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

LiDAR Surveys and Flood Mapping of Dolores River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
Visayas State University

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LIST OF ACRONYMS AND ABBREVIATIONS

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

CHAPTER 1: INTRODUCTION

[ ]

1.1 Background of the Phil-LiDAR 1 Program

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

The program also aimed to produce 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 titled Flood Mapping of Rivers in the Philippines Using Airborne LiDAR: Methods (Paringit et al., 2017) available separately.

The implementing partner university for the Phil-LiDAR 1 Program is the Visayas State University (VSU). VSU 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 28 river basins in the Eastern Visayas Region. The university is located in Baybay City in the province of Leyte.

1.2 Overview of the Dolores River Basin

The Dolores River Basin covers three (3) municipalities; namely, the municipalities of Dolores and Maslog in Eastern Samar and San Jose de Buan in Samar. It also covers some portions of the municipalities of Arteche, Jipadpad, Dolores, and Can-Avid in Eastern Samar and some portions of the municipalities of Paranas and Matuguinao in Samar. The DENR River Basin Control Office (RBCO) states that the Dolores Basin has a drainage area of 702 km^2 and an estimated 1,334 cubic meter (MCM) annual run-off (RBCO, 2015).

Its main stem, Dolores River, is among the twenty-eight (28) river systems in the Eastern Visayas Region. According to the 2015 national census of PSA, a total of 14,109 persons distributed among barangays Dampigan, 1 (Poblacion), 2 (Poblacion), 10 (Poblacion), 12 (Poblacion), Santo Niño, Bonghon, Malaintos, Tanauan, and Santo Niño in the Municipality of Dolores and barangays Carolina and Rawis in the Municipality of Can-Avid. are residing within the immediate vicinity of the river, In terms of economy, major industries in the province include agriculture and fishing with traditional crops such as palay, corn, vegetables, and fruits as the main products (National Economic and Development Authority, 2011). Last December 17, 2016, floods hit Eastern Samar as rivers swelled and overflowed towards villages in the province due to continuous heavy rains. A state of calamity has been declared in the flooded municipality of Dolores in Eastern Samar due to non-stop rain during the weekend. Up to 4,675 families in 28 out of 46 barangays were affected by flooding, according to the Municipal Disaster Risk Reduction and Management Council (MDRRMC) (ABS-CBN News, 2016).

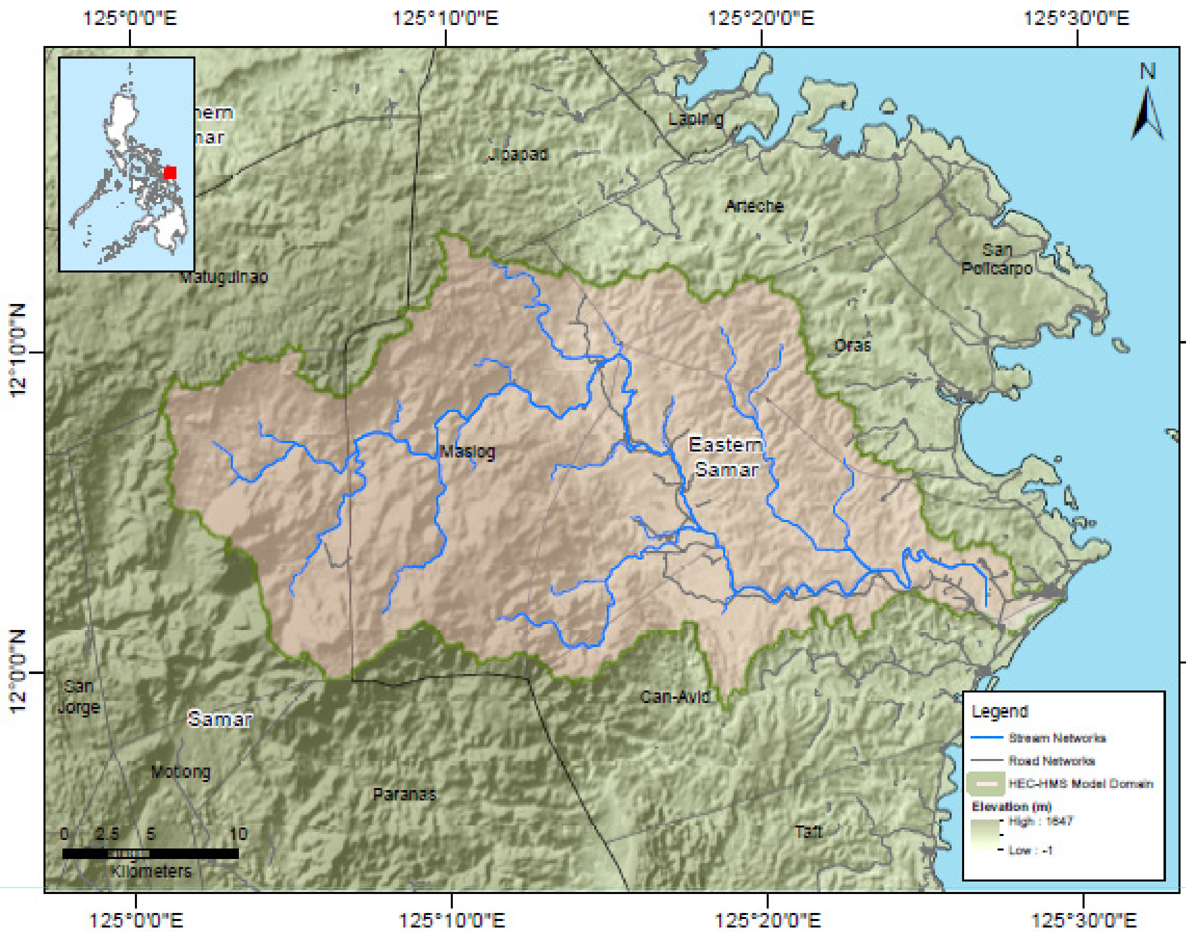

Figure 1. Map of Dolores River Basin (in brown)

CHAPTER 2: LIDAR ACQUISITION IN DOLORES 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 Dolores Floodplain in Eastern Samar. These missions were planned for 17 lines that ran for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for Aquarius LiDAR system are found in Table 1. Figure 2 shows the flight plan for Dolores floodplain survey.

Table 1. Flight planning parameters for Aquarius LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (KHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK33J	500	20	44	50	45	120	5

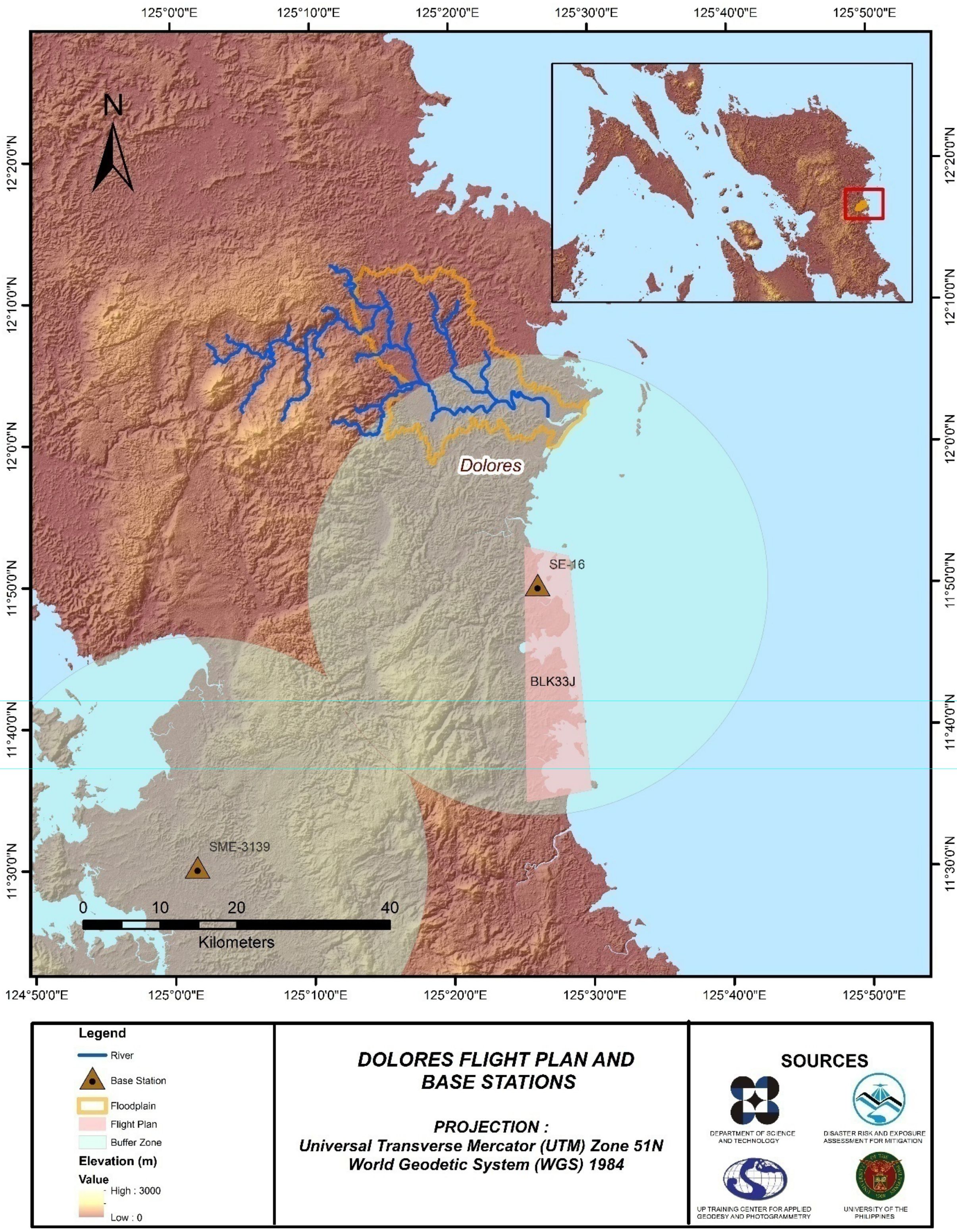

Figure 2. Flight plan and base stations used for Dolores floodplain.

2.2 Ground Base Stations

The project team was able to recover one (1) NAMRIA horizontal ground control points, SME-3139 which is of fourth (4th) order accuracy and a Benchmark (SE-16) which is of first order accuracy. These benchmark was used as vertical reference point and was also established as ground control point. The certification for the NAMRIA reference point is found in ANNEX 2 while the baseline processing report for the established control point is found in ANNEX 3. These were used as base stations during flight operations for the entire duration of the survey (June 9, 2014). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and SPS 985. Flight plans and location of base stations used during the aerial LiDAR acquisition in Dolores Floodplain are shown in Figure 2.

Figure 3 to Figure 4 show the recovered NAMRIA reference points within the area. In addition, Table 2 to Table 3 show the details about the following NAMRIA control stations and established points, while Table 4 lists all ground control points occupied during the acquisition together with the dates they are utilized during the survey.

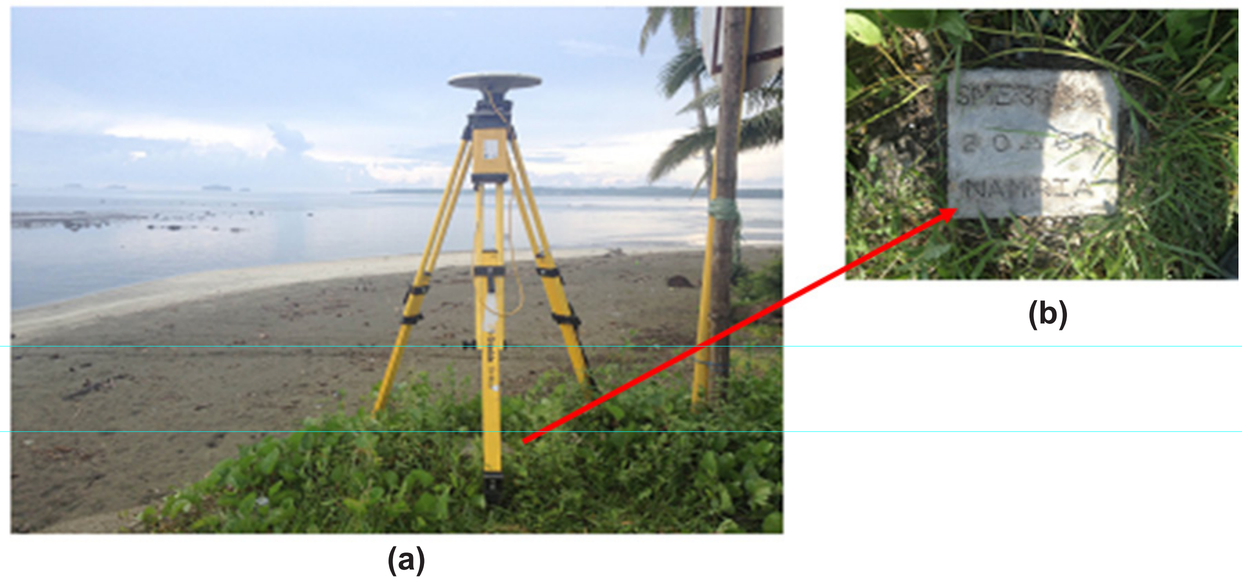

Figure 3. GPS set-up over SME-3139 located along the highway in Brgy. Sto. Nino, Dolores, Eastern Samar (a) and NAMRIA reference point SME-3139 (b) as recovered by the field team.

Table 2. Details of the recovered NAMRIA horizontal control point SME-3139 used as base station for the LiDAR acquisition.

Station Name	SME-3139	
Order of Accuracy	4th Order	
Relative Error (horizontal positioning)	1:10,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11° 30’ 17.85657” North 125° 1’ 29.837339” East 26.13400 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	502722.403 meters 1272180.079 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 30’ 13.52495” North 125° 1’ 34.96980” East 87.78700 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	720874.14 meters 1272513.40 meters

Table 3. Details of the recovered NAMRIA horizontal control point SE-16 used as base station for the LiDAR acquisition.

Station Name	SE-16	
Order of Accuracy	4th Order	
Relative Error (horizontal positioning)	1:10,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11° 50’ 03.05106” North 125° 26’ 03.03429” East 0.472 meters
Grid Coordinates, Universal Transverse System 1984 Datum (WGS84)	Latitude Longitude Ellipsoidal Height	11° 49’ 58.67117” North 125° 26’ 08.13400” East 62.301 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	765219.942 meters 1309292.154 meters

Table 4. Ground control points used during LiDAR data acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
9 JUN 14	1558A	3BLK33J160A	SE-16,SME-3139
9 JUN 14	1560A	3BLK33JS160B	SE-16,SME-3139

2.3 Flight Missions

Two (2) missions were conducted to complete LiDAR data acquisition nearest Dolores Floodplain, for a total of eight hours and thirty four minutes (8+34) of flying time for RP-9122. The missions were acquired using Aquarius 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 nearest Dolores floodplain

Date Surveyed	Flight Number	Flight Plan Area (km²)	Surveyed Area (km²)	Area Surveyed within the Floodplain (km²)	Area Surveyed outside the Floodplain (km²)	No. of Images (Frames)	Flying Hours	
							Hr	Min
9 JUN 14	1558A	225.57	117.98	NA	117.98	98	4	41
9 JUN 14	1560A	225.57	127.54	NA	127.54	1294	3	53
TOTAL		**451.14**	**245.52**	**NA**	**245.52**	**1392**	**8**	**34**

Table 6. Actual parameters used during the LiDAR data acquisition

Date Surveyed	Flight Number	Flying Height (AGL) (m)	Overlap (%)	Field of View	PRF (kHz)	Scan Frequency (Hz)	Speed of Plane (Kts)
1558A	500	30	44	50	45	120	5
1560A	500	20	44	50	45	120	5

2.4 Survey Coverage

Dolores floodplain is located in the province of Eastern Samar with majority of the floodplain situated within the municipality of Dolores. 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 Dolores Floodplain is presented in Figure 4.

Table 7. List of municipalities and cities surveyed during Dolores floodplain LiDAR survey nearest Dolores Floodplain.

Province	Municipality/City	Area of Municipality/ City (km²)	Total Area Surveyed (km²)	Percentage of Area Surveyed
Eastern Samar	Sulat	150.05	39.95	27%
	San Julian	127.43	22.72	18%
	Borongan City	596.08	69.2	12%
	Dolores	230.27	1.95	1%
Total		**1,103.83**	**133.82**	**12.12%**

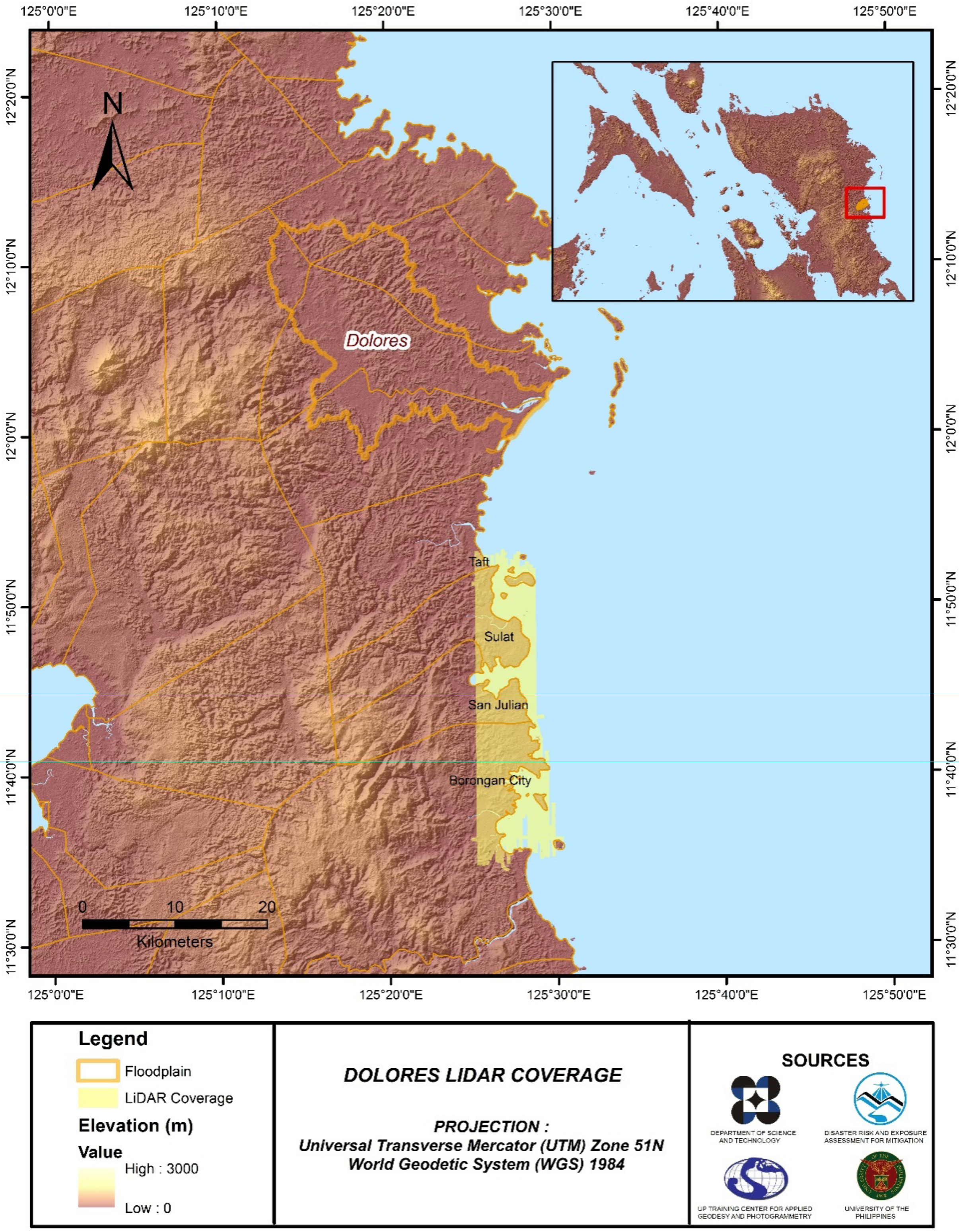

Figure 4. Actual LiDAR survey coverage nearest Dolores floodplain

CHAPTER 3: LIDAR DATA PROCESSING FOR DOLORES FLOODPLAIN

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

3.1 Overview of the LIDAR Data Pre-Processing

The data transmitted by the Data Acquisition Component were 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 wasdone to obtain the exact location of the LiDAR sensor when the laser was shot.

Point cloud georectification was performed to incorporate correct position and orientation for each point acquired. The georectified LiDAR point clouds weresubject 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 werethen 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 werecalibrated. Portions of the river that are barely penetrated by the LiDAR system werereplaced by the actual river geometry measured from the field by the Data Validation and Bathymetry Component. LiDAR acquired temporally werethen mosaicked to completely cover the target river systems in the Philippines. Orthorectification of images acquired simultaneously with the LiDAR data wasdone 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 5.

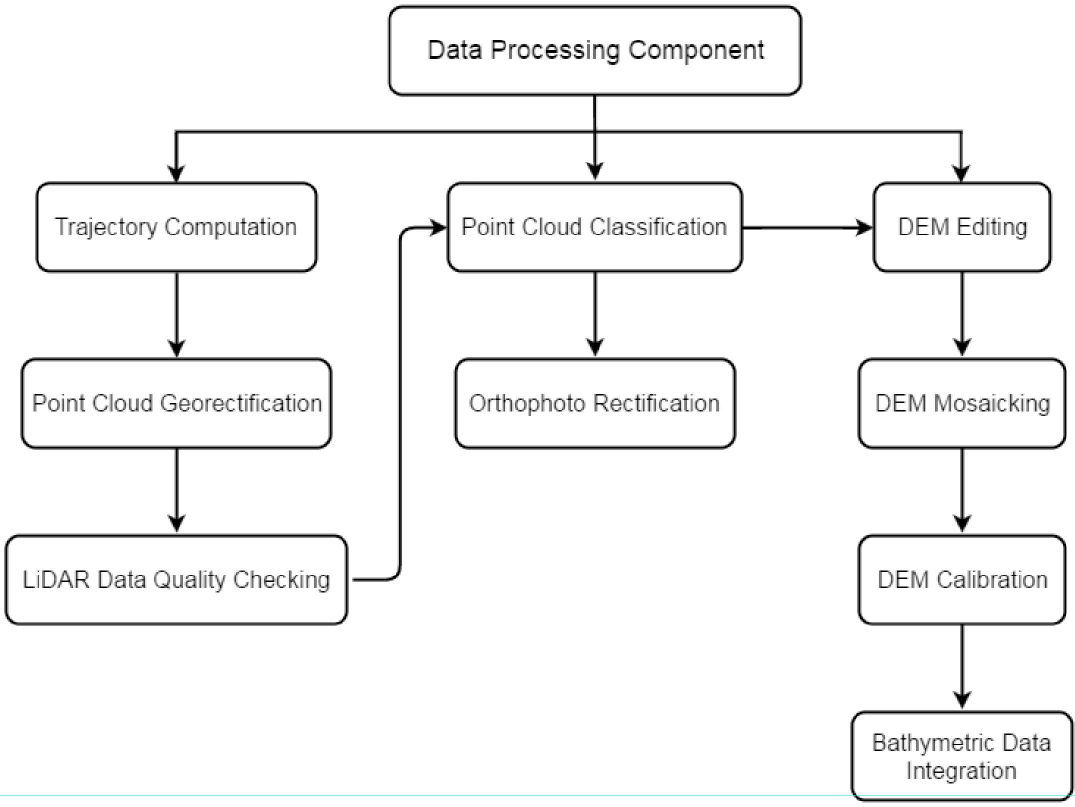


Figure 5. Schematic diagram for the Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Dolores Floodplain can be found in ANNEX A-5.Missions flown during all the surveys conducted on June 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Aquarius system over Samar and Leyte. The Data Acquisition Component (DAC) transferred a total of 26.30 Gigabytes of Range data, 0.50 Gigabytes of POS data, 32.20 Megabytes of GPS base station data, and 167.90 Gigabytes of raw image data to the data server on June 9, 2014 for the first and second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Dolores was fully transferred on June19, 2014, as indicated on the Data Transfer Sheets for Dolores floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for flight 1560A, one of the Dolores flights, which is the North, East, and Down position RMSE values are shown in Figure 6. 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 June9, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

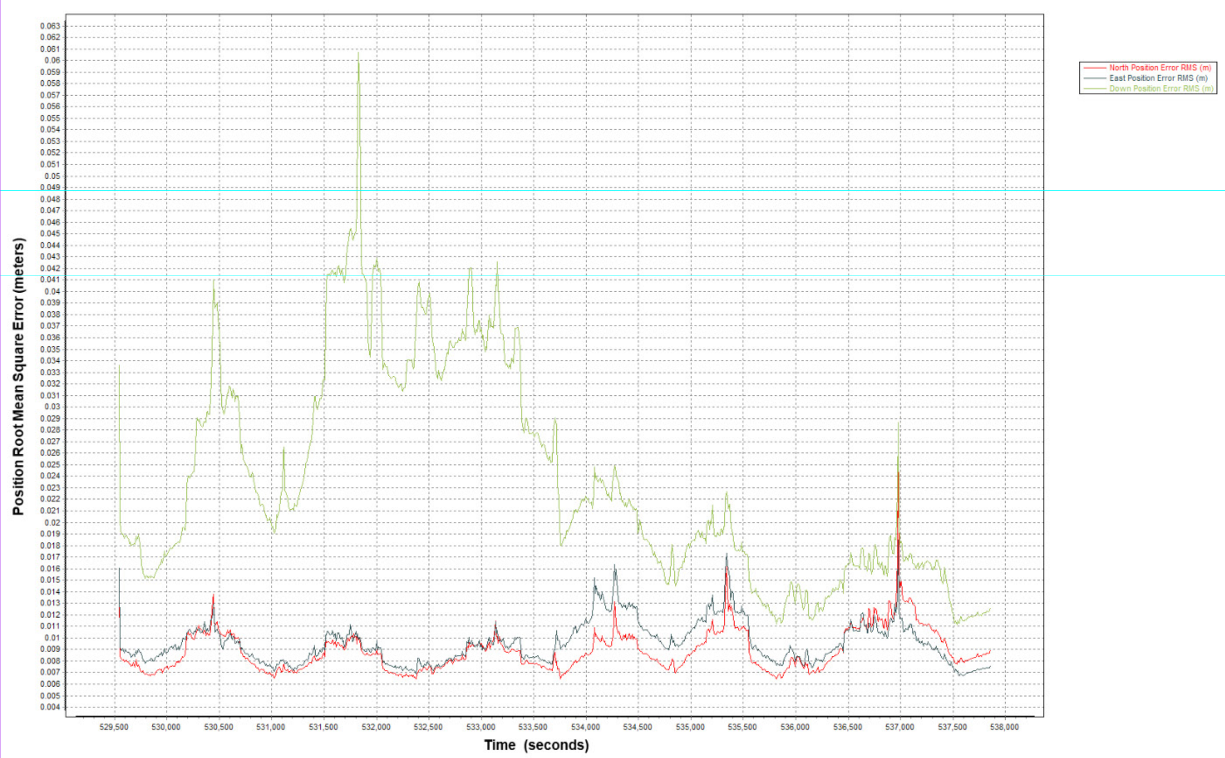


Figure 6. Smoothed Performance Metric Parameters of a Dolores Flight 1560A.

The time of flight was from 529500 seconds to 538000 seconds, which corresponds to afternoon of June9, 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 6 shows that the North position RMSE peaks at 2.50 centimeters, the East position RMSE peaks at 1.90 centimeters, and the Down position RMSE peaks at 6.10 centimeters, which are within the prescribed accuracies described in the methodology.

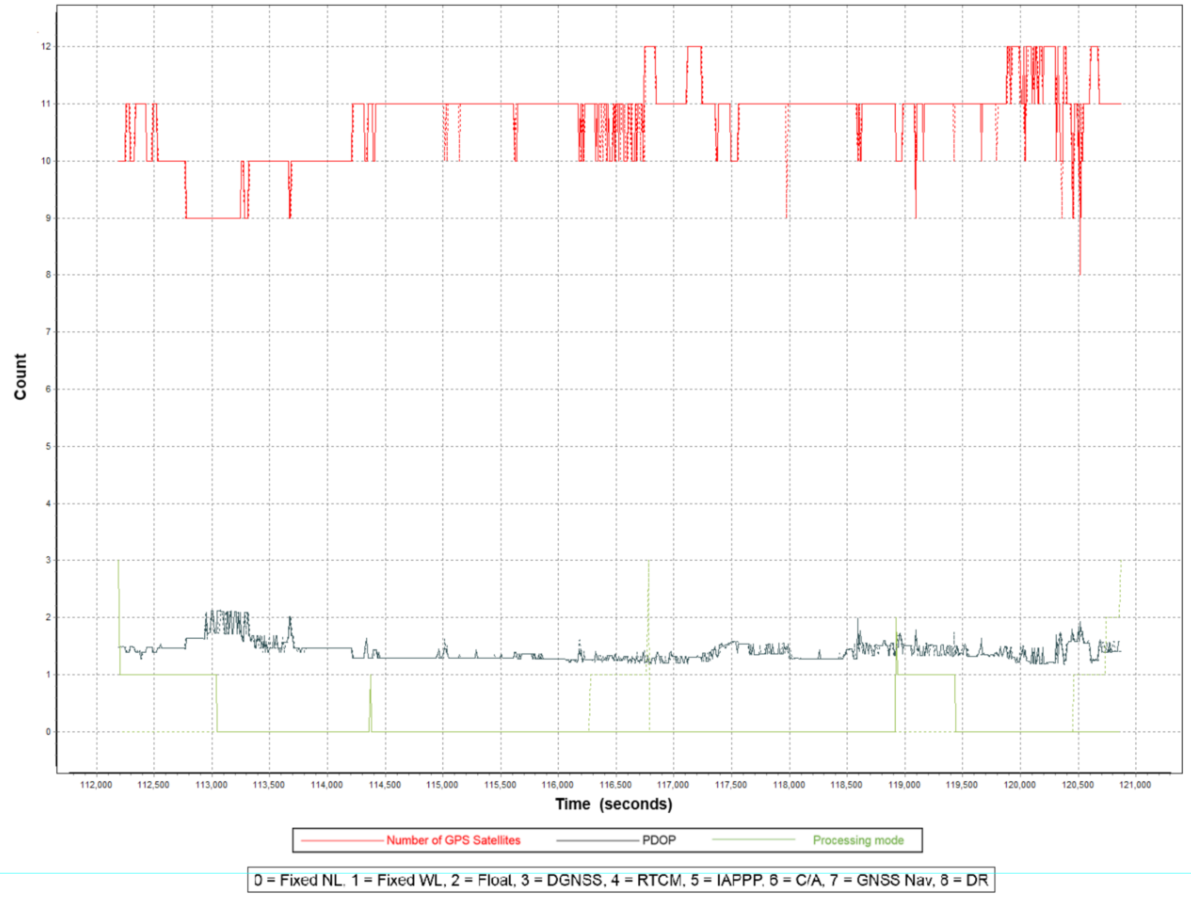


Figure 7. Solution Status Parameters of Dolores Flight 1560A.

The Solution Status parameters of flight 1560A, one of the Dolores flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 8. 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 9 and 12. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 1 or 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 Dolores flights is shown in Figure 9.

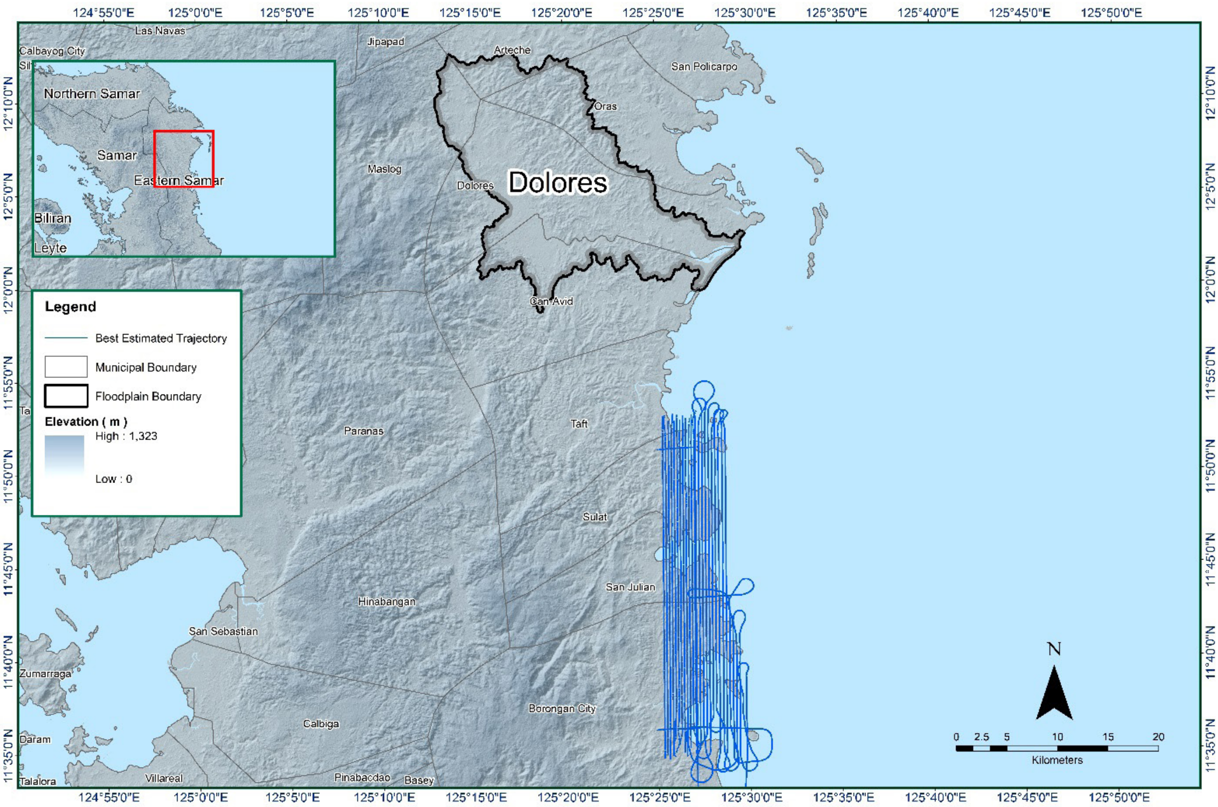


Figure 8. Best Estimated Trajectory for Dolores Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 28 flight lines, with each flight line containing one channel, since the Aquarius 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 Dolores Floodplain are given in Table 8.

Table 8. Self-calibration results for the Dolores flights

Parameter		Acceptable Value
Boresight Correction stdev	(<0.001degrees)	0.000327
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.000811
GPS Position Z-correction stdev	(<0.01meters)	0.0098

The optimum accuracy is obtained for all Dolores 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.

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Dolores Floodplain is shown in Figure 9. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

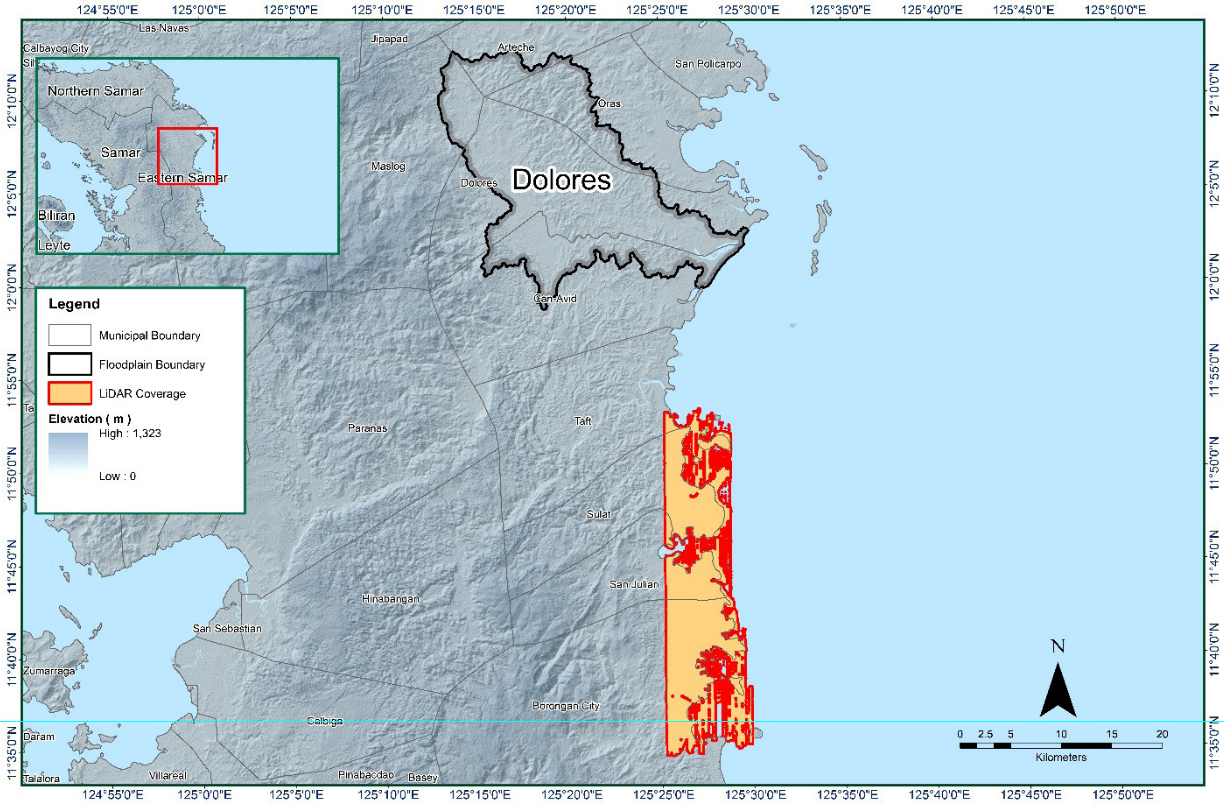


Figure 9. Boundary of the processed LiDAR data over Dolores Floodplain

The total area covered by the Doloresmissions is 174.99 sq.km comprised of two (2) flight acquisitions grouped and merged into one (1) block as shown in Table 9.

Table 9. List of LiDAR blocks for the Dolores floodplain

LiDAR Blocks	Flight Numbers	Area (sq. km)
Samar_Leyte_Blk33J	1558A	174.99
	1560A	
TOTAL		**174.99 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 10. Since the Aquarius system employs one channel, we would expect an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines.

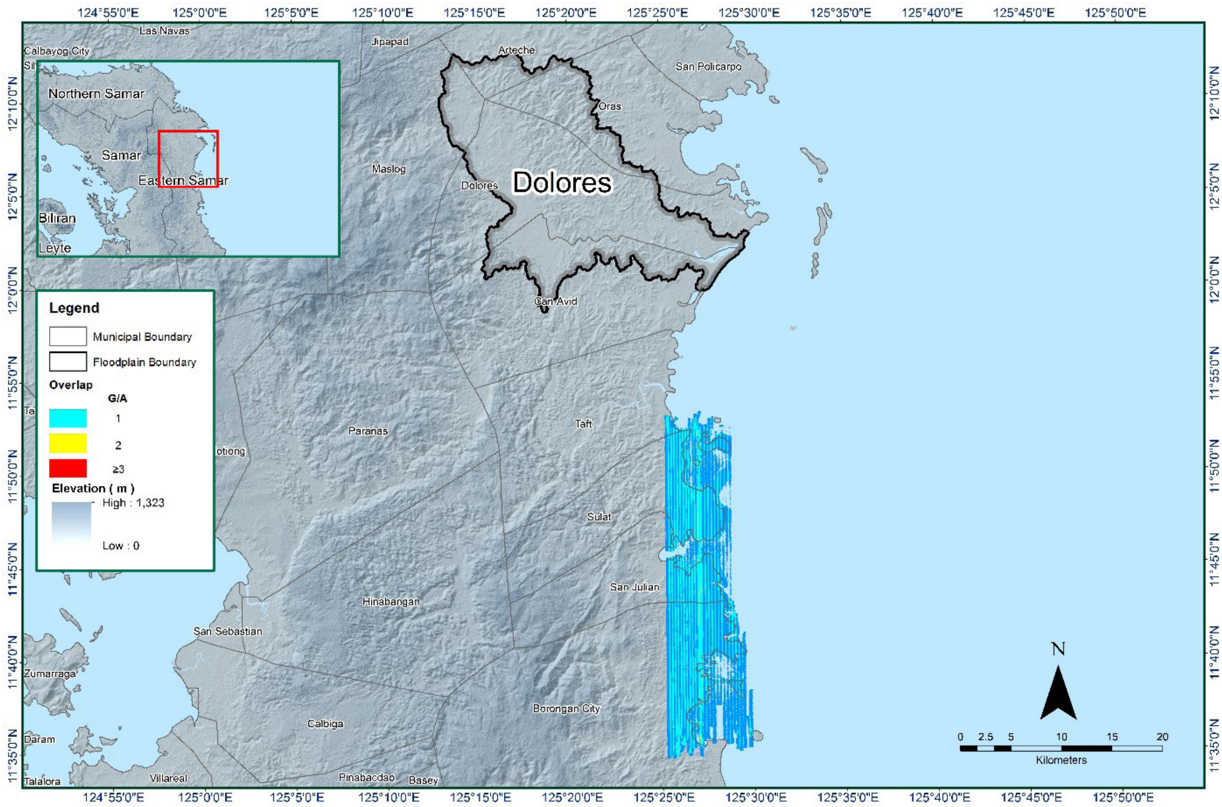


Figure 10. Image of data overlap for Dolores floodplain.

The overlap statistics per block for the Dolores floodplain can be found in ANNEX B-1. One pixel corresponds to 25.0 square meters on the ground. For this area, the percent overlap is 36.01%, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 11. It was determined that all LiDAR data for Dolores floodplain satisfy the point density requirement, and the average density for the entire survey area is 2.71 points per square meter.

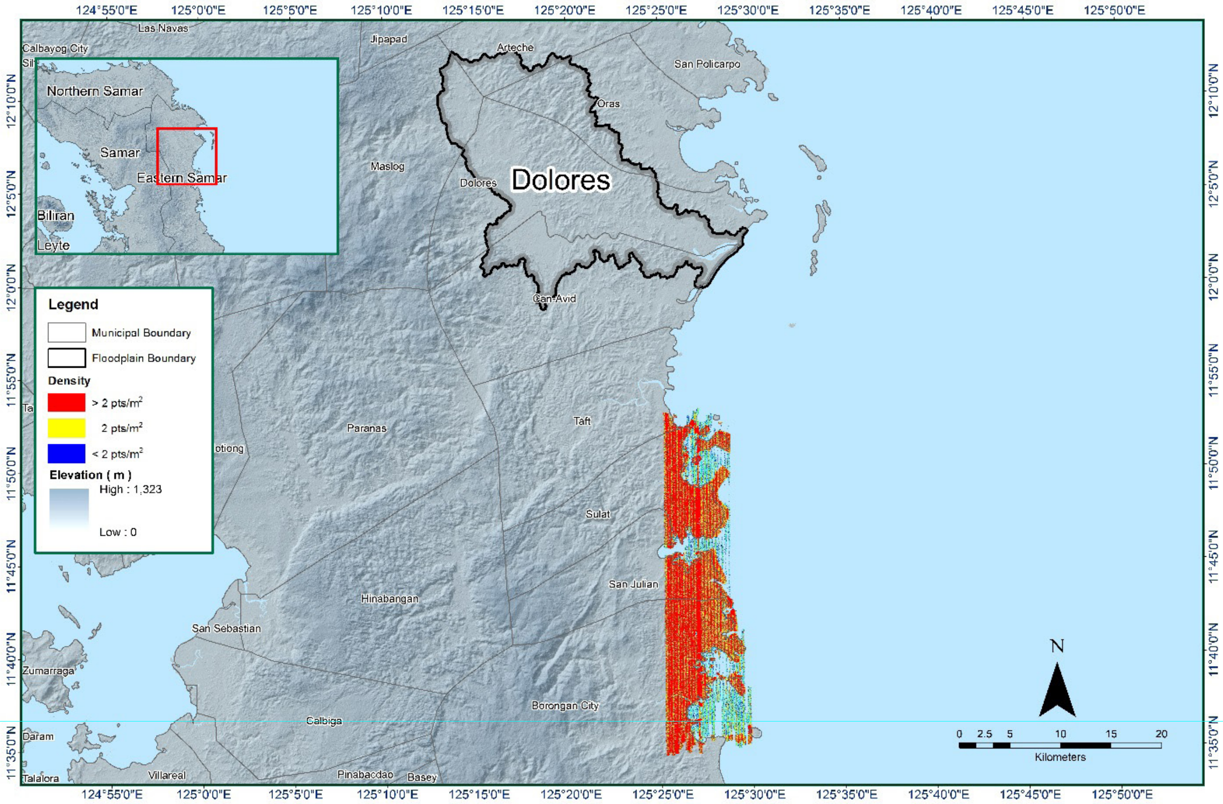


Figure 11. Pulse density map of merged LiDAR data for Dolores Floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 12. 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.

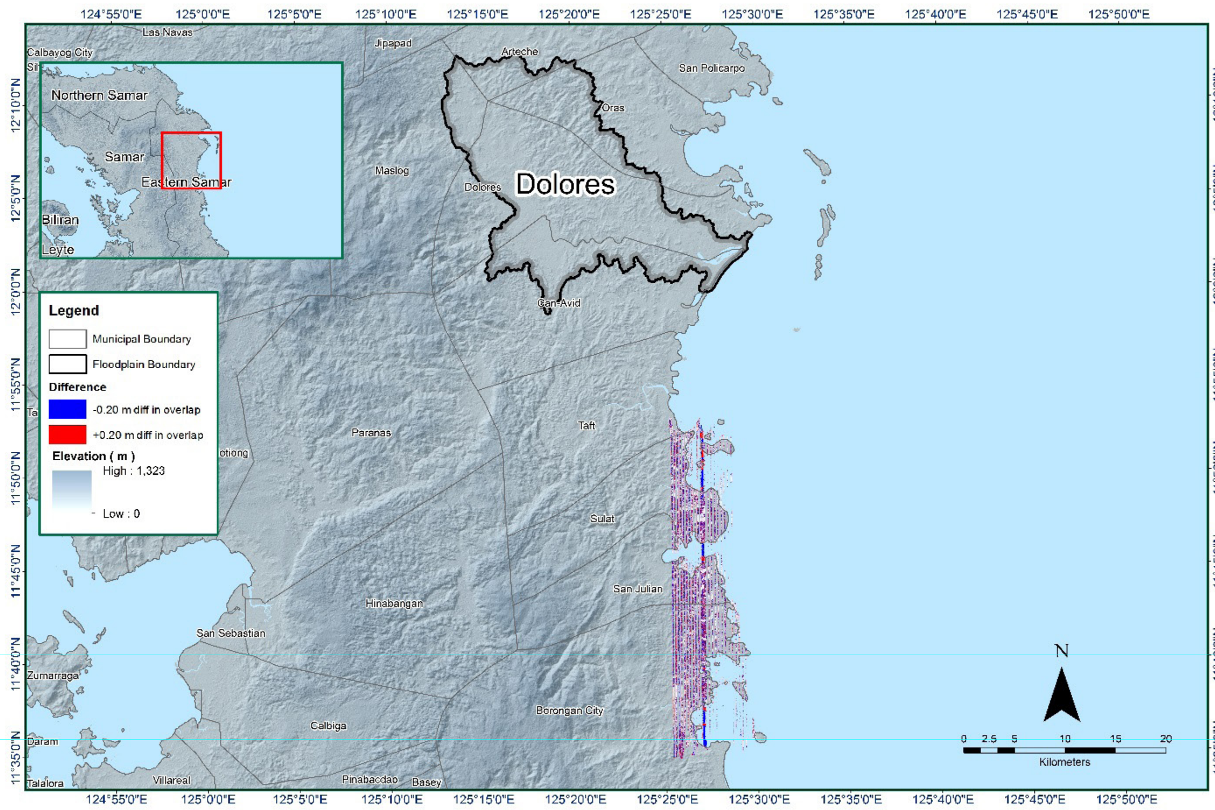


Figure 12. Elevation difference map between flight lines for Dolores Floodplain.

A screen capture of the processed LAS data from a Dolores flight 1560A loaded in QT Modeler is shown in Figure 13. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

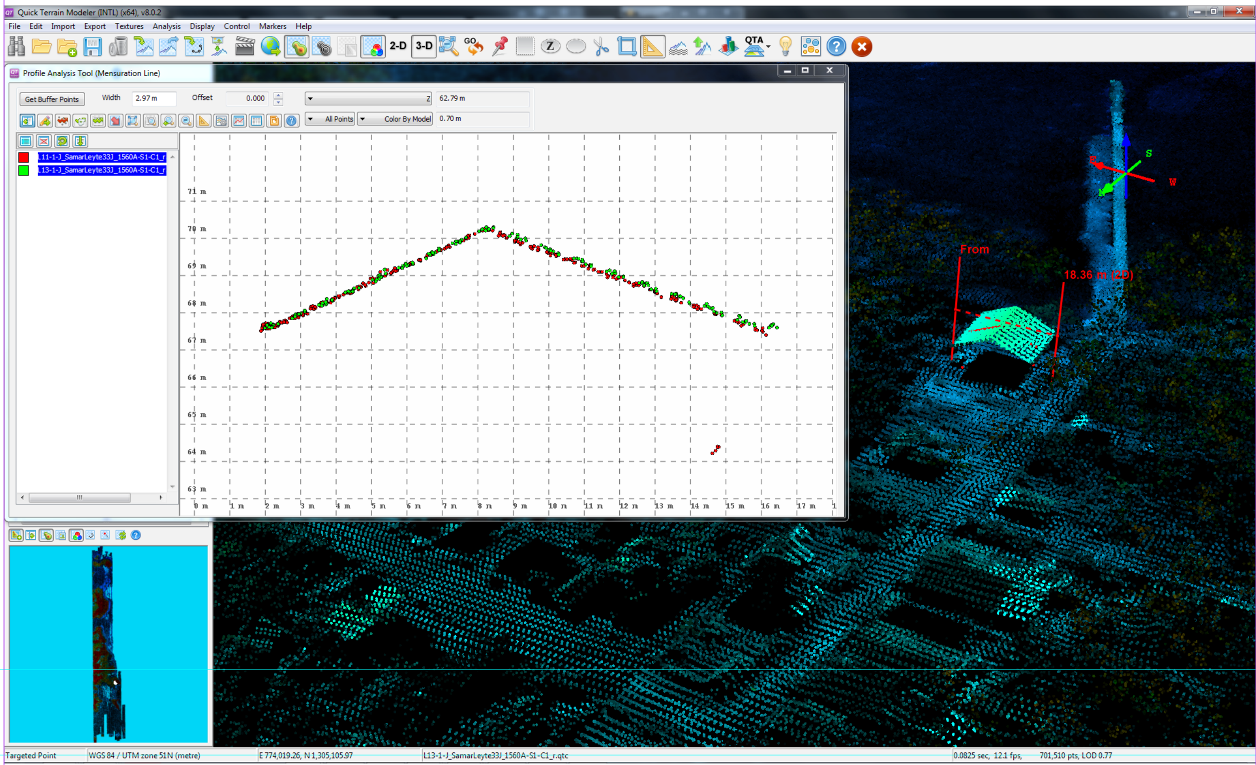


Figure 13. Quality checking for a Dolores flight 1560A using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 10. Dolores classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	110,486,647
Low Vegetation	51,277,620
Medium Vegetation	61,095,498
High Vegetation	151,119,077
Building	2,518,830

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block near Dolores Floodplain is shown in Figure 14. A total of 291 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 248.48 meters and 49.30 meters, respectively.

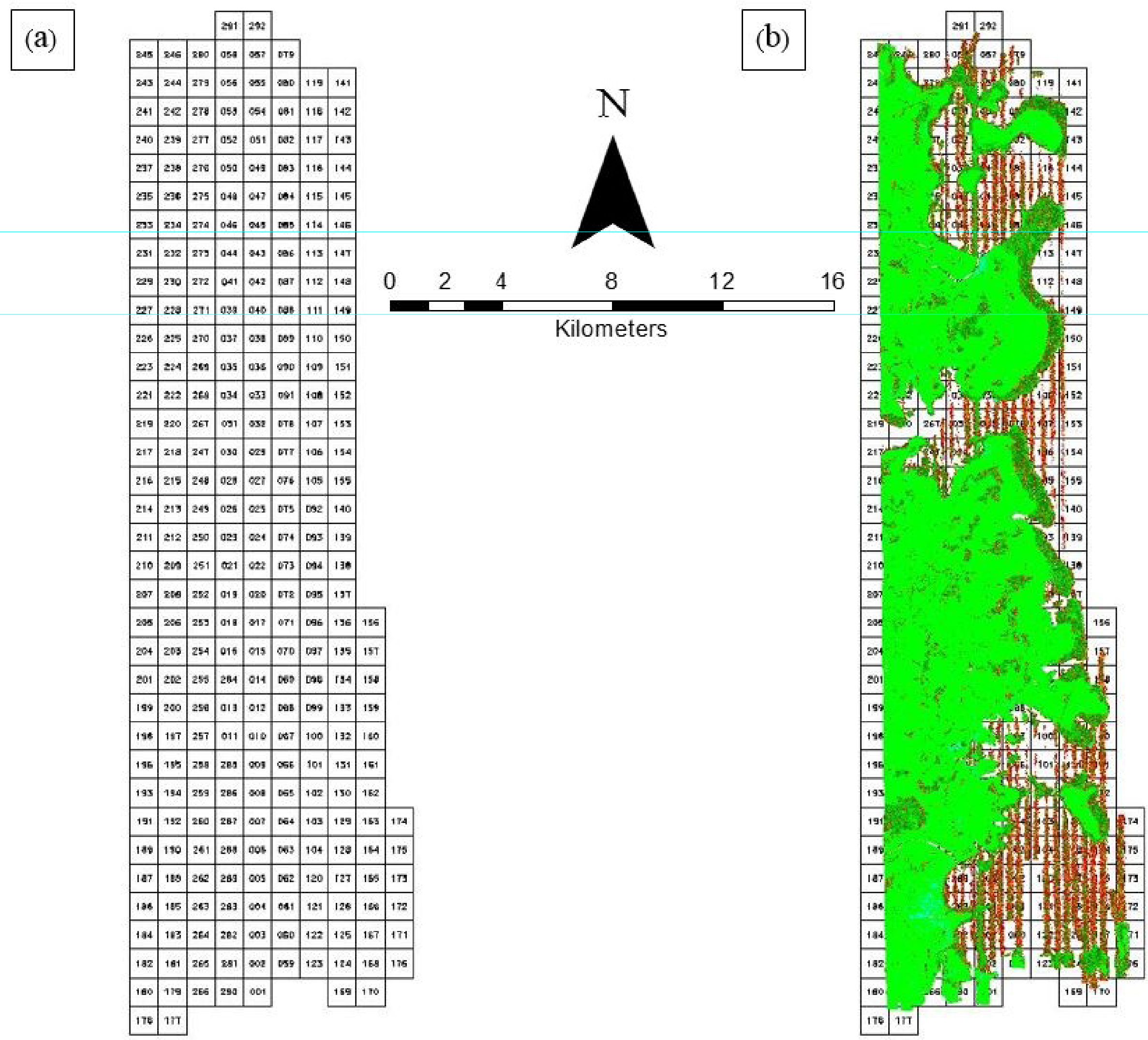


Figure 14. Tiles for Dolores floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 15. 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.

