Barangay IV			
Silay South Elementary School	Barangay IV			
St. Theresitas Academy	Barangay V			
Hawaiian Elementary School	Barangay VI Pob			
E Lopez Day Care Center	Eustaquio Lopez			
E. Lopez Elementary School	Eustaquio Lopez			
E. Lopez Health Center	Eustaquio Lopez			
E. Lopez National High School	Eustaquio Lopez	Low	Low	Low
Hinicayan Elementary School	Eustaquio Lopez			
Guimbala-on Elementary School	Guimbala-On			
Guimbala-on High School	Guimbala-On			
Don EmilianoLizares Elementary School	Kapitan Ramon			
Hinicayan Elementary School	Kapitan Ramon	Low	Low	Low
Silay South Elementary School	Mambulac			
Gov. Emilio Gaston	Rizal		Low	Medium

Silay North Elementary School	Rizal		Low	Low
Silay South Elementary School	Rizal		Low	Low

Annex 13 . Medical Institutions Affected in Malogo-Imbang Flood Plain

Negros Occidental				
Enrique B. Magalona				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Brgy. Health Center	Latasan			
Poblacion1 Health Center	Poblacion I			
Pob2HealthCenter	Poblacion II		Low	Low
San Jose Brangay Health Center	San Jose			
Barangay Health Center	Santo Niño			
Brgy. Health Center	Tuburan			
Silay City				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Balaring Health Center	Balaring			
Bio Clinica Diagnostic Center	Barangay V			
Teresita L. Jalandoni Provincial Hospital	Rizal			

Annex 14. UPC Phil-LiDAR 1 Team Composition

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