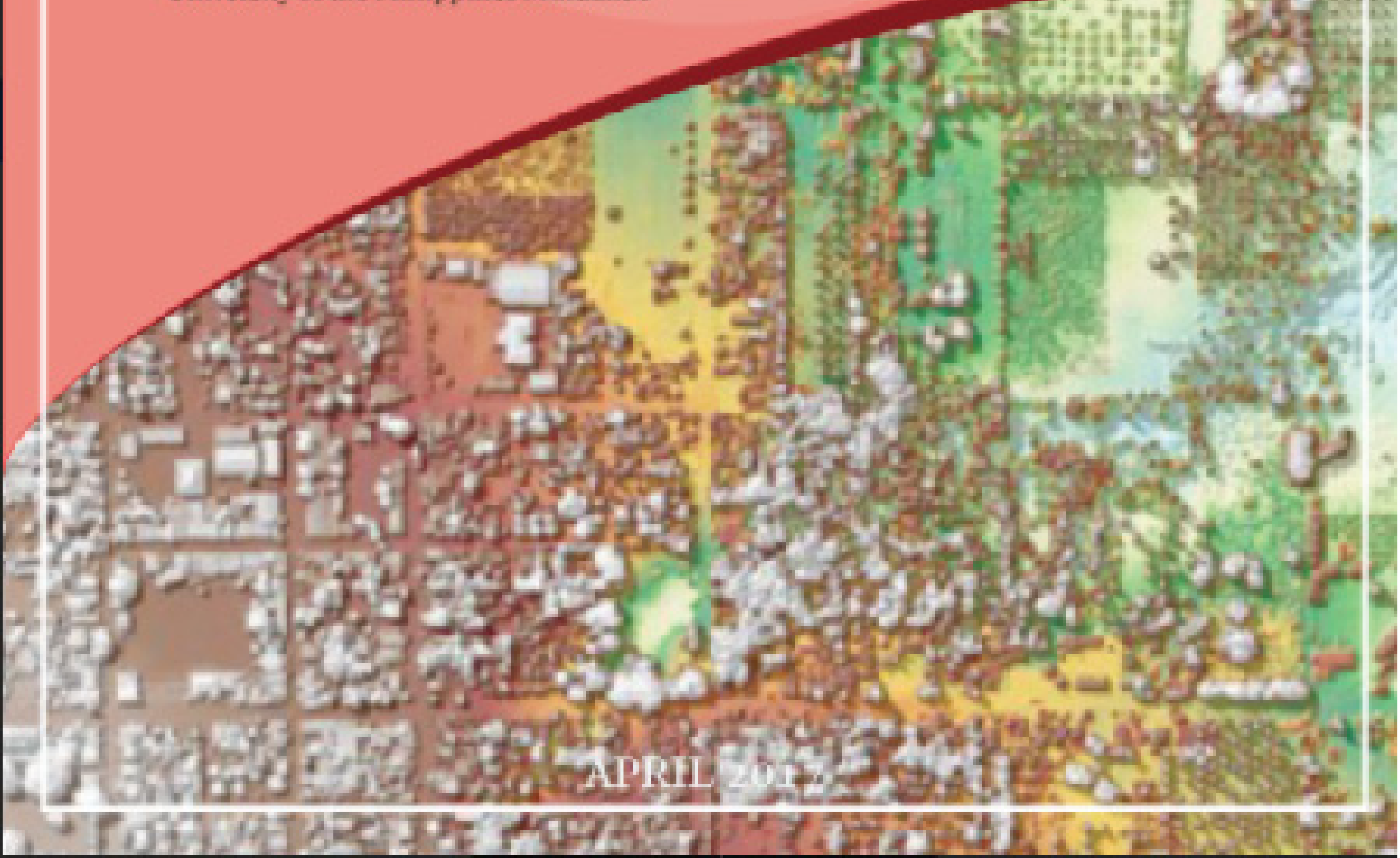
HAZARD MAPPING OF THE PHILIPPINES USING LIDAR (PHIL-LIDAR 1)

LiDAR Surveys and Flood Mapping of Padada River

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



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LIST OF ACRONYMS AND ABBREVIATIONS

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

[ ]

1.1 Background of the Phil-LiDAR 1 Program

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

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

The implementing partner university for the Phil-LiDAR 1 Program is the University of the Philippines Mindanao (UPM). UPM 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 13 river basins in the Southern Mindanao Region. The university is located in Davao City in the province of Davao del Sur.

1.2 Overview of the Padada Mainit River Basin

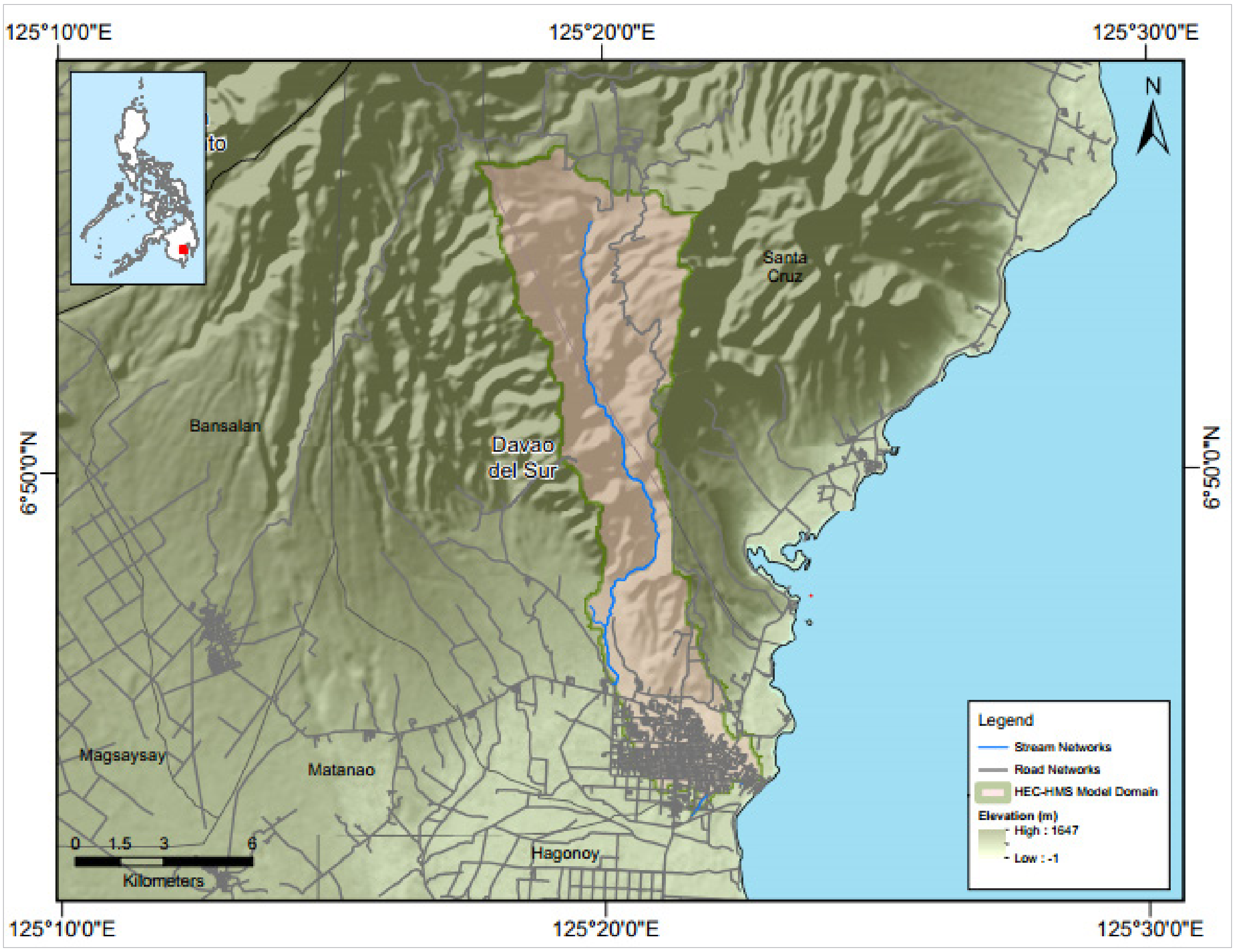

Figure 1. Map of Digos River Basin.

CHAPTER 2. LIDAR ACQUISITION OF THE PADADA MAINIT FLOODPLAIN

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

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Padada Mainit floodplain in Davao del Sur. These missions were planned for 15 lines and ran for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR system is found in Table 1. Figure 2 shows the flight plan for Padada Mainit floodplain.

Table 1. Flight planning parameters for Gemini 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)
BLK87A	1000	30	40	100	50	130	5
BLK87B	1000	30	40	100	50	130	5
BLK87C	1000	30	40	100	50	130	5
BLK87D	1000	30	40	100	50	130	5
BLK87E	1000	30	40	100	50	130	5
BLK87F	1000	35	40	100	50	130	5

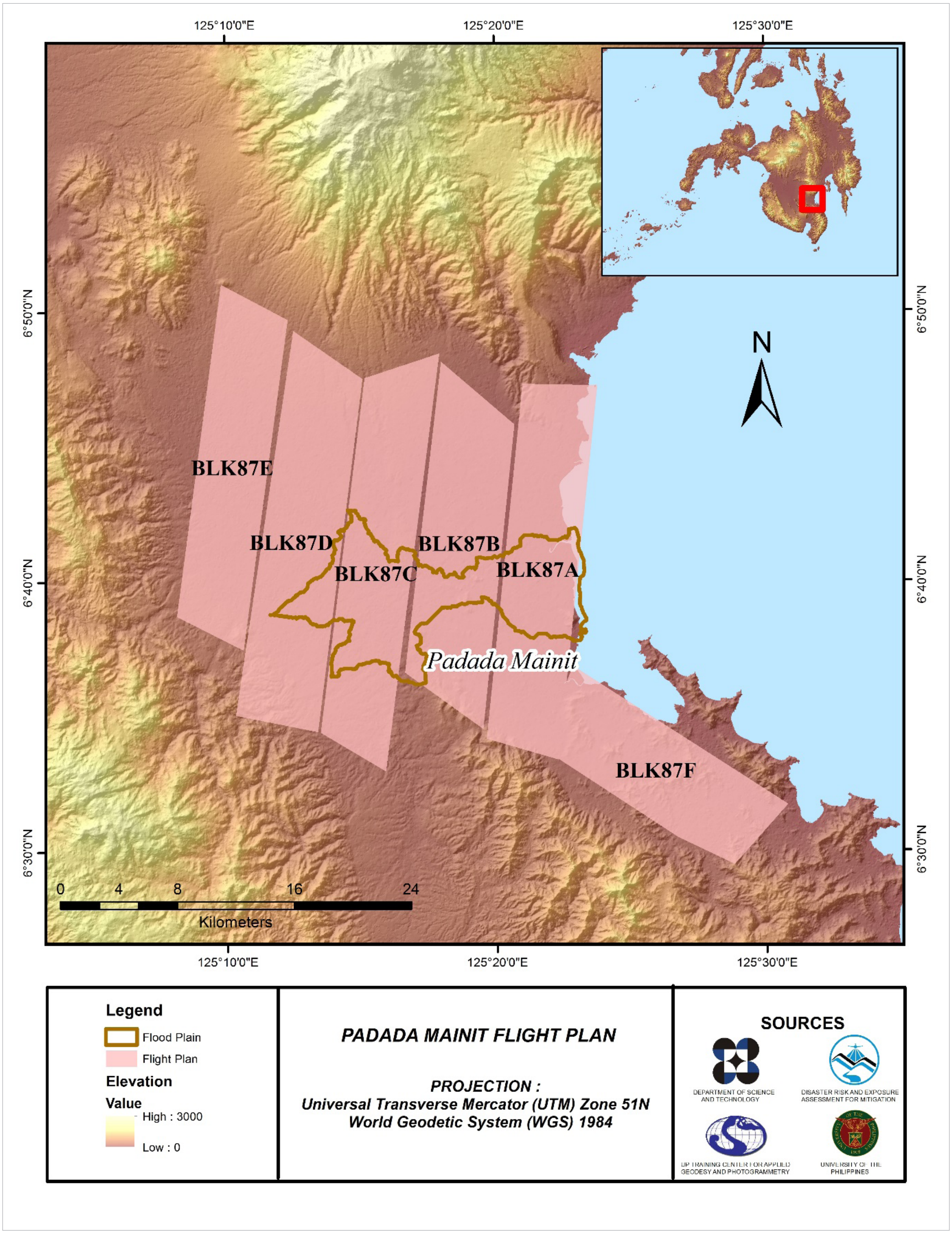


Figure 2. Flight plans used for Padada-Mainit floodplain.

2.2 Ground Base Stations

The project team was able to recover one (1) NAMRIA ground control point: DVS-85 with second (2nd) order accuracy. The project team was able to recover BLLM-20 with fourth (4th) order accuracy. BLLM-20 was then re-processed to obtain coordinates of 2nd order accuracy. The certification for the NAMRIA reference point is found in ANNEX 2 while the baseline processing report for the re-processed control point is found in ANNEX 3. These were used as base stations during flight operations for the entire duration of the survey (July 29 – August 7, 2014). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 882 and SPS 985. Flight plans and location of base stations used during the aerial LiDAR acquisition in Padada Mainit floodplain are shown in Figure 3.

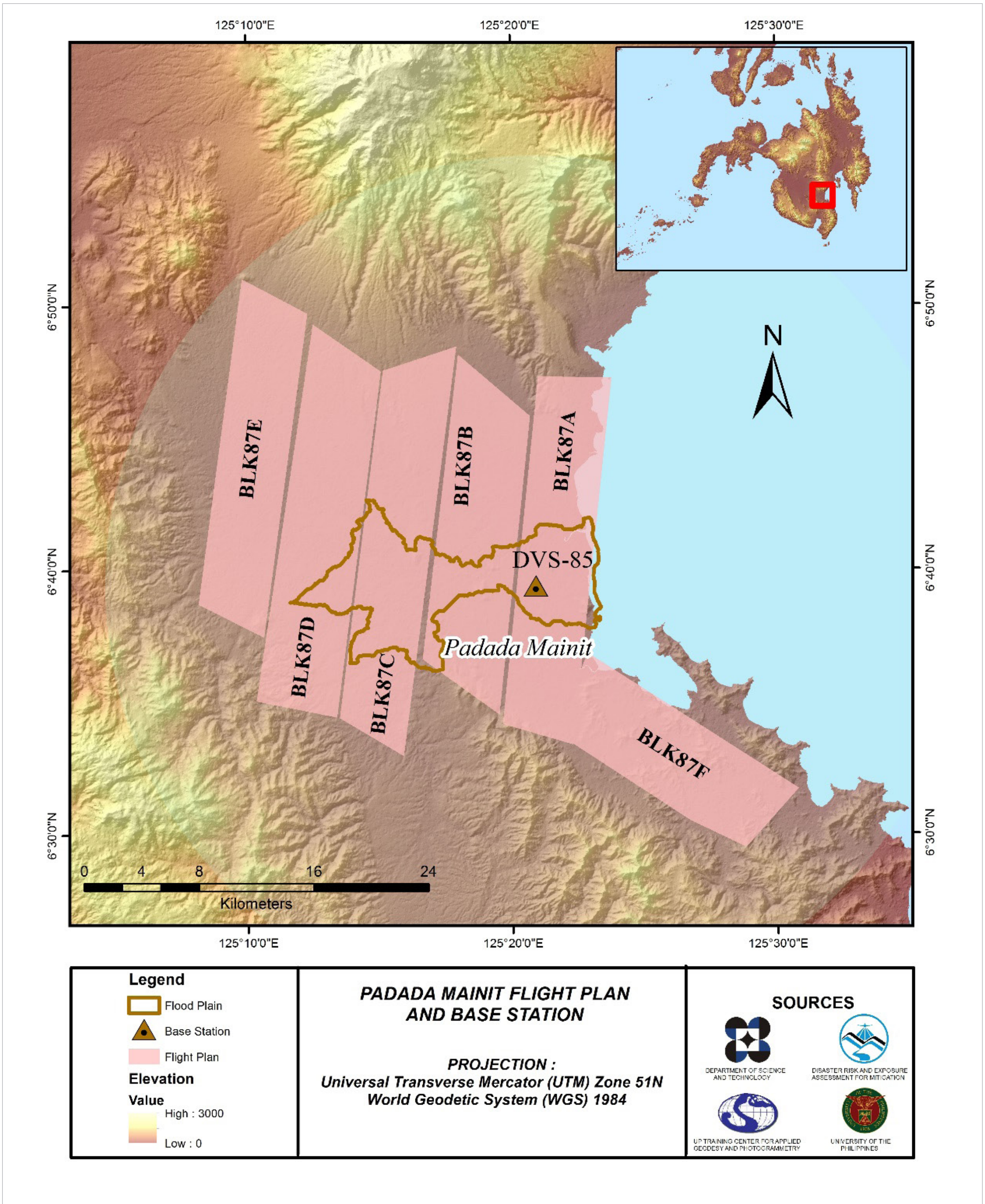
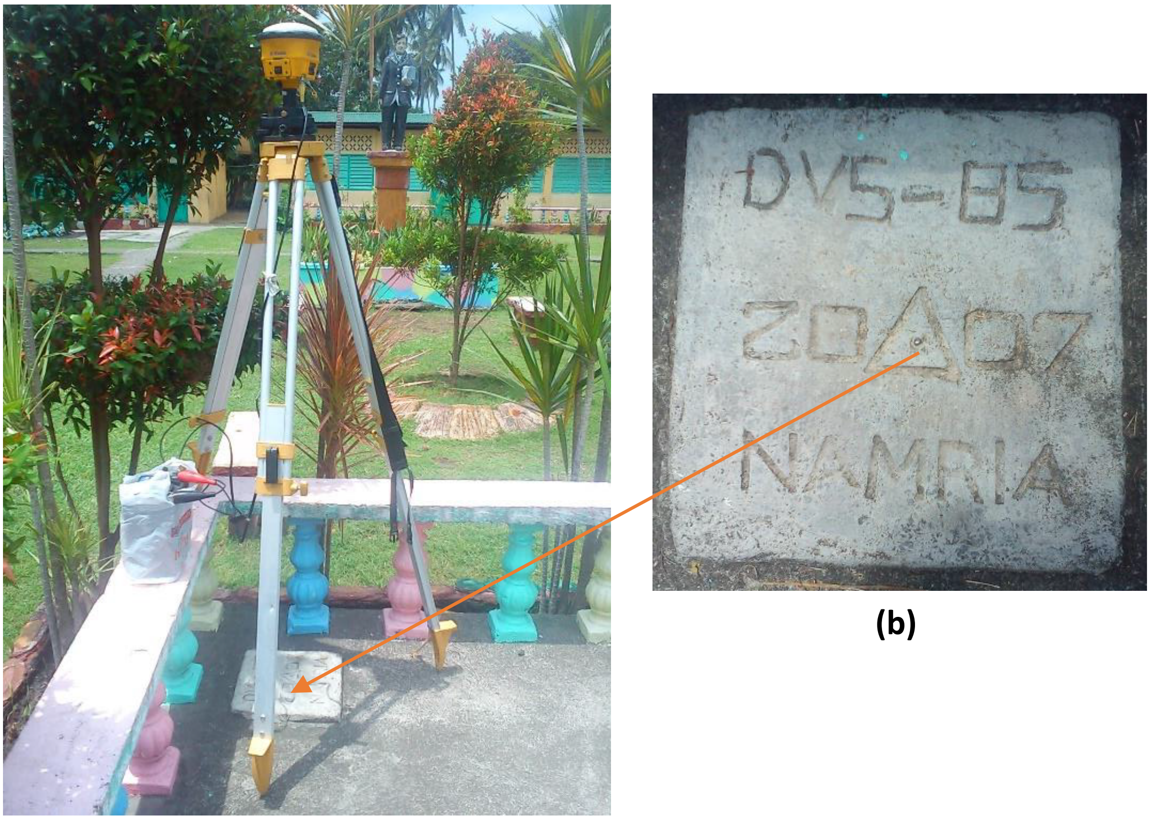


Figure 3. Flight plans and base stations for Padada Mainit floodplain.

Figure 4 to Figure 5 show the recovered NAMRIA reference point and established ground control point within the area. In addition, Table 2 to Table 3 show the details about the following NAMRIA control station and the established GCP while Table 4 shows the list of all ground control points occupied during the acquisition together with the corresponding dates of utilization.



(a) (b)

Figure 4. GPS set-up over DVS-85 located inside Mariano Sarona Elementary School, inside the fence of the flagpole (a) and NAMRIA reference point DVS-85 (b) as recovered by the field team.

Table 2. Details of the recovered NAMRIA horizontal control point DVS-85 used as base station for the LiDAR acquisition.

Station Name	**DVS-85**	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	6°39’26.23973” North 125°20’48.72707” East 6.143 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	538185.160 meters 736134.492 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	6°39’23.20570” North 125°20’54.29136” East 79.008 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	759472.609 meters 736433.274 meters

(a) (b)

Figure 5. GPS set-up over BLLM-20 located inside Mariano Sarona Elementary School, inside the fence of the flagpole (a) and reference point BLLM-20 (b) as recovered by the field team.

Table 3. Details of the recovered horizontal control point BLLM-20 used as base station for the LiDAR acquisition with established coordinates.

Station Name	**BLLM-20**	
Order of Accuracy	**2^{nd}**	
Relative Error (horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	6°39’25.99473” North 125°20’48.37658” East 5.656 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	538174.400 meters 736126.960 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	6°39’22.96071” North 125°20’53.94087” East 78.521 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	759461.875 meters 736425.694 meters

Table 4. Ground control points used during LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
July 29, 2014	7400GC	2BLK87A210A	DVS-85 & BLLM-20
July 31, 2014	7404GC	2BLK87AS212A	DVS-85 & BLLM-20
August 1, 2014	7406GC	2BLK87BC213A	DVS-85 & BLLM-20
August 2, 2014	7408GC	2BLK87E214A	DVS-85 & BLLM-20
August 4, 2014	7412GC	2BLK87CSD216A	DVS-85 & BLLM-20
August 5, 2014	7414GC	2BLK87F217A	DVS-85 & BLLM-20
August 6, 2014	7416GC	2BLK87F218A	DVS-85 & BLLM-20
August 7, 2014	7418GC	2BLK87FV219A	DVS-85 & BLLM-20

2.3 Flight Missions

Eight (8) missions were conducted to complete the LiDAR data acquisition in Padada Mainit floodplain, for a total of twenty six hours and four minutes (26+04) of flying time for RP-C9322. All missions were acquired using the Gemini LiDAR system. Table 5 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 6 presents the actual parameters used during the LiDAR data acquisition.

Table 5. Flight missions for LiDAR data acquisition in Padada Mainit floodplain.

Date Surveyed	Flight Number	Flight Plan Area (km^2)	Surveyed Area (km^2)	Area Surveyed within the Floodplain (km^2)	Area Surveyed outside the Floodplain (km^2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
July 29, 2014	7400GC	126.830	48.522	10.930	37.592	NA	2	5
July 31, 2014	7404GC	126.830	169.442	36.996	132.446	NA	3	35
August 1, 2014	7406GC	128.067	193.272	35.864	157.408	NA	3	41
August 2, 2014	7408GC	110.715	187.645	0.023	187.622	NA	4	11
August 4, 2014	7412GC	118.656	214.753	40.086	174.667	NA	3	53
August 5, 2014	7414GC	96.261	70.780	0	70.780	NA	2	41
August 6, 2014	7416GC	353.270	139.714	3.721	135.993	NA	2	41
August 7, 2014	7418GC	353.270	127.479	8.166	119.313	NA	3	17
TOTAL		**1413.89**	**1151.607**	**135.786**	**1015.821**	**NA**	**26**	**4**

Table 6. 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)
7400GC	1000	30	40	100	50	130	5
7404GC	1000	30	40	100	50	130	5
7406GC	1000	30	40	100	50	130	5
7408GC	1000	30	40	100	50	130	5
7412GC	1000	35	40	100	50	130	5
7414GC	1000	35	40	100	50	130	5
7416GC	1000	35	40	100	50	130	5
7418GC	1000	35	40	100	50	130	5

2.4 Survey Coverage

Padada Mainit floodplain is located in the provinces of Davao del Sur with the majority of the floodplain situated within the municipalities of Padada and Kiblawan. Municipalities of Hagonoy, Kiblawan, Padada and Sulop are fully covered by the survey. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 7. The actual coverage of the LiDAR acquisition for Padada Mainit floodplain is presented in Figure 6.

Table 7. List of municipalities and cities surveyed during Padada Mainit floodplain LiDAR survey.

Province	Municipality/City	Area of Municipality/ City (km²)	Total Area Surveyed (km²)	Percentage of Area Surveyed
Davao del Sur	Hagonoy	85.69	85.69	100 %
	Kiblawan	80.03	80.03	100 %
	Padada	55.97	55.97	100%
	Sulop	50.8	50.8	100%
	Matanao	123.39	121.26	98%
	Magsaysay	109.8	68.01	61%
	Digos	226.71	90.29	39%
	Bansalan	136.18	54	39%
	Santa Maria	263.25	93.37	35%
	Malalag	444.99	107.61	24%
Sultan Kudarat	Columbio	574.07	26.29	5%
TOTAL		**2150.88**	**833.32**	**64%**

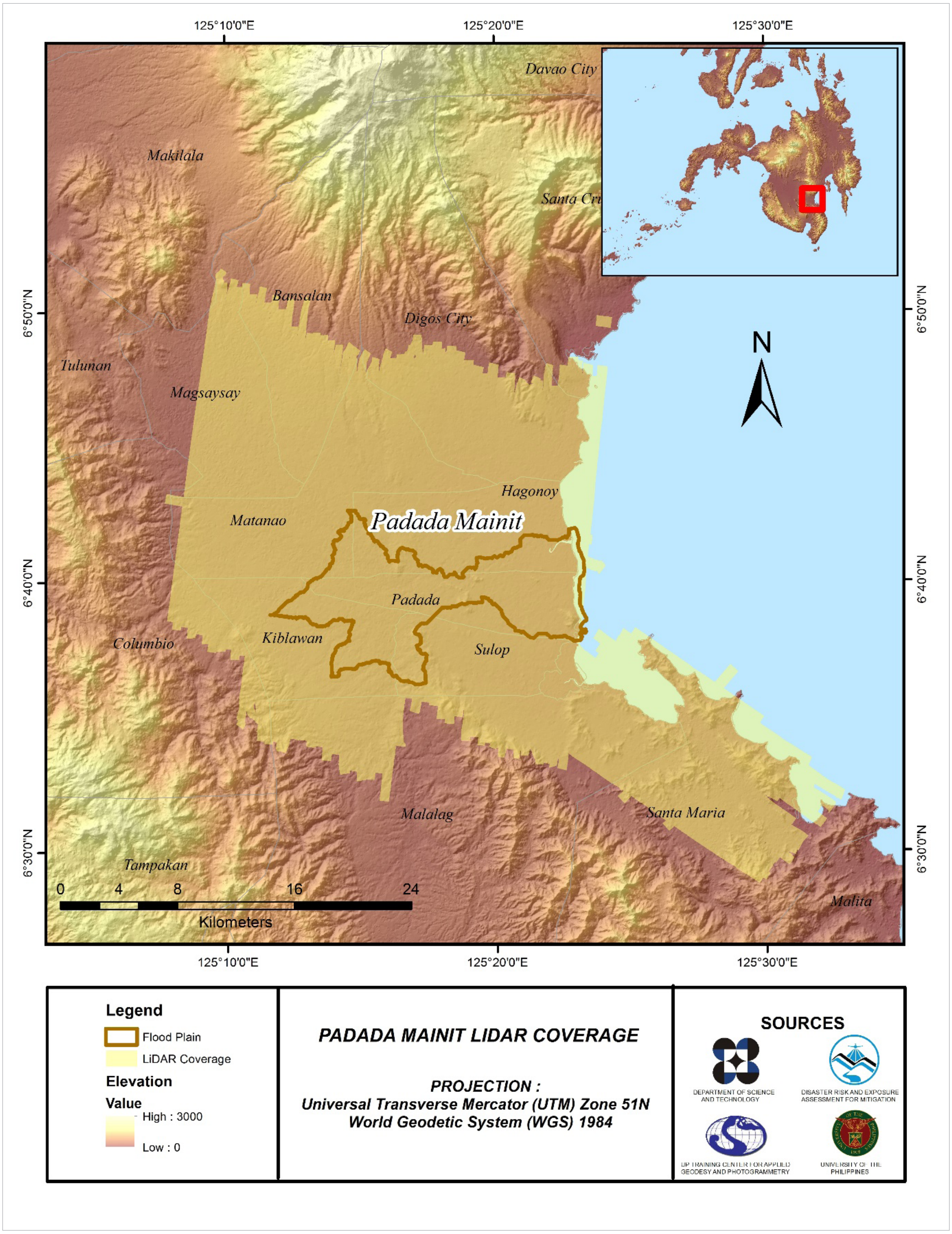


Figure 6. Actual LiDAR survey coverage for Padada Mainit floodplain

CHAPTER 3. LIDAR DATA PROCESSING OF THE BALANGA FLOODPLAIN

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

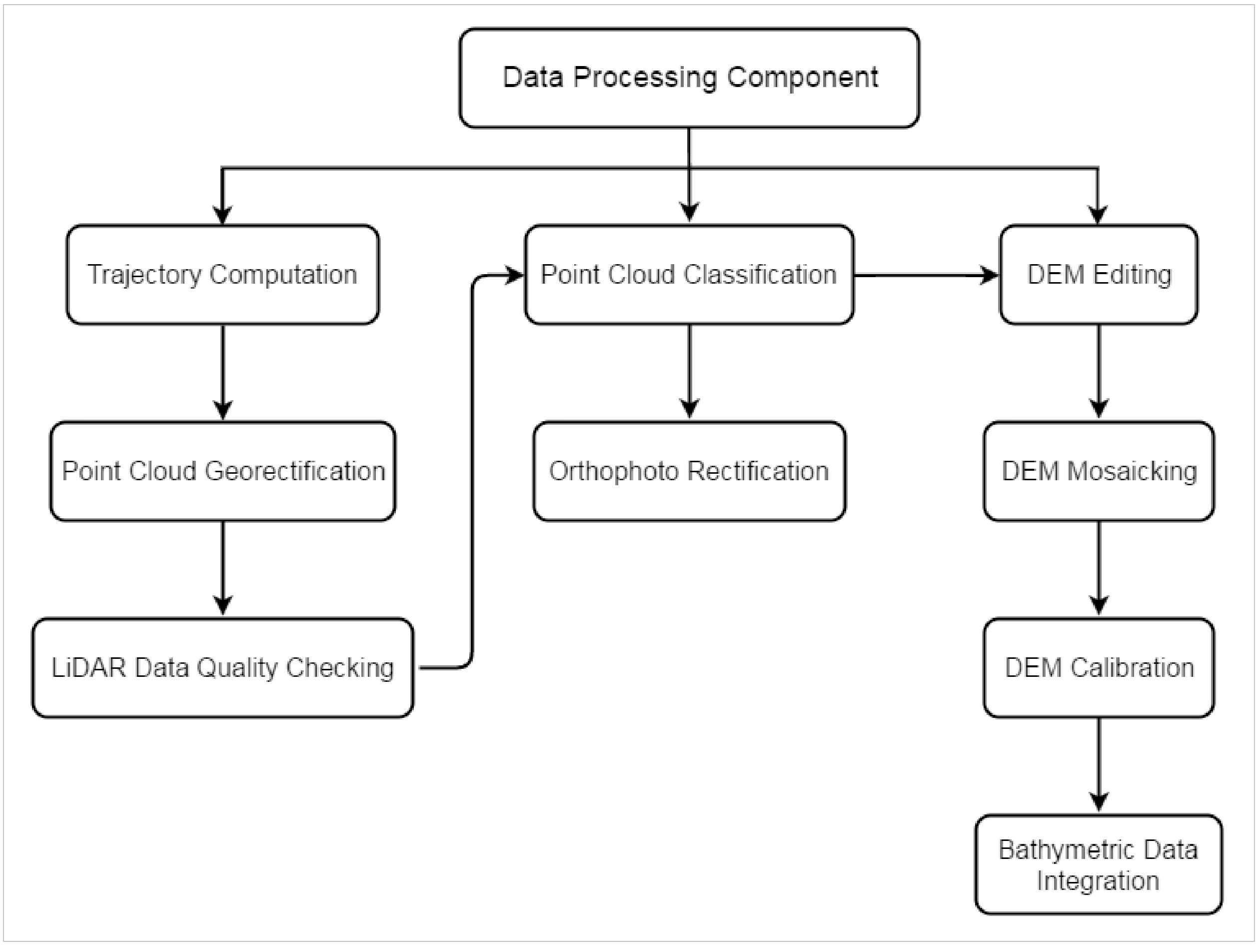

Figure 7. Schematic Diagram for Data Pre-Processing Component

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 trajectory is done in order to obtain the exact location of the LiDAR sensor when the laser was shot. Point cloud georectification is performed to incorporate correct position and orientation for each point acquired. The georectified LiDAR point clouds are subject for quality checking to ensure that the required accuracies of the program, which are the minimum point density, vertical and horizontal accuracies, are met. The point clouds are then classified into various classes before generating Digital Elevation Models such as Digital Terrain Model and Digital Surface Model.

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

These processes are summarized in the flowchart shown in Figure 7.

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Padada floodplain can be found in ANNEX 5. Missions flown during the first survey conducted on August 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Gemini system over Hagonoy, Davao Del Sur. The Data Acquisition Component (DAC) transferred a total of 116.47 Gigabytes of Range data, 1.40 Gigabytes of POS data, 34.65 Megabytes of GPS base station data, and 0 Gigabytes of raw image data to the data server on August 28, 2014 for the first survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Padada was fully transferred on August 29, 2014, as indicated on the Data Transfer Sheets for Padada floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for flight 7481GC, one of the Padada flights, which is the North, East, and Down position RMSE values are shown in Figure B-2. 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 August 28, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

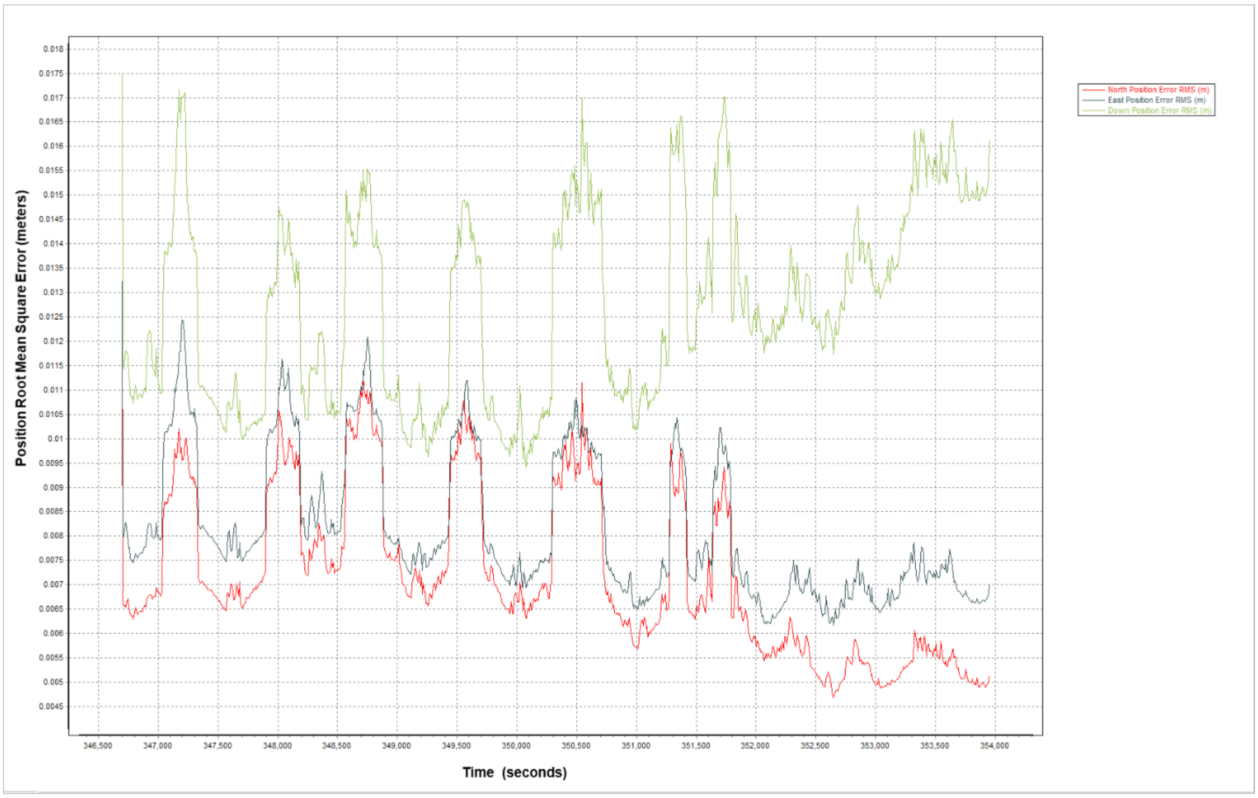

Figure 8. Smoothed Performance Metric Parameters of a Padada Flight 7418GC.

The time of flight was from 347,700 seconds to 354,000 seconds, which corresponds to morning of August 28, 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 8 shows that the North position RMSE peaks at 1.75 centimeters, the East position RMSE peaks at 1.33 centimeters, and the Down position RMSE peaks at 1.13 centimeters, which are within the prescribed accuracies described in the methodology.

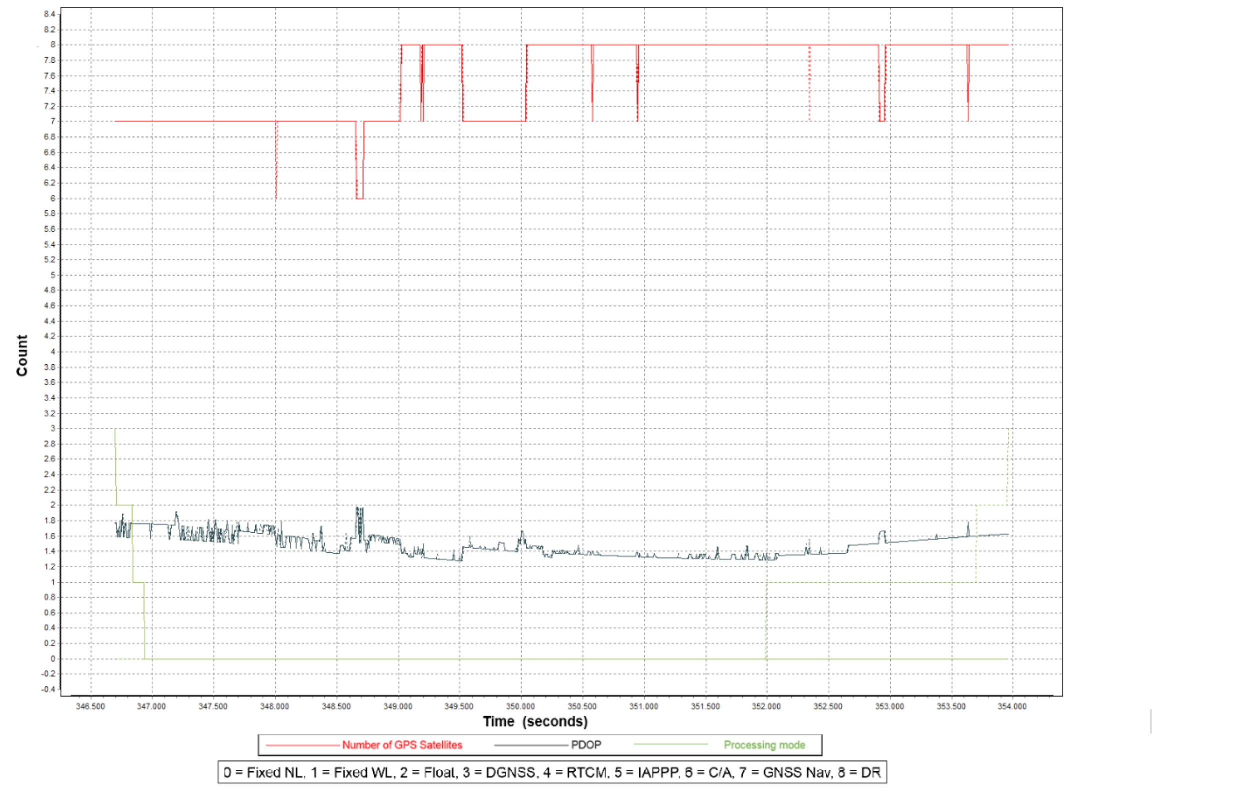

Figure 9. Solution Status Parameters of Padada Flight 7481GC.

The Solution Status parameters of flight 7418GC, one of the Padada flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 9. 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 6 and 8. 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 2 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 Padada flights is shown in Figure 10.

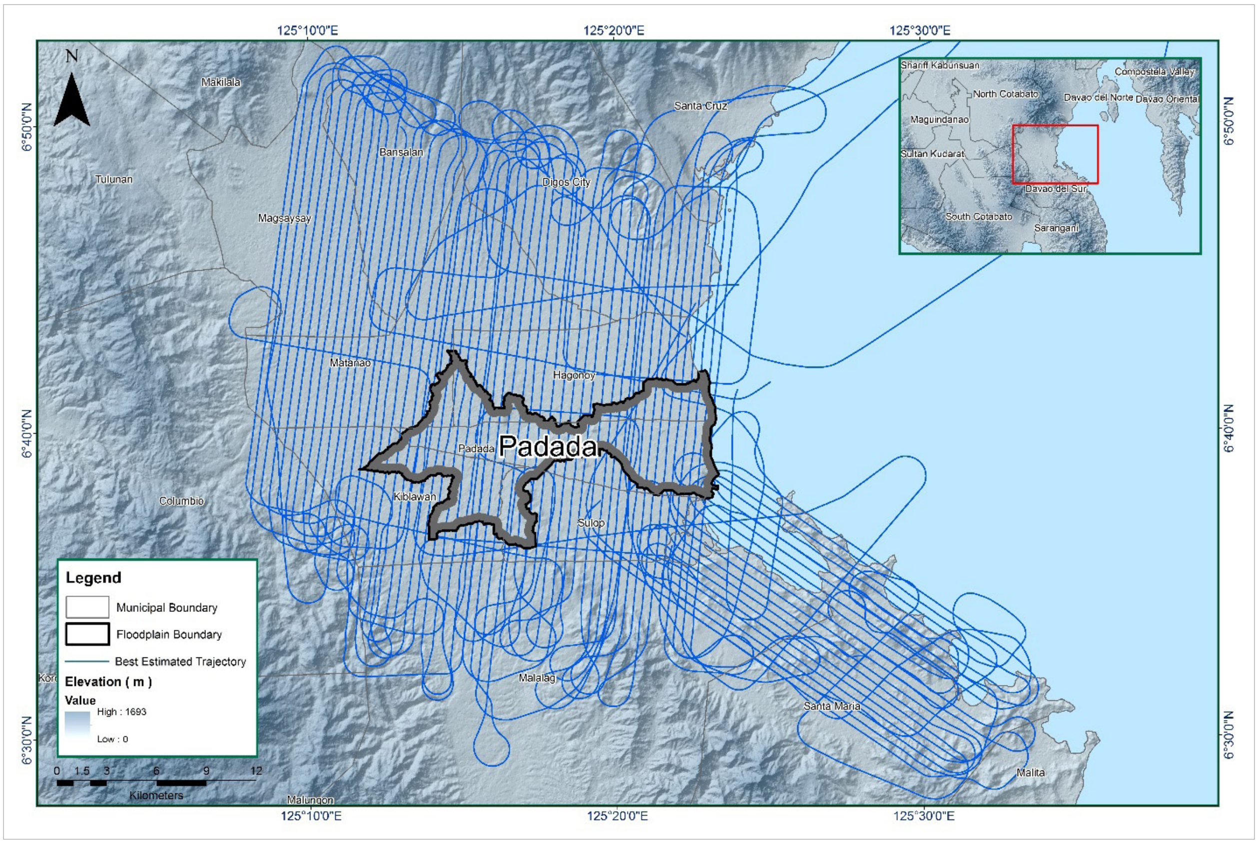

Figure 10. Best estimated trajectory for the Padada floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 88 flight lines, with each flight line containing one channel, since the Gemini system contains one channel only. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Padada floodplain are given in Table 8.

Table 8. Self-Calibration Results values for Padada flights.

Parameter		Acceptable Value
Boresight Correction stdev	(<0.001degrees)	0.000368
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.000843
GPS Position Z-correction stdev	(<0.01meters)	0.0082

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

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Padada Floodplain is shown in Figure 11. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

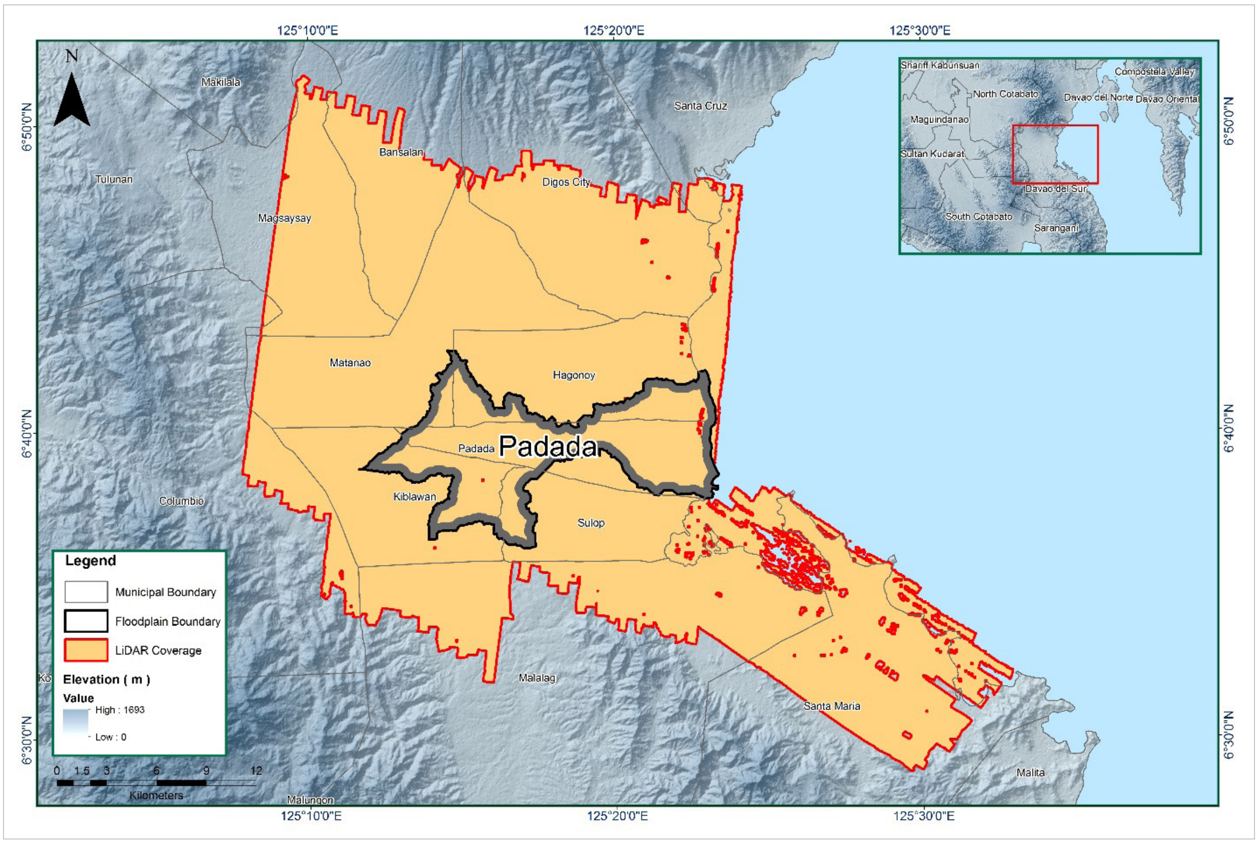

Figure 11. Boundary of the processed LiDAR data over Padada Floodplain

The total area covered by the Padada missions is 951.55 sq.km that is comprised of twelve (12) flight acquisitions grouped and merged into six (6) blocks as shown in Table 9.

Table 9. List of LiDAR blocks for Padada floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
DavaoDelSur_Blk87A	7400GC	164.20
	7404GC	
DavaoDelSur_Blk87B	7406GC	189.17
DavaoDelSur_Blk87C	7412GC	214.47
	7416GC	
	7418GC	
DavaoDelSur_Blk87D	7416GC	96.69
	7418GC	
DavaoDelSur_Blk87E	7408GC	184.12
DavaoDelSur_Blk87F	7414GC	102.89
	7416GC	
	7418GC	
TOTAL		**951.55 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 12. Since the Gemini system employs one channel, we would expect an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines.

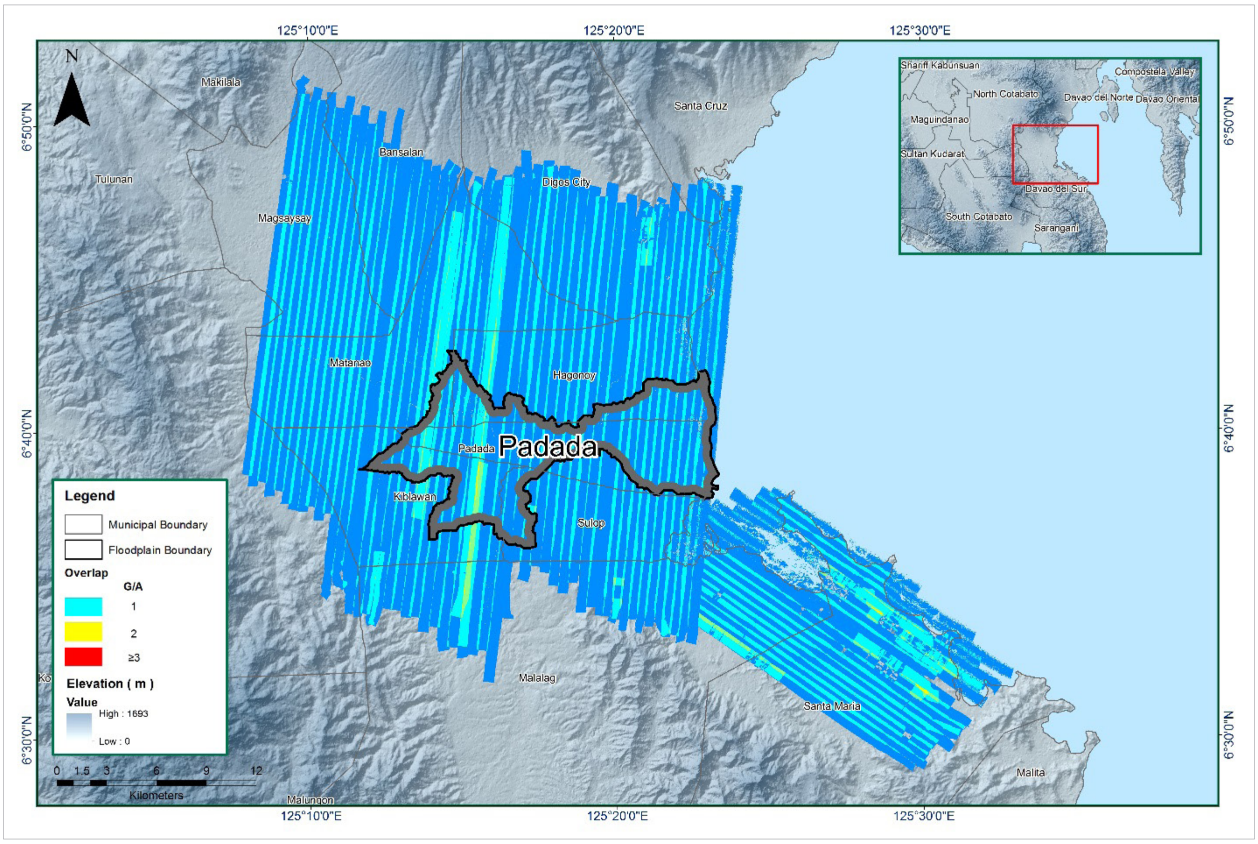

Figure 12. Image of data overlap for Padada floodplain.

The overlap statistics per block for the Padada floodplain can be found in ANNEX B-1. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 25.84% and 39.32% respectively, which passed the 25% requirement.

The 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 13. It was determined that all LiDAR data for Padada floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.19 points per square meter.

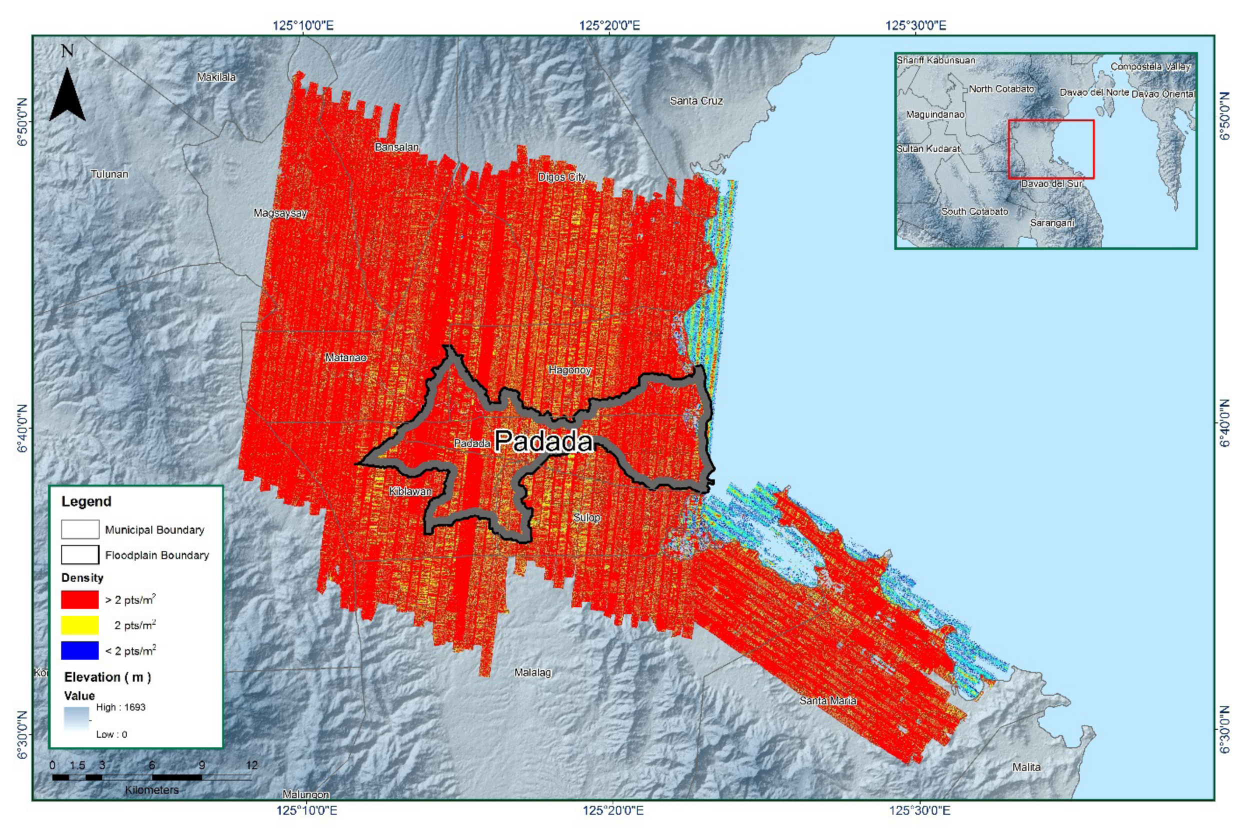

Figure 13. Density map of merged LiDAR data for Padada floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 14. 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.

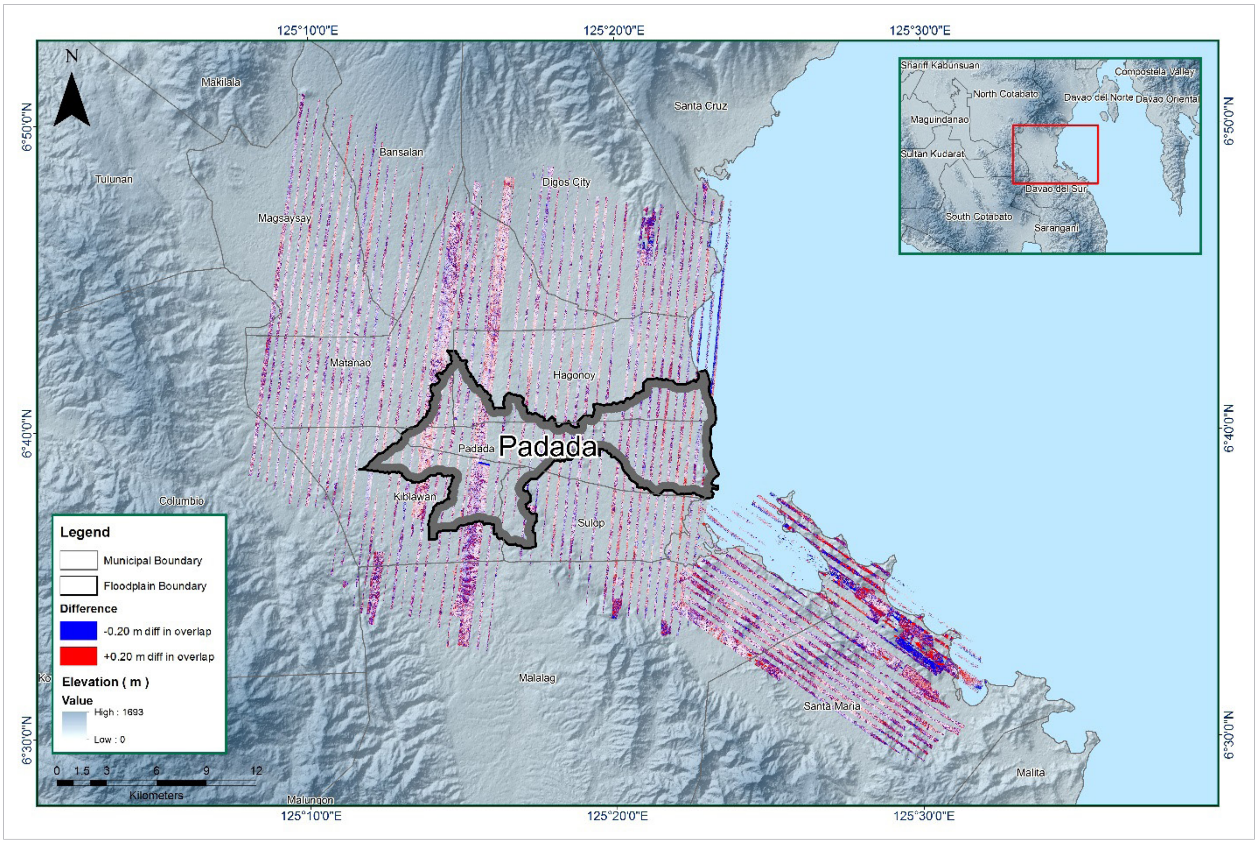

Figure 14. Elevation difference map between flight lines for Padada floodplain.

A screen capture of the processed LAS data from a Padada flight 7418GC loaded in QT Modeler is shown in Figure 15. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed yellow line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

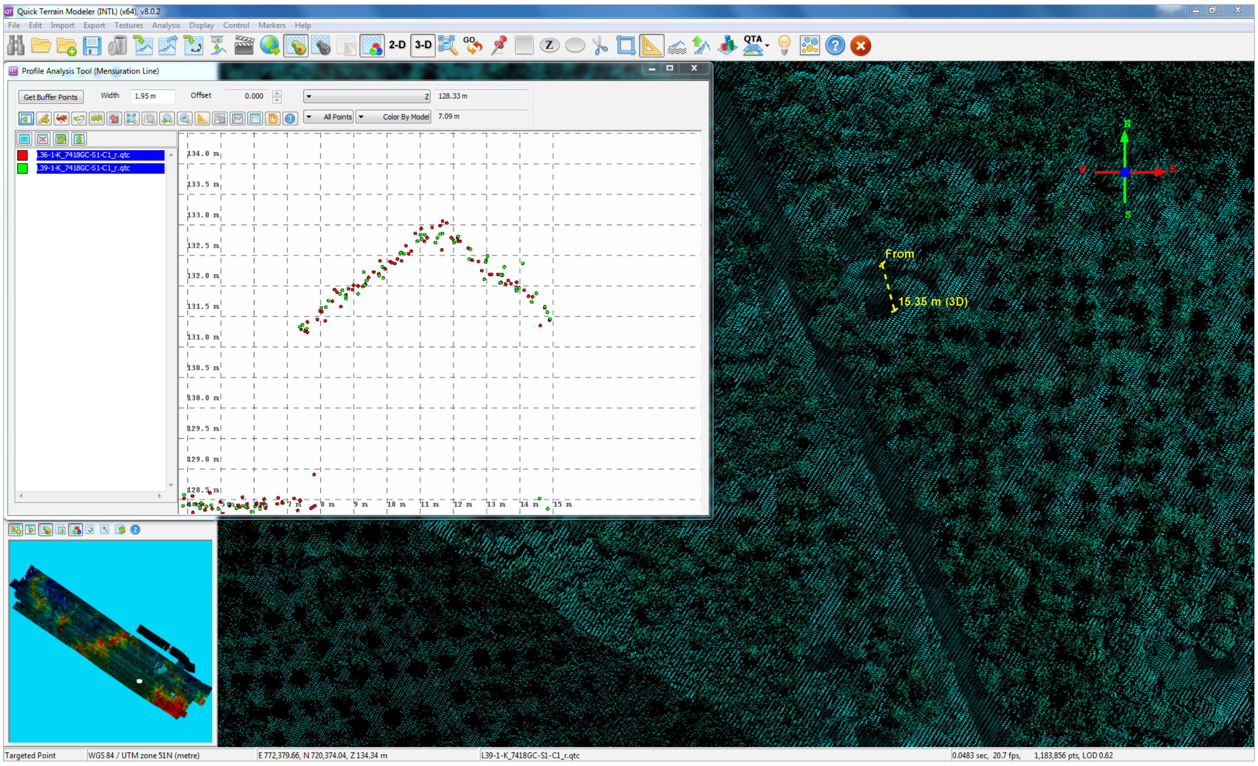

Figure 15. Quality checking for a Padada flight 7418GC using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 10. Padada classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	411,528,005
Low Vegetation	493,419,283
Medium Vegetation	750,468,680
High Vegetation	1,095,920,912
Building	23,770,774

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Padada floodplain is shown in Figure 16. A total of 1,267 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 10. The point cloud has a maximum and minimum height of 1,039.27 meters and 52.50 meters respectively.

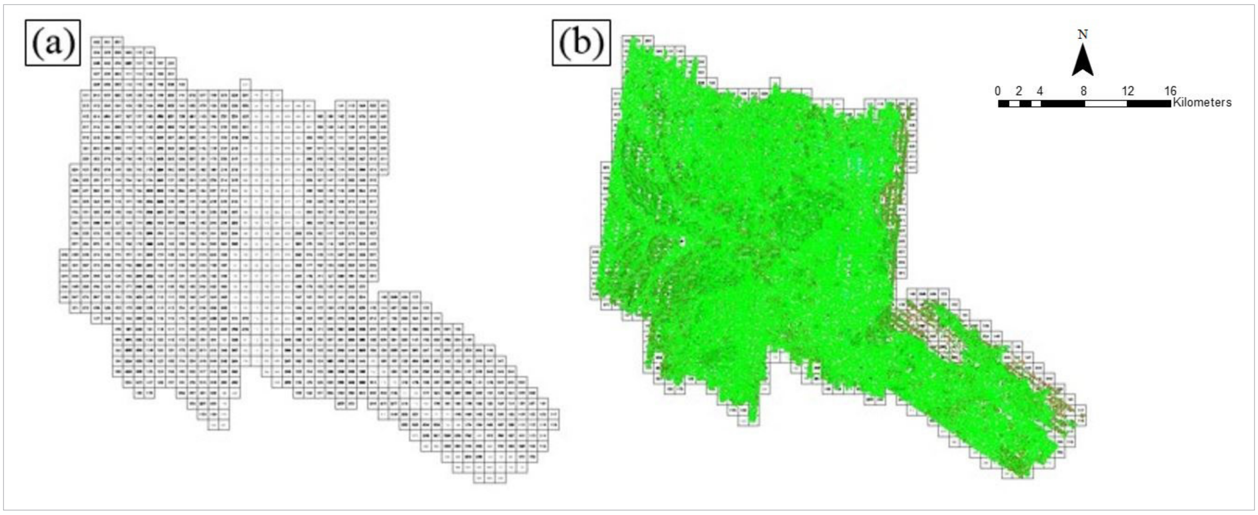

Figure 16. Tiles for Padada floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 17. 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.

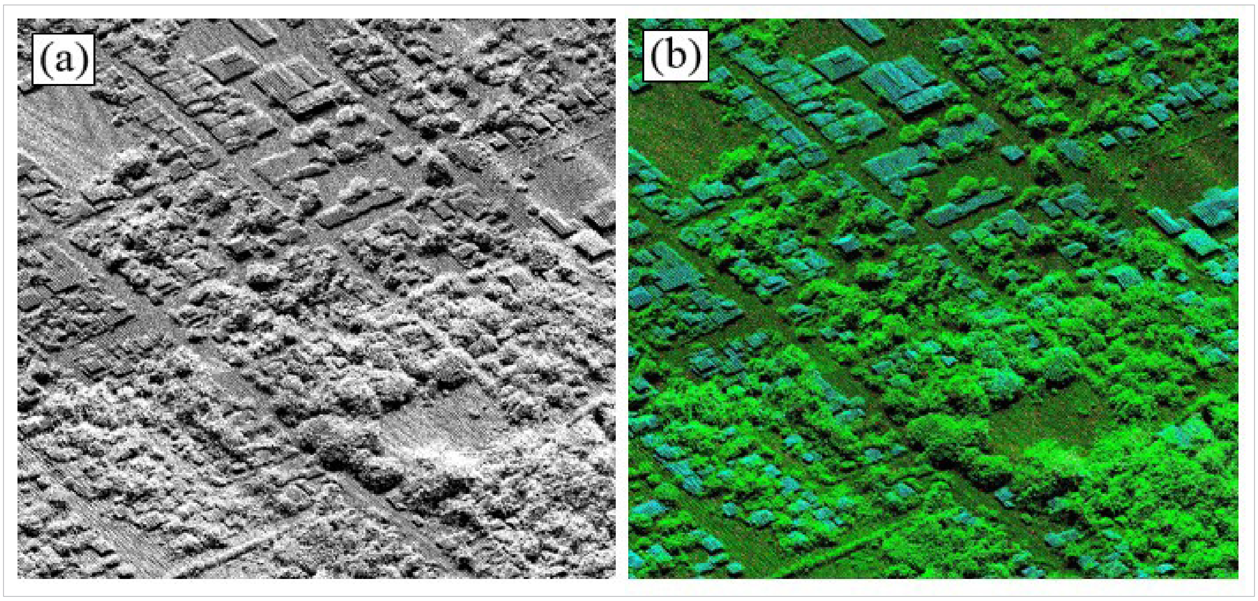

Figure 17. Point cloud before (a) and after (b) classification.

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

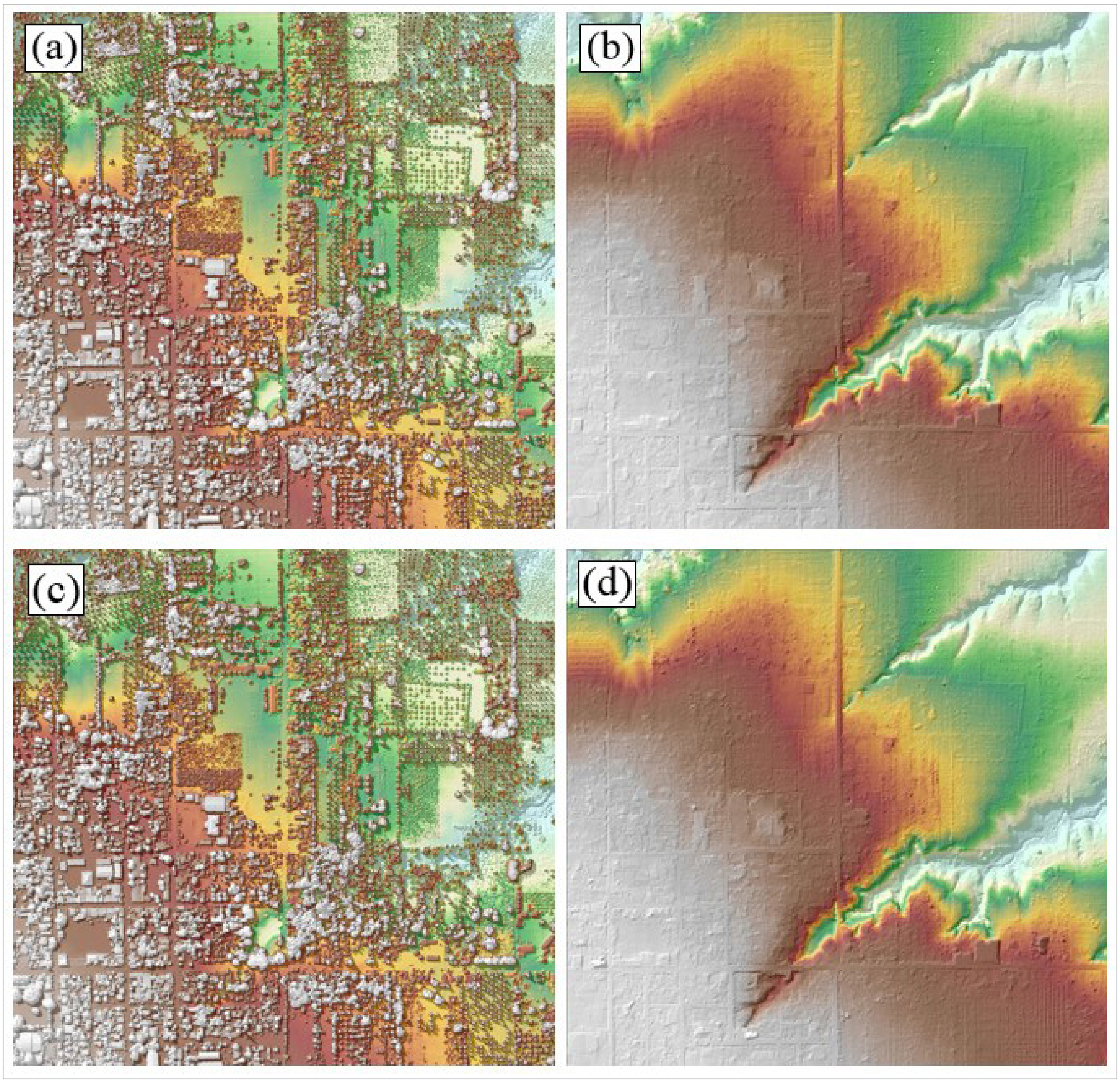

Figure 18. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Padada floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

There are no available orthophotographs for the Padada floodplain.

3.8 DEM Editing and Hydro-Correction

Six (6) mission blocks were processed for Padada flood plain. These blocks are composed of DavaoDelSur blocks with a total area of 951.55 square kilometers. Table 11 shows the name and corresponding area of each block in square kilometers.

Table 11. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq.km)
DavaoDelSur_87A	164.20
DavaoDelSur_87B	189.17
DavaoDelSur_87C	214.47
DavaoDelSur_87E	184.12
DavaoDelSur_87D	96.69
DavaoDelSur_87F	102.89
TOTAL	**951.55 sq.km**

Portions of DTM before and after manual editing are shown in Figure 19. The river embankment (Figure 19a) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 19b) to allow the correct flow of water. The bridge (Figure 19c) is also considered to be an impedance to the flow of water along the river and has to be removed (Figure 19d) in order to hydrologically correct the river. Another example is a building that is still present in the DTM after classification (Figure 19e) and has to be removed through manual editing (Figure 19f).

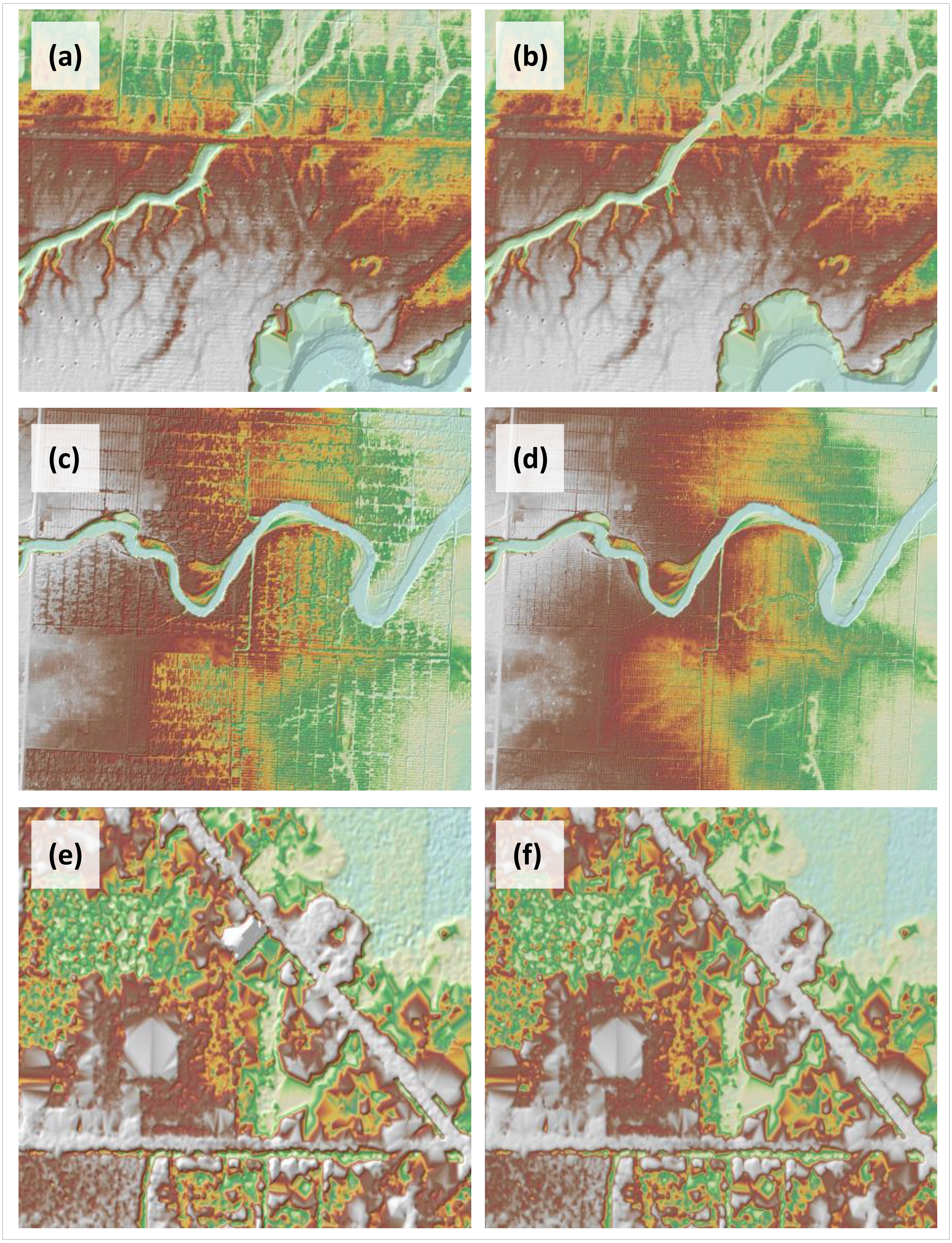

Figure 19. Portions in the DTM of Padada floodplain – a bridge before (a) and after (b) manual editing; a paddy field before (c) and after (d) data retrieval; and a building before (e) and after (f) manual editing.

3.9 Mosaicking of Blocks

Davao Oriental Blk87A was used as the reference block at the start of mosaicking because it was referred to a base station with an acceptable order of accuracy. Table 12 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Padada floodplain is shown in Figure 20. It can be seen that the entire Padada floodplain is 99.50% covered by LiDAR data.

Table 12. Shift Values of each LiDAR Block of Padada floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
DavaoDelSur_87A	0.00	0.00	-0.80
DavaoDelSur_87B	0.00	0.00	0.00
DavaoDelSur_87C	0.00	0.00	0.00
DavaoDelSur_87E	0.00	0.00	0.28
DavaoDelSur_87D	3.00	1.00	1.06
DavaoDelSur_87F	3.10	0.50	-0.14

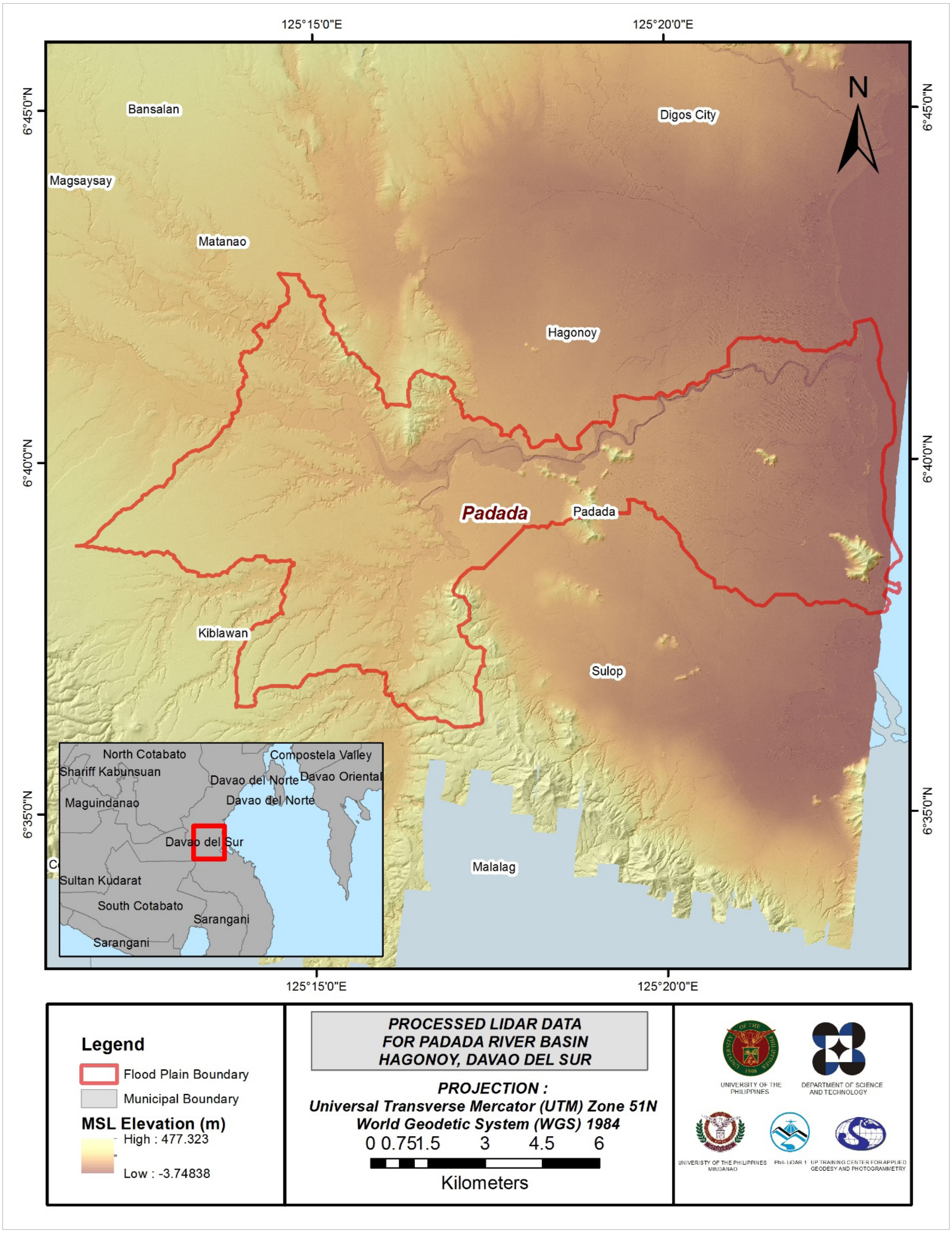

Figure 20. Map of Processed LiDAR Data for Padada Flood Plain.

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 Padada to collect points with which the LiDAR dataset is validated is shown in Figure 21. A total of 21,221 survey points were used for calibration and validation of Padada LiDAR data. Random selection of 80% of the survey points, resulting to 16,977 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 22. 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 0.20 meters with a standard deviation of 0.12 meters. Calibration of Padada LiDAR data was done by adding the height difference value, 0.20 meters, to Padada mosaicked LiDAR data. Table 13 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

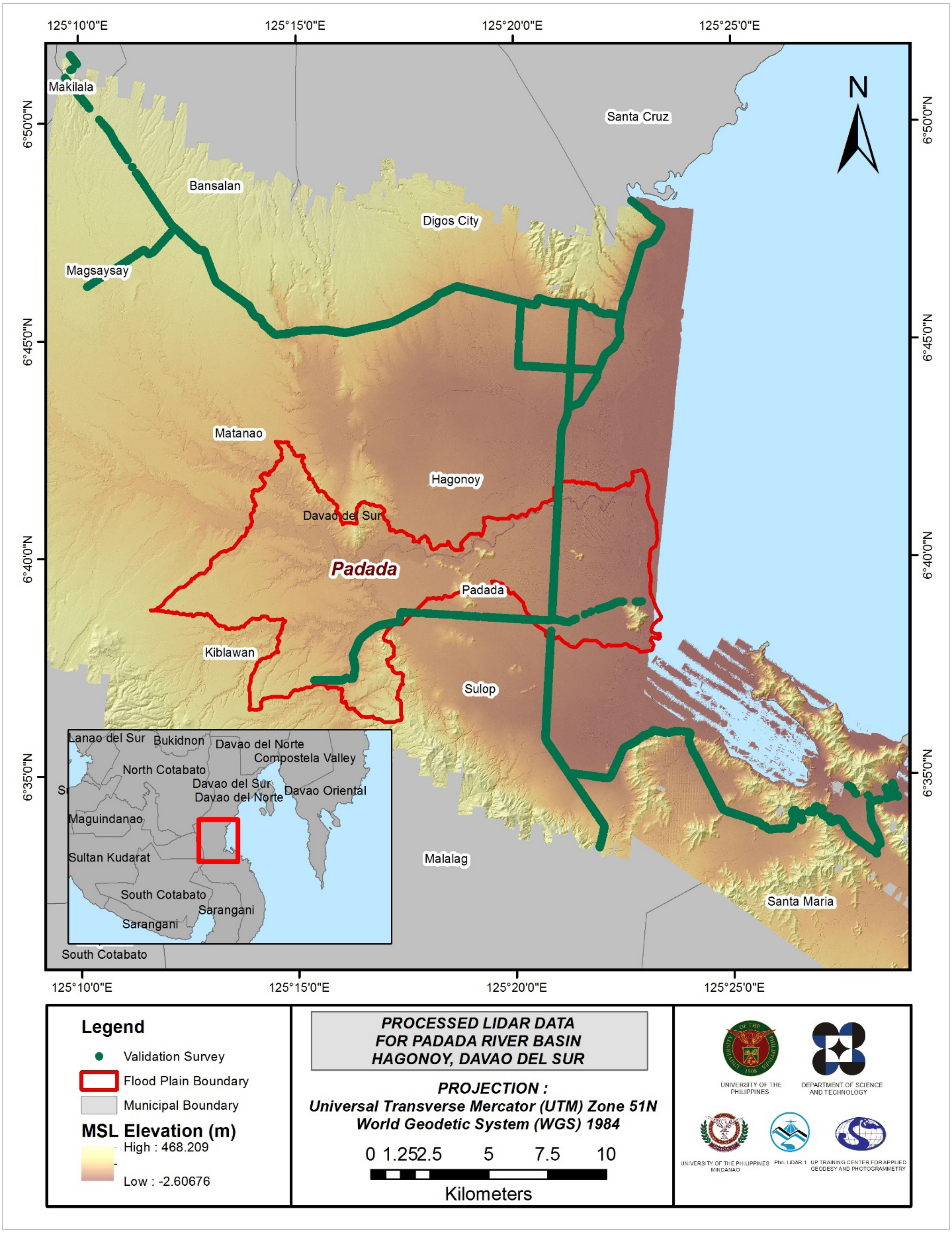

Figure 21. Map of Padada Flood Plain with validation survey points in green.

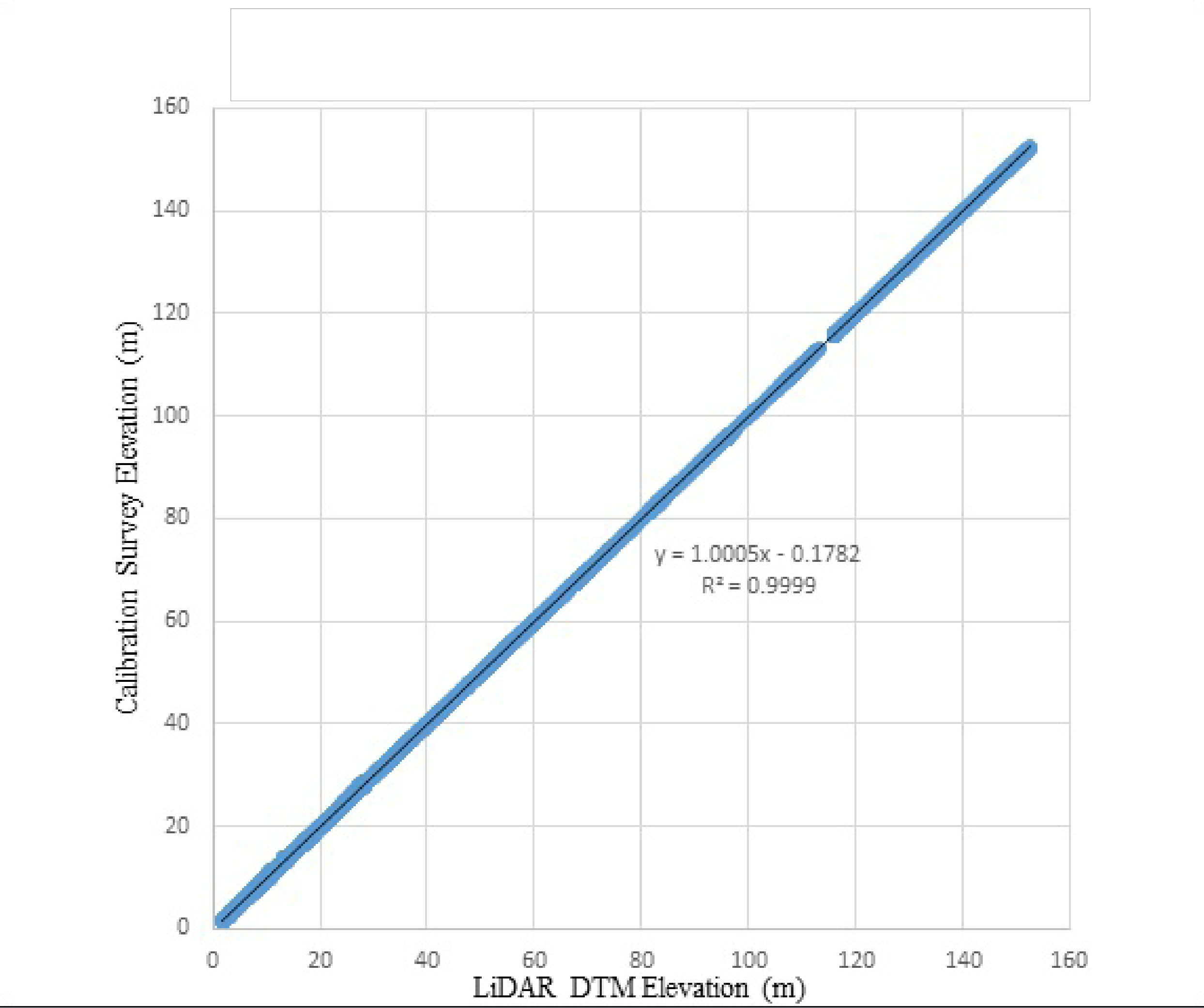

Figure 22. Correlation plot between calibration survey points and LiDAR data

Table 13. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	0.20
Standard Deviation	0.12
Average	0.16
Minimum	-0.07
Maximum	0.39

The remaining 20% of the total survey points, resulting to 4,244 points, were used for the validation of calibrated Padada 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 23. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.20 meters with a standard deviation of 0.13 meters, as shown in Table 14.

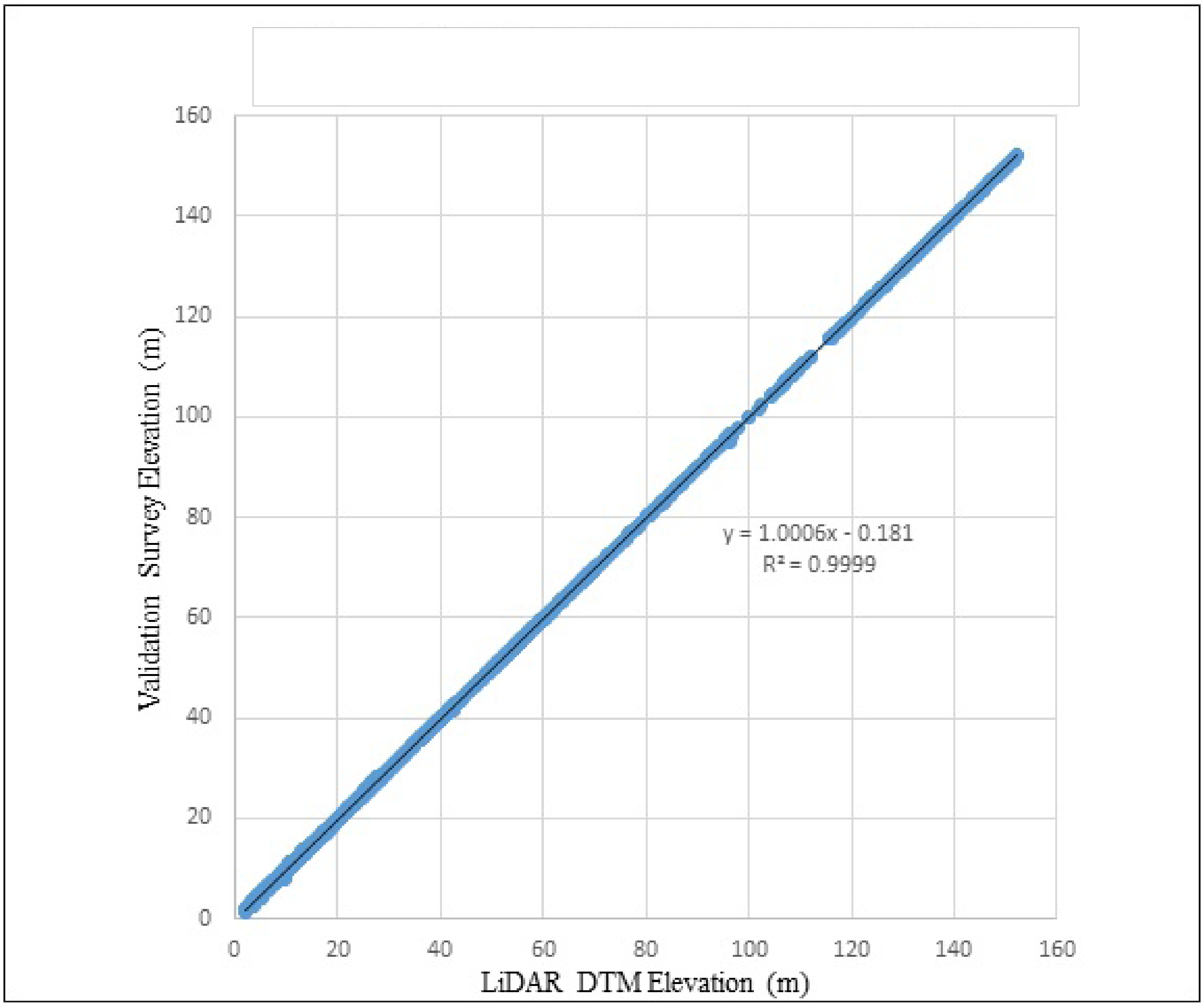

Figure 23. Correlation plot between validation survey points and LiDAR data.