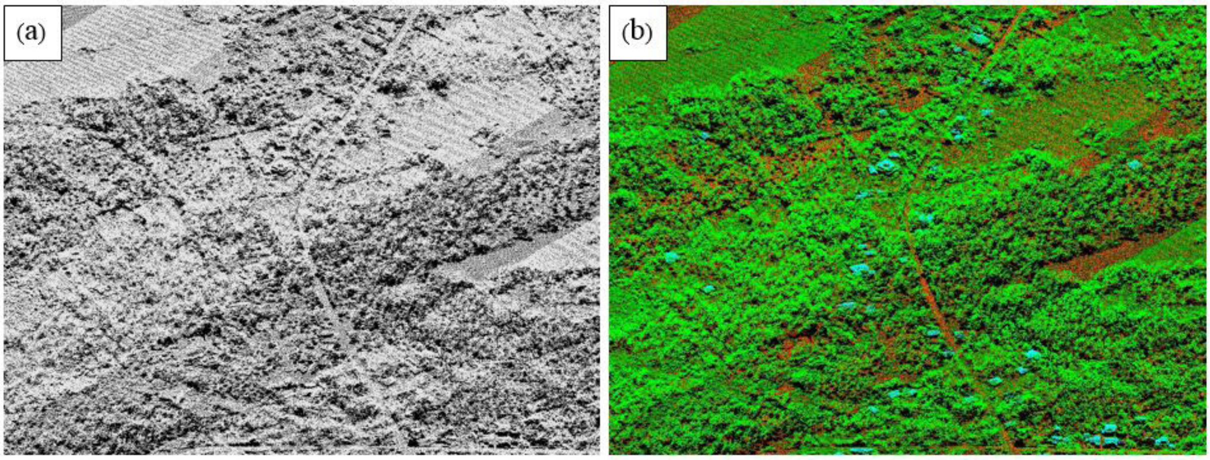


Figure 15. Point cloud before (a) and after (b) classification.

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

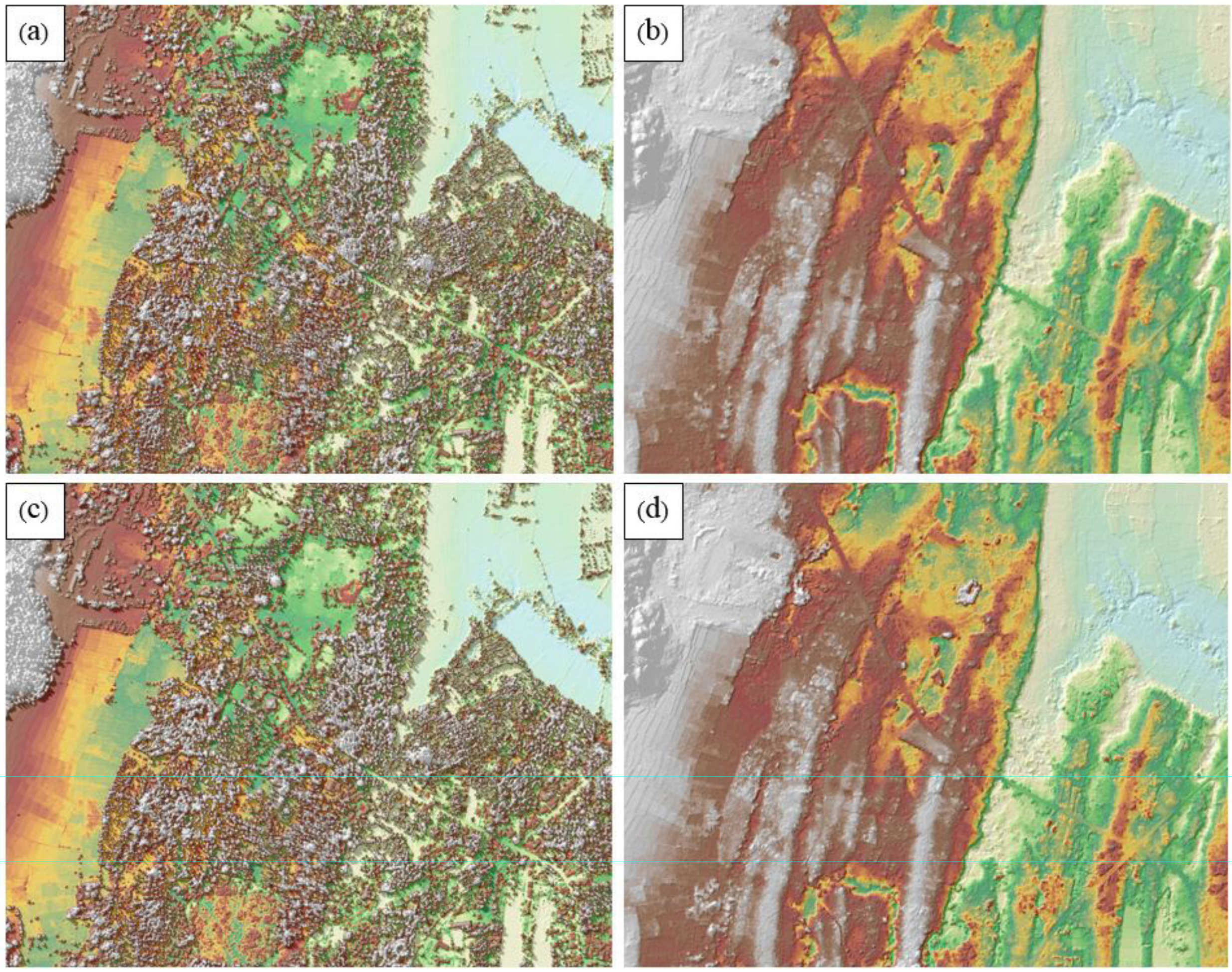


Figure 16. The Production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion near Dolores Floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 290 1km by 1km tiles of the block covering the Dolores Floodplain is shown in Figure 17. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Dolores Floodplain has a total of 219.66 sq.km orthophotogaph coverage comprised of 2,657 images. However, the block does not have a complete set of orthophotographs and no orthophotographs cover the area of the Dolores Floodplain.A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 18.

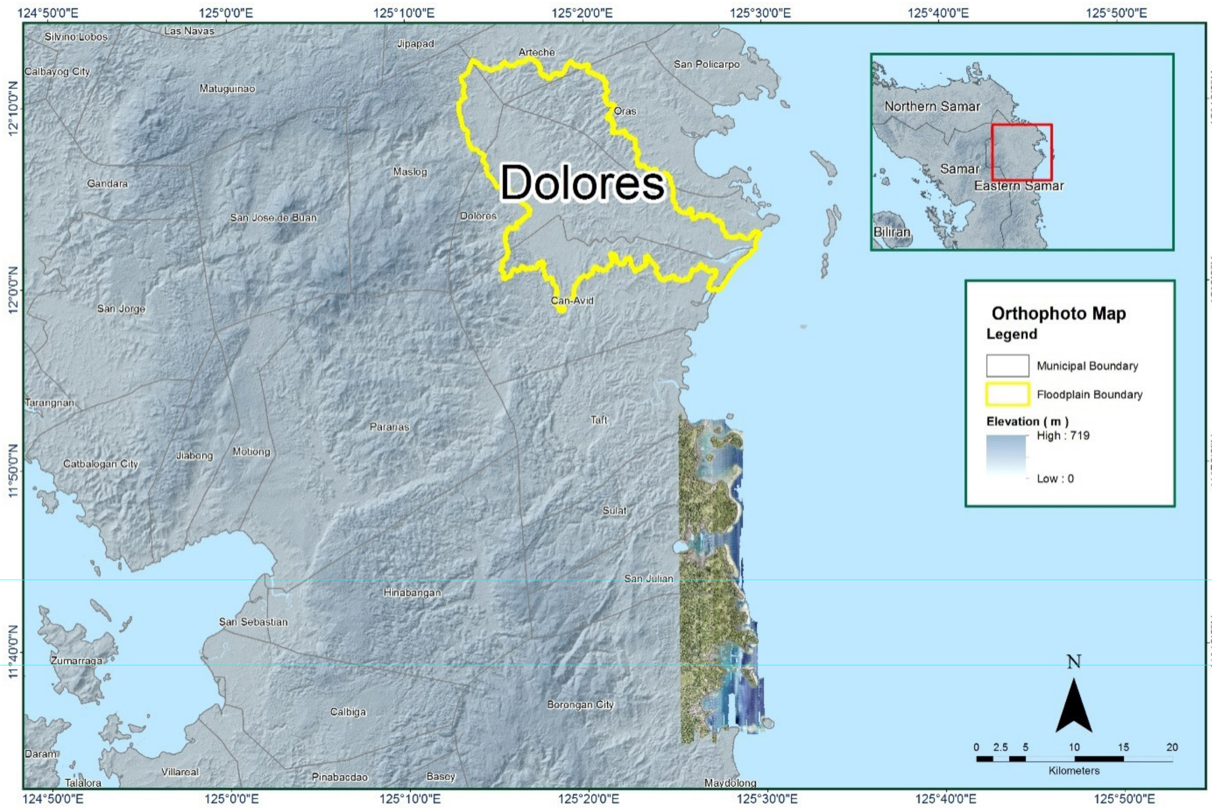


Figure 17. Available orthophotographs near Dolores floodplain.

Figure 18. Sample orthophotograph tiles near Dolores floodplain.

3.8 DEM Editing and Hydro-Correction

SamarLeyteBlk 33J is the nearby block to the Dolores Floodplain. It was processed in order to produce DEMs covering municipalities neighboring the Dolores floodplain. It has an area of 174.99 square kilometers. Table 11 shows the LiDAR block/s and their corresponding area in square kilometers.

Table 11. LiDAR block/s with its corresponding area.

LiDAR Blocks	Area (sq.km)
SamarLeyte_Blk33J	174.99

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

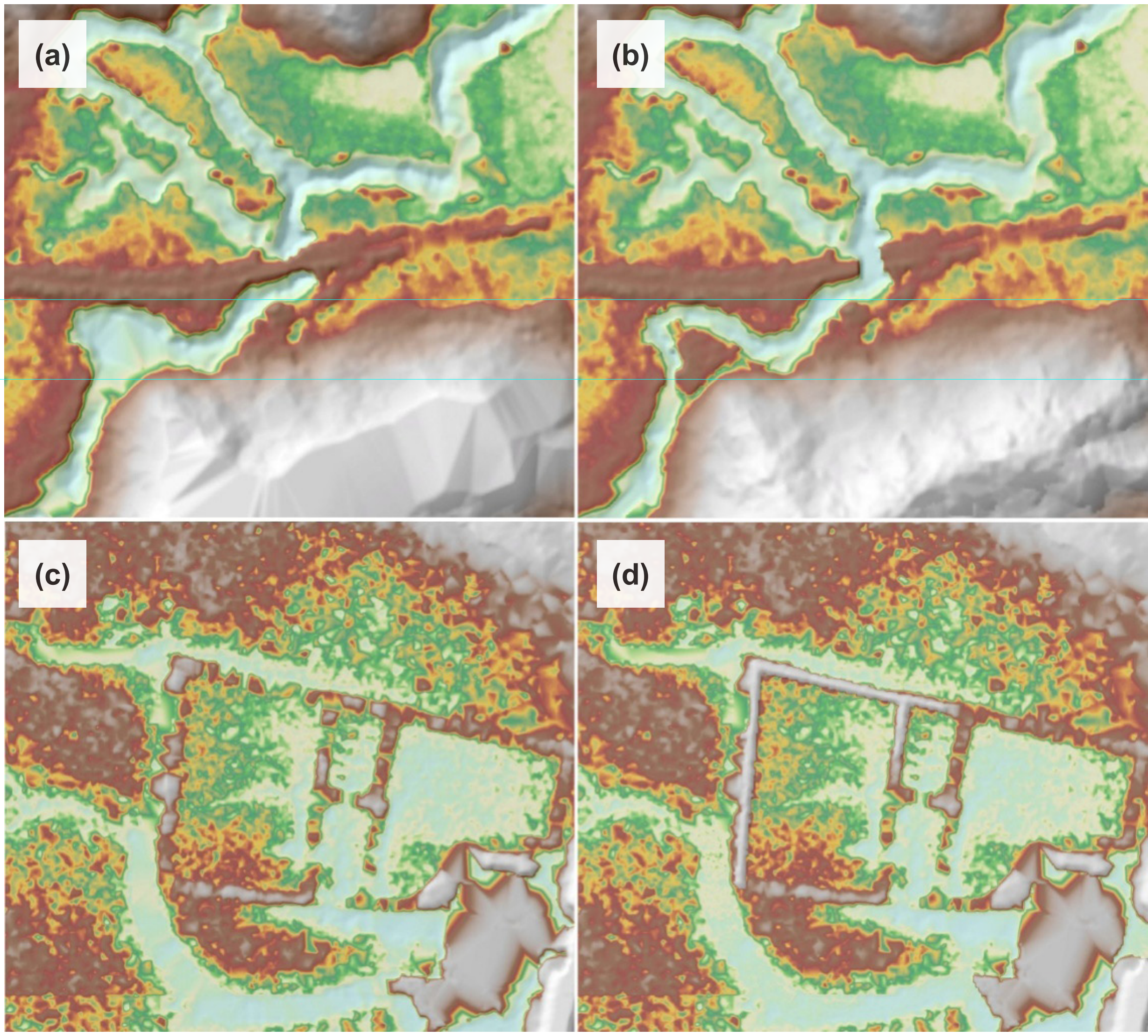


Figure 19. Portions in the DTM of Dolores Floodplain – a bridge before (a) and after (b) manual editing; and a paddy field before (c) and after (d) data retrieval.

3.9 Mosaicking of Blocks

The IFSAR data covering all flood plains located in Eastern Samar such as Ulot, Dolores and Oras and the processed LiDAR data Samar Leyte Blk 33J were mosaicked to the calibrated Tacloban LiDAR data. Table 12 shows the shift values applied to the LiDAR/IFSAR during mosaicking.

IFSAR data for Dolores Floodplain is shown in Figure 20.

Table 12. Shift Values of each IFSAR Block of Dolores Floodplain and the nearby LiDAR Block.

Mission Blocks	Shift Values (meters)		
	x	y	z
4025-II-1-5,6-10,11-15,16-20,21-25	0.77	1.54	-1.00
4025-III-5,10,15,20,25	0.58	2.00	-1.00
4024-IV-5	-0.04	3.22	-1.00
4024-I-1-5	0.12	1.32	-1.00
4124-IV-1,6,11,16,21	0.90	1.08	-1.00
SamarLeyte_Blk33J	-1.00	2.00	-1.00

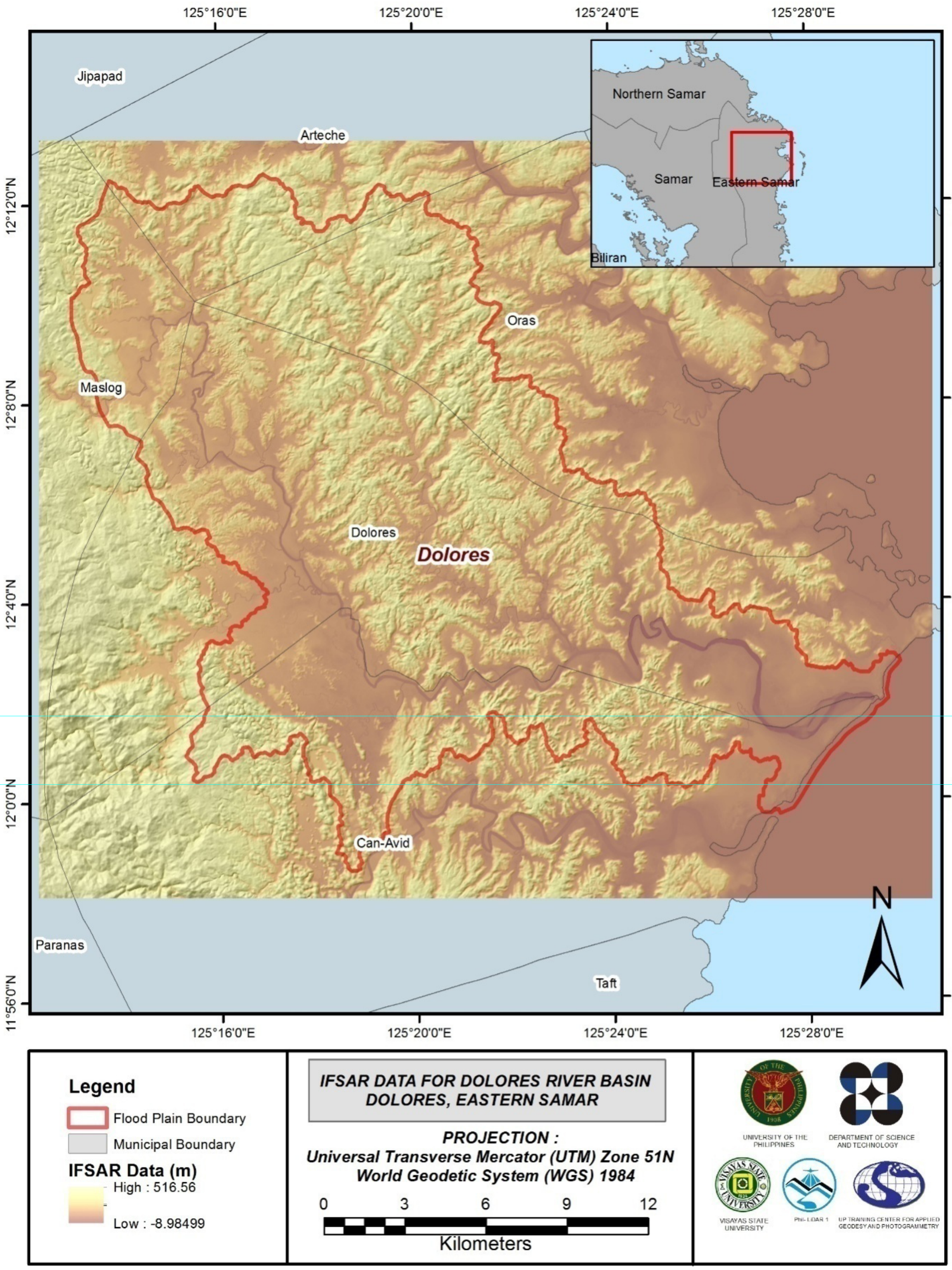


Figure 20. Map of IFSAR Data for Dolores Flood Plain.

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 Dolores to collect points with which the LiDAR dataset is validated is shown in Figure 21. A total of 11,686survey points were gathered for the Dolores flood plain. However, the point dataset was not used for the calibration of the LiDAR data for Dolores because during the mosaicking process, the IFSAR was referred to the calibrated Tacloban DEM. Therefore, the IFSAR DEM of Dolores can already be considered as a calibrated DEM.

A good correlation between the uncalibrated Tacloban LiDAR DTM and 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 points is 0.14 meters with a standard deviation of 0.13 meters. Calibration of Tacloban LiDAR data was done by subtracting the height difference value, 0.14 meters, to Tacloban mosaicked LiDAR data. Table 13 shows the statistical values of the compared elevation values between Tacloban LiDAR data and calibration data. These values were also applicable to the Dolores DEM.

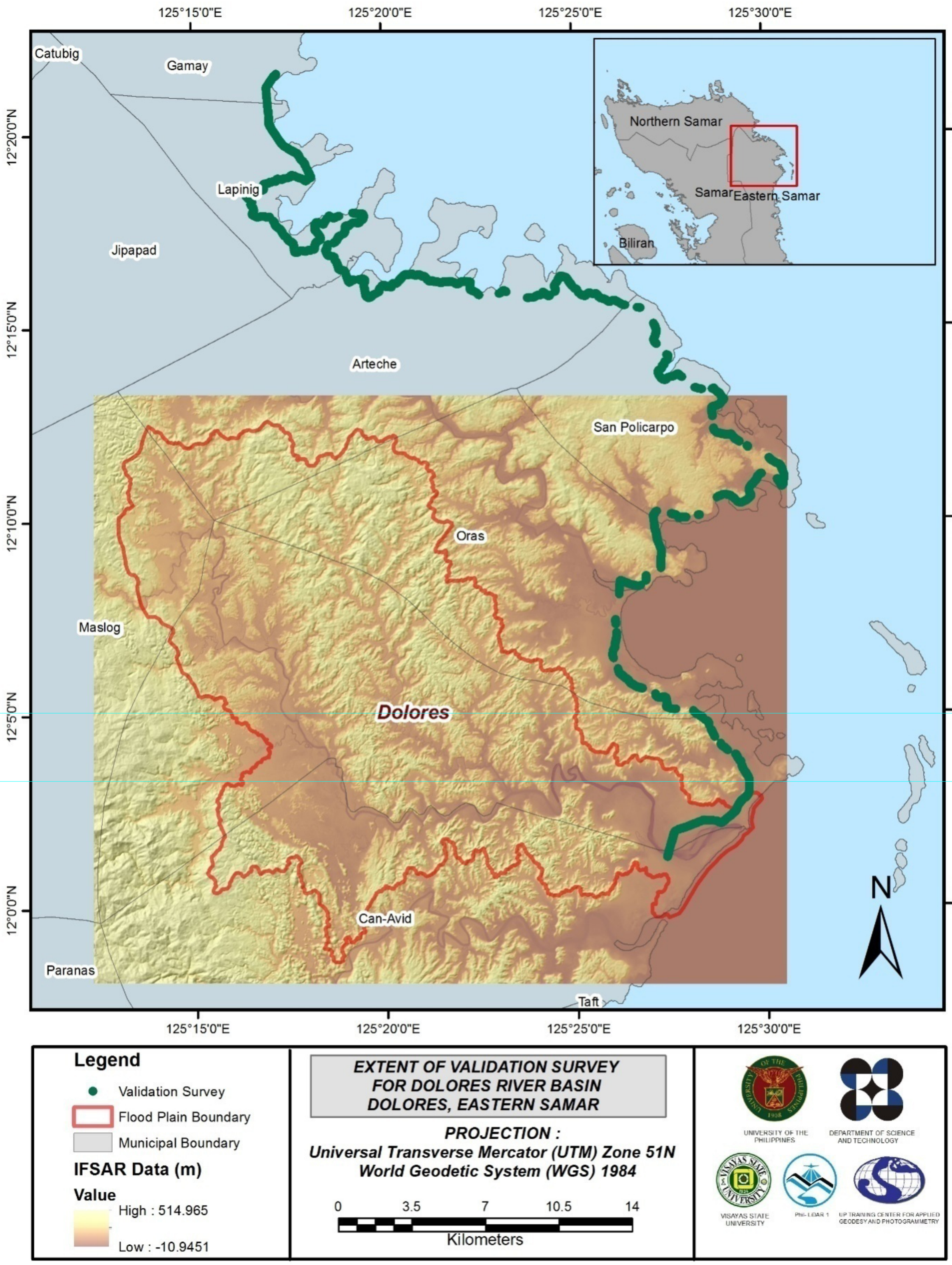


Figure 21. Map of Dolores Flood Plain with validation survey points in green.

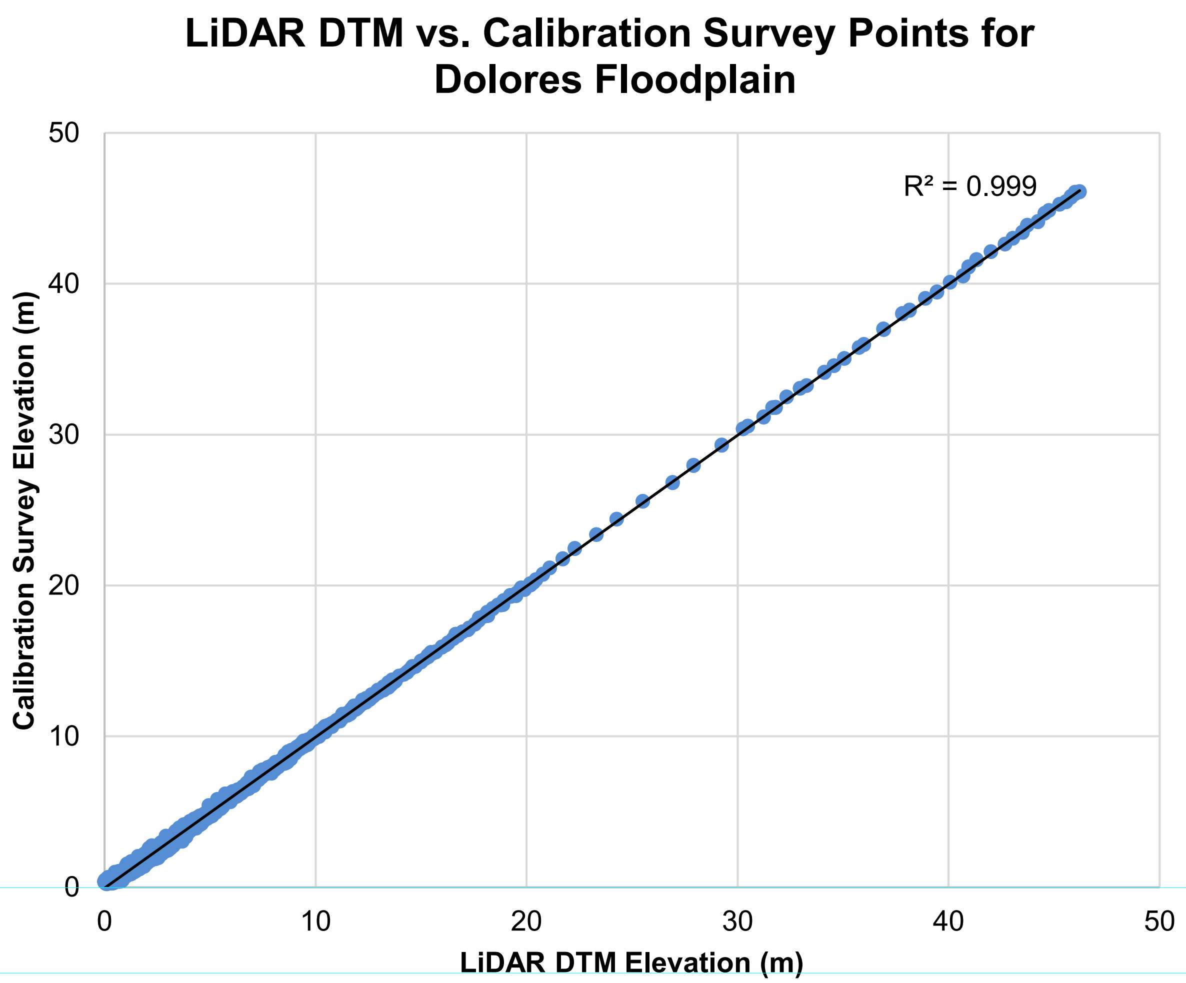


Figure 22. Correlation plot between calibration survey points and LiDAR data.

Table 13. Calibration statistical measures

Calibration Statistical Measures	Value (meters)
Height Difference	0.14
Standard Deviation	0.13
Average	-0.05
Minimum	-0.32
Maximum	0.22

A total of 467 survey points were used for the validation of the calibrated Dolores DTM. A good correlation between the calibrated mosaicked IFSAR elevation values and the ground survey elevation, which reflects the quality of the IFSAR DTM is shown in Figure 23. The computed RMSE between the calibrated IFSAR DTM and validation elevation values is 1.58meters with a standard deviation of 0.55meters, as shown in Table 14.

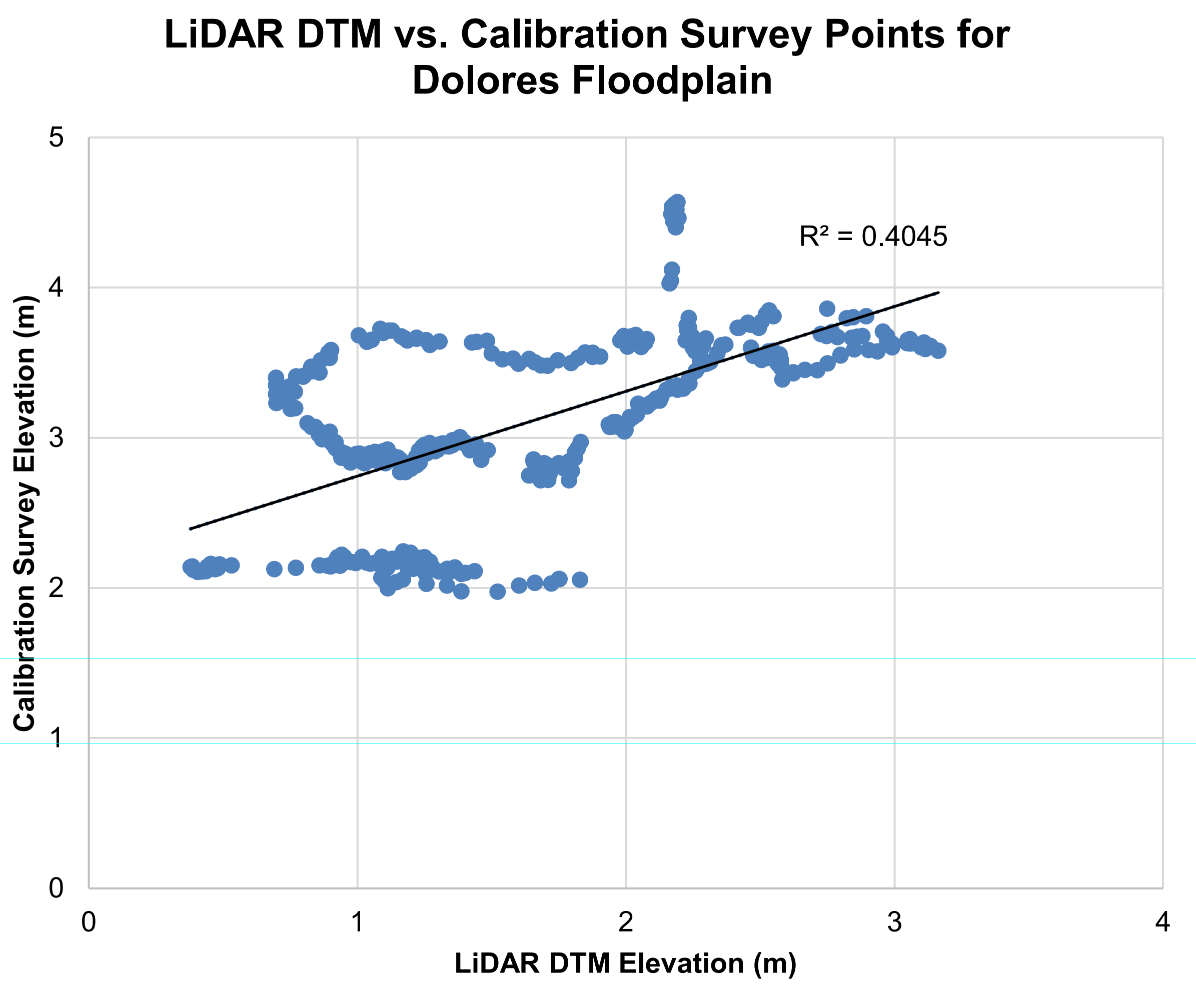


Figure 23. Correlation plot between validation survey points and IFSAR data.

Table 14. Validation statistical measures

Calibration Statistical Measures	Value (meters)
RMSE	1.58
Standard Deviation	0.55
Average	1.48
Minimum	0.22
Maximum	2.70

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and zigzag are the available data for Dolores with 14,803 bathymetric survey points. The resulting raster surface was obtained using the Kernel Interpolation with Barriers method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.53 meters. The extent of the bathymetric data surveyed by the Data Validation and Bathymetry Component (DVBC) in Dolores integrated with the processed IFSAR DEM is shown in Figure 24.

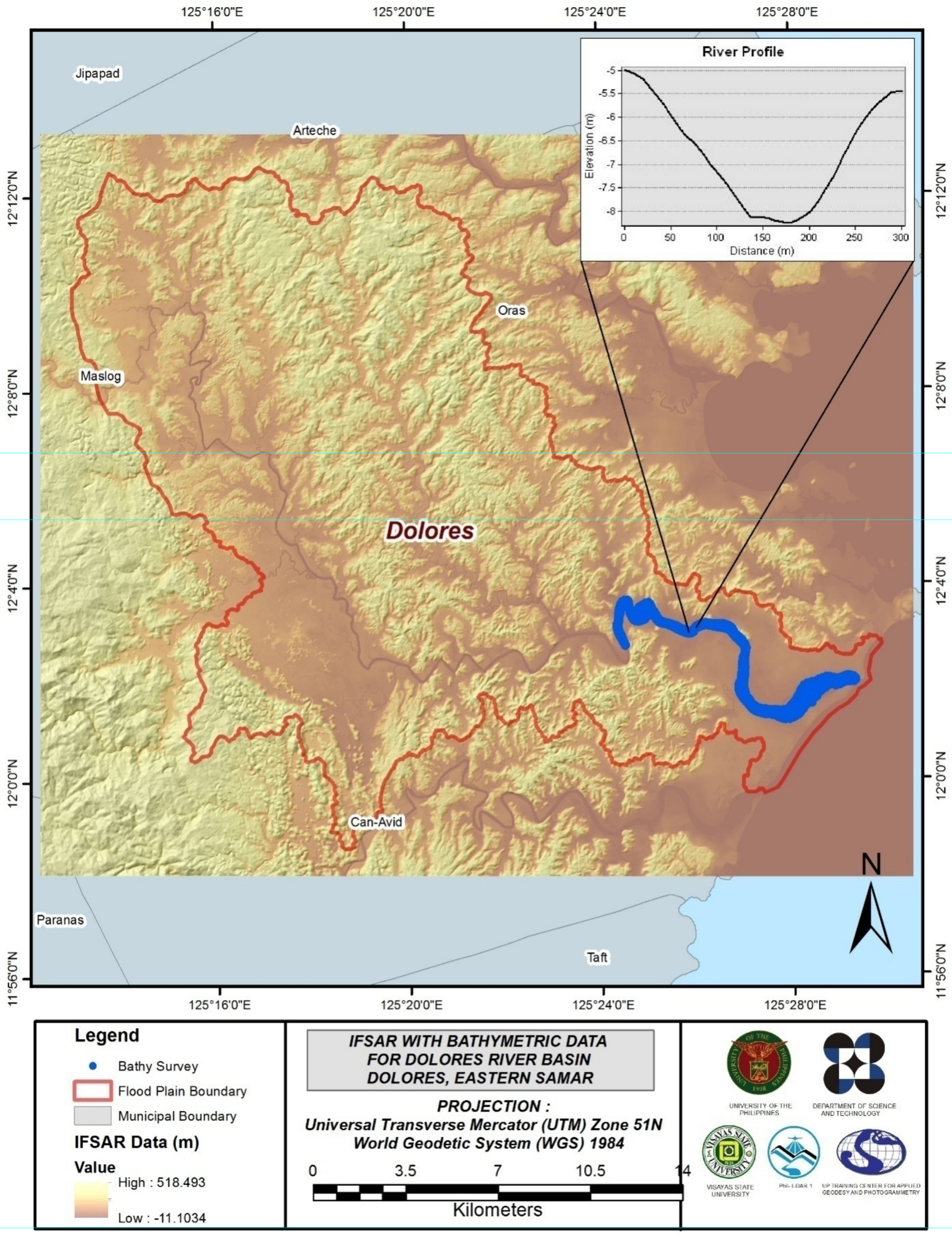


Figure 24. Map of Dolores Flood Plain with bathymetric survey points shown in blue.

3.12 Feature Extraction

[ ]

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS OF THE DOLORES RIVER BASIN

Engr. Louie P. Balicanta, Engr. Joemarie S. Caballero, Ms. Patrizcia Mae. P. dela Cruz, Engr. Kristine Ailene B. Borromeo Ms. Jeline M. Amante, Marie Angelique R. Estipona, Charie Mae V. Manliguez, Engr. Janina Jupiter, and Vie Marie Paola M. Rivera

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

The H.O. Noveloso Surveying (HONS) conducted a field survey in Dolores River onDec. 10 and 12, 2016, Feb. 11, 13, 15-16, and Feb. 19, 2017 with the following scope: reconnaissance; control survey; cross-section and as-built survey of Dolores Bridge in Brgy. Carolina, Can-Avid, Eastern Samar; and bathymetric survey of the river from the upstream in Brgy. Tanauan, Dolores to the mouth of the river in Brgy. 12 (Poblacion), Dolores, Eastern Samar with an approximate length of 15.57 km. Random checking points for the contractor's cross-section and bathymetry data were gathered by DVBC on January27–February 9, 2017 using an Ohmex™ Single Beam Echo Sounder and Trimble® SPS 985 GNSS PPK survey technique. In addition to this, validation points acquisition survey was conducted covering the Dolores River Basin area. The entire survey extent is illustrated in Figure 25.

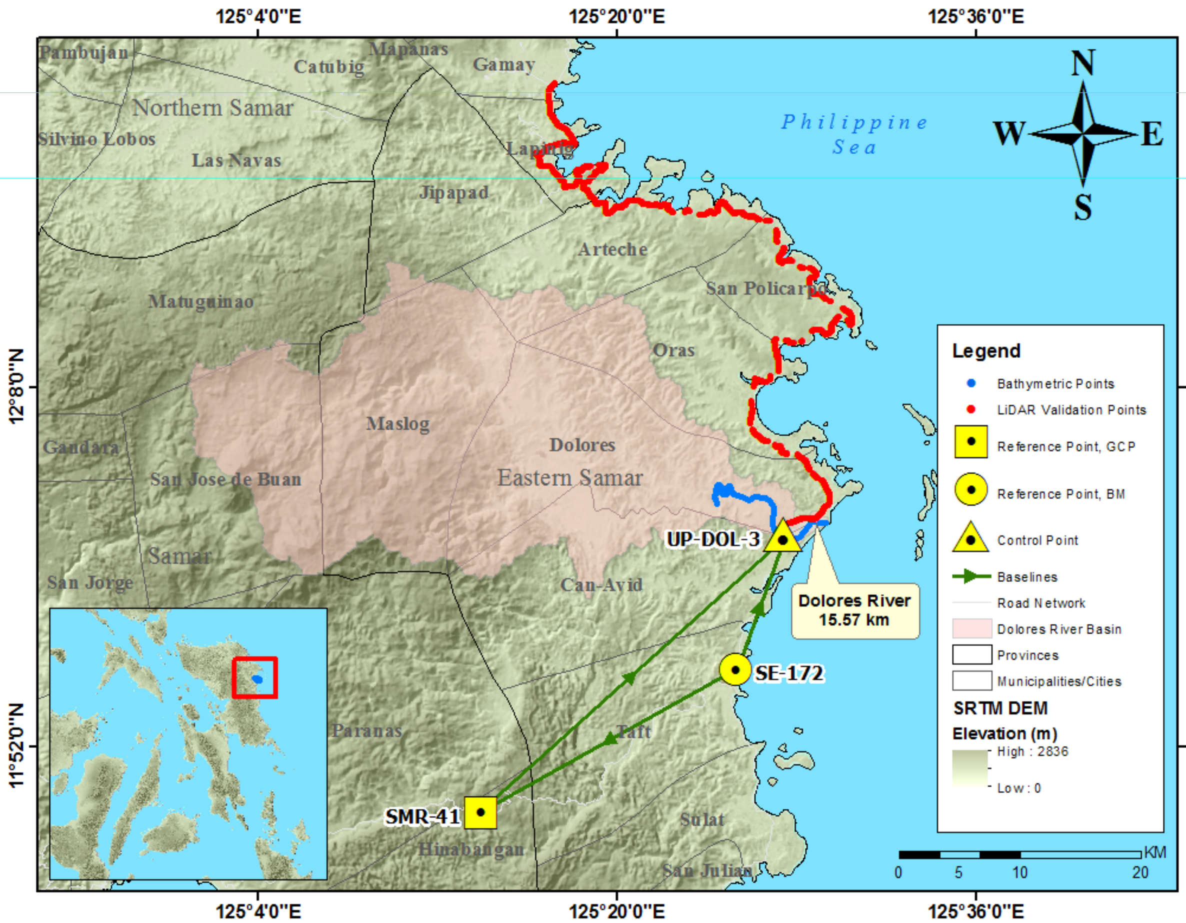


Figure 25. Dolores River Survey Extent

4.2 Control Survey

The GNSS network used for Dolores River is composed of one (1) loop established on February 3, 2017 occupying the following reference points: SMR-41, a second-order GCP, in Brgy. Bagacay, Hinabangan, Eastern Samar and SE-172, a first-order BM in Brgy. Nato, Taft, Eastern Samar.

One (1) control point established in the area by HONS was also occupied: UP-DOL-3, located at the approach of Dolores Bridge in Brgy. 1 (Poblacion), Dolores, Eastern Samar.

The summary of reference and control points and its location is summarized in Table 15 while GNSS network established is illustrated in Figure 26.

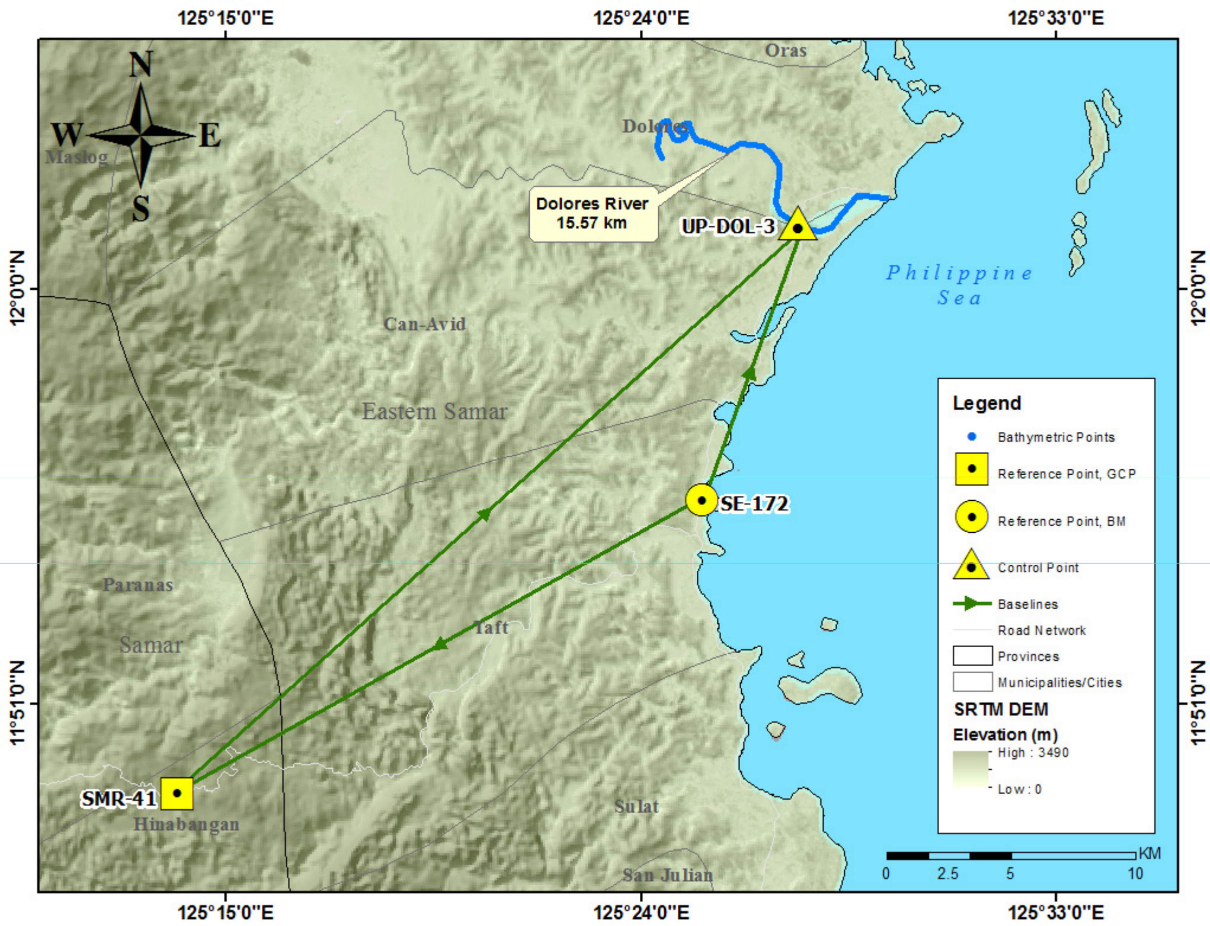


Figure 26. Dolores River Basin Control Survey Extent

Table 15. List of reference and control points used during the survey in Dolores River (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
SMR-41	2nd Order, GCP	11°49'03.09527"	125°13'56.04673"	-	171.203	2007
SE-172	1st Order, BM	11°55'25.95793"	125°25'18.96212"	-	3.155	2007
UP-DOL-3	Established	-	-	-	-	10-12-16

The GNSS set-ups on recovered reference points and established control points in Dolores River are shown from Figure 27 to Figure 29.

Figure 27. GNSS base set up, Trimble® SPS 985, at SMR-41, located 20 m SW from the flagpole in Bagacay Elementary School playground in Brgy. Bagacay, Hinabangan, Eastern Samar

Figure 28. GNSS receiver set up, Trimble® SPS 885, at SE-172, located beside the walkway leading to the office of Nato Elementary School in Brgy. Nato, Taft, Eastern Samar

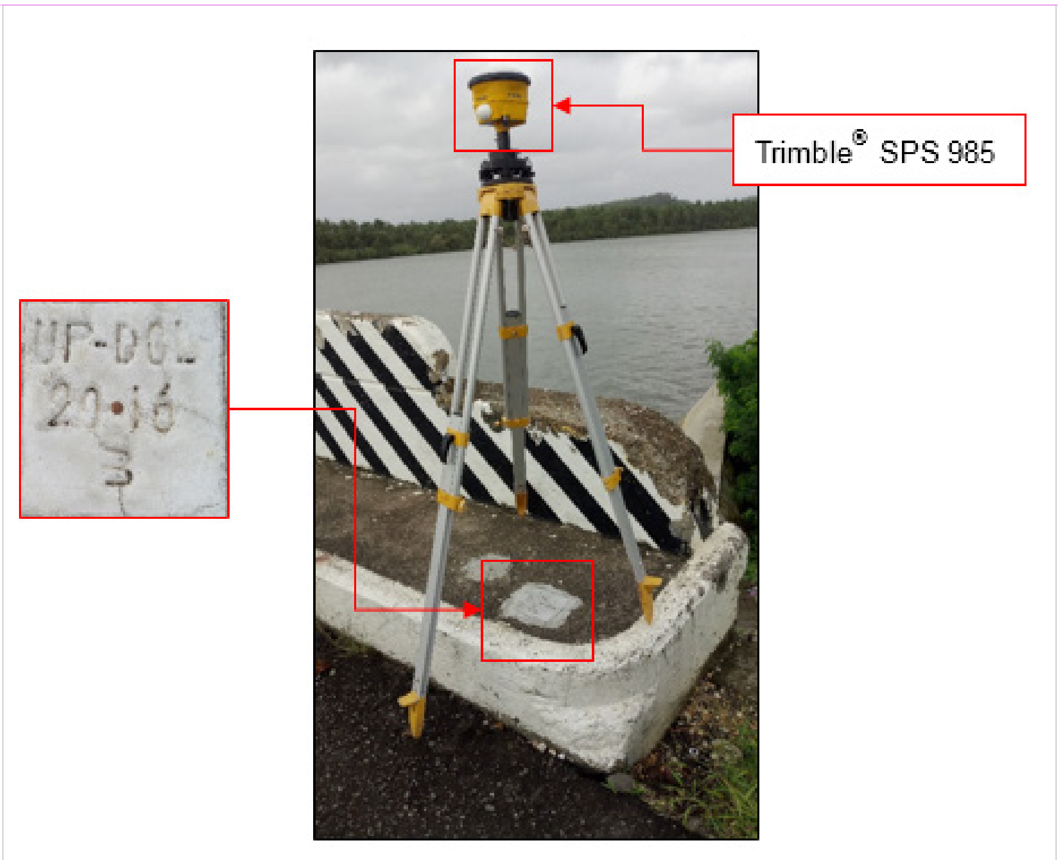


Figure 29. GNSS receiver set up, Trimble® SPS 985, at UP-DOL-3, located at the approach of Dolores Bridge in Brgy. 1 (Poblacion), Dolores, Eastern Samar

4.3 Baseline Processing

GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement, respectively. In case where one or more baselines did not meet all of these criteria, masking was performed. Masking is done by removing/masking portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. Baseline processing result of control points in Dolores River Basin is summarized in Table 16 generated by TBC software.

Table 16. Baseline Processing Report for Dolores River Static Survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	Height (m)
SE-172 --- SMR-41	2-3-2017	Fixed	0.003	0.017	240°22'16"	23782.986	170.788
SE-172--- UP-DOL-3	2-3-2017	Fixed	0.003	0.014	18°55'25"	11711.323	1.881
SMR-41--- UP-DOL-3	2-3-2017	Fixed	0.003	0.017	46°56'26"	33471.448	-168.907
SE-172--- UP-DOL-3	2-3-2017	Fixed	0.008	0.017	18°55'25"	11711.319	1.884
SMR-41--- UP-DOL-3	2-3-2017	Fixed	0.010	0.020	46°56'26"	33471.446	-168.945

As shown Table 16 a total of five (5) baselines were processed with coordinate and elevation values of SMR-41 and SE-172 held fixed. All of them passed the required accuracy.

4.4 Network Adjustment

Looking at the Adjusted Grid Coordinates table of the TBC generated Network Adjustment Report, it is observed that the square root of the squares of x and y must be less than 20 cm and z less than 10 cm in equation form:

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

Where:

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

for each control point. See the Network Adjustment Report shown from Table C- 3 to Table C- 5 for the complete details. Refer to Appendix C for the computation for the accuracy of HONS.

The three (3) control points, SMR-41, SE-172, and UP-DOL-3 were occupied and observed simultaneously to form a GNSS loop. The coordinate and elevation values of SMR-41 and SE-172were held fixed during the processing of the control points as presented in Table 17. Through this reference point, the coordinates and elevations of the unknown control points will be computed.

Table 17. Control Point Constraints

Point ID	Type	North (Meter)	East (Meter)	Height (Meter)	Elevation (Meter)
SE-172	Grid	Fixed	Fixed		Fixed
SMR-41	Grid	Fixed	Fixed		Fixed
Fixed = 0.000001(Meter)					

Table 18. Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
SE-172	763795.614	?	1319288.604	?	3.155	?	ENe
SMR-41	743218.063	?	1307346.858	?	171.203	?	ENe
UP-DOL-3	767497.878	0.005	1330404.771	0.004	6.392	0.019	

With the mentioned equation, $\sqrt{((x_e)^2 + (y_e)^2)} < 20$ cm for horizontal and $z_e < 10$ cm for the vertical; the computation for the accuracy are as follows:

a. SE-172

horizontal accuracy = Fixed
vertical accuracy = Fixed

b. SMR-41

horizontal accuracy = Fixed
vertical accuracy = Fixed

c. UP-DOL-3

horizontal accuracy = $\sqrt{((0.5)^2 + (0.4)^2}$
= $\sqrt{(0.25 + 0.16)}$
= 0.64< 20 cm
vertical accuracy = 1.9< 10 cm

Following the given formula, the horizontal and vertical accuracy results of the three (3)occupied control pointsare within the required precision.

Table 19. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
SE-172	N11°55'25.95793"	E125°25'18.96212"	61.761	?	ENe
SMR-41	N11°49'03.09527"	E125°13'56.04673"	232.562	?	ENe
UP-DOL-3	N12°01'26.46436"	E125°27'24.51951"	63.645	0.019	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 19. Based on the result of the computation, the equation is satisfied; hence, the required accuracy for the program was met.

The summary of reference control points used is indicated in Table 20.

Table 20. Reference and control points used and its location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoid Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
SMR-41	2nd Order, GCP	11°49'03.09527"	125°13'56.04673"	232.562	1307346.858	743218.063	171.203
SE-172	1st Order, BM	11°55'25.95793"	125°25'18.96212"	61.761	1319288.604	763795.614	3.155
UP-DOL-3	Established	12°01'26.46436"	125°27'24.51951"	63.645	1330404.771	767497.878	6.392

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

Cross-section and as-built surveys were conducted on February 10, 2017 at the downstream side of Dolores Bridge in Brgy. Carolina, Can-Avid, Eastern Samar as shown in Figure 30. A Hi-Target™ V30 GNSS in RTK survey technique was utilized for this survey as shown in Figure 31.The Automated Water Level System (AWLS) is located on the downstream side of the bridge and its elevation was measured 9.996 m above MSL.

Figure 30. Dolores Bridge facing upstream

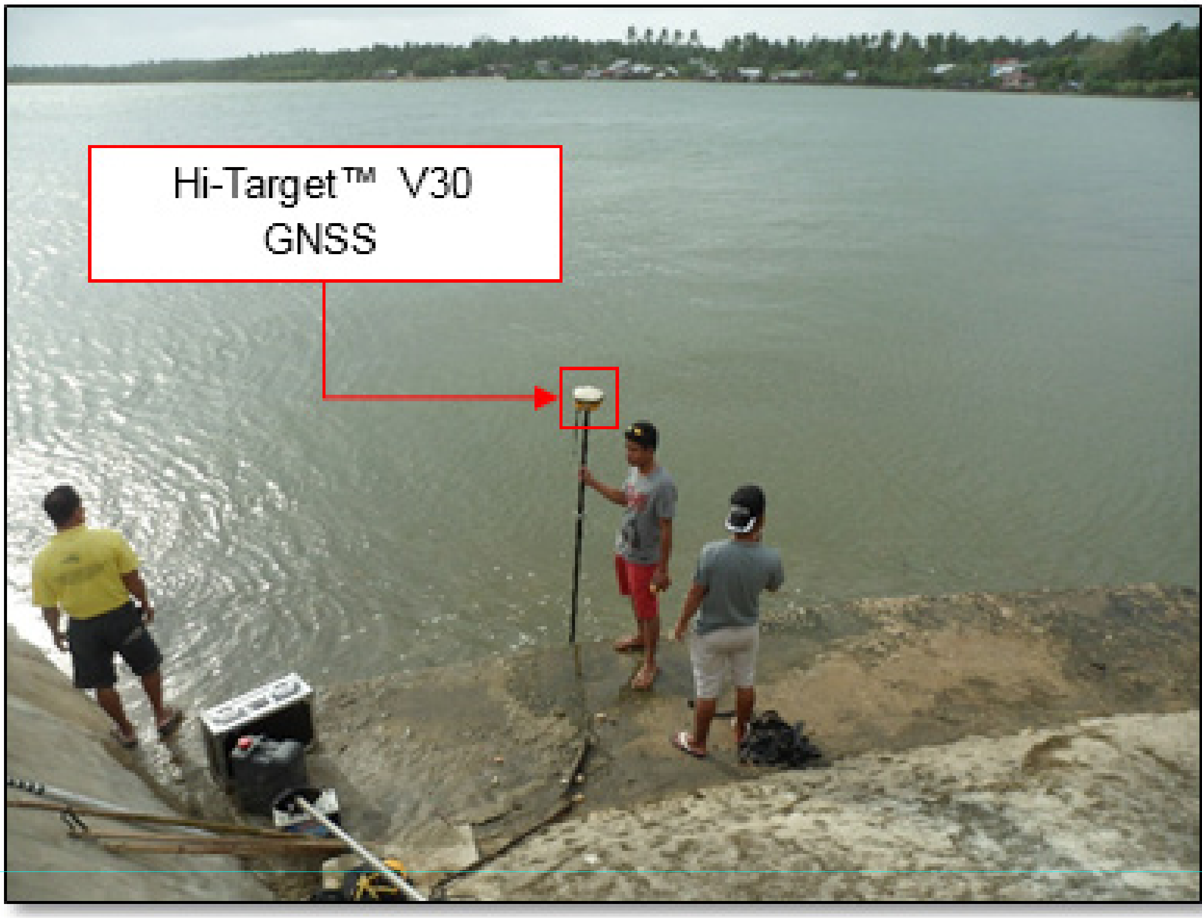


Figure 31. As-built survey of Dolores Bridge

The cross-sectional line of Dolores Bridgeis about 322 m with six hundred eighteen (618) cross-sectional points using the control points UP-DOL-4 as the GNSS base station. The cross-section diagram, location map, and the bridge data form are shown in Figure 33 to Figure 35.

Gathering of random points for the checking of HONS's bridge cross-section and bridge points data was performed by DVBC on February 4, 2017 using a survey grade GNSS Rover receiver attached to a 2-m pole as seen in Figure 32.