Table 14. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.20
Standard Deviation	0.13
Average	0.16
Minimum	-0.10
Maximum	0.42

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data and cross-section was available for Padada with 2,293 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 0.39 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Padada integrated with the processed LiDAR DEM is shown in Figure 24.

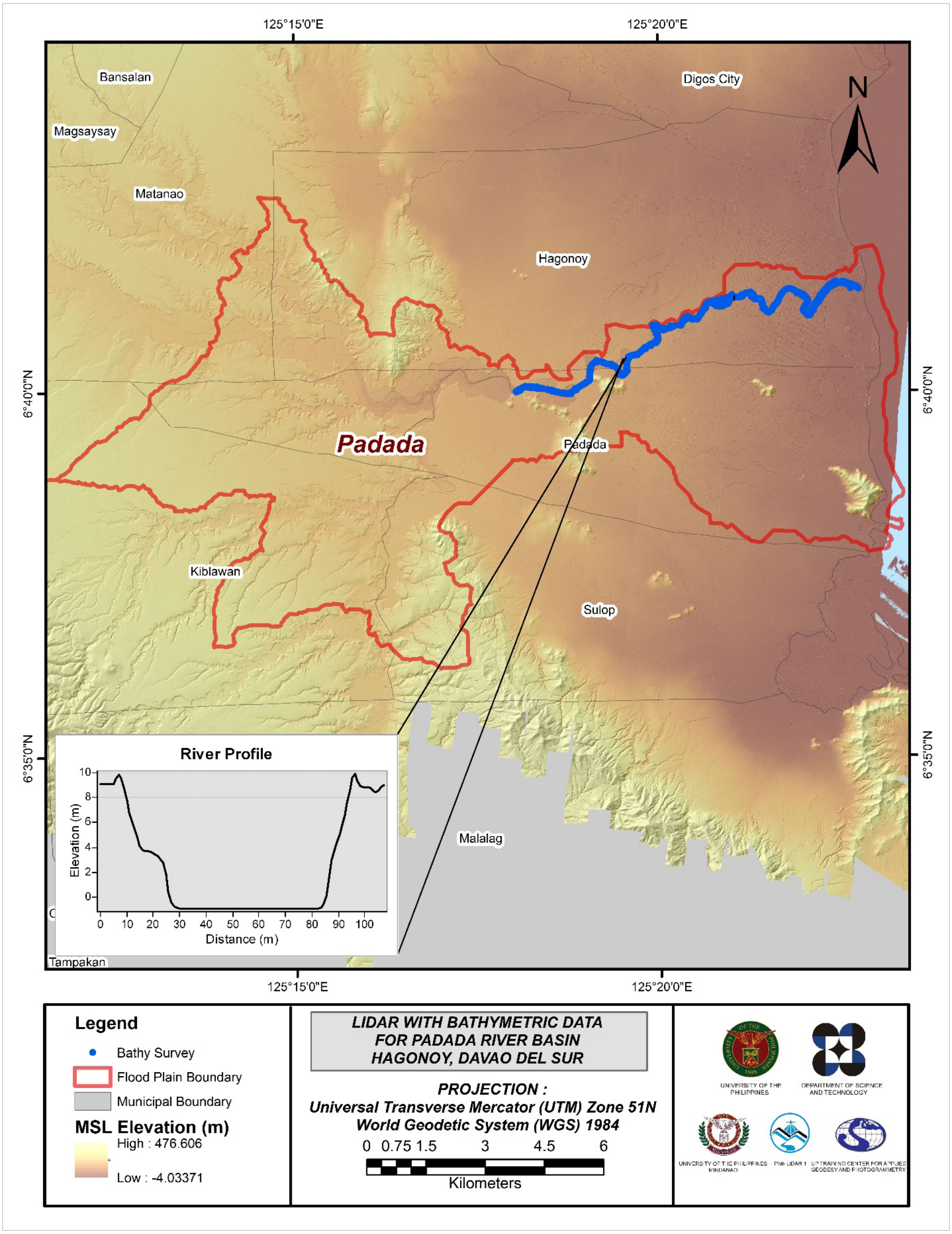

Figure 24. Map of Padada Flood Plain with bathymetric survey points shown in blue.

3.12 Feature Extraction

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

3.12.1 Quality Checking of Digitized Features' Boundary

Padada floodplain, including its 200 m buffer, has a total area of 127.48 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 1,139 building features, are considered for QC. Figure 26. shows the QC blocks for Padada floodplain.

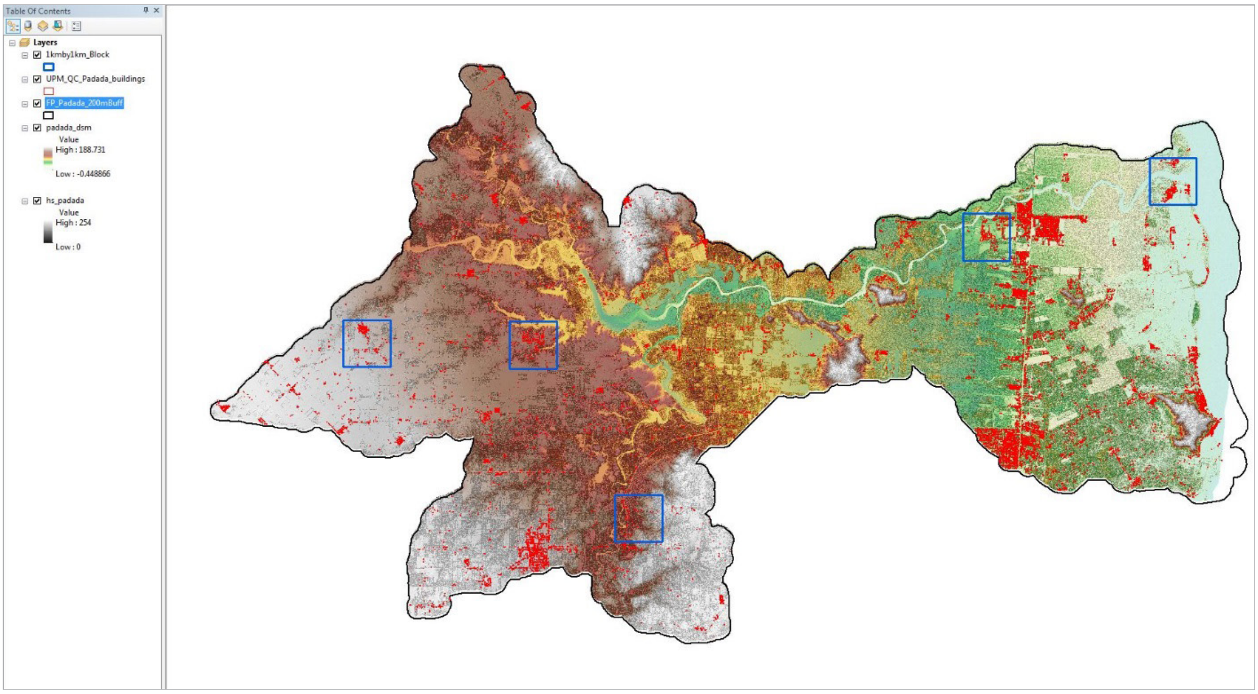

Figure 25. Padada building features that were subjected to QC blocks

Quality checking of Padada building features resulted in the ratings shown in Table 15.

Table 15. Quality Checking Ratings for Padada Building Features.

Floodplain	Completeness	Correctness	Quality	Remarks
Padada	97.18	93.68	84.37	PASSED

3.12.2 Height Extraction

Height extraction was done for 17, 365 building features in Padada floodplain. Of these building features, 1,406 were filtered out after height extraction, resulting to 15,959 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 16.27 m.

3.12.3 Feature Attribution

Before the actual field validation, courtesy calls were conducted to seek permission and assistance from the Local Government Units of each barangay. This was done to ensure the safety and security in the area for the field validation process to go smoothly. Verification of barangay boundaries was also done to finalize the distribution of features for each barangay.

The courtesy calls and project presentations were done on February 15 - 18, 2016. Barangay Health Workers (BHWs) were requested and hired to guide the University of the Philippines Mindanao Phil-LiDAR1 field enumerators during validation. The field work activity was conducted from February 29 to April 1, 2016. The local hires deployed by the barangay captains were given a brief orientation by the field enumerators before the actual field work. Some of the personnel volunteered to use their own motorcycle vehicles during the validation proper. The team surveyed the thirty-eight (38) barangays covered by the floodplain namely Paligue, Guihing, Aplaya, Poblacion, Hagonoy Crossing, Tologan, Mahayahay, Lapulabao, New Quezon, La Union, Maliit Digos, Clib, Malabang, San Guillermo, Piape, San Isidro, Punta Piape, Lower Limonzo, Upper Limonzo, NCO District, Almendras, Southern Paligue, Northern Paligue, Don Sergio Osmeña, Lower Katipunan, Lower Malinao, Upper Malinao, Molopolo, New Sibonga, Bagumbayan, Manual, Santo Niño, Poblacion, Buri, Kauswagan, Bagumbayan, Katipunan, and Tanwalang.

One of the concerns of the team during field validation was the steepness of the roads in the area which are very difficult to pass through via van. It was also raised that the Balutakay River affects northern reaches of the Municipality of Hagonoy. Also, the Mainit River causes floods in Kiblawan and the western reaches of Padada. Flood waters from there then flow towards Sulop.

Table 16 summarizes the number of building features per type. On the other hand, Table 17 shows the total length of each road type, while Table 18 shows the number of water features extracted per type.

Table 16. Building Features Extracted for Padada Floodplain.

Facility Type	No. of Features
Residential	14,627
School	361
Market	23
Agricultural/Agro-Industrial Facilities	166
Medical Institutions	59
Barangay Hall	35
Military Institution	1
Sports Center/Gymnasium/Covered Court	33
Telecommunication Facilities	0
Transport Terminal	2
Warehouse	34
Power Plant/Substation	3
NGO/CSO Offices	11
Police Station	3
Water Supply/Sewerage	6
Religious Institutions	158
Bank	4
Factory	86
Gas Station	17
Fire Station	1
Other Government Offices	33
Other Commercial Establishments	296
Total	**15,959**

Table 17. Total Length of Extracted Roads for Padada Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/ Municipal Road	Provincial Road	National Road	Others	
Padada	253.75	38.31		6.94	0.00	**299.00**

Table 18. Number of Extracted Water Bodies for Padada Floodplain.

Floodplain	Water Body Type						Total
	Rivers/ Streams	Lakes/ Ponds	Sea	Dam	Fish Pen	Irrigation	
Padada	4	0	0	0	84	1	**88**

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 26 shows the Digital Surface Model (DSM) of Padada floodplain overlaid with its ground features.

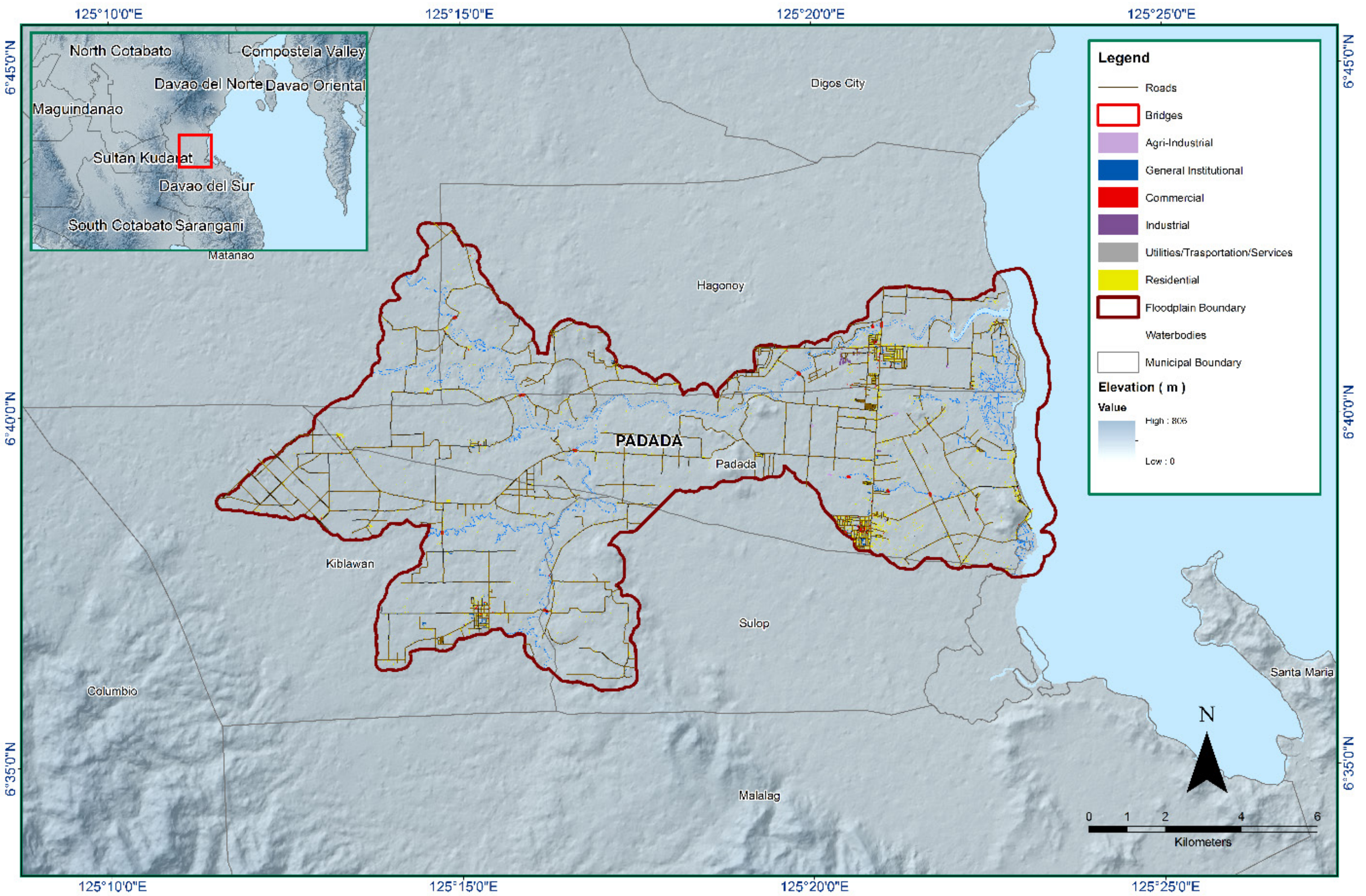

Figure 26. Extracted features for Padada floodplain.

CHAPTER 4. LIDAR VALIDATION SURVEY AND MEASUREMENTS OF THE BALANGA RIVER BASIN

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

4.1 Summary of Activities

Padada-Mainit River Basin is located in the Province of Davao del Sur. It covers the Municipalities of Bansalan, Magsaysay, Kiblawan, Malalag, and Matanao in Davao del Sur, a portion of the Municipalities of Columbio, Tulunan, and Tampakan in Sultan Kudarat, North Cotabato, and South Cotabato, respectively. The basin has a catchment area of 1,303 km² with an estimated annual run-off of 2,606 MCM according to DENR-RCBO.

Padada River originates from Matanao, Davao del Sur and is joined by Mainit River downstream in Brgy. San Guillermo, Hagonoy, Davao del Sur. It empties to Davao Gulf at Guihing Aplaya, Hagonoy, Davao del Sur. The river is used to irrigate rice fields, banana and mango plantations, and as a cooling water of a sugar mill along its banks (Davao Sugar Central Corporation). The University of the Philippines Mindanao is the partner HEI that is responsible for monitoring Padada-Mainit River.

In line with this, a field survey in Padada-Mainit River from June 28 to July 12, 2015 was conducted with the following scope of work: reconnaissance survey to assess the actual condition of the river and recovery of existing control points; courtesy call with UP Mindanao and LGUs of Davao del Sur; control survey for the establishment of a control point at the approach of Tologan Bridge; cross-section, bridge-as-built and water level marking in Tologan Bridge in Brgy. Tologan, Municipality of Hagonoy, Davao Del Sur; validation points acquisition along concrete roads with estimated distance of 122 km; and bathymetric survey of Padada-Mainit River with an approximate length of 10 km as shown in Figure 27.

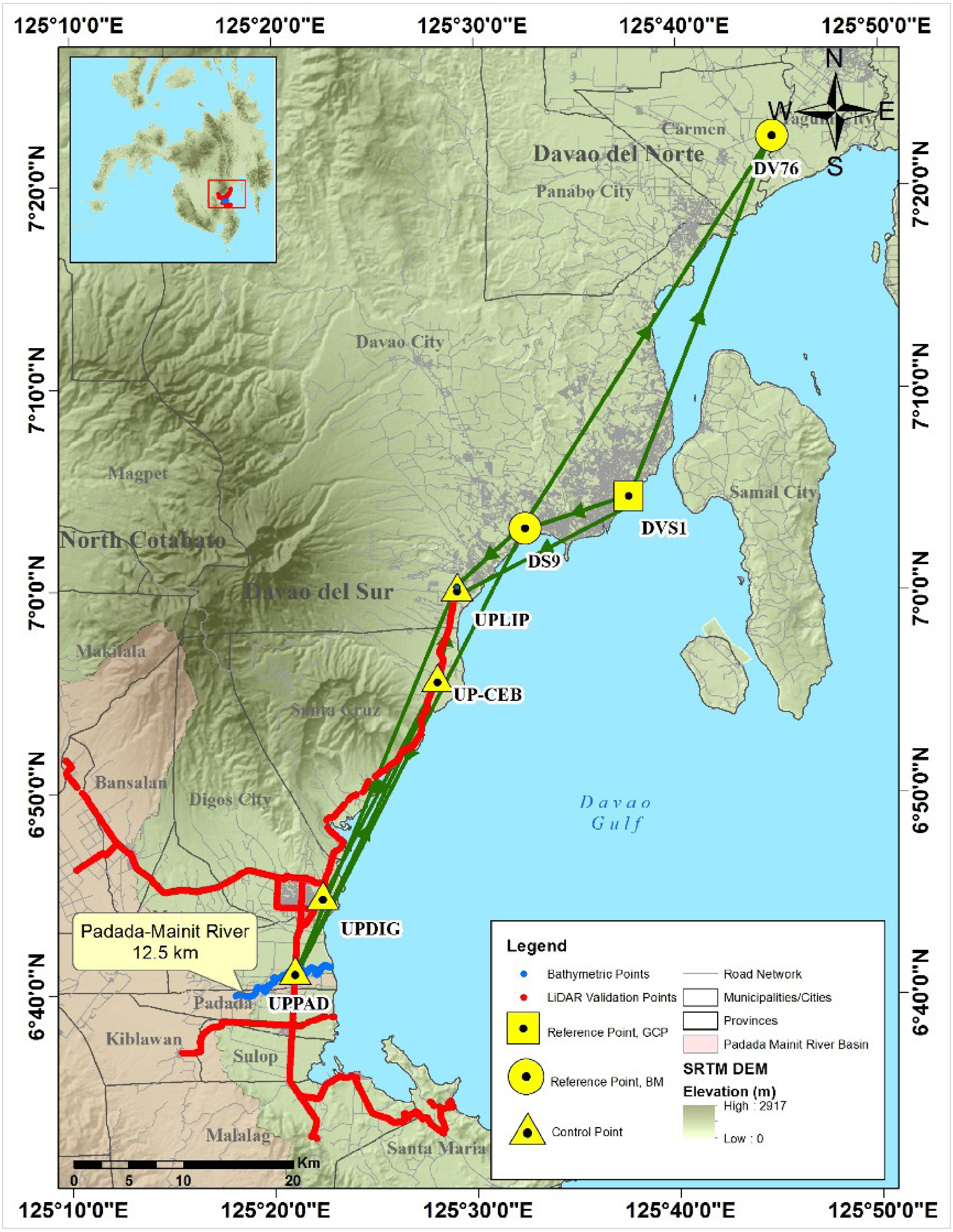


Figure 27. Padada-Mainit River survey extent

4.2 Control Survey

The GNSS network used in Padada-Mainit River survey was composed of six (6) loops established on July 4 and 5, 2015 with the following reference points: DVS-1, a first order GCP in Brgy. Leon Garcia Sr, Davao City, Davao Del Sur; and DV-76, a first order benchmark located Brgy. Guadalupe, Municipality of Carmen, Davao Del Norte.

Five (5) control points were established along approach of bridges namely: UP-CEB at Cebulan Bridge in Brgy. Darong, Municipality of Sta. Cruz Davao Del Sur; UP-DIG in Digos Bridge in Brgy. Aplaya, Digos City, Davao Del Sur; UP-LIP2 at Lipadas Bridge approach in Brgy. Lizada, Davao City, Daao Del Sur; and UP-PAD at Padada Bridge, in Brgy. Guihing, Muncipality of Hagonoy, Davao Del Sur. A NAMRIA established control point namely DS-9, located in Brgy. Talomo, Davao City, was also occupied to use as marker during the survey.

The summary of reference and control points and its location is summarized in Table 19 , and the GNSS network established is illustrated in Figure 28.

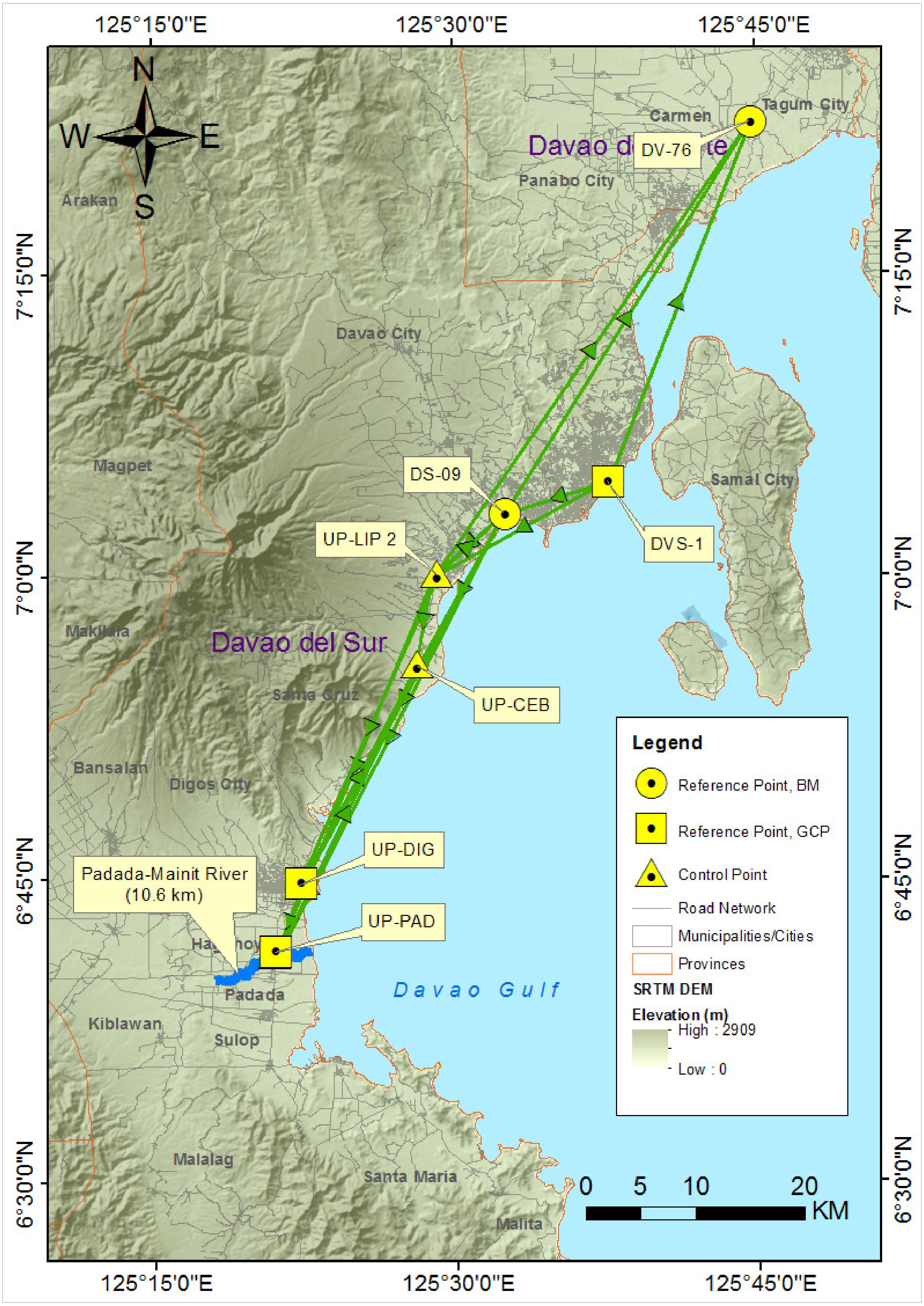


Figure 28. Overall GNSS Survey loop of Padada Mainit River Basin

Table 19. List of Reference and Control Points used in Padada Mainit River Survey
(Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS UTM Zone 52N)				
		Latitude	Longitude	Ellipsoid Height (m)	Elevation (MSL) (m)	Date of Establish-ment
DVS-1	1st order GCP	7°04'38.36201"	125°37'36.77094"	68.5	-	2013
DV-76	1st order BM	-	-	76.155	8.359	2007
DS-9	Used as Marker	-	-	-	-	2007
UP-CEB	UP Established	-	-	-	-	7-5-2015
UP-DIG	UP Established	-	-	-	-	7-5-2015
UP-LIP2	UP Established	-	-	-	-	7-4-2015
UP-PAD	UP Established	-	-	-	-	7-5-2015

The GNSS set up for control points used are shown in Figure 29 to Figure 35 respectively.

Figure 29. GNSS base receiver setup, Trimble® SPS 852 at DVS-1 at the east side of Pier, in Brgy. Leon Garcia Sr., Davao City, Davao Del Sur

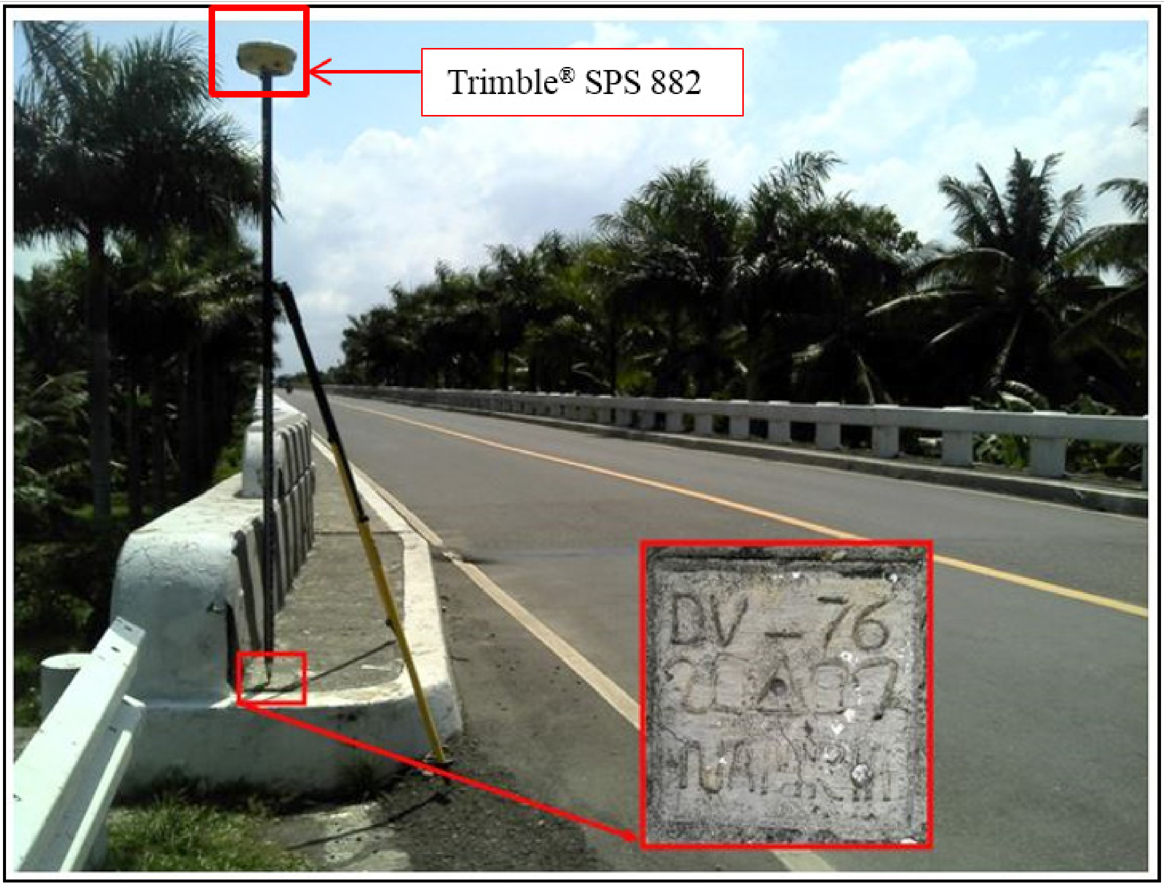


Figure 30. GNSS base receiver setup, Trimble® SPS 882 at DV-76 at the Gov. Miranda Bridge Approach, Brgy. Guadalupe, Municipality of Carmen, Davao Del Norte

Figure 31. GNSS base receiver setup, Trimble® SPS 882 at DS-09 located at stair of Nograles Park along Mac Arthur Highway, in Brgy. Talomo, Davao City, Davao Del Sur

Figure 32. GNSS base receiver setup, Trimble® SPS 852 at UP-CEB on the right approach of Cebulan Bridge in Brgy Darong, Municipality of Santa Cruz, Davao Del Sur

Figure 33. GNSS base receiver setup, Trimble® SPS 882 at UP-DIG, right approach of Digos Bridge in Brgy. Aplaya, Digos City, Davao Del Sur

Figure 34. GNSS base receiver setup, Trimble® SPS 852 at UP-LIP2, on the right approach of Lipadas Bridge along National Highway in Brgy. Lizada, Toril District, Davao Del Sur

Figure 35. GNSS base receiver setup, Trimble® SPS 882 at UP-PAD, Padada Bridge, Brgy. Guihing, Municipality of Hagonoy, Davao del Sur

4.3 Baseline Processing

The GNSS baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement, respectively. In cases where one or more baselines did not meet all of these criteria, masking is performed. Masking is done by removing 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. Baseline processing result of control points in Padada Mainit River Basin is summarized in Table 20, generated by TBC software.

Table 20. Baseline Processing Report for Padada Mainit River Basin Static Survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	Δ Height (m)
UPPAD --- UPCEB	7-4-2015	Fixed	0.005	0.024	26°11'09"	29668.539	20.427
DVS1 --- DS9	6-30-2015	Fixed	0.004	0.013	252°53'03"	9875.482	3.720
DVS1 --- UPLIP2	7-4-2015	Fixed	0.003	0.016	242°19'23"	17735.680	10.641
UPLIP2 --- UPPAD	7-4-2015	Fixed	0.004	0.017	203°09'13"	37929.527	4.455
UPLIP2 --- UPCEB	7-4-2015	Fixed	0.004	0.024	192°23'44"	8451.500	24.864
UPPAD --- UPTOL	7-4-2015	Fixed	0.003	0.014	240°13'14"	2487.973	1.230
DVS1 --- DS9	6-30-2015	Fixed	0.006	0.033	252°53'03"	9875.477	3.723
DS9 --- UPLIP2	6-30-2015	Fixed	0.006	0.042	229°36'22"	8229.009	6.907
UPLIP2 --- DS9	6-30-2015	Fixed	0.006	0.035	229°36'23"	8228.967	6.965
DS9 --- UPPAD	6-30-2015	Fixed	0.011	0.036	207°47'10"	45445.416	11.450
DS9 --- UPCEB	7-5-2015	Fixed	0.011	0.046	210°44'50"	15809.215	31.878
DS9 --- DV76	6-30-2015	Fixed	0.005	0.049	32°23'13"	42306.620	3.850
DVS1 --- DV76	7-5-2015	Fixed	0.003	0.015	21°57'24"	35381.584	7.644
UPLIP2 --- DV76	7-5-2015	Fixed	0.006	0.021	35°09'36"	50225.907	-2.996
DS9 --- UPDIG	6-30-2015	Fixed	0.006	0.039	209°08'05"	38212.638	8.511
UPLIP2 --- UPDI	7-5-2015	Fixed	0.003	0.017	203°44'17"	30638.805	1.495
UPDIG --- UPPAD	7-5-2015	Fixed	0.004	0.017	200°41'13"	7298.998	2.930
UPDIG --- UPCEB	7-5-2015	Fixed	0.004	0.025	27°58'39"	22414.077	23.379

As shown in Table 20 a total of 18 baselines were processed and all of them passed the required accuracy set by the project.

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 form:

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

Where:

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

for each control point. See the Network Adjustment Report shown in Table C-3 to Table C-5 for the complete details.

The seven (7) control points, DVS-1, DV-76, DS-9, UP-CEB, UP-DIG, UP-LIP2 and UP-PAD were occupied and observed simultaneously to form GNSS LOOP. Coordinates of DVS-1 and elevation value of DV-76 were held fixed during the processing of the control points as presented in Table 21. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 21. Control Point Constraints

Point ID	Type	North (Meter)	East (Meter)	Height (Meter)	Elevation (Meter)
DVS-1	Global	Fixed	Fixed		
DV-76	Grid				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 22. The fixed control point DV-76 and DVS-1, has no values for standard elevation and coordinates error, respectively.

Table 22. Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
DS9	780765.613	0.009	780155.271	0.007	3.801	0.079	
DV76	803241.598	0.008	816030.498	0.008	8.359	?	e
DVS1	790192.921	?	783116.705	?	0.771	0.064	LL
UPCEB	772752.259	0.012	766517.370	0.011	34.883	0.097	
UPDIG	762330.012	0.011	746661.467	0.009	10.556	0.090	
UPLIP2	774523.929	0.008	774785.649	0.007	10.067	0.072	
UPPAD	759783.560	0.011	739817.613	0.010	13.208	0.089	

The networks are fixed at reference points DVS-1 and DV-76. With the mentioned equation, $\sqrt{((x_e)^2 + (y_e)^2)} < 20\ cm$ and $z_e < 10\ cm$ for the vertical, the computations for the horizontal and vertical accuracy are as follows:

a. DVS-1

horizontal accuracy = Fixed
vertical accuracy = 6.4cm < 10 cm

b. DV-76

horizontal accuracy = √((0.8)² + (0.8)²
= √(0.64 + 0.64)
= 1.13 cm < 20 cm
vertical accuracy = Fixed

c. DS-09

horizontal accuracy = √((0.9)² + (0.7)²
= √(0.81 + 0.49)
= 1.14 cm < 20 cm
vertical accuracy = 7.9 cm < 10 cm

d. UP-CEB

horizontal accuracy = √((1.2)² + (1.1)²
= √(1.44 + 1.21)
= 2.69 cm < 20 cm
vertical accuracy = 1.63 cm < 10 cm

e. UP-DIG

horizontal accuracy = √((1.1)² + (0.9)²
= √(1.21 + 0.81)
= 1.42 cm < 20 cm
vertical accuracy = 9.0 cm < 10 cm

f. UP-LIP2

horizontal accuracy = √((0.8)² + (0.7)²
= √(0.64+ 0.49
= 1.06 cm < 20 cm
vertical accuracy = 7.2 cm< 10 cm

g. UP-PAD

horizontal accuracy = √((1.1)² + (1.0)²
= √(1.21 + 1.0)
= 1.49 cm < 20 cm
vertical accuracy = 8.9 cm < 10 cm

Following the given formula, the horizontal and vertical accuracy result of the seven (7) occupied control points are within the required accuracy of the program.

Table 23. Adjusted geodetic coordinates

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
DS9	N7°03'03.72282"	E125°32'29.23786"	72.195	0.079	
DV76	N7°22'26.51286"	E125°44'48.14120"	76.155	?	e
DVS1	N7°04'38.36201"	E125°37'36.77094"	68.500	0.064	LL
UPCEB	N6°55'41.41306"	E125°28'05.94638"	104.051	0.097	
UPDIG	N6°44'57.07991"	E125°22'23.41362"	80.677	0.090	
UPLIP	N7°00'10.77316"	E125°29'05.16478"	78.215	0.089	
UPLIP2	N7°00'10.11838"	E125°29'05.04512"	79.165	0.072	
UPPAD	N6°41'14.79422"	E125°20'59.46050"	83.620	0.089	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 23. Based on the result of the computation, the accuracy conditions are satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table 24.

Table 24. Reference and control points and its location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoid Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
DVS-1	1st Order GCP	7°04'38.36201"	125°37'36.77094"	68.5	783116.705	790192.921	0.771
DV-76	1st Order M	7°22'26.51286"	125°44'48.14120"	76.155	816030.498	803241.598	8.359
DS-9	Used as Marker	7°03'03.72282"	125°32'29.23786"	72.195	780155.271	780765.613	3.801
UP-CEB	UP Established	6°55'41.41306"	125°28'05.94638"	104.051	766517.37	772752.259	34.883
UP-DIG	UP Established	6°44'57.07991"	125°22'23.41362"	80.677	746661.467	762330.012	10.556
UP-LIP2	UP Established	7°00'10.11838"	125°29'05.04512"	79.165	774785.649	774523.929	10.067
UP-PAD	UP Established	6°41'14.79422"	125°20'59.46050"	83.62	739817.613	759783.56	13.208

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

Cross-section and as-built survey were conducted on July 8, 2015 at the downstream side of Tologan Bridge in Brgy. Tologan, Municipality of Hagonoy, Davao Del Sur using a GNSS receiver Trimble® SPS 882 in PPK survey technique as shown in Figure 36. The control point UP-PAD was used as the GNSS base station for both cross-section and bridge as-built surveys.

Figure 36. Cross-section and bridge as-built survey at the downstream side of Tologan Bridge, Brgy. Tologan, Hagonoy, Davao del Sur

A total of fifty seven (57) cross-section points were gathered with an estimated length of 106.7 m from left to right banks. The location map, cross-section diagram, and as-built data form for Tologan Bridge are displayed in Figure 37 to Figure 39, respectively.

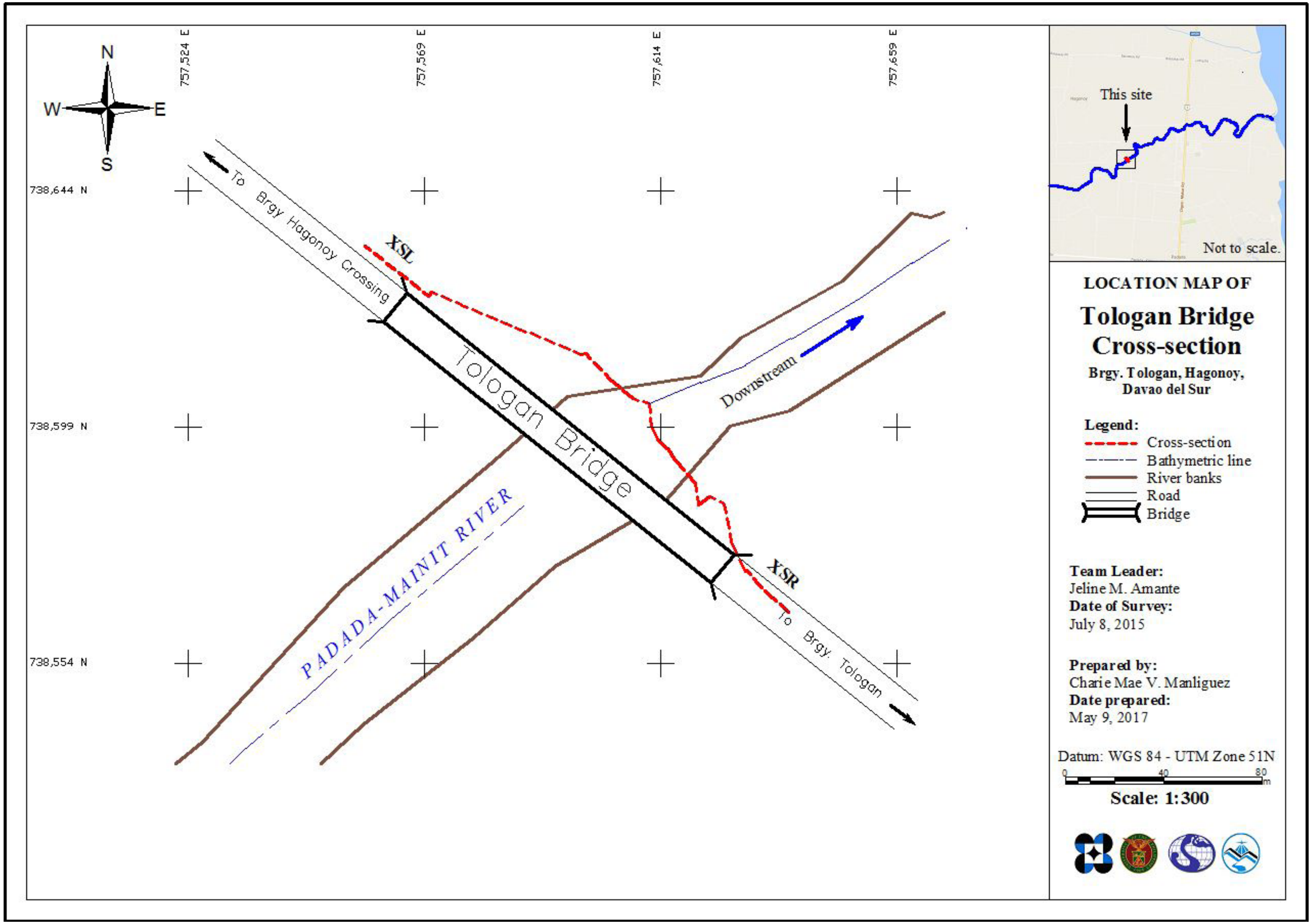


Figure 37. Tologan bridge cross-section location map

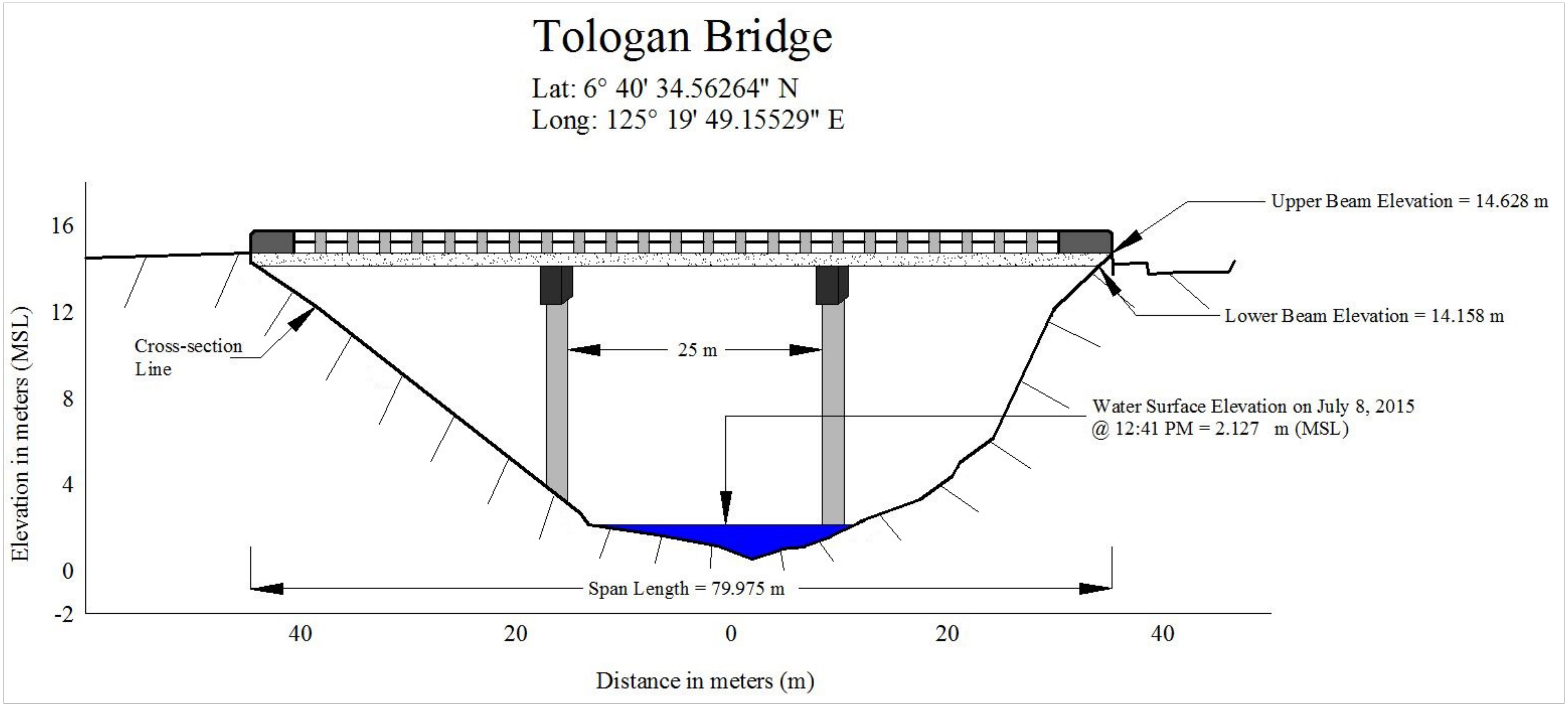


Figure 38. Tologan bridge cross-section location map

Bridge Data Form

Bridge Name: TOLOGAN BRIDGE **Date:** July 08, 2015

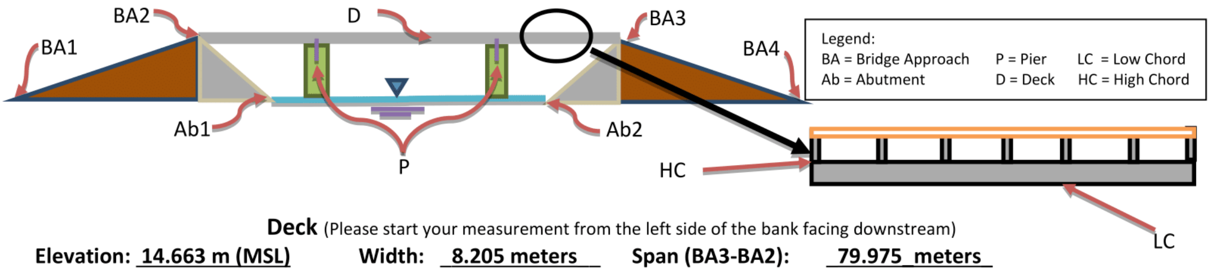
River Name: PADADA-MAINIT RIVER **Time:** 4:55 pm

Location (Brgy, City, Region): Brgy. Tologan, Hagonoy, Davao del Sur

Survey Team: DVBC/DVC Davao del Sur Survey Team

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

Latitude: 6°40'34.56264"N **Longitude:** 125°19'49.15529" E



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

Elevation: 14.663 m (MSL) **Width:** 8.205 meters **Span (BA3-BA2):** 79.975 meters

	Station	High Chord Elevation	Low Chord Elevation
1	-	14.628 m	14.158 m
2			
3			
4			

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	14.479	BA3	95.288	14.655
BA2	15.333	14.728	BA4	106.092	13.813

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

	Station (Distance from BA1)	Elevation
Ab1	89.850	12.113
Ab2	80.379	4.342

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

Shape: CYLINDRICAL **Number of Piers:** 2 **Height of column footing:** ___________

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	42.825	14.627	-
Pier 2	67.830	14.640	-
Pier 3			
Pier 4			

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

Figure 39. Tologan Bridge Data Form

Figure 40. Water level markings on the post of Tologan Bridge

Water surface elevation in MSL of Tologan Bridge was determined using Trimble® SPS 882 in PPK mode survey on July 8, 2015 at 12:42 PM. This was translated onto marking the bridge's pier using a digital level. The marked pier, see Figure 40, shall serve as reference for flow data gathering and depth gauge deployment by the accompanying HEI, UP Mindanao, who is responsible for Padada-Mainit River.

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted from July 8 to 11, 2015 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted on a range pole which was attached on the left side of the vehicle as shown in Figure 41. It was secured with a cable tie to ensure that it was horizontally and vertically balanced. The antenna height was measured and recorded to be 2.463 m from the ground up to the bottom of notch of the GNSS Rover receiver.

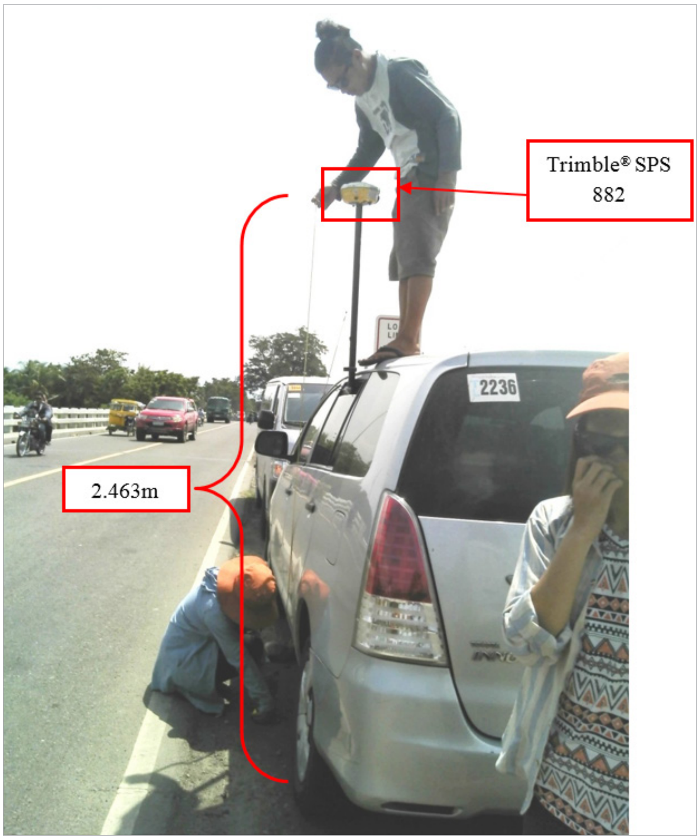


Figure 41. Validation points acquisition survey set-up for Davao del Sur.

The survey was conducted using PPK technique on a continuous topography mode, which covered the major roads of the Municipalities of Bansalan, Magsaysay, Manatao, Kiblawan, Sulop, Santa Maria, Santa Cruz, Padada, and Hagonoy and Digos City as illustrated in Figure 42. The survey gathered a total of 21, 217 validation points covering an approximate distance of 122 km using the control point UP-PAD as the GNSS base station.

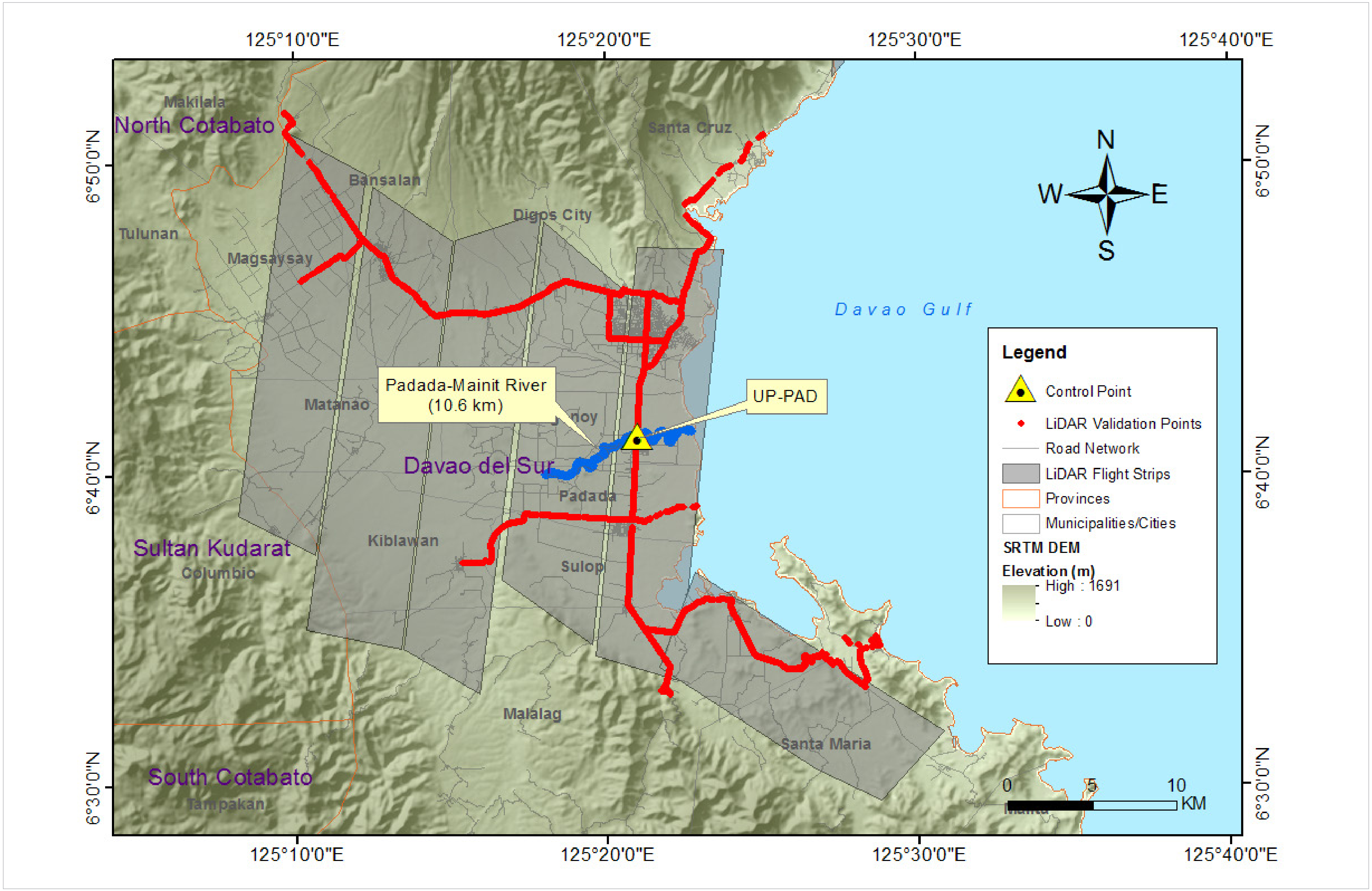


Figure 42. Validation points acquisition survey coverage for Padada-Mainit River

4.7 River Bathymetric Survey

Bathymetric survey was conducted from July 3 and 10, 2015 using a survey grade GNSS Rover receiver Trimble® SPS 882 in PPK survey technique as shown in Figure 43. The control point UP-PAD was used as base station for the survey. The river was traversed manually which started at the upstream portion of the river in Brgy. Son Sergio Osmeña Sr., Municipality of Padada with coordinates 6°39'59.70560" 125°18'02.19947", down to the mouth of the river in Brgy. Guihing Aplaya, also in Padada with coordinates 6°41'23.82323" 125°22'44.41592".

Figure 43. Bathymetric survey setup in Padada-Mainit River (upstream)

The entire coverage for the bathymetric survey for Padada-Mainit River is 12.5 km with a total of 2,262 bathymetric points gathered as shown in Figure 44. A CAD drawing was also produced to illustrate the riverbed profile of Padada Mainit river. As shown in Figure 45, an elevation drop of 16.85 m in MSL was observed within the approximate distance of 12.5 km from downstream in Brgy. Tologan to Brgy. Guihing Aplaya. The lowest elevation was measured at -5.516 m located near the mouth of the river. The surveyed portion of the river passed at the barangay boundaries of Brgy. Tologan to Brgy. Guihing Aplaya

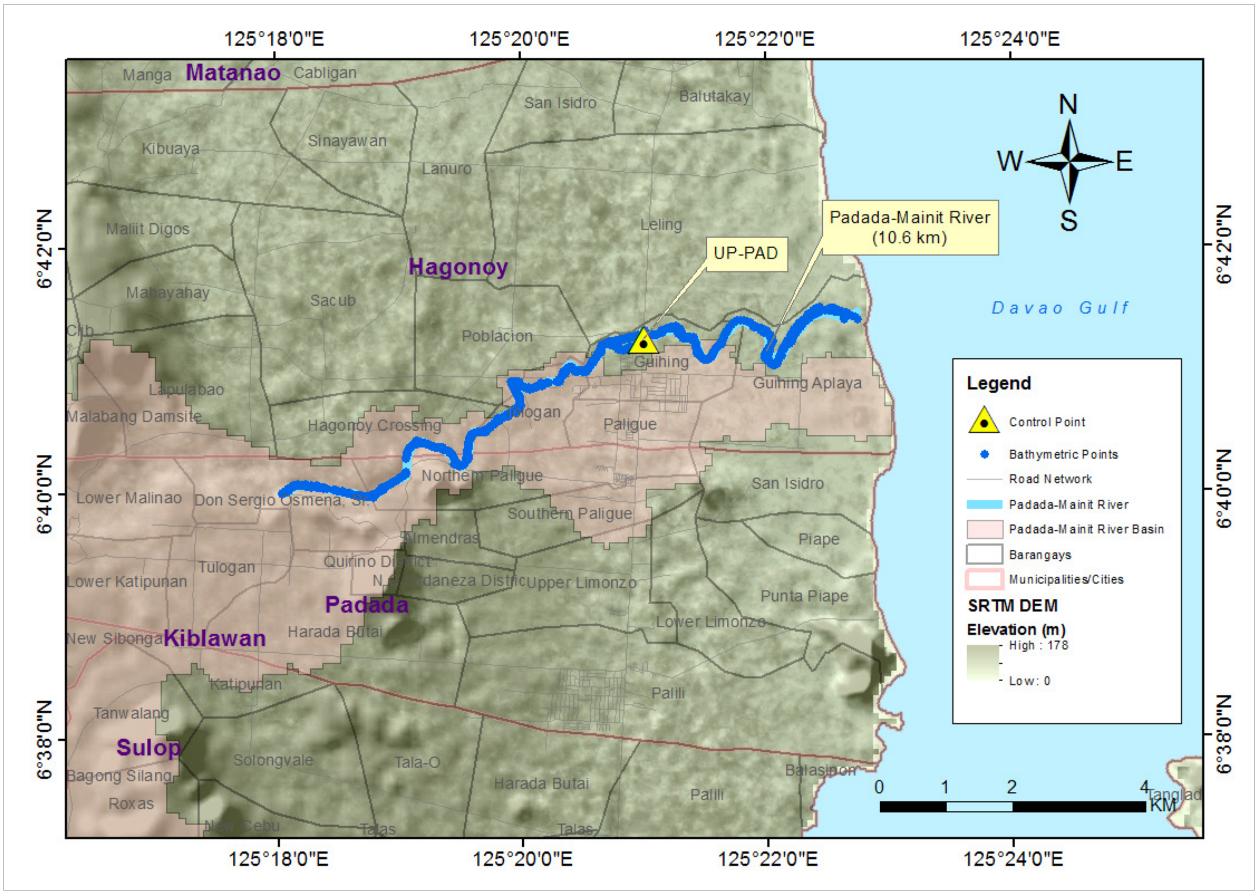


Figure 44. Bathymetric survey of Padada-Mainit River

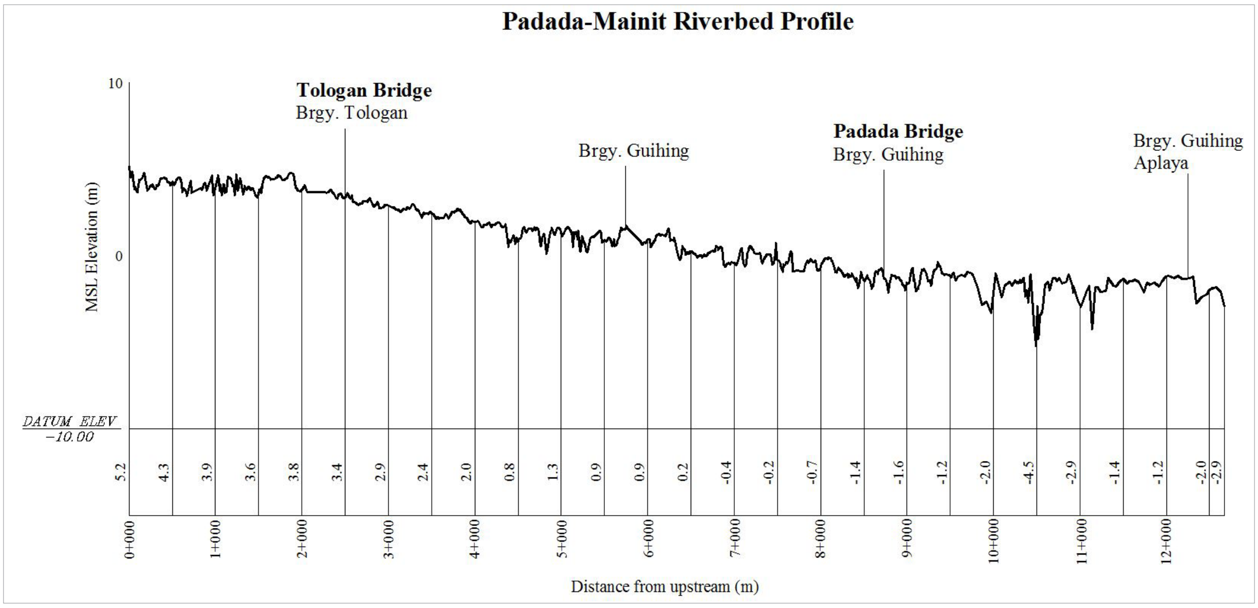


Figure 45. Padada-Mainit Riverbed Profile

CHAPTER 5. FLOOD MODELING AND MAPPING

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

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

Components and data that affect the hydrologic cycle of the river basin was monitored, collected, and analyzed. Rainfall, water level, and flow in a certain period of time, which may affect the hydrologic cycle of the Padada-Mainit river were monitored, collected and analyzed.

5.1.2 Precipitation

Precipitation data was taken from the rain gauge installed by the University of the Philippines Mindanao Phil. LiDAR 1. This rain gauge is located in Barangay Bagumbayan, Matanao, Davao del Sur with the following coordinates: 6° 38' 26.3" N, 125° 13' 40.4" E (Figure 46). The precipitation data collection started from October 1, 2015 at 12:00 NN to October 3, 2015 at 11:00 PM with a 10-minute recording interval.

The total precipitation for this event in the installed rain gauge was 12.8 mm. It has a peak rainfall of 6.6 mm. on October 1, 2015 at 12:50 PM. The lag time between the peak rainfall and discharge is 14 hours and 20 minutes.

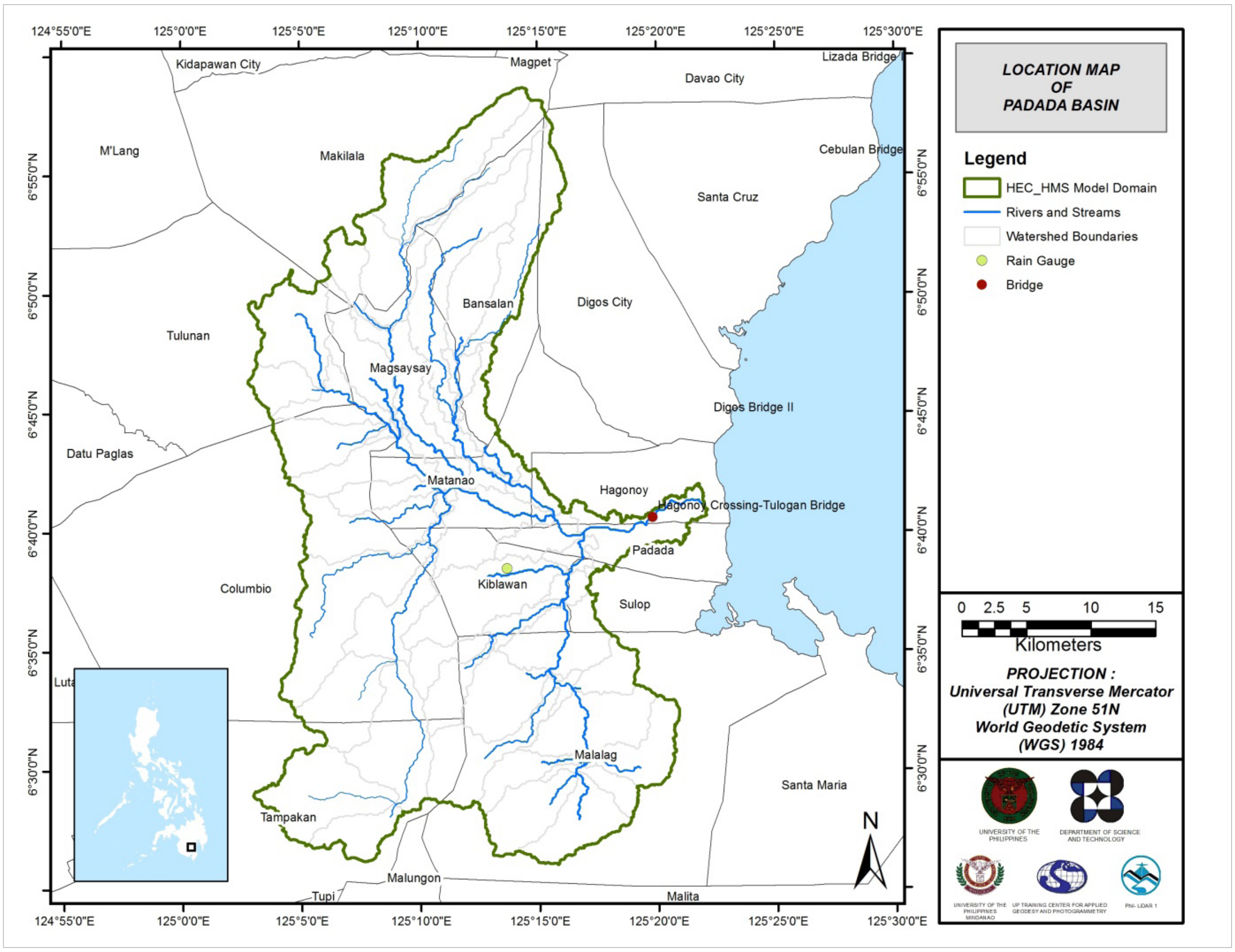


Figure 46. Padada-Mainit Riverbed Profile

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Diversion Bridge or Tologan Bridge AWLS, Barangay Hagonoy Crossing, Matanao, Davao del Sur (6° 40' 35.4" N, 125° 19' 47.78" E). It gives the relationship between the observed water level at Tologan Bridge and outflow of the watershed at this location.

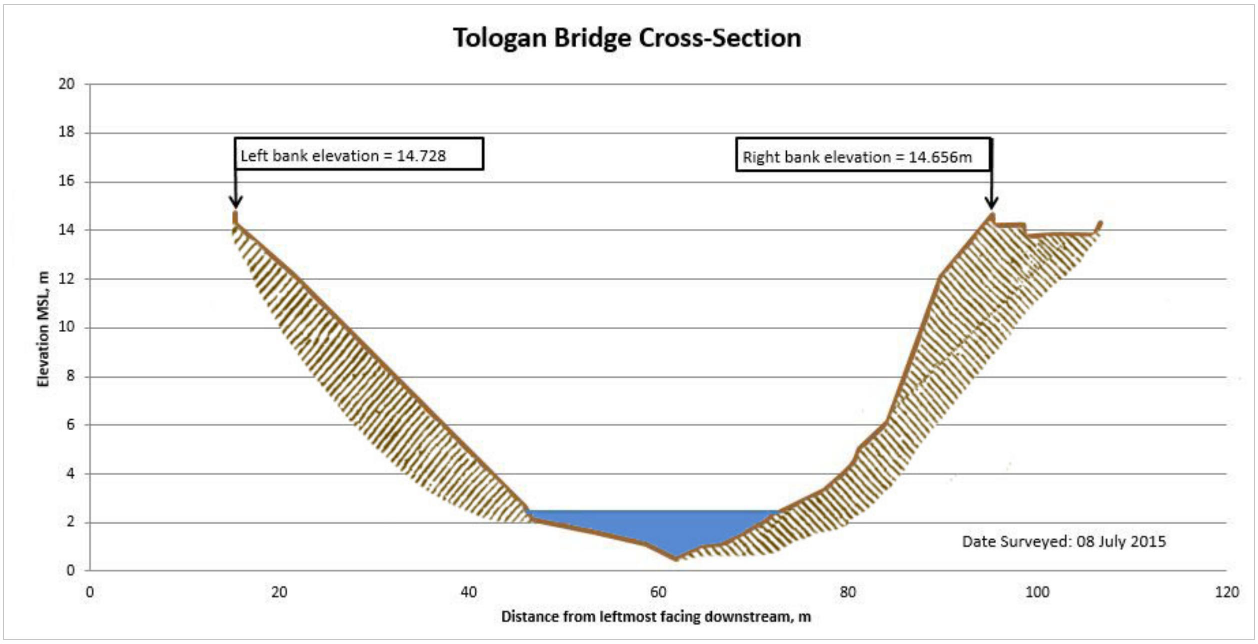


Figure 47. Cross-Section Plot of Tologan Bridge

For Tologan Bridge, the rating curve is expressed as $Q = 0.0031e^{3.5497x}$ as shown in Figure 48.

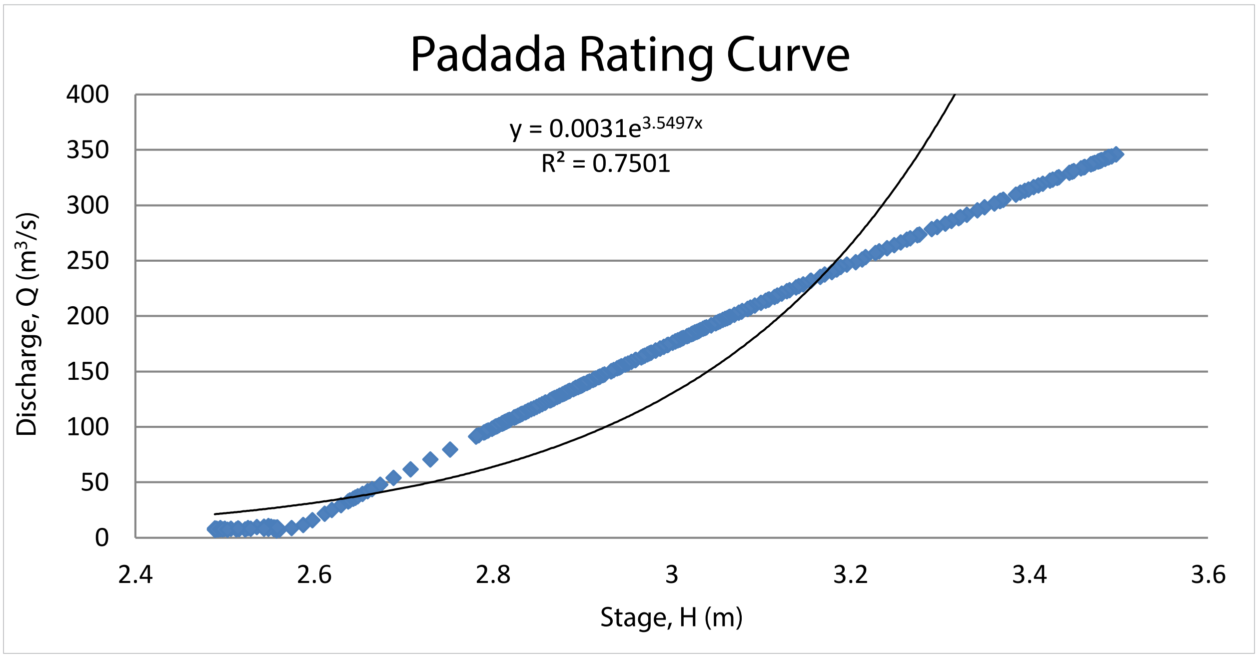


Figure 48. Rating Curve at Tologan Bridge, Matanao, Davao del Sur

The rating curve equation was used to compute for the river outflow at Tologan Bridge for the calibration of the HEC-HMS model for Padada, as shown in Figure 49. The total rainfall for this event is 12.8 mm and the peak discharge is 345.8 m³/s at 3:10 AM ofOctober 2, 2015.

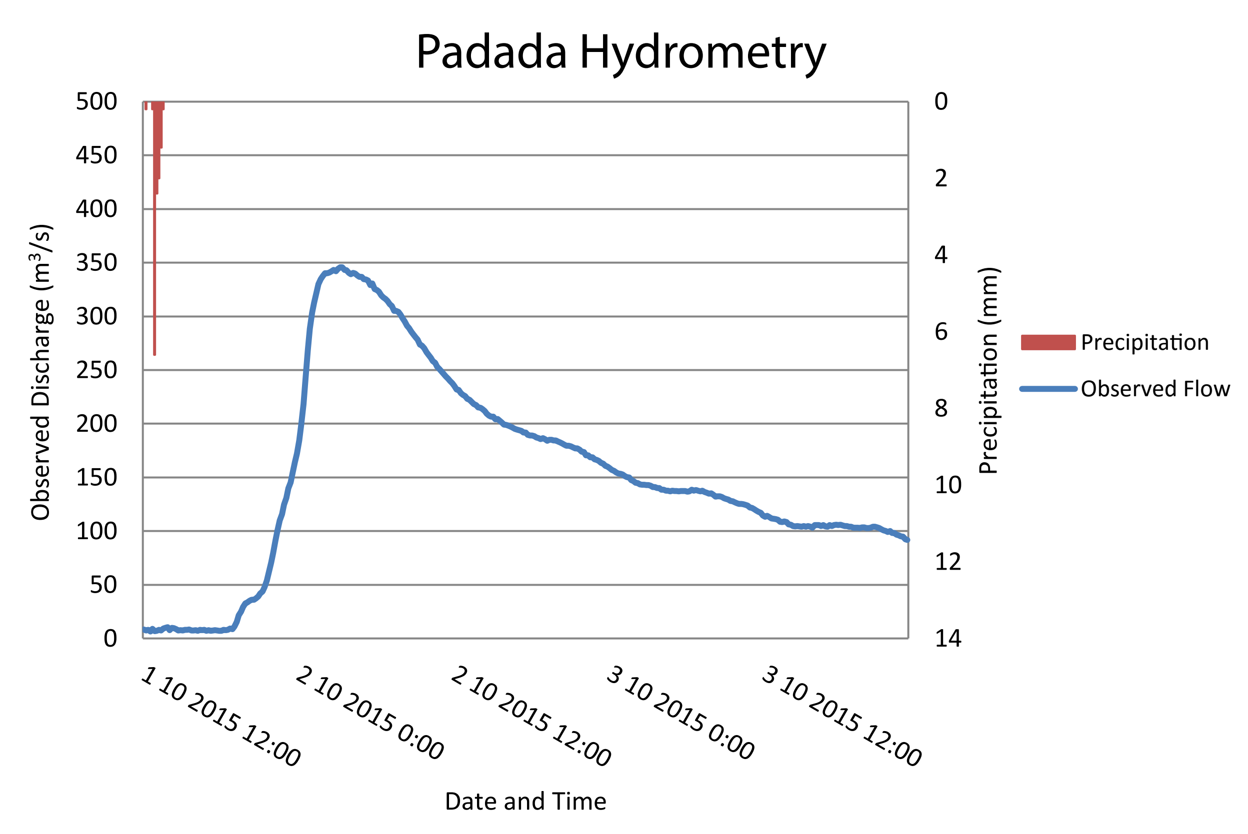


Figure 49. Rainfall and outflow data at Tologan Bridge used for modeling

5.2 RIDF Station

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

Table 25. RIDF values for Davao 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
2	19.5	30	38.2	53.2	65.2	71.6	80.3	85.8	91.4
5	25.1	39.3	51	73.2	88.8	96.4	108.7	114.9	121.1
10	28.8	45.4	59.4	86.5	104.5	112.8	127.5	134.1	140.7
15	30.9	48.9	64.2	94	113.3	122.1	138.1	145	151.8
20	32.4	51.3	67.6	99.3	119.5	128.6	145.5	152.6	159.5
25	33.5	53.2	70.1	103.3	124.2	133.6	151.2	158.5	165.5
50	37	59	78.1	115.8	138.9	149	168.8	176.5	183.9
100	40.5	64.7	85.9	128.1	153.5	164.2	186.3	194.4	202.1

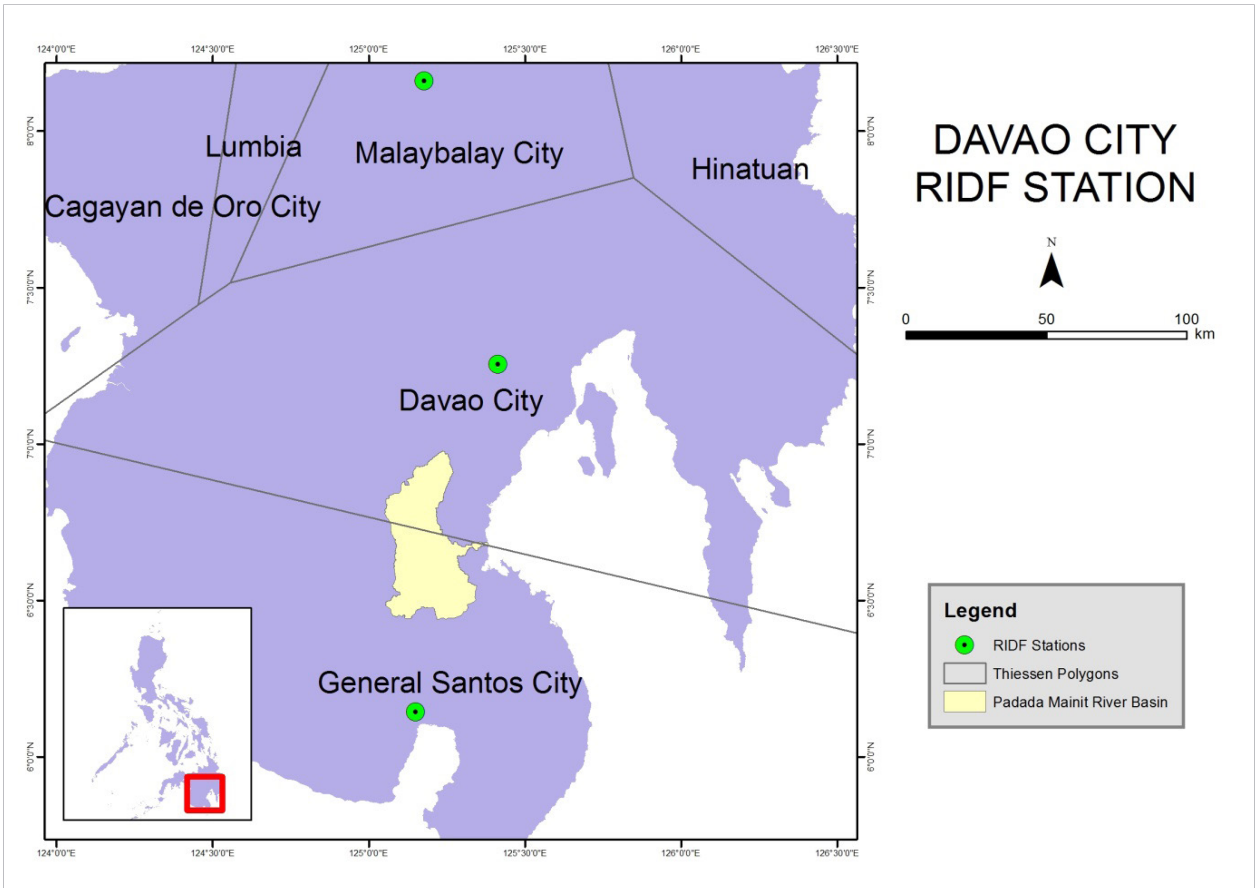


Figure 50. Location of Davao RIDF Station relative to Padada River Basin

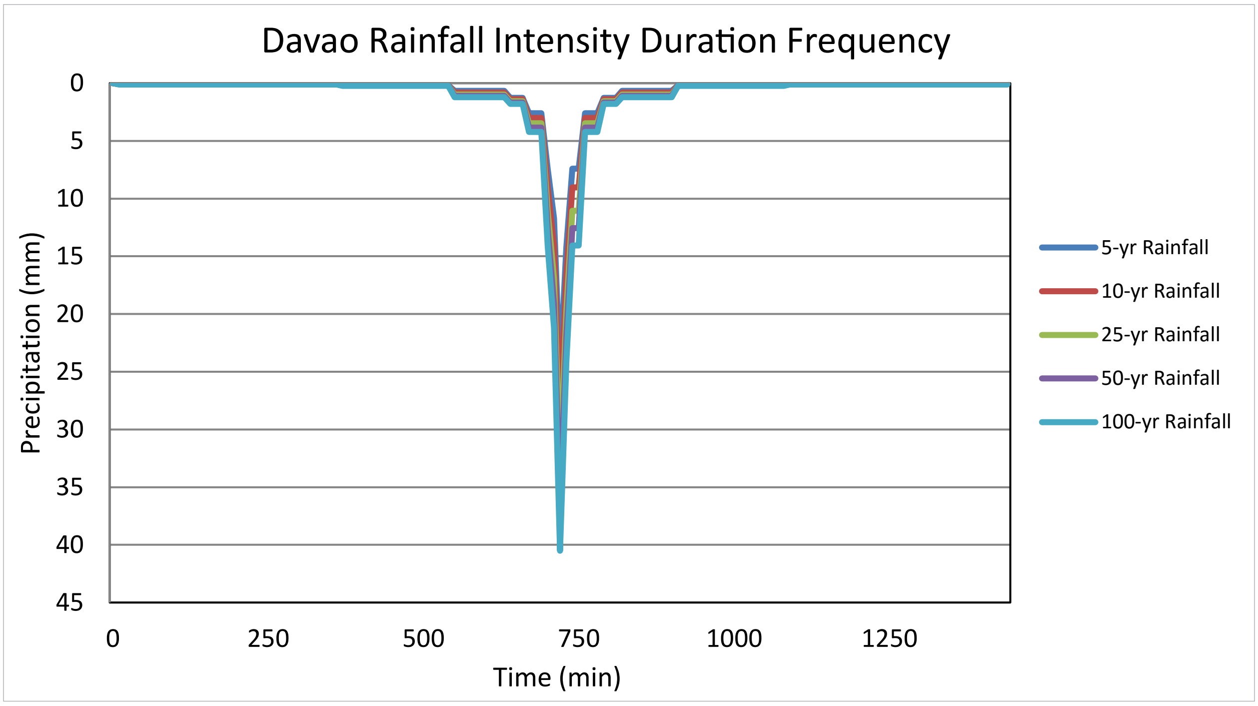


Figure 51. Synthetic storm generated for a 24-hr period rainfall for various return periods

5.3 HMS Model

The soil dataset was taken before 2004 by the Bureau of Soils and Water Management (BSWM), under the Department of Agriculture (DA). The land cover dataset file is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Musi-Musi River Basin are shown in Figures 52 and 53, respectively.

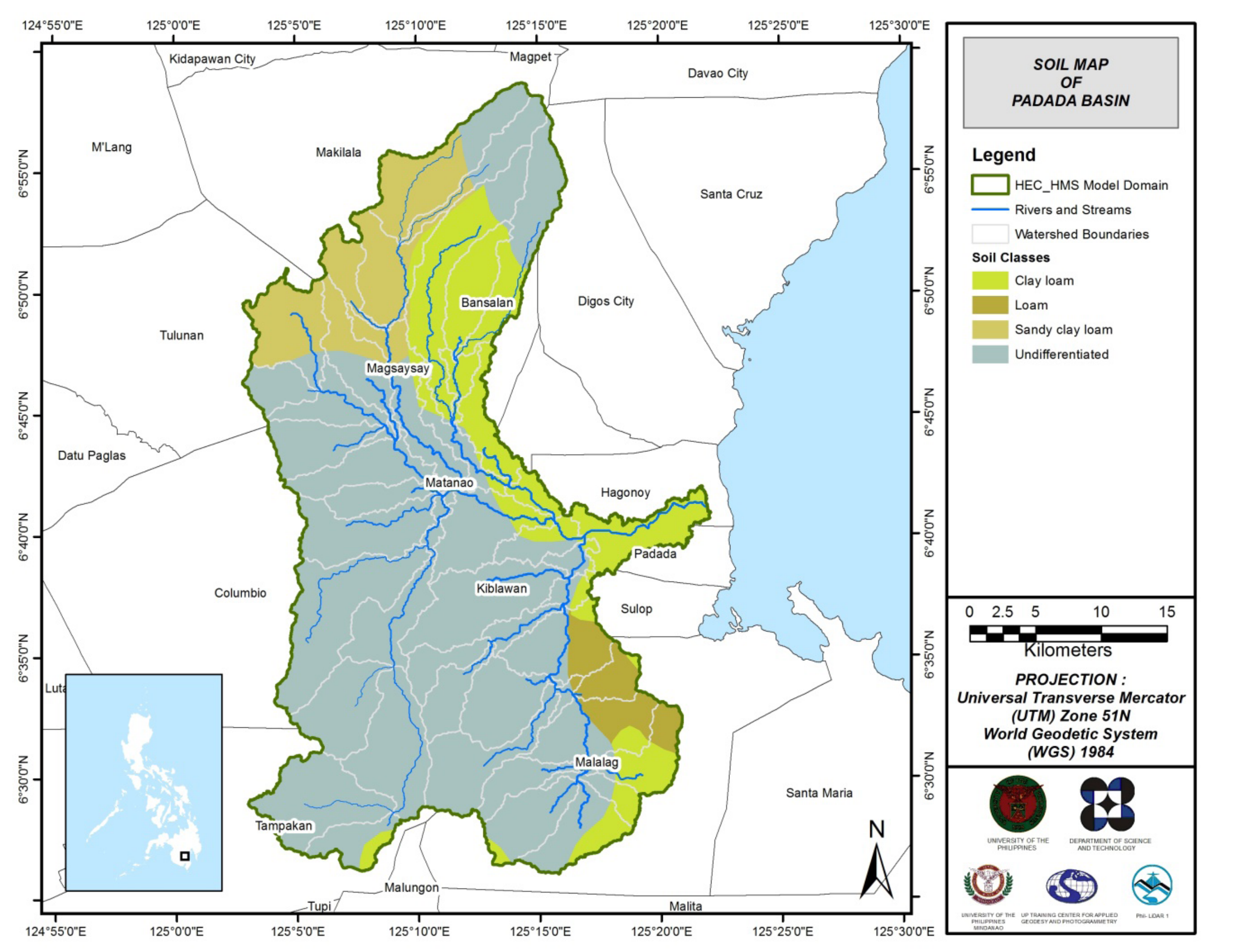


Figure 52. Soil Map of Padada River Basin (Source: NAMRIA)

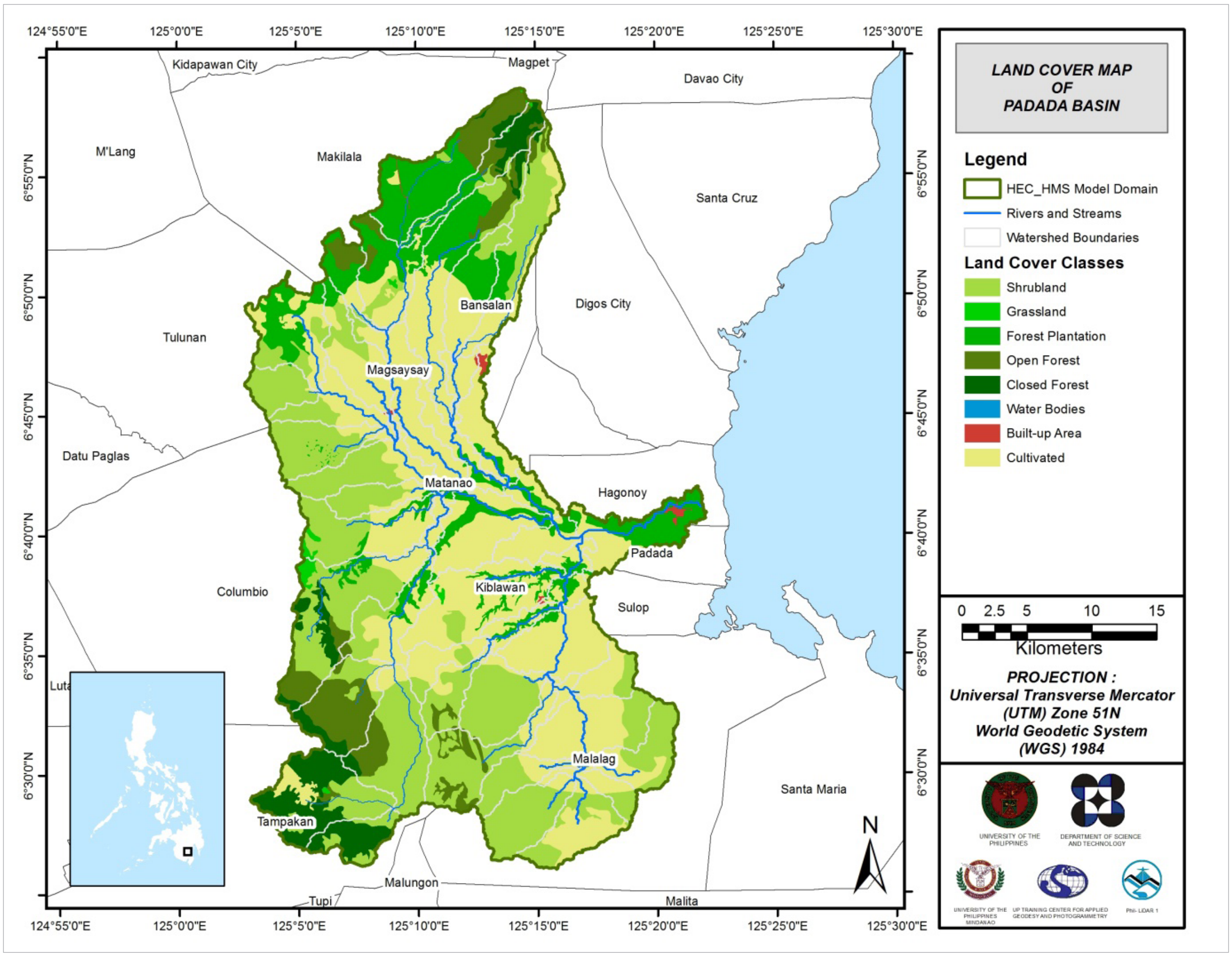


Figure 53. Land Cover Map of Padada River Basin (Source: NAMRIA)

For Padada, four soil classes were identified. These are loam, clay loam, silty clay loam and undifferentiated land. Moreover, eight land cover classes were identified. These are shrublands, grasslands, forest plantations, open forests, close forests, water bodies, built-up areas, and cultivated land.

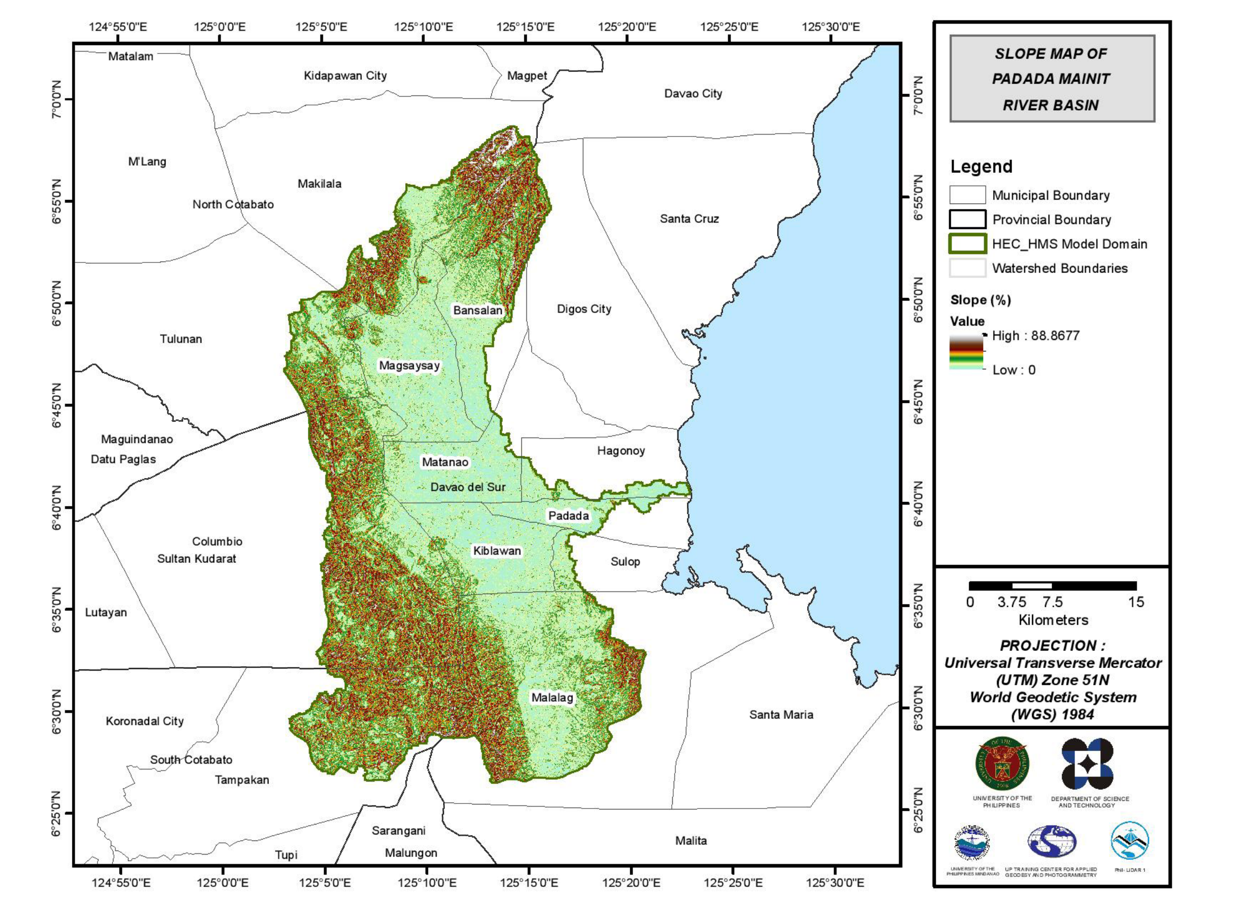


Figure 54. Slope Map of Padada River Basin

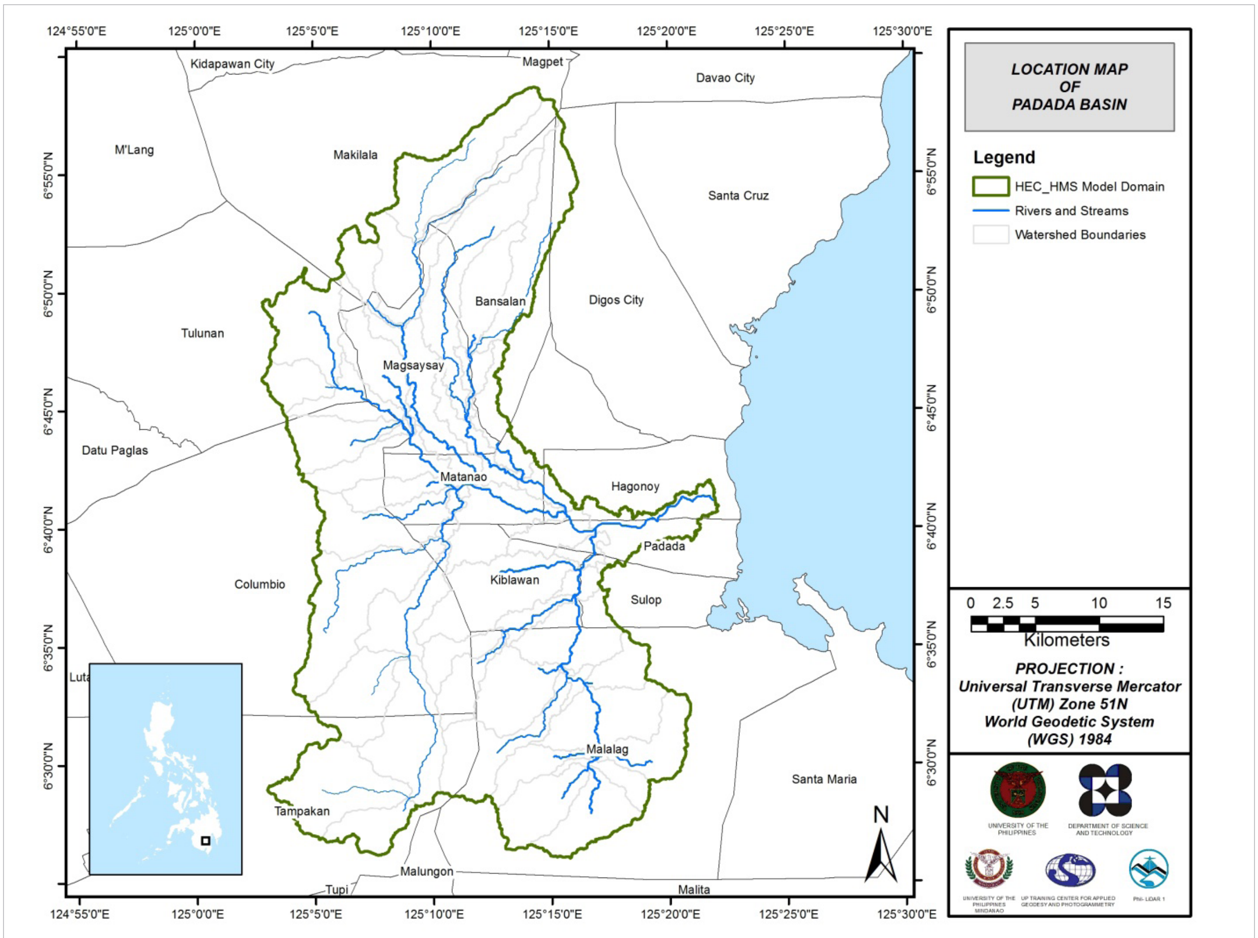


Figure 55. Stream Delineation Map of Padada River Basin

Using the SAR-based DEM, the Padada basin was delineated and further subdivided into subbasins. The model consists of 53 sub basins, 26 reaches, and 26 junctions, as shown in Figure 56. The main outlet is at Tologan Bridge.

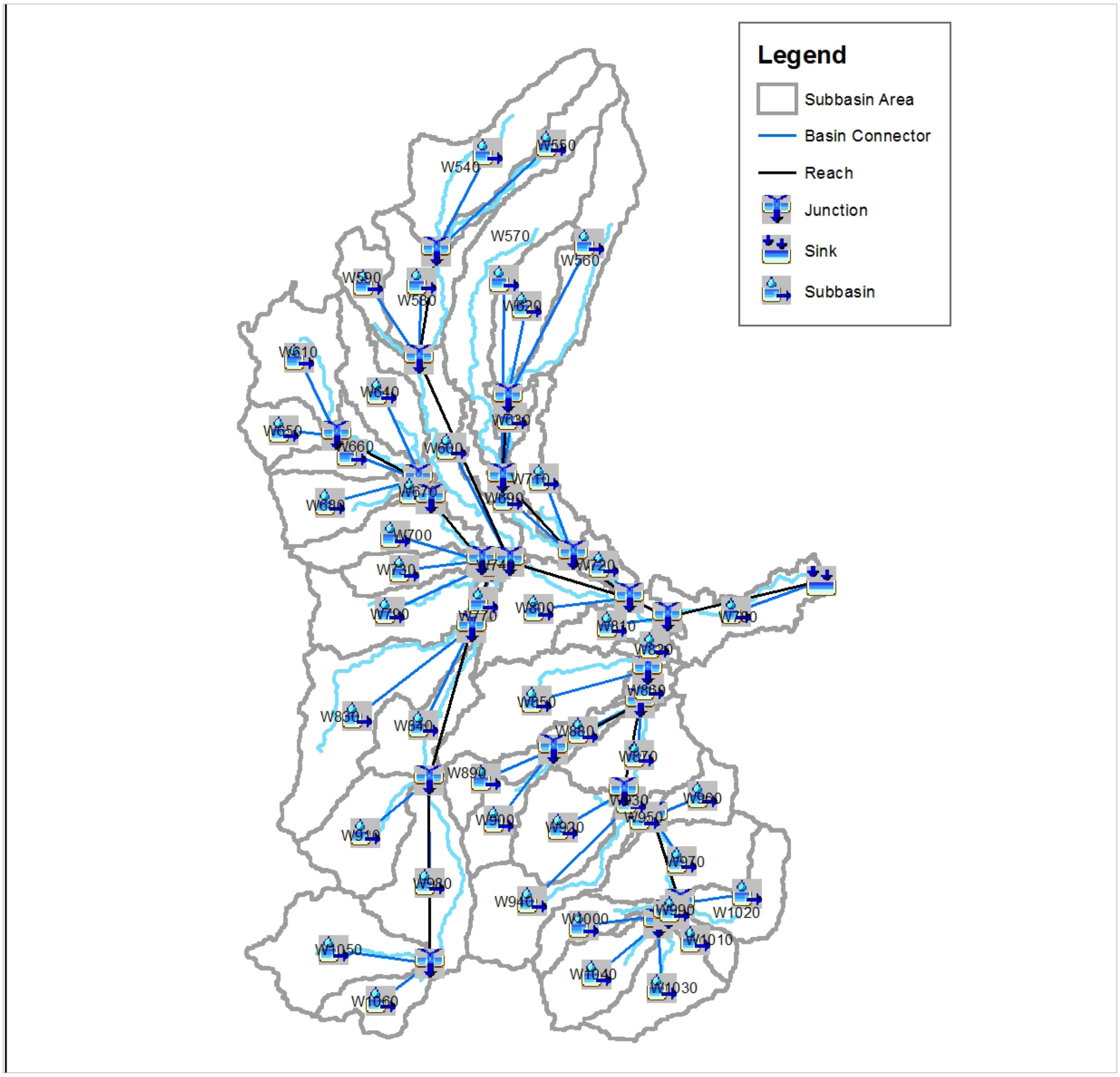


Figure 56. The Padada river basin model generated using HEC-HMS.

5.4 Cross-Section Data

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

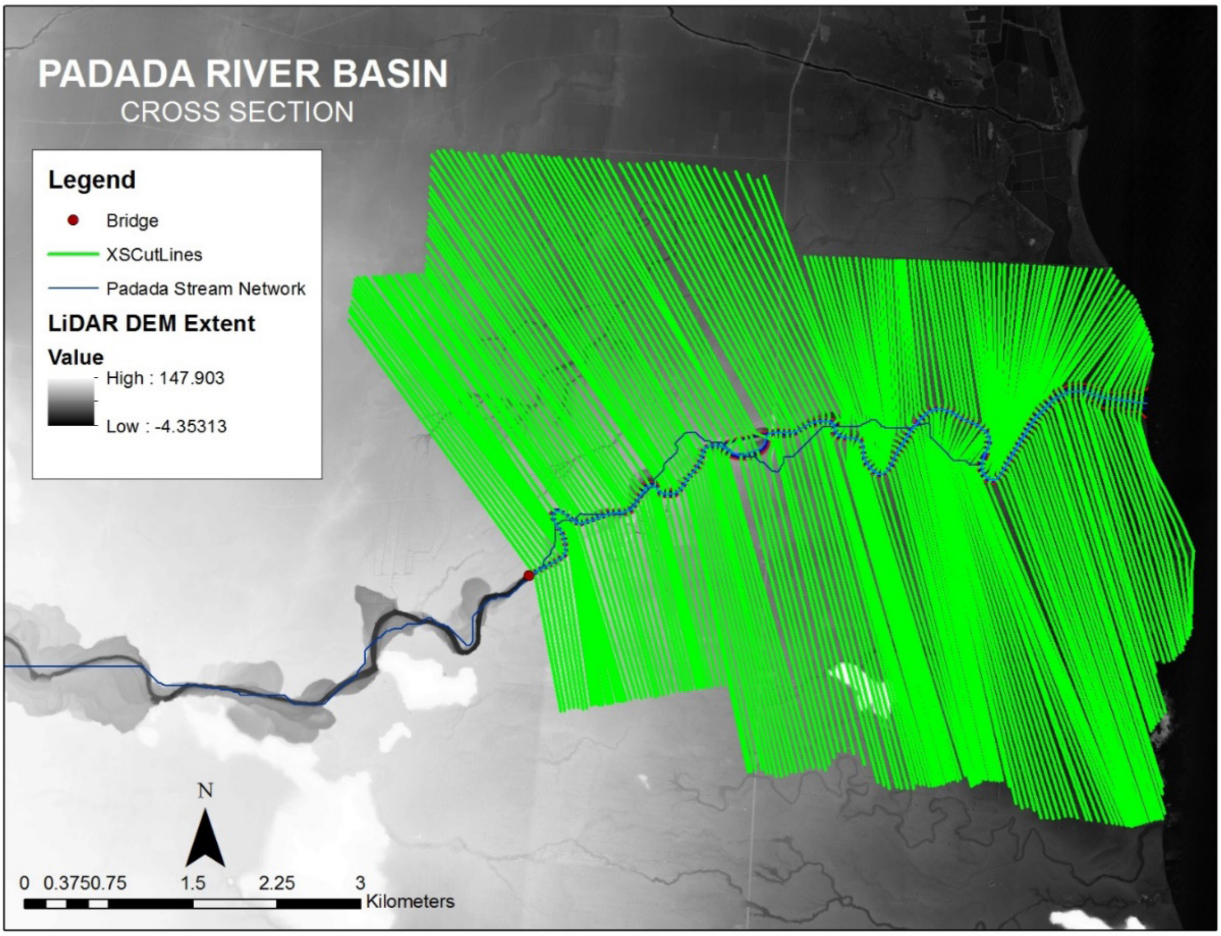


Figure 57. River cross-section of Padada River generated through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

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

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

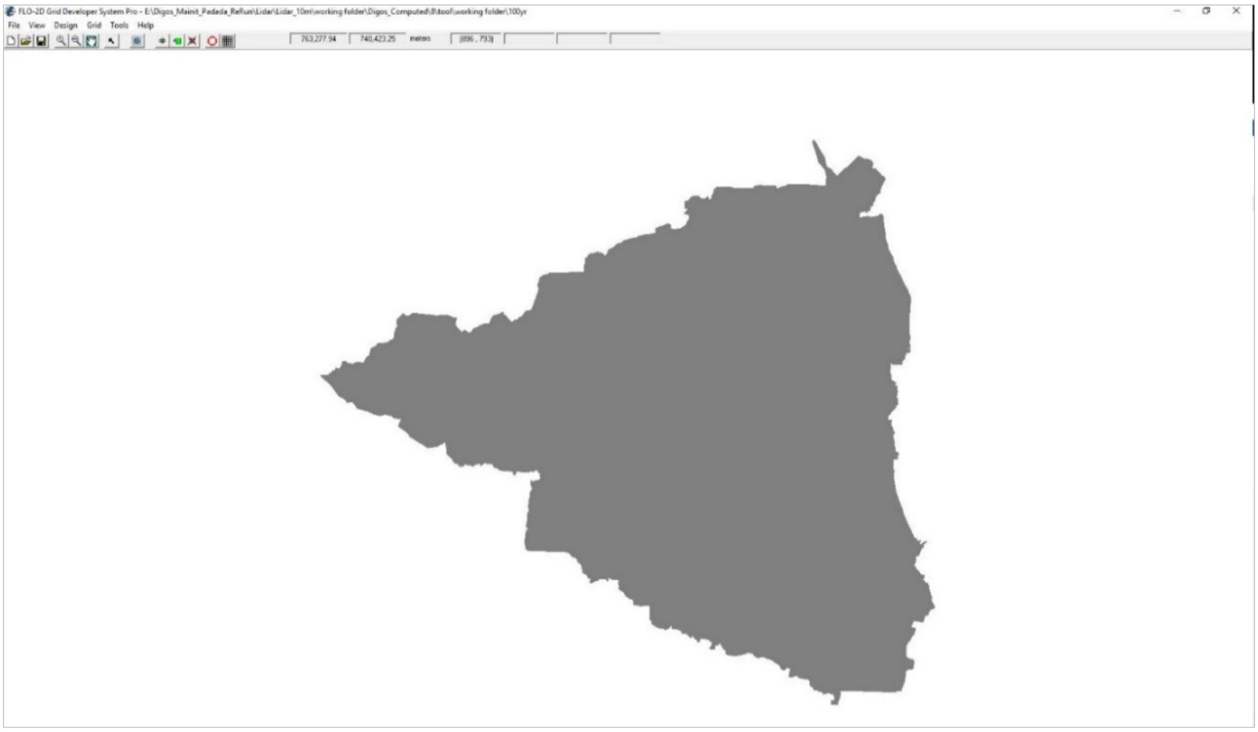


Figure 58. A screenshot of the river subcatchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro)

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 58.36890 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m^2/s. The generated hazard maps for Padada are in Figures 72, 74, and 76.

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 43894900.00 m^2. The generated flood depth maps for Padada are in Figures 73, 75, and 77.

There is a total of 34088534.89 m^3 of water entering the model. Of this amount, 15257043.87 m^3 is due to rainfall while 18831491.02 m^3 is inflow from other areas outside the model. 6156764.50 m^3 of this water is lost to infiltration and interception, while 19224428.46 m^3 is stored by the flood plain. The rest, amounting up to 8707324.78 m^3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Padada HEC-HMS river basin model, its accuracy was measured against the observed values. The Padada Model Basin Parameters are on ANNEX 9. Figure 59 shows the comparison between the two discharge data.

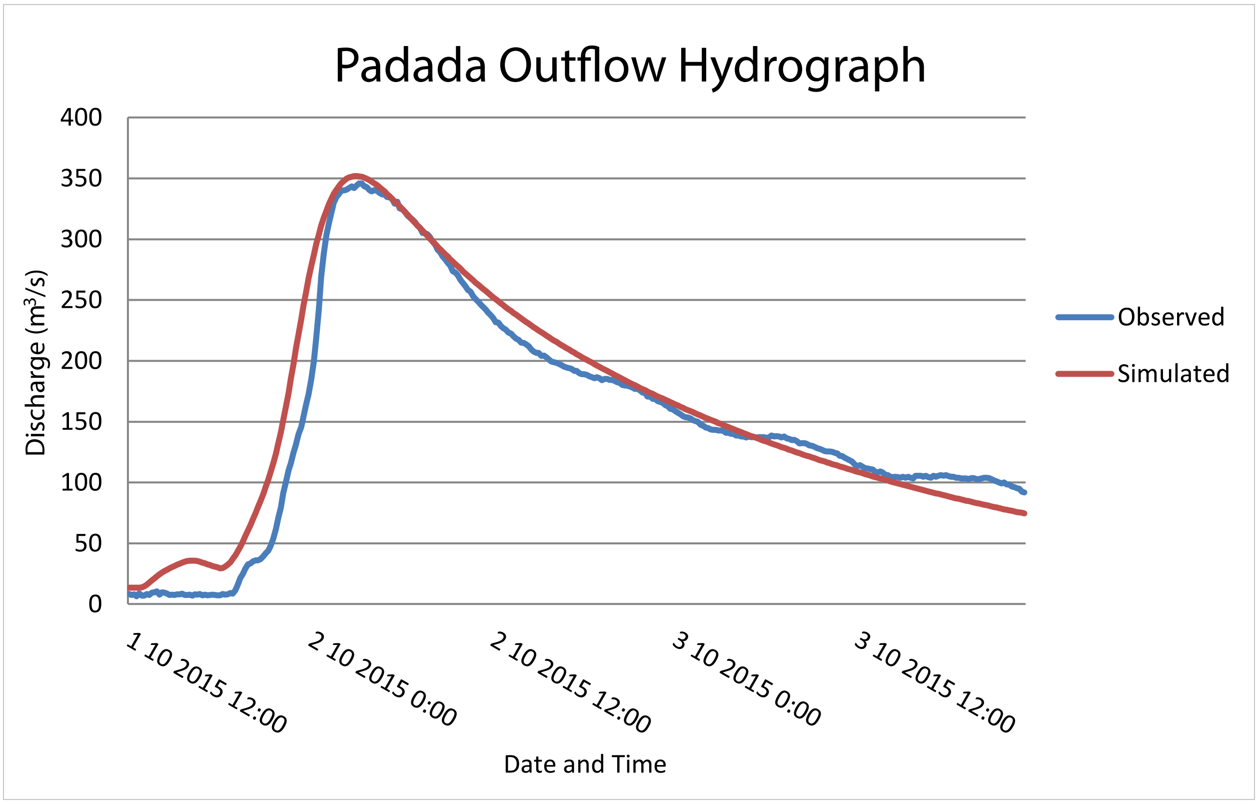


Figure 59. Outflow Hydrograph of Padada produced by the HEC-HMS model compared with observed outflow

Enumerated in Table 26 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 26. Range of Calibrated Values for Padada

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve Number	Initial Abstraction (mm)	0.0048 – 0.014
			Curve Number	80.5 - 99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	1.937 – 22.848
			Storage Coefficient (hr)	0.0656 – 0.764
	Baseflow	Recession	Recession Constant	0.4
			Ratio to Peak	0.402 – 0.8
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.1

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 0.0048 mm to 0.014 mm means that there is a very small initial fraction of the storm depth after which runoff begins, increasing the river outflow.

The curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 65 to 90 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For Padada, the basin consists mainly of brushlands, built-up areas, forests, inland water, and cultivated areas and the soil consists of mostly undifferentiated land, loam, and clay loam.

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.0656 hours to 22.848 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.4 indicates that the basin will go back relatively quickly to is original discharge. Ratio to peak values of 0.402 – 0.8 indicate an average receding limb of the outflow hydrograph.

Manning's roughness coefficients correspond to the common roughness of Philippine watersheds. Padada river basin reaches' Manning's coefficient is 0.1, showing that the catchment is mostly filled with floodplains with trees (Brunner, 2010).

Table 27. Summary of the Efficiency Test of Padada HMS Model

Root Mean Square Error (RMSE)	23.3
Pearson Correlation Coefficient (r^2)	0.949
Nash-Sutcliffe (E)	0.94
Percent Bias (PBIAS)	-5.35
Observation Standard Deviation Ratio (RSR)	0.25

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 23.3 m^3/s.

The Pearson correlation coefficient (r^2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.949.

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 -5.35.

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 0.25.

5.7 Calculated Outflow Hydrographs and Discharge Values for Different Rainfall Return Models

5.7.1 Hydrograph Using the Rainfall Runoff Model

The summary graph in Figure 60 shows the Padada outflow using the Davao Rainfall Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

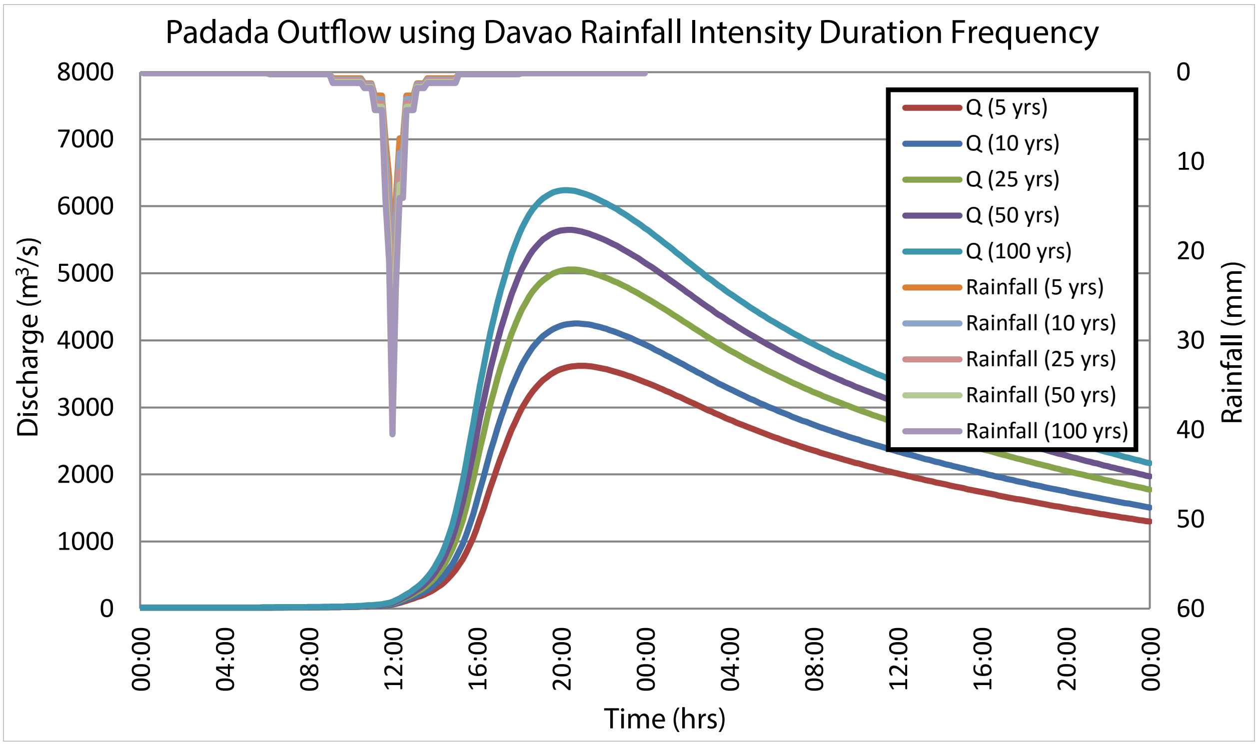


Figure 60. Outflow hydrograph at Padada Station generated using the Davao RIDF simulated in HEC-HMS.

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Padada discharge using the Davao Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 28.

Table 28. Peak values of the Padada HEC-HMS Model outflow using the Davao RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m^3/s)	Time to Peak	Lag Time
5-yr	121.1	25.1	3621.4	9 hours	10 minutes
10-yr	140.7	28.8	4253	8 hours, 40 minutes	10 minutes
25-yr	165.5	33.5	5057.1	8 hours, 30 minutes	10 minutes
50-yr	183.9	37	5647.2	8 hours, 20 minutes	10 minutes
100-yr	202.1	40.5	6241.2	8 hours, 10 minutes	10 minutes

5.7.2 Discharge Data Using Dr. Horritt's Recommended Hydrologic Method

The river discharge values for the three rivers entering the floodplain are shown in Figure 61 to Figure 70 and the peak values are summarized in Table 29 to Table 38.

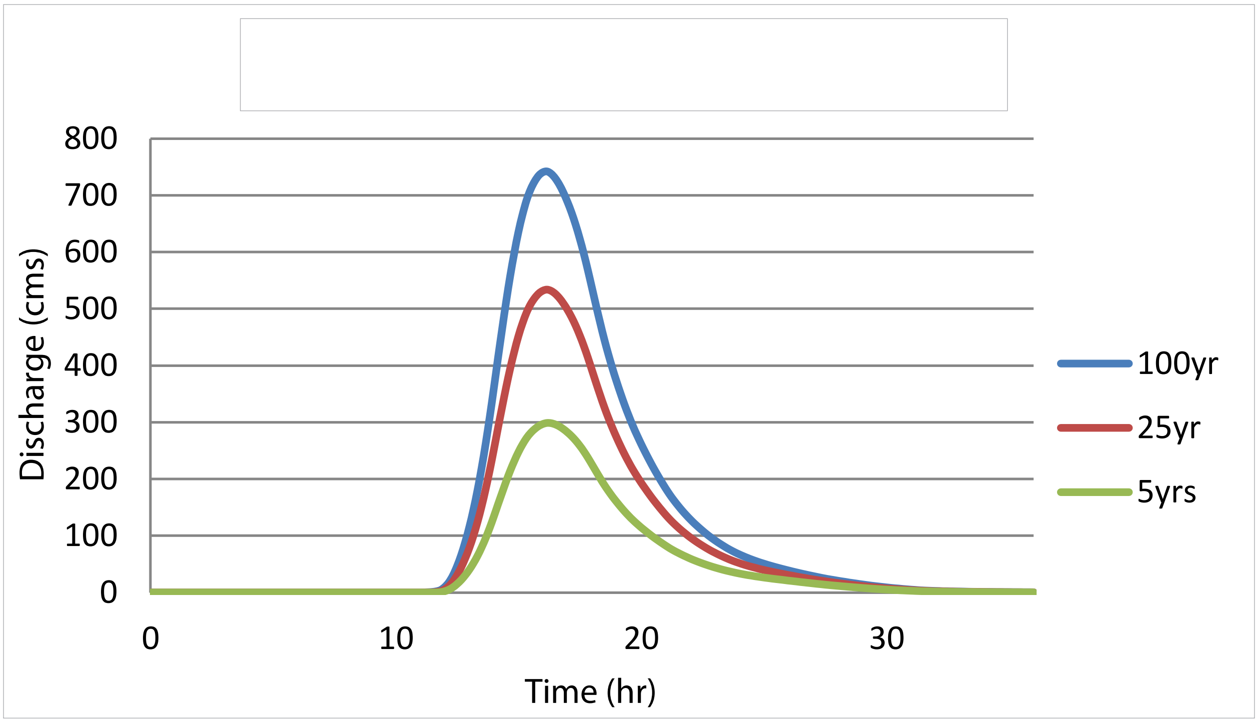


Figure 61. Digos Padada-Mainit river (1) generated discharge using 5-, 25-, and 100-year GenSan rainfall intensity-duration-frequency (RIDF) in HEC-HMS

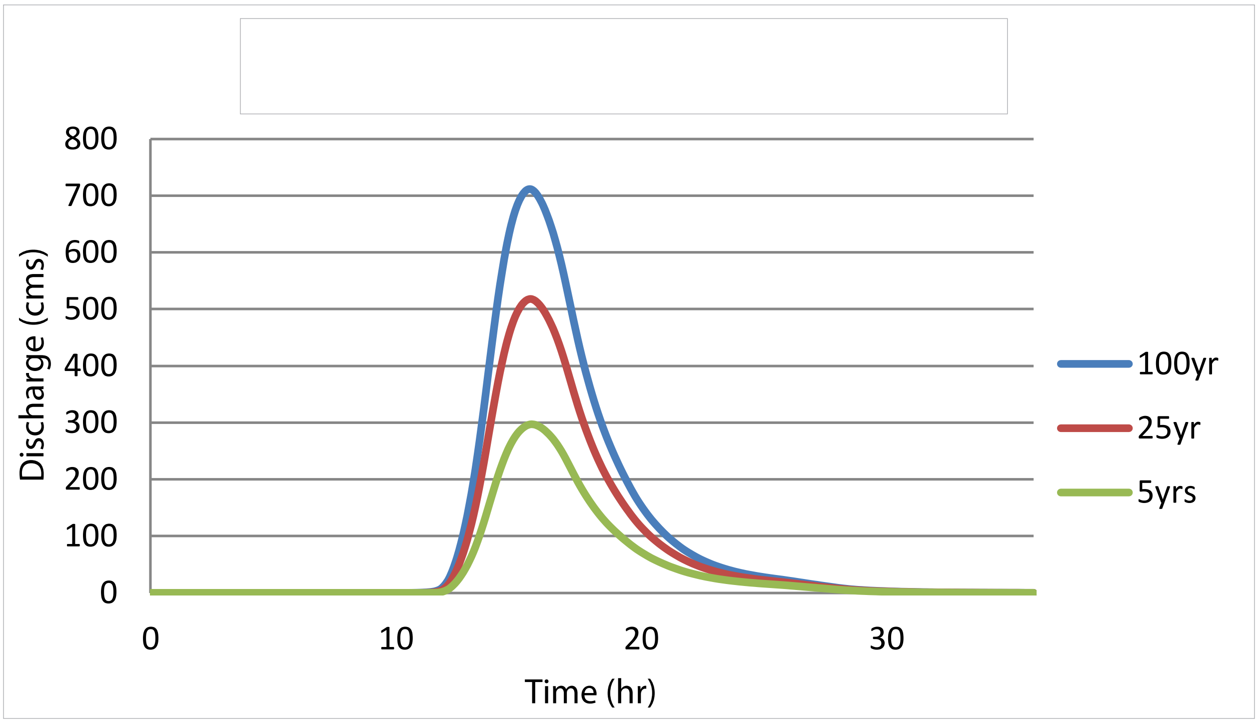


Figure 62. Digos Padada-Mainit river (2) generated discharge using 5-, 25-, and 100-year GenSan rainfall intensity-duration-frequency (RIDF) in HEC-HMS

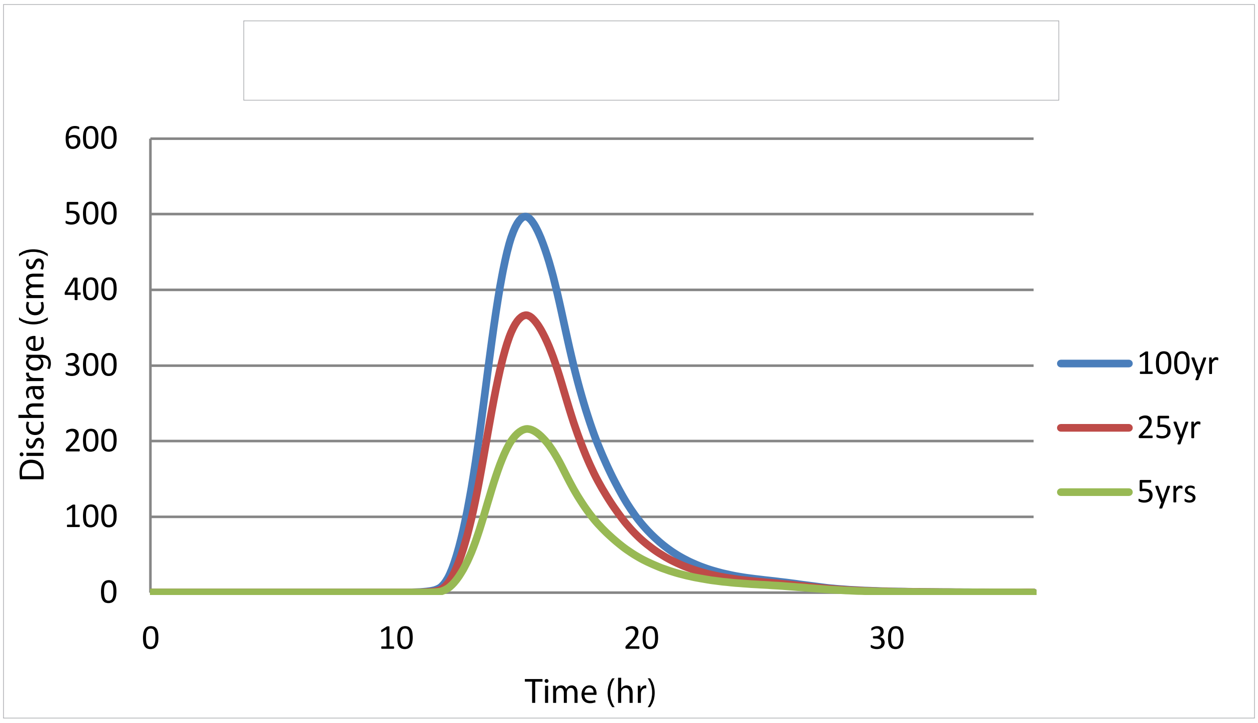


Figure 63. Digos Padada-Mainit river (3) generated discharge using 5-, 25-, and 100-year GenSan rainfall intensity-duration-frequency (RIDF) in HEC-HMS

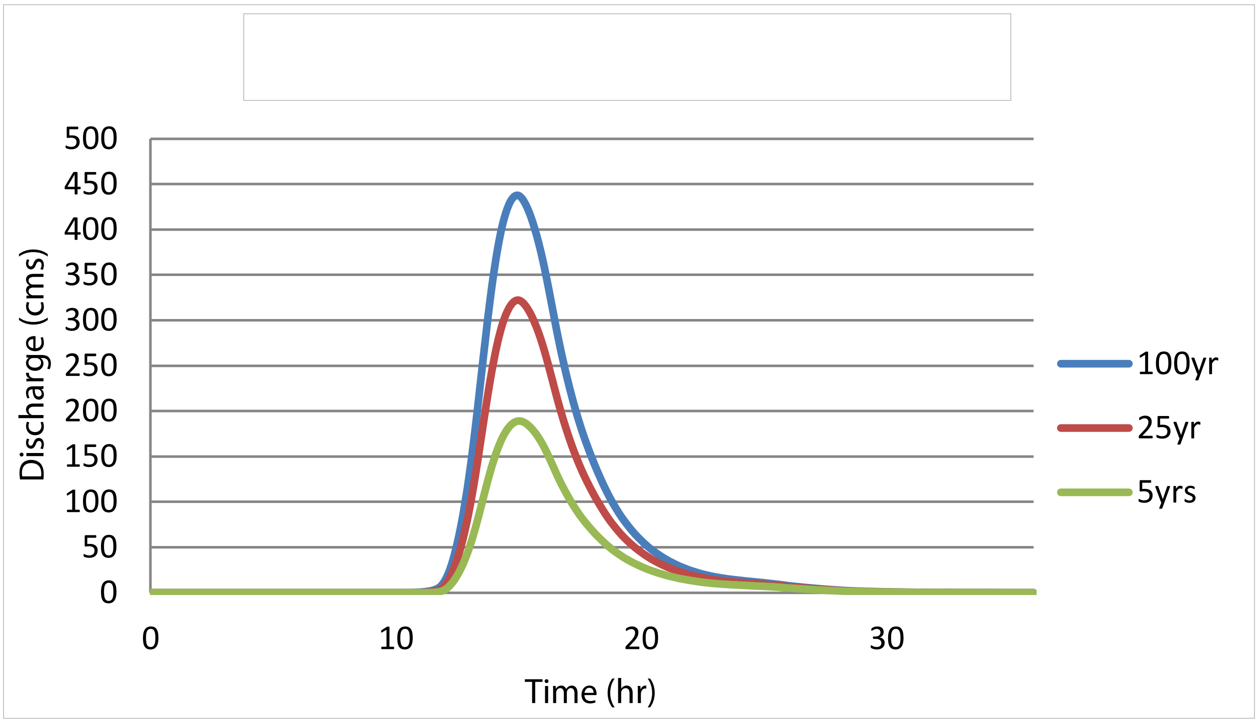


Figure 64. Digos Padada-Mainit river (4) generated discharge using 5-, 25-, and 100-year GenSan rainfall intensity-duration-frequency (RIDF) in HEC-HMS

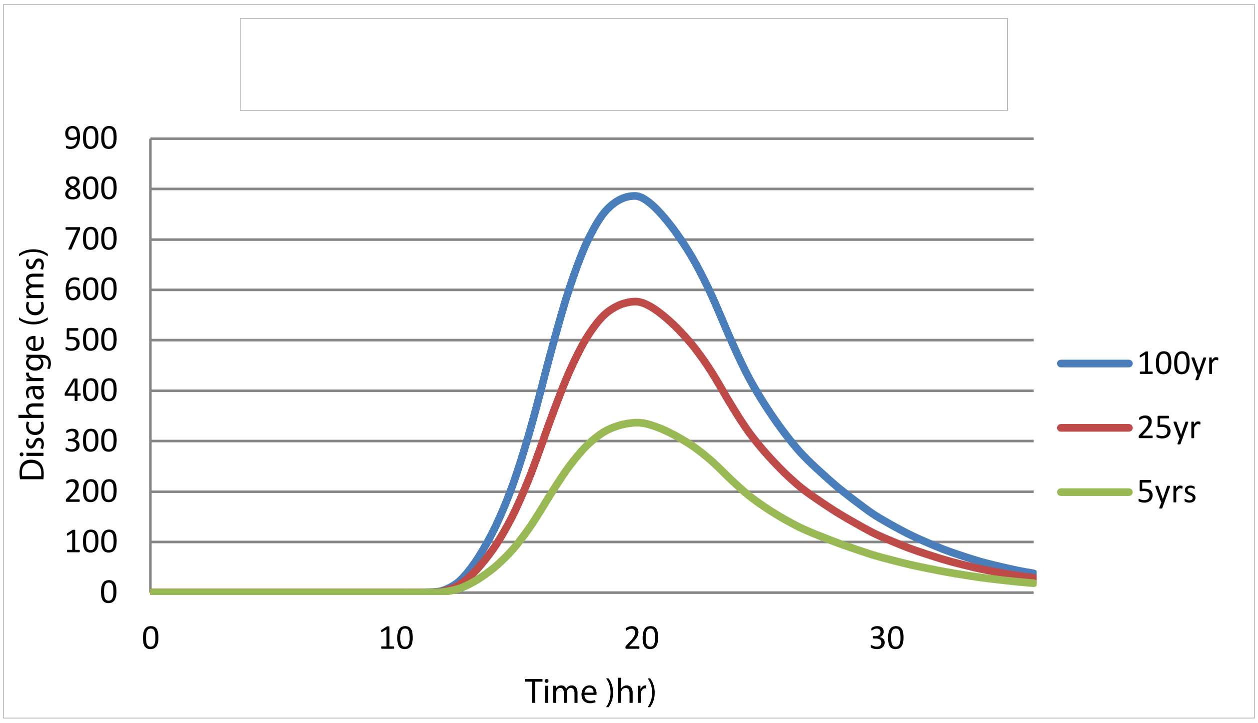


Figure 65. Digos Padada-Mainit river (5) generated discharge using 5-, 25-, and 100-year GenSan rainfall intensity-duration-frequency (RIDF) in HEC-HMS

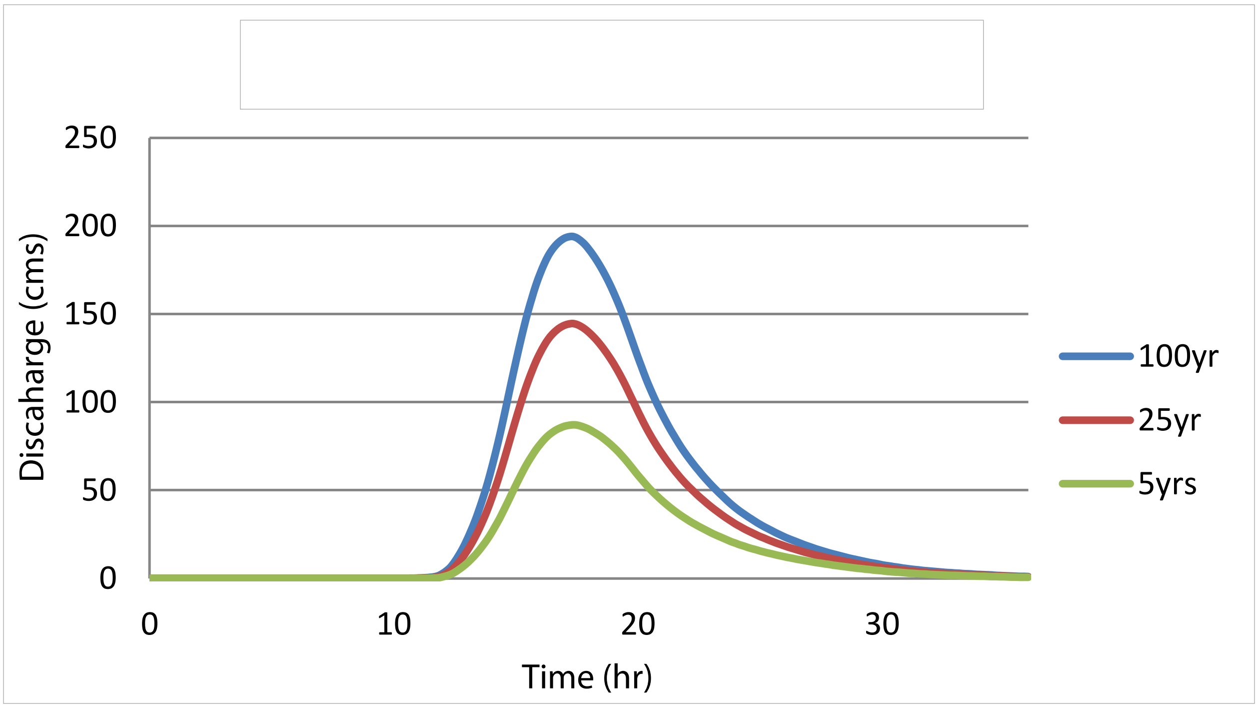


Figure 66. Digos Padada-Mainit river (6) generated discharge using 5-, 25-, and 100-year GenSan rainfall intensity-duration-frequency (RIDF) in HEC-HMS

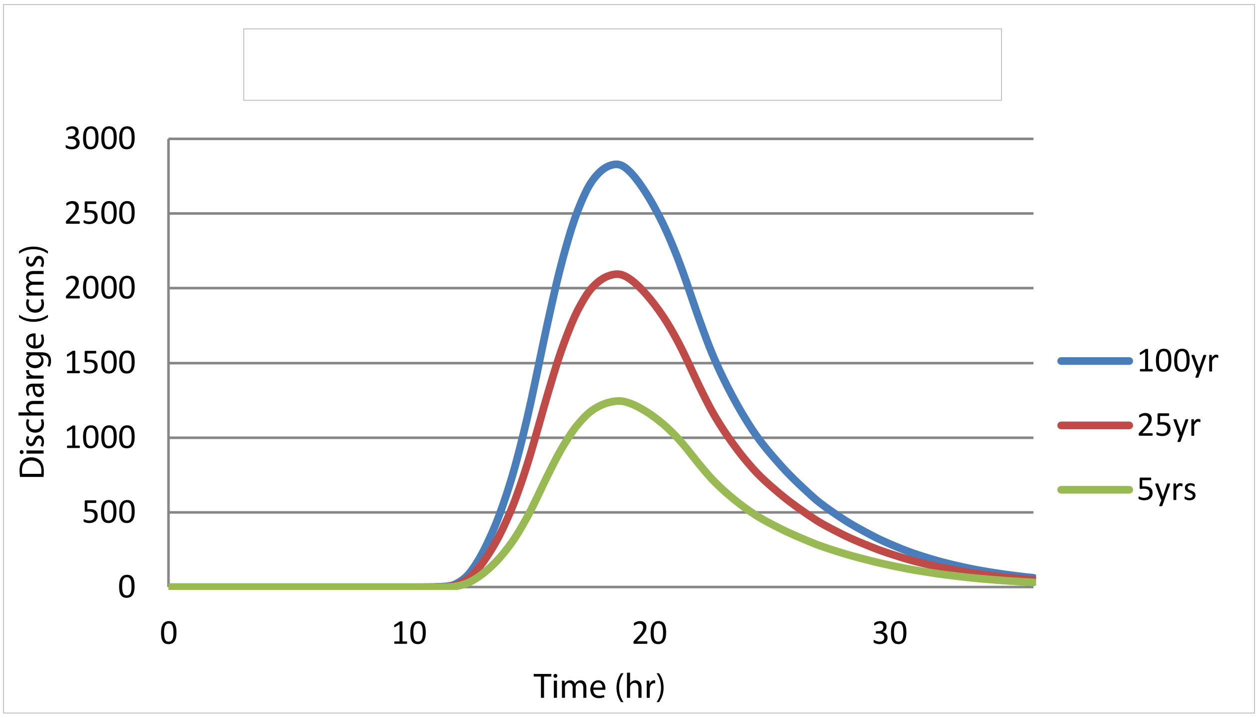


Figure 67. Digos Padada-Mainit river (7) generated discharge using 5-, 25-, and 100-year GenSan rainfall intensity-duration-frequency (RIDF) in HEC-HMS

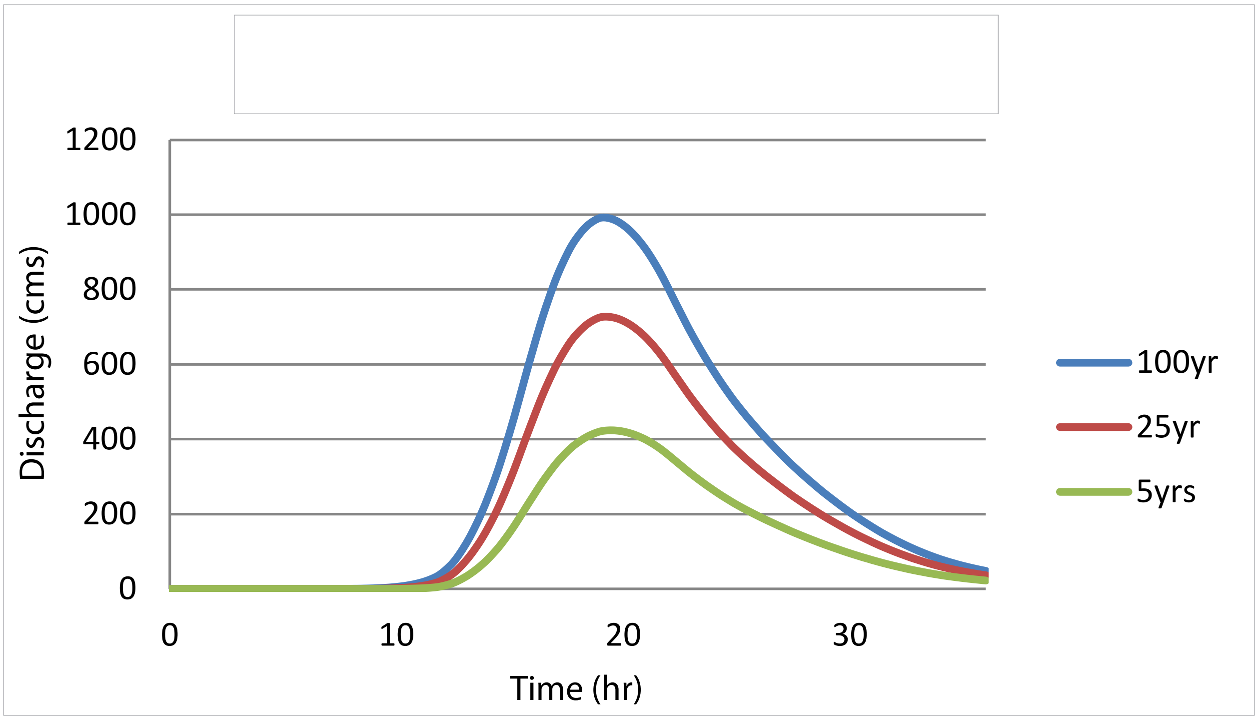


Figure 68. Digos Padada-Mainit river (8) generated discharge using 5-, 25-, and 100-year GenSan rainfall intensity-duration-frequency (RIDF) in HEC-HMS

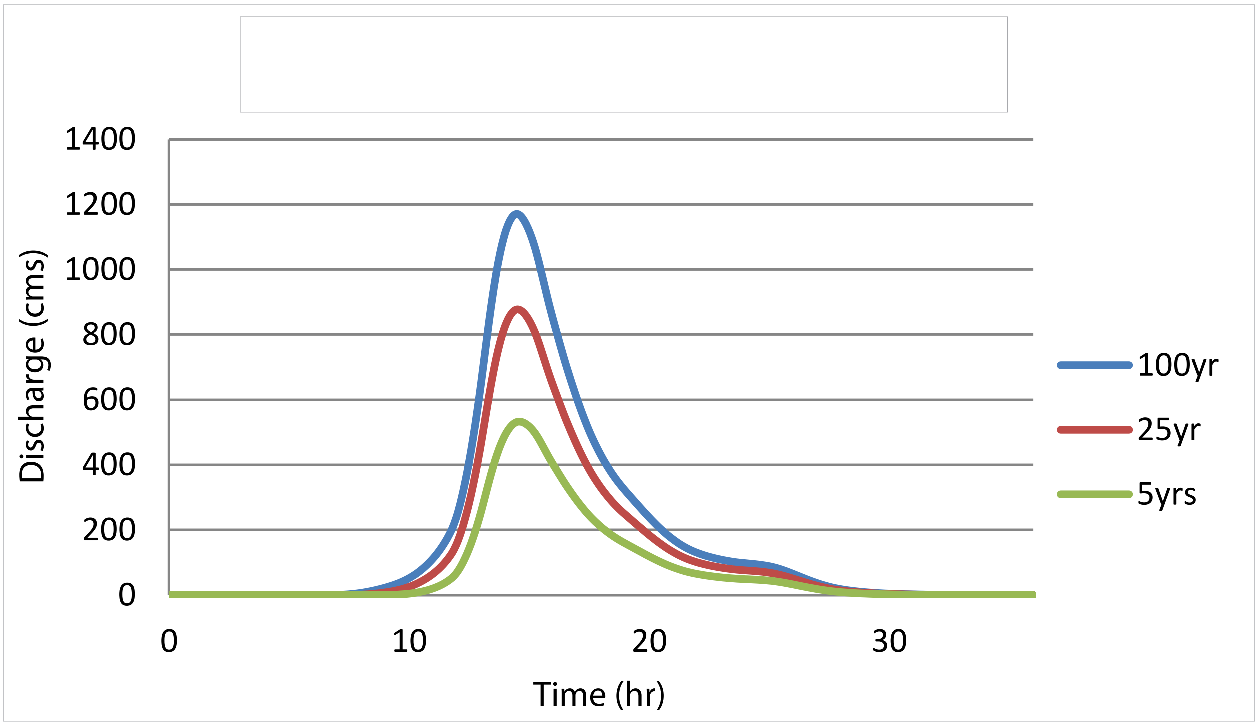


Figure 69. Digos Padada-Mainit river (9) generated discharge using 5-, 25-, and 100-year GenSan rainfall intensity-duration-frequency (RIDF) in HEC-HMS

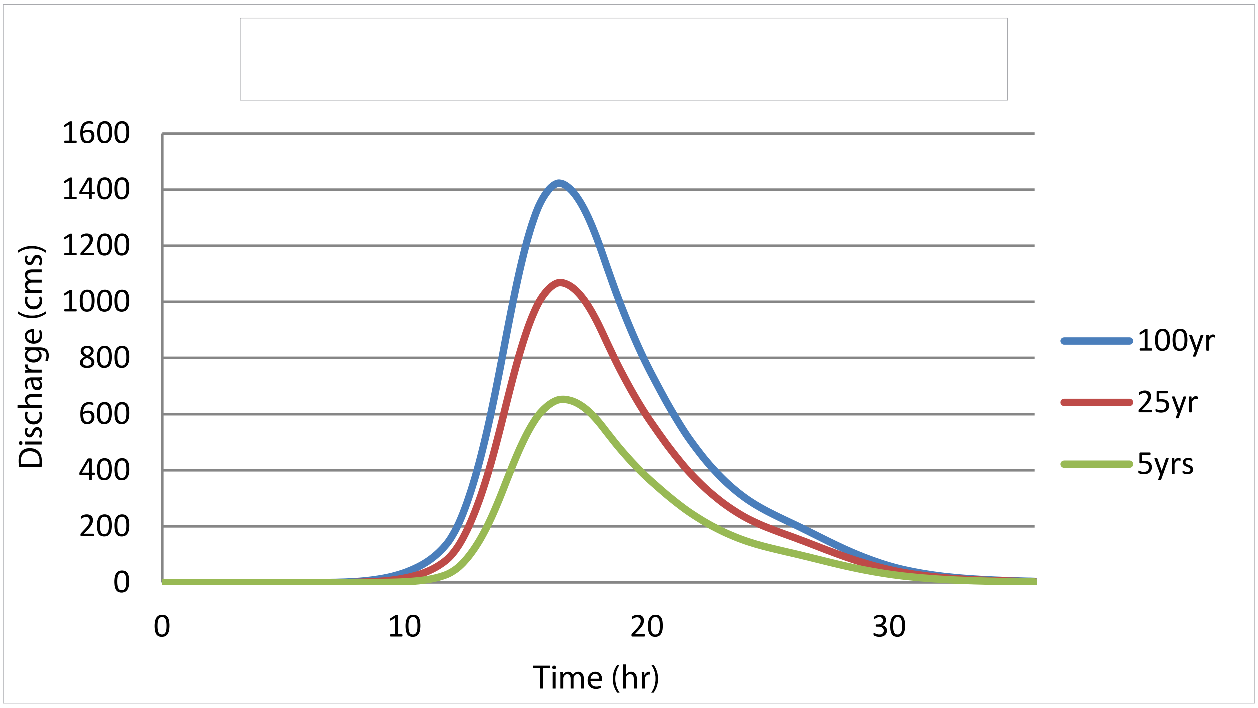


Figure 70. Digos Padada-Mainit river (10) generated discharge using 5-, 25-, and 100-year GenSan rainfall intensity-duration-frequency (RIDF) in HEC-HMS

Table 29. Summary of Digos Padada-Mainit river (1) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	742.1	16 hours, 10 minutes
25-Year	533.8	16 hours, 10 minutes
5-Year	298.8	16 hours, 10 minutes

Table 30. Summary of Digos Padada-Mainit river (2) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	711.4	15 hours, 30 minutes
25-Year	517.9	15 hours, 30 minutes
5-Year	297.0	15 hours, 30 minutes

Table 31. Summary of Digos Padada-Mainit river (3) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	496.6	15 hours, 20 minutes
25-Year	366.5	15 hours, 20 minutes
5-Year	216.1	15 hours, 20 minutes

Table 32. Summary of Digos Padada-Mainit river (4) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	437.5	15 hours
25-Year	322.2	15 hours
5-Year	189.1	15 hours

Table 33. Summary of Digos Padada-Mainit river (5) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	786.1	19 hours, 40 minutes
25-Year	576.6	19 hours, 50 minutes
5-Year	336.7	19 hours, 50 minutes

Table 34. Summary of Digos Padada-Mainit river (6) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	194.0	17 hours, 20 minutes
25-Year	144.6	17 hours, 20 minutes
5-Year	87.1	17 hours, 20 minutes

Table 35. Summary of Digos Padada-Mainit river (7) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	2828.5	18 hours, 40 minutes
25-Year	2094.0	18 hours, 40 minutes
5-Year	1245.1	18 hours, 40 minutes

Table 36. Summary of Digos Padada-Mainit river (8) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	992.5	19 hours, 10 minutes
25-Year	727.4	19 hours, 10 minutes
5-Year	423.7	19 hours, 10 minutes

Table 37. Summary of Digos Padada-Mainit river (9) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	1170.7	14 hours, 30 minutes
25-Year	877.5	14 hours, 30 minutes
5-Year	532.2	14 hours, 40 minutes

Table 38. Summary of Digos Padada-Mainit river (10) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	1422.6	16 hours, 20 minutes
25-Year	1068.2	16 hours, 30 minutes
5-Year	652.6	16 hours, 30 minutes

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

Table 39. Validation of river discharge estimates

Discharge Point	$Q_{MED(SCS)}$, cms	$Q_{BANKFUL}$, cms	$Q_{MED(SPEC)}$, cms	VALIDATION	
				Bankful Discharge	Specific Discharge
Digos Padada-Mainit (1)	174.416	124.630	259.924	Pass	Pass
Digos Padada-Mainit (2)	261.360	505.830	221.683	Pass	Pass
Digos Padada-Mainit (3)	190.168	203.899	162.377	Pass	Pass
Digos Padada-Mainit (4)	166.408	151.237	140.196	Pass	Pass
Digos Padada-Mainit (5)	296.296	731.433	36743.401	Fail	Fail
Digos Padada-Mainit (6)	76.648	76.674	107.938	Pass	Pass
Digos Padada-Mainit (7)	1095.688	1309.632	690.353	Pass	Fail
Digos Padada-Mainit (8)	372.856	15.040	447.020	Fail	Pass
Digos Padada-Mainit (9)	468.336	5882.497	312.181	Fail	Fail
Digos Padada-Mainit (10)	574.288	7881.141	430.064	Fail	Pass

Eight out of nine of the results from the HEC-HMS river discharge estimates were able to satisfy the conditions for validation using the bankful and specific discharge methods. One did not pass and will need further recalculation. The eight passing values are based on theory but are supported using other discharge computation methods so they were good to use flood modeling. These values will need further investigation for the purpose of validation. It is therefore recommended to obtain actual values of the river discharges for higher-accuracy modeling.

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. For this publication, only a sample output map river was to be shown. The sample generated map of Padada River using the calibrated HMS base flow is shown in Figure 71.

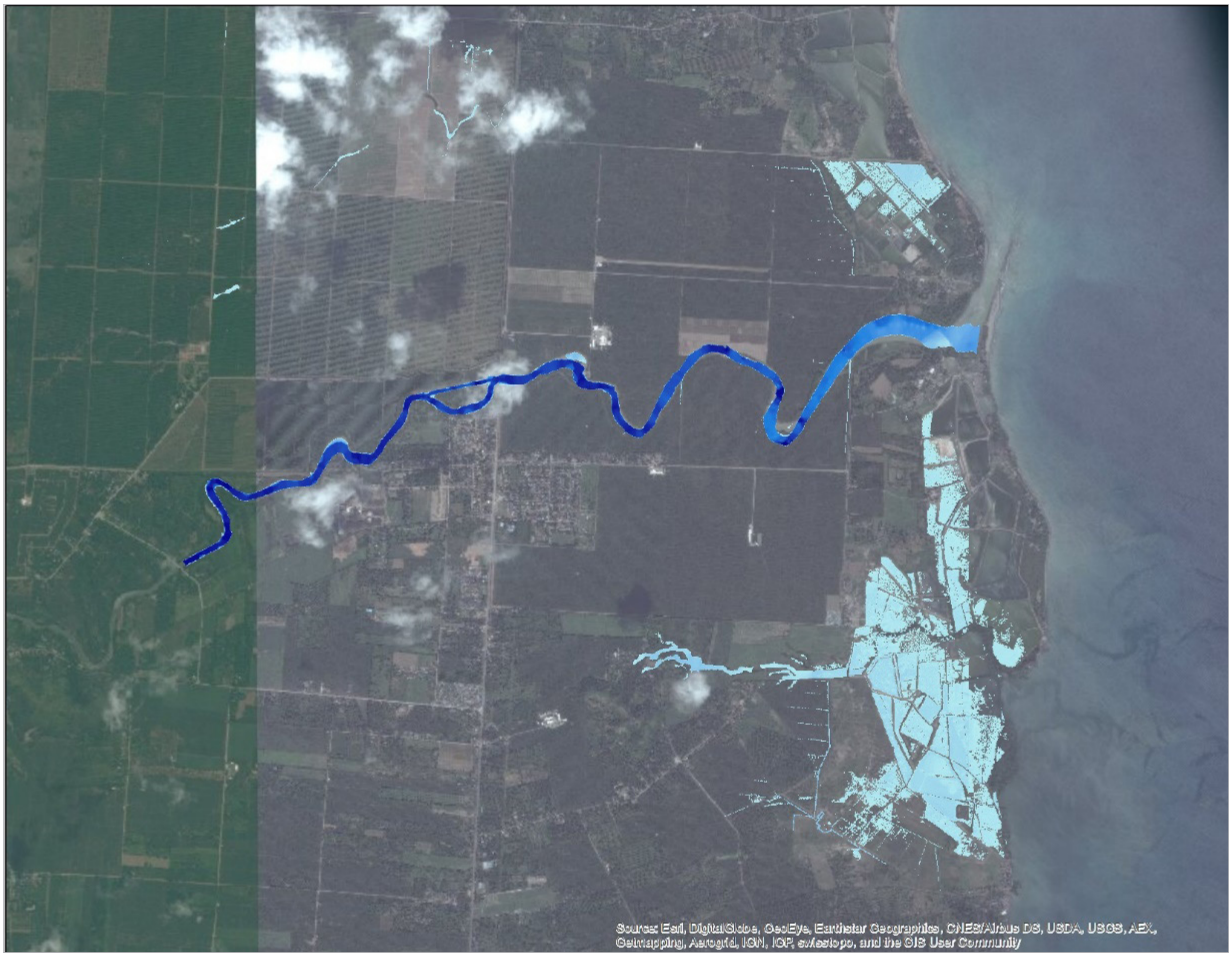


Figure 71. Sample output of Padada RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. The 5-, 25-, and 100-year rain return scenarios of the Padada floodplain are shown in Figures 72 to 77. The floodplain, with an area of 512.4 sq. km., covers 11 municipalities from two provinces. Table 40 shows the percentage of area affected by flooding per municipality.

Table 40. Municipalities affected in Padada floodplain

Province	Municipality	Total Area	Area Flooded	% Flooded
Davao del Sur	Bansalan	136.179	20.2365	14.86%
Davao del Sur	Digos City	226.709	86.3046	38.07%
Davao del Sur	Hagonoy	85.6941	85.5357	99.82%
Davao del Sur	Kiblawan	80.0285	56.3096	70.36%
Davao del Sur	Magsaysay	109.802	0.4289	0.39%
Davao del Sur	Malalag	444.995	64.6711	14.53%
Davao del Sur	Matanao	123.395	80.772	65.46%
Davao del Sur	Padada	55.9731	55.9232	99.91%
Davao del Sur	Santa Cruz	267.54	3.58132	1.34%
Davao del Sur	Sulop	50.7967	50.5043	99.42%
Sultan Kudarat	Columbio	574.067	1.47215	0.26%

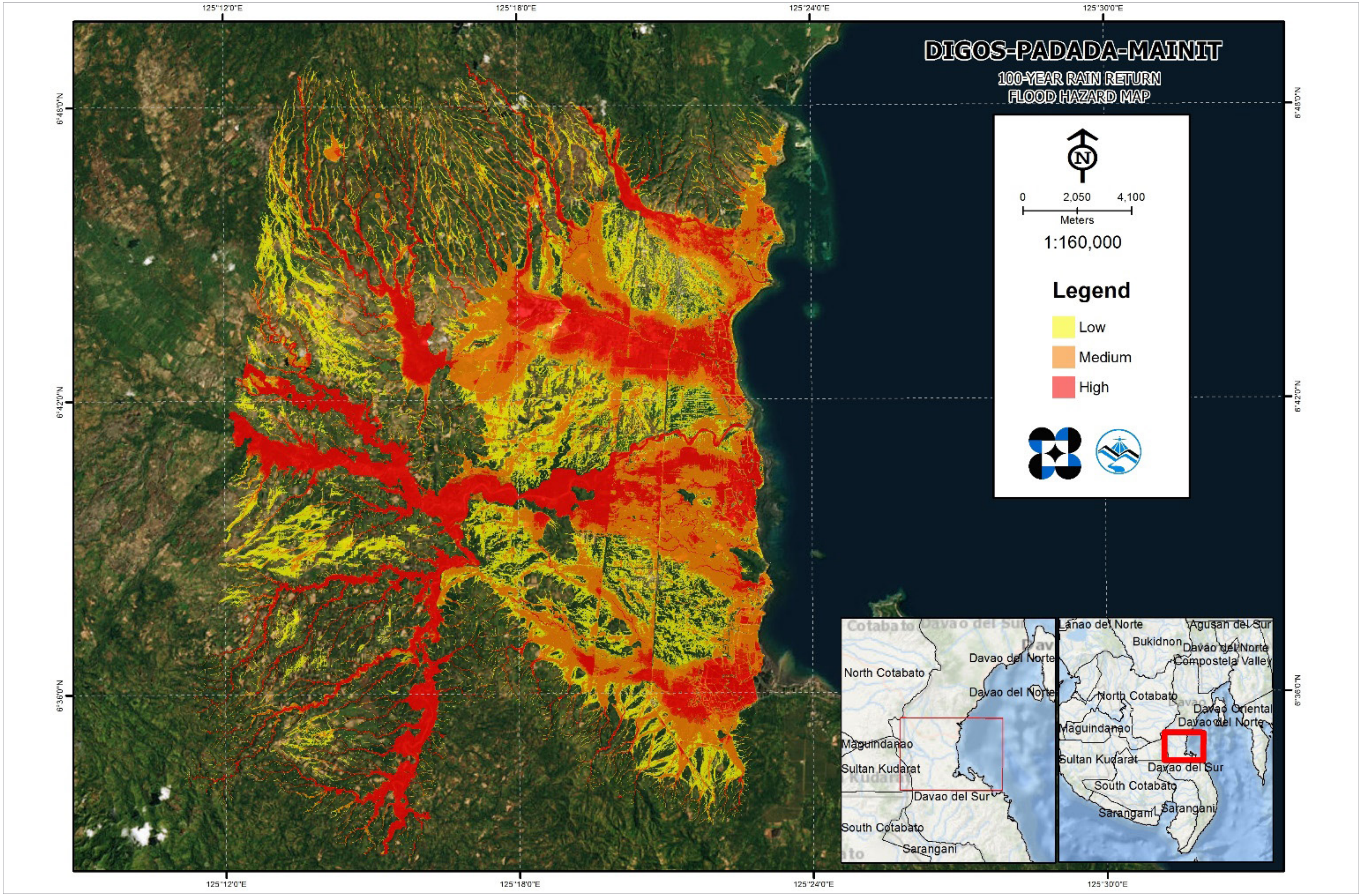


Figure 72. 100-year Flood Hazard Map for Padada Floodplain overlaid on Google Earth imagery

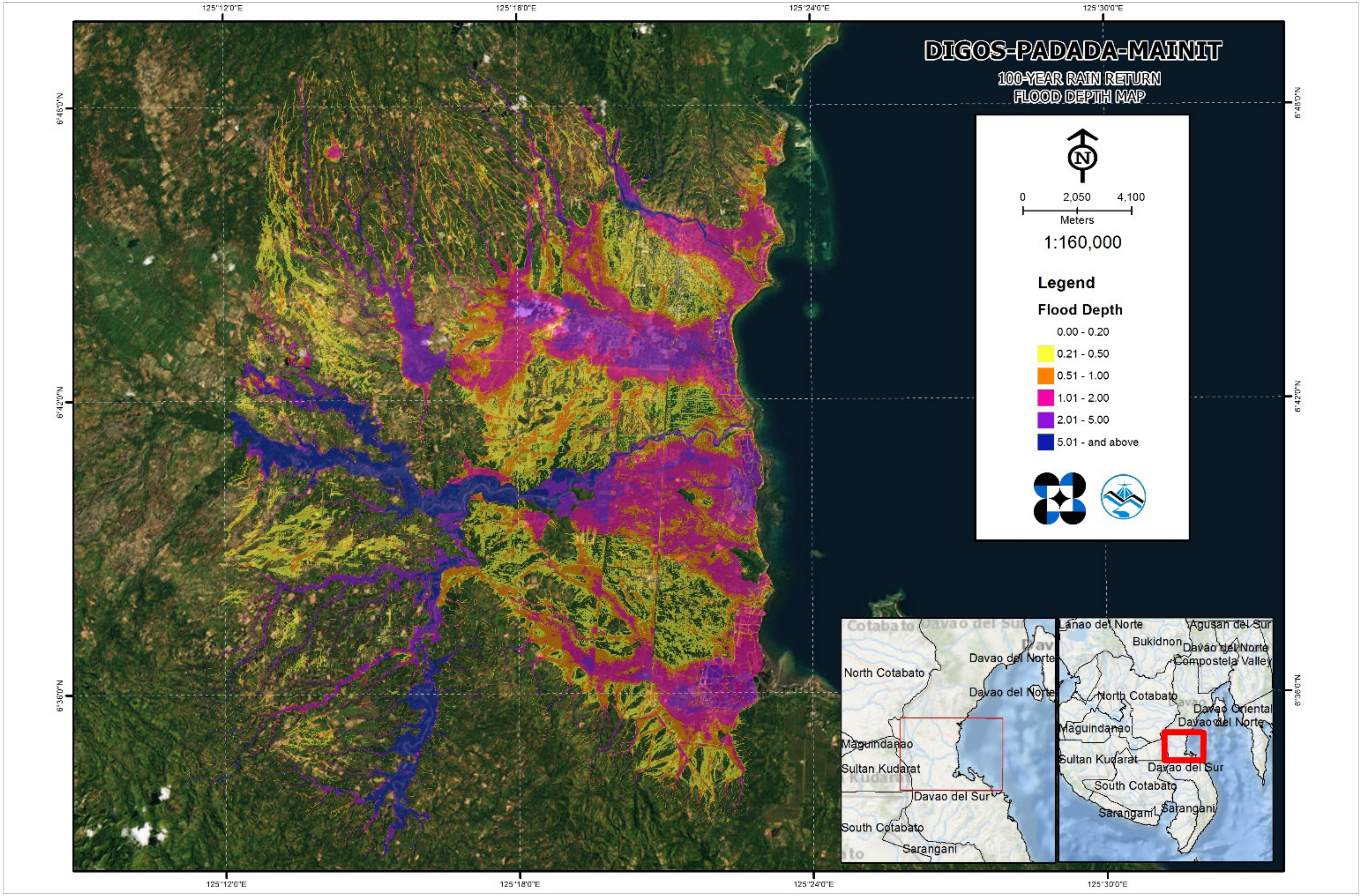


Figure 73. 100-year Flow Depth Map for Padada Floodplain overlaid on Google Earth imagery

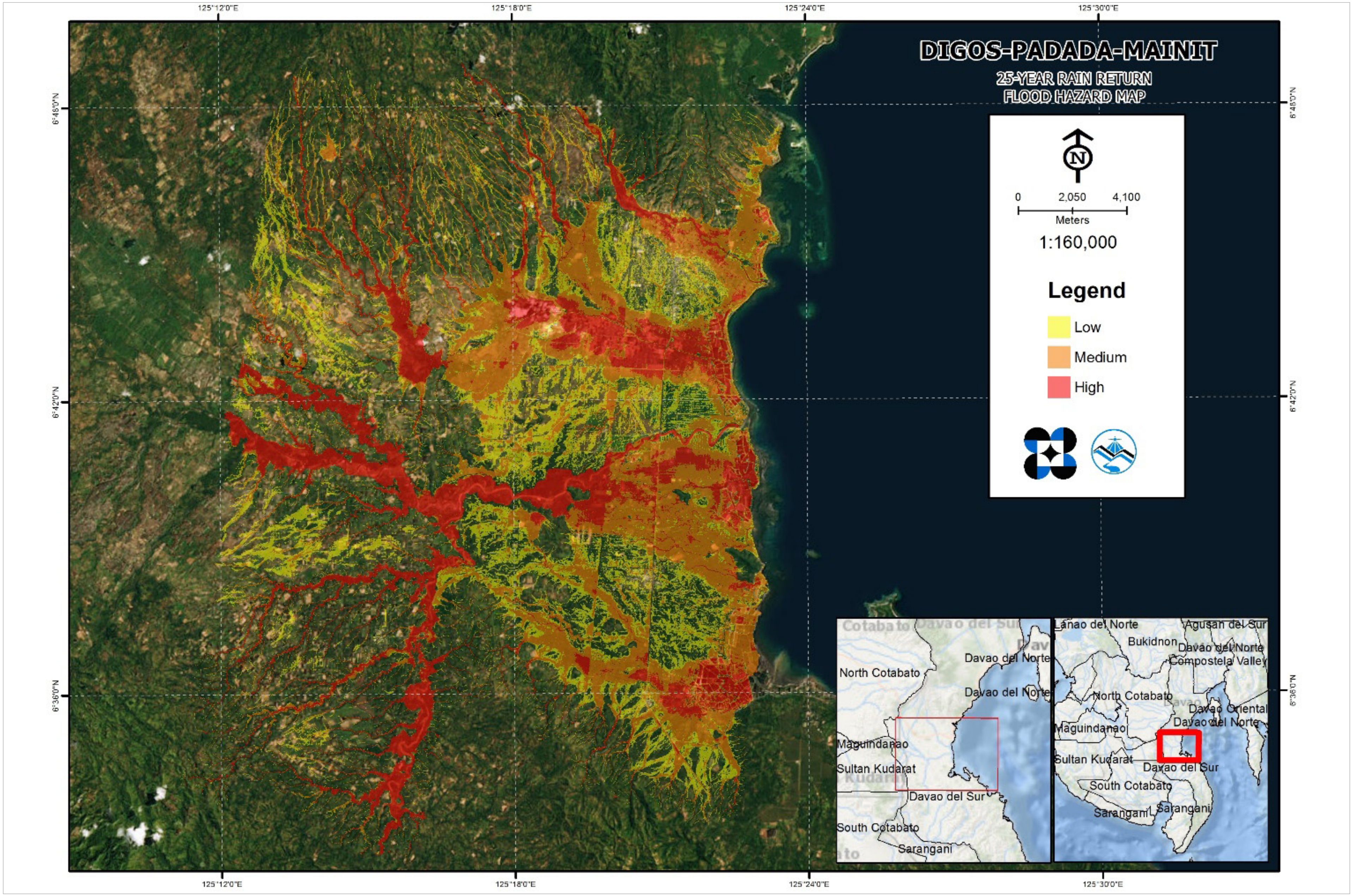


Figure 74. 25-year Flood Hazard Map for Padada Floodplain overlaid on Google Earth imagery

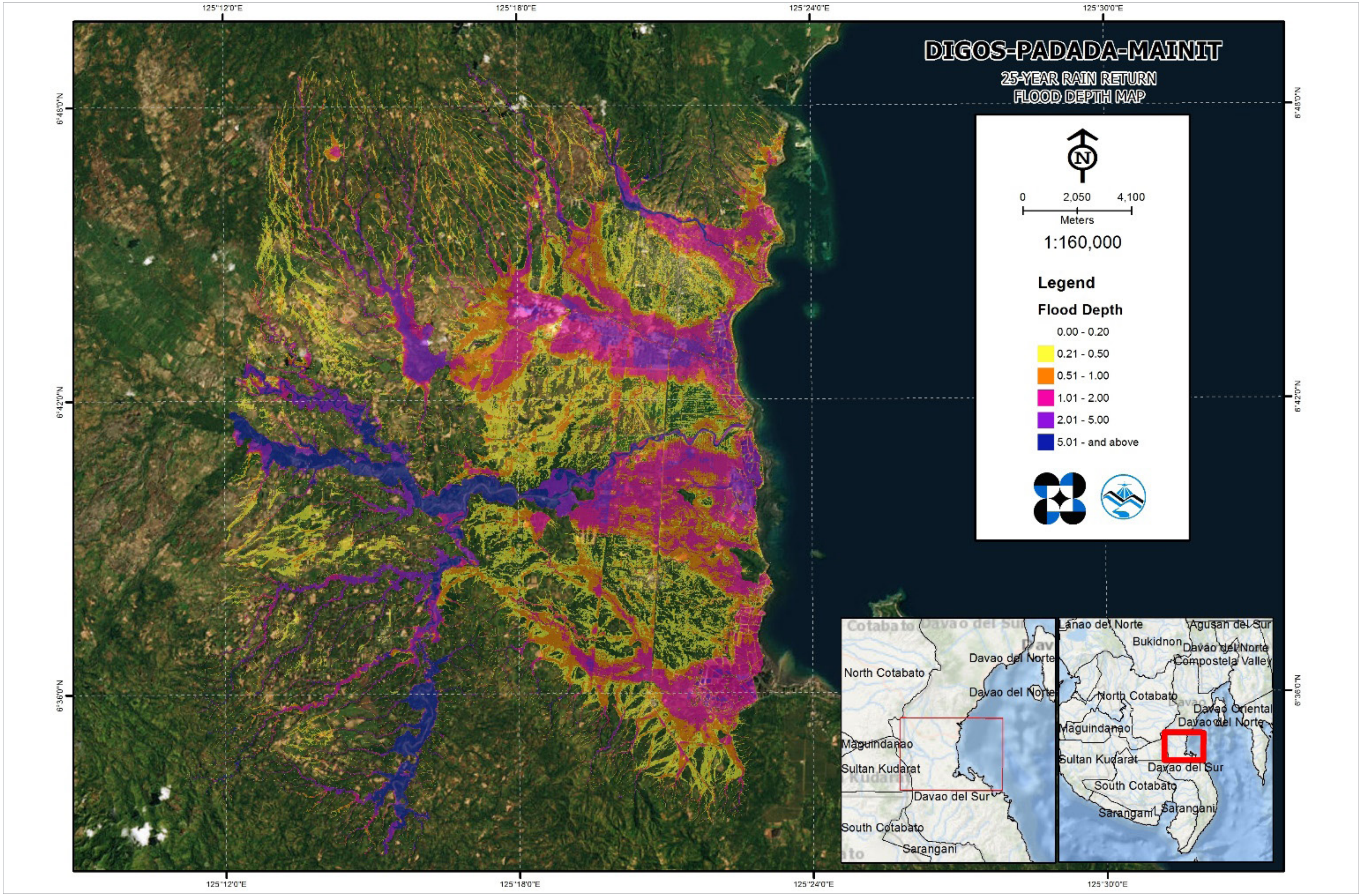


Figure 75. 25-year Flow Depth Map for Padada Floodplain overlaid on Google Earth imagery

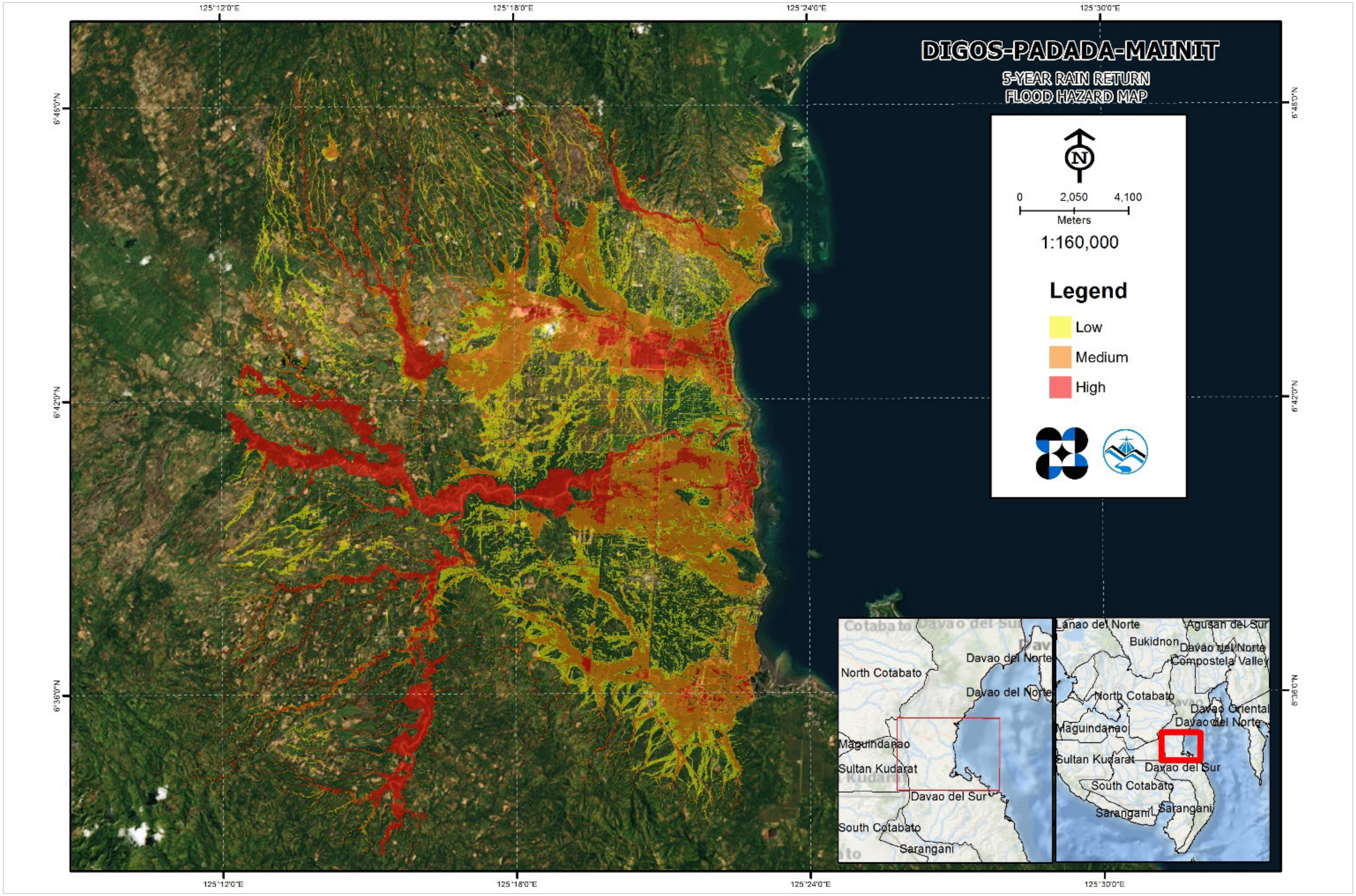


Figure 76. 5-year Flood Hazard Map for Padada Floodplain overlaid on Google Earth imagery

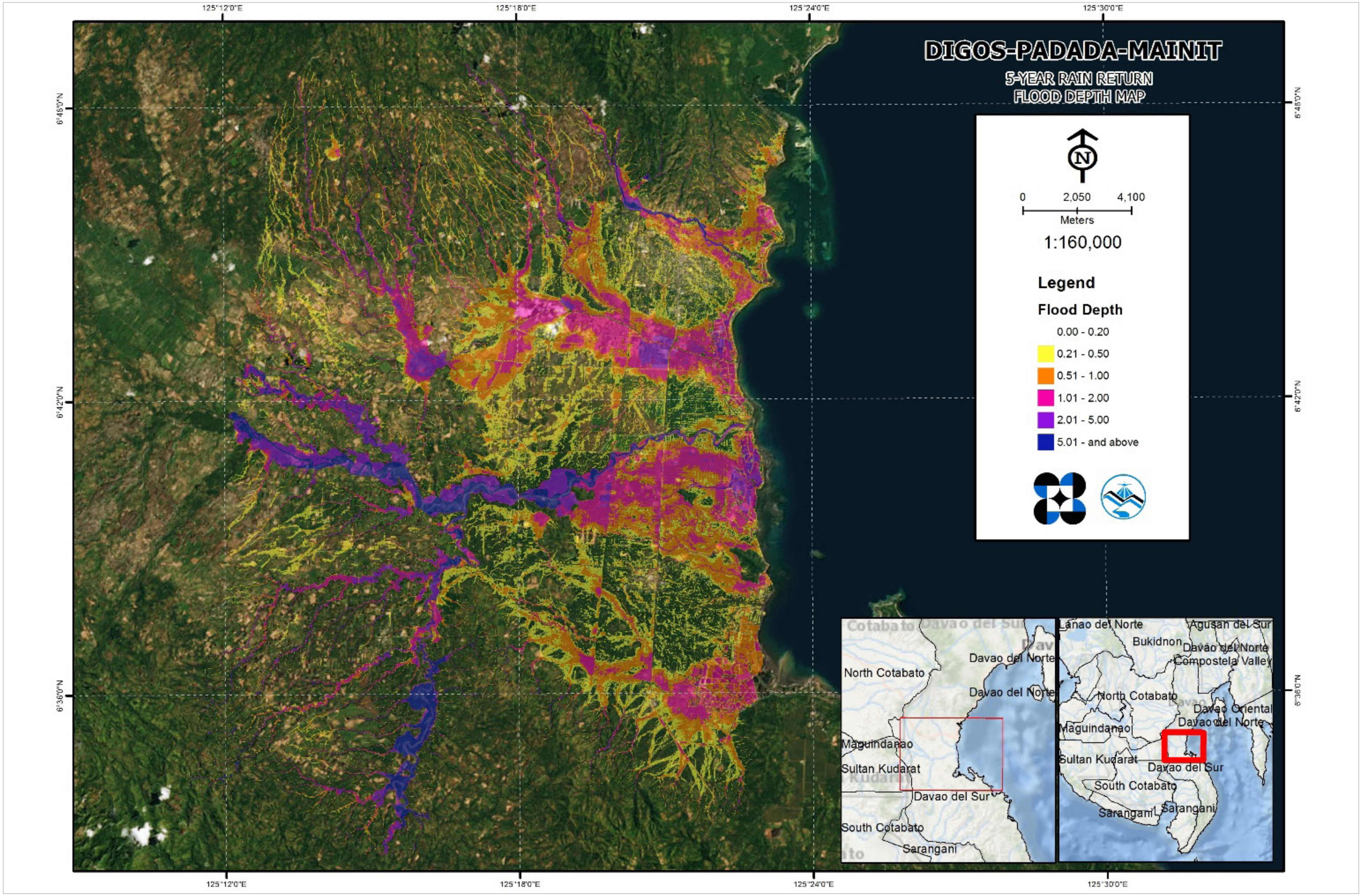


Figure 77. 5-year Flow Depth Map for Padada Floodplain overlaid on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Padada river basin, grouped by municipality, are listed below. For the said basin, two provinces with 11 municipalities consisting of 165 barangays are expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 11.95% of the municipality of Bansalan with an area of 136.18 sq. km. will experience flood levels of less than 0.20 meters. 1.83% of the area will experience flood levels of 0.21 to 0.50 meters while 0.71%, 0.26%, and 0.11% 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 the table are the affected areas in square kilometers by flood depth per barangay.