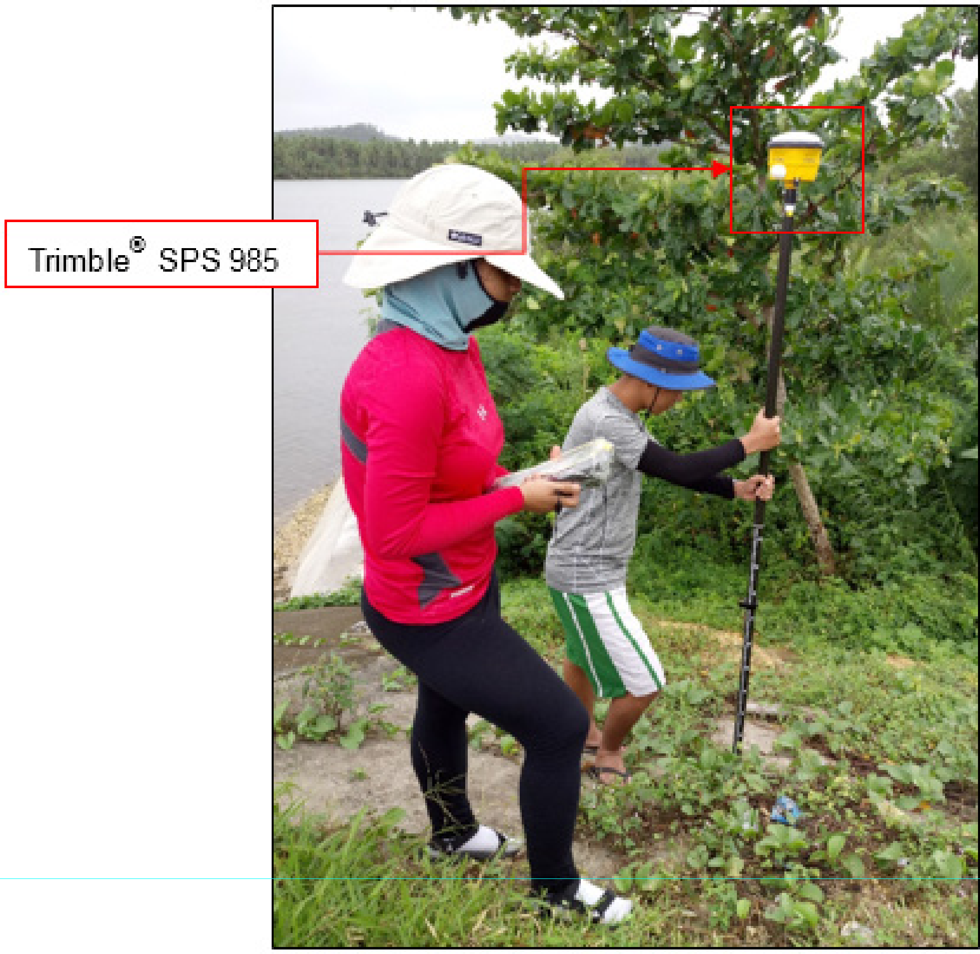


Figure 32. Gathering of random cross-section points along Dolores Bridge

Linear square correlation (R2) and RMSE analysis were performed on the two (2) datasets. The linear square coefficient range is determined to ensure that the submitted data of the contractor is within the accuracy standard of the project which is ±20 cm and ±10 cm for horizontal and vertical, respectively. The R2 value must be within 0.85 to 1. An R2 approaching 1 signifies a strong correlation between the vertical (elevation values) of the two datasets. A computed R2value of 0.989 was obtained by comparing the data of the contractor and DVBC; signifying a strong correlation between the two (2) datasets.

In addition to the Linear Square correlation, Root Mean Square (RMSE) analysis is also performed in order to assess the difference in elevation between the DVBC checking points and the contractor's.The RMSE value should only have a maximum radial distance of 5 m and the difference in elevation within the radius of 5 meters should not be beyond 0.50 m. For the bridge cross-section data, a computed value of 0.330 was acquired. The computed R2 and RMSE values are within the accuracy requirement of the program.

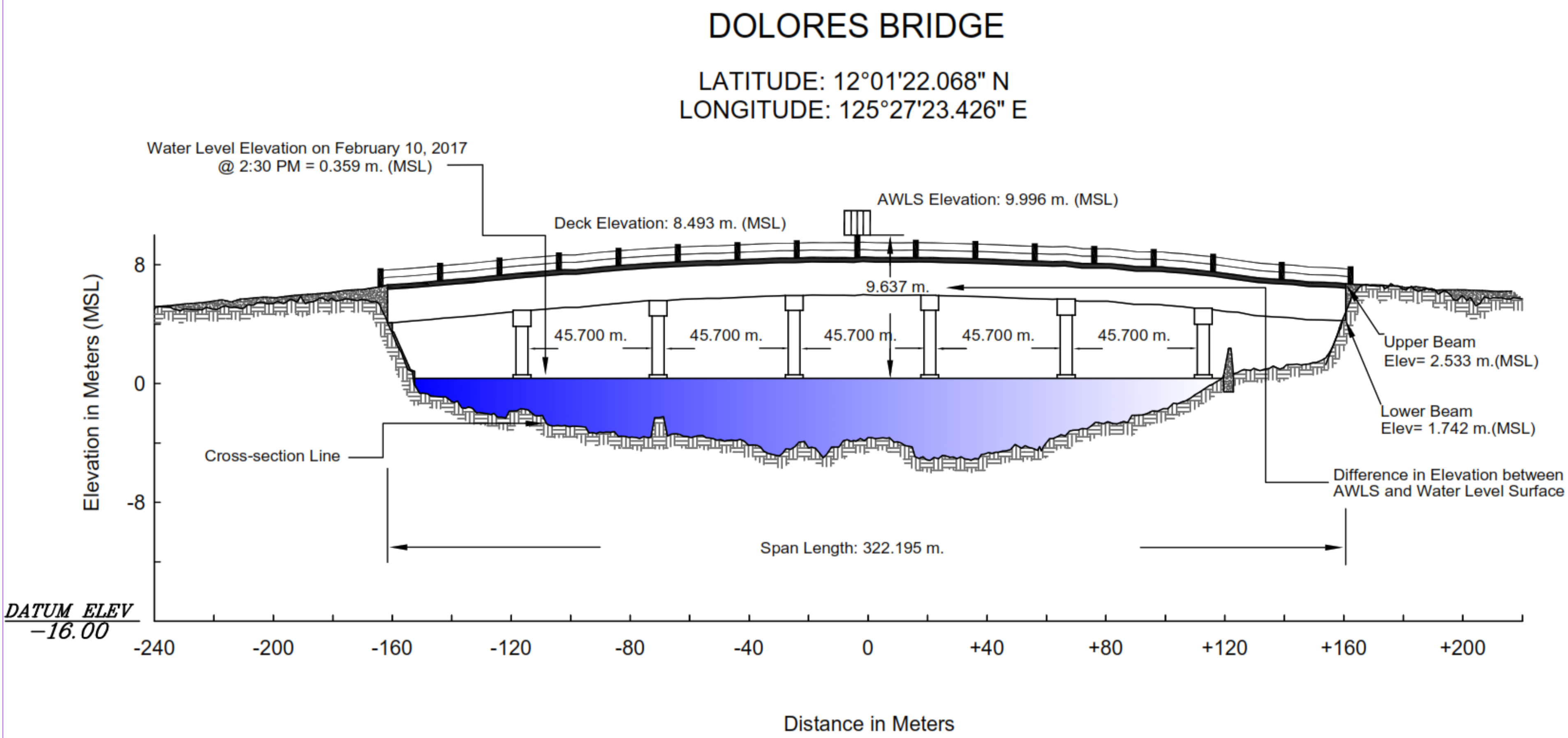


Figure 33. Dolores Bridge Cross-section Diagram

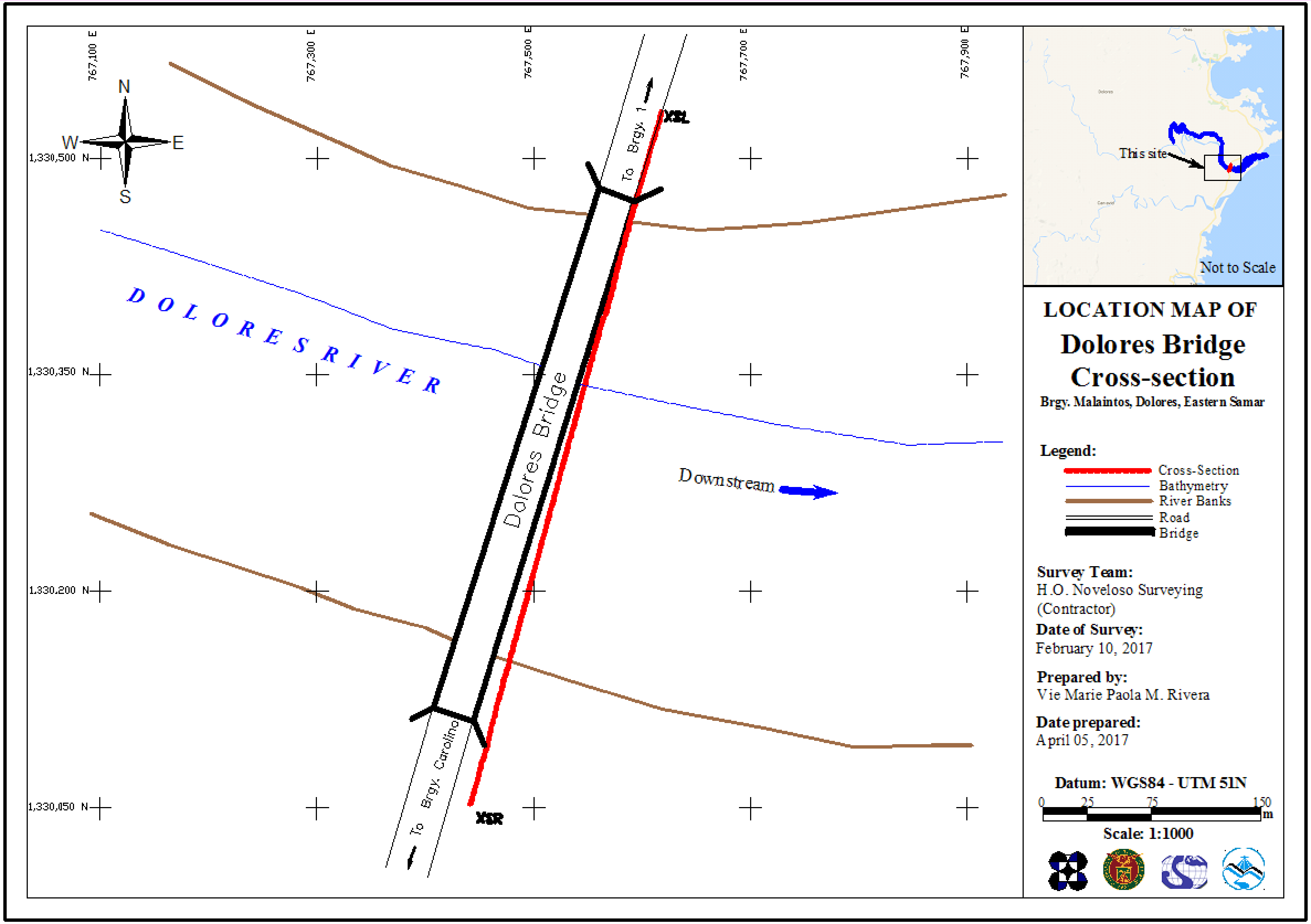


Figure 34. Dolores Bridge Cross-section Diagram

BRIDGE DATA FORM

Bridge Name: Dolores Bridge

River Name: Dolores River

Location (Brgy., City, Region): Brgy. Carolina, Can-Avid, Province of Eastern Samar

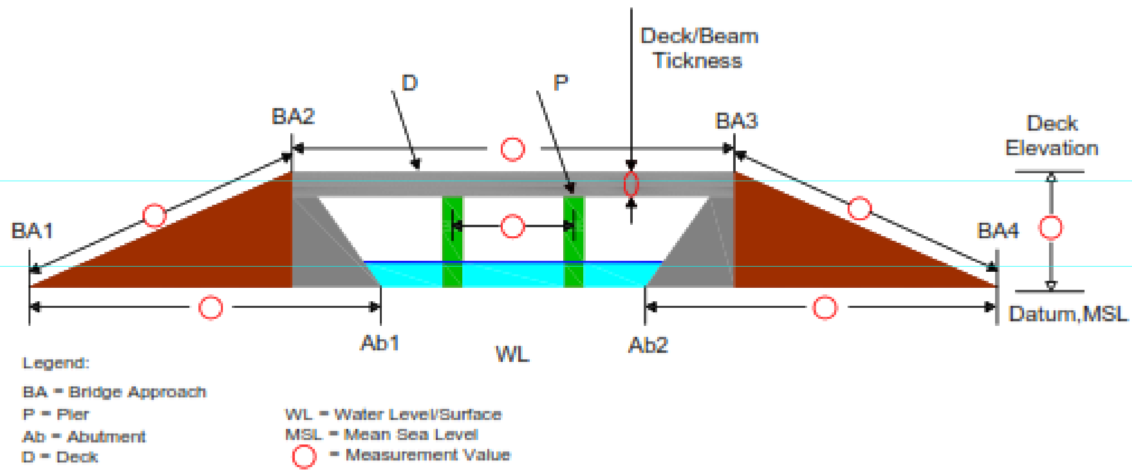
Survey Team: Julieto Cabilin, Urbano Castillo, Jodel dela Cruz, Oscar Agustin, Rhey Joseph Domingo, and Eduardo Cuizon

Date and Time: February 10, 2017 @ 8:00 AM - 5:00 PM

Flow Condition: Low <u>Normal</u> High

Weather Condition: <u>Fair</u> Rainy

Cross-sectional View (not to scale)



Line Segment	Measurement, m	Remarks	Line Segment	Measurement, m	Remarks
1. BA1-BA2	2.349 m.	Concrete Pavement	11. P4-P5	45.700 m.	Concrete
2. BA2-BA3	322.195 m.	Wooden Deck	12. P5-P6	45.700 m.	Concrete
3. BA3-BA4	1.684 m.	Concrete			
4. BA1-Ab1	11.464 m.	Concrete			
5. Ab2-BA4	8.400 m.	Concrete			
6. Beam thickness	0.522 m.	Steel Beam			
7. Deck Elevation	8.493 MSL	Wooden Deck			
8. P1-P2	45.700 m.	Concrete			
9. P2-P3	45.700 m.	Concrete			
10. P3-P4	45.700 m.	Concrete			

Note: Observer should be facing downstream

Figure 35. Dolores Bridge Data Sheet

Water surface elevation of Dolores River was determined by a Sokkia™ Set CX Total Station on February 10, 2017 at the railings of Dolores Bridge in Brgy. Carolina, Can-avid, Eastern Samar with a value of 8.535 m in MSL. This was translated into marking on the bridge's sidewalk 2.5 m away from the centerline as shown in Figure 36.

Figure 36. Water surface elevation marking on Dolores Bridge sidewalk

Water surface elevation of Dolores River was also determined by a Sokkia™ Set CX Total Station on February 10, 2017 at 2:30 PM at Dolores Bridge area with a value of 0.359 m in MSL as shown in Figure 34. This was translated into marking on the bridge's pier as shown in Figure 37.The markings will serve as reference for flow data gathering and depth gauge deployment of the partner HEI responsible for Dolores River, the Visayas State University.

Figure 37. Water level markings on the pier of Dolores Bridge

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted by DVBC onFebruary 5, 2017 using a survey grade GNSS Rover receiver, Trimble® SPS 985, mounted on a range pole which was attached on the front of the vehicle as shown in Figure 38.It was secured with cable ties and ropes to ensure that it was horizontally and vertically balanced. The antenna height was 2.188 m and measured from the ground up to the bottom of the antenna mount of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with UP-ORA-5 occupied as the GNSS base station in the conduct of the survey.

Figure 38. Validation points acquisition survey set-up for Dolores River.

The survey started from Brgy. Cagamutan Del Norte, Gamay, Northern Samar going southeast along the national highway, covering 1 (1) barangay inGamay, Northern Samar, eleven (11) barangays in Lapinig, nine (9) barangays in Arteche, Eastern Samar, twelve (12) barangays in San Policarpio, Eastern Samar, twelve (12) barangays in Oras, Eastern Samar, twelve (12) barangays in Dolores, Eastern Samar, and ended in Brgy. Carolina, Can-Avid, Eastern Samar. The survey gathered a total of 11,695 points with approximate length of 54.53 km using UP-ORA-5 as GNSS base station for the entire extent of validation points acquisition survey as illustrated in the map in Figure 39.

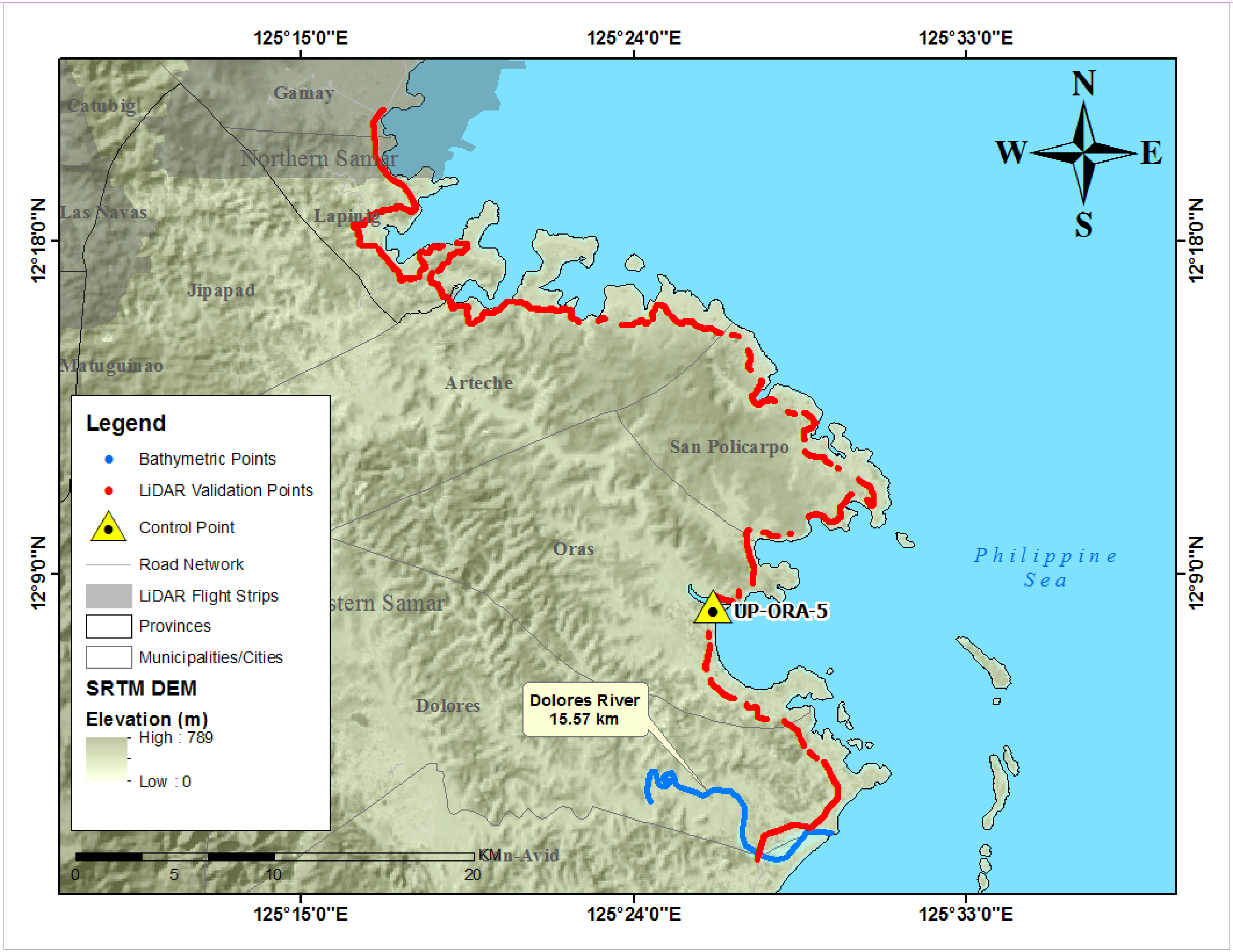


Figure 39. Validation points acquisition covering the Dolores Basin Area

4.7 Bathymetric Survey

Bathymetric survey was executed on February 11, 13, 15-16, and 19, 2017 using a dual frequency Hi-Target™ V30 GNSS and a Hi-Target™ Single Beam Echo Sounder mounted in a motor boat as illustrated in Figure 40. The survey started in Brgy. Tanauan, Dolores, Eastern Samar with coordinates 12°02' 45.5570"N, 125°24' 29.7711"E and ended at the mouth of the river in Brgy. 12 (Poblacion), also in the Municipality of Dolores with coordinates 12°01'58.7110"N, 125°29'17.4607"E. The control points UP-DOL-1, UP-DOL-3, and UP-ORA-6 were used as the GNSS base stations throughout the survey.

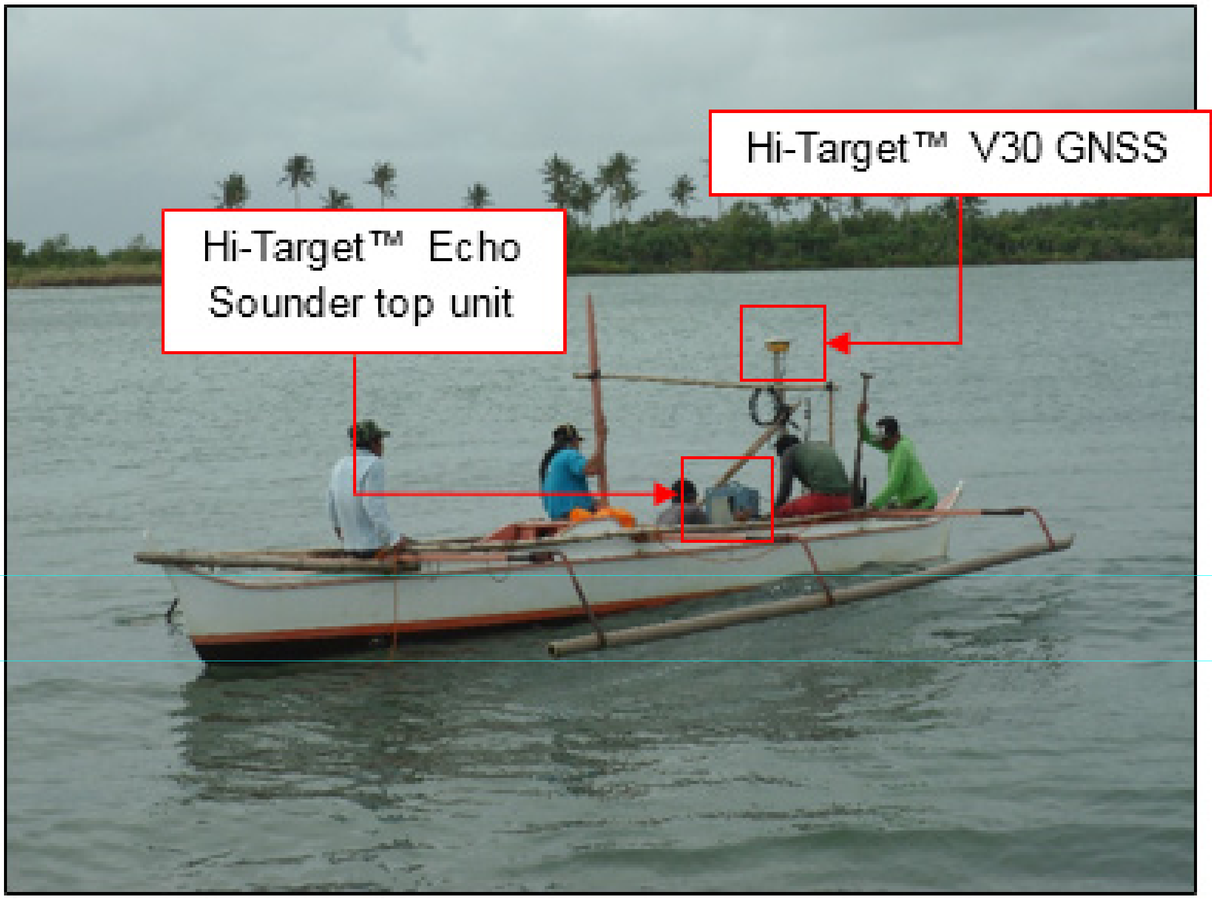


Figure 40. Bathymetric survey of HONS along Dolores River

Gathering of random points for the checking of HONS's bathymetric data was performed by DVBC on February 4, 2017 using a survey grade GNSS Rover receiver attached to a boat as seen in Figure 41. A map showing the DVBC bathymetric checking points is shown in Figure 43.

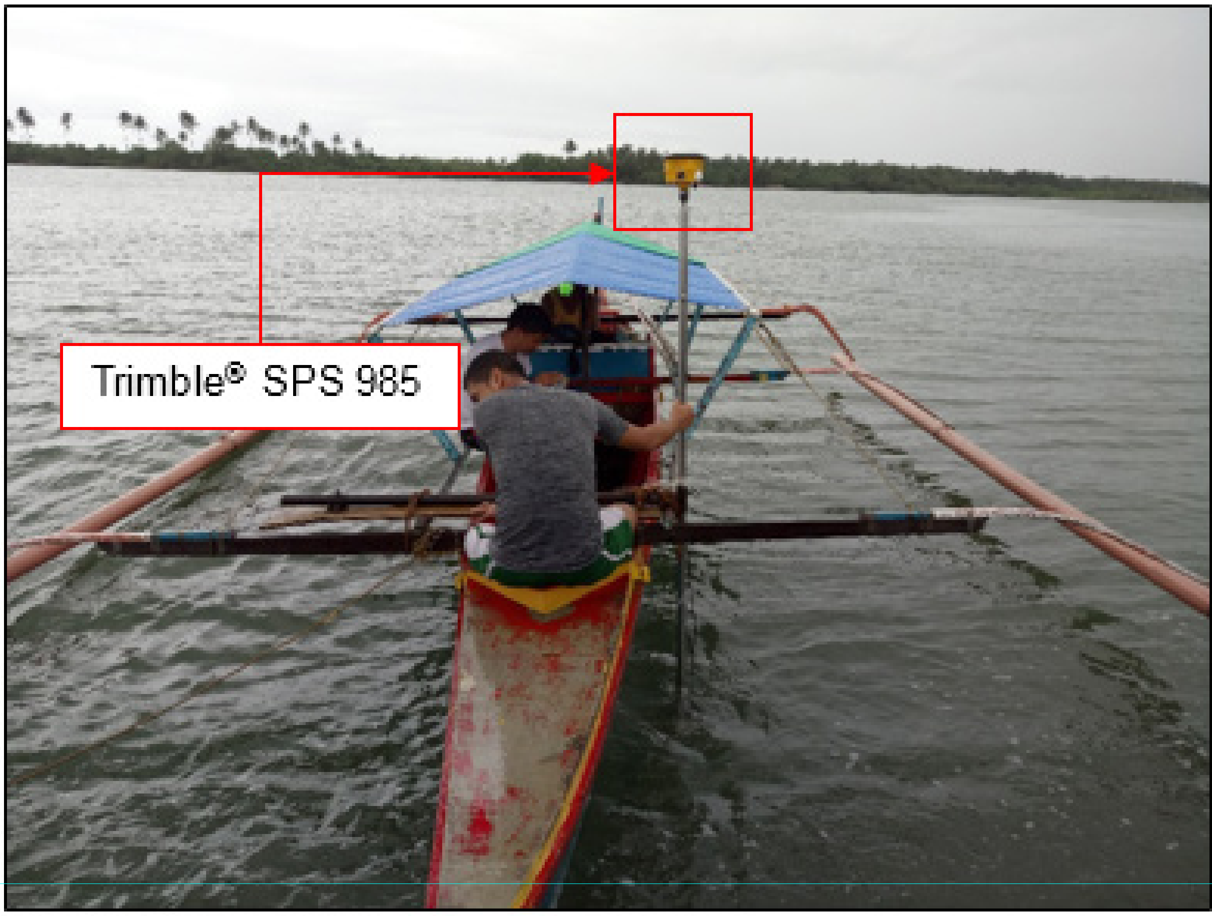


Figure 41. Gathering of random bathymetric points along Dolores River

Linear square correlation (R2) and RMSE analysis were also performed on the two (2) datasets and a computed R2value of 0.950 for the bathymetric data is within the required range for R2, which is 0.85 to 1. Additionally, an RMSE value of 0.333 for the bathymetric data was obtained. Both the computed R2 and RMSE values are within the accuracy required by the program.

The bathymetric survey for Dolores River gathered a total of 14,935 points covering 15.57 km of the river traversing barangays Dampigan, 1 (Poblacion), 2 (Poblacion), 10 (Poblacion), 12 (Poblacion), Santo Niño, Bonghon, Malaintos, Tanauan, and Santo Niño in the Municipality of Dolores and barangays Carolina and Rawis in the Municipality of Can-Avid. A CAD drawing was also produced to illustrate the riverbed profile of Dolores River. As shown in Figure 44, the highest and lowest elevation has a 14.75-m difference. The highest elevation observed was -1.561 m below MSL located in Brgy. Rawis, Dolores, Eastern Samar while the lowest was –16.314 m below MSL located in Brgy. Santo Niño, Dolores, Eastern Samar.

Figure 42. Bathymetric survey of Dolores River

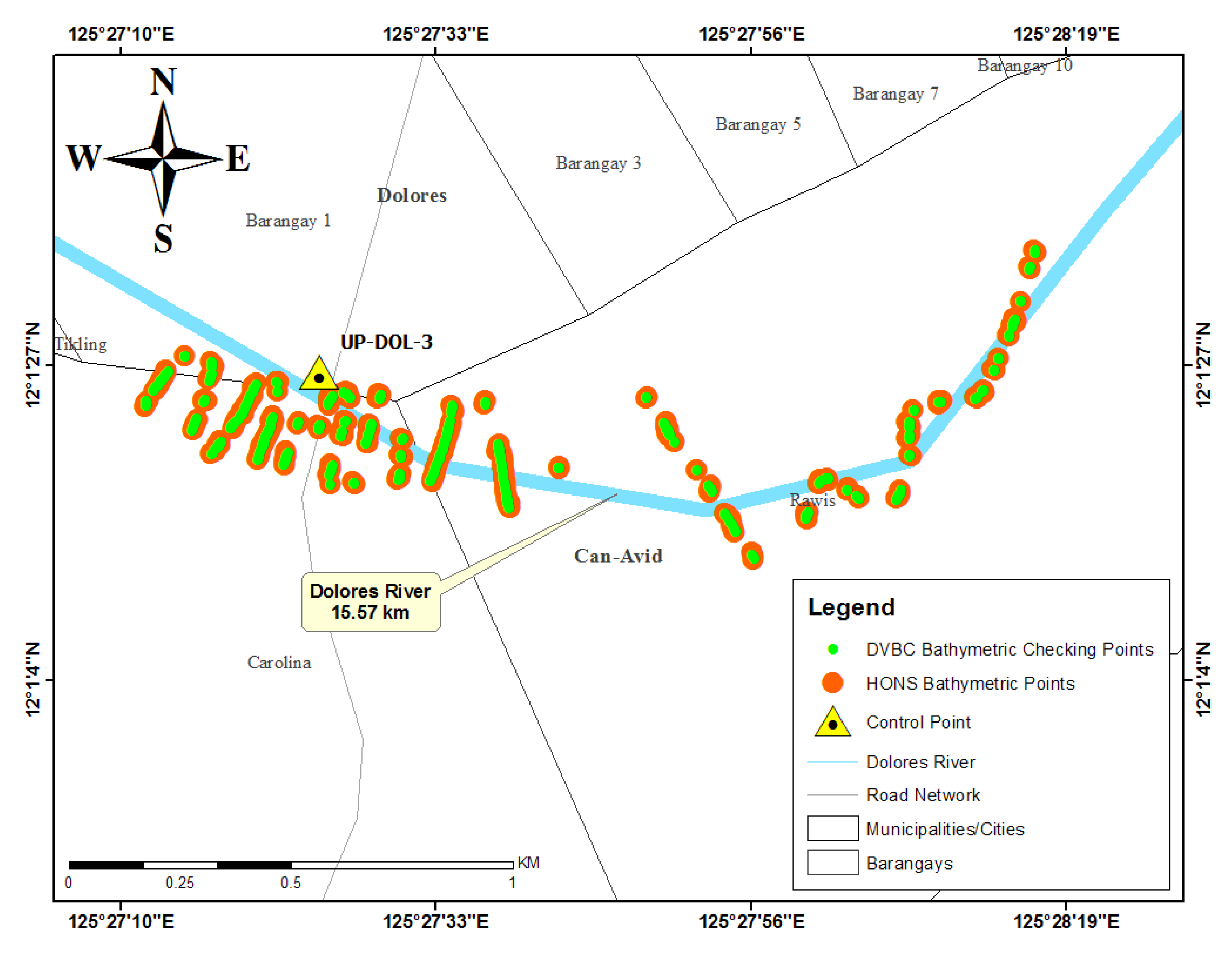


Figure 43. Quality checking points gathered along Dolores River by DVBC

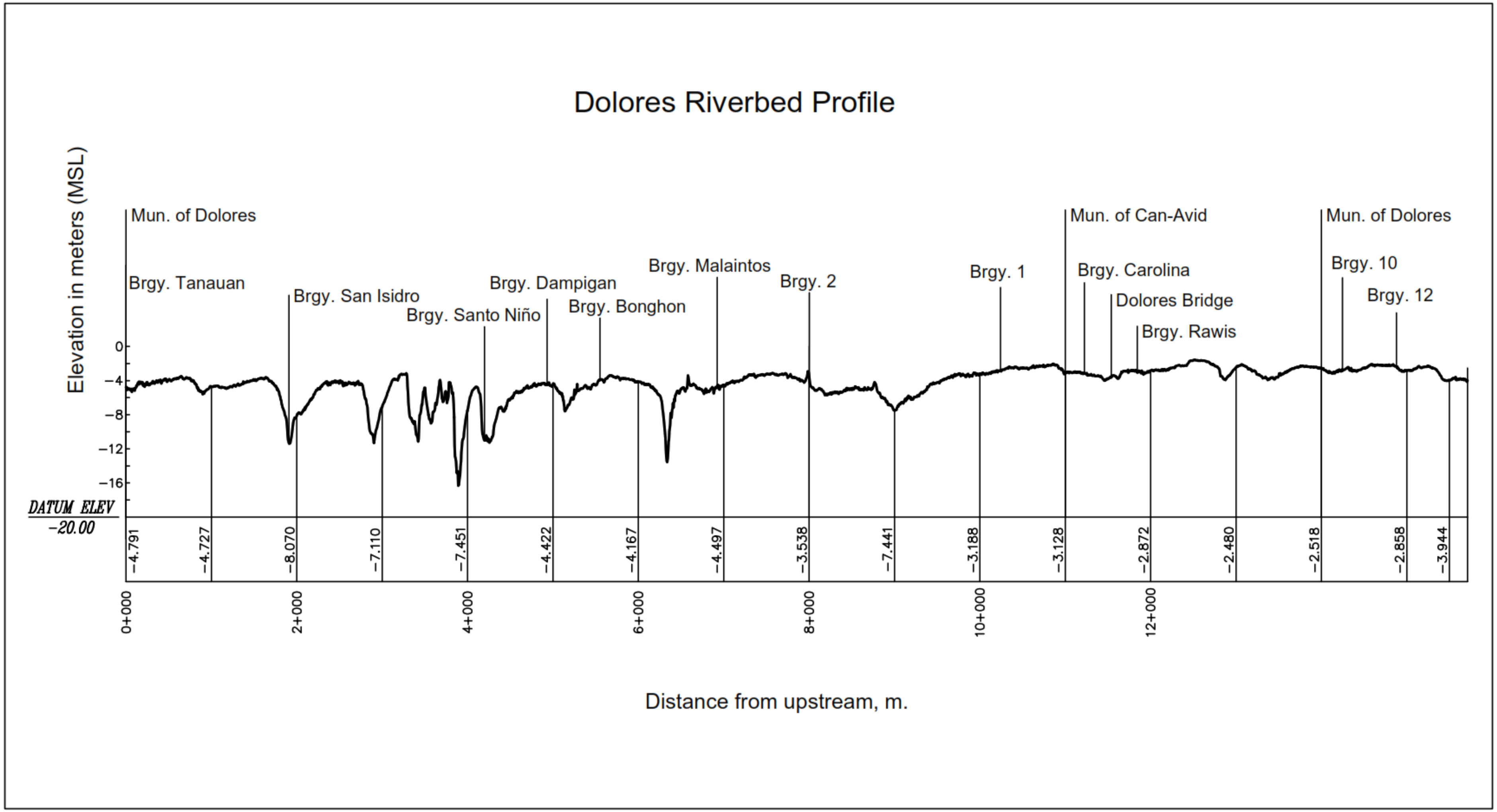


Figure 44. Dolores Riverbed Profile

CHAPTER 5: FLOOD MODELING AND MAPPING

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

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. These include the rainfall, water level, and flow in a certain period of time.

5.1.2 Precipitation

Precipitation data was taken from the automatic rain gauge (ARG) installed by the Flood modeling Component at Brgy. Malinao, Dolores, Eastern Samar. The location of the rain gauges is seen in Figure 45.

Total rain from Malinao rain gauge is 173.8 mm. It peaked to 10.2 mm on 30 July 2016, 7:00 to 7:15 PM. A summary of the data is seen in Table 1.1. The lag time between the peak rainfall and discharge is five hours and fifty minutes, as seen in Figure 6.

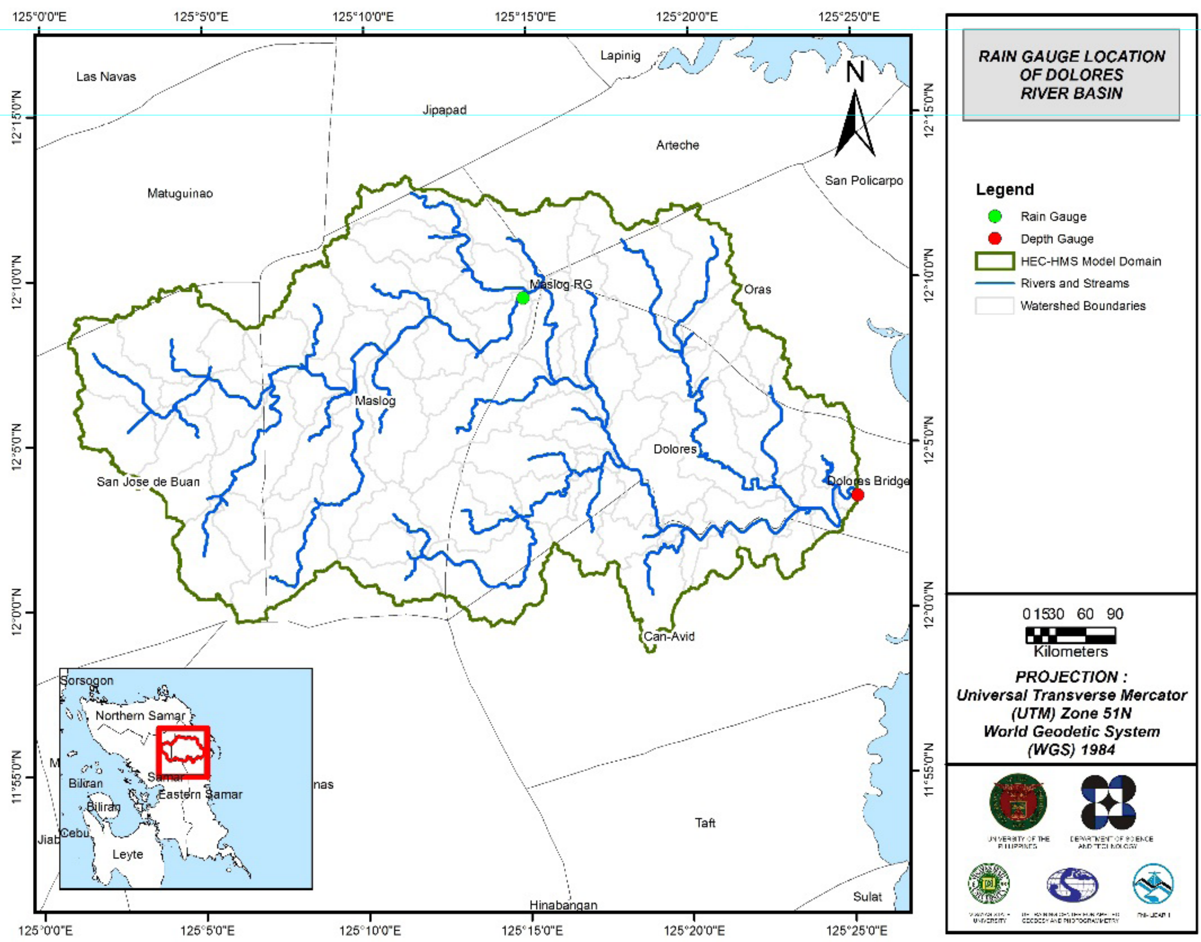


Figure 45. The location map of Dolores HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Dolores Bridge, Dolores, Eastern Samar. It gives the relationship between the observed water levels from the depth gauge deployed at Dolores Bridge and outflow of the watershed at this location. It is expressed in the form of the following equation:

$$Q = anh$$

where,

Q: Discharge (m^3/s),
h: Gauge height (reading from Dolores Bridge depth gauge), and
a and n: Constants.

For Dolores Bridge, the rating curve is expressed as $Q = 1E\text{-}21e^{14.076h}$ as shown in Figure .

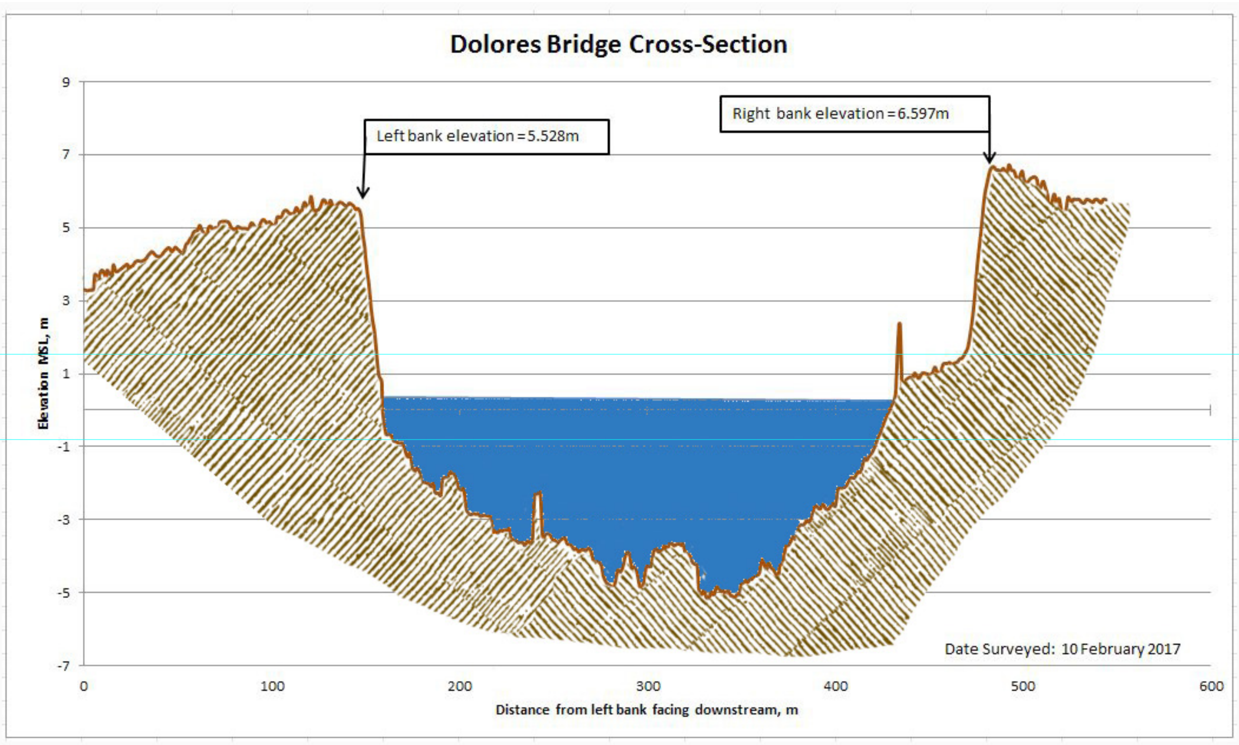


Figure 46. Cross-Section Plot of Dolores Bridge

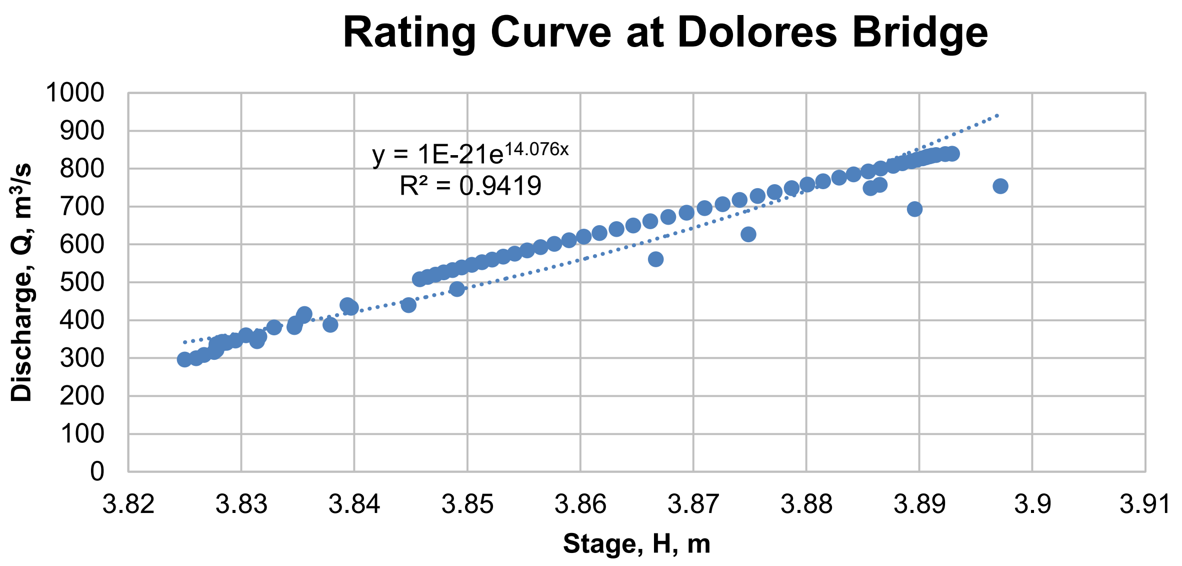


Figure 47. Rating Curve at Dolores Bridge

The resulting rating curve equation was used to compute the river outflow at Dolores Bridge for the calibration of the HEC-HMS model shown in Figure 47. Peak discharge is 838.9 cu.m/s at 12:40 PM, December 30, 2014.

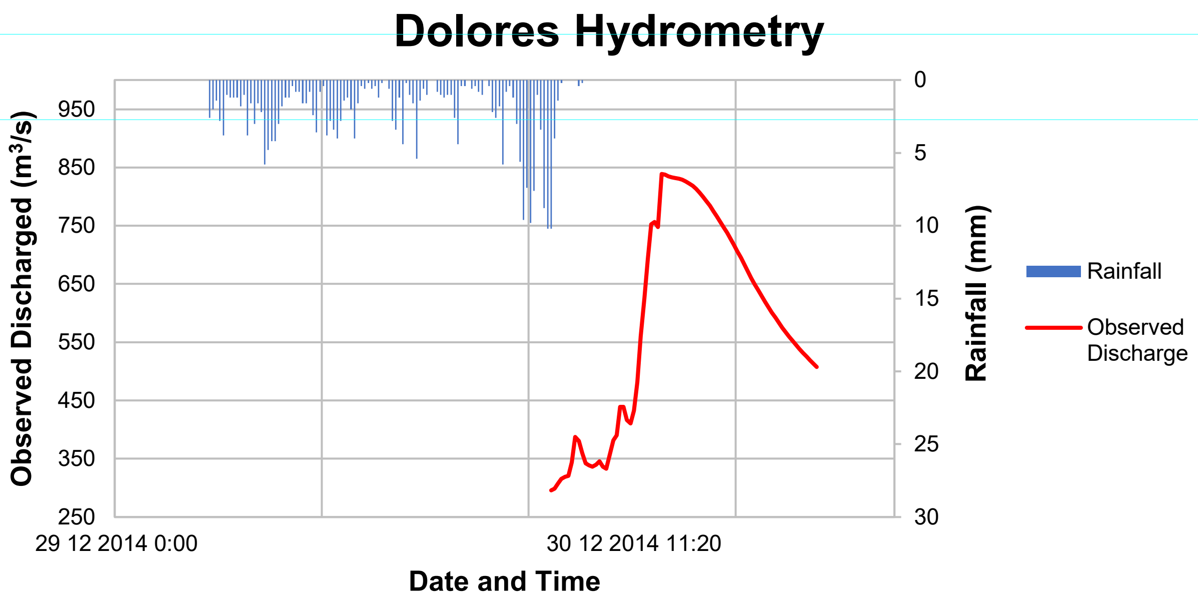


Figure 48. Rainfall and outflow data at Dolores Bridge used for modelng

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Catbalogan Rain Gauge. This station chosen based on its proximity to the Dolores watershed. The extreme values for this watershed were computed based on a 26-year record.

Table 21. RIDF values for Catbalogan 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	18.5	28.1	35.6	48.1	68	82.1	104.6	124.9	145
5	25.9	38.3	63.8	63.8	90.4	108.8	137.5	165.2	190.8
10	30.8	45	74.2	74.2	105.3	126.5	159.3	191.9	221.2
15	33.5	48.8	80.1	80.1	113.7	136.5	171.5	206.9	238.4
20	35.5	51.5	84.2	84.2	119.6	143.5	180.1	217.5	250.4
25	37	53.6	87.3	87.3	124.1	148.9	186.7	225.6	259.6
50	41.5	59.9	97.1	97.1	138.1	165.5	207.1	250.6	288.1
100	46.1	66.2	106.8	106.8	151.9	181.9	227.4	275.4	316.3

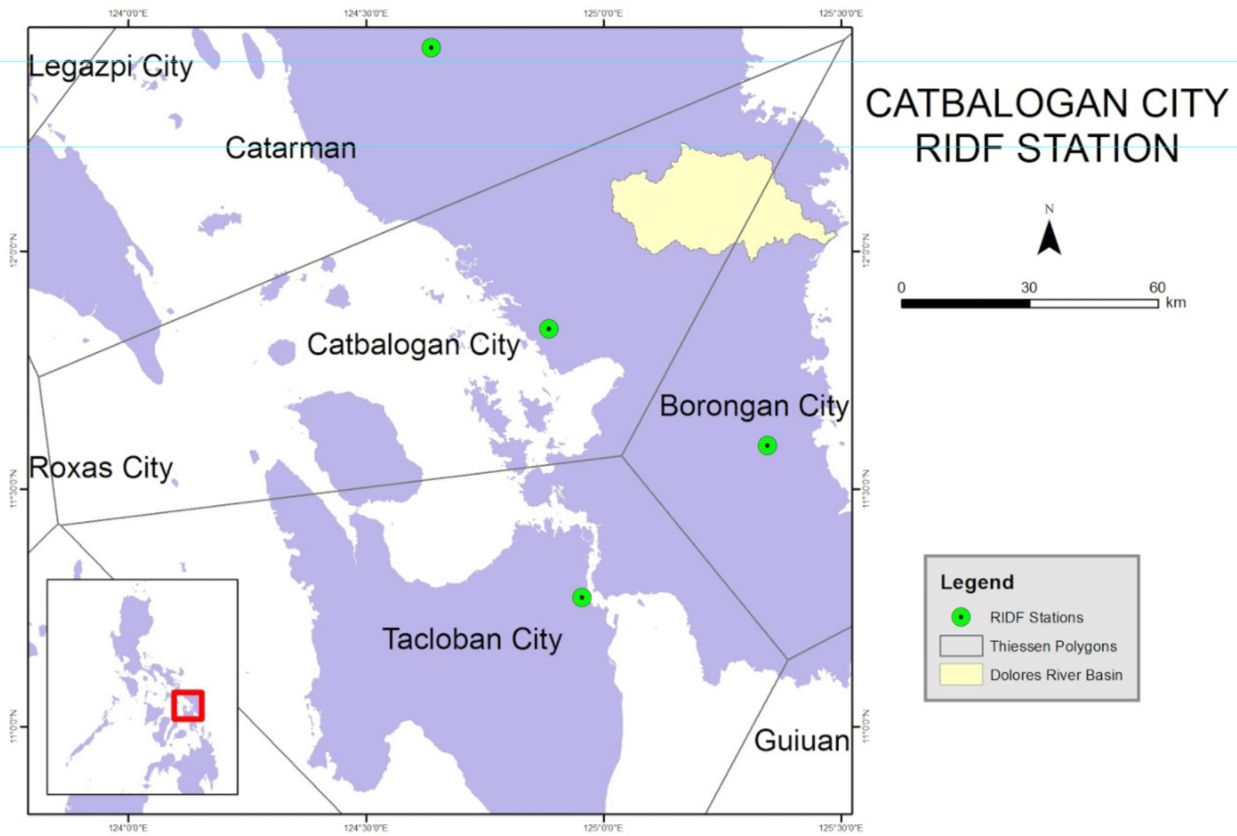


Figure 49. Location of Catbalogan RIDF station relative to Dolores River Basin

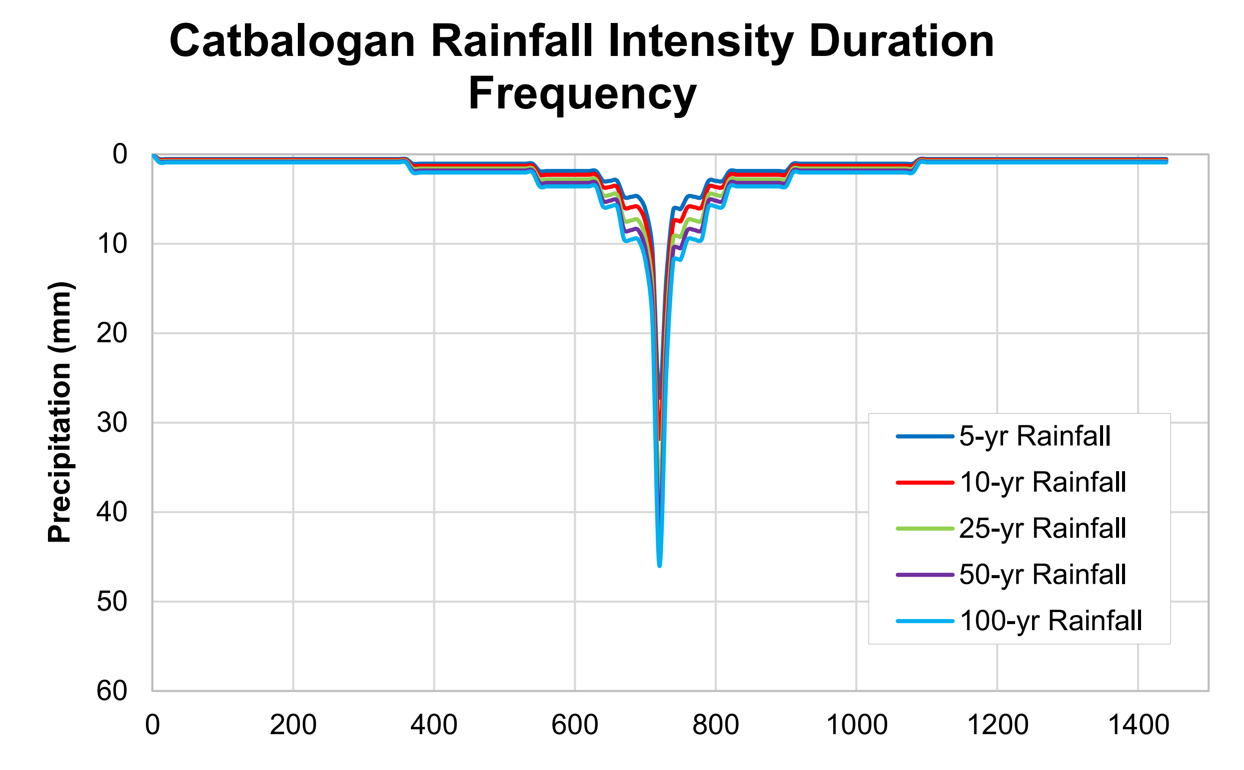


Figure 50. Synthetic storm generated for a 24-hr period rainfall for various return periods

5.3 HMS Model

The soil shape file was taken on 2004 from the Bureau of Soils; this is under the Department of Environment and Natural Resources Management. The land cover shape file is from the National Mapping and Resource information Authority (NAMRIA).