Table 41. Affected Areas in Bansalan, Davao del Sur during 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Bansalan							
	Anonang	Bonifacio	Buenavista	Mabunga	New Clarin	Poblacion	Poblacion Dos	Union
0.03-0.20	1.67915	1.40863	2.22078	4.29807	0.5692	1.40413	1.50362	3.19673
0.21-0.50	0.121015	0.11589	0.26014	1.0222	0.047251	0.175816	0.388758	0.354758
0.51-1.00	0.066026	0.038871	0.134543	0.184573	0.05079	0.105444	0.101234	0.284573
1.01-2.00	0.020667	0.015584	0.035893	0.107132	0.037899	0.041852	0.019058	0.078693
2.01-5.00	0.0004	0.0071	0.013889	0.027019	0.00504	0.052679	0	0.049307
> 5.00	0	0	0	0	0	0.0002	0	0.0007

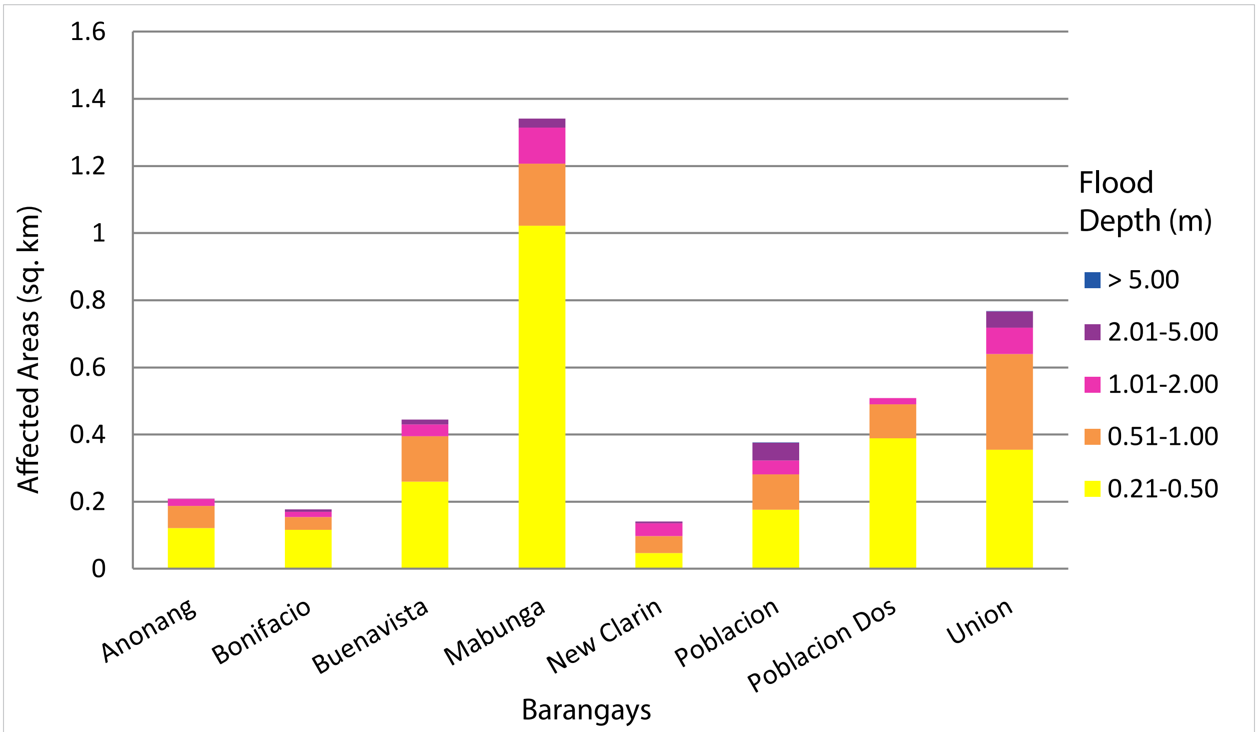


Figure 78. Affected Areas in Bansalan, Davao del Sur during 5-Year Rainfall Return Period

For the 5-year return period, 27.32% of the municipality of Digos City with an area of 226.71 sq. km. will experience flood levels of less than 0.20 meters. 5.85% of the area will experience flood levels of 0.21 to 0.50 meters while 3.21%, 1.26%, 0.39%, and 0.07% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 42. Affected Areas in Digos City, Davao del Sur during 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Digos City											
	Aplaya	Balabag	Cogon	Colorado	Dawis	Dulangan	Goma	Igpit	Kiagot	Lungag	Mahayahay	Matti
0.03-0.20	2.92945	0.112932	2.6713	4.1491	2.06728	0.101149	2.70938	1.6613	1.95339	4.78706	4.38347	5.0093
0.21-0.50	1.41359	0.002507	1.51115	1.25046	0.790991	0.004682	0.244052	0.910955	0.057042	0.320497	0.356018	0.72687
0.51-1.00	0.200393	0.003217	0.855973	1.54851	0.15673	0.000004	0.09489	0.917193	0.029165	0.154681	0.208859	0.540675
1.01-2.00	0.069054	0.000972	0.10881	0.457001	0.052785	0	0.050043	0.713219	0.032202	0.056105	0.121394	0.366419
2.01-5.00	0.062249	0.0003	0.002335	0.11688	0.0001	0	0.010127	0.076261	0.014475	0.006024	0.068814	0.126065
> 5.00	0.01379	0	0	0.0005	0	0	0	0	0.0003	0	0	0.0026

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Digos City											
	Ruparan	San Agustin	San Jose	San Miguel	San Roque	Sinawilan	Soong	Tiguman	Tres de Mayo	Zone 1	Zone 2	Zone 3
0.03-0.20	3.12452	4.52138	1.79551	1.16728	5.33558	3.57716	0.801675	1.55843	2.28727	2.15671	1.01792	2.05706
0.21-0.50	0.131282	0.497939	0.719523	0.954988	0.592635	0.539769	0.02295	0.760809	0.44748	0.064203	0.293495	0.639876
0.51-1.00	0.068775	0.249661	0.243097	0.512346	0.345792	0.249701	0.010368	0.342499	0.36562	0.037197	0.08828	0.060973
1.01-2.00	0.040714	0.102573	0.175979	0.120351	0.091661	0.057018	0.007206	0.029812	0.127611	0.027953	0.032234	0.008187
2.01-5.00	0.032788	0.044078	0.001979	0	0.029253	0.022749	0.003465	0.0003	0.123843	0.034302	0.098808	0.005806
> 5.00	0.0022	0	0	0	0	0.008126	0	0	0.024907	0.0017	0.095596	0.009481

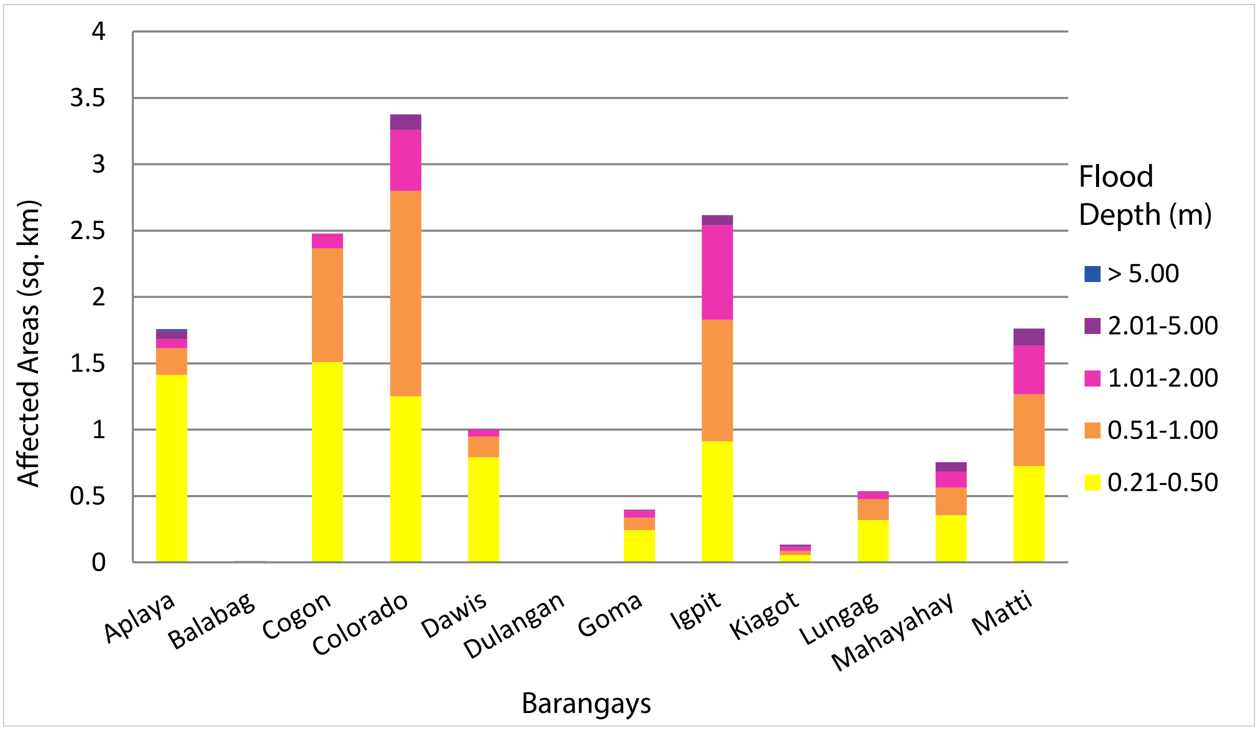


Figure 79. Affected Areas in Digos City, Davao del Sur during 5-Year Rainfall Return

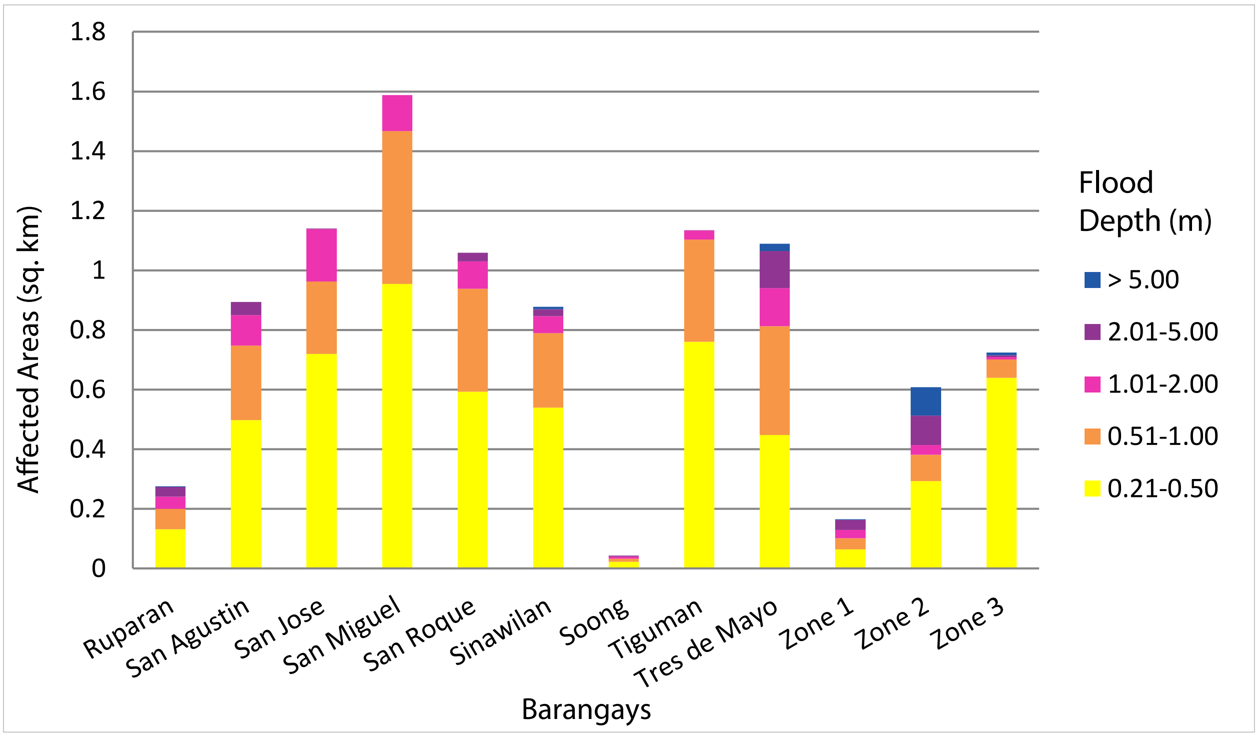


Figure 80. Affected Areas in Digos City, Davao del Sur during 5-Year Rainfall Return Period

For the 5-year return period, 53.04% of the municipality of Hagonoy with an area of 85.69 sq. km. will experience flood levels of less than 0.20 meters. 20.20% of the area will experience flood levels of 0.21 to 0.50 meters while 12.37%, 10.31%, 3.61%, and 0.36% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 43. Affected Areas in Hagonoy, Davao del Sur during 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Hagonoy											
	Balutakay	Clib	Guihing	Guihing Aplaya	Hagonoy Crossing	Kibuaya	La Union	Lanuro	Lapulabao	Leling	Mahayahay	Matti
0.03-0.20	0.842103	2.53232	1.63413	3.37478	1.88948	1.65609	3.18745	1.71696	2.9779	6.12276	1.74853	5.0093
0.21-0.50	0.633555	0.352124	0.582032	1.48033	0.643721	1.03481	0.256456	1.06218	1.21617	3.13614	0.61428	0.72687
0.51-1.00	0.797702	0.364171	0.099986	0.326116	0.07971	1.94376	0.193428	0.619508	0.554742	1.79245	0.079514	0.540675
1.01-2.00	1.67474	0.130356	0.024617	0.092583	0.032277	1.00317	0.14449	0.741511	0.094742	2.33812	0.014634	0.366419
2.01-5.00	0.573128	0.070317	0.077667	0.052672	0.173962	0.341736	0.048333	0.000342	0.010646	0.392902	0.007234	0.126065
> 5.00	0	0.0182	0.090307	0.001795	0.076688	0	0.010373	0	0.002068	0	0.0003	0.0026

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Hagonoy											
	Malabang Damsite	Maliit Digos	New Quezon	Paligue	Poblacion	Sacub	San Guillermo	San Isidro	Sinayawan	Tologan	Zone 2	Zone 3
0.03-0.20	2.4554	1.60266	2.87716	0.778971	2.7191	4.10097	0.811025	0.09294	1.26823	1.05821	1.01792	2.05706
0.21-0.50	0.27126	0.374943	0.427615	0.395995	0.862653	2.46689	0.215026	0.245245	0.818808	0.216562	0.293495	0.639876
0.51-1.00	0.228327	0.717182	0.278955	0.135718	0.100368	0.370824	0.398174	0.784243	0.673931	0.056948	0.08828	0.060973
1.01-2.00	0.074643	0.182375	0.559358	0.0173	0.065699	0	0.202793	1.1602	0.24773	0.035761	0.032234	0.008187
2.01-5.00	0.046788	0.018928	0.85146	0	0.027508	0	0.123705	0.231291	0	0.044894	0.098808	0.005806
> 5.00	0.0001	0.0002	0	0	0.011804	0	0	0	0	0.095576	0.095596	0.009481

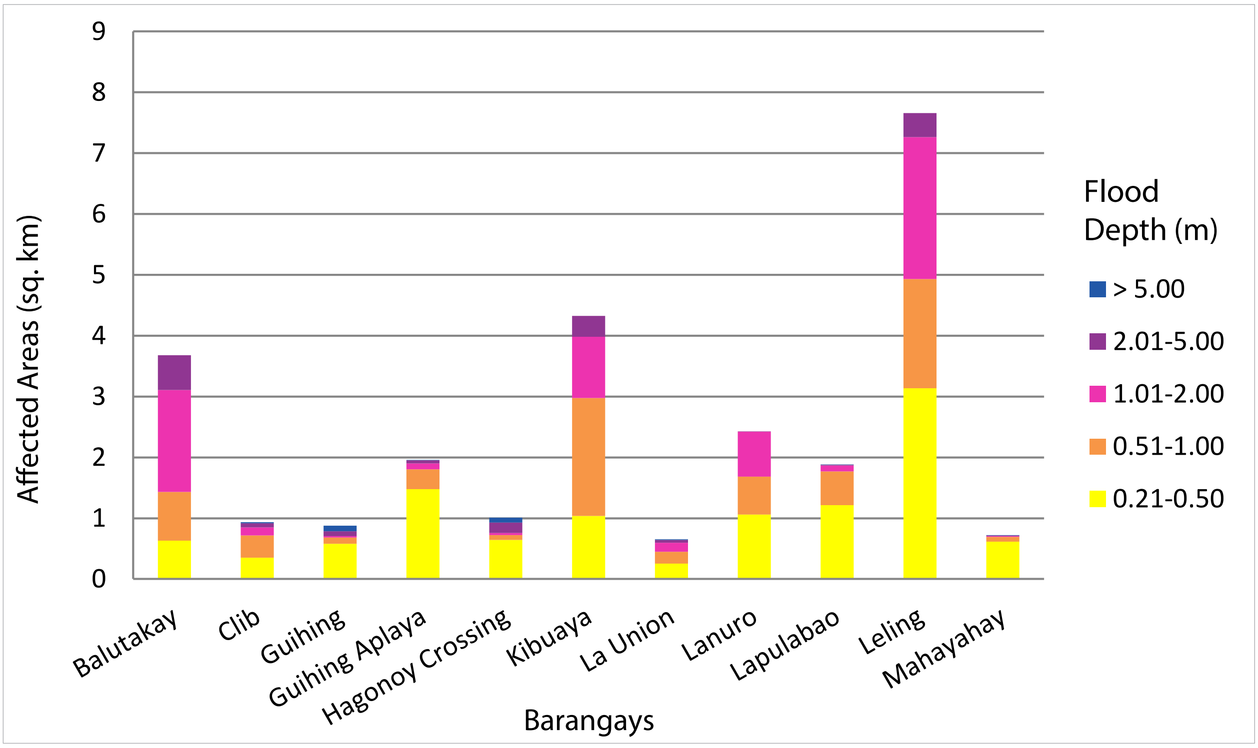


Figure 81. Affected Areas in Hagonoy, Davao del Sur during 5-Year Rainfall Return Period

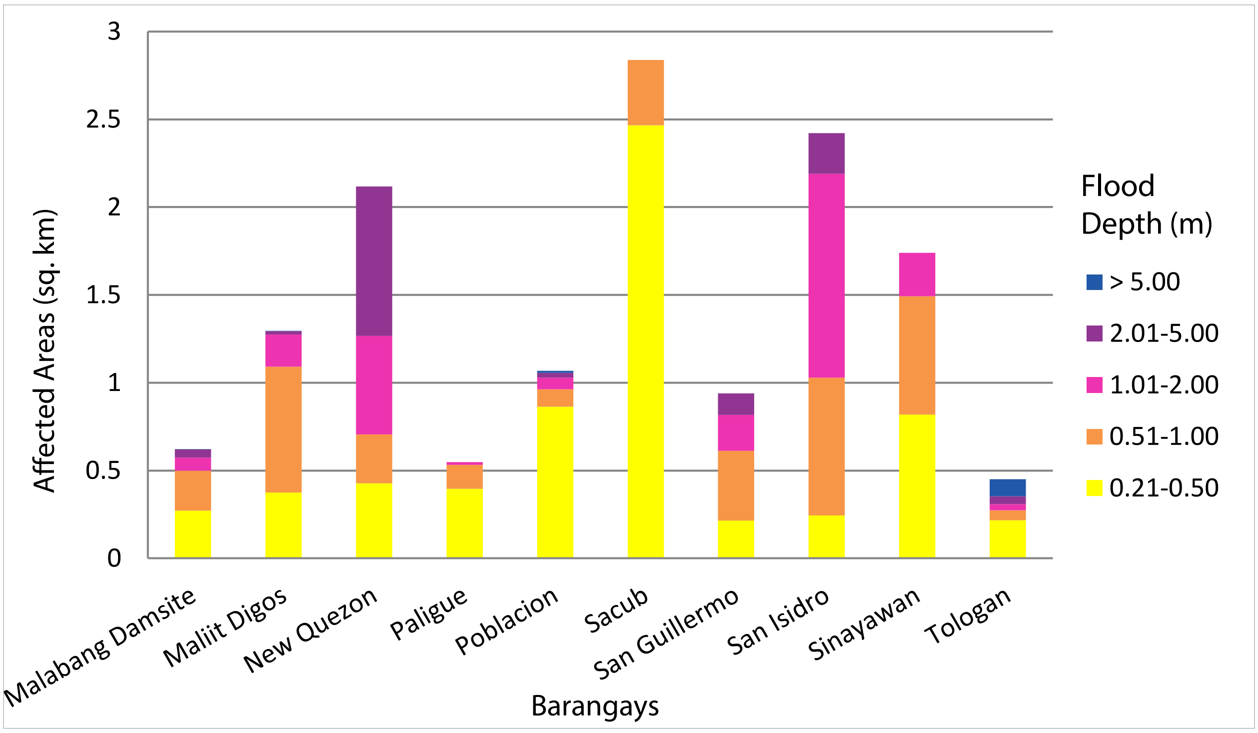


Figure 82. Affected Areas in Hagonoy, Davao del Sur during 5-Year Rainfall Return Period

For the 5-year return period, 57.20% of the municipality of Kiblawan with an area of 80.03 sq. km. will experience flood levels of less than 0.20 meters. 4.78% of the area will experience flood levels of 0.21 to 0.50 meters while 2.34%, 3.37%, 2.45%, and 0.25% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 44. Affected Areas in Kiblawan, Davao del Sur during 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Kiblawan									
	Abnate	Bagong Negros	Bagong Silang	Bagumbayan	Balasiao	Bonifacio	Bulol-Salo	Bunot	Cogon-Bacaca	Dapok
0.03-0.20	2.82741	1.2883	1.37987	4.98015	1.70666	2.31437	0.900342	2.7004	0.586506	1.72966
0.21-0.50	0.449643	0.026808	0.069695	0.281088	0.082685	0.072136	0.018012	0.101329	0.029886	0.12702
0.51-1.00	0.080711	0.011439	0.100389	0.21953	0.1556	0.05215	0.021318	0.070099	0.008729	0.131447
1.01-2.00	0.020754	0.011376	0.159544	0.45454	0.169588	0.054724	0.052349	0.043304	0.010081	0.108294
2.01-5.00	0.0001	0.003062	0.092004	0.129622	0.059095	0.04519	0.022119	0.041266	0.005928	0.061641
> 5.00	0	0	0.002112	0	0.0023	0.0026	0.0004	0.0073	0	0.035073

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Kiblawan									
	Ihan	Kibongbong	Kimlawis	Kisulan	Lati-An	Manual	Maraga-A	Molopolo	New Sibonga	Panaglib
0.03-0.20	0.505869	0.778326	1.414	0.893574	1.21386	1.32143	1.47403	2.45045	1.56539	0.499435
0.21-0.50	0.051943	0.101185	0.021937	0.029713	0.05193	0.409952	0.038083	0.118485	0.111794	0.066177
0.51-1.00	0.051136	0.013412	0.016585	0.0135	0.07772	0.014596	0.034026	0.073652	0.169808	0.080438
1.01-2.00	0.102293	0.011829	0.024286	0.007802	0.129498	0	0.070139	0.117746	0.28194	0.14902
2.01-5.00	0.066708	0.015261	0.027	0.003184	0.109134	0	0.010513	0.083817	0.270666	0.331911
> 5.00	0.023805	0	0.0035	0	0.034511	0	0.0006	0.0002	0.011993	0.056724

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Kiblawan									
	Pasig	Poblacion	Pocaleel	San Isidro	San Jose	San Pedro	Santo Niño	Tacub	Tacul	Waterfall
0.03-0.20	0.594276	1.71435	1.20053	1.33346	0.802458	3.3504	1.1455	1.45783	0.934851	0.710668
0.21-0.50	0.028787	0.048391	0.045752	0.222199	0.0569	0.410438	0.043301	0.251451	0.291734	0.169881
0.51-1.00	0.02227	0.02488	0.09497	0.027063	0.041365	0.12513	0.045672	0.02675	0.045214	0.024144
1.01-2.00	0.049732	0.033916	0.130698	0.059544	0.066859	0.194481	0.124881	0.047575	0.008659	0.001791
2.01-5.00	0.011391	0.036663	0.035661	0.065506	0.084439	0.06687	0.249261	0.029806	0.000497	0.000314
> 5.00	0	0.0027	0	0.000262	0.0127	0	0.000338	0.0008	0	0

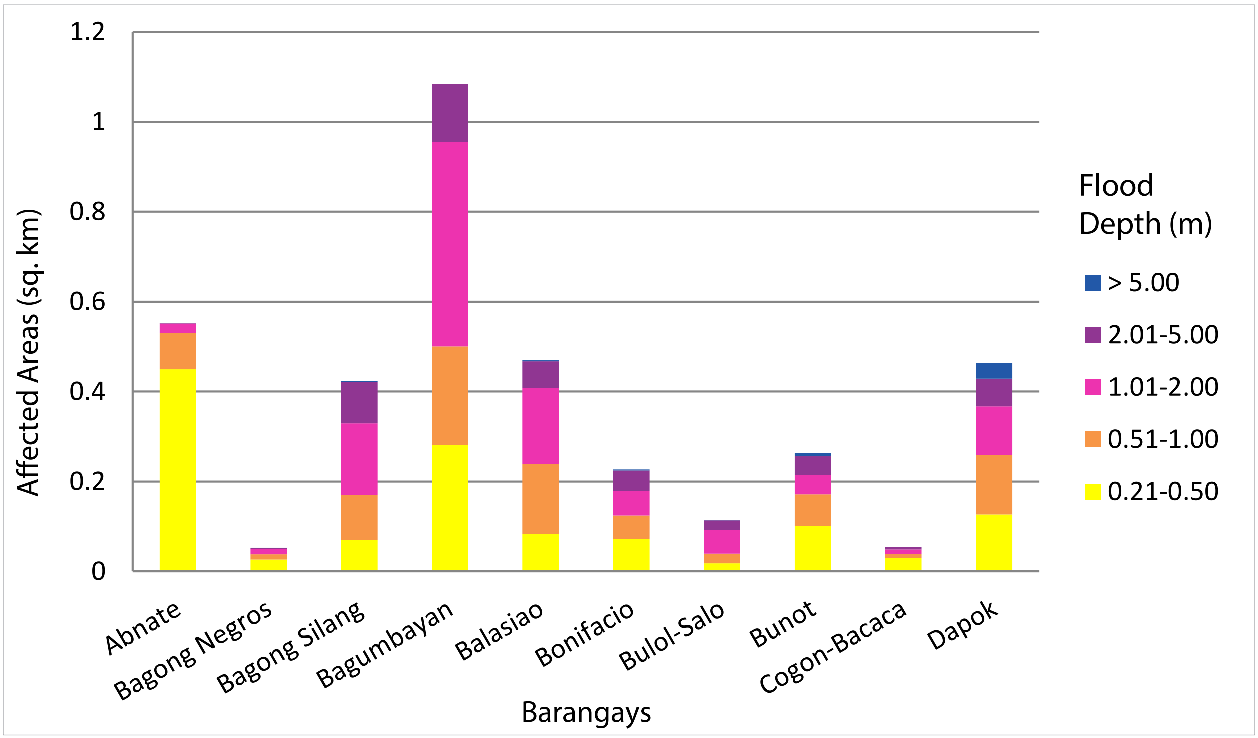


Figure 83. Affected Areas in Kiblawan, Davao del Sur during 5-Year Rainfall Return Period

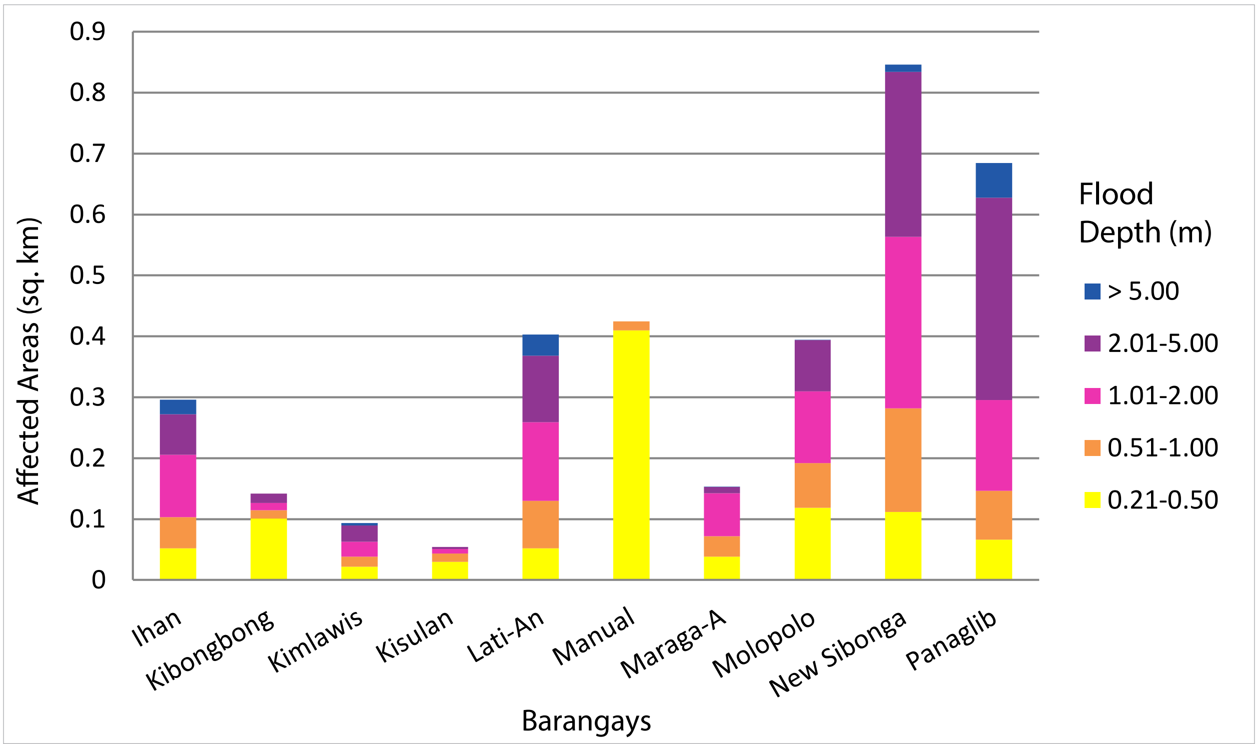


Figure 84. Affected Areas in Kiblawan, Davao del Sur during 5-Year Rainfall Return Period

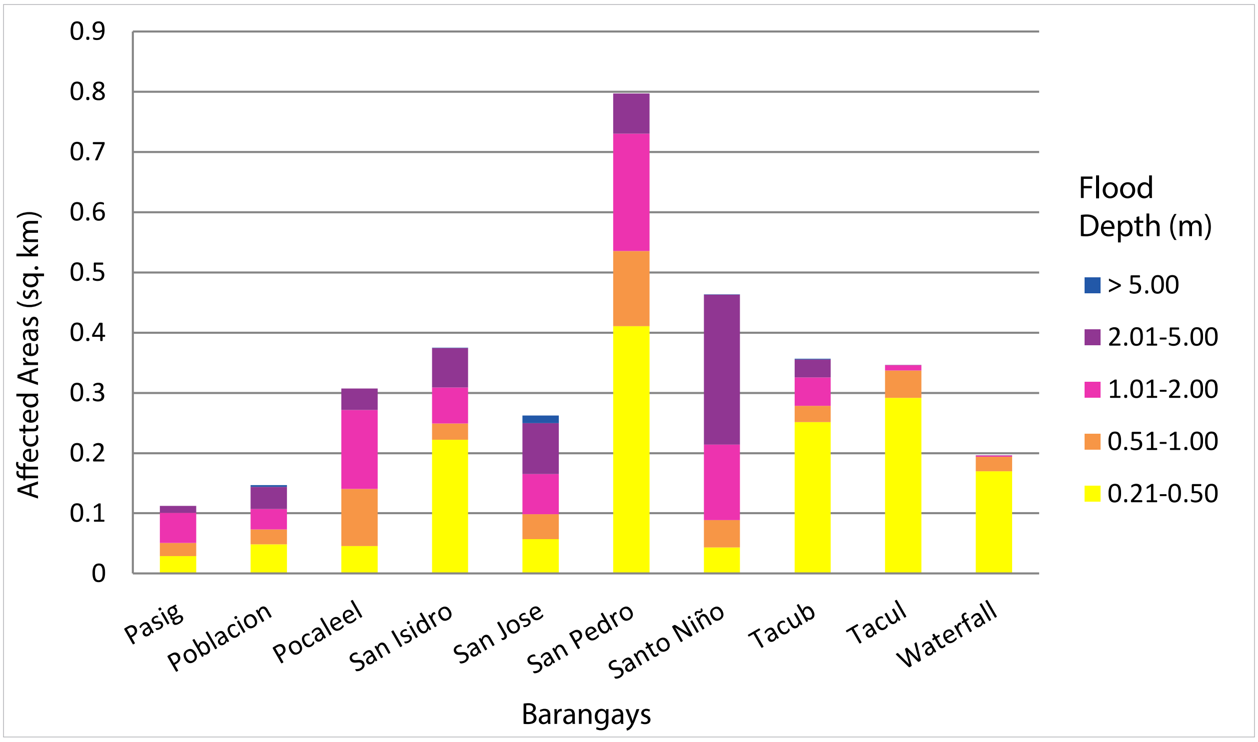


Figure 85. Affected Areas in Kiblawan, Davao del Sur during 5-Year Rainfall Return Period

For the 5-year return period, 0.33% of the municipality of Magsaysay with an area of 109.8 sq. km. will experience flood levels of less than 0.20 meters. 0.04% of the area will experience flood levels of 0.21 to 0.50 meters while 0.01% and 0.01% of the area will experience flood depths of 0.51 to 1 meter and 1.01 to 2 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 45. Affected Areas in Magsaysay, Davao del Sur during 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangay in Magsaysay
	New Ilocos
0.03-0.20	0.362584
0.21-0.50	0.040246
0.51-1.00	0.015465
1.01-2.00	0.009809
2.01-5.00	0.0008
> 5.00	0

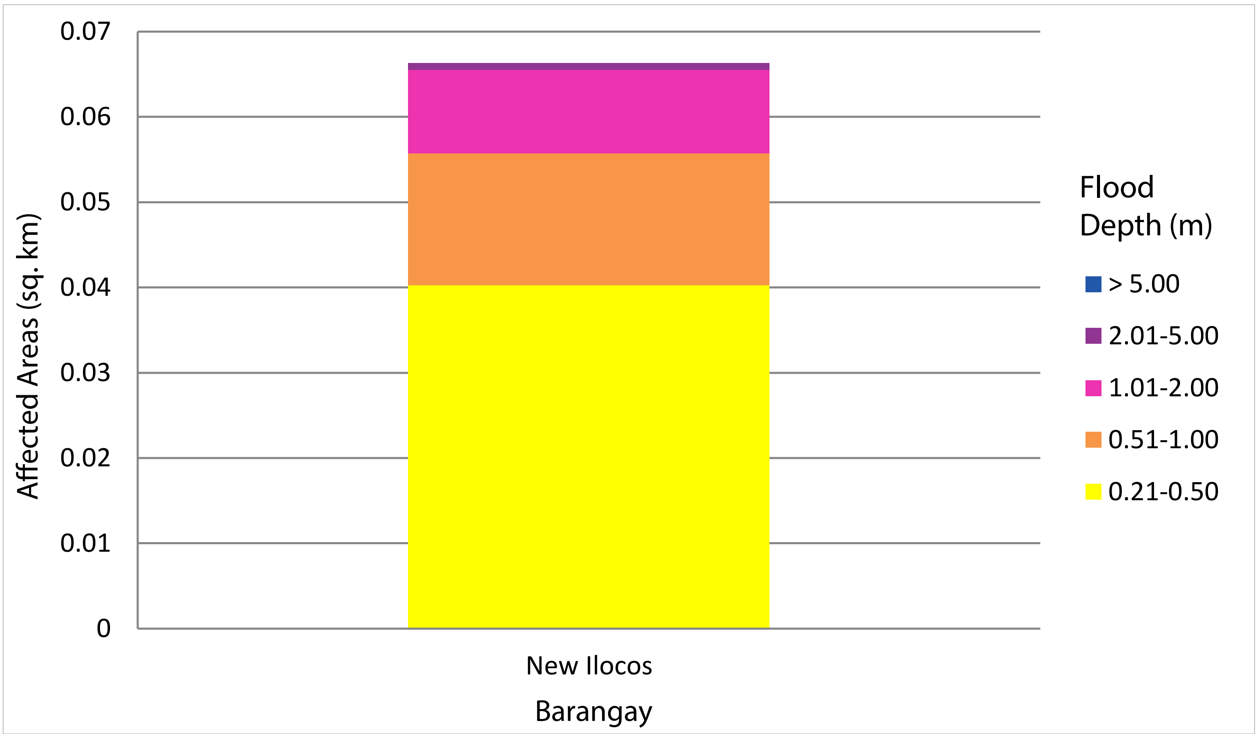


Figure 86. Affected Areas in Magsaysay, Davao del Sur during 5-Year Rainfall Return Period

For the 5-year return period, 11.03% of the municipality of Malalag with an area of 445 sq. km. will experience flood levels of less than 0.20 meters. 1.43% of the area will experience flood levels of 0.21 to 0.50 meters while 1.08%, 0.71%, 0.27%, and 0.02% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 46. Affected Areas in Malalag, Davao del Sur during 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Malalag					
	Bagumbayan	Bolton	Kiblagon	Lapu-Lapu	Mabini	New Baclayon
0.03-0.20	0.018046	0.592654	13.3678	31.2595	1.37987	2.47581
0.21-0.50	0.007853	0.073941	3.95435	1.60857	0.031577	0.666991
0.51-1.00	0.004997	0.017773	2.63575	1.35888	0.018455	0.766998
1.01-2.00	0.000815	0.012296	1.3522	1.53614	0.009436	0.237191
2.01-5.00	0	0.008087	0.169522	1.00224	0.013002	0.006784
> 5.00	0	0.0003	0.008867	0.0702	0.00422	0

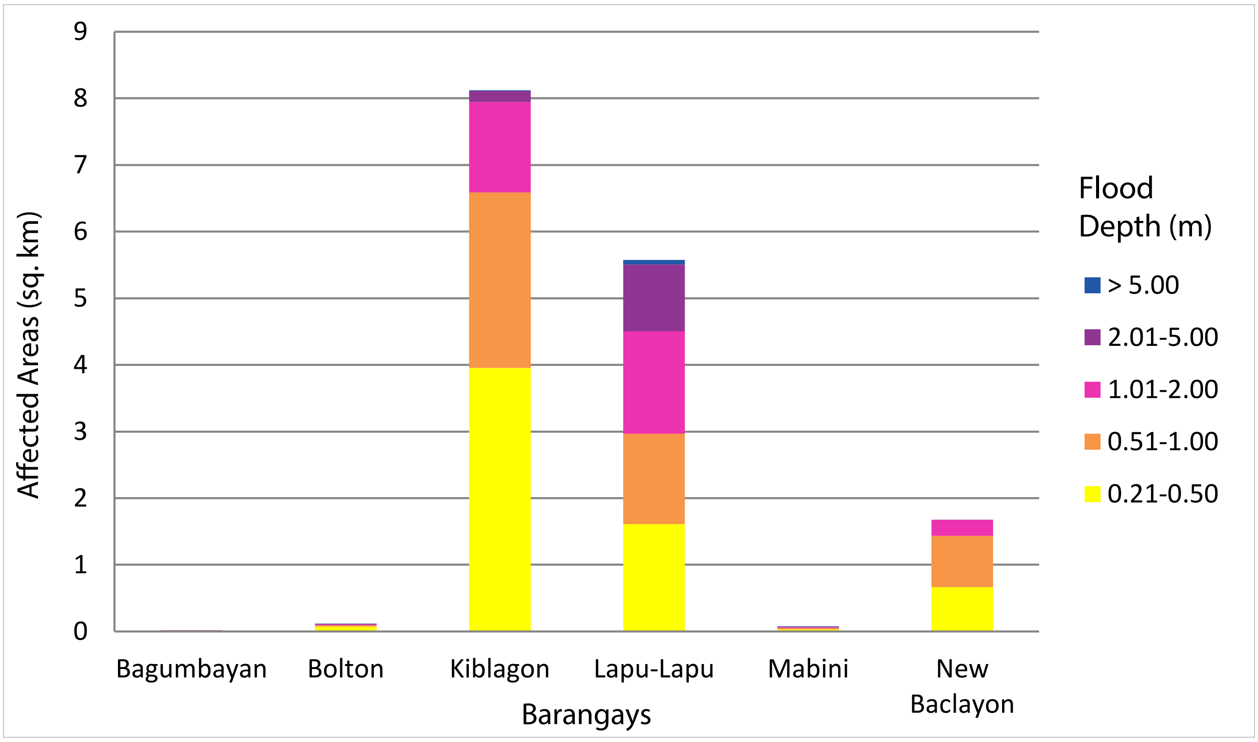


Figure 87. Affected Areas in Malalag, Davao del Sur during 5-Year Rainfall Return Period

For the 5-year return period, 46.46% of the municipality of Matanao with an area of 123.4 sq. km. will experience flood levels of less than 0.20 meters. 6.59% of the area will experience flood levels of 0.21 to 0.50 meters while 5.22%, 5.60%, 1.54%, and 0.07% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 47. Affected Areas in Matanao, Davao del Sur during 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Matanao									
	Asbang	Asinan	Bagumbayan	Bangkal	Buas	Buri	Cabligan	Camanchiles	Ceboza	Colonsabak
0.03-0.20	0.039863	1.06975	3.20139	0.701123	0.090418	0.102914	0.322749	2.28688	2.9108	0.740093
0.21-0.50	0.001219	0.139629	0.309275	0.070631	0.009874	0.008842	0.349119	0.21207	0.575872	0.112582
0.51-1.00	0.000001	0.06078	0.195076	0.03106	0.000904	0.001273	0.810952	0.133041	0.140318	0.052028
1.01-2.00	0	0.039038	0.257353	0.031695	0.000102	0	1.9415	0.093508	0.101359	0.037025
2.01-5.00	0	0.023103	0.233527	0.0058	0	0	0.100848	0.05679	0.054883	0.0022
> 5.00	0	0	0.010908	0	0	0	0	0.001293	0.01098	0

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Matanao									
	Dongan-Pekong	Kabasagan	Kapok	Kibao	La Suerte	Langa-An	Lower Marber	Manga	New Katipunan	New Visayas
0.03-0.20	2.78303	1.14435	0.496025	1.05957	1.98441	1.41512	1.27362	6.08191	5.76656	2.50995
0.21-0.50	0.164202	0.101344	0.044859	0.049531	0.521194	0.26182	0.117475	1.67473	0.4356	0.617242
0.51-1.00	0.204678	0.021346	0.014355	0.046218	0.278294	0.017748	0.084038	2.34483	0.284868	0.042899
1.01-2.00	0.14223	0.014829	0.020015	0.039454	0.097886	0.024623	0.091706	2.36141	0.232494	0.001282
2.01-5.00	0.110087	0	0.0024	0.022761	0.125379	0.010455	0.107742	0.376113	0.168893	0.0002
> 5.00	0	0	0	0.0013	0.025502	0.00009	0.006194	0.002	0.0157	0

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Matanao									
	Poblacion	Saboy	San Jose	San Vicente	Saub	Sinaragan	Sinawilan	Tamlangon	Tibongbong	Towak
0.03-0.20	1.29893	0.828118	2.76818	1.48369	1.29297	4.38951	6.2145	0.789739	1.21396	1.07575
0.21-0.50	0.150252	0.251038	0.311693	0.185562	0.344065	0.595647	0.346805	0.051778	0.047964	0.068062
0.51-1.00	0.146788	0.325568	0.103031	0.095454	0.189325	0.501194	0.210853	0.020264	0.036275	0.044484
1.01-2.00	0.094955	0.295307	0.124482	0.036213	0.123447	0.354879	0.246637	0.012657	0.031991	0.057748
2.01-5.00	0.08199	0.130416	0.053793	0.010386	0.010318	0.020339	0.161852	0.011022	0.000892	0.017537
> 5.00	0.013561	0	0	0	0	0.0014	0.0003	0.0002	0.0007	0

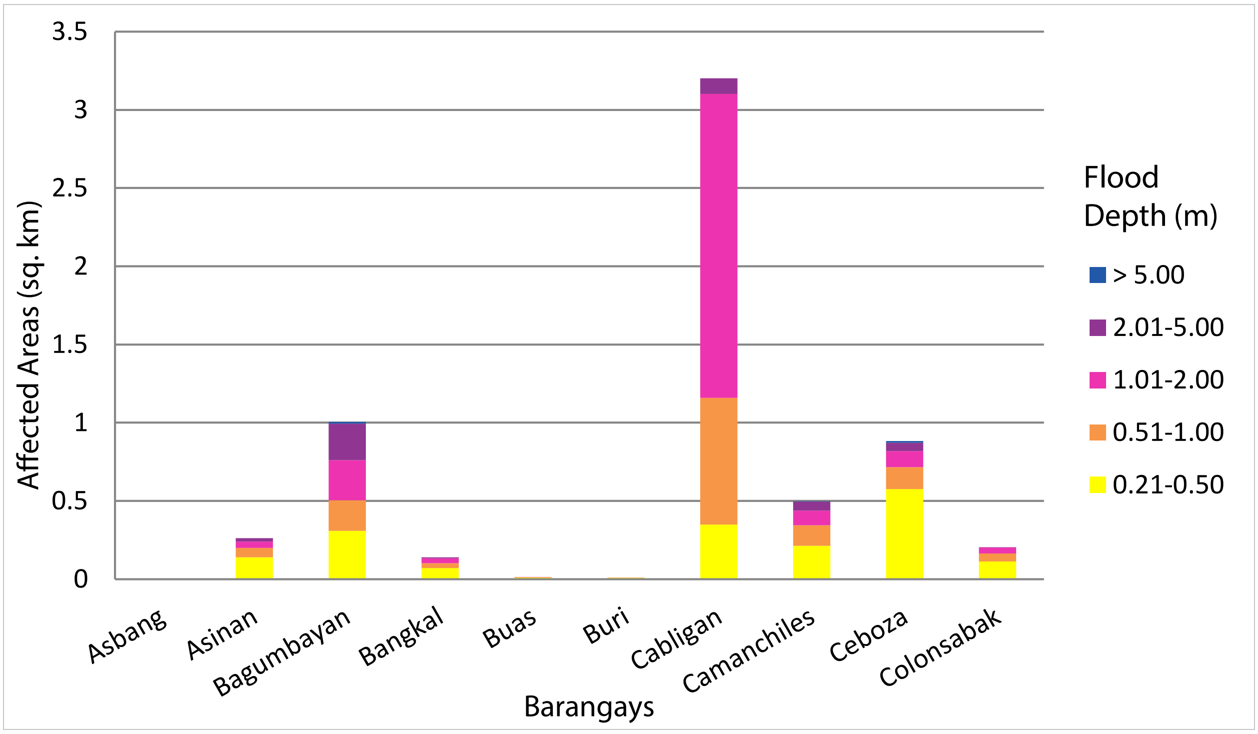


Figure 88. Affected Areas in Matanao, Davao del Sur during 5-Year Rainfall Return Period

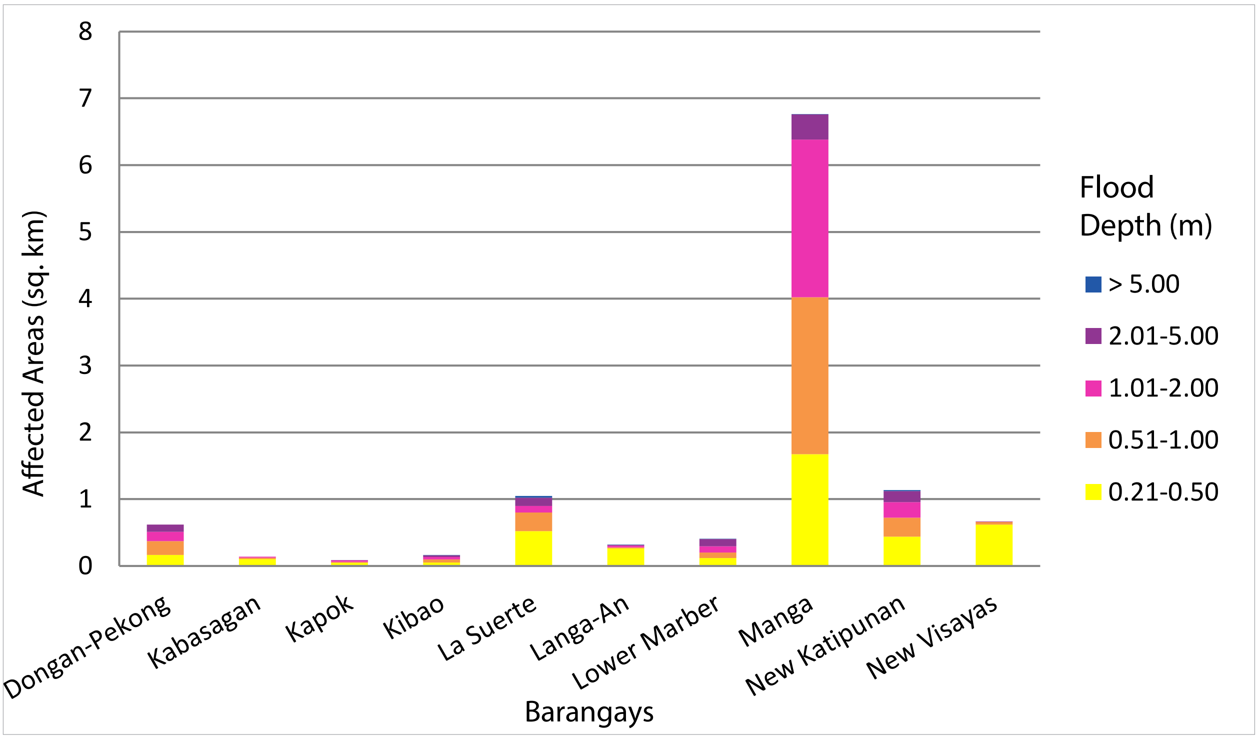


Figure 89. Affected Areas in Matanao, Davao del Sur during 5-Year Rainfall Return Period

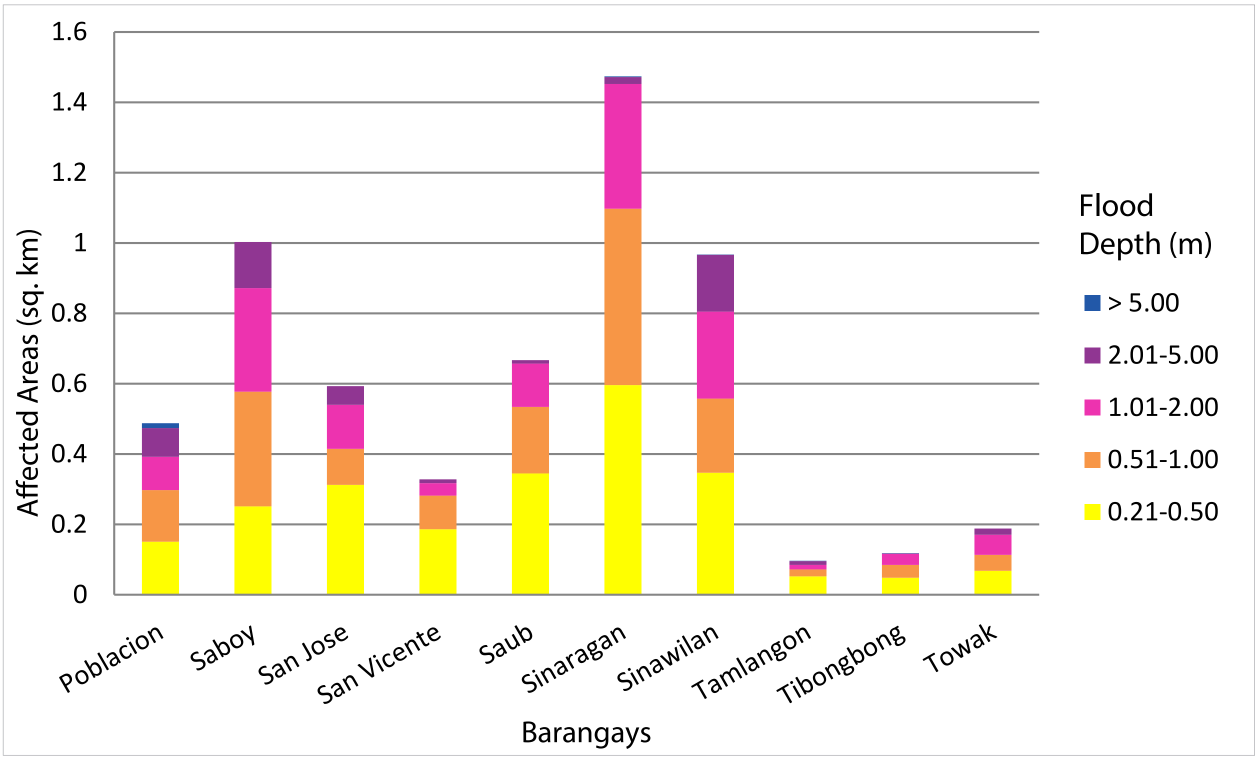


Figure 90. Affected Areas in Matanao, Davao del Sur during 5-Year Rainfall Return Period

For the 5-year return period, 65.79% of the municipality of Padada with an area of 55.97 sq. km. will experience flood levels of less than 0.20 meters. 21.36% of the area will experience flood levels of 0.21 to 0.50 meters while 6.70%, 2.42%, 2.49%, and 1.19% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 48. Affected Areas in Padada, Davao del Sur during 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Padada								
	Almendras	Don Sergio Osmena, Sr.	Harada Butai	Lower Katipunan	Lower Limonzo	Lower Malinao	N C Ordaneza Distric	Northern Paligue	Palili
0.03-0.20	0.622305	1.53652	3.15229	4.30497	1.83783	3.32775	0.673851	2.11406	5.94933
0.21-0.50	0.280609	0.513307	1.71104	0.376542	0.673046	0.578493	0.174694	0.810332	2.50134
0.51-1.00	0.034125	0.372988	0.527557	0.149083	0.146774	0.330406	0.042539	0.194392	0.578611
1.01-2.00	0	0.28336	0.08948	0.172243	0.050936	0.459752	0.0118	0.045441	0.063941
2.01-5.00	0	0.394535	0.0077	0.209678	0.002	0.702399	0	0.054111	0.0003
> 5.00	0	0.232211	0	0.136612	0	0.147446	0	0.149493	0

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Padada							
	Piape	Punta Piape	Quirino District	San Isidro	Southern Paligue	Tulogan	Upper Limonzo	Upper Malinao
0.03-0.20	0.679639	2.46921	0.457198	1.52497	1.52117	1.41883	2.53527	2.69686
0.21-0.50	0.418943	0.653036	0.032504	0.650722	0.627855	0.79484	0.733036	0.424097
0.51-1.00	0.147664	0.233314	0.0005	0.476957	0.124457	0.170363	0.154598	0.064133
1.01-2.00	0.0008	0.0228	0	0.0484	0.004852	0.0006	0.044297	0.056744
2.01-5.00	0	0	0	0	0	0	0.0057	0.018978
> 5.00	0	0	0	0	0	0	0	0

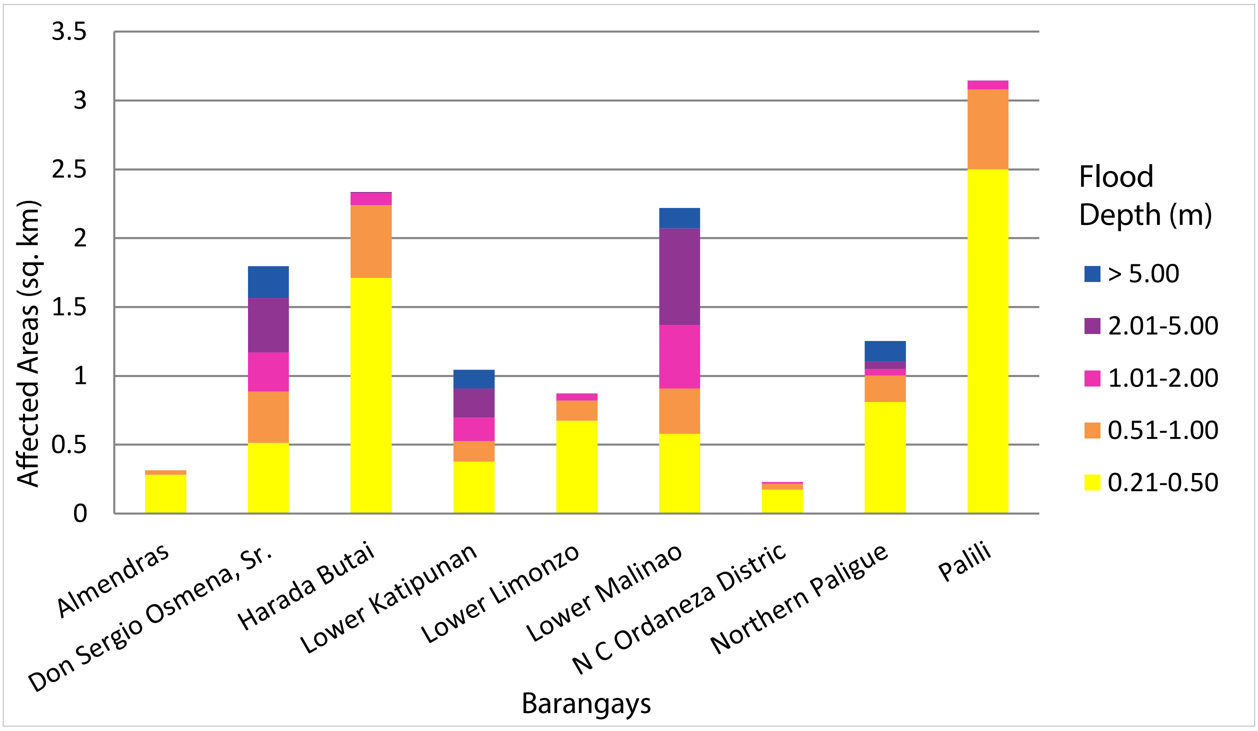


Figure 91. Affected Areas in Padada, Davao del Sur during 5-Year Rainfall Return Period

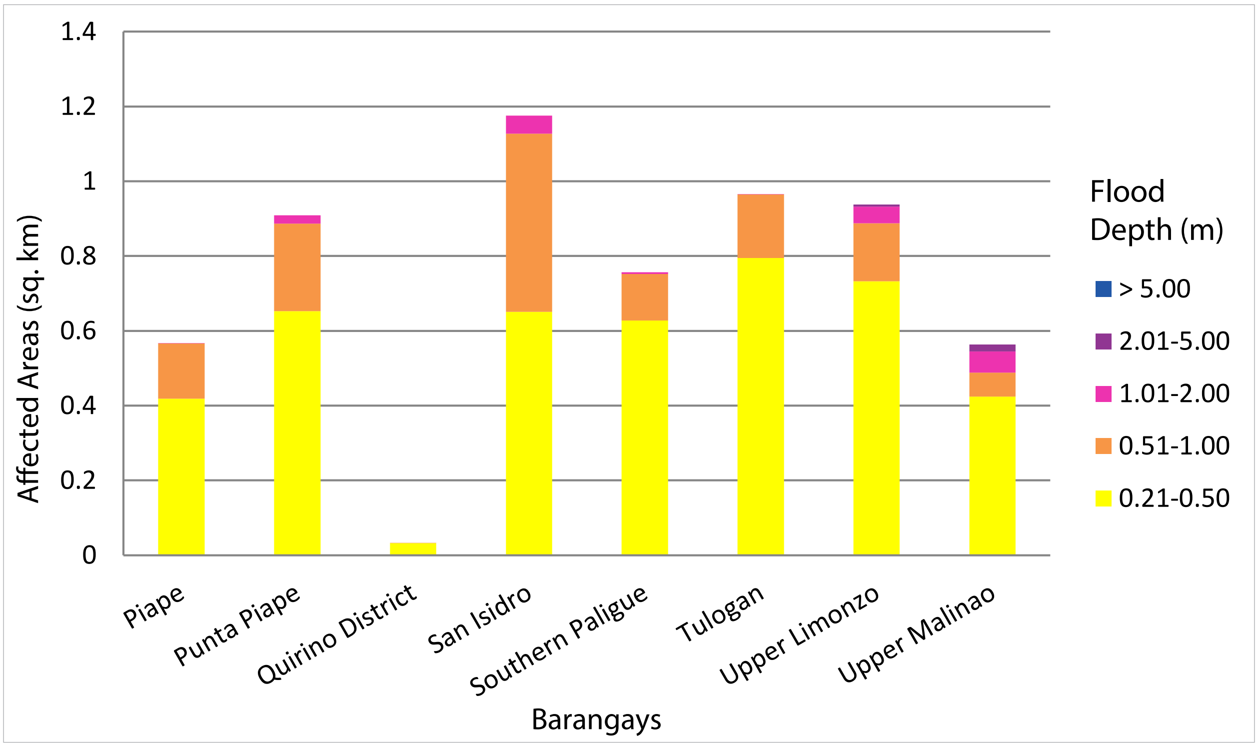


Figure 92. Affected Areas in Padada, Davao del Sur during 5-Year Rainfall Return Period

For the 5-year return period, 0.95% of the municipality of Santa Cruz with an area of 267.54 sq. km. will experience flood levels of less than 0.20 meters. 0.15% of the area will experience flood levels of 0.21 to 0.50 meters while 0.15%, 0.08%, and 0.01% 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 the table are the affected areas in square kilometers by flood depth per barangay.

Table 49. Affected Areas in Santa Cruz, Davao del Sur during 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Santa Cruz	
	Bato	Tagabuli
0.03-0.20	2.4827	0.068196
0.21-0.50	0.378281	0.011563
0.51-1.00	0.408695	0.000769
1.01-2.00	0.21032	0
2.01-5.00	0.0208	0
> 5.00	0	0

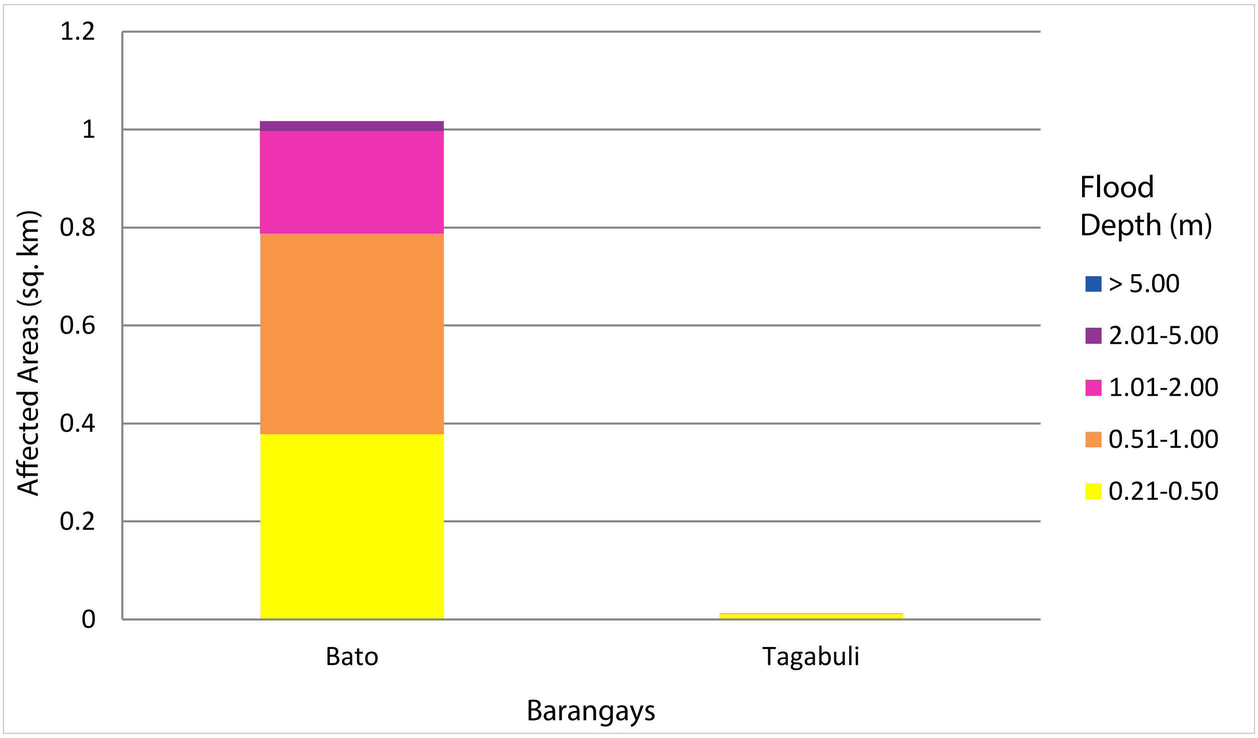


Figure 93. Affected Areas in Santa Cruz, Davao del Sur during 5-Year Rainfall Return Period

For the 5-year return period, 61.40% of the municipality of Sulop with an area of 50.8 sq. km. will experience flood levels of less than 0.20 meters. 19.77% of the area will experience flood levels of 0.21 to 0.50 meters while 11.38%, 5.59%, 0.95%, and 0.34% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 50. Affected Areas in Sulop, Davao del Sur during 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Sulop								
	Balasinon	Buguis	Carre	Clib	Harada Butai	Katipunan	Kiblagon	Labon	Laperas
0.03-0.20	0.232376	1.18957	0.902191	0.520821	2.09956	1.18273	0.427775	0.479456	0.825669
0.21-0.50	0.153349	0.045935	0.039682	0.01488	0.954898	0.447894	0.672708	0.017984	0.27799
0.51-1.00	0.055409	0.03339	0.024439	0.007807	0.481306	0.067209	0.958601	0.00814	0.090703
1.01-2.00	0.000742	0.034754	0.020764	0.001664	0.098963	0.016136	0.24747	0.005413	0.002539
2.01-5.00	0	0.034131	0.01699	0.001182	0.0028	0.047404	0	0.004834	0.0006
> 5.00	0	0	0.0036	0.000142	0	0.010675	0	0.001413	0

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Sulop							
	Lapla	Litos	Luparan	Mckinley	New Cebu	Osmeña	Palili	Parame
0.03-0.20	0.697052	0.668059	0.33992	0.795141	1.80916	0.350832	4.75894	0.50938
0.21-0.50	0.021817	0.026214	0.008487	0.038055	0.456737	0.010519	2.19199	0.012963
0.51-1.00	0.010536	0.02322	0.004472	0.061533	0.266138	0.00535	0.802617	0.010909
1.01-2.00	0.014104	0.012853	0.005747	0.049815	0.067089	0.002493	0.964308	0.009726
2.01-5.00	0.018713	0.013541	0.009281	0.00609	0.009555	0.001096	0.005142	0.010636
> 5.00	0.004213	0.0104	0.001388	0	0.0004	0	0	0.0003

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Sulop							
	Poblacion	Roxas	Solongvale	Tagolilong	Tala-O	Talas	Tanwalang	Waterfall
0.03-0.20	0.502378	3.21777	2.30219	1.0386	2.5489	1.11639	1.7747	0.90055
0.21-0.50	0.575323	0.17489	1.1267	0.028328	0.768714	0.836738	0.650765	0.491826
0.51-1.00	0.683321	0.183019	0.455963	0.011463	0.374304	0.593017	0.270374	0.296274
1.01-2.00	0.702245	0.115154	0.092488	0.011142	0.113209	0.170207	0.059928	0.02239
2.01-5.00	0.0007	0.05018	0.0005	0.005614	0.0001	0.0004	0.241515	0.000992
> 5.00	0	0.016045	0	0.0005	0	0	0.12452	0

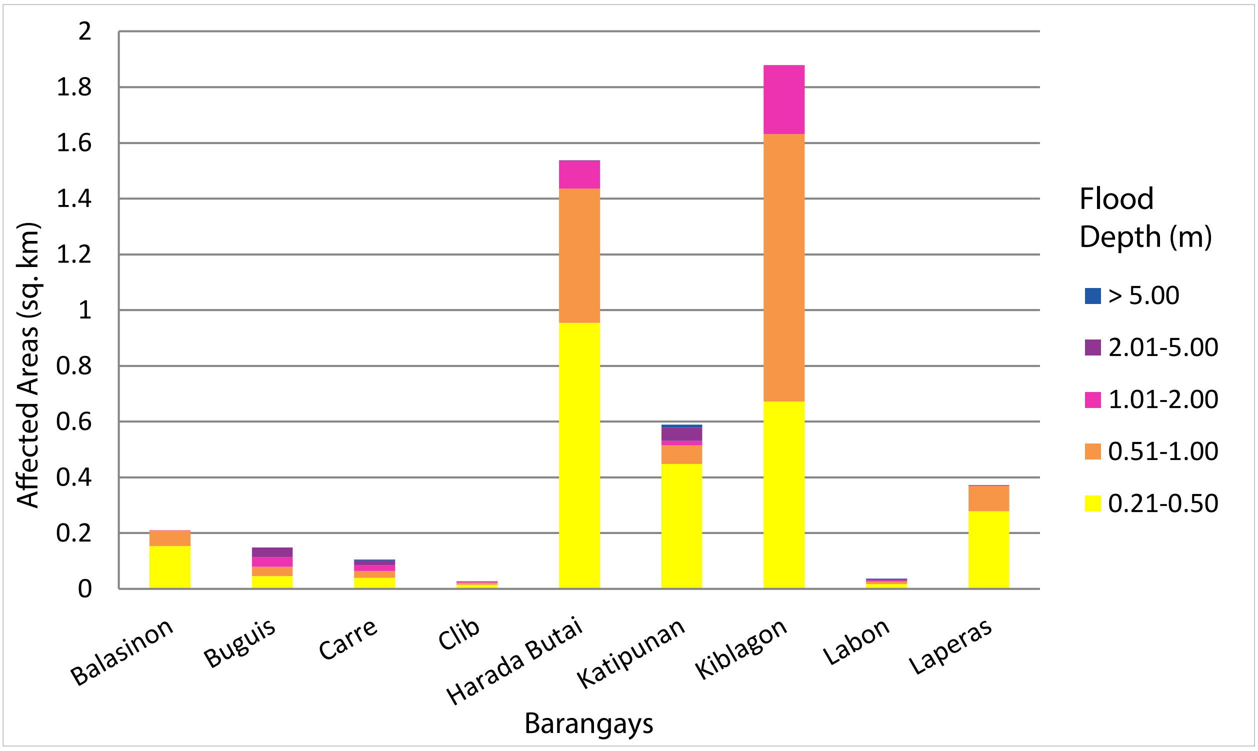


Figure 94. Affected Areas in Sulop, Davao del Sur during 5-Year Rainfall Return Period

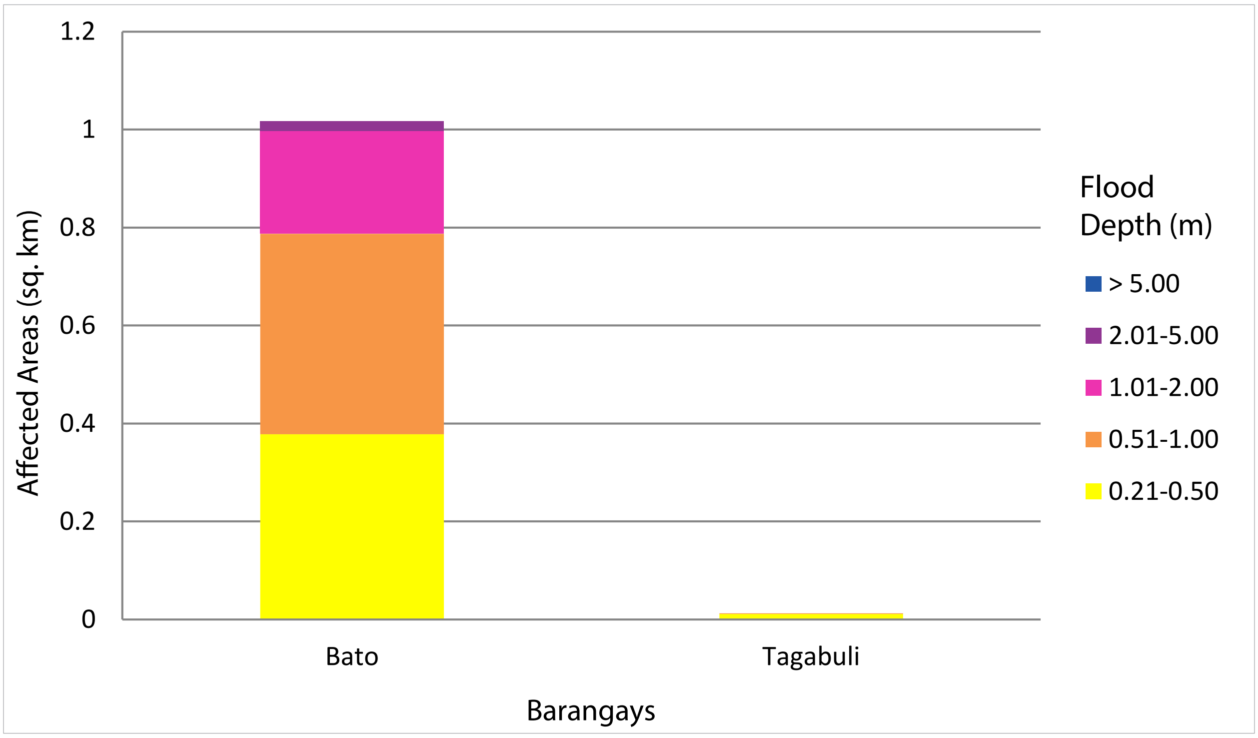


Figure 95. Affected Areas in Sulop, Davao del Sur during 5-Year Rainfall Return Period

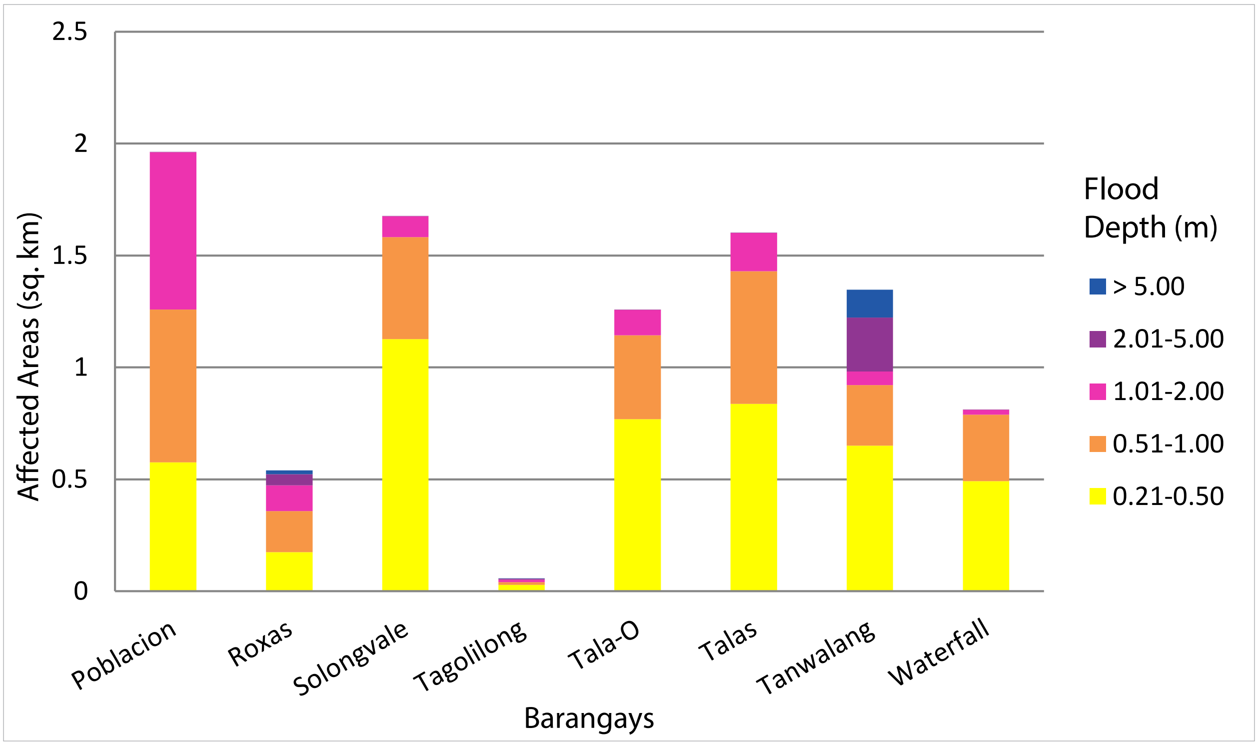


Figure 96. Affected Areas in Sulop, Davao del Sur during 5-Year Rainfall Return Period

For the 5-year return period, 0.24% of the municipality of Columbio with an area of 574.067 sq. km. will experience flood levels of less than 0.20 meters. 0.01% of the area will experience flood levels of 0.21 to 0.50 meters while 0.00% of the area will experience flood depths of 0.51 to 1 meter. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 51. Affected Areas in Columbio, Sultan Kudarat during 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangay in Columbio
	Datablao
0.03-0.20	1.39067
0.21-0.50	0.02969
0.51-1.00	0.014751
1.01-2.00	0.01476
2.01-5.00	0.017973
> 5.00	0.0043

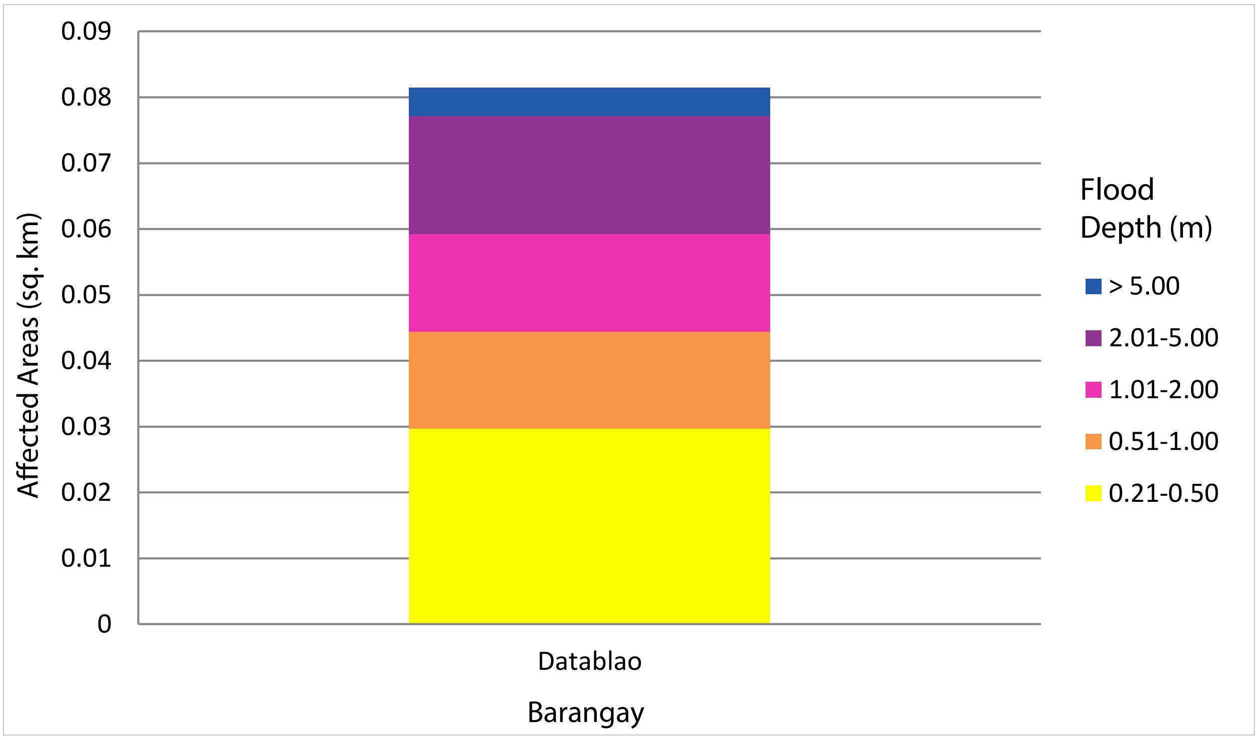


Figure 97. Affected Areas in Columbio, Sultan Kudarat during 5-Year Rainfall Return Period

For the 25-year return period, 10.62% of the municipality of Bansalan with an area of 136.18 sq. km. will experience flood levels of less than 0.20 meters. 2.59% of the area will experience flood levels of 0.21 to 0.50 meters while 0.98%, 0.48%, 0.19%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 52. Affected Areas in Bansalan, Davao del Sur during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Bansalan							
	Anonang	Bonifacio	Buenavista	Mabunga	New Clarin	Poblacion	Poblacion Dos	Union
0.03-0.20	1.60987	1.34427	2.0714	3.33942	0.532855	1.28824	1.27358	3.00853
0.21-0.50	0.142879	0.147071	0.314918	1.81209	0.054655	0.194801	0.525083	0.341582
0.51-1.00	0.085356	0.05411	0.183677	0.284251	0.056757	0.150779	0.178833	0.342422
1.01-2.00	0.035793	0.026919	0.064771	0.160398	0.055009	0.070182	0.036369	0.197738
2.01-5.00	0.013359	0.013509	0.030382	0.047548	0.010903	0.070421	0.0006	0.069594
> 5.00	0	0.0002	0.0001	0.0001	0	0.0057	0	0.0049

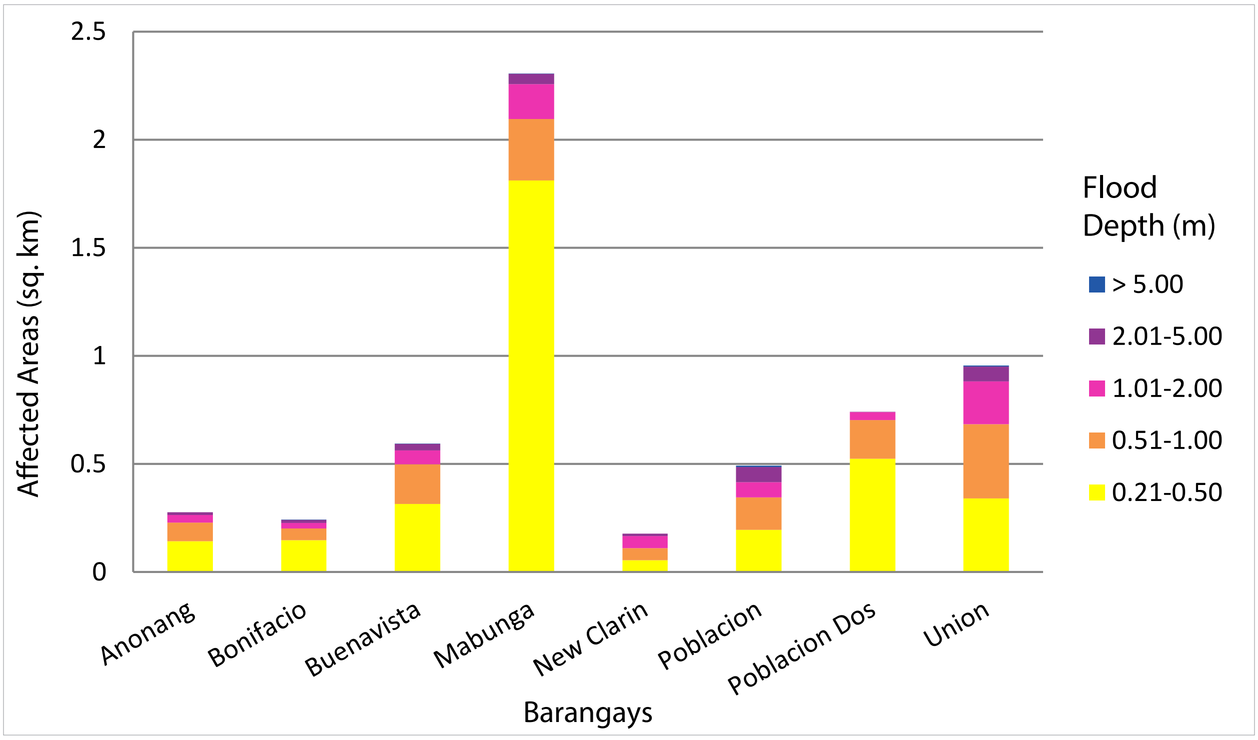


Figure 98. Affected Areas in Bansalan, Davao del Sur during 25-Year Rainfall Return Period

For the 25-year return period, 24.44% of the municipality of Digos City with an area of 226.71 sq. km. will experience flood levels of less than 0.20 meters. 6.71% of the area will experience flood levels of 0.21 to 0.50 meters while 4.44%, 2.15%, 0.63%, and 0.11% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 53. Affected Areas in Digos City, Davao del Sur during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Digos City											
	Aplaya	Balabag	Cogon	Colorado	Dawis	Dulangan	Goma	Igpit	Kiagot	Lungag	Mahayahay	Matti
0.03-0.20	2.12476	0.167608	2.08466	3.78364	1.65599	0.097516	2.49115	1.17526	1.92244	4.69374	4.35425	4.69692
0.21-0.50	1.7767	0.007106	1.29816	1.02291	1.07252	0.007934	0.370198	0.939615	0.070934	0.369055	0.443953	0.813748
0.51-1.00	0.617703	0.004442	1.45577	1.81519	0.269134	0.000369	0.166749	0.945263	0.031028	0.224049	0.267246	0.604391
1.01-2.00	0.08512	0.003898	0.303453	0.889769	0.057212	0.000015	0.066244	1.20477	0.035918	0.085471	0.177809	0.511883
2.01-5.00	0.071049	0.0027	0.007535	0.221087	0.017828	0	0.025624	0.124232	0.025479	0.029934	0.120258	0.25378
> 5.00	0.01549	0	0	0.0027	0	0	0	0	0.000782	0	0.0046	0.0068

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Digos City											
	Ruparan	San Agustin	San Jose	San Miguel	San Roque	Sinawilan	Soong	Tiguman	Tres de Mayo	Zone 1	Zone 2	Zone 3
0.03-0.20	3.03244	4.07376	1.31386	0.708851	5.04226	3.39011	0.787975	1.13373	2.0441	2.12395	0.837083	1.67405
0.21-0.50	0.183075	0.785167	1.04285	1.05533	0.671242	0.493485	0.031481	0.934216	0.455377	0.071215	0.352008	0.93906
0.51-1.00	0.081044	0.331871	0.294143	0.689102	0.463411	0.433955	0.012143	0.545798	0.459694	0.047035	0.158341	0.140589
1.01-2.00	0.052867	0.153941	0.281845	0.301684	0.194882	0.089734	0.008	0.077473	0.208089	0.030453	0.048536	0.012238
2.01-5.00	0.046753	0.074994	0.00338	0	0.055827	0.037362	0.006065	0.000627	0.159183	0.043666	0.092426	0.006663
> 5.00	0.004104	0	0	0	0	0.009877	0	0	0.055783	0.00574	0.137943	0.010182

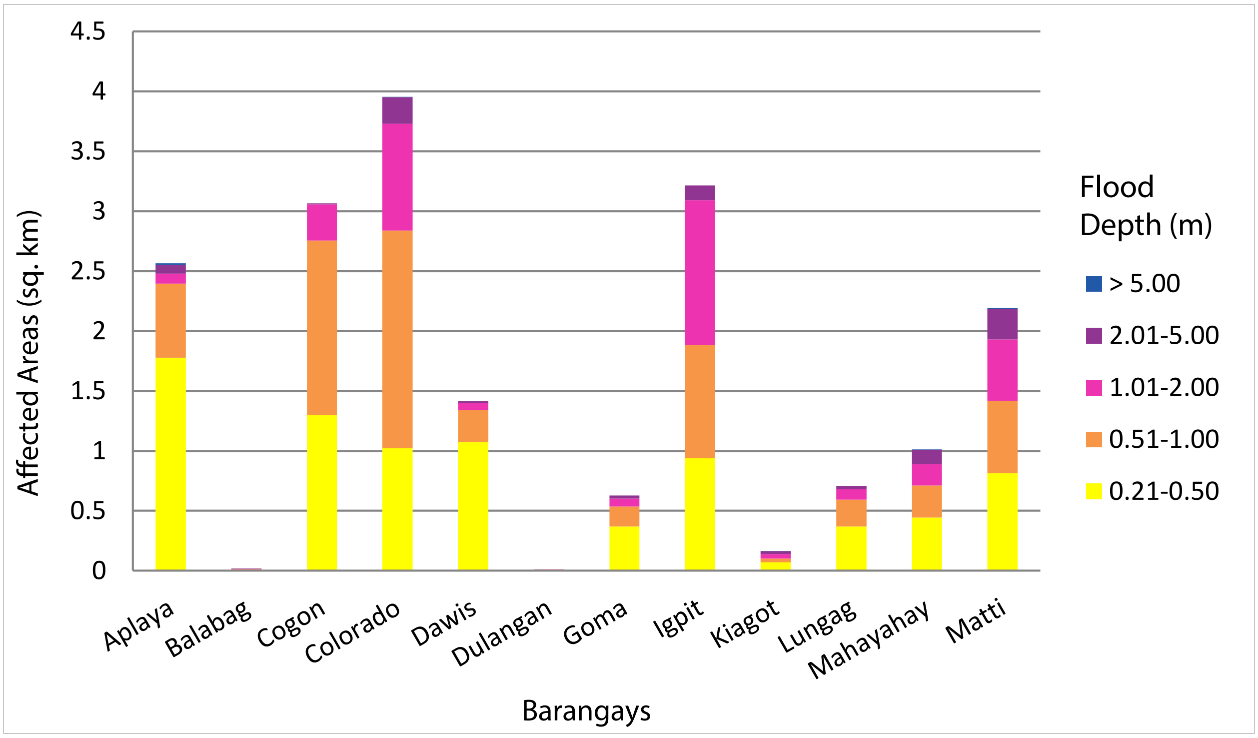


Figure 99. Affected Areas in Digos, Davao del Sur during 25-Year Rainfall Return Period

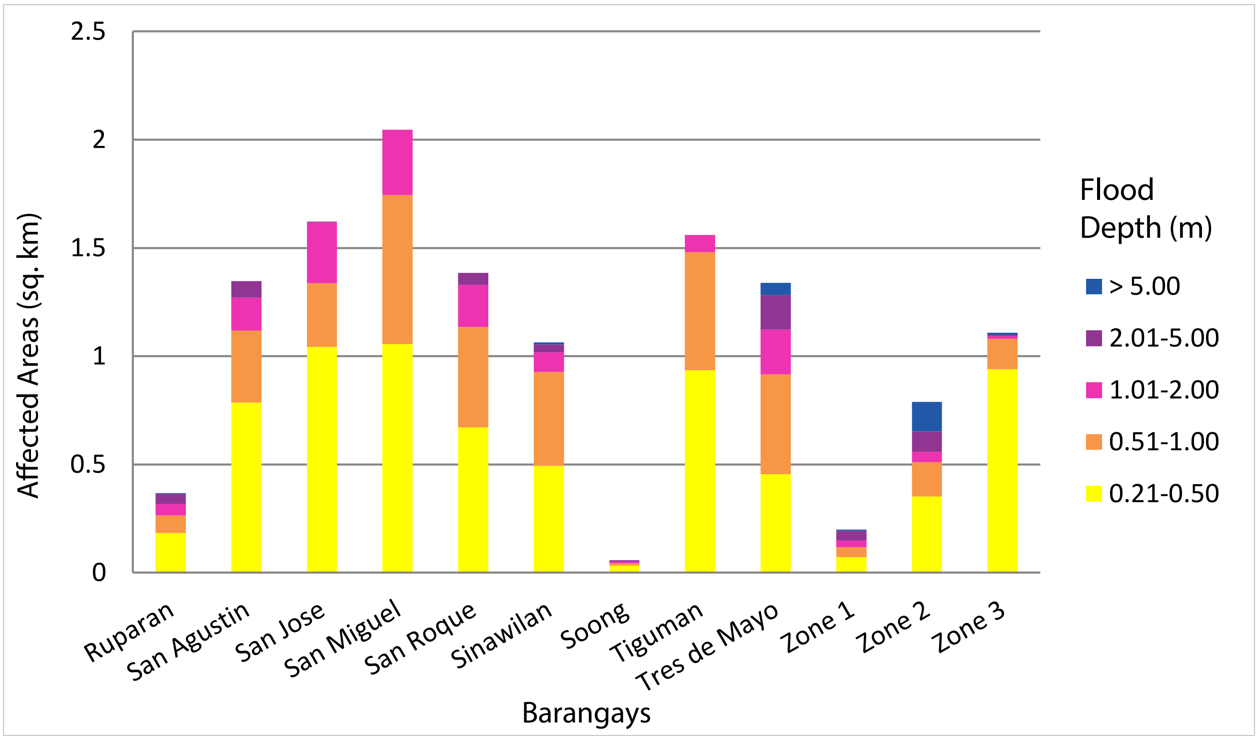


Figure 100. Affected Areas in Digos, Davao del Sur during 25-Year Rainfall Return Period

For the 25-year return period, 41.93% of the municipality of Hagonoy with an area of 85.69 sq. km. will experience flood levels of less than 0.20 meters. 23.70% of the area will experience flood levels of 0.21 to 0.50 meters while 13.07%, 14.16%, 7.07%, and 0.71% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 54. Affected Areas in Hagonoy, Davao del Sur during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Hagonoy											
	Balutakay	Clib	Guihing	Guihing Aplaya	Hagonoy Crossing	Kibuaya	La Union	Lanuro	Lapulabao	Leling	Mahayahay	Matti
0.03-0.20	0.481004	2.40266	1.23222	2.59957	1.39879	1.72093	3.03403	1.035	2.62579	3.94768	1.52078	5.0093
0.21-0.50	0.515667	0.202709	0.745425	1.8009	0.936761	1.19393	0.287483	1.2653	1.3527	3.63542	0.7519	0.72687
0.51-1.00	0.610233	0.321313	0.239636	0.639601	0.205427	1.22528	0.210202	0.485031	0.769009	2.17208	0.164641	0.540675
1.01-2.00	1.58028	0.415705	0.054132	0.187195	0.05775	1.48417	0.225951	1.11204	0.307673	2.88087	0.021302	0.366419
2.01-5.00	1.33404	0.095866	0.077857	0.083839	0.096843	0.405944	0.071832	0.243123	0.027734	1.15122	0.012989	0.126065
> 5.00	0	0.029434	0.160074	0.017166	0.213624	0.0013	0.012267	0	0.002868	0	0.0012	0.0026

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Hagonoy											
	Malabang Damsite	Maliit Digos	New Quezon	Paligue	Poblacion	Sacub	San Guillermo	San Isidro	Sinayawan	Tologan	Zone 2	Zone 3
0.03-0.20	2.3014	1.44492	2.55979	0.518151	2.07265	2.74329	0.71244	0.023295	0.804839	0.746868	1.01792	2.05706
0.21-0.50	0.258942	0.378643	0.473802	0.531469	1.35832	3.19957	0.112472	0.053475	0.889785	0.364049	0.293495	0.639876
0.51-1.00	0.289188	0.708603	0.246301	0.236864	0.213901	1.08956	0.249034	0.331711	0.664516	0.128173	0.08828	0.060973
1.01-2.00	0.164583	0.357386	0.2939	0.0414	0.079395	0.0052	0.49815	1.49689	0.819718	0.051246	0.032234	0.008187
2.01-5.00	0.061207	0.062728	1.42086	0.0001	0.050532	0	0.164045	0.608554	0	0.092817	0.098808	0.005806
> 5.00	0.001308	0.0004	0.0001	0	0.020912	0	0.014581	0	0	0.133449	0.095596	0.009481

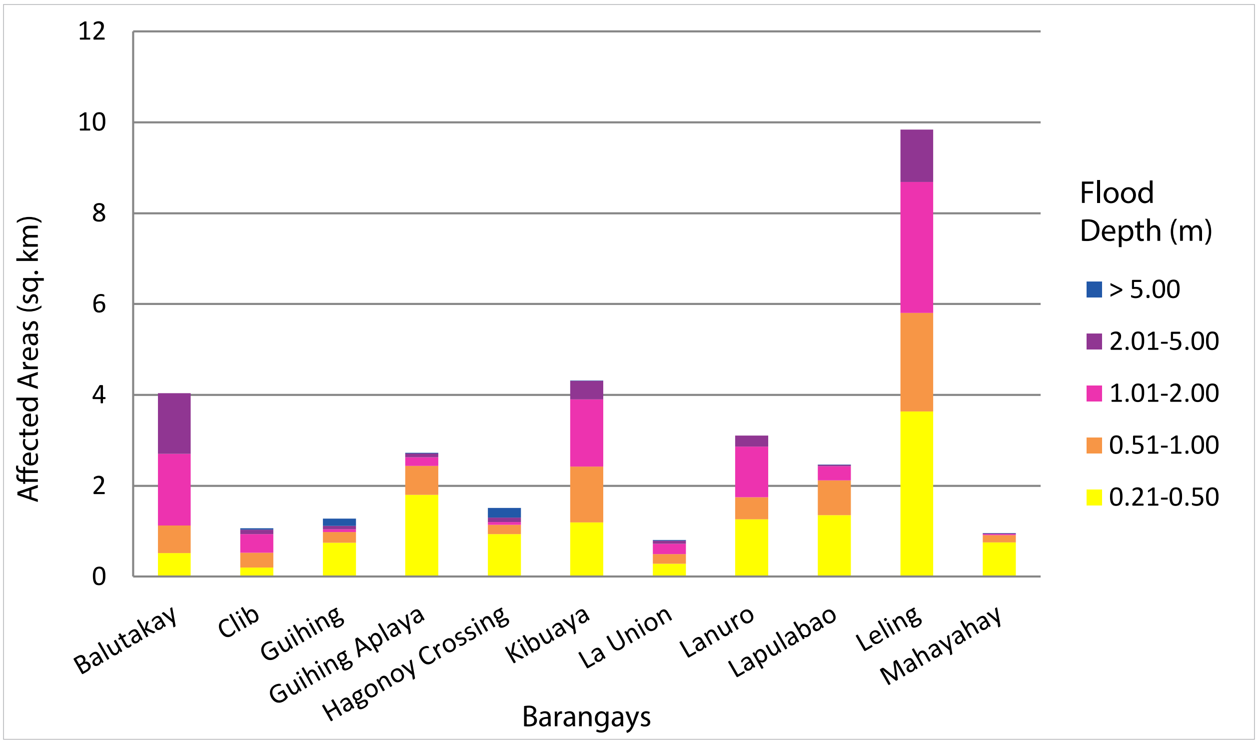


Figure 101. Affected Areas in Hagonoy, Davao del Sur during 25-Year Rainfall Return

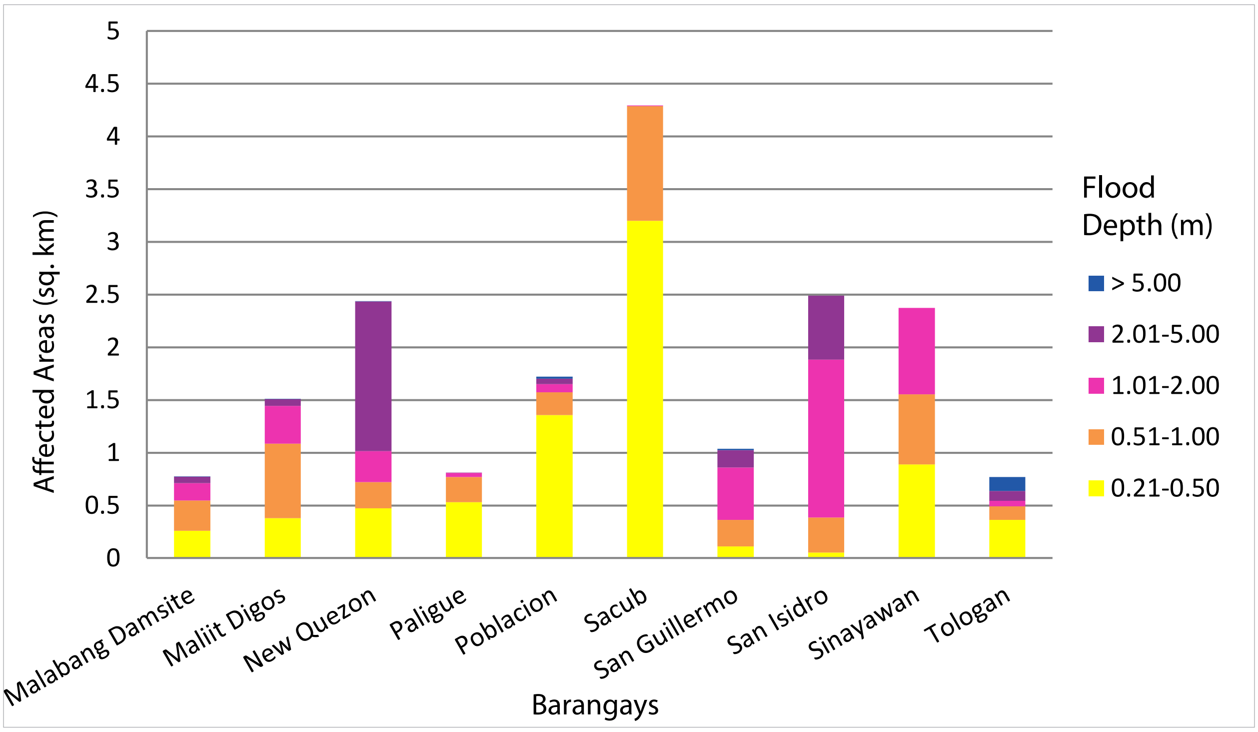


Figure 102. Affected Areas in Hagonoy, Davao del Sur during 25-Year Rainfall Return Period

For the 25-year return period, 52.90% of the municipality of Kiblawan with an area of 80.03 sq. km. will experience flood levels of less than 0.20 meters. 7.21% of the area will experience flood levels of 0.21 to 0.50 meters while 2.17%, 3.18%, 4.32%, and 0.61% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 55. Affected Areas in Kiblawan, Davao del Sur during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Kiblawan									
	Abnate	Bagong Negros	Bagong Silang	Bagumbayan	Balasiao	Bonifacio	Bulol-Salo	Bunot	Cogon-Bacaca	Dapok
0.03-0.20	2.46201	1.23485	1.3028	4.66288	1.63852	2.25917	0.874019	2.64378	0.530959	1.64104
0.21-0.50	0.753098	0.074076	0.081482	0.45217	0.06696	0.092945	0.027457	0.112713	0.079929	0.106071
0.51-1.00	0.124227	0.011751	0.075679	0.164892	0.104165	0.050256	0.017455	0.085244	0.009245	0.090482
1.01-2.00	0.038079	0.014081	0.122856	0.357448	0.24561	0.054829	0.033798	0.057589	0.010209	0.195005
2.01-5.00	0.0012	0.00622	0.212649	0.425996	0.116969	0.076575	0.058248	0.052368	0.010689	0.111258
> 5.00	0	0	0.008148	0.001542	0.0037	0.007399	0.003563	0.012	0.0001	0.049278

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Kiblawan									
	Ihan	Kibongbong	Kimlawis	Kisulan	Lati-An	Manual	Maraga-A	Molopolo	New Sibonga	Panaglib
0.03-0.20	0.392791	0.635541	1.39436	0.864682	1.15627	1.03224	1.44373	2.345	1.45496	0.456867
0.21-0.50	0.063017	0.230474	0.026379	0.052926	0.044127	0.678893	0.046783	0.166378	0.084967	0.038232
0.51-1.00	0.084859	0.018702	0.015765	0.013488	0.051183	0.035285	0.029078	0.062435	0.110265	0.040254
1.01-2.00	0.117106	0.015181	0.0251	0.010992	0.128247	0	0.054843	0.125297	0.280604	0.073665
2.01-5.00	0.105007	0.021208	0.039237	0.005684	0.169395	0	0.052065	0.139193	0.452777	0.391641
> 5.00	0.038975	0.000485	0.006458	0	0.067434	0	0.0009	0.006047	0.028022	0.183046

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Kiblawan									
	Pasig	Poblacion	Pocaleel	San Isidro	San Jose	San Pedro	Santo Niño	Tacub	Tacul	Waterfall
0.03-0.20	0.570904	1.6553	1.16666	1.10197	0.761655	3.06889	1.08595	1.21774	0.720178	0.56341
0.21-0.50	0.042449	0.083333	0.046094	0.426862	0.04989	0.579378	0.045867	0.464613	0.453268	0.297342
0.51-1.00	0.01867	0.029183	0.051551	0.031982	0.04525	0.168812	0.037643	0.028843	0.090651	0.042723
1.01-2.00	0.047325	0.031271	0.15882	0.032179	0.061956	0.119534	0.068194	0.047056	0.016226	0.002412
2.01-5.00	0.027108	0.057164	0.084486	0.113558	0.111839	0.215561	0.345777	0.054765	0.000932	0.00091
> 5.00	0	0.004654	0	0.00148	0.03413	0.0003	0.025516	0.002219	0	0

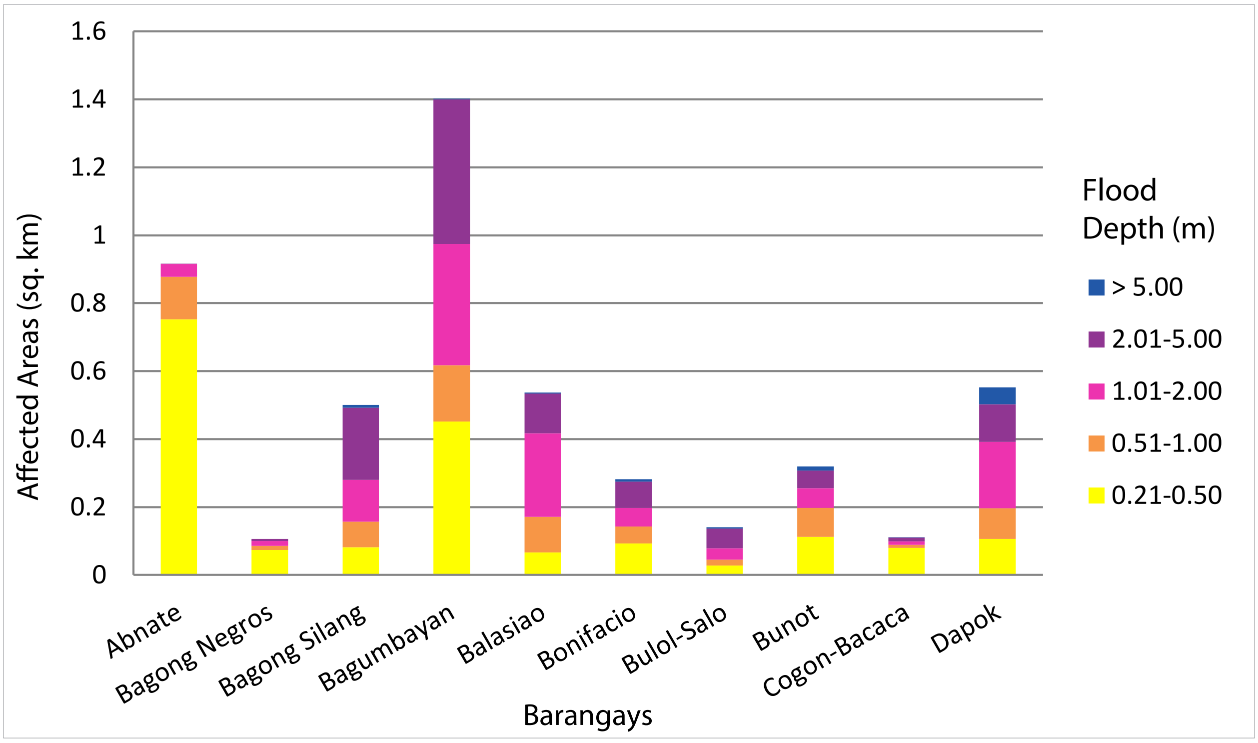


Figure 103. Affected Areas in Hagonoy, Davao del Sur during 25-Year Rainfall Return

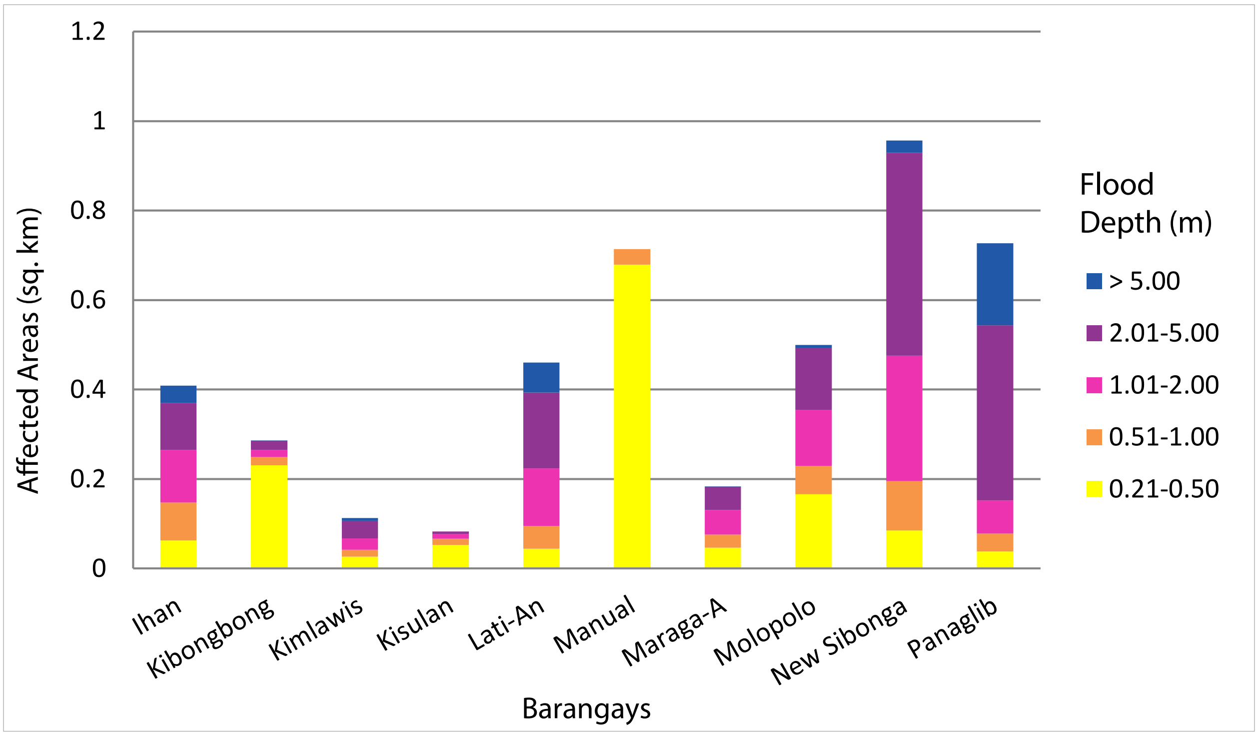


Figure 104. Affected Areas in Hagonoy, Davao del Sur during 25-Year Rainfall Return Period

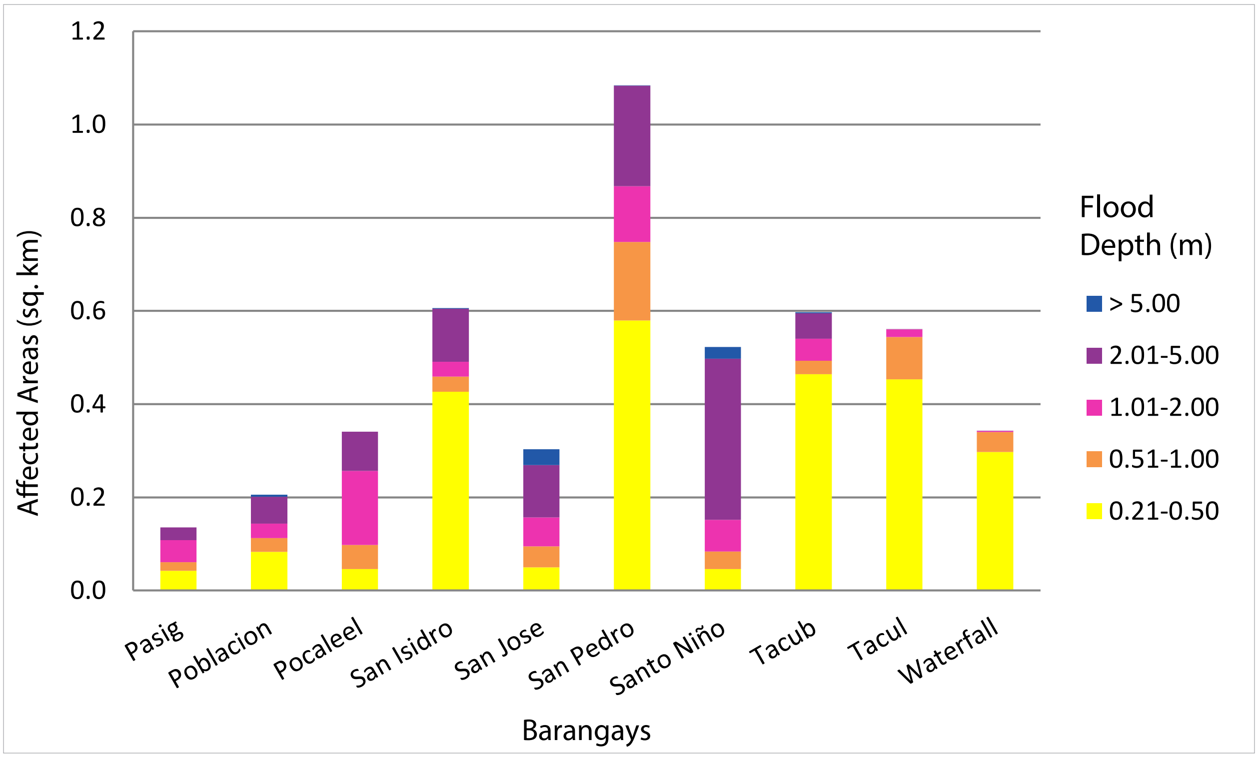


Figure 105. Affected Areas in Kiblawan, Davao del Sur during 25-Year Rainfall Return

For the 25-year return period, 0.30% of the municipality of Magsaysay with an area of 109.8 sq. km. will experience flood levels of less than 0.20 meters. 0.05% of the area will experience flood levels of 0.21 to 0.50 meters while 0.02%, 0.01%, and 0.01% 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 the table are the affected areas in square kilometers by flood depth per barangay.

Table 56. Affected Areas in Magsaysay, Davao del Sur during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangay in Magsaysay
	New Ilocos
0.03-0.20	0.327891
0.21-0.50	0.058881
0.51-1.00	0.02084
1.01-2.00	0.015593
2.01-5.00	0.0057
> 5.00	0

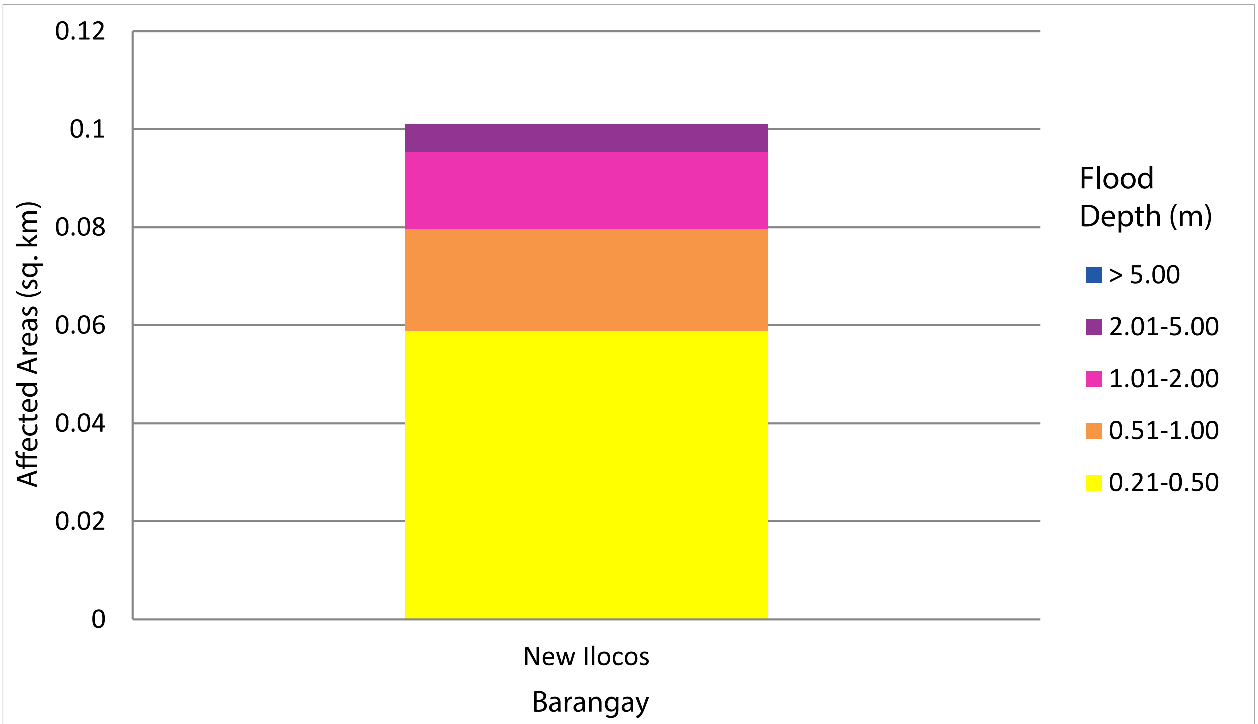


Figure 106. Affected Areas in Magsaysay, Davao del Sur during 25-Year Rainfall Return Period

For the 25-year return period, 10.34% of the municipality of Malalag with an area of 445 sq. km. will experience flood levels of less than 0.20 meters. 1.32% of the area will experience flood levels of 0.21 to 0.50 meters while 1.24%, 1.03%, 0.54%, and 0.06% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 57. Affected Areas in Malalag, Davao del Sur during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Malalag					
	Bagumbayan	Bolton	Kiblagon	Lapu-Lapu	Mabini	New Baclayon
0.03-0.20	0.014434	0.534189	11.8301	30.0538	1.36073	2.21588
0.21-0.50	0.006012	0.103109	3.44947	1.72941	0.040211	0.557039
0.51-1.00	0.00795	0.036677	3.585	1.19268	0.020286	0.672696
1.01-2.00	0.003315	0.01768	2.19409	1.68152	0.013221	0.676106
2.01-5.00	0	0.012496	0.405185	1.94553	0.015095	0.032056
> 5.00	0	0.0009	0.024666	0.23263	0.00702	0

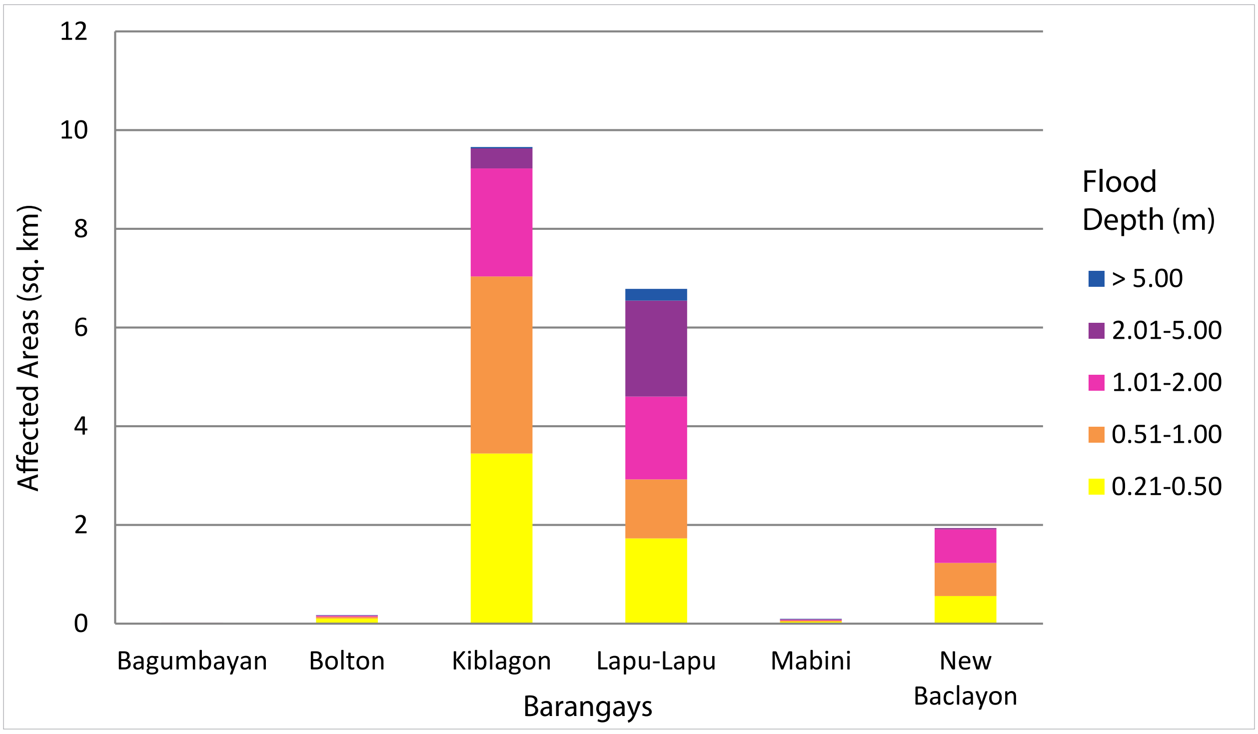


Figure 107. Affected Areas in Malalag, Davao del Sur during 25-Year Rainfall Return Period

For the 25-year return period, 42.34% of the municipality of Matanao with an area of 123.4 sq. km. will experience flood levels of less than 0.20 meters. 7.58% of the area will experience flood levels of 0.21 to 0.50 meters while 5.57%, 6.45%, 3.68%, and 0.17% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay

Table 58. Affected Areas in Matanao, Davao del Sur during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Matanao									
	Asbang	Asinan	Bagumbayan	Bangkal	Buas	Buri	Cabligan	Camanchiles	Ceboza	Colonsabak
0.03-0.20	0.039204	0.963495	2.89695	0.646398	0.08498	0.099914	0.083898	2.14644	2.42861	0.67578
0.21-0.50	0.001728	0.213538	0.395015	0.095856	0.013684	0.010335	0.211946	0.266516	0.904423	0.139964
0.51-1.00	0.000151	0.059894	0.228349	0.04215	0.002028	0.002779	0.567989	0.177365	0.217006	0.069977
1.01-2.00	0	0.062445	0.290087	0.04016	0.000607	0	2.20648	0.12483	0.168918	0.049007
2.01-5.00	0	0.032926	0.365512	0.015746	0	0	0.621142	0.110142	0.062018	0.0092
> 5.00	0	0	0.031609	0	0	0	0	0.015691	0.017644	0

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Matanao									
	Dongan-Pekong	Kabasagan	Kapok	Kibao	La Suerte	Langa-An	Lower Marber	Manga	New Katipunan	New Visayas
0.03-0.20	2.68333	1.04435	0.445036	1.02633	1.74011	1.19285	1.1178	5.52767	5.44779	2.0596
0.21-0.50	0.205898	0.187056	0.084081	0.085666	0.399468	0.458544	0.168655	1.32887	0.545604	0.971038
0.51-1.00	0.121757	0.024955	0.016223	0.045187	0.537484	0.033625	0.125193	2.27841	0.323312	0.140214
1.01-2.00	0.241637	0.024001	0.022115	0.056423	0.174306	0.023723	0.105683	2.1999	0.280072	0.002206
2.01-5.00	0.150961	0.0015	0.0102	0.039143	0.140767	0.021562	0.142701	1.57094	0.269439	0.0004
> 5.00	0.000651	0	0	0.0027	0.040524	0.000458	0.020742	0.0045	0.0379	0

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Matanao									
	Poblacion	Saboy	San Jose	San Vicente	Saub	Sinaragan	Sinawilan	Tamlangon	Tibongbong	Towak
0.03-0.20	1.18536	0.691479	2.49557	1.40193	1.11094	4.07984	5.97094	0.741232	1.18605	1.02793
0.21-0.50	0.140034	0.211967	0.486631	0.209886	0.372669	0.618388	0.390698	0.082512	0.059956	0.090633
0.51-1.00	0.136751	0.240936	0.134136	0.145796	0.263594	0.570891	0.255149	0.027673	0.03752	0.044973
1.01-2.00	0.179812	0.458575	0.127036	0.066057	0.170998	0.514651	0.248779	0.018495	0.043843	0.055965
2.01-5.00	0.122415	0.227042	0.11779	0.020241	0.041923	0.076802	0.306182	0.013356	0.003507	0.044085
> 5.00	0.022108	0.000449	0.000021	0	0	0.0024	0.0092	0.002392	0.000903	0

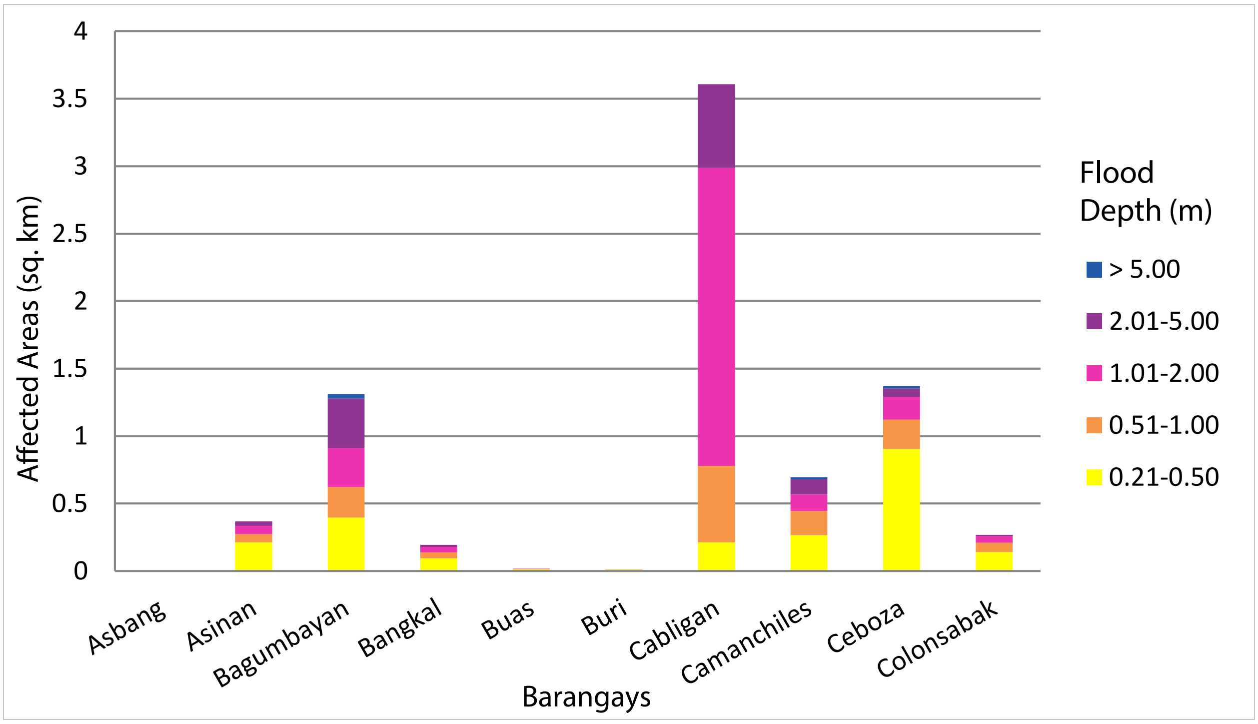


Figure 108. Affected Areas in Matanao, Davao del Sur during 25-Year Rainfall Return Period

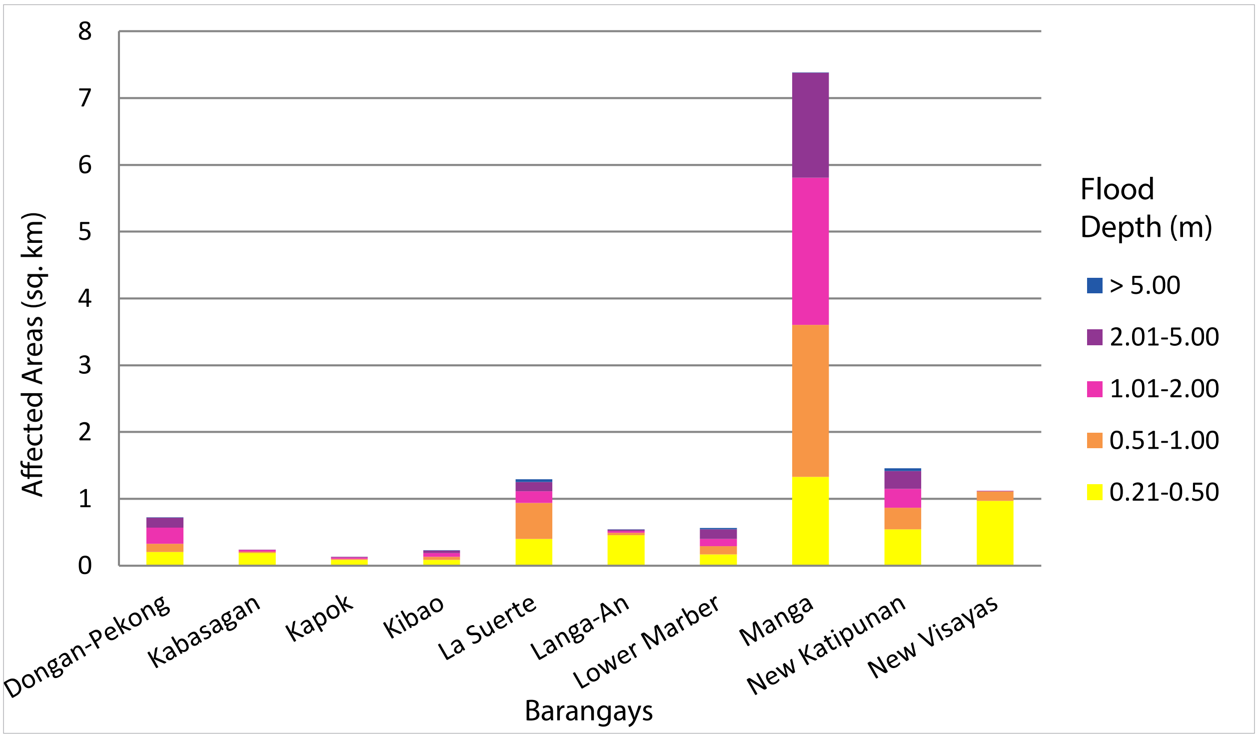


Figure 109. Affected Areas in Matanao, Davao del Sur during 25-Year Rainfall Return Period

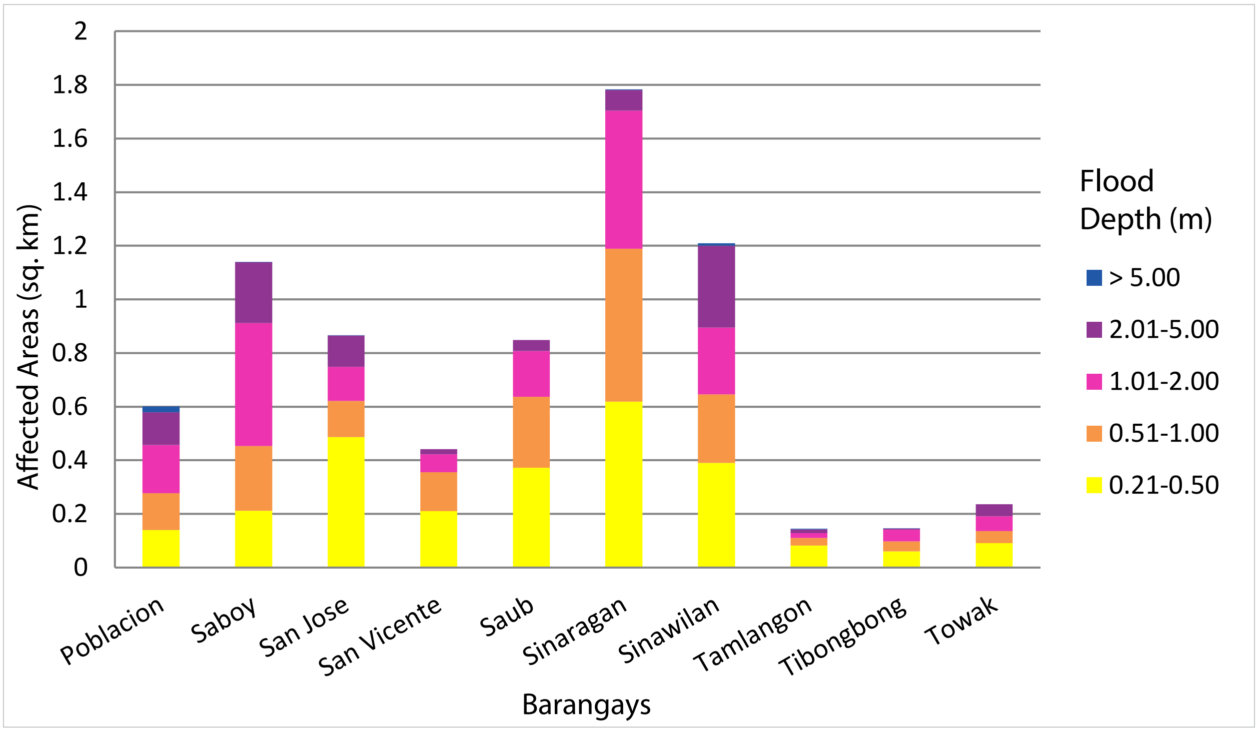


Figure 110. Affected Areas in Matanao, Davao del Sur during 25-Year Rainfall Return Period

For the 25-year return period, 52.76% of the municipality of Padada with an area of 55.97 sq. km. will experience flood levels of less than 0.20 meters. 27.14% of the area will experience flood levels of 0.21 to 0.50 meters while 11.38%, 3.92%, 2.67%, and 2.11% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 59. Affected Areas in Padada, Davao del Sur during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Padada								
	Almendras	Don Sergio Osmena, Sr.	Harada Butai	Lower Katipunan	Lower Limonzo	Lower Malinao	N C Ordaneza Distric	Northern Paligue	Palili
0.03-0.20	0.45618	1.21713	2.30474	4.00344	1.23832	2.8857	0.590004	1.58183	4.58444
0.21-0.50	0.395401	0.395819	1.95072	0.50757	1.13457	0.626726	0.233578	1.11153	3.19077
0.51-1.00	0.085278	0.448606	0.961284	0.242839	0.267349	0.392734	0.062834	0.368878	1.16583
1.01-2.00	0.0003	0.54624	0.257622	0.166286	0.067346	0.445639	0.017749	0.065357	0.154178
2.01-5.00	0	0.216529	0.0137	0.280993	0.003	0.870774	0.0001	0.046078	0.0016
> 5.00	0	0.510397	0	0.152801	0	0.325177	0	0.194151	0

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Padada							
	Piape	Punta Piape	Quirino District	San Isidro	Southern Paligue	Tulogan	Upper Limonzo	Upper Malinao
0.03-0.20	0.489671	2.01539	0.445701	1.20343	1.19119	0.982411	1.97955	2.35888
0.21-0.50	0.353223	0.899048	0.039664	0.610526	0.829514	1.05277	1.14707	0.71048
0.51-1.00	0.384451	0.413458	0.004838	0.637092	0.245748	0.33736	0.265336	0.085173
1.01-2.00	0.019701	0.050468	0	0.237293	0.011874	0.012092	0.072941	0.066914
2.01-5.00	0	0	0	0.0127	0	0	0.0085	0.039371
> 5.00	0	0	0	0	0	0	0	0

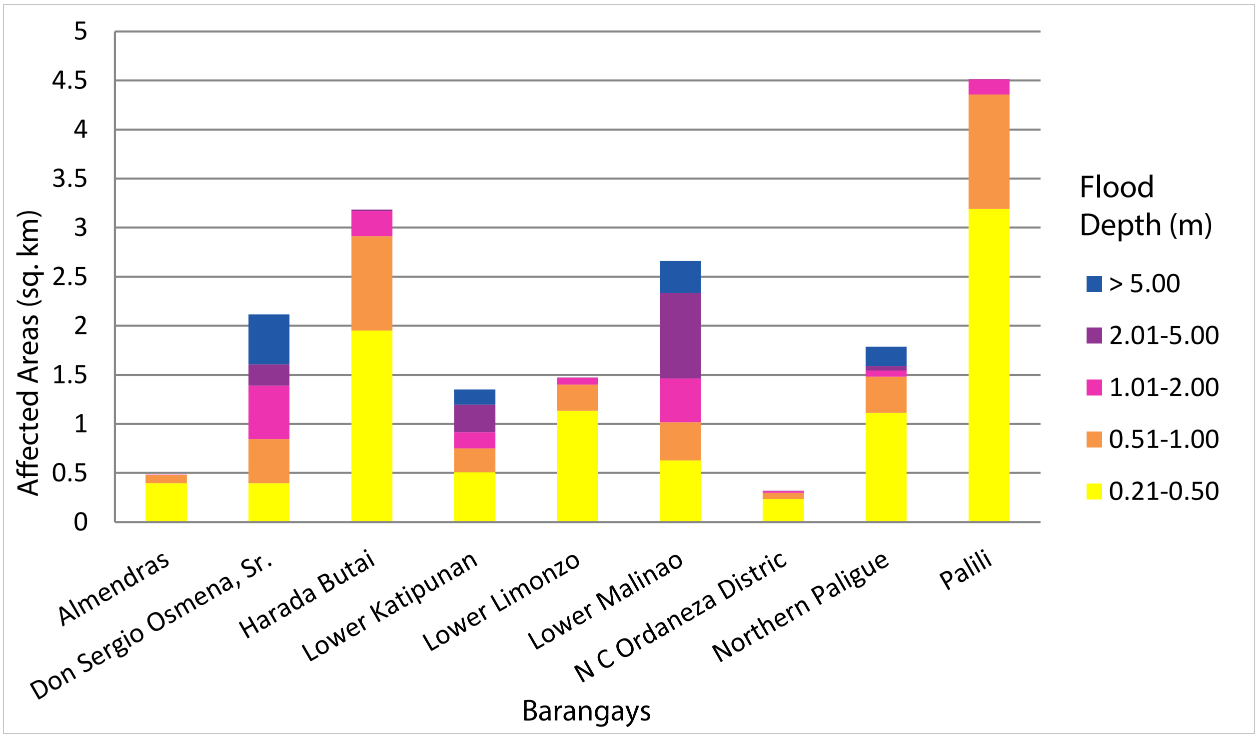


Figure 111. Affected Areas in Padada, Davao del Sur during 25-Year Rainfall Return Period

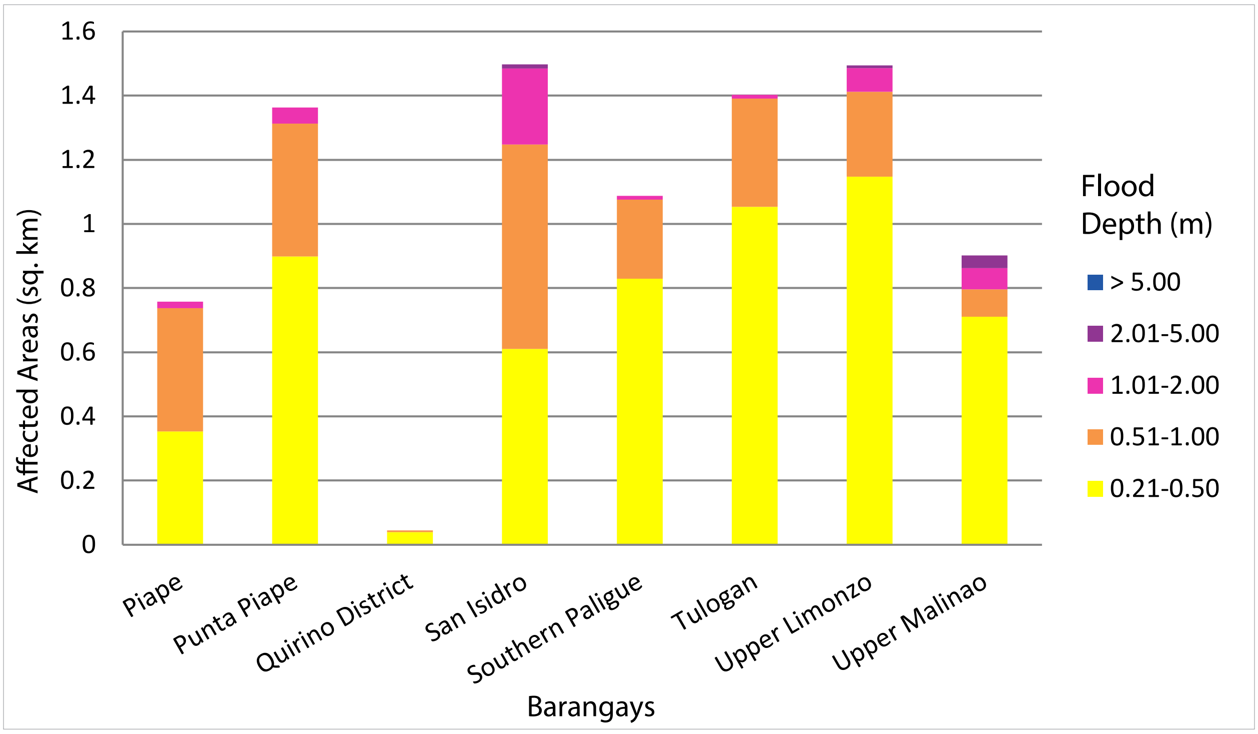


Figure 112. Affected Areas in Padada, Davao del Sur during 25-Year Rainfall Return Period

For the 25-year return period, 0.86% of the municipality of Santa Cruz with an area of 267.54 sq. km. will experience flood levels of less than 0.20 meters. 0.13% of the area will experience flood levels of 0.21 to 0.50 meters while 0.14%, 0.19%, and 0.02% 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 the table are the affected areas in square kilometers by flood depth per barangay.

Table 60. Affected Areas in Santa Cruz, Davao del Sur during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Santa Cruz	
	Bato	Tagabuli
0.03-0.20	2.24871	0.054899
0.21-0.50	0.324265	0.015493
0.51-1.00	0.354022	0.010038
1.01-2.00	0.505296	0.0001
2.01-5.00	0.0652	0
> 5.00	0.0033	0

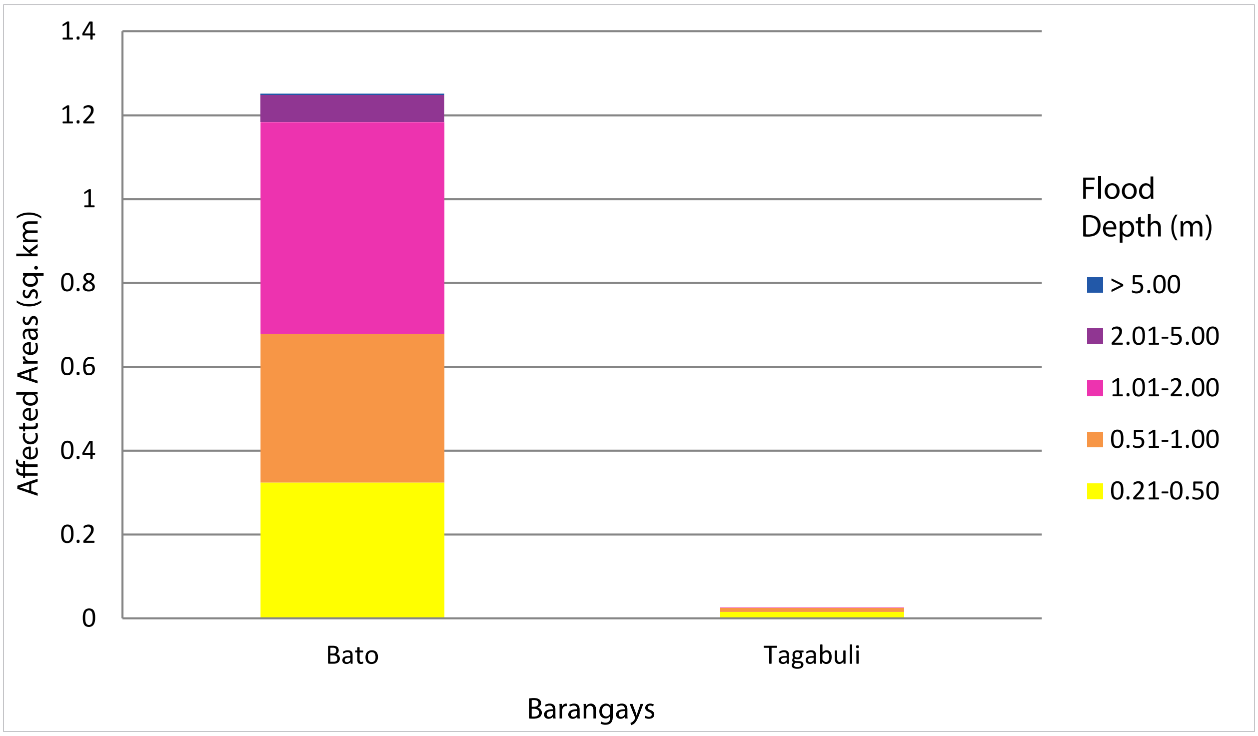


Figure 113. Affected Areas in Santa Cruz, Davao del Sur during 25-Year Rainfall Return Period

For the 25-year return period, 51.93% of the municipality of Sulop with an area of 50.8 sq. km. will experience flood levels of less than 0.20 meters. 20.28% of the area will experience flood levels of 0.21 to 0.50 meters while 15.39%, 9.42%, 1.92%, and 0.52% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 61. Affected Areas in Sulop, Davao del Sur during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Sulop								
	Balasinon	Buguis	Carre	Clib	Harada Butai	Katipunan	Kiblagon	Labon	Laperas
0.03-0.20	0.177924	1.16099	0.88147	0.51323	1.53343	0.932934	0.205748	0.470354	0.76692
0.21-0.50	0.152299	0.047441	0.043008	0.017886	1.09214	0.603761	0.428304	0.022371	0.245398
0.51-1.00	0.108412	0.031641	0.030507	0.010285	0.798269	0.153521	0.940891	0.009955	0.176169
1.01-2.00	0.00374	0.036575	0.024728	0.003033	0.205882	0.02013	0.67485	0.007125	0.008415
2.01-5.00	0	0.059789	0.022653	0.001523	0.0082	0.048829	0.05676	0.005286	0.000446
> 5.00	0	0.001343	0.0055	0.000541	0	0.012973	0	0.002148	0.000154

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Sulop							
	Lapla	Litos	Luparan	Mckinley	New Cebu	Osmeña	Palili	Parame
0.03-0.20	0.683415	0.654229	0.33282	0.769171	1.70133	0.346021	3.40226	0.502136
0.21-0.50	0.025141	0.022642	0.011347	0.036927	0.316804	0.013223	2.87211	0.013618
0.51-1.00	0.012761	0.024013	0.005475	0.041808	0.471754	0.006357	1.01818	0.01219
1.01-2.00	0.01388	0.024098	0.005204	0.084123	0.082734	0.003293	1.16708	0.010734
2.01-5.00	0.022225	0.016623	0.010849	0.018604	0.035161	0.001396	0.265566	0.014936
> 5.00	0.009013	0.012683	0.003599	0	0.0013	0	0	0.0003

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Sulop							
	Poblacion	Roxas	Solongvale	Tagolilong	Tala-O	Talas	Tanwalang	Waterfall
0.03-0.20	0.277924	3.09981	1.93936	1.02222	2.07255	0.726794	1.45036	0.755546
0.21-0.50	0.3575	0.163978	0.968507	0.036183	0.979699	0.747008	0.633977	0.449236
0.51-1.00	0.626037	0.138849	0.869097	0.016092	0.51107	0.83533	0.558381	0.413047
1.01-2.00	1.15506	0.252139	0.199633	0.011797	0.239805	0.373582	0.087004	0.091933
2.01-5.00	0.04745	0.082011	0.001251	0.00885	0.0021	0.03404	0.208009	0.002272
> 5.00	0	0.020364	0	0.0006	0	0	0.195569	0

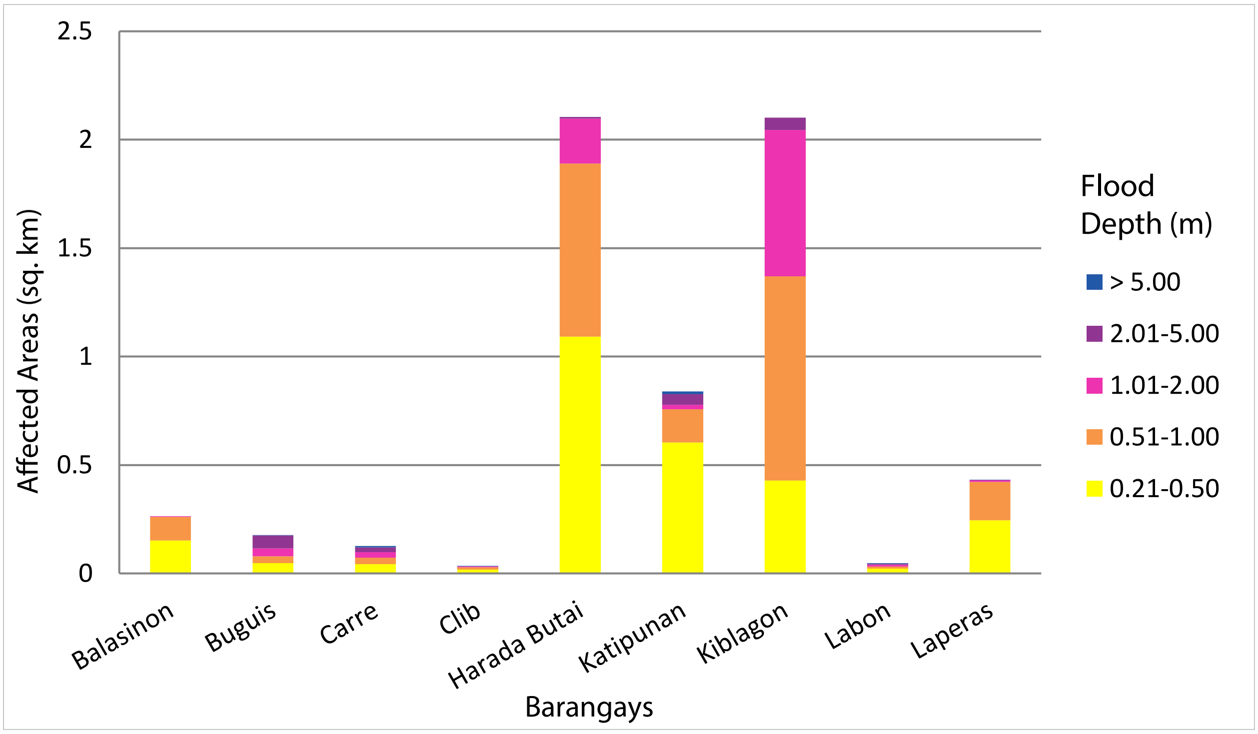


Figure 114. Affected Areas in Sulop, Davao del Sur during 25-Year Rainfall Return Period

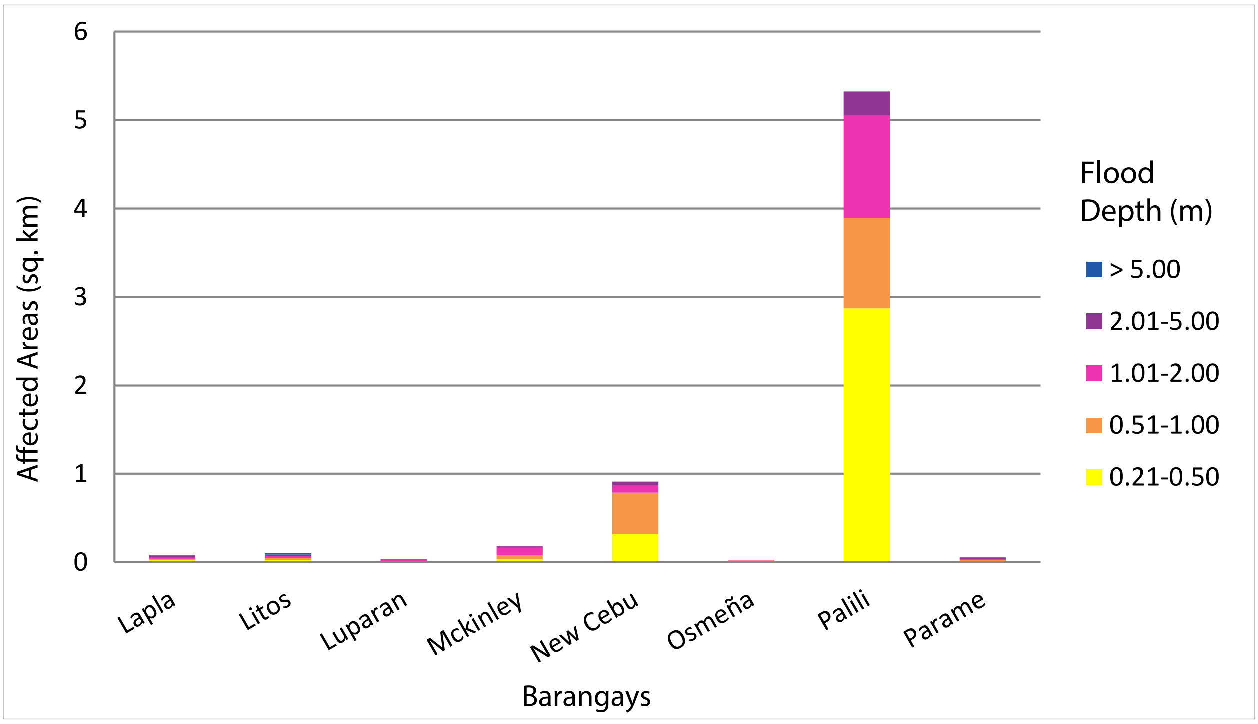


Figure 115. Affected Areas in Sulop, Davao del Sur during 25-Year Rainfall Return Period

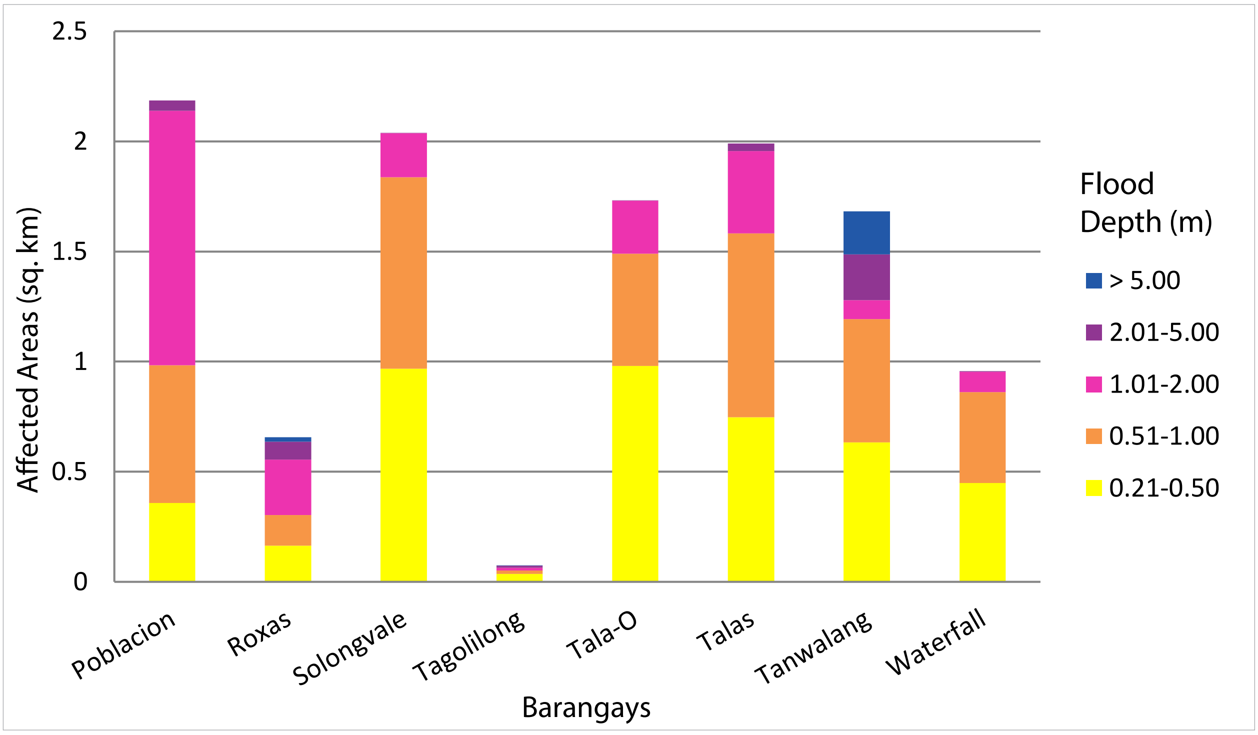


Figure 116. Affected Areas in Sulop, Davao del Sur during 25-Year Rainfall Return Period

For the 25-year return period, 0.24% of the municipality of Columbio with an area of 574.067 sq. km. will experience flood levels of less than 0.20 meters. 0.01% of the area will experience flood levels of 0.21 to 0.50. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 62. Affected Areas in Columbio, Sultan Kudarat during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangay in Columbio
	Datablao
0.03-0.20	1.37677
0.21-0.50	0.030386
0.51-1.00	0.019288
1.01-2.00	0.015963
2.01-5.00	0.022633
> 5.00	0.0071

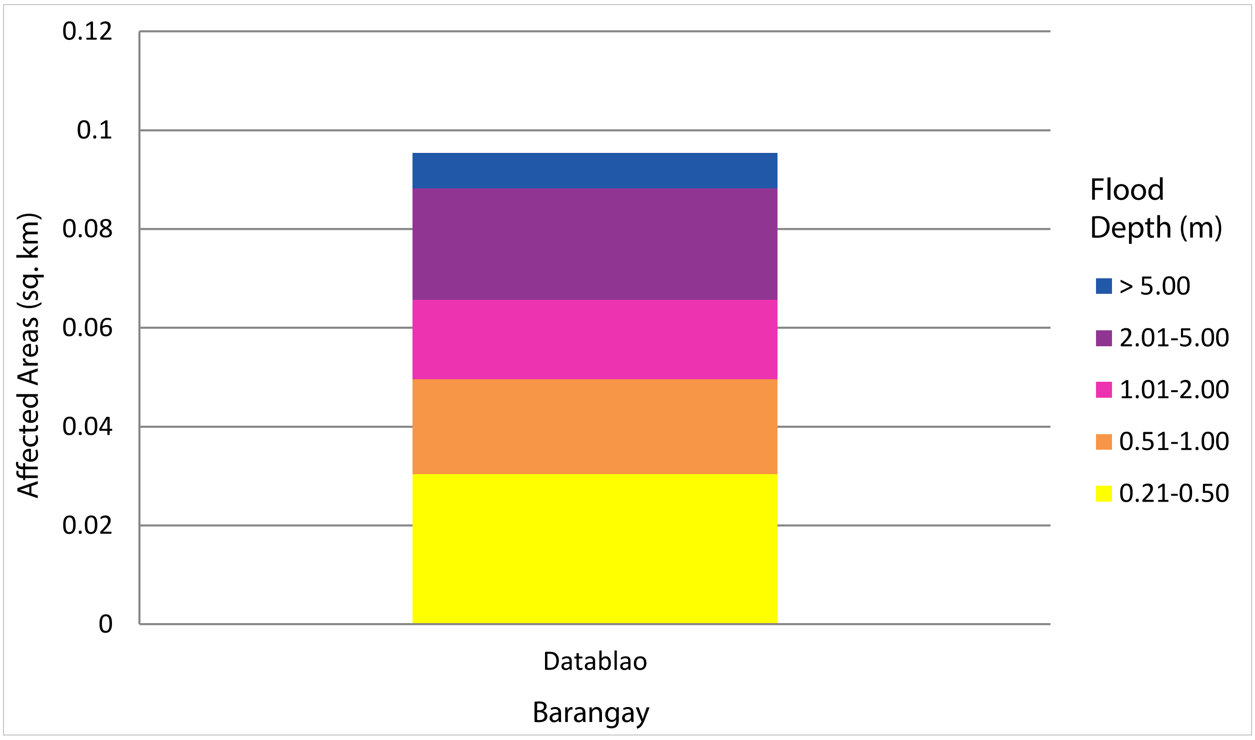


Figure 117. Affected Areas in Columbio, Sultan Kudarat during 25-Year Rainfall Return Period

For the 100-year return period, 9.70% of the municipality of Bansalan with an area of 136.18 sq. km. will experience flood levels of less than 0.20 meters. 3.08% of the area will experience flood levels of 0.21 to 0.50 meters while 1.16%, 0.67%, 0.25%, and 0.02% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 63. Affected Areas in Bansalan, Davao del Sur during 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Bansalan							
	Anonang	Bonifacio	Buenavista	Mabunga	New Clarin	Poblacion	Poblacion Dos	Union
0.03-0.20	1.55252	1.29378	1.95713	2.70031	0.503187	1.21131	1.12	2.87078
0.21-0.50	0.156801	0.164428	0.34312	2.28128	0.063945	0.22064	0.609809	0.356113
0.51-1.00	0.105476	0.069183	0.235033	0.401933	0.057686	0.167085	0.229844	0.319034
1.01-2.00	0.051269	0.040475	0.083127	0.198865	0.067434	0.093917	0.054318	0.317687
2.01-5.00	0.021193	0.017412	0.045538	0.064147	0.017927	0.076175	0.0016	0.091046
> 5.00	0	0.0008	0.0013	0.0004	0	0.011	0	0.0101

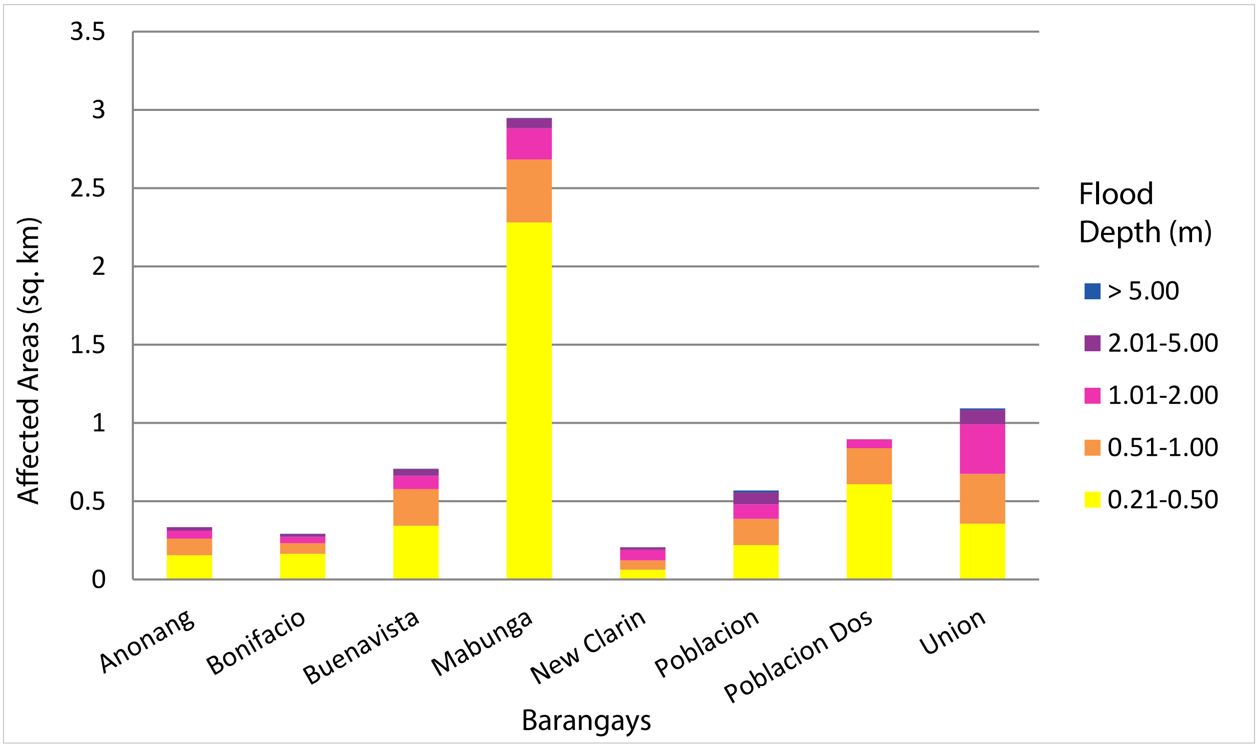


Figure 118. Affected Areas in Bansalan, Davao del Sur during 100-Year Rainfall Return Period

For the 100-year return period, 22.01% of the municipality of Digos City with an area of 226.71 sq. km. will experience flood levels of less than 0.20 meters. 6.92% of the area will experience flood levels of 0.21 to 0.50 meters while 5.18%, 2.95%, 0.90%, and 0.15% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 64. Affected Areas in Digos City, Davao del Sur during 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Digos City											
	Aplaya	Balabag	Cogon	Colorado	Dawis	Dulangan	Goma	Igpit	Kiagot	Lungag	Mahayahay	Matti
0.03-0.20	1.5858	0.111392	1.78985	3.35438	1.37203	0.039846	2.23185	0.808834	1.90087	4.55897	4.06312	4.3165
0.21-0.50	1.62719	0.002871	1.03556	0.916381	1.21589	0.02324	0.48318	0.770008	0.083743	0.353477	0.454912	0.832813
0.51-1.00	1.2278	0.002275	1.83472	1.60329	0.391405	0.038577	0.206165	1.00027	0.03063	0.254776	0.268522	0.647093
1.01-2.00	0.15569	0.003061	0.47332	1.34907	0.072332	0.003278	0.135477	1.40436	0.037643	0.104566	0.204471	0.602778
2.01-5.00	0.078849	0.000328	0.016135	0.300715	0.025725	0.000894	0.05937	0.297955	0.031662	0.052876	0.142996	0.361103
> 5.00	0.01679	0	0	0.005119	0	0	0	0	0.002028	0	0.0074	0.013281

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Digos City											
	Ruparan	San Agustin	San Jose	San Miguel	San Roque	Sinawilan	Soong	Tiguman	Tres de Mayo	Zone 1	Zone 2	Zone 3
0.03-0.20	2.94381	3.51863	1.00792	0.490088	4.84502	3.30059	0.780458	0.871794	1.86563	2.10261	0.639257	1.40491
0.21-0.50	0.231369	1.10376	1.17641	1.02798	0.705364	0.443304	0.035648	1.06421	0.470285	0.076789	0.439721	1.1079
0.51-1.00	0.094983	0.428917	0.386104	0.756211	0.505878	0.534585	0.013519	0.546714	0.462247	0.049738	0.224757	0.237529
1.01-2.00	0.063488	0.235721	0.354154	0.480687	0.258004	0.119238	0.008074	0.20789	0.302578	0.035098	0.069792	0.015504
2.01-5.00	0.059726	0.126368	0.011501	0	0.080755	0.045729	0.007865	0.001236	0.185142	0.047766	0.094789	0.006763
> 5.00	0.006901	0.010488	0	0	0.0002	0.011077	0.0001	0	0.099229	0.010063	0.158143	0.010482

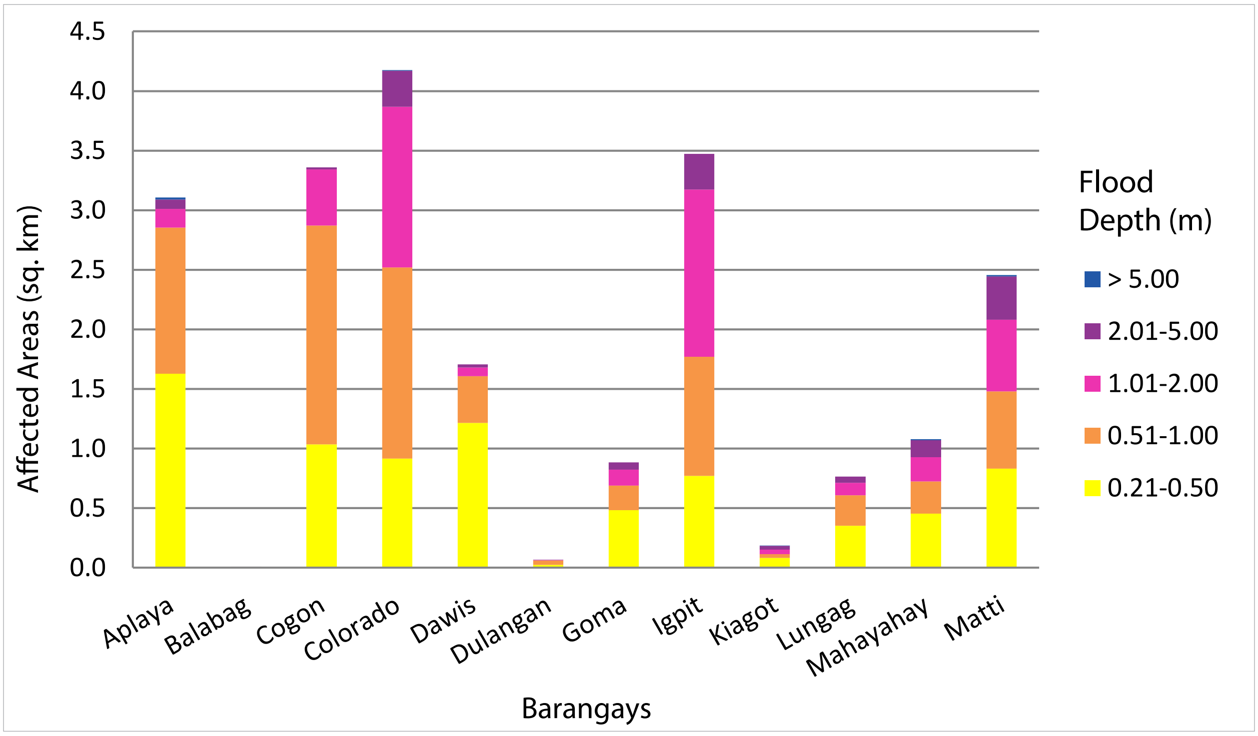


Figure 119. Affected Areas in Digos, Davao del Sur during 100-Year Rainfall Return Period

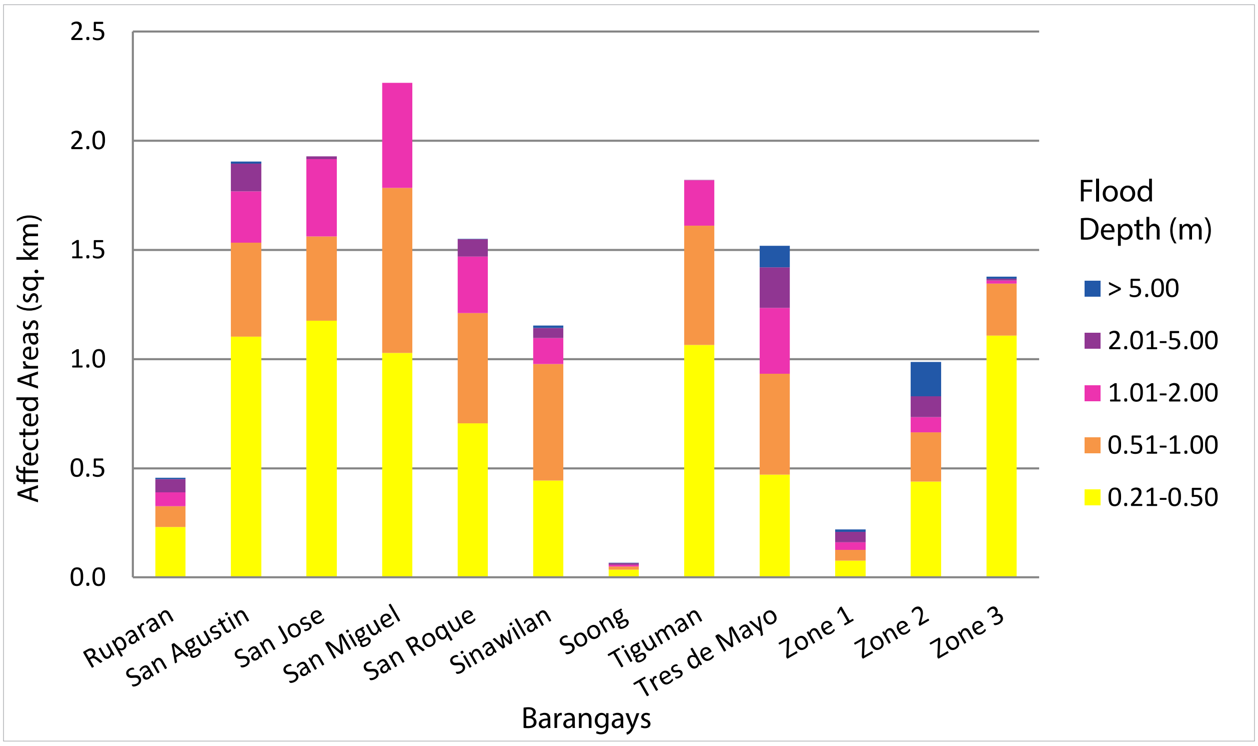


Figure 120. Affected Areas in Digos, Davao del Sur during 100-Year Rainfall Return Period

For the 100-year return period, 34.70% of the municipality of Hagonoy with an area of 85.69 sq. km. will experience flood levels of less than 0.20 meters. 22.79% of the area will experience flood levels of 0.21 to 0.50 meters while 15.47%, 15.99%, 10.20%, and 0.82% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 65. Affected Areas in Hagonoy, Davao del Sur during 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Hagonoy											
	Balutakay	Clib	Guihing	Guihing Aplaya	Hagonoy Crossing	Kibuaya	La Union	Lanuro	Lapulabao	Leling	Mahayahay	Matti
0.03-0.20	0.316036	2.33531	0.889063	2.12987	1.08146	1.15715	2.89832	0.669907	2.33624	2.84892	1.44219	5.0093
0.21-0.50	0.442023	0.199844	0.797521	1.63605	1.0111	0.632222	0.357491	1.22394	1.18684	3.74027	0.656557	0.72687
0.51-1.00	0.593656	0.195022	0.480747	1.06551	0.259816	1.67579	0.181689	0.648499	0.855753	2.34018	0.319552	0.540675
1.01-2.00	1.45295	0.528787	0.091569	0.387445	0.238187	2.06002	0.295279	0.831677	0.448892	3.05005	0.028702	0.366419
2.01-5.00	1.71656	0.171238	0.083657	0.085039	0.089063	0.451883	0.094199	0.766471	0.040587	1.81045	0.015689	0.126065
> 5.00	0	0.037571	0.170974	0.024366	0.236176	0.002207	0.013567	0	0.002714	0	0.0018	0.0026

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Hagonoy											
	Malabang Damsite	Maliit Digos	New Quezon	Paligue	Poblacion	Sacub	San Guillermo	San Isidro	Sinayawan	Tologan	Zone 2	Zone 3
0.03-0.20	2.22628	1.36244	2.30957	0.340101	1.54813	2.12232	0.658575	0.014503	0.513835	0.538001	1.01792	2.05706
0.21-0.50	0.252466	0.332858	0.566044	0.554297	1.66949	3.08162	0.08693	0.020427	0.715609	0.369341	0.293495	0.639876
0.51-1.00	0.262259	0.458604	0.220642	0.351245	0.400993	1.70798	0.183826	0.130434	0.64325	0.280152	0.08828	0.060973
1.01-2.00	0.244089	0.67732	0.289257	0.08214	0.100357	0.0307	0.53372	1.25839	0.982074	0.091153	0.032234	0.008187
2.01-5.00	0.089116	0.064762	1.58235	0.0002	0.058056	0	0.268736	1.09017	0.165232	0.095952	0.098808	0.005806
> 5.00	0.002408	0.0003	0.028893	0	0.022112	0	0.018935	0	0	0.144378	0.095596	0.009481

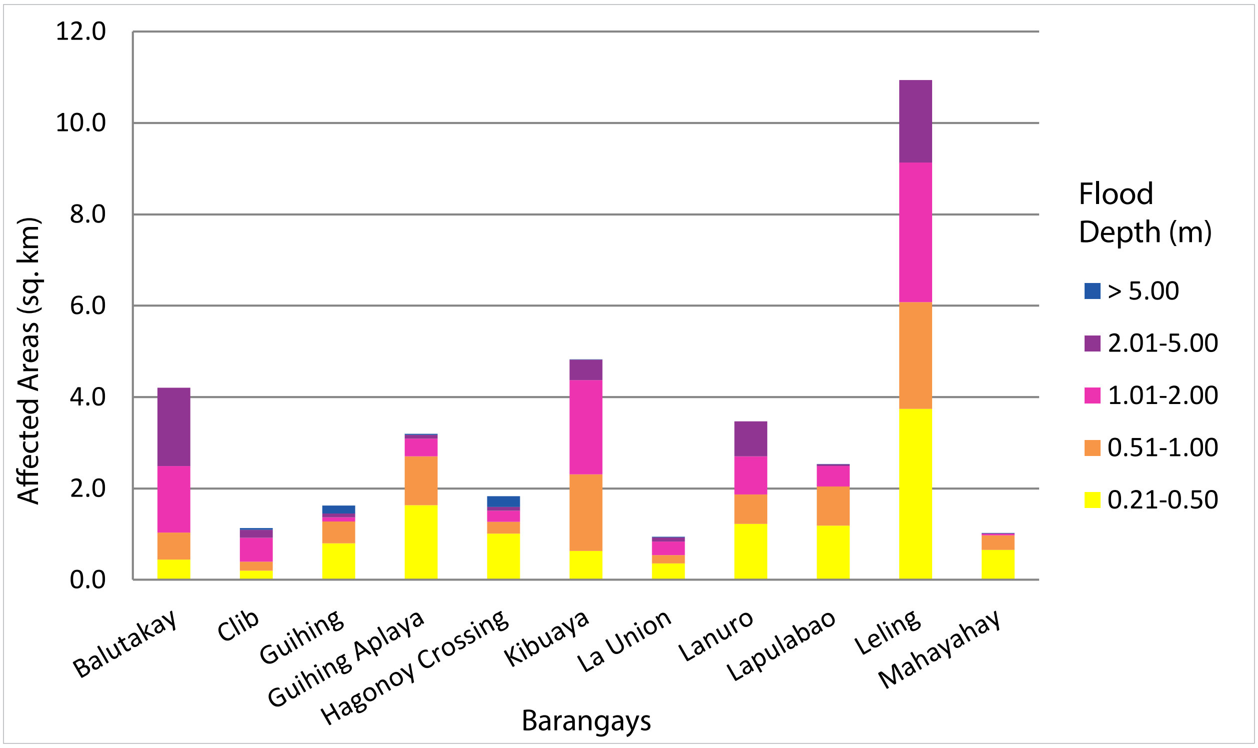


Figure 121. Affected Areas in Hagonoy, Davao del Sur during 100-Year Rainfall Return

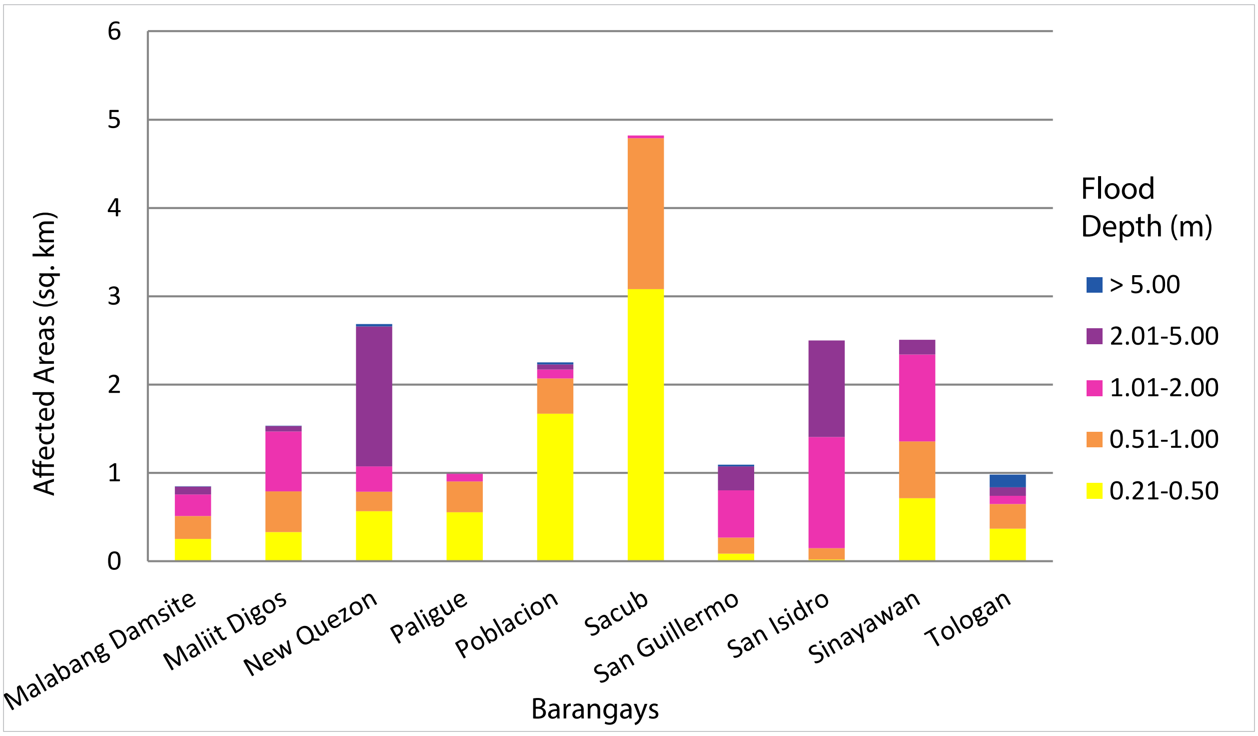


Figure 122. Affected Areas in Hagonoy, Davao del Sur during 100-Year Rainfall Return Period

For the 100-year return period, 49.73% of the municipality of Kiblawan with an area of 80.03 sq. km. will experience flood levels of less than 0.20 meters. 9.12% of the area will experience flood levels of 0.21 to 0.50 meters while 2.36%, 2.89%, 5.12%, and 1.18% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 66. Affected Areas in Kiblawan, Davao del Sur during 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Kiblawan									
	Abnate	Bagong Negros	Bagong Silang	Bagumbayan	Balasiao	Bonifacio	Bulol-Salo	Bunot	Cogon-Bacaca	Dapok
0.03-0.20	2.17018	1.1763	1.25352	4.38141	1.6066	2.21576	0.85357	2.6033	0.470841	1.5865
0.21-0.50	0.987084	0.128199	0.080033	0.630897	0.062762	0.113919	0.034602	0.118848	0.13655	0.118579
0.51-1.00	0.163086	0.012286	0.075994	0.163542	0.079635	0.052074	0.018806	0.09741	0.009346	0.069498
1.01-2.00	0.053974	0.015801	0.129014	0.258237	0.245376	0.056111	0.026193	0.065357	0.010416	0.172567
2.01-5.00	0.004291	0.008394	0.252856	0.606903	0.177156	0.087077	0.074231	0.061175	0.013776	0.188039
> 5.00	0	0	0.012203	0.023936	0.0044	0.016232	0.007138	0.0176	0.000203	0.057957

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Kiblawan									
	Ihan	Kibongbong	Kimlawis	Kisulan	Lati-An	Manual	Maraga-A	Molopolo	New Sibonga	Panaglib
0.03-0.20	0.320479	0.551974	1.37799	0.837594	1.11521	0.863083	1.42038	2.26768	1.40673	0.428852
0.21-0.50	0.08042	0.292716	0.03157	0.075215	0.04578	0.792304	0.055209	0.211383	0.098293	0.02651
0.51-1.00	0.077781	0.033168	0.018329	0.013988	0.046072	0.091028	0.029066	0.057372	0.092927	0.023901
1.01-2.00	0.113541	0.017784	0.021811	0.013892	0.116447	0	0.043791	0.097893	0.267174	0.061001
2.01-5.00	0.160274	0.021895	0.047638	0.007084	0.195831	0	0.077552	0.193406	0.500709	0.291343
> 5.00	0.049259	0.005371	0.009966	0	0.097322	0	0.0014	0.016616	0.045761	0.352099

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Kiblawan									
	Pasig	Poblacion	Pocaleel	San Isidro	San Jose	San Pedro	Santo Niño	Tacub	Tacul	Waterfall
0.03-0.20	0.552789	1.5959	1.14435	0.911813	0.73119	2.84582	1.04485	1.0495	0.553758	0.460497
0.21-0.50	0.053981	0.127258	0.048626	0.592102	0.052517	0.72065	0.042781	0.596486	0.569025	0.37773
0.51-1.00	0.015207	0.029626	0.0379	0.038769	0.043793	0.210279	0.03849	0.045046	0.136781	0.063901
1.01-2.00	0.03193	0.035033	0.129268	0.031082	0.06881	0.114856	0.062138	0.028719	0.020882	0.003527
2.01-5.00	0.05226	0.062932	0.14681	0.129212	0.114231	0.255126	0.279073	0.085922	0.001305	0.001143
> 5.00	0.000288	0.01015	0.000662	0.005057	0.05418	0.008449	0.141619	0.010447	0	0

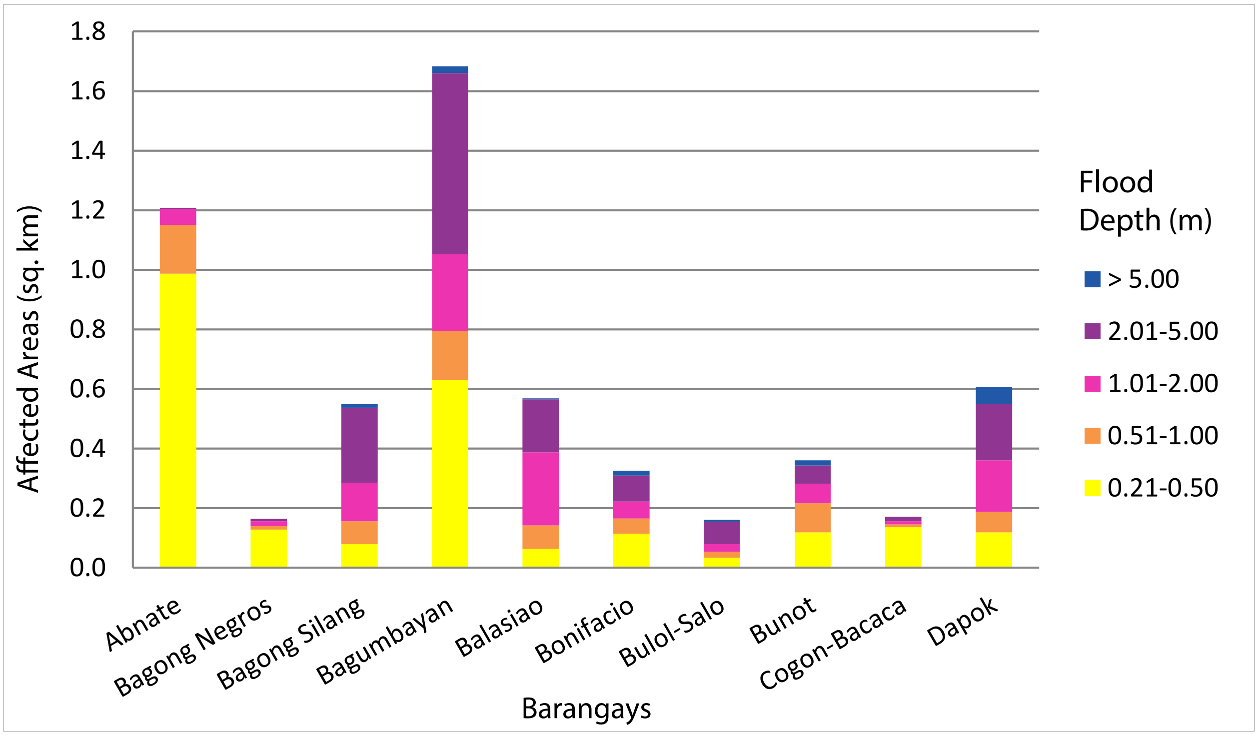


Figure 123. Affected Areas in Hagonoy, Davao del Sur during 100-Year Rainfall Return

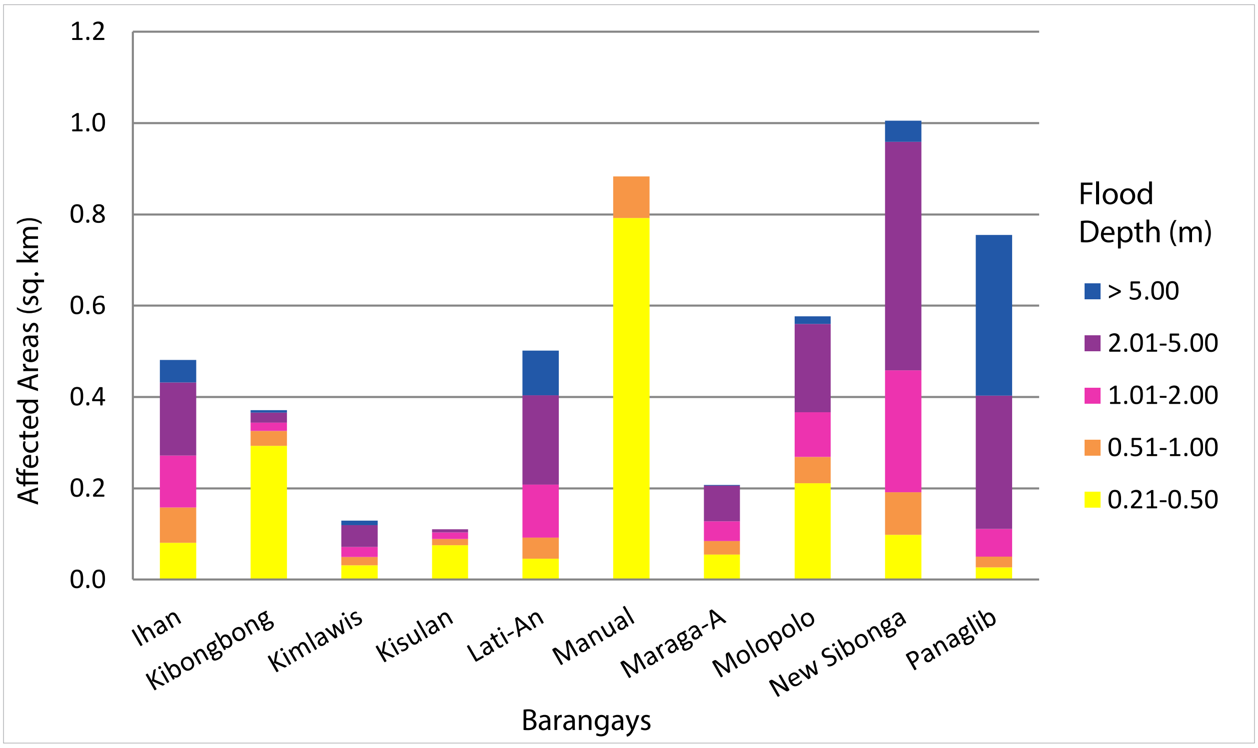


Figure 124. Affected Areas in Hagonoy, Davao del Sur during 100-Year Rainfall Return Period

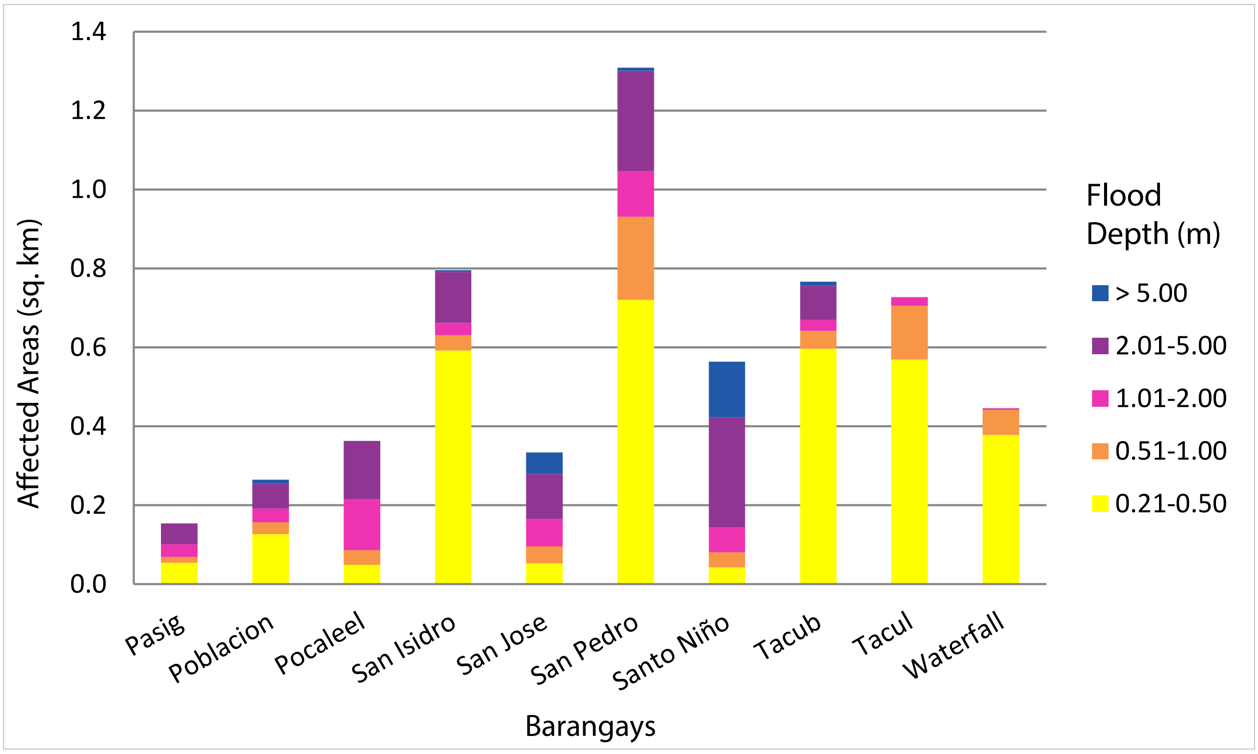


Figure 125. Affected Areas in Hagonoy, Davao del Sur during 100-Year Rainfall Return Period

For the 100-year return period, 0.27% of the municipality of Magsaysay with an area of 109.8 sq. km. will experience flood levels of less than 0.20 meters. 0.06% of the area will experience flood levels of 0.21 to 0.50 meters while 0.03%, 0.02%, and 0.01% 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 the table are the affected areas in square kilometers by flood depth per barangay.