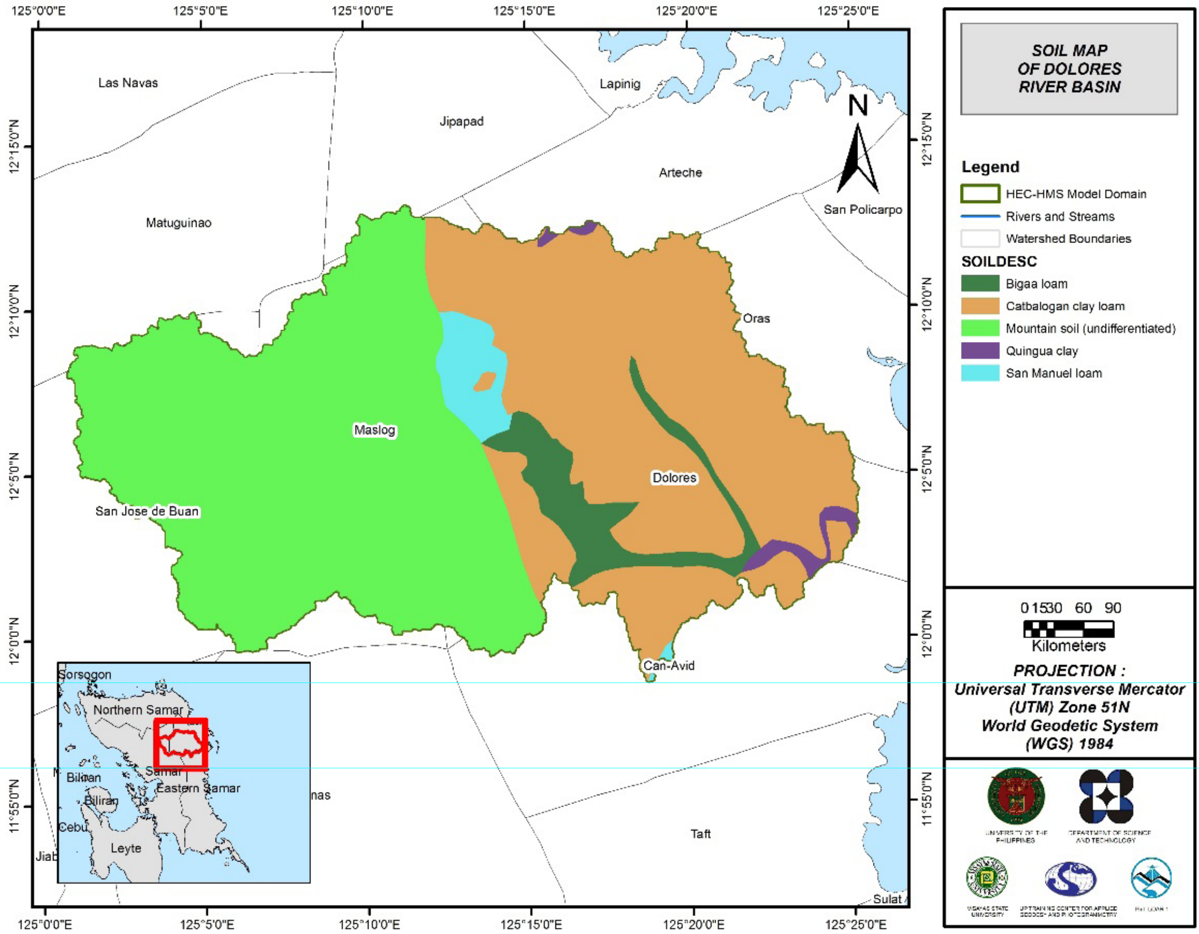


Figure 51. Soil Map of Dolores River Basin

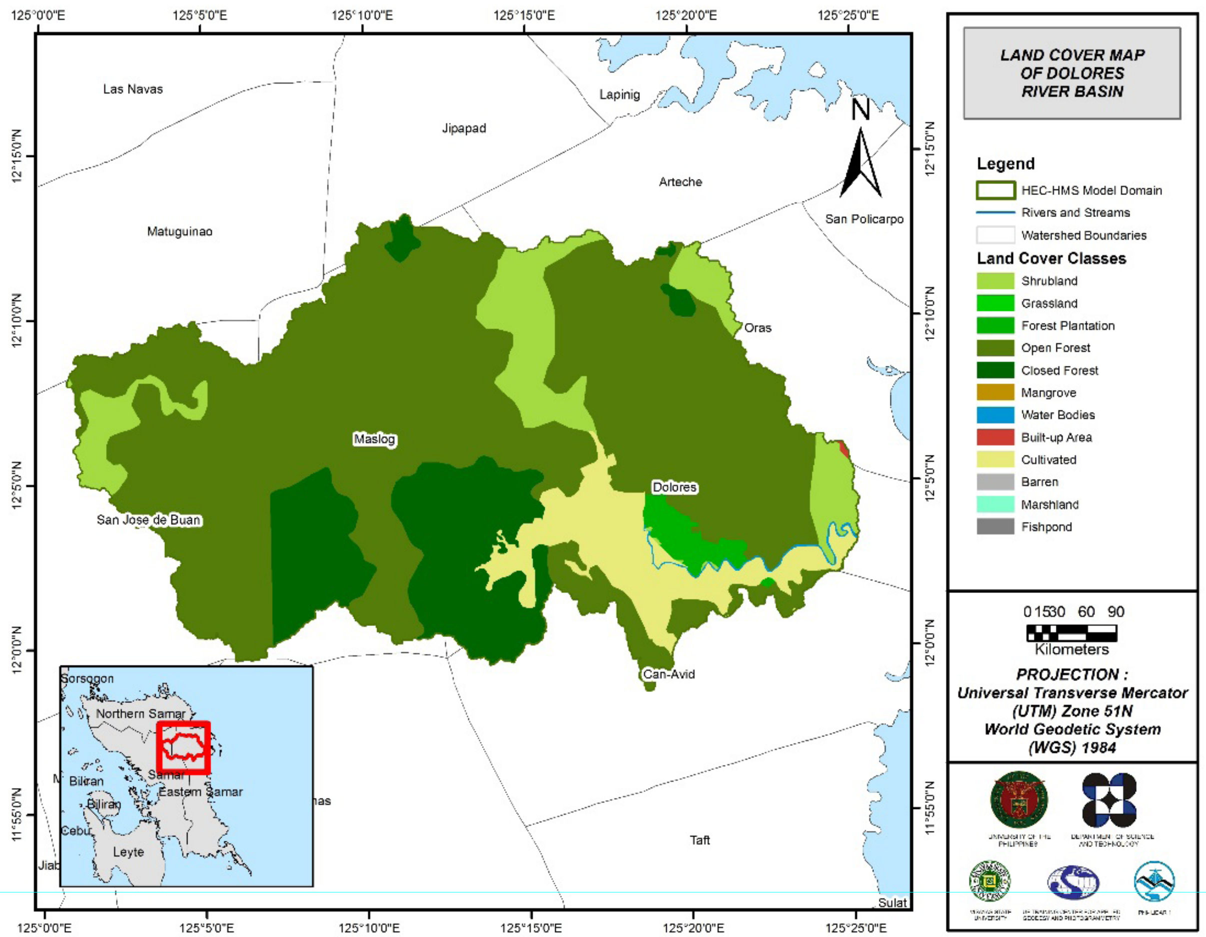


Figure 52. Land Cover Map of Dolores River Basin

For Dolores, the soil class identified were Bigaa loam, clay loam, mountain soil, clay and San Miguel loam. The land cover types identified were shrubland, forest plantation, open forest, closed forest, built-up area and cultivated.

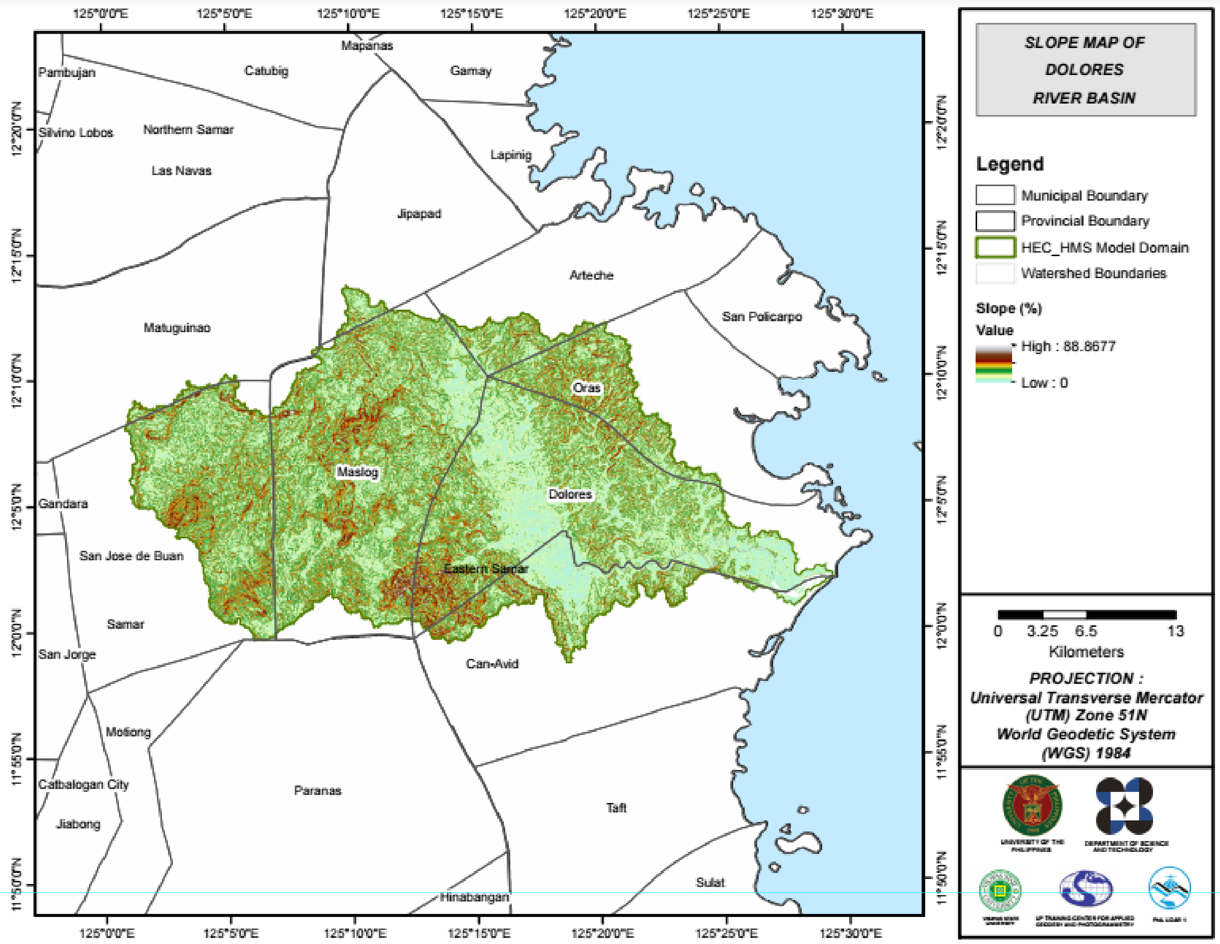


Figure 53. Slope Map of the Dolores River Basin

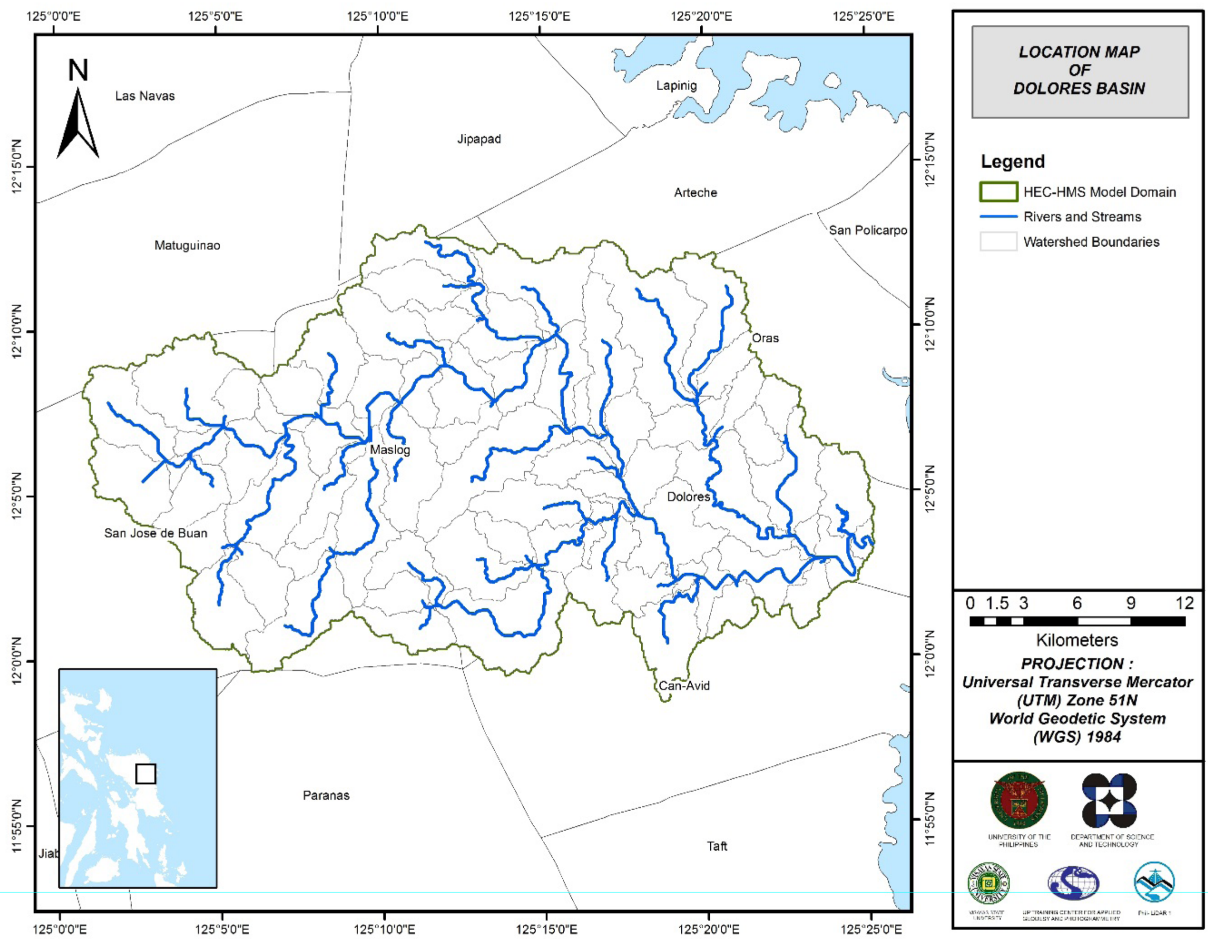


Figure 54. Stream delineation map of Dolores river basin

Dolores River Basin is located in Eastern Visayas, at the Eastern portion of Samar. It traverses through the municipalities of Arteche, Can-avid, Oras, Matuguinao, San Jose de Buan, Maslog, Jipapad and the municipality of Dolores. It covers an area of 754.44 square kilometers and travels for approximately 57.86 kilometers from its source to its mouth in Dolores Bay.

The Dolores basin model consists of 13 sub basins, 6 reaches, and 6 junctions. This basin model is illustrated in Figure 55. The basins were identified based on soil and land cover characteristics of the area. Precipitation from the 28-31 December (Typhoon Seniang) was taken from the rain gauge installed by the Flood Modelling Component. Finally, it was calibrated using the water level data from the Dolores depth gauge.

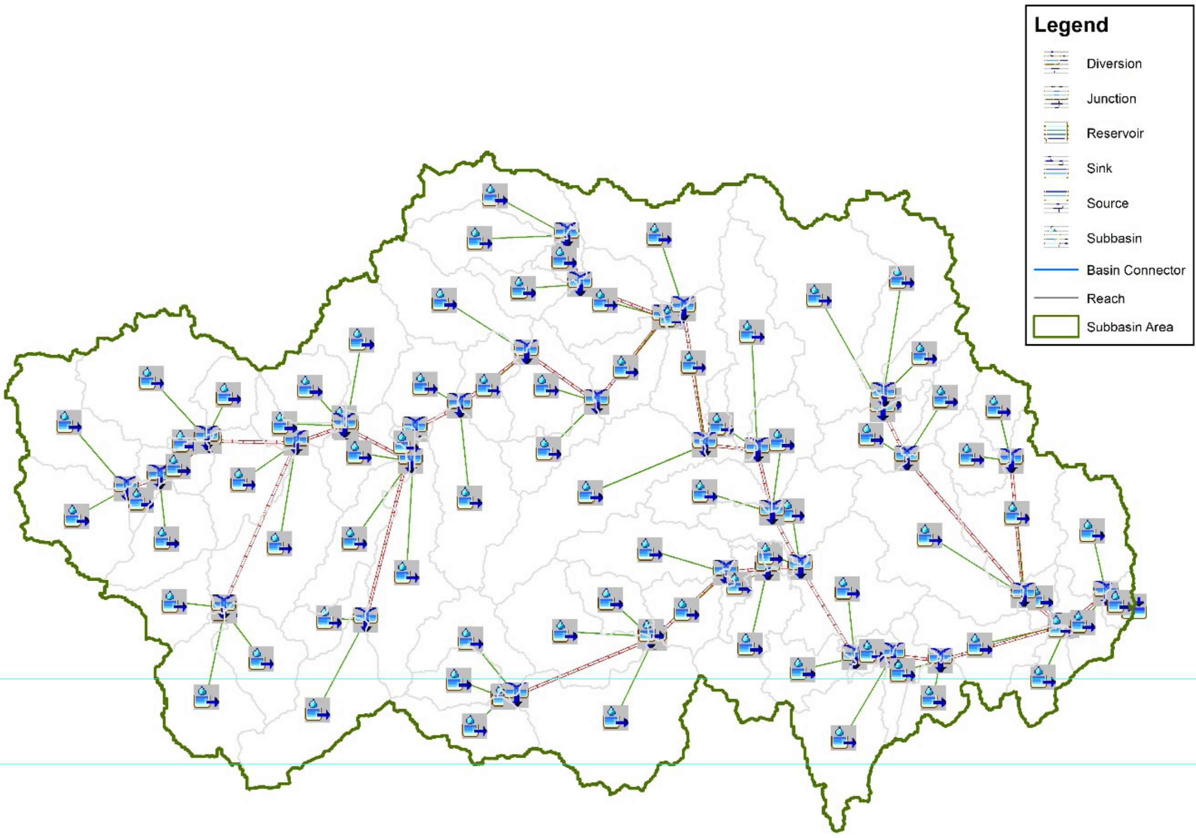


Figure 55. The Dolore river basin model generated using HEC-HMS

5.4 Cross-section Data

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

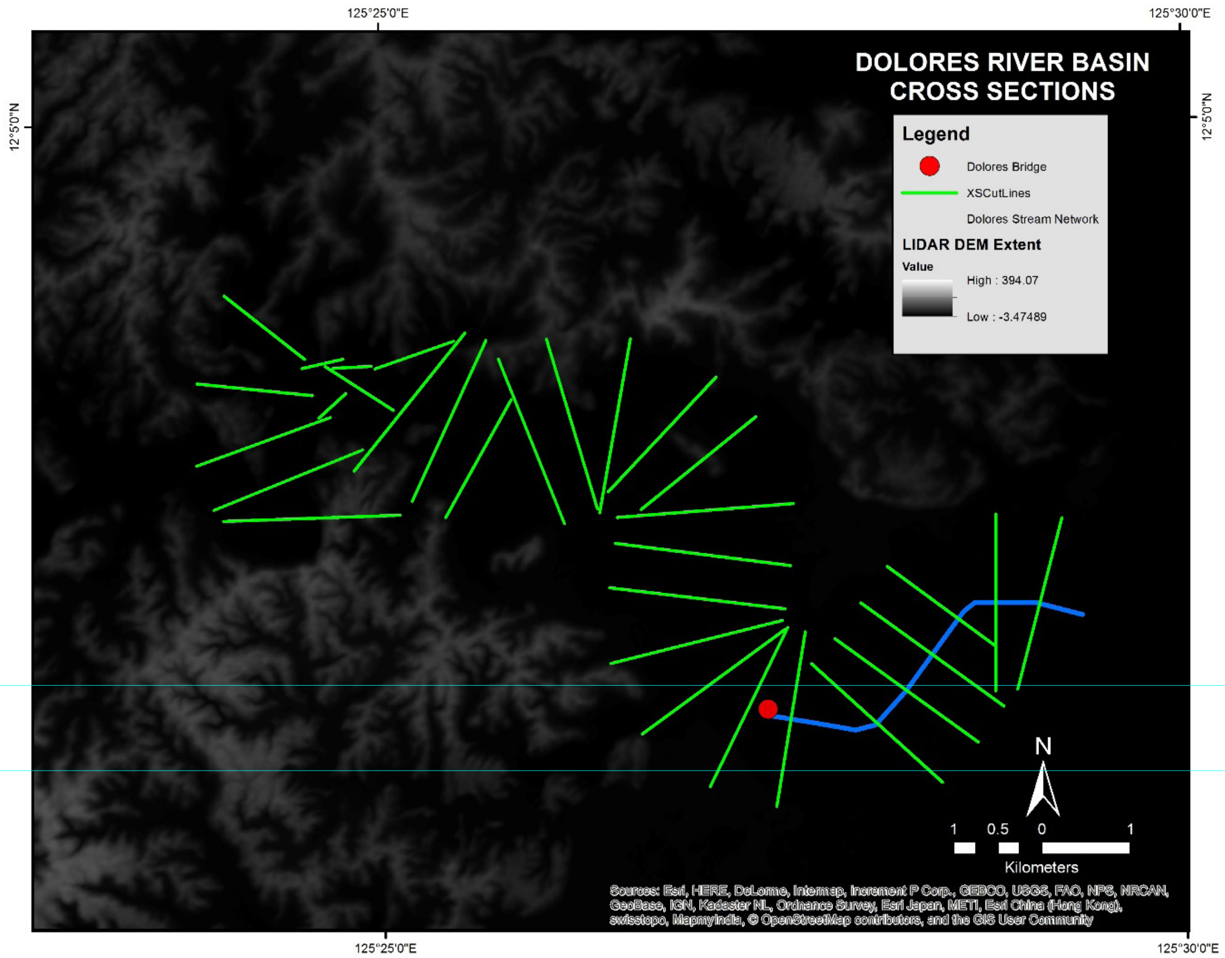


Figure 56. River cross-section of Dolores River generated through ArcMap HEC GeoRAS tool

5.5 Flo 2D Model

The automated modelling process allowed 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 was divided into square grid elements, 10 meter by 10 meter in size. Each element was assigned a unique grid element number which served 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 were 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 northwest and west of the model to the east, following the main channel. As such, boundary elements in those particular regions of the model were assigned as inflow and outflow elements respectively.

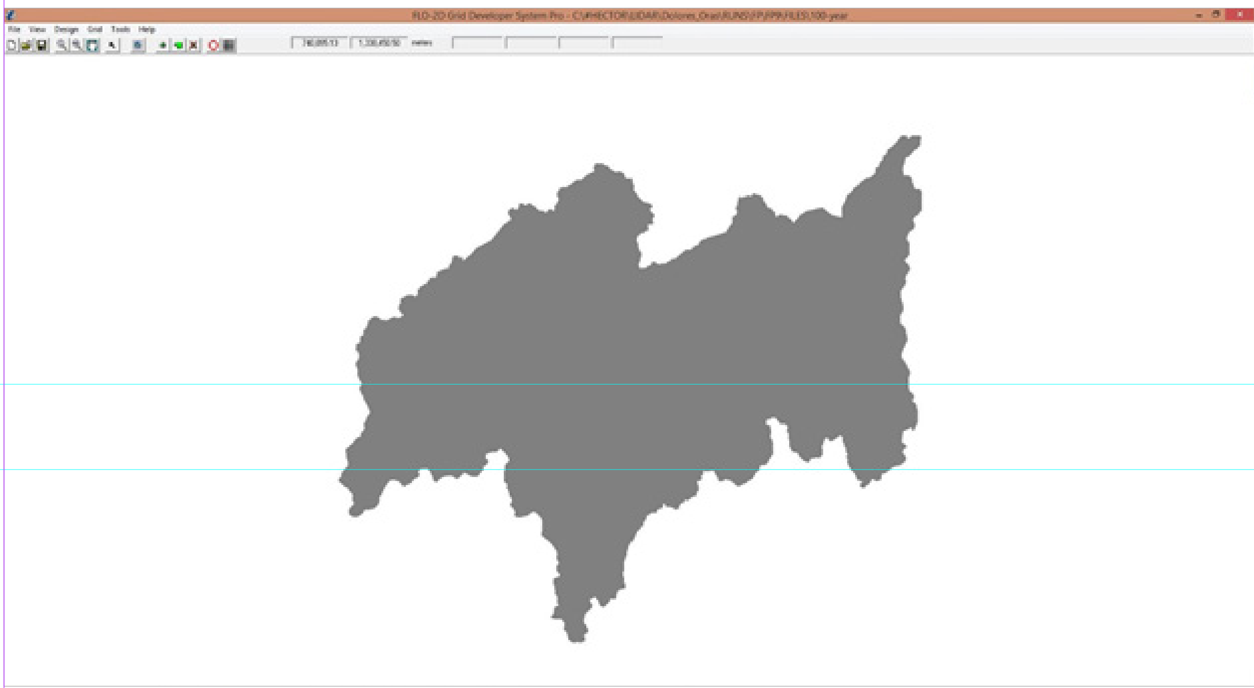


Figure 57. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation was then run through FLO-2D GDS Pro. This particular model had a computer run time of 340.63477 hours. After the simulation, FLO-2D Mapper Pro was 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 were used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m2/s.

The creation of a flood hazard map from the model also automatically created 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 was used for the layout. In this particular model, the inundated parts cover a maximum land area of 101888832.00 m2.

There is a total of 123882502.65 m3 of water entering the model. Of this amount, 56053832.76 m3 is due to rainfall while 67828669.89 m3 is inflow from other areas outside the model. 15998612.00 m3 of this water is lost to infiltration and interception, while 86013382.46 m3 is stored by the flood plain. The rest, amounting up to 21869788.88 m3,is outflow.

5.6 Results of HMS Calibration

After calibrating the Catubig HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 57 shows the comparison between the two discharge data.

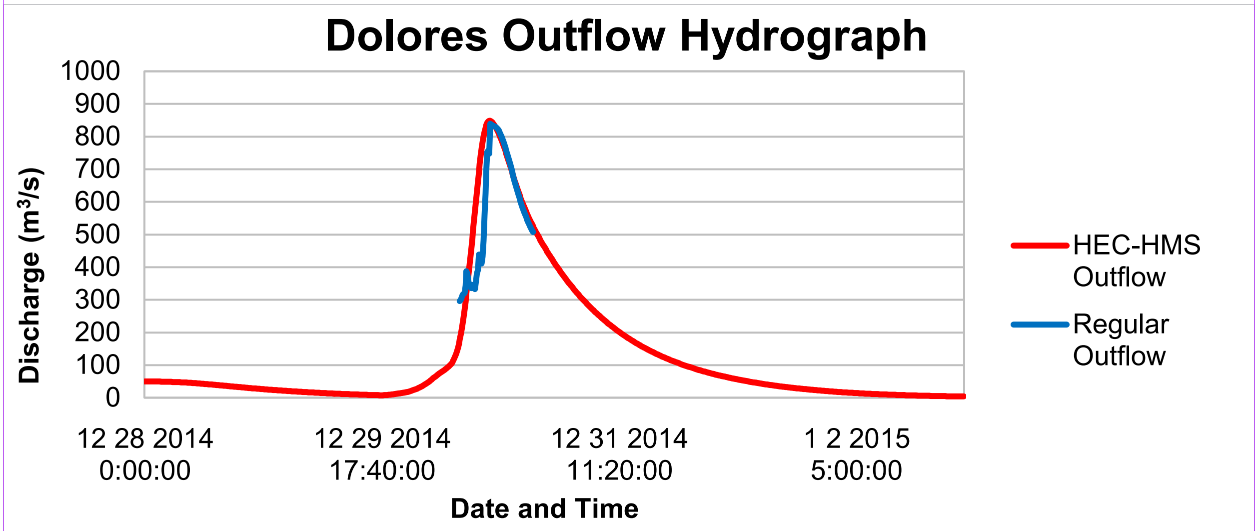


Figure 58. Outflow Hydrograph of Dolores Bridge generated in HEC-HMS model compared with observed outflow

Enumerated in Table 22 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 22. Range of Calibrated Values for Dolores

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	61 - 402
			Curve Number	52 - 88
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.3 - 10
			Storage Coefficient (hr)	0.09 - 3
	Baseflow	Recession	Recession Constant	0.2
			Ratio to Peak	0.65
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.04

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 61 to 402mm means that there is a high amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 52 to 88 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012).

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 0.09 hours to 10 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 0.2 indicates that the basin is likely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.65 indicates a milder slope of receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.04 corresponds to the common roughness of Dolores watershed, which is determined to be cultivated with mature field crops (Brunner, 2010).

Table 23. Summary of the Efficiency Test of Dolores HMS Model

Accuracy measure	Value
RMSE	36.9
r^2	0.81
NSE	0.54
PBIAS	-8.90
RSR	0.68

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 36.9.

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 0.8115.

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 0.54.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. The optimal value is 0. In the model, the PBIAS is -8.90.

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 0.68.

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

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graphs show the Dolores outflow using the Catbalogan RIDFcurves in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the PAG-ASA data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

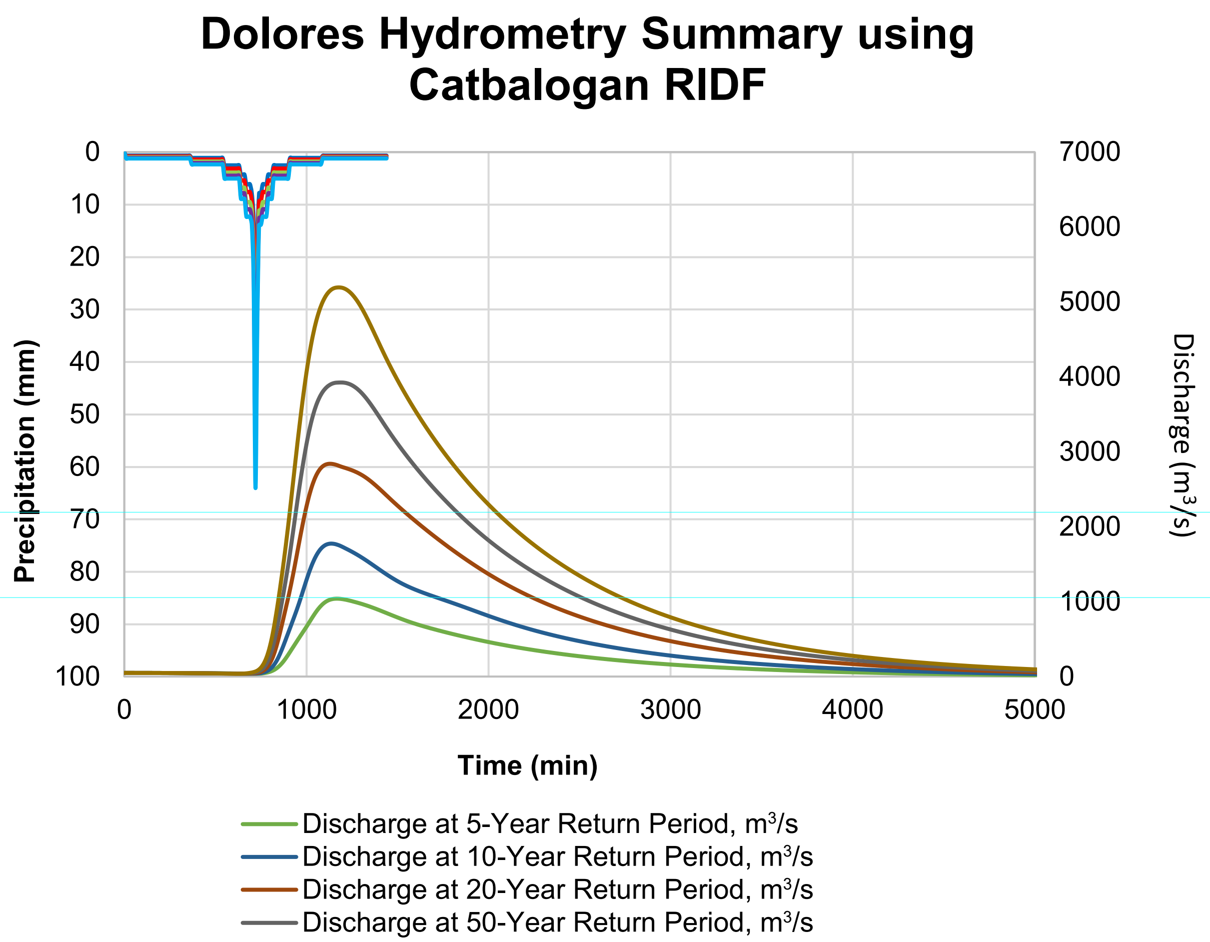


Figure 59. Outflow hydrograph at Dolores Station generated using Catbalogan RIDF simulated in HEC-HMS

Table 24. Peak values of the Dolores HEC-HMS Model outflow using the Catbalogan RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m^3/s)	Time to Peak
5-Year	225.3	27.2	1041.1	5 hours, 10 minutes
10-Year	272.1	31.8	1775.6	4 hours, 40 minutes
25-Year	331.3	37.5	2841.3	4 hours, 30 minutes
50-Year	375.2	41.8	3926.4	5 hours, 40 minute
100-Year	418.8	46	5195.2	5 hours, 30 minutes

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model was 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, a sample output for the river flow during Typhoon Seniang was to be shown, since the model was calibrated from this event. The sample generated map of Dolores River using the calibrated HEC-HMS model for Typhoon Seniang is shown in Figure 59.

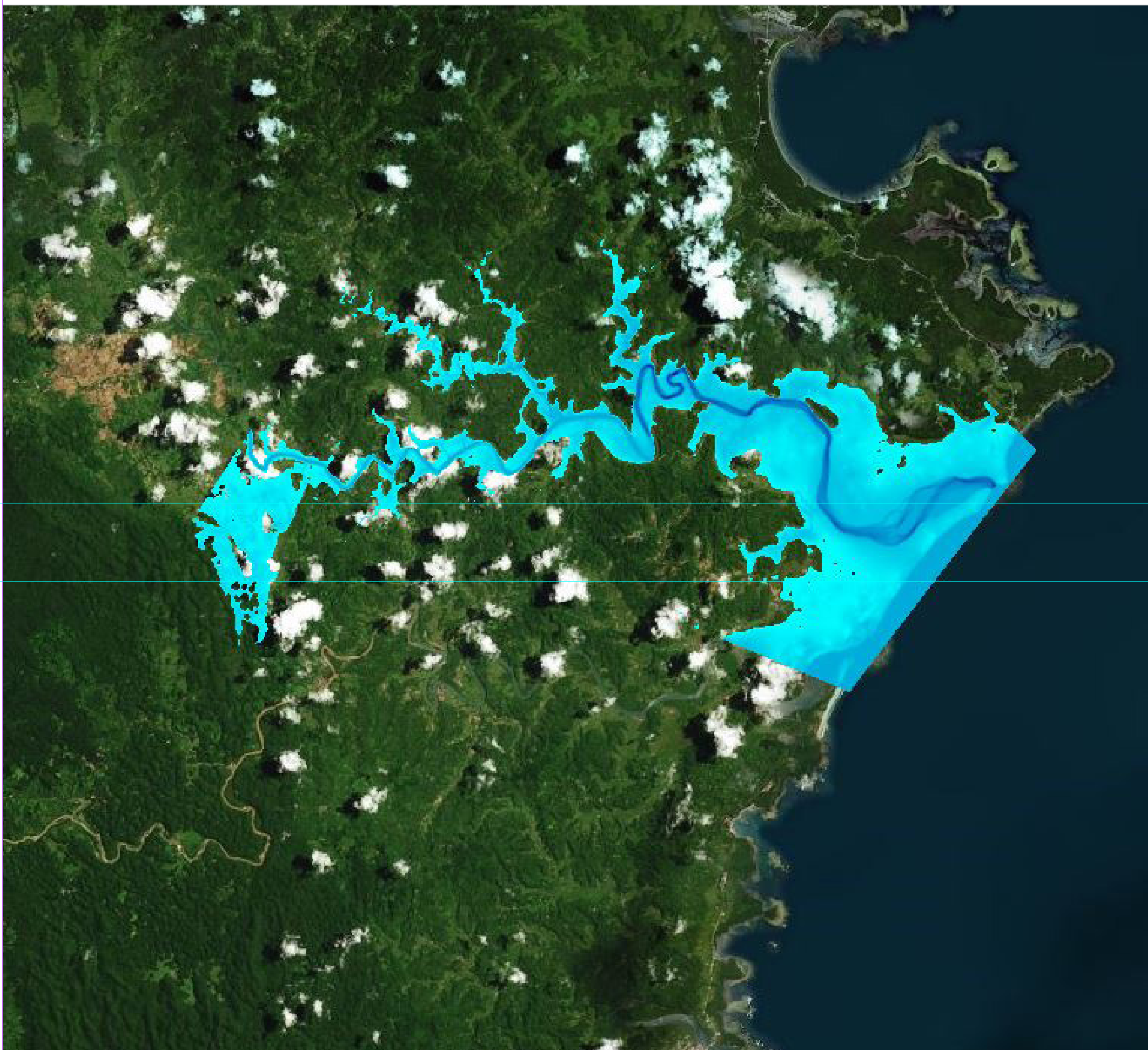


Figure 60. Sample output of Dolores RAS Model

5.9 Flood Hazard and Flow Depth

The resulting hazard and flow depth maps for 100-, 25-, and 5-year rain return scenarios of the Dolores Floodplain are shown in Figure 61 to 66. The floodplain, with an area of 634.31 sq. km., covers six municipalities namely Catbalogan City, Gandara, Pagsanghan, San Jorge, Santa Margarita, and Tarangnan. Table 25 shows the percentage of area affected by flooding per municipality.

Table 25. Municipalities affected in Dolores Floodplain

City / Municipality	Total Area	Area Flooded	% Flooded
Arteche	162.30	22.43	13.82%
Can-Avid	285.22	198.13	69.47%
Dolores	281.67	274.57	97.48%
Maslog	284.92	64.21	22.54%
Oras	173.99	72.20	41.50%
Paranas	536.76	1.82	0.34%

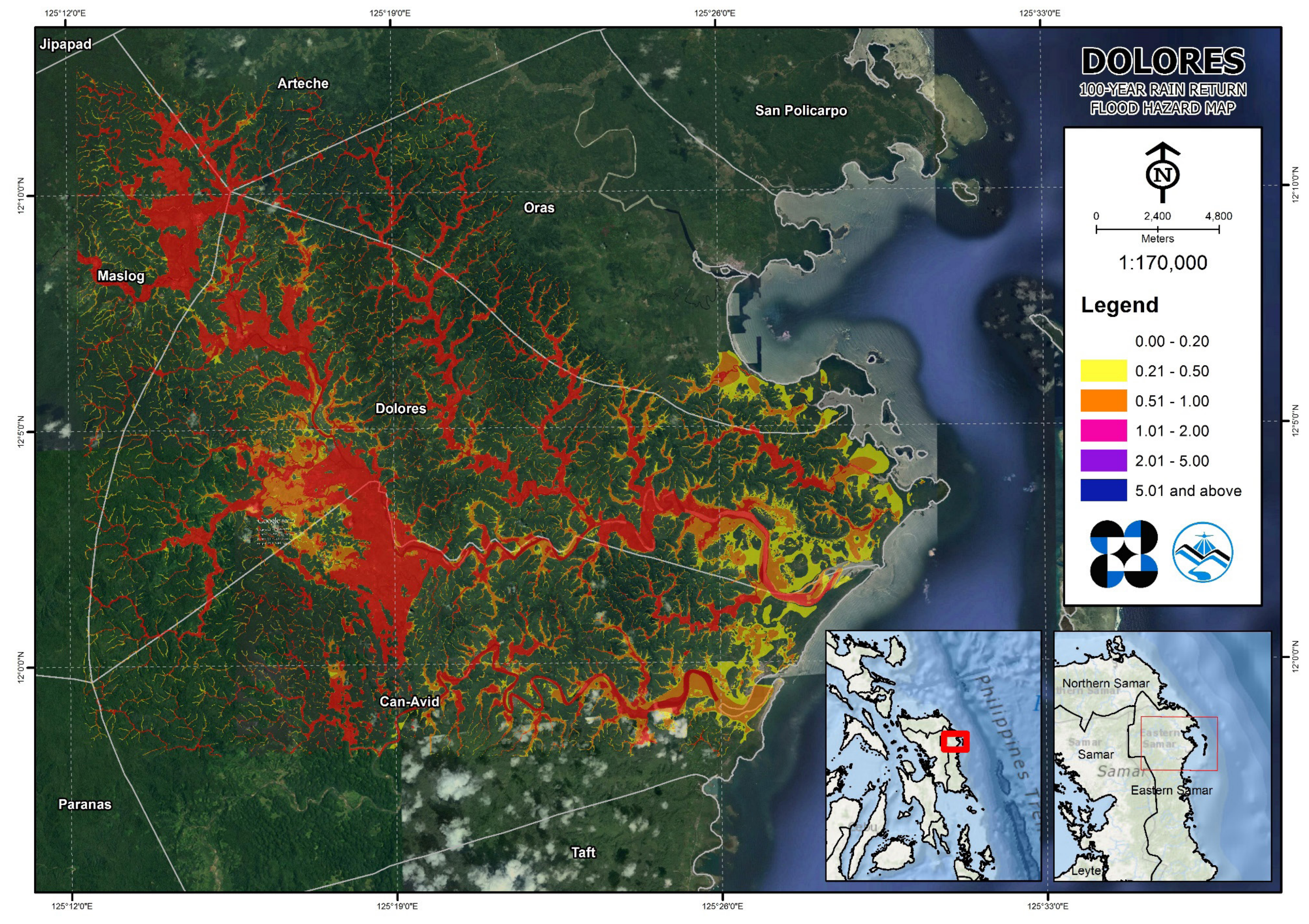


Figure 61. 100-year Hazard Map for Dolores Floodplain

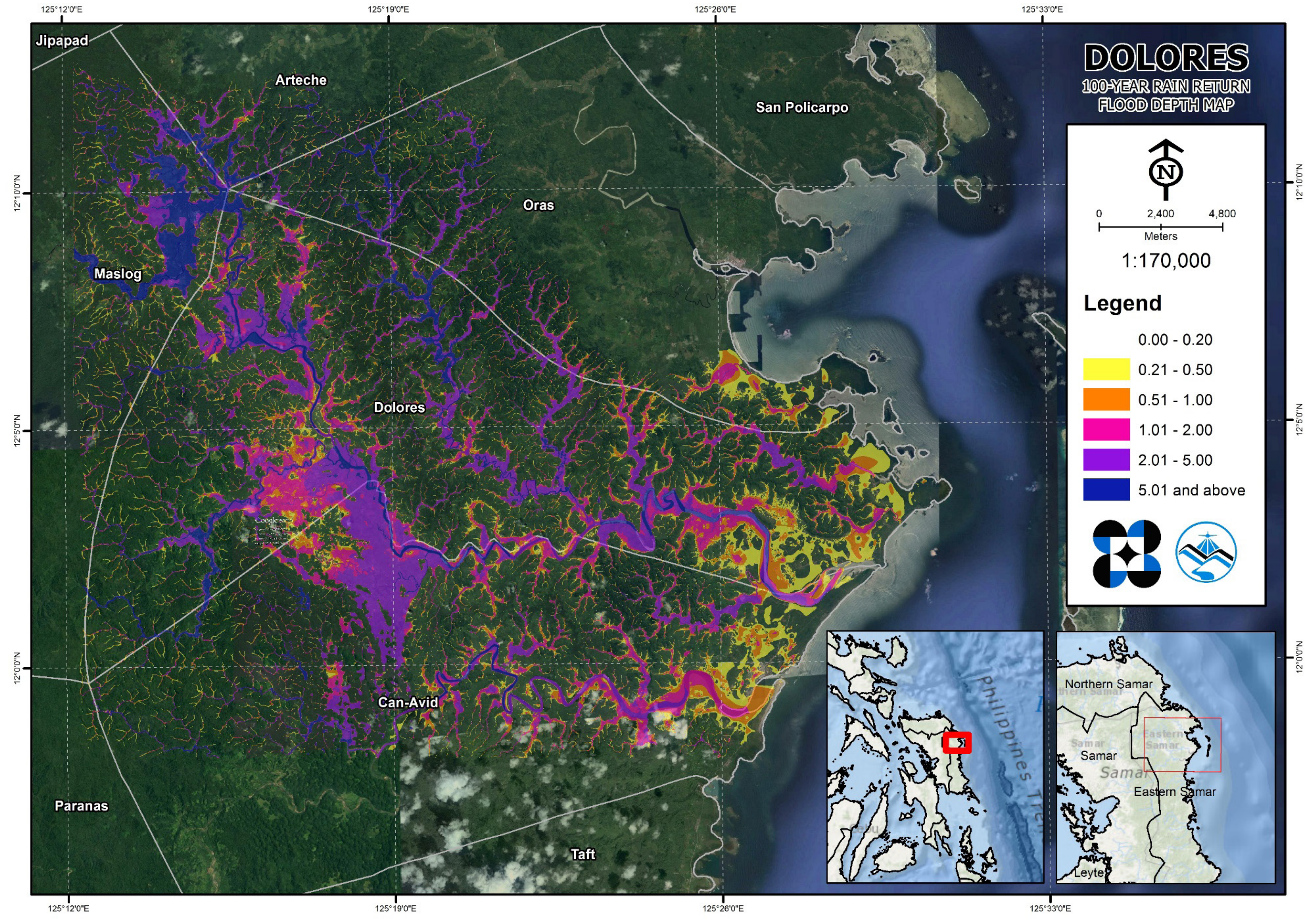


Figure 62. 100-year Flood Depth Map for Dolores Floodplain

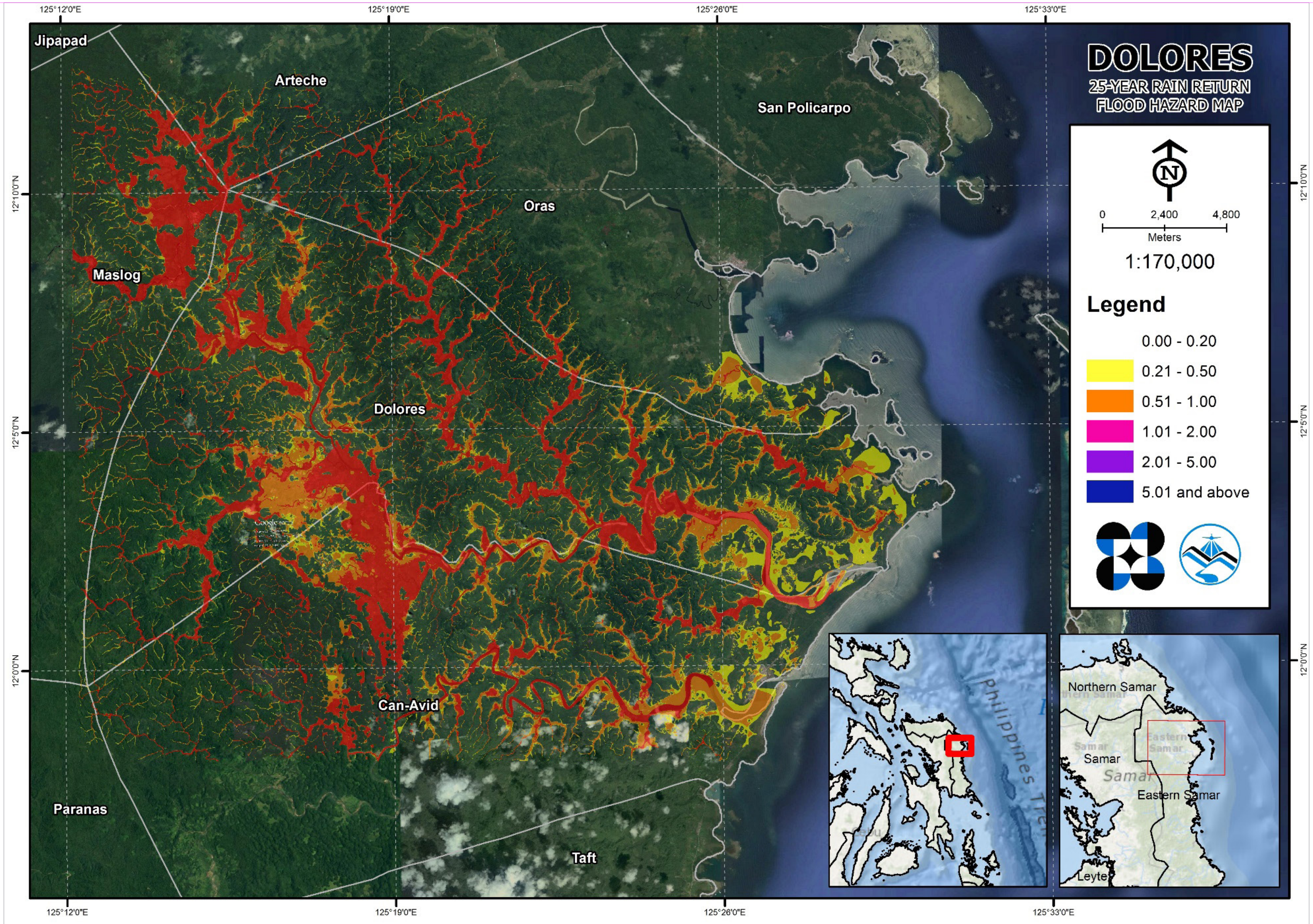


Figure 63. 25-year Hazard Map for Dolores Floodplain

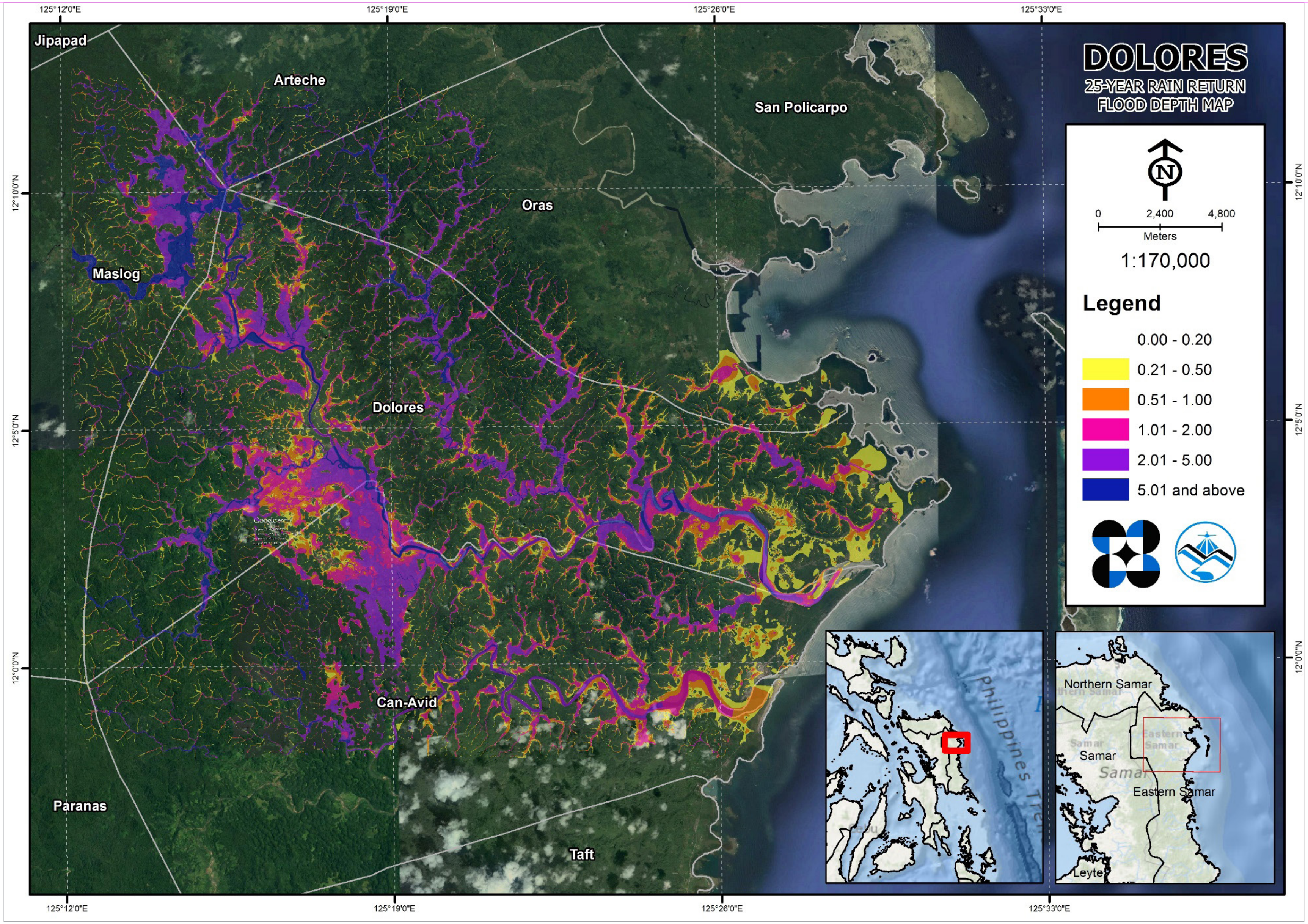


Figure 64. 25-year Flood Depth Map for Dolores Floodplain

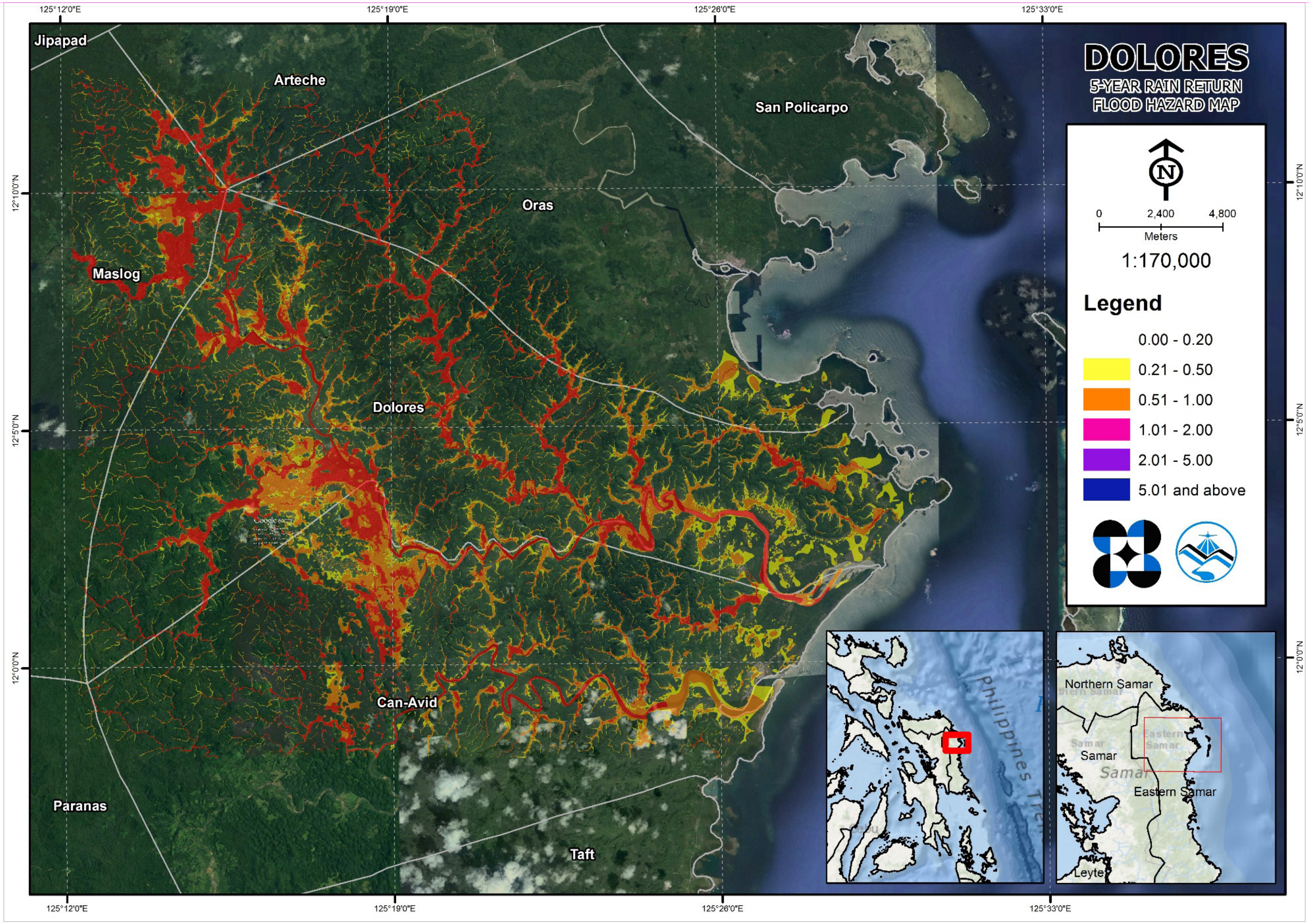


Figure 65. 5-year Hazard Map for Dolores Floodplain

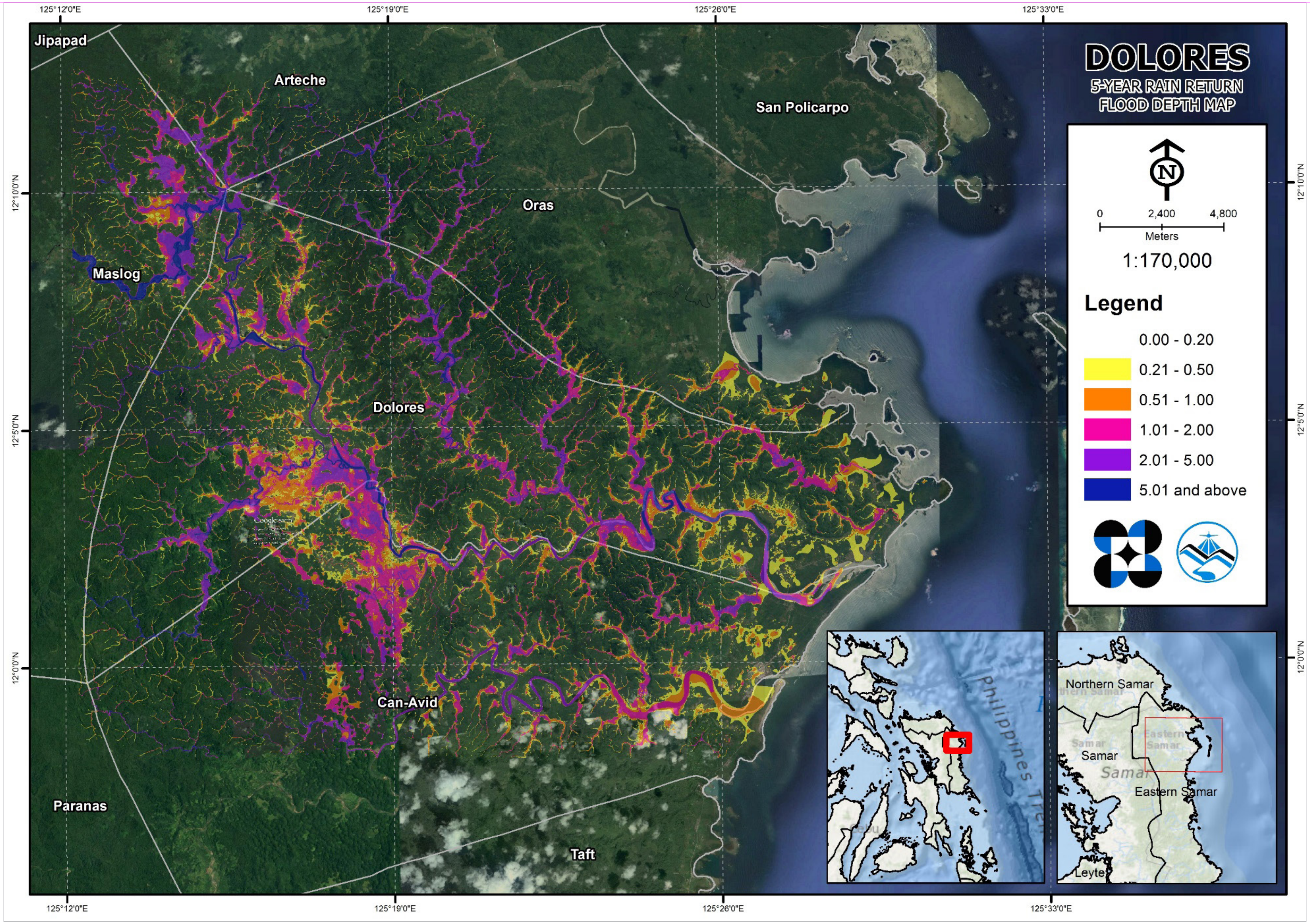


Figure 66. 5-year Flood Depth Map for Dolores Floodplain

5.10 Inventory of Areas Exposed to Flooding

Listed below are the barangays affected by the Dolores River Basin, grouped accordingly by municipality. For the said basin, six(6) municipalities consisting of 98 barangays are expected to experience flooding when subjected to a 5-year rainfall return period.