Table 67. Affected Areas in Magsaysay, Davao del Sur during 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangay in Magsaysay
	New Ilocos
0.03-0.20	0.299809
0.21-0.50	0.070381
0.51-1.00	0.029933
1.01-2.00	0.017602
2.01-5.00	0.011179
> 5.00	0

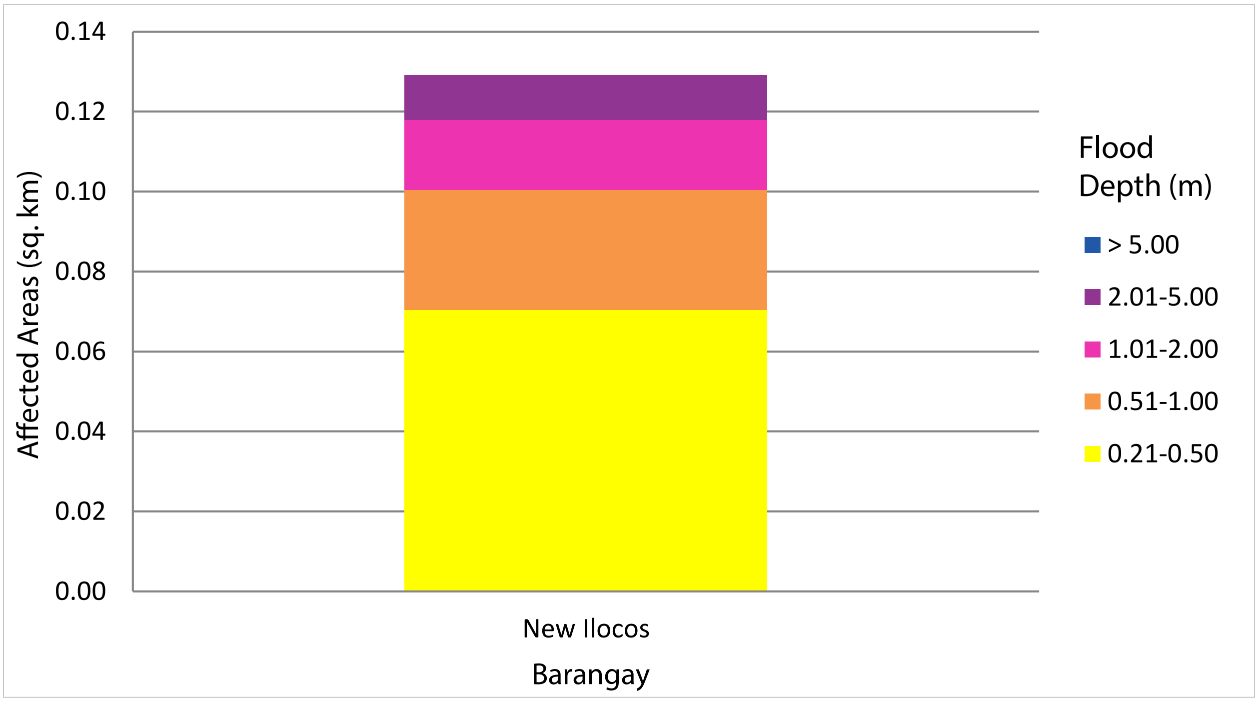


Figure 126. Affected Areas in Magsaysay, Davao del Sur during 100-Year Rainfall Return Period

For the 100-year return period, 9.96% of the municipality of Malalag with an area of 445 sq. km. will experience flood levels of less than 0.20 meters. 1.26% of the area will experience flood levels of 0.21 to 0.50 meters while 1.26%, 1.13%, 0.78%, and 0.15% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 68. Affected Areas in Malalag, Davao del Sur during 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Malalag					
	Bagumbayan	Bolton	Kiblagon	Lapu-Lapu	Mabini	New Baclayon
0.03-0.20	0.013733	0.513317	11.1762	29.1547	1.34489	2.1025
0.21-0.50	0.003771	0.095823	3.07571	1.92267	0.049678	0.438467
0.51-1.00	0.009517	0.057665	3.78266	1.10549	0.020958	0.640359
1.01-2.00	0.004691	0.021153	2.5697	1.50071	0.015827	0.905333
2.01-5.00	0	0.015694	0.833742	2.52603	0.015788	0.067113
> 5.00	0	0.001397	0.050514	0.625923	0.00942	0

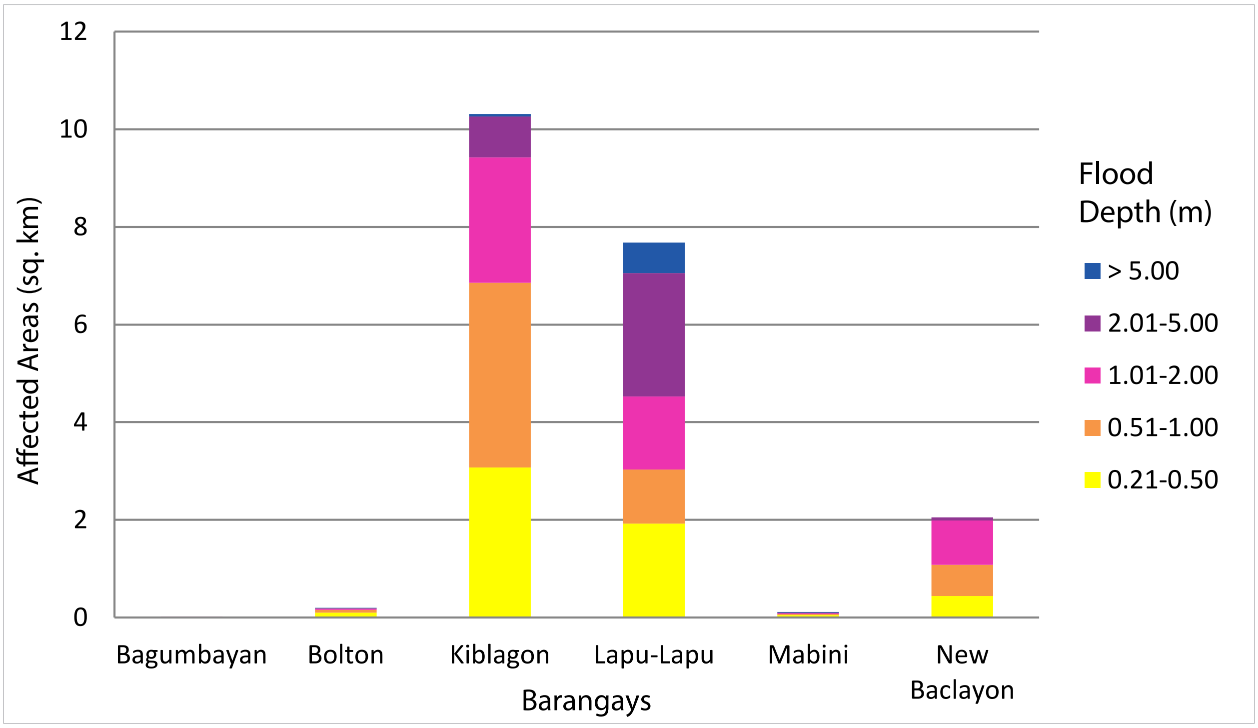


Figure 127. Affected Areas in Malalag, Davao del Sur during 100-Year Rainfall Return Period

For the 100-year return period, 39.50% of the municipality of Matanao with an area of 123.4 sq. km. will experience flood levels of less than 0.20 meters. 8.25% of the area will experience flood levels of 0.21 to 0.50 meters while 5.44%, 6.26%, 5.77%, and 0.29% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 69. Affected Areas in Matanao, Davao del Sur during 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Matanao									
	Asbang	Asinan	Bagumbayan	Bangkal	Buas	Buri	Cabligan	Camanchiles	Ceboza	Colonsabak
0.03-0.20	0.039102	0.886932	2.64985	0.608199	0.081179	0.096536	0.0401	2.02568	2.06888	0.626818
0.21-0.50	0.001831	0.267968	0.481176	0.108874	0.016348	0.012424	0.106211	0.309074	1.17975	0.157673
0.51-1.00	0.000151	0.059528	0.259755	0.048994	0.002966	0.003967	0.386636	0.187577	0.193168	0.084767
1.01-2.00	0	0.075615	0.315177	0.04675	0.000807	0.0001	1.46364	0.127129	0.251074	0.05516
2.01-5.00	0	0.042049	0.425402	0.027492	0	0	1.53579	0.119184	0.087675	0.019509
> 5.00	0	0.000207	0.076161	0	0	0	0	0.015337	0.023062	0

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Matanao									
	Dongan-Pekong	Kabasagan	Kapok	Kibao	La Suerte	Langa-An	Lower Marber	Manga	New Katipunan	New Visayas
0.03-0.20	2.59236	0.9595	0.417662	0.972719	1.6115	1.04602	1.06599	5.09176	5.22483	1.76287
0.21-0.50	0.259291	0.260117	0.10472	0.091181	0.344297	0.57702	0.15285	1.04356	0.612944	1.179
0.51-1.00	0.105869	0.033047	0.018257	0.033194	0.545858	0.057194	0.151297	1.99063	0.359808	0.230738
1.01-2.00	0.26294	0.021333	0.021	0.062427	0.332023	0.021355	0.126265	2.12785	0.324046	0.003122
2.01-5.00	0.179327	0.007868	0.016015	0.053911	0.145444	0.029734	0.158628	2.58438	0.323583	0.0007
> 5.00	0.004448	0	0	0.0056	0.053538	0.000933	0.025742	0.0048	0.0589	0

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Matanao									
	Poblacion	Saboy	San Jose	San Vicente	Saub	Sinaragan	Sinawilan	Tamlangon	Tibongbong	Towak
0.03-0.20	1.11994	0.615762	2.3017	1.33478	0.991524	3.89573	5.77979	0.699941	1.1584	0.98081
0.21-0.50	0.15606	0.186267	0.598668	0.218245	0.372368	0.62323	0.445798	0.113276	0.076579	0.120055
0.51-1.00	0.107427	0.227023	0.174838	0.147861	0.324404	0.566514	0.290349	0.032878	0.038785	0.046519
1.01-2.00	0.215629	0.461517	0.125701	0.08305	0.18933	0.642329	0.246468	0.021506	0.044896	0.053614
2.01-5.00	0.154455	0.337028	0.15653	0.026474	0.082499	0.130867	0.380549	0.015166	0.012156	0.062585
> 5.00	0.03297	0.002852	0.003748	0.000899	0	0.0043	0.038001	0.002892	0.000965	0

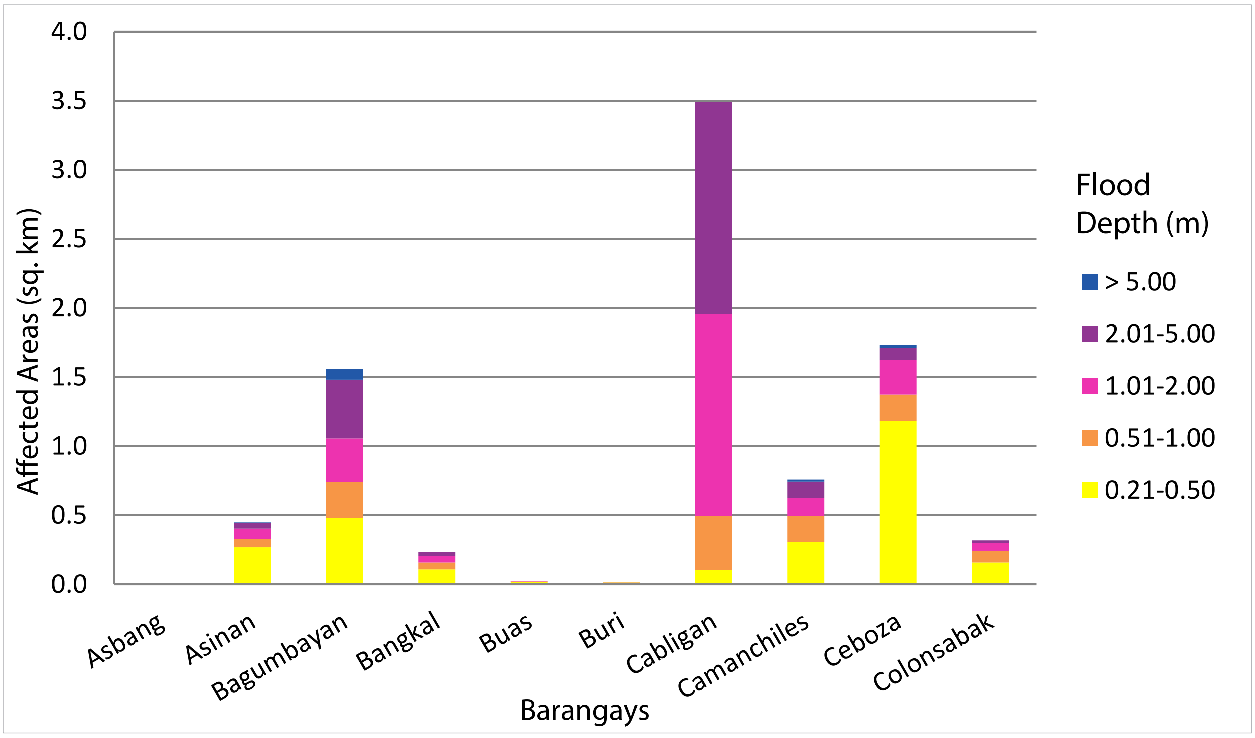


Figure 128. Affected Areas in Matanao, Davao del Sur during 100-Year Rainfall Return Period

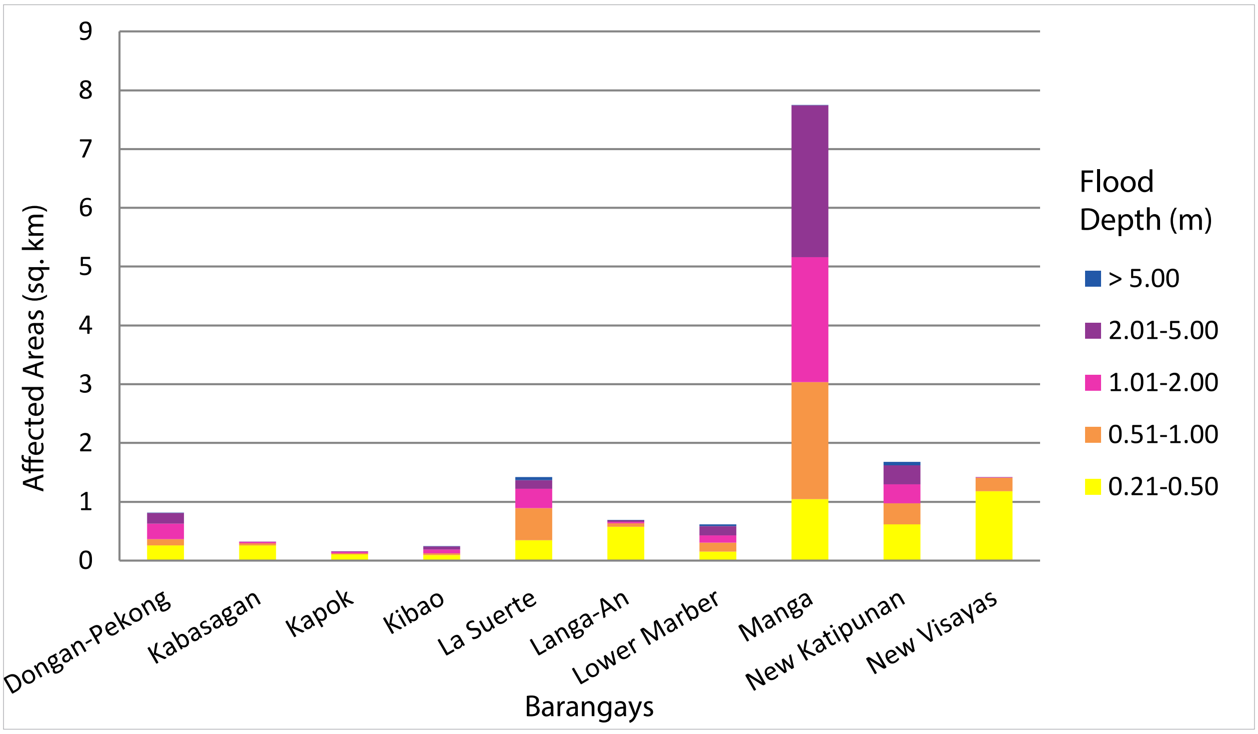


Figure 129. Affected Areas in Matanao, Davao del Sur during 100-Year Rainfall Return Period

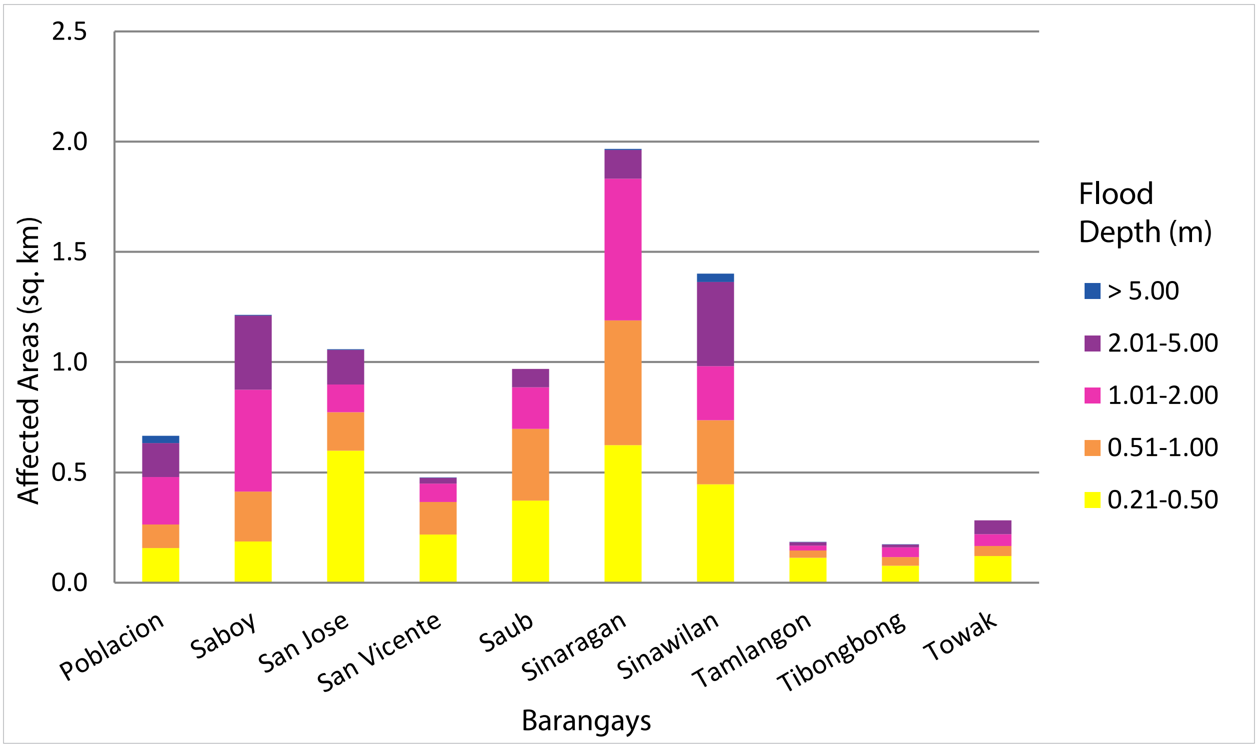


Figure 130. Affected Areas in Matanao, Davao del Sur during 100-Year Rainfall Return Period

For the 100-year return period, 43.91% of the municipality of Padada with an area of 55.97 sq. km. will experience flood levels of less than 0.20 meters. 28.94% of the area will experience flood levels of 0.21 to 0.50 meters while 15.59%, 5.92%, 3.04%, and 2.58% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 70. Affected Areas in Padada, Davao del Sur during 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Padada								
	Almendras	Don Sergio Osmena, Sr.	Harada Butai	Lower Katipunan	Lower Limonzo	Lower Malinao	N C Ordaneza Distric	Northern Paligue	Palili
0.03-0.20	0.350171	0.987384	1.87146	3.79575	0.86392	2.58481	0.523847	0.887134	3.69403
0.21-0.50	0.417283	0.389224	1.9124	0.627322	1.28571	0.568645	0.277356	0.96022	3.52858
0.51-1.00	0.162186	0.395655	1.26491	0.284143	0.475653	0.413225	0.081812	1.09388	1.55119
1.01-2.00	0.007419	0.695575	0.421589	0.174883	0.080802	0.538368	0.021649	0.181073	0.322123
2.01-5.00	0	0.330596	0.0177	0.31021	0.0045	0.900997	0.0001	0.044153	0.0032
> 5.00	0	0.541552	0	0.162621	0	0.540703	0	0.201369	0

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Padada							
	Piape	Punta Piape	Quirino District	San Isidro	Southern Paligue	Tulogan	Upper Limonzo	Upper Malinao
0.03-0.20	0.393461	1.73191	0.438897	1.02697	0.963334	0.731483	1.60797	2.12158
0.21-0.50	0.331962	0.977003	0.040758	0.630399	0.891022	1.11501	1.35721	0.890019
0.51-1.00	0.452941	0.587359	0.010547	0.53671	0.385446	0.500766	0.405424	0.121857
1.01-2.00	0.068682	0.08209	0	0.484365	0.038528	0.037498	0.090705	0.070517
2.01-5.00	0	0	0	0.0226	0	0	0.0127	0.05684
> 5.00	0	0	0	0	0	0	0	0

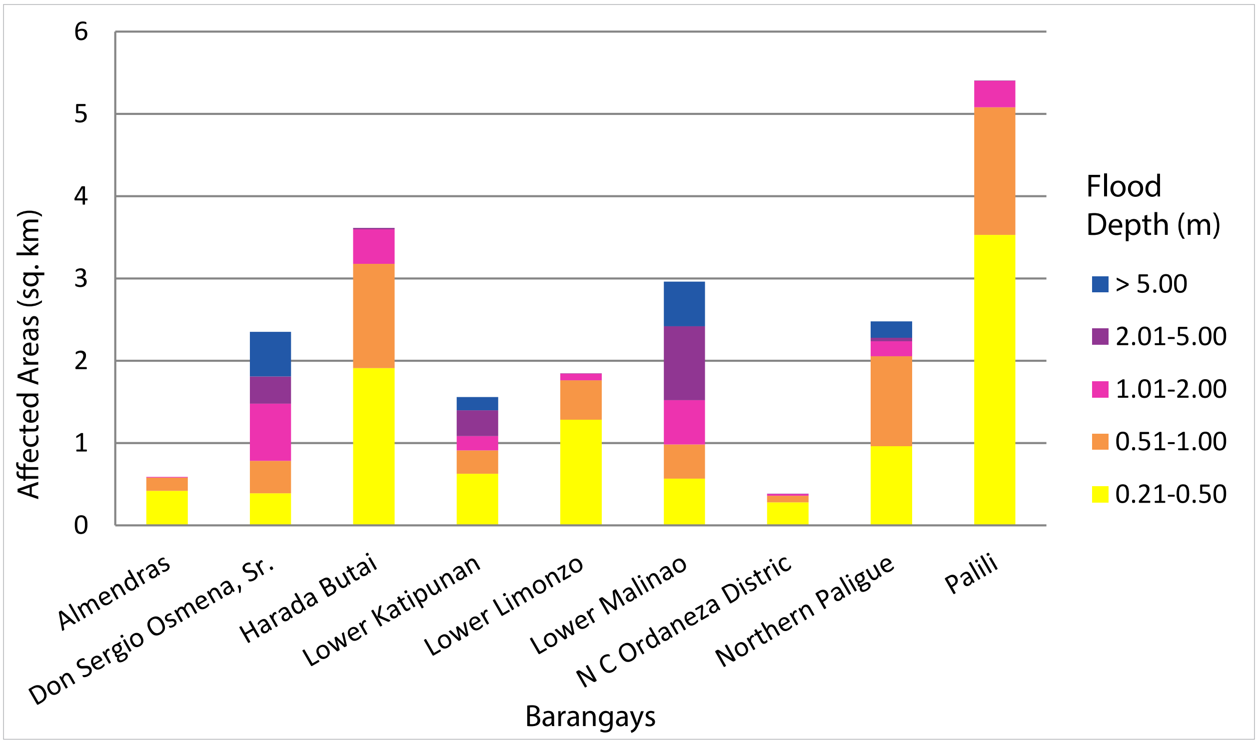


Figure 131. Affected Areas in Padada, Davao del Sur during 100-Year Rainfall Return Period

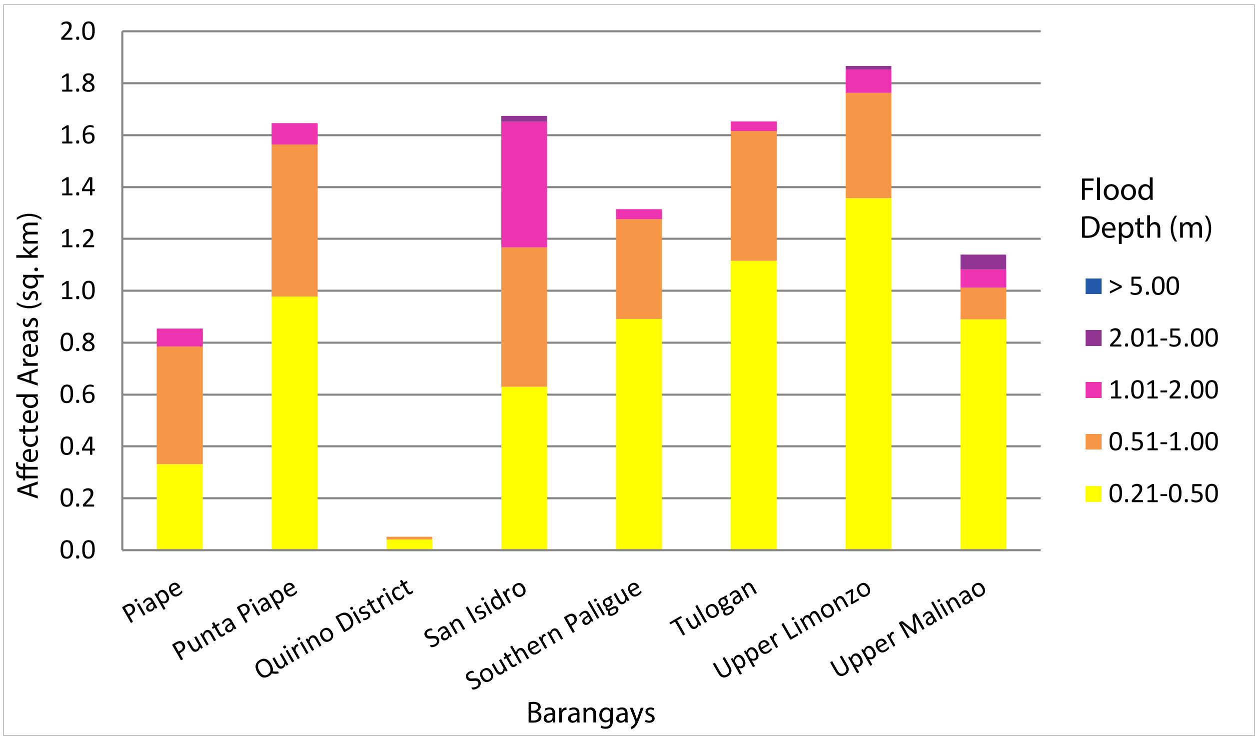


Figure 132. Affected Areas in Padada, Davao del Sur during 100-Year Rainfall Return Period

For the 100-year return period, 0.79% of the municipality of Santa Cruz with an area of 267.54 sq. km. will experience flood levels of less than 0.20 meters. 0.12% of the area will experience flood levels of 0.21 to 0.50 meters while 0.12%, 0.24%, and 0.06% 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 the table are the affected areas in square kilometers by flood depth per barangay.

Table 71. Affected Areas in Santa Cruz, Davao del Sur during 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Santa Cruz	
	Bato	Tagabuli
0.03-0.20	2.06787	0.040796
0.21-0.50	0.313401	0.019218
0.51-1.00	0.30898	0.009883
1.01-2.00	0.625145	0.010632
2.01-5.00	0.1736	0
> 5.00	0.0118	0

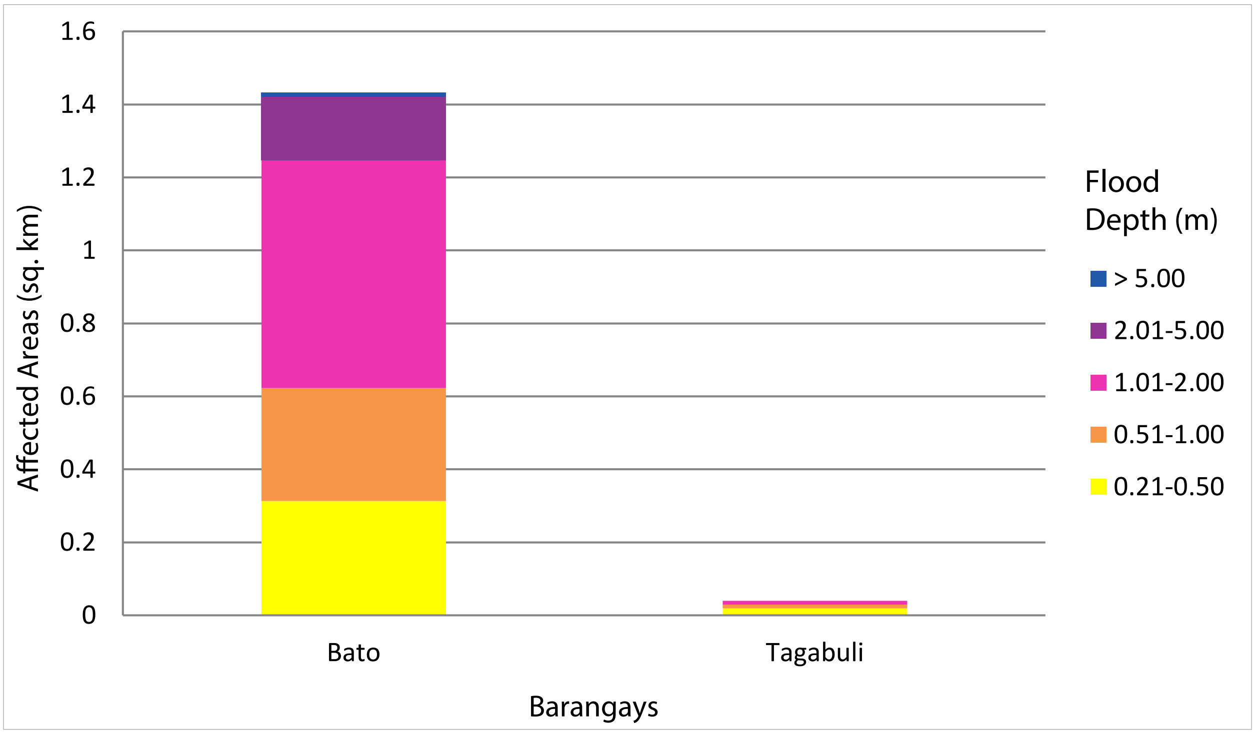


Figure 133. Affected Areas in Santa Cruz, Davao del Sur during 100-Year Rainfall Return Period

For the 100-year return period, 46.68% of the municipality of Sulop with an area of 50.8 sq. km. will experience flood levels of less than 0.20 meters. 20.09% of the area will experience flood levels of 0.21 to 0.50 meters while 16.71%, 11.57%, 3.82%, and 0.61% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 72. Affected Areas in Sulop, Davao del Sur during 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Sulop								
	Balasinon	Buguis	Carre	Clib	Harada Butai	Katipunan	Kiblagon	Labon	Laperas
0.03-0.20	0.149261	1.14446	0.86772	0.507219	1.18287	0.764506	0.153272	0.464914	0.729619
0.21-0.50	0.138633	0.050396	0.046457	0.021048	1.12581	0.673556	0.276403	0.024302	0.208842
0.51-1.00	0.147363	0.028432	0.033417	0.010848	0.961789	0.249152	0.726917	0.011941	0.241786
1.01-2.00	0.007522	0.03551	0.027944	0.004555	0.354061	0.021221	1.06285	0.00805	0.016279
2.01-5.00	0	0.067801	0.025886	0.001734	0.0135	0.050376	0.087111	0.005406	0.00074
> 5.00	0	0.01118	0.006542	0.001093	0	0.013436	0	0.002626	0.000235

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Sulop							
	Lapla	Litos	Luparan	Mckinley	New Cebu	Osmeña	Palili	Parame
0.03-0.20	0.674971	0.644306	0.328988	0.752904	1.65027	0.341597	2.54363	0.497588
0.21-0.50	0.026929	0.025319	0.013136	0.040798	0.244691	0.01478	3.25115	0.014933
0.51-1.00	0.014035	0.022619	0.00519	0.036418	0.554416	0.007624	1.10634	0.011123
1.01-2.00	0.013334	0.027013	0.005233	0.08561	0.106422	0.004793	1.21079	0.012234
2.01-5.00	0.024973	0.021044	0.010831	0.034904	0.051127	0.001496	0.614486	0.017139
> 5.00	0.012192	0.013986	0.005917	0	0.002158	0	0	0.000897

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Sulop							
	Poblacion	Roxas	Solongvale	Tagolilong	Tala-O	Talas	Tanwalang	Waterfall
0.03-0.20	0.194961	3.04853	1.75752	1.01089	1.74206	0.526414	1.34547	0.690945
0.21-0.50	0.27338	0.149958	0.839697	0.042217	1.14368	0.64141	0.491717	0.425804
0.51-1.00	0.448546	0.121791	1.08884	0.018543	0.534671	0.897101	0.770479	0.438579
1.01-2.00	1.14397	0.24537	0.288884	0.012847	0.373667	0.547754	0.106859	0.152675
2.01-5.00	0.403106	0.167406	0.002909	0.01055	0.011142	0.104074	0.206607	0.00403
> 5.00	0	0.024106	0	0.0007	0	0	0.215167	0

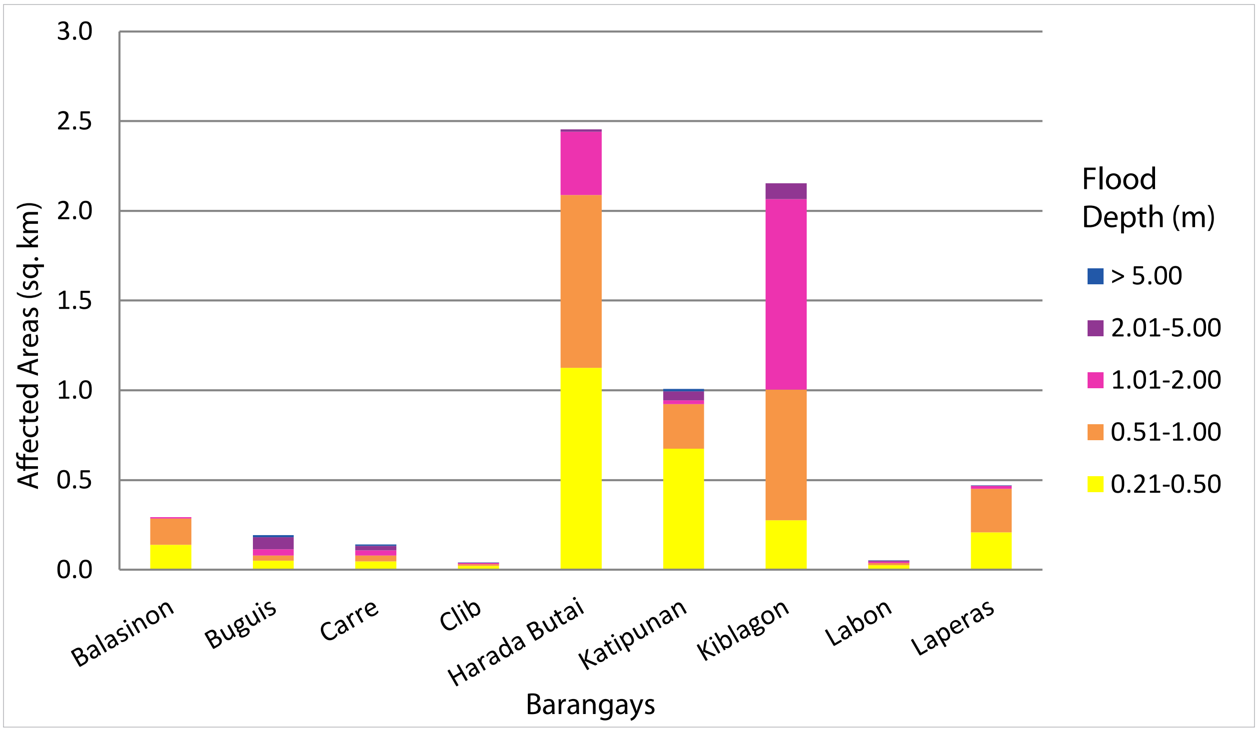


Figure 134. Affected Areas in Sulop, Davao del Sur during 100-Year Rainfall Return Period

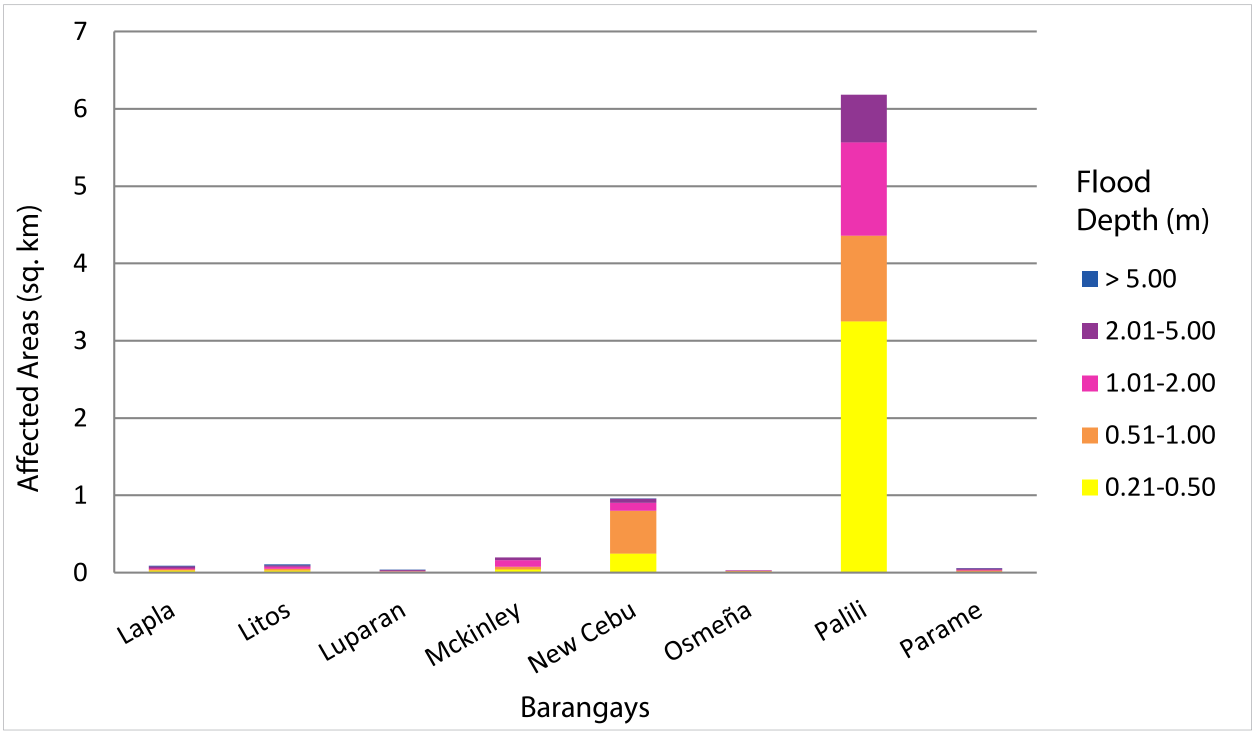


Figure 135. Affected Areas in Sulop, Davao del Sur during 100-Year Rainfall Return Period

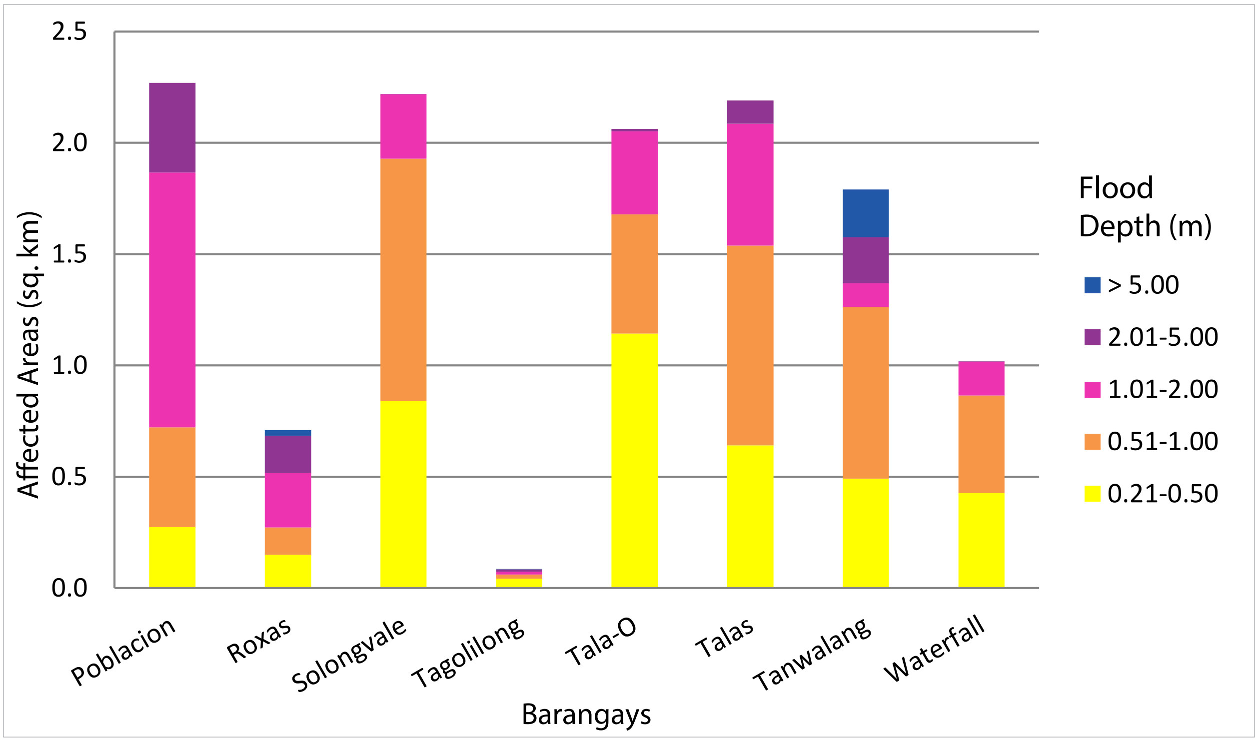


Figure 136. Affected Areas in Sulop, Davao del Sur during 100-Year Rainfall Return Period

For the 100-year return period, 0.24% of the municipality of Columbio with an area of 574.067 sq. km. will experience flood levels of less than 0.20 meters. 0.01% of the area will experience flood levels of 0.21 to 0.50 meters while 0.00% of the area will experience flood depths of 0.51 to 1 meter. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 73. Affected Areas in Columbio, Sultan Kudarat during 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangay in Columbio
	Datablao
0.03-0.20	1.36294
0.21-0.50	0.035573
0.51-1.00	0.02114
1.01-2.00	0.0173
2.01-5.00	0.025596
> 5.00	0.0096

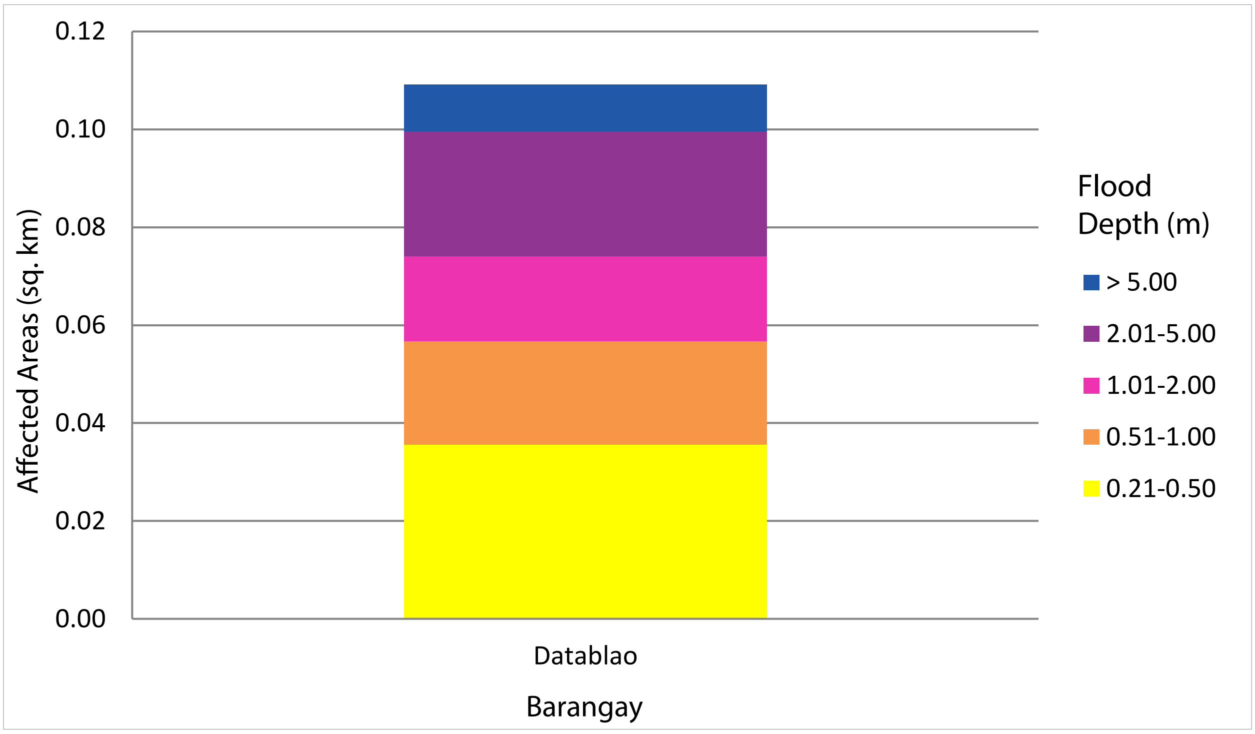


Figure 137. Affected Areas in Columbio, Sultan Kudarat during 100-Year Rainfall Return Period

Among the barangays in the municipality of Bansalan in Davao del Sur, Mabunga is projected to have the highest percentage of area that will experience flood levels at 4.15%. Meanwhile, Union posted the second highest percentage of area that may be affected by flood depths at 2.91%.

Among the barangays in the municipality of Digos City in Davao del Sur, Colorado is projected to have the highest percentage of area that will experience flood levels at 3.32%. Meanwhile, Matti posted the second highest percentage of area that may be affected by flood depths at 2.99%.

Among the barangays in the municipality of Hagonoy in Davao del Sur, Leling is projected to have the highest percentage of area that will experience flood levels at 16.09%. Meanwhile, Sacub posted the second highest percentage of area that may be affected by flood depths at 8.10%.

Among the barangays in the municipality of Kiblawan in Davao del Sur, Bagumbayan is projected to have the highest percentage of area that will experience flood levels at 7.58%. Meanwhile, San Pedro posted the second highest percentage of area that may be affected by flood depths at 5.19%.

Brgy. New Ilocos is the only barangay affected in the municipality of Magsaysay in Davao del Sur. The barangay is projected to experience flood in 0.39% of the municipality.

Among the barangays in the municipality of Malalag in Davao del Sur, Lapu-Lapu is projected to have the highest percentage of area that will experience flood levels at 8.28%. Meanwhile, Kiblagon posted the second highest percentage of area that may be affected by flood depths at 4.83%.

Among the barangays in the municipality of Matanao in Davao del Sur, Manga is projected to have the highest percentage of area that will experience flood levels at 10.41%. Meanwhile, Sinawilan posted the second highest percentage of area that may be affected by flood depths at 5.82%.

Among the barangays in the municipality of Padada in Davao del Sur, Palili is projected to have the highest percentage of area that will experience flood levels at 16.26%. Meanwhile, Lower Malinao posted the second highest percentage of area that may be affected by flood depths at 9.91%.

Among the barangays in the municipality of Santa Cruz in Davao del Sur, Bato is projected to have the highest percentage of area that will experience flood levels at 1.31%. Meanwhile, Tagabuli posted the second highest percentage of area that may be affected by flood depths at 0.03%.

Among the barangays in the municipality of Sulop in Davao del Sur, Palili is projected to have the highest percentage of area that will experience flood levels at 17.18%. Meanwhile, Solongvale posted the second highest percentage of area that may be affected by flood depths at 7.83%.

Brgy. Datablao is the only barangay affected in the municipality of Columbio in Sultan Kudarat. The barangay is projected to experience flood in 0.26% of the municipality.

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

Table 74. 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	77.86	88.36	92.38
Medium	64.82	79.54	89.35
High	24.82	43.29	57.18
TOTAL	**167.5**	**211.19**	**238.91**

Of the 94 identified educational institutions in the Padada floodplain, one school was assessed to be relatively prone to flooding as it is exposed to the Medium level flooding in the 5-year return period, and High level flooding in the 25- and 100-year rainfall scenarios. This would be Felipe-Inocencia Deluao National High School. Six other institutions were found to be also susceptible to flooding, experiencing Medium level flooding in the 5-year return period, and Medium level flooding in the 25- and 100-year rainfall scenarios. See Appendix 12 for a detailed enumeration of schools in the Padada floodplain.

Nine medical institutions were identified in the Padada floodplain. J.P Laurel Health Center in Brgy. Vicente Hizon Sr. was found to be relatively prone to flooding, having Medium level flooding in the 5-year return period, and High level flooding in the 25- and 100-year rainfall scenarios. See Appendix 13 for a detailed enumeration of hospitals and clinics in the Padada floodplain.

5.11 Flood Validation

In order to check and validate the extent of flooding in different river systems, validation survey work was done. 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 can be done through a local DRRM office to obtain maps or situation reports about the past flooding events or interview some residents with knowledge of or have had experienced flooding in a particular area.

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

The flood validation survey was conducted on May 23-31, 2016. The flood validation consists of 180 points randomly selected all over the Padada flood plain. It has an RMSE value of 0.99.

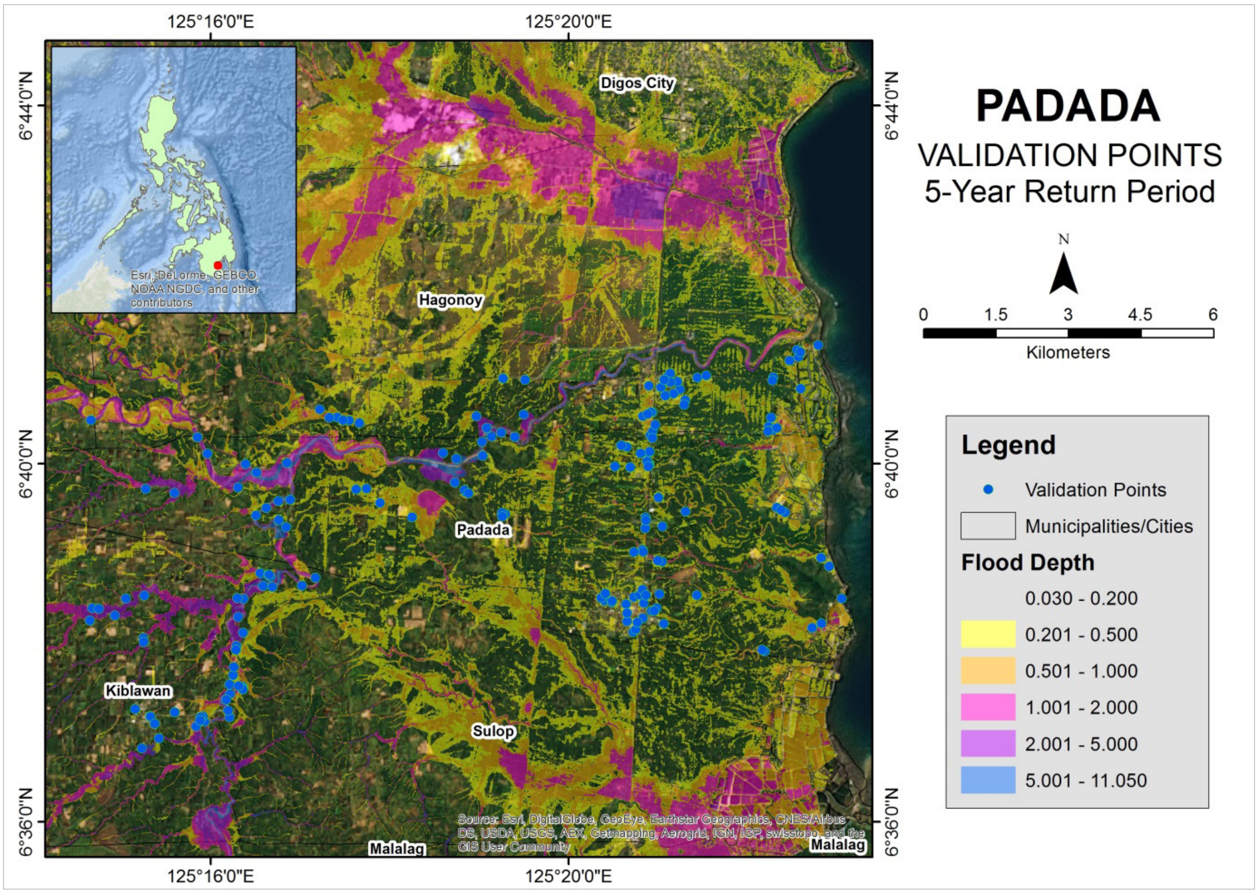


Figure 138. Flood Validation Points of Padada River Basin

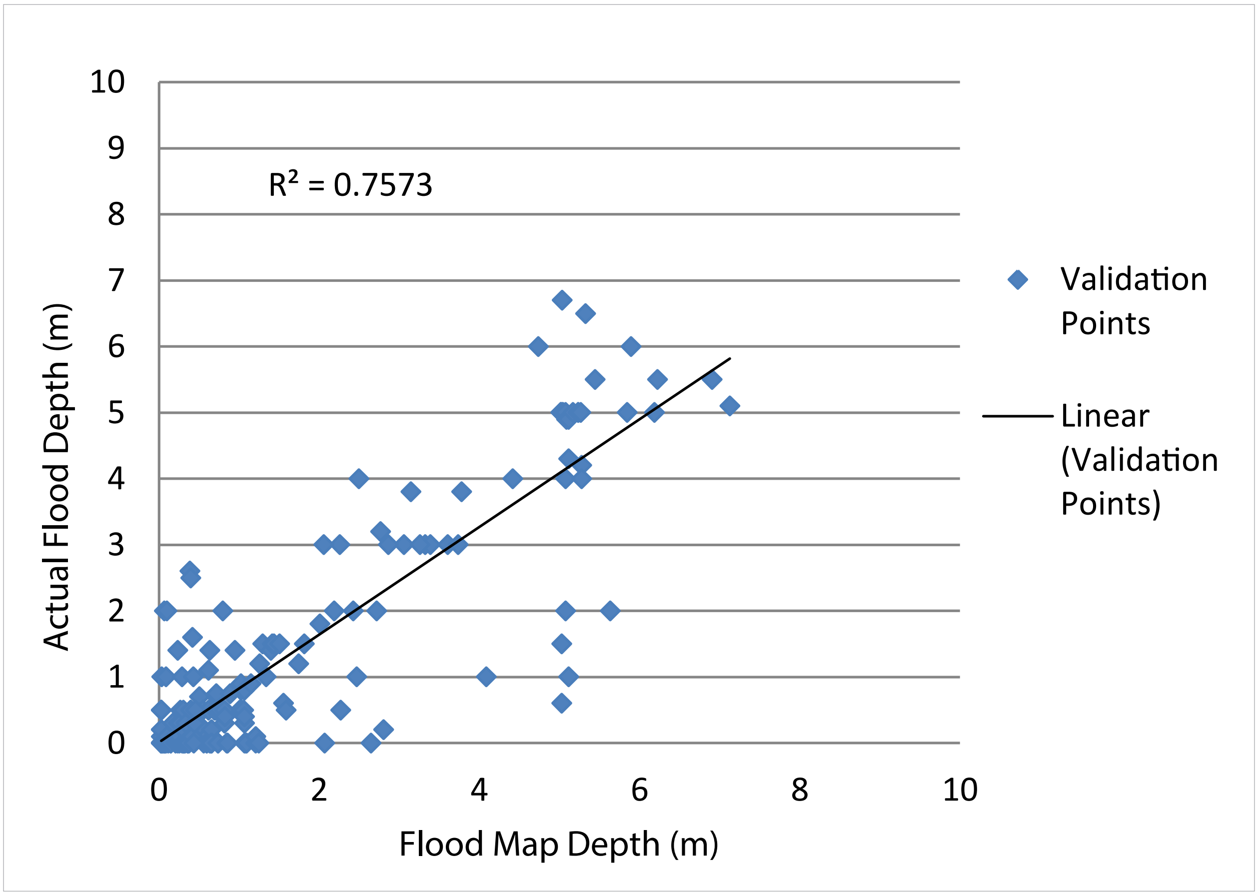


Figure 139. Flood Map Depth vs Actual Flood Depth for Padada

Table 75. Actual Flood Depth vs Simulated Flood Depth in Padada

PADADA BASIN		MODELED FLOOD DEPTH (m)						
		0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
Actual Flood Depth (m)	0-0.20	26	16	15	6	3	0	66
	0.21-0.50	4	10	9	8	1	0	32
	0.51-1.00	2	2	4	6	2	2	18
	1.01-2.00	2	2	4	8	4	3	23
	2.01-5.00	0	2	0	0	14	17	33
	> 5.00	0	0	0	0	1	7	8
	Total	34	32	32	28	25	29	180

The overall accuracy generated by the flood model is estimated at 38.33%, with 69 points correctly matching the actual flood depths. In addition, there were 63 points estimated one level above and below the correct flood depths while there were 32 points and 16 points estimated two levels above and below, and three or more levels above and below the correct flood depth. A total of 92 points were overestimated while a total of 19 points were underestimated in the modelled flood depths of Padada.

Table 76. Summary of Accuracy Assessment in Padada

	No. of Points	%
Correct	69	38.33
Overestimated	92	51.11
Underestimated	19	10.56
Total	**180**	**100**

REFERENCES

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

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

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

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

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

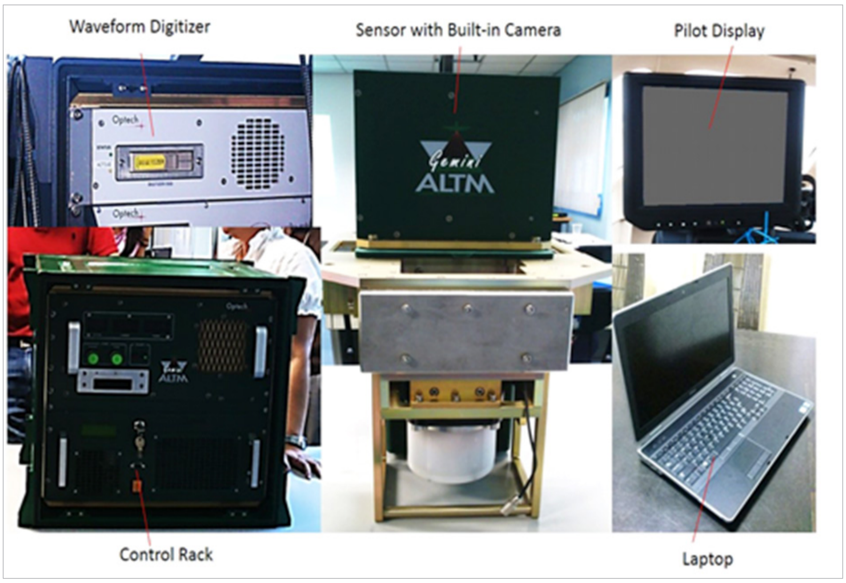
Sarmiento C., Paringit E.C., et al. 2014. *DREAM Data Acquisition Component Manual.* Quezon City, Philippines: UP Training Center for Applied Geodesy and Photogrammetry.

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

ANNEXES

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

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



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

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

1. DVS-85

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

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

August 08, 2014

CERTIFICATION

To whom it may concern:

This is to certify that according to the records on file in this office, the requested survey information is as follows -

Province: **DAVAO DEL SUR**
Station Name: **DVS-85**
Order: **2nd**

Island: **MINDANAO**
Municipality: **PADADA**

Barangay: **NORTHERN PALIGUE**
MSL Elevation:

PRS92 Coordinates

Latitude: **6° 39' 26.23973"**	Longitude: **125° 20' 48.72707"**	Ellipsoidal Hgt: **6.14300 m.**

WGS84 Coordinates

Latitude: **6° 39' 23.20569"**	Longitude: **125° 20' 54.29139"**	Ellipsoidal Hgt: **79.00800 m.**

PTM / PRS92 Coordinates

Northing: **736088.049 m.**	Easting: **538353.357 m.**	Zone: **5**

UTM / PRS92 Coordinates

Northing:	Easting:	Zone:

Location Description

DVS-85
Is in Barangay Northern Talige, Padada, Davao Del Sur. To reach the station travel about 4.7 kms from Digos towards Malita taking the national highway until reaching Mariano Sarona Elementary School. Station is located inside the fence of the flagpole. Mark is the head of a 4" copper nail set on a drilled hole and cemented on top of a 30 x 30 cm cement putty with inscription DVS-85 2007 NAMRIA.

Requesting Party: **ENGR. CHRISTOPHER CRUZ**
Pupose: **Reference**
OR Number: **8799670 A**
T.N.: **2014-1781**

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

9 9 0 8 0 8 2 0 1 4 1 4 0 6 0 2

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 Reports of Reference Points Used in the LiDAR Survey

1. BLLM-20

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

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
DVS-85 --- BLLM-20 (B1)	DVS-85	BLLM-20	Fixed	0.002	0.002	235°02'39"	13.135	-0.487
DVS-85 --- BLLM-20 (B2)	DVS-85	BLLM-20	Fixed	0.003	0.003	234°58'48"	13.129	-0.370

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

Vector Components (Mark to Mark)

From:	DVS-85				
Grid		Local		Global	
Easting	759472.609 m	Latitude	N6°39'26.23973"	Latitude	N6°39'23.20570"
Northing	736433.274 m	Longitude	E125°20'48.72707"	Longitude	E125°20'54.29136"
Elevation	8.556 m	Height	6.143 m	Height	79.008 m

To:	BLLM-20				
Grid		Local		Global	
Easting	759461.875 m	Latitude	N6°39'25.99473"	Latitude	N6°39'22.96071"
Northing	736425.694 m	Longitude	E125°20'48.37658"	Longitude	E125°20'53.94087"
Elevation	8.068 m	Height	5.656 m	Height	78.521 m

Vector					
ΔEasting	-10.734 m	NS Fwd Azimuth	235°02'39"	ΔX	8.556 m
ΔNorthing	-7.580 m	Ellipsoid Dist.	13.135 m	ΔY	6.545 m
ΔElevation	-0.489 m	ΔHeight	-0.487 m	ΔZ	-7.532 m

Standard Errors

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

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000006677		
Y	-0.0000002217	0.0000006603	
Z	-0.0000000325	0.0000000893	0.0000001088

ANNEX 4. The LiDAR Survey Team Composition

Table A-4.1. The LiDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency / Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. CZAR JAKIRI SARMIENTO	
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	
		ENGR. LOVELYN ASUNCION	
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	JULIE PEARL MARS	UP-TCAGP
	Research Associate (RA)	FOR. MA. VERLINA TONGA	
	RA	ENGR. LARAH KRISELLE PARAGAS	
Ground Survey	RA	JERIEL PAUL ALAMBAN, GEOL	UP-TCAGP
LiDAR Operation	Airborne Security	TSG. MIKE DIAPANA	Philippine Air Force (PAF)
	Pilot	CAPT. JOHN BRYAN DONGUINES	Asian Aerospace Corporation (AAC)
		CAPT. NEIL ACHILLES AGAWIN	AAC

ANNEX 5. Data Transfer Sheet for Padada Floodplain

Table A-5.1. Data Transfer Sheet for Padada Floodplain

DATA TRANSFER SHEET
08/12/2014(Davao City- ready)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
7/31/2014	7400GC	2BLK87A210A	Gemini	NA	74	142	108	NA	NA	5.84	NA	3.78	1KB	1KB	3	7	Z:\Airborne_Raw
7/31/2014	7404GC	2BLK87AS212A	Gemini	NA	258	339	208	NA	NA	15.1	NA	4.9	1KB	1KB	3	7	Z:\Airborne_Raw
8/1/2014	7406GC	2BLK87BC213A	Gemini	NA	244	428	204	NA	NA	19.3	NA	5.41	1KB	1KB	3/3/6/3/3	NA	Z:\Airborne_Raw
8/2/2014	7408GC	2BLK87E214A	Gemini	NA	272	480	242	NA	NA	21.7	NA	8.02	1KB	1KB	5	13	Z:\Airborne_Raw

Received from

Name T.N. ANDAYA
Position RA
Signature

Received by

Name JOIDA F. PRIETO 8/12/14
Position SSRS
Signature

DATA TRANSFER SHEET
08/28/2014(Davao- ready)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	QUICK PROCESS (kml (Boundary)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)			Actual	KML	
8/4/2014	7412GC	2BLK87CSD216A	Gemini	21	310	537	165	NA	NA	24.2	NA	4.99	1KB	1KB	3382	3/3/7/3/3	NA	Z:\DAC\RAWDATA
8/5/2014	7414GC	2BLK87E217A	Gemini	3.68	88	158	146	NA	NA	7.62	NA	3.11	1KB	1KB	786	5/5	NA	Z:\DAC\RAWDATA
8/6/2014	7416GC	2BLK87F218A	Gemini	5.39	184	194	148	NA	NA	8.31	NA	3.55	1KB	1KB	1616	5	11	Z:\DAC\RAWDATA
8/7/2014	7418GC	2BLK87FV219A	Gemini	12.7	181	355	180	NA	NA	14.4	NA	3.49	1KB	1KB	1233	9/10	NA	Z:\DAC\RAWDATA
7/9/2014	7422GC	2COMA221A	Gemini	16.5	248	423	219	NA	NA	19.8	NA	9.95	1KB	1KB	2848	5	12	Z:\DAC\RAWDATA
8/9/2014	7423GC	2COMBSCD221B	Gemini	11	210	395	175	NA	NA	16.6	NA	9.95	1KB	1KB	1090	7/5/3	NA	Z:\DAC\RAWDATA
8/10/2014	7424GC	2COMDS222A	Gemini	8.44	39	236	157	NA	NA	9.69	NA	4.38	1KB	1KB	1064	3/3	8	Z:\DAC\RAWDATA
8/11/2014	7426GC	2BLK82V223A	Gemini	8.44	119	279	135	NA	NA	9.61	NA	7.83	1KB	1KB	1813	7/11	NA	Z:\DAC\RAWDATA
8/11/2014	7427GC	2BLK82V223B	Gemini	4.32	64	184	132	NA	NA	5.65	NA	7.83	1KB	1KB	434	8	6	Z:\DAC\RAWDATA
8/12/2014	7428GC	2TAGV224A	Gemini	20.1	287	530	223	NA	NA	22.6	NA	4.44	1KB	1KB	2667	23/23	NA	Z:\DAC\RAWDATA
8/13/2014	7430GC	2TAGV225A	Gemini	5.95	34	326	179	NA	NA	9.38	NA	3.58	1KB	1KB	1283	18/18	NA	Z:\DAC\RAWDATA

Received from

Name TIN ANDAYA
Position RA
Signature

Received by

Name JOIDA PRIETO
Position SSRS
Signature 8/29/14

ANNEX 6. Flight Logs for the Flight Missions

Table A-6.1. Flight Logs for the Flight Missions

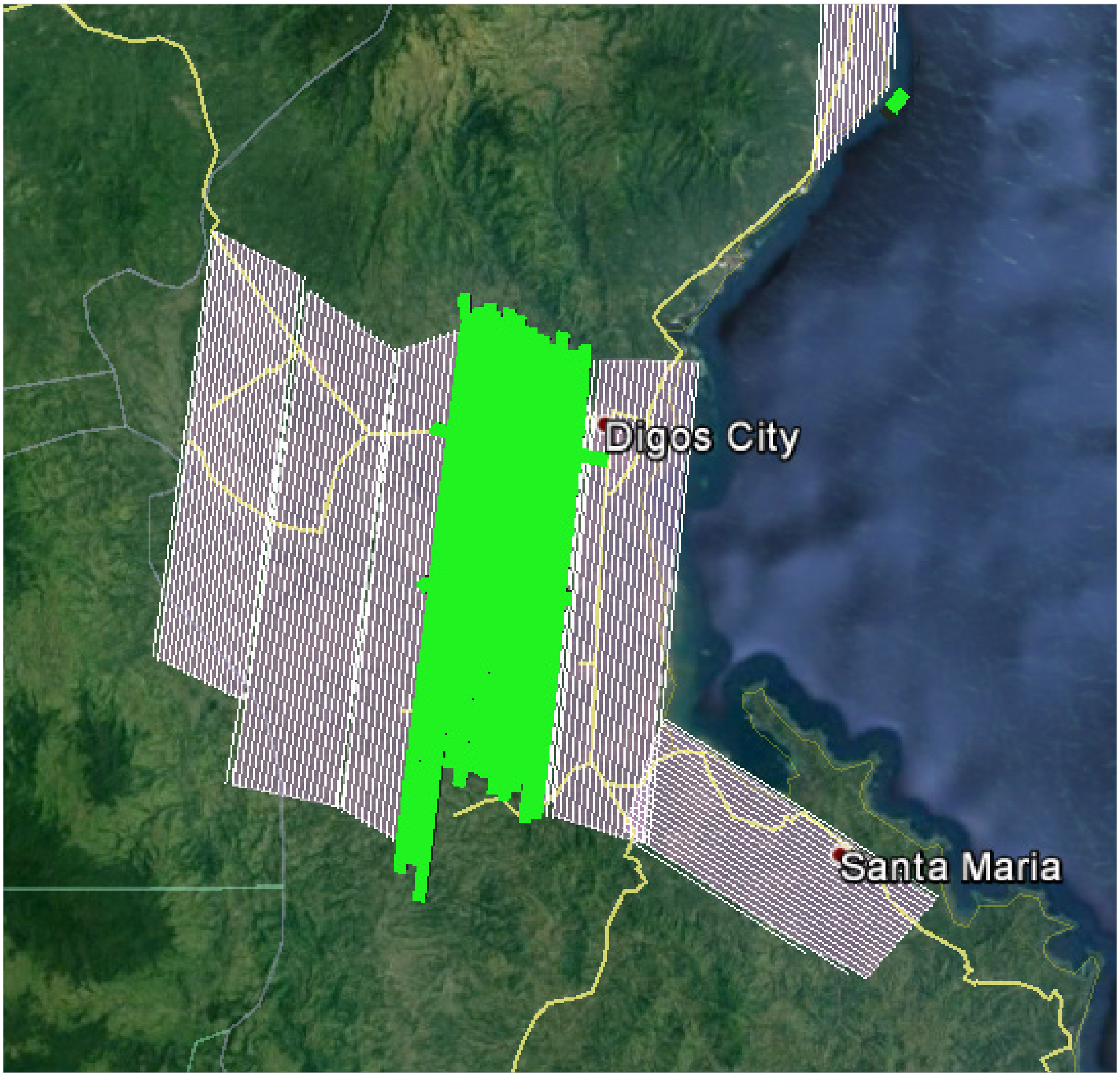
DAVAO CITY AND COMPOSTELA VALLEY
(July 16 - August 13, 2014)

Flight No	Area	Mission	Operator	Date Flown	Remarks
7400GC	BLK87A	2BLK87A210A	MV TONGA	July 29, 2014	Surveyed BLK87A (3 lines) then aborted the mission due to strong wind gustiness; flown without CASI @ 1000 AGL
7404GC	BLK87A	2BLK87AS212A	MV TONGA	July 31, 2014	Completed the remaining lines of BLK87A (9 lines) without CASI @ 1000 AGL
7406GC	BLK87C	2BLK87BC213A	LK PARAGAS	August 1, 2014	Surveyed BLK87B (9 lines) and BLK87C (4 lines) without CASI A @ 1000 AGL
7408GC	BLK87E	2BLK87DE214A	MVE TONGA	August 2, 2014	Completed BLK 87E (11 lines) and covered BLK87D (3 lines) without CASI @ 1000 AGL
7412GC	BLK87B	2BLK87CSD216A	LK PARAGAS	August 4, 2014	Completed the remaining lines of BLK87CD (15 lines) without CASI @ 1000 AGL
7414GC	BLK87F	2BLK87E217A	JP MARS	August 5, 2014	5 lines @1000m. aborted due to rain and strong wind
7416GC	BLK87B, BLK87D, BLK87F	2BLK87F218A	MVE TONGA	August 6, 2014	7 lines @1000m; filled up voids in BLK 87D
7418GC	BLK87B, BLK87D, BLK87F	2BLK87FV219A	LK PARAGAS	August 7, 2014	17 lines @1000m, filled up voids in BLK 87

Flight No. : 7400GC
Area: BLK87A
Mission name: 2LK87A210A
Parameters:
  Altitude: 1000 m;
  Scan Frequency: 50 Hz;
  Scan Angle: 20 deg;
  Overlap: 30 %
Area covered: 48.522 km²

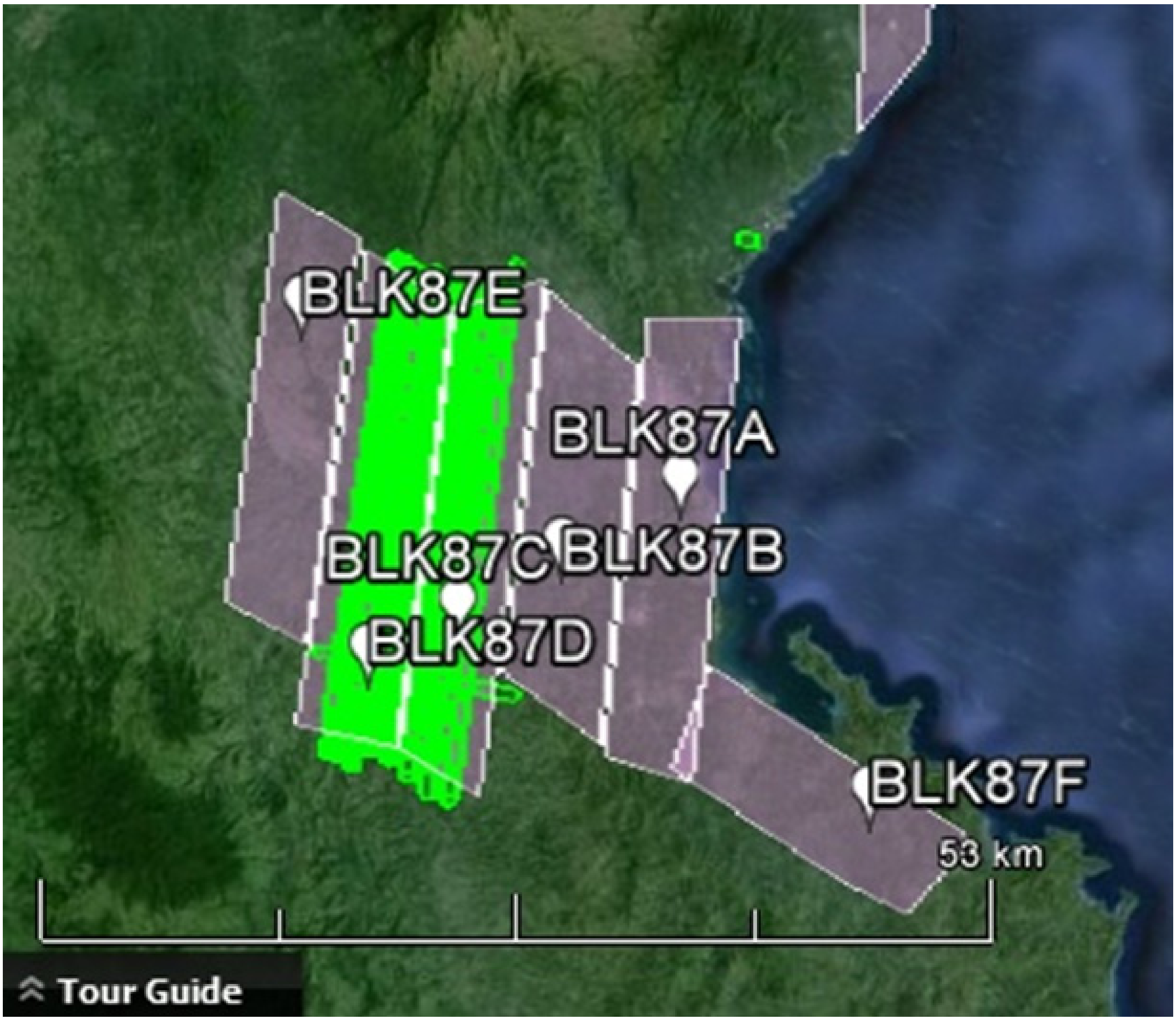
Flight No. : 7404GC
Area: BLK87A
Mission name: 2BLK87AS212A
Parameters:
Altitude: 1000 m;
Scan Frequency: 50 Hz;
Scan Angle: 20 deg;
Overlap: 30 %
Area covered: 169.442 km²

Flight No. : 7406GC
Area: BLK87C
Mission name: 2BLK87BC213A
Parameters:
Altitude: 1000 m;
Scan Frequency: 50 Hz;
Scan Angle: 20 deg;
Overlap: 30 %
Area covered: 193.272 km²

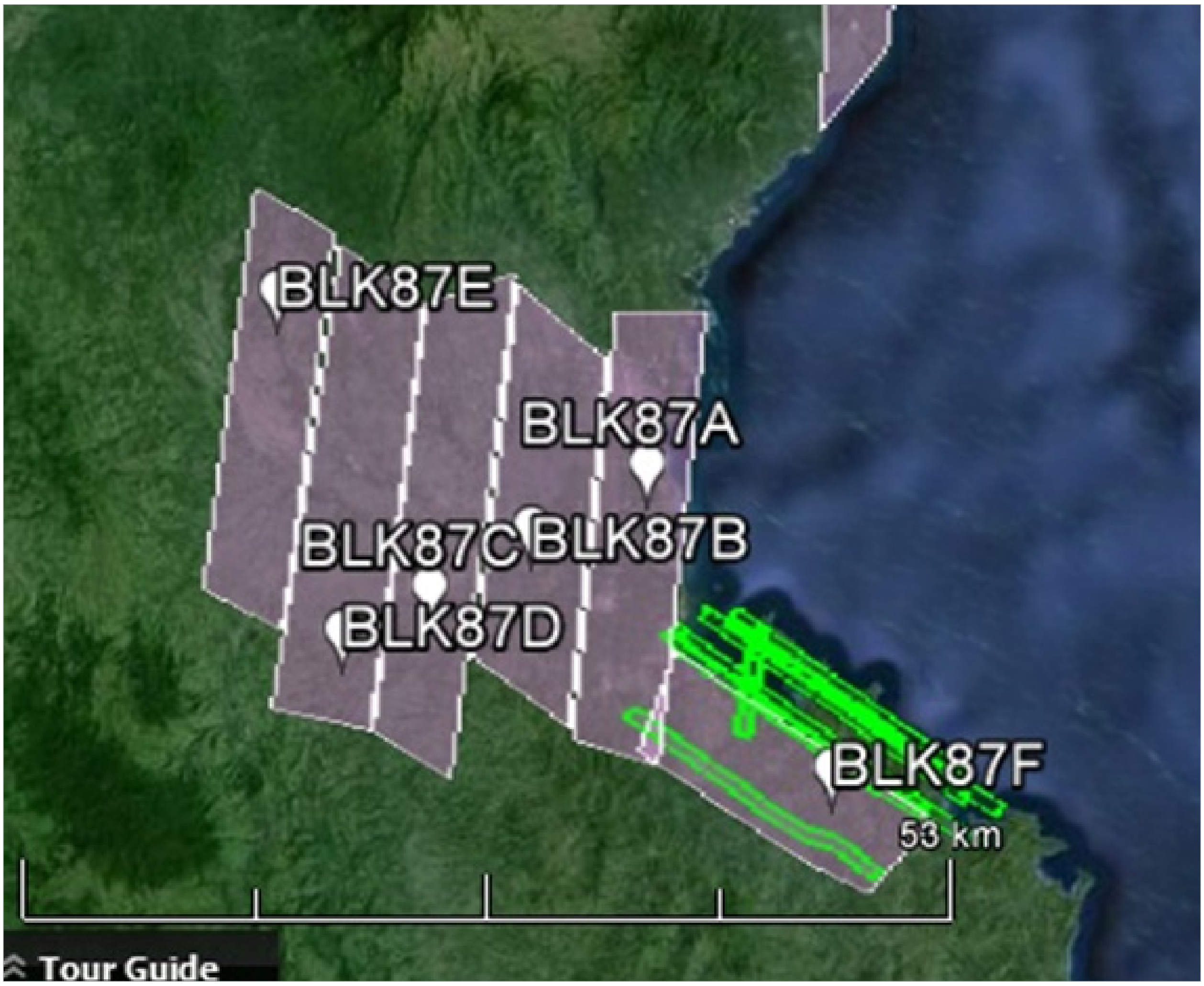


Flight No. : 7408GC
Area: BLK87E
Mission name: 2BLK87E214A
Parameters:
Altitude: 1000 m;
Scan Frequency: 50 Hz
Scan Angle: 20 deg;
Overlap: 30 %
Area covered: 187.645 km²

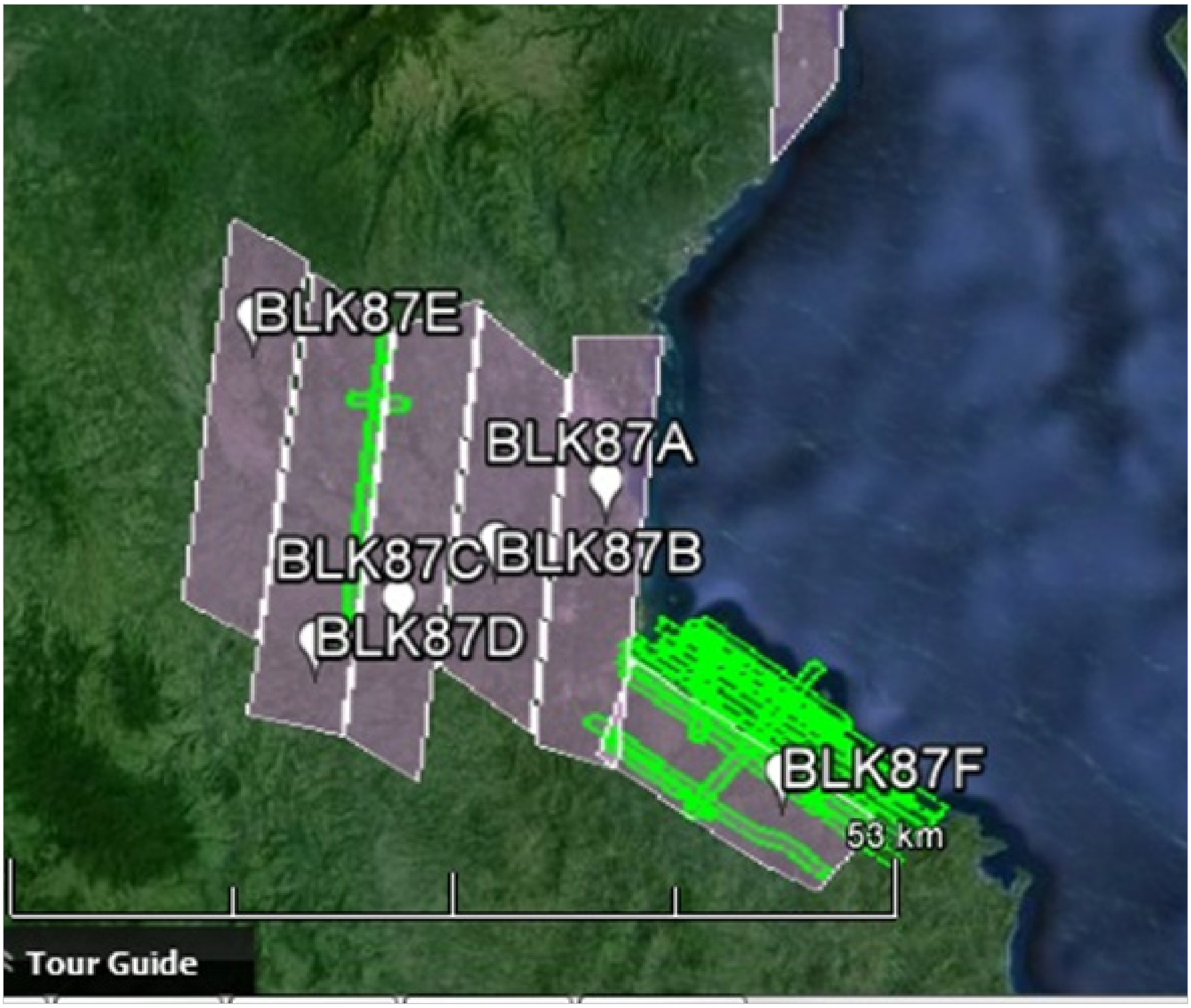
Flight No. : 7412GC
Area: BLK87B
Mission name: 2BLK87CSD216A
Parameters:
  Altitude: 1000 m;
  Scan Frequency: 50 Hz
  Scan Angle: 20 deg;
  Overlap: 35 %
Area covered: 70.780 km²