For the 5-year return period, 11.9% of the municipality of Arteche with an area of 162.3 sq. km. will experience flood levels of less 0.20 meters, while 0.37% of the area will experience flood levels of 0.21 to 0.50 meters; 0.33%, 0.47%, 0.7%, and 0.05% 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. Table 26 depicts the areas affected in Arteche in square kilometers by flood depth per barangay.

Table 26. Affected areas in Arteche, Eastern Samarduring a 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Arteche (in sq. km.)				
	Bigo	Cagsalay	Casidman	Macarthur	Tawagan
0.03-0.20	Bigo	Cagsalay	Casidman	Macarthur	Tawagan
0.21-0.50	0.74	0.12	4.29	10.25	3.91
0.51-1.00	0.015	0.001	0.13	0.32	0.13
1.01-2.00	0.011	0.0004	0.17	0.3	0.06
2.01-5.00	0.0084	0.0009	0.21	0.5	0.05
> 5.00	0.0086	0	0.3	0.78	0.05
	0.783	0.1223	5.115	12.186	4.224

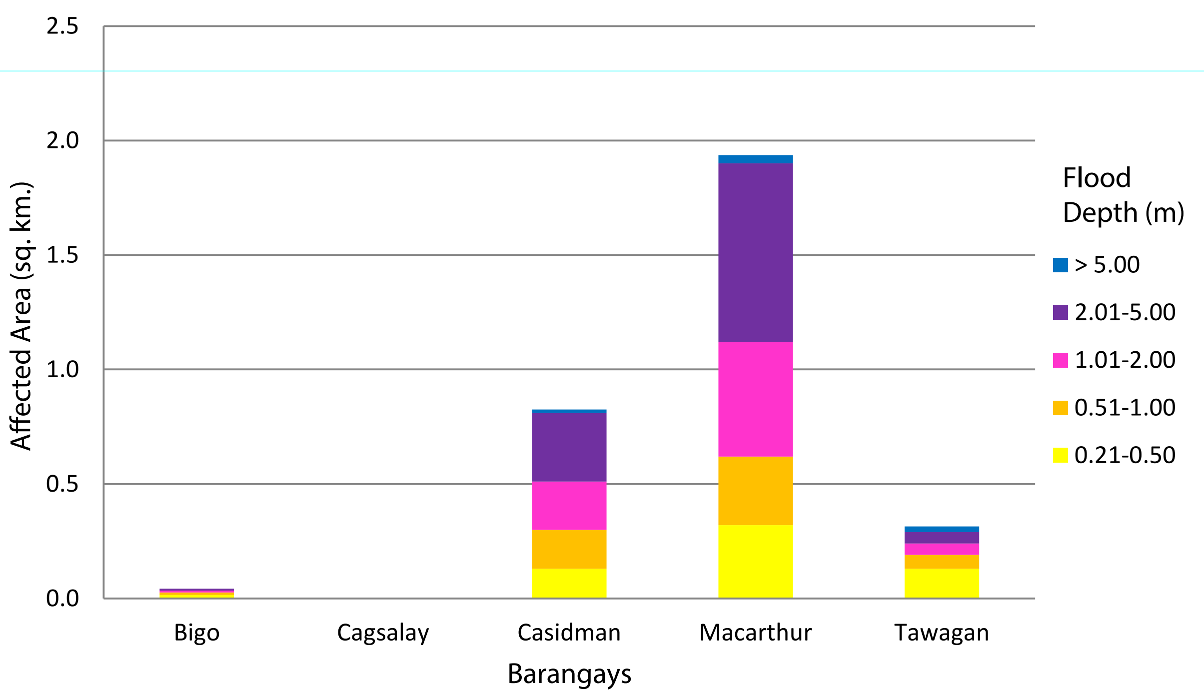


Figure 67. Affected areas in Arteche, Eastern Samar during a 5-Year Rainfall Return Period

For the municipality of Can-Avid, with an area of 285.22 sq. km., 53.12% will experience flood levels of less 0.20 meters. 4.11% of the area will experience flood leves of 0.21 to 0.50 meters while 4.2%, 5.07%, 2.63%, and 0.37% 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. Table 27 depicts the affected areas in square kilometers by flood depth per barangay.

Table 27. Affected areas in Can-Avid, Eastern Samar during a 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Can-Avid (in sq. km.)								
	Barangay 1 Poblacion	Barangay 10 Poblacion	Barangay 2 Poblacion	Barangay 3 Poblacion	Barangay 4 Poblacion	Barangay 5 Poblacion	Barangay 6 Poblacion	Barangay 7 Poblacion	Barangay 8 Poblacion
0.03-0.20	0.63	1.71	0.15	0.44	0.89	0.21	0.29	0.49	0.54
0.21-0.50	0.16	0.32	0.021	0.064	0.4	0.14	0.049	0.24	0.086
0.51-1.00	0.047	0.17	0.01	0.029	0.15	0.047	0.022	0.039	0.032
1.01-2.00	0.015	0.12	0	0.0002	0.0086	0.0004	0.0024	0.02	0.021
2.01-5.00	0	0.00028	0	0	0	0	0	0	0
> 5.00	0	0	0	0	0	0	0	0	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Can-Avid (in sq. km.)								
	Barangay 9 Poblacion	Baruk	Caghalong	Camantang	Can-Ilay	Cansangaya	Canteros	Carolina	Guibuangan
0.03-0.20	0.2	25.57	19.27	3.92	15.34	2.41	4.1	2.31	6.19
0.21-0.50	0.14	1.64	2.12	0.23	0.59	0.19	1.17	0.25	0.6
0.51-1.00	0.056	1.88	3.46	0.17	0.9	0.1	1.09	0.083	0.54
1.01-2.00	0.0043	1.63	6.53	0.19	1.07	0.11	0.98	0.095	0.63
2.01-5.00	0	1.69	2.51	0.3	0.8	0.02	0.001	0.23	0.34
> 5.00	0	0.023	0.44	0.0059	0.31	0	0	0.0014	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Can-Avid (in sq. km.)								
	Jepaco	Mabuhay	Malogo	Obong	Pandol	Rawis	Salvacion	Solong	
0.03-0.20	2.33	6.25	5.29	10.75	18.01	2.08	16.6	5.55	151.52
0.21-0.50	0.19	0.36	0.7	0.72	0.46	0.17	0.47	0.25	11.73
0.51-1.00	0.22	0.44	0.65	0.84	0.25	0.21	0.27	0.27	11.975
1.01-2.00	0.17	0.36	0.76	0.73	0.17	0.27	0.2	0.38	14.4669
2.01-5.00	0.14	0.024	0.18	0.37	0.22	0.13	0.27	0.27	7.49528
> 5.00	0	0	0	0.0001	0.13	0.0033	0.15	0	1.0637

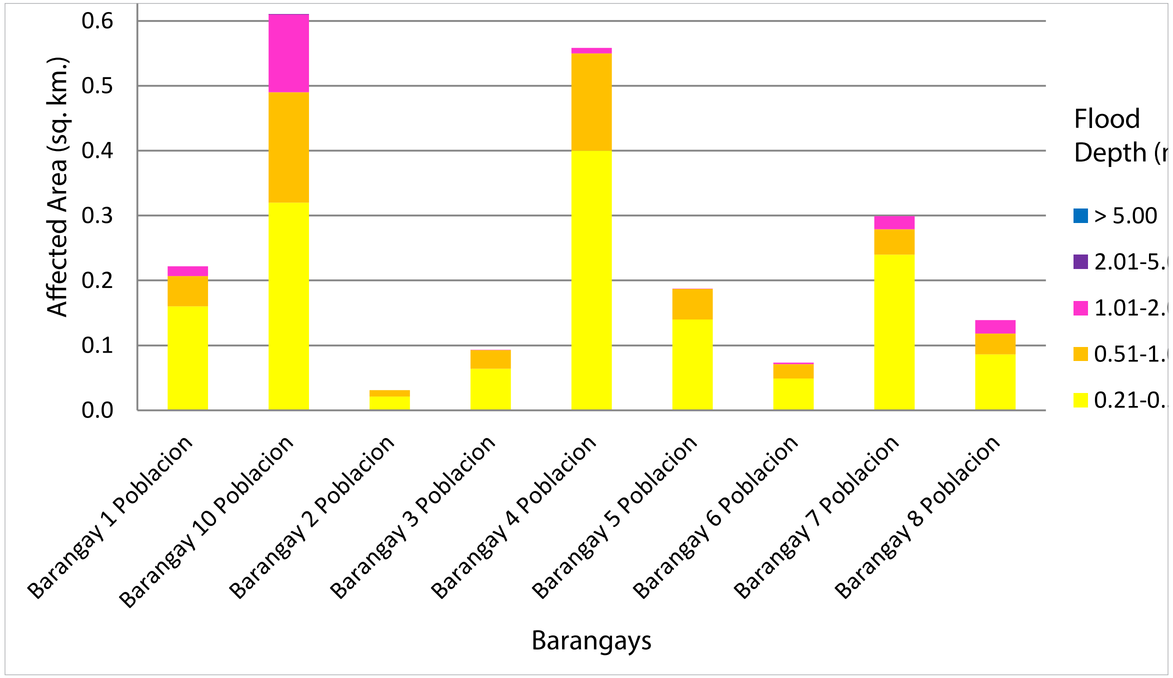


Figure 68. Affected areas in Can-Avid, Eastern Samar during a 5-Year Rainfall Return Period.

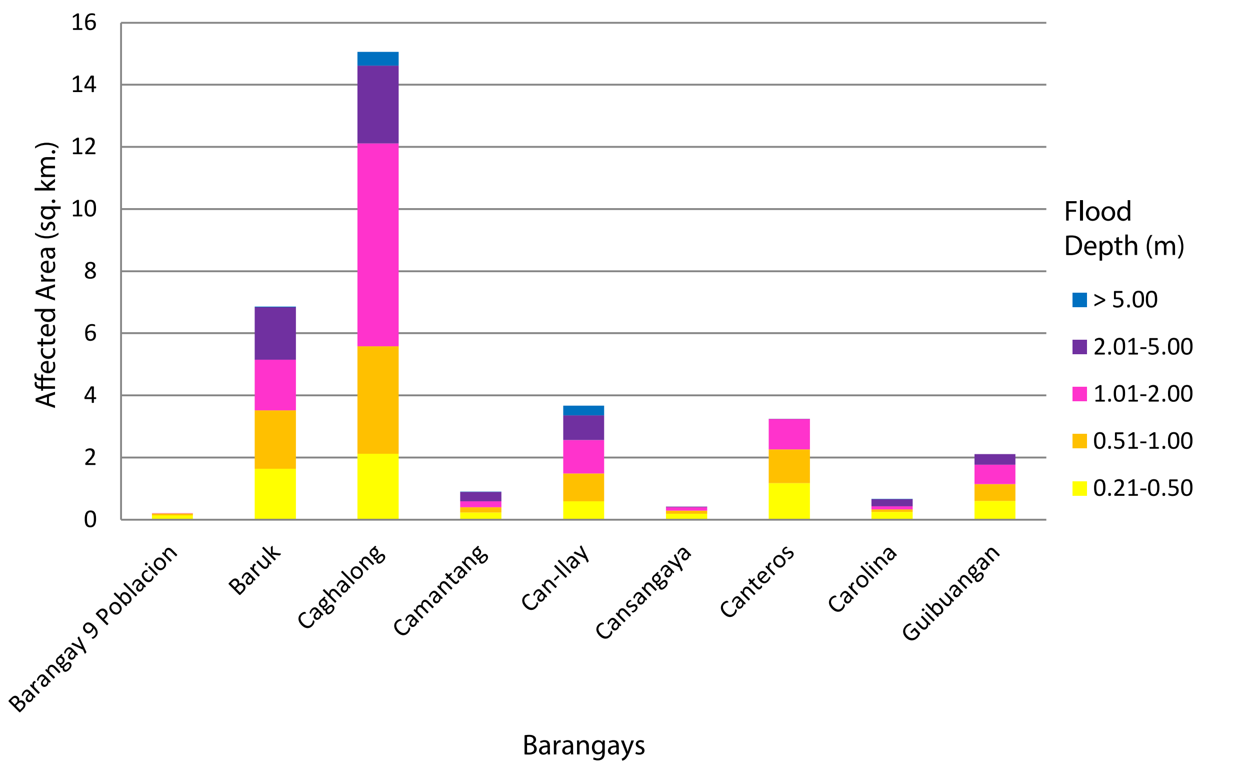


Figure 69. Affected areas in Can-Avid, Eastern Samar during a 5-Year Rainfall Return Period.

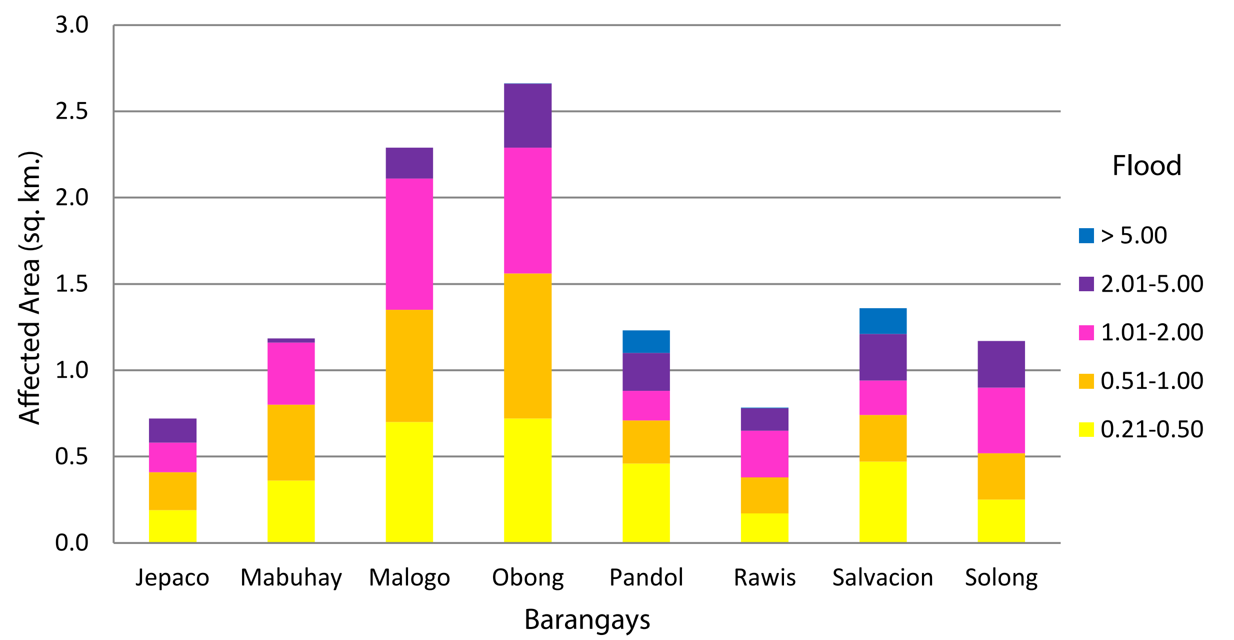


Figure 70. Affected areas in Can-Avid, Eastern Samar during a 5-Year Rainfall Return Period.

For the municipality of Dolores, with an area of 281.67 sq. km., 73.11% will experience flood levels of less 0.20 meters. 6.36% of the area will experience flood levels of 0.21 to 0.50 meters while 5.92%, 6.01%, 5.09%, and 1.79% 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. Table 28 depicts the affected areas in square kilometers by flood depth per barangay.

Table 28. Affected areas in Dolores, Eastern Samar during a 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Dolores (in sq. km.)								
	Aroganga	Barangay 1	Barangay 10	Barangay 11	Barangay 12	Barangay 13	Barangay 14	Barangay 15	Barangay 2
0.03-0.20	2.99	0.74	0.75	0.67	0.4	0.7	1.56	1.3	0.78
0.21-0.50	0.27	0.31	0.24	0.097	0.094	0.26	0.15	0.35	0.2
0.51-1.00	0.29	0.042	0.019	0.012	0.0017	0.0014	0.18	0.22	0.029
1.01-2.00	0.15	0.056	0.0025	0.000013	0	0	0.064	0.21	0.026
2.01-5.00	0.084	0.091	0	0	0.0002	0	0.0043	0.015	0.27
> 5.00	0	0.00046	0	0	0	0	0	0	0.089

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Dolores (in sq. km.)								
	Barangay 3	Barangay 4	Barangay 5	Barangay 6	Barangay 7	Barangay 8	Barangay 9	Bonghon	Buenavista
0.03-0.20	0.42	0.6	0.49	0.47	0.3	0.14	0.31	2.51	3.04
0.21-0.50	0.1	0.11	0.034	0.19	0.028	0.1	0.23	0.35	0.1
0.51-1.00	0.017	0.02	0.0065	0.031	0.0076	0.00012	0.13	0.24	0.11
1.01-2.00	0.00073	0.0014	0	0	0	0	0.02	0.11	0.14
2.01-5.00	0	0.0035	0	0	0	0	0	0.066	0.095
> 5.00	0	0.004	0	0	0	0	0	0.037	0.026

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Dolores (in sq. km.)								
	Cabago-An	Caglao-An	Cagtabon	Dampigan	Dapdap	Del Pilar	Denigpian	Gap-Ang	Hinolaso
0.03-0.20	2.47	12.13	4.01	3.69	5	16.06	12.54	3	6.79
0.21-0.50	0.091	0.79	0.27	0.84	0.64	1.38	0.48	0.23	0.9
0.51-1.00	0.12	0.91	0.34	0.59	0.35	1.55	0.47	0.19	1.36
1.01-2.00	0.094	1.17	0.69	0.13	0.43	1.87	0.62	0.14	1.36
2.01-5.00	0.056	0.69	0.6	0.095	0.2	1.56	0.83	0.17	1.08
> 5.00	0	0.027	0.00092	0.17	0	0.67	0.19	0.059	0.19

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Dolores (in sq. km.)								
	Japitan	Jicontol	Libertad	Magongbong	Magsaysay	Malaintos	Malobago	Osmeña	Rizal
0.03-0.20	2.29	1.34	2.73	5.71	2.63	3.58	5.73	19.62	24.49
0.21-0.50	0.67	0.34	0.29	0.43	0.22	0.84	0.49	1.36	1.13
0.51-1.00	0.072	0.56	0.41	0.39	0.31	0.65	0.43	2.29	1.02
1.01-2.00	0.04	1.16	0.82	0.24	0.48	0.57	0.46	1.14	0.82
2.01-5.00	0.00097	1.5	0.62	0.093	0.3	0.24	0.023	1.02	0.74
> 5.00	0	0.29	0.46	0.0096	0.029	0.057	0.74	0.38	0.073

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Dolores (in sq. km.)								
	San Isidro	San Pascual	San Roque	San Vicente	Santa Cruz	Santo Niño	Tanauan	Tikling	Villahermosa
0.03-0.20	3.02	5.9	9.81	3.53	10.14	2.54	0.99	1.81	16.21
0.21-0.50	0.23	0.18	0.31	0.18	0.4	0.24	0.17	0.58	1.02
0.51-1.00	0.25	0.16	0.35	0.19	0.41	0.27	0.39	0.23	1.05
1.01-2.00	0.36	0.22	0.59	0.16	0.89	0.088	0.56	0.077	0.98
2.01-5.00	0.2	0.39	0.97	0.092	0.64	0.0064	0.38	0.078	1.12
> 5.00	0.04	0.049	0.24	0	0.088	0.043	0.47	0.0044	0.6

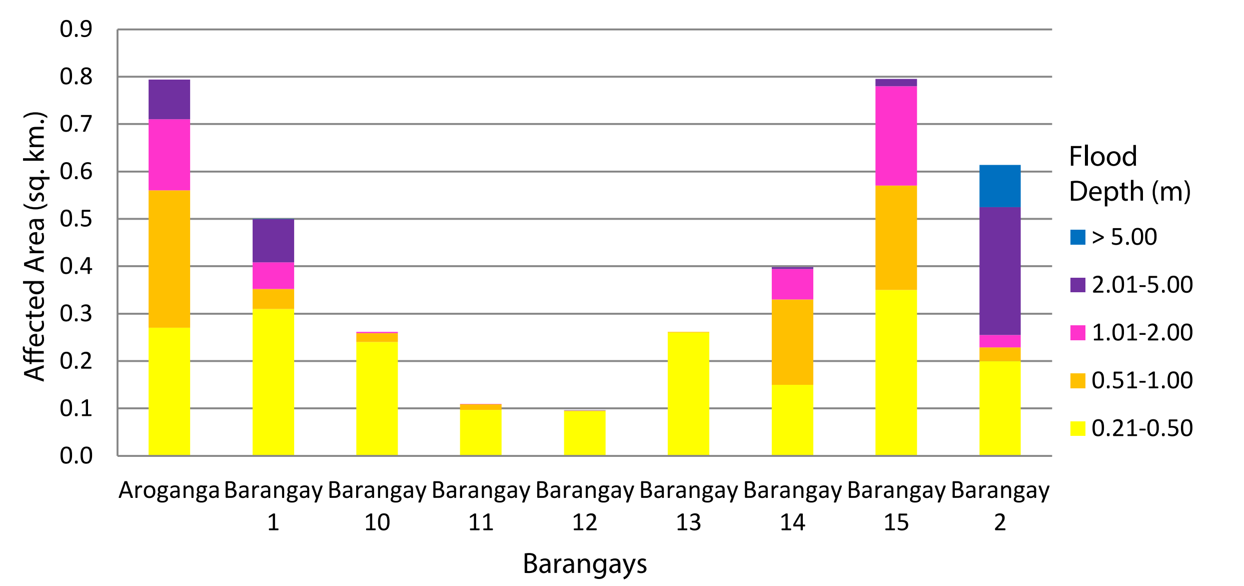


Figure 71. Affected areas in Dolores, Eastern Samar during a 5-Year Rainfall Return Period.

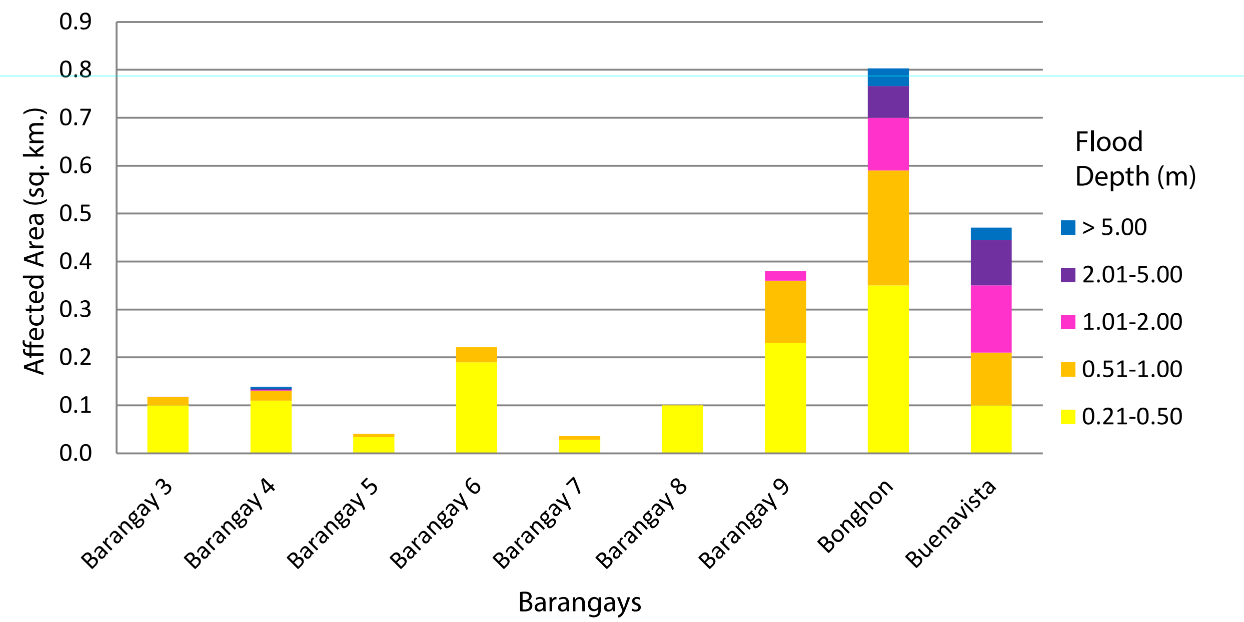


Figure 72. Affected areas in Dolores, Eastern Samar during a 5-Year Rainfall Return Period.

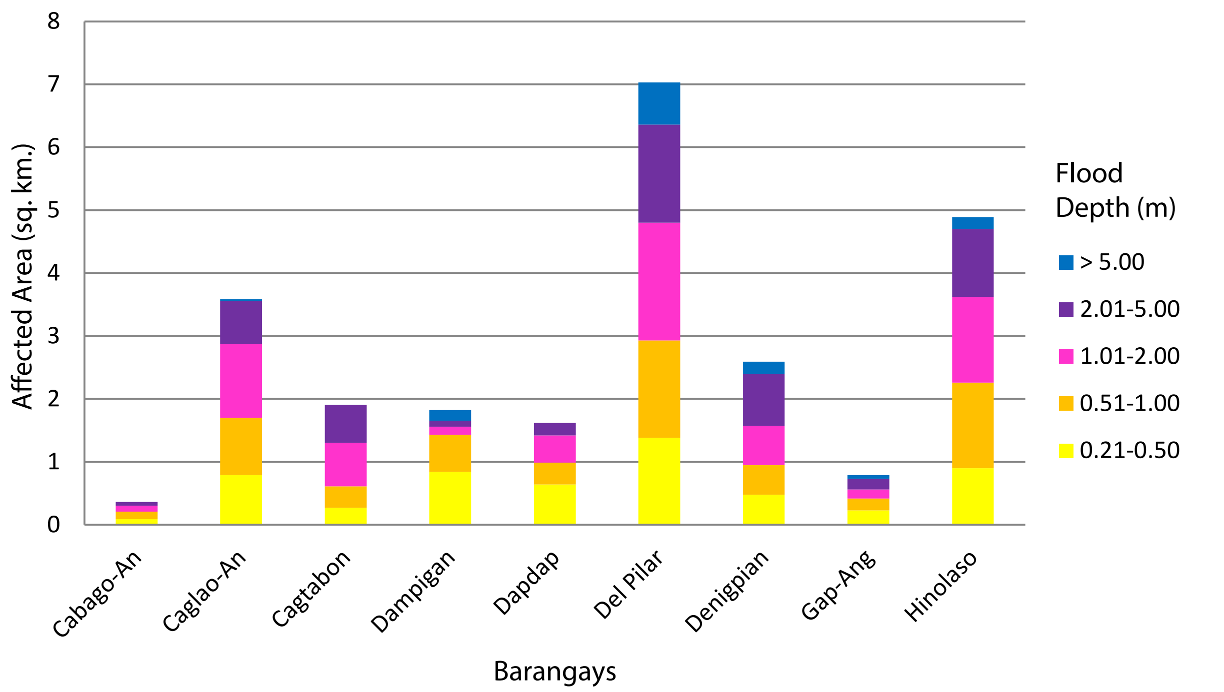


Figure 73. Affected areas in Dolores, Eastern Samar during a 5-Year Rainfall Return Period.

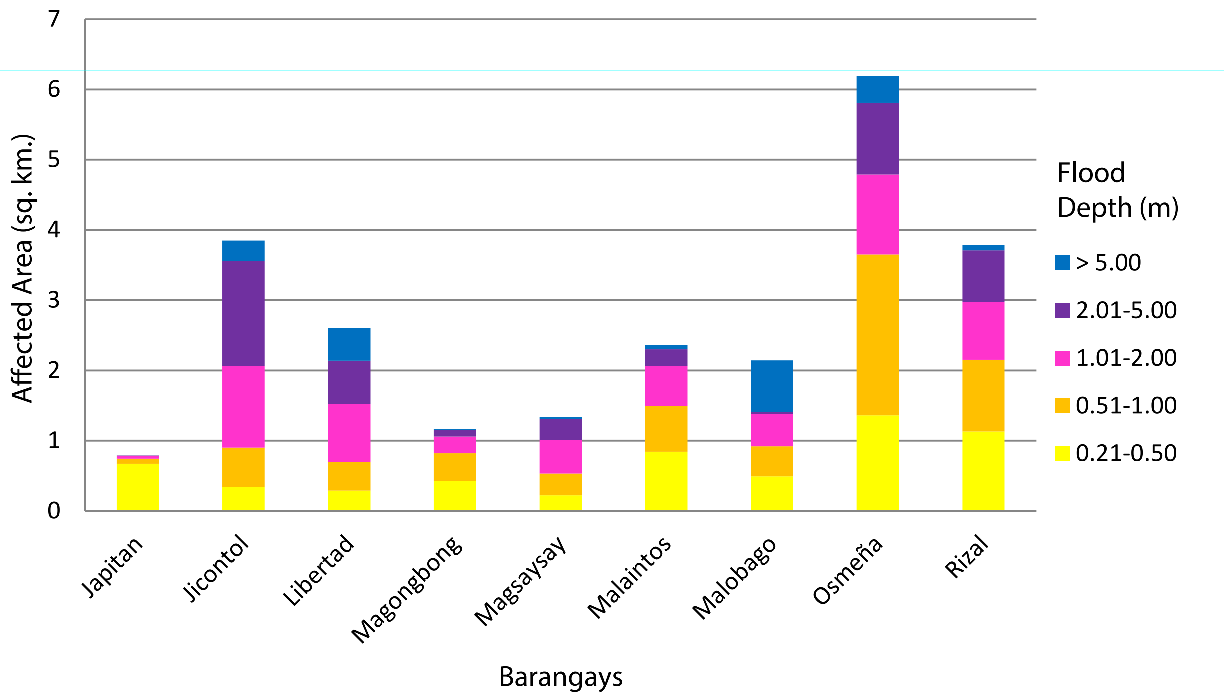


Figure 74. Affected areas in Dolores, Eastern Samar during a 5-Year Rainfall Return Period.

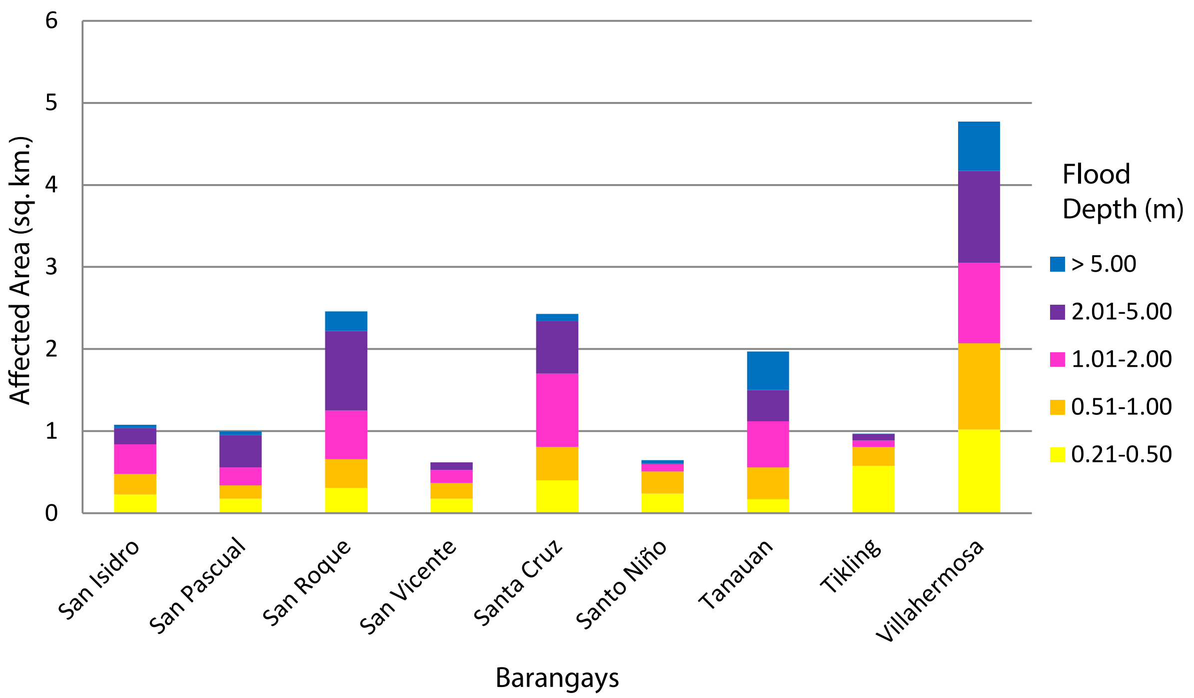


Figure 75. Affected areas in Dolores, Eastern Samar during a 5-Year Rainfall Return Period.

For the municipality of Maslog, with an area of 284.92 sq. km., 17.38% will experience flood levels of less 0.20 meters. 0.83% of the area will experience flood levels of 0.21 to 0.50 meters while 0.73%, 1%, 1.7%, and 0.9% 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. Table 29 depicts the affected areas in square kilometers by flood depth per barangay.

Table 29. Affected areas in Maslog, Eastern Samar during a 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Maslog (in sq. km.)						
	Libertad	Malobago	Maputi	San Miguel	San Roque	Tangbo	Tugas
0.03-0.20	5.68022	16.29644	18.15	0.022	3.562437	5.8	0.00077
0.21-0.50	0.253161	0.782295	0.97	0.0024	0.100065	0.25	0
0.51-1.00	0.126133	0.395548	1.35	0.00073	0.080661	0.13	0
1.01-2.00	0.058791	0.321717	2.29	0	0.086449	0.085	0
2.01-5.00	0.07717	0.41102	4.18	0	0.103043	0.07	0.0002
> 5.00	0.455629	0.741106	1.34	0	0.0287	0.0097	0.00047

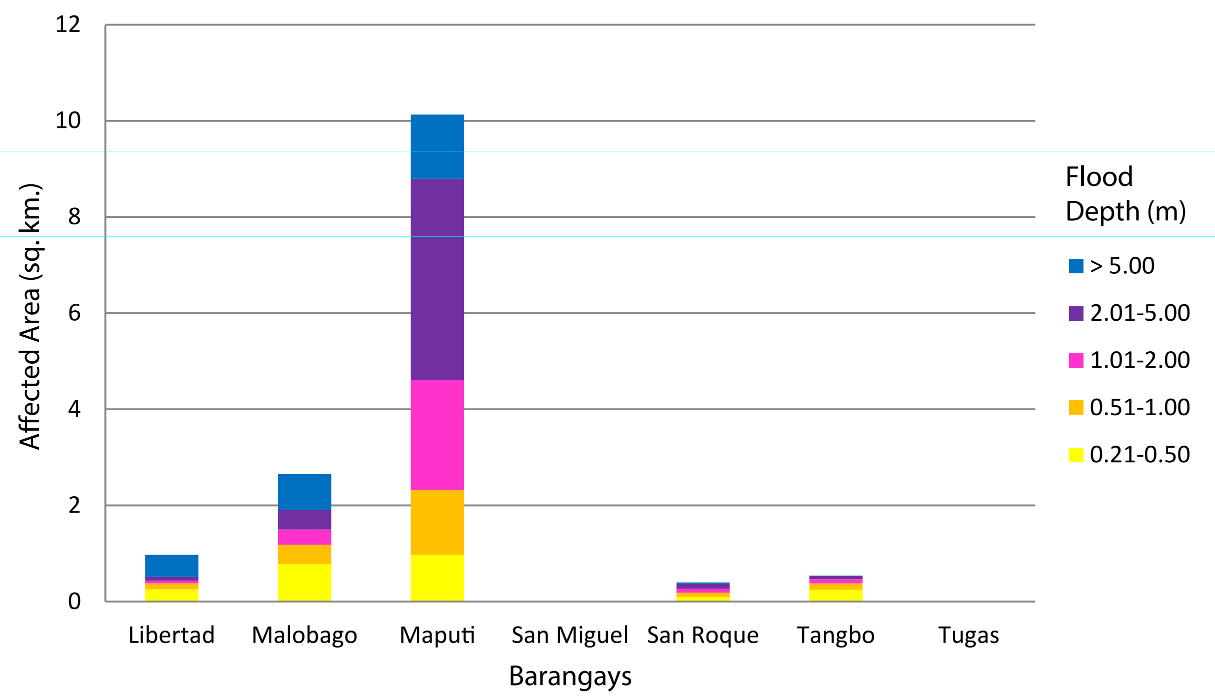


Figure 76. Affected areas in Maslog, Eastern Samar during a 5-Year Rainfall Return Period.

For the municipality of Oras, with an area of 173.99 sq. km., 35.29% will experience flood levels of less 0.20 meters. 1.95% of the area will experience flood levels of 0.21 to 0.50 meters while 1.44%, 1.36%, 1.32%, and 0.13% 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. Table 38 depicts the affected areas in square kilometers by flood depth per barangay.

Table 30. Affected areas in Oras, Eastern Samar during a 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Oras (in sq. km.)						
	Bagacay	Balingasag	Bato	Cagpile	Dalid	Dao	Factoria
0.03-0.20	2.69	20.27	1.18	1.1	2.97	0.56	1.95
0.21-0.50	0.49	0.49	0.11	0.031	0.51	0.16	0.48
0.51-1.00	0.36	0.43	0.13	0.026	0.56	0.0088	0.13
1.01-2.00	0.18	0.72	0.085	0.043	0.17	0	0.037
2.01-5.00	0.0025	1.1	0.078	0.14	0.0005	0	0
> 5.00	0	0.14	0	0.0091	0	0	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Oras (in sq. km.)						
	Gamot	Japay	Kalaw	Minap-Os	Naga	Saugan	Trinidad
0.03-0.20	8.89	1.42	1.47	5.56	3.52	2.32	7.5
0.21-0.50	0.29	0.097	0.085	0.15	0.085	0.16	0.26
0.51-1.00	0.15	0.068	0.1	0.14	0.065	0.037	0.3
1.01-2.00	0.19	0.041	0.039	0.32	0.11	0.0028	0.43
2.01-5.00	0.38	0.0016	0.0011	0.29	0.081	0	0.22
> 5.00	0.081	0	0	0.0018	0	0	0

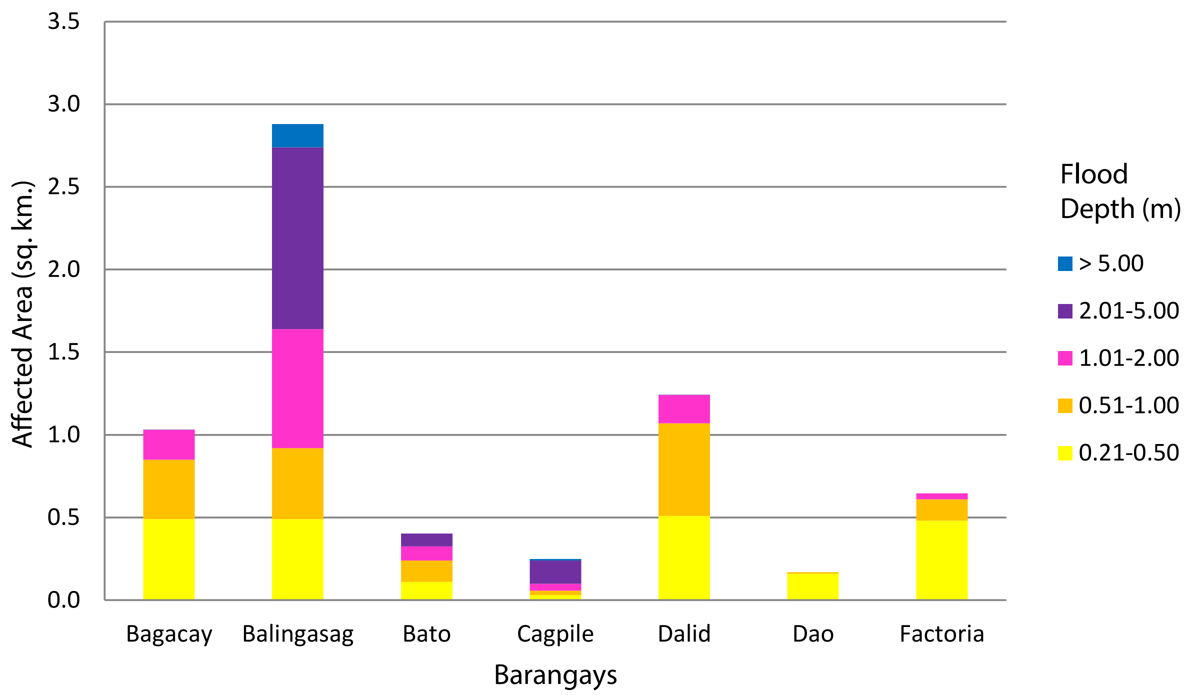


Figure 77. Affected areas in Oras, Eastern Samar during a 5-Year Rainfall Return Period.

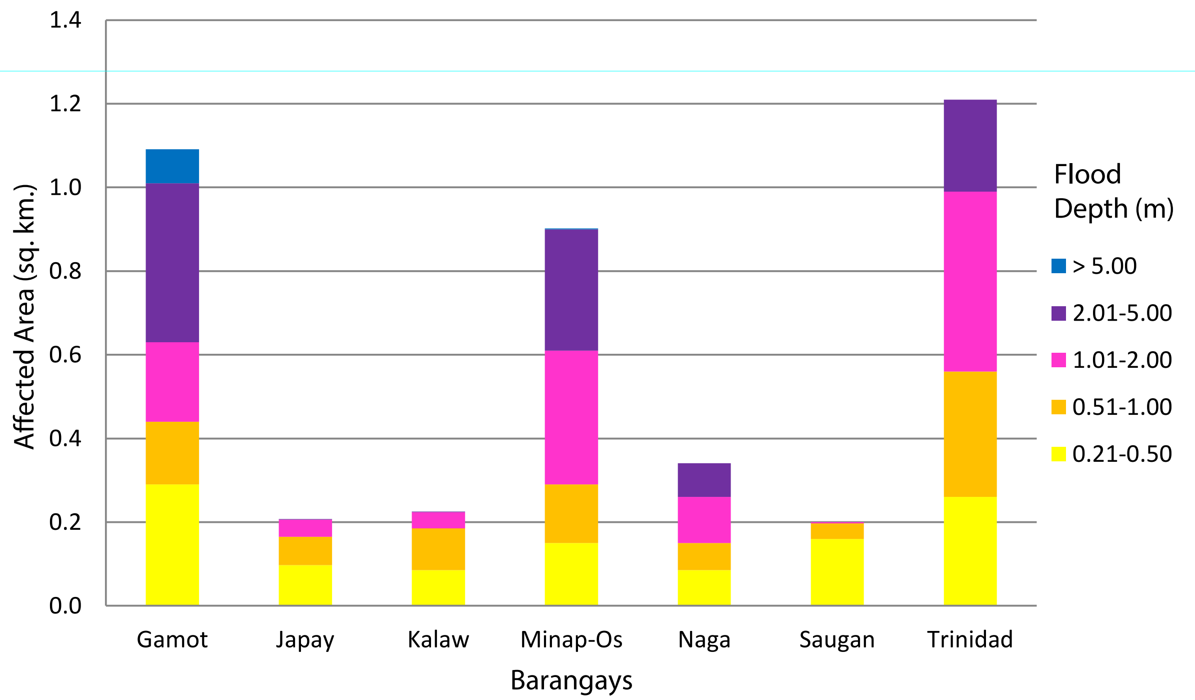


Figure 78. Affected areas in Oras, Eastern Samar during a 5-Year Rainfall Return Period.

For the municipality of Paranas, with an area of 536.76 sq. km., 0.32% will experience flood levels of less 0.20 meters. 0.009% of the area will experience flood levels of 0.21 to 0.50 meters while 0.006%, 0.003%, and 0.001% of the area will experience flood depths of 0.51 to 1 meter,1.01 to 2 meters, and more than 2 meters, respectively. Table 30 depicts the affected areas in square kilometers by flood depth per barangay.

Table 31. Affected areas in Paranas, Samar during a 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Paranas (in sq. km.)
	Anagasi
0.03-0.20	1.72
0.21-0.50	0.048
0.51-1.00	0.03
1.01-2.00	0.015
2.01-5.00	0.0057
> 5.00	0

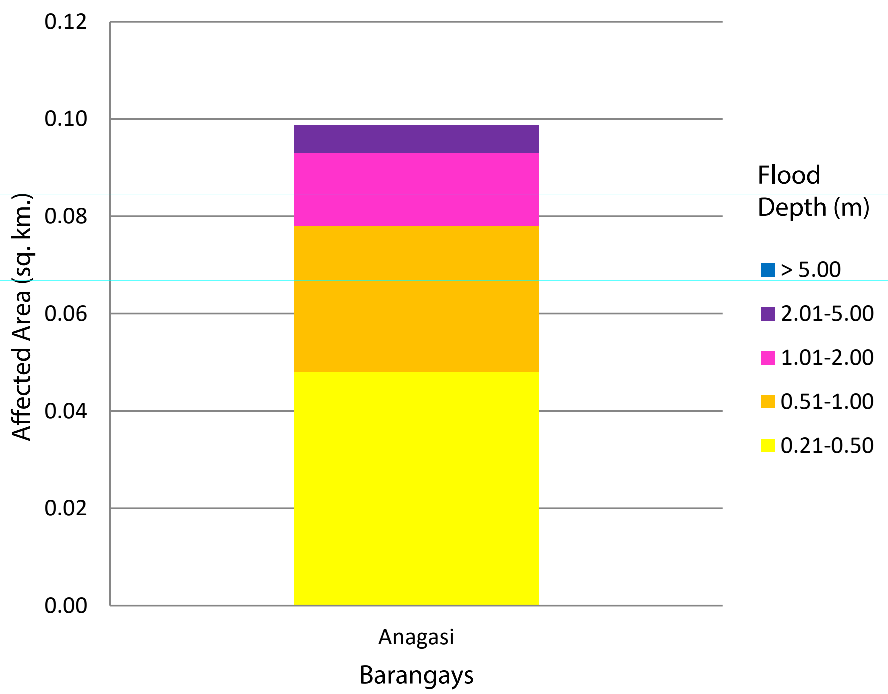


Figure 79. Affected areas in Paranas, Samar during a 5-Year Rainfall Return Period.

For the 25-year return period, 11.62% of the municipality of Arteche with an area of 162.3 sq. km. will experience flood levels of less 0.20 meters, while 0.37% of the area will experience flood levels of 0.21 to 0.50 meters; 0.29%, 0.38%, 0.78%, and 0.39% 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. Table 31 depicts the areas affected in Arteche in square kilometers by flood depth per barangay.

Table 32. Affected areas in Arteche, Eastern Samar during a 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Arteche (in sq. km.)				
	Bigo	Cagsalay	Casidman	Macarthur	Tawagan
0.03-0.20	0.74	0.12	4.18	9.96	3.86
0.21-0.50	0.016	0.0013	0.12	0.33	0.14
0.51-1.00	0.012	0.0004	0.13	0.25	0.073
1.01-2.00	0.009	0.001	0.18	0.37	0.054
2.01-5.00	0.01	0	0.34	0.86	0.055
> 5.00	0	0	0.19	0.41	0.034

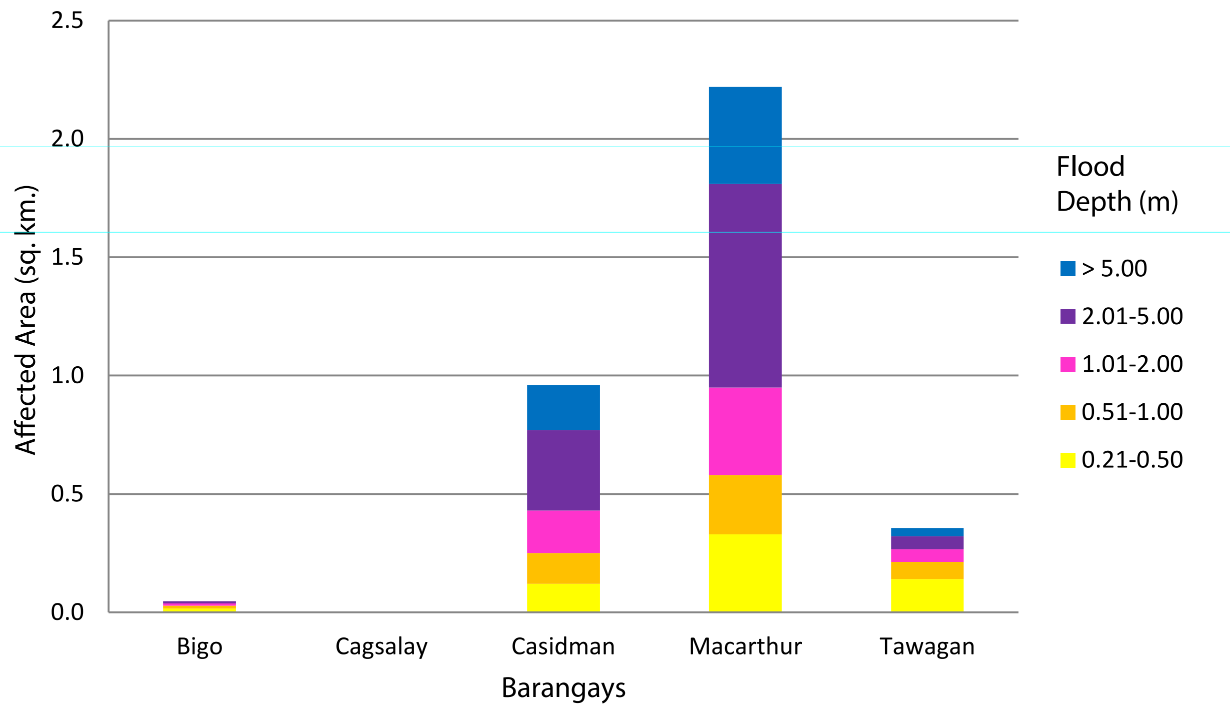


Figure 80. Affected areas in Arteche, Eastern Samar during a 25-Year Rainfall Return Period

For the municipality of Can-Avid, with an area of 285.22 sq. km., 50.16% will experience flood levels of less 0.20 meters. 4.02% of the area will experience flood leves of 0.21 to 0.50 meters while 3.78%, 5.21%, 5.67%, and 0.65% 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. Table 32 depicts the affected areas in square kilometers by flood depth per barangay.

Table 33. Affected areas in Can-Avid, Eastern Samar during a 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Can-Avid (in sq. km.)								
	Barangay 1 Poblacion	Barangay 10 Poblacion	Barangay 2 Poblacion	Barangay 3 Poblacion	Barangay 4 Poblacion	Barangay 5 Poblacion	Barangay 6 Poblacion	Barangay 7 Poblacion	Barangay 8 Poblacion
0.03-0.20	0.57	1.51	0.14	0.34	0.67	0.15	0.25	0.33	0.48
0.21-0.50	0.19	0.41	0.025	0.14	0.49	0.16	0.079	0.29	0.13
0.51-1.00	0.07	0.21	0.016	0.039	0.27	0.083	0.03	0.14	0.041
1.01-2.00	0.022	0.18	0.00096	0.007	0.019	0.0051	0.0046	0.031	0.029
2.01-5.00	0	0.0089	0	0	0	0	0	0	0
> 5.00	0	0	0	0	0	0	0	0	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Can-Avid (in sq. km.)								
	Barangay 9 Poblacion	Baruk	Caghalong	Camantang	Can-Ilay	Cansangaya	Canteros	Carolina	Guibuangan
0.03-0.20	0.13	24.29	17.22	3.77	14.85	2.29	3.29	2.08	5.77
0.21-0.50	0.15	1.52	1.33	0.27	0.55	0.23	1.19	0.38	0.54
0.51-1.00	0.11	1.88	1.78	0.19	0.62	0.11	1.13	0.13	0.67
1.01-2.00	0.0071	2.31	4.62	0.17	1.24	0.16	1.52	0.1	0.69
2.01-5.00	0	2.13	8.84	0.41	1.23	0.032	0.2	0.25	0.64
> 5.00	0	0.31	0.54	0.013	0.52	0	0	0.014	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Can-Avid (in sq. km.)								
	Jepaco	Mabuhay	Malogo	Obong	Pandol	Rawis	Salvacion	Solong	
0.03-0.20	2.24	6.08	5	10.35	17.77	1.75	16.34	5.41	143.07
0.21-0.50	0.17	0.34	0.57	0.63	0.54	0.32	0.56	0.26	11.464
0.51-1.00	0.23	0.43	0.72	0.89	0.28	0.19	0.29	0.24	10.789
1.01-2.00	0.24	0.48	0.93	0.97	0.19	0.34	0.23	0.37	14.86576
2.01-5.00	0.18	0.11	0.35	0.57	0.25	0.25	0.28	0.44	16.1709
> 5.00	0	0	0	0.0013	0.2	0.0089	0.25	0	1.8572

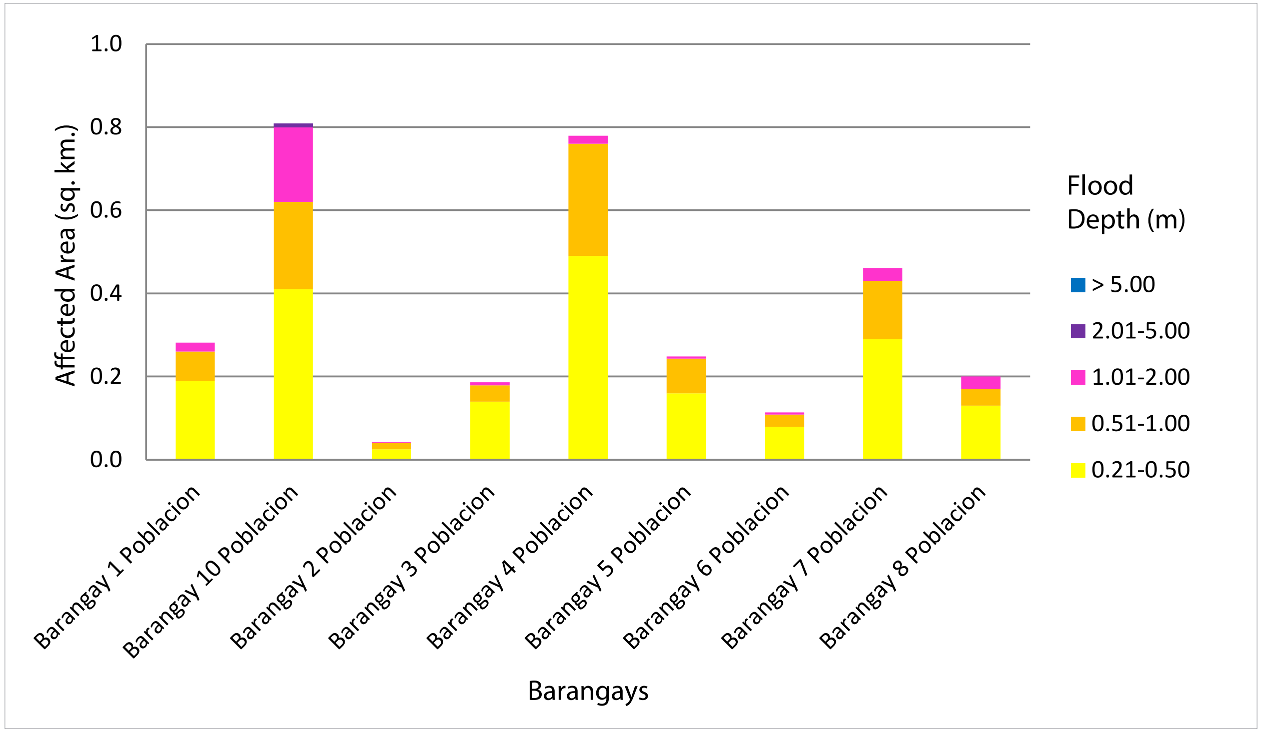


Figure 81. Affected areas in Can-Avid, Eastern Samar during a 25-Year Rainfall Return Period.

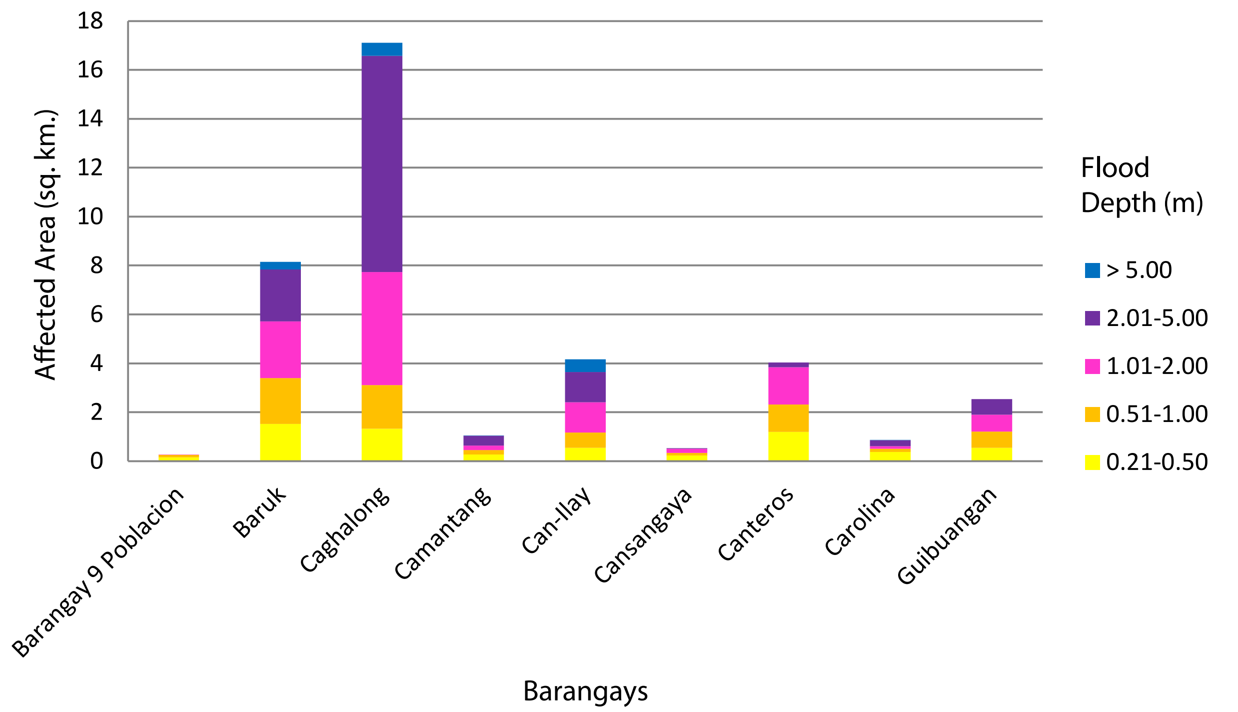


Figure 82. Affected areas in Can-Avid, Eastern Samar during a 25-Year Rainfall Return Period.

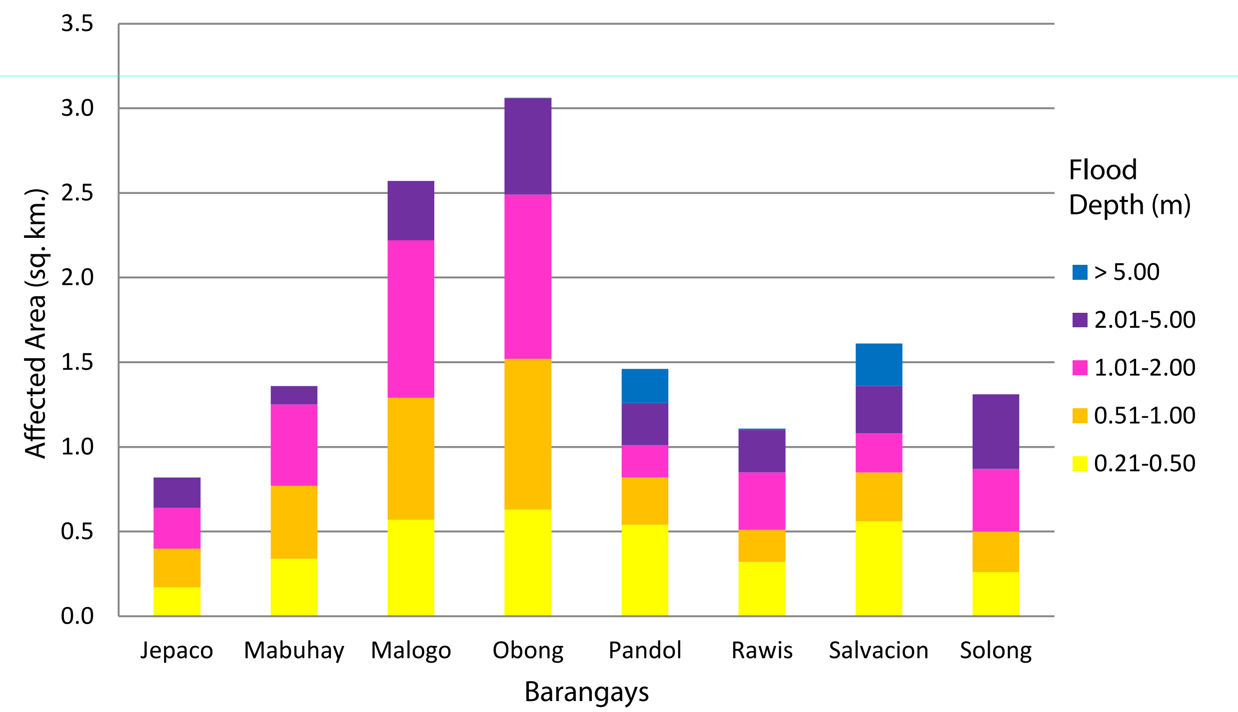


Figure 83. Affected areas in Can-Avid, Eastern Samar during a 25-Year Rainfall Return Period.

For the municipality of Dolores, with an area of 281.67 sq. km., 68.55% will experience flood levels of less 0.20 meters. 6.34% of the area will experience flood levels of 0.21 to 0.50 meters while 5.49%, 7.24%, 7.96%, and 2.66% 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. Table 33 depicts the affected areas in square kilometers by flood depth per barangay.

Table 34. Affected areas in Dolores, Eastern Samar during a 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Dolores (in sq. km.)								
	Aroganga	Barangay 1	Barangay 10	Barangay 11	Barangay 12	Barangay 13	Barangay 14	Barangay 15	Barangay 2
0.03-0.20	2.75	0.44	0.66	0.62	0.31	0.47	1.51	1.13	0.33
0.21-0.50	0.28	0.5	0.29	0.13	0.19	0.49	0.13	0.35	0.41
0.51-1.00	0.3	0.088	0.05	0.023	0.0044	0.0091	0.19	0.31	0.19
1.01-2.00	0.32	0.062	0.0069	0.00056	0	0	0.12	0.28	0.073
2.01-5.00	0.13	0.13	0	0	0.0001	0	0.014	0.028	0.21
> 5.00	0	0.009	0	0	0.0001	0	0	0	0.19

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Dolores (in sq. km.)								
	Barangay 3	Barangay 4	Barangay 5	Barangay 6	Barangay 7	Barangay 8	Barangay 9	Bonghon	Buenavista
0.03-0.20	0.33	0.52	0.46	0.32	0.25	0.11	0.22	2.33	2.99
0.21-0.50	0.19	0.17	0.064	0.3	0.052	0.13	0.25	0.26	0.12
0.51-1.00	0.021	0.039	0.0079	0.072	0.03	0.00074	0.19	0.14	0.093
1.01-2.00	0.0023	0.0033	0	0	0.0003	0	0.038	0.42	0.15
2.01-5.00	0	0.0036	0	0	0	0	0	0.13	0.13
> 5.00	0	0.0056	0	0	0	0	0	0.045	0.03

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Dolores (in sq. km.)								
	Cabago-An	Caglao-An	Cagtabon	Dampigan	Dapdap	Del Pilar	Denigpian	Gap-Ang	Hinolaso
0.03-0.20	2.43	11.71	3.81	2.89	4.26	14.82	12.12	2.85	6.22
0.21-0.50	0.097	0.72	0.25	0.46	1.12	1.06	0.47	0.13	0.73
0.51-1.00	0.1	0.88	0.23	0.9	0.44	1.34	0.44	0.2	1.17
1.01-2.00	0.13	1.1	0.53	0.96	0.38	1.87	0.55	0.29	1.77
2.01-5.00	0.071	1.23	0.97	0.063	0.42	2.89	1.07	0.24	1.41
> 5.00	0.0019	0.079	0.12	0.24	0	1.11	0.49	0.067	0.37

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Dolores (in sq. km.)								
	Japitan	Jicontol	Libertad	Magongbong	Magsaysay	Malaintos	Malobago	Osmeña	Rizal
0.03-0.20	1.92	1.03	2.49	5.45	2.41	3.12	5.52	18.95	23.91
0.21-0.50	0.98	0.19	0.25	0.36	0.19	0.69	0.5	1.05	1.06
0.51-1.00	0.12	0.38	0.29	0.34	0.24	0.7	0.44	1.69	1.05
1.01-2.00	0.05	0.95	0.5	0.51	0.4	0.94	0.53	2.26	1.05
2.01-5.00	0.0029	2.31	1.22	0.22	0.65	0.31	0.14	1.14	1.05
> 5.00	0	0.35	0.14	0.01	0.081	0.15	0.97	0.76	0.15

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Dolores (in sq. km.)								
	San Isidro	San Pascual	San Roque	San Vicente	Santa Cruz	Santo Niño	Tanauan	Tikling	Villahermosa
0.03-0.20	2.86	5.78	9.57	3.41	9.92	2.41	0.83	1.4	15.25
0.21-0.50	0.21	0.19	0.29	0.15	0.39	0.22	0.079	0.83	0.88
0.51-1.00	0.18	0.16	0.29	0.17	0.35	0.23	0.077	0.35	0.96
1.01-2.00	0.35	0.2	0.5	0.14	0.61	0.24	0.53	0.11	1.48
2.01-5.00	0.47	0.41	1.25	0.28	1.19	0.044	0.93	0.068	1.6
> 5.00	0.042	0.17	0.39	0.0011	0.11	0.045	0.52	0.026	0.81

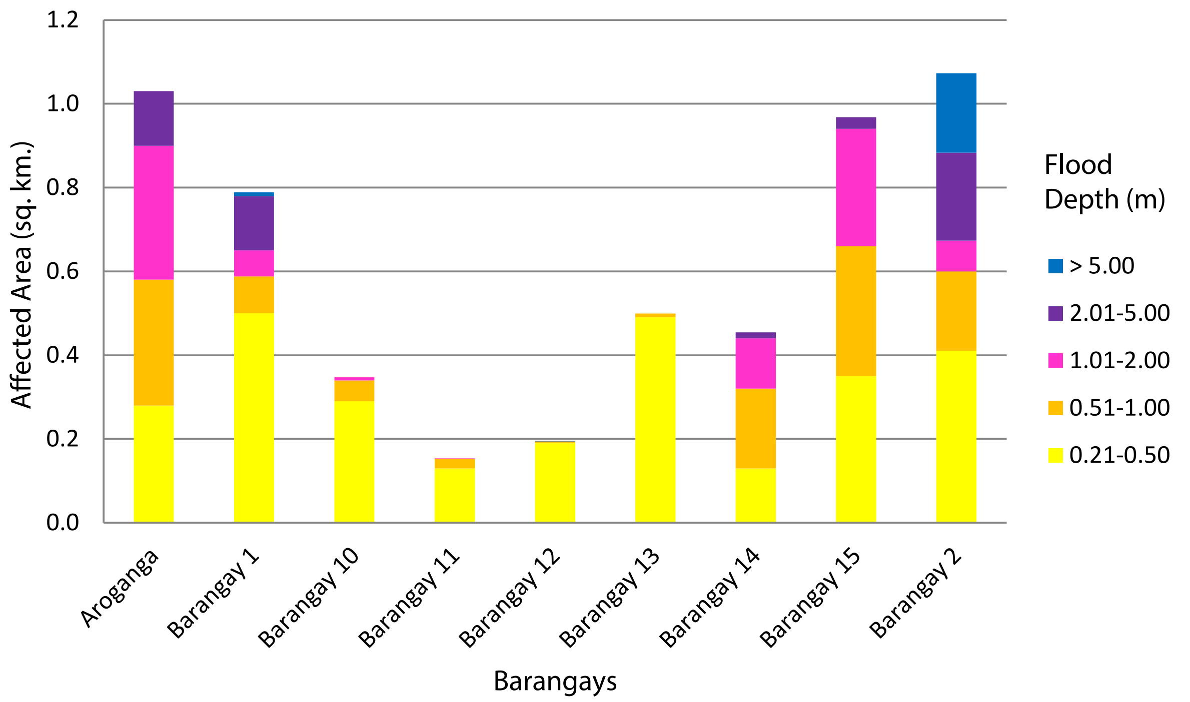


Figure 84. Affected areas in Dolores, Eastern Samar during a 25-Year Rainfall Return Period.

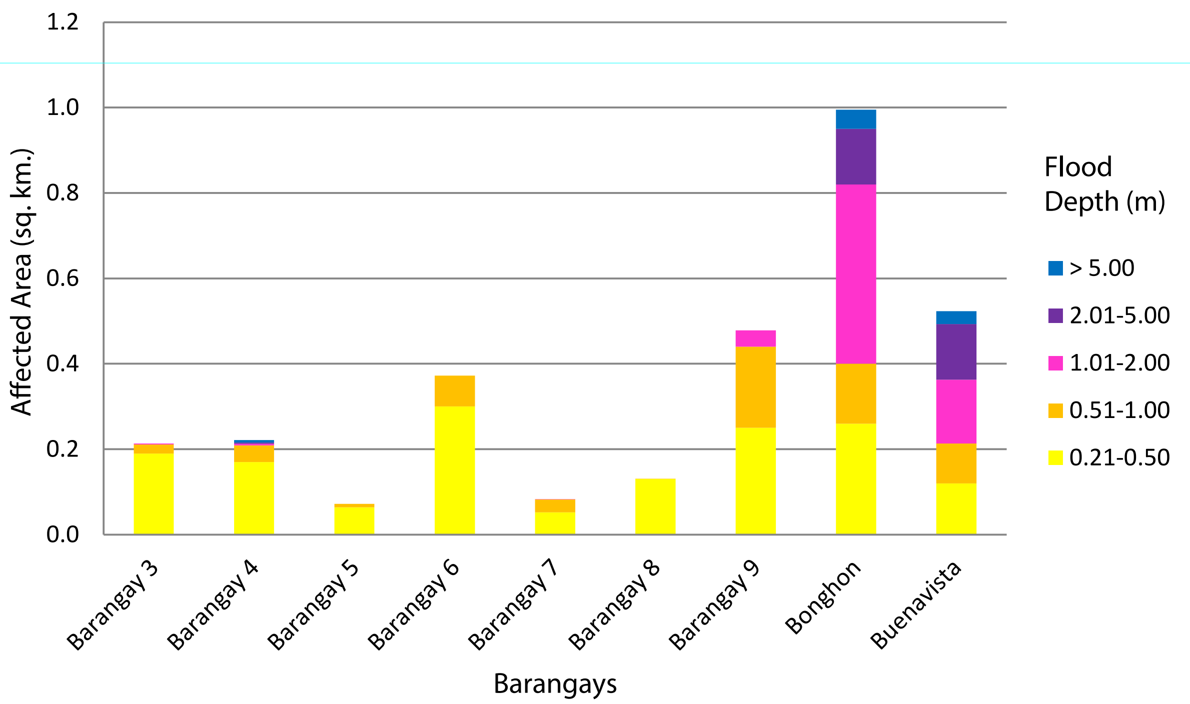


Figure 85. Affected areas in Dolores, Eastern Samar during a 25-Year Rainfall Return Period.

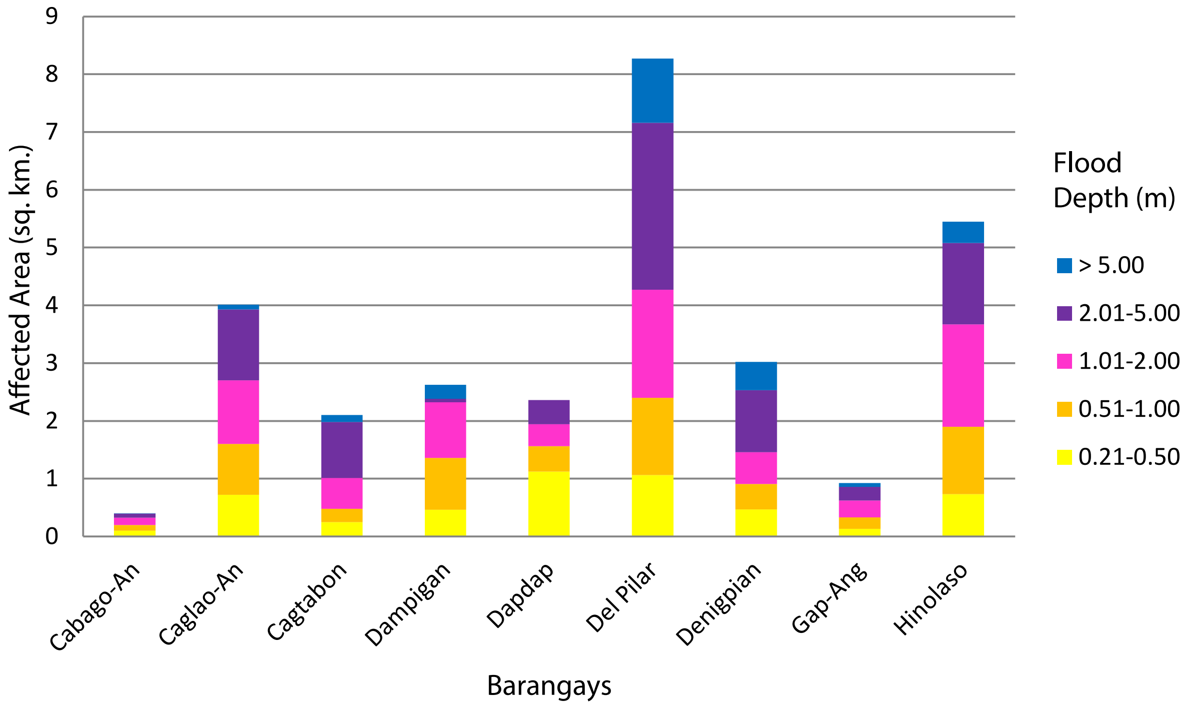


Figure 86. Affected areas in Dolores, Eastern Samar during a 25-Year Rainfall Return Period.

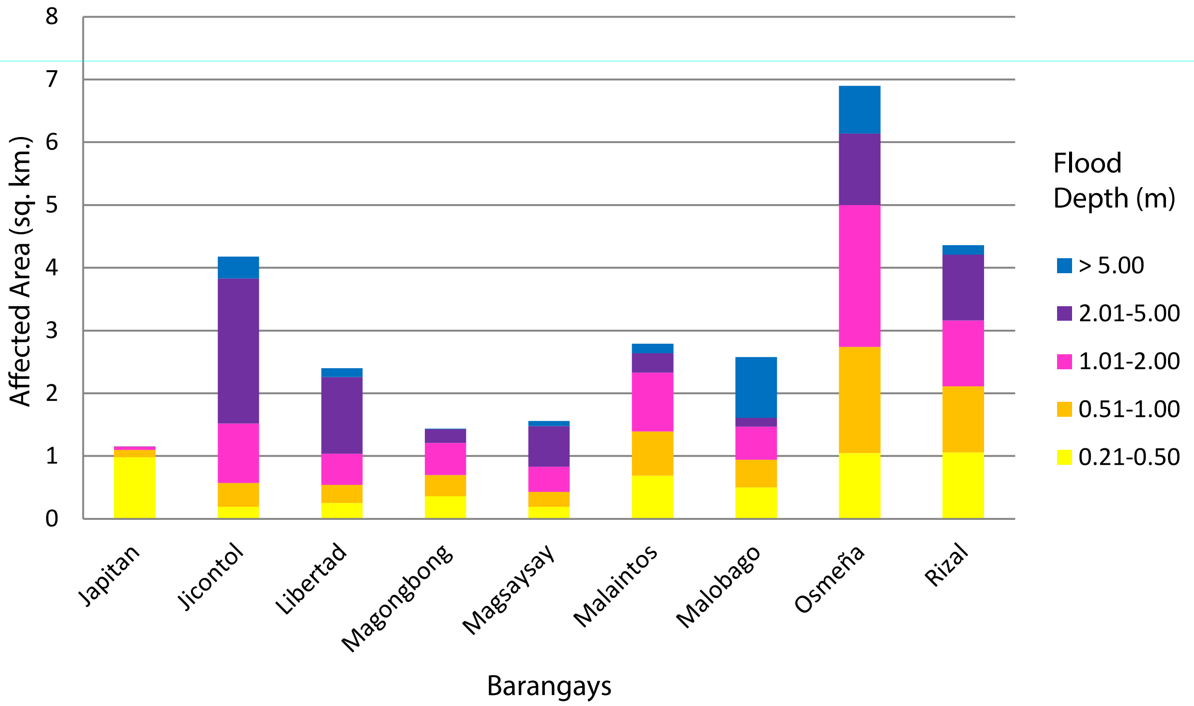


Figure 87. Affected areas in Dolores, Eastern Samar during a 25-Year Rainfall Return Period.

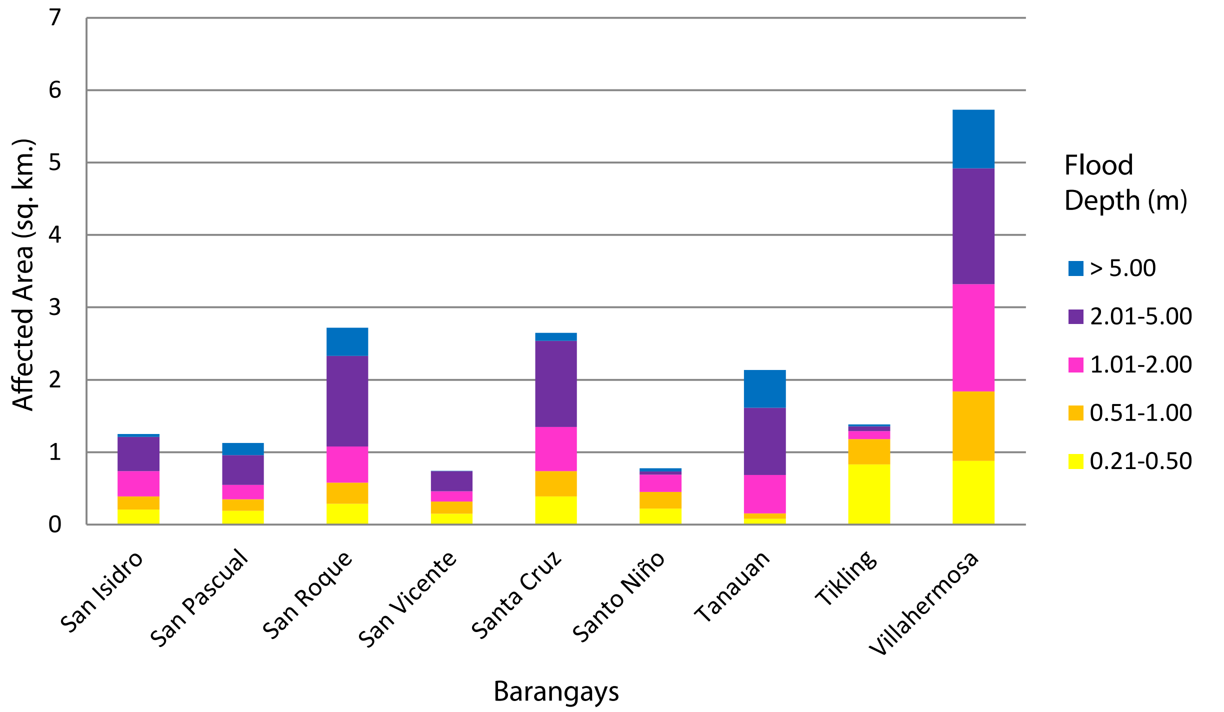


Figure 88. Affected areas in Dolores, Eastern Samar during a 25-Year Rainfall Return Period.

For the municipality of Maslog, with an area of 284.92 sq. km., 16.74% will experience flood levels of less 0.20 meters. 0.8% of the area will experience flood levels of 0.21 to 0.50 meters while 0.49%, 0.58%, 2.12%, and 1.81% 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. Table 34 depicts the affected areas in square kilometers by flood depth per barangay.

Table 35. Affected areas in Maslog, Eastern Samar during a 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Maslog (in sq. km.)						
	Libertad	Malobago	Maputi	San Miguel	San Roque	Tangbo	Tugas
0.03-0.20	5.52	15.79	17.16	0.022	3.5	5.7	0.00058
0.21-0.50	0.27	0.85	0.76	0.0022	0.11	0.28	0
0.51-1.00	0.15	0.42	0.6	0.0012	0.082	0.14	0
1.01-2.00	0.077	0.35	1.04	0	0.089	0.096	0.000092
2.01-5.00	0.082	0.56	5.17	0	0.13	0.094	0.0001
> 5.00	0.54	0.97	3.55	0	0.063	0.022	0.00067

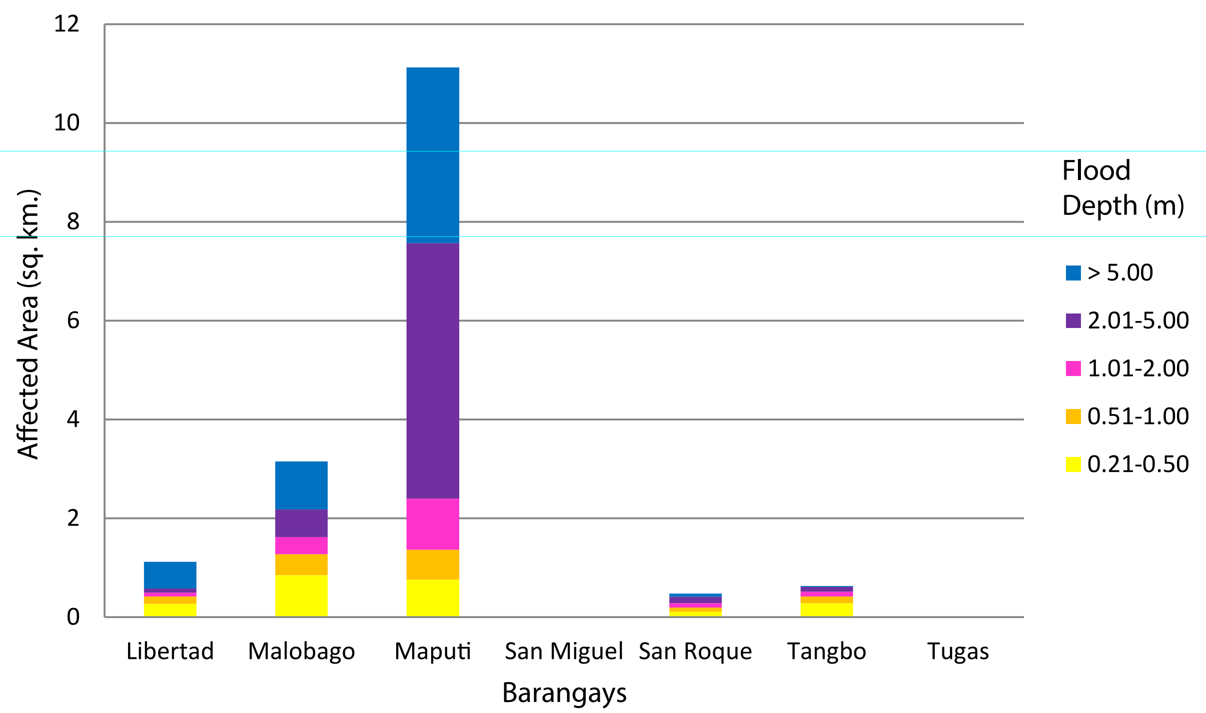


Figure 89. Affected areas in Maslog, Eastern Samar during a 25-Year Rainfall Return Period.

For the municipality of Oras, with an area of 173.99 sq. km., 34.17% will experience flood levels of less 0.20 meters. 2.22% of the area will experience flood levels of 0.21 to 0.50 meters while 1.51%, 1.41%, 1.83%, and 0.38% 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. Table 35 depicts the affected areas in square kilometers by flood depth per barangay.

Table 36. Affected areas in Oras, Eastern Samar during a 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Oras (in sq. km.)						
	Bagacay	Balingasag	Bato	Cagpile	Dalid	Dao	Factoria
0.03-0.20	2.51	19.93	1.14	1.06	2.65	0.43	1.75
0.21-0.50	0.52	0.52	0.065	0.033	0.65	0.21	0.57
0.51-1.00	0.37	0.39	0.14	0.027	0.56	0.091	0.22
1.01-2.00	0.31	0.53	0.11	0.037	0.35	0	0.063
2.01-5.00	0.0033	1.39	0.13	0.15	0.0027	0	0.0009
> 5.00	0	0.4	0	0.043	0	0	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Oras (in sq. km.)						
	Gamot	Japay	Kalaw	Minap-Os	Naga	Saugan	Trinidad
0.03-0.20	8.72	1.39	1.44	5.44	3.47	2.17	7.35
0.21-0.50	0.32	0.098	0.083	0.16	0.088	0.3	0.25
0.51-1.00	0.16	0.083	0.099	0.12	0.062	0.051	0.25
1.01-2.00	0.17	0.052	0.071	0.21	0.085	0.006	0.46
2.01-5.00	0.44	0.0067	0.0024	0.51	0.15	0	0.4
> 5.00	0.19	0	0	0.021	0.0006	0	0.0038

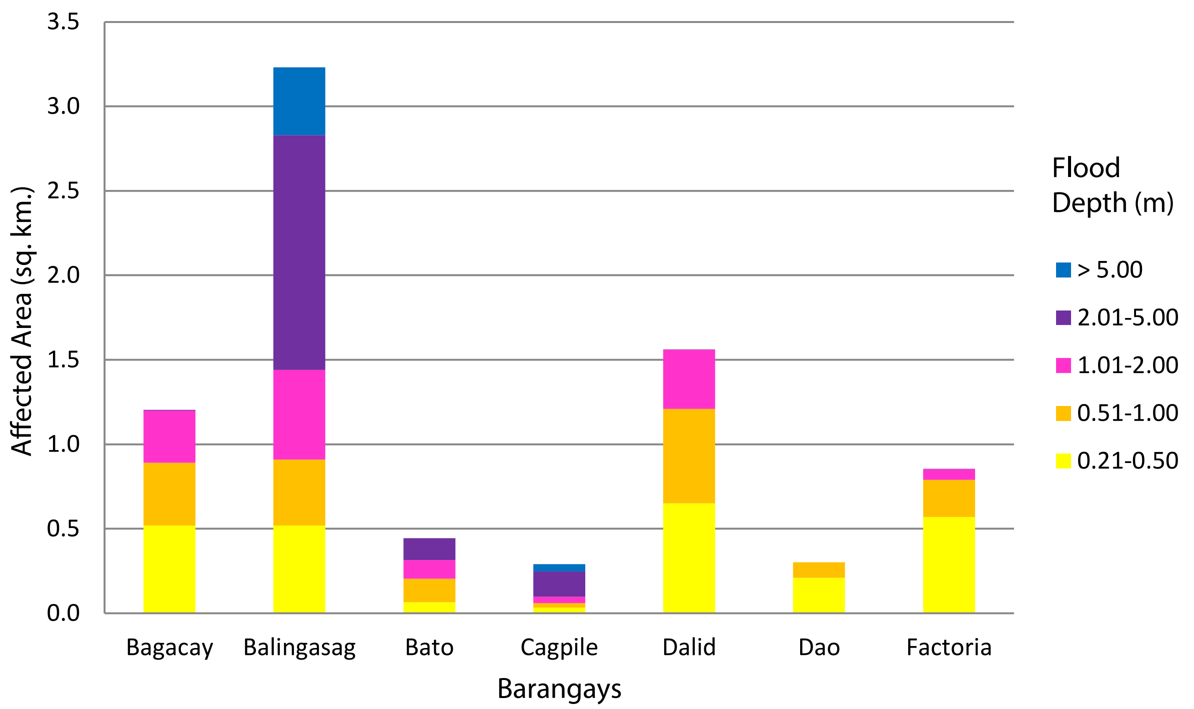


Figure 90. Affected areas in Oras, Eastern Samar during a 25-Year Rainfall Return Period.

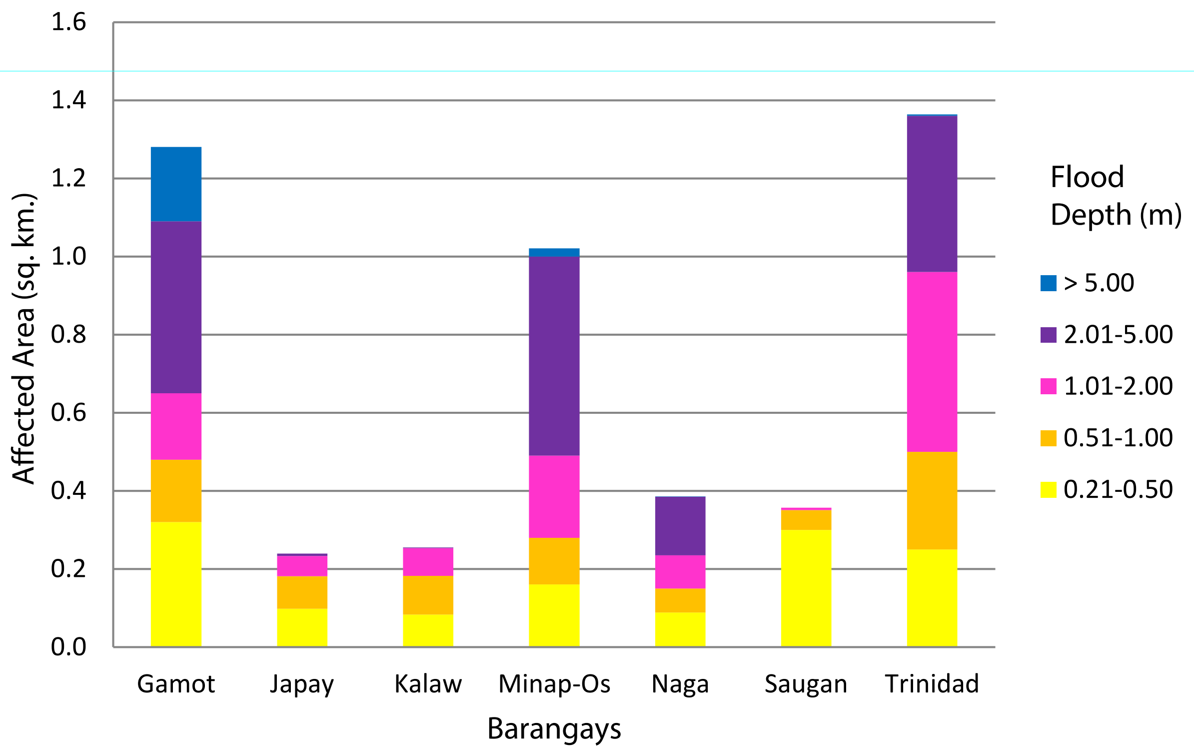


Figure 91. Affected areas in Oras, Eastern Samar during a 5-Year Rainfall Return Period.

For the municipality of Paranas, with an area of 536.76 sq. km., 0.32% will experience flood levels of less 0.20 meters. 0.01% of the area will experience flood levels of 0.21 to 0.50 meters while 0.006%, 0.004%, and 0.002% of the area will experience flood depths of 0.51 to 1 meter,1.01 to 2 meters, and more than 2 meters, respectively. Table 36 depicts the affected areas in square kilometers by flood depth per barangay.

Table 37. Affected areas in Paranas, Samar during a 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Paranas (in sq. km.)
	Anagasi
0.03-0.20	1.7
0.21-0.50	0.055
0.51-1.00	0.034
1.01-2.00	0.021
2.01-5.00	0.0094
> 5.00	0

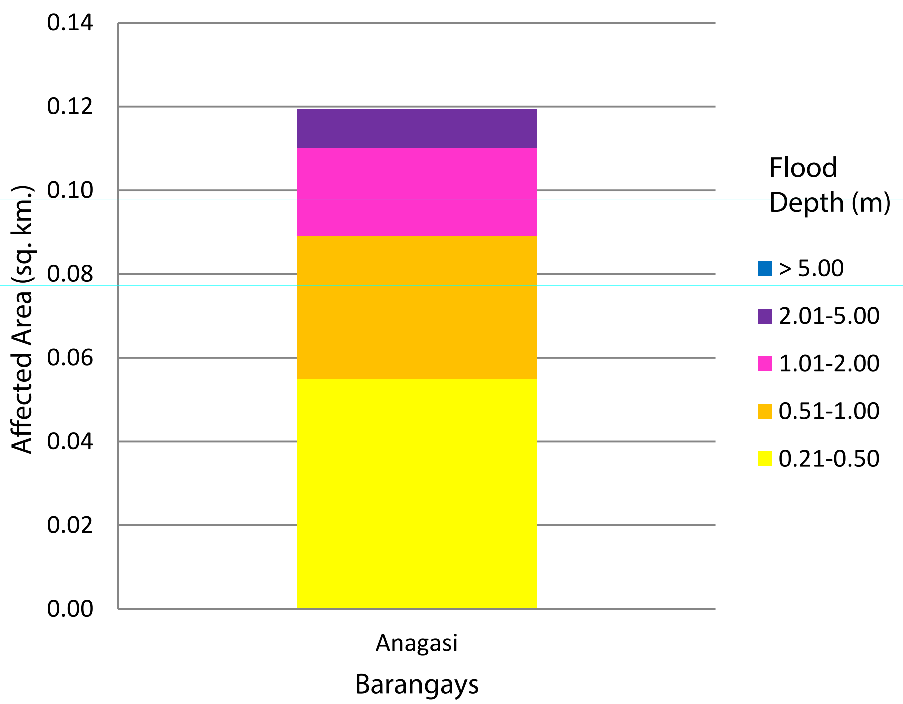


Figure 92. Affected areas in Paranas, Samar during a 25-Year Rainfall Return Period.

For the 100-year return period, 11.43% of the municipality of Arteche with an area of 162.3 sq. km. will experience flood levels of less 0.20 meters, while 0.39% of the area will experience flood levels of 0.21 to 0.50 meters; 0.27%, 0.36%, 0.7%, and 0.69% 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. Table 37 depicts the areas affected in Arteche in square kilometers by flood depth per barangay.

Table 38. Affected areas in Arteche, Eastern Samar during a 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Arteche (in sq. km.)				
	Bigo	Cagsalay	Casidman	Macarthur	Tawagan
0.03-0.20	0.74	0.12	4.08	9.78	3.83
0.21-0.50	0.017	0.0011	0.11	0.35	0.15
0.51-1.00	0.011	0.0006	0.1	0.24	0.08
1.01-2.00	0.011	0.001	0.16	0.35	0.06
2.01-5.00	0.011	0	0.37	0.69	0.059
> 5.00	0.0007	0	0.28	0.79	0.043

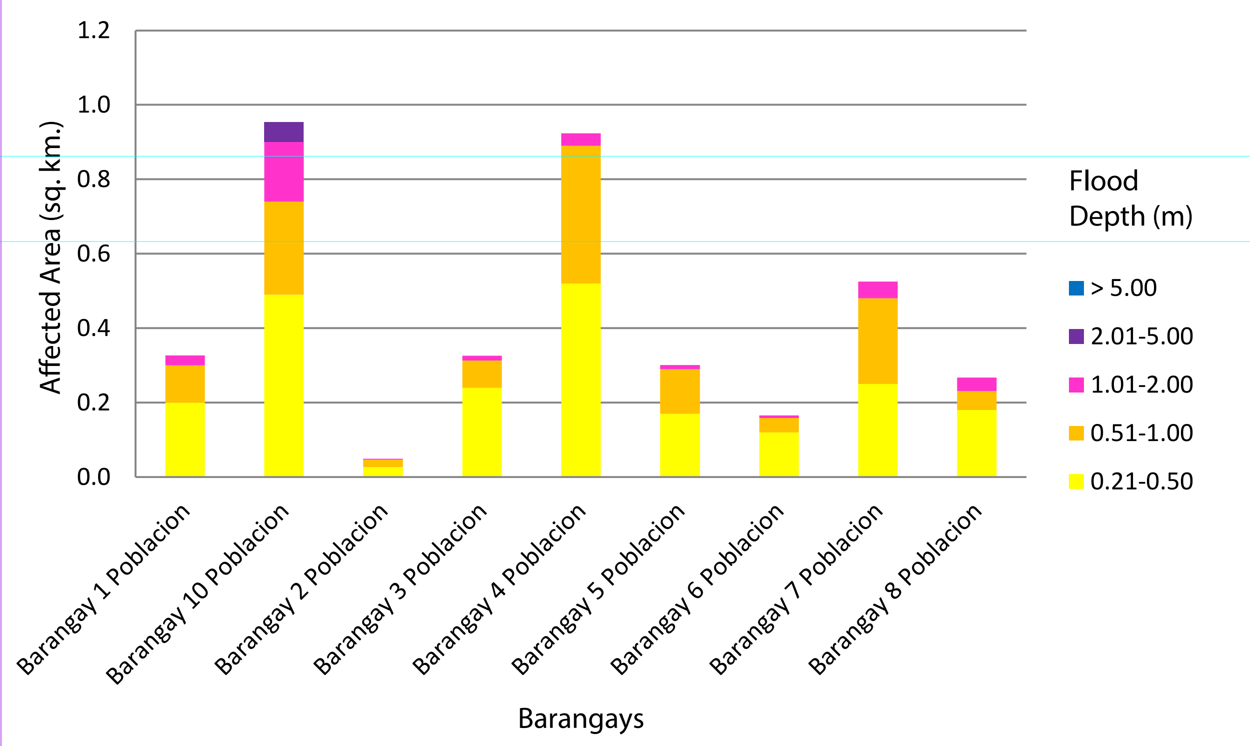


Figure 93. Affected areas in Arteche, Eastern Samar during a 100-Year Rainfall Return Period

For the municipality of Can-Avid, with an area of 285.22 sq. km., 48.35% will experience flood levels of less 0.20 meters. 4.03% of the area will experience flood leves of 0.21 to 0.50 meters while 3.64%, 5.04%, 7.36%, and 1.07% 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. Error! Reference source not found. depicts the affected areas in square kilometers by flood depth per barangay.

Table 39. Affected areas in Can-Avid, Eastern Samar during a 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Can-Avid (in sq. km.)								
	Barangay 1 Poblacion	Barangay 10 Poblacion	Barangay 2 Poblacion	Barangay 3 Poblacion	Barangay 4 Poblacion	Barangay 5 Poblacion	Barangay 6 Poblacion	Barangay 7 Poblacion	Barangay 8 Poblacion
0.03-0.20	0.52	1.37	0.13	0.2	0.52	0.092	0.2	0.26	0.41
0.21-0.50	0.2	0.49	0.027	0.24	0.52	0.17	0.12	0.25	0.18
0.51-1.00	0.1	0.25	0.02	0.073	0.37	0.12	0.039	0.23	0.051
1.01-2.00	0.027	0.16	0.0026	0.013	0.034	0.011	0.0067	0.045	0.036
2.01-5.00	0	0.053	0	0	0	0	0	0	0
> 5.00	0	0	0	0	0	0	0	0	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Can-Avid (in sq. km.)								
	Barangay 9 Poblacion	Baruk	Caghalong	Camantang	Can-Ilay	Cansangaya	Canteros	Carolina	Guibuangan
0.03-0.20	0.096	23.52	16.31	3.66	14.56	2.23	2.93	1.73	5.55
0.21-0.50	0.15	1.43	1.09	0.3	0.5	0.24	0.99	0.64	0.46
0.51-1.00	0.15	1.68	1.36	0.2	0.57	0.13	1.21	0.19	0.61
1.01-2.00	0.0093	2.59	3.03	0.18	1.07	0.14	1.65	0.12	0.91
2.01-5.00	0	2.31	11.8	0.44	1.57	0.078	0.56	0.26	0.77
> 5.00	0	0.91	0.73	0.036	0.74	0	0	0.024	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Can-Avid (in sq. km.)								
	Jepaco	Mabuhay	Malogo	Obong	Pandol	Rawis	Salvacion	Solong	
0.03-0.20	2.17	5.98	4.83	10.11	17.6	1.46	16.15	5.31	137.898
0.21-0.50	0.16	0.32	0.51	0.57	0.6	0.45	0.62	0.27	11.497
0.51-1.00	0.21	0.39	0.64	0.72	0.3	0.25	0.31	0.22	10.393
1.01-2.00	0.29	0.58	1.03	1.27	0.21	0.35	0.25	0.36	14.3746
2.01-5.00	0.21	0.16	0.56	0.75	0.27	0.35	0.3	0.55	20.991
> 5.00	0.0023	0	0	0.0023	0.26	0.015	0.33	0	3.0496

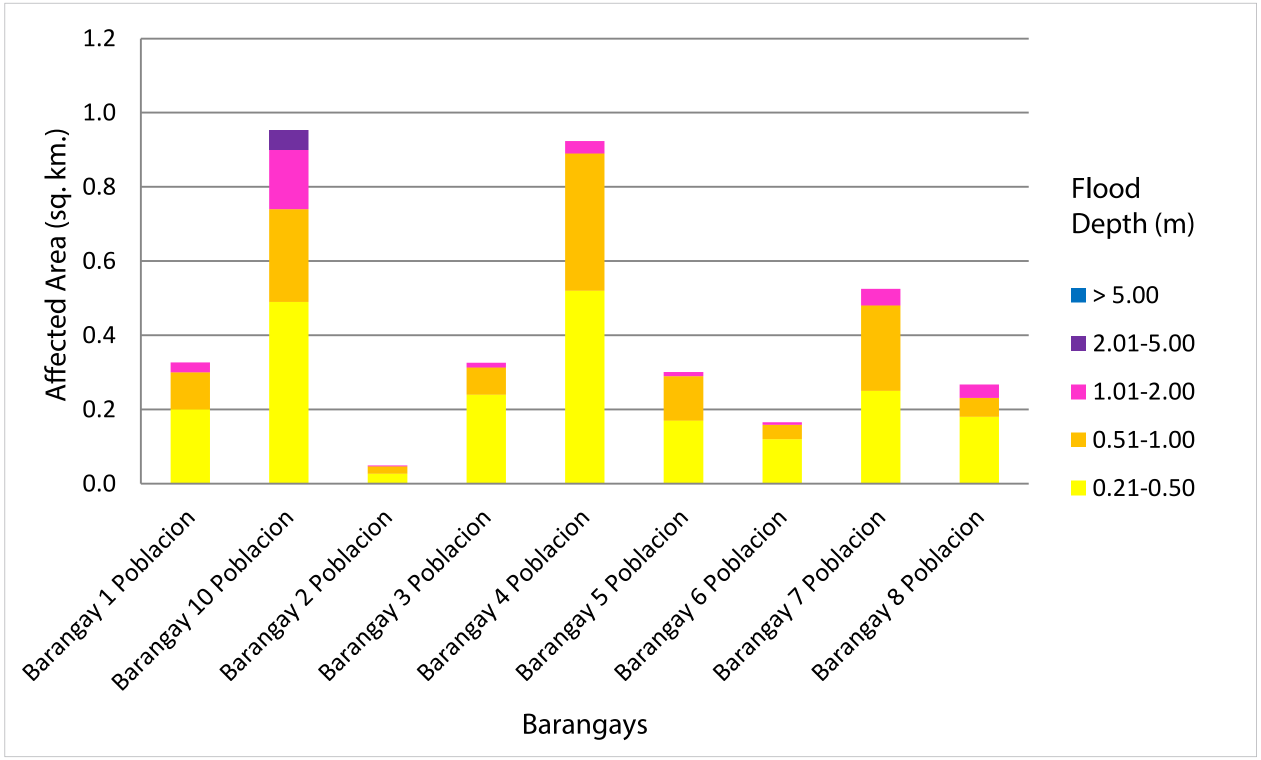


Figure 94. Affected areas in Can-Avid, Eastern Samar during a 100-Year Rainfall Return Period.

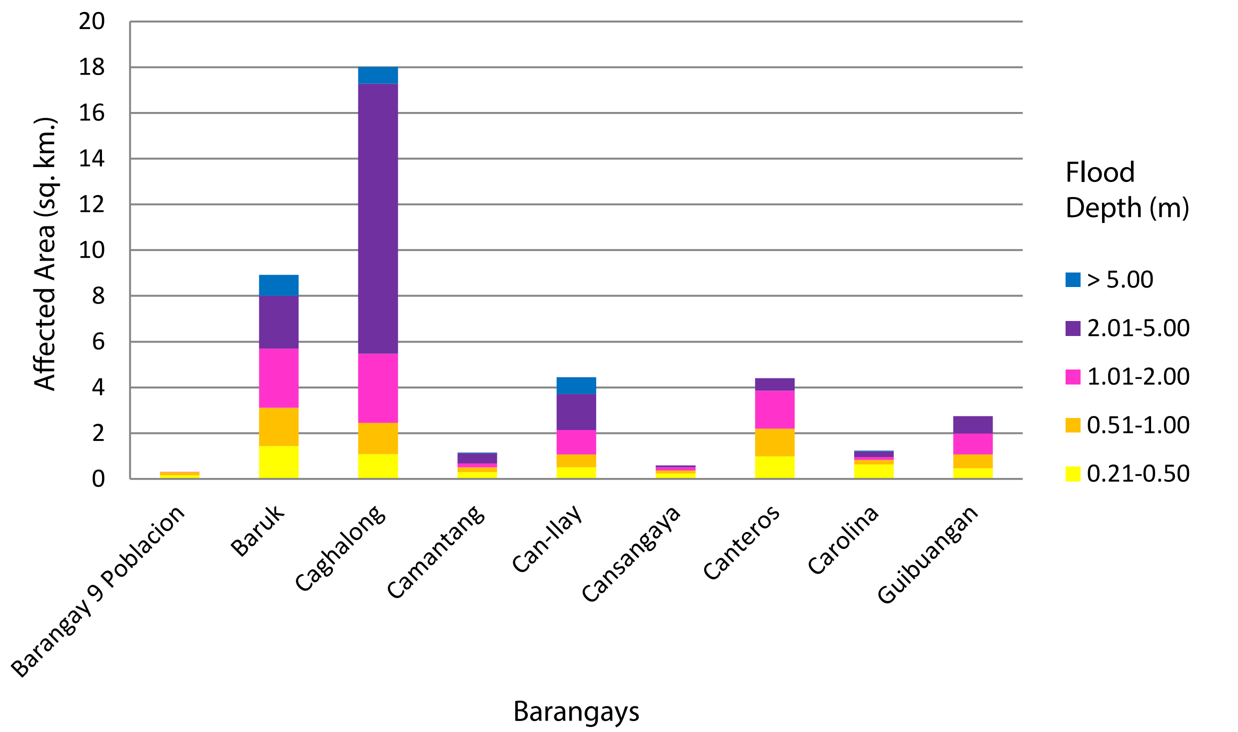


Figure 95. Affected areas in Can-Avid, Eastern Samar during a 100-Year Rainfall Return Period.