Flight No. : 7214GC
Area: BLK87F
Mission name: 2BLK87F217A
Parameters:
  Altitude: 1000 m;
  Scan Frequency: 50 Hz
  Scan Angle: 20 deg;
  Overlap: 35 %
Area covered: 70.780 km²



Flight No. : 7216GC
Area: BLK87B, BLK87D, BLK87F
Mission name: 2BLK87F218A
Parameters:
Altitude: 1000 m;
Scan Frequency: 50 Hz
Scan Angle: 20 deg;
Overlap: 35 %
Area covered: 139.714 km²



Flight No. : 7418GC
Area: BLK87B, BLK87D, BLK87F
Mission name: 2BLK87FV219A
Parameters:
Altitude: 1000 m;
Scan Frequency: 50 Hz
Scan Angle: 20 deg;
Overlap: 35 %
Area covered: 127.479 km²

ANNEX 7. Flight Status Reports

ANNEX 8. Mission Summary Reports

Table A-8.1. Mission Summary Reports

Flight Area	Davao Oriental
Mission Name	Blk87A
Inclusive Flights	7400G, 7404G
Range data size	20.94 GB
Base data size	8.08 MB
POS	316 MB
Image	na
Transfer date	August 12, 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)	4.0
RMSE for East Position (<4.0 cm)	2.0
RMSE for Down Position (<8.0 cm)	12.0
Boresight correction stdev (<0.001deg)	0.000347
IMU attitude correction stdev (<0.001deg)	0.22618
GPS position stdev (<0.01m)	0.0104
Minimum % overlap (>25)	25.84%
Ave point cloud density per sq.m. (>2.0)	3.07
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	209
Maximum Height	565.04
Minimum Height	68.87
Classification (# of points)	
Ground	60085896
Low vegetation	64666486
Medium vegetation	97681467
High vegetation	217149246
Building	9552969
Orthophoto	No
Processed by	Engr. Analyn Naldo, Engr. Edgardo Gubatanga, Jr., Engr. Jeffrey Delica

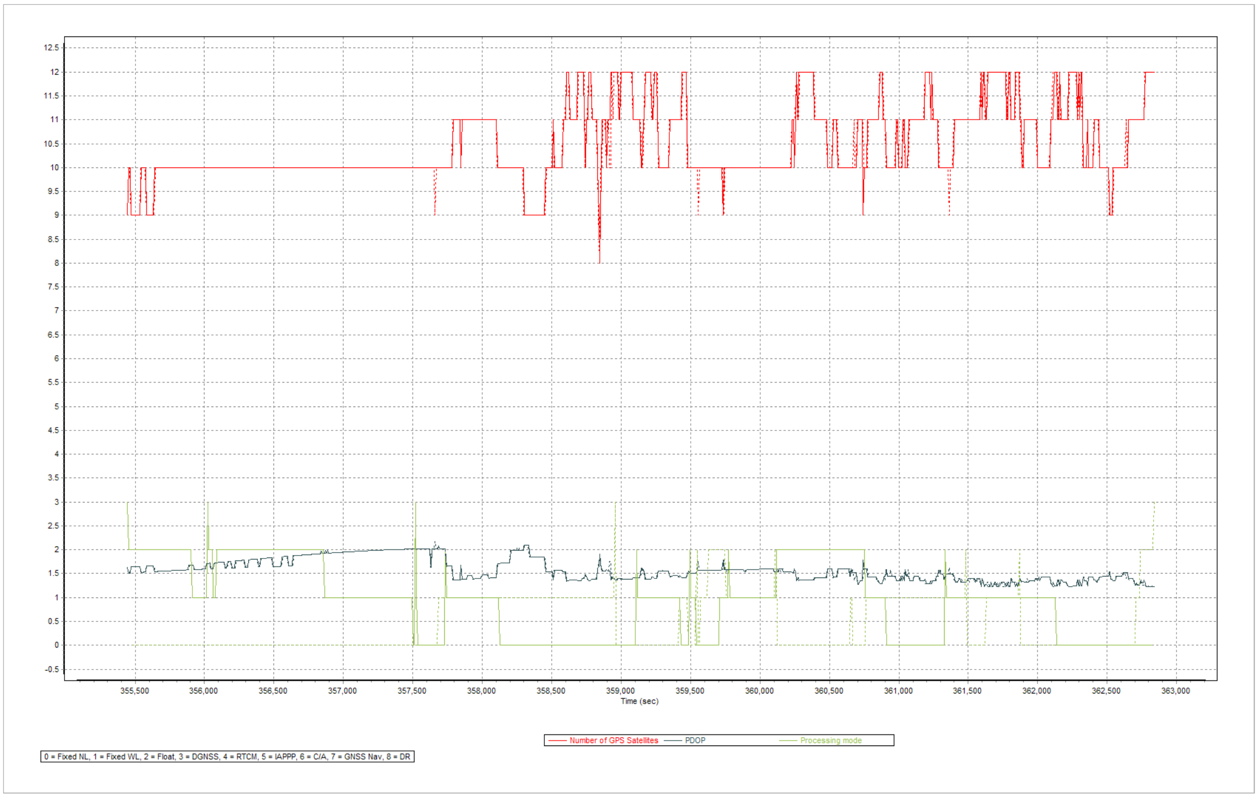


Figure 1.1.1 Solution Status

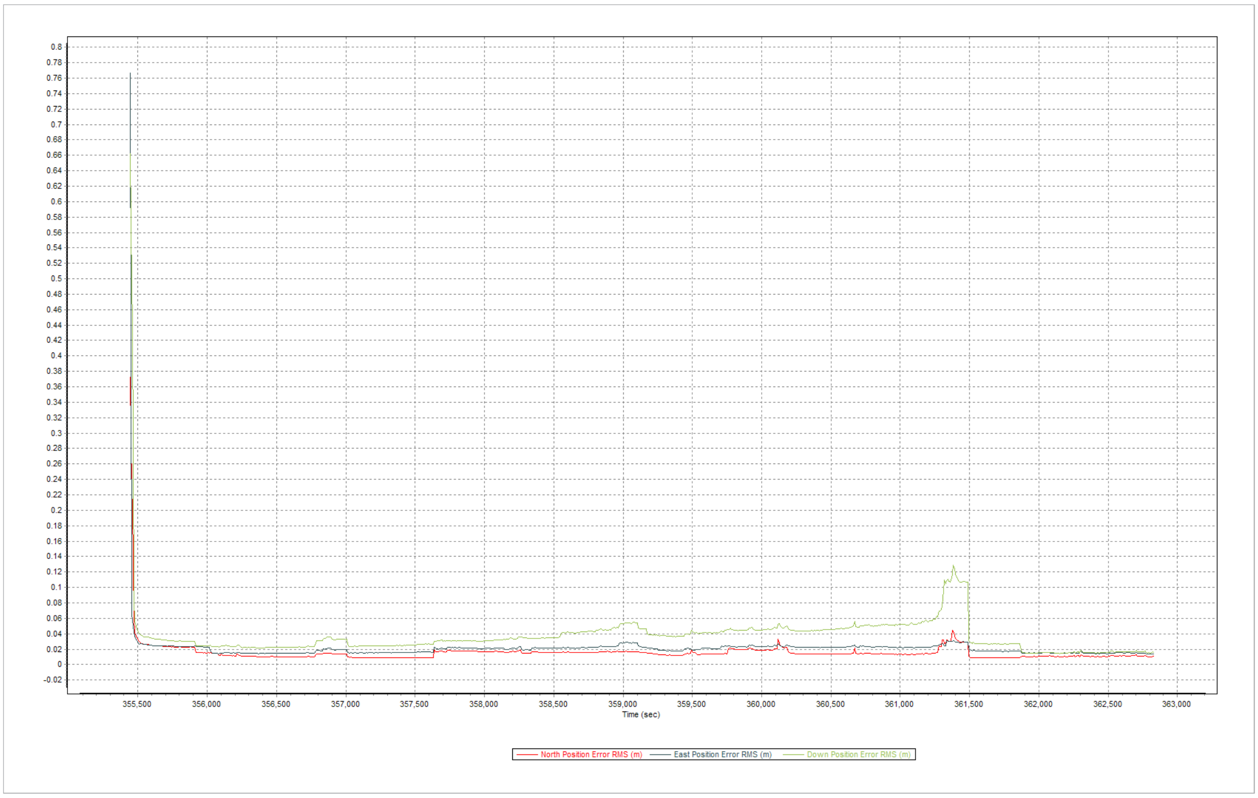


Figure 1.1.2 Smoothed Performance Metric Parameters

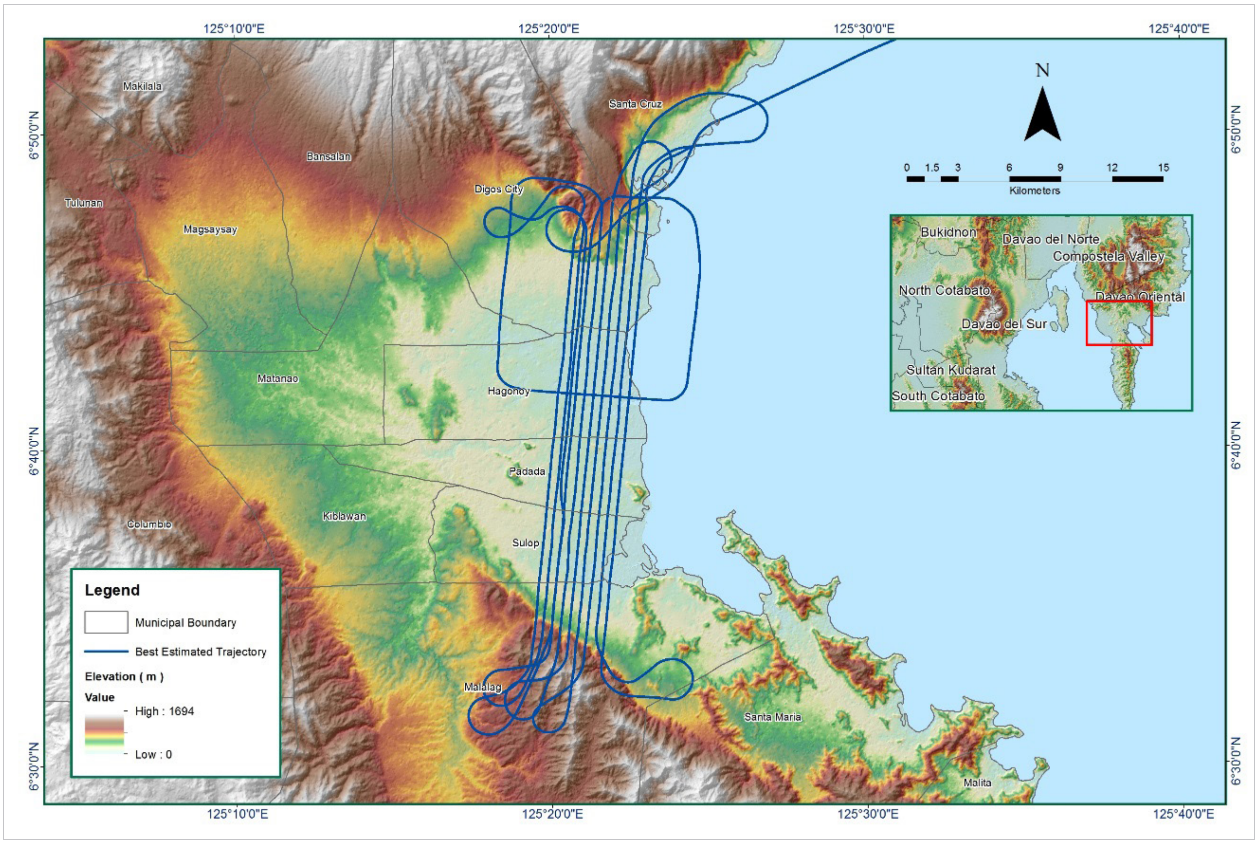


Figure 1.1.3 Best Estimated Trajectory

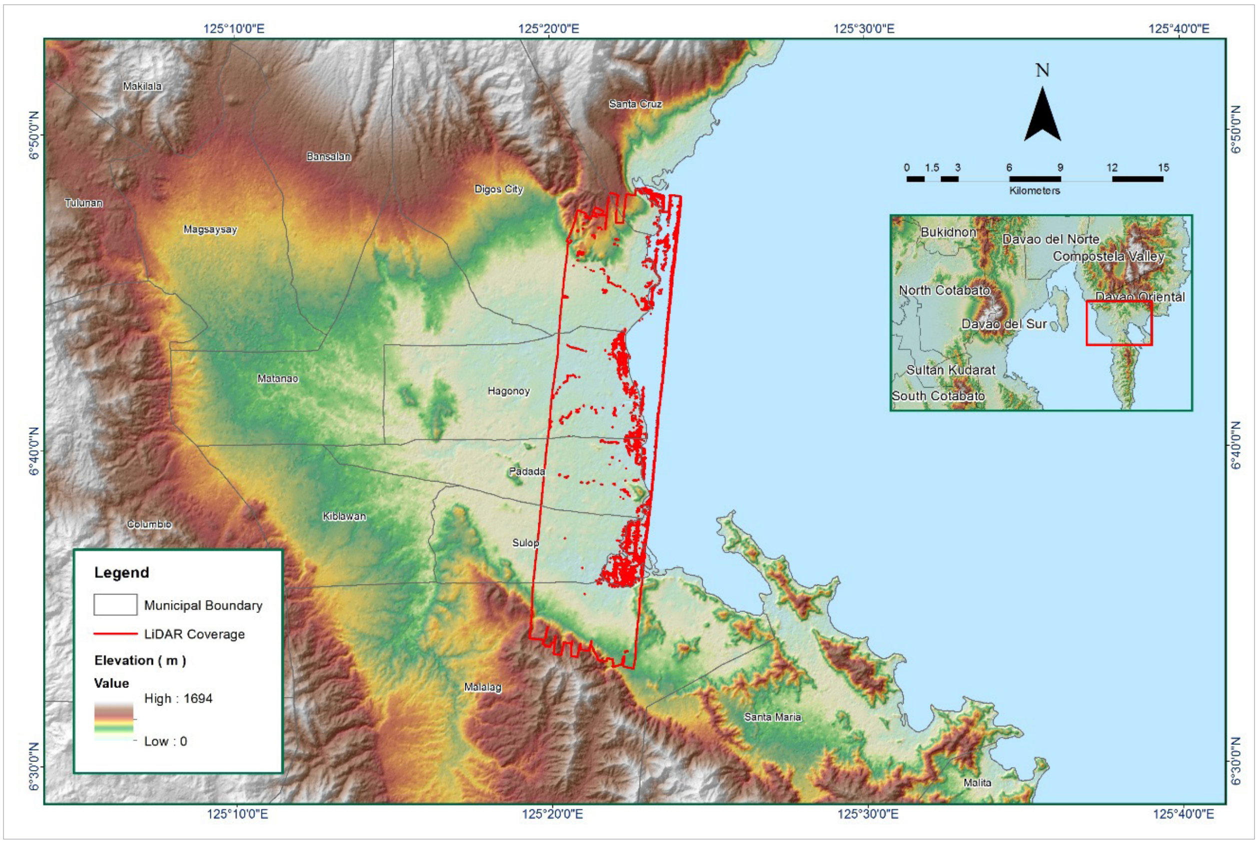


Figure 1.1.4 Coverage of LiDAR data

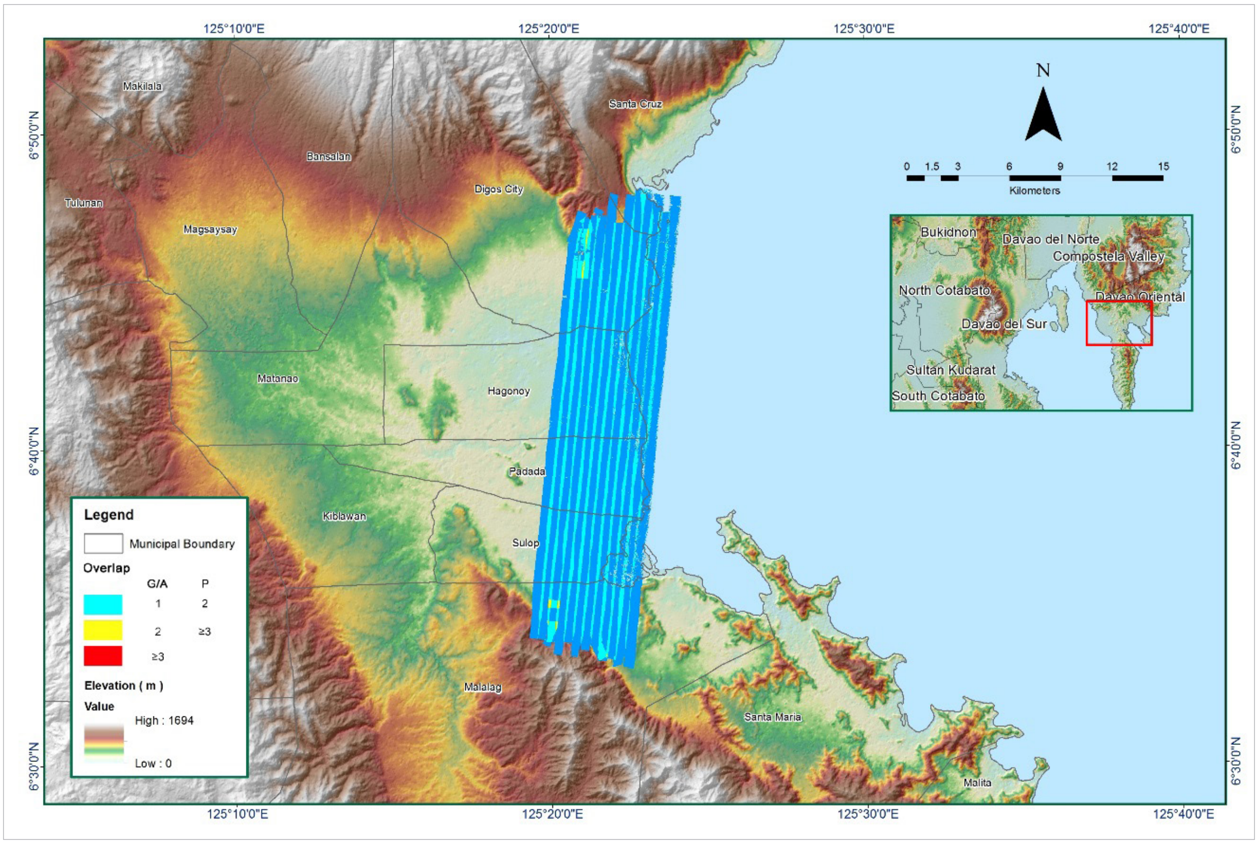


Figure 1.1.5 Image of data overlap

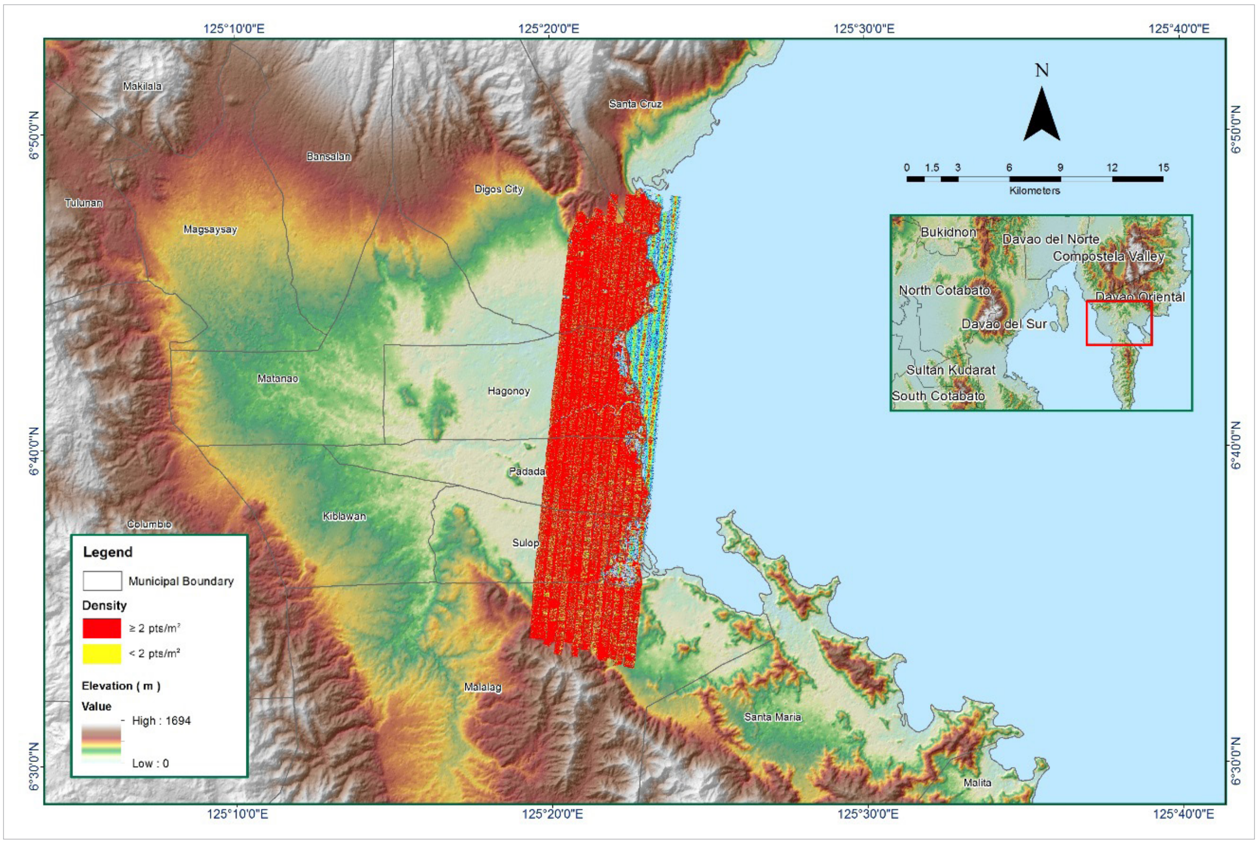


Figure 1.1.6 Density map of merged LiDAR data

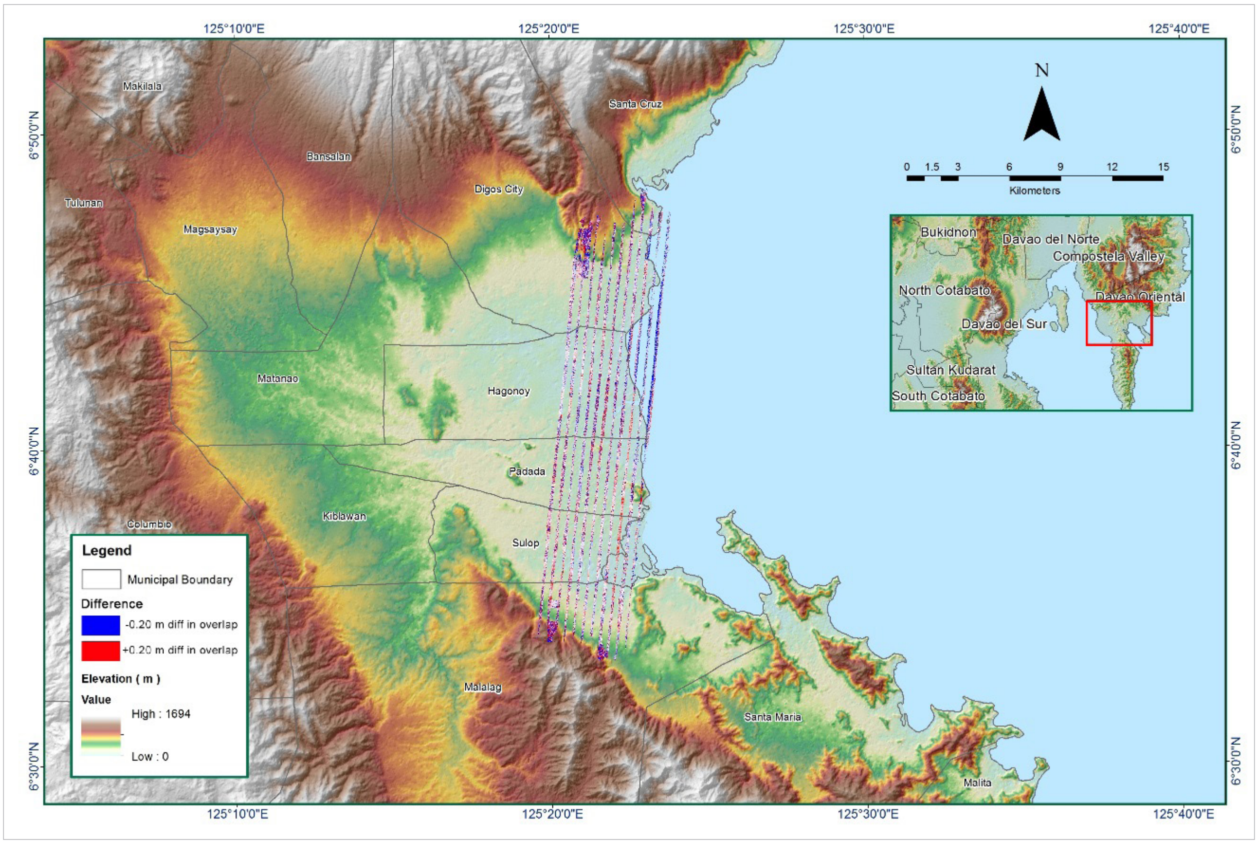


Figure 1.1.7 Elevation difference between flight lines

Flight Area	**Davao Oriental**
Mission Name	Blk87B
Inclusive Flights	7406G
Range data size	19.3 GB
Base data size	5.41 MB
POS	204 MB
Image	n/a
Transfer date	August 12, 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)	1.15
RMSE for East Position (<4.0 cm)	1.85
RMSE for Down Position (<8.0 cm)	3.4
Boresight correction stdev (<0.001deg)	0.000252
IMU attitude correction stdev (<0.001deg)	0.000532
GPS position stdev (<0.01m)	0.0017
Minimum % overlap (>25)	18.61%
Ave point cloud density per sq.m. (>2.0)	2.81
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	237
Maximum Height	450.25 m
Minimum Height	71.22 m
Classification (# of points)	
Ground	82393954
Low vegetation	95202868
Medium vegetation	138559665
High vegetation	184854717
Building	3481798
Orthophoto	No
Processed by	Engr. Irish Cortez, Engr. Chelou Prado, Engr. Gladys Mae Apat

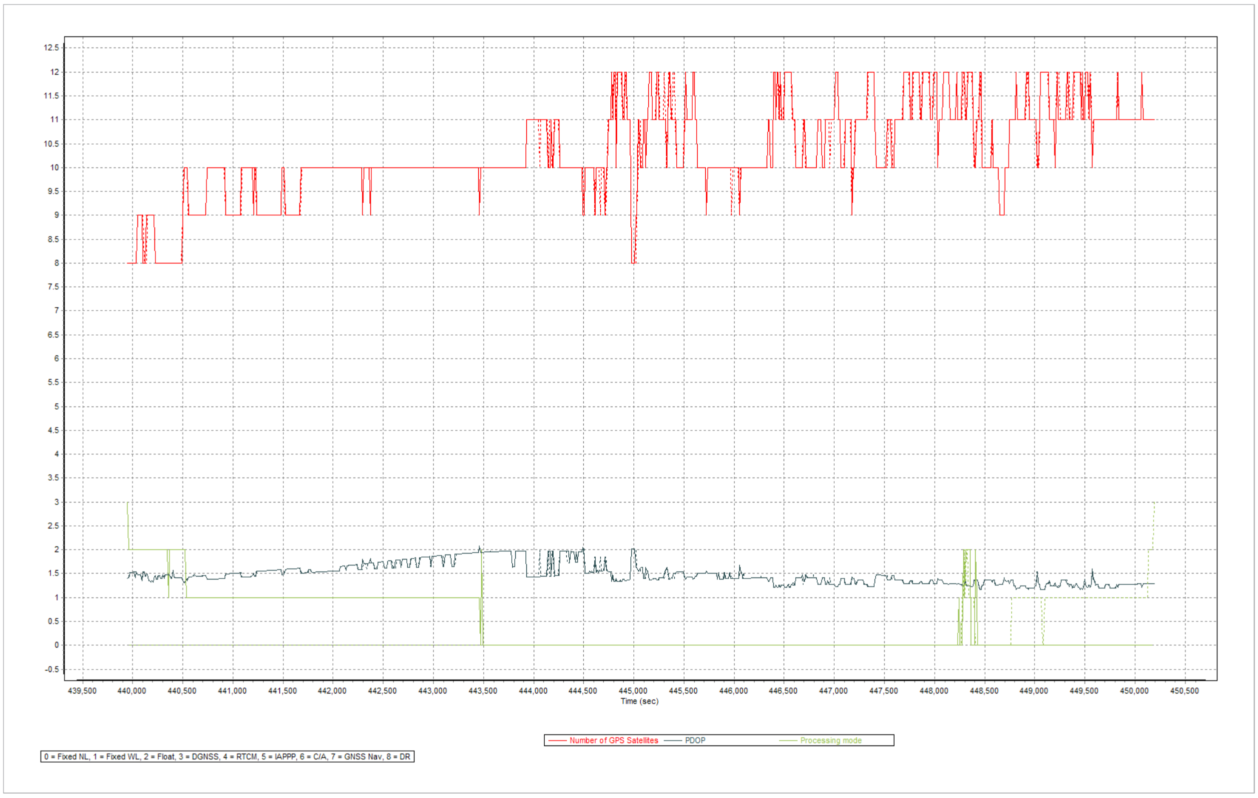


Figure 1.2.1 Solution Status

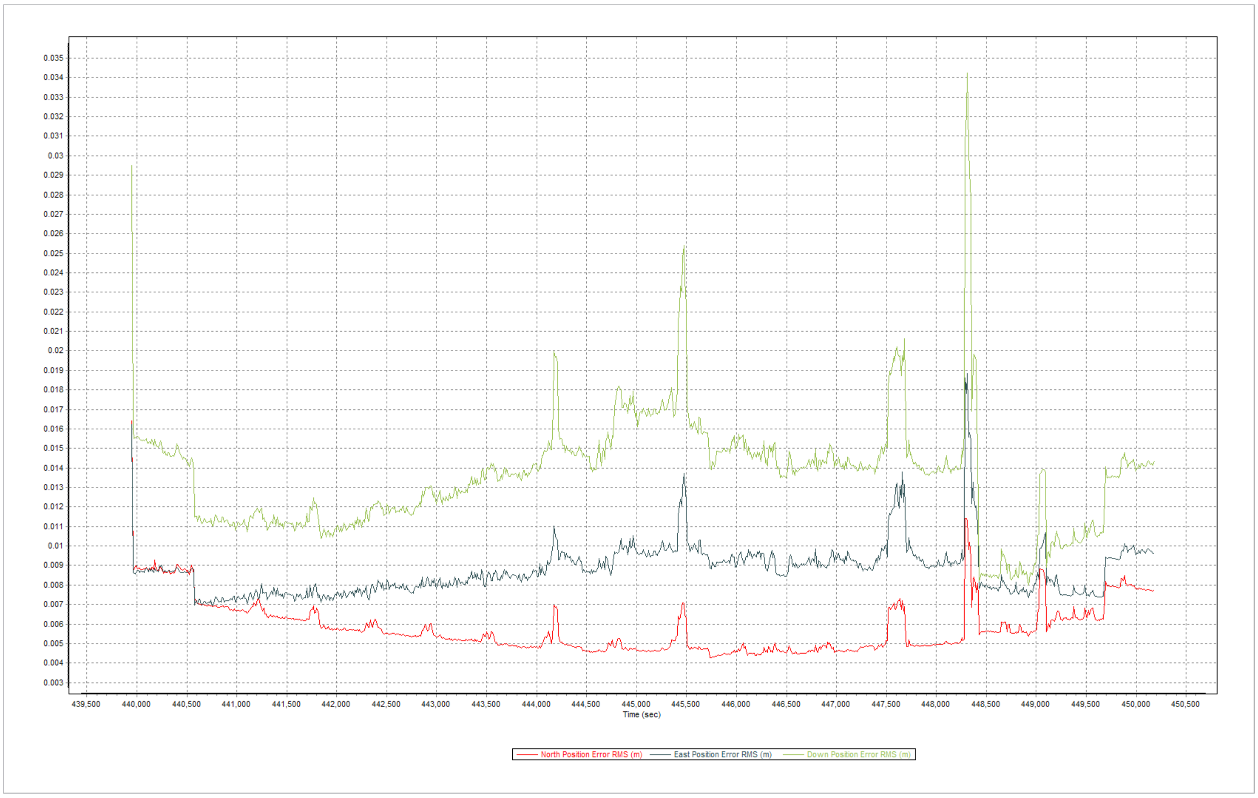


Figure 1.2.2 Smoothed Performance Metric Parameters

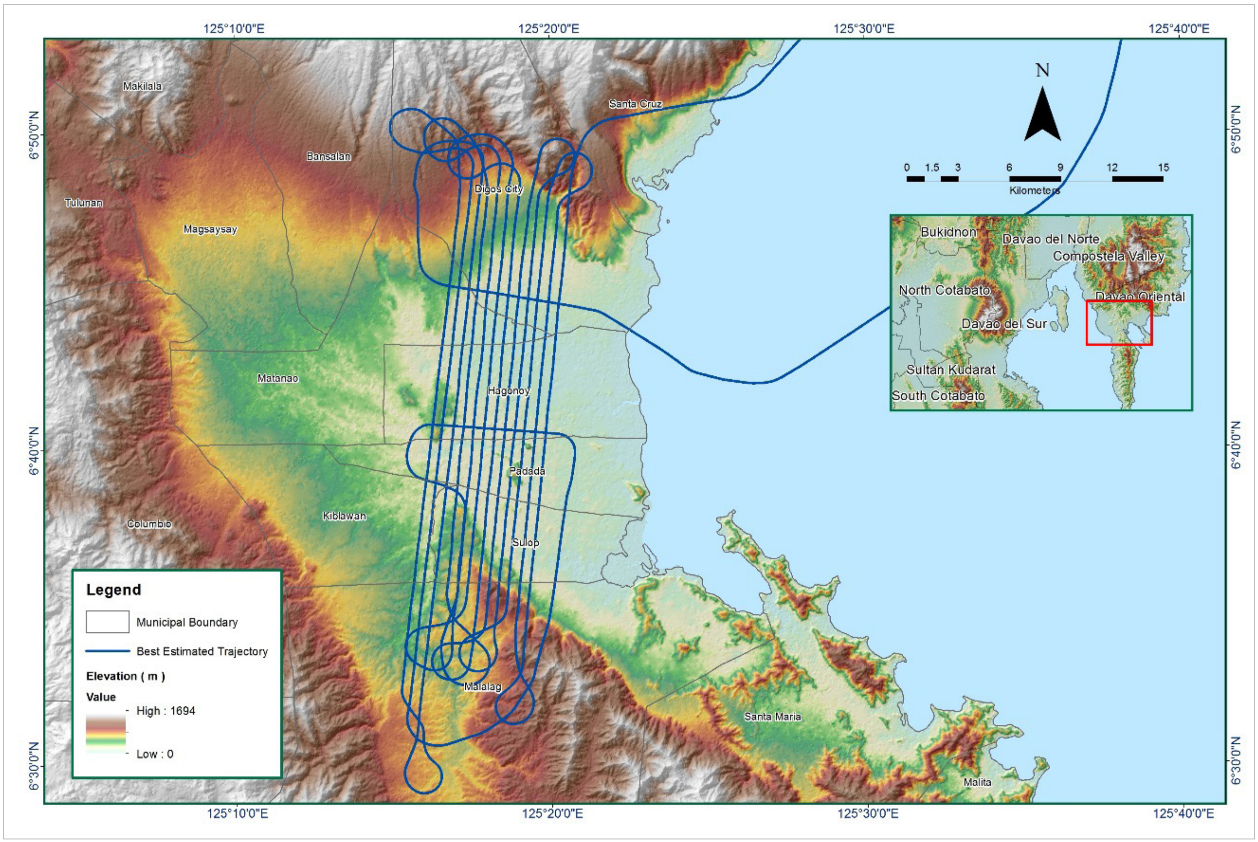


Figure 1.2.3 Best Estimated Trajectory

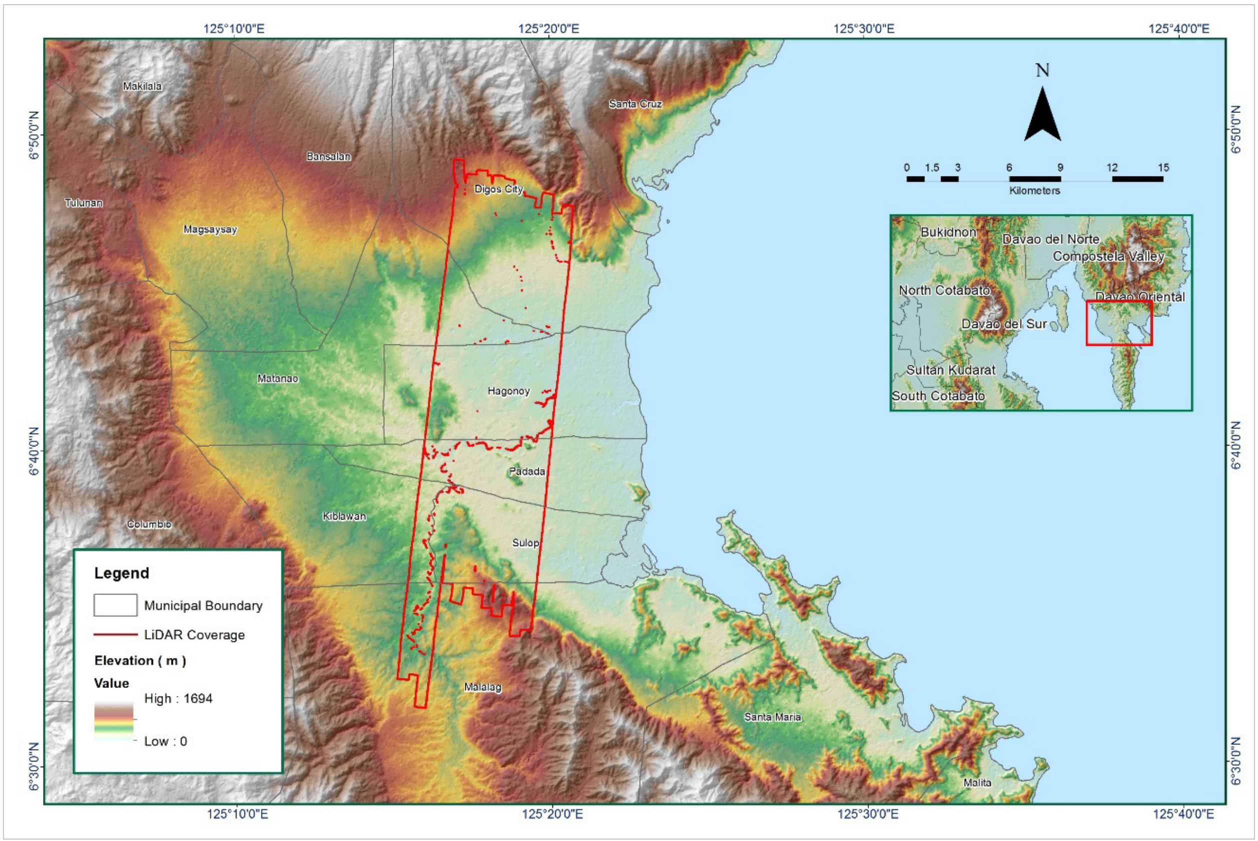


Figure 1.2.4 Coverage of LiDAR data

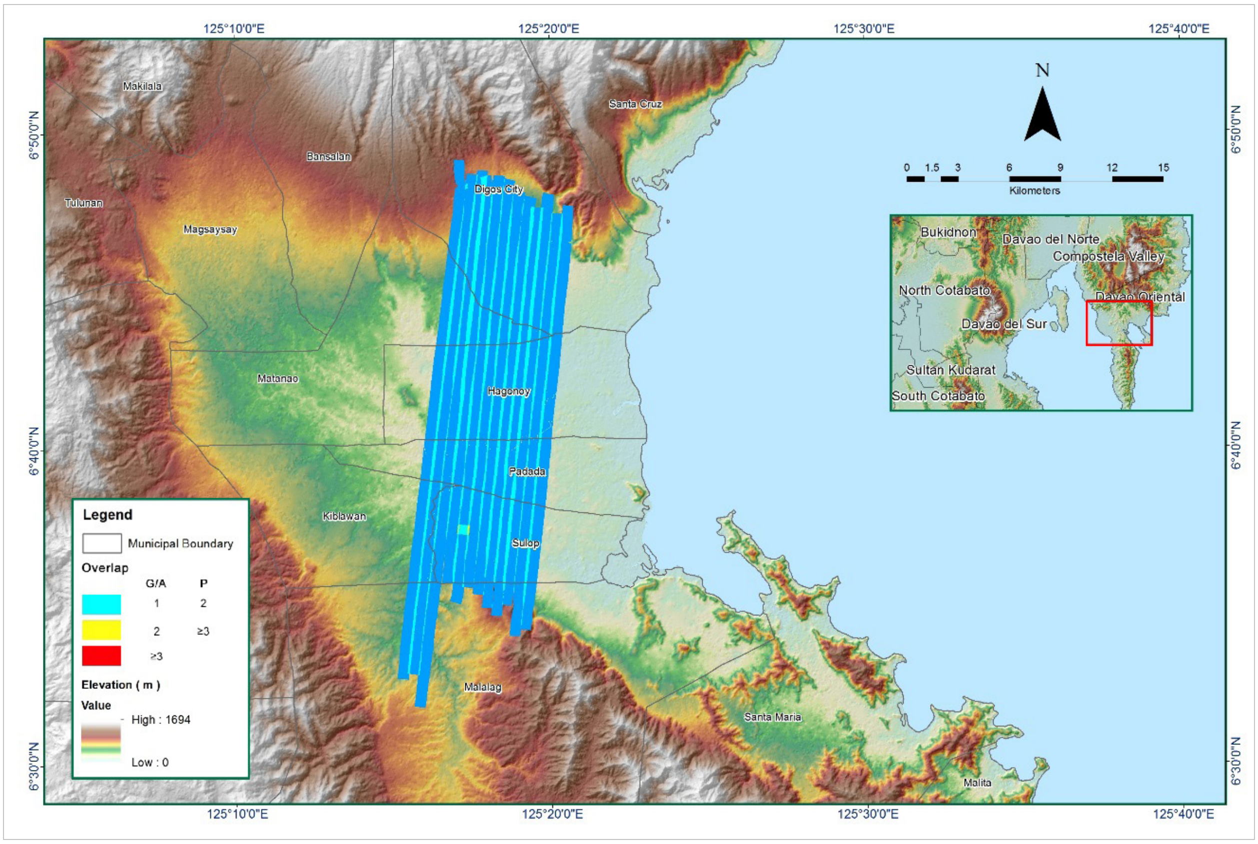


Figure 1.2.5 Image of data overlap

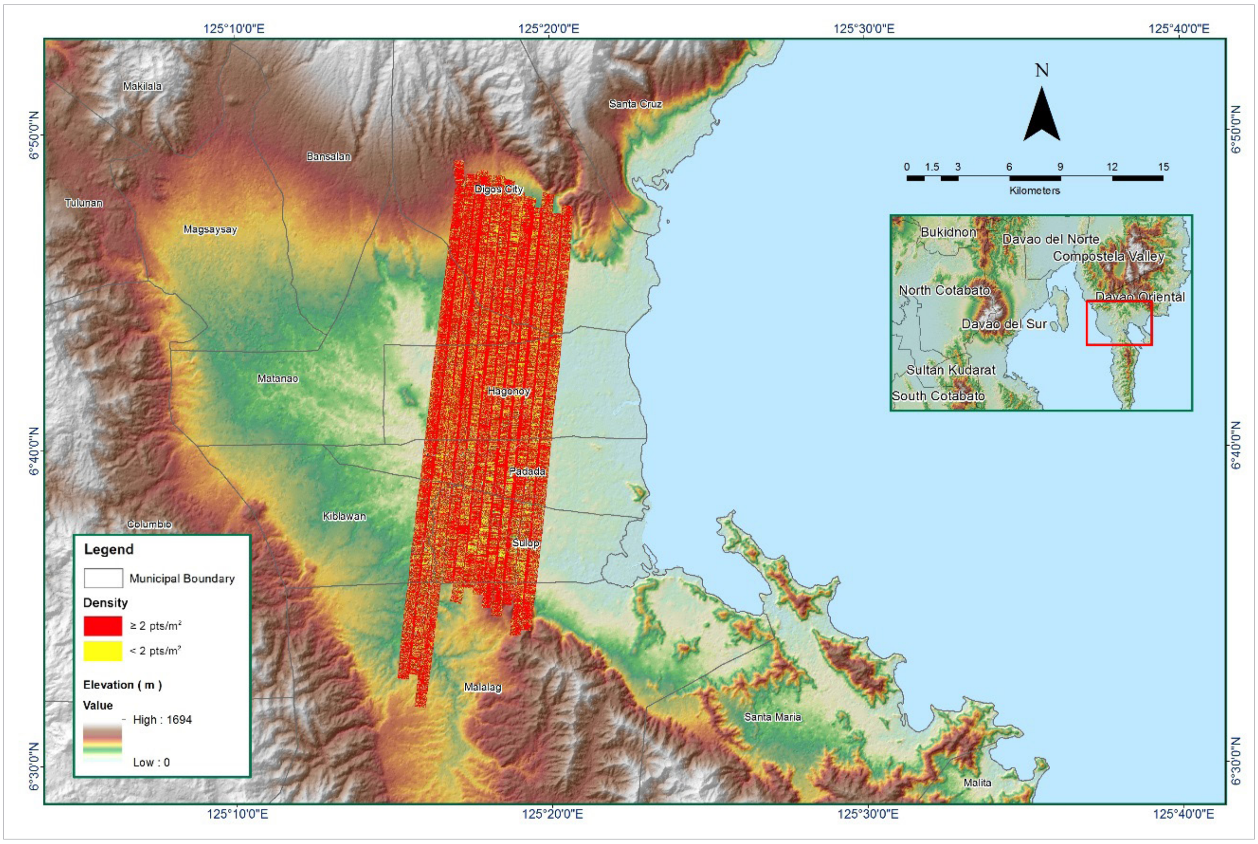


Figure 1.2.6 Density map of merged LiDAR data

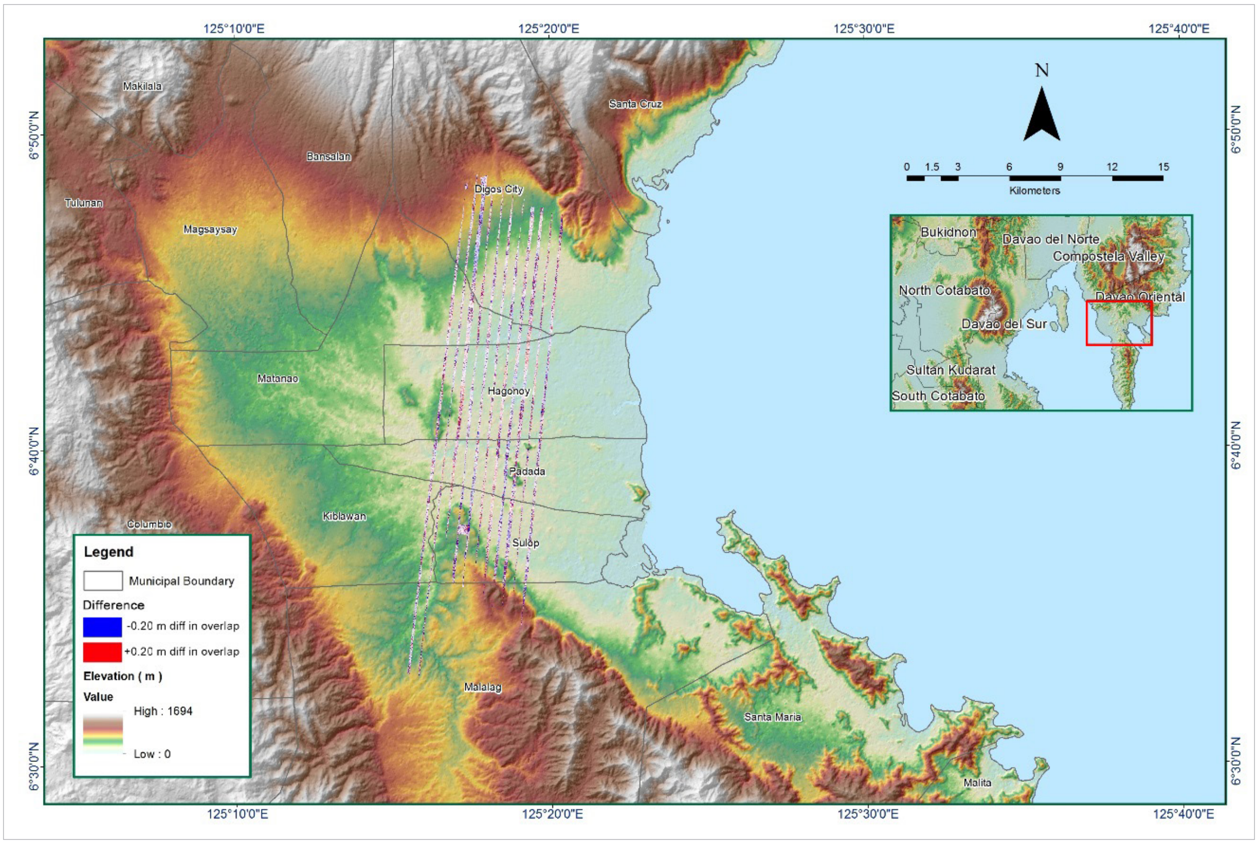


Figure 1.2.7 Elevation difference between flight lines

Flight Area	Davao Oriental
Mission Name	Blk87C
Inclusive Flights	7412G,7416G,7418G
Range data size	46.91 GB
Base data size	12.03 MB
POS	483 MB
Image	na
Transfer date	August 29, 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)	0.086
RMSE for East Position (<4.0 cm)	1.3
RMSE for Down Position (<8.0 cm)	1.7
Boresight correction stdev (<0.001deg)	0.000338
IMU attitude correction stdev (<0.001deg)	0.001055
GPS position stdev (<0.01m)	0.0217
Minimum % overlap (>25)	34.74%
Ave point cloud density per sq.m. (>2.0)	3.51
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	272
Maximum Height	974.67 m
Minimum Height	85.76 m
Classification (# of points)	
Ground	103627080
Low vegetation	138780410
Medium vegetation	238339931
High vegetation	233212584
Building	4306437
Orthophoto	No
Processed by	Engr. Kenneth Solidum, Engr. Harmond Santos, Ailyn Biñas

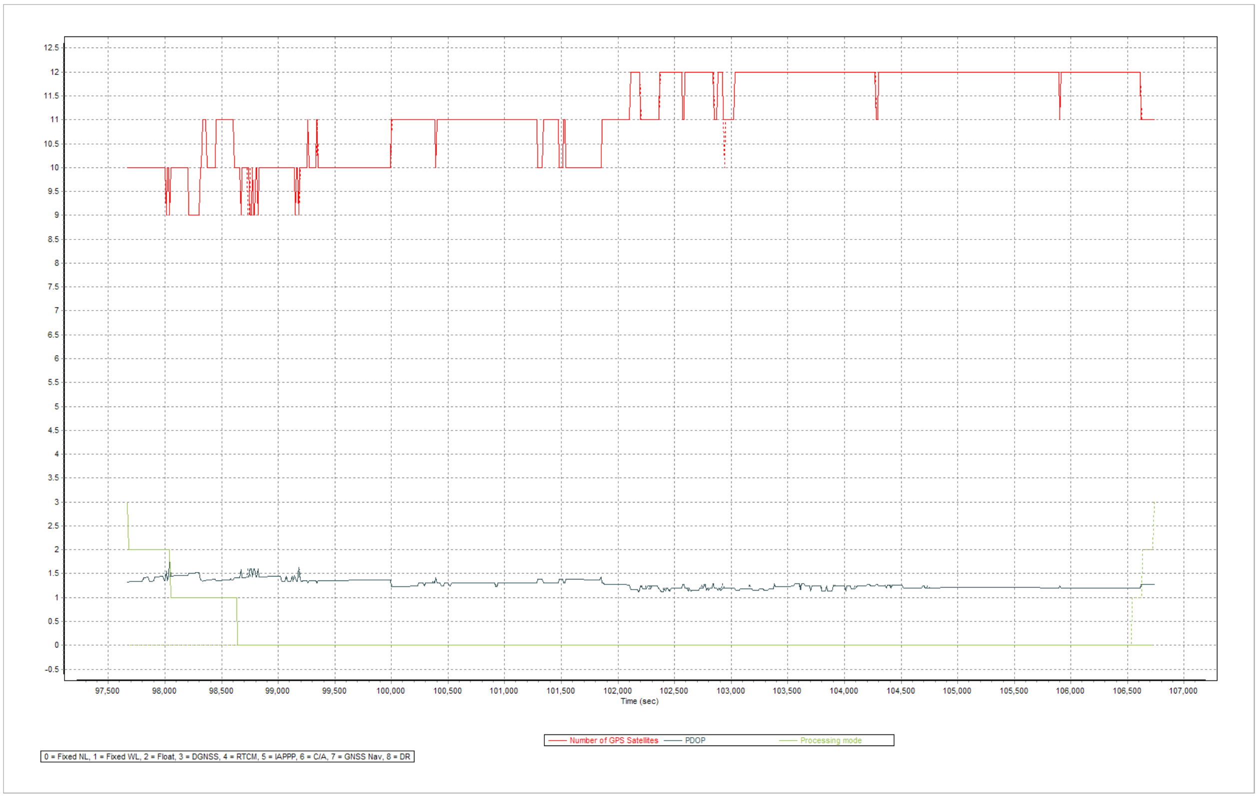


Figure 1.3.1 Solution Status

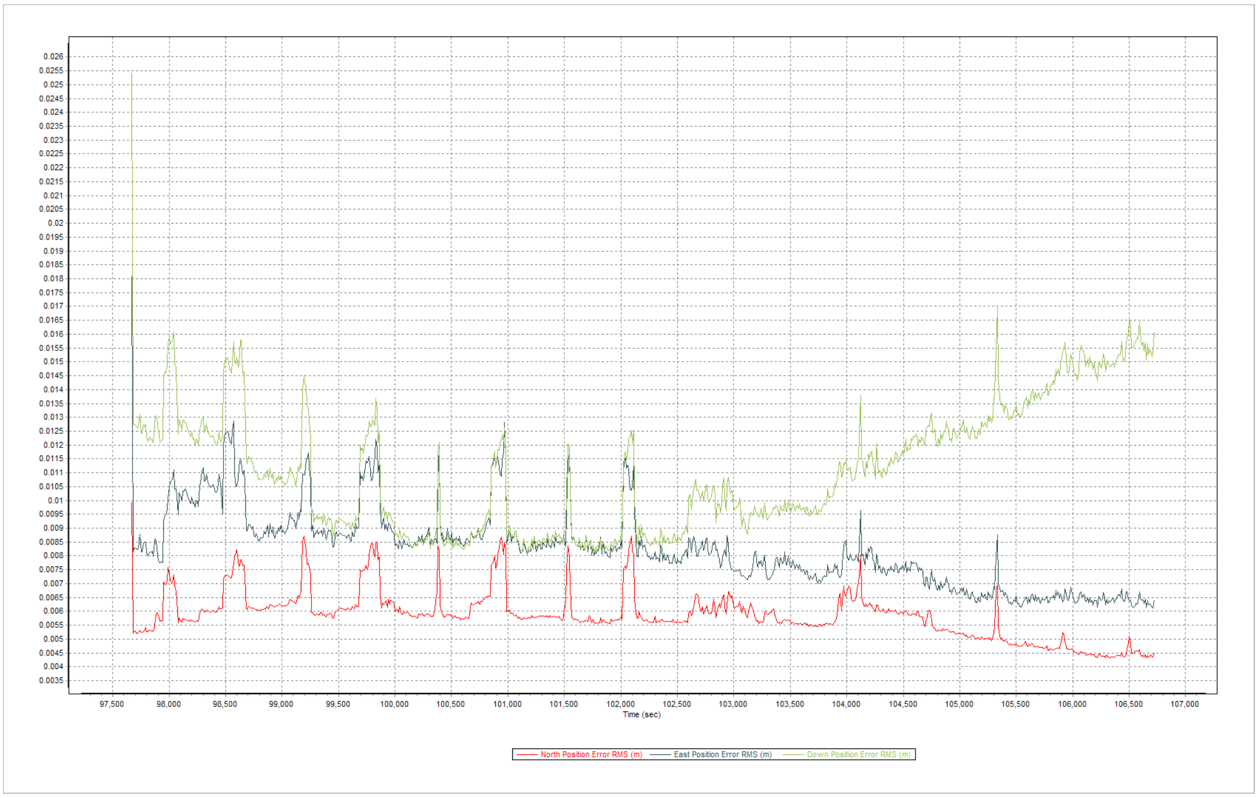


Figure 1.3.2 Smoothed Performance Metric Parameters

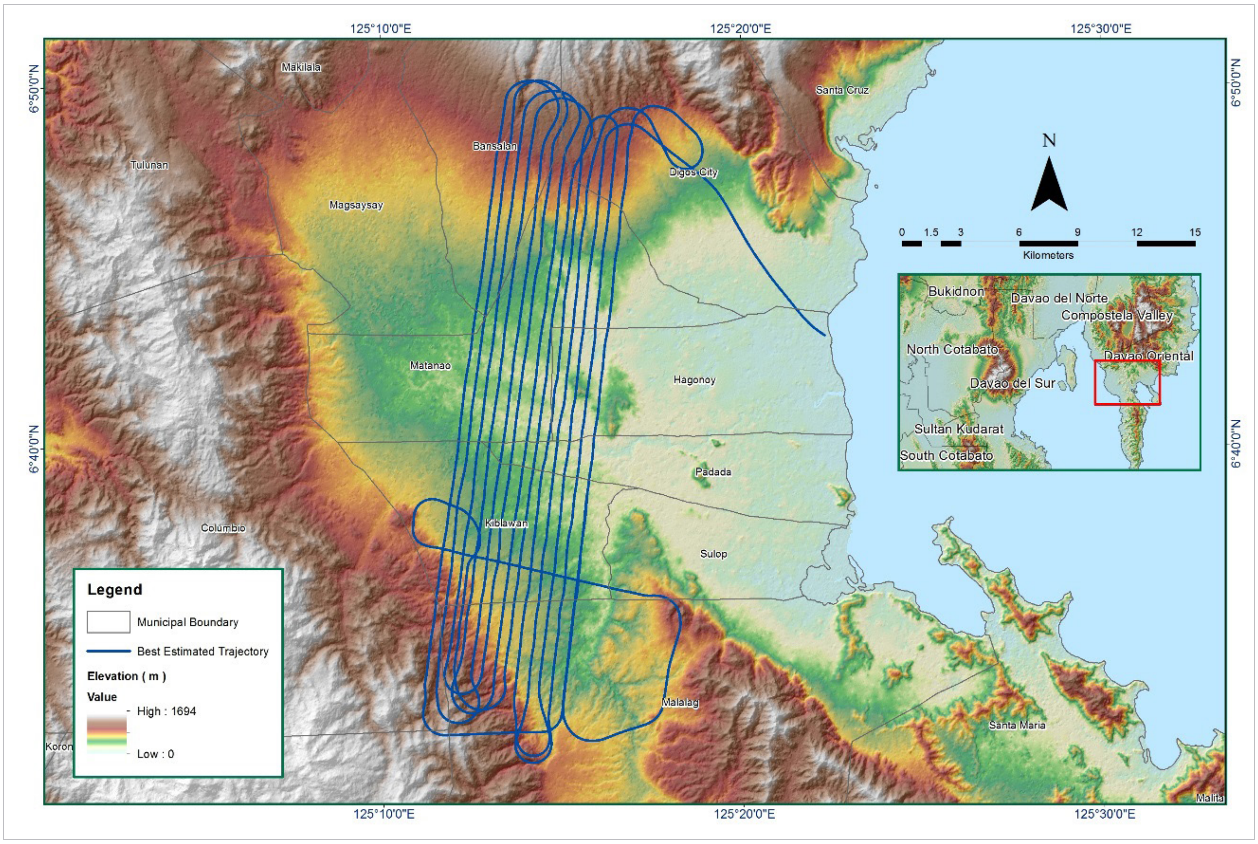


Figure 1.3.3 Best Estimated Trajectory

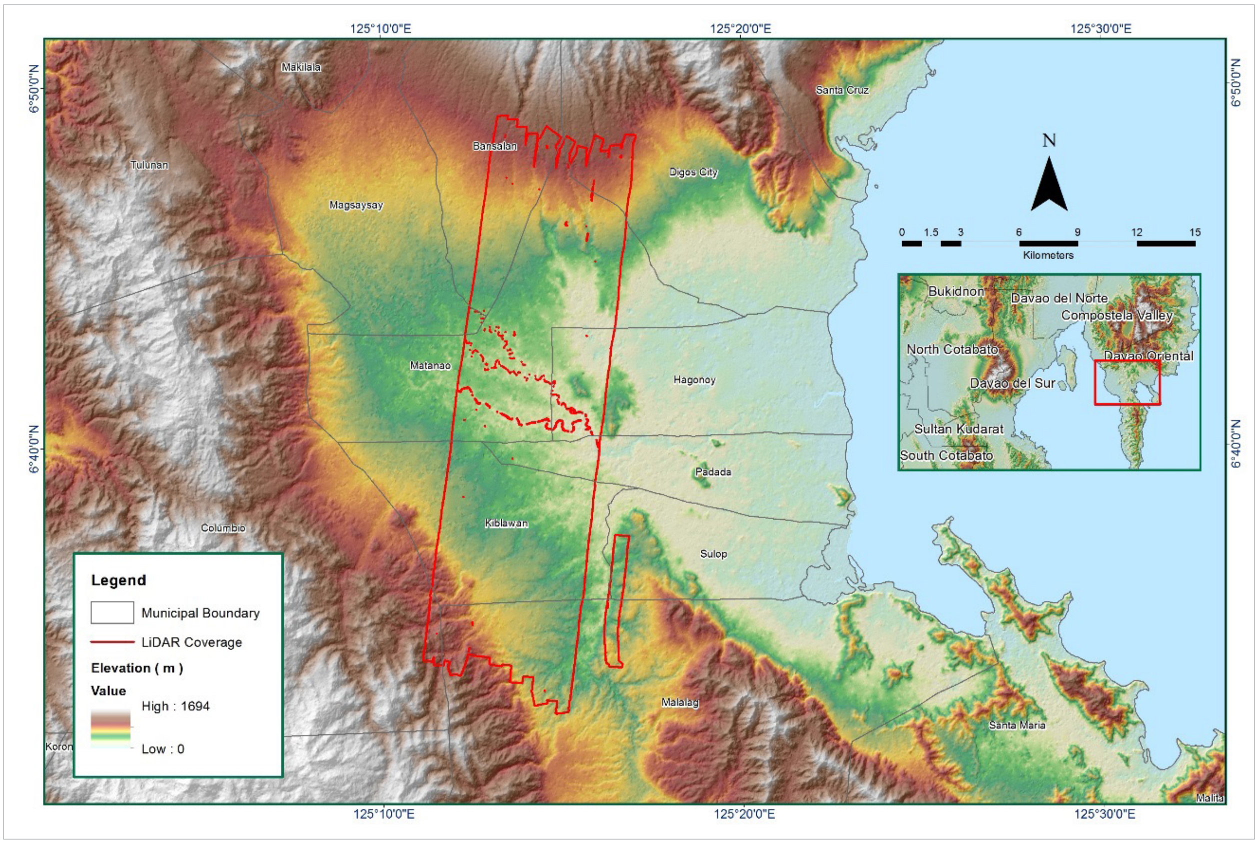


Figure 1.3.4 Coverage of LiDAR data

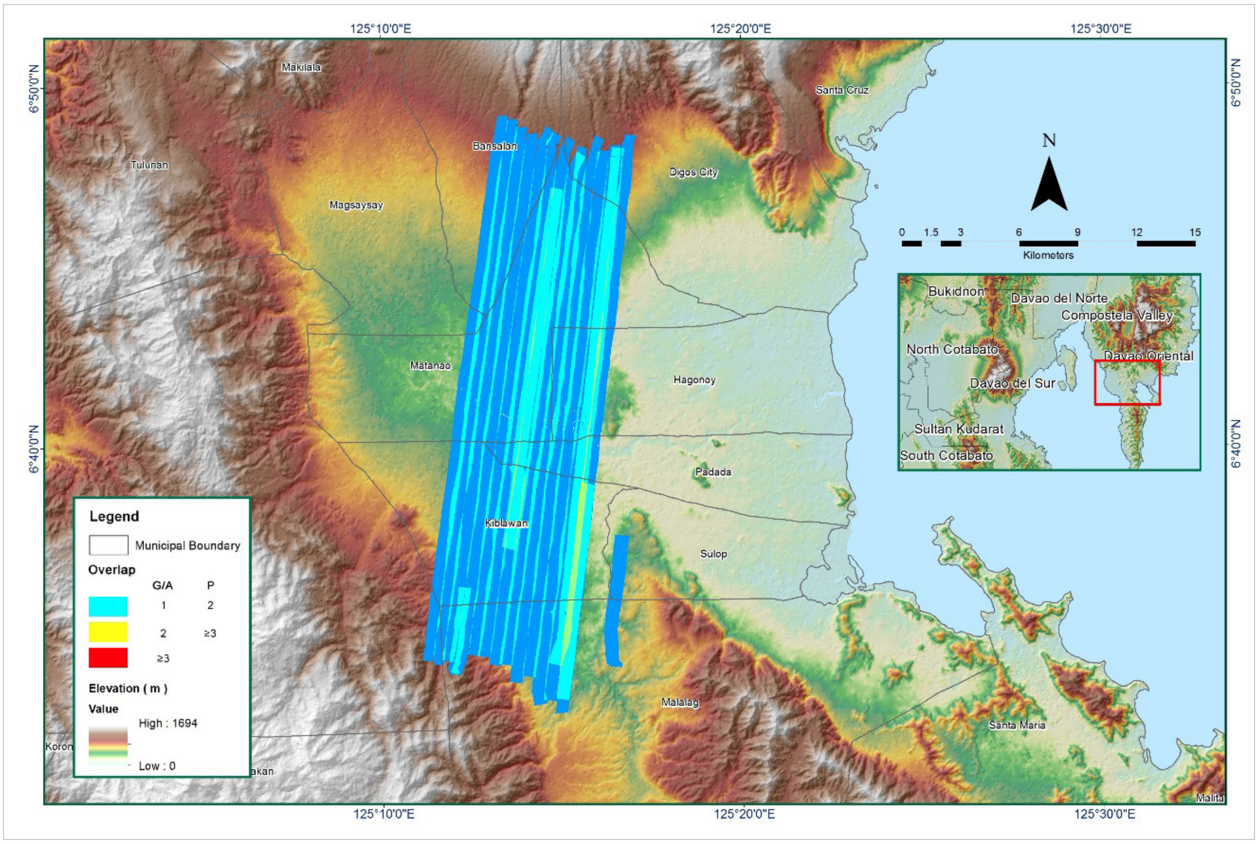


Figure 1.3.5 Image of data overlap

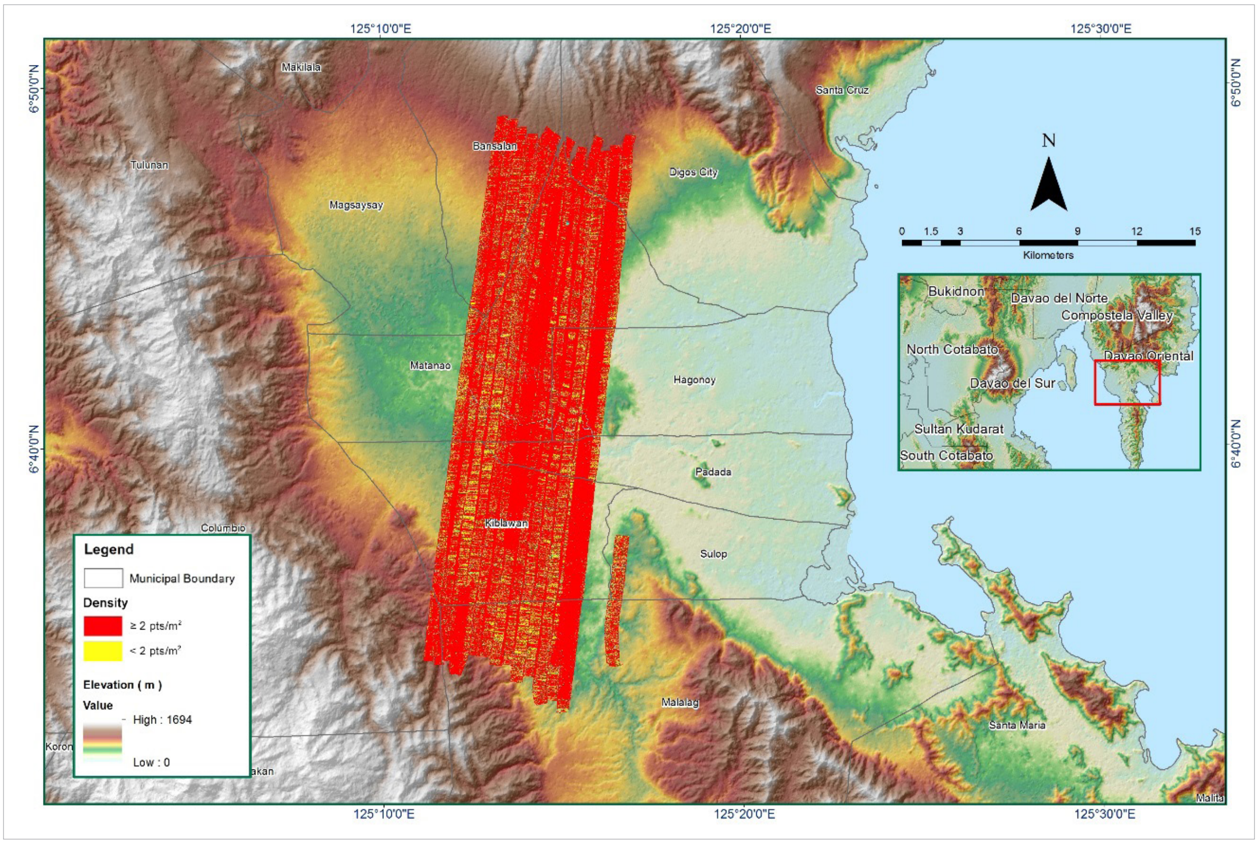


Figure 1.3.6 Density map of merged LiDAR data

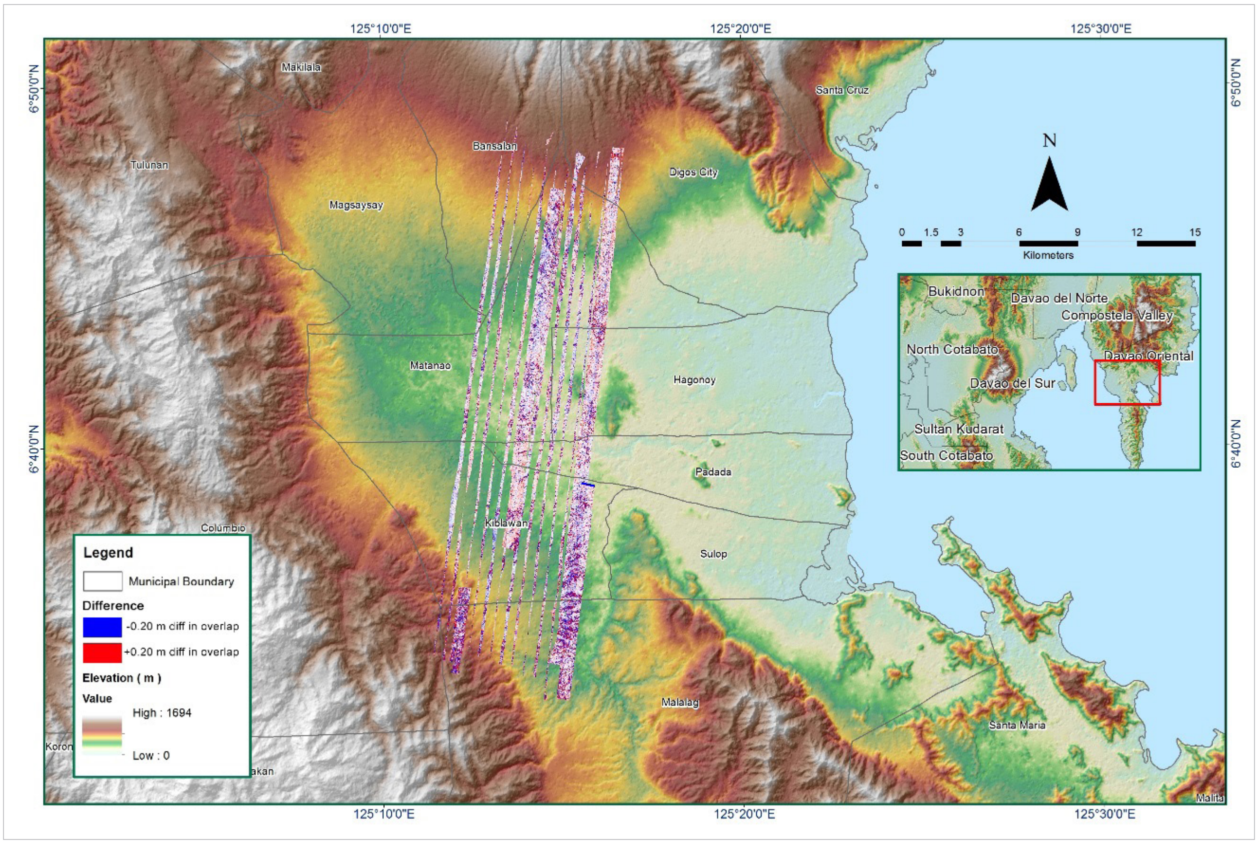


Figure 1.3.7 Elevation difference between flight lines

Flight Area	**Davao Oriental**
Mission Name	Blk87E
Inclusive Flights	7408G
Range data size	21.7 GB
Base data size	6.02 MB
POS	242 MB
Image	na
Transfer date	August 12, 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)	1.15
RMSE for East Position (<4.0 cm)	1.55
RMSE for Down Position (<8.0 cm)	2.8
Boresight correction stdev (<0.001deg)	0.000618
IMU attitude correction stdev (<0.001deg)	0.001499
GPS position stdev (<0.01m)	0.0076
Minimum % overlap (>25)	37.86%
Ave point cloud density per sq.m. (>2.0)	3.32
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	233
Maximum Height	576.07 m
Minimum Height	112.62 m
Classification (# of points)	
Ground	97064594
Low vegetation	137647512
Medium vegetation	156988685
High vegetation	182232363
Building	3955979
Orthophoto	No
Processed by	Engr. Kenneth Solidum, Engr. Antonio Chua, Jr., Engr. Elainne Lopez

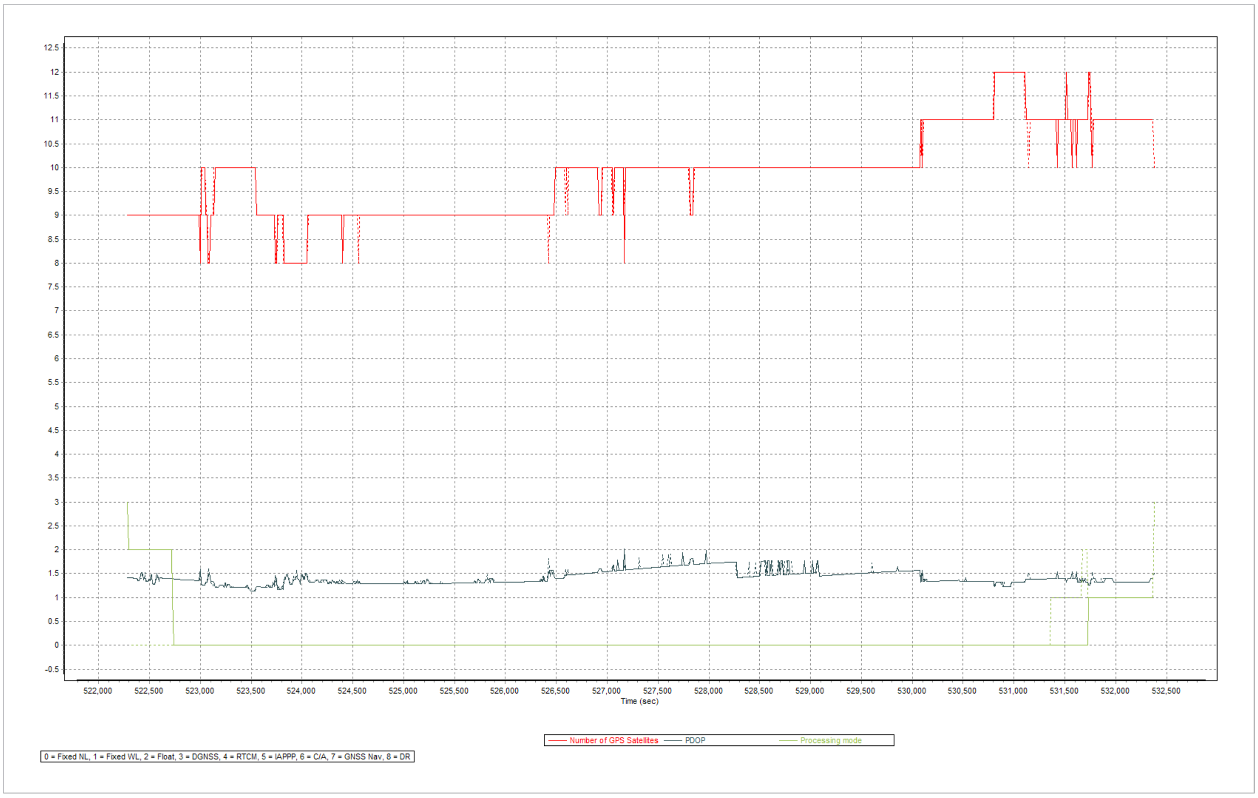


Figure 1.4.1 Solution Status

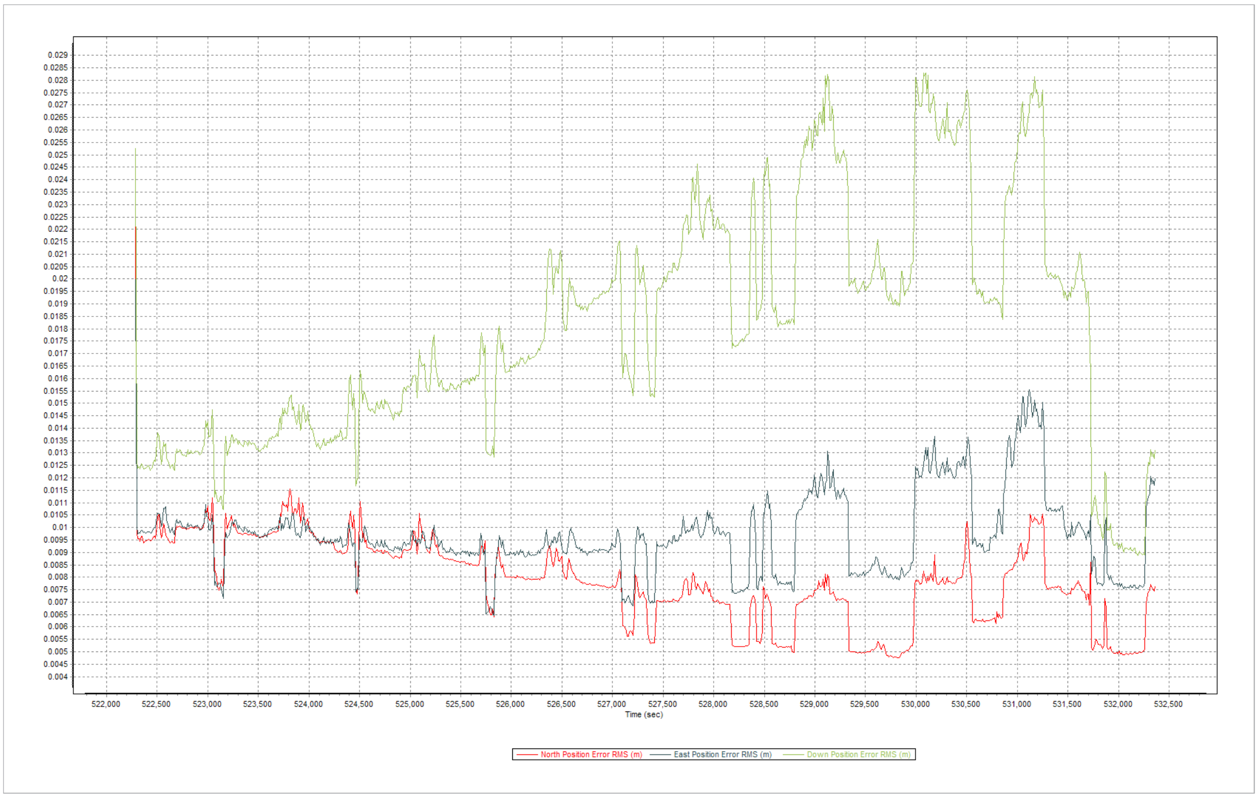


Figure 1.4.2 Smoothed Performance Metric Parameters

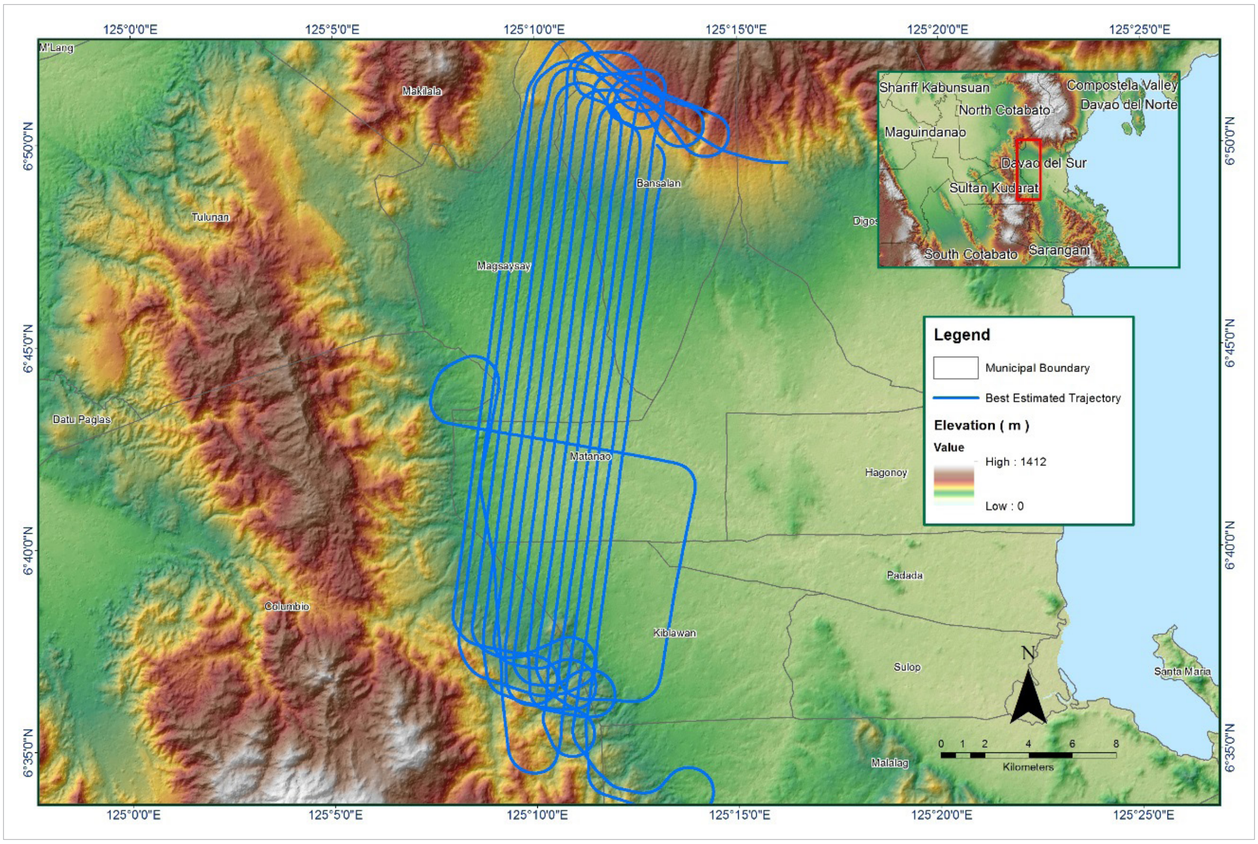


Figure 1.4.3 Best Estimated Trajectory

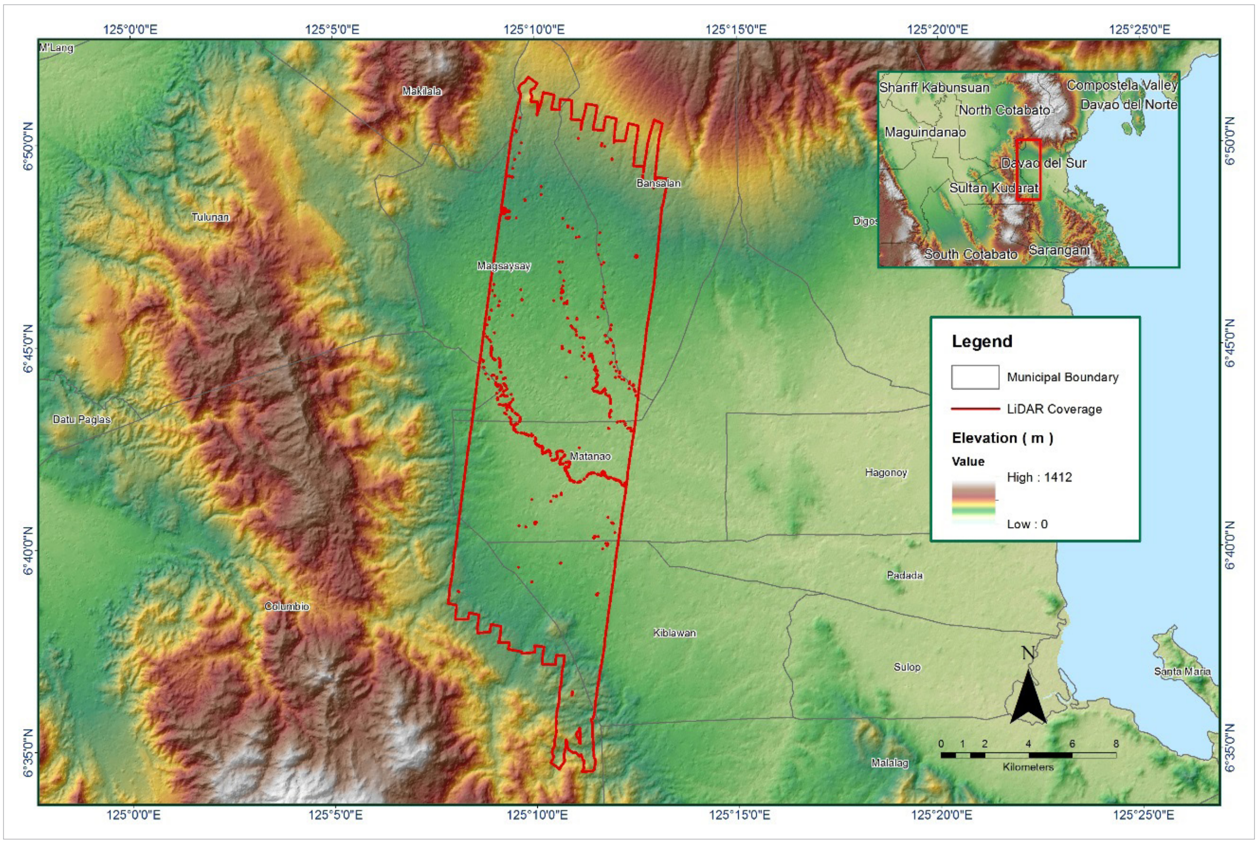


Figure 1.4.4 Coverage of LiDAR data

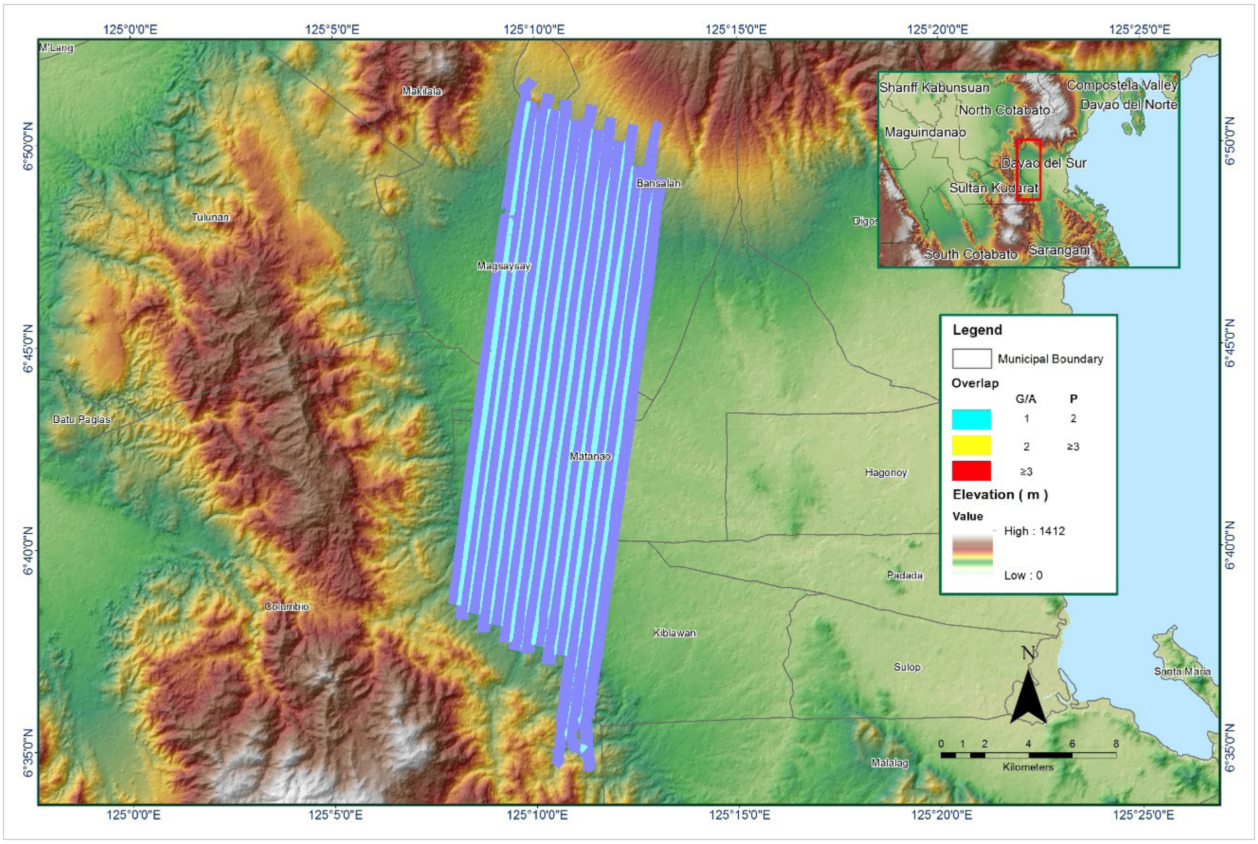


Figure 1.4.5 Image of data overlap

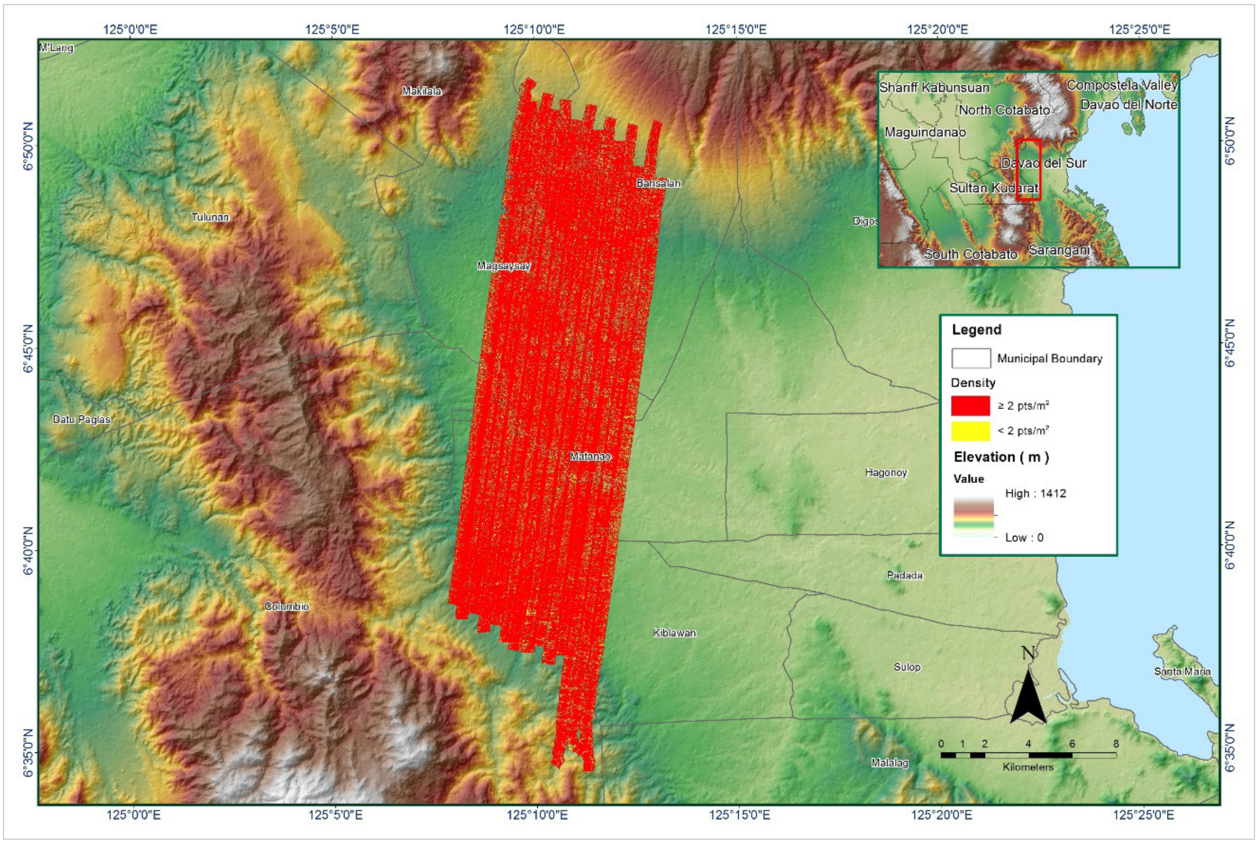


Figure 1.4.6 Density map of merged LiDAR data

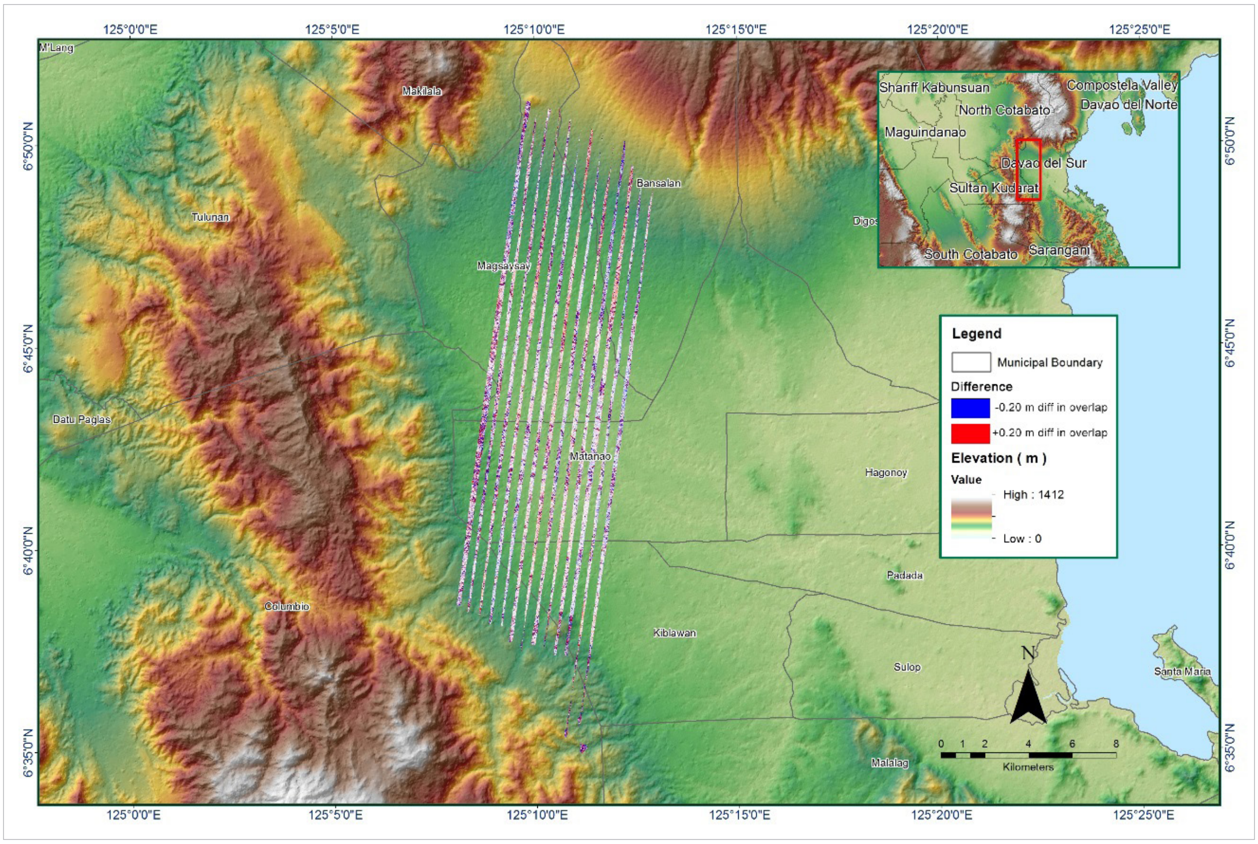


Figure 1.4.7 Elevation difference between flight lines

Flight Area	Davao Oriental
Mission Name	Blk87D
Inclusive Flights	7416G,7418G
Range data size	22.71 GB
Base data size	7.04 MB
POS	328 MB
Image	na
Transfer date	August 29, 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)	1.12
RMSE for East Position (<4.0 cm)	1.24
RMSE for Down Position (<8.0 cm)	1.7
Boresight correction stdev (<0.001deg)	none
IMU attitude correction stdev (<0.001deg)	
GPS position stdev (<0.01m)	
Minimum % overlap (>25)	39.32%
Ave point cloud density per sq.m. (>2.0)	3.59
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	133
Maximum Height	569.06 m
Minimum Height	52.5 m
Classification (# of points)	
Ground	39876217
Low vegetation	37379107
Medium vegetation	66825805
High vegetation	161736747
Building	1338775
Orthophoto	No
Processed by	Engr. Kenneth Solidum, Engr. Melanie Hingpit, Jovy Narisma