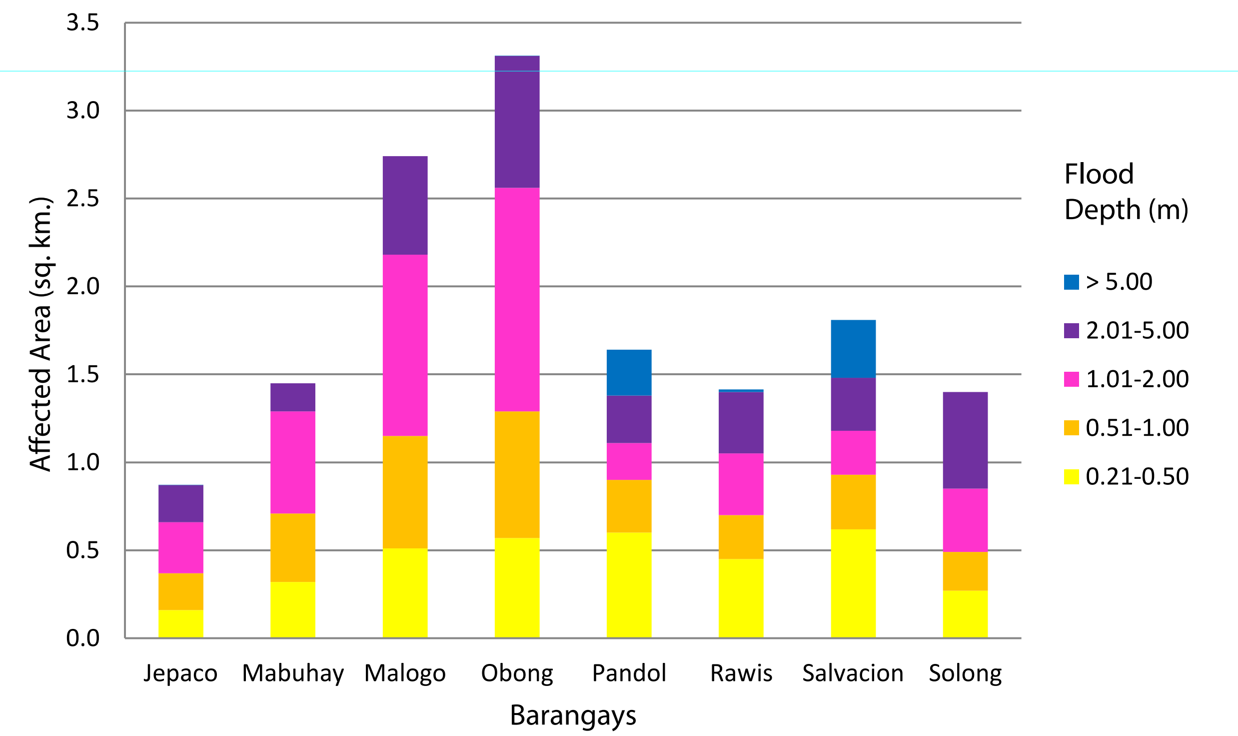


Figure 96. Affected areas in Can-Avid, Eastern Samar during a 100-Year Rainfall Return Period.

For the municipality of Dolores, with an area of 281.67 sq. km., 66.13% will experience flood levels of less 0.20 meters. 6.21% of the area will experience flood levels of 0.21 to 0.50 meters while 5.36%, 7.35%, 9.55%, and 3.75% 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. Table 39 depicts the affected areas in square kilometers by flood depth per barangay.

Table 40. Affected areas in Dolores, Eastern Samar during a 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Dolores (in sq. km.)								
	Aroganga	Barangay 1	Barangay 10	Barangay 11	Barangay 12	Barangay 13	Barangay 14	Barangay 15	Barangay 2
0.03-0.20	2.63	0.16	0.58	0.58	0.26	0.39	1.47	1.05	0.18
0.21-0.50	0.24	0.34	0.35	0.17	0.21	0.38	0.13	0.31	0.27
0.51-1.00	0.28	0.49	0.073	0.029	0.035	0.19	0.17	0.38	0.39
1.01-2.00	0.41	0.08	0.016	0.0024	0	0	0.17	0.33	0.16
2.01-5.00	0.21	0.15	0.0001	0	0.0001	0	0.022	0.042	0.17
> 5.00	0.01	0.015	0	0	0.0001	0	0	0	0.23

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Dolores (in sq. km.)								
	Barangay 3	Barangay 4	Barangay 5	Barangay 6	Barangay 7	Barangay 8	Barangay 9	Bonghon	Buenavista
0.03-0.20	0.26	0.46	0.34	0.26	0.12	0.075	0.16	2.26	2.95
0.21-0.50	0.25	0.2	0.18	0.31	0.18	0.16	0.26	0.24	0.12
0.51-1.00	0.025	0.057	0.01	0.12	0.034	0.002	0.22	0.17	0.094
1.01-2.00	0.0036	0.0059	0	0.00027	0.0044	0	0.058	0.37	0.15
2.01-5.00	0	0.004	0	0	0	0	0	0.22	0.16
> 5.00	0	0.0059	0	0	0	0	0	0.047	0.033

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Dolores (in sq. km.)								
	Cabago-An	Caglao-An	Cagtabon	Dampigan	Dapdap	Del Pilar	Denigpian	Gap-Ang	Hinolaso
0.03-0.20	2.4	11.45	3.69	2.67	3.93	14.23	11.8	2.78	5.82
0.21-0.50	0.1	0.66	0.24	0.49	1.14	0.91	0.48	0.12	0.68
0.51-1.00	0.093	0.85	0.2	0.67	0.62	1.03	0.42	0.11	1.14
1.01-2.00	0.16	1.09	0.32	1.29	0.4	1.79	0.53	0.29	1.92
2.01-5.00	0.085	1.52	1.23	0.15	0.53	3.45	0.96	0.4	1.58
> 5.00	0.0044	0.17	0.22	0.25	0	1.71	0.93	0.08	0.54

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Dolores (in sq. km.)								
	Japitan	Jicontol	Libertad	Magongbong	Magsaysay	Malaintos	Malobago	Osmeña	Rizal
0.03-0.20	1.75	0.93	2.39	5.35	2.29	2.94	5.37	18.6	23.5
0.21-0.50	1.07	0.14	0.24	0.32	0.14	0.64	0.51	1.01	1.05
0.51-1.00	0.2	0.26	0.28	0.29	0.21	0.72	0.46	1.23	0.95
1.01-2.00	0.057	0.67	0.48	0.42	0.33	1	0.5	2.69	1.21
2.01-5.00	0.0047	2.73	1.33	0.49	0.84	0.44	0.29	1.3	1.32
> 5.00	0	0.47	0.17	0.013	0.15	0.17	1.21	1.06	0.23

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Dolores (in sq. km.)								
	San Isidro	San Pascual	San Roque	San Vicente	Santa Cruz	Santo Niño	Tanauan	Tikling	Villahermosa
0.03-0.20	2.79	5.69	9.41	3.34	9.76	2.35	0.81	1.16	14.87
0.21-0.50	0.21	0.19	0.29	0.14	0.4	0.21	0.08	0.89	0.83
0.51-1.00	0.17	0.16	0.27	0.14	0.34	0.24	0.075	0.48	0.72
1.01-2.00	0.34	0.2	0.45	0.18	0.51	0.23	0.41	0.15	1.32
2.01-5.00	0.55	0.35	1.19	0.3	1.4	0.11	1.06	0.071	2.23
> 5.00	0.043	0.31	0.67	0.059	0.15	0.046	0.52	0.036	1.01

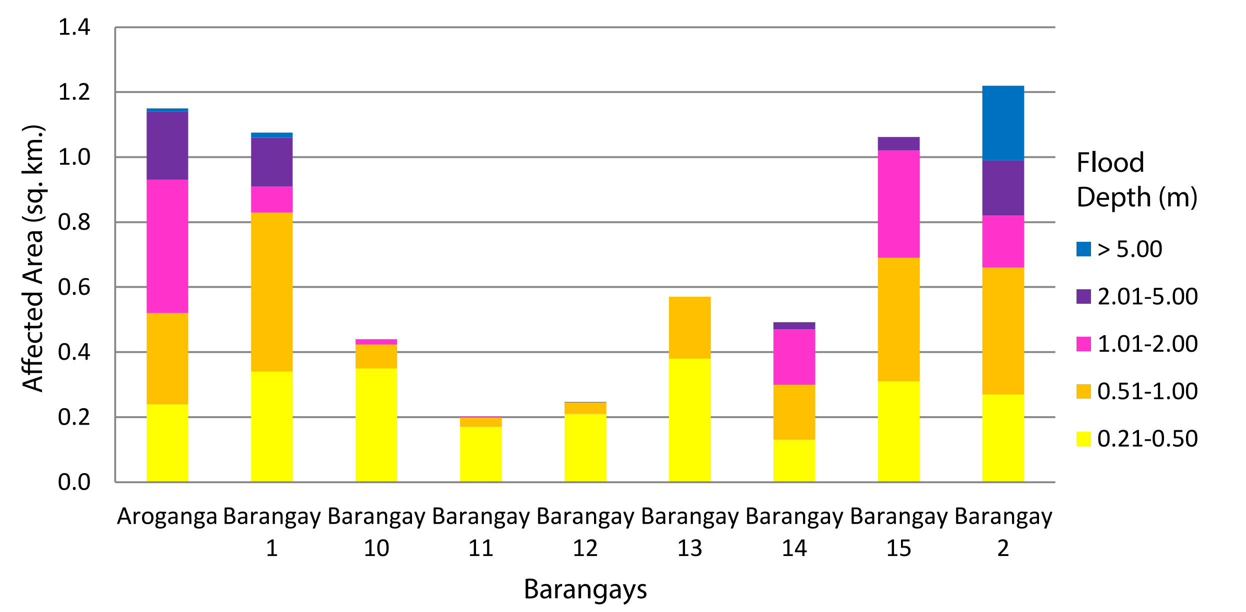


Figure 97. Affected areas in Dolores, Eastern Samar during a 100-Year Rainfall Return Period.

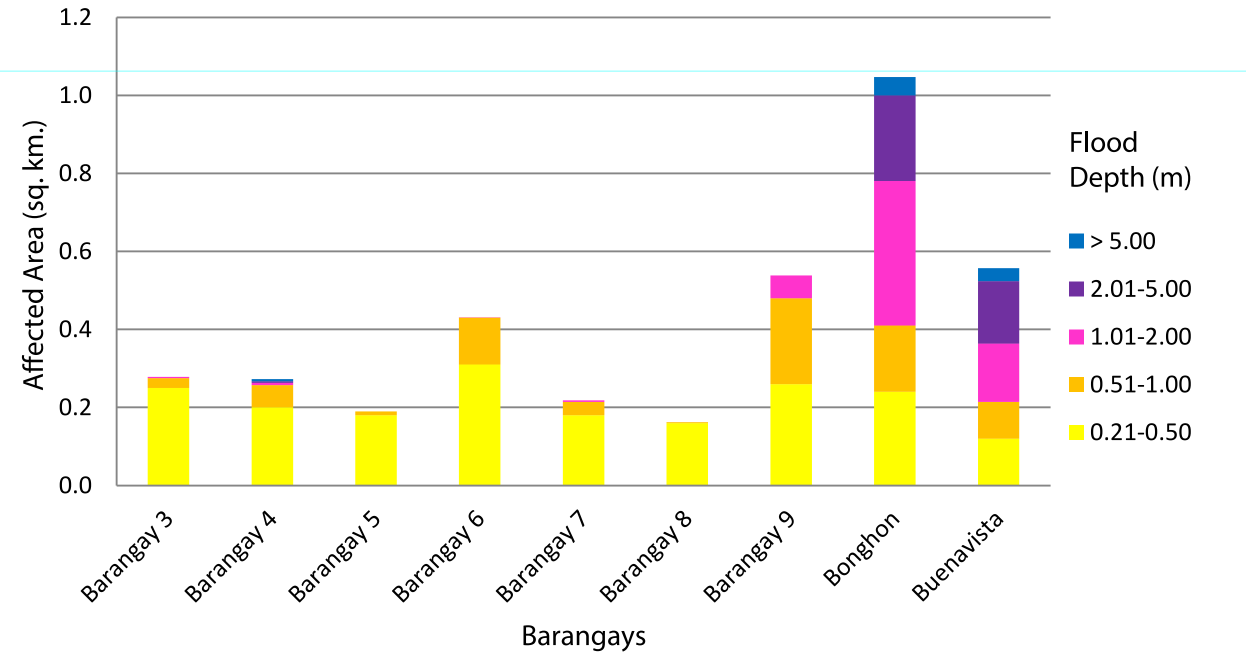


Figure 98. Affected areas in Dolores, Eastern Samar during a 100-Year Rainfall Return Period.

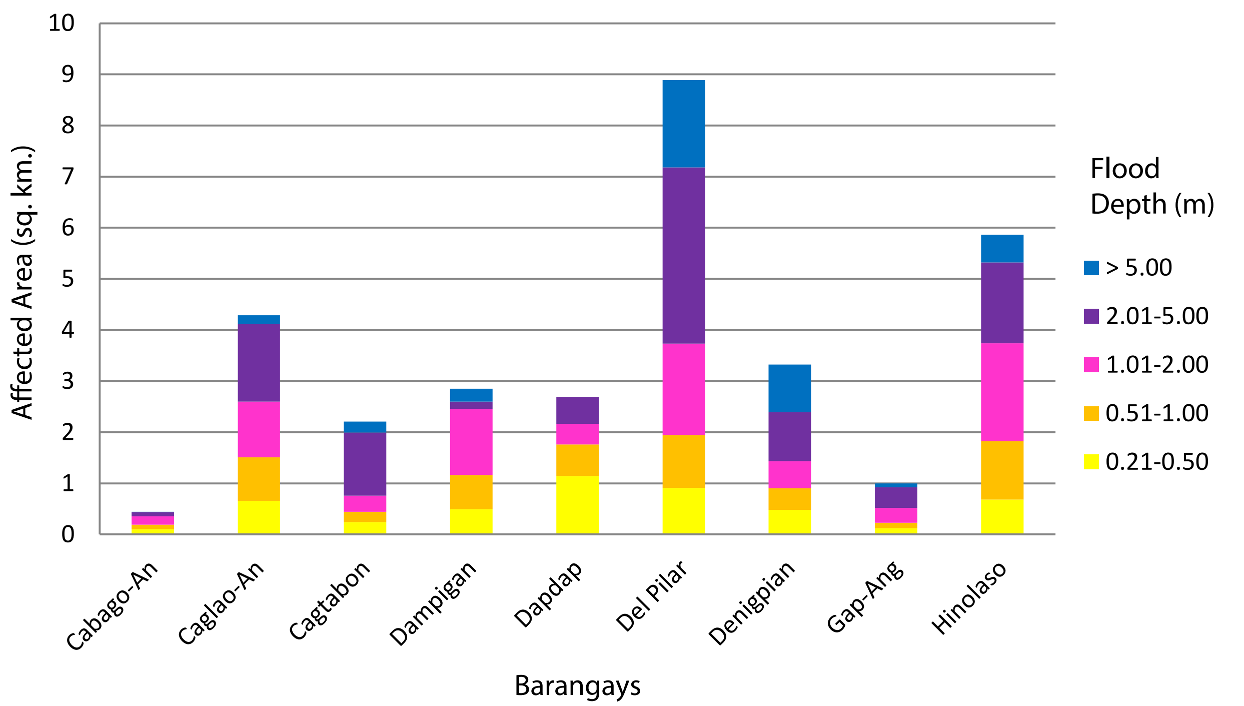


Figure 99. Affected areas in Dolores, Eastern Samar during a 100-Year Rainfall Return Period.

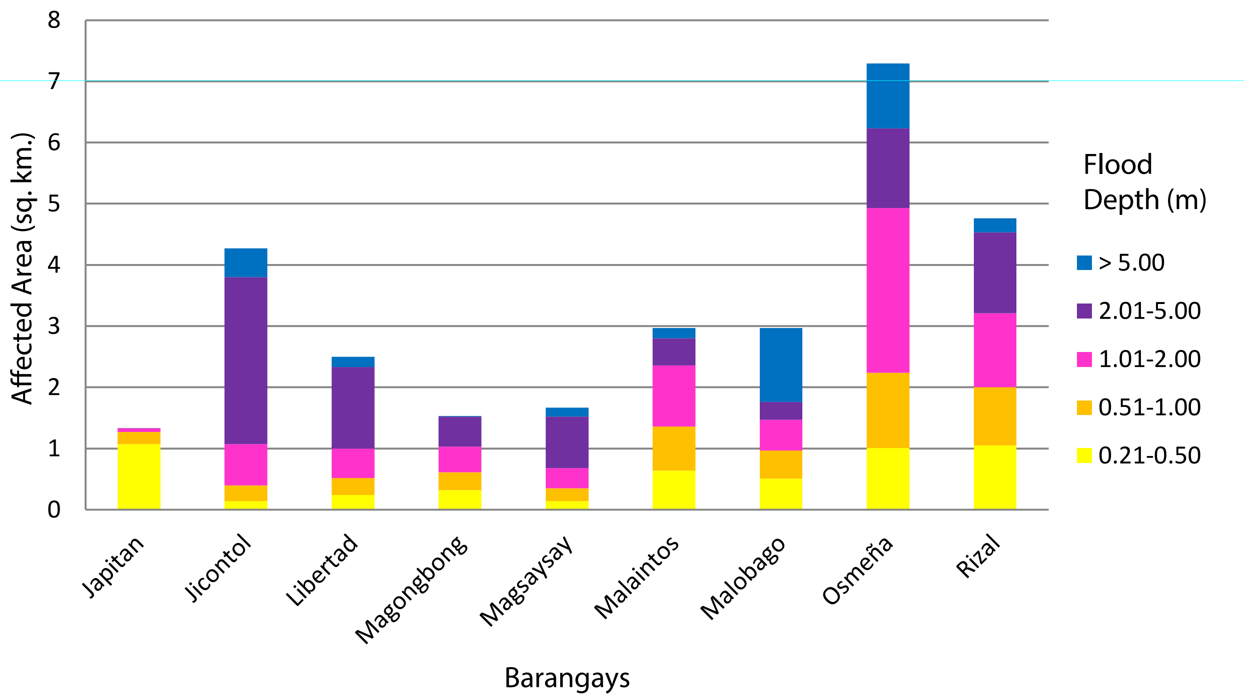


Figure 100. Affected areas in Dolores, Eastern Samar during a 100-Year Rainfall Return Period.

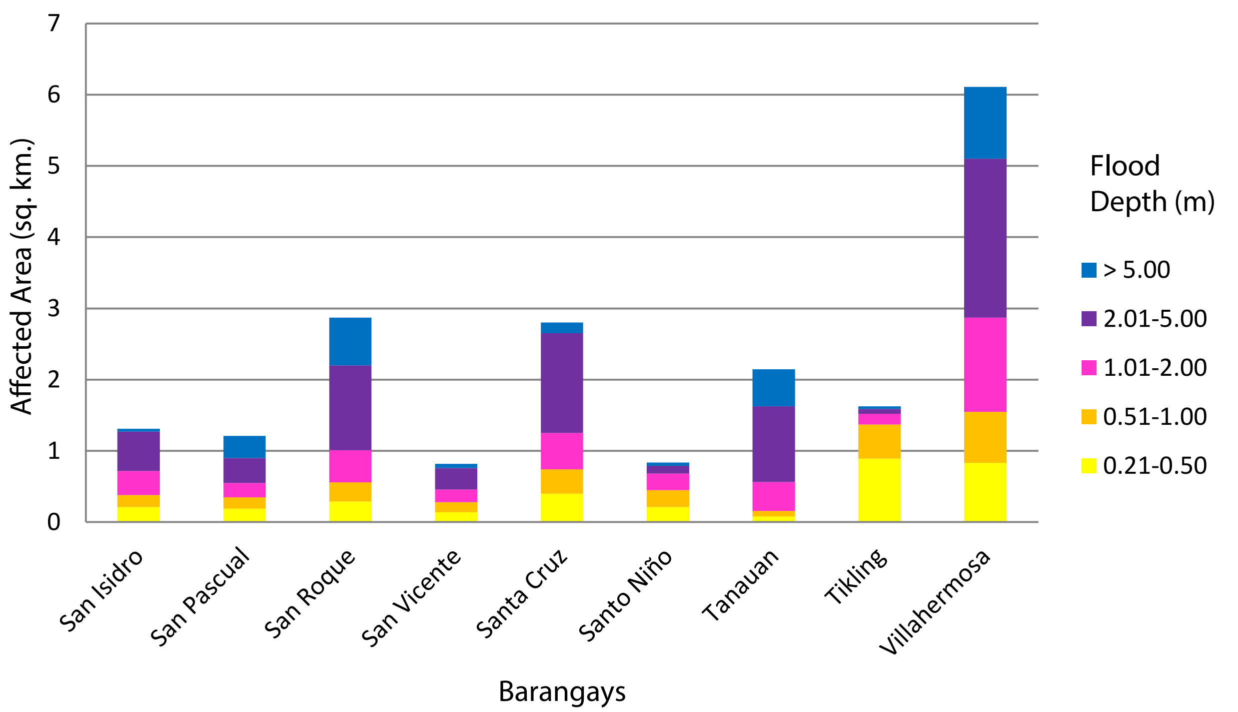


Figure 101. Affected areas in Dolores, Eastern Samar during a 100-Year Rainfall Return Period.

For the municipality of Maslog, with an area of 284.92 sq. km., 16.34% will experience flood levels of less 0.20 meters. 0.84% of the area will experience flood levels of 0.21 to 0.50 meters while 0.5%, 0.49%, 1.38%, and 2.99% 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. Table 40 depicts the affected areas in square kilometers by flood depth per barangay.

Table 41. Affected areas in Maslog, Eastern Samar during a 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Maslog (in sq. km.)						
	Libertad	Malobago	Maputi	San Miguel	San Roque	Tangbo	Tugas
0.03-0.20	5.41	15.48	16.57	0.022	3.44	5.63	0.00056
0.21-0.50	0.3	0.92	0.76	0.0021	0.12	0.3	0
0.51-1.00	0.17	0.48	0.54	0.0018	0.082	0.15	0
1.01-2.00	0.09	0.33	0.77	0.000024	0.096	0.11	0.000016
2.01-5.00	0.089	0.54	3.07	0	0.13	0.11	0.000092
> 5.00	0.6	1.21	6.59	0	0.088	0.03	0.00077

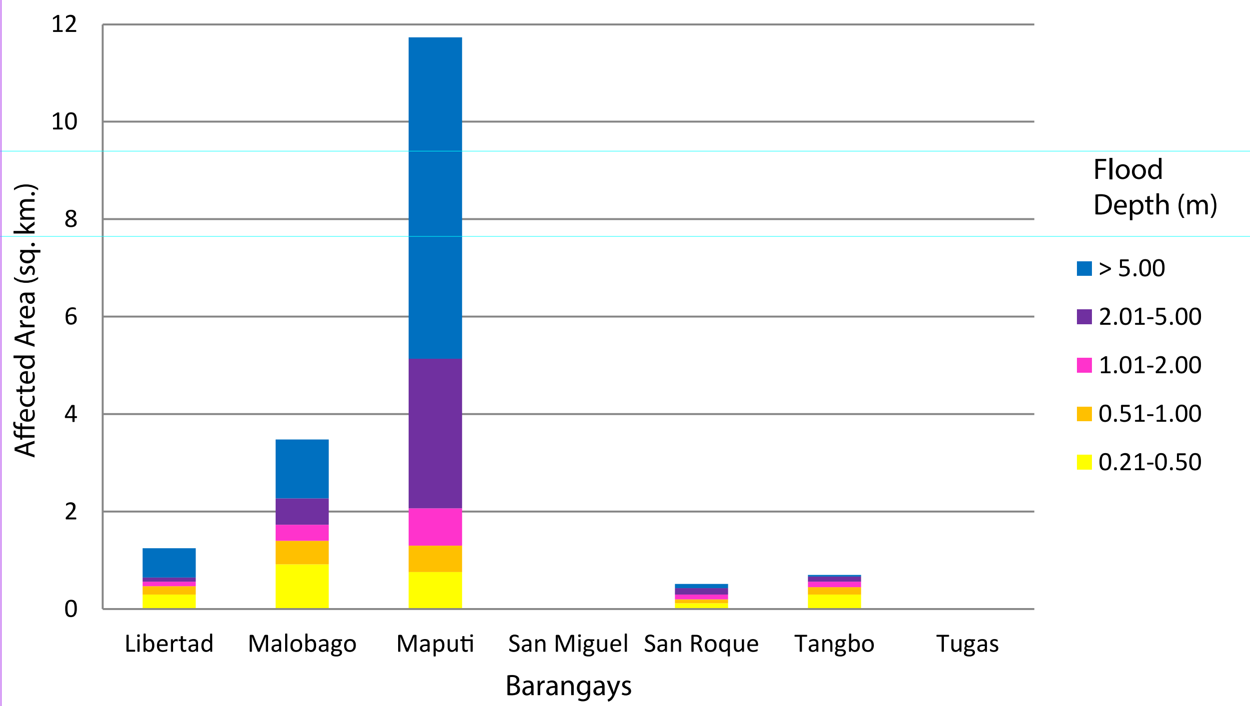


Figure 102. Affected areas in Maslog, Eastern Samar during a 100-Year Rainfall Return Period.

For the municipality of Oras, with an area of 173.99 sq. km., 33.4% will experience flood levels of less 0.20 meters. 2.36% of the area will experience flood levels of 0.21 to 0.50 meters while 1.56%, 1.51%, 2.01%, and 0.65% 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. Table 41 depicts the affected areas in square kilometers by flood depth per barangay.

Table 42. Affected areas in Oras, Eastern Samar during a 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Oras (in sq. km.)						
	Bagacay	Balingasag	Bato	Cagpile	Dalid	Dao	Factoria
0.03-0.20	2.41	19.68	1.11	1.04	2.42	0.37	1.62
0.21-0.50	0.5	0.55	0.06	0.035	0.75	0.17	0.58
0.51-1.00	0.37	0.39	0.093	0.027	0.52	0.19	0.31
1.01-2.00	0.42	0.47	0.15	0.037	0.49	0	0.09
2.01-5.00	0.01	1.42	0.17	0.12	0.03	0	0.0048
> 5.00	0	0.64	0.0014	0.096	0	0	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Oras (in sq. km.)						
	Gamot	Japay	Kalaw	Minap-Os	Naga	Saugan	Trinidad
0.03-0.20	8.59	1.37	1.41	5.36	3.44	2.04	7.26
0.21-0.50	0.35	0.1	0.085	0.17	0.096	0.41	0.25
0.51-1.00	0.17	0.091	0.09	0.12	0.062	0.061	0.22
1.01-2.00	0.15	0.061	0.098	0.17	0.08	0.009	0.41
2.01-5.00	0.41	0.01	0.0045	0.57	0.18	0	0.57
> 5.00	0.32	0	0	0.071	0.0027	0	0.0063

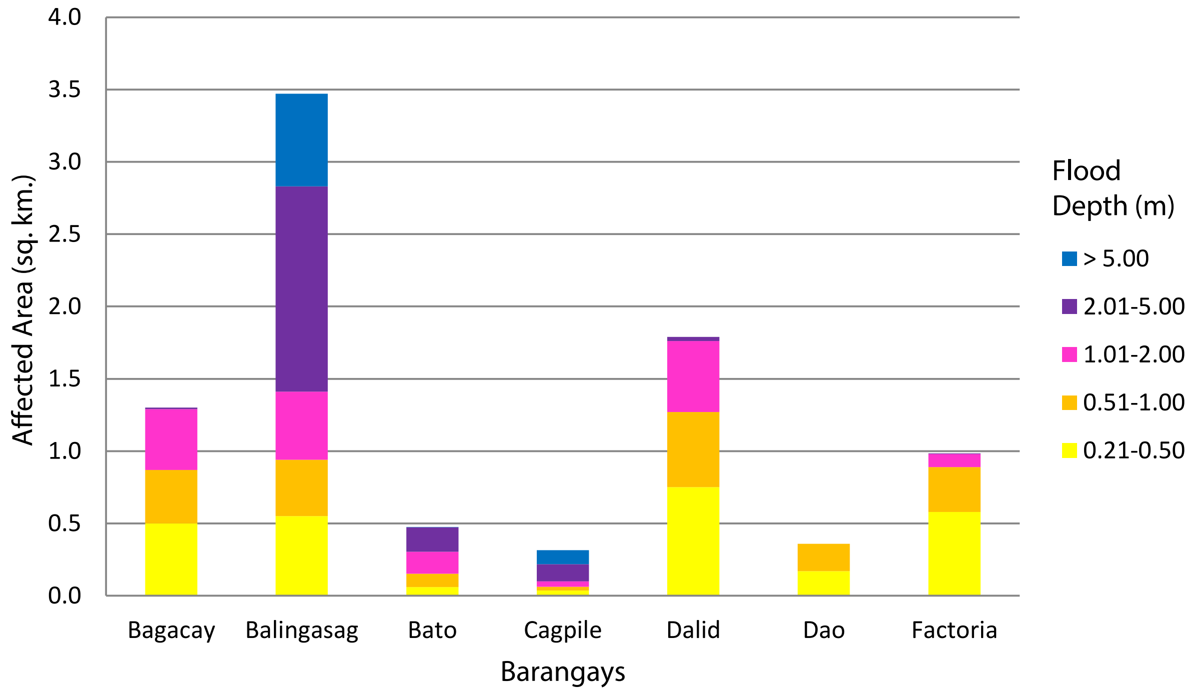


Figure 103. Affected areas in Oras, Eastern Samar during a 100-Year Rainfall Return Period.

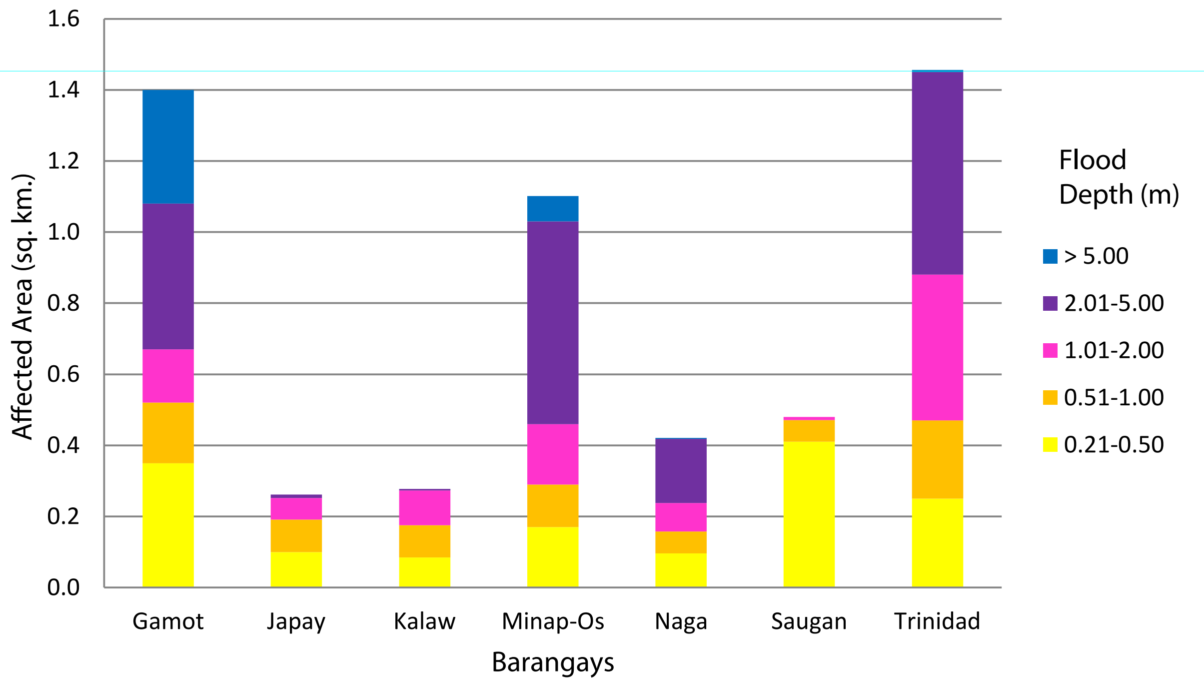


Figure 104. Affected areas in Oras, Eastern Samar during a 100-Year Rainfall Return Period.

For the municipality of Paranas, with an area of 536.76 sq. km., 0.31% will experience flood levels of less 0.20 meters. 0.01% of the area will experience flood levels of 0.21 to 0.50 meters while 0.007%, 0.005%, and 0.002% of the area will experience flood depths of 0.51 to 1 meter,1.01 to 2 meters, and more than 2 meters, respectively. Table 42 depicts the affected areas in square kilometers by flood depth per barangay.

Table 43. Affected areas in Paranas, Samar during a 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Paranas (in sq. km.)
	Anagasi
0.03-0.20	1.68
0.21-0.50	0.062
0.51-1.00	0.038
1.01-2.00	0.025
2.01-5.00	0.012
> 5.00	0

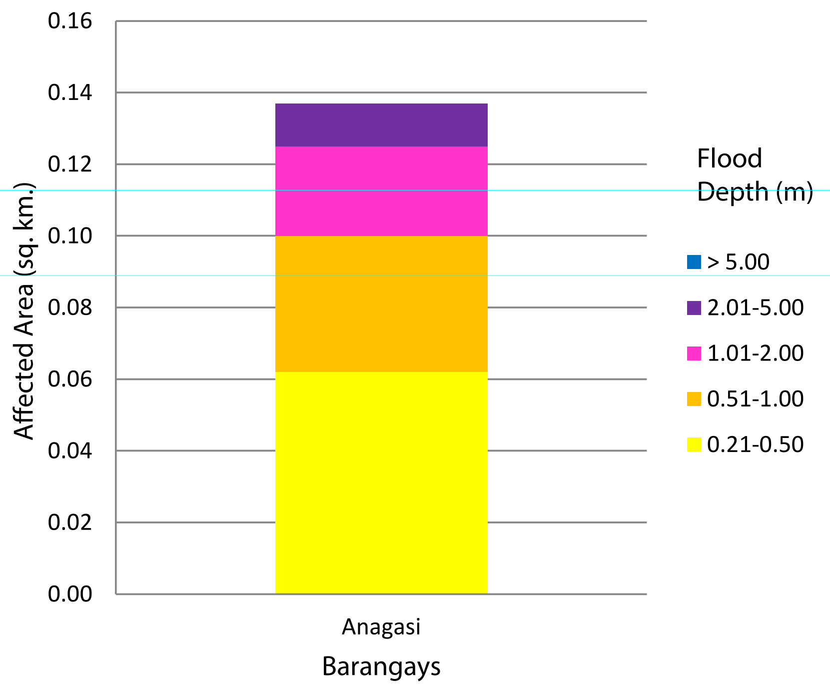


Figure 105. Affected areas in Paranas, Samar during a 100-Year Rainfall Return Period.

Among the barangays in the municipality of Arteche, Macarthur is projected to have the highest percentage of area that will experience flood levels of at 7.51%. On the other hand, Casidman posted the percentage of area that may be affected by flood depths of at 3.15%.

Among the barangays in the municipality of Can-Avid, Caghalong is projected to have the highest percentage of area that will experience flood levels of at 12.04%. On the other hand, Baruk posted the percentage of area that may be affected by flood depths of at 11.37%.

Among the barangays in the municipality of Dolores, Rizal is projected to have the highest percentage of area that will experience flood levels of at 10.04%. On the other hand, Osmeña posted the percentage of area that may be affected by flood depths of at 9.16%.

Among the barangays in the municipality of Maslog, Maputi is projected to have the highest percentage of area that will experience flood levels of at 9.93%. On the other hand, Malobago posted the percentage of area that may be affected by flood depths of at 6.65%.

Among the barangays in the municipality of Oras, Balingasag is projected to have the highest percentage of area that will experience flood levels of at 13.31%. On the other hand, Gamot posted the percentage of area that may be affected by flood depths of at 5.74%.

Among the barangays in the municipality of Paranas, Anagasi is projected to have the highest percentage of area that will experience flood levels of at 0.34%.

5.11 Flood Validation

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

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

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

After which, the actual data from the field will be compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed. The points in the flood map versus its corresponding validation depths are shown in Figure 106.

The flood validation consists of 178 points randomly selected all over the Dolores flood plain. Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 0.41m. Table 43 shows a contingency matrix of the comparison.

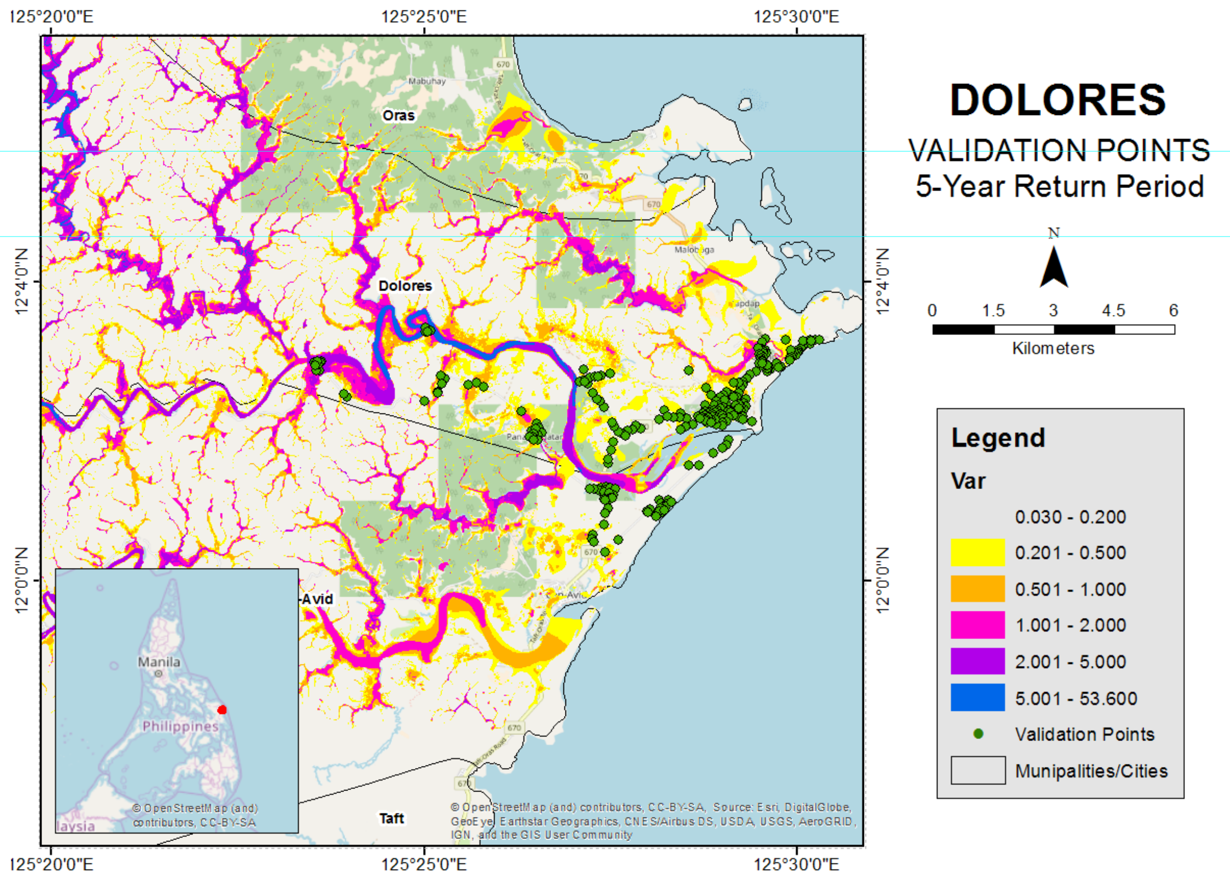


Figure 106. Validation points for 5-year Flood Depth Map of Dolores Floodplain

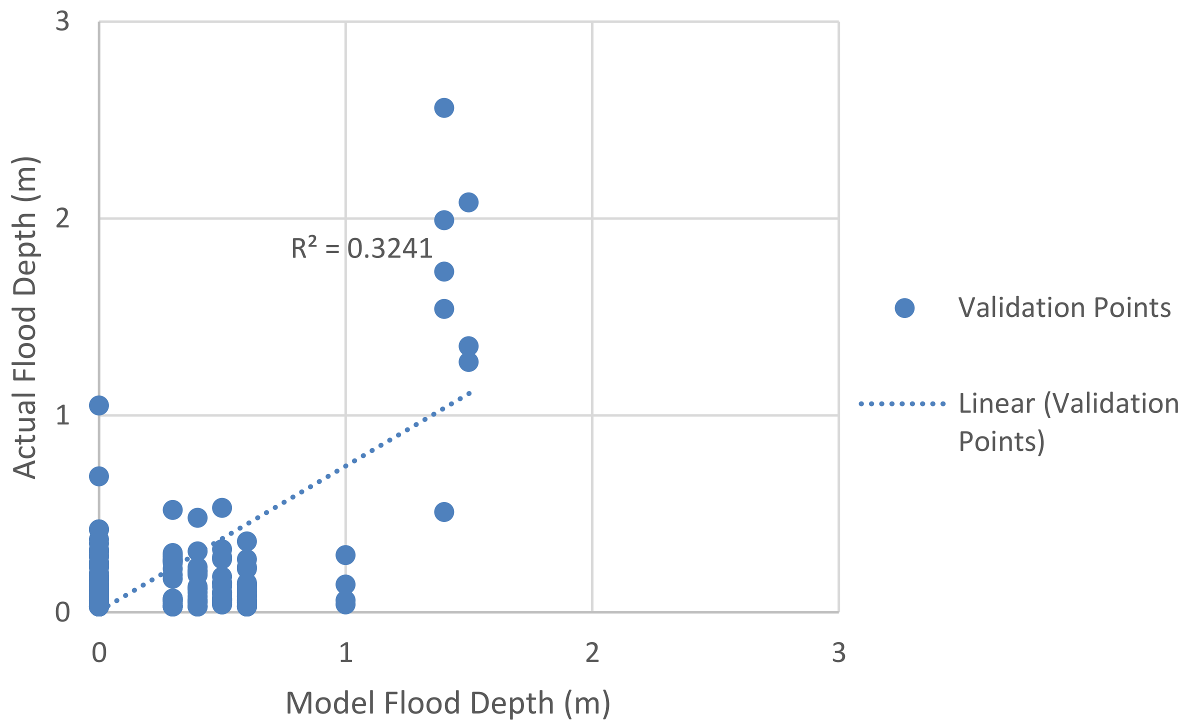


Figure 107. Flood map depth vs actual flood depth

Table 44. Actual Flood Depth vs Simulated Flood Depth at different levels in theDolores River Basin.

Dolores 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	65	42	22	0	0	0	**129**
	0.21-0.50	15	16	5	0	0	0	**36**
	0.51-1.00	1	2	0	1	0	0	**4**
	1.01-2.00	1	0	0	5	0	0	**6**
	2.01-5.00	0	0	0	3	0	0	**3**
	> 5.00	0	0	0	0	0	0	**0**
	Total	**82**	**60**	**27**	**9**	**0**	**0**	**178**

The overall accuracy generated by the flood model is estimated at 48.31% with 86 points correctly matching the actual flood depths. In addition, there were 66 points estimated one level above and below the correct flood depths while there were 23 points and 1 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 4 points were overestimated while a total of 22 points were underestimated in the modelled flood depths of Dolores.

Table 45. Summary of Accuracy Assessment in the Dolores River Basin Survey

	No. of Points	%
Correct	86	48.31
Overestimated	70	39.33
Underestimated	22	12.36
Total	**178**	**100.00**

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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.

LDRRM Office of Siay

Philippine Information Agency- IX

Mines and Geosciences Bureau- IX

ANNEX

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

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

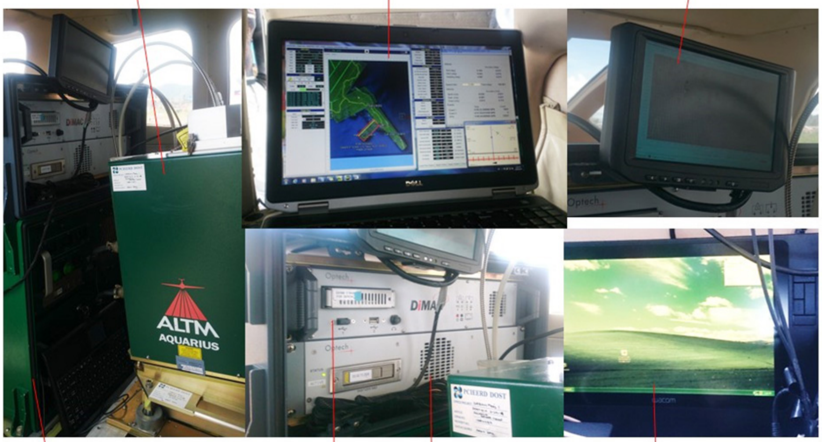

Figure A-1.1 [ ]

Table A.1.1 Parameters and Specifications

Parameter	Specification
Operational altitude	300-600 m AGL
Laser pulse repetition rate	33, 50. 70 kHz
Scan rate	0-70 Hz
Scan half-angle	0 to ± 25 ˚
Laser footprint on water surface	30-60 cm
Depth range	0 to > 10 m (for k < 0.1/m)
Topographic mode	
Operational altitude	300-2500
Range Capture	Up to 4 range measurements, including 1st, 2nd, 3rd, and last returns
Intensity capture	12-bit dynamic measurement range
Position and orientation system	POS AVTM 510 (OEM) includes embedded 72-channel GNSS receiver (GPS and GLONASS)
Data Storage	Ruggedized removable SSD hard disk (SATA III)
Power	28 V, 900 W, 35 A
Image capture	5 MP interline camera (standard); 60 MP full frame (optional)
Full waveform capture	12-bit Optech IWD-2 Intelligent Waveform Digitizer (optional)
Dimensions and weight	Sensor:250 x 430 x 320 mm; 30 kg; Control rack: 591 x 485 x 578 mm; 53 kg
Operating temperature	0-35˚C
Relative humidity	0-95% no-condensing

ANNEX 2. Namria Certification of Reference Points used in the LiDAR Survey

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

1. SME-3139

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

June 24, 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: **EASTERN SAMAR**
Station Name: **SME-3139**
Order: **4th**

Island: **VISAYAS**
Municipality: **SULAT**
Barangay: **SANTO NIÑO**

PRS92 Coordinates		
Latitude: **11° 50' 2.95701"**	Longitude: **125° 26' 3.02189"**	Ellipsoidal Hgt: **0.35600 m.**
WGS84 Coordinates		
Latitude: **11° 49' 58.57713"**	Longitude: **125° 26' 8.12160"**	Ellipsoidal Hgt: **62.18500 m.**
PTM Coordinates		
Northing: **1308628.152 m.**	Easting: **547309.911 m.**	Zone: **5**
UTM Coordinates		
Northing: **1,309,289.26**	Easting: **765,219.59**	Zone: **51**

Location Description

SME-3139

From Tacloban City, travel about 70 Km. NE towards the junction of Buena Vista, Quinapondan. Then travel about 170 Km. NW pass Gen. Mc Arthur, Hernani, Llorente, Balangkayan, Maydolong, Borongan and San Julian pass Sulat proper towards Brgy. Sto. Niño until reaching a bridge near the Km. post 900 S-4. Station is located at the right side of the road about 1 m S of the bridge, about 100 m S of Km. post 900 S-4, about 500 m S of the brgy. basketball court. Mark is the head of a 4 in. copper nail centered on a 0.20 m x 0.20 m x 1.00 m concrete monument with inscriptions, "SME-3139, 2008, NAMRIA".

Requesting Party: **Engr. Cruz**
Pupose: **Reference**
OR Number: **8796376 A**
T.N.: **2014-1442**

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

9 9 0 6 2 4 2 0 1 4 1 1 1 7 1 8

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.1 SME-3139

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

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

SME-3139 - SE-16 (6:11:03 AM-11:04:02 AM) (S2)

Baseline observation:	SME-3139 --- SE-16 (B2)
Processed:	6/30/2014 5:42:19 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.001 m
Vertical precision:	0.002 m
RMS:	0.000 m
Maximum PDOP:	3.434
Ephemeris used:	Broadcast
Antenna model:	Trimble Relative
Processing start time:	6/9/2014 6:11:10 AM (Local: UTC+8hr)
Processing stop time:	6/9/2014 11:04:02 AM (Local: UTC+8hr)
Processing duration:	04:52:52
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	SME-3139				
Grid		Local		Global	
Easting	765219.591 m	Latitude	N11°50'02.95701"	Latitude	N11°49'58.57713"
Northing	1309289.260 m	Longitude	E125°26'03.02189"	Longitude	E125°26'08.12160"
Elevation	2.987 m	Height	0.356 m	Height	62.185 m

To:	SE-16				
Grid		Local		Global	
Easting	765219.942 m	Latitude	N11°50'03.05106"	Latitude	N11°49'58.67117"
Northing	1309292.154 m	Longitude	E125°26'03.03429"	Longitude	E125°26'08.13400"
Elevation	3.103 m	Height	0.472 m	Height	62.301 m

Vector					
ΔEasting	0.350 m	NS Fwd Azimuth	7°23'58"	ΔX	-0.028 m
ΔNorthing	2.894 m	Ellipsoid Dist.	2.914 m	ΔY	-0.608 m
ΔElevation	0.116 m	ΔHeight	0.116 m	ΔZ	2.852 m

Standard Errors

Vector errors:					
σ ΔEasting	0.000 m	σ NS fwd Azimuth	0°00'35"	σ ΔX	0.001 m
σ ΔNorthing	0.000 m	σ Ellipsoid Dist.	0.000 m	σ ΔY	0.001 m
σ ΔElevation	0.001 m	σ ΔHeight	0.001 m	σ ΔZ	0.000 m

Figure A-3.1 SE-16

ANNEX 4. The LiDAR Survey Team Composition

Table A.4.1 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	
		ENGR. LOUIE P. BALICANTA	
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUNA	
		LOVELYN ASUNCION	
FIELD TEAM			
LiDAR Operation	Research Associate (RA)	PAULINE JOANNE ARCEO	UP-TCAGP
		MARY CATHERINE ELIZABETH BALIGUAS	
Ground Survey, Data Download and Transfer	RA	JERIEL PAUL ALAMBAN, GEOL.	
LiDAR Operation	Airborne Security	SSG. RAYMUND DOMINE	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. NEIL ACHILLES AGAWIN	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. JACKSON JAVIER	

ANNEX 5. Data Transfer Sheet for the Dolores Floodplain

Table A-5.1. Data Transfer Sheet for the Dolores Floodplain

DATA TRANSFER SHEET
6/19/2014 (Samar - Leyte) Twan

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES	MISSION LOG FILE	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)		MB	GB		GB		BASE STATION(S)	Base Info (.txt)		Actual	KML	
30-May-14	1520A	3BLK33VSS150A	Aquarius	NA	424/602	1.48	289	88.5	748	14	164	10.5	1KB	1KB	4	NA	X:\Airborne_Raw\1520A
31-May-14	1522A	3BLK33SS151A	Aquarius	NA	288	469KB	112	9.78/21	164/69	4.87	59.1	4.53	1KB	1KB	5	NA	X:\Airborne_Raw\1522A
1-Jun-14	1526A	3BLK33SSR152A	Aquarius	NA	456/784	1.68	277	119	403	15.5	204	8.36	1KB	1KB	6	NA	X:\Airborne_Raw\1526A
2-Jun-14	1530A	3BLK33RSQ153A	Aquarius	NA	353/605	1.48	254	30.9/80.2	555/246	15.6	165	7.88	1KB	1KB	3	NA	X:\Airborne_Raw\1530A
3-Jun-14	1534A	3BLK33QS154A	Aquarius	NA	1175	1.49	250	56.9/35.1	399/154	14.5	114/95.5	6.6	1KB	1KB	7	NA	X:\Airborne_Raw\1534A
7-Jun-14	1550A	3BLK33P158A	Aquarius	NA	657	1.03	199	52.9	na	10.8	149	7	1KB	1KB	3	NA	X:\Airborne_Raw\1550A
8-Jun-14	1554A	3BLK33PSM159A	Aquarius	NA	533/1012	1.78	257	99.8	695	14.5	27.2/59/32.2	16.4	1KB	1KB	3	NA	X:\Airborne_Raw\1554A
8-Jun-14	1556A	3BLK33MS159B	Aquarius	NA	982	1.52	291	97.2	477	15.9	216	16.4	1KB	1KB	5	NA	X:\Airborne_Raw\1556A
9-Jun-14	1558A	3BLK33J160A	Aquarius	NA	833	1.27	277	95.7	452	14.2	95.6/80.5	16.1	1KB	1KB	4	NA	X:\Airborne_Raw\1558A
9-Jun-14	1560A	3BLK33J	Aquarius	NA	1583	1.67	223	72.2	357	12.1	123	16.1	1KB	1KB	5	NA	X:\Airborne_Raw\1560A

Received from
Name: O. JOAQUIN
Position: RA
Signature:

Received by
Name: JOIDA PRIETO
Position: SSRS
Signature:
6/19/14

14-43

Figure A-5.1 Transfer Sheet for Dolores Floodplain

ANNEX 6. Flight Logs for the Flight Missions

1. Flight Log for 3BLK33J160A Mission

Table A-6.1. Flight Logs for the Flight Missions

DREAM Data Acquisition Flight Log

Flight Log No.: 1558

1 LiDAR Operator: P. ARCEO	2 ALTM Model: AQUA	3 Mission Name: 3BLK33P158A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: J. JAVIER	8 Co-Pilot: N. ALAWIN	9 Route:			
10 Date: 09 JUN 14	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1030	14 Engine Off: 1353	15 Total Engine Time: 3+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks:					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
LOVELYT ACUNA	A1C RAPHAEL O LEDAMA	JR S JAVIER	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.1 Flight Log for 3BLK33J160A Mission.