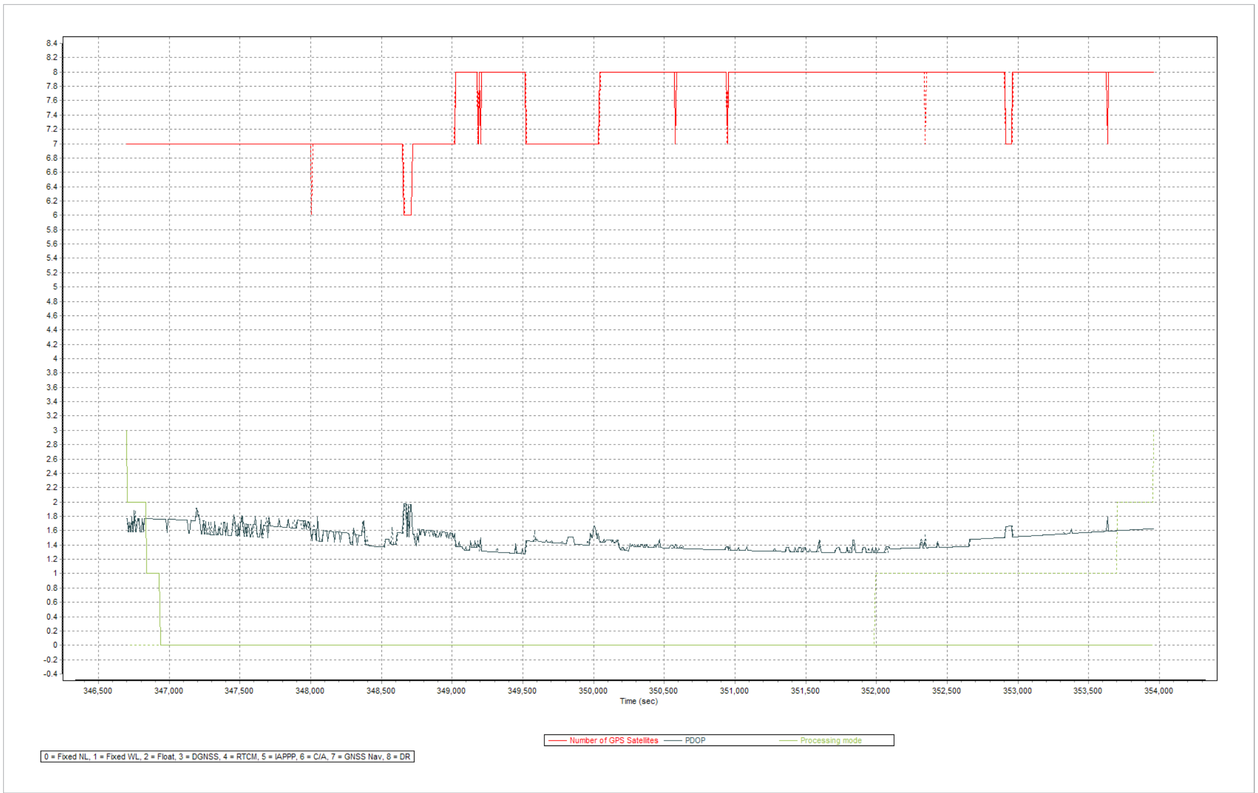


Figure 1.5.1 Solution Status

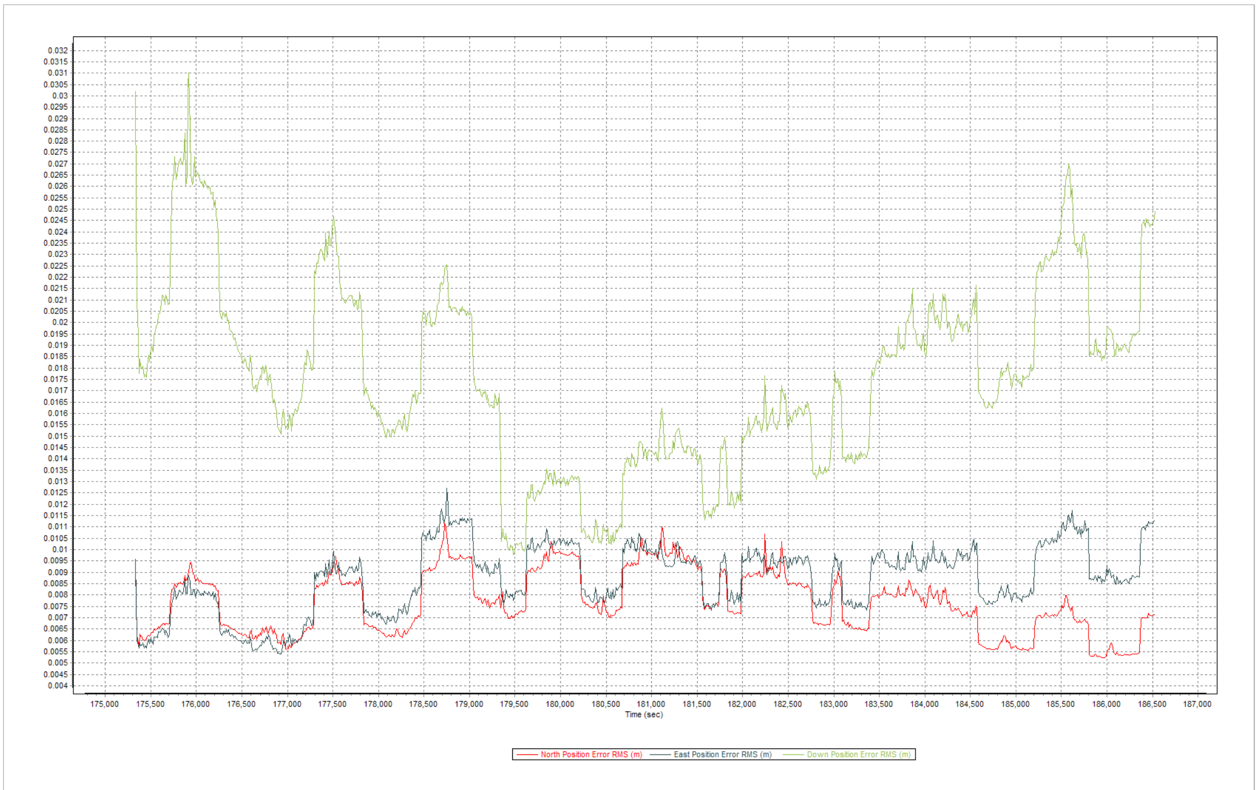


Figure 1.5.2 Smoothed Performance Metric Parameters

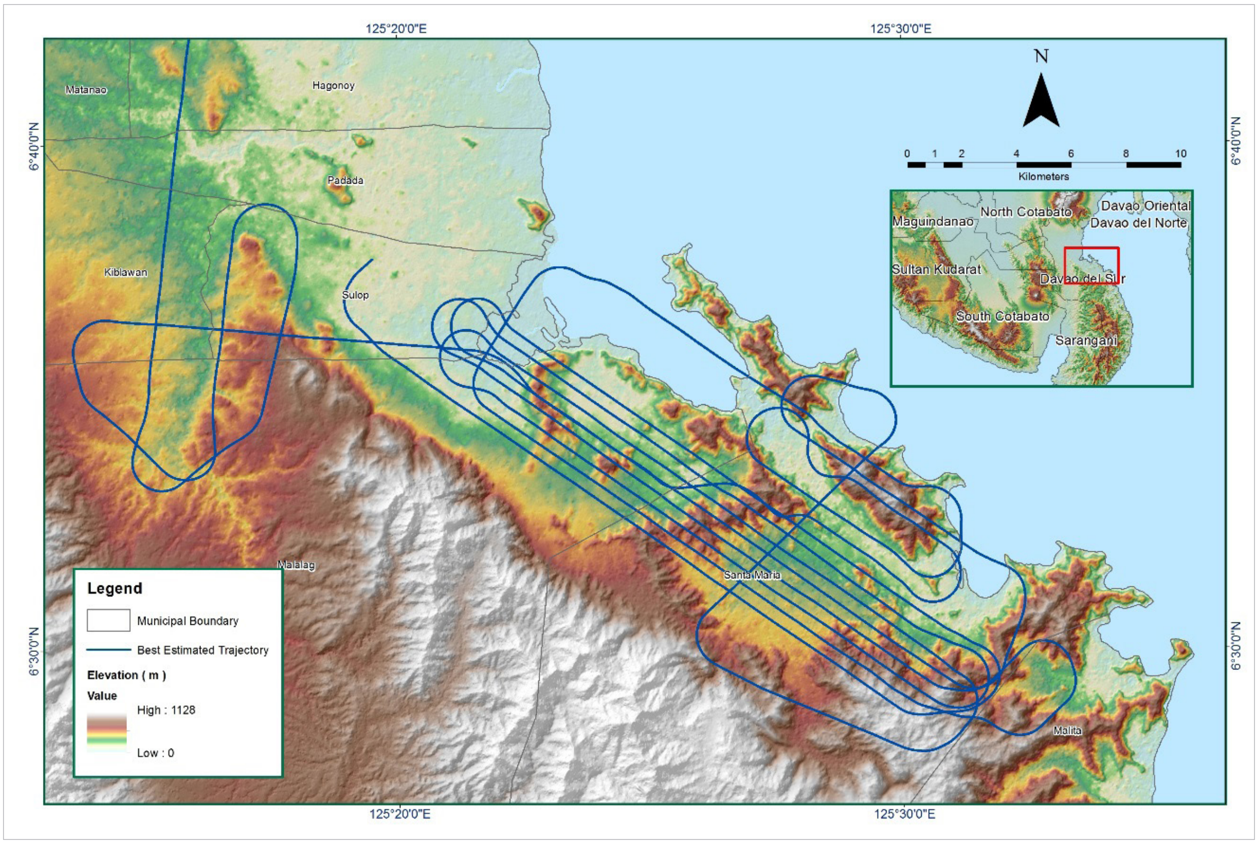


Figure 1.5.3 Best Estimated Trajectory

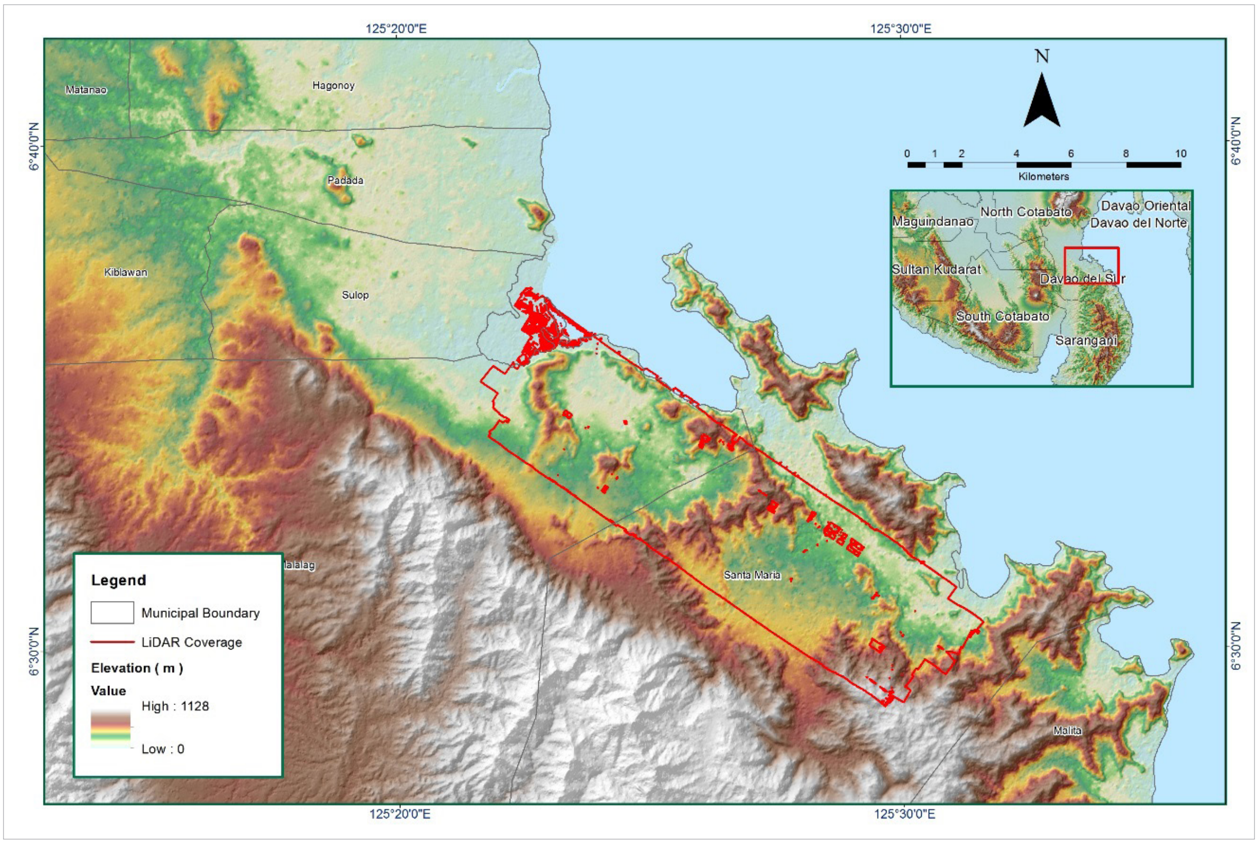


Figure 1.5.4 Coverage of LiDAR data

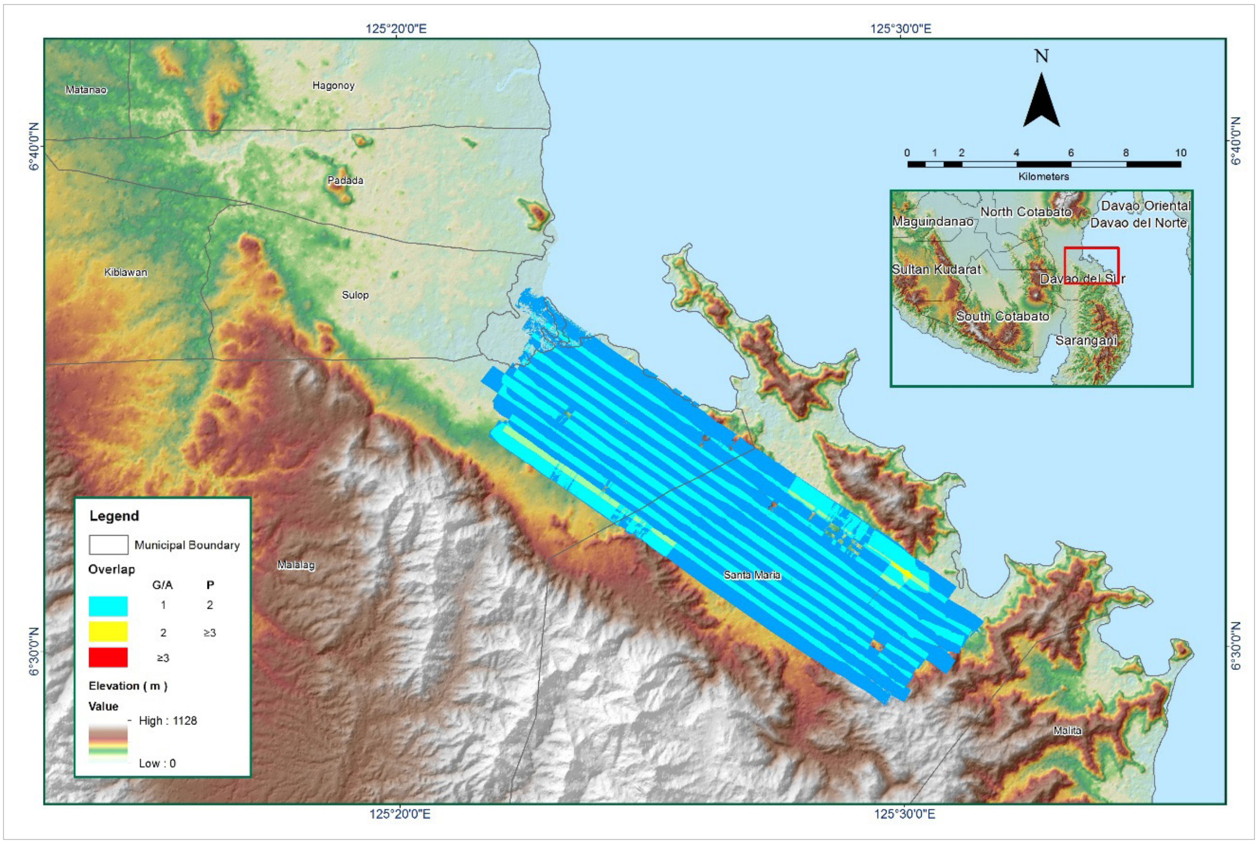


Figure 1.5.5 Image of data overlap

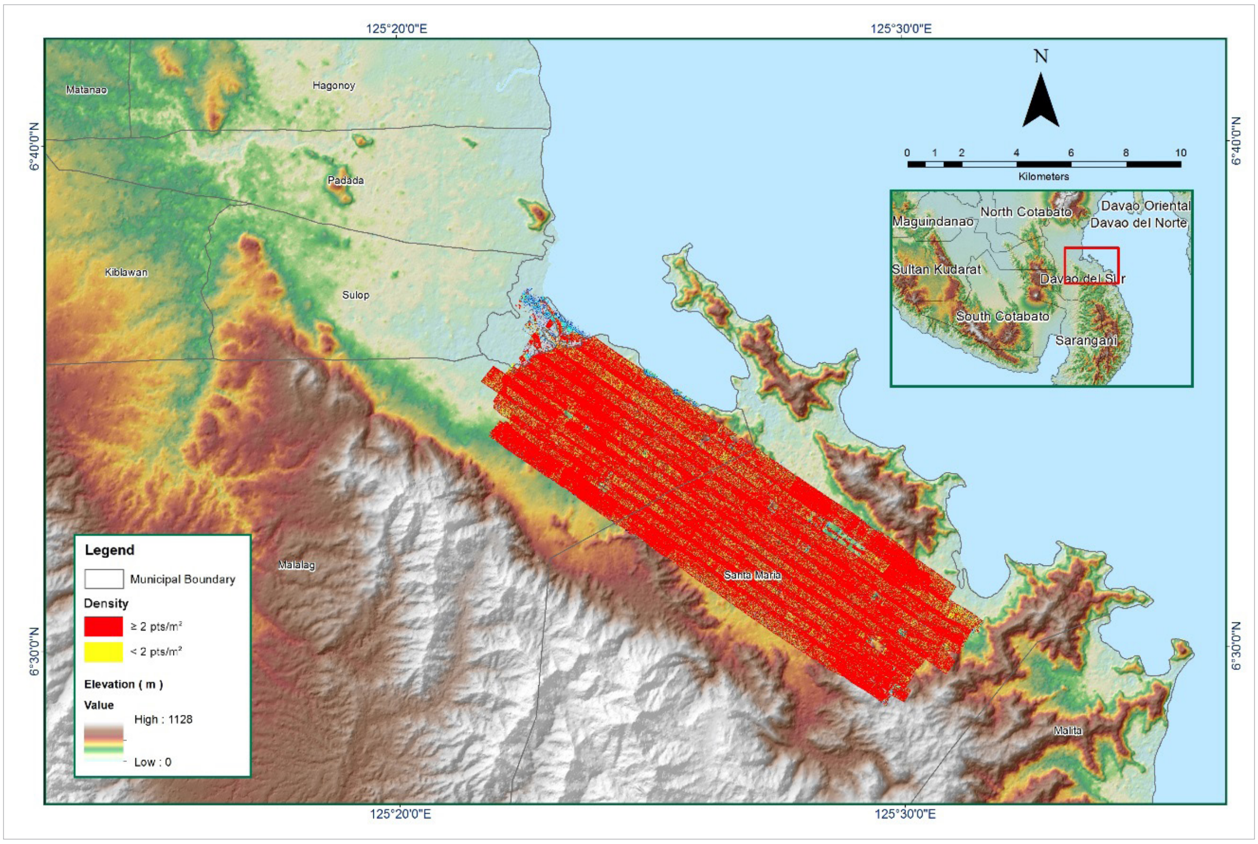


Figure 1.5.6 Density map of merged LiDAR data

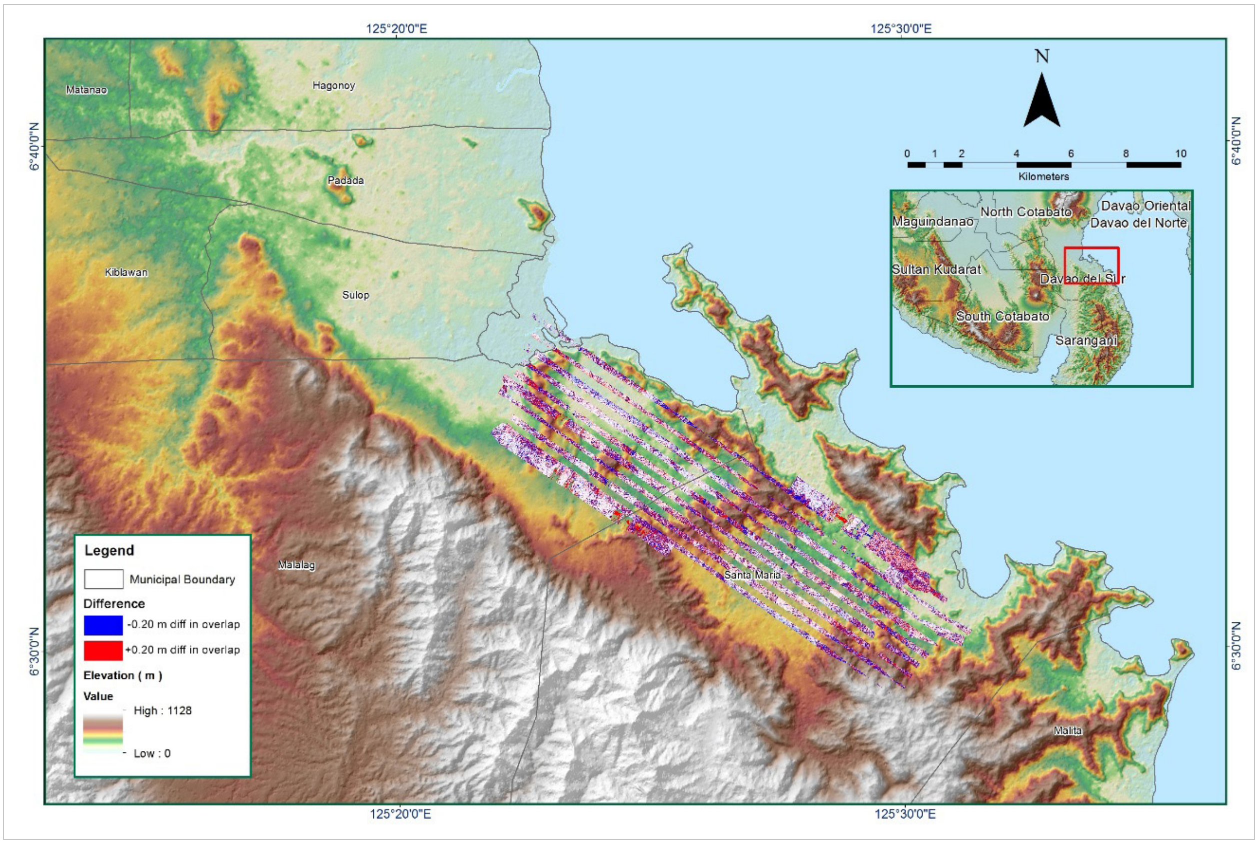


Figure 1.5.7 Elevation difference between flight lines

Flight Area	Davao Oriental
Mission Name	Blk87F
Inclusive Flights	7414G,7416G,7418G
Range data size	30.33 GB
Base data size	10.15 MB
POS	474 MB
Image	na
Transfer date	August 29, 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)	1.06
RMSE for East Position (<4.0 cm)	1.05
RMSE for Down Position (<8.0 cm)	1.8
Boresight correction stdev (<0.001deg)	0.002173
IMU attitude correction stdev (<0.001deg)	0.017677
GPS position stdev (<0.01m)	0.0275
Minimum % overlap (>25)	23.82%
Ave point cloud density per sq.m. (>2.0)	2.86
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	183
Maximum Height	1039.27 m
Minimum Height	53.5 m
Classification (# of points)	
Ground	28480264
Low vegetation	19742900
Medium vegetation	52073127
High vegetation	116735255
Building	1134816
Orthophoto	No
Processed by	Engr. Kenneth Solidum, Engr. Edgardo Gubatanga, Jr., Engr. John Dill Macapagal

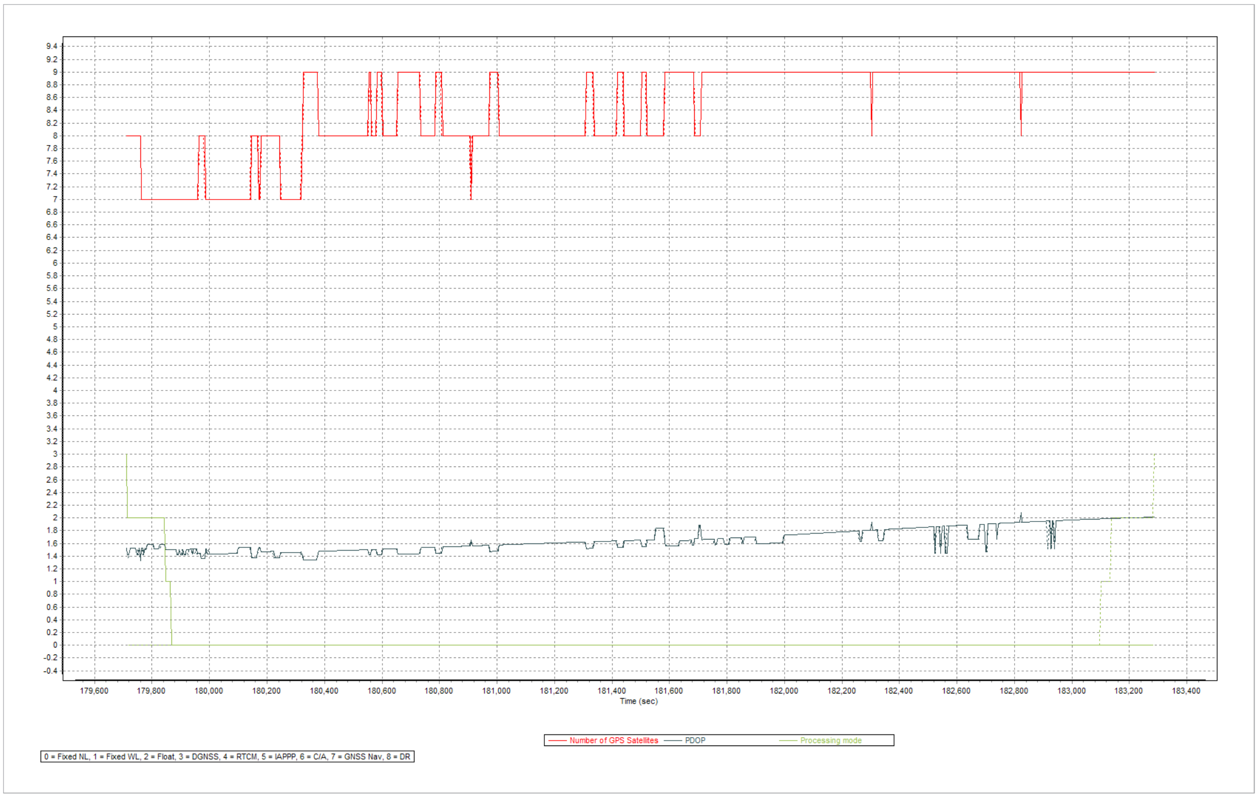


Figure 1.6.1 Solution Status

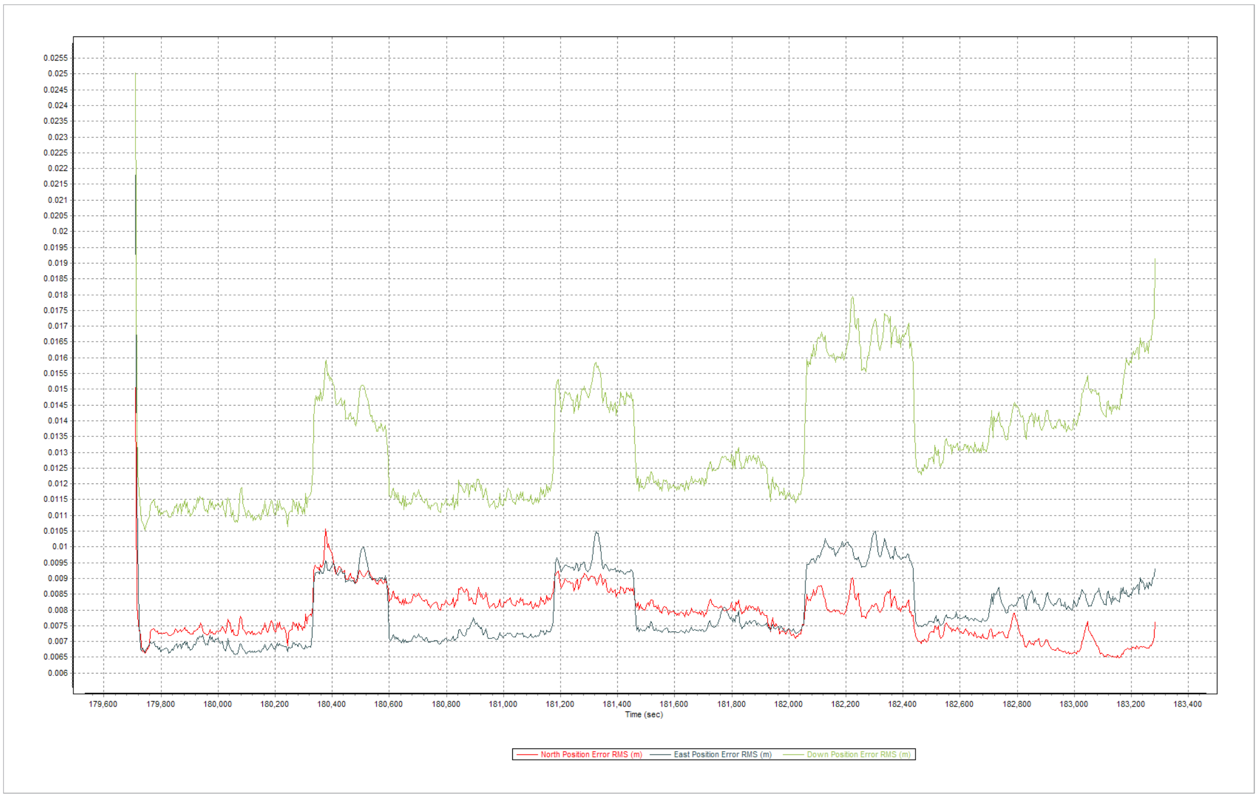


Figure 1.6.2 Smoothed Performance Metric Parameters

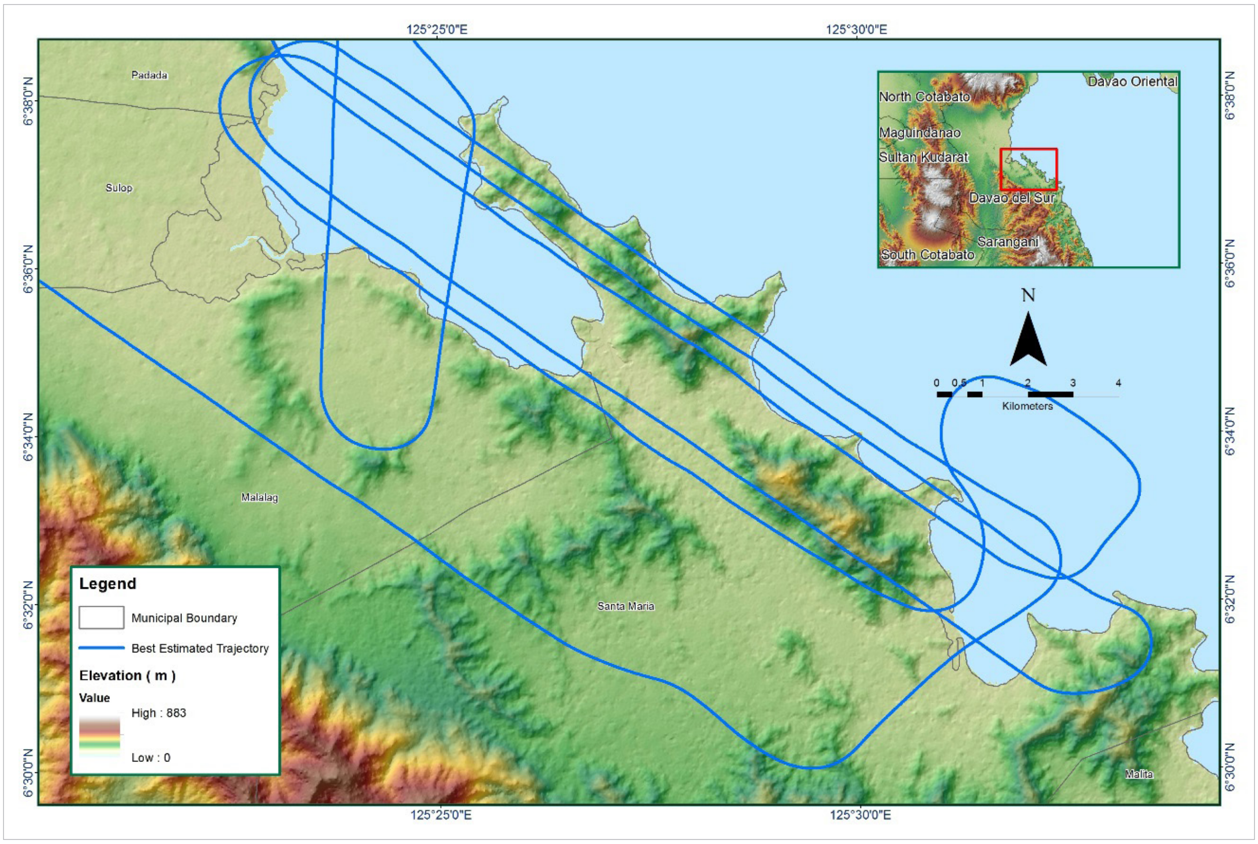


Figure 1.6.3 Best Estimated Trajectory

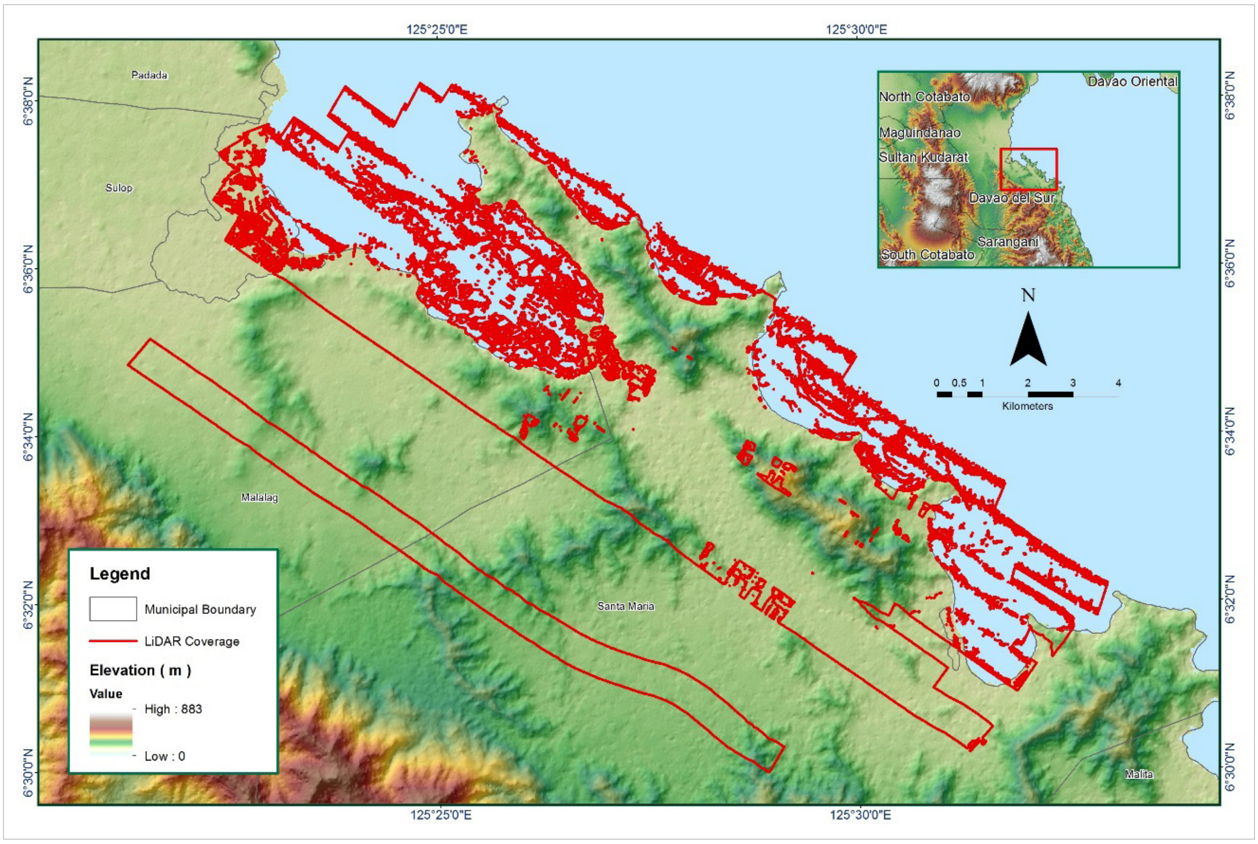


Figure 1.6.4 Coverage of LiDAR data

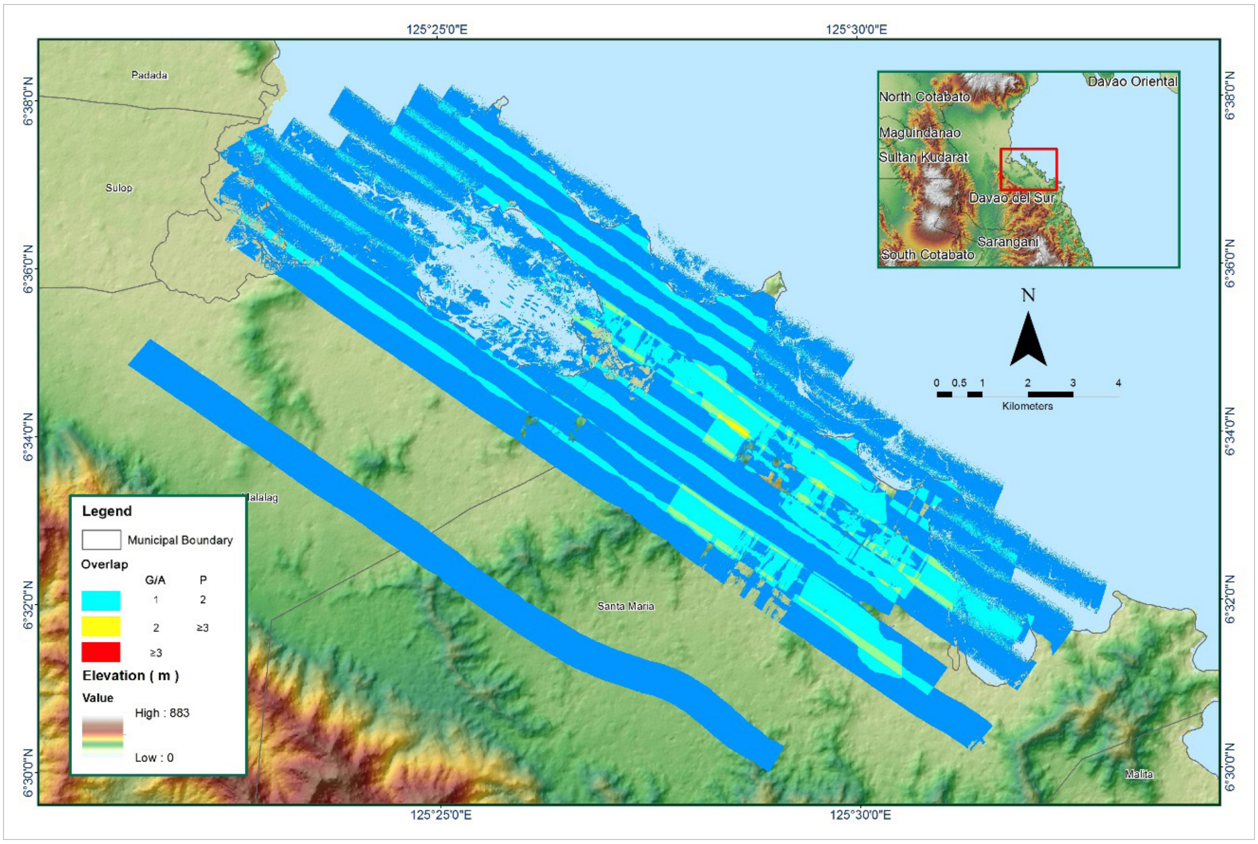


Figure 1.6.5 Image of data overlap

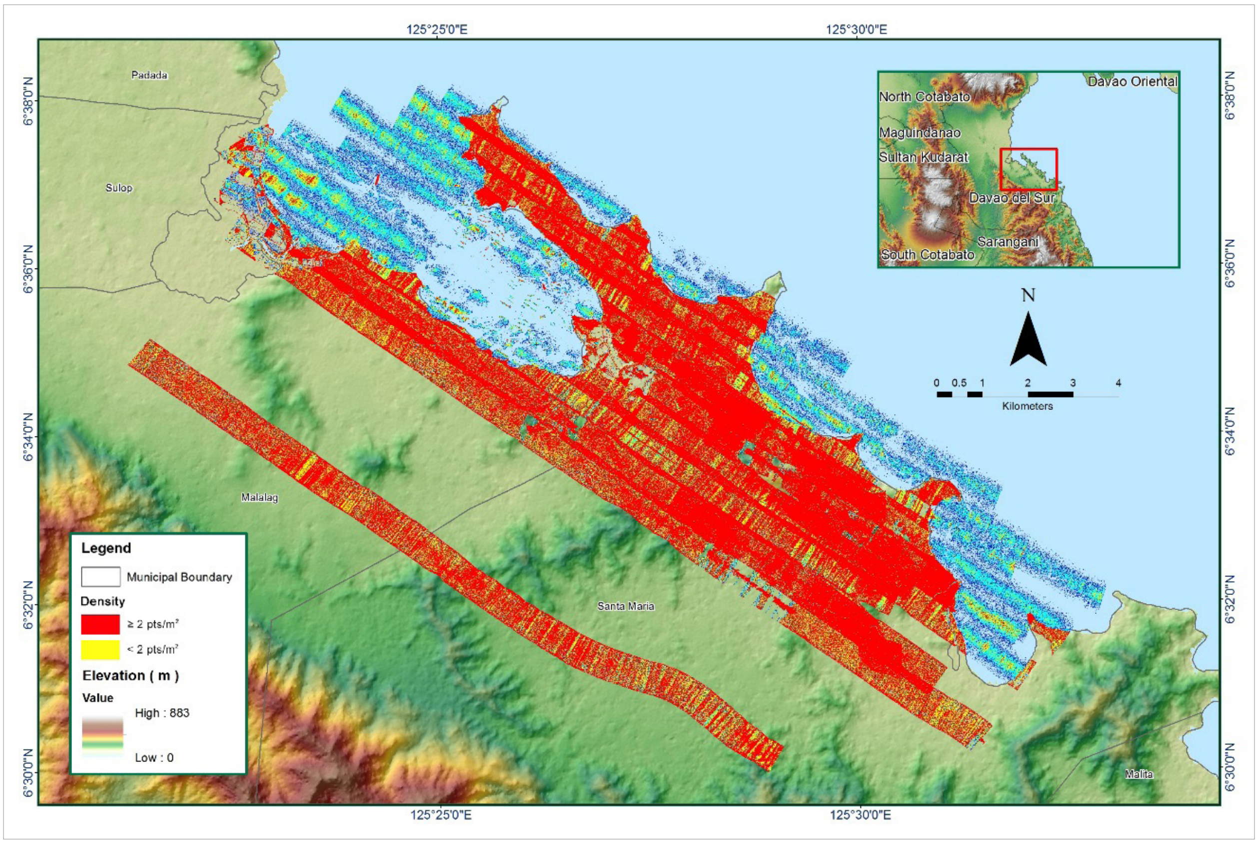


Figure 1.6.6 Density map of merged LiDAR data

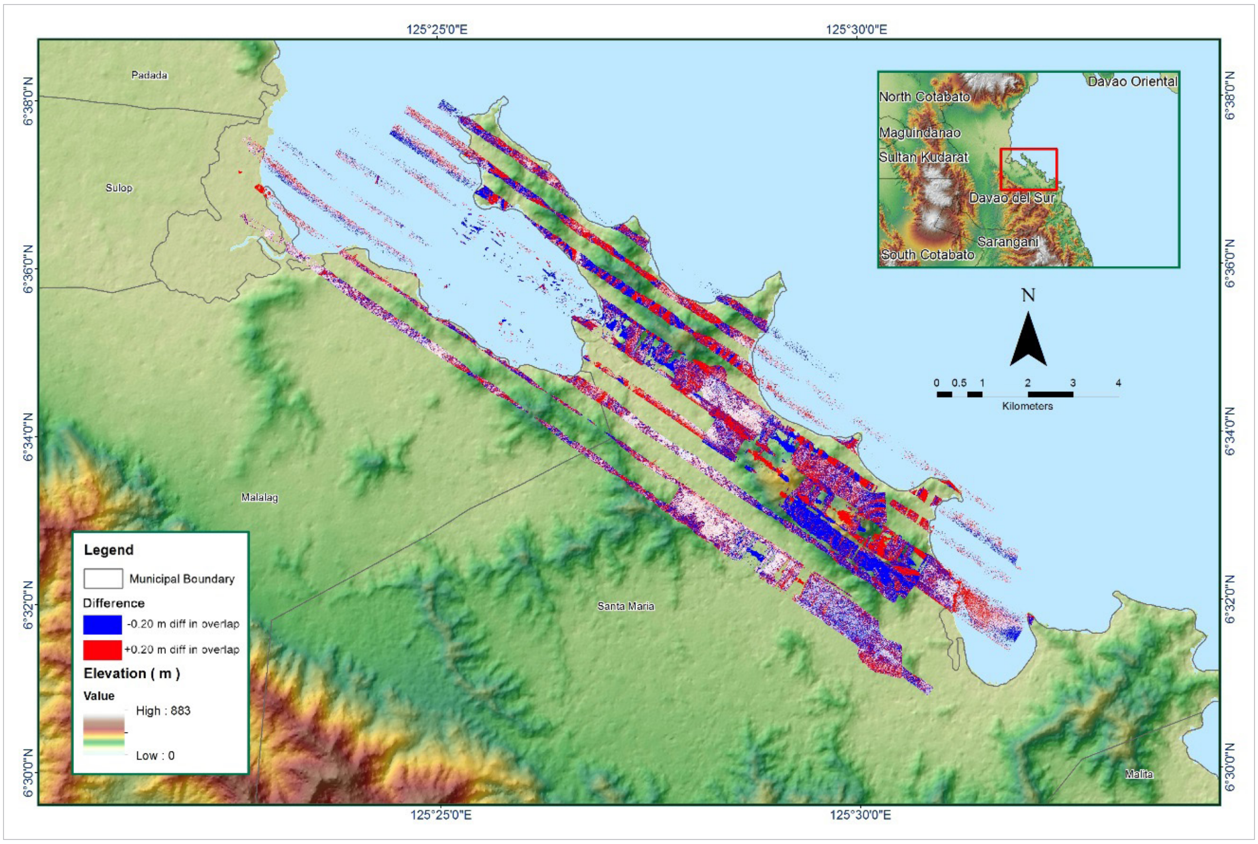


Figure 1.6.7 Elevation difference between flight lines

ANNEX 9. Padada-Mainit 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 (cms)	Recession Constant	Threshold Type	Ratio to Peak
W1000	0.0066	99	0	14.1057	0.226709	Discharge	0.17609	0.4	Ratio to Peak	0.6
W1010	0.0066	99	0	4.36977	0.155111	Discharge	0.11062	0.4	Ratio to Peak	0.603
W1020	0.0066	99	0	15.345	0.512919	Discharge	0.26566	0.4	Ratio to Peak	0.603
W1030	0.0066	99	0	8.39817	0.141089	Discharge	0.30515	0.4	Ratio to Peak	0.603
W1040	0.0048474	99	0	8.58843	0.155928	Discharge	0.30559	0.4	Ratio to Peak	0.6
W1050	0.0066	99	0	17.5311	0.194897	Discharge	0.50811	0.4	Ratio to Peak	0.6
W1060	0.0066	99	0	4.71771	0.166145	Discharge	0.18962	0.4	Ratio to Peak	0.6
W540	0.0066	99	0	10.4193	0.22869	Discharge	0.5562	0.4	Ratio to Peak	0.8
W550	0.0047758	99	0	8.7777	0.218682	Discharge	0.22608	0.4	Ratio to Peak	0.8
W560	0.0066	99	0	20.8026	0.420066	Discharge	0.47467	0.4	Ratio to Peak	0.8
W570	0.0066	99	0	14.6313	0.764127	Discharge	0.63743	0.4	Ratio to Peak	0.603
W580	0.0066	99	0	4.03767	0.148127	Discharge	0.35731	0.4	Ratio to Peak	0.602232
W590	0.0066	99	0	6.00768	0.215568	Discharge	0.15917	0.4	Ratio to Peak	0.602992
W600	0.0066	99	0	21.3156	0.361125	Discharge	0.38534	0.4	Ratio to Peak	0.60288
W610	0.0066	99	0	11.4507	0.40878	Discharge	0.40005	0.4	Ratio to Peak	0.602912
W620	0.0066	99	0	7.34202	0.268384	Discharge	0.29147	0.4	Ratio to Peak	0.603
W630	0.0066	99	0	8.9973	0.151678	Discharge	0.093004	0.4	Ratio to Peak	0.8
W640	0.0066	99	0	20.8035	0.342522	Discharge	0.31058	0.4	Ratio to Peak	0.8
W650	0.0057952	99	0	5.93901	0.223217	Discharge	0.16634	0.4	Ratio to Peak	0.6
W660	0.0066	99	0	4.85847	0.592353	Discharge	0.21336	0.4	Ratio to Peak	0.602696
W670	0.0066	99	0	3.1104	0.117272	Discharge	0.019589	0.4	Ratio to Peak	0.602992

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 (cms)	Recession Constant	Threshold Type	Ratio to Peak
W680	0.0052214	99	0	8.60562	0.674379	Discharge	0.28281	0.4	Ratio to Peak	0.6
W690	0.0066	99	0	21.4668	0.309096	Discharge	0.17129	0.4	Ratio to Peak	0.6008
W700	0.0095422	99	0	7.79022	0.410049	Discharge	0.30931	0.4	Ratio to Peak	0.6
W710	0.0066	99	0	8.50401	0.316305	Discharge	0.21667	0.4	Ratio to Peak	0.403632
W720	0.0066	99	0	4.58874	0.250412	Discharge	0.091433	0.4	Ratio to Peak	0.403744
W730	0.011278	99	0	15.48	0.552906	Discharge	0.16589	0.4	Ratio to Peak	0.402
W740	0.0066	99	0	7.71858	0.127556	Discharge	0.015626	0.4	Ratio to Peak	0.602992
W750	0.0083504	99	0	3.05244	0.075125	Discharge	0.00181	0.4	Ratio to Peak	0.404008
W760	0.0141364	99	0	2.95965	0.160901	Discharge	0.00072	0.4	Ratio to Peak	0.603
W770	0.0066	99	0	6.01272	0.212023	Discharge	0.045939	0.4	Ratio to Peak	0.603
W780	0.0066	99	0	5.70366	0.440046	Discharge	0.34943	0.4	Ratio to Peak	0.603
W790	0.0066	99	0	16.8084	0.408402	Discharge	0.42677	0.4	Ratio to Peak	0.602696
W800	0.0066	99	0	9.1485	0.333828	Discharge	0.38894	0.4	Ratio to Peak	0.602864
W810	0.0066	99	0	5.71041	0.21069	Discharge	0.165	0.4	Ratio to Peak	0.602992
W820	0.0066	99	0	5.21406	0.18313	Discharge	0.073144	0.4	Ratio to Peak	0.603
W830	0.0066044	99	0	22.8483	0.368496	Discharge	0.69282	0.4	Ratio to Peak	0.6
W840	0.0103426	99	0	8.11008	0.443124	Discharge	0.31473	0.4	Ratio to Peak	0.602992
W850	0.0066	99	0	7.75359	0.48519	Discharge	0.55671	0.4	Ratio to Peak	0.602904
W860	0.0066	99	0	7.72002	0.12497	Discharge	0.072697	0.4	Ratio to Peak	0.602888
W870	0.0066	99	0	10.7748	0.258374	Discharge	0.3789	0.4	Ratio to Peak	0.602936
W880	0.0066	99	0	7.61193	0.409266	Discharge	0.096814	0.4	Ratio to Peak	0.603
W890	0.0066	99	0	9.0225	0.302616	Discharge	0.15413	0.4	Ratio to Peak	0.8

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 (cms)	Recession Constant	Threshold Type	Ratio to Peak
W900	0.0066	99	0	16.2396	0.489645	Discharge	0.18753	0.4	Ratio to Peak	0.603
W910	0.0066	99	0	13.9815	0.506169	Discharge	0.37911	0.4	Ratio to Peak	0.60288
W920	0.0077994	80.501	0	12.717	0.321678	Discharge	0.3539	0.4	Ratio to Peak	0.402
W930	0.0066	99	0	2.99799	0.072409	Discharge	0.00614	0.4	Ratio to Peak	0.603
W940	0.0066	99	0	13.7106	0.467235	Discharge	0.3999	0.4	Ratio to Peak	0.6
W950	0.0066	99	0	3.19068	0.173048	Discharge	0.036984	0.4	Ratio to Peak	0.603
W960	0.0066	99	0	13.4091	0.472473	Discharge	0.14874	0.4	Ratio to Peak	0.602976
W970	0.0066	99	0	10.9242	0.276372	Discharge	0.42128	0.4	Ratio to Peak	0.401992
W980	0.0106928	99	0	8.21655	0.194311	Discharge	0.50371	0.4	Ratio to Peak	0.6
W990	0.0066	99	0	1.93725	0.065634	Discharge	0.007246	0.4	Ratio to Peak	0.8

ANNEX 10. Padada-Mainit Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R100	Automatic Fixed Interval	5831.7	0.009068	0.099504	Trapezoid	52.4	1
R110	Automatic Fixed Interval	7172	0.013854	0.099504	Trapezoid	52.4	1
R120	Automatic Fixed Interval	1703.4	0.006005	0.099504	Trapezoid	52.4	1
R150	Automatic Fixed Interval	8834.2	0.00349	0.099504	Trapezoid	52.4	1
R170	Automatic Fixed Interval	6176.4	0.004808	0.099504	Trapezoid	52.4	1
R180	Automatic Fixed Interval	18580	0.005911	0.099504	Trapezoid	52.4	1
R200	Automatic Fixed Interval	544.97	0.000397	0.099504	Trapezoid	52.4	1
R210	Automatic Fixed Interval	270.71	0.0033	0.099504	Trapezoid	52.4	1
R220	Automatic Fixed Interval	1263	0.000394	0.099504	Trapezoid	52.4	1
R230	Automatic Fixed Interval	5288.4	0.003653	0.099504	Trapezoid	52.4	1
R240	Automatic Fixed Interval	9442.8	0.003111	0.099504	Trapezoid	52.4	1
R260	Automatic Fixed Interval	12045	0.000773	0.099504	Trapezoid	52.4	1
R270	Automatic Fixed Interval	3427.1	0.003216	0.099504	Trapezoid	52.4	1
R280	Automatic Fixed Interval	5664.7	0.009287	0.099504	Trapezoid	52.4	1
R290	Automatic Fixed Interval	4551.3	0.005118	0.099504	Trapezoid	52.4	1
R310	Automatic Fixed Interval	2672.4	0.002994	0.099504	Trapezoid	52.4	1
R330	Automatic Fixed Interval	7432.1	0.008984	0.099504	Trapezoid	52.4	1
R350	Automatic Fixed Interval	12594	0.016843	0.099504	Trapezoid	52.4	1
R370	Automatic Fixed Interval	6829.1	0.002192	0.099504	Trapezoid	52.4	1

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R390	Automatic Fixed Interval	1104.7	0.003444	0.099504	Trapezoid	52.4	1
R40	Automatic Fixed Interval	8668.2	0.018854	0.099504	Trapezoid	52.4	1
R400	Automatic Fixed Interval	2032.4	0.010641	0.099504	Trapezoid	52.4	1
R430	Automatic Fixed Interval	6782.1	0.002993	0.099504	Trapezoid	52.4	1
R460	Automatic Fixed Interval	1084.7	0.00407	0.099504	Trapezoid	52.4	1
R480	Automatic Fixed Interval	1008.4	0.003721	0.099504	Trapezoid	52.4	1
R500	Automatic Fixed Interval	13818	0.029372	0.099504	Trapezoid	52.4	1

ANNEX 11. Padada-Mainit Field Validation

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Rain Return/ Scenario
	Lat	Long					
1	6.643977	125.283658	5.02	5.00	0.0004	Buhawi/ 2010	5-Year
2	6.619464	125.270169	5.02	5.00	0.0004	Buhawi/ 2000	5-Year
3	6.659733	125.279311	5.03	1.50	12.4609	Heavy rain	5-Year
4	6.638153	125.271794	5.03	0.60	19.6249	Heavy rain/ 2015	5-Year
5	6.672456	125.320767	5.04	5.00	0.0016	Buhawi/Heavy rain/ 2015	5-Year
6	6.666795	125.280864	5.04	6.70	2.7556	Buhawi/ 2014	5-Year
7	6.632740	125.271421	5.05	5.00	0.0025	Heavy rain	5-Year
8	6.667613	125.312417	5.08	5.00	0.0064	Heavy rain/ 2009	5-Year
9	6.654851	125.280733	5.08	2.00	9.4864	Buhawi/ 2010	5-Year
10	6.673287	125.318062	5.08	4.00	1.1664	Heavy rain / 2015	5-Year
11	6.620724	125.269905	5.09	4.90	0.0361	Buhawi/ 2000	5-Year
12	6.646266	125.275892	5.12	4.90	0.0484	Heavy rain/ 2015	5-Year
13	6.643729	125.278142	5.12	4.30	0.6724	Heavy rain/ 2015	5-Year
14	6.656196	125.279380	5.12	1.00	16.9744	Heavy rain	5-Year
15	6.668129	125.317326	5.17	5.00	0.0289	Heavy rain/ 2009	5-Year
16	6.658473	125.277051	5.24	5.00	0.0576	Heavy rain	5-Year
17	6.632010	125.271405	5.24	5.00	0.0576	Yolanda/ 2014	5-Year
18	6.618685	125.265541	5.27	5.00	0.0729	Heavy rain/ 2015	5-Year
19	6.641522	125.272782	5.28	4.20	1.1664	Heavy rain/ 2015	5-Year
20	6.643919	125.276428	5.28	4.00	1.6384	Heavy rain/ 2015	5-Year
21	6.671645	125.323302	5.33	6.50	1.3689	Buhawi/Heavy rain/ 2015	5-Year
22	6.645632	125.277795	5.45	5.50	0.0025	Heavy rain/ 2015	5-Year
23	6.665004	125.275266	5.64	2.00	13.2496	Buhawi/ 2014	5-Year
24	6.627306	125.270857	5.85	5.00	0.7225	Heavy rain	5-Year
25	6.623777	125.270268	5.9	6.00	0.0100	Buhawi/ 2000	5-Year
26	6.657041	125.275122	6.19	5.00	1.4161	Heavy rain	5-Year
27	6.659985	125.281472	6.23	5.50	0.5329	Heavy rain	5-Year
28	6.625599	125.270217	6.91	5.50	1.9881	Heavy rain	5-Year
29	6.670757	125.317229	7.13	5.10	4.1209	Heavy rain / 2013	5-Year
30	6.639751	125.244599	2.07	0.00	4.2849		5-Year
31	6.674803	125.244383	2.19	2.00	0.0361	Milenyo/ 2014	5-Year
32	6.668561	125.266059	2.26	3.00	0.5476	Heavy rain/ 2015	5-Year
33	6.666629	125.273190	2.5	4.00	2.2500	Buhawi/ 2014	5-Year
34	6.646032	125.277451	2.65	0.00	7.0225		5-Year
35	6.671572	125.264229	2.72	2.00	0.5184	Heavy rain/ 2015	5-Year
36	6.615551	125.257034	3.33	3.00	0.1089	Ondoy	5-Year
37	6.645420	125.286206	3.61	3.00	0.3721	Buhawi/ 2010	5-Year
38	6.663176	125.312162	4.09	1.00	9.5481	Buhawi/ 2013	5-Year
39	6.675512	125.316131	4.74	6.00	1.5876	Titang	5-Year
40	6.671702	125.319006	3.39	3.00	0.1521	Heavy rain / 2015	5-Year
41	6.637428	125.244175	2.06	3.00	0.8836	Ondoy	5-Year
42	6.638402	125.248790	3.78	3.80	0.0004	Heavy rain/ 2015	5-Year
43	6.641556	125.250884	2.81	0.20	6.8121	Heavy rain/ 2014	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Rain Return/ Scenario
	Lat	Long					
44	6.642083	125.254321	4.42	4.00	0.1764	Heavy rain/ 2014	5-Year
45	6.634220	125.254105	2.77	3.20	0.1849	Bagyo/ November 2015	5-Year
46	6.633496	125.254192	3.06	3.00	0.0036	Bagyo/ November 2015	5-Year
47	6.613702	125.253831	3.74	3.00	0.5476	Ondoy	5-Year
48	6.635219	125.272732	2.47	1.00	2.1609	Heavy rain/Buhawi/ 2003	5-Year
49	6.662251	125.271771	3.15	3.80	0.4225	Buhawi/ 2014	5-Year
50	6.668672	125.309951	3.26	3.00	0.0676	Heavy rain/ 2009	5-Year
51	6.675832	125.324992	2.87	3.00	0.0169	Upstream rain/ 2012	5-Year
52	6.661220	125.259923	2.43	2.00	0.1849	Heavy rain/ August 2015	5-Year
53	6.661968	125.254593	2.27	0.50	3.1329	Heavy rain/ August 2015	5-Year
54	6.622714	125.269601	2.01	1.80	0.0441	Buhawi/ 2000	5-Year
55	6.675298	125.290212	1.01	0.50	0.2601	Titang/ 1971	5-Year
56	6.674690	125.292426	1.02	0.50	0.2704	Titang/ 1971	5-Year
57	6.625159	125.272624	1.03	0.80	0.0529	Heavy rain/ Yearly	5-Year
58	6.624865	125.272641	1.03	0.90	0.0169	Heavy rain/ Yearly	5-Year
59	6.666584	125.348325	1.04	0.50	0.2916	Heavy rain/ Yearly	5-Year
60	6.675231	125.288797	1.04	0.50	0.2916	Titang/ 1971	5-Year
61	6.666340	125.348343	1.06	0.50	0.3136	Heavy rain/ Yearly	5-Year
62	6.641849	125.345470	1.07	0.30	0.5929	Heavy rain/ 2008	5-Year
63	6.619639	125.265206	1.07	0.40	0.4489	Buhawi/ 2014	5-Year
64	6.624638	125.272647	1.07	0.80	0.0729	Heavy rain/ Yearly	5-Year
65	6.654980	125.350783	1.07	0.00	1.1449		5-Year
66	6.641205	125.339972	1.09	0.00	1.1881		5-Year
67	6.640543	125.344037	1.1	0.00	1.2100		5-Year
68	6.619677	125.255356	1.15	0.90	0.0625	Heavy rain/ 2006	5-Year
69	6.642229	125.347015	1.21	0.00	1.4641		5-Year
70	6.676238	125.348967	1.21	0.10	1.2321	Heavy rain/ May 2016	5-Year
71	6.617765	125.263931	1.25	0.00	1.5625		5-Year
72	6.641619	125.271617	1.26	1.20	0.0036	Heavy rain/ 2015	5-Year
73	6.650673	125.347071	1.3	1.50	0.0400	Heavy rain/ 2010	5-Year
74	6.646022	125.277558	1.34	1.00	0.1156	Heavy rain/ 2015	5-Year
75	6.676235	125.348625	1.4	1.40	0.0000	Titang/ 1970	5-Year
76	6.642238	125.346566	1.42	1.50	0.0064	Heavy rain/ June 2015	5-Year
77	6.639651	125.245788	1.44	1.50	0.0036	Heavy rain/ 2015	5-Year
78	6.648398	125.350757	1.51	1.50	0.0001		5-Year
79	6.619494	125.264757	1.56	0.60	0.9216	Heavy rain/ 2015	5-Year
80	6.618874	125.264653	1.59	0.50	1.1881	Buhawi/ 2014	5-Year
81	6.619605	125.255467	1.75	1.20	0.3025	Heavy rain/ 2006	5-Year
82	6.648626	125.349943	1.82	1.50	0.1024		5-Year
83	6.657762	125.355153	0.07	0.00	0.0049		5-Year
84	6.657563	125.373677	0.51	0.70	0.0361	Bagyo/ 2009	5-Year
85	6.643229	125.347118	0.55	0.10	0.2025	Heavy rain/ 2015	5-Year
86	6.631735	125.369839	0.55	0.50	0.0025	Titang/ 1970	5-Year
87	6.678513	125.355090	0.56	0.00	0.3136		5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Rain Return/ Scenario
	Lat	Long					
88	6.685864	125.374537	0.57	0.20	0.1369	Heavy rain/ 2006	5-Year
89	6.668625	125.348220	0.6	0.00	0.3600		5-Year
90	6.656662	125.347705	0.6	0.10	0.2500	Heavy Rain	5-Year
91	6.661298	125.314216	0.6	0.00	0.3600		5-Year
92	6.668911	125.348418	0.62	0.50	0.0144	Heavy rain/river overflow	5-Year
93	6.641729	125.339360	0.62	1.10	0.2304	buhawi/ 2010	5-Year
94	6.675529	125.347155	0.64	1.40	0.5776	Titang/ 1970	5-Year
95	6.657346	125.321493	0.64	0.00	0.4096		5-Year
96	6.654653	125.347638	0.65	0.00	0.4225		5-Year
97	6.674235	125.294360	0.66	0.20	0.2116	Heavy rain/ 2000	5-Year
98	6.686568	125.376173	0.66	0.00	0.4356		5-Year
99	6.659354	125.298203	0.66	0.00	0.4356		5-Year
100	6.625329	125.271824	0.7	0.50	0.0400	Heavy rain/ Yearly	5-Year
101	6.671971	125.348524	0.71	0.50	0.0441	Heavy rain/ 2008	5-Year
102	6.658511	125.372160	0.72	0.70	0.0004	Bagyo/ 2009	5-Year
103	6.636106	125.378708	0.72	0.75	0.0009	Heavy rain/ 2009	5-Year
104	6.674775	125.291294	0.73	0.50	0.0529	Titang/ 1971	5-Year
105	6.667105	125.347953	0.74	0.00	0.5476		5-Year
106	6.640818	125.341408	0.74	0.00	0.5476		5-Year
107	6.658030	125.372958	0.76	0.50	0.0676	Bagyo/ 2009	5-Year
108	6.681187	125.348315	0.8	2.00	1.4400	Buhawi/ 1986	5-Year
109	6.639783	125.349746	0.82	0.30	0.2704	Heavy rain/ 2009	5-Year
110	6.632014	125.369384	0.82	0.50	0.1024	Titang/ 1970	5-Year
111	6.676778	125.286964	0.83	0.40	0.1849	Heavy rain/ 2000	5-Year
112	6.628856	125.270958	0.85	0.00	0.7225		5-Year
113	6.666172	125.348155	0.86	0.00	0.7396		5-Year
114	6.636921	125.380439	0.89	0.75	0.0196	Heavy rain/ 2009	5-Year
115	6.675936	125.348059	0.95	1.40	0.2025	Titang/ 1970	5-Year
116	6.688735	125.379821	0.03	0.50	0.2209	Heavy rain/ Yearly	5-Year
117	6.680614	125.376578	0.03	0.20	0.0289	Heavy rain/ 2006	5-Year
118	6.673578	125.370597	0.03	0.00	0.0009		5-Year
119	6.675245	125.371092	0.03	0.00	0.0009		5-Year
120	6.680471	125.354097	0.03	0.00	0.0009		5-Year
121	6.682952	125.351829	0.03	0.10	0.0049	Heavy rain/ 42515	5-Year
122	6.677637	125.354892	0.03	0.00	0.0009		5-Year
123	6.672749	125.349021	0.03	0.50	0.2209	Heavy rain/ 1970	5-Year
124	6.671444	125.348929	0.03	0.50	0.2209	Heavy rain/ 2013	5-Year
125	6.668594	125.346767	0.03	0.00	0.0009		5-Year
126	6.642509	125.340181	0.03	0.00	0.0009		5-Year
127	6.637914	125.347172	0.03	0.00	0.0009		5-Year
128	6.637323	125.344262	0.03	0.00	0.0009		5-Year
129	6.635330	125.345392	0.03	0.20	0.0289	Upstream rain/ 2002	5-Year
130	6.641609	125.384241	0.03	0.00	0.0009		5-Year
131	6.687832	125.375930	0.04	1.00	0.9216	Titang/ 1960	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Rain Return/ Scenario
	Lat	Long					
132	6.672890	125.371410	0.04	0.00	0.0016		5-Year
133	6.640720	125.347376	0.04	0.01	0.0009	Heavy rain/ May 2016	5-Year
134	6.618257	125.256237	0.04	0.00	0.0016		5-Year
135	6.672690	125.370489	0.05	0.00	0.0025		5-Year
136	6.620420	125.259960	0.05	0.00	0.0025		5-Year
137	6.679695	125.352887	0.07	2.00	3.7249	Buhawi/ 1984	5-Year
138	6.673923	125.349515	0.07	0.00	0.0049		5-Year
139	6.669826	125.344160	0.07	0.00	0.0049		5-Year
140	6.679281	125.351366	0.08	0.00	0.0064		5-Year
141	6.680893	125.350518	0.09	1.00	0.8281	Titang/ 1972	5-Year
142	6.660384	125.350093	0.09	0.00	0.0081		5-Year
143	6.681973	125.353609	0.1	2.00	3.6100	Buhawi/ 1980	5-Year
144	6.620988	125.252603	0.1	0.10	0.0000	Heavy rain/ 2015	5-Year
145	6.682743	125.371434	0.12	0.00	0.0144		5-Year
146	6.670038	125.343164	0.15	0.00	0.0225		5-Year
147	6.642395	125.350287	0.15	0.00	0.0225		5-Year
148	6.639233	125.348720	0.18	0.30	0.0144	Heavy rain/ 2009	5-Year
149	6.657519	125.320932	0.21	0.00	0.0441		5-Year
150	6.682167	125.371355	0.24	0.00	0.0576		5-Year
151	6.666006	125.344867	0.24	1.40	1.3456	Titang/ 1970	5-Year
152	6.636865	125.351087	0.25	0.30	0.0025	Heavy rain/ 2009	5-Year
153	6.661752	125.313946	0.26	0.00	0.0676		5-Year
154	6.656739	125.304162	0.26	0.10	0.0256	Heavy rain	5-Year
155	6.687474	125.376532	0.27	0.50	0.0529	Heavy rain/ 1985	5-Year
156	6.650268	125.347253	0.27	0.30	0.0009	Heavy rain/ 2013-2014	5-Year
157	6.635829	125.345815	0.27	0.30	0.0009	Heavy rain/ 2014	5-Year
158	6.682698	125.357328	0.29	0.00	0.0841		5-Year
159	6.683511	125.352278	0.29	1.00	0.5041	Heavy rain/ 1994-1996	5-Year
160	6.637113	125.346171	0.31	0.00	0.0961		5-Year
161	6.661178	125.314667	0.31	0.00	0.0961		5-Year
162	6.661913	125.293777	0.31	0.50	0.0361	Heavy rain/ 2014	5-Year
163	6.642203	125.357240	0.31	0.20	0.0121	Heavy rain	5-Year
164	6.641106	125.341435	0.32	0.00	0.1024		5-Year
165	6.656821	125.320978	0.33	0.00	0.1089		5-Year
166	6.639239	125.349285	0.34	0.30	0.0016	Heavy rain/ 2009	5-Year
167	6.666116	125.341956	0.36	0.00	0.1296		5-Year
168	6.638827	125.344239	0.36	0.00	0.1296		5-Year
169	6.650176	125.345523	0.37	0.00	0.1369		5-Year
170	6.673306	125.372118	0.38	0.00	0.1444		5-Year
171	6.681789	125.352265	0.39	2.60	4.8841	Titang/ 1969	5-Year
172	6.683060	125.358968	0.4	0.50	0.0100	Buhawi/ 1985	5-Year
173	6.682283	125.351148	0.4	2.50	4.4100	Titang/ 1969	5-Year
174	6.647548	125.381867	0.4	0.50	0.0100	Titang/ November 1970	5-Year
175	6.682520	125.321154	0.42	1.60	1.3924	Titang/ 1971	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Rain Return/ Scenario
	Lat	Long					
176	6.642141	125.347735	0.42	0.10	0.1024	Heavy rain/ May 2016	5-Year
177	6.649127	125.380339	0.43	1.00	0.3249	Titang/ 1970	5-Year
178	6.682306	125.325262	0.44	0.00	0.1936		5-Year
179	6.656094	125.347738	0.45	0.30	0.0225	Heavy rain	5-Year
180	6.662004	125.295676	0.46	0.50	0.0016	Titang/ 1970	5-Year
RMSE = 0.993702							

ANNEX 12. Educational Institutions Affected In Padada-Mainit Flood Plain

Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
HAGONOY				
CIRIACO B. GAYUD ELEMENTARY SCHOOL	Clib			
CIRIACO B. GAYUD ELEMENTARY SCHOOL CANTEEN	Clib			
CLIB PRIMARY SCHOOL	Clib			
DAY CARE CENTER	Clib			
LA UNION ELEMENTARY SCHOOL	Clib			
COMMUNITY RESOURCE CENTER	Guihing	Low	Low	Medium
DAY CARE	Guihing	Medium	Medium	Medium
GUIHING CENTRAL ELEMENTARY SCHOOL	Guihing	Low	Medium	Medium
HAGONOY NATIONAL HIGH SCHOOL	Guihing	Low	Medium	Medium
LITTLE JOSEPH CHRISTIAN LEARNING CENTER	Guihing	Low	Low	Medium
ALTERNATIVE LEARNING CENTER(ALS)	Guihing Aplaya		Low	Low
APLAYA-GUIHING ELEMENTARY SCHOOL	Guihing Aplaya	Low	Medium	Medium
CHRYSANTHEMUM DAY CARE CENTER	Guihing Aplaya	Low	Low	Medium
GADECO ELEMENTARY SCHOOL	Guihing Aplaya		Low	Low
MAGIC CROSS DAYCARE	Guihing Aplaya		Low	Low
TOLOGAN ELEMENTARY SCHOOL	Hagonoy Crossing		Medium	Medium
WALING WALING DAY CARE CENTER	Hagonoy Crossing			
DAY CARE CENTER	La Union			
ALTERNATIVE LEARNING CENTER(ALS)	Lapulabao	Low	Low	Low
GUIHING HIGH SCHOOL - ANNEX	Lapulabao			
GUIHING HIGH SCHOOL ANNEX	Lapulabao		Low	Low
LAPULABAO DAY CARE CENTER	Lapulabao		Low	Low
LAPULABAO ELEMENTARY SCHOOL	Lapulabao			
CIRIACO B. GAYUD ELEMENTARY SCHOOL	Malabang Damsite			
MADRASAH	Malabang Damsite			
MALIIT DIGOS ELEMENTARY SCHOOL	New Quezon			
HAGONOY NATIONAL HIGH SCHOOL	Paligue	Low	Medium	Medium
SAMPAGUITA DAY CARE CENTER	Paligue	Medium	Medium	Medium
KIBLAWAN				
FELIPE-INOCENCIA DELUAO NATIONAL HIGH SCHOOL	Bagong Silang	Medium	High	High

Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
FELIPE-INOCENCIA DELUAO NATIONAL HIGH SCHOOL CANTEEN	Bagong Silang	Medium	High	High
FELIPE-INOCENCIA NATIONAL HIGH SCHOOL K-12 BUILDING	Bagong Silang	Medium	Medium	High
FELIPE-INOCENCIA DELUAO NATIONAL HIGH SCHOOL	Dapok	Low	Medium	Medium
KIBLAWAN CENTRAL ELEMENTARY SCHOOL	Dapok	Low	Low	Low
POBLACION COMMUNITY LEARNING CENTER (ABANDONED)	Dapok			Low
SERAPION C. BASALO MEMORIAL FOUNDATION COLLEGES. INC.	Dapok	Low	Low	Low
DAY CARE CENTER	Kibongbong	Low	Low	Low
MOLOPOLO ELEMENTARY SCHOOL	Kibongbong			
HOLY CROSS OF KIBLAWAN	Kisulan	Low	Low	Medium
KIBLAWAN CENTRAL ELEMENTARY SCHOOL	Kisulan		Low	Low
DAY CARE CENTER	New Sibonga			
NEW SIBONGA ELEMENTARY SCHOOL	New Sibonga			
MOLOPOLO NATIONAL HIGHSCHOOL	San Isidro	Low	Low	Low
MARANATA DAYCARE CENTER	San Jose			
DAYCARE CENTER	San Pedro			
LA SUERTE ELEMENTARY SCHOOL	San Pedro	Low	Low	Low
MARCIANO APIAG ELEMENTARY SCHOOL	San Pedro			
BAGUMBAYAN DAY CARE CENTER	Santo Niño			
BENITO PEREZ ELEMENTARY SCHOOL	Santo Niño			
MARCIANO APIAG ELEMENTARY SCHOOL	Tacub			
MARCIANO APIAG ELEMENTARY SCHOOL	Tacul			
SULATORIO ELEMENTARY SCHOOL	Waterfall	Low	Low	Medium
MATANAO				
DAY CARE CENTER	Dongan-Pekong			
LEONCIO PILINO ELEMENTARY SCHOOL	Dongan-Pekong			
CEBOZA ELEMENTARY SCHOOL	Tibongbong			
CEBOZA ELEMENTARY SCHOOL	Towak			
PADADA				
DAISY DAY CARE CENTER	Don Sergio Osmena, Sr.	Low	Medium	Medium
KATIPUNAN DAY CARE CENTER	Harada Butai	Low	Low	Low
KATIPUNAN ELEMENTARY SCHOOL	Harada Butai	Low	Low	Low
SAN GUILLERMO ELEMENTARY SCHOOL	Lower Katipunan			
ECCD CENTER (SOUTHERN PALIGUE DAY CARE)	Lower Limonzo		Low	Low

Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
PADADA NATIONAL HIGH SCHOOL	Lower Limonzo	Low	Medium	Medium
ROMAGERA ELEMENTARY SCHOOL	Lower Limonzo		Low	Low
DON SERGIO OSMEÑA ELEMENTARY SCHOOL	N C Ordaneza Distric	Medium	Medium	Medium
CATLEYA DCC	Northern Paligue			
LMC KINDERGARTEN	Northern Paligue	Low	Low	Medium
TOLOGAN ELEMENTARY SCHOOL	Northern Paligue			
ATO PADADA CHRISTIAN SCHOOL	Palili			
DAY CARE CENTER	Palili			
FIDEL A. RAZONABLE SR. PRIMARY SCHOOL	Palili	Low	Medium	Medium
GAUDIOSO ORBITA ELEMENTARY SCHOOL	Palili	Low	Low	Low
LOWER LIMONZO DAY CARE ECCD CENTER	Palili			Low
NCO DAY CARE CENTER	Palili	Low	Low	Low
PADADA CENTRAL SCHOOL	Palili			Low
PADADA STAR BRIGHT LEARNING CENTER	Palili			
SAINT MICHAEL	Palili	Low	Medium	Medium
SOUTHEASTERN COLLEGE	Palili	Medium	Medium	Medium
SUNRISE LEARNING CENTER	Palili			
MARIA CLETA R. DELOS SANTOS NATIONAL HIGH SCHOOL	Punta Piape	Low	Medium	Medium
PHILIPPINE NIPPON TECHNICAL COLLEGE OF DAVAO DEL SUR	Punta Piape	Low	Medium	Medium
PIAPE ELEMENTARY SCHOOL	Punta Piape	Low	Low	Low
PUNTA PIAPE DAY CARE CENTER	Punta Piape			
ROMAGERA ELEMENTARY SCHOOL	Punta Piape	Low	Low	Low
DAHLIA DAY CARE CENTER	San Isidro			
MALINAO ELEMENTARY SCHOOL	Tulogan	Low	Medium	Medium
PADADA NATIONAL HIGH SCHOOL	Tulogan	Medium	Medium	Medium
CARMELO C. DELOS CIENTOS NATIONAL TRADE SCHOOL	Upper Limonzo	Low	Medium	Medium
MARIANO SARONA ELEMENTARY SCHOOL	Upper Limonzo		Low	Low
NORTHERN PALIGUE DAY CARE CENTER	Upper Limonzo	Low	Medium	Medium
SULOP				
NEW CEBU ELEMENTARY SCHOOL	Buguis			
NEW CEBU ELEMENTARY SCHOOL	Carre			
NEW CEBU ELEMENTARY SCHOOL	Osmeña			
TANWALANG DAY CARE CENTER	Roxas			
TANWALANG ELEMENTARY SCHOOL	Roxas	Low	Medium	High
TANWALANG ELEMENTARY SCHOOL LIBRARY	Roxas	Low	Medium	Medium

ANNEX 13. Medical Institutions Affected in Padada-Mainit Flood Plain

Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
HAGONOY				
BARANGAY HEALTH CENTER	Clib			
GUIHING COMMUNITY HOSPITAL	Guihing	Low	Low	Low
GUIHING HEALTH CENTER	Guihing		Low	Medium
J. HAGONOY MEDICAL CLINIC	Guihing			
NUTRITION CENTER	Guihing	Low	Low	Medium
BOTIKANG BARANGAY	Guihing Aplaya	Low	Low	Low
HEALTH CENTER	Guihing Aplaya			
BOTIKANG BARANGAY	Lapulabao	Low	Low	Low
HEALTH CENTER	Lapulabao	Low	Low	Low
GUIHING HEALTH CENTER	Paligue			Low
KIBLAWAN				
HEALTH CENTER	Abnate	Low	Low	Low
KIBLAWAN HEALTH CENTER	Dapok			
MAILA GARCIA-ARELLANO MATERNITY & LYING-IN CLINIC	Dapok			
CAMINERO DENTAL CLINIC	Kisulan			
KIBLAWAN HEALTH CENTER	Kisulan			
NEW SIBONGA HEALTH CENTER	New Sibonga			
GREGORIO MATAS DISTRICT HOSPITAL	Poblacion		Low	Low
HEALTH CENTER	San Pedro			
HEALTH CENTER	Santo Niño			
HEALTH CENTER	Abnate	Low	Low	Low
KIBLAWAN HEALTH CENTER	Dapok			
MAILA GARCIA-ARELLANO MATERNITY & LYING-IN CLINIC	Dapok			
CAMINERO DENTAL CLINIC	Kisulan			
KIBLAWAN HEALTH CENTER	Kisulan			
NEW SIBONGA HEALTH CENTER	New Sibonga			
GREGORIO MATAS DISTRICT HOSPITAL	Poblacion		Low	Low
HEALTH CENTER	San Pedro			
HEALTH CENTER	Santo Niño			
PADADA				
HEALTH CENTER	Lower Katipunan			
NEW SIBONGA HEALTH CENTER	Lower Katipunan			
SOUTHERN PALIGUE HEALTH CENTER	Lower Limonzo	Low	Low	Low

Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
DON SERGIO OSMEÑA HEALTH CENTER	N C Ordaneza Distric			Low
ASILO HOSPITAL	Palili			
BARON-YEE HOSPITAL	Palili	Medium	Medium	Medium
FN RAMIR PAANAKAN	Palili			
GLORY MATERNITY CLINIC	Palili	Low	Medium	Medium
HEALTH CENTER	Palili	Low	Low	Low
MUNICIPAL EMERGENCY HOSPITAL	Palili			
PHL MEDICALAND DIAGNOSTIC CENTER	Palili			
SOUTH DAVAO MEDICAL SPECIALIST HOSPITAL	Palili			
PIAPE BARANGAY HEALTH CENTER	Punta Piape			Low
GONZALES HOSPITAL	Southern Paligue			
HEALTH CENTER	Tulogan	Low	Low	Medium
NORTHERN PALIGUE HEALTH CENTER	Upper Limonzo	Medium	Medium	Medium
SOUTH DAVAO MEDICAL SPECIALIST HOSPITAL	Upper Limonzo			
SOUTH DAVAO MEDICAL SPECIALIST HOSPITAL - CANTEEN	Upper Limonzo	Medium	Medium	Medium
BARANGAY HEALTH CENTER	Upper Malinao			
SULOP				
HEALTH CENTER (ABANDONED)	Katipunan		Low	Low