2. Flight Log for 3BLK33J160A Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 1560A

1 LiDAR Operator: C. BALICUAS	2 ALTM Model: AQUA	3 Mission Name: 3BLK33JS160B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: J. JAVIER	8 Co-Pilot: N. AGAWIN	9 Route:			
10 Date: 09 JUNE 14	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On:	14 Engine Off:	15 Total Engine Time: 2+53	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Flight Classification

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

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

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

21 Remarks

Mission completed over BLK33J

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Technician
[signature]	K. [signature]	JR Javier	[signature]	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.2 Flight Log for 3BLK33J160A Mission

ANNEX 7. Flight Status Reports

Dolores FLOODPLAIN
(January 28, May 15-26, 2014; January 21-February 17, 2015; March 9-19, April 16, 2016)

Table A.7.1 Flight Status Report

Flight No	Area	Mission	Operator	Date Flown	Remarks
1558A	BLK33J	3BLK33J160A	PJ ARCEO	9 JUN 14	Completed 12 lines over BLK33J
1560A	BLK33J	3BLK33JS160B	MCE BALIGUAS	9 JUN 14	Mission completed over BLK33J

SWATH PER FLIGHT MISSION

Flight No. : **1558A**
Area: BLOCK 33J
Total Area: 115.55 sq. km.
Mission Name: 3BLK33J60A
Altitude: 500m
PRF: 50 kHz SCF: 45 Hz
Lidar FOV: 22 deg Sidelap: 30%

Figure A-7.1 Swath for Flight No.1558A

ANNEX 8. Mission Summary Reports

Table A.8.1 Mission Summary Report for Mission Blk33J

Flight Area	Samar-Leyte
Mission Name	Blk33J
Inclusive Flights	1560A, 1558A
Range data size	26.3 GB
POS	500 MB
Image	167.9 GB
Transfer date	June 19, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.1
RMSE for East Position (<4.0 cm)	2.2
RMSE for Down Position (<8.0 cm)	3.1
Boresight correction stdev (<0.001deg)	0.000327
IMU attitude correction stdev (<0.001deg)	0.000898
GPS position stdev (<0.01m)	0.0098
Minimum % overlap (>25)	36.01%
Ave point cloud density per sq.m. (>2.0)	2.71
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	291
Maximum Height	248.48 m
Minimum Height	49.30 m
Classification (# of points)	
Ground	110,486,647
Low vegetation	51,277,620
Medium vegetation	61,095,498
High vegetation	151,119,077
Building	2,518,830
Orthophoto	Yes
Processed by	Engr. Jommer Medina, Engr. Edgardo Gubatanga Jr., Engr. Gladys Mae Apat

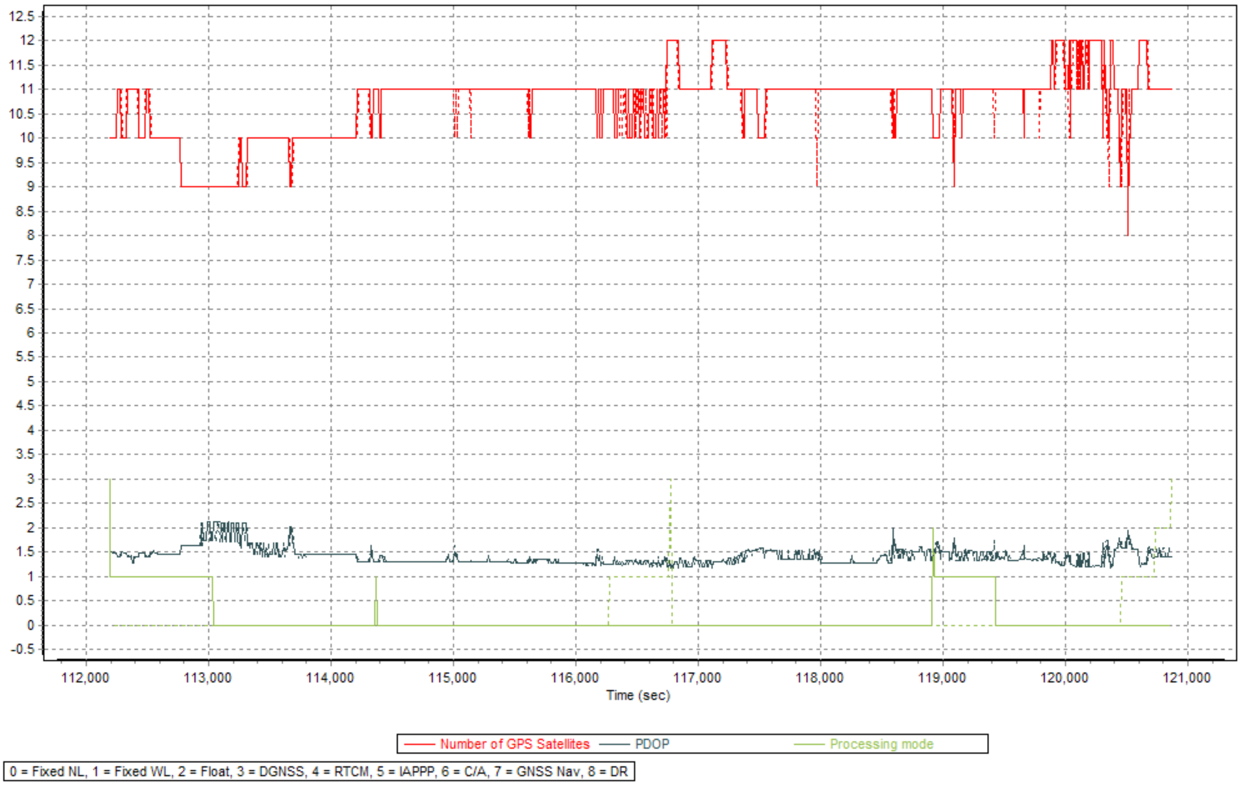

Figure A-8.1 Solution Status

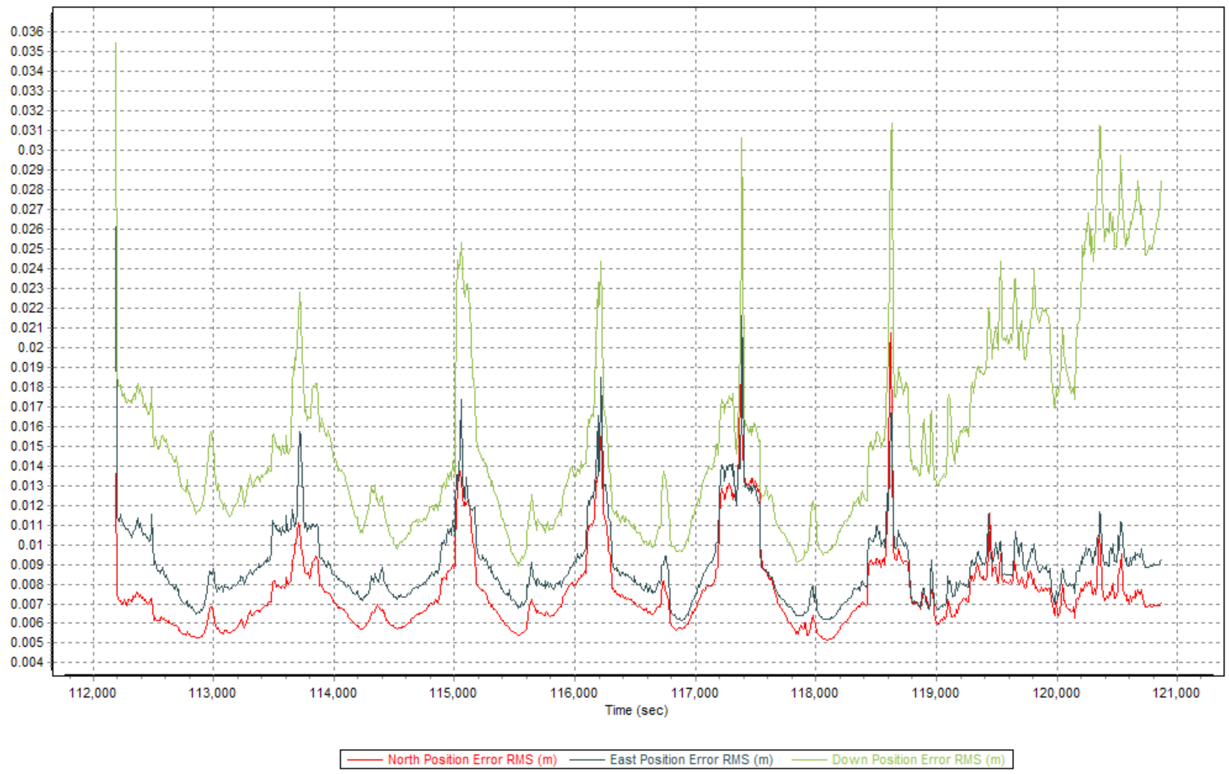

Figure A-8.2 Smoothed Performance Metrics Parameters

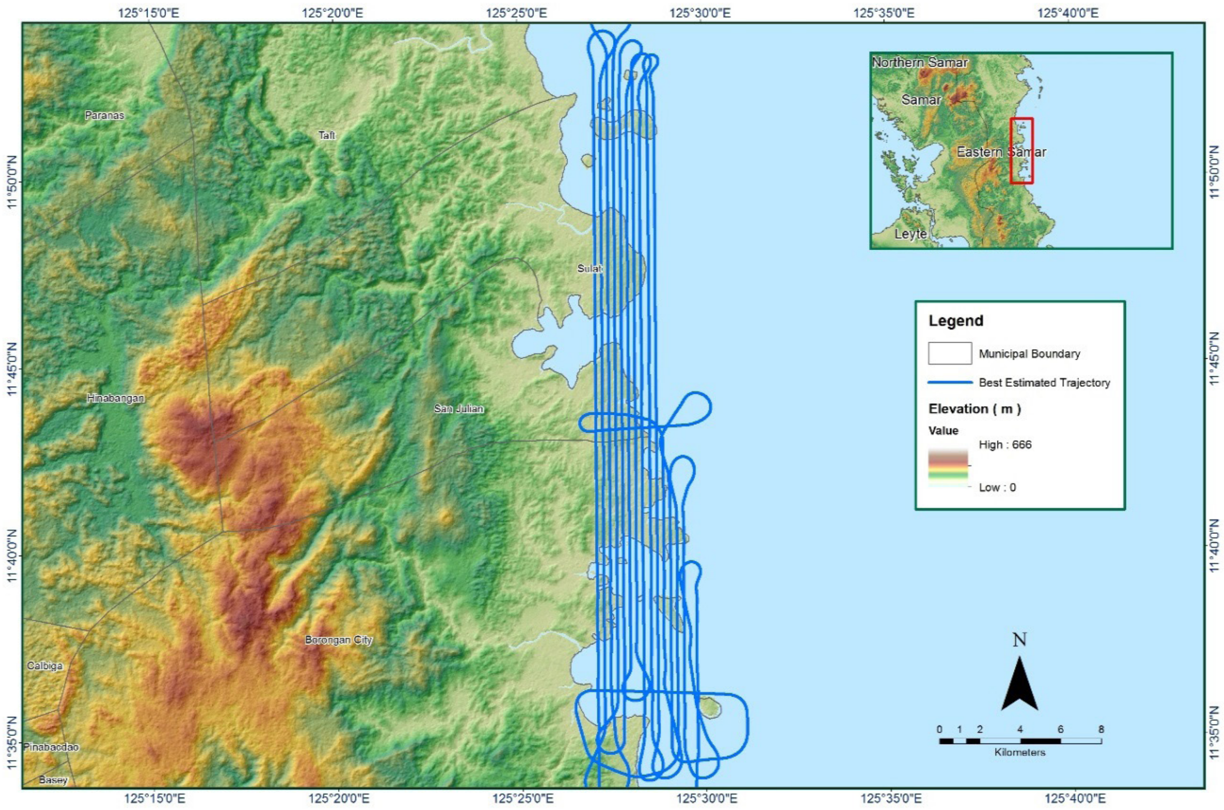

Figure A-8.3 Best Estimated Trajectory

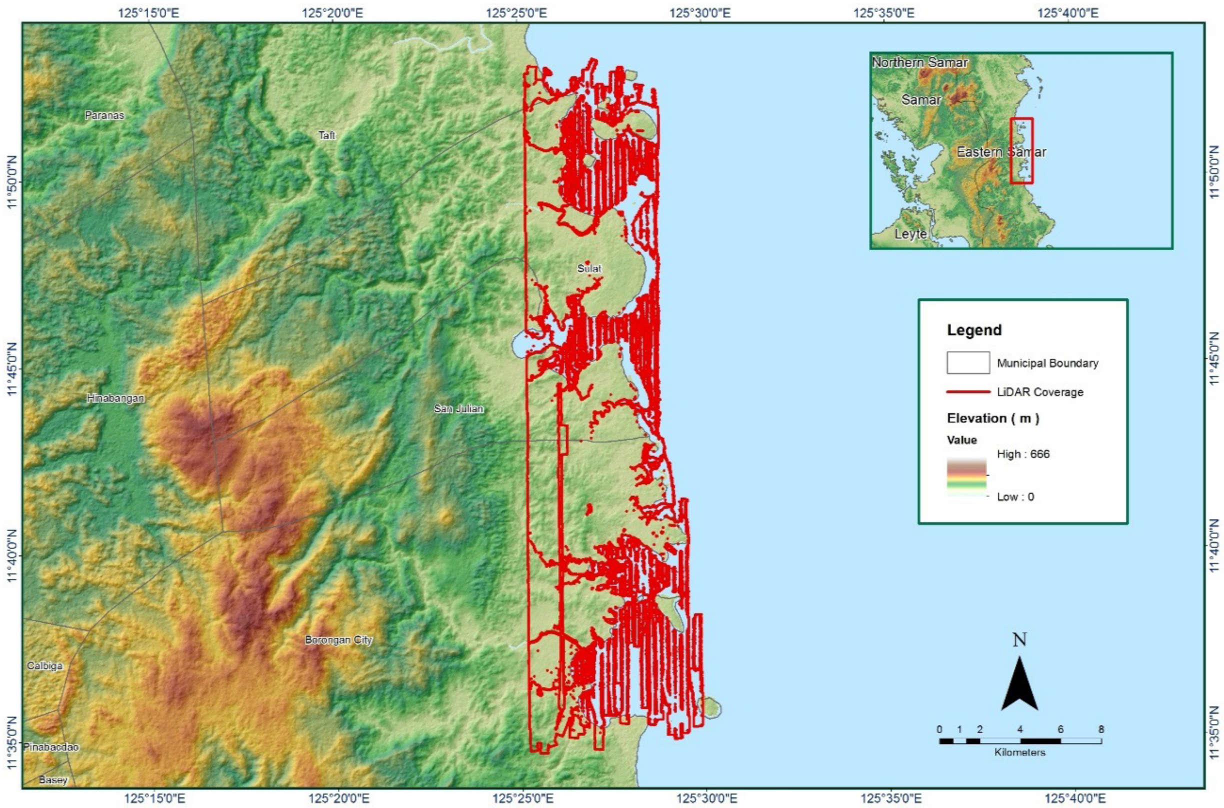

Figure A-8.4 Coverage of LiDAR data

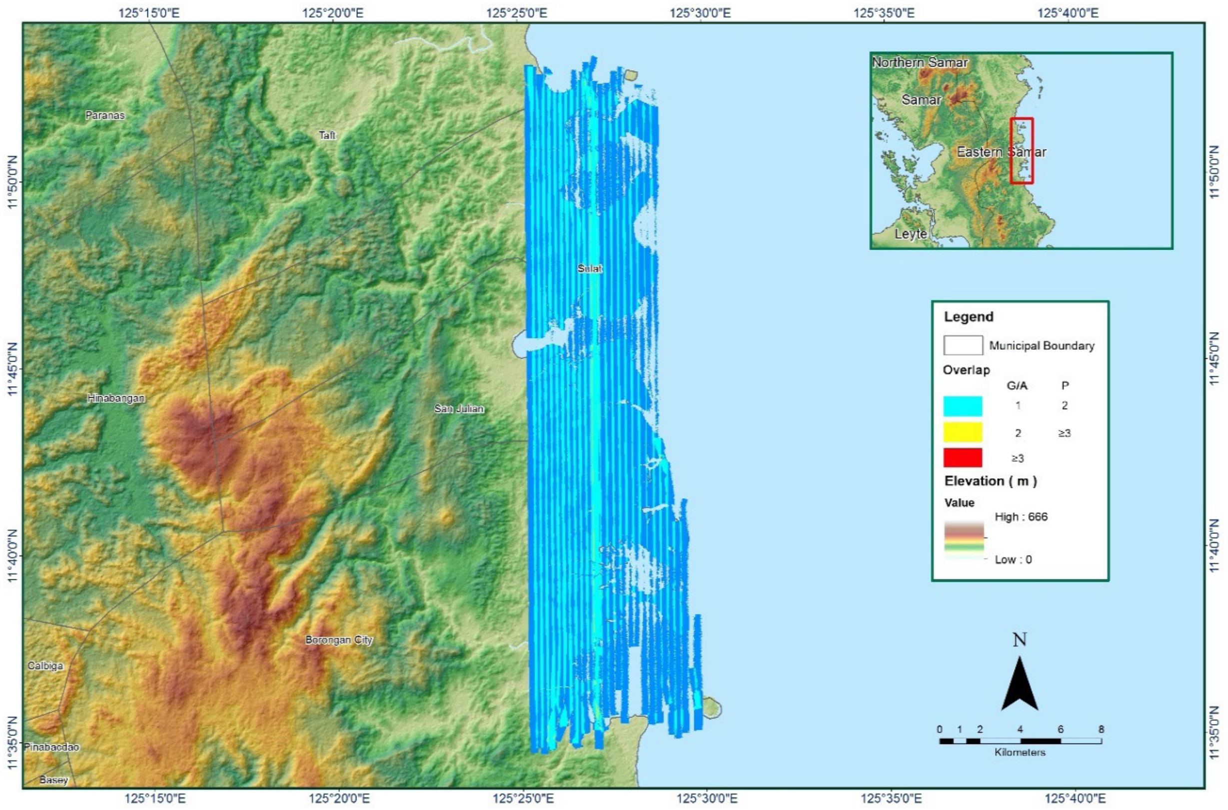

Figure A-8.5 Image of data overlap

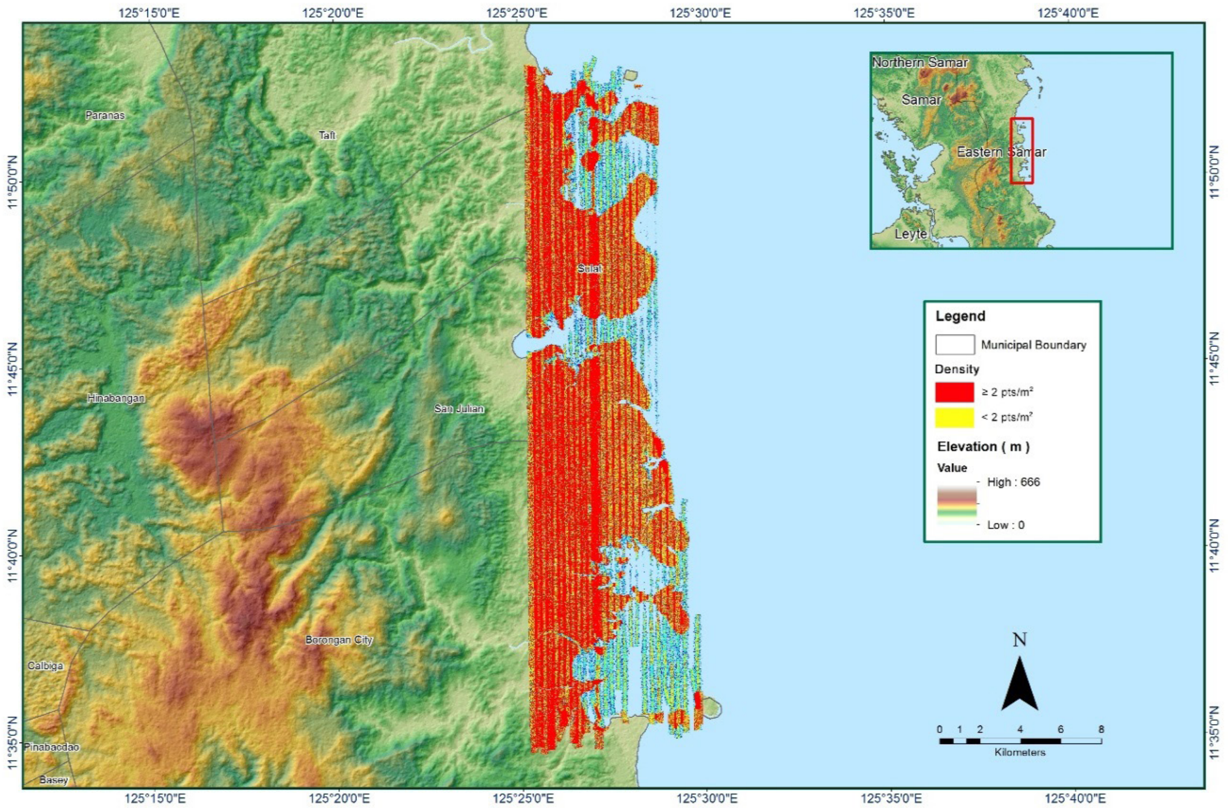

Figure A-8.6 Density map of merged LiDAR data

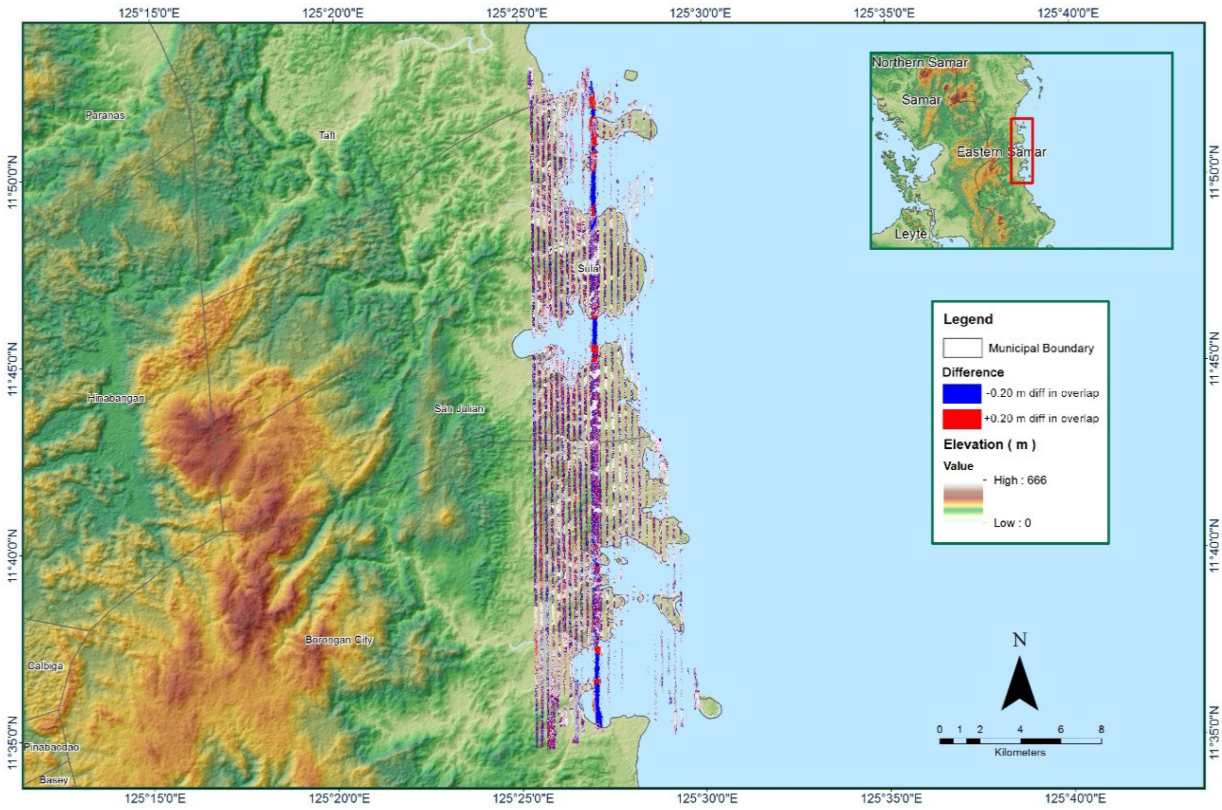

Figure A-8.7 Elevation difference between flight lines

ANNEX 9. Dolores Model Basin Parameters

Table A.9.1 Dolores 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	291.7301232	60	0.0	2.9285	0.825876	Discharge	0.55180	0.2	Ratio to Peak	0.65
W1010	116.3213886	79	0.0	0.452075	0.12749	Discharge	0.0167807	0.2	Ratio to Peak	0.65
W1020	284.0201568	60.641	0.0	3.66075	1.0323504	Discharge	0.40762	0.2	Ratio to Peak	0.65
W1030	295.2519597	59.712	0.0	5.787375	1.6321176	Discharge	1.1173	0.2	Ratio to Peak	0.65
W1040	137.9619261	76.03	0.0	4.445625	1.2537072	Discharge	0.57325	0.2	Ratio to Peak	0.65
W1050	291.7301232	60	0.0	2.71075	0.7644456	Discharge	0.50342	0.2	Ratio to Peak	0.65
W1060	349.9888018	55.562	0.0	6.107125	1.7222544	Discharge	1.0413	0.2	Ratio to Peak	0.65
W1070	291.7301232	60	0.0	3.054625	0.861408	Discharge	0.25903	0.2	Ratio to Peak	0.65
W1080	305.9350504	58.854	0.0	2.75325	0.7764336	Discharge	0.37305	0.2	Ratio to Peak	0.65
W1090	291.7301232	60	0.0	0.83825	0.2363904	Discharge	0.0104183	0.2	Ratio to Peak	0.65
W1100	291.7301232	60	0.0	1.8265	0.5150952	Discharge	0.0629541	0.2	Ratio to Peak	0.65
W1110	325.6718924	57.332	0.0	8.382125	2.363904	Discharge	1.2588	0.2	Ratio to Peak	0.65
W1120	291.7301232	60	0.0	5.286	1.4907024	Discharge	0.51064	0.2	Ratio to Peak	0.65
W1130	401.9484882	52.123	0.0	1.836125	0.5178168	Discharge	0.0289155	0.2	Ratio to Peak	0.65
W1140	116.3213886	79	0.0	3.615375	1.0195848	Discharge	0.36295	0.2	Ratio to Peak	0.65
W1150	302.9283315	59.092	0.0	3.6175	1.020168	Discharge	0.30463	0.2	Ratio to Peak	0.65
W1160	291.8868981	59.987	0.0	5.31375	1.4985216	Discharge	0.69813	0.2	Ratio to Peak	0.65
W1170	294.2049272	59.797	0.0	9.0755	2.559384	Discharge	1.2800	0.2	Ratio to Peak	0.65
W1180	274.6472565	61.439	0.0	8.75375	2.468664	Discharge	1.7079	0.2	Ratio to Peak	0.65
W1190	143.1970885	75.344	0.0	4.3385	1.2235104	Discharge	0.22670	0.2	Ratio to Peak	0.65

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
W1200	114.8152296	79.215	0.0	3.737875	1.0541232	Discharge	0.55861	0.2	Ratio to Peak	0.65
W1210	116.3213886	79	0.0	2.962875	0.8355744	Discharge	0.34553	0.2	Ratio to Peak	0.65
W1220	139.3169093	75.852	0.0	9.778125	2.757456	Discharge	1.4965	0.2	Ratio to Peak	0.65
W1230	116.3213886	79	0.0	2.181	0.6150816	Discharge	0.38826	0.2	Ratio to Peak	0.65
W1240	116.3213886	79	0.0	6.253625	1.7635968	Discharge	1.0786	0.2	Ratio to Peak	0.65
W1250	326.1926091	57.292	0.0	5.979375	1.6862256	Discharge	0.63372	0.2	Ratio to Peak	0.65
W1260	291.7301232	60	0.0	1.3955	0.393552	Discharge	0.10922	0.2	Ratio to Peak	0.65
W1270	372.7771556	53.999	0.0	3.07625	0.8675424	Discharge	0.94660	0.2	Ratio to Peak	0.65
W1280	191.5509518	69.554	0.0	4.626625	1.304748	Discharge	0.51825	0.2	Ratio to Peak	0.65
W1290	291.7301232	60	0.0	3.993375	1.1261808	Discharge	0.64769	0.2	Ratio to Peak	0.65
W1300	112.793953	79.507	0.0	4.617	1.302048	Discharge	0.78363	0.2	Ratio to Peak	0.65
W1310	221.5509518	66.388	0.0	4.943875	1.3942368	Discharge	0.88541	0.2	Ratio to Peak	0.65
W1320	146.075028	74.973	0.0	5.89125	1.6613856	Discharge	0.77291	0.2	Ratio to Peak	0.65
W1330	61.136	87.742	0.0	3.667625	1.0342944	Discharge	0.11027	0.2	Ratio to Peak	0.65
W1340	85.134	83.713	0.0	4.824625	1.360584	Discharge	1.1413	0.2	Ratio to Peak	0.65
W1350	114.9888018	79.191	0.0	3.066125	0.8646696	Discharge	0.20168	0.2	Ratio to Peak	0.65
W1360	137.9115341	76.037	0.0	3.906125	1.1015568	Discharge	0.80954	0.2	Ratio to Peak	0.65
W1370	97.917	81.715	0.0	3.51	0.9898632	Discharge	0.48657	0.2	Ratio to Peak	0.65
W1380	95.940	82.017	0.0	2.4545	0.6921936	Discharge	0.13180	0.2	Ratio to Peak	0.65
W1390	291.7301232	60	0.0	2.99475	0.8445384	Discharge	0.52751	0.2	Ratio to Peak	0.65
W1400	291.7301232	60	0.0	0.4099875	0.11562	Discharge	0.0011996	0.2	Ratio to Peak	0.65
W1410	291.7301232	60	0.0	4.318	1.2177	Discharge	0.93013	0.2	Ratio to Peak	0.65

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
W1420	292.0380739	59.974	0.0	3.309125	0.9332064	Discharge	0.65954	0.2	Ratio to Peak	0.65
W1430	344.7760359	55.931	0.0	4.88225	1.3768488	Discharge	0.34174	0.2	Ratio to Peak	0.65
W1440	331.7693169	56.877	0.0	8.711375	2.456784	Discharge	1.1763	0.2	Ratio to Peak	0.65
W1450	116.3213886	79	0.0	2.200375	0.6205248	Discharge	0.17518	0.2	Ratio to Peak	0.65
W1460	316.2709966	58.046	0.0	3.175375	0.8954928	Discharge	0.38904	0.2	Ratio to Peak	0.65
W1470	94.894	82.18	0.0	3.385875	0.954828	Discharge	0.37824	0.2	Ratio to Peak	0.65
W1480	116.3213886	79	0.0	0.638875	0.18017	Discharge	0.0013851	0.2	Ratio to Peak	0.65
W1490	76.002	85.202	0.0	2.798625	0.7892424	Discharge	0.36142	0.2	Ratio to Peak	0.65
W1500	84.25	83.855	0.0	0.3045	0.0858730	Discharge	0.0073101	0.2	Ratio to Peak	0.65
W1510	326.9764837	57.233	0.0	5.729375	1.6157232	Discharge	1.0340	0.2	Ratio to Peak	0.65
W1520	103.4382979	80.882	0.0	6.3275	1.7844192	Discharge	0.77190	0.2	Ratio to Peak	0.65
W1530	93.701	82.364	0.0	3.08775	0.8707824	Discharge	0.13431	0.2	Ratio to Peak	0.65
W1540	103.7734043	80.831	0.0	3.5595	1.0037952	Discharge	0.32354	0.2	Ratio to Peak	0.65
W1550	310.7390817	58.475	0.0	4.313	1.2163176	Discharge	0.61817	0.2	Ratio to Peak	0.65
W1560	100.5265957	81.319	0.0	5.01475	1.4142168	Discharge	0.4522235	0.2	Ratio to Peak	0.65
W1570	77.167	85.009	0.0	2.145375	0.605016	Discharge	0.35492	0.2	Ratio to Peak	0.65
W1580	88.494	83.179	0.0	5.324125	1.5014376	Discharge	0.95448	0.2	Ratio to Peak	0.65
W1590	309.7088466	58.557	0.0	2.514375	0.7090632	Discharge	0.39655	0.2	Ratio to Peak	0.65
W1600	289.619261	60.174	0.0	8.460125	2.38572	Discharge	1.7310	0.2	Ratio to Peak	0.65
W1610	352.4580067	55.387	0.0	0.7233375	0.20399	Discharge	0.0070980	0.2	Ratio to Peak	0.65
W1620	308.4994401	58.651	0.0	3.546125	1.0000584	Discharge	0.59005	0.2	Ratio to Peak	0.65
W820	221.7525196	66.368	0.0	5.709625	1.610172	Discharge	0.74996	0.2	Ratio to Peak	0.65

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
W830	116.3213886	79	0.0	1.842	0.5194584	Discharge	0.17462	0.2	Ratio to Peak	0.65
W840	259.9552071	62.733	0.0	4.200625	1.1846304	Discharge	0.69628	0.2	Ratio to Peak	0.65
W850	136.4893617	76.225	0.0	8.174625	2.305368	Discharge	1.1388	0.2	Ratio to Peak	0.65
W860	142.4132139	75.446	0.0	4.384	1.2363192	Discharge	1.2742	0.2	Ratio to Peak	0.65
W870	123.4546472	77.996	0.0	7.80225	2.200392	Discharge	2.0124	0.2	Ratio to Peak	0.65
W880	211.506159	67.415	0.0	3.192375	0.9002664	Discharge	0.34098	0.2	Ratio to Peak	0.65
W890	161.8477044	73	0.0	0.9447875	0.266436	Discharge	0.0393074	0.2	Ratio to Peak	0.65
W900	176.8980963	71.212	0.0	3.193	0.9004392	Discharge	0.73746	0.2	Ratio to Peak	0.65
W910	121.0246361	78.334	0.0	5.970375	1.6836984	Discharge	1.0691	0.2	Ratio to Peak	0.65
W920	198.2698768	68.819	0.0	3.809125	1.0742112	Discharge	0.60581	0.2	Ratio to Peak	0.65
W930	291.7301232	60	0.0	5.598	1.5786792	Discharge	0.99491	0.2	Ratio to Peak	0.65
W940	291.7301232	60	0.0	4.728	1.3333248	Discharge	0.84540	0.2	Ratio to Peak	0.65
W950	291.7301232	60	0.0	3.580875	1.0098648	Discharge	0.46547	0.2	Ratio to Peak	0.65
W960	149.4960806	74.536	0.0	6.444875	1.8175104	Discharge	0.71643	0.2	Ratio to Peak	0.65
W970	118.8745801	78.637	0.0	3.049125	0.859896	Discharge	0.40103	0.2	Ratio to Peak	0.65
W980	291.4557671	60.023	0.0	5.39025	1.5201	Discharge	0.69966	0.2	Ratio to Peak	0.65
W990	310.8958567	58.463	0.0	5.1535	1.4533128	Discharge	1.3794	0.2	Ratio to Peak	0.65

ANNEX 10. Dolores Model Reach Parameters

Table A-10.1. Dolores Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
Reach	Time Step Method	Length	Slope	Manning's n	Shape	Width	Side Slope
R110	Automatic Fixed Interval	3870.3	.00070803	0.04	Trapezoid	30	1
R120	Automatic Fixed Interval	5097.7	0.0020185	0.04	Trapezoid	30	1
R130	Automatic Fixed Interval	3806.9	0.0066024	0.04	Trapezoid	30	1
R150	Automatic Fixed Interval	617.99	0.0172059	0.04	Trapezoid	30	1
R180	Automatic Fixed Interval	113.14	0.0366957	0.04	Trapezoid	30	1
R200	Automatic Fixed Interval	3337.5	0.0196248	0.04	Trapezoid	30	1
R230	Automatic Fixed Interval	155.56	.00067730	0.04	Trapezoid	30	1
R240	Automatic Fixed Interval	2592.4	0.0036797	0.04	Trapezoid	30	1
R250	Automatic Fixed Interval	7117.4	.00067730	0.04	Trapezoid	30	1
R270	Automatic Fixed Interval	2465.9	.00074388	0.04	Trapezoid	30	1
R30	Automatic Fixed Interval	2960.2	0.0204378	0.04	Trapezoid	30	1
R300	Automatic Fixed Interval	3354.2	.00067730	0.04	Trapezoid	30	1
R310	Automatic Fixed Interval	1334.6	.00067730	0.04	Trapezoid	30	1
R330	Automatic Fixed Interval	3439.2	.00071907	0.04	Trapezoid	30	1
R340	Automatic Fixed Interval	2641.9	.00067730	0.04	Trapezoid	30	1
R350	Automatic Fixed Interval	5509.8	0.0041700	0.04	Trapezoid	30	1
R370	Automatic Fixed Interval	1873.1	0.0219443	0.04	Trapezoid	30	1
R390	Automatic Fixed Interval	2884.9	.00067730	0.04	Trapezoid	30	1
R450	Automatic Fixed Interval	2615.6	.00067730	0.04	Trapezoid	30	1
R460	Automatic Fixed Interval	2526.6	.00067730	0.04	Trapezoid	30	1
R480	Automatic Fixed Interval	2197.6	.00099419	0.04	Trapezoid	30	1
R500	Automatic Fixed Interval	6834.9	0.0031672	0.04	Trapezoid	30	1
R510	Automatic Fixed Interval	14052	.00081110	0.04	Trapezoid	30	1
R520	Automatic Fixed Interval	10251	0.0085525	0.04	Trapezoid	30	1
R530	Automatic Fixed Interval	146.57	.00067730	0.04	Trapezoid	30	1
R540	Automatic Fixed Interval	2527.6	.00067730	0.04	Trapezoid	30	1
R580	Automatic Fixed Interval	10583	0.0294082	0.04	Trapezoid	30	1

ANNEX 11. Dolores Field Validation Points

Table A-11.1. Dolores Field Validation Points for the 5-Year Flood Depth Map

GPS Code	Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Error²	Event	Date	Rain Return/ Scenario
	Lat	Long							
360	12.0561	125.4172	1.5	2.08	-0.58	0.3364	December heavy rain	12/17/2016	5-Year
460	12.05562	125.417	1.5	1.27	0.23	0.0529	December heavy rain	12/17/2016	5-Year
660	12.04334	125.4301	0	0.03	-0.03	0.0009	Ruby	12/7/2014	5-Year
760	12.04413	125.4284	0	0.69	-0.69	0.4761	Ruby	12/7/2014	5-Year
860	12.04382	125.4266	0	0.03	-0.03	0.0009	Ruby	12/7/2014	5-Year
1070	12.04519	125.4212	0	0.06	-0.06	0.0036	Ruby	12/7/2014	5-Year
1270	12.04589	125.4204	0	0.35	-0.35	0.1225	Ruby	12/7/2014	5-Year
1360	12.04215	125.4197	0	0.09	-0.09	0.0081	Ruby	12/7/2014	5-Year
1470	12.04183	125.4198	0	0.03	-0.03	0.0009	Ruby	12/7/2014	5-Year
1570	12.04005	125.4168	0	1.05	-1.05	1.1025	Ruby	12/7/2014	5-Year
1670	12.041	125.3994	0.4	0.03	0.37	0.1369	December heavy rain	12/17/2016	5-Year
1770	12.04169	125.3988	0.4	0.48	-0.08	0.0064	December heavy rain	12/17/2016	5-Year
1860	12.04884	125.3923	1.4	1.99	-0.59	0.3481	December heavy rain	12/17/2016	5-Year
1950	12.04692	125.3932	1.4	1.54	-0.14	0.0196	December heavy rain	12/17/2016	5-Year
2060	12.0469	125.3926	1.4	0.51	0.89	0.7921	December heavy rain	12/17/2016	5-Year
2170	12.05578	125.4181	1.5	1.35	0.15	0.0225	December heavy rain	12/17/2016	5-Year
2260	12.04907	125.3938	1.4	4.42	-3.02	9.1204	December heavy rain	12/17/2016	5-Year
2360	12.04874	125.3936	1.4	2.56	-1.16	1.3456	December heavy rain	12/17/2016	5-Year
2624	12.04797	125.3924	1.4	1.73	-0.33	0.1089	December heavy rain	12/17/2016	5-Year
3016	12.05382	125.4974	0.4	0.31	0.09	0.0081	Ruby	12/7/2014	5-Year
3118	12.05251	125.5014	0.6	0.03	0.57	0.3249	Yolanda	11/8/2013	5-Year
3315	12.05206	125.5008	0.6	0.05	0.55	0.3025	Yolanda	11/8/2013	5-Year
3412	12.0535	125.5013	0.6	0.04	0.56	0.3136	Yolanda	11/8/2013	5-Year
3512	12.05135	125.5005	0.6	0.03	0.57	0.3249	Yolanda	11/8/2013	5-Year
3612	12.05146	125.5001	0.6	0.06	0.54	0.2916	Yolanda	11/8/2013	5-Year
3812	12.05081	125.4999	0.6	0.03	0.57	0.3249	Yolanda	11/8/2013	5-Year
4214	12.05071	125.4988	0.6	0.05	0.55	0.3025	Yolanda	11/8/2013	5-Year
4312	12.05145	125.4985	0.6	0.27	0.33	0.1089	Yolanda	11/8/2013	5-Year

GPS Code	Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Error ²	Event	Date	Rain Return/ Scenario
	Lat	Long							
4412	12.04994	125.4988	0.6	0.03	0.57	0.3249	Yolanda	11/8/2013	5-Year
5714	12.04793	125.4918	0	0.03	-0.03	0.0009	Ruby	12/7/2014	5-Year
5812	12.05406	125.493	0.4	0.03	0.37	0.1369	Ruby	12/7/2014	5-Year
5912	12.05321	125.4923	0.4	0.08	0.32	0.1024	Ruby	12/7/2014	5-Year
6012	12.05174	125.4923	0.4	0.05	0.35	0.1225	Ruby	12/7/2014	5-Year
6513	12.05074	125.4924	0.4	0.05	0.35	0.1225	Ruby	12/7/2014	5-Year
6612	12.05196	125.4913	0.4	0.21	0.19	0.0361	Ruby	12/7/2014	5-Year
6712	12.05066	125.4916	0	0.03	-0.03	0.0009	Ruby	12/7/2014	5-Year
6912	12.04987	125.4924	0	0.42	-0.42	0.1764	Ruby	12/7/2014	5-Year
7012	12.0497	125.492	0	0.03	-0.03	0.0009	Ruby	12/7/2014	5-Year
7214	12.04892	125.4922	0	0.06	-0.06	0.0036	Ruby	12/7/2014	5-Year
7312	12.04859	125.4915	0.3	0.03	0.27	0.0729	December heavy rain	12/17/2016	5-Year
7512	12.04672	125.4909	0.3	0.19	0.11	0.0121	December heavy rain	12/17/2016	5-Year
7612	12.04609	125.4895	0.3	0.03	0.27	0.0729	December heavy rain	12/17/2016	5-Year
7712	12.04501	125.4887	0.3	0.05	0.25	0.0625	December heavy rain	12/17/2016	5-Year
7812	12.04449	125.488	0.3	0.06	0.24	0.0576	December heavy rain	12/17/2016	5-Year
7912	12.04378	125.4879	0.3	0.06	0.24	0.0576	December heavy rain	12/17/2016	5-Year
8012	12.04298	125.4875	0.3	0.07	0.23	0.0529	December heavy rain	12/17/2016	5-Year
8116	12.04428	125.4871	0.3	0.22	0.08	0.0064	December heavy rain	12/17/2016	5-Year
8214	12.04191	125.4869	0.3	0.07	0.23	0.0529	December heavy rain	12/17/2016	5-Year
8312	12.04415	125.4858	0.3	0.26	0.04	0.0016	December heavy rain	12/17/2016	5-Year
8412	12.0411	125.4865	0.3	0.04	0.26	0.0676	December heavy rain	12/17/2016	5-Year
8512	12.04157	125.4853	0.3	0.25	0.05	0.0025	December heavy rain	12/17/2016	5-Year
8612	12.0421	125.4843	0.3	0.28	0.02	0.0004	December heavy rain	12/17/2016	5-Year
8712	12.04096	125.4858	0.3	0.17	0.13	0.0169	December heavy rain	12/17/2016	5-Year
8812	12.04053	125.4885	0.3	0.52	-0.22	0.0484	December heavy rain	12/17/2016	5-Year
8912	12.0396	125.4882	0.4	0.13	0.27	0.0729	Yolanda	12/17/2016	5-Year
9012	12.03905	125.4885	0.4	0.06	0.34	0.1156	Yolanda	12/17/2016	5-Year

GPS Code	Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Error ^{2}	Event	Date	Rain Return/ Scenario
	Lat	Long							
9116	12.03825	125.4881	0.4	0.06	0.34	0.1156	Yolanda	12/17/2016	5-Year
9215	12.03886	125.4875	0.4	0.21	0.19	0.0361	Yolanda	12/17/2016	5-Year
9312	12.03807	125.4874	0.4	0.12	0.28	0.0784	Yolanda	12/17/2016	5-Year
9413	12.03679	125.488	0.6	0.11	0.49	0.2401	Ruby	12/7/2014	5-Year
10014	12.03644	125.4869	0.6	0.12	0.48	0.2304	Ruby	12/7/2014	5-Year
10117	12.03602	125.4878	0.6	0.14	0.46	0.2116	Ruby	12/7/2014	5-Year
10215	12.03934	125.4869	0.4	0.1	0.3	0.09	Yolanda	12/17/2016	5-Year
10413	12.03795	125.4864	0.4	0.12	0.28	0.0784	Yolanda	12/17/2016	5-Year
10613	12.04142	125.4835	0.4	0.19	0.21	0.0441	Yolanda	12/17/2016	5-Year
10713	12.04095	125.483	0.4	0.23	0.17	0.0289	Yolanda	12/17/2016	5-Year
10813	12.03933	125.4843	0.4	0.2	0.2	0.04	Yolanda	12/17/2016	5-Year
10913	12.04023	125.4838	0.4	0.03	0.37	0.1369	Yolanda	12/17/2016	5-Year
11018	12.04299	125.4798	0	0.42	-0.42	0.1764	Ruby	12/7/2014	5-Year
11100	12.044	125.4206	0	0.03	-0.03	0.0009	Ruby	12/7/2014	5-Year
11117	12.04699	125.4758	0	0.04	-0.04	0.0016	Ruby	12/7/2014	5-Year
11214	12.04156	125.4809	0	0.31	-0.31	0.0961	Ruby	12/7/2014	5-Year
11314	12.04014	125.4819	0.5	0.28	0.22	0.0484	Yolanda	12/17/2016	5-Year
11413	12.03868	125.4836	0.3	0.03	0.27	0.0729	Yolanda	12/17/2016	5-Year
11513	12.03925	125.4824	0.3	0.3	0	0	Ruby	12/7/2014	5-Year
11613	12.03918	125.4814	0.3	0.29	0.01	0.0001	Ruby	12/7/2014	5-Year
11713	12.03833	125.4802	0.5	0.18	0.32	0.1024	Yolanda	12/17/2016	5-Year
11813	12.03909	125.4795	0.6	0.1	0.5	0.25	Ruby	12/7/2014	5-Year
11913	12.03784	125.4795	0.5	0.05	0.45	0.2025	Yolanda	12/17/2016	5-Year
12013	12.0374	125.4789	0.5	0.1	0.4	0.16	Yolanda	12/17/2016	5-Year
12117	12.03675	125.478	0	0.18	-0.18	0.0324	Ruby	12/7/2014	5-Year
12313	12.03702	125.4796	0.5	0.07	0.43	0.1849	Yolanda	12/17/2016	5-Year
12413	12.0365	125.4789	0	0.14	-0.14	0.0196	Ruby	12/7/2014	5-Year
12513	12.03799	125.4848	0	0.18	-0.18	0.0324	Ruby	12/7/2014	5-Year
12713	12.03752	125.4851	0	0.14	-0.14	0.0196	Ruby	12/7/2014	5-Year
12813	12.03681	125.4858	0	0.14	-0.14	0.0196	Ruby	12/7/2014	5-Year
12913	12.03636	125.4848	0	0.17	-0.17	0.0289	Ruby	12/7/2014	5-Year
13013	12.0384	125.4829	0.3	0.26	0.04	0.0016	Yolanda	12/17/2016	5-Year
13214	12.03807	125.4815	0.3	0.27	0.03	0.0009	Ruby	12/7/2014	5-Year
13413	12.03716	125.481	0.5	0.15	0.35	0.1225	Yolanda	12/17/2016	5-Year
13513	12.03719	125.4828	0	0.25	-0.25	0.0625	Ruby	12/7/2014	5-Year
13613	12.03655	125.4821	0	0.25	-0.25	0.0625	Ruby	12/7/2014	5-Year
13813	12.03587	125.4824	0	0.25	-0.25	0.0625	Ruby	12/7/2014	5-Year
13913	12.03687	125.4834	0	0.23	-0.23	0.0529	Ruby	12/7/2014	5-Year

GPS Code	Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Error ^{2}	Event	Date	Rain Return/ Scenario
	Lat	Long							
14013	12.03631	125.4835	0	0.25	-0.25	0.0625	Ruby	12/7/2014	5-Year
14214	12.0354	125.4833	0.6	0.13	0.47	0.2209	Ruby	12/7/2014	5-Year
14413	12.03476	125.4819	0.6	0.14	0.46	0.2116	Ruby	12/7/2014	5-Year
14513	12.03594	125.4818	0.6	0.22	0.38	0.1444	Ruby	12/7/2014	5-Year
14613	12.03605	125.4807	0.6	0.15	0.45	0.2025	Ruby	12/7/2014	5-Year
14713	12.0354	125.48	0.6	0.23	0.37	0.1369	December heavy rain	12/17/2016	5-Year
14913	12.03596	125.4797	0	0.1	-0.1	0.01	Ruby	12/7/2014	5-Year
15214	12.03528	125.4808	0.6	0.06	0.54	0.2916	December heavy rain	12/17/2016	5-Year
15313	12.03491	125.4768	0.6	0.08	0.52	0.2704	Ruby	12/7/2014	5-Year
15413	12.03628	125.4754	0	0.17	-0.17	0.0289	Ruby	12/7/2014	5-Year
15513	12.03743	125.4741	0	0.32	-0.32	0.1024	Ruby	12/7/2014	5-Year
15613	12.03648	125.4737	0	0.31	-0.31	0.0961	Ruby	12/7/2014	5-Year
15713	12.03653	125.4723	0	0.04	-0.04	0.0016	Ruby	12/7/2014	5-Year
15813	12.03798	125.4704	0	0.17	-0.17	0.0289	Ruby	12/7/2014	5-Year
15913	12.0367	125.4709	0	0.04	-0.04	0.0016	Ruby	12/7/2014	5-Year
16013	12.03447	125.4752	0	0.03	-0.03	0.0009	Ruby	12/7/2014	5-Year
16118	12.0338	125.4739	0	0.2	-0.2	0.04	Ruby	12/7/2014	5-Year
16214	12.03601	125.4693	0	0.13	-0.13	0.0169	Ruby	12/7/2014	5-Year
16313	12.03388	125.4651	0	0.12	-0.12	0.0144	Ruby	12/7/2014	5-Year
16413	12.03458	125.4641	0	0.08	-0.08	0.0064	Ruby	12/7/2014	5-Year
16513	12.03364	125.4634	0	0.08	-0.08	0.0064	Ruby	12/7/2014	5-Year
16613	12.03346	125.4622	0	0.06	-0.06	0.0036	Ruby	12/7/2014	5-Year
16713	12.0327	125.4611	0	0.07	-0.07	0.0049	Ruby	12/7/2014	5-Year
16813	12.03338	125.4601	0	0.07	-0.07	0.0049	Ruby	12/7/2014	5-Year
16913	12.03435	125.4592	0	0.08	-0.08	0.0064	Ruby	12/7/2014	5-Year
17013	12.03532	125.4588	0	0.18	-0.18	0.0324	Ruby	12/7/2014	5-Year
17117	12.0388	125.4569	0.5	0.13	0.37	0.1369	Ruby	12/7/2014	5-Year
17214	12.04017	125.456	0.5	0.05	0.45	0.2025	Ruby	12/7/2014	5-Year
17413	12.04187	125.4544	0.5	0.32	0.18	0.0324	Ruby	12/7/2014	5-Year
17513	12.04388	125.4532	0	0.03	-0.03	0.0009	Ruby	12/7/2014	5-Year
17612	12.04483	125.4529	0	0.06	-0.06	0.0036	Ruby	12/7/2014	5-Year
17712	12.04537	125.4536	0	0.03	-0.03	0.0009	Ruby	12/7/2014	5-Year
17813	12.04708	125.4524	0	0.03	-0.03	0.0009	Ruby	12/7/2014	5-Year
17913	12.04468	125.4522	0	0.23	-0.23	0.0529	Ruby	12/7/2014	5-Year
18013	12.04437	125.4515	0	0.05	-0.05	0.0025	Ruby	12/7/2014	5-Year
18117	12.04618	125.4582	0	0.17	-0.17	0.0289	Ruby	12/7/2014	5-Year

GPS Code	Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Error²	Event	Date	Rain Return/ Scenario
	Lat	Long							
18214	12.04573	125.4563	0	0.13	-0.13	0.0169	Ruby	12/7/2014	5-Year
18312	12.04557	125.4548	0	0.06	-0.06	0.0036	Ruby	12/7/2014	5-Year
18612	12.03235	125.4617	0	0.06	-0.06	0.0036	Ruby	12/7/2014	5-Year
18712	12.03089	125.459	0	0.16	-0.16	0.0256	Ruby	12/7/2014	5-Year
18810	12.02918	125.4585	0	0.04	-0.04	0.0016	Ruby	12/7/2014	5-Year
18912	12.02624	125.4577	0	0.11	-0.11	0.0121	Ruby	12/7/2014	5-Year
19012	12.02705	125.4578	0	0.37	-0.37	0.1369	Ruby	12/7/2014	5-Year
19116	12.03136	125.4846	0.5	0.04	0.46	0.2116	Ruby	12/7/2014	5-Year
19214	12.03034	125.4842	0.5	0.06	0.44	0.1936	Ruby	12/7/2014	5-Year
19312	12.02972	125.4833	0.5	0.06	0.44	0.1936	Ruby	12/7/2014	5-Year
19411	12.02852	125.4813	0.5	0.06	0.44	0.1936	Ruby	12/7/2014	5-Year
19512	12.02575	125.4781	0.5	0.07	0.43	0.1849	Ruby	12/7/2014	5-Year
19612	12.02575	125.4759	0.5	0.09	0.41	0.1681	Ruby	12/7/2014	5-Year
19712	12.01801	125.4692	0.5	0.07	0.43	0.1849	December heavy rain	12/17/2016	5-Year
19812	12.01722	125.4697	0.5	0.04	0.46	0.2116	December heavy rain	12/17/2016	5-Year
20912	12.01599	125.4672	0	0.03	-0.03	0.0009	Ruby	12/7/2014	5-Year
21214	12.01543	125.4664	0.6	0.09	0.51	0.2601	Ruby	12/7/2014	5-Year
21413	12.00922	125.4601	0	0.1	-0.1	0.01	Ruby	12/7/2014	5-Year
21512	12.00643	125.4572	0	0.06	-0.06	0.0036	Ruby	12/7/2014	5-Year
21612	12.02073	125.4561	0	0.1	-0.1	0.01	Ruby	12/7/2014	5-Year
21712	12.02012	125.456	0	0.09	-0.09	0.0081	Ruby	12/7/2014	5-Year
21912	12.02055	125.4547	0	0.07	-0.07	0.0049	Ruby	12/7/2014	5-Year
22012	12.02058	125.4536	0	0.08	-0.08	0.0064	Ruby	12/7/2014	5-Year
22116	12.02091	125.4573	0	0.12	-0.12	0.0144	Ruby	12/7/2014	5-Year
22312	12.01978	125.457	0	0.09	-0.09	0.0081	Ruby	12/7/2014	5-Year
22412	12.02064	125.4583	0	0.13	-0.13	0.0169	Ruby	12/7/2014	5-Year
22512	12.02051	125.4594	0	0.1	-0.1	0.01	Ruby	12/7/2014	5-Year
22612	12.01919	125.4589	0	0.14	-0.14	0.0196	Ruby	12/7/2014	5-Year
22712	12.0195	125.4581	0	0.13	-0.13	0.0169	Ruby	12/7/2014	5-Year
22812	12.01853	125.4583	0	0.12	-0.12	0.0144	Ruby	12/7/2014	5-Year
22912	12.018	125.4579	0	0.12	-0.12	0.0144	Ruby	12/7/2014	5-Year
23116	12.01832	125.4568	0	0.13	-0.13	0.0169	Ruby	12/7/2014	5-Year
23312	12.0161	125.4577	0	0.07	-0.07	0.0049	Ruby	12/7/2014	5-Year
23412	12.01264	125.4569	0	0.03	-0.03	0.0009	Ruby	12/7/2014	5-Year
23512	12.01496	125.4572	0	0.08	-0.08	0.0064	Ruby	12/7/2014	5-Year
23612	12.01033	125.4544	0	0.29	-0.29	0.0841	Ruby	12/7/2014	5-Year

GPS Code	Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Error ^{2}	Event	Date	Rain Return/ Scenario
	Lat	Long							
23712	12.00932	125.4541	0	0.28	-0.28	0.0784	Ruby	12/7/2014	5-Year
23812	12.00864	125.4545	0	0.17	-0.17	0.0289	Ruby	12/7/2014	5-Year
23912	12.03501	125.4418	0.5	0.53	-0.03	0.0009	Ruby	12/7/2014	5-Year
24012	12.03785	125.4384	0.6	0.36	0.24	0.0576	Ruby	12/7/2014	5-Year
24116	12.03414	125.4422	0.5	0.27	0.23	0.0529	Ruby	12/7/2014	5-Year
24214	12.03297	125.4431	0.5	0.1	0.4	0.16	Ruby	12/7/2014	5-Year
24312	12.03355	125.4406	0.5	0.15	0.35	0.1225	Ruby	12/7/2014	5-Year
24411	12.03249	125.4422	1	0.14	0.86	0.7396	Ruby	12/7/2014	5-Year
24512	12.03146	125.4421	1	0.29	0.71	0.5041	Ruby	12/7/2014	5-Year
24711	12.03282	125.4412	1	0.06	0.94	0.8836	Ruby	12/7/2014	5-Year
24911	12.03211	125.4403	0.6	0.08	0.52	0.2704	Ruby	12/7/2014	5-Year
25011	12.03136	125.4411	1	0.04	0.96	0.9216	Ruby	12/7/2014	5-Year

ANNEX 12. Educational Institutions affected by flooding in Dolores Floodplain

Table A-12.1. Educational Institutions affected by flooding in Dolores Floodplain

Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year

ANNEX 13. Health Institutions affected by flooding in Dolores Floodplain

Table A-13.1. Health Institutions affected by flooding in Dolores Floodplain

Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year

UP Training Center for Applied Geodesy and Photogrammetry (TCAGP)
College of Engineering
University of the Philippines – Diliman
Quezon City 1101
PHILIPPINES